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

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Introduction

Satellite altimetry is by far the best measurement for observing the trans Polar Oceans sea level. The dynamic sea ice challenges the observations, but with the newest satellite techniques the precision has improved. The data used, **DTU2021 Arctic Sea Level Anomaly** (SLA) [In prep.], is an updated version of [1], which describes the monthly gridded DTU/TUM Arctic Ocean SLA record from 1991-2018. The whole processing has been updated, but most important is the change of CryoSat-2 processing and a shift of the Mean Sea Surface (MSS). The CryoSat SAR and SARIn data are processed by European Space Agency's (ESA) Grid Processing on Demand (GPOD) SARvatore/SARINvatore service [2]. The new data set is available on request.

Sea level Anomaly Trends (1995-2020)

In Fig. 1, the SLA is shown from the ESA's satellites: ERS-2, Envisat and CryoSat-2 (1995-2020) for the Pan-Arctic Ocean (blue) with an annual signal peaking in November and having a low in April. The annual signal is large, removing it gives the orange curve. The trend is mapped in Fig 2 for three time periods 1995-2010 (15 years), 2010-2020 (10 years), 1995-2020 (whole time series). We see a significant amplification in the SLA trends in the latest 10 years. The Beaufort Gyre trend extent seams smaller, but more intense.

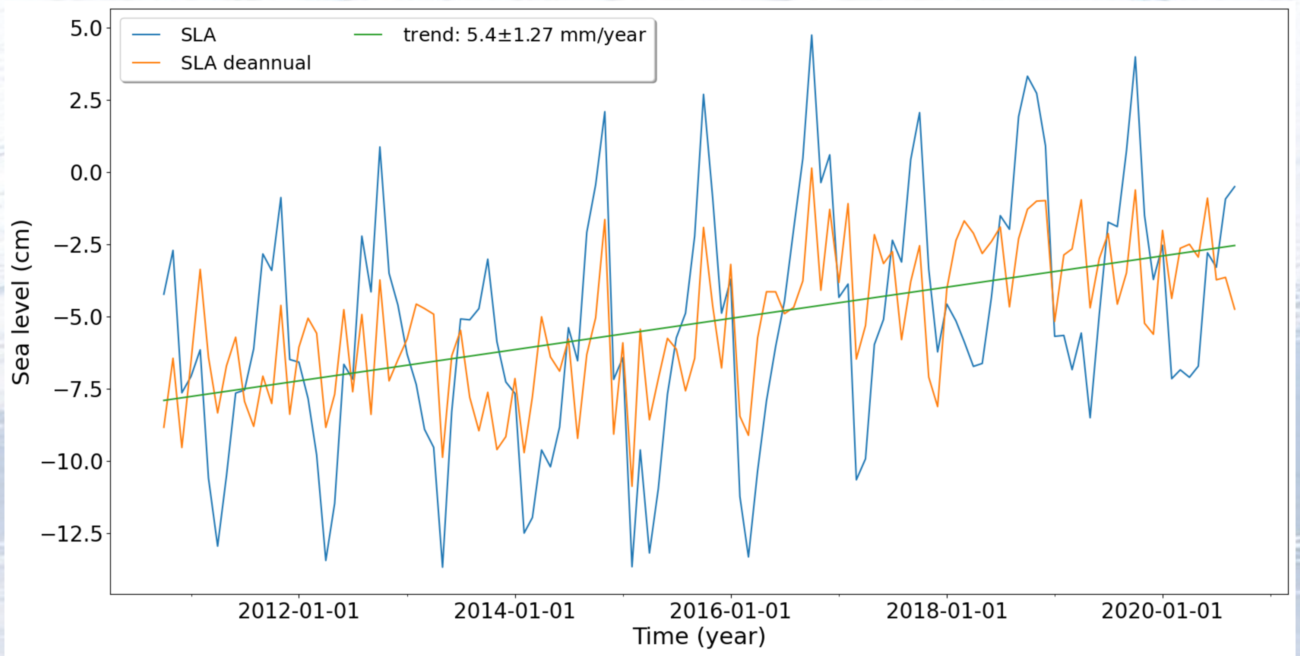

Figure 1

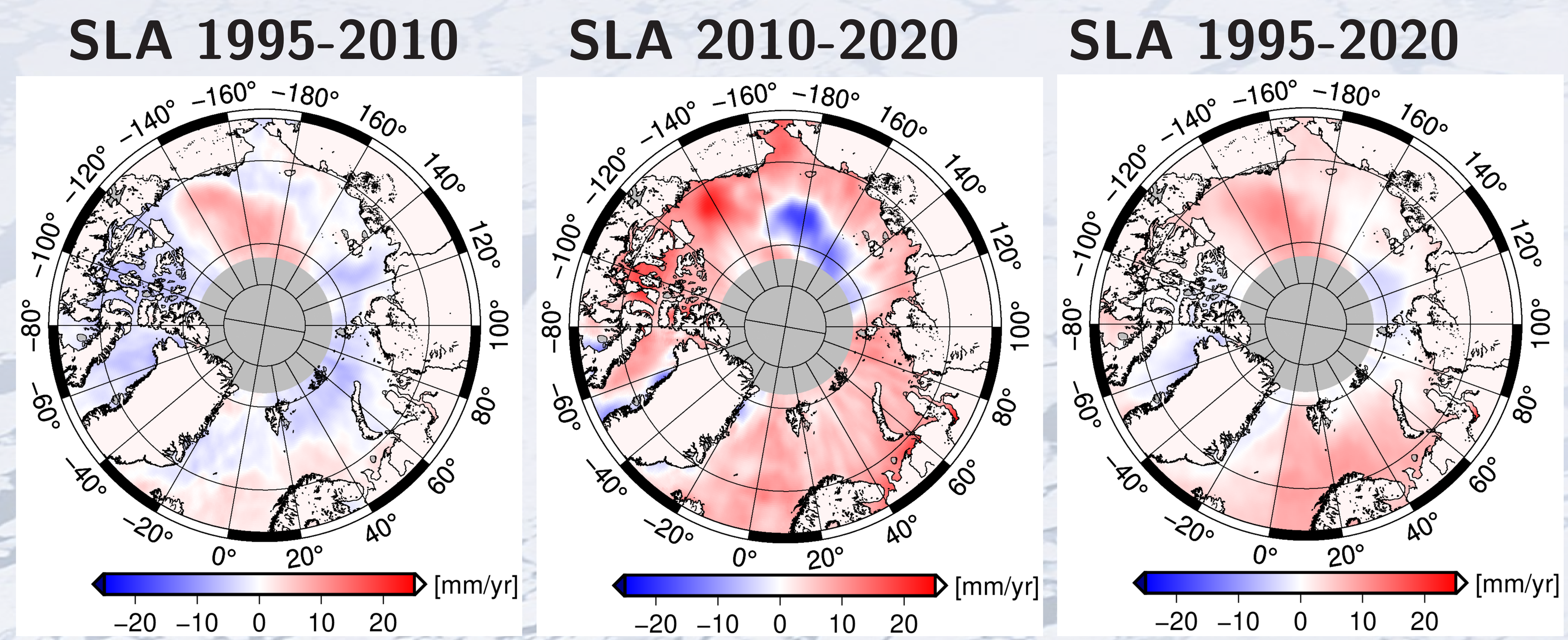

Figure 2

The Dynamic Ocean

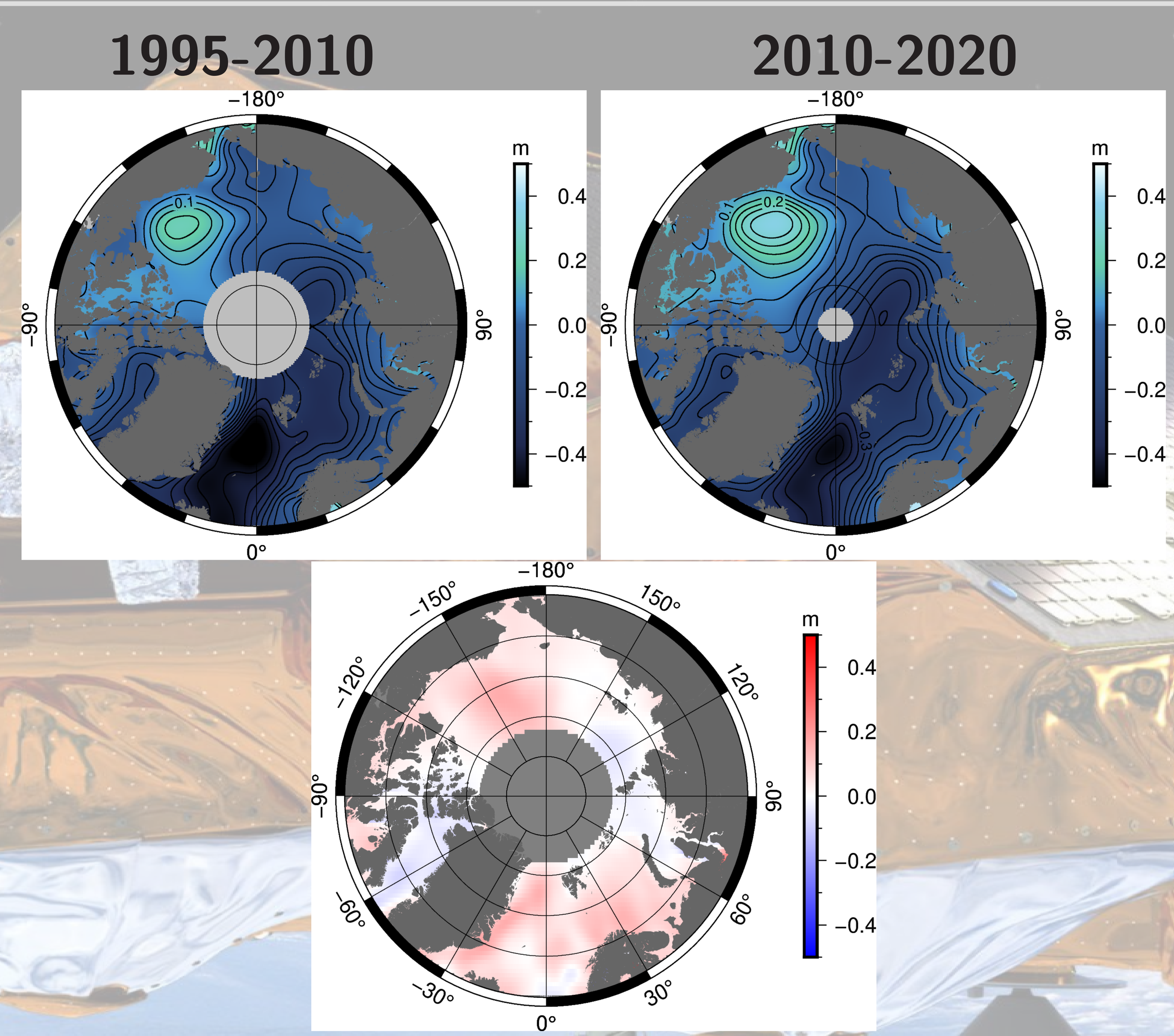

Figure 3

The Dynamic Ocean Topography (DOT) is derived with the DTU21 Arctic SLA and the geodetic DTU17 MDT [3] and w.r.t. the OCMOG geoid. Fig. 3 show the monthly Mean DOT (MDT) in the periods 1995-2010 and 2010-2020, together with the difference between the periods. The MDTs show a high in the Beaufort Gyre and a low in the Greenland Sea. It is clear from the figures that the circulation pattern has changed between the time periods.

The monthly averaged DOT is used to estimate geostrophic currents. The surface geostrophic can be assumed to be in equilibrium, and then horizontal pressure gradients in the ocean almost exactly balance the Coriolis force resulting from horizontal currents. The geostrophic currents can be expressed as eq. (1) and (2).

Fig. 4 show the median geostrophic current anomaly (2011-2020) wrt. the 1995-2021 mean

$$v_g = \frac{g}{f}\frac{\partial\eta}{\partial x} = \frac{g}{f\,R\cos\phi}\frac{\partial\eta}{\partial\lambda}\,, \quad (1)$$

$$u_g = -\frac{g}{f}\frac{\partial\eta}{\partial y} = -\frac{g}{f\,R}\frac{\partial\eta}{\partial\phi}\,, \quad (2)$$

where v_g, u_g, are the east and north velocity components, respectively. $f = 2\omega\sin\phi$, with ω being the Earth's rotational rate; R is the average radius of the Earth, ϕ and λ are the latitude and longitude; η, g is gravity.

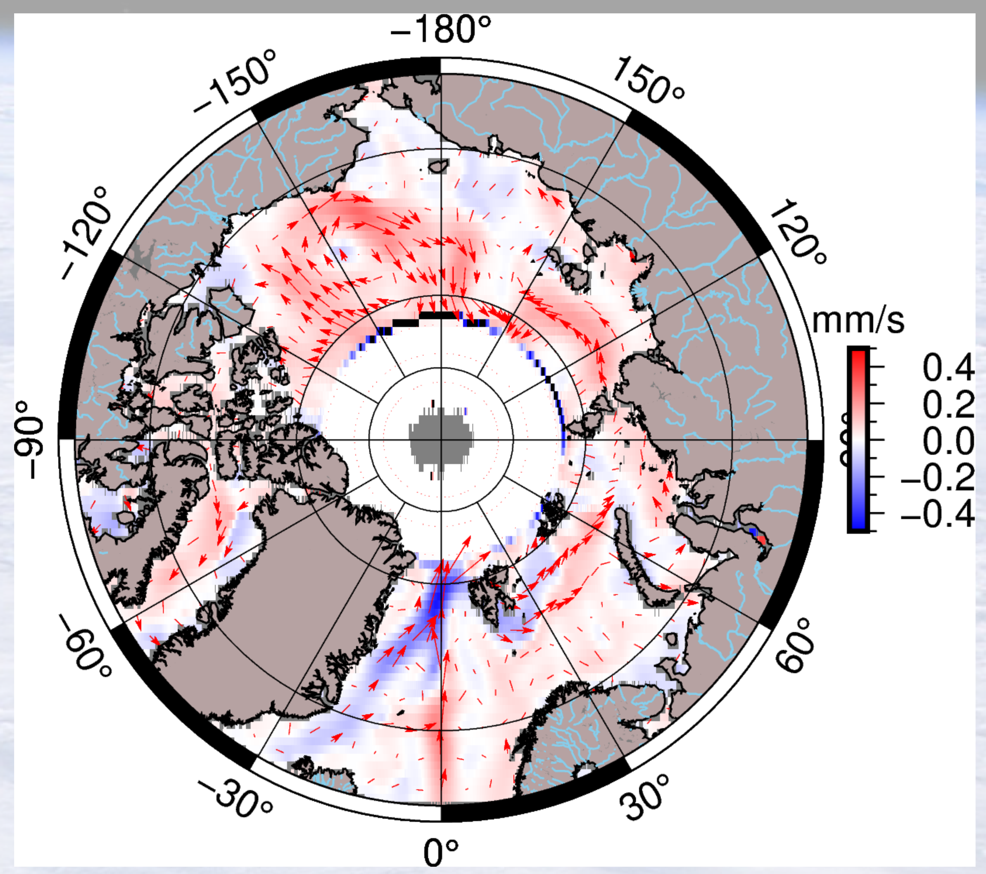

Figure 4

The Southern Ocean

As part of **the ESA project CryoSat+ Antarctica**, the SLA has been studied for the Southern Ocean. Among other things, the objectives are to better understand: the ocean circulation, the ocean/sea ice interaction influence of deep water formation and thermohaline circulation, pan-antarctic sea ice and ocean fields in response to anthropogenic warming and marginal ice zone flooded by large waves.

This dataset [In prep.] contains only CryoSat-2 data. SAR, SARIn are processed with GPOD similar to the Arctic data, and the LRM is taken from RADS [4].

Figure 5 show the mean DOT from CryoSat-2 (2010.10-2020.12) superimposed with the mean geostrophic current (red arrows) in the time period. The drawn white arrows indicate the large Southern Ocean circulation patterns which follows the mean geostrophic currents.

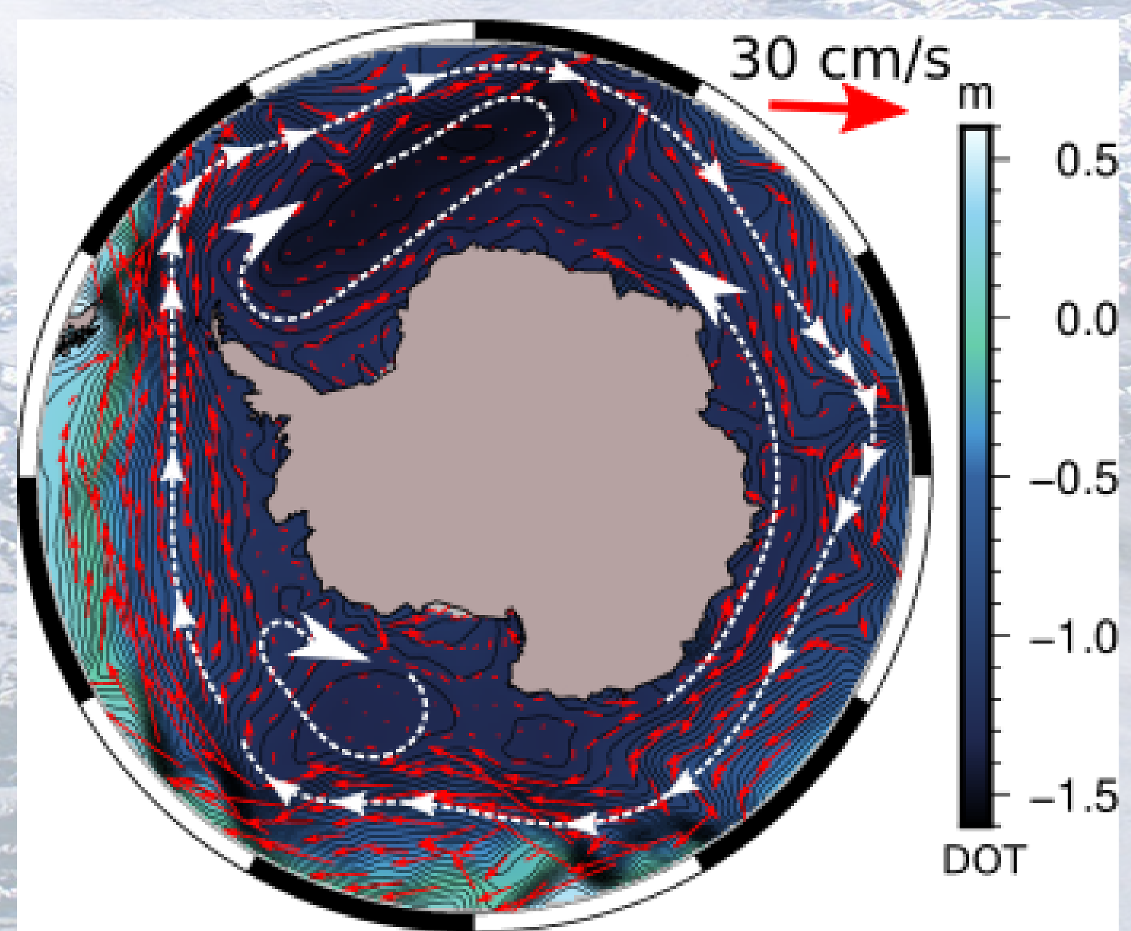

Figure 5

References

[1] Stine Kildegaard Rose, Ole Baltazar Andersen, Marcello Passaro, Carsten Ankjær, and Christian Schwatke. Arctic Ocean Sea Level Record from the Complete Radar Altimetry Era : 1991-2018. *Remote Sensing*, 11:1672, 2019.

[2] Salvatore Dinardo, Marco Restano, Américo Ambrózio, and Jérôme Benveniste. SAR Altimetry processing on demand service for CryoSat-2 and Sentinel-3 at ESA G-POD. *Proceedings of the 2016 conference on Big Data from Space*, (March):268–271, 2016.

[3] Per Knudsen, Ole Andersen, and Nikolai Maximenko. A new ocean mean dynamic topography model, derived from a combination of gravity, altimetry and drifter velocity data. *Advances in Space Research*, pages 1–13, 2019.

[4] Remko Scharroo, Eric Leuliette, John Lillibridge, Deirdre Byrne, Marc Naeije, and Gary Mitchum. RADS : Consistent multi-mission products. In *The Symposium on 20 Years of Progress in Radar Altimetry, Venice,*, number 2, pages 5–8. Eur. Space Agency Spec. Publ., ESA SP-710, 2013.