Modelling the global freshwater resources using WaterGAP 2.2 – model overview, selected results and applications

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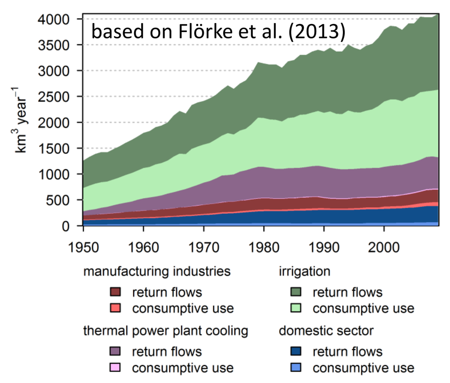
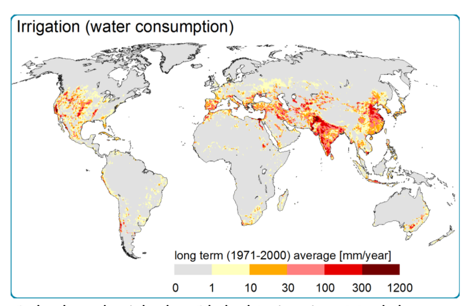
Introduction

WaterGAP (**Water** – **G**lobal **A**ssessment and **P**rognosis) is a global water availability and water use model that has been developed from 1996 onwards to assess the current state of water resources and to estimate the impact of global change on freshwater resources, particularly water scarcity. With a spatial resolution of 0.5°, the raster-based model is designed to simulate the characteristic macro-scale behaviour of the terrestrial water cycle, including the human impact. WaterGAP calculates freshwater fluxes and water storages taking advantage of all pertinent information that is globally available.
This poster gives an overview of version 2.2 of WaterGAP, its output and selected model applications. A detailed model description and a sensitivity analysis of freshwater fluxes and storages to input data, model structure, water use and calibration can be found at Müller Schmied et al. (2014).

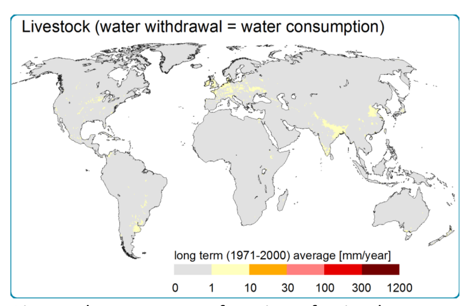
Water Use Models

Human water use is simulated for the sectors irrigation, livestock farming, domestic, manufacturing and thermal power plant cooling as water consumption and/or water withdrawal. Since the 1950s, global water withdrawals have tripled with irrigation water demand dominating in large parts of the world.

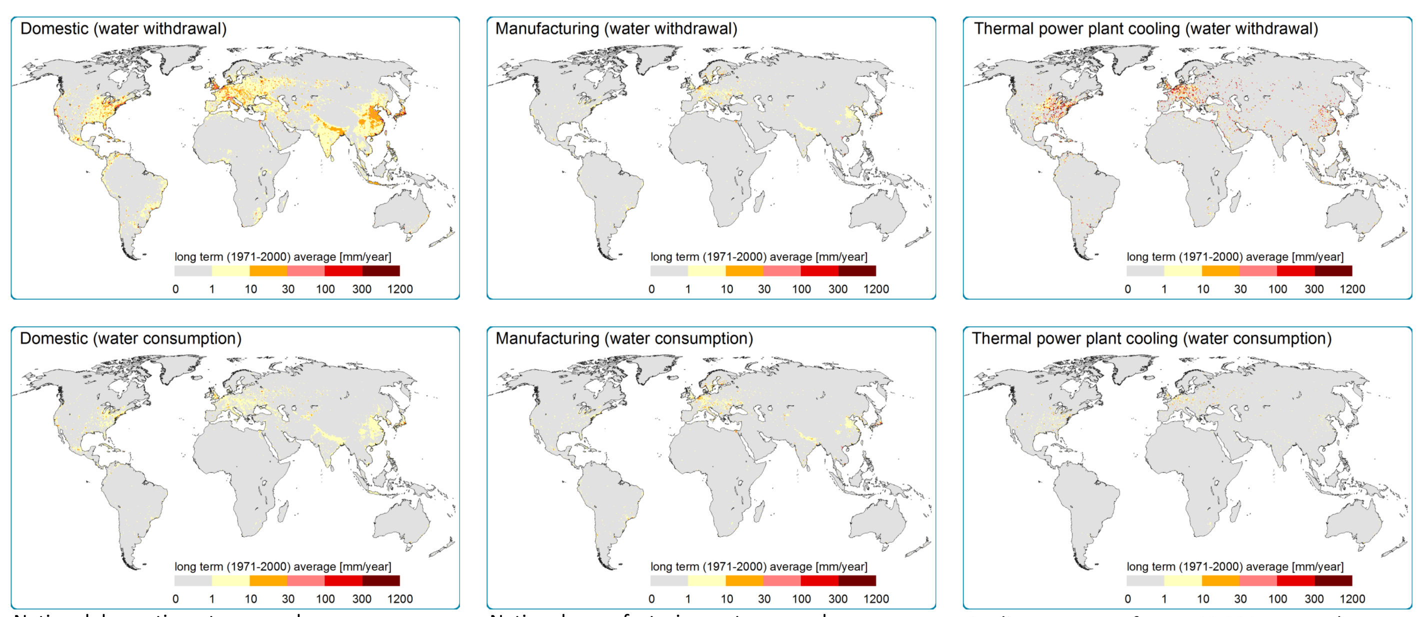




Calculated with the Global Irrigation Model (GIM) based on Siebert et al. (2005, 2007) and Döll & Siebert (2002)



Livestock water use as function of animal numbers per grid cell and water requirements per capita for ten different livestock types (Flörke et al. 2013)



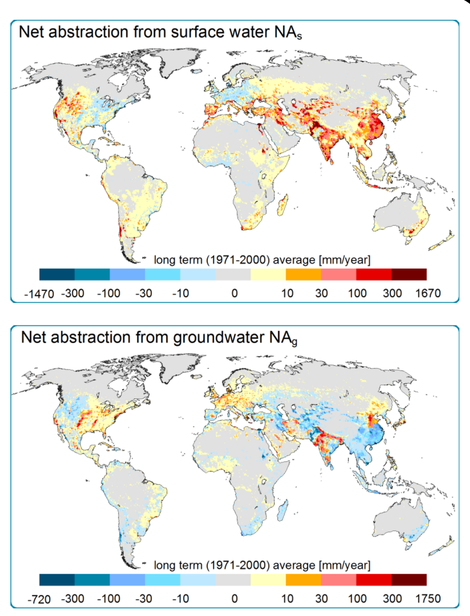
National domestic water use values are downscaled to grid cells using population density (Flörke et al. 2013)

National manufacturing water use values are downscaled to grid cells using population density (Flörke et al. 2013)

Cooling water use from > 60 000 power plants with cooling and combustion type and electricity production (Flörke et al. 2013, Vassolo & Döll 2005)

GWSWUSE

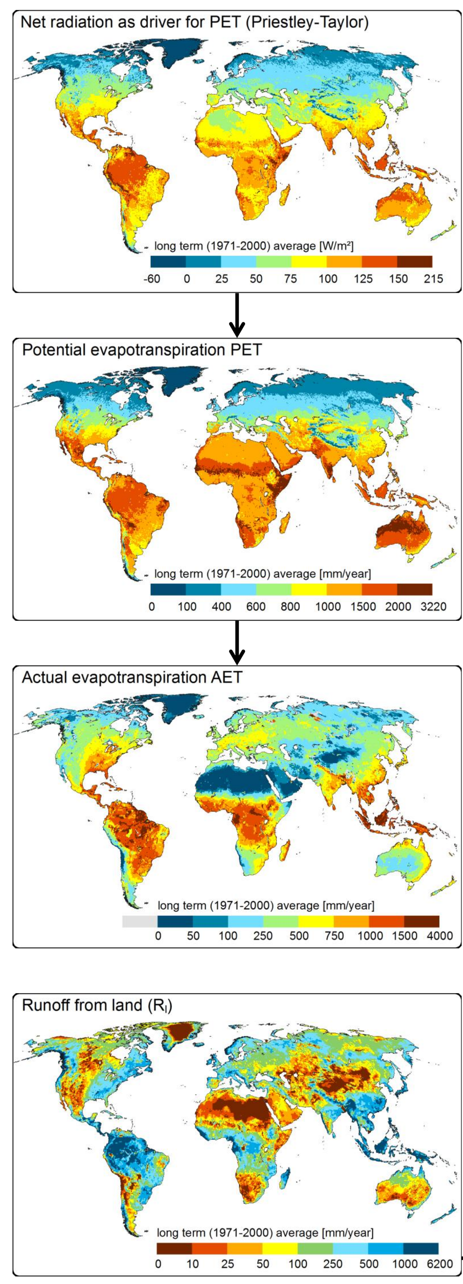
GWSWUSE (**G**round**W**ater-**S**urface-**W**ater-**USE**) links the water use models and the global hydrology model in computing, for each grid cell, net abstraction from surface water (NA_s) and net abstraction from groundwater (NA_g), taking into account return flows. Due to return flows, net abstraction can be positive (water is abstracted from storage) or negative (water is added to storage). In addition, water withdrawal for irrigation is computed by using country specific time series of irrigated area.



Net abstraction from surface water and groundwater (details: Döll et al. 2012)

Results

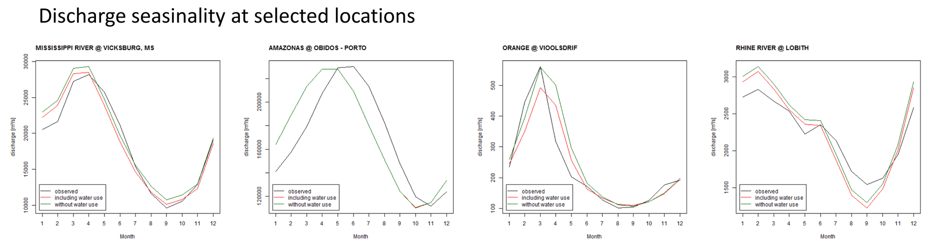
Model output can be analyzed on a daily or monthly time step either as global distribution (see maps), statistics (see table) or for traditional hydrograph analyses (see diagrams). For an animation of mean monthly variable dynamics, please follow the QR-code (Q, TWS and R_g).



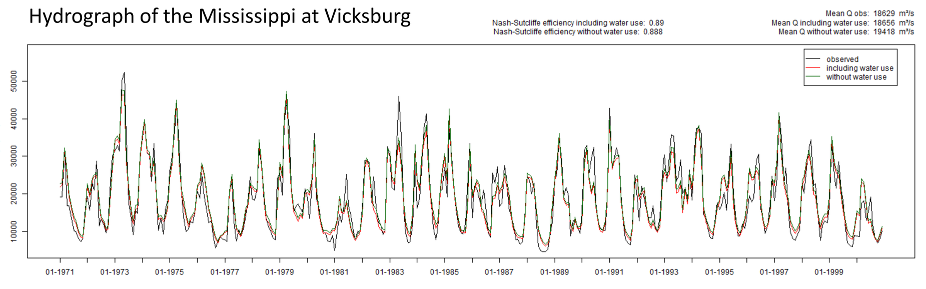
Long-term average (1971-2000) freshwater fluxes from global land area (except Antarctica and Greenland) of WaterGAP 2.2 considering human water use (column „including water use") and in a model run without human water use (column „without water use"). Values in in km³/year, from Müller Schmied et al. (2014).

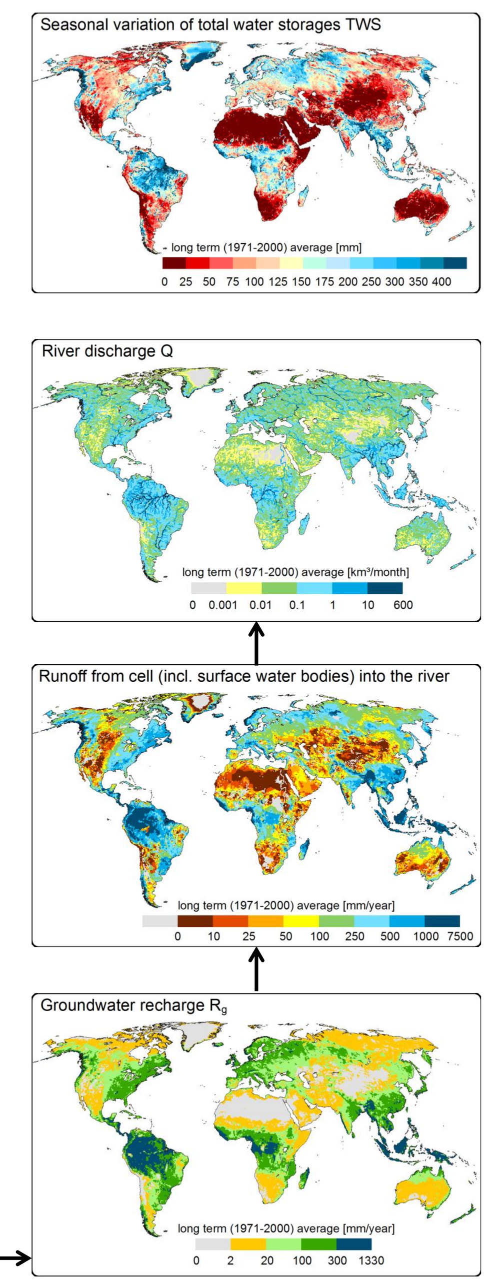
Global water balance component	Including water use	Without water use
Precipitation P	111 070	111 070
Actual evapotranspiration AET	69 803	69 934
Discharge into oceans and inland sinks Q	40 458	41 216
Water consumption (actual) WC_a (add to AET)	1031	0
Net abstraction from surface water (actual)	1102	0
Net abstraction from surface water (demand) NA_s	1154	0
Net abstraction from groundwater NA_g	-72	0
Change of total water storage dS/dt	-215	-73
Long-term averaged yearly volume balance error ($P-AET-Q-WC_a-dS/dt$)	-7	-7

Discharge seasinality at selected locations



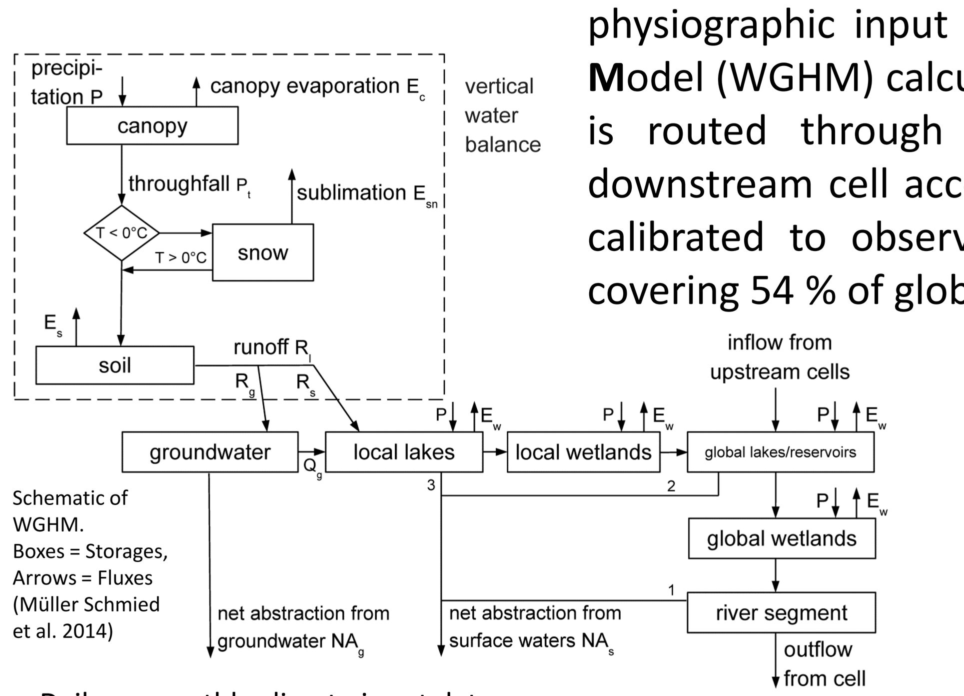
Hydrograph of the Mississippi at Vicksburg



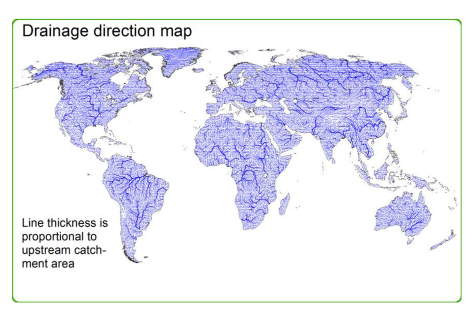


WaterGAP Global Hydrology Model

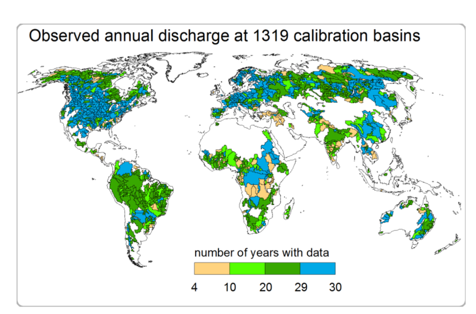
Based on gridded meteorological time series, net water abstractions (both with blue outlines) and physiographic input maps (green outlines), **W**aterGAP **G**lobal **H**ydrology **M**odel (WGHM) calculates the daily water balance in each grid cell. Runoff is routed through lakes, wetlands and the river segment to the downstream cell according to a global drainage direction map. WGHM is calibrated to observed mean annual discharges at 1319 river basins, covering 54 % of global land area (except Antarctica and Greenland).



Schematic of WGHM. Boxes = Storages, Arrows = Fluxes (Müller Schmied et al. 2014)

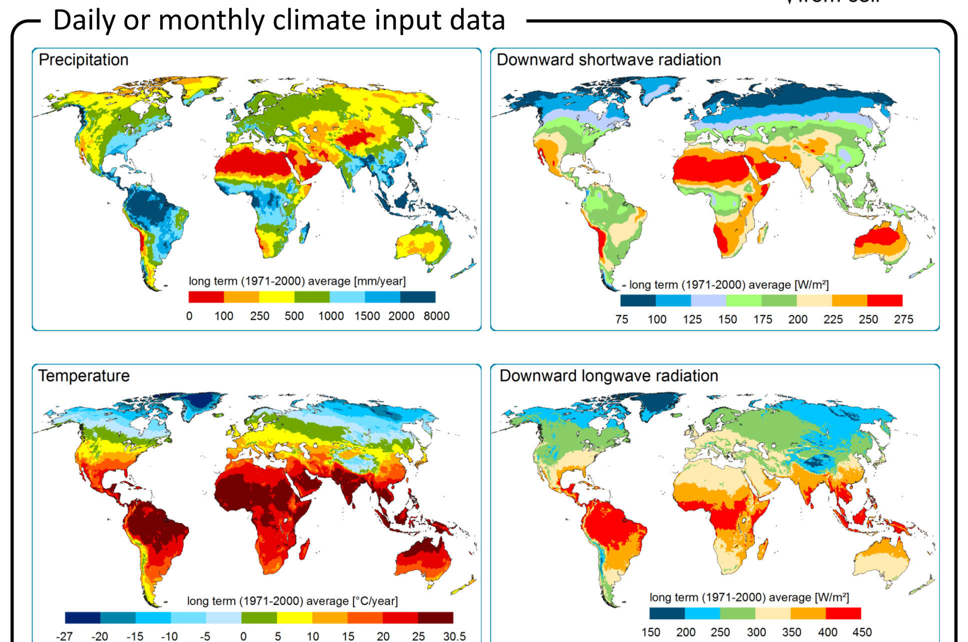


Döll & Lehner (2002)



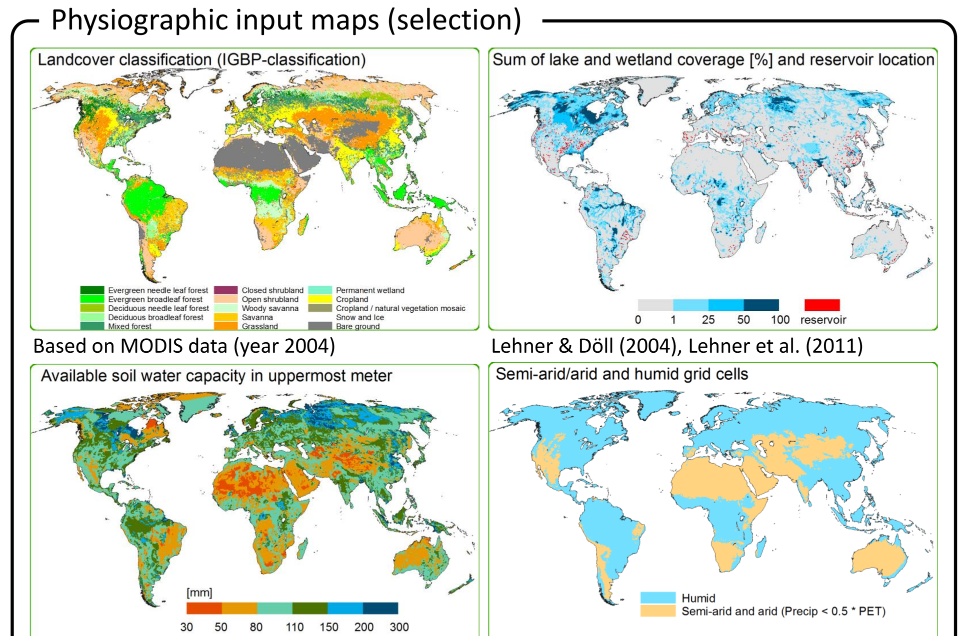
GRDC database (http://www.bafg.de/GRDC)

Daily or monthly climate input data



Displayed and used here: WFD/WFDEI (Weedon et al. 2011)

Physiographic input maps (selection)



Based on MODIS data (year 2004)

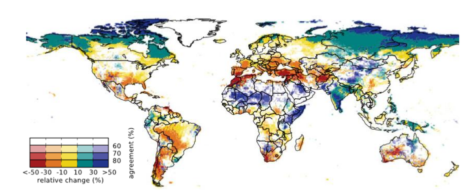
Lehner & Döll (2004), Lehner et al. (2011)

Batjes (1996)

For PET limitation and special R_g in arid regions

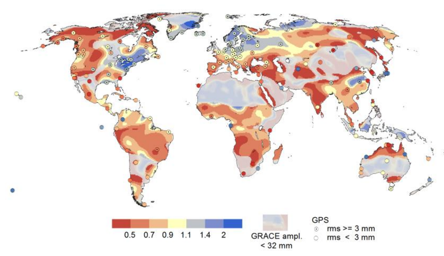
Applications

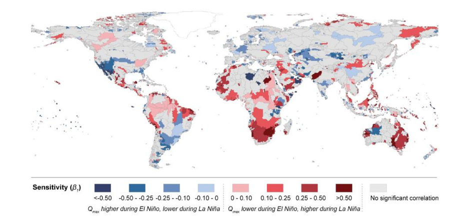
WaterGAP model outputs contributed to global environment assessments including the UN World Water Development Reports, the Millenium Ecosystem Assesment, the UN Global Environmental Outlooks as well as to reports of the Intergovernmental Panel on Climate Change. In addition, modelling results were included in the 2012 and 2014 Environmental Performance Index. Some scientific contributions are listed hereafter. A complete list of WaterGAP publications can be found at www.watergap.de.



Multimodel studies
WaterGAP has participated in multimodel studies (e.g. WATER-MIP, ISI-MIP). This example is taken from Schewe et al. (2014) and shows the relative change in annual discharge at 2 °C global warming compared with present day, under RCP8.5. The color hues show multimodel mean change, and saturation shows the agreement on the sign of change across all global hydrology model and global circulation model combinations.

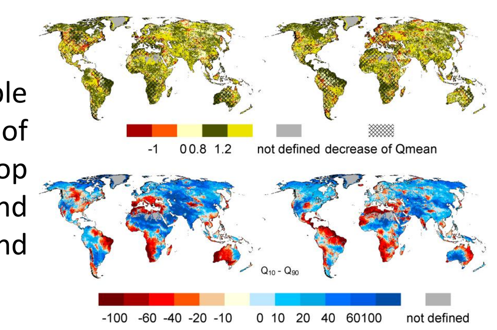
Comparison with gravity and GPS data
WaterGAP is often used in the GRACE community to interpret temporal variations of the Earth's gravity field. In turn, Total Water Storage (TWS) variations from GRACE can be used to improve WaterGAP. This example from Döll et al. (2014) shows the scaling factors for GRACE (solids) and GPS (dots) needed to apply for WaterGAP to get the same seasonal TWS variations as GRACE. For red areas, WaterGAP underestimates seasonal TWS variations.





Innovative global assessments
As WaterGAP is a global-scale model, global phenomena can be assessed. This example from Ward et al. (2014) shows the sensitivity of logarithmic annual flood peaks to variations in the Southern Oscillation Index.

Impacts of climate change on river flow regimes
Many applications of WaterGAP focus on global change. This example from Döll & Müller Schmied (2012) shows the combined impact of changes in low flow indicator Q_{90} as ratio to changes in Q_{mean} (top panel) and the per cent changes of the difference between Q_{10} and Q_{90} (bottom panel) for climate scenarios ECHAM4 A2 (left) and HadCM3 A2 (right), with 1961-90 and 2041-70 as time periods.



WaterGAP@Wikipedia: http://en.wikipedia.org/wiki/WaterGAP

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