

Robust influences of super-parameterization on land-surface fluxes and their response to climate change

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&
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Thank you to Cristiana Stan, Li Xu, Mark Branson,
Melissa Burt, David Randall for simulations

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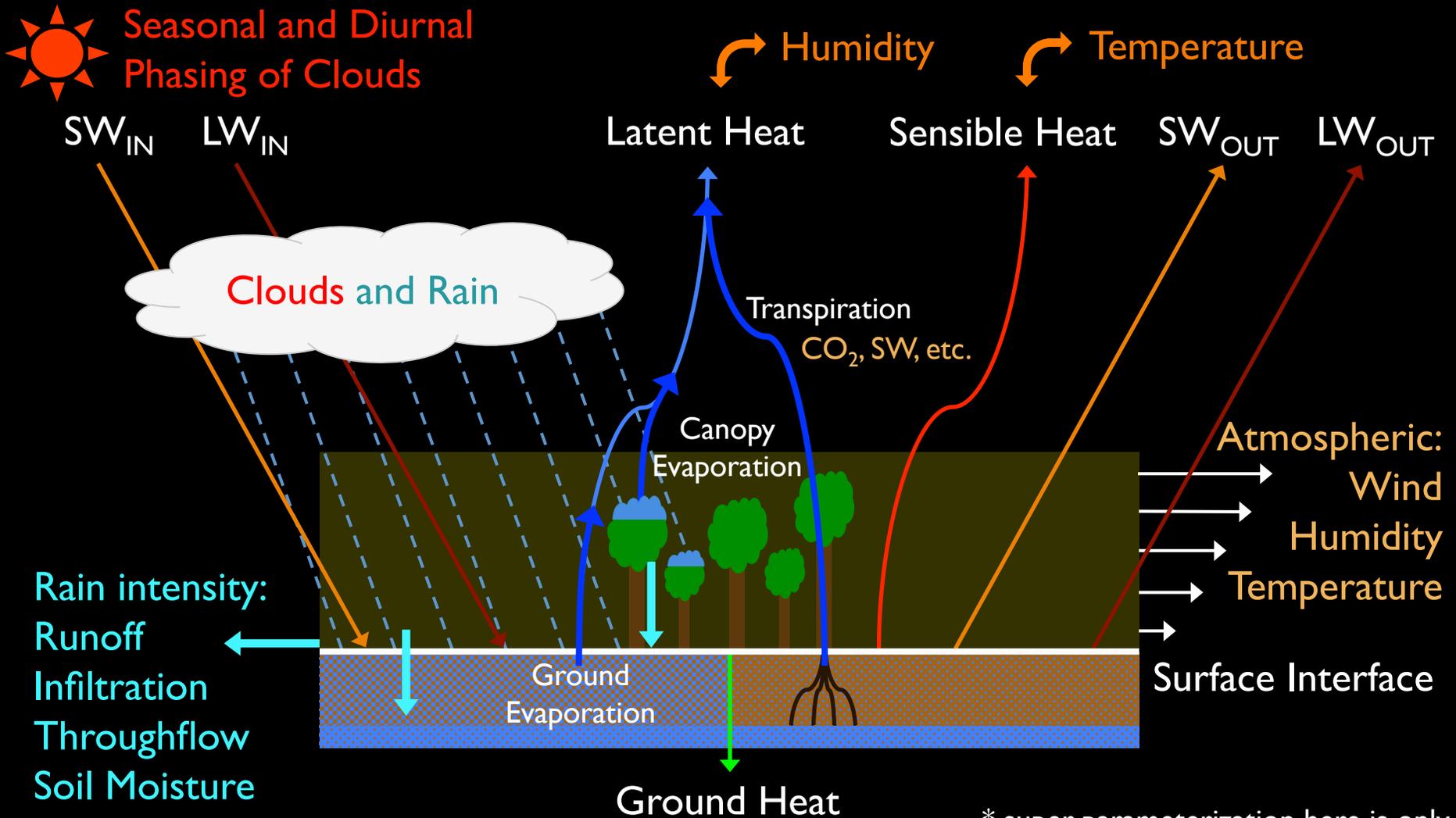


Land-surface interactions investigated in two versions of SPCAM (SPCCSM and SPCEM)

	SP(CCSM)	SP(CESM)
Configuration:		
Model Versions	SP-CCSM4	SP-CESM1-CAM4
GCM Resolution	0.9° x 1.25°	1.9° x 2.5°
CRM Resolution	3 km	4 km
Experiments:		
Control	Present-day	Pre-Industrial
Climate Change	RCP8.5	4x CO ₂
Time Analyzed	10 years	5 years

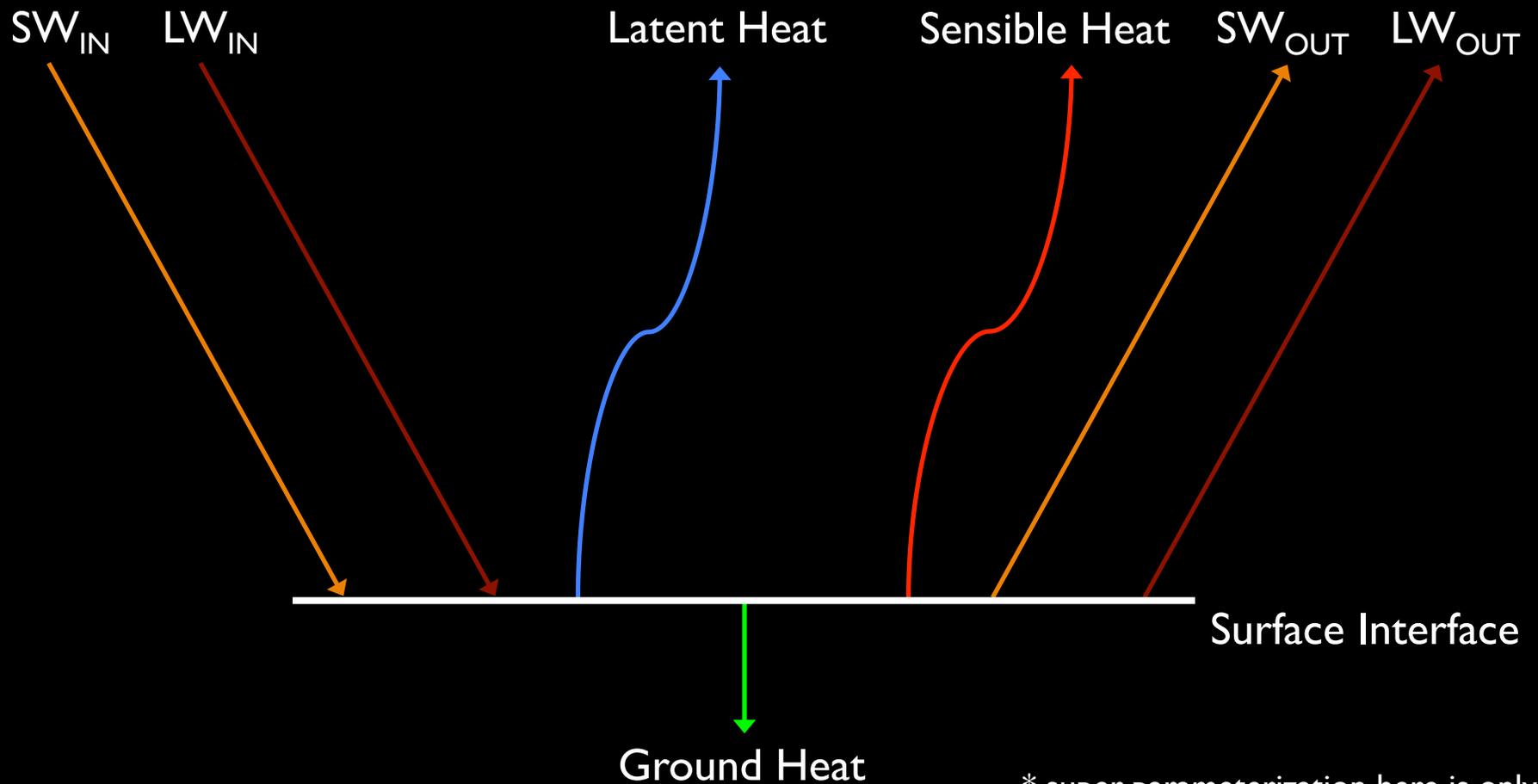
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How can super-parameterization impact land-surface energy exchange?



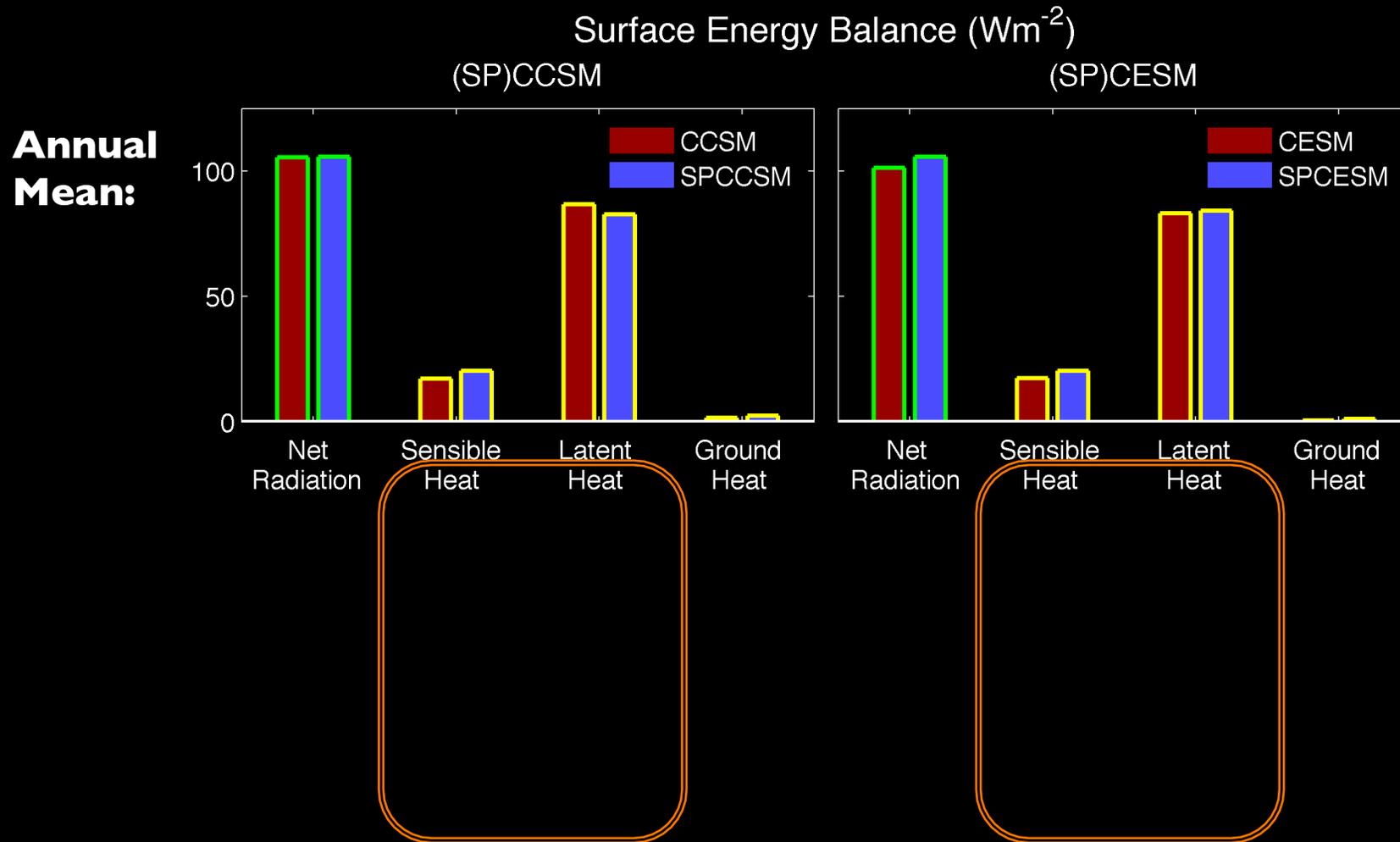
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How can super-parameterization impact land-surface energy exchange?



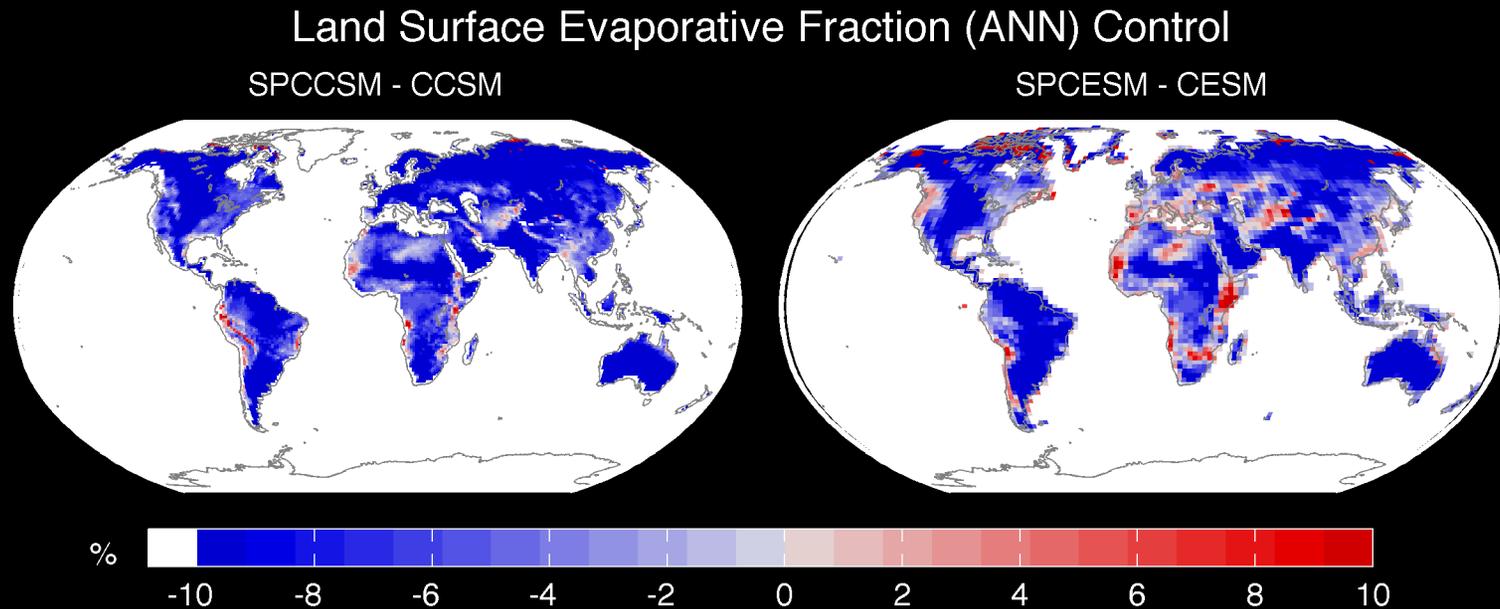
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Super-parameterization consistently has less latent heat and more sensible heat over land



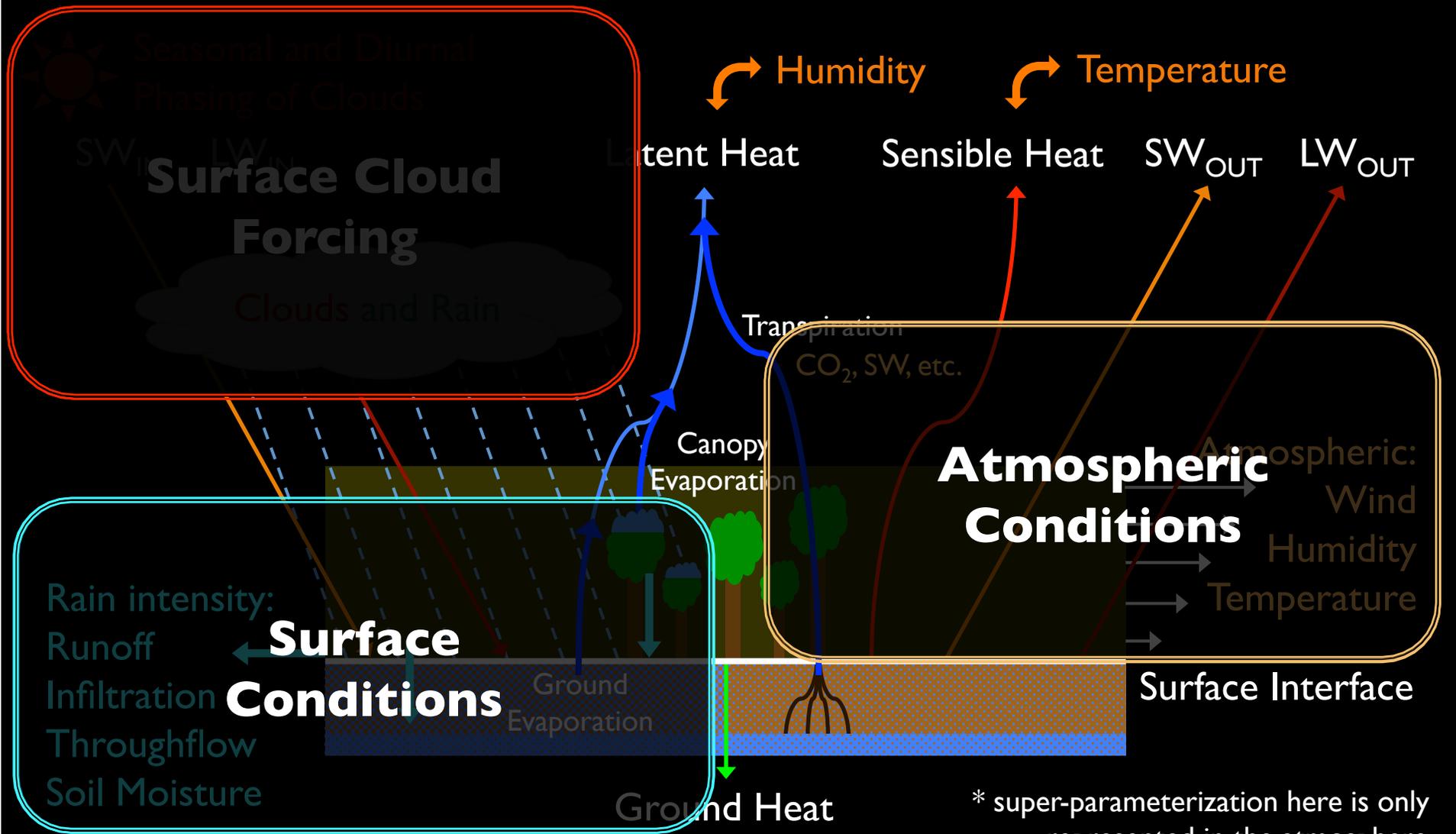
- Net Radiation = $SW_{IN} + LW_{IN} + SW_{OUT} + LW_{OUT}$

Robust regional and seasonal impact of super-parameterization on surface fluxes over land



- Latent heating is consistently lower over land in SPCAM than CAM, while sensible heating is consistently higher
- The difference between models is strongest during the summer growing season

How can super-parameterization impact sensible and latent heat partitioning?



* super-parameterization here is only represented in the atmosphere (MASL in Scott's definitions).

How can super-parameterization impact sensible and latent heat partitioning?

```
graph TD; A[How can super-parameterization impact sensible and latent heat partitioning?] --> B[Surface Conditions]; A --> C[Atmospheric Conditions]; B --- D[Rainfall, Soil Moisture, and Evapotranspiration]; C --- E[Temperature and Humidity];
```

**Surface
Conditions**

**Rainfall, Soil Moisture,
and Evapotranspiration**

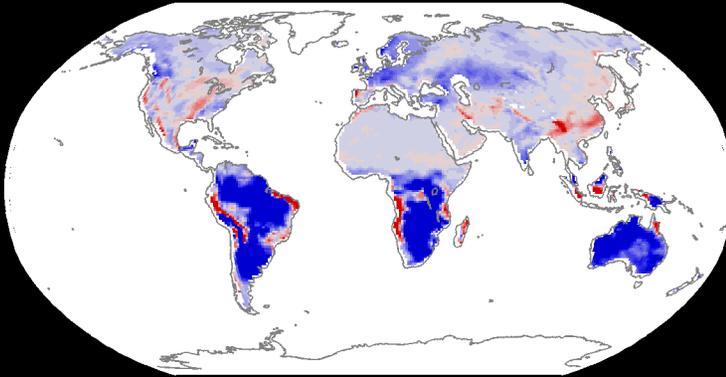
**Atmospheric
Conditions**

**Temperature and
Humidity**

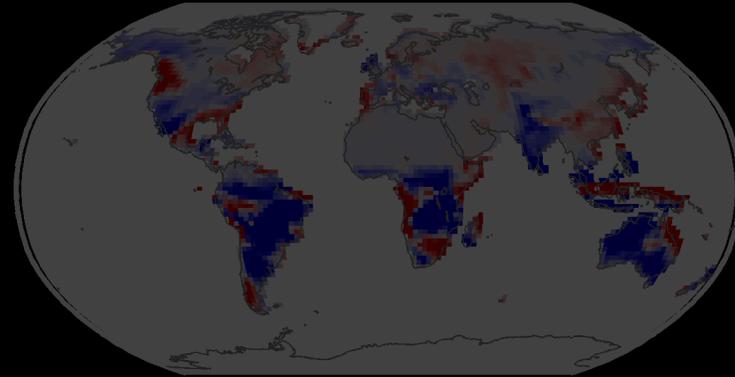
Less rainfall over land in SPCAM reduces soil moisture, especially during summer

Land Surface Precipitation (DJF) Control

SPCCSM - CCSM

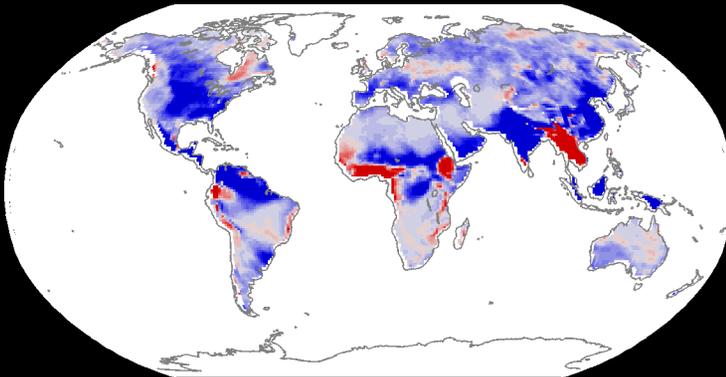


SPCESM - CESM

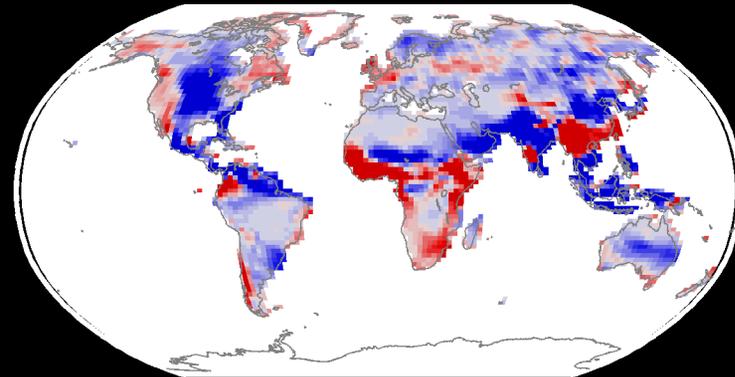


Land Surface Precipitation (JJA) Control

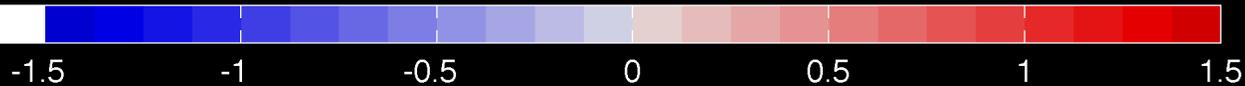
SPCCSM - CCSM



SPCESM - CESM

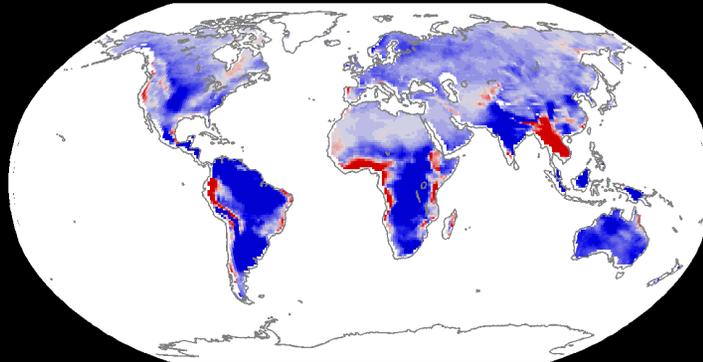


mmd^{-1}

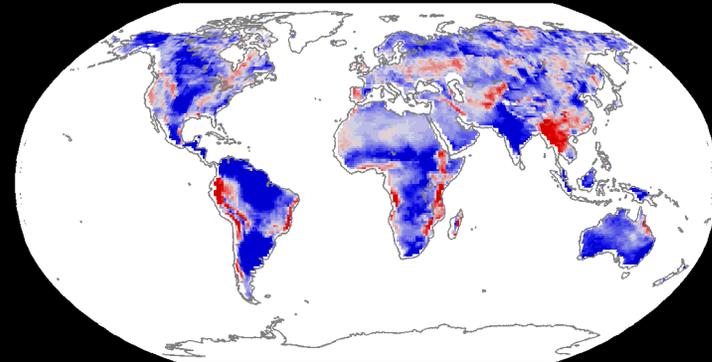


Less rainfall over land in SPCAM reduces soil moisture, especially during summer

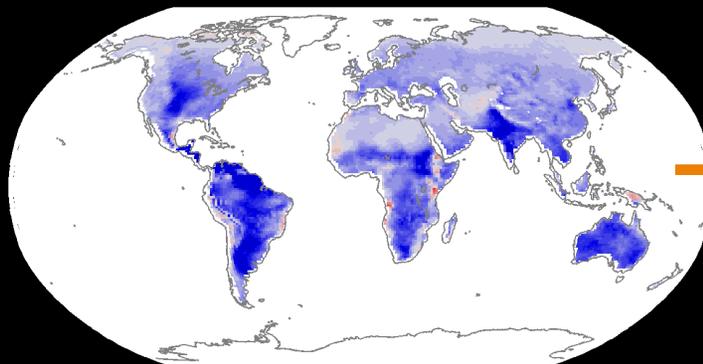
Surface Precipitation (ANN) Control
SPCCSM - CCSM



Surface Soil Moisture (ANN) Control
SPCCSM - CCSM



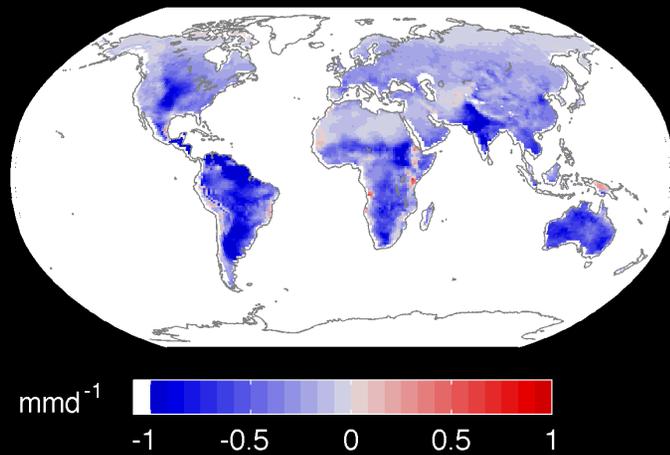
Total Evapotranspiration (ANN) Control
SPCCSM - CCSM



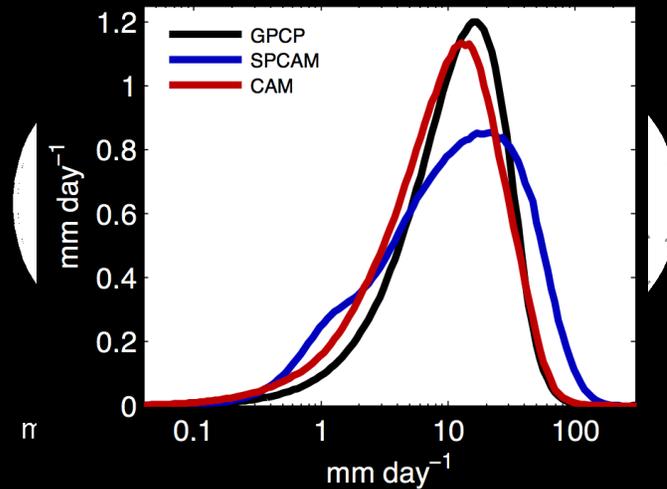
- Surface soil moisture does not completely explain evapotranspiration
- Something else limits evapotranspiration in regions with more rain

Reduction from all components of latent heat but regional influence from rain intensity

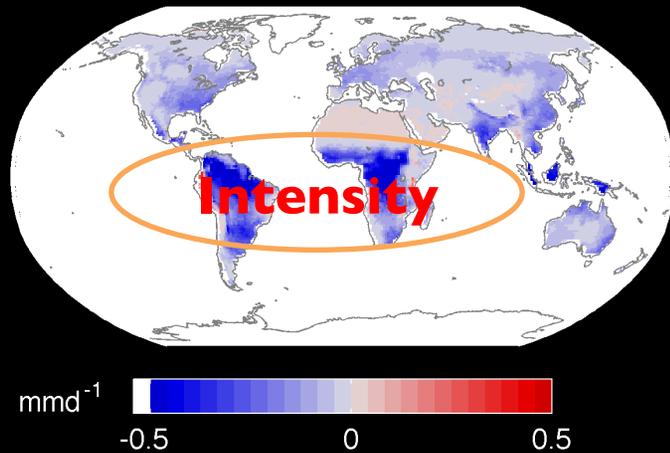
Total Evapotranspiration (ANN) Control
SPCCSM - CCSM



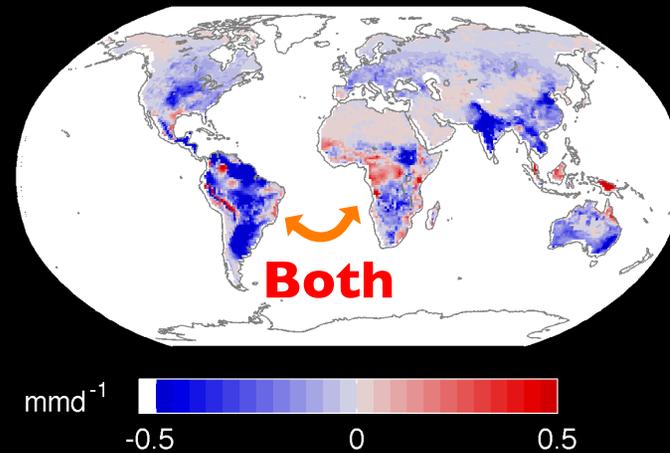
Soil CESM Rain Amount



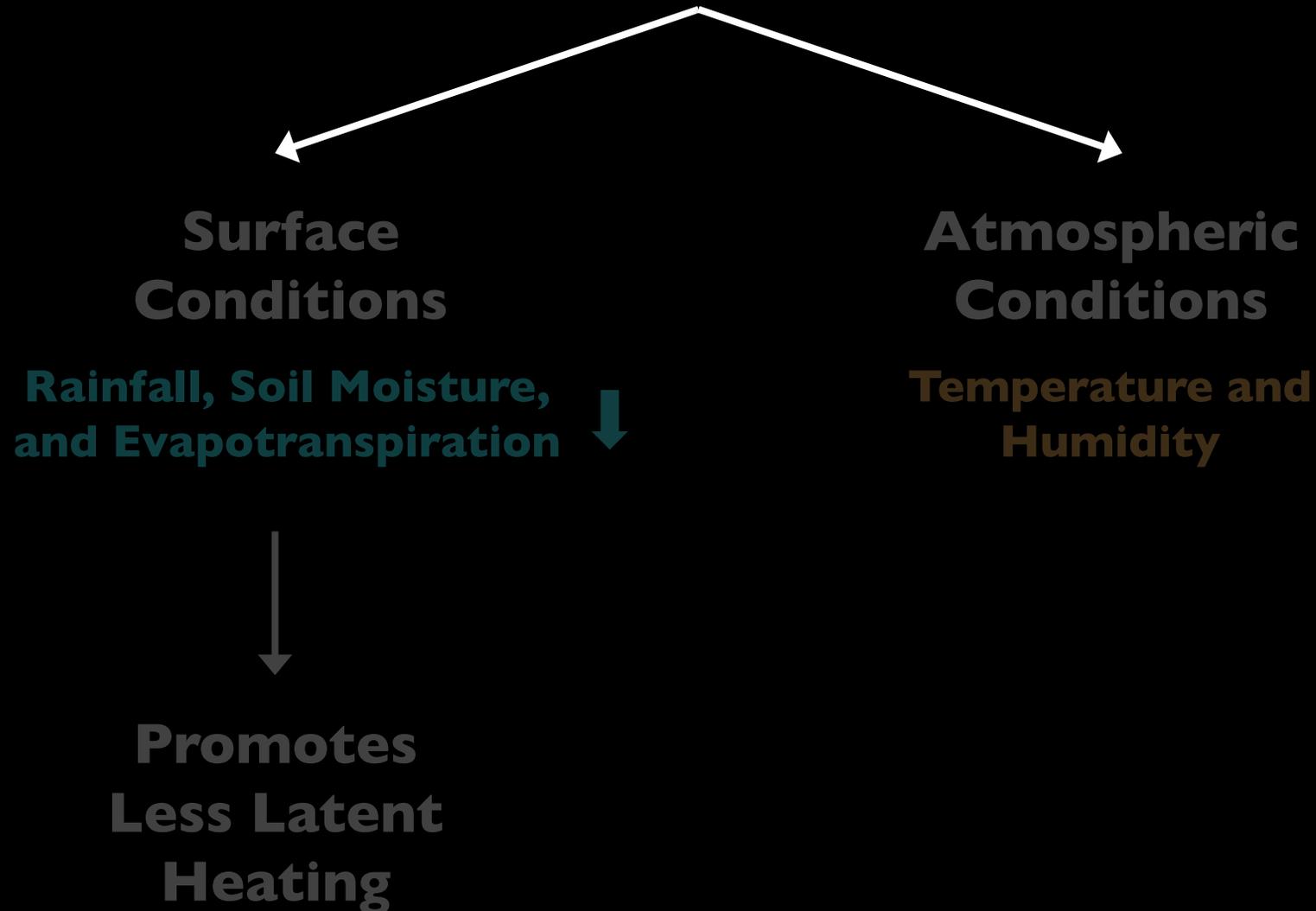
Canopy Evaporation (ANN) Control
SPCCSM - CCSM



Transpiration (ANN) Control
SPCCSM - CCSM



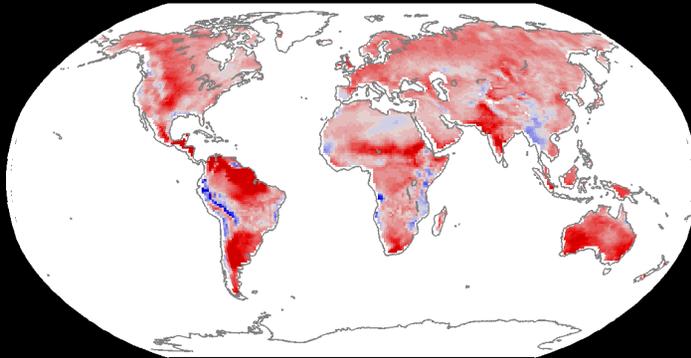
How can super-parameterization impact sensible and latent heat partitioning?



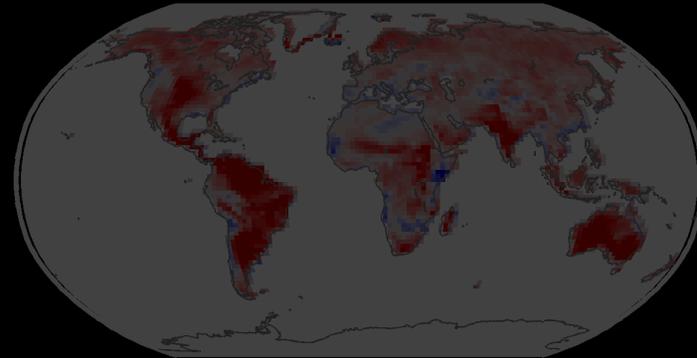
Amplified land-atmosphere thermal contrast enhances sensible heating?

Land Surface Sensible Heat (ANN) Control

SPCCSM - CCSM

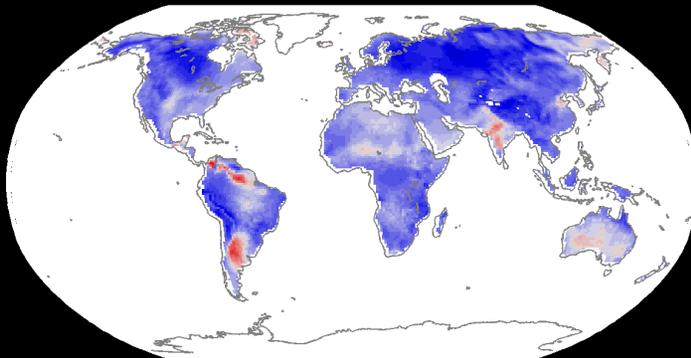


SPCESM - CESM



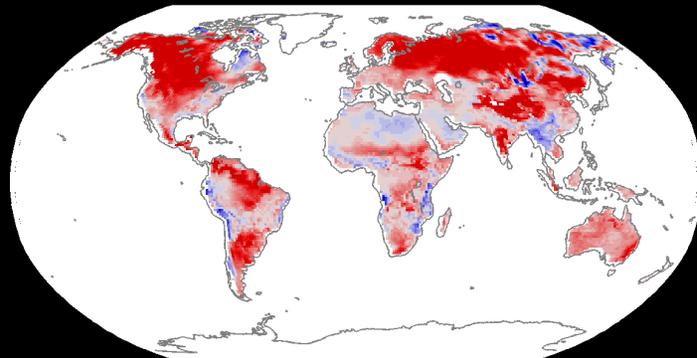
Surface Temperature (ANN) Control

SPCCSM - CCSM



Soil-Surface Temperature (ANN) Control

SPCCSM - CCSM



Does

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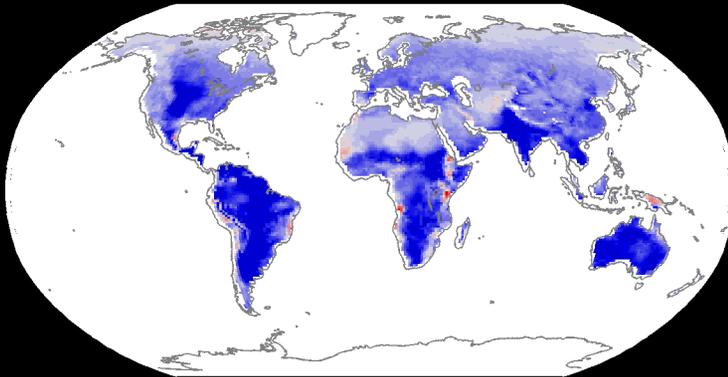
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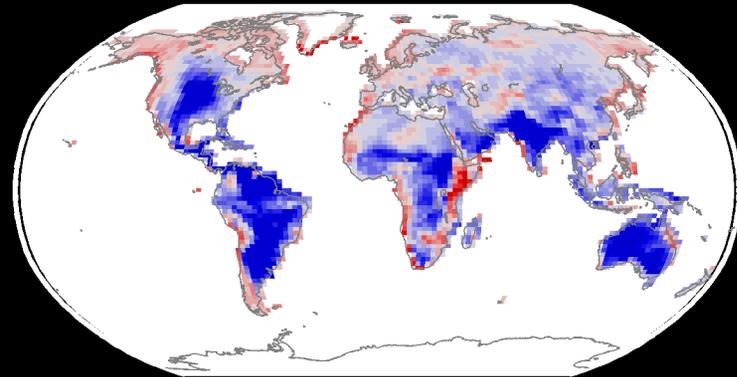
Lower soil moisture reduces surface humidity

Land Surface Latent Heat (ANN) Control

SPCCSM - CCSM



SPCESM - CESM



Wm^{-2}

-20

-15

-10

-5

0

5

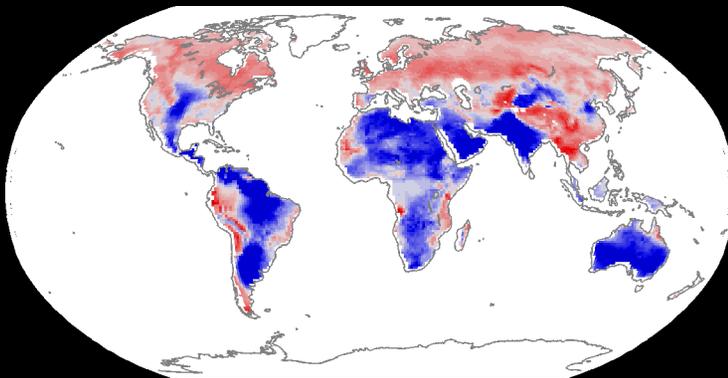
10

15

20

Land Surface Relative Humidity (ANN) Control

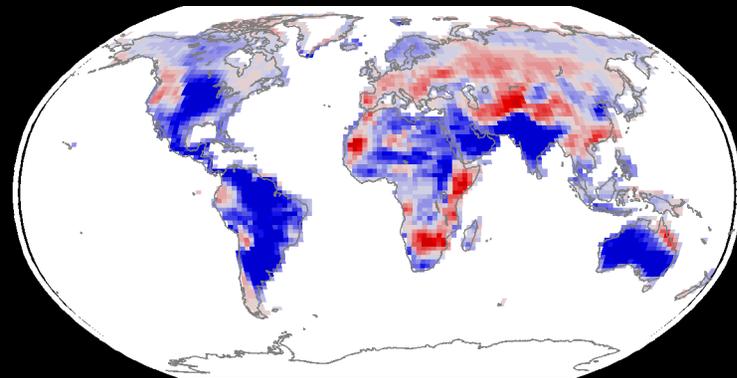
SPCCSM - CCSM



Do

Do

SPCESM - CESM



e?

gg?

%

-8

-6

-4

-2

0

2

4

6

8

How can super-parameterization impact sensible and latent heat partitioning?

```
graph TD; Q[How can super-parameterization impact sensible and latent heat partitioning?]; S[Surface Conditions]; A[Atmospheric Conditions]; Q --> S; Q --> A; S --> S1[Rainfall, Soil Moisture, and Evapotranspiration]; A --> A1[Temperature and Humidity]; S1 --> S2[Promotes Less Latent Heating]; A1 --> A2[Promotes More Sensible Heating];
```

**Surface
Conditions**

**Rainfall, Soil Moisture,
and Evapotranspiration**

**Promotes
Less Latent
Heating**

**Atmospheric
Conditions**

**Temperature and
Humidity**

**Promotes
More Sensible
Heating**

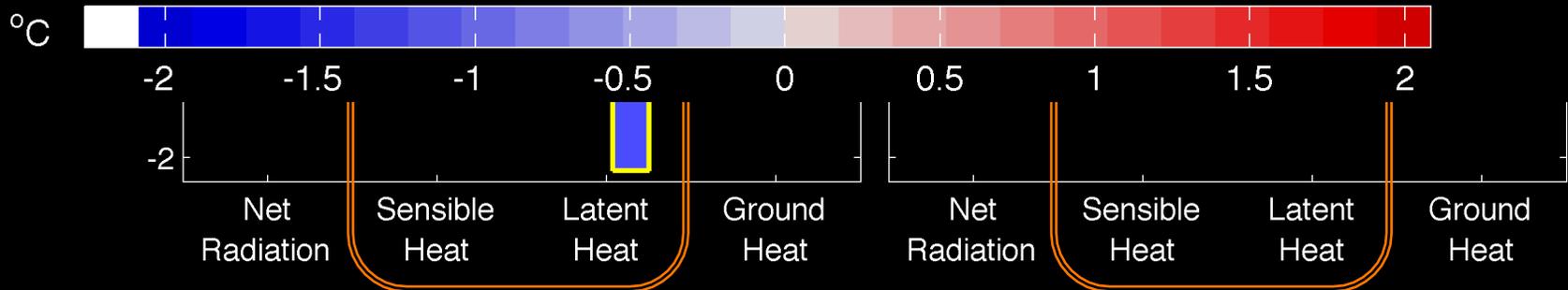
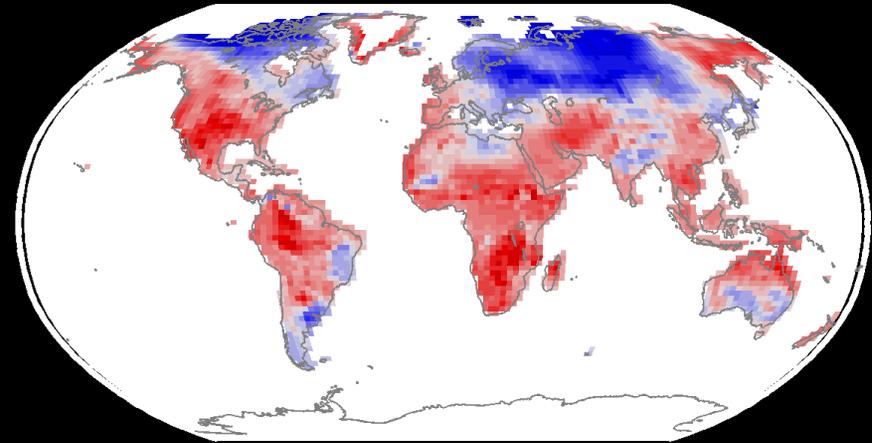
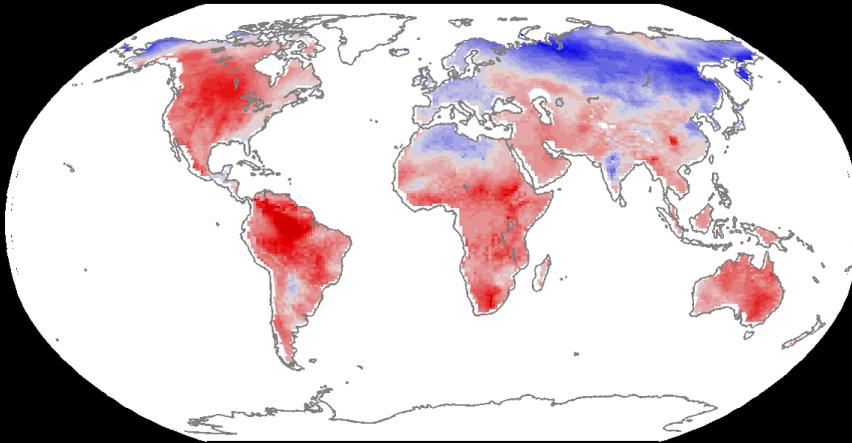
SP-CAM further reduces evaporative fraction with climate change relative to CAM

Land Surface Energy Balance Climate Change (Wm^{-2})
 (SP)CCSM (SP)CESM

Land Surface Temperature (ANN) Climate Change

SPCCSM - CCSM

SPCESM - CESM



- Climate Change = $(\text{SPCAM}_{\text{Forcing}} - \text{SPCAM}_{\text{Control}}) - (\text{CAM}_{\text{Forcing}} - \text{CAM}_{\text{Control}})$

Conclusions:

- **SP-CAM enhances sensible over latent heating**
- **SP-CAM has less rainfall over land and lower soil moisture, limiting latent heating**
- **A colder overlying atmosphere in SPCAM associates with more sensible heating**
- **Climate change amplifies Bowen ratio in both models, but more in SP-CAM**

Questions:

- **Does super-parameterization have a more/less realistic representation of land-surface fluxes?**
- **Why does SPCAM rain less over land (feedbacks)?**
- **Why does SPCAM cool the surface atmosphere?**