GFDL's next generation climate models: CM4 and ESM4

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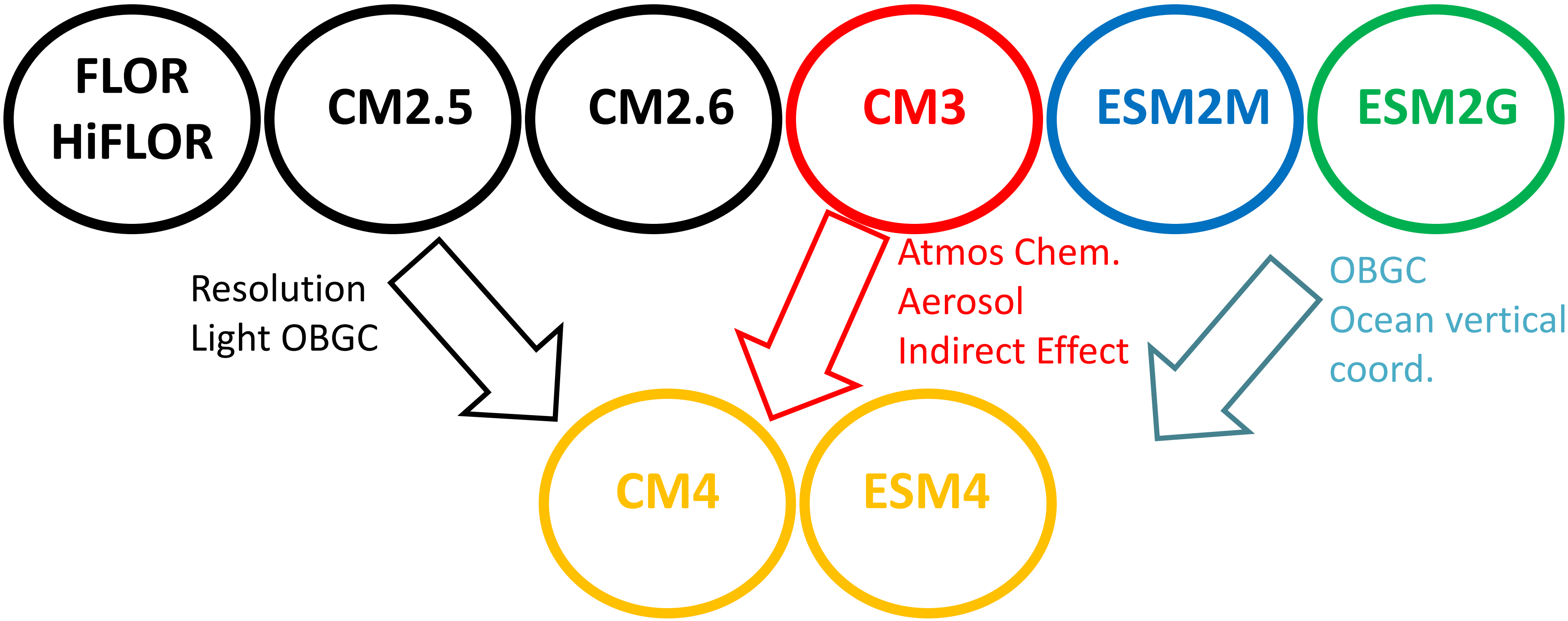
Geophysical Fluid Dynamics Laboratory Fall Science Symposium
November 2, 2017

Rationalizing GFDL's CMIP5 generation models



5-10 year Strategic Science Plan (2011) goal:
high resolution Earth System Model combining strengths of GFDL's multiple AR5 modeling streams

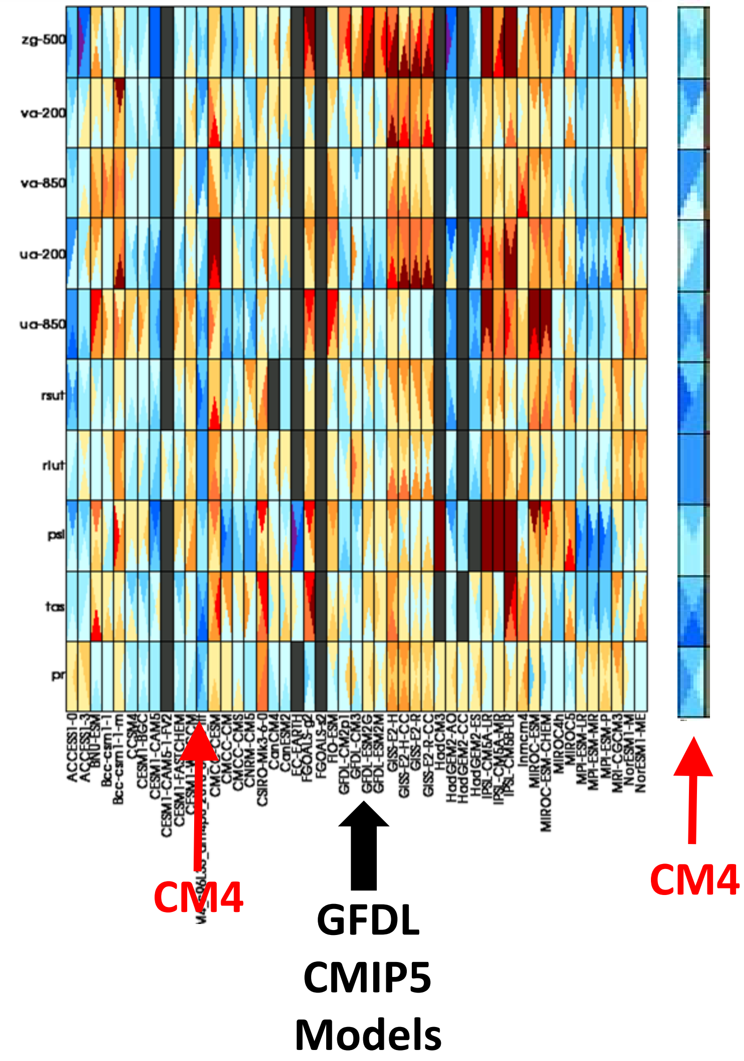
GFDL's CMIP6 generation models: CM4 and ESM4

	CM4 (frozen, starting DECK)	ESM4(in final development)
Atmosphere: AM4	100 km, 33 levels	100 km, 49 levels
Atmos. Chem	for aerosol (21 tracers)	aerosol+ozone (103 tracers)
Ocean: MOM6	$1/4^{o}$, 75 levels	$1/2^{o}$, 75 levels
Ocean BGC	BLINGv2 (6 tracers)	COBALTv2 (30 tracers)
Land	LM4.0	LM4.1 - PPA
Sea Ice	SIS2	SIS2

Note: All CM4 results shown are *preliminary* (based on potential vegetation historical, 1850- and 2010-forced experiments). We haven't yet run the official CMIP6 experiments with CM4.

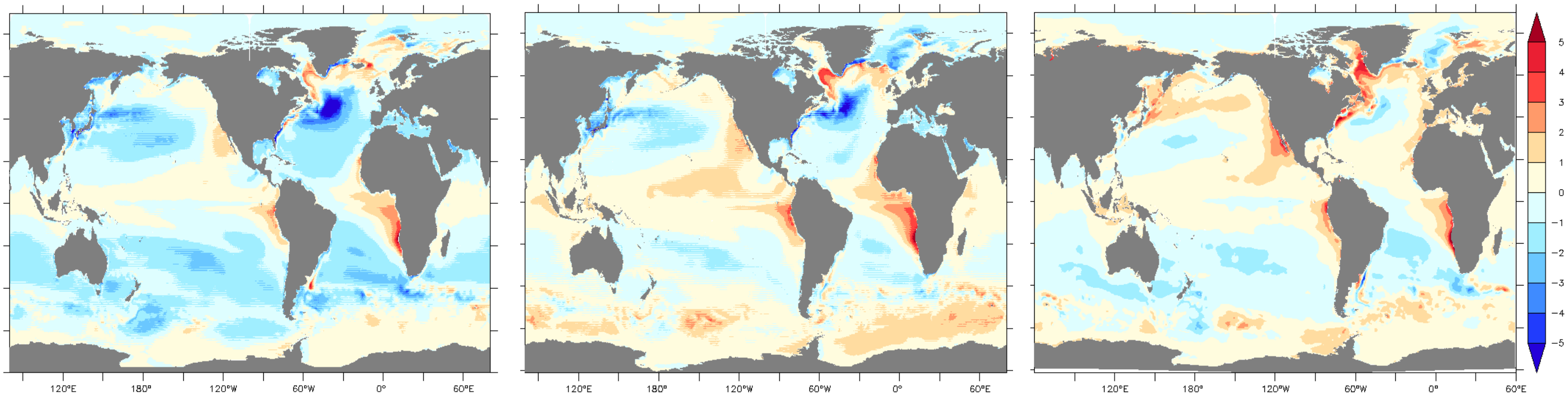
CM4 Surface Climate

- CM4's climatology is a distinct improvement over previous GFDL models
- CM4 temp., precip., OLR and reflected SW are the best in this CMIP5 ensemble
- Wind fields are good but not the best



CM4 SST errors

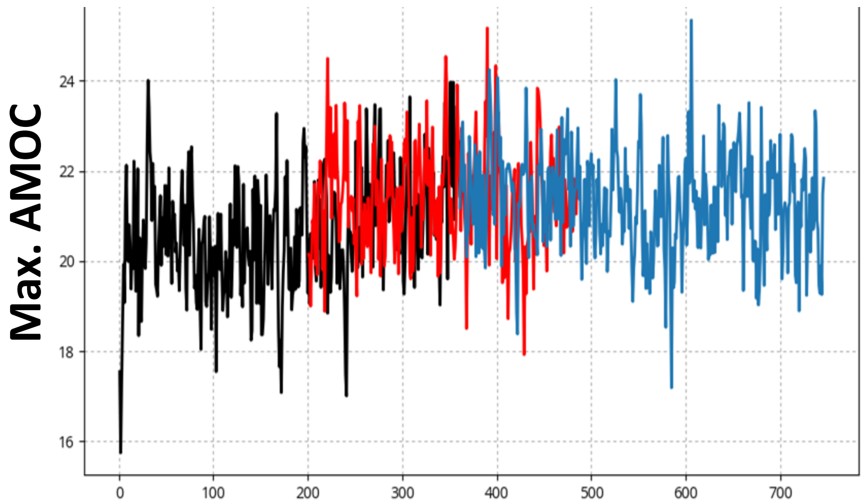
CM2.5 RMSE=1.17°C | **CM2.6** RMSE=0.95°C | **CM4** RMSE=0.84°C

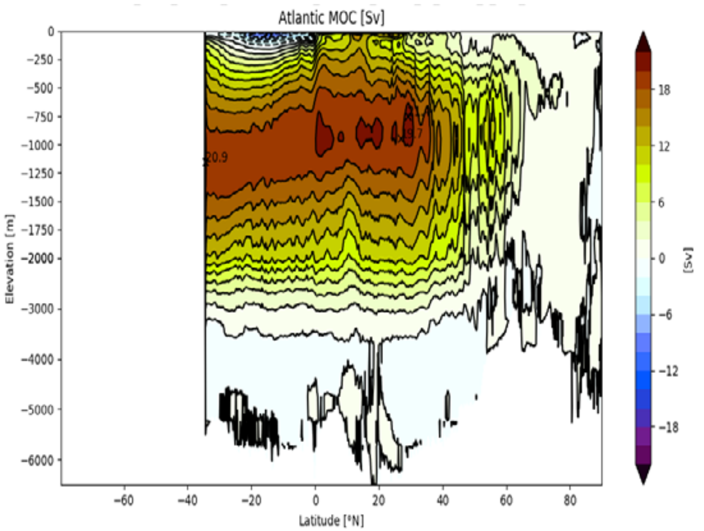


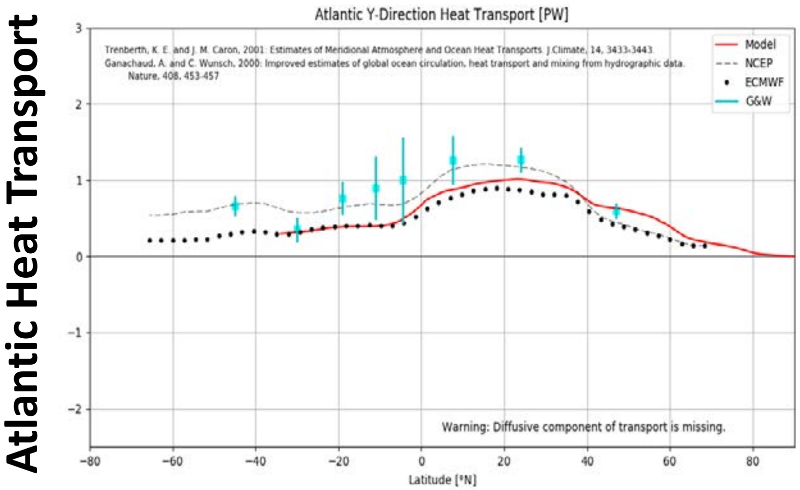
Ocean Res. = 1/4° | 1/10° | 1/4°

- CM4 SST error is smaller than CM2.6 (GFDL's previous best simulation)
- We expect CM4's SSTs can be improved further with higher ocean resolution (as seen refining CM2.5 to CM2.6) or with an eddy parameterization

Atlantic Meridonal Overturning



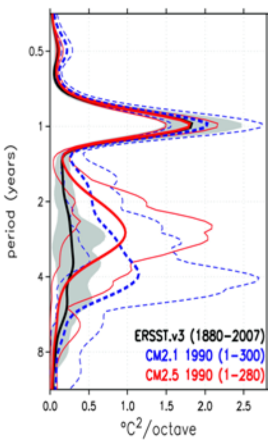




- Strong, stable AMOC
- Deep flow is too shallow and warm
- Heat transport less than observed

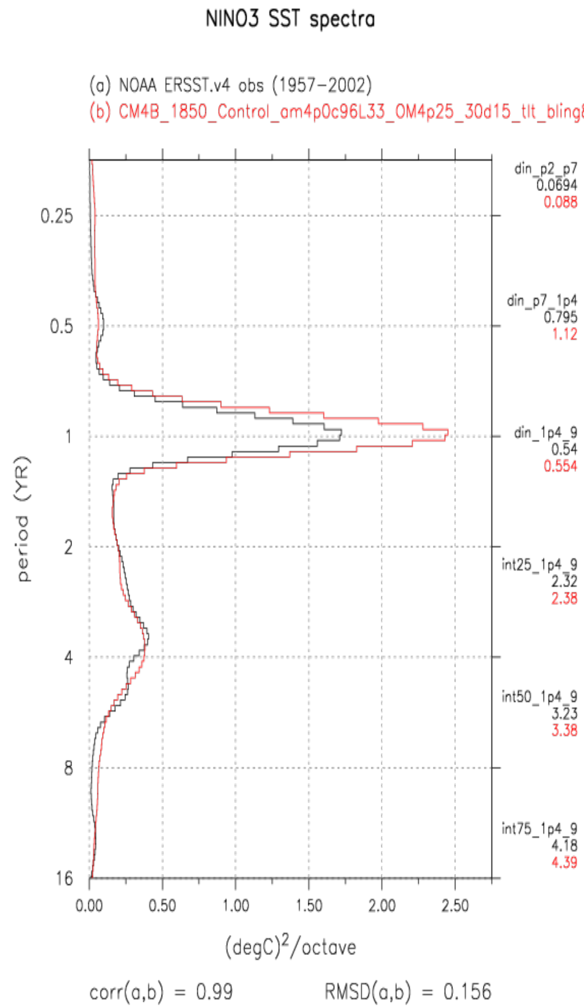
Variability: Improved ENSO

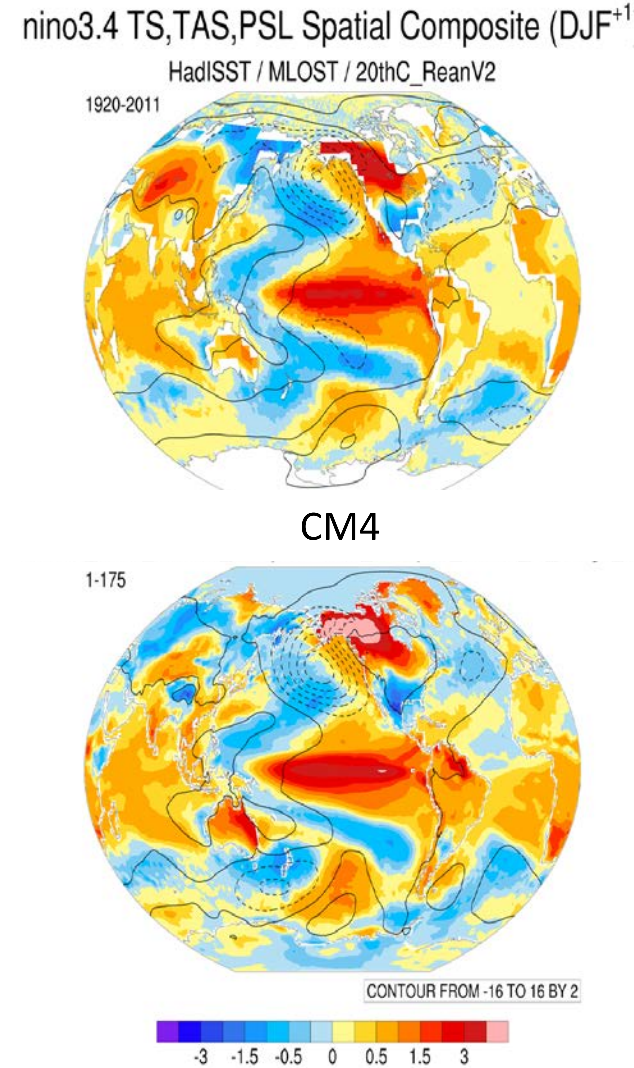
- ENSO magnitude is more realistic than previous GFDL models which tended to be too large



Delworth et al 2012

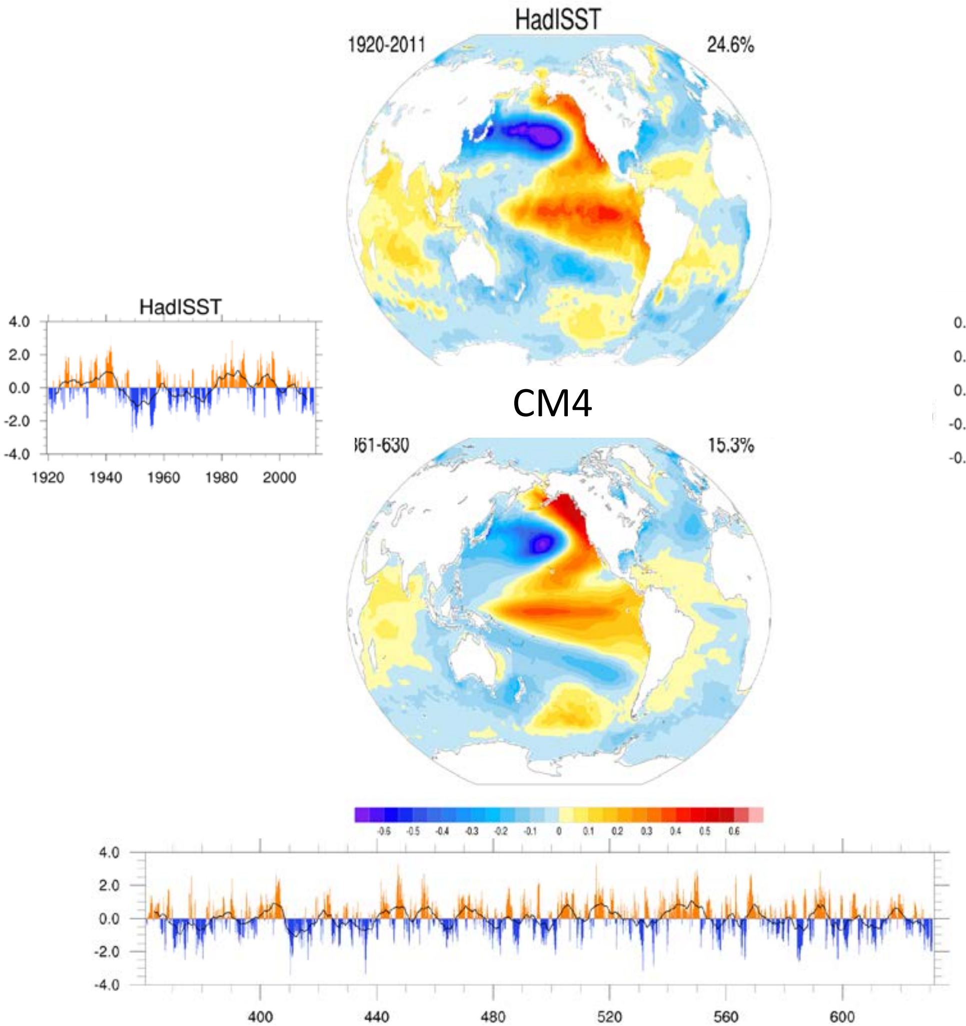
- ENSO teleconnection pattern is well simulated



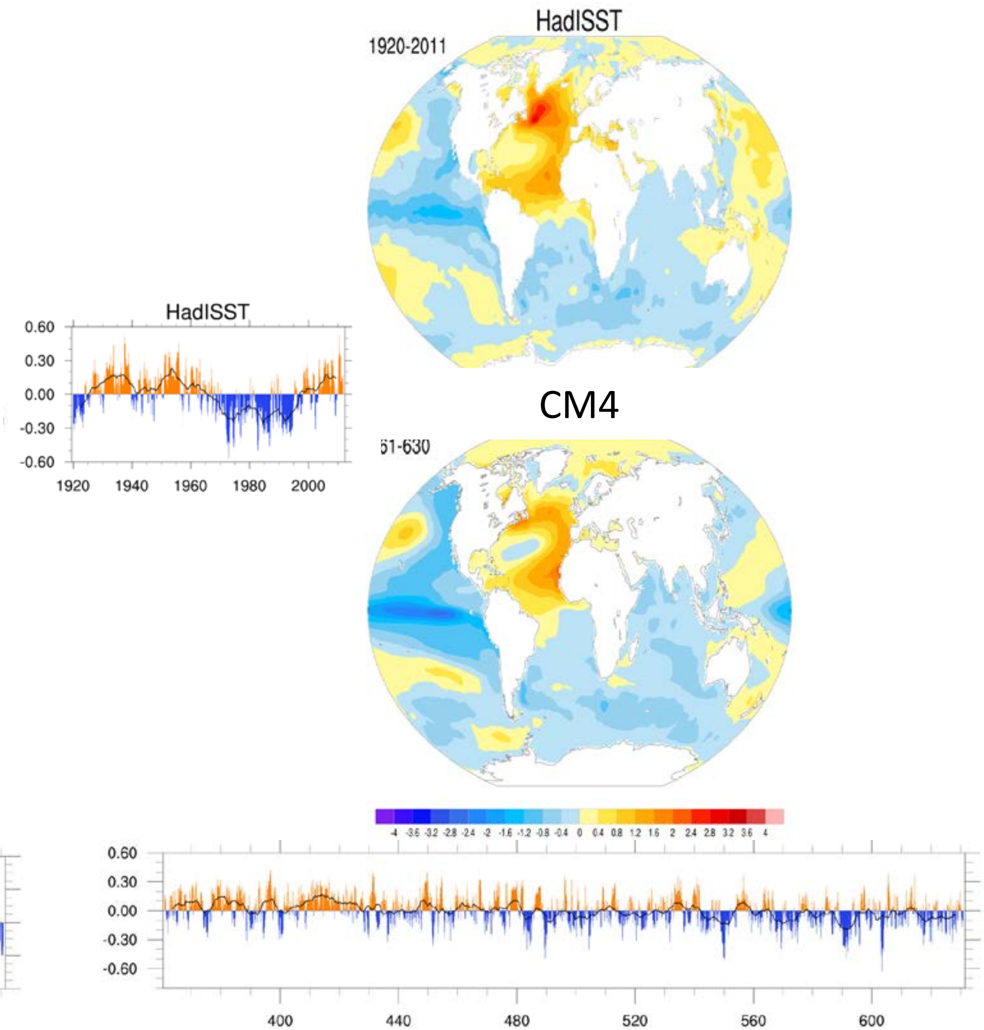


Variability:
PDO and AMO patterns are well-simulated

Pacific Decadal Oscillation

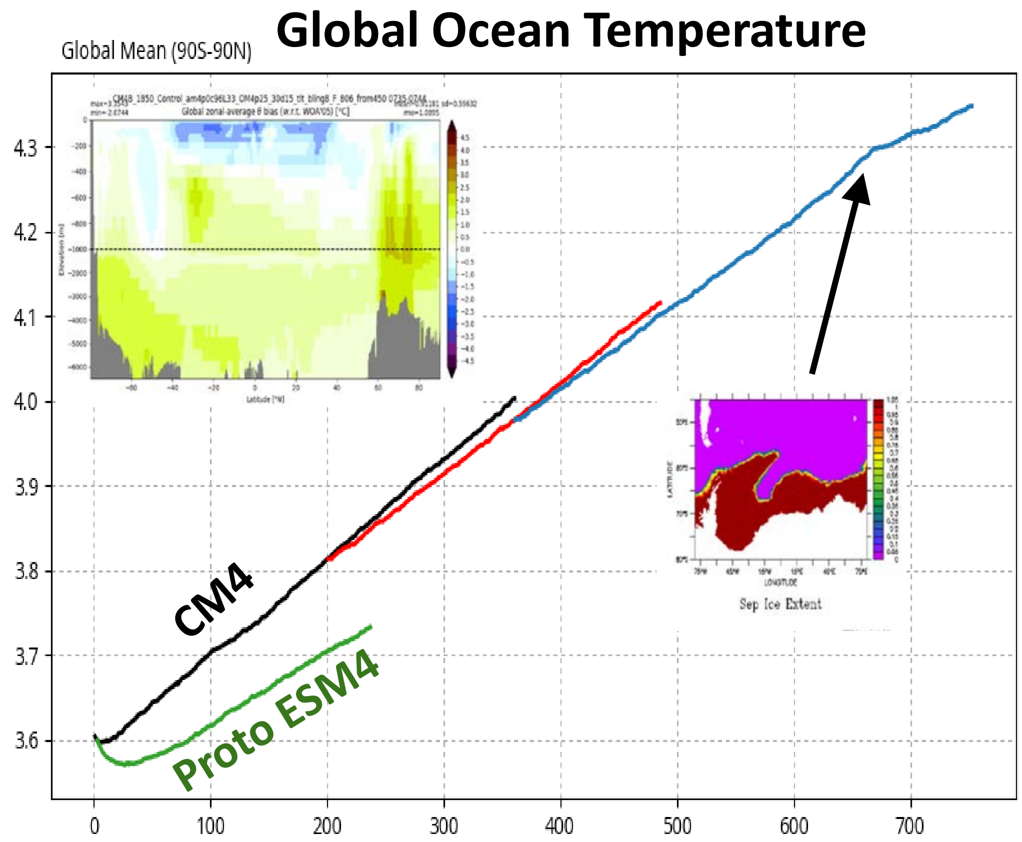


Atlantic Multi-decadal Oscillation



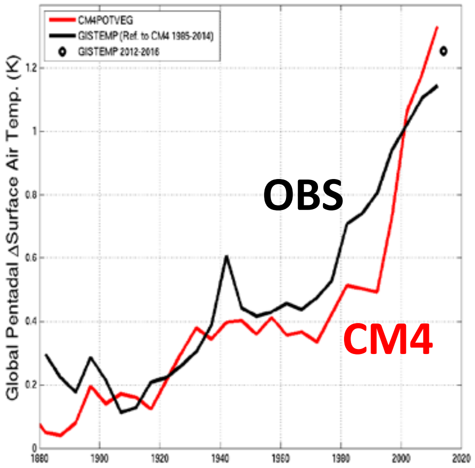
Global Ocean Temperature Drift

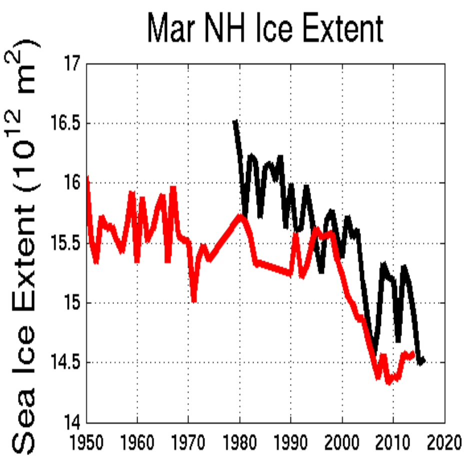
- Heat uptake is less than CM2.5 (also using 1/4° ocean)
- Heat uptake is less than the difference in heat uptake between CM2.6 and CM2.5 (eddy-permitting res. effect)
- Warming of deep water points to inadequacy of deep water formation representation (in both hemispheres)

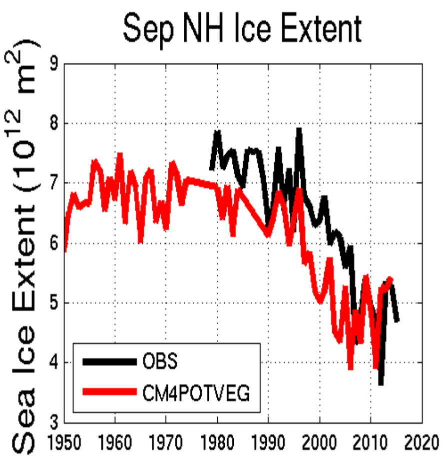


Historical Simulation: Global Temperature and NH Sea Ice Extent

- Historical warming roughly consistent with observed with possible exception of post-Pinatubo period.
- Good simulation of NH extent and its satellite era trend.
- SH sea ice low biased in summer, high biased in winter; recent observed increase is not simulated (not shown).





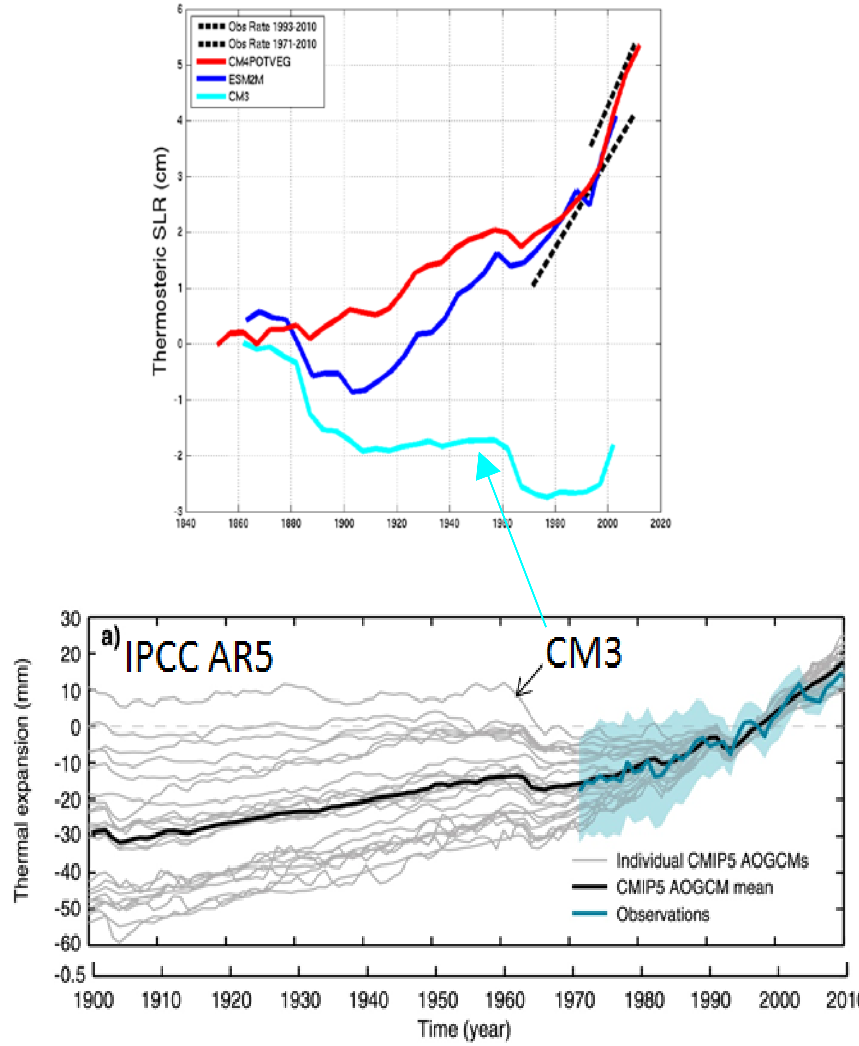


Thermosteric Sea Level Rise

CM3 thermosteric sea level rise problems:

- Excessive response to volcanoes (common to all CMIP5 models) due to lack of volcanic forcing in control experiment
- Lack of rise due to excessive aerosol forcing

CM4 has reduced aerosol forcing and improved simulation of ocean warming/thermosteric SLR



Summary

- CM4/ESM4 combine strengths of GFDL's CMIP5 generation of models into two, related models based on the same code with differing emphases on resolution and complexity.
- Expected CM4 strengths:
  - Surface climatology
  - ENSO variability; ENSO, AMO and PDO teleconnection patterns.
  - Reasonable historical climate change simulation
- Expected CM4 weaknesses:
  - NADW too shallow and warm as in previous models
  - AABW formation only appears after 600 years of spin up
  - Ocean warm drift