Revisiting GLACE: The Role of the Land Surface in Land-Atmosphere Coupling

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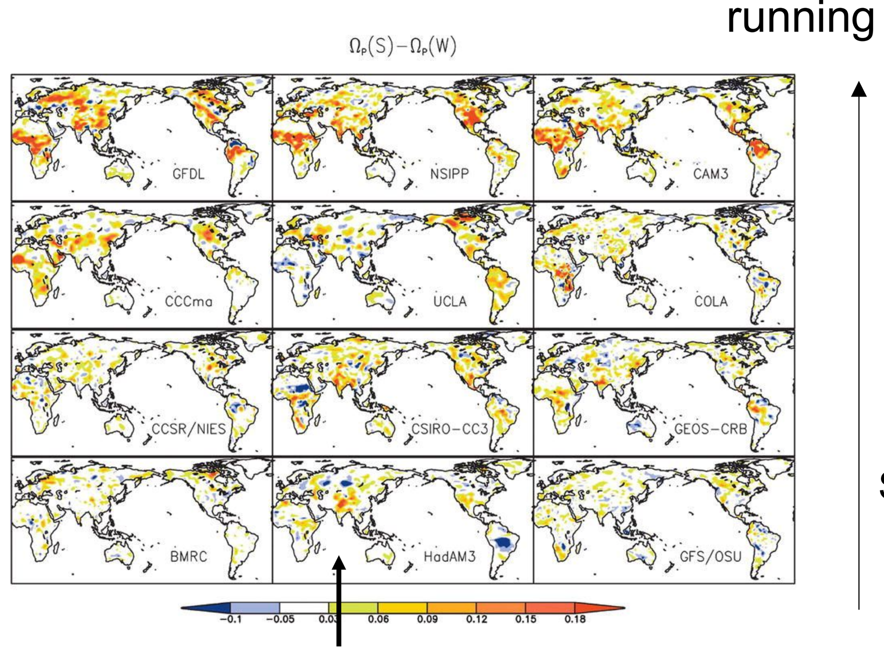
The GLACE method is applied to a new AGCM to establish:

- How does the new model compare to our old model where coupling was weak?
- What difference does a soil parameter change make to the coupling diagnostic?

Background: The GLACE Method

The Global Land-Atmosphere Coupling Experiment (GLACE; Koster et al., 2004, 2006) established a method for measuring the influence of soil moisture on precipitation in a GCM. Two ensembles are run for the model and,

GLACE coupling diagnostic = $\Omega_P(S)$-$\Omega_P(W)$
= Similarity of precipitation across ensemble “S” (all members forced with same soil moisture)
- Similarity of precipitation across ensemble “W” (free running soil moisture)



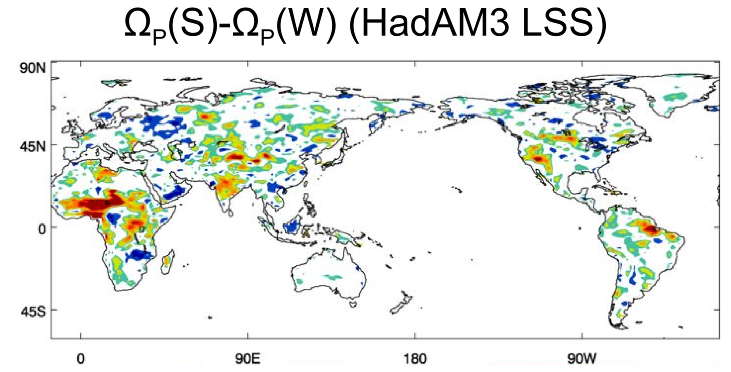
Coupling strength for 12 AGCMs (Koster et al. 2006)

New Model: HadGEM3-A

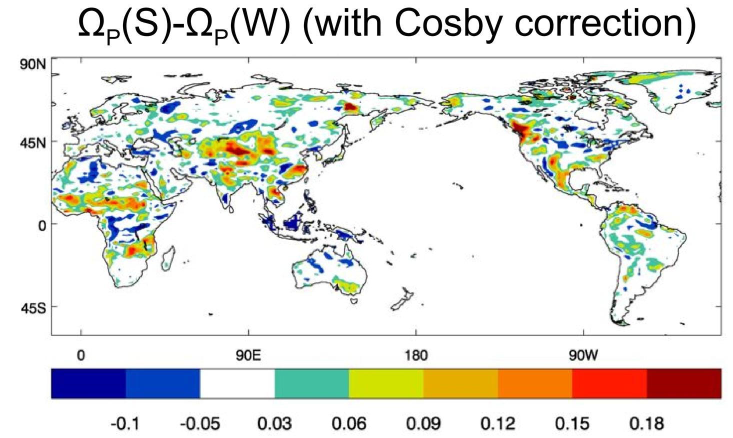
- Latest MOHC AGCM, under development (this version ~2 years old)
- Used for seasonal forecasting
- Atmosphere much developed from HadAM3
  - New dynamics
  - New convection and boundary layer parametrizations
  - Higher resolution: 1.875° lon x 1.25° lat; 85 vertical levels
- Land surface scheme similar to HadAM3

HadGEM3-A Coupling Strength

$\Omega_P(S)$-$\Omega_P(W)$ (HadAM3 LSS)



$\Omega_P(S)$-$\Omega_P(W)$ (with Cosby correction)



HadGEM3-A with HadAM3-like LSS has stronger GLACE signal than HadAM3

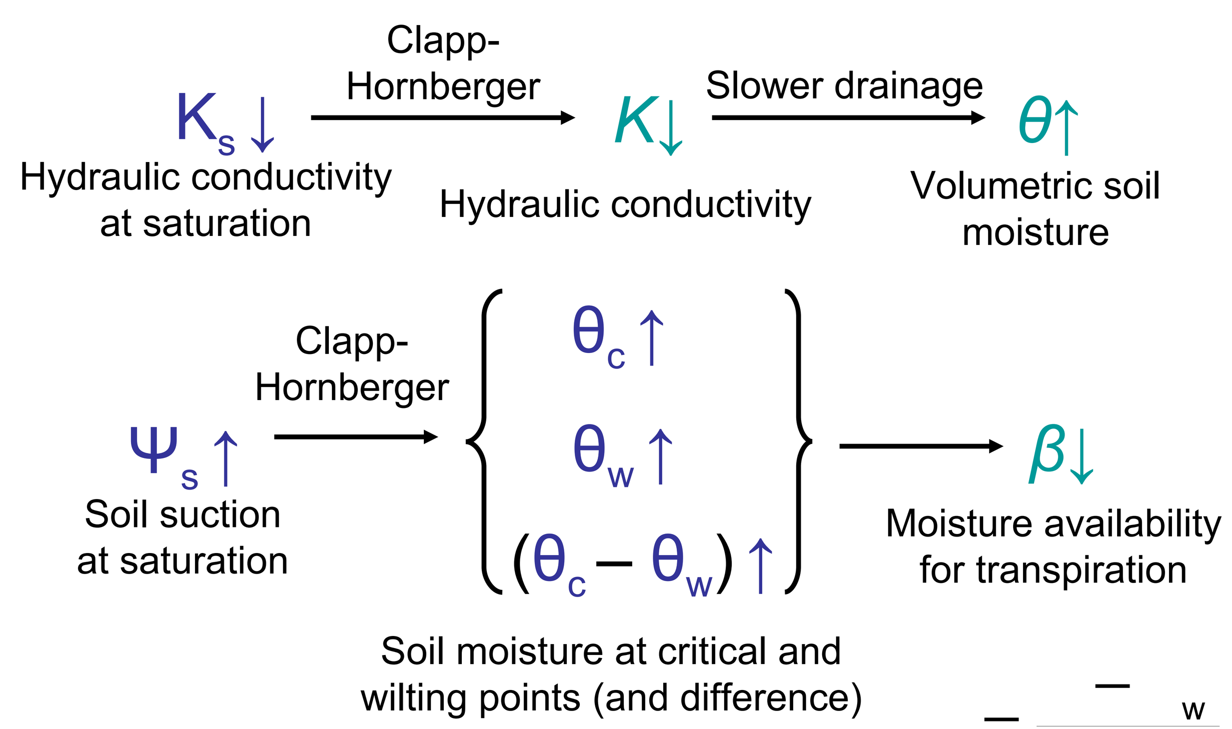
➔ **New atmospheric configuration more sensitive to soil moisture variability**

BUT a recent correction to soil hydraulic parameter derivation reduces the GLACE signal

About The Correction

K_s and Ψ_s are derived from the equations of Cosby et al. (1984), but an error was recently found with the way they are implemented for the UKMO model

Soil Parameter and *Variable* Changes:

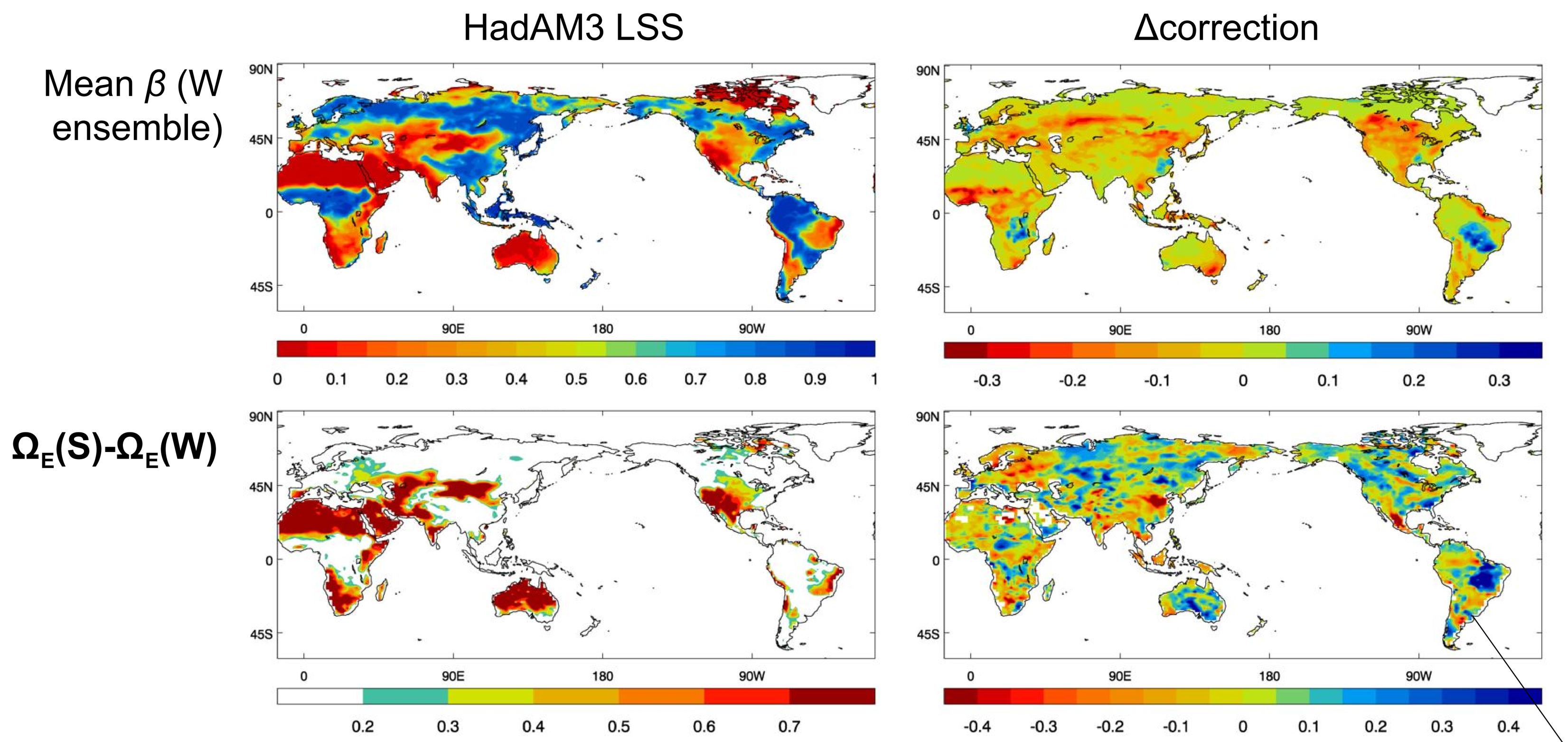


$$= \frac{- \quad _w}{_c - \square_w}$$

for $\theta_w \leq \theta \leq \theta_c$

Correction **increased soil moisture** nearly everywhere but **decreased moisture availability for transpiration**

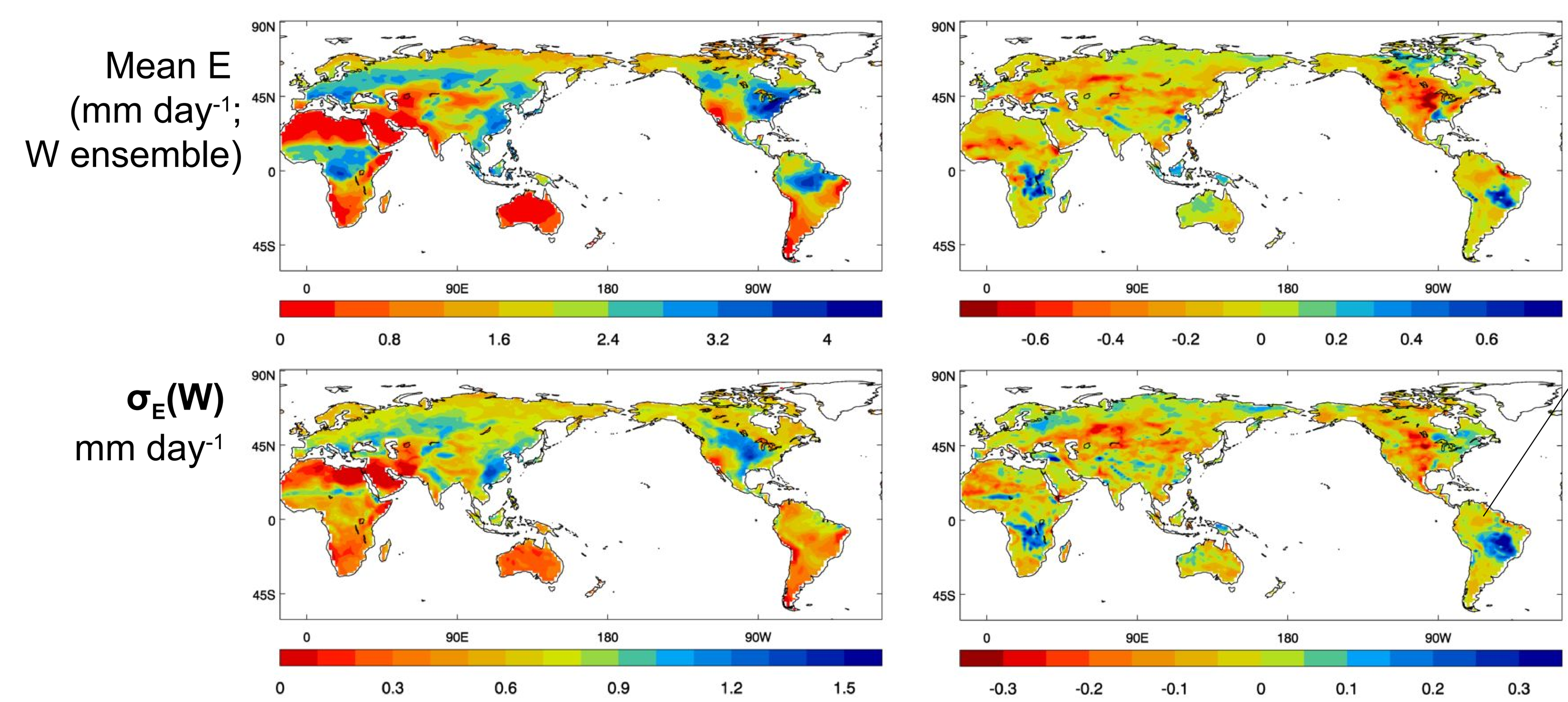
Soil moisture influence on the atmosphere depends on both the soil moisture influence on evaporation and evaporation variability (Guo et al., 2006):



Low moisture availability ➔ Strong influence of soil moisture on evaporation

High moisture availability ➔ evaporation more dependent on atmospheric conditions and light

Though noisy, we have a general increase in soil moisture influence on evaporation with the reduction in moisture availability.



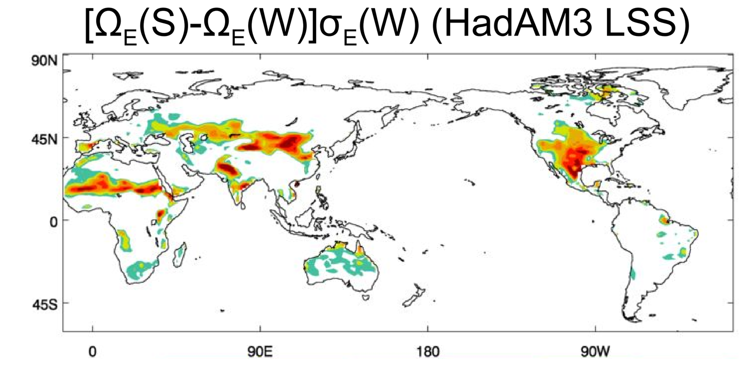
Mean and variability of evaporation are both strongly affected by moisture availability…

…and therefore reduced by the correction.

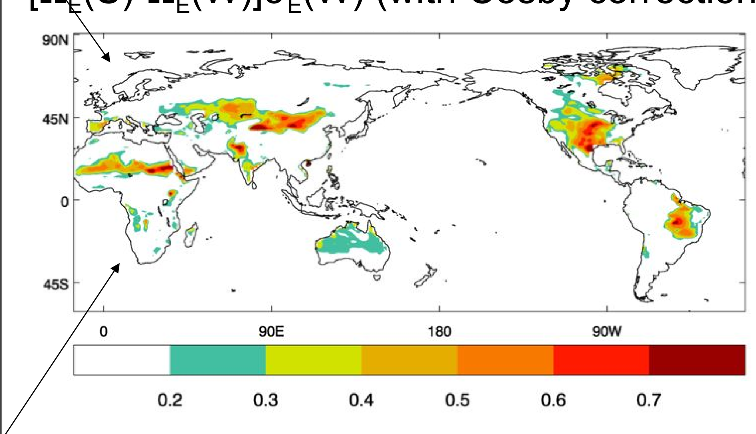
Land Surface Branch of HadGEM3-A Coupling

Soil moisture influence on evaporation and evaporation variability combine to give the land surface branch of land-atmosphere coupling (Guo et al., 2006).

[$\Omega_E(S)$-$\Omega_E(W)$]$\sigma_E(W)$ (HadAM3 LSS)



[$\Omega_E(S)$-$\Omega_E(W)$]$\sigma_E(W)$ (with Cosby correction)



Overall, the correction produces a reduction in the land surface branch of the coupling (and therefore in $\Omega_P(S)$-$\Omega_P(W)$)

➔ Effect via evaporation variability is dominant for our case.

Summary

- HadGEM3-A has stronger land-atmosphere coupling than its predecessor HadAM3
- This is due to changes in the atmospheric, rather than the land surface configuration
- Land surface changes do make some difference, but with competing effects
  - Decreased moisture availability ➔ Increased soil moisture-evaporation coupling
  - Decreased evaporation ➔ Decreased evaporation variability

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