CESM2 development simulations: Are we there yet ?

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Julio Bacmeister, David Bailey, Pete Bogenschutz, Gokhan Danabasoglu, Andrew Gettelman, Jim Edwards, Marika Holland, Jean-Francois Lamarque, David Lawrence, Keith Lindsay, Rich Neale, Keith Oleson, Bill Sacks, Joe Tribbia, John Truesdale, Mariana Vertenstein, and gazillions of others.

CESM 2 development at a glance

- **Huge team effort started in Mid November 2015**
- **2 co-chair meetings/week**

Land
CLM5

Atmosphere
CAM6

Sea-ice
CICE5

Land Ice
CISM2

River Model
MOSART

Ocean
POP2

CESM 2 development simulations

http://www.cesm.ucar.edu/working_groups/Atmosphere/development/cesm1_5/

Nov 2015: First coupled

- First coupled simulation

Feb 2016: Winter Working Group Meeting

- 34 experiments ("cases")
- 1300+ years of simulations + diagnostics

June 2016: Breckenridge workshop

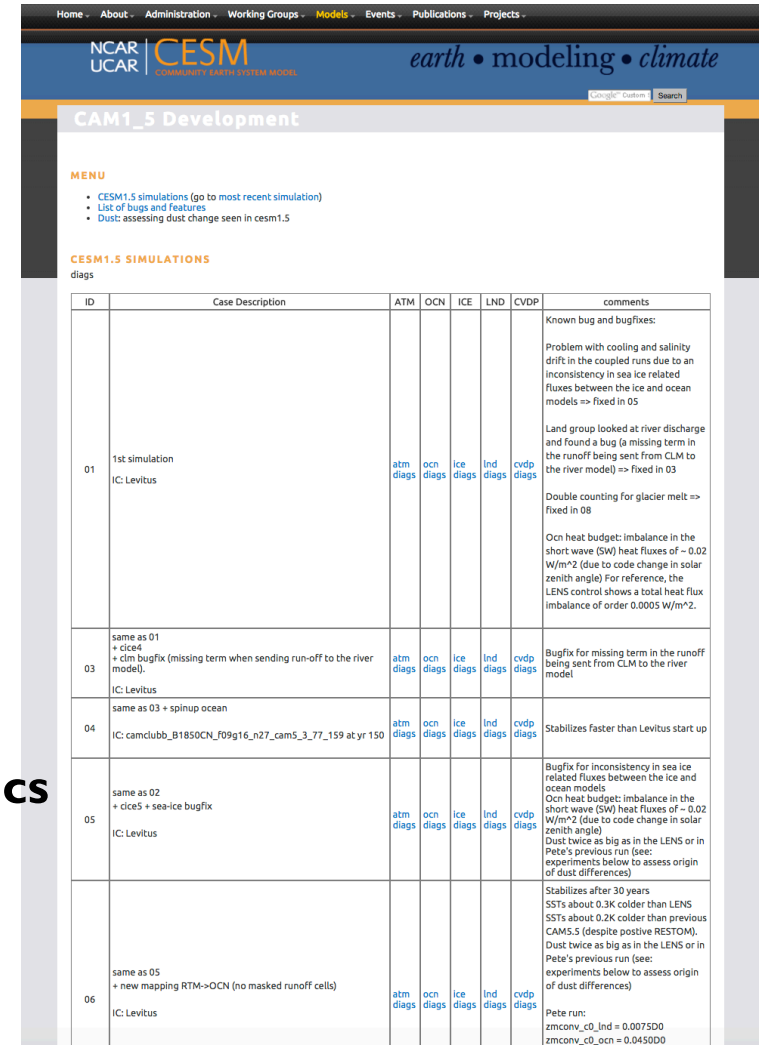
- 94 experiments ("cases")
- 2890+ years of simulations + diagnostics

Feb 2017: Winter Working Group Meeting

- 150 experiments ("cases")
- Thousands of simulated years + diagnostics

And also

- Many standalone simulations in individual working groups



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CAM1_5 Development

MENU

- CESM1.5 simulations (go to most recent simulation)
- List of bugs and features
- Dust: assessing dust change seen in cesm1.5

CESM1.5 SIMULATIONS

diags

ID	Case Description	ATM	OCN	ICE	LND	CVDP	comments
01	1st simulation IC: Levitus	atm diags	ocn diags	ice diags	lnd diags	cvdp diags	Known bug and bugfixes: Problem with cooling and salinity drift in the coupled runs due to an inconsistency in sea ice related fluxes between the ice and ocean models => fixed in 05 Land group looked at river discharge and found a bug (a missing term in the runoff being sent from CLM to the river model) => fixed in 03 Double counting for glacier melt => fixed in 08 Ocn heat budget: imbalance in the short wave (SW) heat fluxes of ~ 0.02 W/m^2 (due to code change in solar zenith angle) For reference, the LENS control shows a total heat flux imbalance of order 0.000S W/m^2.
03	same as 01 + cice4 + clm bugfix (missing term when sending run-off to the river model). IC: Levitus	atm diags	ocn diags	ice diags	lnd diags	cvdp diags	Bugfix for missing term in the runoff being sent from CLM to the river model
04	same as 03 + spinup ocean IC: camclubb_B1850CN_f09g16_n27_cam5_3_77_159 at yr 150	atm diags	ocn diags	ice diags	lnd diags	cvdp diags	Stabilizes faster than Levitus start up
05	same as 02 + cice5 + sea-ice bugfix IC: Levitus	atm diags	ocn diags	ice diags	lnd diags	cvdp diags	Bugfix for inconsistency in sea ice related fluxes between the ice and ocean models Ocn heat budget: imbalance in the short wave (SW) heat fluxes of ~ 0.02 W/m^2 (due to code change in solar zenith angle) Dust twice as big as in the LENS or in Pete's previous run (see: experiments below to assess origin of dust differences)
06	same as 05 + new mapping RTM->OCN (no masked runoff cells) IC: Levitus	atm diags	ocn diags	ice diags	lnd diags	cvdp diags	Stabilizes after 30 years SSTs about 0.3K colder than LENS SSTs about 0.2K colder than previous CAM5.5 (despite postive RESTOM). Dust twice as big as in the LENS or in Pete's previous run (see: experiments below to assess origin of dust differences) Pete run: zmconv_c0_lnd = 0.0075D0 zmconv_c0_ocn = 0.0450D0

CESM 2 development simulations

Are you lost in translation ?

Simplified terminology for this talk

CESM1	Large Ensemble (2013)	LENS
CESM1.5	Winter Working Group (Feb 2016)	28 or 36
CESM2_dev	Breckenridge (June 2016)	63, 64, 66, 79
CESM2	Winter Working Group (Feb 2017)	125

Caveat: 125 is not the "final" version of CESM2 but no major change in climate.

What happened since Breckenridge ?

At Breckenridge: we had a preliminary version of CESM2

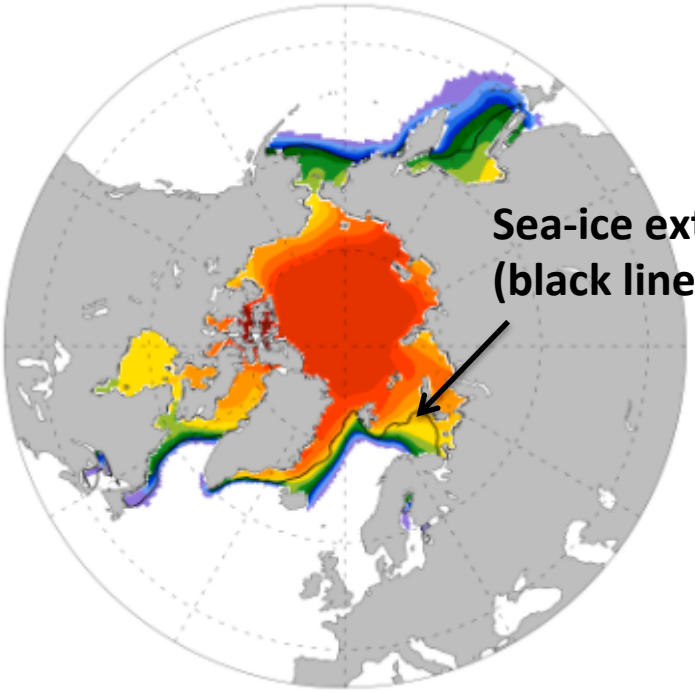
FAQ: "I thought CESM2 was almost ready at Breckenridge, what happened since then ? "

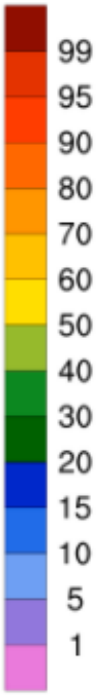
Can you spot the difference ? **The word "Almost"**

Houston, we have a problem: The Labrador Sea is freezing

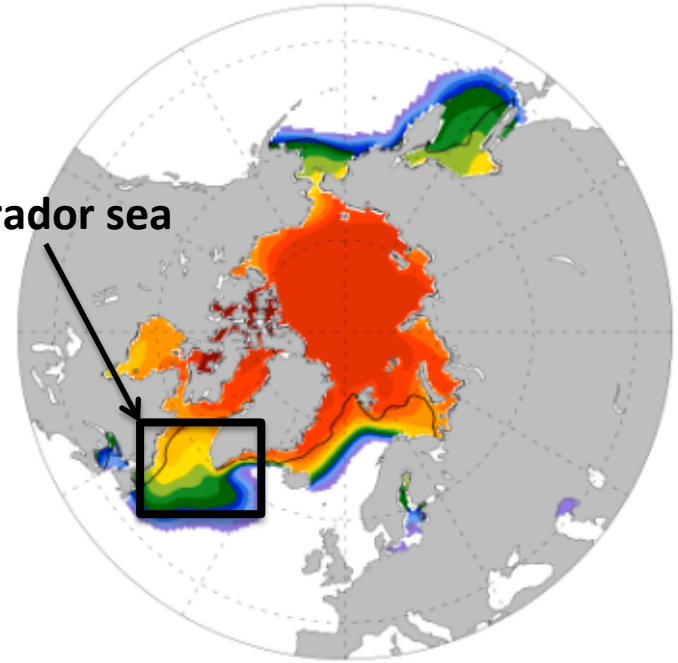
Sea-ice extent (ANN)

CESM1.5





CESM2_dev (Breckenridge)



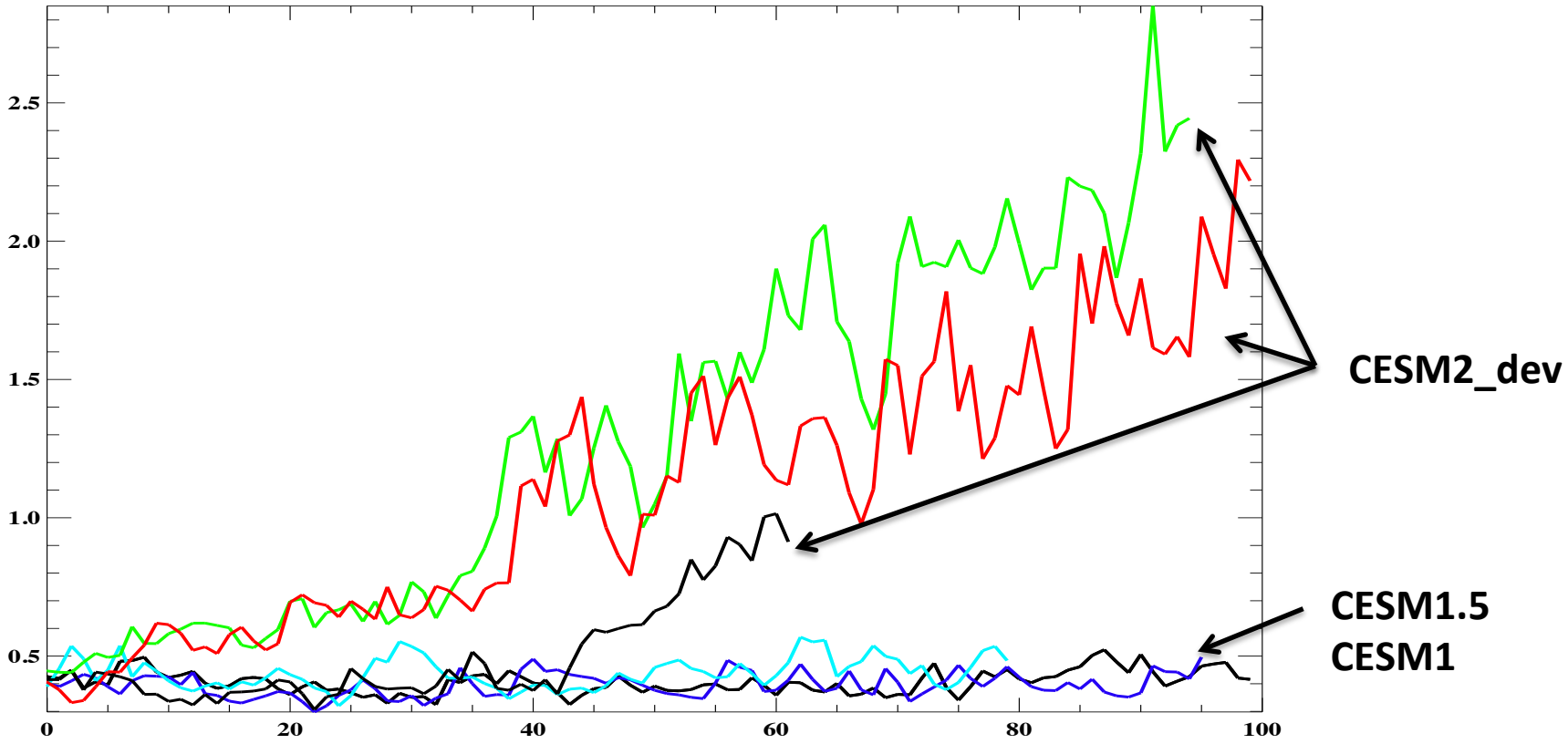
Sea-ice extent is close to obs
Labrador sea is ice free

(This is also true for LENS)

Extensive sea-ice cover
Labrador sea is ice covered

Trouble in the Labrador Sea

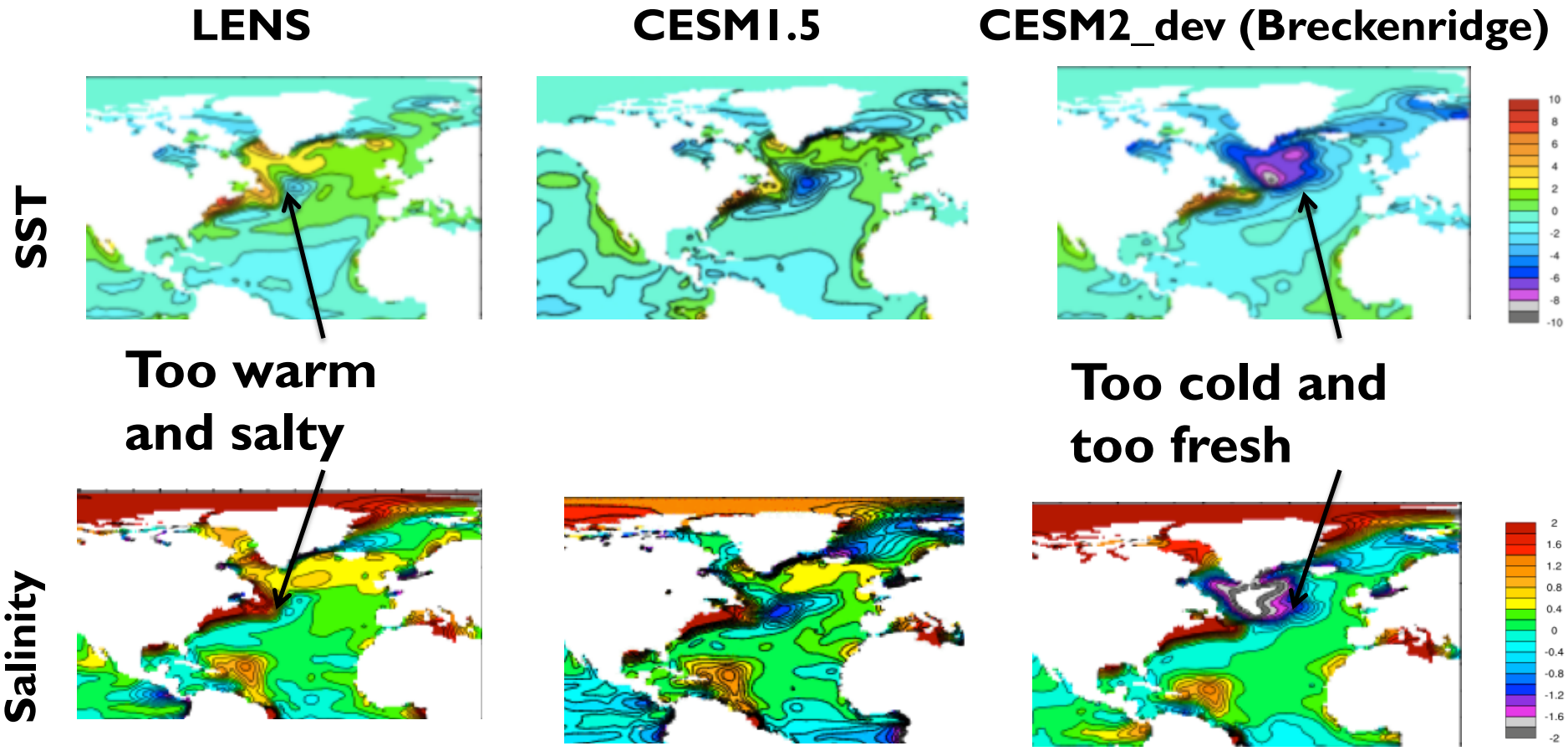
Timeseries of sea ice thickness in Labrador sea



Sea ice is building up in Labrador sea

This can happen after 1 yr, 40 yr, 100^{+} yr

SST and salinity bias



CESM2_dev: Too cold and too fresh South of Greenland.
Fresh water pool prevent further mixing

Solving the Labrador Sea problem

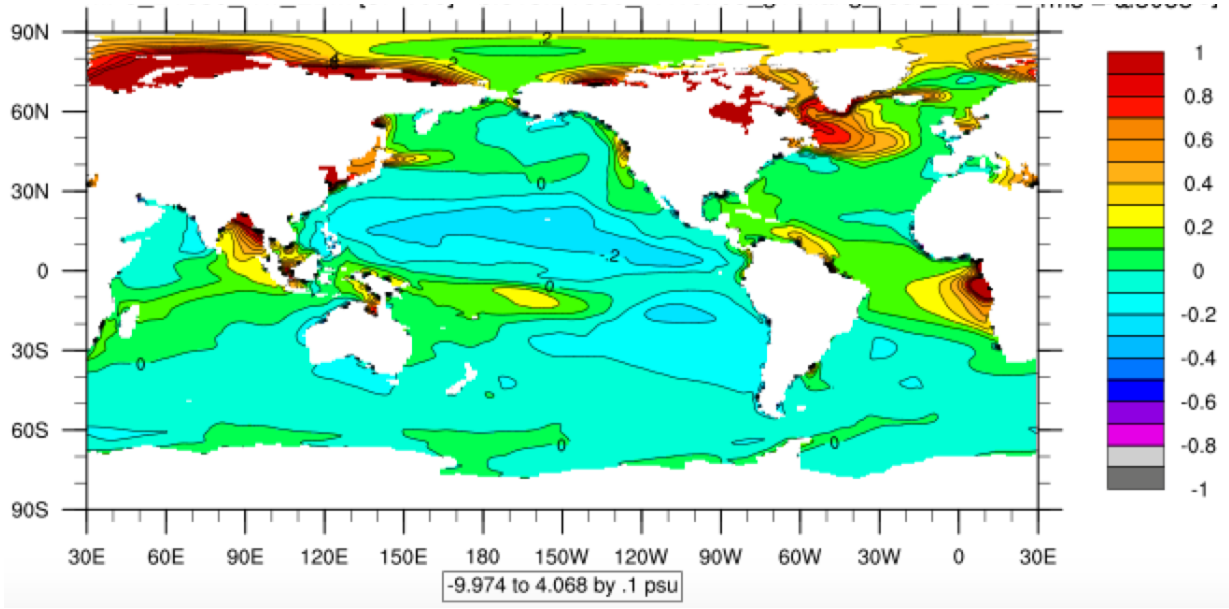
After Breckenridge, multiple attempts to solve the issue

We found out it is a very robust feature in CESM2_dev

Estuary Box Model (EBM) to the rescue!

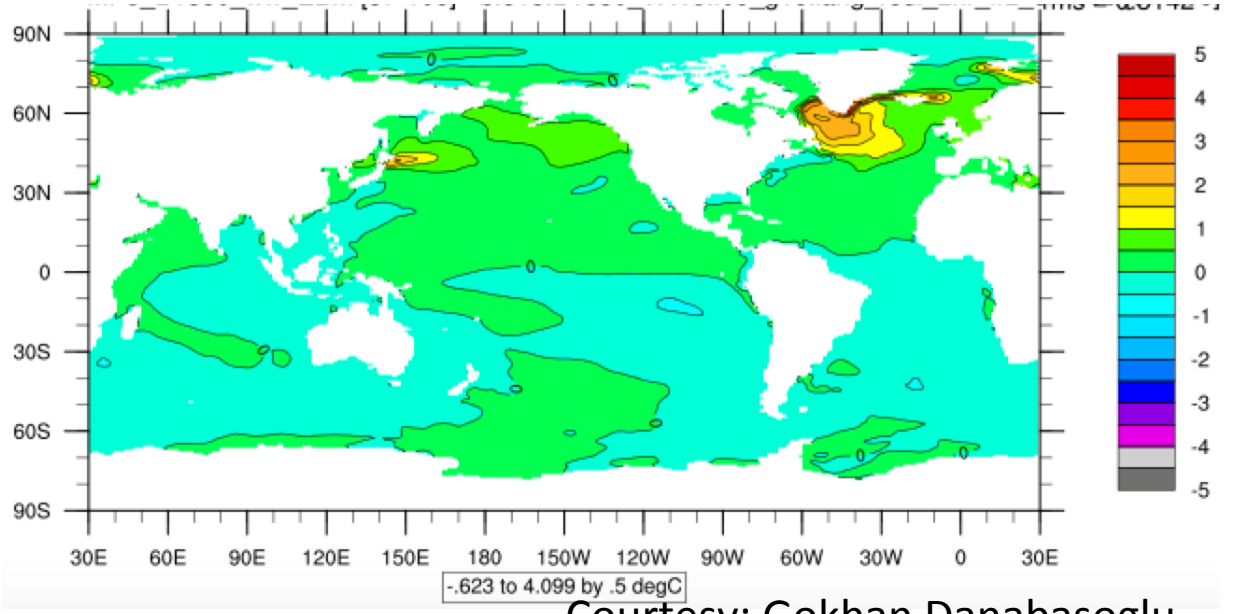
EBM – CONTROL (COUPLED)

Sea surface salinity



Sea surface temperature

EBM – CONTROL (COUPLED)



Courtesy: Gokhan Danabasoglu

What happened since Breckenridge ?

It was not only fixing the Labrador Sea

Nitrogen cycle

CMIP6 emission

Caspian Sea

crop

Robert Filter

CESM2

CLUBB bugfix

Tuning

GW tuning

1 hour coupling

Climate sensitivity

Angular momentum

Greenland precipitation

Volcanos

Quick glance at CESM milestones

The rest of the talk will highlight some differences between:

CESM1
LENS

2014

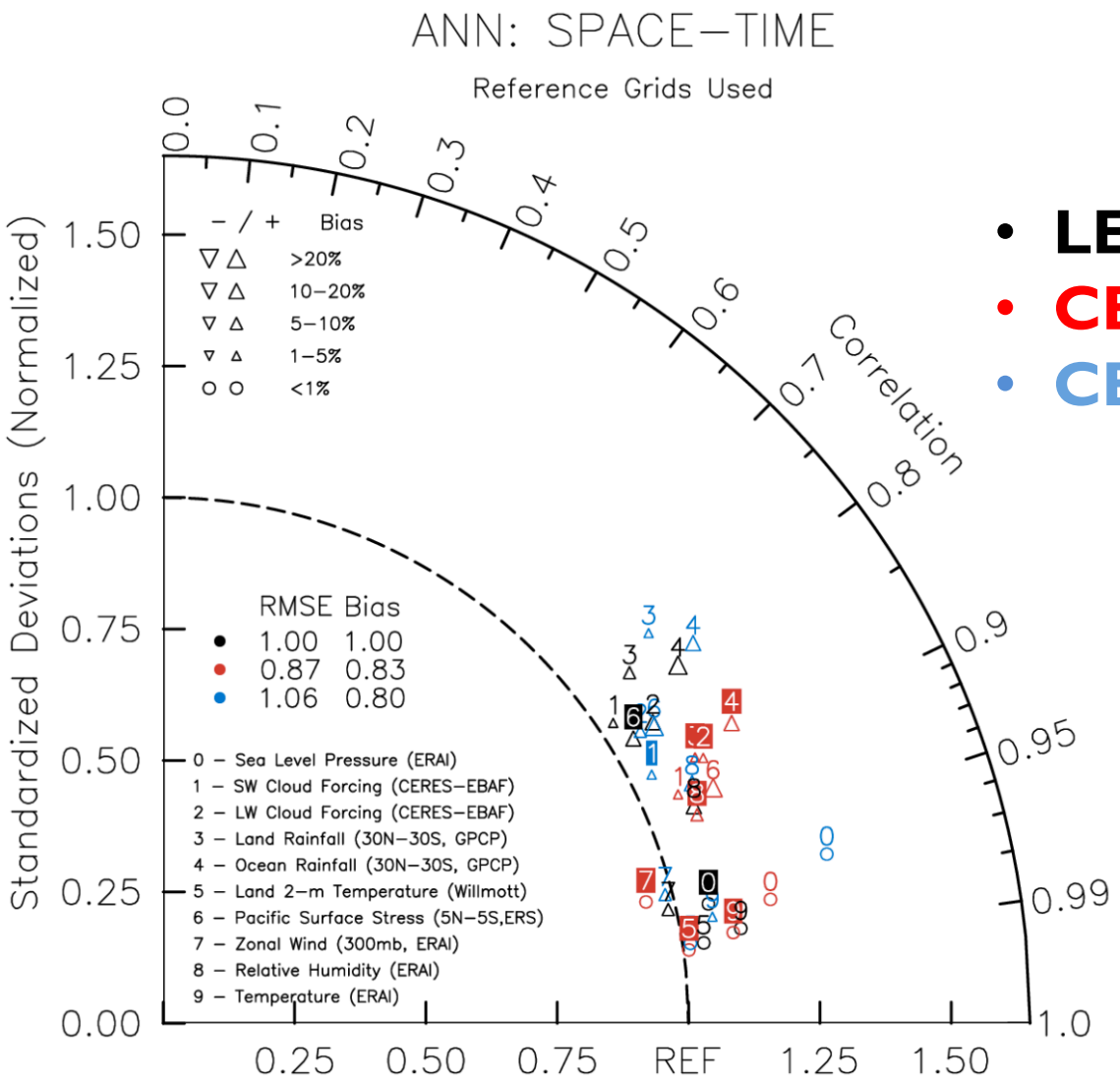
CESM1.5

Feb 2016

CESM2

Feb 2017

Taylor Diagram

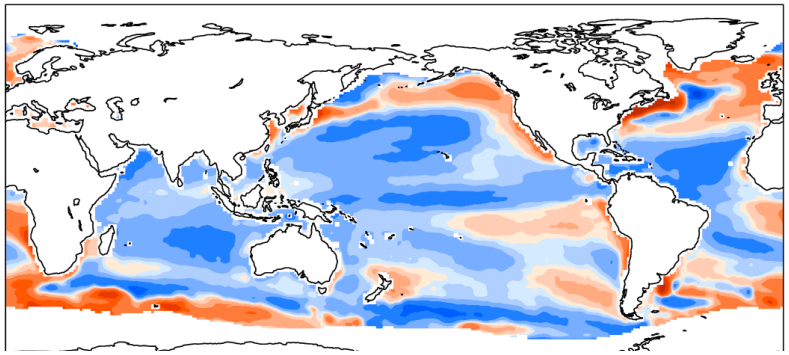


	RMSE	Bias
• LENS	1.00	1.00
• CESM2	0.87	0.83
• CESM1.5	1.06	0.80

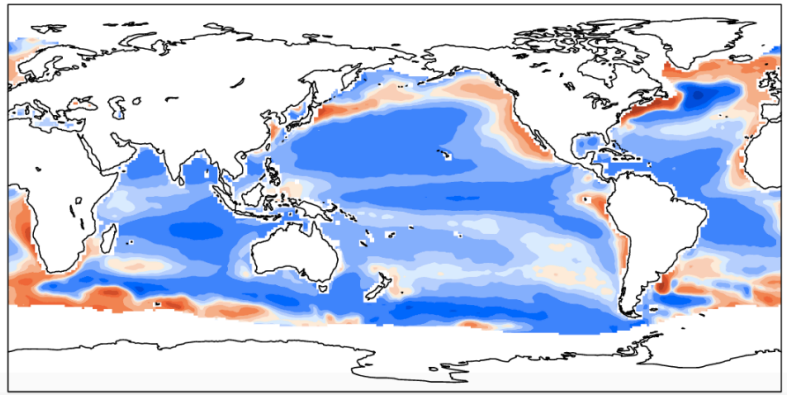
Taylor score was degraded in CESM1.5
CESM2 is better than LENS

Sea Surface Temperature (SST) bias (ANN)

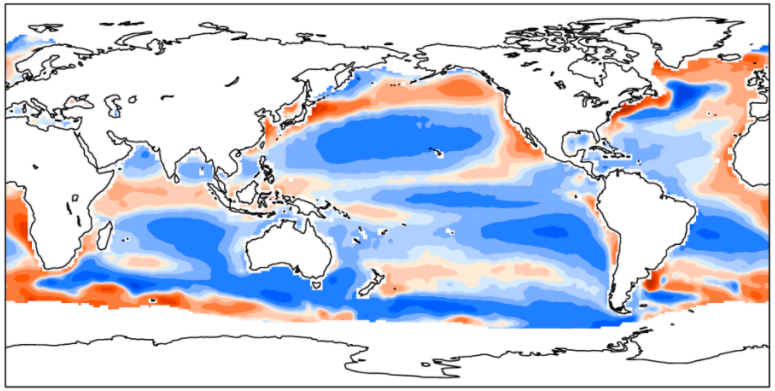
LENS
Bias = -0.24K
RMSE = 0.91

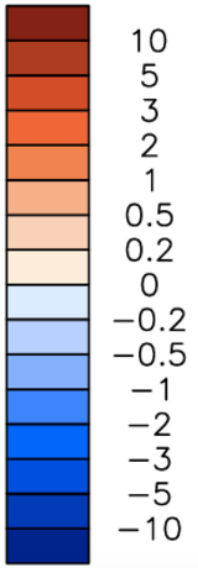


CESM1.5
Bias = -0.62K
RMSE = 1.12



CESM2
Bias = -0.32K
RMSE = 0.98

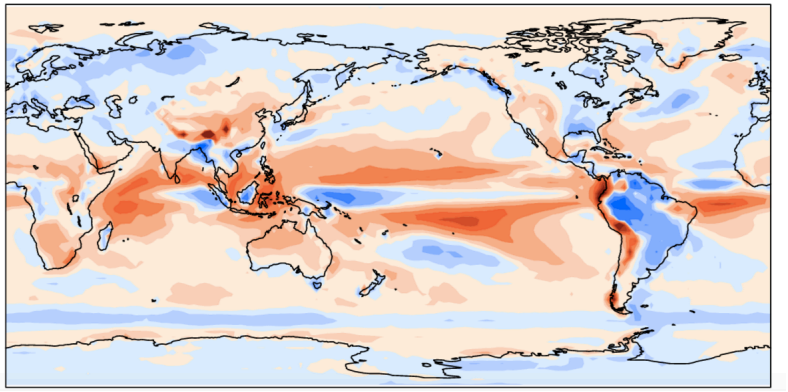




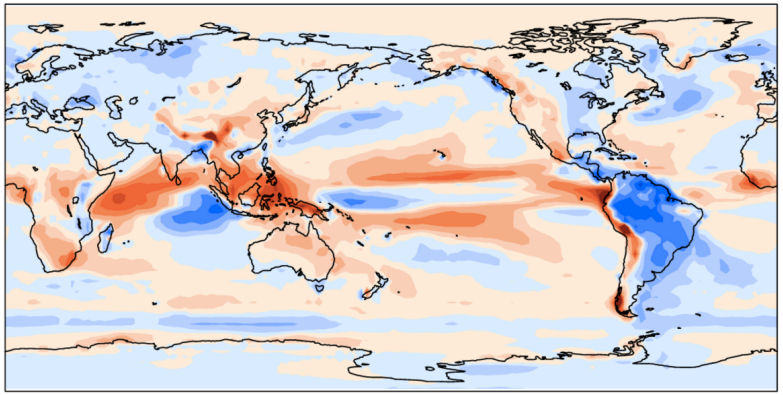
RMSE improves in CESM2 compared to CESM1.5 but not as good as in LENS

Precipitation bias versus GPCP (ANN)

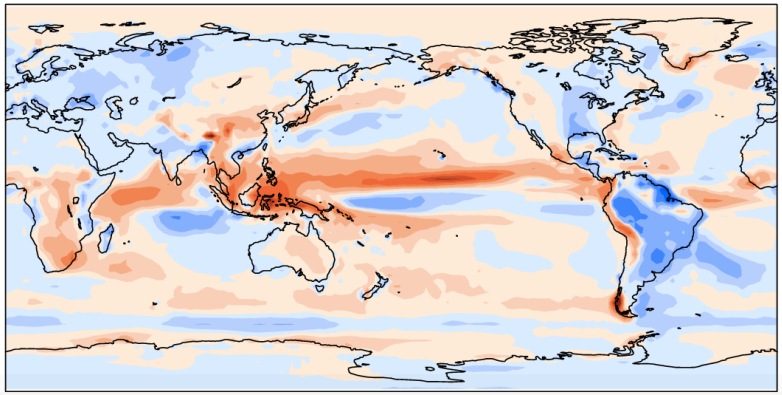
LENS
Bias = 0.37
RMSE = 1.13
(mm/day)

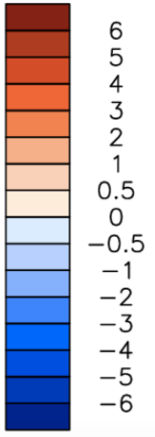


CESM1.5
Bias = 0.19
RMSE = 1.12
(mm/day)



CESM2
Bias = 0.18
RMSE = 0.89
(mm/day)

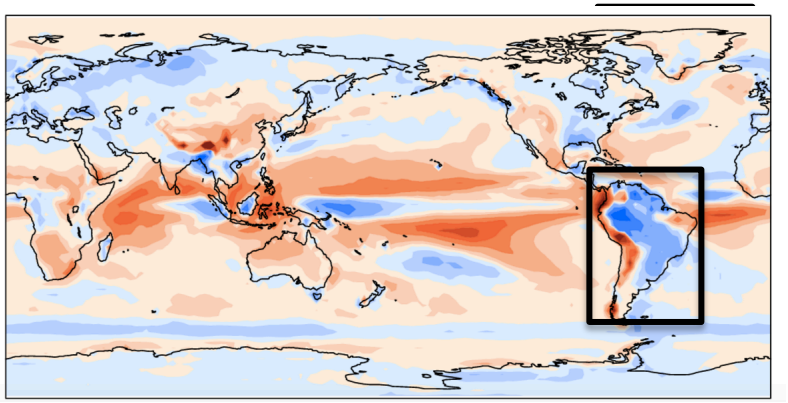


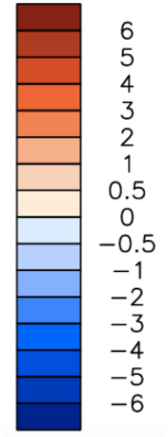


Improved precip RMSE

Precipitation bias versus GPCP (ANN)

LENS
Bias = 0.37
RMSE = 1.13
(mm/day)





CESM1.5
Bias = 0.19
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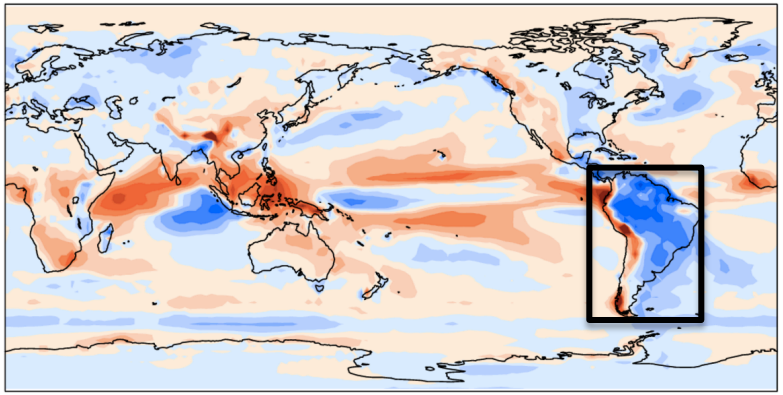
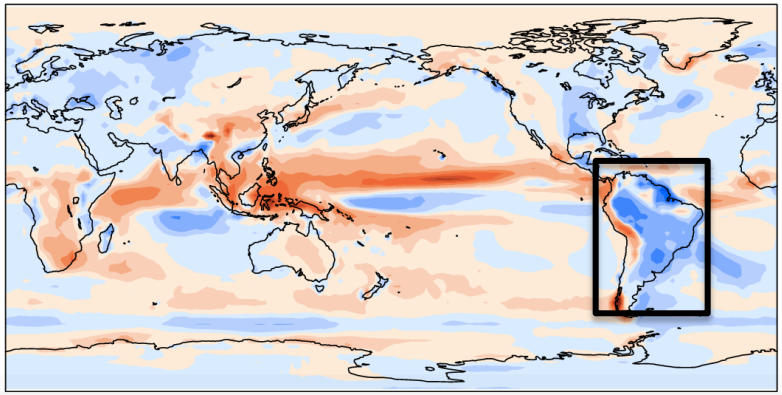
(mm/day)



CESM2
Bias = 0.18
RMSE = 0.89
(mm/day)

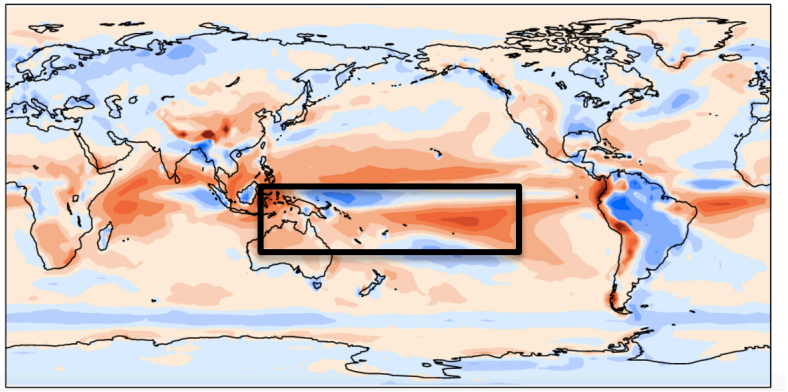


Improved precip RMSE

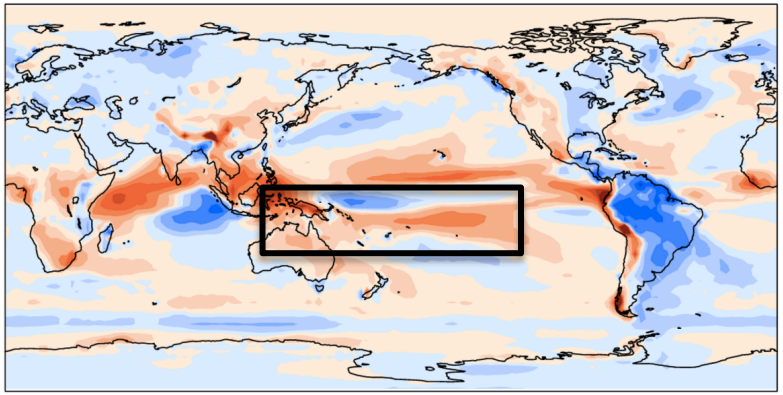
Better precip over Amazon

Precipitation bias versus GPCP (ANN)

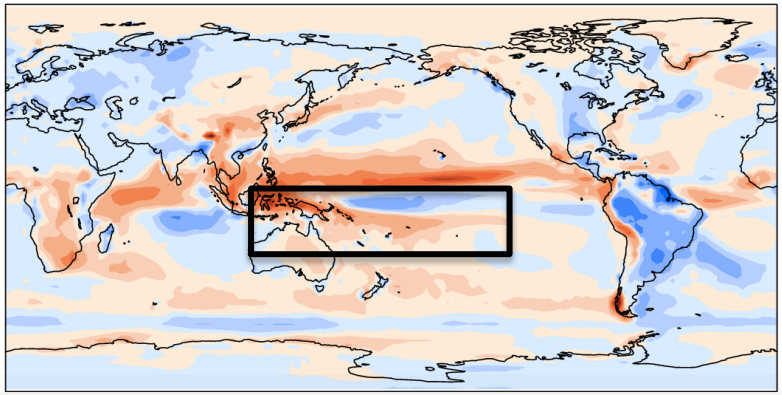
LENS
Bias = 0.37
RMSE = 1.13
(mm/day)

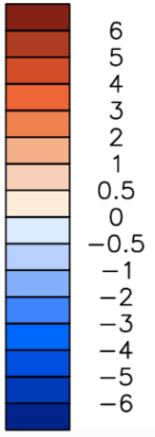


CESM1.5
Bias = 0.19
RMSE = 1.12
(mm/day)



CESM2
Bias = 0.18
RMSE = 0.89
(mm/day)





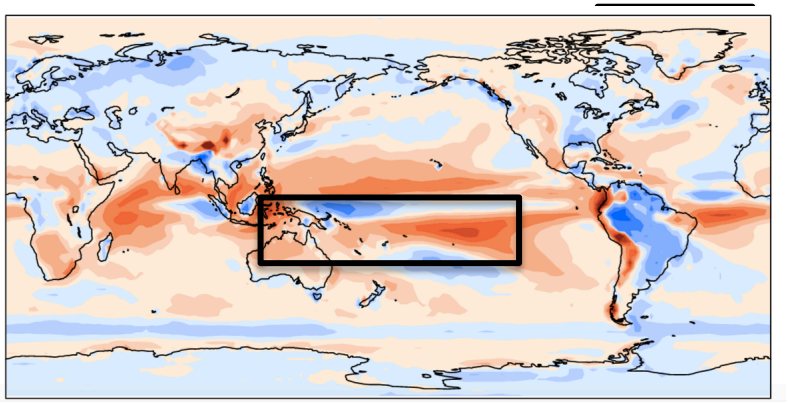
Improved precip RMSE

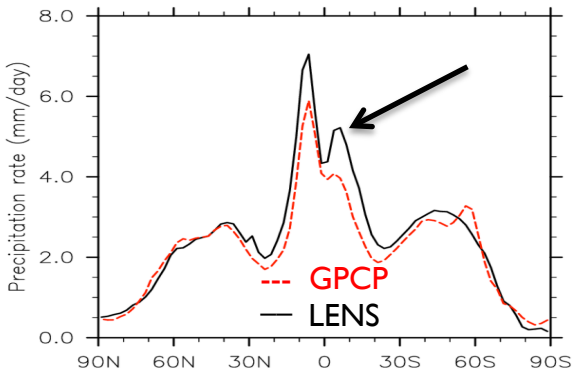
Better precip over Amazon

Improved tropical precip

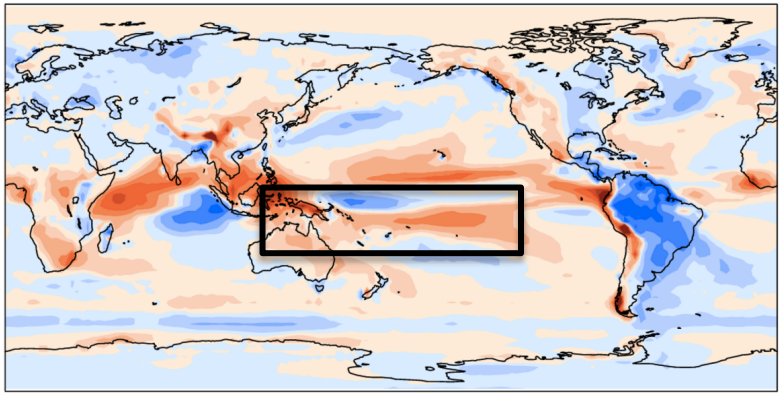
Precipitation bias versus GPCP (ANN)

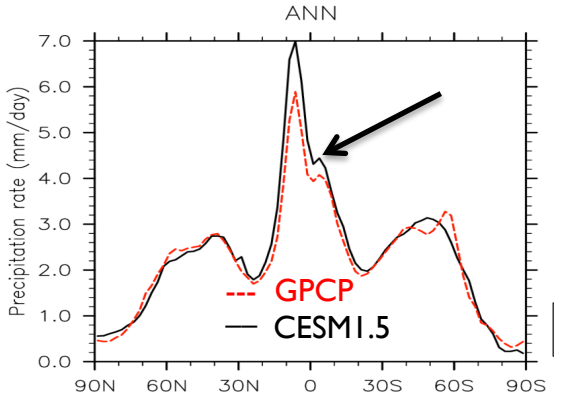
LENS
Bias = 0.37
RMSE = 1.13
(mm/day)



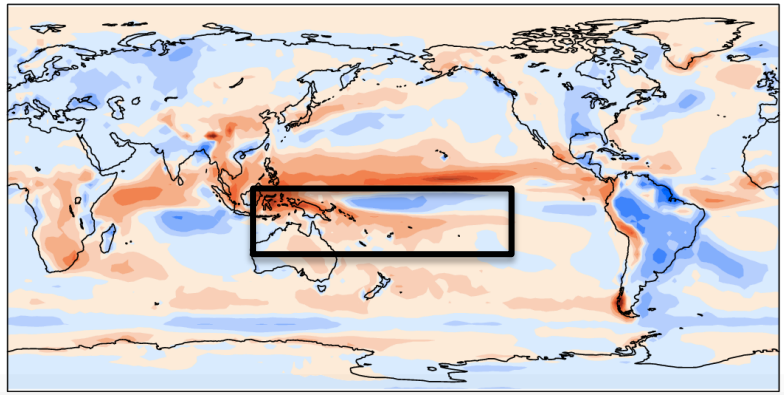


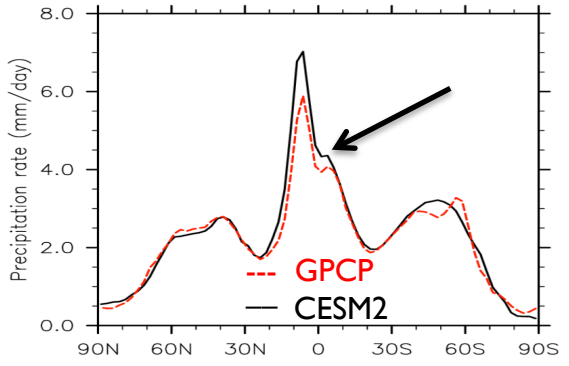
CESM1.5
Bias = 0.19
RMSE = 1.12
(mm/day)





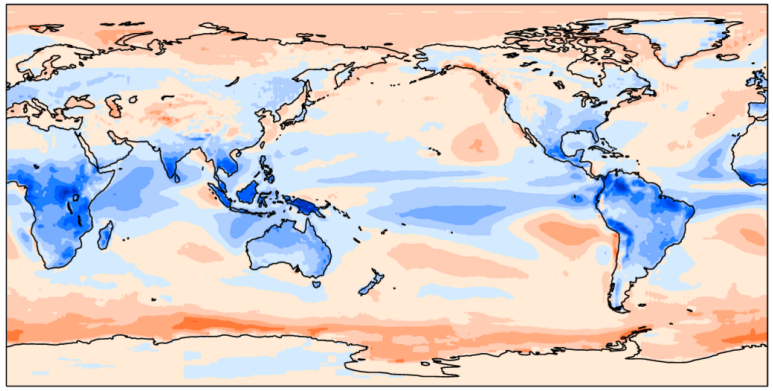
CESM2
Bias = 0.18
RMSE = 0.89
(mm/day)

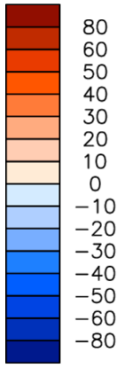




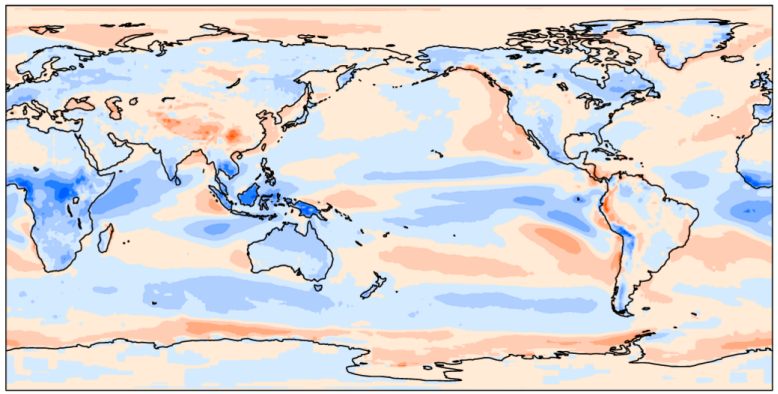
SWCF bias versus CERES-EBAF (ANN)

LENS
Bias = -1.18
RMSE = 13.7
(W/m2)



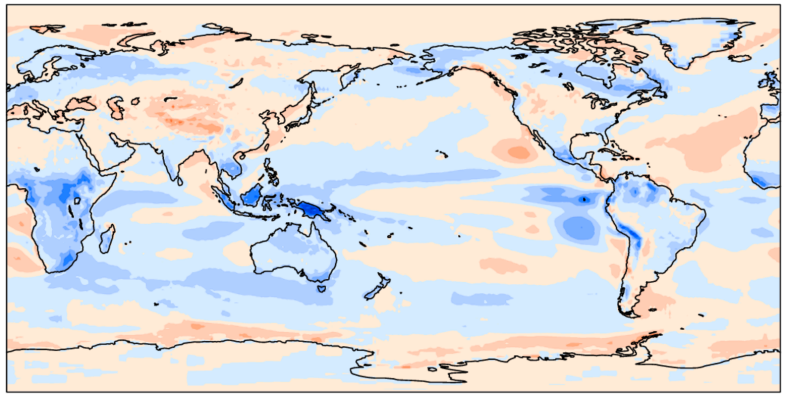


CESM1.5
Bias = -0.98
RMSE = 10.9
(W/m2)



CESM1.5: improved SWCF

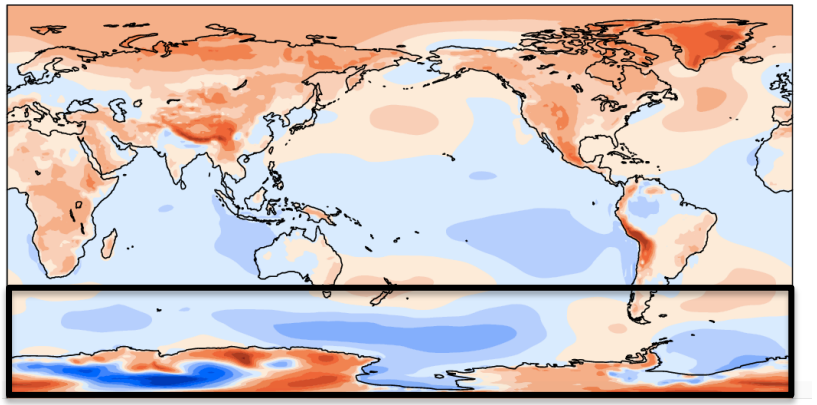
CESM2
Bias = -1.43
RMSE = 8.97
(W/m2)



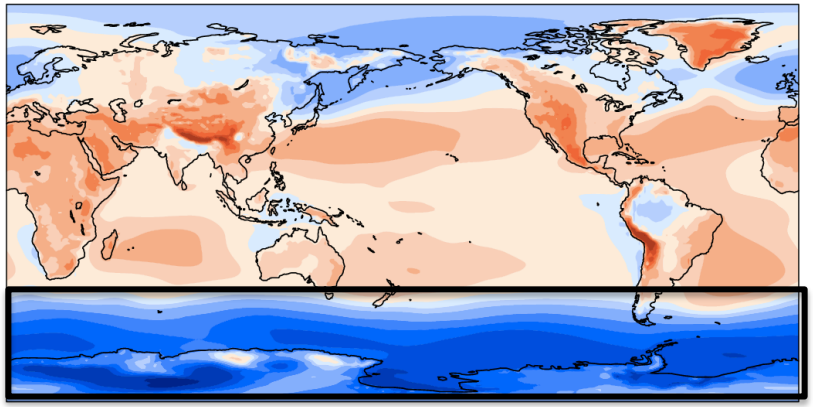
CESM2: even better

Sea-level pressure versus MERRA (ANN)

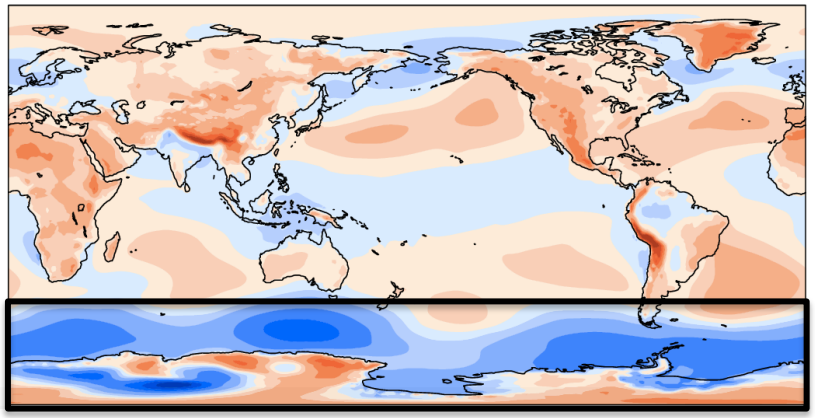
LENS
Bias = 0.29
RMSE = 1.61
(mbar)

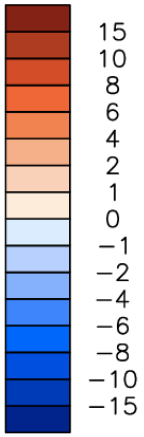


CESM1.5
Bias = 0.09
RMSE = 3.02
(mbar)



CESM2
Bias = 0.29
RMSE = 1.86
(mbar)





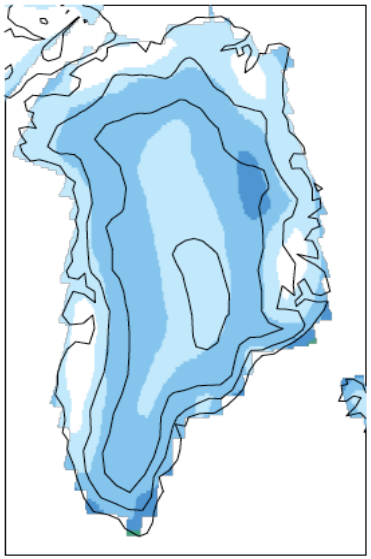
Improved SLP in Southern Ocean

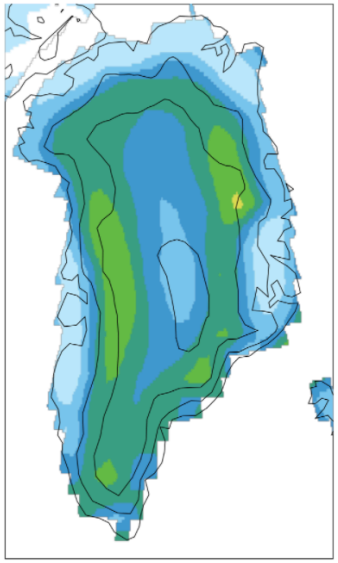
RMSE improves in CESM2 compared to CESM1.5 but not as good as in LENS

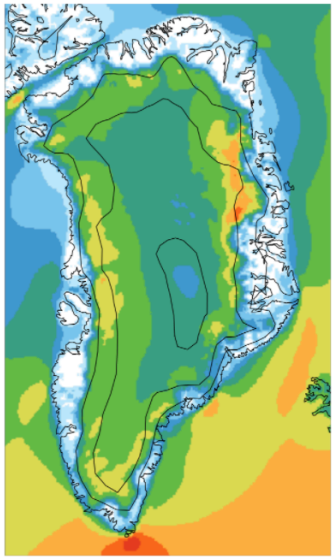
Greenland and Antarctica surface winds

CESM1.5 CESM2 Obs (RACMO2.3)

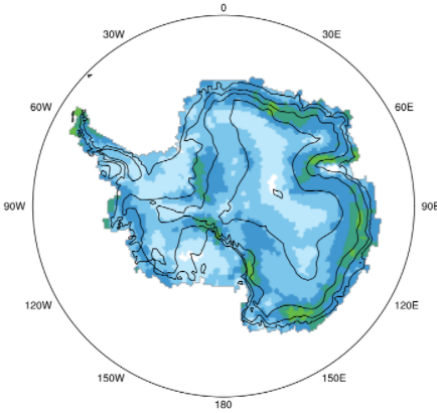
Greenland

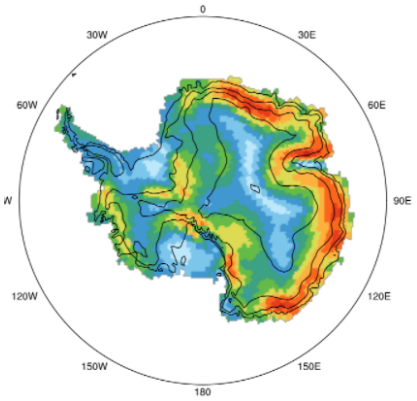


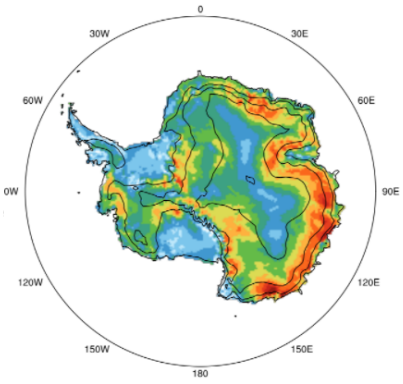




Antarctica



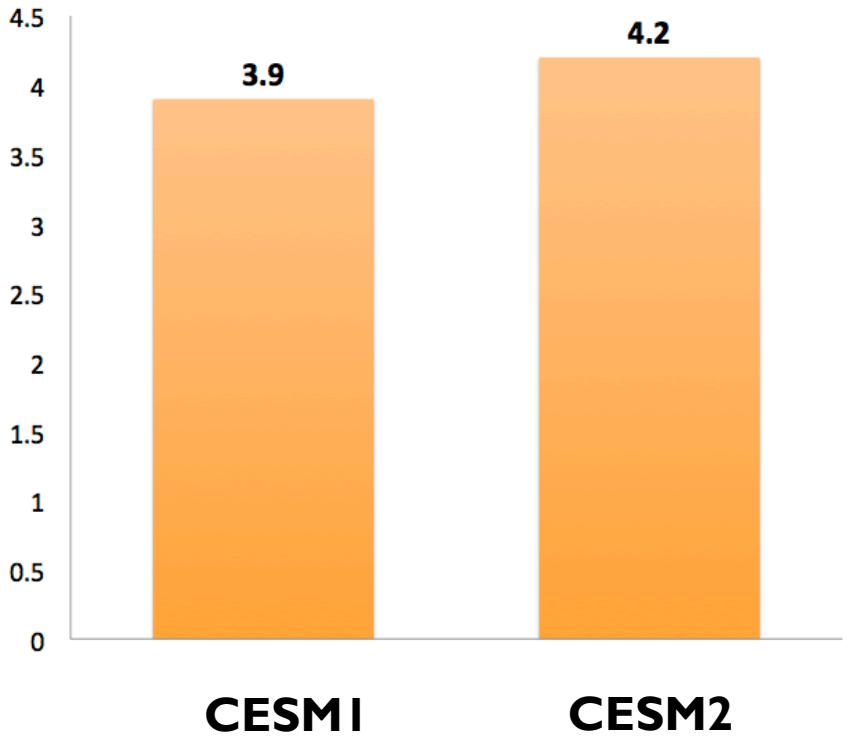




Courtesy Lenaerts

Climate sensitivity

- **Climate sensitivity in Slab Ocean Model experiments**
- **Qfluxes computed from 1850 control**
- **CS = $T_{equilibrium}$ (2xco2) - $T_{equilibrium}$ (1xco2)**

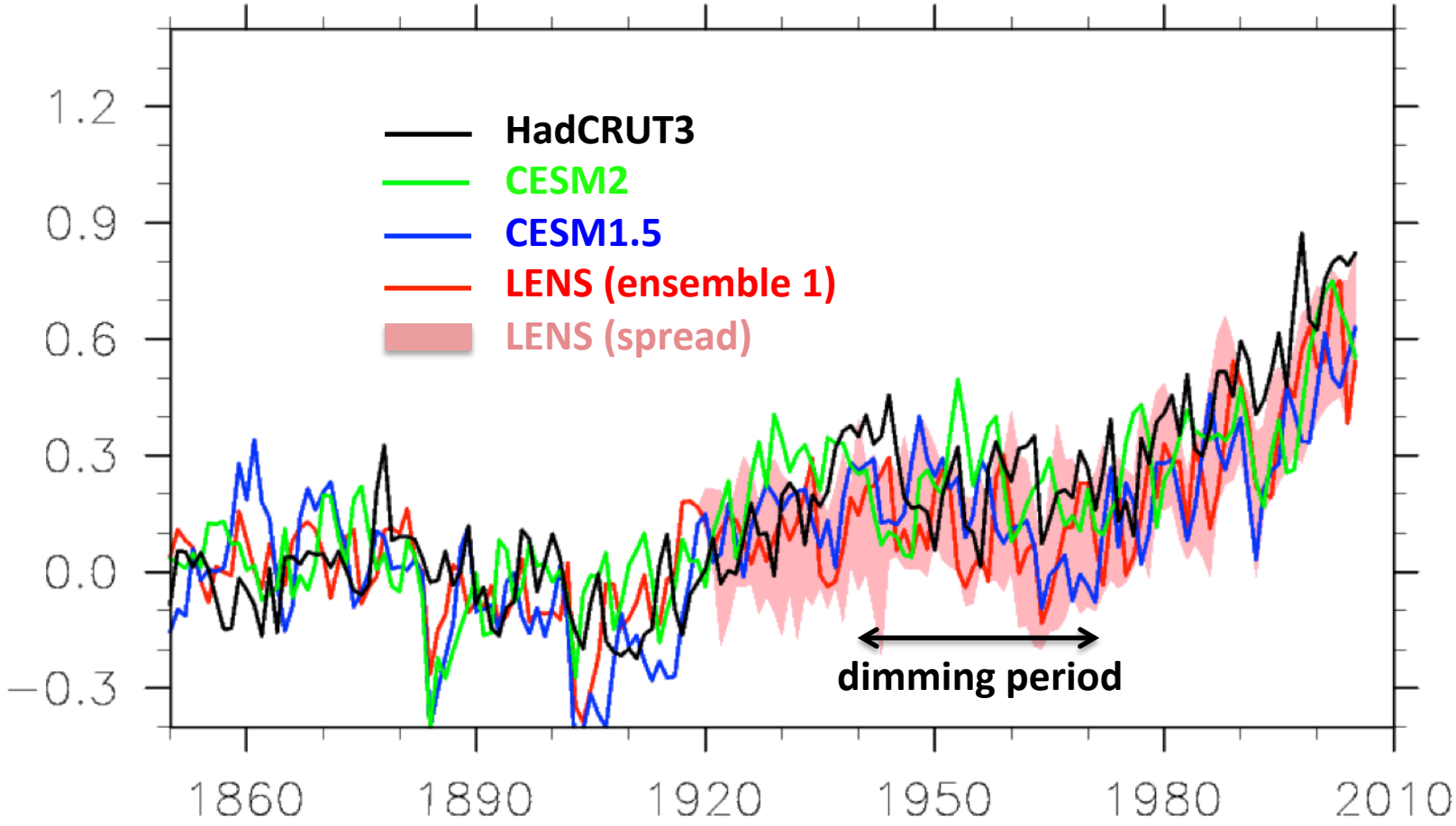


Aerosol indirect effect

	Direct (W/m2)	Indirect (W/m2)
IPCC values	-0.5 [-0.9 to -0.1]	-0.7 [-1.8 to -0.3]
LENS	-0.2	-1.4
CESM1.5	-0.4	-1.8
CESM2	-0.3	-1.6

CESM1.5: aerosol indirect effect were too strong
CESM2: New autoconversion reduced indirect effect

20th century warming



CESM1.5

- **not enough warming over 20thC**
- **too much cooling during dimming period**

CESM2

- **warmer 20th century**
- **aerosol effect reduced during dimming period**

Are we there yet ?

Yes, we are

This has been 15 months of intense work

We had good days

We had bad days

We always found the cause of our problems

Extra slides

Beyond 125

Changes for final version:

- **Subgrid-scale topography representation around Greenland (different scale due to very strong winds)**
- **Caspian sea: from ocean model to land model (lake)**
- **Update to land vegetation parameters (little climate impact, mostly for carbon-cycle improvements)**
- **Crop improvement**
- **CMIP6 emissions**
- **Robert Filter**
- **1 hour coupling atm ⇔ ocn**
- **Ocean initial conditions from LENS**
- **Dust tuning**
- **Ocean biogeochemisty**