Sensitivity of water cycle changes over land to horizontal resolution

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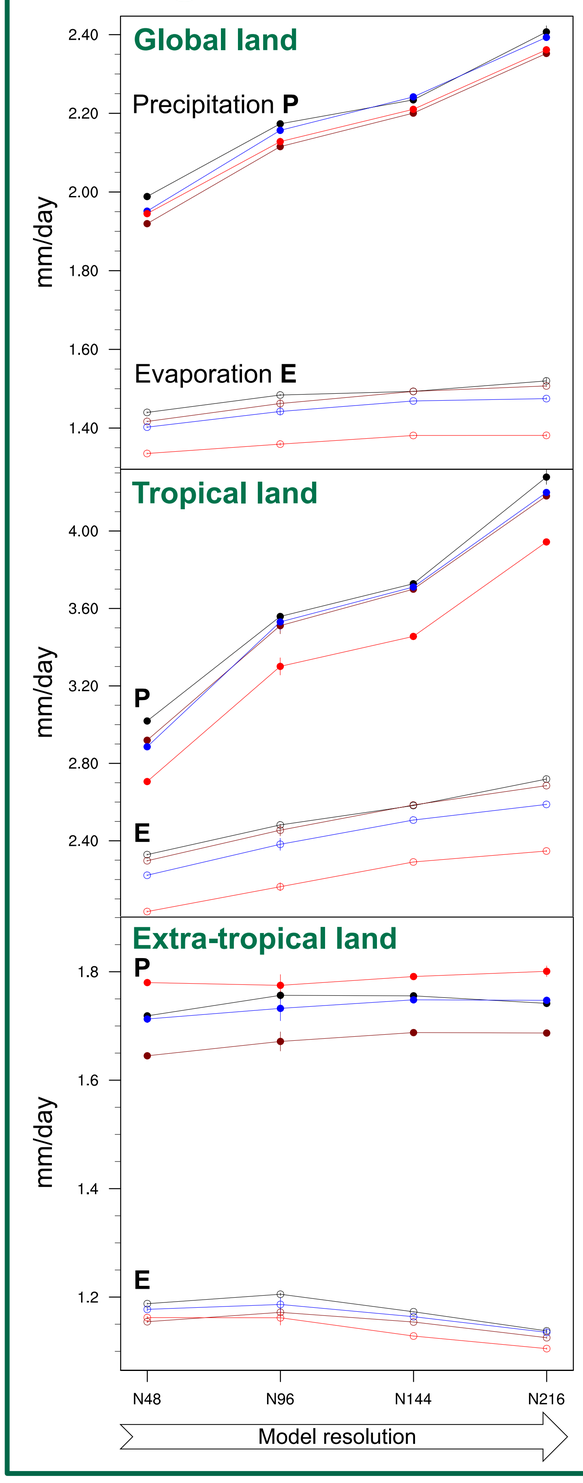
Context

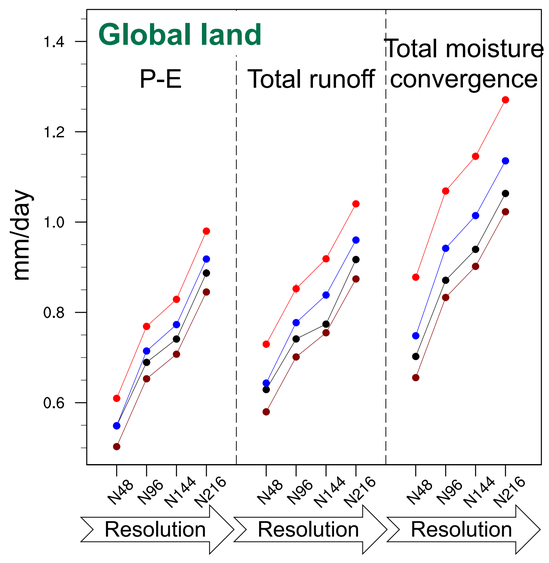
While general circulation models agree well on the changes in temperature with climate change, they disagree with regards to projections of components of the hydrological cycle (precipitation, evaporation, moisture transport), particularly at continental and regional scales (IPCC, 2007): is this because climate models cannot resolve fundamental dynamical mechanisms that govern the hydrological cycle? This question has been addressed in this study by using a model with increasing horizontal resolutions and investigating the causes of the systematic changes in the hydrological cycle over land.

Approach

We exploit a global land-atmosphere model based on the Hadley Centre HadGEM1a version of the IPCC AR4 at four horizontal resolutions: **n48 (270 km), n96 (135 km), n144 (90 km) and n216 (60 km)**. We performed some multi-decadal **AMIP2**-style mini-ensemble simulations of 3 members with varying initial conditions, and created idealised climate change simulations with SST and sea ice forcings provided by the coupled HiGEM model (Shaffrey et al., 2009) run under **current** and stabilised **2*CO2** and **4*CO2** conditions.

Changes in water fluxes over land





All **moisture fluxes** generally **increase over land with resolution**.

Globally and over the tropics, moisture convergence over land is mainly **sustained by the mean flow**, while it is **carried out by eddy transport** over the extra-tropics.

The models at all resolutions **agree on the sign of changes** in the hydrological cycle at these scales.

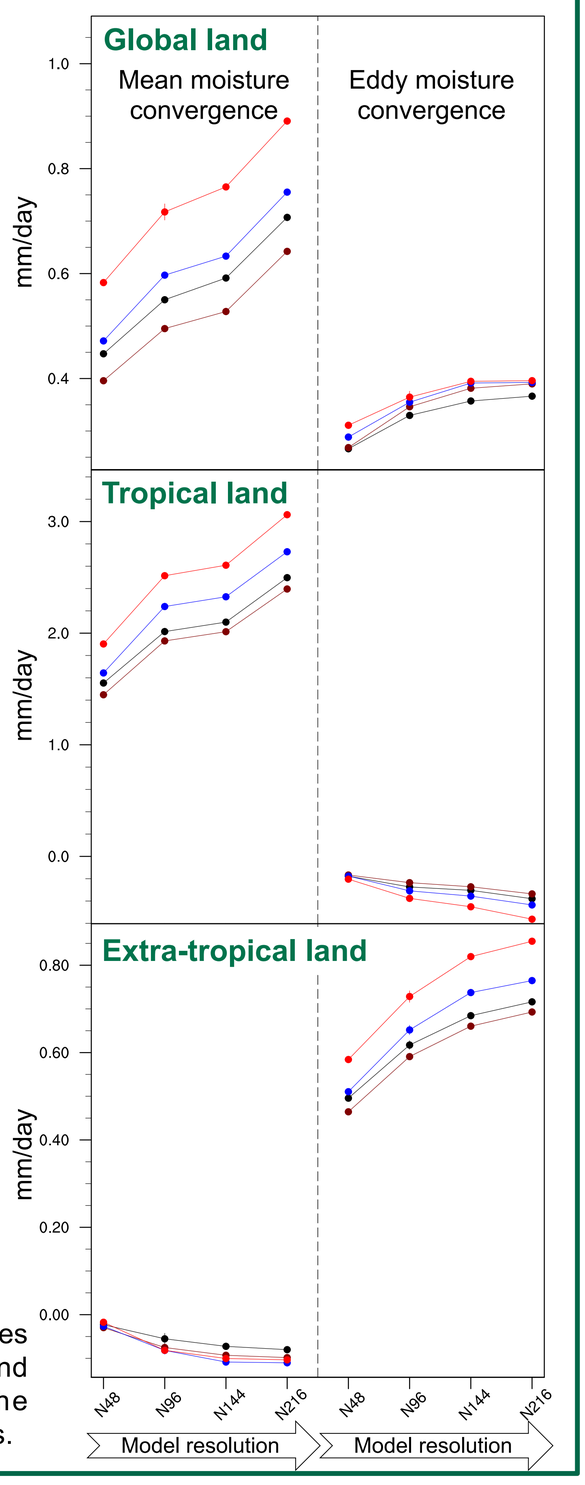


Figure 1: Climatological mean of water fluxes (mm/day) for **AMIP**, **current**, **2*CO2** and **4*CO2** conditions. Dots represent the ensemble means, bars the ensemble spreads.

Examples at regional scale

The models simulate an **increase in moisture convergence** with climate change.

The increase in the **mean** (Europe) and **eddy** (North America) components with climate change however systematically **reduces with resolution and even decreases at high-resolution**.

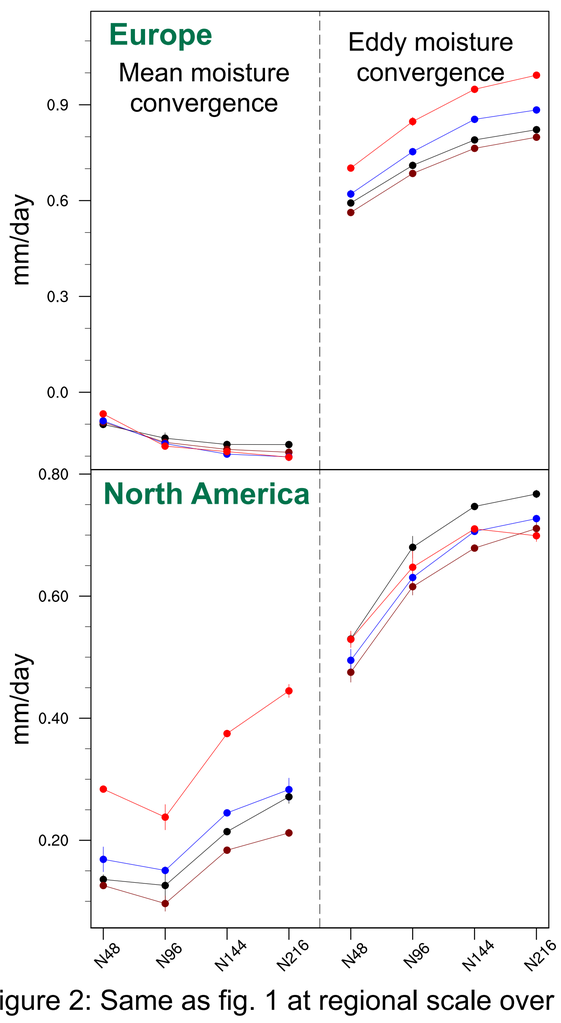


Figure 2: Same as fig. 1 at regional scale over land.

Relative contribution of eddies to moisture convergence over land

At global scale, the contribution of eddies to moisture convergence over land does not change with resolution.

At continental and regional scales, eddies play a stronger role in high-resolution models.

The tendency is toward less **eddy convergence and more eddy divergence with climate change**.

		n48	n96	n144	n216
Global land	CTL	41%	42%	42%	38%
	4*CO2	35%	34%	34%	31%
Tropical land (20S-20N)	CTL	-13%	-14%	-16%	-17%
	4*CO2	-12%	-18%	-21%	-23%
NH extra-tropical land (30N-90N)	CTL	106%	114%	116%	116%
	4*CO2	103%	112%	113%	114%

Table 1: **Ratio** of vertical-integrated **eddy moisture convergence to total moisture convergence** (%).

Summary

- **Using climate models at higher resolution does not change the sign of changes in the hydrological cycle components over land with climate change.**
- **The dynamical mechanisms governing these changes however differ gradually with resolution, particularly at regional scale.**
- **The relative contribution of eddies to moisture convergence over land generally seem to decrease with climate change, at all resolutions.**

References:

IPCC, 2007: In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

Shaffrey, L.C., and co-authors, 2009: U.K. HiGEM: The New U.K. High-Resolution Global Environment Model - Model Description and Basic Evaluation. *J. Clim.*, **22**, 1861-1896.

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