Return Periods and Use of Extreme Value Theory

Forecast Product User Meeting
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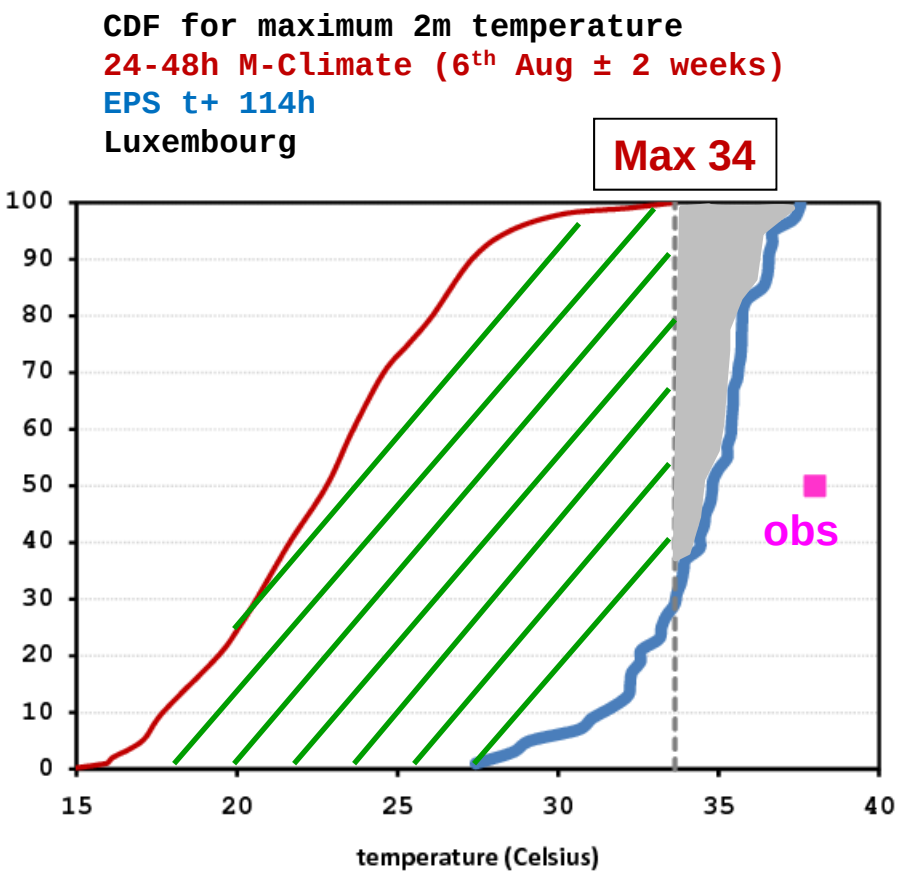
Recent Rare Events (from Global Hazards-NOAA…)

- **"In a 24-hour period, Seathwaite (NW England) had 12.4 inches (314 mm) of rain, setting a new U.K. record for rainfall in a 24 hour period—records go back to 1914." (Nov 2009, source: Met Office)**
- **"Reports from Saudi Arabia's Civil Defence claim the floods were the worst in 27 years and the heaviest rainfall for the country in over a decade ."(Nov 2009 source: Saudi Gazette).**
- **"In November 2007 a storm occurred […]. In Hoek van Holland the water reached the highest level since the disaster in 1953. It was the first time in more than 30 years that warnings and alarms had to be issued […] barriers […]near Rotterdam had to be closed", (newsletter 114)**
- **" A cold snap hit a large portion of USA […] This was the 2nd lowest temperature ever recorded at the most southern weather station (Key West, FL) in the contigous US". (Nov 2009)**
- **"Preliminary reports indicated that more than 200 daily, monthly, and all-time precipitation records were broken across the three states (Mississippi, Tennessee and Arkansas)." (May 2010 source: National weather service)**
- **"According to a local U.S. Geological Survey official, the flows on various rivers in the Nashville area exceeded those from the historic1927 and 1975 floods." (May 2010)**

Motivation



- **The aim of this study is to extend the concept of EFI by providing better information on the intensity and rarity of severe weather**.
- The **EFI** is a measure of the difference between EPS forecast and the M-Climate.
- However the EFI index takes no account of the distance of any EPS members that are beyond the maximum of the M-Climate (area in grey).
- In this example, 70% of the EPS members are above 34°C and below 37.5 °C.
- How often Luxembourg would experience temperatures above 34 °C? Once every 18 years?
- What can be used to describe the frequency of extreme events?

Extreme Value Theory

- **Most of the existing infrastructures require some knowledge of the statistical behaviour of the extreme events (rainfall amounts for sewerage systems, dams, bridges)**
- **Extreme value theory (EVT) provides the statistical framework to make inferences about the probability of very rare or extreme events.**
- **In particular, the Generalised Extreme Value (GEV) distribution can be used to fit a sample of extremes. From the fitted distributions, the extreme quantiles can be extrapolated (if necessary) beyond the period covered by the climate data.**
- **Estimates of the extreme quantiles can be obtained from the chosen distribution, ie, the level (return level) expected to exceed on average, once every interval of time (return period).**

Methodology & Data

- ***Data***: **18-years (1997-2008) of EPS (5 members) re-forecasts (used to compute the EFI). The annual maximum (minimum) of 2-m Tmax (Tmin) are obtained from this dataset.**

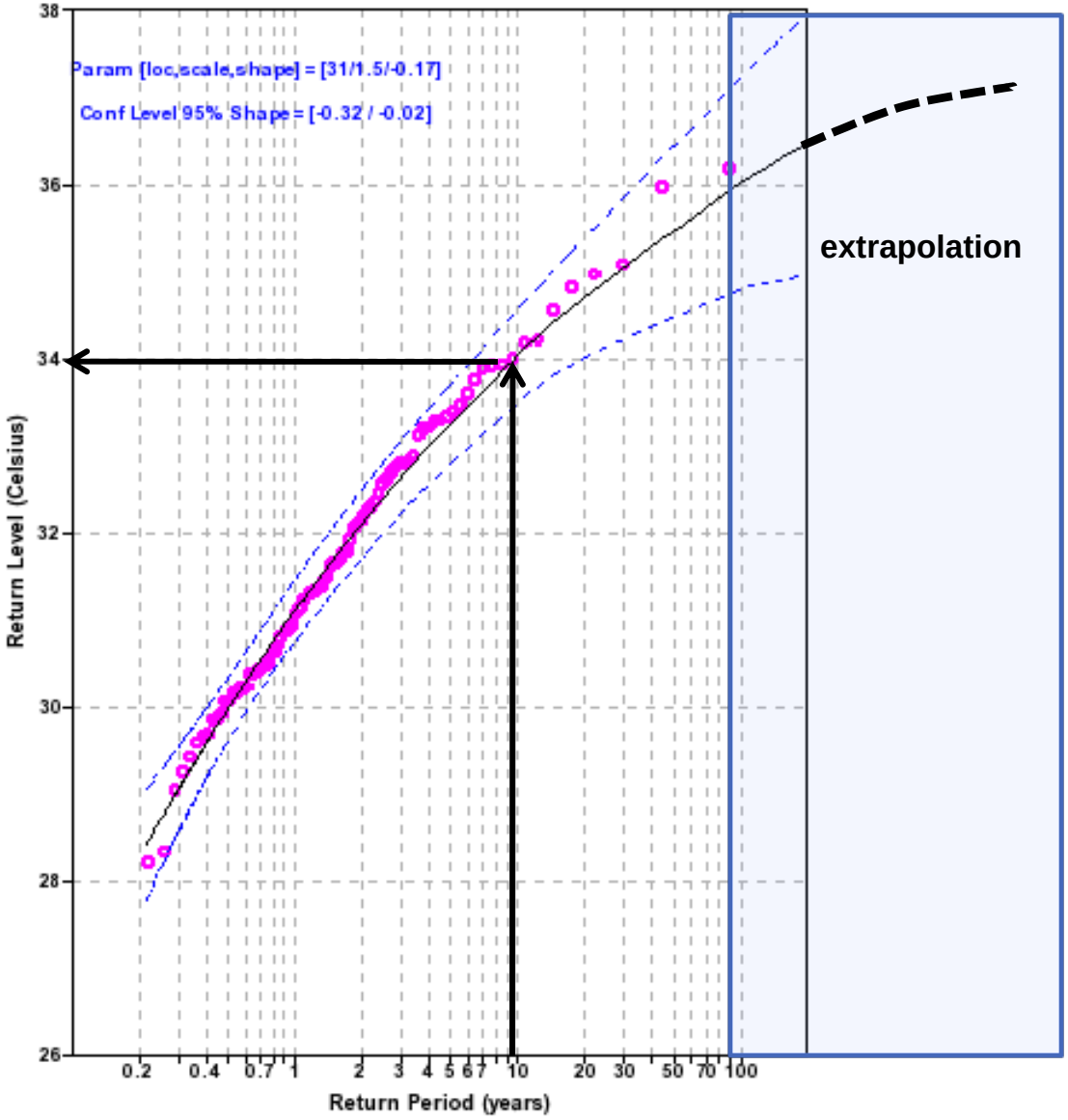
- ***Estimation***: **these 90 Tmax (Tmin) values were used to parameterize the GEV distributions at each grid point (model-GEV). The computations were carried out using the statistical package R (www.r-project.org). The maximum likelihood method was applied to infer the parameters of the GEV distribution.**

- **From the fitted distribution, at each grid point, return values were obtained for any extreme quantile.**

- ***Verification:*** **the same methodology was applied to the observations (obs-GEV) available from European Climate Assessment & Dataset project (ECA&D, see Klein Tank et al. 2002).**

Return Level plot for 2-m Tmax (estimated quantiles)

Black: fitted distribution; Blue: 95% conf. interval; Magenta: M-Climate

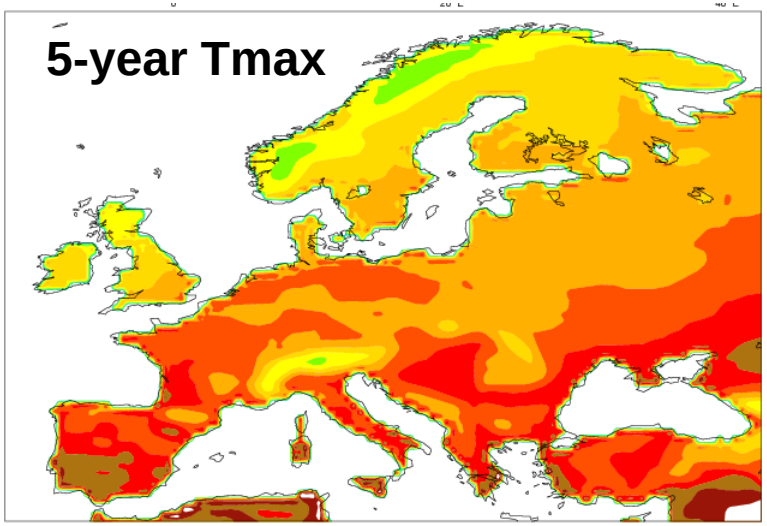


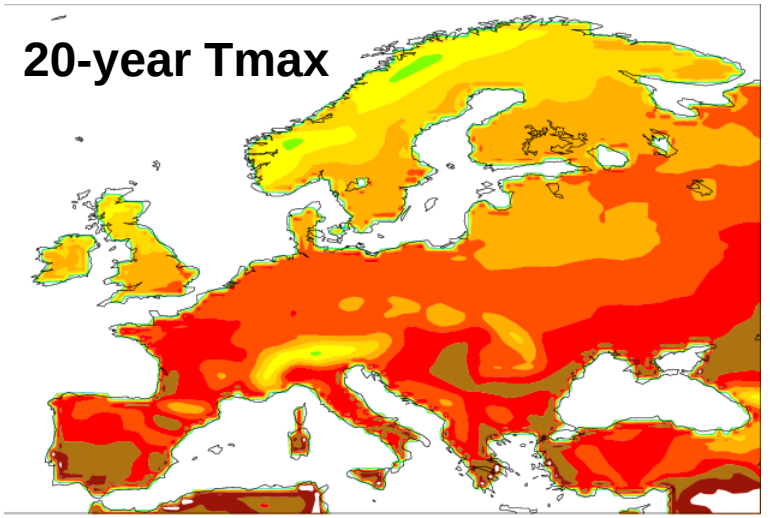
At each grid point the fitted GEV distribution is used to compute the return values for the return periods. The fitted distribution can be applied beyond the available data of the M-climate (18 years).

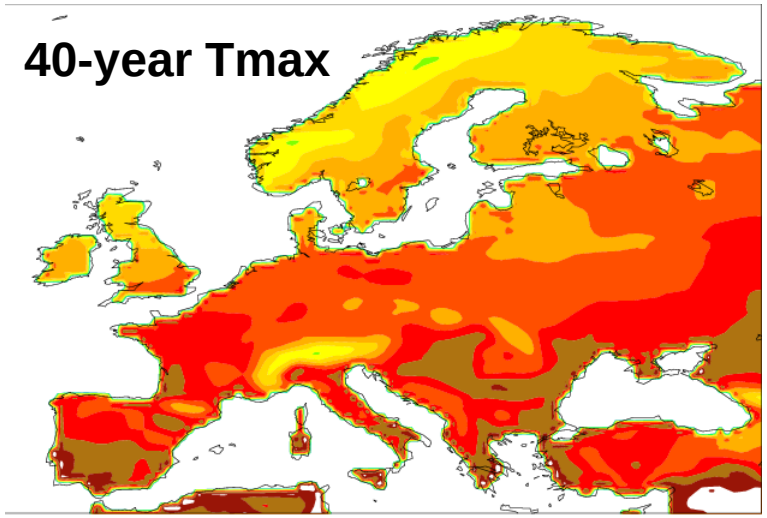
The 95% confidence interval (Blue) for the return levels is computed for any fitted distribution. Generally, the confidence decreases for longer return periods.

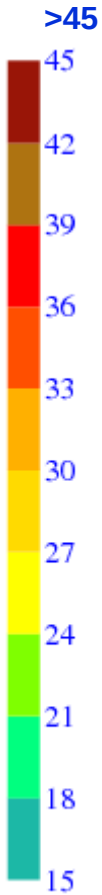
ECMWF

Spatial distribution of annual return values for Tmax for 5-, 20- and 40-year return period from model climate.



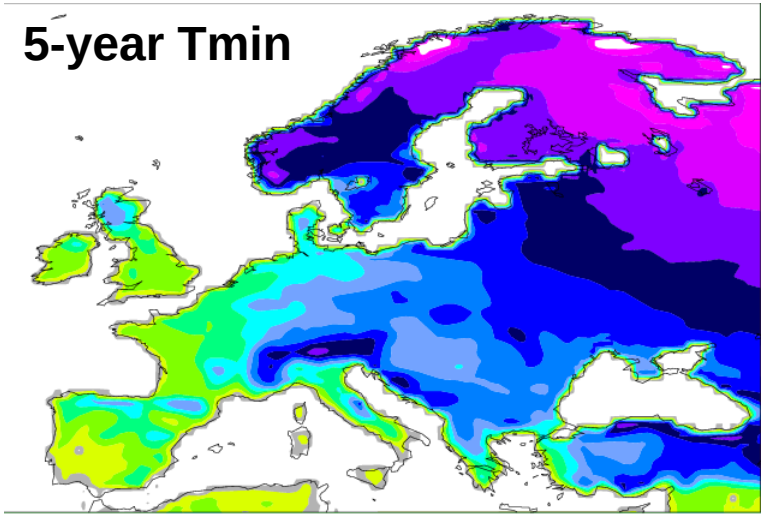


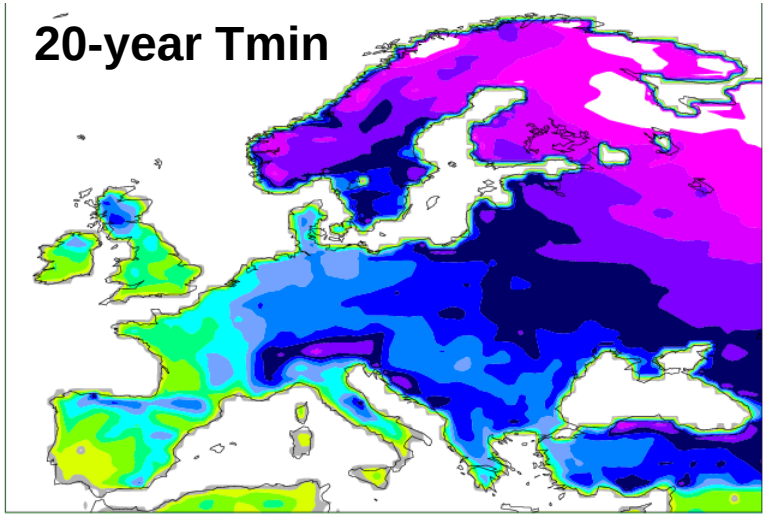


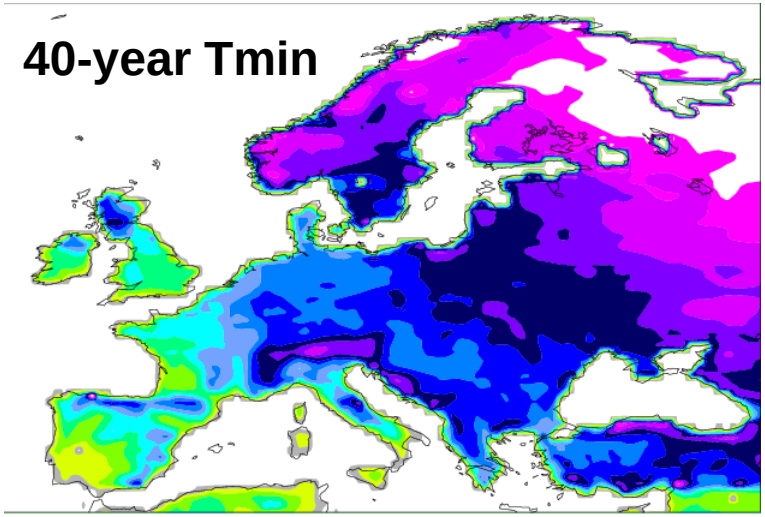


ECMWF

Spatial distribution of annual return values for Tmin for 5-, 20- and 40-year return period from model climate.



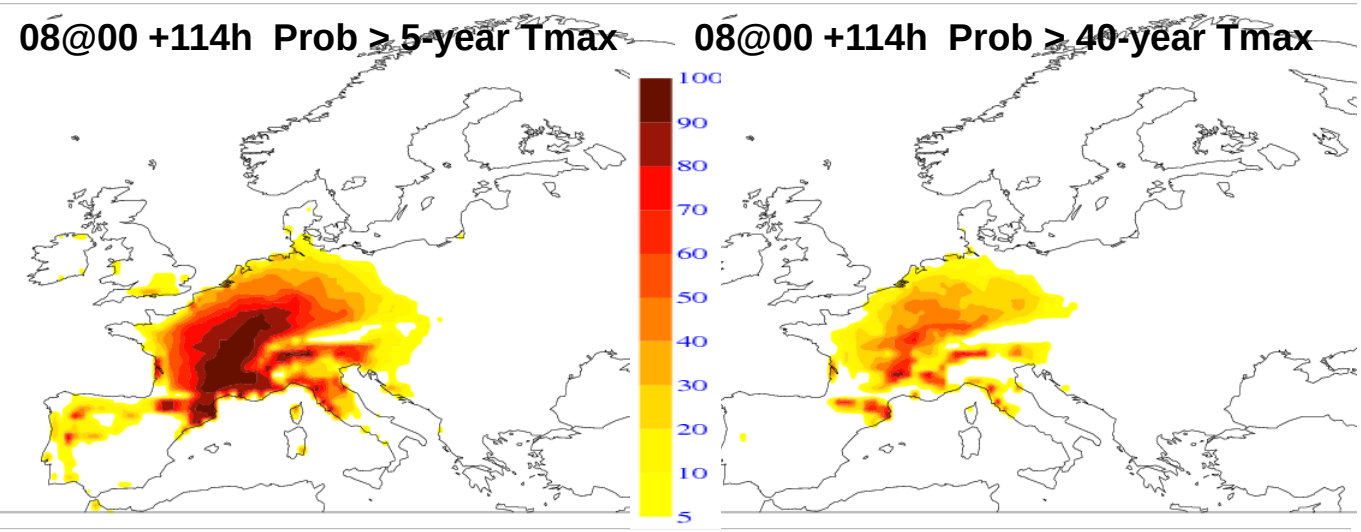




ECMWF

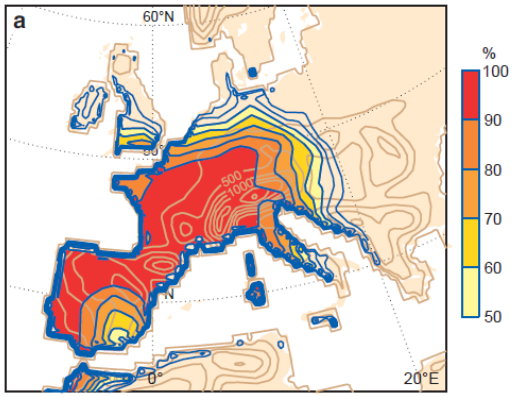
Case study – Summer 2003 European heat wave
VT: 18Z 12th Aug 2003 (Probability of RETurn value)

08@00 +114h Prob > 5-year Tmax

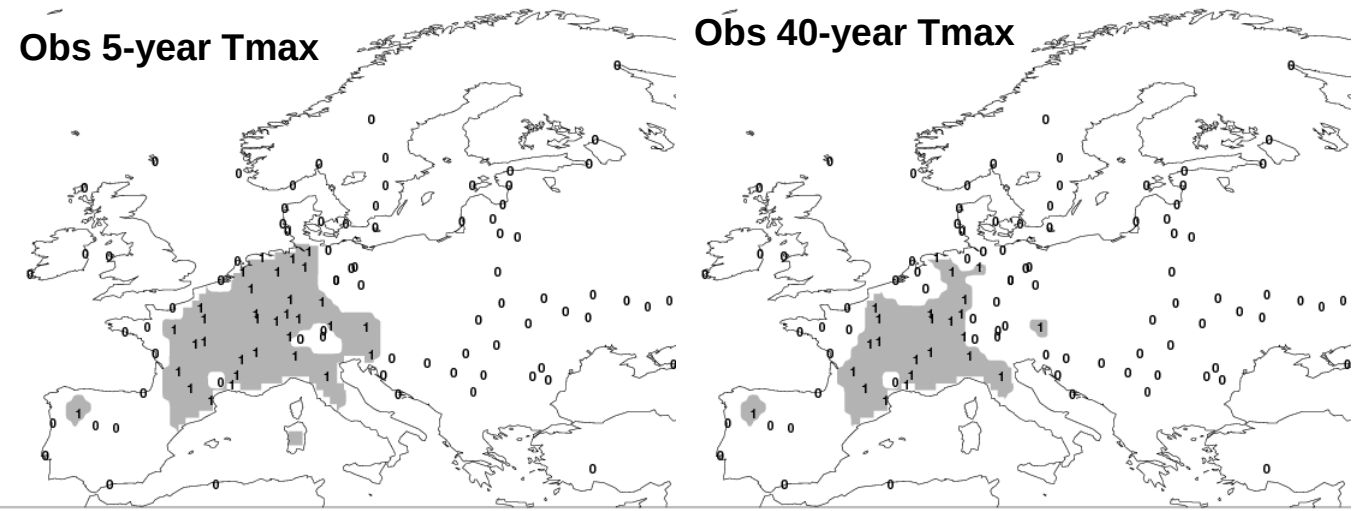


08@00 +114h Prob > 40-year Tmax

EFI 2m temp D+5



Obs 5-year Tmax

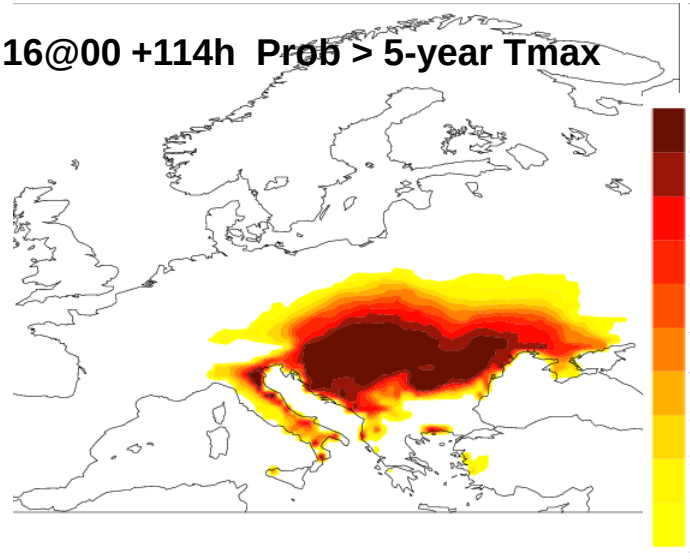


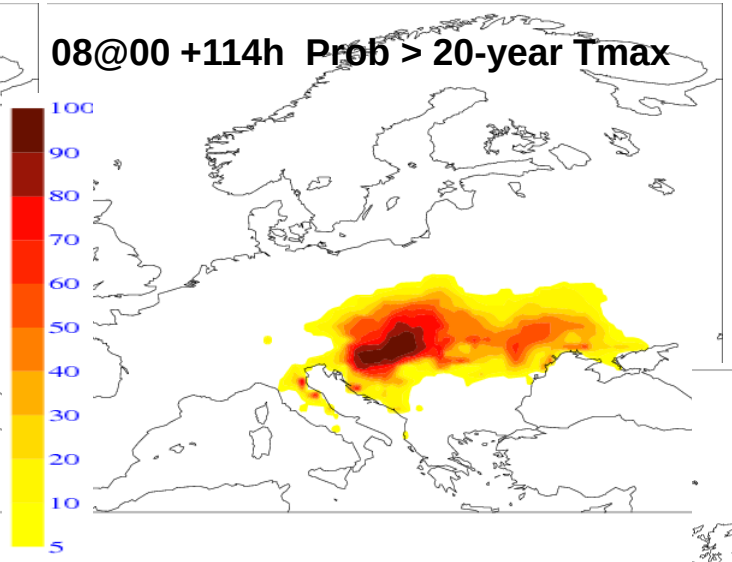
Obs 40-year Tmax

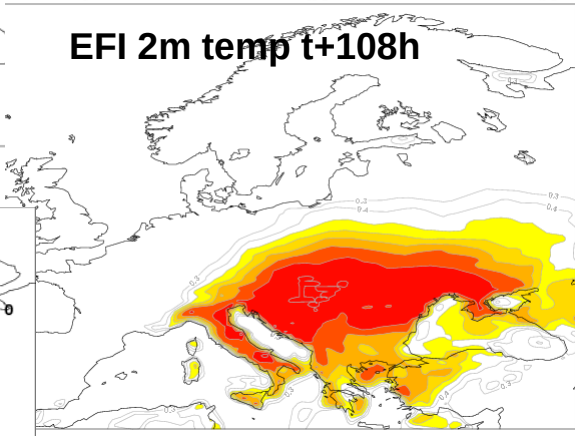
The PRET forecast is based on the number of EPS members that exceed the N-year return period event.

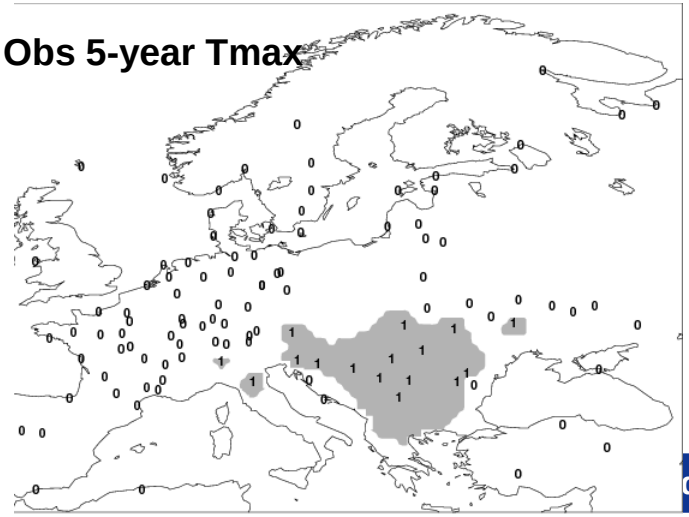
ECMWF

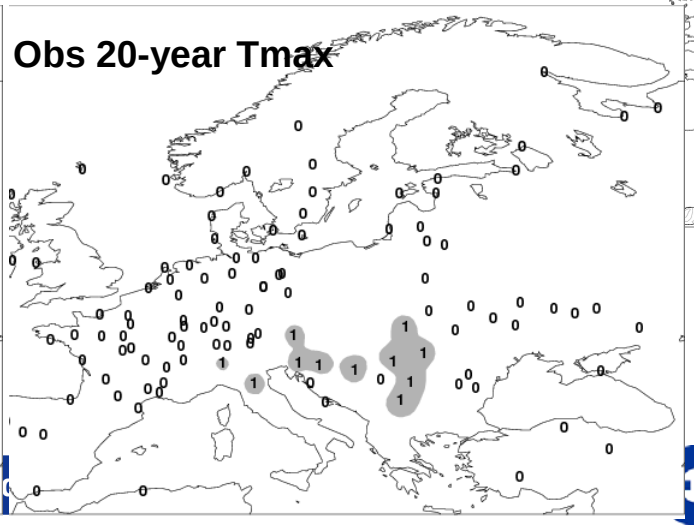
Case study – Summer 2007 SE European heat wave
VT: 18Z 20th July 2007





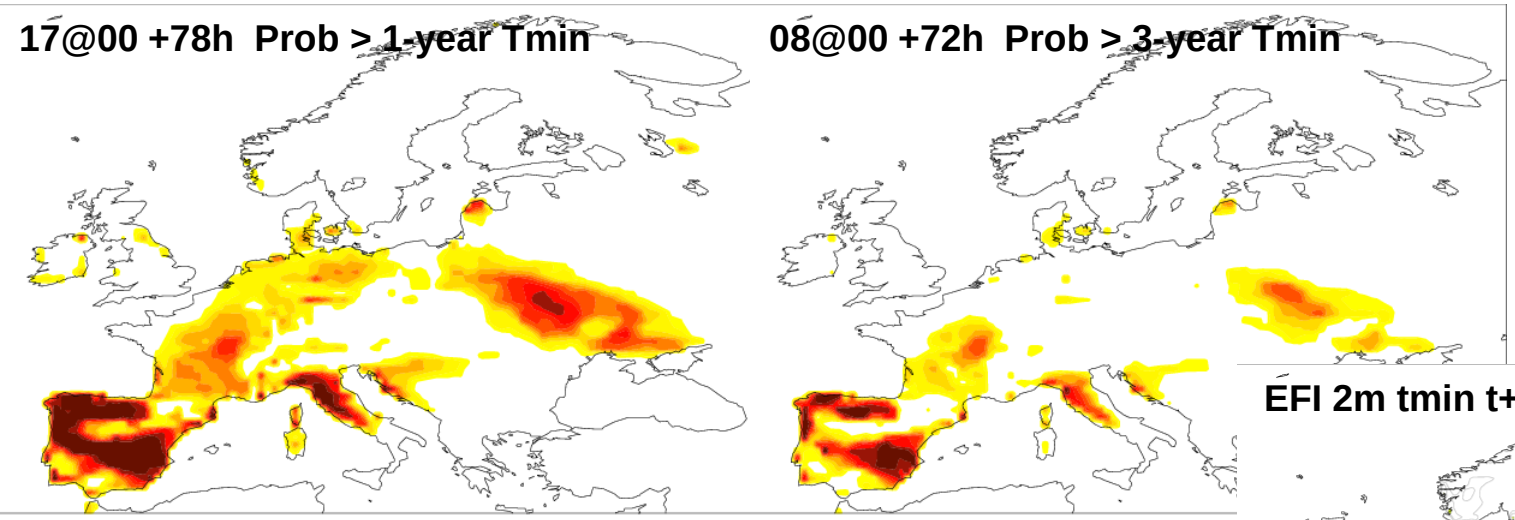


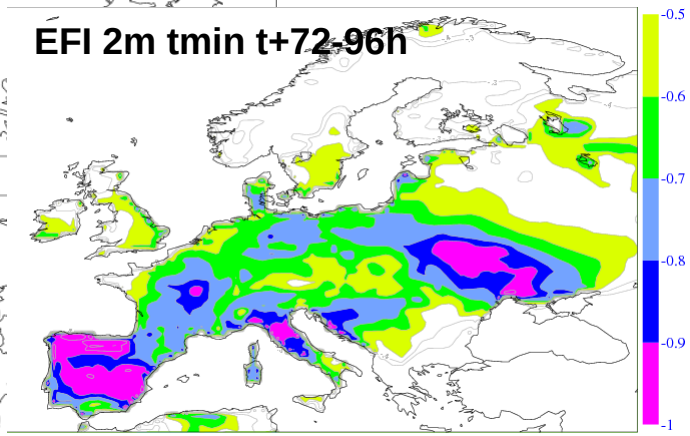


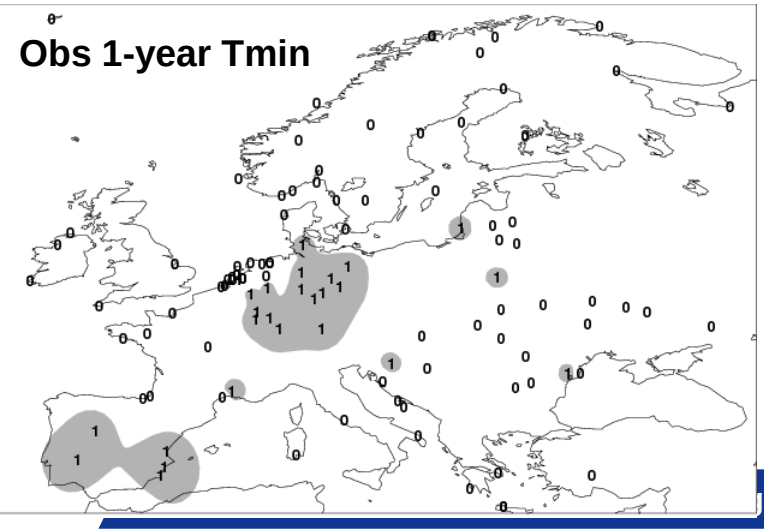


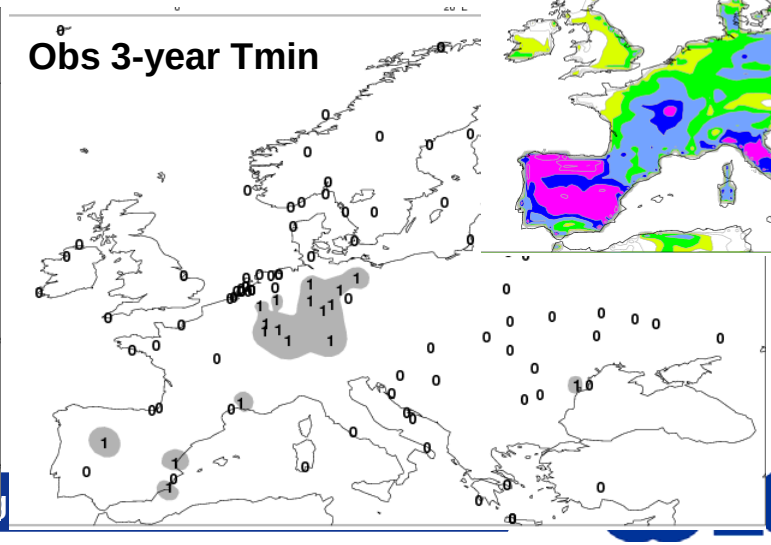
ECMWF

Case study – Winter 2009 European cold snap
VT: 06Z 20th December 2009

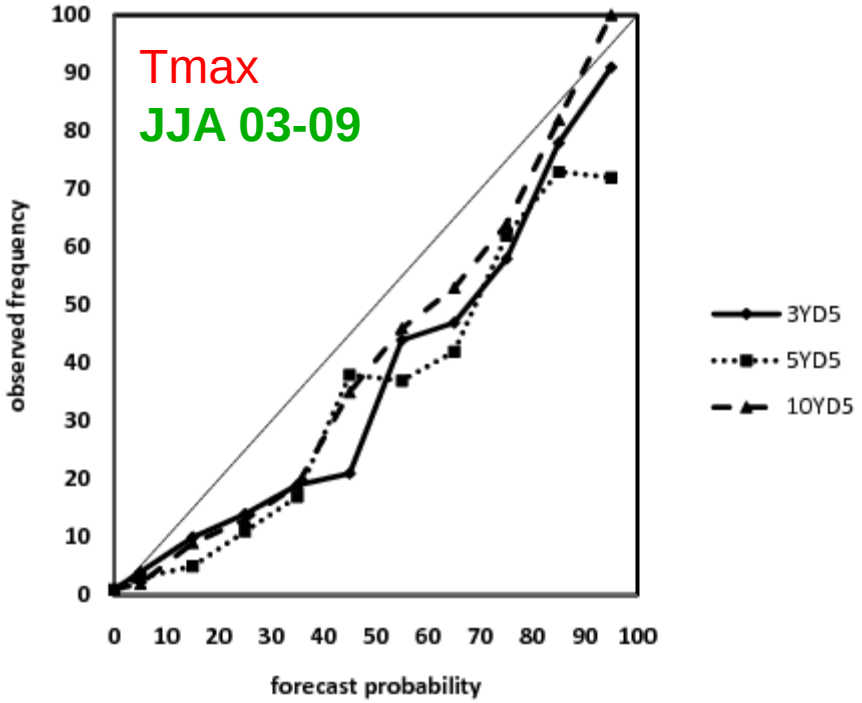


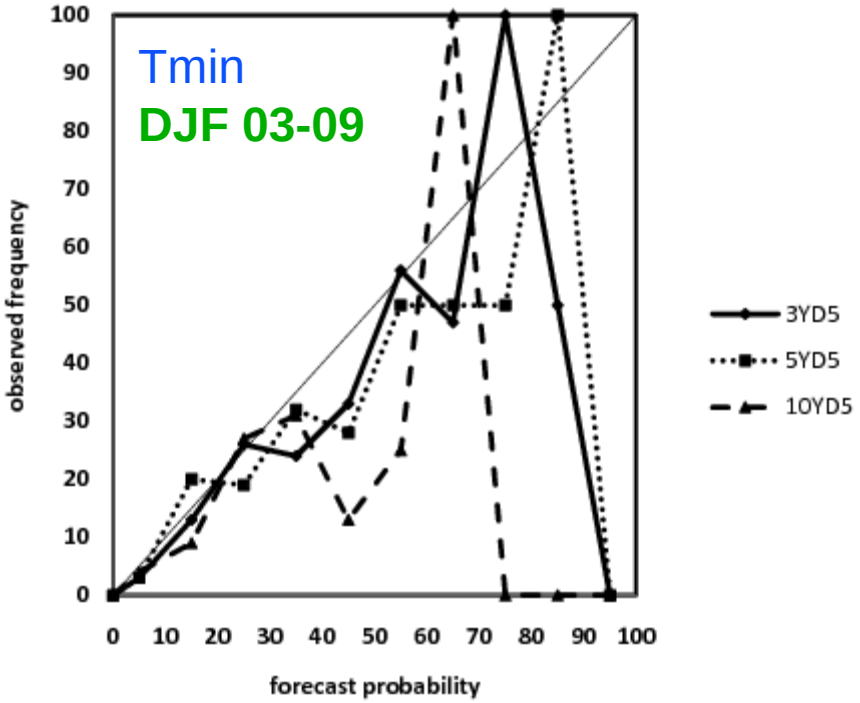






Verification statistics of forecast probability of return periods (3-, 5- and 10-years) for Tmax & Tmin for D+5





Day 5 forecast Tmax (Tmin)	ROC area	Brier Skill Score
3-y return period	0.71 (0.73)	0.11 (0.10)
5-y return period	0.64 (0.72)	0.06 (0.09)
10-y return period	0.59 (.68)	0.03 (0.05)

ECMWF

Conclusions

- **The computation of the extreme quantiles (return periods) beyond the 18 years M-Climate cannot be done without a fitted GEV distribution for annual maxima (minima) sample.**
- **The Probability of RETurn, based on the concept of return period of a rare event has been introduced. PRET forecasts are designed to provide a more complete information about the severity of extreme event.**
- **Since PRET product is more similar to risk management products available in other fields, it should further increase the value of ensemble-based probabilistic forecasts for weather risk.**
- **Objective performance of EPS PRET forecasts (paper in preparation) for 6 seasons are skillful (as showed by ROCA and BSS) up to day 5.**
- **The PRET could be extended to wind speed (pressure gradient), total precipitation, wave height … and weather parameter anomalies (Monthly Forecast)**