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for Climate Research

Exploitation of high-resolution datasets for sea level studies in the Nordic Seas and Arctic Ocean

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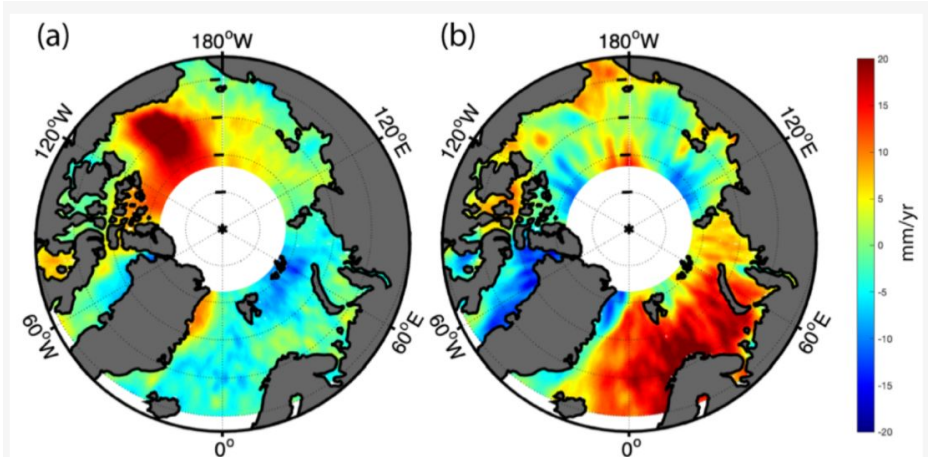
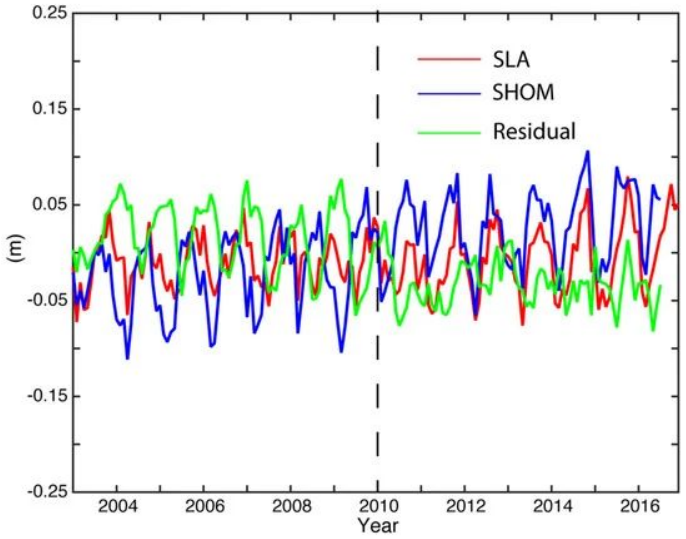
Motivation

- One of major gaps in contemporary sea-level research is for example the **disclosure of sea-level budget in the Arctic region**



SLA trends over (a) **2003-2009** (b) and **2010-2016**



Arctic SLB disclosure (2003-2016)

(ESA SLBC Project; Raj et al., 2020)

- **Monitor sea level changes** using all possible tools that the climate science community has developed, such as **in-situ and remote sensing-based observational** products, **model-based products,** and products **fusing models and observations**

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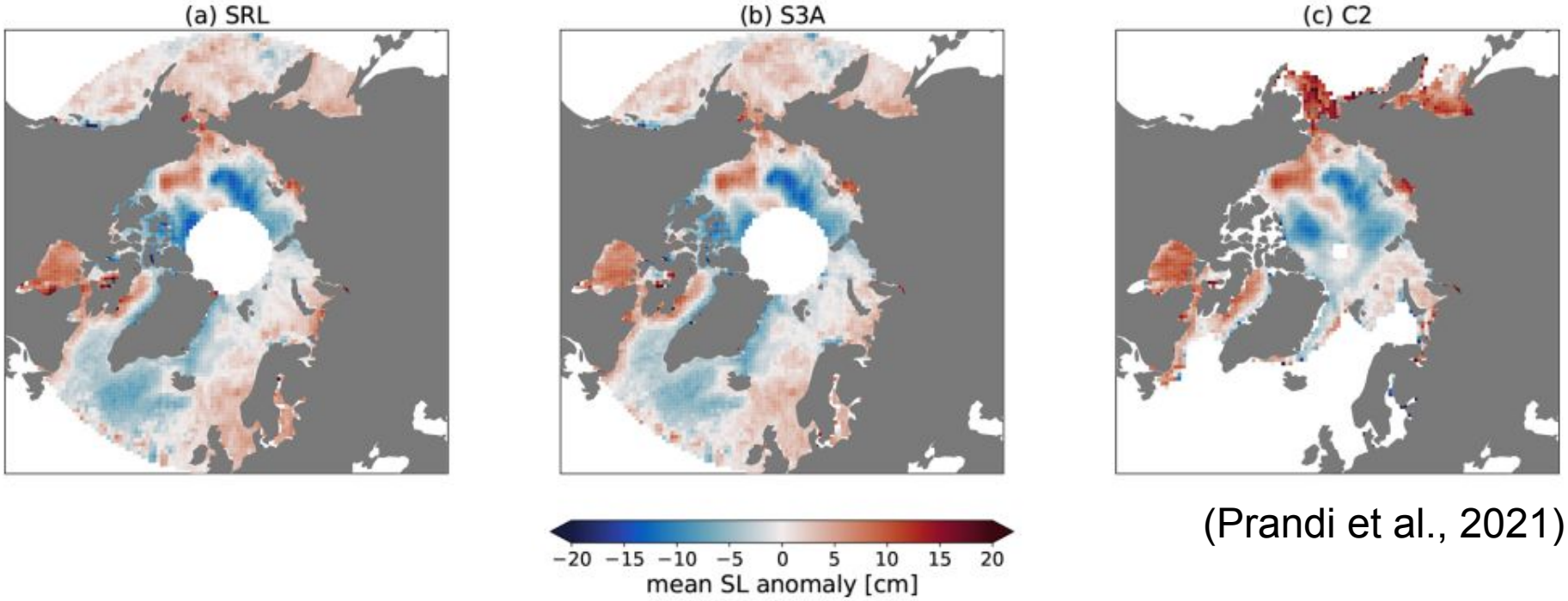
Multi-altimetry combination in the Arctic (2016-2020)

- **Waveform classification:** echoes labeled as **class 1** (Brownian echoes) **open ocean** and **class 2** (peaky echoes) associated with **sea ice leads**
- **Retracking:** several retracking algorithms used depending on the measurement mode (LRM or SAR) and echo type.
- **Ocean leads classification**: based on **SIC** (OSISAF), **waveform class** and radar backscatter coefficient
- **OI:** Open ocean along-track data to **5 Hz** before optimal interp. (25 km)



(Prandi et al., 2021)

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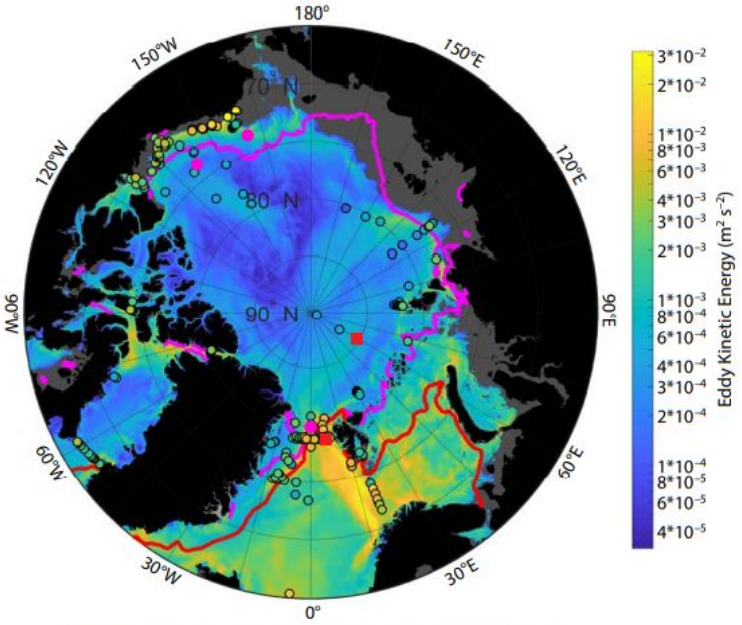
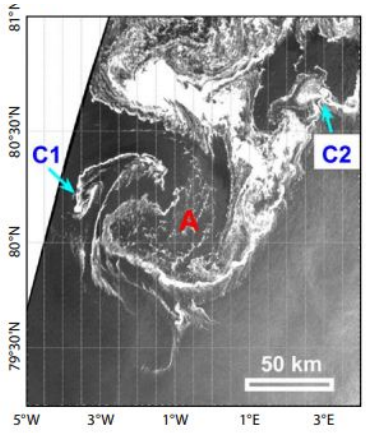
Eddies and EKE in the Arctic

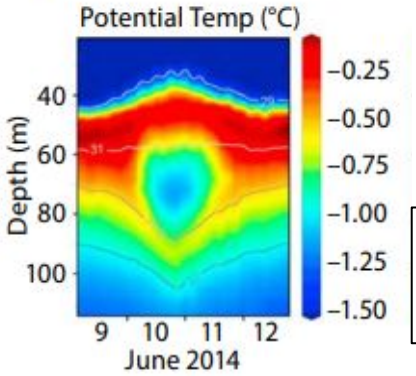
EKE (50–100 m) from moorings (von Appen et al., 2022) and 1 km simulation (Wang et al., 2020)

- Eddies crossing the Fram Strait highlight a likely mechanism of **export of Atlantic Water** and an associated heat flux **to the Nansen Basin** from the boundary current (Våge et al., 2016; Renner et al., 2018)
- In the **Laptev Sea** mooring shown eddies (Pnyushkov et al., 2018) which have likely been **advected from the western Nansen Basin or Fram Strait**, while others may have formed locally



SAR image of an anticyclone (A) and two cyclones (C1, C2) **in the MIZ of Fram Strait** (Kozlov et al., 2020)





Ice-Tethered Profiler (Zaho et al. 2016)

Objective and Methods

Objective

- Build on recent efforts based on the *"multi-altimetry combination in the Arctic (Prandi et al., 2021)"* to characterize the **mesoscale contributions to ocean dynamics and thermodynamics** which in turn can affect sea-level variability and budget

Methods

- Automated **eddy detection** starting from (2D) conventional and enhanced satellite altimetry maps and (3D) numerical simulation fields.

- **Assimilative experiments** to assess the potential of enhanced altimetry (L3) retrievals

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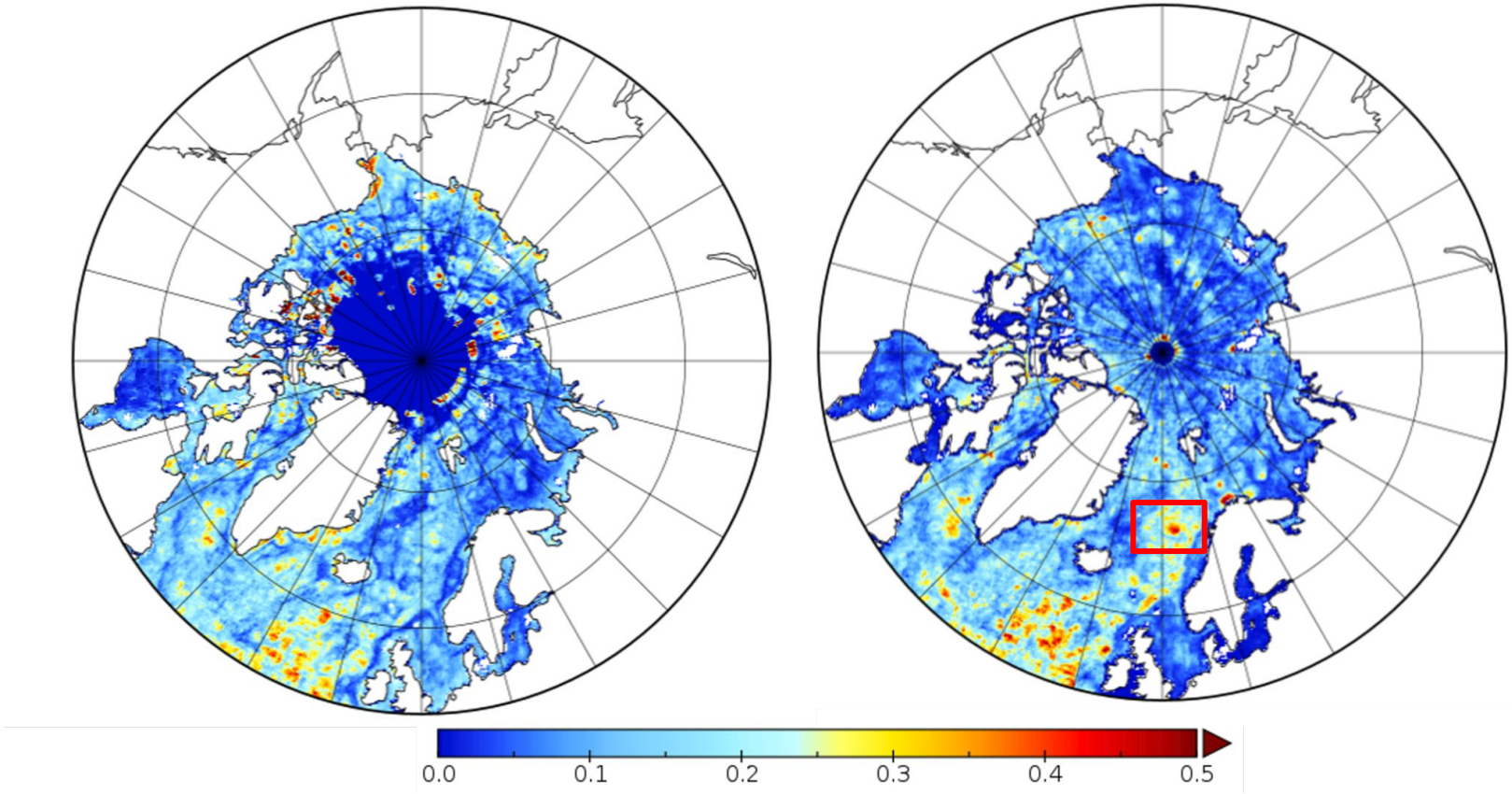
Eddy Contribution to Ocean Dynamics



Relative Eddy Kinetic Energy (REKE): fraction of ocean kinetic energy carried by eddies in the **conventional** (left) and **enhanced** (right) **altimetry maps** considering eddy **lifetime > 1 month**; values expressed as a percentage (%).

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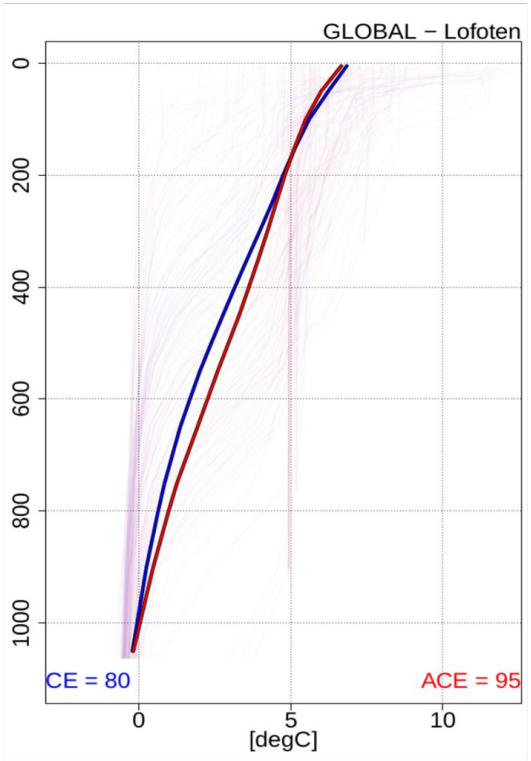
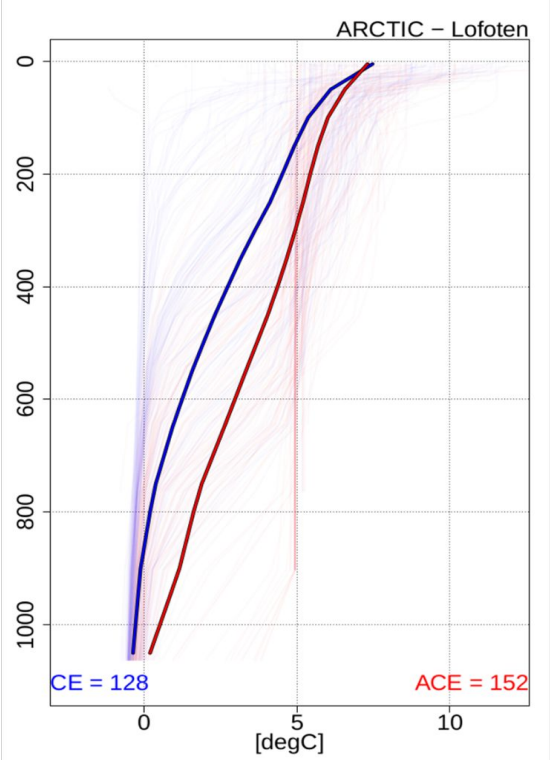
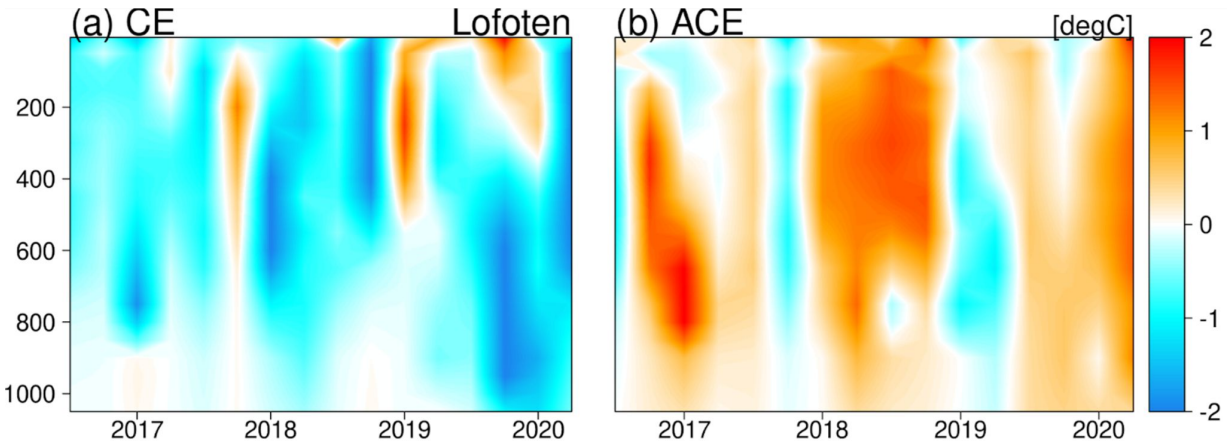
Eddy-driven temperatures – Lofoten Basin





- **Argo profiling floats trapped** by eddies in the Lofoten Basin.
- In-situ temperature profiles collocated with mesoscale features as a function of **eddy size, lifetime (> 1 month) and polarity:** cyclonic (CE; blue lines) and anticyclonic (ACE red lines) features.



- **Differences** between Temp. profiles.
- Negative (positive) values show **colder (warmer) Temp. in enhanced altimetry**

Assimilative experiments: Sentinel-3, Cryosat-2, AltiKa

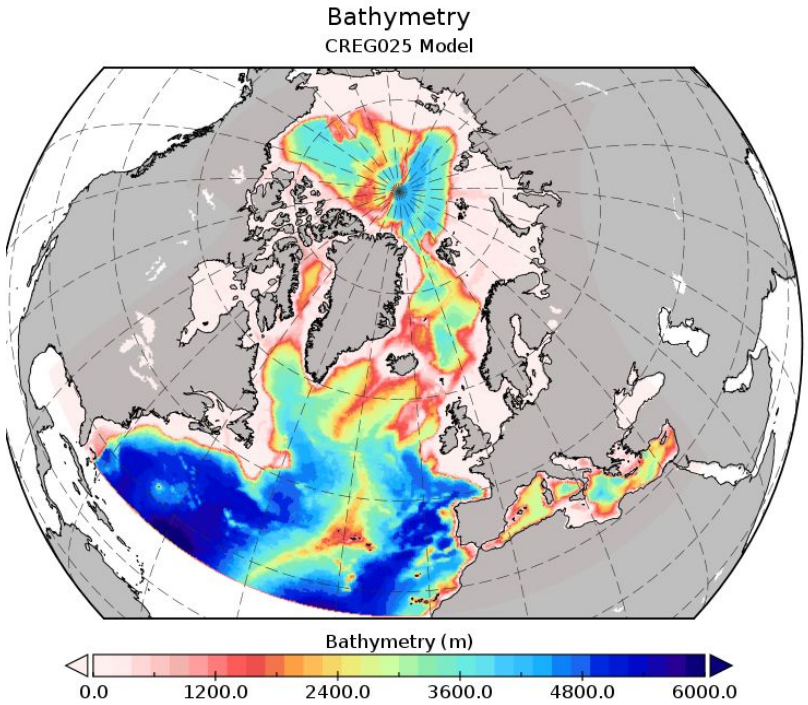
Assess the **impact of enhanced altimetry** on the ocean mesoscale field emerging from ocean monitoring and forecasting systems

Experimental Set-up

OGCM
NEMO (4.07), TKE vertical mixing, SI^3

Data Assimilation Scheme
- 3DVAR (Storto al., 2017)
- Multivariate EOFs
- Obs. Operator SLA based on dynamic height ⟶ T, S increments

Forcings
ERA5-hourly (Bulk Formula for momentum, heat, freshwater)



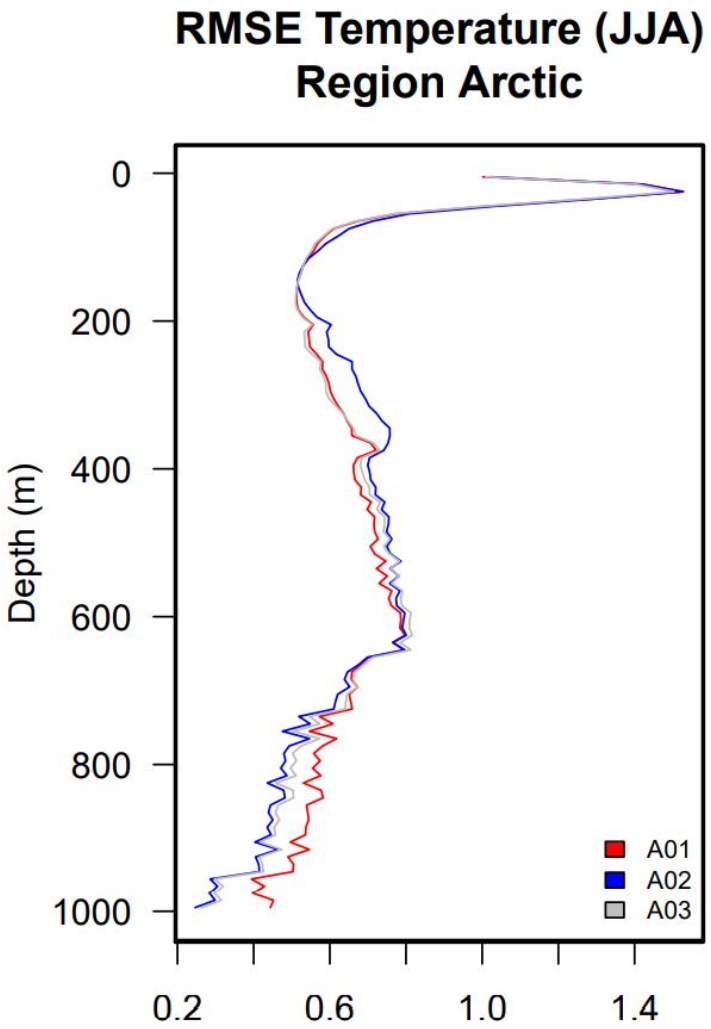
Period: 2016-2019

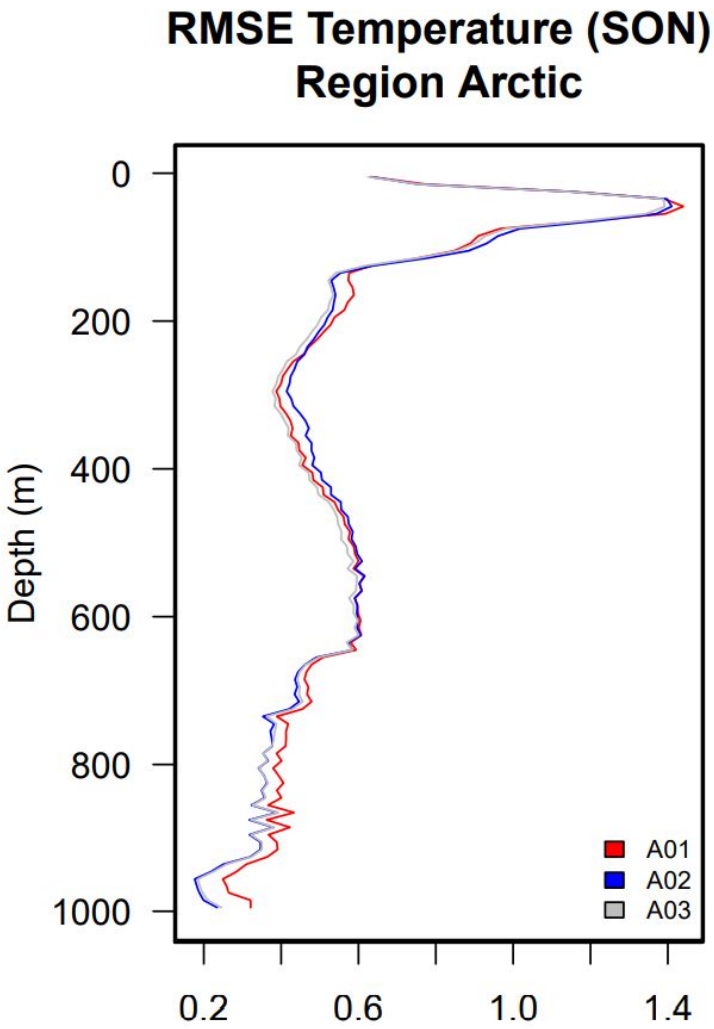
A01: in-situ data (T, S, profiles)

A02: EXP1+ altimetry (5Hz)

A03: EXP1 + altimetry (1Hz)

Ocean Analysis impact: Temperature Profiles in the Arctic





- The **skill** of the experiments is **comparable**
- **Improvements** can be observed **at depth** > 500 m during JJA

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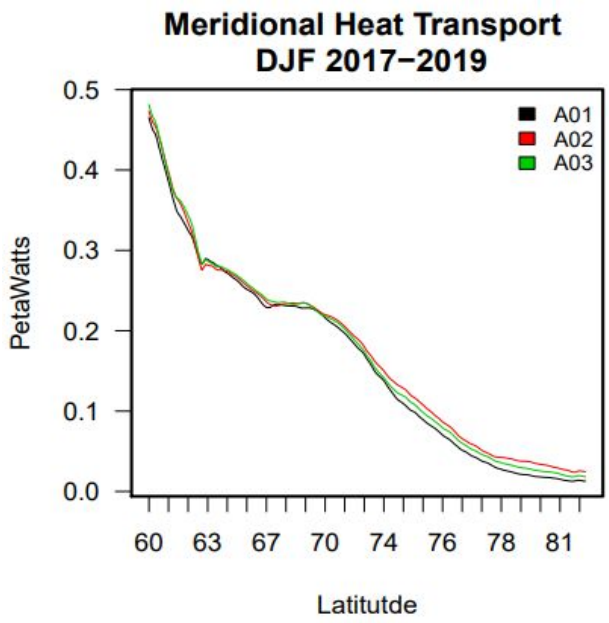
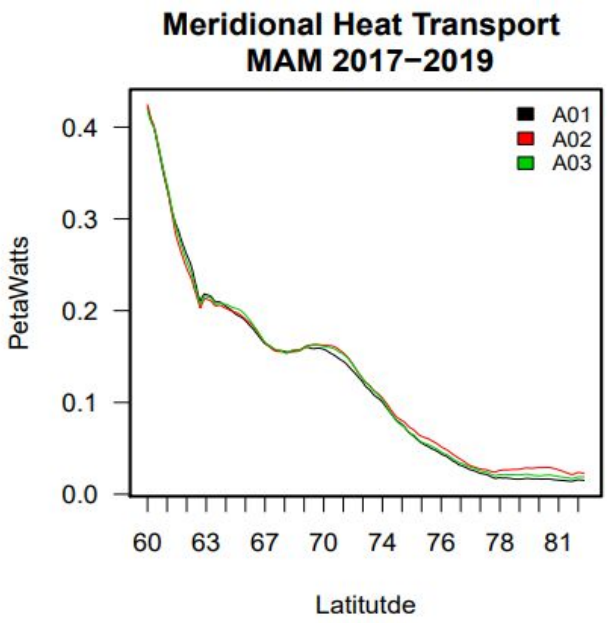
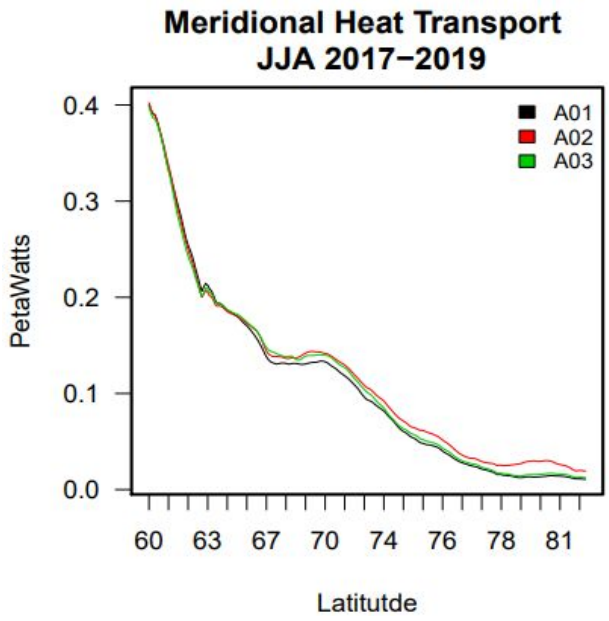
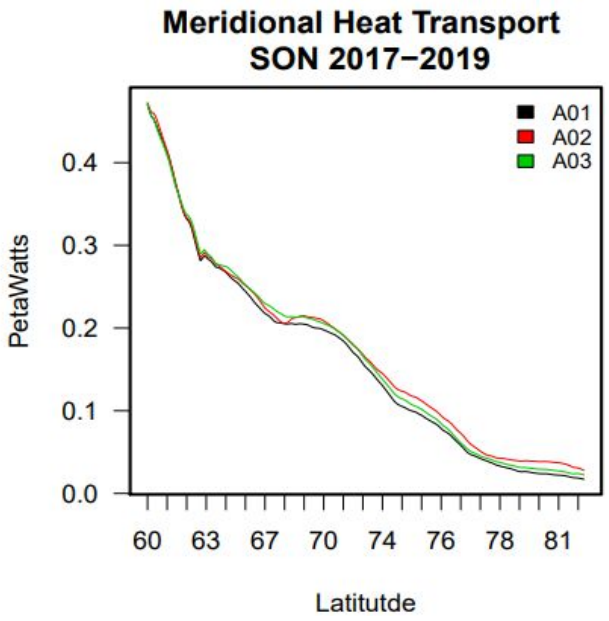
Ocean Analysis impact: Meridional Heat Transport









- Significant **increase of MHT** at the high latitudes
- The experiment performed ingesting **enhanced altimetry** shows the **largest increase** in all the seasons

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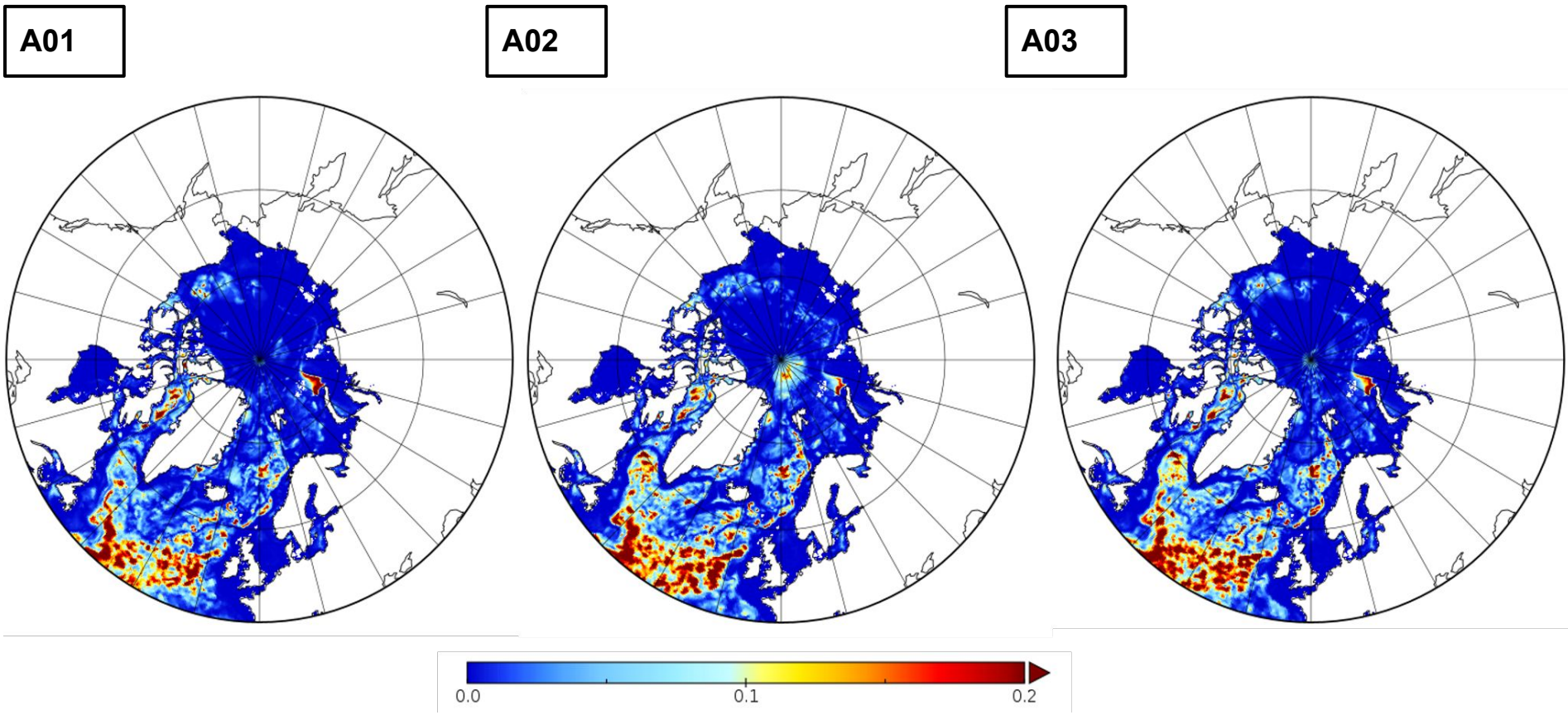
3D Detection: Relative Eddy Kinetic Energy



- **REKE** (%) explained by eddies > 14 days lifetime considering **0-200m** depth range
- The impact of enhanced altimetry data shows off at the high latitudes: **energetic mesoscale features** in the Arctic (Nansen basin)

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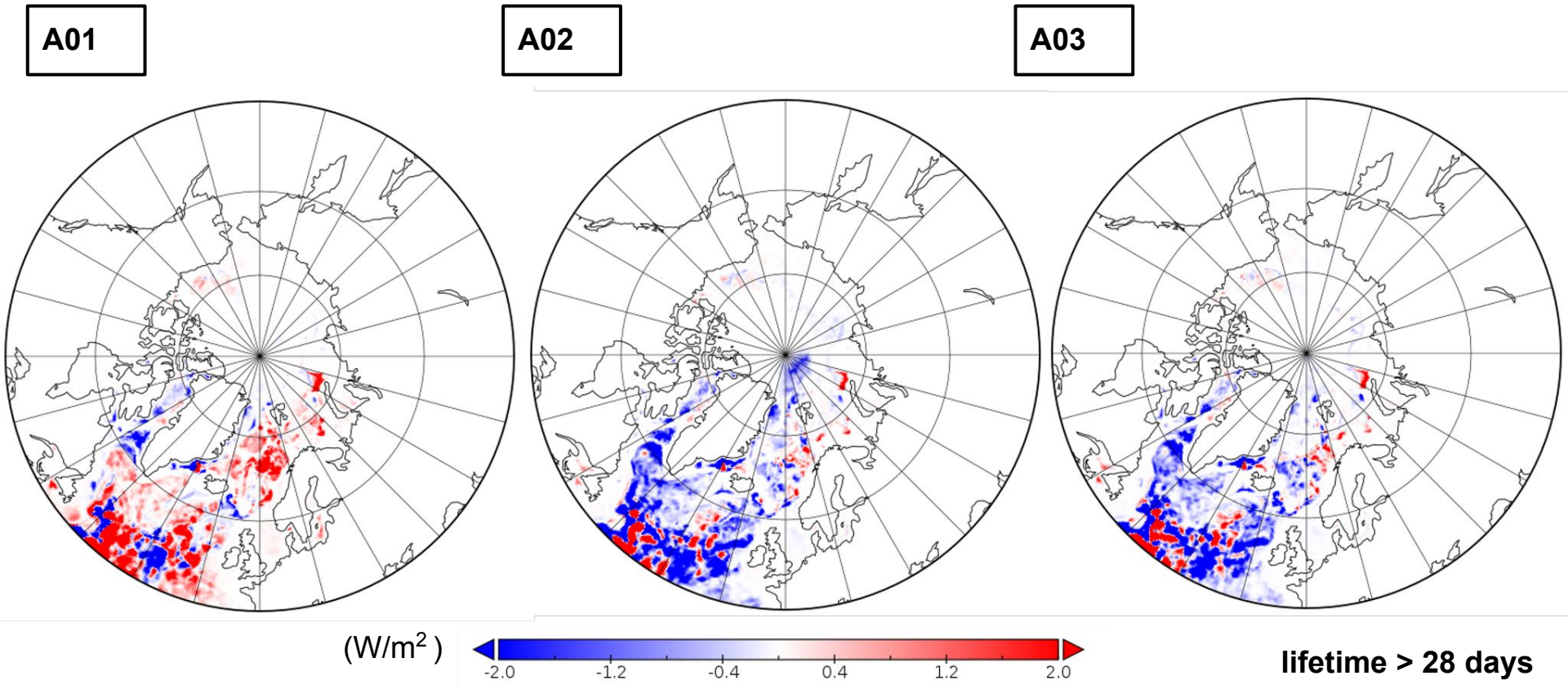
Eddy Influence on the Ocean-Atmosphere Heat Fluxes



- Constraining the **mesoscale variability largely affect the heat fluxes** between atmosphere and ocean

- Enhanced altimetry helps to disclose **eddy driven heat fluxes** in the Arctic

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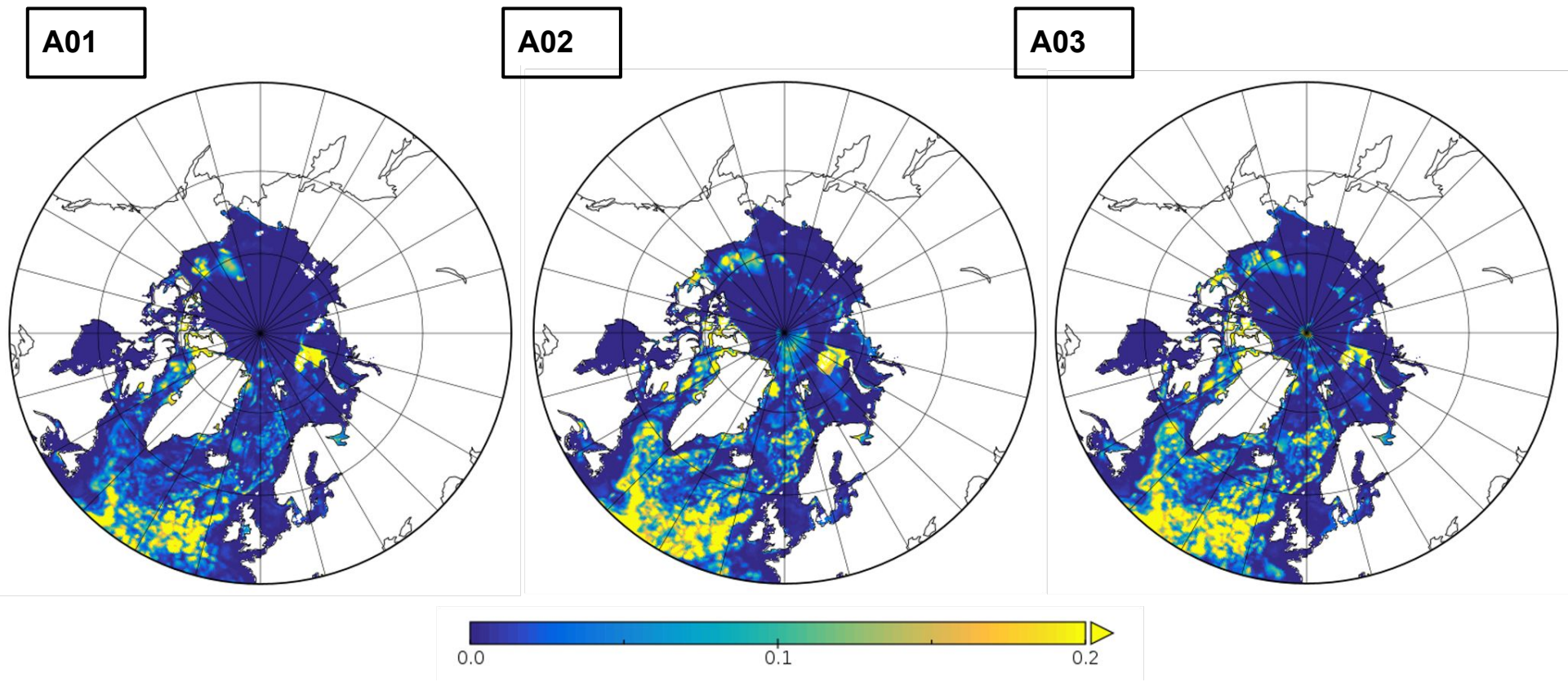
Mesoscale influence on the SSH variability



- Percentage of **variance of SSH** explained by eddies as a function of lifetime (>1 month)
- **Mesoscale** features show their **signature in the SSH field** in Nordic Seas and Arctic

Outlook

- The eddy population detected from enhanced altimetry shows **more energetic mesoscale features** in the Nordic Seas, compared to conventional data, showing an impact on **eddy driven temperature** profiles (Argo floats)
- **Assimilative experiments** clearly show the impact of the enhanced altimetry data on the mesoscale field
- **3D eddy detection** (model-based) disclose **eddies penetrating in the Arctic**, in agreement with the findings of recent studies
- Constraining the **mesoscale variability** features influence the **ocean-atmosphere heat exchange** and modifies the ocean meridional **heat transport**
- The variance of **SSH fields** show a potential towards sea-level studies in the Nordic Seas and in the Arctic