Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

Circulation in the Chukchi Sea from a long-term dataset of satellite radar altimetry

Maria N. Pisareva, ***maria.pisareva@tum.de***

Felix L. Müller, Florian Seitz, Denise Dettmering, Christian Schwatke
Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM)

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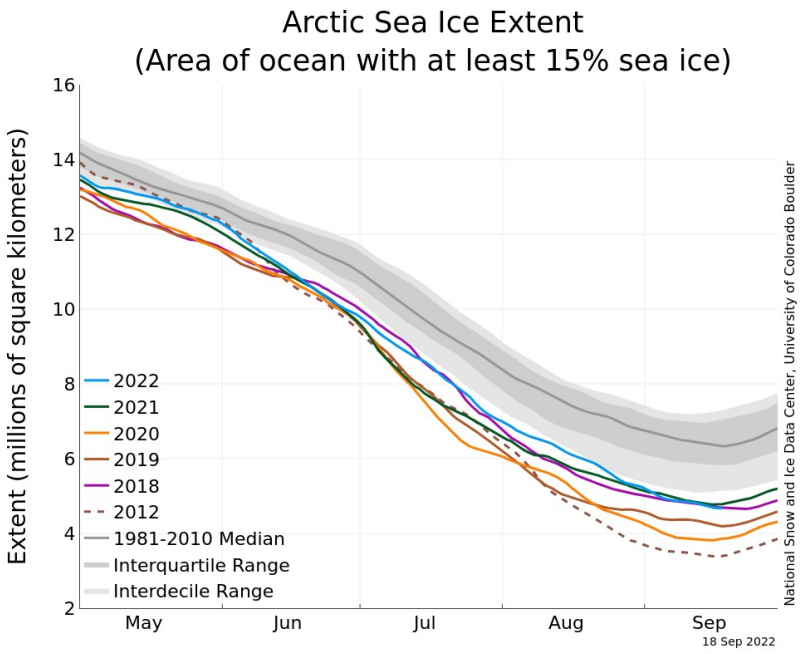
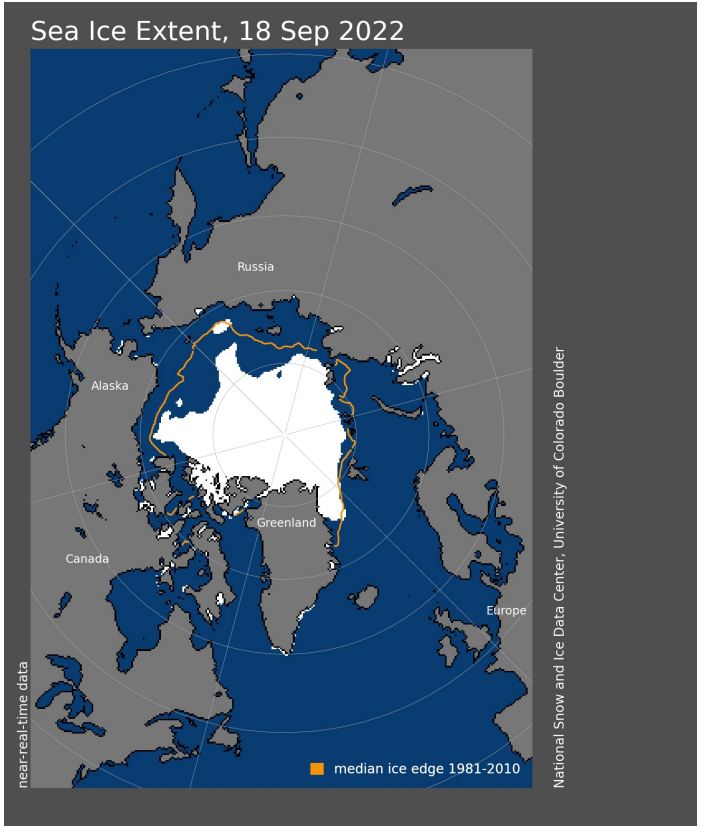
Outline

1. Motivation and AROCCIE project overview
2. Data and Methodology
3. Chukchi Sea case study
4. Take-aways and ongoing work

Motivation



Summer Arctic sea ice extent is shrinking by 12.6% per decade as a result of global warming (NASA).



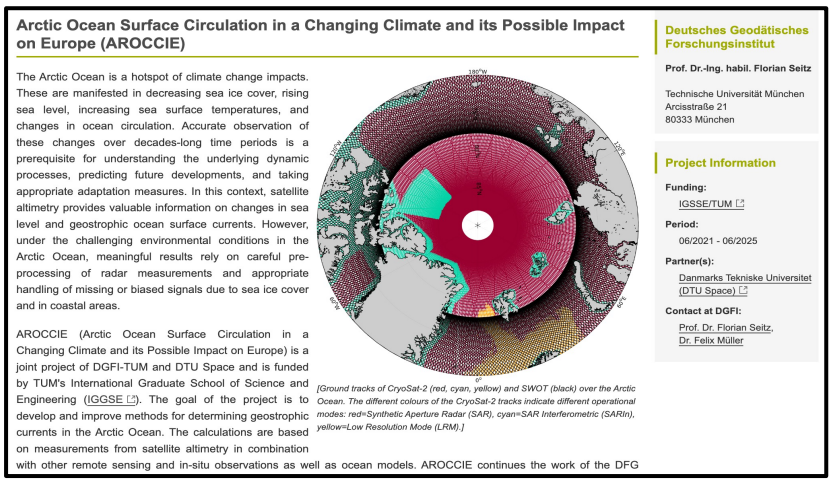
- Arctic is changing, but challenging to monitor;
- Satellite altimetry provides precise information about the sea surface on various scales

AROCCIE project: Arctic Ocean Surface Circulation in a Changing Climate and its Possible Impact on Europe

Time span: 2022 – 2026; partners: TUM+DTU; funding IGSSE

- **Creation of a long-term high-resolution dataset** of sea surface heights (SSH), dynamic ocean topography (DOT), and geostrophic currents in the Arctic Ocean from multi-mission satellite altimetry

- **Scientific analysis** of the resulting dataset (currents patterns in terms of signatures of climate change and potential impacts on Europe)



Arctic Ocean Surface Circulation in a Changing Climate and its Possible Impact on Europe (AROCCIE)

The Arctic Ocean is a hotspot of climate change impacts. These are manifested in decreasing sea ice cover, rising sea level, increasing sea surface temperatures, and changes in ocean circulation. Accurate observation of these changes over decades-long time periods is a prerequisite for understanding the underlying dynamic processes, predicting future developments, and taking appropriate adaptation measures. In this context, satellite altimetry provides valuable information on changes in sea level and geostrophic ocean surface currents. However, under the challenging environmental conditions in the Arctic Ocean, meaningful results rely on careful pre-processing of radar measurements and appropriate handling of missing or biased signals due to sea ice cover and in coastal areas.

AROCCIE (Arctic Ocean Surface Circulation in a Changing Climate and its Possible Impact on Europe) is a joint project of DGFI-TUM and DTU Space and is funded by TUM's International Graduate School of Science and Engineering (IGGSE). The goal of the project is to develop and improve methods for determining geostrophic currents in the Arctic Ocean. The calculations are based on measurements from satellite altimetry in combination with other remote sensing and in-situ observations as well as ocean models. AROCCIE continues the work of the DFG

[Ground tracks of CryoSat-2 (red, cyan, yellow) and SWOT (black) over the Arctic Ocean. The different colours of the CryoSat-2 tracks indicate different operational modes: red=Synthetic Aperture Radar (SAR), cyan=SAR Interferometric (SARIn), yellow=Low Resolution Mode (LRM).]

Deutsches Geodätisches Forschungsinstitut

Prof. Dr.-Ing. habil. Florian Seitz

Technische Universität München
Arcisstraße 21
80333 München

Project Information

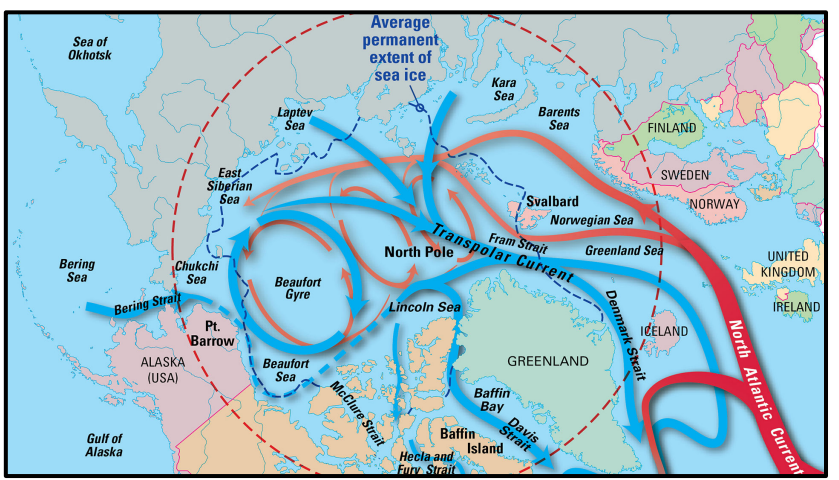
Funding:
IGSSE/TUM

Period:
06/2021 - 06/2025

Partner(s):
Danmarks Tekniske Universitet (DTU Space)

Contact at DGFI:
Prof. Dr. Florian Seitz,
Dr. Felix Müller

https://www.dgfi.tum.de/en/projects/aroccie/

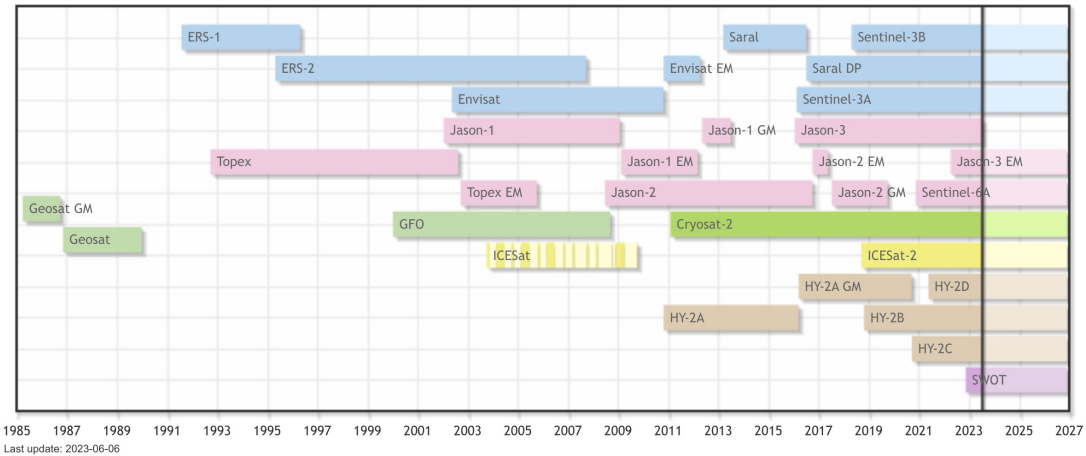


(Jack Cook, WHOI)

AROCCIE Altimetry missions

***	ERS2	1995/05 – 2003/07
****	ENVISAT + extended mission	2002/05 – 2010/10 2010/10 – 2012/04
	Jason-2 (up to 66N -> Bering Strait)	2008 – 2019
***	CryoSat-2 + extended mission	2010/07 – 2020/07 2020/07 – 2021/08
*	SARAL + drifting phase	2013/03 – 2016/07 2016/07 – 2022/01
	Sentinel-3A	2016/12 – 2021/01
	Sentinel-3B	2018/11 – 2021/02
	SWOT (Surface Water and Ocean Topography)	Launched on 15/12/2022
	ICESat-2	October 2018 to present

*** e.g.:** Cheng et al., 2014; Armitage et al., 2017; Rose et al., 2019; Müller et al., 2019; Doglioni et al., 2023



DGFI-TUM; https://openadb.dgfi.tum.de/en/missions/

Methodology

1. Computation and preparation of altimetry datasets (along-track, gridded)

SSH = Hsat – (Range+ corrections)

Altimeter range from physical retracker ALES+, developed for sea ice conditions *(Adaptive Leading Edge Subwaveform+; Passaro et al., 2018);*

DTU22MDT (Knudsen et al., 2022)

Ice-ocean-lead detection: Unsupervised classification of Müller et al., 2017

2. Adaptation of the multi-mission cross-calibration method to the datasets *(Bosch et al., 2014)*

3. Gridding of altimetry-derived DOT height (physical heights in respect to geoid) and/or combination with a numerical ocean model

(following Müller, Dettmering, Wekerle, et al., 2019)

4. Geostrophic currents calculation

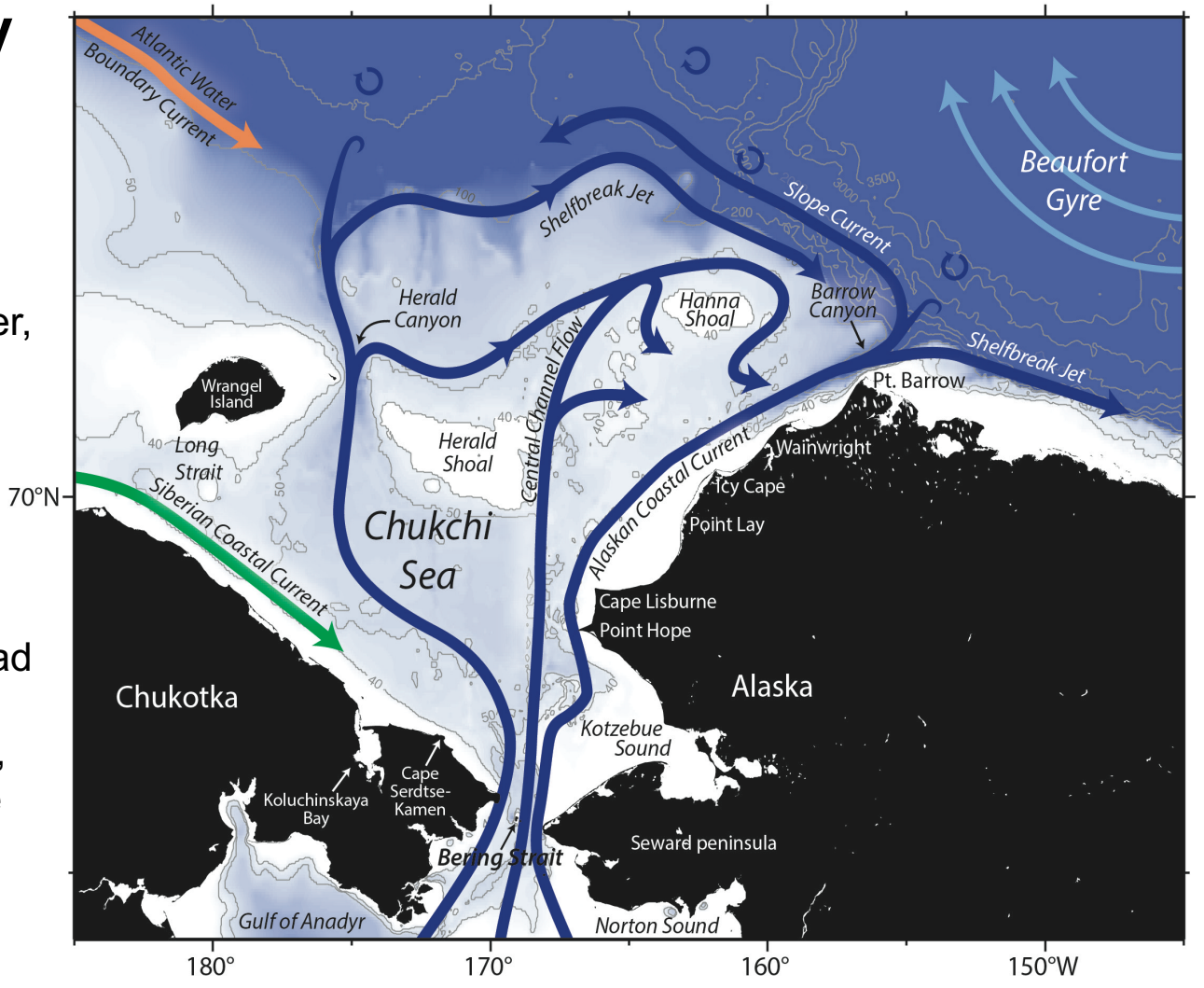
5. Dataset validation with in-situ data (tide gauges, moorings, etc.); comparison with other datasets

6. Scientific dataset exploitation

Chukchi Sea case study

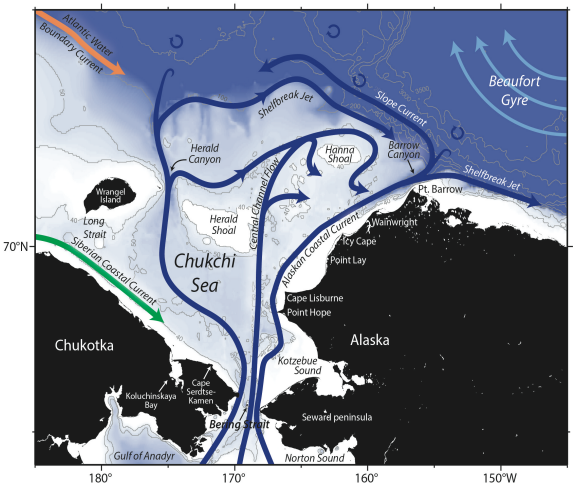
- The only oceanic gateway between the Pacific and Arctic
- Pacific waters bring heat, freshwater, and nutrients to the Arctic
- Currents are susceptible to atmospheric forcing (winds & ice)
- Flow through Bering Strait is northwards due to the pressure head between the Arctic and Pacific

(but winds also influence the sea level, creating Ekman transport+ oppose the pressure-head in winter)

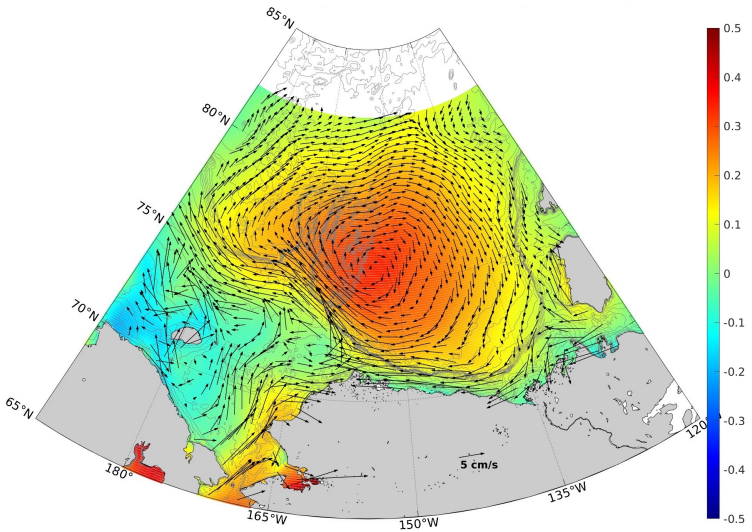


Chukchi Sea expected state

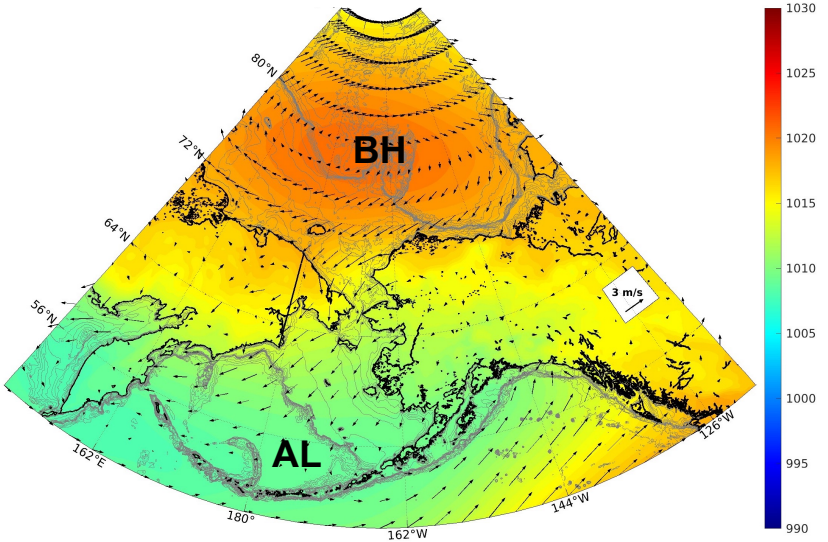
- northward flow
- northeasterly winds (BH+AL)



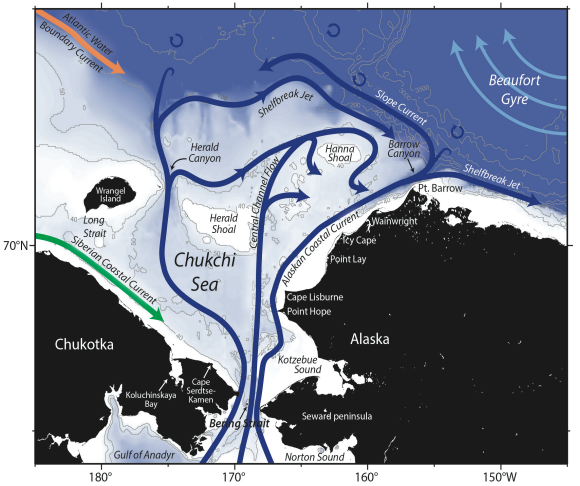
Geostrophic currents overlaid on gridded DOT (SARAL)

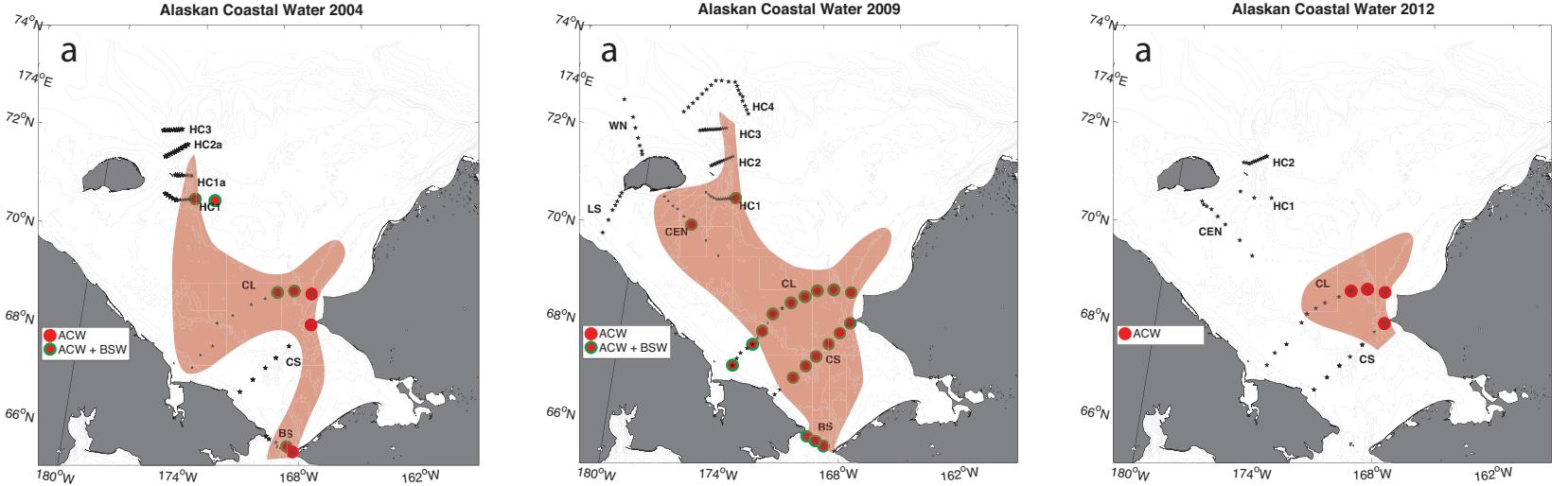


Mean winds overlaid on SLP (ERA5)



Anomalously strong winds can cause Ekman transport of the coastal current westward to the Chukotka coast



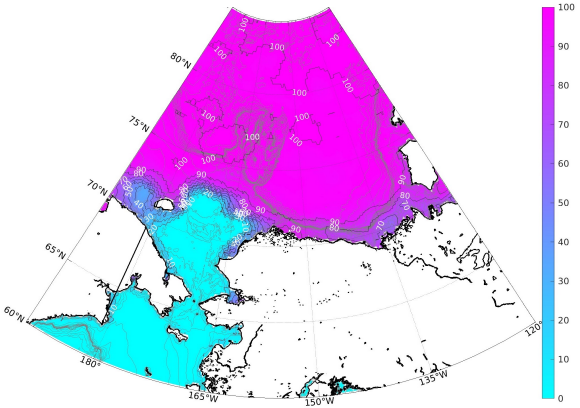


Pisareva et al., 2015

Anomalously strong winds can cause Ekman transport of the coastal current westward to the Chukotka coast →

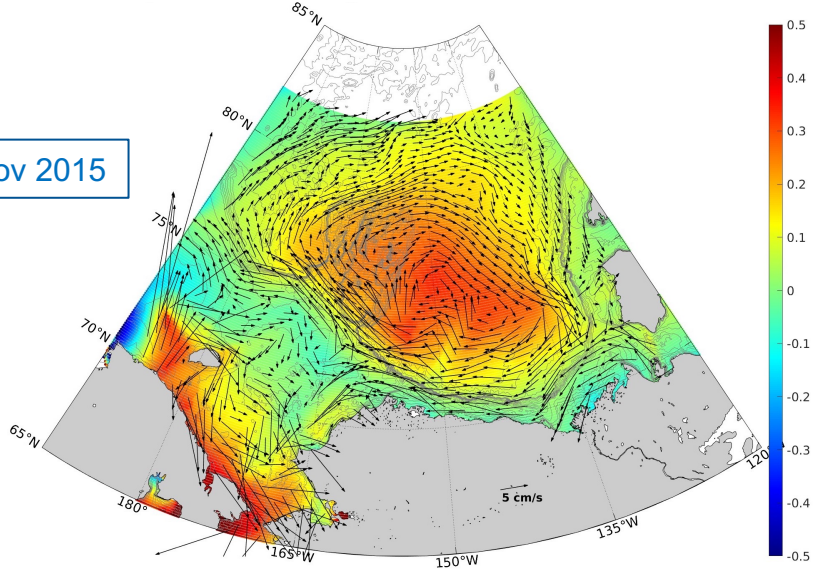
change in sea level

Ice concentration (NSIDC)



Geostrophic currents overlaid on gridded DOT (SARAL)

e.g., 9-19 Nov 2015



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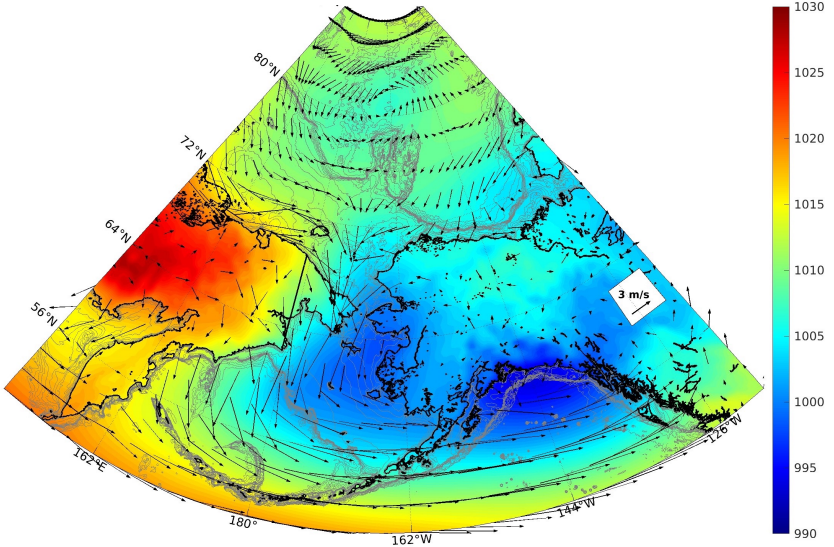
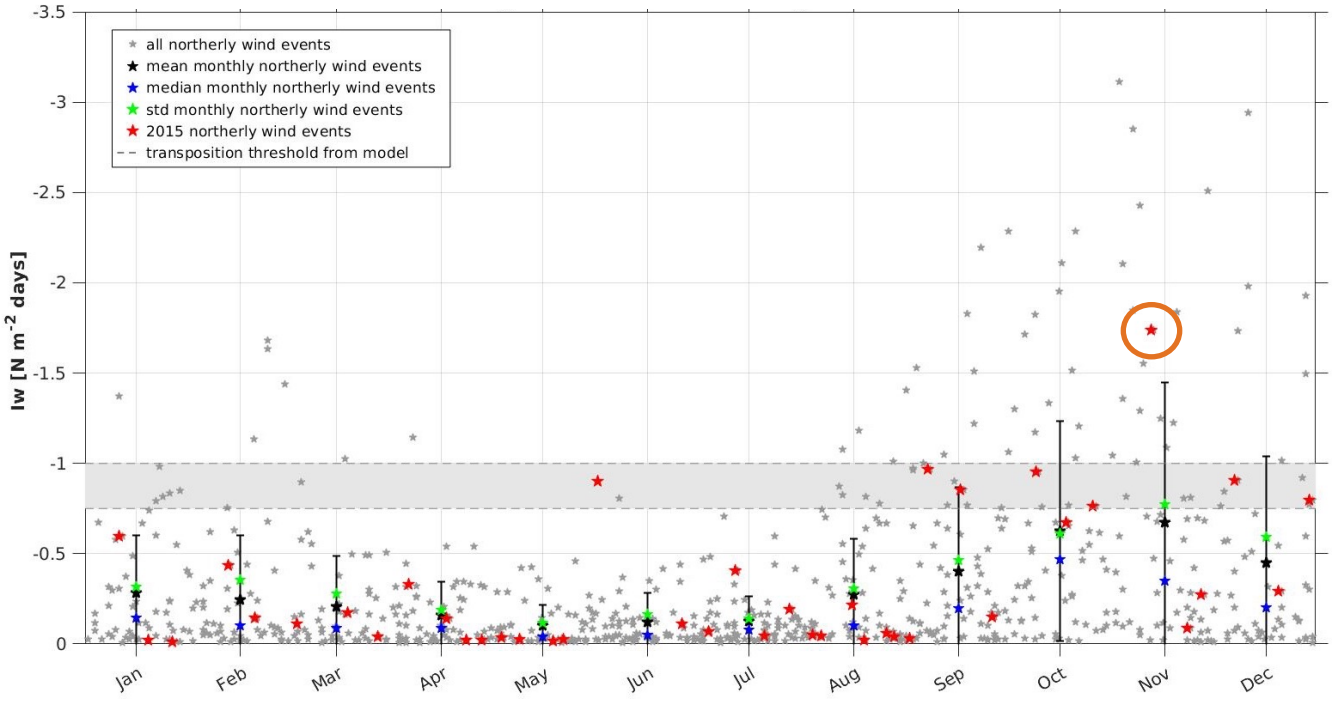
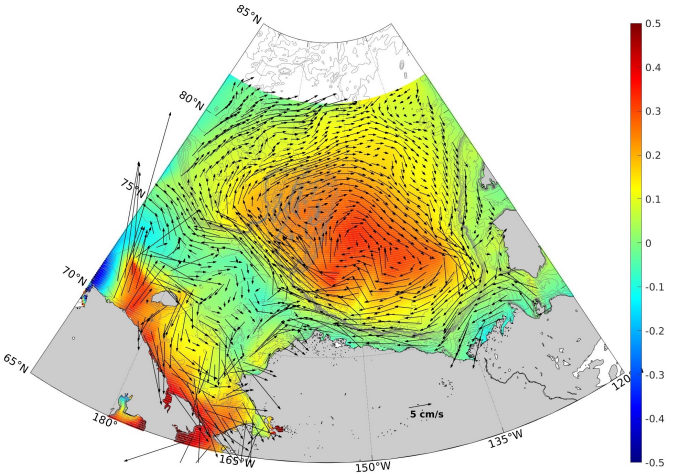


Assessment of the strength of a storm, needed for a transposition to happen

Time integral of the windstress for northerly wind events in Bering Strait for 2000-17



Geostrophic currents overlaid on gridded DOT



Take-aways

- Satellite altimetry provides precise information on sea surface at different spatial and temporal scales and can be used for studies of the current patterns:

E.g., in the absence of ice and depending on changing atmospheric patterns, surface water masses in highly dynamic regions (e.g., Chukchi Sea) can be diverted from the known pathways, which has potential consequences on the freshwater and heat transport on the Arctic shelf, as well as on the ecosystem of the region

- AROCCIE will provide SSH + currents for the entire Arctic (10 days, 4.5 km resolution), which can be used for oceanographic studies

- Ongoing work by DGFI-TUM and collaborators: **AROCCIE dataset and evaluation**, but also:

  - Development of the new gridding approaches (DGFI-TUM)
  - Development of the Arctic tidal model (DGFI-TUM with collaborators), new tidal corrections for the altimetry data

Thank you!