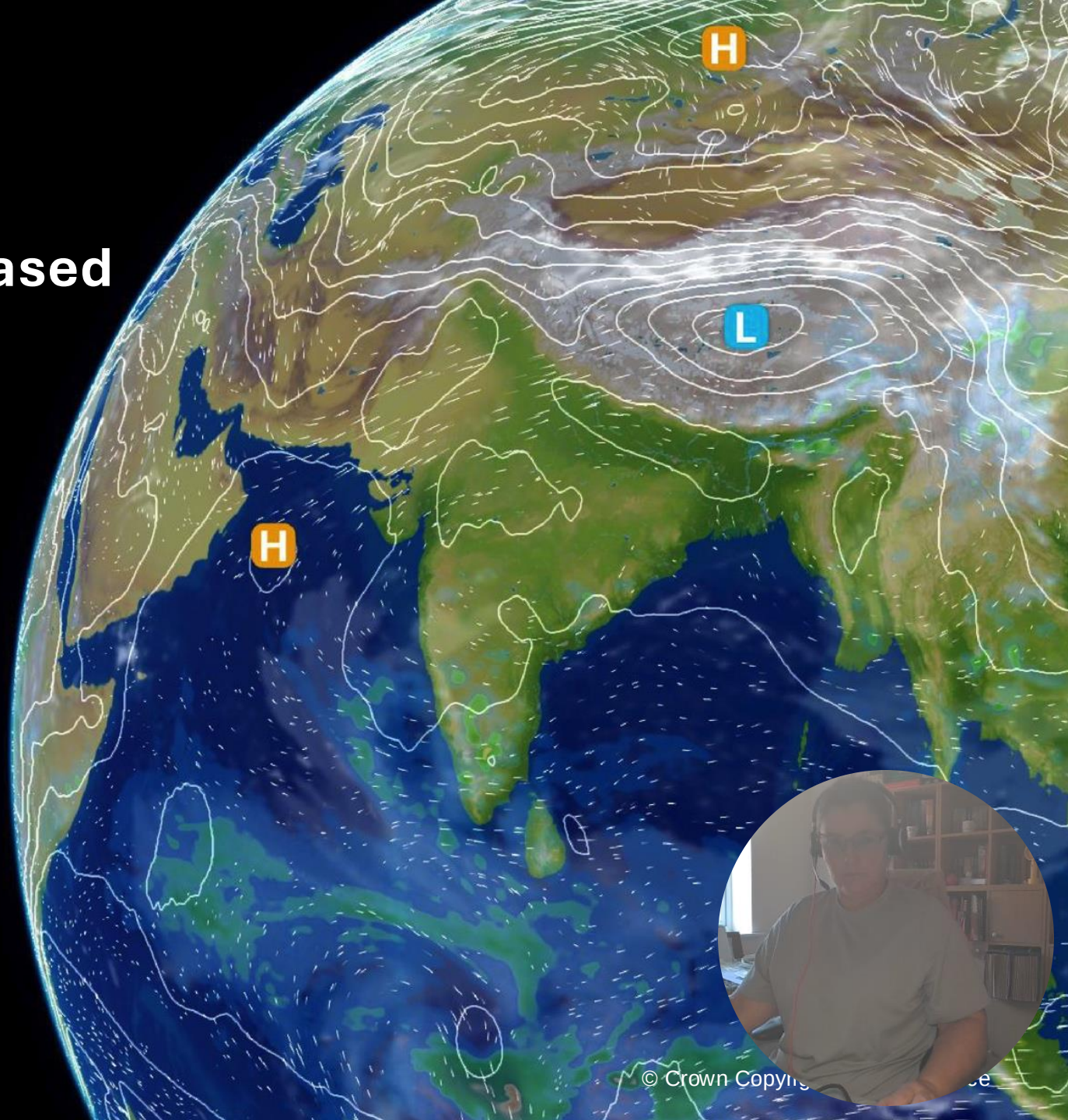
Using the multivariate feature-based diagnostic capability in METplus to identify the predictable large-scale synoptic drivers for flood-producing rains

Marion Mittermaier



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Kerala floods

Floods occurred in Kerala in three successive years.

This has never happened before.

2018:

Onset 8 June

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

2019:

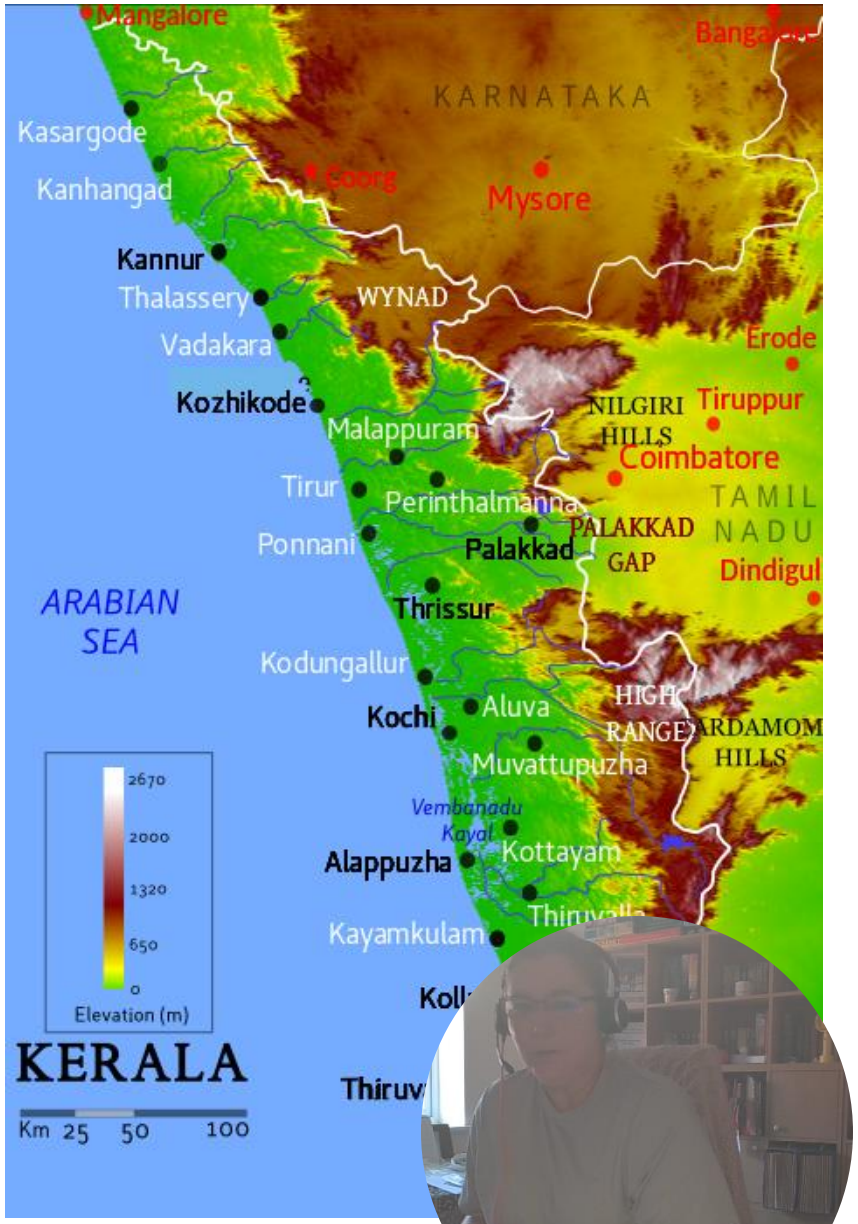
Onset 28 May

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

2020:

Onset 1 June

Heavy rains 7-8 Aug



Did these years have anything in common?

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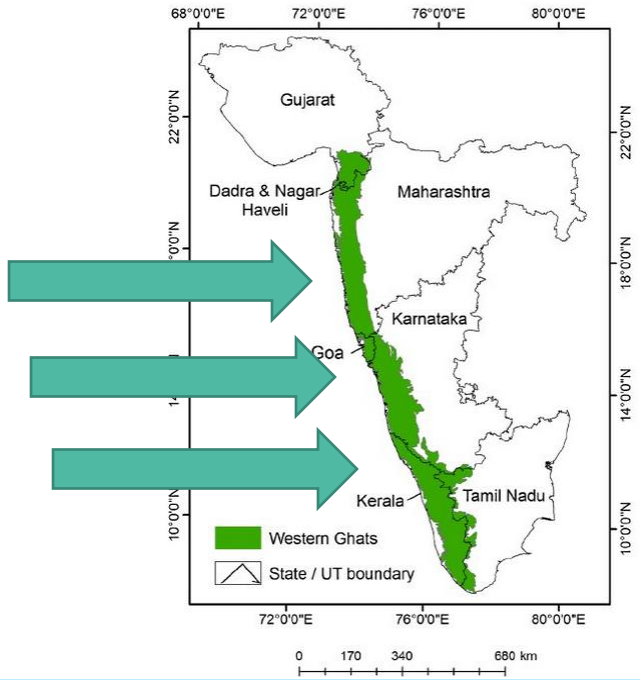
Atmospheric rivers

The Western Ghats are 900--2600 m ASL, average ~1600 m

- The original AR is dubbed the “Pineapple Express” and brings moisture all the way from Hawaii to the W coast of the US, where the presence of the mountainous terrain provides for significant orographic enhancement and responsible for many hydrologically significant events.
- Though not in the mid-latitudes the Indian W coast and the Western Ghats provide a similar exposure to low-level moist flows with a barrier which will act to enhance precipitation.



Question 1: *Does the moist low-level air stream impinging on the Indian west coast behave like quasi-ARs (noting this is not in the mid-latitudes), leading to high-impact events such as the Kerala floods in 2018, 2019 and 2020.*

Question 2: *Can a multivariate feature-based approach identify the potential locati heavy rainfall associated with a specific juxtaposition of wind & humidity, providing enhanced predictability of events such as the Kerala floods, with a particular focus medium-range. Here the focus will be on day 5 operational global UM forecasts.*

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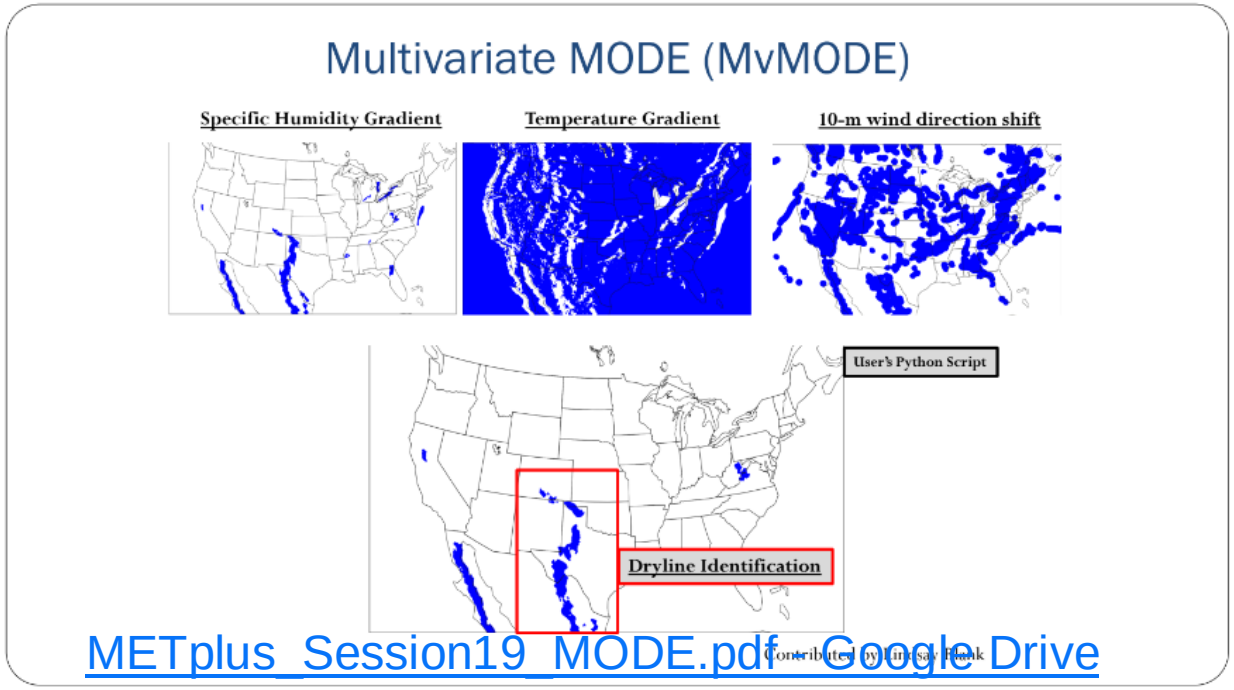
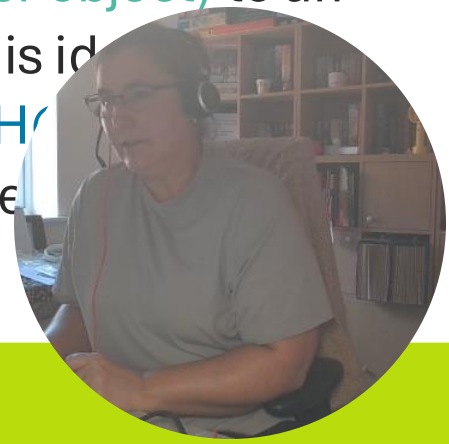
MvMODE

- MvMODE is a multivariate extension of the Method for Object-based Diagnostic Evaluation (MODE) (Davis et al 2006) available via METplus.
- MODE was developed for evaluating CS precipitation forecasts but really lends itself very well to large domain & large-scale driver analysis.
- It provides the logic capability to, for example, find the intersection between the objects identified in a number of different variables to then analyse one of the variables which are part of the logic, or indeed a different variable entirely.



- 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 id
using UWIND@850 > 15 m/s, RH
and DAILY_PRECIP > 12.5 mm (e
2004). Here GPM is used.

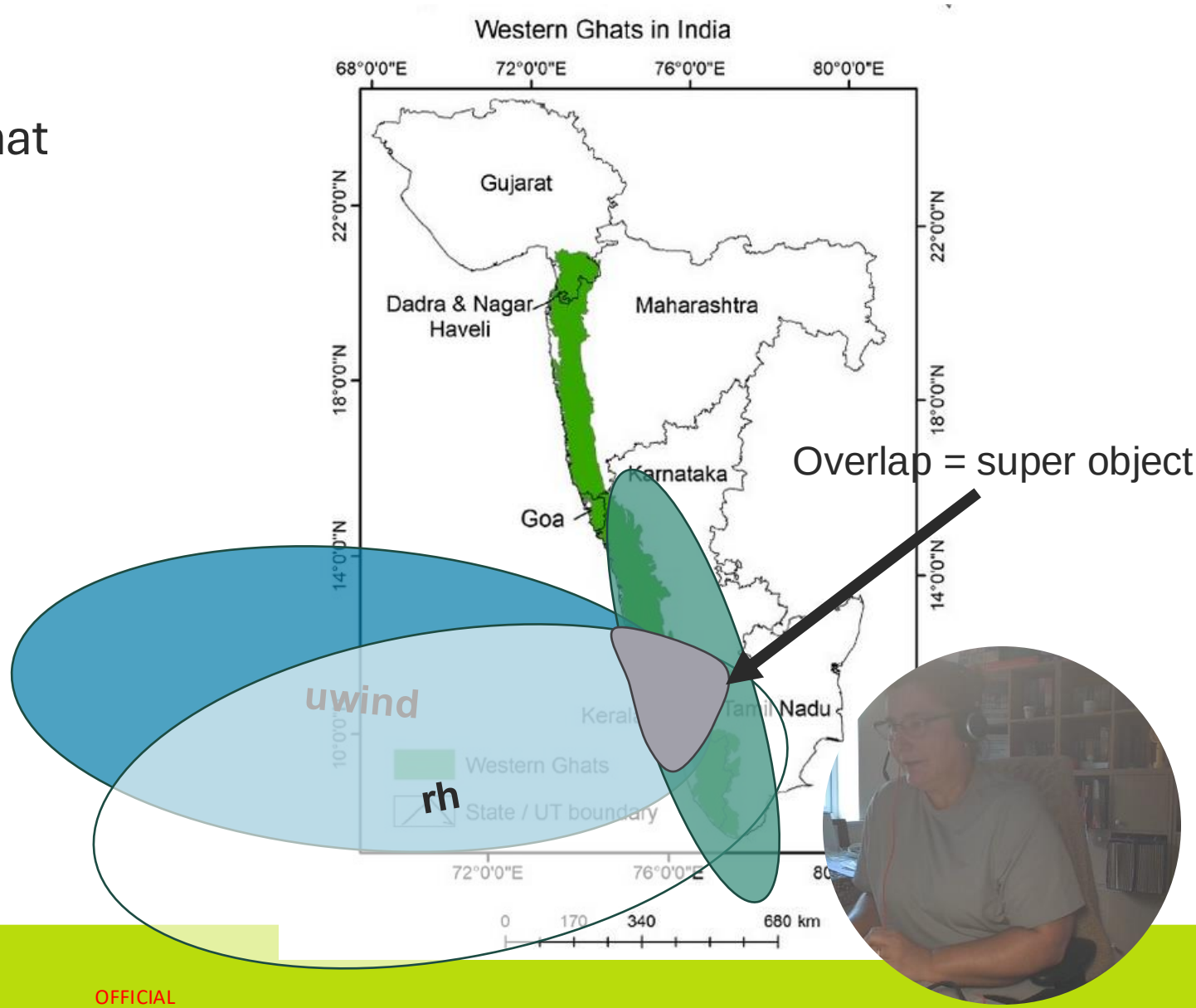


What are we looking for?

- What MvMODE does to identify the "super" objects is defined by the logic that is provided.
- The process is repeated in the forecast and analysis/observed fields.
- Following on "super" objects in the forecast and observed fields can be matched and analysed.

Questions asked:

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



What does this look like?

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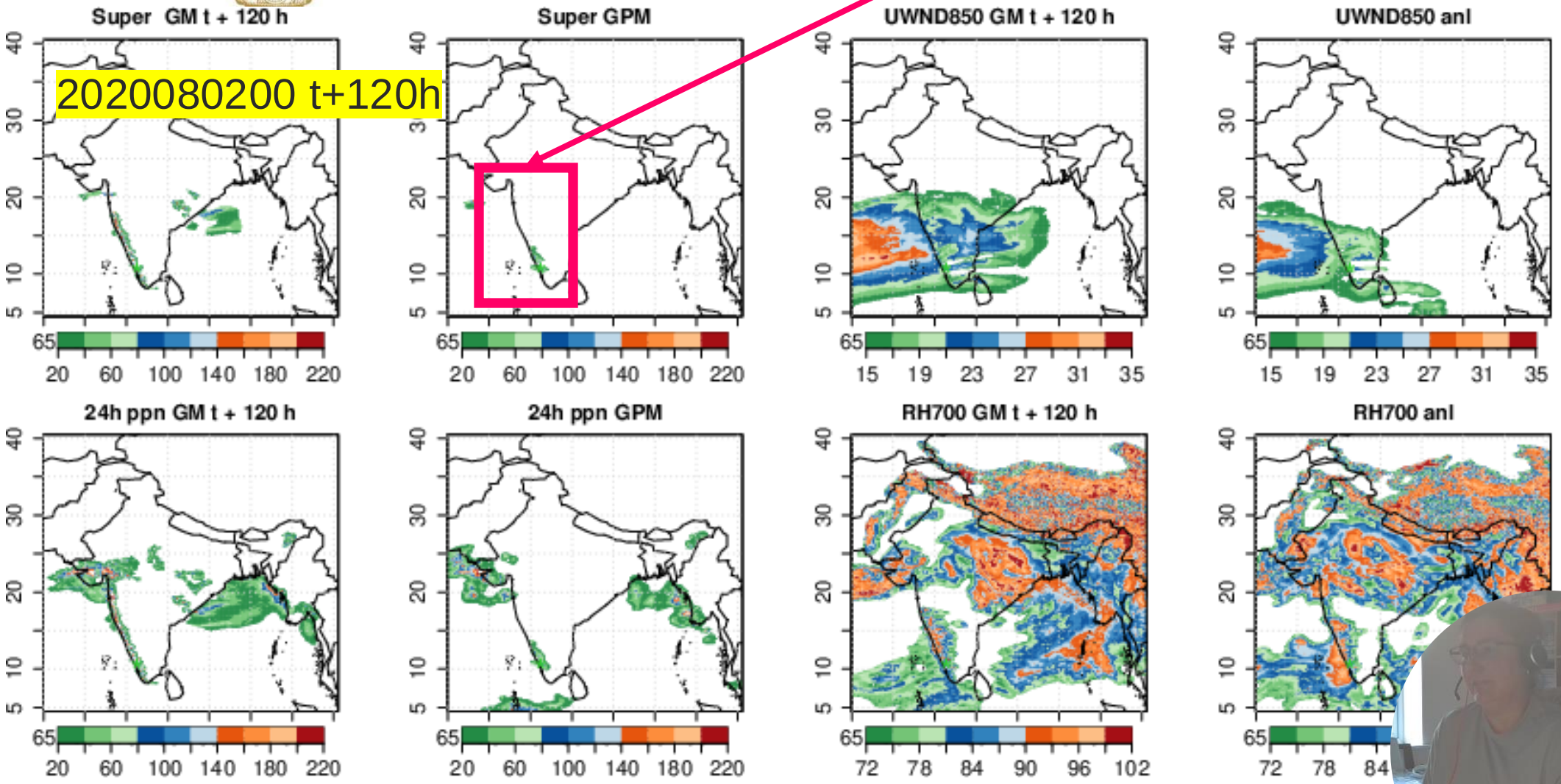
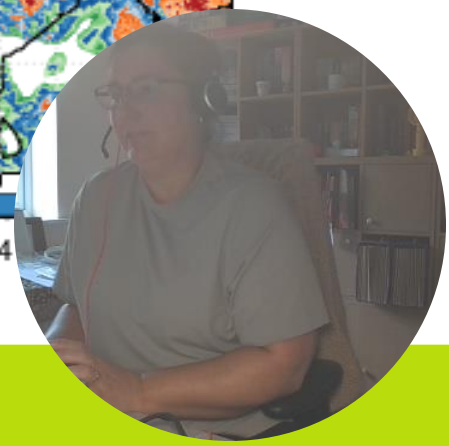
Centroid filter area (for subsequent results section)

2020080200 t+120h



Valid at 2020080700



Example analysis from 2020

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Super object summary statistics (full domain)

Derived for all the t+120h forecast objects and analysis (observed) objects in July/August of each year.

	Jul/Aug 2018	Jul/Aug 2019	Jul/Aug 2020
Total number of single objects:	356	273	233
Number of single fcst objects:	**171**	**148**	**122**
Number of matched single fcst objects:	**56**	**65**	**41**
Number of single obs objects:	**185**	**125**	**111**
Number of matched single obs objects:	**71**	**61**	**53**
Total area of objects (grid squares):	126826	140943	102846
Area of single fcst objects:	**72375**	**71443**	**5853**
Area of matched single fcst objects:	**54174**	**57394**	**43**
Area of single obs objects:	**54451**	**69500**	**44**
Area of matched single obs objects:	**33299**	**52804**	**32**

There is some inter-annual variability, most likely related to the monsoon onset and north- and westwa

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Paired object attributes for each season

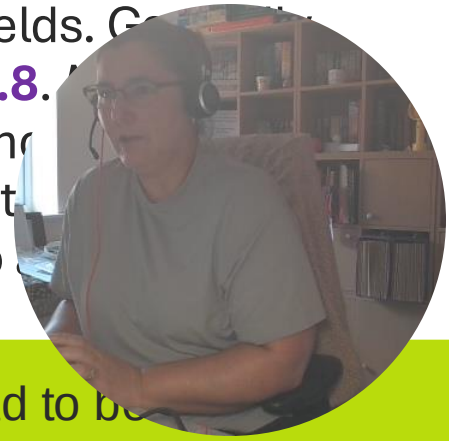
Compare mean vs median and two specific statistics "***intersection-over-area***" which provides the degree of overlap between the matched forecast-observed pair and the "***percentile intensity ratio***" which compares the median intensities in the matched forecast-observed pair.

Intersection-over-area (aka overlap)	Mean	Median
2018	0.48	0.53
2019	0.52	0.53
2020	0.49	0.53

The median overlap is a little higher than the mean, but all values are ~0.5, which implies that **~50% of DAY 5 forecast-observed pairs physically overlap**.

Percentile-intensity ratio	Mean	Median
2018	0.75	0.76
2019	0.69	0.74
2020	0.73	0.79

The percentile intensity ratio suggests that there is a bias between the forecast and the observed fields. G… median > mean, **but all ratios are ~0.7-0.8**. … are written as the ratio is always [0,1], hen… infer which is higher/lower from the ratio it… individual objects need to be examined to … question.



Based on a region defined as 5-25N and 68-80E (box annotated on slide 6). Object centroids had to b…

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Persistence of rainfall

Floods are often the product of several days of rain, i.e. a compound effect.

Identify date sequences >=3 days with matched super object pairs

Do they match the observed flood-producing rain periods? → YES

2018

July 11
July 12
July 13

July 15
July 16
July 17
July 18

August 14
August 15
August 16
August 17

2019

August 3
August 4
August 5
August 6
August 7
August 8
August 9
August 10
August 11

2020

August 2
August 3
August 4
August 5
August 6
August 7
August 8

August 13
August 14
August 15
August 16
August 17

August 22
August 23
August 24
August 25

Recall:

2018:

Heavy rains 8-10 Aug, 12-18 Aug

2019:

Heavy rains 6-11 Aug

2020:

Heavy rains 7-8 Aug

MvMODE captures most periods but also identifies other extended spells of prolonged rain at day 5

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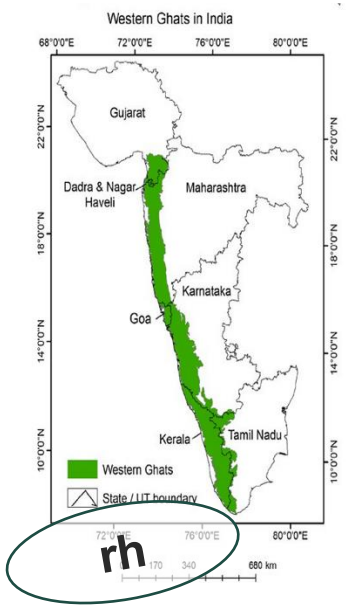
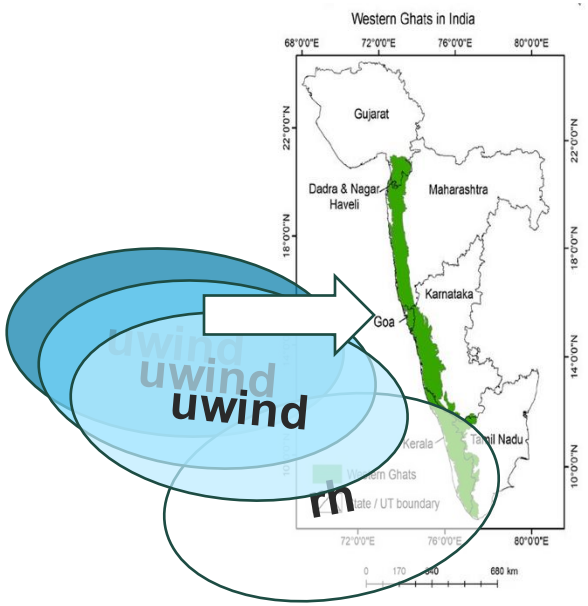
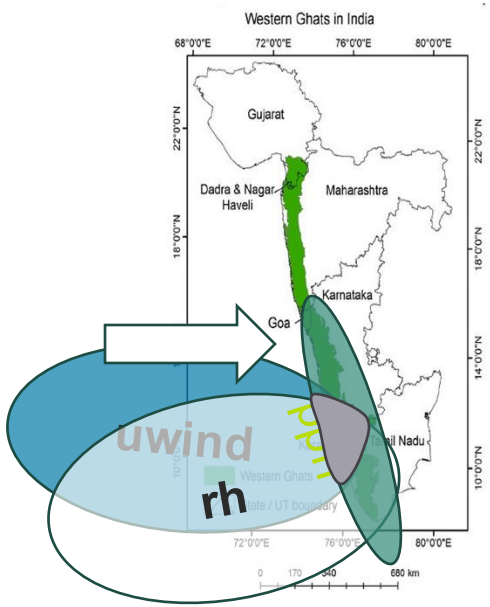
Conceptual schematic of the quasi-AR life cycle



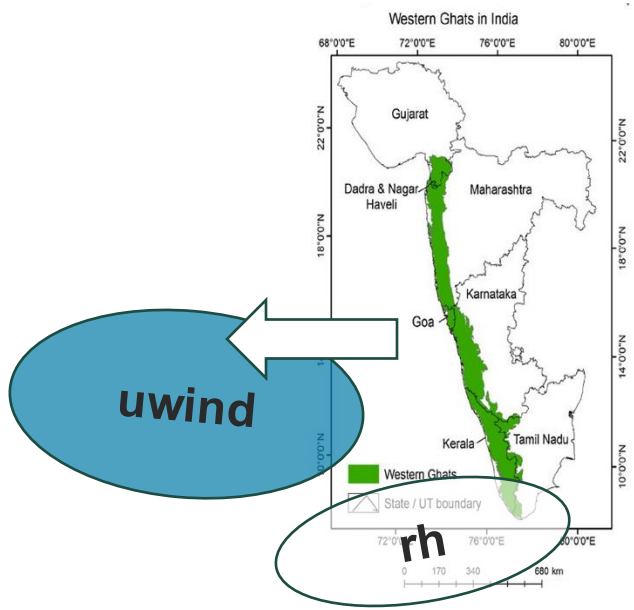
No sign of low-level w'ly jet.
Building reservoir of moisture
Little precipitation



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



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



Low-level jet weakens/re
Moisture c
shifted. P
stops.

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To summarise:

- **Does MvMODE identify matched pairs of super objects given the variables and logic?** *Yes*.
- **Do any of the day 5 matched pairs coincide with the flood-producing periods in 2018, 2019 and 2020?** *Most do, yes*.
- **Do the super objects contain the precipitation peak?** *Not necessarily, at least not on day 5. It does highlight the area potentially at risk*. Note also GPM isn't perfect and may be smearing the rain out too much and the fields have not been debiased.
- **Do these flood producing events appear to share the same large-scale synoptic drivers which can be described as a quasi-AR?** *Yes*.

Next steps / considerations

- Collaboration plans with NCMRWF to extend the analysis to beyond day 5.
- Working together on updating and enhancing the workflows to the latest versions of MET and METplus which offer substantial changes to the prototype capability used in this study.
- Writing this up!

- **Thanks for listening! Any questions, please email me.**