First Prof. R. Ananthakrishnan Memorial Conference

on

Atmospheric Science, Climate Change and Environment Studies

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Extended Abstracts

Technical Editors
Sachin Gunthe & Vikas Singh

Indian Institute of Tropical Meteorology
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About Prof R Ananthakrishnan…

<u>1911 - 1999</u>

Late Prof. R. Ananthakrishnan (Ex-Director and Honorary Fellow of IITM, Pune) started his research carrier as a research scholar in the field of light scattering under the guidance of noble laureate Prof. C. V. Raman and awarded D.Sc. in 1937 from University of Madras. Then he joined IMD and occupied several positions up to DDG and then he worked as Director IITM during 1968-1971. He was awarded Padmashree by President of India in 1969 and C.V. Raman Centenary Medal in 1988. He was elected as an INSA Fellow in 1961 and was also member of many learned and professional societies like (Indian Academy of Sciences, Maharashtra Academy of Sciences). He was associated with some technical committees and working groups of WMO Geneva. He was an editor of some national and international reputed journals in Meteorology.

Prof. Ananthakrishnan was deeply associated in organizing and teaching Msc./M.Tech. Courses in Meteorology at University of Cochin and University of Pune.

Research contribution of Prof. R. Ananthakrishnan includes various topics viz. Light scattering and Raman effect, Solar Physics and Meteor Astronomy and Meteorology. In the field Meteorology his work covers different topics: Aerological Diagrams, Dynamics, Thermodynamics, Errors in upper air data, monsoon circulation, Tracks of storms and depressions, Atmospheric pressure and oscillations, Indian rainfall and features associated with onset of southwest monsoon. To meet defense need he organized the publications entitled 'Climatology of Himalayas, Tibet and adjoining areas'. There are 110 national/international (research papers/technical contributions) papers to his credit and one book entitled 'An Introduction to Meteorology'. This textbook is found to be extremely useful to all the new comers in the field of meteorology. Prof. R. Ananthakrishnan pursuied his research and guidance in the field of atmospheric sciences after retirement as an honorary fellow in the IITM till his last days.

भारतीय उष्णदेशीय मौसम विज्ञान संस्थान
INDIAN INSTITUTE OF TROPICAL METEOROLOGY
(विज्ञान और प्रौद्योगिकी मंत्रालय का एक स्वायत्त संस्थान, भारत सरकार के अधीन)
(An Autonomous Institute of the Ministry of Science and Technology, Govt. of India)

Dr G. B. Pant
Director
January 18, 2005

The idea of this conference has its origin in the reminiscence of my entry into research in Atmospheric Sciences way back in 1968. As a young Junior Scientific Officer (may sound less academic than a Research Scholar), I came across a scientist and personality par excellence in Prof. R.Ananthakrishnan, the then Deputy Director General at IMD, Pune. The association became much closer when he headed the Institute till 1971 and continued his academic activities since then. A lot might have been discussed argued upon and learnt from him by many of us who had the opportunity to interact with him. Today a large number of young minds looking for Atmospheric Science as a career need, inspiration and courage to tackle a much more challenging task with many complexities of problems and opportunities. Inspite of enormous developments since then the basic requirements of new ideas, understanding, prediction tools and appreciation of basic issues need free frank and inquisitive interaction. I am sure that the deliberations of this conference will generate new ideas and build self-confidence. I wish you all success in your endeavor. I thank the Scientific Advisory Committee and the Local Organizing Committee for their dedication and efforts in organizing this unique event.

G B Pant

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Dr.(Mrs.)P.S.Salvekar
Convenor, FPRAMC

January 18, 2005

First Prof. R. Ananthakrishnan Memorial Conference is an important event for the Indian Institute of Tropical Meteorology, Pune as it is for the first time that such a national level students conference in the field of atmospheric science is arranged. The conference visualises excellent interactions between young and talented researchers, as there is considerable activity in the development of atmospheric sciences and related fields.

This publication is an attempt to faster an early inter change of information among many researchers in Atmospheric Science, Climate Change and Environmental Studies. The material in this publication is a result of overwhelming response received electronically from all over India in the short notice of about 1½ month. Most of the submission received through e-mail and very few are by post. All the contributions are arranged in a specific format to retain uniformity. To facilitate location to specific contribution they are ordered alphabetically by author in various special areas. An over all index by author is also included. Immense efforts taken for this publication by Mr. Sachin Gunthe and Mr. Vikas Singh in formatting the contents and preparation of cover page are highly appreciated.

P S Salvekar

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Preface…….

It is a great privilege and honour for us to present this first volume of Extended Abstracts of First Prof R Ananthakrishnan Memorial Conference on Atmospheric Science, Climate Change and Environmental Studies. This volume is only a small contribution to the immense research efforts by the young researchers in the above-mentioned areas. But, we sincerely feel that this initiative will definitely mark a new beginning to encourage and broader the skills of young researchers.

Dr. (Mrs.) P S Salvekar proposed an idea of First Prof R Ananthakrishnan memorial conference, exclusively by students and for students, in the last week of September 2004. To bring this idea into a reality we started working from that moment itself and as a result of which the Brochure and the first circular (Poster) of the conference was ready by the second week of October 2004 for the circulation. In the first week of November the separate web page was launched for the conference to convey the importance of it to all young researchers working in the field of Atmospheric Science. Because of Deepawali Holidays the postal delay was a major barrier of concern for communicating the calls for abstracts. But due to the web page and emails we could overcome the difficulties involved in the communication. In this regards the response from the participants is overwhelming which is really appreciable. It would have been impossible to achieve such a great recognition and success without restless pain taking efforts taken by Dr. (Mrs) P. S. Salvekar.

Undoubtedly the success of this volume is due to the hard work of each and every member of Local Organizing Committee, and an eagerness they have shown in pursuing it for a great and grand success. It will be unfair not to mention the constant experienced guidance provided by Scientific Advisory Committee. It is our honour to reiterate our deep gratitude to the Local Organizing Committee members, Library Information and Publication Division, GA Section, Accounts Section of IITM for their timely help to make the event a success. At the distance to this we also like to express our gratitude towards some senior officials like Dr Rajeevan, IMD, Pune and Dr B M Mishra General Dynamics/MIT Lincoln Laboratory Lexington, Mass, USA for their contribution in this event. **Dr G B Pant, Director**, IITM was a constant source of inspiration and support during the conference. We sincerely express our appreciation for the faith he has shown in us.

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Dr. R. Ananthakrishnan - Recollection of a Student

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Dr. R. Ananthakrishnan was a physicist and a humanist. A person of extreme integrity, infinite kindness and deep erudition, he was dignified as well as ordinarily common. While engaged in research and busy directing research programs, he had time for everyone from a minor employee to a high-level officer. I had the blessings of working with him as a student and this is a short recollection of this profitable period of my life.

Dr. Ananthakrishnan met me some time during February of 1969 at the Santa Cruz office of Air India in a Fellowship interview. This was the first time I had faced a major interview and with the disorganization of the journey, I had an accident that injured my left hand. There was a Board of eight officials, with Dr. Pisharoty presiding. At the end of the interview, Dr Pisharoty made a thunderous comment – 'Do you not want to study the air between you and me?' To my young mind, that was very compelling and we had an interesting exchange of ideas. There were some seven persons still waiting to be interviewed. After all was completed, two of the Board members came towards me and offered congratulations. I didn't know their names and I said that 'I will join as soon as my hand healed.' Both gentlemen took interest in my story at the train and I could feel the affection they had towards me. The gentleman with Dr Pisharoty was Dr. Ananthakrishnan.

IITM was then called only ITM (Institute of Tropical Meteorology). I joined as an Air India Research Fellow on April 15, 1969, at Ramdurg House. It was a Monday. Space was extremely tight in the building and the Reserch Fellows were seated in the office of the Administrative Officer. Though the arrangement was odd, Mr. Sharma, the Administrative Officer was a friendly person and I felt I was in good company.

The same day in the evening, I was called upstairs to the Director's office and Dr. Ananthakrishnan shook hands with me. In a few minutes, we were up on the roof and he showed me the theodolite pedestal that he had constructed. He explained to me how the theodolites would be used to measure the cloud heights. We were down in his office and he showed me his notes on the trigonometry of triangulation that he had created from the first principles. He took fancy in the fact that I knew photography and then we were off at the backroom shed, which was used as a Photography Laboratory. Mr Puranik (the Photo Laboratory Manager) was still there around at 8 PM and gave us a tour. Dr. Ananthakrishnan paced from building to building and I followed him as a respectful pupil. He had a knack of introducing a student to the individuals and it all happened on the first day of my arrival. I was going to be 21!

The next several weeks were very interesting in setting up the experiment and reworking the trigonometry. Our second theodolite was at the Agricultural Observatory, about a mile away and we would use the ITM vehicle to commute. Mr. Pappu, the driver of the vehicle, was extremely loyal to Dr. Ananthakrishnan and was a sincere employee. The success of our work was very much due to the timely availability of Mr. Pappu.

One evening, while returning from the second site, Dr. Ananthakrishnan said that we would be meeting the next morning at 4 AM for the pole star observations in order that the theodolite scales could be calibrated. (We observe early morning to get relief from air turbulence. We have to choose the days of observation depending on the projected sky conditions.) I gave a puzzled look at Mr. Pappu. Dr. Ananthakrishnan intervened – 'Mr. Pappu doesn't have to come. I'll drive you up.' Life was certainly getting interesting.

We took pole star observations on several days to get a mean position for calibration. During such occasions, Dr. Ananthakrishnan would tell me about his life as a research student with Sir C. V. Raman. I had done some work in night sky spectroscopy before and had some experience on long exposures and continued experimental failures. He would counsel on the accuracy of the experimental procedures and the need for good record keeping. With the weak theodolite objective the pole star was a difficult object to observe even at the tranquil environment of 4 AM. However everything was written down in the light of a small flashlight in the coolness of early morning. He would write himself and saw to it I did my part.

We worked through the summer and had thousands of cloud photographs tabulated and measured. For the first time on Indian soil, we established that the cumulus cloud bases could be as low as 600 meters and the altocumulus cells could be at 6 km height with 3 km to 6 km in lateral dimensions. The cirrus was easy to measure and we established that the summer cirrus over Poona formed at about 13km height. How the moisture gets pumped there and how the cirrus could be used as a precursor to large systems were questions of dynamical importance. Dr. Ananthakrishnan made sure that the synoptic forecast group of the India Meteorological Department connected the upper atmosphere humidity to medium range forecasting. A detailed report of our study was published as an ITM Scientific Report in November of 1969.

Being a physicist by training, Dr Ananthakrishnan was not comfortable with the correlation analysis of physical phenomena. While working as the Deputy Director General of Forecasting in India Meteorological Department, he had real issue with the adopted techniques of the long range forecasting of weather events. From a physics point of view, everything on earth points to the sun and there was work in the west about the solar influence on the terrestrial weather. There were some climatological studies correlating solar flares and rainfall. Parallel with our cloud studies, Dr. Ananthakrishnan asked me to look into the solar flares and their effect on the surface pressure. Russians were active in the field at that time and my training in Russian helped me to translate a few key papers and understand their work. They were finding an increase in surface pressure on the fourth day after a solar flare passes the earth-facing sector. Pressure rise in some stations should potentially lead to pressure fall in some other stations, and Dr. Ananthakrishnan's idea was to check the effect at the Indian stations. He knew people at the Colaba Observatory and had personal contact with Dr. Vaini Bappu in Kodaikanal.

We had a massive data gathering and concentrated work for a couple of months. "Superposed Epoch Analysis" could work when the signal strength is high. We had mixed results, not very consistent. I suggested that I undertake a global study and try to understand the mechanism that could connect the surface pressure to the solar emissions. He did not think it would be a tractable idea in the limited time I had. Then one afternoon, he spoke to me about the geographical trends in the pressure tendency variations.

Sir John Eliot, among his many contributions to meteorology, had observed simultaneous pressure drop in wide areas of Indian Ocean region and periodic variation of pressure tendencies had been noticed at many observation stations. Dr Ananathakrishnan was fascinated to know how wide a region such simultaneous fluctuations might extend. I was not much interested in local phenomena and suggested that we might undertake a larger study. As a research scholar, I also had to think if the work could lead to a good dissertation. Dr. Ananthakrishnan smiled and said 'There is a whole stack of IGY data that nobody has opened yet. If you can make use of it, you will serve the Department well. Try, but you have to check the data very well.'

He immediately assigned Mr. J. M. Pathan as an Assistant to me. Mr. Pathan was a sincere and friendly person, and more importantly, very hardworking. Fresh from college, he wanted to work and learn. We proceeded to the vaults of India Meteorological department and located the hundreds of dusty trays of computer cards. International Geophysical Year was launched from July 1, 1957, to December 31, 1958, to watch the earth during the period of a maximum of geomagnetic activity. The India Meteorological Department had procured a full set of data with a significant investment. I made a global grid of stations that were approximately five degrees apart in latitude and thirty degrees apart in longitude. There would be data blank areas over the world's oceans and we had to compromise in finding nearest neighbors. In order to get coverage and with the phase angles in view, we chose the 12 GMT observations around the globe.

Computers were new and ITM was home to an IBM 1620 machine that was installed at Ramdurg House. Our first task was to make simple subtractions to determine the daily pressure tendency. As we did on the computers, Dr. Ananthakrishnan did by hand. He would get amused by the numerical round-offs and particularly with the computer going wild with a bad data point in sequence. He would counsel me on the propagation of errors in experimental work and I would try to convince him about the logic of a machine code. While I thought he was old school, I myself have made a practice of doing sample hand calculations before engaging in large voluminous work. Dr. Ananthakrishnan's hand calculations were instrumental in making sure that our data cards were properly sequenced and reviewed.

We first observed individual station data in long time sequences and did notice the periodic sign reversals in pressure tendency. A quasi-periodic rate of change appeared to be a signature property, two to three days of successive drops would be followed by a similar epoch of rise. This was both interesting and we were getting curious. Dr. Anathakrishnan would be quite animated to observe the pattern and would proceed to work on data from new stations. I learned new computer skills and put together a Fortran code to compute power spectral estimates. Work became intense with stationarity, filters, covariance calculations and statistical significance. Dr. Ananthakrishnan helped me in understanding the statistical estimation theories. We wrote several papers and reports. I prepared a report to Monthly Weather review for publication. More extensive work was reported in symposia and IITM scientific reports. We were working sixteen to eighteen hour days.

Dr. Ananthakrishnan retired from the position as the Director of the Institute in 1971 and was succeeded by Dr. K. R. Saha. He vacated his official residence and lived in an apartment in a colony a block away from Ramdurg House. Here he had peaceful reflections on to life, purpose and philosophy. He was strongly influenced by the writings of philosopher J. Krishnamurti and loaned me several volumes from his collection. "We are human beings first and never ever our humanity must be compromised for any personal gain." This was a strong statement and not easy to practice. We would be watched every minute of our life if we vouch to practice the principle. Dr. Ananthakrishnan was finally in a period where he could pursue the philosophy freely. Personally I have been attracted to the principle, but nowhere close to Dr Ananthakrishnan's ideals.

I visited the National Center for Atmospheric Research, USA, as a visiting scholar during the summer of 1972 and returned back to complete my thesis. I needed to stay in India for family reasons and needed an employment since my Fellowship was coming to a close. As luck would have it, the employment did not materialize in the newly formed autonomous institute. This was the time when Dr. Ananthakrishnan became a personal mentor to me. He counseled me not to break down and advised me to make an appeal to the Governing Council of the Institute to consider a position. I took my plight to many notable scientists and the efforts did not yield any results. While I was resigned and exhausted, he directed me to meet Dr. Koteswaram, the Director General of the Observatories, in New Delhi. Dr. Koteswaram was kind and a new IMD Scholarship was instituted, of which I was the first awardees. Dr Anathakrishnan was a person of patience and fortitude during this period of my life.

In this period of uncertainty, I had applied to graduate schools in the US and was accepted at the Massachusetts Institute of Technology. In July of 1974, a telegram showed up from Geneva that I had won the World Meteorological Organization Award for Young Scientists. Dr. Ananthakrishnan was overjoyed. He reminded me again – 'Mr. Misra! Never feel let down in life. Our humanity is our greatest test.'

Dr. Ananthakrishnan encouraged me to complete the thesis and it was submitted to Poona University in September, 1974. He remained as a mentor and inspiration till I left Poona and loaned me funds for my passage. While the period was difficult for me, Dr. Ananthakrishnan's intellect and affection guided me through.

Dr. Anathakrishnan was a life-long student and a voracious reader. No topic on earth was alien to him and he would take interest in plants, sky and life in all forms. Never one would find him irritated or uncheerful. His best personality was when anyone told him his or her grief, which he mostly sought out. He was above politics and petty discussions and understood the banes of egotism as he saw them. He was a quick-thinker and I must confess, he was a hard task-master.

Dr. Ananthakrishnan was a staunch nationalist. He loved India, her heritage, culture and literature. He was offended if India's position was belittled in any manner, and did his best to uphold the reputation of decency and integrity of Indian people. By being approchable to all irrespective of position or power, he practiced the humanity that he often talked about in private meetings. A child-like laughter and a deep scientific curiosity were the ornaments in his personality. A good friend, he would not let down a friend, and, he would rescue a student at the expense of his own resources! Ethics came to him higher than any other attribute and he reinforced his ethics via austere religious practice (morning visits to a local shrine was a daily ritual for him.)

Dr Ananthakrishnan was in the tradition of those eternal experimentalists, for whom the means are always more important than the goal. While we tread our path with discipline and complete respect to our humanity, we learn from the path we tread. We may think knowledge as a goal, but there is more to know where we walk than where we reach. An honor to the scholarship of Dr. Ananthakrishnan is an honor to the path we walk. He would say "Observe!"

* * *

Bijoy M Misra was a student with Dr. Ananthakrishnan from 1969 to 1974. He attended MIT from 1974 to 1976 and then became a Technical Staff Member in MIT Energy Laboratory. He joined Harvard-Smithsonian Center for Astrophysics in 1982 and worked as a Computer Scientist till 1992. He taught and led research in electronic imaging at Harvard University from 1992 till 2002, when he joined General Dynamics Corporation as a Consulting Physicist. Currently he is at MIT Lincoln Laboratory, Lexington, Mass. besides engaged in research in various areas of Physics and technology, he has been active in Indology, linguistics, and education.

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Abstract

Measurements of aerosol optical depth (AOD) have been carried out from a high altitude location, Nainital (29.4^{o}N, 79.5^{o}E; 1951 m above m.s.l) situated in the Shivalik ranges of Central Himalayas, using a 10-Channel Multi-Wavelength solar Radiometer (MWR) under the ISRO's Geosphere Biosphere Program (Sagar et al., 2004). The temporal variation of AODs exhibited a well-behaved seasonal variation, with a maximum occurring during summer/pre-monsoon season (March to June) and minimum during winter and post-monsoon season (January, February and September). These results are compared with AOD measurements made using CIMEL Sun Photometer under NASA's AERONET program (Holben et al., 1998) at nearby urban location Kanpur (26.4^{o}N, 80.3^{o}E; 142 m above m.s.l), which is located ~350 km away from Nainital (Dey et al., 2004). The implications of the results will be presented.

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Aerosol Optical Depth over Arabian Sea: Effect of Long-Range Transport

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Abstract:

Investigations on the spatial distribution of spectral aerosol optical depth (AOD) were made over the Arabian Sea and tropical Indian Ocean during January to March of the years 1998 and 1999 using a 10-channel Multi-Wavelength solar Radiometer (MWR) and 4-channel Eko Sun Photometer (ESP) onboard Oceanographic Research Vessel (ORV) Sagar Kanya, during the two field phase campaigns of Indian Ocean Experiment (INDOEX).

The results revealed regions of high AODs near coastal India, which gradually decreased on moving away into the northern Indian Ocean [North of Inter-Tropical Convergence Zone (ITCZ)] and then more rapidly over the southern Indian Ocean (across the ITCZ). over and above this general pattern, the results showed a region of enhanced AODs (termed as ‘West Asian High’) over Central and Western Arabian Sea, far away from the Indian subcontinent and separated from the coastal high values by a region of low AODs. This feature was consistently observed during both the years (1998 and 1999). The occurrence of high AODs over oceans farther away from the continents are indicative of long-range transport, in the absence of any local production. This aspect was examined with the help of air back trajectories worked out following the HYbrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT 4) model of National Oceanic and Atmospheric Administration (NOAA). Results indicate that the air trajectories from West Asia and in some cases even from East Africa have a significant impact on the spatial distribution of the AOD over Arabian Sea. Even for the locations closer to the Indian subcontinent, the air trajectories from West Asia had a significant effect.

Columnar Size Distribution of Aerosols over Arabian Sea and Tropical Indian Ocean

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Abstract:

Investigations of spectral aerosol optical depth (AOD) and retrieved columnar size characteristics were made over Arabian Sea and tropical Indian Ocean during the northern hemispheric winter season (January to March), based on the extensive ship borne measurements using a 10-channel Multi-Wavelength solar Radiometer (MWR) and 4-channel Eko Sun Photometer (ESP) during the Indian Ocean Experiment (INDOEX) campaigns in 1998 and 1999. The columnar size distributions (CSDs) were retrieved from the AOD spectra following the constrained linear inversion technique (Saha and Moorthy, 2004).

The columnar size distributions over the oceanic regions to the north of the ITCZ were either bimodal (BM) or power law + uni-modal (PL+UM), with the primary mode not explicit. To the south of the ITCZ, they tend to be unimodal. The aged background aerosols in the southern Indian Ocean gave rise to the UM distribution, when the main production mechanisms are less effective. When these are also significantly active (during period of high wind speeds), the distributions changed to BM, with the secondary sea-salt mode also becoming conspicuous. The number concentration of accumulation mode aerosols and mass loading were high at all locations lying to the north of the ITCZ and they decreased remarkably to the south of the ITCZ. Associated with this, the effective radius showed a three fold increase from very low values over coastal Indian and central Arabian Sea to remarkably high values to the south of the ITCZ. The coarse aerosols concentration did not show any significant variation over the entire oceanic region, indicating the origin of these particles to be different from that of the sub-micron particles.

References:

Auromeet Saha, and K.K. Moorthy, Impact of precipitation on aerosol spectral optical depth and retrieved size distributions: A case study, *J. Appl. Meteorol.*, 43, 902-914, 2004.

Measurements of $PM_{2.5}$ and PM_{10} particle concentrations and their Chemical Composition in Kolkata, India

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Abstract:

Kolkata city, the second-largest metropolis in South Asia is centered on latitude 22°34'N and longitude 88°24'E. With high population density and increasing vehicular emissions have been degrading the air quality severely here since a decade. During the period of 1Nov 2003 to 31 March 2004, $PM_{2.5}$ and PM_{10} concentration were measured at three different urban sampling sites (Park Street, Salt Lake and Minto Park) in Kolkata Metropolitan City, India. Daily PM_{10} and $PM_{2.5}$ samples were collected using Anderson high volume samplers and the concentrations of Benzene Soluble Organic Fraction (BSOF), heavy metals were quantified.

Recent epidemiological studies (Dockery et al., 1993) have suggested a statistical association between health effects and ambient fine particle concentrations, especially the submicron fraction that can penetrate into the alveolar region of the lungs. There is an abundance of mass concentration of, distribution, and chemical component measurements for ambient $PM_{2.5}$ and PM_{10} in many urban and heavily industrialized areas. However, much less is known, and even less has been done about $PM_{2.5}$. Fine particles in urban areas arise predominantly from the gas-to-particle conversion process with in the atmosphere, or they consist of secondary anthropogenic combustion products originating mainly from vehicular traffic and energy production (Kleeman and Cass, 1998; Chaloulakou et al., 2003; Lin and Lee, 2004). The research presented in this study is intended to provide knowledge on the concentration and chemical composition of fine particles.

$PM_{2.5}$ and PM_{10} samples were collected by two high volume samplers manufactured by Thermo Anderson, USA. All filters were maintained in a condition of 50% RH and 25°C for over 24h and then weighted (Mettler Toledo, Germany) with precision 10 µg before sampling. The high volume samplers were operated at flow rate of $68m^3$/hr. Both $PM_{2.5}$ and PM_{10} were collected on 20.3cm and 25.4cm Whatman quartz microfibre filters. $PM_{2.5}$ and PM_{10} samples were collected for 24h simultaneously at three different sites (Table 1). Locations of the sites are shown in Fig 1. After sampling, the loaded filters were conditioned and weighed again to determine the mass concentration of the filtered particles. The ratio's of $PM_{2.5}$/ PM_{10} were 0.61 and 0.76 at Mino Park and Salt Lake, respectively. These results indicated that the concentration of $PM_{2.5}$ contribute the majority of PM_{10} fraction. In winter the PM_{10} concentrations of exceeded the National Ambient Air Quality Standards (NAAQS) i.e.500µg/m^3, India whereas daily $PM_{2.5}$ concentrations exceeds the USEPA 24-h average concentration (i.e.60µg/m^3). Seasonal variation of $PM_{2.5}$ and PM_{10} was significant, with the highest concentrations observed from mid-November through January and lowest in March.

For, Heavy metals analysis the filters were digested using a laboratory microwave extraction system to extract metals with a HCl/HNO_3 acid solution (USEPA Methods IO 3.1) and analyzed by ICP-AES (Perkin-Elmer, 2002). Concentrations of heavy metals like Pb, Cd were exceeded the WHO standards and indicates the intensity of vehicular emissions and other anthropogenic sources.

Benzene soluble organic fraction was computed extracting 10 cm^2 of the deposited area of the filter in benzene. Extensive ultrasonication was employed for extraction of the organic phase solubles from the particulates and the estimate was done gravimetrically evaporating out the benzene and conditiong the test tubes in desiccators for at least 18 hours. Thus the mass fraction of BSOF was 12% higher in $PM_{2.5}$ than PM_{10}. It could help in the determination of Poly Aromatic Hydrocarbons (prone to cancer) and exposure to inhalable particulates (i.e. fine and coarse particles).

Table 1: Summary statistics for particulate measurement at three monitoring sites from November 2003 to March 2004

Station	**? g/m³**	**Max**	**Min**	**Mean**	**SD**	**$PM_{2.5}/PM_{10}$**	**BSOF**	**BSOF (%w/w)**
Park Street	PM_{10}	637.70	127.02	288.74	112.22	0.55	47.02	16.28
	$PM_{2.5}$	363.63	69.14	158.59	69.11		34.76	19.14
Salt Lake	PM_{10}	602.63	45.10	191.58	143.53	0.76	49.31	16.62
	$PM_{2.5}$	537.77	21.11	128.72	112.37		44.87	20.30
Minto Park	PM_{10}	508.67	83.02	283.77	133.68	0.61	38.34	14.14
	$PM_{2.5}$	330.85	53.94	172.39	83.61		31.34	19.08

In future to understand the quality of air at Kolkata or any metropolitan city PAHs analysis should be done. Since the measurements and conclusions obtained in this study are initial and preliminary due to the small amount of data, further research on the chemical composition, source contribution, and formation of submicrion or nanoparticles in urban area needs to be carried out.

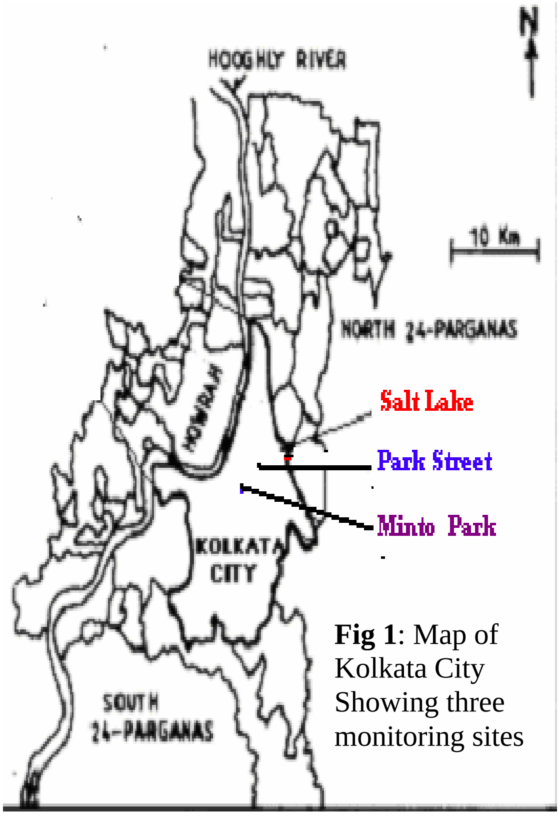

Fig 1: Map of Kolkata City Showing three monitoring sites

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Monitoring of Tropospheric Ozone at Chennai City

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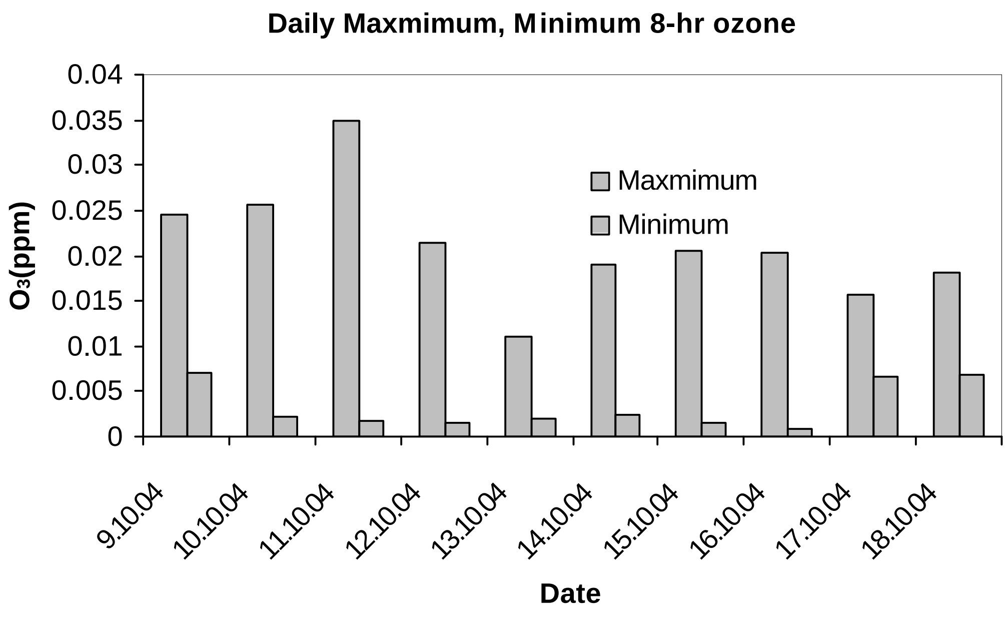
Abstract:
As per the National Ambient Air Quality Standard (NAAQS) the ozone standard is attained when the expected number of days per calendar year with a maximum hourly average concentration above 0.12 ppm (235μg/m^3) is equal to or less than 1. In, Environmental Protection Agency (EPA) adopted New 8-hr standard for ozone, requires that a community's ozone levels be no higher than 0.08 parts per million when averaged an 8-hour period [1]. Several studies have been made concerning the ozone behavior in the natural troposphere. However, information about 8- hour standard has not yet been reported in our continent. Hence, Tropospheric ozone concentrations were measured continuously for the period of 10 days during the North-East Monsoon period (September–November) at Chennai city.

Continuous measurement of ozone is made by UV-absorption based analyzer, and averaged data were collected at 15-min interval. This technique is standard and well known. More description of the system used in this includes its calibration, Zero checking, maintance and other details have been given elsewhere [2]. The twenty-four 8-hour averages ozone concentration for a given day were calculated based on the EPA Guideline [3]. The average 8-hr ozone concentrations are between (0.034) and (0.0009 ppm)(Fig-1). The values of Troposphere ozone concentration at Chennai City were below the US NAAOS standard (0.080ppm, maximum 8-hr permissible concentration). The 10 day average concentration of surface ozone in above monitoring period was higher than Nilgiri Biosphere Reserve were have been recorded at April [4].



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Backscatter Lidar Observation of the Aerosol Stratification Above Neuchâtel (Switzerland) During Winter Bise: a Case Study

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Introduction

The 'Bise' is a regional wind system in Switzerland midlands (Fig. 1), being channeled between the Alps and Jura mountain ranges (see Wanner and Furger, 1990 for details). The basic cause of Bise is a northeast-southwest (NE-SW) pressure gradient of the order of 1 hPa / 100 km or more at the 850 hPa level and it decreases substantially the surface temperature along its pathway.

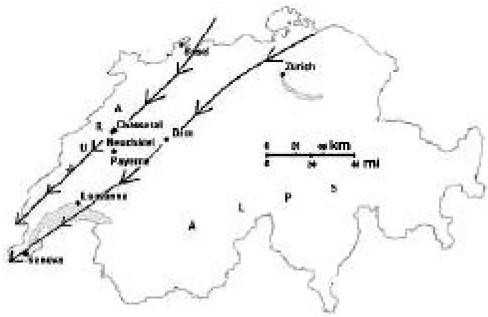

Figure 1: Bise flow and location of Neuchâtel in the Swiss-Midland.

The objective of this work is to observe the altitude profile of the aerosol backscatter coefficient (ABC) in the free troposphere during one Bise case, effected the Neuchâtel, Switzerland (47.00^{0}N, 6.95^{0}E, 488 m asl, Fig. 1) during Dec. 5-18, 2001. using a ground based backscatter Lidar system; and further to analyze the observed ABC for the character of the Bise as aerosol transportation character (as suggested by Furger et al., 1989, Wanner and Furger, 1990). The observed ABC are traced back using FLEXTRA back trajectories (Stohl et. al., 1995).

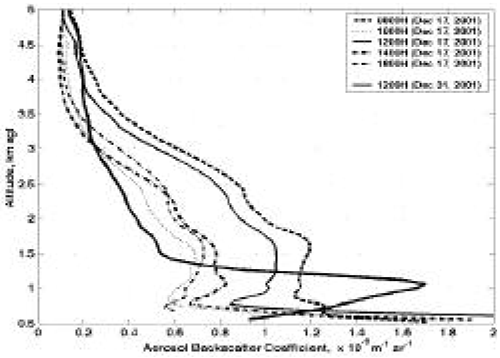

Figure 2: ABC for Bise (Dec 17, 2001) and non-Bise days (Dec 31, 2001).

Used Lidar and weather during the Bise event:

Details of the backscatter lidar is described in other studies (e.g. Frioud et al., 2003). A vertical resolution of 60 m and time resolution of 30-50 minutes is considered for the present study.

During Dec. 5-18, 2001, it was a clear sky for most of the days except Dec 13-14, 2001. Temperature variation shows a sharp drop on Dec. 6 (morning) within a time span of few hours for Neuchâtel; along with changes in wind speed and wind direction, resulting to the strong winds from NE. The temperature drop and the strong wind from NE indicate the onset of the Bise flow for the region.

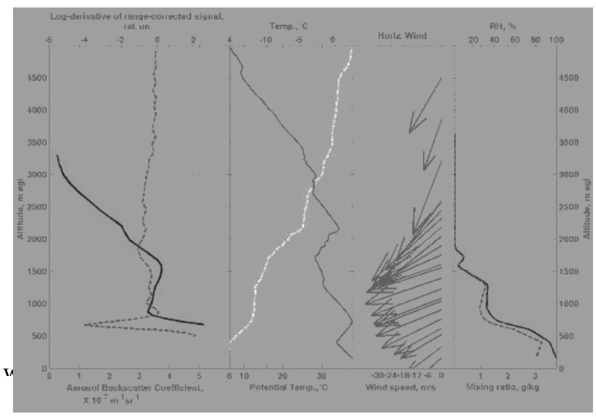

Figure 3: Lidar derived aerosol parameters and weather parameters for Dec. 7, 2001 for Neuchatel.

Results and Discussion

Figure 2 presents successive ABC profiles with 2 hours intervals observed during the Bise day of Dec. 17, 2001. For a comparison we presented ABC profile measured during the non-Bise day (Dec. 31, 2001, noon). The altitudes for the sharp decrease in the ABC value on the profiles from Dec. 17 show two aerosol layers above the planetary boundary layer (PBL) top for the entire day, with maxima at around 1.5 km agl and 2.5 km agl. The ABC values for these maxima vary between 0.5-1.2*10^{-6} (m sr)$^{-1}$ at 1.5 km agl and 0.4-0.9*10^{-6} (m sr)$^{-1}$ at 2.5 km agl. For non-Bise day, the ABC value above PBL shows a sharp drop to lower values i.e. 0.5*10^{-6} (m sr)$^{-1}$. Figure 3 is a representative figure for altitude profiles of meteorological parameters as well as the profiles of ABC and the corrected signal gradient of the lidar signal for Dec. 7, 2001. The Bise was fully established with a layer depth till about 3 km agl on Dec. 7, 2001 and it is also evidenced in corresponding meteorological parameters. Aerosol layers are seen extending from around 1.0 km agl till 3-3.5 km agl, demonstrating maxima at around 1.5 km agl and 2.5 km agl for all the effected Bise day. These aerosol layers occur above the temperature inversion and coincide with the layer of the strong northeasterly Bise wind. Relating to low RH at aerosol layers, suggests that the aerosol layers are not influenced by the relative humidity (due to an increase of the aerosol particles size, Dupont et al, 1994), rather, these layers are due to the increase of the aerosol particles number density likely connected to the Bise. Arrays of three-dimensional 10-day back trajectories for Dec. 7 and Dec. 17, 2001 at 1200 local time (Fig. 4 a and Fig. 4 b respectively) suggest that on Dec. 7, the back trajectories end near North American west coast at low altitudes and over Arctic region. And on Dec. 17, all back trajectory spiral around the high-pressure region over Great Britain and some of the other back trajectories pass through low altitudes over the North Sea and northern Europe. These all suggest air mass containing aerosol from more than one potential source, and most likely is finer sea-salt aerosols from the top of mixing layer and/or the lower troposphere above the ocean (Jaenicke, 1993).

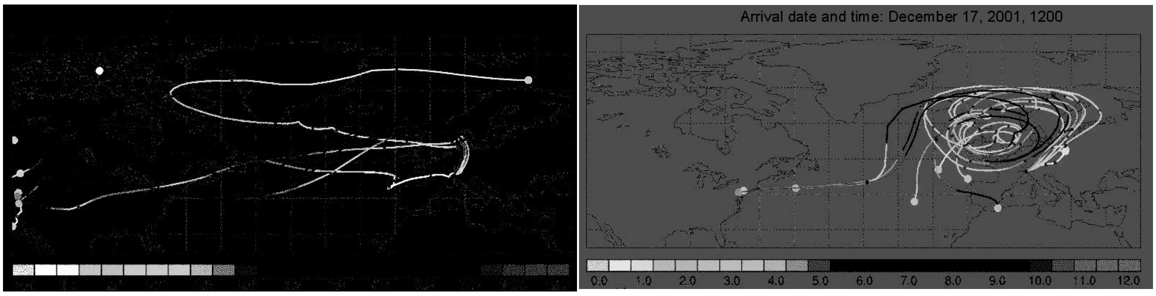

Figure 4a,b: Back trajectories for Dec 7, 2001 and Dec 17, 2001 for arrival at Neuchatel.

Conclusions

Aerosol layers (1.5 km and 2.5 km agl) are observed for Bise event. A 10-day back trajectory shows a rather complex origin of the observed layers with a variety of possibly contributing sources. The Atlantic Ocean is likely determining the basic contribution with a fine fraction of sea-salt aerosols from ocean surface.

Acknowledgements

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Characterisation of the Boundary-Layer Aerosols Using LIDAR

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Abstract:
The role of atmospheric aerosols (both natural and anthropogenic) in various atmospheric processes is being increasingly realized by several scientists. The radiative forcing due to aerosols is a hot subject in the scientific community, as some of the aerosols cause cooling (for example, sulfate aerosols) while others make heating (for example, soot particles), which results eventually in the local and/or global climate change (Charlson et al., 1992). Studies have shown that aerosol also can affect the cloud properties like lifetime, height, albedo, etc and so they influence the precipitation (Rosenfield, 2000). The aerosols also play a significant role in the indoor air quality, material damage, occupational risk, pollution, residues, health (Mustafa et al., 1992). Thus the aerosols have great importance in environmental studies (Devara et al., 2002).

A large portion of atmospheric aerosols is contained in the boundary-layer. The linkage between aerosols and meteorological parameters can be used to study the lower atmospheric dynamics (Murayama et al., 1999). The heating due to absorbing aerosols in the boundary-layer can inhibit cumulus cloud formation by stabilizing the layer and reducing the relative humidity. The direct measuring instruments (like Optical Counters) give good temporal resolution, but the active remote sensing technique (like LIDAR) gives high spatial and temporal resolution (Devara, 1998). Due to these unique advantages, among others, the lidar technique is being widely used for the study of aerosols all over the globe.

In the present paper, different LIDAR techniques such as DIAL, Doppler, Raman, Fluorescent for studies in Atmospheric Science are briefly described. It also explains details of the bi-static Argon-ion lidar system, available with the IITM, Pune, and its direct application for retrieving the aerosol properties such as particle concentration, size distribution, extinction coefficient and optical depth (hence visibility). Added, application of this facility, using aerosols as tracers, for retrieving information on some of the parameters like boundary-layer structure, stratification, mixed layer / stable layer heights and their role in environmental pollution / air quality, will also be presented.

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Study of aerosol optical depth at 1020 nm and precipitable water content at Udaipur

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Abstract:

Measurements of aerosol optical depth (AOD) and precipitable water content at 1020 nm and 936 nm, respectively have been made at Udaipur (Geog. Lat. 24.35' N, Geog. Long. 73.42" E) using Microtops II sun photometer. The photometer measures the direct solar radiation at 305, 312,320,936 and 1020 nm using narrow-band interference filters. The filters have a full width at half maximum of 2.5 nm for UV radiation and 10 nm for IR radiation. The field-of-view of each optical channel is 2.5^o.

The observations have been made over a period of about two years during the years 2002-2004. The aerosol optical depth at 1020 nm is found to be minimum following the monsoon months and is highest during the pre monsoon periods. This is in qualitative agreement with the results obtained at other Indian stations[1-4]. The precipitable water content during the same period is found to follow a similar trend. The monthly distribution of the most frequent AOD is also obtained. The anuual average value of the AOD thus obtained is found to be about 0.3 with a standard deviation of about 0.15.

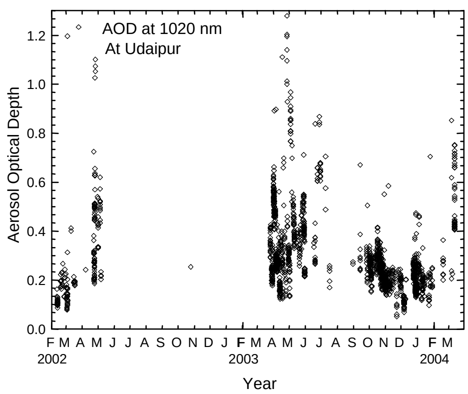

Fig.1 Variation of Aerosol optical depth During different months over a period of two years

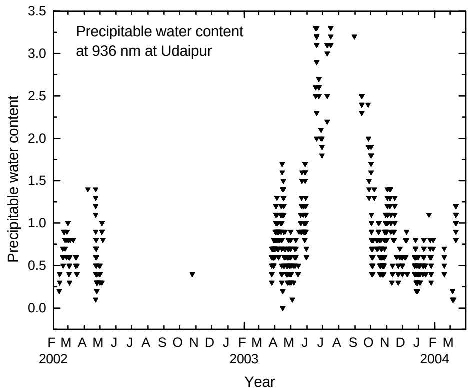

Fig. 2 Variation of precipitable water During different months over a period of two years

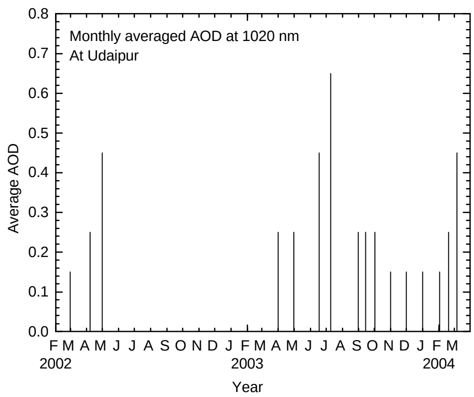

Fig. 3 Monthly averaged AOD values over a period of two years

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Pandey R and Vyas B. M, "Study of total ozone, precipitable water content and aerosol optical depth at Udaipur, a tropical station, Curr. Sc. 305-309, 86, 2004.

Study of Variations in Columnar Ozone Concentration at Rajkot

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Abstract:

The ozone data obtained from Total Ozone Mapping Spectrometer (TOMS) and Solar Back scatter Ultra Violet spectrometer (SBUV) on Nimbus 7 satellite have been used to study the variability of the total column amount of ozone and ozone concentration in different atmospheric layers respectively at Rajkot (22.3^{0}N, 70.8 ^{0}E) over a period from 1980 –2004. An examination of the monthly mean values obtained from TOMS indicates a marked seasonal variation with a maximum around June and a minimum around December. The SBUV profile of springtime ozone indicates that the stratospheric ozone concentration at Rajkot has decreased consistently from 1982 to1999. The concentration is found to have increased suddenly in 2000 and further in 2001. Thereafter it decreased in 2002 and again increased in 2003. An insignificant overall downward trend is observed in the total column amount of ozone (0.85%) from 1997 to 2004. Latitudinal variation of ozone from Srinagar to Kanyakumari has also been studied, which indicates an increase in ozone concentration with latitude. The results are discussed in the light of photochemical and dynamical effects.

Introduction:

One of the most important constituents in the middle atmosphere is ozone, because it is the only atmospheric species that effectively absorbs ultraviolet solar radiation from 2000 ^{0}A to 3000 ^{0}A, protecting plant and animal life from exposure to harmful radiation. Hence a decrease in stratospheric ozone will result in an increase in ultraviolet B radiation, which will have negative impacts on human health. However as ozone is toxic to the living system, elevated tropospheric ozone concentration will damage the tissues of plants and animals and will also cause the temperature of the atmosphere to rise. Thus there is a great need to monitor the atmospheric ozone concentration. For the past several decades, ozone has been regularly monitored on a global basis by means of Total Ozone Mapping Spectrometer (TOMS) and Solar Back Scatter Ultraviolet Spectrometer (SBUV) carried on Nimbus -7 satellite. These methods require the sun as the background source of radiation and are therefore limited to daytime observations in good weather conditions. The tropical region has special significance since most of the ozone is formed in this region due to availability of the high dose of solar UV radiation.

Results and discussions:

(A) Seasonal variation:

A clear seasonal variation that is repeated consistently year after year is observed. The ozone concentration is found to be maximum around May –June. It decreases during monsoon and autumn and reaches a minimum in December. Thereafter it gradually increases throughout the winter and spring and reaches a peak in summer. This trend is consistently observed in all the years from 1996 to 2004. The observed seasonal variation in total columnar ozone at Rajkot is about 19% of the total column content from June to December, which may indicate a major contribution of Tropospheric ozone below 5 Kms.

(B) Solar cycle variation:

Variation of ozone trends with sunspot activity has been studied for Rajkot from 1980-2003.The observed variability of solar flux at wavelength < 3000 ^{0}A shows that the production of ozone is more sensitive to variations in solar UV output than the loss rate of ozone.

(C) Latitudinal variation:

The ozone concentration is found to increase as we move northwards from Kanyakumari to Srinagar, i.e. with increasing latitude. This is because ozone is produced at the tropics and then transported to the poles where it is relatively inert photo chemically. The Hadley cell circulation observed in India is different compared to that observed globally due to the presence of the Himalayas. The air ascends near 24^0N and descends in the higher latitudes near the Himalayas to give a pole ward drift in the upper air, with a return current towards $24\ ^0$ N at the surface. The upwelling of the Hadley cell circulation is usually felt up to the tropopause, but sometimes it also reaches the lower stratosphere. This reverse Hadley cell circulation may have a pronounced effect on the distribution of the ozone at different locations in the Indian subcontinent resulting in an earlier peak ozone concentration at Srinagar (34^0N) compared to Kanyakumari (8^0N).

(D) Trend analysis:

An insignificant overall down ward trend of 0.85% in the total columnar ozone is observed from 1996 to 2004, which may be due to the global decrease in CO concentration. The production of tropospheric ozone is mainly from CO and CH_4 in presence of hydrocarbons and nitrogen oxides. Hence a decrease in chemical fuels may ultimately lead to a decrease in production of NO_2, consequently affecting the ozone production.

The average ozone concentration from 1st to 15th March has been used to study the distribution of ozone and its variations in different atmospheric layers during springtime at Rajkot using SBUV data. It is observed that the stratospheric ozone concentration at Rajkot has decreased consistently from 1982 to 1999. This may be due to the catalytic destruction of ozone by compounds containing Bromine, chlorine, fluorine, carbon (chloro fluro carbons) and oxides of Nitrogen (NO_x), which are produced in the stratosphere by the reaction of O ^{1}D with N $_2$O (which is released from the biosphere below) and from the emission of supersonic aircraft. NO $_x$ is the most important destroyer of ozone in the 25-45 Kms altitude region. Br takes part in catalytic destruction of ozone and is 40 times more reactive than CL_2 in ozone depletion. The ozone concentration is found to have increased suddenly in 2000 and further in 2001. Thereafter it decreased in 2002 and again increased in 2003. This recovery may be attributed to the international agreements like Montreal Protocol to reduce emissions due to CFC'S. It is observed that the ozone concentration is different for different years up to an altitude of approximately 37.5 kms. Beyond 37.5 kms the O_3 profile is found to remain constant from 1982-2003. Maximum variation in ozone concentration is observed in the altitude range from 15.5 to 37.5 kms. Thus the variation in ozone concentration in this altitude range has a measurable effect on the total column amount of ozone.

Impact of Aerosol Particulate Matter Pollution in and around Mangalore Region.

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Abstract:
Atmosphere is very essential for all aerobic organisms even before water and food requirements. Monitoring of pollution, particularly in the troposphere is important in order to understand the anthropogenic emissions on the climate and health. Measurement of total suspended particulate matter (TSPM), characterisation of aerosols are some important parameters required for understanding the effect of anthropogenic activities on natural processes. It is also important to identify the sources and sinks for atmospheric materials, which play an important role in the cycling of contaminants in the various environmental compartments of the earth through aerosol dry deposition as well as wet removal.

The study area Mangalore is a part of southern west coast of India is under industrial expansion and urban development. There are 9 large-scale, 34 medium-scale and as many as 8200 small-scale industries functioning in the area. In this context, the physico-chemical properties of atmospheric particulate matter has been studied to trace local origin as well as long-range transport of aerosols. The soils of south-western India are characterised by the depletion of alkali and alkaline earth elements, but enriched with immobile elements due to the prevalence of high rainfall and humid climate. The aerosols were enriched with Na^+, Cl^-, NO_3^-, both sea-salt (ss) and non-sea-salt (nss)-derived cations Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, but strongly depleted in H^+ as compared to high rainfall regions in the tropics suggesting the potential input of sea-salt and mineral aerosol from arid regions surrounding the Arabian Sea. The main reason for atmospheric pollution is confined to be due to high aerosol loading with particulate contaminants like sulphate, nitrate, organic soot, fly-ash, etc.

Mapping of Aerosol Properties over Land using OCM-Land Data

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Introduction:

Suspended particulate matter present in the earth's atmosphere is known as aerosols. Particles of different physical, chemical and optical properties come under this category. Depending upon their properties they can either scatter or absorb the Solar and terrestrial radiation traveling through the atmosphere. These particles affect the earth's climate directly by attenuating the radiation traveling through the atmosphere and indirectly by modifying the cloud properties. They also affect scientific studies based upon satellite-based remote sensing techniques (Potdar et al. 2004). They exhibit large spatial and temporal variation and their effects on various processes are global in nature.

The properties of aerosol being studied using various point based measurement tool viz. Sunphotometer, Lidar and in-situ collected samples since long (Devara et al. 1995). Given the spatial and temporal variability of aerosols, ground based point observations alone do not meet the requirement of global mapping, though they provide the more realistic values of aerosol characteristics at the point of measurement. Because of instantaneous large area coverage of the satellites, with the use of satellite data it is possible to study aerosols on global scale (Kaufman et al. 2002).

In the present work a methodology to retrieve aerosol properties from the satellite data is reported. Also a primary analysis for studying the change in aerosol types and their distribution in time is reported.

Data used: For the present analysis, IRS-P4 Ocean Color Monitoring (OCM) land data and synchronously collected Ground based sun photometric data at IITM, Pune (Latitude: 18^o 32', Longitude: 73^o 48') and SAC Ahmedabad (Latitude: 23^o20', Longitude: 72^o31') are used to model and map the AOT at 412, 443, 500 and 670 nm. Overall 60 dates data for the years 2001 and 2002 at IITM Pune and for the years 2003 and 2004 at SAC, Ahmedabad were selected on the basis of atmospheric stability and sky conditions for the model development (Potdar et al. 2004).

Model Development and Analysis: The thick vegetation targets act as low background targets on land in the spectral region around 440 and 670 nm. This feature of the vegetation is due to the strong absorption by the leaf chlorophyll in the both the blue and red spectral regions. The spectral signature curve of the vegetation targets indicates that vegetation show low reflectance in green band as well. Therefore, the radiance from thick vegetation pixels consist mostly that due to the atmospheric Rayleigh scattering by air molecules, which is nearly constant at any wavelength, and Mie scattering by the aerosols. Hence, the radiance at 412, 443, 500 and 670 nm measured by the OCM sensor from thick vegetation targets are used for modeling the AOT at the respective wavelength. The thick vegetation targets are identified by the Normalized Difference Vegetation Index (NDVI) derived from the NIR and Red band data of the OCM. It is found that the radiances in the three channels decrease with increasing NDVI and ultimately reach asymptotic values at large NDVI > 0.5.

An 18 km x 18 km area centered at IITM Pune and similar dimension area centered at SAC, Ahmedabad are chosen. A plot of the radiance vs. NDVI is generated and by fitting a power law in NDVI, the limiting value of the Top of Atmosphere (TOA) radiances are computed. The measured radiances are corrected for the solar zenith angle and sensor view angle. These, then, are related to the AOT measured at nearly time of pass of the IRS-P4 satellite.

Models to retrieve AOT from the Top of the Atmosphere [TOA] radiance are developed. Model performance was checked. The modeled AOTs, angstrom exponent and turbidity coefficients are found to be in good agreement with measured ones at the point of measurement. Models are validated at a place named Daund, situated nearly 85 km east of Pune.

From the AOT vs ? ?curves size index were derived for the dates used in model development. Size index values can be grouped into three different groups corresponding to Dec.-Jan., Feb-Mar and Apr.-May time periods. This analysis shows that the mean size index for each group decreases significantly from Dec. to May.

Results and Discussion: We have got three different regression models for retrieving AOT at each of three wavelengths 412, 443 and 670 nm and two models at 500 nm. Model performances have been tested for the IITM and SAC sites and have been validated using an independent data set collected at Daund, which is situated nearly 85 km east of IITM Pune. Maps are generated for aerosol characteristics, viz. AOT, Angstrom exponent and turbidity coefficient, over an area of 200km x 200km centered at IITM, Pune. Different models representing different period of the year is an indication of some systematic change in aerosol types and their distribution from Dec. to May, which is responsible for the change in reflectance by the target. Temporal variation of the size index also exhibit similar trend. This also supports the possibility of change in aerosol types and their distribution in time. It should be noticed here that the analysis is done using data for three years and for two different places namely Ahmedabad and Pune.

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Study of Chemical Species in rainwater at a rural environment of Northeast India

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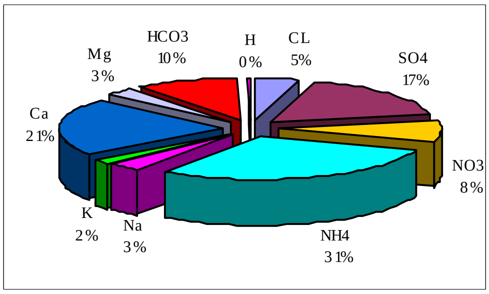
Introduction:

Chemical composition of precipitation succeeded to explain contents of the atmosphere through which it falls as precipitation. It is an efficient pathway for removing the gases and particles from the atmosphere. Since quality of rainwater varies from one place to other and one season to other, its chemical composition is highly dependant upon the location of site, topography, climate, natural and anthropogenic sources of acidifying compounds etc. Study of chemical composition at rural area along with urban is equally important to understand the role of natural sources over precipitation, and also, to study long-range transport of pollutants from urban areas.

Considering above, the present study is carried out at Ballia, a rural environment in northeast India during monsoon season of 2001.The site is quite and mostly free from vehicular pollution. Samples were collected and analyzed for pH, cations and anions using sophisticated instruments.

Ionic Composition of rainwater:

Figure1. describes the contribution of each ionic constituent to the total ion mass. General trend of the abundances of different chemical constituents is as follows:
$NH_4^+ > Ca^{2+} > SO_4^{2-} > HCO_3^- > NO_3^- > Cl^- > Na^+ > Mg^{2+} > K^+ > H^+$



NH_4^+, Ca^{2+} and SO_4^{2-} are the three dominant ions found in the Ballia rainwater samples. Role of these ions are more important to decide the acidity or alkalinity in the rainwater. The pH values are found to be in between 6.1 and 6.8. The average value is 6.32, which shows that rainwater samples are in alkaline range. Higher pH may be due to the influence of soil dust particles, which are suspended in atmosphere. Calcium ion shows second largest dominance among all other ions. Both calcium and ammonium acts as neutralizing agents for neutralizing the acidic effects due to presence of SO_4 and NO_3 in the form of their acids.

Correlation Analysis:

It was seen that, there is strong correlation found between Na^+ and Cl^-. Also, both of them show good correlation with Mg^{2+}. This indicates that some part of sodium, chloride and magnesium are brought from marine aerosols. SO_4^{2-} is observed well correlated with Ca^{2+}, since soil in this region is calcareous, it indicates the possibility of SO_4^{2-} associated with Ca^{2+} in form of $CaSO_4$. Good relationship of Calcium with marine components shows that marine particles may deposit on the soil of the region during monsoon period. Correlation of NH_4^+ with Cl^-, NO_3^- and SO_4^{2-} indicate existence of compounds of ammonium salt with chloride, nitrate and sulphate. Here NO_3 is more correlated with NH_4 than SO_4 indicating dominance of NH_4NO_3 over $(NH_4)_2SO_4$.

Marine contribution:

Equivalent ratios for different ionic components like Cl, Mg, K, Ca, and SO_4 are calculated with respect to sodium, by considering sodium of having marine origin. All the ratio values of Cl/Na, Mg/Na, K/Na, Ca/Na, and SO_4/Na for rainwater are found to be higher than that of seawater values. It gives indication of dominance of Non-marine contribution of above components and influence of anthropogenic and crustal sources. Similar result was obtained when we calculated the sea salt fraction (SSF) and non-sea salt fraction (NSSF), by considering sodium as the reference element.

Quantitative Analysis:

NH_4, Ca, Mg, K are considered as the neutralizing agents. To visualize contribution of each of them and their importance, neutralization factors [NF] for each of them are computed. The order of neutralization along with NF values was found as:

NF[NH4] (1.228) > NF[Ca] (0.859) > NF[Mg] (0.078) > NF[k] (0.072)

The result suggests that, major neutralization was occurred due to the contribution of Ammonia. A higher value of ammonia is mainly due to the agricultural fields around the site location. Calcium also shows significant contribution to the neutralization. Calcium is mainly comes from the calcareous nature of soil in the region.

To evaluate qualitative characteristics of ions in the rainwater, two types of indexes are computed. They are acidifying potential index (AP) and neutralizing potential index (NP). The relationship [NP > AP] holds good at our station, indicating that, although the value of [AP] is high, but in relation with it, value of NP was also high. The ratio of [NP/AP] gives clearer picture of balance between acidity and alkalinity.

It was seen that, the measured acidity of precipitation gives the value of acidity after neutralization. So original acidity was also computed, value of which indicates acidic nature of rainwater before neutralization.

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Ozone Weekend Effect over Pune (18°N, 73°E), India

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Abstract:
Surface measurements of ozone (O_3) and its precursors, have been taken regularly at a semi-urban site (IITM) in Pune (18°N, 73°E) during the last one-year period (2003-2004). To study the pattern of variation in ozone and its short-lived precursor namely NOx on weekdays and weekends, data have been analyzed on diurnal scale over the entire observed period. The variation in ozone is found to be more on weekends as compared to weekdays during the day hours and partially during nights. This phenomenon, which is called as 'Ozone Weekend Effect', occurs despite decrease in weekend abundance of major ozone precursors led by NOx but not for all hours. An overall 8% increase in peak ozone concentration and a decrease by 10% in peak NO_X values for weekends is observed. Strong positive and negative correlations are found between ozone and oxides of nitrogen when separated out for day and night period during weekdays and weekends respectively. The primary cause of the higher O_3 concentration on weekends and the day-night anomaly has been investigated in this work. It appears that the analysis strengthens the hypothesis of "reduced emission in NO_X on weekends" as one of the primary cause for increase in ozone concentration on weekends. The details will be discussed and presented.

Study of Atmospheric Aerosols at Pune

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Abstract:

Atmospheric aerosols are a mixture of solid and/or liquid particles suspended in air. Tropospheric aerosols generally have a substantial anthropogenic component. Because of variability in aerosol properties it is necessary to monitor their characteristics such as aerosol optical depth (AOD), their average and effective radius, etc. the authors have carried out ground-based intensity measurements of direct solar radiation using a suntracking multiple wavelengths radiometer (MWR) on cloud-free clear-sky days from the Environmental Sciences Department of the Pune University since 1998. These data are analysed to study aerosol characteristics and the influence of meteorological processes on them. The results are discussed in this paper.

Diurnal variation of AOD

Analysis of the Langley plots shows that on about 50% of observing days magnitude of AOD undergoes a change from the forenoon to the afternoon part of the observing day. On most occasions AOD decreases from forenoon to afternoon. Often this decrease in AOD occurs at all the optical wavelengths used in the observation while on a small number of days the decrease is prominent only at shorter wavelengths. Along with the decrease in AOD a change in the size spectrum of aerosol particles is also seen. Characteristics of this observed phenomenon are discussed in the light of the influence of local meteorological parameters.

Annual Variation of AOD

The AOD characteristics depend on the origin and removal of aerosols and the effect of meteorological and other processes acting on aerosol during its lifetime. In the urban environment the origin of particles is rather complicated. In addition to natural sources of aerosols there are dominant anthropological processes contribution to aerosol production. Due to these factors the observed characteristics of aerosols vary from year to year. The data are discussed with reference to observed spectral variation of AOD, aerosol size distribution and meteorological processes prevailing in different years.

Chemical Composition of Rainwater at Panipat Inside NCR of Delhi

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Abstract

The pH variation and the chemical characteristics of rainwater have been studied during the monsoon period of 2003 at Panipat an industrialized town of Hariyana under the National Capital Region (NCR) of Delhi. The pH varied from 4.78 and 6.88 with an average of 5.93 that is in alkaline range considering 5.6 as the neutral pH of rainwater with atmospheric CO_2 equilibrium. 28% rain events were observed in acidic range. The equivalent concentration of components followed the order: SO_4> Ca > NH_4 > NO_3 F > Na > Cl >Mg > K. The ratios of different components with respect to seawater ratios were observed to be higher, indicating the significant influence of non-marine sources at this area.

Introduction

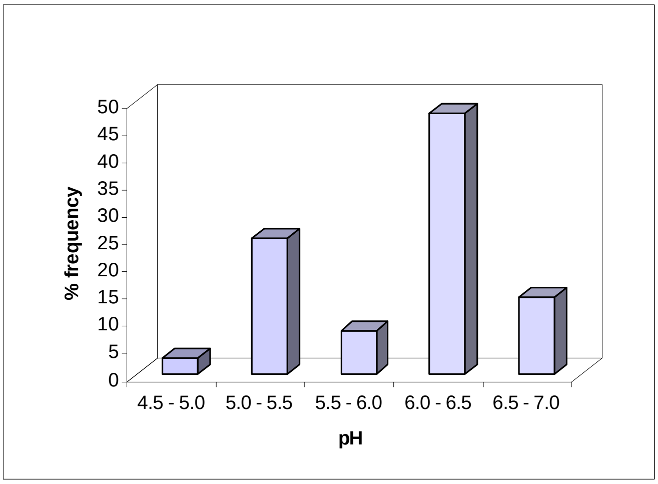
Rainwater chemistry has been the subject of intense research for the last two decades because of increased awareness towards environmental problems caused by acid rain. (Khemani et al. 1987b & 1993, Kulshresta et al., 1993 & 2003, Galloway et al. 1995). Nowadays, rural areas are vastly converted to urban and semi urban areas as a result of increased industrial development. Rainwater composition plays an important role in scavenging soluble components from the atmosphere and helps us to understand the relative contribution of different sources of atmospheric pollutants.

Site description

Panipat, Haryana, is 85 km away in north from Delhi and is an industrialized town. Thermal power plant, oil refinery, National fertilizer limited plant; textile, chemical, paper mill and dyeing factories are located there. It is a premier city of Haryana and lies downwind of Karnal where a major refinery is being established

Results and discussion

The relative percentage contribution of chemical composition of rainwater of each ion towards the total deposition is shown in fig.1. It indicates that about 55% of measured ionic composition was contributed by cations whereas, anions, contributed about 45%. From the figure, it is found that the contribution of chloride and sodium were mostly equal. The contribution of sulphate and ammonium shared the maximum concentration. SO_4 is derived from both anthropogenic and natural activities. Sulfate is also formed by the oxidation of sulphur dioxide emitted from the burning of fossil fuels and biomass in this area. The major sources of nitrate in this area in rainwater are emissions of oxides of nitrogen from automobiles, biomass burning and from soil also. Ammonium in precipitation emanates from the action of bacteria on nitrogen compounds in the soil and also from urine. It is also released from industrial plants. Bouwman et al. (1997) showed that, after china, India is the largest ammonia producer in the world. Being semi urban area, having a large number of factories, agricultural field and automobile emissions are the main cause of fairly high concentration of Fluorides in this region. The ratios of different components with respect to seawater ratios were calculated. The all ratios values are higher except sea salt indicating the significant influence of non-marine sources at this area.



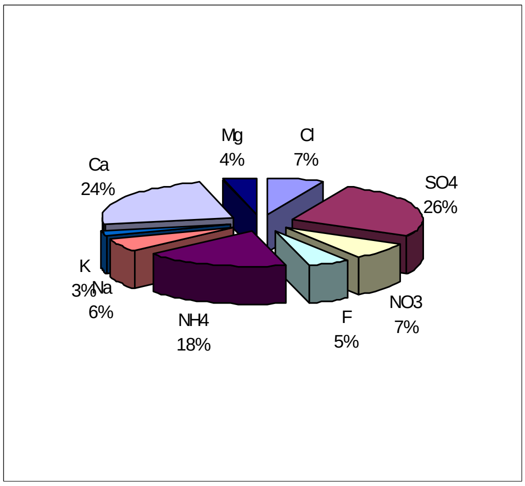


Fig.1: Frequency distribution of pH at Panipat
Fig.2: Relative percentage contribution of each ion towards the total deposition

Fig.2 shows the percent frequency distribution of pH for 35 rain events collected during the monsoon of 2003 at Panipat. Out of total rain events 28% reflects the pH of rainwater to be in the acid range as compared to 5.6 pH of rainwater at equilibrium with atmospheric CO_2. The observed acidity of rainwater is neutralized by sufficient loading of alkaline particulate matters in the atmosphere commonly abundant in Indian regions. The suspended particulate matter which is rich in carbonate /bicarbonate of calcium, buffers the acidity of rainwater. Due to high concentration of SO_4 and NO_3, in some cases rainwater is acidic in nature. It may be due to various reasons. The presence of national fertilizer plant Ltd. may be the one of the reason. Important neutralizing factor in the current study is the presence of high concentration ammonium and calcium.

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Some Characteristics of Dry Deposition at a Hill Station, Sinhagad

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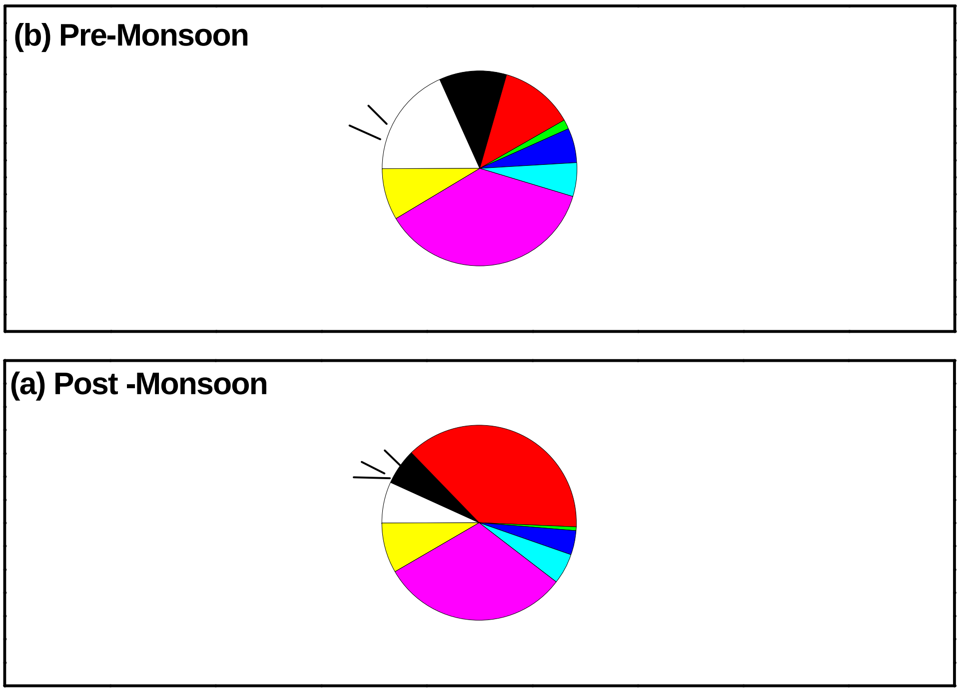
Abstract:

The deposition of gaseous and particulate species on the earths surface plays an important role in limiting the atmospheric concentrations of many biogeochemically important trace species. Dry deposition involves the physical, chemical, or biological uptake of gases and particles from the atmosphere by soils, natural water and vegetation whereas, wet deposition involves scavenging of gases and aerosols through incorporation in precipitation. Both dry and wet deposition pathways are important in assessing qualitatively the biogeochemical cycles of major species in the atmosphere. Studies on deposition in tropical areas are very essential since these regions are undergoing rapid land use change as well as accelerated industralisation in certain regions.

Dry deposition plays a crucial role in precipitation chemistry in India due to prevailing high concentration of Total suspended particulates (TSP). Numerous studies have been reported on chemical characteristics of wet deposition in India but those on dry deposition, especially from non urban regions are very few. The chemistry of deposition in remote site such a mountain tops is of interest in the study of atmospheric pollution. The chemical composition of deposited pollutants at mountain site which is away from industrial and urban areas is useful as a reference level and it allows to determine the extent of anthropogenic contamination. Hence, dry deposition samples were collected at Sinhagad (18^0 21'N, 73^0 45'E , 1450 m asl), a hill station near Pune, during the pre-monsoon (Jan-May) and post-monsoon (Oct-Dec) season of 2003 and were analysed for major ions using ion chromatograph and atomic absorption spectrophotometer.

The chemical analysis of the dry deposition samples revealed that Ca was the dominant constituent with contribution of about 37% in pre-monsoon and 31% in post-monsoon. In post-monsoon, NO_3 contributed more about 38%. The ionic ratio (ratio of sum of anions to sum of cations) was computed and was 0.83 in pre-monsoon and 1.03 in post-monsoon, which indicates more presence of anions in post-monsoon (especially NO_3). It was observed that the ratio of Neutralization Potential to the Acidic Potential (NP/AP) was 1.59 in pre-monsoon and 0.81 in post-monsoon which shows more acidic nature of deposition in post-monsoon season. Sinhagad fort is situated about 100 Km away from Arabian sea and so the contribution of marine sources was computed, using Na as a reference element. Marine source contributed about 6% in pre-monsoon and 9% in post-monsoon for SO_4 and 12% in both the season for Mg.



Percentage contributions of different ionic constituents to dry deposition fluxes at Sinhagad in 2003

Vertical Distribution of Ozone over Ahmedabad

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Abstract:

Tropospheric ozone is a trace gas that plays a controlling role in the oxidation capacity of the atmosphere. Ozone and its photochemical derivative, OH are the major oxidants for most of the reduced trace gases, without ozone, reduced gases such as co, hydrocarbons and most of the sulphar and reactive nitrogen compounds would accumlate to the levels substantially above those in the present atmosphere. Tropospheric ozone also plays a important role in global warming, because of its strong absorption band centered at 9.6 μm. Particularly, in the upper troposphere where the temp is low.

We have been studying the vertical distributions of ozone, temperature and relative humidity using balloonsonde sensors over Ahmedabad (lat=23.03 E, long=72.54 N). These measurements have been done in every 15 days to study the temporal variability in the distribution of ozone and other parameters. Preliminary analyses of this data set reveal the seasonal changes in the vertical distribution of ozone and other parameters. In general maximum value of ozone are observed during winter season and minimum value are observed during summer season in the troposphere over Ahmedabad. Many small scales features are also observed in ozone and relative humidity parameters over Ahmedabad. Detailed results will be presented.

Impact of changes in aerosol advection pathways on direct shortwave radiative forcing: Results from the ARMEX field campaign

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Abstract:

The transport of aerosols from distinct source regions on the continents to the oceans is a major contributor to the spatial and temporal heterogeneity in aerosol characteristics over the oceans and it could have a significant role in the regional climate. In this context, the Arabian Sea assumes significance because of different potential pathways for long-range transport of aerosols from Africa, West Asia, the North West regions including Iran, Afghanistan and Pakistan, besides from the continental India and Southeast Asia across the Bay of Bengal round the peninsula. These regions have distinct geographic characteristics and human activities and hence the changes in advection paths are likely to contribute distinctly to the aerosol properties over the Arabian Sea, where they meet.

During the second phase of the Arabian Sea Monsoon Experiment (ARMEX-II), extensive and collocated measurements of spectral aerosol optical depth (AOD), mass concentration and mass size distribution of ambient aerosols as well as mass concentration of aerosol black carbon (BC) were made onboard the oceanographic research vessel, *Sagar Kanya*, during the inter-monsoon period (i.e., when the monsoon winds are in transition from north-easterlies to westerlies/ south-westerlies) over the Arabian Sea adjoining the Indian Peninsula. The results clearly indicated that aerosol properties responded distinctly to the changes in the advection pathways as revealed by the air-back trajectory analyses. Highest AODs with the flattest spectra were found to be characteristically associated with trajectories indicating advection from West Asia, northwest regions and west-coastal India (Western trajectory), while the AODs were lowest and spectra steepest when the advection was across the BoB and Indian peninsula (Eastern trajectory). The cases when the advection was primarily from India (Indian trajectory) came in-between. The resulting shortwave, direct aerosol radiative forcing showed large variations; with the surface and atmospheric forcing being in the range -40 to -57 W m^{-2}, and +27 to +39 W m^{-2} respectively for the western trajectories, where as they were as low as -19 W m^{-2} and +10 W m^{-2} respectively for the eastern trajectories. Not only the absolute forcing magnitudes, but also the forcing efficiencies showed these features, suggesting that the aerosols associated with western advection are more efficient in producing large atmospheric forcing. This large inhomogeneity in aerosol forcing at a rather short-time, even over a small oceanic region, points to the need of addressing these heterogeneities in assimilation models for regional and global climate impact assessments.

Scavenging ratios of ionic pollutants at Pune

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Abstract:

Introduction

Coupling between rain and aerosol is well expressed by the term "Scavenging Ratio" (Chamberlain, 1960) which shows the efficiency of precipitation for washing the pollutants from the atmosphere. It can be used in estimating long term air or precipitation concentration when only one of these is available. Moreover, the scavenging ratios can also be used to investigate the relative importance of certain parameters involved in the mechanism of transfer between two phases i.e., aerosol and precipitation (Barrie, 1985). These ratios are useful tools for investigating in-cloud conversion and for parameterising the precipitation removal. Also, the scavenging ratios are useful to compute the wet deposition of pollutants (Rao, 1987 and Rao et al., 1995).

Based on the simple premise that the concentration of pollutants in precipitation (C) should depend on their concentration in air (K) within the precipitation forms, the scavenging ratio or washout ratio (w) is defined as

$$W=(C/K)^{*}\ \rho$$

Where, C is in µg/g, K is in µg/ m^3 and ρ =1200 g/ m^3 (density of air)

In order to study the scavenging ratios of ionic pollutants, chemical composition of aerosols and rain water is studied. The aerosol samples collected before the occurrence of rain has been considered in this study.

Sampling and analyses

Aerosol and precipitation samples were collected over the terrace of IITM building at a height of 12m above the ground for a period of four months (monsoon season, from June to September). TSP samples were collected using High Volume Sampler and precipitation samples were collected using wet-only and bulk collectors. All the TSP samples collected during this period were extracted for water-soluble components using the standard extraction methods. The water-soluble extracts and the precipitation samples were analyzed for Cl, SO_4, NO_3, NH_4, Na, K, Ca and Mg using Ion-chromatograph, Atomic Absorption Spectrophotometer and Spectrophotometer. Scavenging ratios of various ionic pollutants were estimated.

Results:

The pH of rain water at Pune was found to be alkaline which is due to the dominance of cations (Ca, K, Mg, Na and NH_4) over anions (SO_4, NO_3 and Cl). The average and range of the scavenging ratios of different ionic pollutants are estimated from the consequent samples of aerosols and rain water and are given in table. It is found that the scavenging ratios were maximum for Ca which is a coarse size particle and minimum for NH_4 which is in fine size. The scavenging ratios are higher for coarse size aerosols i.e., Cl, Na, Ca, Mg and K, whereas they are lower for the fine size aerosols i.e., NH_4, NO_3 and SO_4. This reveals that the scavenging ratios are directly proportional to the size of the aerosols.

Table: Scavenging ratios of various ionic species at Pune

Ion / Element	Wet-Only		Bulk- collector	
	Mean	Range	Mean	Range
Cl	667	553-844	751	293-1519
SO_4	446	83-1243	615	75-1593
NO_3	83	48-117	157	33-277
NH_4	70	14-104	109	93-110
Na	1125	318-2273	1338	504-2613
K	710	173-2006	737	132-1531
Ca	1824	1264-2565	2080	1265-3765
Mg	831	234-1768	1180	207-2763

Acknowledgements – The authors are thankful to Director, IITM, Pune for support, and also to the members of the IITM Air pollution Group for cooperation. One of the authors (SKM) would like to thank Dr. P. Pradeep Kumar, Phys. Dept., UoP, Pune for his keen interest in the study reported in the paper.

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Study of Ångström Parameters over Nainital

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Abstract:

Extensive measurements of spectral aerosol optical depth (AOD) are being carried out at Nainital (29.4°N 79.5°E; ~2 km above m.s.l) using a 10-channel multi-wavelength solar radiometer (MWR) since January 2002 (Sagar et al., 2004). From the spectral AOD data, the Ångström parameters α and β were estimated using the equation (Ångström, 1961)

$$\tau_{p\lambda} = \beta.\lambda^{-\alpha}$$

Where α is the wavelength exponent and β is the Ångström turbidity coefficient. α and β values estimated from the MWR data for the period 2002 to 2004 have been used to examine their temporal and seasonal variations. Results shows that, α was high during winter months (November to March) and minimum during summer/pre-monsoon (April to June). On the other hand, β was found to be maximum during summer/pre-monsoon and minimum during post-monsoon and winter season. These results clearly indicate that there is a relative dominance of sub-micron particles during winter season and abundance of coarse particles during summer season. The implication of the results will be presented.

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Long Term Changes in Ozone Pollutants over India: 3-D Model Simulations

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Abstract:

It has been recognized during the recent decades that human activities have an increasing influence on the global budget of tropospheric ozone and have potential to increase its concentration. The emission rate of source gases like CO, NOx, VOCs, responsible for producing ozone, in this region has increased considerably during the past decade over the Indian region. The aim of the present study is to study the variation in surface ozone and related chemical tracers during the past 10 years (1991-2001) using the three dimensional chemical transport model of the troposphere over the Indian tropical region. The basis of the emission scenario in the model input is based on the growth rate of several pollutants due to bio-mass burning, fossil fuel combustion, residues, agricultural practices, paddies, etc. Percentage variation of these pollutants has been studies for winter, pre-monsoon monsoon and post-monsoon season. In general there is an increase in the level of all pollutants, magnitude of which is different in different sessions due to prevailing dynamics. An increase of the order of 10-14% in CO, 6-10 % in ozone, and ~10-40 in NOx is simulated during the past 10 years for winter and pre-monsoon seasons over the Indian region. The percentage change in ozone (2-3%) is found to be minimum during the monsoon season. The regional variations are very high during post-monsoon season. Present results also indicate that during summer season, the pollutants emerging from plains (via combustion, etc) affects the Indo-Gangetic region through convection (South-Easterly winds), as a result of which concentration of toxic gases, whose life time is relatively larger like Carbon-monoxide suddenly get enhanced thereby likely to impact the ecosystem. A noticeable feature observed is that decrease in ozone and NOx concentration is observed over Gujarat coast for all the seasons. Details will be presented.

Atmospheric Electricity

Active Thunderstorm Induced Heating in the Ionosphere

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Abstract:

It has been realized in recent years that the ionospheric temperatures and ion densities are influenced by the lightning activity. The ionospheric temperatures (electron and ion temperatures) were measured by the RPA payload aboard the Indian SROSS-C2 satellite (Garg and Das, 1995). The SROSS-C2 satellite was launched by Indian Space Research Organization (ISRO) on May 4, 1994 to study the ionospheric composition and temperature anomalies. To see the effect of active thunderstorm the ionospheric electron and ion temperatures have been compared to the values on normal days. The data collected by SROSS-C2 satellite using RPA payload during the period from 1995-1998 has been analyzed for anomalous variations due to thunderstorm activity in the altitude range from 425 to 625 km. The data on thunderstorm activity for the same period was obtained from India Meteorological Department (IMD), Pune. The measurements corresponding to three different locations viz. Bhopal (23.16° N, 77.36° E), Panji (15.30° N, 73.55° E) and Trivandrum (08.29° N, 76.59° E) have been analyzed. It is a difficult task to study the ionospheric temperature using the satellite data in respect of thunderstorm activity because very rarely passes of satellite match the thunderstorm activity at a meteorological data station. The first task is to match the satellite data corresponding to the thunderstorms activities. During the period from 1995 to 1998, it has been found that seven events of thunderstorms correspond to the satellite data. The recorded average electron and ion temperature during active thunderstorms have been compared with the average normal days electron and ion temperature for the same time interval. Care has been taken to select the satellite data, which is free from diurnal, seasonal, latitudinal, longitudinal and altitude effects. The average of normal time electron and ion temperatures have been made for a month, starting almost 15 days before the thunderstorm day and continuing to 15 days more after that. Thus the possibility of seasonal effect has completely been ruled out because all data points correspond to the same season. A window of 5° in latitude and longitude for the satellite observation at the meteorological data center has enabled the latitudinal and longitudinal effect to be ineffective. The averaging of electron and ion temperatures at nearly the same hours of the day as that of the active thunderstorm has made it free from the diurnal effect. The analysis has been made for the altitude range 425-625 km only, thus making it independent of the altitude.

To remove the effect of solar flare activity, the data on solar flares were obtained from National Geophysical Data Center (NGDC), Boulder, Colorado (USA). Only those thunderstorm days have been considered in this study, which are free from the solar flares. Care has also been taken to choose the data only from those days, which are free from earthquakes. All temperature data recorded by SROSS-C2 satellite are within the error limit of ± 50 K.

It has been found that there is a consistent enhancement of ionospheric electron and ion temperatures recorded during active thunderstorms period. This enhancement was for the average electron temperature ranging from 1.2 to 1.7 times compared to the average normal day's temperature. However, for ion temperature this enhancement was from 1.1 to 1.5 times. It is worth mentioning here that in the present analysis the data

were selected in such way that the effect of diurnal, seasonal, latitudinal, longitudinal and altitude effects are minimized. Thus the temperature anomalies are directly related to the thunderstorm events.

The enhancements in ionospheric electron and ion temperatures have been attributed to different kind of lightning activity, which are associated with active thunderstorms. Recent observation of optical phenomena such as sprites, blue jets, blue starters, elves and associated phenomena (Pasko et al., 1995, 1997; Sentman et al., 1995; Lehtimen et al., 2000; Bell et al., 1995) propagating from top of the active thunderstorm may generate radiations from ULF to VLF (Inan et al., 1991, 1996), which in turn, may propagate still upward and heat the local plasma in the ionosphere.

Acknowledgements:
One of the authors (DKS) is thankful to Council of Scientific and Industrial Research (CSIR), New Delhi for providing the financial support for the present study. The authors are also thankful to India Meteorological Department for providing the valuable data on thunderstorm activity and NGDC, USA for providing the data on solar flares.

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Effect of Ions on Cloud Condensation

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Abstract:

Theoretical and experimental studies on the effect of ions on cloud formation and precipitation have been made by Varshneya (1969, 71), Chan (1980), Singh *et. al* (1985), Kamra (2001) and others. The present authors have studied this effect experimentally. A thermal diffusion chamber was designed and fabricated for this purpose. The diffusion chamber has a holder for the ionizing source. Am^{241} in the form of a thin foil was used to ionize the air in the diffusion chamber. The vapors released into the chamber were charged positively or negatively by applying a suitable potential to the sources. The size and concentration of droplets formed due to condensation were measured by employing a SMW He-Ne laser. The leaser beam scattered at 45° and 135° were detected by a photo multiplier tube and the intensity ratio was obtained. The droplet size and concentration were computed from the intensity ratio.

The presence of ions decreases the size of the droplets. The model size in the presence of ions decreases from (0.8 ± 0.14) μm to (0.6 ± 0.15) μm. There is no appreciable change in the droplet concentration. When the water vapor released in the diffusion chamber is negatively charged, the steady state droplet condensation increases from 7.10×10^5 /cm^3 to 9.85×10^5 /cm^3. Thus the enhancement in the droplet concentration comes out to be 38% with an experimental error of 4.5%. The model size changes from 0.67 μm to 0.51 μm. Thus the reduction in the model size is 23.8% with an experimental error of 2.9%. No appreciable effect of positively charged vapor has been found on droplet concentration. However, the model size has decreased by 10.4% that is quite significant as the experimental error is only 2.9%. It has been conclude that the ions play an important role in cloud condensation and the negative ions are more effective than the positive ions.

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Magnetic storm effect on the amplitude of 24 kHz NAA VLF transmitter signals

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Abstract

The effect of magnetic storm on the amplitude of the signal along the GCP between Agra and NAA transmitter has been examined during three months of data between July to September, 2002. It is seen that the average amplitude is enhanced following the period of severe magnetic storm (? Kp>30). This result is interpreted in terms of dumping of plasma in the D region from overlying ionosphere.

On the capacity of negative ions for cleaning the pollution

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Abstract:

Negative air ionizers have been widely used for indoor air cleaning. Daniels (2002) reported that negative air ionization reduces particulates, air born microbes, odors and volatile organic compounds (VOCs) in indoor air. A negative air ionizers generate the negative air ions, which can affect the contaminants in gas phase. Negative air ionizers increase gaseous H_2O_2, which helps for the plant growth along with oxidation of the air pollutants. Excess of negative ions is useful for reducing harmful Serotonin, which is responsible for depression. Higher positive ion concentrations reported to increase depression, nausea, insomnia, irritability, migraine, asthma attacks and normal functioning of thyroid glands. Where as negative air ions reduce above effects. Negative air ions neutralize the effect of positive air ions and attaches to the aerosols, which causes settling of suspended aerosols to the ground. Dry desert winds like California's, Santa anas produces higher densities of the positive ions, which showed the physical and psychological side effects. This paper reviews the effect of negative air ionizers used for reducing air pollution. We have developed negative ion generator and the design of air ion counter is completed.

Keywords: Negative air ions, Volatile organic compounds (VOCs)

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Idealized Simulation of Thunderstorm Event Using ARPS

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Introduction

Indian region is affected by weather systems like thunderstorm, cyclone etc. There is loss of property and lives because of strong winds, heavy precipitation as well as the hails associated with them. Hence timely and location specific prediction is very much required. Recently attempts are made to simulate these systems using mesoscale models.

Model and Data

Nonhydrostatic compressible mesoscale model Advanced Regional Prediction System (ARPS) developed at Oklahoma State University, USA has been utilized for the simulation of thunderstorm over Kolkata. RS/RW data at 12 Z over Kolkata on 30 September 2001 has been used for constructing 3D fields on ARPS grid of horizontal resolution 1 km & 35 equally spaced (300m) levels in the vertical. Thus the model covers 88.13 ^{0}E to 88.77 ^{0} E and 22.3 ^{0} N to 22.94 ^{0} N. Initial sounding profile is perturbed by a thermal bubble of size 20 km x 20 km x 3 km by 2^0 K. Further the model is integrated for 2 hrs.

Results

The predicted fields are stored at each 30 minutes interval to study the evolution of the storm. Cross section (x-z) of predicted vertical velocity (m/s) at Kolkata latitude (22.6 ^{0}N) at each 30 min is shown in Fig 1 & predicted rainfall accumulated at each 30 minutes is shown in Fig 2. In the first half hour of integration vertical velocity is found to be very strong and it extends more than 8 km. The simulated thunderstorm appears to be in the developing stage (fig 1 a). The rainfall accumulated during this period is very less (fig 2a). In the next half hour, the vertical velocity increases up to 9 m/s but the vertical extent is reduced to 5 km. The x-z cross section of vertical velocity and streamline of u, w suggest that the storm has further organized and reached maturity during this time. 30 min accumulated rainfall of 5 cm is predicted during this time (fig 2 b). After 1 hour, vertical velocity is found to decrease very much and thunderstorm appears to be in the dissipating stage. Precipitation is found to be maximum during this phase and it reaches up to 9 cm (fig 2 c) which is in good agreement with the reported rainfall of 8.1 cm .After one and a half hour of integration the cell is found to have moved in eastward direction.

Conclusion

Strong vertical velocities as well as heavy precipitation are the most important features associated with thunderstorm. The idealized simulation of the thunderstorm by ARPS is found to be in good agreement with the observation.

Acknowledgements

The authors wish to thank Dr. G. B. Pant, Director, IITM for his keen interest in mesoscale modelling research. The first author also wishes to thank the faculty of Cochin University of Science & Technology for their support & encouragement.

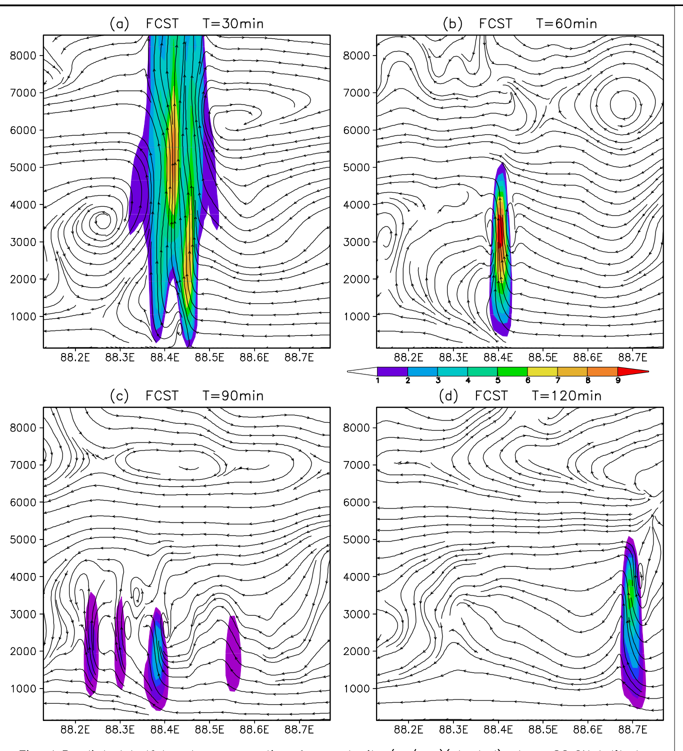

Fig. 1:Predicted half hourly u–w section & z–velocity (m/sec)(shaded) along 22.6N latitude

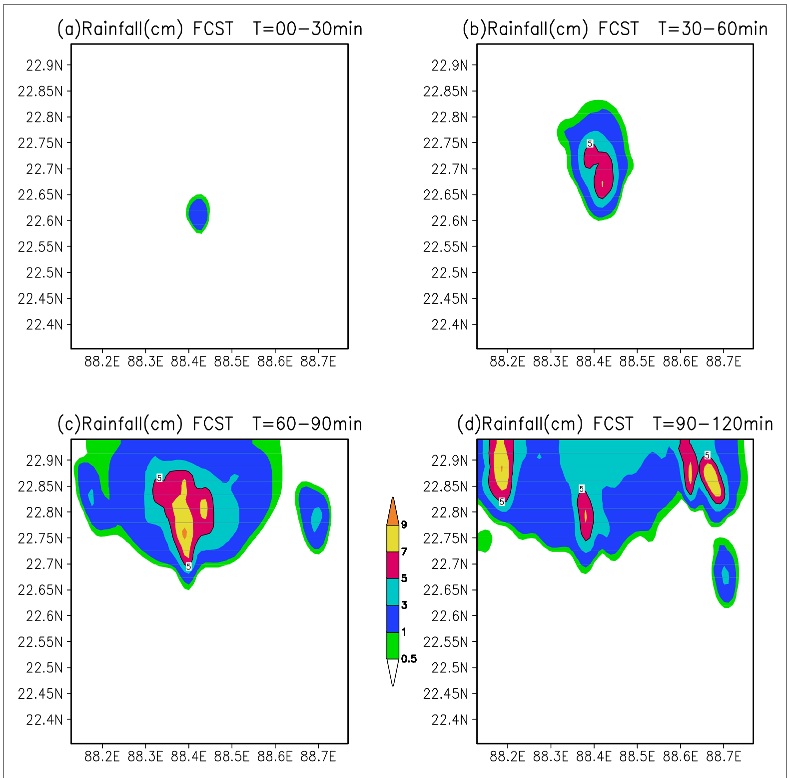

Fig. 2:Predicted half hourly accumulated rainfall(cm)

A New Whistler Recorder Developed at Agra and Initial Results

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Abstract-

A new experimental setup for recording and analysis of low latitude whistlers and VLF emissions has been developed at Agra, which is less expensive, automatic, and time saving in comparison to earlier experimental setup being used in different whistler stations in India. The new experimental setup employs a crossed loop antenna, amplifiers, low pass filter, a sound card, and PC with a software specially designed for recording and analysis of VLF data. Some examples of whistlers and VLF emissions recorded by the new setup have been presented and their frequency time characteristics have been thoroughly discussed.

Simultaneous ULF/VLF amplitude anomalies observed during moderate earthquakes in Indian region

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Abstract:
A three component search coil magnetometer to monitor ultra low frequency (ULF) magnetic field emissions (frequency = 0.01-30 Hz) and an Absolute phase and amplitude data logger (AbsPAL) to monitor the phase and amplitude variation of very low frequency (VLF) 19.8, 21.4, and 24 kHz fixed frequency transmitter signals have been installed at Bichpuri, Agra (Geograph. Lat. 27.2^0N, Long. 78^0E) in India and regular simultaneous observations have been taken since 1 August, 2002. The analysis of the VLF amplitude data has been carried out for the period of nine months and it is seen that the amplitude decreased abnormally by 1 to10 dB from normal daily averages. The results of ULF data analysis show that the back ground magnetic field amplitudes of the three components which are usually low in the range of 0.03 – 0.30 nT are enhanced to the range of 0.26-0.96 nT either on the same days or within ± 2 days of the decrease in amplitude of the VLF signal. The possible causes for the observed ULF/ VLF amplitude anomalies are examined and it is found that they are caused by moderate seismic activities that occurred along the VLF propagation path in the region.

Atmospheric Remote Sensing

Potential Utility of IRS-P4 MSMR for better depiction of Atmospheric Systems and the Antarctic Sea-Ice Extent

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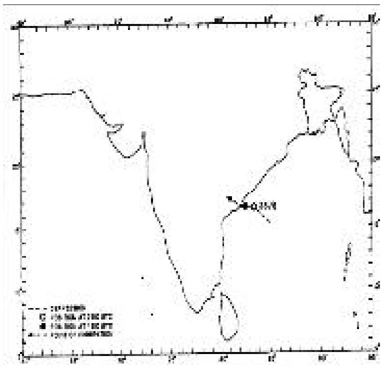
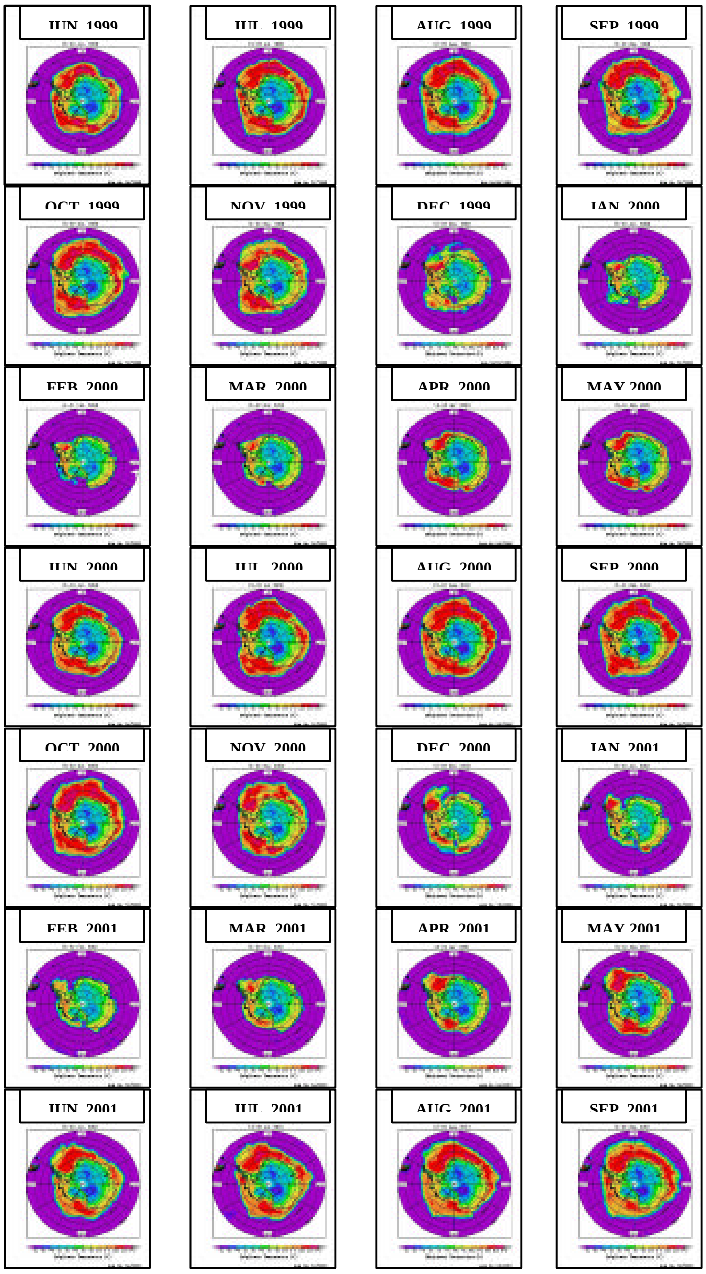
The first indigenous polar orbiting sun-synchronous satellite IRS-P4 also called as OCEANSAT-1 launched on 26th of May 1999 showed potential utility in providing the images and information over the entire globe for ocean-atmosphere studies. IRS-P4 carries two payloads onboard, viz., Multi-frequency Scanning Microwave Radiometer (MSMR) and Ocean Colour Monitor (OCM) that are designed to provide polar coverage with a repeat cycle of two days.

In this paper, the data of MSMR over the domain, 0°-25° N and 40° E-100° E, has been used in bringing out the daily variations of satellite-derived geophysical parameters such as the integrated water vapour (IWV), cloud liquid water content (CLW), sea surface temperature (SST) and sea surface wind speed (SSW) for a case of monsoon depression that formed over the Bay of Bengal during 19th – 24th August 2000 (see Fig. 1).



An integrated approach of satellite data obtained from IRS-P4, METEOSAT-5 and INSAT was made for getting a signal for the development of monsoon depression over the Indian region (Mahajan *et al* 2004). Geophysical parameters such as SST, SSW, IWV and CLW, computed using suitable algorithms are used for evaluating a proper consistency of these parameters with the dynamical aspects of major convective activity occurring during the formation, development and dissipation of depression. Gohil *et al* 2000 developed suitable algorithms for deriving geophysical parameters from MSMR. One of these parameters, i.e. the IWV distribution (in gm/cm^2) during the period 19th-24th Aug. 2000 is shown in Fig. 2.

Since, MSMR channels measures the thermal microwave emission from the Earth during both day and night without being impeded by the presence of clouds, it has been extensively used for mapping the Antarctic sea ice extent (Lat. range: 50° S – 90° S and Lon. range: 0° - 360°) for a period of 28 months i.e., from June 1999 to September 2001. Weekly average maps of sea-ice extent over the southern polar oceans surrounding the Antarctic continent have been generated to study the spatial distribution (Fig. 3) and the seasonal cycle of waxing and waning of the sea-ice cover (Fig. 4). The brightness temperature images besides clearly demarcating the sea-ice from open water, also vividly portray a variety of features relating to the formation and dynamics of sea-ice (Vyas *et al* 2000 and *Vyas et al* 2001*).* The sea-ice extent estimates of Antarctica observed from MSMR have helped in extending the long-term trends obtained using data from Scanning Multi-channel Microwave Radiometer (SMMR) onboard Nimbus-7 and Scanning Sensor Microwave Imager (SSM/I) onboard Defense Meteorological satellite Programs (DMSP) series of satellites. Thus, the analysis of the last 25 years of sea-ice extent measurement based on SMMR, SSM/I and MSMR seems to indicate a slowly increasing trend with time as seen in Fig. 5. This presents a great challenge to our understanding of the response of sea-ice to the issue of global warming and requires continued in-depth investigations. Thus, the results obtained reveal the potential use of MSMR data in Tropical as well as in the Polar regions with the aid of data provided by other satellites.



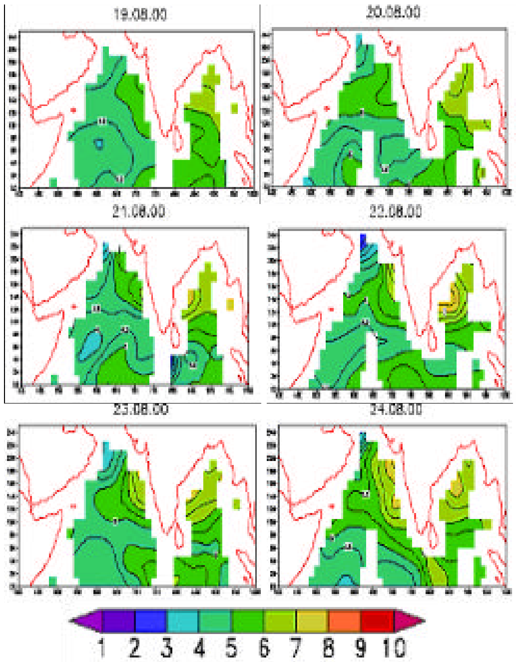


Fig. 2: MSMR derived IWV (gm/cm^2) distribution

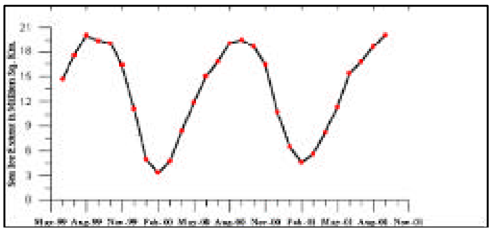


Fig. 4: Seasonal behaviour of Sea Ice Extent for total Antarctic & the surrounding southern ocean

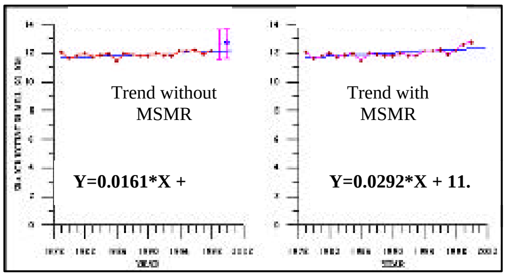


Fig. 3: Brightness temperature maps from MSMR for 28 months, June-1999 to September-2001

Fig. 5: Trend of Antarctic Sea Ice Extent (1979-2001) Data Used: SMMR (1979-1987), SSM/I (1988-1998), MSMR (1999-2000, 2000-2001, last 2 pts.

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Initial outbreak of Nor'westers in relation to water vapor boundaries in satellite images

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Abstract

A few features of initial outbreak of Nor'wester are investigated using high resolution half-hourly METEOSAT-5 water vapor (WV) channel (5.7-7.1 *μm*) imageries. The detailed image analysis reveals that the boundary between relatively humid and dry air at the middle and upper troposphere indicates one of the possible soft spots for the initiation of convective cells of Nor'wester. The fact of the first appearance of convective cells at WV boundaries on the satellite imageries can be used for Nowcasting Nor'westers.

Keywords: **Nor'wester, water vapor boundary, Meteosat-5.**

1 Introduction

The Nor'wester is a typical case of severe thunderstorm in West Bengal and the adjoining areas during the pre-monsoon season [4]. Its meso-scale structure with a very rapid development makes it difficult to study. Although conventional sounding data are usually being used to provide information about temperature structure and water vapor gradients in pre-storm environments, the timing and spacing of these observations are often inadequate to diagnose the evolution of pre-convective conditions. Consequently, forecasting the initiation of Nor'wester becomes a very difficult task.

For the present study, we investigate few interesting features of initial outbreak of Nor'wester using high resolution METEOSAT-5 WV channel imageries. A detailed investigation gives indication that a preferred area for the first appearance of convective cells of Nor'wester is associated with the boundary between relatively humid and dry air at the middle and upper troposphere.

The next section describes the data used in this study. The results are discussed in Section 3, and conclusions are given in Section 4.

2 Data

For the present study, we use METEOSAT-5 WV channel (5.7-7.1 *μm*) imageries taken over West Bengal and its neighborhood for the period from 0000 UTC, 17th April 2003 to 2330 UTC, 22nd April 2003. The high resolution (approximately 5 X 5 sq. km at sub-satellite position) half-hourly METEOSAT-5 WV images are provided by European Organization for Exploration of Meteorological Satellite (EUMETSAT).

3 Results

The WV channel measures the water vapor content in middle and upper troposphere. The dry pixels appear dark while the moist one looks comparatively brighter on the WV images [1, 3]. Total 286 WV images are being enhanced, analysed and animated using Matlab image processing toolbox. Fig. 1 displays the sequence of METEOSAT-5 WV images for the growing Nor'westers on 21st April 2003. In early morning (0300-0230 UTC) of 21st April 2003, few convective cells (A, B, and C) initiate over North Bengal and Assam (Fig 1 a-c). In later hours (0330-0430 UTC), cells A and B dissipate, while cell C grows up (Fig. 1 d-f) and spread into the humid parts of the WV structure during further development (Fig. 1 g-i). These are the *type B Nor'westers* [4]. Just before noon (0430-0630 UTC), another group of cells (D, E, F, and G) stats at the WV boundary of a distinct sharp dry strip (Fig. 1 f-g) over Bihar Plateau and adjoining areas. At the next time steps (0730-0830 UTC), few more new cells (H, I, J, and K) come up, while other cells (C, D, E, F, and G) show further development. Few cells (D, E, and H) are also merged together and taking form of a mature Nor'wester (Fig. 1 h-i).This is a *type A Nor'wester*.

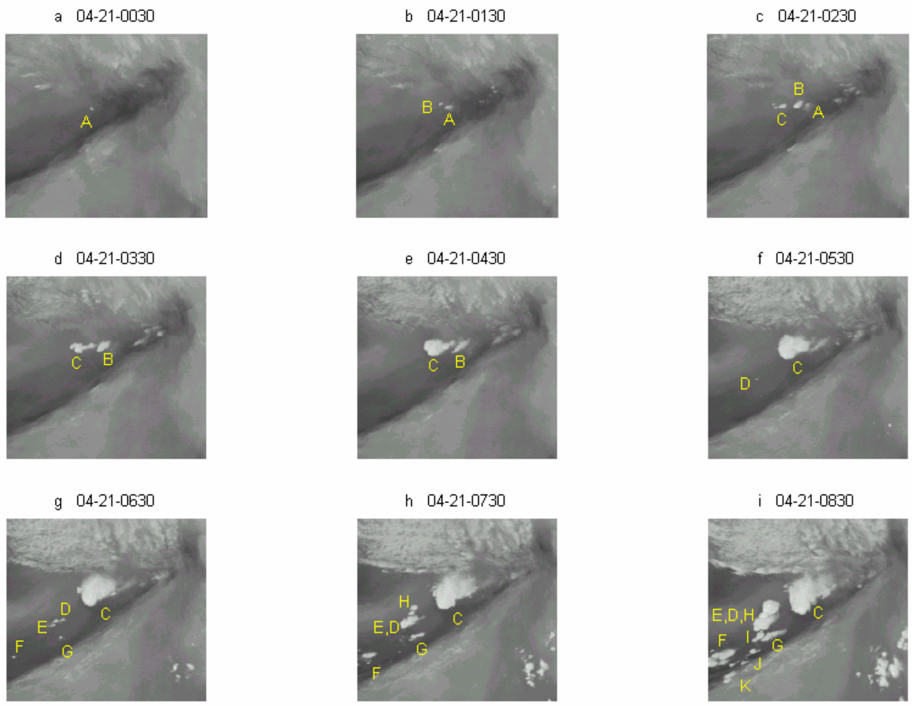

Fig. 1 METEOSAT-5 WV images on 21st April 2003; (a) 0030 UTC, (b) 0130 UTC, (c) 0230 UTC, (d) 0330 UTC, (e) 0430 UTC, (f) 0530 UTC, (g) 0630 UTC, (h) 0730 UTC, and (i) 0830 UTC.

On summarizing, one can say that, in many cases, the first appearance of Nor'wester may be associated with the narrow transition zone between relatively high and low pixel values in the WV imageries, i.e., the boundary between relatively humid and dry air at the middle and upper troposphere indicates one of the possible soft spot for the initiation of convective cells of Nor'wester. Another observation shows that, deeply growing cells which start at a WV boundary spread into the humid parts of the WV structure during further development (Fig. 1 i, C, (D+E+H)).

4 Conclusions

The first appearance of Nor'wester are associated with the boundary between relatively humid and dry air at the middle and upper troposphere indicates one of the possible soft spot for the initiation of convective cells of Nor'wester. The WV boundaries, along with other meteorological parameters (e.g., spatial distribution of different stability indexes), could be the interesting clues for Nowcasting Nor'westers.

Acknowledgement

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Tropospheric Refraction of Microwaves With Application To GPS Based Ranging System

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Abstract:

The refractive characteristics of the neutral atmosphere (mainly troposphere) are governed by its composition. All the gases except water vapor are non-polar molecules that do not have permanent dipole moment. But water vapor molecules are polar in nature. When microwave propagates through atmosphere, a dipole moment is induced among non-polar gases and water molecules are reoriented according to the polarity of propagating wave. This causes a change in the dielectric constant (refractive index) of the atmosphere. The refractive index of troposphere is a function of pressure, temperature and water vapor pressure. The tropospheric refraction affects the microwave propagation by retarding and bending, thus causing an error in microwave ranging. This limits the accuracy in radar ranging, the mapping of terrain elevation by space borne interferometric SAR and in real-time satellite based GPS navigation. In real-time GPS navigation, the tropospheric range error is corrected using the easily available models based on atmospheric pressure, temperature and humidity at surface.

In order to model the tropospheric range error for microwaves over Indian region atmospheric models are generated using the upper air data obtained from IMD through their regular Radiosonde ascendings. Using this, the linear models based on Surface pressure (P_s) and Surface Temperature (T_s) for dry component, and Surface Water vapor pressure (e_s) for the wet component of the tropospheric error were developed. In addition to this, the required parameters to implement Hopfield model [1], which accounts for vertical profiles of atmospheric refractive index in total range error estimation, are also derived. These models are validated, with actual GPS measurements. For this the data from Bangalore International GPS Service (IGS) station is used. The dual frequency GPS receiver was installed at IISC - campus, Bangalore, India, as a part of International GPS station network in 1994. The data from this receiver is available at the IGS site (http://www.ngs.noaa.gov/CORS/Data.html). The daily GPS data for one year (1997) along with other IGS stations around Bangalore (required for data processing) was downloaded for this study. These data were processed with GAMIT version 10.05 [2] installed on Linux machine for estimating Tropospheric Zenith Error. The total error in GPS signal is mainly due to satellite ephimerides, clock biases, ionosphere and troposphere. In GAMIT most of these errors are reduced by processing the GPS data in post-processing mode (after 16 days of measurements) to remove the satellite ephemerides errors, double differencing to remove clock biases and using dual frequency data to remove ionospheric errors. The precise GPS orbits were obtained from IGS sites. The tight constraints (0.005 m) were given to the IGS station Coordinates in this analysis. The final output is the Total Zenith Error (TZE). The TZE derived from the GPS data showed a seasonal variation, which is mainly due to the variability of the atmospheric parameters. The P_s, T_s and e_s values at 00 UTC and at 12 UTC from the daily Radio sonde data were used in the linear models to estimate the daily TZE. These values were compared with the TZE from GPS data. The model values are in good agreement with that of GPS measurements for all seasons, however, there is a small disagreement within

few centimeters. This difference could be attributed to the accuracy in the Radiosonde measurement; the meteorological and GPS (IGS) stations are not collocated and the lack of IGS or GPS stations nearer to Bangalore in 1997.

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Non-linear Internal Waves on Envisat ASAR Images

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Abstract:

The Advanced Synthetic Aperture Radar (ASAR) on Envisat is sensitive to changes in the small scales surface, which is alter by the velocity field associated with internal waves. Short-period oceanic internal waves are commonly observed in SAR images as systems of Quasi–periodic parallel bands, typically bright and dark bands on a gray background, and some times simply as dark bands. A very long alternate dark–bright group patterns on Envisat ASAR of image mode images along the coast of the North Bay of Bengal taken on 4th October 2003, were recognized to be the sea surface manifestations of non-linear internal waves. Simultaneously observed Quik scat wind vectors also showed an offshore wind of 5-9 m/s, which is in the Bragg's- scattering wavelength band of C band Envisat ASAR.

Introduction:

The funnel shape of the Bay of Bengal, and the shoaling of its bottom, causes high tides seiches, and internal waves of varying period and heights. Internal waves of shorter period are also prominent because they occur between the shallow, low-density surface layer and the denser water below. Vertical oscillations, or internal waves, by convergence and divergence water below, generate surface currents that modulate the spectral density of Bragg Waves, causing the large-scale wave like pattern signatures in SAR images. The Envisat satellite equipped with C- band, Dual polarization offering horizontal (HH) & vertical (VV) or cross-polarization (HH&HV or VV&VH) ASAR, can image internal wave signatures for wind speeds in the 2-10m/s range. Since these waves, 8-10 meters height, refract when crossing the continental shelf, the bands tend to parallel the coast as they move slowly shoreward.

Results:

Observed internal wave packets showing the following common imaged features: the leading wave, which is the most energetic one, characterized by the longest crest line and the greatest wave length, is located on the western side of a packet, and the orientation of the curvature of the crest lines generally westward. These internal wave groups are may be generated at the continental shelf by interaction of the tidal current with under water bottom topography. With in each group the wavelength decreases with distance from the leading crest, indicating that they represent non-linear dispersive wave trains.

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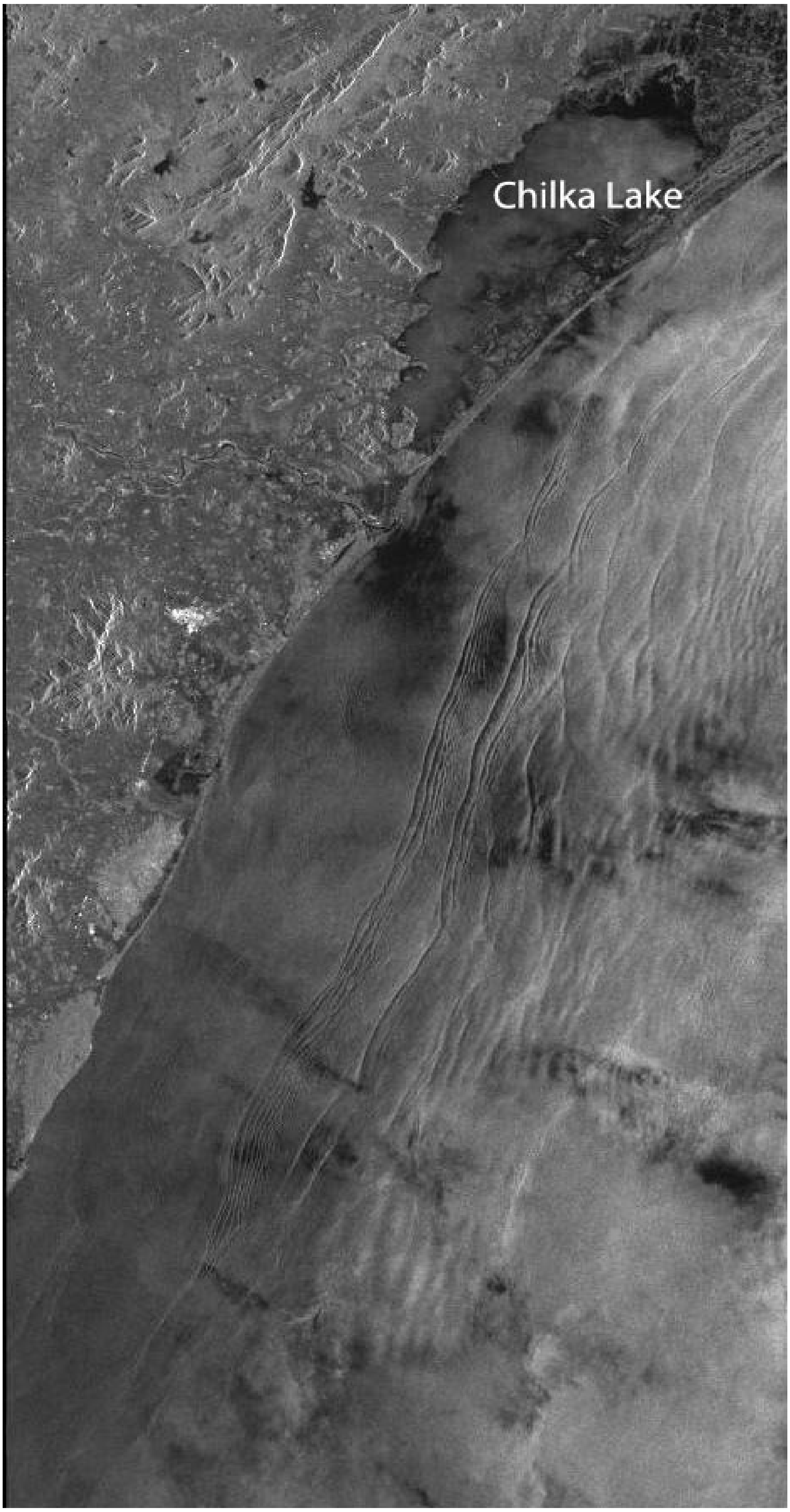

Figure. ENVISAT ASAR image mode shows Sea surface magnifications of non-linear internal waves on 4th October 2003 along the coast of North Bay of Bengal

Comparison of Precipitable Water Measured by Sun Photometer and that Estimated from Surface Meteorological Parameters

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Introduction

Water vapor is an important link connecting the various components of the hydrological cycle and hence an understanding of its role in the hydrological climate system and its variability on all spatial and time scales is very essential. Meteorologists are currently not just interested in dewpoint or humidity at the surface, but in the moisture content in the entire atmosphere. An important water vapor parameter is Precipitable Water (PW) which is a measure of the total water vapor contained a small vertical column extending from surface to the top of the atmosphere. However, the majority of moisture in the atmosphere is contained roughly within the lowest 10,000 feet. Climate models have shown significant increases in water vapor in response to global warming. Precipitable water climatologies on long-term scale are necessary to verify these model results. Distribution of PW is a good indicator of the dynamics of the circulation systems in the atmosphere. Latitudinally, there is a decrease of precipitable water from equatorial regions, where it attains the highest values, to the north and south poles.

Water vapor absorption of solar radiation has been studied for several decades and several researchers have used the optical technique (sun photometer) to determine precipitable water in the atmosphere (for eg. Volz, 1974; Michalsky et al., 1995; Morys et al., 2001; Ernest Raj et al., 2004). Sun photometer derived precipitable water at a midlatitude station (Luxemburg) over a six year period (1998-2003) has been used in the present study to examine seasonal variations and also to compare with the estimations made from surface meteorological parameters and satellite derived data.

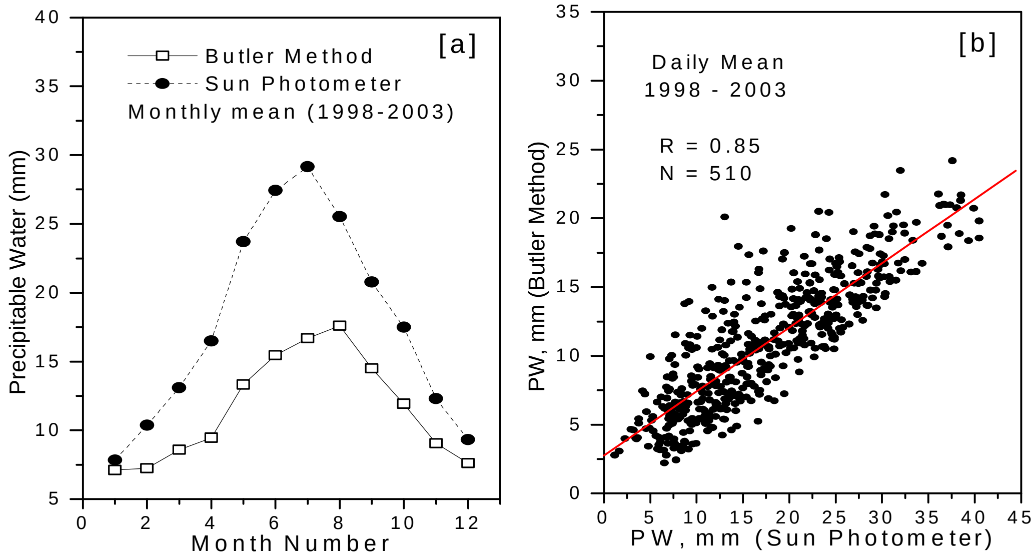
Data

Observations made at Diekirch, Luxemburg (49.848$^{?}$ N, 6.332$^{?}$ E), a midlatitude station using a five-channel sun photometer (Microtops-II, Solar Light Inc., USA) for the 6 year period 1998-2003 have been used in the study. PW retrieval is based on measurements in the 940 and 1020 nm channels. Surface temperature and R.H. for the same station available at 30 minute interval have also been collected from the web site and used to estimate PW using Butler method. For comparison with sun photometer data daily and monthly means have been computed. MODIS satellite retrievals of PW in the 'clear sky NIR' and 'IR' channels have been obtained for the above station location for further comparisons. The results are presented and discussed.

Results and Discussion

The overall six year monthly mean precipitable water obtained from sun photometer measurements and estimated from surface meteorological parameters for Luxemburg is shown plotted in Figure 1(a). The seasonal variation is identical in both the data sets, but sun photometer values are higher by almost 15 mm during the summer months of June to September.

Figure 1(b) shows the scatter plot of daily mean PW data by the two techniques. On daily scale also there is a very good agreement with a correlation coefficient of 0.85. On 75% of the days the agreement is within ± 10 mm. The deviation in summer season is mainly



due to the fact that ground-based sun photometer measures the total moisture content including the water vapor content at upper tropospheric layers. The Butler method of estimation assumes some sort of an exponential decrease of temperature with height and does not account for the upper level moisture influx. PW values by the two techniques have been examined for different months separately and the agreements were good except for the month of April. MODIS satellite derived PW by clear sky NIR and IR methods for the same latitude-longitude position have been collected and compared with the above observations and estimations. Variations on monthly mean scale have been found to be very consistent. Results of the study will be presented and discussed.

Acknowledgements – Authors are grateful to the Director, IITM for encouragement and support. The data source is the web site of Meteorological Station of the Lycée Classique de Diekirch [Luxembourg] and the authors are thankful to Prof. Francis Massen and his research group at Diekirch.

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Vertical Temperature structure of atmosphere as revealed by Indian MST radar

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Introduction

The Indian MST radar at Gadanki (13.4ºN, 79.18ºE) is a monostatic pulse radar with an active phased array antenna system operating at 53 MHz in VHF band. The radar system description can be found in Rao et al. (1995). The radar echoes can be used for the study of turbulence and atmospheric stability of the lower and middle atmosphere. The background stability of the atmosphere can be described in terms of temperature variations in the region of interest.

A method for determining the vertical temperature profile of the lower atmosphere (5 – 20 km) from MST radar backscatter echo was proposed by Kumar and Das (2003) and Das et al., (2004). The temperature profile deduced by them shows departures from termeratures inferred from radiosonde observations for the lower height range below 9 or 10 km. In the present communication we devise a method to reduce these discrepancies.

Methodology

The backscatter power received by MST radar ($S_V = P_r r^2$) for dry atmosphere cab be written as (Gage et al., 1985; Jaya Rao and Jain, 2001; Kumar and Das, 2003 and Das et al., 2004)

$$S_v = B * \frac{P_0^2}{T^4} * \left(\Gamma_d + \frac{\partial T}{\partial Z} \right)^2 * e^{\frac{3*(Z_0 - Z)}{H}} \quad (1)$$

where B is a constant which depends radar specifications and the pressure is assumed to vary exponentially with height. Equation (1) can be conveniently put as

$$\ln\left(F(T) \right) = 0.5 \ \ln\left(S_v \right) - \left(\frac{1.5}{H_0} \right) \left(z - z_0 \right) - 0.5\,\zeta \quad (2)$$

where $F(T) = \left(\frac{\frac{dT}{dZ} + \Gamma_d}{T^2} \right)$ and $V = \ln\left(BP_0^2 \right)$ is constant for all range-bins with respect to some reference height z_0 where pressure P_0 is defined. If the constant ζ could be estimated somehow then the temperature can be derived as a solution of the equation

$$\frac{\partial T}{\partial z} - F(T)T^2 + \Gamma_d = 0 \quad (3)$$

Results and discussion

Equation (3) has been used to estimate temperature above 9 km assuming dry atmosphere following the procedure outlined by Kumar and Das (2003) and Das et al., (2004). For lower heights, our numerical calculations have shown that if the contribution of the exponential term in Equation (1) is neglected and z_0 is suitably chosen, then the temperature estimated using Equation (3) agrees well with radiosonde observed temperature profile even in the lower height. Identification of suitable z_0 for lower height range is possible if a new constant $V^* = \ln(BP^2)$ is defined. The constant V^* is calculated for each range-bin as the reference height z_0 is varied in the range 9.0 – 13.0

km. The

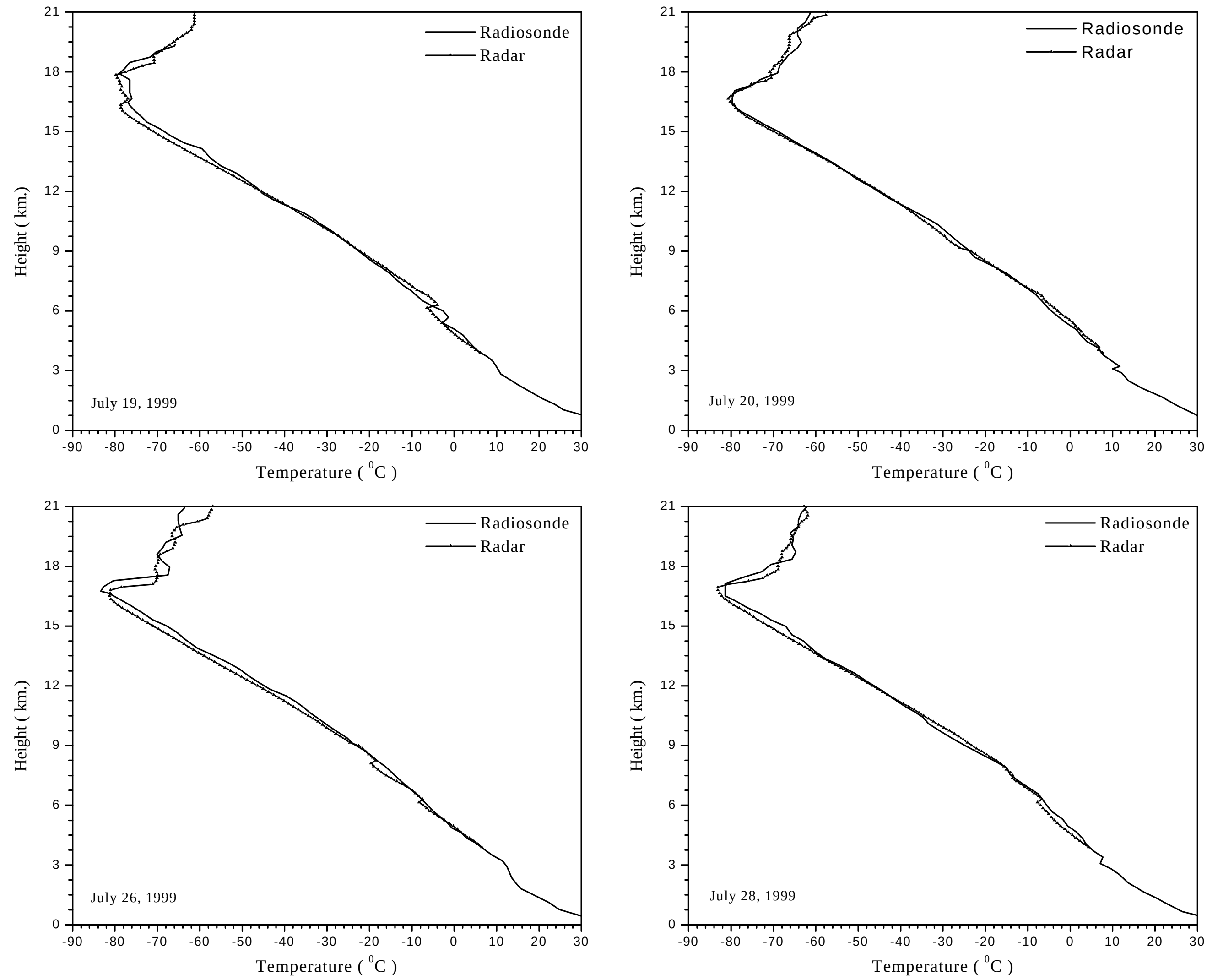

Figure 3. Temperature deduced from MST Radar. Simultaneous Radiosonde temperature profiles are also shown.

suitable z_0 for lower height range is the height where ζ and ζ^* intersect each other. From the measured ground temperature, the temperature T_i at 3.6 km (lowest height for which S_V can be determined from MST radar) is obtained assuming a constant lapse rate of 6 °K/km (Sasi, 1994). Since $\partial T/\partial z$ is estimated for each range bin, value of the temperature T_i at lowest range-bin can reproduce the complete vertical profile as $T_{i+1} = T_i + \left(\frac{dT}{dZ}\right)(Z_{i+1} - Z_i)$. The good agreement between the estimated temperature and observed values justifies our method. This method is very much empirical below z_0. But the advantage is that the temperature in lower atmosphere can be derived without humidity taken into consideration.

Acknowledgement
This work was carried out with financial support from ISRO. Authors express their gratitude to the National MST Radar Facility and UGC – SV University Center for MST Radar Applications for providing radar data and other necessary support. Thery are also

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Height variation of Tropical Tropopause: a study using Radiosonde and VHF Radar

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Abstract:

The tropopause is characterized by a strong vertical mixing and decrease in temperature with height. The main heat source for this region is the solar radiation absorbed by the earth's surface which re-radiates absorbed solar radiation as known as infrared radiation. Troposphere is most important to humankind, consists of 80% of the mass of the atmosphere and all weather phenomena are occurred in this layer. The mean lapse rate in the troposphere is about 6.5^0C/Km.The upper boundary of the troposphere which separates it from the stratosphere is referred to as Tropopause and it is characterized by atmospheric stability. Tropopause consists of several discrete overlapping levels-a multiple tropopause rather than single tropopause. The level descends stepwise from the equator to the pole. Yet thickness of the troposphere is not same everywhere, it extends to 16 Km in the tropics, whereas in the polar region it's thickness of about 8-9 Km. Warm temperatures and highly developed thermal mixing are responsible for greater vertical extent of tropopause. Tropopause is characterized by hydrostatic stability and plays key role in Stratosphere-Troposphere exchange which is the mixing of the tropospheric and stratospheric air due to adjustment of the height of the tropopause as a result of the propagation of atmospheric waves.

Doppler radar operating in VHF and UHF band of electromagnetic spectrum is a powerful tool to monitor the atmospheric dynamics on near continuous basis. Very powerful clear air radar is referred to as Mesosphere, Stratosphere and Troposphere (MST) radar. Echoes for this type of radar arise primarily from inhomogeneities in refractive index induced by clear air turbulence and stable laminae. Indian MST (operating frequency 53MHz) radar has been installed at Gadanki (13.5^0N, 79.2^0E, 375m above the mean sea level), near Tirupati. It is a powerful tool to probe the atmosphere with good height and time resolution to study the dynamics of the atmosphere.

In the present investigation, an attempt has been made to compare tropical tropopause height variation using Radiosonde and VHF Radar data for the year 2002. The study is provided by the results of upper air sounding made twice daily 00Z and 12Z from three radiosonde stations (Madras, Bangalore, and Hyderabad). Tropopause height has minimum value in monsoon because of less outgoing long wave radiation is emitted from the earth's surface as compared to the pre-monsoon and post-monsoon. The dynamic effect of this variation is due to the presence of oscillations (50-70 days, 30-50 days and 10-20 days) with rapid attenuation in the amplitudes for longer periodicities as compared to that of smaller period oscillation on tropical tropopause.

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Aerosol direct radiative forcing estimation from space-borne and ground-based sun-photometry

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Abstract:

Atmospheric aerosols play an important role in modulating the Earth-atmosphere radiation balance through their scattering and absorption of the solar radiation entering into the atmosphere. Radiative forcing due to aerosols is important to study due to its effect on climate change (Charlson et al., 1992). The various sizes and composition of aerosols affect the atmospheric radiation (Ramanathan et al., 2001). The two important parameters; *aerosol optical depth* and *radiative flux* determine radiative forcing by aerosols. The fluxes derived from the satellite measurements and aerosol optical depth obtained from a land-based sun-photometer over an urban station Pune, are combined to determine the radiative forcing in the present study.

The solar irradiance measured by the TOMS (Total Ozone Mapping Spectrometer) satellite at 380 nm wavelength and the aerosol optical depth at the same wavelength recorded by the sun photometer version of the MICROTOPS II have been normalized for the air mass and utilized to determine the direct radiative forcing (DRF) due to aerosols. Such data sets archived for a typical month of April for the years 1999, 2000, 2001 and 2002 have been studied in this paper to examine the year-to-year variation in radiative forcing during the study period. The study reveals that basically, aerosols over Pune contribute to cooling of the atmosphere. The estimated radiative forcing values are –71.06, -82.85, -54.16 and -41.82, respectively during the above four years, and are found to be in fair agreement with those reported in the literature for urban stations(Maheshkumar and Devara 2004). The decrease of DRF from 1999 & 2000 to 2001 & 2002 is considered to be due to abundance of absorbing aerosols from sources like dust, vehicles, industries and building constructional activities over the experimental station, partly from local and also from neighboring regions due to transport. The details of the data archival and its analysis procedures along with the results of DRF in other months during the four years’ period considered in the study will be presented.

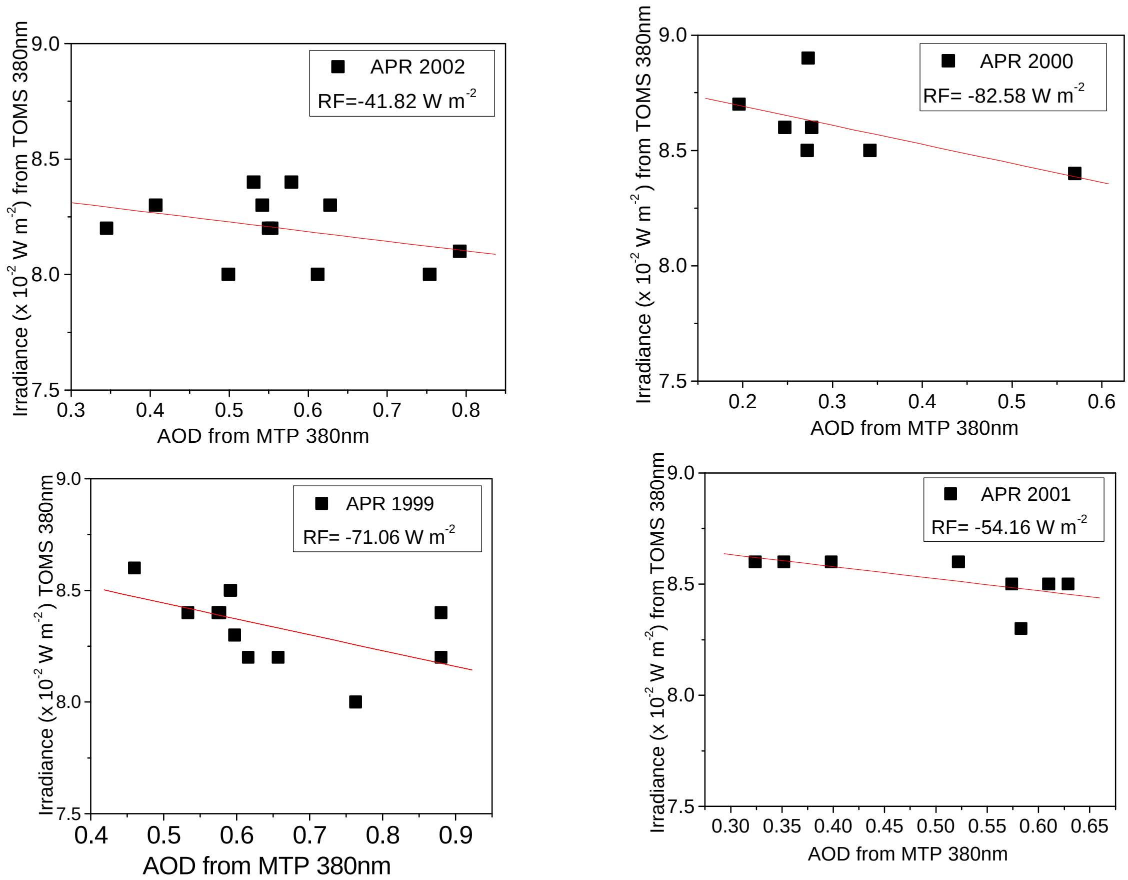

Figure 1: Direct radiative forcing due to aerosols during 1999-2002 over Pune, a fast growing city.

Acknowledgements – We gratefully acknowledge the support from the Director, IITM, Pune. Thanks are also due to the Members of the IITM Lidar and Radiation Group for their cooperation.

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Study of Aerosol Size Distribution from Remote Sensing Techniques

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Abstract:

Aerosols are defined as suspension of small (solid/liquid) particles in the atmosphere. These are one of the most complex and not fully understood atmospheric constituents, which are either generated by mechanical disintegration of soil and sea spray, yielding primary particles of size greater than 1μm or from gas-to-particle conversion resulting in particles usually smaller than 1 μm. In the troposphere, they dominate the optical properties of the atmosphere and show large variability in both space and time. The interaction of small particles with light is a sensitive function of the particle size and their optical properties. The light scattered per unit mass of aerosols often passes through a maximum as a function of particle size for incident radiation with wavelengths in the visible range. Aerosols have relatively large optical scattering cross-sections. The scattered signal from the atmosphere contains contributions from both air molecules and aerosols (at visible wavelengths) whose scattering cross-sections differ from each other mainly because of their size differences.

Different optical remote sensing techniques have been in use for retrieving the aerosol physical properties (Devara, 1989). The two most efficient techniques that have been put into use by many researchers over the globe are, Lidar (active remote sensing) and Sun-Photometry (passive remote sensing). In both these techniques, basically the scattered intensity (termed as irradiance in the case of passive remote sensing) at different wavelengths is measured. Using inversion algorithms (King et al., 1978), aerosol size distribution is retrieved from the wavelength dependence on aerosol extinction (optical depth). In brevity, Angstrom law that connects the optical depth and probing wavelength is often used to derive the aerosol size index (Angstrom / wavelength exponent), which represents size distribution. It may be noted that the passive techniques yield columnar (height-integrated) while the lidars provide vertical distributions of aerosol size spectrum.

By adopting the multi-wavelength, bistatic, Argon ion lidar facility available at the Indian Institute of Tropical Meteorology, Pune (Devara et al., 1995), attempts are being made to determine the space-time variations in aerosol size distribution. The details of the data acquisition procedures and data inversion algorithms together with the sample vertical profiles of the aerosol size index (υ) will be presented.

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Land Surface Processes and Hydrology

Studies on modeling soil wetness

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Abstract:

Soil wetness is one of the important elements of the hydrological cycle that has a profound socio - economic significance. Soil wetness is defined as the ratio of the soil water to the field capacity of the soil expressed in percentage. The crop performance has a bearing on the soil wetness. In obtaining the daily soil wetness for the monsoon period, the revised water balance model of Thoronthwaite and Mather (1955) is consulted. The study area is Andhra Pradesh and the period of study is 1999 to 2002. The investigation commences by presenting the pattern of basic mean daily agroclimatic elements over Andhra Pradesh for the monsoon period. Average soil wetness pattern for the humid and dry situations during the study period over AP are also dealt and the implications are discussed. The paper also deals with the study of soil moisture adequacy for the monsoon period over Andhra Pradesh.

The paper then proceeds in modeling mean daily brightness temperature data (BTD) of monsoon period retrieved from Multichannel Scanning Microwave Radiometer (MSMR) of IRS-P4 satellite data for the monsoon periods of 1999 to 2001 using the soil wetness data. Correlation and regression analysis have been made for the soil wetness derived from the water balance model with that of the brightness temperature data from 6.6GHz channel of IRS-P4 for the footprints over Andhra Pradesh. The study points out the inverse relation of BTD with the soil wetness.

Variation of advective fluxes of CO_2 and water vapor over Vasco da Gama , Goa during monsoon 2002.

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Abstract

Data were collected using fast sensors, like sonic anemometer (Metek, Germany) to measure wind speed and IR hygrometer (LI-COR, LI-7500) to measure CO_2 and water vapor mass density, which were installed in the premises of National Centre for Antarctic and Ocean Research (NCAOR), Goa under Arabian Sea Monsoon Experiment (ARMEX) program. Half hour averages of wind speed, prevailing wind direction and advective fluxes of CO_2 and water vapor were computed for some selected days in July, August and September 2002. Analysis shows that whenever the wind is from the Arabian Sea (AS) there is an increase in water vapor flux and decrease in CO_2 flux most of the time. This reveals that the decrease in CO_2 flux is probably due to the fact that sea is a sink for CO_2 and source for water vapor. However studies during the South West (SW) monsoon show that Arabian Sea becomes a source for CO_2 (Sharma, et al. (1998)). Our results (see Figs 1, 2, 3) showing decrease in CO_2 flux from the sea may be the result of bad monsoon in 2002. More case studies are required to confirm the results.

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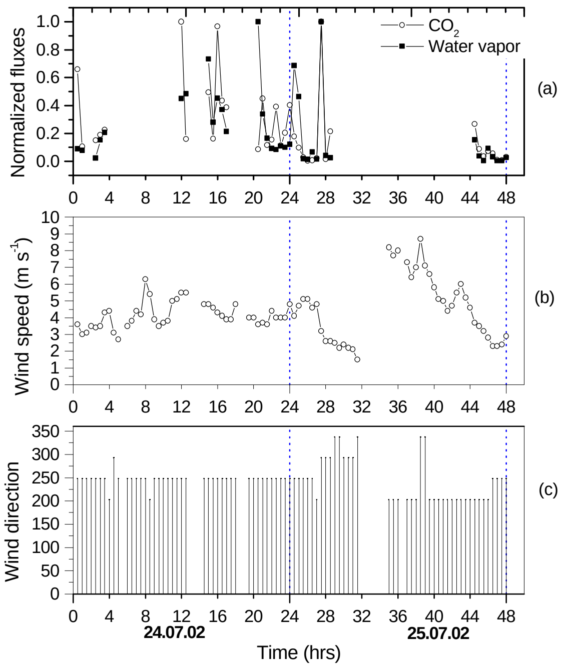
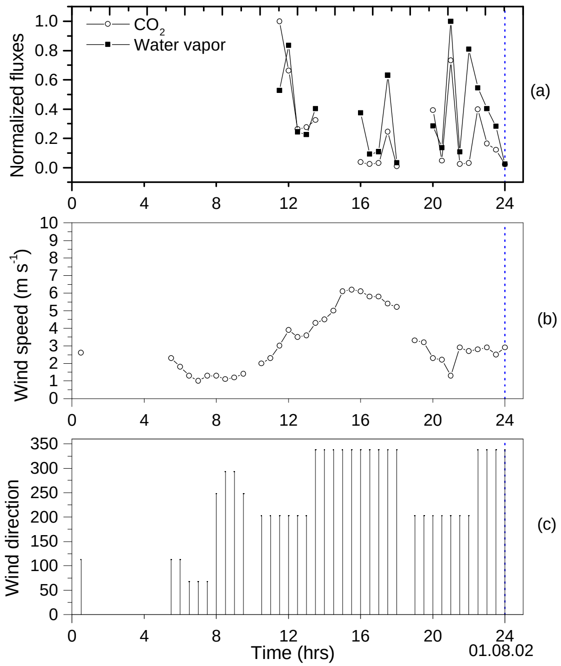
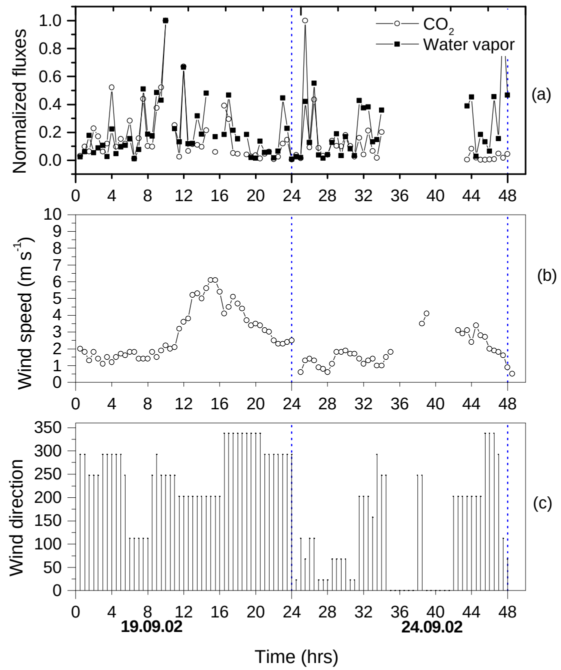


F.2 Diurnal variation of (a) Advective flux of CO_2 and Water vapor (b) Wind speed and (c) Wind direction on July 24, 25 2002 at NCAOR, Goa.



F.1 Diurnal variation of (a) Advective flux of CO_2 and Water vapor (b) Wind speed and (c) Wind direction on August1 2002 at NCAOR, Goa.



F.3 Diurnal variation of (a) Advective flux of CO_2 and Water vapor (b) Wind speed and (c) Wind direction on September 19, 24 2002 at NCAOR, Goa.

Estimation of Turbulence Parameters Using UHF Wind Profiler Radar

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Abstract

The 404.37 MHz wind profiler radar is capable of measuring all three components of vector wind viz. zonal, meridional and vertical velocities. These quantities are derived from the observed first spectral moments. The system also estimates signal to noise ratio for every range bin for a valid signal and by combining with the known radar parameters it is possible to calculate the turbulence parameter. In this study the vertical profile of refractive index structure constant $\left\langle C_n^2 \right\rangle$ (which is proportional to the radar volume reflectivity) from about 1.05 Km to 10.35 km has been estimated for the months of July 2003, December 2003 and April 2004 (angle brackets denote average over the radar range resolution of 300m). The method of determining such profiles from the radar Doppler spectra as obtained by radar observations over Pune is described. Six to eight hourly averaged profiles (depending upon the observations taken on a particular day) are used to calculate daily average C_n^2 and hence the monthly averaged C_{nRadar}^2. Here, all available hourly GMT observations data have been used for the C_n^2 calculations to get the monthly average and standard deviation. The estimates of C_n^2 from back scattered radar power are found to vary between 10^{-17} to 10^{-14} of the order of magnitude, depending on the atmospheric conditions. The comparison between C_{nRadar}^2 and C_n^2 from RS/RW data for July 2003 is seen to be in a good agreement.

Observations of pre-monsoon thunderstorm vertical velocities and reflectivity's at UHF wind profiler: A case study

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Abstract:

A 404 MHz wind profiler radar system at India Metrological Department, Pune was operated before and during a pre-monsoon thunderstorm activity, which occurred on 16th May 2004. We give here preliminary analysis of observations of vertical velocities and associated reflectivities calculated from the observed spectral signal to noise (S/N) ratio. We show based on these calculations, that precipitation signals (Rayleigh scattering) dominate the UHF signal during the thunderstorm period. The measured vertical velocity profile shows upward motions (negative Doppler shift) in the morning hours up to 3 km (at 8 a.m. 11 a.m. wind profiler observations). When the thunderstorm starts developing or gets initiated a strong downdraft (positive Doppler shift) with vertical velocities between -1m/sec to even -4 m/sec are seen in the height region of 3 to 10 km. In the growing stage, the downdraft can be seen to be prevalent right from lowest observable height of 1.05 km. In this stage the vertical velocities reach even values of as much as -8 m/sec. The reflectivity profiles during clear air conditions before thunderstorm activity were predominantly negative (at 8 a.m. 11 a.m. & 2 p.m.). The reflectivity increases by more than 0 dB, at times touching 20 dB once the heavy precipitation starts falling during that period (at 5 p.m. 6 p.m. 7 p.m. 8 p.m.). The vertical velocity fluctuations (s_w) show a turbulent region with high s_w values in the thunderstorm period.

Estimation of river water discharge by using IBIS- HYDRA model over 3 major river basins in India

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Introduction:

Water is a renewable but finite resource. No matter who we are, where we are, and what we do, we all dependent on water. We need it every day, in so many ways we need it to stay healthy and for growing food, irrigation and industry. We need it for plants and animals, for changing colors and seasons. However, despite the importance of water in our lives and well-being, we are increasingly disrespectful to it.

Urbanisation and industrial development have led to serious concern about the quality and quantity of water supplies. Natural and human induced variations in climate added further uncertainty to the future availability and distribution of water. Successful management of river water requires knowledge of how much water flows in a river and factors controlling the quality as well as the quantity of surface water flow. Very little quantitative information is available on river water discharge of the country.

To address the above issues, quantitative framework called HYDRA (Hydrologic Routing Algorithm) and IBIS (Integrated Biosphere Simulator) in conjunction with climate data have been used to study river water discharge over 3 major river basins(the Krishna, the Godavari and the Ganga)in India.

Procedure-:

In this study, high resolution girded precipitation and temperature data sets developed by Climatic Research Unit (CRU), University of East Angial, UK have been used. HYDRA [*Coe, M.T. 2000*] simulates seasonal river discharge on a spatial scale of 5^0 x 5^0 and a 1-hr time step. HYDRA is forced with monthly mean or daily runoff, precipitation and evaporation. The model derives the river path and maximum lake area and wetland volumes from digital elevation model (DEM). IBIS [*Foley ET all. 1996*] and HYDRA are used to investigate the changes in the water balance. IBIS has been used to derive estimates of the land surface water balance. The IBIS simulations of runoff are used as input to the HYDRA model to estimate river discharges.

Data used for validation:

Monthly observed discharge data at 14 sites in the Krishna basin having for 23 years from 1972- 1994 were used for the analysis. The long period data at Vijaywada available for the period of 1901-1994 with missing years 1961-1964 was also used. In this study, discharge data from the sage website *(http://www.sage.wisc.edu/riverdata/)* were also used for the analysis for sites in the Godavari and the Ganga basins.

Results:

Comparison between observed and simulated mean annual river discharges was made at 15 discharge sites in the Krishna basin, at 8 Sites in the Godavari basin and at 1 site in the Ganga basin. The simulated annual mean discharges were found to be much greater than the observed data at many sites including Bagalkot, Sarati, Takali, Yadgir and Pondugala in the Krishna river basin but for the sites like Karad, Galgali, Huvenhegdi and Vijaywada, simulated annual mean discharges were in good agreement with observed annual river discharges. The simulated annual discharges were much less than the observed annual discharge at many sites including Shimoga, Harhalli, Oolenur, Mantralayam and Bawapuram in the Krishna basin.

In case of the Godavari river basin simulated annual mean discharges were found to be much greater than observed annual river discharges for all the sites except Polavaram.

For the Ganga river basin simulated discharges is in good agreement with the observed river discharges for the Farakka site.

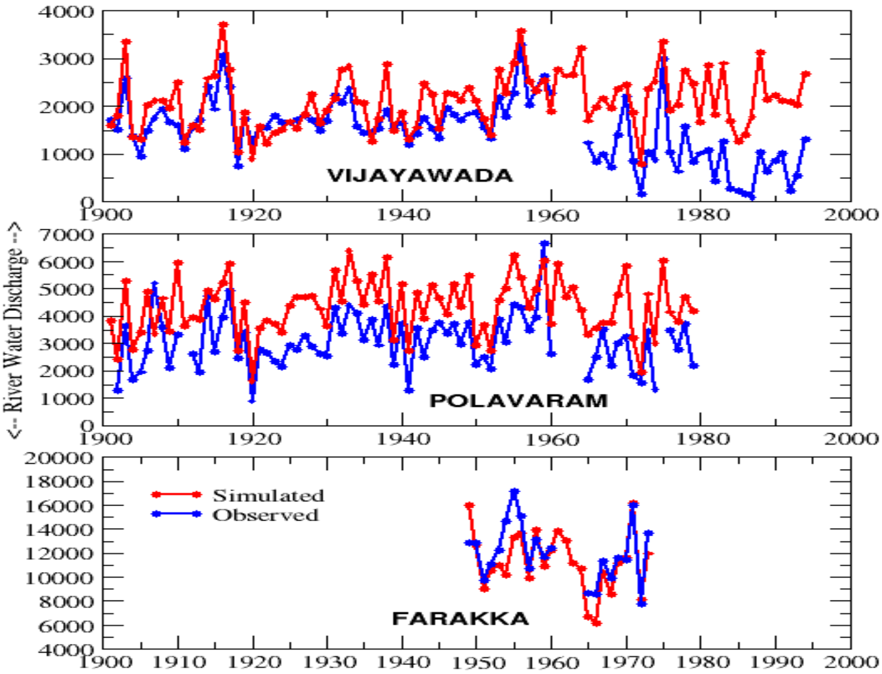

Fig.1: Observed and simulated river water discharges (m^3s^{-1}) at selected sites over 3 major river basins.

Conclusions:

This analysis showed that observed and simulated river discharge data for sites representing the basin as a whole like Vijayawada in the Krishna, Polavaram in the Godavari and Farakka in the Ganga basin are in reasonably in good agreement. However, mean annual discharges were found to be overestimated by the model except at certain sites. Lakes, wetlands and dams change the seasonal amplitude of the river discharge. Including dams and reservoirs within the HYDRA will reduce the biases. These differences may be due to biases introduced by the incompatibility between the DEM used and the actual river basin area.

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Gridded Rainfall Data over India For Numerical Model Validation

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Introduction

The objective of this study is to prepare the uniformly gridded rainfall data sets over India for numerical model validation. In this preliminary stage, we utilize two simple interpolation schemes to convert the irregularly spaced raingauge station data into uniformly gridded data. We briefly describe the methodology used in the two interpolation schemes and compare the results for June 1998.

Methodology

(i) Inverse Square Weighting Method

In this method the unknown gridded rainfall is estimated as a weighted average of surrounding raingauge station values, the weights being reciprocal to the square distances from the grid point. Only station data within 2^o lat./ long.of the grid location is considered.

(ii)Binning method

In this scheme first a fine mesh or super grid subset for each grid box is made and then the closest station value is assigned to each of this super-grid box. Finally the values of all the super-grid is averaged to get the gridded rainfall.

Data and computational domain

The raingauge station data used is the one day accumulated precipitation amounts provided by the India Meteorological Department (IMD) for each day of June 1998 at 1467 station locations widely spread over India.

The domain for interpolation over Indian region was chosen to consist of 35x32 grids at 1^ox1^o lat./ long. resolution covering 66.5^oE to 100.5^oE and 6.5^oN to 37.5^oN.

Results

Figure 1 shows the gridded monthly total rainfall (mm) and the standard deviation using the inverse square weighting method (RF1) and the binning method (RF2). In general, the spatial variation of the monthly total rainfall (Fig. 1 (a) & (c)) is found to be similar. The heavy rainfall patterns along the western coast and in the north-eastern region are brought out reasonably well by both the interpolation schemes. These are found to be comparable with the long term climatic mean rainfall for the month of June.
The regional variability in the daily rainfall for June 1998 is found to be different for the two interpolation schemes as shown in the standard deviation plots (Fig. 1 (b) & (d)).

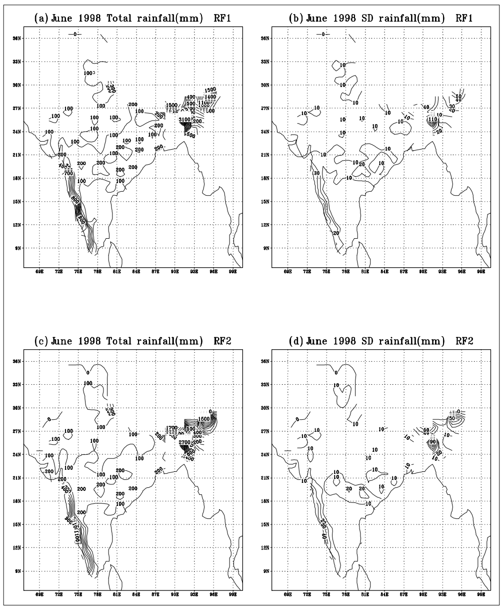

Figure 1: Gridded monthly total rainfall (mm) and standard deviation for June 1998; (a&b) using the inverse square weighting method [RF1] and, (c&d) the binning method [RF2].

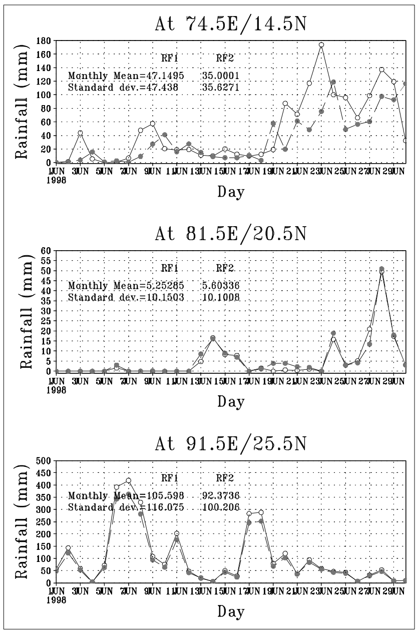

Figure 2: Daily rainfall during June 1998 at selected grid locations over India; (a) west coast, (b) east coast, and (c) north-east region.

In order to make a more detailed comparison, we have plotted in Figure 2 the time series of rainfall at selected grid locations over (a) west coast, (b) east coast, and (c) north-east region. The monthly mean and standard deviations from the two interpolation schemes are also plotted for comparison. It is found that for the grid point in the west coast heavy rainfall events started after mid June leading to high monthly mean values together with large daily variability. over the east coast also the rainfall variability is found to be significant even though the monthly mean values are less. Similarly large rainfall variability is also seen for the grid point over north east where frequently heavy rainfall of localized orographic nature occurs. The two interpolation schemes are found to behave similarly at all locations.

Concluding remarks

Rainfall at a daily time scale is the most important numerical model forecast product. The validation of its spatial distribution is often difficult because there is no known accurate interpolation technique to convert observed rain gauge measurements to a surface that describes the spatial pattern over an area. In this short study we have attempted to use two well-documented simple interpolation techniques found in literature. The scope of this study is not to determine the best or most suitable interpolation technique but to determine what differences there exist between them. Further studies are being planned utilizing more sophisticated rainfall interpolation schemes using smoothing splines.

Acknowledgements

This work is being carried out as a part of the Regional Climate Modelling project under the ISRO-GBP. Thanks are due to IMD, Pune for providing the station daily rainfall data and ISRO through SAC Ahmedabad for financial support.

Study of Indian Summer Monsoon Break Spells

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Abstract:
Indian summer monsoon (ISM) undergoes intraseasonal oscillations (ISO) on subseasonal scale, which consists of the active and break phases. During the prevalence of southwest (SW) monsoon season, there are periods when clouding ceases over the country, outside the Himalayan belt and southeast peninsula. This is the "break monsoon" condition. The break spell is associated with a general rise in pressure over the country, shifting of monsoon trough to the foothills of Himalayas, reduction or complete cessation of rainfall activity in the central and part of north India and enhanced convection and rainfall activity in the southeast peninsular India, northeast India and foothills of Himalayas. Ramamurthy (1969) noted that the duration of ISM break varies from 3-5 days to 17-20 days. If the break conditions persist for more than one week, it may lead to drought conditions.

In the present investigation, we propose criteria for identifying breaks in the ISM based on the daily outgoing longwave radiation (OLR) data. The daily OLR data is satellite data available globally on 2.5^o longitude X 2.5^o latitude resolution. The data is obtained from the website http://www.cdc.noaa.gov/cdc/data.uninterp_OLR.html. The details of the data are described in Gruber and Krueger (1984).

The criteria proposed for identifying breaks is that when the standardized OLR anomaly averaged over a region 73^o E – 82^o E; 18^o N - 28^o N latitude exceeds 0.9 for consecutive 4 days and the average anomaly over the region in these break days exceeds 1.25 (Krishnan et.al., 2000). The breaks are classified as long, medium and short breaks when the number of break days is more than 10 days, between 5 -10 days and less than 5 days respectively.

Total 37 break spells and 289 break days have been identified based on the proposed criteria for the ISMs during the period 1974 - 2003. During this period, the maximum number of breaks in a particular ISM season is found to be 5 and the longest duration break is found to be 19 days. Both these have been noticed in the pronounced drought year 1979. The ISM drought of 1987 associated with El-Nino is characterized by 3 breaks as per the OLR criteria used in the present study, two of which are medium and one short break. The unprecedented below normal rainfall conditions over India in the month of July 2002 have been extensively studied (Gadgil et.al., 2002, Kriplani et.al., 2004, Kalsi et.al., 2004). Two break spells were observed in July 2002, one of which is long break (12 days) and other medium (7 days).

Composite OLR anomaly for long, medium, short and all breaks have been calculated. The spatial distribution of composite OLR anomaly over the region 30^o E – 80^o W, 30^o S – 40^o N has been studied. The common features noticed in all types of break conditions are strong positive anomalies (> 38 W/m^2 indicating suppressed convective activity) over central and peninsular India contrasted by negative anomalies (~ 17 W/m^2 indicating increased convective activity) over East Indian Ocean and South China Sea. Positive anomalies extend southeastwards towards the maritime continent and southwards over Arabian Sea in all the break types. In long breaks, negative anomalies over East Indian Ocean and South China Sea are stronger compared to all breaks. In addition, there are negative anomalies over north India suggesting increased convection. During the

medium breaks, positive anomalies over the southern tip of peninsular India and northeast India are weaker compared to all break composite. The peculiar feature noticed during the short break composite is the presence of negative OLR anomalies over the northern tropical Pacific Ocean and increased positive anomalies over maritime continents.

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Monsoon Climate and Ocean Studies

Monsoon Performance From Eta Model

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Abstract:

Forecasting of rainfall for the monsoon period (June-September) is a crucial one for India's economic growth in terms of agricultural production. The country receives about 75% of its total annual rainfall during these four months. So, the real time monitoring and prediction of monsoon rains therefore have considerable significance. In the present investigation an attempt is made in simulating rainfalls of July 2003 and July 2004 in an attempt to understand the anomalies in SW monsoon circulation pattern compared to normal and for which Eta model (version 0.2) is made use of in achieving this. The analysis and forecasts of operational global spectral model (T80/L18) are used as initial and boundary conditions for the Eta model runs.

The present investigation deals with the adverse wind circulation at various atmospheric levels over India along with the physical process causing subdued rainfall in different parts of the country. One of the important features revealed from this study is the establishment of a ridge over NW India and is one of the reasons also for that region not getting good rain fall. Other feature is the location of monsoon trough near the foothills of Himalayas. Also, the lower pressure analysis in the monsoon trough region suggests that the heating over this belt is higher, which in turn could be due to week monsoon conditions in July 2004. Other features such as i) weak east-west shear zone in the middle troposphere locates much to the south in July 2004, ii) drier atmosphere over north and NW India in July 2004 and iii) very high sensible heat flux values over NW India and Arabian sea in July 2004 were clearly brought out in the model analysis and forecasts. Diagnostic study of wind and physical parameters also show certain interesting features corroborating anomalous monsoon performance during July 2004 over the country.

Study of heavy rainfall events over Mangalore region, the west coast of India during 2003

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Abstract:

India is a country blessed with the world's most gigantic monsoon system popularly known as southwest (summer) monsoon. This is the most prominent rain-giving season of India and about 80% of the rainfall is received during these four months (June-September). The study area in Mangalore region (12°49'00''N latitude and 74°56'23"E longitude and elevation of 80m above the MSL) is situated on the west coast of India at the foothills of Western Ghats. The southwesterly winds from the Arabian Sea loaded with moisture, due to orographic lifting give copious rains in this region. In this study the heavy rainfall episodes are considered. The surface air observations up to 20meters heights (2m, 6m, 10m, 15m, 20m) at regular synoptic hours with additional observations obtained from the satellites pictures (Dundee satellite receiving station) during the rainy season of 2003 are presented.

Thermocline variability in the Equatorial Indian Ocean

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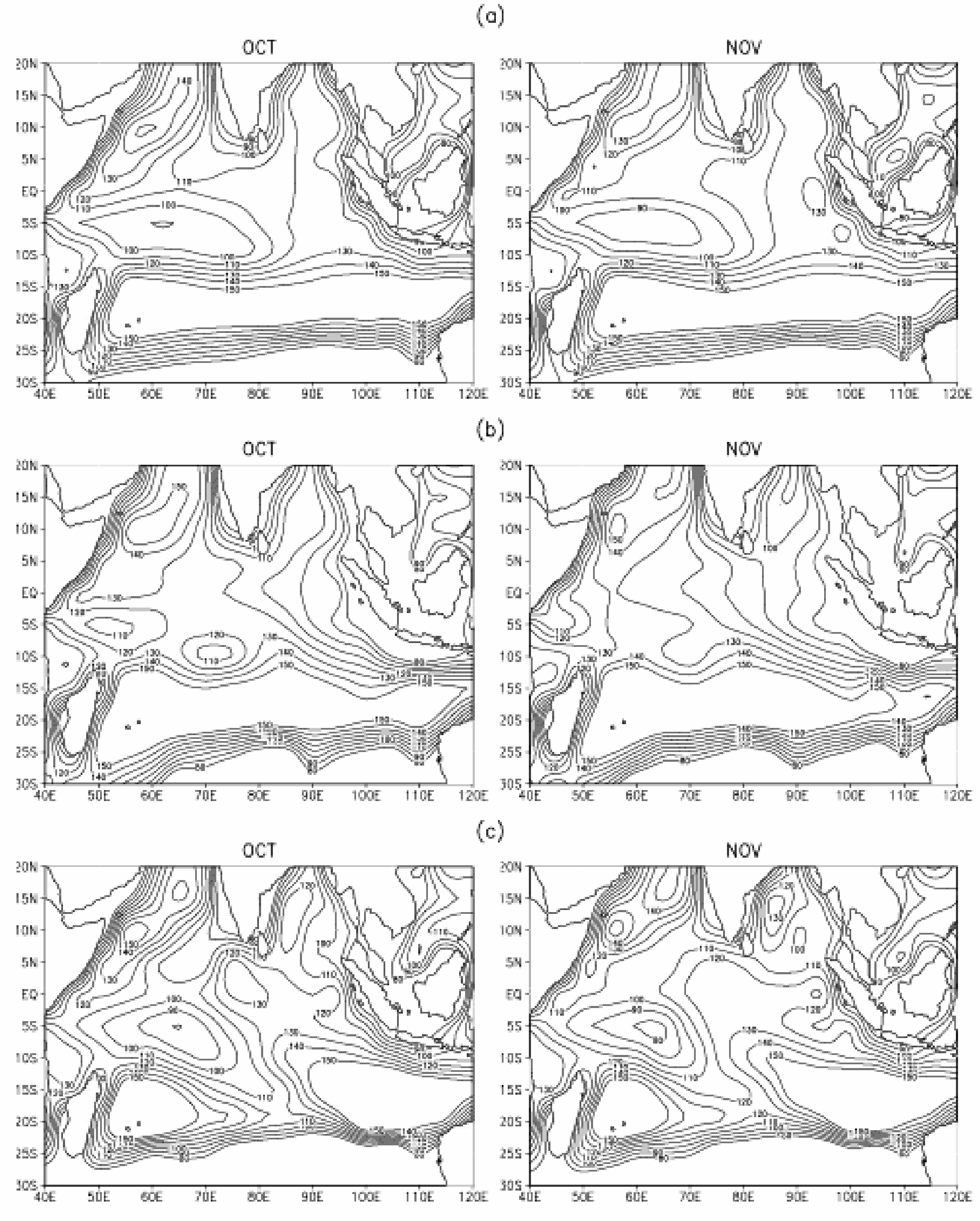
Introduction:

The Simple Ocean Data assimilation (SODA) temperature datasets for the period 1950-2001 are used to understand the variability in the thermocline in the Equatorial Indian Ocean. The study is mainly focused on the interannual variability, the Indian Ocean Dipole. During the study period 1961,1963,1972,1982,1994,1997 are the positive dipole events with the 1972,1982,1997 events co-occurring with ENSO in the Pacific, and 1954-55, 1958-60,1964,1975,1984,1989,1992,1996 being the negative dipole events(Suryachandra Rao et al 2002). In contrast to the Pacific, in the Indian Ocean the sea surface temperature (SST) is high in the eastern Equatorial Indian Ocean and low in the Western Equatorial Indian Ocean. But in some years the SST gradient reverses and causes shifting of convective activities over the western equatorial Indian Ocean. This has been identified as the Indian Ocean Dipole (IOD)(Saji et al 1999). A positive IOD is characterized by cold SST anomaly in the southeastern tropical Indian Ocean and warm SST anomaly in the western tropical Indian Ocean. Whereas a negative IOD is characterized by warm SST anomaly in the south eastern tropical Indian Ocean and cold SST anomaly in the western tropical Indian Ocean

Discussions:

The climatological thermocline depth shows that in the equatorial Indian Ocean the eastern region shows deeper thermocline compared to the western region. Thus there is a downward slope in the thermocline from west to east. In contrast to this the thermocline depth during the positive dipole event of 1997 shows shoaling of thermocline in the eastern Equatorial region and deepening in the western equatorial region in October, which further intensifies in November. This suggests that IOD is not merely a surface phenomenon but also has subsurface signatures in the form of oscillation in the thermocline. In another IOD year, 1972, the western equatorial region shows shallow thermocline depth while the eastern equatorial region shows deeper thermocline in October. And in November the western Indian Ocean thermocline becomes shallower while the eastern equatorial Indian Ocean becomes deeper. This implies that in contrast to 1997 where the subsurface signature of IOD was very strong and reached its peak strength in November, in 1972 the subsurface signature is weak and reaches its peak strength in October and starts decaying after that. Both 1972 and 1997 being El Nino years these contrasting signatures further reiterates that IOD is an independent event, which has very little influence of the Pacific Ocean.



(a)Climatological depth of 20 degree isotherm (b)Depth of 20 degree isotherm during 1997
(c)Depth of 20 degree isotherm during 1972

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A statistical analysis of Topex/Poseidon altimetry data with emphasis on Indian Ocean Dipole

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Abstract:

Indian Ocean Dipole (IOD) has been shown to be the leading mode of the interannual variability of the upper ocean heat content and sea level anomalies. In this paper we attempted to study positive and negative dipole pattern by applying statistical techniques. Heat storage anomalies (HSA) [calculated from Topex/Poseidon sea level anomalies (TPSSHA)], bi annual Rossby wave signals (filtered from TPSSHA by Finite Impulse Response Filter) and thermocline depth (D20) derived from SODA (Simple Ocean Data Assimilation) were plotted for October 94, October 96, November 97 (Figure 1). Positive dipole structure has found in October 94, November 97 and negative dipole structure was found in October 96. HSA, D20, biannual Rossby wave component have showed that signals were stronger in 1997 than 1994. Figure 2 shows the correlations calculated in the IOD box [90^o-110^{o}E, Eq.-10^{o}S] between the time series of parameters and a suitably fixed time (fixed based on peak IOD month which is given in Figure 2) of the same parameter. This give a correlation series [say c(t)] for particular parameter. It was seen that positive and negative dipole years are inversely correlated. Moreover mean amplitude of c(t), which is given by Ac= v2 σ [c(t)] has also been calculated and given in Figure 2. Now before applying similar procedure to positive IOD box [50^o – 70^{o}E, 10^{o}S – 10^{o}N] we divided it into two region one northern region say Region 1 [50^o – 70^{o}E, Equator – 10^{o}N] and other southern region say Region 2 [50^o – 70^o, Equator – 10^{o}S]. It was observed that both region behave differently in different dipole. The Ac values calculated for region 1 and region 2 for different parameter are given in Table 1. Figure 3 shows IOD index calculated for HSA, biannual Rossby wave and D20 anomalies. It confirms the existence of dipole modes in 1994 and 1997. The Biannual Rossby waves are found to have played an important role in generating dipole like variability in the Indian Ocean.

Table-1

Region 1	
Heat Storage Anomalies	**D20 Anomalies**
Oct. 94, Ac =.477510	Oct. 94, Ac =.64236
Oct. 96, Ac =.455022	Oct. 96, Ac =.611283
Nov. 97, Ac =.31152	Nov. 97, Ac =.471956

Region 2		
Heat Storage Anomalies	**Biannual Rossby waves**	**D20 Anomalies**
Oct. 94, Ac =.51993	Oct. 94, Ac =.71756	Oct. 94, Ac =.52271
Oct. 96, Ac =.29735	Oct. 96, Ac =.57692	Oct. 96, Ac =.54149
Nov. 97, Ac =.48274	Nov. 97, Ac =.89233	Nov. 97, Ac =.60053

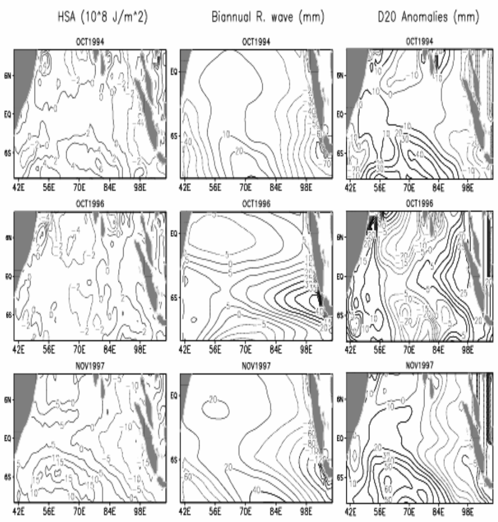

Figure 1: IOD structure. Equator-10°S

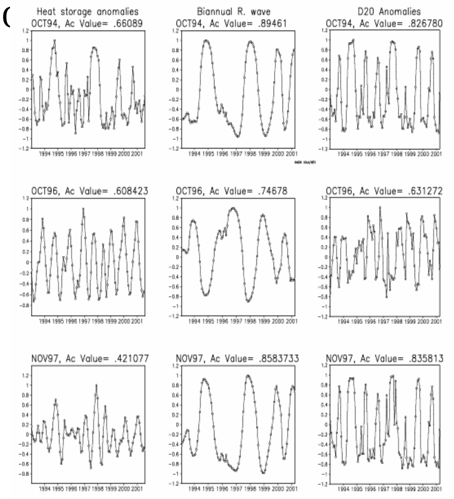

Figure 2: Correlation calculated Domain90°E-110°E.

Acknowledgement:

We are thankful to Director and Head TSD for providing facilities. We are great thankfull to Dr. P. S. Polito (Instituto Oceanográfico da Universidade de Sao Paulo (IOUSP), Brazil., for providing FIR filter and suggestions from time to time. The financial support was provided by Department of Ocean Development, Govt. of India through DOD - INDOMOD) project. The authors are thankful to the T/P team and AVISO altimetrie for provision of altimeter data. We acknowledge Dr. D. P. Chamber for providing monthly thermal expansion coefficient for the Indian Ocean region.

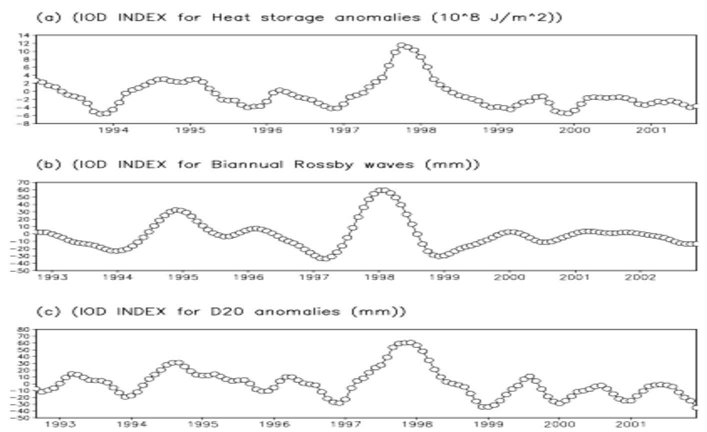

Figure 3: IOD index.

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Dynamic Response of Indian Ocean to Inter-annually Varying Surface Forcing in an OGCM

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Introduction

`The equatorial Indian Ocean is characterised by strong upwelling in the western region and insignificant upwelling in the east. The bewitching feature of EIO is the semi-annual equatorial Kelvin waves and the associated eastward jets (Wyrtki, 1973). The Sea Surface temperature (SST) in the east equatorial Indian Ocean is warmer than 27.5^{o}C throughout the year. The cooling in the east and warming in the western Indian Ocean were enough to reverse the climatological SST gradient along the equator. This unusual development of strong cooling off the Sumatra Coast and warming in the west equatorial Indian Ocean leads to the recognisation of existence of a major mode called dipole/zonal mode in the Indian Ocean (Webster et al., 1999, Saji et al., 1999). A three dimensional Ocean General Circulation model could successfully simulate the dynamical and thermo dynamical processes associated with unusual phenomenas in the Indian Ocean.

Model

In the present ocean modeling scenario, perhaps Geophysical Fluid Dynamics Laboratories (GFDL) Modular Ocean Model (MOM4poc) may be the versatile model with increased realism in the simulation of oceanic parameters. MOM is a numerical representation of the ocean's hydrostatic primitive equations. MOM is a 3-Dimensional Z-co-ordinate Ocean General Circulation Model (OGCM). MOM evolved from numerical ocean models developed in the 1960's - 1980's by Kirk Bryan and Mike Cox at GFDL.

Methodology

The model has zonal and meridional resolution of 1^{o} x 1^{o} and 25 vertical levels. The model started integration from rest (u=0, v=0) with the initial conditions of temperature and salinity from Levitus climatology. The model was forced with monthly climatological precipitation, daily climatological radiative fluxes of downwelling shortwave and longwave radiations and 6 hourly climatologies of 10- zonal and meridional winds, air temperature, humidity and sea level pressure from National Center for Atmospheric Research (Large and Yeager, 2004). Monthly chlorophyll-a climatology from Sea-wifs is used for shortwave penetration. After attaining a steady state with 20 years of spin up the model was integrated with inter-annually varying surface forcing fields (1958 -2000) of monthly precipitation, daily fluxes of downwelling shortwave and longwave radiations, 6 hourly 10- zonal and meridional winds, air temperature, humidity and sea level pressure from NCAR.

Results and Discussions

The model simulated Sea Surface Temperature Anomaly (SSTA) shows good agreements with the Observed (HADISST) anomalies (Fig. 1) during peak phase of Dipole mode years October 1996 and November 1997. Where 1996 was a negative dipole mode year and 1997 strong positive dipole mode year. The model shows a maximum cooling of 2^{o}C during November 1997. This is well coincides with the observations.

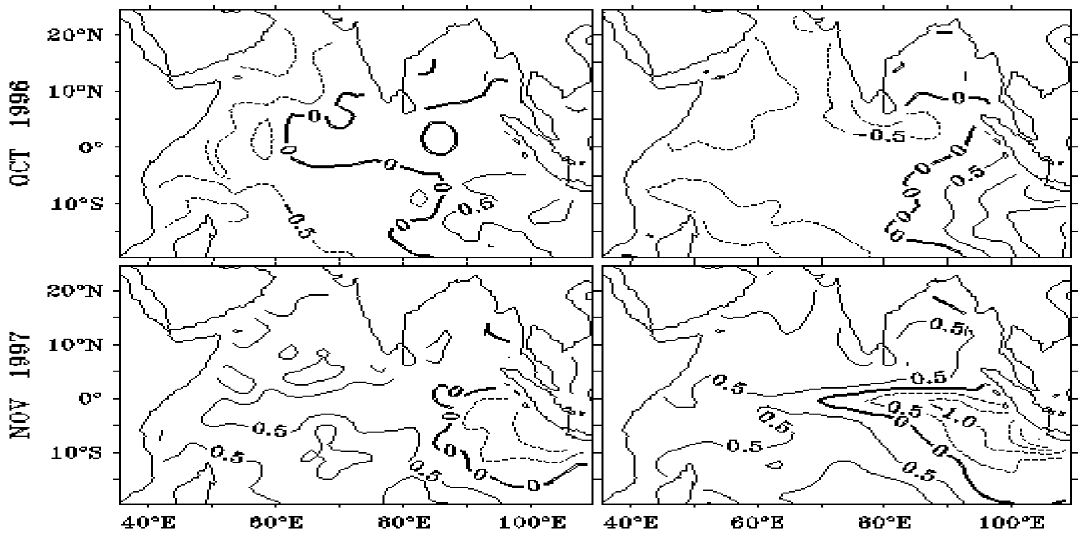

Fig 1. The SST Anomalies HADISST (left) and model (right)

The model could simulate well the current systems in the Indian Ocean. The strong currents associated with the peak phase of negative dipole mode year and absence of Wyrtki jets in the positive dipole mode year (Fig 2). During November 1997 the eastward equatorial jets were replaced by westward current. Strong variability in the circulation of Bay of Bengal especially during the dipole mode years was also seen in the model simulations.

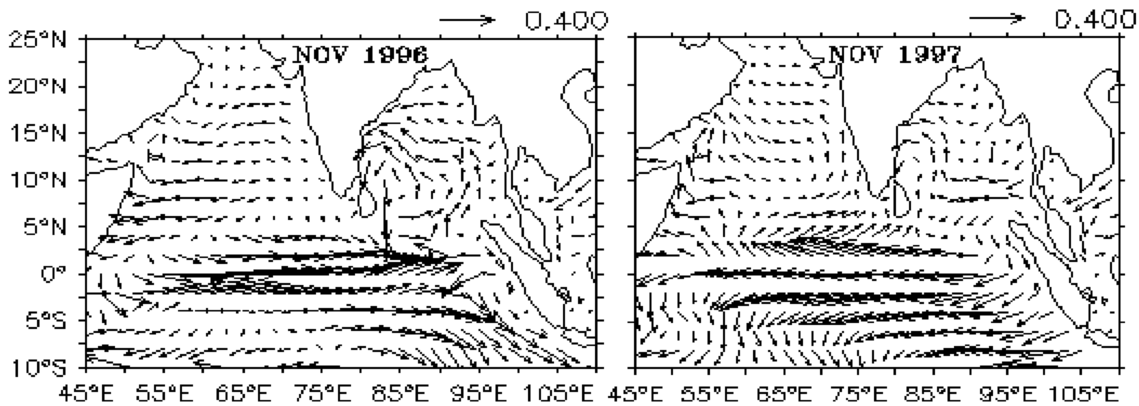

Fig 2. Model Simulated currents during peak phase of dipole mode years

Acknowledgements

First author is acknowledging CSIR,India for financial support. Acknowledgements are also due to GFDL for making available MOM model and Director, IITM for providing infrastructure.

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Structure of Sea Breeze and Land Breeze Before and After the Onset of Monsoon- A Case Study for a Coastal Station

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Abstract:

Sea breeze plays a key role in controlling the meteorological conditions along coastal areas. It is also the most important meteorological variable for using in air pollution studies. The direction and speed of transport of pollutants released from industrial and vehicular sources are governed by wind vector. The primary branches associated with the circulation are the low level sea breeze and the return flow aloft while rising and sinking motion occurs over land and ocean respectively. It has been shown however that the direction and strength of the synoptic flow affects the structure and evolution of sea breeze. The duration and intensity of sea breeze circulation vary with rain or cloud as it reduces the differential heating. With the exception of wind profiles, there has not been sufficient data to show the structure in the upper layers. Because of the vertical scale of the order of 1km and the horizontal dimension of 100km, only rarely organized extensive experiments can deal with the three dimensional structure of sea breeze. It is in this context that the role of mathematical modeling comes into effect. over the past three decades, mathematical modeling of coastal flows has continuously been evolved. The study of vertical structure of sea breeze is of interest not only with respect to air pollution studies but also to thermodynamics of sea breeze as it interacts with urban metrology. The structure of sea/land breeze over Cochin is studied using the mesoscel model MM5. Data for the domain (9ºN- 11ºN & 75ºE-77ºE) are studied for representative days of May and June. The strength, direction and sea breeze component are studied to quantify the contribution of southwest monsoon. Earlier studies on surface wind (Bindu 1998) showed some influence of south west monsoon on the speed and direction of sea /land breeze. This paper describes the combined observational and theoretical study of Lake Breeze and related diurnal variations. It is our goal to understand more completely the trajectories of individual air parcels. These data will be then used as input to a kinematics diagnostic analysis of pollution transport within coastal flows in future work. They will also be subsequently employed for a detailed comparison on observed wind fields versus computations by the three dimensional mesoscale models.

Key words-Sea breeze-MM5-return flow-vertical structure

Numerical simulation of the mesoscale vortices associated with heavy precipitation over the west coast of India during the southwest monsoon season

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Abstract

During the onset phase of the Indian southwest monsoon gives good amount of rainfall over the west coast of India, characterised by the occurrence of heavy rainfall. It is observed that heavy precipitation occurs over small regions of few kilometers radius, attributed to mesoscale vortices. The heavy rainfall event over west coast of India associated with mesoscale vortices during 26- 28 June 2002 (ARMEX Phase- I) is simulated using a high-resolution mesoscale model - NCAR MM5. The model with four nested domains of 81, 27, 9 and 3 km resolutions, is integrated for 72 hr from 00 UTC of 25 June 2002. The initial and boundary conditions are derived from NCEP analysis available at 1-degree resolution. The model derived rainfall and the wind fields are analysed. The horizontal and vertical structure, and the life period of the mesoscale vortices are analysed from the model output. The model results indicate the formation of a mesoscale convective system, and associated heavy rainfall on 27 and 28 June 2002. The model could predict heavy rainfall up to about 30 cm/day though some observations at isolated locations are up to 50 cm/day. The radius of these mesoscale vortices is only few kilometers and these vertically extend up to 700 to 500 hPa levels and the life period of these vortices are noted as a few hours. During the period of formation and development stages of the mesoscale vortices, it is noted that the maximum rainfall occurred.

Wind Driven Transports in the Arabian Sea during 2000 – 2003

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Introduction

The Arabian Sea is directly forced by the strong seasonal reversal of monsoon winds. During southwest monsoon period, winds remain remarkably unidirectional though magnitudes vary some what with time and space over the Arabian Sea (Weller et al. (1998). Southwesterly winds pickup the moisture from western Arabian Sea and deposit rainfall over 80% of the Indian subcontinent. The Surface wind speed is largest in July, actually twice as large in January. The Sea Surface Temperature (SST) of the Arabian Sea displays the large seasonal variations with two warming phases in spring and fall and two cooling phases during summer and winter monsoons. In the summer monsoon SST cools due to wind mixing, horizontal and vertical heat advection and air-sea heat fluxes. Presently we shall describe the possible relation between wind driven transport and monthly SST variability in the summer monsoon period.

Data and Method

Surface wind vectors at 25km resolution over a single 1600 km swath centered on the satellite ground track were obtained from the sea winds instrument on board Quikscat Satellite. These surface winds were interpolated to 1° × 1° resolution, averaged for each month in order to remove the synaptic weather systems. Wind driven transports are computed based on Stommel (1965).

Results and Discussions

The total monthly mean north-south Ekman transport along a latitude exhibited a strong annual cycle during the period 2000 to 2003 over the Arabian Sea (Fig 1a). Latitude - Time plot showed that there was less interannual variability in both meridional Ekman and Sverdrup transports. The total monthly Sverdrup transport along a latitude were southward below 13° N and northward above 13° N in the Summer monsoon season (Fig 1b). Mean monthly vertical transport at the bottom of Ekman layer over the Arabian Sea (north of 8? N), meridional Ekman transport and Sverdrup transport along the Arabian Sea at 8.5? N were computed using Quikscat surface wind fields. Fig 2 shows time series of the zonally integrated north south Ekman transport and Sverdrup transport between 52? E and 76? E correspond to the Arabian Sea at 8.5? N during the period January 2000 to December 2003. The maximum negative (southward) Ekman transport and Sverdrup transport occurred in July and maximum positive (northward) Ekman transport occurred during winter period (January and February) of each year. The vertical transport over the Arabian Sea north of 8? N, maximum positive value observed in the month of July and gradually decreases thereon, these results are well comparable with Halpern et al (1998). During Southwest monsoon period both Ekman and Sevrdrup transports are in phase with SST and vertical transport showed opposite in phase. Strong southword transports at 8.5? N (Ekman and Sevrdrup) and drop in SST over Arabian Sea indicating that, wind driven transports have significant effect on SSTs in summer monsoon. In June when SST begins to decrease, the average vertical velocity through the Arabian Sea was upward. It is important to note that there was relatively large interannual variability in the north-south Ekman transport observed as compared to the Sevrdrup transports between contrasting monsoons of 2002 and 2003.

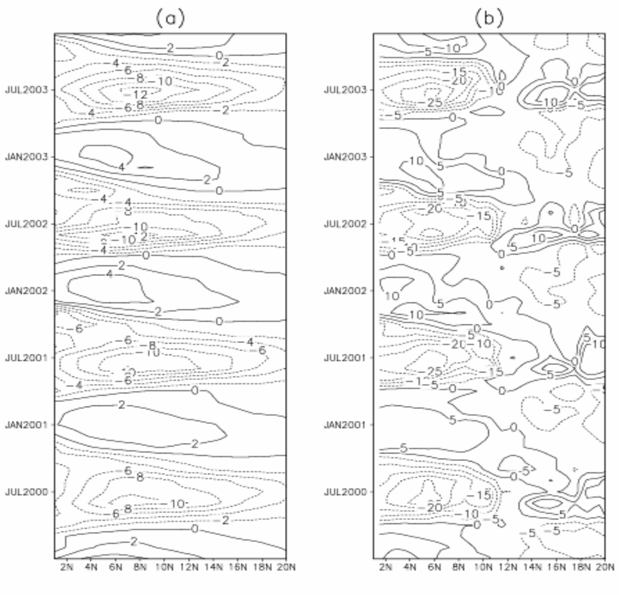

Figure 1. Time series of total monthly north-south Ekman transport along latitude (a) North- South Ekman Transport (b) Sevrdrop Transport.

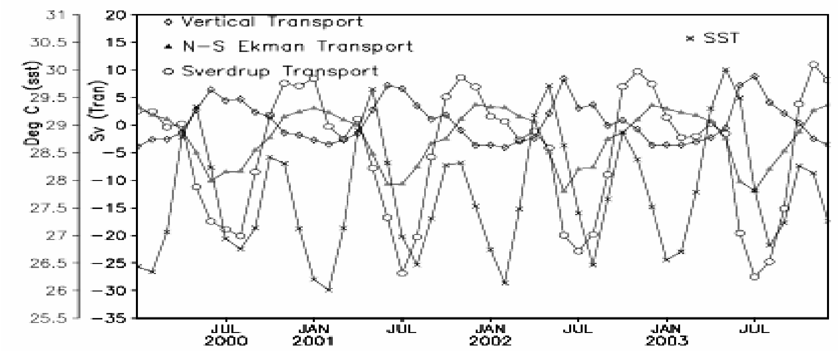

Figure 2. Monthly mean vertical transport at the bottom of Ekman layer, SST in the Arabian Sea (north of 8? N), meridional Ekman transport and Sverdrup transport along the Arabian Sea at 8.5? N.

Acknowledgment

The authors wish to acknowledge Department of Ocean Development, Government of India, for providing the financial support. Acknowledgments are also due to Director IITM, for his interest in the work. We acknowledge PODAAC- JPL for Quikscat winds.

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Climate and Tree-growth relationship of Teak (*Tectona grandis*) from Central India

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Introduction

One potential source of annual resolution paleoclimate data lies in dendrochronology, the science linking tree-rings to the environmental conditions. In India, dendroclimatological analyses of conifers from Himalayan region have been extensively studied. However, the central and peninsular parts of India are yet to be explored. This part of India occupies vast area of teak (*Tectona grandis*) forest. Teak shows distinct annual growth ring patterns useful to study the past climatic variations. Earlier studies from tropical regions suggest that teak is useful for dendroclimatic reconstructions like monsoon rainfall and ENSO Index (Pant and Borgaonkar,1983; Bhattacharya *et al*., 1992; D' Arrigo *et al.*, 1994; Pumijumnong *et al*., 1995; Borgaonkar *et al*., 2001). In this study, we developed three tree-ring chronologies from central India to understand the relationship between climate and tree- growth.

Data and Methods

In this paper, recently collected teak tree-ring samples from three different sites of Central India viz. Bori (Madhya Pradesh), Sajpur (Madhya Pradesh) and Edgurapalli (Andhra Pradesh) were used. 26 samples from Bori, 16 from Sajpur and 18 from Edgurapalli were precisely dated and ring widths of individual samples were measured using an increment measuring machine. To remove non-climatic signals in the individual series, appropriate filter such as cubic spline, negative exponential or linear regression was used. All the index series were averaged over the site to prepare the tree-ring width index chronology for the respective site.

Dendroclimatic Analysis

The statistical analysis of these three tree-ring chronologies indicates high dendroclimatic potential. Most of the chronologies contains large amount of common signal, may be related to climate. The high values of mean sensitivity, common variance, signal to noise ratio indicate high dendroclimatic potential of the chronologies. These chronologies along with monthly rainfall and mean temperature data were used in response function and correlation analysis to study the tree growth-climate relationship.

Results and Discussion:

The correlation and response function analysis indicate significant positive relationship of rainfall during pre-monsoon and monsoon months with tree growth. Temperature during pre-monsoon months (April-May) shows significant negative relationship (Fig-1). This is mainly related to the availability of moisture. Small amount of rainfall during these months is conducive for tree growth in its early phase of growing season. Monsoon (June-July) rainfall maintains sufficient moisture requirement. Hence, pre-monsoon and monsoon rainfall plays an important role in teak growth. Old teak chronologies over the region can be used to reconstruct the monsoon variability in the recent past.

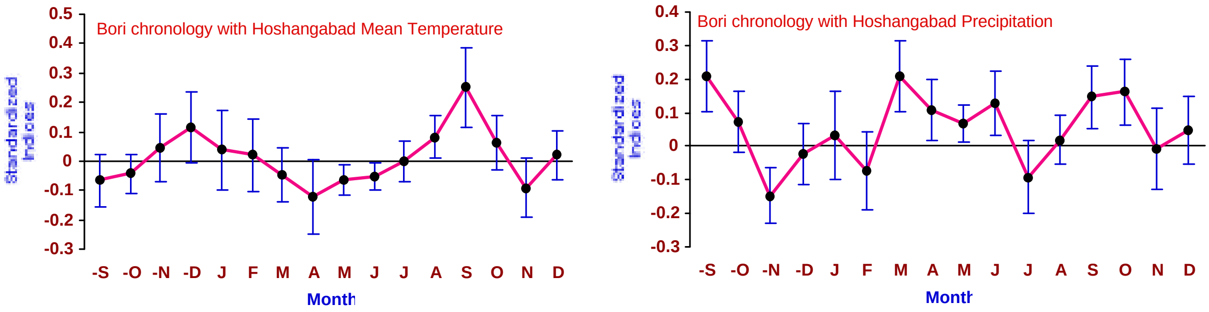

Fig-1. Response fuction analysis of Bori chronology with Hoshangabad Mean temperature and Precipitation

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Future climate change scenarios as simulated by PRECIS for the Indian summer monsoon and its variability

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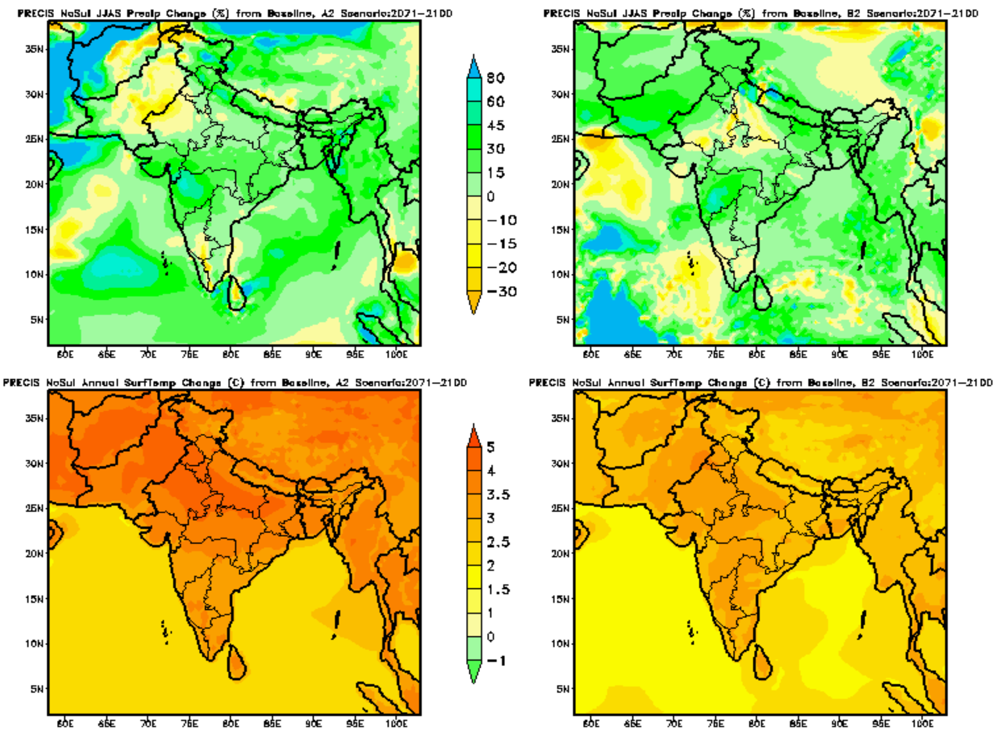
Abstract

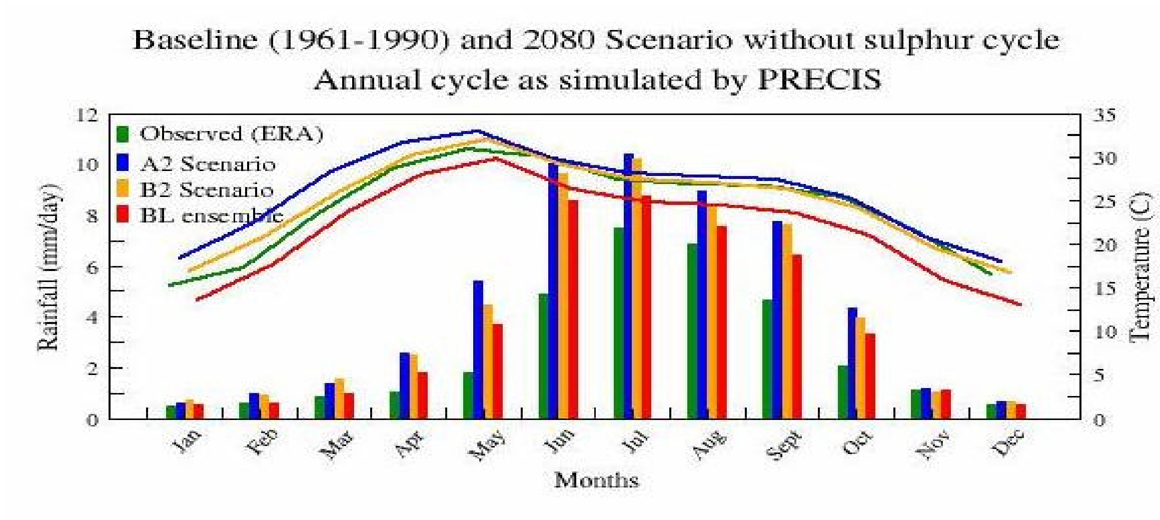
A high resolution climate change simulations generated using (Providing Regional Climate for Impact Assessment) PRECIS with response to Indian Summer Monsoon rainfall and annual surface air temperature are presented for the present (1961-1990) and a future period (2071-2100) under two different socio-economic scenarios (A2 and B2 scenarios) in this paper. A comparison of observed and model simulated annual surface air temperature and monsoon rainfall over India provide evidence of the skill of regional climate model in simulating the regional climatological features, especially the summer monsoon characteristics. The onset of monsoon over Kerala, monsoon trough are well simulated by the regional climate model PRECIS.

Introduction

Atmospheric general circulation models (AGCMs) play an important role to study different aspects of climate, to simulate the present climate, to predict the future climate and to conduct numerical experiments to understand the mechanism of climate variability and its predictability (Sperber and Palmer 1996). The ability of an AGCM to predict the climate variations depends on the models ability to simulate the mean climate and its space-time variability (Webster et al. 1998).

Due to coarse resolution, in recent years, an attempt has been made to simulate the climate features on a smaller scale to few tens of kilometers in order to explore the possibility of simulating regional climate characteristics, which could not be simulated with the GCM resolution. There have been several regional climate simulation studies for western United States of America and Europe since the pioneering work by Dickinson et al. 1989 and the earlier studies by Giorgi 1994. While the regional climate models (RCM) have been used to predict the regional climate change due to the increase of CO_2 concentrations (Jones et al., 1997).





Discussion and Results:

In the present study, the latest version of Hadley Centre Regional Climate Model, PRECIS developed by Hadley Centre has been installed at IITM and is run to generate the climate for the present (1961-1990) and a future period (2071-2100) with the grid size of 0.44° x 0.44° and the spatial domain is 55° E -104.72° E; 0.04° S - 40° N. The scenario runs for two socio-economic scenarios i.e. A2 and B2 scenarios for the period 2071 - 2100, three ensembles have been simulated for the baseline for the period 1960-1990. The annual cycle and inter annual variability of precipitation as well as mean temperature is well simulated by the model. The model captures the regional features like Western Ghats very well which were not well simulated by the GCMs due to its coarse resolution. It is found that there is slight increase in summer monsoon rainfall over the eastern parts of India in regional climate simulations. The simulations indicate an overall warming over the Indian subcontinent associated with increasing greenhouse gas concentrations. The model simulates rise in the monsoon rainfall and annual surface air temperature in the A2 Scenario than B2 Scenario.

Acknowledgements

The authors are grateful to Dr. G. B. Pant, Director, Indian Institute of Tropical Meteorology, for the kind encouragement and all facilities to carry out this work. Thanks are also due to Hadley Center for Climate Prediction and Research (UK), for their regional climate model, PRECIS.

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Prediction of Sea Surface Temperature in the Indian Ocean using Artificial Neural Network

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Abstract

Artificial Neural Network (ANN) has been used for the prediction of sea surface temperature anomaly from the Reynolds and Smith reconstructed SST from 1st January 1950 to 1st December 2001 in the Indian Ocean region (100 °E, 30 °S).

Introduction

Sea Surface Temperature (SST) is an important parameter that contributes to the interaction of tropical atmosphere and ocean. It significantly affects the monsoon over the Indian sub-continent. ANN is a massively parallel-distributed processor made up of simple processing units, which has a natural propensity for storing experiential knowledge and making it available for use. This is the reason for ANNs are now widely used for the prediction of various atmospheric and oceanic phenomena

Methodology

The SST values have a very low variation from the mean. Hence, instead of working with the SST values directly, their deviation from the mean is calculated and the anomalies have been predicted. The anomalies for two previous consecutive years form the input to predict that for the third year. We have used a multilayer feed-forward neural network with error back-propagation algorithm to predict the SST anomalies (*Zurada*, 2002; *Bishop*, 1995). The data is divided into four parts containing SST anomalies of three months each. Each block of three months is used to train the networks for the corresponding months. The anomaly data was scaled in the range 0-1and then partitioned into two sets, training set (1950 to 1994) and test set (1993 to 2001). The training set was further partitioned into the estimation and validation sets randomly. An ANN was constructed using the SNNS software for the extraction of SST anomalies.

Results

The typical plots between the observed SST anomaly and the predicted anomalies are shown in figures 1 to 12 for the months of June, July, August, September, October and November. In view of the successful application of ANN in extracting the SST, in future we envisage extracting SST from the extended dataset of COADS.

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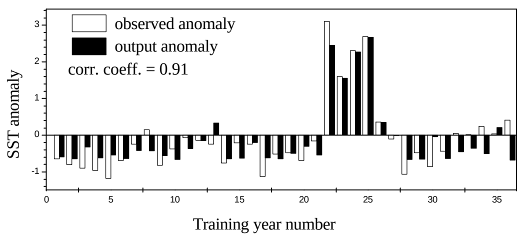

Figure 1 SST anomalies for the month of june

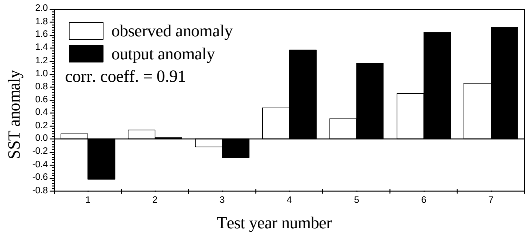

Figure 2 SST anomalies for the month of june

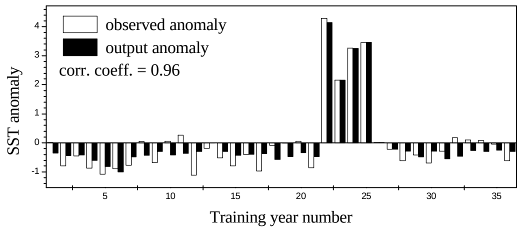

Figure 3 SST anomalies for the month of july

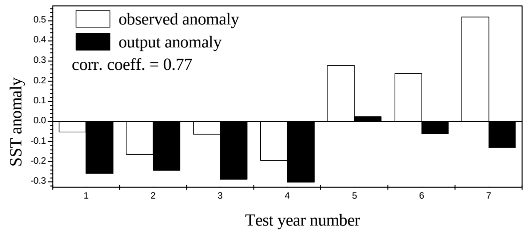

Figure 4 SST anomalies for the month of july

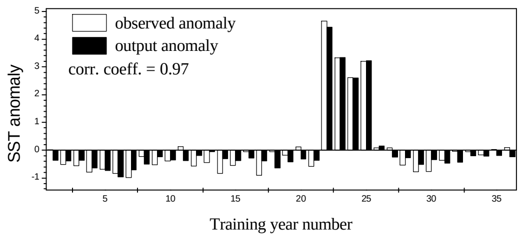

Figure 5 SST anomalies for the month of august

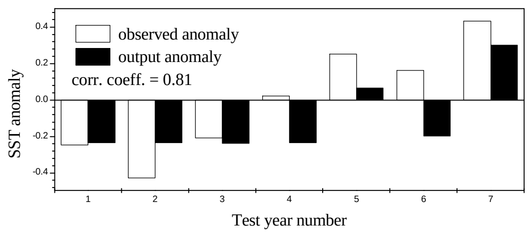

Figure 6 SST anomalies for the month of august

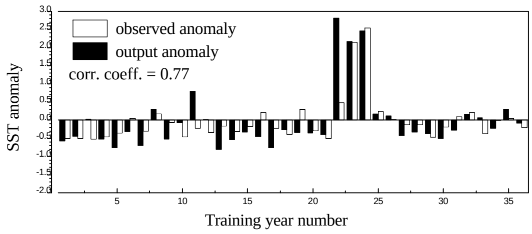

Figure 7: SST anomaly for the month of September

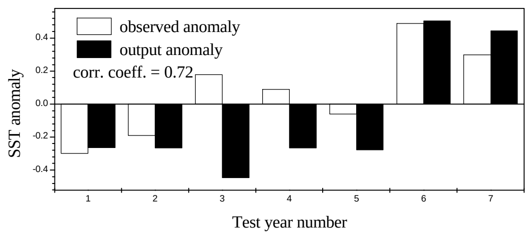

Figure 8 SST anomalies for the month of September

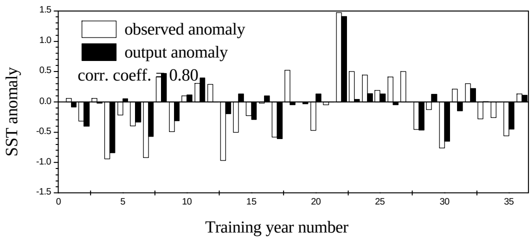

Figure 9 SST anomalies for the month of October

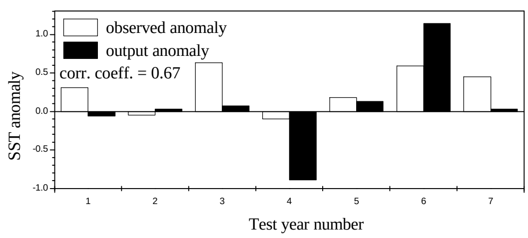

Figure 10 SST anomalies for the month of October

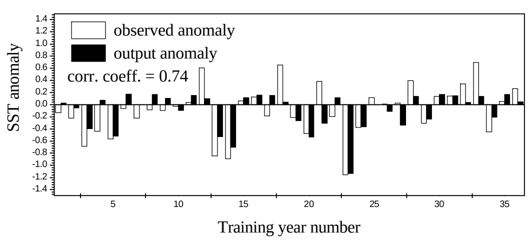

Figure 11 SST anomalies for the month of November

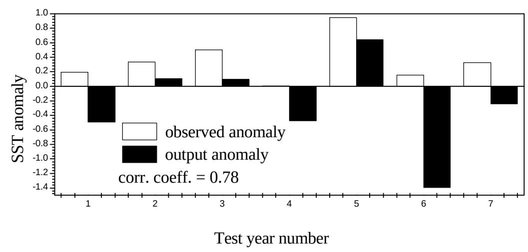

Figure 12 SST anomalies for the month of November

Seasonal circulation in the Gulf of Aden

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Abstract:
The circulation in the Gulf of Aden is inferred from diversified data sets like historical ship drift data, hydrographic data, and merged altimeter data products (Topex/Poseidon, Jason and ERS). The circulation in this semi-enclosed basin is marked with strong seasonal variability with reversals in the direction of flows twice a year following the reversal in monsoonal winds. During the winter monsoon (November - February) there is an inflow from Arabian Sea along the northern and southern boundaries and an out flow in the center as can be inferred from ship drift data. During this season the easterly wind is favourable of upwelling along the eastern part of the southern coast, where the Ekman Drift shows drift towards offshore. During southwest monsoon (June - August) the flow is generally towards east everywhere over the Gulf of Aden except for a weak inflow along the southern coast. Also during this season the upwelling favourable westerly wind along the Yemen coast shwoed Ekman drift towards offshore. The geostrophic currents derived from the Sea Surface Hight Anomalies (SSHA) measured by satellite altimetry also show similar circulation patterns embedded with mesoscale eddies. These westward propagating eddies appear to enter the Gulf of Aden from the western Arabian Sea in winter. They appear to play an important role in modifying the circulation pattern. The effect of these mesoscale eddies extend over the entire water column. Bower et al., 2004 have observed several eddies that affect the spreading of the Red Sea Water (RSW) in the Gulf of Aden at 650 m. The geostrophic currents derived using the hydrographic data confirms the presence of eddies at different depths. The propagation speeds, of these eddies, estimated using weekly spaced altimeter for winter season (2002 - 2003) is ~ 4 cm/s. The propagation speeds of Rossby waves due to first and second baroclinic modes (estimated using the Brunt-Vaisala frequency profiles derived from the hydrographic data for the winter season) works out to be 8 cm/s and 2.5 cm/s respectively and the speed of westward flowing current during winter was 1.3 cm/s. The vector sum of the speeds of second mode Rossby wave and the mean current (3.8 cm/s) matches with the propagation speeds of eddies estimated from the altimeter data (4 cm/s). Hence, it is concluded that the second mode baroclinic Rossby waves are responsible for the westward propagating eddies in the Guld of Aden. The presence of these eddies in the temperature-salinity climatology data confirms that they are not transient features.

Monsoon History since the Last Glacial Maximum (~18,000 a BP)

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Abstract:

The western Arabian Sea experiences intense productivity variations due to wind-induced upwelling during the South West monsoon (Nair et al, 1989). Variations in productivity derived from marine sediment cores can prove to be an excellent indicator of monsoon wind strength. A sediment core (collected during 1998 onboard the Department of Ocean Development research vessel ORV Sagar Sampada) SS 4018 G ($13^0$21.8'N, $53^0$15.4'E; length 130 cm, water depth 2830 m) from the western Arabian Sea, near the mouth of Gulf of Aden was selected for examining the variations in monsoon proxies.

The proxies studied in this core are ? ^{18}O, ? ^{13}C on selected species of foraminifera, ? ^{15}N in the sedimentary organic matter and $CaCO_3$, C_{org}, C/N content in the bulk sedimentary matter. The $CaCO_3$ (wt. %) varies from 52% to 75%. At ~15 ka BP a sudden increase in $CaCO_3$ content is observed pointing towards strengthening of SW monsoon winds that coincides with the major deglaciation episode (T Ia). Thereafter it stays more or less uniform upto 9 ka BP where it shows a sudden increase indicating monsoon enhancement. This episode of monsoon enhancement follows just after the maximum summer insolation in the latitude 20^{o}N to 35^{o}N at 10 ka BP (Loutre et al, 1992). Such a trend was also seen by workers like Sirocko et al (1993) and Gupta et al (2003) in the cores 74 KL and 723A respectively from the nearby regions. Sirocko et al (1993) also observed an increase in the monsoon intensity at ~15 ka BP as evident by the increased calcareous productivity at that time and an enhancement at ~9 ka BP. Thereafter they found a decreasing trend in the calcareous productivity which they attributed to the decreasing monsoon intensity during the Holocene (past 10,000 years). But the major limitation of these studies was that they were based on a single proxy. When multiple proxies are taken into account then they point towards a different picture. In the present study $CaCO_3$ % shows a decreasing trend after 8 ka BP. Had this decrease been due to decreasing monsoon and therefore productivity, then C_{org} should also have shown a decrease, as it is manifestation of organic productivity. But such a decrease is not seen, which indicates that productivity probably hasn't decreased during the Holocene. This is further supported by the ? ^{13}C, ? ^{15}N studies carried out on this core, which exhibit increasing trends during Holocene. But the calcareous productivity in the western Arabian Sea shows a decreasing trend during the Holocene. One way to reconcile this contrasting behaviour is that increasing monsoon strength favours silicate rather than carbonate production (Naidu et al, 1993; Rixen et al, 1996) and causes cross equatorial transport of the nutrient poor water (Rixen et al, 1996) along the Somali current (Duing et al, 1980; Schott and Fieux, 1985), which causes further reduction in the productivity. Oxygen isotope measurements (? ^{18}O) were carried out in three different species of planktonic foraminifera. In the western Arabian Sea, ? ^{18}O values are interplay of two competing processes viz. evaporation-precipitation balance (more precipitation decreases ? ^{18}O values) and upwelling of colder water (colder the water, more the ? ^{18}O). During Holocene ? ^{18}O stays more or less uniform indicating that although upwelling increased due to enhanced SW monsoon winds, precipitation also increased that counterbalanced it. Thus, to conclude, monsoon did not decrease during the Holocene as proposed by earlier studies in this region.

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India's Nuclear Energy Program and the Extent of Abatement in Global Warming and Climate Change During the Present Century

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Abstract

Knowing that global warming is predominantly caused by CO_2 emissions due to fossil fuel burning in the present study we have tried to find out the effects of using nuclear power and afforestation in the case of India only, in combating CO_2 emissions globally. For the year 2020, with nuclear installed capacity taken as 20 GW(e) for India and with steady increases in fossil fuel burning and afforestation going on simultaneously, the overall effect of India appears as almost 2 % without aerosol, and 2.5 % with aerosols in reducing global warming. Beyond 2020, the business-as-usual scenario (scenario C) gives effects not very different from the case when a cap is placed on nuclear capacity at 20 GW(e) for the period 2020 and beyond (scenario A). The scenario B, where a cap is put on fossil fuel burning after 2020 appear, however impossible to realize so that the indicated percentages namely 15 % and 17 % for cases without and with aerosols in the year 2100, cannot be taken as realistic unless a radical change of technology takes place in the mean time. Meeting its development needs and at the same time using its maximum potential of nuclear power India, in spite of its vast size and resources, can hope to reduce global warming by 2 to 6 % at most.

Introduction

Last few decades have witnessed an increasing demand for electricity in the developing countries, which is mostly fulfilled by electricity generation from fossil fuel, based thermal power plants. These, in turn, being major sources of CO_2, leads to warming of the whole globe. This trend has also been observed from the studies in the upper layers of the atmosphere, which show cooling taking place in the stratosphere, which may be due to increased warming in the layers below [2]. Thus, the present study was done to look more closely at some qualitative as well as quantitative aspects of expected CO_2-increases in the Earth's atmosphere in the next 100 years or so, and to examine the effectiveness of some projected strategies of abatement of CO_2 emissions involving nuclear energy production in India [1,3], along with expected extents of afforestation [4] in terms of CO_2 emissions and concentrations, contributions to radiative forcing, rise in mean global surface air temperatures and mean global sea level rise, and compared these with the business-as-usual scenarios, as has been usual in studies done by international climate change study groups.

Methodology

The methodology chosen is one that makes use of extrapolations from an average of results of some sixteen global climate models without sulfate aerosol effects, and of one climate model that also incorporates the effect of aerosols. Programs MAGICC/SCENGEN (Model for the Assessment of Greenhouse-gas Induced Climate Change/SCENario GENerator), used, were kindly supplied to us by the Climate Research Unit of the University of East Anglia, Great Britain working in tandem with the National Communications Support Programme, UNDP/GEF, New York, USA.

Results

Results for global mean temperature both with and without aerosols included and the resulting sea level change for all the scenarios A, B and C were obtained.

1. The percent reduction in global warming brought about by the scenarios (as given in table) indicates a cooling effect approximately from 2%-6% for scenario C which is almost identical to scenario A since thermal energy plays dominant role in both scenarios. The effects of scenario B, indicated as 14.6 % and 17.0 % without and with aerosol, for the year 2100, appear quite unrealistic unless radical new inventions like controlled thermonuclear fusion come into vogue.

Reduction in global warming

	Climate Sensitivity	Temperature Decrease (%)		
Year	? T_{2x} = 2.5 °C	Scenario A	Scenario B	Scenario C
2020	Without aerosol*	1.9	1.9	1.9
	With aerosol*	2.5	2.5	2.5
2050	Without aerosol*	5.6	8.00	5.6
	With aerosol*	7.6	11.90	7.6
2100	Without aerosol*	5.0	14.6	5.8
	With aerosol*	5.8	17.0	6.8

* Baseline reference year has been taken as 1990.

2. Map outputs from SCENGEN, for mean annual warmings and general global distributions, both for the sulphate aerosols included and not included case, indicates stronger global warming effects near the poles and not so strong as one moves towards the equator. This effect becomes progressively more obvious as we move to the years 2050 and 2100. It is the progressive effect in time that seems to be far more important than the differences in scenarios.
3. The sea level change (in cms) for the year 2100, for scenarios A, B and C was found to be 46.93cms, 44.07cms and 46.76cms respectively, which closely followed the value 48.8cms for IS92a. As in the case of maps for the global warming, stronger overall time dependence but a relatively weaker scenario dependence is seen also for global sea level rise curves because of our restricting changes to only a small part of the world (namely India).
4. On looking at the precipitation trend, it was found that intensity of precipitation decreases in areas having less rainfall and increases in areas experiencing good rainfall, which is in accordance with the various international study groups.

The study can also be extended to give regional patterns, as well as year-to-year and season-to-season patterns, and as a next step we will be looking at some of these features also.

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ENSO and Northeast Monsoon Rainfall Variability

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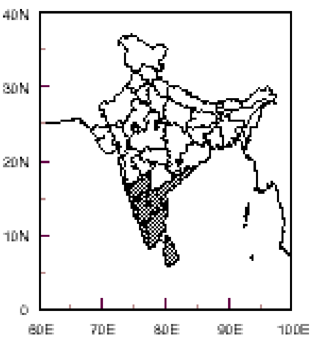
Abstract:
The southeastern parts of India and Sri Lanka receive substantial rainfall from the northeast monsoon (NEM) during October through December. The interannual variability in NEM rainfall is known to be significantly influenced by the El Niño/Southern Oscillation (ENSO). Unlike the southwest monsoon (SWM) during June through September, NEM is enhanced during the ENSO events, and vice versa. In the context of the recent weakening of the inverse relationship between SWM and the ENSO, we examine the secular variations in the positive relationship between ENSO and NEM rainfall over South Asia. We show that the relationship has strengthened during the recent years. Based on the analysis of CRU precipitation, GISST and NCEP/NCAR reanalysis data, we suggest that this secular variation of the relationship is due to epochal changes in the low-level circulation over the region.

1. Introduction

The influence of ENSO on SWM has been extensively explored, quantified and successfully used in its seasonal prediction, but the relationship between ENSO and NEM has not received similar attention. In recent years, there is also considerable debate on the secular variations in the link between ENSO and SWM, suggesting a recent weakening (e.g., Krishna Kumar et al., 1999). In this background, we address the interannual variability of NEM rainfall over South Asia and its relationship with ENSO, with special focus on its secular variations.

2. Data and Analysis

The basic data for the preparation of the NEM rainfall time series are taken from the global gridded (0.5° x 0.5°) precipitation data sets of Climatic Research Unit (CRU; New et al., 2002). A contiguous region of NEM has been delineated (Figure 1), and a homogeneous monthly rainfall data set for the period 1901-2000 was prepared based on an average of the grid-pont values of precipitation within this region, for the present study. Monthly NIÑO-3 sea surface temperature (SST) data for the period 1901-2000 have been extracted from the Global sea Ice coverage and Sea Surface Temperature(GISST) data available at a spatial resolution of 1° x 1°. In addition, monthly



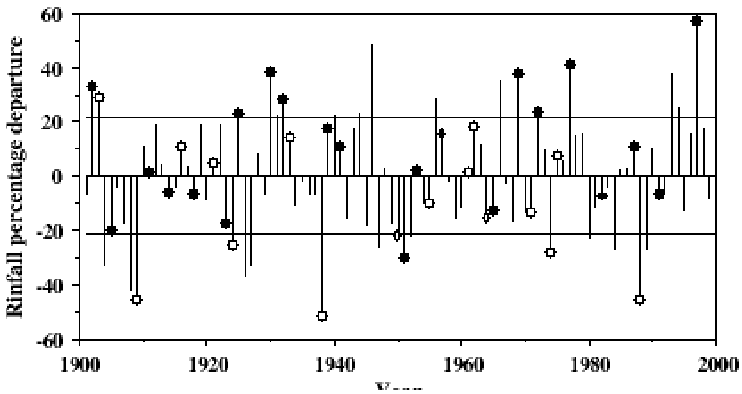


Figure 1: NEM region of South Asia

Figure 2: NEM rainfall variability over South Asia. Filled circles are El-Niño years and unfilled circles are La-nina years.

mean tropospheric winds from the NCEP/NCAR reanalysis data for the period 1950-2000 have also been used.

3. Results and Discussion

The NEM rainfall over South Asian region has a long-term mean of 338 mm and standard deviation of 73mm, accounting for about 28% of the annual rainfall. The NEM rainfall time series over the past century (1901-2000) is dominated by large interannual variability, with a coefficient of variation of 22% (Figure 2).

The spatial patterns of correlation coefficients (CCs) between NEM rainfall and seasonal SST (OND) suggest that above normal NEM rainfall is associated with warm SSTs over the equatorial Pacific region, as also reported earlier (e.g., Suppiah, 1989, De and Mukhopadhyay, 1999). However, the relationship is statistically significant only during the recent (1976-2000). During the earlier period 1951-76, the CCs are near-zero over the central and eastern Pacific (not shown). This **secular variation in the ENSO-**NEM relationship can be clearly demonstrated by means of 21-year sliding correlations of NEM rainfall with NIÑO-3 SST index for the two seasons JJA and OND over the period 1901-2000, as shown in Figure 3.

The low-level circulation during NEM season is dominated by northeasterly/easterly winds over south peninsular India and Sri Lanka (Kripalani and Kumar, 2004). To examine the low-level circulation anomalies during the years of extremes in NEM rainfall, composite 1000 hPa wind anomalies and moisture divergence during the same season have been worked out for excess and deficient years. Figures 4a,b show the composite low-level (1000 hPa) wind anomalies and moisture divergence during these excess and deficient years respectively. Similar composites have also been worked out for the 11 El Niño years that occurred during the period 1950-2000, by dividing them into two groups representing the periods 1950-75 and 1976 -2000. The

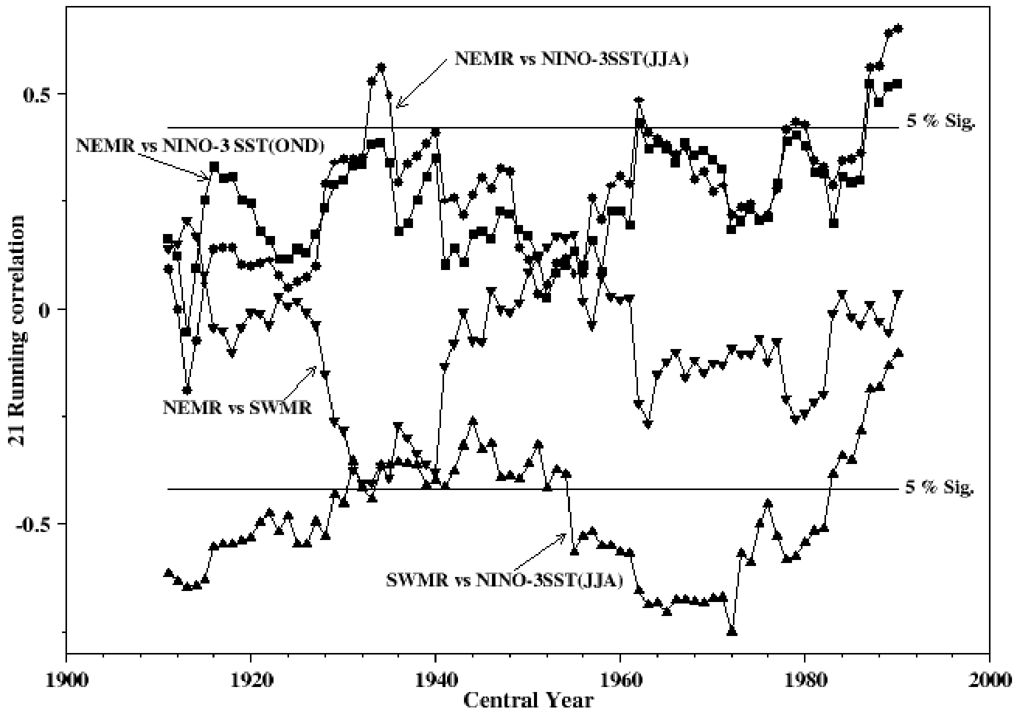


Figure 3: 21-year sliding correlation of NEM rainfall with Niño-3 SSTs and SWM rainfall, and of SWM rainfall with Niño-3 SSTs.

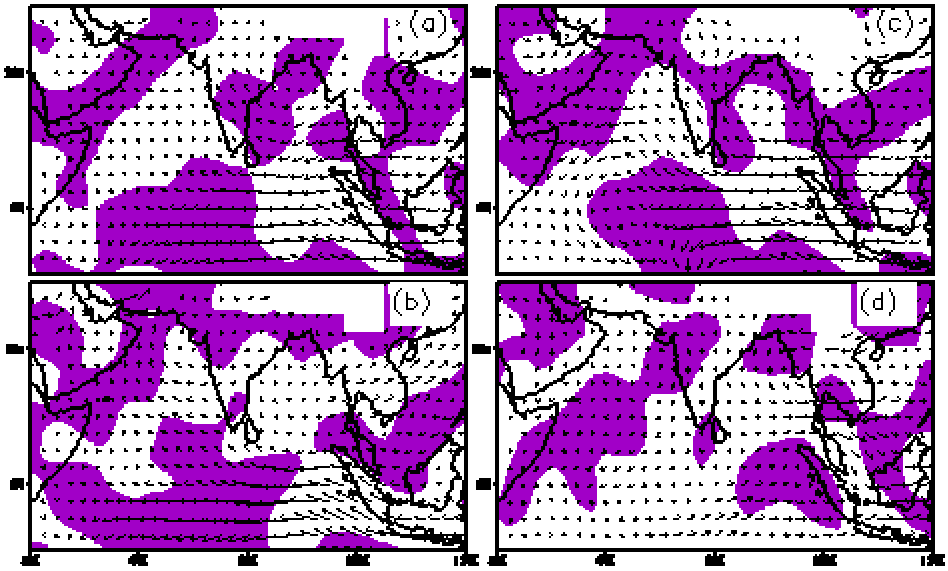


Figure 4: Composite wind anomalies (m/s) at 1000 hPa during the NEM season for excess years (a) and deficient years (b) during the period 1950-2000, and for El Niño years during the two sub-periods 1976-2000 (c) and 1950-75 (d). Shaded area in all the panels represents moisture convergence (gm/kg/day).

composite circulation anomalies during the El Niño years of the period 1976-2000 are strikingly similar to those associated with typical excess NEM rainfall years, viz., easterly to southeasterly wind anomalies over south Bay of Bengal, south peninsular India and Sri Lanka (Figures 4a and c). El Niño composites of this period also suggest anomalously higher levels of moisture convergence in the region. However, the El Niño composite of NEM circulation during the earlier period 1950-1975 (Figure 4d) has considerably weaker wind anomalies and does not seem to represent the typical excess NEM rainfall situation. There is also relatively weaker low-level moisture convergence over the region, and therefore the conditions do not seem to be favorable for good NEM rainfall activity.

Thus, the above analysis clearly indicates that the nature of ENSO impact on NEM is opposite to that on the SWM not only on the interannual scale, but also in terms of the epochal variations. Thus, while it has been conjectured that the ENSO-SWM relationship has been weakening over the past couple of decades (e.g., Krishna Kumar et al., 1999), the present study indicates that the ENSO-NEM relationship has strengthened during the same period.

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On the Relationship Between Synoptic Systems over the Bay of Bengal and Trends in Monsoon Rainfall over Eastern India

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Abstract:

Summer Monsoon (June to September) is the major rainy season in which most parts of India receive major proportion of their annual rainfall. Most of the studies have shown that Indian summer monsoon rainfall (ISMR) is basically trendless. Rupa Kumar et.al. (1992), had reported the presence of pockets of significant increasing/decreasing trend in annual, seasonal and monthly (June to Sept.) rainfall. They identified areas with significant decreasing trend in seasonal rainfall over the eastern Madhya Pradesh and northeast India and increasing trend over north Andhra Pradesh.

Depressions are recognized as the main synoptic weather systems over India during monsoon season. Hence, this increasing and decreasing trends in rainfall can be associated with increasing/decreasing trends in monsoon depressions or spatial shifting of depression tracks. Recent studies (Patwardhan and Bhalme, 2001, Dash et. al. 2004) show that there is significant decreasing trend in the frequency of occurrence of monsoon depressions and cyclonic storms and an increasing trend in the number of low pressure systems from 1970s to the recent decades. In the present study we have examined whether the trend in monsoon rainfall pattern over eastern parts of India is associated with the position of formation of depressions and cyclonic storms in Bay of Bengal. Yearly and decadal variation of mean position of formation of depressions over the Bay of Bengal have shown a trend towards the southern latitudes, especially in the recent decades. Latitudinal shifts, if any, in the landfall of monsoon depressions will also be discussed.

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Morlet Wavelet analysis of tropical convection and propagation of ITCZ

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Abstract:

The Indian summer monsoon, which comes regularly every year from June to September, as we know, shows strong Intraseasonal oscillation. It is characterized by having an onset phase, a withdrawal phase and a couple of active and break phases in between. The Intraseasonal oscillation have the periodicities of synoptic scale (~3-7 days), super synoptic scale (~10-20 days), and Madden-Julian scale (~30-60 days). These oscillations (anyone or all) can be seen on all parameters characterizing the monsoon like pressure, precipitation, winds etc. The study of Intraseasonal oscillation of the Indian summer monsoon is very important from both theoretical and practical point of view.

Various techniques such as maximum entropy method (MEM), power spectrum, empirical orthogonal function (EOF), wavelet analysis (Torence and Compo,1998) etc. are used to study the Intraseasonal Oscillation. Off let the wavelet analysis seem to be used as a very handy tool in studying the Intraseasonal oscillation of to identify the dominant temporal and spatial scale of oscillation. This technique can skillfully separate the powers present in the dominant and statistically significant scales of oscillation present in the data. Recently it has been shown (Shankar and Nanjundiah, 2004 and the references therein) that the Morlet wavelet analysis can be used to identify the dominant spatial scale of oscillation and that information can be used to study the temporal evolution of dominant spatial scale, hence one can study the pole ward propagation of ITCZ.

The present study uses the Morlet Wavelet analysis to identify the dominant spatial scale of oscillation. The GPCP daily precipitation data from 1997 to 2003 is used. The data is first averaged over different bands of longitudes starting from 50^0E to 160^0E for a band of 10^0 from 15^{th} May to 30^{th} September. It is found that the 32^0 spatial scales are dominant as well as statistically significant over most of the regions. The scale is isolated and the poleward propagation of the band is then plotted for various years. The plot for pentad mean power for the year 2001 is given here for example. The region contoured by maximum powered zone is actually representing the ITCZ since maximum power occurs at the region of highest precipitation and convection. The following conclusion can be drawn from them:

(i) 32^0 spatial scale is dominant for all the bands like 50^0E-60^0E,……upto 160^0E-170^0E. Significant powers are evident from all plots.

(ii) The poleward advancement and retreat of ITCZ (maximum precipitation and convection zone) is evident from the region 70^0E-80^0E that is over the Indian region. The dominant scale power has moved from 10^0S to 10^0N and again then it retreated to lower latitudes. This movement of ITCZ is a well established fact.

(iii) For the region 80^0E to 90^0E the ITCZ shows slight oscillation.

(iv) For all the other bands not much oscillation is evident. The maximum power is present between equator to 5^0N region. The northward propagation is thus present only over Indian region or Indian Ocean region.

(v) The movement of tropical convection is very well established during monsoon season over Indian region.

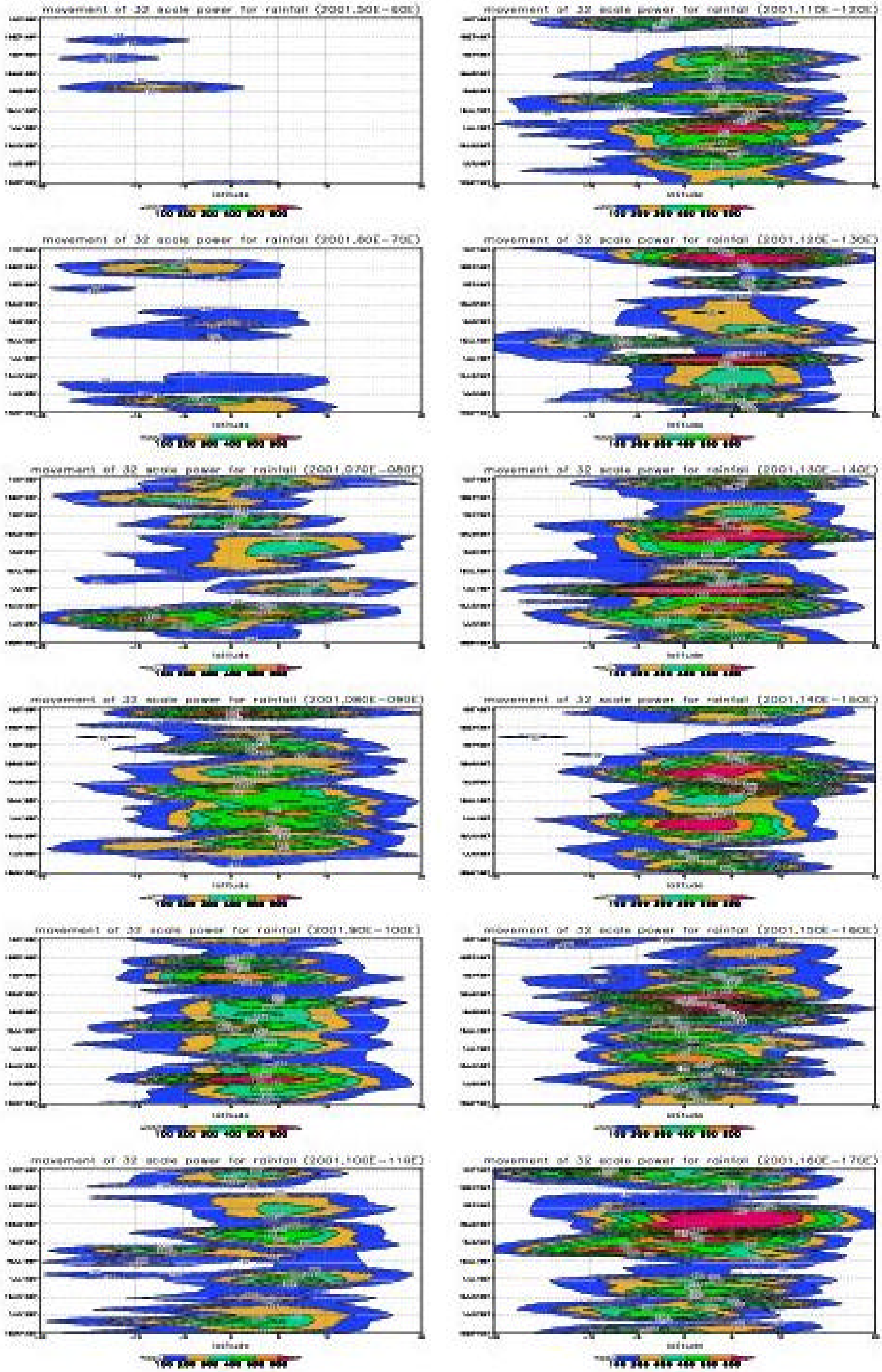

Fig.1 Time latitude plot (averaged over different bands of longitude) for year 2001 to show the propagation of ITCZ using wavelet analysis. Latitude is from 20^0S to 20^0N. Time is from 15^{th} May to 30^{th} Sept.

Conclusion:

The Morlet wavelet analysis is thus an effective tool in isolating significant power of convection or propagation of ITCZ over Indian region. The padding with zero is made to plot purpose here, for a cyclic data the padding is not required. The dominant spatial scale shows significant movement during the season of Indian summer monsoon. The oscillation of ITCZ, though, varies from year to year or region to region due to interannual variability.

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Upper tropospheric circulation features during extreme monsoon years

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Abstract:

The conditions of excess as well as deficient monsoon rainfall which arise due to the high inter-annual variability of monsoon rainfall, usually have adverse impact on Indian economy and social life. The monsoon as a component of global general circulation has strong teleconnections with the anomalies of interannual to longer scale phenomenon elsewhere, hence a complete understanding of the atmospheric circulation during the southwest monsoon assumes an important position in the study of Indian weather and climate. Monsoons, though a regular seasonal phenomenon, have large temporal and spatial variability. The performance of southwest monsoon over India is important not only for its own region but also for the regions outside. In the same way the monsoon is influenced to different degrees by the circulation features horizontally and vertically far away from the main monsoon circulation regime. These relations, some time referred as teleconnections, are used in the seasonal forecast models of the monsoon. Thus, the study of circulation features particularly their anomalous behaviour is important for the prediction of seasonal monsoon rainfall over India and other parts of the globe. The observational studies in the initial stages were handicapped in visualizing the general circulation mainly due to lack of upper air data. With the availability of three dimentional data on global scale for a long enough period to define the normal long-term features of the atmospheric flow and role of eddies, the general circulation characteristics are better documented now. It is well known that the troposphere is a lowest layer of the atmosphere, where weather phenomena and turbulence are most marked and has aptly been described as the weather-making layer of the atmosphere. There are several components of the global and regional circulation which are linked with the performance of summer monsoon. These components are extensively studied during the last many years and are at present in use of the operational long-range forecast (Gowariker et al. 1989 and 1991). Many studies have been done in relation to the anomalous features of the tropospheric general circulation globally and regionally confined to particular extreme monsoon years (Krishnamurti et al., 1989 and 1990; Kanamitsu and Krishnamurti, 1978; Raman and Rao, 1981; Raman, 1982; Banerjee et al., 1978; Hingane et al., 1985). In the present work, we have focused on the upper tropospheric circulation (200 hPa) over the Indian region during excess and deficient years composites.

In the present study, using NCEP reanalysis data for the seasons spring (March, April and May) and summer (June, July, August and September) an attempt have been made to bring out the contrasting features in the anomalies in the meteorological parameters viz., velocity potential at 200 hPa, upper air zonal and meridional wind components at 200 hPa, upper air temperature at 200 hPa and surface air temperatute between deficient and excess monsoon years during the period 1949-2003. The evolution of the planetary scale divergent motions exhibit prominent differences during extreme monsoon seasons in the present work. We have chosen 12 deficient (1951,65,66,68,72,74,79,82,85,86,87 and 2002) and 9 excess 1955,56,59,61,70,75,83,88 and 1994) monsoon years from the period 1949-2003 and their composite study have been made.

The following results are noteworthy :

- Interestingly, 200 hPa velocity potential (divergent field) exhibits a pronounced development of the divergent outflow over southern tip and eastern part of India during spring season composite of excess monsoon years anomalies whereas it shows downward motion (weak) in the deficient years composite. It is found that these anomalies generally persist in the subsequent summer monsoon season i.e. during excess years composite the divergent outflow become very much stronger and covers whole Indian region whereas during deficient composite it shows more downward motion.
- Surface air temperature anomalies shows El Nino and La Nina signals over the Pacific region during summer monsoon composite especially. During excess years composite, it shows negative (cold) anomalies whereas during deficient years composite it is positive (warm).
- Upper air temperature anomalies at 200 hPa is found to be warm over the Indian region during excess years and cold during deficient years in the spring. These features are also persisting in the summer monsoon season during excess and deficient years respectively.
- 200 hPa zonal winds (easterlies) are found stronger over north India during excess years in the summer monsoon season whereas during deficient years they were replaced by westerlies.

The above contrasting features are detected during excess and deficient years composites for the upper troposphere including the surface level in the spring and summer monsoon seasons. We have observed that the anomalies in the deficient years during spring season generally persist through the subsequent monsoon season and this may be a link with the below normal rainfall activity. This study may be useful for the long-range forecasting of Indian summer monsoon rainfall.

Sensitivity of Indian Summer Monsoon to afforested deserts

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Abstract

The feedbacks from vegetal forcing, especially the forest, on intraseasonal activity of Indian Summer Monsoon (ISM) are investigated with idealized sensitivity experiments with a general circulation model after including rainforest over Thar Desert.

The control simulation despite being ideal in nature, yields simulated time-mean monsoon climate satisfactorily close to observational and earlier simulative counterparts. The mean precipitation points to the significant role the vegetation could play in defining model land surface feedbacks into the atmosphere.

The active/break phases characteristic to the modulated monsoon in July associated with the propagation of the Continental Tropical Convergence Zone (CTCZ) are simulated in agreement with observations. The northward propagation of model precipitation events is identified to be systematically influenced by potential forestation of the deserts. Consequently, it emphasizes important role of vegetation, deserts inclusive, in redefining the internal mode of dynamics. In fact, it is observed to restrict the northward movement of CTCZ, hence the precipitation events over Indian subcontinent.

Generally speaking, land-atmosphere interaction identified as external forcing can be made as follows. First, the land surface physiographic characteristics play an important role in defining the spatial structures of Indian monsoon regimes in conjunction with internal dynamics. Secondly, they are also crucial in defining the temporal behavior of Indian monsoon through its influence on propagation of CTCZ.

On the role of air-sea interaction parameters over the north Indian Ocean on the prolonged Break in monsoon conditions in 2002

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Abstract:

The summer monsoon of 2002 was unusual in several aspects a) all India rainfall deficit in July was one of the highest about 49% (Gadgil et al., 2003) b) the season had not even a single depression during the last 133 years (Kalsi et al., 2004) and c) it had also one of the longest breaks in the recent decades (Ramesh Kumar and Uma Prabhudessai, 2004). We have examined the role of various air-sea interaction parameters, such as sea surface temperature, wind speed, precipitable water, precipitation and cloud liquid water obtained from the Tropical Rainfall Monitoring Mission (TRMM) satellite data for different study areas namely a) Arabian Sea b) Bay of Bengal c) South China Sea and d) Southern Indian Ocean, prior to, during and after the break in monsoon conditions. We have also computed the cross equatorial flow from the meridional wind at 850 hPa obtained from NCEP/NCAR Reanalysis (Kalnay et al., 1996).

The study revealed that the prolonged break in July 2002 could be due to the combination of the following factors:

1. decreased precipitable water in the Arabian Sea from the middle of June to end July could have resulted in decreased rainfall activity over the subcontinent (figure1a). Ramesh Kumar and Schluessel, (1998) have obtained similar results for another deficit year 1987.
2. decreased cloud liquid water over the Arabian Sea from middle of June to end of July (figure 1b). Narayanan et al., (2004) have also mentioned about the absence of cloudiness due to the stratification in the Arabian Sea.
3. above normal convective activity (figure 1c) over the south China sea can affect the southwest monsoon rainfall over India through large scale subsidence over the subcontinent as observed in July 2002 (figure 1c).
4. weaker cross equatorial flow at 850 hPa (figure 1d) has also led to weak monsoon activity over the Indian sub-continent. Earlier studies have shown that the cross equatorial flow plays a major role in the monsoon activity.

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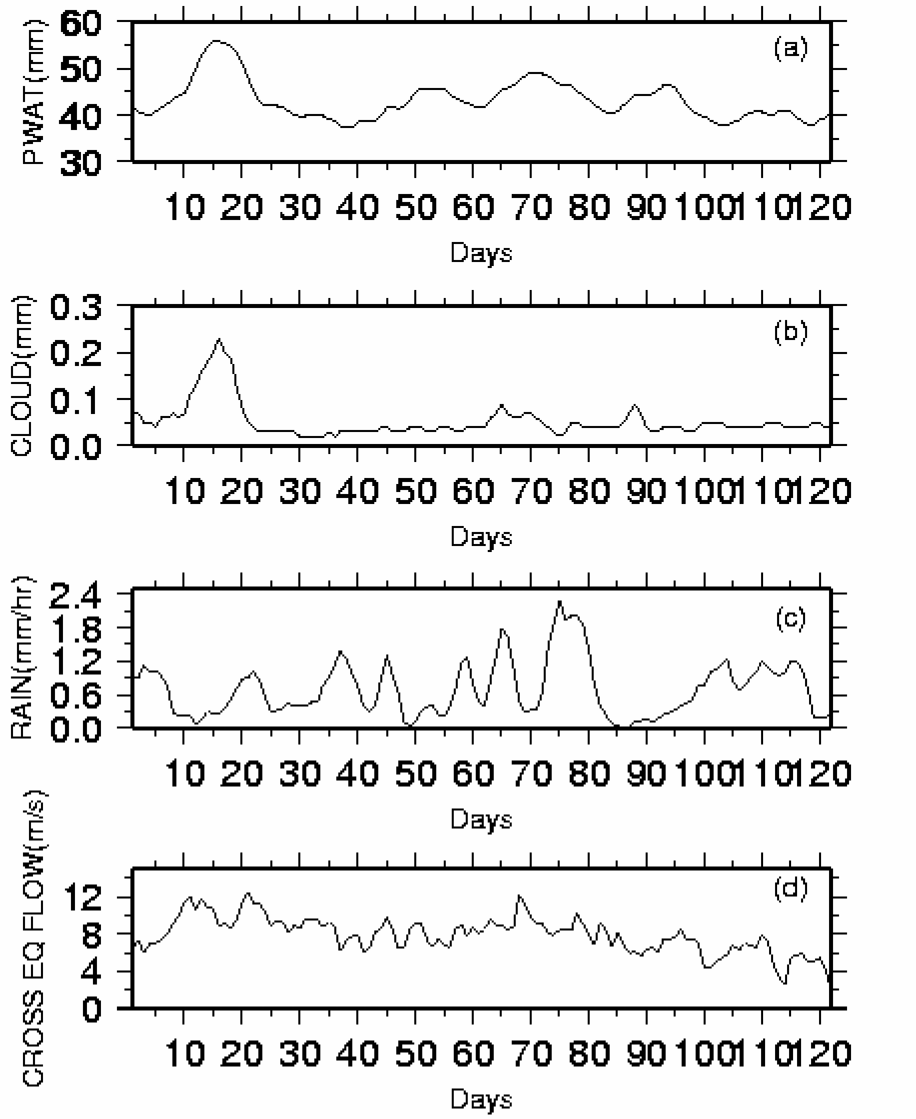

Tree-ring analysis of *Cedrela toona* Roxb. in Dendroclimatic perspective from Kalimpong, Darjeeling Himalaya

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Abstract:

A quite good number (about 25%) of tropical trees of India produce growth rings (Gamble, 1902; Chowdhary, 1939). But except two taxa, Teak (*Tectona grandis*) and Toon (*Cedrela toona* Roxb.) exact dating of growth rings for most of these trees to the years of their formation, which is a prerequisite for the tree-ring analyses, is yet to be established. It is felt necessary to explore potentiality of a variety of tree taxa from new geographical regions to understand various aspects of climatic changes. Till date much attention has been paid only on one tree taxon, teak for tree ring /climatic analyses not only from India but also from several sites of South-East Asia as a whole. The present study deals with Toon, a fast growing deciduous tree to understand its dendroclimatic potentiality growing at Kalimpong subdivision, Darjeeling Himalaya. The growth ring in this tree has been recorded clear and countable. A belt of large, numerous pores and initial parenchyma usually mark growth rings of this tree. There is gradual transition of large early wood pores to smaller late wood pores. Based on ring width data, a 180-year (A.D. 1824-2003) chronology of this tree has been made from this region.

Analyses of tree growth climate relationship suggest that precipitation during April and May have direct relationship whereas August, September and October have negative role on the growth of this tree. With temperature, April and August have positive role but it exhibit negative role with February and March. Attempt has been made here to explain this growth/climate relationship through phenological information of this tree. It has been recorded that trees remain entirely leafless in January and new leaves emerges during February. Renewal of cambial activity takes place in the first week of March when the leaves are yet to reach full size and by the third week of March two to three rows of early vessels are formed adjacent to the initial parenchyma band. The growth is noticed moderate in April-May and is fast during June, July and August. It gets slower during September before ceasing altogether sometime in the first week of October (Chowdhary, 1939) Thus negative relationship recorded with temperature during February and March may be explained as increased temperature during these months inhibits photosynthesis when leaves are not fully grown size under physiologically water stress condition.

This study reveals that warmer conditions during April and August are favorable for growth. Low temperature during April may delay the cambial activity. It is general observation that for trees growing cool humid conditions increased summer temperature is favorable for tree growth. However negative relationship with the Feb-March Temperature may be due to persistent low temperature for a longer period in winter at the higher elevation are detrimental for both photosynthesis and respiration but increase in temperature for a short period favors respiration over photosynthesis as a result there is loss of stored food

Increased temperature during April may be suitable for enhanced photosynthetic activity, which induces rapid cambial activity. During monsoon months though cambial activity is reported to be fast as revealed by the phenological data discussed earlier but increased precipitation exhibits negative relationships. Trees at this site are confined in the area where plenty of rains occur during rainy season. Thus, the excess precipitation

during post monsoon months i.e., August, September and October may cause water logged condition and hamper the growth of this tree though pre-monsoon precipitation at this region has important role in growth of these trees.

There are not much tree ring data is available from broad-leaved tropical trees from India, tree ring analysis carried out here from Toon growing in the moist deciduous forest, Eastern Himalaya has shown its potentiality for dendroecological analyses from a new geographical region. Except pioneered work (Chowdhary, 1939) and subsequent study (Bhattacharyya et. al, 1992) there is no information available regarding growth/climate relationship of this tree. However, earlier analyses were based on either on small number of trees or from tree ring data covering shorter time span. The present study based on good replication of data indicated that pre-monsoon precipitation during April and May plays important role in growth of trees at this region. Interestingly, growth of tree at this region is found negatively correlated with the precipitation during monsoon months i.e. August, September and October. The tree ring statistics discussed earlier indicates that the present tree ring site chronology of Toon do not have the desired characteristics which could be considered ideal for the climatic reconstruction. Its fast growth along with non-circuit uniformity due to presence of buttress in most of trees analyzed here may cause such low correlation both within trees and between trees. Moreover pronounced disturbance over time in this region caused by logging, lopping faulty agricultural practice forest fire may change the microenvironment, which vary tree to tree, and it perturbs the macroclimatic signal within the tree ring sequences. Due to non-availability of information regarding temporal and magnitude of disturbances of this region, it has not been possible to derive better understanding of the temporal and spatial tree growth climate relationship. In future it is expected that collection of more samples from homogeneous sites may enhance the growth /climate relationship. Nevertheless the present study indicates that there is common variance within trees and contains ecophysiological signal that can be used for dendroeco logical research.

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Understanding the Tropical Indian Ocean Surface Wind Stress in the Behaviour of Indian Southwest Monsoon

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Introduction: -

The tropical continents and adjacent oceans experience a semiannual reversal of wind directions, blowing from cold continents to the warm oceans during winter, and from the cold oceans to the warm continents during summer. These reversals of wind system are usually referred to as Monsoon.' Strong southeasterly trades in the lower level in the south Indian Ocean cross the equator over the east coast of Africa and become southwesterly flow in the northern hemisphere transporting a huge amount of moisture from the Indian Ocean to the Indian subcontinents and forming the Indian Southwest or Summer Monsoon.

The oceanic circulation is forced primarily by the fresh water, momentum, and heat fluxes at its surface. Of these fluxes the most studied is the momentum flux associated with the stress of the wind on the surface, as it is the most important forcing for upper ocean circulation. The wind stress curl also plays an important role in understanding the upper ocean dynamics. In comparison to the other oceans, the north Indian Ocean exhibits the most pronounced seasonal change of surface conditions. Thus it seems valuable to look into detail the time varying surface forcings in the North Indian Ocean.

Data and Methodology: -

In the present study the NCEP Reanalyzed monthly mean surface winds (u, v) for the period 1980 - 2003 (24yrs) are extracted over the tropical Indian Ocean region (22.5^0E-112.5^0E & 28.5^0N-31.5^0S) and the data is converted at $1^0 \times 1^0$ using bi-cubic spline technique. The interpolated data are used to compute wind stress ($\mathbf{t}$) by the formula $\mathbf{t} = \mathbf{?_a}\, C_d \mid V \mid \mathbf{V}$ [where $?_a$ = air density and C_d = drag co-efficient]. Further, to understand the surface ocean dynamics the wind stress curl (? ? × $\mathbf{t}$) is also computed. The computations are carried out for all the months of 24 years and also for the 24-year climatology. We all know that there exists a large interannual variability in the southwest monsoon. In the 24 yrs. period (1980-2003) two severe drought years viz. 1987 and 2002 are noticed. Therefore, in this study the computed parameters are examined in details for the years 1986-1988, 2001-2003 as well as for the 24-year climatology.

Results: -

The surface wind stress are found to be weak almost throughout in the region during 1987 from the month of March onwards till July as compared to that for the years 1986,1988 as well as for climatology. As a result of which the formation of Somali gyre did not take place in May 1987, and hence weak surface wind stress ($\sim10^{-3}$) is seen in Arabian Sea and Bay of Bengal in the early monsoon months (Fig.). For the case of year 2002 the central equatorial Indian Ocean are found to be much different from the other normal years and that of climatology from November 2001. The magnitudes of wind stress are found to be weak in May 2002 rather than from March (as in the case of 1987) near Somali coast. This may the reason that beginning of monsoon 2002 was normal but after June the performance of monsoon was weak. It seems that the weak wind stress over Indian Ocean and its impact on southwest monsoon rainfall over Indian continents requirs about one month time lag.

The mean monthly distribution of the wind stress curl shows that during winter, positive values are generally observed in the region north of equator to 10 ^{0}S. However, there are relatively large negative areas in the northwestern Arabian Sea and in the northwestern Bay of Bengal. This patterns predominates more or less from November until March. During summer (May through September), the curl field north of equator to 10 ^{0} S. is reversed in sign. A narrow coastal strip near about 500km wide, running from Madagascar along the coasts of East Africa, Arabia, and India has strong positive values.

Conclusion

- Weak surface wind stress is one of the main cause for failure of monsoon.
- The variability in the wind stress and wind stress curl exists only in the north of 15º S
- The formation of Somali Jet, which is the most important competent of the southwest monsoon, can be understood by studying wind stress and wind stress curl.

1987 **2002** **Climatology**

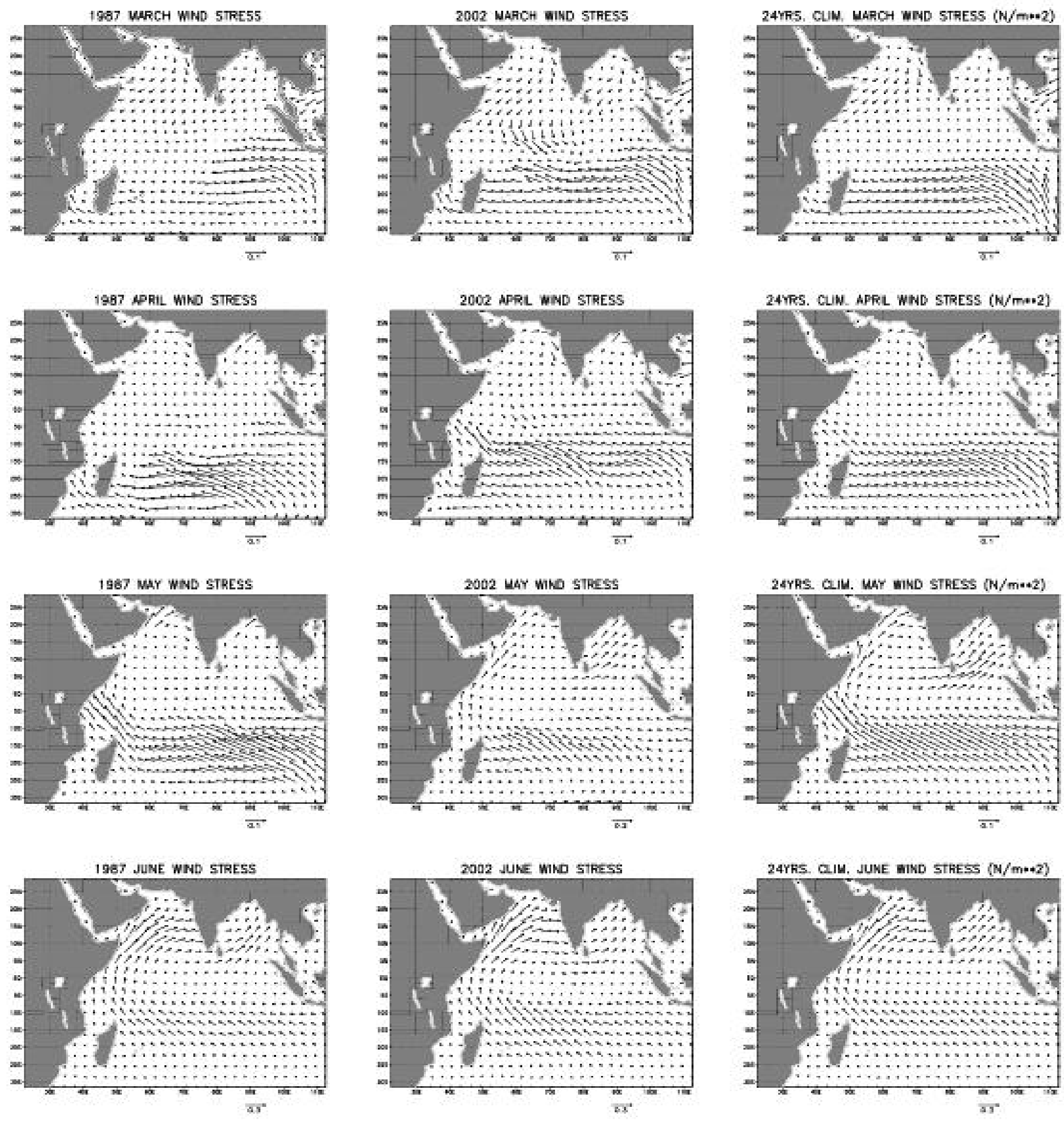

Fig. 1987,2002 and 24yrs clim. wind stress(N/m**2) for the month of MARCH, APRIL, MAY, JUNE

Variation of Thermohaline structure during three consecutive monsoon years as revealed from Argo floats

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Abstract:
Sea surface temperature is important parameter for the temporal evolution of the tropical atmosphere-ocean coupled system for shorter time scales, but the upper ocean thermal structure is more important as the time scale increases, since heat storage play a key role in the tropical atmosphere ocean coupled system. Descriptions of the annual cycle of the heat content for the global ocean and individual basins are available in the literature. However, annual variations of subsurface thermal structure of the Indian Ocean, especially in the Arabian Sea are not available due to paucity of measurements and immediate availability of upper ocean data. With the availability of Argo floats, now it is possible to monitor continuously the upper ocean temperature and salinity structure once in 10 days. Here, we are presenting the upper ocean variations of heat content, mixed layer depth, temperature and salinity observed by Argo floats during three consecutive monsoon periods (2002-2004). Since the availability of Argo floats starts from the year 2002 was confined to Arabian Sea, we limited our study to the region 40 to 80 E and 5 to 25 N.

Argo Project aims to deploy 3000 floats in the global ocean by the year 2006, which enables us to obtain 1,00,000 vertical temperature and salinity profiles annually. About 450 floats will be deployed in Indian Ocean and already more than 270 floats are providing data in Indian Ocean. More details about the Argo Project and the data availability, readers may refer Ravichandran et al (2004).

Sea surface temperature and temperature at 100 m depth averaged over the Arabian Sea during three monsoon periods show that temperature variations at the surface between three years are only 0.5 deg, where as at 100 m depth the variations are more than 2 deg C. The average wind speed over the Arabian Sea is more or less same for all the years and hence the sea surface temperature variations during monsoon for different years are small but not below the surface. During the monsoon period, the surface and subsurface (100 m) temperature are more in the year 2003 compared to other years. Fig 1 a shows the heat content upto 26 deg isotherm (HC26), which is readily available to atmosphere for evaporation, averaged over the selected area. Before the onset of the monsoon, HC26 is more in the year 2004 and less in the year 2002. However, during the monsoon period, HC26 is almost same for all the three years. Rao and Sivakumar (1998) pointed out that there is a high correlation between SST and HC26. But our observation does not show such high correlation. The correlation varies between the years, and for the year 2002, the correlation was negative. Dube et al (1990) concluded that the upper layer thickness and its heat content is less during wet monsoon years and vice versa for dry monsoon years using model studies. We have also computed heat content upto 20 deg isotherm (HC20 – representative for thermocline depth) and is shown in Fig. 1 b. During peak monsoon

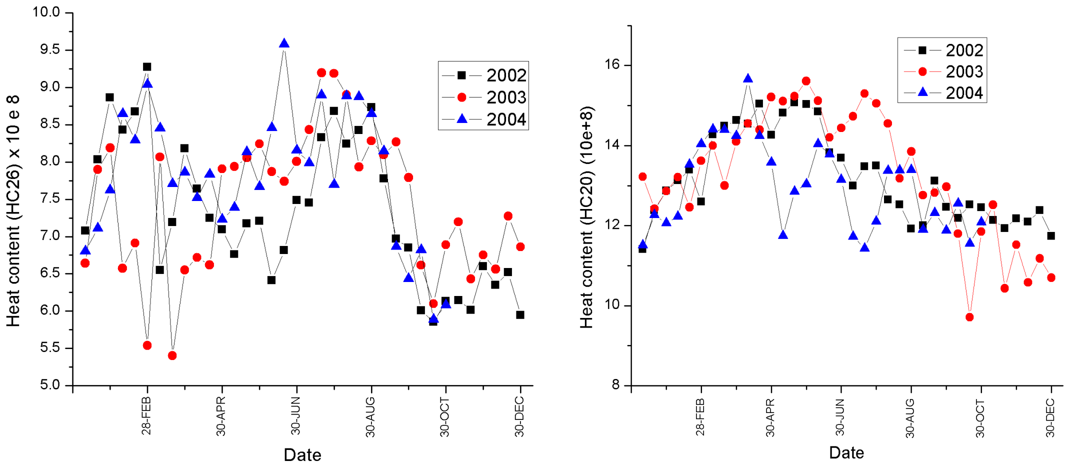

Fig 1a. Heat content upto 26 deg isotherm and Fig. 1b Heat content upto 20 deg isotherm averaged over the entire Arabian Sea during the year 2002 to 2004.

month (July), HC20 is higher in 2003 compared to other two years and minimum in the year 2004. This is contradictory to the one proposed by Dube etal (1990). It is to be noted that heat content alone will not decide the Indian Monsoon variability. The observation shows that the heat content differences between 20 and 26 deg isotherm is important parameter to underpin the effective heat available for atmosphere. The variability of HC20 is controlled primarily by vertical motion of the thermocline in association with time varying Ekman pumping, geostrophic flow, and eddy and propagating wave fields, rather than by surface heat fluxes alone. Though the winds are responsible to change the upper ocean thermal characteristics upto mixed layer depth, the heat content upto thermocline depth determines the present state and future evolution of upper ocean temperature. In order to understand total coupled system, we need to quantify each component mentioned above.

Fig 2 shows the sea surface salinity averaged over Arabian Sea during the year 2002 to 2004. Low salinity was observed during pre-monsoon for the year 2002 and 2004 where as this anomaly was not noticed in the year 2003. The low salinity formation may be due to precipitation or low salinity water advected to Arabian Sea from equator (Southerly current during Feb-Mar). Since there is no precipitation over Arabian Sea during pre-monsoon month, the low salinity is due to advection from equator. Whether this salinity features will give clue for the monsoon needs further investigation.

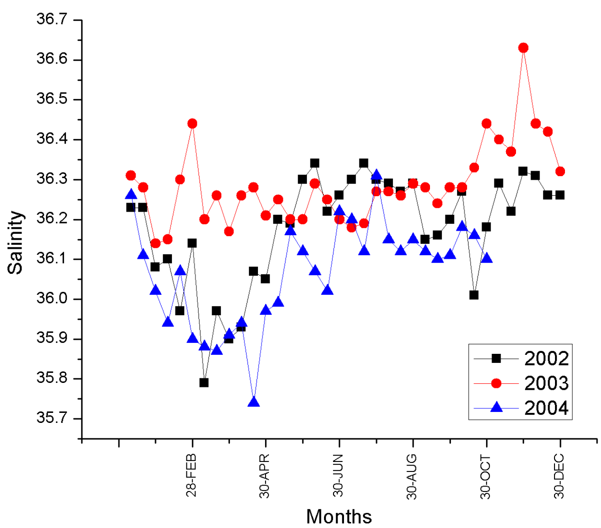

Fig 2. Surface salinity variations during three years observed from Argo

Acknowledgement:
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Extremes of the Indian summer monsoon rainfall, ENSO and equatorial Indian Ocean oscillation

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Abstract:

The link of the Indian Summer Monsoon rainfall (ISMR) with El Nino and southern Oscillation (ENSO) with a high propensity for droughts (excess rainfall) during El Nino (La Nina) has been well established over the last two decades *[Sikka 1980, Pant and Parthasarathy 1981, Rasmussan and Carpenter 1983]*. However, for fourteen consecutive years beginning with 1988, there were no droughts despite the occurrences of El Nino events. Further, during the strongest El Nino event of the century in 1997, the ISMR was higher than the long term mean while ISMR was excess (above 1std) in 1994 even though there was no La Nina event. Hence it was suggested that the relationship between the Indian monsoon and ENSO had weakened in the recent decades *[Kumar et al 1999]*. In this paper we show that the Equatorial Indian Ocean Oscillation *[EQUINOO, Gadgil et al 2003]* also plays an important role in the interannual variation of the Indian summer monsoon rainfall. EQUINOO, which is the atmospheric component of the Indian Ocean Dipole *[IOD, Saji et al 1999, Webster et al 1999]*, is characterized by anomalies of opposites signs in the convection and sea level pressure over the western parts of equatorial Indian Ocean (WEIO) and eastern parts of the equatorial Indian Ocean (EEIO). During the positive (negative) phase of EQUINOO, convection is enhanced over WEIO (EEIO) while it is suppressed over EEIO (WEIO) and with an easterly (westerly) anomaly of the wind along the equatorial Indian Ocean. The positive phase of EQUINOO is favourable for monsoon and negative phase is unfavourable for monsoon.

The impact of El Nino (La Nina) is the overall suppression (enhancement) of convection over the Indian region and the Indian Ocean. The interplay of ENSO and the EQUINOO can lead to different patterns of SST and convection anomalies over the equatorial Indian Ocean (depending on the phases and strengths of the two modes) with different implications for the Indian Monsoon. In Figure 1, the category of ISMR for each season during 1958-2004 is shown in the phase plane of the ENSO index (negative of SST anomaly of Nino3.4 region) and EQWIN (negative of zonal wind anomaly averaged over 60^{o}E-90^{o}E, 2.5^{o}S-2.5^{o}N). Both the indices are normalized by standard deviation. We consider first the extreme years i.e., the years with large excess or deficits (droughts). The interannual variation of ISMR during 1958-2004 shows that droughts (excess rainfall seasons) are associated with either ENSO or EQUINOO, or both being unfavourable (favourable). The most striking feature of the distribution of extreme years is the clear separation between the years with excess and deficits with all the surplus years located above a certain line in the phase plane (the line L in Figure 1). This suggests that an appropriate index would be a composite index, which is a linear combination of the ENSO index and EQWIN. Further, it should be noted that since the coefficients of both the indices in the composite index are comparable, the influence of EQUINOO on the extremes of ISMR is comparable to that of ENSO. If the ISMR is related to the composite index, we expect the years with low rainfall to have lower value of the composite index. We see that each of the 12 drought years have lower composite index than each of the 7

surplus years. The probability of this happening by chance (i.e., when ISMR is unrelated to the composite index) is 7!12!/19!, i.e., 0.000019%, which is extremely small. Thus there is a very significant relation between the composite index and extreme ISMR events. However, it appears that there is no relationship between the composite index and the variations of ISMR within one standard deviation.

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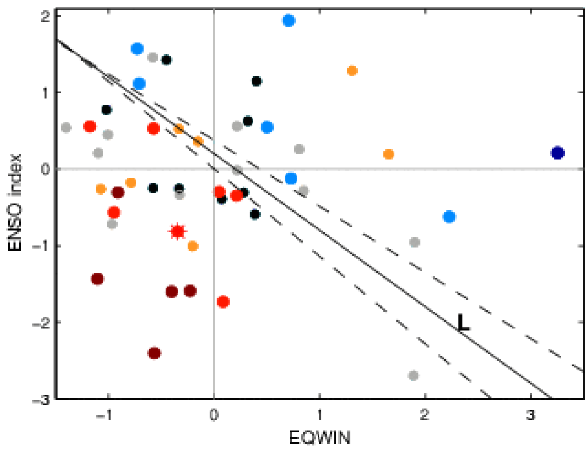

Figure 1. Each season of extreme ISMR during 1958-2003 is shown on the phase plane of the June to September average of the ENSO index (negative of Nino 3.4 index) and EQWIN. The corresponding ISMR anomaly (normalized by the standard deviation) is represented with different symbols: large dark blue (red) closed circles for values above (below) 1.5 (-1.5), blue (red) closed circles for values between 1 (-1) and 1.5 (-1.5), small black (orange) closed circles for values between 0.25 (-0.25) and 1 (-1) and gray closed circles for values between -0.25 and 0.25. Star represents the year 2004.

On the association between the Indian summer monsoon and the tropical cyclone activity over Northwest Pacific

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Abstract:

An analysis of observed typhoon tracks and daily global wind data for 55-years (1948-2003) reveals that large-scale circulation anomalies associated with the interannual variability of the Indian monsoon play an important role in influencing the tropical Pacific cyclone activity. The cyclogenesis over northwest and tropical west-central Pacific is found to be about 1.33 times higher during weak monsoon years as compared to strong monsoon years. Also there is greater tendency for the Pacific cyclones to move northward and recurve (to the north of 20^{o}N) during weak monsoon years. The enhanced cyclogenesis during weak monsoon years is found to be associated with enrichment of low-level cyclonic vorticity anomalies over a wide-region of the sub-tropical Pacific extending from the China Sea, Taiwan and Philippines region to the central Pacific; while the movement of the tropical cyclones is associated with anomalies of upper-tropospheric steering currents. Given that the interannual variability of the large-scale circulation over the Indo-Pacific sector is crucially determined by the El Nino / Southern Oscillation (ENSO) conditions, the present findings raise several questions pertaining to interactions among the large-scale circulation anomalies, tropical convection and the Pacific cyclonic disturbances, which are likely to provide better understanding of the dynamical linkages between monsoon variability and ENSO.

Keywords: Indian summer monsoon; Tropical Pacific cyclones; Teleconnection patterns.

Author Index

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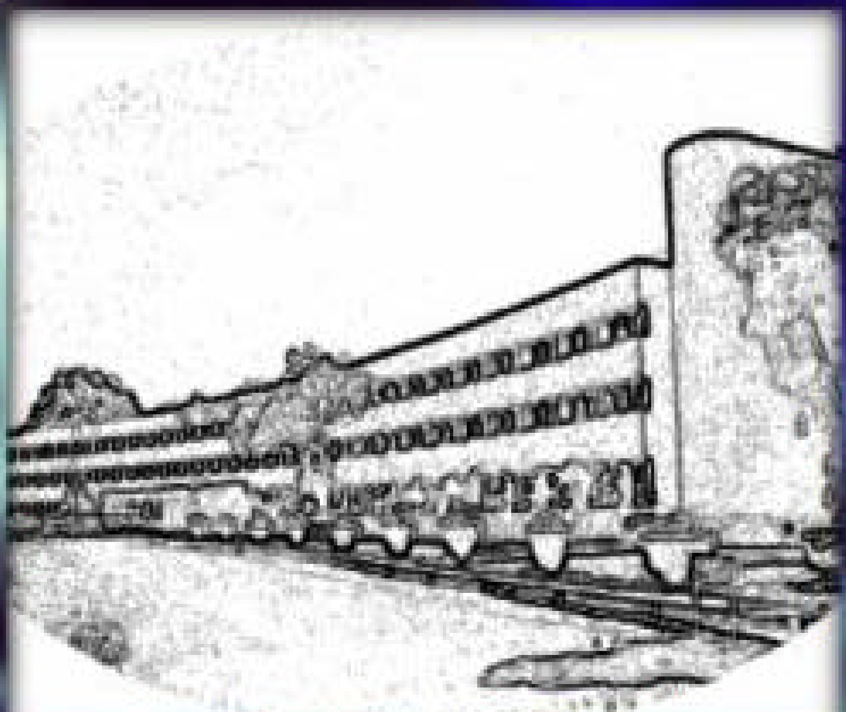

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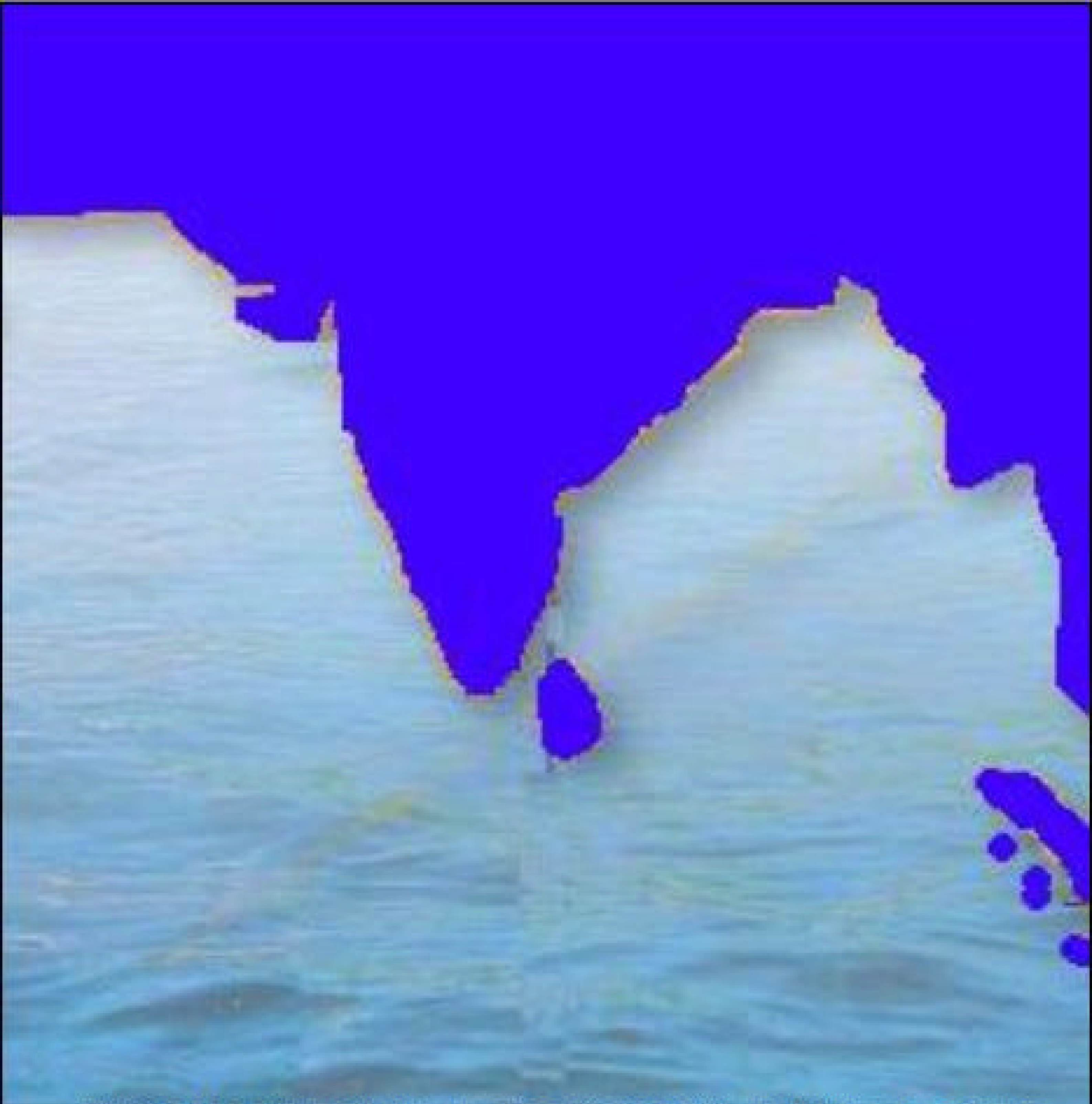

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