Program: Radar and Satellite Meteorology

Research Highlights

High-Resolution Gridded CAPE Estimates from Indian Geostationary Satellite (INSAT-3D)

Background

- Convective available potential energy (CAPE) is a measure of convective potential in the atmosphere that incorporates the instability and moisture ingredients. In a physical sense, it is the energy available for the free lifting of the air parcel from the level of free convection to the level of neutral buoyancy. CAPE is also the measure of maximum kinetic energy per unit mass of air parcel achievable by convection of moist air. So it can also be used as an estimator of maximum possible updraft velocity.
- CAPE provides valuable information in assessing the risk of severe weather. CAPE is an indicator of deep convection, one of the key indices for determining the occurrence of thunderstorms and tornadoes. CAPE can be used as a predictor of electrification/lightning intensity in deep tropical convection.

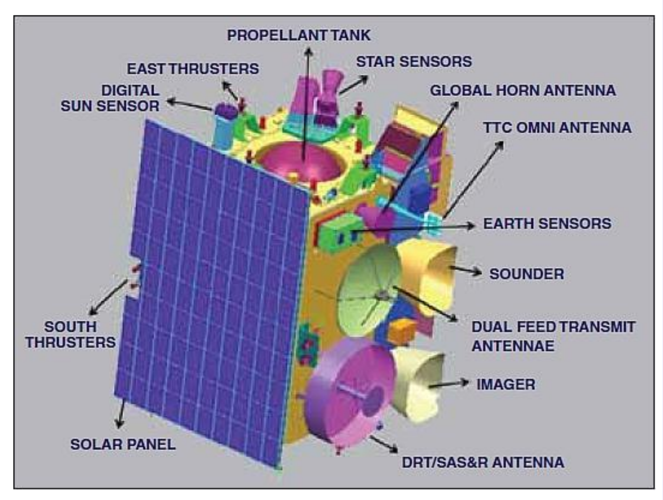
Significance of CAPE

- Convective schemes in GCMs use CAPE as a variable for calculating convective heating.
- Many cumulus parameterization schemes make use of CAPE in constructing closures.
- Diurnal variation of CAPE is of primary importance in the model for producing the diurnal cycle of precipitation.
- CAPE is an important indicator of model performance, particularly in the tropics.
- Seasonal and diurnal changes in CAPE are important to provide validation of the capacity to simulate future changes in the models.

Estimation of CAPE is imperative, not only for assessing the conditional instability of the atmosphere and for the convective parameterization, but also for the studies related to climatic change

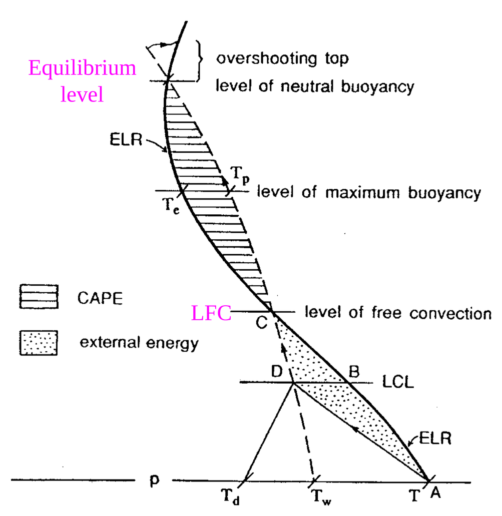
INSAT Satellite

- INSAT is a series of multipurpose geostationary satellites launched by the ISRO, India.
- The main objective of the mission is to monitor the earth and ocean continuously and also provide data dissemination capabilities. The INSAT-3D also provides an operational, environmental and storm warning system to protect life and property.
- The INSAT-3D spacecraft carries two meteorological payloads: (i) an imager (optical radiometer) provides high-resolution images of mesoscale phenomena in the visible and infrared (IR) spectral bands (0.55 to 12.5 μm) and (ii) a sounder has one visible and 18 IR (7 in long-wave IR, 5 in mid-IR, and 6 in short-wave IR) channels. The sounder measures the irradiance and provide profiles of temperature, water vapour, and integrated ozone over the Indian landmass and surrounding ocean every hour and over the whole of the Indian Ocean every 6 h with a spatial resolution of 0.1◦. Temperature and water vapour data collected from the INSAT-3D sounder during the clear (cloud free) conditions are used.



Courtesy: ISRO

Methodology



$$CAPE = \int_{LFC}^{EL} g\frac{(T_p - T_e)}{T_e} dZ$$

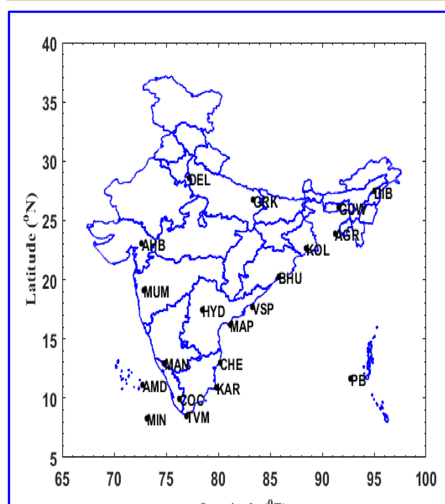
T_p is the virtual temperature of the air parcel

T_e is the virtual temperature of the environment

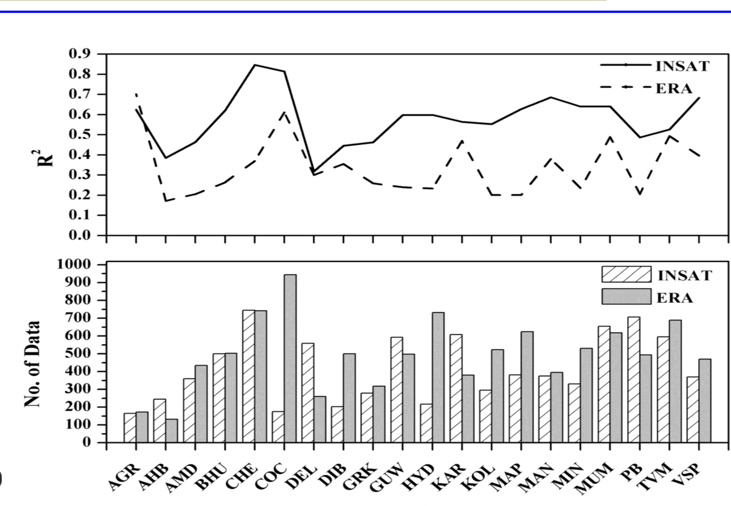
g is the acceleration due to gravity

❖ **Data Used: April 2014 – March 2017**

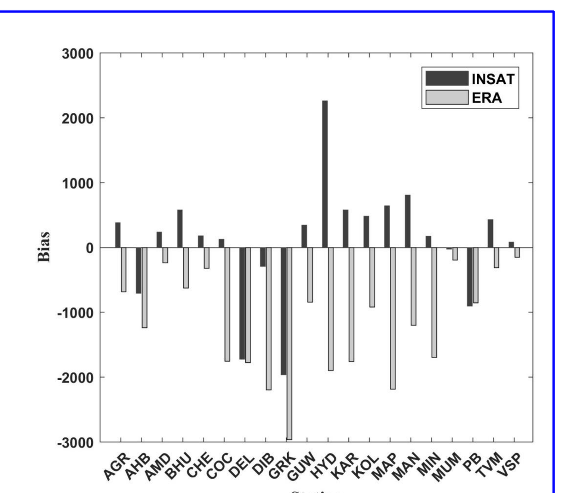
Evaluation of INSAT-3D CAPE with Radiosonde and ERA-interim data



Locations of radiosonde stations



Correlation coefficient and population in the comparison of INSAT-3D and ERA CAPE with radiosonde derived CAPE



Bias in the comparison INSAT-3D CAPE and ERA-Interim CAPE with radiosonde

❖ For the first time, CAPE is estimated from INSAT-3D measurements with high spatial and temporal resolution.

❖ INSAT-3D estimates are better than ERA reanalysis estimates when compared to radiosonde measurement.

Skill Score of CAPE Estimation from INSAT-3D

Contingency table for the comparison of INSAT-3D estimated CAPE with radiosonde measured CAPE

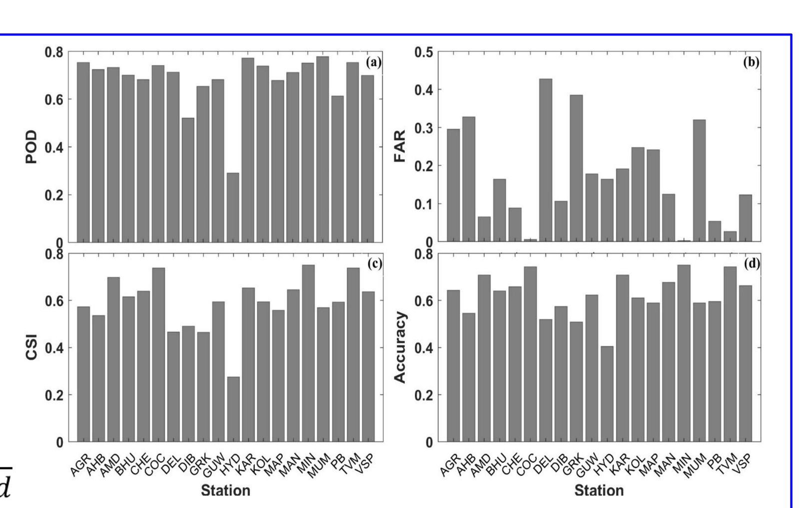
	Radiosonde ≥Threshold	Radiosonde < Threshold
Satellite ≥Threshold	Hits (a)	False alarms (b)
Satellite <Threshold	Misses (c)	Correct negatives (d)

$$POD = \frac{a}{a+c}$$

$$FAR = \frac{b}{a+b}$$

$$CSI = \frac{a}{a+b+c}$$

$$ACC = \frac{a+d}{a+b+c+d}$$

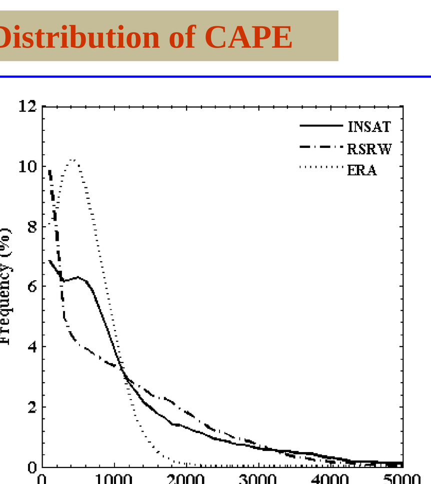


Statistical indices (a) POD, (b) FAR, (c) CSI and (d) ACC in between INSAT-3D CAPE and radiosonde CAPE

❖ Coastal stations show higher POD, CSI, and ACC.

❖ INSAT-3D is unable to detect CAPE over Hyderabad, may be due to less availability of data and the inability to catch the short-lived convective storms frequently observed over this region.

Distribution of CAPE



Distribution of INSAT-3D, radiosonde and ERA reanalysis CAPE

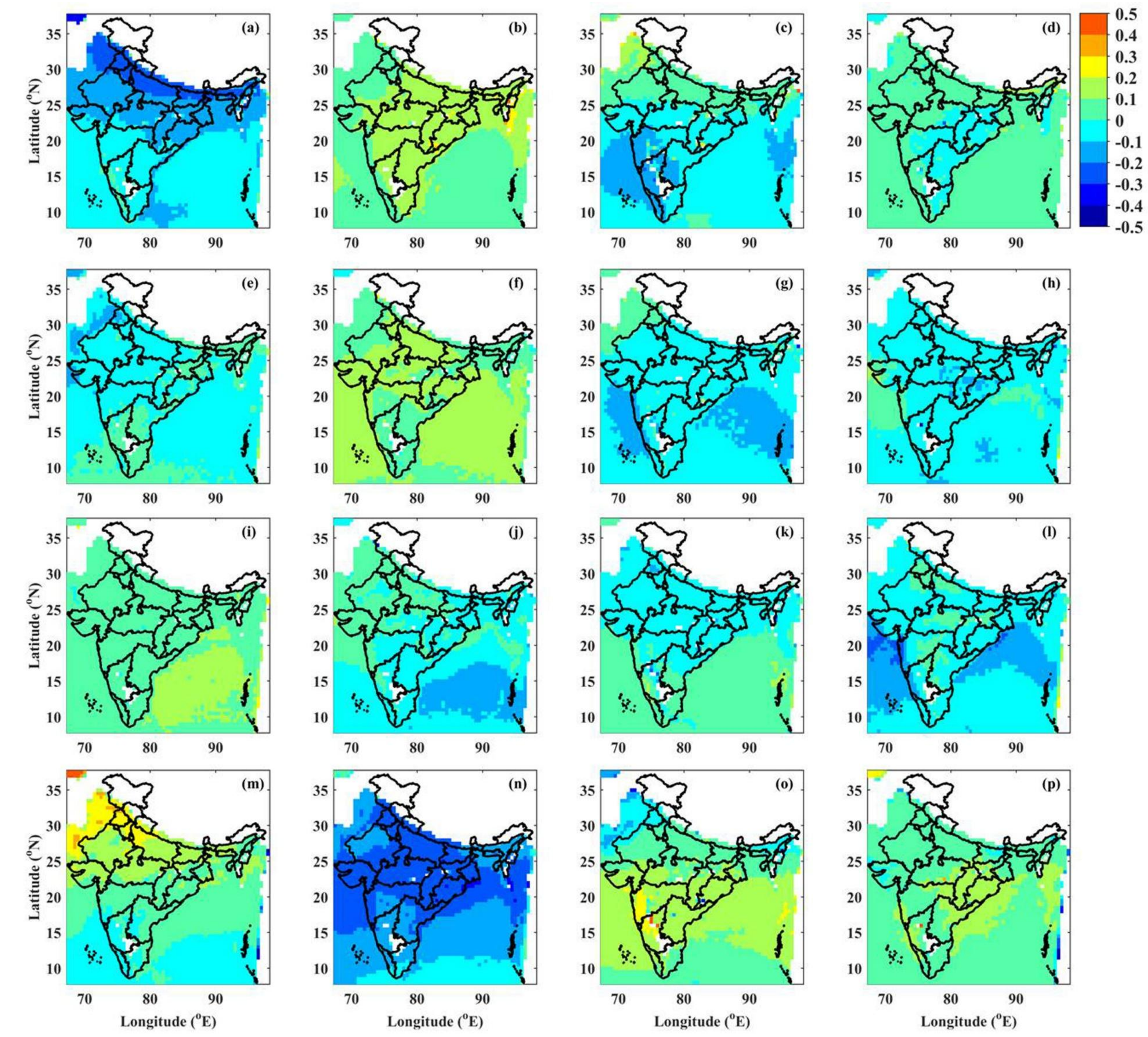
❖ CAPE distribution is higher for lower values

❖ INSAT-3D estimated CAPE matches well with the radiosonde measurements above ~3000 J kg^{-1}.

❖ ERA-Interim CAPE distribution shows higher values below 1200 J kg^{-1}

Spatial distribution of INSAT-3D CAPE: Seasonal Scale

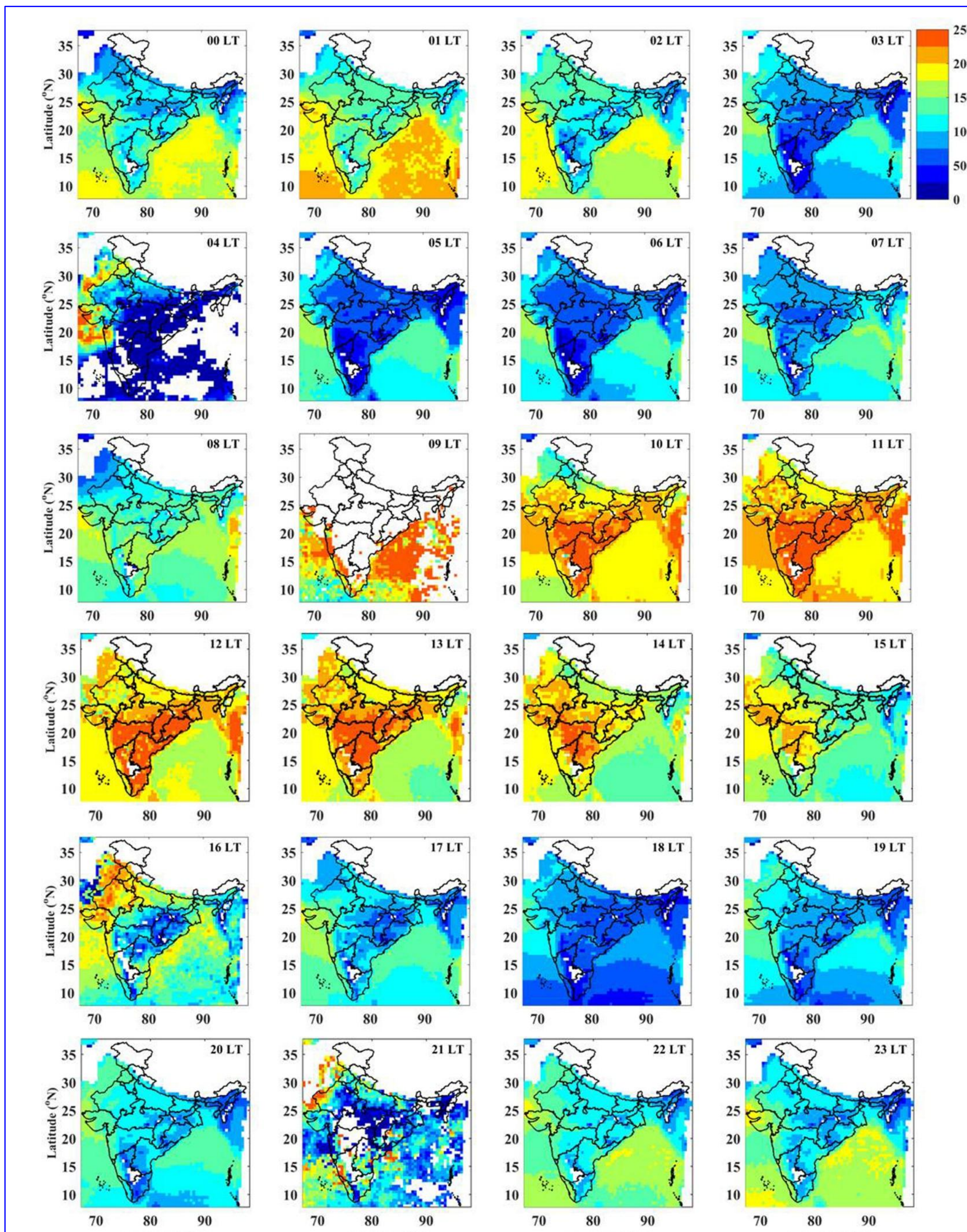
To observe the spatial distribution of extreme weather events, the estimated CAPE is divided into four categories: weak instability (<500 J/kg), moderate instability (501-1500 J/kg), strong instability (1501-3000 J/kg), and extreme instability (>3000 J/kg).



The normalized anomaly distribution of CAPE in the four instability conditions during (a)-(d) winter, (e)-(h) pre-monsoon, (i)-(l) monsoon and (m)-(p) post-monsoon seasons

➢ Weak instability is predominant during winter, moderate instability is higher during post-monsoon, strong instability is more during monsoon and extreme instability is higher during pre-monsoon season.

Spatial distribution of INSAT-3D CAPE: Diurnal Scale



Summary:

Developed algorithm provides high-resolution gridded CAPE product from the INSAT-3D measurements that can be used for nowcasting and severe weather warnings in the numerical prediction models

Murali Krishna, U. V., Subrata Kumar Das, K. N. Uma, and G. Pandithurai (2019), Retrieval of convective available potential energy from INSAT-3D measurements: Comparison with radiosonde data and their spatial-temporal variations, *Atmos. Meas. Tech.*, 12(2), 777–790.

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