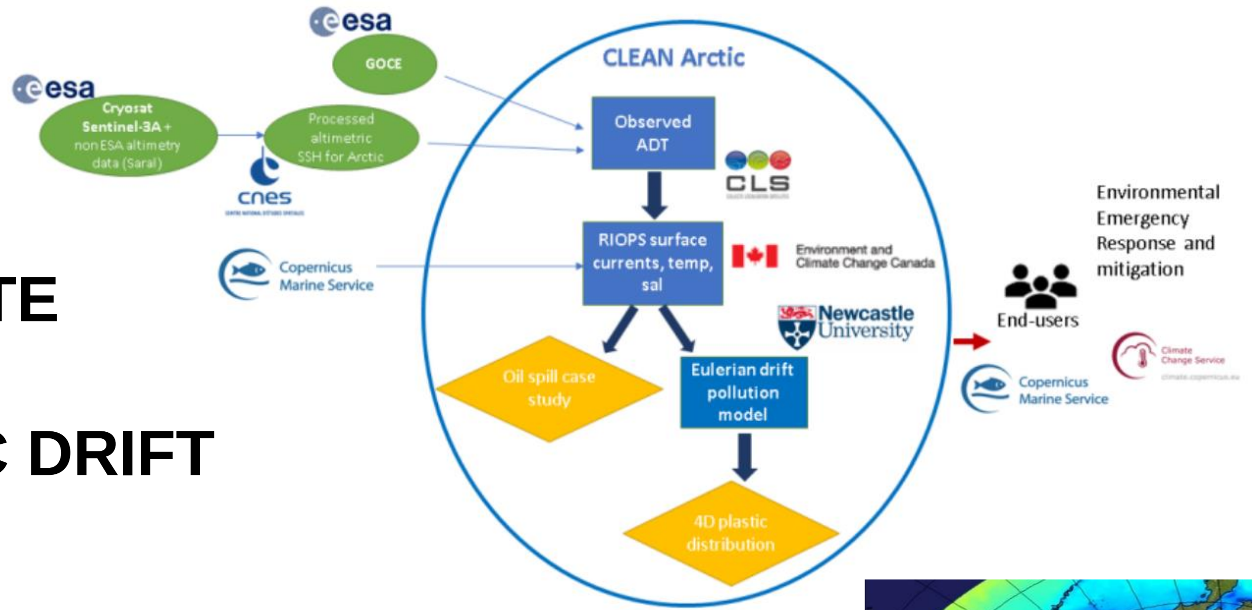
Environment and Climate Change Canada — Environnement et Changement climatique Canada

esa — CLS Collecte Localisation Satellites — Newcastle University

CLEAN ARCTIC: USE OF ABSOLUTE DYNAMIC TOPOGRAPHY DATA TO IMPROVE ESTIMATES OF PLASTIC DRIFT IN THE ARCTIC



Gregory Smith[1], Charlie Hébert-Pinard[1], Audrey-Anne Gauthier[2], Andrew Peterson[1], François Roy[1], Pierre Veillard[3], Yannice Faugère[3], Sandrine Mulet[3], Miguel Morales Maqueda[4]

[1] Meteorological Research Division, ECCC

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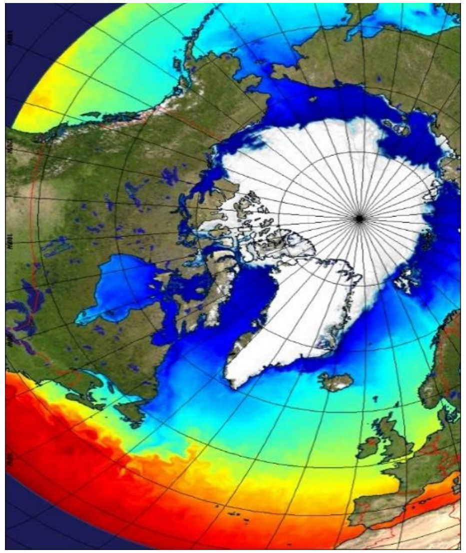
[3] Collecte Localisation Spatiale (CLS), France

[4] Univeristy of Newcastle, UK



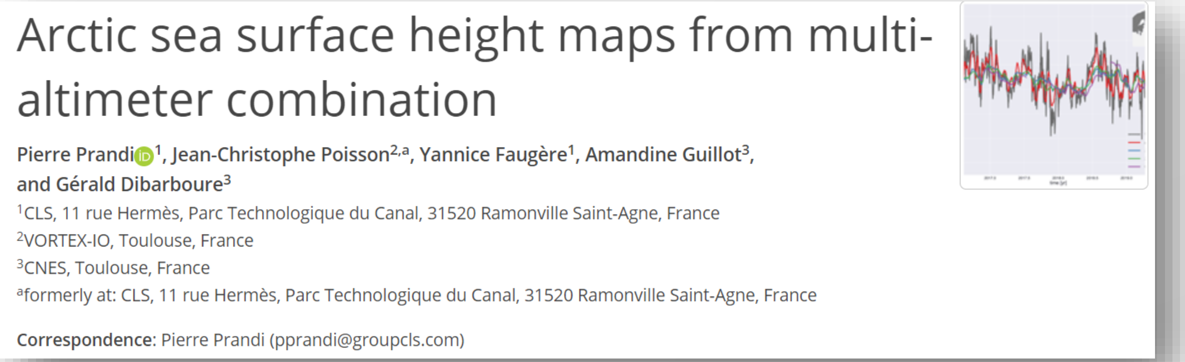
Coastal Ocean Shelf Seas Task Team Workshop, Montréal, May 2-4, 2023

CONCEPTS — Canadian Operational Network of Coupled Environmental Prediction Systems

Canada

CLS Arctic sea level anomaly product

› Gridded and <u>**along-track**</u> Arctic ocean product
  - from July 2016 to June 2020
  - 25 km, 3 day grid
  - 50 °N < lat < 88 °N



Arctic sea surface height maps from multi-altimeter combination

Pierre Prandi[1], Jean-Christophe Poisson[2,a], Yannice Faugère[1], Amandine Guillot[3], and Gérald Dibarboure[3]
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[2]VORTEX-IO, Toulouse, France
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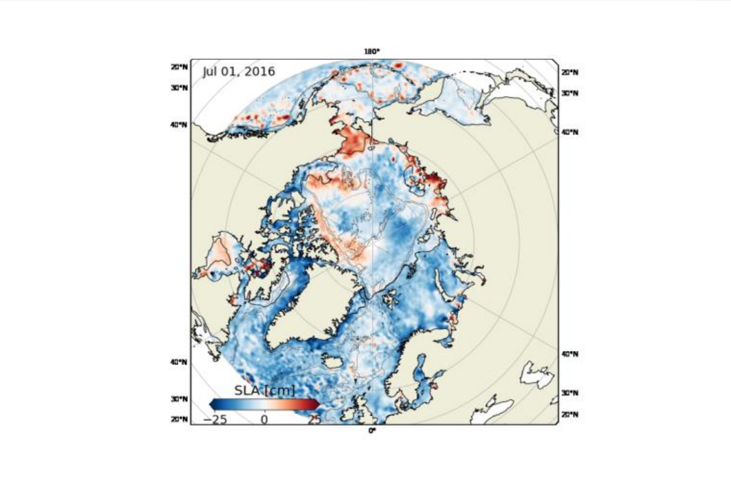
[a]formerly at: CLS, 11 rue Hermès, Parc Technologique du Canal, 31520 Ramonville Saint-Agne, France

Correspondence: Pierre Prandi (pprandi@groupcls.com)



- Can altimetry observations under ice help to constrain Arctic circulation?
- How can we make best use of the data?

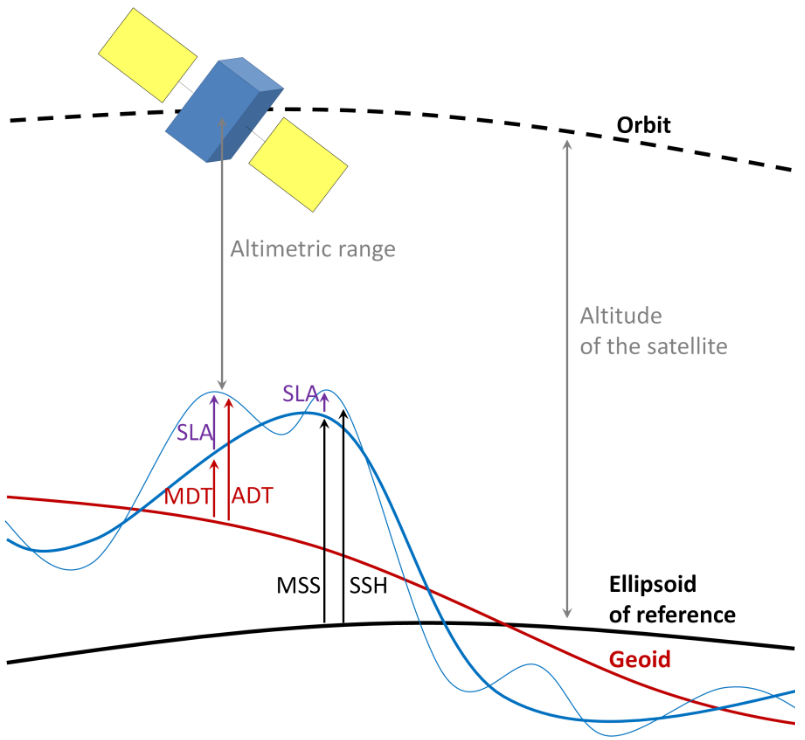
Approach

$$SLA = SSH - MSS$$
$$ADT = MDT + SLA$$

« classical » method to compute ADT

MDT computed from MSS and geoid model (and also in-situ data for the smaller scales)

MSS estimated from altimetric mission mean profiles



What about in polar regions ?

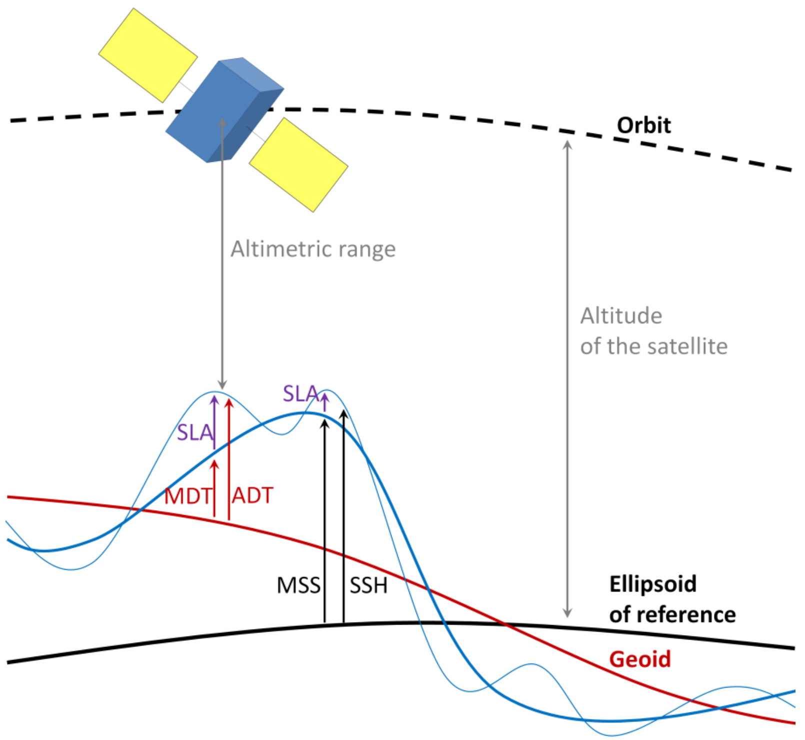
- **Seasonal variability of sea ice coverage**
  - Mean Sea Surfaces biased towards summer conditions
- **Recent years have seen an increase of the summer melting**
  - Altimeter data are now measured in areas never observed before

→ Higher error in MSS/MDT results in poorer representation of SSH in ocean prediction systems

- **SSH: Sea Surface Height**
- **SLA: Sea Level Anomaly**
- **MSS: Mean Sea Surface**
- **ADT: Absolute Dynamic topography**
- **MDT: Mean Dynamic Topography**

New direct ADT method

$$ADT = SSH - Geoid$$



Approach

Avantage

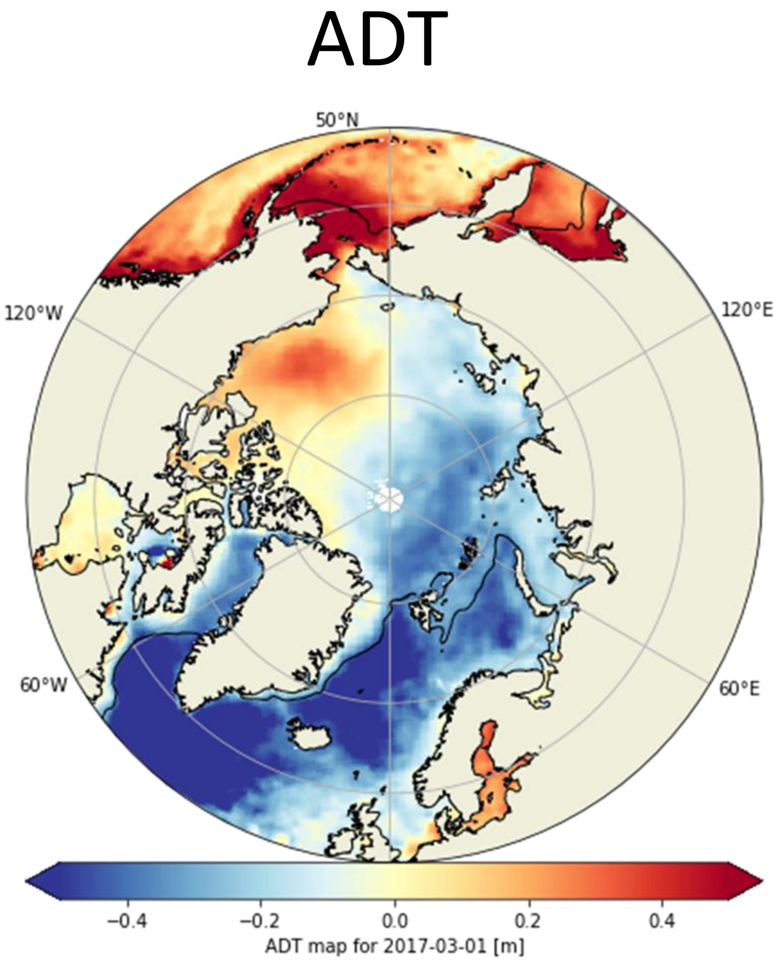
No need of 'mean' field (MSS/MDT)

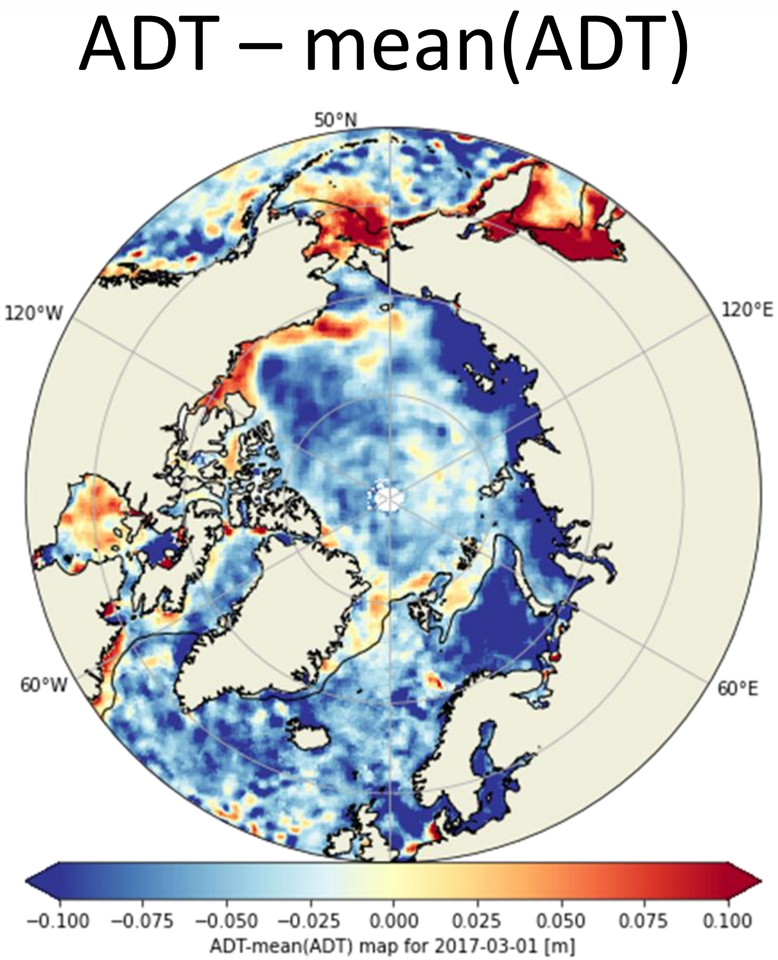
Limitations

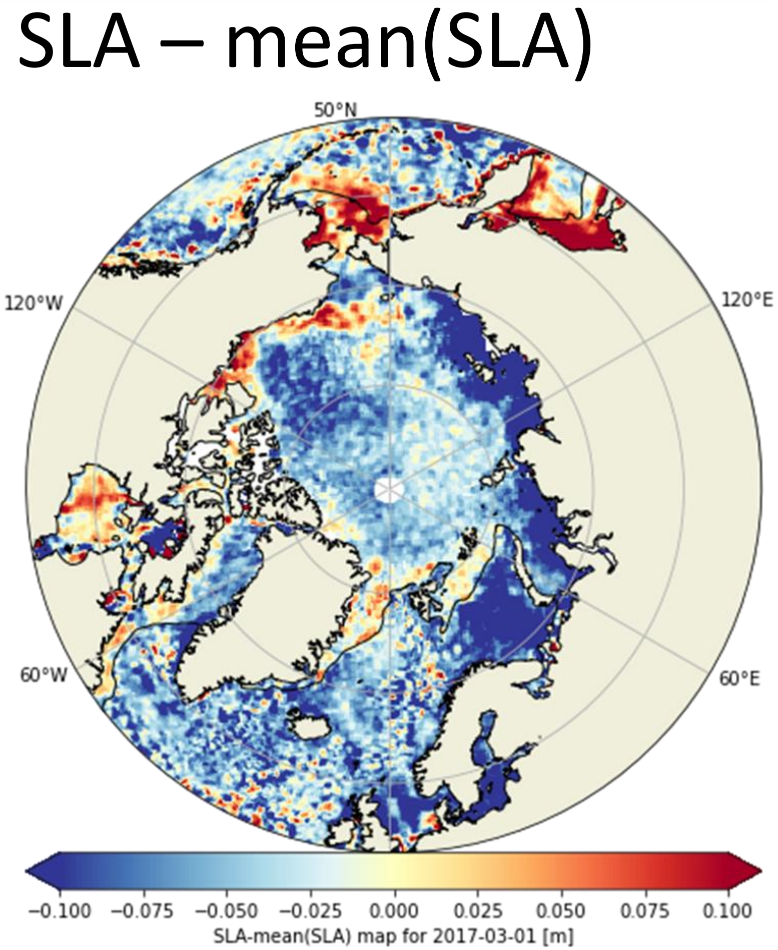
Geoid model limits the spatial resolution (> 125 km pour GOCE)

- **SSH: Sea Surface Height**
- **SLA: Sea Level Anomaly**
- **MSS: Mean Sea Surface**
- **ADT: Absolute Dynamic topography**
- **MDT: Mean Dynamic Topography**

ADT map for 2017-03-01 (reference period : 06/2016 – 06/2018)

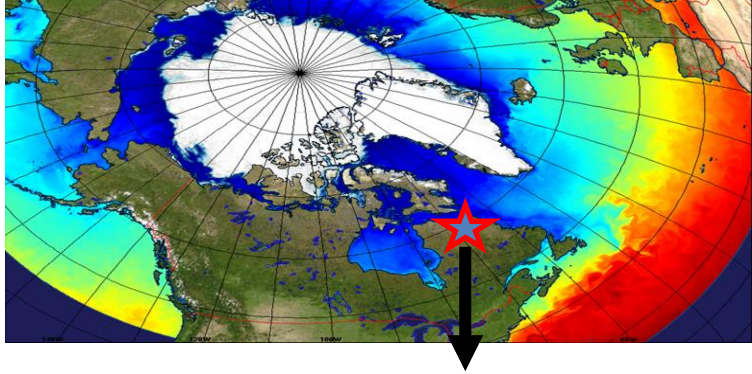






SLA leads (Prandi, 2021)

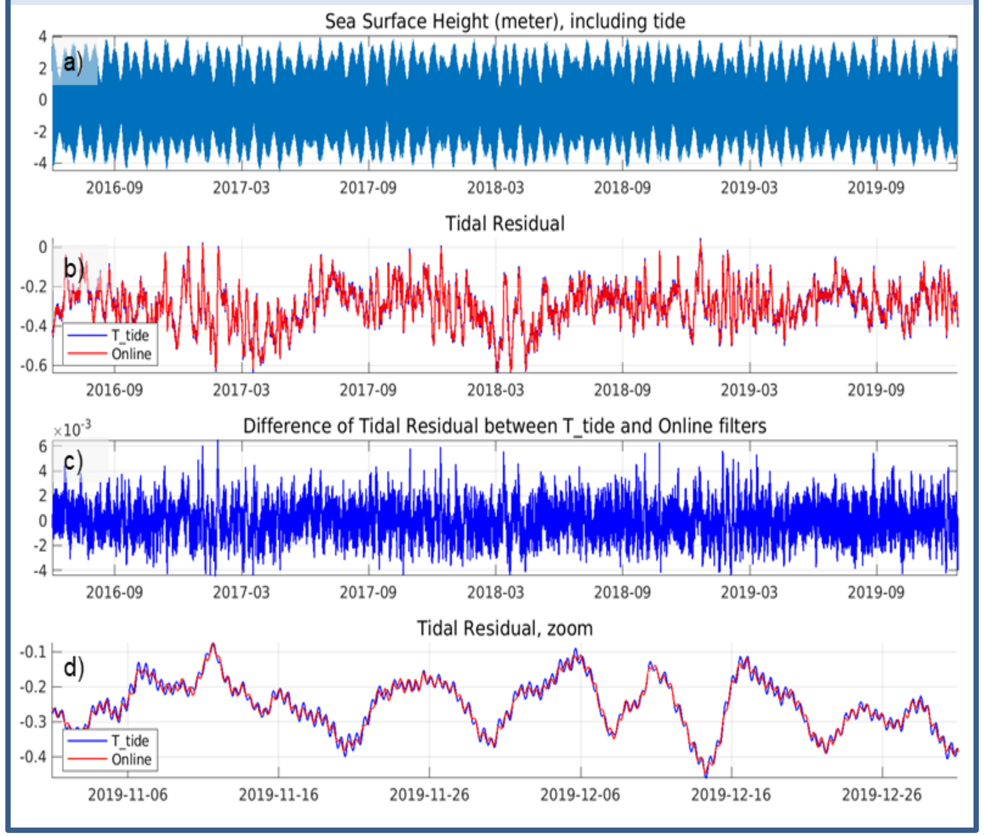
REGIONAL ICE OCEAN PREDICTION SYSTEM



RIOPS developed for Arctic METAREAs support:

- NEMO-CICE (3-8 km)
  - Z-level, k-eps, landfast ice
  - OBC from GIOPS + tidal harmonics
  - 84hr Ice-ocean forecasts
  - Coupled to 3km pan-Arctic atmospheric model for YOPP
- Data Assimilation
  - 2x7-day analysis cycles and daily 1d cycles
  - Multivariate SEEK filter (SAM2)
  - Background error from 10-year hindcast (sub-monthly anomalies)
  - Assimilates SLA, SST, in situ T/S profiles
  - Hybrid MDT: CNES-CLS13 + innov from GLORYS
  - Blended with 3DVar ice analysis
    - CIS charts, SSMI, SSMI/S, AVHRR, AMSR2
  - 3DVar T/S bias correction
  - 7d Incremental Analysis Updating
  - Online sliding window tidal filter allows non-stationary tides (e.g. due to sea ice)

Online tidal filter results for Ungava Bay



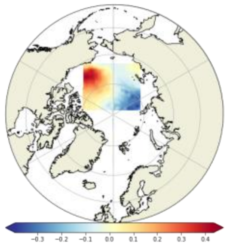
Canada

CONCEPTS

MERCATOR OCEAN INTERNATIONAL

Smith et al. (QJRMS2015, MWR2018, GMD2021)

ASSIMILATION OF ARCTIC ADT IN RIOPS

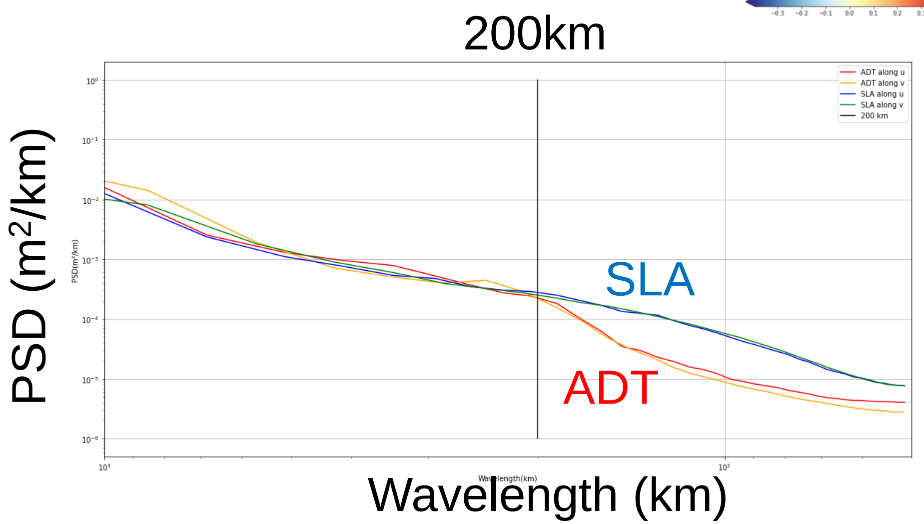


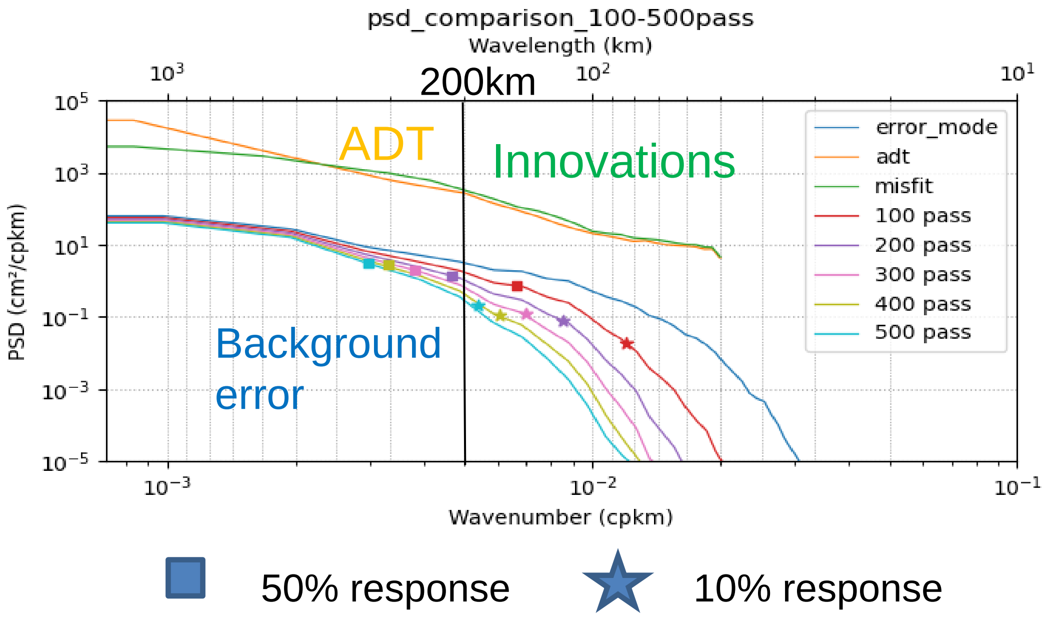
Several technical changes required to assimilate under-ice altimetry:

- De-activate use of under-ice Bogus observations
- Modify observation error estimates (MDT vs Geoid)
- Need to adjust background error used to accommodate different scales represented in ADT
  - 100 additional pass Shapiro filter
- Smooth trial fields as part of observation operator to avoid misrepresentation of small scales as error

Evaluation strategy:

- Produce experiments over 1-yr evaluation period
- Produce final 4-yr reanalysis with final configuration
- Assess impact on plastic drift





COMPARISON OF INNOVATIONS FROM SLA VS ADT

Performed 1-yr experiments to investigate impact of ADT and SLA-leads (under ice) products,.

EXP-SLA :

- Operational settings but with SLA-leads assimilated under ice
- Under-ice bogus obs deactivated.
- SLA-global in open water

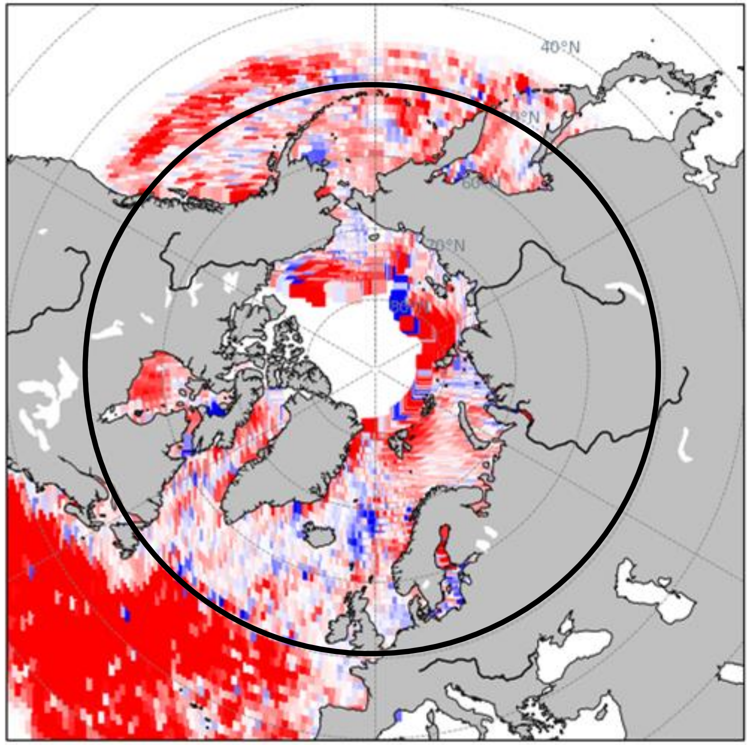
EXP-ADT :

- Operational settings, but assimilate ADT in place of conventional SLA. No bogus obs under ice

✓ Generally, innovations are smaller for the dataset that is assimilated.

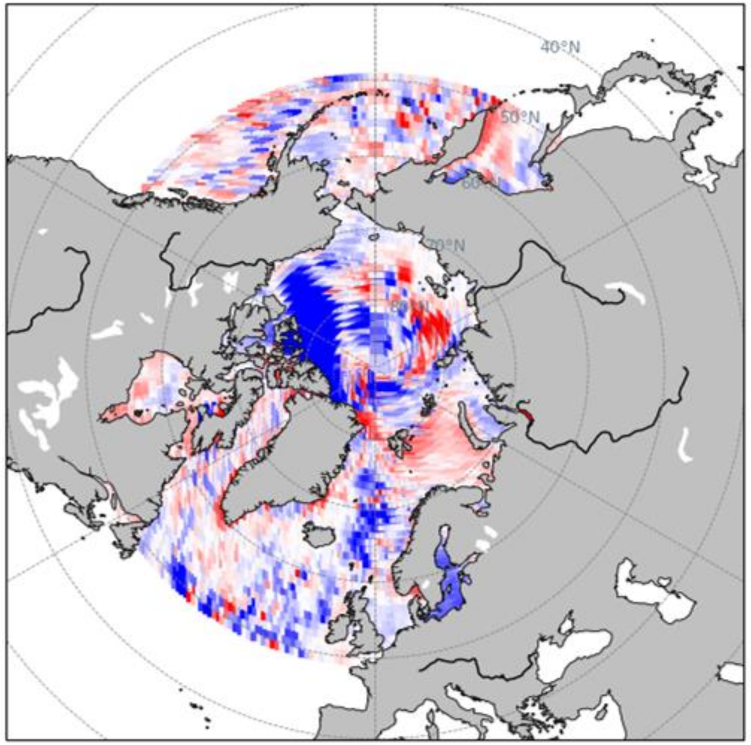
✓ Significant difference between products!

diff RMS Cryosat2
EXP-ADT – EXP-SLA



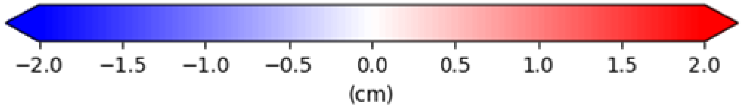
Rx_sla_leads – rx_cl_v0 RMS for C2

diff RMS ADT
EXP-ADT – EXP-SLA



Rx_sla_leads – rx_cl_v0 RMS for ADT

RMS smaller for EXP-ADT



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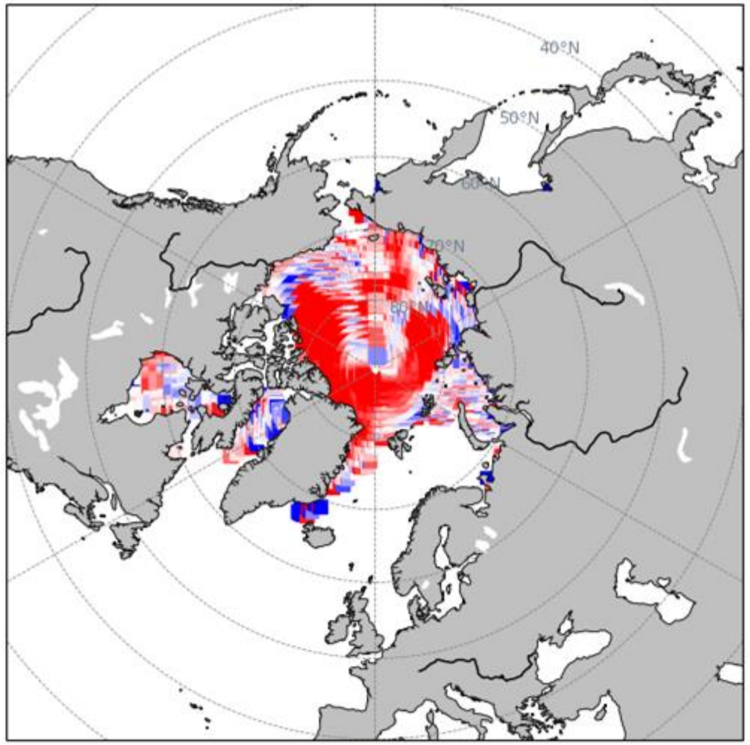
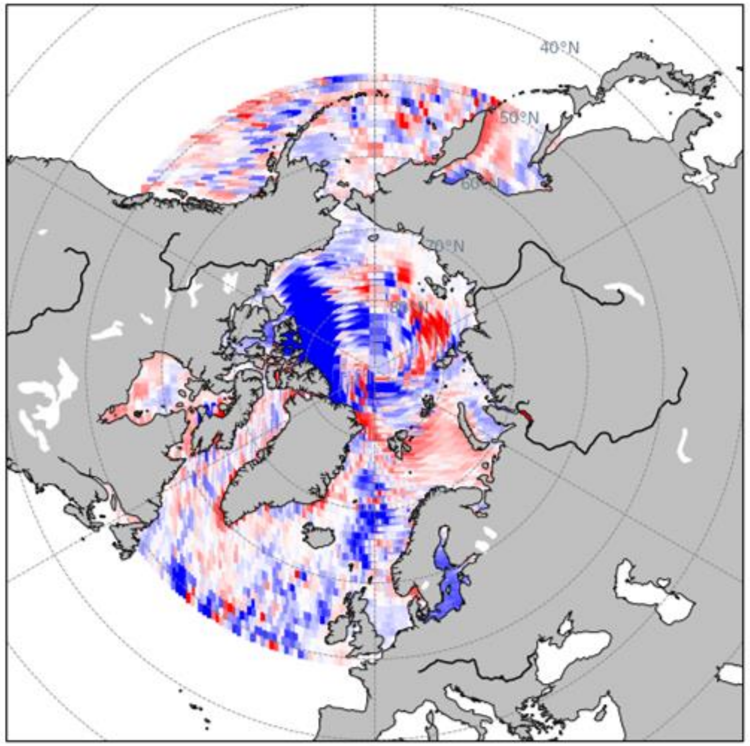
diff RMS Cryosat2-leads EXP-ADT – EXP-SLA



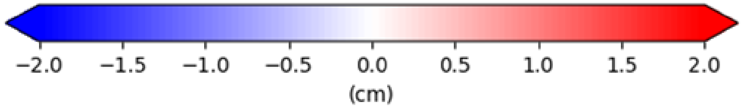
Rx_sla_leads – rx_cl_v0 RMS for C2-leads

diff RMS ADT EXP-ADT – EXP-SLA



Rx_sla_leads – rx_cl_v0 RMS for ADT

RMS smaller for EXP-ADT

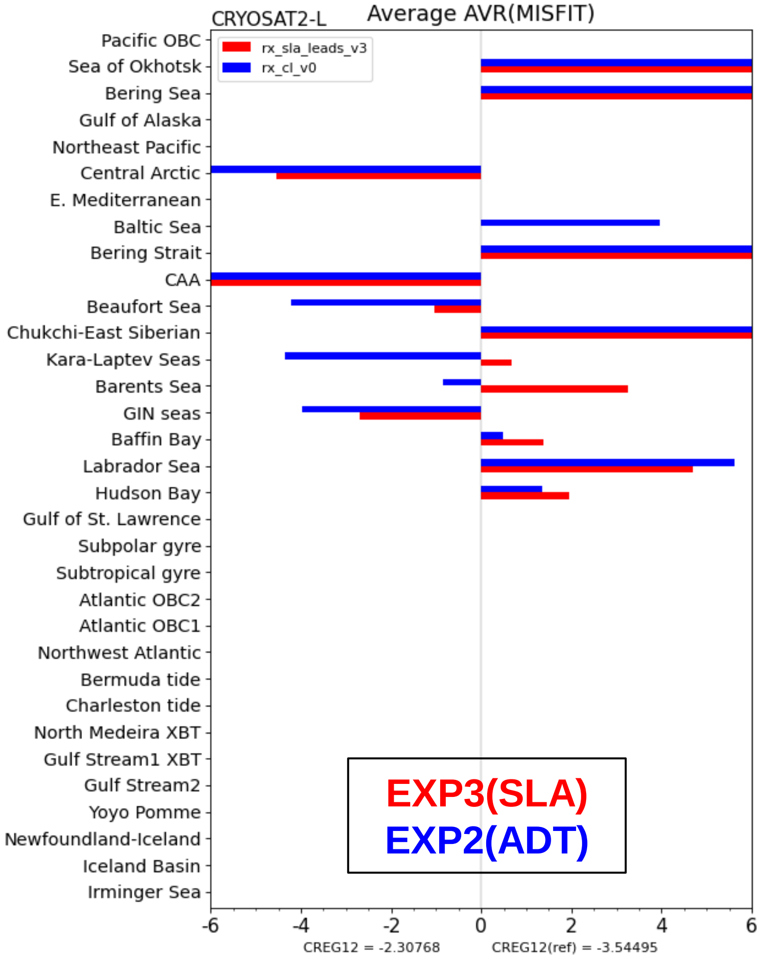


RMS smaller for EXP-SLA

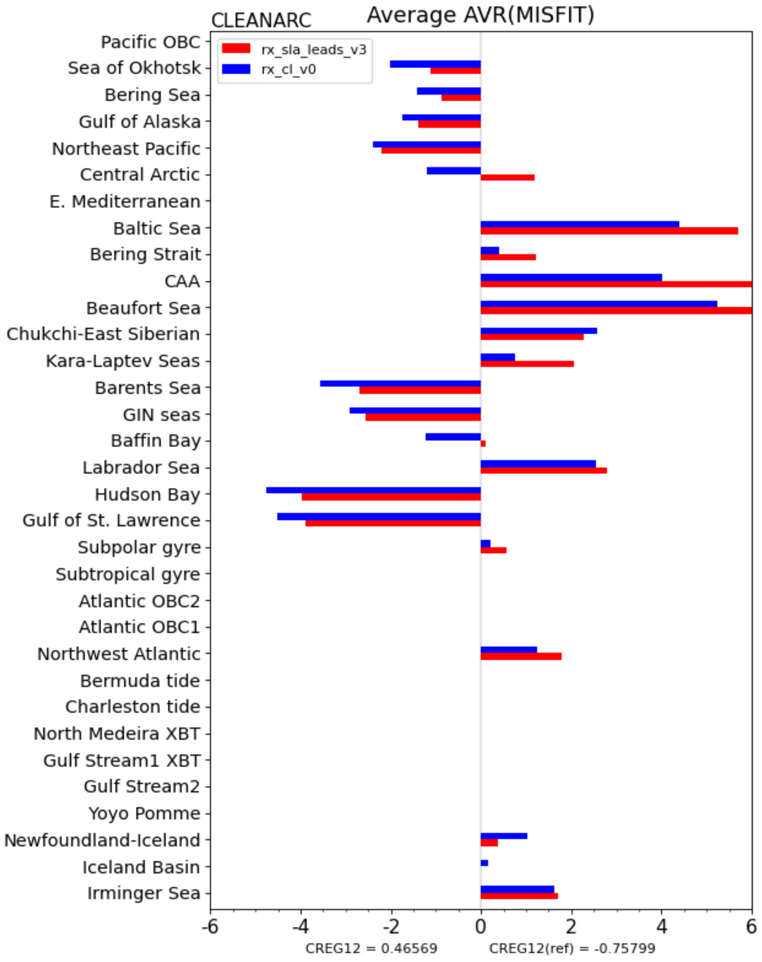
COMPARISON OF INNOVATIONS FROM SLA VS ADT

- ✓ Mean innovations for Cryosat2-leads have large values (>6cm) that vary from one region to another.
- ✓ Mean innovations for ADT show reasonable values
- ✓ Avoids use of MDT that has unreliable values under and near ice.

Mean Innovations C2-leads



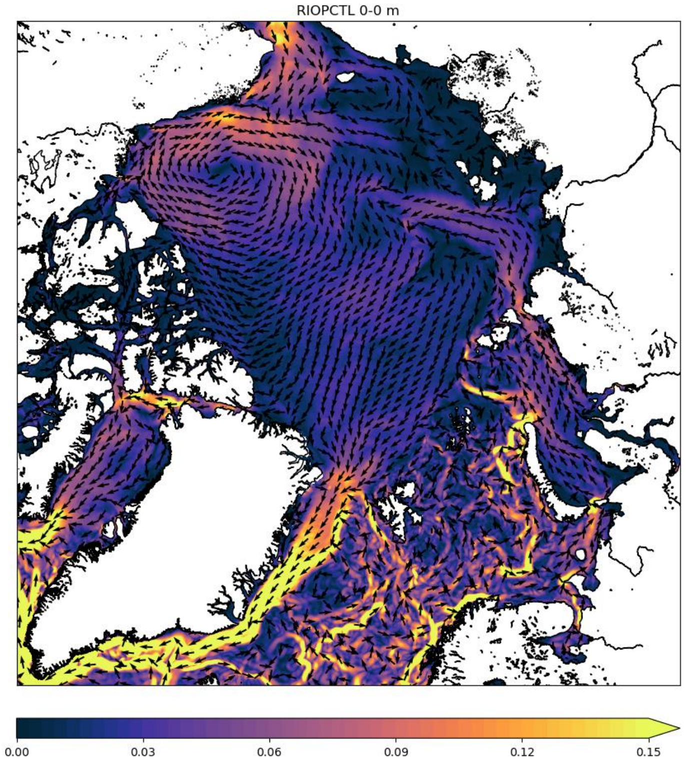
Mean Innovations ADT



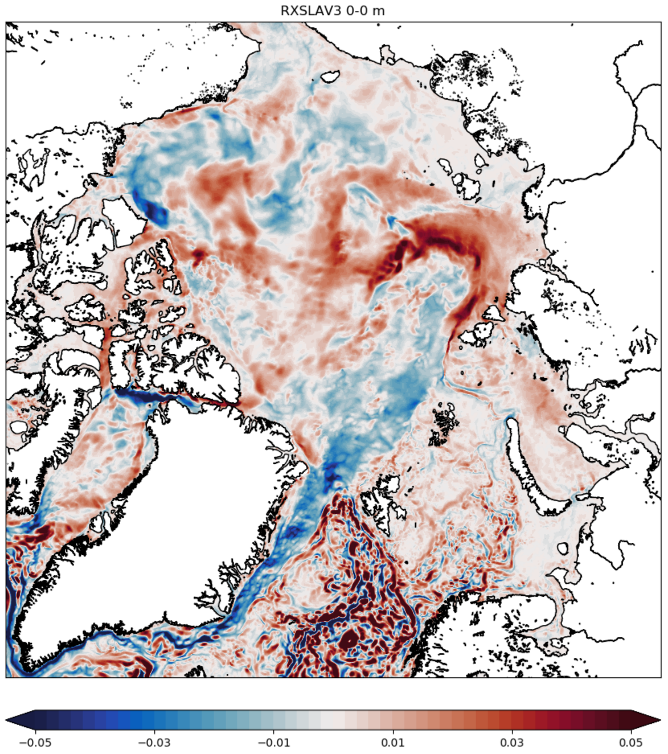
ADT VS SLA – SURFACE CURRENTS (JAN-MAR)

- ✓ Under-ice assimilation impacts various Arctic regions (e.g. Beaufort Gyre and Laptev Sea shelf break current).
- ✓ The impact differs considerably between experiments using SLA-leads vs ADT!
- ✓ Large potential impact for estimates of transports across the Arctic!

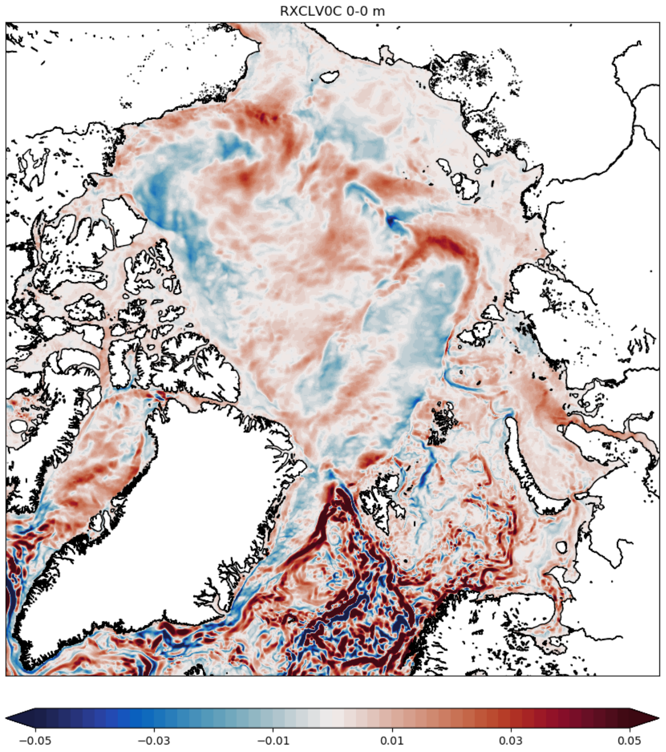
Operational (OPS)



EXP-SLA – OPS



EXP-ADT – OPS



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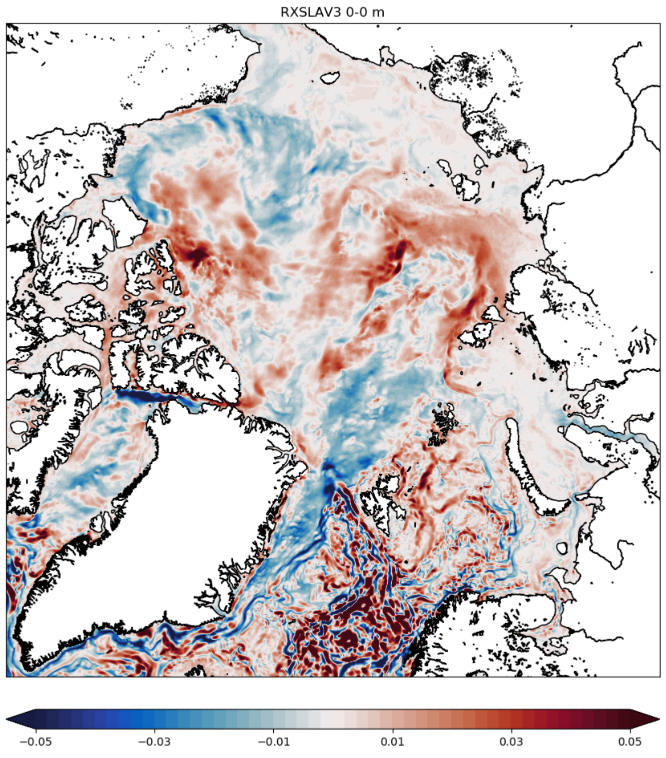
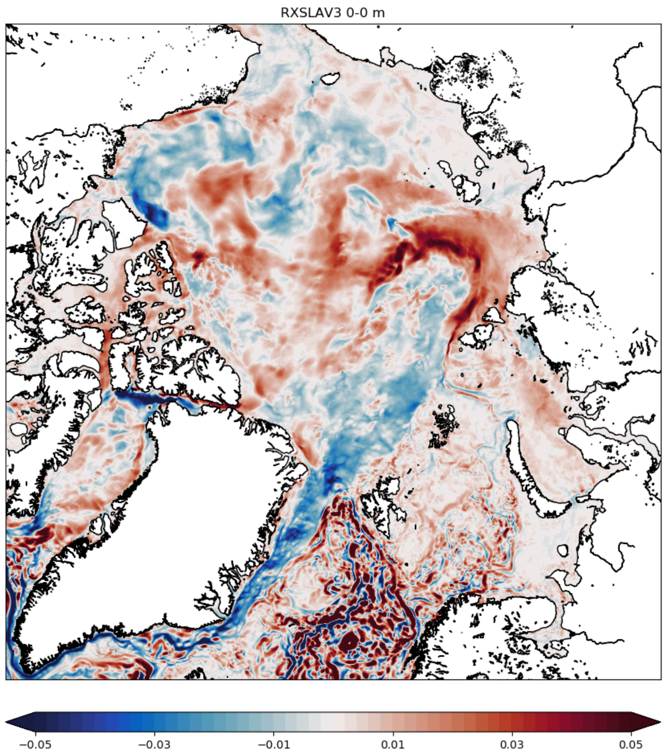
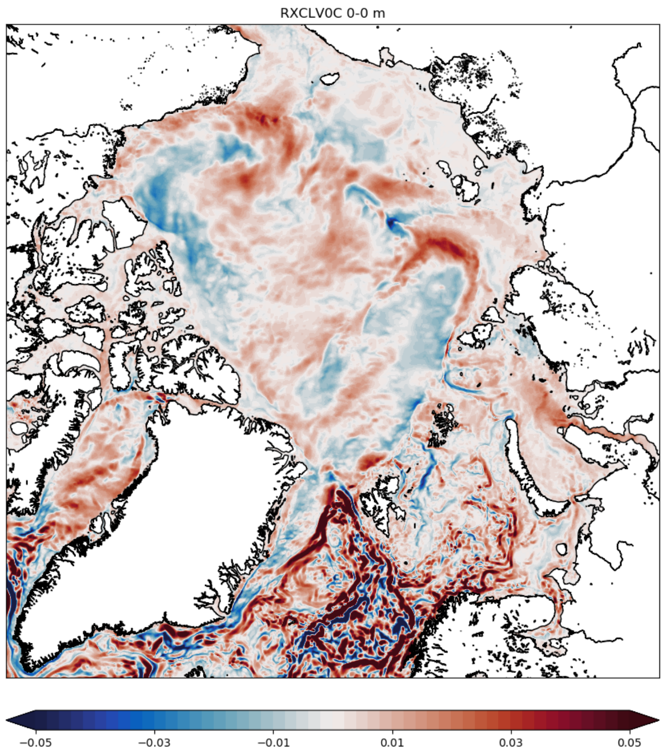
EXP-SLA – EXP-ADT



EXP-SLA – OPS



EXP-ADT – OPS

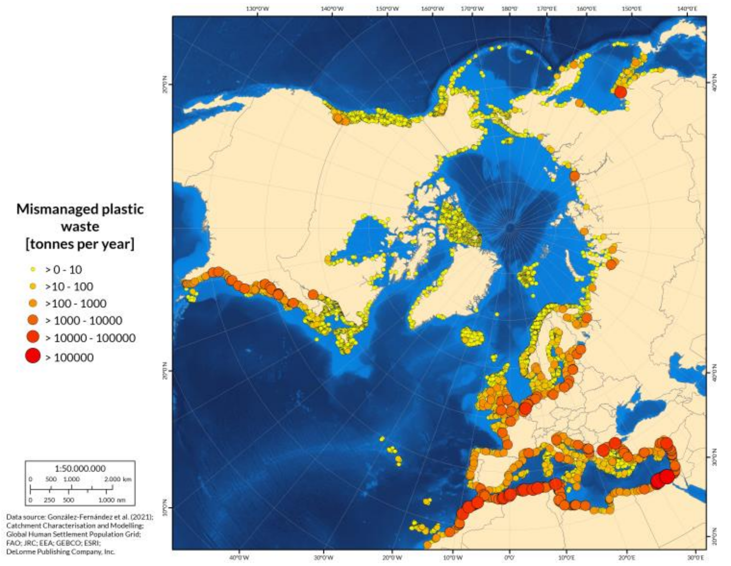


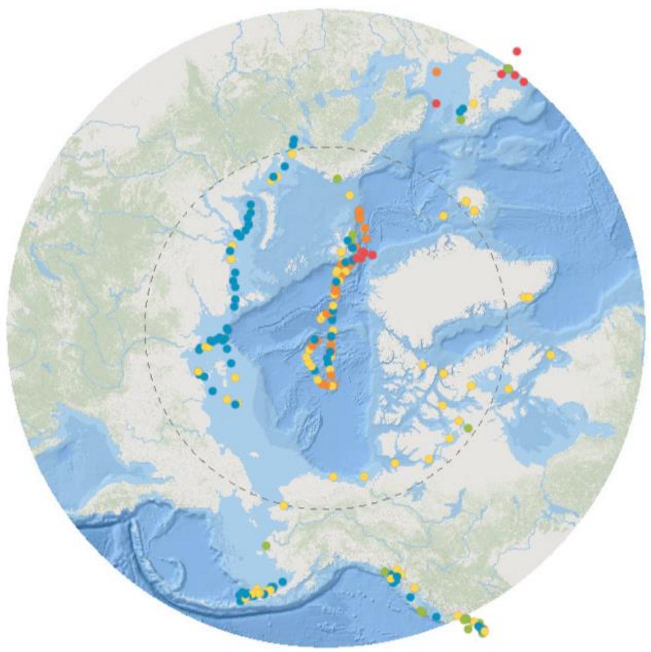
SUMMARY

- Recent under-ice altimetry products open the door to improved constraints on circulation in polar regions in operational prediction systems
  - Uncertainty in MDT is a major limitation
  - Significant sensitivity to use of SLA-leads vs ADT
- Assimilation of ADT appears beneficial provided assimilation system is adjusted appropriately
  - R-geoid, B-matrix and H-operator filtering
  - Significant impact on major features of Arctic circulation
    - Beaufort Gyre, Laptev Shelf current, East Greenland current
  - Multi-year reanalysis underway….
- Next steps: Assess impact on drift of microplastics….

DISPERSION OF MICROPLASTICS IN THE ARCTIC

- Use Mountford and Morales Maqueda (2019, 2020) Eulerian model for the dispersion of microplastics in the ocean
- **Microplastic model coupled to NEMO**
  - provides Eulerian currents, Gent-McWilliams (1990) bolus eddy velocities, isopycnal and diapycnal diffusivities, and seawater density fields to drive the microplastic model.
- Different plastic types characterized by a nominal particle size and density.
- Changes in concentrations are governed by source-sink, advection-diffusion equations, but with an added settling velocity.
- **Assess sensitivity of ADT assimilation in RIOPS on distribution of microplastics.**





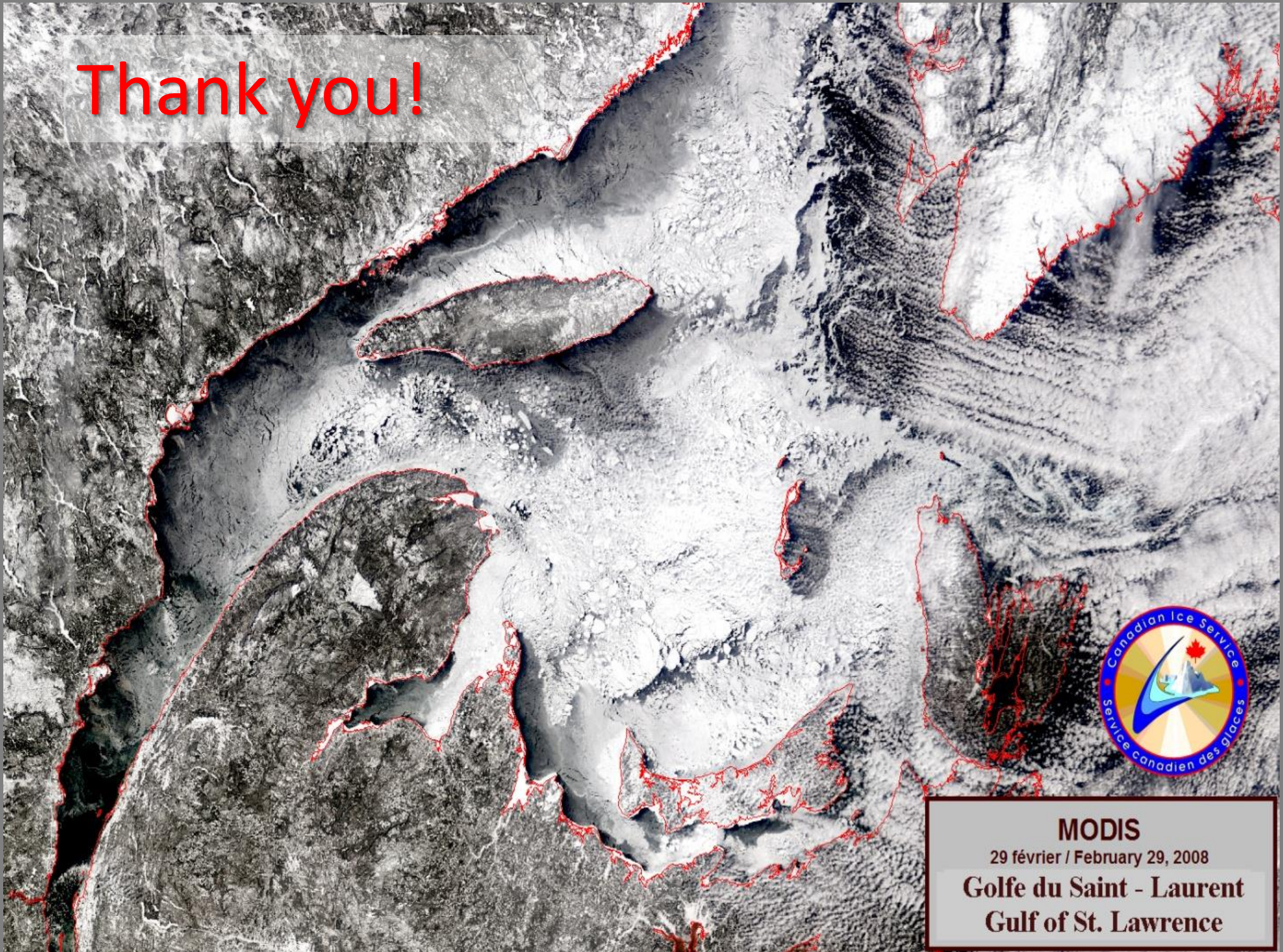
- Very Low (0-0.0005 items/m^3)
- Low (0.0005- 0.005 items/m^3)
- Medium (0.005 – 1 items/m^3)
- High (1-10 items/m^3)
- Very High (>10 items/m^3)

Ranges based on NOAA microplastic database

Water samples mainly collected using tow nets and vessel underway pump systems

Newcastle University

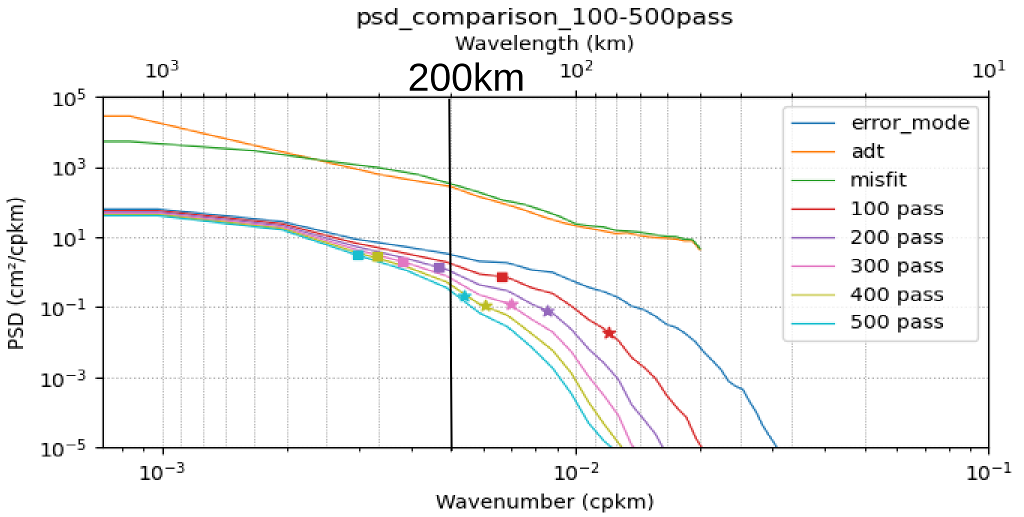
Thank you!


Canadian Ice Service
Service canadien des glaces
MODIS
29 février / February 29, 2008
Golfe du Saint - Laurent
Gulf of St. Lawrence

EXTRAS

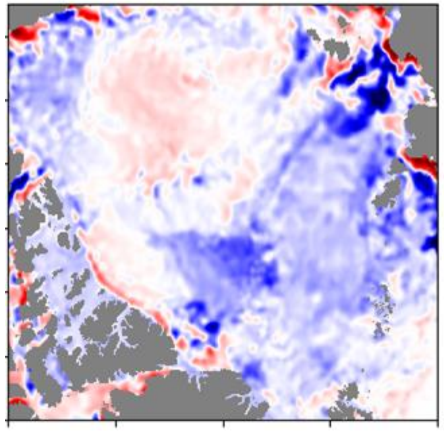
FILTERING OF BACKGROUND ERROR MODES

- ✓ Reduce variance for lengthscales smaller than 200 km to improve coherence with ADT.
- ✓ Optimal number of passes between 100 and 200 passes.

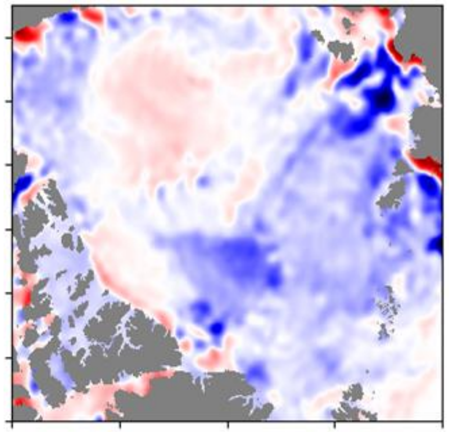


■ 50% response ★ 10% response

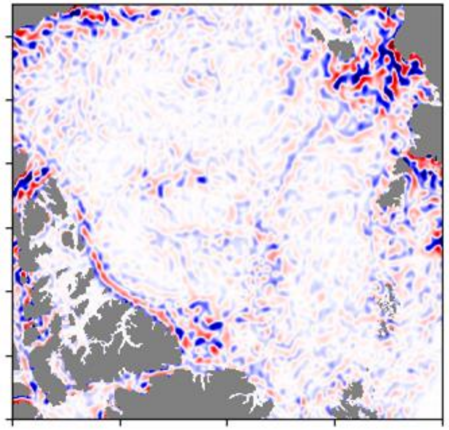
Example for Sea surface salinity over the Arctic Ocean



Initial



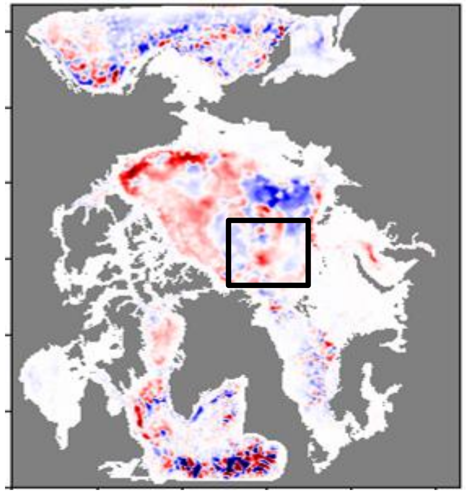
100 pass Shapiro filter



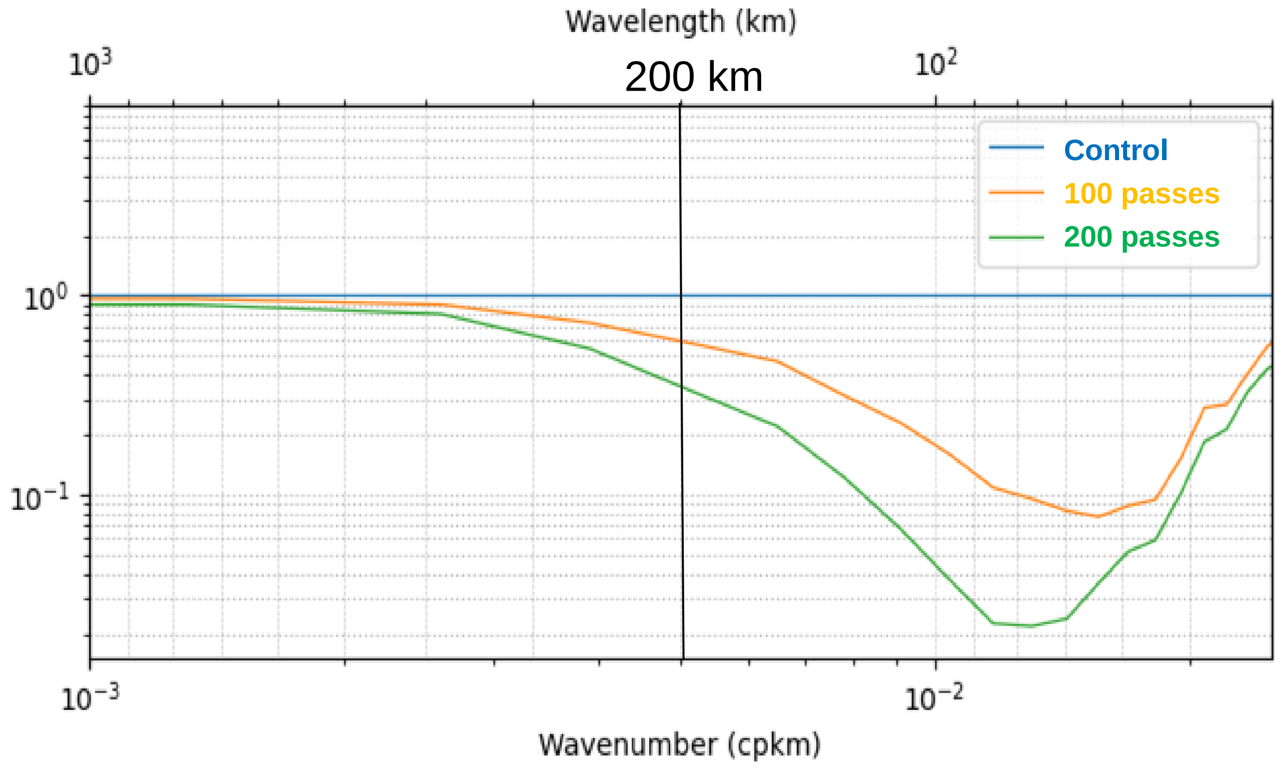
Difference

IMPACT OF BACKGROUND ERROR FILTERING

Dynamic height increment



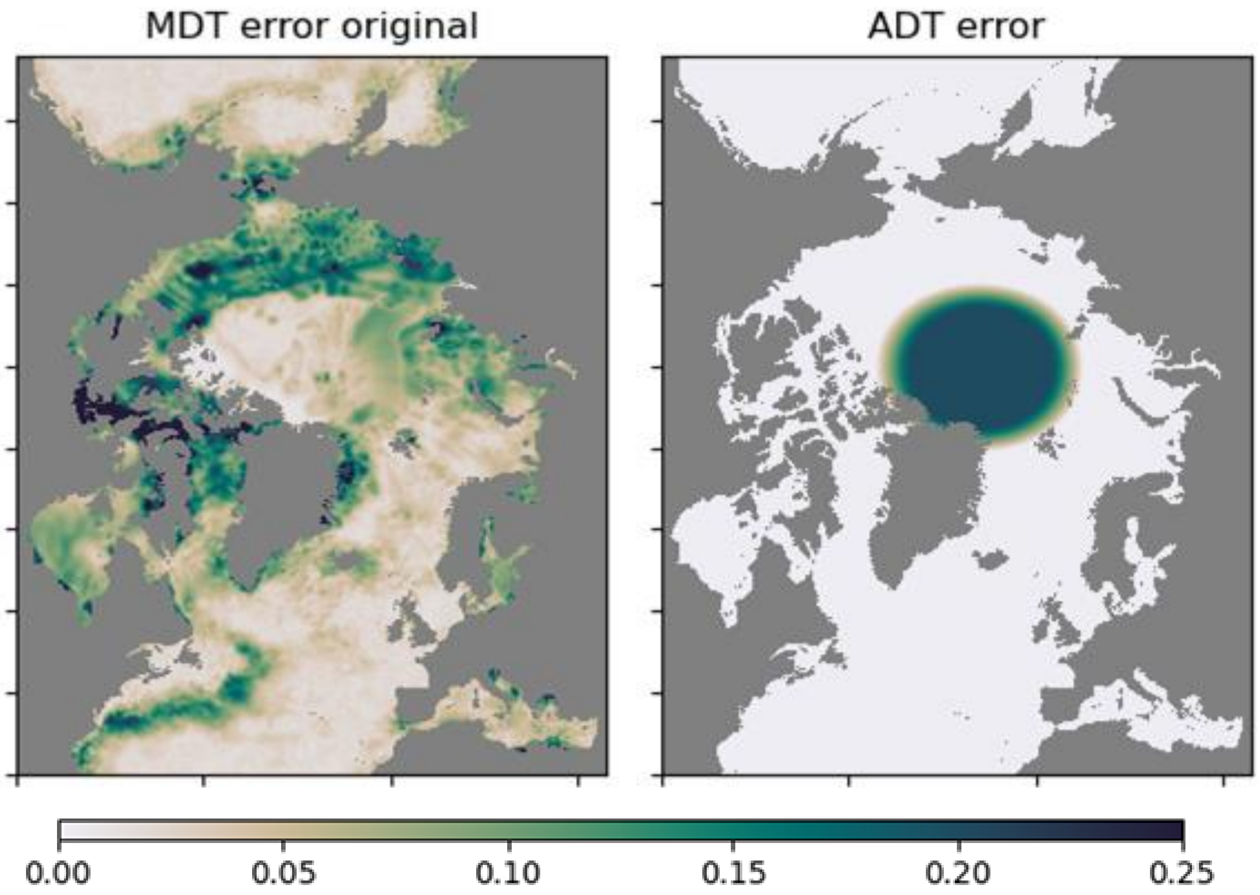
- Power spectral density (PSD) of dynamic height increment for experiments with 100 and 200 additional passes of Shapiro filter on background error.
- Significant attenuation of energy for wavelengths less than 300 km.
- Attenuation consistent with filtering applied to background error.



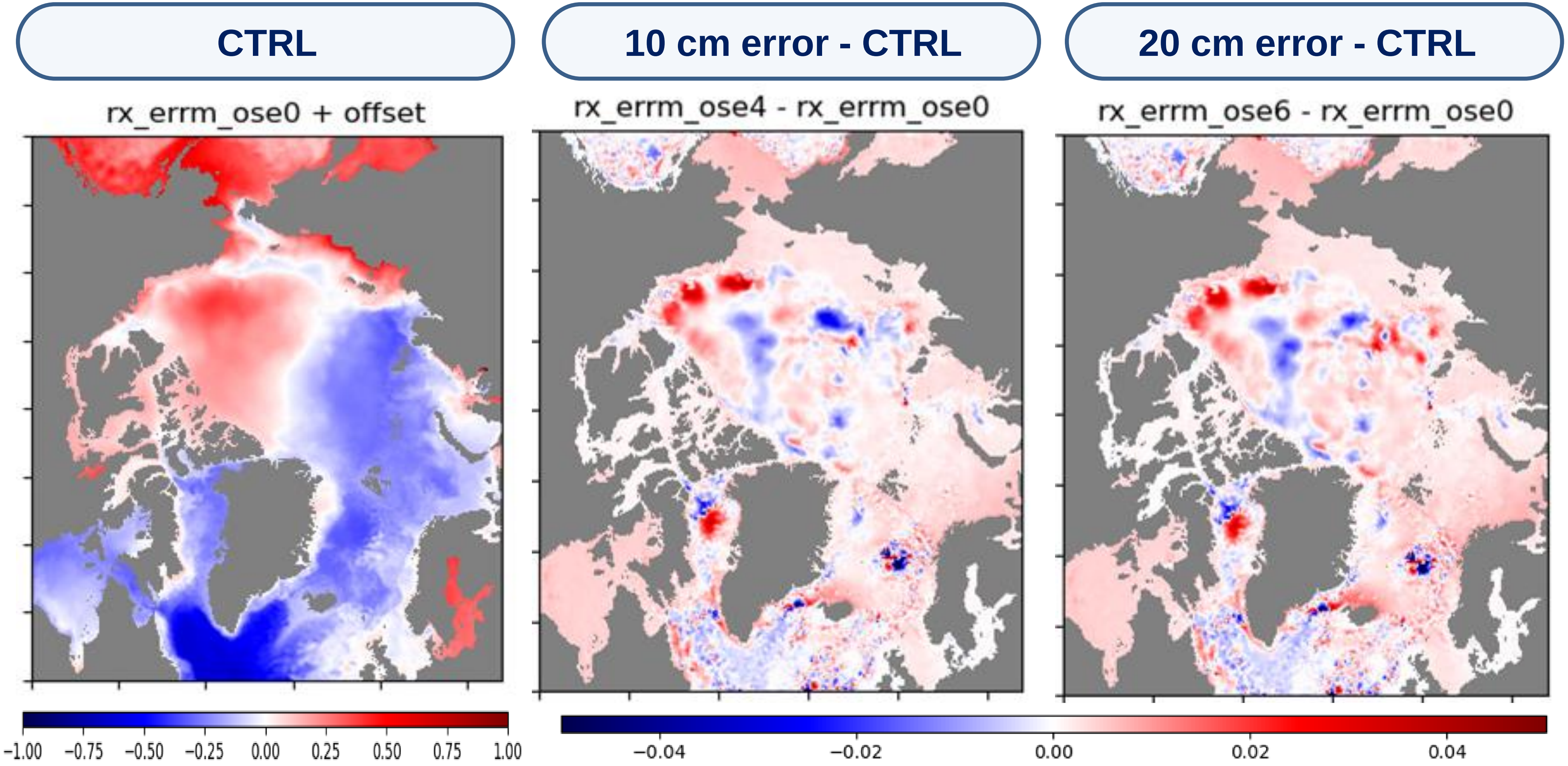
MODIFICATION TO OBSERVATION ERRORS

- Altimetry obsevation errors in RIOPS depend on instrument error, coastal error and MDT error.

- Here, replace MDT errror with Geoid/ADT error to avoid Gibbs oscillations near pole.
  - 5cm south of 80°N
  - Ramp from 80-83°N up to 25cm



IMPACT OF ADT OBSERVATION ERROR ON SSH

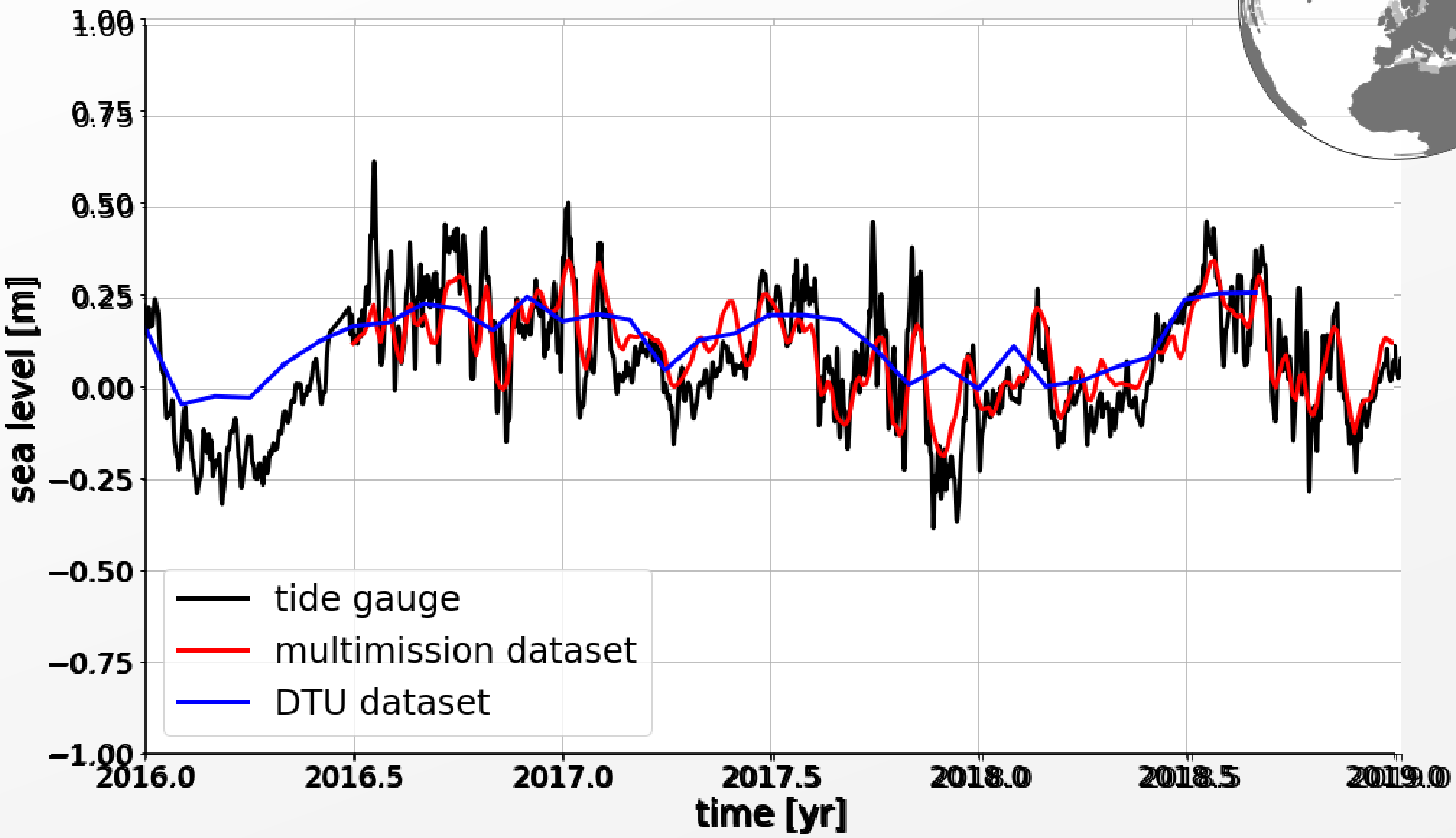


Tide gauge comparisons

Prudhoe Bay tide gauge is seasonally ice-covered

Monthly DTU dataset can not represent high frequency sea level signals

Better agreement with our multi-mission dataset



CLS
COLLECTE LOCALISATION SATELLITES