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# Monsoon low-pressure systems in subseasonal-to-seasonal forecasts

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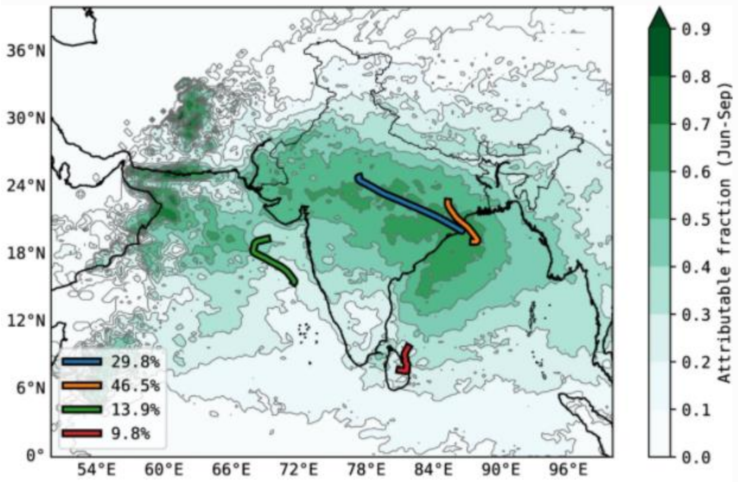
# Introduction

- Monsoon depressions and low-pressure systems bring about half the total monsoon rainfall over India (top right)

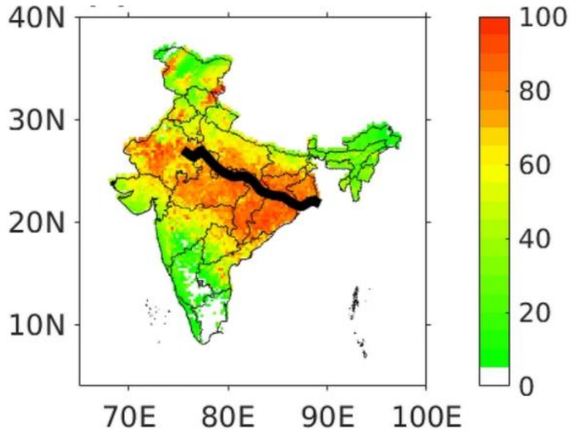
- They are also associated with the majority of extreme precipitation events in the monsoon core zone (bottom right)

- Good subseasonal forecasts of LPS activity can help mitigate against flooding or local water resource crises

- Good seasonal forecasts of LPS activity can help in developing mitigation strategies for the agricultural sector




Total monsoon rainfall attributable to monsoon LPSs (Hunt and Fletcher, 2019)




Fraction of extreme precipitation events (>64.5 mm/day) occurring within 1000 km of monsoon LPSs (Thomas et al., 2021)

# Tracking MDs in S2S models

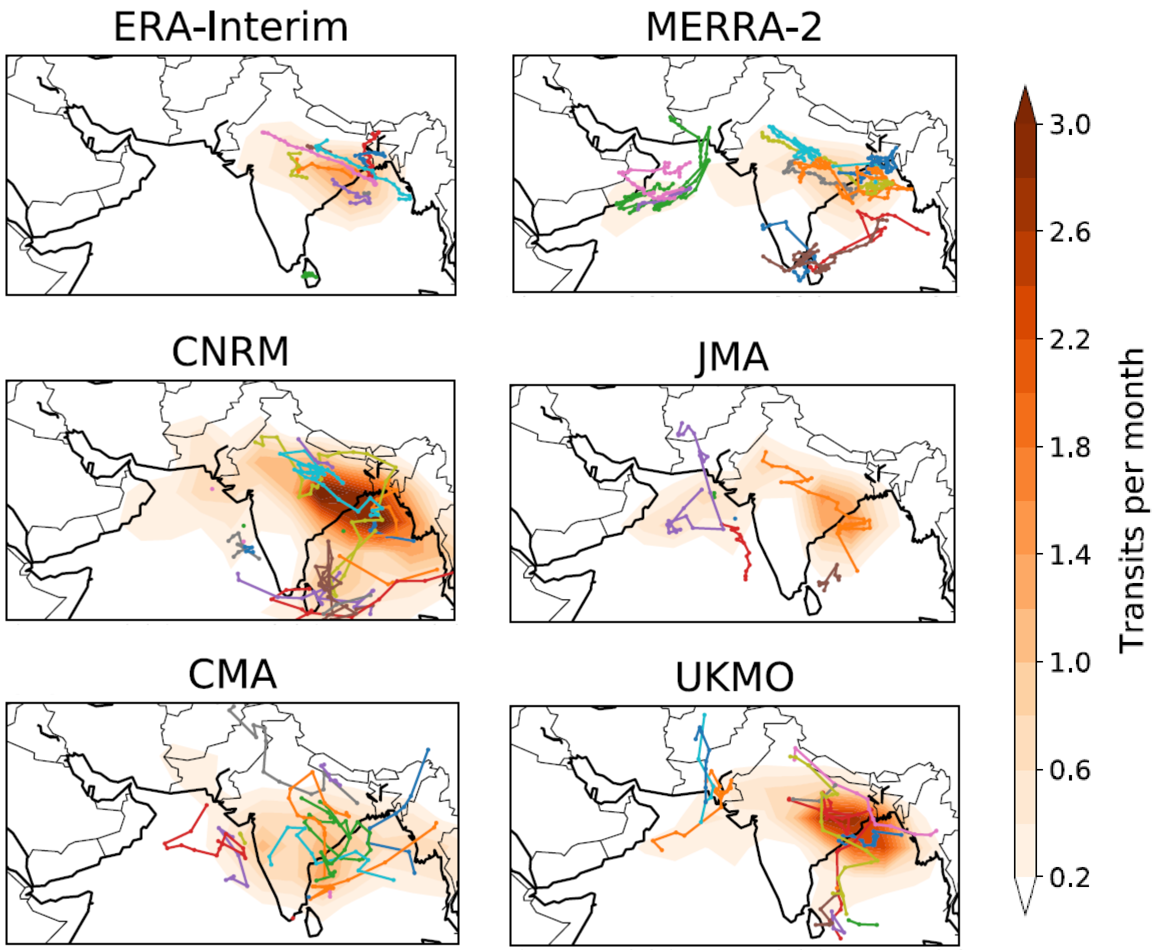
- Uses the S2S dataset (Vitart et al., 2017) with the LPS vorticity-based tracking algorithm outlined in Hund and Fletcher (2019)

- But… winds only available at daily frequency

- So, additional filters required:
  - 925 hPa temperature anomaly < +0.5 K
  - negative surface pressure anomaly

- All analysis limited to a “common” re-forecast period of 1999-2010

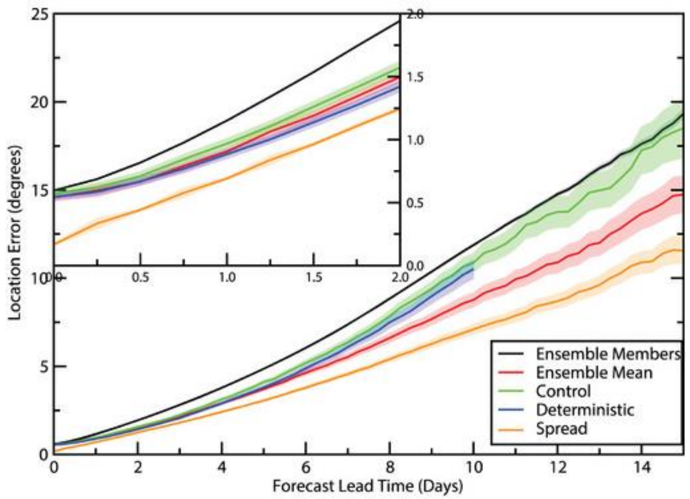
- Initial analysis done in NWP framework, so all S2S tracks are “matched” to those from reanalysis



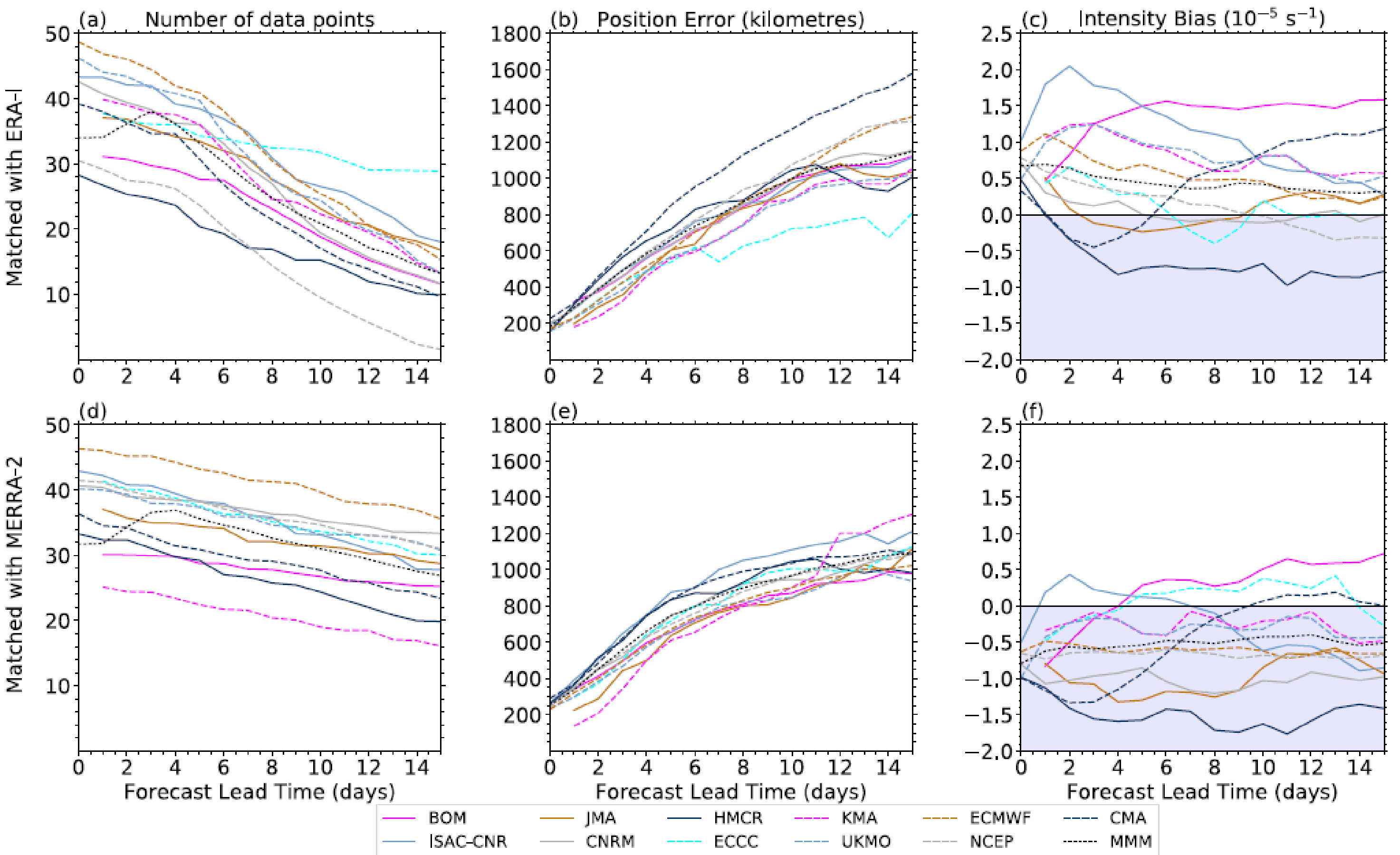

Example tracks from the 1999 season for two reanalyses and selected S2S reforecasts. Stated track density is for 1999-2010.

# Reforecast verification

- Lower counts in S2S due to matching
- No systematic trend in intensity bias

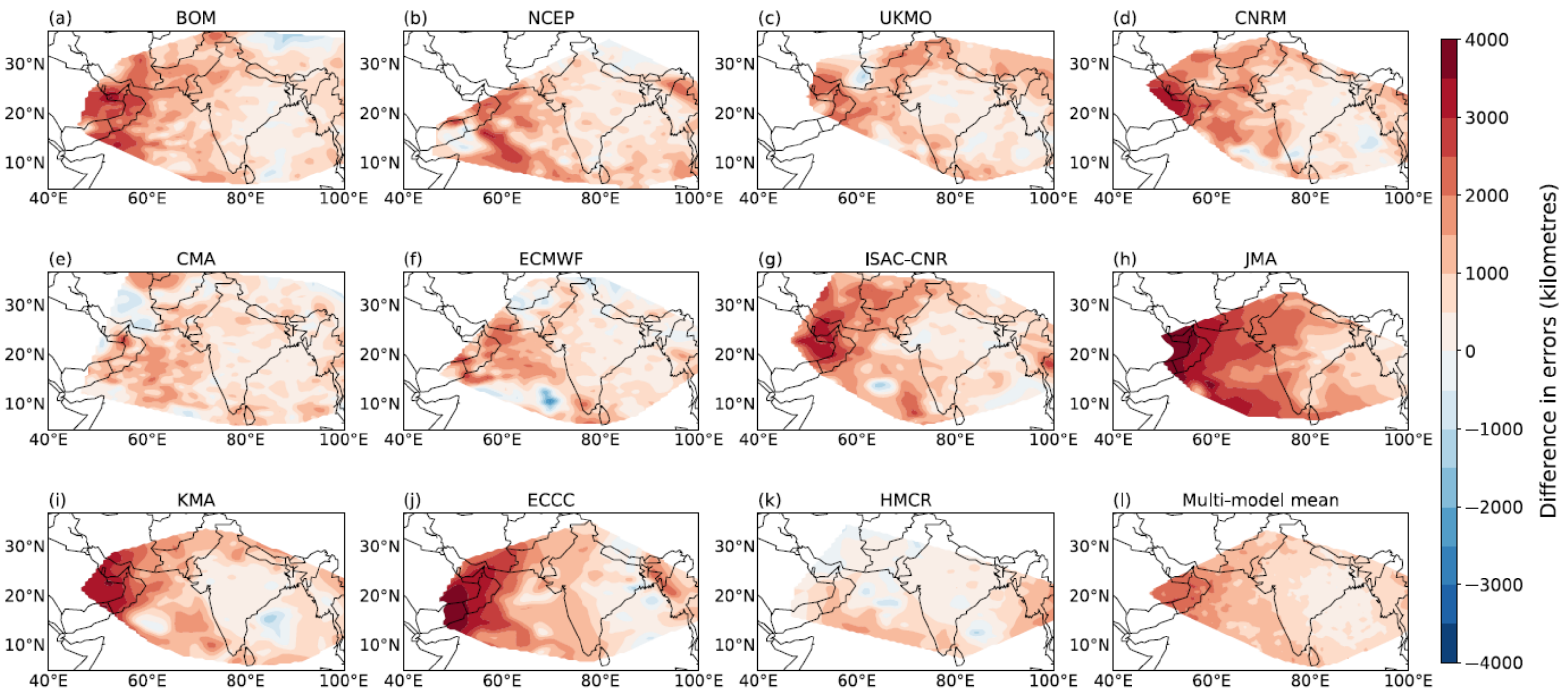



Position error for TCs (compared against IBTrACS), from Hodges and Emerton (2015).



# Growth of forecast errors

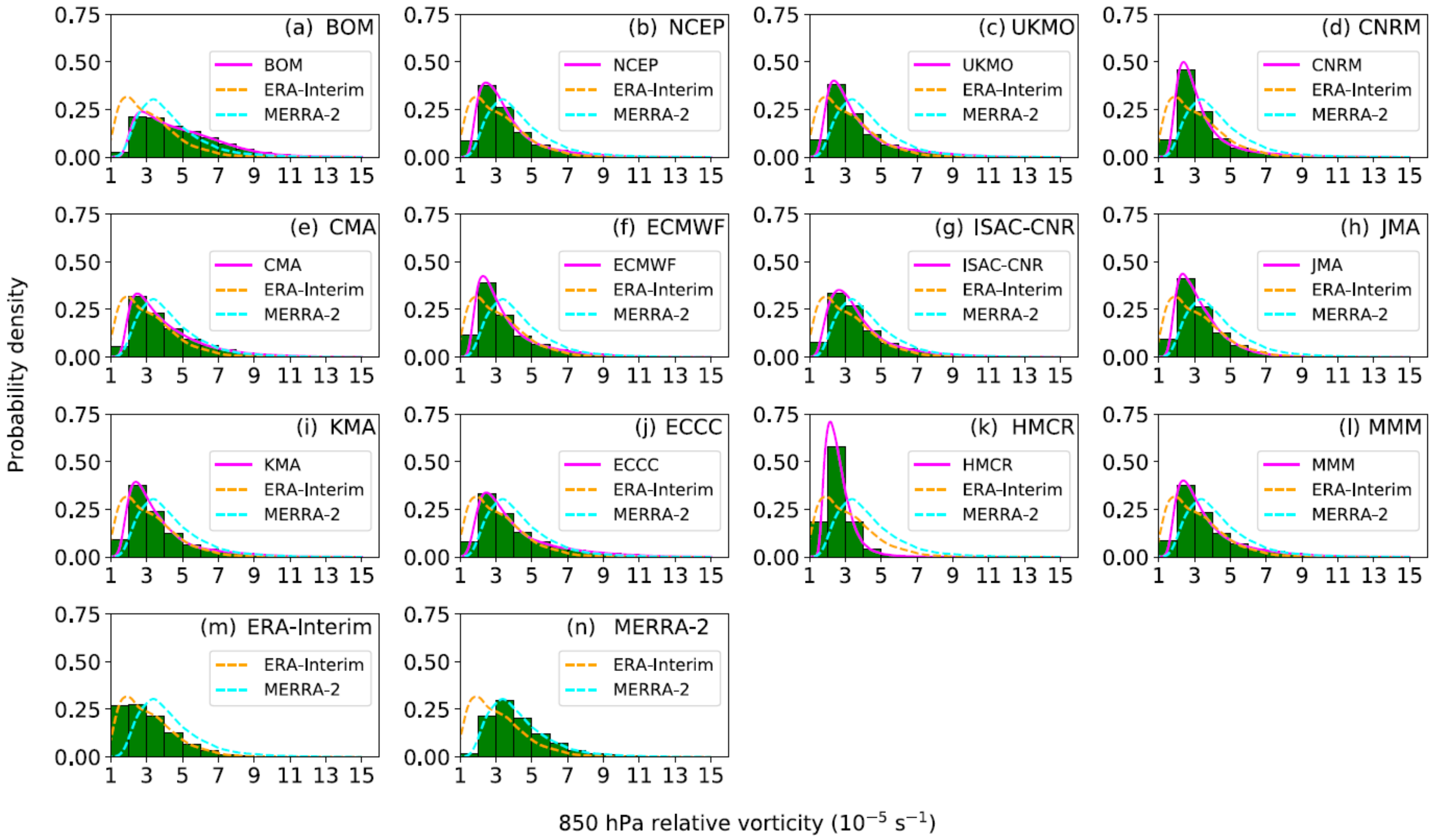
- As lead time increases, track forecasts degrade much more quickly over the Arabian Sea than India or the Bay of Bengal




Growth in forecast depression track error for each S2S model. Computed as the difference in track error at lead times of 12-15 days and 0-3 days.

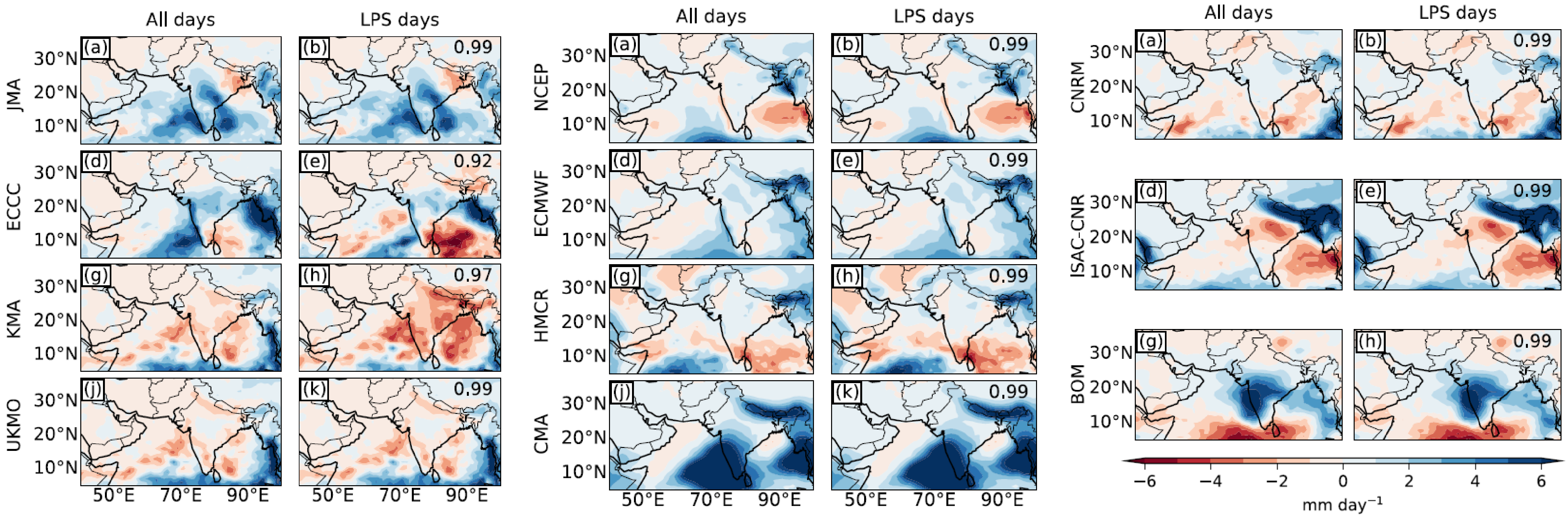
# System intensity

- Intensity PDFs generally fall between the two reanalyses
- But significant variability in right-hand tail




Distributions of LPS intensity (measured using central relative vorticity) in S2S reforecasts.

# Precipitation biases

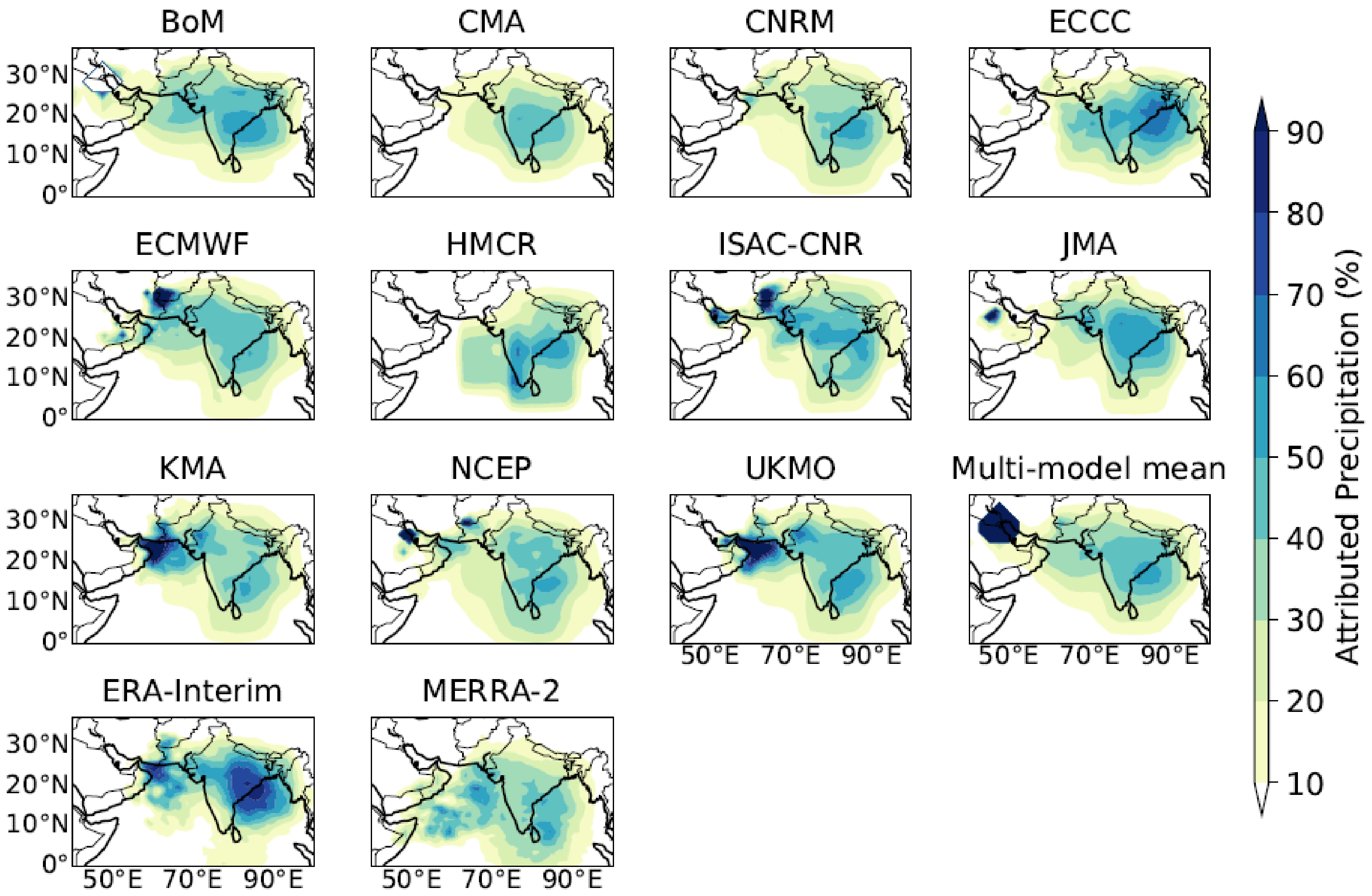



Mean precipitation error (compared with IMERG) for each S2S model (left columns) and for LPS days only (right columns).

- LPSs appear to responsible for the majority of monsoon rainfall biases in S2S models

# Rainfall attribution

- S2S models have largely self-consistent monsoons




Fraction of monsoon rainfall (Jun–Sep 2001–2010) that falls within 800 km of an LPS centre. IMERG is used for the reanalysis tracks.

# Composite precipitation

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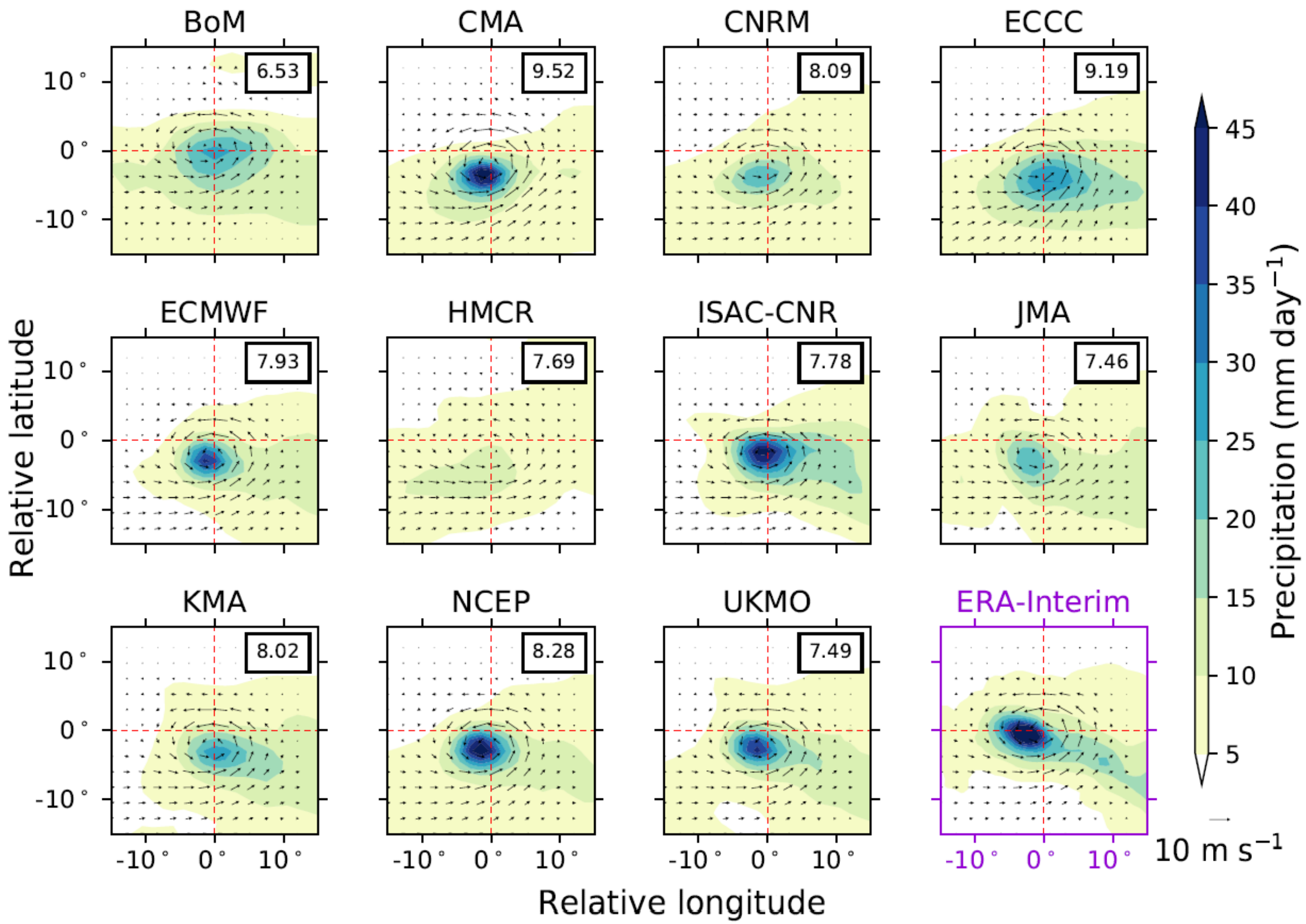
- QG theory predicts that monsoon LPS precip maximum is southwest of the centre

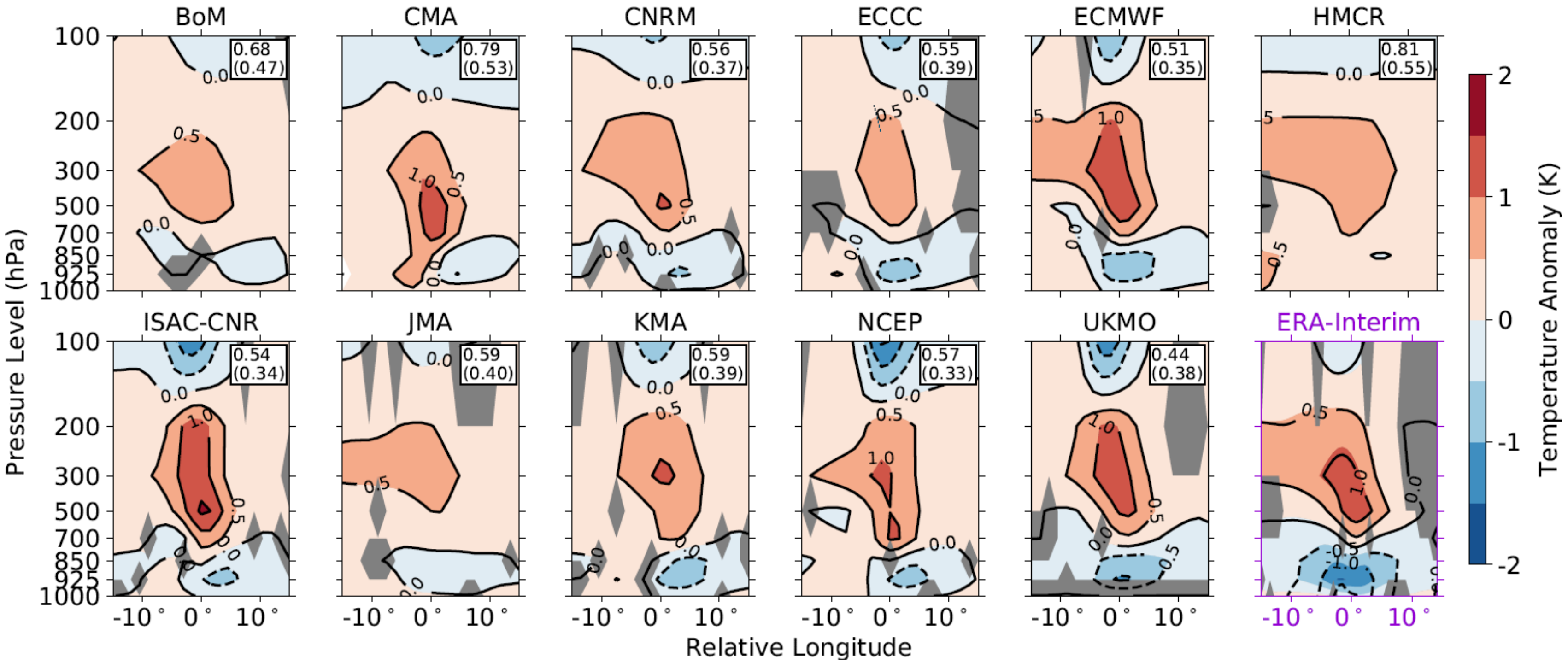
- Almost all models capture this but with very variable magnitude and footprint




Composite storm-centred precipitation and anomalous 850 hPa wind for depressions in each S2S model, compared with ERA-Interim/IMERG. Number in top left indicates RMSE.

# Composite thermal structure

- Strong correlation between magnitude of mid-tropospheric warm core and mean precipitation in model composites

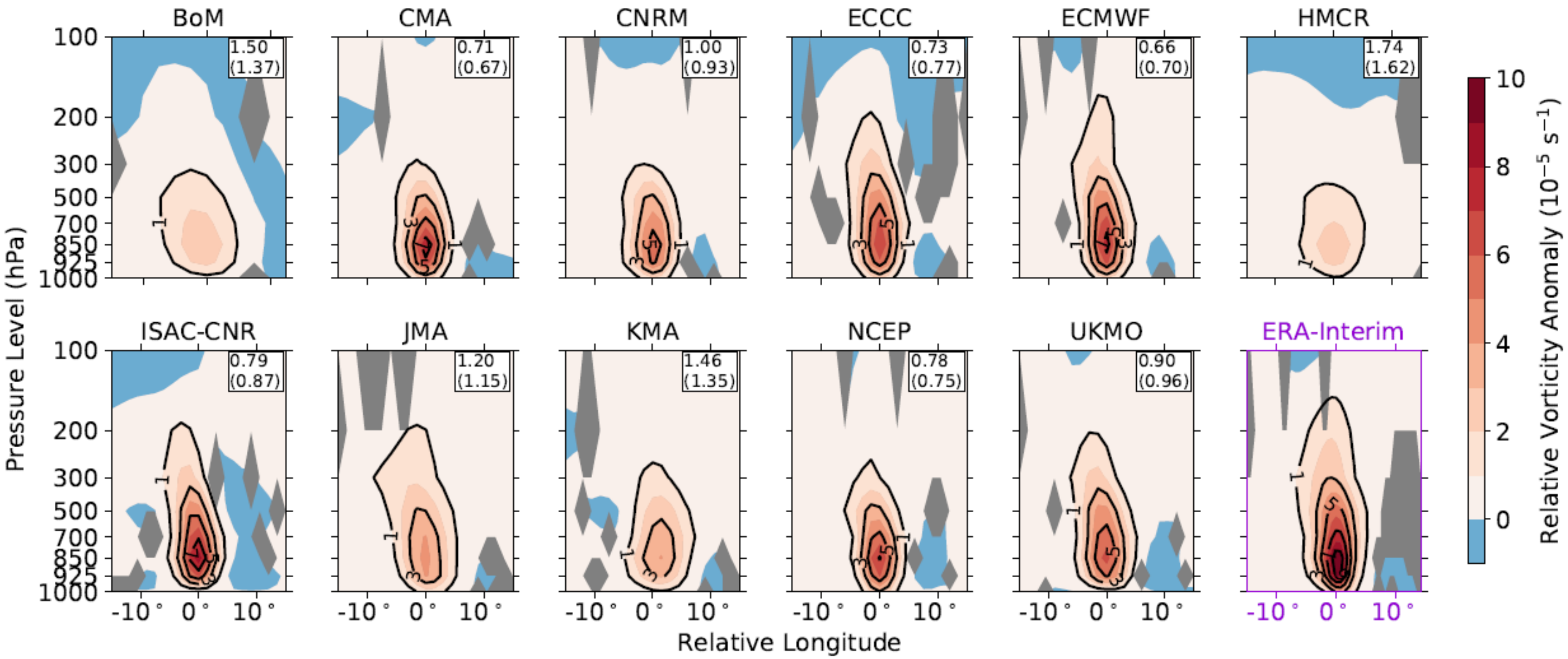



Composite storm-centred temperature anomaly for depressions in each S2S model and ERA-Interim.

# Composite structure of vorticity

- Magnitude of composite warm core related to vorticity its vertical gradient

- Source of precipitation error may lie in representation of embedded MCSs




Composite storm-centered relative vorticity anomaly for depressions in each S2S model and ERA-Interim.

# Conclusions and outlook

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- Tracking of monsoon LPSs and depressions performed in S2S re-forecasts from eleven models
- Forecast track error less than those found for northern hemisphere TCs
- Intensity biases mostly comparable with difference between reanalyses
- Errors in precipitation (which can be very large) are partially related to errors in vorticity structure, which may come about through inadequate representation of convective organisation

- What controls LPS behaviour on seasonal timescales, and how well are such relationships captured in S2S models?

References:

Deoras, Hunt, and Turner (2020). Comparison of the prediction of Indian monsoon low-pressure systems by Subseasonal-to-Seasonal prediction models. *Weather and Forecasting*. doi:10.1175/WAF-D-20-0081.1

Deoras, Hunt, and Turner (2020). The simulation of the structure of strong Indian monsoon low-pressure systems by Subseasonal-to-Seasonal prediction models. *QJRMS*. In preparation.

# Supplementary: S2S model metadata

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| Model | Re-forecast length (days) | Resolution | Ensemble size | Re-forecast frequency | Ocean coupled | Intensity threshold ($10^{-5}$ $s^{-1}$) |
|---|---|---|---|---|---|---|
| BoM | 62 | ~2° × 2° (T47), L17 | 33 | Six per month | Yes | 6.16 |
| CMA | 60 | ~1° × 1° (T266), L40 | 4 | Daily | Yes | 4.97 |
| ECMWF | 46 | 0.25° × 0.25° (Tco639), L91: days 0-15<br><br>0.5° × 0.5° (Tco319), L91: after day 15 | 11 | Two per week | Yes | 4.16 |
| ECCC | 32 | 0.45° × 0.45°, L40 | 4 | Weekly | No | 3.99 |
| HMCR | 61 | 1.1° × 1.4°, L28 | 10 | Weekly | No | 2.97 |
| ISAC-CNR | 32 | 0.8° × 0.56°, L54 | 5 | Every five days | No | 4.43 |
| JMA | 33 | ~0.5° × 0.5° (TL479), L100 | 5 | Three per month | No | 3.92 |
| KMA | 60 | ~0.5° × 0.5° (N216), L85 | 3 | Four per month | Yes | 4.31 |
| CNRM | 61 | ~0.7° × 0.7° (T255), L91 | 15 | Four per month | Yes | 3.80 |
| NCEP | 44 | ~1° × 1° (T126), L64 | 4 | Daily | Yes | 4.17 |
| UKMO | 60 | ~0.5° × 0.8° (N216), L85 | 7 | Four per month | Yes | 4.35 |
| ERA-Interim | | ~0.7° × 0.7° (N128), L60 | | | | 3.97 |
| MERRA-2 | | 0.625° × 0.5° | | | | 5.11 |