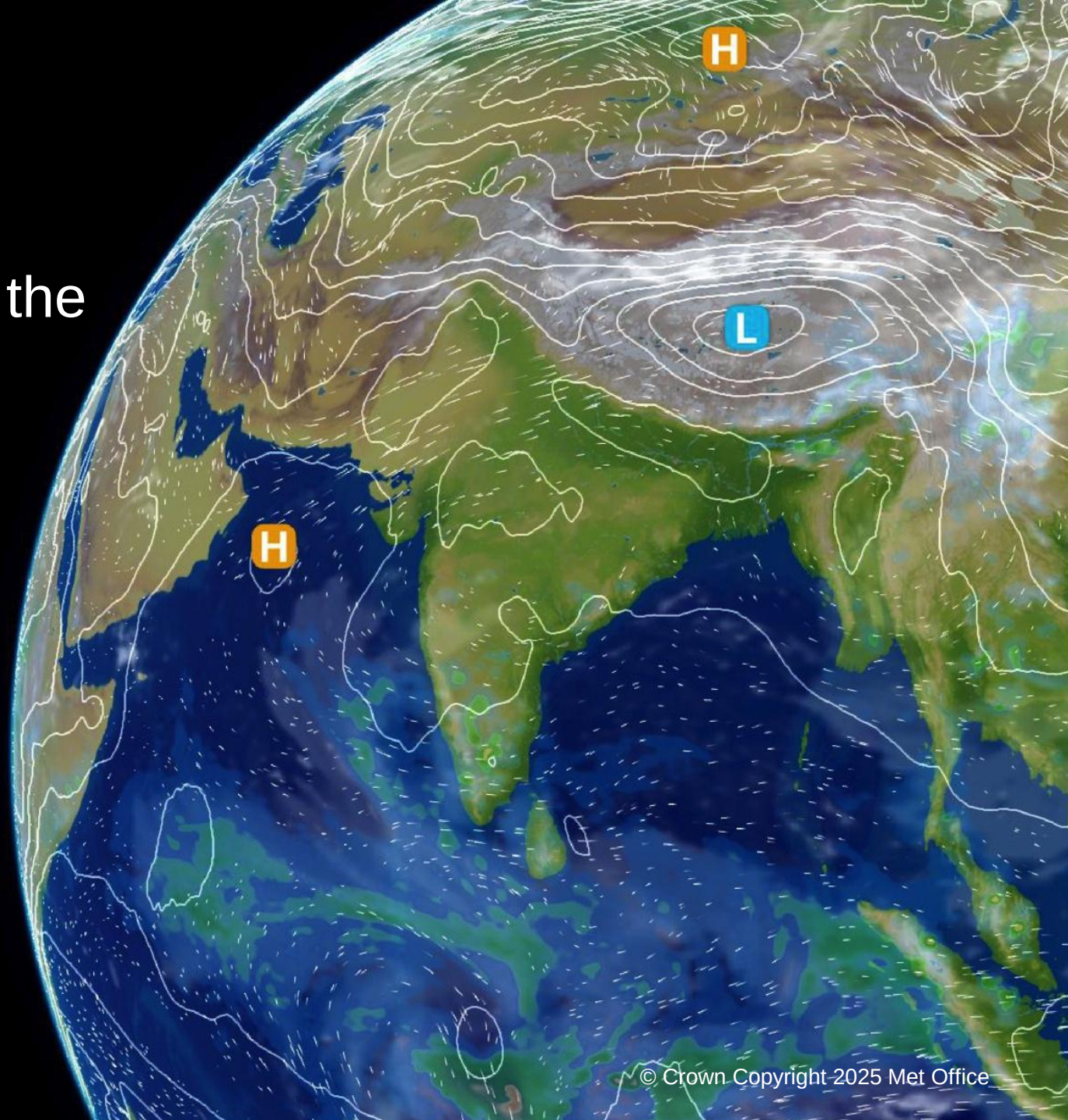
Identification and predictability of the large-scale synoptic drivers contributing to the Kerala floods using multivariate feature-based analysis

Marion Mittermaier



Kerala floods

Occurred in Kerala for an unprecedented three successive years.

One of the key purposes of this work was to establish whether we can identify if there are any common features between these flooding events.

2018:

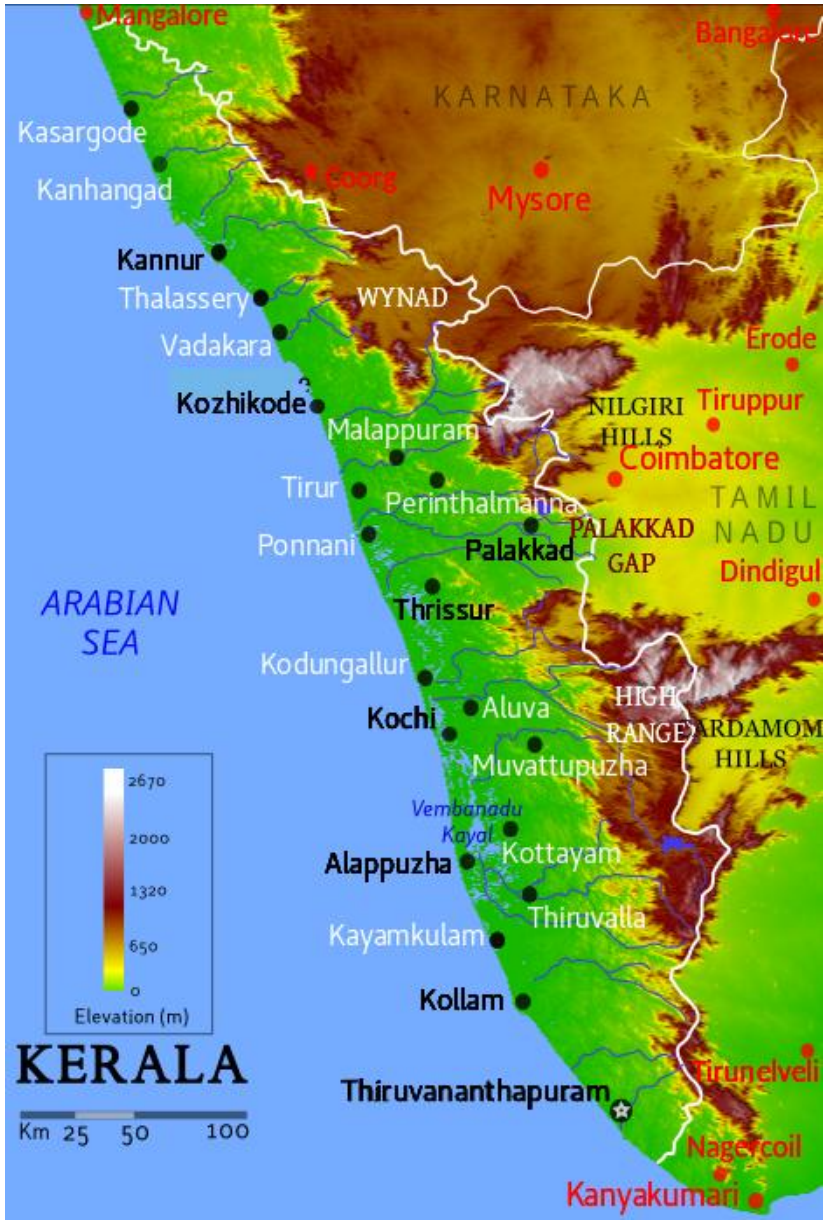
Heavy rains 8-10 Aug, 12-18 Aug with 140 mm on Aug 15

2019:

Heavy rains 6-11 Aug with 150 mm in one day

2020:

Heavy rains 7-8 Aug

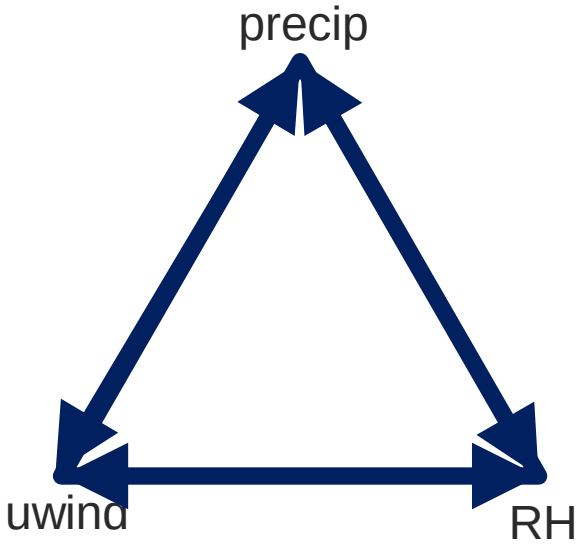


These were compound events.

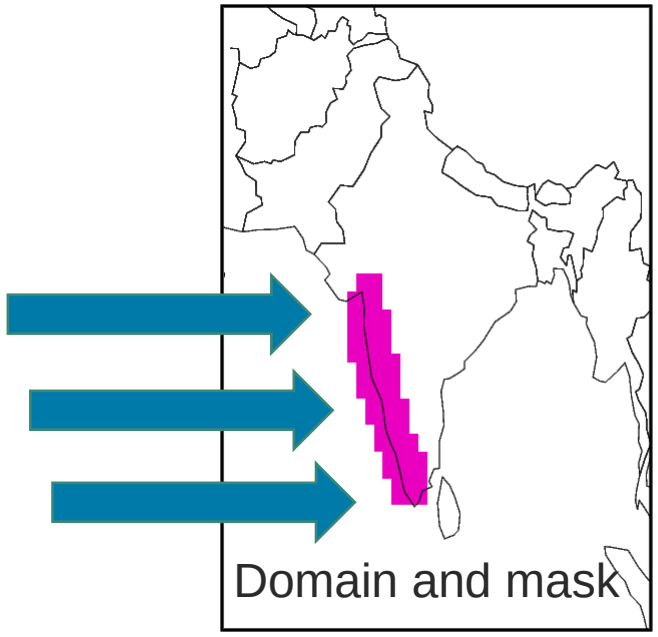
It's about forecasting sequences.

Background

- During the monsoon the Western Ghats can be subjected to a strong westerly flow with relatively high humidity (**like an atmospheric river**).
- The **relationships between RH, UWIND and daily precip are examined** in the analyses and the daily GM forecasts.
- T+0h model fields are used except fowhich are daily GPM accumulations



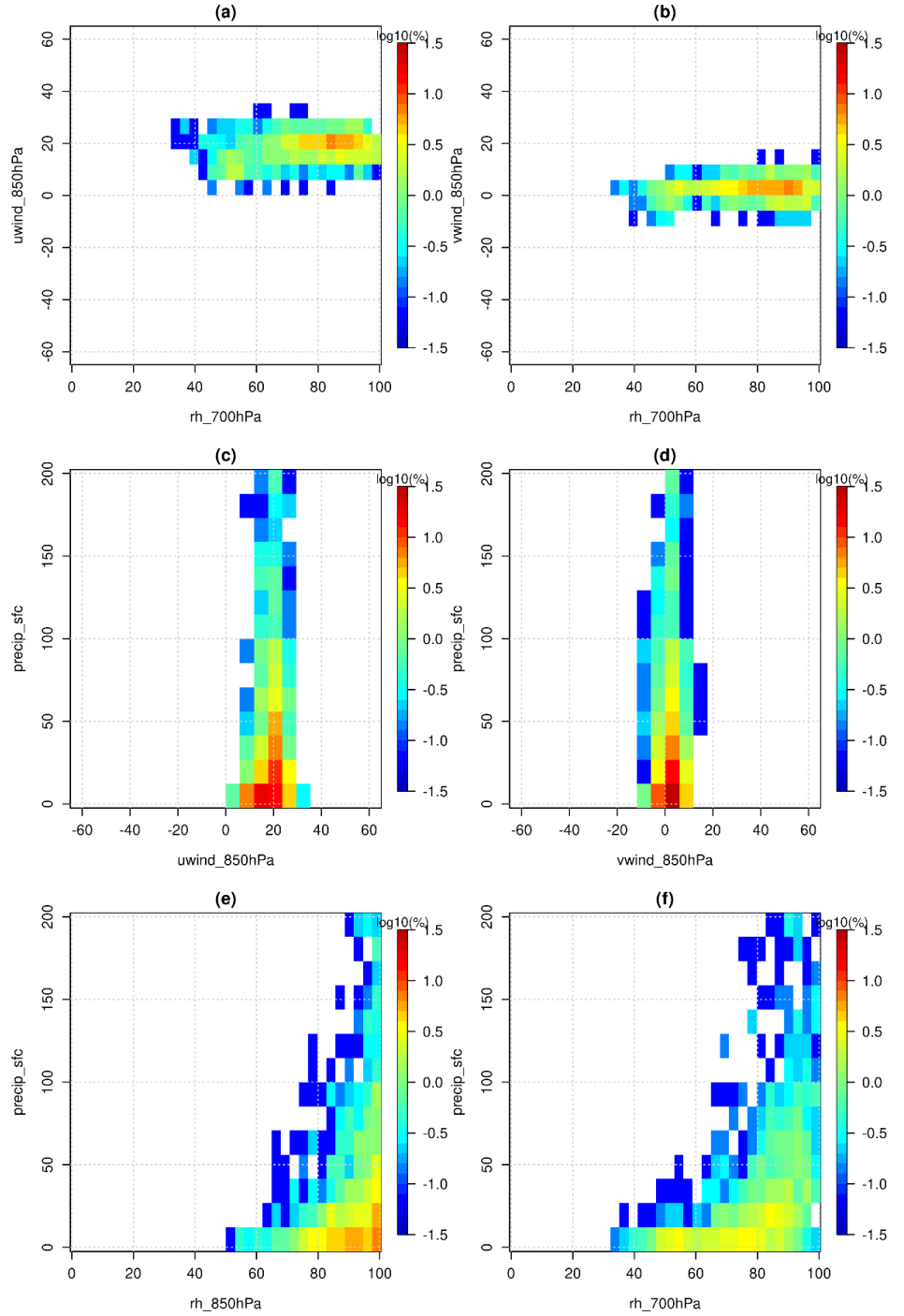
The Western Ghats are between 900 and 2600 m in height with an average of around 1600 m… therefore westerly winds at 850 hPa and even at 700 hPa are forced to decelerate and rise over the terrain. The forced uplift combined with the strength of the moist low-level jet acts to locally enhance precipitation.



Q: *Can a multivariate feature-based approach identify the potential location of heavy rainfall associated with a specific juxtaposition of wind & humidity, providing enhanced predictability of events such as the Kerala floods, with a particular focus on the medium-range? Here the focus will be on day 5.*

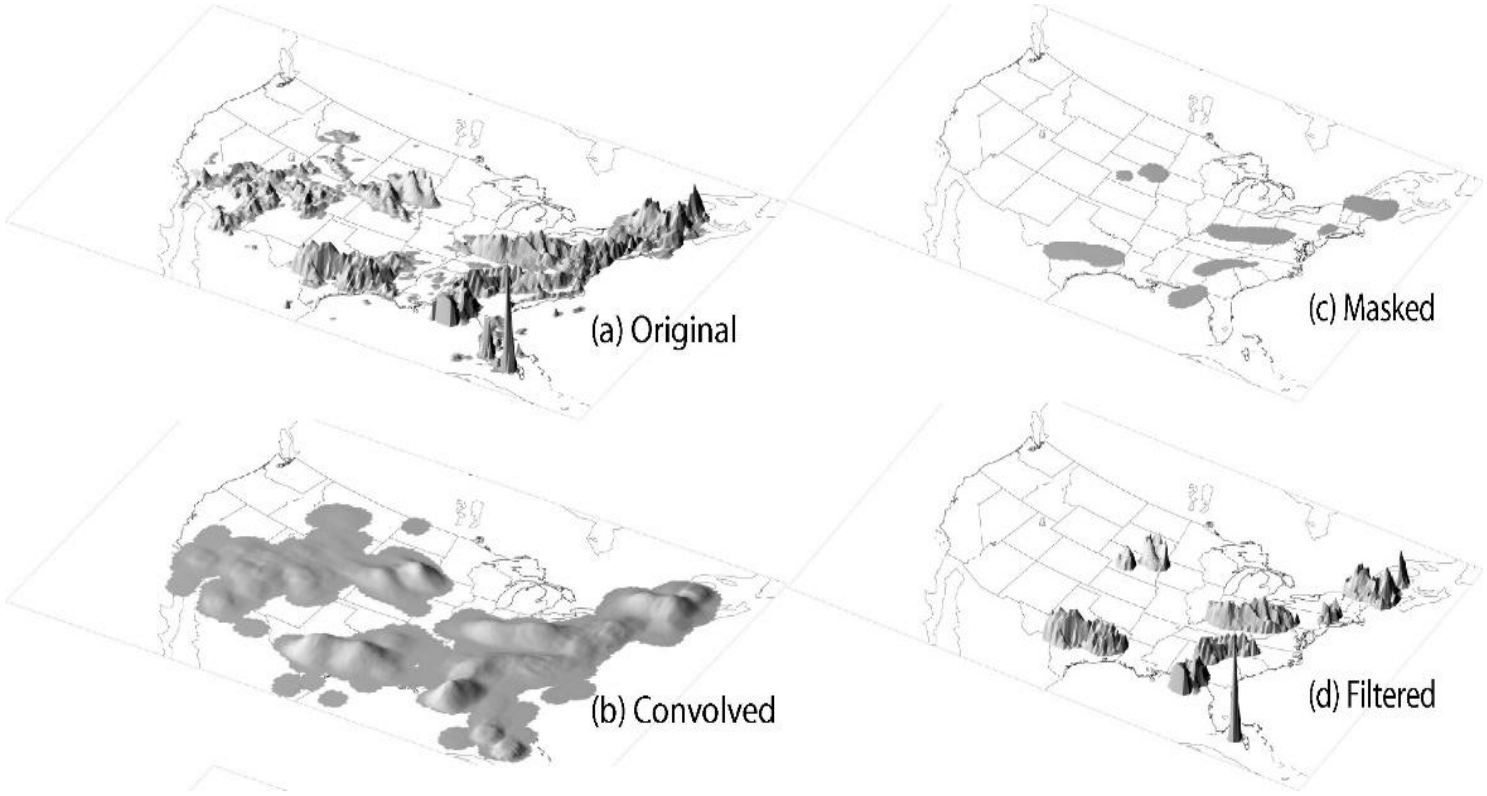
Sensitivity analysis and thresholds

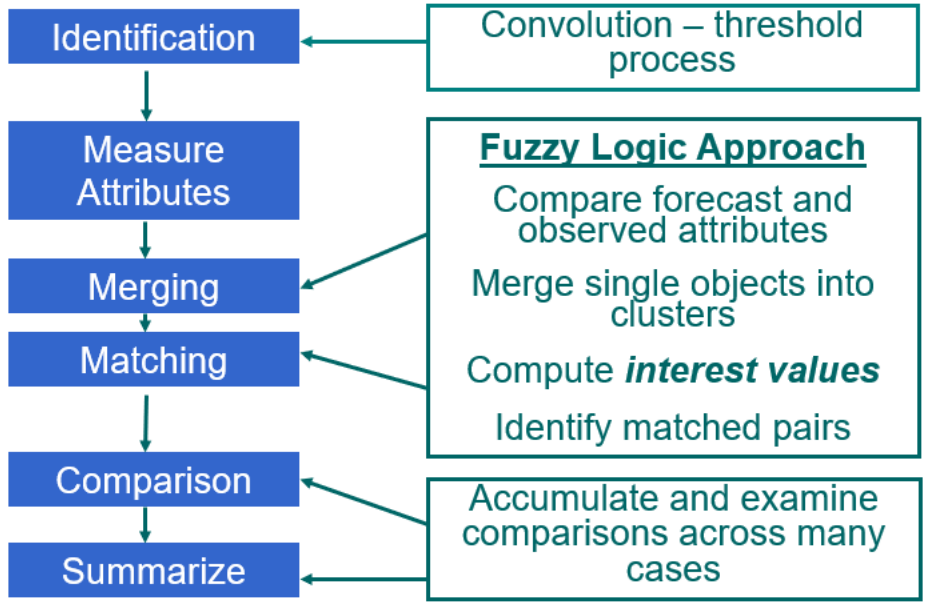
- Analysis using the `GridDiag` tool (METplus) of the 1-11 August 2019 window (and the mask on the previous slide) provided confirmation that the variables and levels which appear important for the region of interest.
- **UWIND@850** is stronger than at @500 with suggestions of a low-level jet with speeds in excess ~20 m/s often predominantly associated with RH@850 between 80—100%.
- VWIND@850 is generally close to 0 with a slight northerly component.
- **Largest rainfall accumulations are associated with UWIND@850 of ~20 m/s** with little meridional contribution (i.e. perpendicular to the coast) suggesting some orographic enhancement is more than likely.
- **Largest accumulations are exclusively associated with >90% RH at 850hPa, with similar results for RH@700**. Because depth of moisture appears important **RH@700** preferred.



MODE

Method for Object-based Diagnostic Evaluation (Davis et al 2006)





Recent MET versions allow for quantile mapping (bias removal)

MvMODE

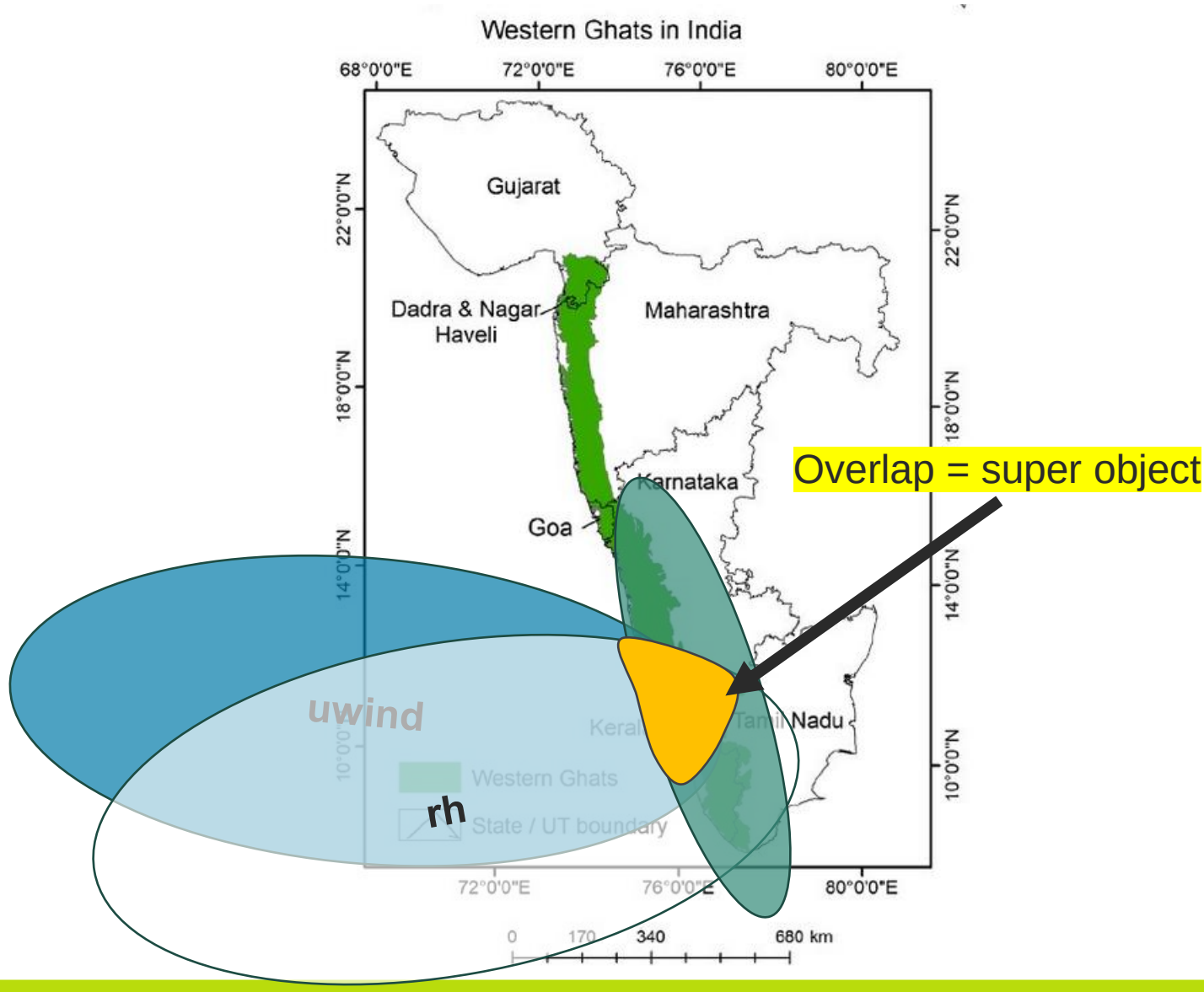
- **MvMODE** is a multivariate extension of the Method for Object-based Diagnostic Evaluation (MODE) (Davis et al 2006) available via METplus.
- It provides the **logic capability to find the intersection between the objects identified in a number of different variables, referred to as super objects.**
- ***Any* variable can be used to populate the super object** to analyse further.
- Using the **GridDiag** results as a starting point, and further experimentation with the logic, the precipitation response (aka super object) to an “atmospheric river”-like feature is identified using **UWIND@850**, **RH@700** and **DAILY_PRECIP** (e.g. Ralph et al 2004)
- **Thresholds must be kept lower** to increase the chances of finding overlaps between the univariate variable objects.
- A **convolution radius of 5 grid lengths** was used with these thresholds:
  - **UWIND@850** objects > 15 m/s in the forecast and the analysis
  - **RH@700** objects > 75% in the forecast and the analysis
  - **24h precipitation** > 25 mm in the forecast and GPM IMERG

What are we looking for?

- **MvMODE** identifies the “super” objects as defined by the logic.
- The process is repeated in the forecast and analysis/observed fields.
- It then allows the “super” objects in the forecast and observed fields to be matched and analysed.

Questions to ask could be:

- Are the events captured in the analysis?
- Does the super object contain the precipitation peak?
- Does the forecast have a similar event?

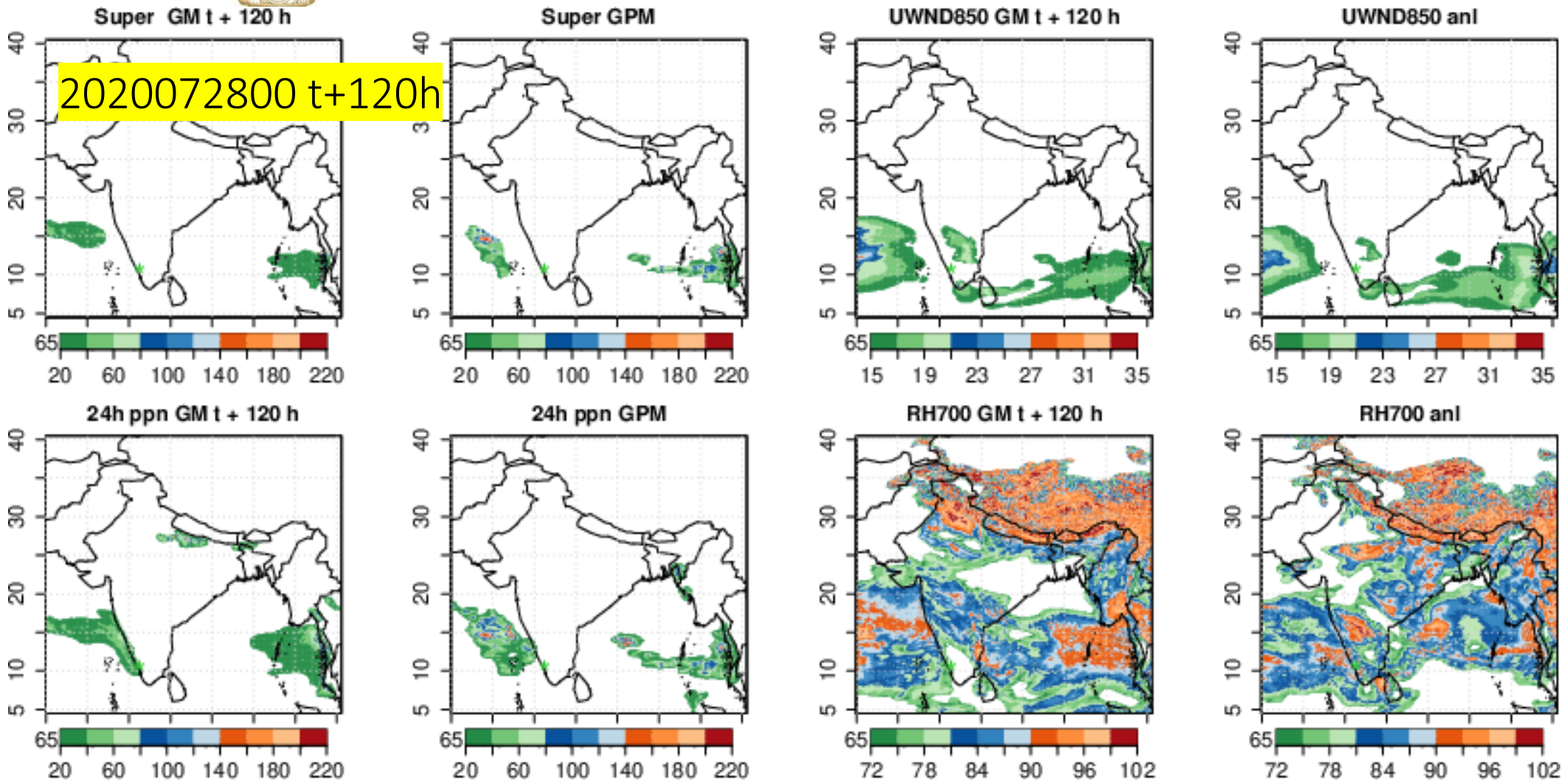


Analysis is based on the UM global deterministic operational model running at the time.

2020 flood sequence in objects

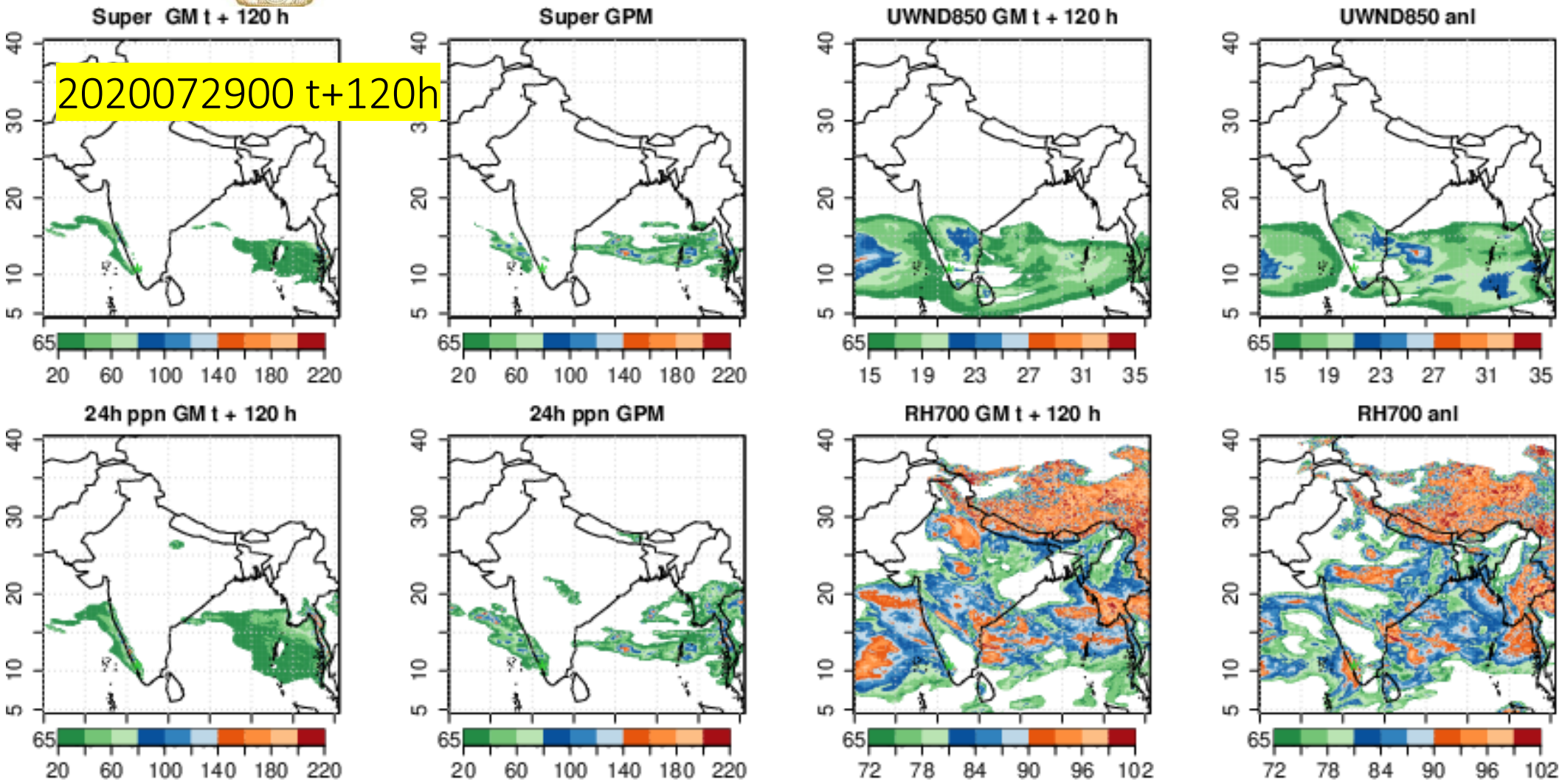
- We're particularly interested in identifying whether there is evidence of predictability in the forecasts 5 days ahead which would be useful for high-impact events which can lead to flooding.
- It is important to note that the **maps shown in subsequent sections only show the physical fields which have been imputed back into the objects.**
- Note in the output that follows there are two different precipitation objects:
  - the univariate precipitation object, which represents the are where the threshold was exceeded
  - the **multivariate *super* object**, which represents the intersection of the three variables: wind, humidity and precipitation, **populated with the precipitation field**

2020072800 t+120h



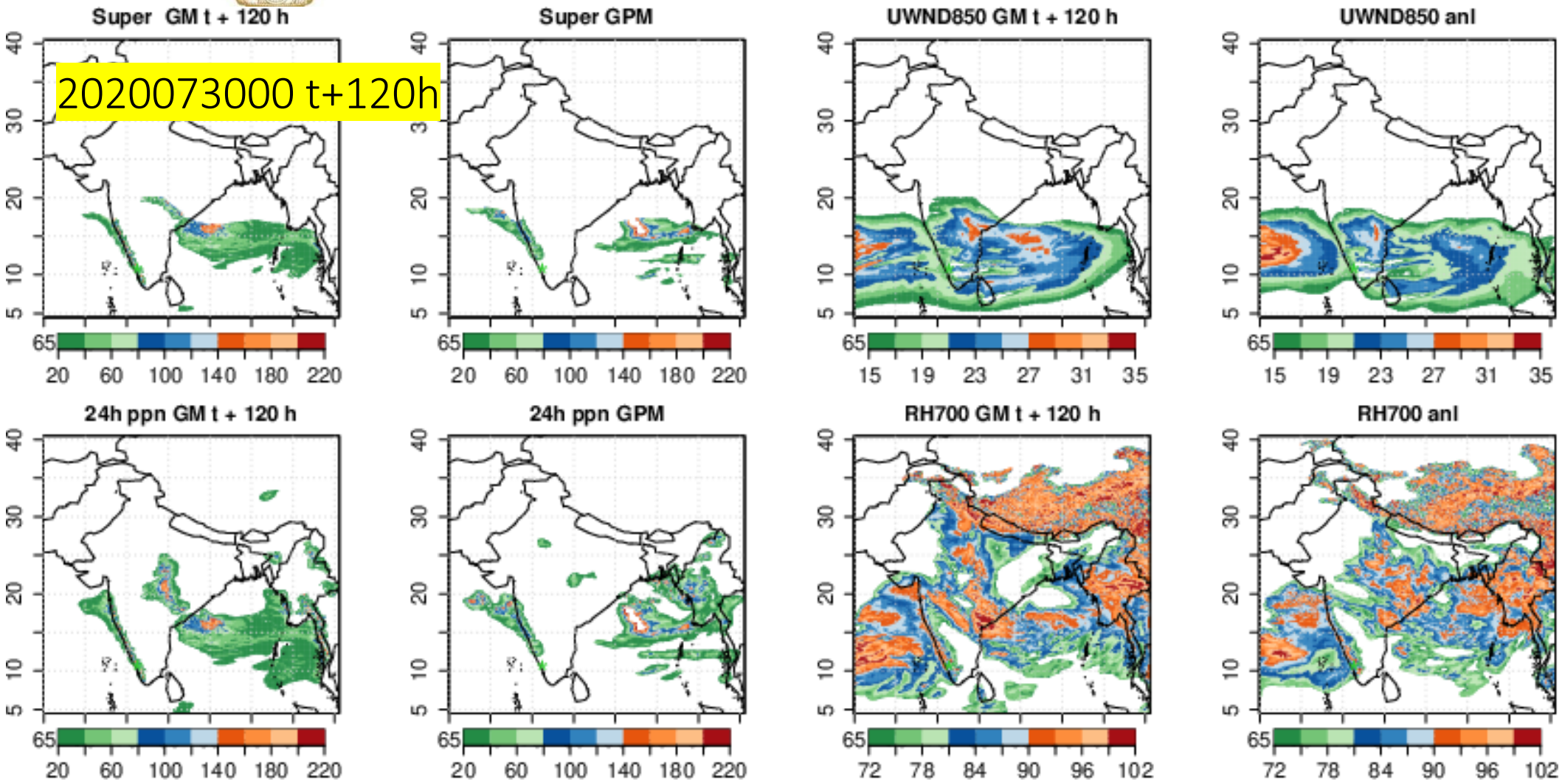
Valid at 2020080200

2020072900 t+120h



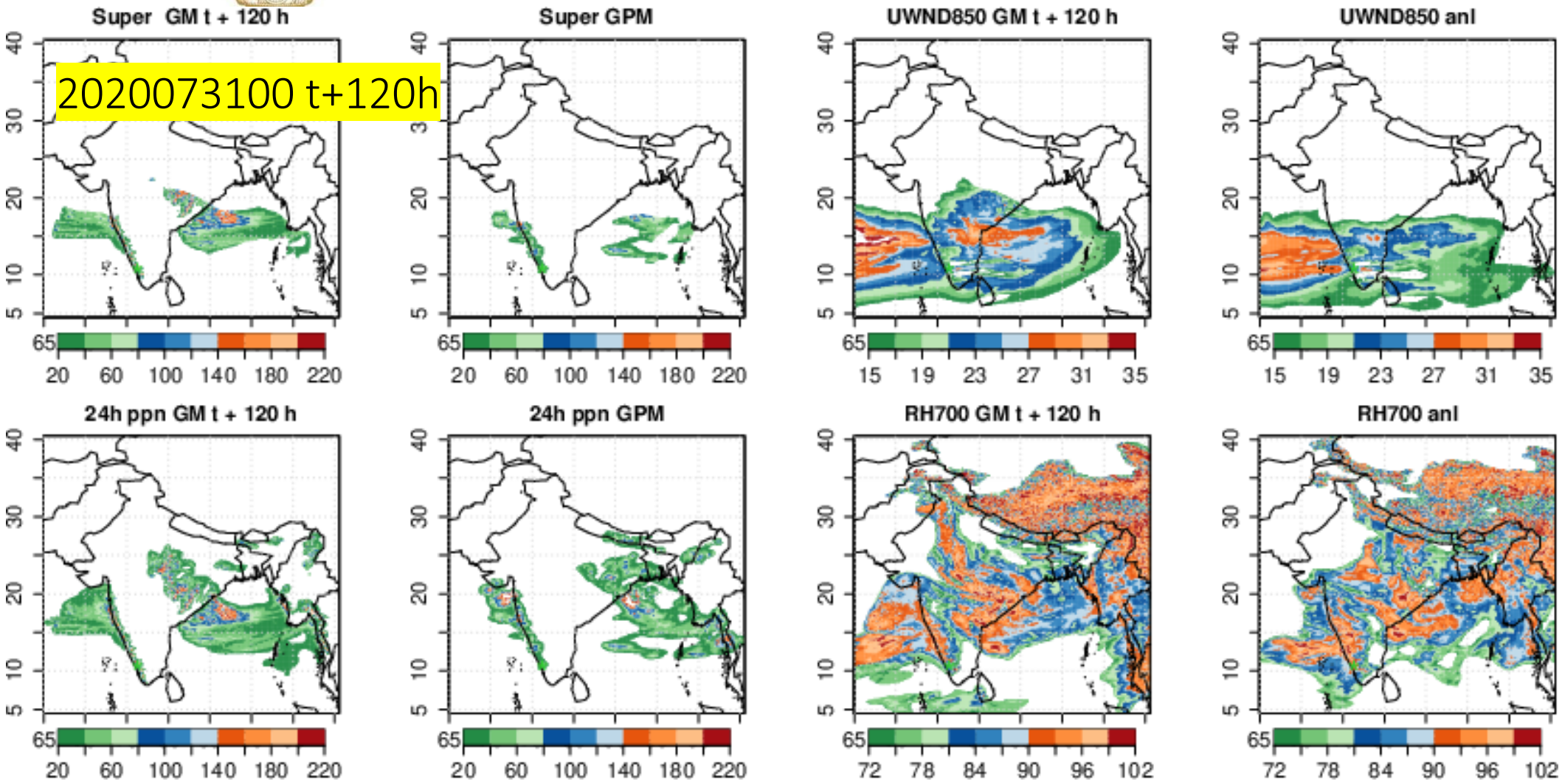
Valid at 2020080300

2020073000 t+120h



Valid at 2020080400

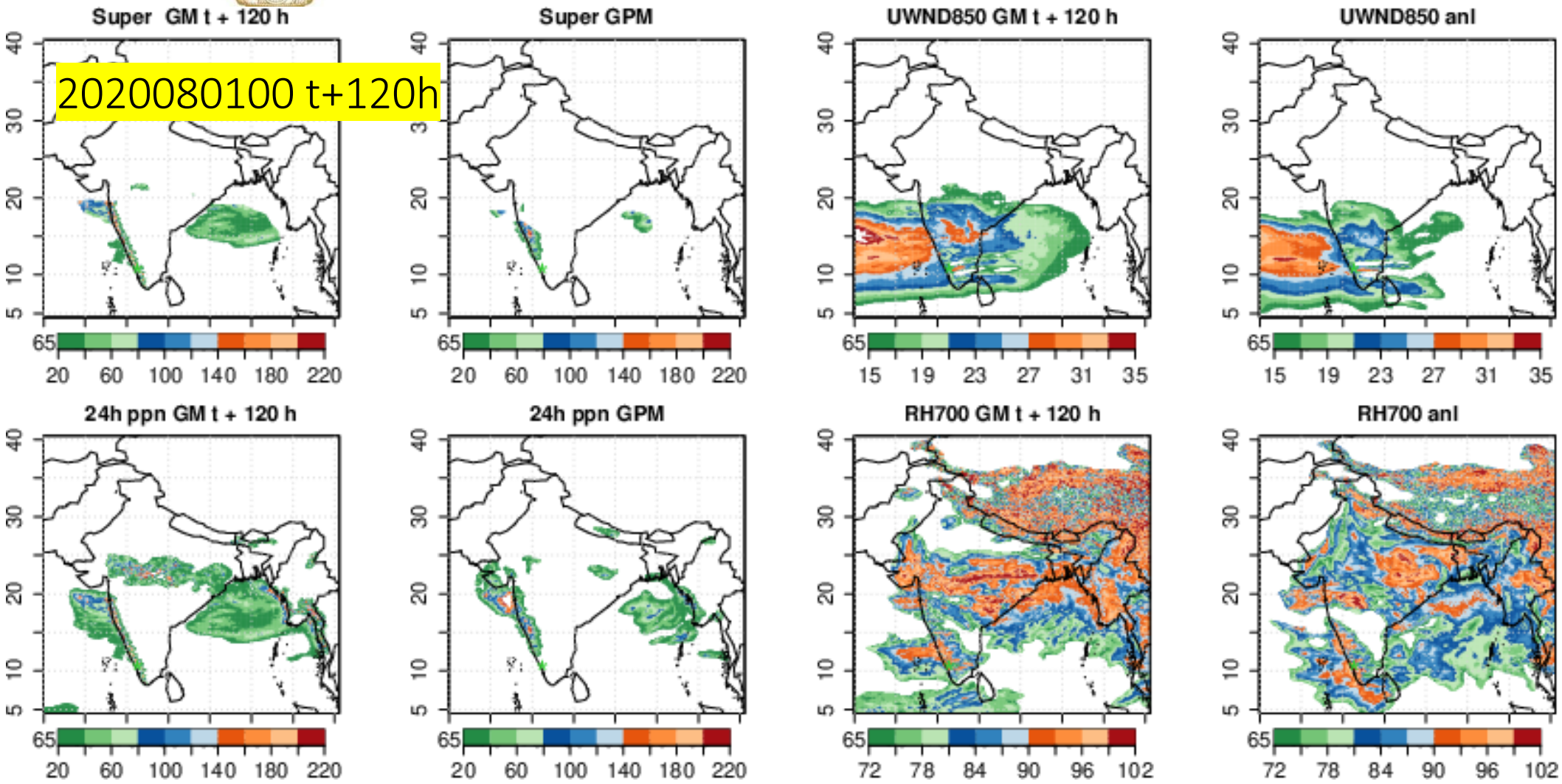
2020073100 t+120h



Valid at 2020080500

Met Office

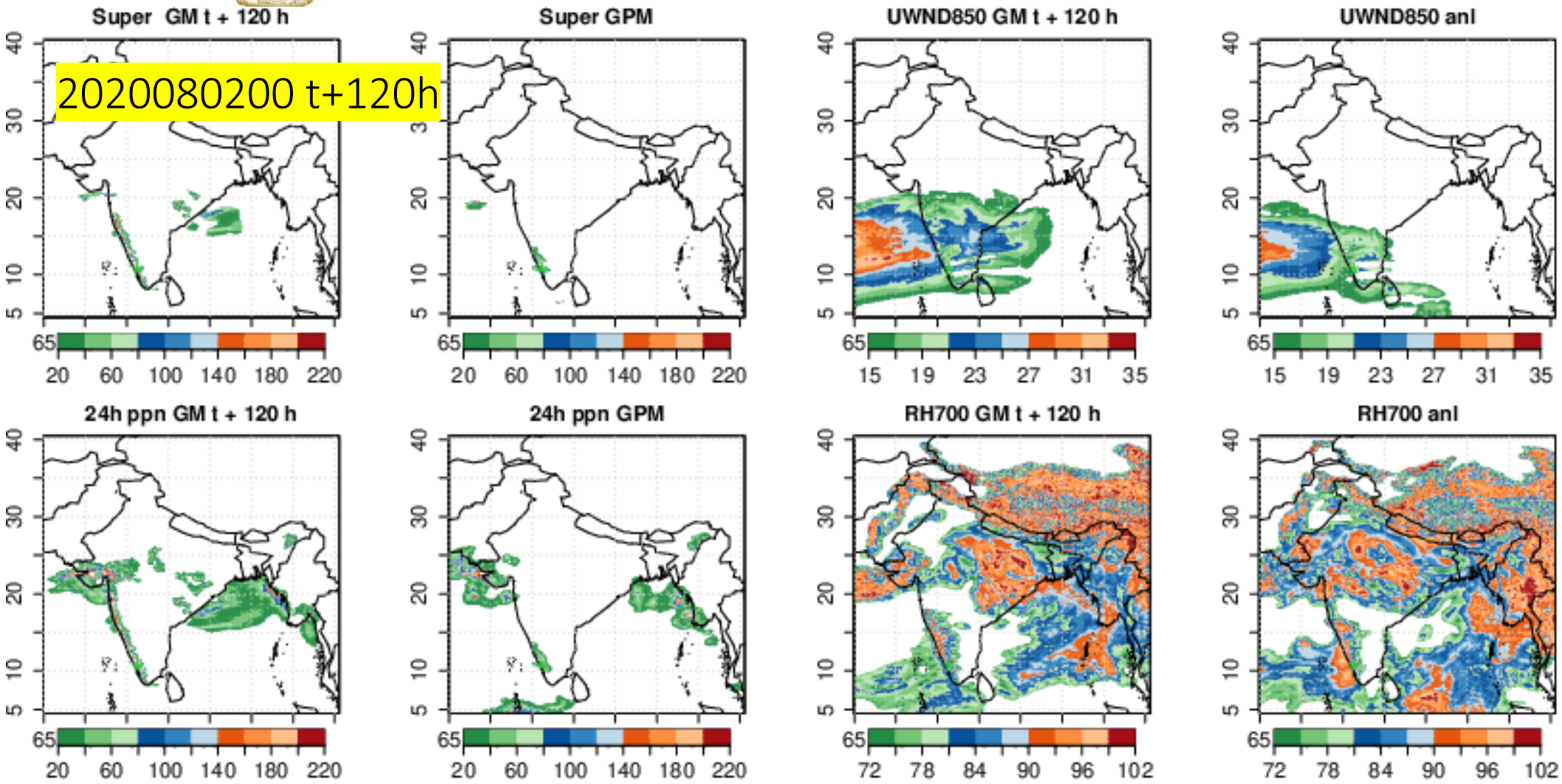
2020080100 t+120h



Valid at 2020080600

Met Office

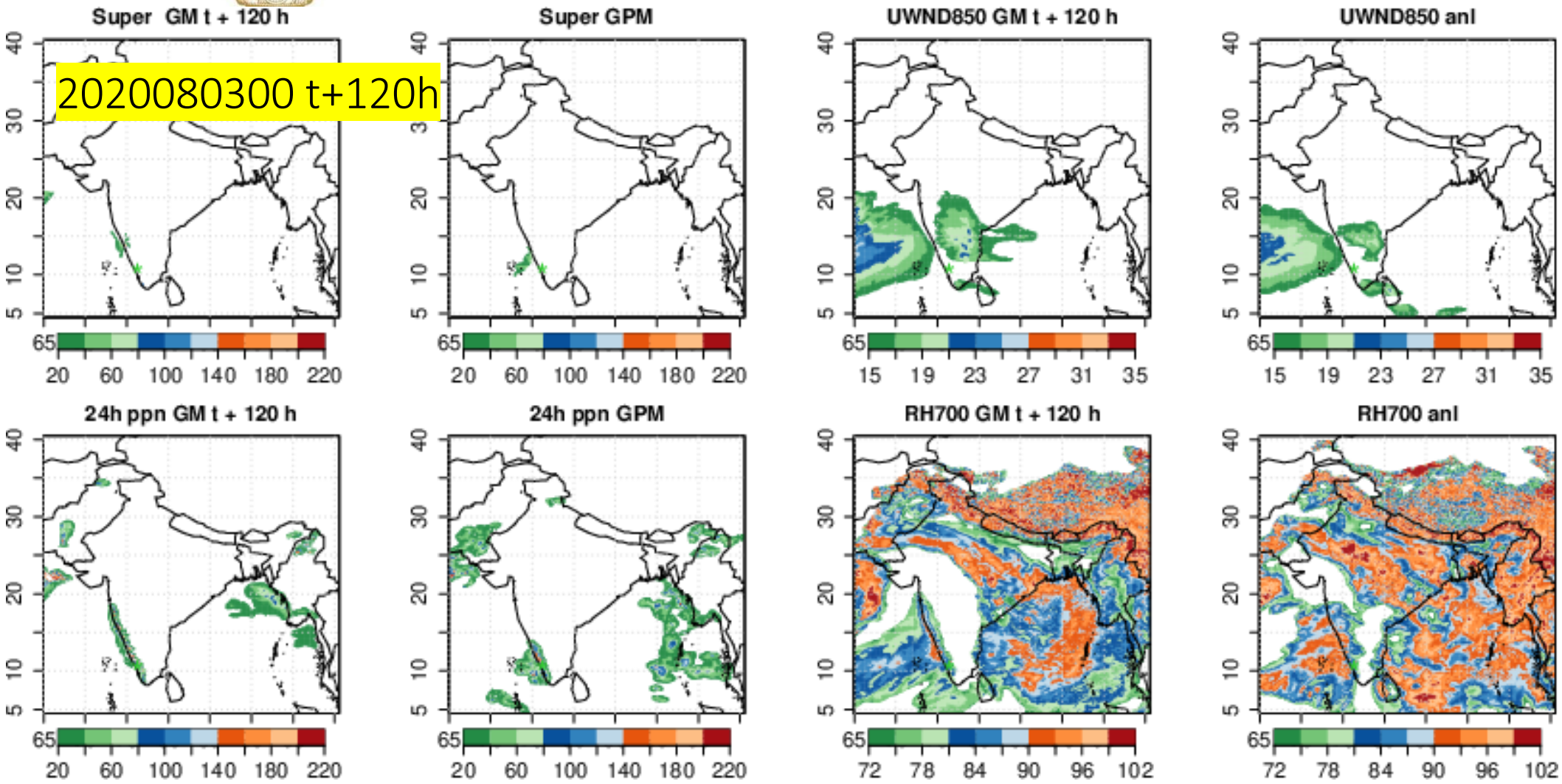
2020080200 t+120h



Valid at 2020080700

Met Office

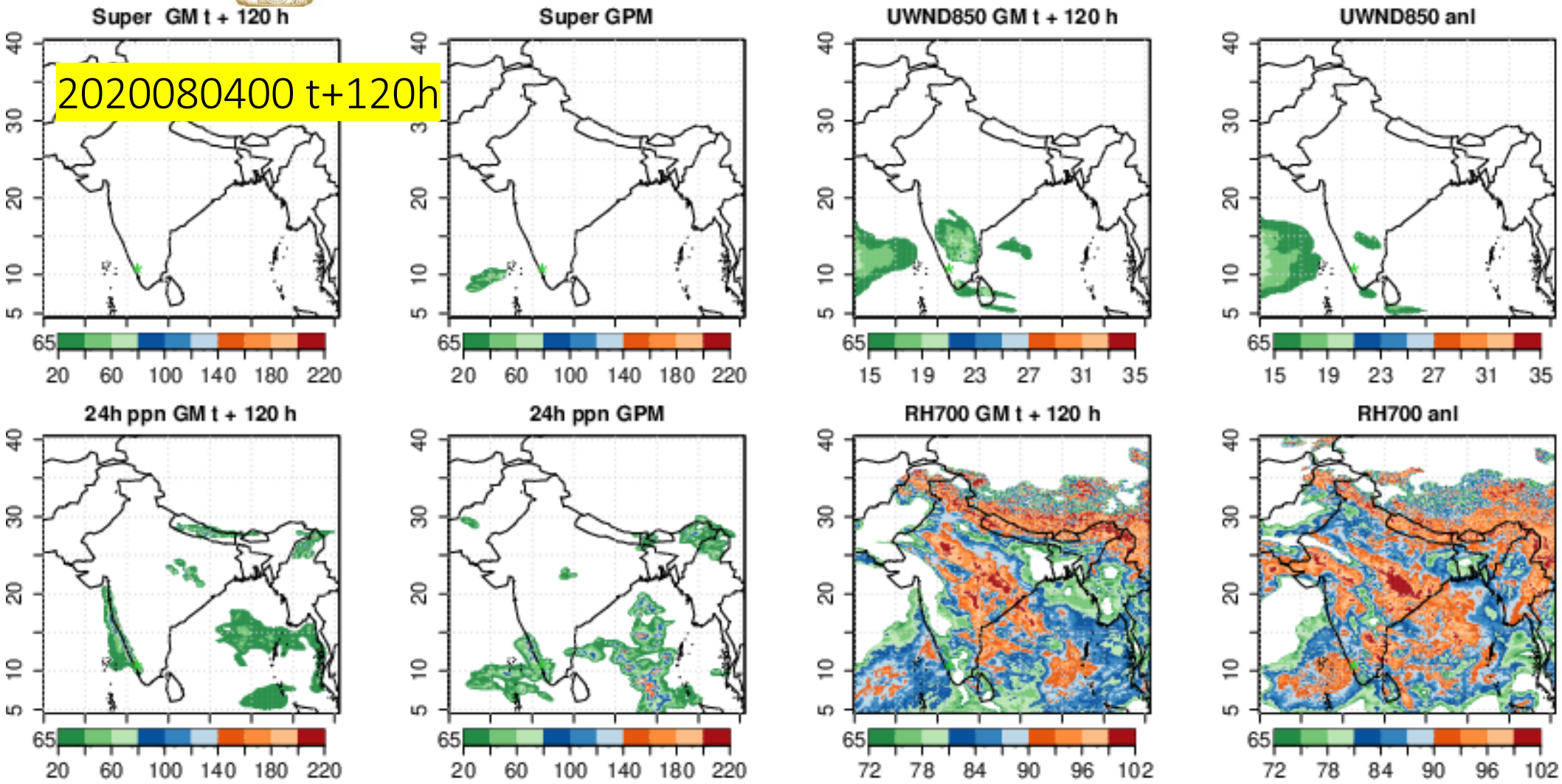
2020080300 t+120h



Valid at 2020080800

Met Office

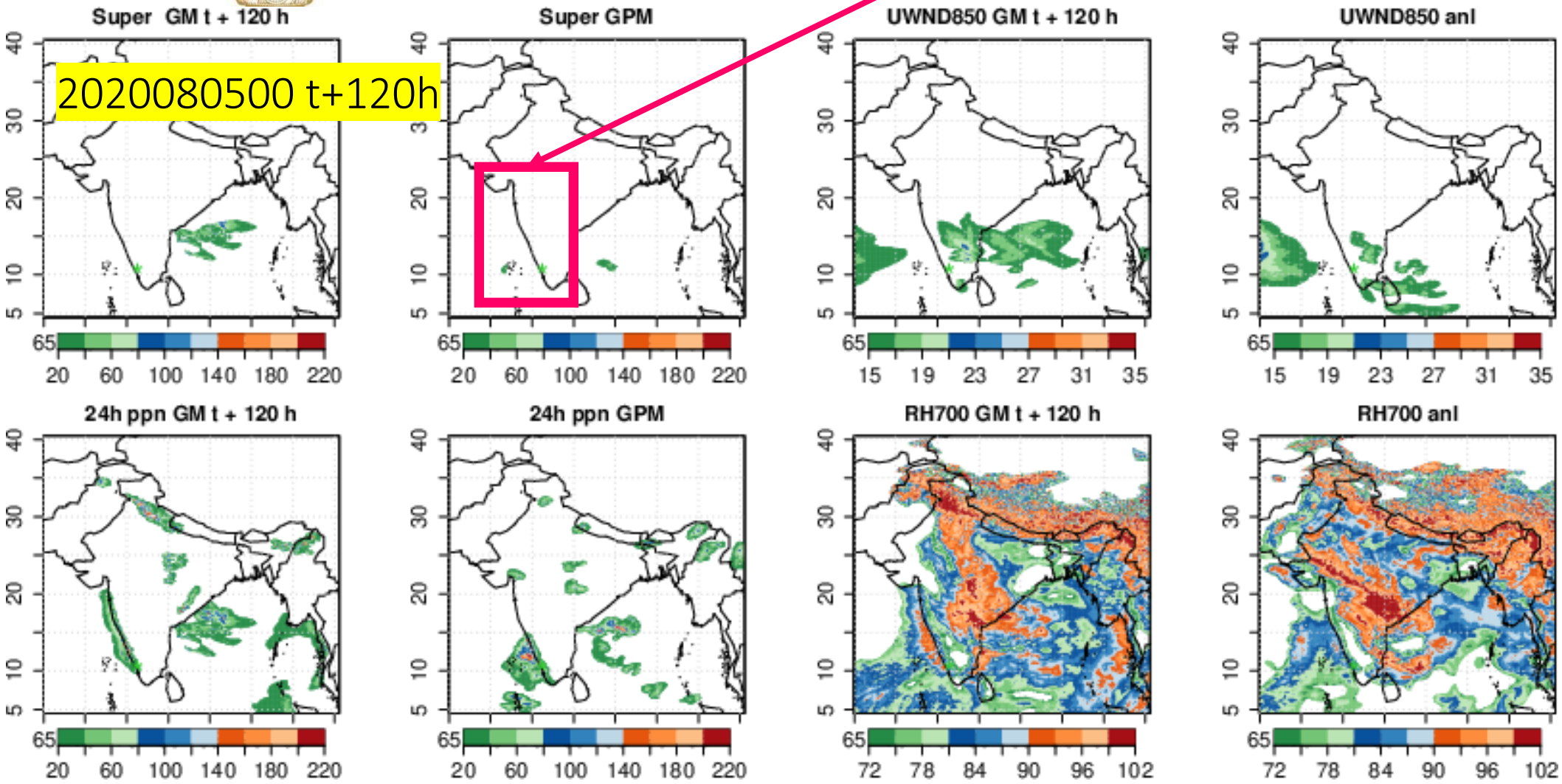
2020080400 t+120h



Valid at 2020080900

Centroid filter area (for subsequent results section)

2020080500 t+120h



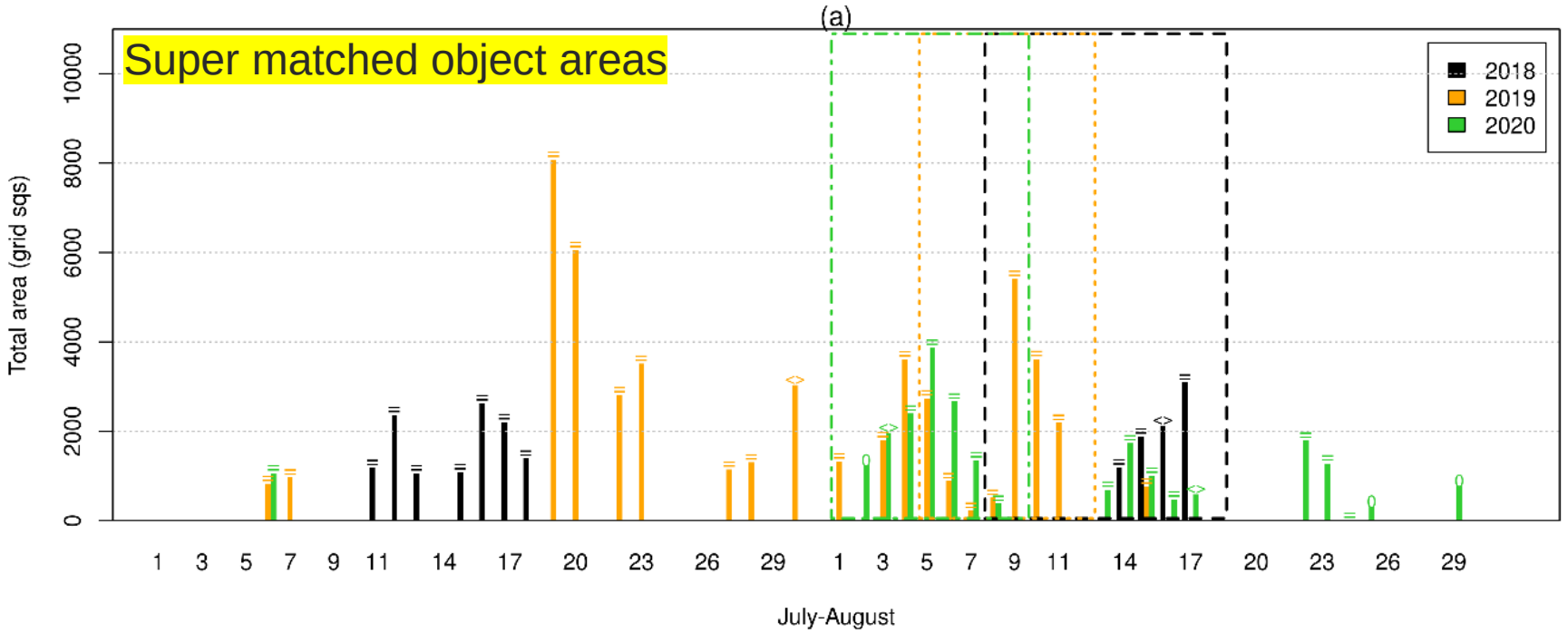
Valid at 2020081000

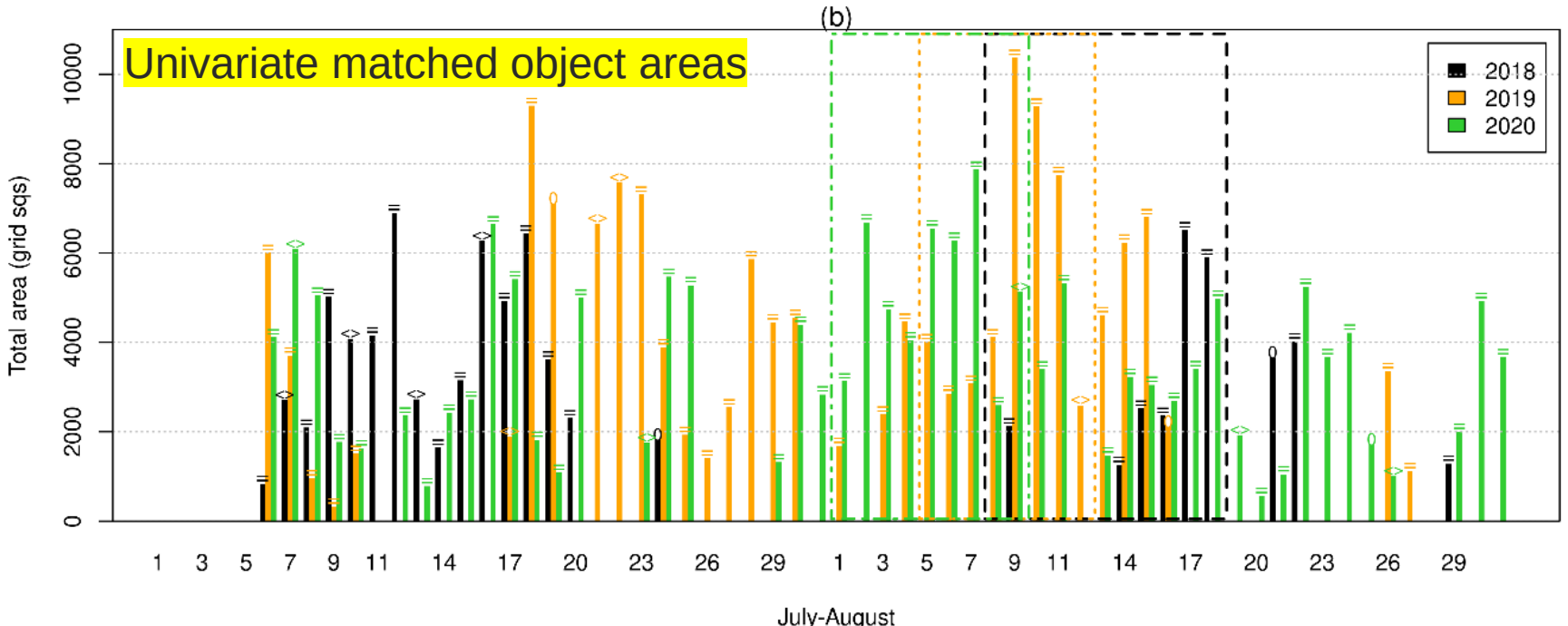
Met Office

Ministry of Earth Sciences

Sequences, predictability and identifying events of interest

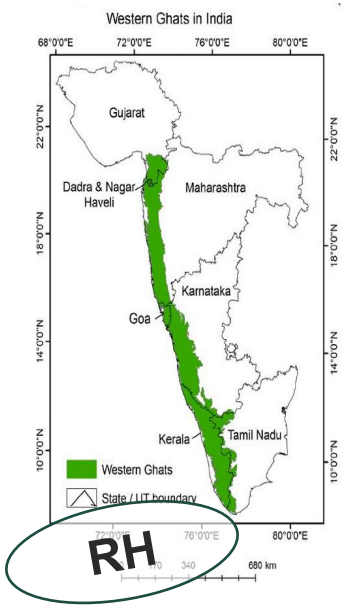
- Sequences defined as >= 3 consecutive days.
- Super object sequences coincide with the observed events (rectangles)
- Hard to differentiate events from univariate output.





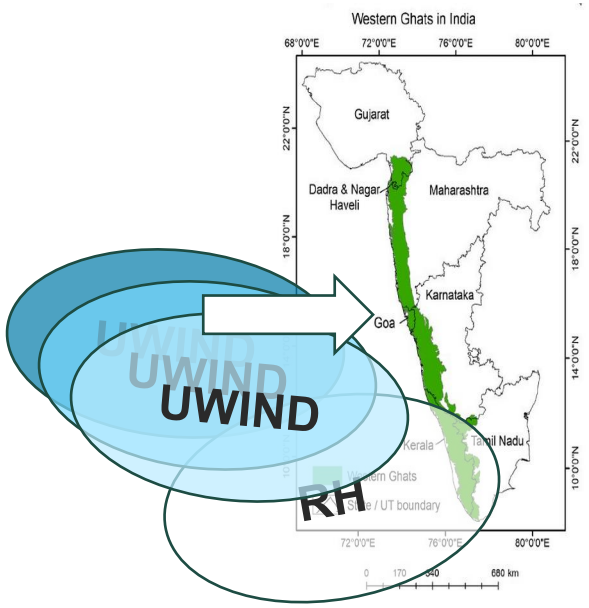
Schematic of a quasi-AR “episode”

(a)



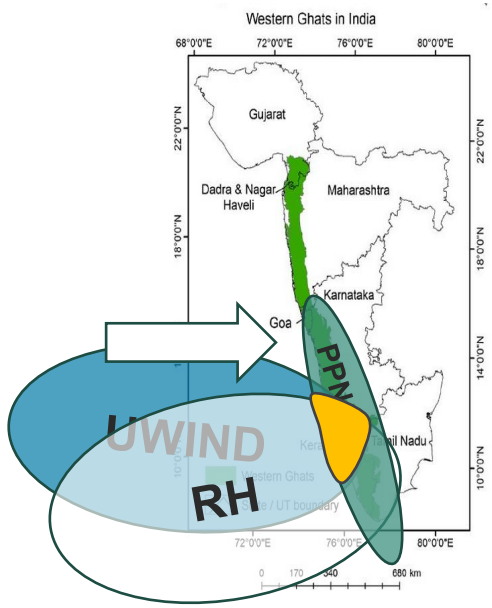
No sign of low-level w’ly jet.
Building reservoir of moisture
Little precipitation

(b)



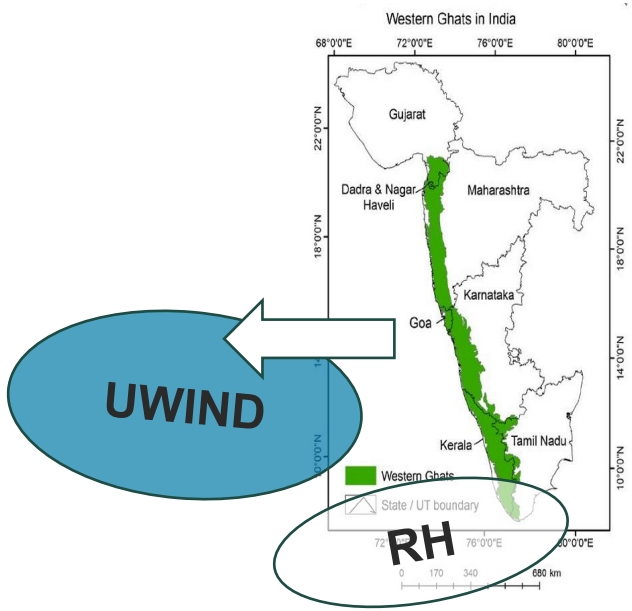
Strengthening low-level jet getting closer
Moisture continues to build.
Still little precipitation due to the interaction

(c)



Persistent low-level jet makes landfall dragging moisture inland, which is forced to rise providing enhancement.

(d)



Low-level jet weakens/retreats.
Moisture depleted and shifted. Precipitation stops.

So, what next?

- We’ve found a set of ingredients which offers potential predictability, at least to day 5. Perhaps beyond. How can we exploit this through post-processing?
- Extend to ensembles, and make more applicable, even into S2S timescales?

Thanks for listening!