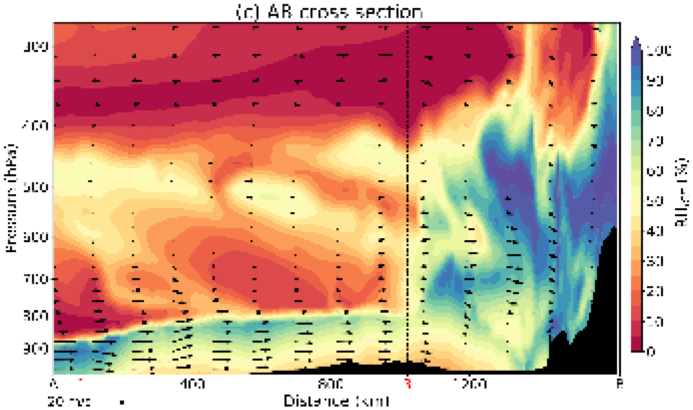
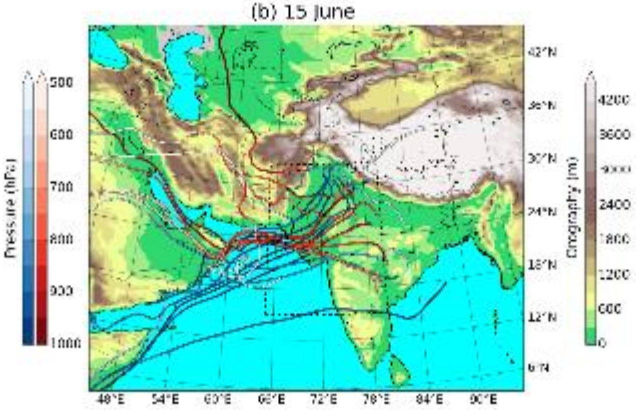
Airmass analysis of the processes driving the progression of the 2016 Indian summer monsoon

Ambrogio Volonté, Andrew G Turner, Arathy Menon





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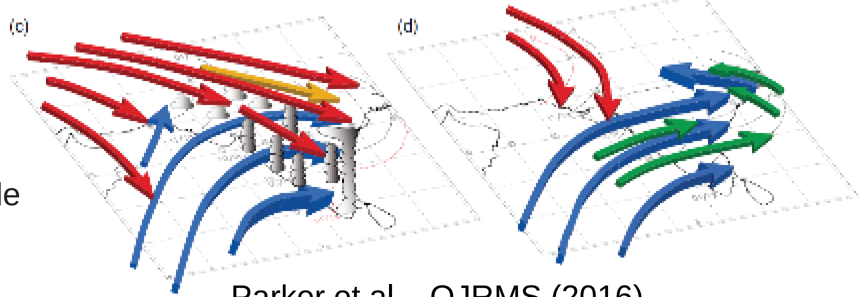
- Monsoon flow is from SW **but** ISM propagation is SE-NW:
- erosion of wedge-shaped dry air layer by moist low-level SW-ly flow underneath

- Link between heavy monsoon rainfall and the passage of mid-latitude troughs, see Martius et al. (2013) and Vellore et al.(2016)

- Link between dry advection over India and:
- blocking over W Asia (Krishnamurty et al., 2010)
- anomalies in the subtropical jet and advected PV (Fletcher et al., 2018)



Parker et al. , QJRMS (2016)

➢ Is ISM progression, along with the erosion of the dry layer, a steady process or does it happen in "bursts", like for the Australian monsoon? (Berry and Reeder, 2016)

➢ How is it linked with the extratropical circulation?

➢ What is the importance of diabatic processes in the removal/moistening from below of the dry layer?

This study (Volonté et al., submitted):

- Regional analysis: 17km UKMO global operational forecast
- Mesoscale analysis: 4.4km convection-permitting UKMO LAM (INCOMPASS seasonal run)

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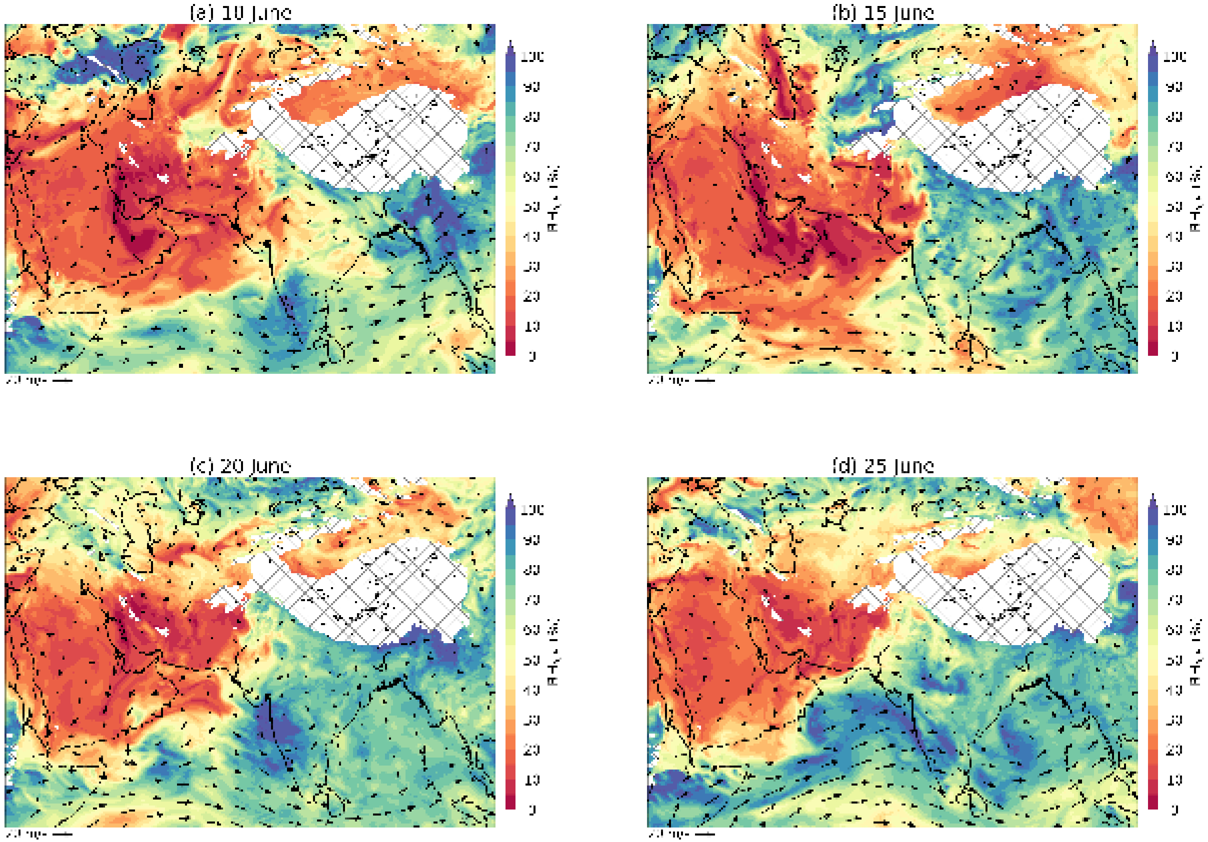
RH at 760 hPa:

- Net reduction in dry-air area between 10 and 25 June: expansion and deepening of moist monsoon flow, particularly over NW India

- Maximum southward expansion of dry air on 15 June

- Cyclonic circulation in the Arabian sea separating dry and moist air on 20 and 25 June



17km UKMO global operational forecast

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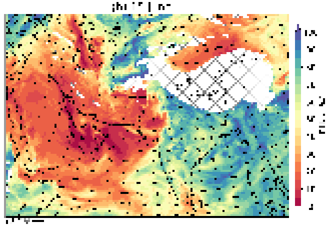
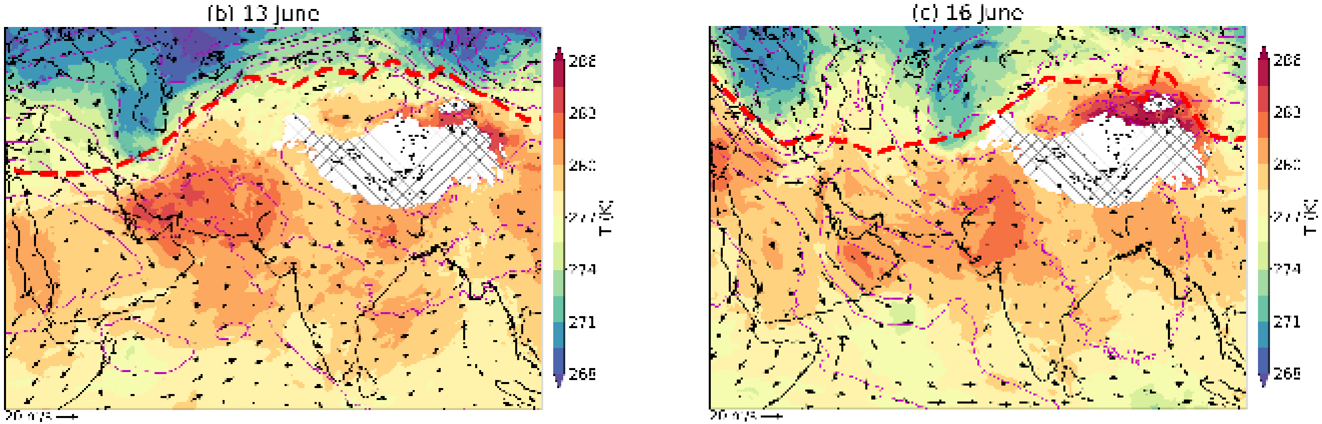
- What causes the southward advection of dry air over the Arabian sea around 15 June?



T & gph at 625 hPa + upper-level jet:

- Passage of mid-latitude trough on 13 June
- Formation of cyclonic circulation over the Arabian Sea on 16 June

- Are these two features linked?



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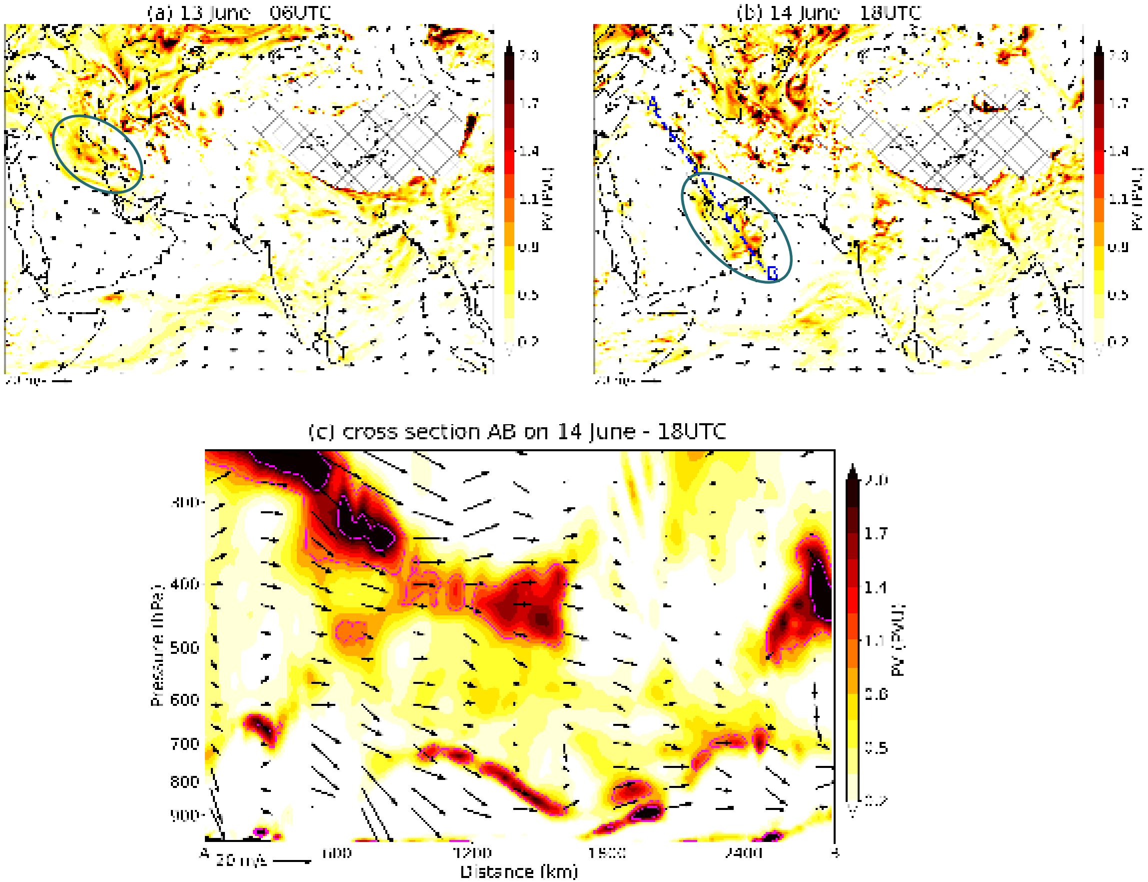
PV at 700 hPa:

- High-PV associated with the trough is advected towards SE, after its passage on 13 June
- The cross section shows the presence of a descending PV streamer
- This streamer helps the formation of a cyclonic system when on top of low-level high-PV air (“PV tower”, see Čampa and Wernli, 2012)



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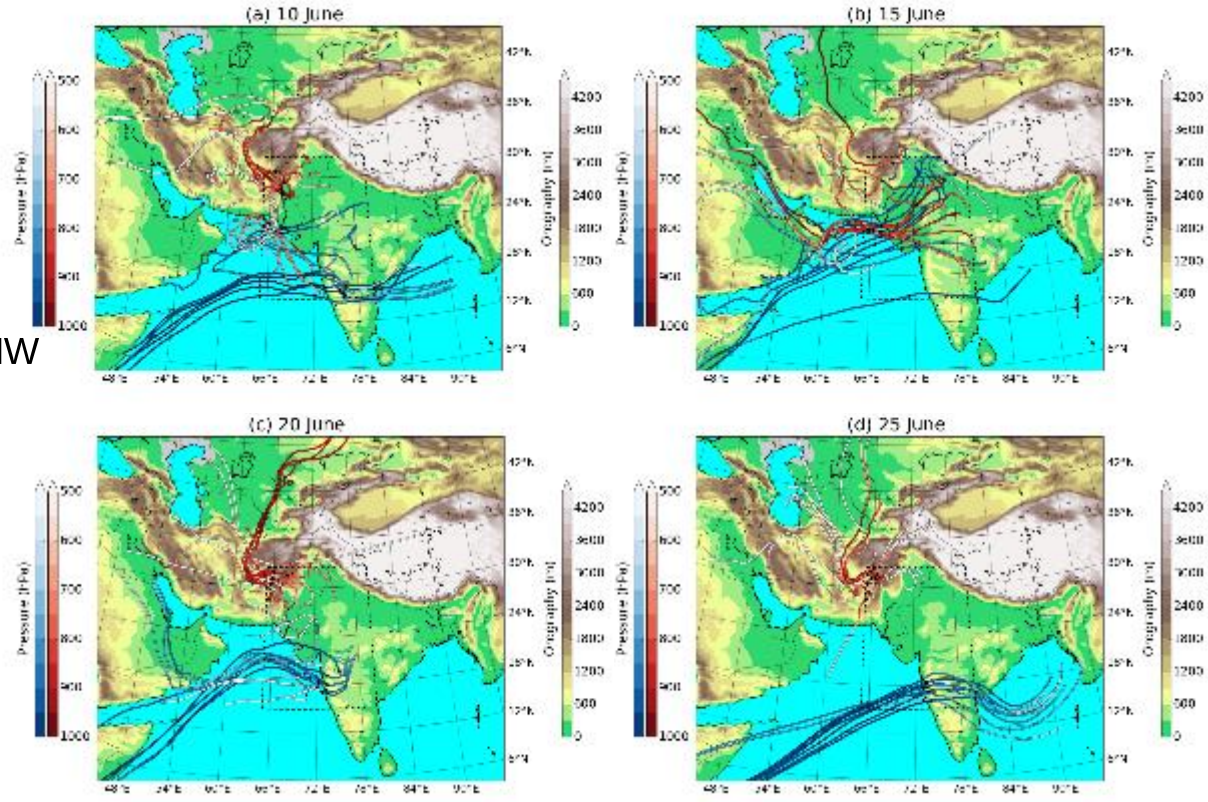
- ➢ Lagrangian trajectories help us understanding origin and path of different air masses

- Core of moist air:
  “classic” Somali Jet path towards India

- Core of dry air:
  partly descending and advected from WNW

- 10-15 June:
  more interaction between dry and moist flows as the dry incursion flows over the Arabian Sea

- 20-25 June:
  Bigger separation between the two air masses, no penetration of the dry air beyond Hindukush range



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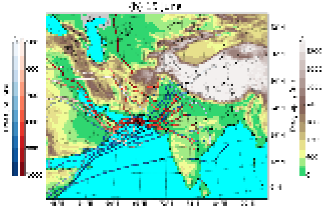
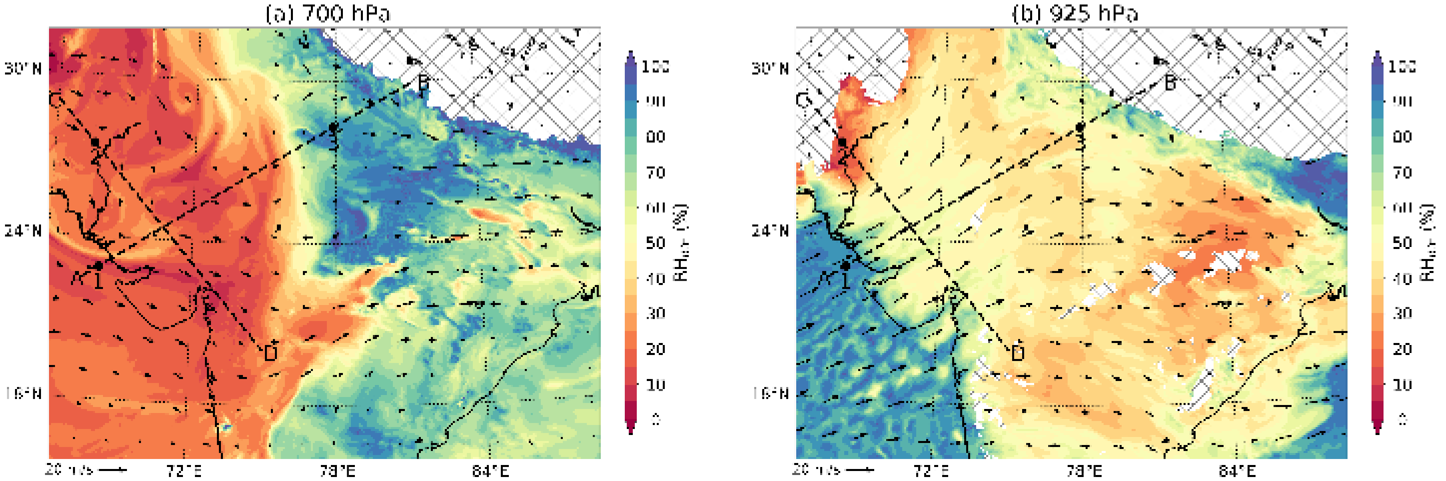
- hi-res LAM simulation: a closer look at the interaction between the two different air masses over the northern stretch of the Arabian Sea (e.g. on 15 June)



- 2-layer structure confirmed with dry NW-ly advection flowing above moist SW-ly monsoon flow



4.4km convection-permitting UKMO LAM (INCOMPASS seasonal run)

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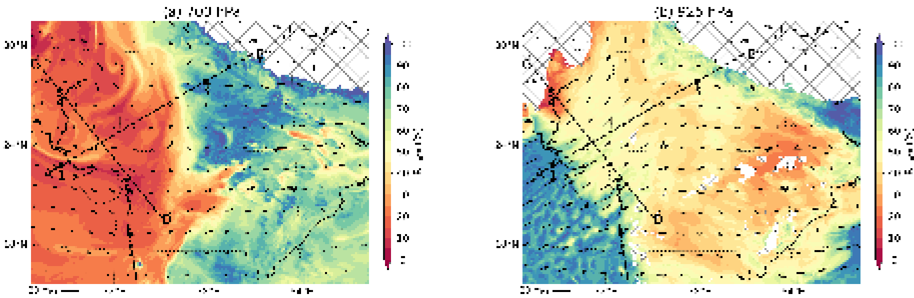
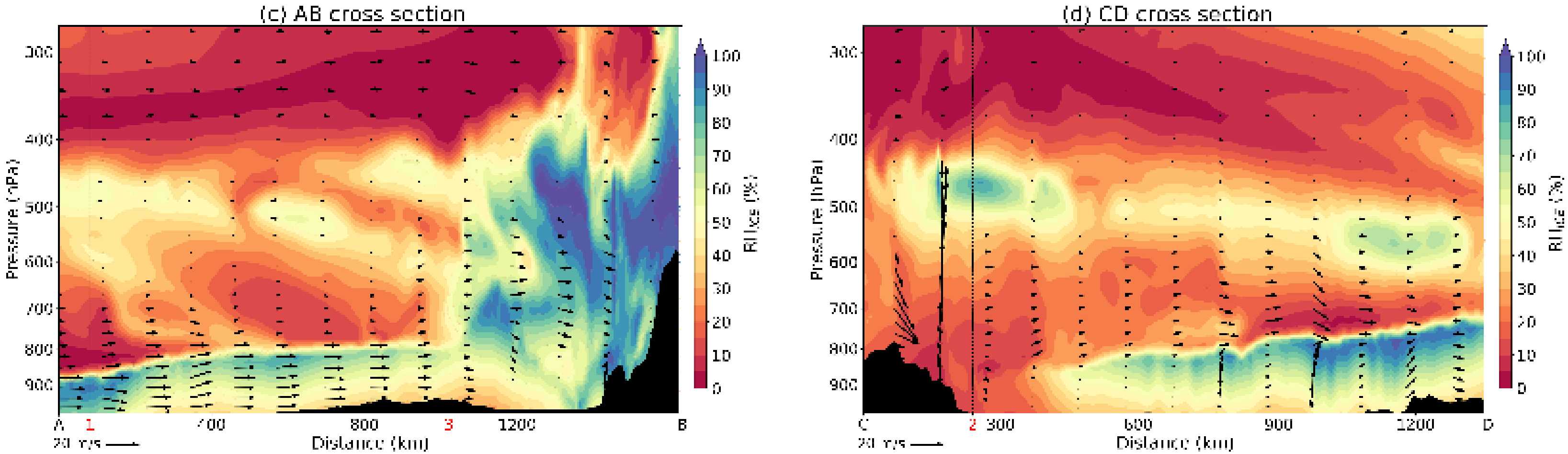
➢ Cross sections show:

- 2 layers: NW-ly dry above, SW-ly moist below
- Sharp boundary between the 2 air masses at 850 hPa
- Occurrence of deep convection prevented by the dry layer





4.4km convection-permitting UKMO LAM (INCOMPASS seasonal run)

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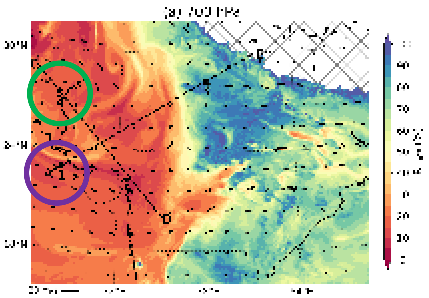
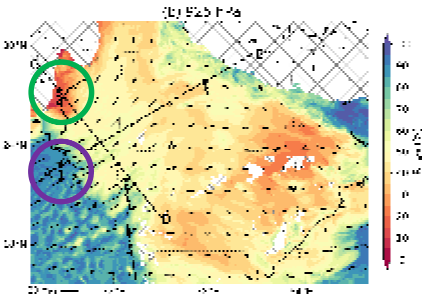
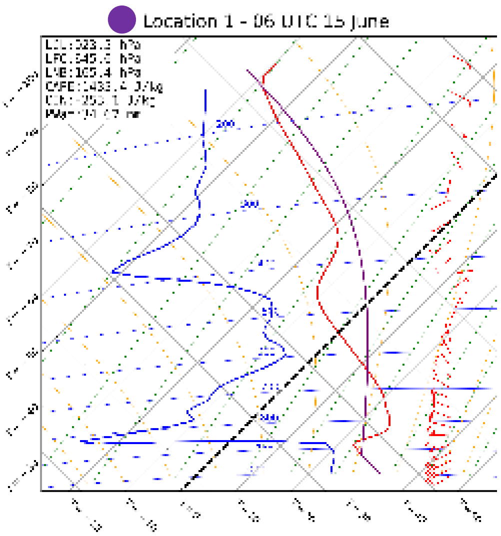
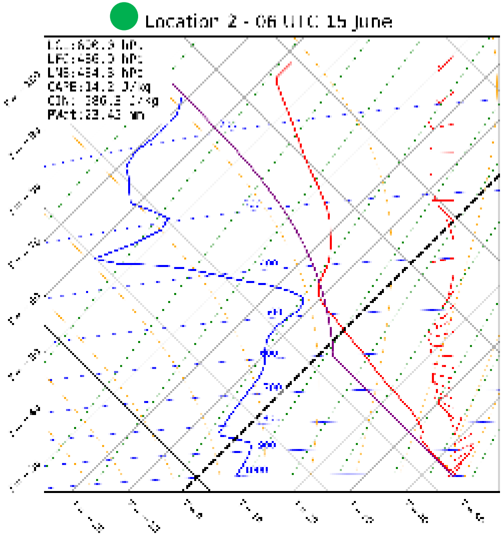
- Thermodynamic profiles show :
  - sharp transition between the two air masses and the role of dry air in suppressing convection (Profile 1)
  - lower troposphere still very dry over the Indus valley (Profile 2)









4.4km convection-permitting UKMO LAM (INCOMPASS seasonal run)

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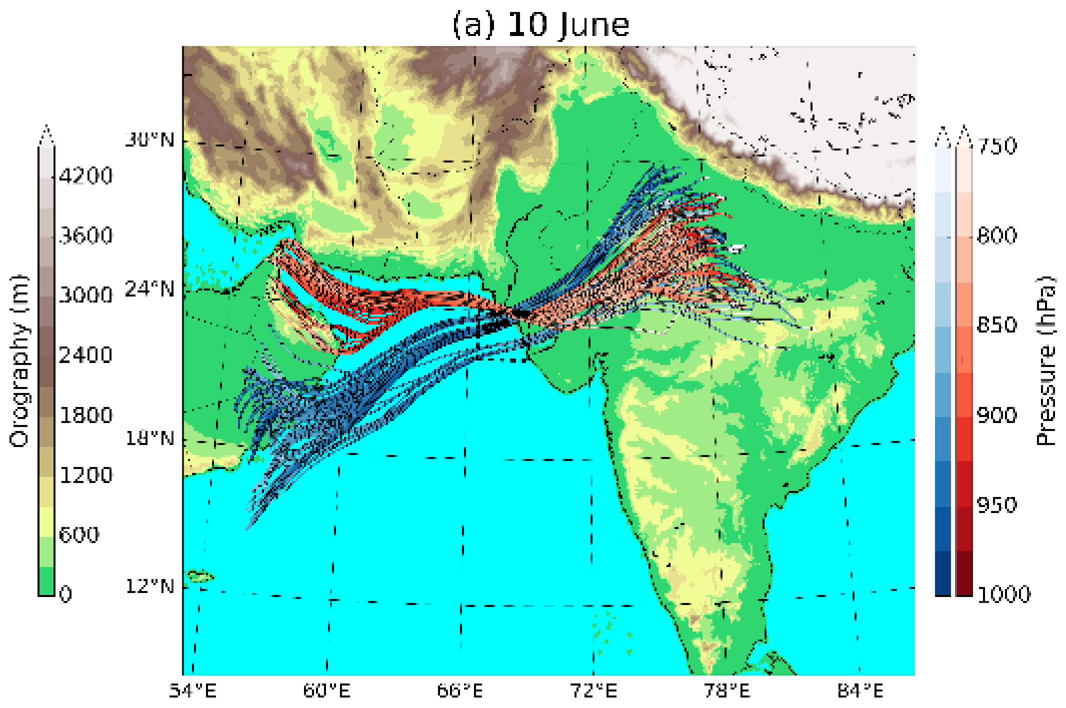
- LAM trajectories (e.g. on 10 June): the cores of the two air masses travel along similar paths over the Arabian Sea and then converge while moving inland



4.4km convection-permitting UKMO LAM (INCOMPASS seasonal run)

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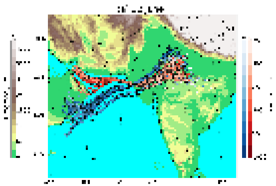
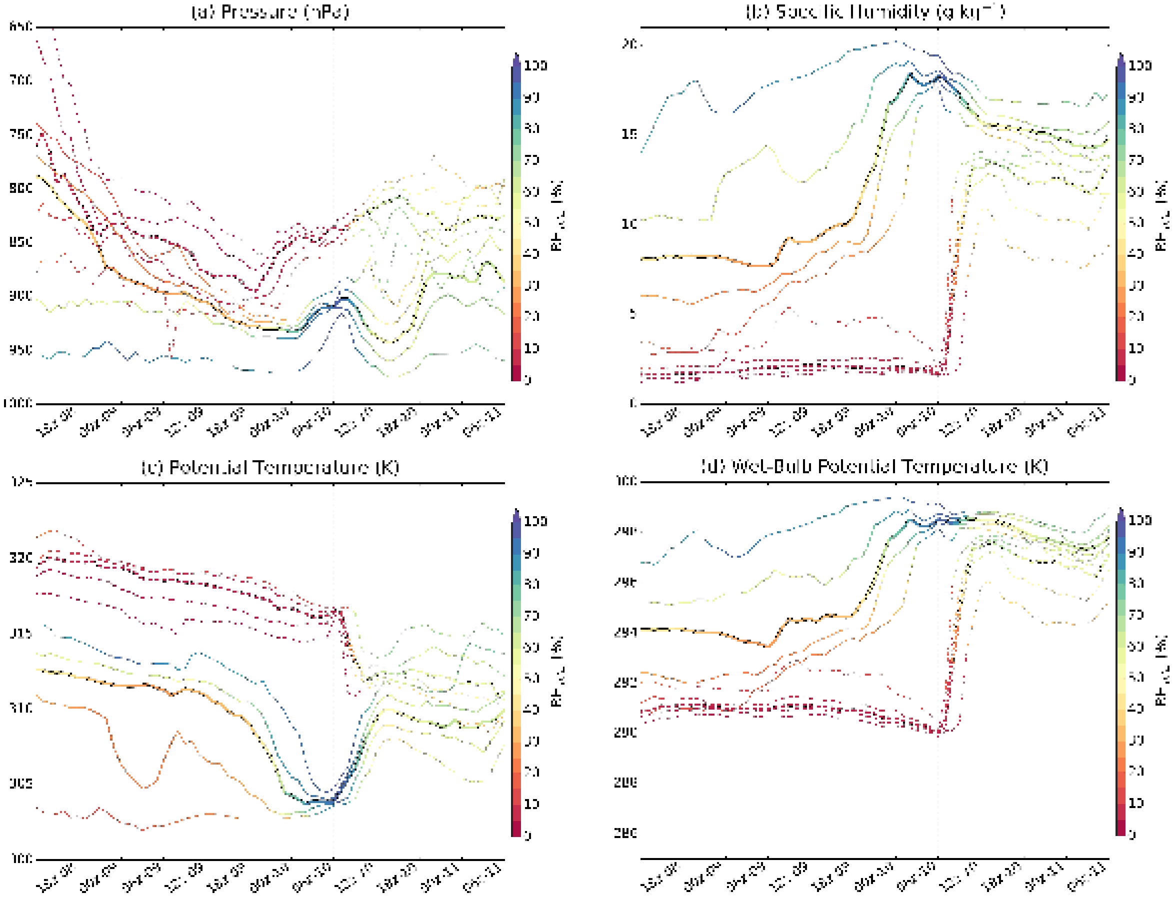


➢ Trajectory profiles reveal that:

- The moist airstream receives a substantial part of its moisture from the Arabian Sea
- Strong mixing occurs over land when the two airstreams interact
- Moist processes, along with mixing, considerably change the thermodynamic properties of these airstreams



4.4km convection-permitting UKMO LAM (INCOMPASS seasonal run)

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Summary:

- Progression of the ISM toward NW India is a non-steady process (2-layer model: “tug-of-war” between SW-ly low-level monsoon flow and NW-ly descending dry-air incursion)
- Balance between these airstreams can be influenced by synoptic-scale dynamics at higher latitudes
- Cores of dry and moist airstreams can interact very closely during the onset and progression of the monsoon,
- Importance of diabatic processes, particularly over the Arabian Sea

Next steps:

- Quantitative diagnostics evaluating equatorial and extratropical influences on dry-air incursion strength and associated monsoon “bursts” (e.g. using reanalysis to compute vorticity fluxes towards the Indian subcontinent, see Narsey et al. (2017) for Australian monsoon)
- Analysis of moisture and heat surface fluxes associated with the evolution of the airstreams to understand which diabatic processes are at play
- Lagrangian analysis of moisture sources to assess the role local and remote evaporation/precipitation in the transport of moisture along the airstreams towards the monsoon core region.

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