Assessment of the Dynamic Topographies in the Arctic Ocean by comparing different methods (direct *versus* classical method)

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References

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ABSTRACT

Altimetry gives information about the Sea Surface Height (SSH), but the interesting quantity for the study of the ocean dynamic is the SSH difference from the geoid height called the Absolute Dynamic Topography (ADT). As the geoid is not known with enough accuracy at high resolution, the ADT is classically computed by an indirect method. A Mean Sea Surface (MSS) is first removed to the SSH; then a Mean Dynamic Topography (MDT) is added. This method is thus impacted by MSS and MDT errors; the Arctic Ocean is particularly challenging because of the poor altimetry coverage of the area which is seasonally covered by sea ice.

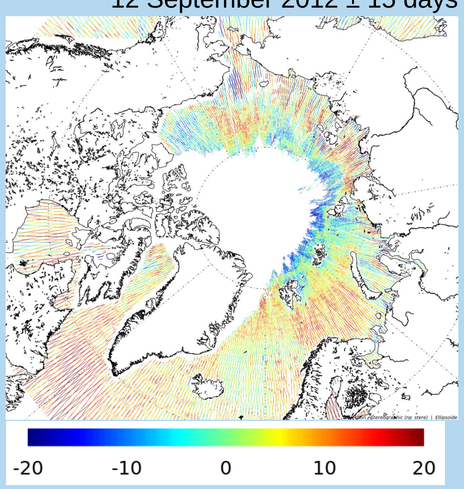
Thanks to the Gravity Field and Steady-State Ocean Circulation (GOCE) mission, the geoid models have reached higher accuracy and a direct method can now be used to compute the ADT. For this propose, we use the EGM_DIR_R5 geoid model computed in the framework of ESA HPF (High Processing Facility) from all the reprocessed GOCE data. The EGM_DIR_R5 geoid height model is subtracted to the Cryosat-2 SSH to compute along track ADT. Errors associated with along track ADT field are evaluated taking into account the omission and the commission geoid errors and also the errors from altimetry measurement. Then the ADT are combined through an optimal analysis to compute a regular gridded ADT map. With this method, we do not need to compute mean quantities (MSS and MDT).

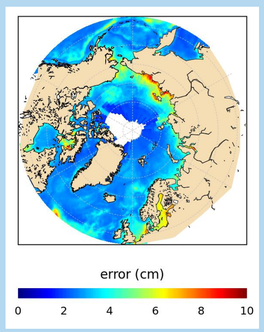
In the study we compare these two methods, that have different error sources, to explore the potential of the direct method and to attempt to evaluate the error of the indirect method in the Arctic Ocean.

METHODS

classical method

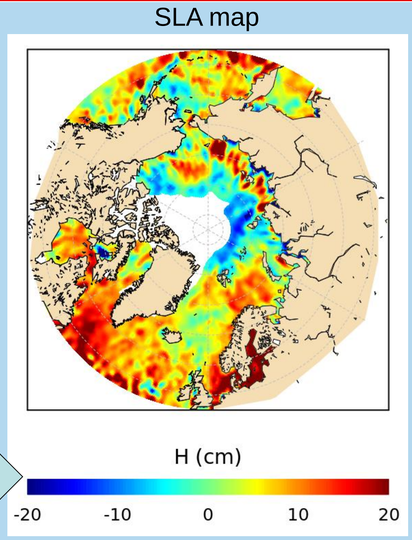
SLA along track (SSH-MSS)
12 September 2012 ± 15 days





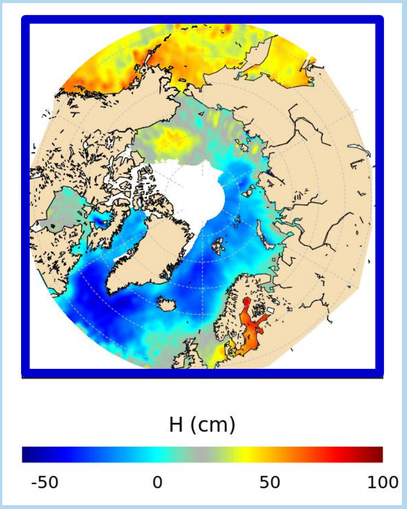
Mapping (objective analysis) at 100 km of resolution

SLA map



+ MDT

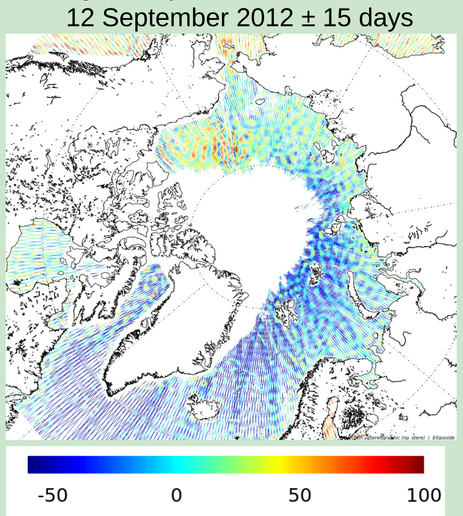
ADT map – 12 September 2012

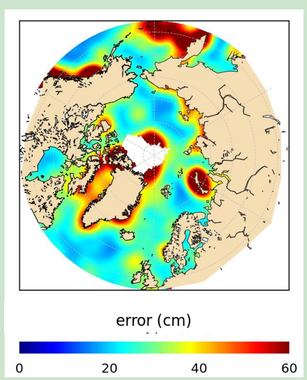


The **classical method** uses intermediate quantities (MSS and MDT) that are complex to compute. Consequently, it is impacted by MSS and MDT errors; the Arctic Ocean is particularly challenging because of the poor altimetry coverage which is seasonally covered by sea ice.

direct method

ADT along track (SSH-DIR5 *Bruinsma et al, 2014*)
12 September 2012 ± 15 days

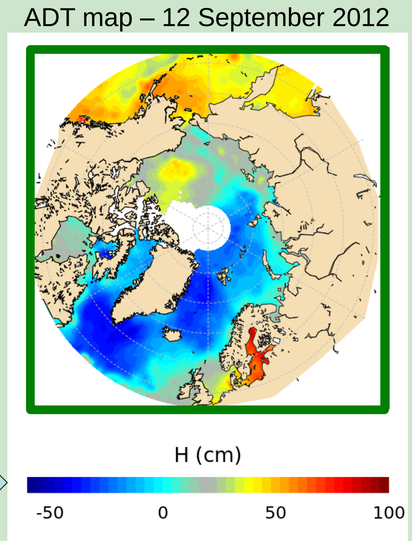




Main errors are from geoid model, and are up to 60 cm.
Note that the errors on ADT are much higher than errors on SLA, consequently the ADT map throught the direct method is smoother than with the classical one.

Mapping (objective analysis) at 100 km of resolution

ADT map – 12 September 2012



The **direct method** is much easier to compute. However it still limited by geoid model resolution: 100 km with GOCE model.

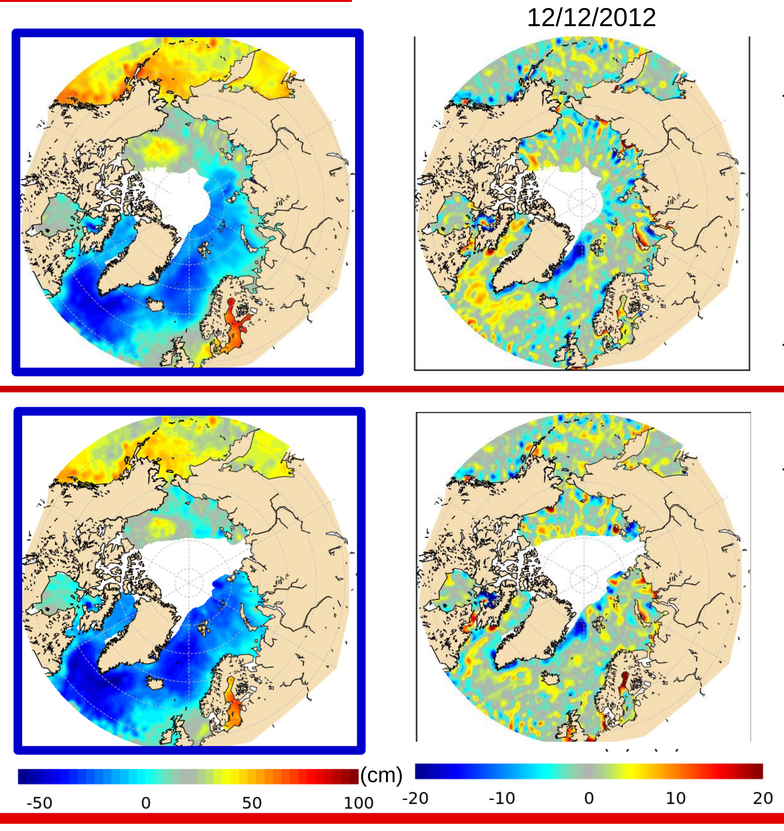
Thus, the **direct method can be used to evaluate the classical method at scales larger than 100 km.**

RESULTS I: error assessment

DTU13
(see classical method part above)
SSH – MSS DTU13 + MDT DTU13
Andersen et al, 2013

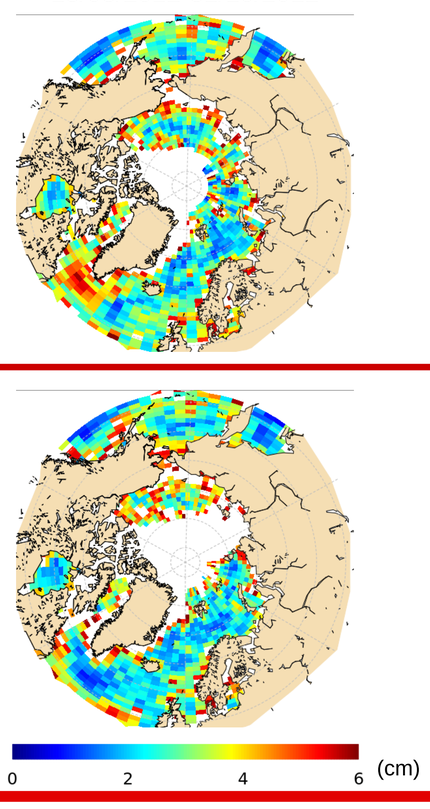
CNES-CLS
(see classical method part above)
SSH – MSS CNES-CLS11 + MDT CNES-CLS13
Schaeffer et al (2012) *Rio et al (2014)*

Difference from the direct method
12/12/2012

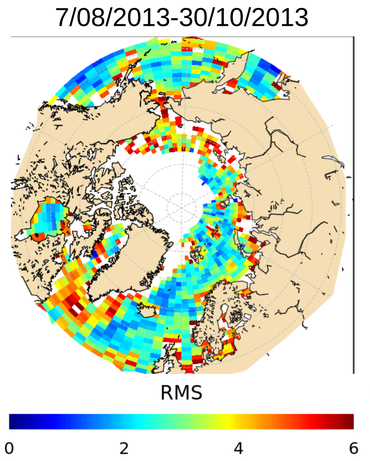


- Negative anomaly east of Greenland is associated with the Greenland current that is not as well resolved with the direct method as the classical one because of smoothing, lack of data and high geoid error in this area.
- Comparison shows negative anomaly with the classical method using DTU13 in the subpolar gyre.
- Away from these 2 areas, differences are up to 10/15 cm and are due to both, error in the methods and difference at small scales because direct map is smoother since error prescribed in the objective analysis is higher (see above the method description).

RMS of the difference over
15/08/2012-31/10/2012



RMS of the difference over
7/08/2013-30/10/2013

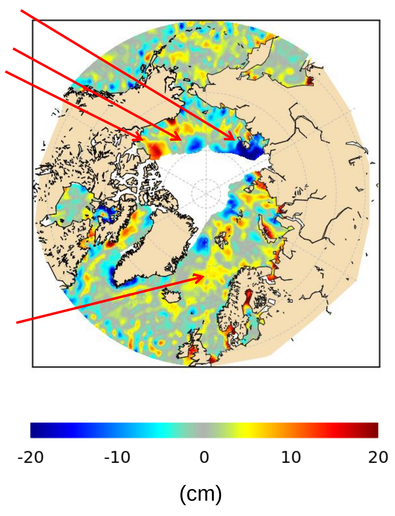


- Error is estimated to be around 4 cm.
- In the Eurasian bassin error is less than 3 cm while in the Beaufort bassin often covered by ice, error is higher, up to 6 cm.
- Also, error increases over a time period for which MSS does not use the altimeter data (compare RMS of the difference for DTU13 computed in 2012 *versus* 2013 ; MSS DTU13 does not include data after the end of 2012)

RESULTS II: Issue of the classical method: consistency of MDT and MSS

Difference of
Direct method (SSH-DIR5)
-
Classical method
(SSH - **MSS DTU13** + **MDT CNES-CLS13**)

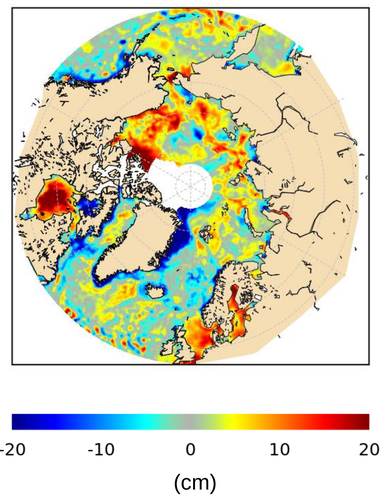
The MDT CNES-CLS13 is re-referenced over the time period 1993-2012 (same reference time period than MSS DTU13)



The MDT/MSS DTU13 and CNES-CLS theoretically cover the same time period 1993-2012 but are processed in a different way. This figure shows the inconsistencies that are likely due to the fact that in Arctic MSS/MDT fail to represent a true mean over 1993-2012 but have residual biais.

This is a huge issue for SLA assimilation in numerical model that often use their own MDT.

Difference of
Direct method
-
Glorys2V3 (numerical model reanalysis produced by Mercator-Ocean and distributed by MyOcean)



Conclusions

Summary

- We have compared 2 different methods to map the Absolute Dynamic Topography. The classical method uses intermediate quantities (Mean Sea Surface and Mean Dynamic Topography) and thus is more complex and impacted by MSS and MDT errors. The directe method is simple and only uses SSH and geoid model, however it is limited by geoid model resolution (100 km with GOCE).
- The direct method is much easier to compute than classical one. Once altimeter measurement is available, a map can be done, however it is not the case for the classical method where computation of MSS is impossible in area never observed.
- Moreover, with the classical method it is mandatory to use very consistent MDT and MSS otherwise ADT maps have arctefacts. This is a huge difficulty for SLA assimilation in numerical model. An idea could be to assimilate ADT map computed from the direct method.
- In the Eurasian bassin RMS of the difference are less than 3 cm while in the Beaufort bassin, more often covered by ice, RMS are higher, up to 6 cm and even higher over a time period for which MSS does not use the altimeter data.

BUT

- This poster shows preliminary results. Further work is needed to well understand the difference between both method.
- We plan to filter ADT maps and give the errors at different lenghtscales to deal with small scales not resolved by the direct method.