Accelerated Climate Modeling for Energy

Diagnosing Coupled Model (problems)

Chris Golaz, Peter Caldwell and the entire Coupled Task.

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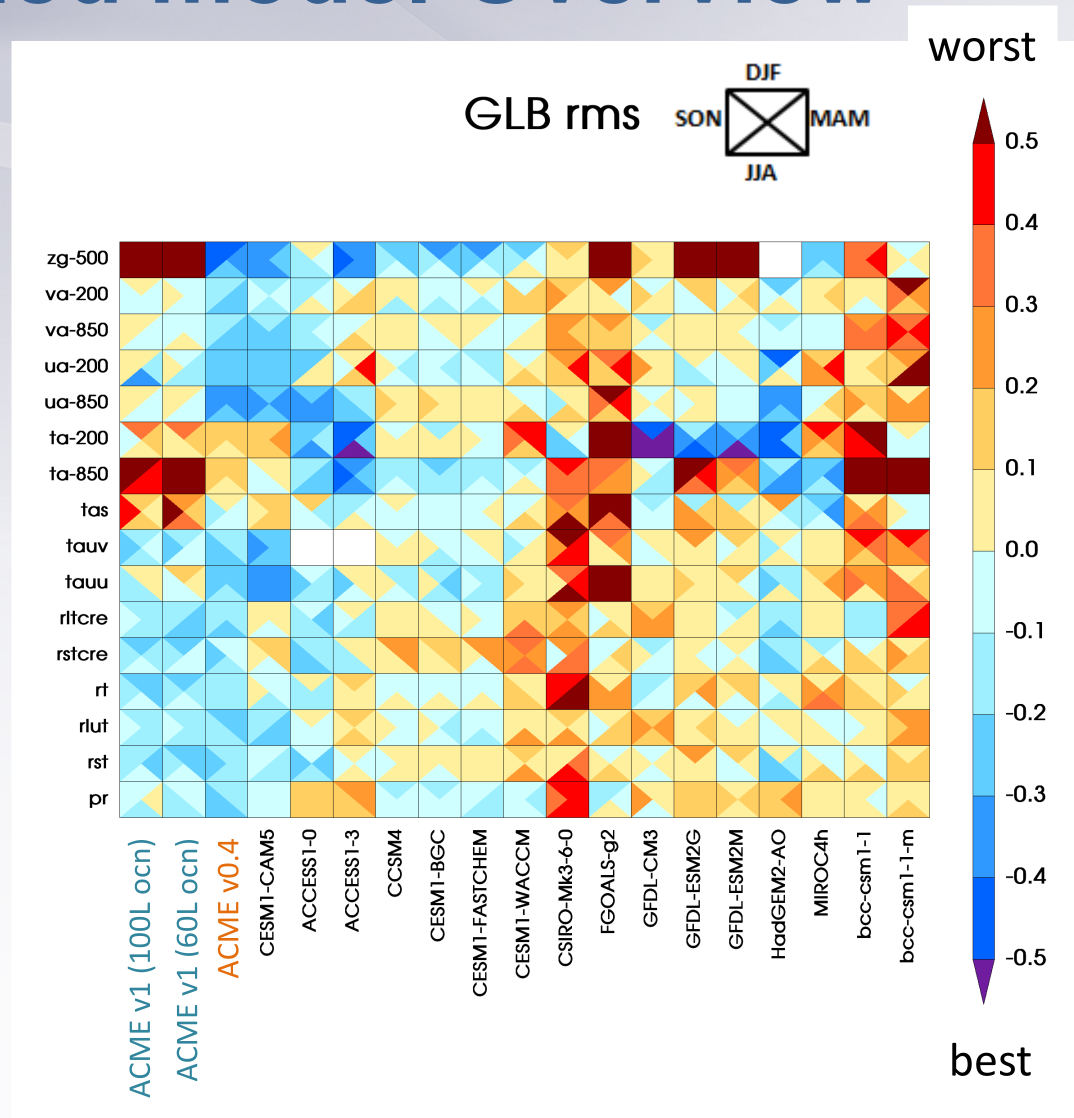
Low-res coupled model Overview

Gleckler plots

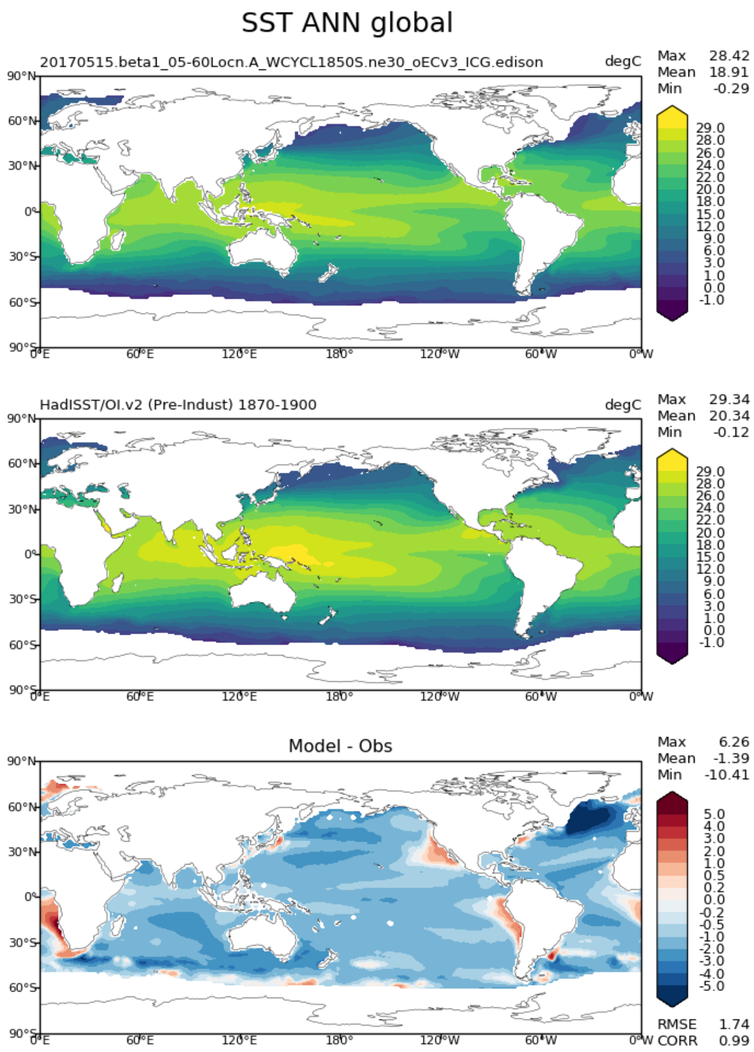
- Normalized **global** RMSE for historical simulations
- ACME v1 (100, 60 level ocean)
- ACME v0.4
- CIMP5



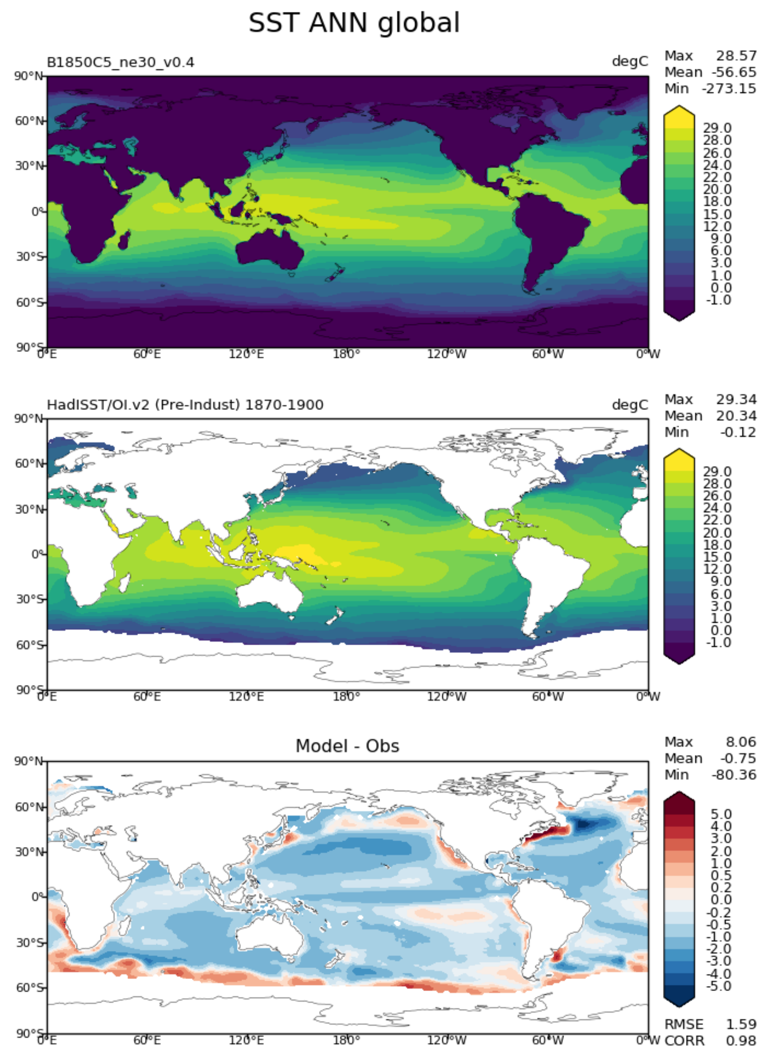
Qi Tang

SST ANN

ACME v1 60L ocn

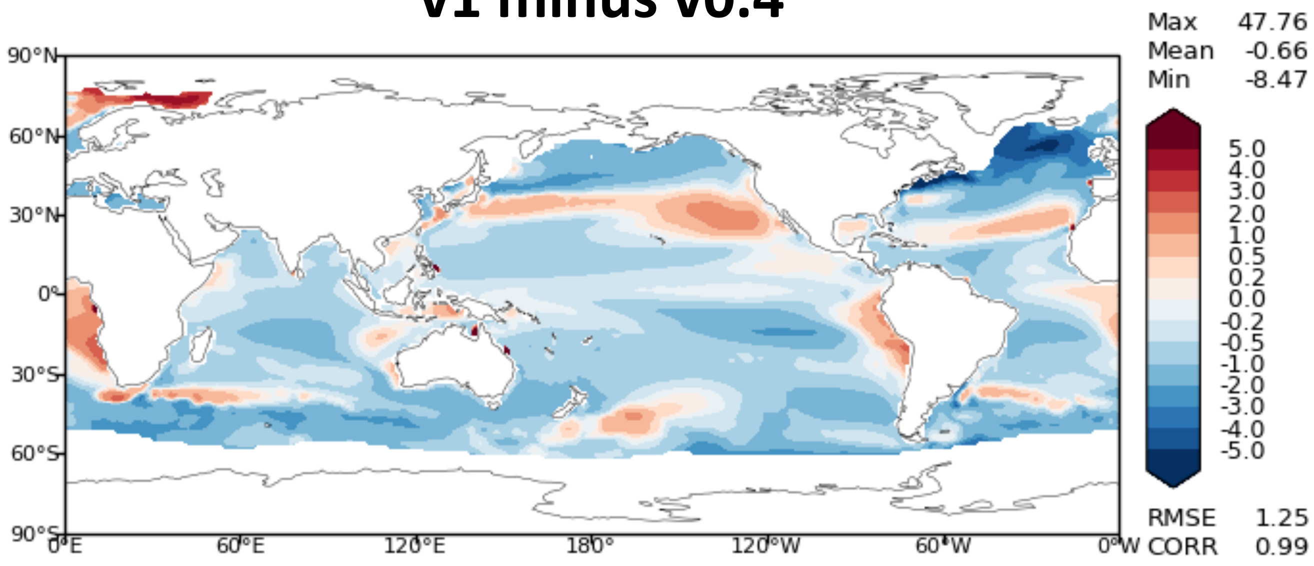


ACME v0.4



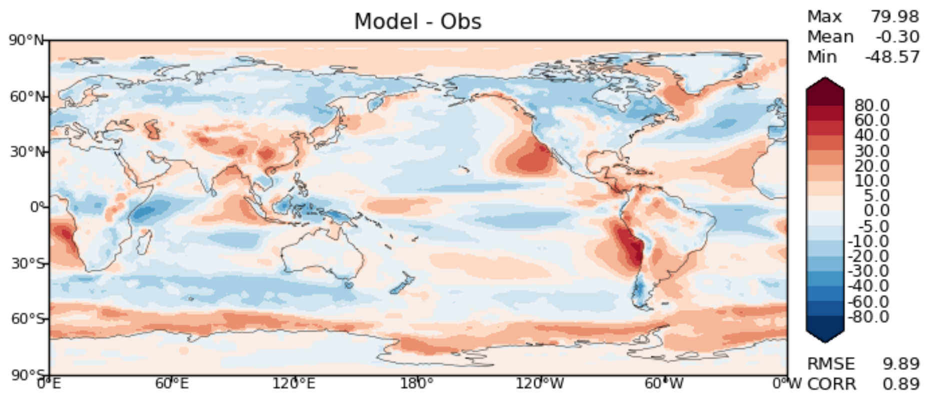
SST difference

v1 minus v0.4

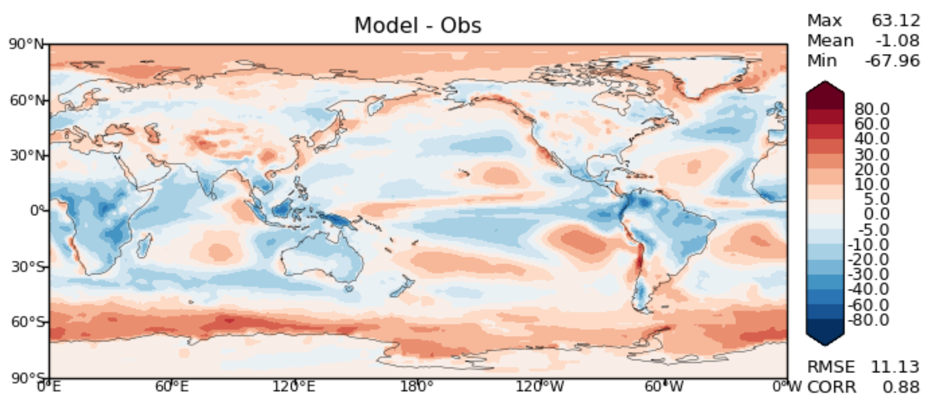


SWCF ANN error

ACME v1 60L ocn

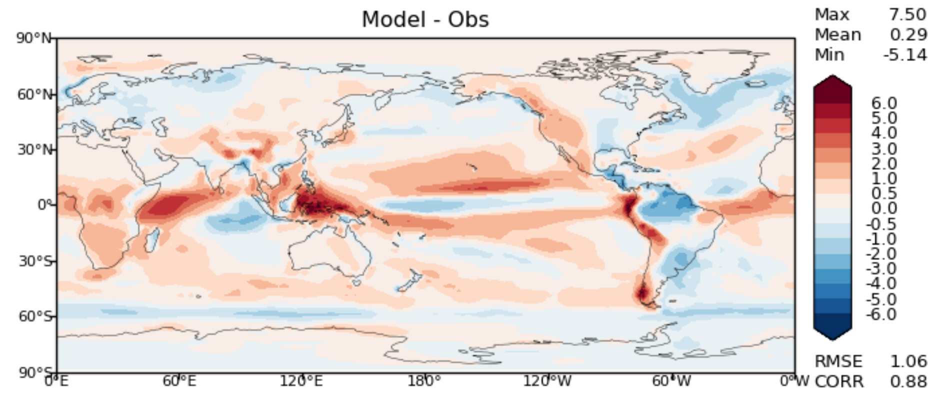


ACME v0.4

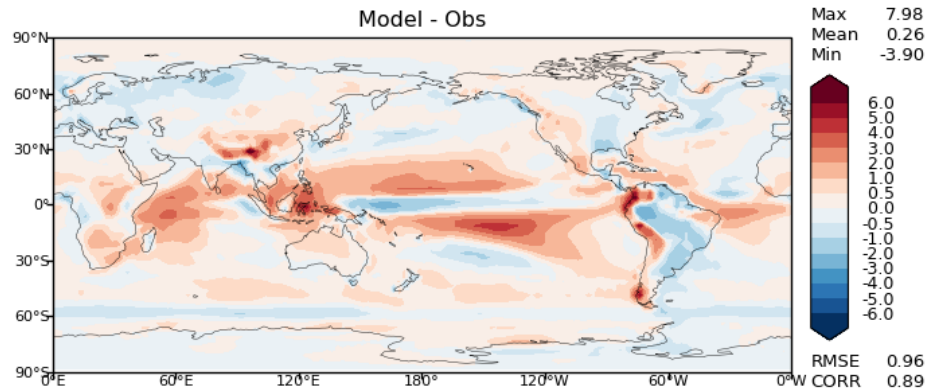


Precipitation ANN error

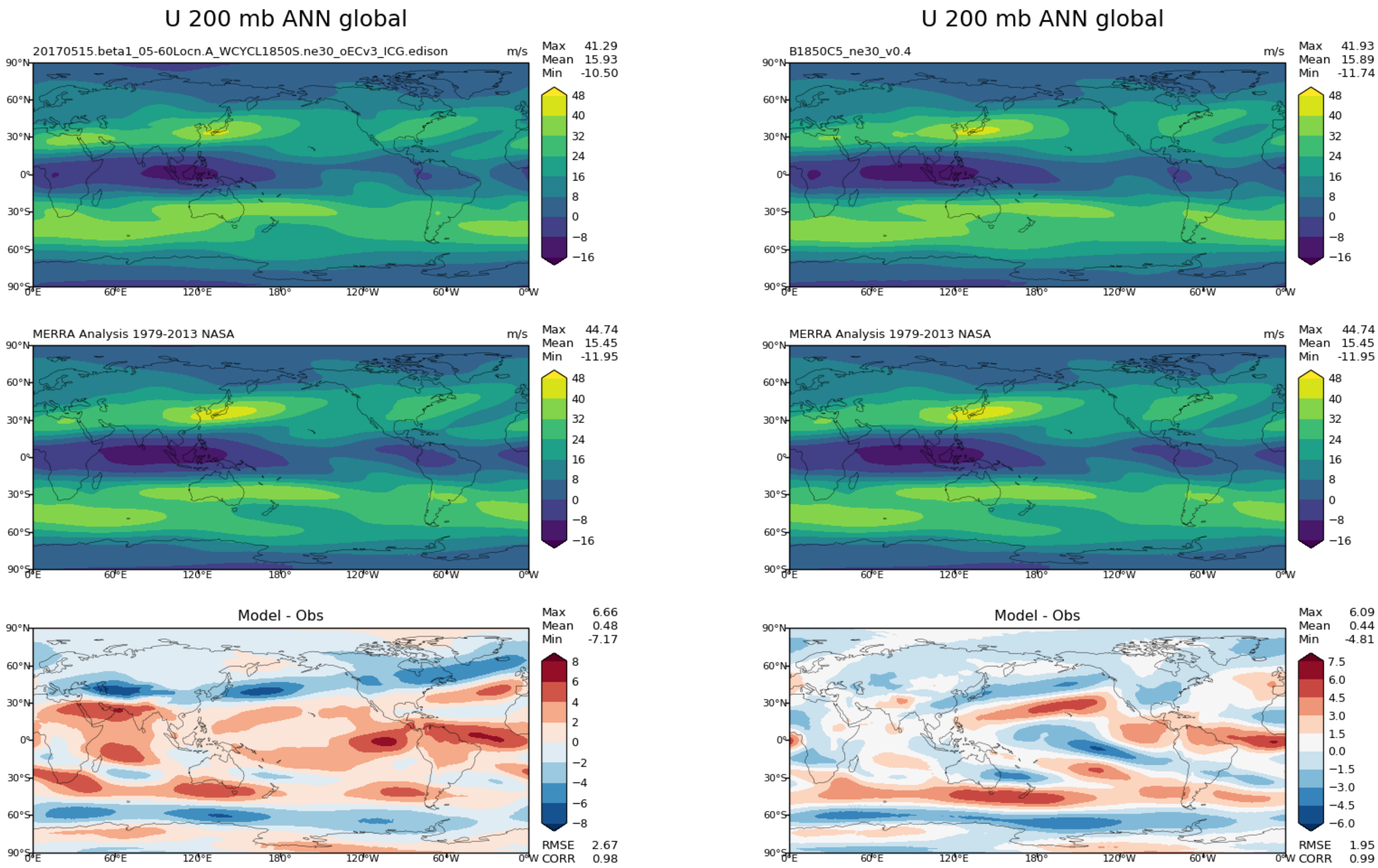
ACME v1 60L ocn



ACME v0.4



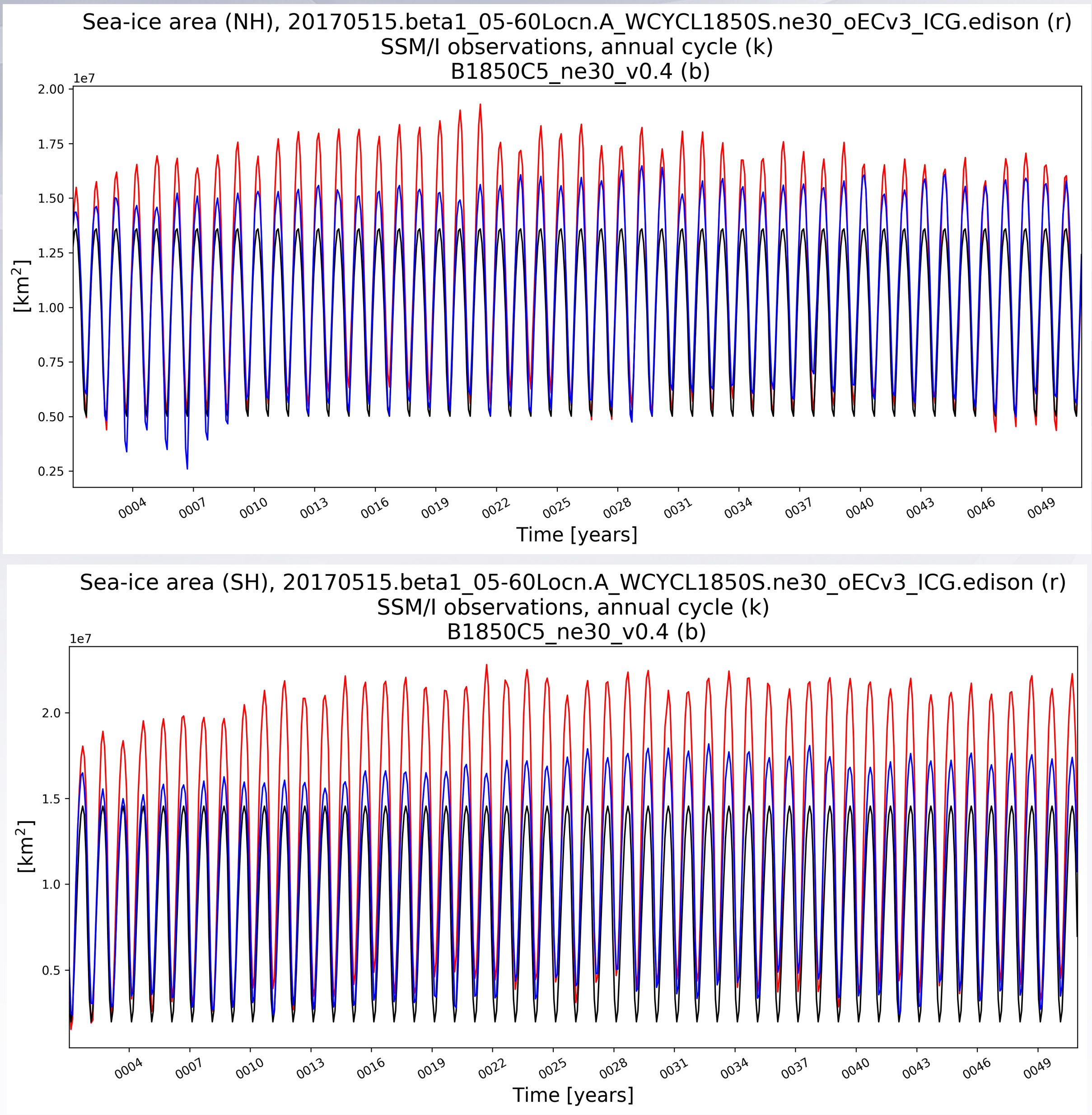
ACME v1 60L ocn — U200 ANN — ACME v0.4



Sea-ice area

NH

SH



NH Sea-ice area

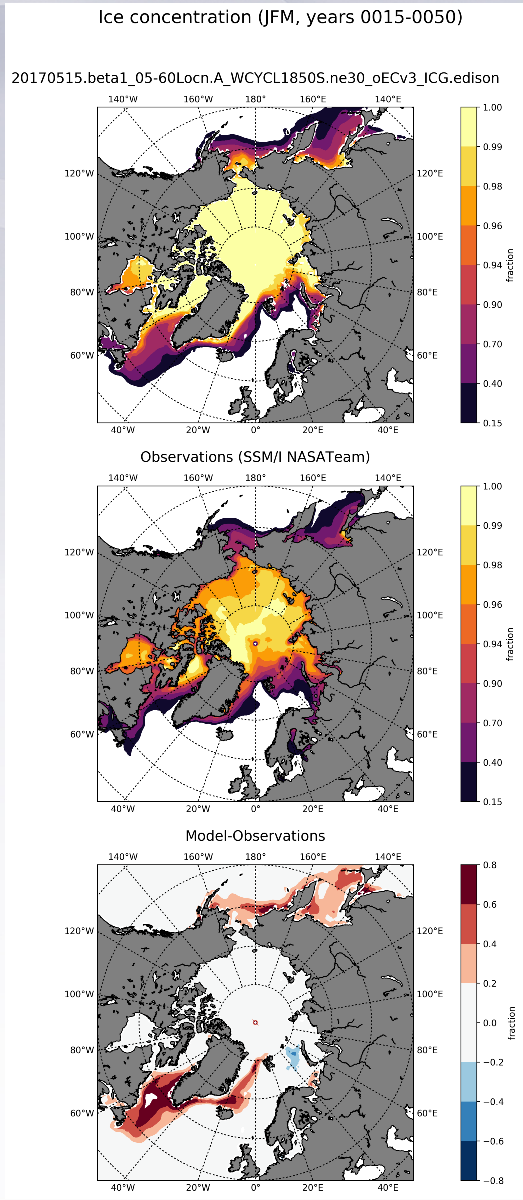
Winter

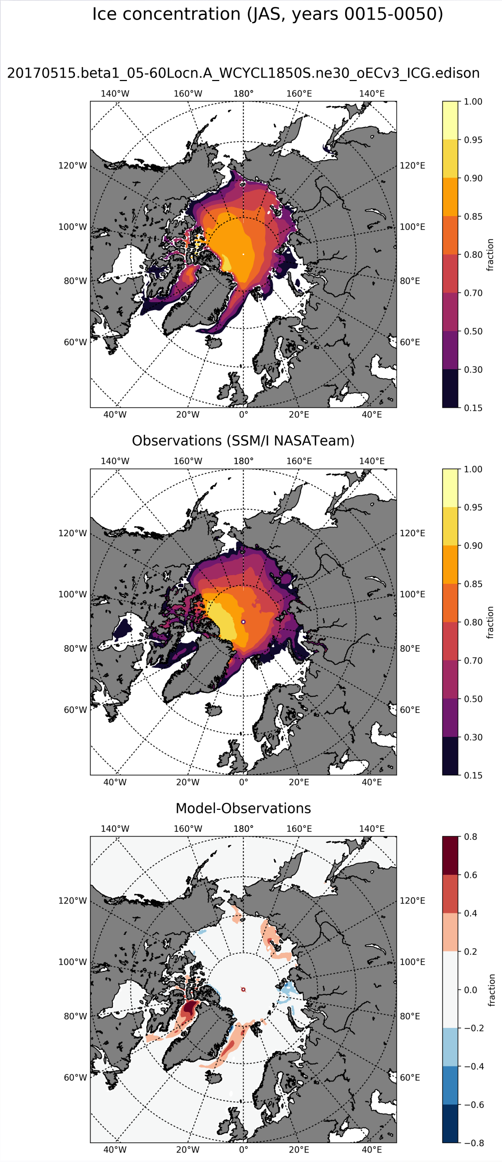
Summer

Model

Obs

Difference





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SH Sea-ice area

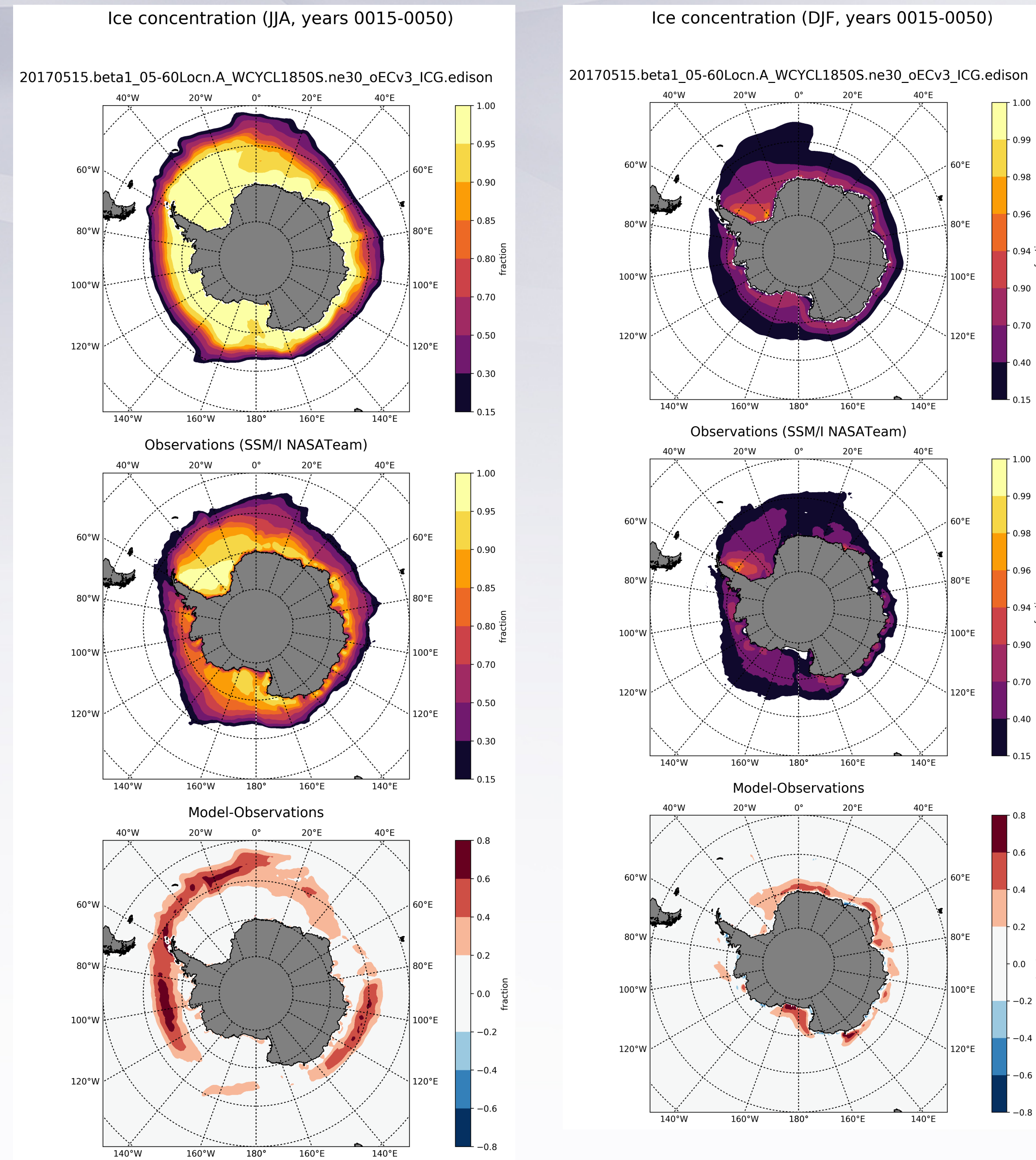
Winter

Summer

Model

Obs

Difference



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Preparing for historical simulations

- Goal is to realistically simulate the evolution of the surface temperature over the historical record
- Historical simulations are expensive (PI spin-up + control + historical: over 300 years)
- Need cheaper alternatives.
- To a large degree, historical warming is controlled by:
  - Total radiative forcing
  - Climate sensitivity (or feedback parameter)
  - Ocean heat uptake

Forcing and sensitivity

- Forcing and sensitivity can be estimated with cheaper simulations
- Total adjusted forcing
  - Pair of atmosphere-only simulations
  - F1850
  - F2000AF: 1850 SST but with 2000 forcings
- Sensitivity
  - Pair of atmosphere-only simulations
  - F1850
  - F1850 with SST uniformly increased by +4 K.
- ➢ Total of 3 (5-10 year each) atmosphere-only simulations

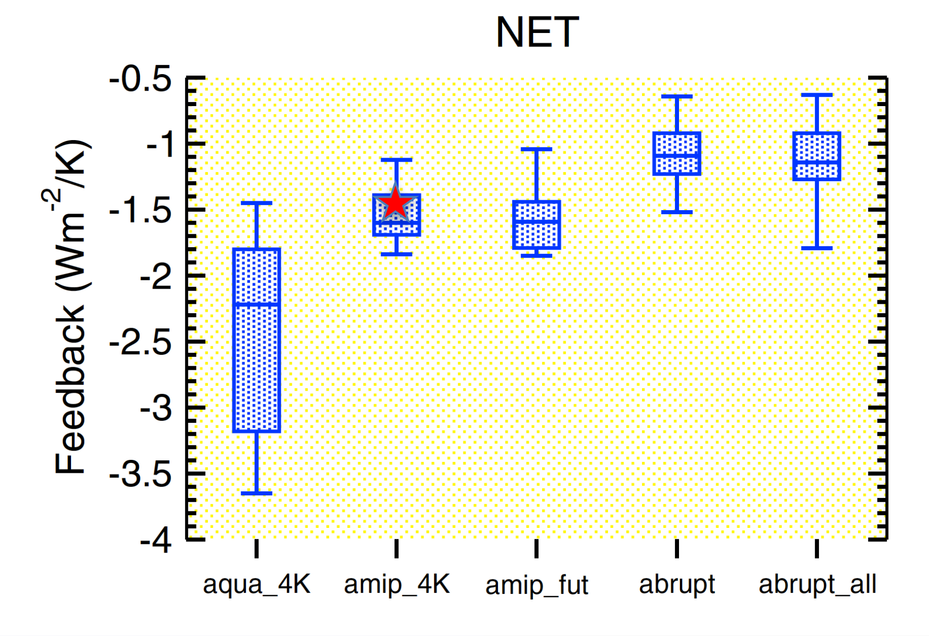
Forcing and sensitivity

Atmos configuration	Total adjusted forcing	Feedback parameter $\lambda=\Delta R/\Delta T_s$
v0-like	ΔR = +1.219 W/m2	λ = -1.8 W/m2/K
v1 (AV1C-04P2)	ΔR = +1.284 W/m2	λ = -1.46 W/m2/K ★

	Hist 2003
ACCESS1-0	1.1
bcc-csm1-1	2.2
bcc-csm1-1-m	2.2
CanESM2	2.0
CCSM4	2.5
CNRM-CM5	1.5
CSIRO-Mk3-6-0	0.9
FGOALS-s2	2.3
GFDL-CM3	1.1
GFDL-ESM2G	2.0
GFDL-ESM2M	2.0
GISS-E2-H	2.3
GISS-E2-R	2.5
HadGEM2-ES	0.8
inmcm4	1.7
IPSL-CM5A-LR	1.9
IPSL-CM5B-LR	1.0
MIROC5	1.6
MIROC-ESM	1.1
MPI-ESM-LR	2.1
MPI-ESM-P	2.3
MRI-CGCM3	1.2
NorESM1-M	**1.4**
Multimodel mean	**1.7**
90% uncertainty	**0.9**

Forster et al. (2013)
doi:10.1002/jgrd.50174

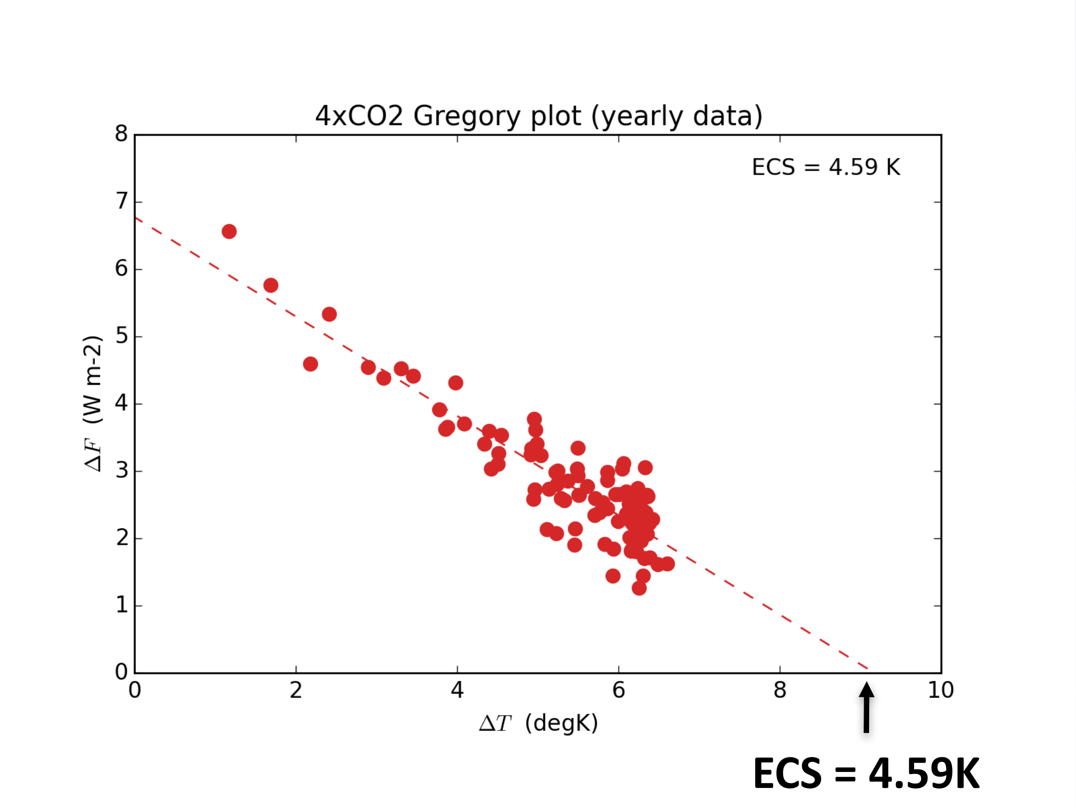
ACME v1:
- Smaller total forcing
- More sensitive



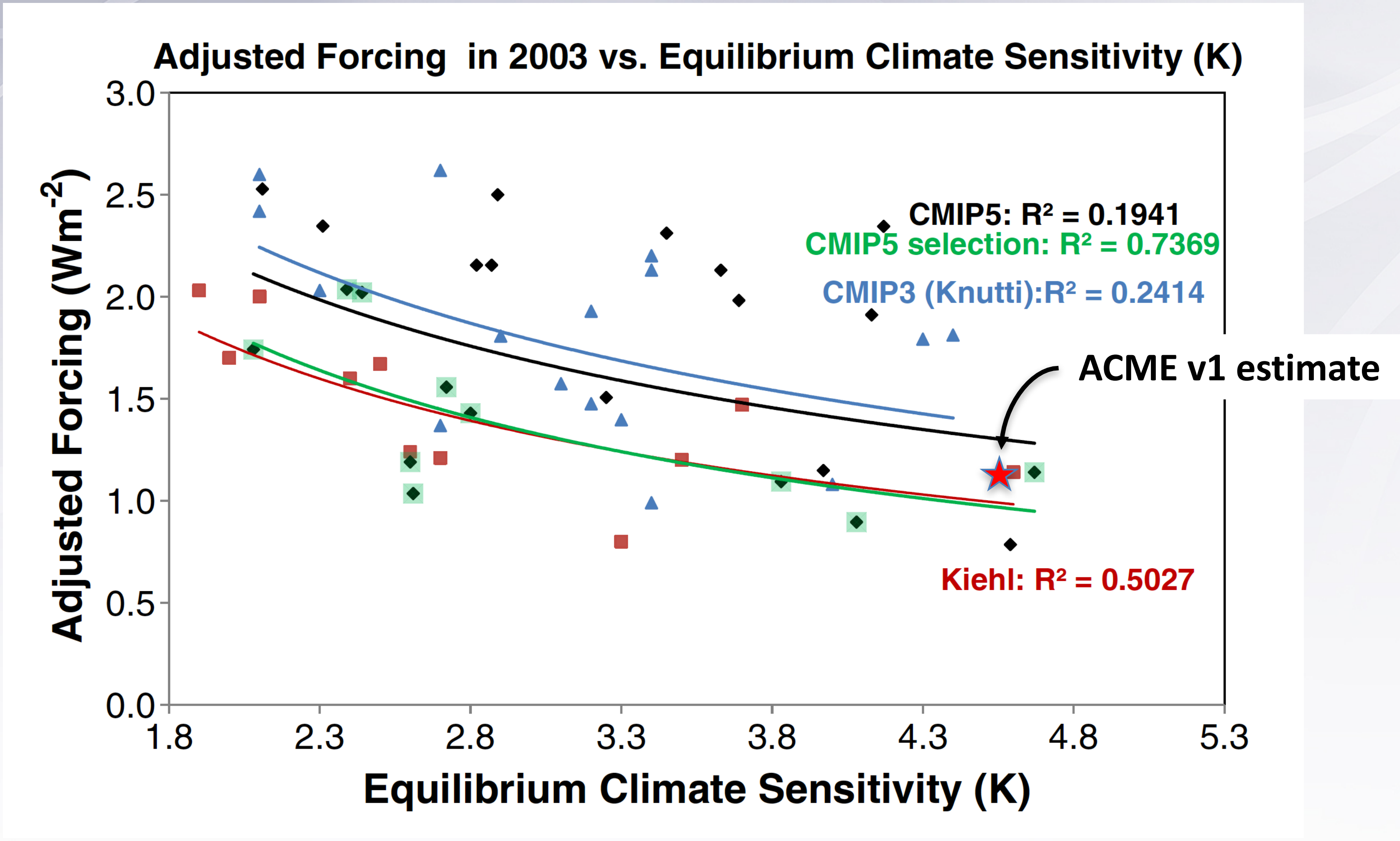
Ringer et al. (2014; doi:10.1002/2014GL060347)

Climate Sensitivity

- Climate sensitivity of the coupled system can also be estimated by performing an abrupt $4xCO_2$ coupled simulation, aka as "Gregory method"



Combining forcing and sensitivity



Problem: Initial Cooling

- v1 cools rapidly when coupled
  - ACME/CESM have always had this problem, but v1 is worse
  - This cooling is a major source of poor temperature metrics in PMP plots

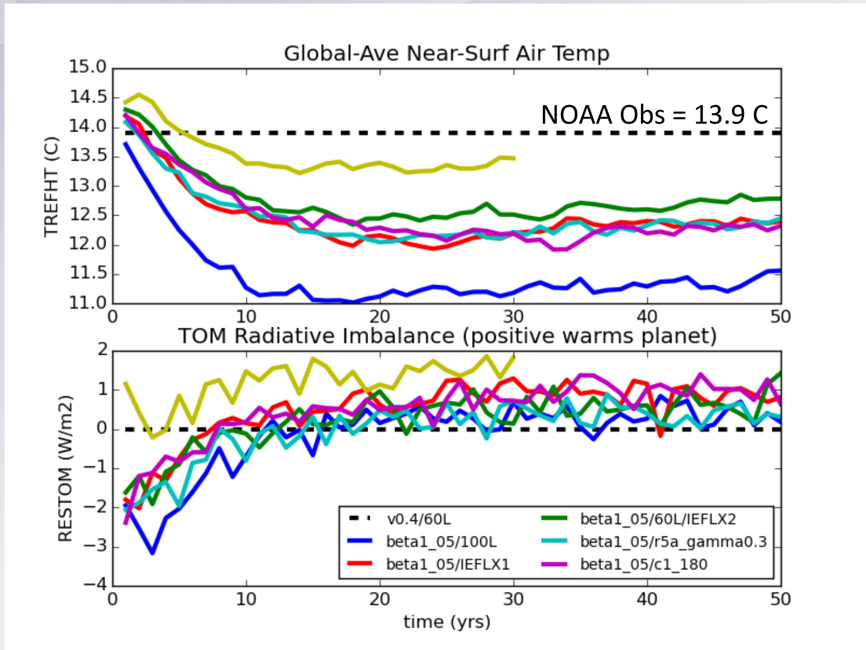


Fig: Global-average surface TOA radiative imbalance and surface temperature from ACME runs

- As the surface is cooling, the Earth system is gaining heat
  - in beta0, this situation continued for 250 yrs with no sign of stopping
  - We thought ignoring enthalpy of water in atmos was responsible, but a crude fix (IEFLX) didn't reduce TOA imbalance
- Retuning to get rid of cold drift (c1=180 run) caused TOA imbalance to get even worse!

Initial Cooling (Cont'd)

- Cooling is caused by ocean moving heat from 0-700m layer (thin solid lines) to 700-2000m layer (dashed lines)
- Exists in v0.4 (blue), but is worse in v1, even with IEFLX (red)

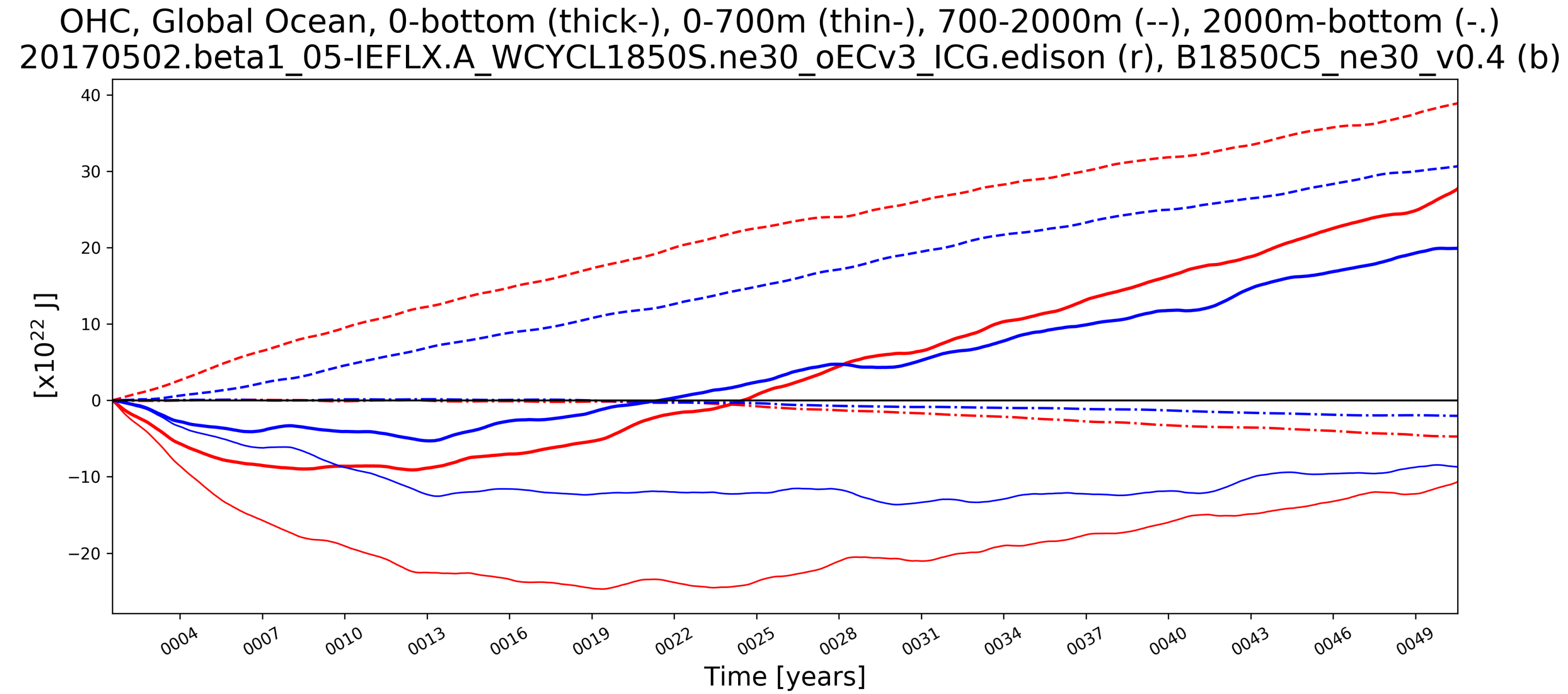


Fig: Ocean Heat Content from v0.4 and beta1_05 IEFLX runs

Nino3.4 Spectra With MPAS/A-Prime Diagnostics

- v1 appears to have no tropical variability
  - 50 yrs isn't long enough to be sure (but we can't afford longer runs)
  - the fact(?) that v0.4 produces ENSO with POP but not MPAS implies the ocean is at fault (See Luke + Mark's talk)
    - Would like to run v1atm/POP to confirm this conclusion…

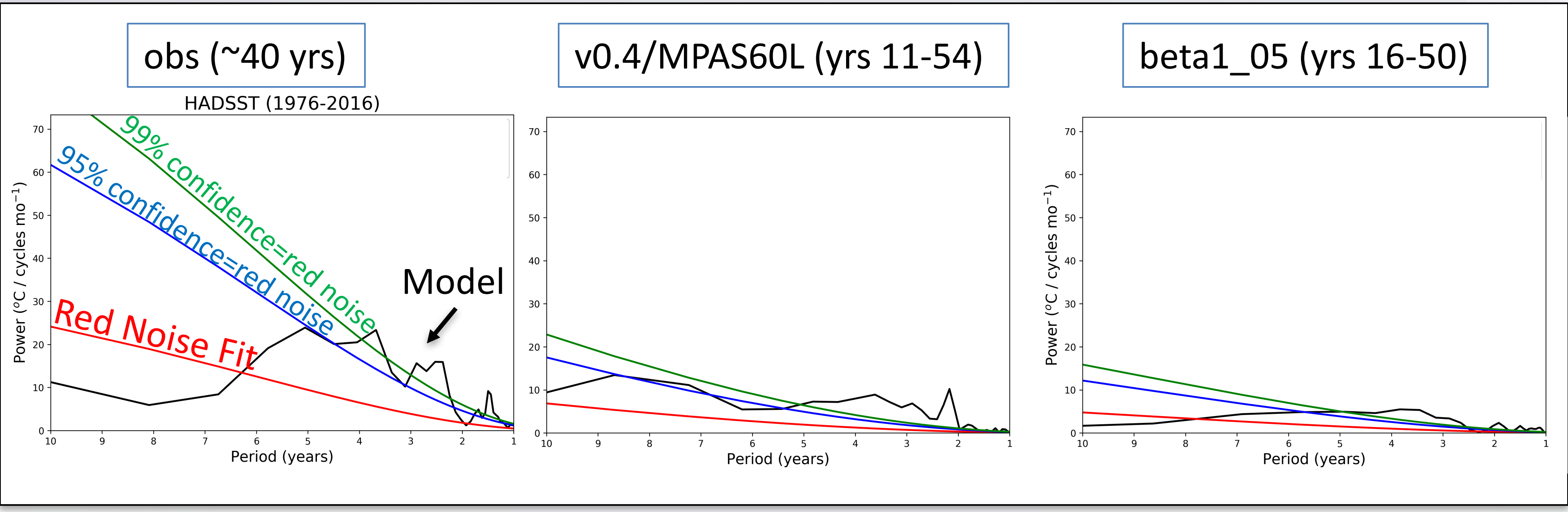


Fig: Nino3.4 spectra using A-Prime/MPAS analysis package.

Problem: Nino3.4 in ACME v1

- ACME v1 coupled runs have extremely weak temporal variance in tropical SST
- Problem is in ocean: Using POP instead of MPAS with same atmosphere (v0.4) causes variance to return (middle panels below, graphic is confusing)
  - Mark and Luke will talk about this later
- Can the v1 atmosphere maintain ENSO?
  - Trying to run v1 atm with POP to confirm
  - Are there useful diagnostics from AMIP runs?

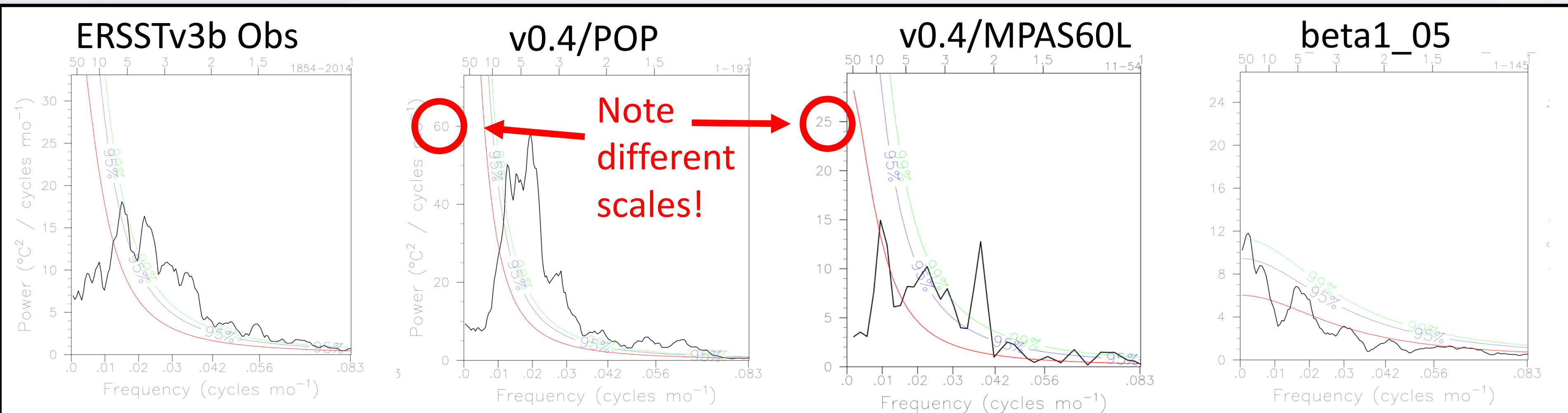
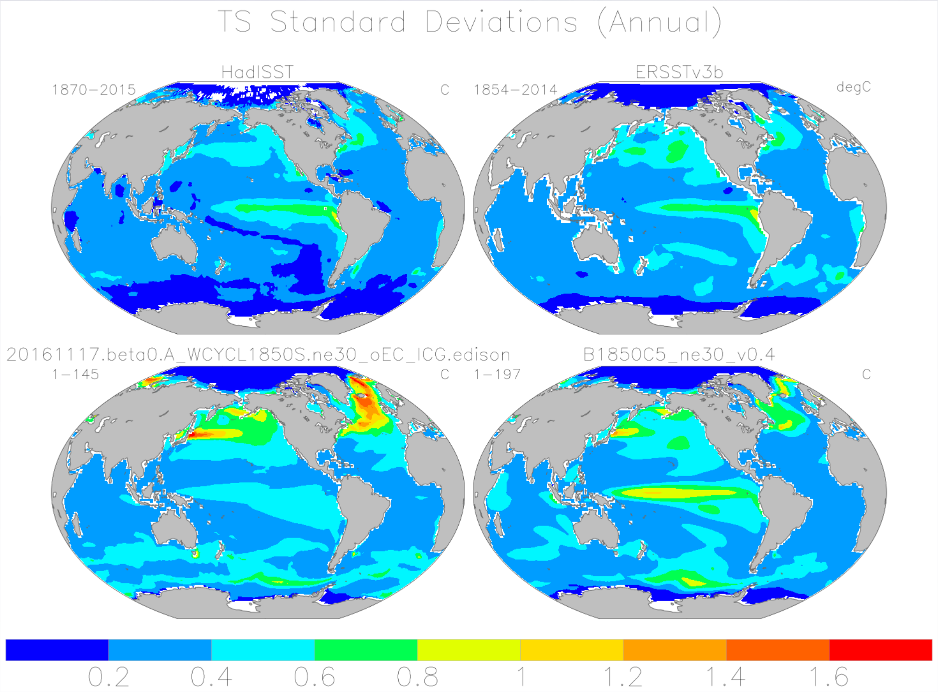


Fig: Power spectra of detrended Nino3.4 timeseries

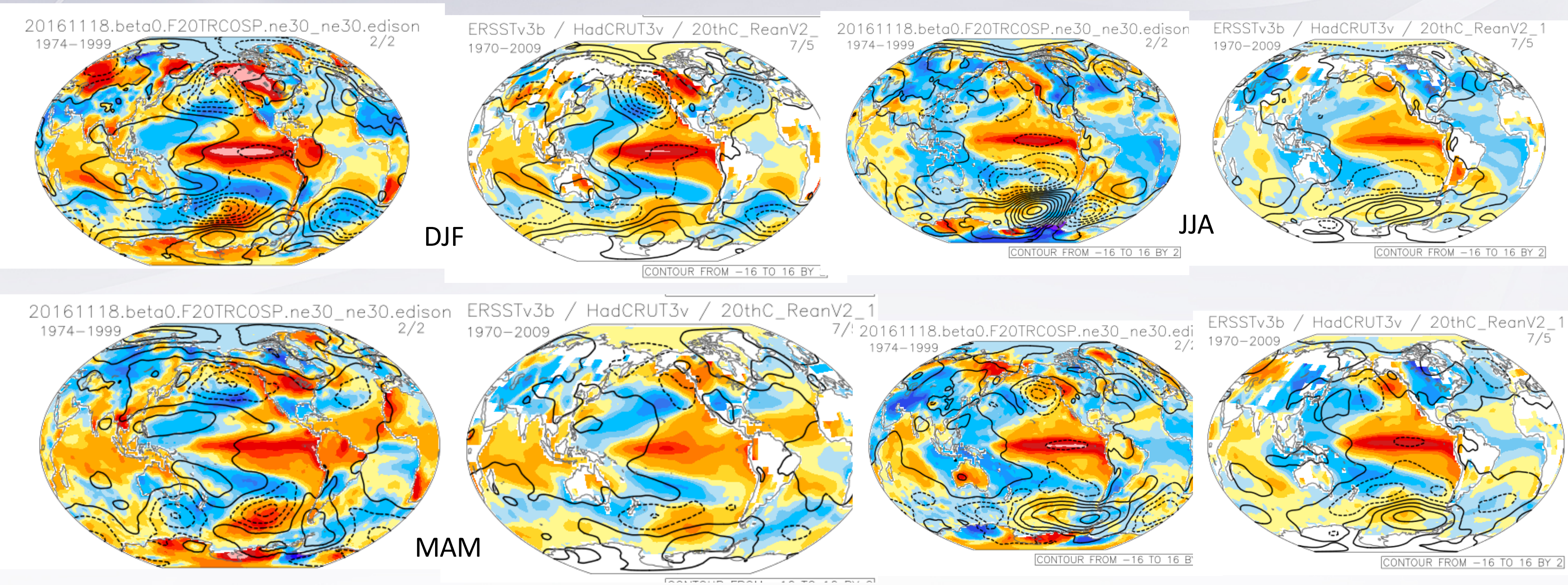
Extra Slides

SST variance

- All runs with MPAS-O have had huge SST variance in the N Atlantic



Difference in TS and SLP between Nino and Nina states



Pressure response to ENSO is too strong in mid/high latitudes. SST response is perfect because it is prescribed.