Status of dust, sea salt aerosols and fire emissions in CCSM3

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Mineral aerosols/dust

- Dust/direct feedbacks published
  - 4 size bins, 0.1-5/10 microns in size, dry and wet deposition
  - Climatology, response to climate in LGM, PI, DCO2 (Mahowald et al., 2006a)
    - Strong response of dust to climate, co2 fertilization in CCSM3 (stronger than other models, Mahowald, submitted)
    - Includes impact of glaciogenic (edge of ice sheets) sources in LGM
  - Impact of dust onto Sahel (Yoshioka et al., 2007)
    - dust could be responsible for 30% of Sahel drought
    - Strong LW makes atmosphere cooling→subsidence→decrease precip over dust regions
  - Feedback of dust onto climate under different climates (Mahowald et al., 2006b)
    - Important in LGM (0.8 degree cooling)
    - Non-neglible under PI, DCO2 using CCSM3 (-0.22, 0.06 degrees T) when co2 fertilization is inicluded

Dust issues

- Change in CLM degrades dust distribution (Asia too big relative to Africa)
  - CCSM3.0 (ok) to CCSM3.1 (bad) or higher
    - Needs to be retuned (fall)
  - Not sure if surface datasets of biogeography (much more bare ground in CLM3.1+) or hydrology (wetter Sahel??)
- Need to include smaller particles for indirect effect
  - Working with Steve Ghan et al on this.

Sea salt aerosols

- Climatology, response to climate published (Mahowald et al., 2006c)
  - 4 size bins (0.1 to 5-10 microns)
  - Ok climatology, but winds too high in CCSM3 (like many other gcms)
  - Can’t capture LGM/preindustrial ice core records, even with new sea ice source (problems with transport/source or parameterizations?)
  - CCSM3 has very little response of surface winds over ocean to climate (other models have much stronger response (e.g. GFDL 40% change in Sea salts under 2100 climate)

Sea salt issues

- Need to include LW interactions (not in model)
- SW crudely done (just put onto 2 size bins already in model)
- Need to include smaller sizes for indirect effect
  - Annica Ekman, Stockholm University incorporating scheme into CCSM3.5

Fire interactions

- CLM-CN has simple fire scheme (Thornicke et al., 2000)
- Gets reasonable fire return interval
- Have predictions of fire in transient runs for preindustrial to current and future (?) (CCSM3.1 versions at T31)
- Will hook to model OC and BC (other emisisons)
- Have funding NSF-Carbon and Water to further develop and explore fire interactions (J. Randerson, J. Foley, P. Hess, P. Thornton)

Net instantaneous radiative forcing to dust (not response): consistent with few observations available

Net TOA cooling from dust

Net atmosphere cooling from dust (some warming over oceans)

Net surface cooling over oceans, heating over high dust sources

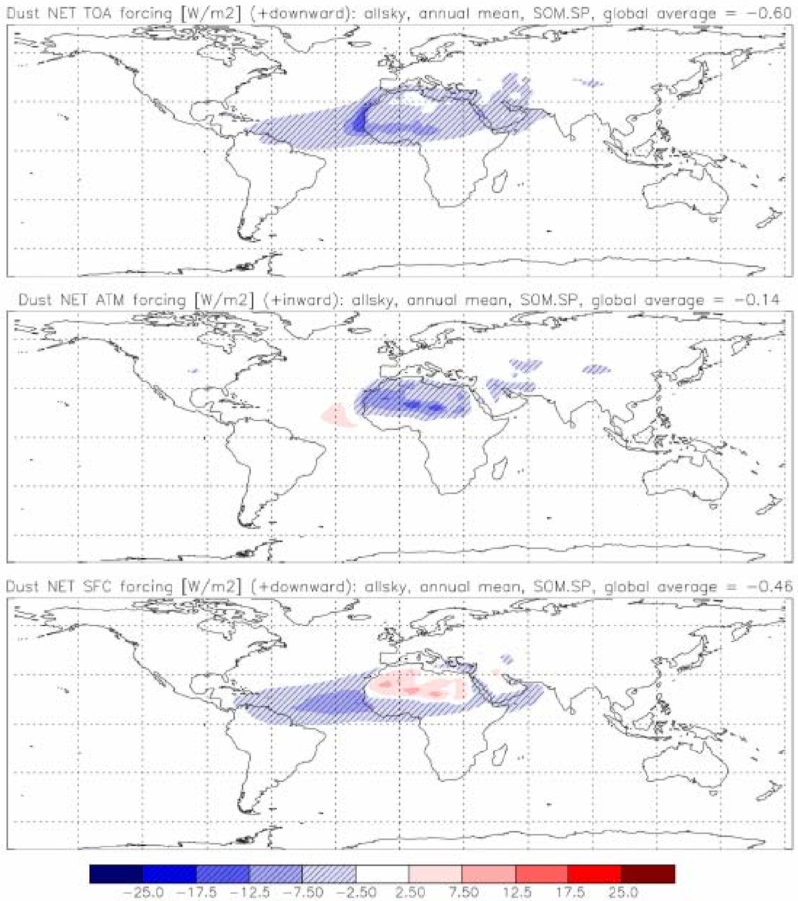


Figure 2c. Same as Figure 2a but for net (shortwave+longwave) radiative forcing.

Surface temperature response to dust radiative forcing:

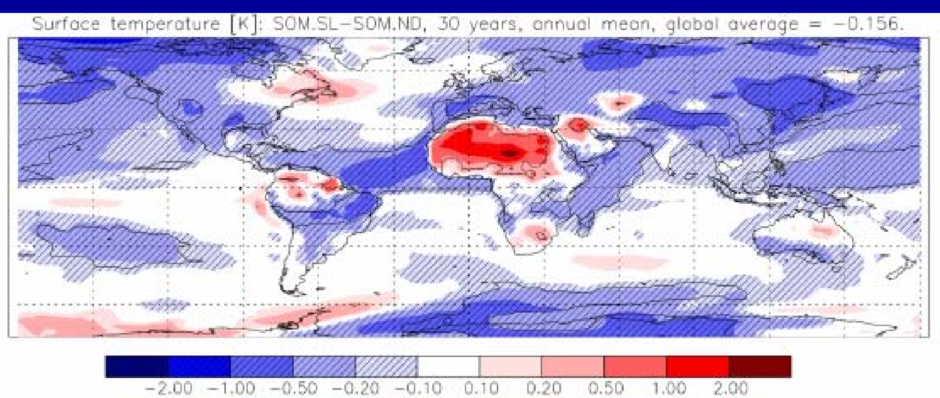


Figure 6. Changes in annual mean land and sea surface temperatures due to dust radiative forcing.
(Top: SOM.S – SOM.ND, bottom: SOM.SL – SOM.ND. Solid curves show a statistical significance of differences between cases at 99% level.)

Yoshioka et al., 2007

Impacts of dust onto climate/precipitation: Precipitation with and without dust direct radiative feedbacks (Only statistically significant results shown).

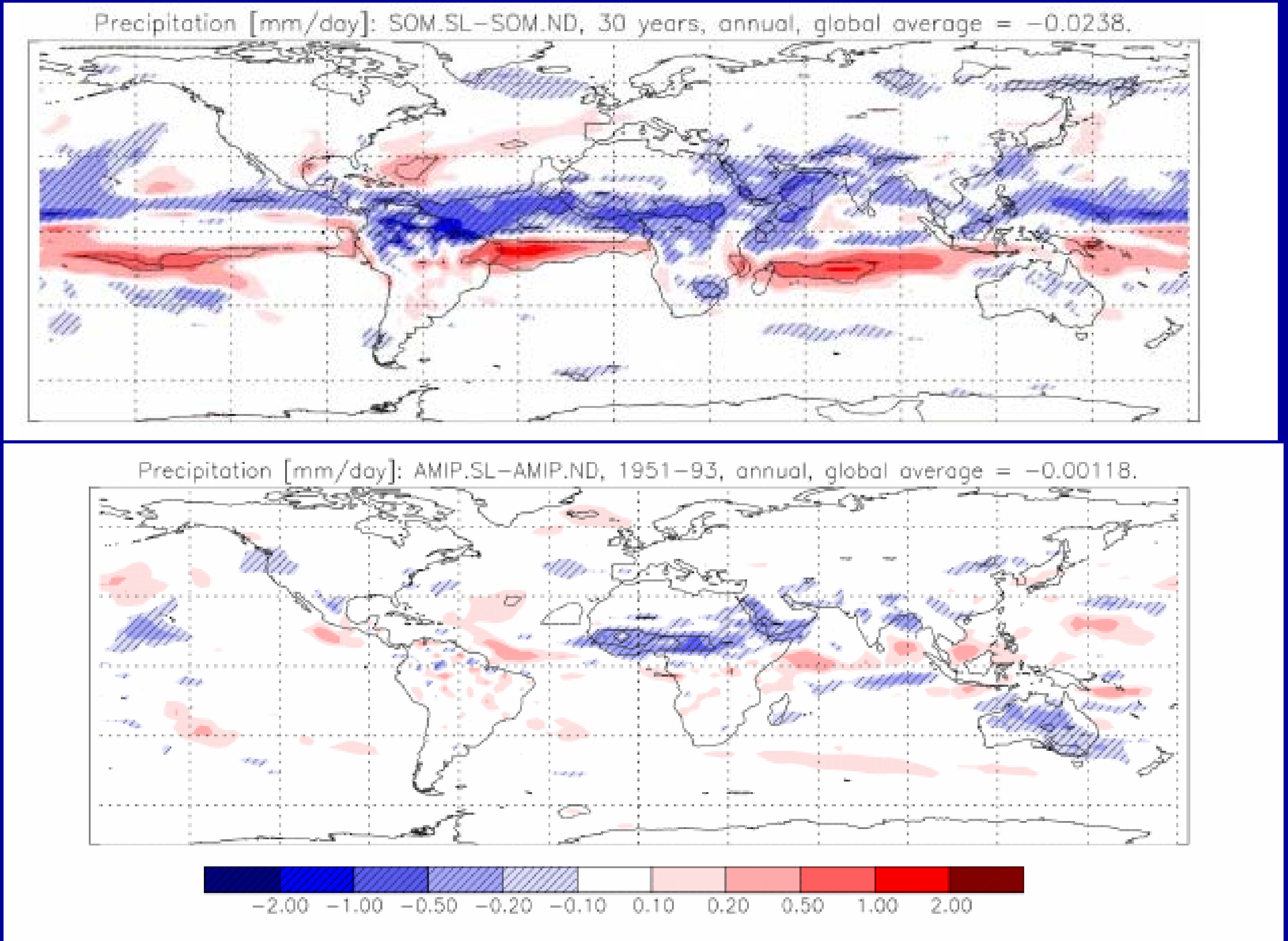


Figure 4a. Differences in AMIP precipitations (1951-93) due to dust radiative

Dust direct radiative forcing tends to shift precipitation away from Sahel. More pronounced over North Atlantic with sst feedbacks

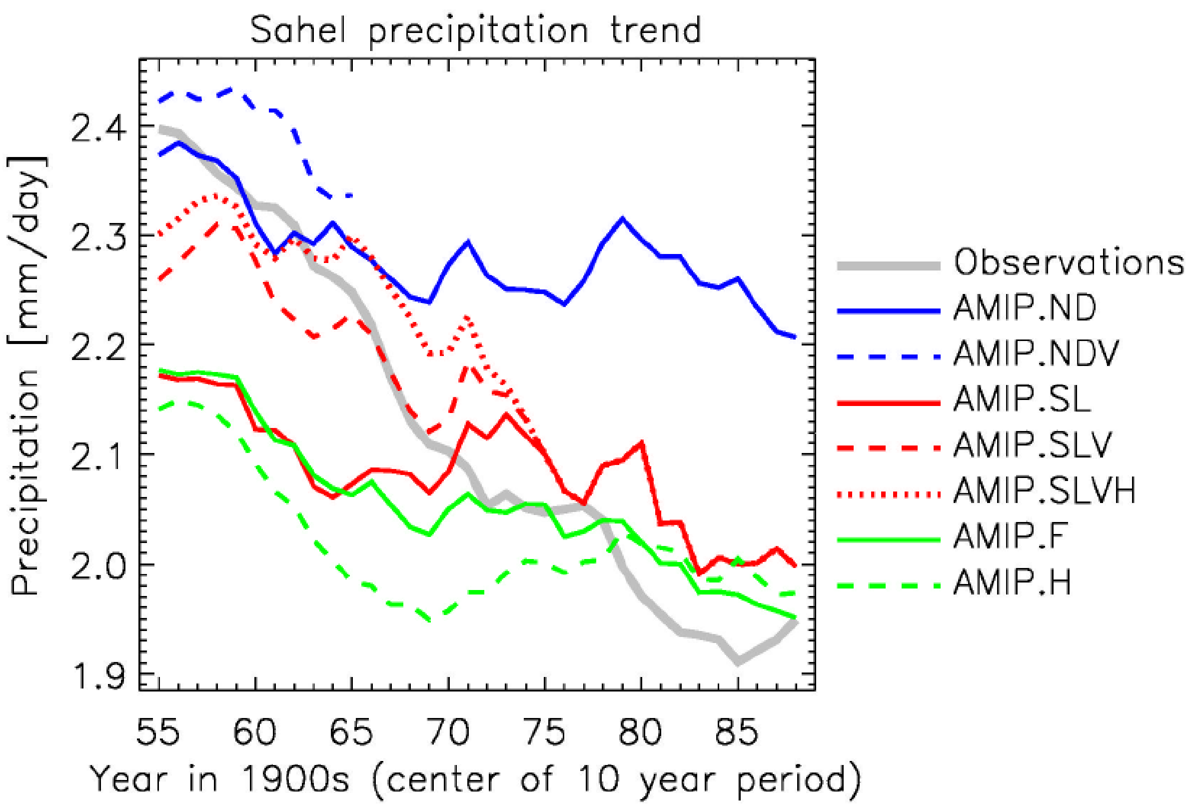


Figure 8. Rainfall trend in the Sahel (10°N–20°N, 18°W–20°E) in observations (gray solid), AMIP.ND (blue solid), AMIP.NDV (blue dashed), AMIP.SL (red solid), AMIP.SLV (red dashed), AMIP.SLVH (red dotted), AMIP.F (green solid), and AMIP.H (green dashed) simulations.
(Precipitation values are 10-year running means. For example, the abscissa value of 55 represents the period from 1951 to 1960.)

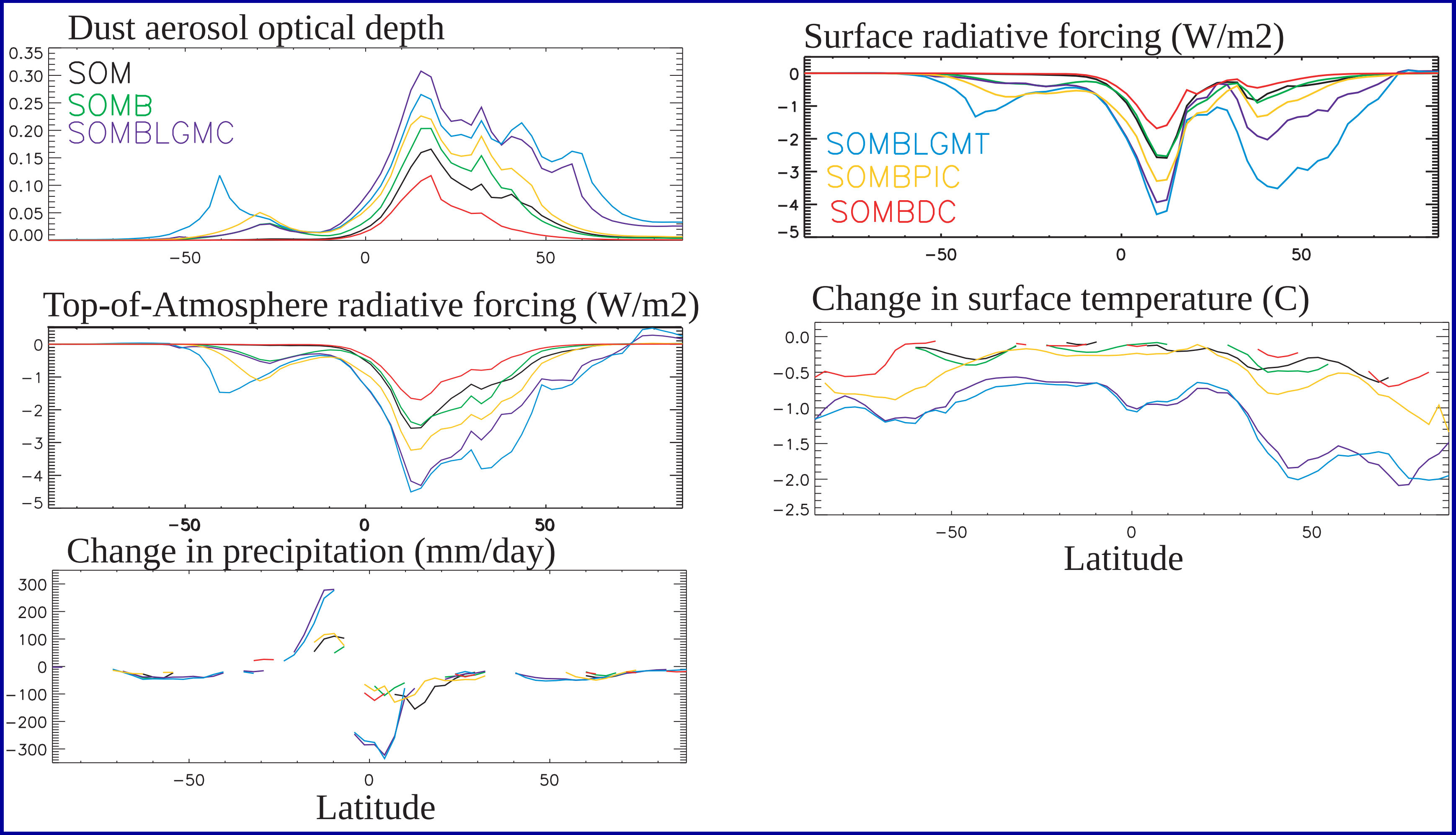
Impacts on Sahel precip.

- SSTs ~50% of observed precip change (1980s vs 1950s)
- Vegetation changes Not significant
- Model can't capture dust changes observed, but observed dust changes (when forced onto model) cause ~30% change in observed precip in Sahel (1950s to 1980s)

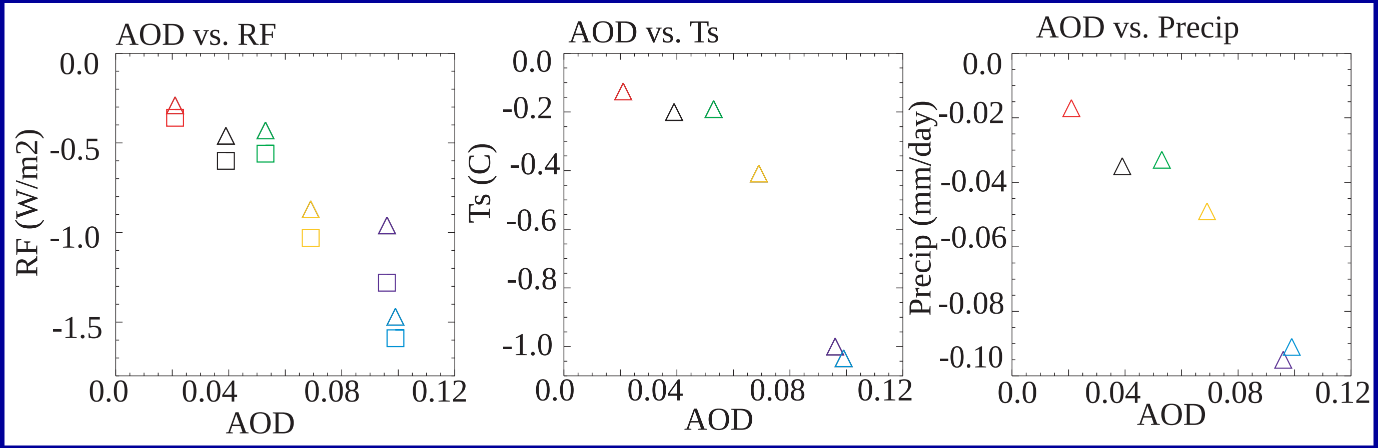
- Dust could be important feedback on Sahel precip

Yoshioka et al., 2007

Climate response to dust under different climates



Linearity in response in RF (surface or top of atmosphere) or global surface temperature or global precipitation in this model



Squares TOA, triangles SFC

True in other models? Compare to sensitivity experiments in the single scattering albedo done in GISS model (values courtesy of R. Miller: Miller and Tegen, 1998; Miller et al., 2004)