Seasonal Rainfall Outlook
Monsoon (June to September – 2025)
Weatherwalay's Multi-Model Meteor (WW3M)

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1. METHODOLOGICAL FRAMEWORK FOR WEATHERWALAY'S MULTI-MODEL METEOR (WW3M)

We utilized the 45 years historical rainfall data from ERA5 Reanalysis at 0.25°×0.25° resolution during the period (1980-2024). The forecast is based on training the historical rainfall dataset with the 29 observed features including:

a. **Springtime Temperature Anomalies** for Pakistan on Monthly/Seasonal Basis, March to May (MAM)
b. **Winter and Spring Snow Cover over Eurasia** on Monthly Basis, January to May (JFMAM)
c. **Monthly Observed Oceanic Indices** during the Monsoon Period: June to September (JJAS) which includes: Indian Ocean Dipole (IOD), NINO 3.4 Region, North Atlantic Oscillation (NAO EOF), Arctic Oscillation (AO), Pacific Decadal Oscillation (PDO)

The Springtime Temperature Anomalies Dataset was made available from Copernicus Climate Datastore site under the product title "Essential climate variables for assessment of climate variability from 1979 to present". The grided temperature dataset with pixel size of 0.25°×0.25° was averaged over the Pakistan and anomalies were calculated from the climatological mean (1991-2020). Similarly, for Winter and Spring Snow Cover dataset, daily fractional snow cover data at 24 km resolution were acquired from Rutgers University's Global Snow Lab, which utilizes NOAA satellite retrievals processed through their standardized snow monitoring system. And the Monthly Observed Oceanic Indices was sourced from the World Climate Service's "Climate Index Data" portal site.

The forecasted indices data for all oceanic parameters for the monsoon season 2025 were obtained from 9 global forecasting models which include (UKMO, BOM, ECCC, MeteoFrance, ECMWF, CMC, DWD, JMA, and CFSv2) as well as Multi-Model Ensemble forecast. All these forecasts were made available by the World Climate Service platform under the title "Copernicus Index Forecast" as part of their paid product. The forecast conditions were initialized on 1st May 2025 with 4 months lead time. Similarly, the observed Springtime Temperature Anomalies and Winter & Spring Snow Cover over Eurasia on both monthly and seasonal basis was obtained from the above-mentioned sources for the monsoon forecast 2025.

Following a comprehensive feature selection process, we quantitatively assessed the associations between the 29 predictor variables and monsoon rainfall using multiple statistical metrics, including Pearson correlation coefficients (r) to evaluate linear relationships, standard deviation (σ) to measure interannual variability, and climatological normals (1991-2020 baseline) for anomaly detection. These statistically validated predictors were subsequently incorporated into our machine learning framework, where ensemble algorithms were employed to capture the complex, non-linear relationships between the predictors and monsoon rainfall variability. The model architecture was specifically designed to:
(1) account for interaction effects between predictors,
(2) Handle the high-dimensional feature space, and
(3) Optimize predictive skill through rigorous cross-validation steps.

After all these processing and validation steps, Weatherwlay's experimental seasonal forecasting model under the title **Weatherwalay's Multi-Model Meteor (WW3M)** was made available for operational use.

2. SEASONAL RAINFALL OUTLOOK FOR JJAS 2025:

According to WW3M, Pakistan's Summer Monsoon (June to September) 2025 is very likely to be **Above Normal**. The long term climatological normal rainfall for whole Pakistan is ~243.5mm and this year it is forecasted to be **~296mm** which is **18%** from the normal (1991-2020). Figure 1 presents the spatial distribution of the climatological mean rainfall alongside the 2025 forecast, while Figure 2 illustrates both the predicted rainfall anomaly (in millimeters) and the percentage departure from the 1991–2020 climatology.

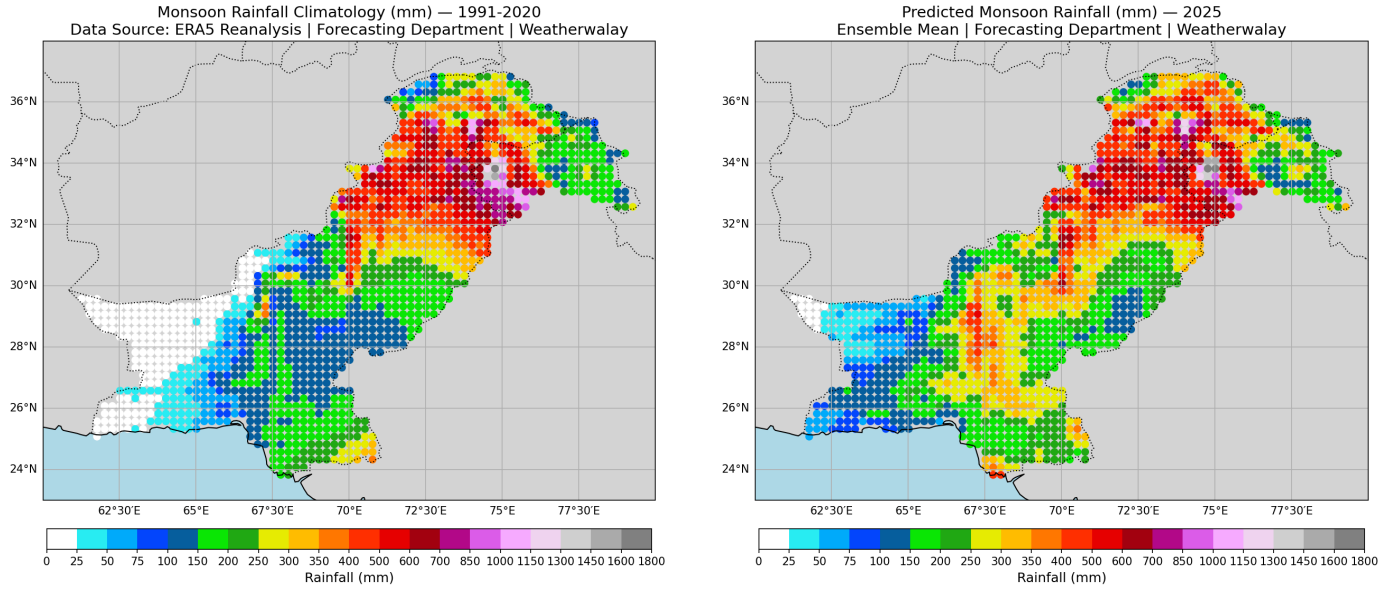

Figure 1: Monsoon Rainfall Climatology (1991-2020) Map (left) and Monsoon 2025 Predicted Rainfall Ensemble Map (right).

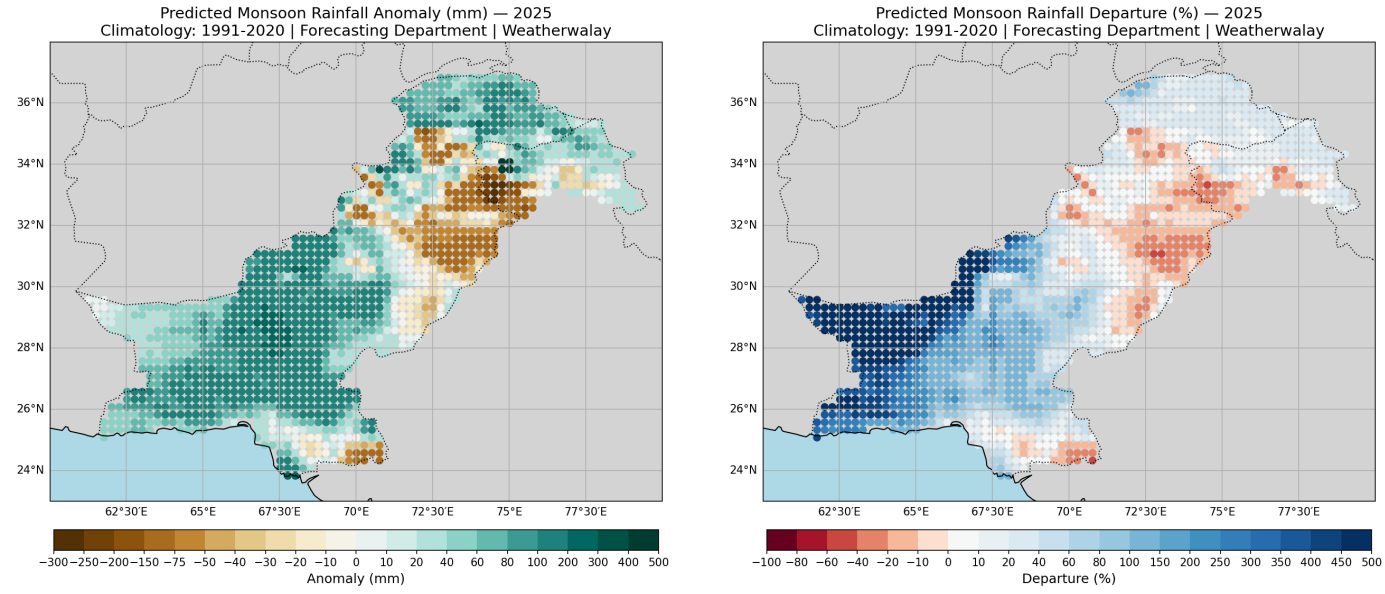

Figure 2: Monsoon 2025 Predicted Rainfall Anomaly Map (left) and Predicted Rainfall Departure Map (right).

On a regional scale, **Punjab** as a whole is very close to climatology (–2.3 %), but with a clear north–south divide: in southern Punjab, cities such as Multan and Bahawalpur are forecast to see moderate above-normal rainfall (roughly +10 % to +30 %), whereas central and northern districts—most notably Lahore and Faisalabad—are expected to remain below normal (on the order of –10 % to –30 %). **Sindh**, by contrast, shows a robust +47.0 % departure. In practical terms, Karachi and Hyderabad are likely to receive roughly +20 % to +60 % more rainfall

than the 1991–2020 mean, with the heaviest positive anomalies along the lower Indus plain and coastal belt. Similarly, **Balochistan** stands out with a very large +124.5 % departure: Quetta and its surrounding highlands could see rainfall more than double the climatological average, raising flood potential even in normally arid areas. In **Khyber Pakhtunkhwa** (+6.7 %), Peshawar and the southern foothills will likely hover around +10 % to +15 % above normal, while the ultrahigh mountain valleys (Dir, Chitral) may see +10 % to +30 %. The Islamabad Capital Territory (+9.5 %) likewise falls into a +10 % to +15 % above-normal range. **Gilgit-Baltistan** (+25.0 %) is expected to have moderately enhanced rainfall (generally +20 % to +40 %), especially in its western sectors. By contrast, **Azad Kashmir** (–4.6 %) is forecast to be slightly below normal (departures near –5 % to –15 %), with the western ridge lines seeing the driest anomalies. **Indian-Occupied Kashmir** (+0.4 %) remains essentially at climatology (±5 % of the mean) (Table 1).

Region	Normal (mm)	Departure (%)	Category
Pakistan	**243.5**	**+17.8**	**Above Normal**
Punjab	317.3	-2.3	Normal
Indian Occupied Kashmir	417.3	+0.4	Normal
Khyber Pakhtunkhwa	466.3	+6.7	Slightly Above Normal
Islamabad Capital Territory	577.6	+9.5	Slightly Above Normal
Gilgit Baltistan	390.2	+25.0	Highly Above Normal
Sindh	249.9	+47.0	Highly Above Normal
Balochistan	179.9	+124.5	Highly Above Normal
Azad Kashmir	604.7	-4.6	Normal

Table 1: Monsoon 2025 Predicted Rainfall Anomaly Map (left) and Predicted Rainfall Departure Map (right).

3. POSSIBLE IMPACTS

- The 2025 monsoon's very high departures in Balochistan and Sindh, especially around urban cities like Karachi, Hyderabad, Sukkur, Larkana, Sibbi, Khuzdar raise significant **Flash-Flood** and **Urban-Flood** risks, while southern Punjab (Multan, Bahawalpur) may see above normal rainfall, increasing localized inundation even though central and northern Punjab (Lahore, Faisalabad, Gujranwala) trend slightly below normal.
- Khyber Pakhtunkhwa and Islamabad should expect modestly above-normal rains, accelerated snowmelt and potential **GLOFs** in upstream valleys demand vigilance. Runoff from the Karakoram foothills will heighten flash-flood and **Landslide** risks along the Swat and Kabul River corridors. Mountainous areas of Azad Kashmir and Indian-Occupied Kashmir face similar short-term river surges (Neelum, Jhelum, Chenab) and landslide threats.
- **Kharif Crops** in Sindh, southern Punjab, and KPK are likely to benefit from higher soil moisture but should prepare for potential **Waterlogging**. Pre-monsoon heatwaves may persist briefly in Karachi, Hyderabad, and Multan, while heatwave conditions elsewhere should remain within typical ranges. Rapid reservoir recharge in Balochistan and Sindh will bolster urban water supplies; however, hill-district roads and urban drainage systems in Lahore and Karachi must be ready for intermittent heavy showers. Public-health agencies should also monitor dengue and **Malaria** risk in low-lying wards.
- Highly variable rainfall patterns can trigger sudden cloudbursts in hilly areas; even a short, intense downpour in upstream catchments can generate rapid runoff, leading to flash floods downstream. **Cloudbursts** or intense headwater showers can cause river flows to spike within minutes; downstream villages and farms must monitor upstream gauges and heed early warnings.