Deutsches Geodätisches Forschungsinstitut
Ingenieurfakultät Bau Geo Umwelt
Technische Universität München

Arctic Ocean Topography from Ocean Modeling and Satellite Altimetry: Correspondence, discrepancies and prospects for combination

Felix L. Müller[1], Claudia Wekerle[2], Denise Dettmering[1], Wolfgang Bosch[1], and Florian Seitz[1]
(felix-lucian.mueller@tum.de)

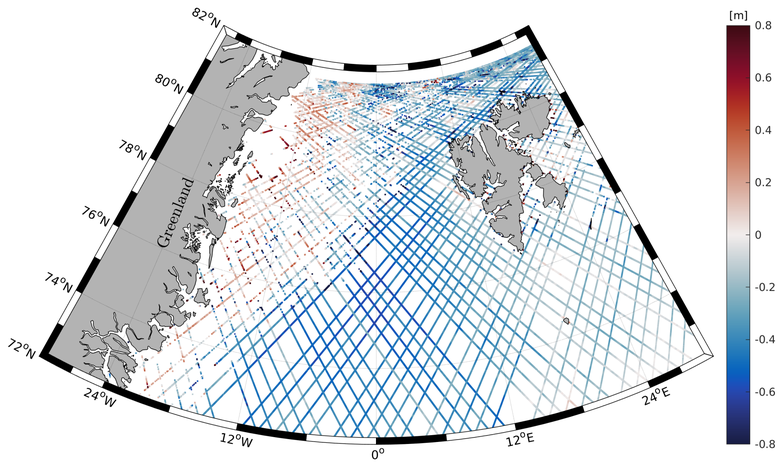
[1] Deutsches Geodätisches Forschungsinstitut der Technischen Universität München
[2] Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung

Motivation: Satellite altimetry is providing instantaneous snapshots of the dynamic oceans topography (DOT) for more than two decades. However, they are characterized by an irregular sampling in seasonally sea-ice covered regions (e.g. the Greenland Sea). Furthermore, the spatio-temporal coverage is limited due to the along-track profiling instrument geometry and the fixed orbit and ground track configurations of most satellites (among them the ESA ENVISAT mission and the CNES/ISRO SARAL mission). In order to fill observation gaps and to bridge periods when altimetry fails, the Finite Element Sea-ice Ocean Model (FESOM), developed at the Alfred Wegener Institute shall be used. It is one of the first global ocean circulation models based on unstructured meshes.
In a first investigation we focus on a comparison between the altimetry-based geodetic DOT and the FESOM derived water level estimates and evaluate the potential for a combination of both data sets. The comparison is based on the analysis of the temporal variability and the frequency domain of both quantities and shall indicate existing systematic differences or consistencies. The study area lies in the Greenland Sea including the Fram Strait, and the investigated period covers eight years of the ENVISAT mission.

Input datasets

Observational database

- High-frequency altimetry data (ENVISAT, SARAL)
- Elimination of ice-contaminated observations by means of an unsupervised classification approach (K-medoids; Müller et al., 2017)
- Consistent along-track sea surface heights (SSH) for open ocean and sea-ice regions through the application of dedicated waveform retracking (ALES+; Passaro et. al, 2017)
- Dynamic Ocean Topography (DOT) by referring the SSH to a geoid (Optimal Geoid for Modelling Ocean Circulation, OGMOC; Fecher and Gruber, 2018)



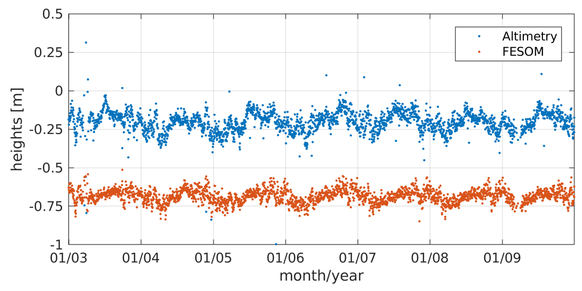
Along-track DOT data as observed by ENVISAT within 15 days in January 2008. Large observation gaps are visible in areas affected by sea-ice.

Model database

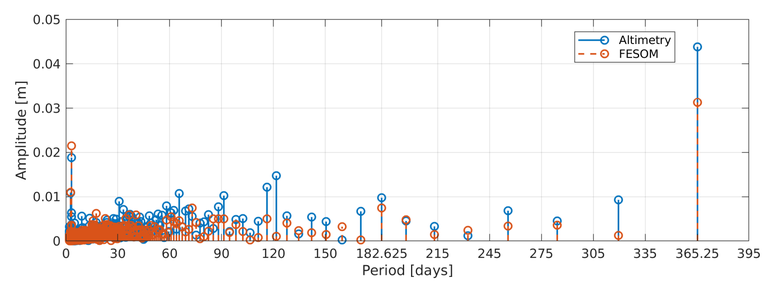
- Finite Element Sea-Ice Ocean Model (FESOM)
- Unstructured mesh ocean model with 1 km mesh resolution in the wider Fram Strait
- Includes differential water heights w.r.t geoid
- the sea-ice component reproduces the major sea-ice drift patterns
- Daily model output

Temporal analysis

- Interpolation of FESOM water elevations to altimetry tracks
- Daily Averaging of all observations in the study area (altimetry DOT and FESOM water heights)
- Harmonic frequency analyses of both time series between 2003-2009
- Estimating harmonic coefficients and constant offsets by applying least-squares based Fourier Analysis



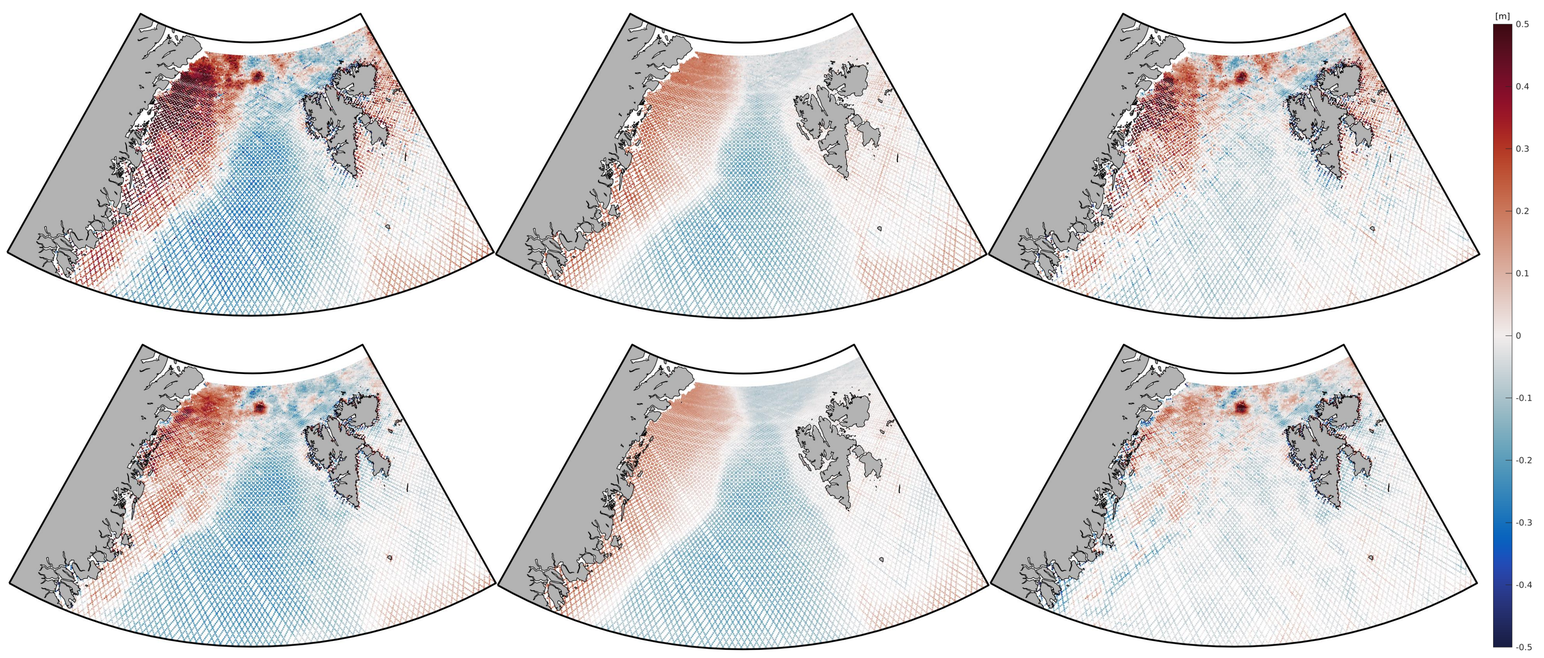
Temporal evolution of daily DOT means from altimetry (blue) and FESOM heights (interpolated to altimetry tracks; red)



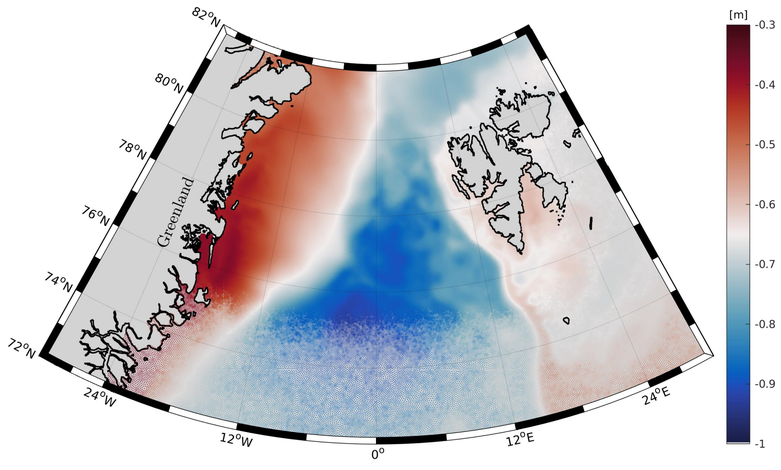
Amplitude spectrum (based on along-track data between 2003 and 2009)

Spatial analysis

- Reduction of annual periods and constant offsets for both data sets; analysis of residual signals
- Bin-wise comparison of along-track data (on a monthly basis)



Mean along-track data (sampled in 7.5 km bins) from altimetry (left) and FESOM (middle) and their differences (right) for February (top) and September (bottom) within 2003 -2009.



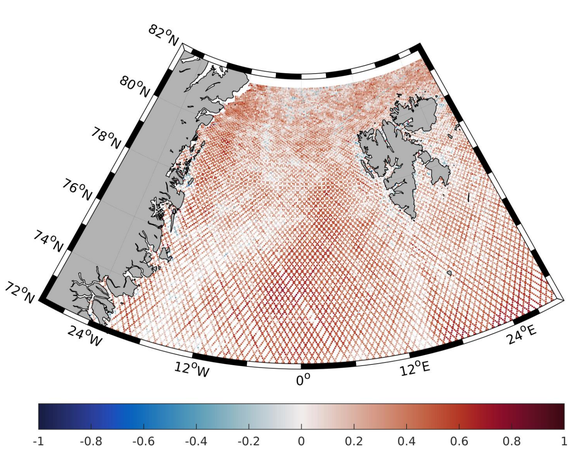
Averaged FESOM water heights for 15 days in Jan-2008. Increased spatial resolution in the central Fram Strait is visible.

Conclusions and Outlook

- Same dominant frequencies in both data sets (mainly annual period)
- Amplitudes show different magnitudes
- Geographical differences show same pattern than signals itself
- Large differences in the northern Greenland Sea due to geoid errors
- Good agreement in the central Greenland Sea for all seasons
- Both residual signals show similar temporal behavior for most regions:
  Predominantly positive correlations in the central Greenland Sea
  Smaller correlations in regions with sea ice or major ocean currents (East Greenland Current, West Spitsbergen Current)

➢ Both data sets show the same sea level behavior, however, FESOM is smoother than altimetry (~2 times).

➢ Based on the good agreement, data combination is very promising



Correlations between altimetry and FESOM along-track data within 2003 – 2009 (without annual signal).

References and Acknowledgements :

- Altimetry data: Envisat and Saral/AltiKa waveforms are provided by ESA and CNES
- FESOM*: Wekerle, C., Wang, Q., von Appen, W.-J., Danilov, S., Schourup-Kristensen, V., & Jung, T. (2017). Eddy-resolving simulation of the Atlantic Water circulation in the Fram Strait with focus on the seasonal cycle. Journal of Geophysical Research: Oceans, 122, 8385–8405. https://doi.org/10.1002/2017JC012974*
- *Müller F.L., Dettmering D., Bosch W., Seitz F. (2017): Monitoring the Arctic Seas: How Satellite Altimetry Can Be Used to Detect Open Water in Sea-Ice Regions. Remote Sensing 9(6), 551, doi: 10.3390/rs9060551*
- *Passaro, M., Kildegaard, R. S., Andersen, O. B., Boergens, E., Calafat, F. M., Dettmering, D., and Benveniste, J*. (2017): ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters*., Remote Sensing of Environment* (accepted) .
- *Fecher, T. and Gruber, T* (2018) .: Optimal Ocean Geoid as Reference Surface for Mean Ocean Circulation and Height Systems, in*: EGU General Assembly Conference Abstracts, vol. 20 , p. 8691*

27th International Polar Conference, Rostock, 25 – 29 March 2018