Data Assimilation Research for improving monsoon simulation and forecast

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Objectives

- To study the impact of temperature profiles Assimilation on the dynamic and thermodynamical characteristics of Indian Summer Monsoon.
- To produce a multi-year downscaled regional reanalysis of the ISM using the NCEP operational analyses and AIRS temperature and moisture retrievals in a regional frame work.
- To evaluate the impact of AIRS profiles on prediction of Indian summer monsoon using WRF 3D-variational data assimilation system
- To study the predictability of monsoon intra-seasonal oscillations in a regional model with and without data assimilation

Outcome

- Improved simulation of ISM circulation in WRF model by assimilating temperature profiles from AIRS due to elimination of asymmetric (north–south) SLP bias; larger error reduction in winds; temperature (at boundary layer and mid-troposphere); vertical wind shear and WVMR.

- Demonstrated improvement in all the predicted fields associated with the ISM, consistent to the month long assimilation of AIRS profiles, is an innovative finding with large implications to the operational seasonal forecasting capabilities over the Indian subcontinent.

- Improvement in the predictability of circulation and precipitation associated with MISO is found when the initial state is produced by assimilating AIRS retrieved temperature and water vapour profiles in WRF model.

Four dimensional Data Assimilation (FDDA) for simulation

- The FDDA is a continuous data dynamic assimilation method that relaxes the model state toward observed state.

- In the analysis, Newtonian relaxation term is added to the prognostic equation

- T is a prognostic variable (i.e., temperature), M represents model which includes the physical processes, x represents the independent variables, and t is time, y is the observation vector, H is the observation operator that transforms or interpolates the model forecast variable to the observation variable and location, G is the nudging magnitude matrix, and Wp, Wg, Wf are the spatial and temporal nudging (or weighting) coefficients.

- The nudging strength is specified to be 3 × 10−4 s−1 and ε denotes observation quality factor.

- Each observation is ingested into the model at its observed time and location with proper space-time weights and the model spreads the information in time and space according to the model dynamics.

Fig. 1 Spatial distribution of bias (a) CTRL and (b) WRF AIRS and RMSE (c) CTRL and (d) WRF AIRS with respect to ERAI for WVMR (kg m−2 shaded), and SLF (hPa; contours), low level winds (at 850 hPa) in m s−1 (vector) for JAS.

Fig. 2 Time series of monsoon indices (a) WPI (ms−1), (b) MHI (ms−1), (c) EIMRI (mm day−1) (d) WNPRI (ms−1) and (e) EASMI (ms−1).

Fig. 3 JAS mean spatial distribution of vertical shear of the zonal winds (U200-U850) (a-c), m s−1 and precipitation (d-f), mm day−1.

Fig. 4 Vertical profile of bias and RMSE of (a) T (°C) and (b) WVMR (kg m−2) in WRF first guess and analysis.

Fig. 5 Vertical profile of RMSE for (a-d) T (K) and (c and d) WVMR (kg m−2) from CTRL, Conv & ConvAIRS at 00:00 UTC on 1 June 2010.

Fig. 6 Vertical profiles of RMSE for (a-d) T (K), (c and d) WV MR (kg m−2) & (e) IWP (kg kg−1) for CTRL, Conv & ConvAIRS during monsoon 2010.

Fig. 7 Temporal variation of RMSE of the predicted (a-d) WVMR, (e) T, & (h) precipitation (mm d−1) compared against ERAI/GPCP during monsoon 2010.

Fig. 8 Time evolution of signal & noise of rainfall (mm d−1) over MCR for active (a-b) and break (c-d) phases from CTRL (upper panel) and ASSIM (bottom panel). Vertical red lines are indicative of the precipitation limit where signal and noise intersects each other.

Fig. 9 Analysis reveals that the limit of predictability of low level zonal wind is improved by four (three) days during active (break) phase. Similarly the predictability of upper level zonal wind (precipitation) is enhanced by four (two) and two (four) days respectively during active and break phases.

Fig. 10 More realistic baroclinic response and better representation of vertical state of atmosphere associated with monsoon enhance the predictability of circulation and rainfall.

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References: