Current simulations with CESM/MOM6

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NCAR

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NSF

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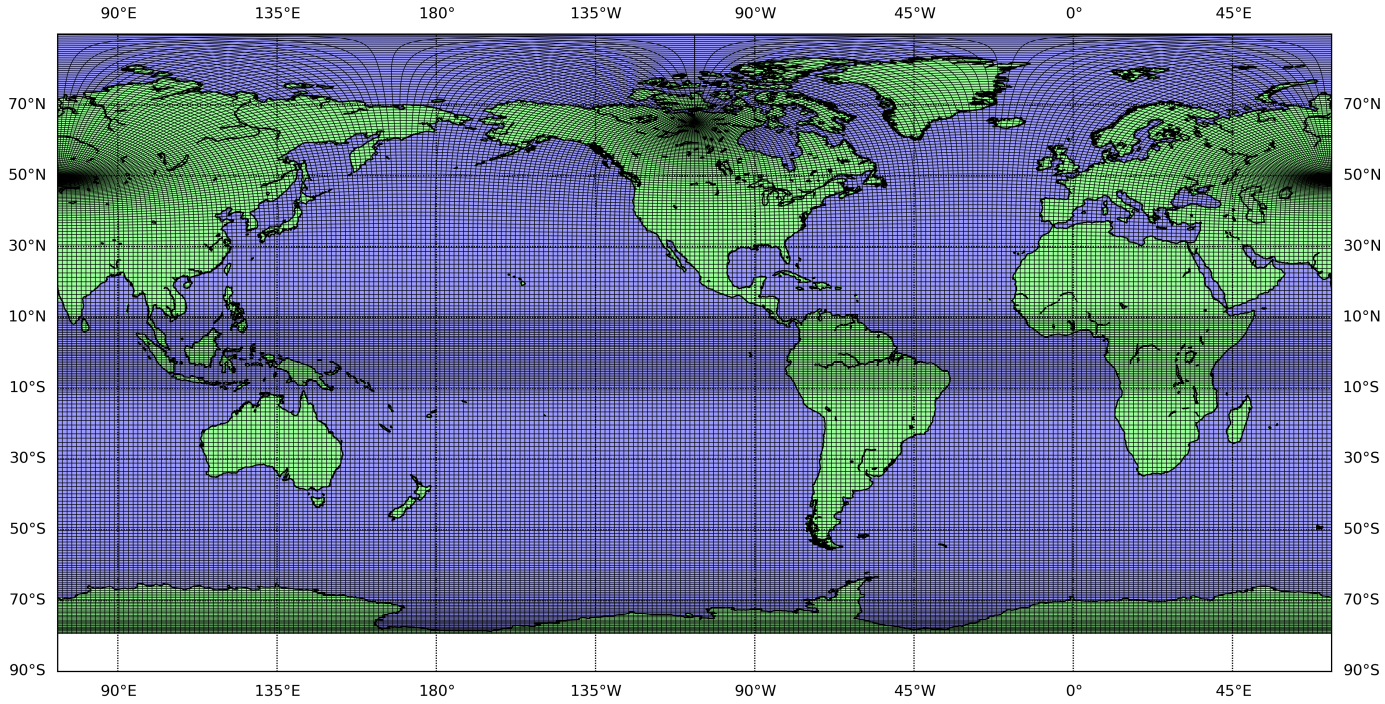
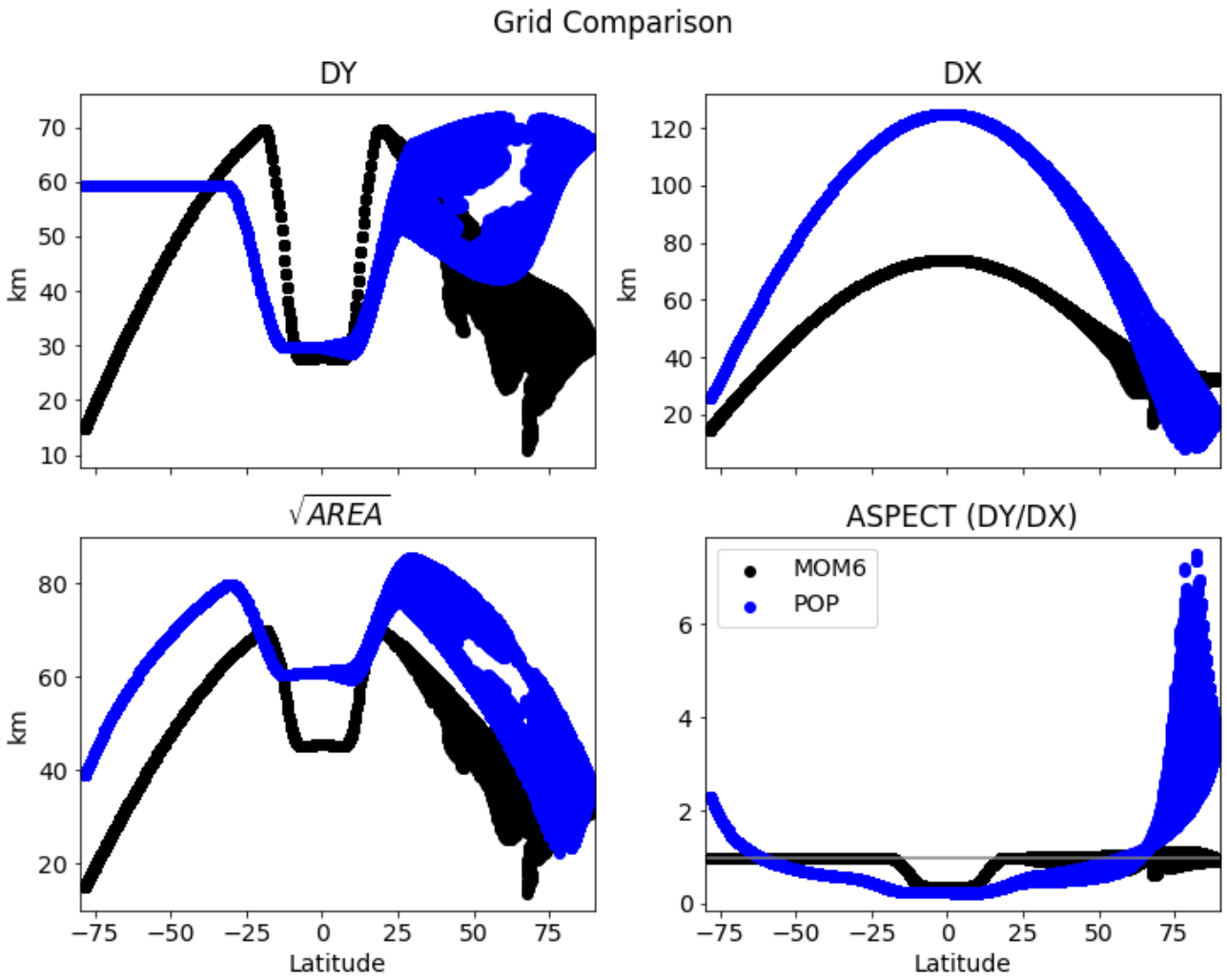
New workhorse configuration (tx0.6)

- Nominal 2/3^{o} horizontal resolution tripolar grid (equatorial refinement)
- Created using a modified version of ORCA grid generator (Fred Castruccio)
- NI = 540; NJ = 458 or ~ 1.7 and 1.2 x POP's 1^{o} grid, respectively

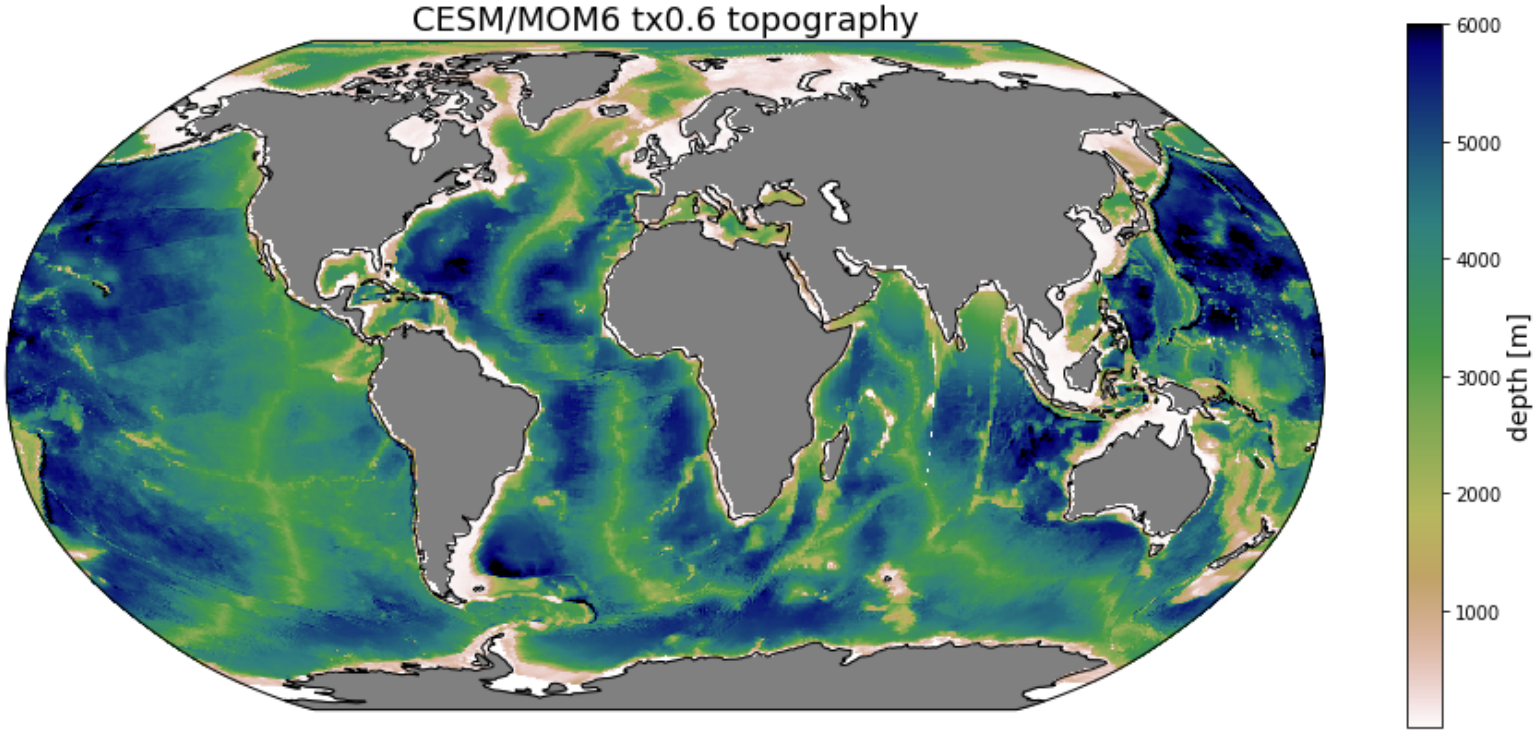


Grid metrics: tx0.6 vs. gx1



Ocean bathymetry

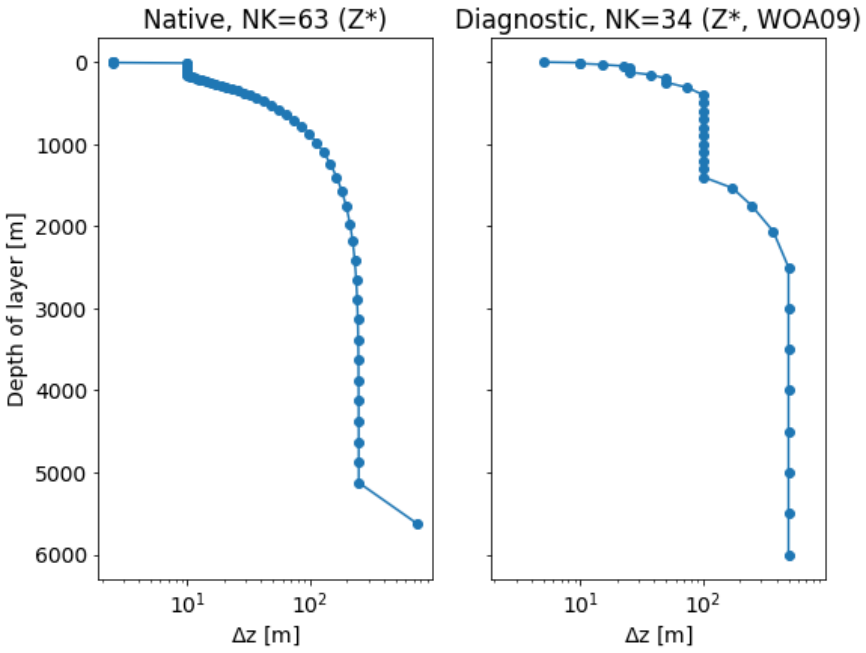
- Based on the ETOPO1 dataset
- Maximum depth = 6000 m
- Minimum depth = 10 m (30 m around Antarctica)

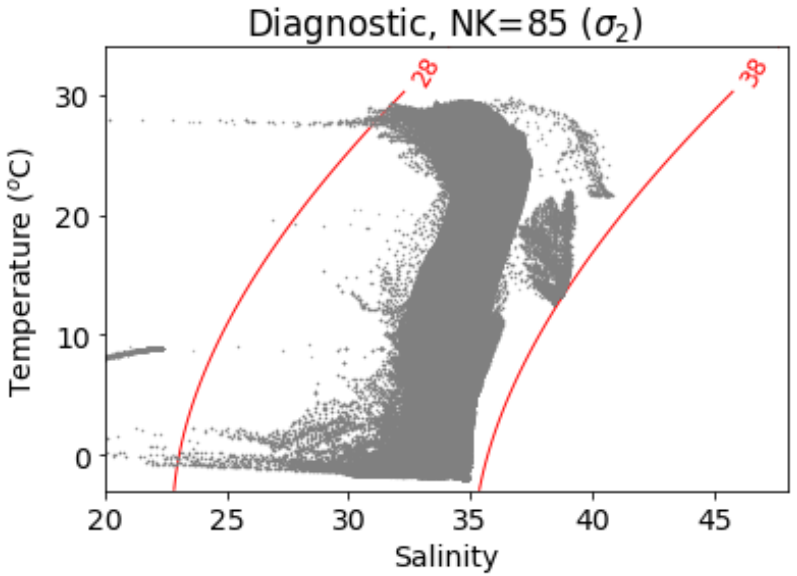


We plan to explore option to restrict channel widths (CHANNEL_CONFIG) in the near future

Vertical coordinate(s)

- Vertical coordinate is Z*, with 63 model layers (ALE reconstruction scheme is 3rd-order accurate)





We plan to explore other vertical coordinate systems (e.g., HyCOM-like hybrid) in the near future

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)

Vertical mixing via CVMix

Parameters set to same values used in POP

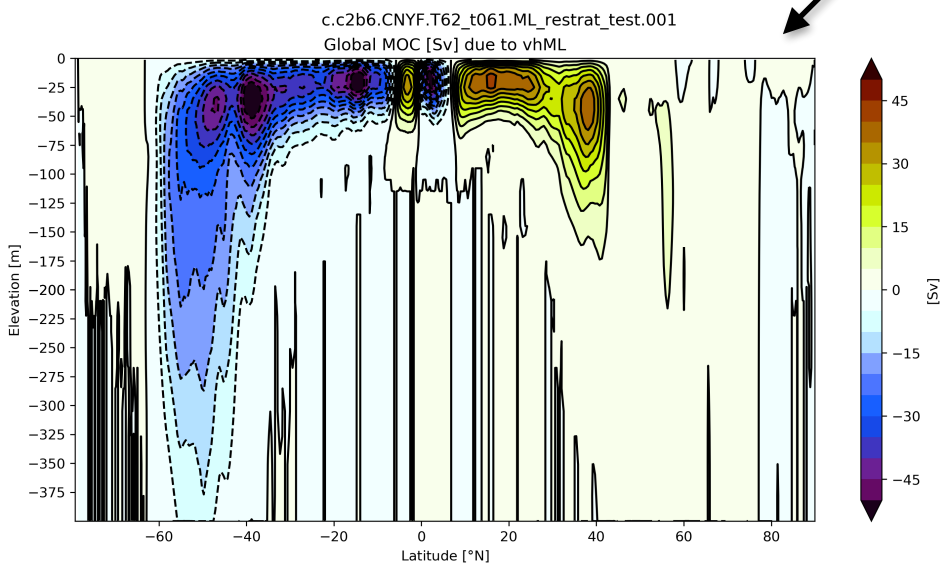
- Constant background diapycnal diffusivity = 2.0E-5 $m^2\ s^{-1}$
- Vertically uniform latitude-dependent background diffusivity (Danabasoglu et al., 2012)
- KPP boundary layer scheme (Large et al., 1994)
- Tidal mixing (Simmons et al, 2004)
- Convection (KD_CONV = 1.0 $m^2\ s^{-1}$)
- Double-diffusion
- Interior shear mixing

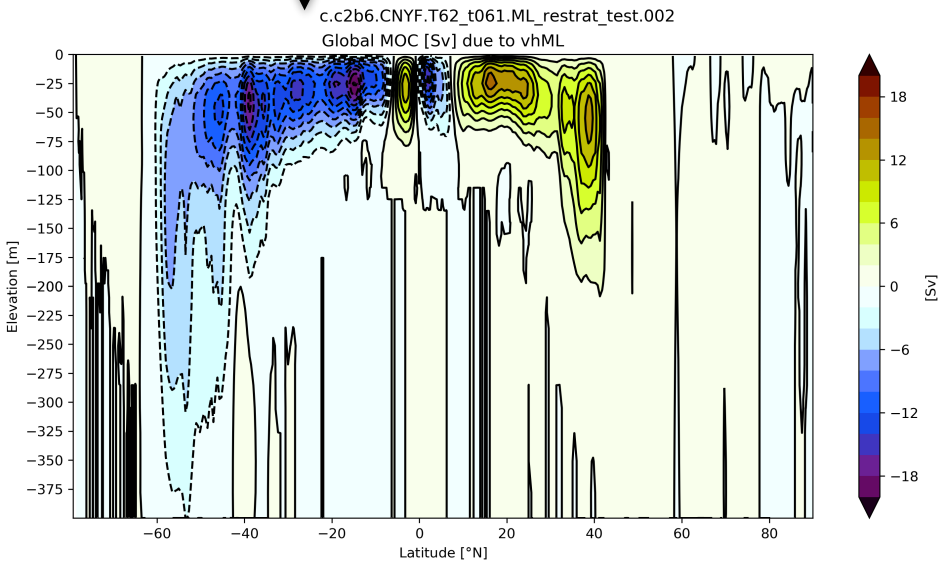
Mixed Layer Baroclinic Eddies

Parameters set to same values used in POP

- Mixed layer re-stratification by sub-mesoscale eddies (Fox-Kemper et al., 2010)

	OM4p5	POP
MLE_FRONT_LENGTH (m)	200	1000
MLE_MLD_DECAY_TIME (days)	30	4





Mesoscale Eddy Parameterizations

- GM and Redi controlled via MEKE/GEOMETRIC:
  - KHTH vertical structure based on equivalent barotropic mode
  - Streamfunction formulation of Ferrari et al., 2010

- Horizontal Laplacian viscosity (ν) set via MEKE:

$$\nu = \sqrt{E} \times L$$

MEKE Length-scale

Implementing MEKE/GEOMETRIC in MOM6

Led by Scott Bachman (new CPT, Energetics and mesoscale parameterization)

Mesoscale eddy kinetic energy (MEKE) (Jensen et al., 2015):

MEKE **SOURCE** **SINK** **SMOOTHING**

$$\partial_t E = \dot{E}_{bg} + \underbrace{\gamma_{GM}\dot{E}_{GM}}_{\text{Energy transferred from GM}} + \cancel{\gamma_\nu \dot{E}_\nu}^{\,0} - \underbrace{\left(2\frac{C_d}{H}|U_b|E_b\right)}_{\text{Energy lost to bottom drag}} + \underbrace{\mathcal{D}_E}_{\text{Diffusion}} \quad (1)$$

GEOMETRIC (Marshall et al., 2012) $\rightarrow$

$$\kappa_{GM} = \alpha E \frac{N}{|\nabla b|} \quad (2)$$

MEKE EQUILIBRIUM $\rightarrow$

$$E_{eq} = \alpha \frac{H^2}{C_D}\frac{|\nabla b|^2}{N^2} \quad \text{Energy transferred from GM} \approx \text{Energy lost to bottom drag} \quad (3)$$

MEKE FINAL

$$\partial_t E = \dot{E}_{bg} + \gamma_{GM}\dot{E}_{GM} + \gamma_\nu \dot{E}_\nu - \left(2\frac{C_d}{H}|U_b|E_b\right) + \mathcal{D}_E - \underbrace{\lambda}_{\text{Time-scale}}(E - E_{eq}) \quad (4)$$

Best runs so far

Forced (G25):

- JRA-55 (v1.3)
- SSS restoring (WOA05) piston velocity = 0.1667 m/day (~ 60 m/year)
- ADJUST_NET_SRESTORE_TO_ZERO = True; adjusts the salinity restoring to zero
- ADJUST_NET_FRESH_WATER_TO_ZERO = True; adjusts the net fresh-water to zero

Fully-coupled (B10):

- Pre-industrial control
- CAM6, CLM5-BGC-CROP, CICE5, MOSART, CISM2-NOEVOLVE

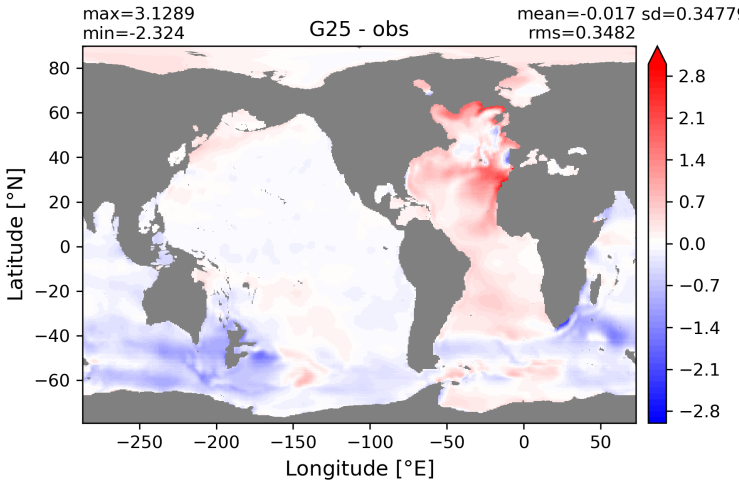
TOA balance = 0.28 W m^{-2}

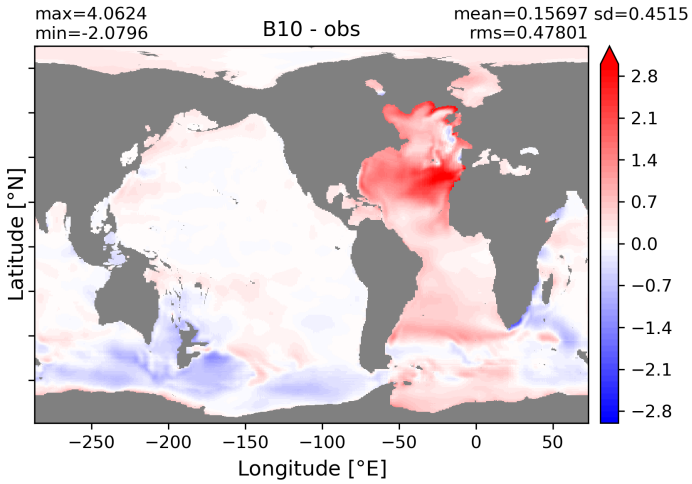
Run for 58 years. All time averages are over last 30 years

Deep (1200m) Temperature & Salinity Mean Biases

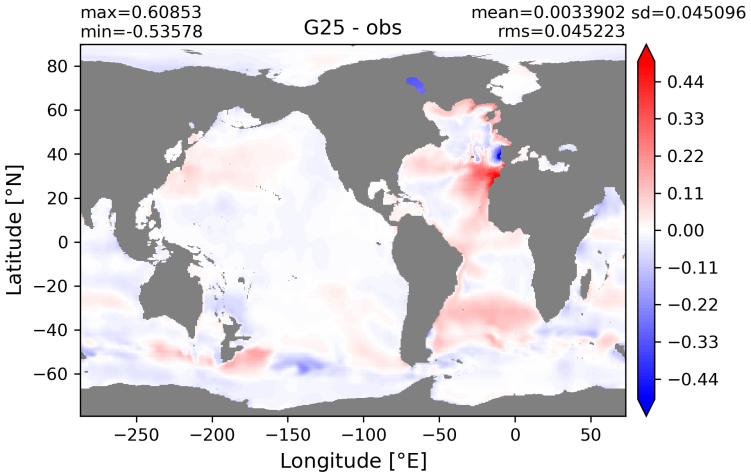
G25 B10

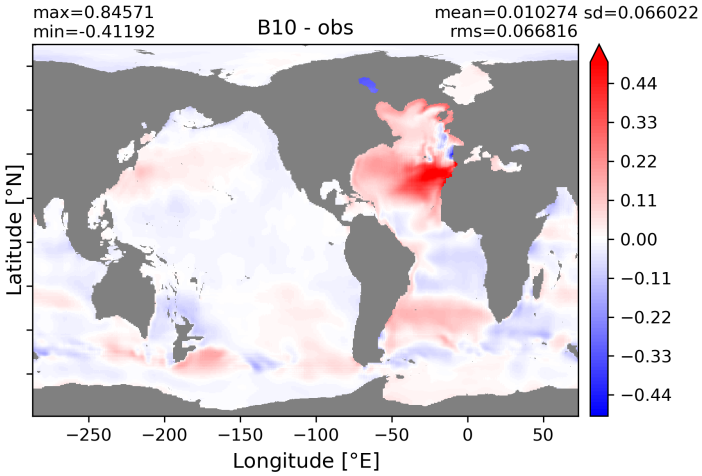
Temp (°C)



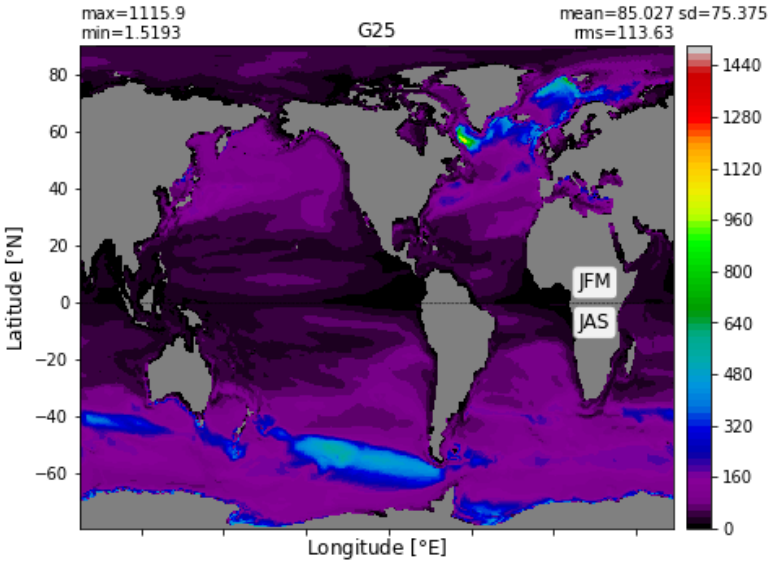


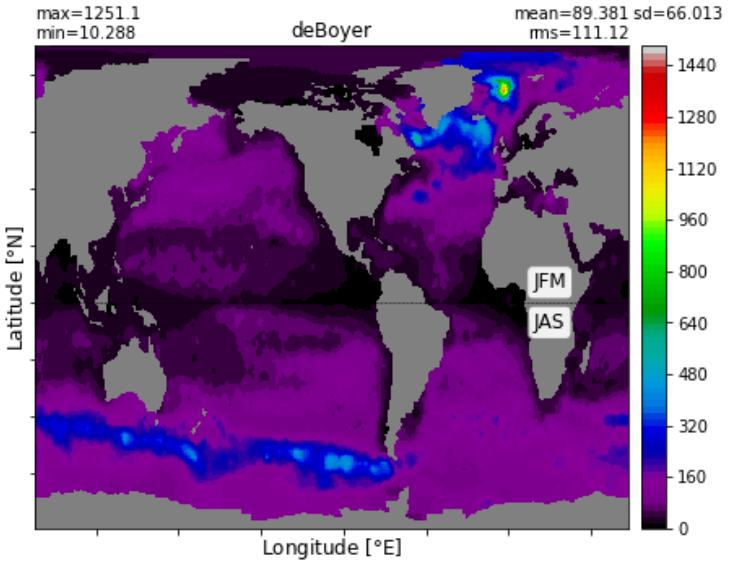
Salt

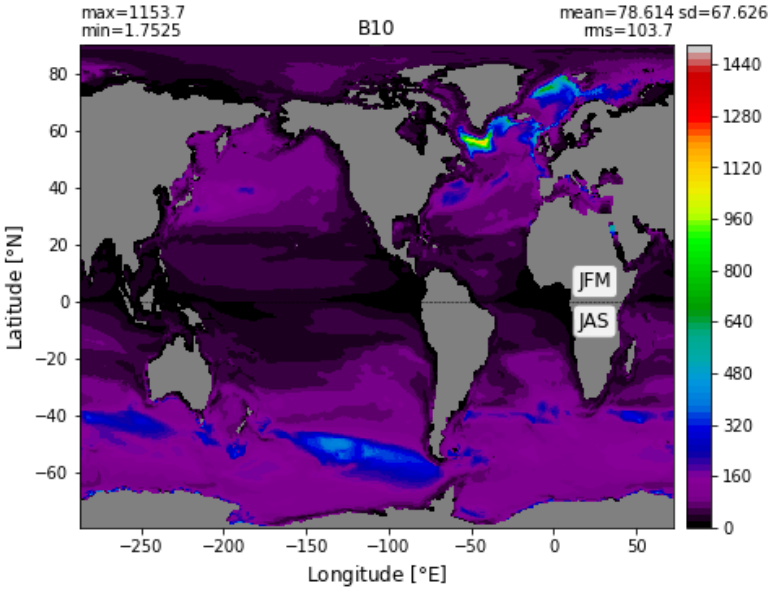


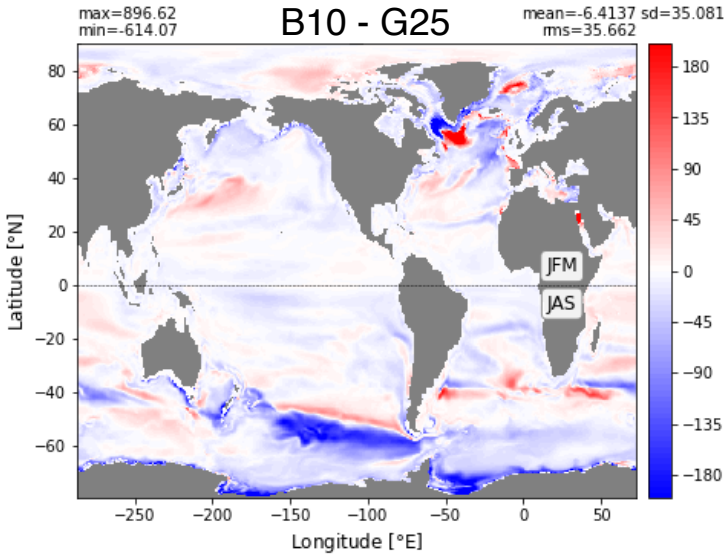


Winter mixed layer depth, $\Delta\rho$ = 0.03 (m)

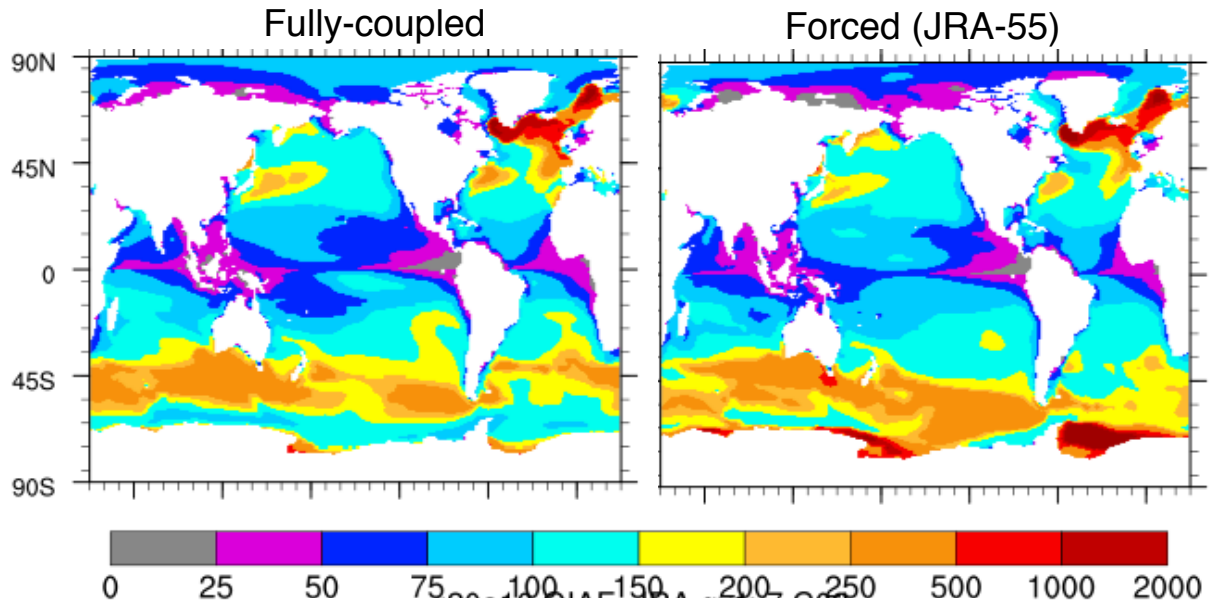






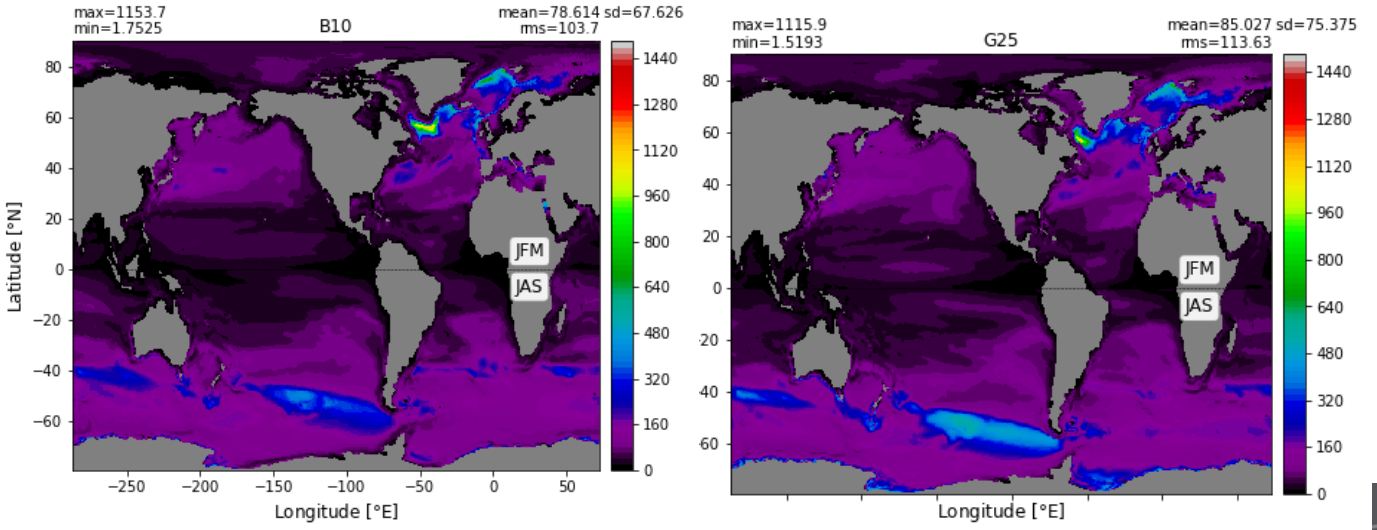


Winter mixed layer depth, MOM vs POP (m)

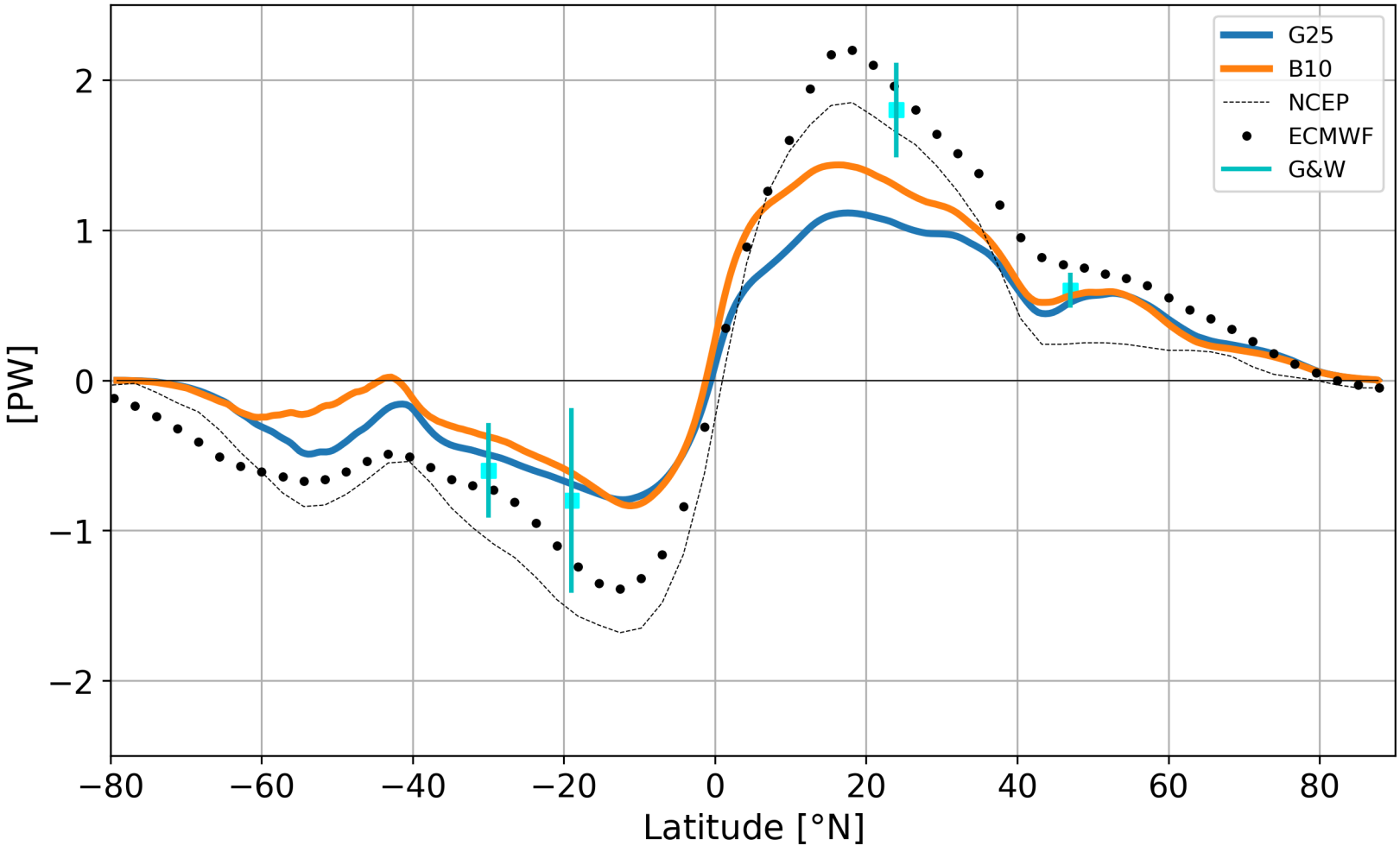


POP's MLD based on 0.125 kg m^{-3} criteria

Thanks to Justin Small for pointing similarity

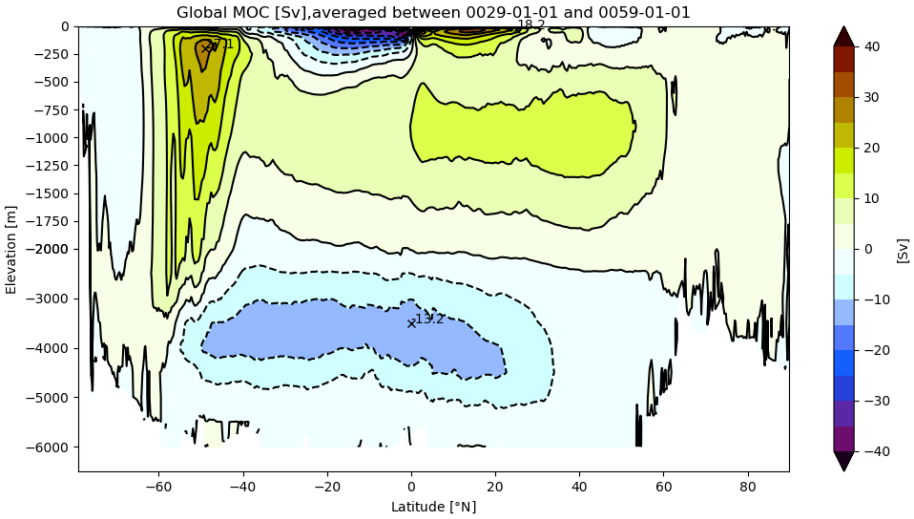


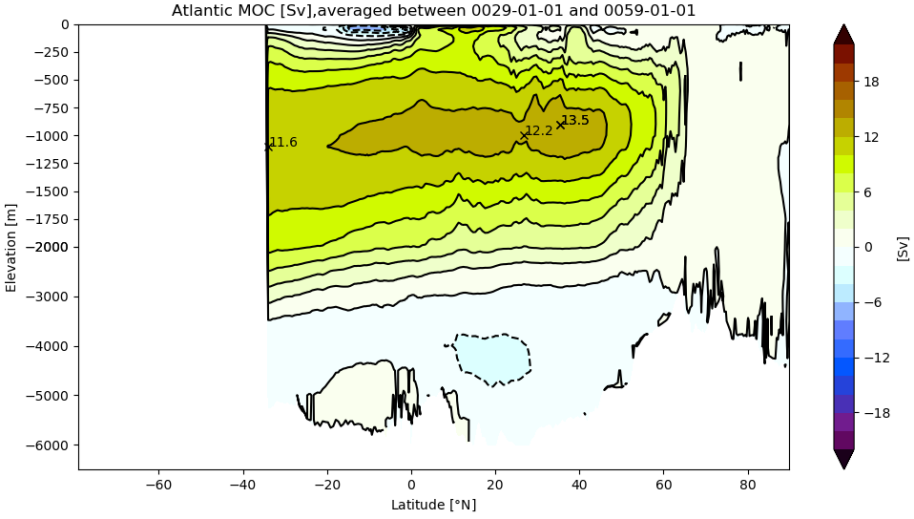
Poleward Heat Transport (Global)



Meridional Overturning Circulation

G25





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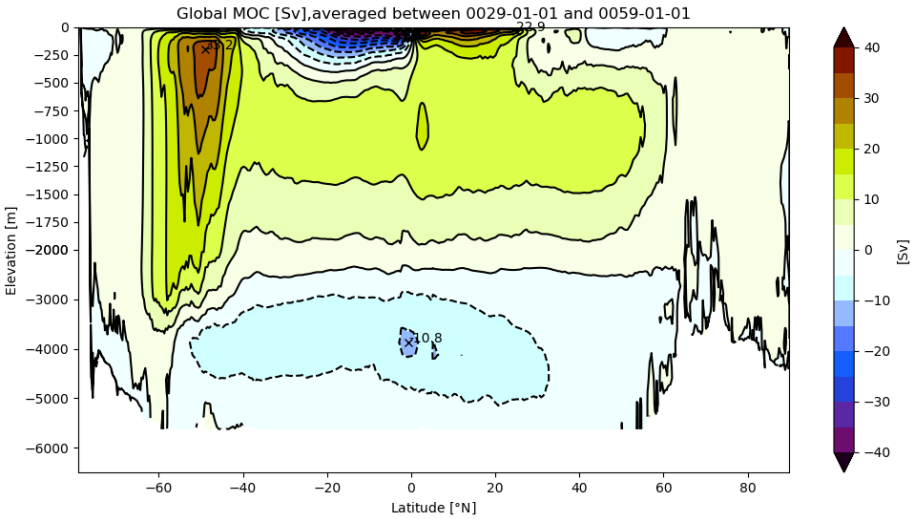
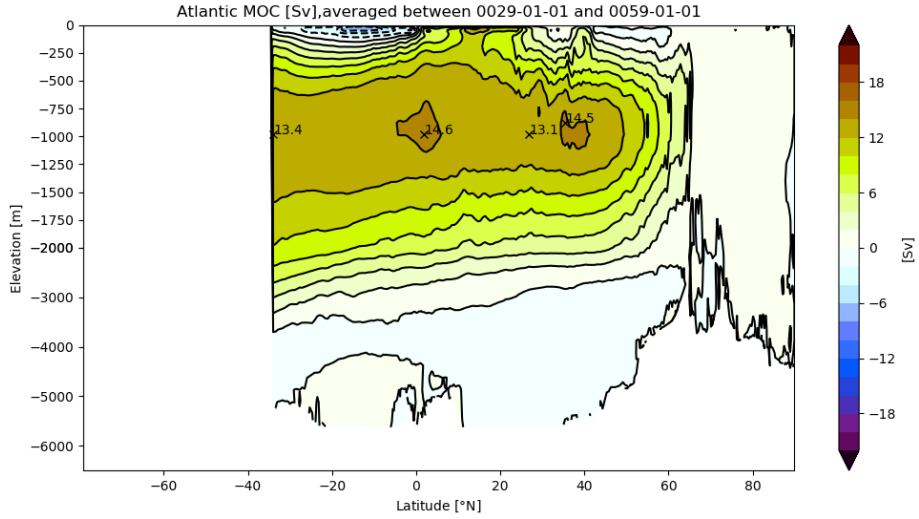
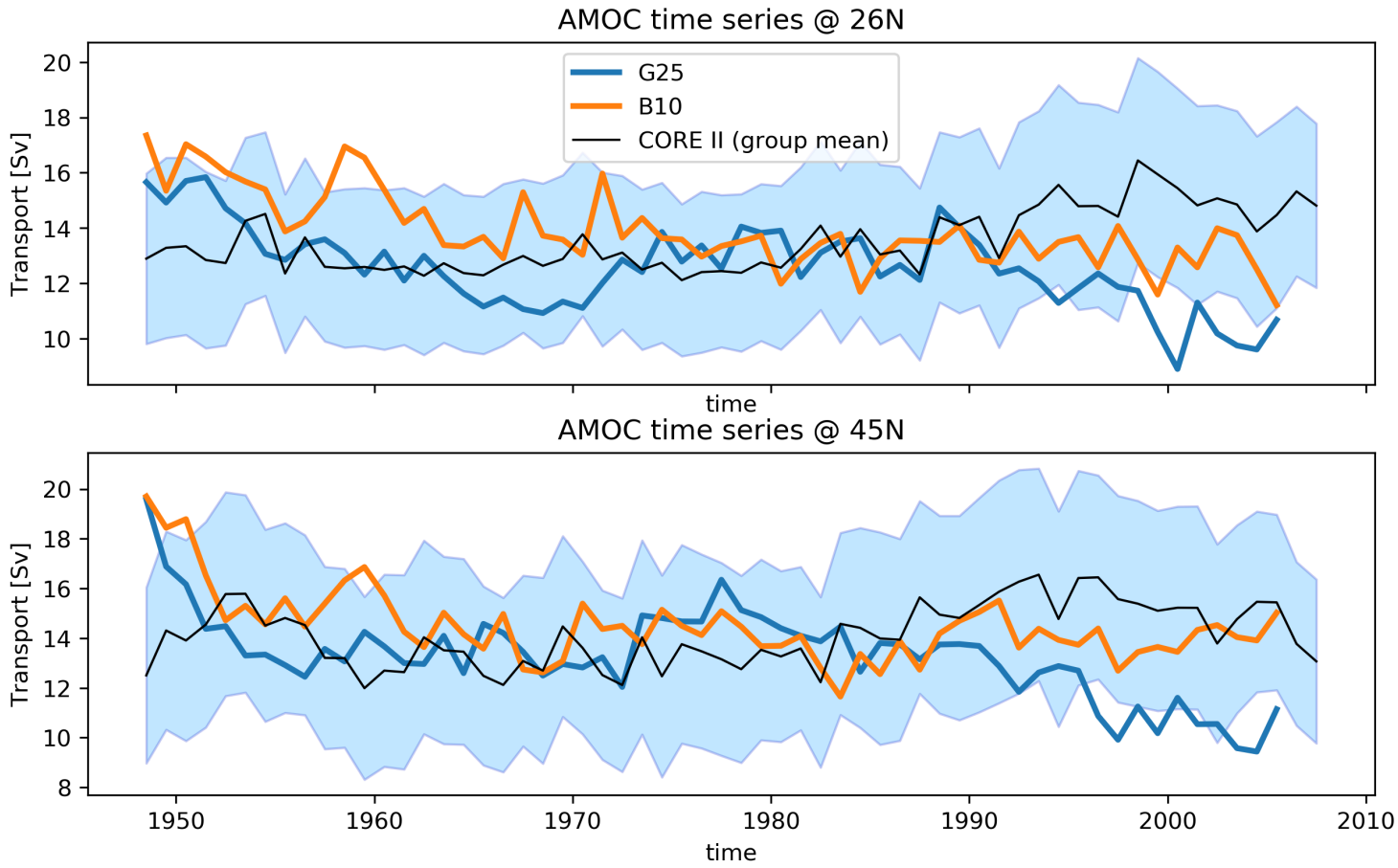




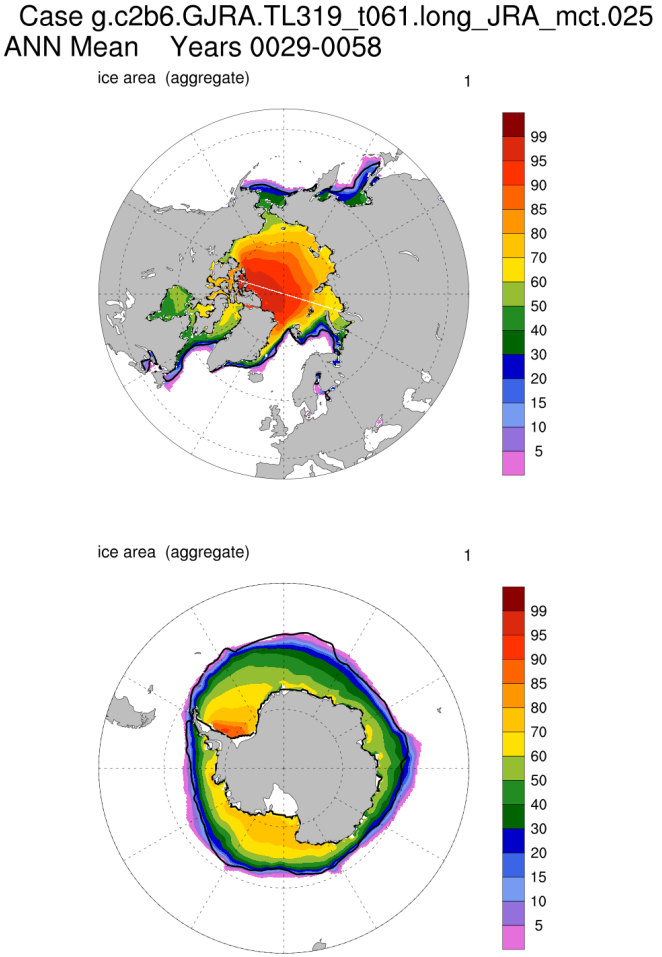
AMOC time series @ 26N and 45N

CORE II time series data (5th) cycle from Danabasoglu et al, 2015



Ice concentration ANN mean

G25



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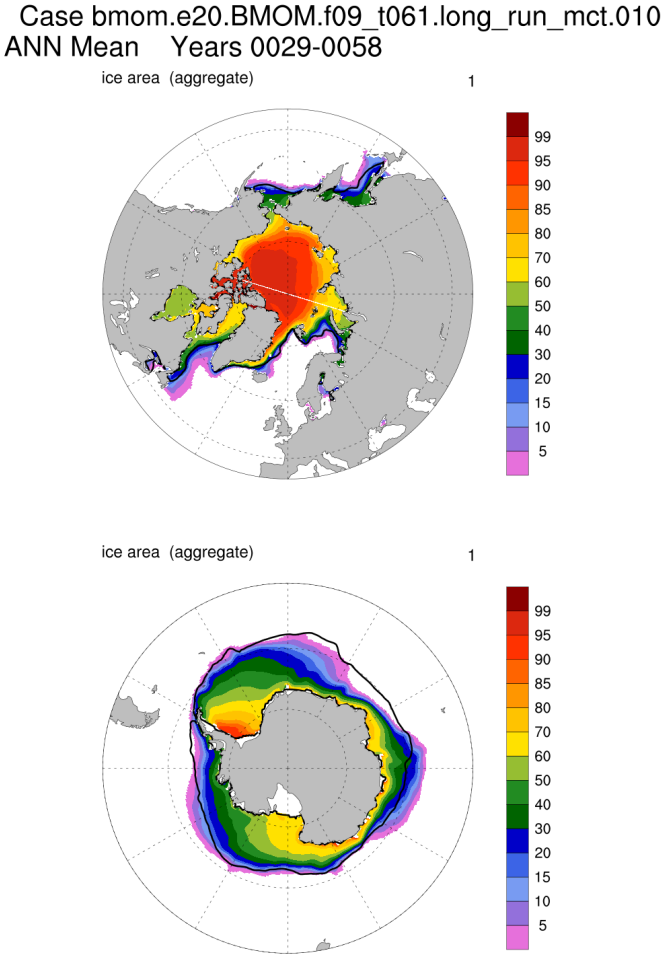
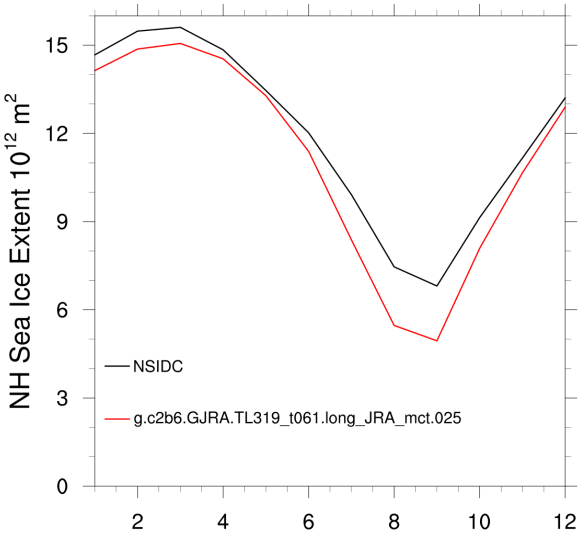
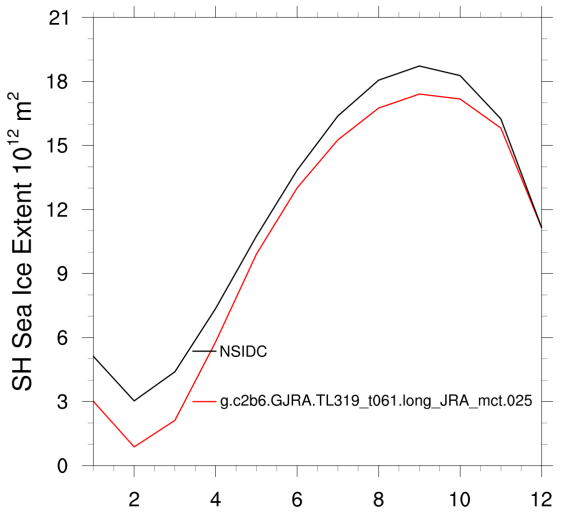


Sea ice extent climatology

G25





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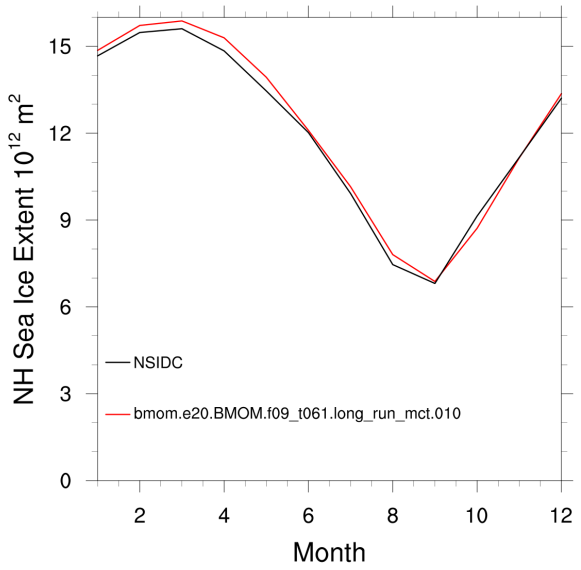

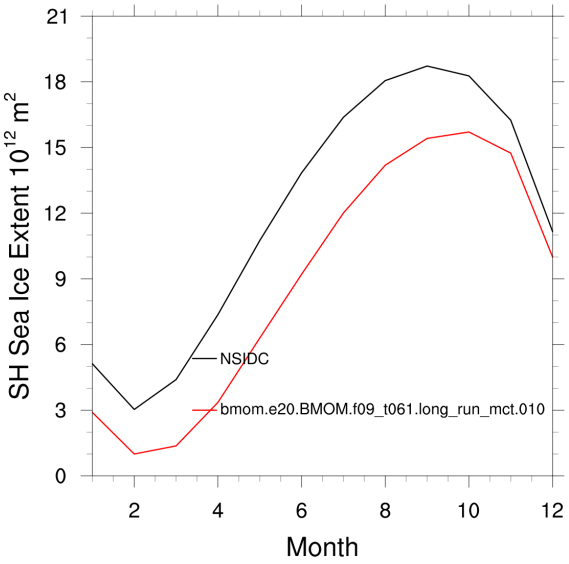

Final remarks

- A preliminary version of MOM6 will be released in CESM 2.2 (mid- to late-June 2020) ⟶ **It won't be the final tuning or configuration!**

- Using MOM6 in CESM (Altuntas, April 27th)

Ongoing efforts:

- Mesoscale horizontal diffusion of tracers within boundary layers (Marques, Shao, Bachman)

- GM+E backscatter (Bachman, Marques)

- Incorporate MARBL BGC into MOM6 (Levy, Lindsay, Shao, Marques)

Thank you!

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