Modeling the Oceanic Exchanges Over the Barents Sea

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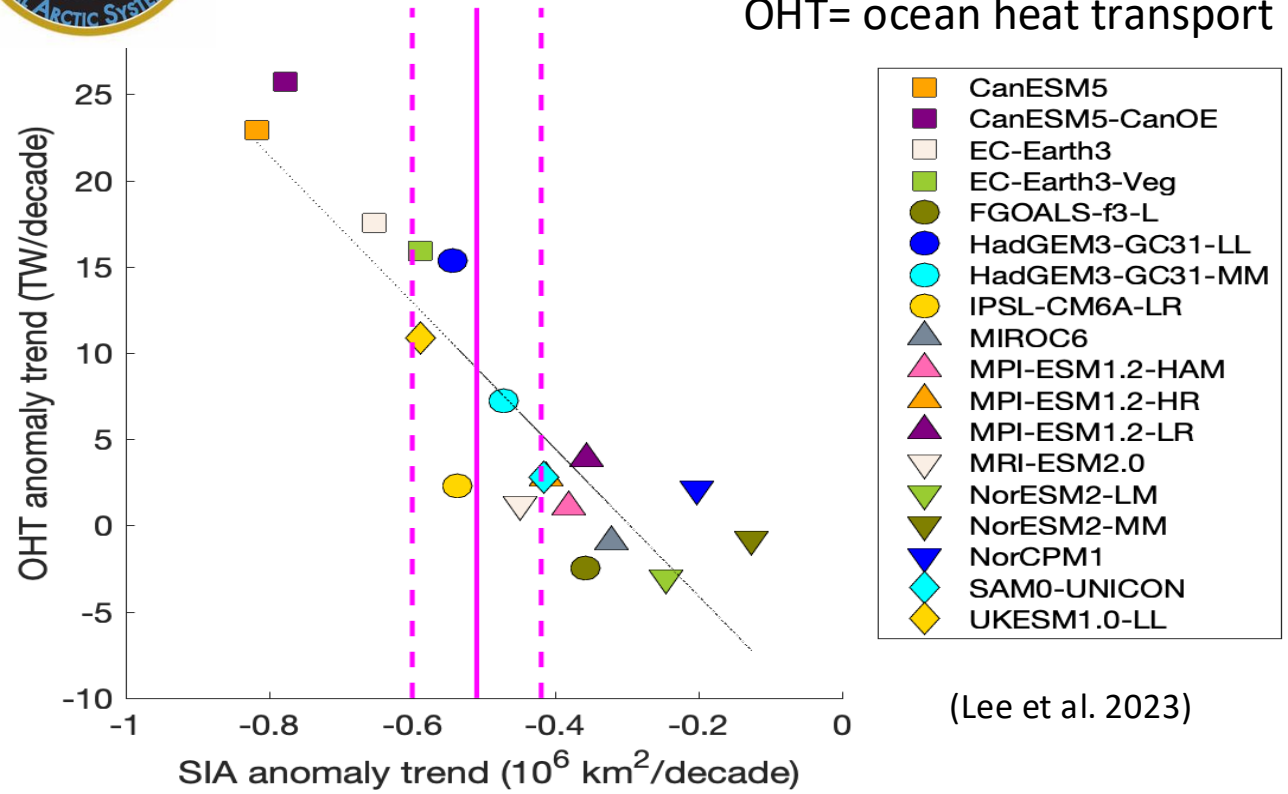
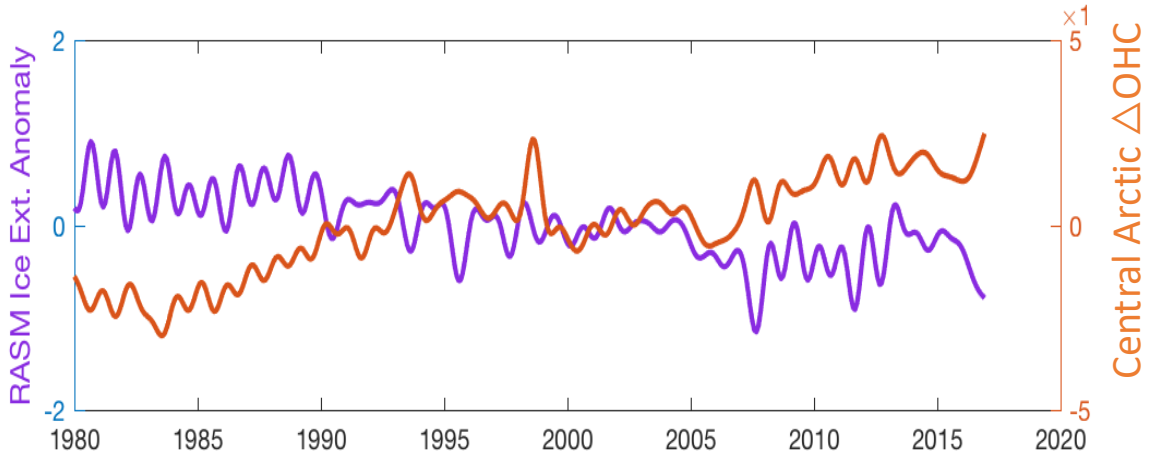
Motivation: An Emergent Constraint between SIA and OHT

SIA = sea ice area
OHT= ocean heat transport



(Lee et al. 2023)

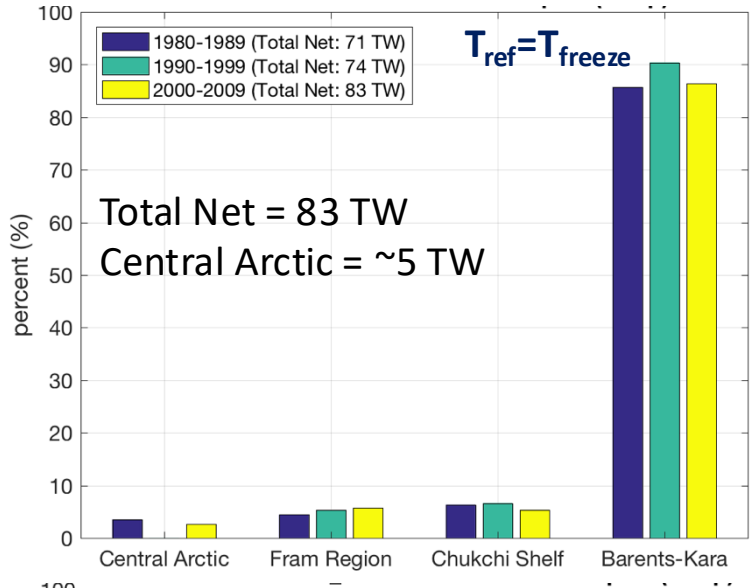


RASM simulates a high correlation (~0.7) between the upper ocean heat content (OHT) and sea ice extent (SIE)

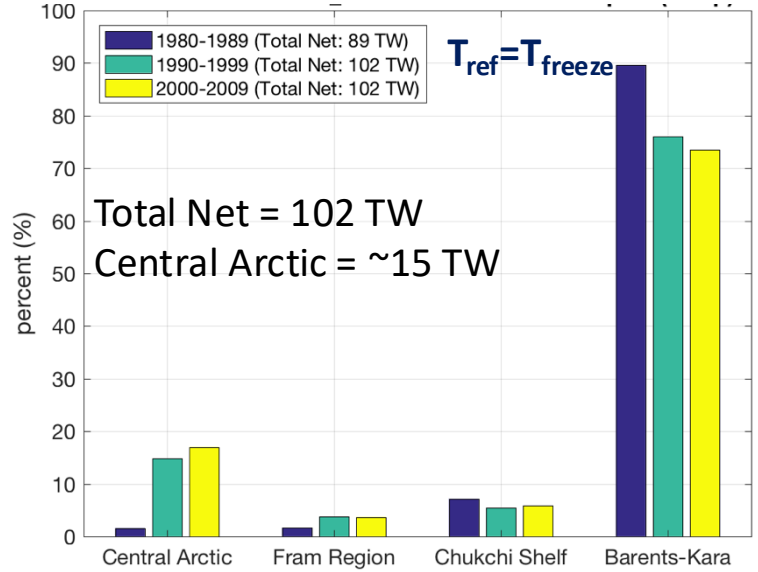
An **emergent constraint** in CMIP6 models, showing a strong linear relationship **between trends in sea ice area (SIA) and the Arctic Ocean heat content (OHT) anomalies**, which is likely to increase in prominence through the 21st century.

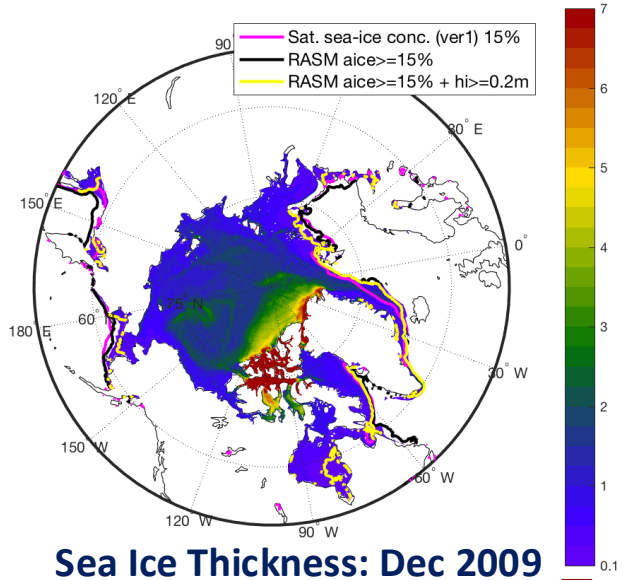
Motivation: RASM Arctic Ocean Heat Convergence

G9-45

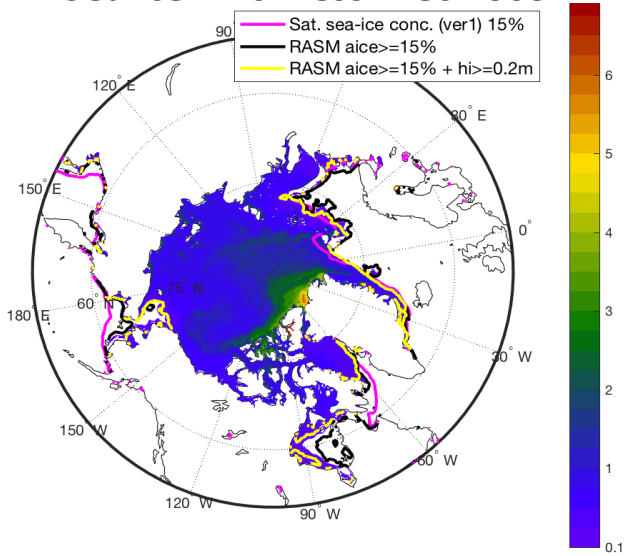


RBR9-45





Sea Ice Thickness: Dec 2009



Total Net Arctic OHC = Central Arctic + Barents/Kara Seas

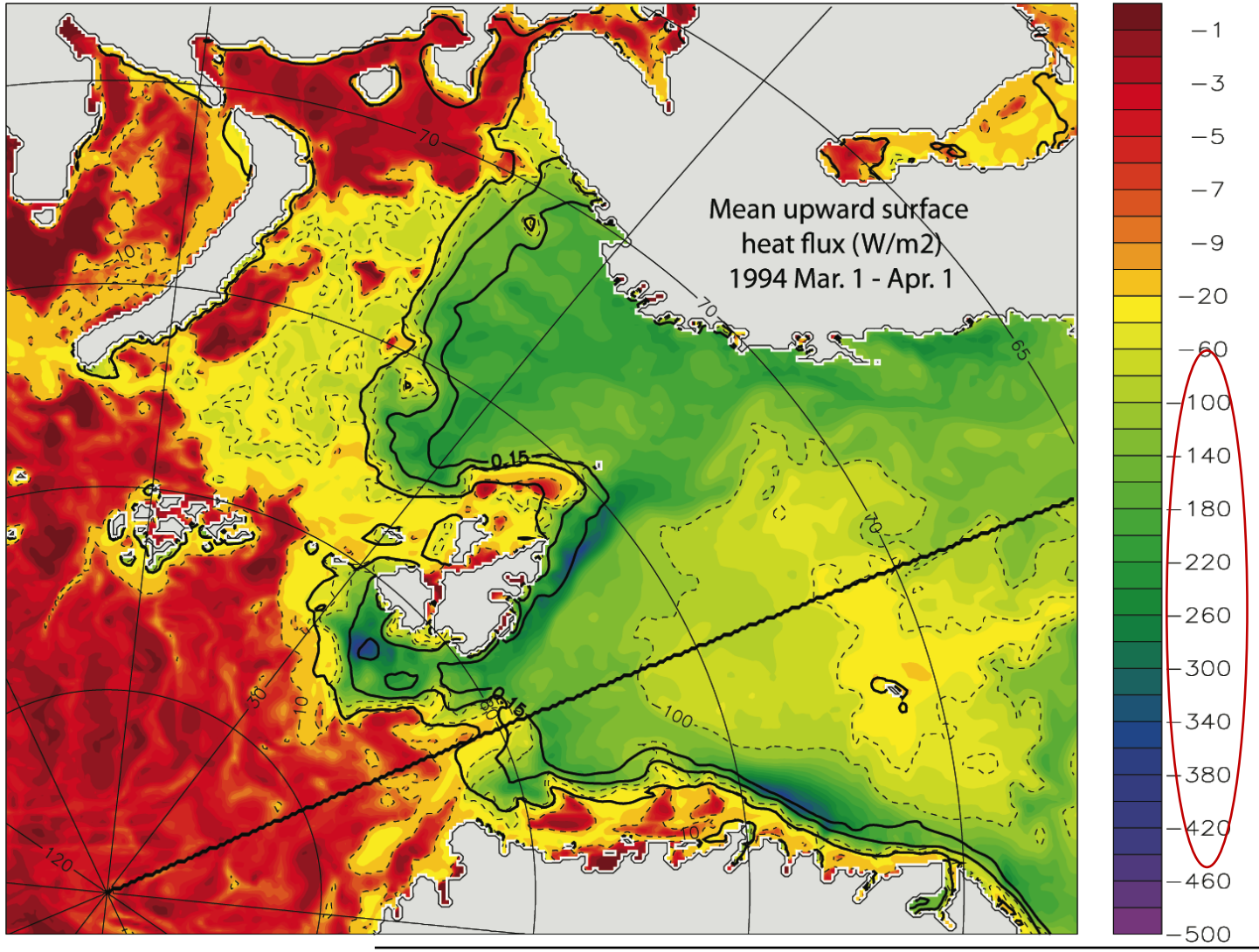
Baffin Bay OHC adds ~11TW

Note: Fraction of the total OHC net 'lost' over the Barents Sea:

- top: 95%
- bottom: 85%

Significantly thinner sea ice with an extra ~10 TW of the central Arctic OHC

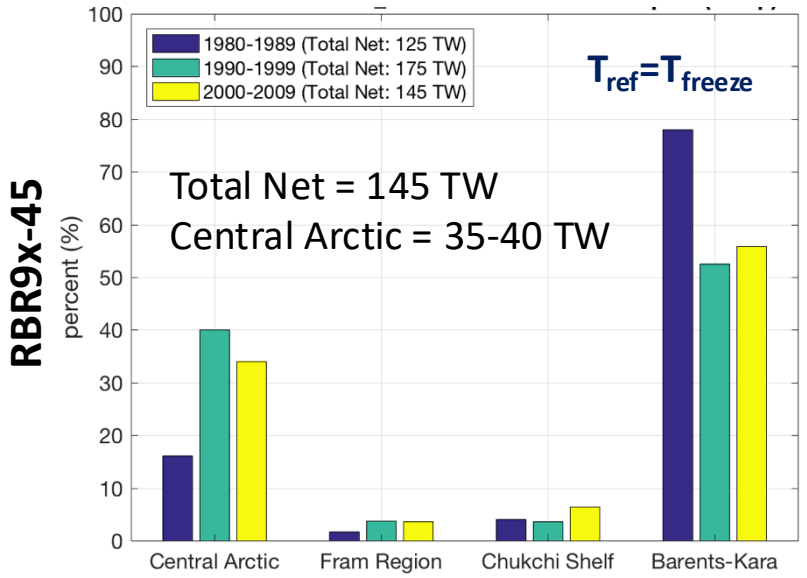
Motivation: Air-Sea Exchanges vs Northward Transport

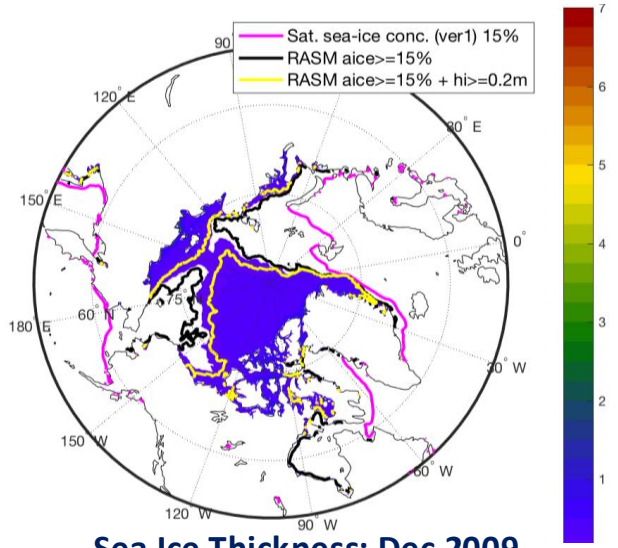


Large mean surface turbulent heat flux (negative = upward) associated with Atlantic water and ice edge dynamics:

- Determine residual oceanic heat convergence into the central Arctic
- Impact the atmospheric circulation
- … and likely Arctic-lower latitudes teleconnection
- not well represented in coarse resolution Earth System Models

Motivation: RASM Oceanic Heat Convergence (OHC)





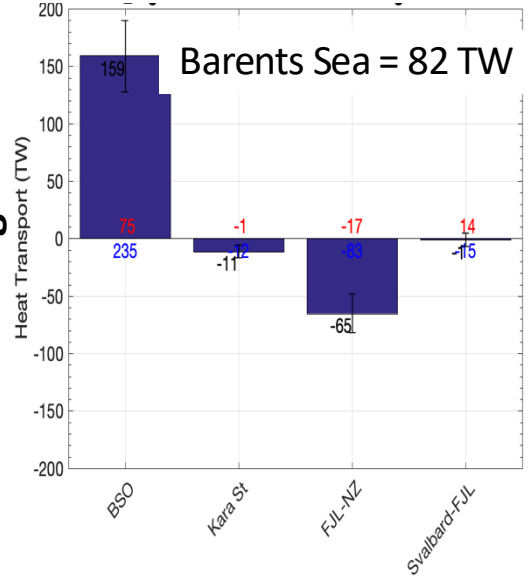
Sea Ice Thickness: Dec 2009

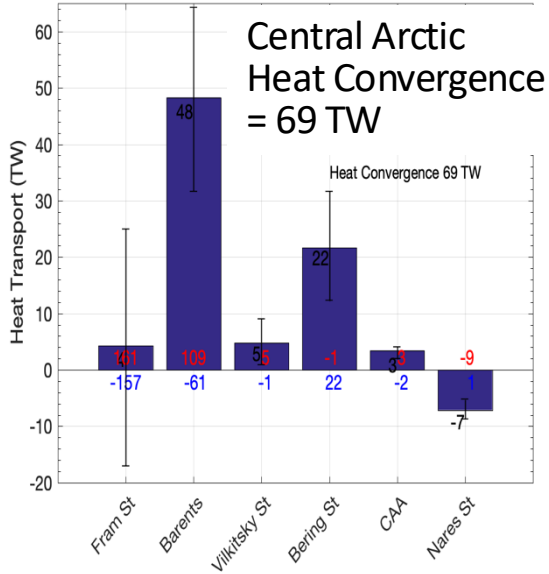
35-40TW (or 5-6 W/m^2) of heat flux into the central Arctic melts sea ice in summer in RASM RBR9x-45

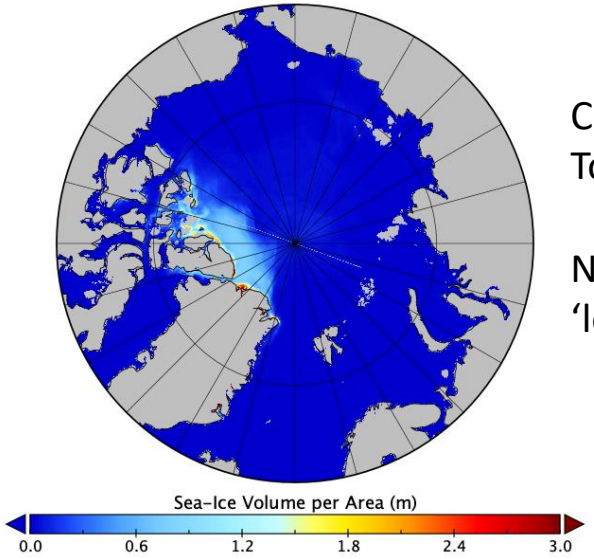
- Central Arctic OHC = 35-40 TW
- Total OHC Net = 145 TW

Note: 72-76% of the total AOHC net 'lost' over the Barents Sea.

CESM1-HighRes



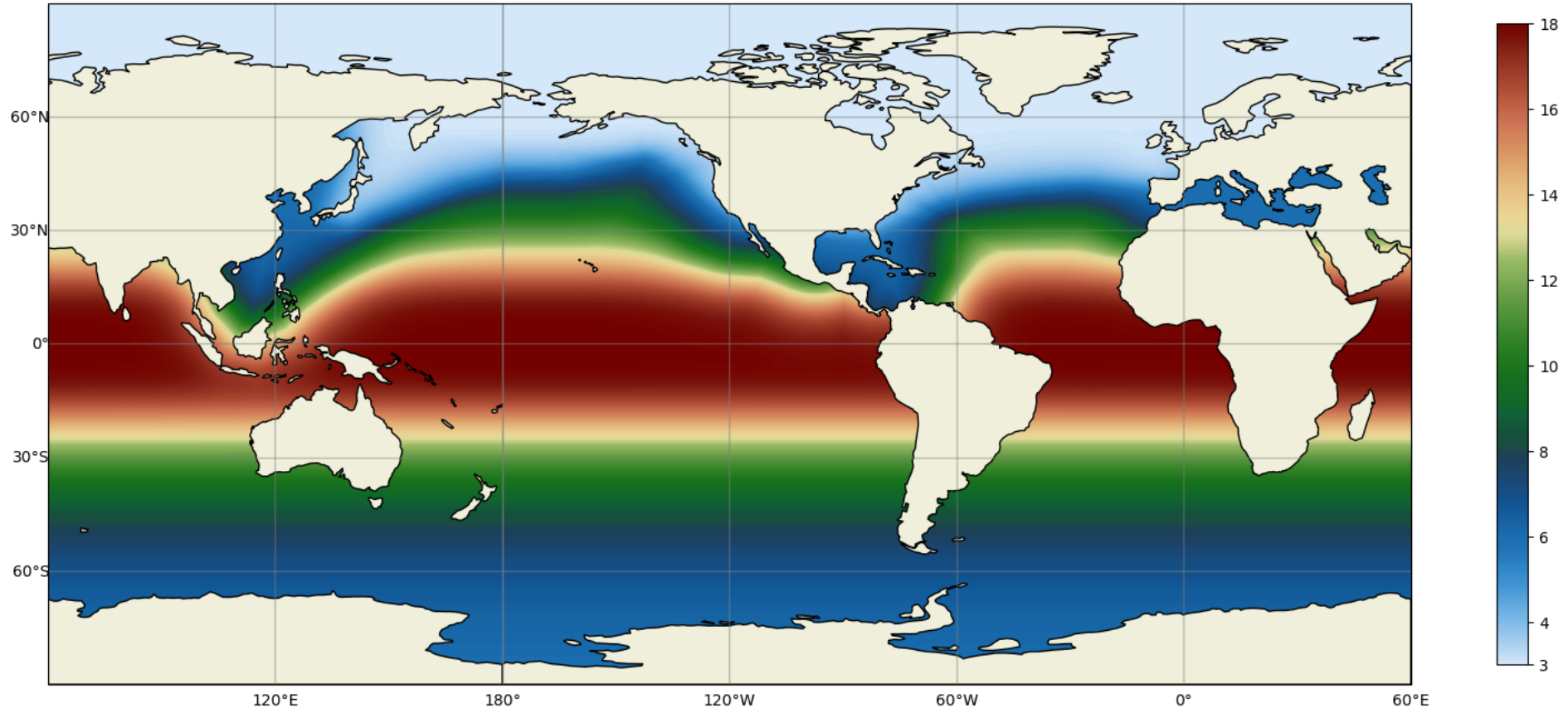




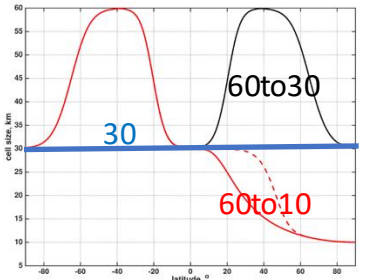
Central Arctic OHC = 69 TW
Total AOHC Net = 82 + 69 = 151 TW

Note: Only 54% of the total net OHC 'lost' over the Barents Sea.

E3SM-AEROSI Overview



- Northern Hemisphere grid: 3 km in the northern high latitudes to 18 km in the subtropics.
- Southern Hemisphere grid: 6to18km
- 1958-2020 ice-ocean simulation (E3SMv3G18to6) forced with JRA55-do
- Compare to JRA55-do forced E3SMv3G simulations: 60to10, 60to30, and 30



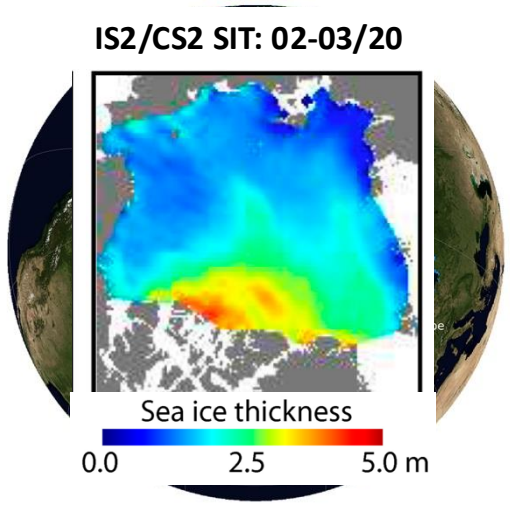
E3SM-AEROSI NH SIT comparison – MOSAiC winter-summer 2020

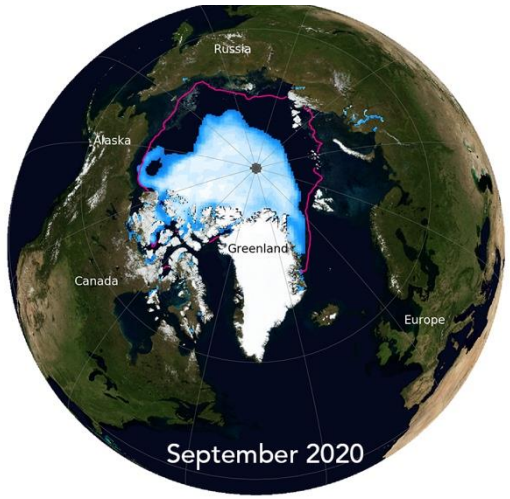
March 2020

September 2020

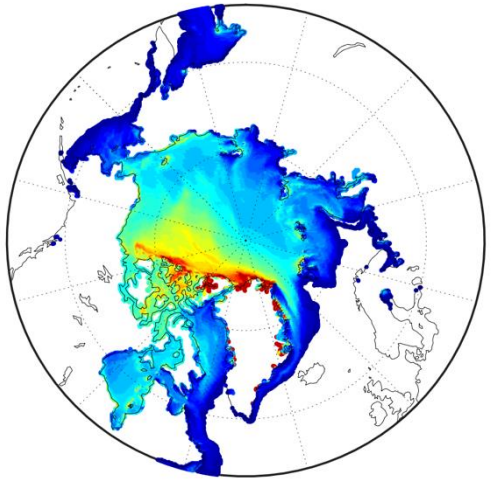
NSIDC SIC

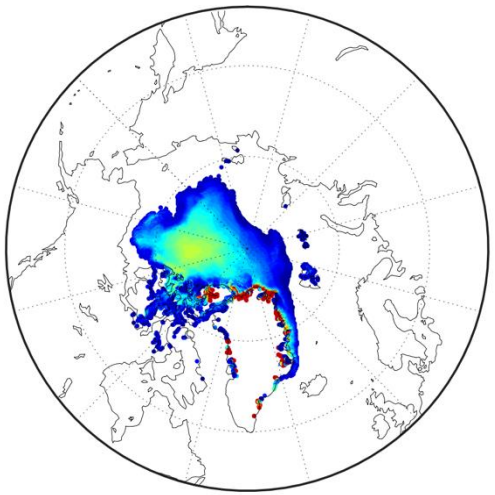
IS2/CS2 SIT: 02-03/20



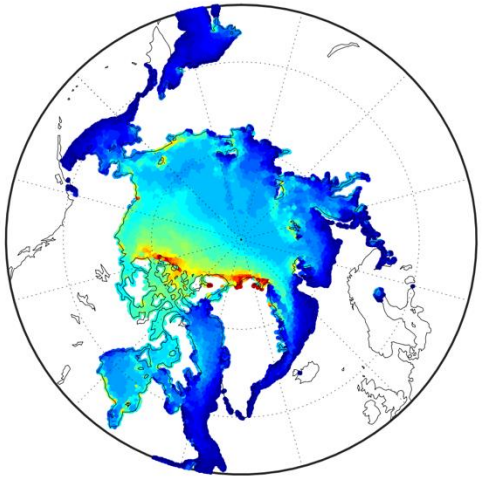


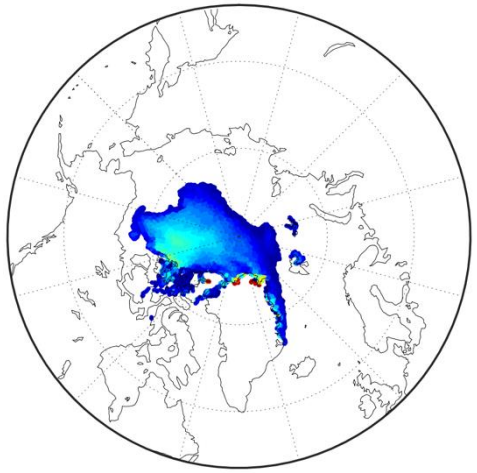
AEROSI



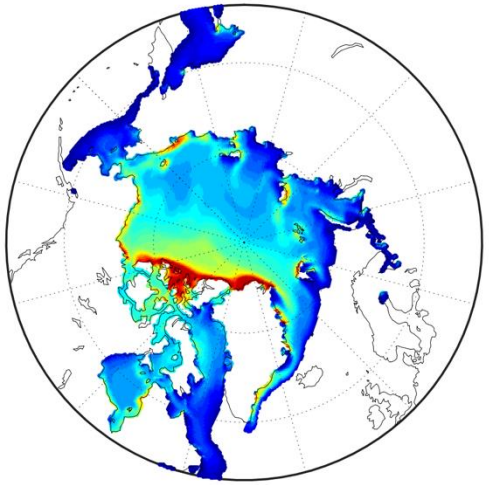


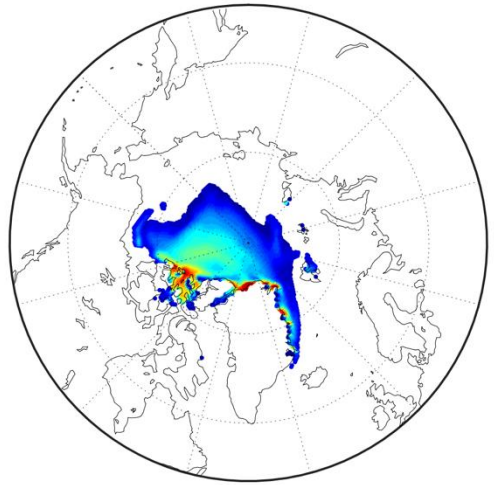
E3SMv3G60to10





E3SMv3G30





E3SM-AEROSI Arctic Ocean Heat Convergence

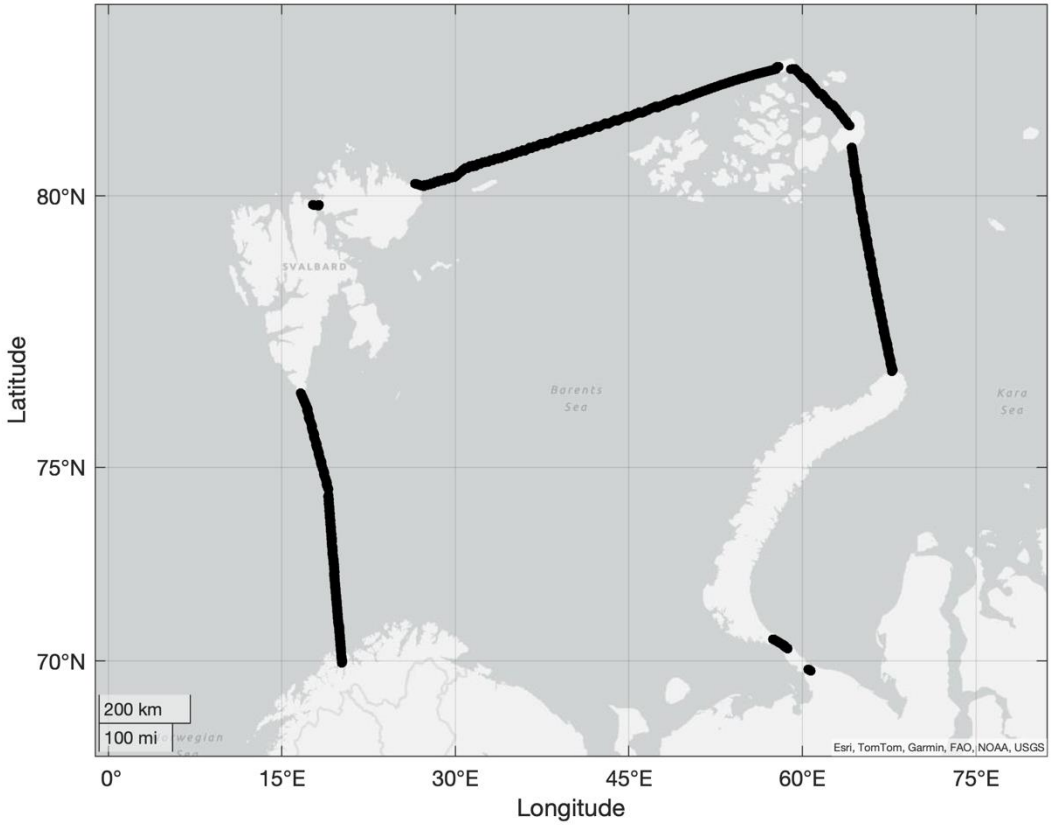
E3SMv3G60to30	Volume (Sv)	Heat (TW)
Fram Strait	-3.161	-11.34
Barents Sea Opening	3.067	89.87
Bering Strait	0.958	9.32
Davis Strait	-0.868	-1.25
Net	-0.004	86.6

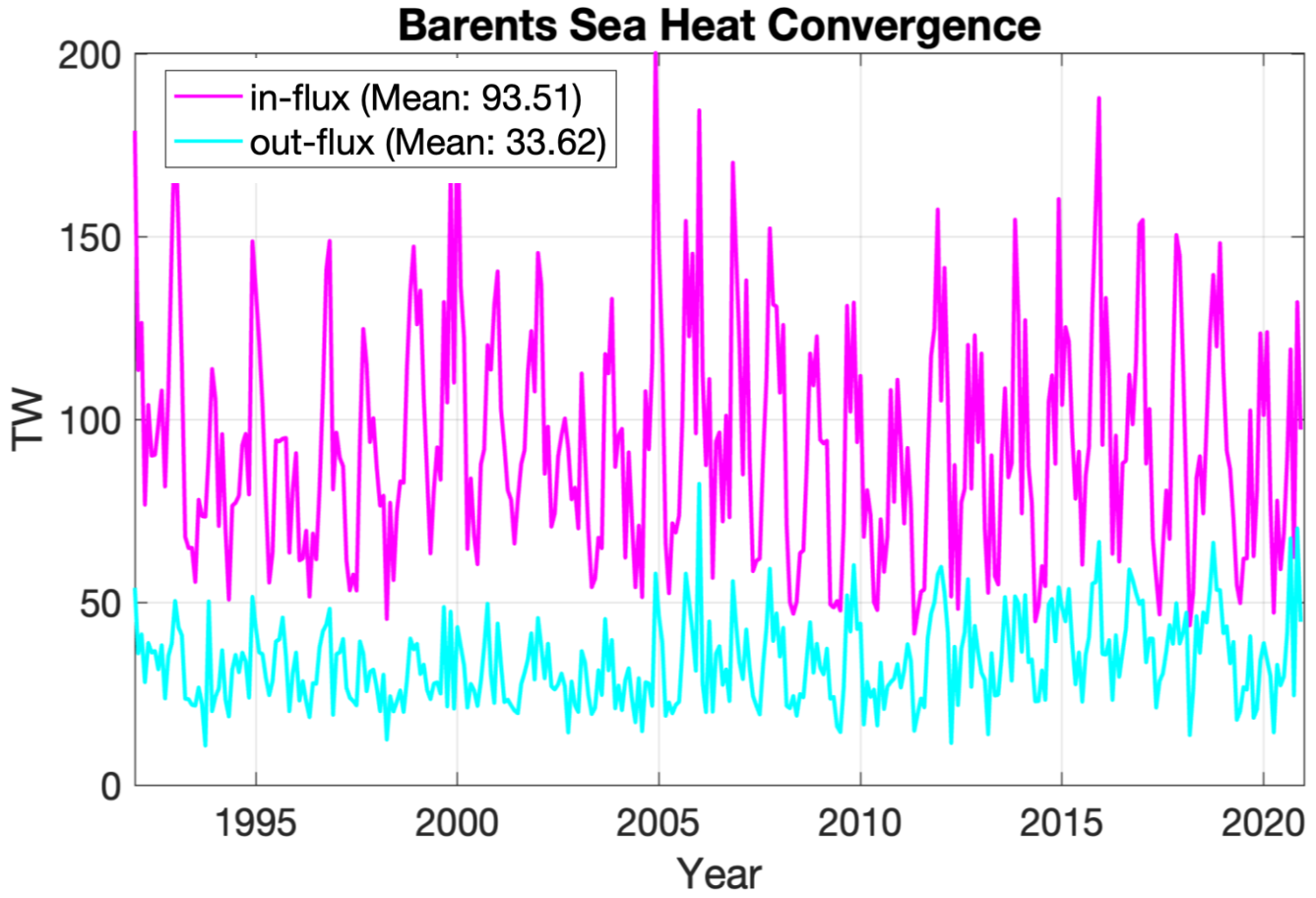
E3SMv3G60to10	Volume (Sv)	Heat (TW)
Fram Strait	-2.751	18.79
Barents Sea Opening	2.54	94.91
Bering Strait	0.986	10.28
Davis Strait	-0.784	4.51
Net	-0.009	128.49

AEROSI (<3km)	Volume (Sv)	Heat (TW)
Fram Strait	-2.509	18.12
Barents Sea Opening	2.766	102.14
Bering Strait	1.099	11.51
Davis Strait	-1.391	-0.21
Net	-0.009	131.56

Observations	Volume (Sv)	Heat (TW)
Fram Strait	-2.0±2.7	+26÷+50
Barents Sea Opening	+2.0±0.8 / +2.5±2.9	+70±5
Bering Strait	+0.8±0.2	+10÷+20
Davis Strait	-2.6/-1.6/-0.8	+20±9 / +18±17
Net	-1.8÷+0.5	124÷160

E3SM-AEROSI Barents Sea Heat Convergence

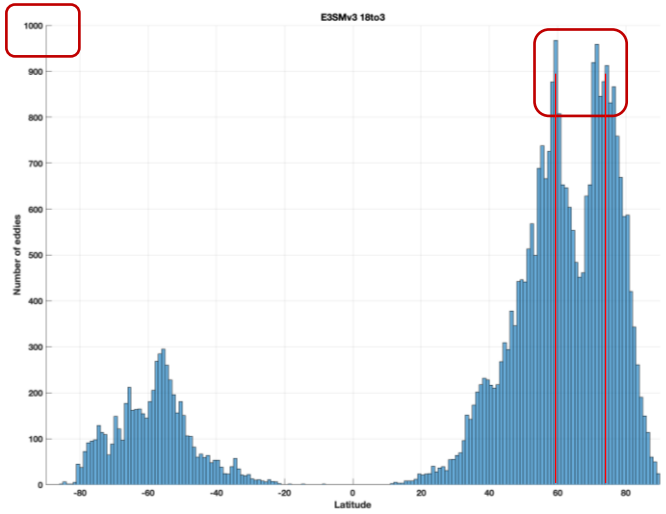


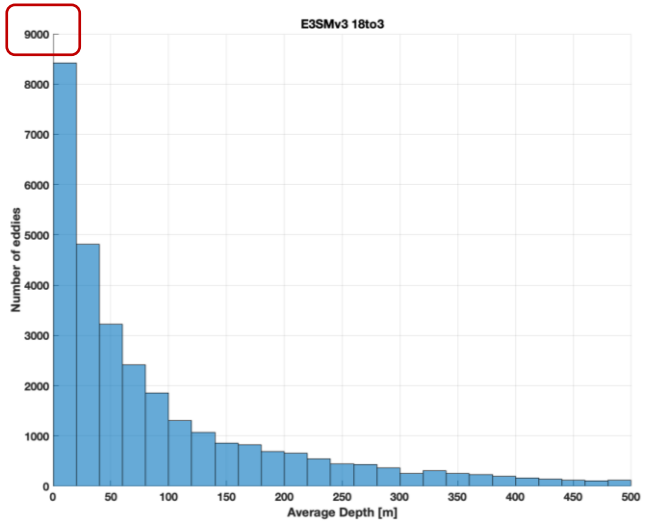


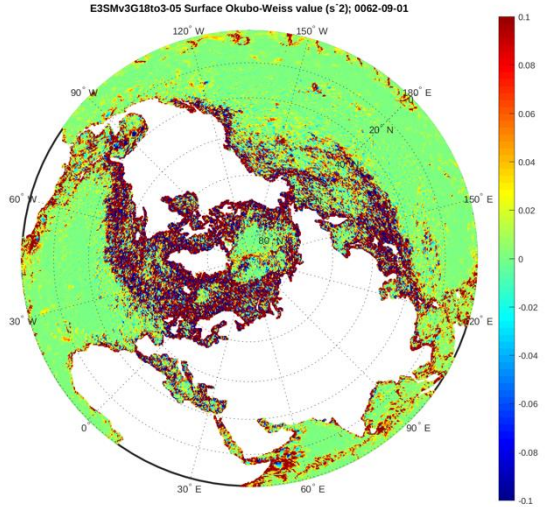
Note: ~60 TW (~65%) net heat loss over the Barents Sea (to sea ice melt and surface turbulent fluxes); additional oceanic heat loss takes place over the Kara Sea

E3SM-AEROSI Ice-Ocean Coupling via Mesoscale Dynamics

AEROSI

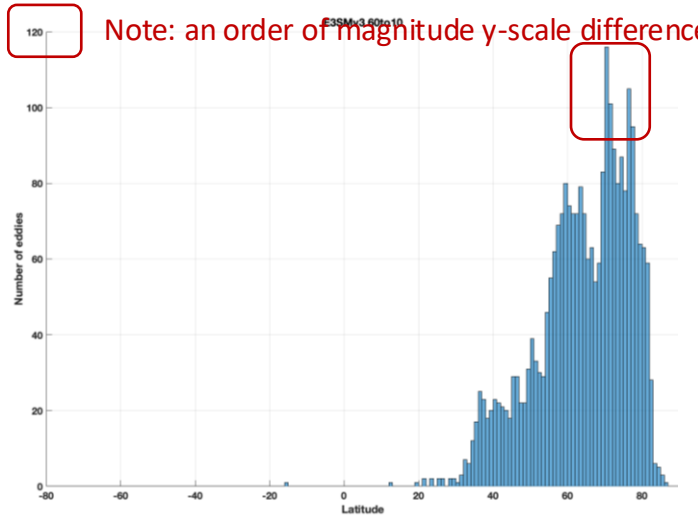


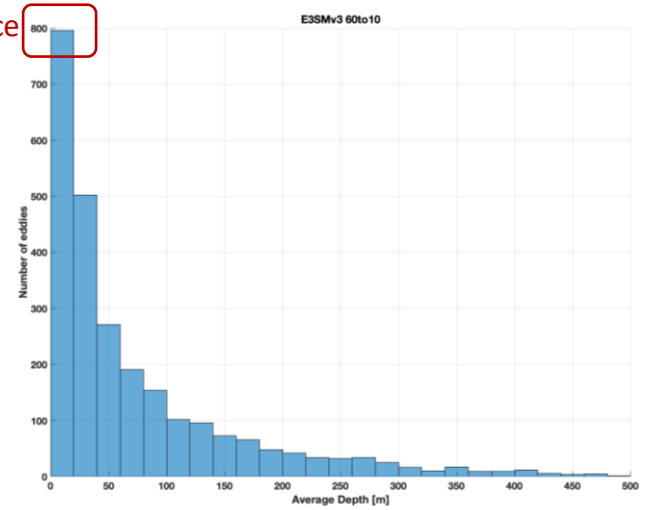


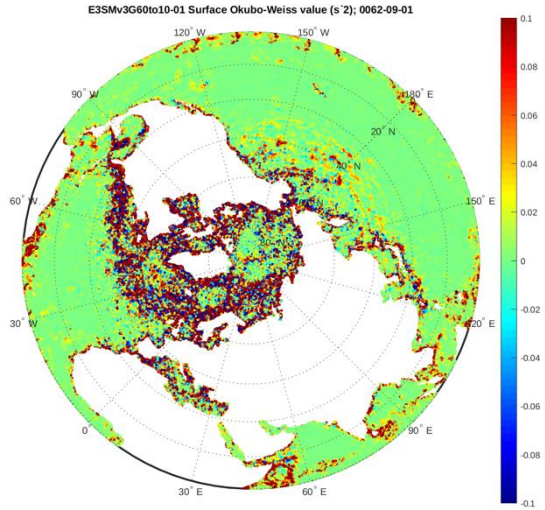


E3SMv3G60to10

Note: an order of magnitude y-scale difference







Daily 'snapshots' of Okubo-Weiss surface eddy census for September 1 2019

Barents - Kara / Arctic Ocean Heat Convergence

Estimate	Tsubouchi et al. 2021	CESM1 - HighRes	RASM-G	RASM-B1	RASM-B2	E3SM-AEROSI
Total OHC (TW)	180	151	83	102	145	132
Arctic OHC (TW)	100-107*	69*	4	14	35-40 (5-6 Wm^{-2})	~50*
Barents-Kara OHC (TW) % of Total	73 41%	82 54%	79 95%	88 85%	105-110 ~74%	~80 60%

* Includes the Baffin Bay

Both observational and modeling **challenge is**:

How this net positive ocean heat flux is 'removed' through the surface?

Summary

1. Arctic Ocean Heat Convergence (OHC) exerts strong control on sea ice, atmosphere, and consequently on Arctic Amplification, yet it is commonly underestimated in Earth System model historical simulations and projections.

2. Majority (>80%?) of AOHC is 'removed' over the Barents Sea to sea ice melt and atmosphere with potential implications for Arctic-lower latitude teleconnections

3. Coupled simulations indicate high sensitivity of Arctic sea ice to a change of 10-15 TW of Arctic OHC, while 35-40 TW can completely melt sea ice in summer.

4. **Large uncertainties persist** in (observationally and model) estimated Arctic-wide volume and heat fluxes, time-integrated surface turbulent fluxes, ocean stratification, upward heat entrainment, etc.

5. **Coordinated** (MOSAiC-type) field campaigns remain necessary for constraining / improving climate model simulations and projections.