# Description of problematic consumptive water use model output from WaterGAP2 within ISIMIP2a and ISIMIP2b

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## Background

Based on feedback of ISIMIP2b WaterGAP2 model output assessment, we were pointed to negative total actual water consumption (atotuse according to ISIMIP2b protocol) values in some grid cells of India. We investigated this and realized an inconsistent handling of water consumption for some situations. This document describes the problem and provides an overview of grid cells with possible problematic (inconsistent) model output for actual water consumption as well as actual evapotranspiration.

## Calculation of atotuse in WaterGAP2 and description of the problem

In WaterGAP, five water use submodels (for irrigation, domestic, manufacturing, cooling of thermal power plant, livestock) calculate sectoral water withdrawals and water consumption. Since model version WaterGAP 2.2 (i.e. used in ISIMIP2a, ISIMIP2b), WaterGAP distinguishes the source of water (groundwater or surface water) within the sub-module GWSWUSE which computes net abstractions from groundwater (NAg) and net abstractions from surface water (NAs) (see appendix of Müller Schmied et al., 2014). NAg and NAs are input to the WaterGAP Global Hydrology Model WGHM.

The linking module GWSWUSE considers return flows for some sectors, but only the irrigation sector is of importance for the inconsistency described here. In case of surface water use for irrigation, a part of the surface water withdrawn is not evapotranspirated but reaches the groundwater as return flow. Therefore, NAg can be negative such that due to irrigation there is an additional man-made recharge to the groundwater. In WaterGAP, NAg is always applied, assuming unlimited groundwater availability, while NAs is only considered up to the available water resources in surface water storages (reservoir, lake, river). Thus actual surface water use (AUsw) can be lower than NAs (NAs is then a demand that cannot be fulfilled). However, as NAg was computed in GWSWUSE assuming that all surface water withdrawals take place, the return flow to groundwater from irrigation with surface water is overestimated in case AUsw is less then NAs. Table 1 describes an illustrative calculation example.

*Table 1: Illustrative calculation example. In column "no problem", surface water availability allows full satisfaction of surface water demand. Column "obvious problem" assumes 20% satisfied surface water use, but the full return flow (500 m³/day) are taken into account, leading into negative total water consumption. In column "no obvious problem" total water consumption is positive, but assumes that full return flows would be considered, even though only 60% of surface water demand are satisfied. NAg: net abstraction from groundwater (unlimited resources), NAs: net abstraction from surface water (limited to water availability), AUsw: actual water use from surface water resources (satisfied NAs), atotuse: actual total water consumption (NAg+AUsw). All values in m³/day.*

| Component | No problem | Obvious problem | No obvious problem |
|---|---|---|---|
| NAg | -500 | -500 | -500 |
| NAs | 1000 | 1000 | 1000 |
| AUsw | 1000 | 200 | 600 |
| atotuse | 500 | -300 | 100 |

# Grid cells affected

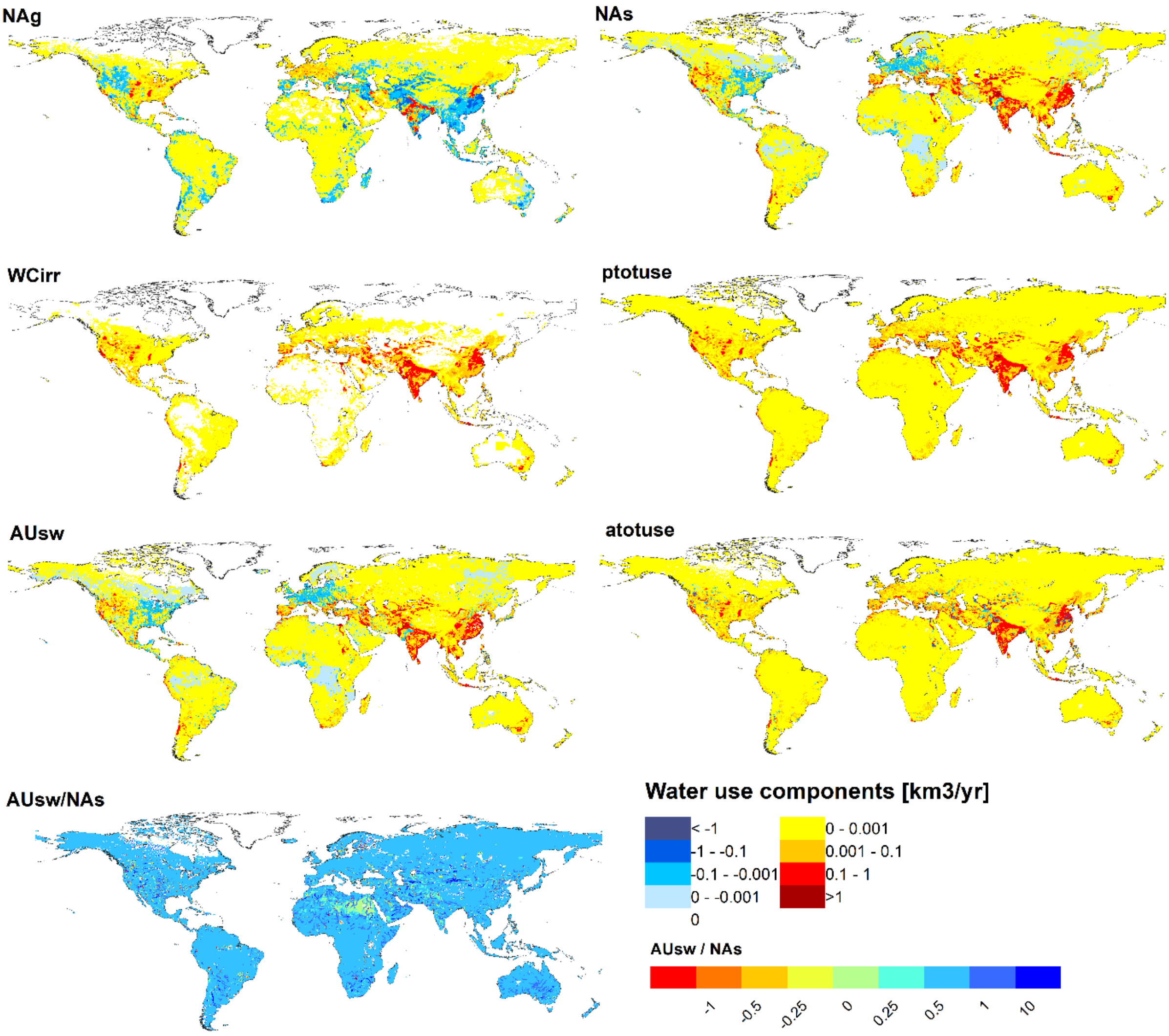


*Fig. 1: 30yr (1971-2000) average of EWEMBI forced WaterGAP 2.2c output: Net abstraction of groundwater (NAg), net abstraction of surface water (NAs), total irrigation water consumption (WCirr), potential total water consumption (ptotuse= NAg+NAs), actual total water consumption (atotuse), actual (satisfied) surface water consumptions (AUsw) and the ratio of AUsw/NAs (ratios can be larger than 1 as water demand can be satisfied also from neighbouring cells). All values in km3/yr except the ratio AUsw/NAs.*

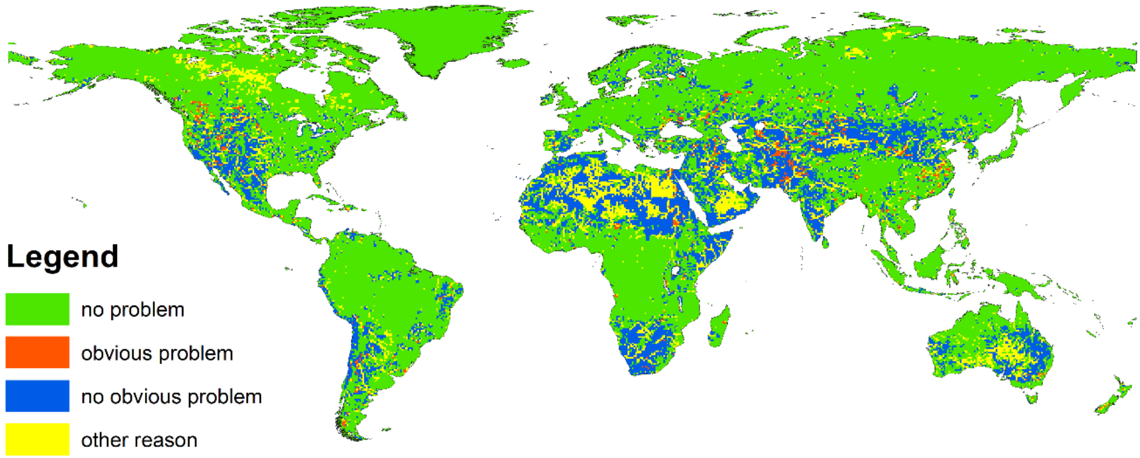


*Fig. 2: Classification of problematic grid cells: category 1 (no problem): atotuse = ptotuse, category 2 (obvious problem): NAg <> 0 && AUsw < NAs && atotuse < 0; category 3 (no obvious problem): NAg <> 0 && AUsw < NAs && atotuse >= 0, category 4 (other reason): all other grid cells (where either NAg == 0 or surface water demand is satisfied from neighboring grid cells, thus AUsw > NAs). Note that many of the red cells are around reservoirs, and as large water bodies are calculated in the outflow cell, additional effects might be added.*

## Other variables affected

Only actual evapotranspiration (AET) directly affected as AET is calculated in post-processing as sum of (natural) actual evapotranspiration plus atotuse. In cases, where atotuse is strongly negative, actual evapotranspiration can get also negative. Indirect affected are groundwater storage, groundwater outflow, total runoff and river discharge. Globally averaged, the effect is assumed to be low (in the order of ~50 $km^3$/yr), but for specific grid cells (e.g. high irrigation water demand from surface water resources together with low surface water availability) the effect could be significant (no quantification currently possible).

## Recommendation for data users

We recommend to set the negative atotuse values to zero and to be careful with assessments in grid cells that are in category 2 and 3.

## Outlook

We have solved the problem in the upcoming WaterGAP version 2.2d that is to be used in ISIMIP3 but do not plan to implement to previous model versions and therefore will not update the simulations of previous ISIMIP phases.

## References

Müller Schmied, H., Eisner, S., Franz, D., Wattenbach, M., Portmann, F. T., Flörke, M. and Döll, P.: Sensitivity of simulated global-scale freshwater fluxes and storages to input data, hydrological model structure, human water use and calibration, Hydrol. Earth Syst. Sci., 18(9), 3511–3538, doi:10.5194/hess-18-3511-2014, 2014.