ALFRED WEGENER INSTITUTE
PHYSICAL
OCEANOGRAPHY

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HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

Large scale forcing of the Arctic sea level seasonality and implications for slope currents

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Observing, Modeling, and Understanding the Circulation of the Arctic Ocean and Sub-Arctic Seas
US CLIVAR Workshop, 27.06.2022

Outline:

BACKGROUND

Measurements of **ocean currents** variability along the the **Arctic continental slopes**.

METHODS / RESULTS

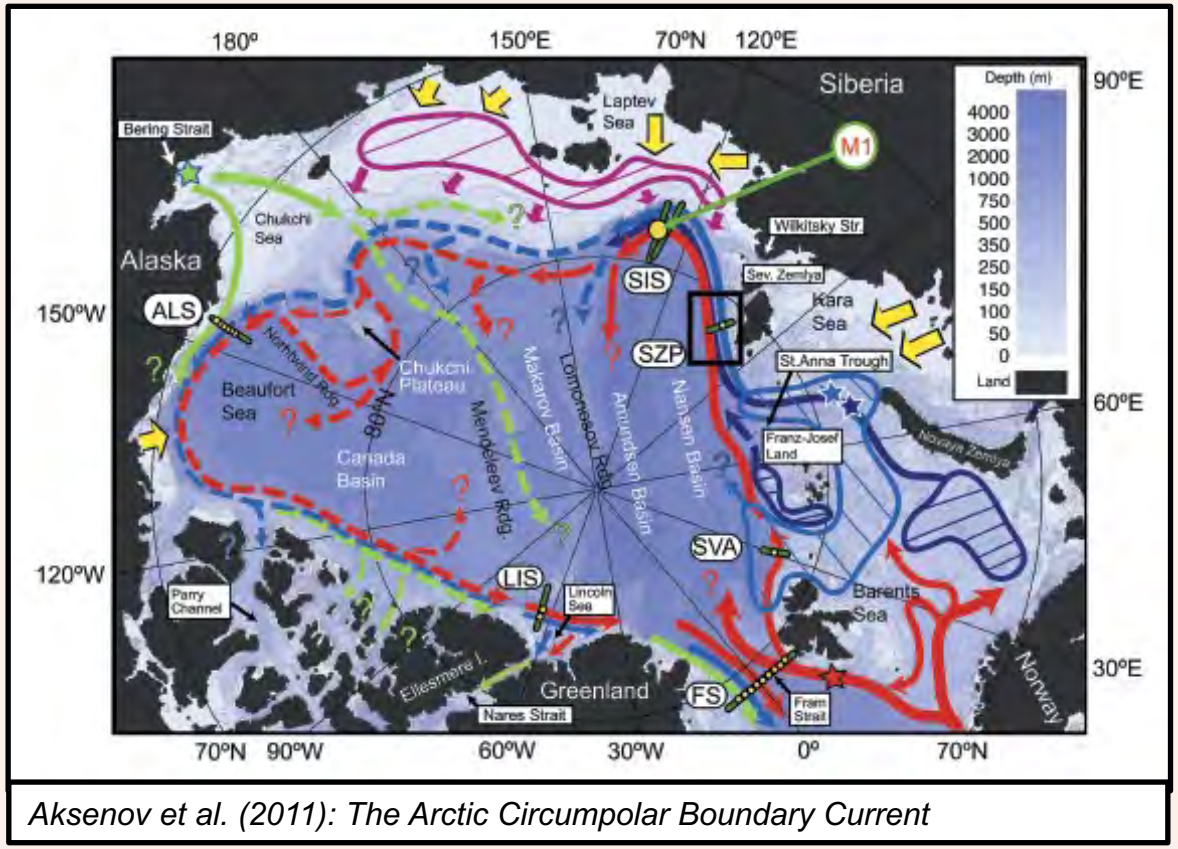
What **temporal and spatial scales** is it possible to observe with a single-mission, gridded product (SAGA dataset)?

RESULTS / DISCUSSION

Satellite data as a **link** between local observations and forcing of **large scale variability.**

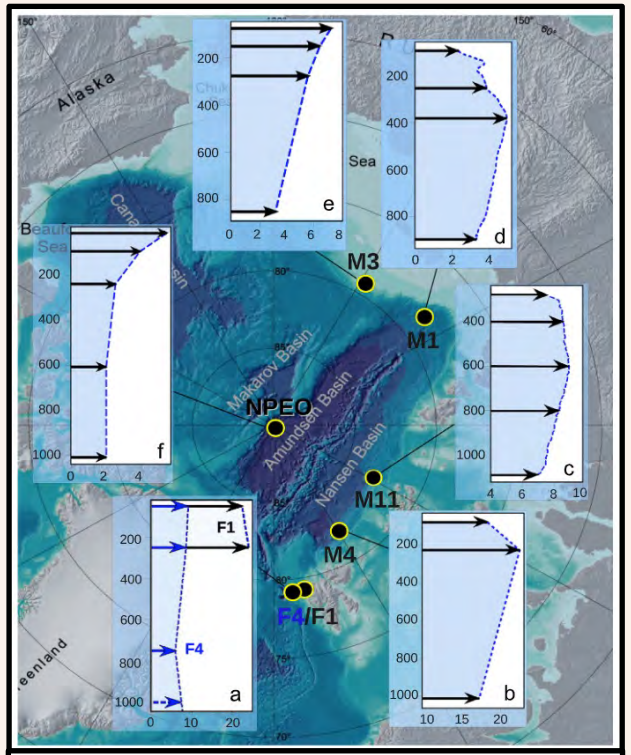
BACKGROUND: SLOPE CURRENTS IN THE ARCTIC OCEAN

System of **topographically guided, narrow currents** exchanges heat and freshwater between the Arctic Ocean and Sub-Arctic Seas



Aksenov et al. (2011): The Arctic Circumpolar Boundary Current

Recent synthesis from **moored observations**



Pnyushkov et al. (2015): Structure and variability of the boundary current in the Eurasian Basin of the Arctic Ocean

Is **satellite altimetry** a viable tool to get insight into the **slope currents variability** in the Arctic, and help understand its drivers?

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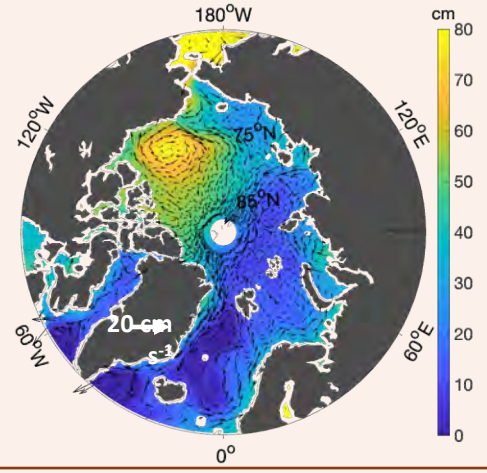
METHOD / RESULTS: ARCTIC MAPS OF SEA SURFACE HEIGHT (SSH) AND GEOSTROPHIC VELOCITY

…among other challenges of **satellite altimetry in the Arctic**:

- Very few missions cover high latitudes of the **central Arctic** (Cryosat-2, ICEsat 1-2)
- observations in **ice-covered** regions require **dedicated processing**
- Only few homogenous, **gridded** datasets

SAGA

***S**ea level*
***A**nomaly and*
***G**eostrophic velocity of the*
***A**rctic ocean*



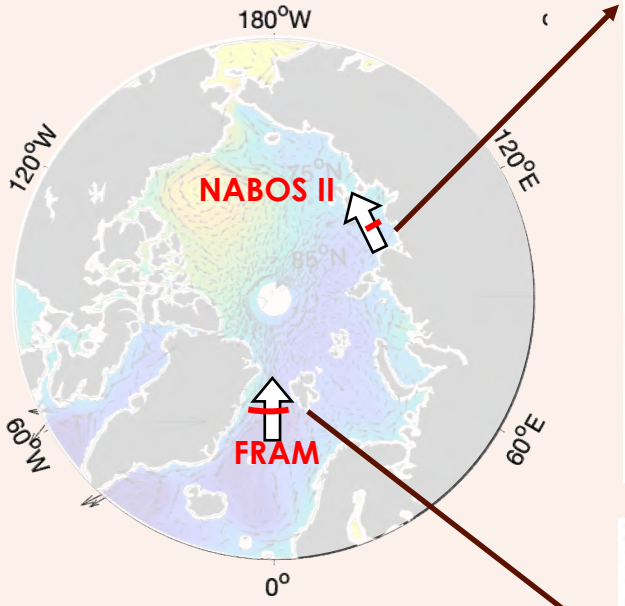
Sea surface height (SSH) and geostrophic velocity

- based on Cryosat-2 mission, up to 88°N
- Pan-Arctic, including ice-covered regions as reprocessed by AWI (Hendricks et al. 2021)
- monthly maps (2011-2020)

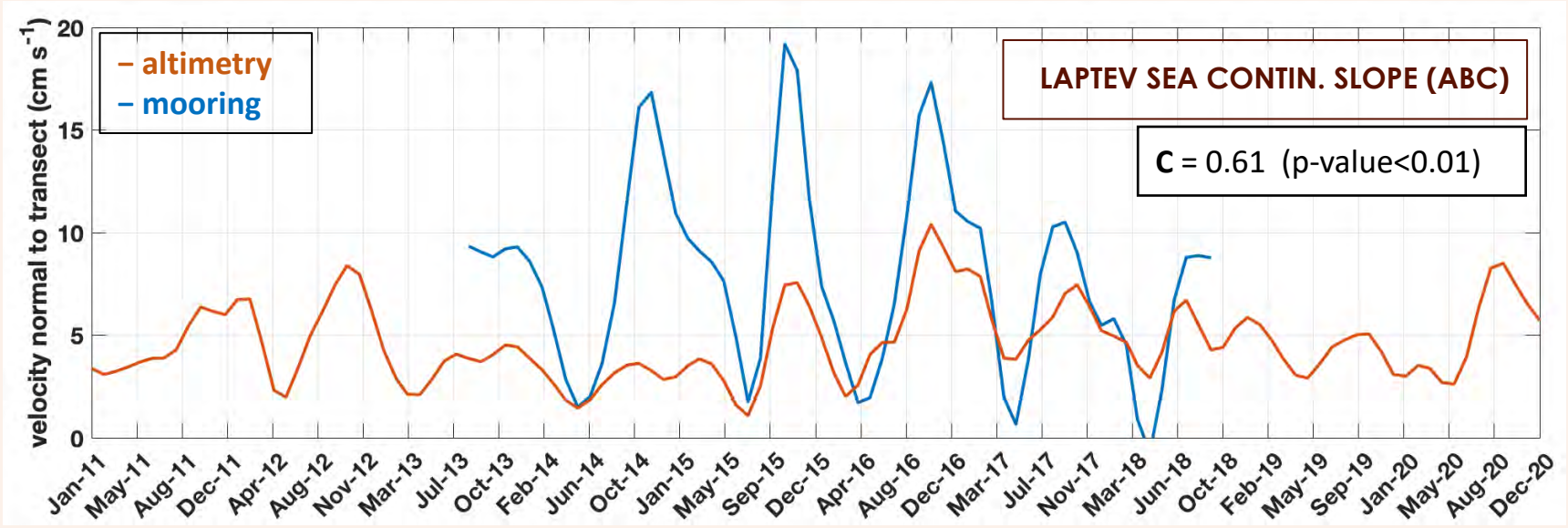
dataset: *Doglioni et al (uploaded to PANGAEA): https://doi.pangaea.de/10.1594/PANGAEA.931869*

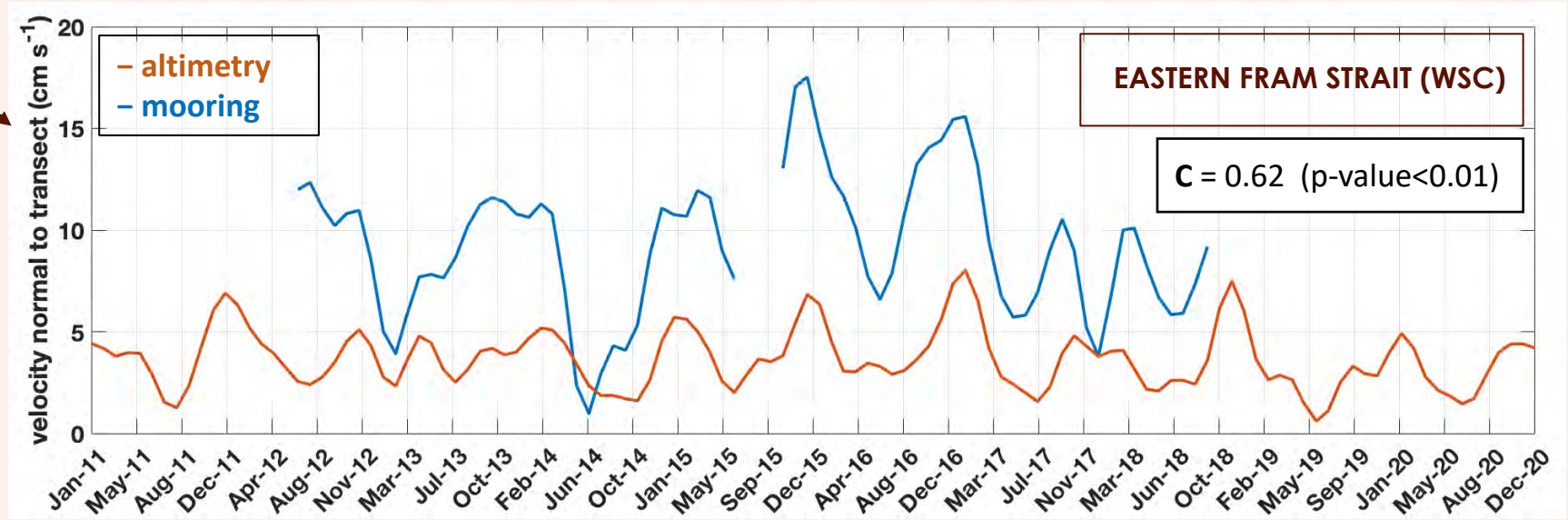
associated manuscript: *Doglioni et al. (subm. 2022, in review at ESSDD): https://doi.org/10.5194/essd-2022-111*

RESULTS: COMPARISON TO SURFACE VELOCITY FROM MOORING ARRAYS



Boundary currents seasonality





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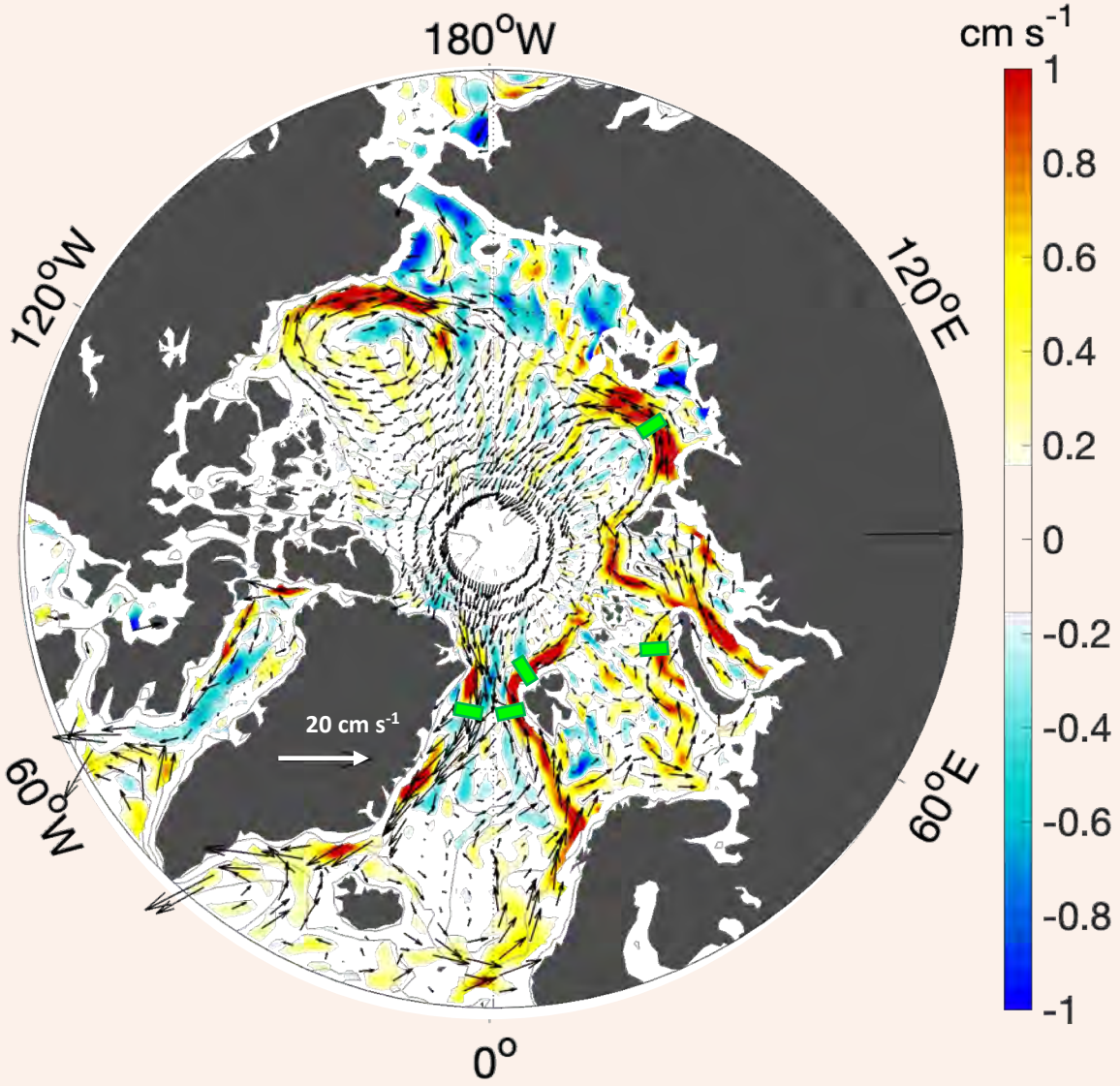
RESULTS: LARGE SCALE SEASONAL ACCELERATION OF BOUNDARY CURRENTS

geostrophic velocity

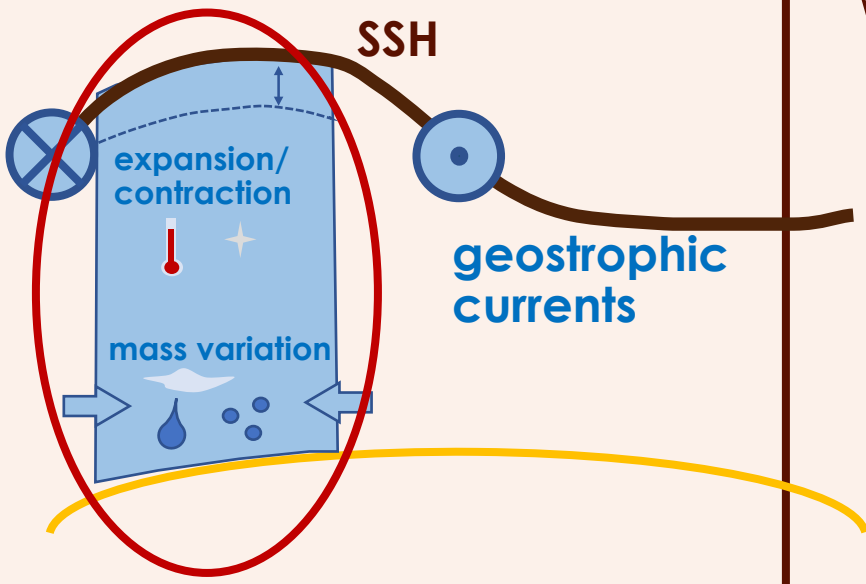
SEASONAL SPEED ANOMALY: **October to December**



A large scale **acceleration in fall/winter** appears in the geostrophic velocity along the continental slopes in the Eurasian Arctic.

This result is consistent with several **mooring** inferred results, integrating them into a **basin-wide perspective**

METHODS: SSH VARIABILITY FROM ALTIMETRY FIELDS AND MODEL OUTPUT

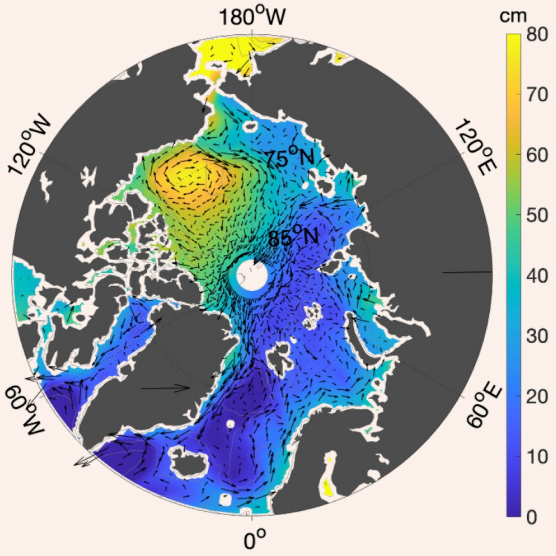


What is the nature of SSH variability that contributes to **slope currents** variability at **seasonal time scales**?

We used monthly maps, over the period 2011-2020, from:

SATELLITE DATA

SAGA



MODEL DATA

FESOM

***F**inite*
***E**lements*
***S**ea ice-*
***O**cean*
***M**odel*

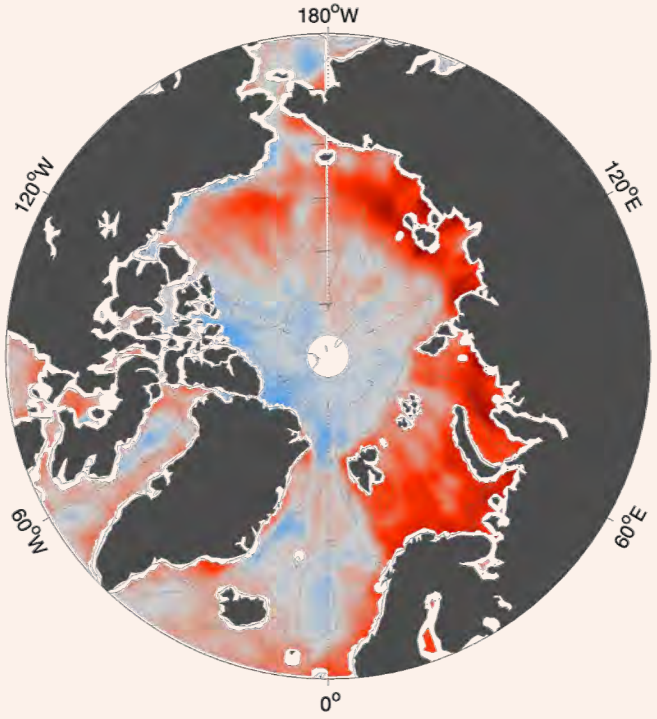
FESOM 1.4, resolution of 4.5 km in the Arctic Ocean, sea ice– ocean coupling.

Using monthly mean maps from an historical run forced by atmospheric reanalysis data of JRA55-do v.1.3 (Tsujino et al., 2018).

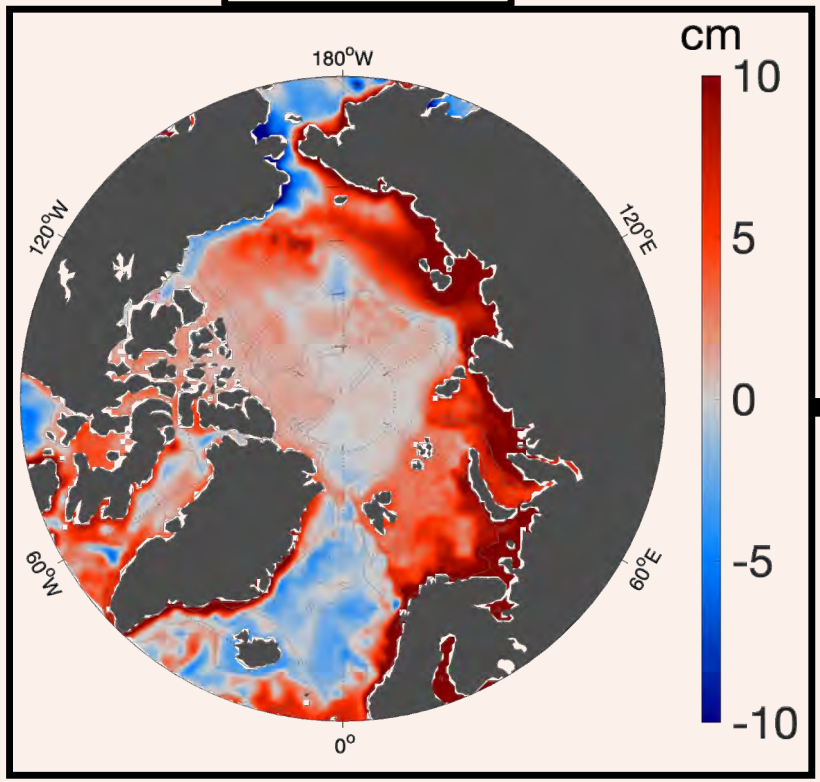
RESULTS: SEASONAL DIFFERENCES → **OND - JJA**

SSH (η)

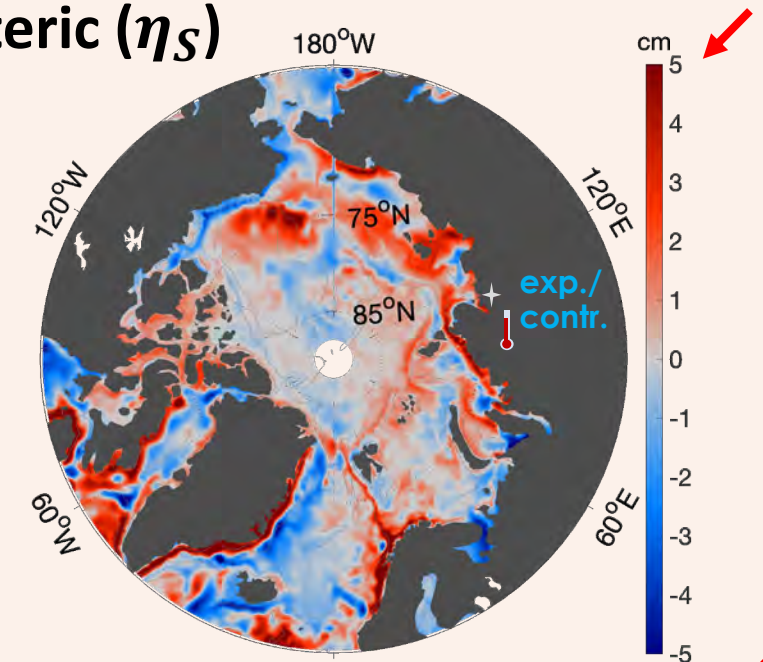
SATELLITE DATA



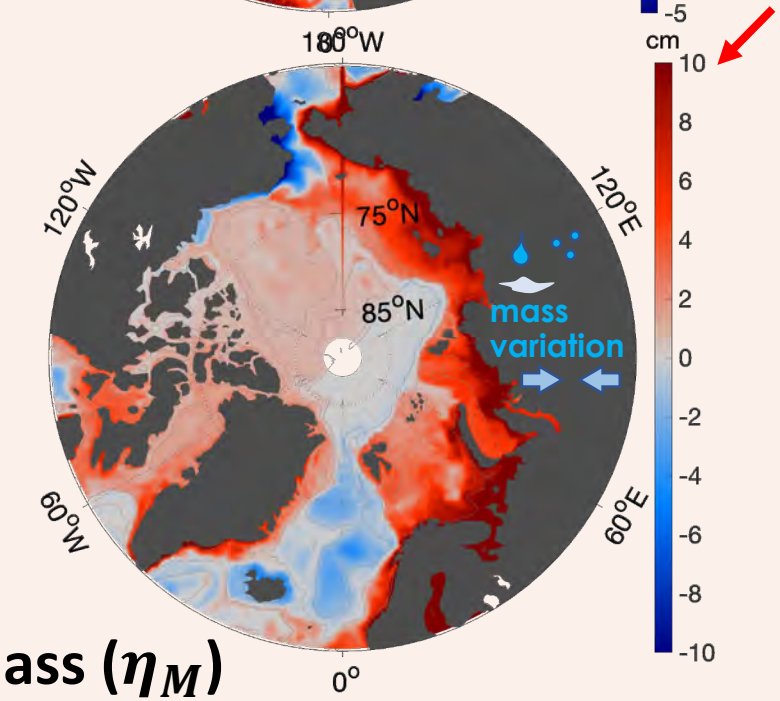
MODEL DATA



steric (η_S)



mass (η_M)



^ **Largest** differences in the **shelf seas**, sharp **divide** at the Eurasian shelf **break**

L**arge-scale behaviour** is attributable to **variations in ocean mass.** →

DISCUSSION: DRIVERS OF OCEAN MASS SEASONALITY

(1) Can the seasonal variability of ocean mass on the shelf seas be explained by **Ekman** transport across the shelf break?

(2) Why are these large oscillations **confined** to the **shelf** seas?

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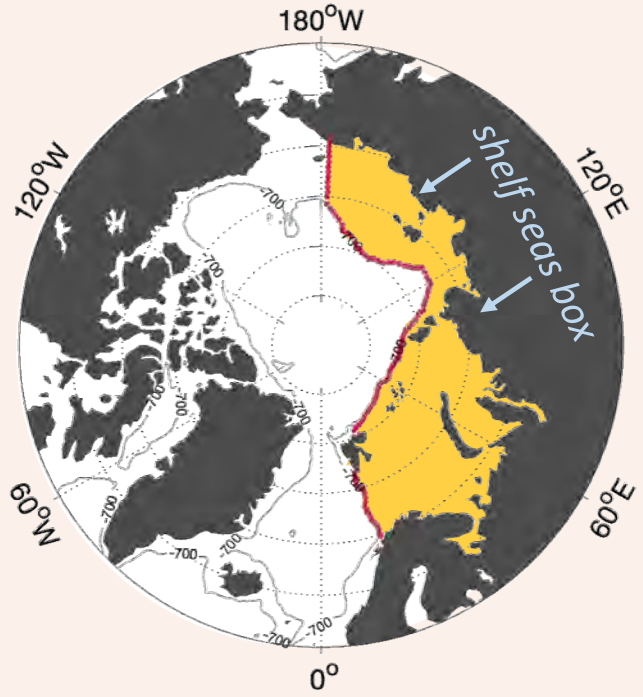
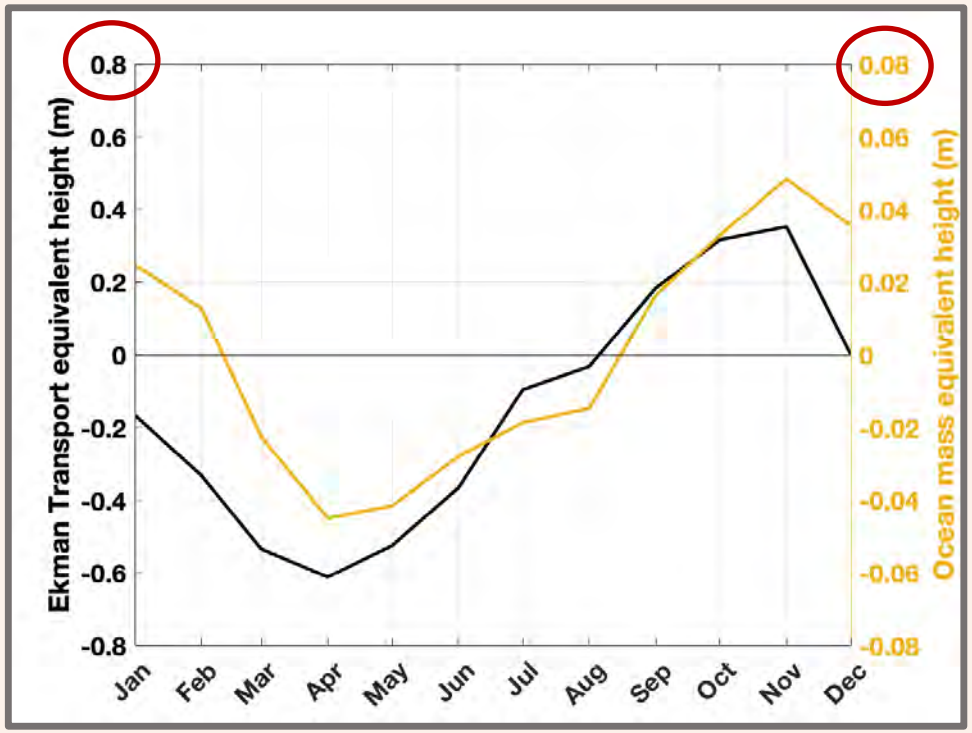
Discussion (1) : Ekman transport(model)



Time-integrated Ekman transport (equivalent height)

η_M (shelf seas average)

Climatologies (model)



Ekman transport:

$$\mathbf{U} = (U, V) = \frac{1}{\rho_0 f}\left(\tau_o^y, -\tau_o^x\right)$$

where ocean surface stress:

$$\tau_o = A\,\tau_{io} + (1 - A)\,\tau_{ao}$$

The $\boldsymbol{\eta_M}$ seasonality is **in phase** with the **time-integrated Ekman transport** across the shelf break, into a "shelf seas box".

What balances the Ekman transport of mass onto the shelves?
… to be continued…

DISCUSSION: DRIVERS OF OCEAN MASS SEASONALITY

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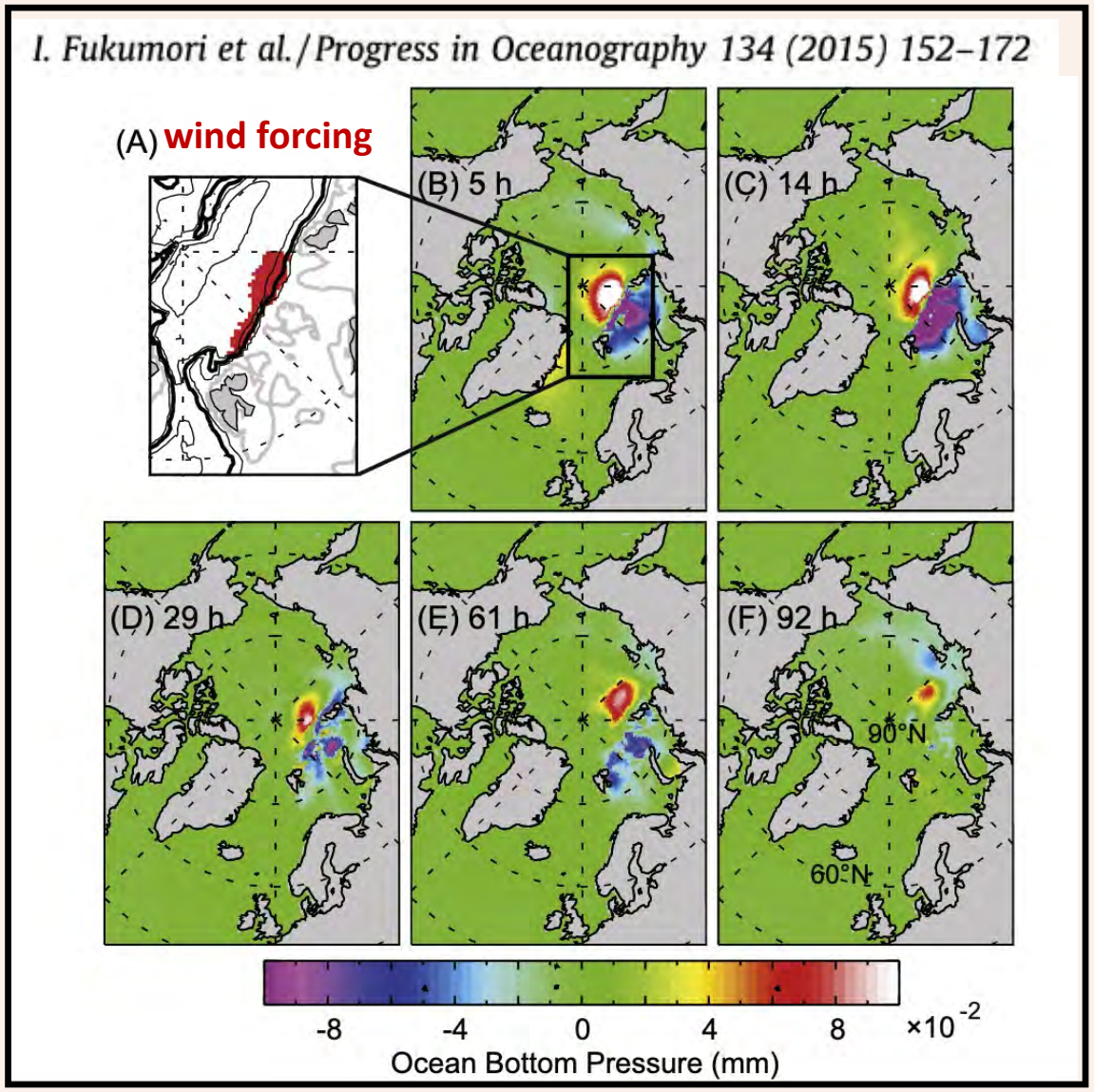
Discussion (2) : eastwards propagating mass anomaly ?



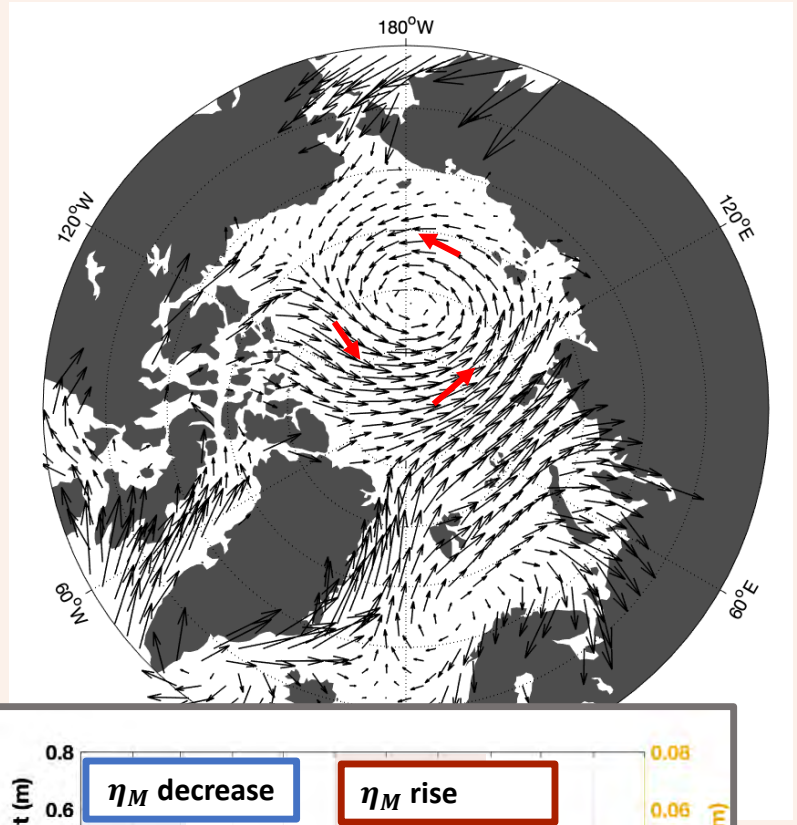
How can we explain the sharp divide at the shelf edge?

← **Fukumori et al. (2015):**
wind forcing applied for 1 h
anomalies travel along shelf break

What happens under persistent anomalous **seasonal winds**?

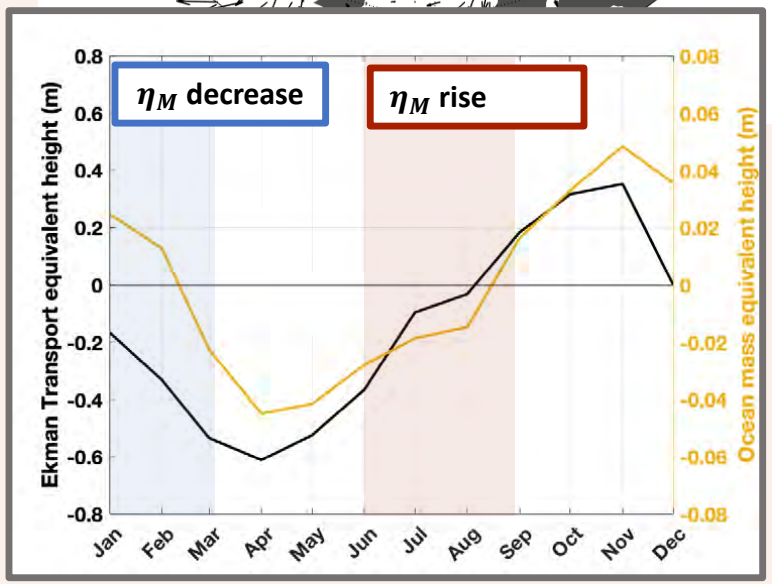
… to be continued..

Discussion (2) : eastwards propagating mass anomaly ?

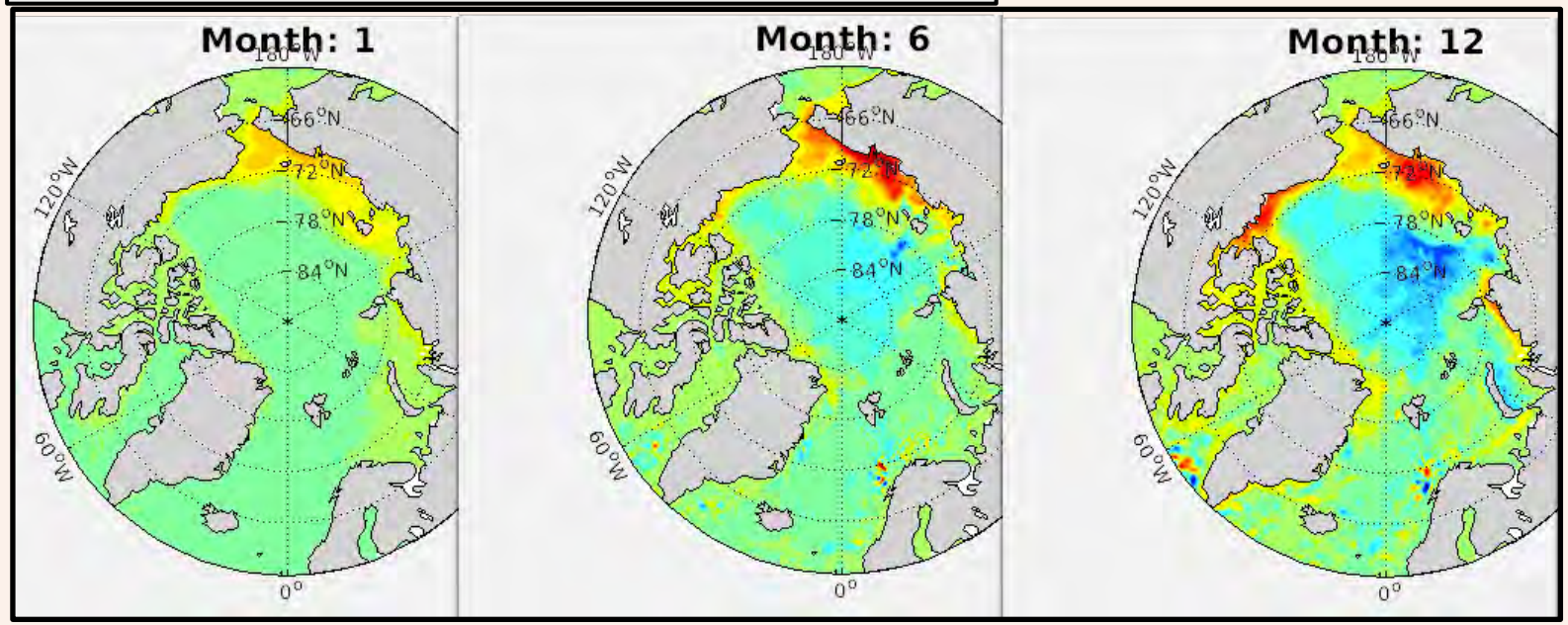


Wind pattern:
ascending minus
descending phase

Similar to AO>0 wind pattern (experiment done!)



AO>0: η experiment - η control



Summary :

BACKGROUND

Status of satellite **altimetry** for oceanography in the **Arctic**: what **challenges** are still to be overcome?

METHODS / RESULTS

What **temporal and spatial scales** is possible to observe with a single-mission, gridded product (SAGA dataset)?

SEASONAL AND LARGER TIME SCALES, **BOUNDARY CURRENTS**

THANK YOU! =)

RESULTS / DISCUSSION

Satellite data as a **link** between local observations and forcing of **large scale variability.**

SEASONAL **MASS OSCILLATIONS** ON **SHELVES**, **EKMAN** TRANSPORT**?**