E3SM Arctic-Refined Eddy-Resolving Ocean and Sea Ice (AEROSI) Model to Explore the Benefits of Regional Refinements and Exascale Readiness

(work in progress)

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Outline

1. Project summary
2. Model configurations and simulations
3. G-case intercomparisons of:
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   b. The upper ocean circulation
   c. Vorticity / Okubo-Weiss parameter
   d. Sea ice thickness distribution and volume timeseries
   e. Gateway transports
   f. Surface turbulent fluxes
4. Summary

E3SM – Arctic Eddy-Resolving Ocean and Sea Ice (AEROSI) Project Summary

The project's overall objectives are to:

develop, optimize/reduce biases, run, and analyze multi-decadal simulations of a globally eddy-resolving **E3SM-AEROSI** model...

... to investigate impacts of the Arctic Ocean mesoscale dynamics on:

(i) the northward mass and property transport into the Arctic Ocean,

(ii) shelf-basin exchanges and their impacts on the upper Arctic Ocean and sea ice,

(iii) air-sea energy (momentum and heat) exchange in the pan-Arctic region,

(iv) export of freshwater into the North Atlantic and its impact on the Atlantic Meridional Overturning Circulation (AMOC)

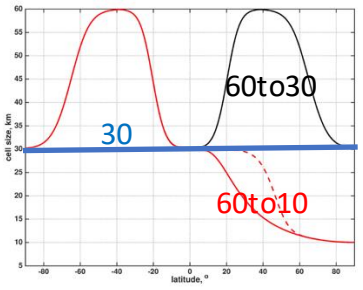
to provide:

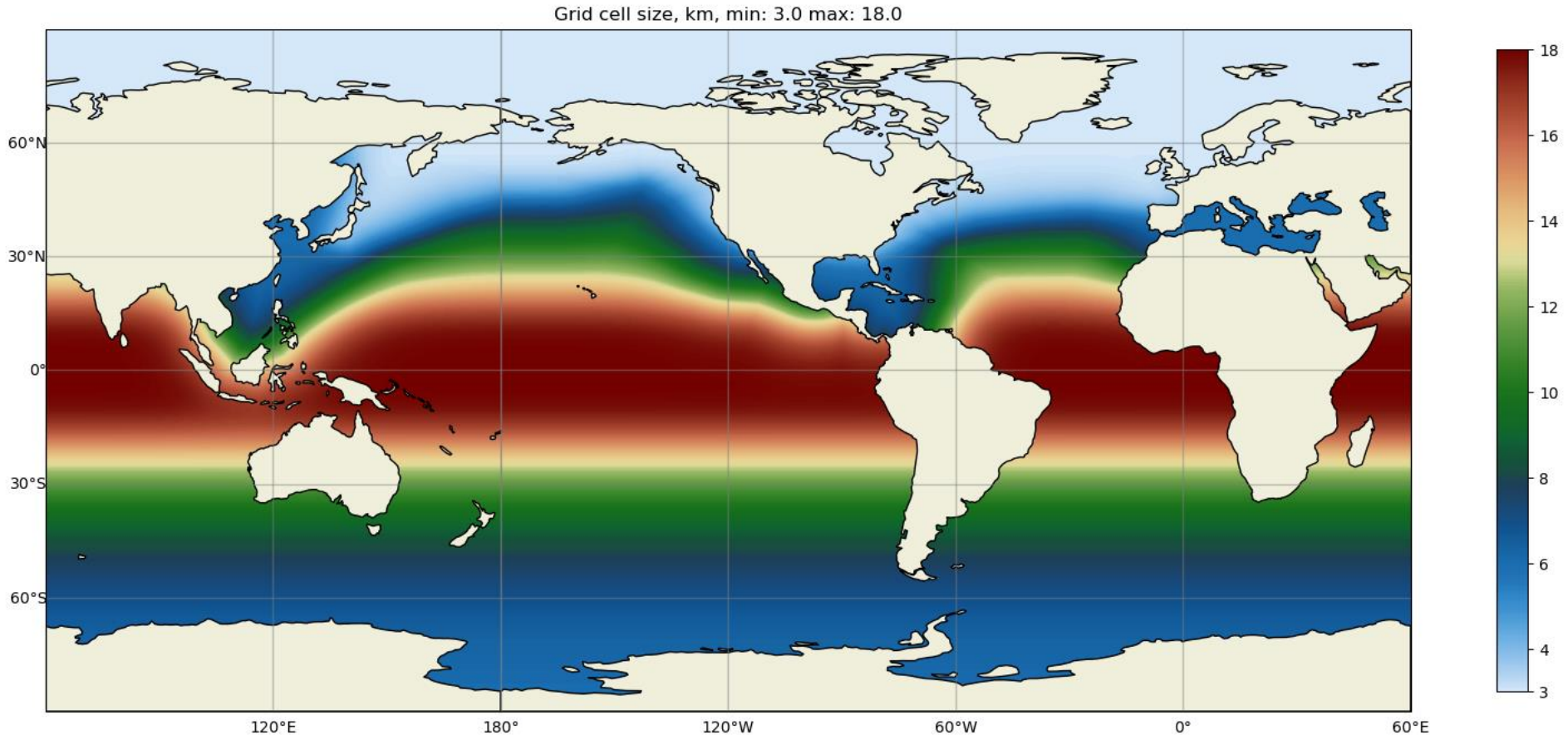
(i) a process-level baseline of the Arctic-focused global ocean and sea ice time-varying states not readily available from observations,

(ii) a guidance for future observations facilitating the development of improved parameterizations of processes and coupling critical to the region.

The E3SM-AEROSI takes advantage and explores the benefits of the core E3SM capability and its **readiness for coupling with cloud/convection resolving atmospheric models in the age of Exascale computing**.

E3SM-AEROSI Overview



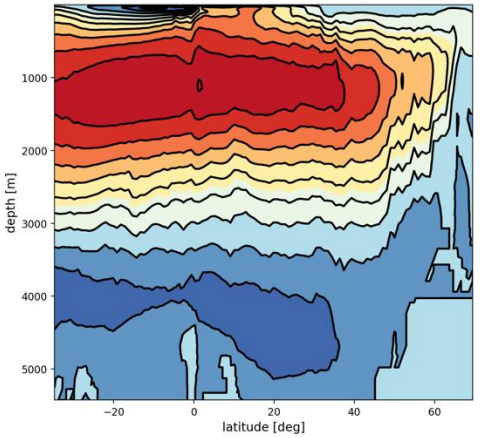


- Grid-cell size ranges from 3 km in the northern high latitudes up to 18 km in the subtropics.
- Southern Hemisphere grid as in the E3SMv3 HR (6to18km)
- 63-year (1st loop) G-case simulation (E3SMv3G18to6) forced with JRA55-do completed
- Compare to JRA55-do forced E3SMv3G simulations: 60to10, 60to30, and 30

Intercomparison of E3SM AMOC

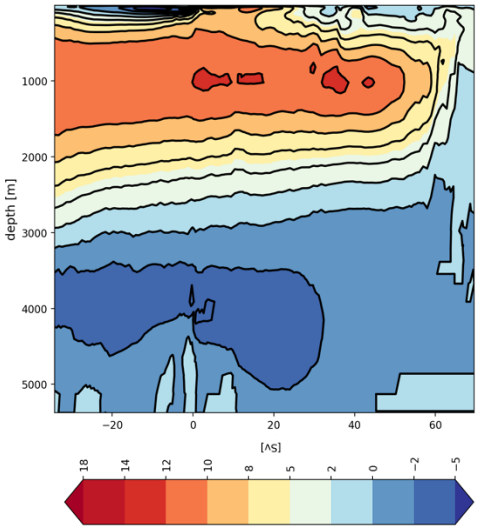
Atlantic MOC (ANN, years 0035-0063)

E3SMv3G18to3

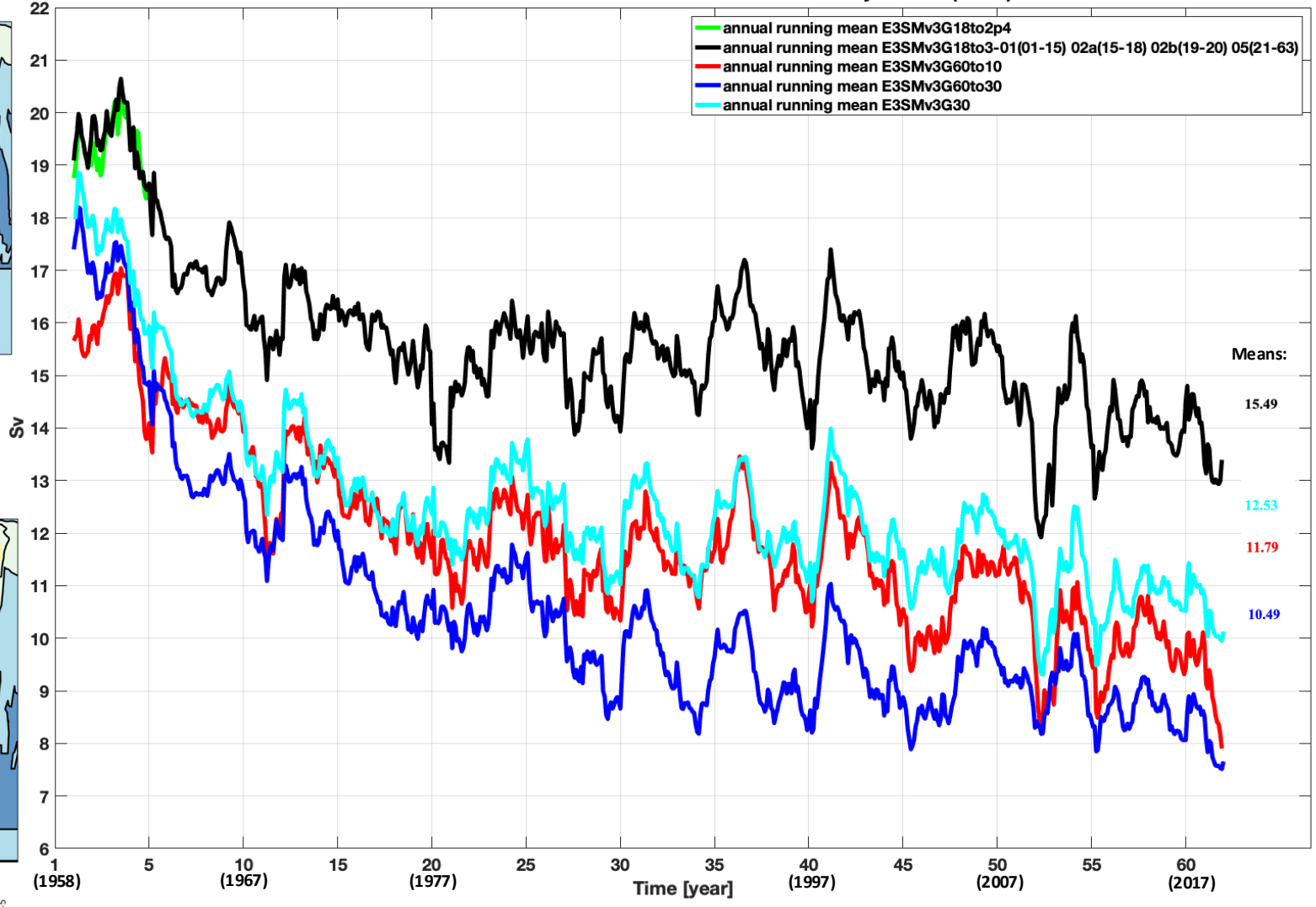


Atlantic MOC (ANN, years 0035-0063)

E3SMv3G30

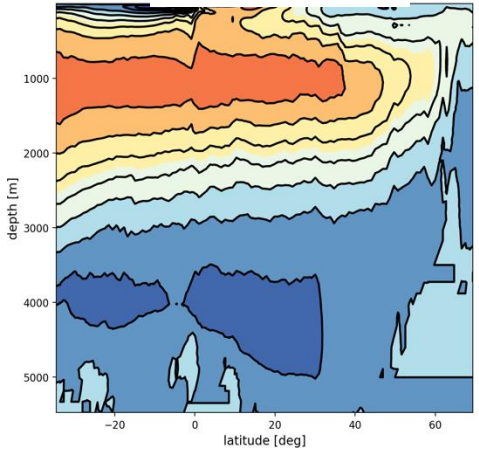


Max MOC Atlantic streamfunction nearest to RAPID Array latitude (26.5N)



Atlantic MOC (ANN, years 0035-0063)

E3SMv3G60to10



Atlantic MOC (ANN, years 0035-0063)

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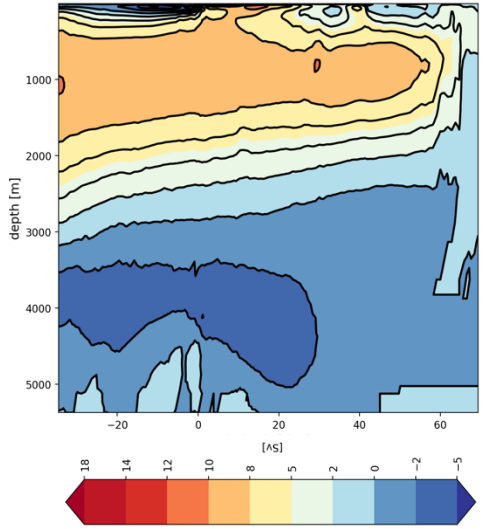
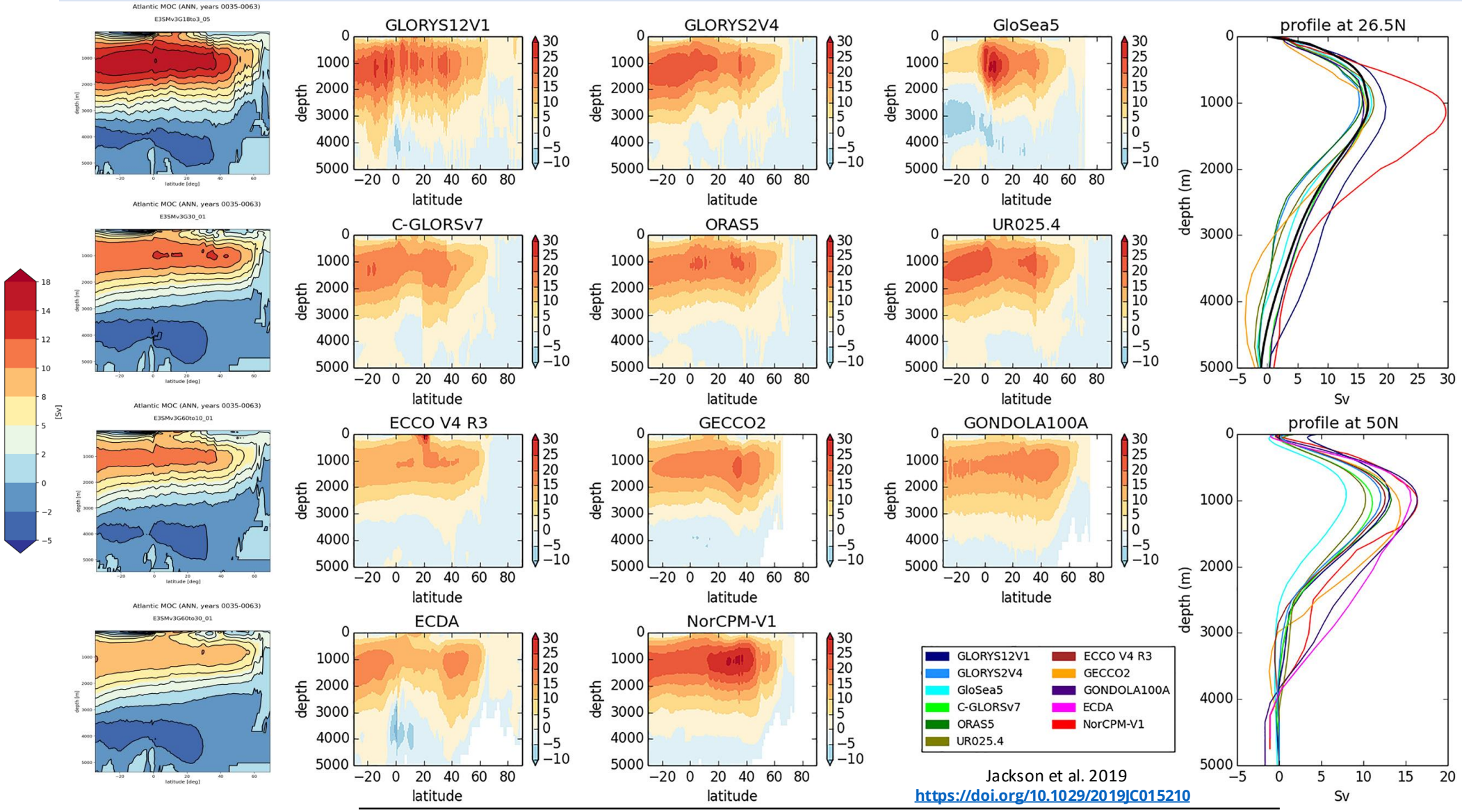


Intercomparison of AMOC streamfunction



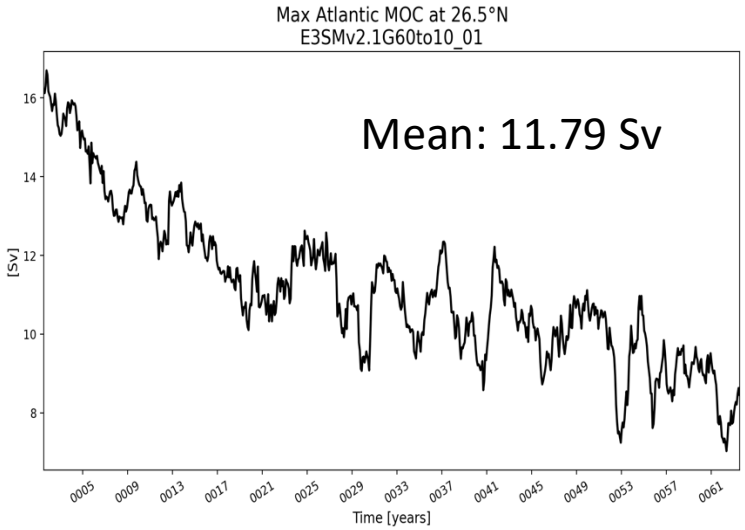
Jackson et al. 2019
https://doi.org/10.1029/2019JC015210

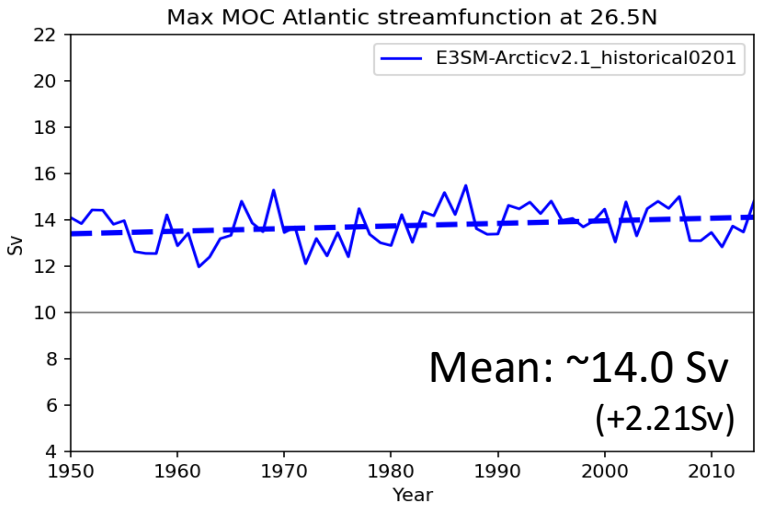
Intercomparison of E3SM AMOC

G-case

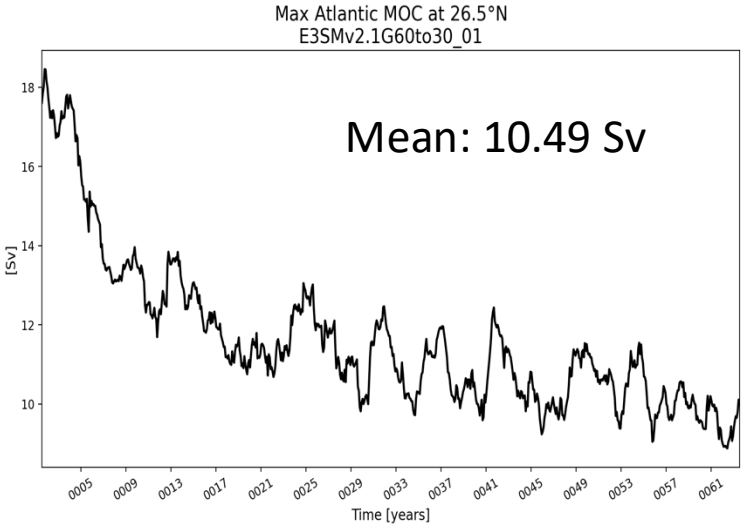
B-case

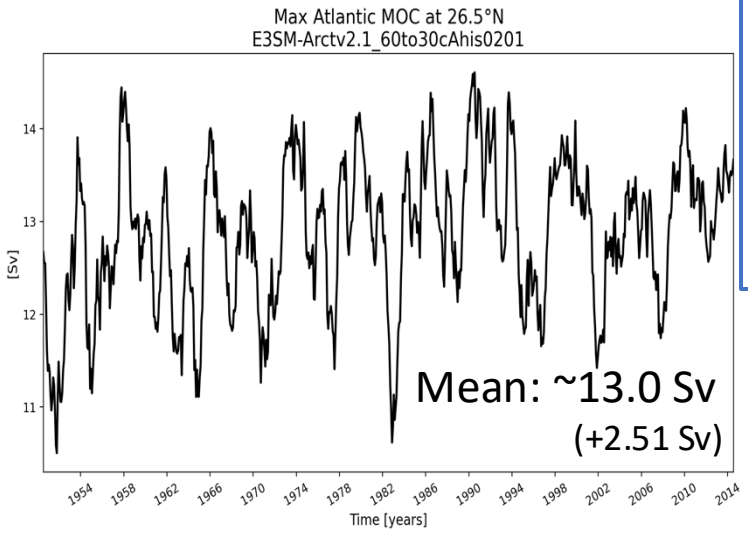
60to10

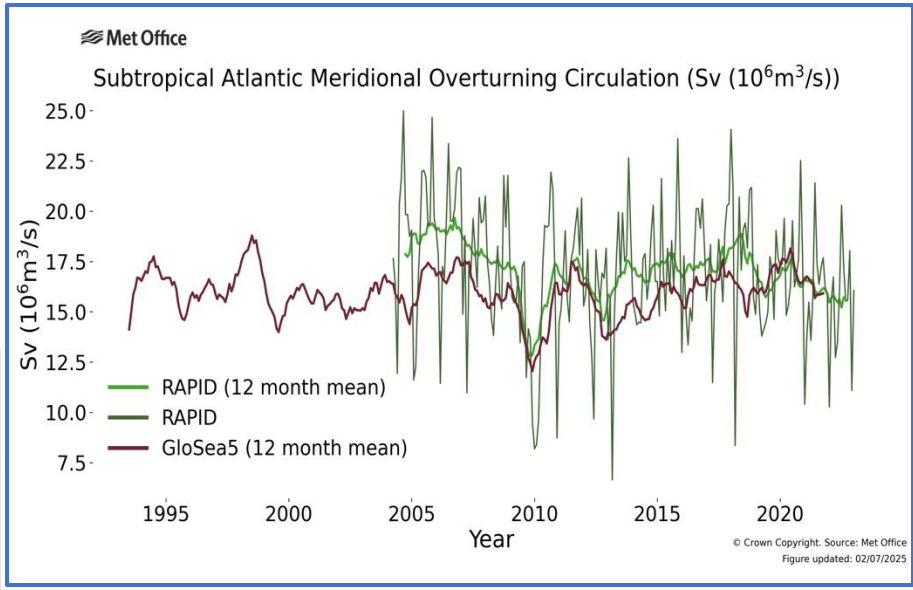




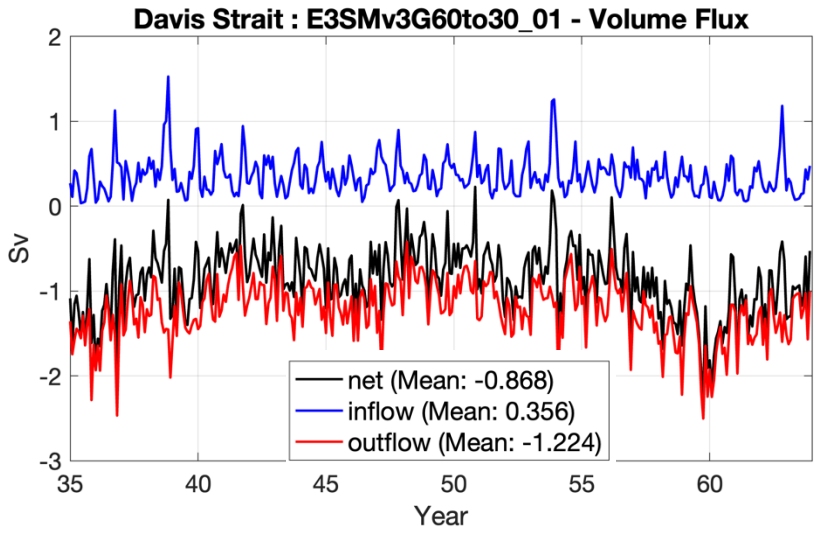
60to30

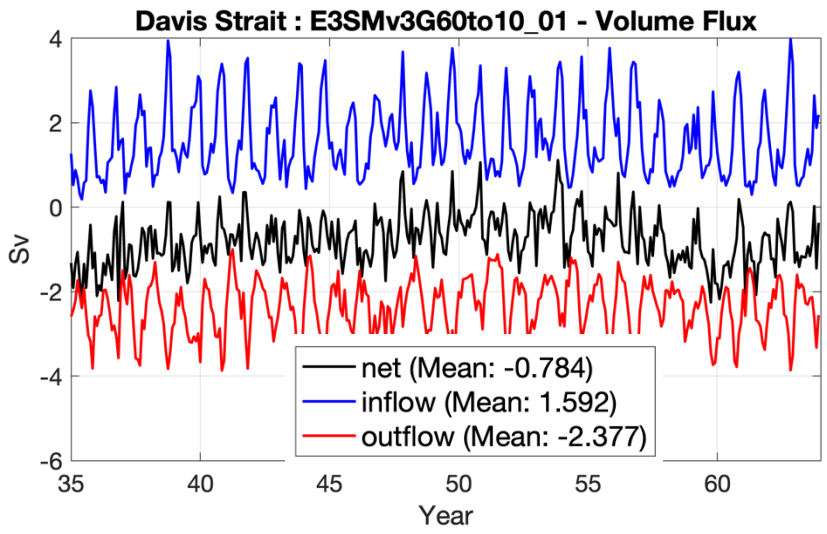


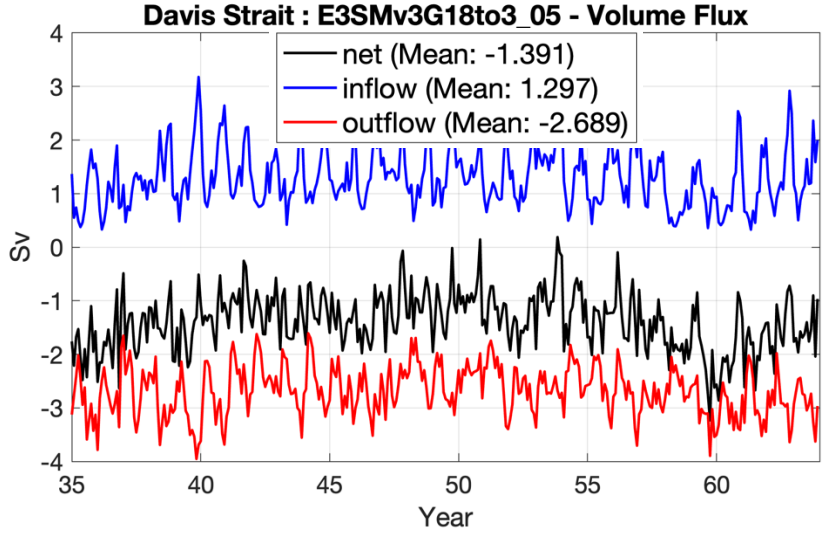


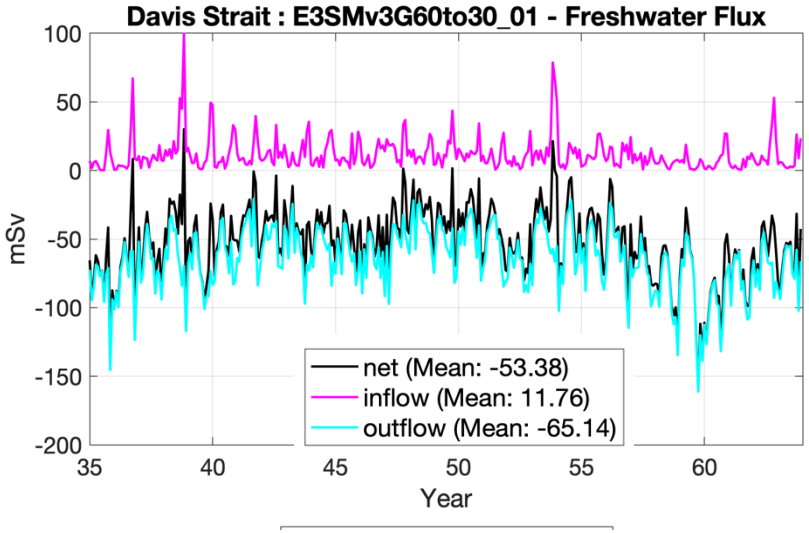


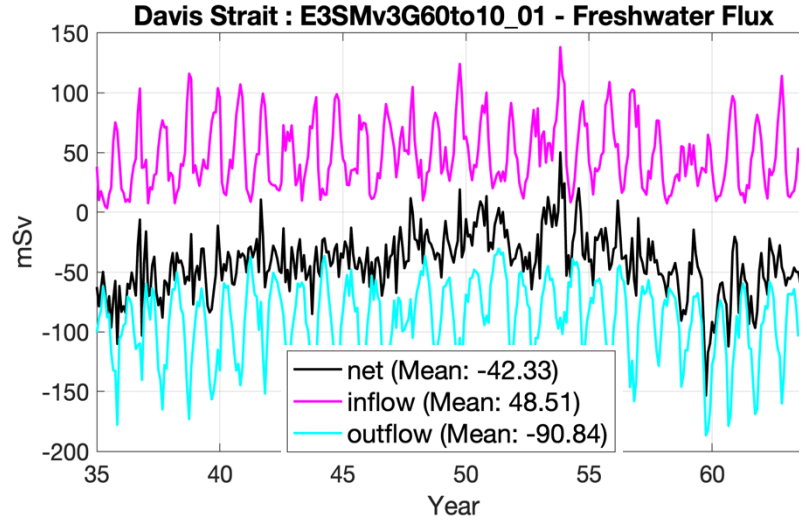
Davis Strait volume/freshwater flux comparison

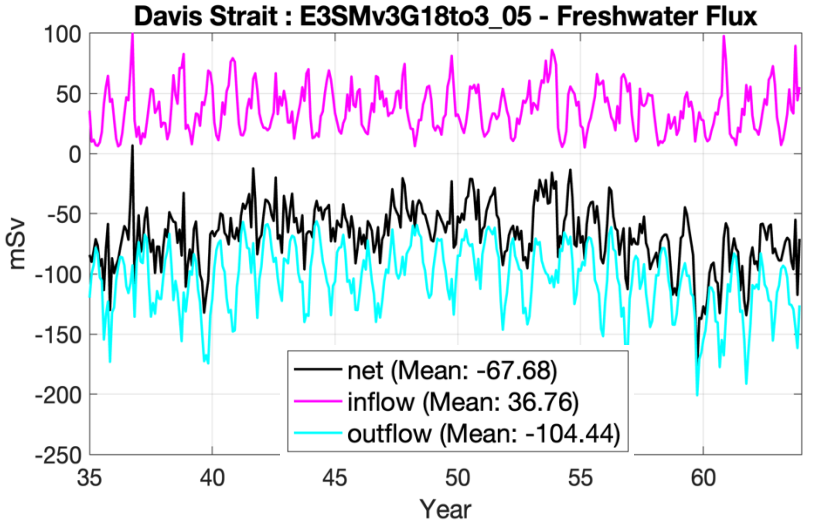




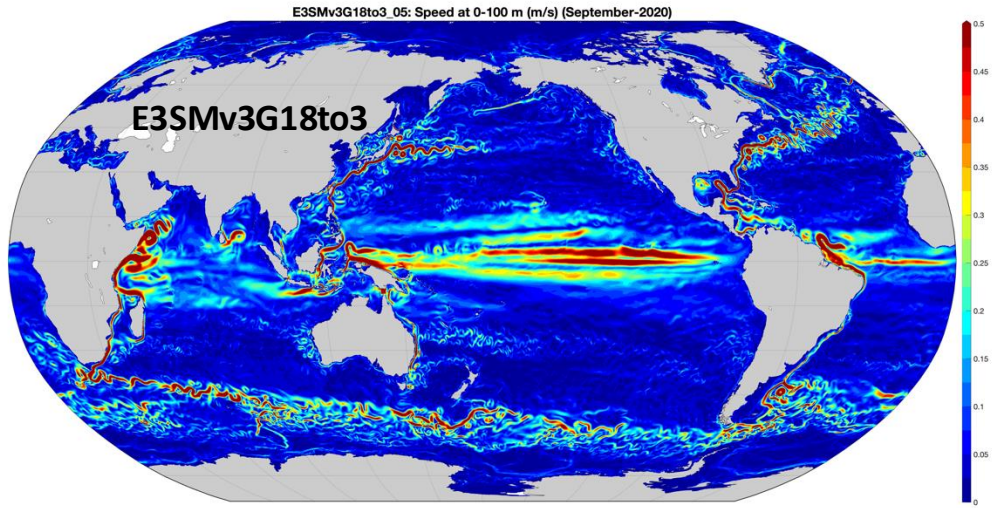


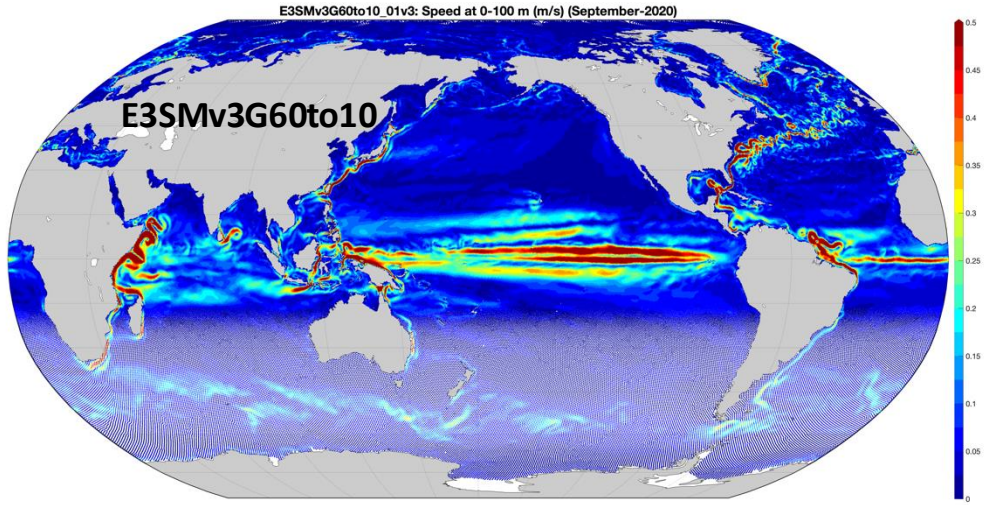


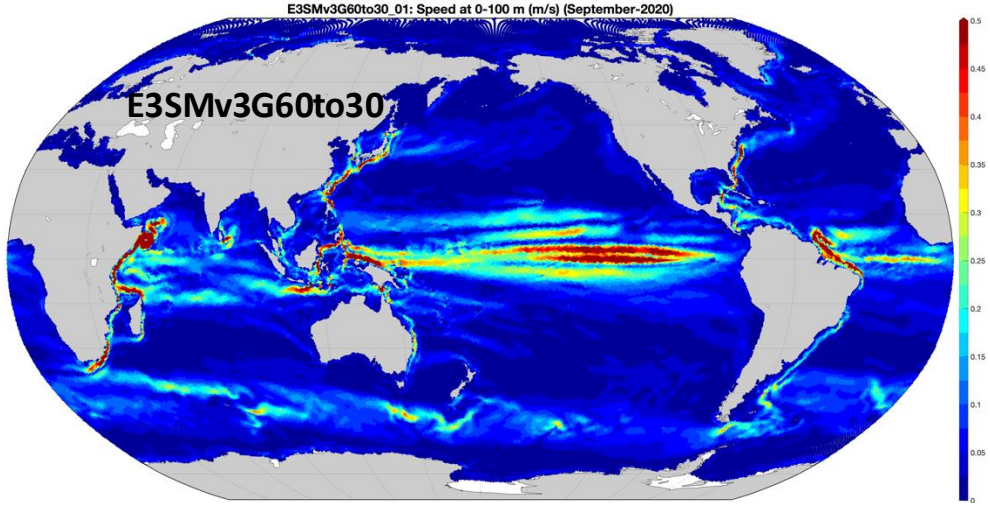




Intercomparison of the upper ocean global circulation

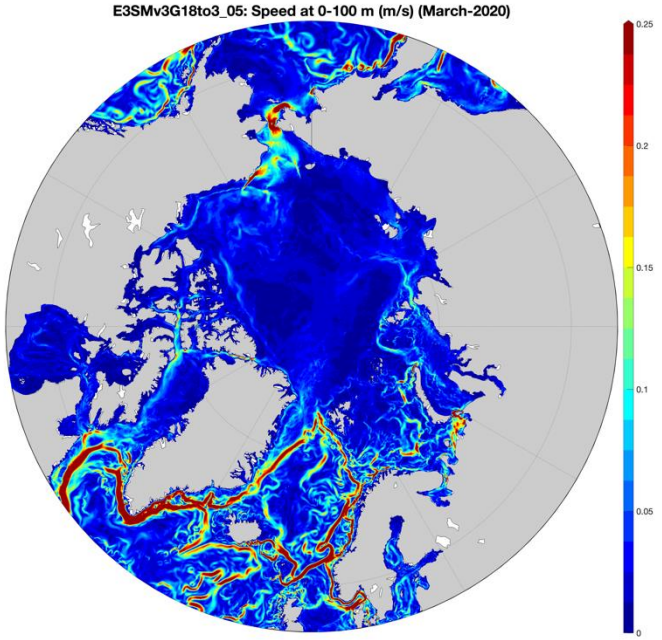




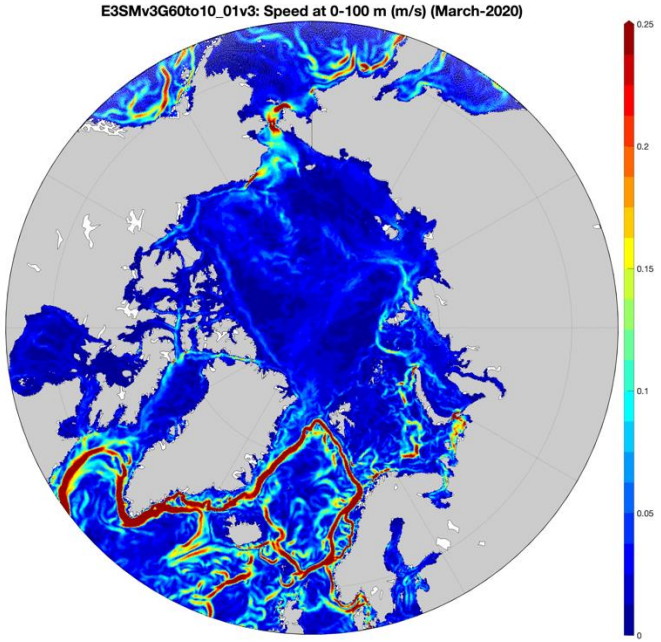


- **Monthly-mean 'snapshots' of speed at 0-100 m (m/s) for September 2020**

Intercomparison of the upper Arctic Ocean circulation



E3SMv3G18to3



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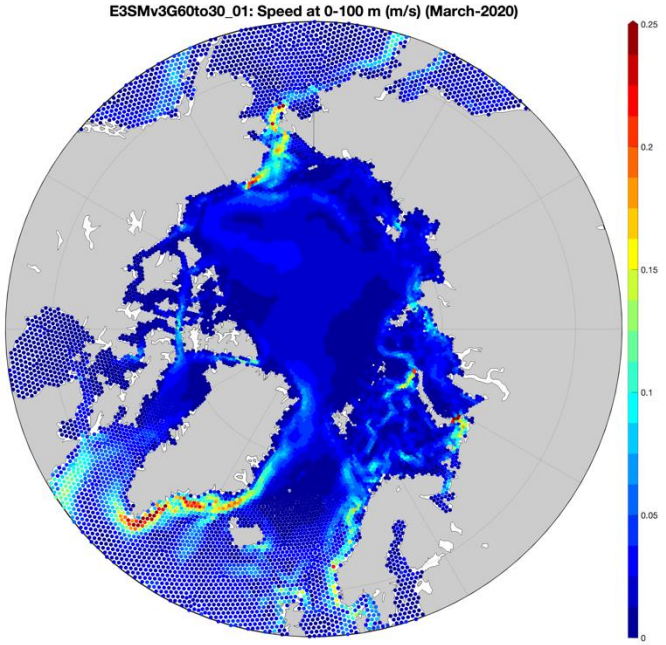
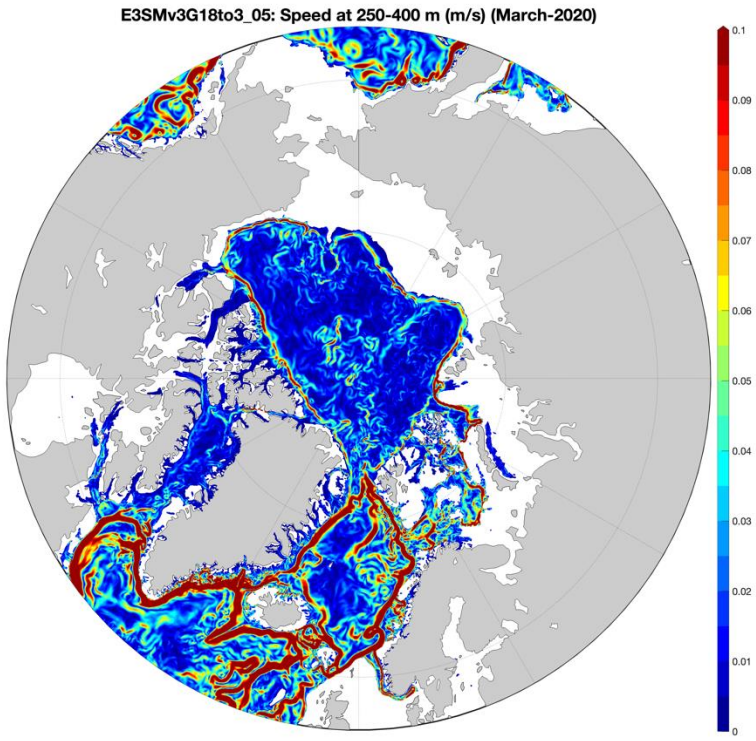


E3SMv3G60to30

➢ **Monthly-mean 'snapshots' of speed at 0-100 m (m/s) for March 2020**

Intercomparison of Atlantic water circulation in the Arctic



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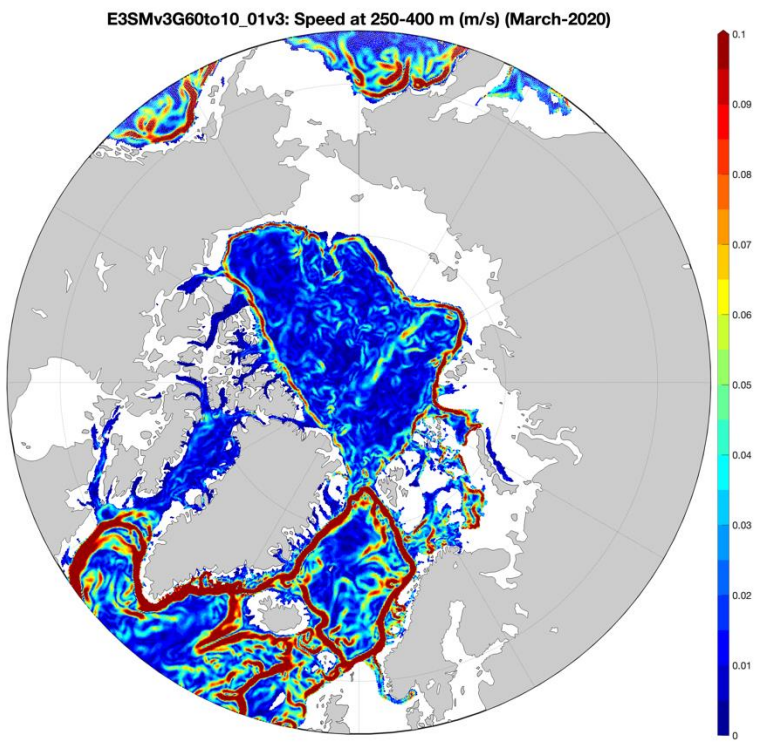

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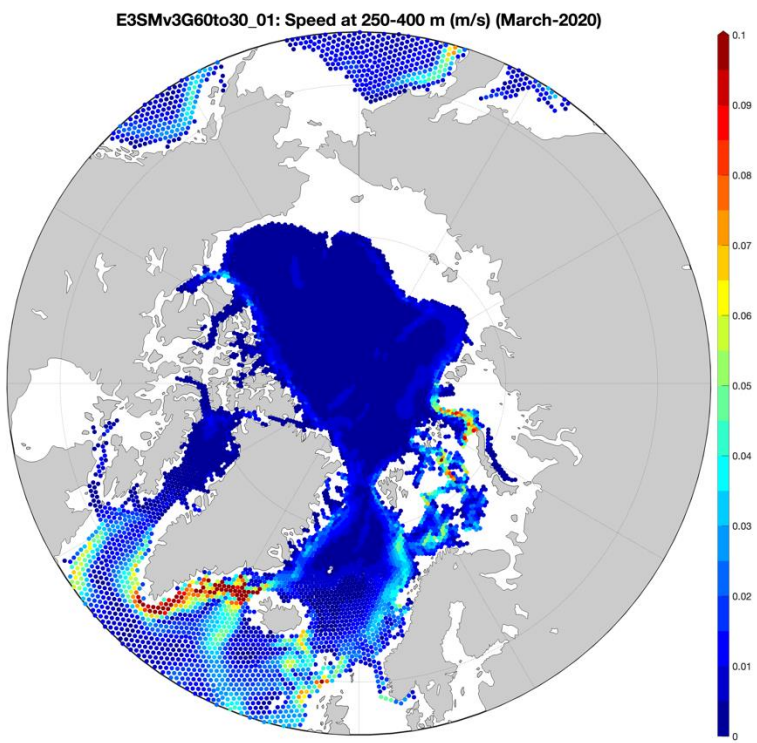
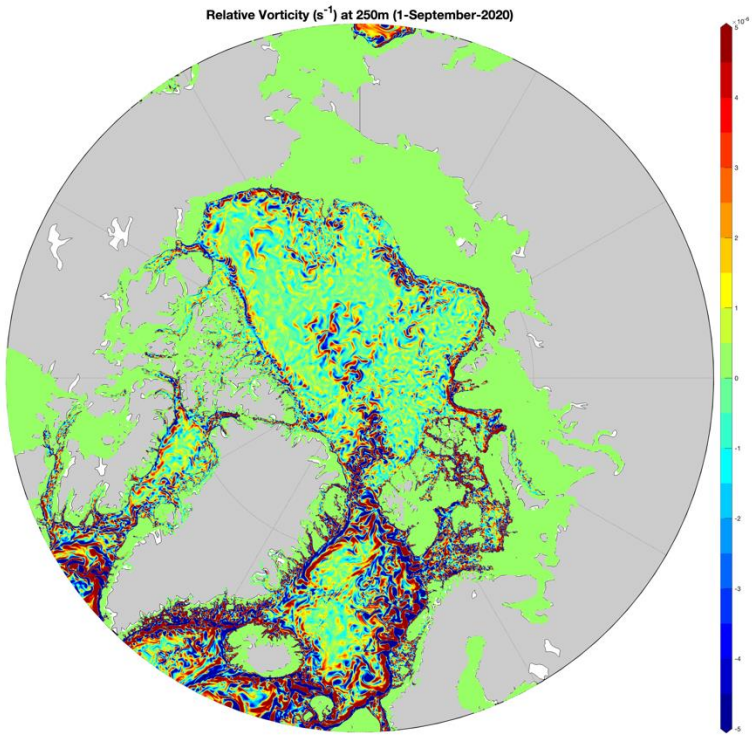


E3SMv3G60to30

- **Monthly-mean 'snapshots' of speed at 250-400 m (m/s) for March 2020**

Intercomparison of relative vorticity



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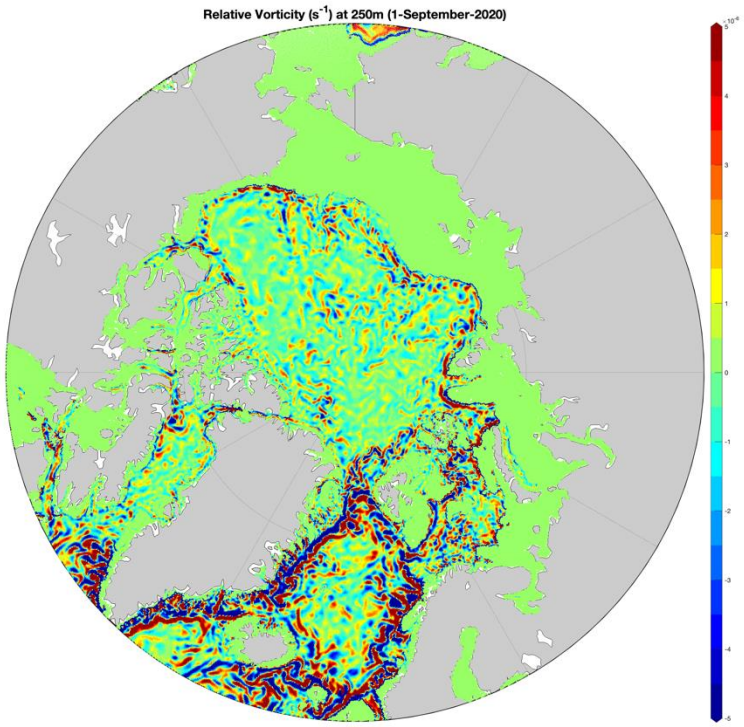

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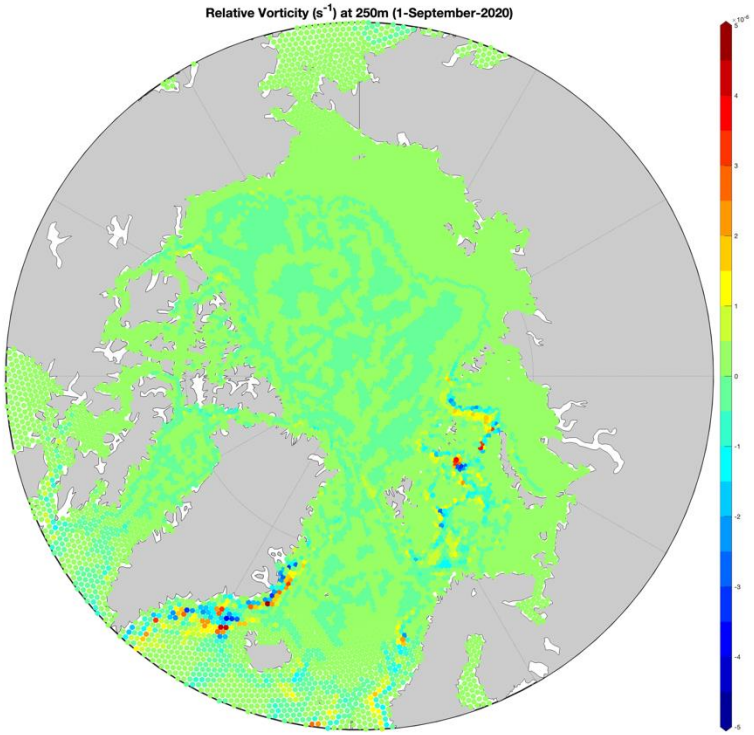
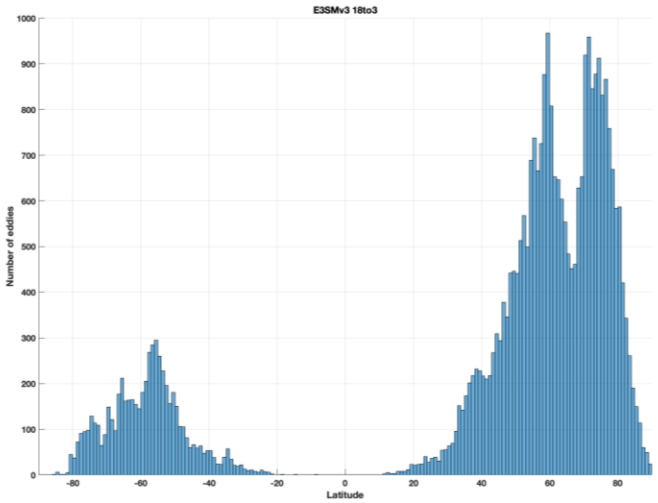


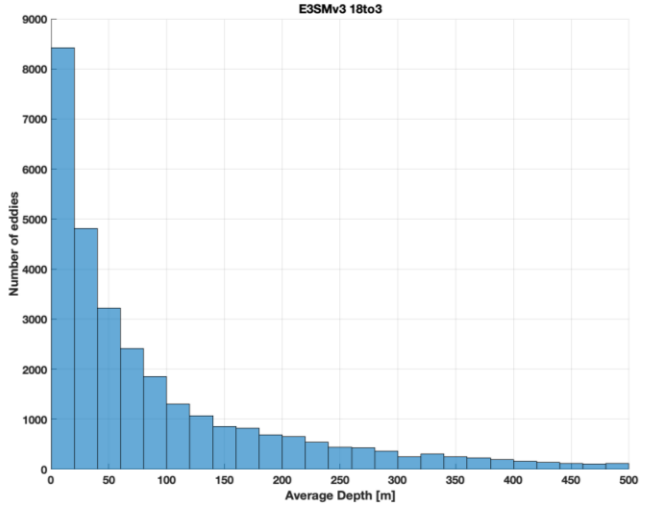
E3SMv3G60to30

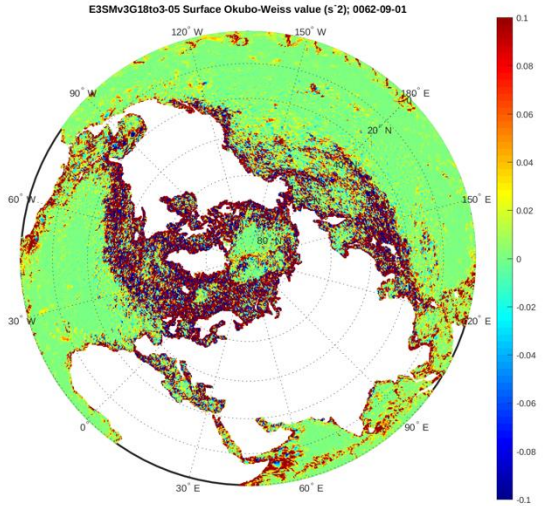
➢ **Monthly-mean 'snapshots' of relative vorticity at 250 m for September 2020**

Intercomparison of Okubo-Weiss parameters

E3SMv3G18to3







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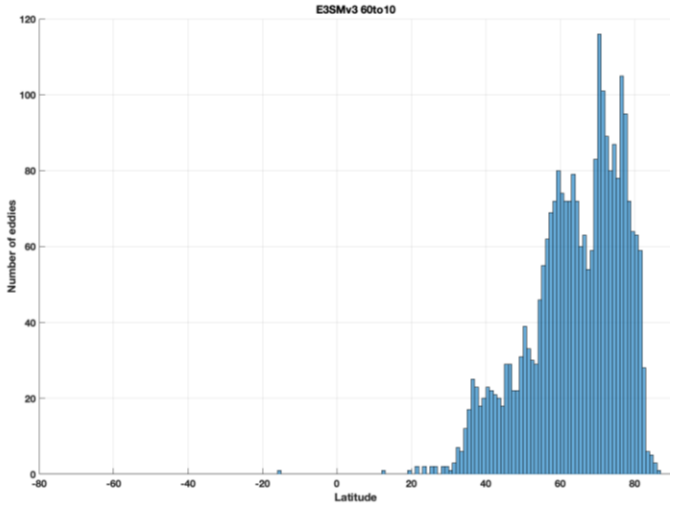
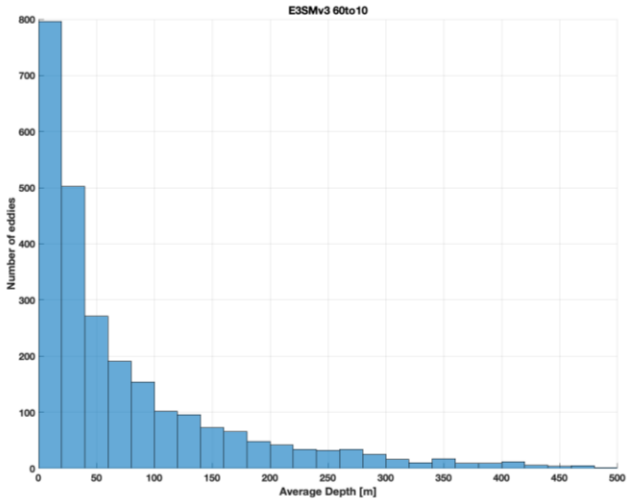
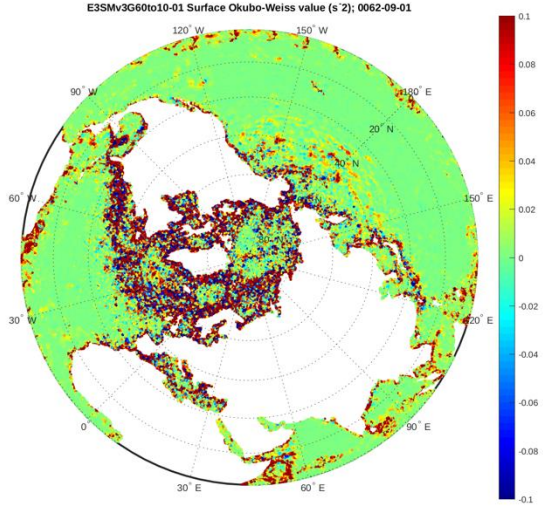
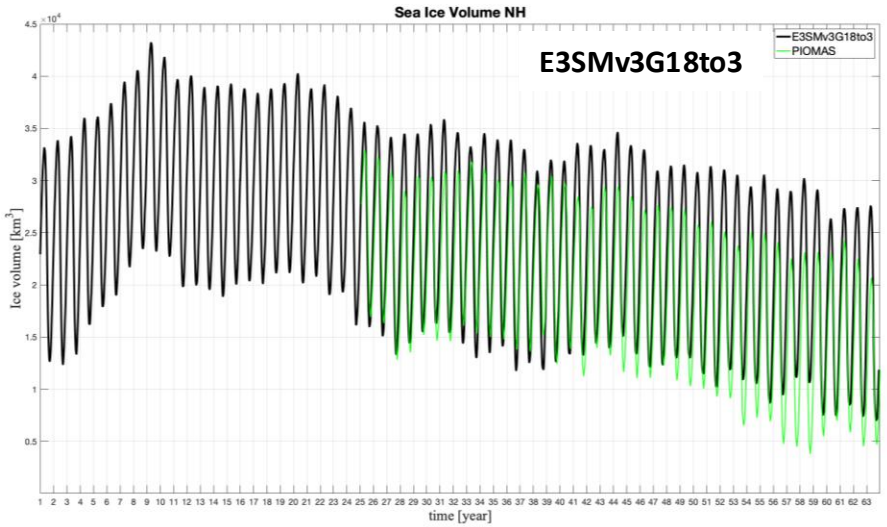


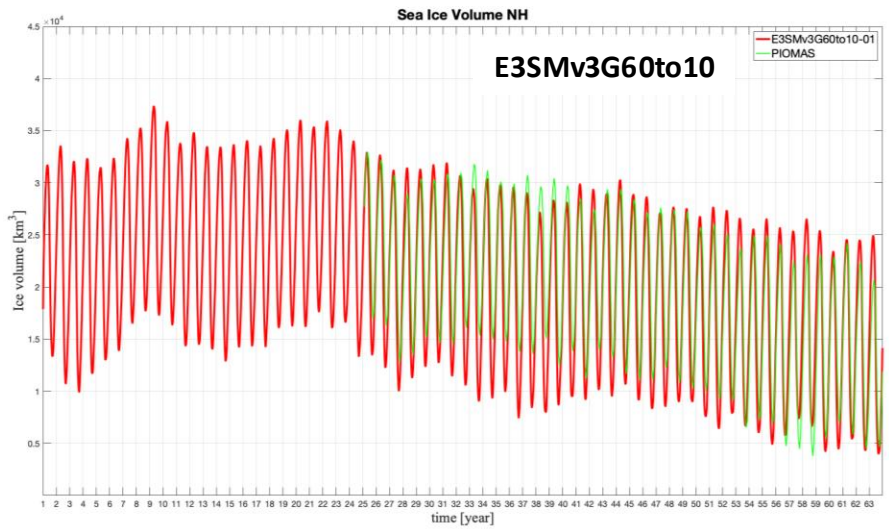


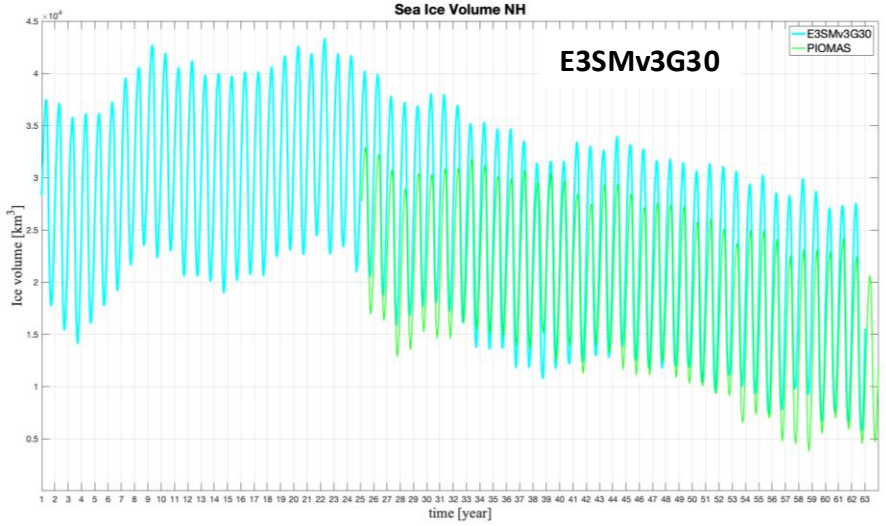


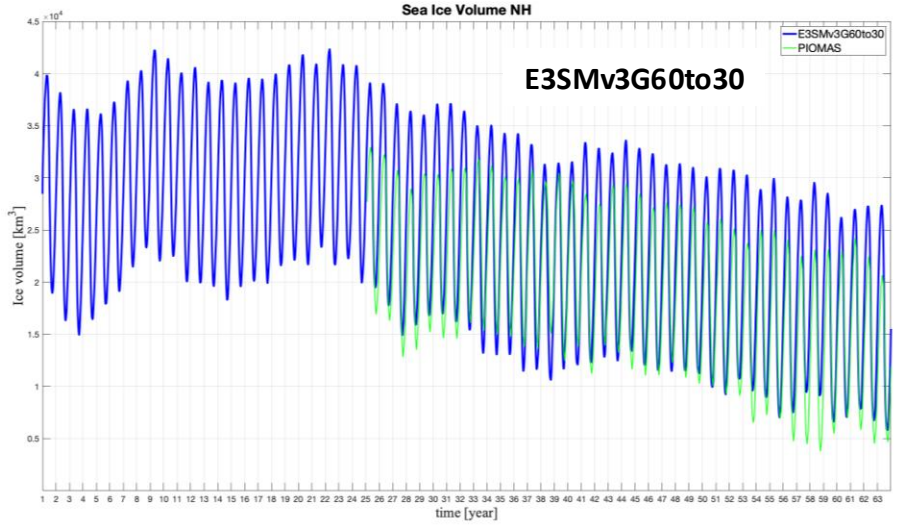
➢ **Daily 'snapshots' of Okubo-Weiss parameters for September 1 2019**

E3SM NH SIV comparison

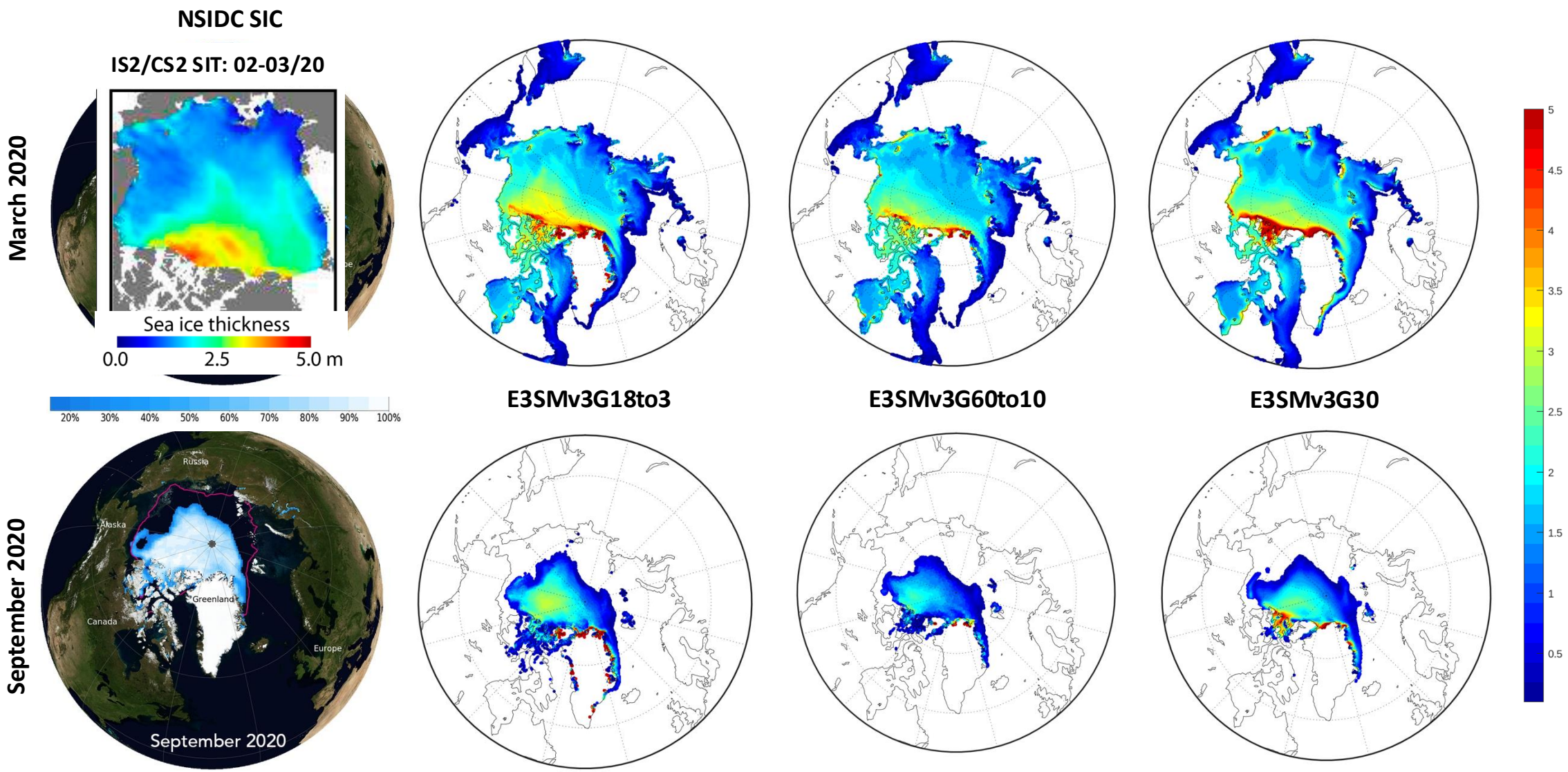






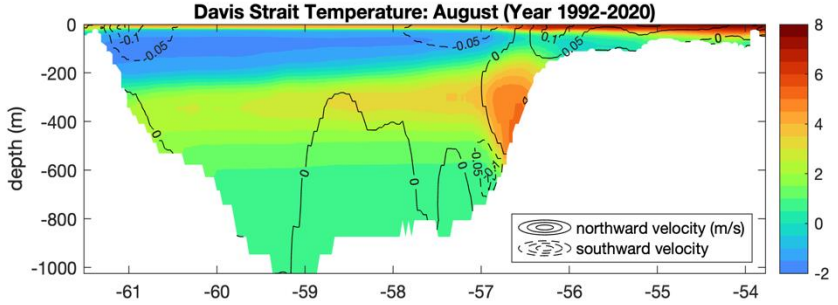


E3SM NH SIT comparison



E3SM gateway transport structure

E3SMv3G18to3_05



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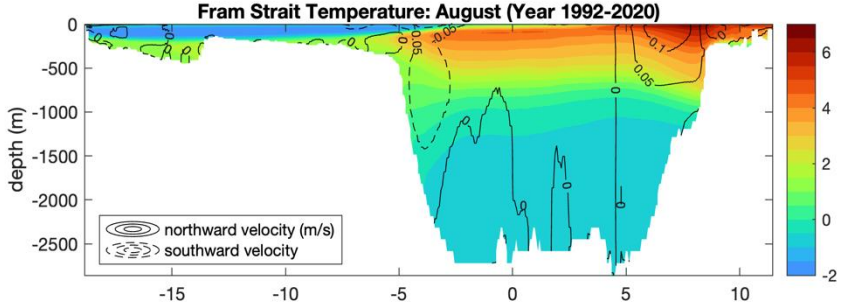

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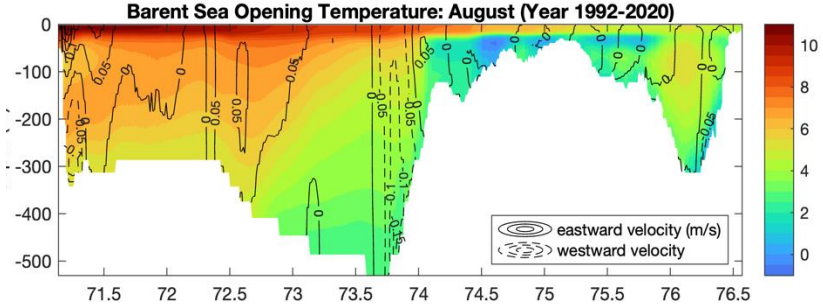

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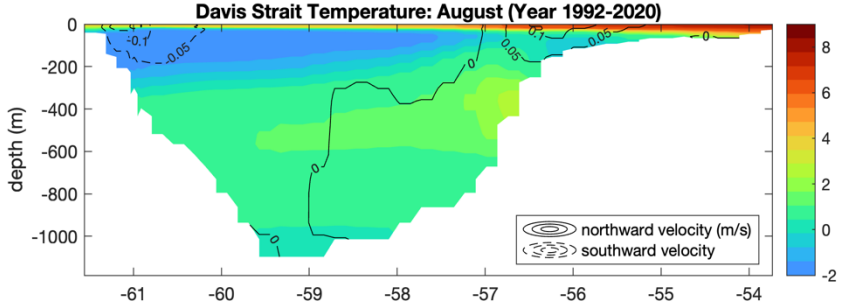

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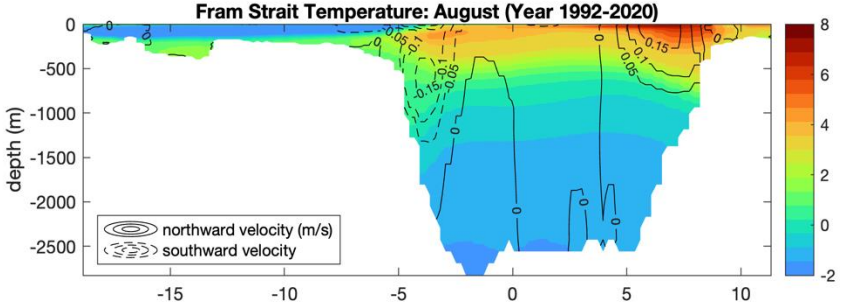

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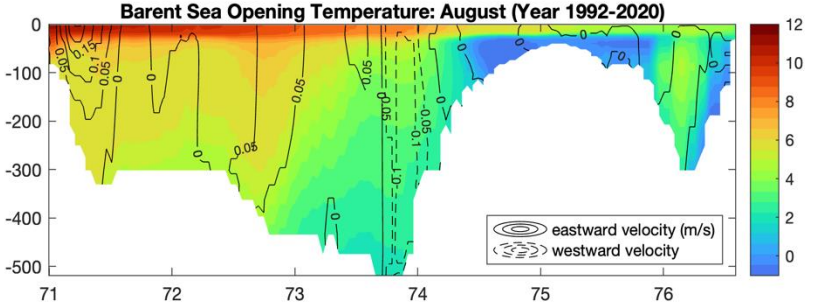

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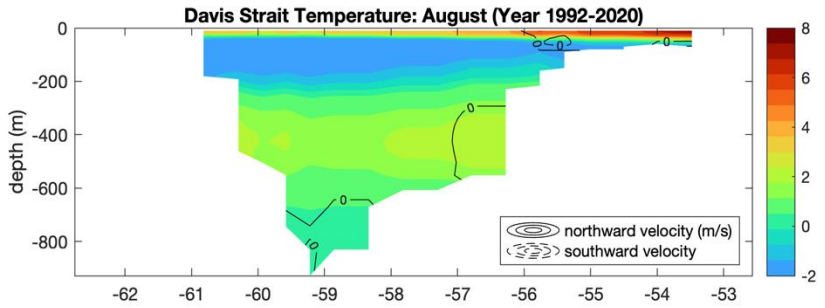

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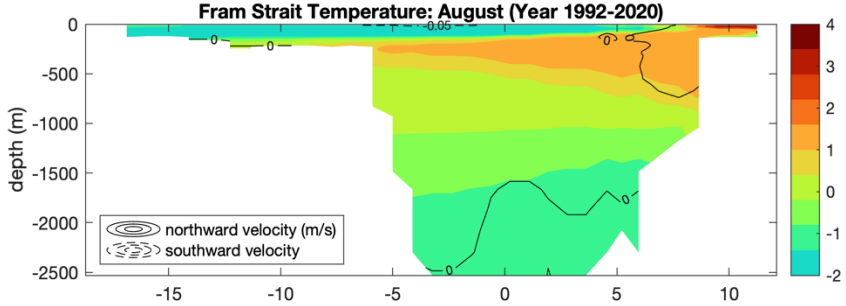
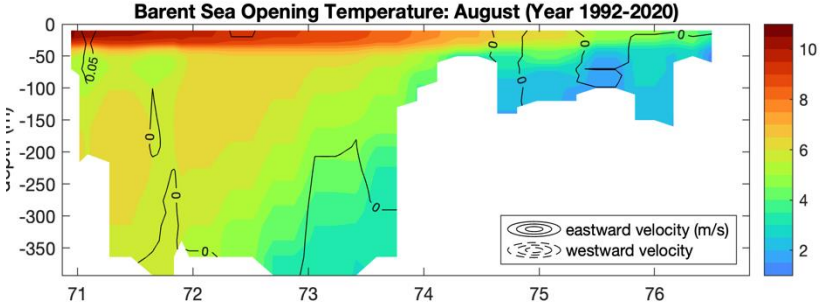


E3SMv3G60to30_01



E3SM Arctic gateways transports

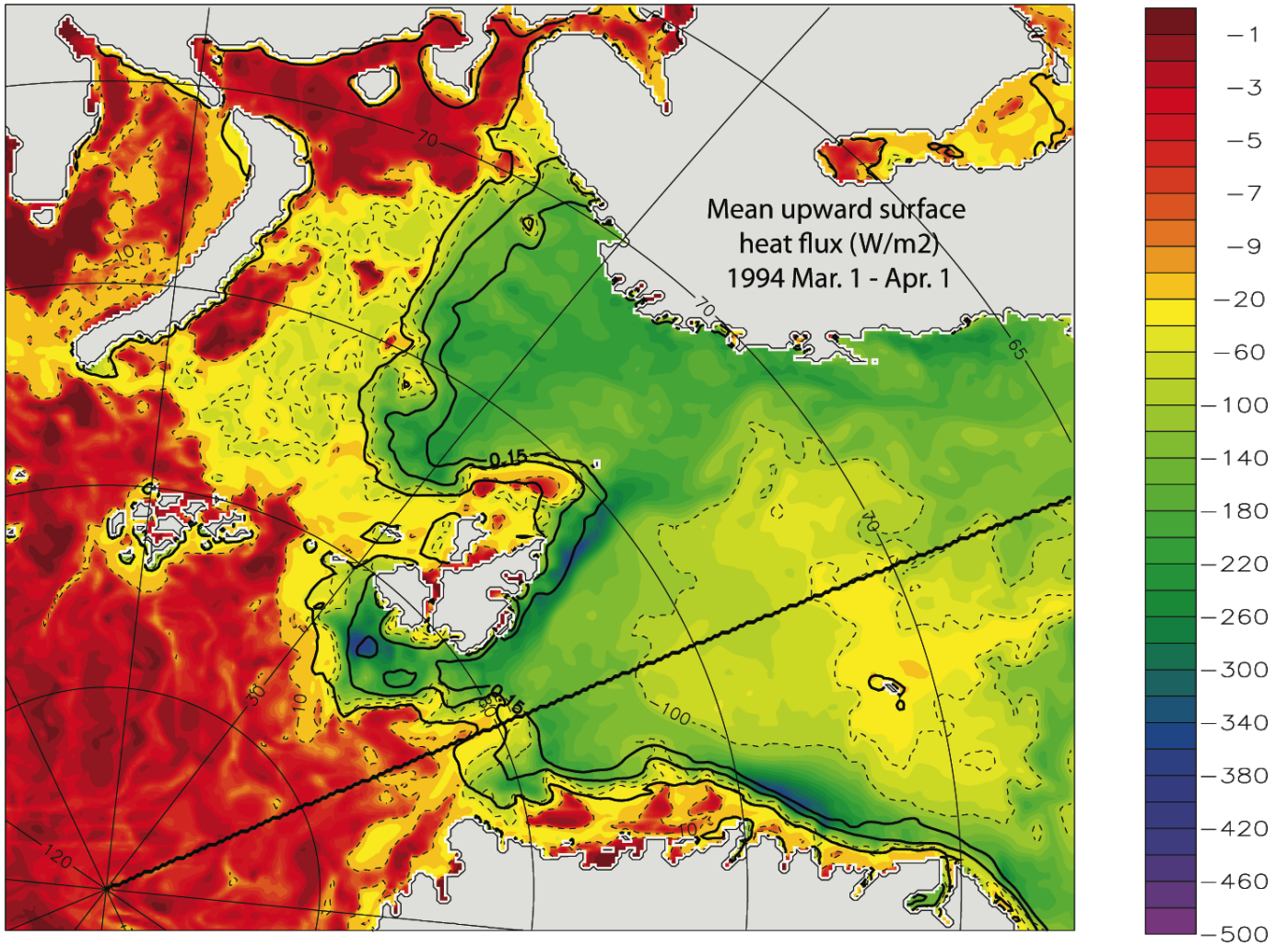
E3SMv3G60to30	Volume (Sv)	Heat (TW)	Freshwater (mSv)
Fram Strait	-3.161	-11.34	-72.77
Barents Sea Opening	3.067	89.87	5.38
Bering Strait	0.958	9.32	73.50
Davis Strait	-0.868	-1.25	-53.38
Net	-0.004	86.6	-55.27

E3SMv3G60to10	Volume (Sv)	Heat (TW)	Freshwater (mSv)
Fram Strait	-2.751	18.79	-82.07
Barents Sea Opening	2.54	94.91	6.62
Bering Strait	0.986	10.28	78.12
Davis Strait	-0.784	4.51	-42.33
Net	-0.009	128.49	-39.66

Gate	FS	BSO	DS	BS	Net (Sv/TW)
Obs	-2.0±2.7 +26÷+50	+2.0±0.8/+2.3±2.9 +70±5	-2.6±1.0/ -1.6±0.2 +20±9/+18±17	+0.8±0.2 10÷20	-1.8÷-0.5 124÷160

E3SMv3G18to3	Volume (Sv)	Heat (TW)	Freshwater (mSv)
Fram Strait	-2.509	18.12	-55.20
Barents Sea Opening	2.766	102.14	-11.18
Bering Strait	1.099	11.51	82.87
Davis Strait	-1.391	-0.21	-67.68
Net	-0.009	131.56	-54.19

Impact of model fidelity on coupling channels



Oceanic Heat Convergence:
(Tsubouchi et al., 2021)

- **Central Arctic OHC: 100-107TW**
- **Total net OHC: 173-180TW**
- **Note: 41-42% of the total AOHC net 'lost' over the Barents Sea.**

Note:

1. CESM1-HighRes

- **Central Arctic OHC: 69TW**
- **Total net OHC: 151TW**

2. RASM:

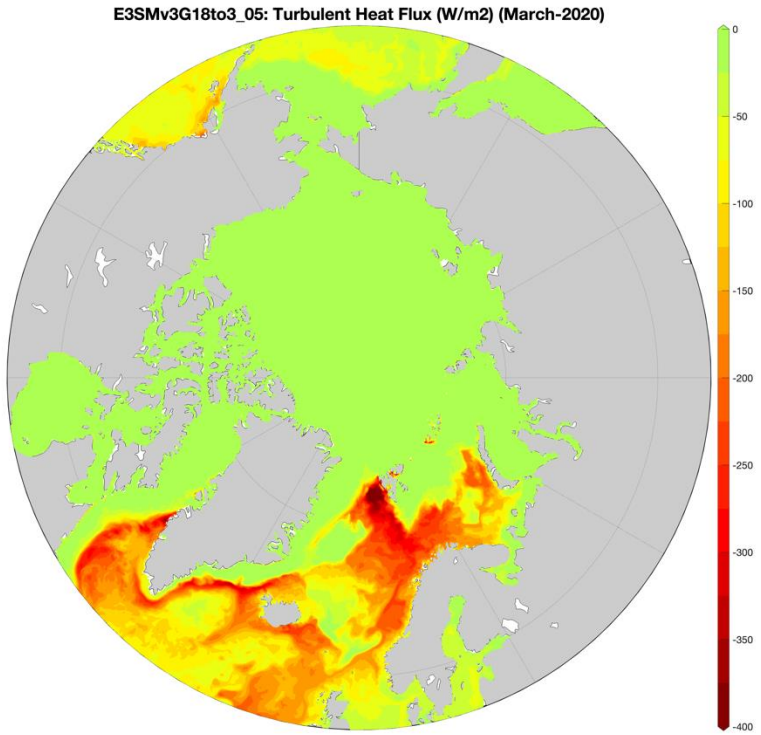
RBR9x-45 – Central Artic OHC: 35-40 TW

RBR9x-45 – Total net OHC: 145 TW

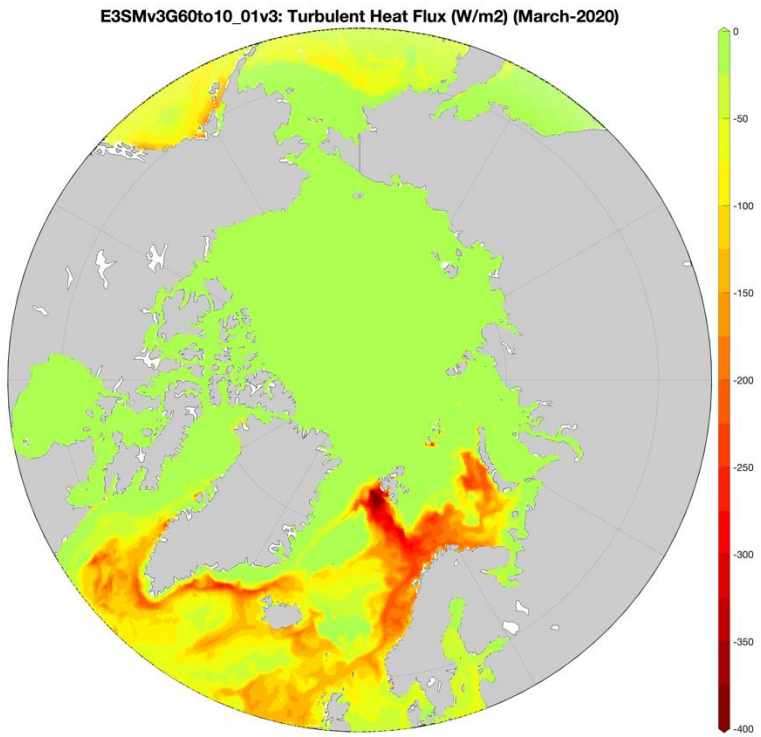
RASM simulated monthly-mean (March 1994) surface turbulent heat fluxes

➢ **Majority (>85%) of oceanic heat convergence lost over the Barents Sea**

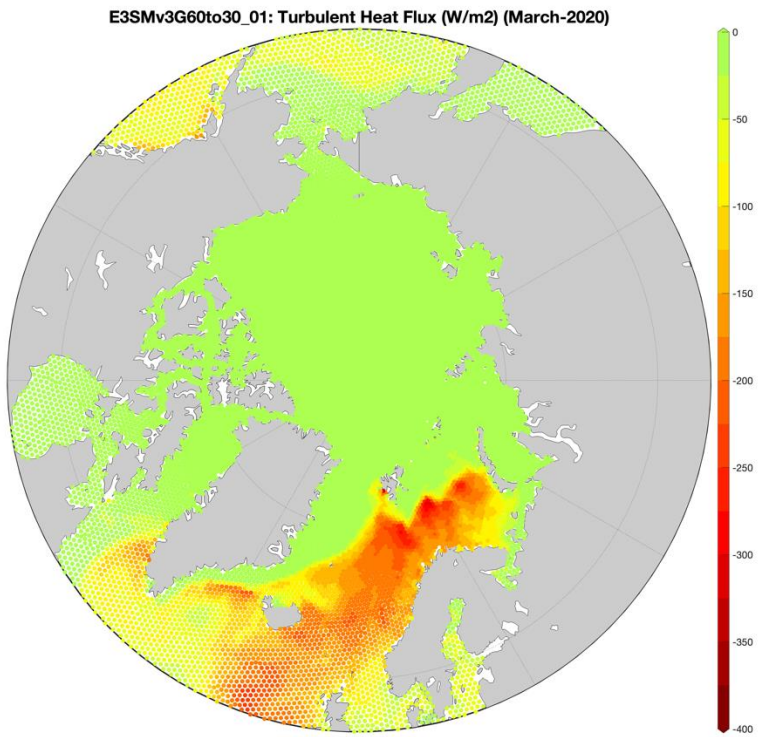
Intercomparison of surface turbulent heat fluxes



E3SMv3G18to3



E3SMv3G60to10



E3SMv3G60to30

➢ **Monthly-mean 'snapshots' of surface turbulent fluxes for March 2020**

Summary

1. AEROSI simulation results represent improvements relative to the comparable coarser resolution E3SM ocean/sea ice configurations;

2. They provide encouragement for:

- Continued integrations (1-2 JRA55-do cycles)
- Further model optimization of scale aware parameterizations
- Evaluation against observations
- Study of mesoscale processes
- **Coupling with high-resolution atmosphere / land E3SM configurations to advance DOE relevant science objectives**

Thank you!

Any questions?