Can CESM simulate the cyclone-driven record sea ice loss of January 2022?

Ed Blanchard-Wrigglesworth, Department of Atmospheric sciences, University of Washington

edwardbw@uw.edu

Extreme events:

Oversized footprint on socioeconomic impacts

Serve as litmus tests for our weather forecast and climate models

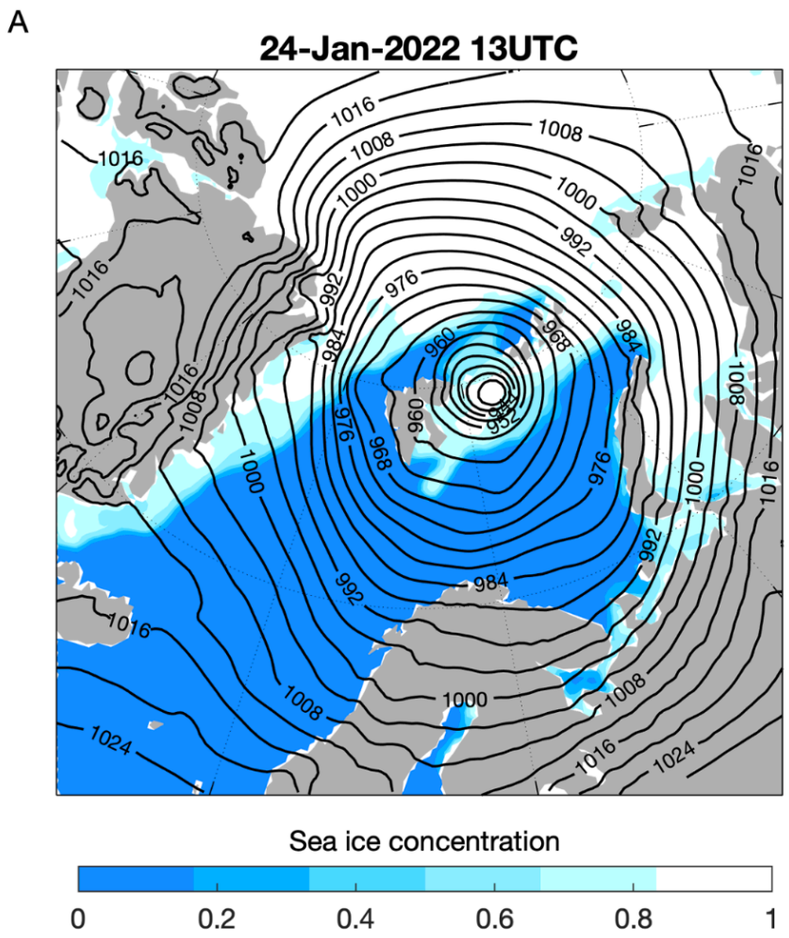
How well do we understand them?

How well can we forecast them?

How might climate change impact them?

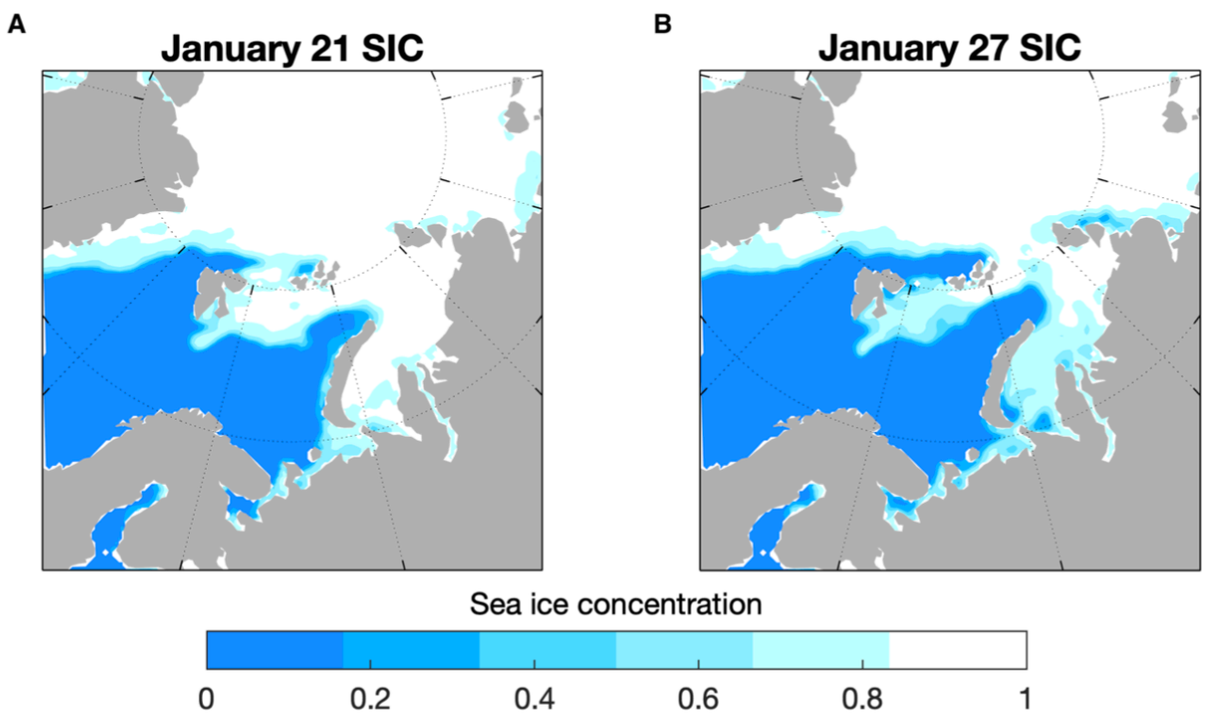
How can we use them to improve our models?

Record January 2022 cyclone led to record weekly sea ice loss

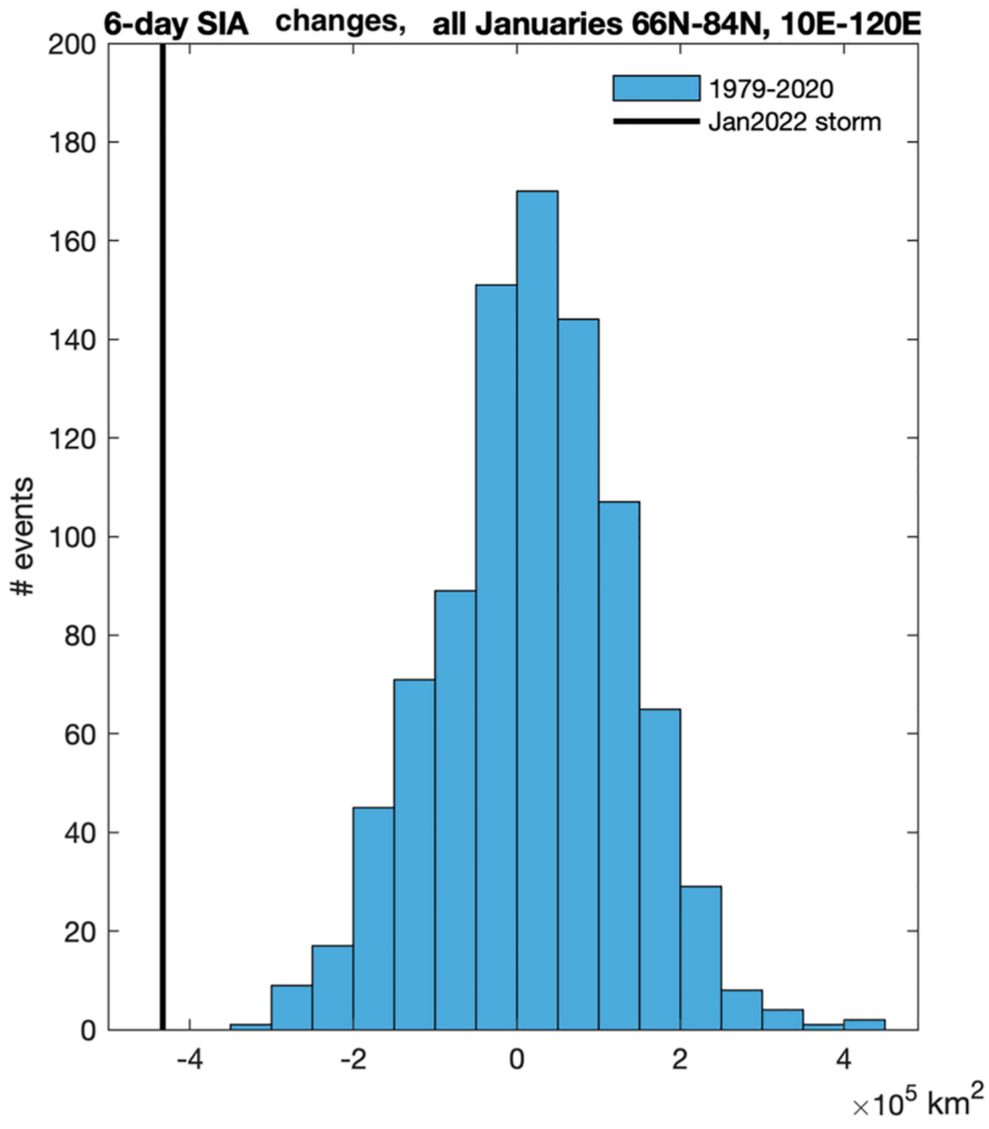


SIC and SLP on January 24 - central SLP reached 932 mb

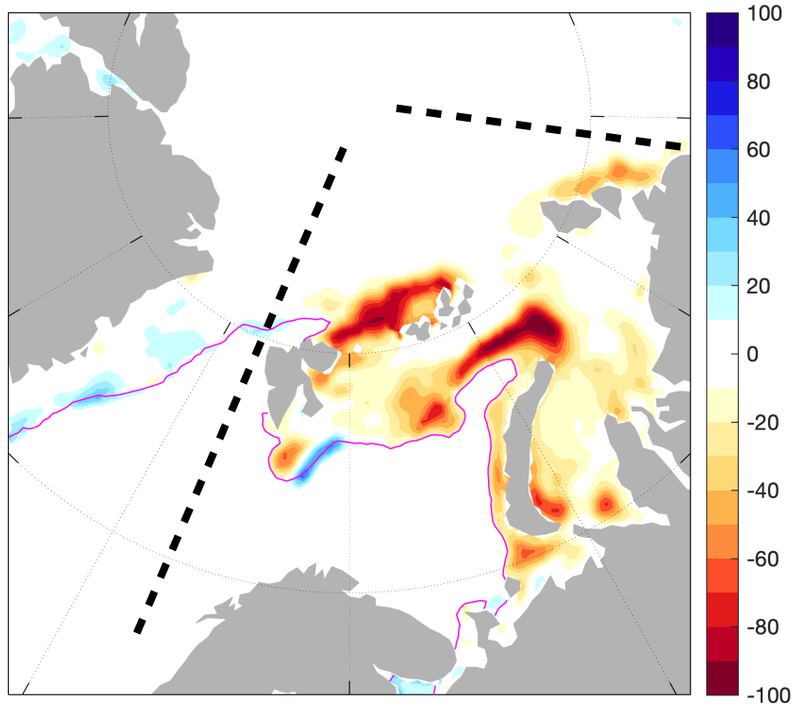
Change in SIC January 21-27, almost 0.5 million km2 loss of SIA in Barents/Kara/West Laptev



Record January 2022 cyclone led to record weekly sea ice loss



Change in SIC January 21-27, almost 0.5 million km2 loss of SIA in Barents/Kara/West Laptev



Studying cyclones & sea ice in CESM1-CAM5

Option 1: analyze relationship between cyclones and sea ice in existing runs

Option 2: run CICE with a ‘data’ (observed) atmosphere

Option 3: replicate observed cyclone in fully coupled CESM by nudging winds above boundary layer

We have run 4 experiments that nudge winds in CESM1-CAM5 to observed January 2022 winds north of 45°N

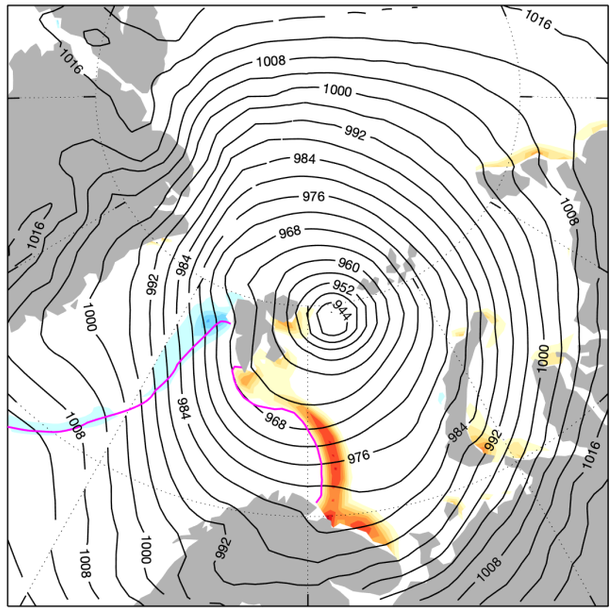
CESM-LE 2022 → Initialized from CESM-Nudge in 2021

CESM-LE 2041
CESM-LE 2061
CESM-LE 2081
⇒ Initialized from CESM-LENS #10 restart files (and forcing) in 2041, 2061, 2081

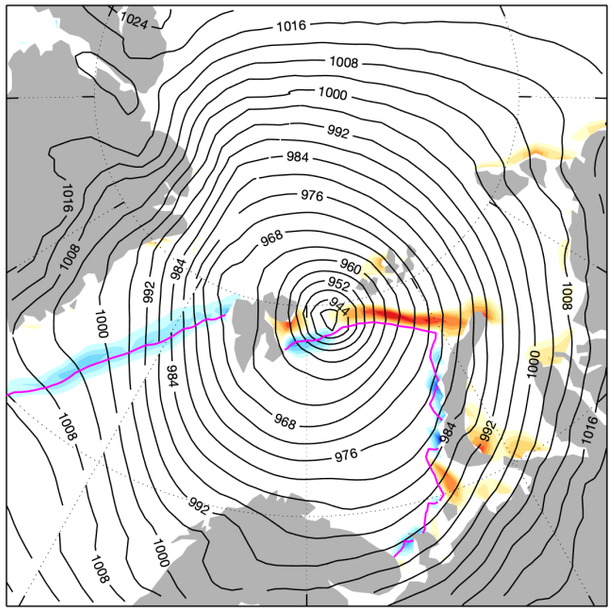
Impact of January 2022 cyclone on sea ice in CESM

SLP on 1/24 12UTC & SIC difference 1/21 -> 1/27

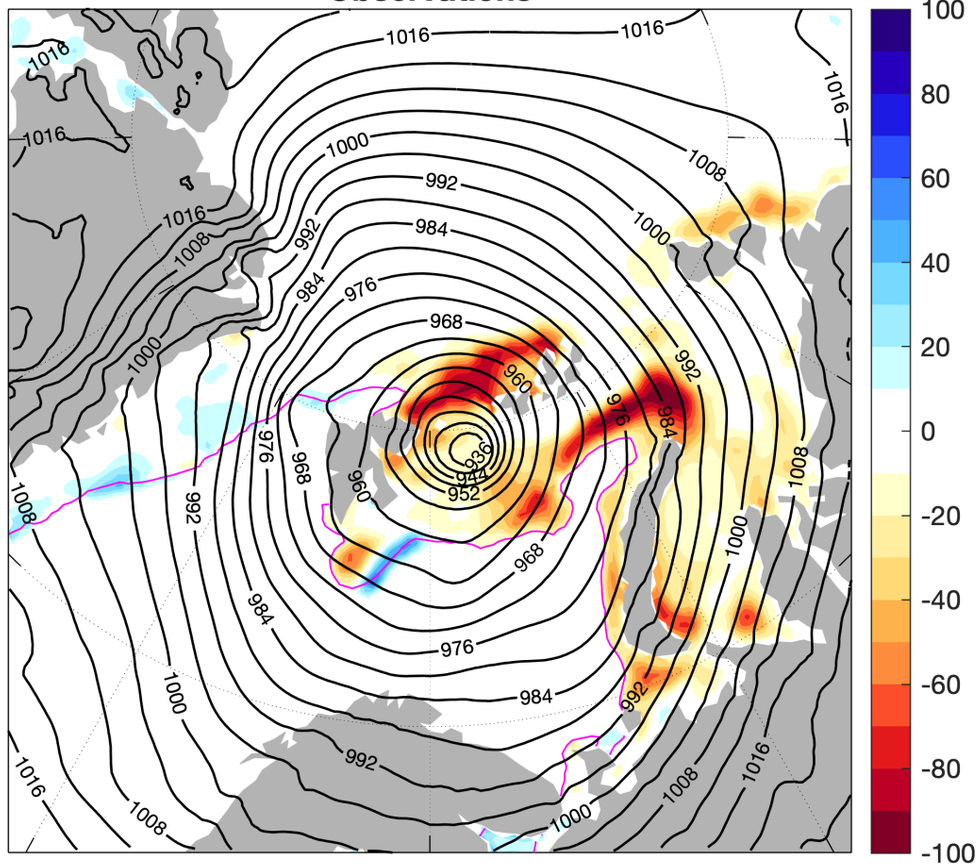
CESM-LE 2022



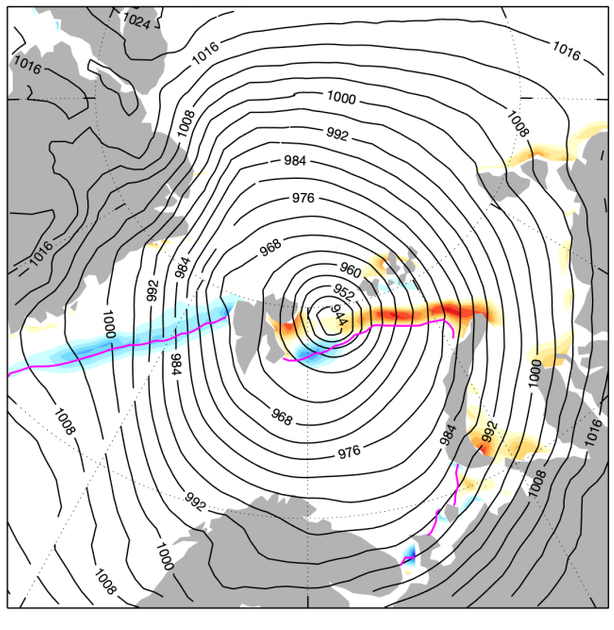
CESM-LE 2041



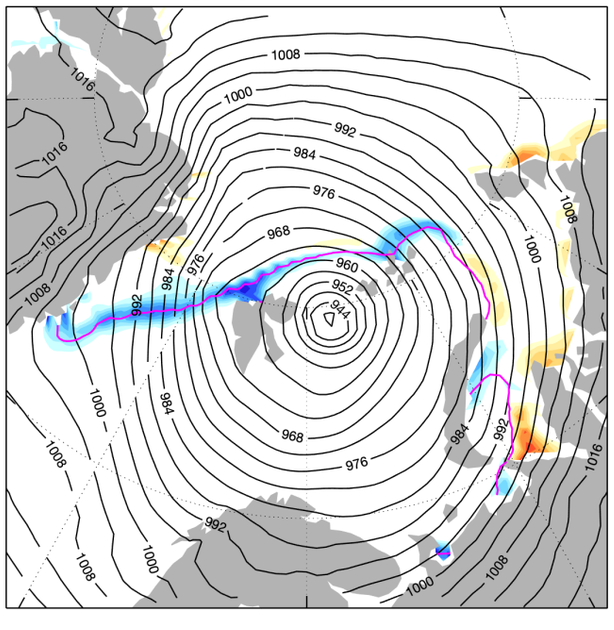
Observations



CESM-LE 2061



CESM-LE 2081

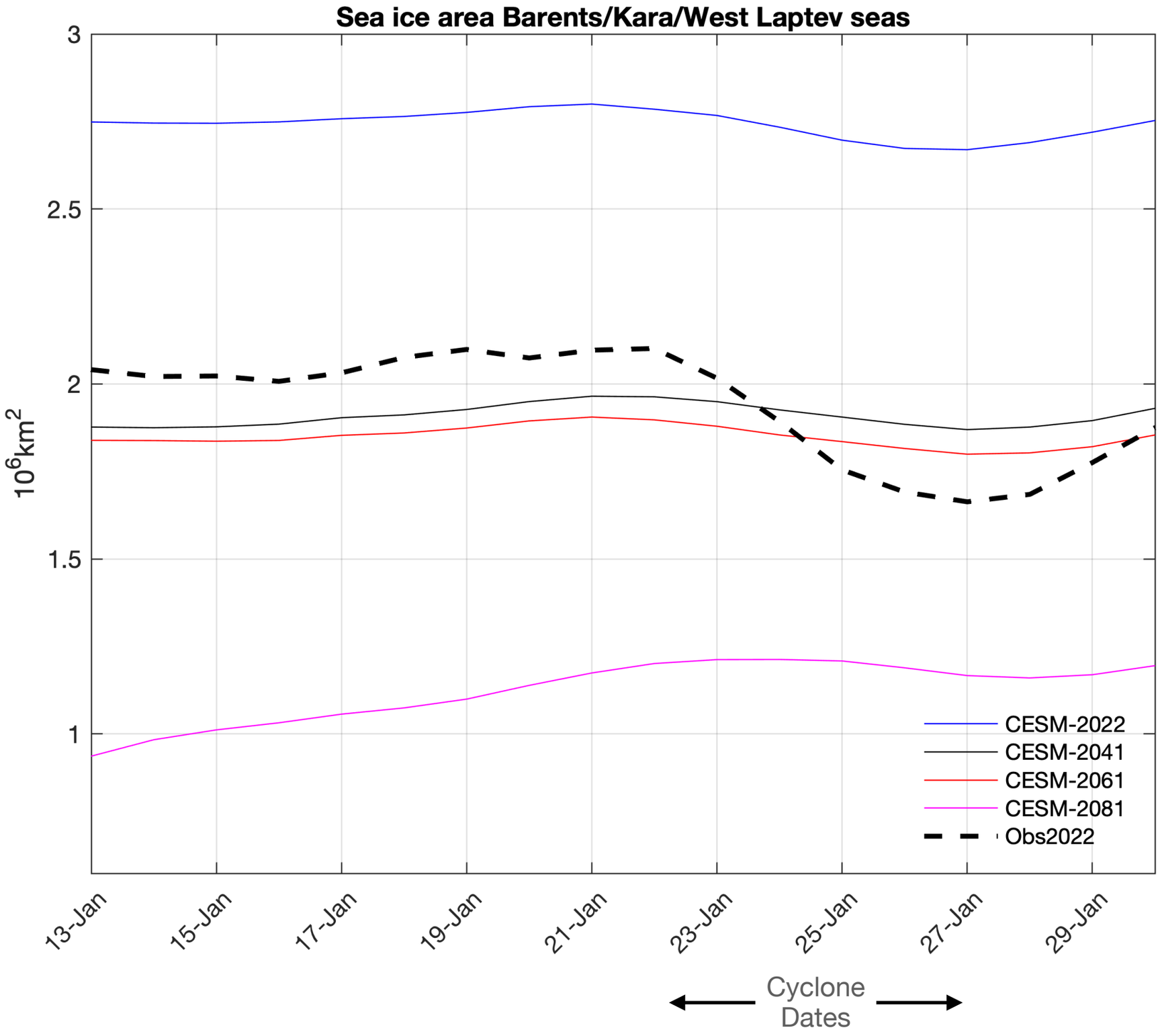


δ SIC

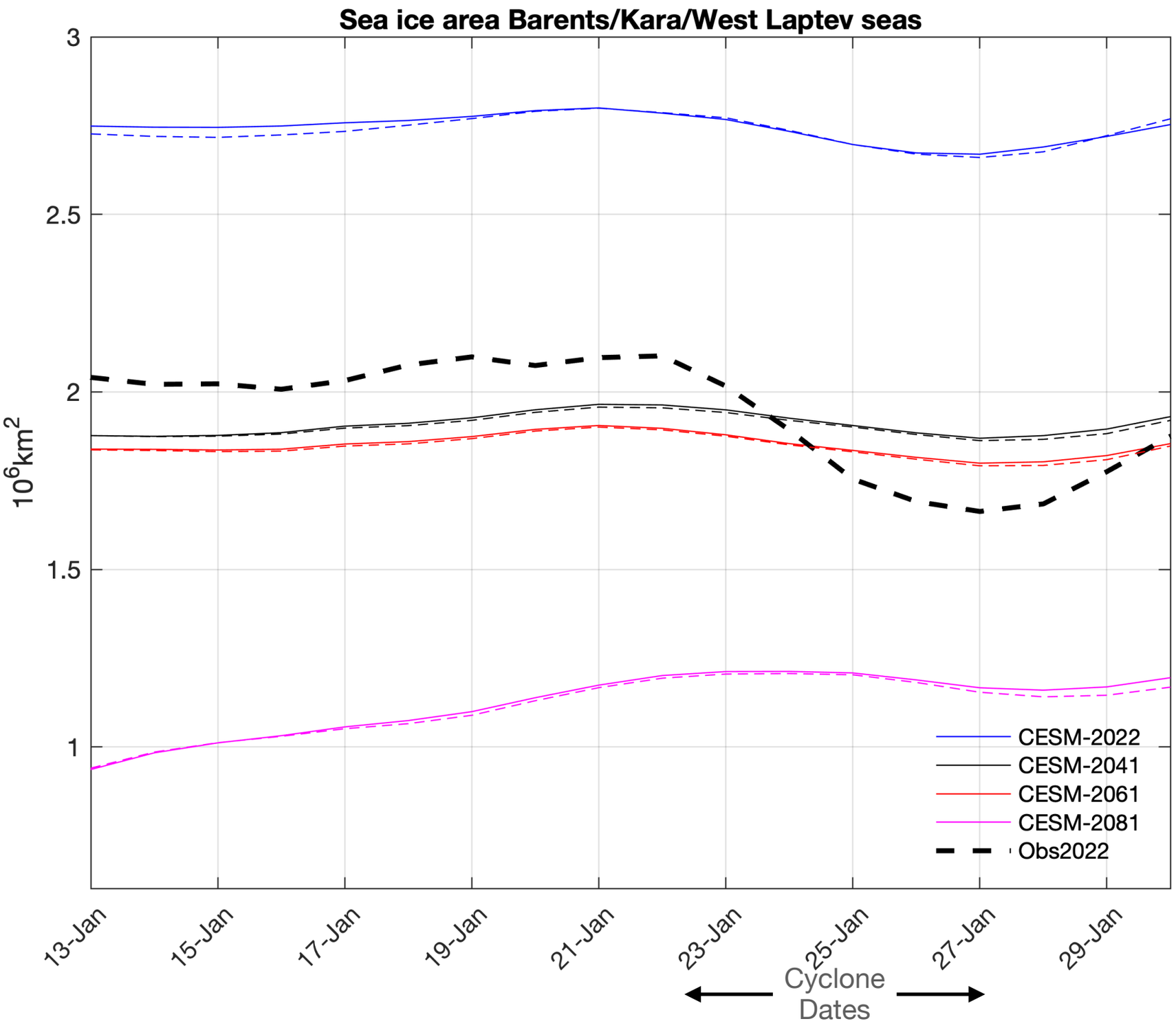
-100 -50 0 50 100

Model replicates cyclone, but sea ice response is biased

Much smaller loss of sea ice in CESM (~0.1 m km2 SIA) compared to observations

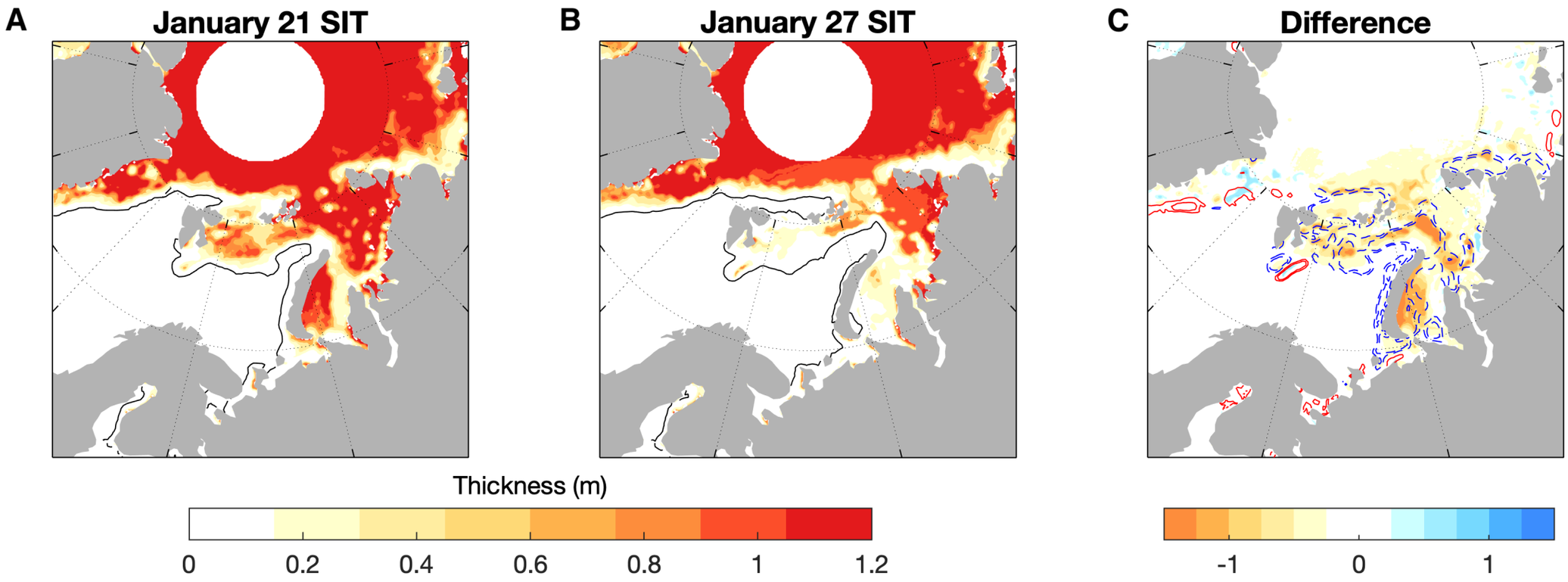


Reducing floe size from 300 m to 3 m has no impact



Dashed: floe size= 3 m

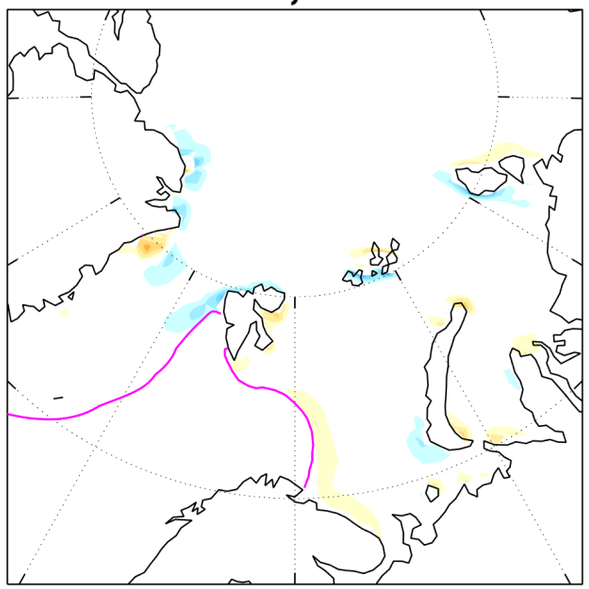
Observed change in sea ice thickness (from SMOS) also showed significant sea ice thinning



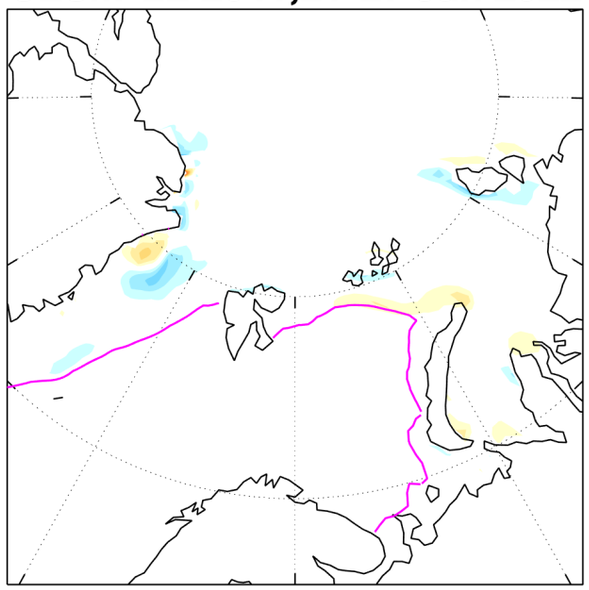
Surface atmospheric fluxes can only account for max=0.1 m, we hypothesize significant melt is caused by ocean fluxes (enhanced by vertical mixing due to waves, winds and fast sea ice motion)

Much smaller changes in SIT in model runs

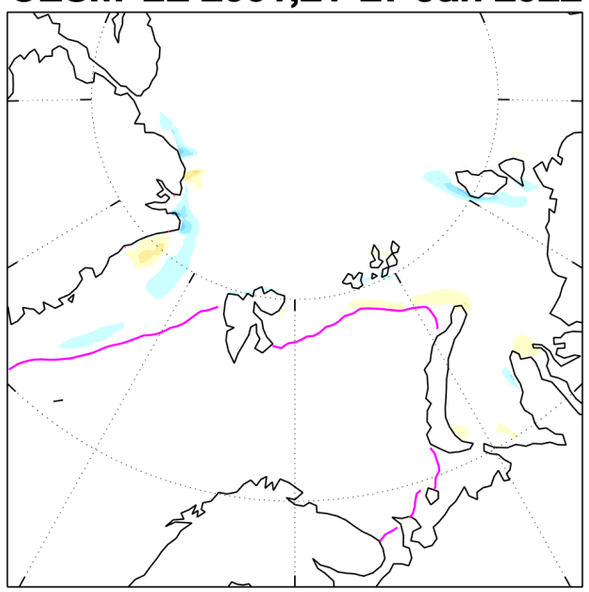
CESM-LE 2022,21-27 Jan 2022



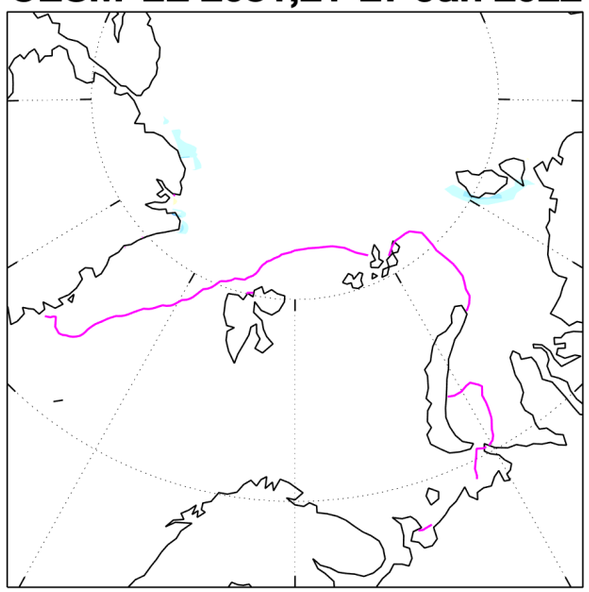
CESM-LE 2041,21-27 Jan 2022



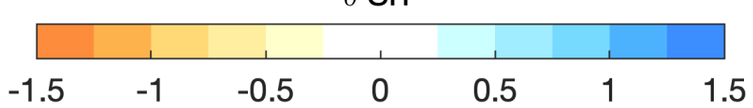
CESM-LE 2061,21-27 Jan 2022



CESM-LE 2081,21-27 Jan 2022

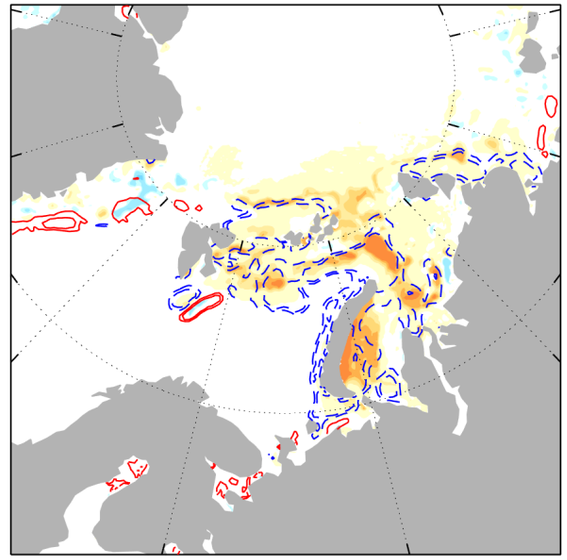


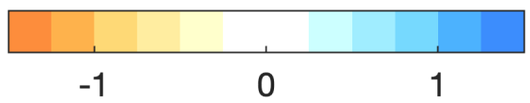
δ SIT



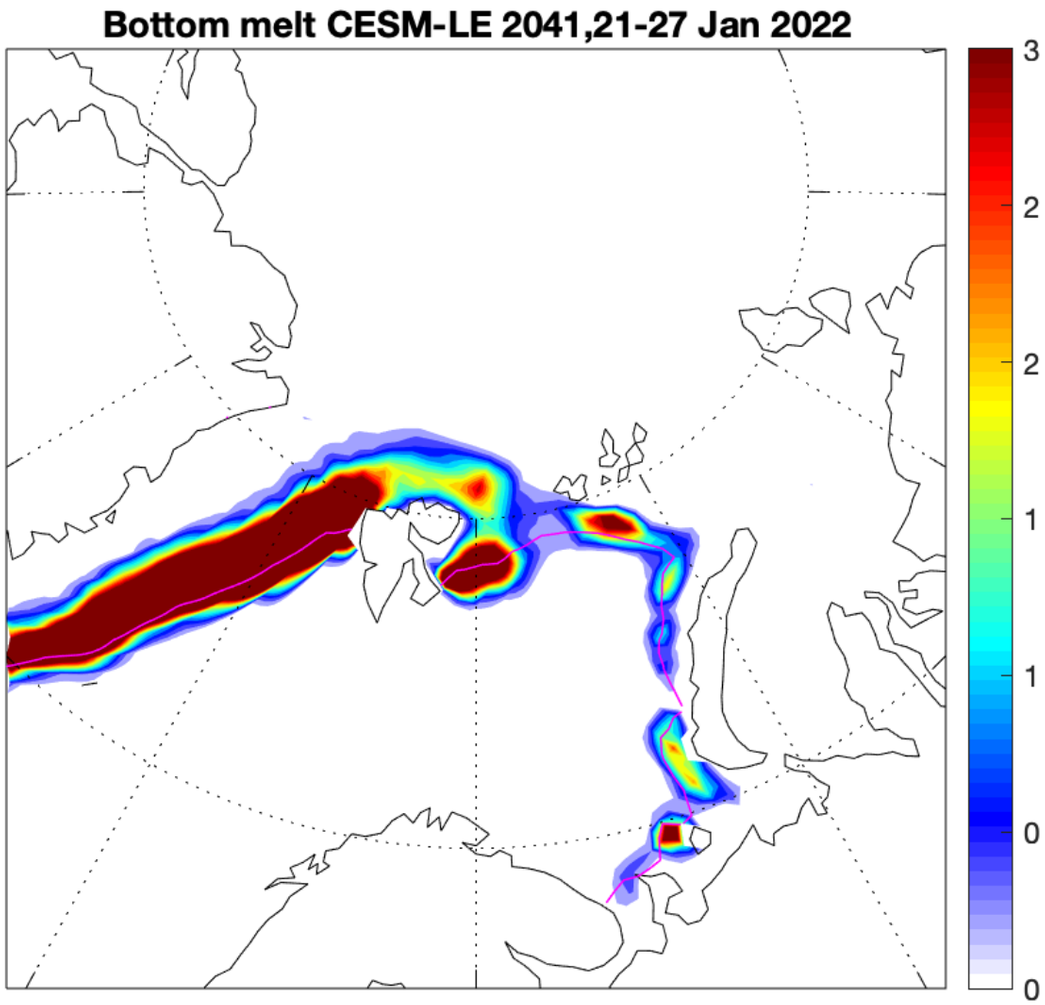
Obs

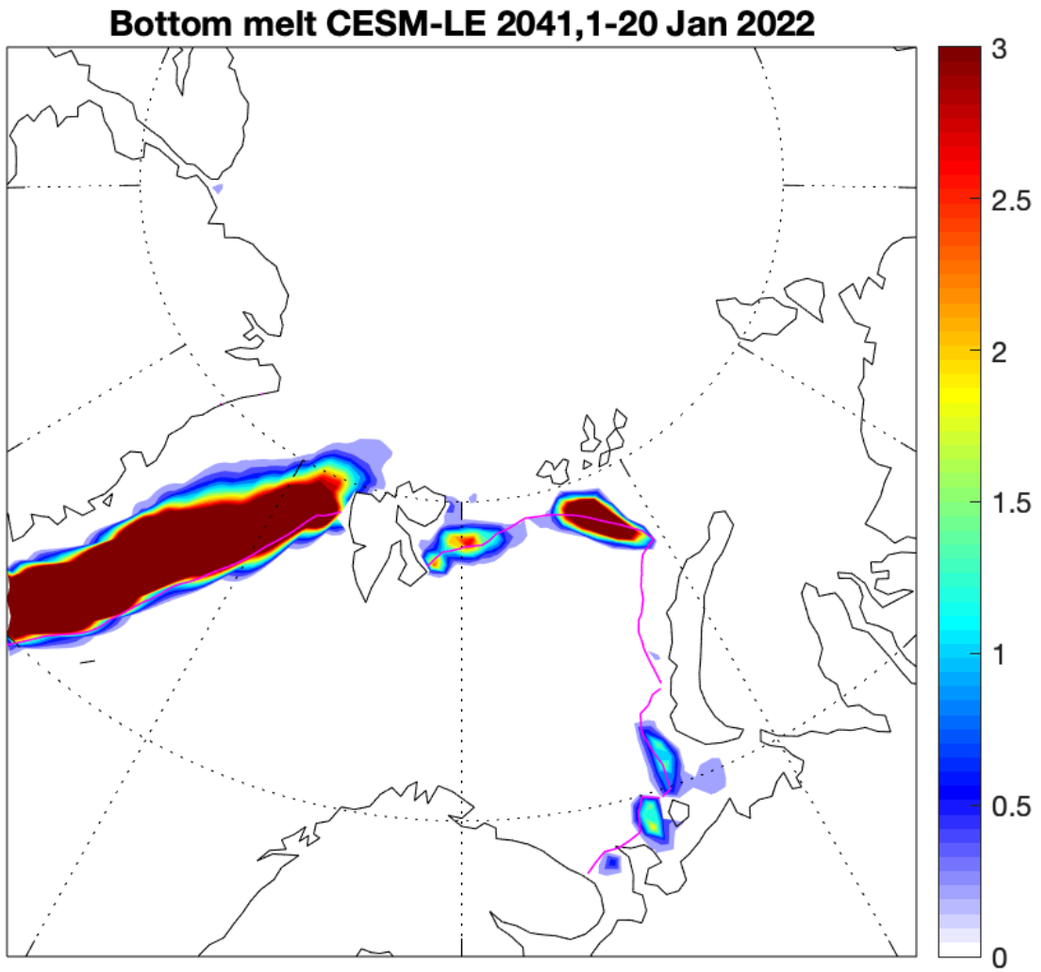
Jan 21-27 Difference





Yet some evidence of cyclone's impact on bottom melt/ocean fluxes to ice in model runs

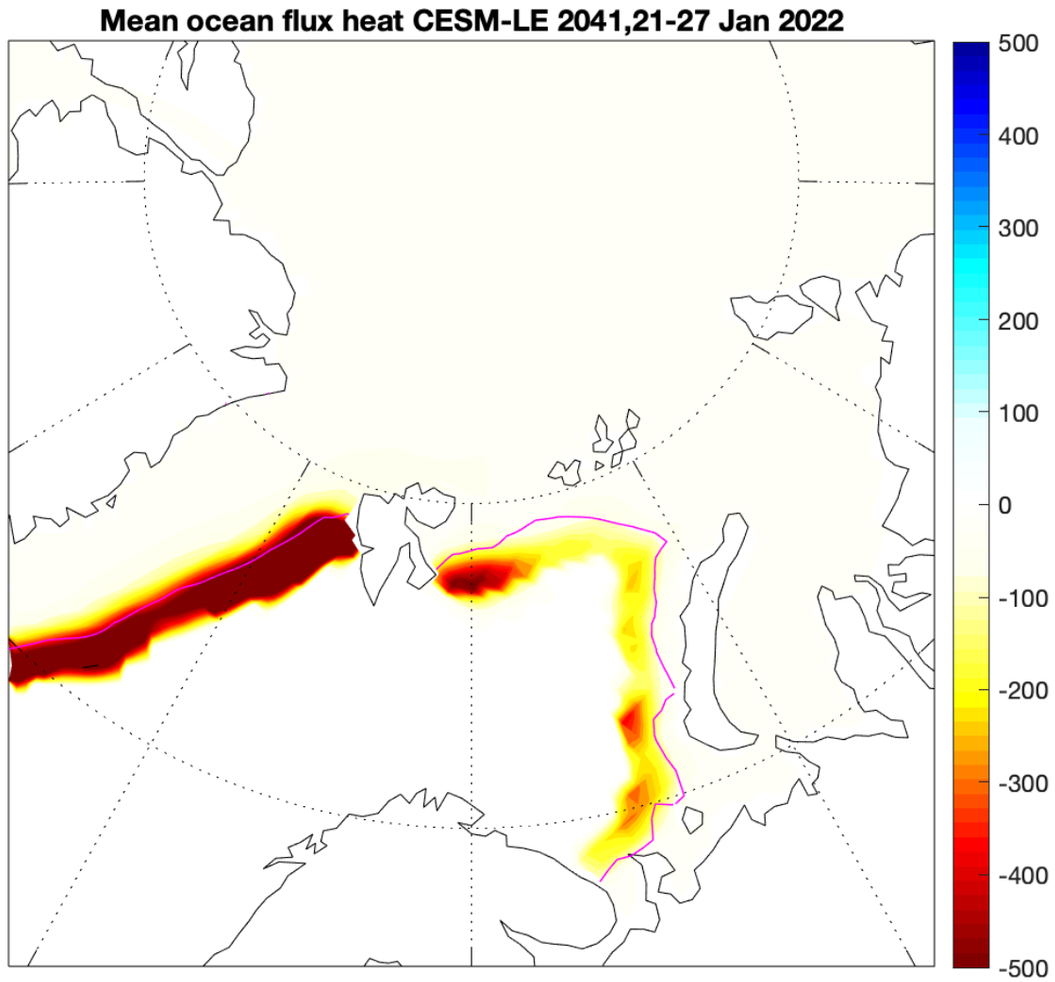


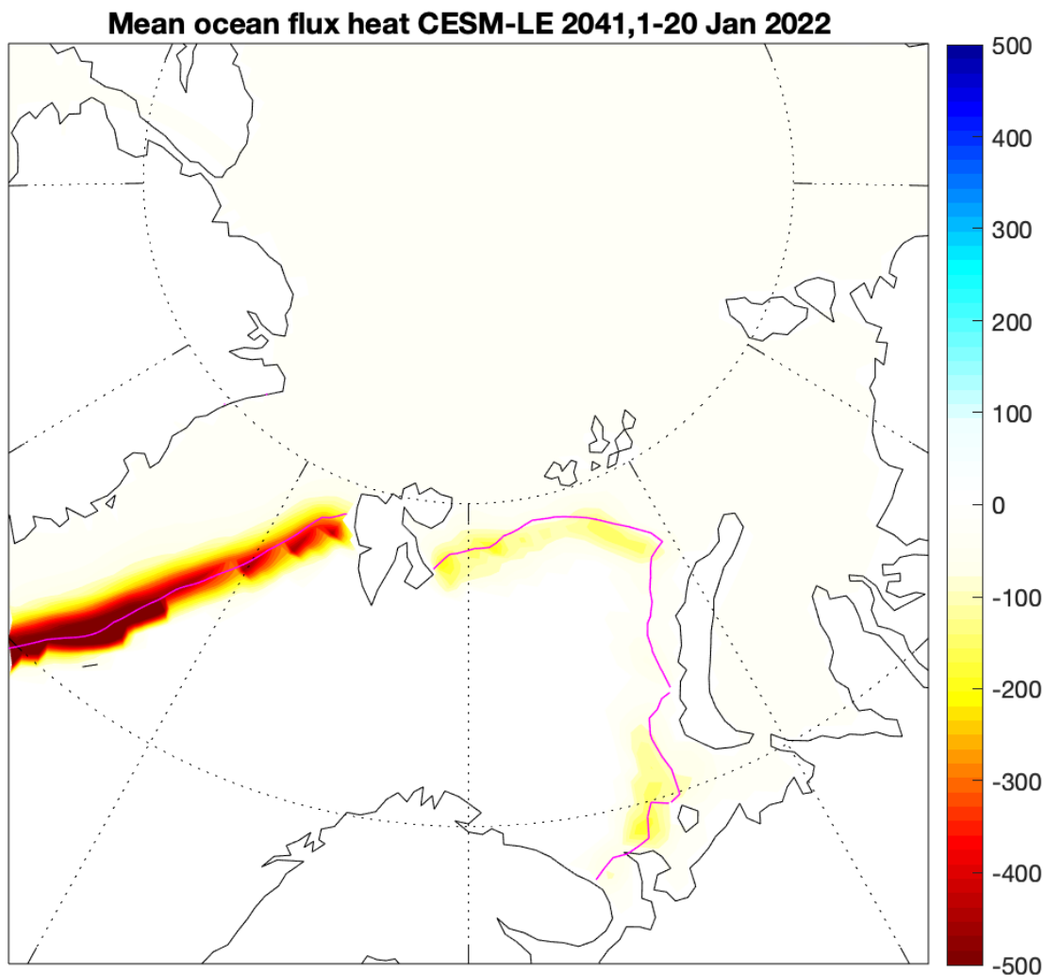


Total Bottom melt during cyclone

Total Bottom melt pre-cyclone in January 2022

Yet some evidence of cyclone's impact on bottom melt/ocean fluxes to ice in model runs

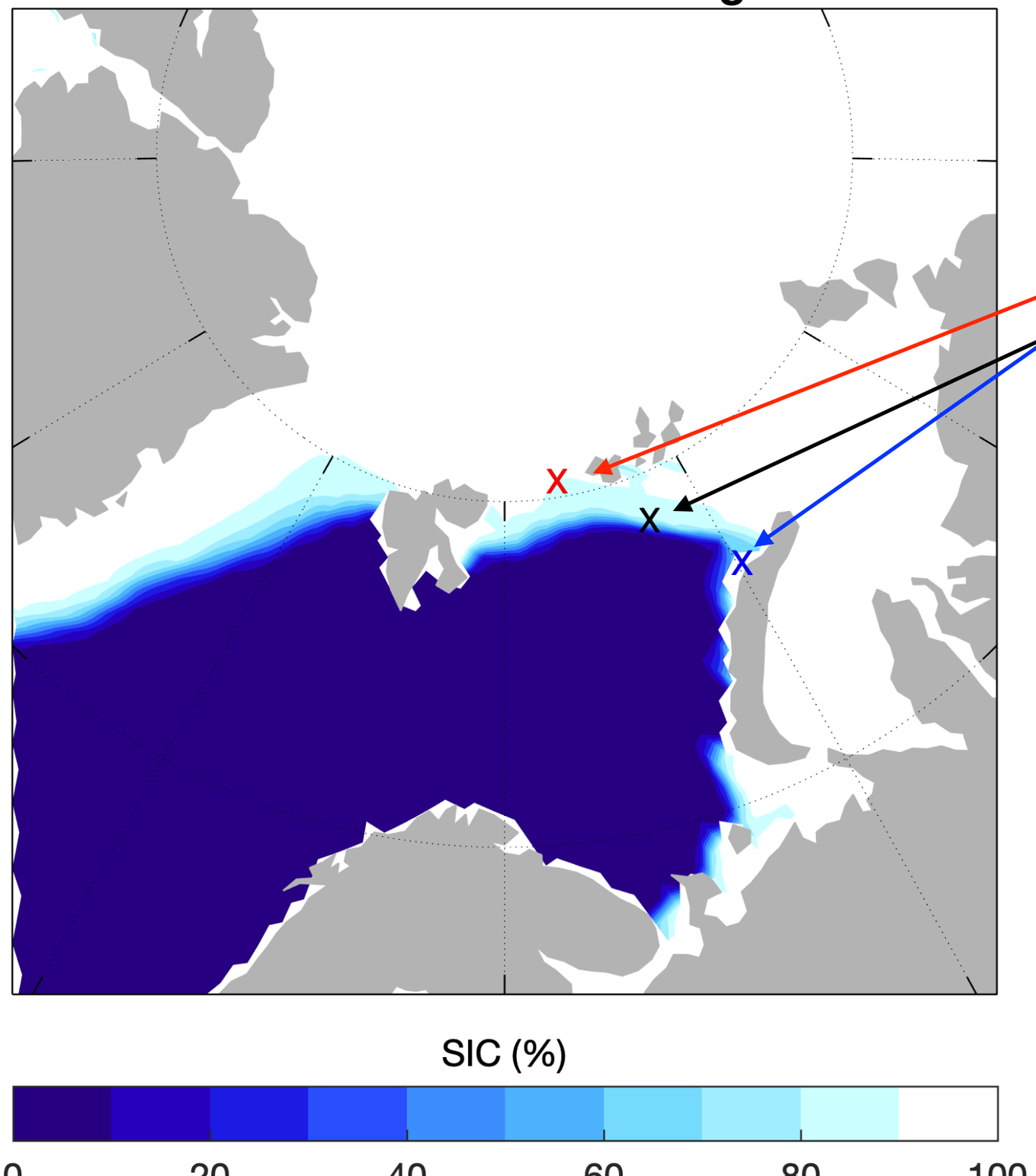




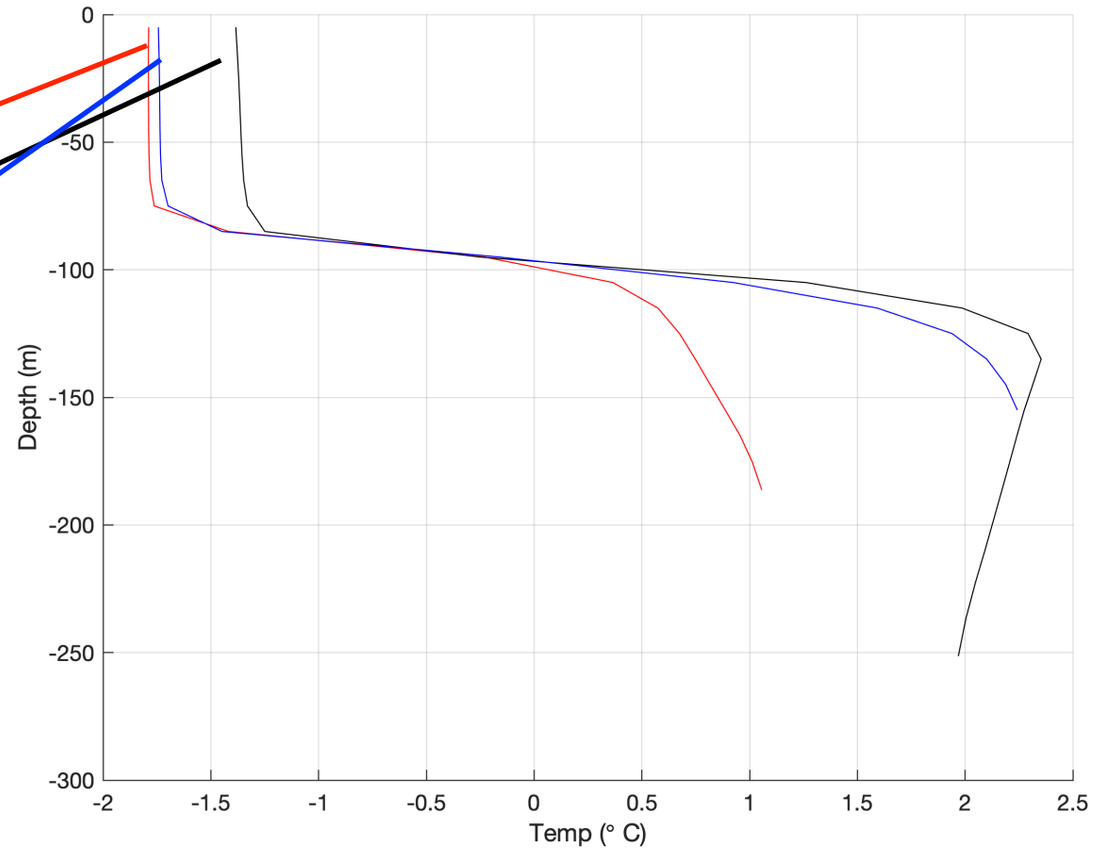
Mean heat flux ocean/ sea ice during cyclone

Mean heat flux ocean/ sea ice pre-cyclone

Impact of ocean mean state on sea ice changes



Ocean temp v depth



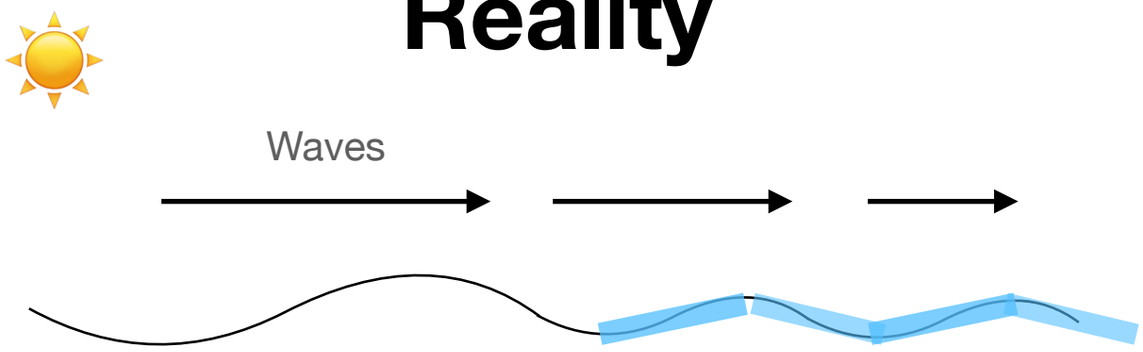
MLs are deep in MIZ in model

Did a shallower MLD in obs help melt sea ice?

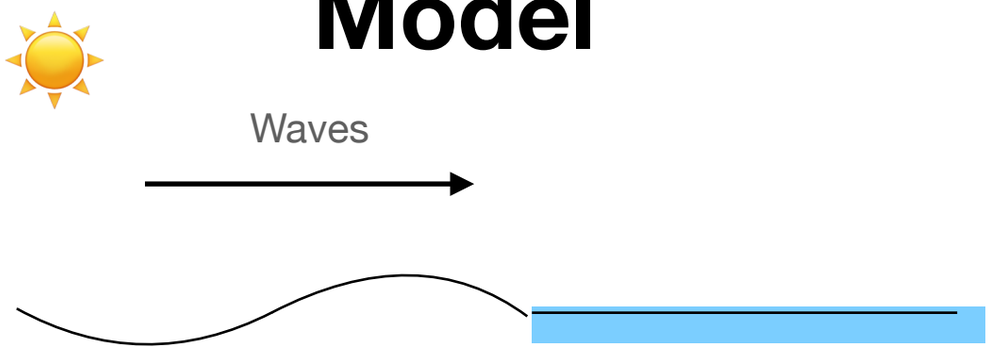
Extra slide

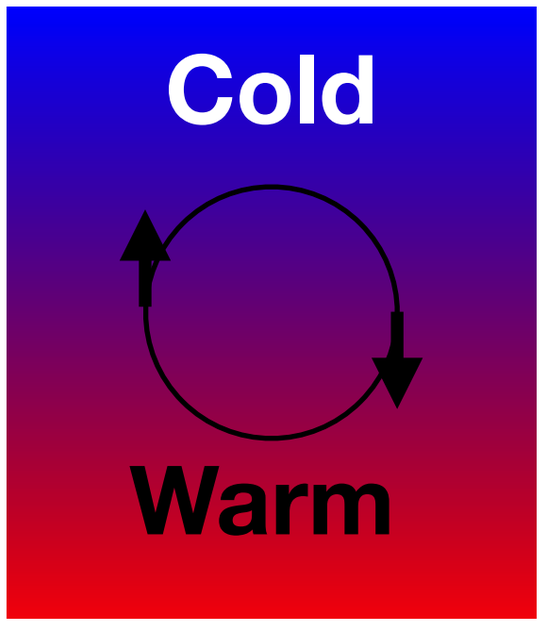
Waves & sea ice may matter

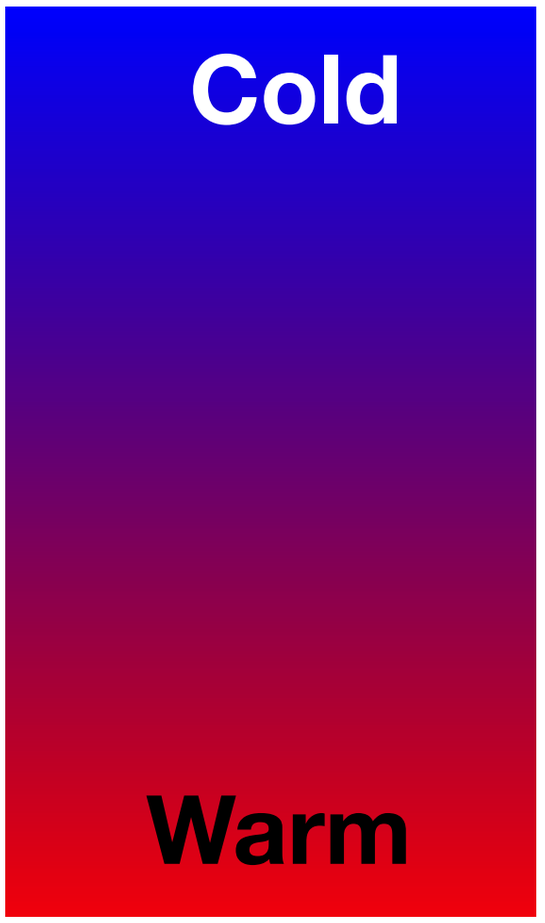
Reality



Model







Waves:

- **Break up ice floes**
- **Mix ocean below sea ice, enhancing heat flux to sea ice**