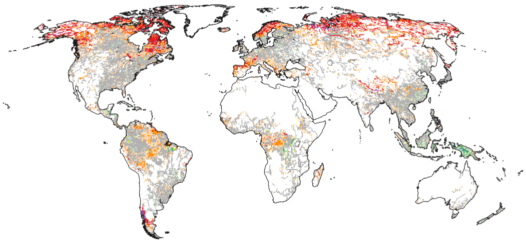
Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4]
Fahad Saeed[5,6] Carl-Friedrich Schleussner[3,5,7]
Affiliation[1,2,3,4,5,6,7]

Risks for the global freshwater system at 1.5°C and 2°C global warming

#+1.5°C vs +2°C #climate change #global water resources #global warming level #hazard #risk #0.5°C additional warming #hydrological indicators (HIs) #income based country groups #HAPPI #ensemble



Döll et al. 2018: Risks for the global freshwater system at 1.5°C and 2°C global warming. Accepted manuscript in ERL.

Methods

Results

Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4]
Fahad Saeed[5,6] Carl-Friedrich Schleussner[3,5,7]
Affiliation[1,2,3,4,5,6,7]

HAPPI DE

This presentation participates in OSPP
EGU
Outstanding Student Poster & PICO Contest

Risks for the global freshwater system at 1.5°C and 2°C global warming

Approach

- Paris Agreement → limit global warming to well below 2°C better to 1.5°C
- Using the new HAPPI ensemble with 4 global circulation models (GCM) with 20 bias-corrected simulations each to force two global hydrolgical models (GHM) WaterGAP and LPJmL HAPPI GHMs
- Assessment of 8 hydrological indicators (HI) in a +1.5°C world vs +2°C world → characterize hazards for human water use, freshwater biota and terrestrial vegetation with respect to statistically significant differences HIs statistical method
- Differentiation to other studies using the HAPPI-ensemble with a quasi-stationary approach instead of transient runs

Results

- All but one HI bigger land areas with significant differences to recent conditions for +2°C than +1.5°C warming level
- On 90% of the area differences between the hazards at the two warming levels are not significant
- Low income countries are most and high income countries least affected by decreased low flows
- The impact of +0.5°C additional warming on high flows would be felt most by low income and low middle income countries

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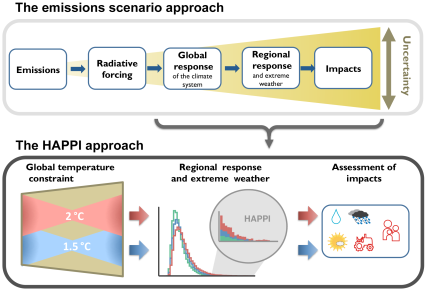
Affiliation[1,2,3,4,5,6,7]

Risks for the global freshwater system at 1.5°C and 2°C global warming

Half a degree Additional warming, Prognosis and Projected Impacts (HAPPI)

The HAPPI project has generated a set of climate data, which describes the world 1.5°C resp. 2.0°C warmer than pre-industrial conditions. Mitchell et al. (2017) chose a non-transient approach with three time slices (10 years each), representing three scenarios: current conditions, +1.5°C and +2.0°C. For each of those a decade long Sea Surface Temperatures (SSTs) were generated. Using those several Global Circulation Models (GCMs) were run with different initial conditions (≥ 50 ensemble members) to generate climate forcing datasets (Mitchell et al., 2017).



The HAPPI approach compared schematically to the emission-scenario-based approaches. From Mitchell et al., 2017.

Mitchell et al. 2017: Half a degree additional warming, prognosis and projected impacts (HAPPI): Background and experimental design. *Geoscientific Model Development*, 10, 571-583, doi:10.5194/gmd-10-571-2017

Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4]
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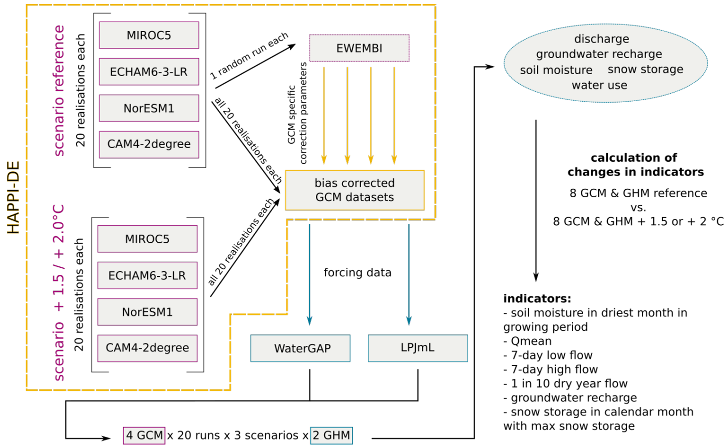
Risks for the global freshwater system at 1.5°C and 2°C global warming



Experimental Design (Model Chain)

Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4] Fahad Saeed[5,6] Carl-Friedrich Schleussner[3,5,7]
Affiliation[1,2,3,4,5,6,7]

Risks for the global freshwater system at 1.5°C and 2°C global warming

Used GHMs

- Spatial resolution of 0.5°
- Temporal resolution of 1d
- Both participating in ISIMIP (Inter-Sectoral Impact Model Intercomparison Project www.isimip.org)

WaterGAP consists of five sectoral water use model linked with an hydrological model. Developed and maintained at Goethe University.

Reference paper:
Müller Schmied H, Eisner S, Franz D, Wattenbach M, Portmann F T, Flörke M, Döll P, 2014: 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, 3511-3538, doi:10.5194/hess-18-3511-2014

LPJmL is a dynamic global vegetation model, fully coupled with the carbon and water cycle. Developed and maintained at Potsdam Institute for Climate Impact Research.

Reference papers:
Rost S, Gerten D, Bondeau A, Lucht W, Rohwer J, Schaphoff S, 2008: Agricultural green and blue water consumption and its influence on the global water system. *Water Resour. Res.*, 44, W09405, doi:10.1029/2007WR006331
Schaphoff et al. 2017: LPJmL4 - a dynamic global vegetation model with managed land: part II - model evaluation. *Geosci. Model Dev. Disc.*, doi:10.5194/gmd-2017-146

HAPPI DE

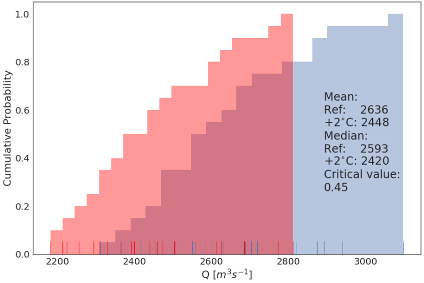
Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4] Fahad Saeed[5,6] Carl-Friedrich Schleussner[3,5,7]

Affiliation[1,2,3,4,5,6,7]

Risks for the global freshwater system at 1.5°C and 2°C global warming

Assessing the differences between the global warming levels in comparison with recent conditions

The indicators were calculated for each ensemble run (i.e. 10-year time period) for assessing the differences between the different worlds for each model combination (MC). Hence 20 values are available for testing their distribution on significant differences. As statistical test the **two-sample Kolmogorov-Smirnmov (KS) test with a level of signifcance of 90%** was chosen. The maximum distance between the empirical cumulative distributed functions (cdf) of the two samples serves as test statistic.



Cdfs of Q_m for + 2.0 °C world vs reference conditions at Rhine, Lobith.

Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4]
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Risks for the global freshwater system at 1.5°C and 2°C global warming

Discharge based indicators

HI	Calculation	Affected by Hazard
mean annual stream flow (Q_m)	arithmetic average of 10 annual streamflow values	number of fish species, groundwater-dependent floodplain vegetation
1-in-10 dry year stream flow ($Q_{1-in-10dy}$)	the lowest annual streamflow value of the 10-year run	human water supply from river water, habitat for freshwater biota, wastewater dilution
7-day low flow (Q_{7lf})	lowest value of all rolling means of daily streamflow during every consecutive seven days period in each year	same as $Q_{1-in-10dy}$ plus inland water transport
7-day high flow (Q_{7hf})	as Q_{7lf} but replacing "lowest" by "highest"	floodplain habitat requiring inundation, human assets that can be damaged by inundation

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Affiliation[1,2,3,4,5,6,7]

Other hydrological indicators

HI	Calculation	Affected by Hazard
mean annual groundwater recharge (GWR)	arithmetic average of 10 annual groundwater recharge values	human water supply from groundwater
critical soil moisture (S_{soil_min})	growing period is determined as months with $\geq$ 5°C, the soil moisture of driest month in growing period is estimated	water supply for terrestial vegetation and crops when it is most critical for survival
maximum monthly snow storage in calendar month with max storage (S_{snow_max})	the month with highest snow water equivalent is determined via the historical runs, the monthly mean of snow storage in this calendar month is evaluated	human water supply in semi-arid and arid regions that depend on snow melt for water supply, habitat for freshwater biota downstream

HAPPI DE

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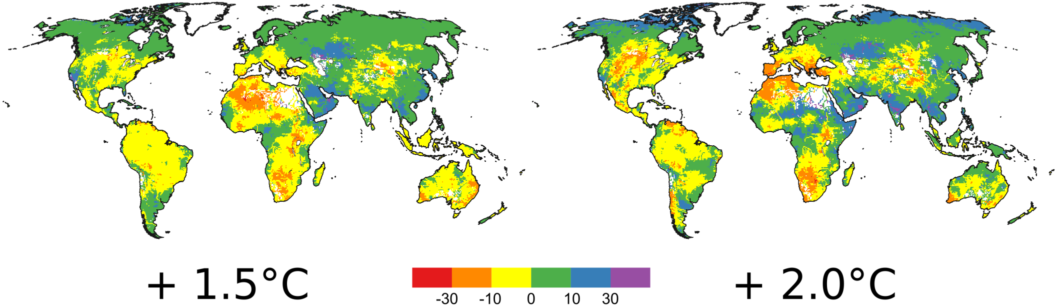
Affiliation[1,2,3,4,5,6,7]

Risks for the global freshwater system at 1.5°C and 2°C global warming

Mean Discharge



Ensemble mean change of discharge in % with +1.5°C and +2°C global warming. All cells are shown. **Caution please click on more!**

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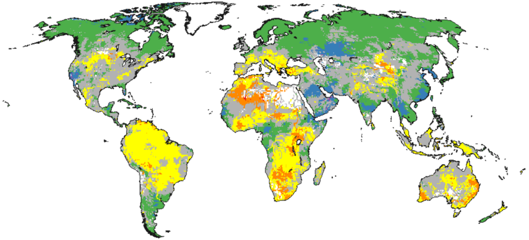
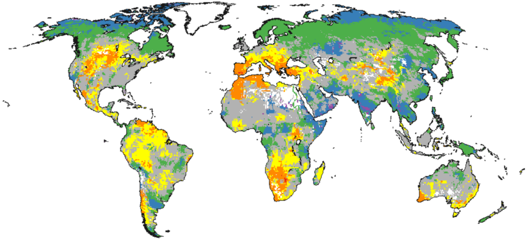
Risks for the global freshwater system at 1.5°C and 2°C global warming

Mean Discharge



+ 1.5°C



+ 2.0°C

Ensemble mean change of discharge in % with $+1.5^{\circ}$C and $+2^{\circ}$C global warming. Only cells with $\geq$**6 model combinations agreeing on direction** of change are shown. **Caution please click on more!**

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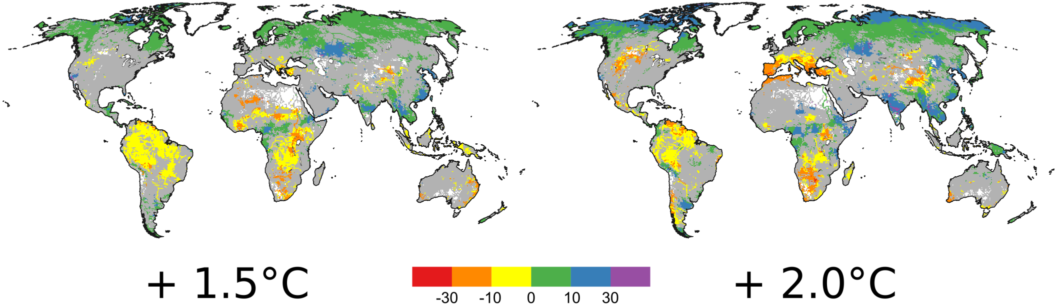
Risks for the global freshwater system at 1.5°C and 2°C global warming

Mean Discharge



Ensemble mean change of discharge in % with +1.5°C and +2°C global warming. Only cells with ≥**6 model combinations agreeing on direction of change and** ≥**5 model combinations with significant differences** are shown.

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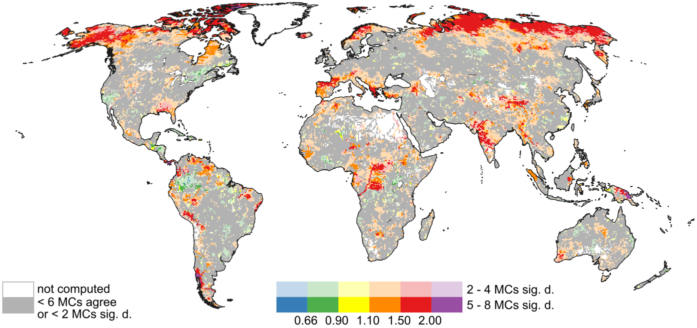
Risks for the global freshwater system at 1.5°C and 2°C global warming

Significant impact differences of the two global warming levels (Q_{mean})



Ratio between absolut value of changes to the +2.0°C world divided by the absolute value of changes to the +1.5°C world. Changes and ratios are only shown if at least 6 MCs agree on the sign and at least 2 MCs show significant differences in the compared worlds.

Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4] Fahad Saeed[5,6] Carl-Friedrich Schleussner[3,5,7]
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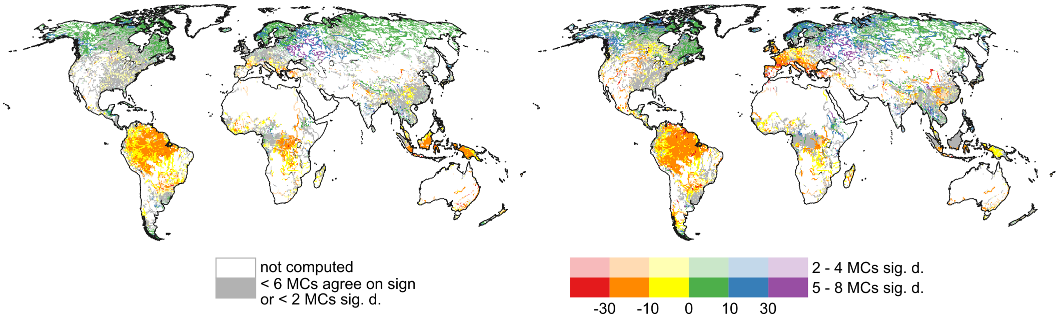
Risks for the global freshwater system at 1.5°C and 2°C global warming

Seven day low flow (Q_{7lf})



Ensemble mean change of Q_{7lf} in % with +1.5°C (left) and +2°C (right) global warming.

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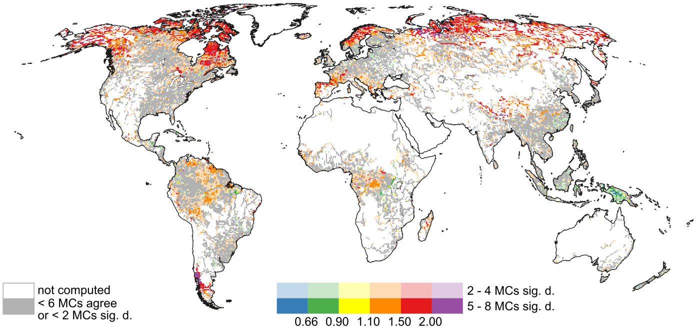
Risks for the global freshwater system at 1.5°C and 2°C global warming

Significant impact differences of the two global warming levels (Q_{7lf})



Ratio between absolut value of changes to the +2.0°C world divided by the absolute value of changes to the +1.5°C world. Changes and ratios are only shown if at least 6 MCs agree on the sign and at least 2 MCs show significant differences in the compared worlds.

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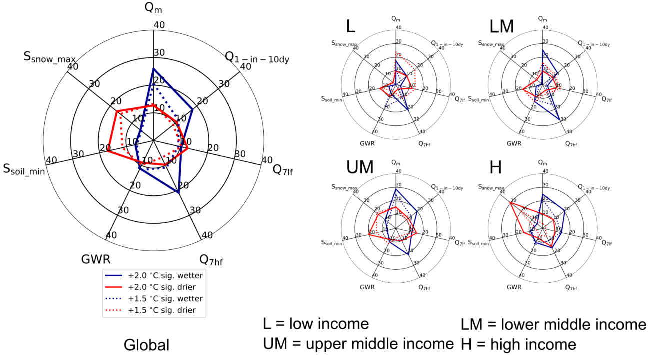

Pecentage of land area on which the HIs become significantly wetter or drier in either the +1.5°C or the +2.0°C world as compared to quasi-stationary conditions at the beginning of the 21st century. All results refer to the mean of the eight model combinations.

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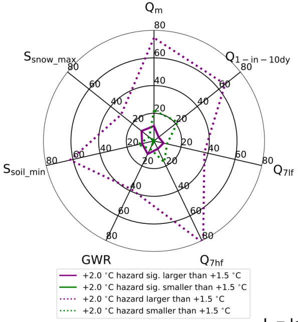
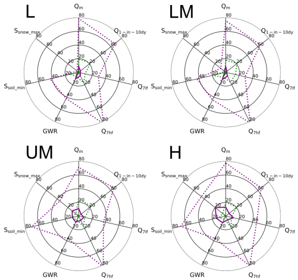
Risks for the global freshwater system at 1.5°C and 2°C global warming



Global



L = low income
LM = lower middle income
UM = upper middle income
H = high income

Pecentage of land area on which the magnitude of the hazard related to a HI is (significantly) larger in either the +1.5°C or the +2.0°C world. All results refer to the mean of the eight model combinations.

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Risks for the global freshwater system at 1.5°C and 2°C global warming

Conclusions

- Area and population affected by HI change more than ± 10% are higher for 2°C than for 1.5°C global warming
- On the majority of the global land area model uncertainty makes it impossible to clearly distinguish the magnitude of hazards at the two global warming levels
- However, 10% of the global population would be spared of a relevant change ($\geq$ 10%) in Q_m and Q_{7lf} if global warming were constrained to 1.5°C
- Among the HIs, mean discharge shows the lowest projected percentage changes $\rightarrow$ climate change hazards should not solely focus on mean discharge or runoff

Tim Trautmann[1] (t.trautmann@em.uni-frankfurt.de) Petra Döll[1,2] Hannes Müller Schmied[1,2] Dieter Gerten[3,4] Sebastian Ostberg[3,4] Fahad Saeed[5,6] Carl-Friedrich Schleussner[3,5,7]

Affiliation[1,2,3,4,5,6,7]

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[1]Institute of Physical Geography, Goethe University Frankfurt,Frankfurt am Main, Germany
[2]Senckenberg Biodiversity and Climate Research Centre (BiK-F), Frankfurt am Main, Germany
[3]Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany
[4]Geography Department, Humboldt-Universität zu Berlin, Berlin, Germany
[5]Climate Analytics, Berlin, Germany
[6]Center of Excellence for Climate Change Research, King Abdulaziz University, Jeddah, Saudi Arabia
[7]IRITHESys, Humboldt University, Berlin, Germany

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