Representation of process-based diagnostics in NCUM global and regional forecasts

Mohana S Thota*, Raghavendra Ashrit, Kondapalli Niranjankumar and Sagili Karuna Sagar

**mohant@ncmrwf.gov.in*

National Center for Medium Range Weather Forecasting

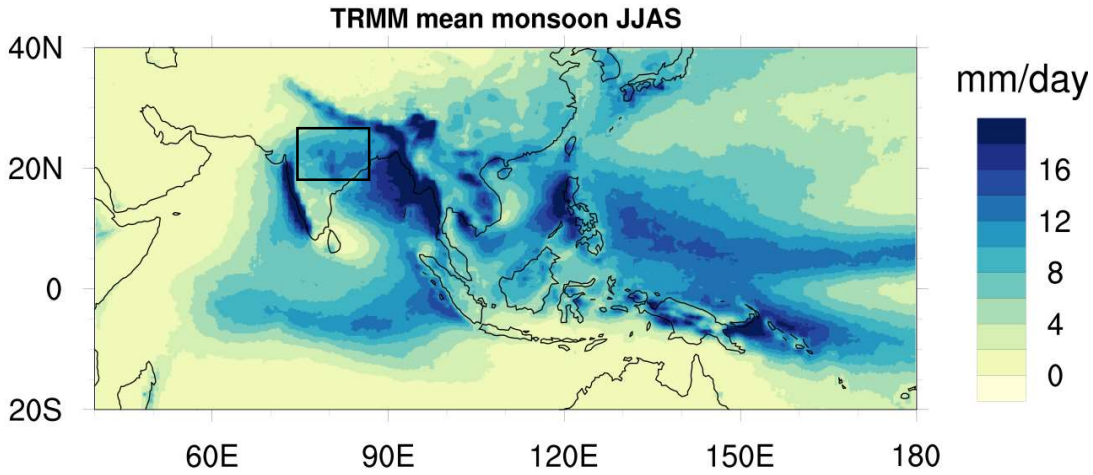
Ministry of Earth Sciences, India

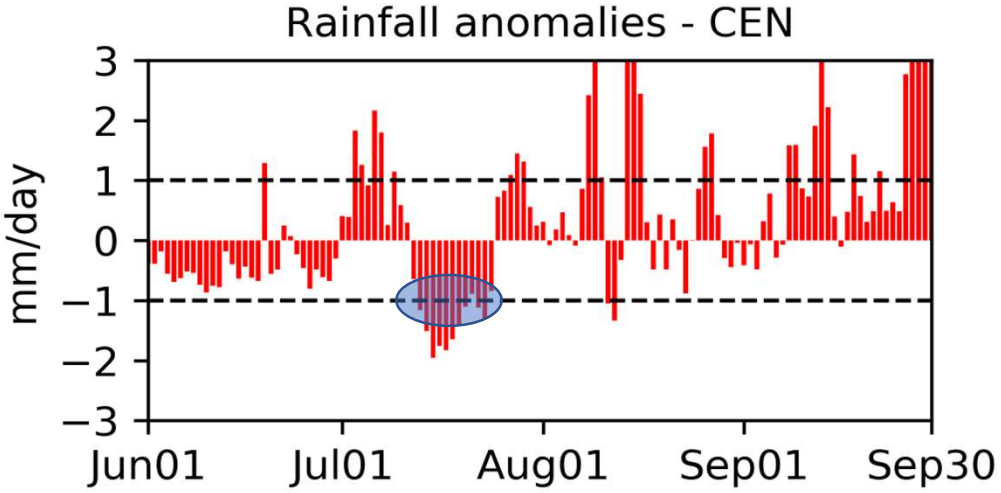
Outline

- Motivation
- Typical break event – July 2019
- NCUM config. - Diagnostic tool
- Key results
- Summary - Take home message

"*How does NCUM model forecasts represent physical processes during BSISV over India*? *(column integrated Moisture budget)*

Motivation



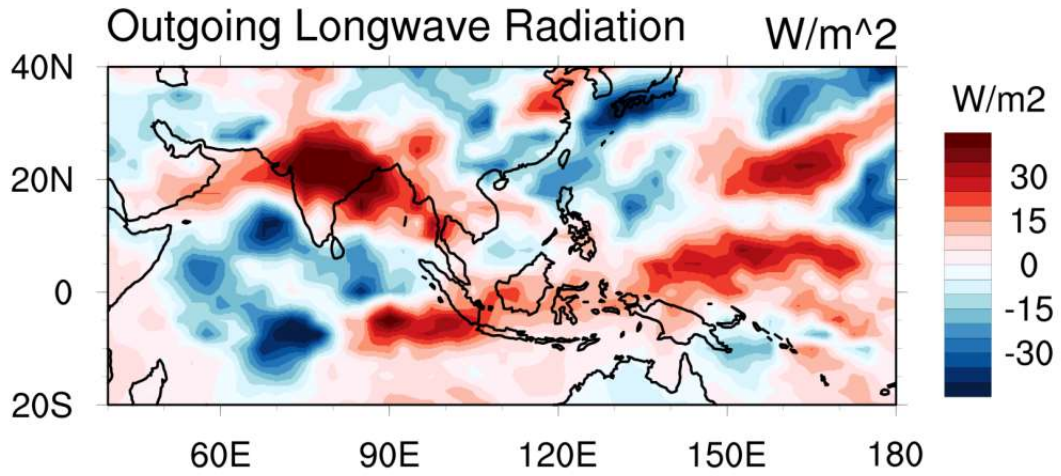


1σ standard deviation – dashed black line.

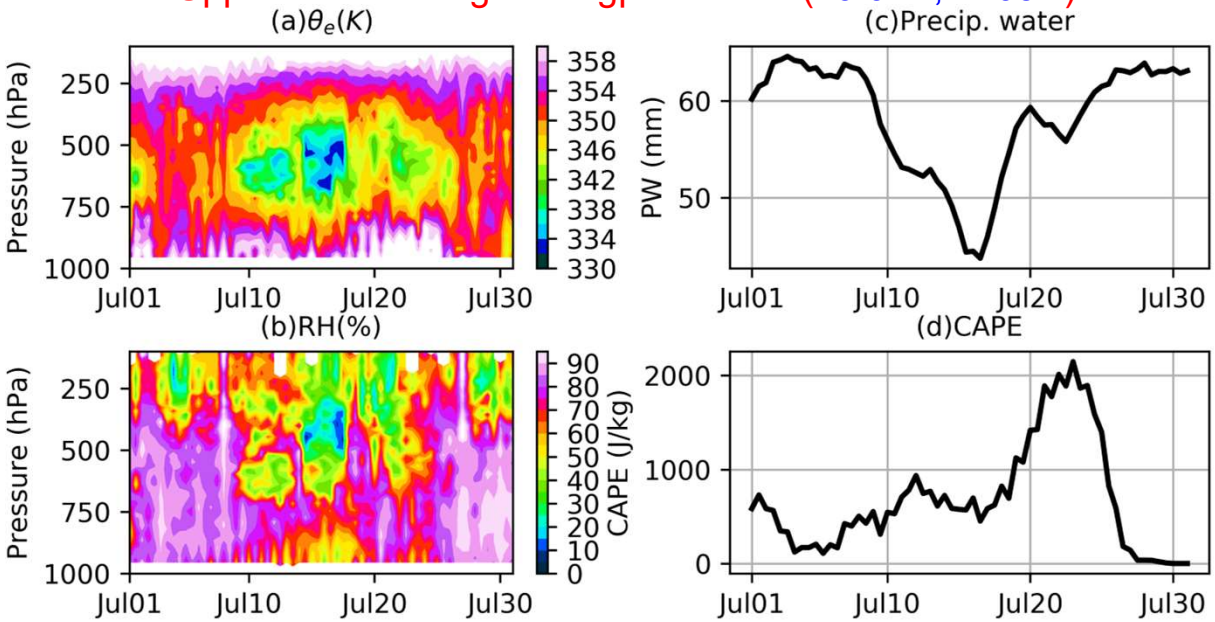
- ✓ Multiple rainfall maxima (heat sources) over South Asia (BoB, EIO, TWP and CI).
- ✓ Absolute mean ascent region.
- ✓ Pulsating nature - Active and break conditions.

- Break conditions persists for more than 10 days in July (peak monsoon month).
- *Models performance?*

Observational Aspects - July 2019 event

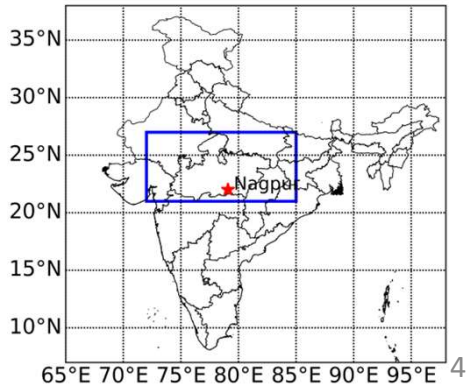


Upper air soundings – Nagpur station (79.01E,21.05N)



Sounding data are obtained from http://weather.uwyo.edu/upperair/sounding.html

- Suppressed convection over most of the central India and Bay of Bengal.
- Low MSE air present around free tropospheric levels (500-700hPa).
- Entire tropospheric column is dry with RH as low as 15%
- Reflected in Column integrated water vapor – associated in large radiative cooling
- Quadrature relationship between moisture and energy.



Diagnostic tool

- Based on the strong correlation between column moisture (RH) and precipitation

- Column integrated moisture budget is applied to understand the physical processes responsible for evolution of negative rainfall anomalies during the break event.

Neglecting cloud water and ice

$$\left\langle \frac{\partial q'}{\partial t} \right\rangle = -\left\langle \nabla .(Vq) \right\rangle' - \left\langle \frac{\partial}{\partial p}(\omega q) \right\rangle' - e' + c'$$

Storage term

Horizontal Moisture advection

Moisture convergence

e-evaporation
c-condensation

(Yanai et al 1973; Su and Neelin 2002; Neelina nd Su 2005; Prasanna and Annamalai 2012)

vertical integration, from 1000 hPa to 100 hPa

Rainfall anomalies are computed

$$std.anom = \frac{(R - \frac{1}{n}\sum_{i=1}^{n} R)}{std(R)}$$

$$R = precipitation$$

NCMRWF Global and Regional Models

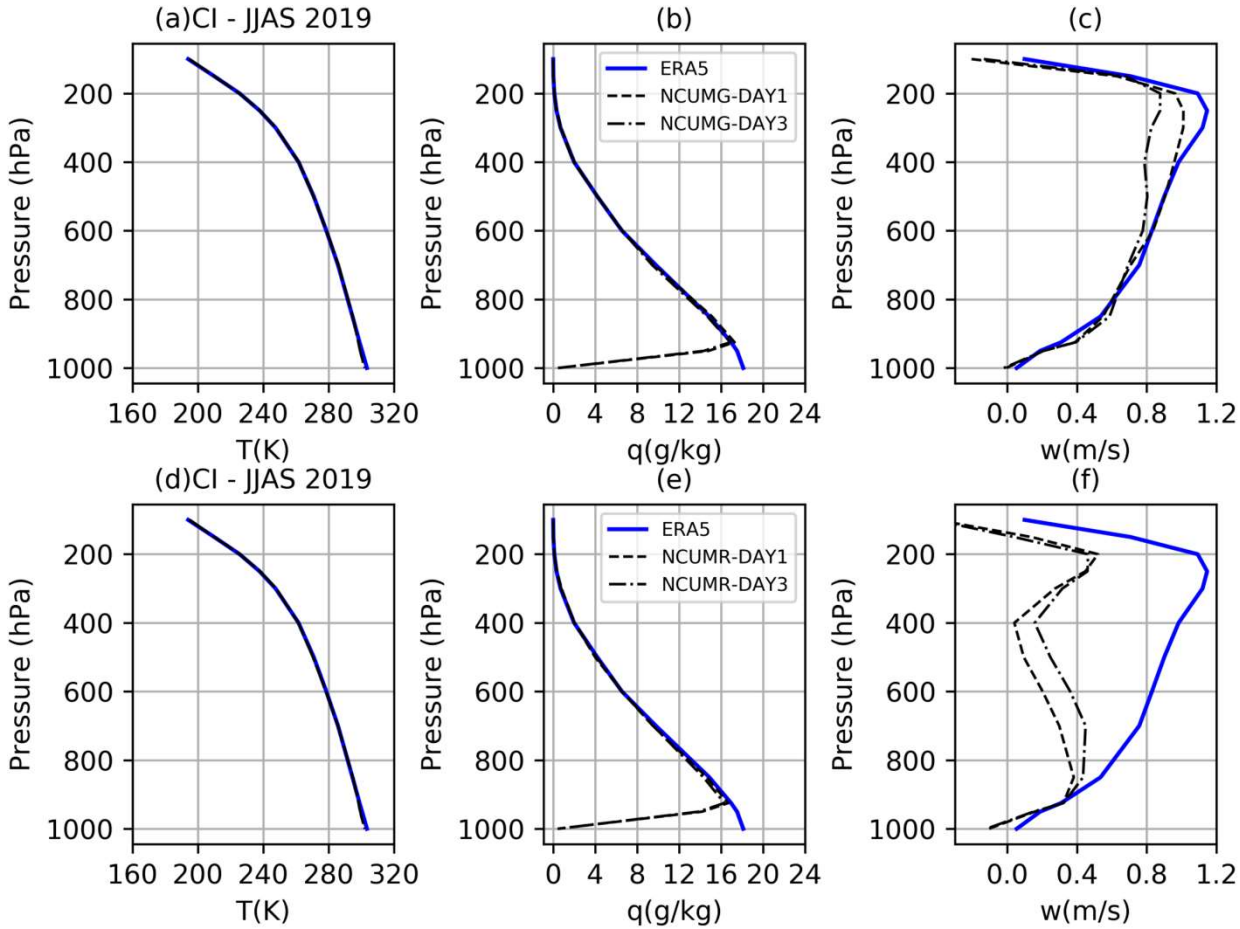
Model	Application & Domain	Resolution	Forecasts*
NCUM-G	Global NWP Forecasts	N1024L70 (12km horizontal resolution with 70 vertical levels)	00UTC: Day0 to Day10 12UTC: Day0 to Day 10
NCUM-R	Regional high resolution over Indian Region (5-40N and 65-100E)	4 km resolution Explicit convection	00UTC: Day0 to Day3

* Up to 72-hour (Day-3) forecasts are considered for the present analysis.

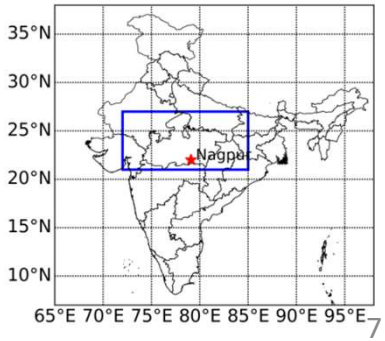
https://www.ncmrwf.gov.in/

Merits and demerits - NCUM models

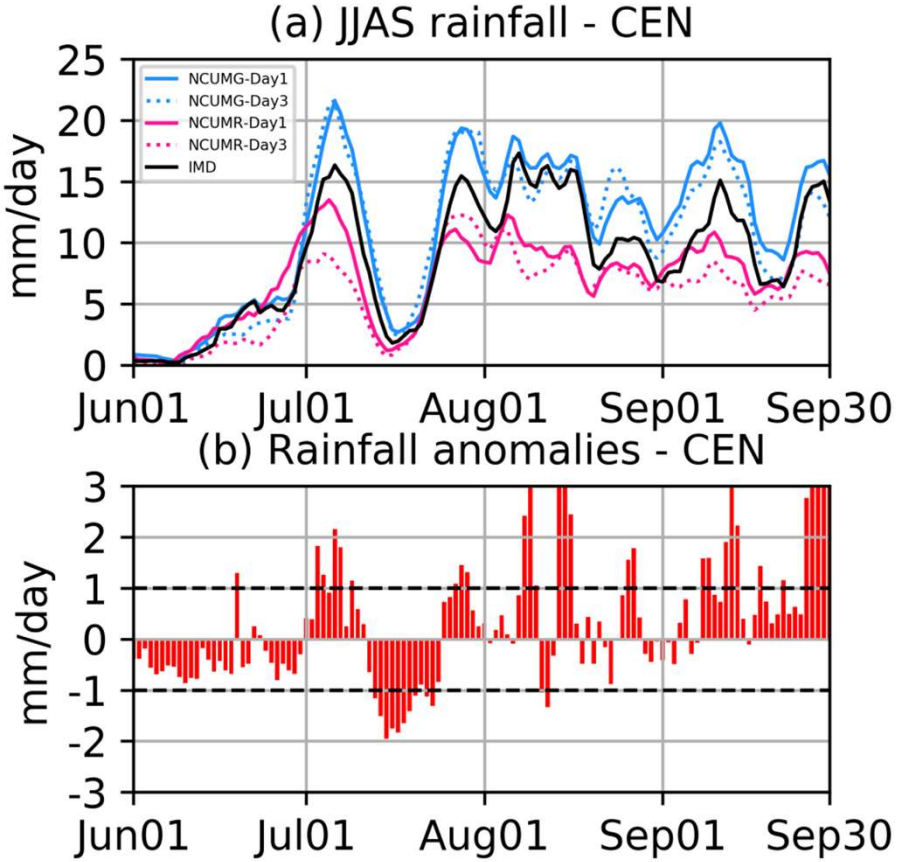
(a) Mean state



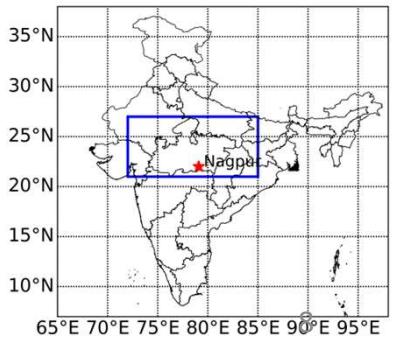
- Largest changes in moisture (*q*) and vertical velocity (w).
- Double peak in mean w in regional model forecasts.
- Weak ascending in the middle-upper troposphere region (Regional)
- *Short comings in cloud micro physics?*



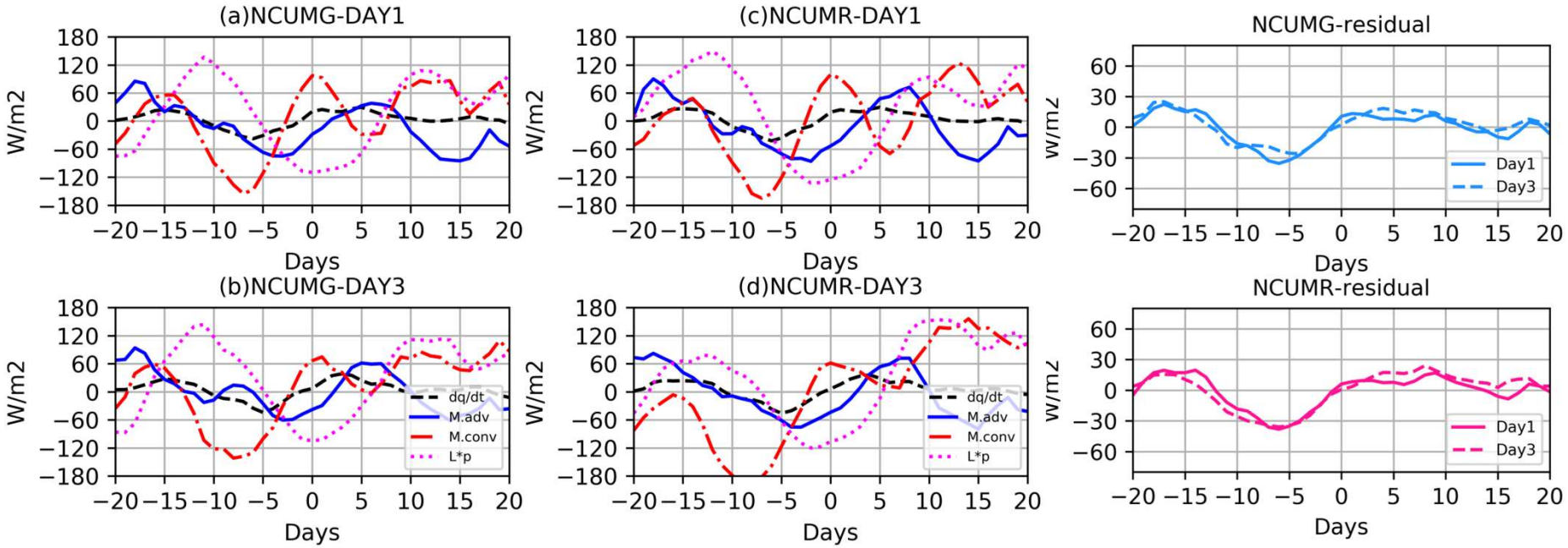
(b) Precipitation variability



- Wet (Dry) bias in NCUM-Global (regional) models. *(Walters et al. 2017; Bush et. Al 2015; Levine and Martin 2018)*
- Westerly wind bias over Indian subcontinent.
- Better one-to-one agreement with observed surface rainfall.
- Tendencies in rainfall forecasts during break phase are in correspondence with observed anomalies.

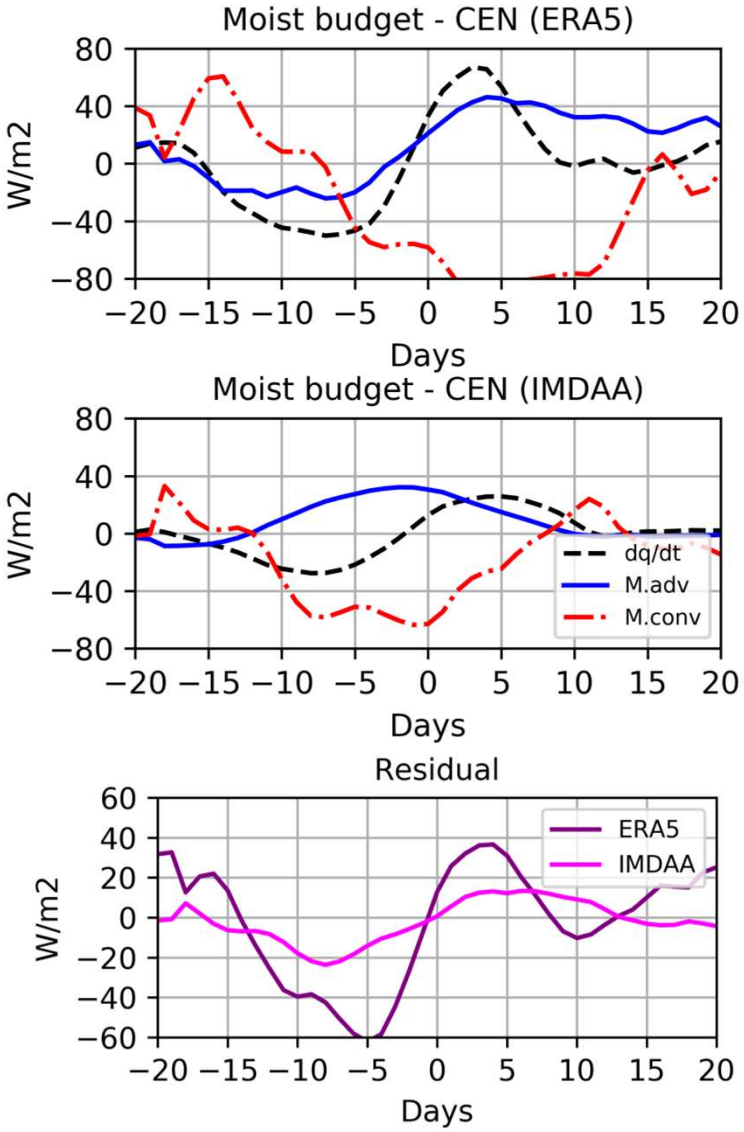


Moisture budget – Model forecasts

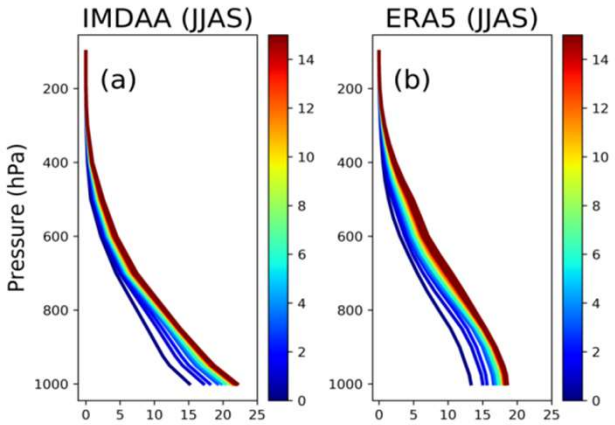


- "0" day corresponds to peak dryness over CI
- Alignment between Moisture convergence and precipitation is off in both the versions. (difference in vertical velocities?)
- Dry air advection is leading precipitation by ~5 days.
- Residuals are as large as tendency term (missing anomalous dry source) *(28W/m2 ~= 1mm/day)*

Moisture budget - Reanalysis products



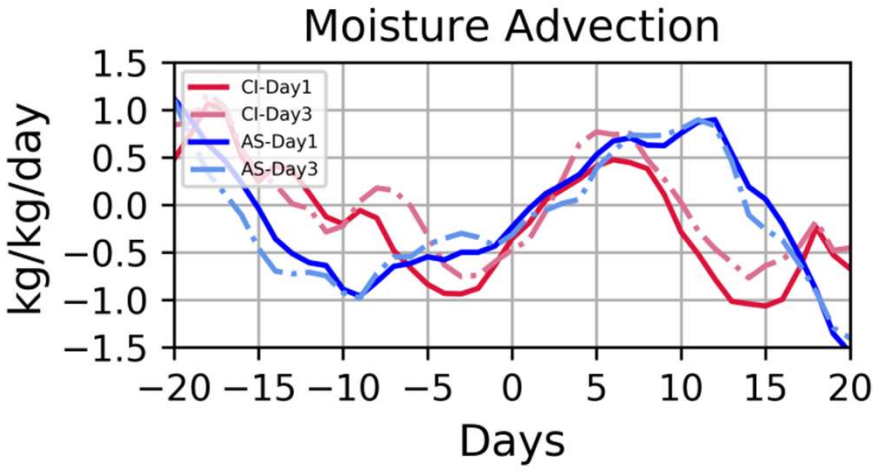
- Moisture convergence – precipitation alignment is better.
- Dryness leads rainfall over CI by ~7-8days in ERA5
- Leading nature of dryness is ~14 days in Indian Monsoon Data Assimilation and Analysis reanalysis (IMDAA) reanalysis *(https://rds.ncmrwf.gov.in/)*.
- Residuals – misrepresenting "some" recharge process (need to look!)



Deep Convection is very sensitive to free-tropospheric moisture. *(Halloway and Neelin (2008)*

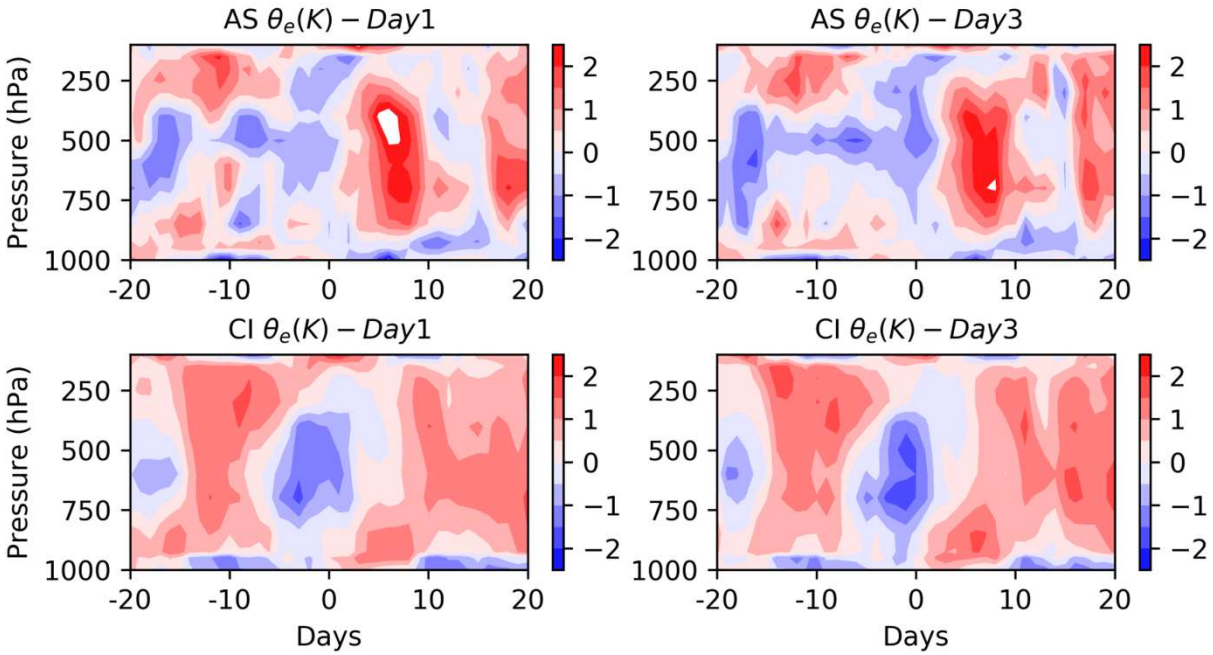
Moisture-convection feedback mechanism?

Source of dryness

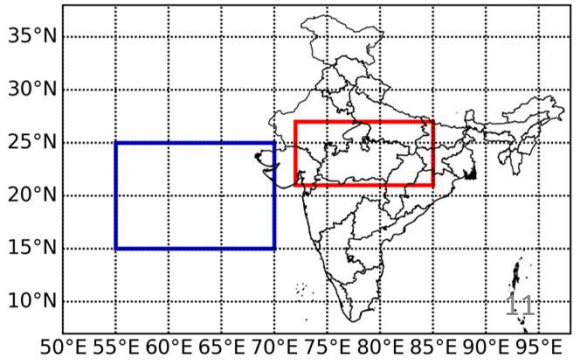


- Dry air advection leading precipitation.
- AS leads CI by ~7 days.

(consistent with Krishnamurti et al 2010, Prasnna and Annamalai 2012; Mohan et al 2018)



- Low MSE air peaking around free tropospheric levels (500-750hPa).
- Over AS it is much earlier than CI (possible source).



Summary & Take home message

- Dry air advection leading the rainfall over CI.
- Dry air from west acts as possible source.
- Budget analysis
  - metric to evaluate model performance
  - Identify possible errors
- Lead times obtained in advection term useful for prediction purpose.
- *Detailed process oriented budgets including radiation and microphysics – Moist static energy (MSE) budget.*

Thanks for your attention

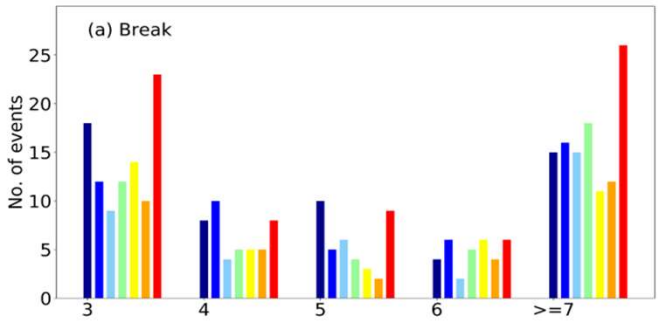
Additional slides

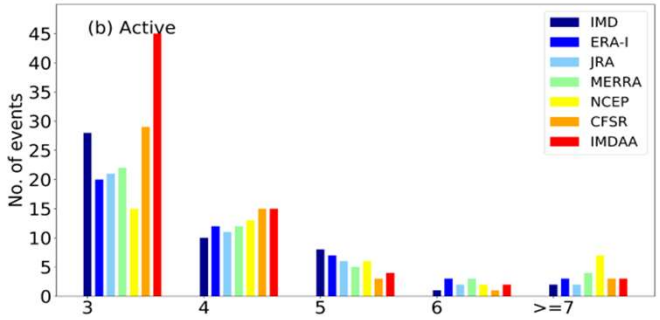
Active break cycles

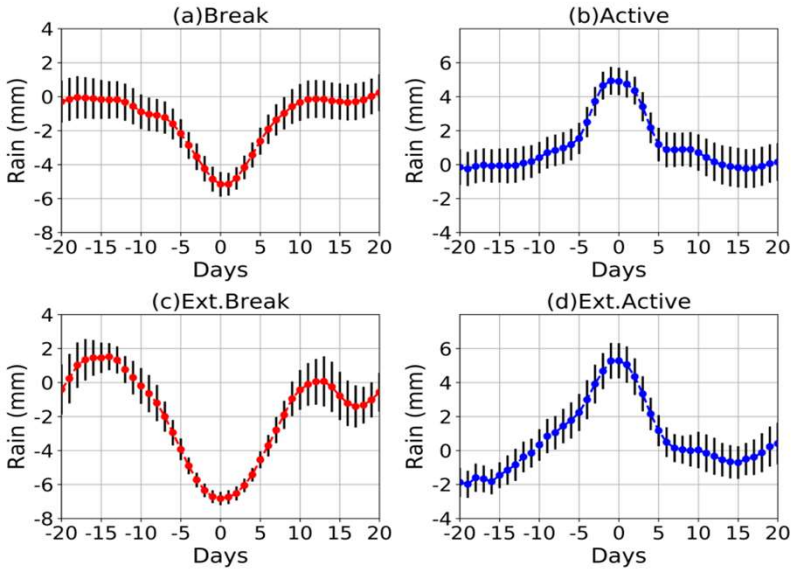
- A-B cycles
  - intrinsic features of monsoon
  - Largely governed by poleward propagation of convective anomalies from equatorial regions.

- Extended episodes.
  - Manifestation of Intraseasonal variability + slowly varying boundary forcing (ex. SST anomalies, ENSO)

(Prasanna and Annamalai 2012; Mohan et al; 2018)



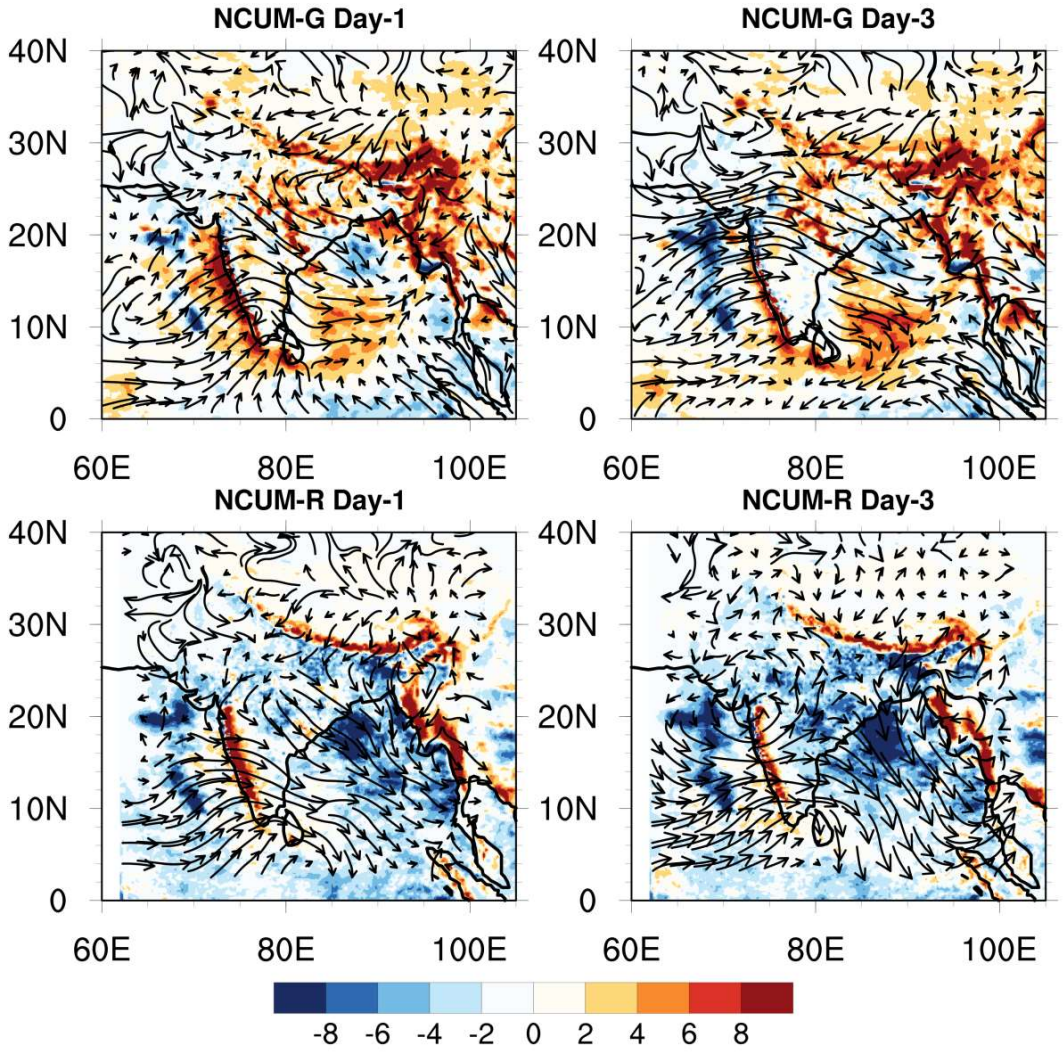




IMDAA

- The Indian Monsoon Data Assimilation and Analysis reanalysis (IMDAA) is a regional atmospheric reanalysis over the Indian subcontinent.
- Collaboration among the Met Office (MO), U.K, National Centre for Medium Range Weather Forecasting (NCMRWF), India and the India Meteorological Department (IMD).
- Funded by Ministry of Earth Sciences, Government of India.
- High resolution (12km) data from 1979 to 2018 (https://rds.ncmrwf.gov.in/)

(c) Mean (JJAS) Spatial biases



- Westerly wind bias over Indian subcontinents in Global model.
- Wet (Dry) bias in NCUM-Global (regional) models.
- Dry bias over CI in NCUMR *(Walters et al. 2017)*
  - *Wet bias over EIO (Bush et al. 2015)*
  - *Inability to simulate LPS (Levine and Martin 2018).*
- Magnitude of dry bias increasing over Indian subcontinent and surrounding oceanic regions – regional forecasts
- Wet bias over Arabian Sea is replaced with dry bias with lead time. (surface fluxes!)

Note:850 hPa wind (vectors) bias w.r.t ERA5 and (shaded) rainfall w.r.t IMD observations

Model configuration

Model	Atmospheric Data Assimilation	Surface analysis
Model: Unified Model; Version 11.2 **Domain:** Global **Resolution:** 12 km, Levels 70 (Top: 80 km) **Grid:** 2048x1536 **Time Step:** 5 minutes **Physical Parametrizations:** Based on GA7.2 **Dynamical Core:** ENDGame **Forecast length:** 10 days (based on 00 UTC and 12 UTC initial conditions)	**Resolution:** N320L70 (~40 km) with N144L70 Hessian based pre-conditioning **Method:** Hybrid incremental 4D-Var. Information on "errors of the day" is provided by NEPS forecast at every data assimilation cycle **Data Assimilation Cycles:** 4 analyses per day at 00, 06, 12 and 18 UTC. Observations within +/- 3 hrs from the cycle time is assimilated in the respective DA cycle **Observations:** Observation Processing System does the quality control of observations. Variational bias correction is applied to satellite radiance observations. List of observations assimilated are given in Table-1	**Soil Moisture analysis:** **Method:** Extended Kalman Filter **Analysis time:** 00, 06, 12 and 18 UTC **Observations assimilated:** ASCAT soil wetness observations, Screen Temperature and Humidity (pseudo observations from 3D-Var screen analysis) **SST:** Updated at 12 UTC DA cycle with OSTIA based SST and sea-ice analysis **Snow Analysis:** Satellitederived snow analysis. Updated at 12 UTC DA cycle