Land-atmosphere interactions across model versions of CESM

Meg Fowler, Dave Lawrence, Rich Neale
Isla Simpson, and Cecile Hannay
*NCAR*

LMWG 2021
February 23rd, 2021

NCAR
UCAR

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 **L**and and **A**tmospheric **S**ubgrid **P**arameterizations (CLASP) CPT

- Goal: communicate land subgrid heterogeneity to the atmosphere
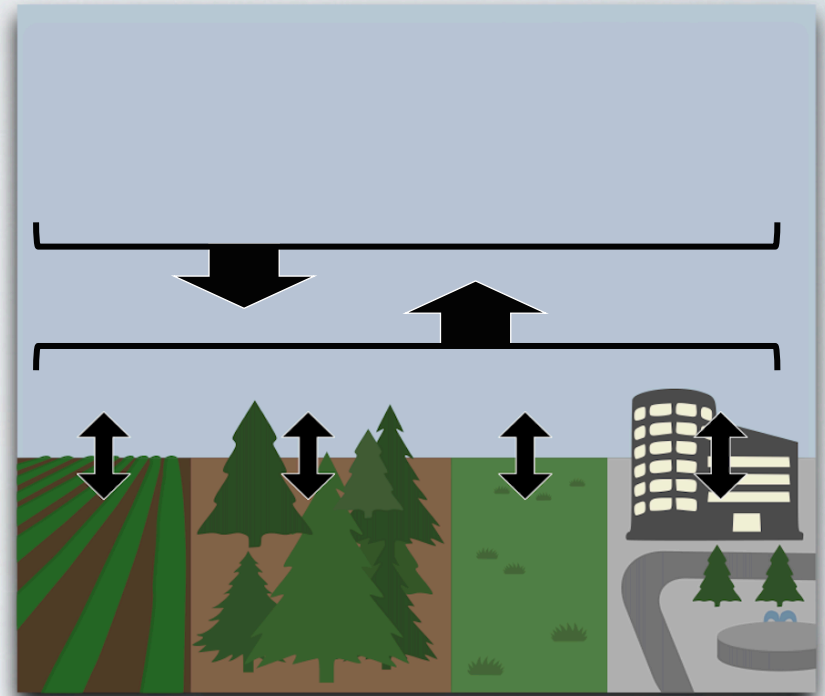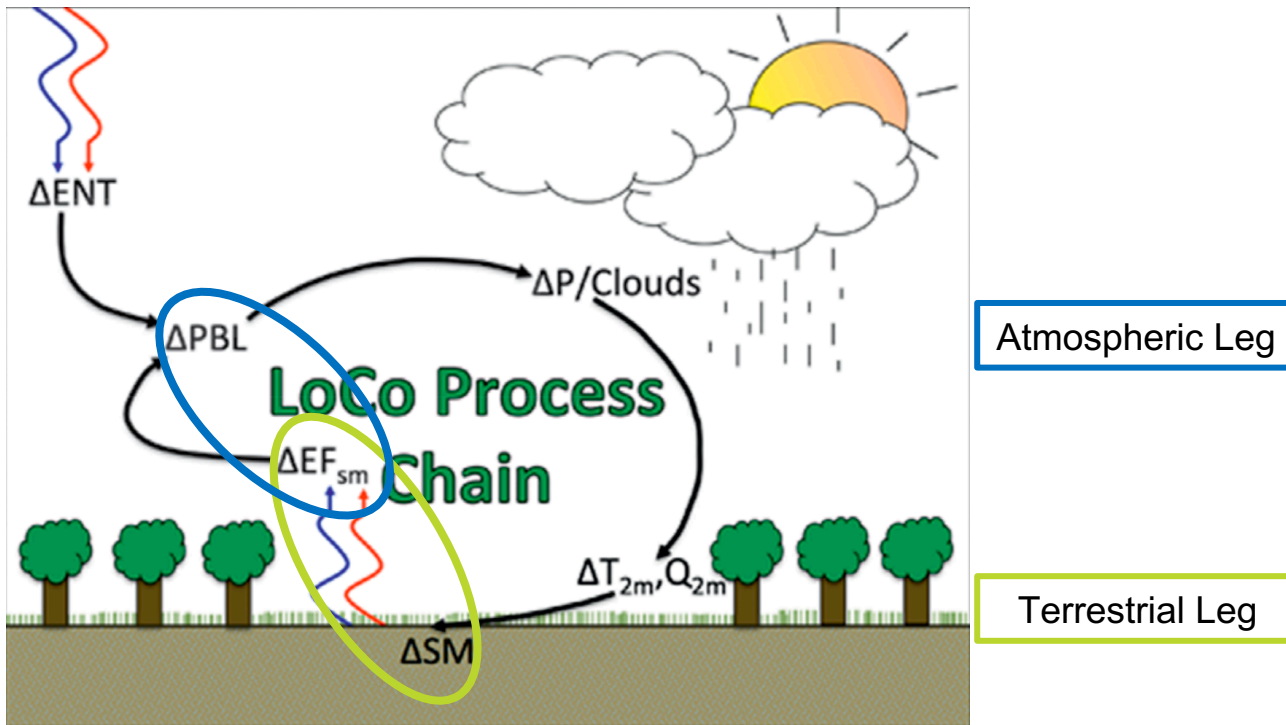

Coupled model: Reality

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?
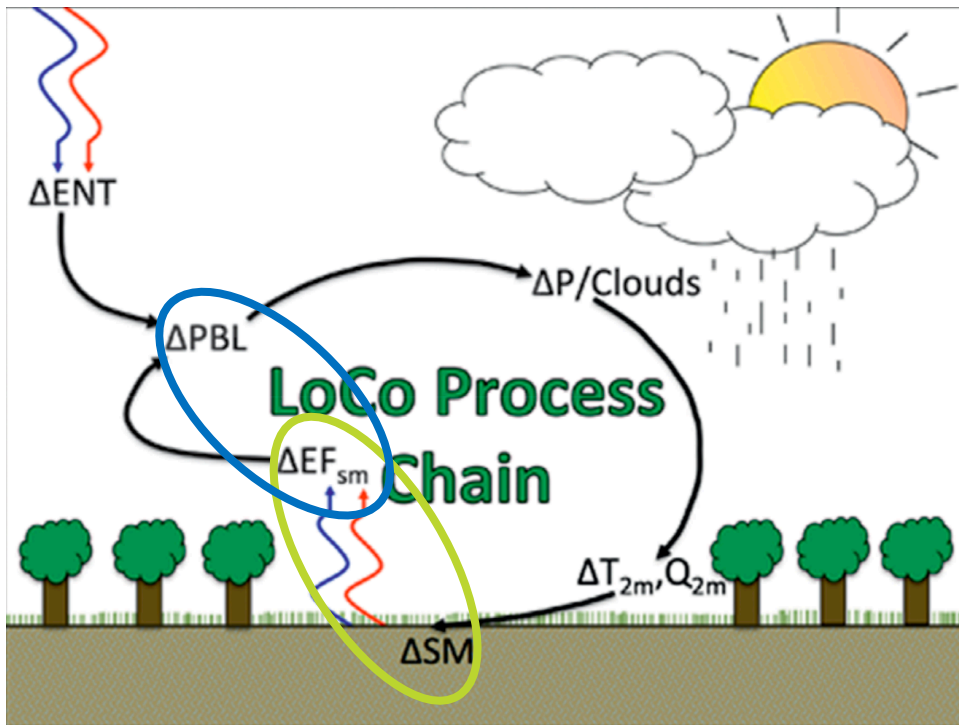
NCAR
UCAR

Method

- Land-atmosphere coupling frequently assessed through LoCo initiative:

Santanello et al. (2017)

Method

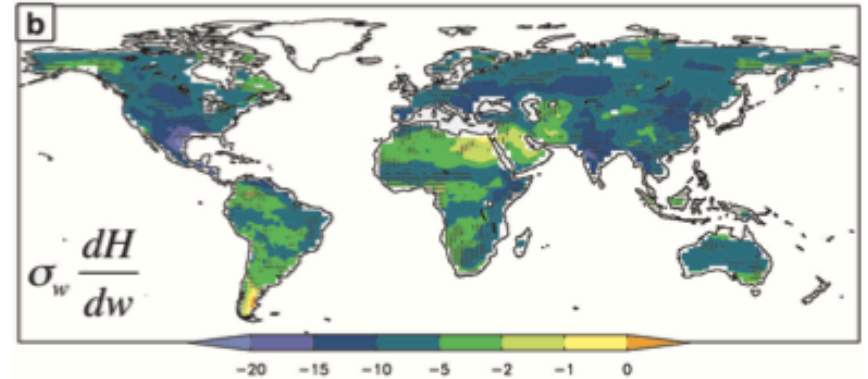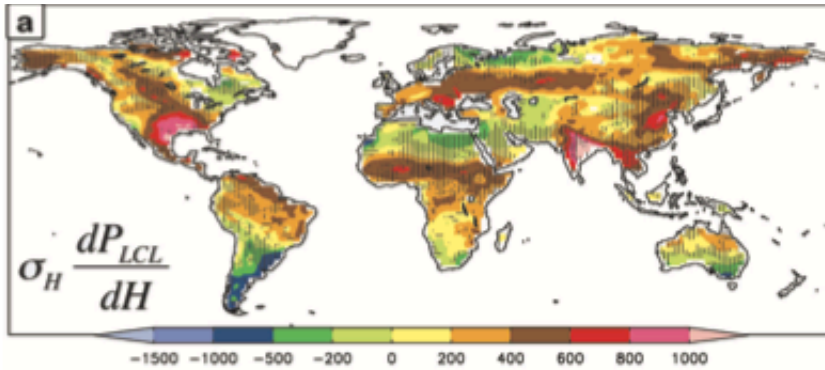- Land-atmosphere coupling frequently assessed through LoCo initiative:

Santanello et al. (2017)

Atmospheric Leg

$$CI = \frac{covar(SHFLX, PBL)}{\sigma_{SHFLX}}$$

Terrestrial Leg

$$CI = \frac{covar(SM, SHFLX)}{\sigma_{SM}}$$
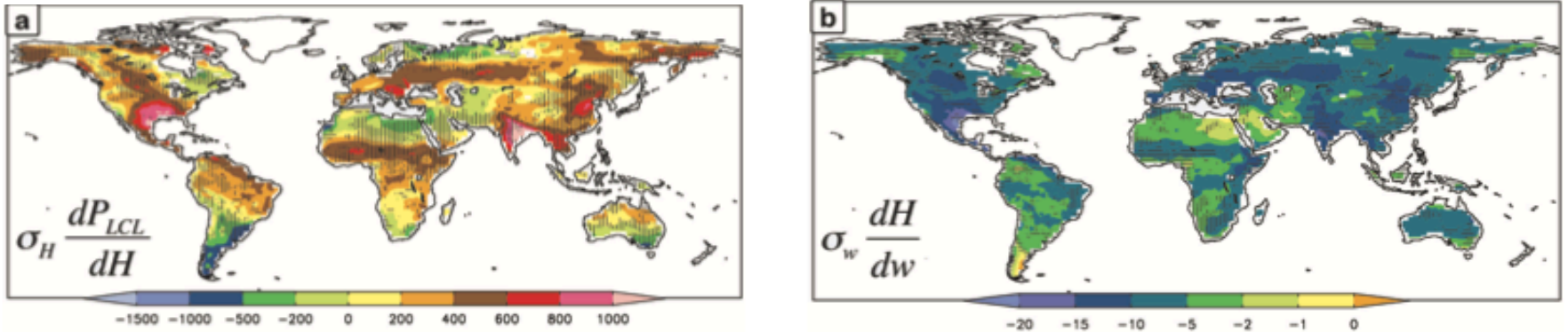
NCAR
UCAR

CMIP5 mean coupling index

Adapted from Figure 1 of *Dirmeyer et al.* (2014)

More positive =
stronger coupling

More negative =
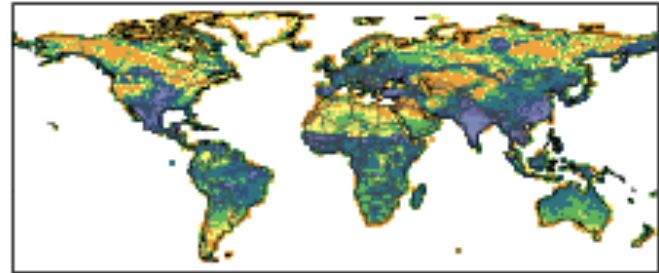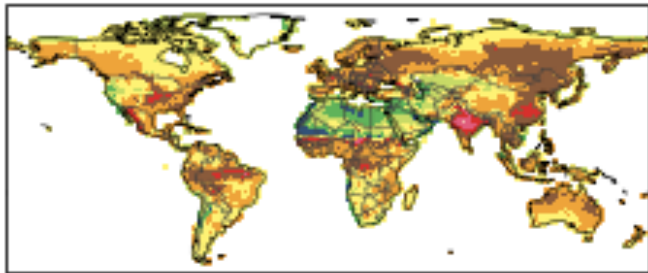stronger coupling

CMIP5 mean coupling index

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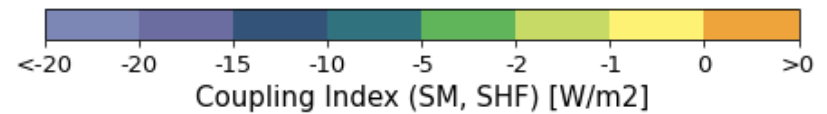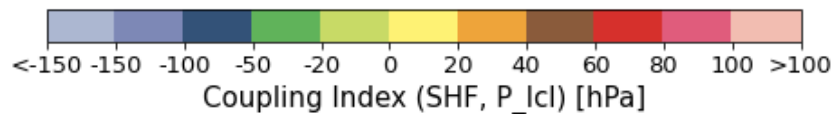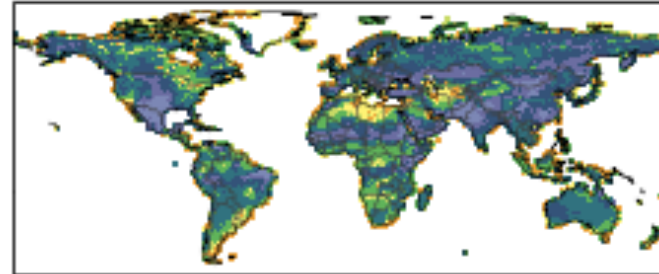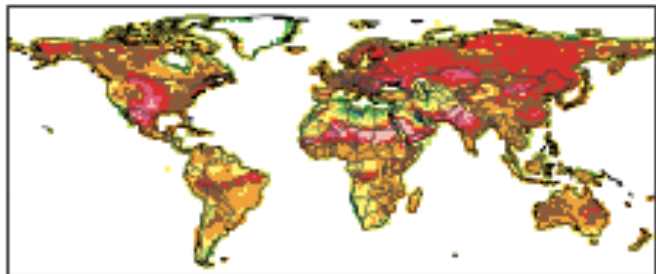
Coupling index across CESM versions

- Series of AMIP simulations with daily output, 1979-2006
  - Different combinations of CESM2 and CESM1 CAM/CLM components
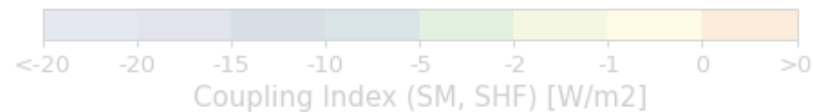 - Focus on JJA

NCAR
UCAR

CESM2 has lowered overall coupling strength relative to CESM1
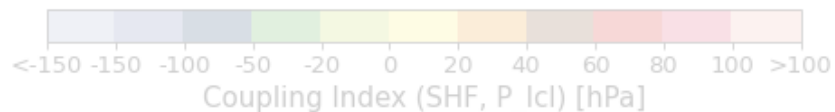

CESM2

CESM1

# CESM2 has lowered overall coupling strength relative to CESM1

CESM2

CESM1

Is that good?

Coupling Index (SHF, P_lcl) [hPa]

<-150 -150 -100 -50 -20 0 20 40 60 80 100 >100

Coupling Index (SM, SHF) [W/m2]

<-20 -20 -15 -10 -5 -2 -1 0 >0

NCAR
UCAR

Comparison to **FLUXNET** observations suggests this is an improvement for the terrestrial leg
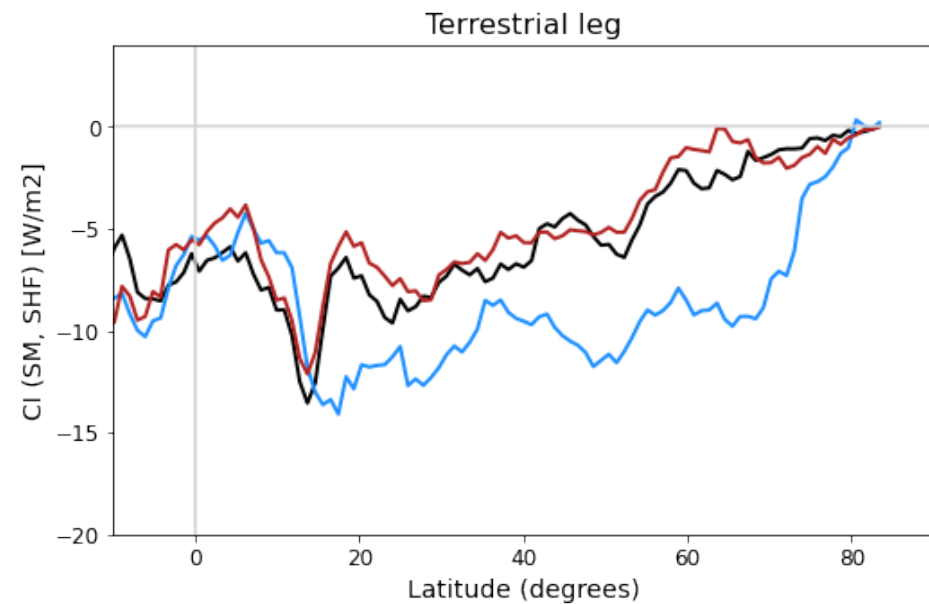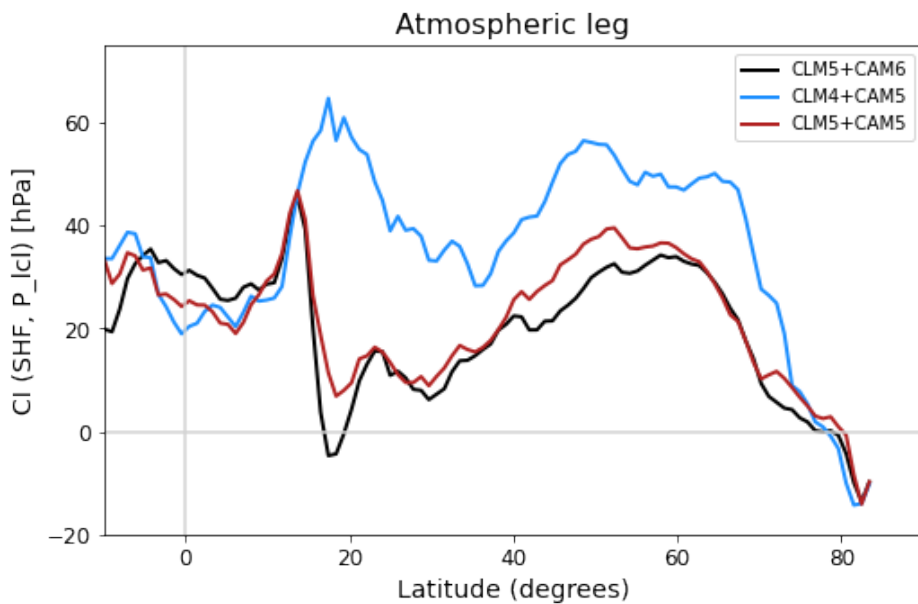
- 115 stations 3+ years of JJA observations for SHFLX and soil moisture (at depths >20 cm)

- Mean absolute bias:

  CESM2:   5.900 W/m^2

  CESM1:   6.679 W/m^2
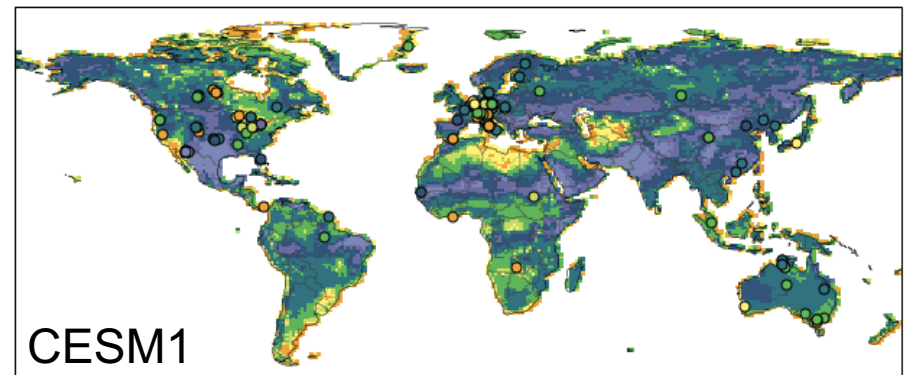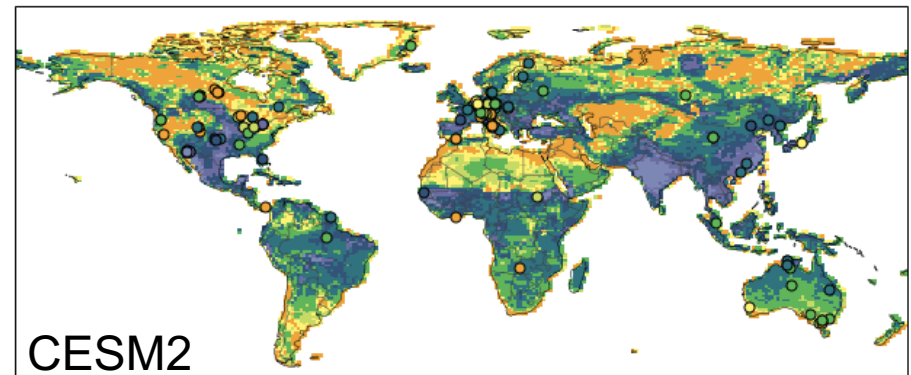
CESM2

CESM1

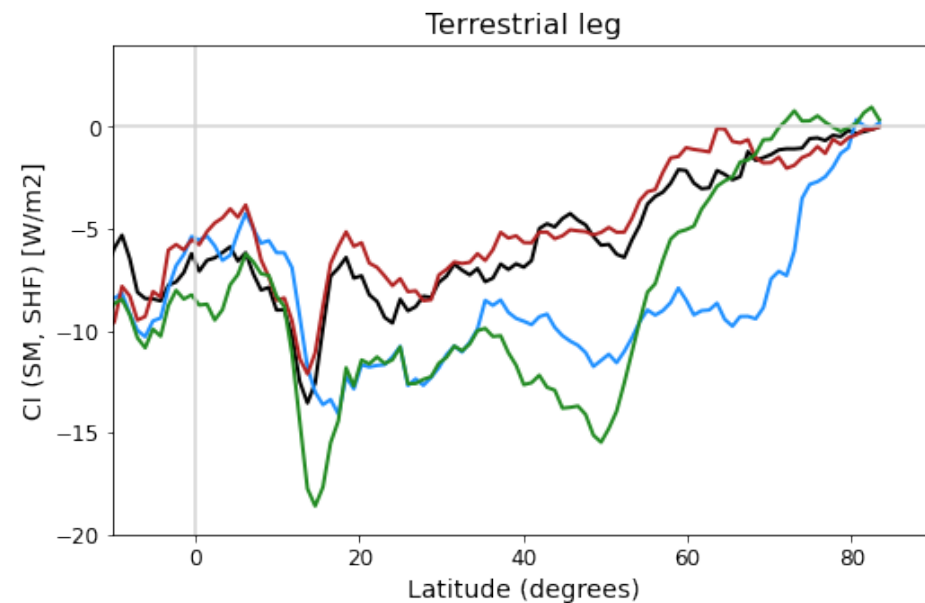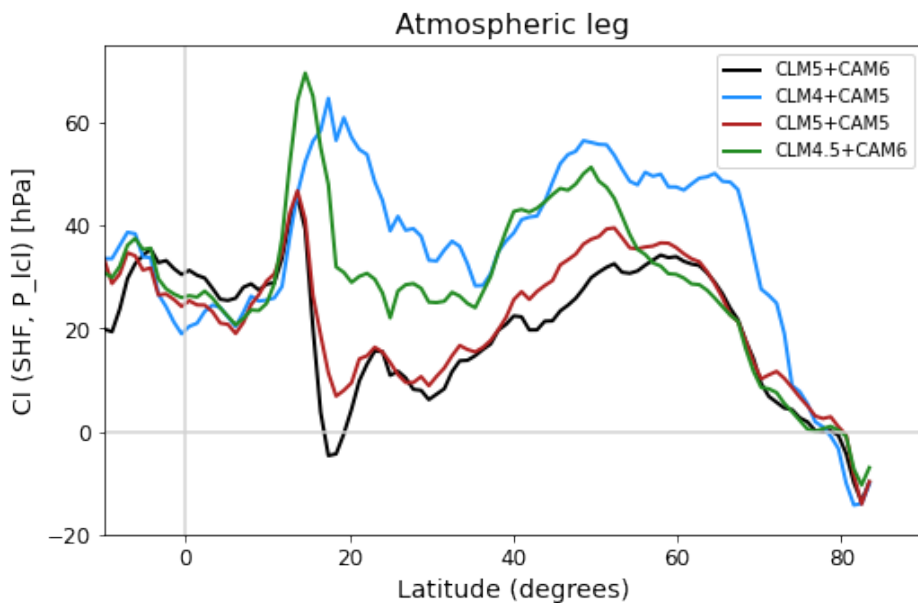Coupling Index (SM, SHF) [W/m2]

NCAR | UCAR

How do changes in CAM vs. CLM contribute to the decreased coupling strength?
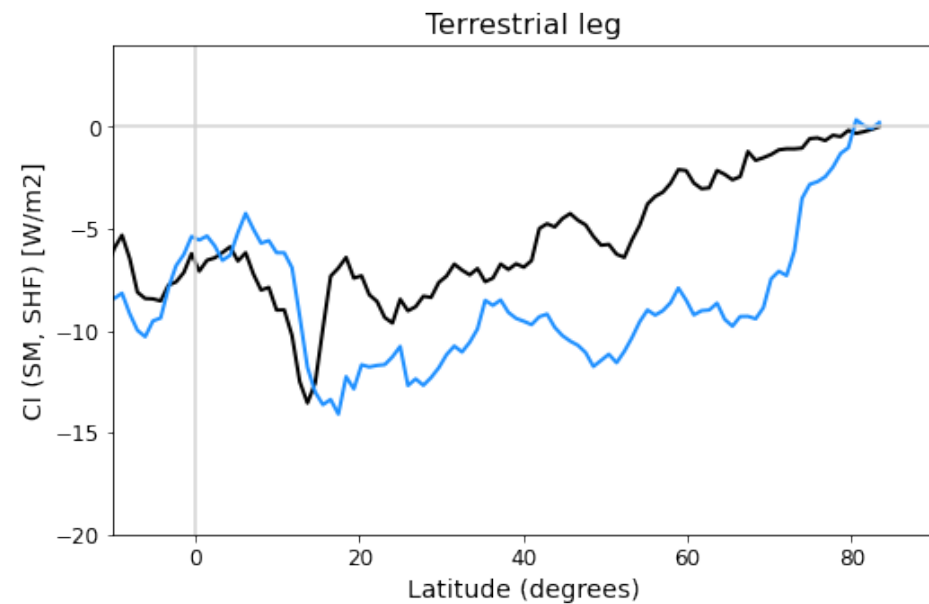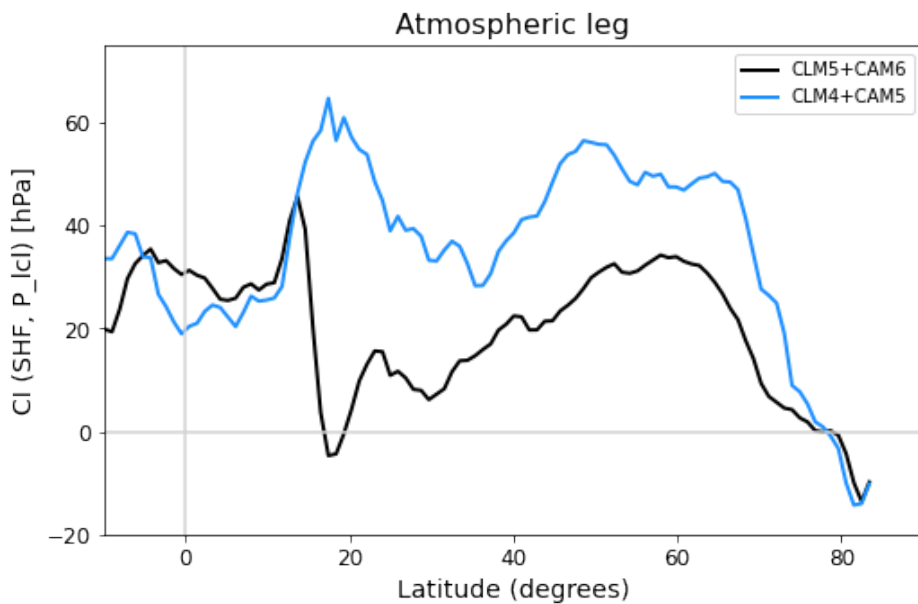
How do changes in CAM vs. CLM contribute to the decreased coupling strength?
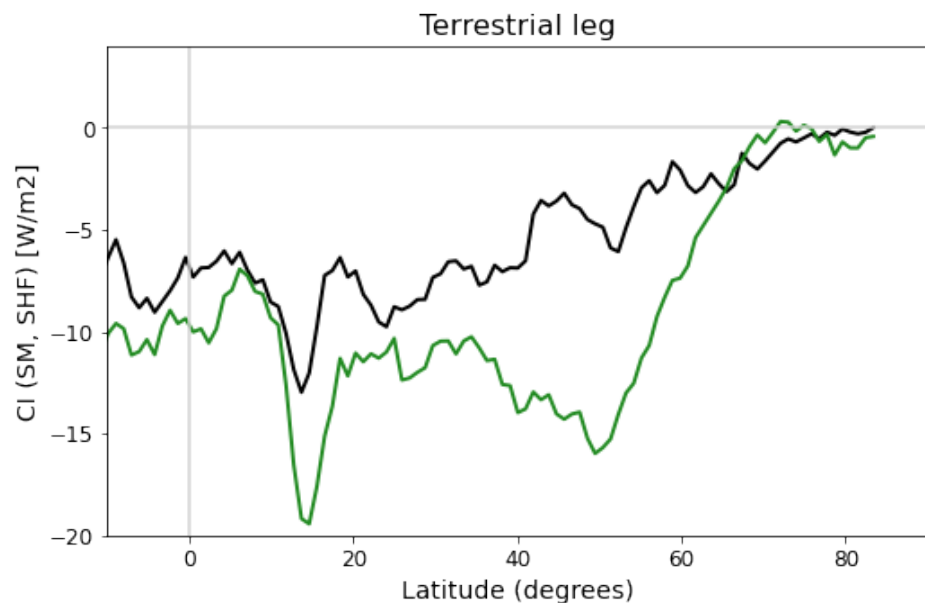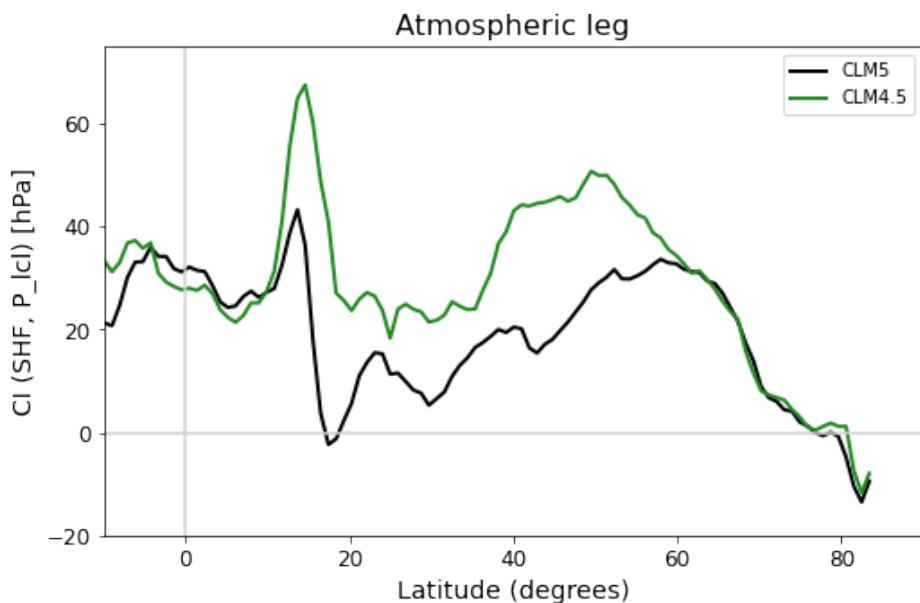
How do changes in CAM vs. CLM contribute to the decreased coupling strength?
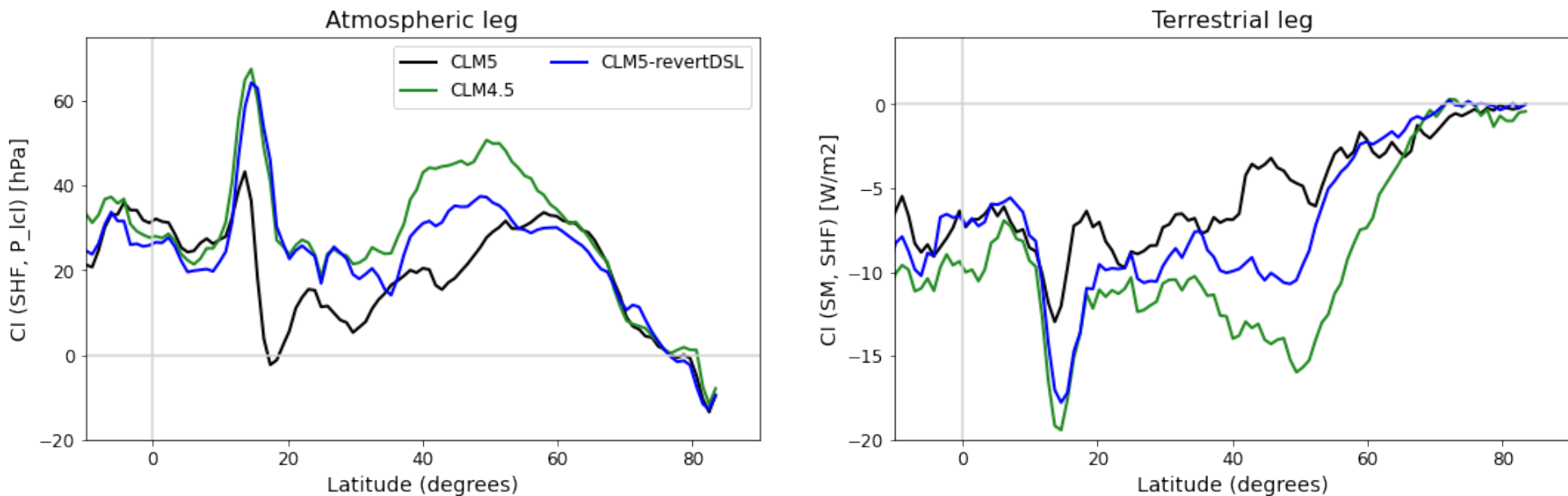

Updates in CLM5 have significantly contributed to a weakening in *both* legs of the coupling index

Was there a particular change in CLM5 that's driving weaker coupling?

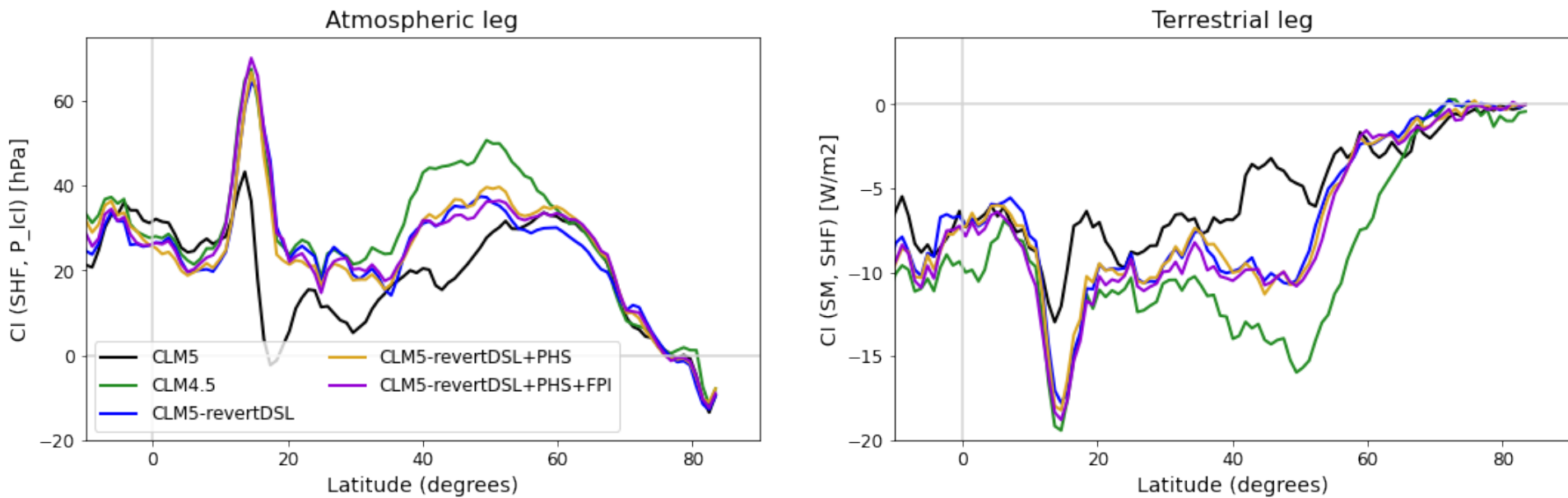All simulations use CAM6, from 1979-83

Was there a particular change in CLM5 that's driving weaker coupling?

All simulations use CAM6, from 1979-83

- Implementation of a dry surface layer *(Swenson and Lawrence, 2014)* decreases coupling markedly in the subtropics
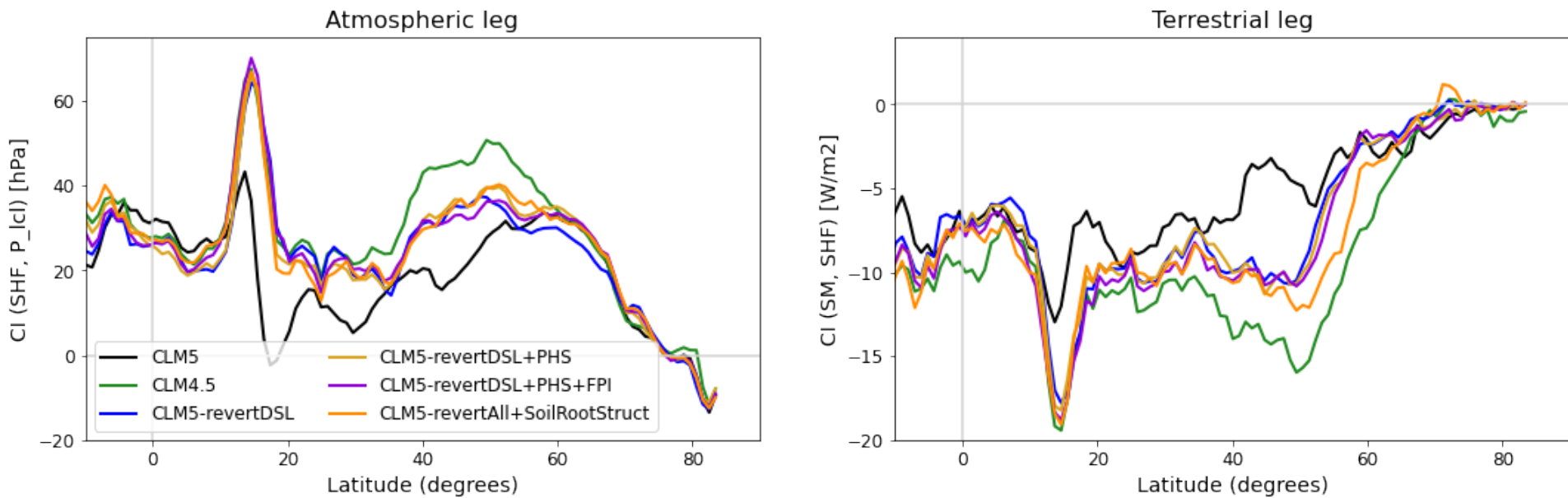
NCAR
UCAR

Was there a particular change in CLM5 that's driving weaker coupling?

All simulations use CAM6, from 1979-83

- 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?

Atmospheric leg

CLM5
CLM4.5
CLM5-revertDSL
CLM5-revertDSL+PHS
CLM5-revertDSL+PHS+FPI
CLM5-revertAll+SoilRootStruct

Terrestrial leg

All simulations use CAM6, from 1979-83

- 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

NCAR
UCAR

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
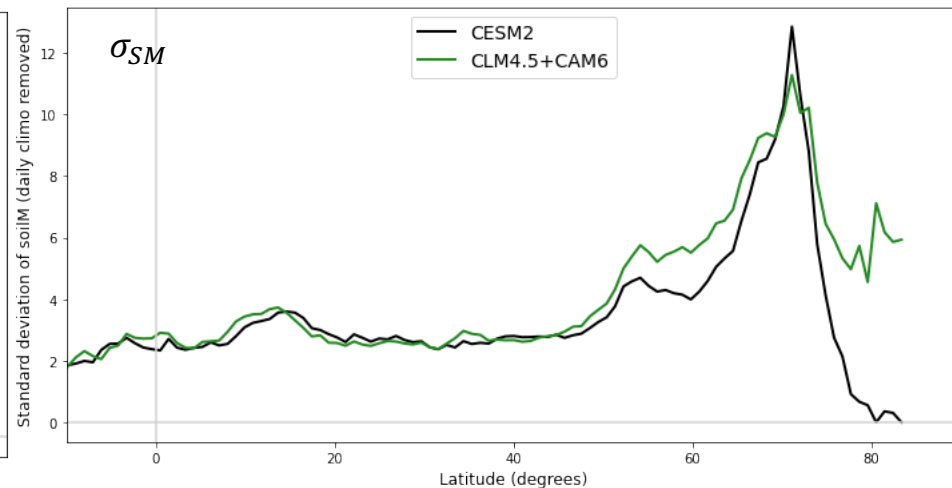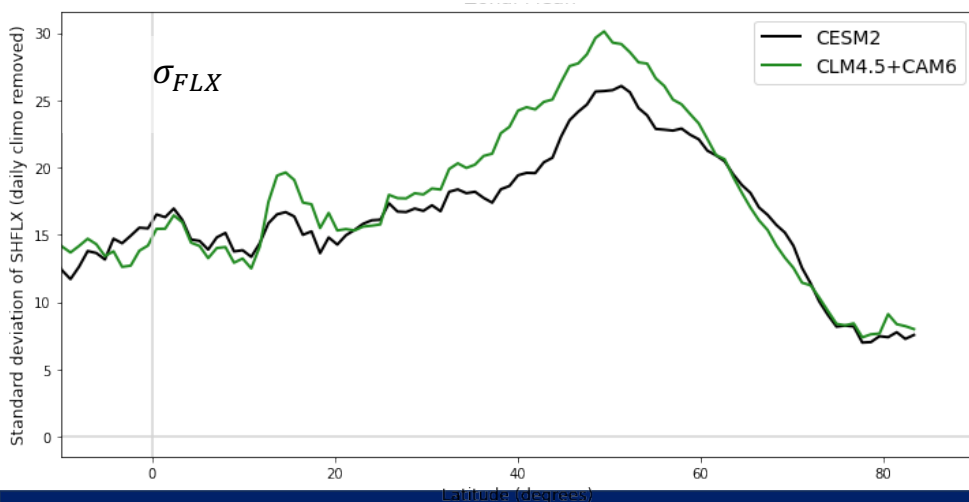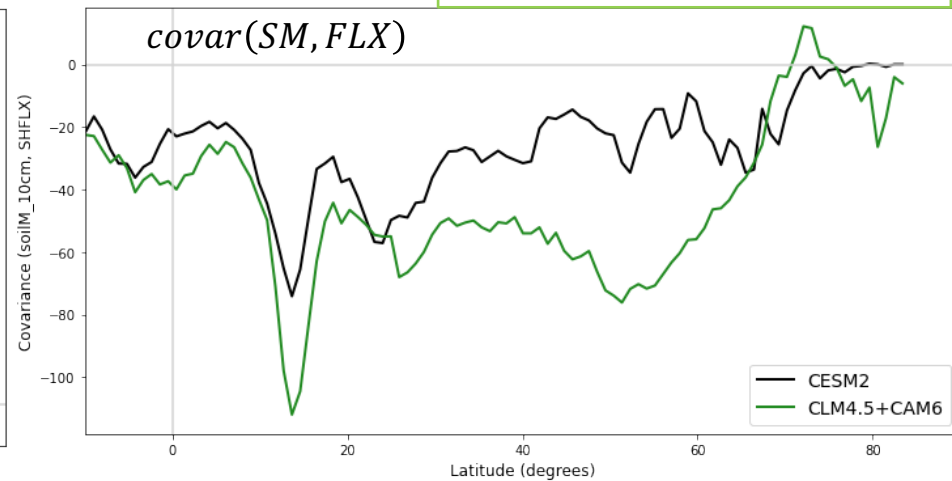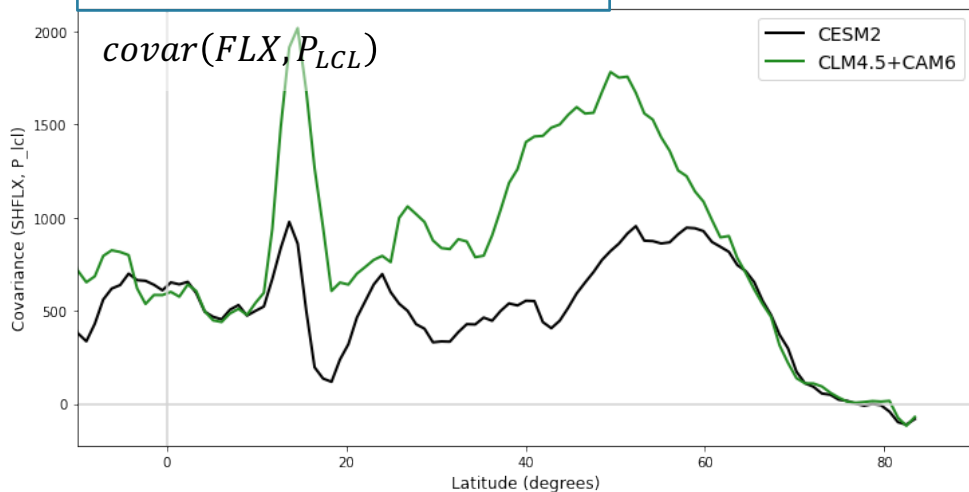
Thanks!

mdfowler@ucar.edu

Differences stem from which part of CI?

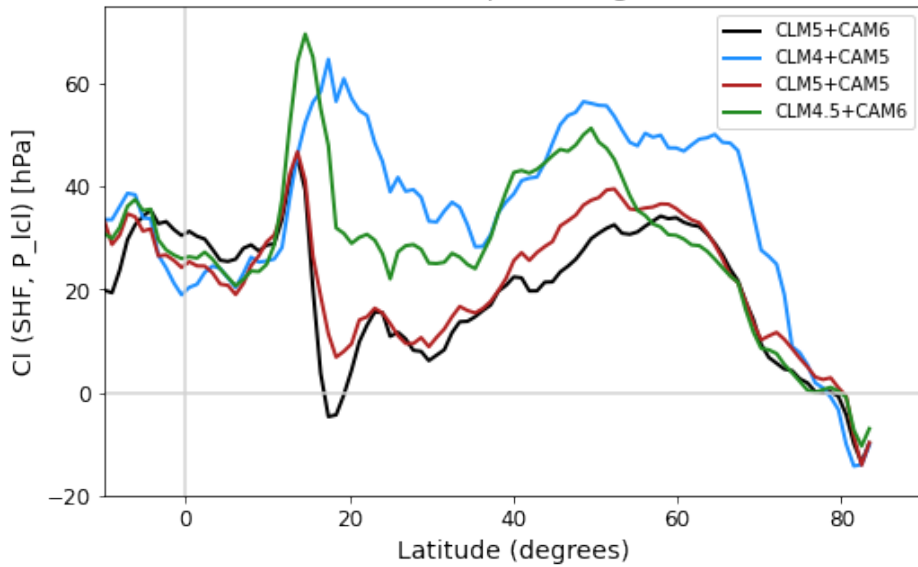*5-year tests*

$$CI = \frac{covar(FLX, P_{LCL})}{\sigma_{FLX}}$$

$$CI = \frac{covar(SM, FLX)}{\sigma_{SM}}$$

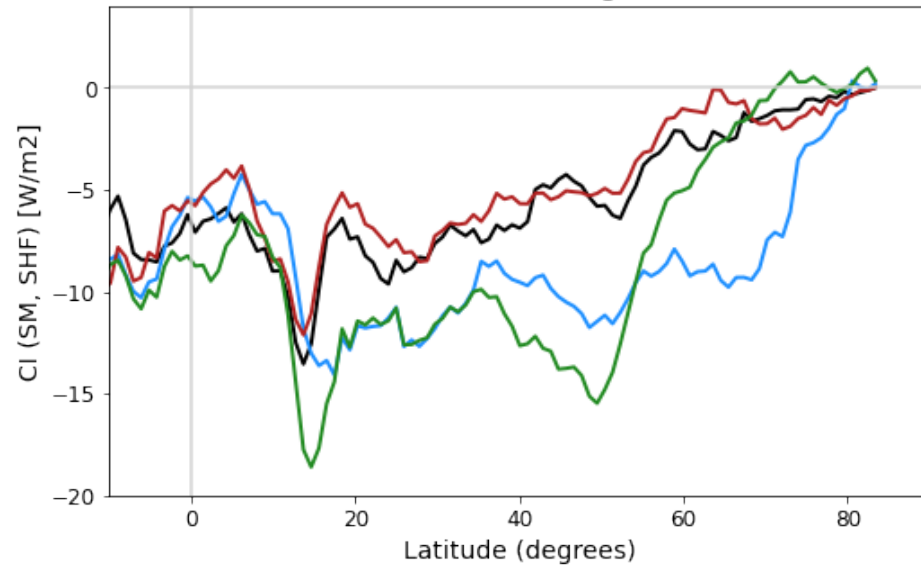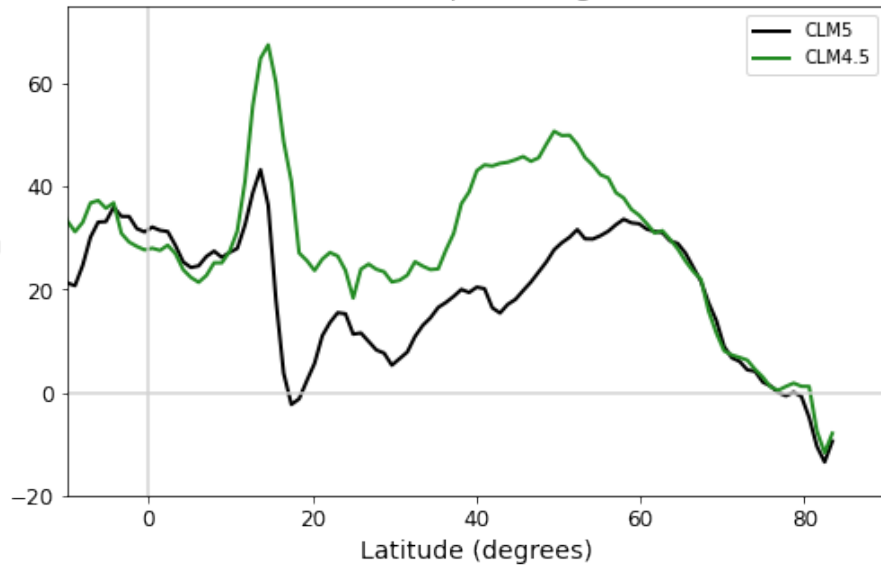# Is 5 years enough for CI?

1979-2006

Is 5 years enough for CI?

1979-1983
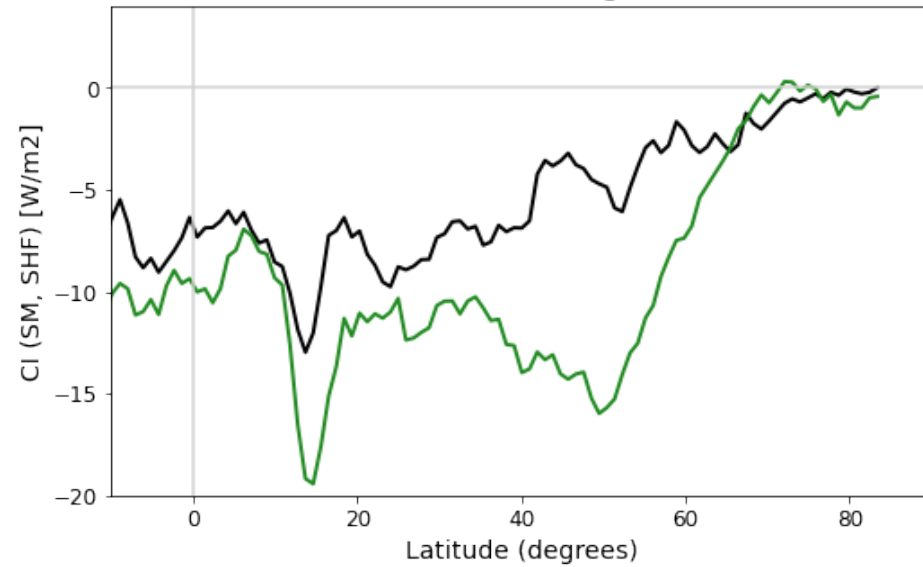
Changes in DJF show weakening in SH as well