# Drought Propagation as Illustrated by the 2018 Nordic Drought Event

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## The extreme drought in Northern Europe in 2018

The event was unique in its northern location of the high-pressure system (Fig.1) as compared to other major European drought events in the last decades (Ionita et al., 2017; Stahl, 2001).

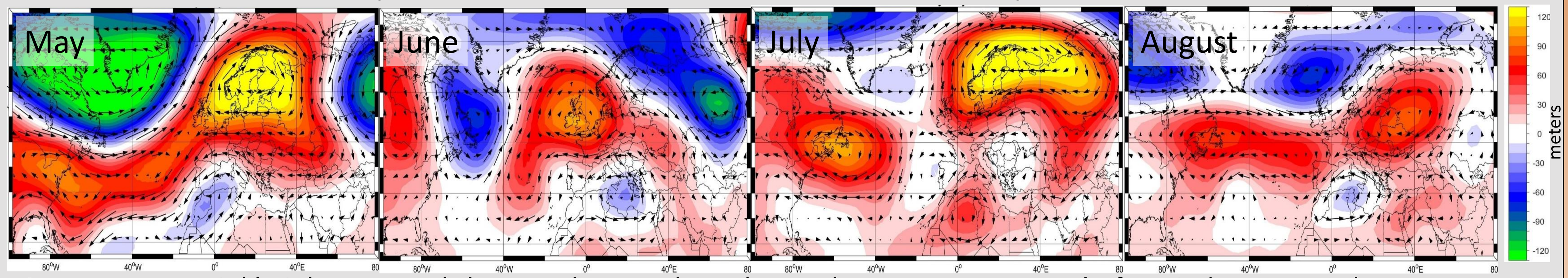
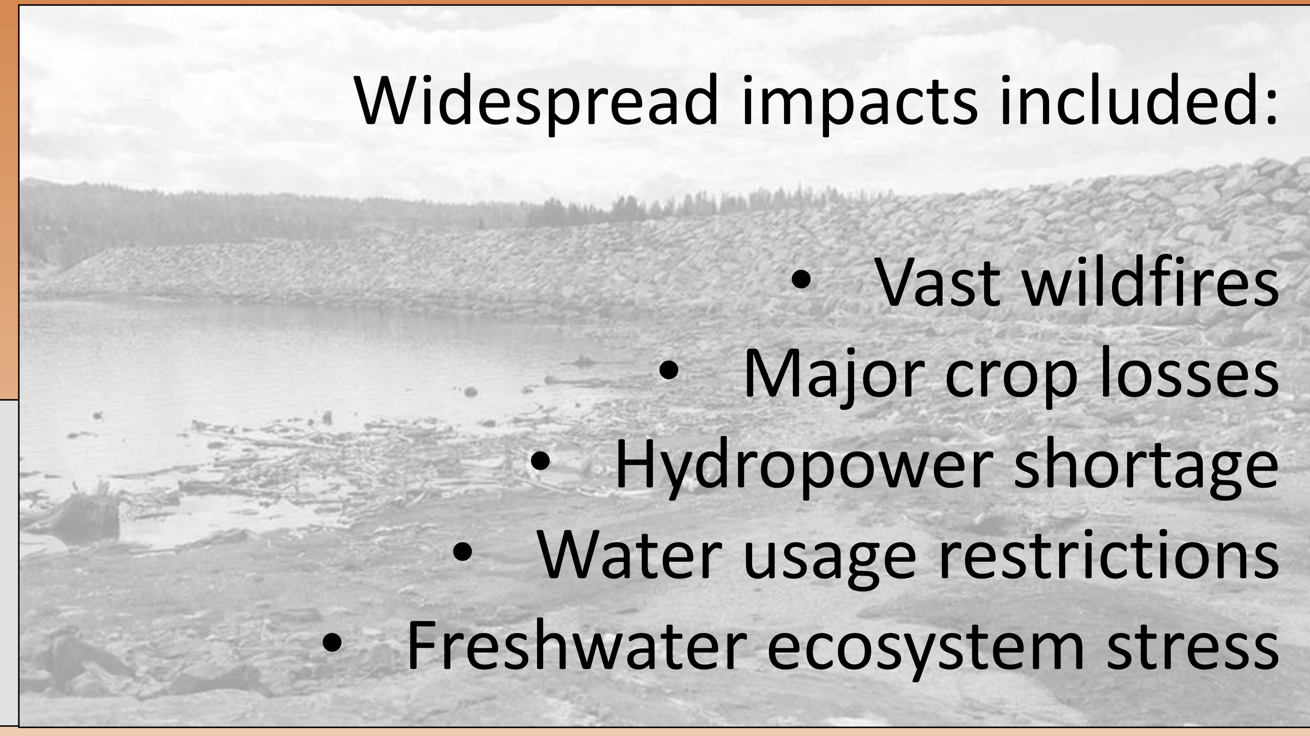



***Fig.1**: Geopotential height at 500mb (HGT500) anomaly each month May-August 2018 (ref. period 1971-2000).*

The affected Nordic region has high heterogeneity in terrestrial and hydroclimatological characteristics.

The hydrological aspect of drought propagation is vital as drought impacts are commonly felt on the ground related to freshwater resources and ecosystems.



Widespread impacts included:

- Vast wildfires
- Major crop losses
- Hydropower shortage
- Water usage restrictions
- Freshwater ecosystem stress

Photo: Stein Roar Leite / NRK

## Our aim: investigate the 2018 event from a climatological and hydrological perspective

May–August 2018 was analysed on a monthly time scale in three steps following the chronology of drought propagation (data providers in *italic*):

**Meteorological situation** was characterized by the 500 mb geopotential height (HGT500) anomaly, using the reference period 1971-2000 (*NCEP*), as well as the 60yr (1959-2018) rank of the 2018 (high) max temperature and (low) precipitation in Europe (*E-OBS*).

**Meteorological drought** in Europe was characterized by the standard precipitation-evapotranspiration index with a three months accumulation period (SPEI3), using reference period 1971-2000 (*E-OBS*).

**Hydrological drought** in the Nordic region was characterized by the 60yr (1959-2018) rank of the 2018 (low) streamflow in Norway (*NVE*), Sweden (*SMHI*), Finland (*SYKE*), and Denmark (*DMP*), and 30yr (1989-2018) rank of the 2018 (low) groundwater level in Norway (*NVE*) and Sweden (*SGU*).

## Data Providers

- **HGT: NCEP reanalysis:** ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis.derived/
- **Temperature and precipitation: E-OBS v19.0e:** surfobs.climate.copernicus.eu/dataaccess/access_eobs.php
- **Streamflow:** The Norwegian Water Resources and Energy Directorate (NVE), Swedish Meteorological and Hydrological Institute (SMHI), Finnish Environment Institute (SYKE) and Danish Environment Portal (DMP)
- **Groundwater:** NVE and Geological Survey of Sweden (SGU)

**References:**
Gottschalk, L, et al. "Hydrologic regions in the Nordic countries." *Hydrology Research* 10.5 (1979): 273-286.
Ionita, M, et al. "The European 2015 drought from a climatological perspective." *Hydrology and Earth System Sciences* 21 (2017): 1397-1419.
Kirkhusmo, L. A. "Groundwater fluctuation patterns in Scandinavia." NHP-report (1988): 32-35.
Stahl, Kerstin. *Hydrological drought: A study across Europe*. Diss. Institut für Hydrologie der Universität, 2001.

## Hydrological data

Hydrological data consists of observed streamflow and groundwater levels with negligible human influence. Fig. 2 and 3 show station locations and seasonal regimes.

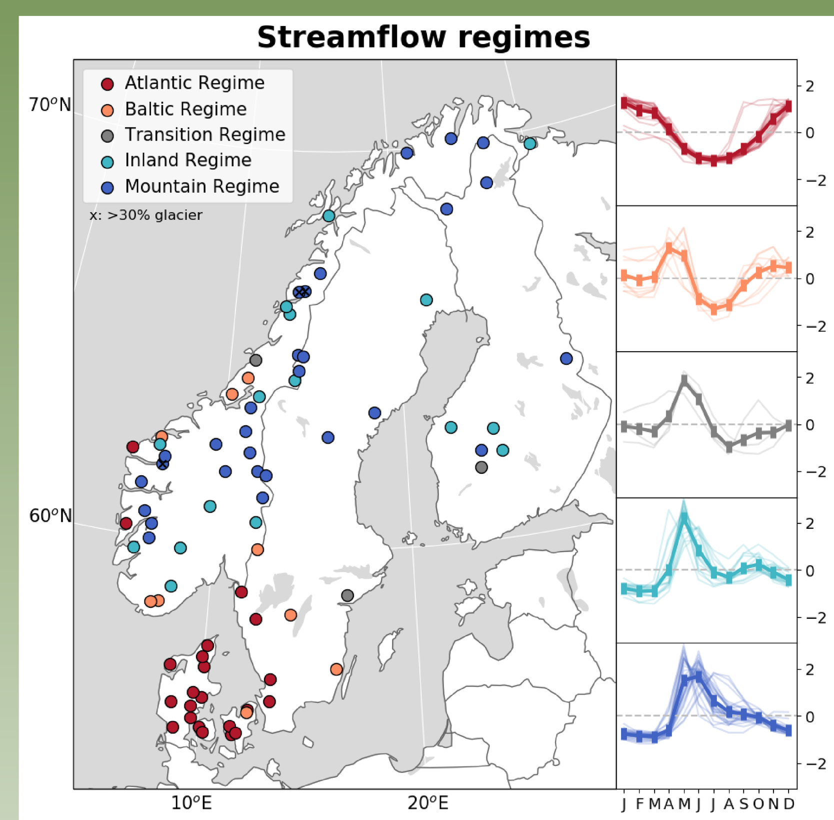



***Fig.2**: Locations and regimes (based on Gottschalk et al., 1979) of the 79 streamflow stations used in the study.*

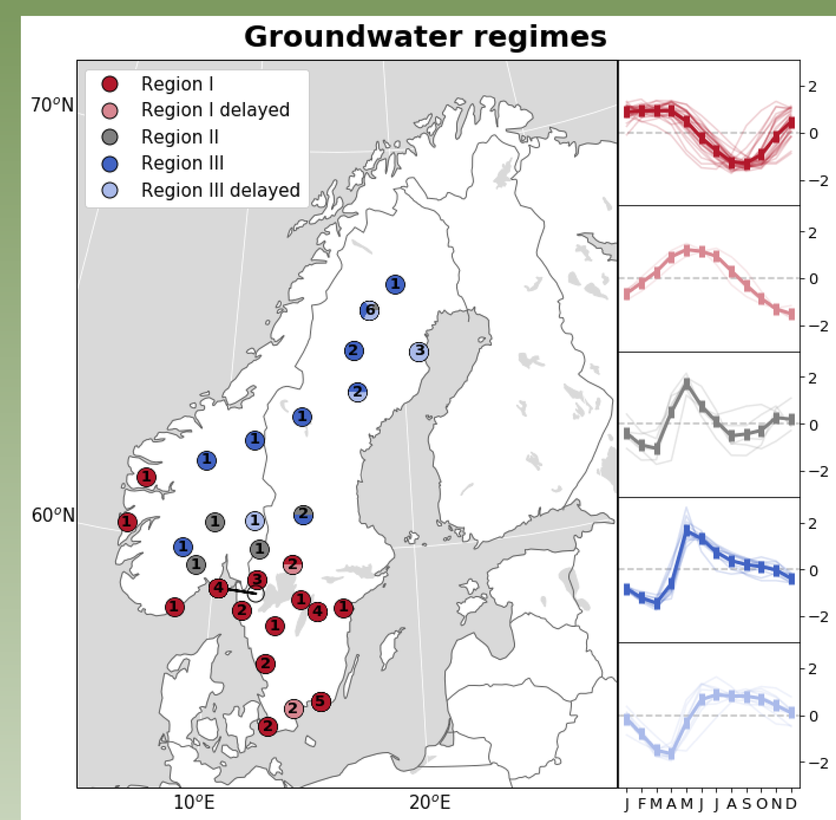



***Fig.3**: Locations and regimes (based on Kirkhusmo, 1988) of the 56 groundwater wells used in the study. Number of stations at each location is given at each point*

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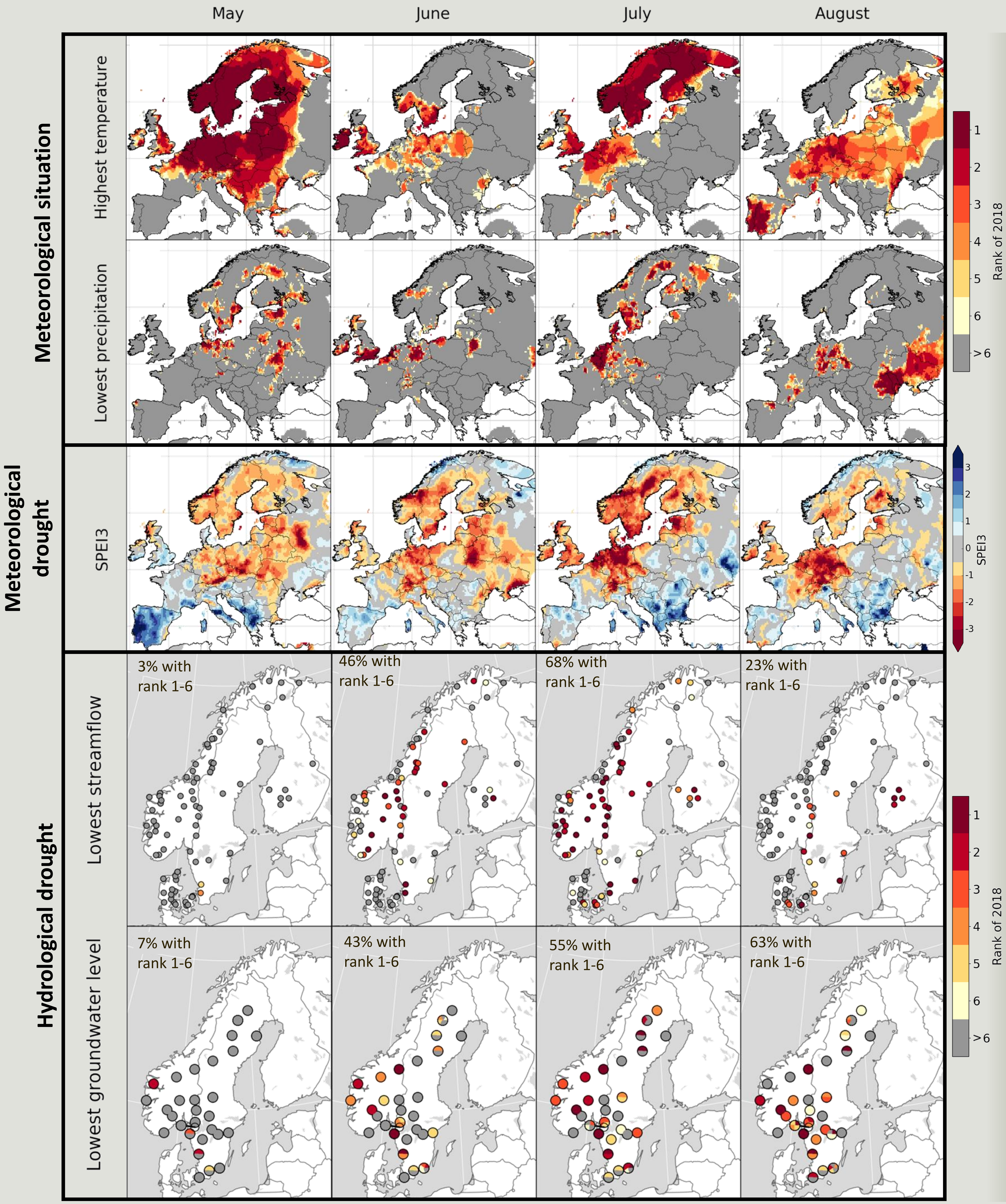


*Fig.4*: From top to bottom panel: Top-six ranking of highest temperature, top-six ranking of lowest precipitation, SPEI3, top-six ranking of lowest streamflow and top-six ranking of lowest groundwater. All variables are shown for each month May-August 2018 (left-right panel).

**Record-breaking high temperatures**.

**Record-breaking low precipitation was not as widespread** as for temperature.

Persistent low precipitation and high temperatures caused **meteorological drought to develop from May**, peaking in July.

Streamflow and groundwater drought developed from June, following **a delay in the hydrological system** due to antecedent water storages, and in particular snow.

Extent of **record-breaking low streamflow** peaked in July. In August, streamflow drought sustained in southeast, whereas heavy precipitation replenished streamflow in north and west.

**A high local variability was seen for groundwater drought**, reflecting the variability in hydrogeological properties.

## Streamflow in 2018 - four different regimes

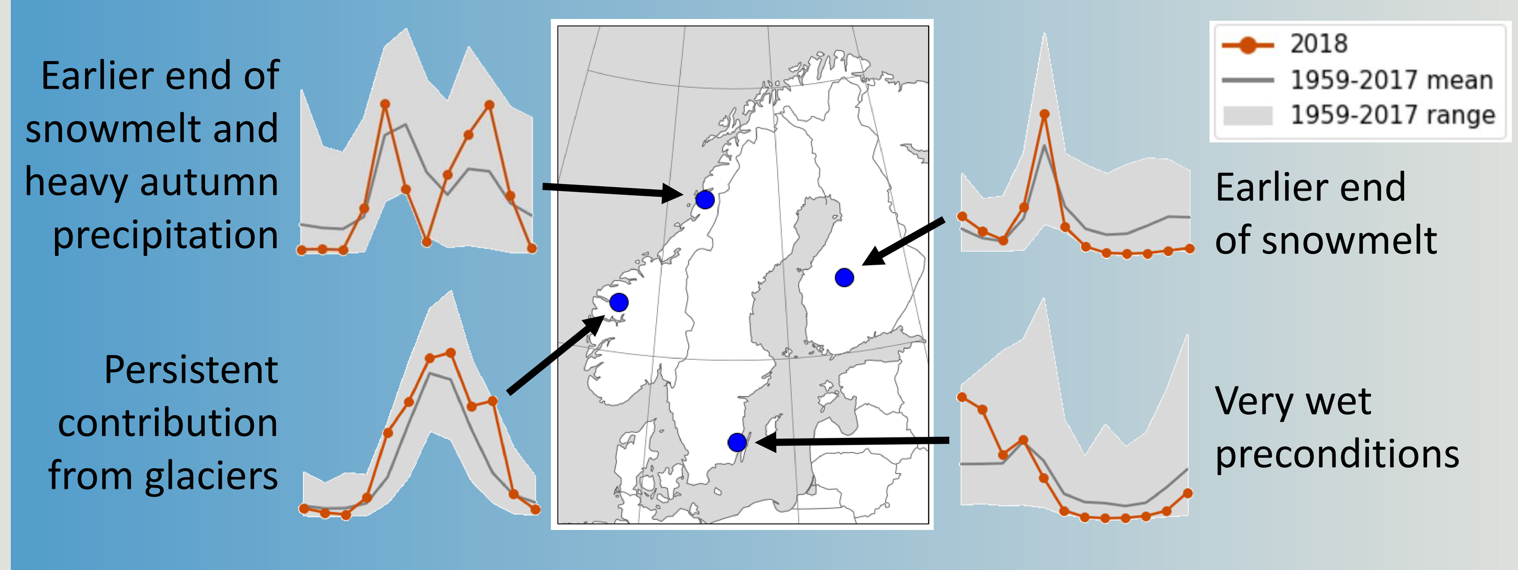


*Fig.5*: Hydrographs of four stramflow stations: 2018 vs 1959-2017 mean and range

## High variability in groundwater response

Groundwater tables vary with depth, soil type and aquifer properties, etc. and thus, respond differently to meteorological drivers, such as precipitation and high temperatures.

The 'response delay', i.e. the overall lag between a precipitation time series and groundwater table response, was estimated as the moving average interval that correlated the best with the daily groundwater time series (Fig.6a).

The delay was found valuable together with mean depth (i.e. mean groundwater level below surface; Fig.6b) in explaining the 2018 groundwater drought development (Fig.7).

Groundwater drought emerged in the shallowest wells already in June. With time, **extreme conditions were found in wells of increasing depth and response delay**. By the end of 2018, 38% of the wells still had rank 1-6.

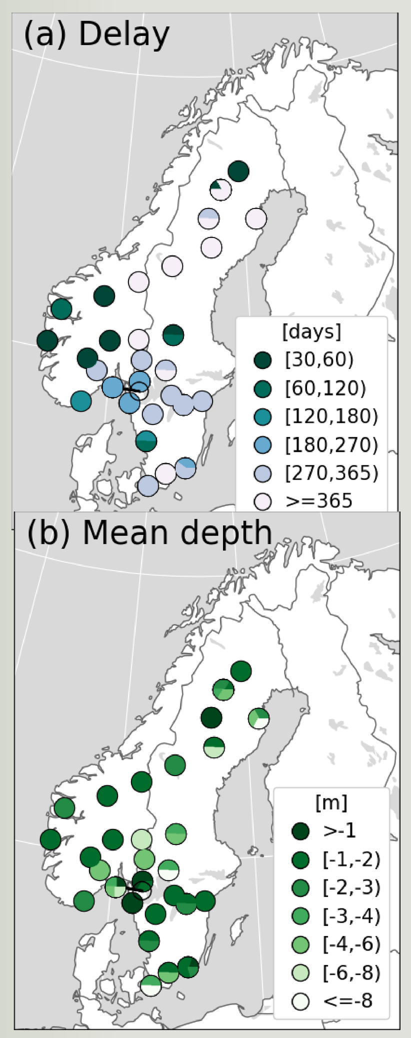


*Fig.6*: Groundwater (a) response delay and (b) mean depth.

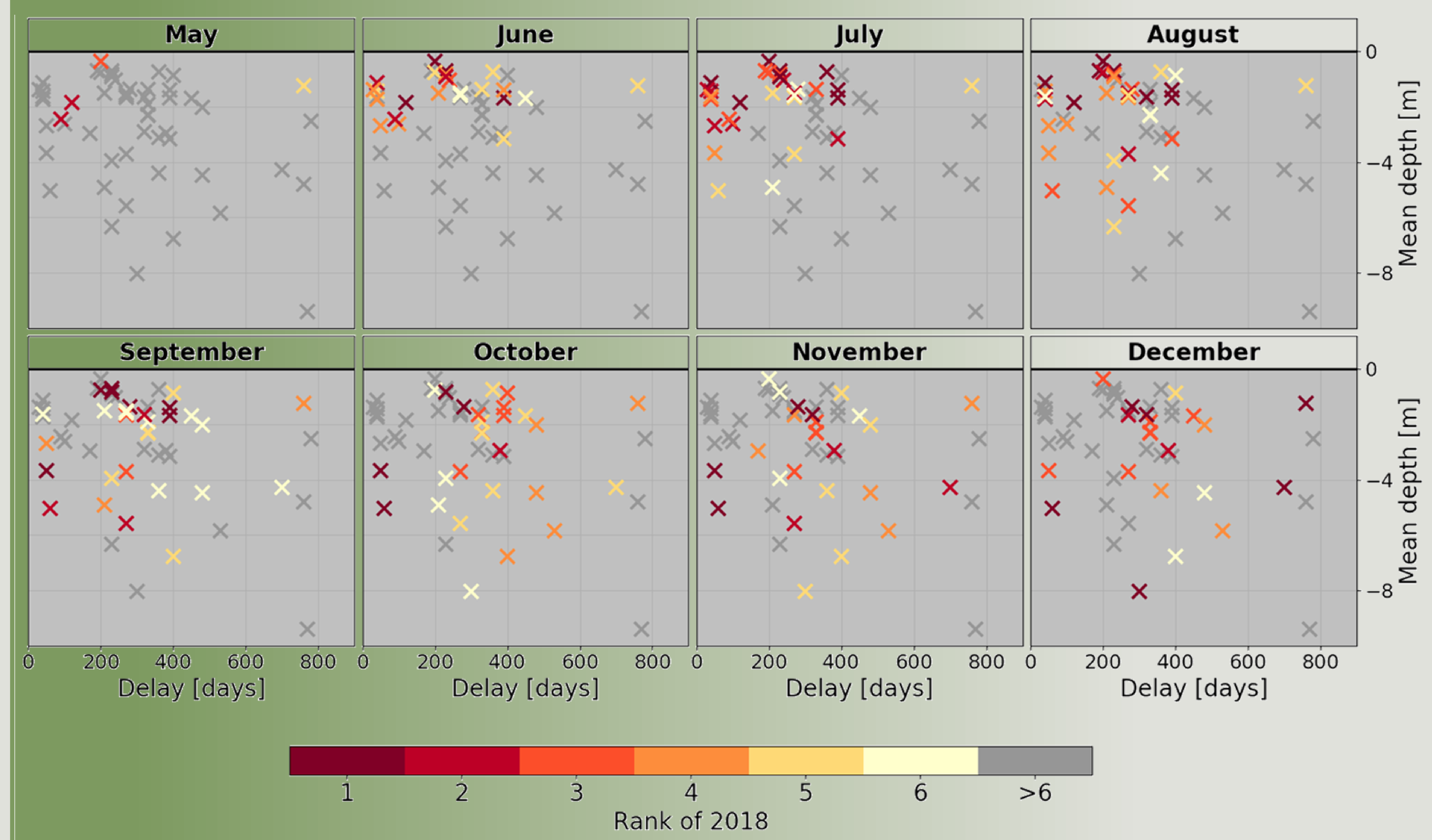


*Fig.7*: Top-six ranking of lowest groundwater level May-December 2018 plotted with each well's delay and mean depth along the x- and y-axis, respectively.