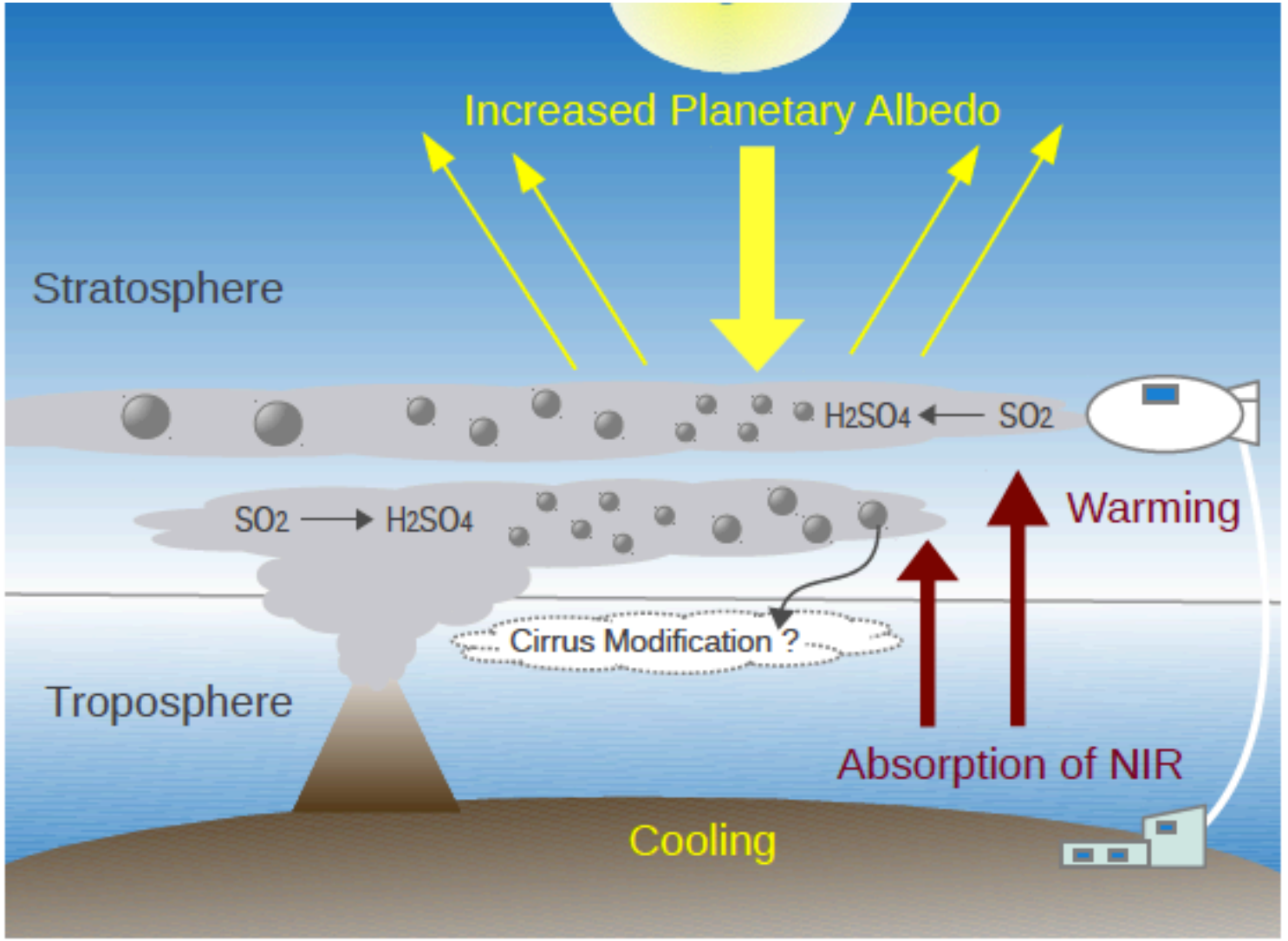
Aerosol and land geo-engineering



(adapted from McCormick et al., 1995, Weisenstein et al.,2010)

Ulrike Lohmann, Thomas Peter, Andrea Stenke, Angela Meyer, Sonia I. Seneviratne, Micah Wilhelm and Edouard Davin

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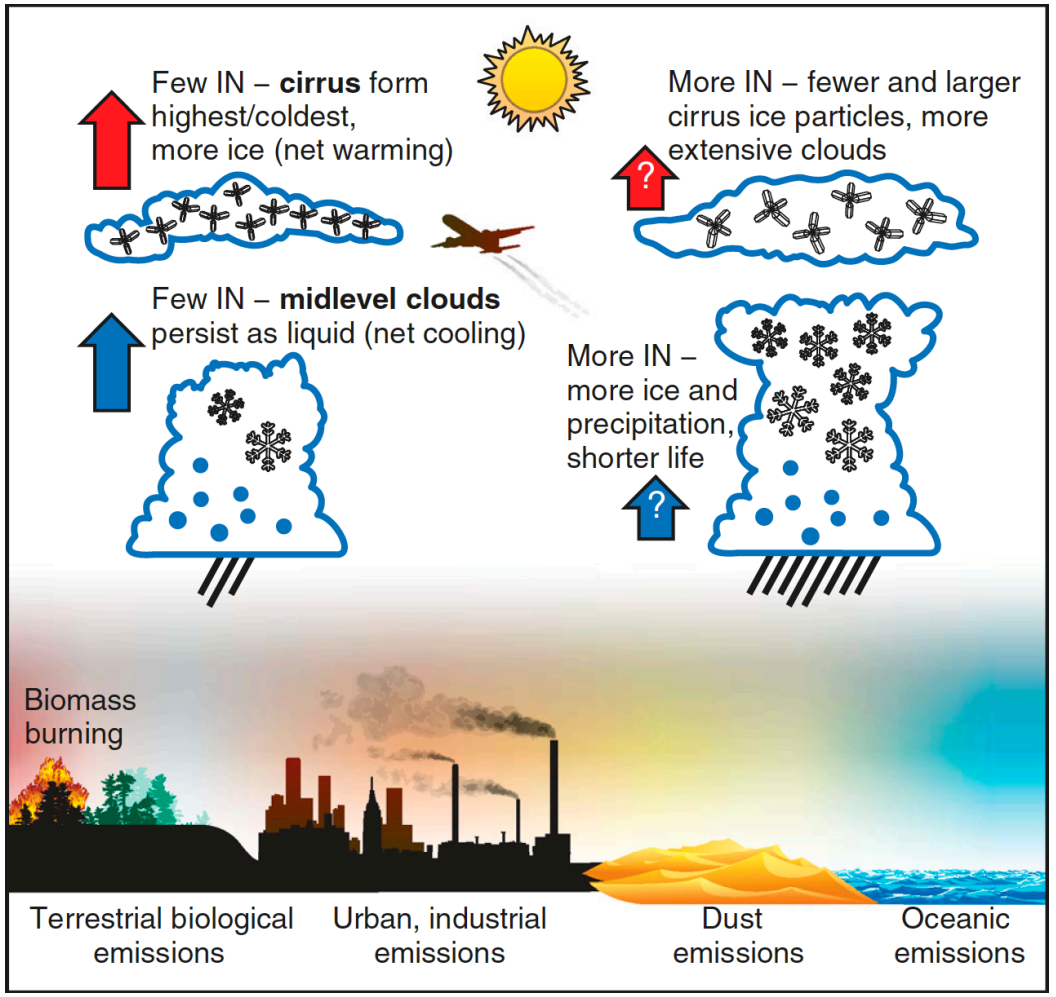
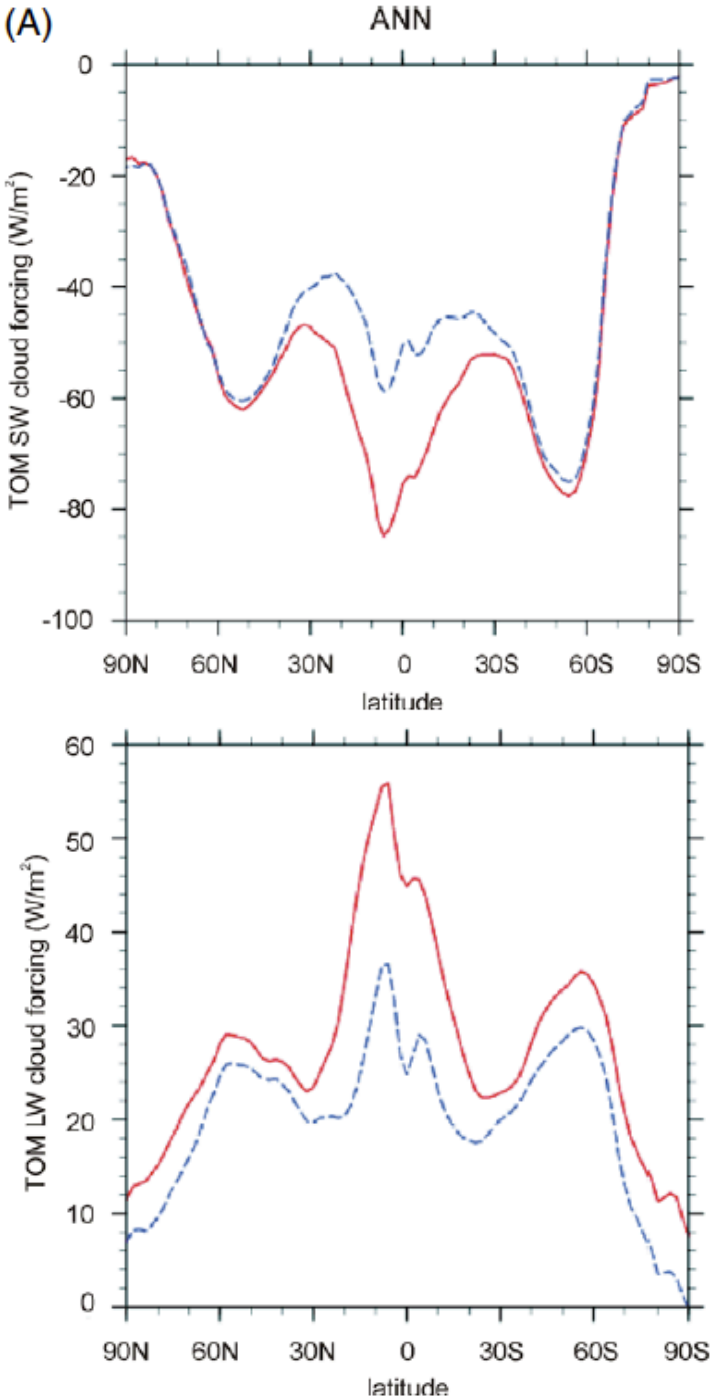
Cirrus-Geoengineering





DeMott et al., 2010; Mitchell and Finnegan, 2009

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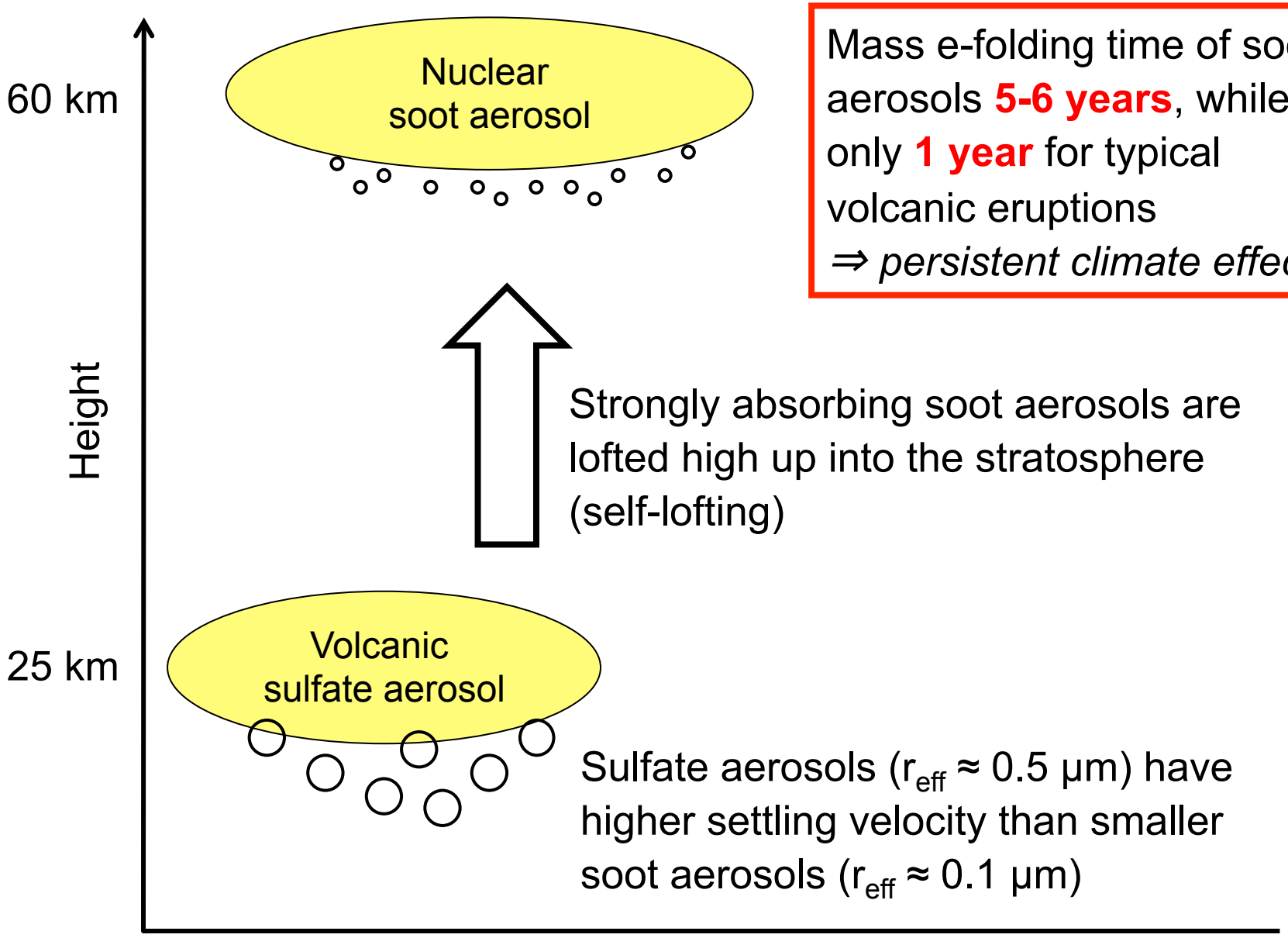
Stratospheric aerosols
- soot vs. sulfate -



Mass e-folding time of soot aerosols **5-6 years**, while only **1 year** for typical volcanic eruptions
⇒ *persistent climate effect*

Strongly absorbing soot aerosols are lofted high up into the stratosphere (self-lofting)

Sulfate aerosols ($r_{eff} \approx 0.5$ µm) have higher settling velocity than smaller soot aerosols ($r_{eff} \approx 0.1$ µm)

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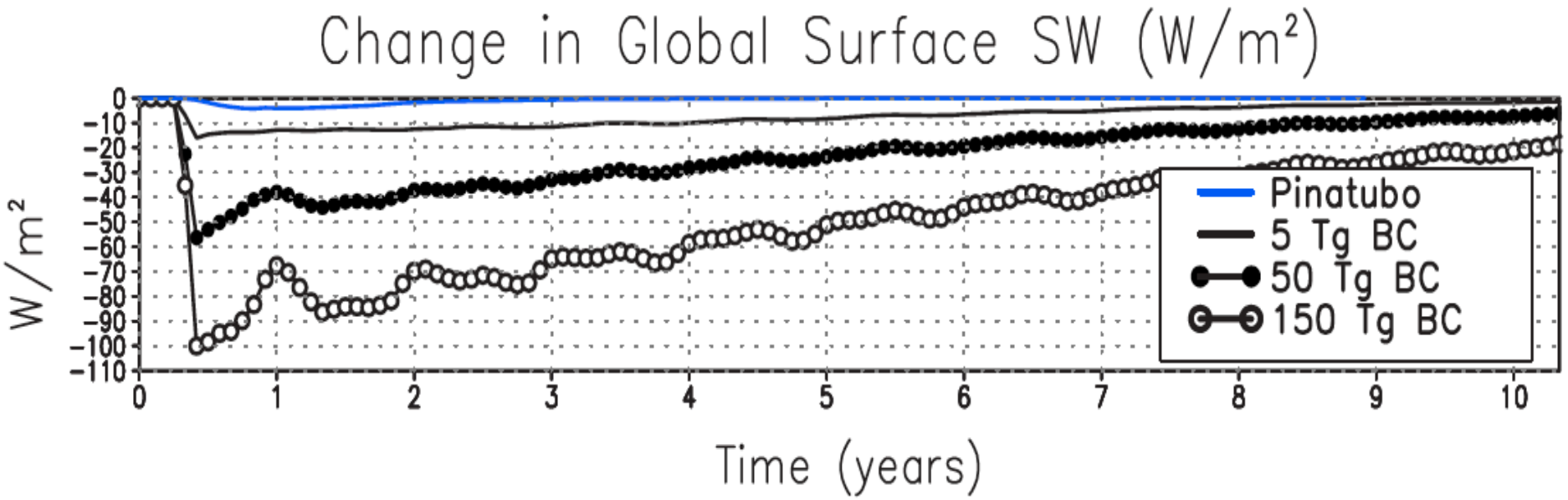
Stratospheric aerosols
- soot vs. sulfate -



- Mt. Pinatubo: max -4 W/m², e-folding time only 1 year
- Nuclear soot aerosol: e-folding time about 6 years

Robock et al., JGR, 2007

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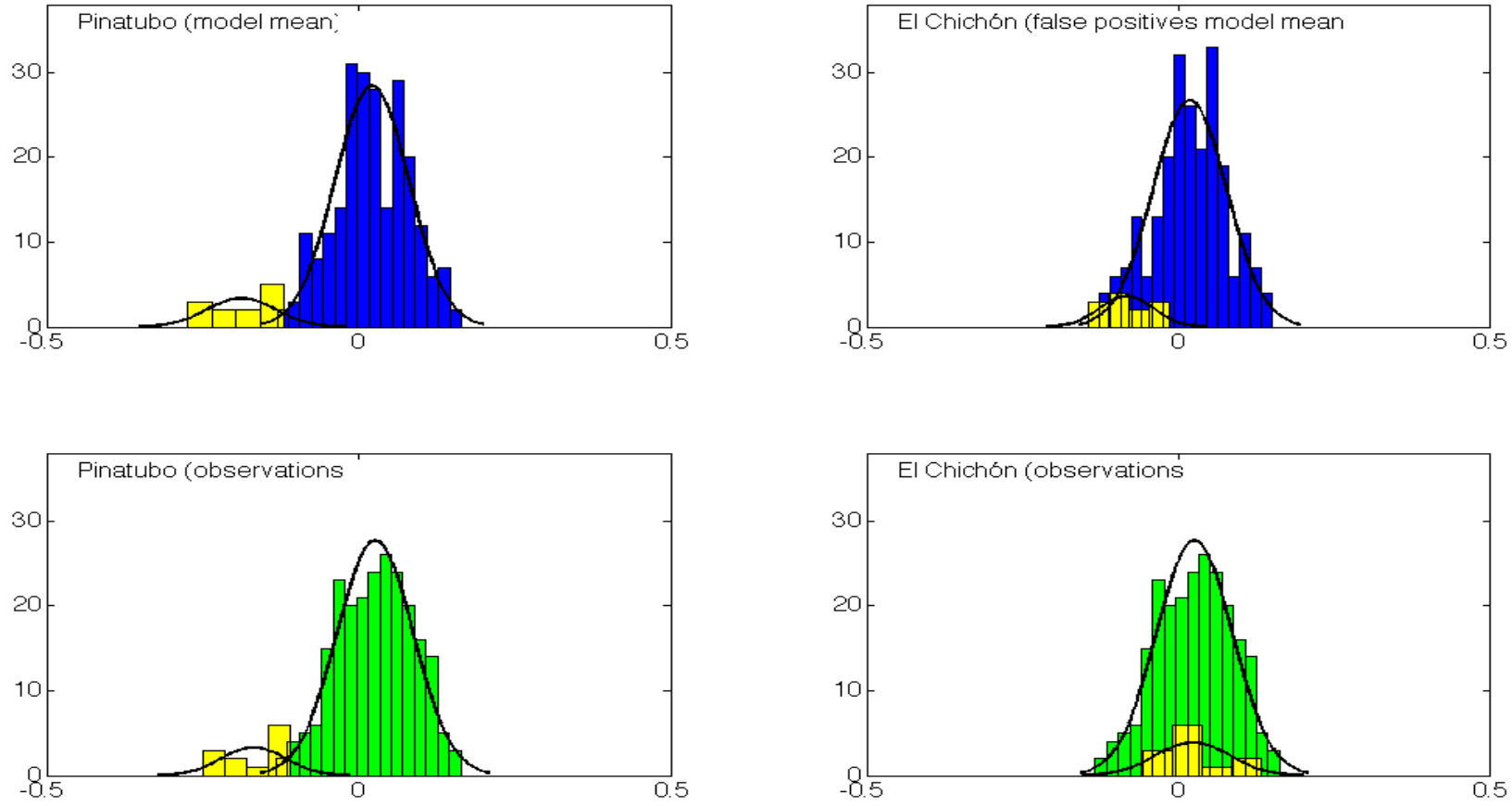
Tropical precipitation anomalies following the eruptions of Pinatubo and El Chichón



Distributions of model mean and observed detrended tropical land precipitation (mm/day), in volcanically quiescent times (blue, green) and after the eruptions of Mt. Pinatubo and El Chichón (yellow), with ENSO impact removed. For El Chichón, only models simulating significant precipitation decreases are shown.

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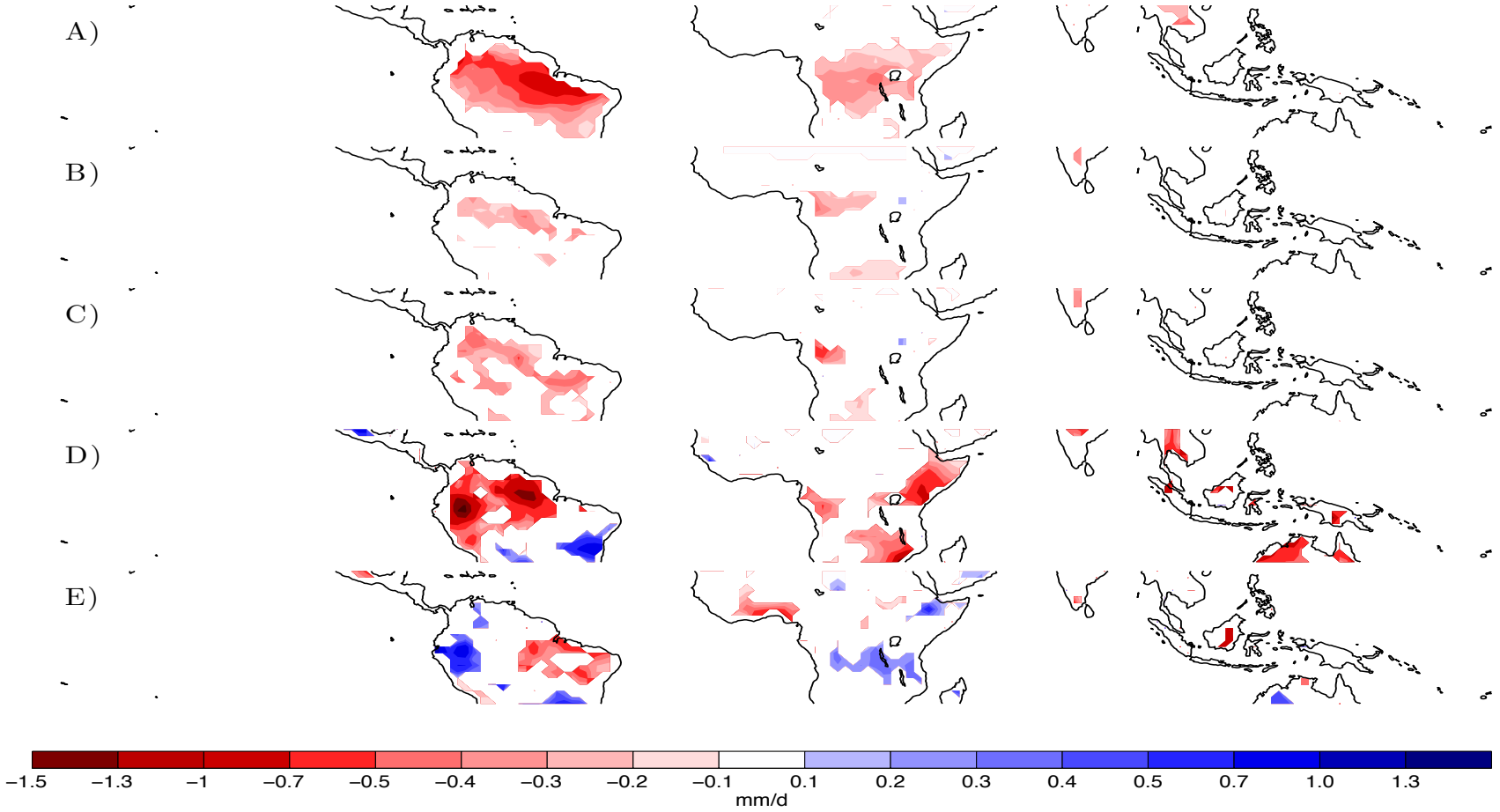
Regional precipitation anomalies following the eruptions of Pinatubo and El Chichón



Precipitation decreases by up to 18% (7%) in parts of the Amazon region. CMIP5 model mean captures significant precipitation decreases observed in the Amazon region after both eruptions.

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Geo-Engineering with stratospheric aerosols

Sulfur-containing particles

- Volcanic aerosols: large uncertainties, models have difficulties simulating effects of volcanic eruptions on hydrology (droughts).
- Geoengineering: large uncertainties in the stratosphere, but also concerning their effect on UT clouds.

Soot particles

- Increase the lifetime of sulfate aerosols

Overarching science questions

- Both, sulfate aerosols and soot at high altitudes lead to dimming and cooling in low atmosphere / surface:
- How good are estimates of the dimming/cooling?
- Why are the models so awfully far off with stratospheric heating?
- Why is the Brewer-Dobson circulation in many models (e.g. ECHAM) too fast, and what does this mean for the quality of the residence time estimates?

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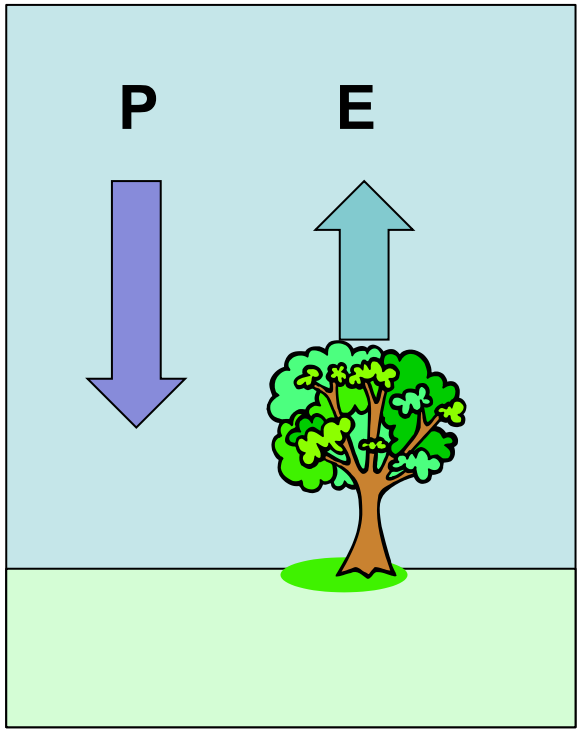
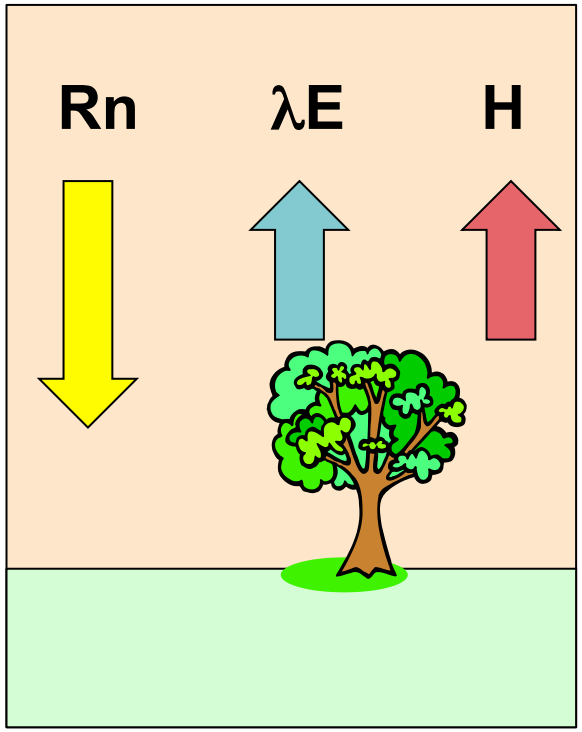
Land impacts on atmospheric water, energy and carbon

Water



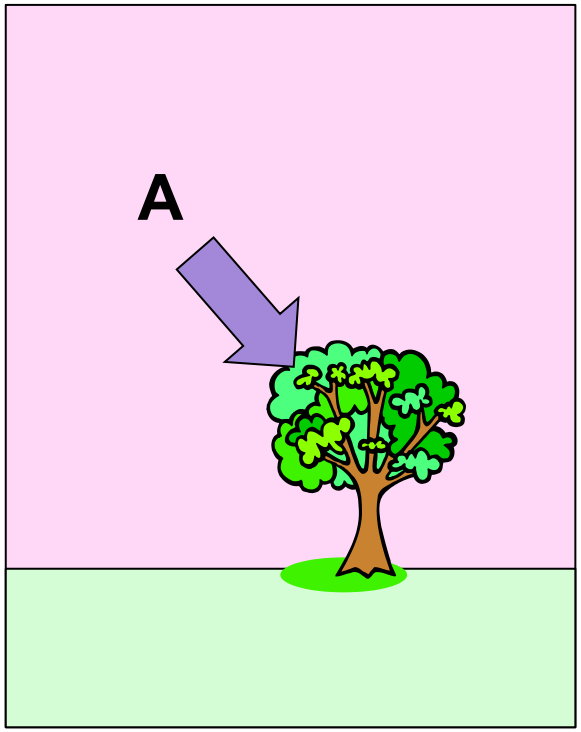
E=60%P

Energy



λE=50-60%Rn
(~2° on Tair)

Carbon

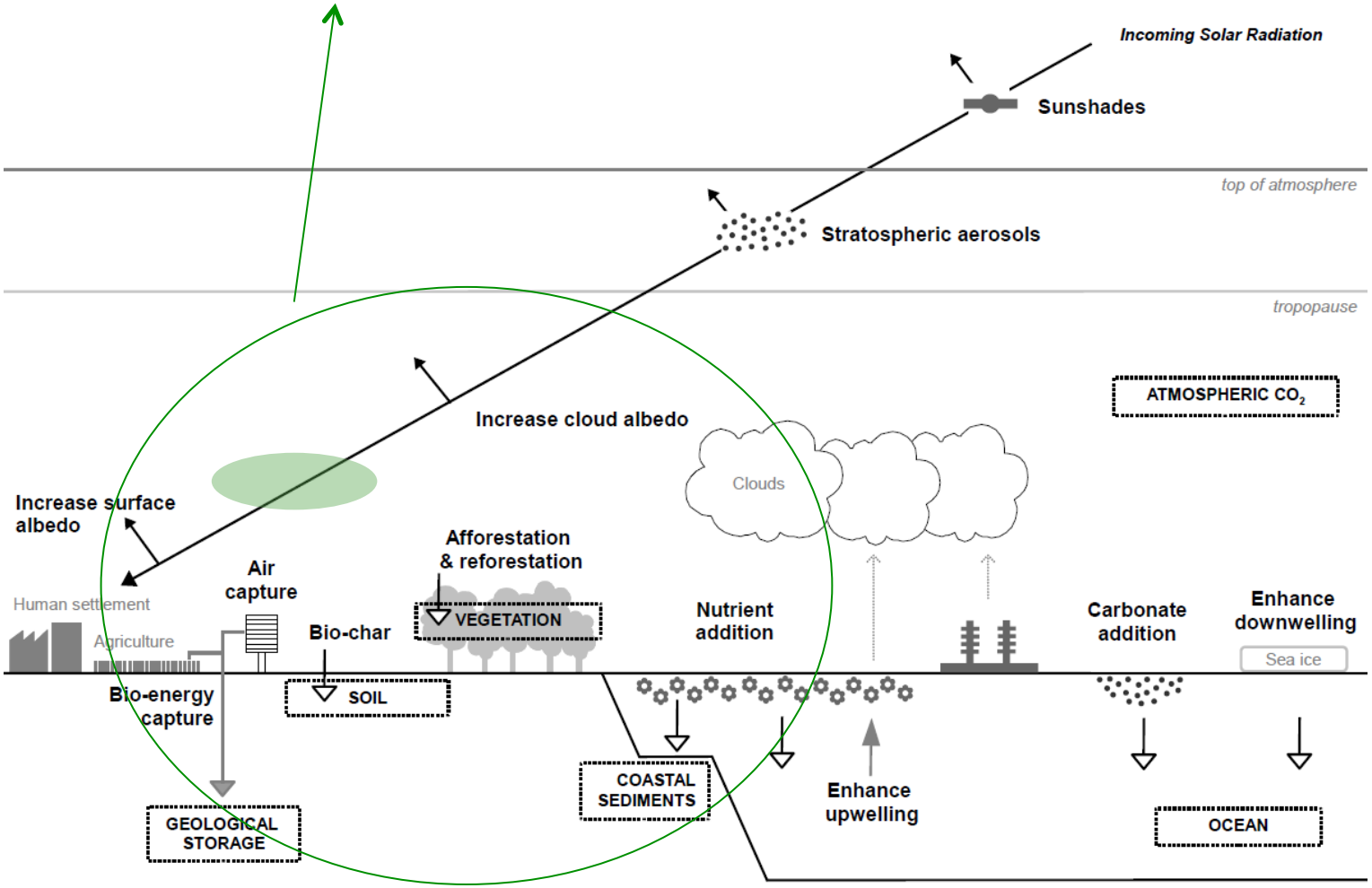


A is a sink for 25-30% of C emissions

Land geoengineering vs other proposed schemes

Several land-based aspects (albedo, forest cover)

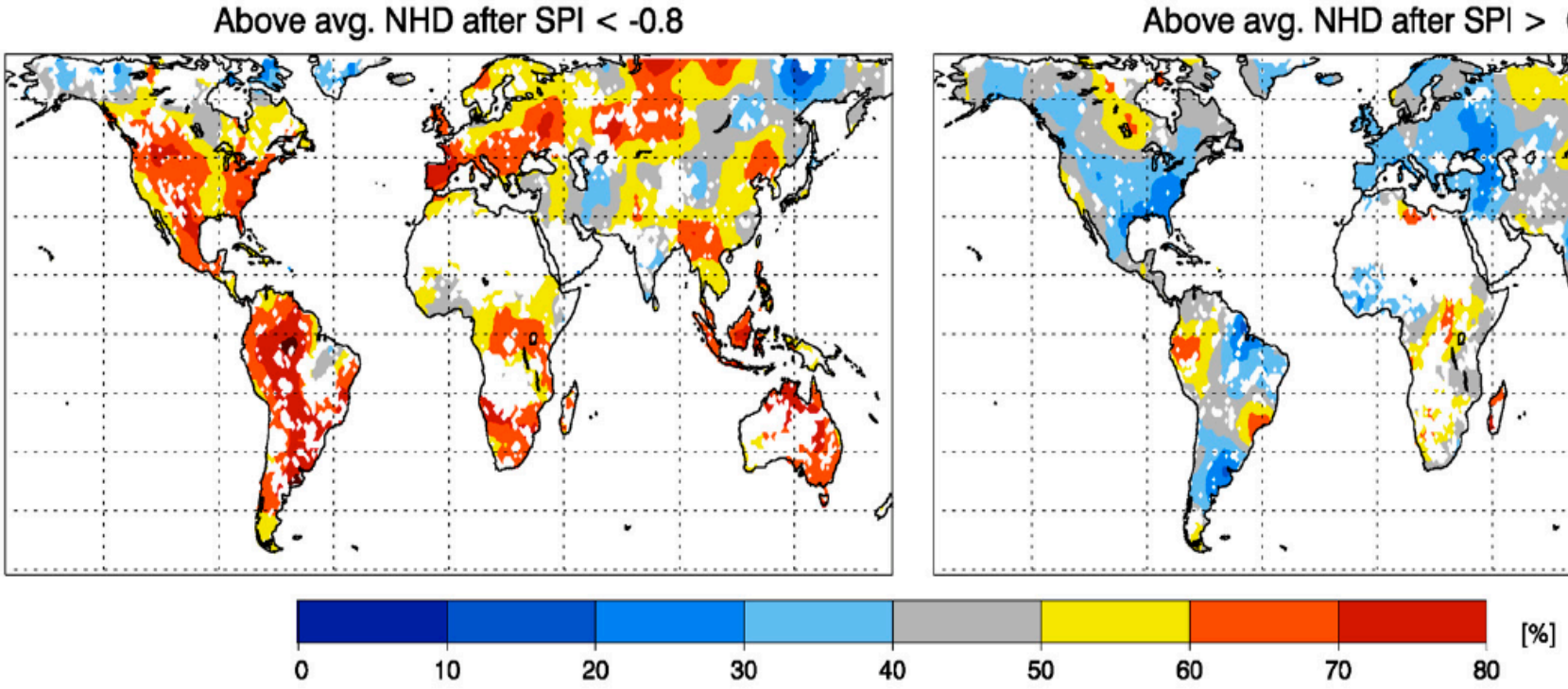
- **Some options missing: e.g. soil moisture management (irrigation), no-till agriculture, …**
- **Some feedbacks missing (impacts of changes in diffuse-direct radiation partitioning on hydrology)**

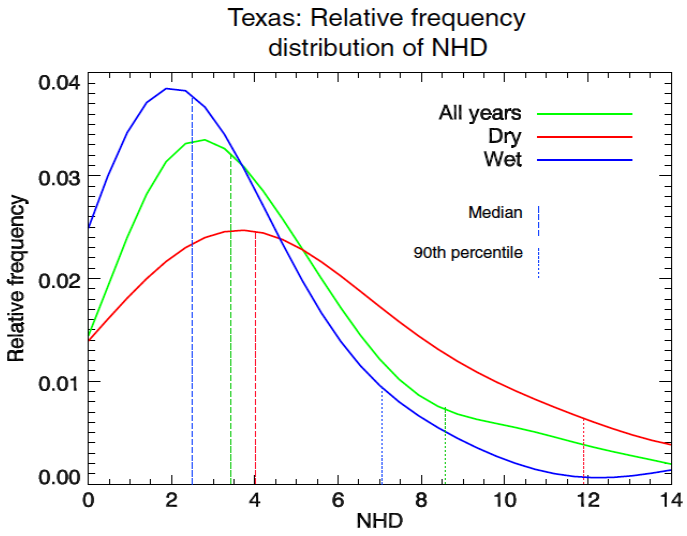


(Lenton and Vaughan, ACP 2009)

Land geoengineering: Option for "extremes geoengineering"?

Conditional probability of hot extremes on surface moisture deficits





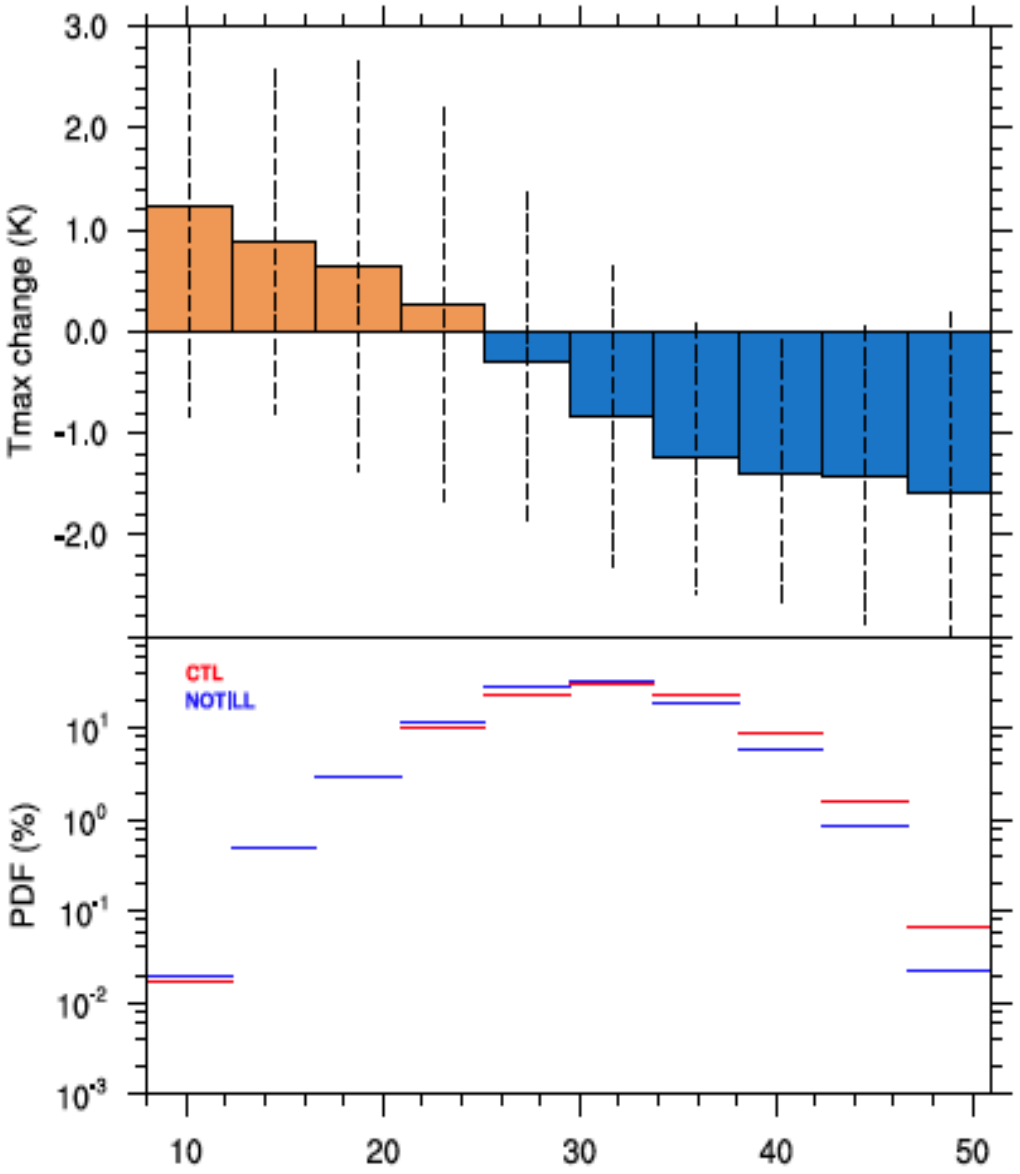
NHD: # hot days
SPI: Standardized Precipitation Index

(Mueller and Seneviratne 2012, PNAS)

Land geoengineering: Option for "extremes geoengineering"?

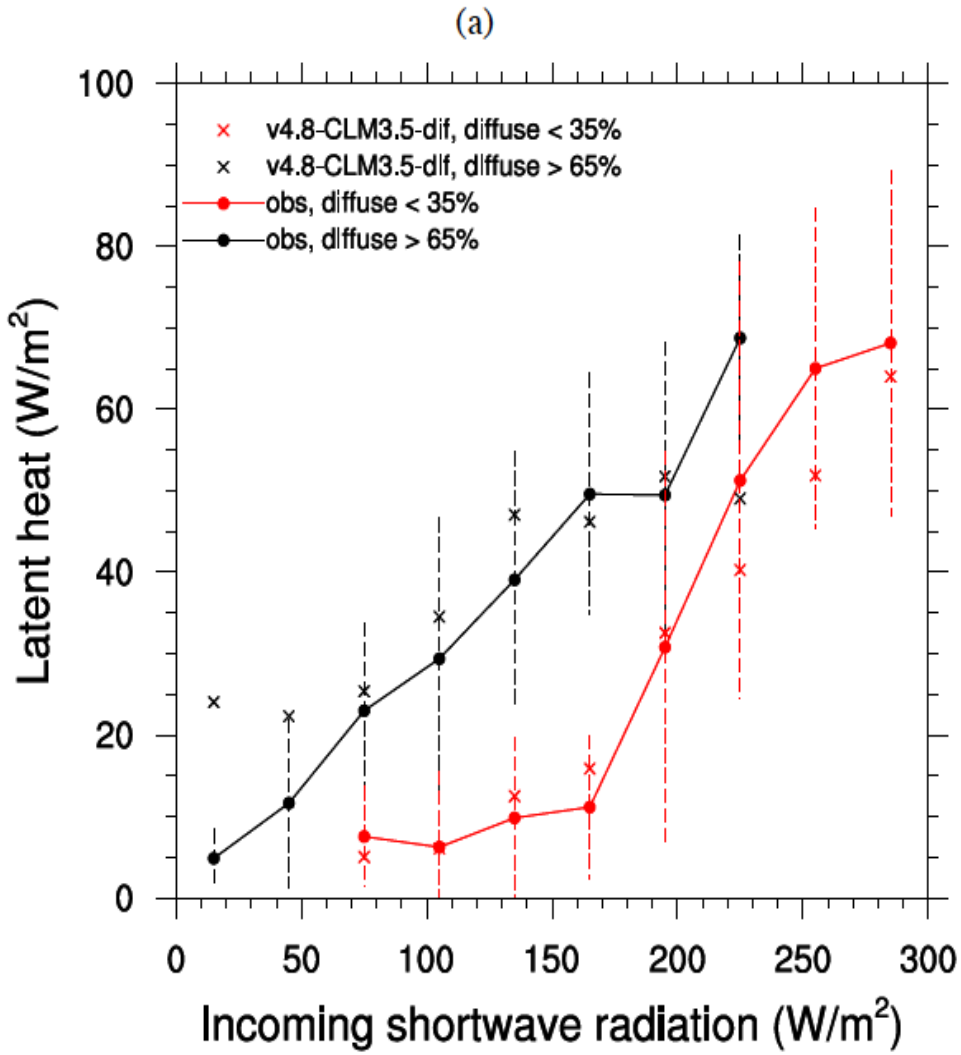
No-till farming and heat waves

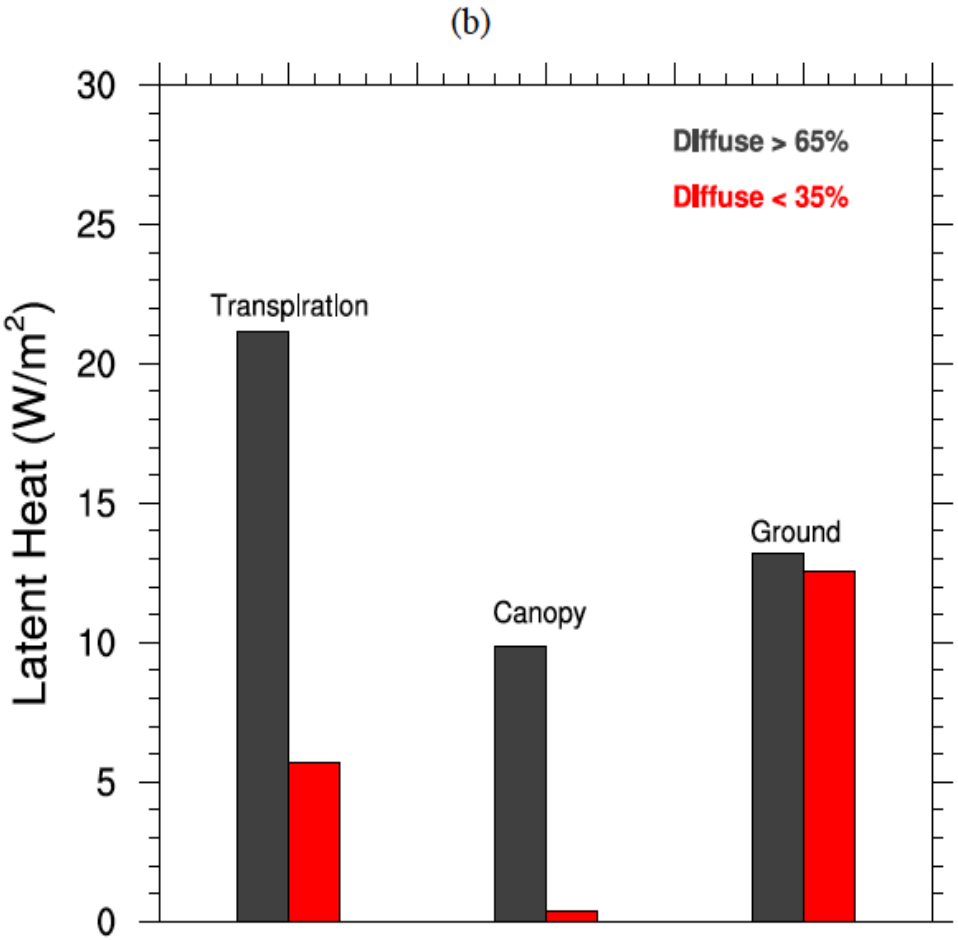
- Climate mitigation potential (cooling effect) of no-till farming particularly strong during heat waves



(Davin et al., in prep.)

Land feedbacks to imposed changes in radiation partitioning





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(Davin and Seneviratne 2012, Biogeosciences)

Land geoengineering: Summary

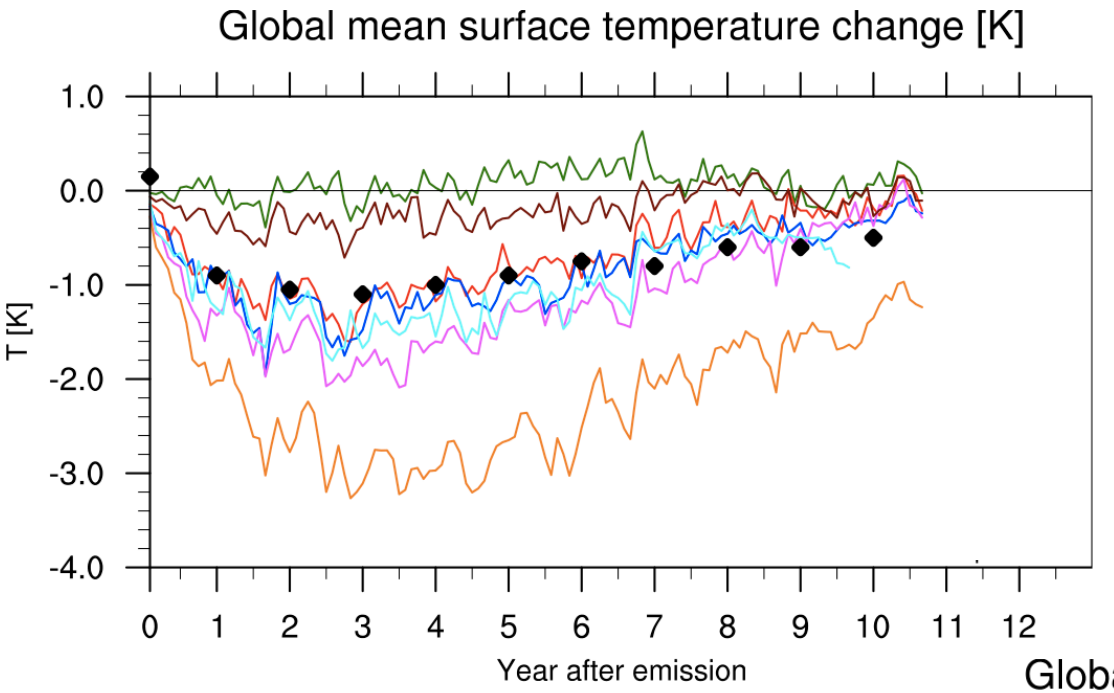
- **"Land geoengineering"** has been little investigated up-to-now (apart from "bio-geoengineering" and CO_2-related effects):

  Provides attractive options for "extremes geoengineering" (i.e. targeted mitigation of most extreme changes in temperature)

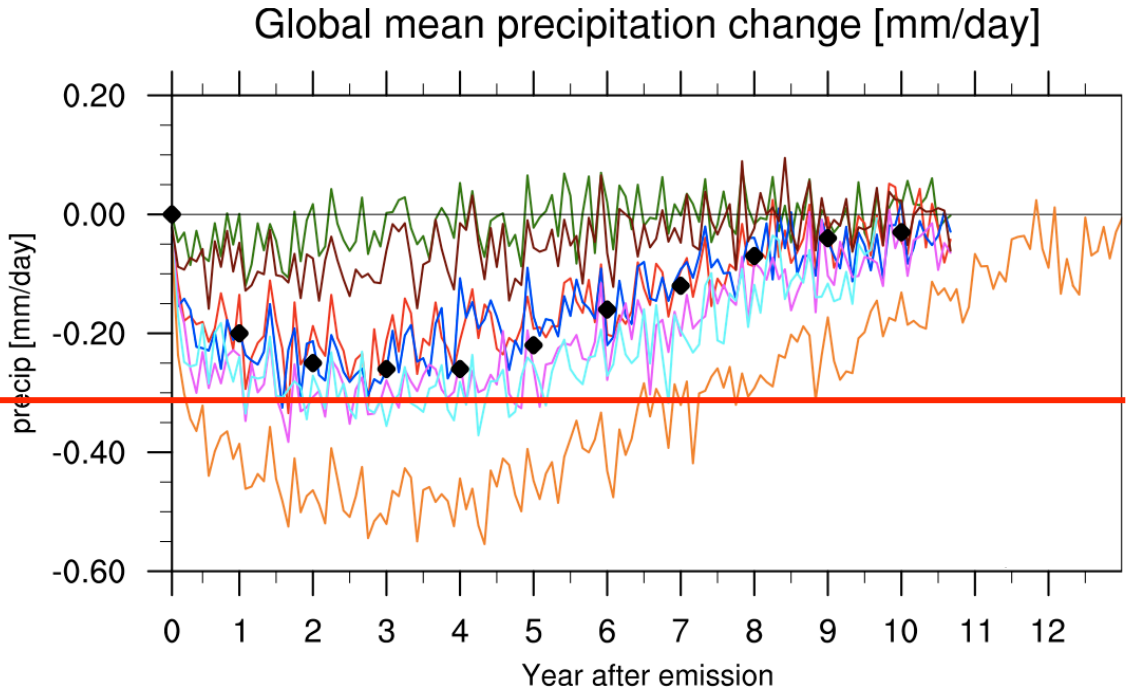
- **Land surface feedbacks to geoengineering-based modifications of radiation** (e.g. diffuse/direct partitioning) also need to be taken into account

NB: Geoengineering is no alternative to reduction of CO_2 emissions, but is an important option in the view of committed climate change

Climate effects of nuclear soot aerosols



Prescribed, 5 Tg
1 Tg
2 Tg
5 Tg
5 Tg, 200 nm
7 Tg
12 Tg
NASA GISS ModelE, 5 Tg (Robock et al., 2007)



10% reduction

Stenke et al., ACPD, 2013

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