Establishment of a climatological frame of reference of cold weather for gas TSOs

Marie CASSAS\textsuperscript{1}, Agathe DROUIN\textsuperscript{1}, Florian GIBIER\textsuperscript{1}, Valérie LAFONT\textsuperscript{2}, Raphaël LEGRAND\textsuperscript{1}, Yann MICHEL\textsuperscript{1}, Marketa PICHLOVA LALLEMENTOVA\textsuperscript{2}, Aurélien RIBES\textsuperscript{1}

\textsuperscript{1}METEO-FRANCE, Toulouse, FRANCE  \textsuperscript{2}GRTgaz, Bois-Colombes, FRANCE

ICEM 2023, Padova, ITALY, 27-29th June 2023
Gas transmission in France

- Two actors in France: GRTgaz and Teréga

- **Continuity and safety of gas supply** in the country:
  - Development, maintenance and safety of the network
  - Dispatching to the local and national distribution operators
  - Storage and LNG terminals interfaces management
  - International transit of gas
  - Support to renewable and sustainable gases development
Need for climate services

- Each winter in France, high energy demand for heating
  - Operational decision making to guarantee the balance of the system
  - Depends on meteorological conditions

  **Need for a climatological reference** to contextualise each real time situation
  - *historical values and return times associated*

- In the long term, provide enough energy for heating during severe cold spells
  - Dimensioning of pipelines, underground storages, etc.
  - While carrying out the partial conversion of the network to H₂ or CO₂

  **Need for an estimation of the magnitude of severe cold spells** in current (and future) climate
  - *2, 10, 20, 50-year return levels*
Methodology overview

1. **Data extraction**, handling of missing values, computing of derived variables of main interest

2. **Statistical modelling** of the distribution of the variables, fitting of the parameters on the dataset

3. Trying different models, checking their quality and **selecting the most adequate** and reliable

4. **Computing the return levels or periods** using the selected model with associated **confidence intervals**
Dataset of the study

- Current climate: study on the past period **1949-2021** with historical data in France
- 2-meter air temperature measured by ground weather stations from MF’s national network
- Climatological reference: **heating degree days** cumulated over different periods (3, 7, 14 days, monthly, whole winter) and over all stations
- Risk of extreme cold spells: daily mean temperature smoothed over 3 days for each station
- Missing measurements, relocations: hard to get complete, continuous, homogeneous series

Locations of the stations of the study

Yearly minimums of smoothed daily temp., Lille
Statistical models

- Statistical modelling to represent distribution of variables:
  - Generalized Extreme Value (GEV) distribution for cold spells (3 to 14 days):
    - Block maxima approach (width = 1 year / 1 or 2 months)
    - Peak-Over-Threshold (GPD) approach tested for degree days
    - 3 parameters:
      - Shape $\xi$
      - Location $\mu$
      - Scale $\sigma$
  - Gaussian distribution for monthly and winterly cumulated degree days
    - Best-suited for cumulated variables (central limit theorem)
    - 2 parameters:
      - Mean $\mu$
      - Variance $\sigma^2$
Taking into account the climate tendency

- Previous models will only work for *homogeneous time series*, which is not the case due to climate change caused by human activities: this tendency needs to be taken into account.

- Robin and Ribes, 2020: covariate $X_T$, proxy of the average tendency on the period → parameters of the distributions vary depending on year / climate state

- **GEV / Gaussian distribution:**
  - GEV: constant shape $\xi$
  - Location / mean: linear dependence
  - Scale / variance: linear + exponential link (positivity)
    \[
    \mu(T) = \mu_0 + X_T \star \mu_1 \quad \sigma(T) = \exp(\sigma_0 + X_T \star \sigma_1)
    \]

- Choosing (arbitrarily) an adequate covariate $X_T$:
  - Ribes et al., 2022: *yearly mean temperature over France* on the 1850-2100 period using **GCMs constrained by regional observations** (also used for IPCC AR6)
Selecting the best models

- Validate the relevance of the non-stationary formulation
- Checking which parameters really need to vary with $X_T$
- Avoiding useless complexity which could deteriorate reliability

**Likelihood ratio test**

e. g. GEV distribution:

- Stationary Gumbel ($\xi = 0$, constant $\mu$ and $\sigma$)
- Stationary GEV (constant $\xi \neq 0$, $\mu$ and $\sigma$)
- Non-stationary GEV Loc (constant $\xi \neq 0$ and $\sigma$, $\mu(T)$)
- Non-stationary GEV Loc+Scale (constant $\xi \neq 0$, $\mu(T)$, $\sigma(T)$)

- Results (same formulation for all stations and time blocks for homogeneity):
  - **Non-stationary** formulation is necessary
  - **Only on location / mean** (non-stationarity on scale /variance = non-profitable complexity)
Main results

- Return levels of cold spells and winterly cumulated degree days follow the same kind of evolution as the covariate:
  - relatively stable until 1970 (high aerosol emissions compensate warming effect)
  - increasingly steeper from 1980 to present (as the aerosol emissions decrease)

- Magnitude of severe cold spells decreases over the period (+0.4°C/dec in 1980, +0.6°C/dec in 2020)

- Similar evolution for the degree days cumulated over the whole winter

- Month by month results have similar characteristics but show some discrepancies
  e. g.: Cumulated degree days decrease slower in December, January and February (7-8% between 1990-2020) than in November / March (10%)
Confidence intervals, uncertainty and limits

- Confidence intervals computed by bootstraping
  - The higher the return level, the larger the confidence interval
  - The width of the intervals remains relatively constant (high return levels, 1-year and winter)
  - Width more variable for smaller return levels and summer months

- Small dataset (73 years): relatively high uncertainty for 50-year return levels
  → confidence intervals are large but need to be exploited

- Month by month results are less reliable (EV theory limits), especially in summer
  → better to consider larger blocks (1-year)

- Some stations opened more recently: smaller dataset, higher uncertainty
  → station by station results might show geographical patterns that are not reliable
Take-away messages

- **Hard to get continuous and homogeneous measured time series**: need for a high resolution unbiased reanalysis to complete missing data, especially on complex terrain

- **Extreme event studying requires a large dataset** to be reliable: 70 years is short to compute 50-year return levels

- **Taking into account the tendency induced by climate change** in the time series is crucial (at least on the mean / location parameter)

- **Severe cold spells and cold winters are becoming less intense** for a same return time, at a faster rate than the mean temperature

- Uncertainty remains high: **confidence intervals are essential** and results still need to be handled carefully
Thank you for your attention
References


References


- ROBIN Yoann, 2019: Librairie SDFC v0.6 : https://github.com/yrobink/SDFC
