Assessing Intraseasonal Rainfall Variability Over India Using a Multi-Physics Multi-Model Ensemble

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Questions asked:

- How is intraseasonal variability (ISV) simulated in CFS and GFS extended-range forecasts using various physics combinations?
- What are the major governing mechanisms for the northward propagation of ISV, and how well do the models capture them?
- How can we address the uncertainties in the models when capturing ISV?
- Can a multi-model, multi-physics ensemble approach provide better insights for extended-range prediction?

Intraseasonal Variability:

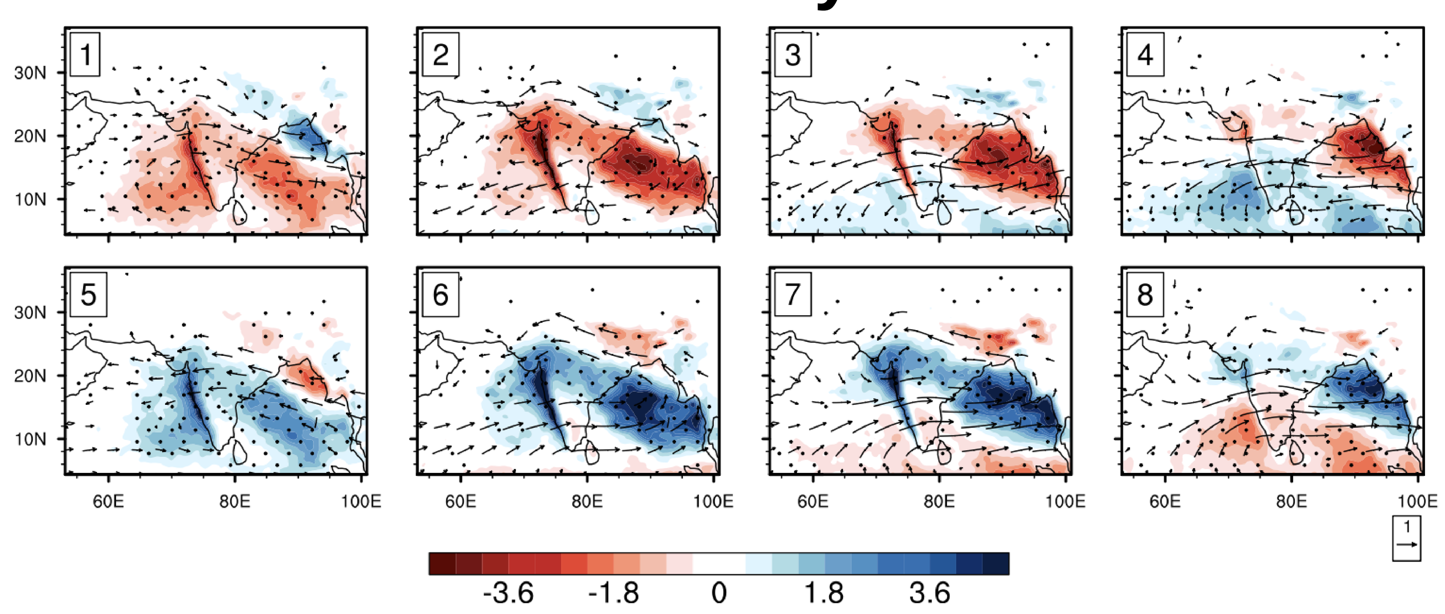


Fig 1. ISV from TRMM rainfall data and 850-hPa winds (ERA-Interim) shown in a phase composite diagram

- Multichannel Singular Spectrum Analysis (MSSA) is used to extract ISV from data

Model simulations:

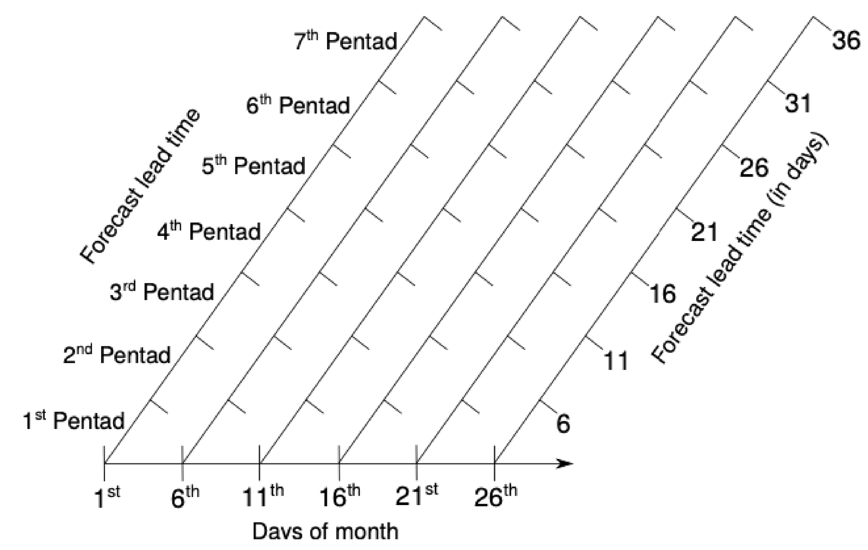


Fig 2. Schematic of the model simulations

- 6 physics combinations: (SAS, NSAS, NSAS_SC) + (ZC, FER).
- 15 years (2001—2015) of simulations
- Simulations are done in a seamless mode, with two horizontal resolutions, T574 (~23 km) and T382 (~38 km). Integrations are done for a total of 36 days with the first 15 days with T574 resolution and the rest of the time-period with T382

Results:

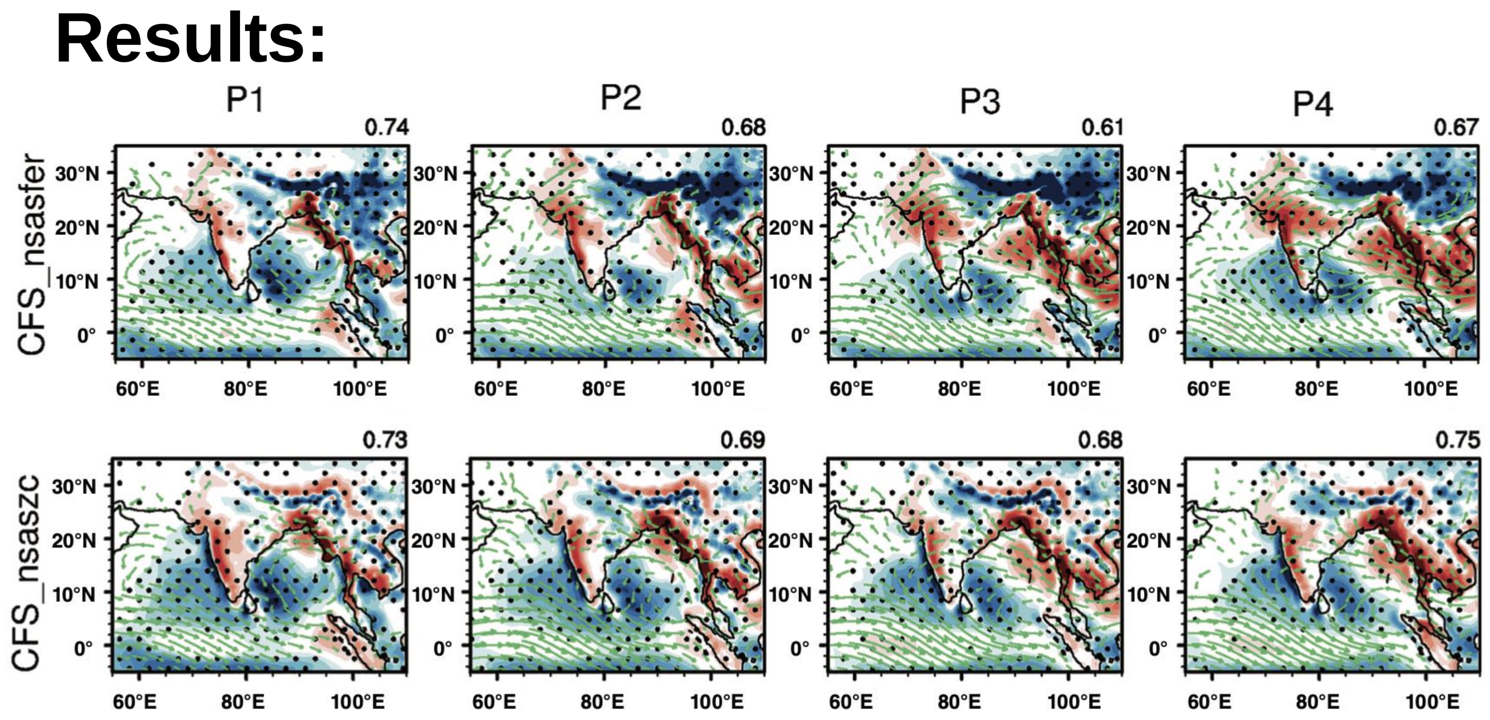


Fig 3. Differences in the JJAS mean rainfall and 850-hPa winds (*model – obs*) for different pentad leads

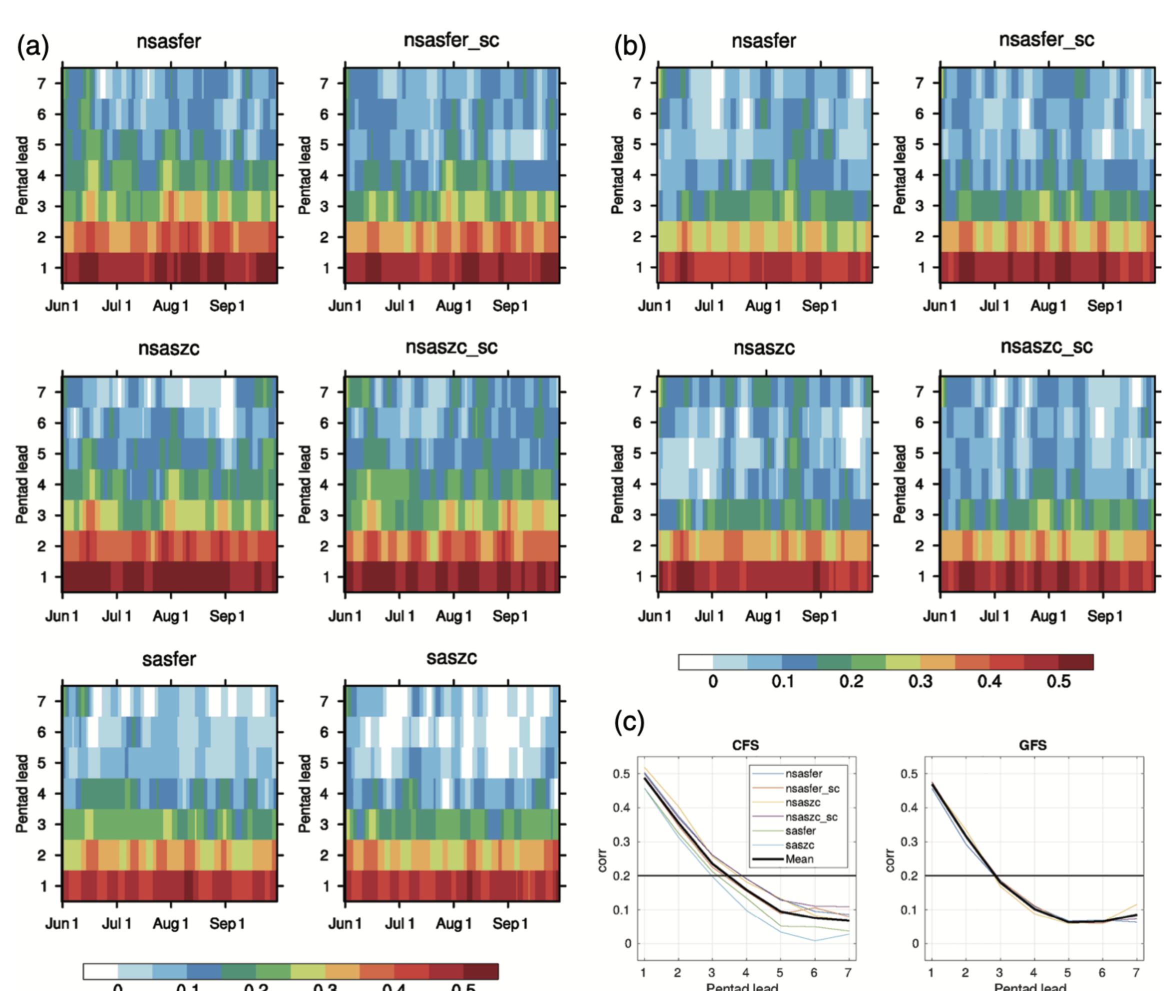


Fig 4. Pattern correlations over the entire domain between the observed and model rainfall ISV during JJAS for 15 years

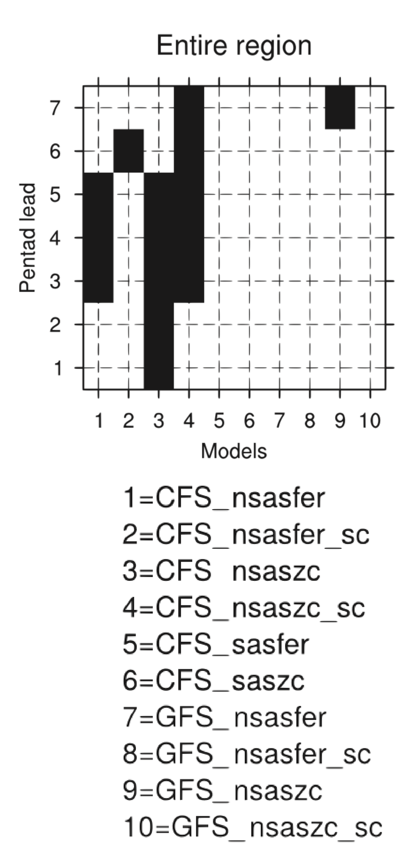


Fig 5. Best physics combination in capturing observed ISV

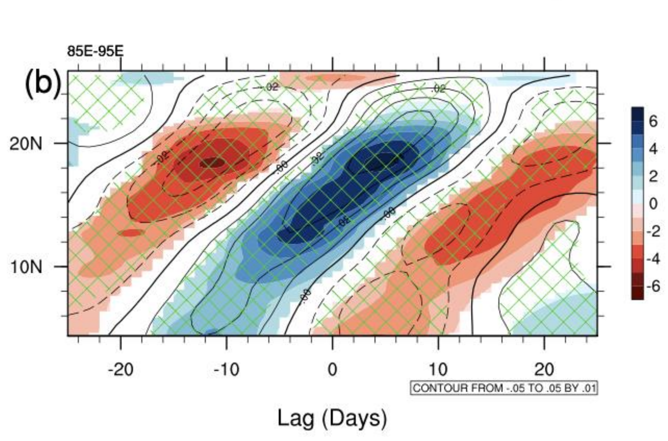


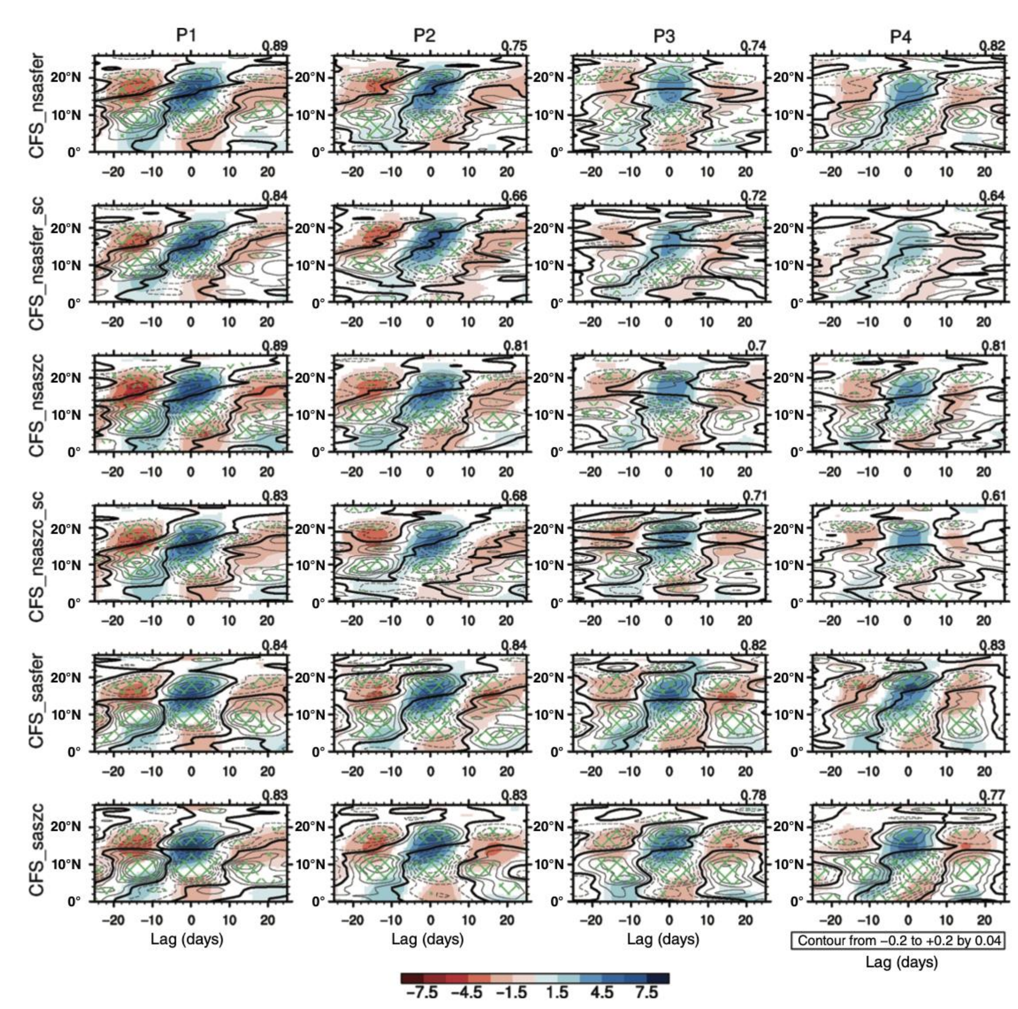
Fig 6. Lag-latitude diagram for rainfall (colors) and vorticity (contours) over BoB during strong ISV

- Generation of barotropic vorticity to the north of an existing convection in the presence of mean vertical shear is essential for northward propagation
- Meridional gradient of intraseasonal vertical winds $\left(\frac{\partial\omega'}{\partial y}\right)$ and vertical shear of mean zonal winds $\left(\frac{\partial\bar{u}}{\partial p}\right)$ are important

Vorticity tendency equation (linearized):

$$\frac{1}{g}\int_{p_1}^{p_2}\frac{\partial\zeta'}{\partial t}dp = \frac{1}{g}\int_{p_1}^{p_2}\left\{\underbrace{\left(-\bar u\frac{\partial\zeta'}{\partial x}-\bar v\frac{\partial\zeta'}{\partial y}-\bar\omega\frac{\partial\zeta'}{\partial p}-u'\frac{\partial\bar\zeta}{\partial x}-v'\frac{\partial\bar\zeta}{\partial y}-\omega'\frac{\partial\bar\zeta}{\partial p}\right)}_{\text{Advection}} + \underbrace{\left[-(f+\bar\zeta)\left(\frac{\partial u'}{\partial x}+\frac{\partial v'}{\partial y}\right)-\zeta'\left(\frac{\partial\bar u}{\partial x}+\frac{\partial\bar v}{\partial y}\right)\right]}_{\text{Stretching}} + \underbrace{\left[\left(\frac{\partial\omega'}{\partial y}\frac{\partial\bar u}{\partial p}+\frac{\partial\bar\omega}{\partial y}\frac{\partial u'}{\partial p}\right)-\left(\frac{\partial\omega'}{\partial x}\frac{\partial\bar v}{\partial p}+\frac{\partial\bar\omega}{\partial x}\frac{\partial v'}{\partial p}\right)\right]}_{\text{Tilting}} + \underbrace{(-\beta v')}_{\text{Beta term}}\right\}dp$$

- Changes in intraseasonal vorticity depend upon the modulation of background winds on intraseasonally varying flow



- Tilting leads to rainfall maxima by about a week
- The first component of tilting, $\left(\frac{\partial\omega'}{\partial y}\right)\left(\frac{\partial\bar{u}}{\partial p}\right)$, mostly modulates the behavior of it
- CFS outperforms GFS

Fig 7. Lag-latitude diagram for rainfall (colors) and tilting term for CFS

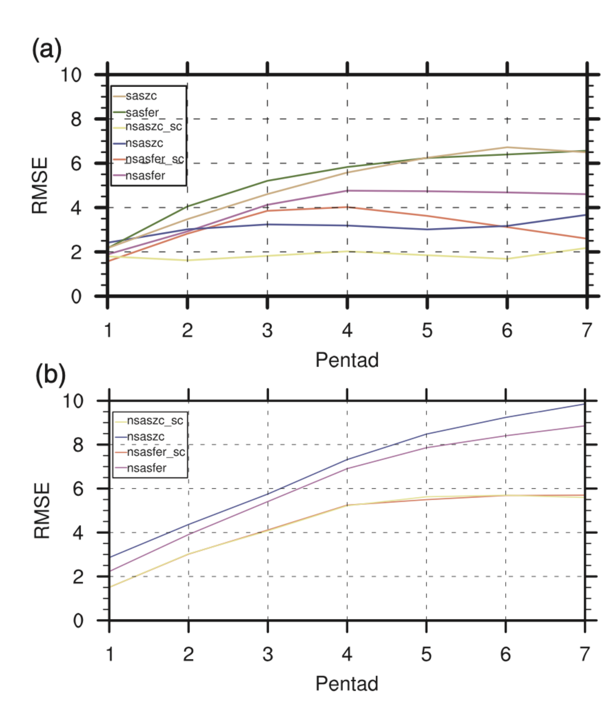


Fig 8. Spatial RMSE of the vertical shear of mean zonal winds

- Different pentad leads shows substantial error growth in vertical shear in the two CFS_sas members compared with CFS_nsas members

Abstract:

Reference in QJRMS:

Take-home messages:

- Statistically significant forecasts extend up to pentad 3 lead time with CFS and up to pentad 2 lead time with GFS.
- The tilting of vortex tubes is important.
- CFS_sas and GFS physics exhibit relatively high errors in the vertical shear of mean zonal winds beyond pentad 3 lead.
- *Erroneous representation of updrafts associated with convective events in the model physics at higher lead times may lead to a misrepresentation of the tilting term, resulting in weaker northward propagation in these physics.*