Investigating hydrogeologic controls on groundwater drought hazard in Sweden and Finland

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1. Problem

- Unexpected and unequally distributed groundwater drought in 2015-2017 (SGU, 2018)
- Many individuals in rural areas and farmers depend on private wells
- Very little data is available about aquifers in terms of:
  - More than 30 years of consecutive, monthly, water table observations (figure 1)

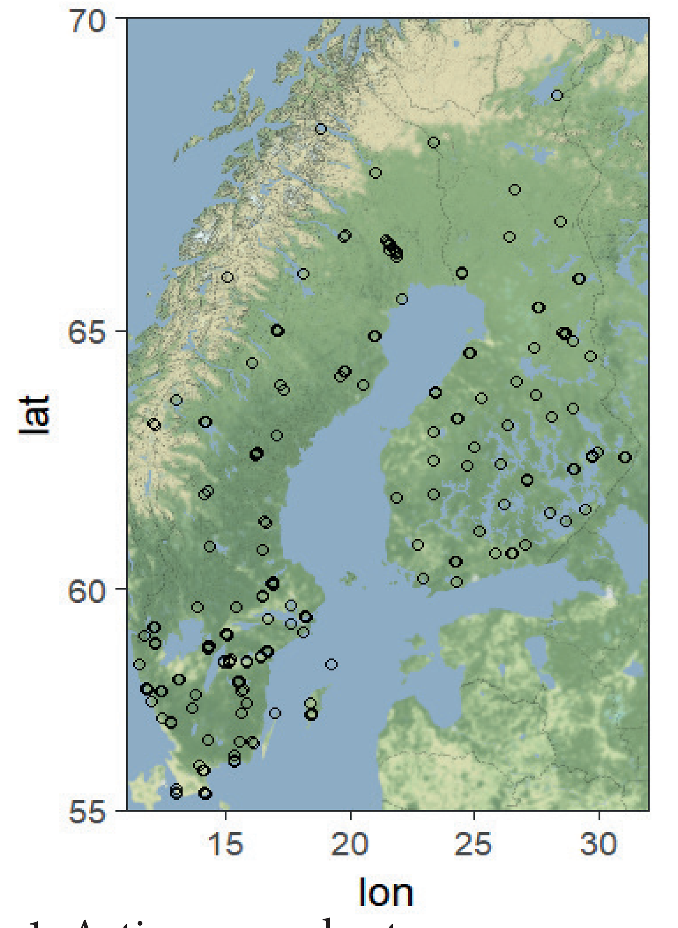

Figure 1: Active groundwater observation wells in Sweden and Finland.

2. Advantages of study area

- Wells are away from anthropogenic disturbance
- Relatively simple and similar hydrogeology:
  - Archaean and Proterozoic granites and gneisses, younger sedimentary bedrock in S. and S.E. Sweden
  - Groundwater hugely affected by unconsolidated glacial deposits of *e.g.* eskers, till, marine clay and glacial outwash
- Regional drought differences mainly due to climate regime

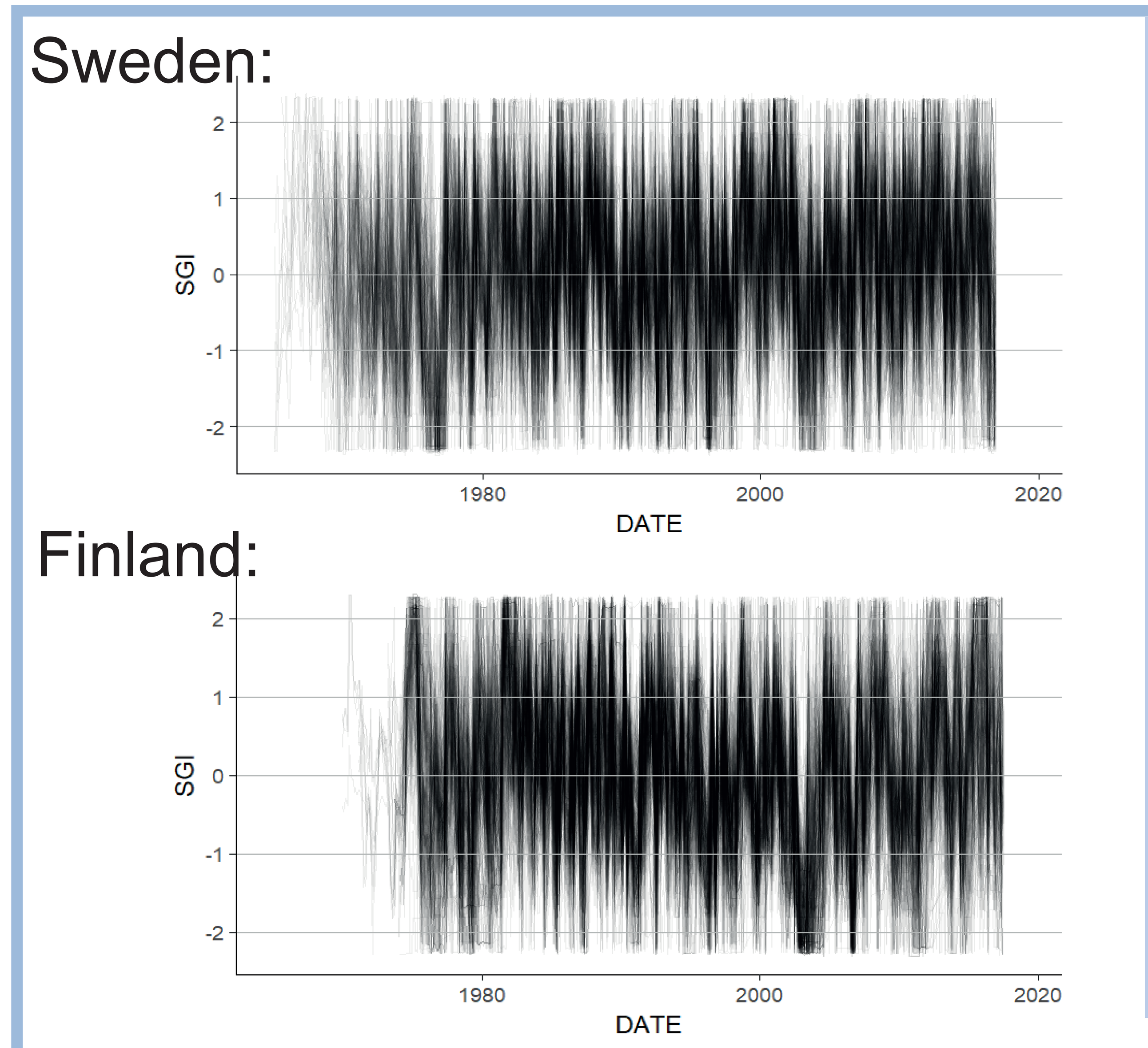

Figure 2: Standardised Groundwater Index (SGI) values of Swedish (above) and Finnish (below) groundwater wells.

3. Drought classification

- The Standardised Groundwater Index (SGI) is used to observe temporal and quantitative patterns of drought (when SGI < 0)
- Indicative of historic, regional, groundwater drought events
- Shows variance in portion of highly-impacted wells
- Sweden and Finland portray differing effects of concurrent drought events:
  - variable severity of droughts (1976-77 in Sweden; 2003 in Finland)
  - some minor/localised events do not correlate at all (*e.g.* beginning of the 1980s)

Result of regional differences in climate regime

4. Approach

Bloomfield and Marchant (2013); Bloomfield *et al.* (2015):

- Use SGI to identify drought periods and affected wells (figure 2)
- Correlate SGI to the Standardised Precipitation Index (SPI) and use resulting SPI aggregation periods to evaluate accumulation of precipitation and lag time of wells (figure 3)
- Gather information on geological, climatological, environmental and geographical data for hydrogeological classification of SPI aggregate cluster groups

Example well:

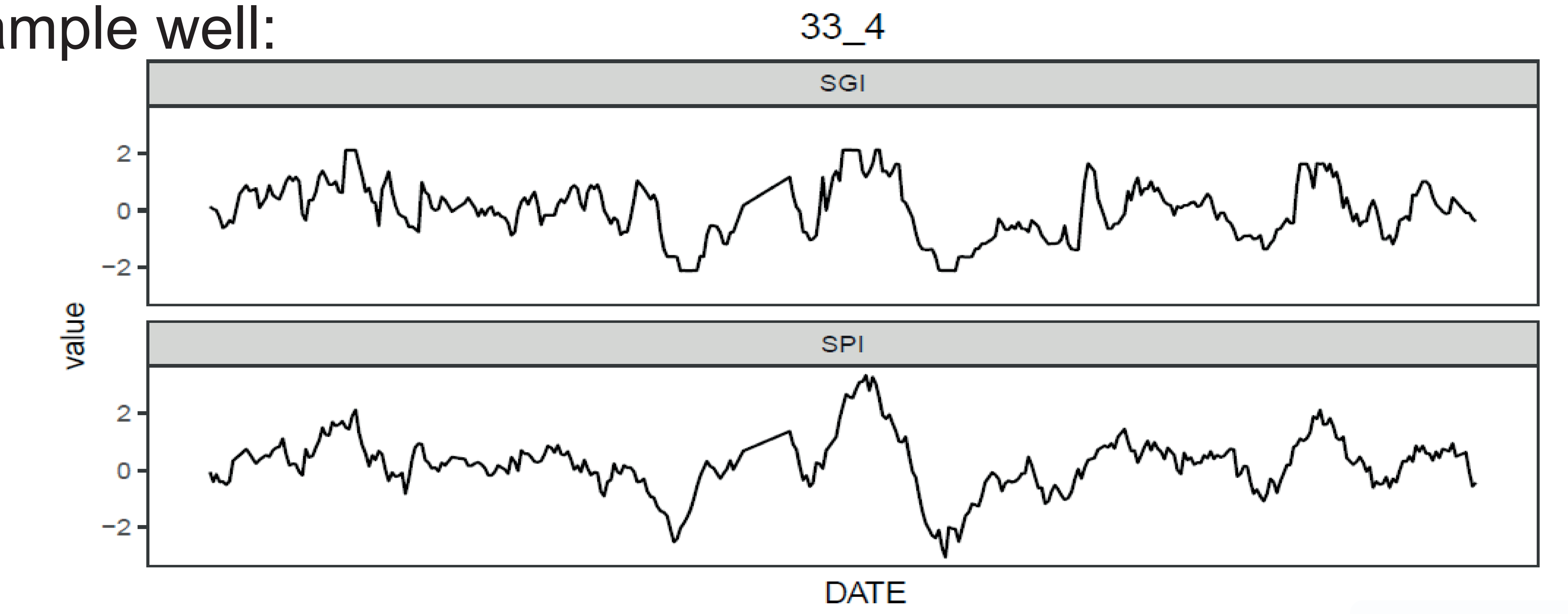

Figure 3: Standardised Groundwater Index (SGI) and Standardised Precipitation Index (SPI) of best correlated aggregation period (16 months, R = 0.77) for one well in Sweden.

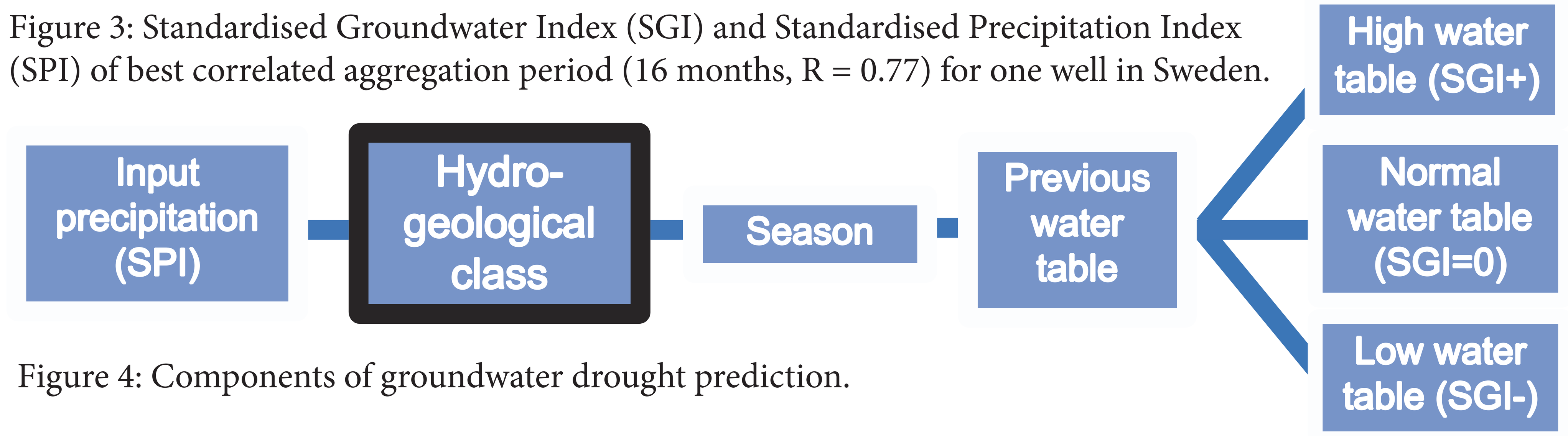

Figure 4: Components of groundwater drought prediction.

- SPI alone cannot account for nor predict groundwater drought (Bloomfield et al. 2015; Kumar et al. 2016)
- Must build robust and sound database of hydrogeological data available to create a classification of SPI groups (figure 4)
- Will use Principal Component Analysis (PCA) and conditional inference trees to deduce strongest parameters affecting SPI aggregation period and drought propagation

5. Results so far

From test-run using 10 Swedish observation wells:

- Results indicates yearly differences in average temperature does not affect well drought occurrence
- SGI and SPI correlations themselves can only account for up to 80 % of SGI, at best

... Results so far

From test-run using 10 Swedish observation wells:

- The magnitude of coeffiecients used in PCA suggest depth to water table, soil thickness, land cover, surface elevation, soil grain size, and magnitude of water table differences are factors correlated to SPI aggregation period (figure 5)

Examples of variables in PCA:

- wt_m.b.surface = water table depth
- soil_thick = soil thickness
- lc_pine = land cover pine forest
- surface_m.a.s.l. = elevation
- wt_diff = water table difference (maximum difference between lowest and highest water table for one well)
- sed = sediment type (finer to coarser grained)
- dry_count = extreme drought (SGI < -2) frequency
- HK_below = highest coastline
- well_len = length of observation well

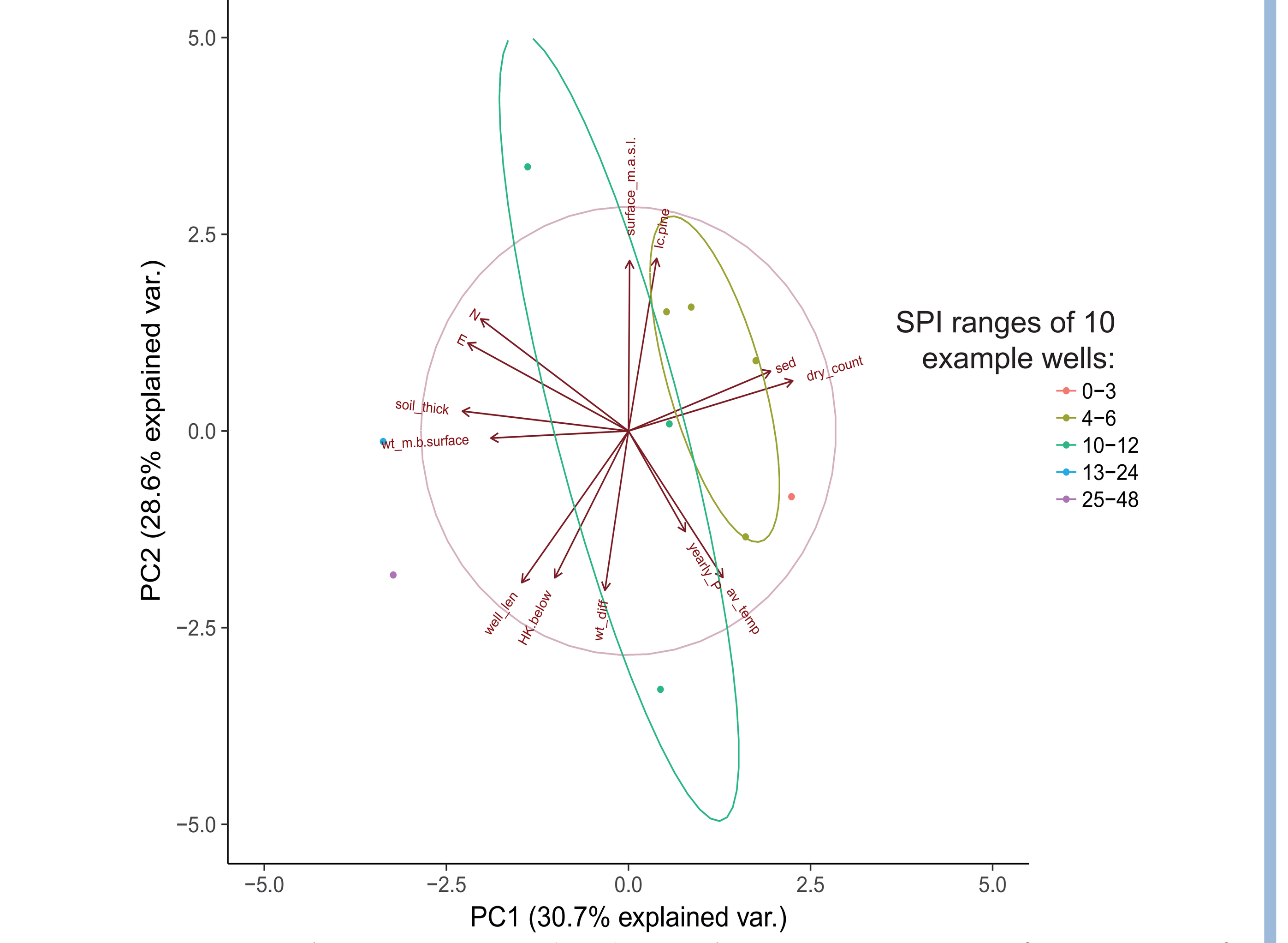

Figure 5: Principal Component (PC)1 and PC2 accounting for ~59 % of the variance in SPI aggregation periods (legend) of 10 example wells.

6. Future work and open questions

- We will include snowmelt via a snowmelt and rain index (SMRI, Staudinger *et al.* 2014)
- Depending on data availability, we will include stratigraphy and additional hydrogeologic parameters to wells and apply these to all available time series in Sweden and Finland

- Is it possible to deduce or estimate transmissivity and/or storativity, without measurements, from geological information about glacial deposit aquifer material, and how would you do it?
- Is there anything else we need to consider?

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