Probabilities and trends of extreme temperatures in Finland
- Some preliminary results

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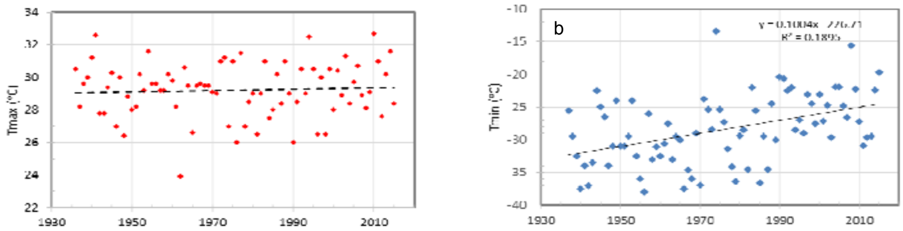

Fig. 1. Annual (a) maximum and b) minimum temperatures at a southwestern station (Salo) in Finland, in 1937-2015. Note the different vertical scales. No inhomogeneities were detected in these two time series.

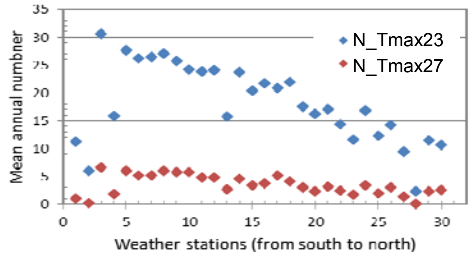

Fig. 2 The mean annual number of days with Tmax ≥ 23°C or 27°C at 30 stations in Finland.

Research questions

1. Based on past weather observations, what are the annual probabilities of occurrence of very high or low temperatures in Finland?
2. Are there any statistically significant trends that should be taken into account in extreme value analysis? If so, how influential are they?
3. How much do the return levels differ across the country?
4. Are the time series influenced by inhomogeneities?

Data and methods

- Time series of past weather observations: i) the longest available in digitized form, or ii) the past 50 years
- Linear trends and extreme value analysis (GEV): functions lm, ismev, evd and extRemes in the R statistical computing environment
- 95% confidence intervals of return levels: the profile likelihood method (Coles 2001).
- Detection of inhomogeneities in time series of monthly mean temperatures: the HOMER software (Mestre et al., 2013), an outcome of the COST Action ES0601 HOME.

Box 1. The number of stations without detected inhomogeneities in time series of monthly mean temperature:
4 out of 34 stations in the long series
10 out of 34 stations in the 50-year series

Table 1. Trends based on observations in 1961-2010. Column 1: Number of stations and the temperature variable. Column 2: The fraction of stations having a statistically significant increasing trend.

30 stations	Portion of stat. sign. trends
Tmax	2 /30
Tmin	12/30
N_Tmax23	10/30
N_Tmax27	3/30
8 stations	
T_7d_summer	5/8
T_7d_winter	1/8

REFERENCES:
Coles 2001: An Introduction to Statistical Modelling of Extreme Value, Springer-Verlag, Berlin and Heidelberg.
Mestre et a. 2013: HOMER: A Homogenization Software—methods and Applications. Időjárás 117 (1): 47–67. http://www.c3.urv.cat/docs/publicacions/2013/117-1-4-mestre.pdf.

Temperature indices
of interest for end users* of our results

- High transient values of temperature (annual maximum temperatures): Tmax (Fig. 1a)
- Low transient values of temperature (annual minimum temperatures): Tmin (Fig.1b)
- The annual numbers of days with Tmax ≥ 23°C (N_Tmax23) or 27°C: (N_Tmax27) (Fig. 2)
- High temperatures that persist for at least 24 hours (T_24h) (Fig. 3)
- High temperatures that persist for at least 7 days in summer (T_7dS) or winter (T_7dW)

Estimates of probabilities of very unlikely events

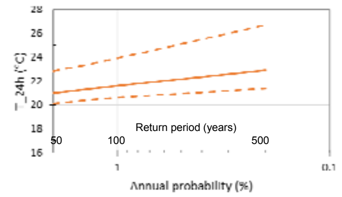

Fig. 3 Return level estimates (with 95% confidence intervals) of temperatures that are uninterruptedly exceeded for at least 24 hours.

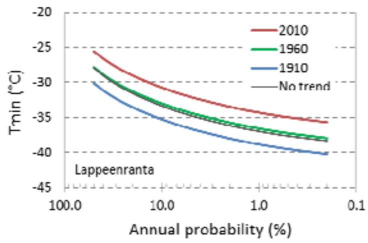

Fig. 4 Estimates of annual probabilities (%) of very low instantaneous temperatures (Tmin) at a southeastern station based on data in 1906-2010. Curves for three selected years: a time-dependent location parameter in GEV. Black: the trend of 0.46°C per decade at this station has been ignored.

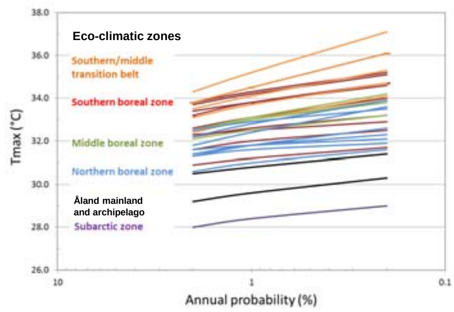

Fig. 6 Estimates of annual probabilities (%) of exceedance of high instantaneous temperatures (Tmax) at 30 weather stations that belong to six different eco-climatic zones in Finland.

Key findings

- ✓ The warming trend has been clearly more pronounced for annual Tmin than for annual Tmax (Table 1)
- ✓ => In estimating probabilities of very low temperatures, the warming trend need to be taken into account (Fig. 4).
- ✓ But: Both the lowest and the highest ever recorded temperatures in Finland have been measured rather recently: -51.5°C in 1999 and 37.2°C in 2010 (Fig. 5).
- ✓ The return levels are 10–15 ºC lower in northern Finland than in the south for Tmin but graphically rather uniform for Tmax (Fig. 6).
- ✓ Inhomogeneities in the time series were detected at most of the stations (Box 1), impacts of which should be considered in further analyses.

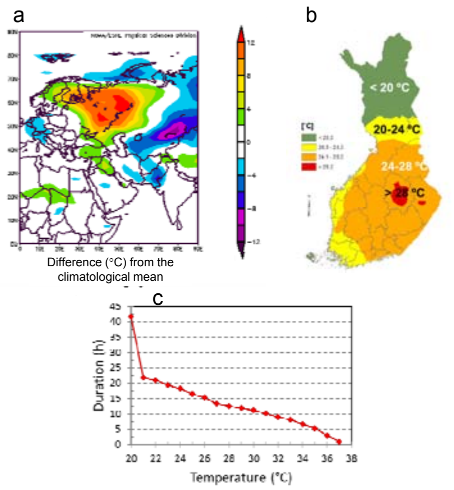

Fig. 5. Temperatures on 29 July.2010:
a) Anomalies of the daily mean temperature from the long-term average. b) Daily mean temperatures in Finland. c) Duration (in hours) of exceedance of temperature values, measured at intervals of 10 min, in Joensuu, the station of the record-high Tmax of 37.2.°C.

Conclusions

Challenges in assessing probabilities of occurrence of extreme weather events are caused by the relatively short periods of observational time series, inhomogeneities in them, and the on-going climate change.

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* Representatives of the Finnish nuclear power companies