The origin and evolution of the Monsoon onset vortex and its subseasonal impacts: Integrating Theory and predictability studies using the UFS

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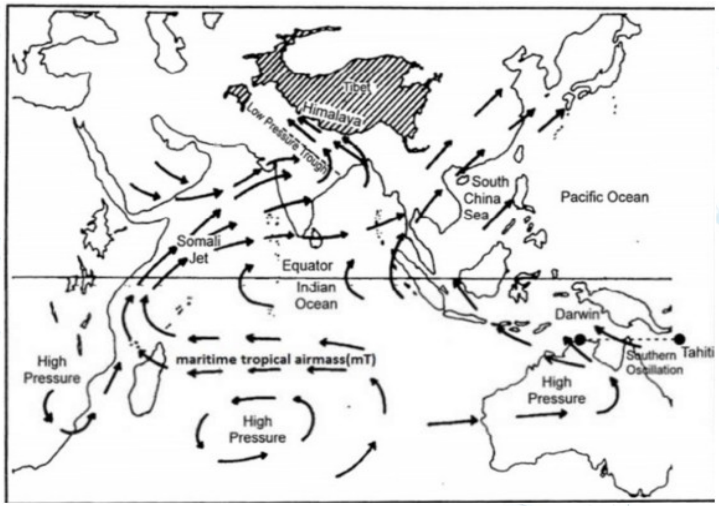
An overview of the Indian Summer Monsoon

- Extends from June to September
- Mascarene High
- Somali Jet (low level jet at 850 hPa)



- Tropical easterly jet (TEJ)
- Tibetan High

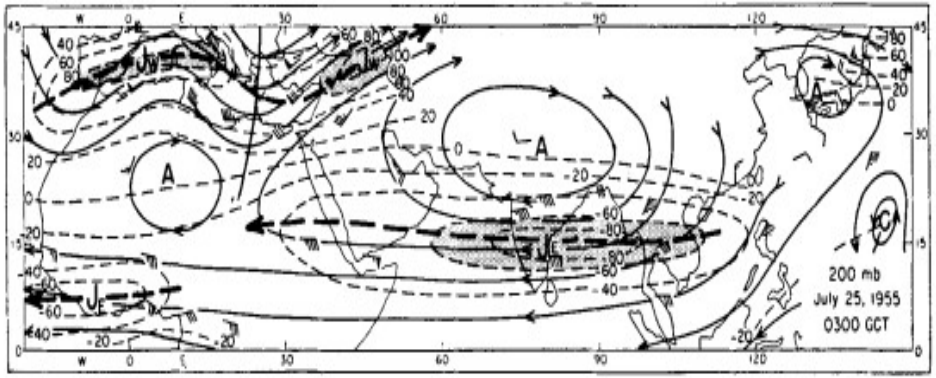


Fig. 4 c. Streamlines and isotachs 200 mbs, July 25, 1955. Jet axis marked heavy and wind maxima shaded.

Image from Koteswaram, P. (1958)

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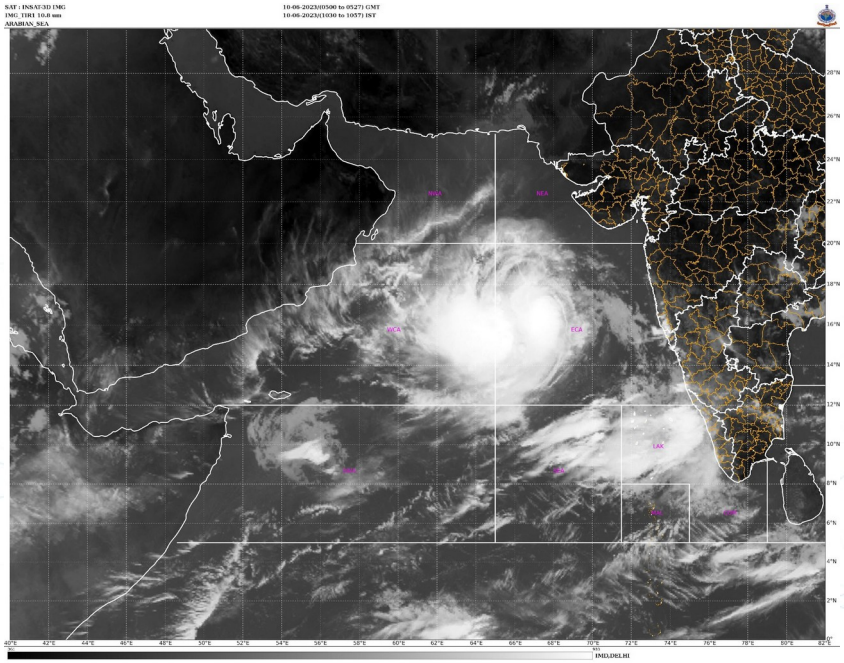
Background

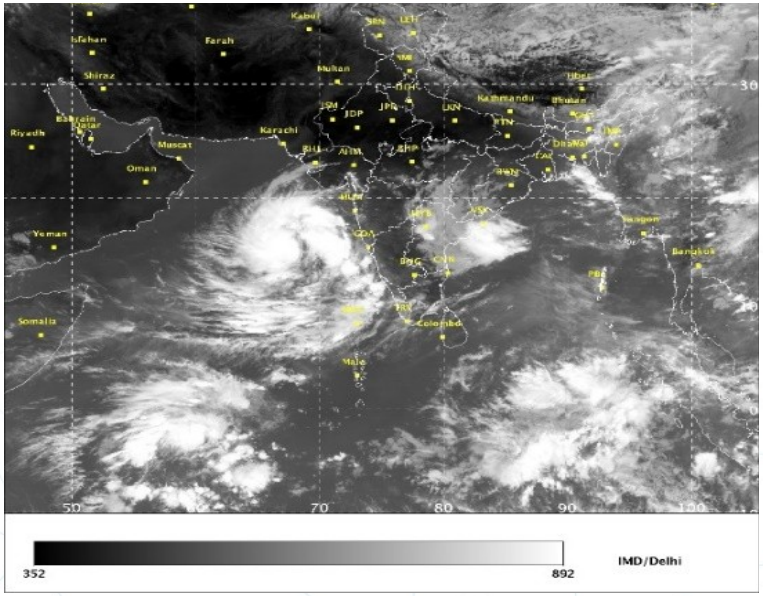
- The Monsoon is characterized by high vertical wind shear: low-level westerlies and upper-level easterlies
- Tropical cyclogenesis is rare during the core monsoon period of July-August
- However, during the Monsoon onset phase (late May-early June), a vortex forms in the Arabian Sea in ~60% of the years
- This vortex is termed as the Monsoon Onset Vortex (MOV)
- Recent example: Cyclone Biparjoy in the Arabian Sea, June 2023

Cyclone Biparjoy - Infrared image from INSAT 3D during June 10, 2023



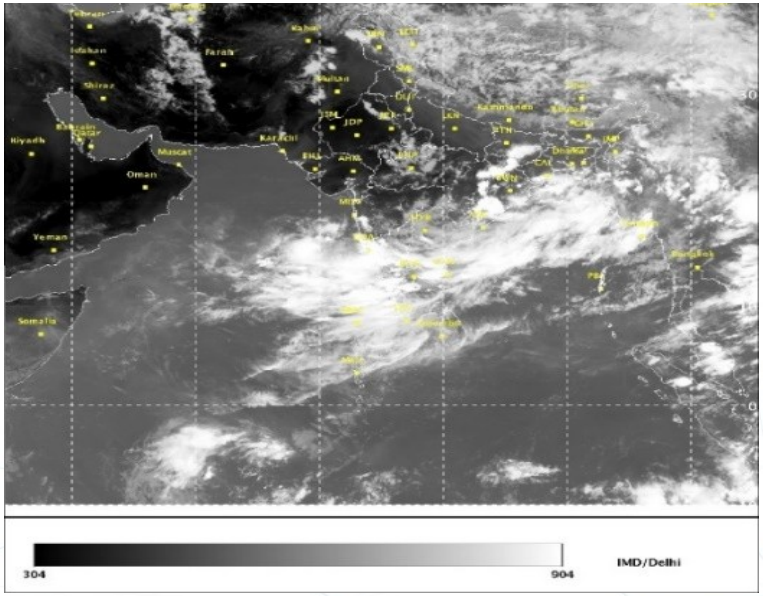
(Image credits: India Meteorological Department)

MOV during monsoon onset



INSAT 3D image dated 7th June 2015

No MOV during monsoon onset



INSAT 3D image dated 8th June 2016

(Image credits: India Meteorological Department)

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Why study the MOV?

1. Affects the advance of the Monsoon

- Helps set in the Monsoon over southern India (e.g., Krishnamurti et al., 1981)
- The MOV track/intensity can possibly delay the monsoon progression over the west coast of India and in the interior peninsula

2. Considerable Socio-Economic impacts

- MOVs often intensify into TCs (~78%), coastal hazards for densely populated coastline
- Past MOVs have caused damages worth $4 billion (Evan and Camargo, 2011)
- Agricultural and hydrological impacts through modulation of subseasonal monsoon rainfall

Previous Literature and Knowledge gaps

- Idealized modeling experiments – single-layer barotropic model to study barotropic instability of Somali Jet (Krishnamurti et al., 1981)
- Dry barotropic-baroclinic instability of basic state – idealized models with 2 or more atmospheric layers (e.g., Mak and Kao, 1982; Krishnakumar et al., 1993)
- Some synoptic studies on the environment of the MOV – Arabian Sea mini-warm pool, Somali jet and east-west shear zone (Rao and Shivakumar, 1999, Deepa et. al., 2007)

- No comprehensive study focusing on the **Physical Mechanisms of MOV formation** and its impact on **subseasonal monsoon rainfall**
- **Predictability** - Need to evaluate the performance of operational models such as the UFS for the MOV

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Preliminary Results

1. Identification of past MOVs

- Combination of reports from the Joint Typhoon Warning Center (JTWC) and India Meteorological Department (IMD) – total 23 MOVs from 1982-2021

2. Role of the Madden-Julian Oscillation (MJO)

- MJO is the leading source of predictability over the Indian Ocean
- MOV's response to the MJO is non-linear convectively active MJO is neither a necessary nor a sufficient condition for MOV formation, but convectively suppressed MJO inhibits MOV more robustly (Dhavale and Aiyyer, 2023 – manuscript under review)

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Preliminary Results

3. Flavors of the MOV

- Presently working on analyzing MOV structure using high-resolution reanalysis datasets and satellite observations
- **Goal:** To develop a synoptic model of the MOV

4. Model Simulations: WRF

- Surface enthalpy fluxes essential for the MOV to sustain and intensify into a tropical cyclone
- MOV simulations in WRF are sensitive to convective parameterization choices.

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WRF Simulations: Importance of surface fluxes

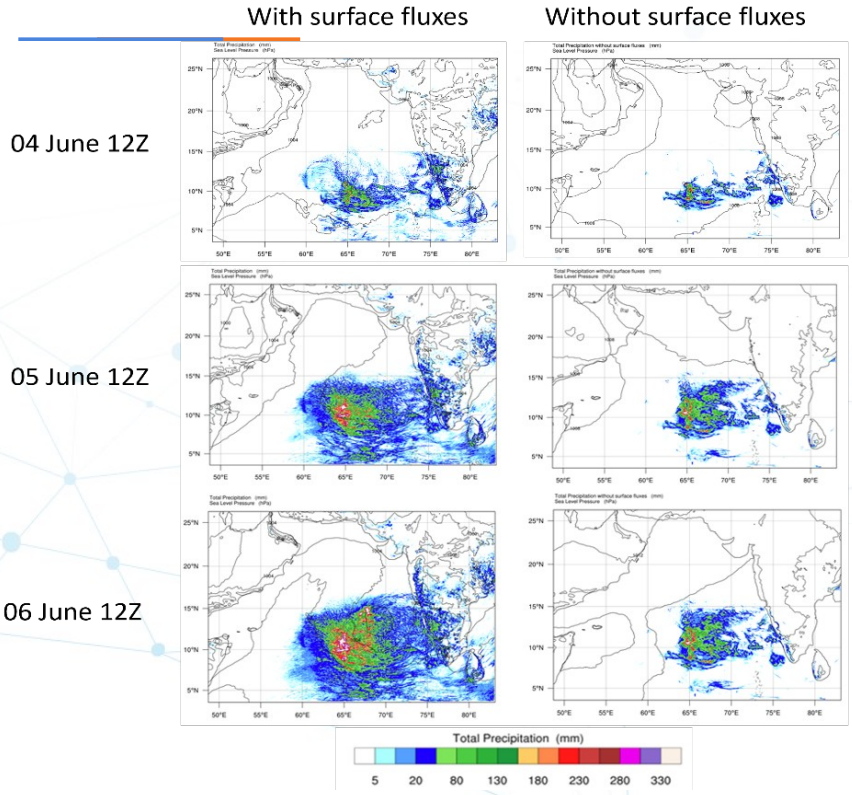

Figure: Sea Level pressure (contours) and total accumulated precipitation (color) as observed in the WRF runs with and without the surface enthalpy fluxes for the 2015 MOV.

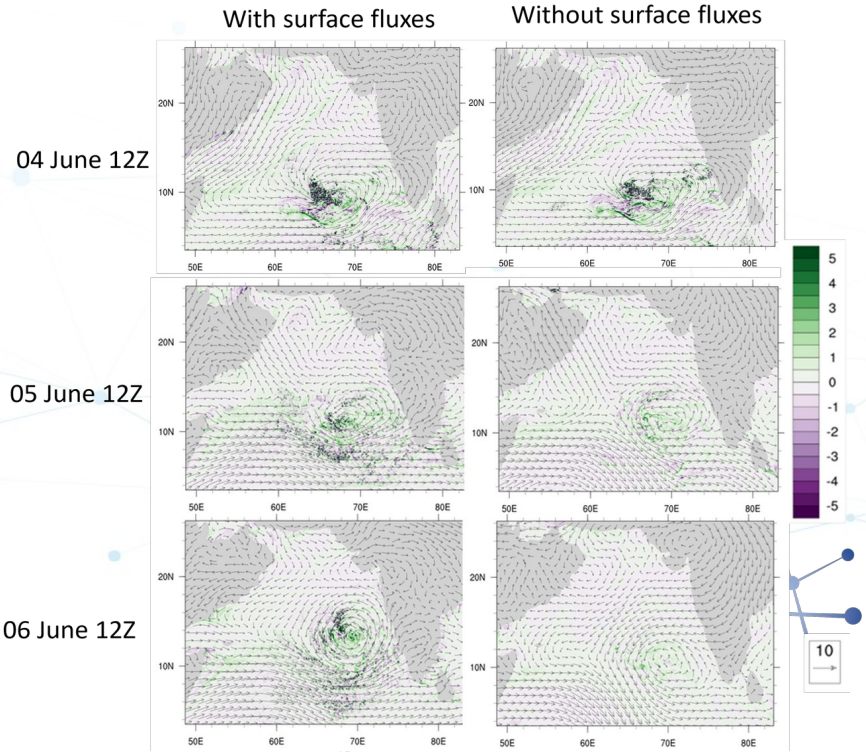

Figure: 850 hPa winds (vectors) and relative vorticity (color).

Proposed Work with the UFS

- Working with Dr. Cristiana Stan and my advisor Dr. Anantha Aiyyer
- **Validating the UFS performance**
  - Study the forecast skill of the UFS prototypes and compare them with reanalysis datasets/observations
  - E.g., Dynamic fields (wind, vorticity) and thermodynamic fields (temperature, SST), cloud properties, and rainfall
  - Identify the model bias
- **Potential Simulations using the UFS SRW/MRW**
  - Check the predictability of the MOV
  - Study mechanisms governing its formation and intensification into a tropical cyclone

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Impacts on Global Science, Meteorology and the Community

- **Help in improving the UFS** – subseasonal predictions of tropical monsoon regions
- A step towards **achieving the objectives of the UFS and NOAA** – to help improve skill and enhance the value of subseasonal weather forecasts
- Most MOVs intensify into tropical cyclones - Understand a **potential pathway to tropical cyclogenesis.**
- Potentially **improve forecast skill for other regions of the world** through teleconnections (tropical convection affects global weather through teleconnections, e.g., Beverly et al., 2021)
- Improved subseasonal weather predictions – a great help to **food and water security in South Asian countries minimizing socio-economic impacts** and benefitting a large section of humanity

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