# Cloud and land surface interactions

Cathy Hohenegger[1] and Christoph Schär[2]

[1] Max Planck Institute for Meteorology, Hamburg, Germany
[2] ETH Zurich, Zurich, Switzerland

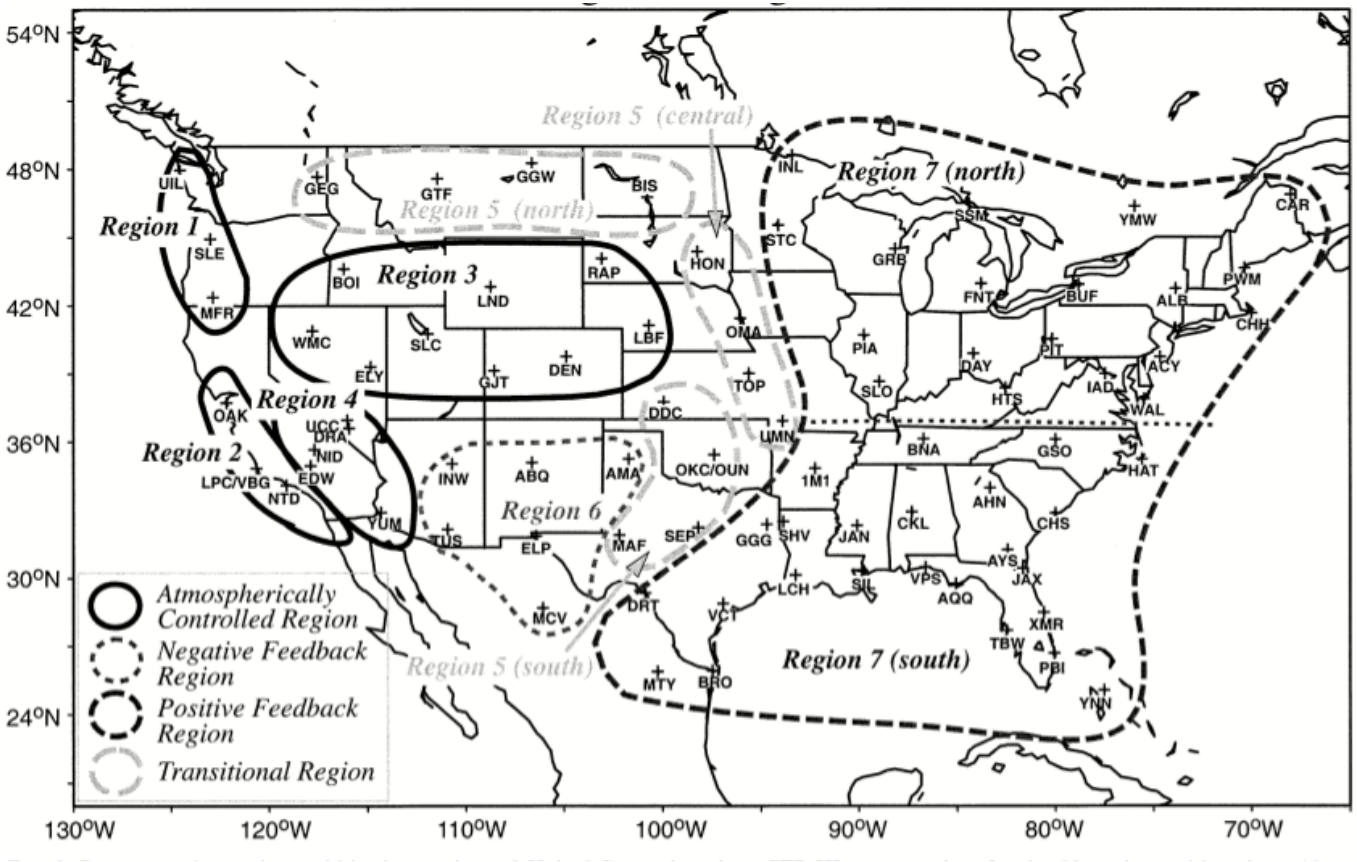
# Homogeneous surface conditions

## Soil moisture-precipitation feedback

1. Process analysis, based on model results
    1. Direct SMP feedback (Direct coupling) +
    2. Circulation +/-
    3. First indirect SMP feedback (Local coupling) +
    4. Second indirect SMP feedback (Local coupling) -
2. Geographical distribution of SMP feedback
3. Open issues

# Geographical distribution Homogeneous surface conditions

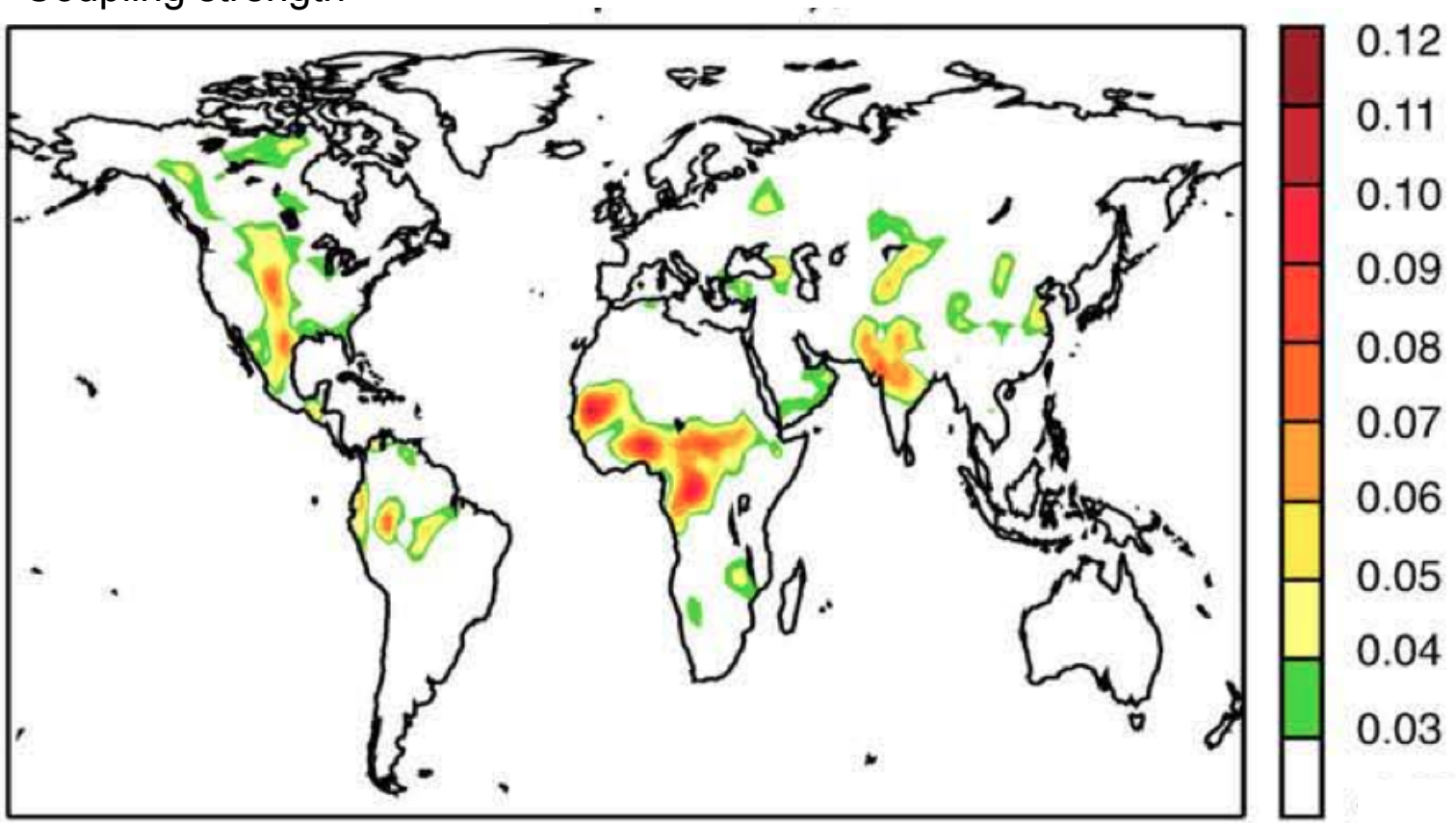
- Combination model and observations, indirect measure (Findell and Eltahir 2003b)



## Geographical distribution  Homogeneous surface conditions

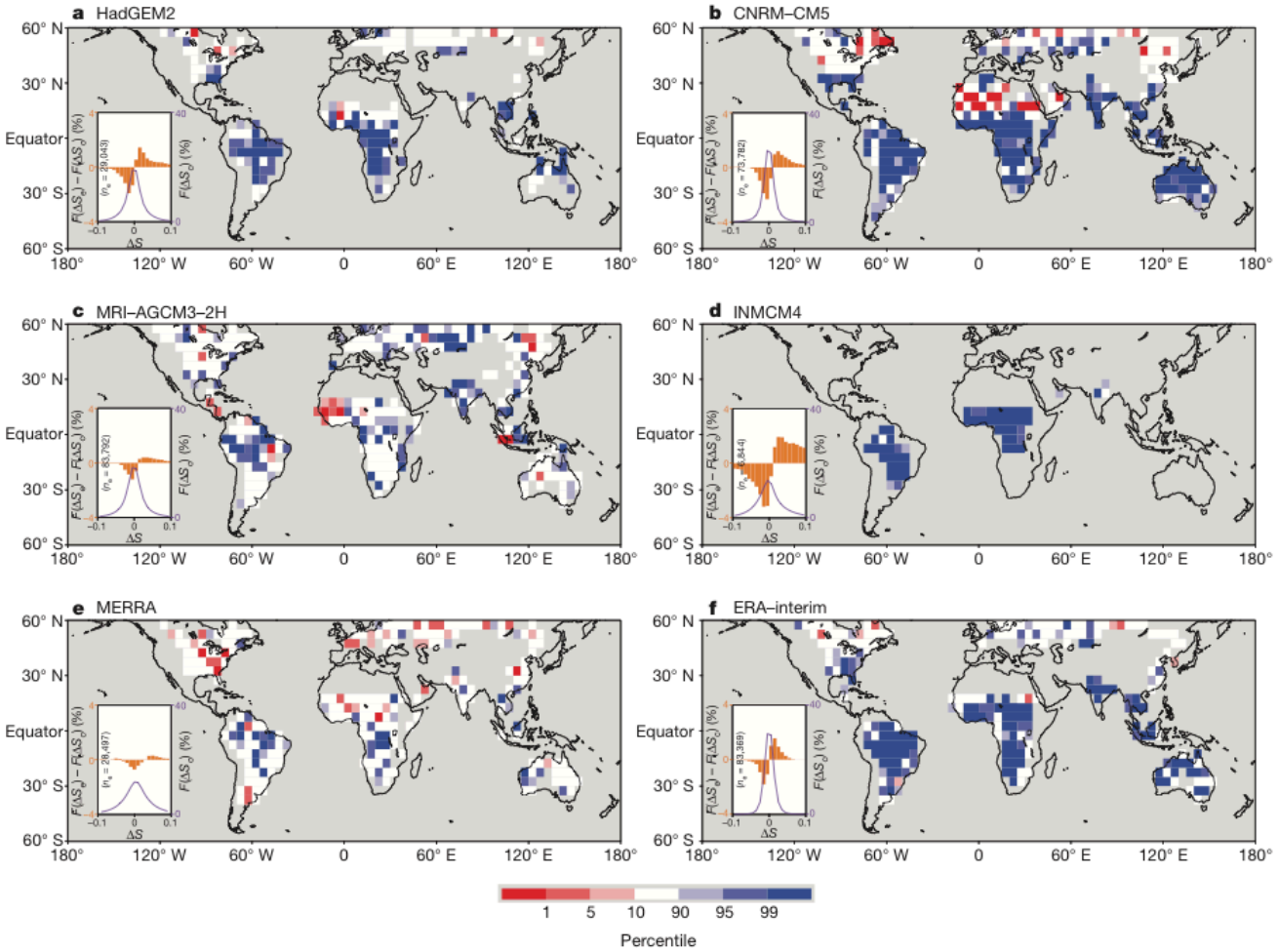
- Global climate models (Koster et al. 2006)

Coupling strength



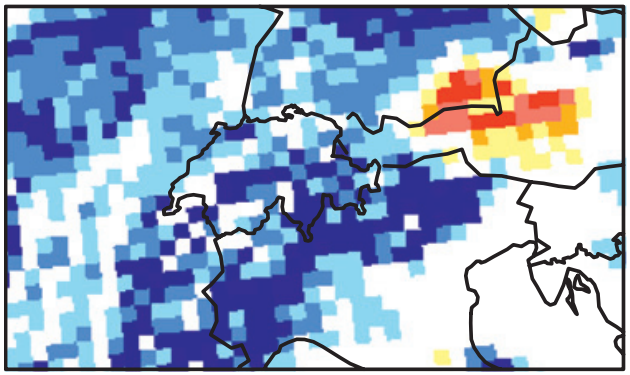
# Geographical distribution  Homogeneous surface conditions

- Global climate models (Taylor et al. 2012)



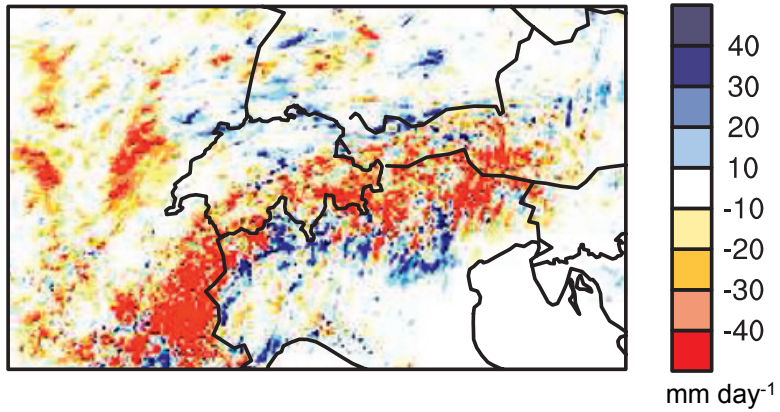
- Is SMP feedback really positive ??

Parameterized convection



Positive feedback

Explicit convection

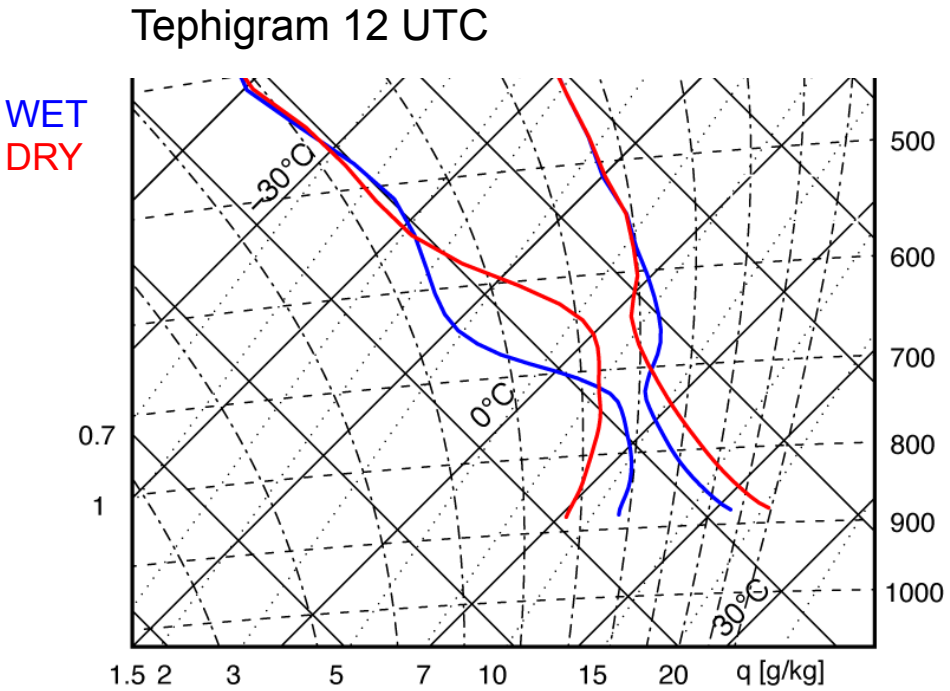



Negative feedback



(Hohenegger et al. 2009)

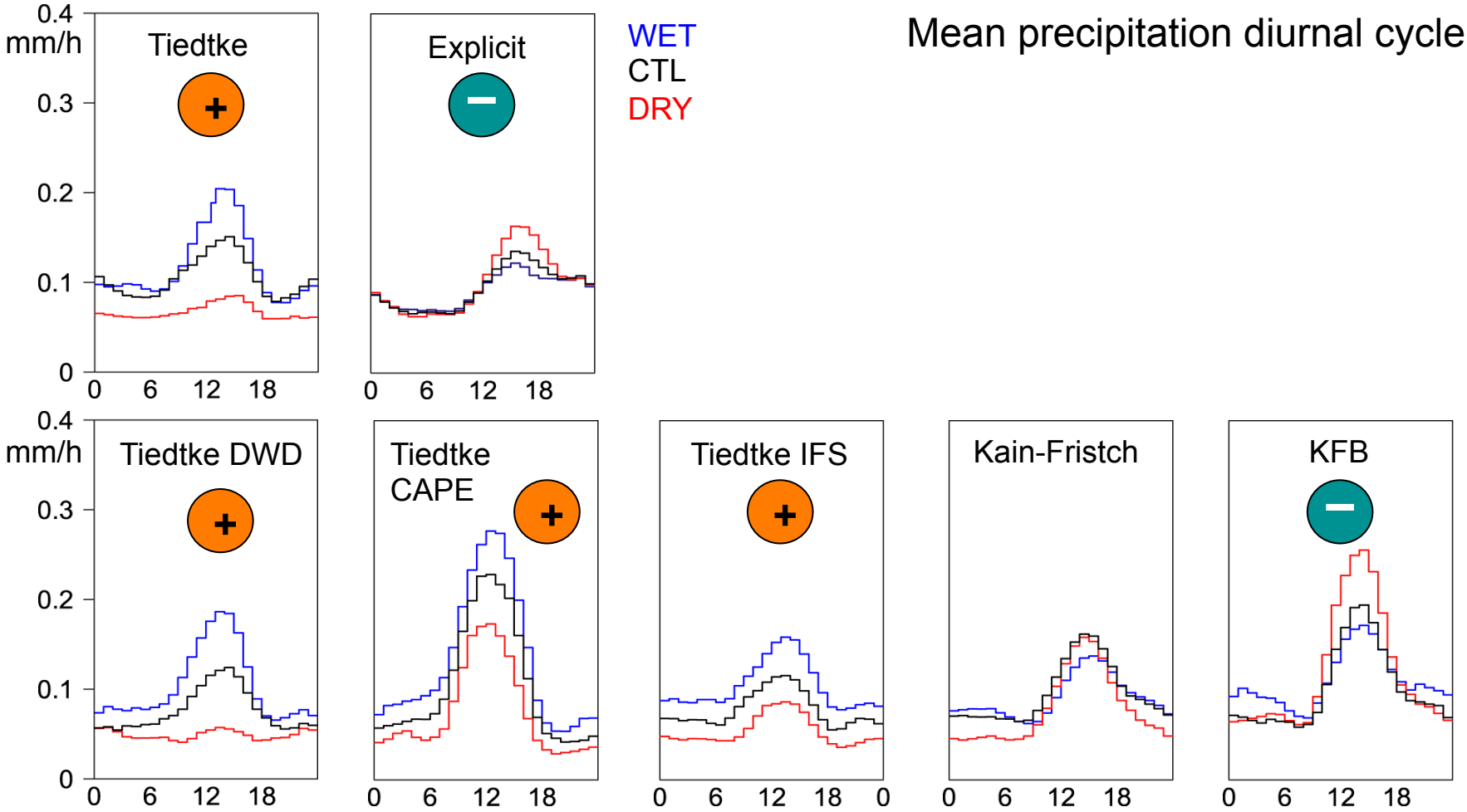
- Is SMP feedback really positive ??






(Hohenegger et al. 2009)

- Is SMP feedback really positive ??

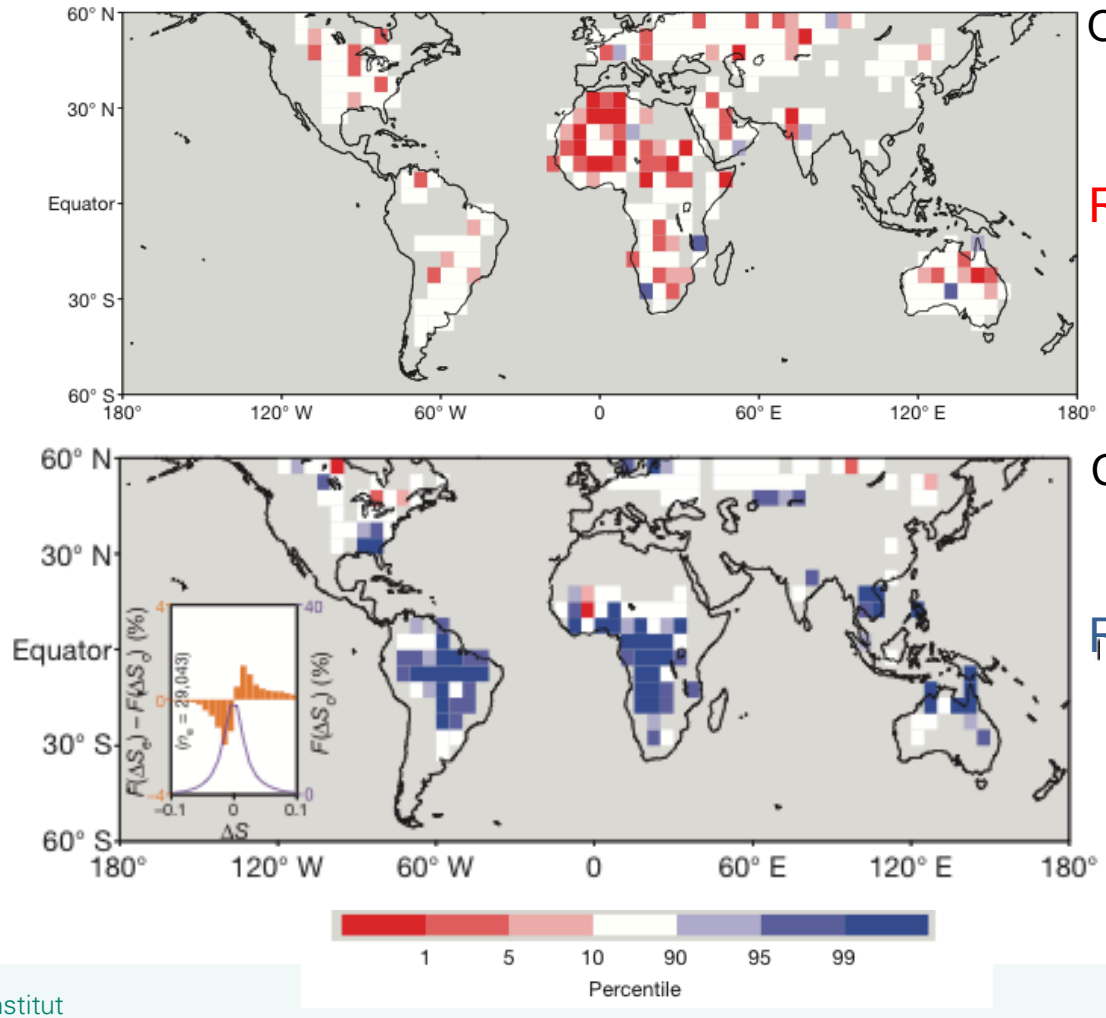



Mean precipitation diurnal cycle



(Hohenegger et al. 2009)

- Is SMP feedback really positive ??




Observations

Rain prefers dry soil

Climate model

Rain prefers wet soil

(Taylor et al. 2012)

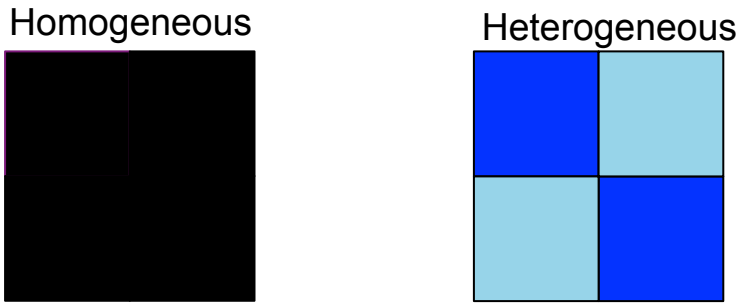
# Outline

1. **Basic concepts and processes**

2. **Feedbacks**
    1. Static heterogeneity
    2. Homogeneous surface conditions
    3. Dynamic heterogeneity

3. **Extremes**

# Dynamic heterogeneity

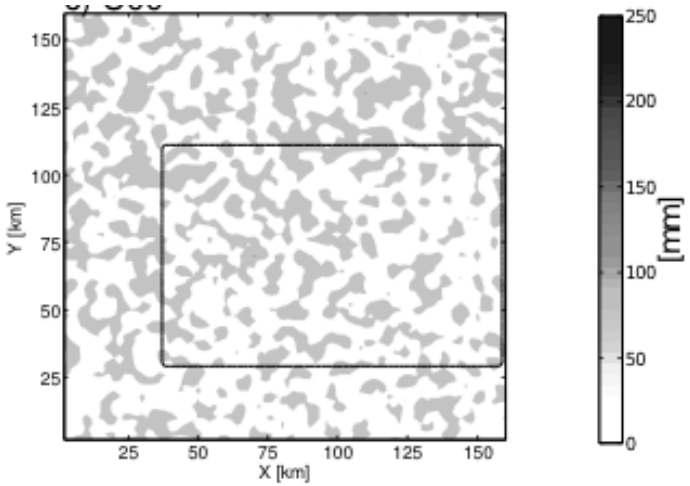



Heterogeneity on the surface created by the convective processes:

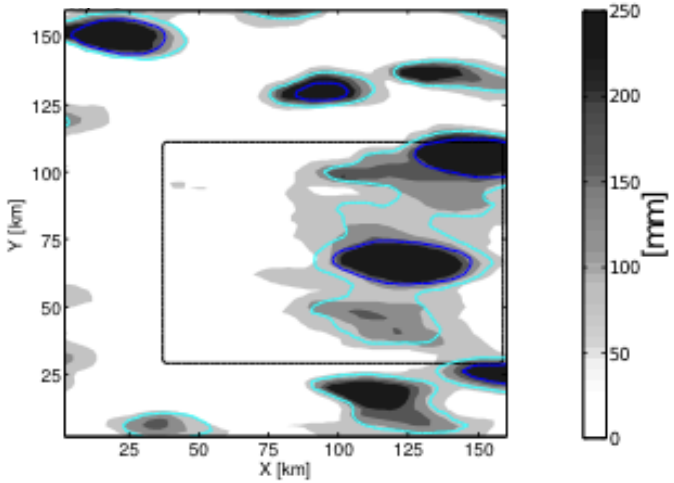
- cloud shading
- precipitation falling into the ground generating wet patches of soil moisture

# Dynamic heterogeneity

- No background wind
- Random distribution

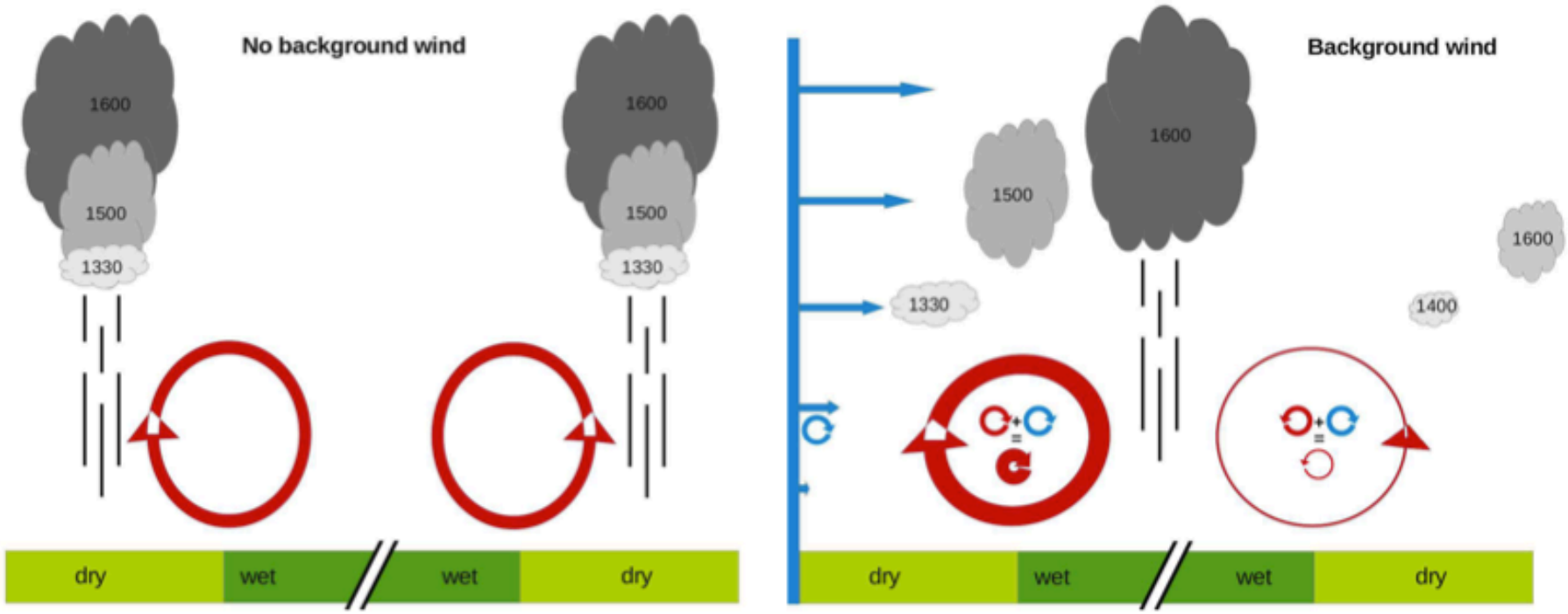



- Background wind
- Precipitation locks on SM anomaly




(Froidevaux et al. 2013, submitted)

# Dynamic heterogeneity

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**Deforestation in Amazon:**

- Increases precipitation?  6
- Decreases precipitation ? most
- No effect on precipitation? 1

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- Increases precipitation?  6
- Decreases precipitation ? most
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| **Feedback** | **Precipitation** | **Likelikhood** |
|---|---|---|
| Direct | Decreases | Unlikely |
| Large-scale circulation | Decreases | Most important if full deforestation (GCM) |
| 1. Indirect | Decreases | Unlikely |
| 2. Indirect | Increases | Unlikely |
| Static heterogeneity | Increases | Yes if local deforestation (RCM, CRM) |
| Observations | No change | Need longer time period |

If we believe the static heterogeneity argument:

- Deforestation -> More convection -> More rain -> Favors vegetation growth:

  **Negative feedback**

- Deforestation -> More convection -> More lightning -> More fire -> More rapid fire propagation in fragmented landscape -> less rain

  **Positive feedback**

## Feedbacks summary

- Different feedbacks exist through which the land surface can affect clouds and precipitation (in those cases where evapotranspiration depends upon the land surface conditions)
- Physical arguments can be given to explain those different feedbacks
- Those feedbacks can have different signs
- It is not clear which feedback ultimately dominates and the use of models, where most of the involved processes have to be parameterized, may yield to wrong conclusions
- The resulting overall feedback also depends upon the scale and strength of the perturbation applied to the land surface.

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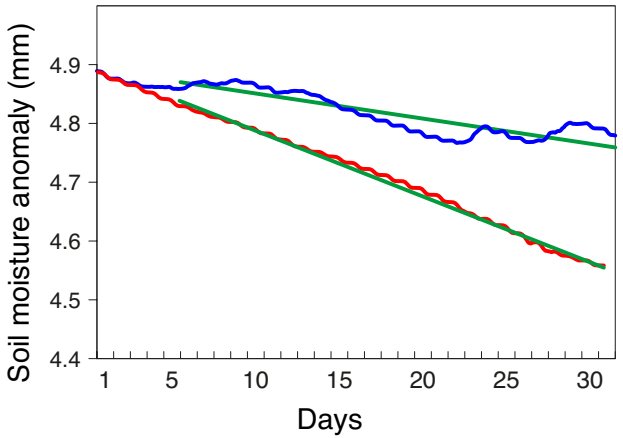
## Note of caution

- Studies on the role of the land surface for climate/climate change uses climate models with parameterized convection

- Different climate models exhibit different sensitivity to soil moisture, but all of them tend to favor a positive feedback




Positive feedback: > 5 months

Negative feedback: 2 months

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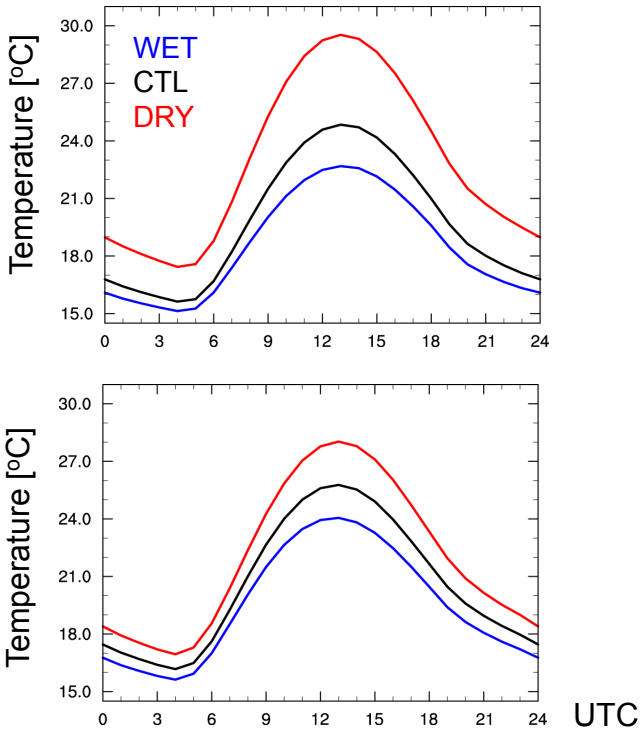
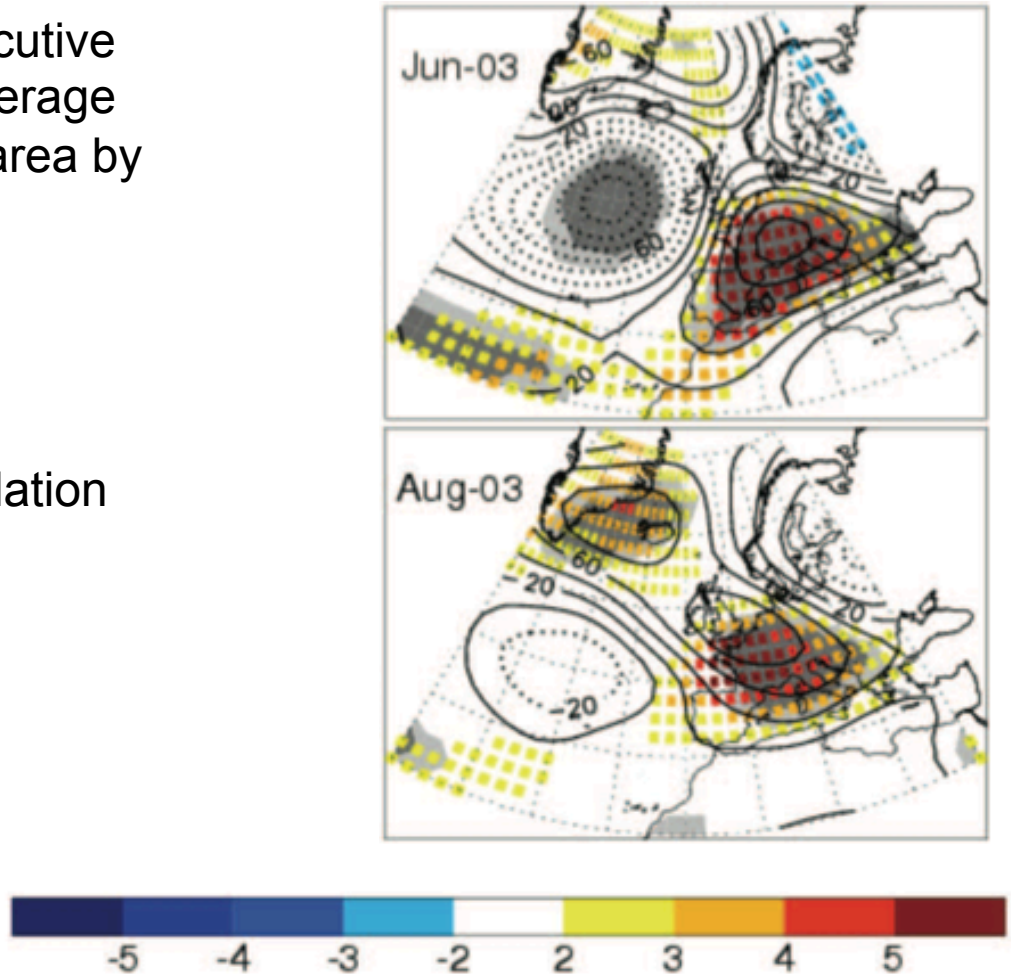



Positive feedback: +4.3° C

Negative feedback: +2.5° C

- A length of five or more consecutive days of heat exceeding the average maximum temperature of the area by 5°C (WMO)
- 35000 people died in 2003
- First cause: atmospheric circulation

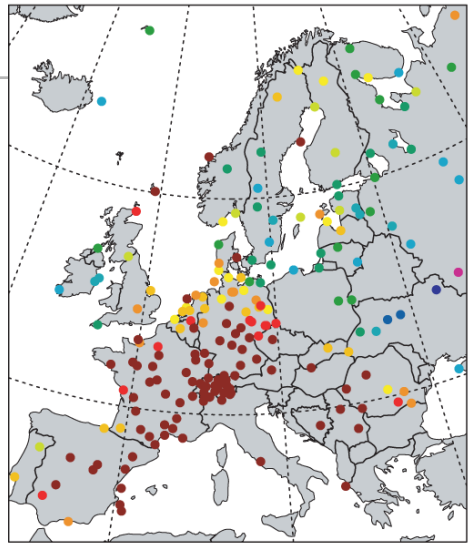



(Garcia-Herrera et al. 2010)

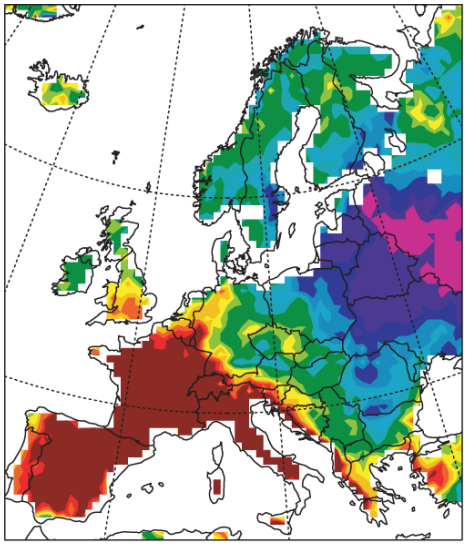
# Heat waves

- Soil moisture may intensify heat waves

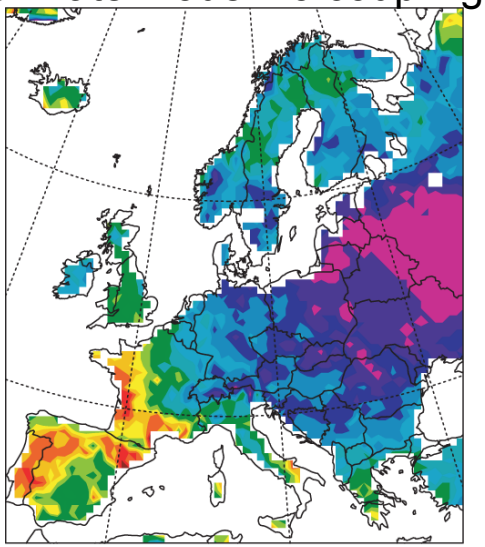
Observations



Climate model



Climate model no coupling

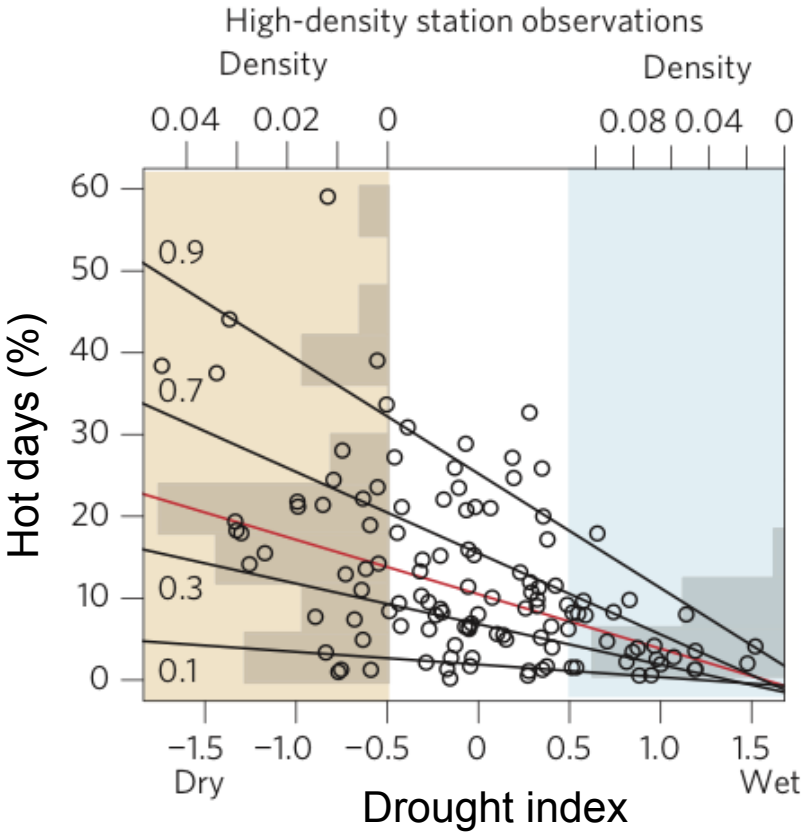


Number of hot days




(Fischer et al. 2007)

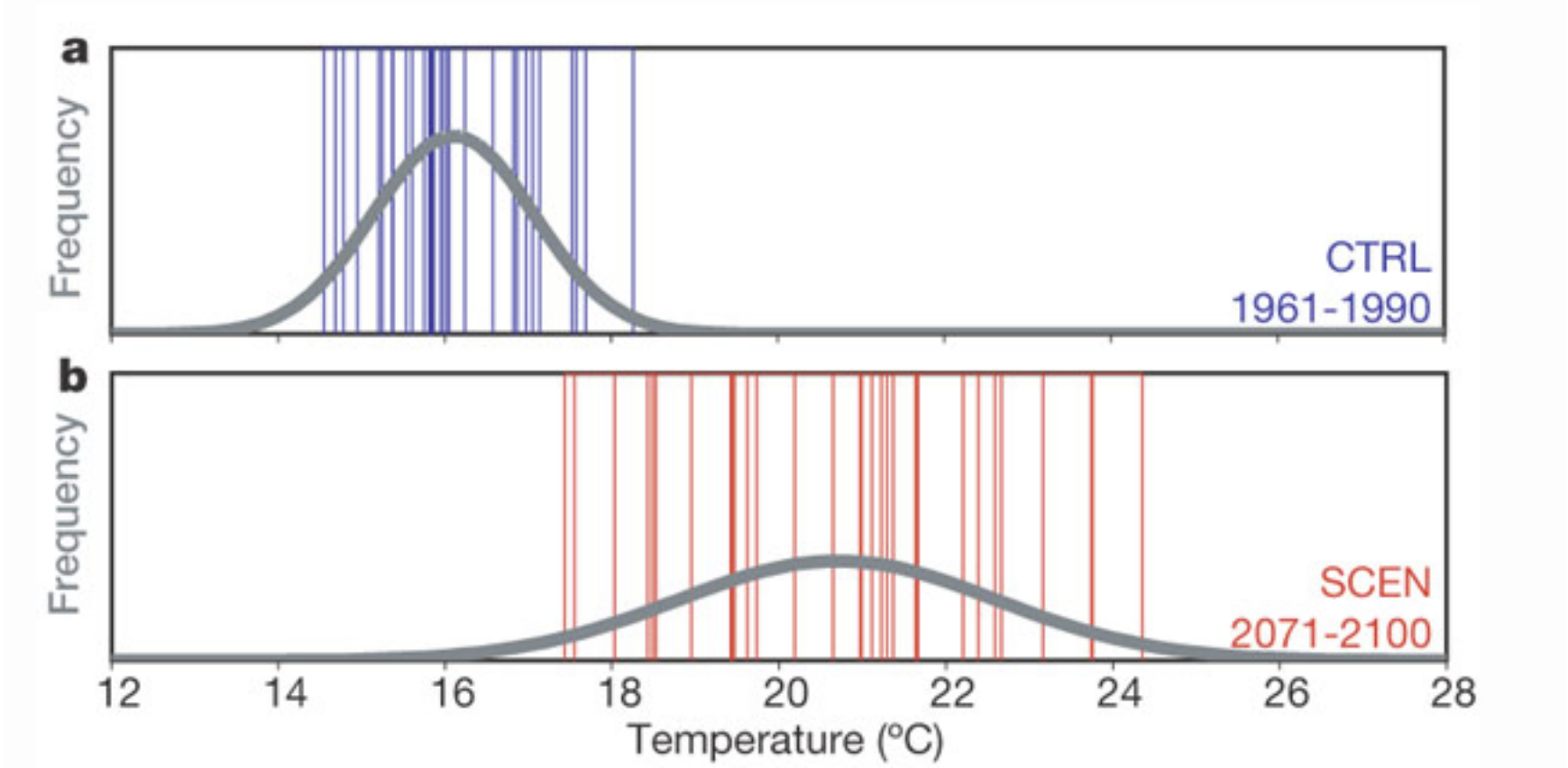
- Observations: more hot days during droughts






(Hirschi et al. 2010)

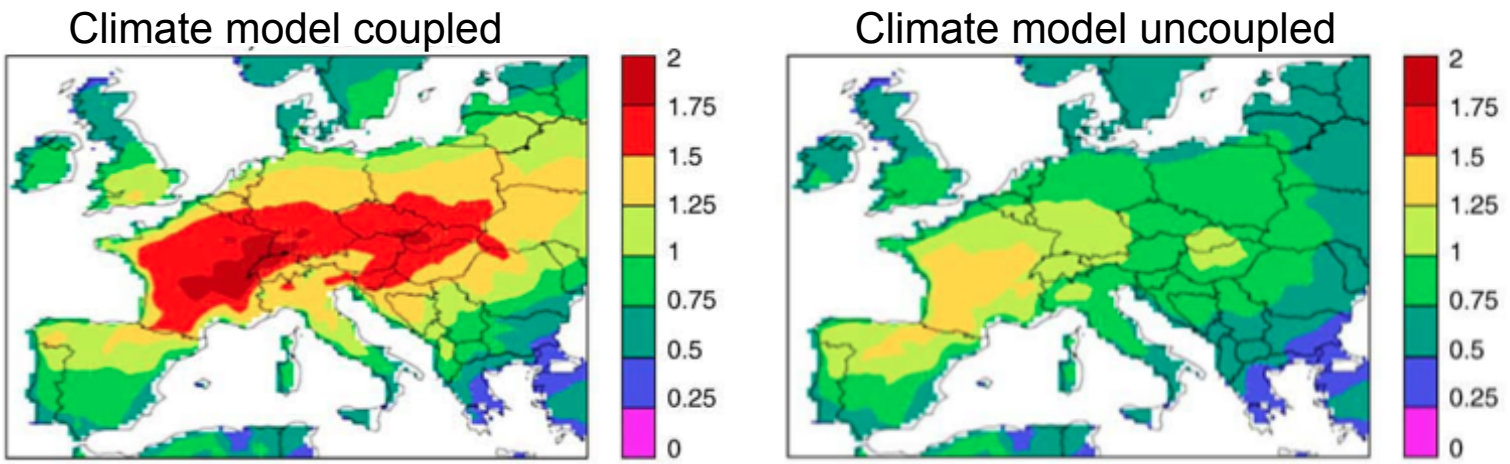
- Change in climate variability




(Schär et al. 2004)

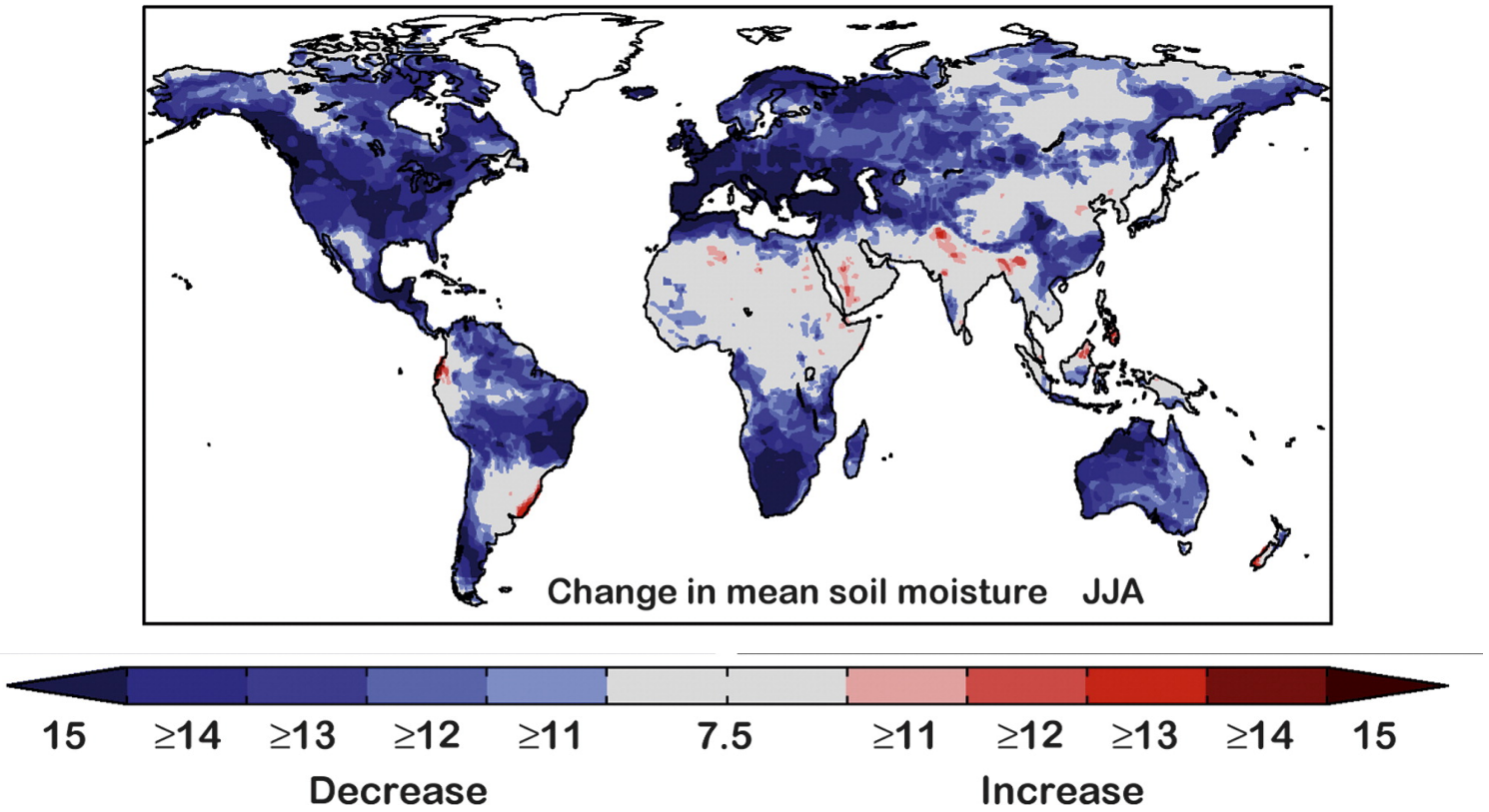
- Change in climate variability: partly due to land-atmosphere interaction?

Variability (2080-2099)



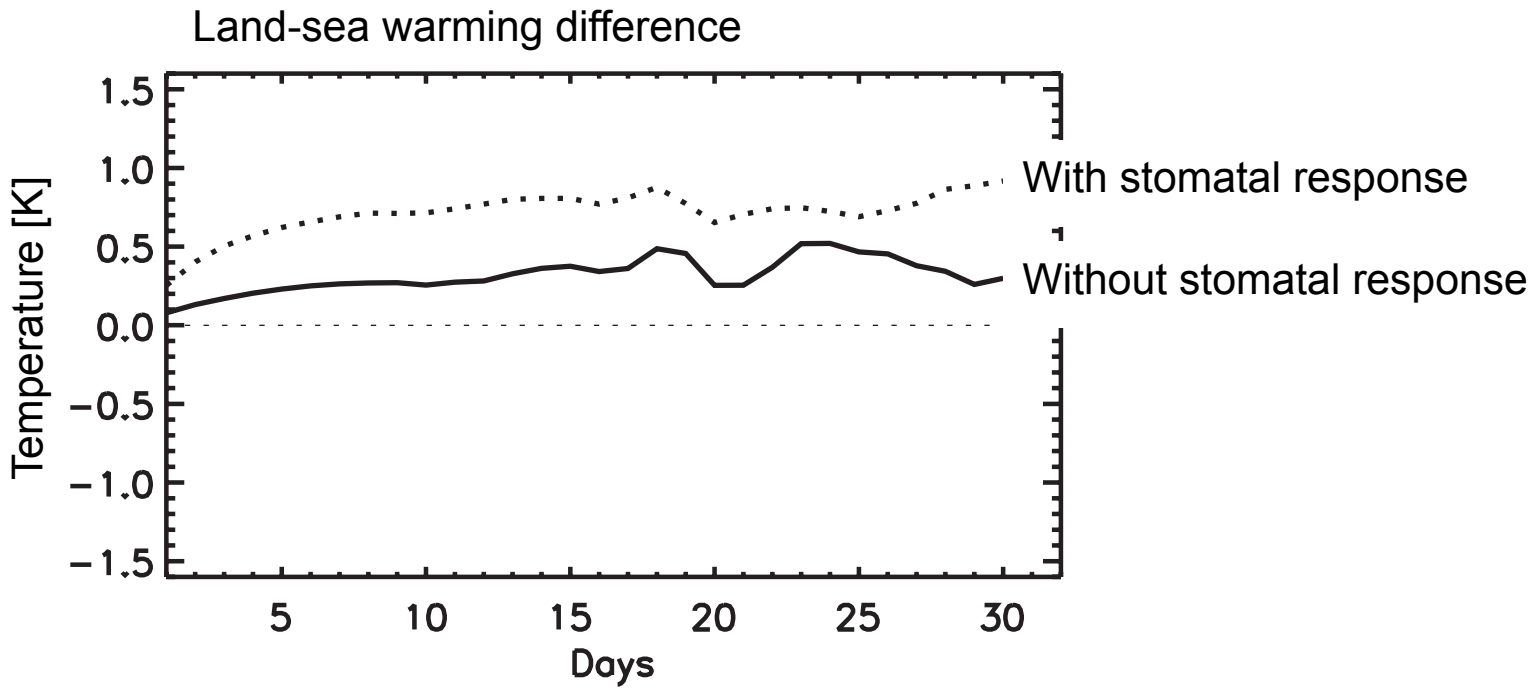

(Seneviratne et al. 2006)

- Change in mean climate: More stressed conditions?



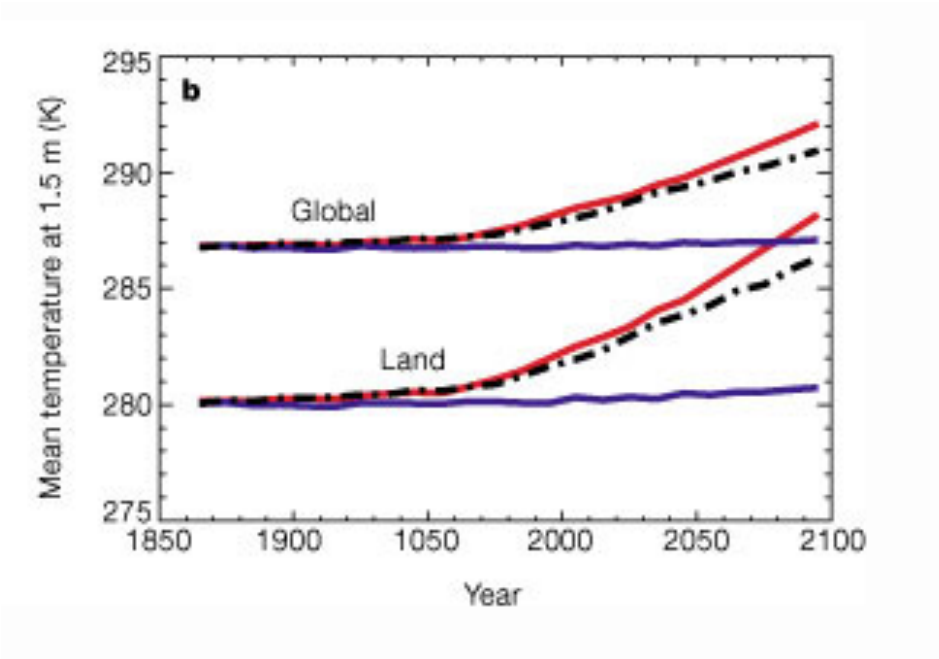

(Dirmeyer et al. 2013)

- Change in mean surface temperature: Larger warming over land due to plants?




(Dong et al. 2009)

- Carbon-cycle feedbacks….current consensus is that those effects were strongly overestimated in the study by Cox et al.




Prescribed $CO_2$ and fixed vegetation

Interactive $CO_2$ and dynamic vegetation but not direct effect of $CO_2$

Fully coupled climate/carbon-cycle simulation

(Cox et al. 2000)

# Conclusions

Complex land surface-vegetation models:

- “Easy” to implement a new process
- “Easy” to find some sensitivity, especially when all other aspects are kept constant
- How much faith should we have??

“Most models do not encompass well the observed relationships between surface and atmospheric state variables and fluxes, suggesting that these models do not represent land–atmosphere coupling correctly. Specifically, there is evidence that systematic biases in near-surface temperature and humidity among all models may contribute to incorrect surface flux sensitivities. However, the multimodel mean generally validates better than most or all of the individual models.” quoted from Dirmeyer et al. (2006)