Calibrated probabilistic sub-seasonal forecasting for Pakistan's monsoon rainfall during 2022

(in review : Climate Dynamics)

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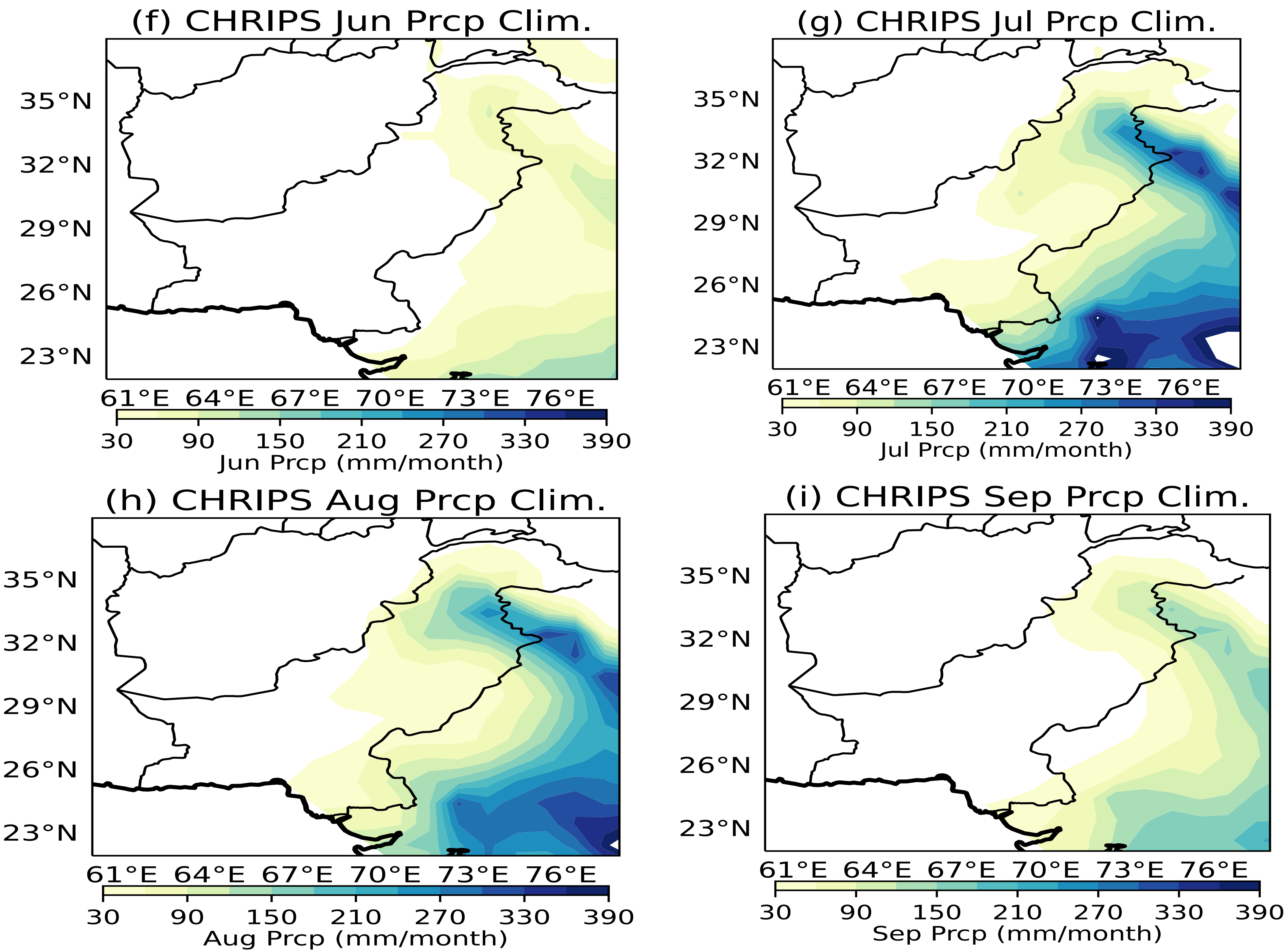
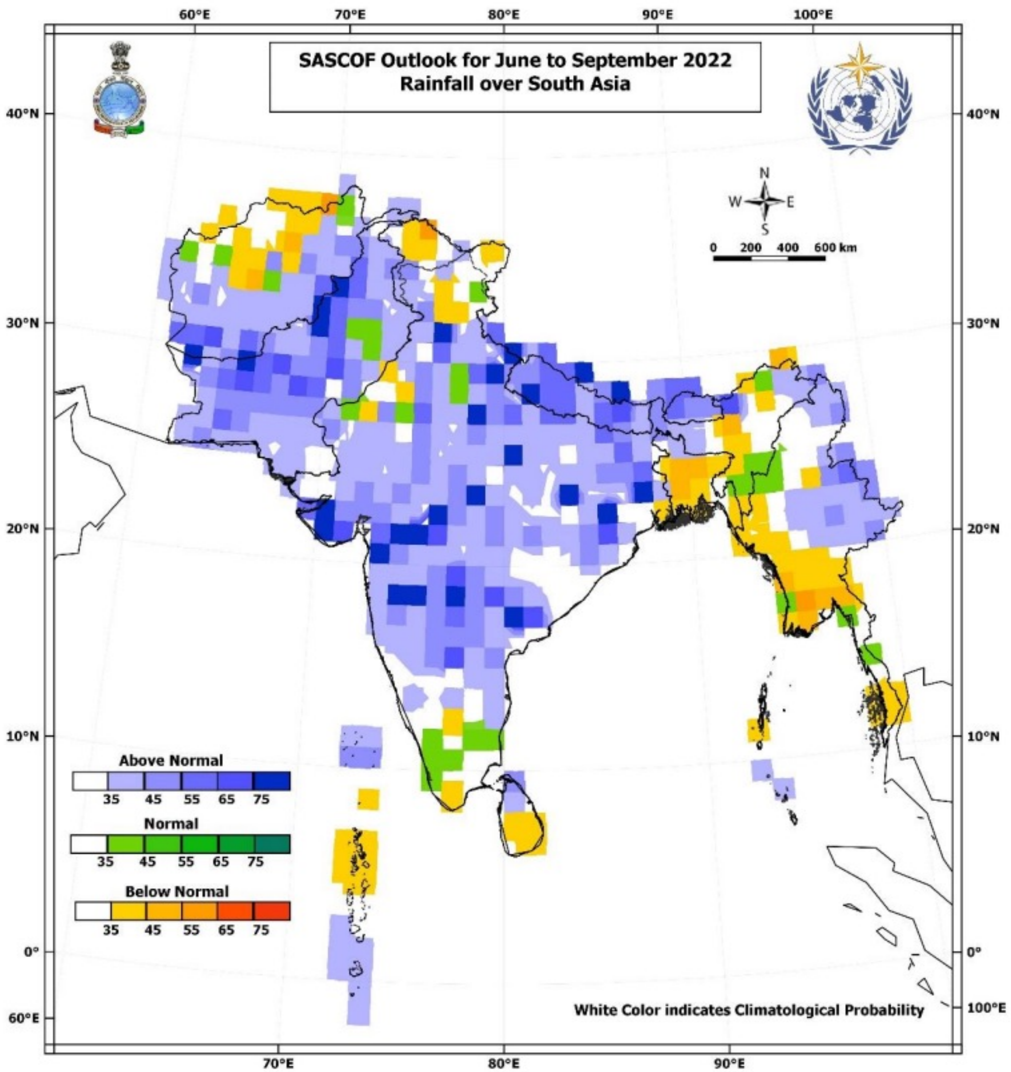
Climatological rainfall over Pakistan (CHIRPS: 1991-2020)

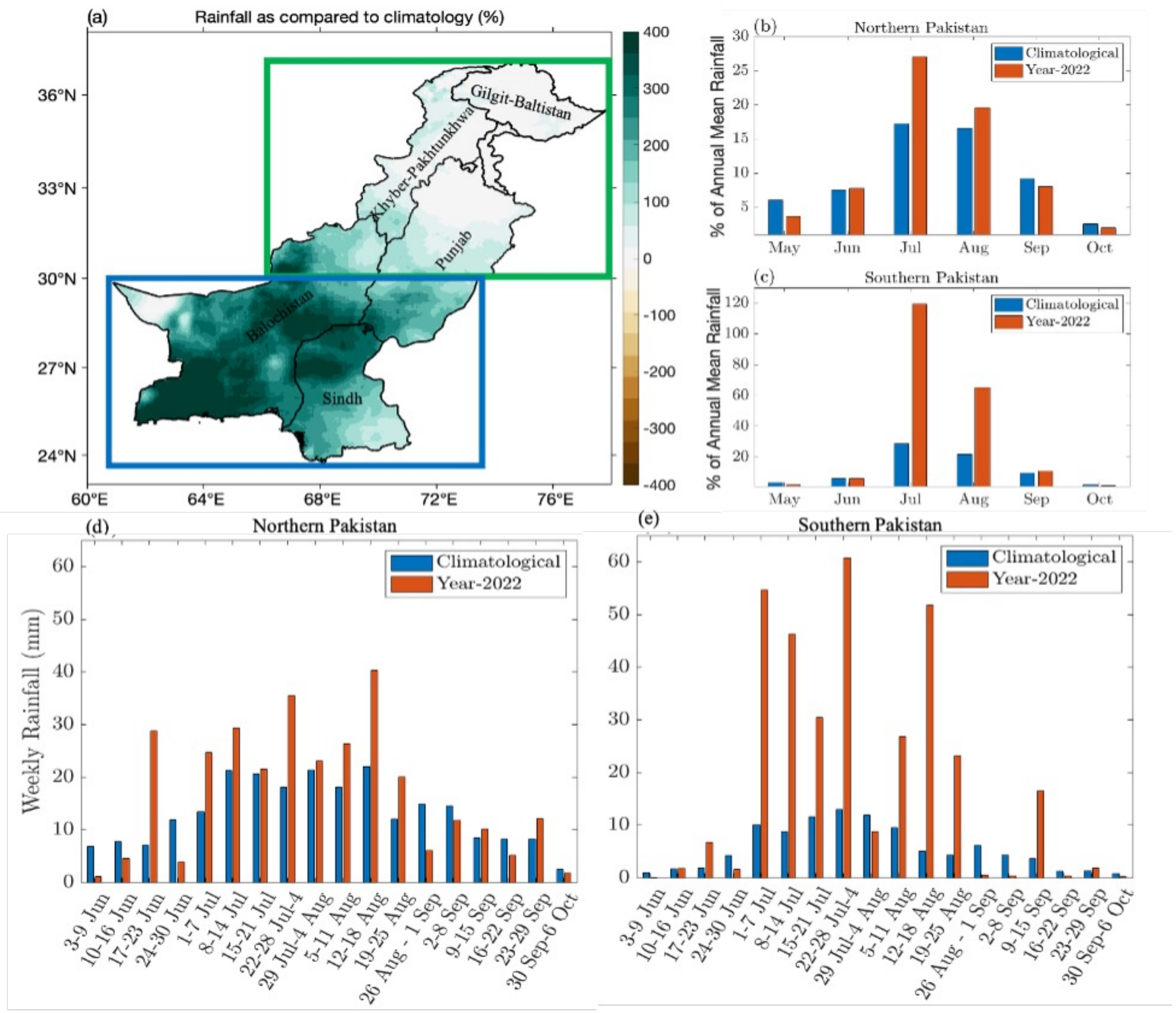


Seasonal forecast : Jun-Sep 2022

SASCOF-22 outlook for South Asia (April IC)



Monsoon:2022



- Seasonal total rainfall in southern Pakistan was almost four times the climatological average and, it was close to average in the north
- Intense rainfall happened in two pulses:
- A four-week pulse of intense rainfall (1-28 July) was followed by a week's break (29 July-4 Aug)
- Second three-week pulse of heavy rain (5-25 Aug)
- Affected 33 million people and resulting in over 1700 deaths, reported loss of $14.9 billion

The aim of this study is to determine the lead time at which state-of-the-art climate forecast systems can offer actionable information for anticipating and managing such climate risks.

Data

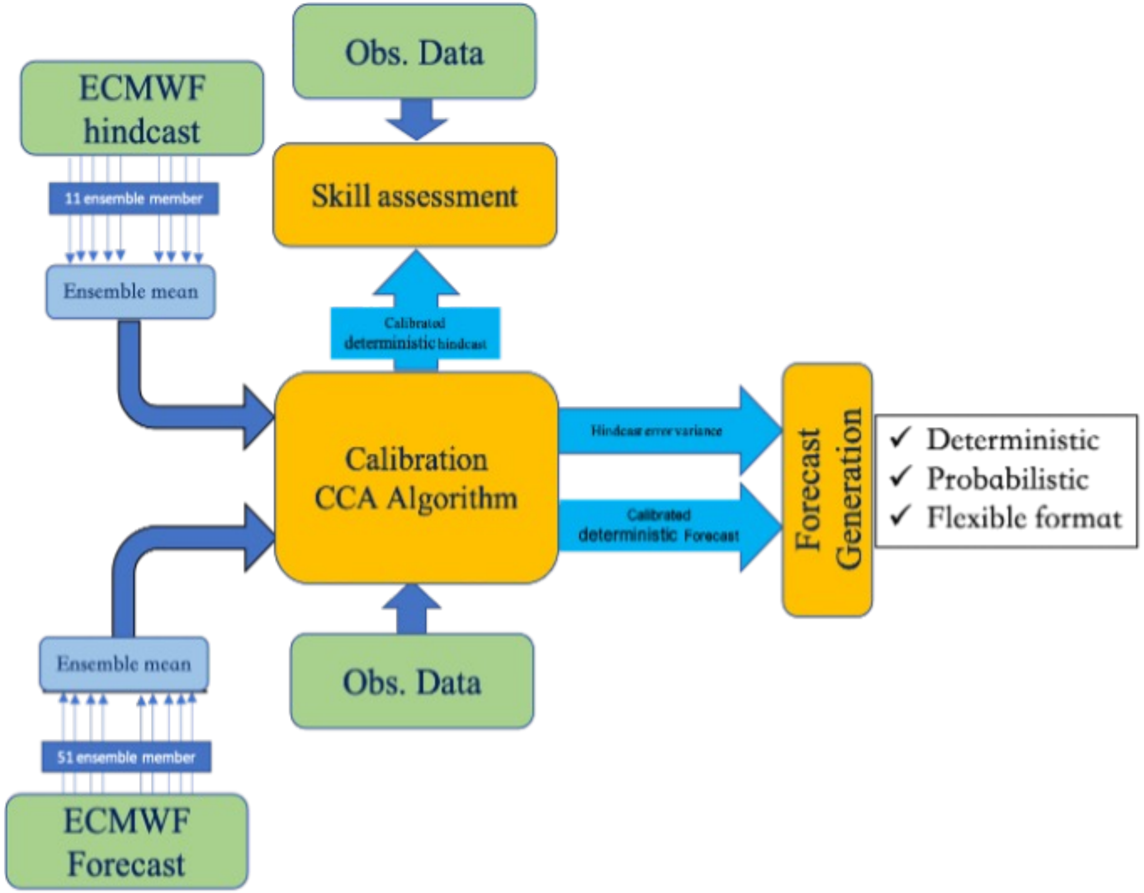
- Forecasts of daily precipitation fields from the ECMWF ensemble prediction system during the summer season of the year 2022 are obtained from Sub-seasonal to Seasonal (S2S) Project database

- ECMWF forecasts are generated by model version CY47R3, which runs at TCO639L137 (~16 km) for the first 15 days and runs at TCO319L137 (~32 km) after day 16 and onwards

- The ECMWF model is initialized twice weekly on Monday and Thursday with 46 days lead time.

- For the analysis, reforecasts from 2002 to 2021 were utilized

Method



PyCPT is used for generation and evaluation of the forecast

Skill Metrics: Ranked Probability Skill Score and Reliability diagrams

Other details ...

- Daily ensemble mean precipitation forecast and reforecasts are summed for days 1-7 for week 1, days 8-14 for week 2, and days 15-28 for bi-week 3-4.

- Forecasts are validated for 2nd June, 30th June, 28th July, and 1st September initializations in 2022

- We have used the CHIRPS v2 for the reference for the 2022 forecast evaluation and bias correction at 0.25°×0.25° resolution for an identical period of model

- National Oceanic and Atmospheric Administration (NOAA) OLR data is used to analyzed the northward propagation over the Indian monsoon region.

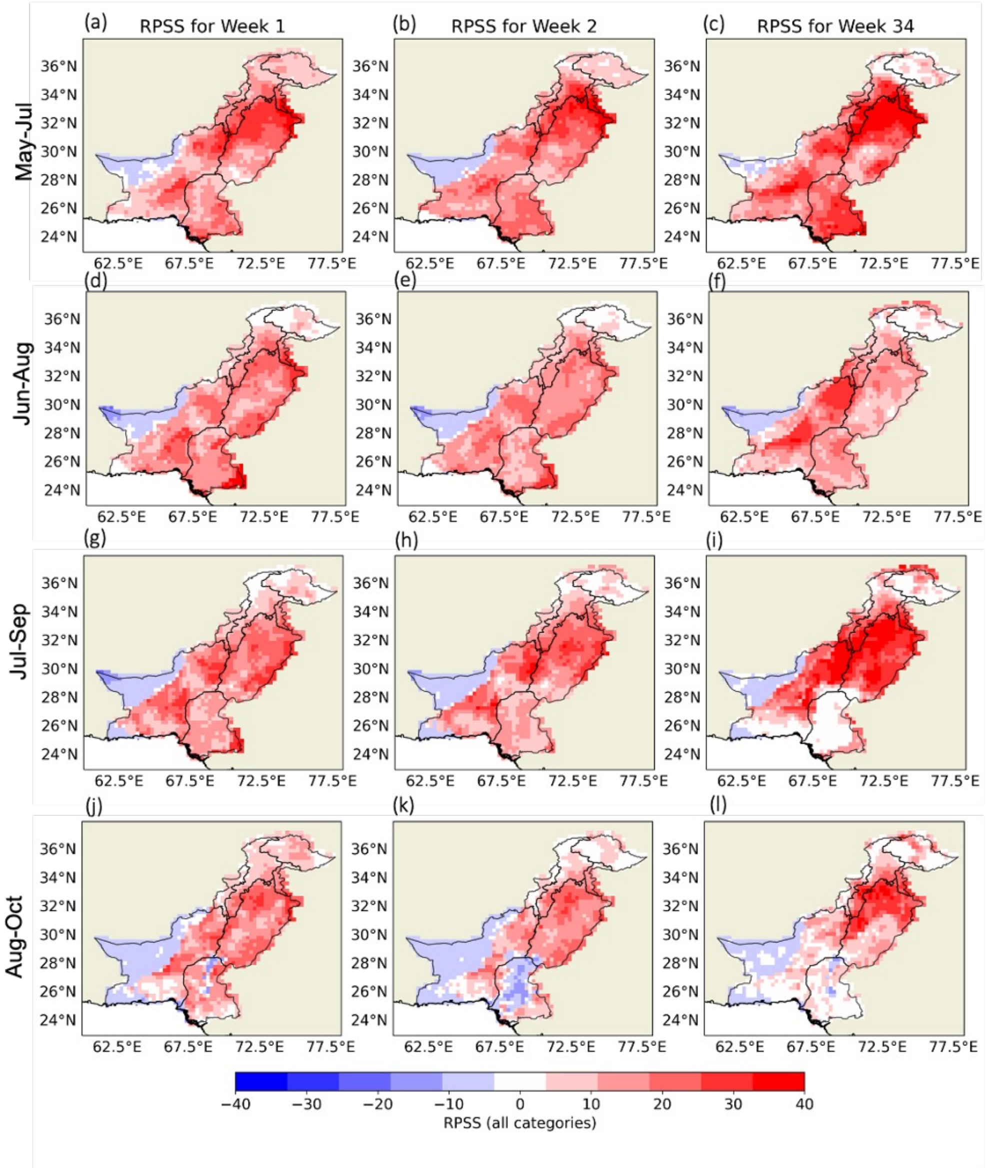
- Twice-weekly reforecasts pooled over three months centered on the forecast initialization month and over the previous 20 years that gives a total of 520-540 reforecast samples train CCA based regression model

- Retroactive cross-validation was used for model validation

- Forecast probabilities are obtained by assuming Student t forecast distribution whose spread is calculated using cross-validated errors of fitted regression model over the hindcast period.

Sub-seasonal Hindcast Skill Assessment

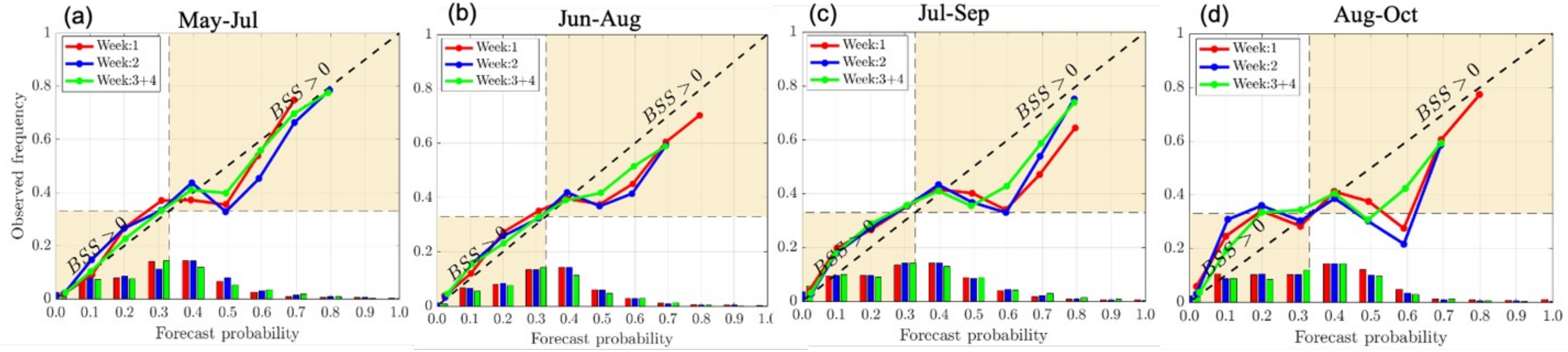
RPSS



- The sub-seasonal predictions remain skillful for 3-4 weeks ahead of time.
- RPSS are positive all over the Pakistan region for week 1 and week 2 except in a small region of Baluchistan which is the dry region.
- Use of a three-month training period with total rainfall as predictor includes some monsoon seasonality.
- This will tend to augment the skill at longer leads if the model forecasts are able to capture the mean seasonal cycle of monsoon rainfall over Pakistan.

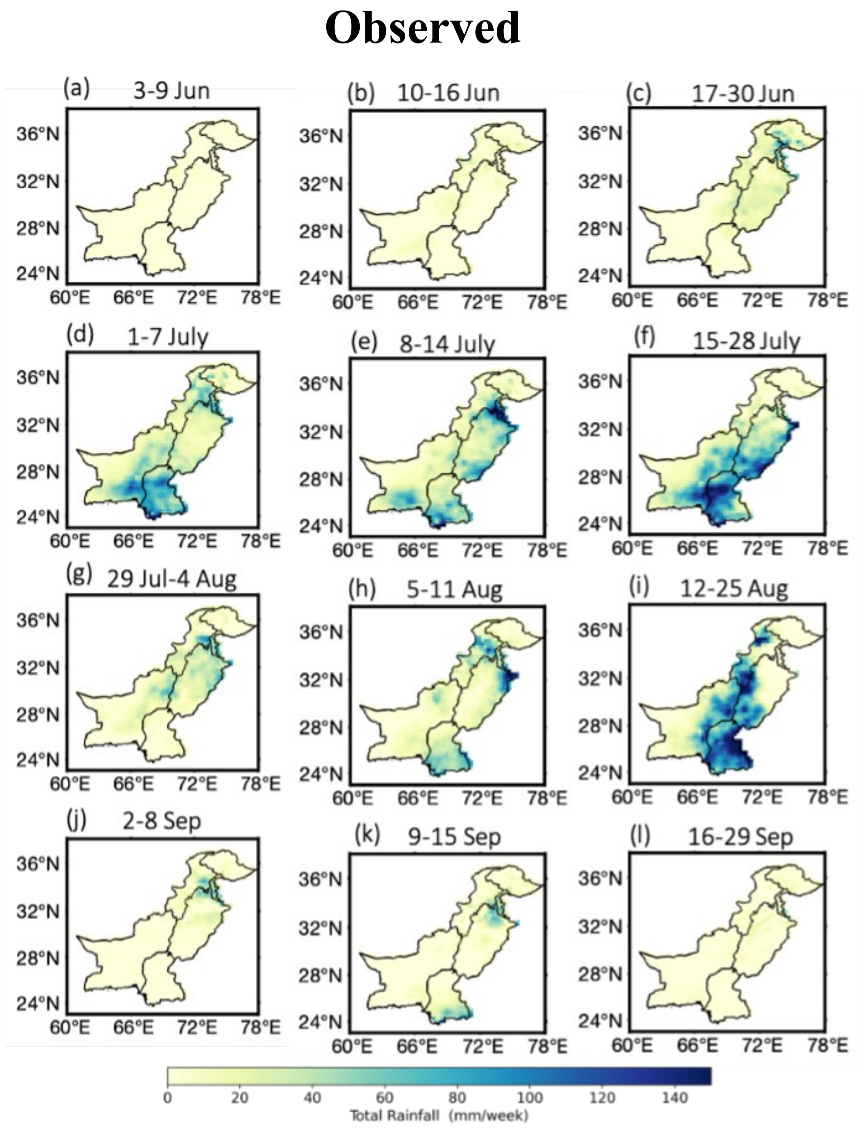
Sub-seasonal Hindcast Skill Assessment

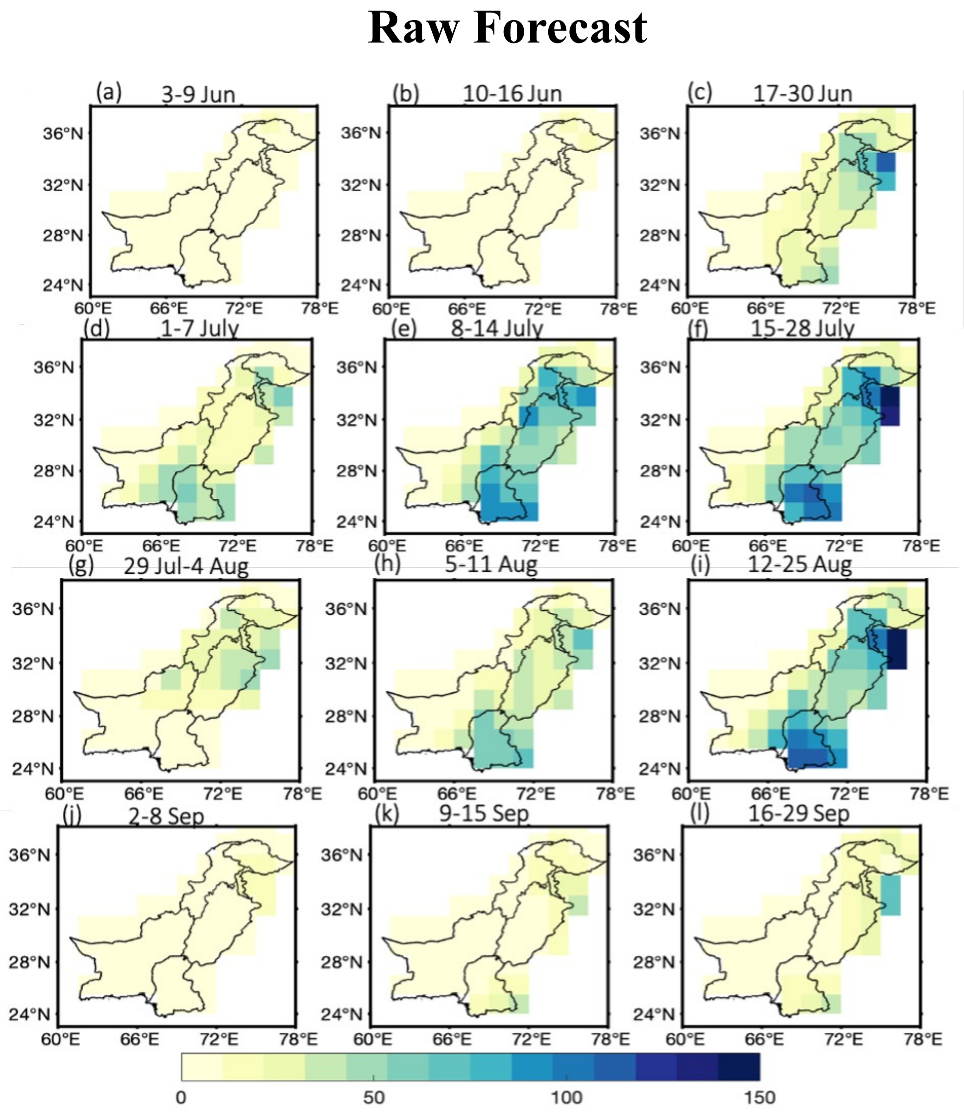
Reliability diagrams



- Reliability diagrams of all tercile category for ECMWF hindcasts pooled over Pakistan.
- The forecasts are reliable as curve falls into positive the Brier Skill Score (BSS) area for a wide range of forecast probabilities.
- The forecasts are sharp; as forecast falls along the diagonal and curves extend over a significant range of forecast probabilities

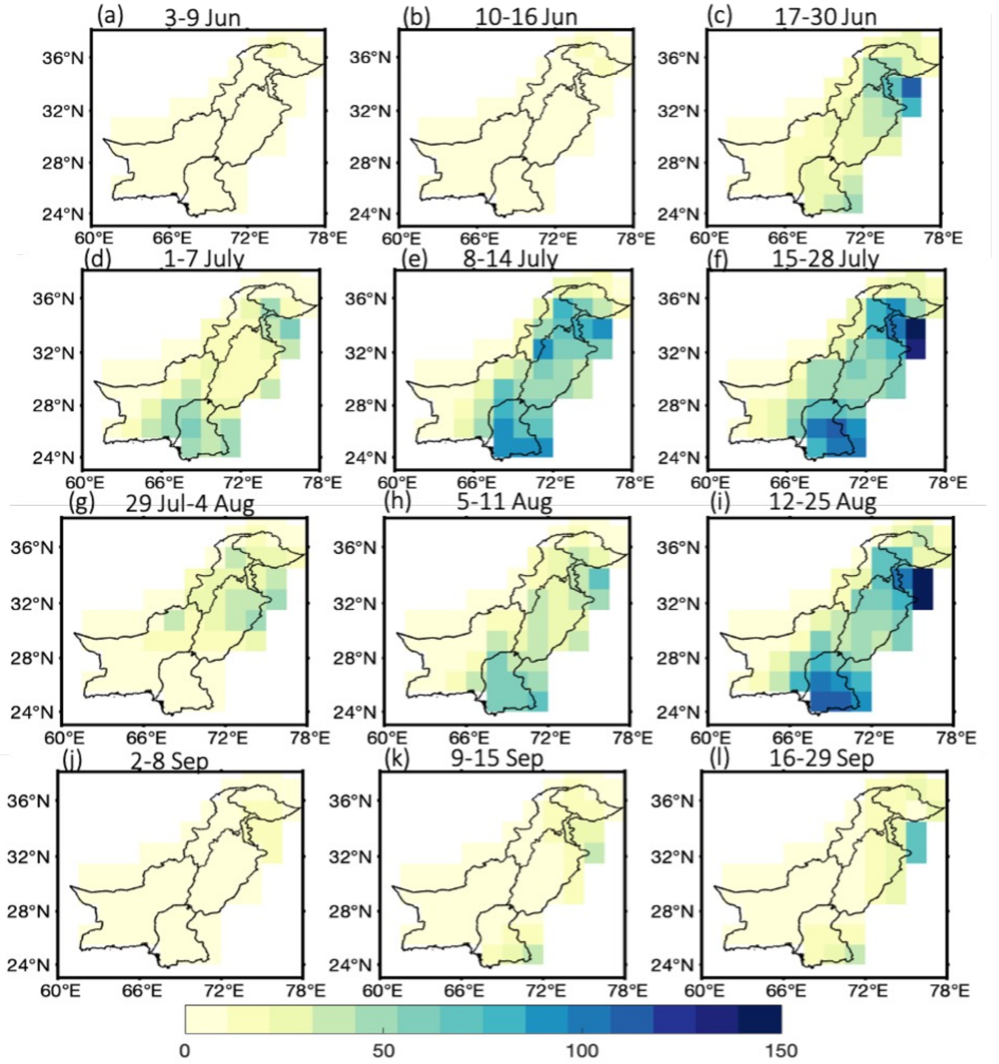
Weekly and bi-weekly accumulated total rainfall



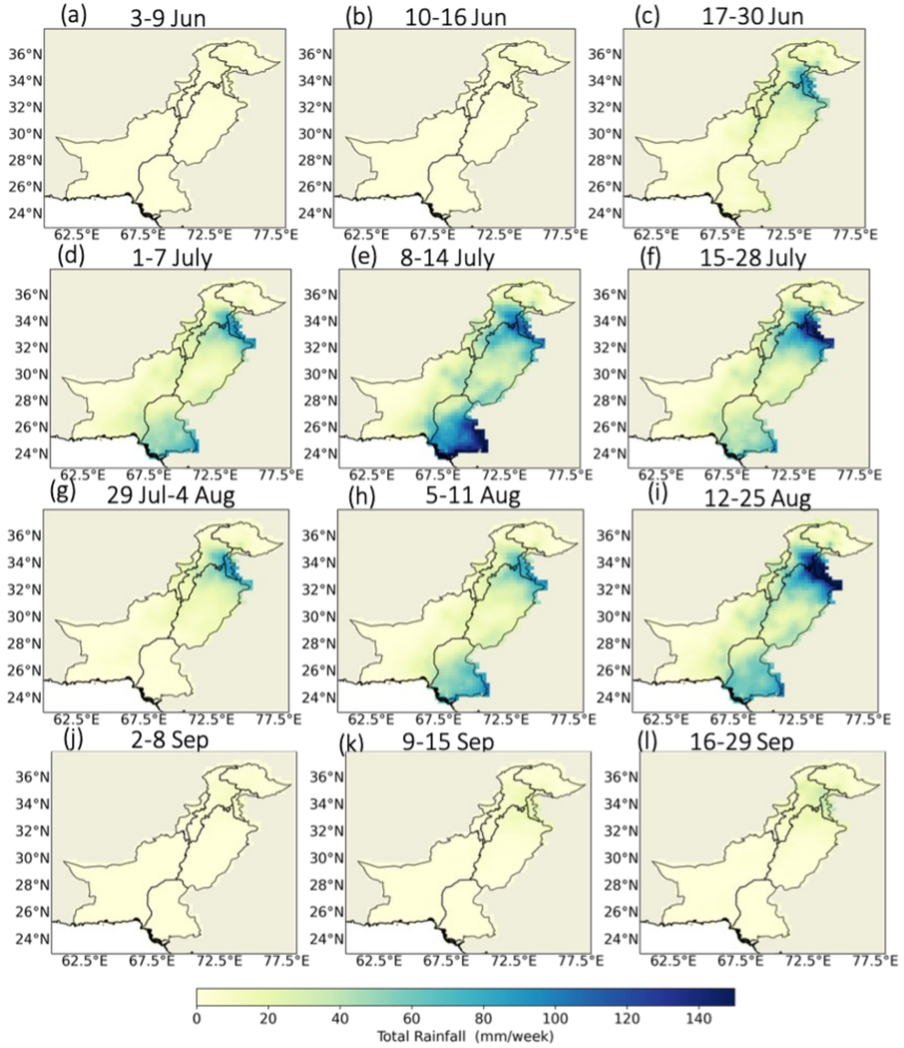


Weekly and bi-weekly accumulated total rainfall

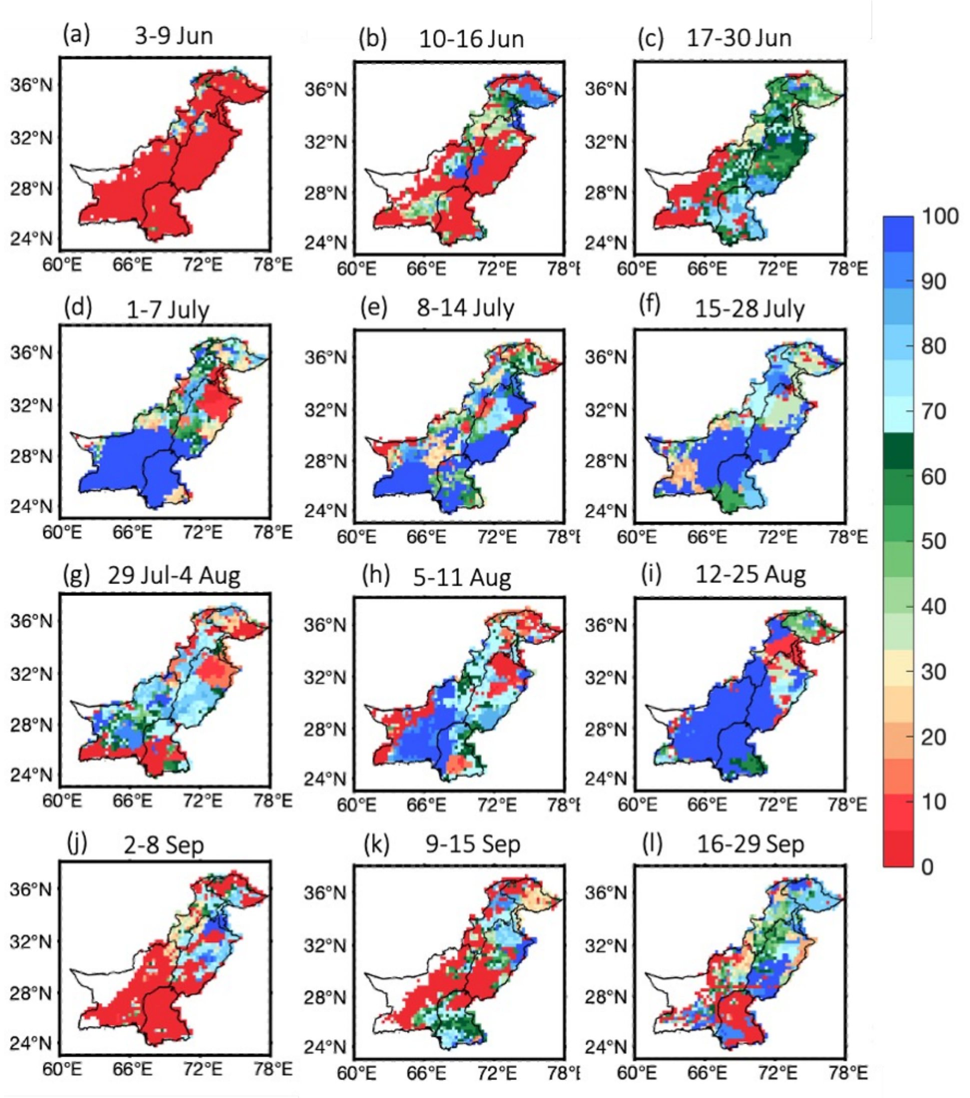
Raw Forecast

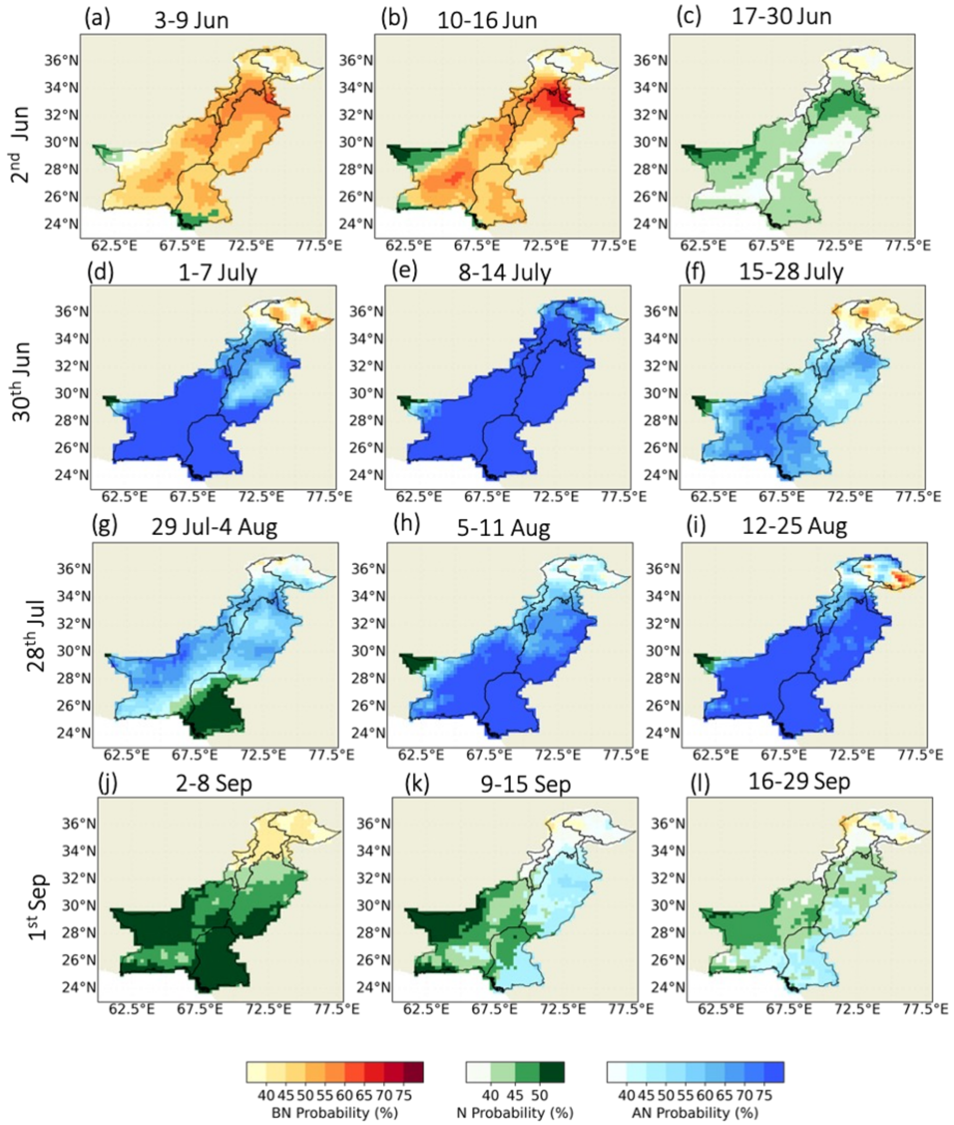


Downscaled and bias corrected Forecast

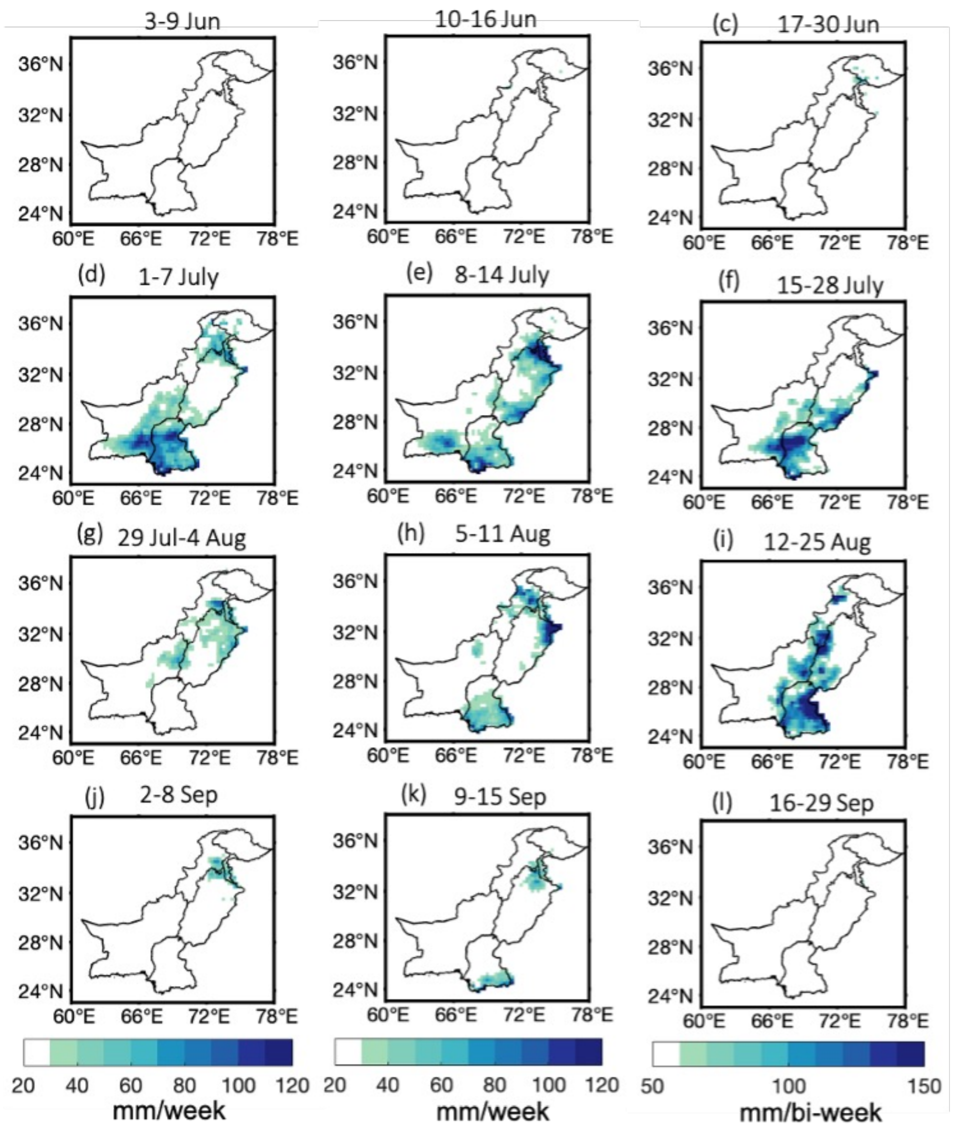


Probabilistic forecast verification : Tercile category

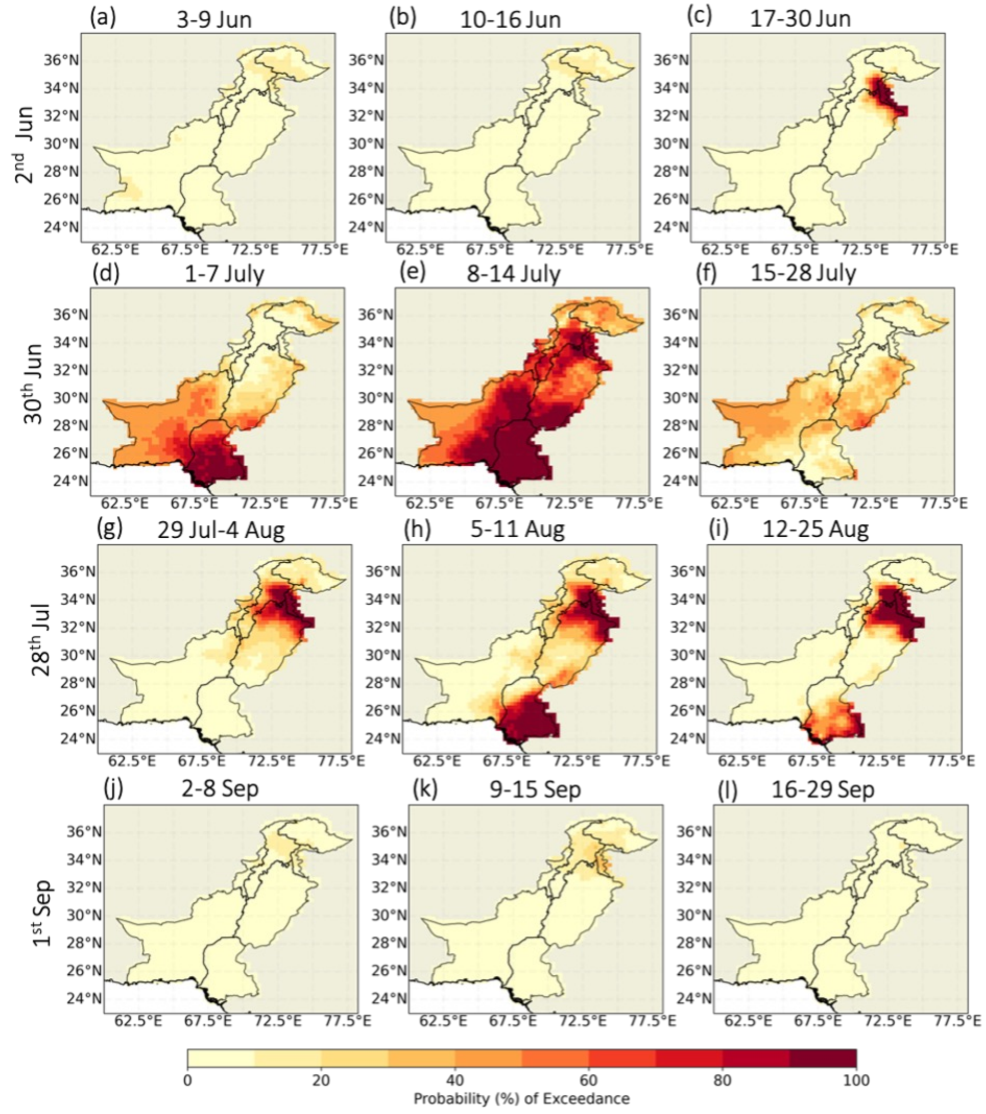




Probabilistic forecast verification: Flexible format

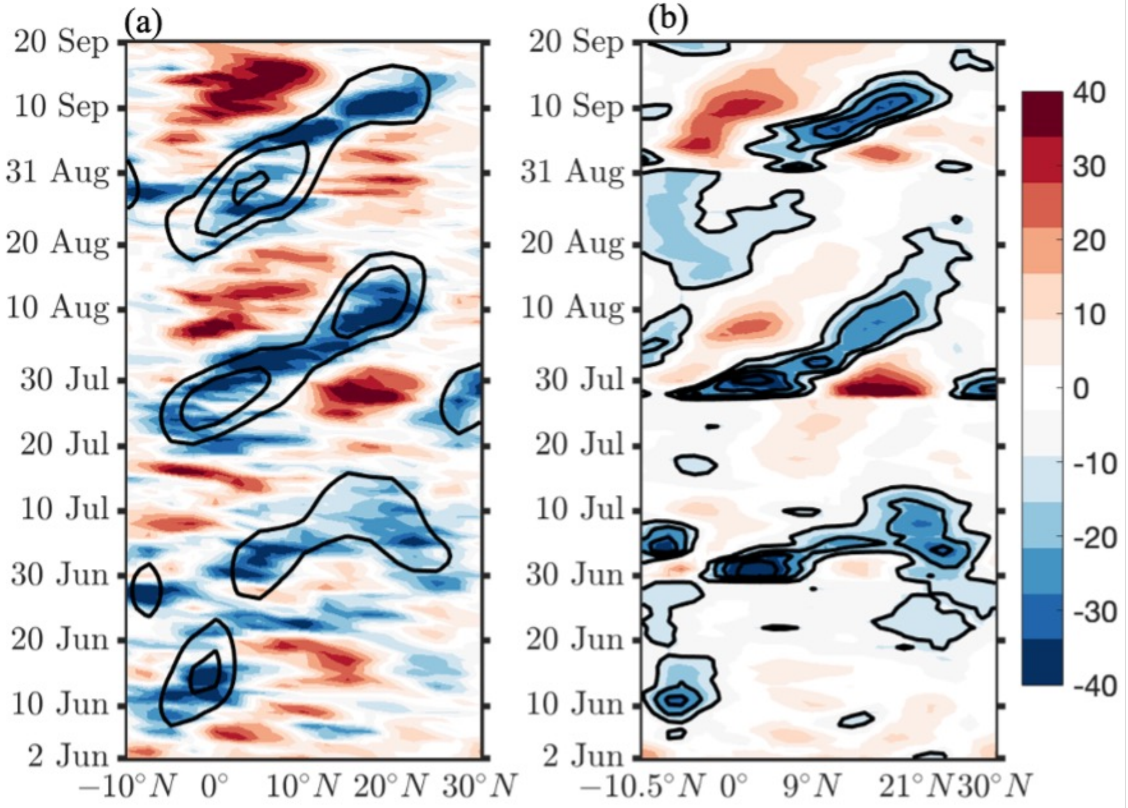


Heavy rainfall if weekly accumulated rainfall > 30 mm



Heavy rainfall if weeks 3-4 accumulated rainfall > 60 mm

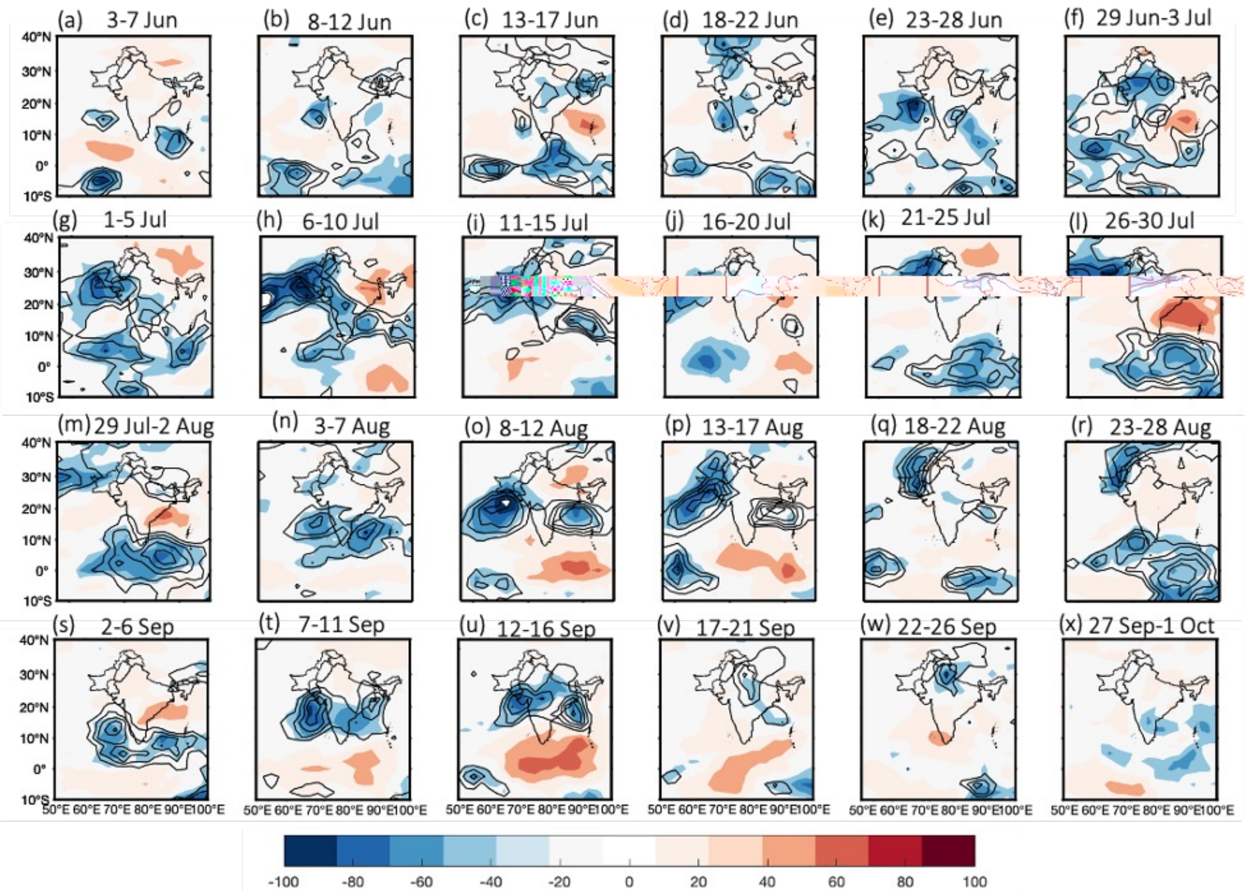
Monsoon intra-seasonal Oscillations during 2022



Hovmöller diagram of (a) observed 30-90 days Lanczos band pass filtered Outgoing Longwave Radiation anomalies for Jun-Sep 2022 and (b) ECMWF forecasted ensemble mean averaged Outgoing Longwave Radiation anomalies from ECMWF forecasted initialized on 2nd June, 30th June, 28th July and 1 September the season 2022. OLR filed is longitudinally averaged between 60-100$°E$. Leads of each initialized forecast are used till the next initialization.

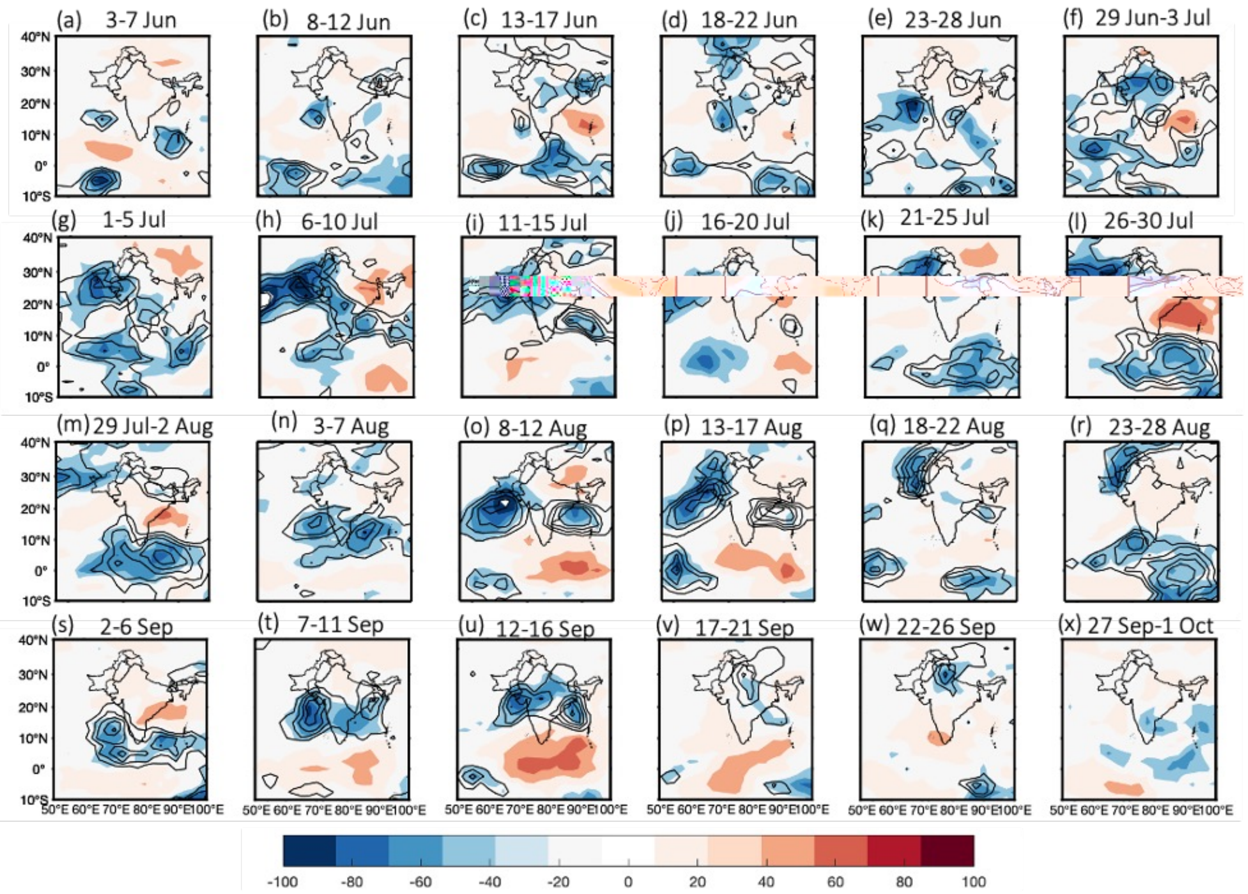
- Three distinct MISO events were observed during the monsoon season of 2022.
- The sub-seasonal forecasts from ECMWF successfully captured all three MISO events when MJO was active in the climate system before forecasts were initialized
- However, forecasts are able to capture initiation of MISO events at three-week lead times, but the signal becomes very weak as ensemble drift apart from each other at longer leads

Monsoon intra-seasonal Oscillations during 2022



Shaded: Raw OLR total anomalies

Contours (negative only) : 30-90 days Lanczos bandpass



Shaded: Raw ensemble mean OLR total anomalies

Contours (negative only) : 21-days running mean of raw ensemble mean OLR anomalies

Conclusions

- Tercile probabilistic forecasts verified informative up to four weeks lead time during the entire monsoon season.

- Forecast of the probabilities of exceedance demonstrated that the heavy rainfall events over southern Pakistan throughout July and August were predictable up to two weeks in advance.

- Skills assessment of retroactively calibrated hindcasts suggests that sub-seasonal forecasts from the ECMWF forecast system are accurate, reliable, and sharp up to 4 weeks of lead times during the mature phase (Jul and Aug) of the monsoon.

- The findings suggest that the representation of MISO in the ECMWF model plays a significant role in successful sub-seasonal prediction over Pakistan during monsoon season 2022

- Had such calibrated probabilistic forecasts been available in real time, they might have helped the Pakistan government, institutions, and water resource managers take appropriate action several weeks before the severe flooding occurred, preventing loss of lives and property damage.