Update on the CESM/MOM6 effort

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Functional release of MOM6 starting in CESM 2.2

Downloading CESM+MOM6

- Clone CESM GitHub repository: (~ 5 sec)

```
$ git clone https://github.com/ESCOMP/CESM.git
```

- Check out the following CESM 2.2 tag, which includes MOM6 : (~ 1 sec)

```
$ cd CESM
$ git clone -b cesm2.2_mom6_201113 https://github.com/alperaltuntas/CESM.git
```

- Check out externals : (~ 2 min)

```
$ ./manage_externals/checkout_externals -o
```

Detailed instructions

https://github.com/ESCOMP/MOM_interface/wiki/Detailed-Instructions

Available configurations

COMPSET	Compatible Resolutions	Description
CMOM	T62_t061, T62_g16, T62_t025	*MOM6 only, CORE2 NYF*
CMOM_IAF	T62_t061, T62_g16, T62_t025	*MOM6 only, CORE2 IAF*
CMOM_JRA	TL319_t061, TL319_g16	*MOM6 only, JRA55*
GMOM	T62_t061, T62_g16, T62_t025	*MOM6 and CICE only, CORE2 NYF*
GMOM_IAF	T62_t061, T62_g16, T62_t025	*MOM6 and CICE only, CORE2 IAF*
GMOM_JRA	TL319_t061, TL319_g16	*MOM6 and CICE only, JRA55*
BMOM	f09_t061	*Fully Coupled*

- t061: tx0.66v1
- t025: tx0.25v1
- g16: gx1v6

t061 → "workhorse"

t025, g16 → testing

CESM “workhorse” configurations

	POP2	MOM6
H. Grid	1.125° dipole w/ equatorial refinement	0.66° tripole w/ equatorial refinement
V. Grid	z-coord., dz = 10 m @ surface, 60 levels	z*-coord. or hybrid (z*/isopyc), dz = 2.5 m @ surface, 65-85 levels
Freshwater B.C.	Constant volume, virtual salt flux	Variable mass, natural B.C
V. Mixing	CVMix-KPP + Langmuir	CVMix-KPP + Langmuir
GM+Redi	Marshall N^2 scaling	MEKE+GEOMETRIC scaling + GME backscatter
H. Viscosity	Anisotropic Laplacian	Isotropic Laplacian + Biharmonic, via MEKE
Solar penetration	Ohlmann (2003)	Manizza (2005)
Advection	3rd order upwind	Horiz. PPM, Vert. ALE w/ 3rd order remapping
Other params	Overflow, Estuary box model	TBD
Coupling API	MCT, NUOPC	MCT, NUOPC

Vertical coordinate exploration

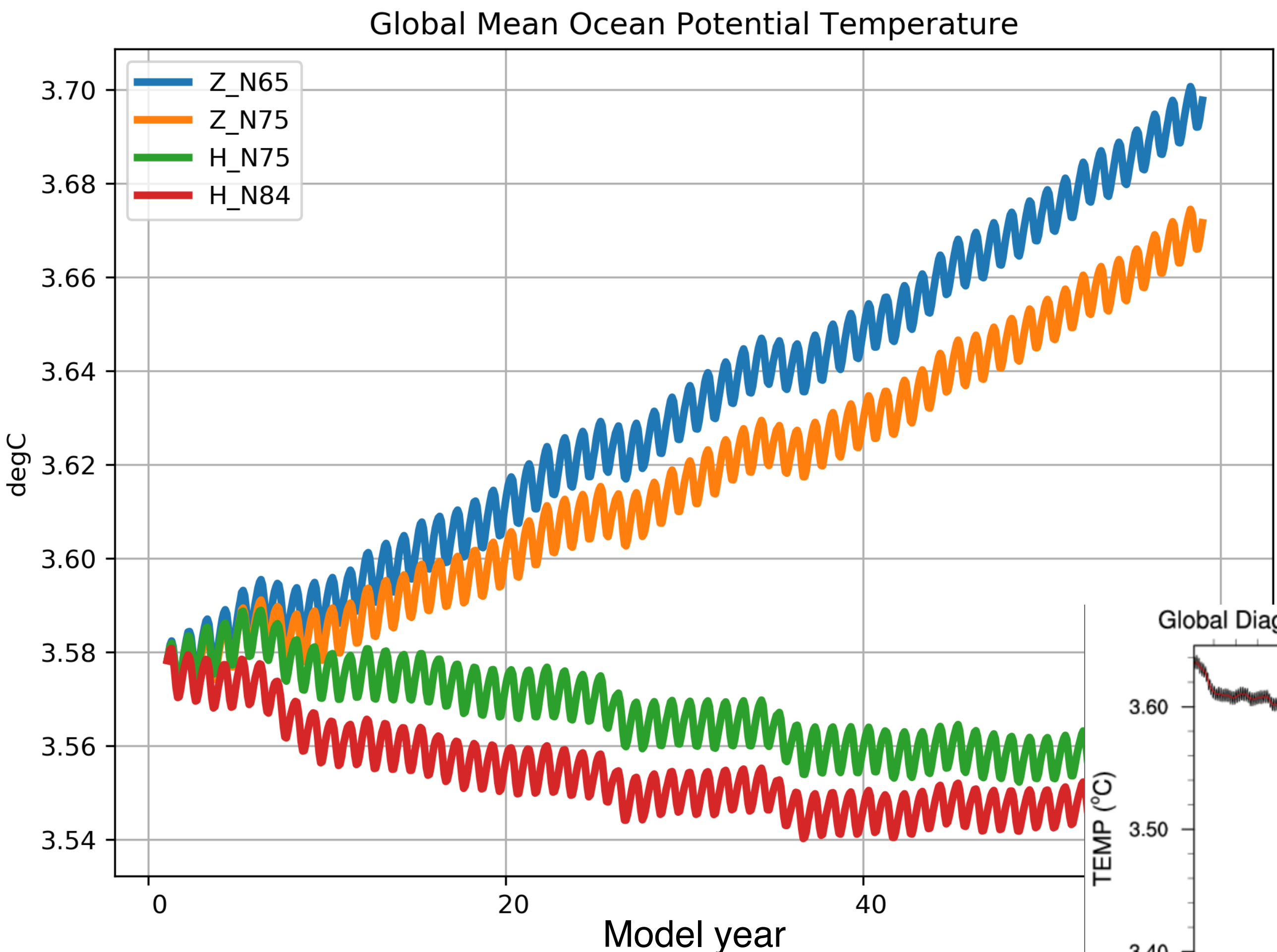
- JRA-55 (v1.3), run for one cycle (58 years)
- Initial Conditions: T and S from WOA18
- SSS restoring from WOA18 monthly climatology (~ 60 m/year)

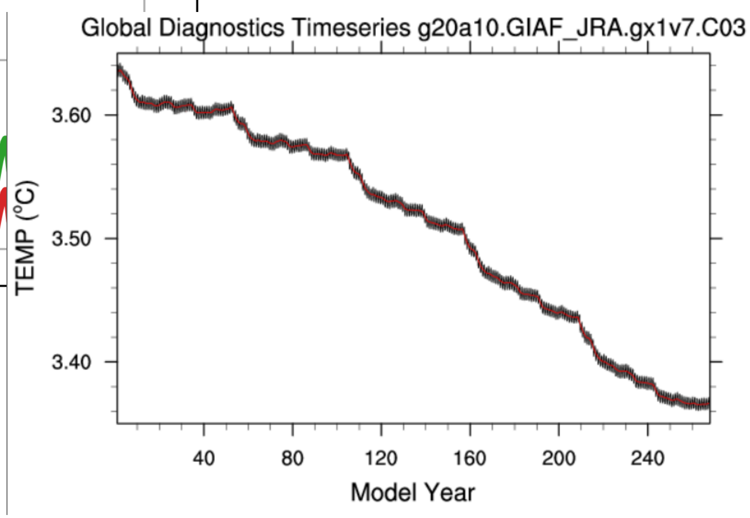
List of experiments:

Experiment	coordinate system	# of vertical layers
Z_N65	z*	65
Z_N75	z*	75
H_N75	Hybrid (z*/isopycnal)	75
H_N84	Hybrid (z*/isopycnal)	84

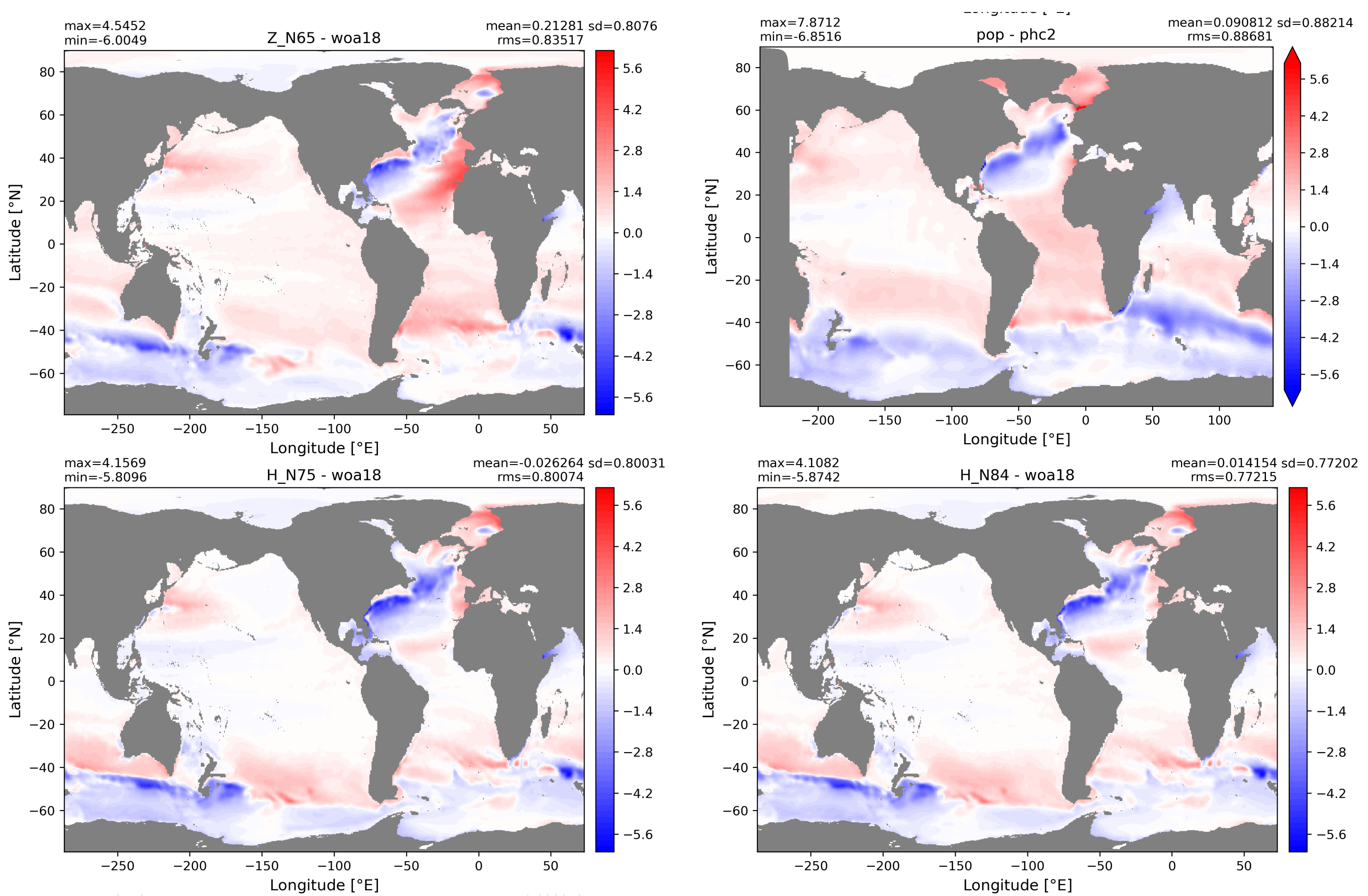
- Compare last 30 years against a similar experiment using POP2

Global mean potential temperature drift

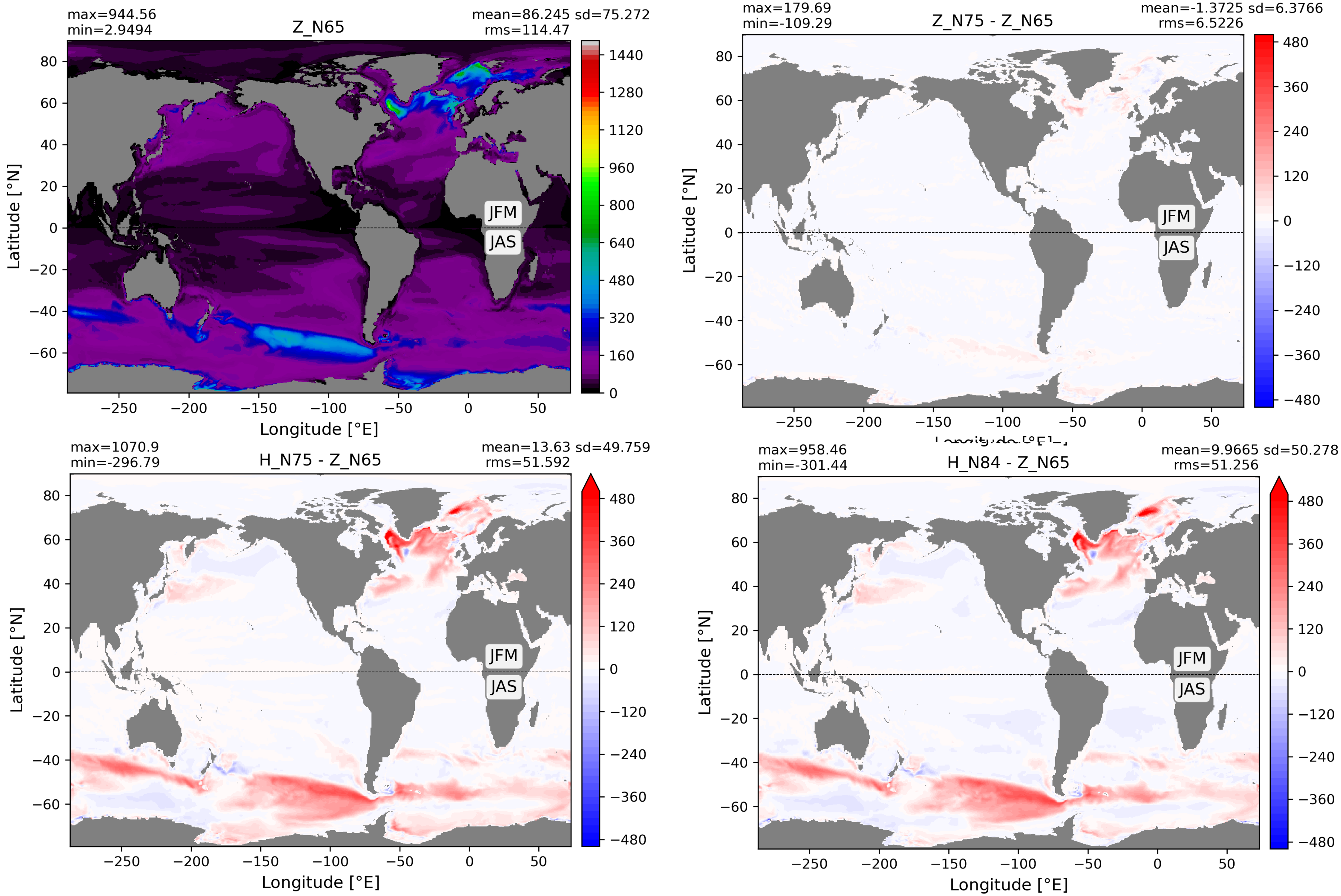




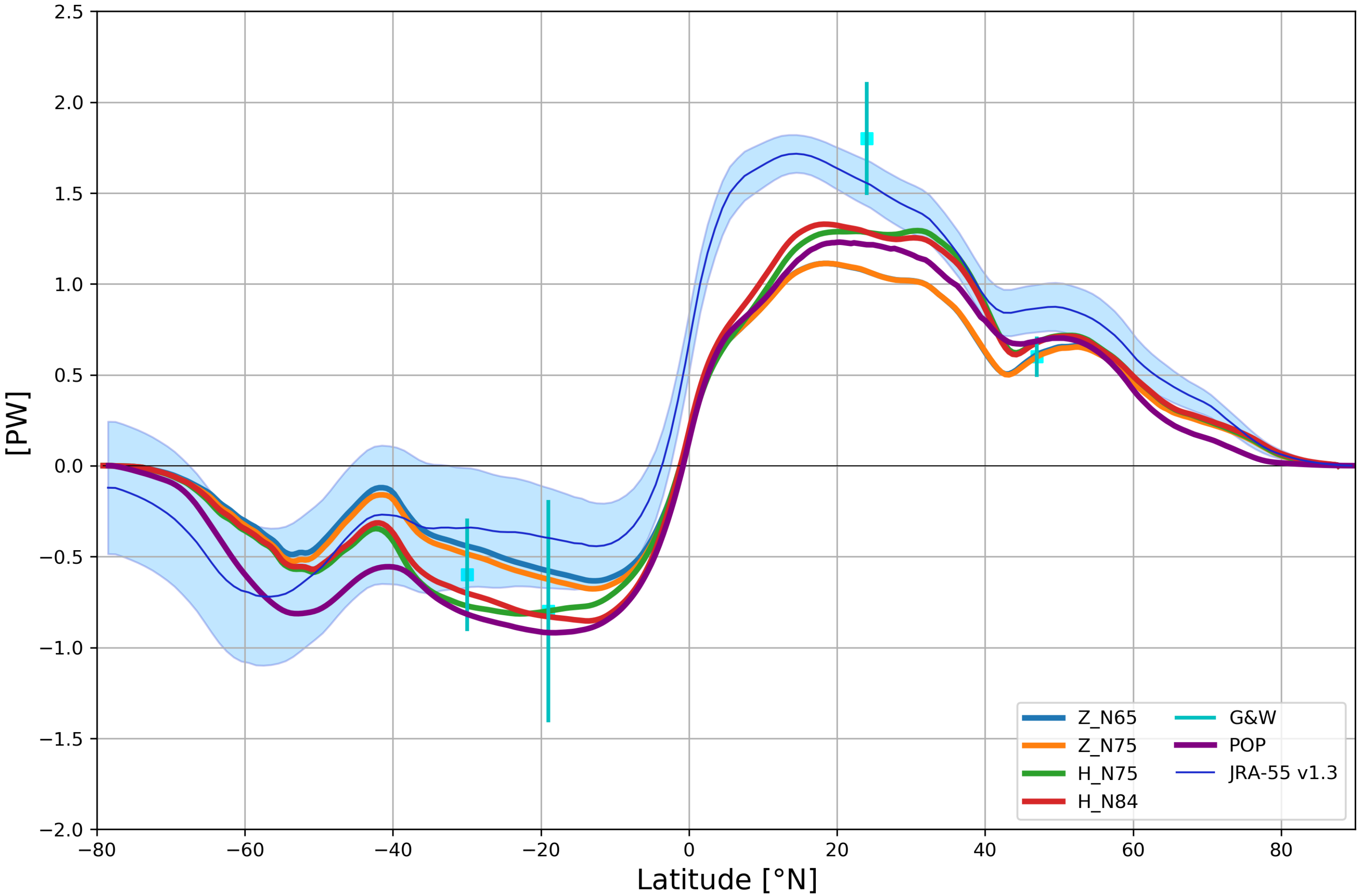
Potential temperature bias (ºC) at z = 700 m



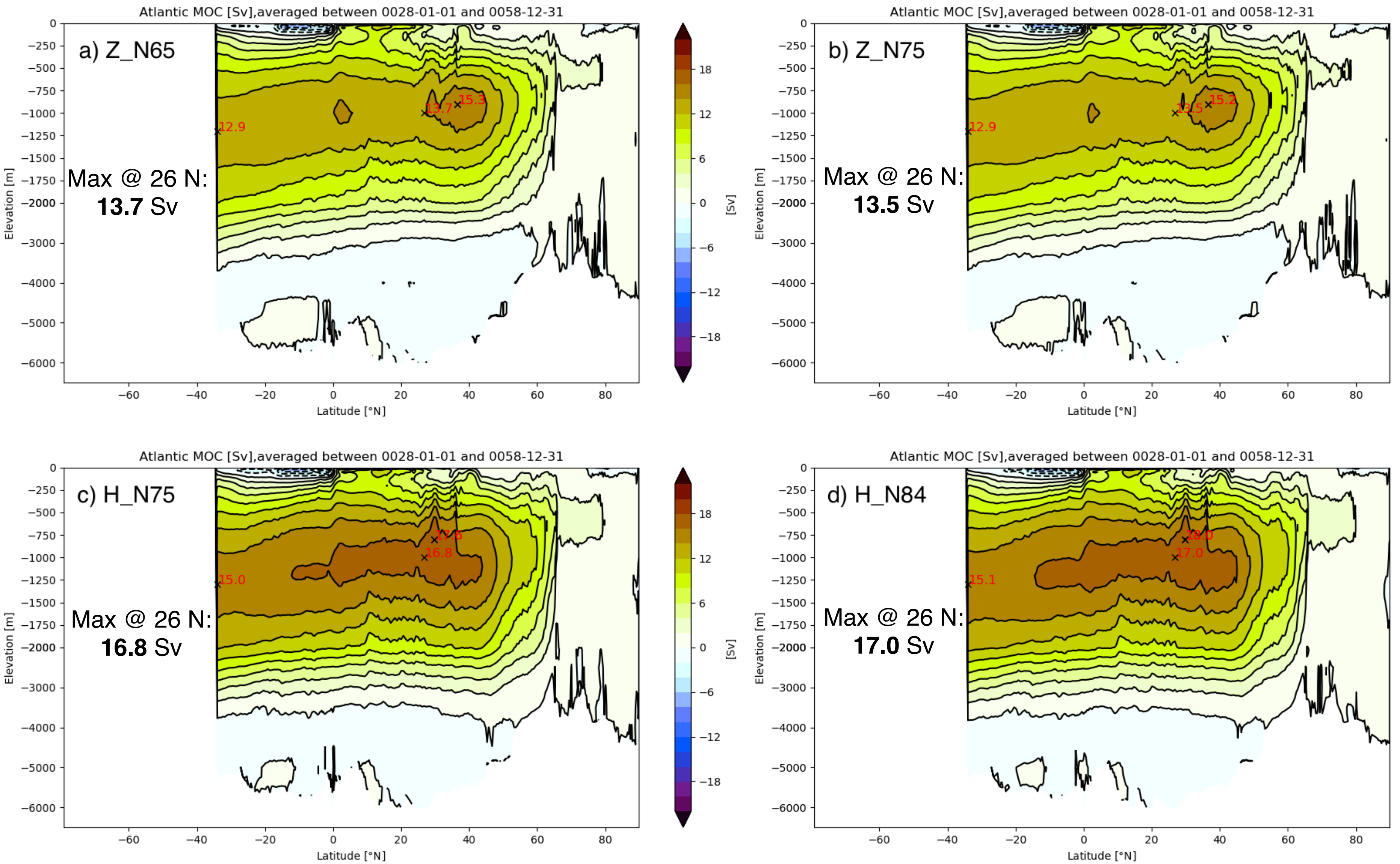
Winter mixed layer depth, $\Delta\rho$ = 0.03 (m)



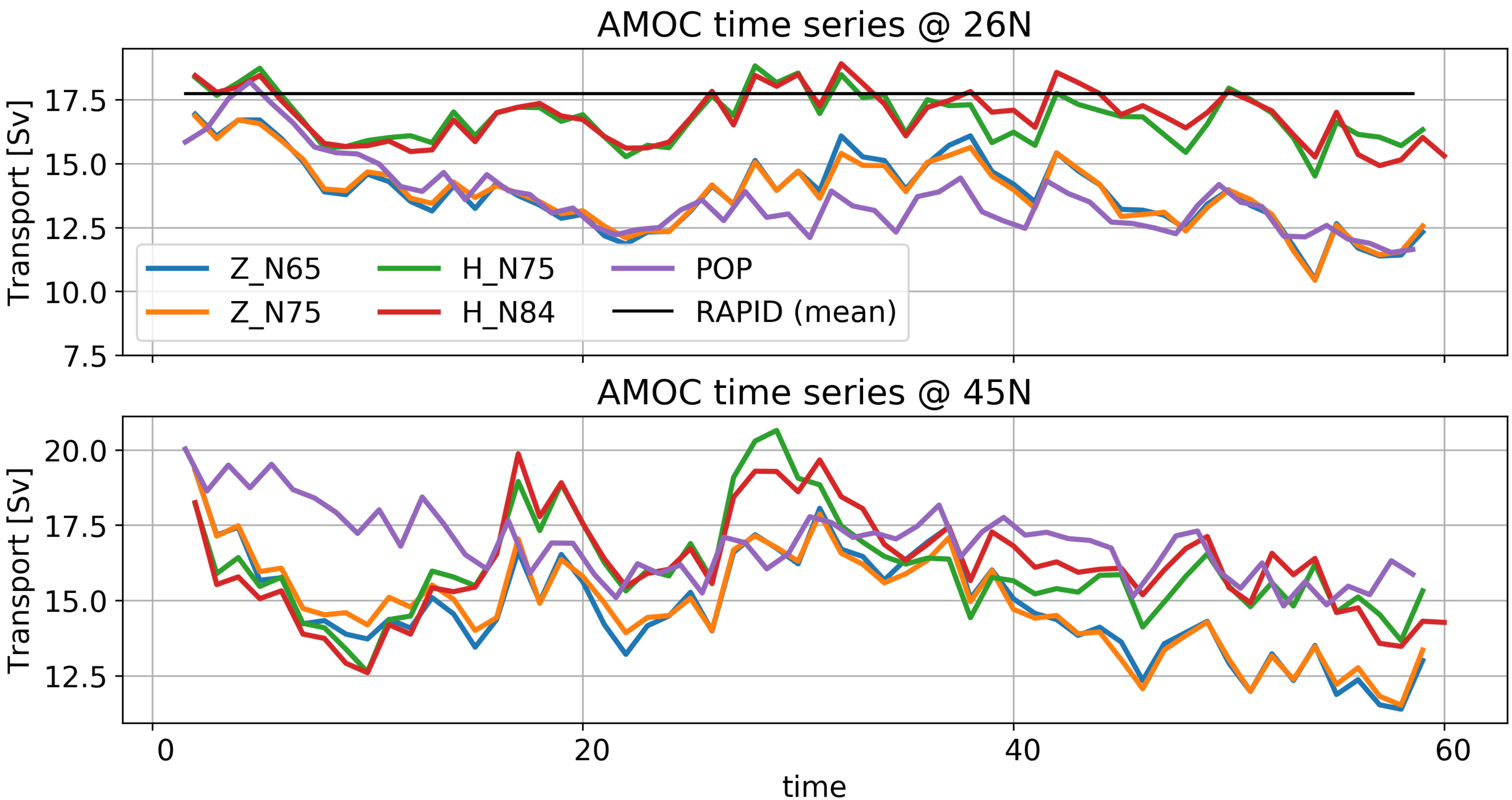
Poleward Heat Transport (Global)



Atlantic meridional overturning circulation (AMOC)



AMOC time series @ 26N and 45N



Reconcile energy exchange with other CESM components

Mass contribution from water exchange in CESM/MOM6

liquid, **solid (frozen)** and **vapor**

Heat exchange from adding/removing mass (e.g., frozen runoff):

Latent → - mass x L_f (latent heat of fusion) ✓

Sensible (enthalpy) → - mass x temp x ρ x cp (heat capacity) **MOM6** ✓ **CESM** ✗

↓

Are these important? **YES**

In a one-year fully-coupled run

Net heat flux from CPL: -0.60 W m^{-2}

Heat content change in MOM6: -0.82 W m^{-2}

Difference (MOM6-CPL): ~ -0.22 W m^{-2}

Summary

- A preliminary functional version of MOM6 was released in CESM 2.2
- The same code base is being used for a wide range of applications: simplified, regional and global (workhorse and high-resolution)

MOM6 versus POP2 in CESM:

- Overall, the quality of forced (G-compsets) solutions with MOM6 are comparable with a baseline solution with POP. However, locally some places are better/worse with MOM6

Vertical coordinate exploration:

- Significant reduction in the heat uptake and T&S biases when using a hybrid isopycnal−z* coordinate (consistent with other studies)
- Other metrics (e.g., PHT, AMOC, MLD) are also better represented in simulations using a hybrid isopycnal−z* coordinate

Next steps: workhorse development

- **Reconcile energy exchange with other CESM components**

  * Conservative mass/enthalpy exchanges (*winter 2021*)

- **Additional parameterizations**

  * Coupling to wind-wave model and associated mixing (*spring 2021*)

  * Estuary/fjord/river plume parameterization (*summer 2021*)

  * Gravity current/overflows (?)

- **Continued experimentation, tuning and bias reduction** (*eternity*)

- **Additional resolutions**

  * Low-res: BGC, paleo, prototyping (?)

  * Eddy-permitting: Leverage work in CPT

Next steps: MOM6/CISM coupling

Possible strategies for computing sub-shelf basal melt rates:

1) Compute basal melt rates in the ice sheet model, using T and S passed from the ocean and regridded to the ice sheet

2) Compute basal melt rates in the ocean, and have the coupler regrid it to the ice sheet (already done via MCT for MISOMIP1)

3) Compute basal melt rates in the coupler, using information received from both ocean and ice sheet

Participate in MISOMIP2:

- Setup regional configuration(s) and perform initial analysis
- Leverage work from a PhD student, collaboration between Utretch University (van de Berg, van de Wal) and NCAR (Lipscomb, Leguy, Marques)

Thank you!

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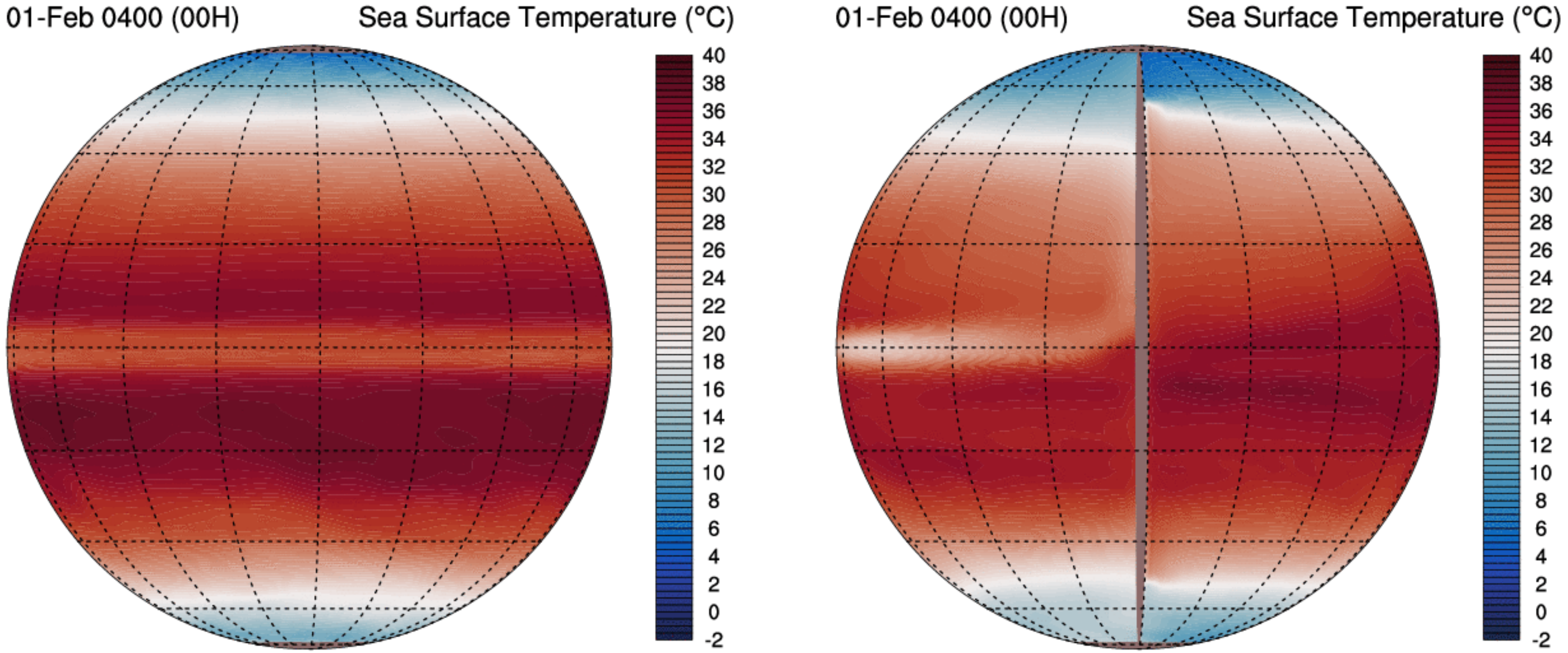
Extra slides

Fully-coupled simplified configurations

CESM Aqua and Ridge: seasonal cycle of SST (yr 400)

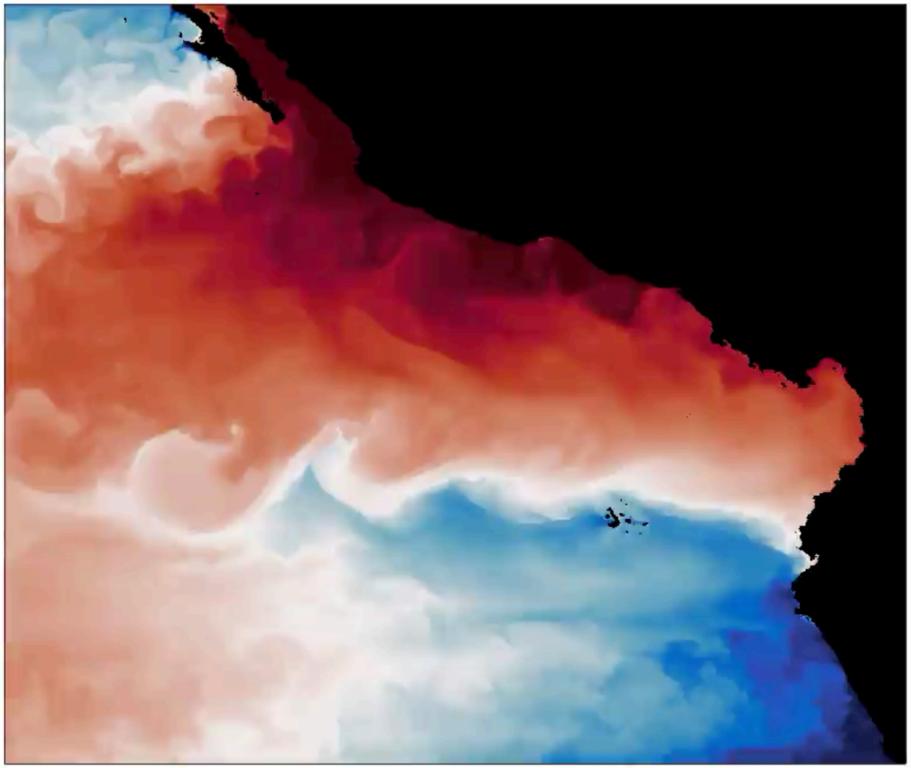


Led by Xiaoning Wu

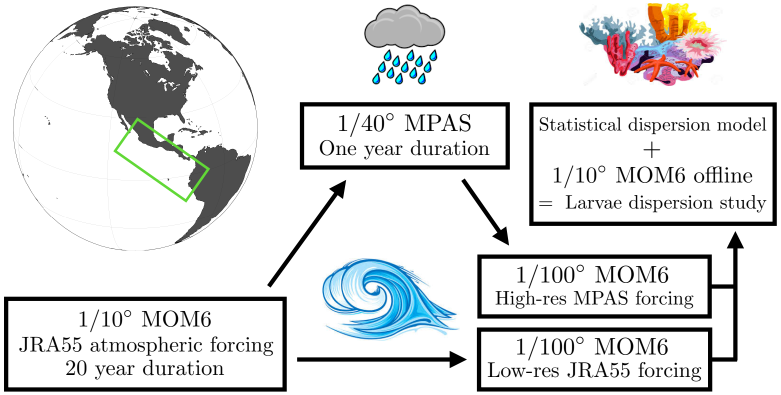
Regional application

Eastern tropical Pacific

SST [°C]



Led by Scott Bachman

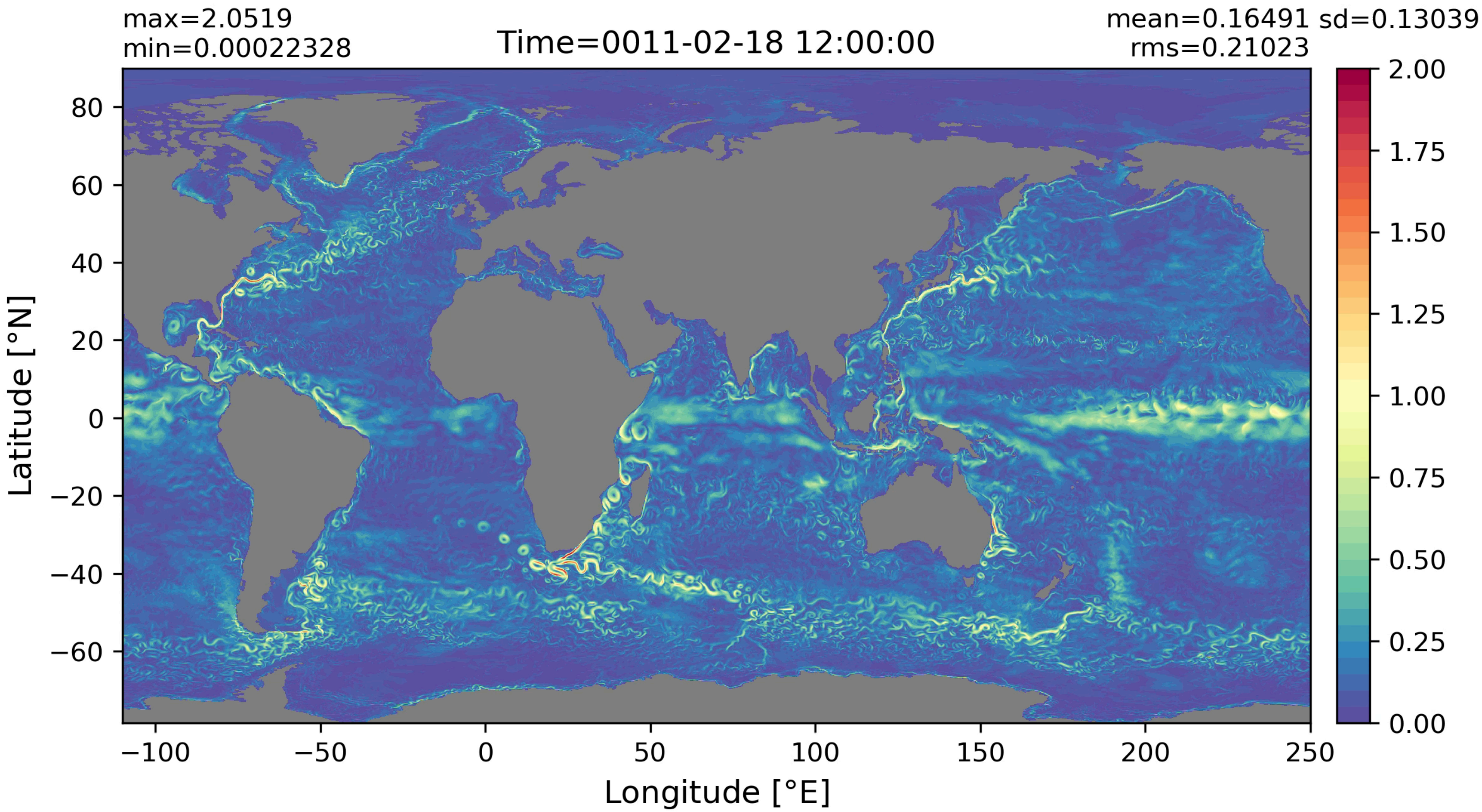


Running regional configuration using same code-base (CESM/MOM6)

One-way downscaling for now

Global high-resolution

G-compset, tx0.1 (same as POP), JRA-v1.3



Cost:	124184.42	pe-hrs/simulated_year
Throughput:	0.59	simulated_years/day

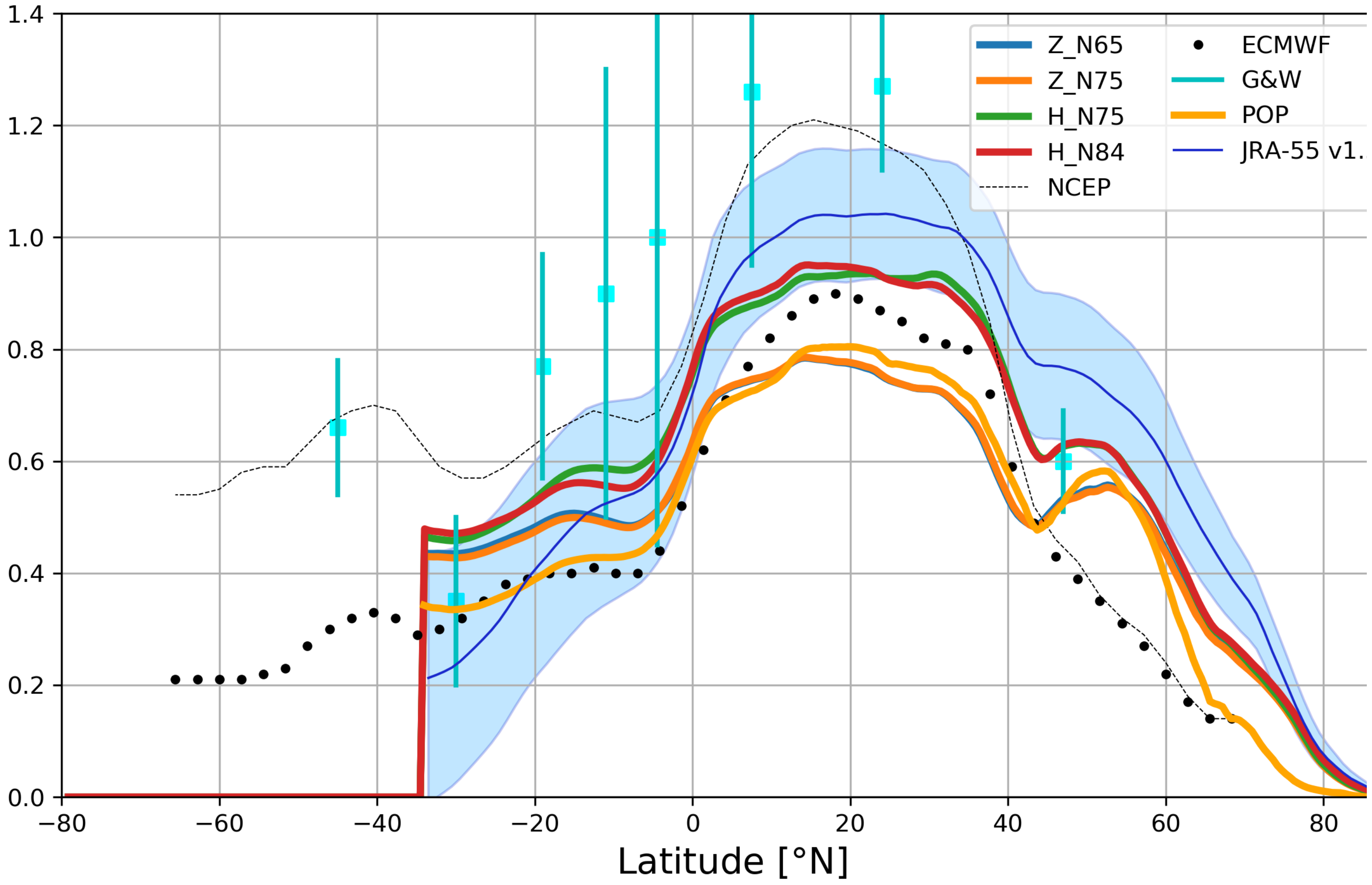
Cost/throughput

	MOM6			POP
	GFDL-OM4p5	CESM - MCT	CESM - NUOPC	POP gx1v6
DT baroclinic	1800	1800	1800	3600
DT thermo	7200	3600	7200	3600
DT couple	3600	3600	3600	3600
NK	75	63	63	60
NI	720	540	540	320
NJ	576	458	458	384
Tot. # Pts	31.1M	15.5M	15.5M	7.4M
PEs	1724	864	864	216
#Pts / PE	18k	18k	18k	34k
Sim Yr/ WC-Day	**14.8**	**19.1**	**25.0**	**53.1**
PE-hrs/ Sim. Yr	**2794**	**1178**	**900**	**97.6**
Cost / Pt / Yr	**6.8**	**5.8**	**4.3**	**1**

Numerical choices

- Boussinesq (ρ_0 = 1035 kg m^3)
- Split time stepping
- Baroclinc DT = 1800 s
- Tracer DT = MCT couple DT = 3600 s
- Barotropic DT: automatically set based on the maximum stable value
- Apply diabatic and thermodynamic processes before stepping the dynamics forward
- Equation of state from Wright (1997)
- Quadratic bottom drag (CDRAG = 0.003)
- Biharmonic horizontal viscosity → coefficient scaled based on run time parameter (biharmonic Reynolds number)

Poleward Heat Transport (Atlantic)



Potential temperature bias at z = 2.5 m