Last TUGO model simulations and perspectives of evolution of the Dynamic Atmospheric Correction for altimetry

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Ocean Surface Topography Science Team Meeting (OSTST)
21-25 October, 2019
Chicago, Illinois

Introduction

Altimeter measurements are corrected for several geophysical effects in order to isolate the oceanic variability and the Dynamic Atmospheric Correction (DAC) is the second most important one after the tide correction. DAC correction allows for the removal of high frequency ocean variability induced by the atmospheric forcing and aliased by the altimetric measurements.
The accuracy of the DAC has been much improved over the last 25 years leading to centimetric accuracy in open ocean. However significant errors remain mainly in shallow waters and in polar regions, due to bathymetric errors, to atmospheric forcing errors, to local lack of resolution of the grid …
Several ways of improvement of the DAC have been tested, including: new model version, new bathymetry and higher resolution mesh, use ERA5 database, a higher frequency temporal forcing and try to improve the bottom friction dissipation in the simulations. Results of these analysis are presented here.

1-Description of models and methodology for analysis

MOG2D : barotropic model forced by atmospheric pressure and wind from ECMWF operational model (Carrere and Lyard 2003)

DAC_GDR for GDR/NTC products :
- uses 6-hours ECMWF operational forcing (S1S2 atmospheric pressure signal is removed = **CLSf** database)
- is composed with the high frequency part of the **MOG2D** sea level and the low-frequency part of the IB, with a 20-days filtering:

DAC_GDR = MOG2D_HF + IB_BF

TUGO is the new version of MOG2D model also developed by LEGOS laboratory:
- it is R&D code allowing performing many tests with different parameters and forcing
- TUGO code has been optimized and deployed on the CNES HAL cluster to ease the tests

Within the present study, TUGO simulations are used to investigate the different ways of improvement of the DAC for altimetry.

Test simulations:
- TUGO simulations are performed on 2014-2015
- TUGO sea level is filtered similarly as what is done for the operational DAC :

DAC_TUGO_tested = TUGO_HF + IB_BF

Validation process :
- **2 years of Jason-2 altimeter data** are used for the validation of the simulations
  - estimation of the variance reduction of the SLA is shown
  - computation of the SSH crossovers variance reduction is also being performed but not yet available
- **Global tidal gauges database** is also used for validation (GLOSS)

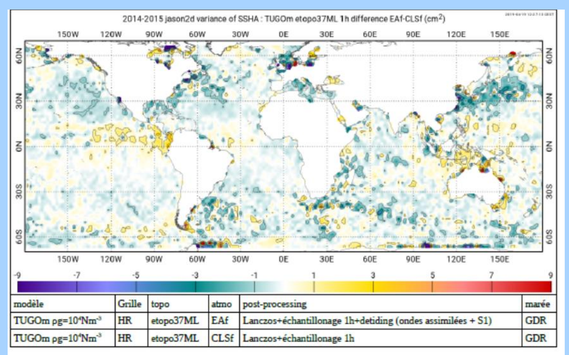
2-Climate applications and use of ERA-5

Meteo model	ECMWF operational	ERA-Interim	ERA-5
Spatial resolution	O1280 / 9 km -> N640 / 137 levels	N128 / 79 km / 60 levels	N320 / 31 km / 137 levels
Temporal sampling	6h analysis	6 h analysis	1h analysis
other	Operational model with evolving data assimilation system, currently Cy46r1	Meteo reanalysis, data assimilation system based on Cy31r2 (2006)	Meteo reanalysis, data assimilation system Cy41r2 (2016), more data assimilated

- Interest to improve the quality of old altimeter missions databases (better spatial resolution, 1-hour fields)
- Interest for climate applications thanks to an homogeneous quality of the dataset in time

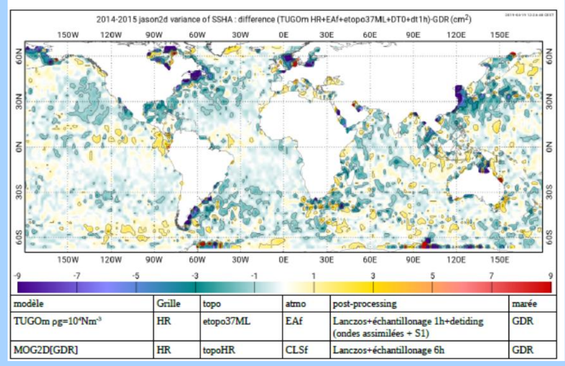
- ERA5 contains very HF noise and a specific filtering is needed for surge simulation and DAC => **EAf** database
- TUGO sea-level forced by EAf need to be detided because ERA5 forcing contains atmospheric gravitational forcing at some frequencies

Using EAf-1h forcing vs operational ECMWF 6h-forcing (1h outputs in both cases) => *blue areas show a global improvement using Eaf,* except in few regions



modèle	Grille	topo	atmo	post-processing	marée
TUGOm pg=10⁹Nm⁻³	HR	etopo37ML	EAf	Lanczos+échantillonage 1h+detiding (ondes assimilées + S1)	GDR
TUGOm pg=10⁹Nm⁻³	HR	etopo37ML	CLSf	Lanczos+échantillonage 1h	GDR

Using EAF-1h forcing and an improved bathymetry vs operational DAC_GDR => *significant improvement of TUGO simulation in many regions* except small variance raise in some areas (yellow dots)



modèle	Grille	topo	atmo	post-processing	marée
TUGOm pg=10⁹Nm⁻³	HR	etopo37ML	EAf	Lanczos+échantillonage 1h+detiding (ondes assimilées + S1)	GDR
MOG2D[GDR]	HR	topoHR	CLSf	Lanczos+échantillonage 6h	GDR

3-Improving the DAC in coastal regions

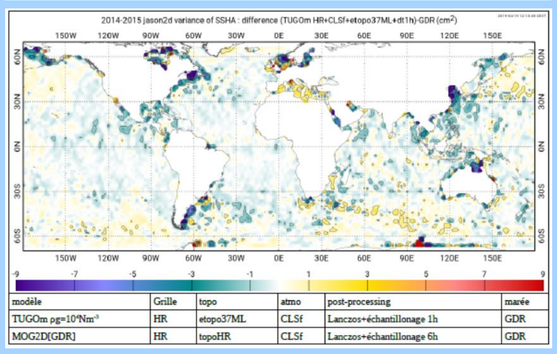
DAC_GDR has an insufficient resolution and a higher error budget in costal ocean; improvements proposed are:

to improve data coverage :
- Use a higher resolution mesh and better coastline: FES2014 mesh => impact on most coastal regions and also in Arctic area

to use more accurate bathymetry fields:
- We use FES2014 bathymetry (Etopo37ML)

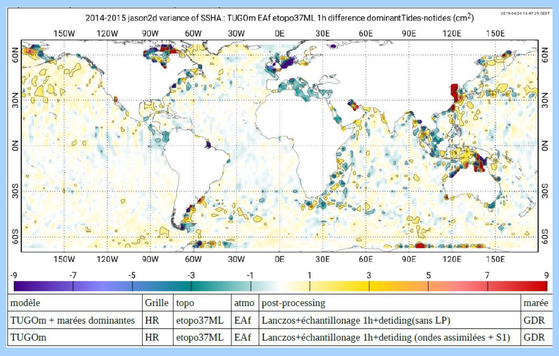
to improve bottom friction dissipation
- Include the dominant tide forcing (M2, N2, S2, K1, O1) within the surge simulation

Using the new FES2014 bathymetry field: blue areas show a *significant improvement on many regions and particularly in shallow waters.* Slight degradation (yellow) is visible in the Mediterranean Sea, south of the North Sea, and in southern Indian and Pacific.



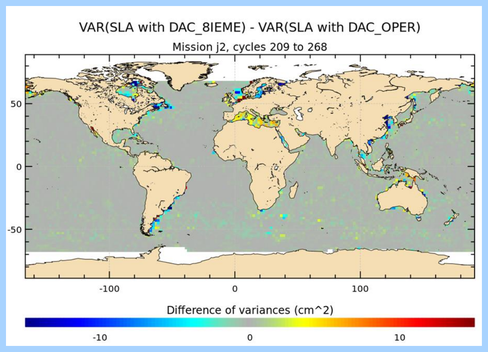
modèle	Grille	topo	atmo	post-processing	marée
TUGOm pg=10⁹Nm⁻³	HR	etopo37ML	CLSf	Lanczos+échantillonage 1h	GDR
MOG2D[GDR]	HR	topoHR	CLSf	Lanczos+échantillonage 6h	GDR

Including dominant tide forcing in the TUGO simulation: blue areas show improvement in some shallow waters and in the Mediterranean Sea, but a degradation is noted in many areas => *this approach is not yet mature and needs more investigations* (consistency between the DAC and the Tide correction, …)



modèle	Grille	topo	atmo	post-processing	marée
TUGOm + marées dominantes	HR	etopo37ML	EAf	Lanczos+échantillonage 1h+detiding(sans LP)	GDR
TUGOm	HR	etopo37ML	EAf	Lanczos+échantillonage 1h+detiding (ondes assimilées + S1)	GDR

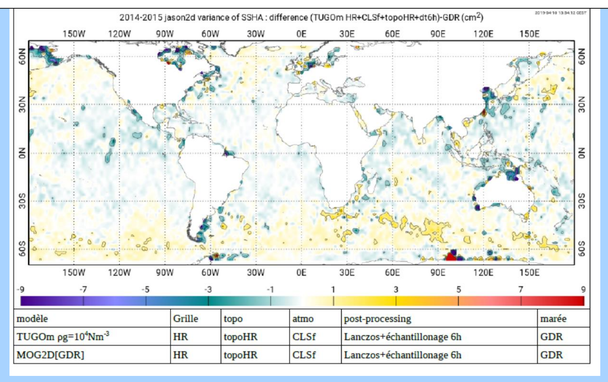
Using the FES2014 higher resolution mesh and bathymetry: blue areas show a *significant improvement in shallow water regions.* Slight variance raise is visible in the Mediterranean Sea.



4-Operational altimetry and improvements for deep ocean

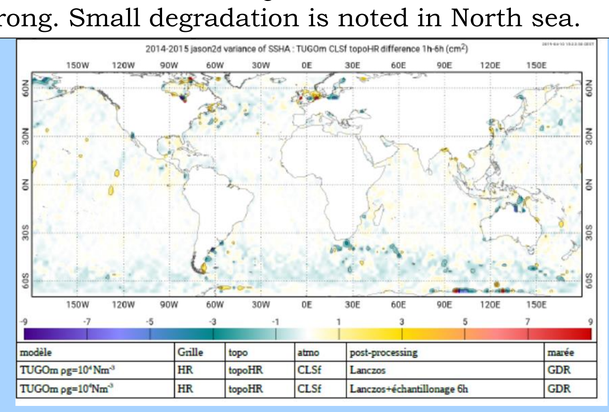
DAC_GDR has a good budget error in deep ocean, but some improvements can still be envisioned:
- **model evolution : MOG2D => TUGO**
- **use higher frequency model outputs (1h)**
- **use higher frequency forcing** (ERA5 1h, cf 2nd section of this poster) => strong improvement even on a recent altimetry period)
- **improve the wind stress forcing** by using ECMWF EW/NS surface fluxes => impact is negligible (not shown)

Using TUGO model instead of MOG2D: blue areas show a *significant improvement in shallow waters + intertropical area.* Slight degradation is visible in the southern ocean, which might be explained by the shorter spin-up of TUGO simulation.



modèle	Grille	topo	atmo	post-processing	marée
TUGOm pg=10⁹Nm⁻³	HR	topoHR	CLSf	Lanczos+échantillonage 6h	GDR
MOG2D[GDR]	HR	topoHR	CLSf	Lanczos+échantillonage 6h	GDR

Producing 1-hour sea-level outputs instead of 6-hours, using the operational ECMWF 6-hours forcing (CLSf): blue areas show a *weak improvement particularly in some shallow waters and at high latitudes* where HF variability is strong. Small degradation is noted in North sea.



modèle	Grille	topo	atmo	post-processing	marée
TUGOm pg=10⁹Nm⁻³	HR	topoHR	CLSf	Lanczos	GDR
TUGOm pg=10⁹Nm⁻³	HR	topoHR	CLSf	Lanczos+échantillonage 6h	GDR

Conclusion and perspectives

- The quality of the DAC is improved when using the new mesh and new bathymetry, using TUGO model instead of MOG2D and also when producing higher frequency maps.
- Using ERA5 1-hour meteorological forcing has a strong positive impact on the DAC solution.

- Other perspectives of improvements of the DAC are : revisit the S1S2 processing when using 1-hour forcing, take into account LSA effects, sea-ice effects and effects of waves on storm surges.

Implementation plan for a new DAC

- A **new DAC-TUGO** taking into account TUGO model, the new mesh/bathymetry and higher frequency surge maps can be implemented in 2020 (October 2020 TBC).
- A **new reanalysis of DAC using ERA5** meteo forcing can also be planned in 2020; it will include some/all improvements of DAC-TUGO listed above depending on schedule constraints.