CESM2 development simulations:

- A brief history of the last year simulations
- Current state of the CESM2 simulation

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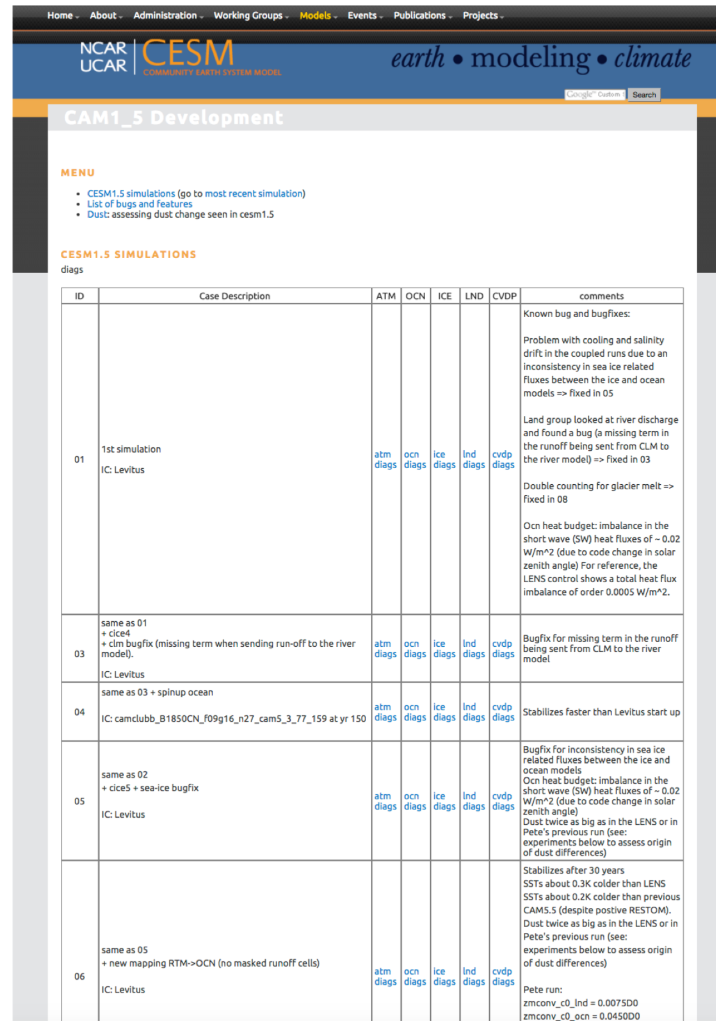
A brief history of the last year simulations

Building CESM2

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



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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

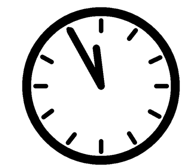
CESM1.5 SIMULATIONS

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/

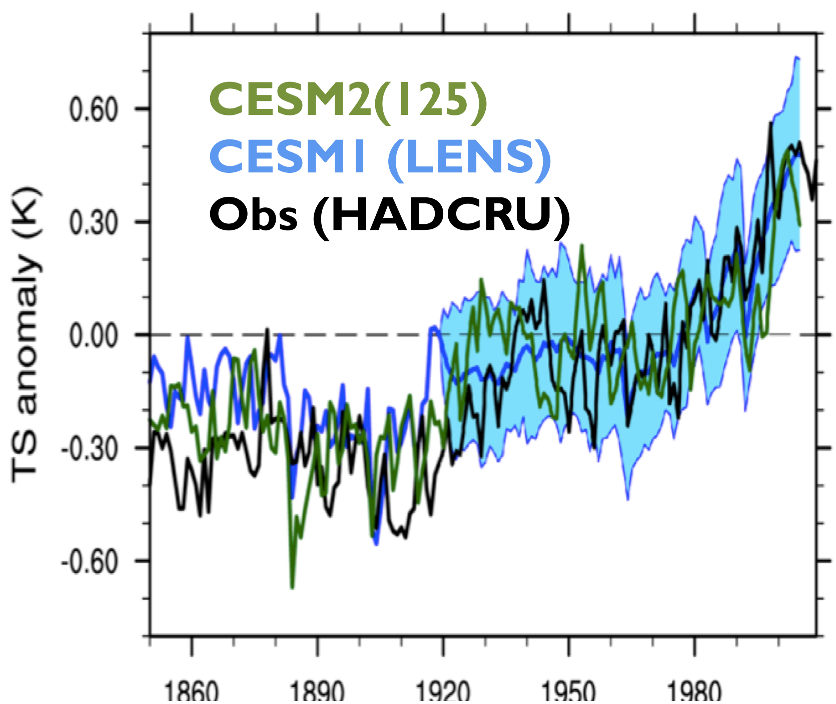
What happened since the last AMWG ?



Feb 2017: Winter Working Groups

- Extensive analysis of configuration #125
- Best CESM simulation ever (precipitation, SWCF, …)
- Need "minor" additions (expected not climate changing)

20th century warming in 125



125 produces credible 20thC warming

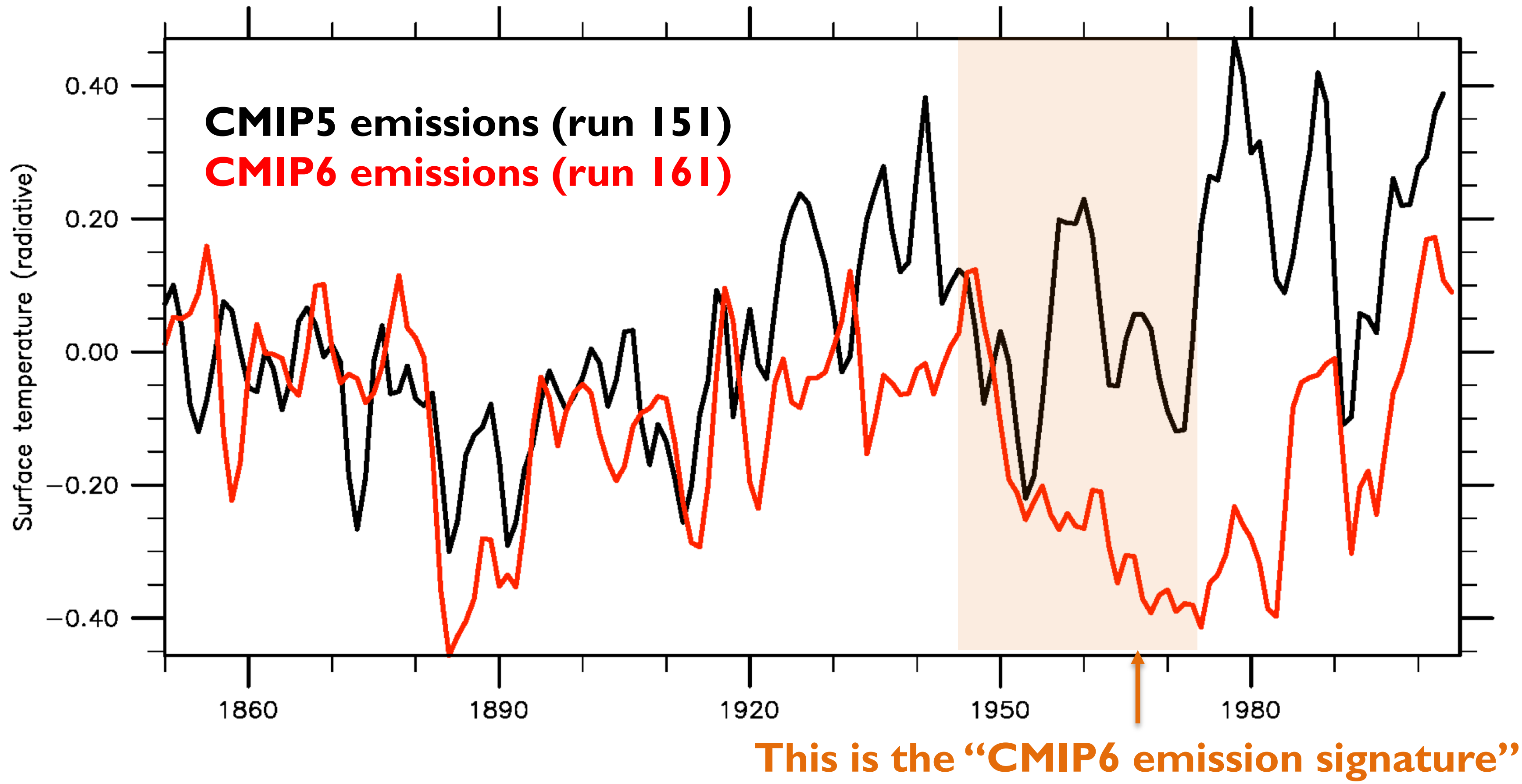
List of changes for final version:

- Greenland subgrid-scale topography
- Dust tuning
- CMIP5 => CMIP6 emissions
- Update to land vegetation parameters
- Crop improvement
- Caspian sea (from ocean to land)
- Robert Filter
- one-hour coupling atm ⇔ ocn
- Ocean initial conditions from LENS
- Ocean biogeochemisty

This is NOT a candidate !

Swapping CMIP5 ⇔ CMIP6 emissions

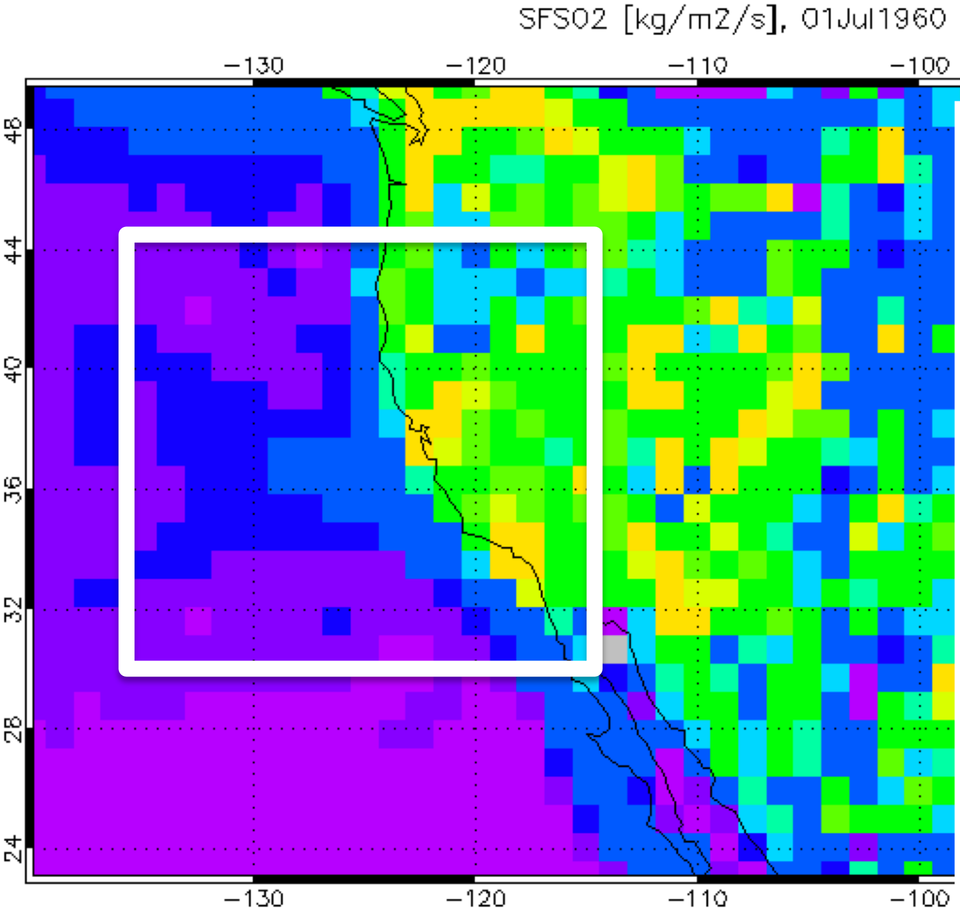
With CMIP6 emissions: cooling in the period 1945-1970

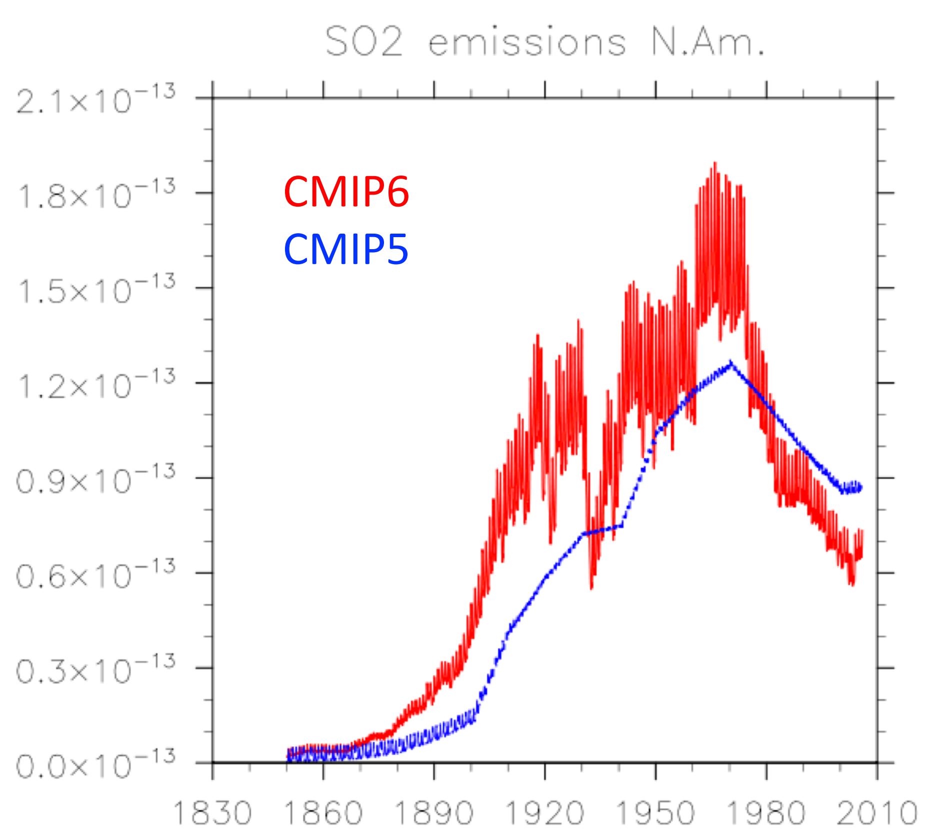


- **Are the CMIP6 emissions "wrong" ?**
- **Is the aerosol indirect effect too strong ?**

Differences in emissions: CMIP5 ⇔ CMIP6

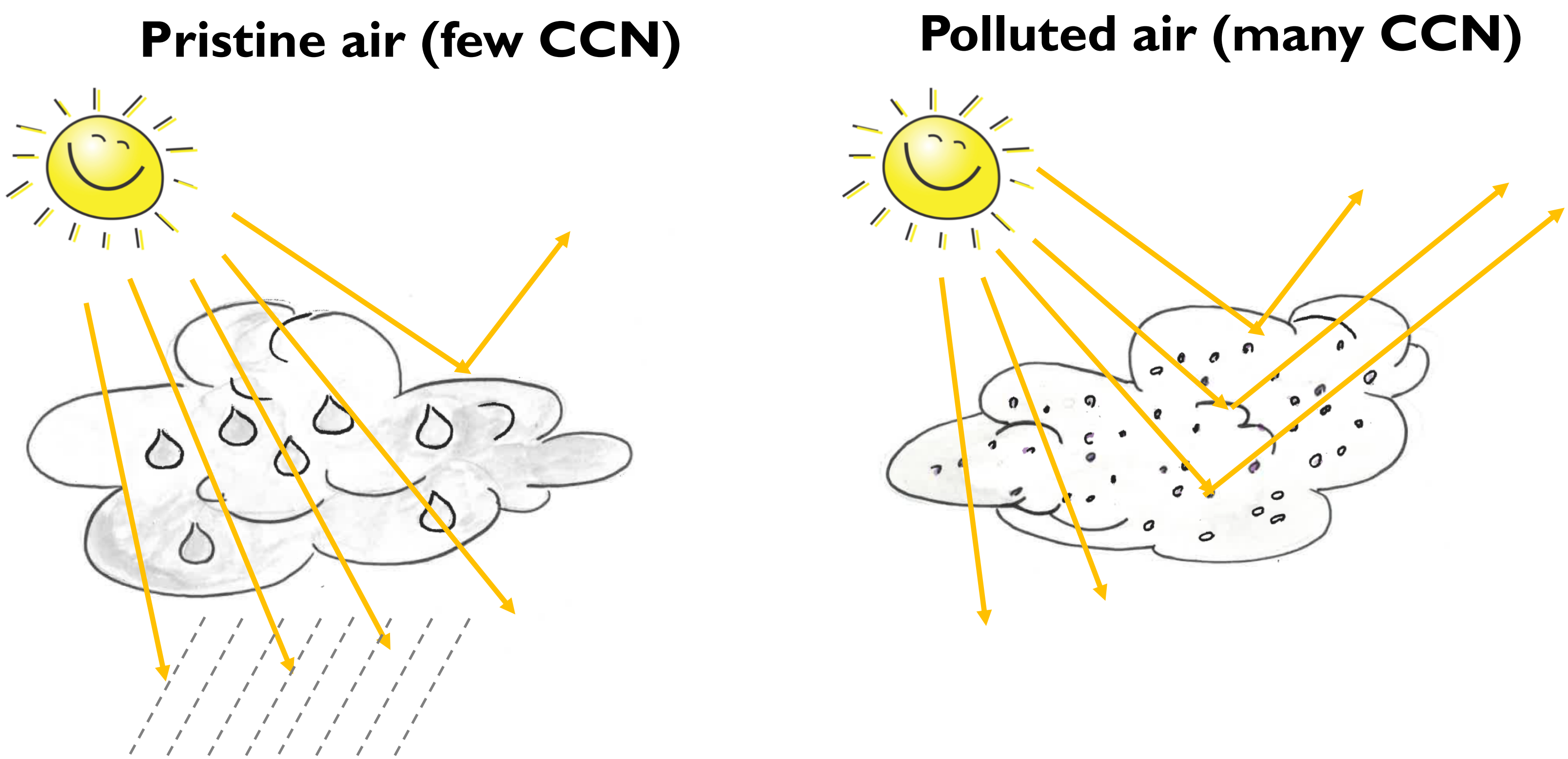
SO2 surface flux





Courtesy: Jean-Francois Lamarque

Aerosol Effects on Clouds



Aerosol – Cloud – Interactions (ACI)

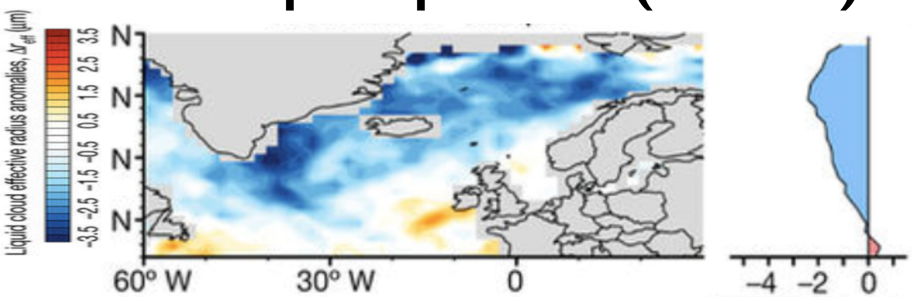
Smaller drops => brighter clouds: 1st indirect effect

=> delay in precipitation: 2nd indirect effect

Holuhraun eruption: Iceland (2014-2015)

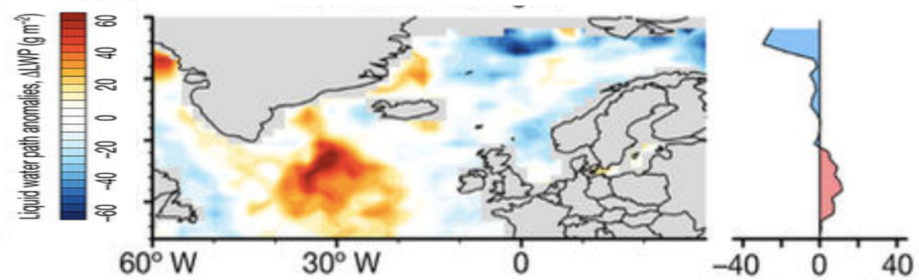
Malavelle et al (2017): Anomalies droplet size and LWP

Cloud Top droplet size (MODIS)



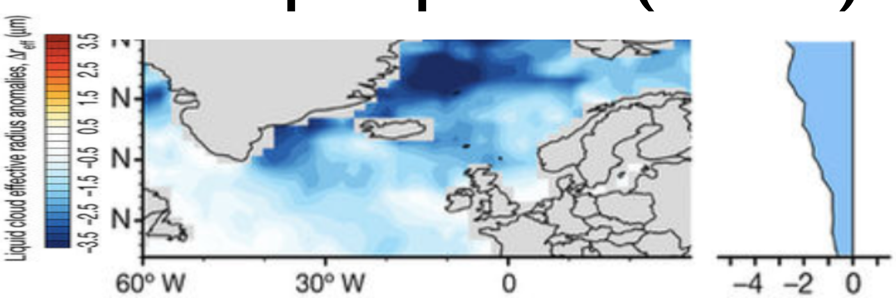
Obs: reduced cloud droplets size

Liquid Water Path (MODIS)

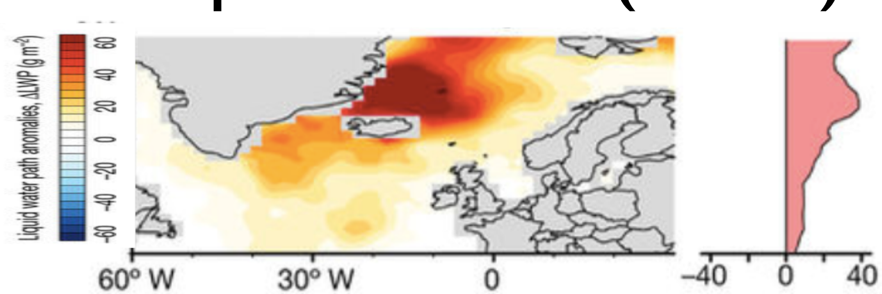


Obs: No change in LWP

Cloud Top droplet size (CESM1)



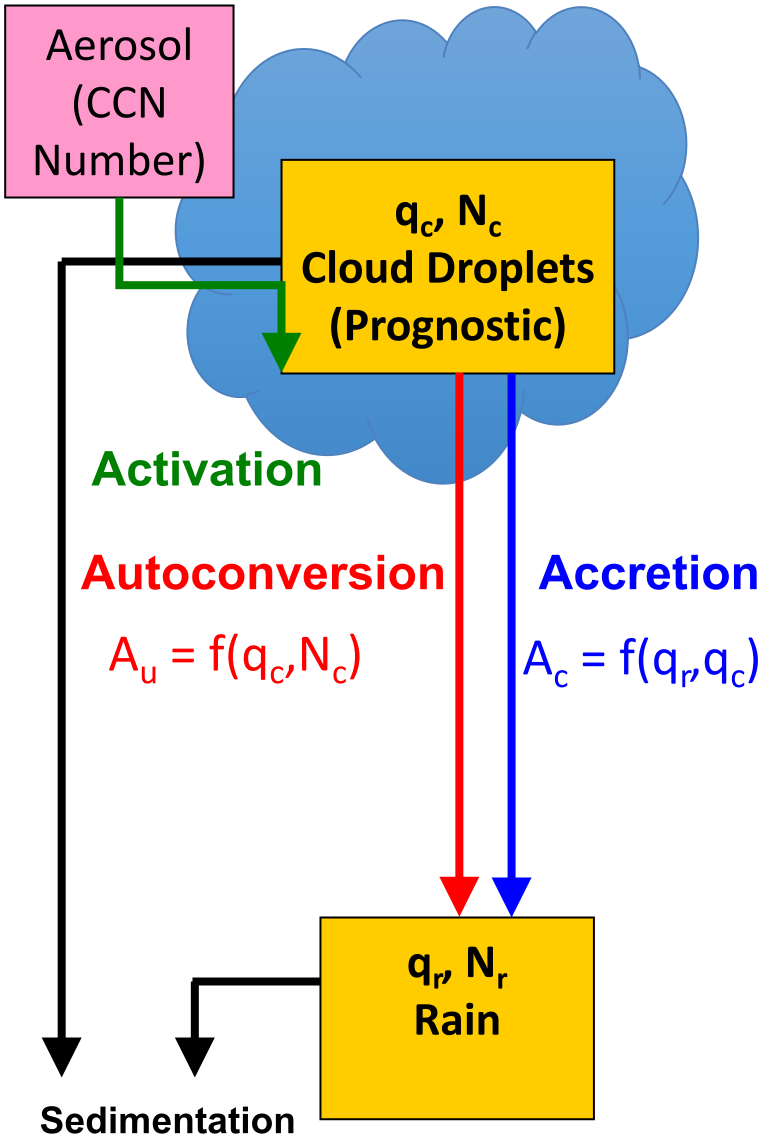
Liquid Water Path (CESM1)



Courtesy:
Andrew Gettelman

CESM1 overestimates the change in LWP
=> Aerosol indirect effect is too strong

Aerosol Cloud Interactions in CESM2



1. **Activation (CCN) = f(RH,w)**
   W at cloud scale is critical

2. **Autoconversion (loss process) is a function of N_c (=ACI)**

3. **Accretion depends on q_r**

Courtesy: Andrew Gettelman

Autoconversion and indirect effect

Khairoutdinov and Kogan scheme (KK2000)

$$A = f(N_c^{-b})$$

A = autoconversion rate
N_c = droplet number (#/kg)

Smaller indirect effect —*b increases*→ *Larger indirect effect*

Lot of uncertainty on b (depends on field campaign)

We can investigate the sensitivity to exponent b (*)

- b = 1.79 (original value: KK2000)
- b = 1.1 (Wood, 2005)
- b = 0.5 (Extreme value)

(*): E3SM pioneered this type of sensitivity (Rasch, Ma, Ghan, Caldwell, ...)

Autoconversion and indirect effect

Khairoutdinov and Kogan scheme (KK2000)

$$A = f(N_c^{-b})$$

A = autoconversion rate
N_c = droplet number (#/kg)

Smaller indirect effect → ***b increases*** → *Larger indirect effect*

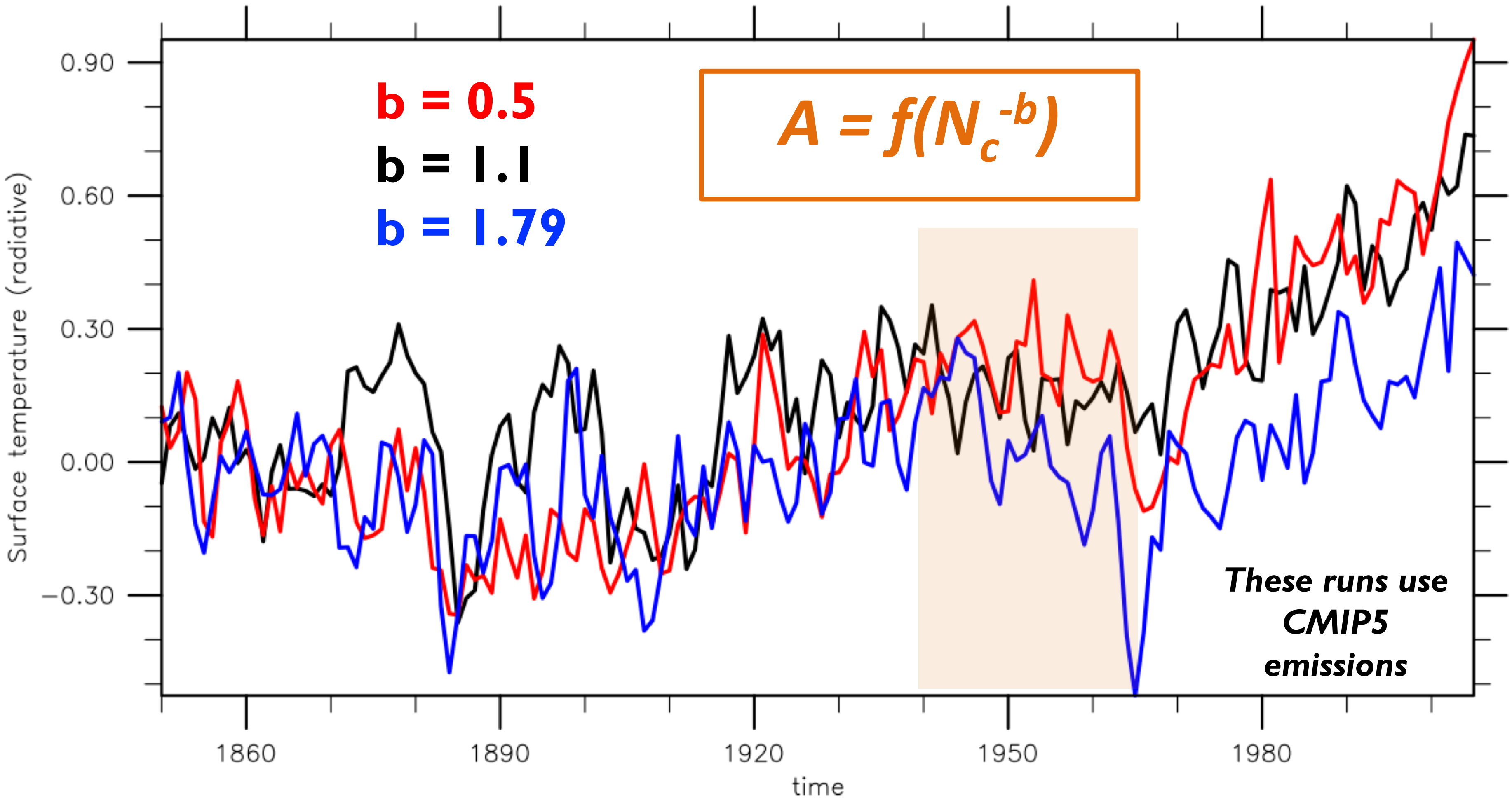
Compare two standalone simulations
→ present day aerosol (2000)
→ pre-industrial aerosol (1850)

	b = 0.5	b = 1.1	b = 1.79	
ΔRESTOM (W/m2)	-1.18	-1.27	-1.56	Total effect
ΔSWCF (W/m2)	-1.11	-1.17	-1.29	1st indirect effect
ΔLWP (%)	2.35%	4.72%	7.3%	2nd indirect effect

Reducing b decreases indirect effect in standalone runs

Impact on 20th century surface temperature

Exponent b as a large impact on the period 1940-1965

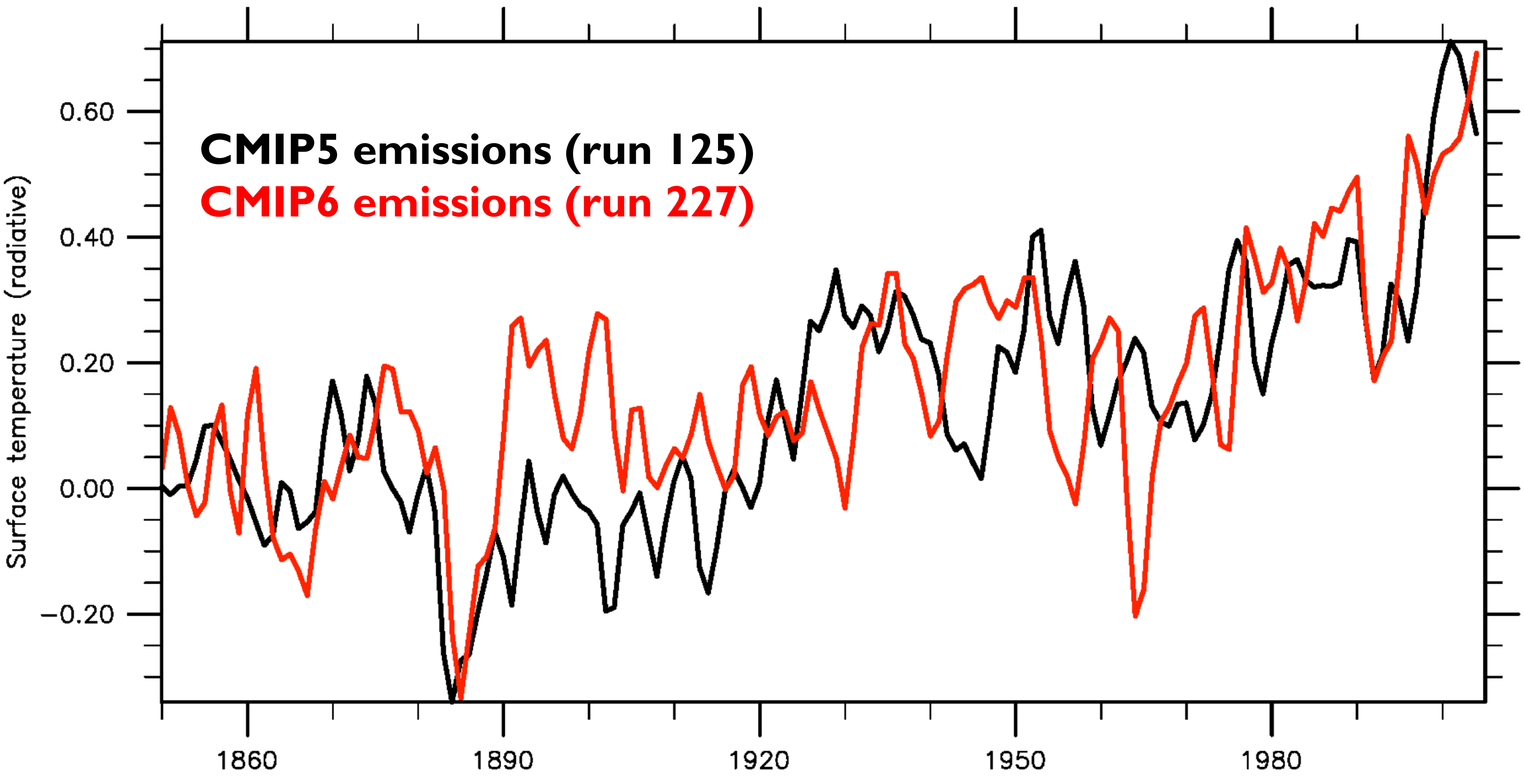


For CESM2, we picked b = 1.1

Credible 20th century with CMIP6 emissions

Fall 2017: Credible 20th century with CMIP6 emissions includes:

- **Modification to autoconversion (exponent b=1.1)**
- **MG2 bugfix + tuning adjustement (evaporation of convective precipitation + stratocumulus: see Julio's talk).**



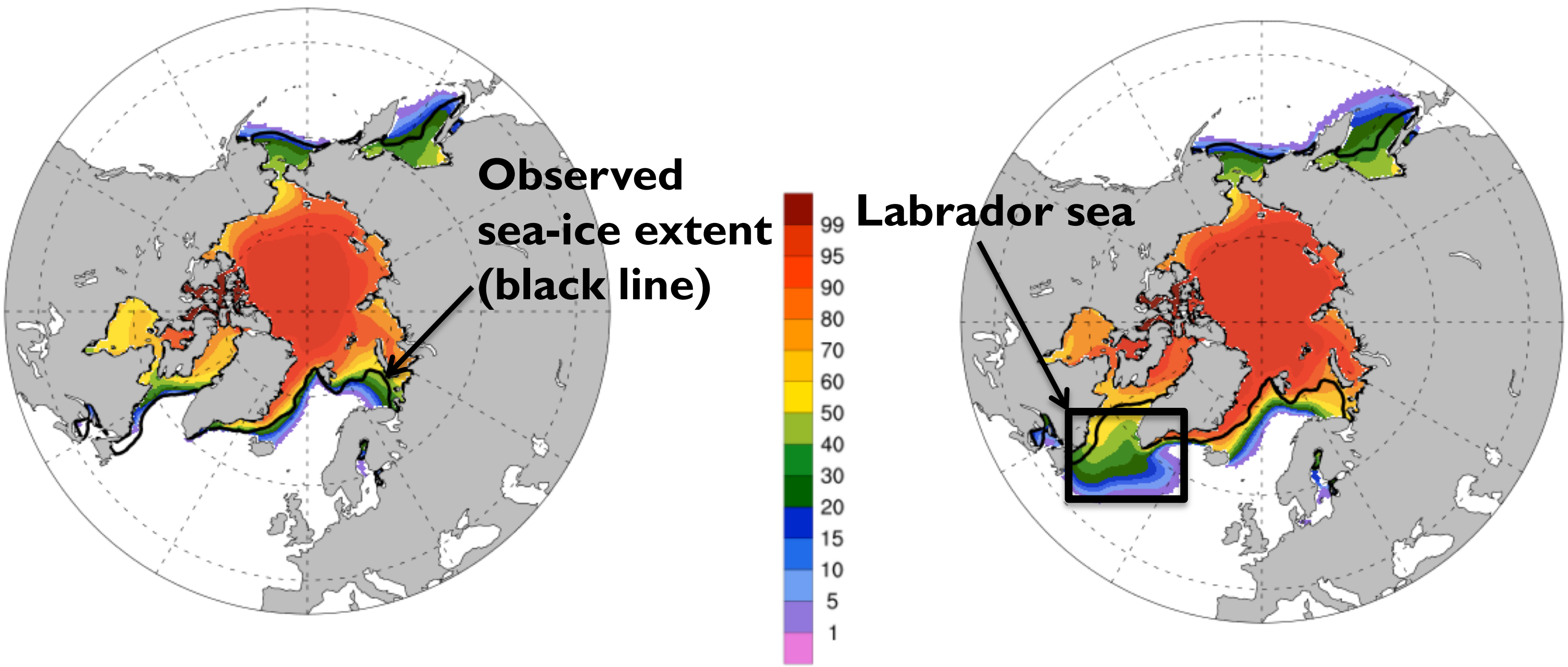
CESM co-chairs

BUT…

The return of the Labrador Sea issue

Sea-ice extent

CESM2 (125) **CESM2 (227)**



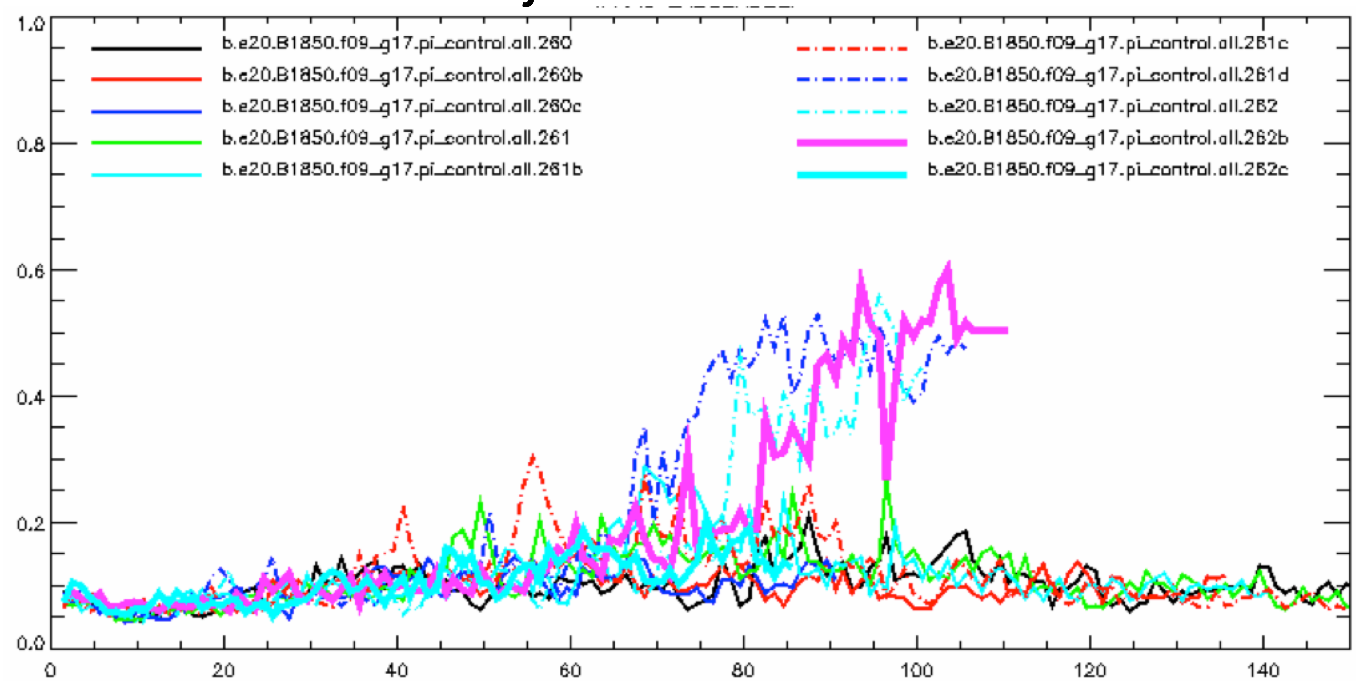
Sea-ice extent is close to obs.
Labrador sea is ice free

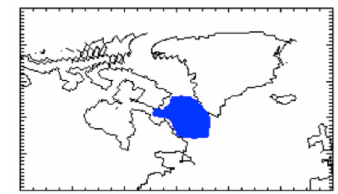
Labrador sea is ice-covered.

Labrador Sea: Perturbed runs

- Very sensitive to small perturbation (size of round off)
- Likely spinup issue (Labrador Sea always freezes in first 100 yrs)

Ice fraction over Labrador Sea





4/10 runs freeze

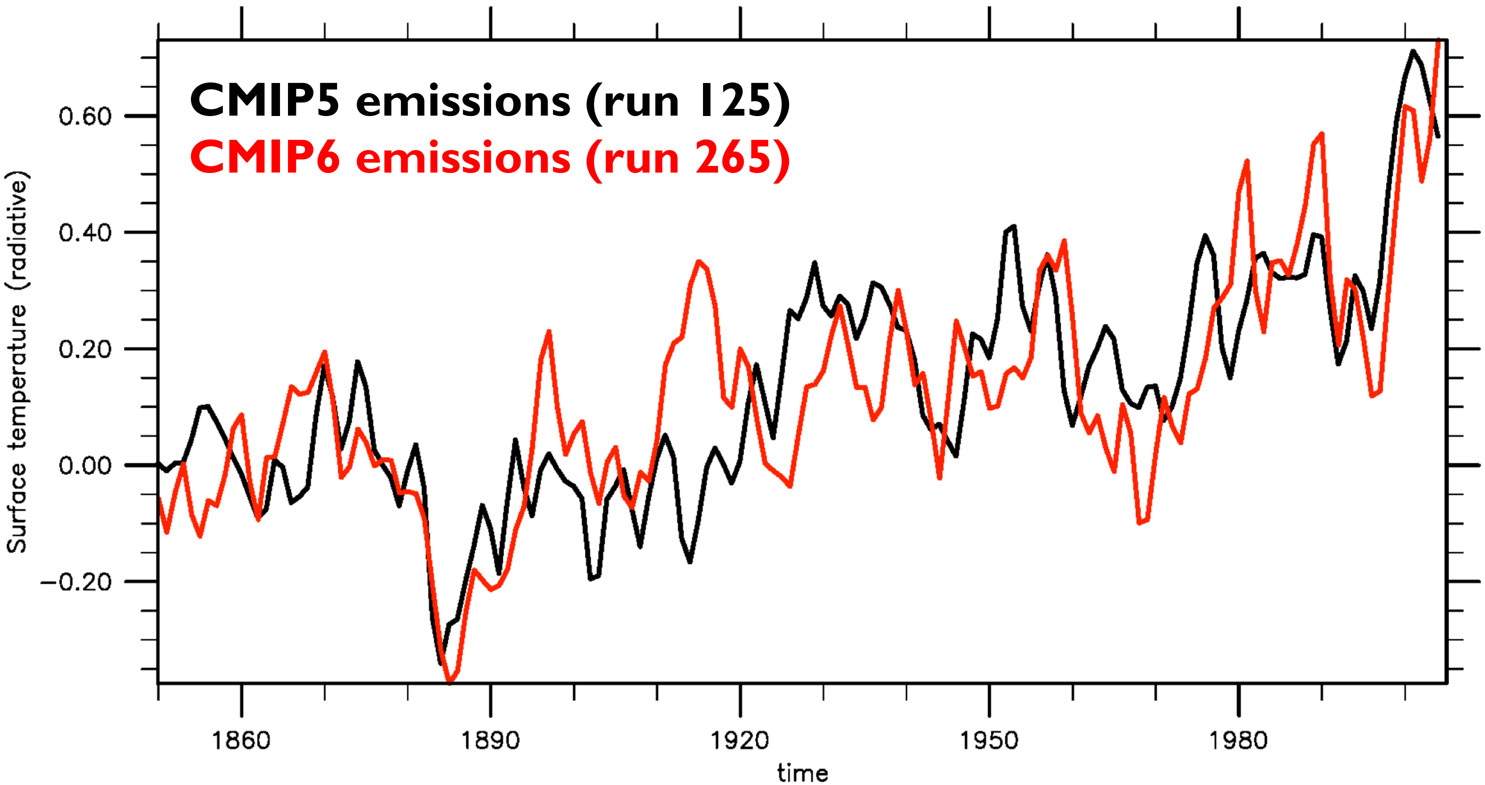
- Labrador Sea very close to the "freeze or not" edge.
- Efforts to move far enough from the edge were unsuccessful.
- CESM2 will be released with a spunup state.

Current state of the CESM2 simulation

20th century warming

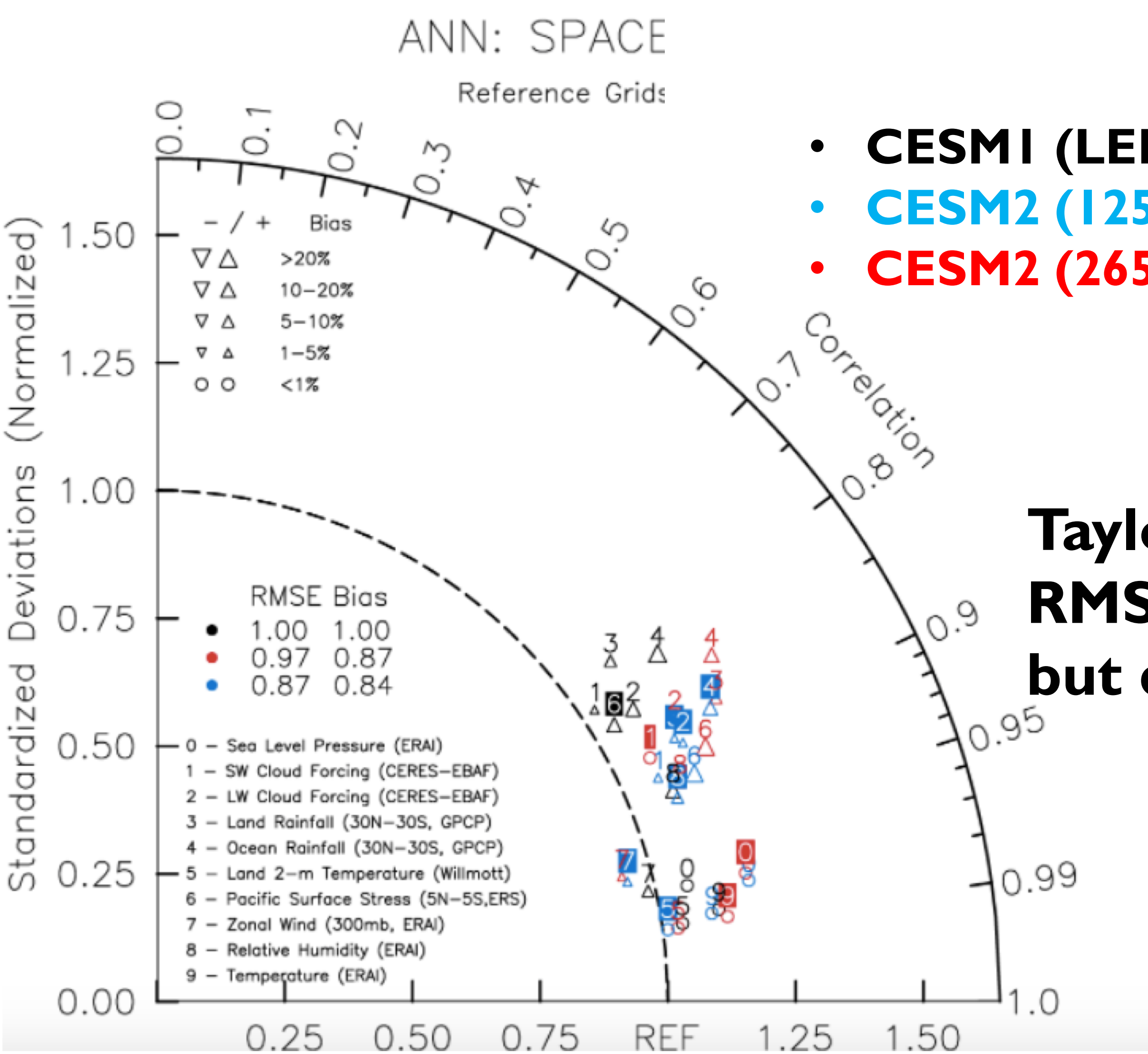
Current simulation = 265

265 produces credible 20th simulation (similar to 125)



... but 20th warming is not the whole story.

Taylor Diagram

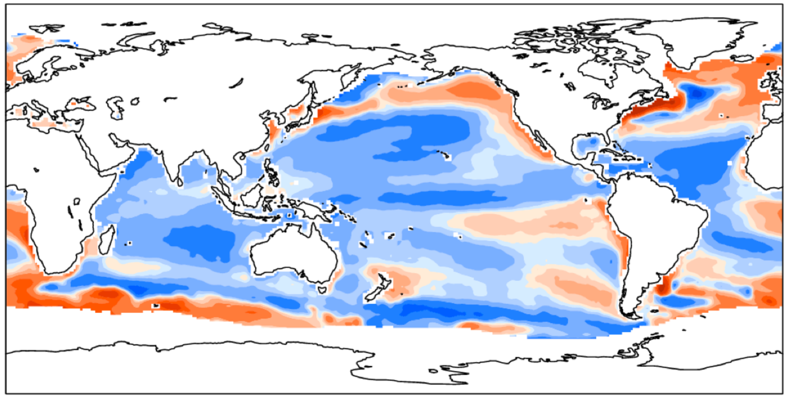


	RMSE	Bias
• CESM1 (LENS)	1.00	1.00
• CESM2 (125)	0.87	0.84
• CESM2 (265)	0.97	0.87

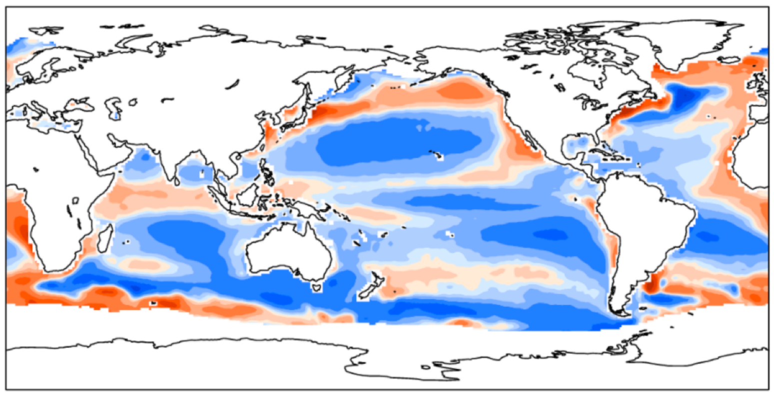
Taylor score:
RMSE better than LENS
but degraded since 125

Sea Surface Temperature (SST) bias (ANN)

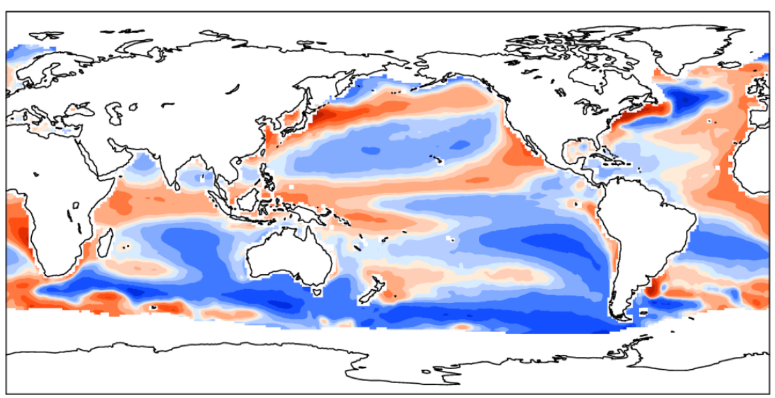
LENS
Bias = -0.24K
RMSE = 0.91

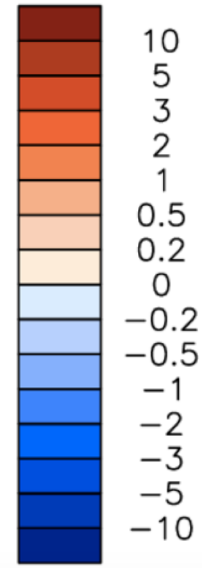


CESM2 (125)
Bias = -0.32K
RMSE = 0.98



CESM2 (265)
Bias = -0.18K
RMSE = 1.09

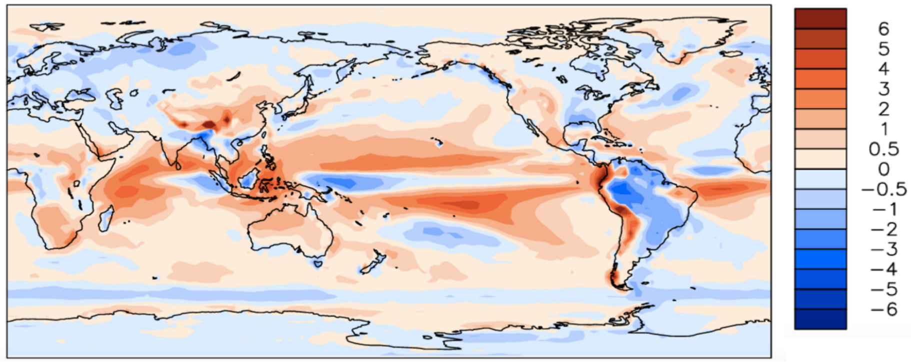




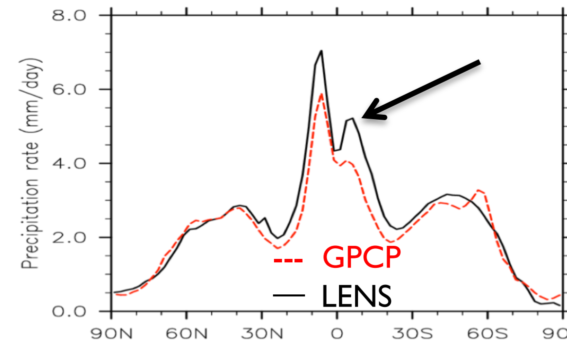
SSTs:
RMSE better than LENS but degraded since 125

Precipitation bias versus GPCP (ANN)

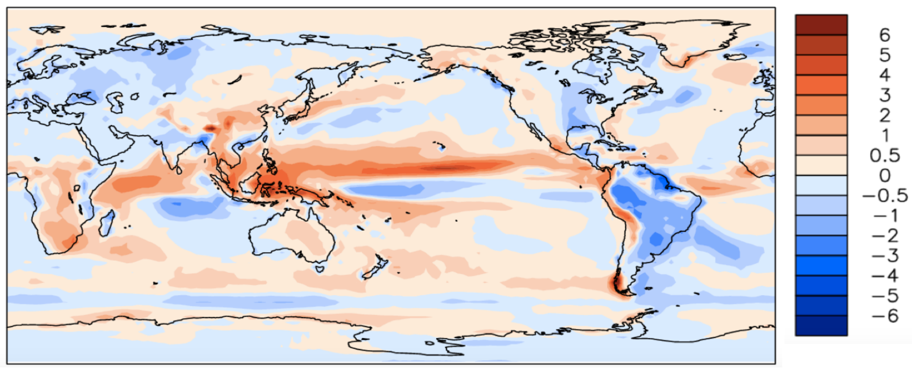
LENS
Bias = 0.37
RMSE = 1.13
(mm/day)

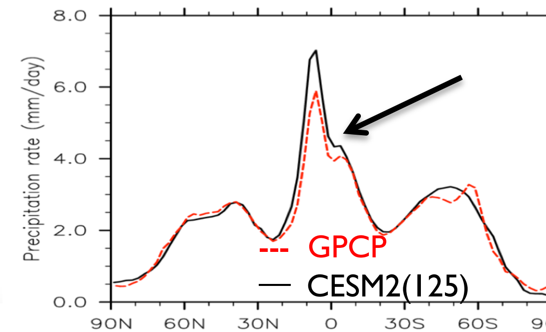


Double ITCZ

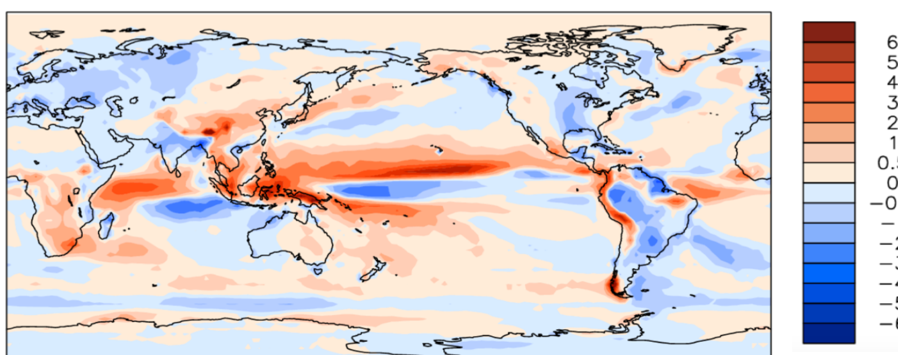


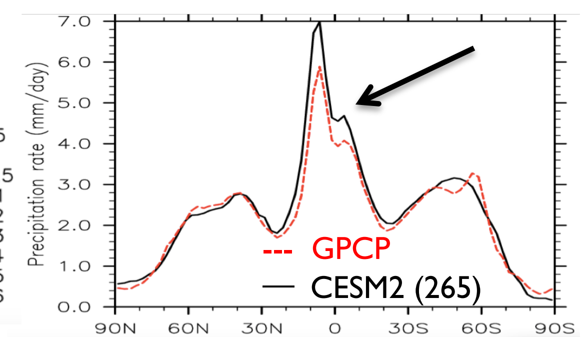
CESM2 (125)
Bias = 0.18
RMSE = 0.89
(mm/day)





CESM2 (265)
Bias = 0.22
RMSE = 1.03
(mm/day)

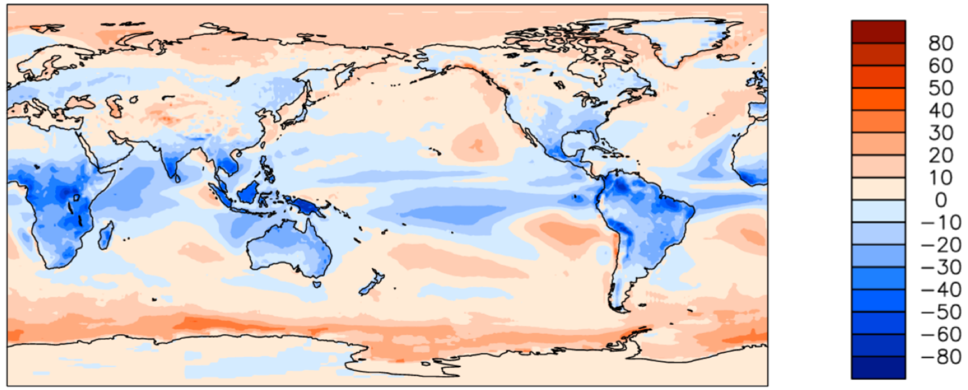




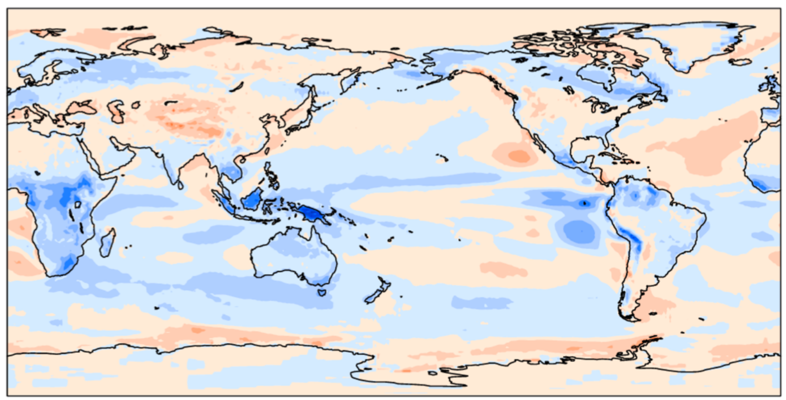
Precipitation: RMSE better than LENS but degraded since 125

SWCF bias versus CERES-EBAF (ANN)

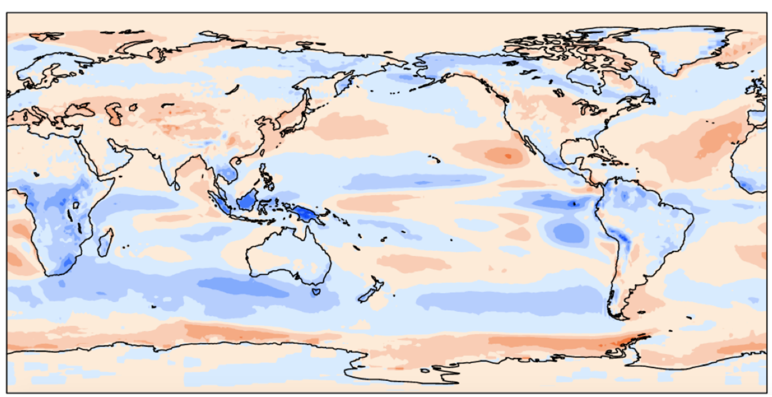
LENS
Bias = -1.18
RMSE = 13.7
(W/m2)



CESM2 (125)
Bias = -1.43
RMSE = 8.97
(W/m2)



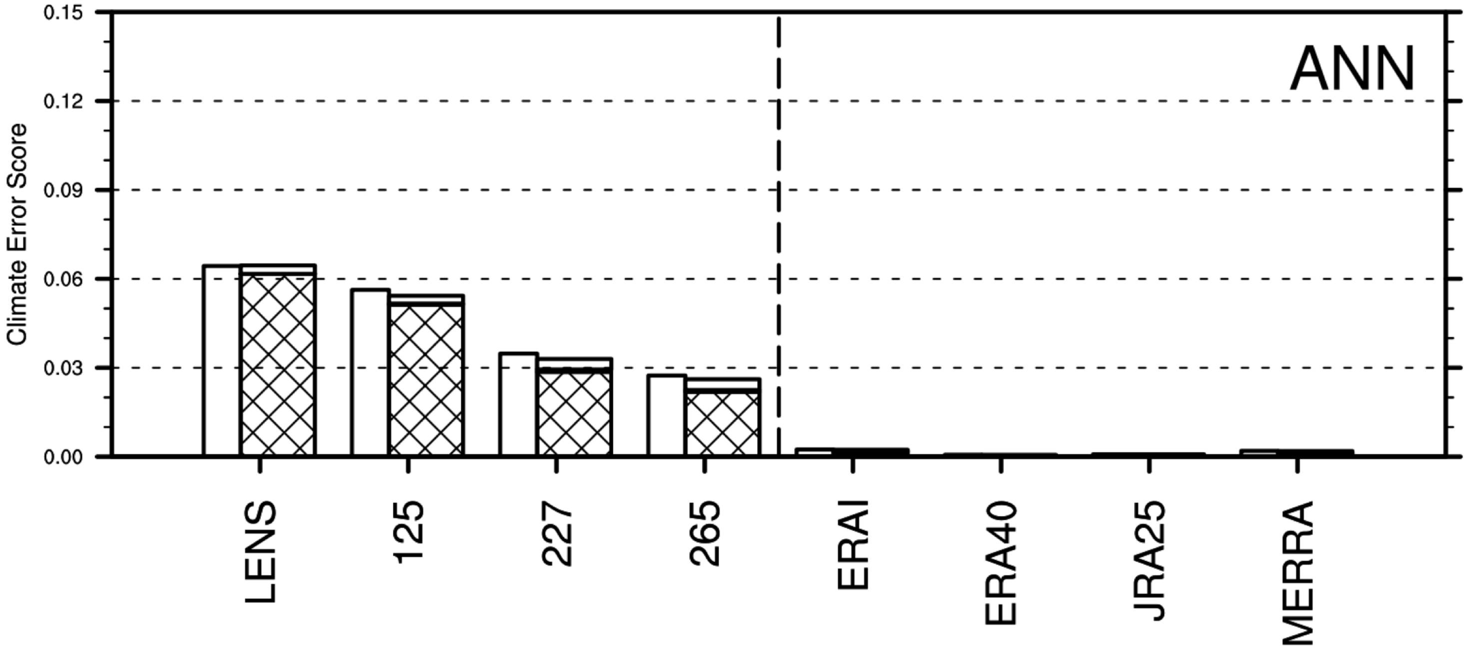
CESM2 (265)
Bias = 0.20
RMSE = 9.20
(W/m2)



SWCF:
better than LENS
and similar to 125

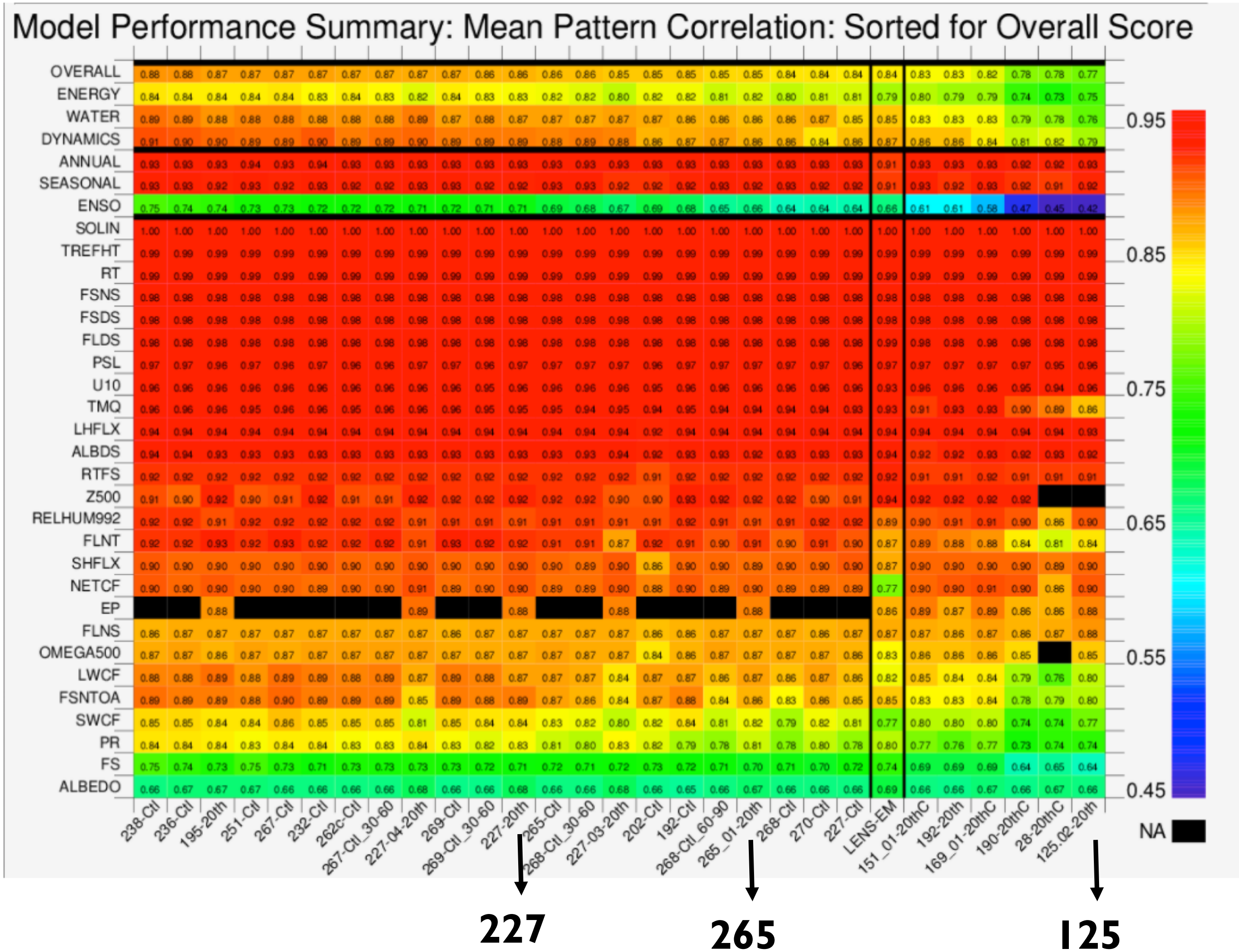
Climate Error Score

Z500 skill score: 20N-80N metrics



Courtesy: Rich Neale

Climate Model Assessment Tool (CMAT)

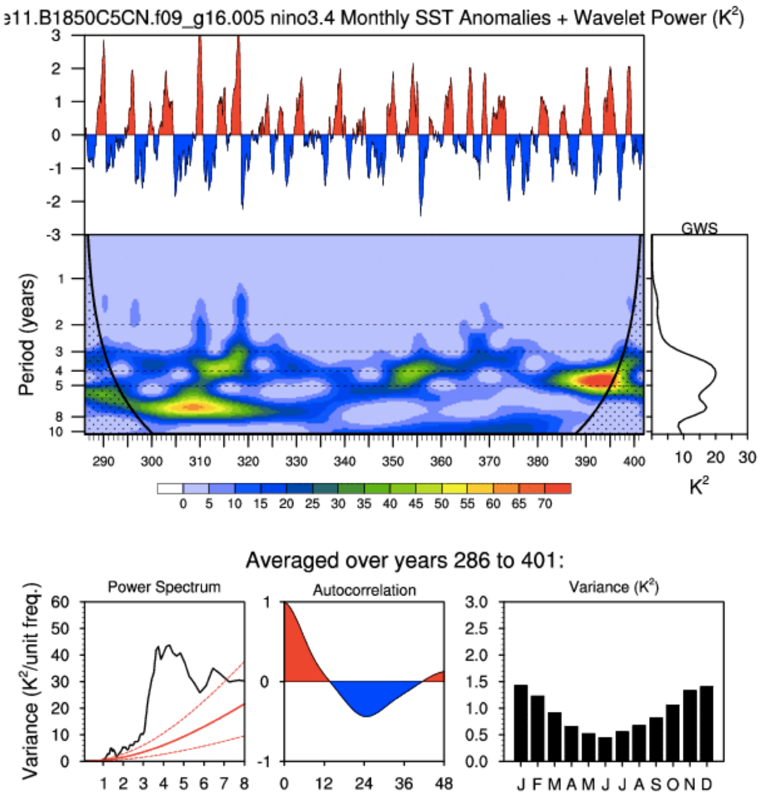


Courtesy: John Fasullo

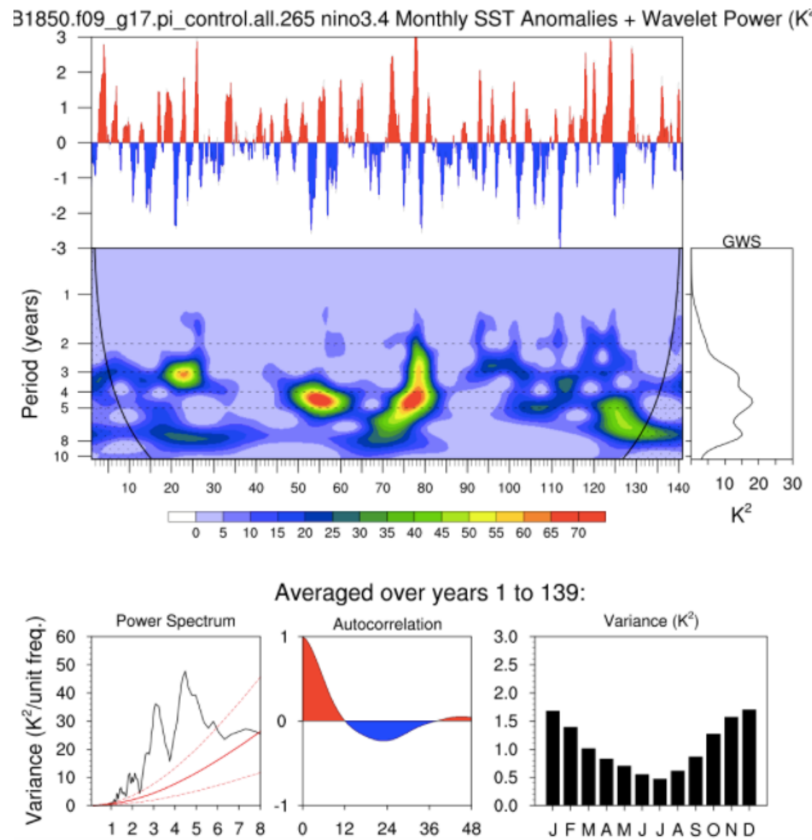
http://webint.cgd.ucar.edu/project/diagnostics/internal/Multi-Case/CMAT/index_overall.html

Nino3.4 is acceptable

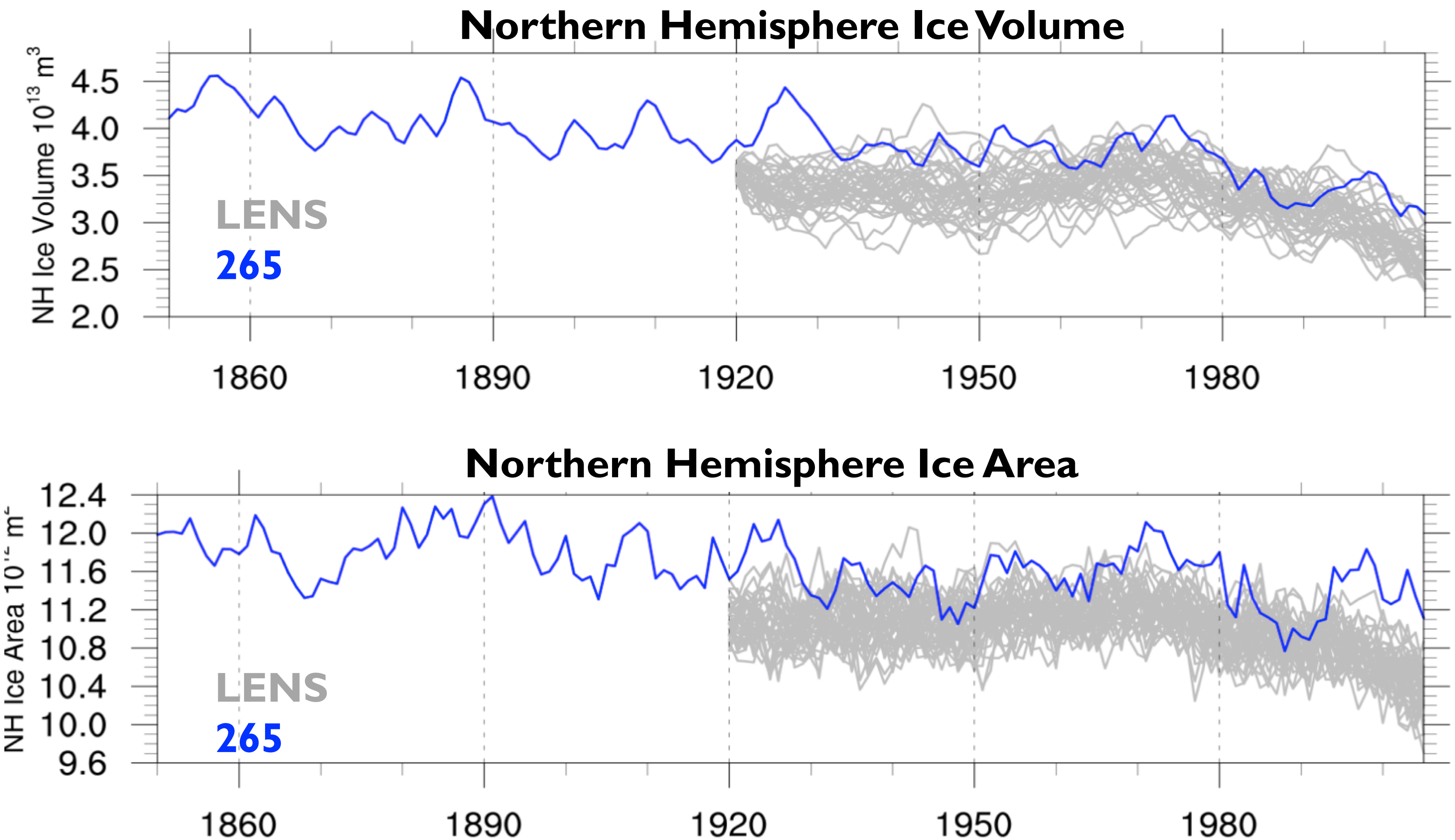
LENS



265



Remaining issues: Sea-ice too thick



Could we live with that ?

Current test changing sea-ice albedo ?

Courtesy: Dave Bailey

Conclusion

A brief history of the last year simulations

- We started at 125 => 265
- 125 is a good simulation but not a candidate for CESM 2 (land issues)
- Problems when introducing CMIP6 emission
- CMIP6 decent 20th century after change to autoconversion to reduce indirect effect and MG2 bugfix + retuning
- The return of the Labrador Sea Freeze
  This seems to to related to spinup issues

Overview of current simulation

- 265: Credible 20th century
- Taylor scores in 265 are not as good as 125 (especially precipitation are degraded)
- 265 looks great in climate score (Z500) and CMAT plot
- Acceptable ENSO
- Remaining issues: sea-ice is too thick