Extreme precipitation events in the Mediterranean region: Their characteristics and connection to large-scale atmospheric patterns

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Motivation

- The Mediterranean region has substantial population, strong contribution to global economy, and locations of global natural, historical and cultural significance.
- Extreme Precipitation Events (*EPEs*) lead to severe negative impacts on society, environment and economy.
- Better understanding of their characteristics and drivers can support improved forecasting, reducing related risks.

Data

❑ ERA5: Global gridded dataset for the period 1979–2019[i].

Selected Variables	Selected Spatial Resolution
Daily Total Precipitation (*TPr*)	0.25° X 0.25°
Daily Mean Seal Level Pressure (*SLP*)	1.00° X 1.00°
Daily Mean Temperature at 850 hpa (*T850*)	1.00° X 1.00°
Daily Mean Geopotential Height at 500 hpa (*Z500*)	1.00° X 1.00°

Methodology

❖ Select 31 locations around the basin (Fig. 1: red circles).

❖ Calculate areal-average TPr over extended areas (Fig. 1: black squares) and identify EPEs based on Q99–Q97 percentiles.

❖ Analyse seasonality and temporal dependency of EPEs (Figs. 9, 10).

❖ Assess spatial connections between the identified EPEs and Q99 extremes at each grid cell (Figs. 2, 6).

❖ Generate composites of SLP, Z500, T850 anomalies for the identified EPEs in the extended domain 10N/70N, 60W/80E and analyse statistical significance (Figs. 3, 4, 7).

❖ Perform Empirical Orthogonal Function (EOF) analysis for Z500 anomalies in the Mediterranean (26N/50N, 11W/41E) and project the EPEs on the six (6) first Principal Components (PCs)[iii, iv] (Figs. 5, 8, 11).

Future Pathways

➢ Use TPr data derived from high-density observations.

➢ Analyse evolution of atmospheric patterns connected to EPEs in the Mediterranean.

KEY FINDINGS

- **West/East divide: Most extremes occur during autumn (winter) for the west (east) Mediterranean (Fig. 10)**
- **Orography enhances precipitation and modulates spatiotemporal connections between locations (Figs. 2, 6, 10)**
- **For most areas, more than 25% (50%) of the Q99 (Q97) events occur within 15 days from the previous Q99 (Q97) event (Fig. 9)**
- **Negative (dipole) anomalies of SLP, Z500 (T850) over (around) the affected area are observed during extreme events (Figs. 3, 4, 7)**
- **EOF analysis corroborates the statement about West/East divide, and can possibly contribute in analysing extremes (Figs. 5, 8, 11)**

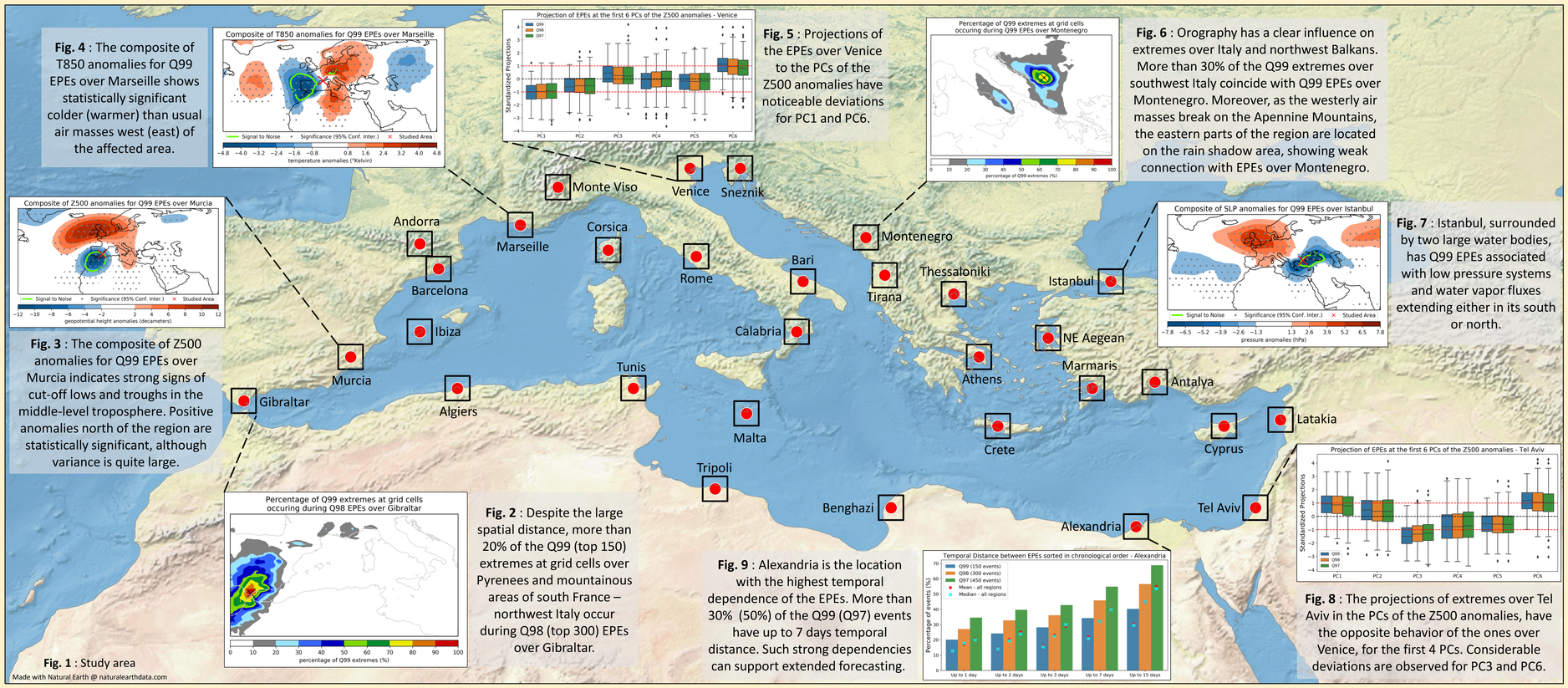

Fig. 1 : Study area
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Fig. 4 : The composite of T850 anomalies for Q99 EPEs over Marseille shows statistically significant colder (warmer) than usual air masses west (east) of the affected area.

Fig. 3 : The composite of Z500 anomalies for Q99 EPEs over Murcia indicates strong signs of cut-off lows and troughs in the middle-level troposphere. Positive anomalies north of the region are statistically significant, although variance is quite large.

Fig. 2 : Despite the large spatial distance, more than 20% of the Q99 (top 150) extremes at grid cells over Pyrenees and mountainous areas of south France – northwest Italy occur during Q98 (top 300) EPEs over Gibraltar.

Fig. 5 : Projections of the EPEs over Venice to the PCs of the Z500 anomalies have noticeable deviations for PC1 and PC6.

Fig. 6 : Orography has a clear influence on extremes over Italy and northwest Balkans. More than 30% of the Q99 extremes over southwest Italy coincide with Q99 EPEs over Montenegro. Moreover, as the westerly air masses break on the Apennine Mountains, the eastern parts of the region are located on the rain shadow area, showing weak connection with EPEs over Montenegro.

Fig. 9 : Alexandria is the location with the highest temporal dependence of the EPEs. More than 30% (50%) of the Q99 (Q97) events have up to 7 days temporal distance. Such strong dependencies can support extended forecasting.

Fig. 7 : Istanbul, surrounded by two large water bodies, has Q99 EPEs associated with low pressure systems and water vapor fluxes extending either in its south or north.

Fig. 8 : The projections of extremes over Tel Aviv in the PCs of the Z500 anomalies, have the opposite behavior of the ones over Venice, for the first 4 PCs. Considerable deviations are observed for PC3 and PC6.

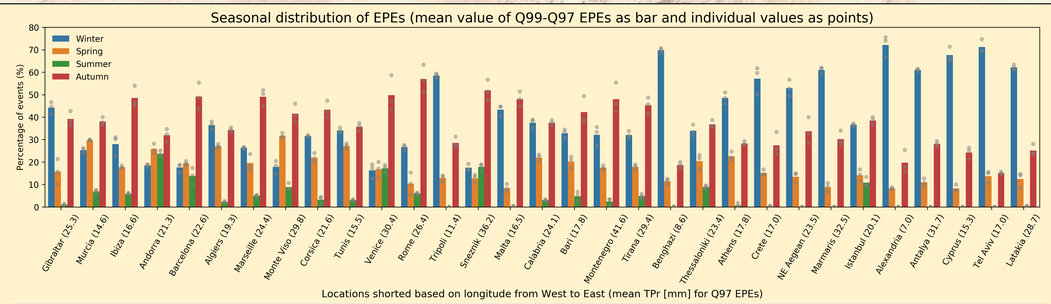

Fig. 10 : West/East divide in EPEs seasonality. For locations in central Mediterranean (e.g. Malta, Sneznik), statistics for south (north) regions have a closer resemblance to locations in East (West) Mediterranean (agreeing with EOF1 & EOF2,Fig. 10). The distinct behaviors for Gibraltar and Istanbul can be associated to the significant influence of the Atlantic and the Black Sea, respectively. In general, locations at northern latitudes (e.g. Barcelona vs. Algiers), as well as at higher altitudes or with mountain ranges in their vicinity (e.g. Antalya vs. NE Aegean), have higher average TPr for EPEs.

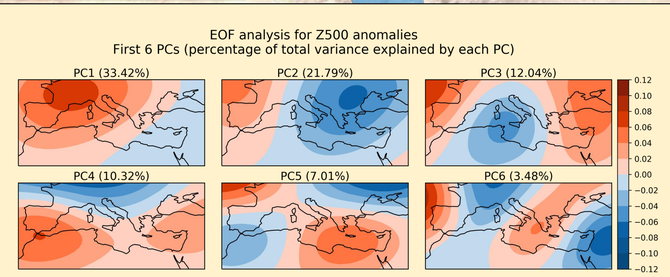

Fig. 11 : EOF analysis for the Z500 anomalies (based on all daily data for period 1979–2019) clearly demonstrates a west (northwest)/east (southeast) divide, with the first two EOFs explaining more than 50% of the total variance. The patterns agree with the known oscillations within the region (Mediterranean Oscillation; West Mediterranean Oscillation[ii]).

References:

[i]Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). https://cds.climate.copernicus.eu/cdsapp#!/home; [ii]Vicente-Serrano, S. M. et al. Daily atmospheric circulation events and extreme precipitation risk in northeast Spain: Role of the North Atlantic Oscillation, the Western Mediterranean Oscillation, and the Mediterranean Oscillation. J. Geophys. Res. 114, D08106 (2009); [iii]Ulbrich, U. et al. Climate of the Mediterranean. in The Climate of the Mediterranean Region 301–346 (Elsevier, 2012). doi:10.1016/B978-0-12-416042-2.00005-7., [iv]Xoplaki, E. et al. Large-Scale Atmospheric Circulation Driving Extreme Climate Events in the Mediterranean and its Related Impacts. in The Climate of the Mediterranean Region (ed. Lionello, P.) 347–417 (Elsevier, 2012). doi:10.1016/B978-0-12-416042-2.00006-9.

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CAFE Climate Advanced Forecasting of sub-seasonal Extremes

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