The influence of Atlantic Water on Eastern Arctic ice/ocean interactions from two mesoscale ocean/sea-ice simulations

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ESSM/RGMA: DOE
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HPC: ASCR/ALCC & NERSC ERCAP

NOPP: Arctic Observing System Simulation Experiments (OSSEs)

HPC: DoD Pathfinder awards 2019, 2020

Overall Goal: Comparison of the Arctic Ocean in two mesoscale ocean/sea-ice models.

UH8to2: Global - 8 km at equator to 2 km at poles.

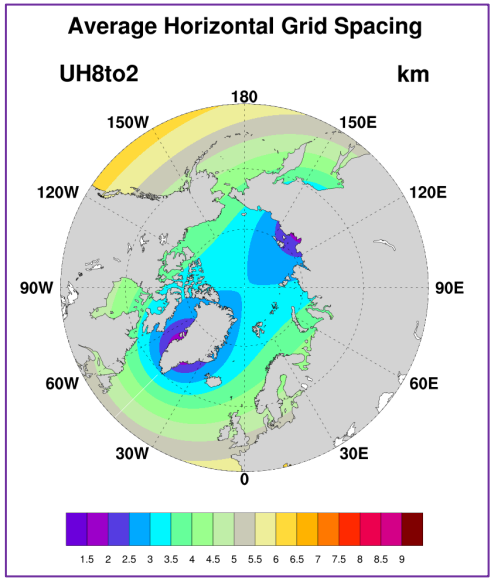
- Ultra-high: higher horizontal resolution than 0.1° grid.
- POP2/CICE5 run in “HiLat” (E3SMv0/CESM) framework.

04HYCICE: Regional Arctic Ocean 0.04º HYCOM/CICE5

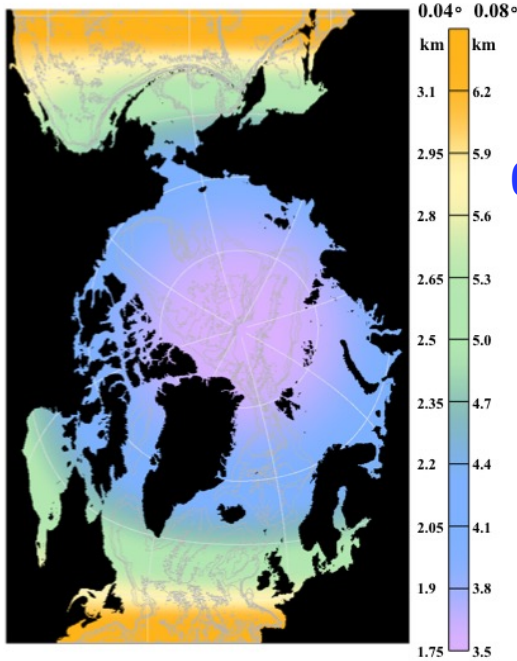
- Both forced with JRA55-do & initialized from1/25º GOFS3.5: data assimilative HYCOM/CICE5.
- Run for 2017-2020 following spin-up period.

- Limited observations for validation - use when available.
- Processes robust if occurring in both models?

Focus today: Atlantification in Eastern Arctic

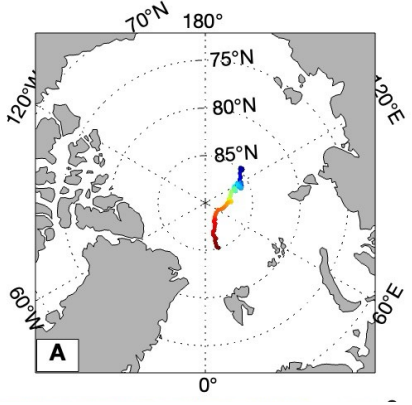


Global UH8to2: POP2-CICE5



0.04º HYCOM-CICE: Model Domain & Grid Spacing (km)

Ice-Tethered Profiler (ITP) #111 section in the eastern Arctic (10/2019-04/2020) compared with concurrent & co-located HYCOM and POP fields

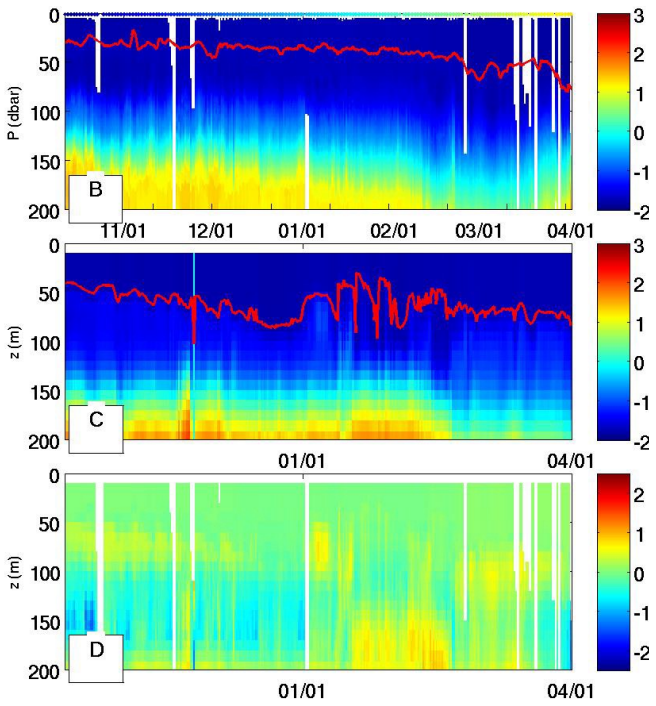


ITP temperature (°C)

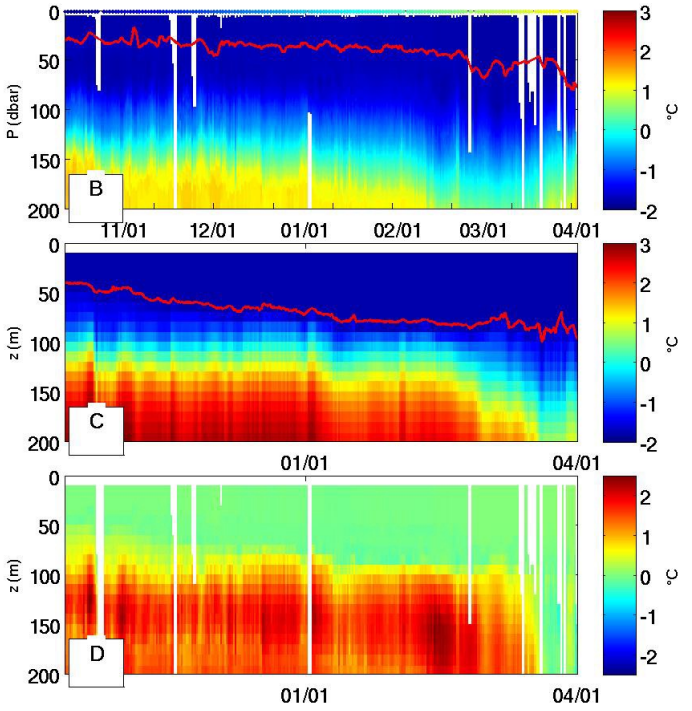
HYCOM (left) & POP (right) temperature (°C)

HYCOM-ITP (left) & POP-ITP(right)

HYCOM Comparison



POP Comparison



- All MLDs (near freezing) deepen in time.
- ITPs: cold MLD above cold halocline layer to ~100m
- POP: deeper MLD, thin cold halocline layer & AW biased warm.
- HYCOM less biased.
- Models have weaker stratification than obs. in upper 100m – lowest in POP (from N^2 sections, not shown)
- Simulated halocline structure less of a barrier to entrainment of AW into ML than in the real ocean.

Mixed layer depth (MLD): red lines in panels B and C. Colors corresponding to locations in panel A) are plotted across the top of B.

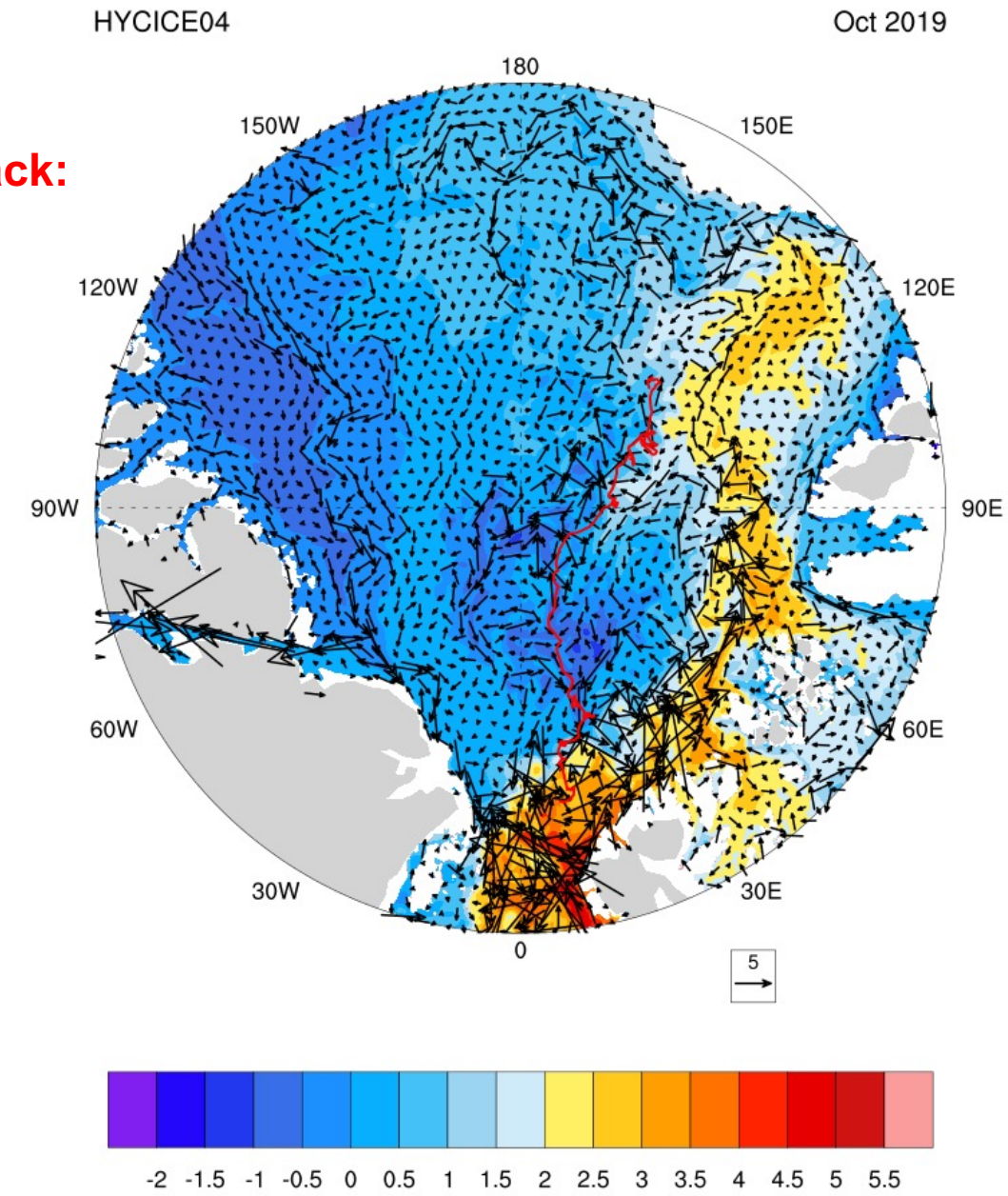
ITP data: collected & made available by the Ice-Tethered Profiler Program (Toole et al., 2011; Krishfield et al., 2008) at WHOI (https://www.whoi.edu/itp).

POP comparison with ITP#111 in Fine et al. (2023, Ocean Modell., Fig. 14)

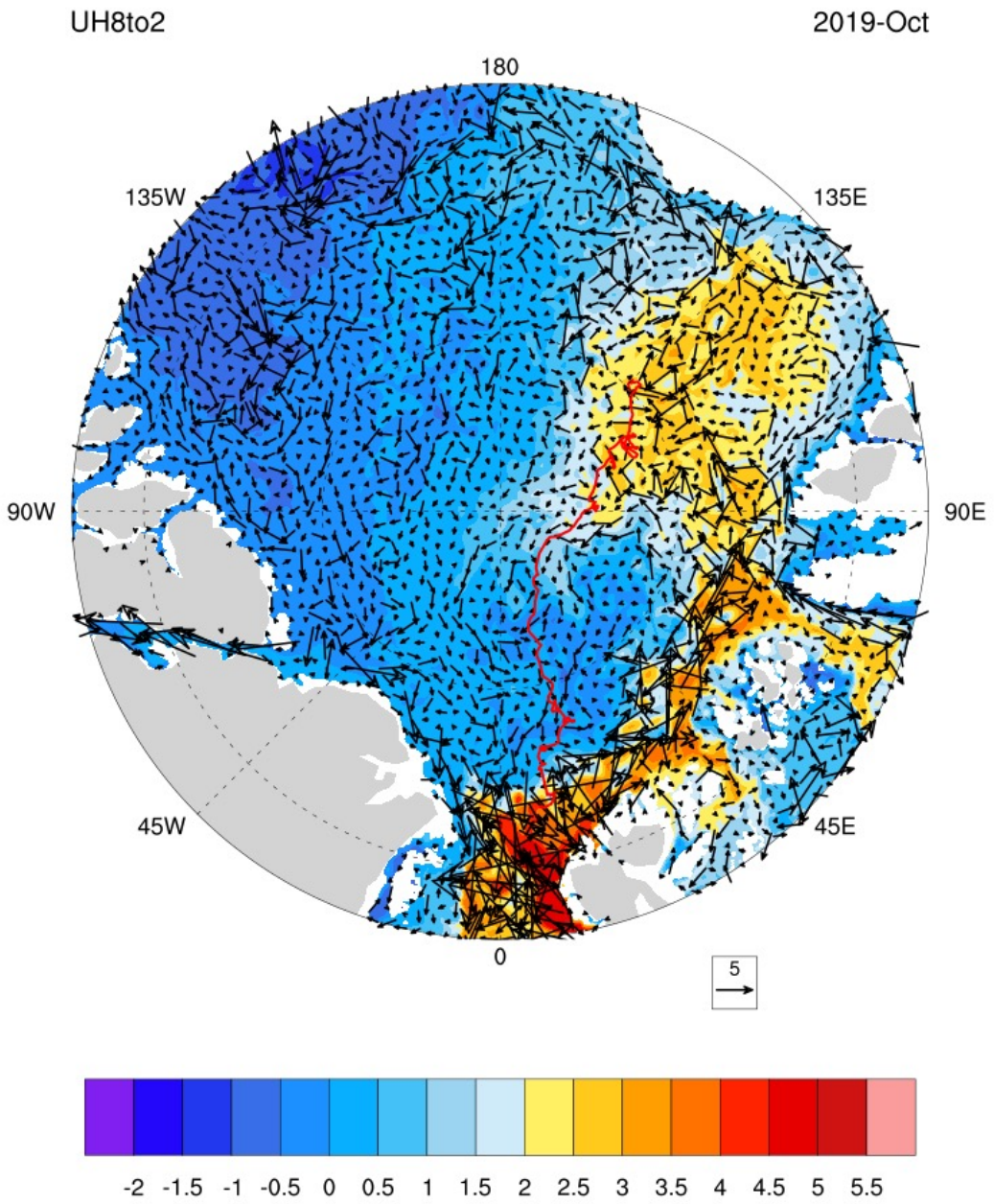
04HYCICE HYCOM

ITP# 111 track: red line

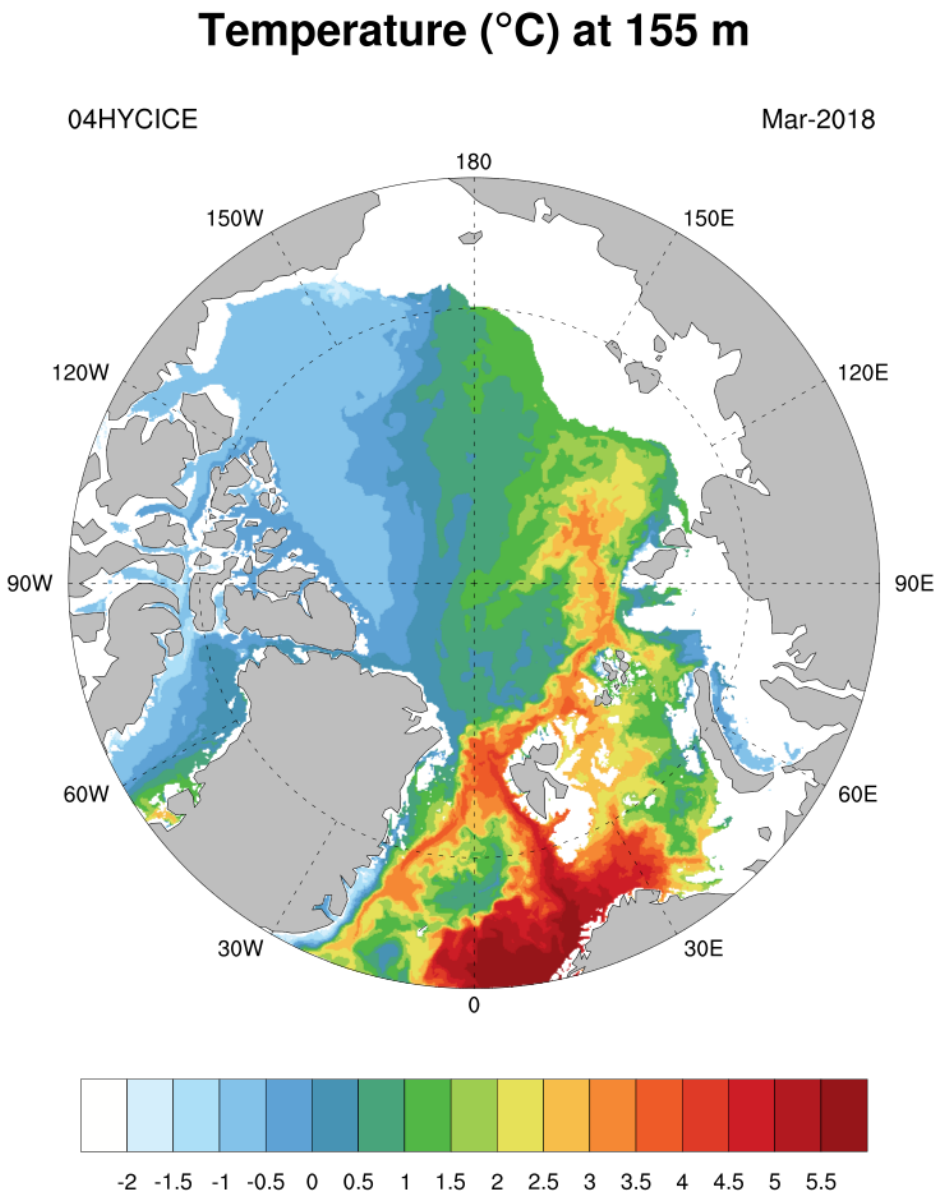
October 2019 is the start date of the ITP track.



UH8to2 POP



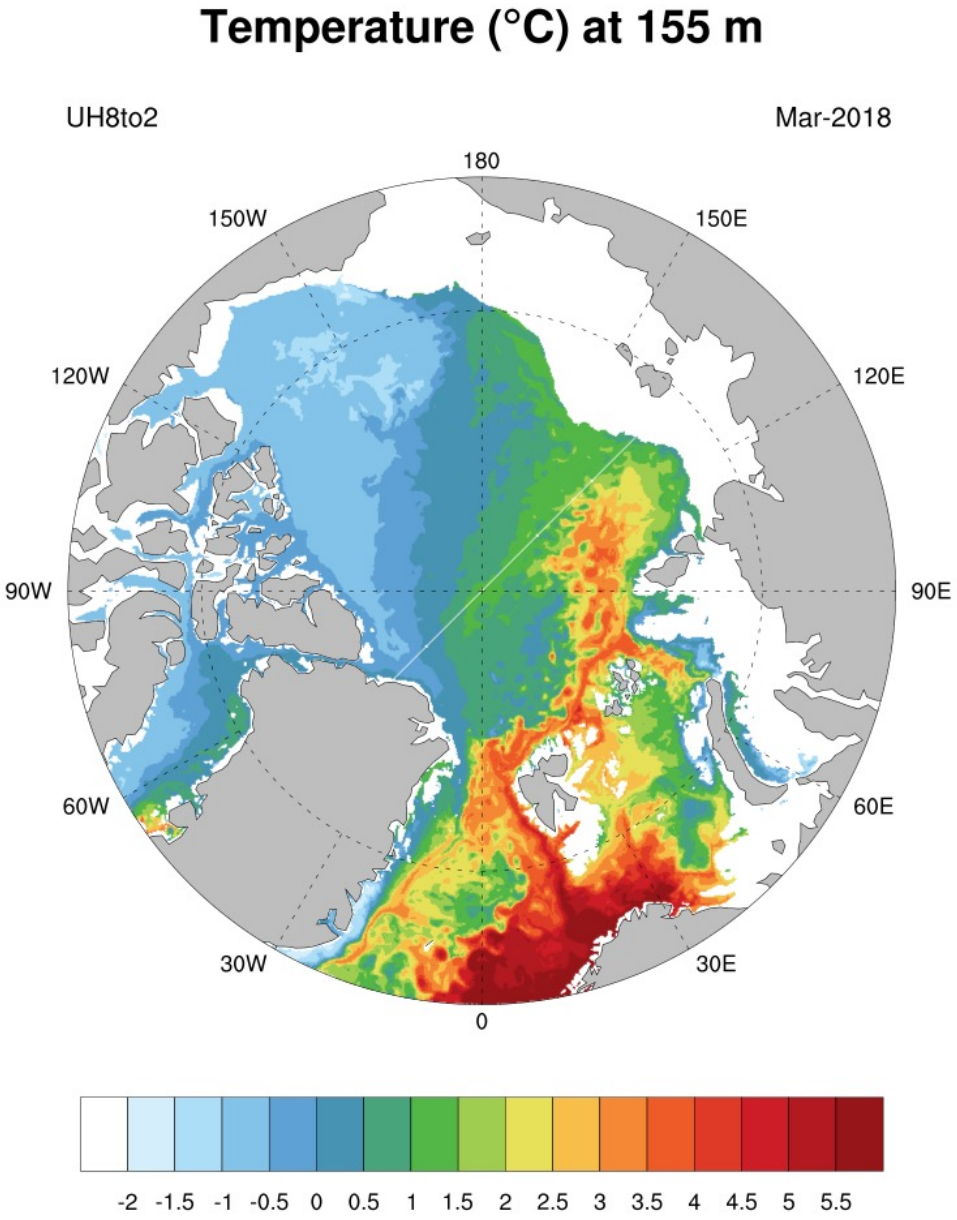
MARCH 2018



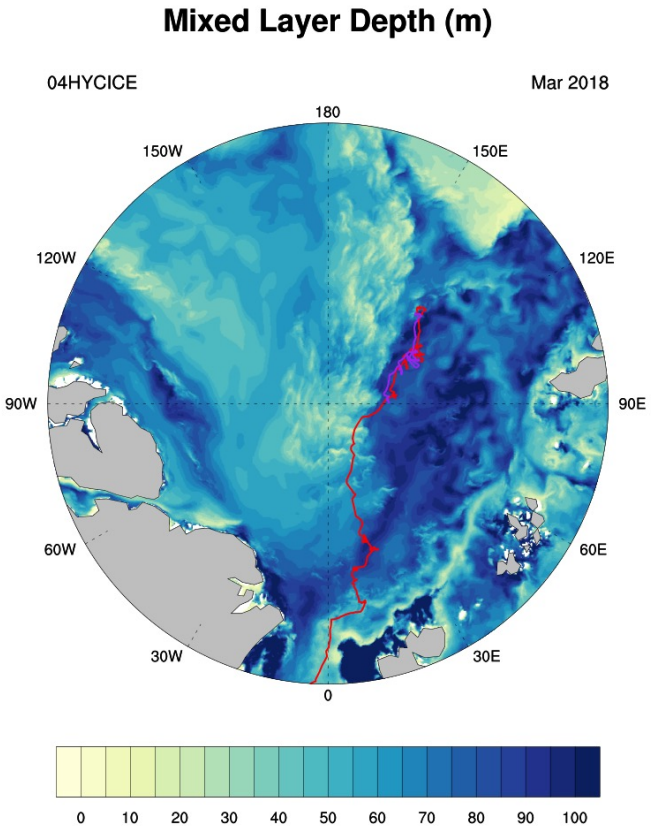
- **Warmest AW temperatures** in eastern Eurasian basin (90ºE-150ºE) in **early 2018.**
- Warming signatures spread and cool through 2020.

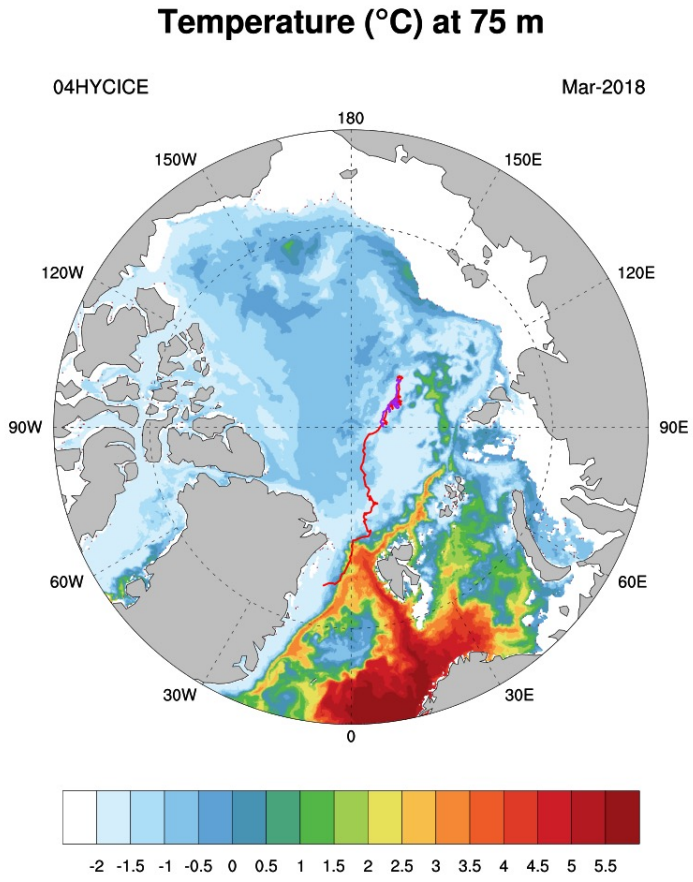
- Atlantic Water (AW) signature in the Arctic is in the initial conditions taken from GOFS3.5

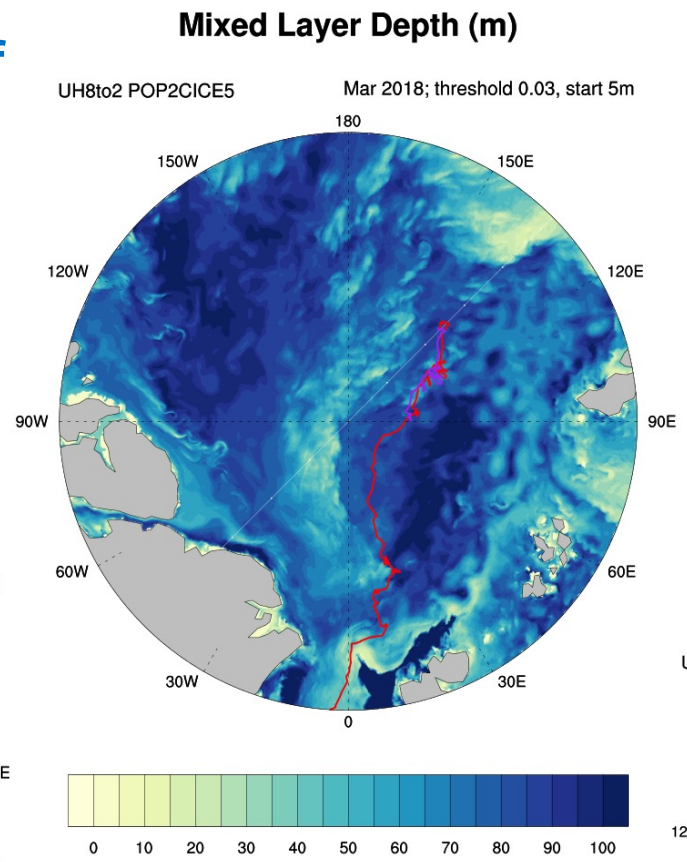
- GOFS3.1 suggests it is an AW pulse that extended eastward of 90ºE in early 2016.

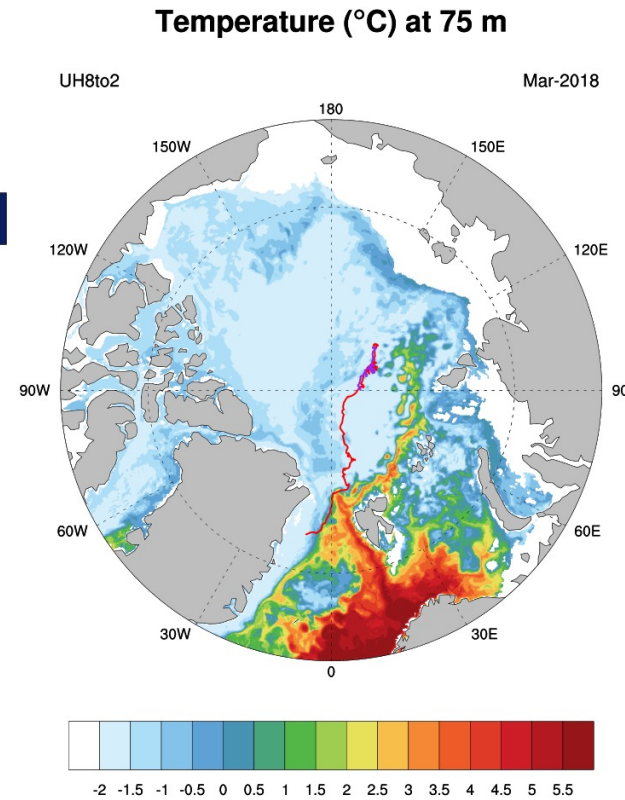


Spatial distributions of simulated winter MLD





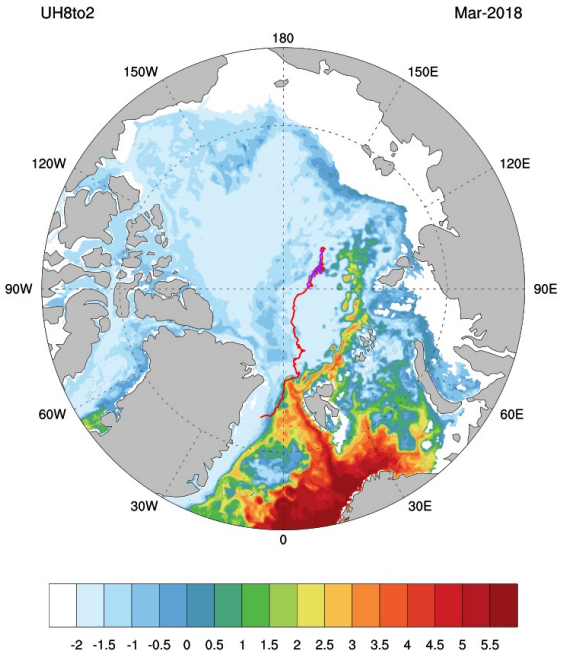




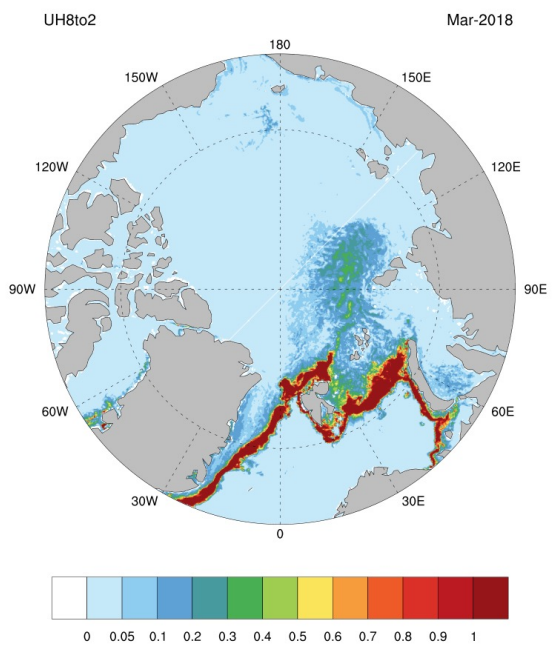
MLD definition:
Potential density threshold of ρ_0 = 0.03 kg/m^3 relative to 5m using daily-averaged fields.

ITP#94 red
ITP#102 purple

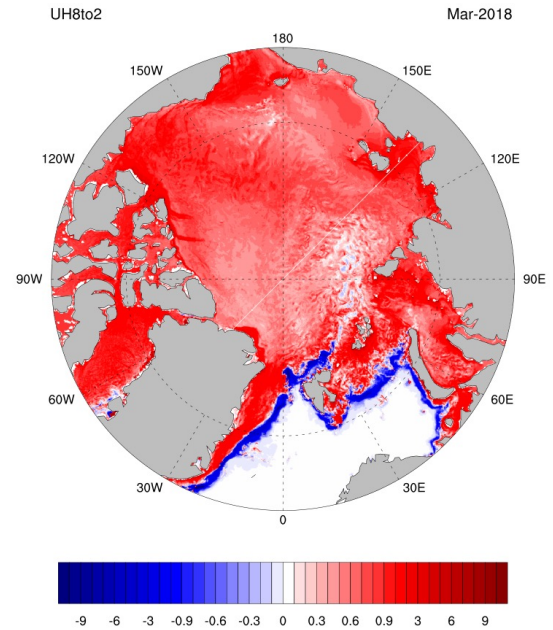
Temperature (°C) at 75 m



Sea Ice MELT_B (cm/day)

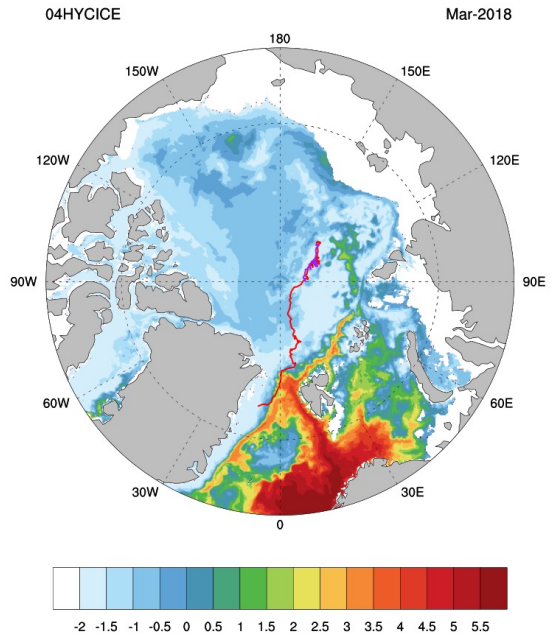


Volume Tendency: Thermodynamics (cm/day)



UH8to2

Temperature (°C) at 75 m



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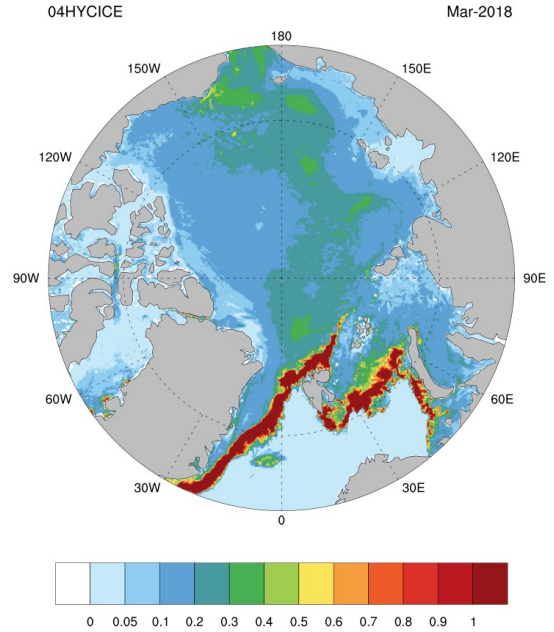

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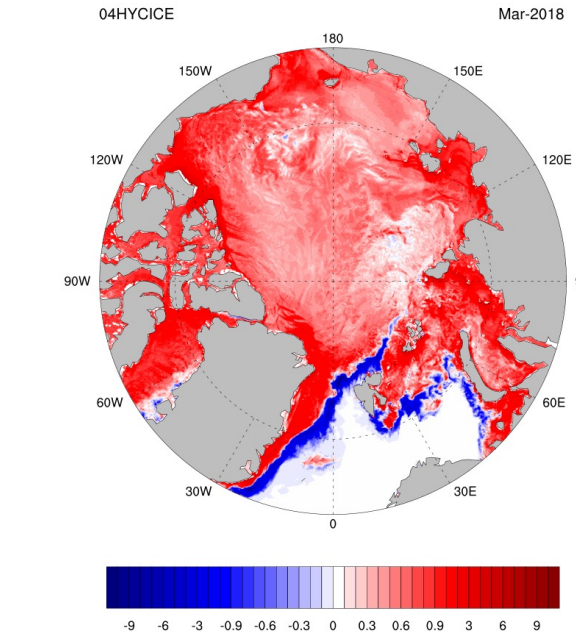
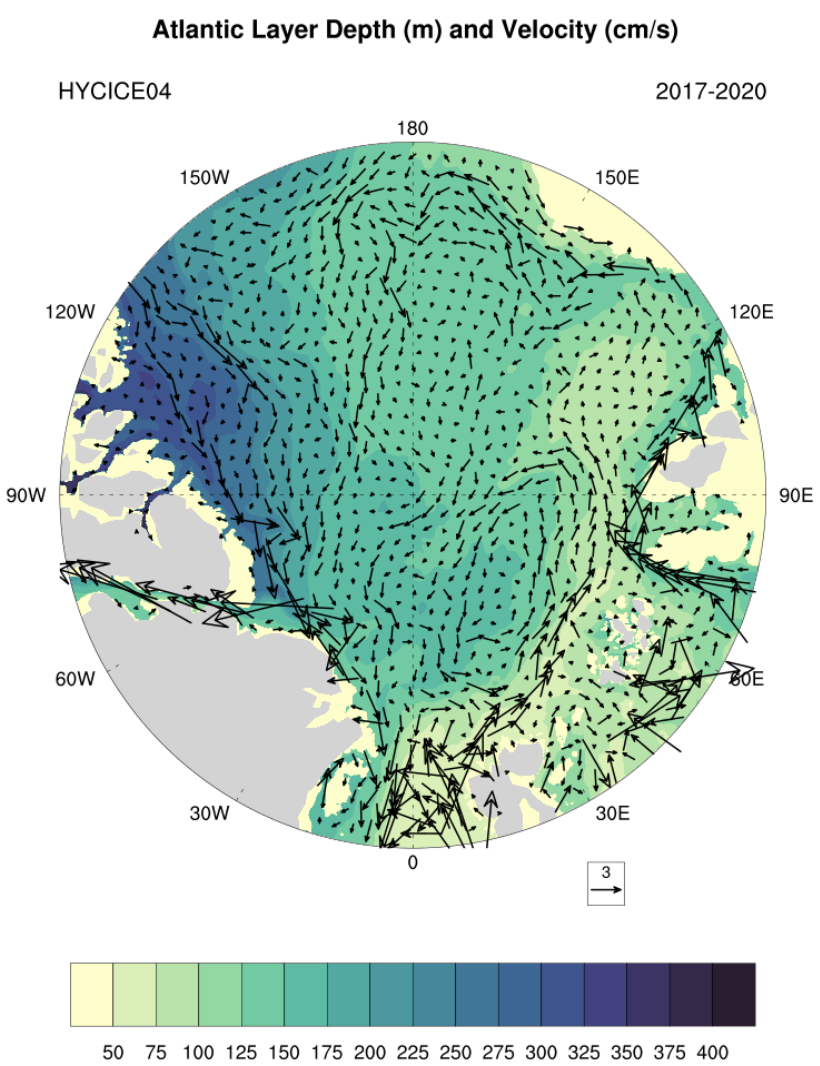


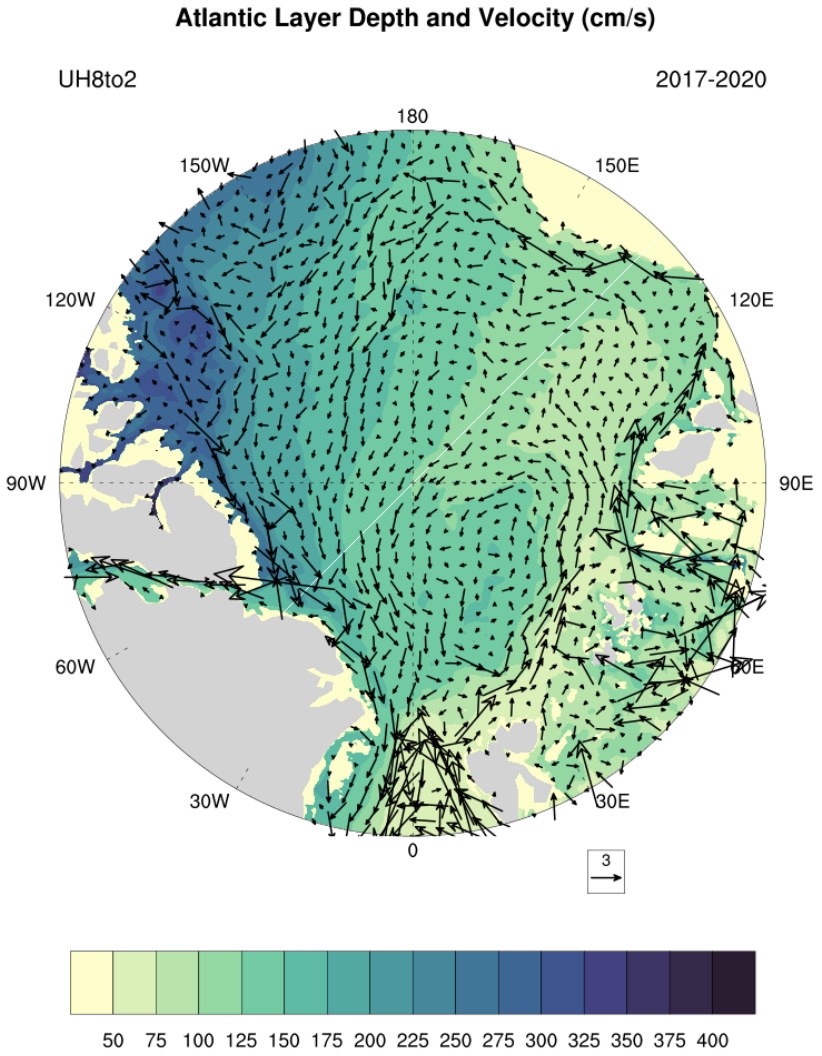
04HYCICE

Summary

- HYCOM & POP simulate a mesoscale-rich pulse of AW in the Eastern Eurasian Basin (EEB). Maximum warm anomalies occur in late winter 2018; AW pulses then spread out and cool through 2020. These pulses are also seen in GOFS3.5 and 3.1.
- Simulated winter mixed layers (MLs) are overly deep, the halocline layer is too thin (POP only), & upper-ocean stratification is too low relative to ITP-derived counterparts under an ITP track in the EEB.
- Doming isopycnals associated with anticyclonic mesoscale eddies just below the ML likely transfer heat into the base of the mixed layer through mesoscale stirring and convection bringing heat into the vicinity of sea-ice.
- Basal melt & negative thermodynamic volume sea-ice tendencies are co-located with AW signatures in the EEB in winter, particularly in 2018.
- An over-supply of heat to the surface from mesoscale eddies could contribute to the low sea-ice thickness biases seen in the models in the EB .
- The models have the potential to be used to understand and quantify ice-ocean feedbacks that will become more important in a warming ocean.

EXTRA SLIDES



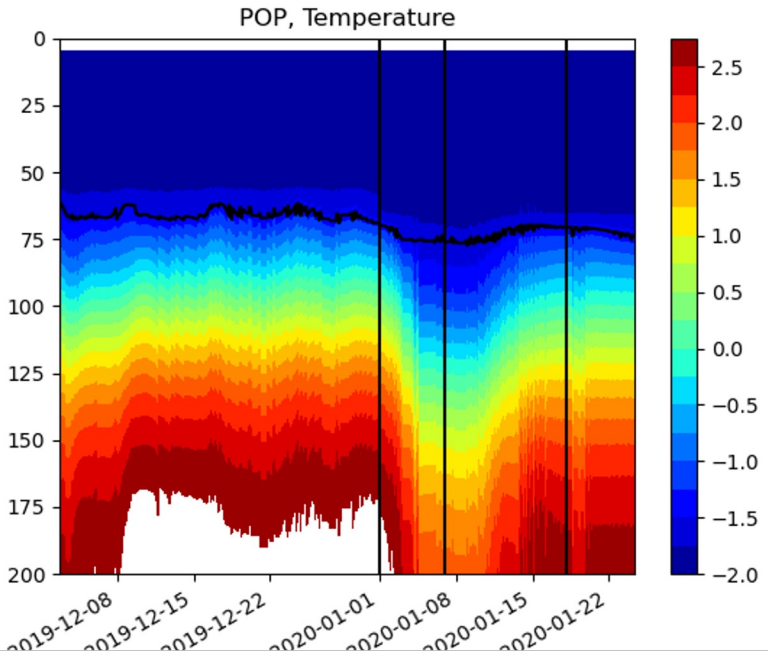


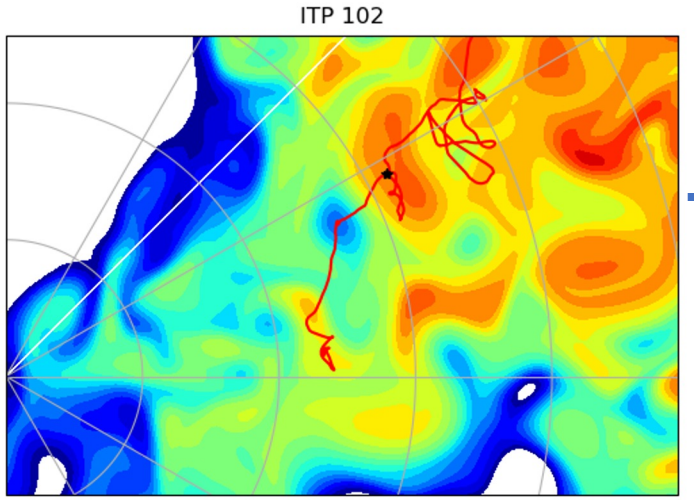
Atlantic Layer depth: is shallow in Eastern Eurasian basin (< 100m in places). Winter mixed layers are overly deep & upper-ocean model stratification is weak leading to entrainment of heat from AW mass into ML in the eastern Arctic.

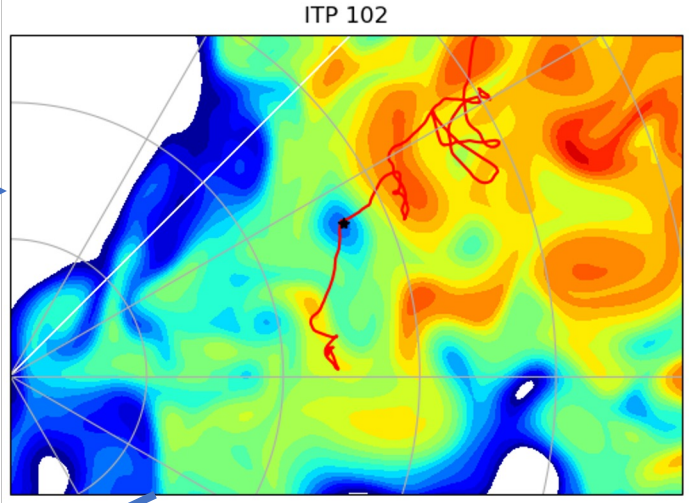
Atlantic Layer depth (m): uppermost depth below 50m of the 0°C isotherm (Rudels et al. 2004)

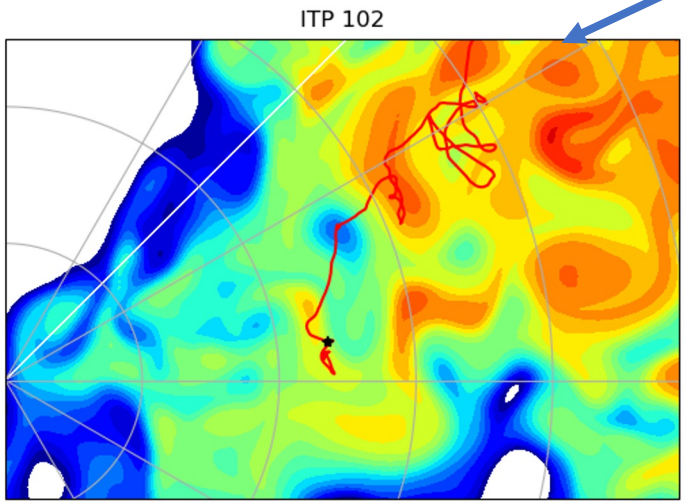
POP: Mesoscale Eddies ITP#102 transect

- Focusing on possible eddies in January 2020
- Vertical lines indicate dates of maps.
- Maps are at a depth of 185 m.









In this case, the “closer look” shows the ITP traversing a nicely formed cold-core eddy.

March Sea Ice Thickness (m)