Universiteit Utrecht

Faculty of Geosciences

Simulating the impact of land cover and climate change on the global hydrological system using PCR-GLOBWB

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1. Research Aims

We aim to improve our understanding of anthropogenic influences on the global hydrological system, specifically river discharge and land surface evapotranspiration. Therefore we investigate two anthropogenic influences on the global hydrological system: land cover change and climate change. Using experiments with the global hydrological model PCR-GLOBWB we assess the separate and combined effects of both land cover and climate change. Furthermore, we compare the effects of land cover change to the effects of water abstraction and irrigation.
Attributing changes in the global hydrological system to land cover change, climate change, and water abstraction and irrigation, will improve projections of future changes in water abundance and scarcity.

2. Model Set-up & Input

PCR-GLOBWB experiments

The PCRaster Global Water Balance model simulates water storage in two vertically stacked soil layers and an underlying soil layer, as well as water exchange between the layers and between the top layer and the atmosphere. Here, we use a resolution of 30 arcmin, roughly 50x50km (for more detail, see e.g. van Beek 2011, Wada 2014). Experiments are summarised in Table 1, methods and inputs are further explained below. The first four experiments are used to compare the effect of climate (FIX 1850-1879 vs 1976-2005) as well as land cover change (TRANS vs FIX). The last three experiments allow us to compare the effect of land cover change (LC2000 vs LC1850) to that of water abstraction and irrigation (HUM2000 vs LC2000).

Experiment name	Land cover	P, T, ET	Time period
FIX_ECEARTH	fixed, 1850	EC-Earth bced	1850-2005
FIX_CESM	fixed, 1850	CESM bced	1850-2005
TRANS_ECEARTH	varying, 1850-2005	EC-Earth bced	1850-2005
TRANS_CESM	varying, 1850-2005	CESM bced	1850-2005
LC1850	fixed, 1850	CRU-ERA-Interim	1979 - 2010
LC2000	fixed, 2000	CRU-ERA-Interim	1979 - 2010
HUM2000	fixed, 2000	CRU-ERA-Interim	1979 - 2010

Table 1: *experiments. P, T and ET stand for precipitation, temperature and reference potential evapotranspiration, respectively. HUM2000 includes water demand and reservoirs for 2000 as well as irrigation (see Wada et al. 2014).*

Land cover change

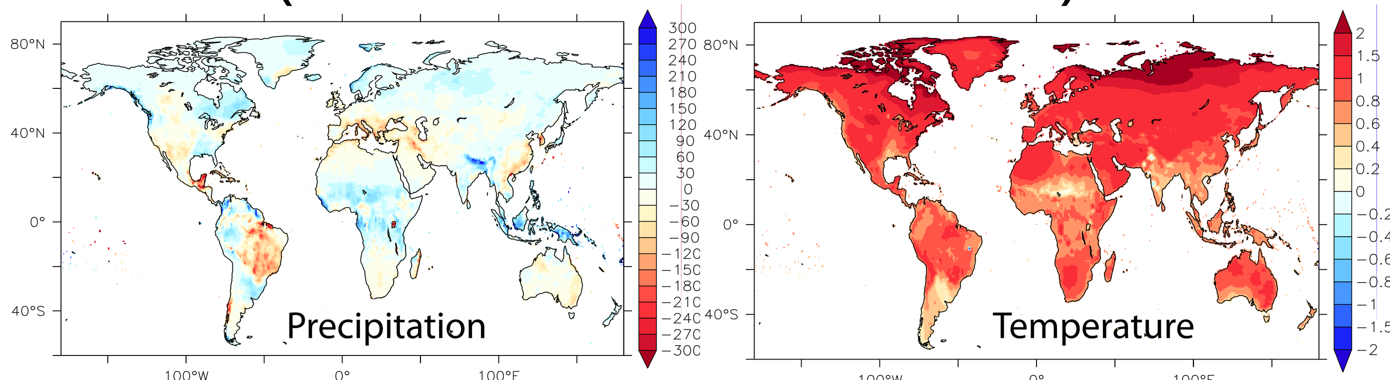
We use fractional crop and pasture cover from the harmonized land use scenarios of Hurtt et al. (2011). Within each 30 arcmin grid cell, suitability based on slope and present-day land cover (GLCC) at 30 arcsec resolution is used to select the most suitable areas for crop and pasture. Any remaining areas are set to natural tall or short vegetation. Crops (rainfed, non-paddy or paddy irrigated) land cover types derive their parameterization from MIRCA, while pasture and natural vegetation derives from GLCC. We either keep land cover parameters fixed to 1850 or 2000 conditions, or vary them from 1850 to 2005. See Dermody et al. (2013) for more detail.

Climatic input

For the first set of four experiments, we apply output of two GCMs (EC-Earth and CESM), allowing us to extend our experiments from 1850 to 2005 (soon to be continued to 2100). Daily precipitation, temperature and reference potential evapotranspiration from the GCMs was bias-corrected (bced) using WATCH data to correct for deviations from observed climate (see Hempel et al, 2013 for more detail). For the last three experiments we apply daily ERA-Interim input, corrected with monthly CRU data.

3. Results

Climate (1976-2005 vs 1850-1879)



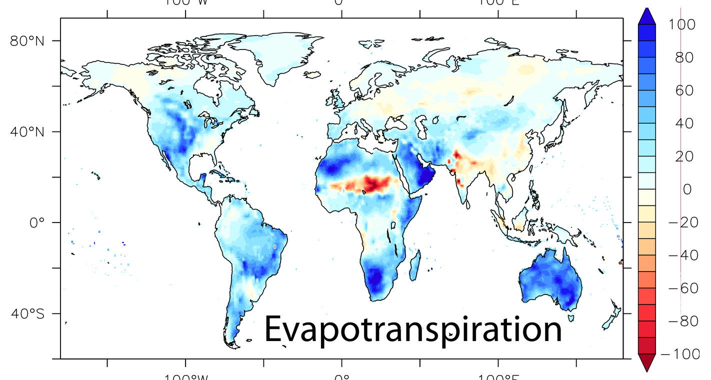


Figure 1: *GCM (EC-Earth) changes in precipitation (mm/yr), surface air temperature (º) and potential reference evapotranspiration (mm/yr, using Penman-Montheith). Differences between the means of 1976-2005 and 1850-1879 are shown. Based on CMIP5 historical forcings.*

Land cover (2000 vs 1850, %)

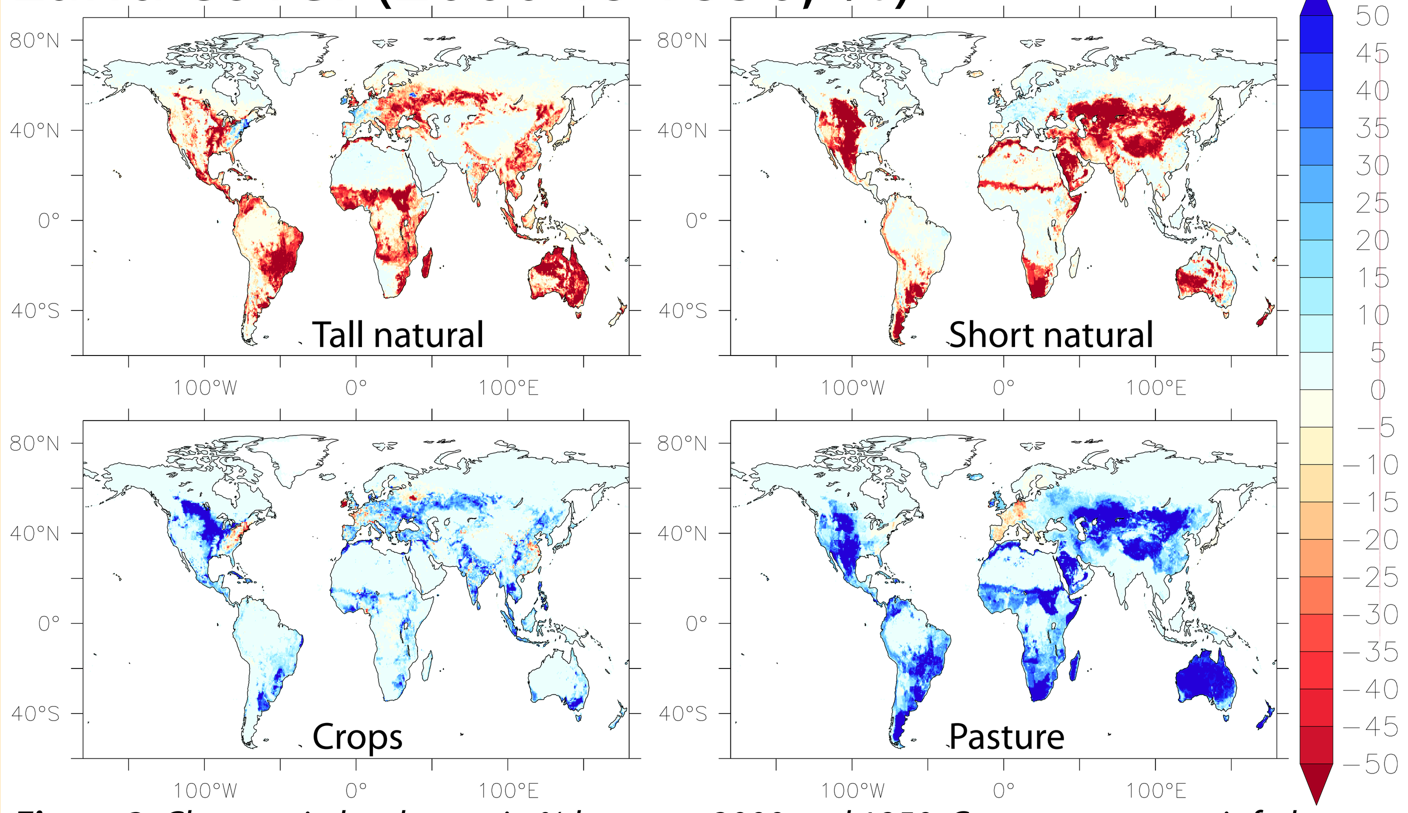


Figure 2: *Changes in land cover in % between 2000 and 1850. Crops represent rainfed, non-paddy and paddy irrigated crops. See 'land cover change' under section 2.*

Water demand 2000, mm/yr

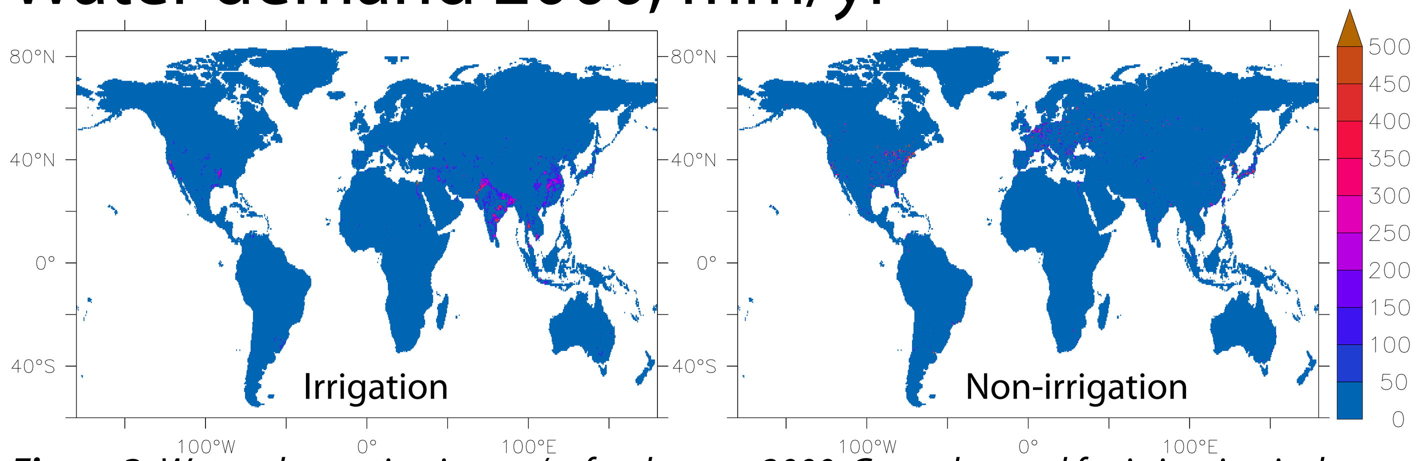


Figure 3: *Water abstraction in mm/yr for the year 2000. Gross demand for irrigation is shown left, non-irrigation demand on the right (domestic, industrial and livestock).*

Discharge m³/s

Evapotranspiration annual total mm/yr

Climate vs. land cover (FIX vs. TRANS)

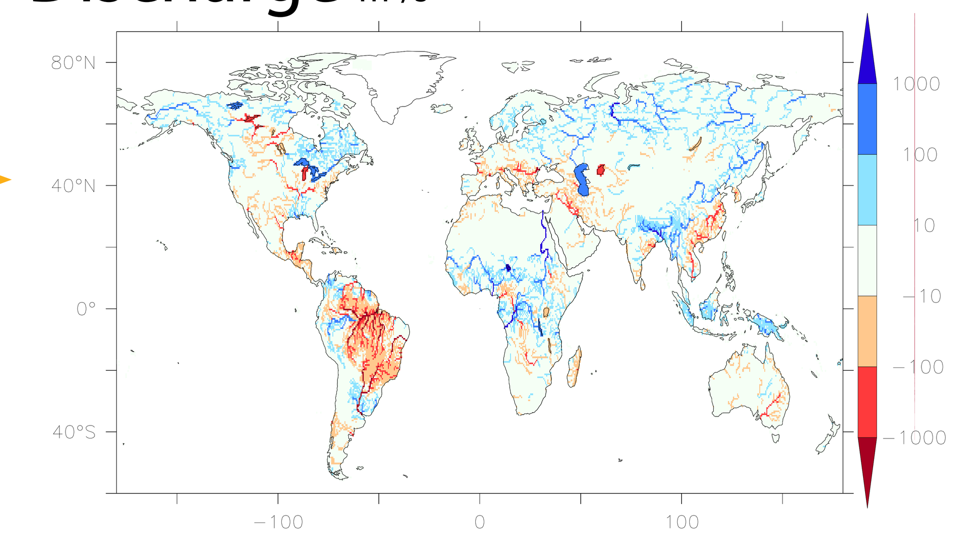


Figure 4a: *FIX_ECEarth 1976-2005 minus 1850-1879 discharge*

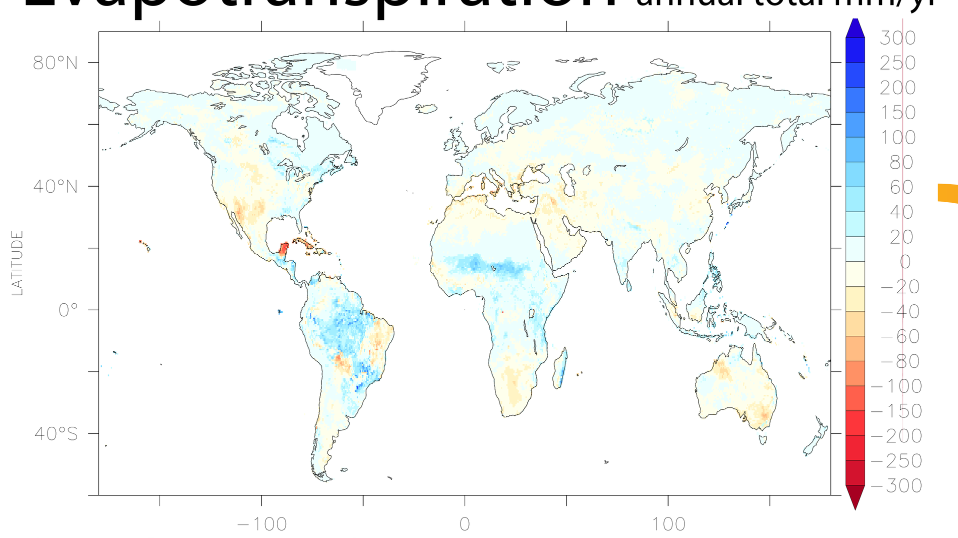


Figure 4b: *FIX_ECEarth 1976-2005 minus 1850-1879 ET*

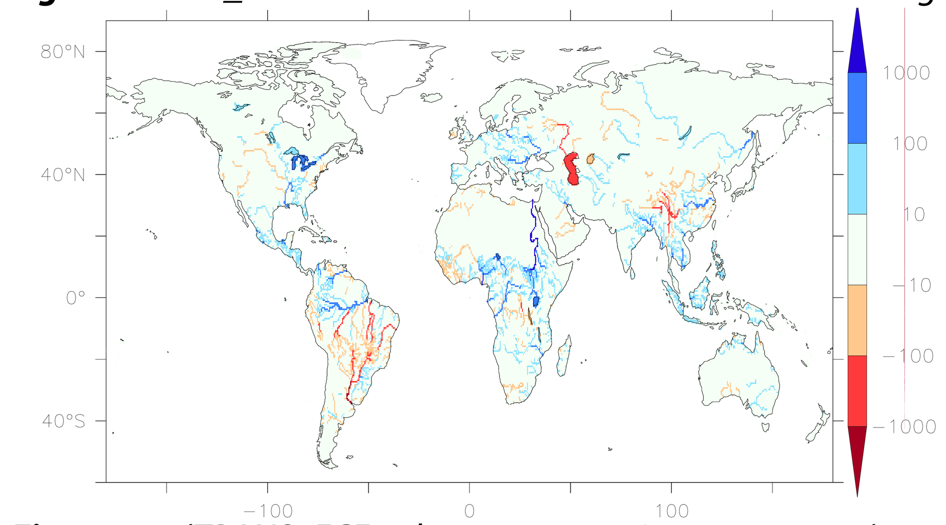


Figure 5a: *(TRANS_ECEarth 1976-2005 minus 1850-1879) - (FIX_ECEarth 1976-2005 minus 1850-1879) discharge*

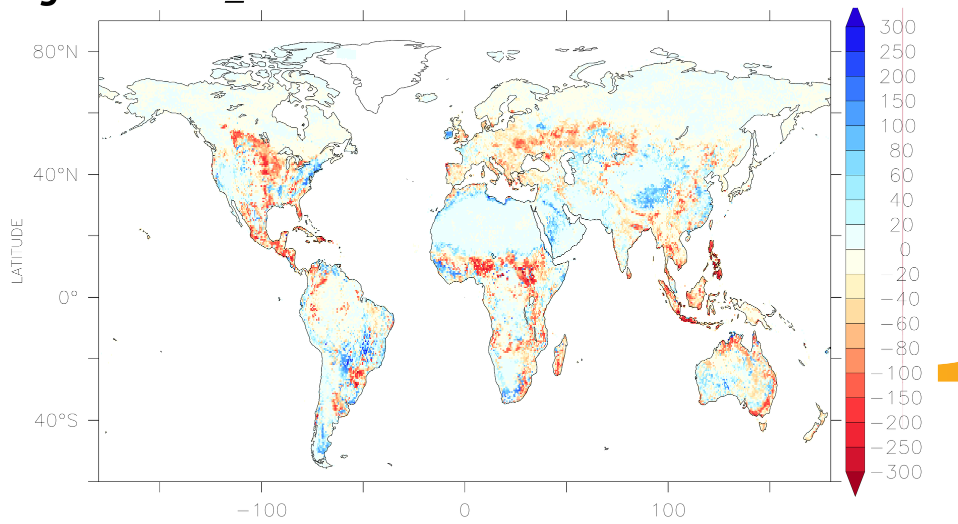


Figure 5b: *(TRANS_ECEarth 1976-2005 minus 1850-1879) - (FIX_ECEarth 1976-2005 minus 1850-1879) ET*

Land cover vs. irrigation and abstraction (LC vs. HUM)

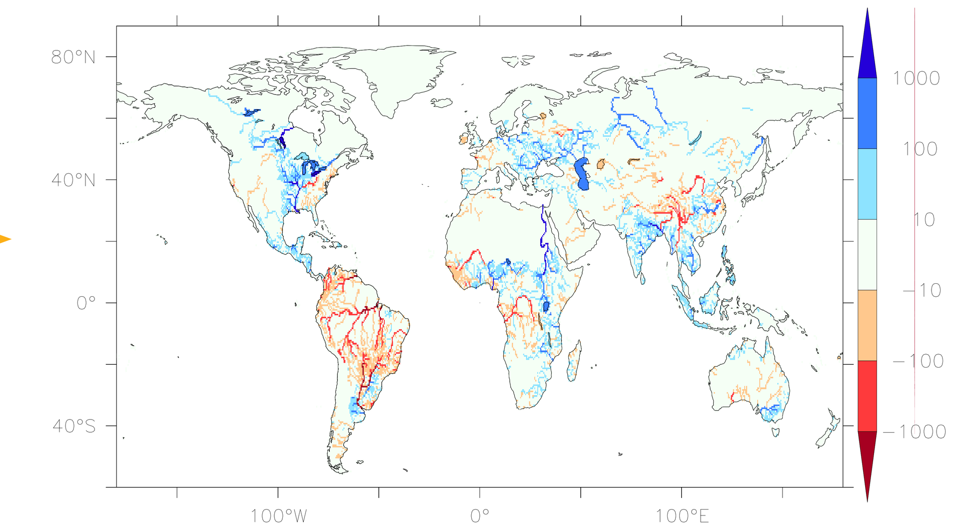


Figure 6a: *LC2000 minus LC1850 discharge (1979-2010 means)*

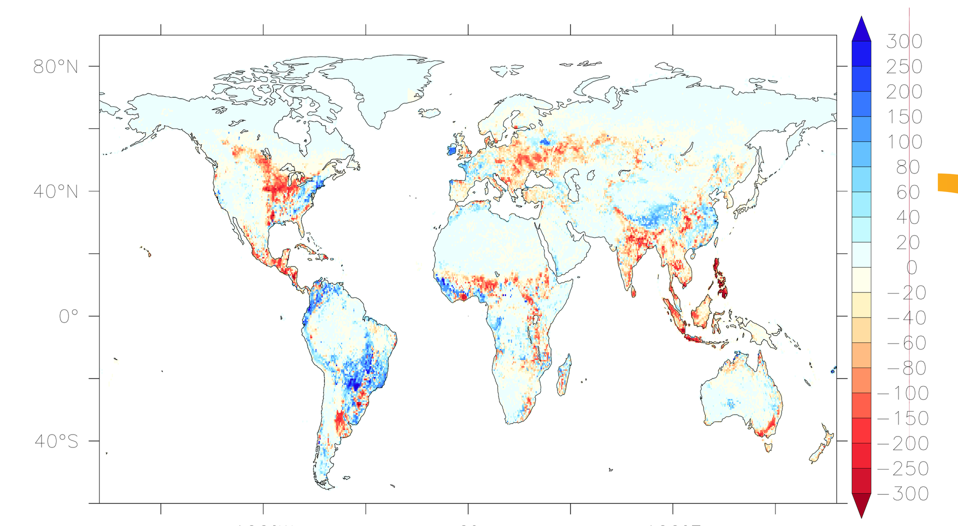


Figure 6b: *LC2000 minus LC1850 ET (1979-2010 means)*

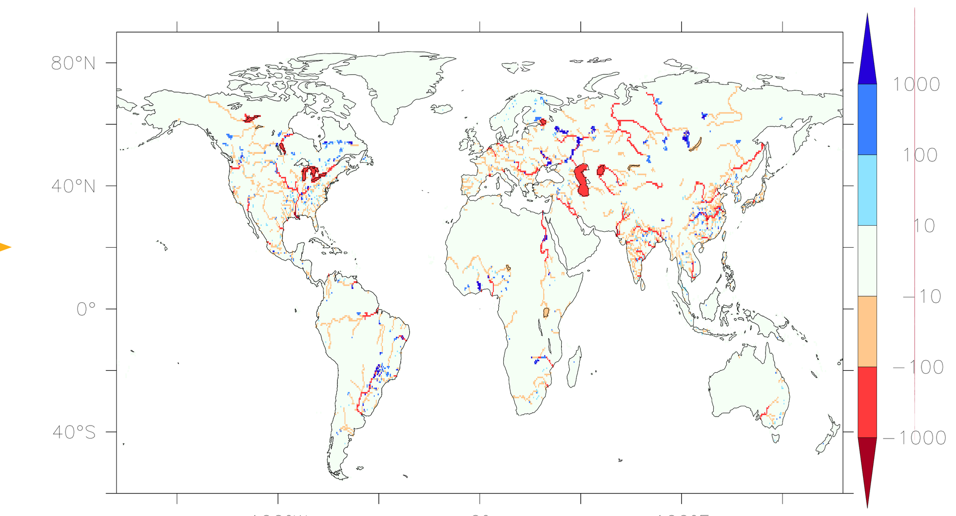


Figure 7a: *HUM2000 minus LC2000 discharge (1979-2010*

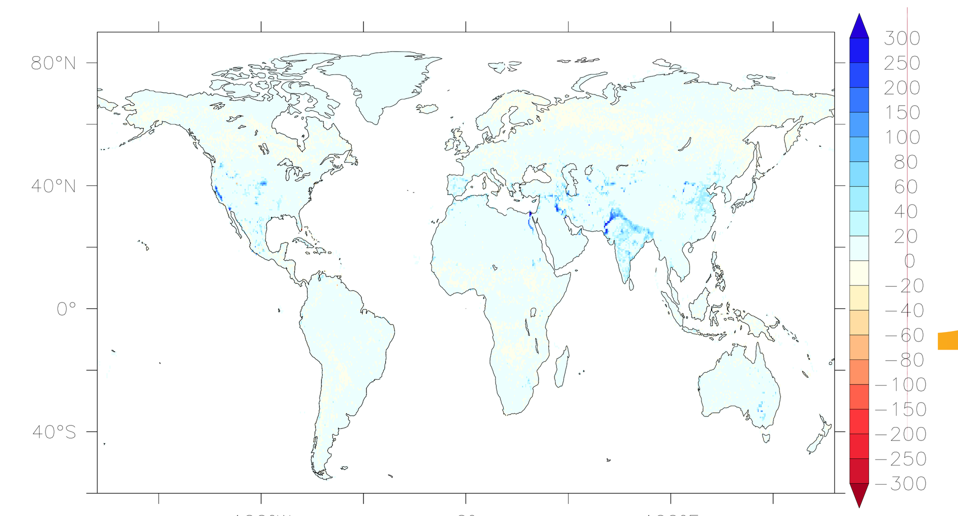


Figure 7b: *HUM2000 minus LC2000 ET (1979-2010 means)*

4. Discussion, conclusions and outlook

Climate vs. land cover (FIX vs. TRANS)

Precipitation dominates discharge changes for both FIX and TRANS experiments. For climate-only (FIX), evapotranspiration (ET) changes play a minor role and are sometimes of opposite sign than the imposed change in potential reference ET. Including land cover change (TRANS) leads to discharge changes of the same sign as in FIX, but the impact of climate is strenghtened or weakened through a large impact on ET.

Land cover vs. irrigation and abstraction (LC vs. HUM)

Changing landcover from 1850 to 2000 (LC2000 vs LC1850) has a bigger impact on discharge and ET than including irrigation and water demand (LC2000 vs HUM2000). The latter mainly causes decreased discharge through abstraction and increased ET through irrigation. Land cover change affects discharge through ET, such as lower ET and higher discharge where forest is replaced by crops.

Outlook

Our next step is to extend the historical period shown here (for FIX and TRANS) towards future scenarios RCP2.6 and 8.5, as well as to include anthropogenic impacts (irrigation, water demand etc) in those experiments. Furthermore, besides annual mean changes as shown here, we can investigate seasonal changes, look at separate ET fluxes (transpiration, bare soil or interception evaporation), examine discharge variability, compare discharge to observations (e.g. GRDC), and much more!!

References

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