Arctic salinity processes and NASA's upcoming Salinity and Stratification at the Sea Ice Edge (SASSIE) experiment

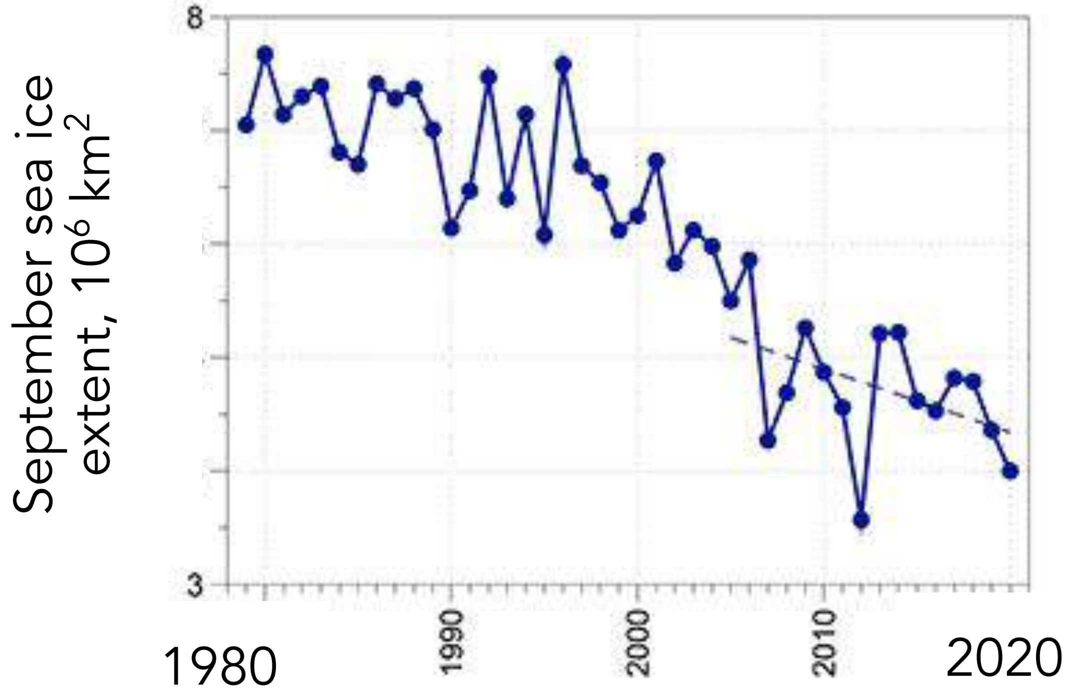
K. Drushka[1], F. Bingham[2], S. Brown[3], E. D'Asaro[1], A. deCharon[3], I. Fenty[4,5], S. Fournier[4], P. Gaube[1], T. Maksym[6], V. Menezes[6], S. Misra[4], J. Schanze[7], A. Shcherbina[1], M. Steele[1], J. Thomson[1], and S. Zippel[6]

1. Applied Physics Lab, Univ. of Washington. 2. Univ. of North Carolina Wilmington. 3. ODYSEA, LLC. 4. NASA JPL. 5. Caltech. 6. WHOI. 7. Earth & Space Research.

salinity.oceansciences.org/sassie.htm

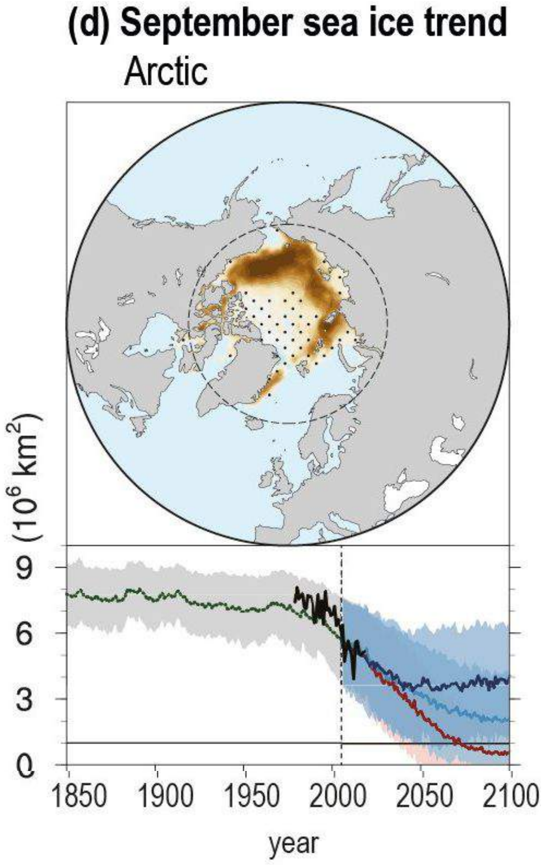
Arctic sea ice is declining dramatically

Sea ice extent, thickness, and volume are decreasing – at accelerating rates



Sea Ice Prediction Network, 2021

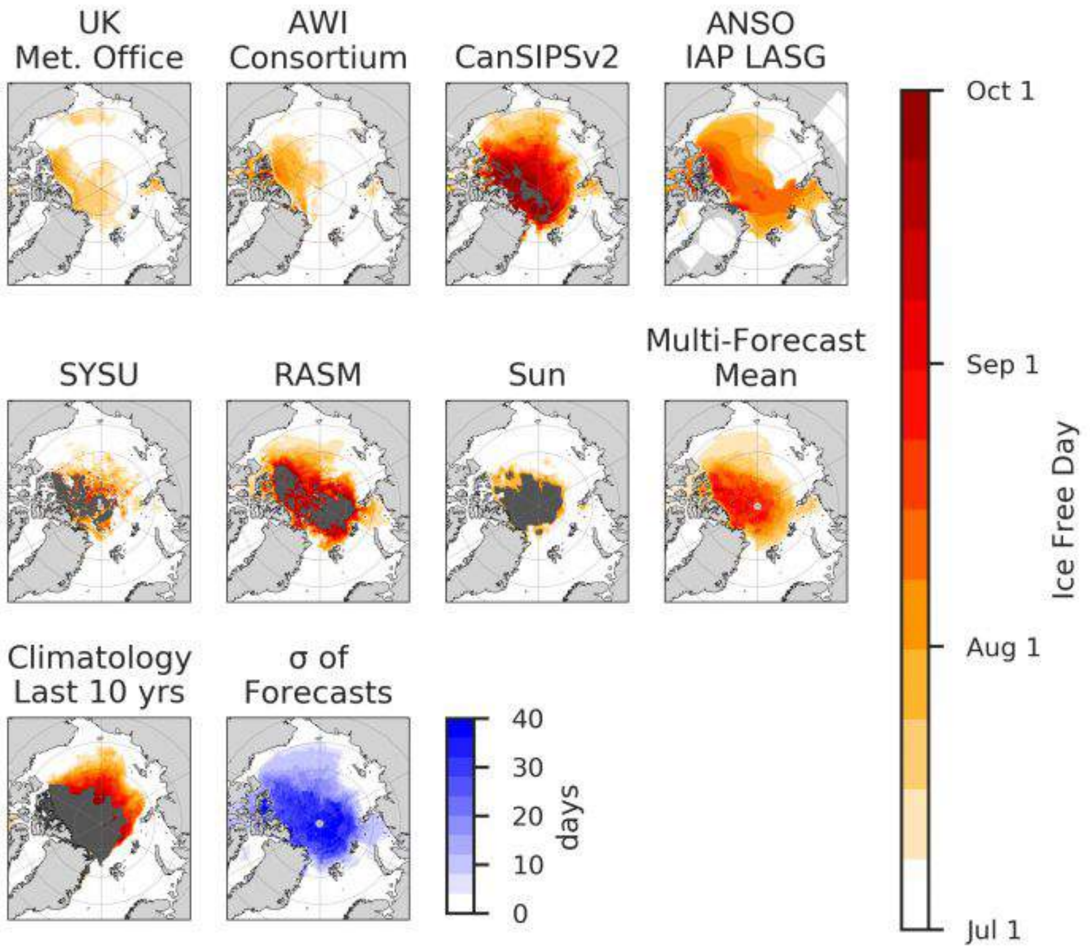
CMIP-6 models predict a nearly ice-free summer Arctic by 2050 under certain scenarios



IPCC Special Report on the Ocean and Cryosphere in a Changing Climate

Seasonal sea ice forecasts are a challenge – particularly regional forecasts

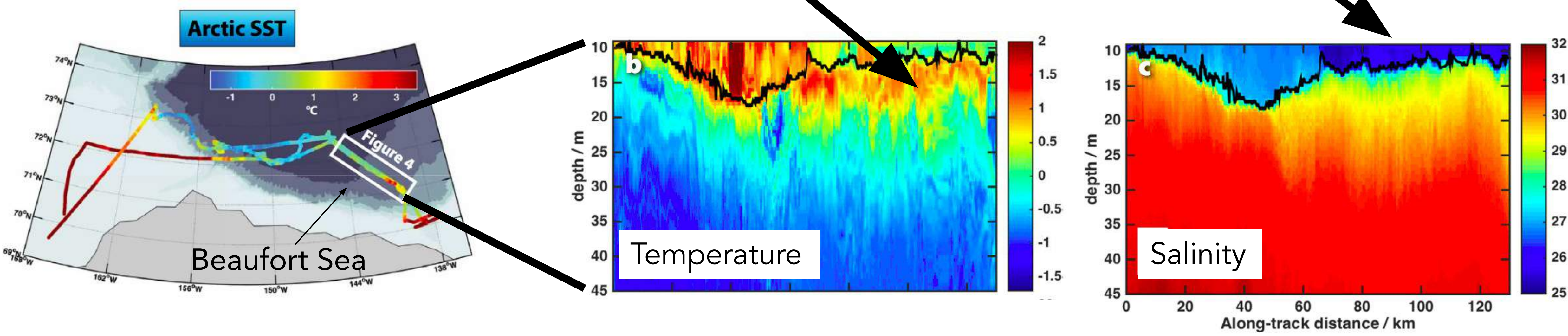
Forecast of 2021 ice free day for 7 different models.
Ice free defined as <15% sea ice concentration.



Improving prediction requires a better understanding of the physical processes, patterns, and timescales of sea ice formation & melt.

Sea Ice Prediction Network, 2021

In the Beaufort Sea, the upper ocean has low salinity and is well stratified, so heat is stored subsurface



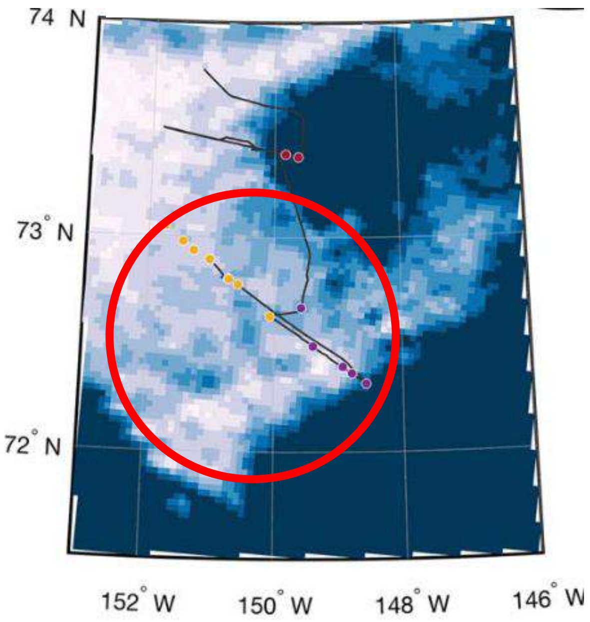
Disruption of this stratification can release stored heat, so processes affecting stratification (air-sea buoyancy & momentum fluxes, mixing, advection, etc.) can have a large impact on sea ice melt/growth

MacKinnon et al 2016

Disruptions to the near-surface salinity stratification can release stored heat, melting sea ice

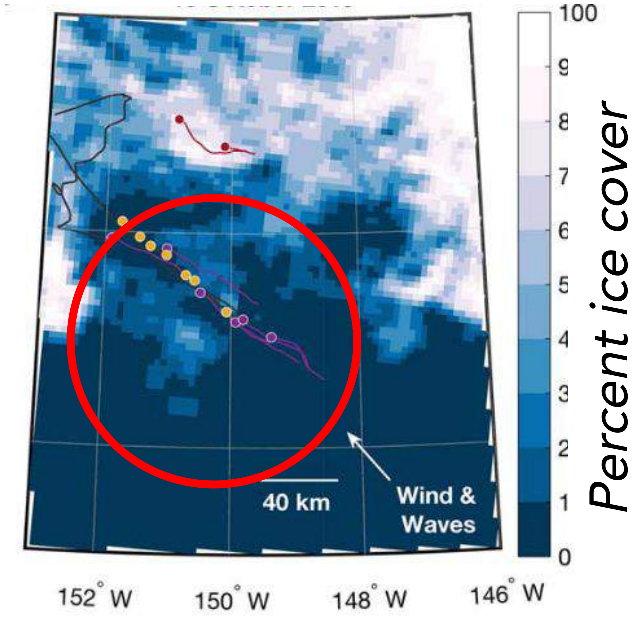
Sea ice concentration in the Beaufort Sea during the 2015 Sea State experiment

October 10



Large area of ice melt in 3 days

October 13



Autumn storm with strong winds/waves

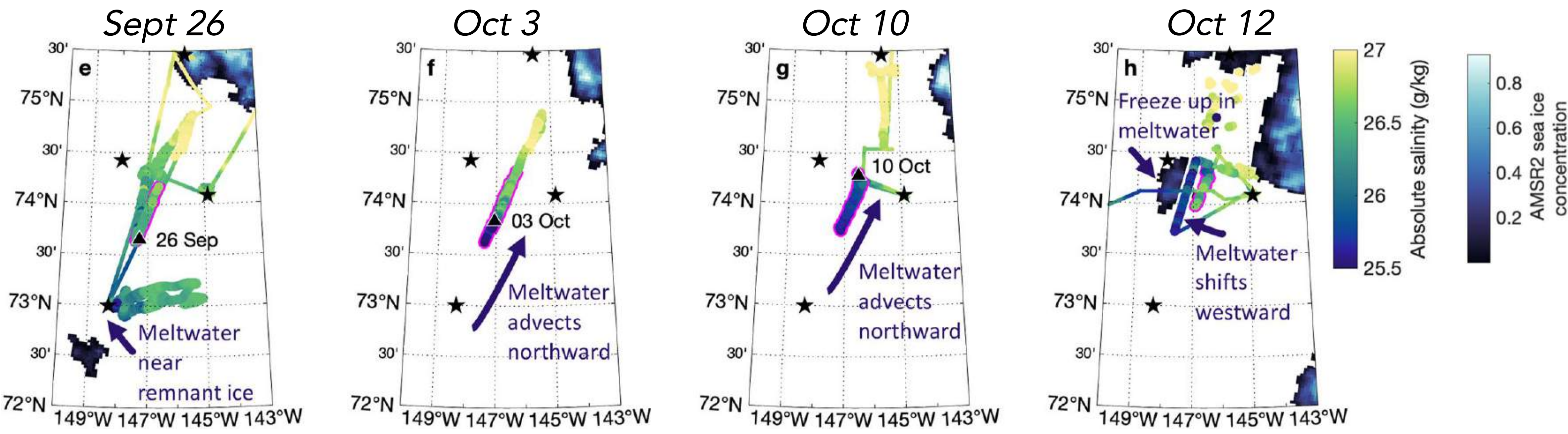
→ heat stored subsurface was mixed upward

→ thin, newly formed sea ice melted

Smith et al 2018

Enhanced salinity stratification can lead to earlier freeze-up in autumn

In situ salinity + satellite sea ice concentration in the Beaufort Sea during the 2018 SODA experiment



Melting sea ice produced a cold + fresh surface layer

→ meltwater advected northward, shoaling + cooling the mixed layer

→ ice formed 1 week earlier in the meltwater

Crews et al. 2022

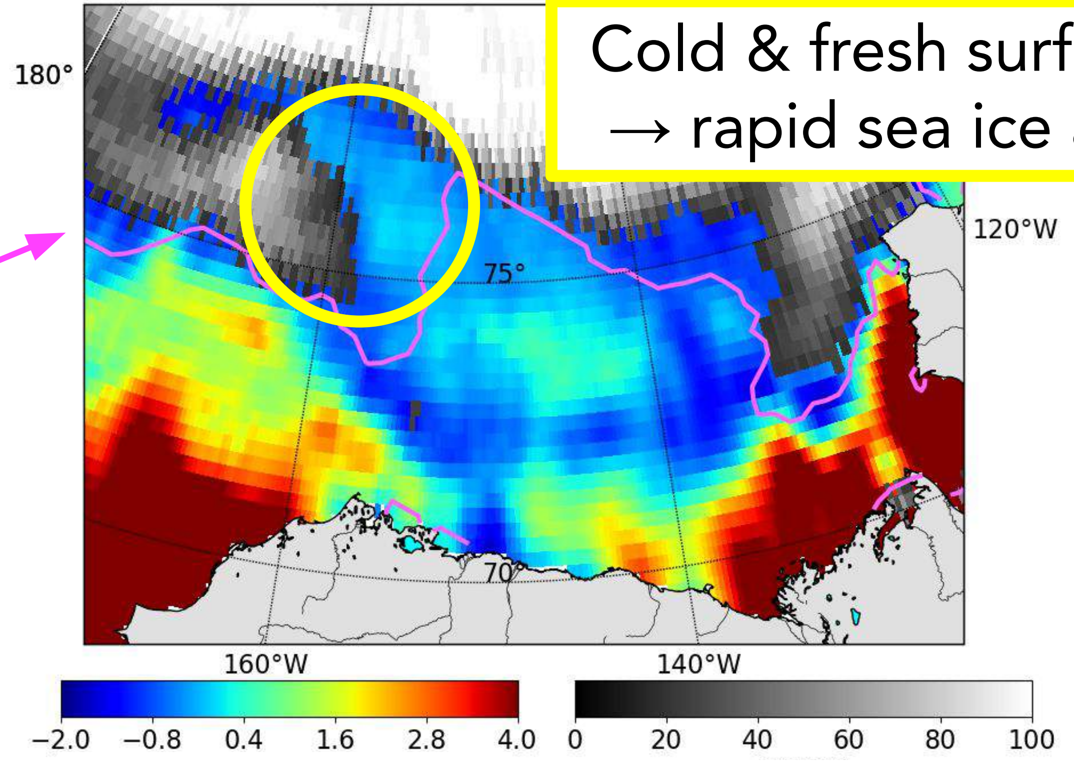
Satellite salinity data show evidence that the presence of a fresh and cold surface layer can precede rapid ice advance on large scales (2015 example)

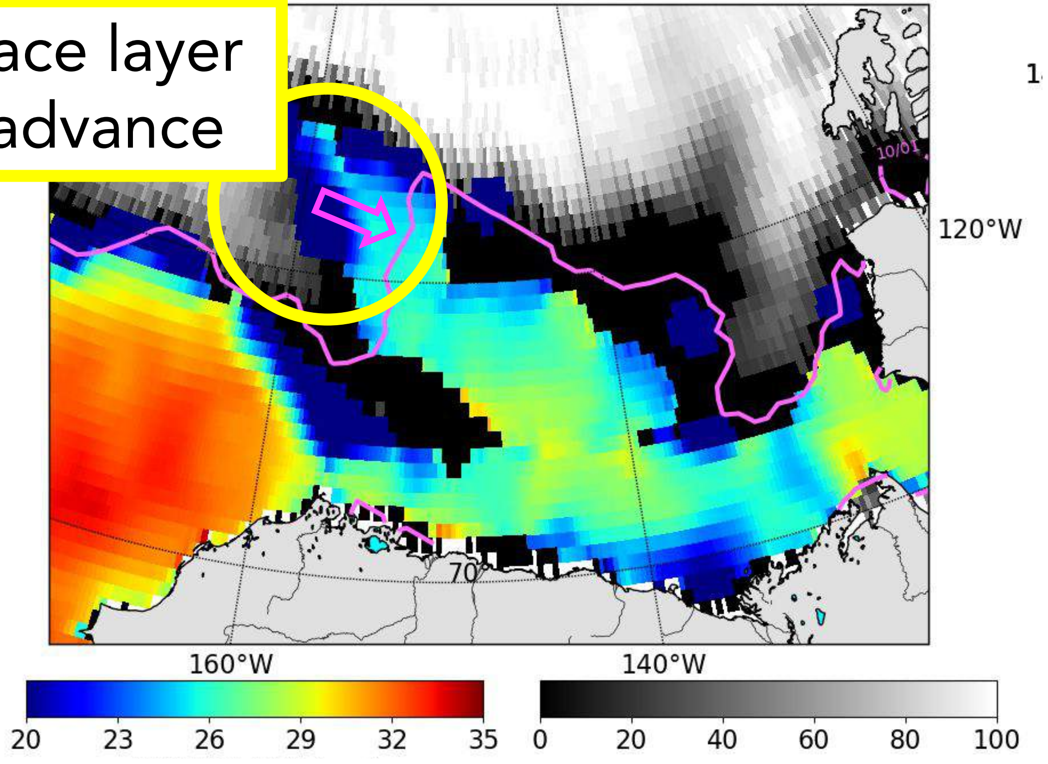
Sept 15 surface temperature (colors) & sea ice concentration (grey)

Sept 15 surface salinity (colors) & sea ice concentration (grey)

Cold & fresh surface layer
→ rapid sea ice advance

Oct 1 ice edge (i.e., two weeks later)





Courtesy of Severine Fournier

Hypothesis: late summer ice melt creates fresh layers that precondition the ocean for autumn ice advance

Mechanism:

Summer ice melt →

near-surface fresh layers with increased stratification →

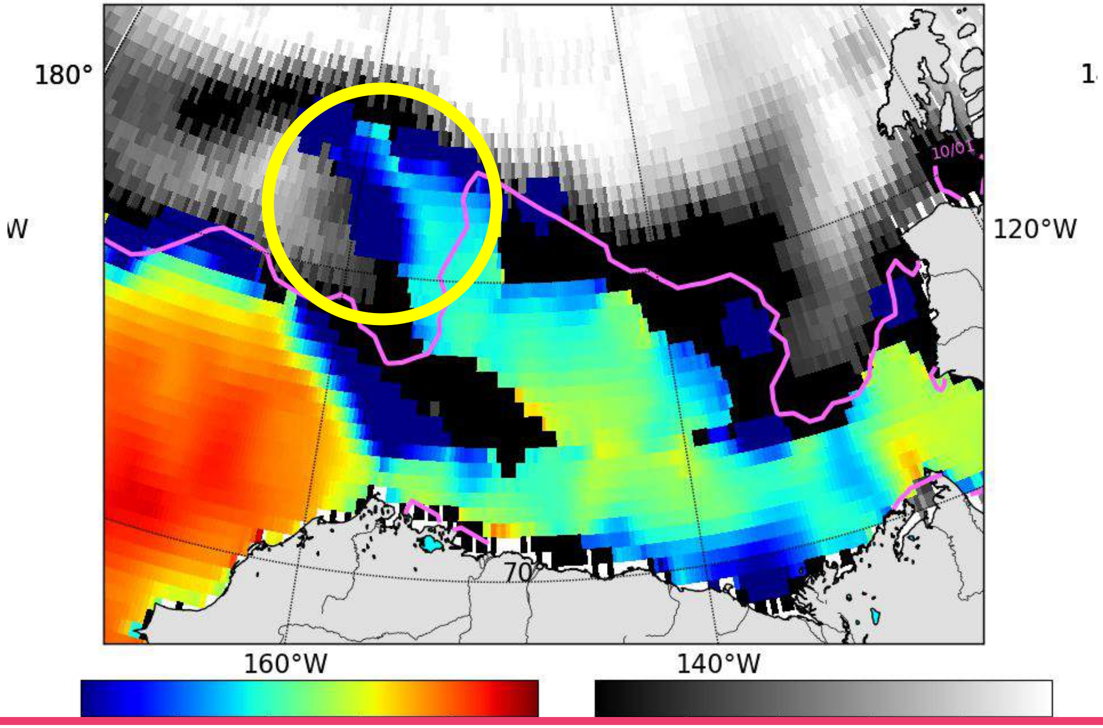
heat trapped subsurface →

SST cooling →

rapid sea ice advance in early autumn (if other conditions are also favorable)

Implies that SSS can be a predictor of autumn ice advance

SSS (colors) & sea ice conc. (grey)

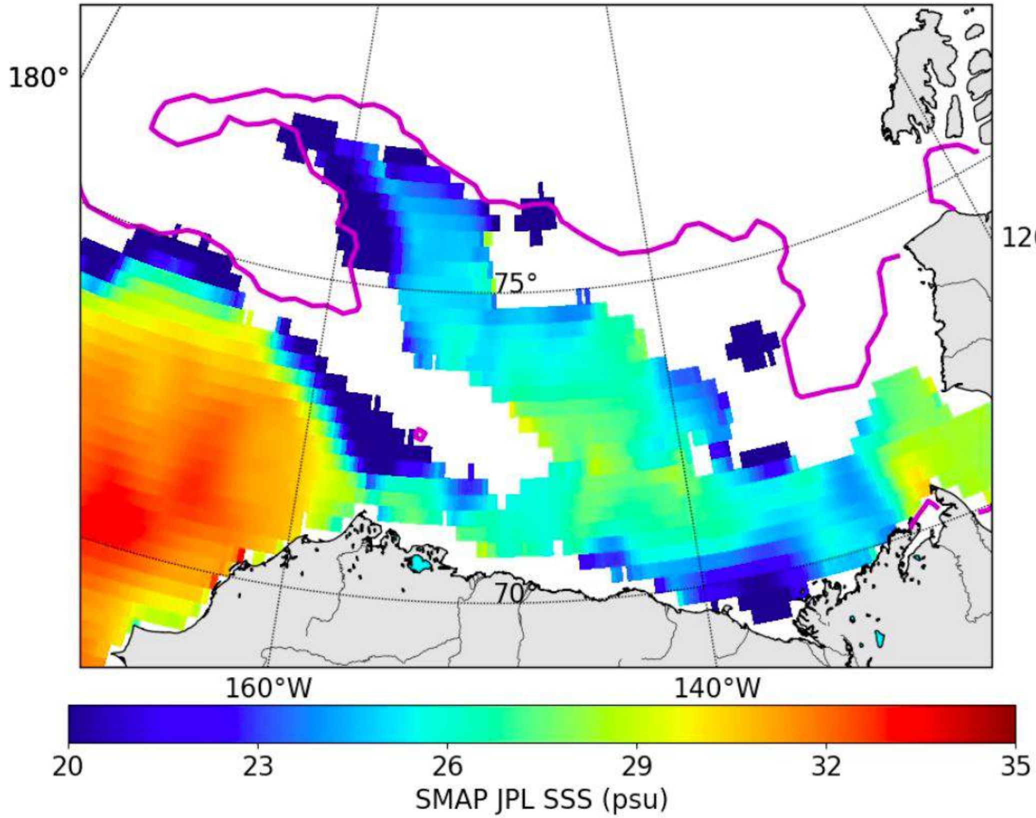


To test this hypothesis, SASSIE will measure and model the transition from summer melt to autumn advance in the Beaufort Sea in 2022

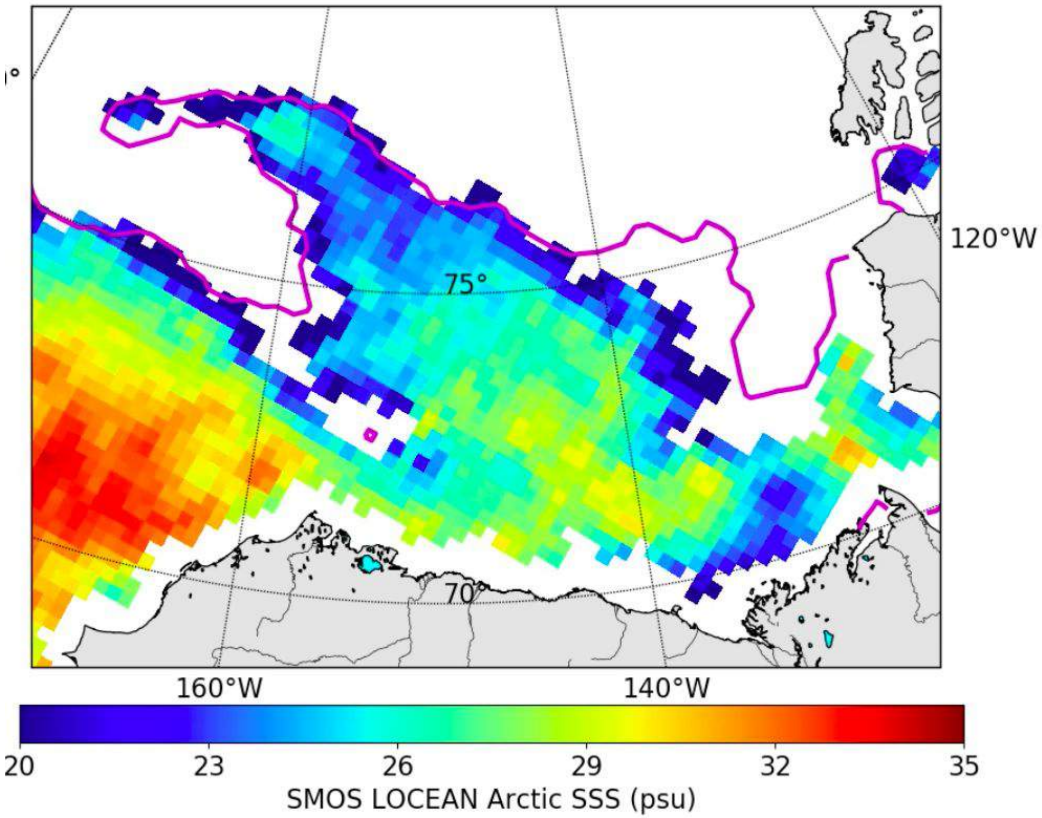
rnier

Satellite SSS retrievals are complicated near the "ice edge"; SMAP & SMOS have significant differences (though latest products are improved)

SSS (SMAP-JPL v5)



SSS (SMOS-LOCEAN Arctic)



Courtesy of Severine Fournier

Major goals & questions of SASSIE

1. Quantify the salinity anomalies generated by melting ice, how they evolve in time & space, and how they affect stratification, SST, and subsequent ice advance
    - How does sea ice meltwater impact stratification and heat storage?
    - How does that stratification erode or persist over summer in the presence of winds, waves, and ocean dynamics?

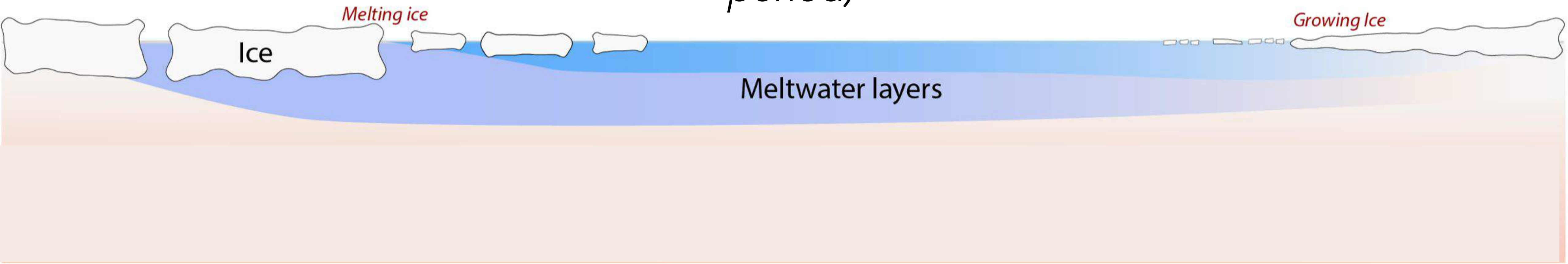
2. Collect data to enable improved satellite salinity retrievals in polar oceans
    - How does the upper ~1 cm measured by satellites relate to deeper values?
    - How can satellite SSS and SST inform us about Arctic upper ocean evolution?
    - Can we better predict autumn ice advance by incorporating salinity measurements?

SASSIE will have three main phases this summer:

August:
melt

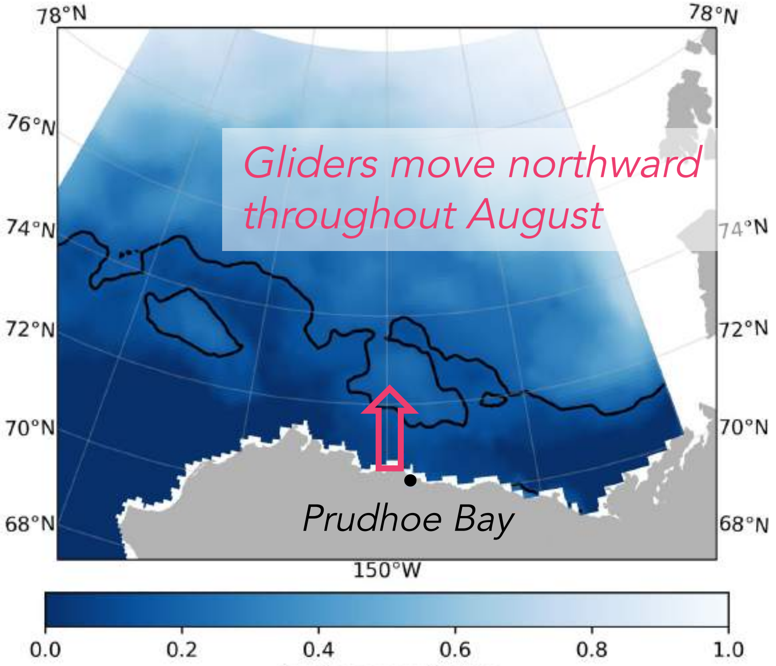
September:
transition
(intensive observing period)

October:
freeze-up



August: A fleet of four Wave Gliders will sample the emerging open ocean as the sea ice retreats, depositing fresh meltwater layers

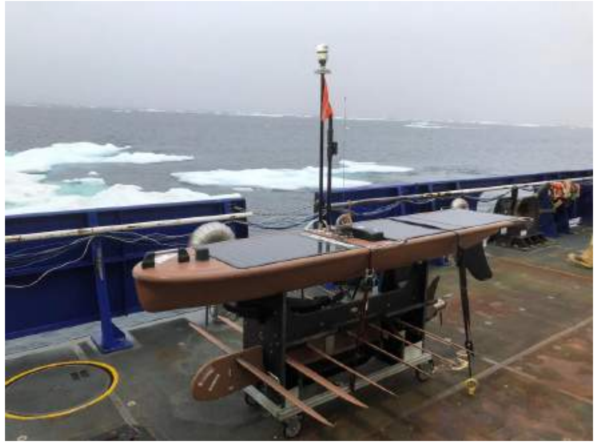
Mean Aug 15 sea ice concentration



Sea ice concentration

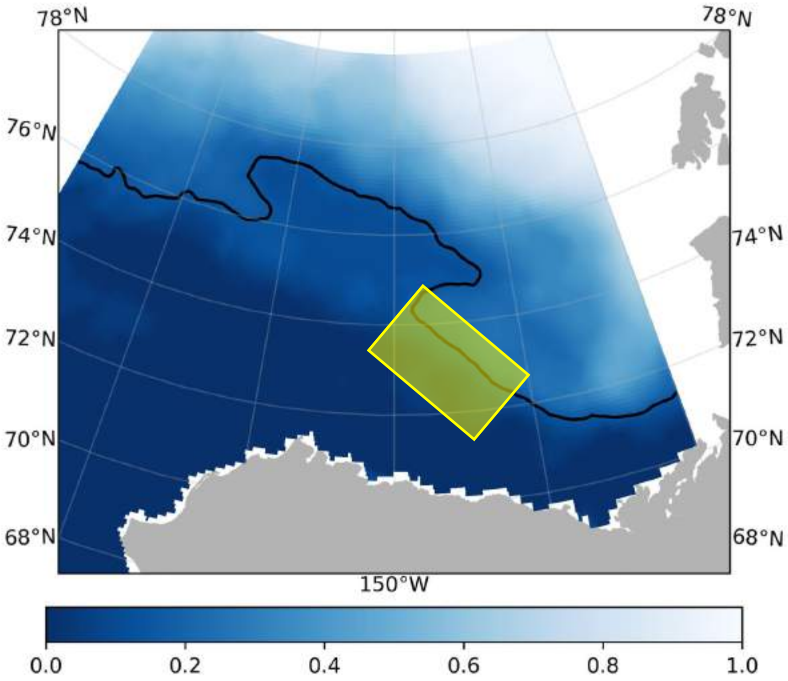
Black contour: 15% SIC

Wave Glider



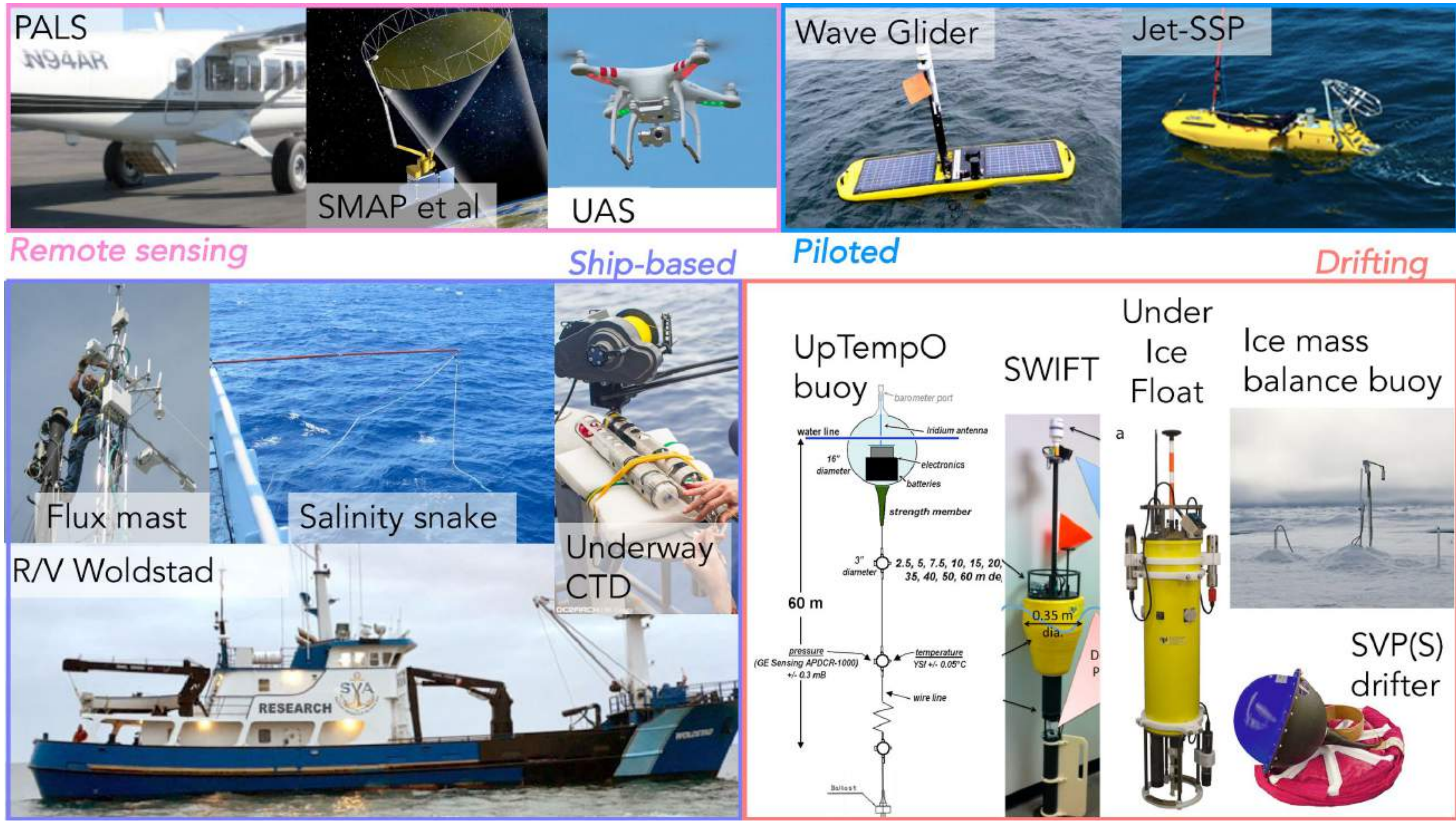
September: Intensive observations within ~200 km of the ice edge with a ship, piloted surface vehicles, drifters & floats, and aircraft, drones, & satellites

Mean Sept 15 sea ice concentration



Sea ice concentration

Black contour: 15% SIC



Eulerian and Lagrangian observations on nested to capture dynamics on O(0.1–100) km scales

Key observations and *measurement platforms*

Ocean temperature, salinity, velocity (surface through ~200m)

Ship, surface vehicles, under ice float, drifters

Surface salinity, temp, and wind from the PALS airborne sensor

Air-sea fluxes

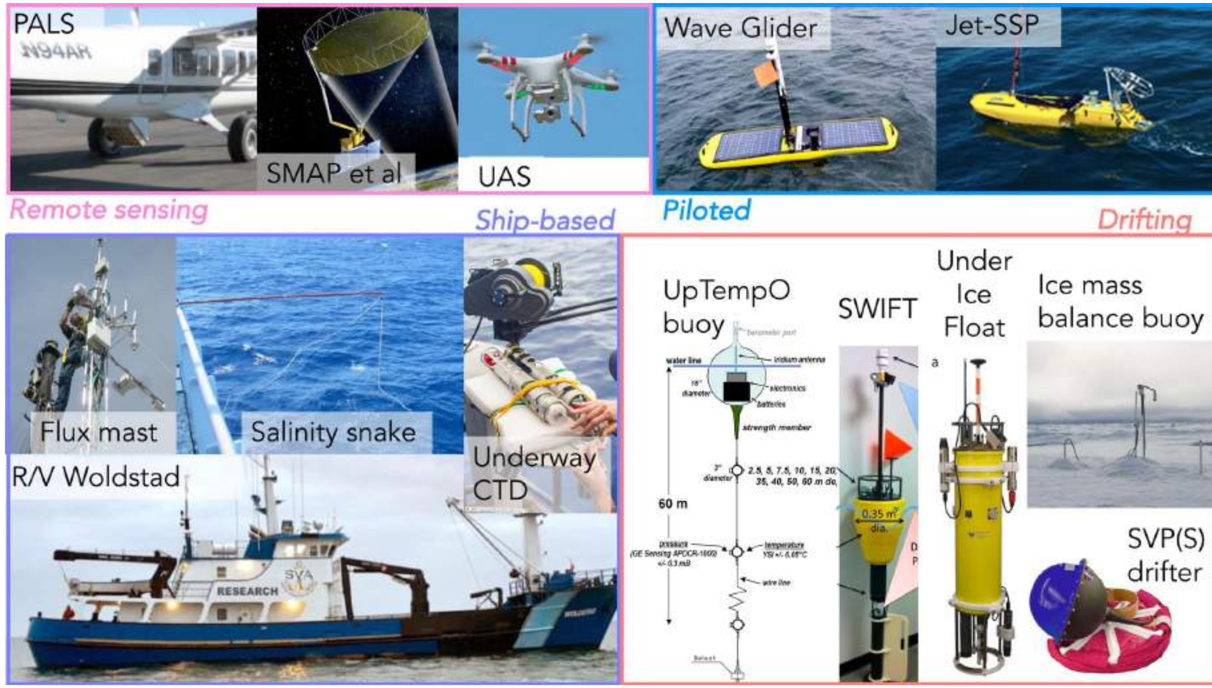
Ship, Wave Gliders

Surface waves

SWIFT drifters

Sea ice properties

Ice mass balance buoys; aircraft & drone; satellite microwave and SAR



October: Drifters and floats will remain in the water to sample early stages of freeze-up

Ocean temperature, salinity, velocity (surface through ~100m)

under ice float, drifters

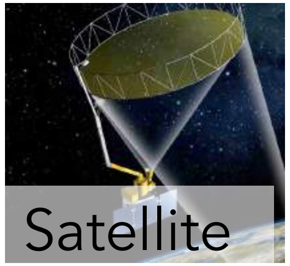
Surface waves

SWIFT drifters

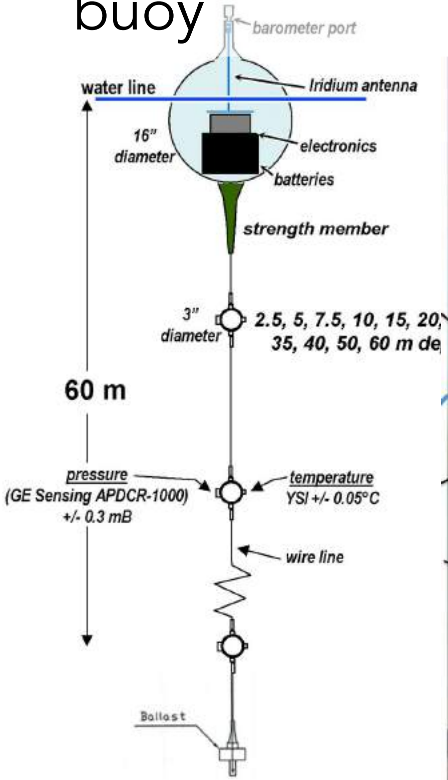
Sea ice properties

Ice mass balance buoys;

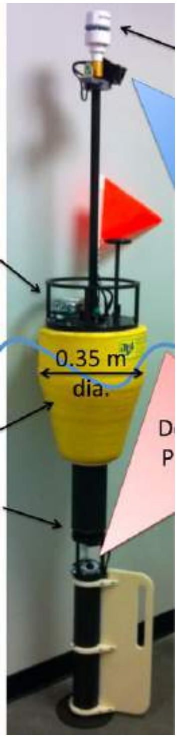
satellite microwave and SAR



UpTempO buoy



SWIFT



Under Ice Float

Ice mass balance buoy

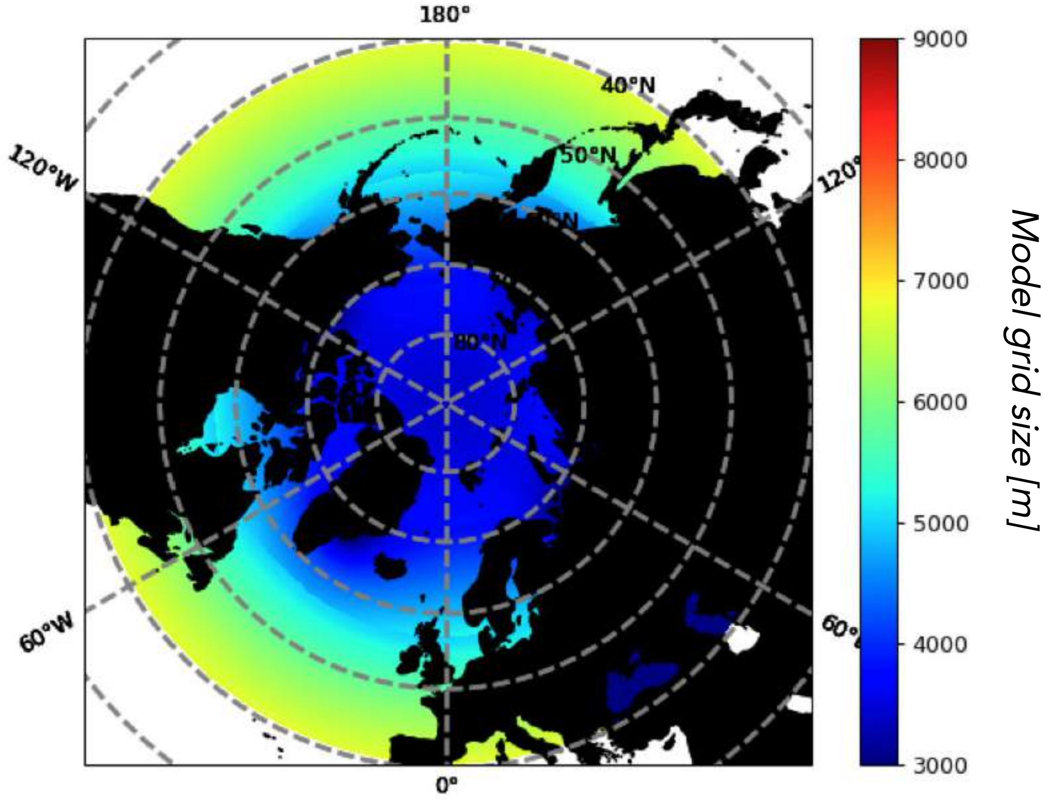
SVP(S) drifter

Model simulations will be used for planning, hypothesis testing, and sensitivity experiments

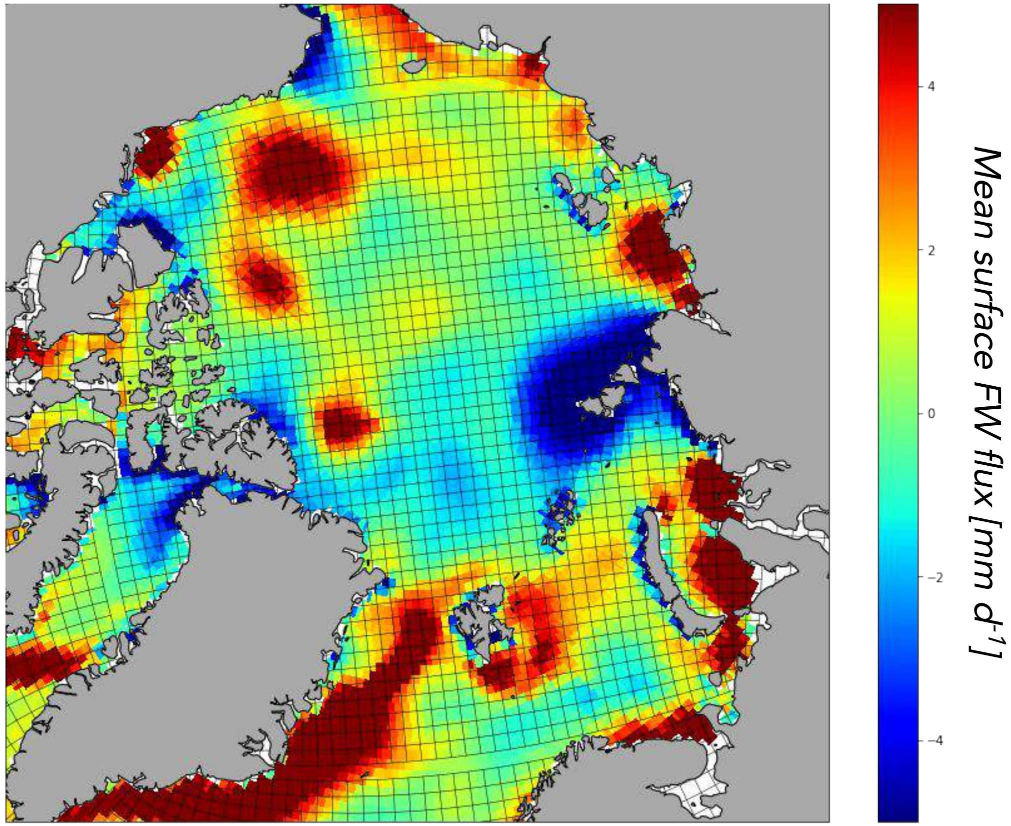
N0: Global ECCO dx=13 km

Two nested ocean model configurations, starting with global ECCO V5 (N0).
Vertical grid spacing 1-10 m in the upper 90 m
Available at https://ecco.jpl.nasa.gov/drive/files/ECCO2/SASSIE

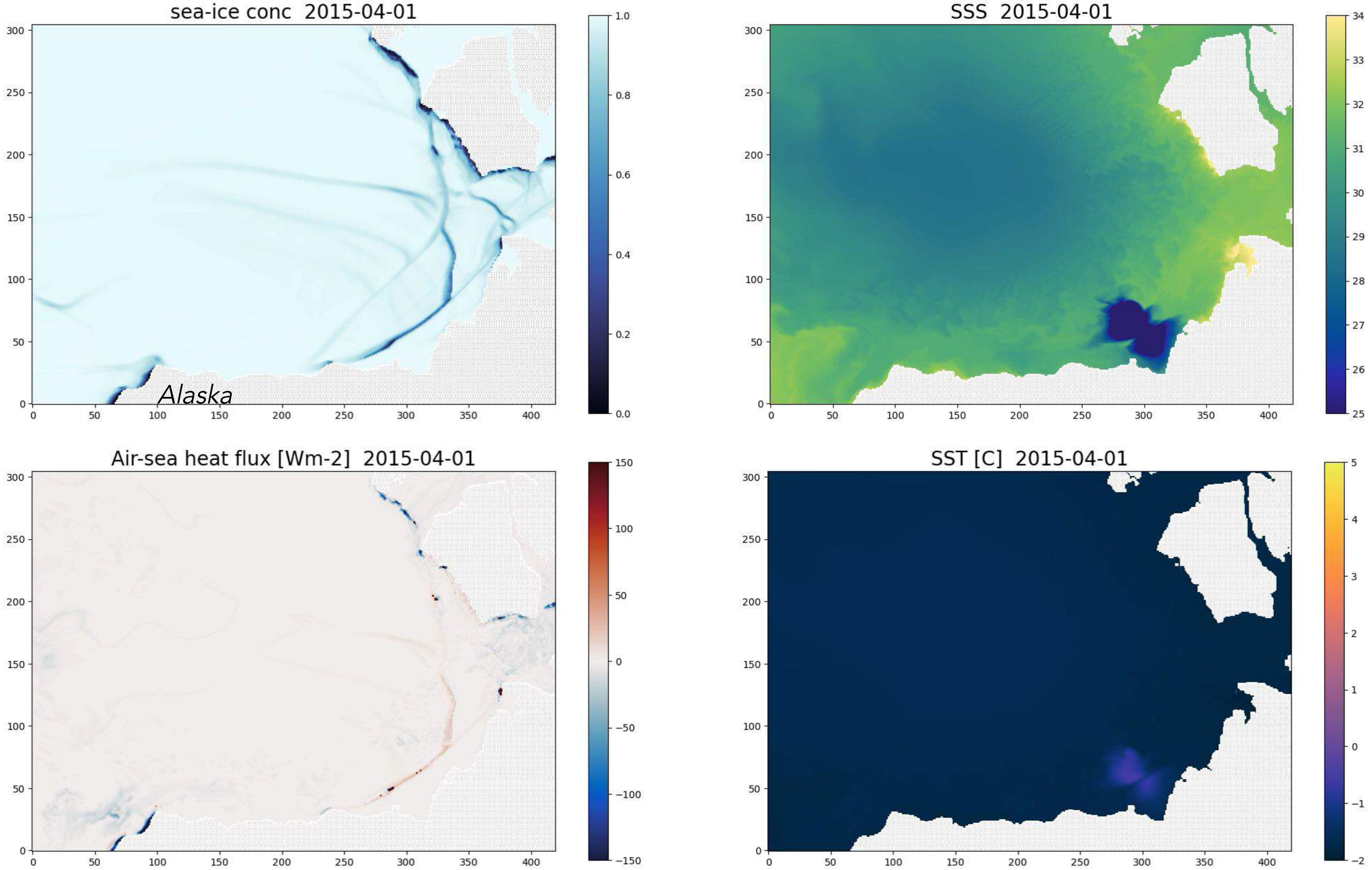
N1. Northern Hemisphere from 41N with 3.5 km grid spacing

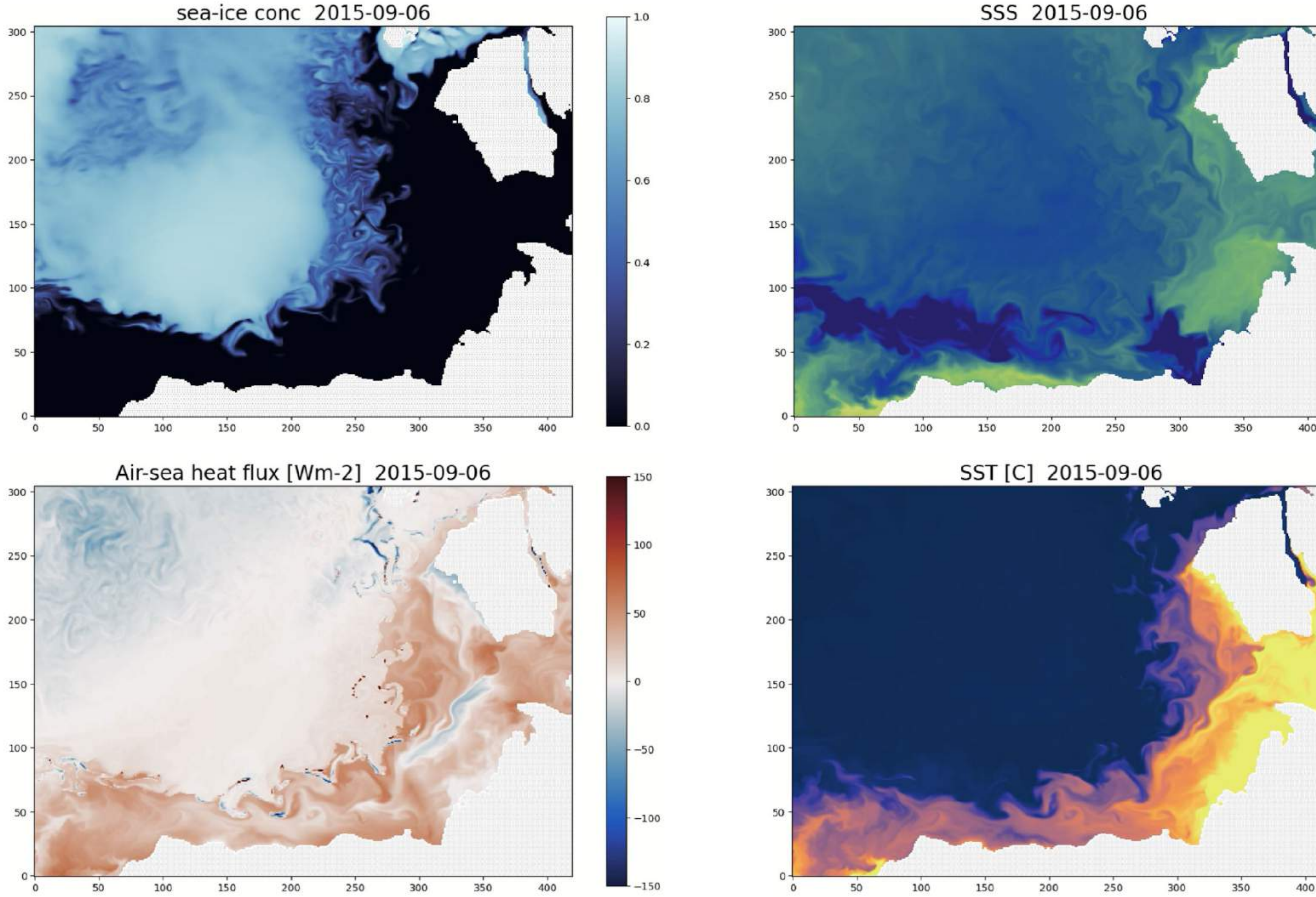


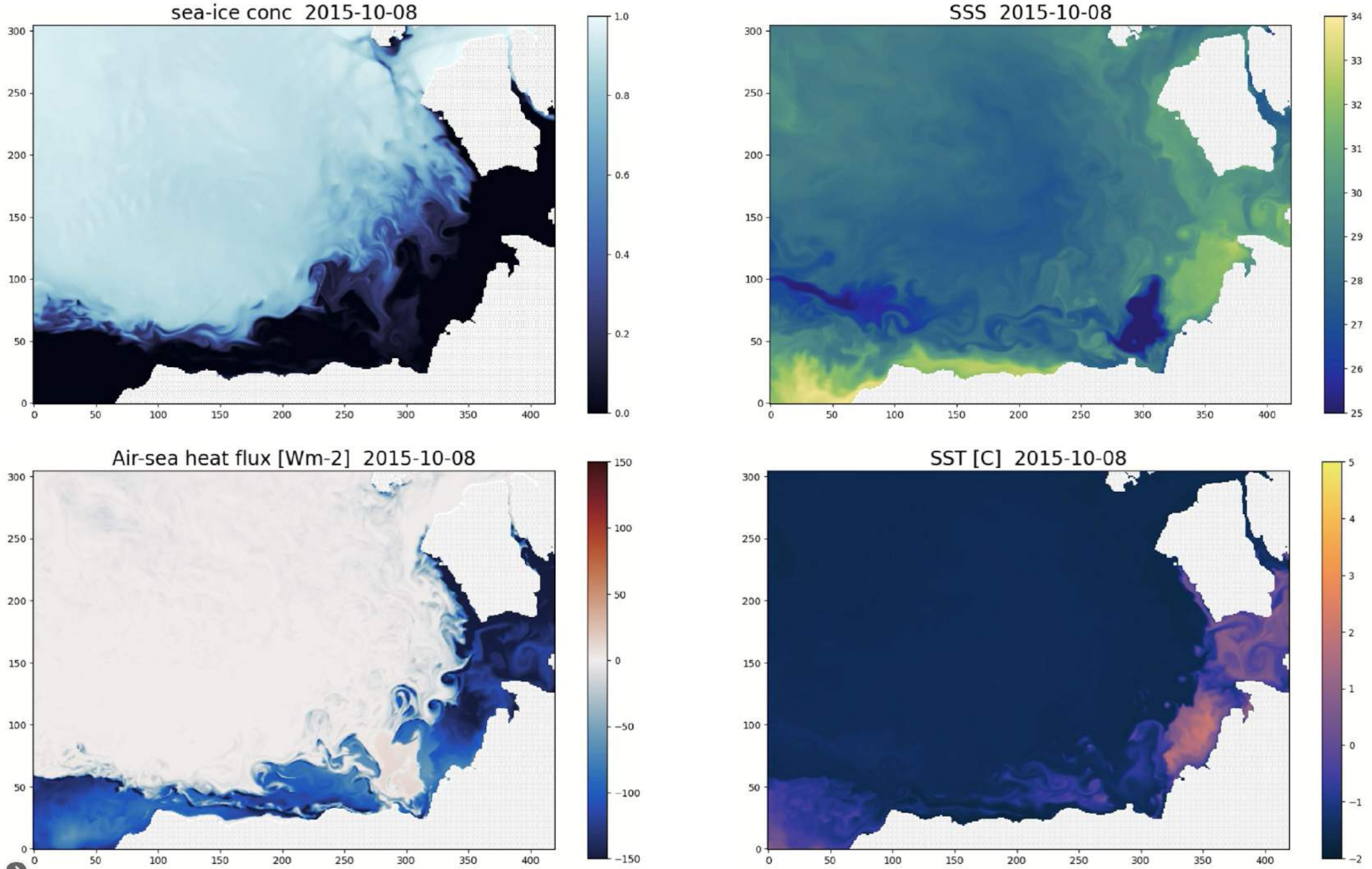
N2: Arctic Ocean setup, 1.2 km grid spacing



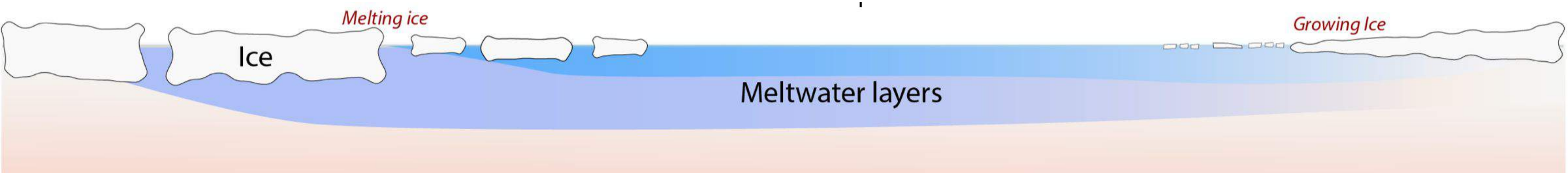
Courtesy of Ian Fenty


sea-ice conc 2015-04-01
Alaska
0.0
0.2
0.4
0.6
0.8
1.0
SSS 2015-04-01
25
26
27
28
29
30
31
32
33
34
Air-sea heat flux [Wm-2] 2015-04-01
−150
−100
−50
0
50
100
150
SST [C] 2015-04-01
−2
−1
0
1
2
3
4
5


sea-ice conc 2015-09-06
SSS 2015-09-06
Air-sea heat flux [Wm-2] 2015-09-06
SST [C] 2015-09-06
0 50 100 150 200 250 300
0 50 100 150 200 250 300 350 400
0.0 0.2 0.4 0.6 0.8 1.0
25 26 27 28 29 30 31 32 33 34
−150 −100 −50 0 50 100 150
−2 −1 0 1 2 3 4 5


sea-ice conc 2015-10-08
SSS 2015-10-08
Air-sea heat flux [Wm-2] 2015-10-08
SST [C] 2015-10-08
0 50 100 150 200 250 300 350 400
0 50 100 150 200 250 300
0.0 0.2 0.4 0.6 0.8 1.0
25 26 27 28 29 30 31 32 33 34
−150 −100 −50 0 50 100 150
−2 −1 0 1 2 3 4 5

Summary



Salinity variations can have important consequences for Arctic sea ice dynamics.

SASSIE will focus on understanding the evolution of salinity & stratification in the Beaufort Sea during the transition from summer melt to autumn ice advance.

Measurements will be used to understand dynamics and improve satellite salinity retrievals.

All data will be made available on the NASA PO.DAAC in spring 2023.

https://salinity.oceansciences.org/sassie.htm
kdrushka@apl.uw.edu