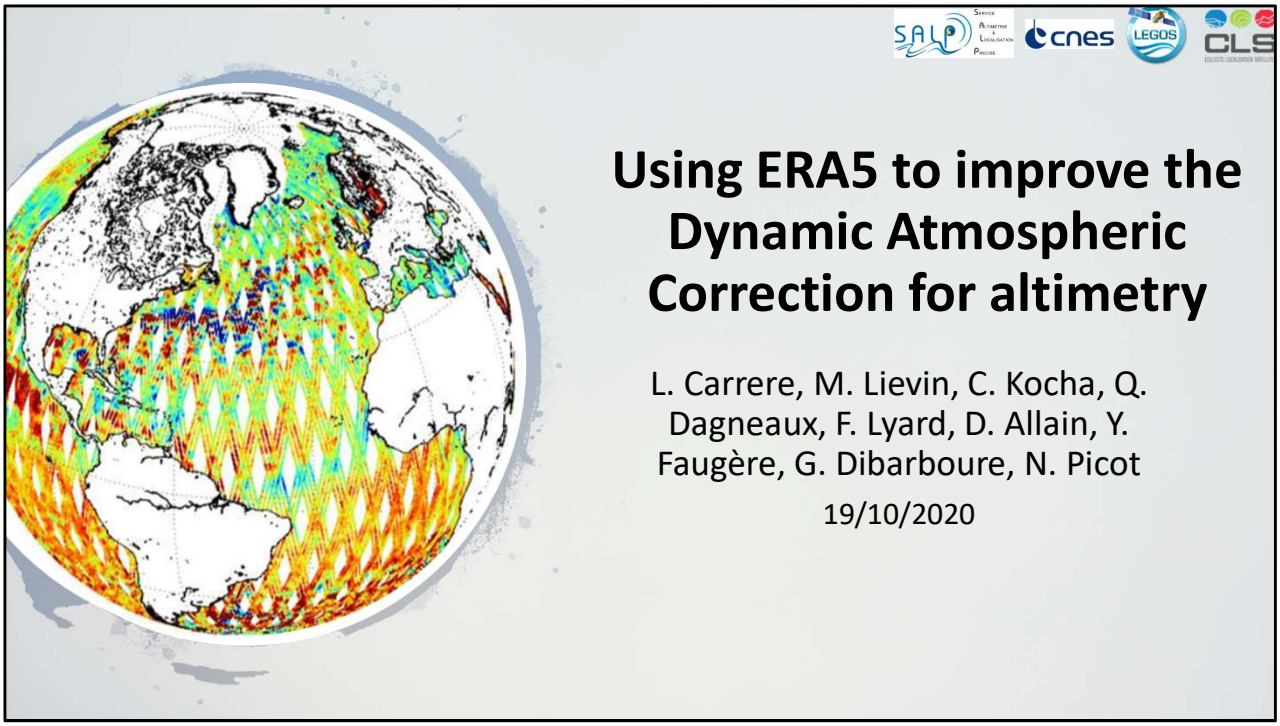

Using ERA5 to improve the Dynamic Atmospheric Correction for altimetry

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19/10/2020

DAC used in altimetry

- **DAC** is computed using a barotropic ocean model forced by atmospheric pressure and wind for high frequencies (HF => T < 20 days) and the inverse barometer (IB) for low frequencies (LF=> T > 20 days) :

  DAC = MOG2D_HF + IB_BF

- Operational DAC is based on MOG2D model and ECMWF operational analysis

- Objective of the study : use new meteo database ERA5 to produce an improved DAC-ERA5 correction for altimetry

Meteo databases used in altimetry

Meteo database	ECMWF operational	ERA-Interim	ERA5
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**
Model and assimilation system	Evolving operational model/data assimilation system, currently Cy46r1 => discontinuities when changing model versions	Meteo reanalysis, data assimilation system based on **Cy31r2 (2006)**	Meteo reanalysis, data assimilation system **Cy41r2 (2016)**, more data assimilated
Altimeter products	Operational products NRT and RT	Reprocessed products DT-2014, and CCI products: ERAi used for old missions only	New reprocessed products to come…

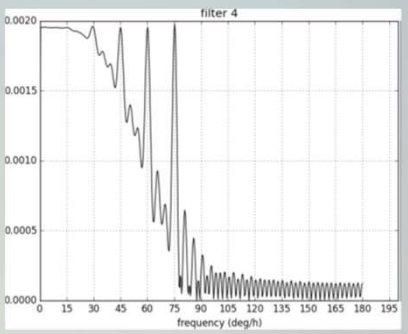
- Interest to improve quality of old altimeter mission databases
- Interest for climate applications thanks to the use of a fixed data assimilation system/model version for the entire database => continuous database

Several meteorological databases are used in altimetry :

- the operational DAC is forced by the ECMWF operational analysis which have 6-hour resolution and 9 km spatial resolution. The operational meteo model is continuously evolving in time and may have discontinuities between model versions which may affect the DAC model.
- The ERA-interim database was used a few years ago to produce the DAC-ERA-Interim product: even it has a degraded spatial resolution, this product showed a strong improvement compared to operational one for old altimeter missions; it has been used in DT-2014 and CCI altimeter products.
- Now ERA5 meteo reanalysis is available that benefits from higher temporal sampling (1h) and better spatial resolution (31 km) : we think it is interesting to use it to improve the quality of old altimeter missions and then participate to a better altimeter database for climate and mesoscale applications.

ERA5 pre-processing needed for DAC computation

- Comparison with some in situ data pointed out some noise at very HF in ERA5
- Several filtering have been tested
- Better results obtained using :
  - cut-freq at 60 deg/h (T = 6h)
  - preserving S1,S2,S3,S4,S5, M2 frequencies
- Filter applied on pressure and winds
  - Fev 90-may 2019 processed :msl,pr,10u,10v



A preprocessing of ERA5 meteo data is needed to inject it in the DAC model. Comparisons with some in situ data have pointed out some very HF noise in ERA5 data, so we decided to use a specific filtering of the meteo data: a low-pass filter with cutting period of 6h is applied while preserving the tidal pics at S1, S2 ... S5 and M2 frequencies.

New DAC computed for altimetry using ERA5 database

DAC-ERA5 correction

- Uses 1-hour ERA5 filtered data as forcing
- New ocean model is used : **TUGO**
- New bathymetry field improved in many regions, particularly on most shelves is used: it is the FES2014 tidal model bathymetry
- Only IB is defined for continental waters

DAC-ERA5 dataset

- Produced data: DAC-ERA5 with global coverage
- Period available: 1992-02 to 2019-07
- Resolution: cartesian grid (1/8 degrees) – hourly files

DAC-ERA5 and S1S2 radiational tides processing

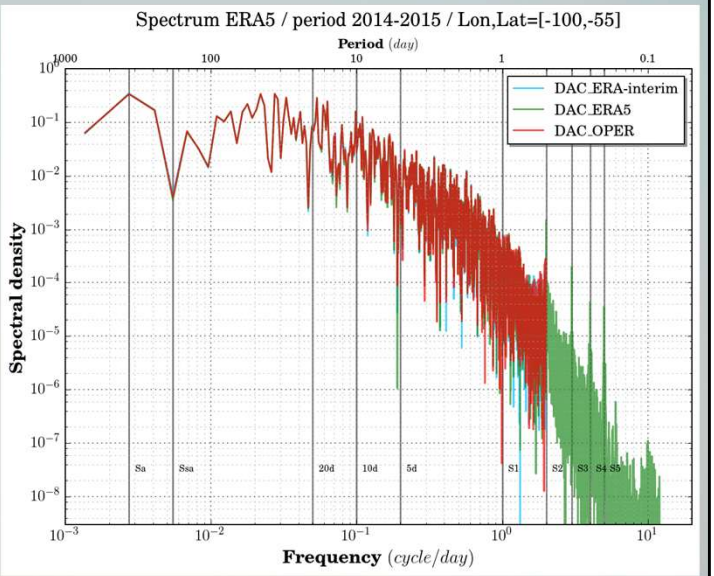
DAC-ERA5 – reprocessing context

- TUGO model is forced by ERA5 1-hour analysis
- As ERA5 pressure, not detided, is injected into TUGO model => SLEV_TUGO contains all tidal pics
- Harmonic analysis of SLEV_TUGO is performed to extract the tidal pics at FES2014 assimilated frequencies + S1 (on FES2014 assimilated period)
- We correct SLEV_TUGO from these tidal pics to avoid multiple altimeter correction of these frequencies

⇒ DAC-ERA5 does not include FES2014 assimilated waves (including S2) nor S1

DAC-ERA5 contains new signals

- S3 and S5 frequencies are a new containt vs DAC-OPER and DAC-ERAi
- Contains also some residual variability at S1, S2 and other frequencies
- S4 frequency : this wave is also contained in FES2014 but not assimilated, so it has not been removed in DAC-ERA5 product



The S1 S2 radiationnal tides is still a tricky question as these frequencies are visible both in the Tides and DAC corrections if no specific processing is done. As DAC-ERA5 benefits from 1-hour forcing a new processing (different from operational one) is applied.

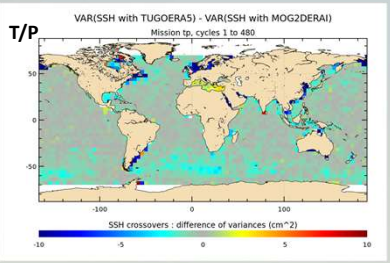
Moreover thanks to this 1-hour forcing, DAC-ERA5 also contains new signals at S3, S5, S4 … frequencies.

Impact of DAC-ERA5 for short temporal scales

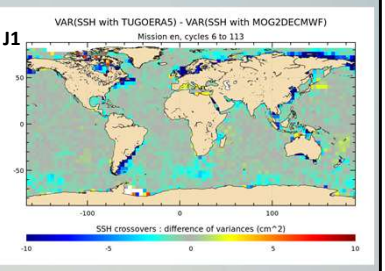
Variance reduction at altimeter crossovers when using the new DAC-ERA5 instead of the reference DAC corrections :
DAC-ERAi for T/P
DAC-ECMWF operational correction for EN, J1, J2

- **Strong variance reduction is noted when using the new DAC-ERA5 on continental shelves and also in deep ocean at high latitudes => this indicates an improvement when using the DAC-ERA5**
- **Small variance raise is noted in the Mediterranean Sea => this is likely a mesh/bathymetry problem and it should be corrected within FES2022 project**

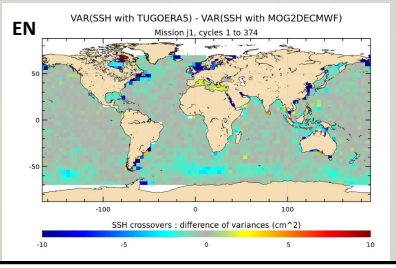
T/P



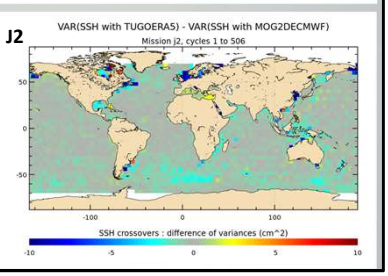
J1



EN

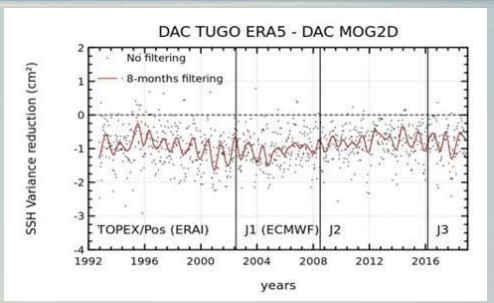


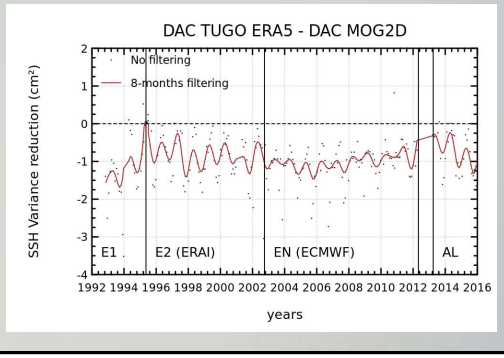
J2



Impact of DAC-ERA5 for short temporal scales

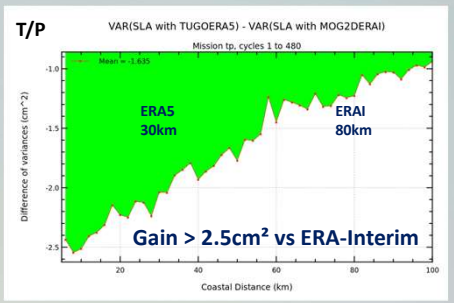
- The curves on the right show the temporal series of the mean variance reduction at altimeter crossovers on global ocean on the altimetric era, when comparing DAC-ERA5 with the reference DAC (DAC-ERA-interim or DAC-ECMWF = operational DAC)
- 2 long-term altimeter series are considered:
  - TP-J1-J2-J3 above
  - E1-E2-EN-AL below
- Comparison shows a mean variance reduction of ~1 cm², stable in time during the entire altimetric era, when using the new DAC-ERA5
- Even on most recent period (J3 and AL), the improvement remains visible showing the interest of the better bathymetry and the higher frequency forcing compared to the operational DAC

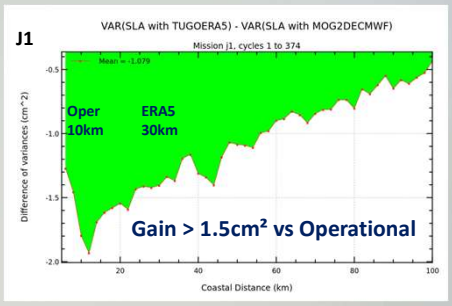




Impact of DAC-ERA5 on coastal areas

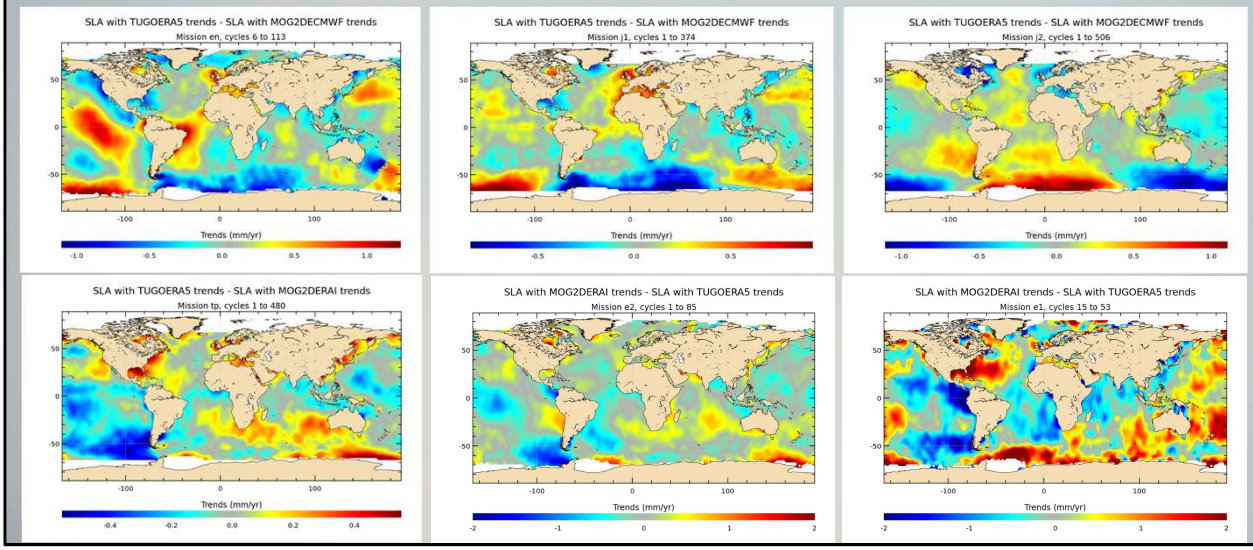
- The curves on the right show the mean SLA variance reduction as a function of coastal distance for T/P and J1 missions, when comparing DAC-ERA5 correction with the reference DAC (DAC-ERA-interim for T/P, DAC-ECMWF = operational DAC for J1)
- Strong positive impact is noted for T/P measurements, likely due to the better bathymetry used and to the better spatial resolution and better temporal resolution of ERA5 meteo database compared to ERA-interim
- Positive impact is also noted vs the operational correction (DAC-ECMWF) on J1 measurements: although ERA5 has a weaker spatial resolution compared to operational ECMWF, this improvement is likely explained by the 1-hour temporal sampling of ERA5 and the better bathymetry used





Impact of DAC-ERA5 on regional and global trends

- **Strong impact on regional trends is noted for each mission :**
  - **several mm/yr locally -> this impact can be interpreted as an improvement thanks to the reduction of noise of the HF series**
  - **regional trends differences observed are as important as the ones noted when changing DAC-ERA-interim vs operational DAC**
- **No impact is noted on global trends as for DAC-ERA-interim**



The maps show the regional trends differences when using DAC-ERA5 instead of the reference DAC (DAC-ERA-interim for ERS1, ERS2, T/P and operational DAC for EN, J1, J2) for each altimeter mission.

Conclusion

Applications	Global MSL	Regional MSL	Mesoscale	Coast	COMMENTS
Missions tested: TP J1 J2 J3 E1 E2 EN AL	Trend >0.15>0.05 mm/yr	Trend >0.5>0.2 mm/yr	(<2months) Var(SSHXo) >1>0.2 cm2	(<100km)	
DAC reference Vs DAC-ERA5	<0.09mm/yr	~ 1 mm/yr	-1 cm²	-2-4 cm²	• Strong improvement on the crossovers SSH variance • Strong impact on regional trends • No significant impact on global trends

Comparing DAC-ERA5 with the reference DAC (DAC-ERA-interim for old missions and operational DAC of other missions) shows:

- A strong improvement on the SSH crossovers variance for all missions
- A strong impact on the regional trends estimation, understood as an improvement of the regional trends thanks to the reduction of the noise of the HF series
- No significant impact on the global trend estimation

Recommandations for DUACS DT-2021, is to use DAC-ERA5 for all missions until the beginning of J3