Identifying Information

Title:

Mean sea surface and mean dynamic topography - high latitude and high-resolution focus

Principal Investigator.

Professor Ole B. Andersen
Phone +45 3532 5754
Email: oa@space.dtu.dk
DTU Space (DTU)
Technical University of Denmark
Elektrovej bldg. 327
DK-2800 Lyngby
Denmark
Phone +45 4525 9754

Co-Investigator

Professor Per Knudsen (DTU Space; pk@space.dtu.dk)

Stine Kildegaard Rose (DTU Space, stine@space.dtu.dk)

Adil Abulaitijiang (DTU Space; adili@space.dtu.dk)

Carsten Ludwigsen (DTU Space; caanlu@space.dtu.dk)

Summary

The overall aim of this research study is fourfold.

- Enhancing the fundamental mean sea surface for referencing sea surface height as well as the mean dynamic topography and associated geostrophic ocean currents focusing on improving short wavelength in preparation for and with SWOT data.
- Improving altimetric data through retracking and investigation of sea state bias in the presence of sea ice.
- Improving and investigating the 30 year climate data record focusing on sea level variations at high latitudes using multiple satellites like T/P, Jason-1, Jason-2, ERS-1, ERS-2, Envisat, ICESat, Cryosat-2 and potentially first years of SWOT
- Investigate Arctic sea level budget through integration of multiple altimeter missions with GRACE, GRACE-Follow On and steric measurements.

Objectives

DTU space has a long record for determining the Mean sea surface and deriving the mean dynamic topography for referencing of the satellite mission.
With the recent initiated drifting mission of Saral/AltiKA and the recently completed 2-year interlaced geodetic mission of Jason-2 we will have an unique opportunity to derive ultra-high resolution mean sea surface on 30 second global grids in preparation for SWOT merging these data with 20 yean mean profiles from i.e. Jasons. We have recently been invited to team up with CLS and Scripps Institute of Technology to form the task-force to improve the short wavelength of the mean sea surface. A large effort in reaching this goal is the scientific research toward improving the quality of the data in the region and extending the time-series.

We are currently investigating several methods to improve the quality of the altimetric data in non-open ocean areas like the coastal regions and the Arctic Ocean. The Arctic ocean is important focus area as the inclination of SWOT is different to that of previous Jasons-1 as the region is experiencing significant changes these years and significant inflow of freshwater from melting glaciers and changes in sea ice cover.

Global mean sea level (GMSL) trend and acceleration presently ignores the Polar Regions. As these estimated converge smaller but important differences entails inclusion of all ocean areas, especially as the Polar Regions are currently the regions that experience the largest changes during the last nearly 30 years

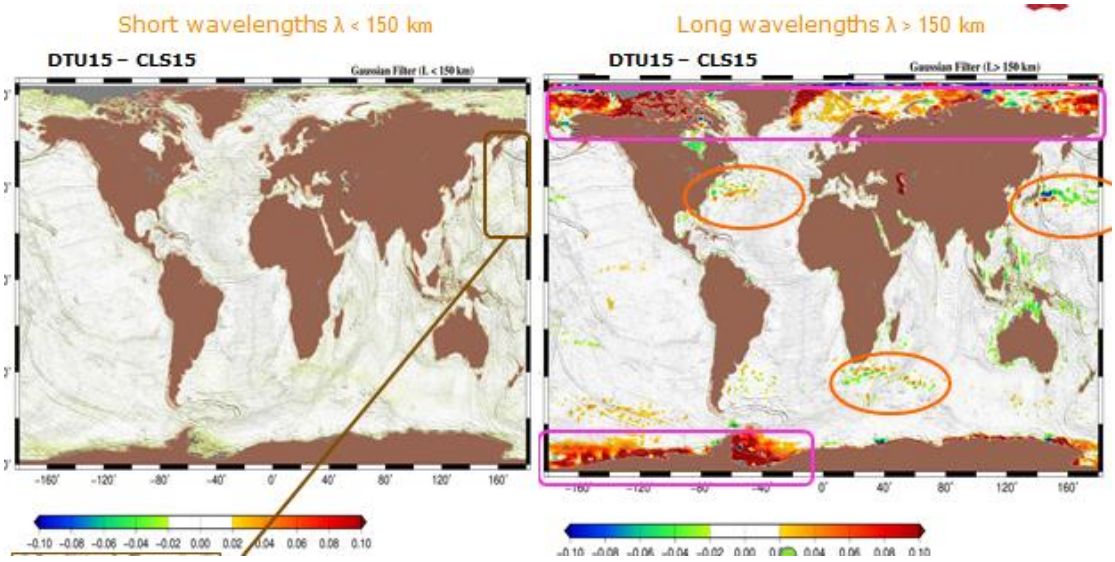

Fig: Differences between DTU15MSS and CLS15MSS filtered by short wavelength (<150km) and long wavelength (>150km) indicate the need for further improvement of the MSS. Figure is courtesy by Schaeffer et al., 2017)

Difference still exists in the near-coastal and high latitude regions between "state of the art" mean sea surface models. In the work by Schaeffer et al., 2017 they investigated differences at wavelength shorter and longer than 150 km. Differences at wavelength longer than 150km can largely be consolidated using satellite altimetry, but there is still an issue of sampling vs track separation. For shorter wavelength information from SWOT will be paramount.

Approach

Precise knowledge of the sea surface height is crucial for studying climate changes, ship navigation, human safety etc. Sea Surface height determination based on the retracking of the power waveforms of the echoes received by radar/SAR altimeters on board satellite missions. In general, echoes received over open ocean correspond well to the existing retrackers and mathematical models used by the space agencies.

With SWOT data being released shortly we need to investigate a method to merge these data into conventional Mean sea surface models in order to derive the next generation MSS. We currently merge 20-year mean profiles with geodetic missions of Saral, Cryosat-2 and Jason-2 but integrating with SWOT data with entail far high resolution (but very short time-span in the beginning). We must initially investigate the quality and resolution possible in different regimes (global ocean, deep ocean, coastal and high latitude) to develop a high resolution MSS for and with SWOT. We have recently been invited to team up with CLS and Scripps Institute of Technology to form the task-force to improve the short wavelength of the mean sea surface.

The Arctic region consists of various cryosphere features such as sea ice, snow, ice sheets, new frozen water, ice-covered land etc. As a result, the radar/SAR altimeters receive echoes consisting of superposition of reflections from various surface types in the same footprint (Quartly et al 2018 for details). The power waveforms of these

echoes do not correspond well to the existing retracking mathematical models as used by the space agencies. We are currently collaborating with ESA on issues related to retracking and sea state bias determination at high latitudes (outside the 66 parallel but important to SWOT)

A crucial step to derive accurate ocean currents from this satellite based MDT is through the use of advanced non-linear filters (Bingham, Knudsen and Andersen, 2010) more recently developed one step further by Sanchez et al., 2012) and Sanchez and Andersen, 2012) investigating the impact of new GOCE geoid model with the recent processing on ocean circulation estimation.

High latitude regions are still challenging when it comes to tidal modeling and the accuracy is lower here than in other parts of the global ocean. Hence, the focus in this part will be towards improving tidal modeling in coastal and high latitude regions where the work towards improving the quality and length of the time series will be taken into account.

True global sea level estimation including the high latitudes can be significantly improved with the use of the ESA altimeter missions (ERS-1&2, ENVISAT AltiKa, Cryosat-2 and Sentinel-3) since they have higher inclination than the Jason satellites and hence covers larger part of the oceans.

One of the largest obstacles in Polar Regions is the presence of sea-ice. Editing of spurious SSH measurements close to sea ice also degrades the quality of SSH determination and seasonal coverage of data hampers the use of these for climate studies. Altimetry range and geophysical correction errors impacts sea level estimation as for instance errors in the oceanic tidal correction, drift in pressure models (in high latitudes), spurious measurements of wet troposphere correction (close to sea ice due to radiometer contamination etc).
With this project, we aim at focusing on improving the quality and the number of the altimetric observations at high latitude in corporation with the ESA CCI sea level budget intitiative. We will particularly focus on issues related to SWOT in the region outside the 66 parallel where conventional altimetry is not available (Johannesen and Andersen, 2018)
Finally the enhanced altimetric record will be used to study the Arctic sea level budget through integration of multiple altimeter missions with GRACE, GRACE-Follow On and steric measurements as well as observations of in-flow / out-flow (mainly fresh water) to the Arctic ocean (Chambers et al., 2017).

Anticipated Results.

We anticipate a number of scientific results, which is foreseen to be published at international meeting, at the OSTST science working team meeting and as articles.
The results will fall within the three aims of the project

The results will be studies and release of the best possible altimetry derived mean sea surface based on Cryosat-2, Saral AltiKa, and 2 years Jason-2 geodetic mission in preparation for SWOT Currently IceSat-2 data are also being investigated.
Solution on for the best dynamic topography and associated geostrophic ocean currently taking into account reprocessed GOCE geoid data is foreseen within the project.Upon availability of SWOT data the next step towards deriving a ultrahigh resolution MSS will be taken in collaboration with CLS and SIO.

New enhanced sae level products will be created for the high latitudes as part of this project along with data for integration into future ocean tide models (e.g., LEGOS FES solutions). These high latitude sea level product are paramount for understanding physics at high latitude covered by SWOT and studies of the sea level variations and improving the climate record for particularly the high latitudes using multiple satellites like T/P, Jason-1, Jason-2, ERS-1, ERS-2, Envisat, ICESat2, Cryosat-2, S3A/B as well as SWOT upon launch.
Through integration of data from GRACE and GRACE-FO along with freshwater fluxes into the Arctic Ocean, we aim to study the sea level budget of the Arctic Ocean

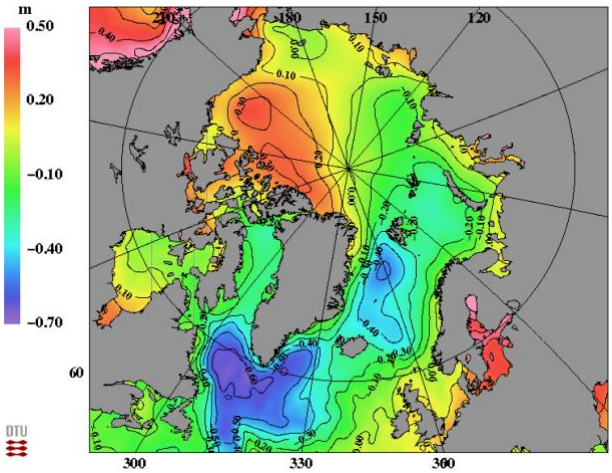

Figure: Geodetic Mean Dynamic Topography derived from Eigen6C4 geoid and DTU15MSS extrapolated across the North Pole.

Significance of the Investigation

This investigation is to some extend a continuation of earlier studies and contribution to the OSTST science team. This investigation is associated with the DTU space contribution into several EU studies (I.e., INTAROS) and ESA programs like the ESA CCI on sea level and ESA CCI on Sea level budget as well as the upcoming Polar + studies. Existing collaboration with numerous international scientist within the existing OSTST science team is paramount and important and is continued in the supporting this project.

DTU has long tradition and expertise for studies in Polar region. This project will focus on high latitudes and particularly focus on developing the next generation MSS to a high enough accuracy to be applicable to SWOT and once data are available determine the shortest wavelength through integration of the SWOT short time series. Thus the combination of geodesists, oceanographers and satellite data experts at DTU

space will be needed to interpret and apply these results and will be the key to ensuring the success of this proposal

The project will also make a critical assessment of the value of a more accurate oceanic geoid in helping to understand the oceans thermohaline circulation in the NE Atlantic. This critical area, which is well observed by both gravitational data and ocean hydrographic data, urgently needs the kind of integrated assessment, which will be made by this project in order to understand and quantify its role in controlling climate.

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