Irrigation from the cryosphere - a global analysis of the contribution of melt water to irrigation water supply

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Abstract: Irrigation water in many regions in the world is partly supplied by snow and glacier melt water (Fig. 1). Changing snow pack dynamics impact the availability of water during the crop growing seasons.

We use PCR-GLOBWB, a global hydrological model to simultaneously simulate water availability and irrigation water use, and estimate the contribution of melt water to irrigation water supply. An analysis for major river basins shows important changes in the timing of runoff, which, in combination with increased demand for irrigation water to supply a growing population, could potentially create additional water stress if the growing season cannot be adapted. Variations in the snow melt can partly be buffered by water resources management options such as reservoirs.

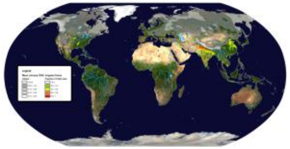

Fig. 1: Geography of irrigated areas and snow dominated regions (mean January snow water equivalent (SWE), modeled with PCR-GLOBWB)

Methods and Data

Water availability and water use is simulated using the global hydrological model PCR-GLOBWB (van Beek et al. 2011, Wada et al. 2010).

Water availability

PCR-GLOBWB is a 'leaky bucket' model that simulates the vertical components of the hydrological cycle based on climate drivers (precipitation and temperature) at a daily time step and a spatial resolution of 0.5 deg globally. Sub-grid variability is taken into account for vegetation cover, snow accumulation and melt (10 elevation zones), and soil types. A HBV-type degree day factor approach is used to model snow melt. Groundwater is represented by a linear reservoir that is recharged from excess water percolating from the soil root zone. Grid cell runoff is routed through the river network with a topography and river bed geometry dependent velocity. Release from large reservoirs (taken from the GRanD database (Lehner et al. 2011)) is simulated to meet downstream demand (below) or mean annual inflow if demand is zero.

Water demand and water use

Irrigation water demand is calculated using the FAO paper 56 method as a function of crop ET, taking into account seasonally varying crop water demand for different crops (taken from the MIRCA database (Portmann et al. 2010)). Computed demand is supplied (in order) by abstractions from (local) groundwater and abstractions from surface water. Surface water availability depends on reservoir operation (Fig.2)

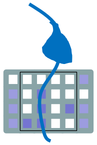

Fig. 2: Reservoir release is simulated such that modeled irrigation water in an area downstream of the reservoir (depending on topography) is met .

Water abstractions

Water originating from snow melt and from rain water is routed through the river network, assuming full mixing in reservoirs (Fig. 3)

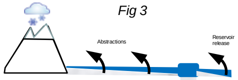

Fig 3

Results – Changes in snow cover

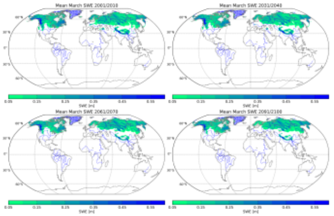

Fig 4: PCR-GLOBWB-modeled mean pre-growing season (March) snow water equivalent for different time slices in the 21st century based on MPI-ECHAM5 climate projections for the A1B scenario

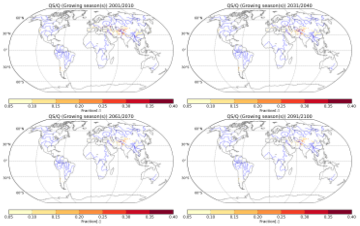

Fig 5.: Projected changes in the contribution of snowmelt (Qs) to total surface water availability (Q) during the growing season(s) for different time slices in the 21st century (ECHAM5-A1B scenario)

Available surface water during the growing season(s)

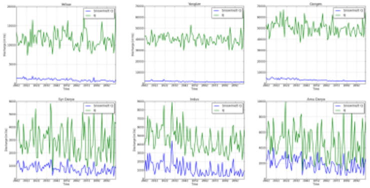

Fig 6.: Projected changes in the contribution of snowmelt (Qs) to total surface water availability (Q) for selected river basins during the growing season(s)

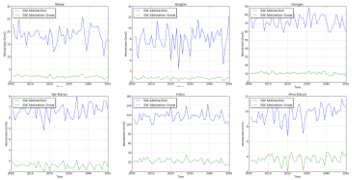

Fig 7: PCR-GLOBWB-modeled surface water abstractions (total and contribution from snowmelt) for selected river basins 2001-2050. Irrigated areas assumed constant.

Global scale results (preliminary)

- Consistent with reported values (Siebert et al. 2010), we find that ~50% of the global irrigation water use (~3,000km^3) can be met by groundwater, ~20% by surface water (10% of which coming from snowmelt). Remainder is from non-renewable sources.
- Contribution of snow melt to local groundwater supplying irrigation water is small

Conclusions

- Snowmelt significantly contributes to growing season water availability and irrigation water supply in many irrigated areas
- Contribution of snowmelt to local groundwater supplying irrigation water is small
- Changing snow melt dynamics impact growing season water availability and irrigation water supply
- Existing reservoirs buffer the changes in snow melt timing

Future work

- Include runoff from glaciers (GLIMS database)
- Simulate future contribution of snowmelt using AR5 scenarios
- Project growing season changes based on weather
- Constrain groundwater abstraction by available groundwater (Wada et al. 2010)
- Include large inter-basin water transfers

Key References:

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