Climate change vs. human impact. A look into Austrian groundwater

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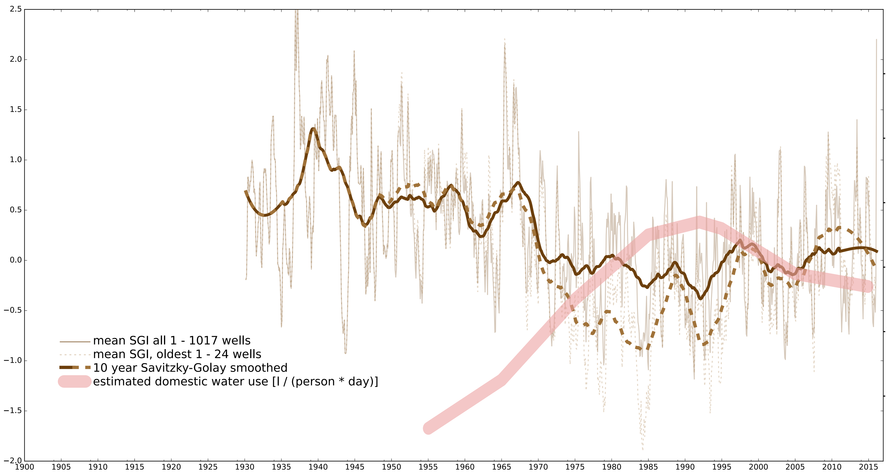
Using standardized hydrological time series from a large dataset covering Austria from earlier than 1930 until 2015, we show that groundwater levels are following the opposite trajectory of human water use [1].
Comparing standardized groundwater levels (SGI), stream stages (SRSI), and precipitation (SPI), we discuss points in support of - and against - a possible causality of this observation.
We conclude that this observation could partly be explained by a causal relationship, but further work is needed. Regarding possible future developments of climate and water use, we deem it possible that water use could increase again and thus dropping groundwater levels could return again.

Due to the change of the EGUs setup this year, this poster has been designed to stand on its own as a somewhat text heavy extended abstract. It should work as one, long, screen width filling PDF.
You are of course still very welcome to ask me questions in the chat!

1 Hypothesis



Countrywide, average, standardized groundwater levels for the oldest 1-24 wells (dashed lines) and all 1-1017 wells (full lines) [1] with an estimate for Austrian domestic water use per person and day (red, wide line), using data from [2] and [3].
● Domestic water use shows opposite pattern as groundwater levels
● Water savings apparently result in rising groundwater levels

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Regarding this possible human cause and fix, the following issues supporting this hypothesis have to be considered:
● Human water use is know to affect groundwater levels, e.g. in the Californian central valley [4] or in the Austrian Marchfeld region [5]
● In the Marchfeld, groundwater levels have recovered due to human intervention [5], [6]
● Austrias public water supply is almost exclusively based on groundwater [7]
● Monitoring wells are mostly situated in the populated valleys
● Industrial water use is likely following a similar trajectory in use increase and reduction [2], [8]

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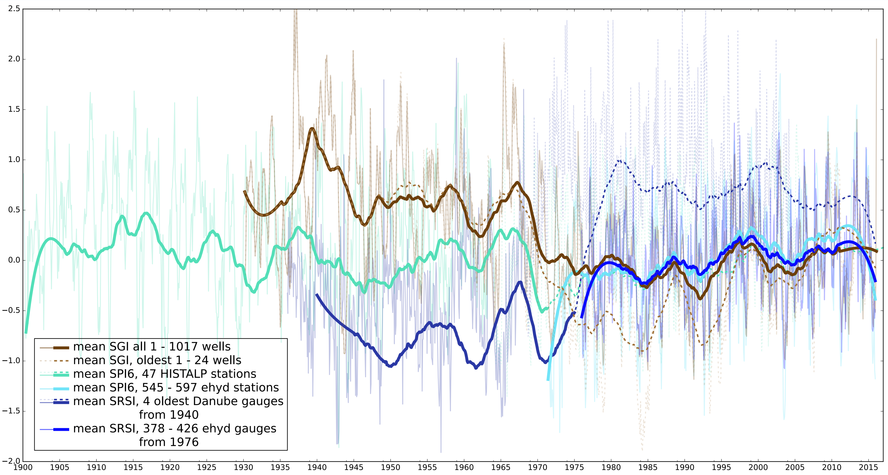
On the other hand, there are many issues that point towards a more complicated situation:
● While sourced from groundwater, ~50% of Austrian drinking water is supplied from springs, draining the unmonitored mountain ranges [9]
● E.g. Vienna sources 100% of its drinking water from a mountain range approx. 100km away, but there is still a large and changing number of private wells in the city [10]
● Most valley fill aquifers are heavily influenced by their rivers
● Rivers have considerable infrastructure, e.g. 10 large hydro power plants on the Danube, 80+ on the other big streams [11], 4000+ small and micro plants on the smaller streams [12] which are changing over time
● The number of wells in the dataset changes over time

3 Discussion



Comparing the countrywide groundwater levels to the other components of the water cycle (Image from [1]. thick lines are 10 year Savitzky-Golay smoothed), a more nuanced picture appears:
● The rise in groundwater follows the rises in precipitation and river stages
● The drop however has no equivalent in precipitation and river stages
● Vast changes in river stages are evident in the Danube gauges, but the rise around 1975 cannot be explained
However, a noticeable difference between precipitation and groundwater before the 1980s remains.
● Part of it is likely an artifact from the changing number of wells, but
● The trend is strongest in the oldest wells
So we assume that the drop in groundwater levels can at least be partly explained by human water abstraction

4 Future?

As shown, the behavior of groundwater can be explained by climate (precipitation and thus river stages) as well as the human factor. What are the possible pathways for those in the future?
● The Alps already show above average warming [13] which is possible to continue
● This however must not necessarily mean dryer conditions [14]
● More frequent and severe extreme events can be expected, as exprienced during the last years
● In the mountain regions, skiing resorts are building considerable infrastructure to collect water for winter use [15], further affecting the water cycle
● Increasing demand for green energy is likely to result in more hydro power plants
● In parts of Austria, agriculture is increasingly using irrigation and storage infrastructure [16]
● Private swimming pools are already increasing in their number [17]
● There are projections that a warmer climate can increase water use again [3]
● (City) populations are increasing [18]

Especially the latter points have precedence in Austrias history:
● In the Marchfeld Region, waterlevels have been dropping due to irrigation (see above)
● The Vienna water supply was built in the late 19th century because of the growing city, exhaustion of local options and declining water quality [10], [19]
● Increased availability in water led to increases in water use [20]
Thus, we deem the following scenario possible:
● Increasing domestic and agricultural water use
● Localized population growth
● Overwhelming of local water supplies and/or regional groundwater exhaustion
● Technical fix by piping in water from the many water rich parts of Austria
● Another wave of water savings by technical means and behavior changes

5 Conclusions

A human influence on groundwater that is visible on a country level cannot be ruled out. This influence can be negative or positive, with the positive one likely dominating at the current time. However, in the future, the negative influence could prevail again.
As a water rich country, Austria appears well positioned to solve these possible issues for domestic water supply with technical means, as exemplified by the history of the Vienna water supply. However, as there are many unknowns for these possible future scenarios, including also environmental and ethical implications of long distance water supplies, further work is needed.
Furthermore, there is work to be done regarding the chemical and biological quality of groundwater under conditions of increasing or decreasing water levels, where extreme events are known to mobilize nitrates deemed to be fixated in the soil column [21], [22].

Acknowledgments

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