Dust flying leap: dust in a coupled carbon cycle model: CCSM3.1

N. Mahowald, K. Lindsay, A. Krishnamurty, K. Moore, S. Doney, P. Thornton, et al.

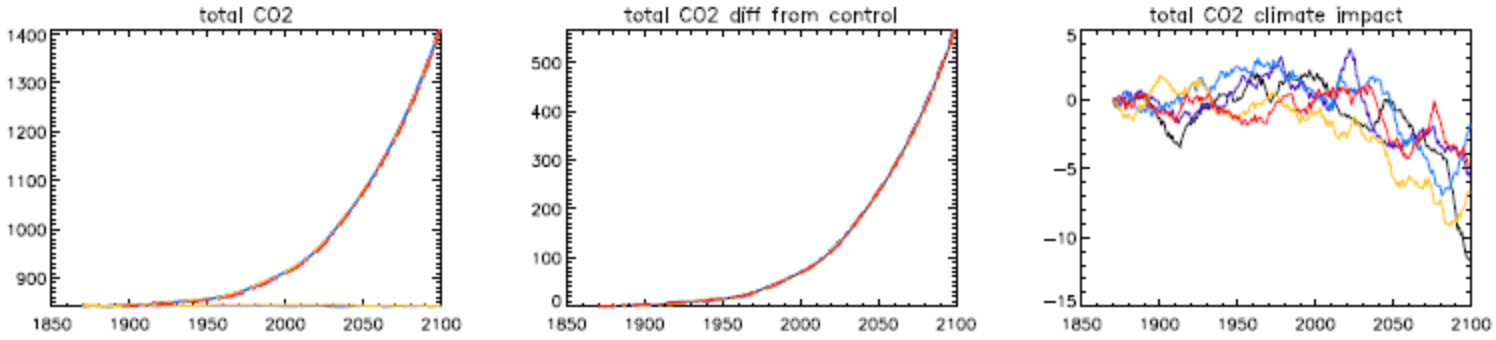
Follow on to : Thornton et al., submitted

What is impact of interactive dust on coupled carbon/climate simulations?

- Desert dust comes from dry, unvegetated soils with strong winds
- Prognostic desert dust included in CCSM3 (Mahowald et al., 2006a)
- Desert dust direct radiative effect shifts precipitation to south (Yoshioka et al., 2007)
- Iron in dust modulates ocean biogeochemistry in CCSM3 (Moore et al., 2006; Krishnamurty et al., submitted)
  - Relieves iron limitation (Martin et al., 1990)
  - Enhances nitrogen fixation (Falkowski 1998)
- Dust appears to be very sensitive to climate: (4x change 1960s to 2000 regionally, 3x globally lgm to cur)

experiments

- No dust (3 ensemble runs for transient)
  - Control simulation
  - Transient interactive CO2
  - Transient, CO2 for radiation constant
- Non equilibrium runs
  - Start out of equilibrium and repeat above to see impact
- Dust runs: couple in dust direct radiative effect and iron impacts on oceanbiogeochemistry and repeat runs

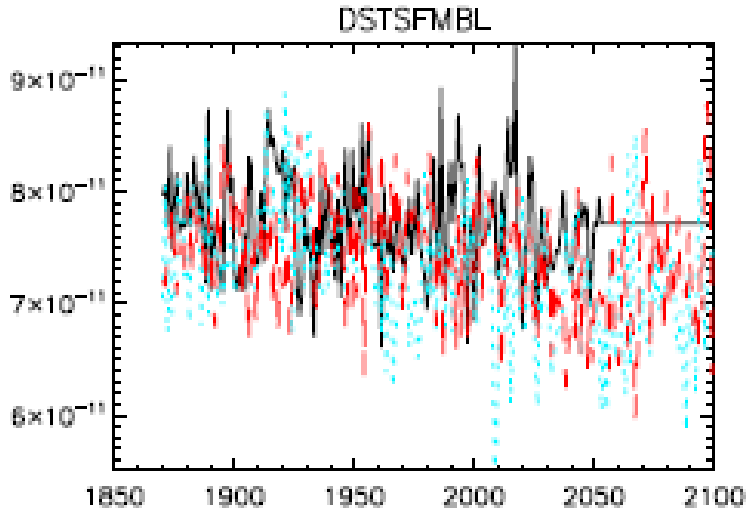


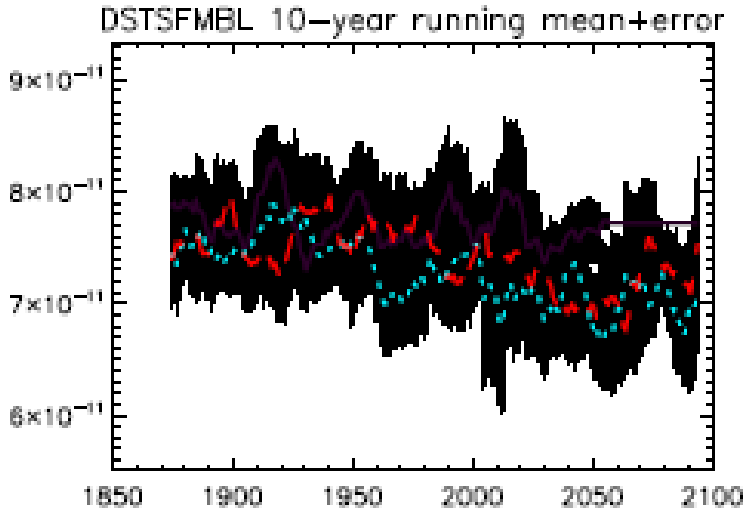
First column: time series from model, second: difference from control, third, with rad-interactive co2-without.

Colors: black, blue and purple: ensembles (black is what peter T. used for paper). Yellow=dust; Red=non-equil.

Result: including dust isn' very important

Result: dust almost different than other runs (lower climate sensitivity). Notice that black line (run peter used for paper) lower than other ensemble members (blue and purple). Non equil run (red) on the low side in terms of feebacks, but not statistically significant.





Dust source goes down slightly in model with time with increasing co2 and goes down slightly more in case with co2 radiatively interactive. This is consistent with analysis of clm-cn offline runs we did this summer—clm-cn does not change desert areas very much.

This is in contrast to results with other models (Mahowald, 2007)

Interactive dust impact on climate/biogeochemistry

Co2 ppm in atmosphere, average over last 10 years of run-control run (so increase since preindustrial at 2090-2099):

	b30.061n/o	b30.061n2/o2	b30.061n3/o3	Average of ensemble runs	dust	non equil
Co2 rad inter	525.795	528.297	528.195	527.429	519.88	523.619
Co2 not rad inter	536.036	532.698	531.921	533.5517	527.694	527.71
Co2 rad-co2 not rad	-10.241	-4.401	-3.726	-6.122667	-7.814	-4.091

Run with interactive dust has less of an increase in co2 (by 7.5ppm?) which appear statistically significant.
Dust: Range of climate feedbacks similar to ensemble member

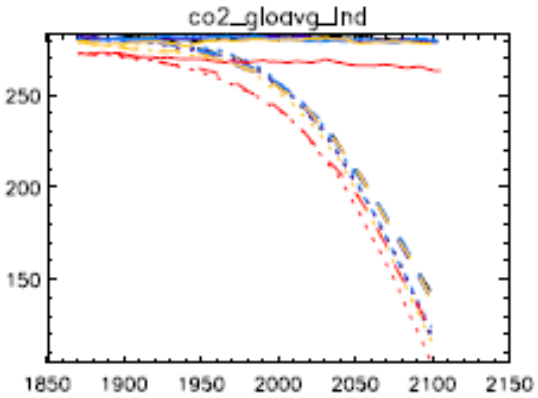
Nonequil run, has slightly less co2 at end of run, and slightly lower climate feedback (-4 vs. -6 average) but within range of ensemble members.

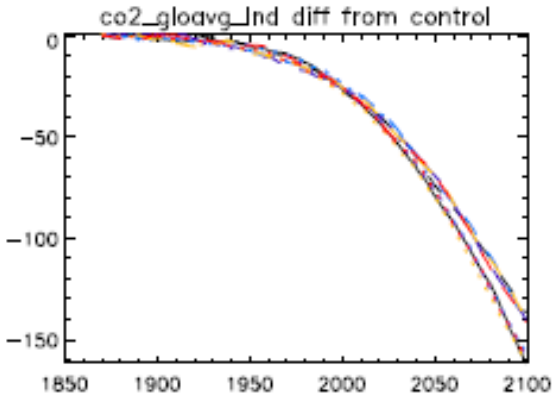
Averages over last 10 years of co2 in atmosphere (ppm).

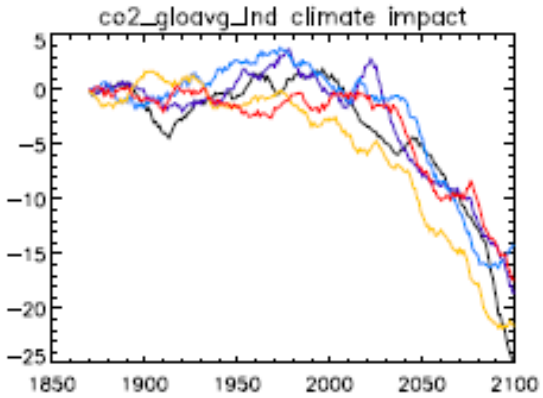
Why is final co2 different with dust? Land takes up more carbon with interactive dust (125 vs. 129), ocean takes up more (99 vs. 101) (roundoff error makes this sum to 7.8ppm)

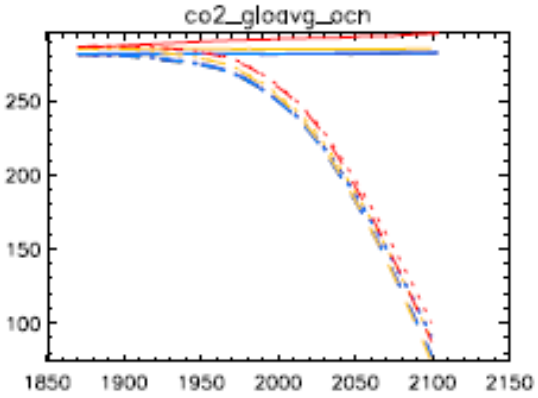
For non-equil run: land takes up more (113 vs. 129) and ocean takes up less (110 vs. 101)! This is not seen in the overall totals.

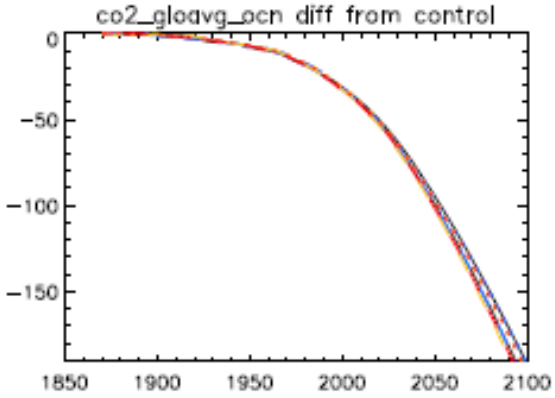
	1	2	3	avg	dust	non-equil
control land	279	279	280	280	278	264
control ocn	282	282	282	282	285	295
co2 inter lnd	127	129	131	129	125	113
co2 inter ocn	101	101	100	101	99	110
co2 non inter lnd	149	146	146	147	146	129
co2 non-inter ocn	89	89	88	89	85	98
co2 inter diff from control lnd	-153	-150	-149	-151	-154	-151
co2 inter diff from control ocn	-181	-181	-182	-181	-186	-185
co2 nonn-inter diff from control lnd	-130	-134	-134	-133	-132	-135
co2 non-inter diff from control ocn	-193	-193	-194	-193	-200	-197
climate diff inter-non: lnd	-22	-16	-15	-18	-22	-16
climate diff: inter-non:ocn	12	12	12	12	14	12
total climate diff	-10.2	-4.4	-3.7	-6.1	-7.8	-4.1

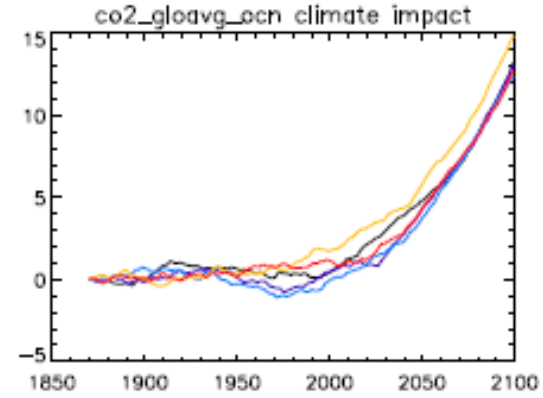




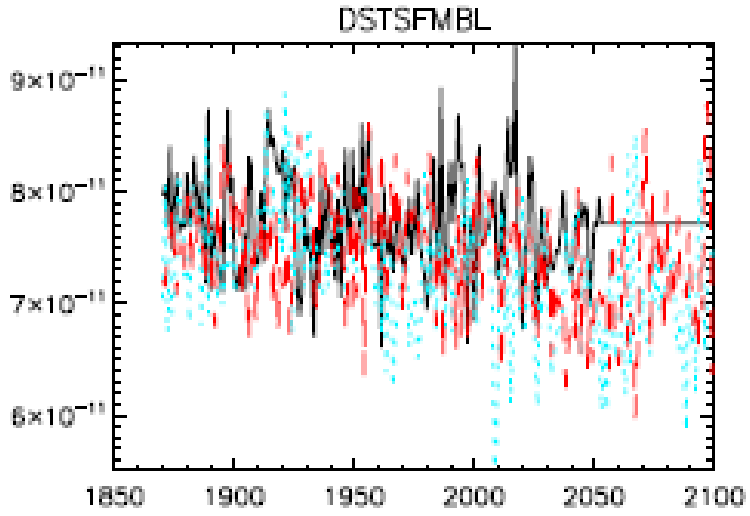


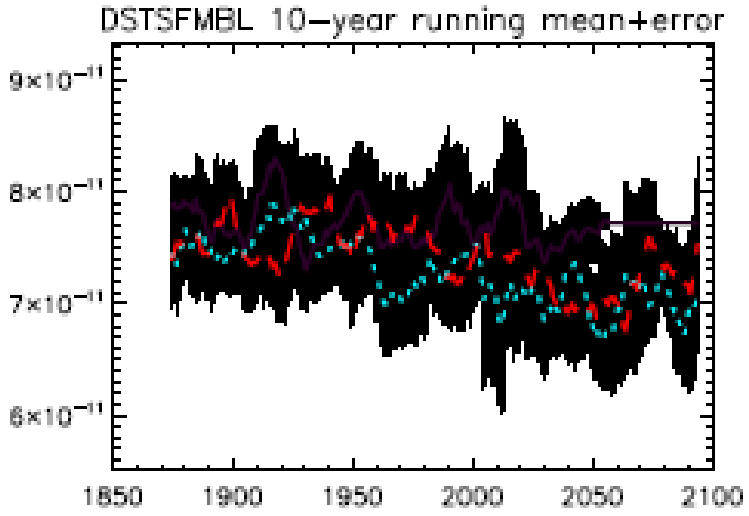






Bottom line: dust run climate feedback almost statistically significantly different for land (lower co2), stat sig different for oceans (higher co2).





Why is co2 lower in dust-co2 interactive run? Why is climate sensitivity on low side?

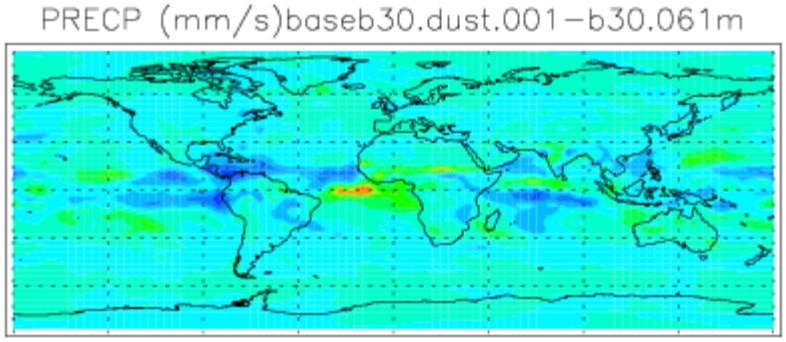
Dust source goes down slightly in model with time with increasing co2 and goes down slightly more in case with co2 radiatively interactive. This is consistent with analysis of clm-cn offline runs we did this summer—clm-cn does not change desert areas very much.

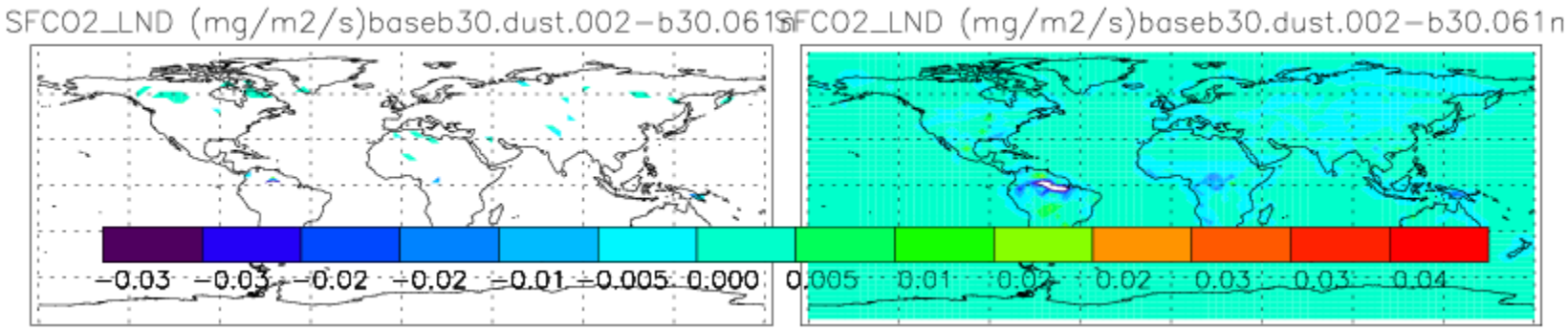
This could explain why climate sensitivity appears this way—ocean gets less dust with change in climate.

But doesn't explain why there is less co2 at 2100 with dust interactive (goes wrong way)? Switch in locations of dust?

Why differences on land side?

- Dust shifts precip south and enhances land uptake of co2 in tropics.





What next?

- Force dust to follow uncertainties
- Dust could be 60% higher now than PI, or 24% lower, depending on relative importance of CO2 fertilization, land use and climate change

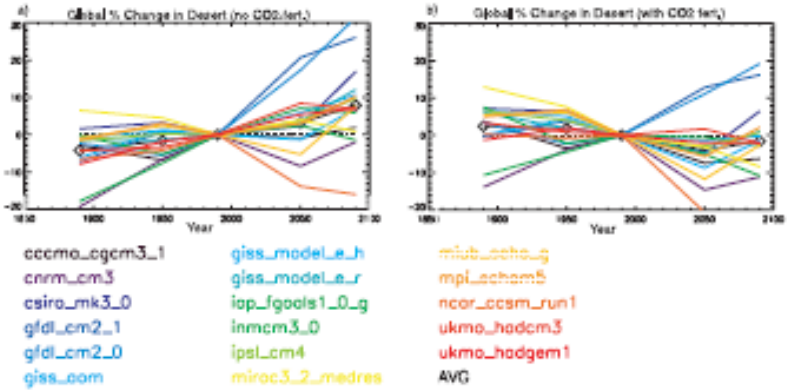


Figure 1. Globally averaged change in desert area predicted for each CMIP3 model simulation using the BIOME4 model (a) without and (b) with carbon dioxide fertilization. Each line represents a different model (listed in color), and average of all models is in black, with diamonds.