Extreme high temperature in France by 2050 for the distribution network

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BACKGROUND

High temperatures are one of the hazards affecting underground (as well as overhead) power lines in particular, and climate change is leading to higher levels. In order to develop its adaptation plan, Enedis, the French DSO, commissioned an impact study in 2020, to analyze the main hazards impacting or expected to impact the network (Parey and Marty, 2020), in the context of climate change. We here propose an update of this study, with a focus on extreme high temperature as projected using CMIP6 projections. 20-year Return Levels for daily maximum temperature, daily minimum temperature and 3-day mean temperature across France have thus been computed at the 2050 horizon.

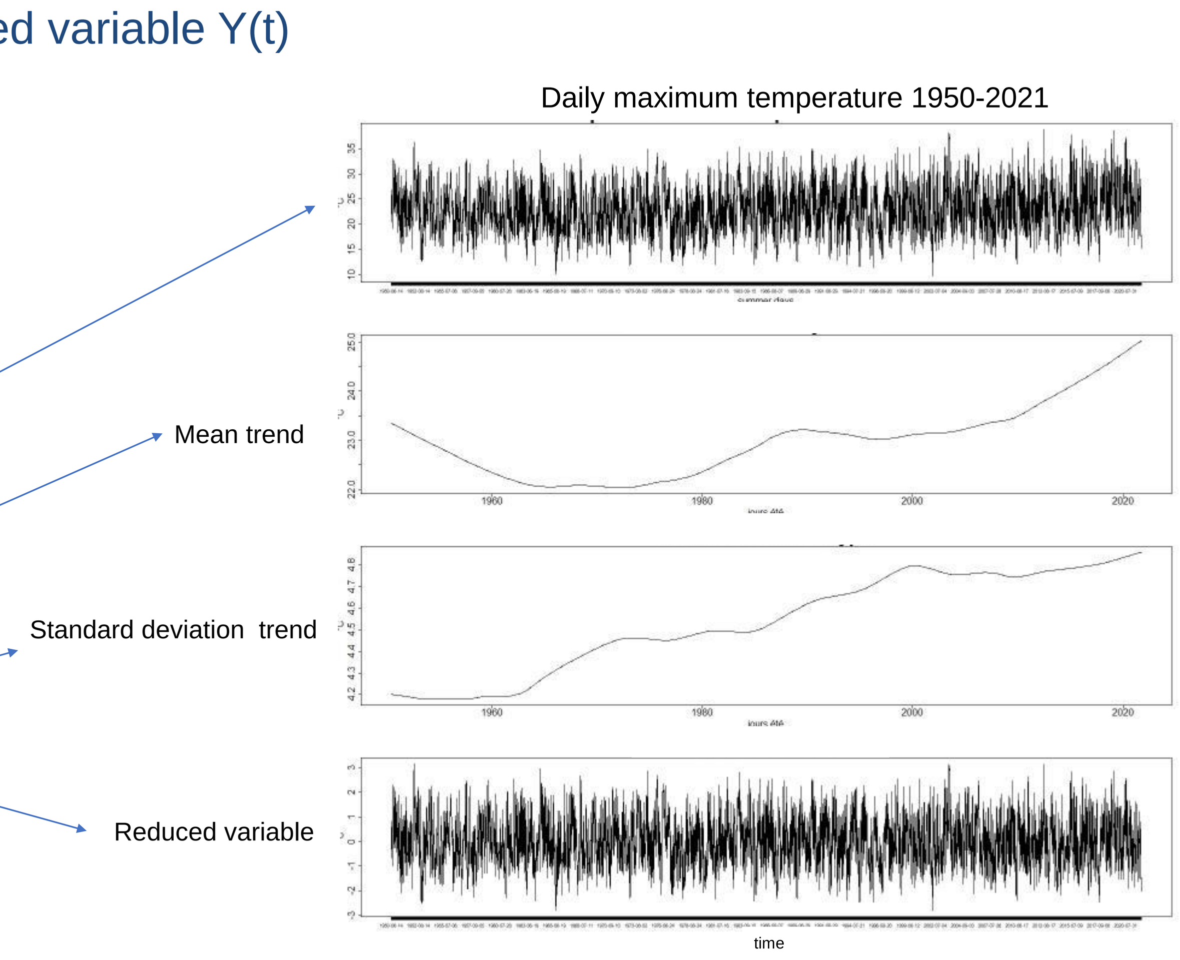
1. METHODOLOGY

The computation of extreme values such as Return Levels is generally done by applying the statistical Extreme Value Theory. However, independency and identical distribution, or at least stationarity, is one of the assumptions of the theory. Because of seasonality and interannual variability, climate variables are not stationary. Moreover, climate-change-induced trends add another type of non stationarity, which has to be accounted for.

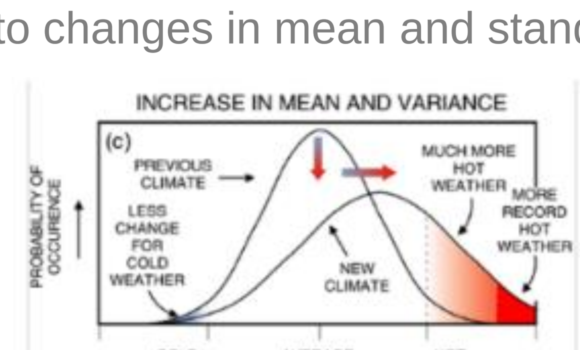
To cope with the aforementioned features of climate variables, a methodology – based on the computation of a standardized variable whose extremes can be considered as stationary – has been developed (Parey et al., 2019). It requires to remove smooth trends in the mean and standard deviation of summer temperature. A test has been designed to check the stationarity of the extremes and its application showed that the extremes of the reduced variable can be considered as stationary.

Building the standardized variable Y(t)

$$Y(t) = \frac{X(t) - m(t)}{s(t)}$$



As extremes are considered as stationary, associated changes can then be assumed as mainly due to changes in mean and standard deviation



Therefore, the future 20-year Return Levels are computed as follows:

- selection of the summer days (between the 14th of June and the 21st of September)
- computation of *Y(t)*: $Y(t)=(X(t)-m(t))/(s(t))$
- estimation of the 20-year Return Level of *Y(t)* using block maxima: *RLy*
- computation of summer temperature mean and standard deviation over the historical period 1995-2014, together with a bootstrap estimation of their uncertainty (used for the confidence interval) => historical 20-year Return Levels
- retrieval of the temperature differences (Δm) and standard deviation ratios (ρs) between the future period 2041-2060 and the historical period 1995-2014 given by different climate models
- computation of future mean and standard deviation: $mf = mo + \Delta m$; $sf = so * \rho s$, *mo* and *so* being respectively the observed summer mean and standard deviation over the historical period
- computation of the future 20-year Return Level: $RL = mf + sf * RLy$
- estimation of the lower and upper bounds of the 95% confidence interval: delta-method with the addition of the uncertainties of the summer temperature mean and standard deviation in the variance-covariance matrix

2. DATA CONSIDERED

Observations = EOBS 0.25° across France, 1950-2020: Tmin, Tmax, Td

Climate models: 15 CMIP6 models available in the EDF/R&D Climate Service for which Tmin, Tmax, Td are available for the historical period and for SSP2-4.5 et SSP5-8.5; the considered future period is 2041-2060, in line with IPCC AR6

3. RESULTS

3.1 CLASSIFICATIONS

20-year Return Levels are estimated through the previously described methodology at each E-OBS grid point for each of the 15 models and both emission scenarios, which leads to 30 Return Level maps

In order to discriminate significantly different maps, the following approach has been used:

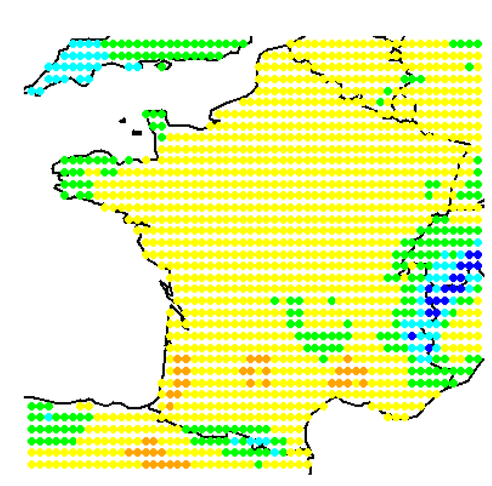
- comparison of 2 maps :
  - * for each grid point, check if the Return Level in one map lies inside the confidence interval of the Return Level in the second map
  - * 2 maps are considered as statistically different if at least 80% of the grid points show statistically different Return Levels
- classification of the projections according to their significant differences, using kmeans, with the optimal number of clusters decided according to the silhouette score and within clusters sum of squares

3.2 RETURN LEVEL MAPS

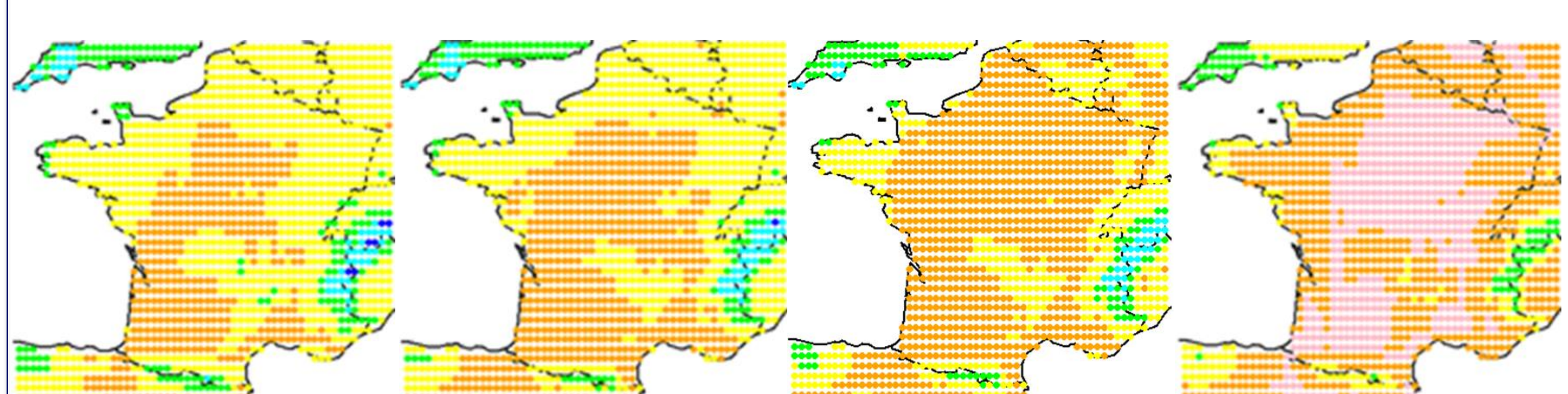
Since the uncertainty linked to the emission scenario remains lower than the modeling uncertainty at the 2050 horizon, all 30 maps (15 models and 2 emission scenarios) are considered together

Daily Maximum Temperature

Observations 1995-2014

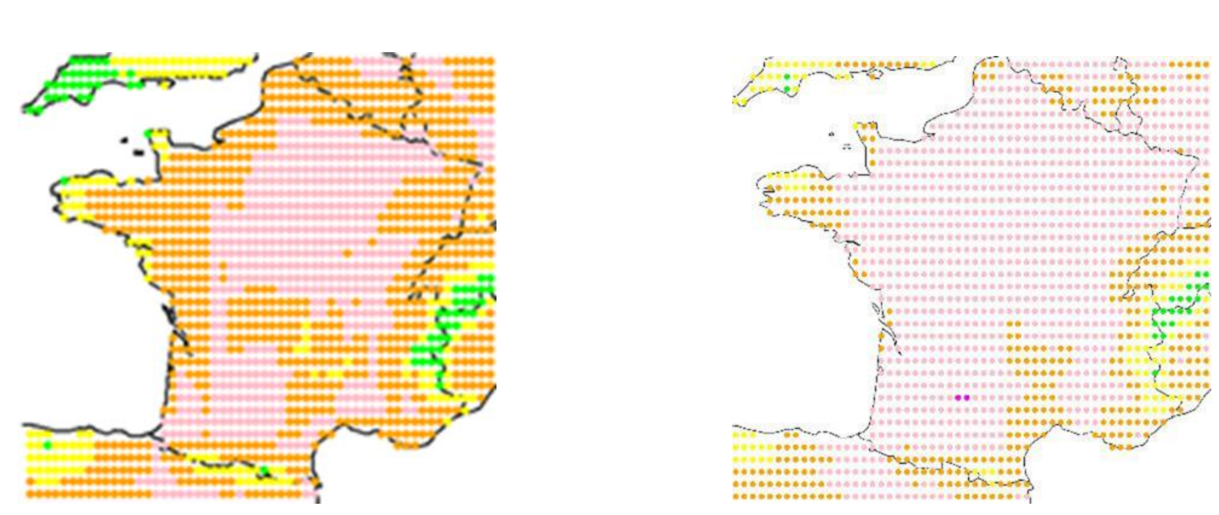


Projections 2041-2060: 4 clusters



• <20 • 20< <25 • 25< <30 • 30< <35 • 35< <40 • 40< <45 • 45< <50 • 50< <55 • >55

Comparison to the 2020 study with CMIP5 for the highest projected levels



The highest projected levels are generally lower compared to those computed in 2020 with the most sensitive CMIP5 model. It leads to the conclusion that the recommendations made for the adaptation plan of Enedis following the previous 2020 study on extreme-temperature-induced hazards are still relevant for the 2050 horizon.

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References:

Parey S. & Marty A. (2021), Resilience of the French distribution network to climate change: projected changes for main meteorological hazards around 2050, CIRED conference, paper 0468
Parey S., Hoang T.T.H., Dacunha-Castelle D. : Future high temperature extremes and stationarity, Natural Hazards, 2019, https://doi.org/10.1007/s11069-018-3499-1