Mechanisms of Autumn Sea Ice Advance in the Western Arctic

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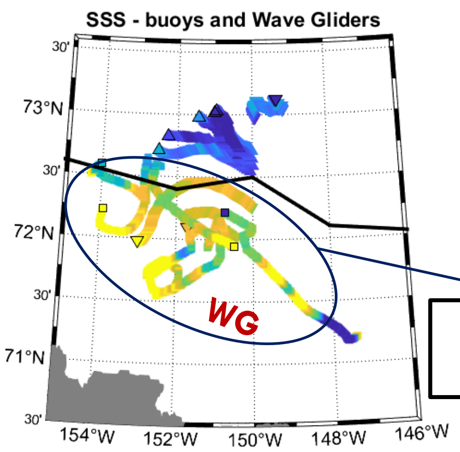
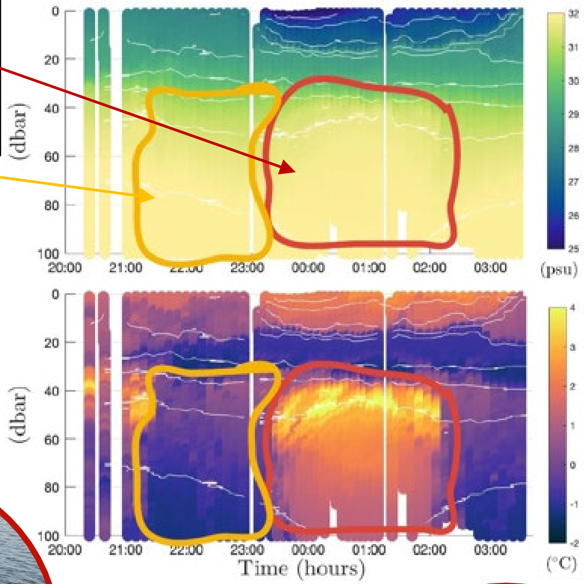
Salinity and Stratification at the Sea Ice Edge

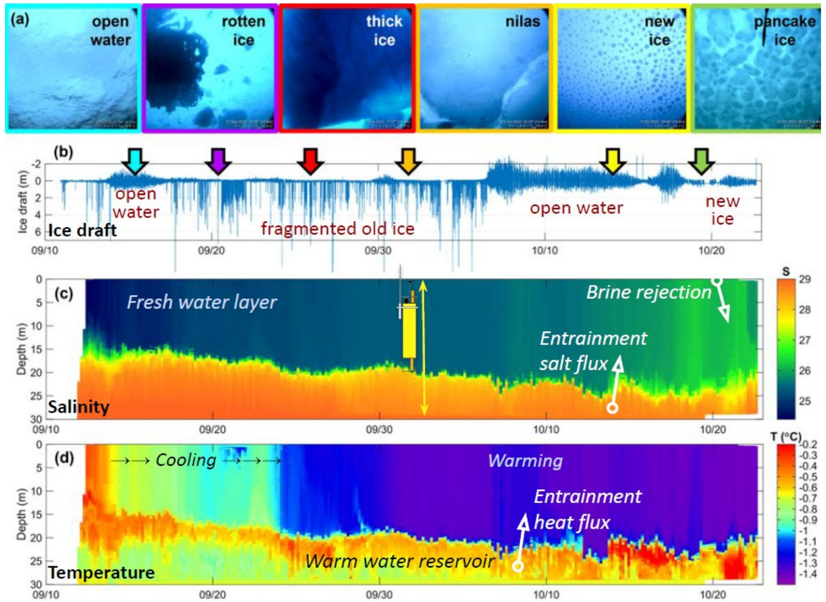


Two classes of PSW observed
Saltier (red) and
Fresher (yellow)

“small scale” S gradients

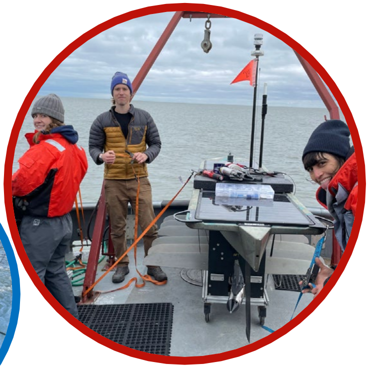
By: Carlyn Schmidgall

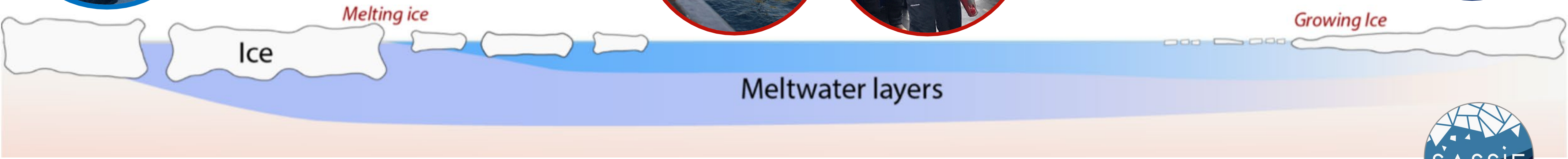




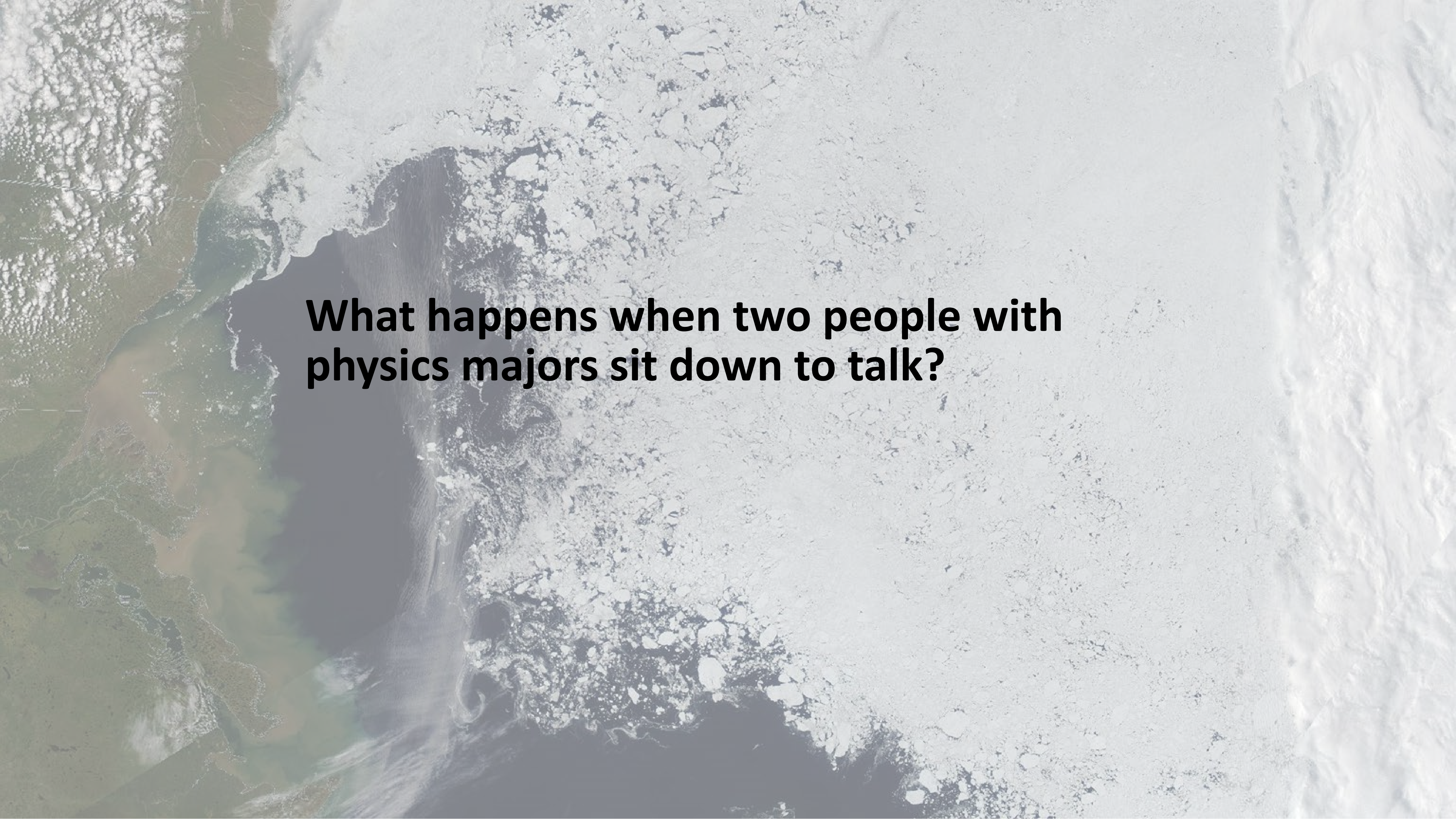
SASSIE Under Ice Float observed salinity stratification supporting refreezing

By: Andrey Scherbina





Hypothesis: Fresh layers at the surface precondition the ocean for fall sea ice advance


What happens when two people with physics majors sit down to talk?


"Well… you know…
what makes sea ice advance?"
<--- Mike

2024/07/11
Aqua MODIS

Tackling a complicated problem in a simplified form….

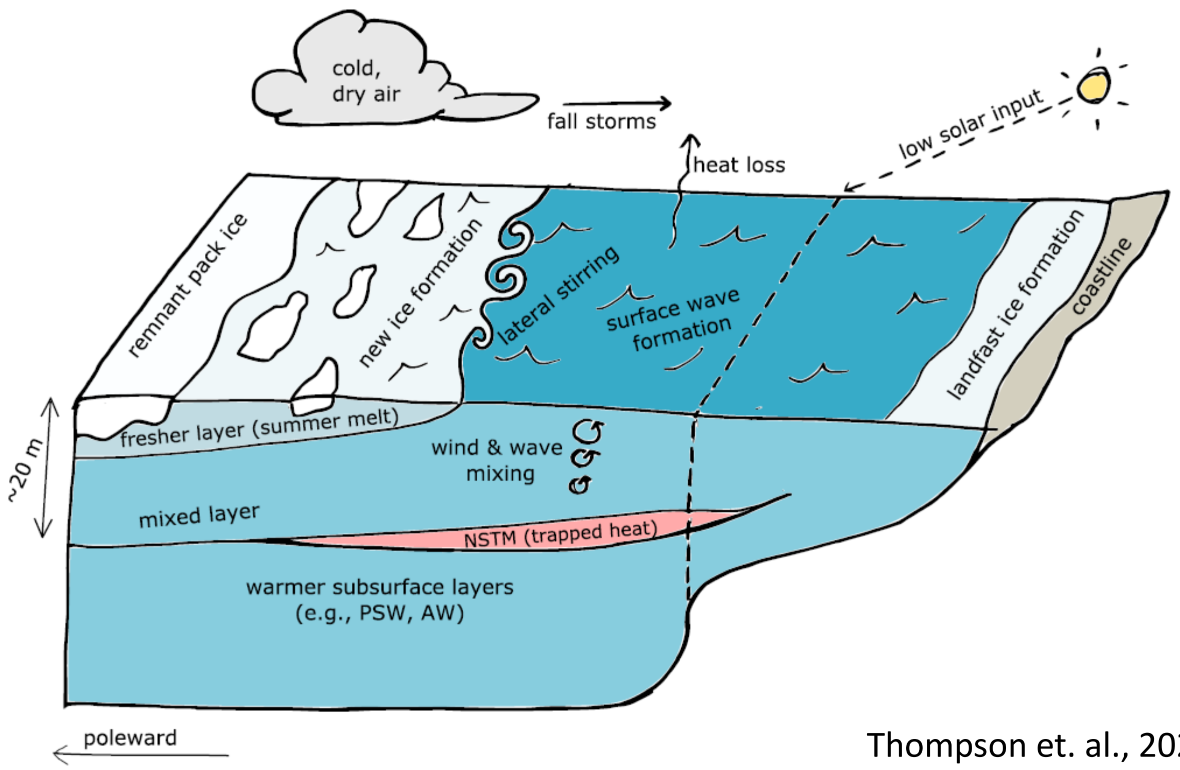
Dynamics — Thermo

$$\Delta h = \Delta ha + \Delta hp$$
$$\Delta V = E + P$$

$$\Delta h_a = -\nabla \cdot (\mathbf{u}\mathrm{h})$$

PIOMAS: Pan-Arctic Ice Ocean Modeling ~~and Assimilation~~

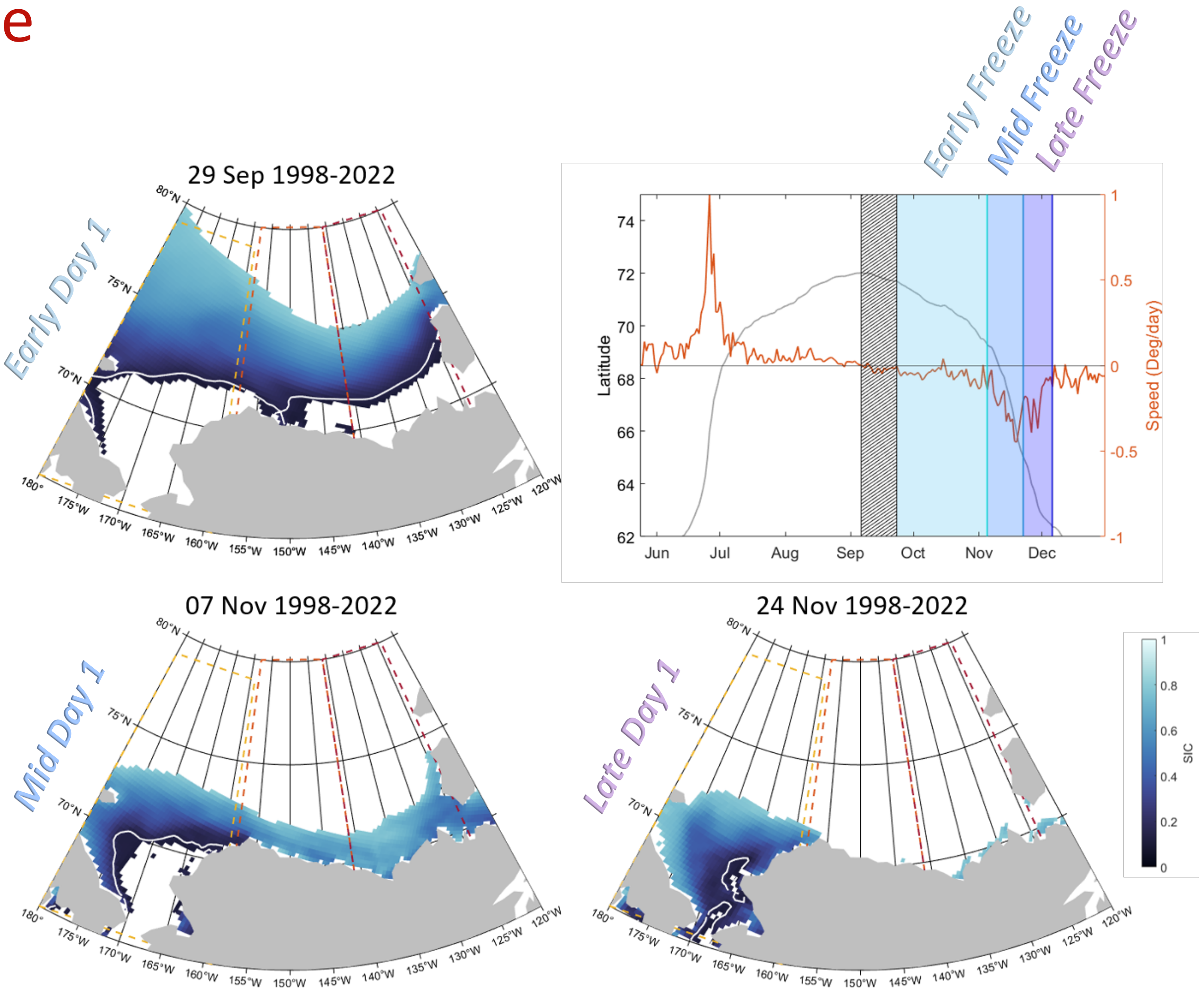
- ERA5: ECMWF Reanalysis Atmospheric Forcing
- POP Ocean model (no waves ☹)
- 25 years of data (1998-2022)



Thompson et. al., 2022

Delimiting sea ice advance

- We define the sea ice advance as the migration of the SIE from its northernmost point
- The inner margin was set to avoid the growth of sea ice from pack ice
- The advance period was further classified into early, mid and late advance
- Loitering period was removed from the advance season by tracking speeds with less than 0.1 degrees per day



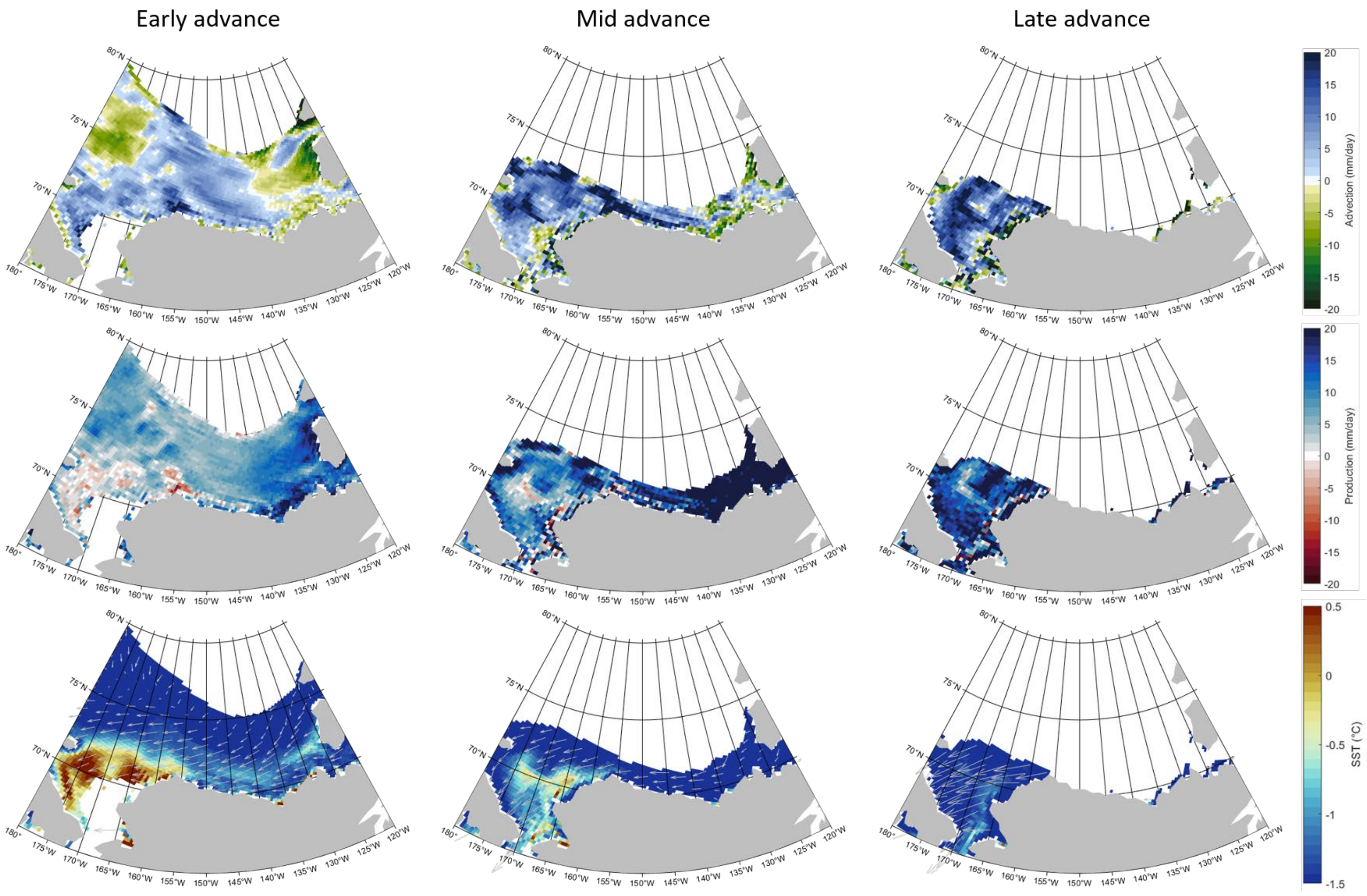
Interplay between dynamics and thermodynamics

Dynamics

- During the early and mid advance, converging ice dominates the west Beaufort as opposed to the east Beaufort, where diverging ice is mostly observed. This pattern comes because of the large-scale clockwise circulation system known as the Beaufort High (BH), which drives the circulation of the Beaufort Gyre (BG).
- Localized negative advection values are observed in the Chukchi sector during early advance around 75N, agreeing with diverging wind patterns followed by sea ice convergence during mid and late advance.
- Ubiquitous divergent sea ice close to the land margins is observed during this early advance season, which can be attributed to ocean currents continually carrying ice offshore as it forms.

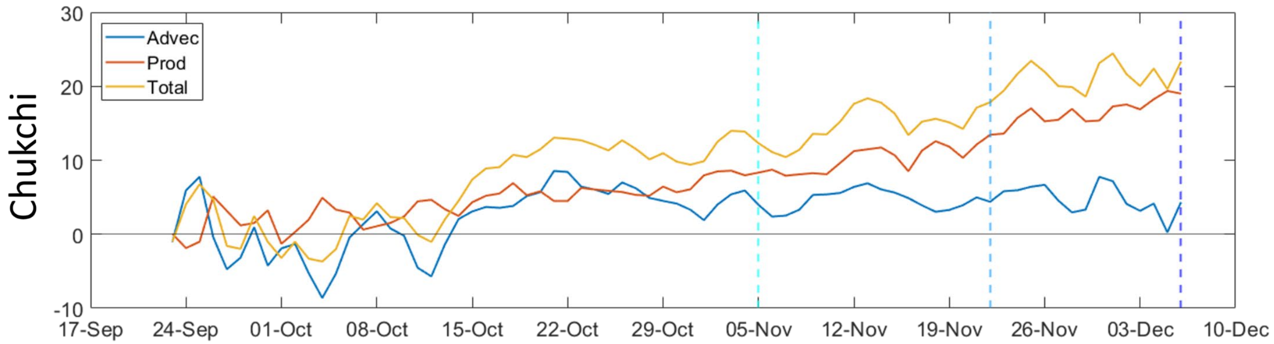
Thermodynamics

- Melting of sea ice is observed around 70N during early advance, agreeing with high SSTs in the Chukchi region. As the season progresses, SSTs decrease, and so comes rapid freezing, specifically in the Eastern Beaufort. Some small-scale melting in the Chukchi Sea is still observed during mid and late advance.

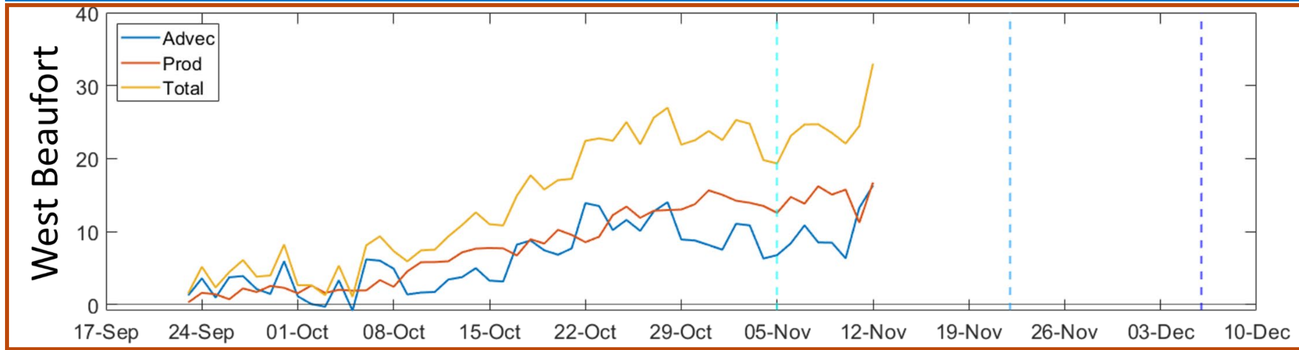


Spatial moving averages of sea ice advection, production, and forcings in the early, mid, and late advance season

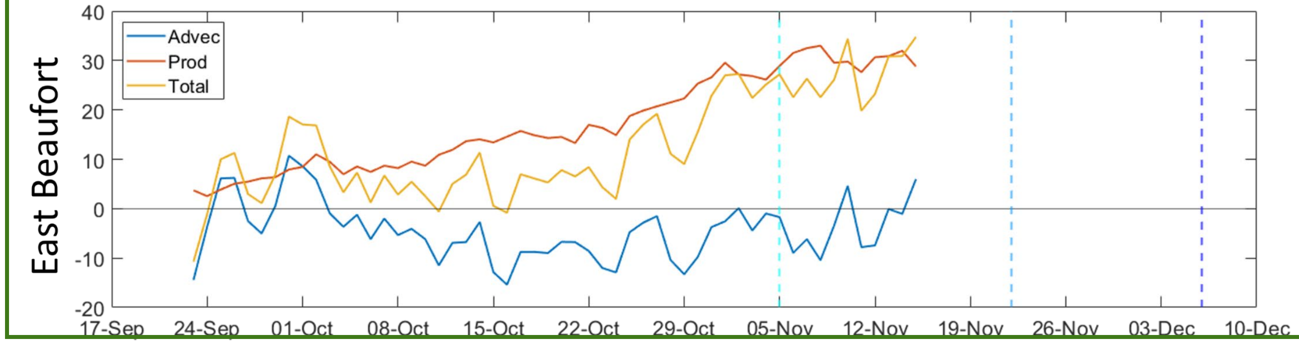
Interplay between dynamics and thermodynamics



- Oscillating advection values observed at the start of early advance are caused by the conflicting spatial divergence region with the surrounding convergence values
- The thermodynamic growth observed from the continuous steady increase into the late advance season is brought from preconditioned SSTs by converging sea ice



- Similar magnitudes of positive thermodynamic and dynamic effects control the total sea ice advance



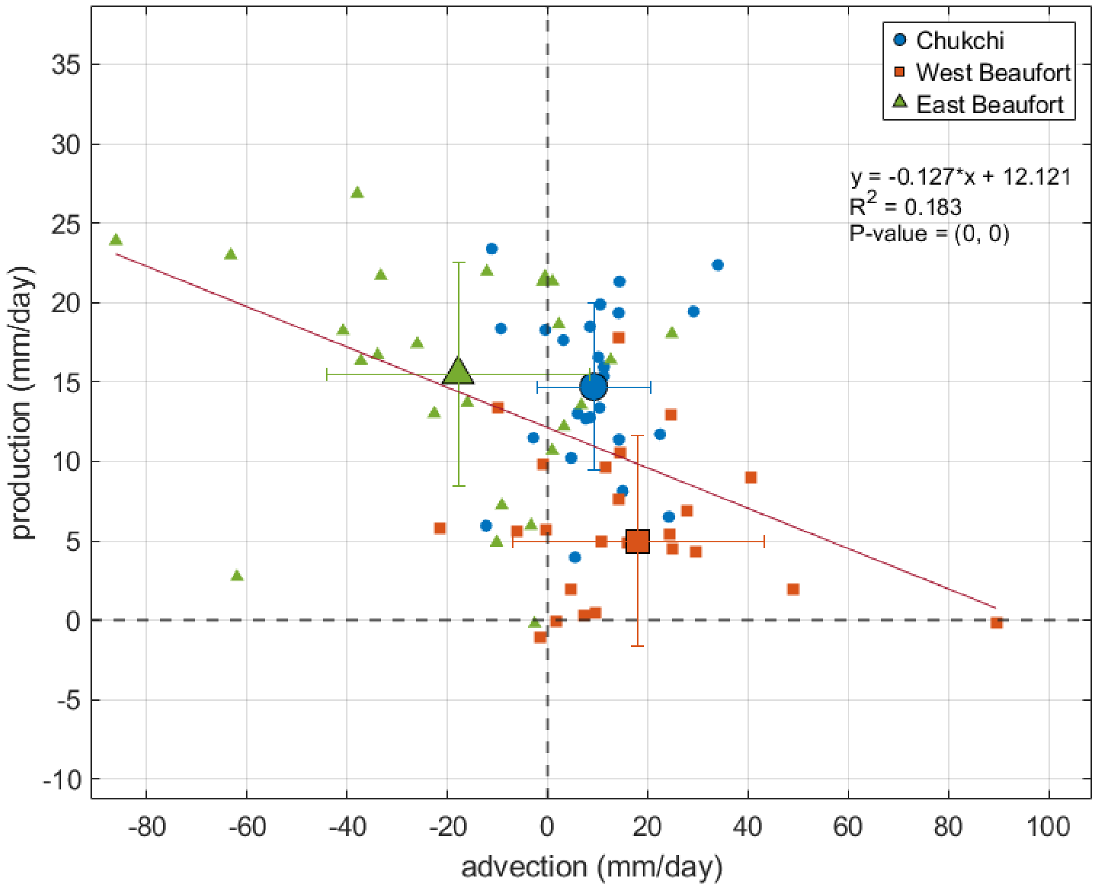
- Production dictates sea ice advance, clashing with the divergence of sea ice from the BG

Thermodynamic and Dynamic Regimes in the Western Arctic

- Overall, we see an inverse relationship between the thermodynamic and the dynamic effects on sea ice in the Western Arctic

- Three distinct regimes control the western and eastern Beaufort, and Chukchi seas.

	Thermodynamics	*Dynamics*
Chukchi	10 mm/day	14 mm/day
W Beaufort	5 mm/day	19 mm/day
E Beaufort	16 mm/day	-19 mm/day



Beaufort High, Beaufort Low, and anomalous SST case studies

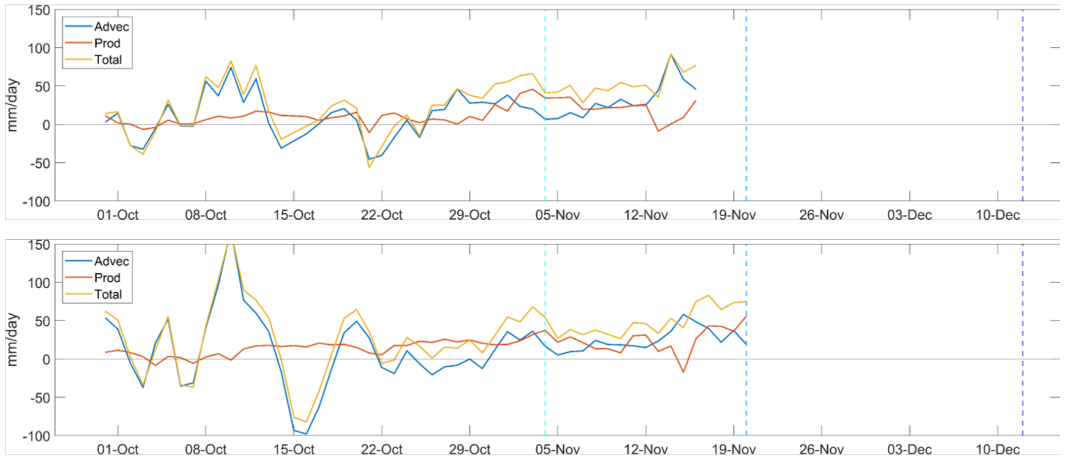
- The reversal of the Beaufort Gyre (BG) is driven by the Beaufort Low (BL) system observed close to (150°W, 75°N)

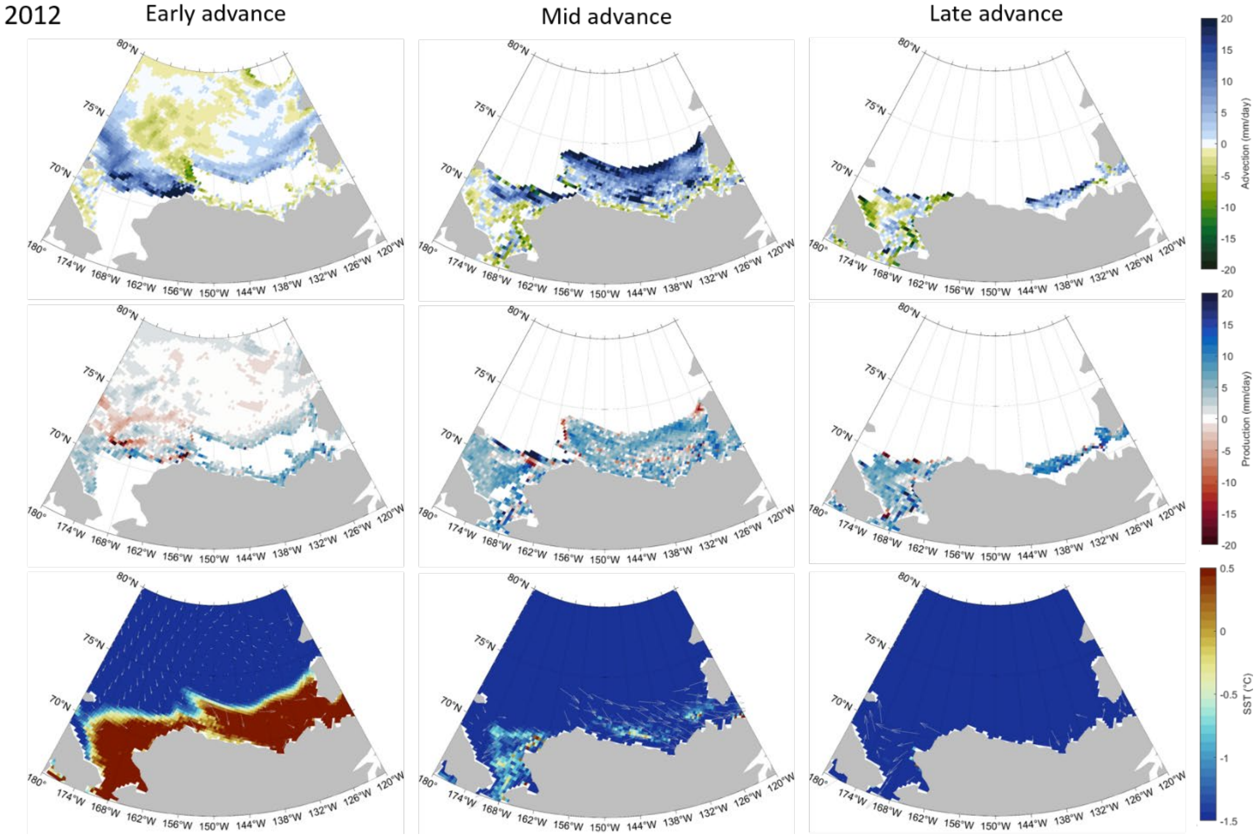
- During mid-advance, atmospheric circulation is observed to intensify (northwesterly wind vectors), driving surface currents southeast towards the coastal margins, enhancing sea ice convergence in this area of the East Beaufort

- Anomalous SSTs are observed in the West and East Beaufort regions during early advance. These high SSTs constrain sea ice advance to the Beaufort region. As a result of enhanced dynamical conditions, a significant reduction of SSTs drives the necessary thermodynamic conditions for sea ice formation

W Beaufort

E Beaufort





Takeaways

- **The Western Arctic exhibits three different regimes in sea ice formation:**
  - **Thermodynamically enhanced: Eastern Beaufort**
  - **Dynamically enhanced: Western Beaufort**
  - **Both Thermodynamically and Dynamically (with one leading the other): Chukchi Sea**

- **Ice convergence plays a crucial role in setting up the necessary conditions for sea ice production (thermodynamics)**

- **Changes in the large-scale atmospheric circulation patterns, like the Beaufort High, affects the spatial distribution in sea ice formation (can be a good thing, like our case study)**