Tracking Land-Atmosphere Coupling in CESM

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Simulations Courtesy of:
Cecile Hannay, Colin Zarzycki, Yu-heng Tseng
Variable Soil Depth
Dry layer soil

CLUBB Updates to MAM
Consistent auto-conversion
Improved momentum and drag
Variable Mesh

More crop types
More realistic Nitrogen cycle
Drought stress pheno correction
Surface datasets

Multi-layer Canopy
CSLAM and dycore changes

Bare
Grass
BDT
CLM
CAM
How sensitive is CLM to changes in CAM and visa-versa?
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![Diagram showing CLM-CAM Connectivity]

- Resolution AMIP
- Changing convection AMIP

**Model Development**
(version, configuration, resolution etc...)
How sensitive is **CLM** to changes in **CAM** and visa-versa?
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- Resolution AMIP
- Changing convection AMIP
- Internal Variability

Comparison with Fully Coupled Latest version

**Model Development**
(version, configuration, resolution etc...)
How sensitive is **CLM** to changes in **CAM** and visa-versa?

**Model Development**
(version, configuration, resolution etc...)

- Resolution AMIP
- Changing convection AMIP
- Internal Variability
- Comparison with Fully Coupled Latest version
Quantifying **CLM-CAM** connectivity

- **Sensible Heat**
- **Latent Heat**
- **Soil Moisture**

**PBL**
Quantifying CLM-CAM connectivity

PBL

Sensible Heat

Latent Heat

Soil Moisture

Terrestrial Coupling
Quantifying CLM-CAM connectivity

Sensible Heat

Latent Heat

Soil Moisture

Two-legged Coupling

Terrestrial Coupling

PBL
Quantifying **CLM-CAM** connectivity

Terrestrial Coupling

Two-legged Coupling
Quantifying **CLM-CAM** connectivity

Terrestrial Coupling  
*latent heat flux* variability controlled by *soil moisture* variation

Two-legged Coupling  
*Some atmospheric variable* variability controlled by *soil moisture* variations through latent heat flux
Quantifying CLM-CAM connectivity

Terrestrial Coupling

Two-legged Coupling

\[ \sigma_{\text{SoilM}} \frac{d(\text{Latent})}{d(\text{SoilM})} \]
Quantifying CLM-CAM connectivity

Terrestrial Coupling

$\sigma_{\text{SoilM}} \frac{d(\text{Latent})}{d(\text{SoilM})}$

Two-legged Coupling

$\sigma_{\text{SoilM}} \frac{d(\text{Latent})}{d(\text{SoilM})} \frac{d(\text{Precip or CAPE})}{d(\text{Latent})}$
Quantifying CLM-CAM connectivity

Terrestrial Coupling

Two-legged Coupling

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Applied to:

Daily data for a given month → July

July
Terrestrial Coupling Across Version and Set-up

% of Land with Terra. Coup > 10 Wm\(^{-2}\)

- CAM5.3
- CLM4.0
- CESM1.5
- AMIP
- GLDAS

△

CAM5.3
CLM4.0
Terrestrial Coupling Across Version and Set-up

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Terrestrial Coupling Across Version and Set-up

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% of Land with Terra. Coup > 10 Wm⁻²

Slight Drop from CLM4 to CLM4.5

Fully Coupled

CESM1.5

AMIP
Terrestrial Coupling Across Version and Set-up

% of Land with Terra. Coup > 10 Wm⁻²

Coupling plummets with CLUBB and CLM5

CAM5.3
CLM4.5

CESM1.5
AMIP

GLDAS

Fully Coupled

CESM1.5
Terrestrial Coupling Across Version and Set-up

- CAM5.3
- CLM4.0
- CESM1.5
- AMIP
- GLDAS

% of Land with Terra. Coup > 10 Wm^{-2}

Subtle drop when adding the Ocean and others

CESM1.5 Fully Coupled
Terrestrial Coupling Across Version and Set-up

- CAM5.3
- CLM4.0
- CESM1.5
- AMIP
- GLDAS

% of Land with Terra. Coup > 10 Wm\(^{-2}\)

- CAM5.3
- CLM4.5

Refined Mesh Resolution has little effect

- CESM1.5 Fully Coupled

Graph showing the percentage of land with terrestrial coupling greater than 10 W m\(^{-2}\) for different models and settings.
Terrestrial Coupling Across Version and Set-up

Changing the Deep Convective Trigger slightly increases coverage.

% of Land with Terra. Coup > 10 Wm\(^{-2}\)

- CAM5.3
- CLM4.0
- CAM5.3
- CLM4.5
- CESM1.5
- AMIP
- CESM1.5
- Fully Coupled

GLDAS
Terrestrial Coupling Across Version and Set-up

CAM5.3 CLM4.0 - AMIP Default Trigger

CAM5.3 CLM4.0 - AMIP New Trigger

W m$^{-2}$
Terrestrial Coupling Across Version and Set-up

Changing Convective Trigger
Weaker Coupling with Convective Inhibition controlled but broader coverage
Terrestrial Coupling Across Version and Set-up

Changing Resolution:
More local maxima but structure is the same
Terrestrial Coupling Across Version and Set-up

Changing Resolution:
More local maxima but structure is the same
Terrestrial Coupling Across Version and Set-up

CESM 1.5

CESM 1.5 - AMIP

W m$^{-2}$
Terrestrial Coupling Across Version and Set-up

“Good” Members

“Bad” Members

W m⁻²
Terrestrial Coupling Across Version and Set-up

CAM 3.5 CLM 3.5 - Assimilation Ensemble

“Good” Members

“Bad” Members

W m⁻²
Terrestrial Coupling Across Version and Set-up

“Good” Members

“Bad” Members

Tseng et al. 2016 Climate Dynamics
What Dominates the **Terrestrial** Coupling Signal?
What Dominates the **Terrestrial** Coupling Signal?

- CLM contains sub-grid plant functional types (PFTs)
- There are ~17 PFTs in CLM4.5
- CLM5 will have 6 new representative crop types
- Each PFT can contribute to terrestrial coupling
What Dominates the *Terrestrial* Coupling Signal?

- CLM contains sub-grid plant functional types (PFTs)
- There are ~17 PFTs in CLM4.5
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- Each PFT can contribute to terrestrial coupling

PFT-level data are available from the CAM5.3 CLM4.5 simulation
What Dominates the Terrestrial Coupling Signal?
What Dominates the **Terrestrial** Coupling Signal?
Two-Legged Coupling Across Version and Set-up

- CAM5.3
- CLM4.0
- CESM1.5
- AMIP

% of Land with Two-Leg > 0.5 mm day⁻¹

- Fully Coupled
- Two-legged Coupling

\[ \sigma_{\text{SoilM}} \frac{d(\text{Latent})}{d(\text{SoilM})} \frac{d(\text{Precip})}{d(\text{Latent})} \]
Two-Legged Coupling Across Version and Set-up

- CAM5.3
- CLM4.0
- CESM1.5
- AMIP

% of Land with Two-Leg > 0.5 mm day⁻¹

- CAM5.3
- CLM4.0
Two-Legged Coupling Across Version and Set-up

- CAM5.3
- CLM4.0
- CESM1.5
- AMIP

% of Land with Two-Leg > 0.5 mm day$^{-1}$

- CAM5.3
  - CLM4.0
- CESM1.5
- AMIP
Two-Legged Coupling Across Version and Set-up

% of Land with Two-Leg > 0.5 mm day$^{-1}$

- CAM5.3
- CLM4.0
- CESM1.5 AMIP
- CESM1.5 Fully Coupled
Two-Legged Coupling Across Version and Set-up

CAM5.3 CLM4.0

CAM5.3 CLM4.0 New Trigger

0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7 mm day-1
Two-Legged Coupling Across Version and Set-up

CESM1.5

CESM1.5 AMIP

CAM5.3 CLM4.0

CAM5.3 CLM4.0 New Trigger

mm day-1
Two-Legged Coupling Across Version and Set-up

Two-legged Coupling

\[ \sigma_{\text{SoilM}} \frac{d(\text{Latent})}{d(\text{SoilM})} \frac{d(\text{CAPE})}{d(\text{Latent})} \]

CAM5.3 CLM4.0

CAM5.3 CLM4.0 New Trigger

J kg\(^{-1}\)
Two-Legged Coupling Across Version and Set-up
Summary

Terrestrial Coupling

% of Land with Terra. Coup > 10 Wm\(^{-2}\)

- CAM5.3
- CLM4.0
- CAM5.3
- CLM4.5
- GLDAS

Two-legged Coupling

% of Land with Two-Leg > 0.5 mm day\(^{-1}\)

- CAM5.3
- CLM4.0
- w/ New Trigger
- CESM1.5
- Fully Coupled
- CESM1.5
- AMIP
- CESM1.5
- Fully Coupled