Land-atmosphere interactions across model versions of CESM

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Wide-ranging impacts of land-atmosphere coupling…

- L-A coupling influences precipitation, cloud cover, hydrometeorological extremes, etc. (Findell & Eltahir, 2003; Roundy et al. 2013; Santanello et al. 2018; Lee et al., 2019)
Wide-ranging impacts of land-atmosphere coupling... have helped spur new efforts at improvement

**Coupling of Land and Atmospheric Subgrid Parameterizations (CLASP)**

- Goal: communicate land subgrid heterogeneity to the atmosphere

*Image courtesy of Nate Chaney*
Wide-ranging impacts of land-atmosphere coupling... have helped spur new efforts at improvement

How sensitive is coupling in CESM to changes that were made *without* the explicit intent of changing its strength?
Method

• Land-atmosphere coupling frequently assessed through LoCo initiative:

Santanello et al. (2017)
Method

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\[ CI = \frac{\text{covar}(\text{SHFLX}, \text{PBL})}{\sigma_{\text{SHFLX}}} \]

\[ CI = \frac{\text{covar}(\text{SM}, \text{SHFLX})}{\sigma_{\text{SM}}} \]

Santanello et al. (2017)
CMIP5 mean coupling index

More positive = stronger coupling

More negative = stronger coupling

Adapted from Figure 1 of Dirmeyer et al. (2014)
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Coupling index across CESM versions

- Series of AMIP simulations with daily output, 1979-2006
  - Different combinations of CESM2 and CESM1 CAM/CLM components
  - Focus on JJA
CESM2 has lowered overall coupling strength relative to CESM1.
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Is that good?
Comparison to FLUXNET observations suggests this is an improvement for the terrestrial leg

- 115 stations 3+ years of JJA observations for SHFLX and soil moisture (at depths >20 cm)

- Mean absolute bias:
  - CESM2: 5.900 W/m²
  - CESM1: 6.679 W/m²
How do changes in CAM vs. CLM contribute to the decreased coupling strength?
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Updates in CLM5 have significantly contributed to a weakening in both legs of the coupling index.
Was there a particular change in CLM5 that’s driving weaker coupling?

All simulations use CAM6, from 1979-83
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- Implementation of a dry surface layer (Swenson and Lawrence, 2014) decreases coupling markedly in the subtropics
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- Changes in plant hydraulic stress (*Kennedy et al.*, 2019) and precipitation interception don’t necessarily alter things much
Was there a particular change in CLM5 that’s driving weaker coupling?

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- Changes in plant hydraulic stress (Kennedy et al., 2019) and precipitation interception don’t necessarily alter things much
- But changes to soil thickness and root profiles impact the terrestrial leg
Key Takeaways

- CESM2 shows a generally weaker coupling strength in JJA than CESM1 (at least by this metric)
  - Appears to be slightly more realistic, at least for terrestrial leg

- The decrease stems primarily from updates made in CLM, even for the atmospheric leg of the index
  - Suggests importance of assessing coupling from both the atmospheric and land perspectives when large model updates are implemented

Thanks!
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Differences stem from which part of CI?

5-year tests

\[ CI = \frac{\text{covar}(FLX, P_{LCL})}{\sigma_{FLX}} \]

\[ CI = \frac{\text{covar}(SM, FLX)}{\sigma_{SM}} \]
Is 5 years enough for CI?

1979-2006

Atmospheric leg

Terrestrial leg

NCAR UCAR
Is 5 years enough for CI?

1979-1983

Atmospheric leg

Terrestrial leg

NCAR
UCAR
Changes in DJF show weakening in SH as well