

CryoSat-2's contribution to the complete sea level record from the Polar Oceans

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Introduction

WHY STUDYING POLAR SEA LEVEL?

- Part of various ESA projects
- White spots on global sea level maps.
- The Arctic SL challenging



Figure 1: ESA's: Sea Level (SL) Climate Change Initiative (CCI) and CryoSat+ Antarctica

SCIENTIFIC AND TECHNICAL CHALLENGING

- * Regional coverage (tide gauges/buoys/satellites)
- * Regional coverage (ice extent)
- * Regional coverage (ice thickness)
- * Regional coverage (ice motion)
- * Regional coverage (ice concentration)
- * Regional coverage (ice age)
- * Regional coverage (ice type)

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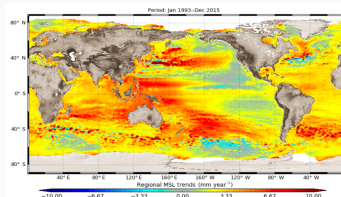


Figure 2: *SL CCI ECV v2.0 1995 - 2015*

SCIENTIFIC AND TECHNICAL CHALLENGING

- Regional coverage (tide gauges/buoys/satellites)
- Seasonal/permanent ice cover
- Data gaps/intermittent
- Inhomogeneous atmospheric conditions
- Limited satellite coverage

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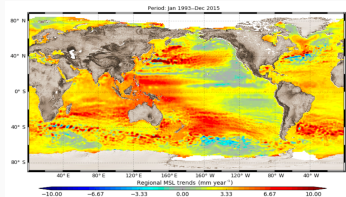


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SCIENTIFIC AND TECHNICAL CHALLENGING

- Regional coverage (tide gauges/buoys/satellites)
- Seasonal/permanent ice cover
- Satellite instruments
- Insufficient geophysical models
- Residual orbit errors
- Retracking



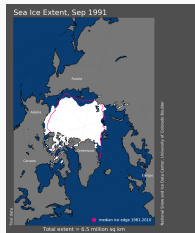
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Credit: NSIDC

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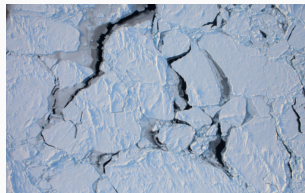


Figure 3: Credit: NASA Earth Observatory

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- Sea-ice affects the range corrections
- Radiometer contamination

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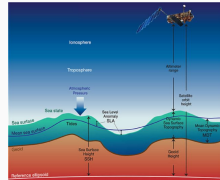


Figure 3: *Geophysical corrections*

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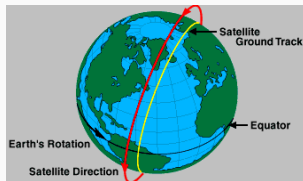


Figure 3: *Satellite orbits*

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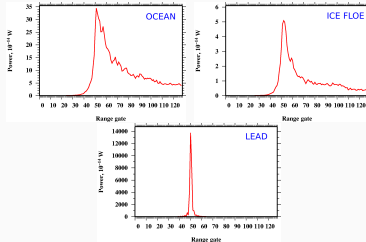


Figure 3: *CryoSat-2* waveforms

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ESA Climate Change Initiative (CCI) Arctic Sea level DTU/TUM product 1991 - 2020

ABOUT

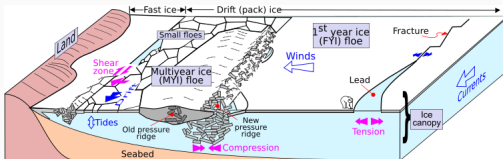
- New improved sea level record up to dec. 2020
- Constant work-in-progress
- Now includes both monthly SLA/DOT
- Only show result from 1995 due to ERS-1 quality

IMPROVEMENTS FROM THE (ROSE ET AL., 2019) PRODUCT

- Physical retracker over all, including SSB correction
- CryoSat-2 Processed with SARvatore G-POD service provided by ESA Research and Service Support
- MSS2015 (before DTU18)
- ALES+ data from ERS-2/Envisat improved, especially lead detection algorithms

OCEAN AND LEAD DISCRIMINATION

- Separating data into ocean/ice cover by EUMETSAT's Global sea-ice Concentration Climate Data Record
- Removing sea-ice/mixed surface measurements



ISSUES

- Inter-satellite bias
- False/Positive leads



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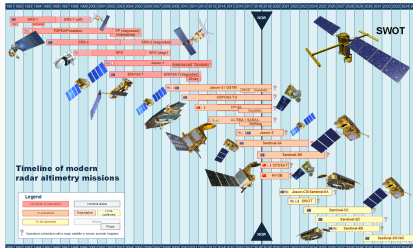
The sea level record

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- Sparse Summer data (June-Aug.)
- Seasonality/transition between open ocean and the ice cover



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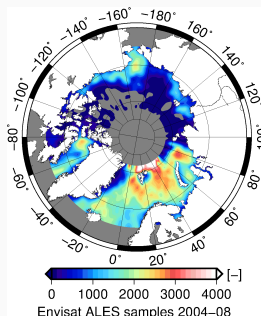
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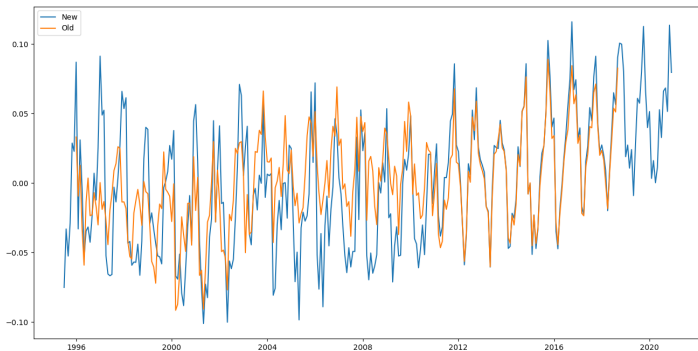
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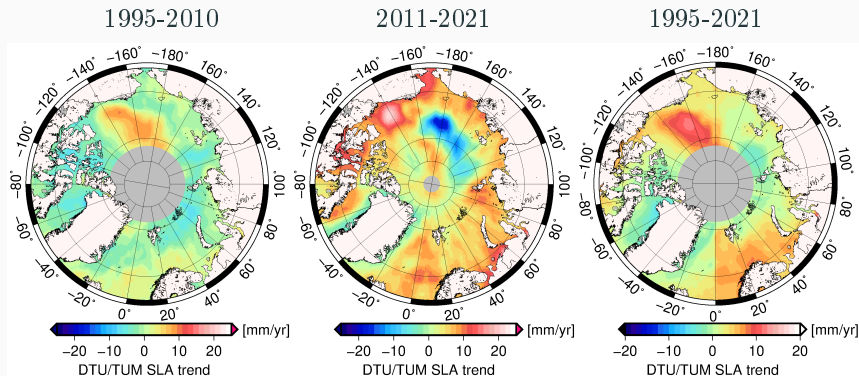
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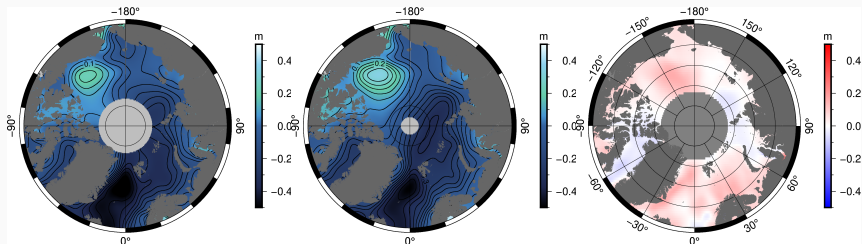
Comparing old (Rose et al., 2019) and new (2021) data set



Arctic Ocean SLA trend maps



Dynamic Ocean Topography w.r.t the OCMOC geoid



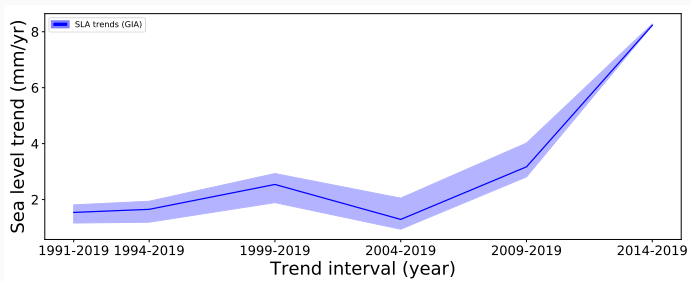
1995-2010
Mean

2010-2021
Mean

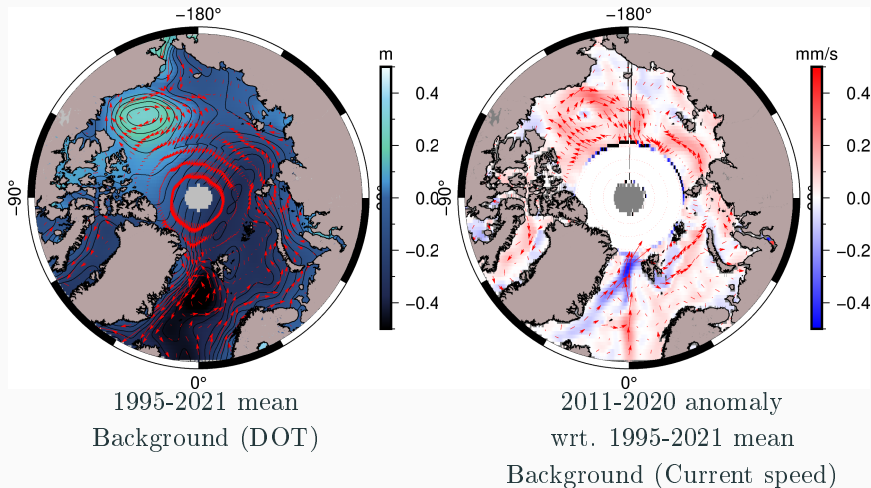
Diff.

27 years of sea level Rose et al. (2019)

- CryoSat-2 has improved the SL by geographical coverage and uncertainty
- 10 years with increasing trends

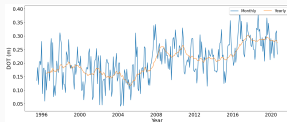


Geostrophic currents

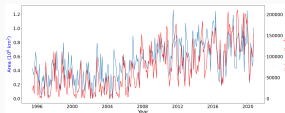


- BG is crucial in understanding the Arctic circulation.
- The BG extent is defined using a principle similar to Regan et al. (2019), where the lowest closed contour of the DOT around the maximum BG defines the gyre edge.
- The altimeter data shows a clearly positive trend of the BG DOT in the time period with a stepping behavior.
- Large drop in extent in early 2015 has to be examined in more details

DOT



Area and volume

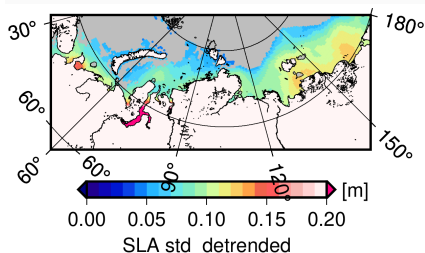
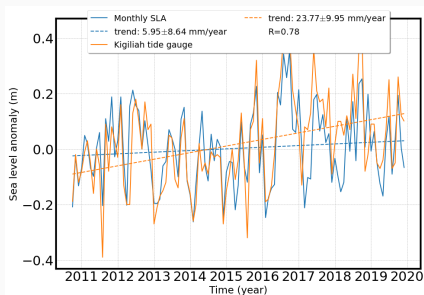


Annual Variation



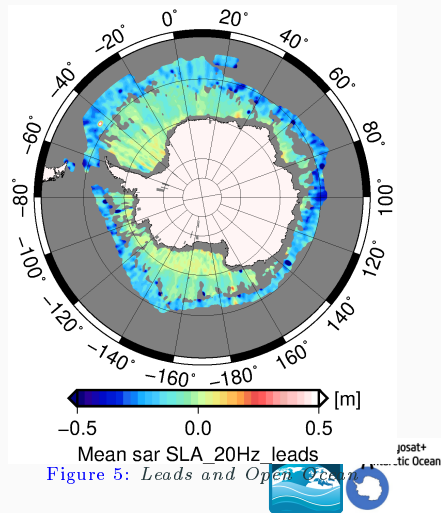
Russian Shelf

- Russian shelf area is historical a difficult area for altimetry
- With CryoSat-2 it is now possible to see oceanic features not possible before
- The seasonal signal in the tide gauges are captured, but the trend is not. For more on this see Ludwigsen et al. (2020).



ESA project: CryoSat+ Antarctica

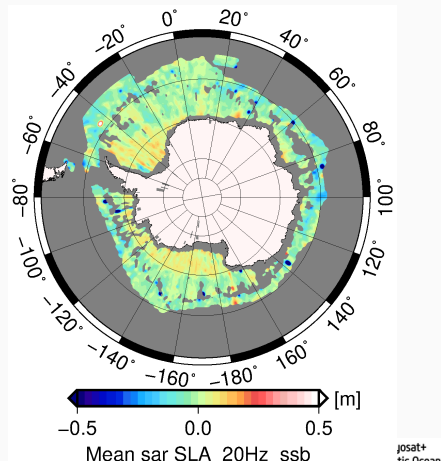
- Ocean circulation and the ocean/sea ice interaction influence of deep water formation and thermohaline circulation
- Pan-antarctic view to better understand the Southern Hemisphere's sea ice and ocean fields in response to anthropogenic warming
- Marginal ice zone flooded by big waves
- More precise product



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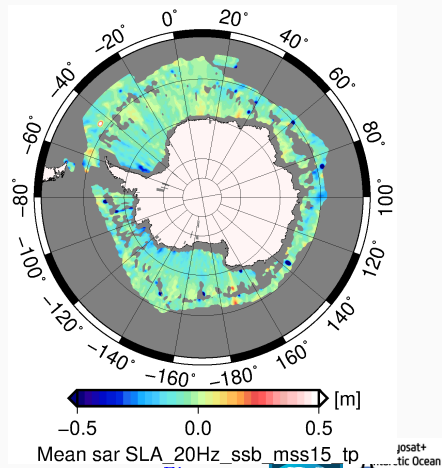
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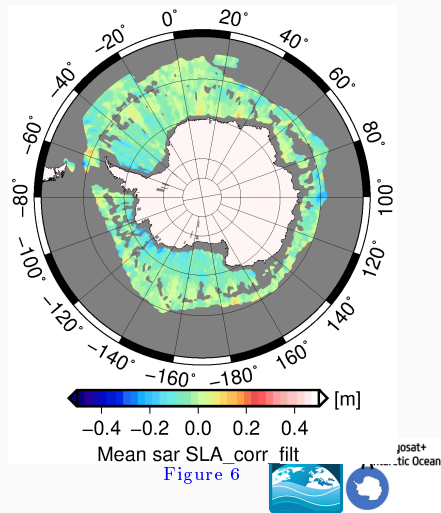
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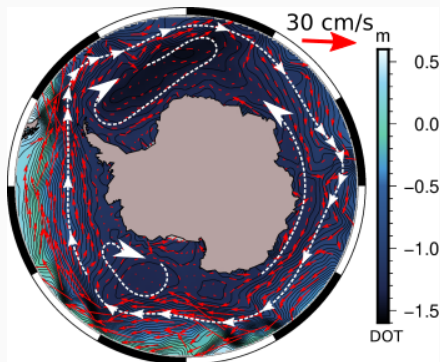
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Geostrophic Circulation

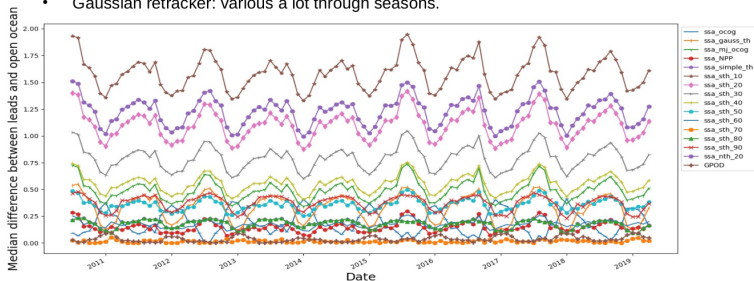
- Geostrophic currents calculated from the DOT (red) show the large circulation patterns
- White arrows are cartoons of the large circulations: Ross Sea Gyre, Weddell Gyre, Polar Current and the Antarctic Front



Note on choosing a retracker (1)

Annual variations of retracker (focus: retracker bias)

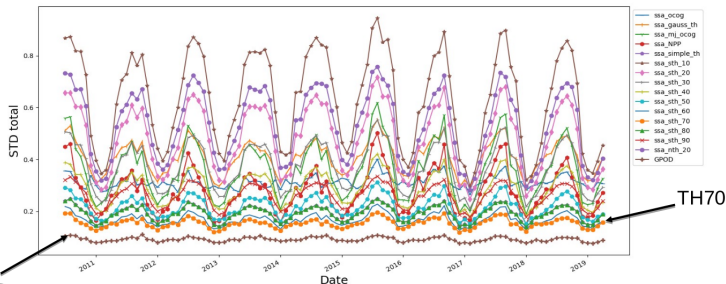
- Retrackers from the DTU LARS retracker system is a system of multiple (emperical) retrackers implemented in C++ (CS baseline C only)
- GPOD: post processed (only ocean surf., geophysical corrections streamlined) **OBS: Old proc.**
- Fig. shows the median difference between the lead and the open ocean retracked obs.
 - Th. 70 performs minimizes the difference between the open ocean and the leads.
 - 2nd best is GPOD. Larger difference in Winter. Why? Poor lead detection?
 - Gaussian retracker: varies a lot through seasons.



Note on choosing a retracker (2)

Annual variations of retracker (continued)

- Fig. below show the total monthly STD.
 - GPOD outperforms the empirical results. Is it too low?
- Open questions:
 - What are causing the annual variations?
 - Is it related to the SSB (empirical retracker)?



GPOD

TH70



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Thank You for Listening!

- C. A. Ludwigsen, O. B. Andersen, and S. K. Rose. Assessment of 21 years of Arctic Ocean Absolute Sea Level Trends (1995–2015). *Ocean Science Discussions*, pages 1–18, 2020. ISSN 1812-0806. doi: 10.5194/os-2020-87.
- H. C. Regan, C. Lique, and T. W. Armitage. The Beaufort Gyre Extent, Shape, and Location Between 2003 and 2014 From Satellite Observations. *Journal of Geophysical Research: Oceans*, 124(2):844–862, 2019. ISSN 21699291. doi: 10.1029/2018JC014379.
- S. K. Rose, O. B. Andersen, M. Passaro, C. Ankjær, and C. Schwatke. Arctic Ocean Sea Level Record from the Complete Radar Altimetry Era : 1991-2018. *Remote Sensing*, 11:1672, 2019. doi: 10.3390.

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