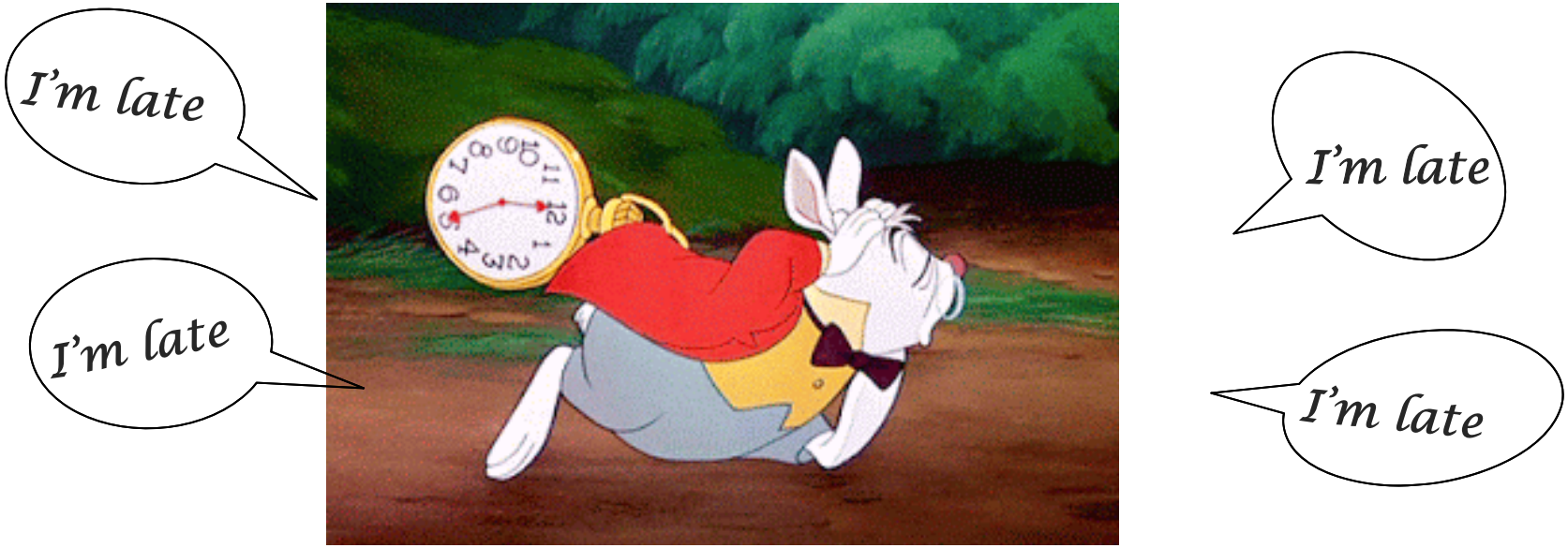
Where are we with the CESM2 coupled simulations ?

Cécile Hannay, Julio Bacmeister, Rich Neale, and Andrew Gettelman,

Jean-Francois Lamarque, Simone Tilmes, Louisa Emmons, Mike Mills, David Lawrence, Keith Oleson, Gokhan Danabasoglu, Keith Lindsay, David Bailey, Marika Holland, Bill Sacks, John Truesdale, Mariana Vertenstein, and gazillions of others.



Development of the individual components

CESM2 - Phase 1: "Let's build it"

- Individual components were built within each working group
- Effort started around 2010

Land
CLM5

Sea-ice
CICE5

Ocean
POP2

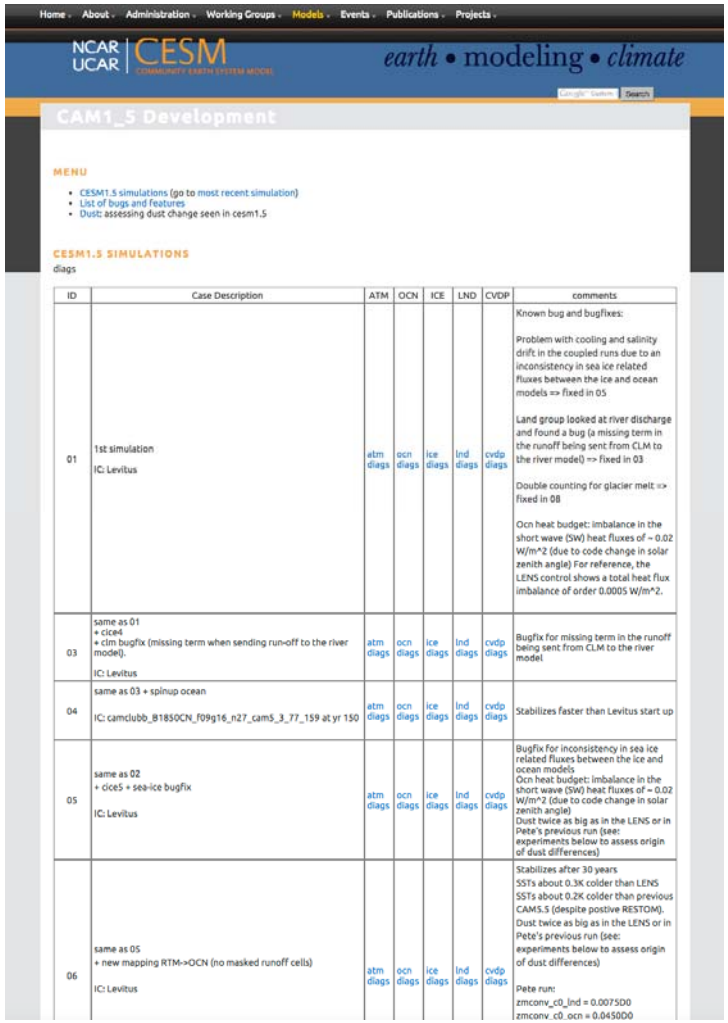
Land Ice
CISM2

Atmosphere
CAM6

Coupling of the individual components

CESM2 - Phase 2: "Let's put it together"

- **Collaborative effort started in Nov 2015**
- **2 co-chair meetings per week**
- **200 cases**
- **Thousands of simulated years and diagnostics**



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NCAR UCAR | CESM COMMUNITY EARTH SYSTEM MODEL — *earth • modeling • climate*

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

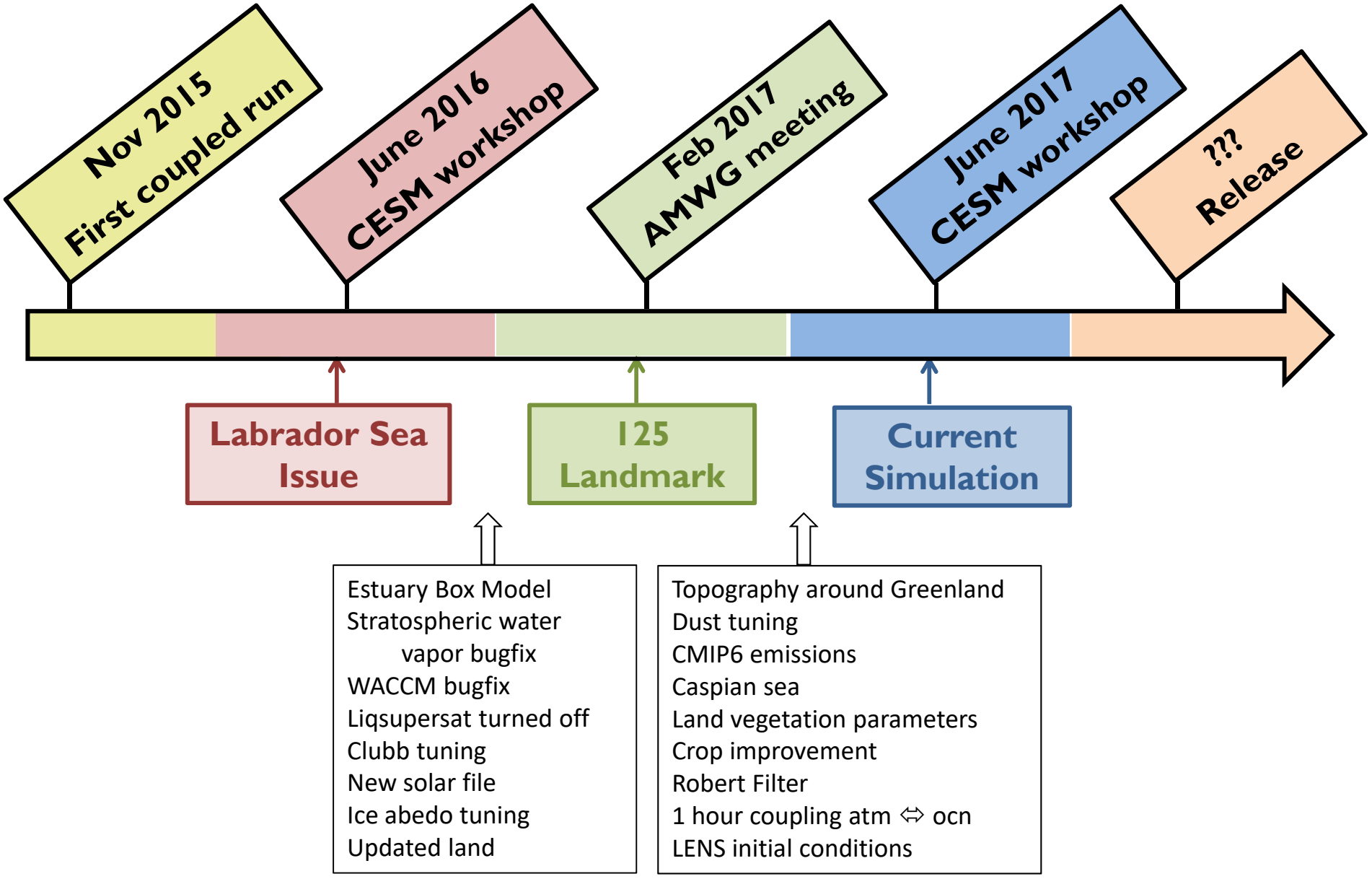
CESM1.5 SIMULATIONS

diags

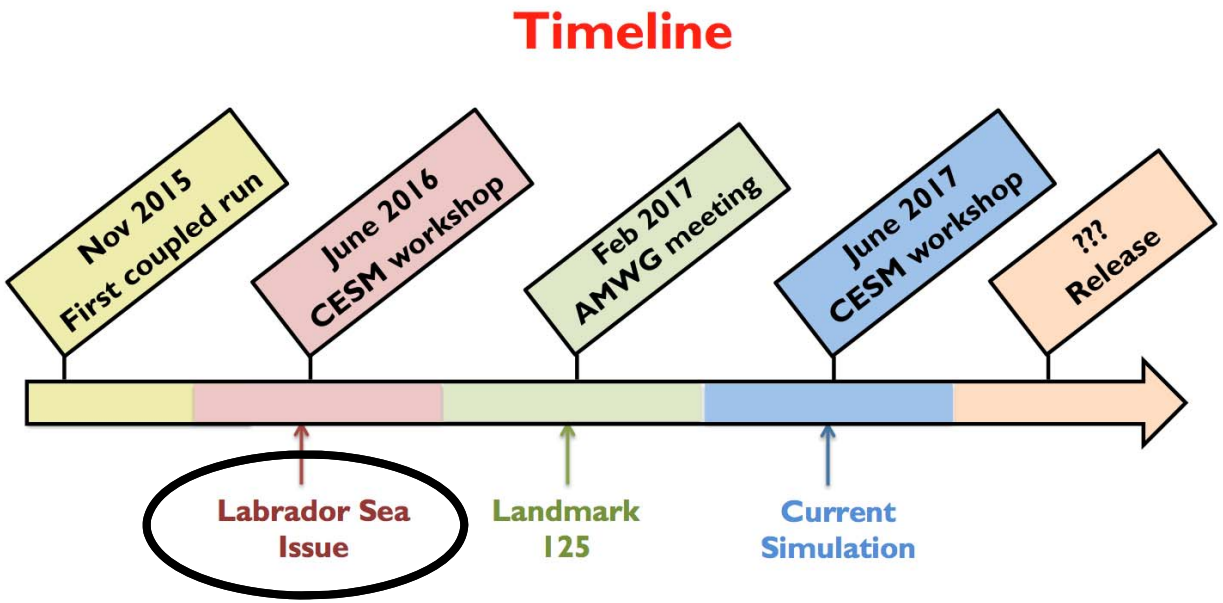
ID	Case Description	ATM	OCN	ICE	LND	CVDP	comments
01	1st simulation IC: Levitus	atm diags	ocn diags	ice diags	lnd diags	cvdp diags	Known bug and bugfixes: Problem with cooling and salinity drift in the coupled runs due to an inconsistency in sea ice related fluxes between the ice and ocean models => 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 0.0005 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

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

Timeline


Nov 2015
First coupled run
June 2016
CESM workshop
Feb 2017
AMWG meeting
June 2017
CESM workshop
???
Release
Labrador Sea Issue
I25 Landmark
Current Simulation
Estuary Box Model
Stratospheric water vapor bugfix
WACCM bugfix
Liqsupersat turned off
Clubb tuning
New solar file
Ice abedo tuning
Updated land
Topography around Greenland
Dust tuning
CMIP6 emissions
Caspian sea
Land vegetation parameters
Crop improvement
Robert Filter
1 hour coupling atm ⇔ ocn
LENS initial conditions

1. The Labrador Sea Issue



The Labrador Sea issue

June 2016: Houston, we have a problem

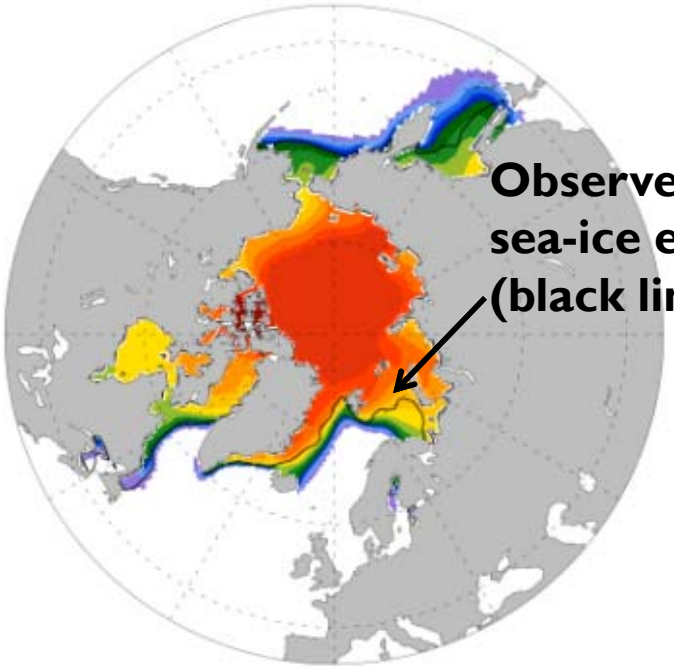
The Labrador Sea is freezing

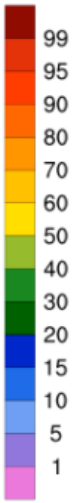
Labrador Sea

The Labrador Sea issue

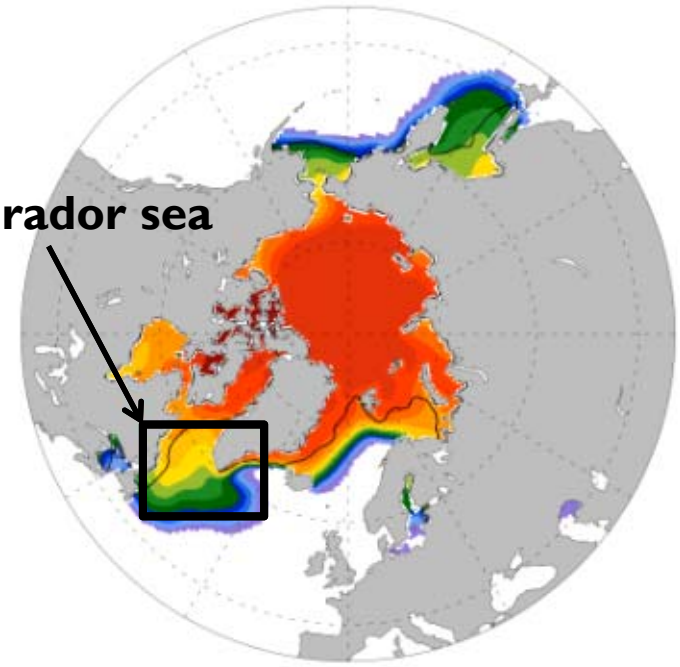
Sea-ice extent

CESM1





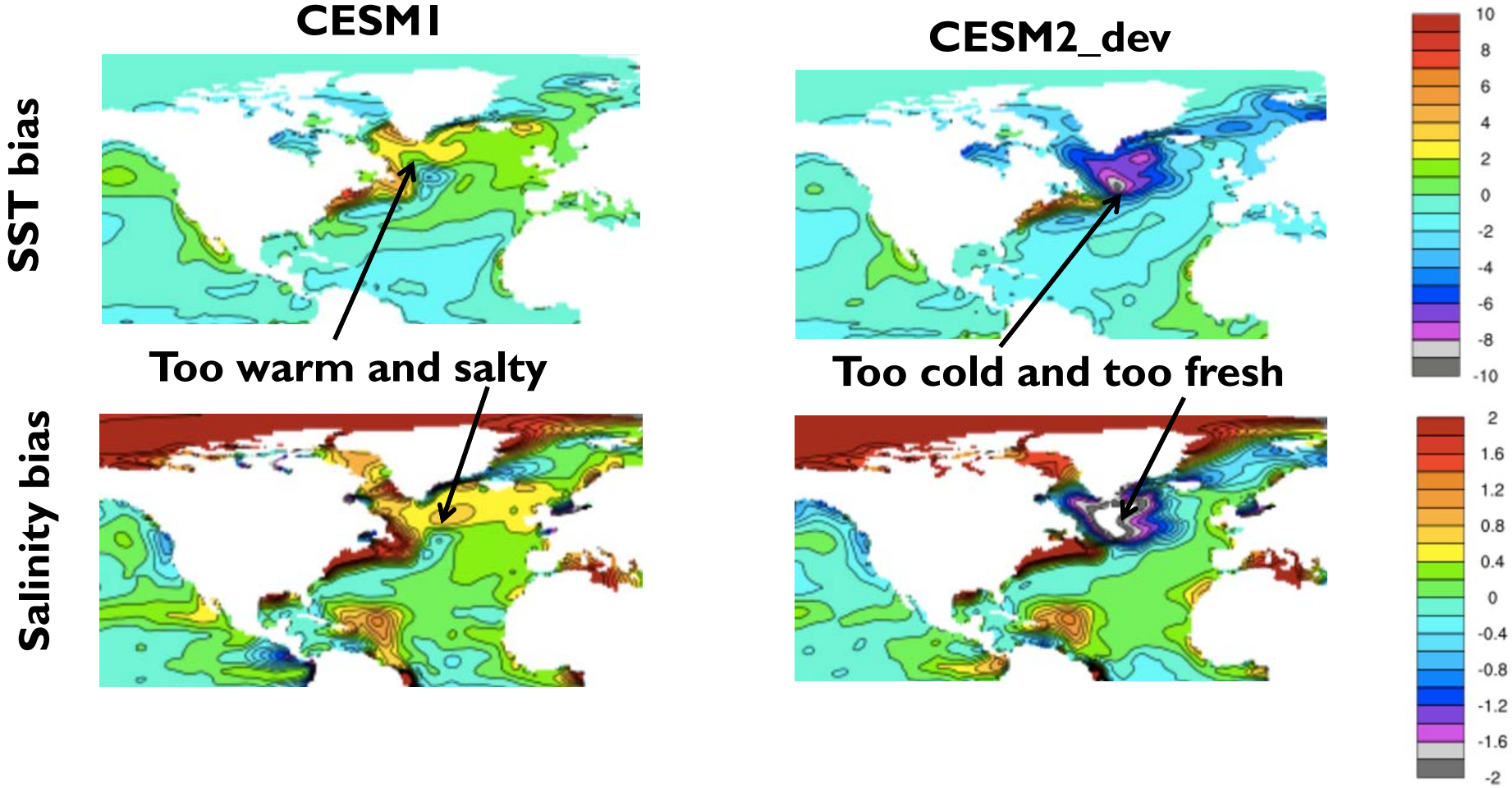
CESM2_dev



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

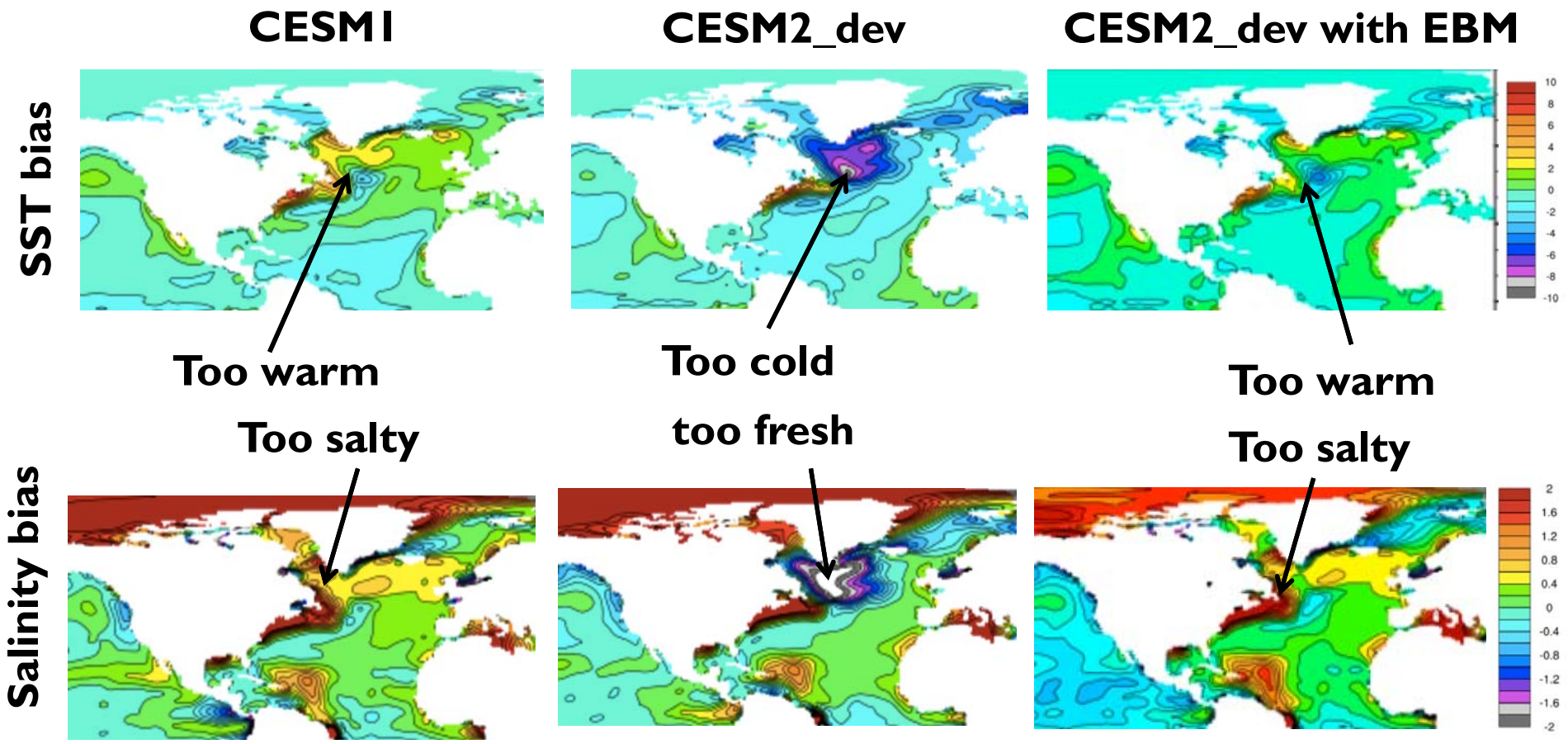
Labrador sea is ice-covered.
Can happen after 1 yr, 40 yr, 100^{+} yr

Why was Labrador Sea freezing ?



This is the result of South of Greenland being too cold and too fresh

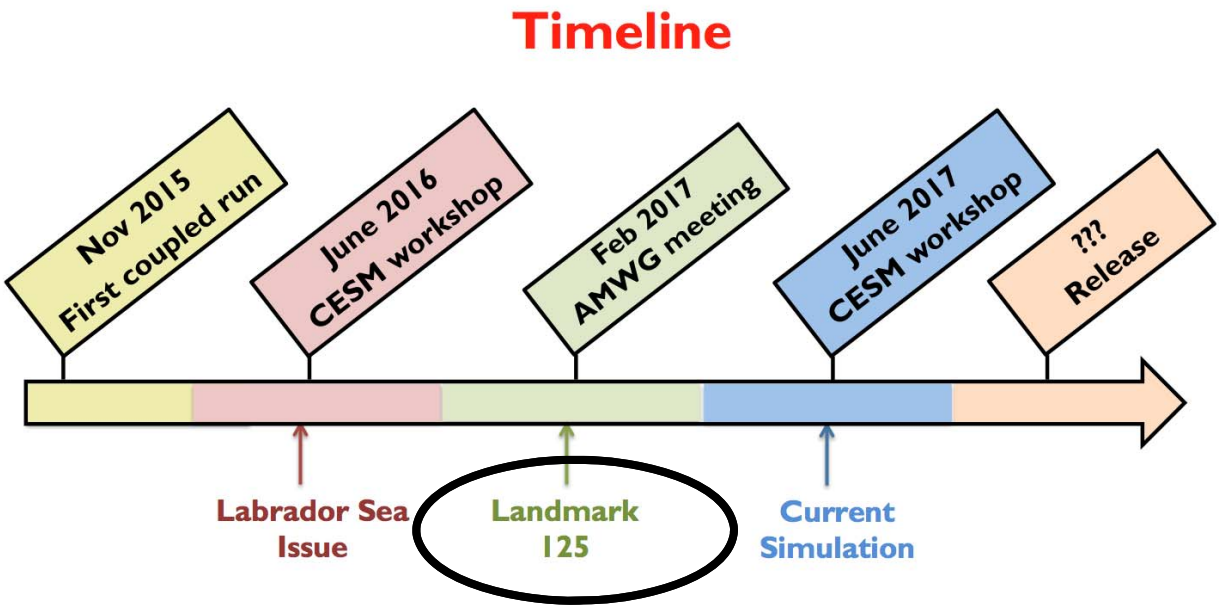
Estuary Box Model (EBM) to the rescue!



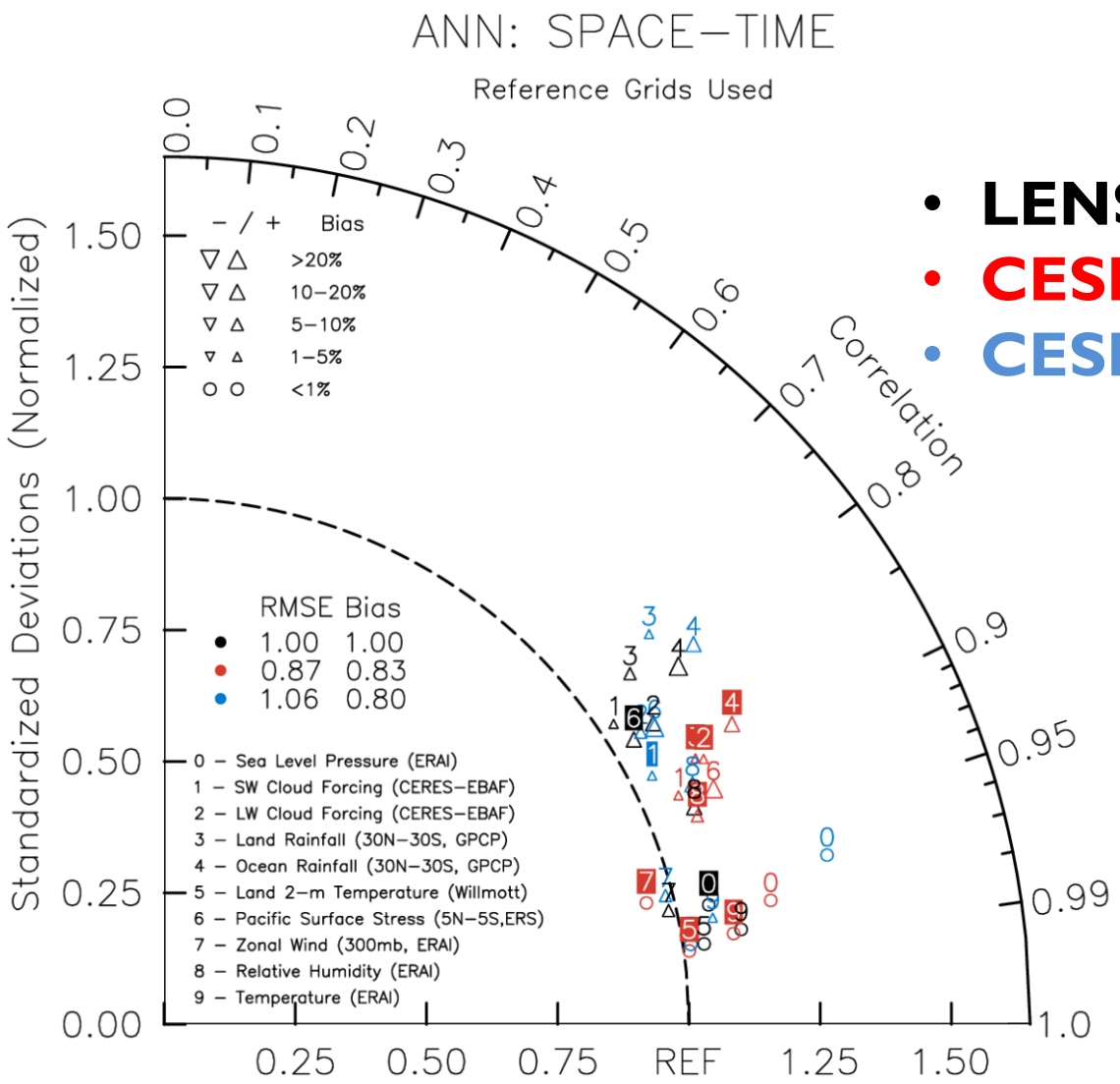
EBM: SST and salinity bias similar to CESM1

This solves the Labrador Sea Issue

2. The 125 Landmark



Taylor Diagram for 125



	RMSE	Bias
• LENS	1.00	1.00
• CESM2 (125)	0.87	0.83
• CESM1.5(36)	1.06	0.80

Taylor score was best we ever had.

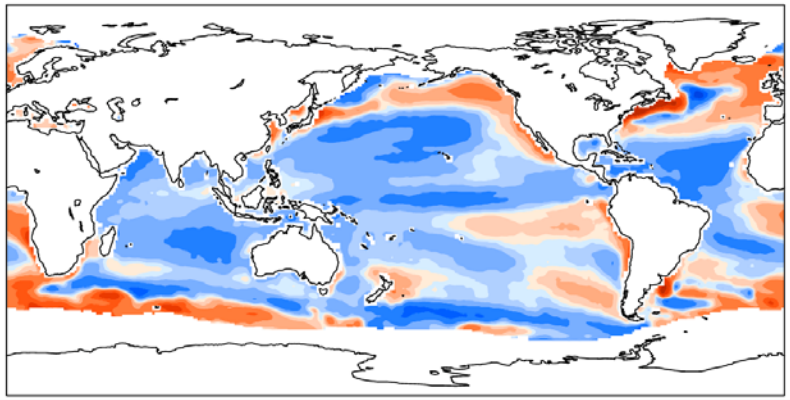
CESM2 is better than LENS

Sea Surface Temperature (SST) bias (ANN)

LENS

Bias = -0.24K

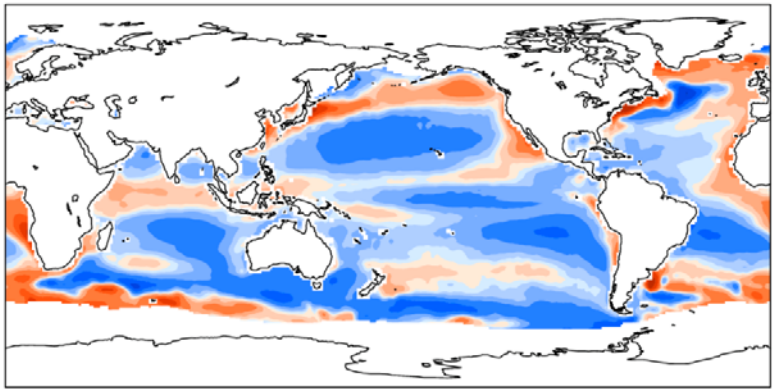
RMSE = 0.91

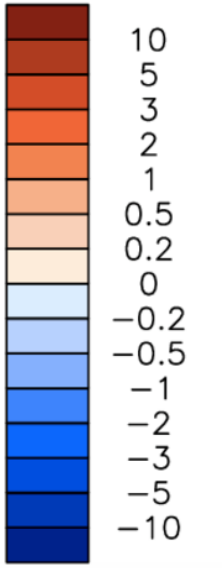


CESM2

Bias = -0.32K

RMSE = 0.98

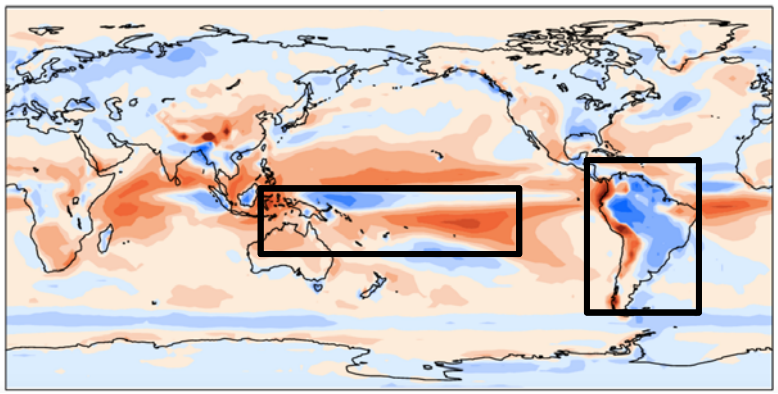




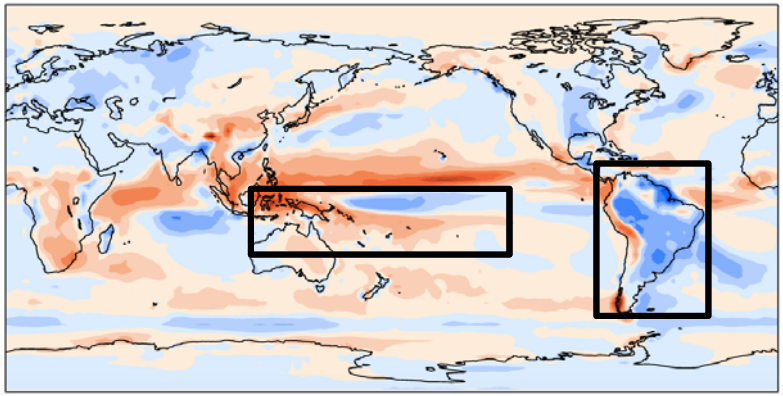
RMSE in CESM2 (125) is not as good as in LENS

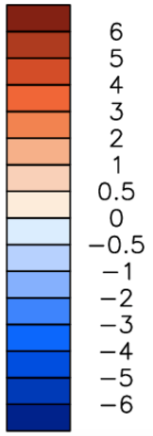
Precipitation bias versus GPCP (ANN)

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



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

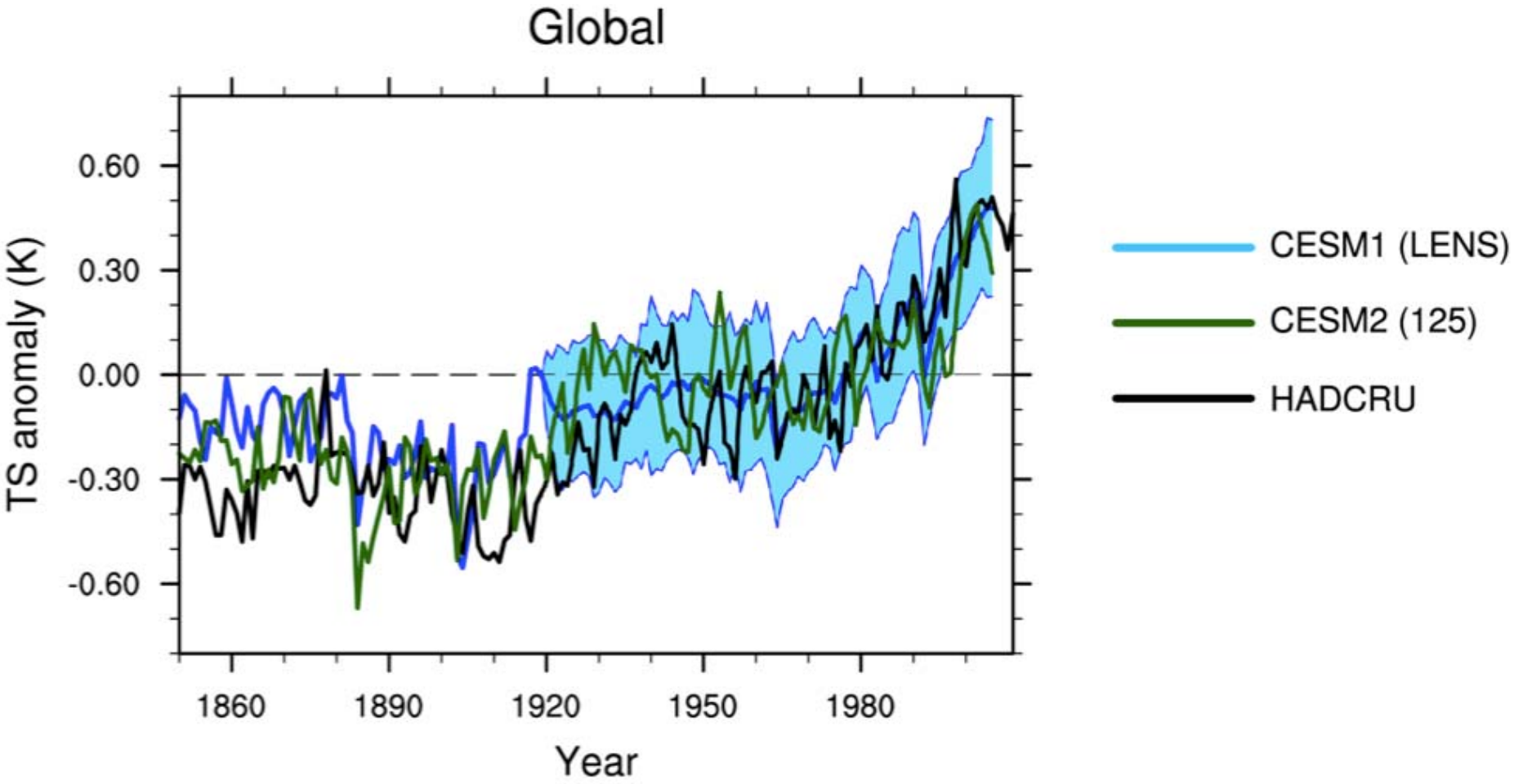




The best precipitation we ever had !

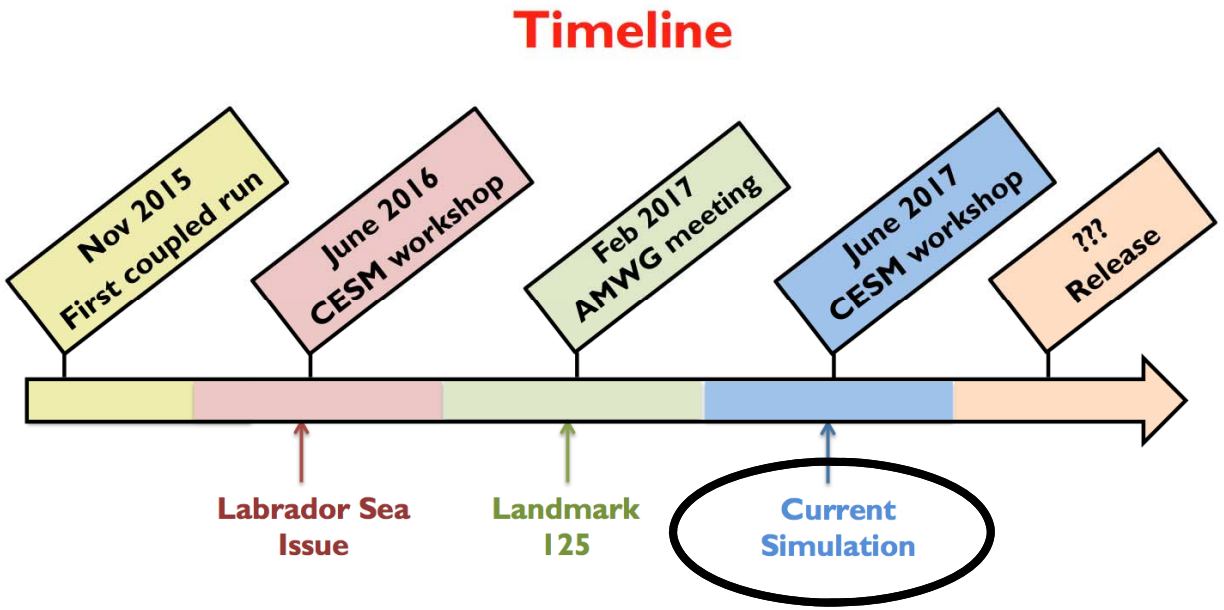
- **Improved precip RMSE**
- **Better precipitation over Amazon**
- **Improved tropical precipitation**

20th century warming in 125

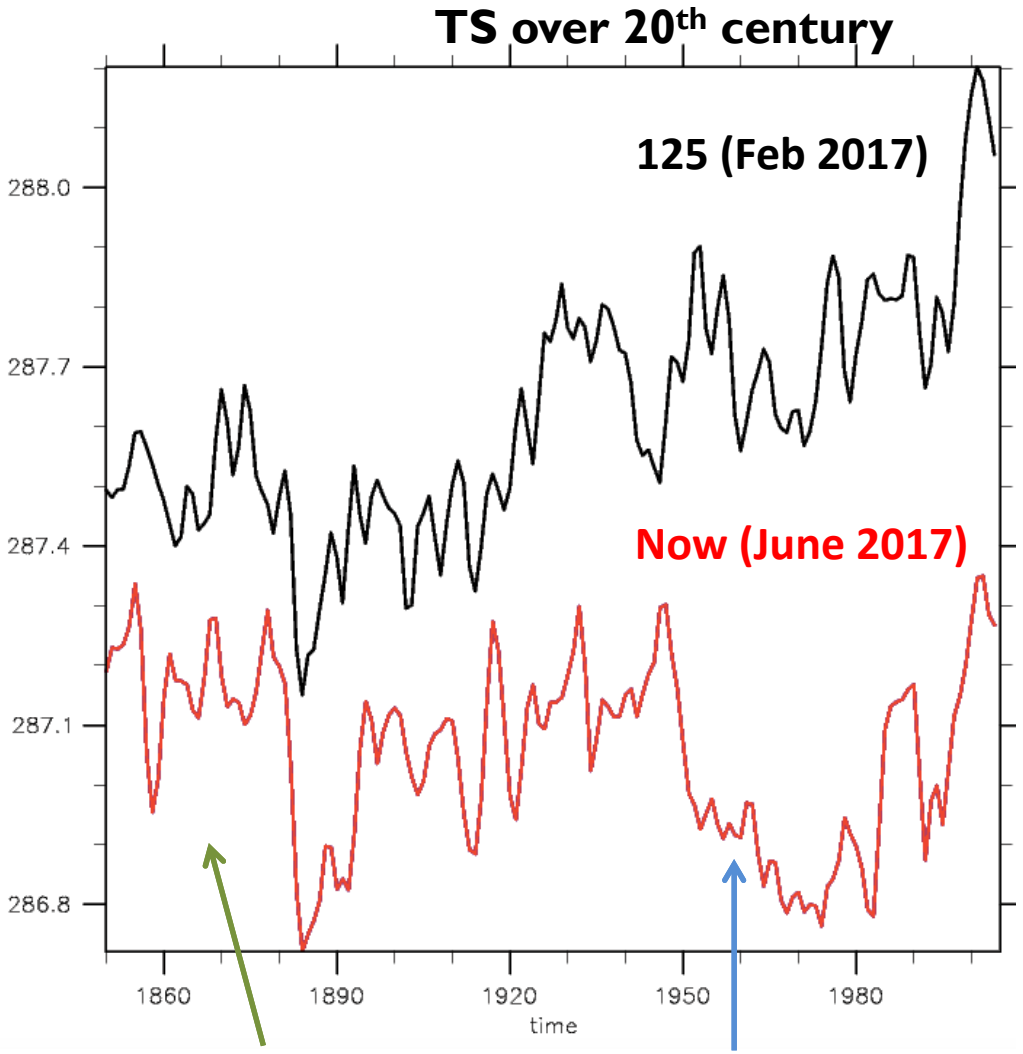


CESM2(125)
CESM1 (LENS)
Obs (HADCRU)

3. The Current Simulation



Current Simulation versus 125



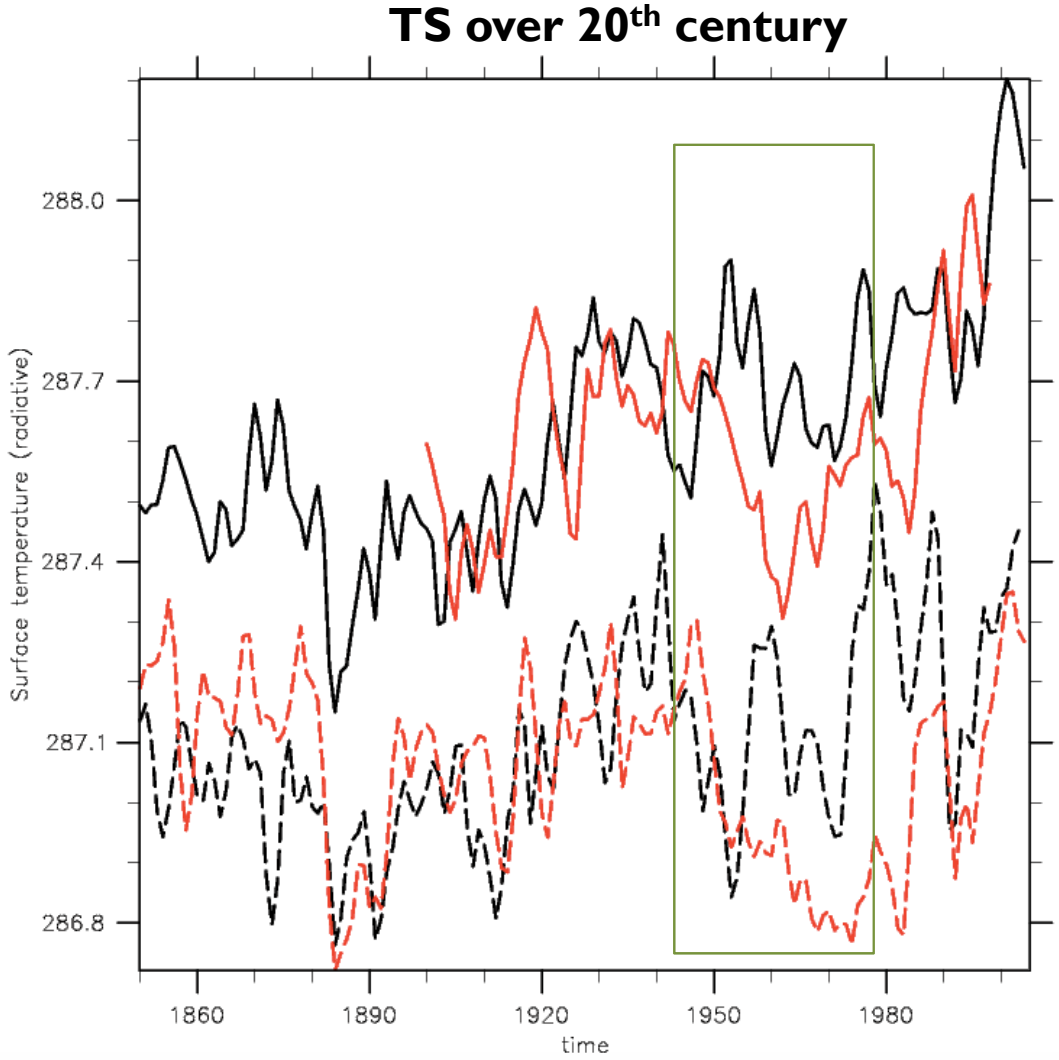
What is different 125 ⇔ now ?

Topography around Greenland
CMIP6 emissions ← 50s cooling
Dust tuning ← cold start (?)

Vegetation parameters
Crop improvement
Caspian sea

Robert Filter
1 hour coupling atm ⇔ ocn
LENS initial conditions

CMIP6 versus CMIP5 emissions



125 + cmip5 emissions

125 + cmip6 emissions

Now + cmip5 emissions

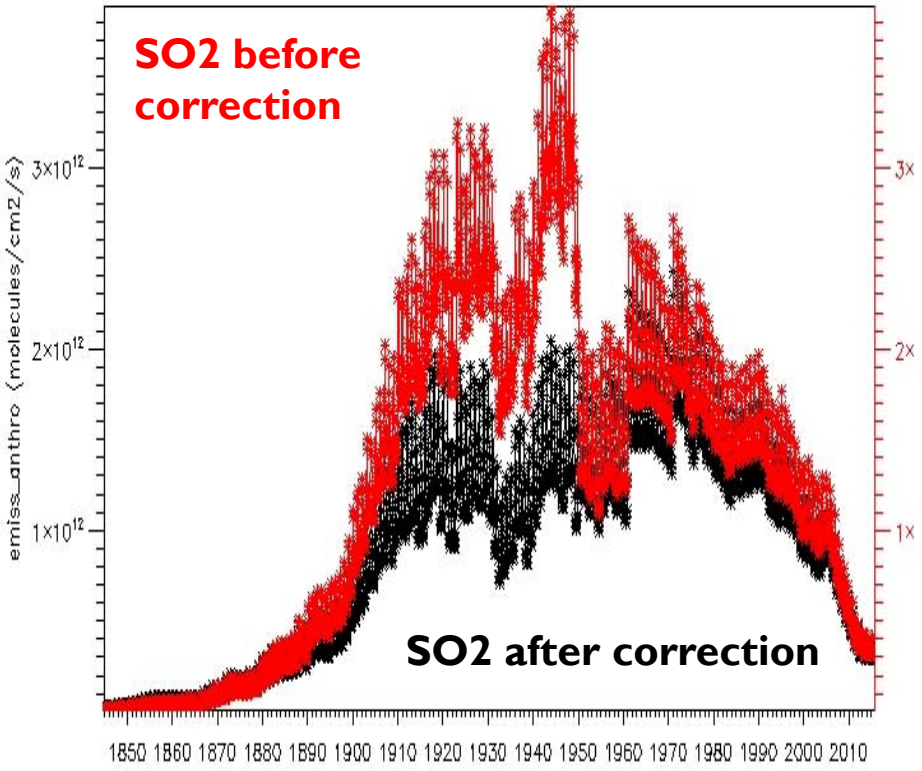
Now + cmip6 emissions

CMIP6 emissions: cooling in 1950s

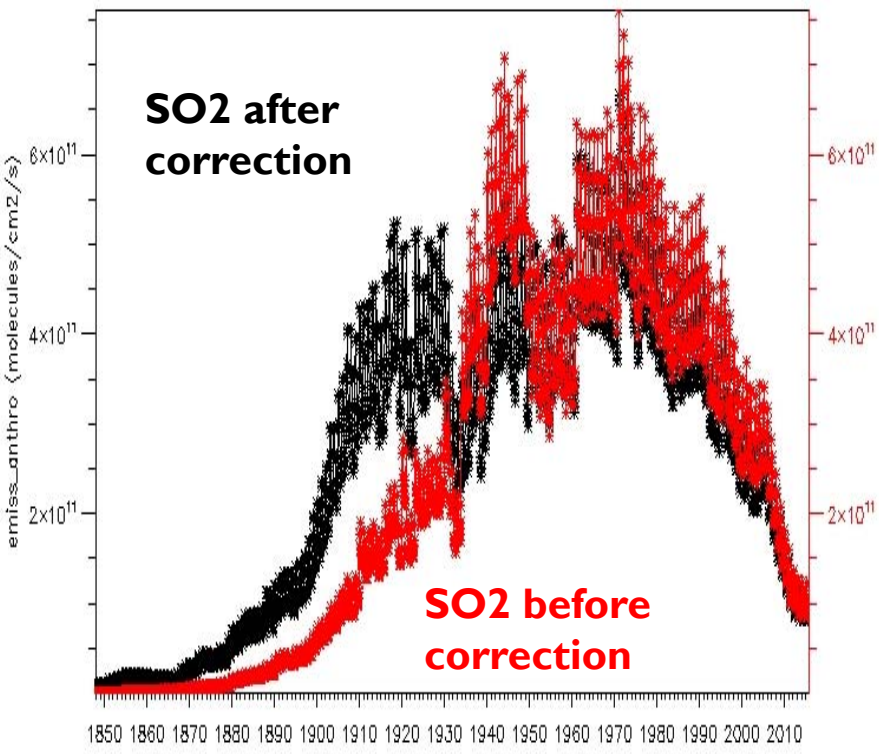
=> Is there a problem with the emissions ?

Corrected CMIP6 emissions: SO2

New York City



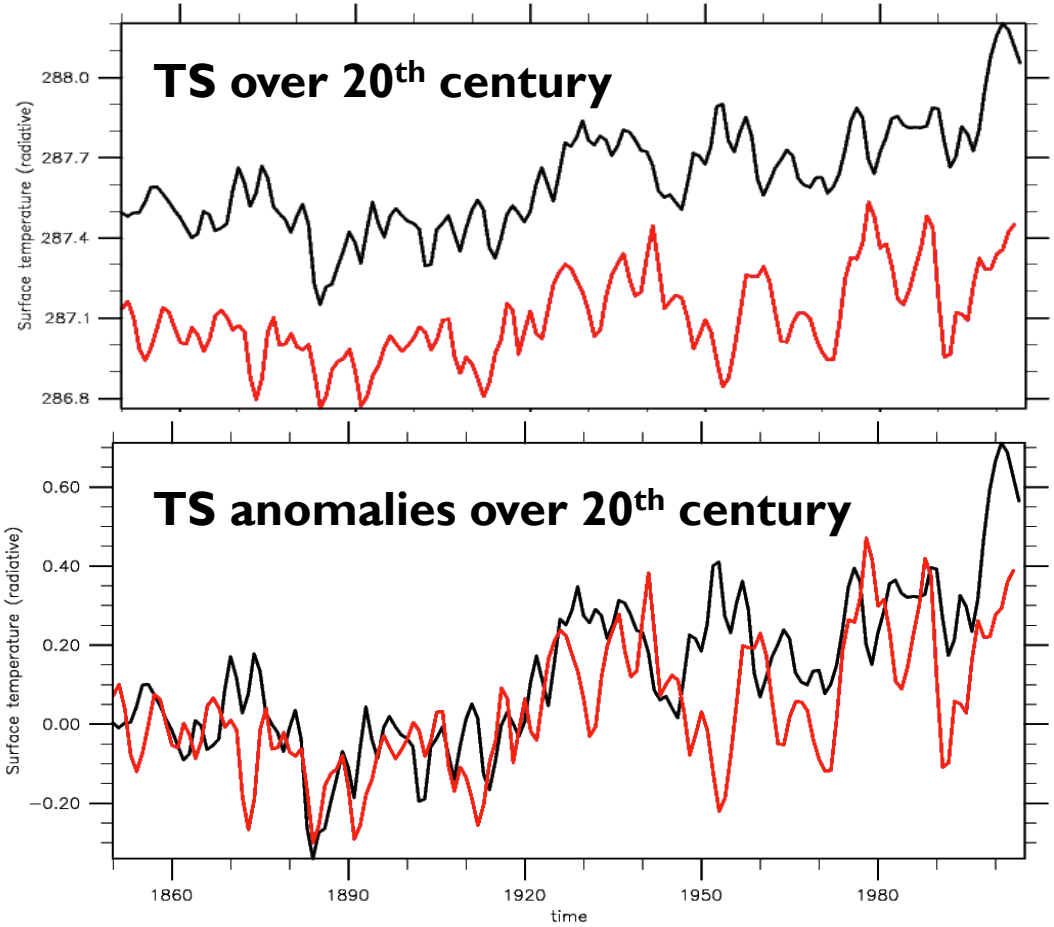
Los Angeles



Figures from L. Emmons

I25 and Now with CMIP5 emissions

Current simulations with CMIP5 emissions => "anemic" warming



I25 + cmip5 emissions

Now + cmip5 emissions

I25 + cmip5 emissions

Now + cmip5 emissions

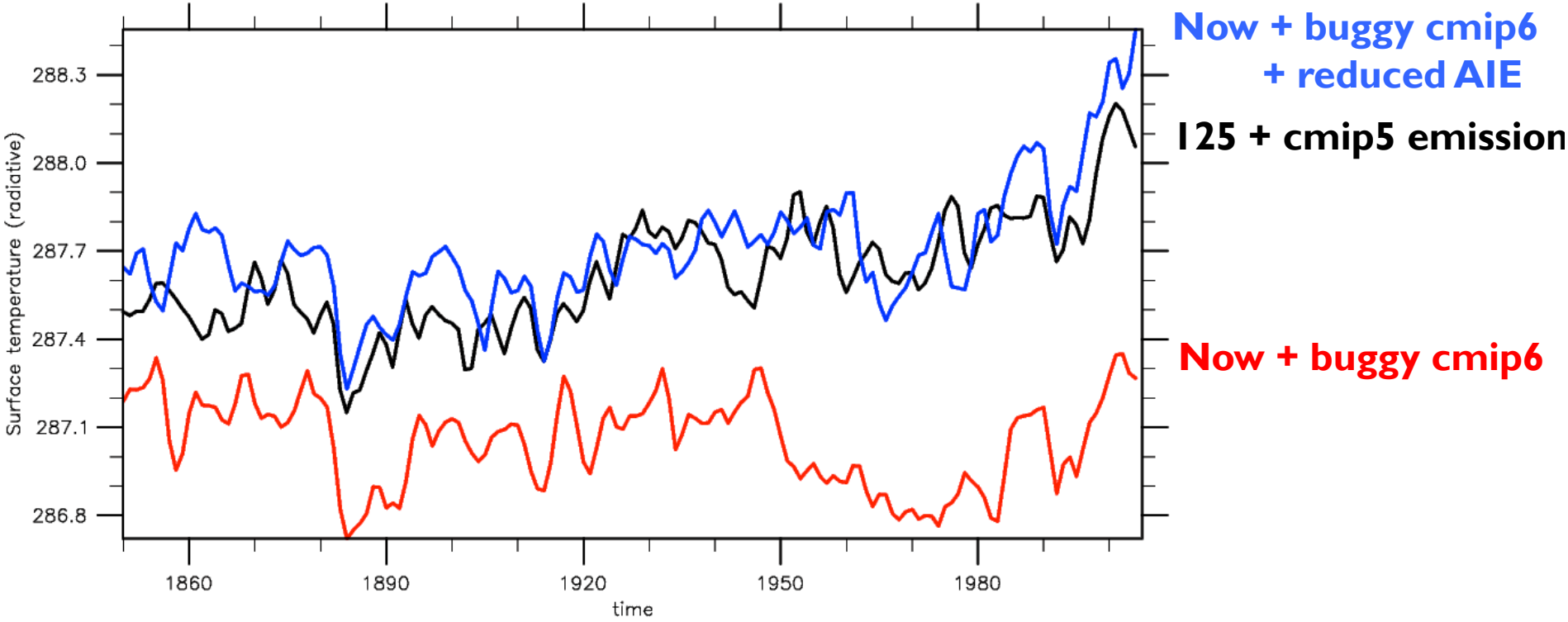
Will corrected CMIP6 emissions be enough ?

Is the indirect effect too strong ?

Note that indirect effect didn't change between 125 and now

Reducing aerosol indirect effect ?

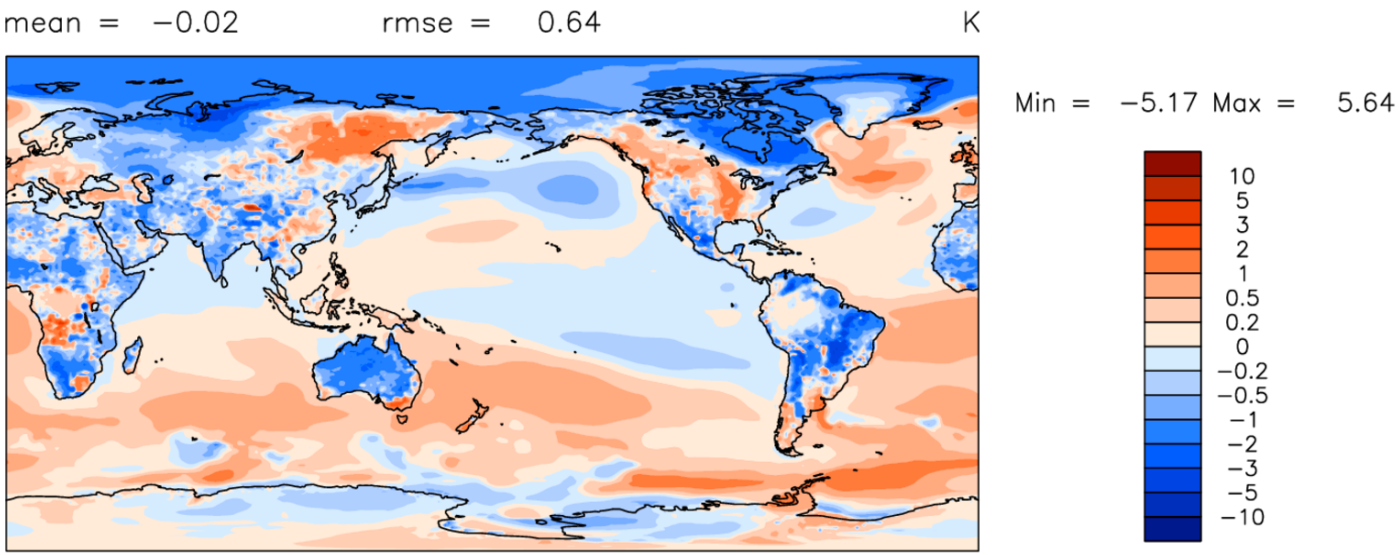
If needed, we have the option to reduce the 2nd aerosol indirect effect (AIE)



Caveat if we go that road: The current simulations were done with the buggy cmip6 emissions and would need to redone

What else ? Change in TS since 125

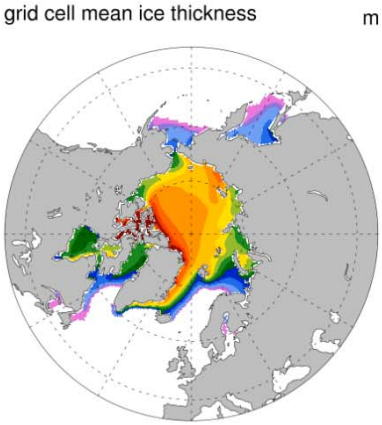
Change in TS since 125

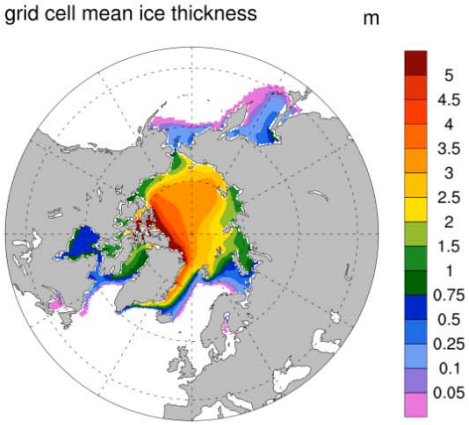


Contrast between land, ocean and Arctic.

What else ? Is sea-ice too thin ?

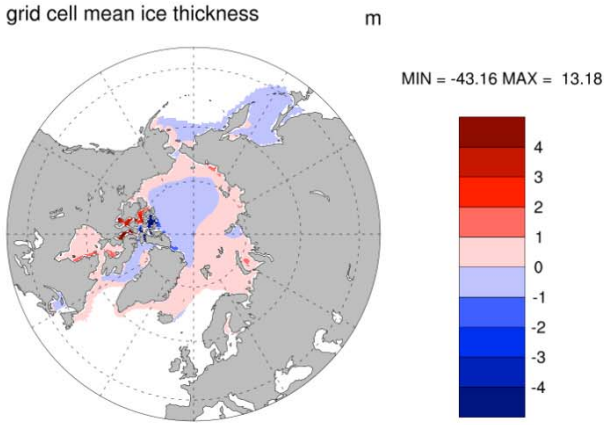
Now





LENS

b.e20.B1850.f09_g17.pi_control.all.179 - b.e11.B1850C5CN.f09_g16.005



Now - LENS

If needed we can adjust snow albedo on sea-ice?

Summary

- **Labrador Sea Issue**
  - **Solved with the introduction of Estuary Box Model**
- **125 Landmark**
  - **Best simulation ever**
- **Current simulation**
  - **Challenge to reproduce 20th century**
  - **Issue with the CMIP6 emissions**
  - **If needed, we could reduce aerosol indirect effect**