The path to CESM2: Coupled-climate experiments

Cécile Hannay

David Bailey, Pete Bogenschutz, Gokhan Danabasoglu, Andrew Gettelman, Cécile Hannay, Marika Holland, Jean-Francois Lamarque, David Lawrence, Keith Lindsay, Rich Neale, Keith Oleson, Bill Sacks, John Truesdale, Mariana Vertenstein and gazillions of others

CESM1.5: Many new babies !

Land
CLM5

Atmosphere
CAM5.5

Sea-ice
CICE5

Land Ice
CISM

River Model
MOSART

Ocean
POP2

CESM1.5: Building individual components

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MOSART

CESM1.5: Coupling individual components

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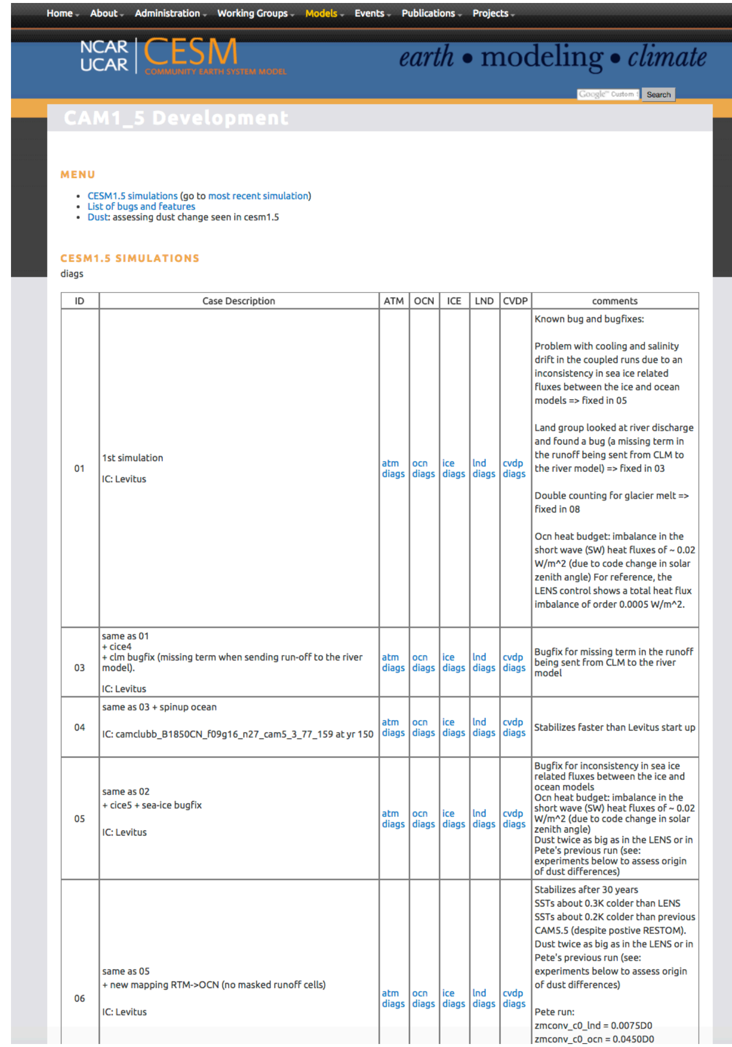
POP2

What could happen at coupling ?

CESM1.5: Development simulations

- **Huge team effort started in Mid November 2015**
- **34 experiments ("cases")**
- **1300^{+} years of simulations**
- **Overall: a lot of progress**
- **Still: a lot more needs to be done**



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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 0.0005 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/

Our best configuration so far: "28"

Completed

- 1850 Control (100 years)
- 20th century (1850-2005)
- AMIP simulation (1979-2005)
- High frequency runs
- Indirect effect (pre-industrial versus present aerosol)

In progress

- Climate sensitivity (2xCO_2 with Slab Ocean Model)

Evaluation of "28"

- versus observations
- versus "predecessors" (LENS, CAM5.4, CAM5.5)

Who are the predecessors ?

Large-ensemble (LENS)
CESM1/CAM5.1

Add MG2, ice microphysics, MAM4, dust

CESM1/CAM5.4

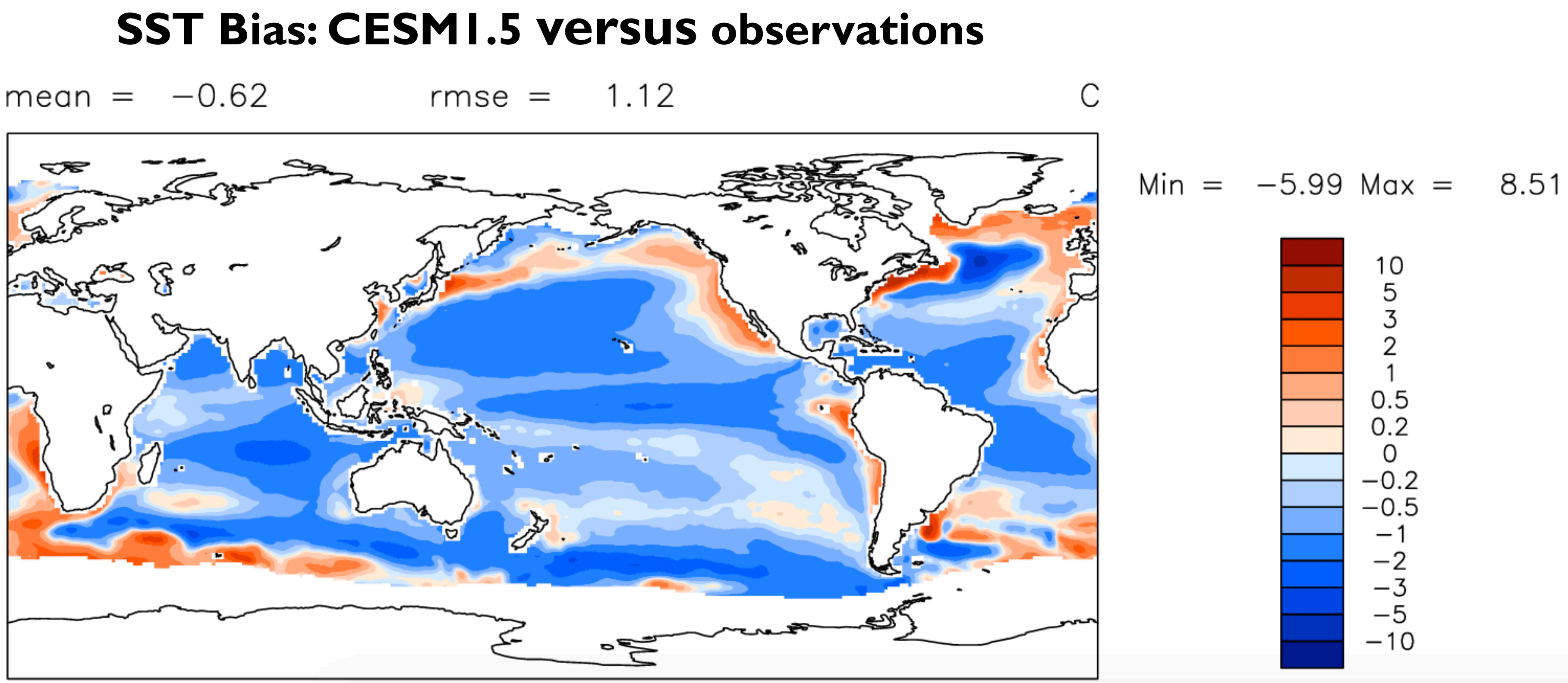
Add CLUBB

CESM1/CAM5.5

Add CLM5, CICE5, MOSART, CSIM

This is "28" alias "CESM.1.5" → CESM1.5/CAM5.5

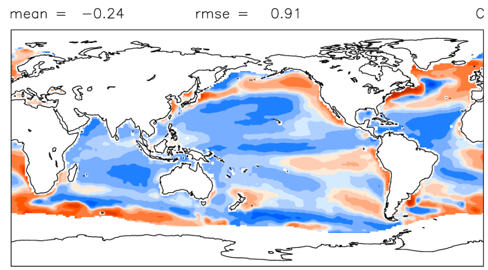
1850 control: Sea Surface Temperature (SST)



➔ **CESM1.5 significantly colder than observations (-0.62K)**

Evolution of the SST bias since LENS

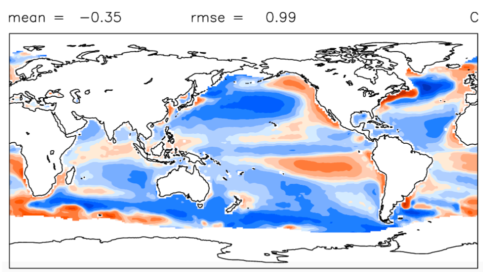
Bias = -0.24K
RMSE = 0.91



Large-ensemble (LENS)
CESM1/CAM5.1

Add MG2, ice microphysics, MAM4, dust

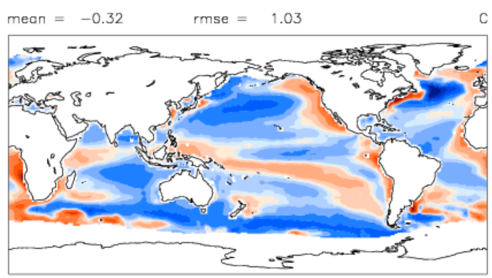
Bias = -0.35K
RMSE = 0.99



CESM1/CAM5.4

Add CLUBB

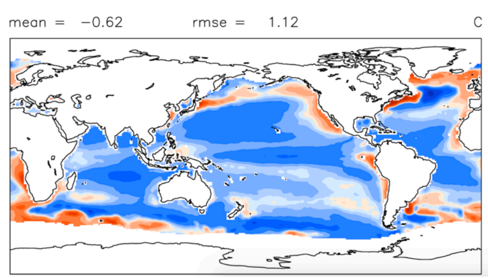
Bias = -0.32K
RMSE = 1.03



CESM1/CAM5.5

Add CLM5, CICE5, MOSART, CSIM

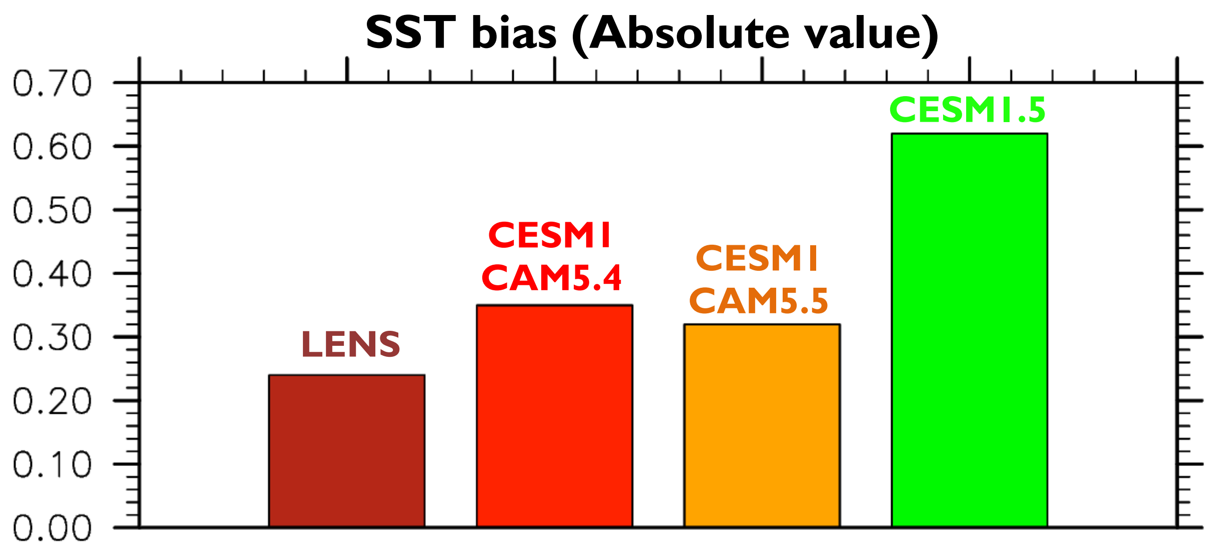
Bias = -0.62K
RMSE = 1.12



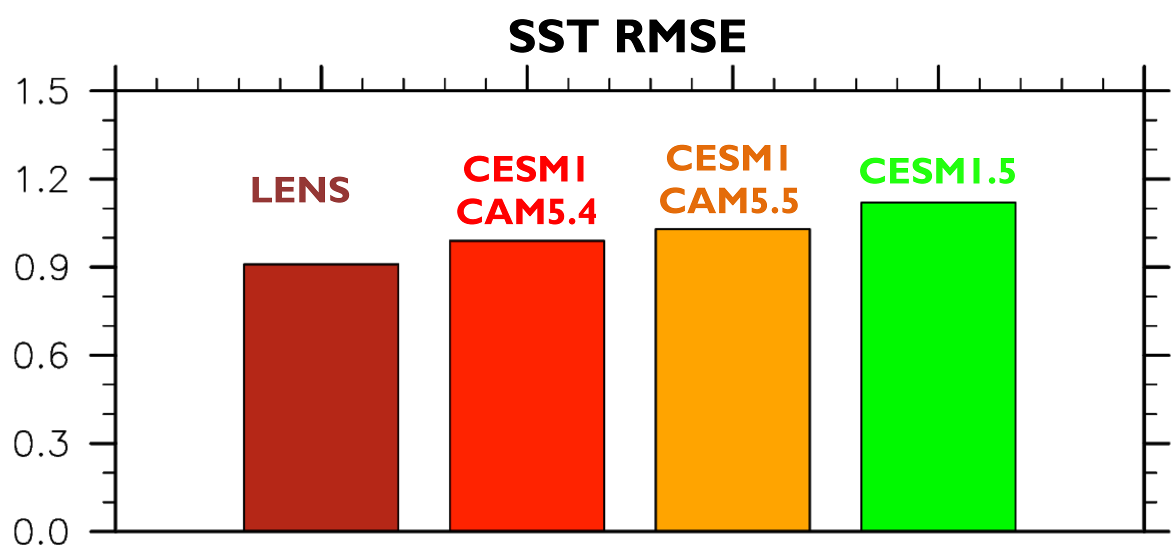
CESM1.5/CAM5.5

Evolution of the SST bias since LENS

Jump in SST bias when introducing other components



Steady increase in RMSE since LENS



Evolution of the SST bias since LENS

Bias = -0.24K
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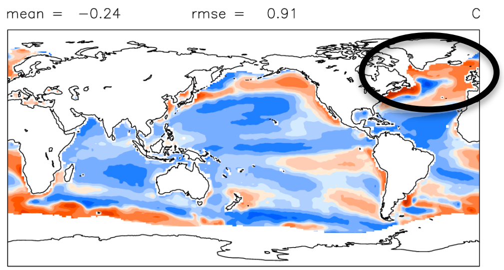

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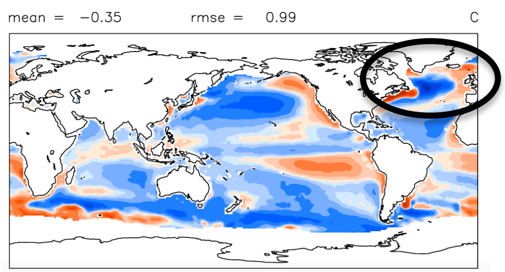

CESM1/CAM5.4

Add CLUBB

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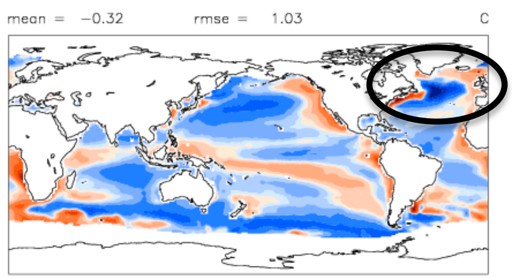

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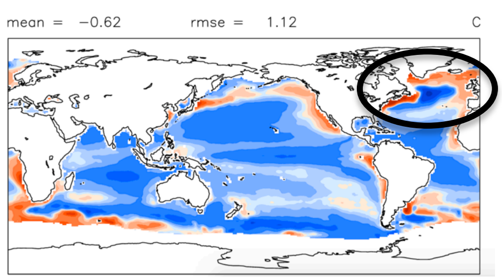
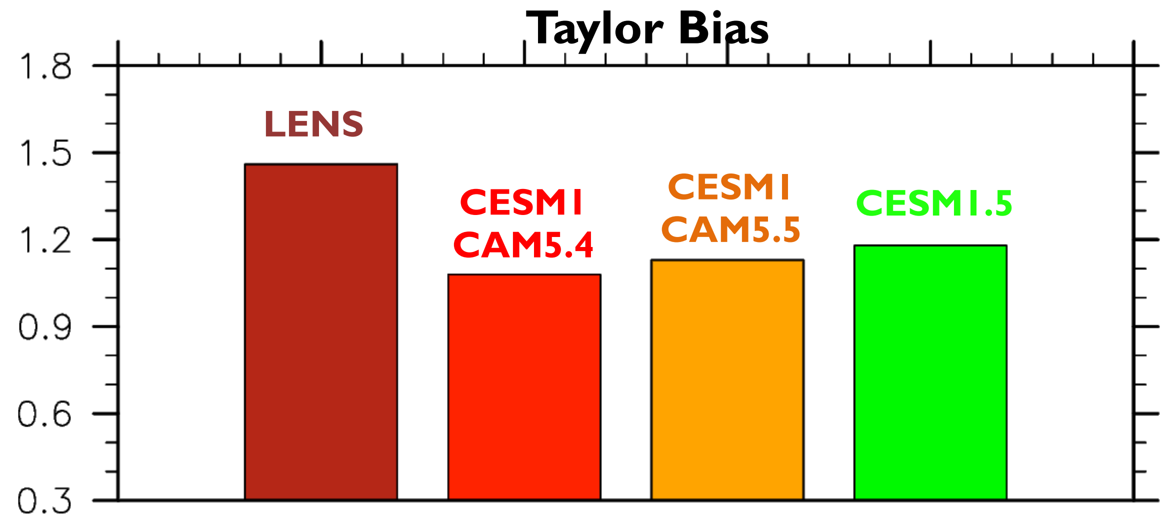


CESM1.5/CAM5.5

- ➔ **Change in SST bias is quite uniform**
- ➔ **Colder North Atlantic starting with CAM5.4**

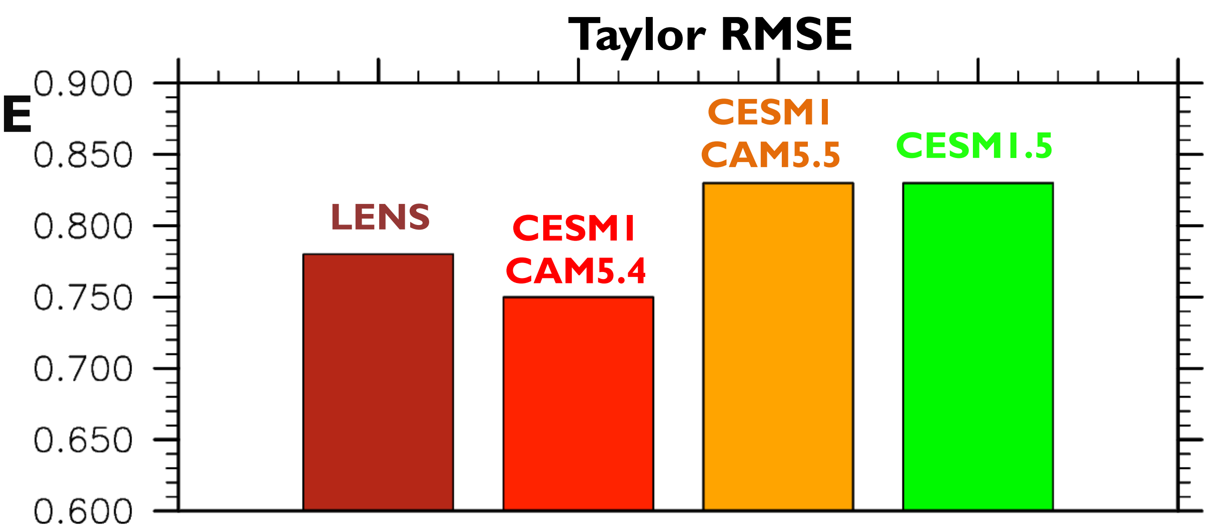
Evolution of the Taylor scores since LENS

Improvement in Taylor bias starting with CAM5.4



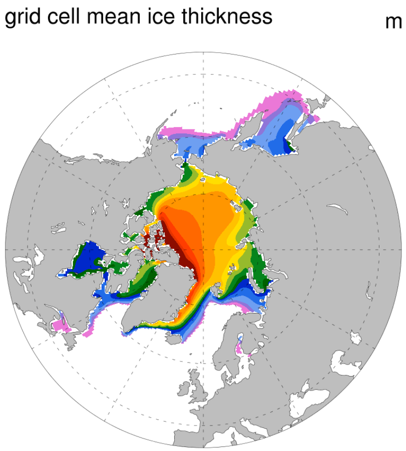
Degradation in Taylor RMSE starting with CAM5.5

Higher RMSE comes from degradation in rainfall (especially over land)

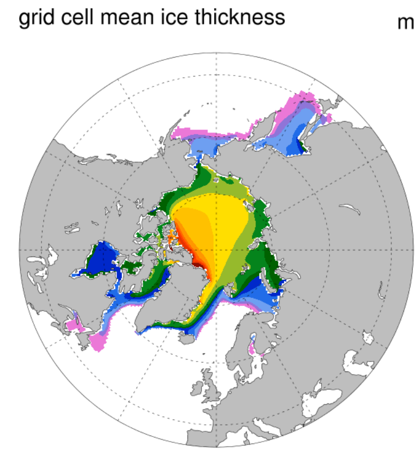


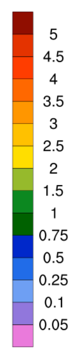
Evolution of sea-ice thickness since LENS

Large-ensemble (LENS)

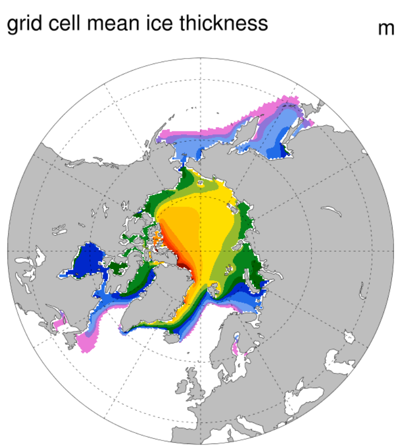


CESM1/CAM5.4

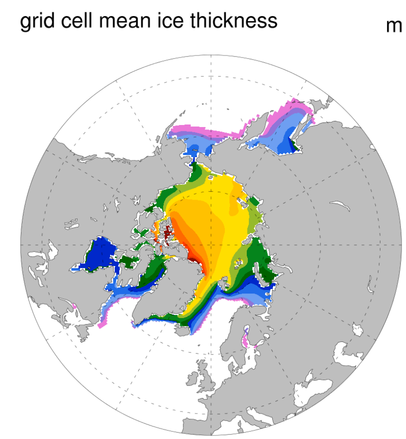




CESM1/CAM5.5



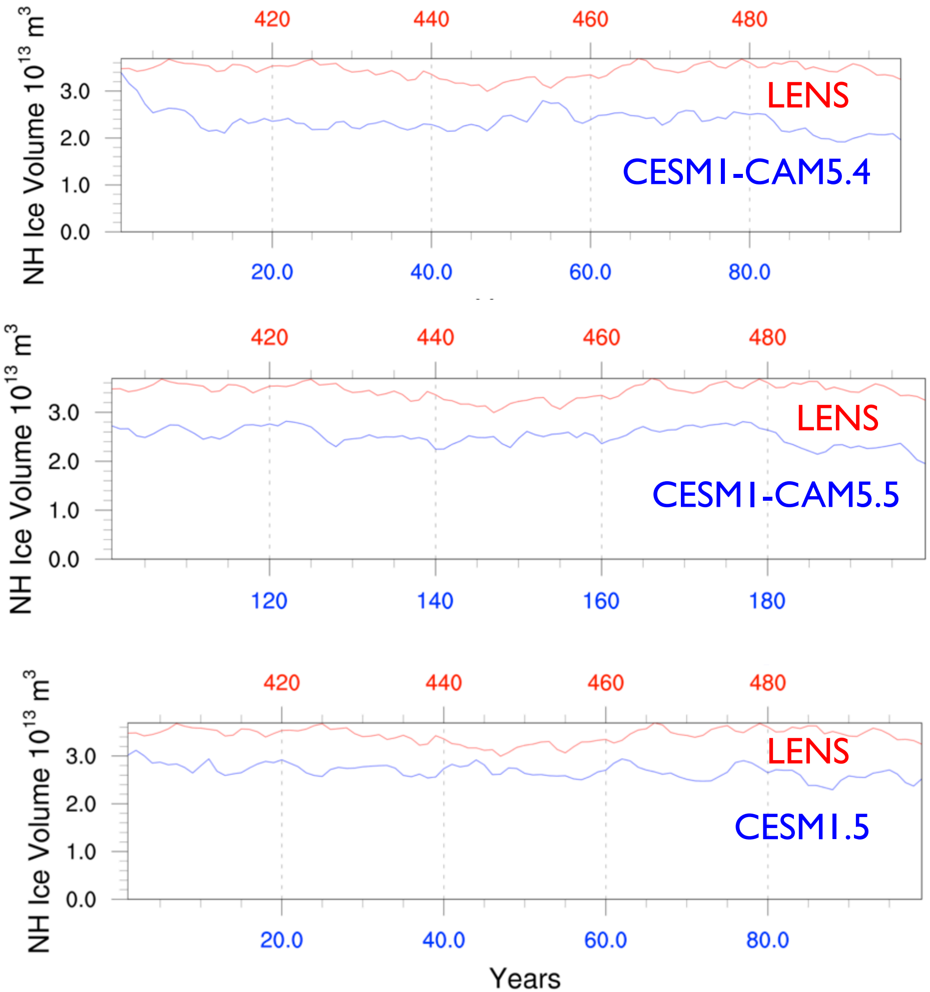
CESM1.5/CAM5.5



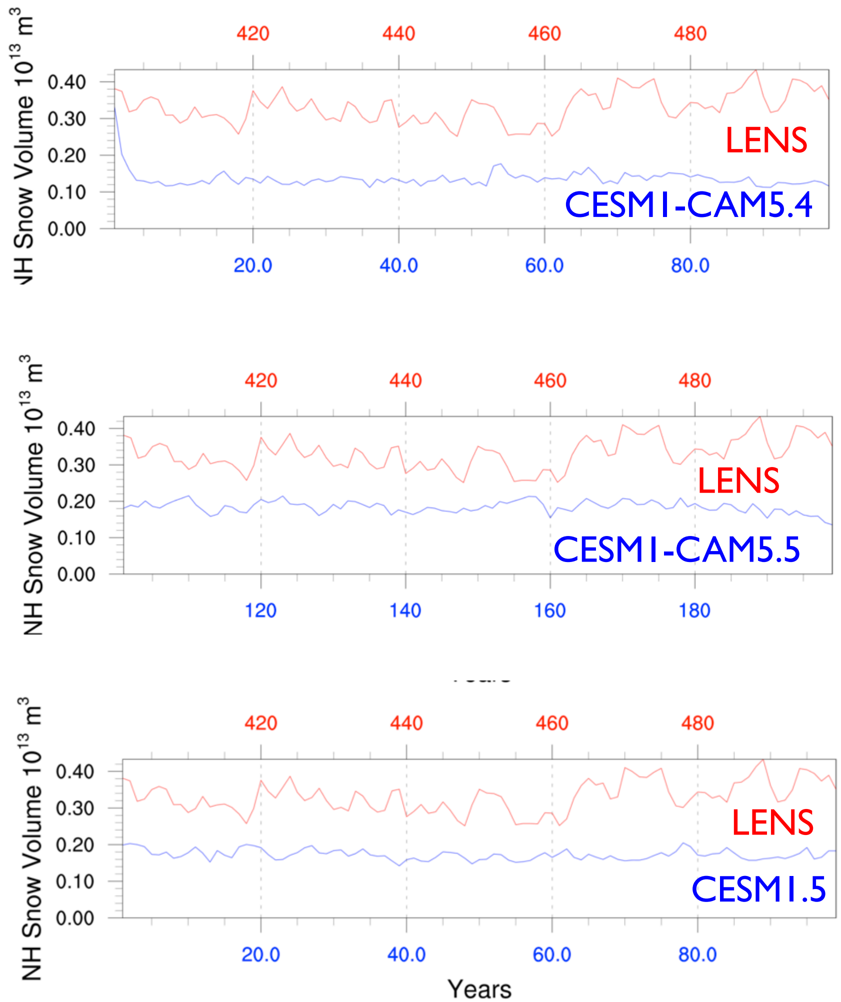
- ➔ **Sea-ice is thinner in CESM1.5 than LENS (despite colder North Atlantic)**
- ➔ **It started with the introduction of CAM5.4**

Sea-ice: Ice and Snow Volume

NH Ice Volume



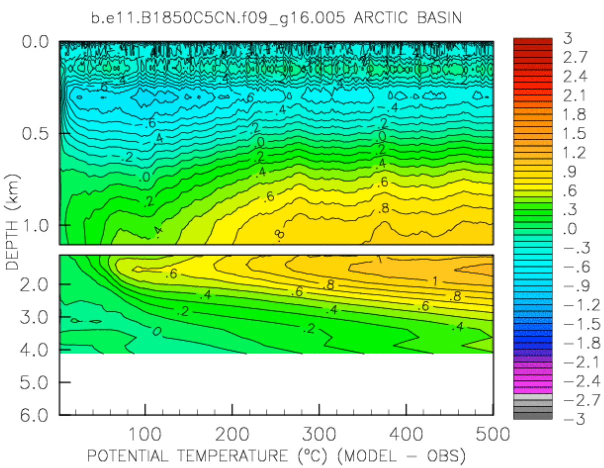
NH Snow Volume



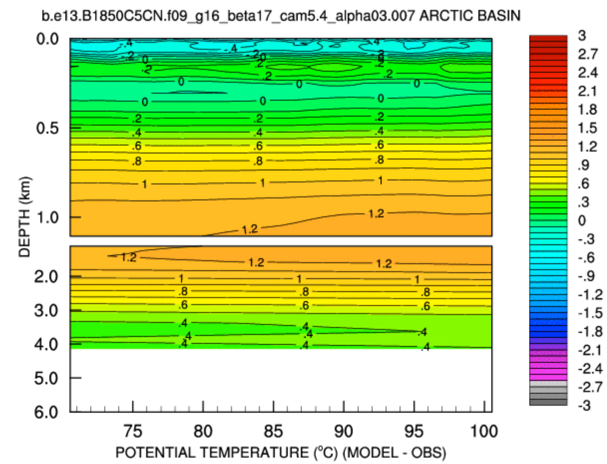
- ➔ Sea-ice is thinner in cesm1.5 than LENS (started with cam5.4)
- ➔ Snow on sea-ice disappears during Summer in cesm1.5

Ocean Temperature Bias in the Arctic

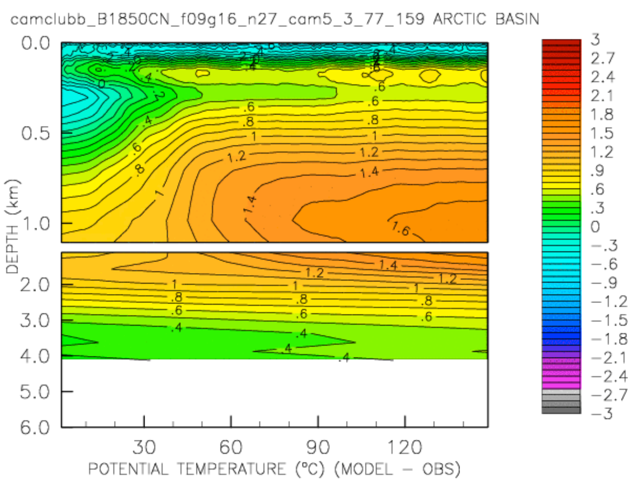
Large-ensemble (LENS)



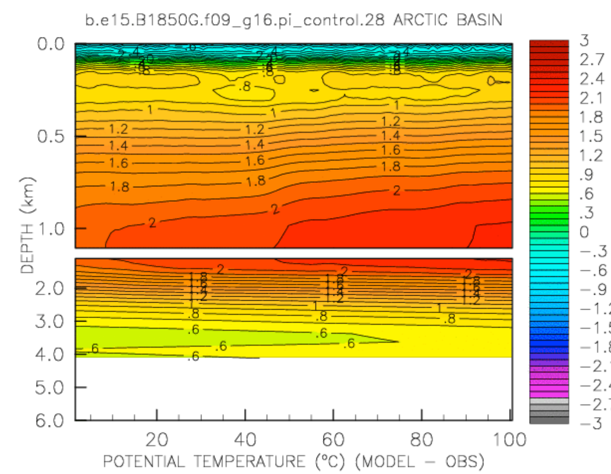
CESM1/CAM5.4



CESM1/CAM5.5

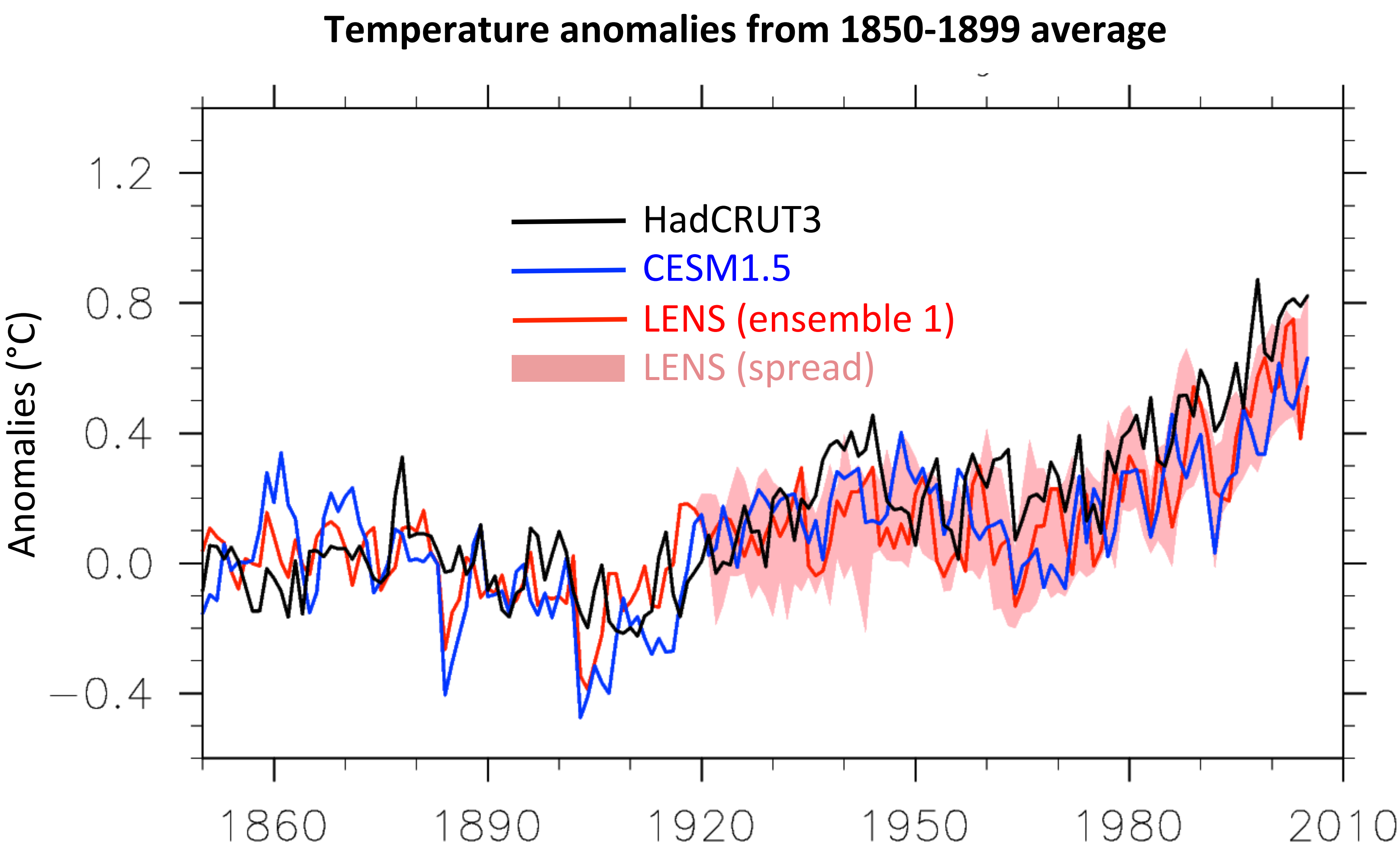


CESM1.5/CAM5.5



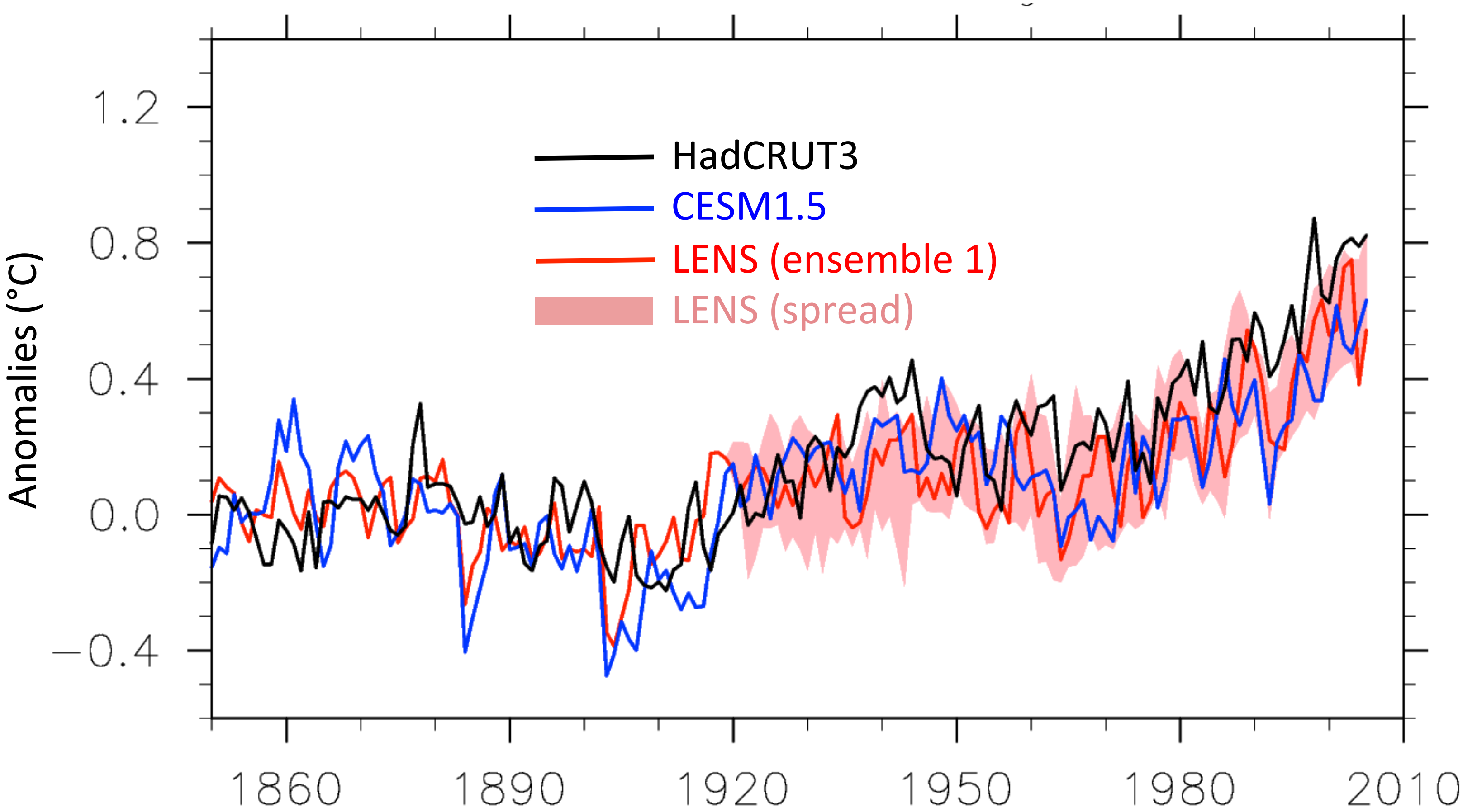
- ➔ **Sub-surface warming in Arctic ocean.**
- ➔ **This might be a concern (or not)**

20th Century Global Surface Temperature



20th Century Global Surface Temperature

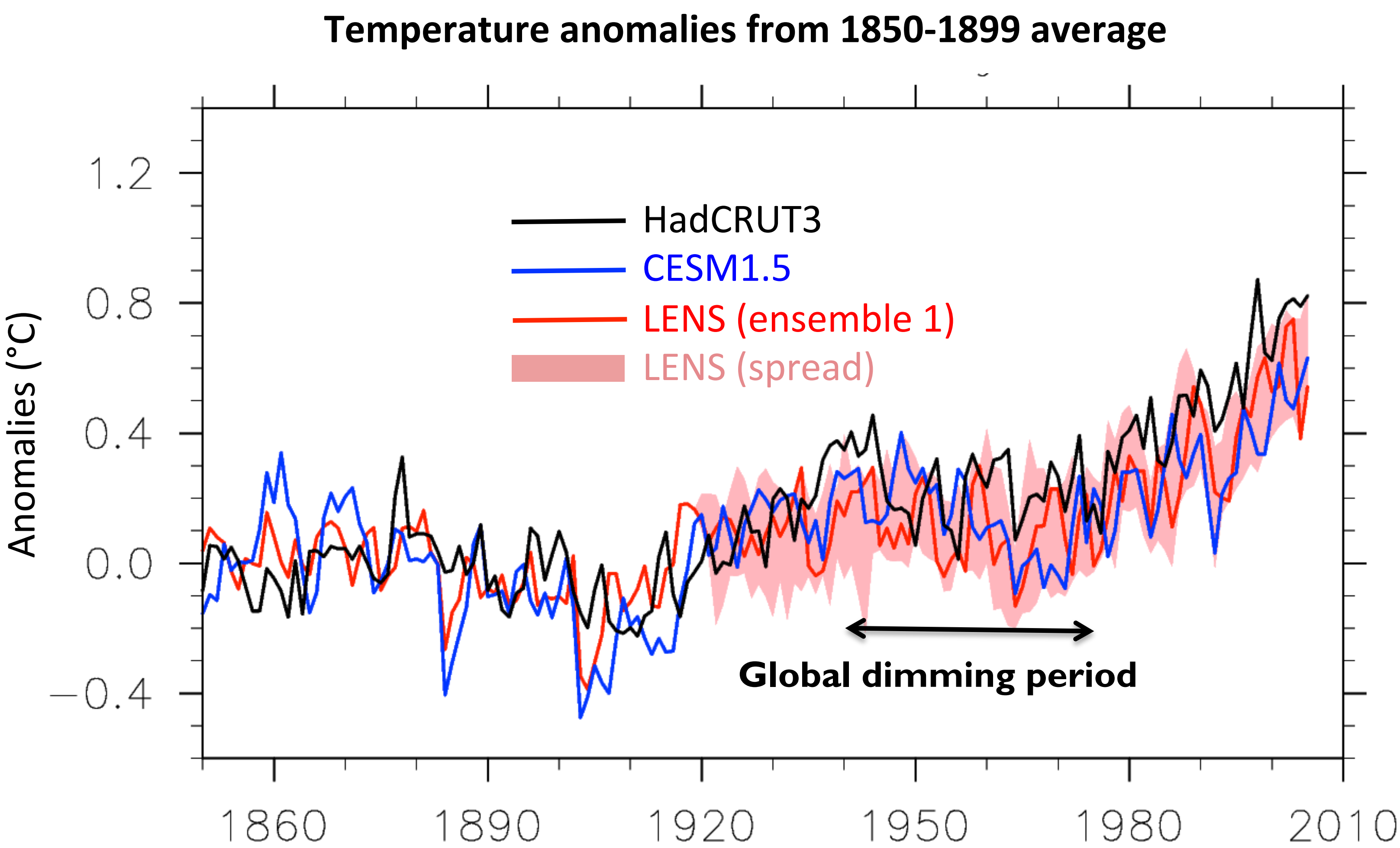
Temperature anomalies from 1850-1899 average



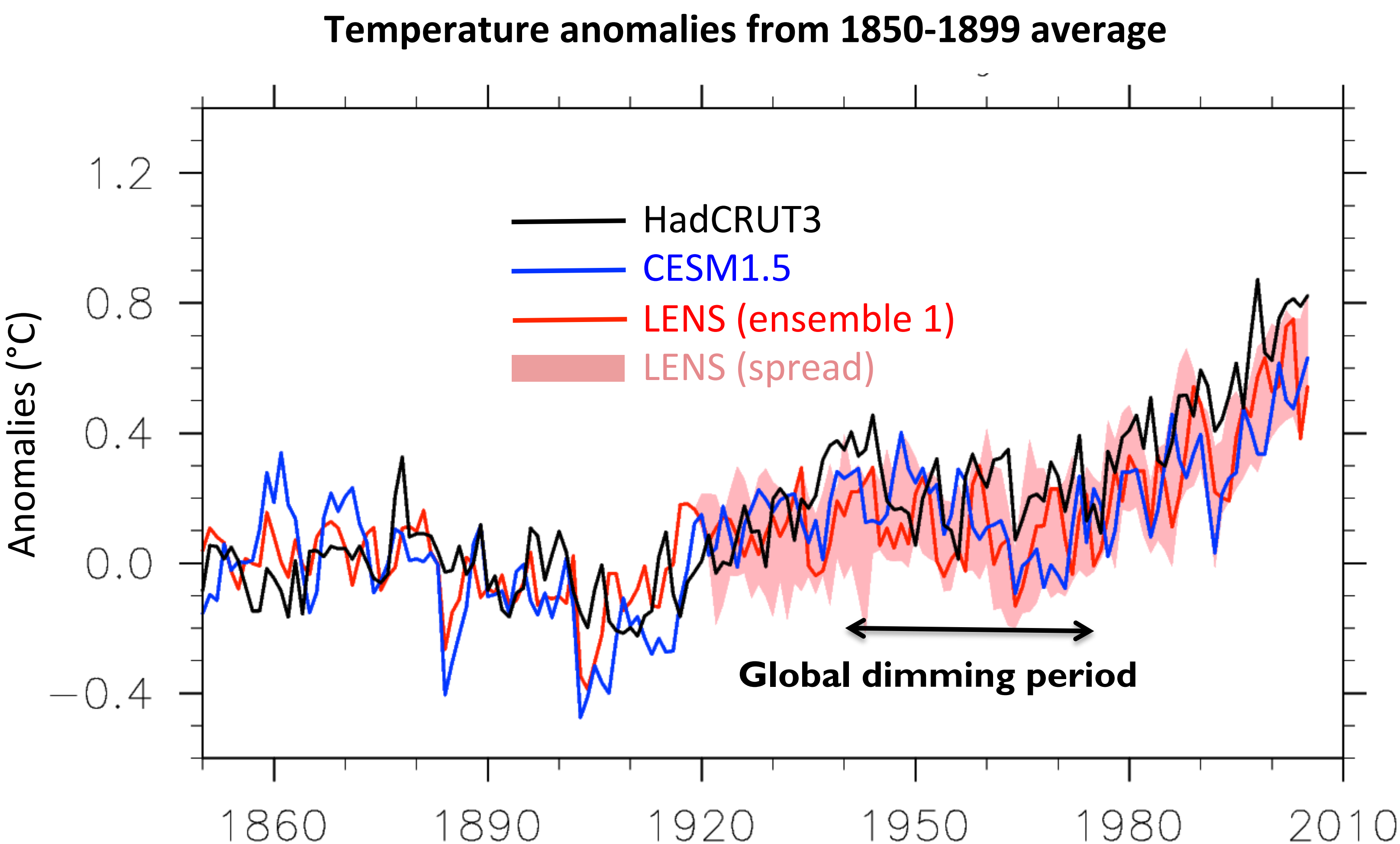
➔ **CESM1.5 is more or less in the spread of LENS**

➔ **LENS is warming a bit less than the HadCRUT3**

20th Century Global Surface Temperature



20th Century Global Surface Temperature

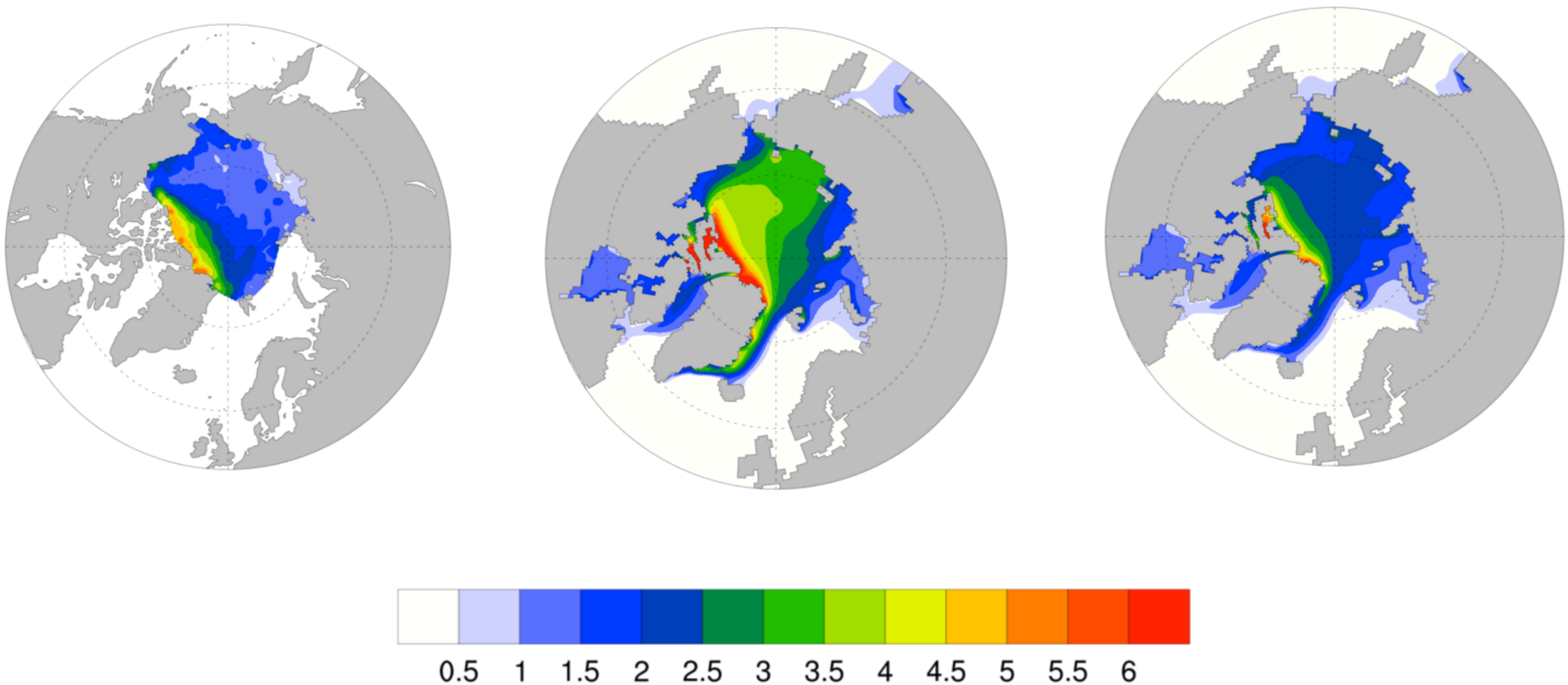


➔ **Aerosol indirect effect is strong in CESM1.5**

➔ **Currently exploring ways to reduce it**

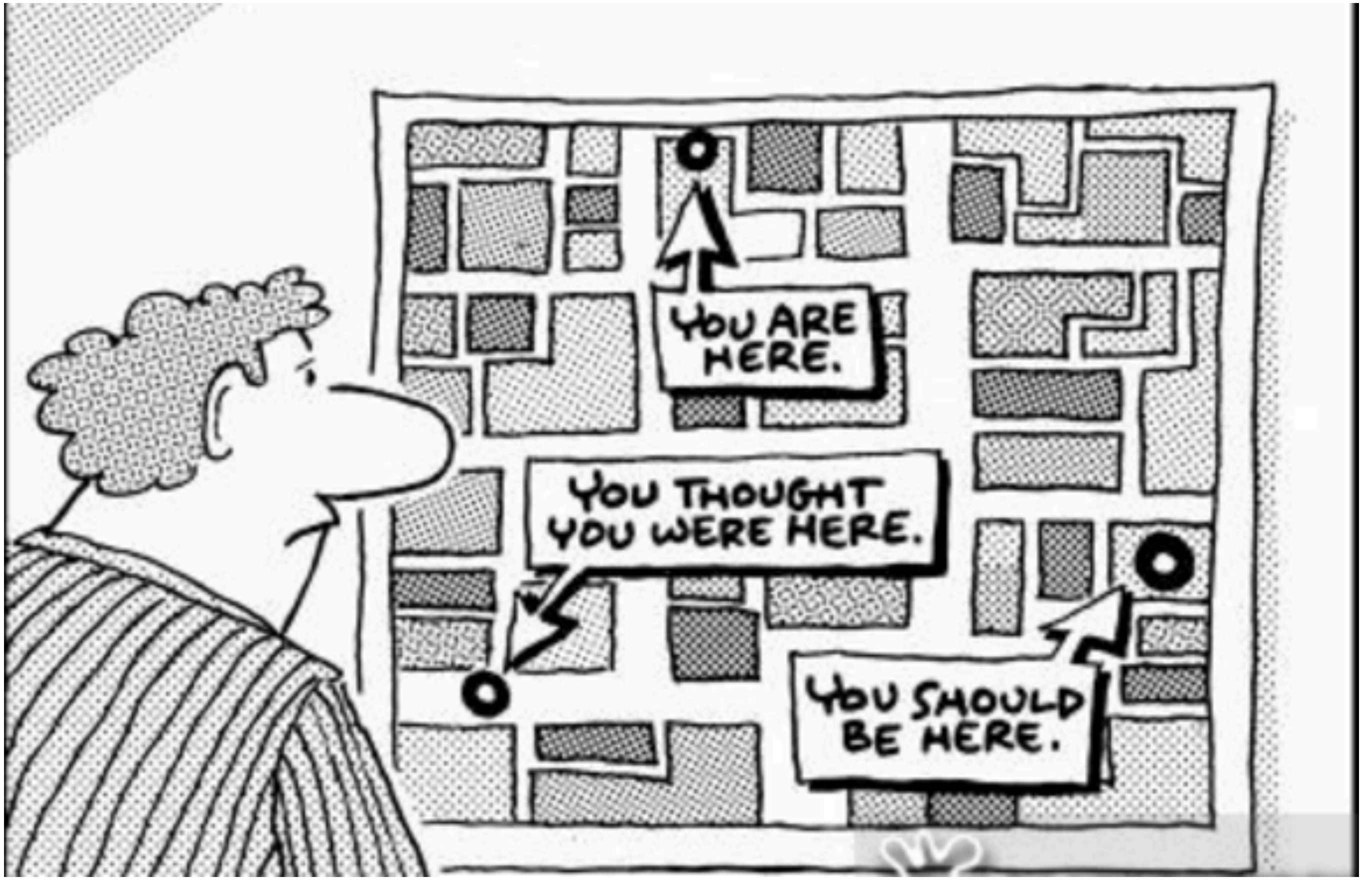
Sea-ice thickness at the end of the 20th century

Obs: Ice Sat 2001-2005 | **LENS 1981-2005** | **CESM1.5 1981-2005**



- ➔ **Sea-ice might be too thin in CESM1.5 (while LENS sea-ice is likely to thick)**
- ➔ **Tuning of sea-ice albedo can be done if needed**

Summary: Where are we ? What's next ?



Summary: Where are we ? What's next ?

- **We provide a first simulation of CESM1.5**

Summary: Where are we ? What's next ?

- **We provide a first simulation of CESM1.5**

- **Evolution of biases in CESM1.5 since LENSE includes:**
  - **SSTs too cold**
  - **Precipitation bias over land increases**
  - **Indirect effect might be too large**
  - **Sea-ice might be too thin**

Summary: Where are we ? What's next ?

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Now who do we blame ?

Summary: Where are we ? What's next ?

- We provide a first simulation of CESM1.5
- Evolution of biases in CESM1.5 since LENSE includes:
  - SSTs too cold ➔ Other components
  - Precipitation bias over land increases ➔ CLUBB
  - Indirect effect might be too large ➔ CLUBB
  - Sea-ice might be too thin ➔ CAM5.4

Now who do we blame ?

Summary: Where are we ? What's next ?

- **We provide a first simulation of CESM1.5**

- **Evolution of biases in CESM1.5 since LENSE includes:**
  - **SSTs too cold → Other components**
  - **Precipitation bias over land increases → CLUBB**
  - **Indirect effect might be too large → CLUBB**
  - **Sea-ice might be too thin → CAM5.4**

Now who do we blame ?

- **Next steps involve:**
  - **New set of tuning parameters to improve SSTs and precipitation biases**
  - **New autoconversion parameterization to reduce aerosol indirect effect**
  - **Tuning sea-ice albedo to increase ice thickness (if needed)**