Towards a sub-seasonal climate forecast service for extreme precipitation associated with cut-off lows: insights from the Valencia 2024 event

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Valencia DANA

On 29 of October 2024, a cut-off low (COL) affected the Spanish region of Valencia. This event was also known as Valencia's DANA (Depresión Aislada en Niveles Altos). The intensity and persistence of the precipitation led to devastating floods, resulting in 232 fatalities, including 224 in the province of Valencia. This event also caused extensive infrastructural destruction and profound physical and mental health impacts.

The AEMET weather station in the municipality of Turís recorded 185 mm in one hour and 621 mm in 6 hours on that day.

- Figure 1a presents the spatial distribution of total precipitation over the Iberian Peninsula on 29 October 2024 based on ERA5. Its resolution smooths the mean total precipitation at each grid cell, with a maximum of 95.5 mm at 39.25°N–0.75°W.
- Figure 1b shows that the weekly mean precipitation exceeded the upper tercile and the extreme p90 during the target week (i.e. 28 October to 3 November 2024).
- Figure 1c displays the observed tercile category during the target week.

Given that the heavy rainfall during the event affected weekly precipitation means, could ECMWF sub-seasonal climate predictions have anticipated it?

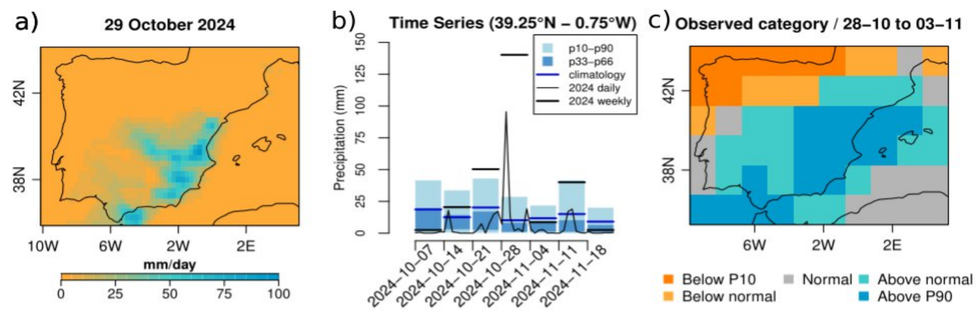


Figure 1. Spatial distribution of total precipitation on 29 October 2024 from ERA5 (a). The daily and weekly temporal evolution from 7 October to 24 November 2024 at the ERA5 grid point where maximum precipitation was recorded on the date of the COL event (b), i.e. 39.25°N–0.75°W, compared with the weekly climatological terciles and extreme probabilities (i.e. p10 and p90) for the period 1991–2020. The spatial distribution of the observed tercile or extreme categories during the target week using the model's spatial resolution of 1.5° × 1.5° (c).

Cut-off low detection

Given the relationship between COLs and heavy precipitation events, **could we use a COL detection algorithm to design a COL forecast product to complement and support the precipitation forecast?** The Kasuga et al. (2021) methodology for COL detection has been applied to Z500 fields. This algorithm quantifies the geometric features of a depression based on its horizontal height profile. The height slope of a line intersecting the depression bottom and the nearest tangential point (optimal slope) locally indicates the intensity and scale of an isolated depression.

By applying the Kasuga et al. (2021) detection algorithm to ERA5 for the period 1991–2020, we find that:

- Between one and two events per season account for more than 30% of the total seasonal precipitation (Figure 3a).
- More than one COL every two years, located between the south-western and central IP, produced more than 90 mm of precipitation on average over Valencia (Figure 3b).

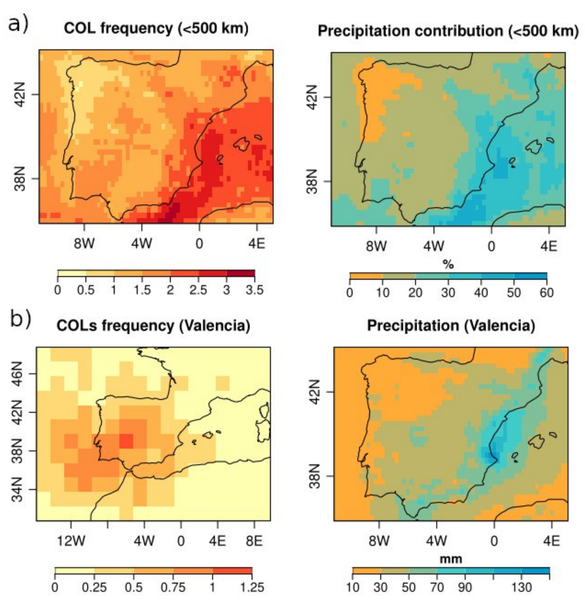


Figure 3. a) Number of days per season in which a COL was detected at less than 500 km with precipitation exceeding p90 (left) and the percentage of precipitation on those days with respect to the total in the SON season (right). b) COLs detected at any distance from Valencia grid points iwhen precipitation exceeded p90 (left) and the average precipitation on these days (right).

Sub-seasonal precipitation forecast

Calibrated weekly accumulated precipitation forecast for 1 to 4 weeks before the DANA event are displayed in Figure 2. Only the forecast issued one week in advance resembles the observed category map in Figure 1c. Wet signals also appear at lead times of 2 and 3 weeks.

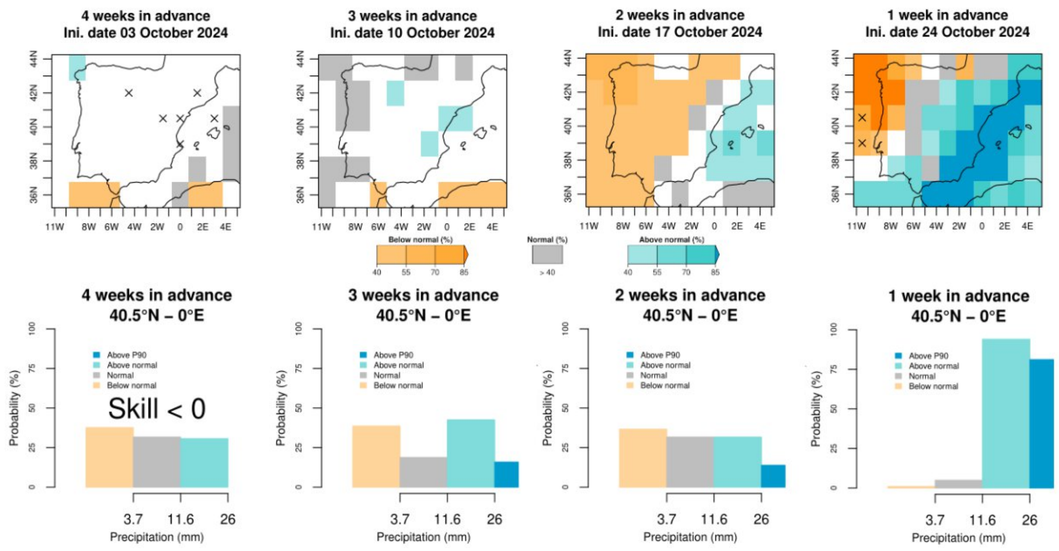


Figure 2. Total accumulated precipitation forecast based on tercile categories (top row) for the target week predicted four, three, two and one weeks in advance (from left to right) for the Iberian Peninsula and the Balearic Islands and for a grid point at 40.5ºN-0ºE (bottom row). Crosses in the maps and the label "Skill < 0" indicate that the climatological forecast significantly outperforms the forecast system, as determined by the Random Walk test applied to the RPSS. White grid cells indicate that probabilities are below 40% for all categories.

Other visualisation products, such as Figure S3, should be explored to better communicate the possibility of precipitation accumulations exceeding 100 mm, as indicated by the forecast system, even at lead times of up to four weeks. In this example, the shaded areas represent the probabilities associated with each category, while the x-axis shows the full range of forecast values without making assumptions about the shape of the underlying distribution.

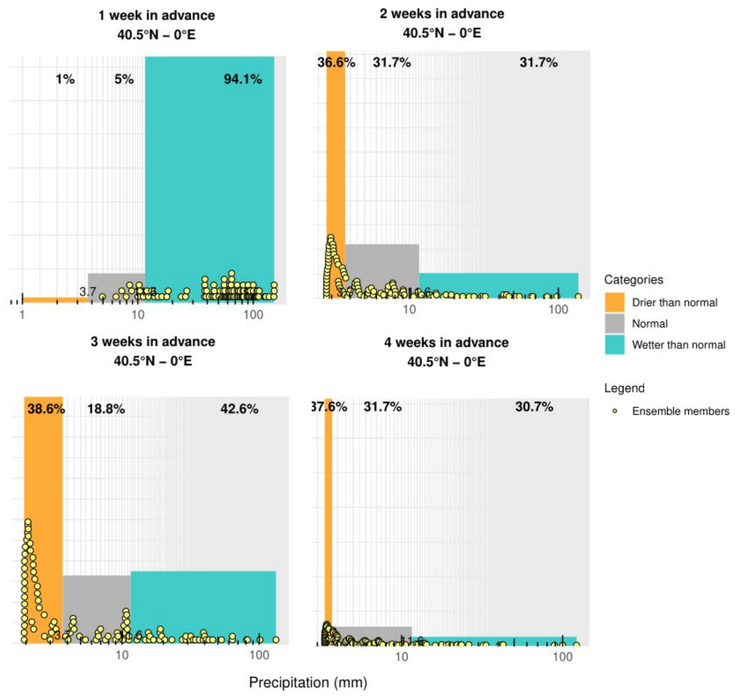
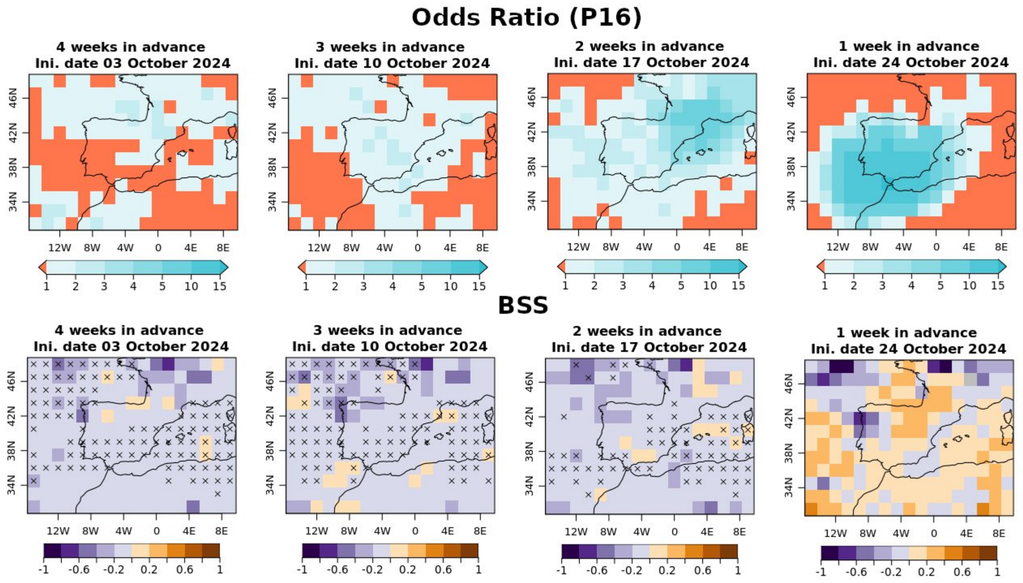


Figure S3. Total accumulated precipitation forecast based on tercile categories for the target week predicted four, three, two and one weeks in advance for a grid point at 40.5ºN-0ºE.

Cut-off lows forecast products

The COL detection algorithm was applied to calibrated forecasts and hindcasts of 500 hPa geopotential height (Z500). Daily detections were aggregated into weekly binary fields and used to derive two forecast products based on odds (Stephenson, 2000) and odds ratio (Prodhomme et al., 2016).

- The **odds-ratio** product (Figure 4) **provides a spatially coherent forecast signal up to three weeks before the event**, whereas the signal becomes weaker and fragmented at four weeks.
- In contrast, the **odds product** only provides a clear signal at shorter lead times.
- Although the **Brier Skill Score** (BSS) is generally low beyond one week, skill at most grid points is not significantly different from climatology, suggesting that the odds-ratio product may still provide useful complementary information alongside precipitation forecasts.



< Figure 4. Odds ratio of the weekly COL forecast (top row) as defined by P16 for the four initialisation dates (3, 10, 17, and 24 October 2024; from left to right), all valid for the target week. Values greater than 1 indicate that a COL centre is more likely to occur than in the climatological reference. BSS (bottom row) for each corresponding initialisation date. Crosses indicate that the Random Walk Test is not significant at the 95 % confidence level.

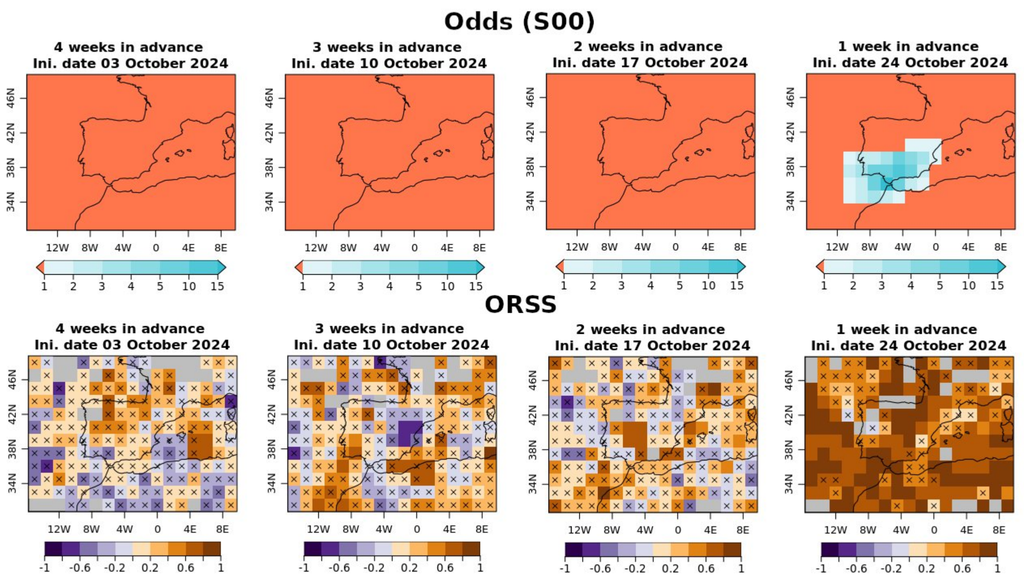


Figure 5. >
Odds of the weekly COL forecast (top row) as defined by S00 for the four initialisation dates (3, 10, 17, and 24 October 2024; from left to right), all valid for the target week. ORSS (bottom row) for each corresponding initialisation date. Crosses indicate that results are not significant.

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