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Quantifying uncertainties in future extremes using a perturbed land surface parameter experiment

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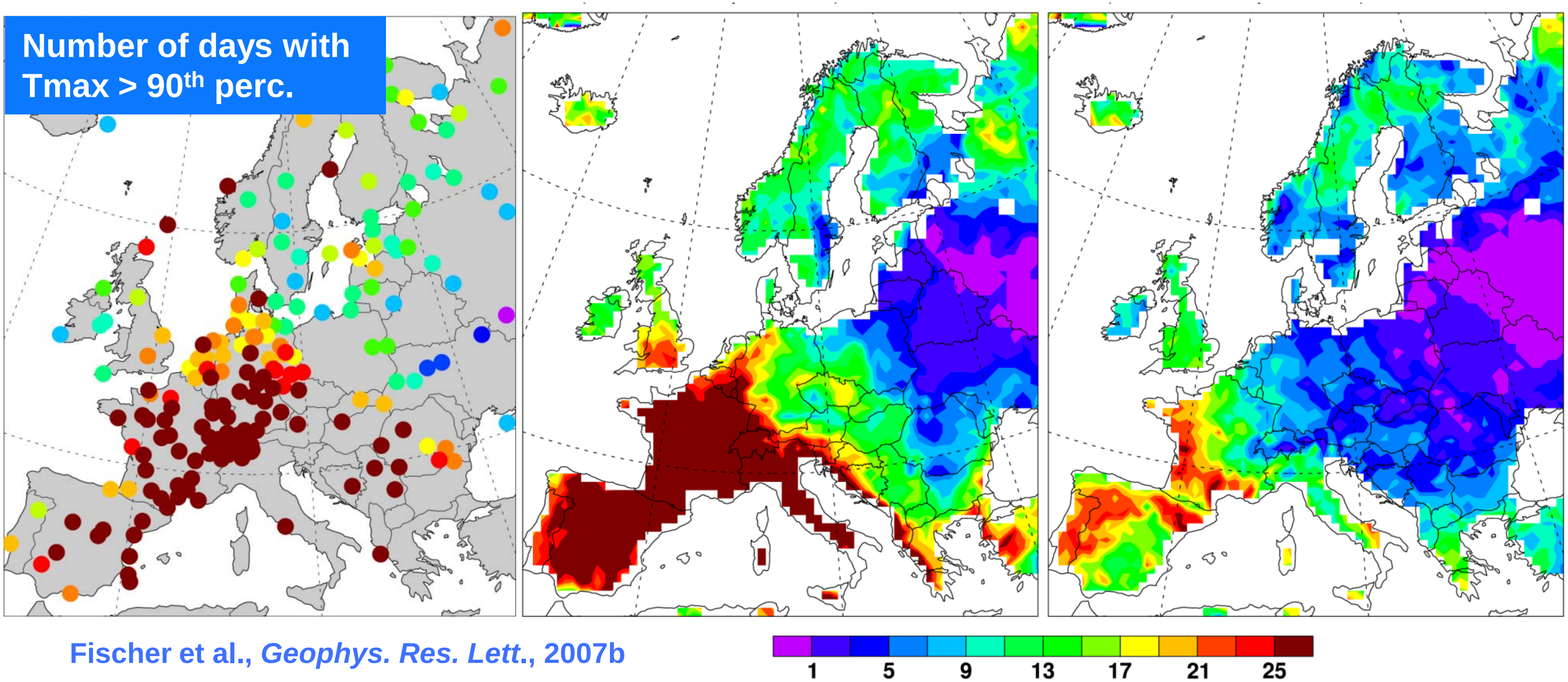
Motivation

European heat wave 2003 was amplified by soil drying
Contribution of feedback uncertain due to LSM parameterizations
-> Uncertainties in projections due to LSM parameters

Observations | Control simulation | Prescribed climatol. SM



Fischer et al., *Geophys. Res. Lett.*, 2007b

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Experimental setup

Model setup (motivated by climateprediction.net and QUMP)

- CAM/CLM 3.5 with slab ocean
- Simulations with 1xCO_2 (30 years) and 2xCO_2 (20 years)

- 5 poorly constrained CLM parameters
- different combinations of perturbed parameters (may interact non-linearly)
- experiment includes 108 ensemble members -> more than 7000 model years of daily data!

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Selected parameters

- Vegetation albedo: leaf albedo perturbed by +/- 20% for all PFTs
- Snow albedo: empirical constant in aging function -> faster and slower decrease in snow albedo
- Momentum roughness length (doubled, corresponds roughly to values used in the ECMWF LSM Tessel)
- Decay factor f in the calculation of subsurface runoff, which affects water table depth (moderate and strong increase of WT depth, based on Niu et al. 2005)
- v_{cmax} (maximum of carboxylation of Rubisco at 25°C), which controls photosynthesis and affects transpiration (Thornton et al. 2007)

$$V_{max} = \frac{1}{SLA \times CN_L} F_{LNR} \frac{1}{F_{NR}} a_R,$$

SLA: specific leaf area, ratio of leaf area to leaf mass
CN_L: leaf carbon:nitrogen ratio ($gC\ gN^{-1}$)

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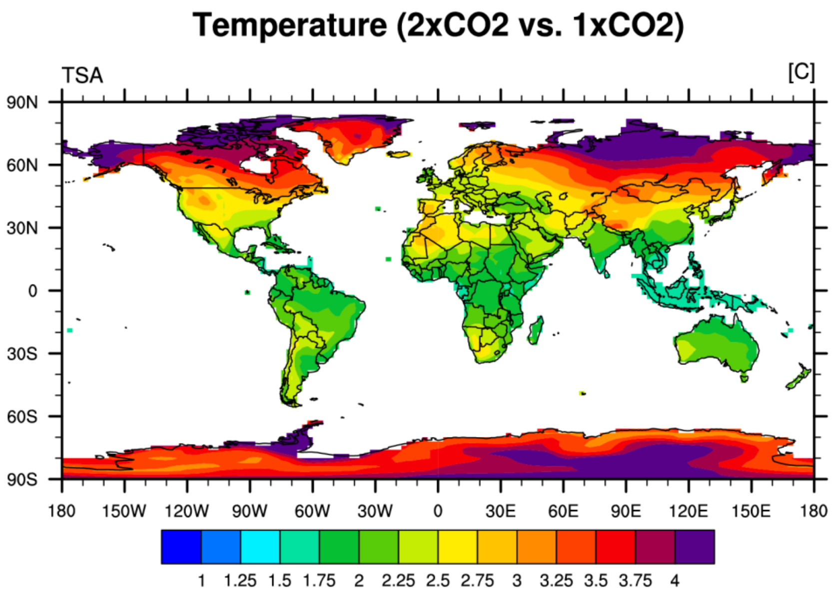
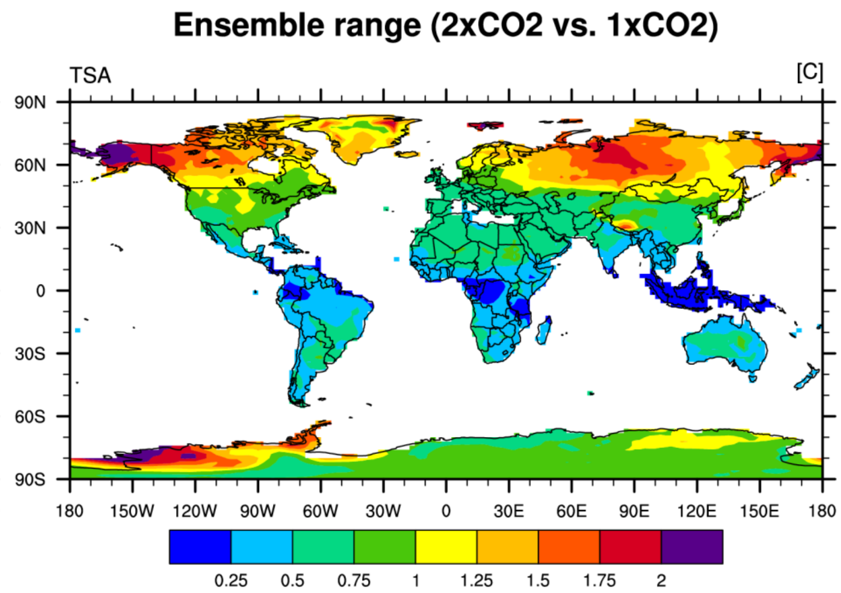
Temperature response to $2xCO_2$





$\Delta Temp_{Land}$ = 2.65K

Range: 2.4K-2.9K

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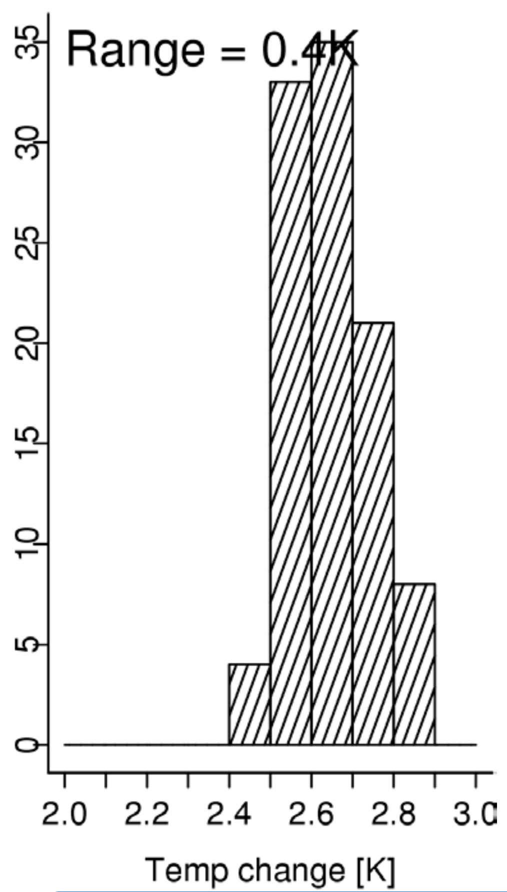
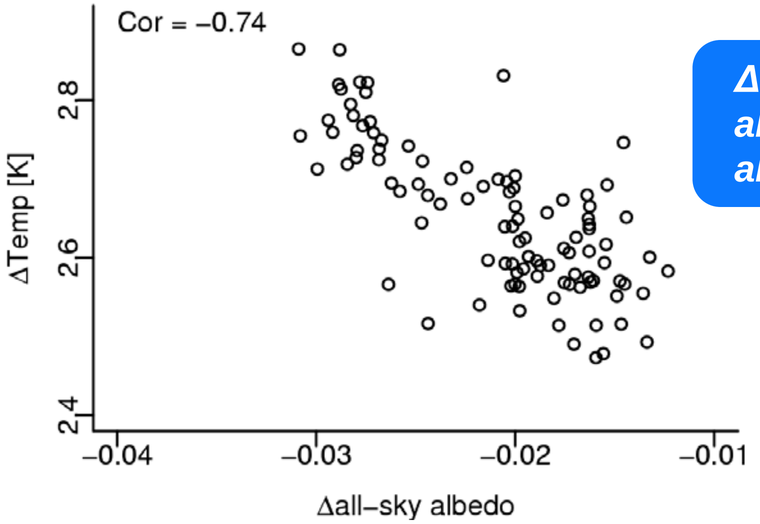
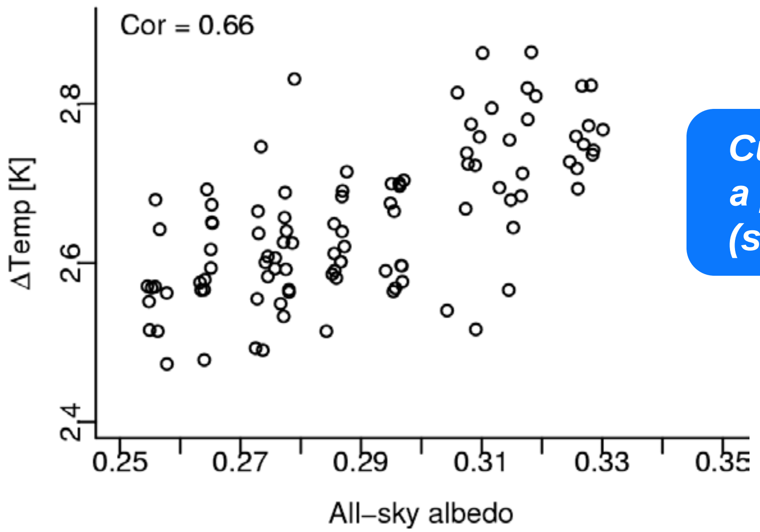
Global mean temperature vs. albedo



Snow albedo dominant: 43% expl. variance



ΔTemp relates to snow albedo change (MAM albedo over 30°-90°N)



Current snow albedo as a predictor of ΔTemp (see Levis et al. 2008)

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Summer temperature extremes

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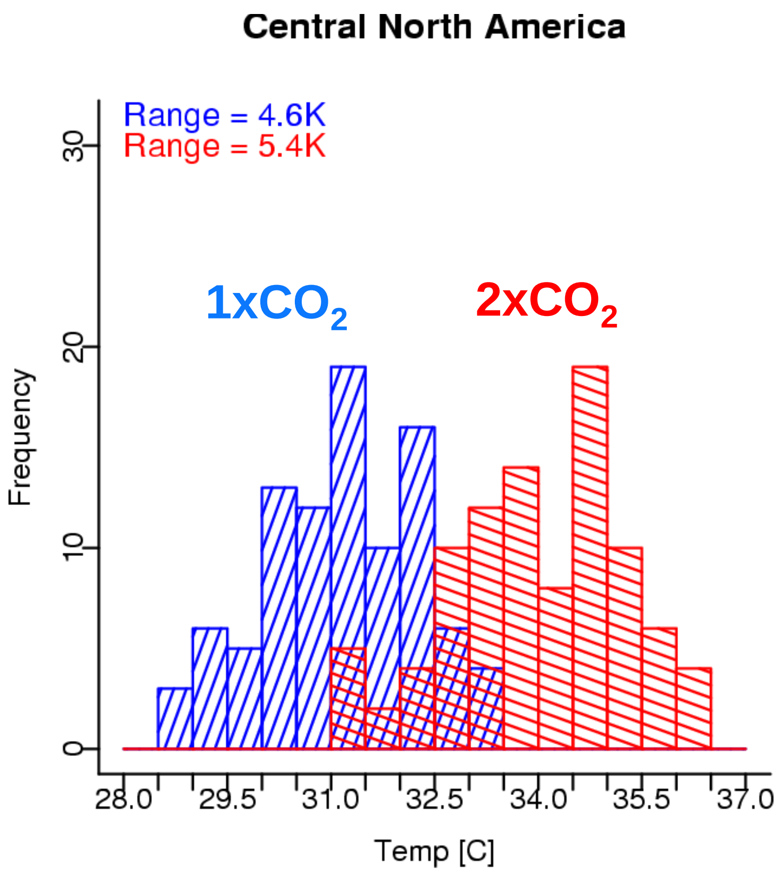
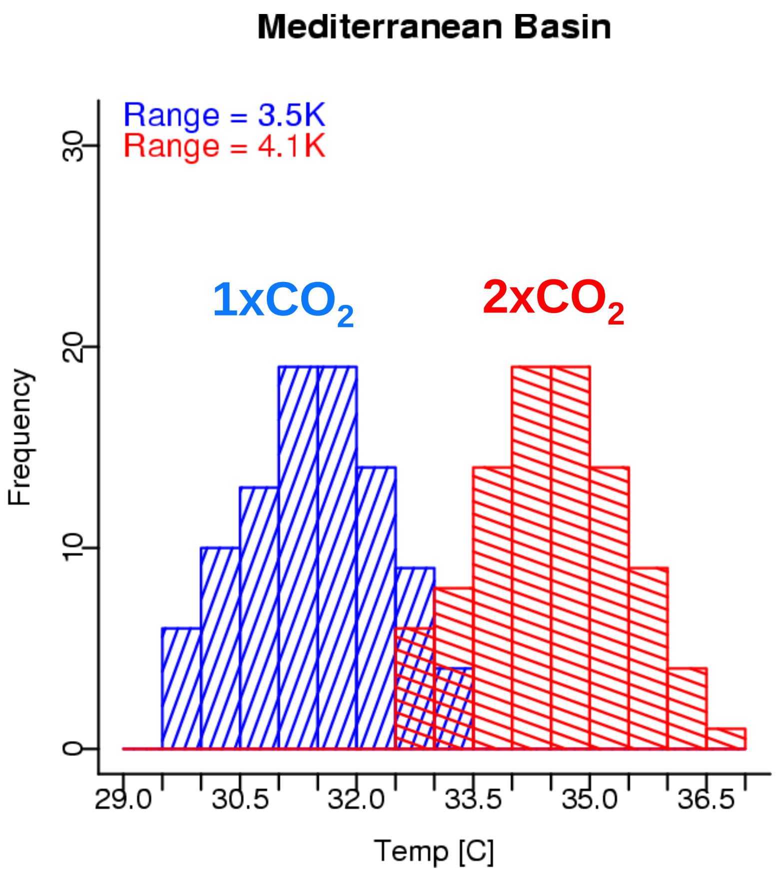
Heat extremes (JJA 95th perc.)





- ***LSM parameters affect not only mean but also interannual to intraseasonal temperature variability!***

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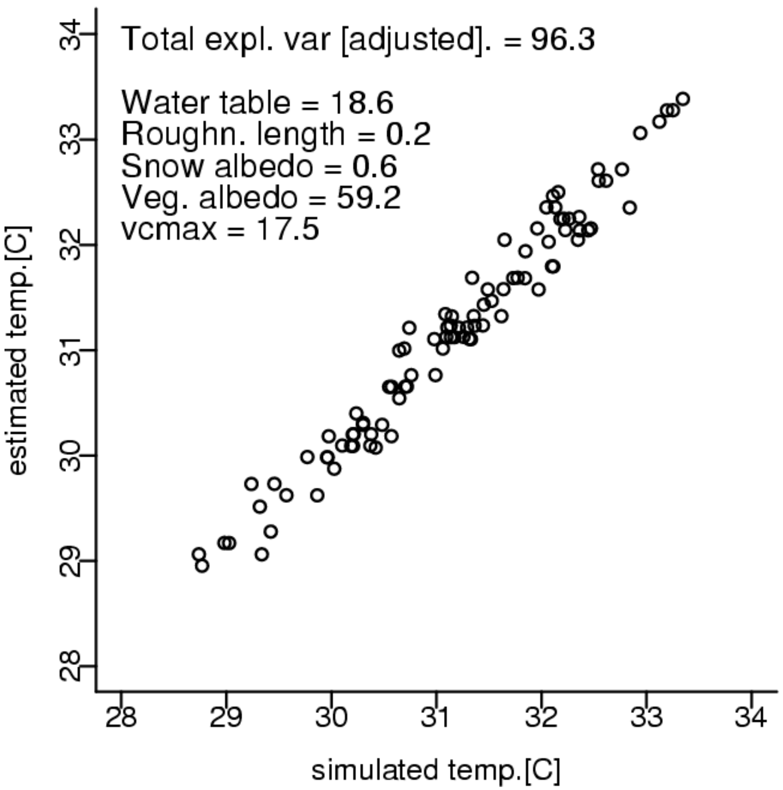
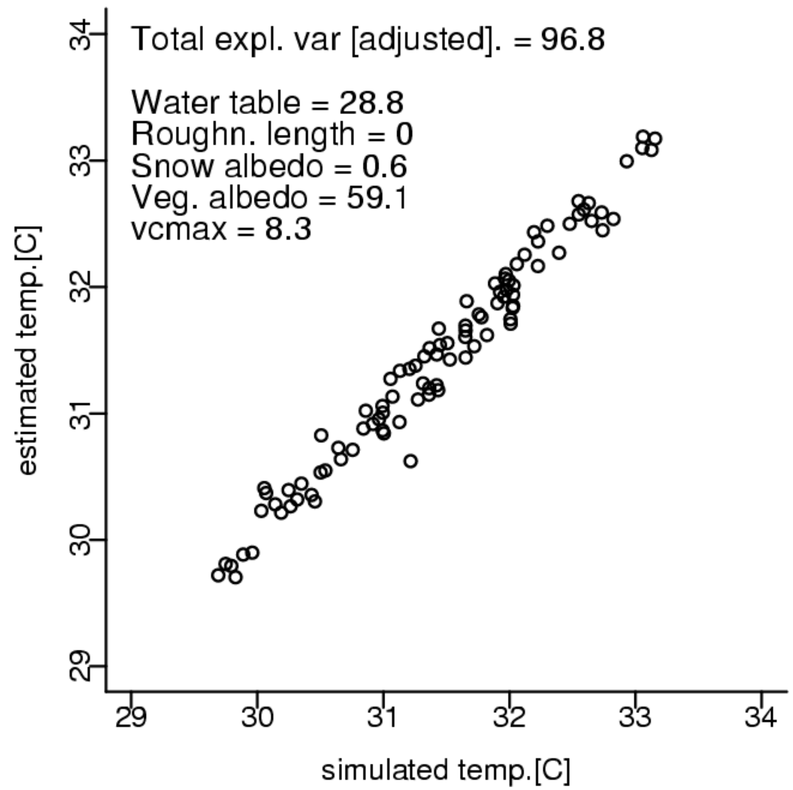
Role of parameters for extremes (1xCO_2)

Central North America



Mediterranean Basin



- ***Role of parameters differs regionally (generally veg. albedo dominant)***
- ***Water table depth important over dry regions***

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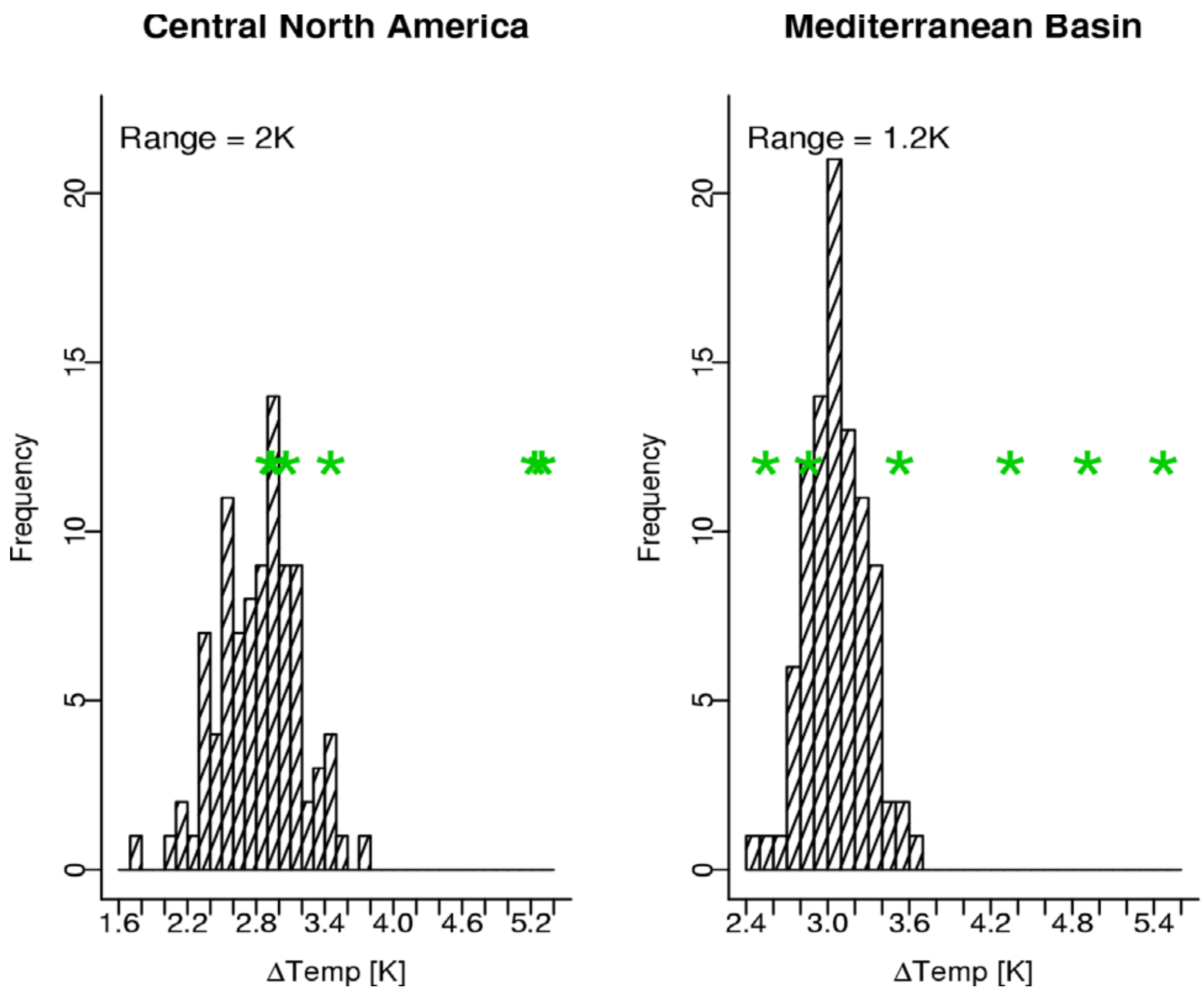
Response of heat extremes to 2xCO_2



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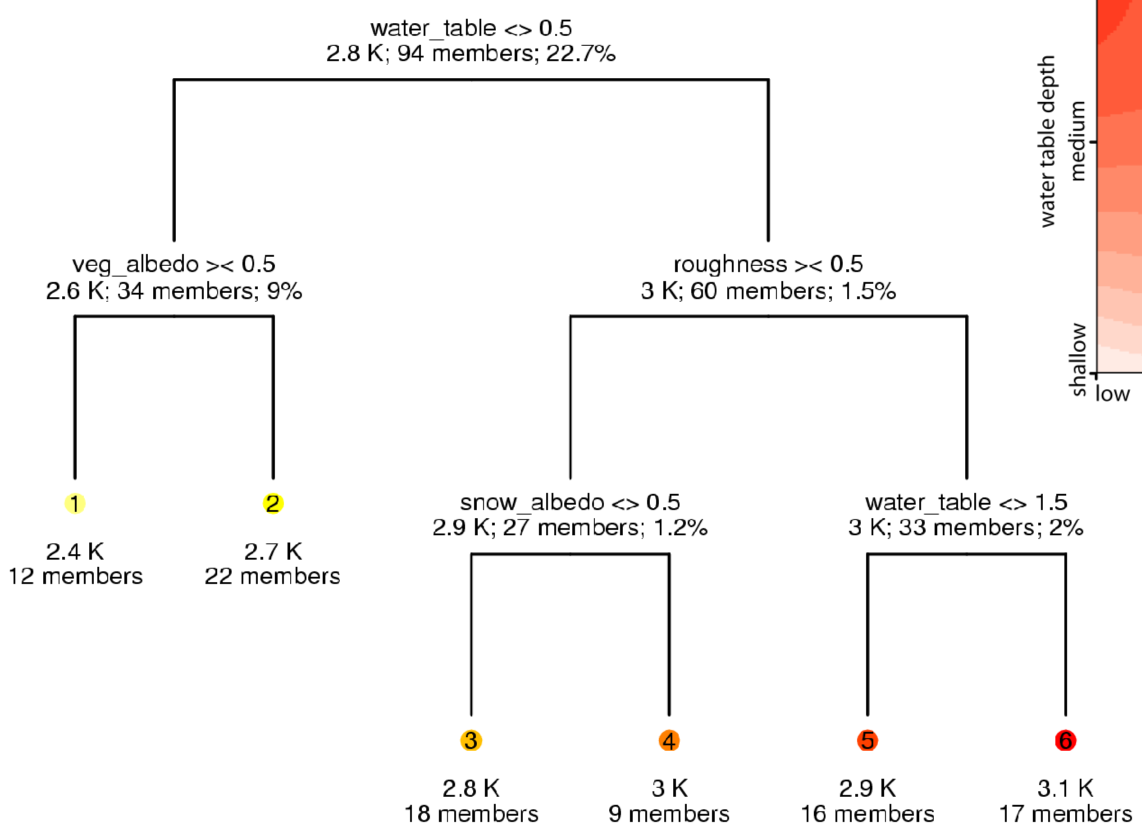
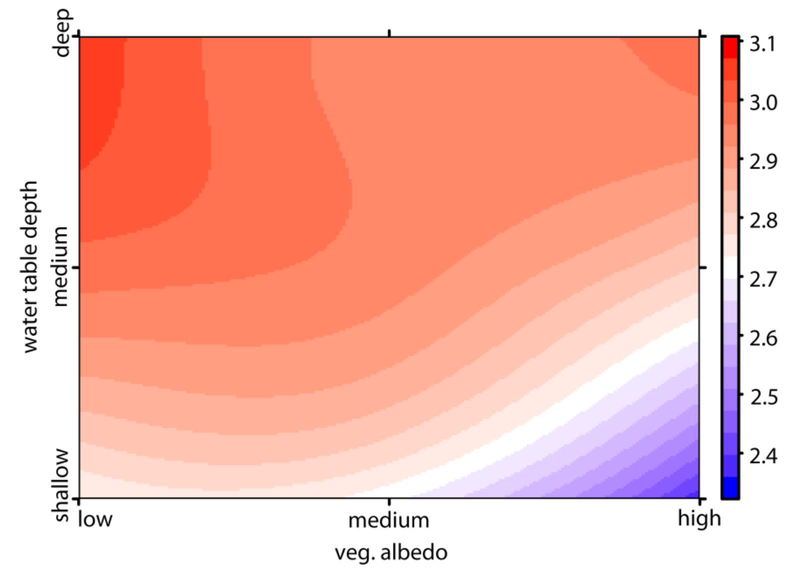
Response of heat extremes to $2xCO_2$

JJA Central North America



Total deviance explained = 36.4 %



- ***Response non-linearly dependent on parameters!***
- ***Water table affects evaporative fraction and may amplify heat extremes***

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Winter cold extremes

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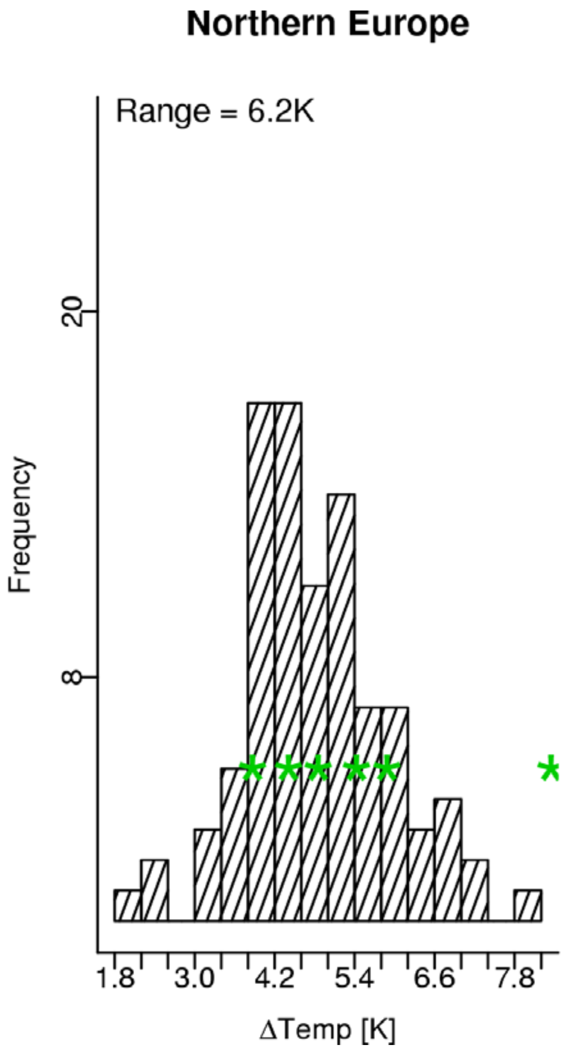
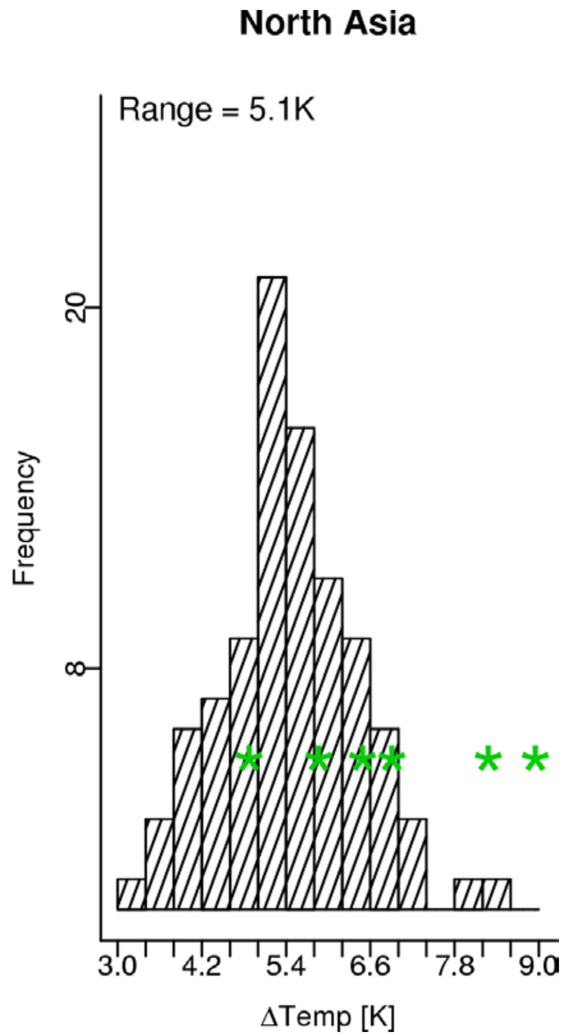
Cold extremes (DJF 5th percentile)





- ***Ensemble range exceeds the range of 6 CMIP3 models providing daily output!***
- ***Initial condition uncertainties and high internal variability contribute to the large ensemble range!***

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Summer precipitation

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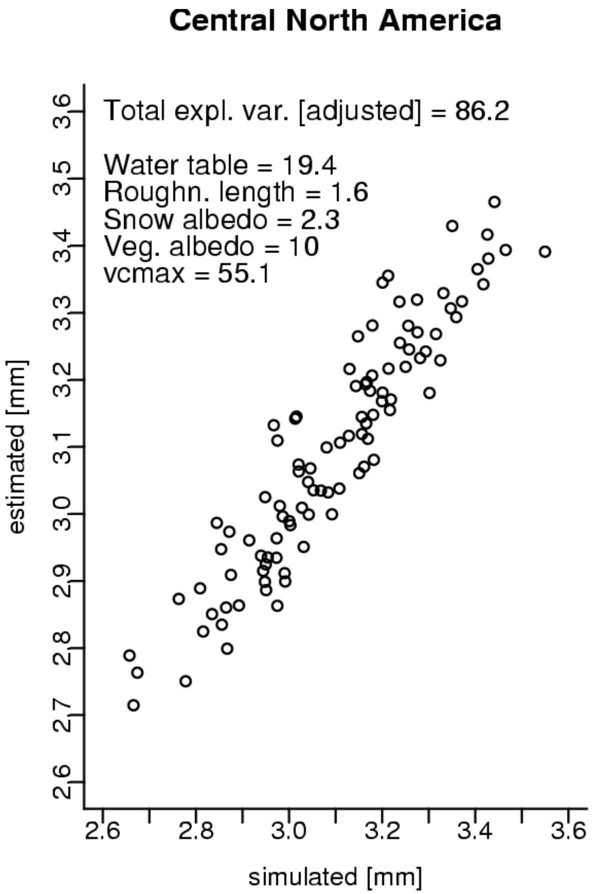
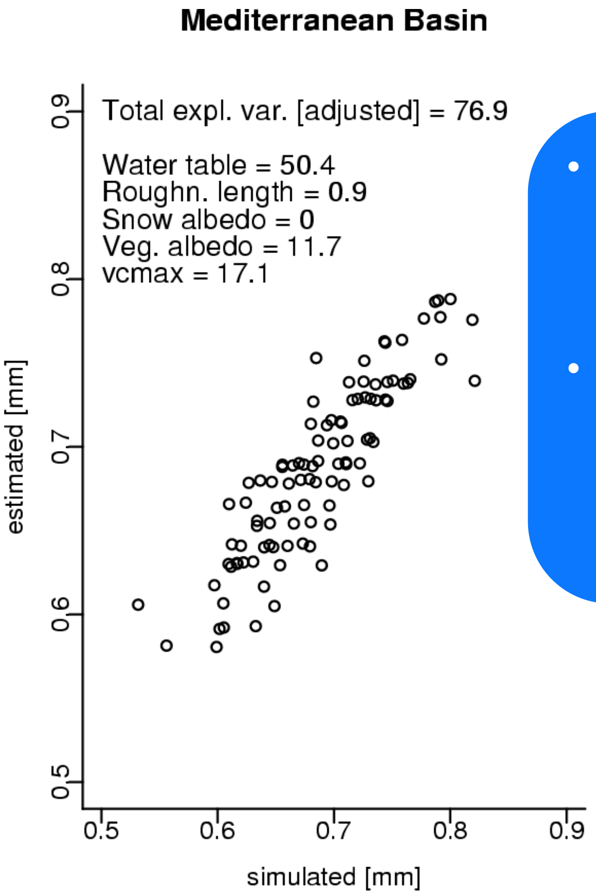
Role of parameters (JJA precipitation)





- ***Different parameters dominant for precipitation than for temperature***
- ***Water table depth is dominant over arid regions; Vcmax dominates vegetated regions***

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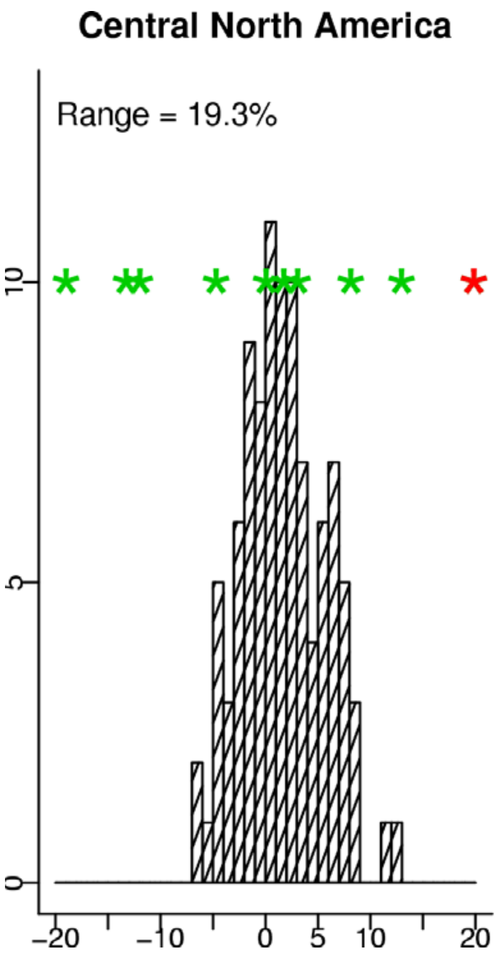
Precipitation response to $2xCO_2$ (JJA)



- *Precipitation response varies between -7% and +12%*
- *Spans half of the CMIP3 range*

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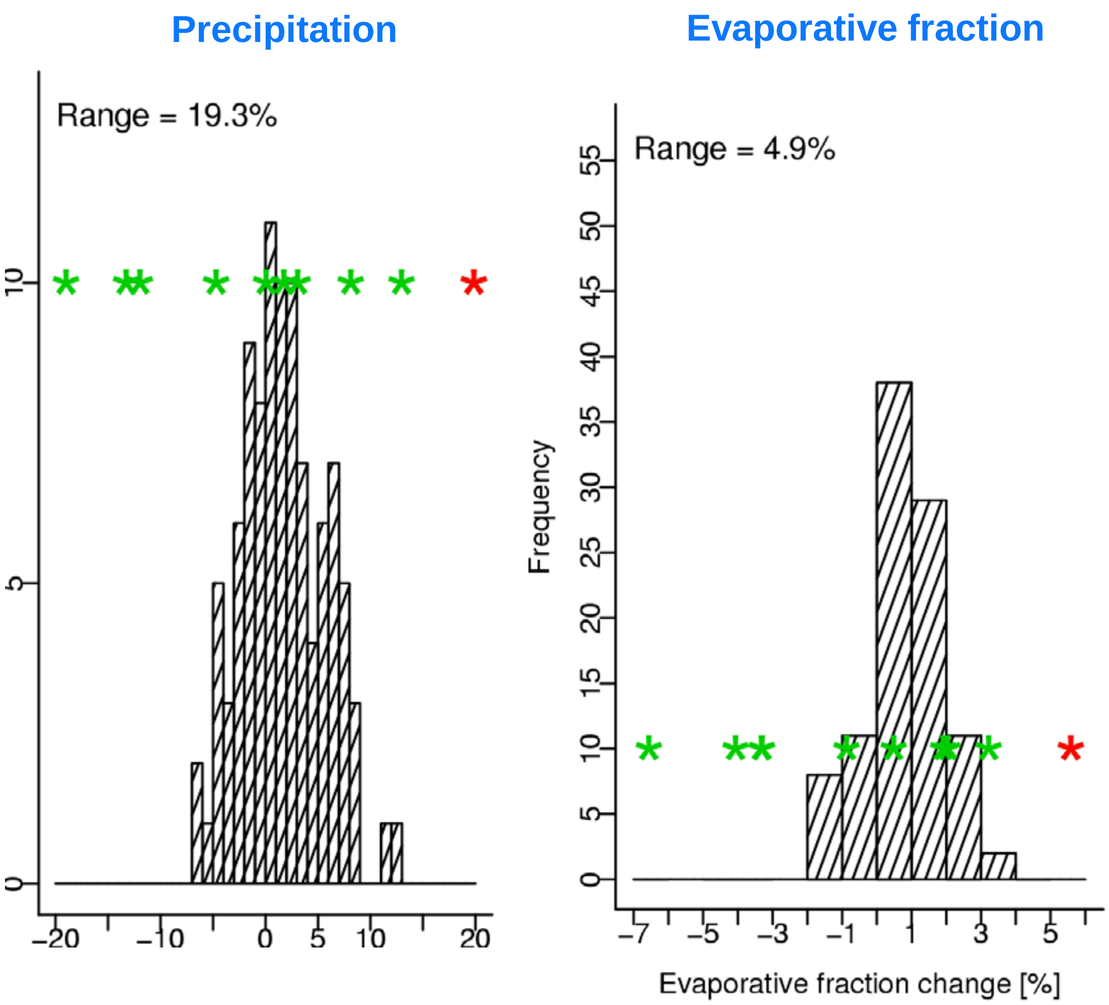
Precipitation response to $2xCO_2$ (JJA)



- *Evaporative fraction correlates with precip change (two-way coupling?)*

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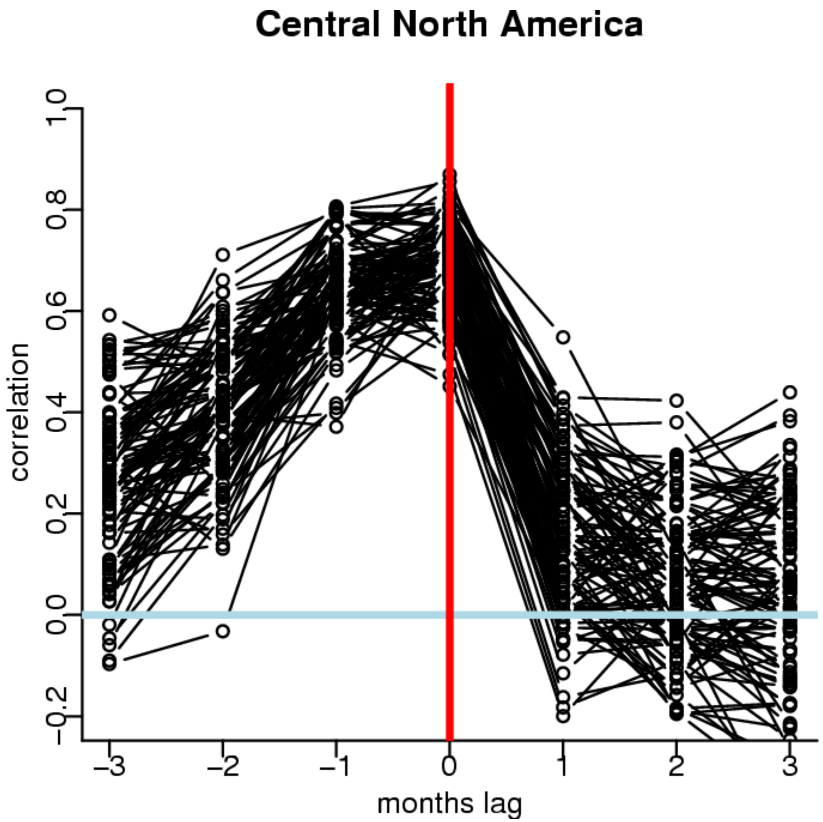
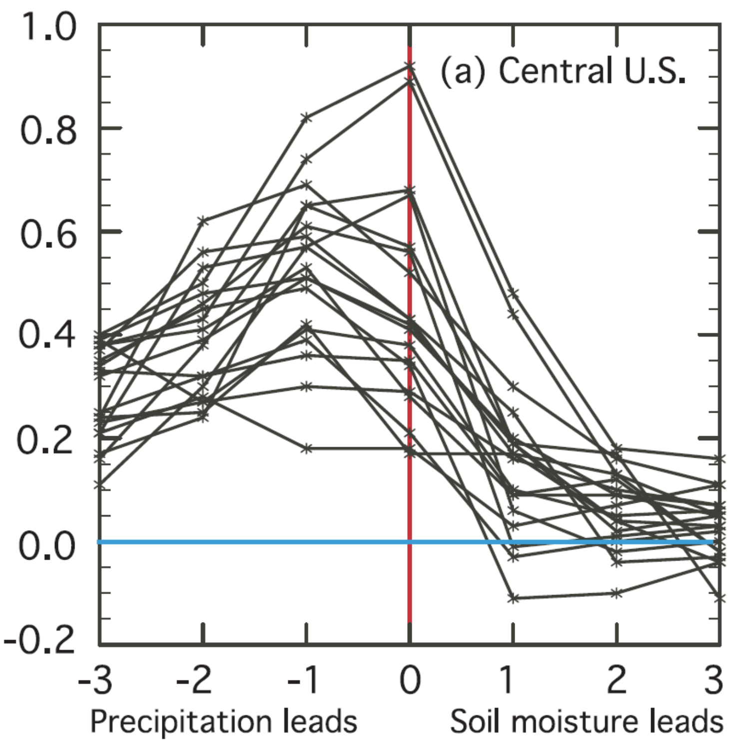
Coupling CLM pert. exp. vs. CMIP3



Notaro et al. 2008



- ***Range of correlations in CLM ensemble exceeds the range of CMIP3 models!***
- ***Note that simulation length is much shorter (-> larger spread)***

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Summary and outlook

- Uncertainties in CLM parameters contribute to relatively large model uncertainties particularly at regional scale
- CLM parameters have larger effect on extremes than on mean climate due to changes in variability
- Role of parameters differs between season, region and climate variables (temperature and precipitation)
- Snow albedo has dominant effect on global mean response
- Vcmax and water table depth are crucial for heat extremes and summer precipitation

Next step:

- Perform ensemble to quantifiy initial conditions uncertainties wrt parameter uncertainties