Heavy Precipitations in South-Eastern Spain DANA mostly strengthened by human-driven climate change

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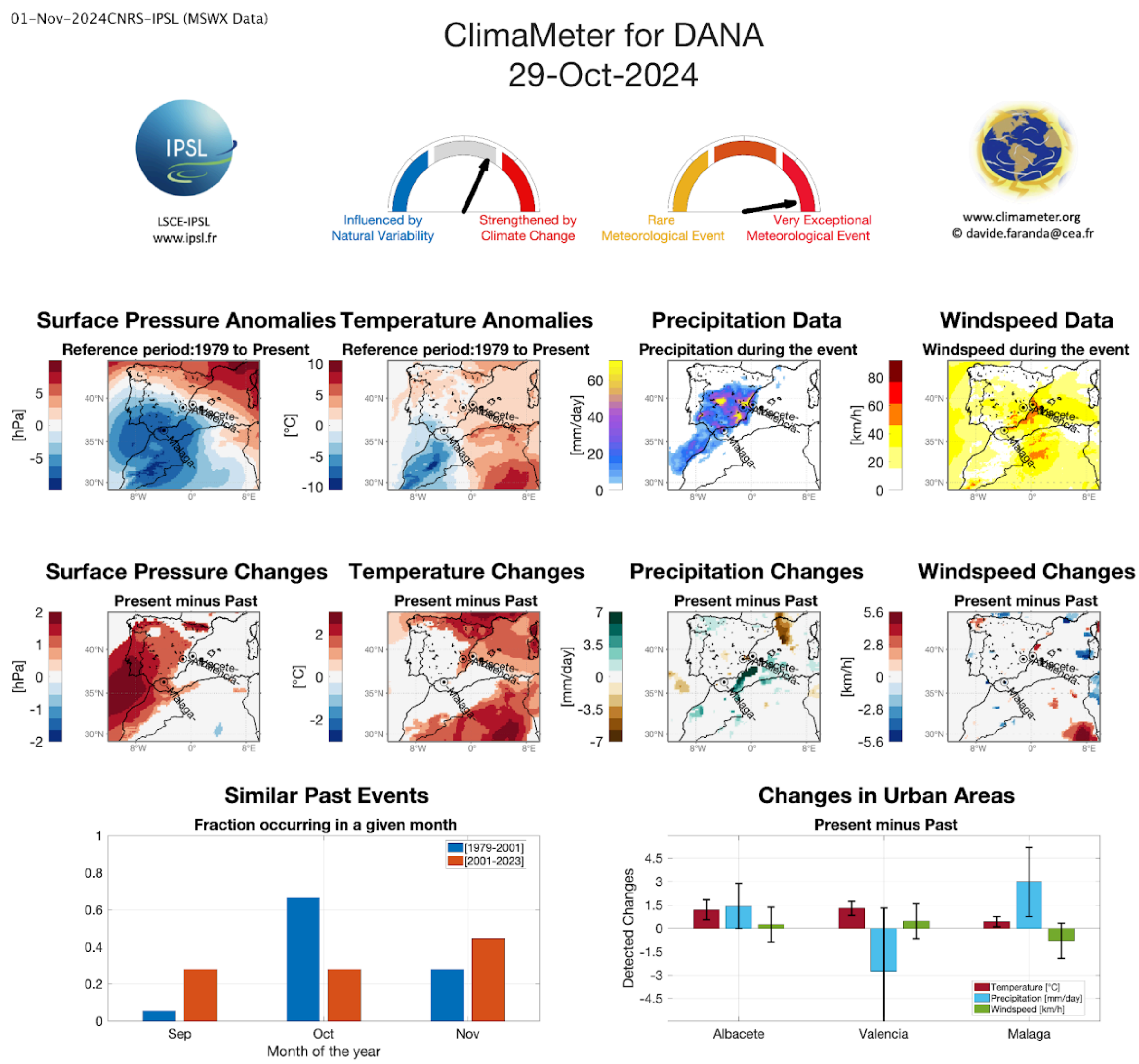
Press Summary (First published 2024/11/01)

- Depressions similar to the DANA that cause floods in southeastern Spain are up to 7 mm/day (an increase of up to 15%) wetter over the Mediterranean coast of Spain in the present than they would have been in the past. Additionally, conditions are up to 4°C warmer in the present compared to the past, which favors the formation of thunderstorms over the Mediterranean basin during DANA events.
- This DANA was driven by very exceptional meteorological conditions.
- We mostly ascribe the strengthened precipitation of this DANA to human driven climate change and natural climate variability likely played a modest role.

Event Description

Between October 24 and 25, 2024, an Atlantic depression approaching Europe was blocked in its progress towards the East by an anticyclonic ridge extending from North Africa across Central Europe, up to the Barents Sea. As a result, on October 29, the trough amplified and became cut off from the main westerly flow, blocked over the Iberian Peninsula by the aforementioned anticyclone insisting over Central Europe, and another one now located over the Eastern North Atlantic. The depression deepened, while remaining mostly stationary, persistently centered between Southern Spain and Morocco. The cut-off low, usually named DANA in Spanish (Isolated Depression at High

Levels), due to its position and to the cyclonic circulation, drove unstable air masses, characterized by an elevated water content and abundant convective potential energy, towards the South and East of Spain, while also producing favorable wind shear for thunderstorm development over the area, being the eastern coasts of Spain the most affected area.



As for other storms that have affected the Mediterranean region in September and October 2024, the convective energy and part of the precipitable water were made available by an anomalously warm sea, with sea surface temperature anomalies up to +2/+3 °C from the 1982-2011 period, in a context of a continued increasing trend.

As a result, extreme stationary storms affected several coastal regions in Eastern Spain. The main impact has been widespread flooding due to intense rainfall exceeding 300 mm within 24 hours in many locations across the province of Valencia, as reported by AEMET, the Spanish Meteorological Agency. In Turís, a town in Valencia, rainfall reached 630 mm in 24 hours, and in Chiva, 491 mm within just eight hours. Severe hailstorms and tornadoes were also recorded. The DANA has had catastrophic impacts in a few hours, leading to more than 200 deaths and dozens of missing people in the Valencian Community, which has been the most severely affected by the intense storm. Throughout October 29, a series of disasters occurred, and since then, incidents have increased, particularly in the provinces of Valencia and Castellón, as well as in Málaga, (Andalusia) and Albacete (Castilla-La Mancha).

The Surface Pressure Anomalies show a negative (cyclonic) anomaly of 5 hPa over Southern Spain, with Temperature anomalies displaying colder temperatures up to -3°C over Southern Spain and warmer anomalies up to 1.5°C over the Eastern coasts. *Precipitation data* reveal high daily rainfall amounts, exceeding 70 mm over Eastern Spain. *Windspeed data* show winds up to 40 km/h over almost all the country during the DANA event with speeds surpassing 60 km/h along the eastern coast.

Climate and Data Background for the Analysis

The IPCC AR6 WG1 states that the water cycle variability and extremes are projected to increase faster than the average change and in most of the tropical and extratropical regions. In the extratropics during the warmer season, interannual variability of precipitation and runoff are increasing faster than the seasonal changes (Chapter 8). The frequency and intensity of extreme precipitation have increased in the majority of land regions including Europe and in the Mediterranean with medium confidence and will increase with high confidence from a 2 °C. (AR6 WGI TS). As the IPCC AR6 states that with further global warming and proportional to the level of warming, starting from 1.5 °C, every region is projected to experience more and more concurrent multiple changes of climatic impact-drivers like the extreme precipitation. Concurrent extreme at multiple locations are more likely to occur at 2 °C compared to 1.5 °C (AR6 WGI SPM). The report also underscores the impact of climate change on storminess in Europe, aggravated by rising sea levels and intense precipitation. Anticipated alterations in atmospheric circulation patterns stem from the uneven warming of land and ocean, potentially resulting in diminished continental near-surface relative humidity and localised decreases in precipitation. In a warmer climate, individual midlatitude storms are expected to produce more precipitation, though changes in wind speed remain less certain. Studies, such asGinesta et al. (2024), found that the intensity of recent storms, including both wind speed and precipitation, is likely to increase in the most impacted regions of Europe. Ferreira examines cut-off lows as the primary drivers of extreme precipitation in the Valencia region of Spain from 1998 to 2018 and projects their future impacts using the Weather Research and Forecasting (WRF) model. DANA events, most frequent from September to November, often remain stationary over Spain for 2–3 days, producing sustained rainfall fueled by low-pressure systems over the Mediterranean. Future climate simulations suggest that extreme DANA-related precipitation could increase by up to 88% in northeastern Spain and 61% over the Mediterranean, posing heightened socio-economic risks to an already vulnerable region.

Our analysis approach rests on looking for weather situations similar to those of the event of interest having been observed in the past. For this event, we have low confidence in the robustness of our approach given the available climate data, as the event is very exceptional in the data record. To ensure robustness of our findings, we have increased the statistics of analogues to include 20 similar events in past and present periods.

ClimaMeter Analysis

We analyze here (see Methodology for more details) how events similar to the low pressure system leading to the Southeastern Spanish Floods changed in the present (2001–2023) compared to what they would have looked like if they had occurred in the past (1979–2001) in the region [14°W 10°E 27°N 44°N]. *Surface Pressure Changes*show that low pressure systems similar to the event in the present are shallower in their cores than those in the past. *Temperature Changes* show that analogues in the present are associated with warmer temperatures of up to 3°C compared to the past. Higher temperatures over the Mediterranean basin are the main driver of thunderstorms formation. *Precipitation Changes* show a localized increase in precipitation close to the Valencian coast of 13 mm/day. There are no remarkable changes in *Wind Speed* in the region affected. We also note that *Similar Past Events* occur more in October while in the present period they are almost equally frequent in September, October and November. *Changes in Urban Areas* reveal that there is a significant increase in precipitation in Albacete and Malaga. Although the Valencia region is the most affected by the floods, precipitation levels in the city of Valencia show non significant changes.

Finally, we find that sources of natural climate variability, notably the Atlantic Multidecadal Oscillation, may have influenced the event. This means that the changes we see in the event compared to the past may be mostly due to human driven climate change.

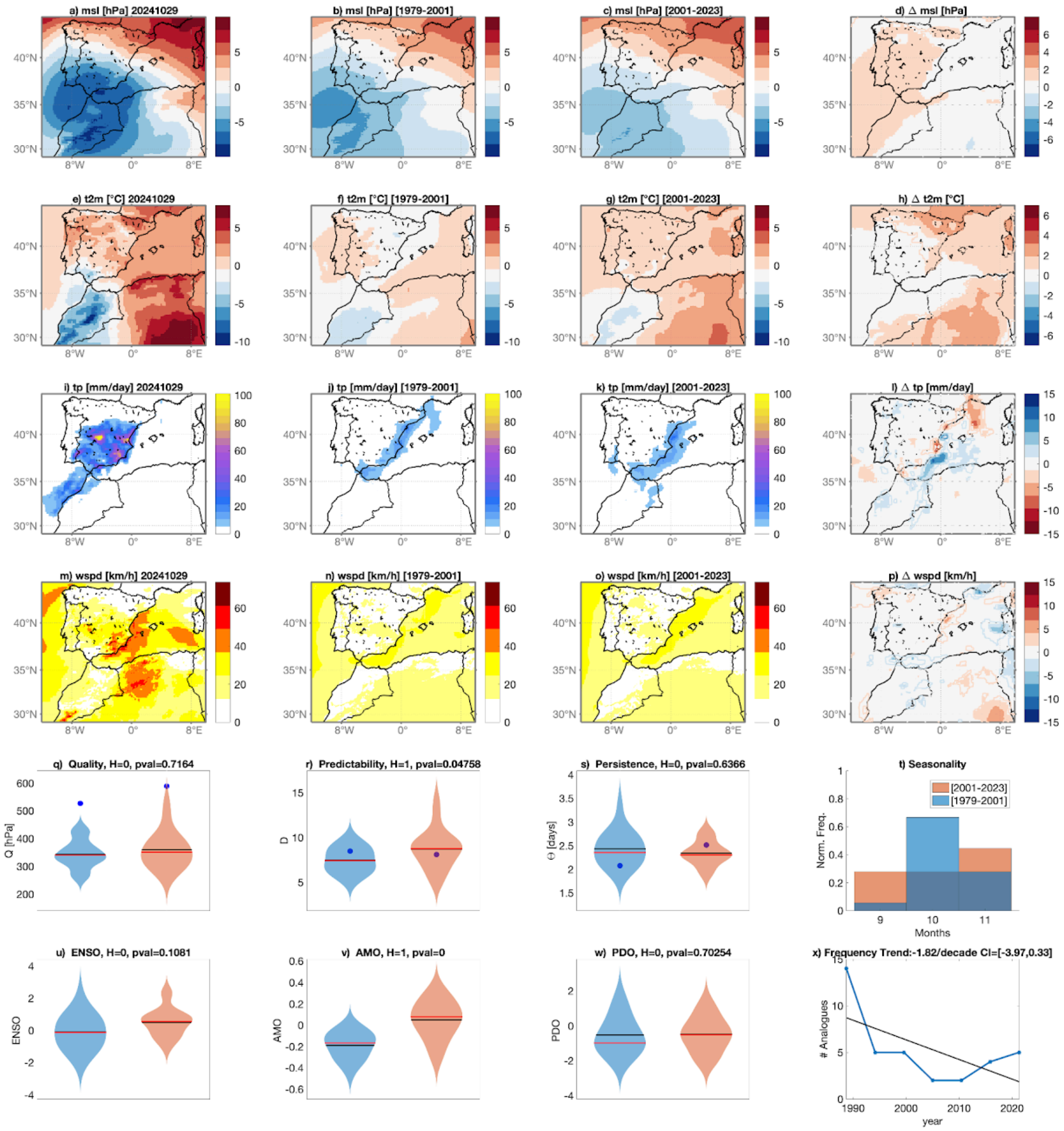
Conclusion

Based on the above, we conclude that depressions similar to the DANA that cause floods in southeastern Spain are up to 7 mm/day (an increase of up to 15%) wetter over the Mediterranean coast of Spain in the present than they would have been in the past. Additionally, conditions are up to 3°C warmer in the present compared to the past, which favors the formation of thunderstorms over the Mediterranean basin during DANA events. We interpret this DANA as an event driven by very exceptional meteorological conditions, whose characteristics can mostly be ascribed to human driven climate change. We remark that, for this event, we have low confidence in the robustness of our approach given the available climate data, as the event is very exceptional in the data record.

Additional Information : Complete Output of the Analysis

NB1: The following output is specifically intended for researchers and contain details that are fully understandable only by reading the methodology described in Faranda, D., Bourdin, S., Ginesta, M., Krouma, M., Noyelle, R., Pons, F., Yiou, P., and Messori, G.: A climate-change attribution retrospective of some impactful weather extremes of 2021, Weather Clim. Dynam., 3, 1311–1340, https://doi.org/10.5194/wcd-3-1311-2022, 2022.

NB2: Colorscales may vary from the ClimaMeter figure presented above.



The figure shows the average of surface pressure anomaly (msl) (a), average 2-meter temperatures anomalies (t2m) (e), cumulated total precipitation (tp) (i), and average wind-speed (wspd) in the period of the event. Average of the surface pressure analogs found in the counterfactual [1979-2000] (b) and factual periods [2001-2022] (c), along with corresponding 2-meter temperatures (f, g), cumulated precipitation (j, k), and wind speed (n, o). Changes between present and past analogues are presented for surface pressure Δslp (d), 2 meter temperatures Δt2m (h), total precipitation Δtp (i), and windspeed Δwspd (p): color-filled areas indicate significant anomalies with respect to the bootstrap procedure. Violin plots for past (blue) and present (orange) periods for Quality Q analogs (q), Predictability Index D (r), Persistence Index Θ (s), and distribution of analogs in each month (t). Violin plots for past (blue) and present (orange) periods for ENSO (u), AMO (v) and PDO (w). Number of the Analogues occurring in each subperiod (blue) and linear trend (black). Values for the peak day of the extreme event are marked by a blue dot. Horizontal bars in panels (q,r,s,u,v,w) correspond to the mean (black) and median (red) of the distributions.