Reprocessing TOPEX/Poseidon precise orbits in the GDRE standards

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Introduction

TOPEX/Poseidon (T/P) was a 13-year altimeter mission, collaboration between the USA and France. Today, the collected data are still used for long-term studies of the oceans.

The TOPEX orbits were reprocessed in the GDRE standards, currently used at the Centre National d'Etudes Spatiales (CNES). Two issues were raised and considered in this analysis: on one hand, the **use of the tracking measurements, in particular the SLR data,** to compute the GDRE orbits, on the other one, the issue of the **lack of a GRACE time-varying gravity (TVG) model** for a major part of the T/P mission

Use of tracking measurements

SLR in the GDRE strategy

The SLR data are not used for the orbit determination but for the validation, as an external set of observations.

Process DORIS-only orbit solutions

Attitude events frequently occurred at the end of a cycle: missing DORIS observations

- ➢ The proposed solution is redefining the cycles by excluding the periods without DORIS observations. Since these orbits are not meant for operations, missing ephemerides would not cause problems.

Process DORIS+SLR orbit solutions

- It is known that the DORIS observations cannot recover well the normal orbit components contrary to the SLR measurements. Therefore, the use of the SLR may correct the normal errors due to DORIS.
- Some SLR stations were biased leading to a radial deformation of the orbit. The best stations, i.e. the ones which are less likely to perturb the radial component of the orbit were identified by analyzing the high-elevation residuals on the DORIS-only orbits.
  - ➢ **A core network of 10 stations, representing nearly 50% of all passes, is used for the orbit determination.**
- The weights of DORIS and SLR data are kept unchanged since the mission operations in the 1990s.

Modeling the time-varying gravity (TVG) field

Adjust the degree-3 order-1 spherical harmonics

For the Jason satellites, TVG-related errors were shown to be mainly sensitive to the degree-3 order-1 harmonics *[1]*. Besides, estimating the degree-3 order-1 harmonics when determining the dynamic solution may recover the residual errors due to the odd degrees order-1 terms. This strategy was applied on both DORIS and DORIS+SLR dynamic orbits.

Application of the reduced-dynamic approach

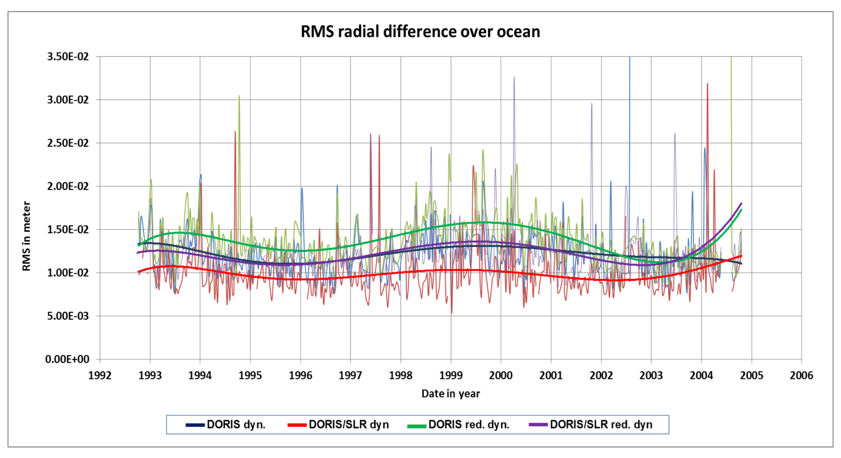
Based on the estimate of a large amount of parameters, this approach enables to recover the errors dues to incorrectly modeled forces like radiative and drag surface forces as well as the errors due to TVG field.

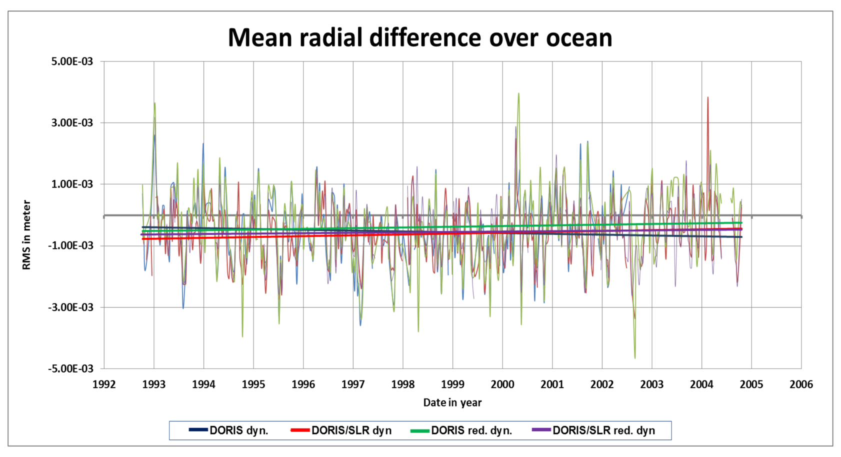
Validation of the new orbits and results

Reference orbits

For the validation, an external sets of DORIS+SLR std1504 dynamic orbits from the Goddard Space Flight Center (GSFC) was used. Available for the cycles 1 to 445 (before the failure of DORIS receiver), they were processed using time series tvg5x5.

Orbit differences between GSFC and CNES orbits, over ocean



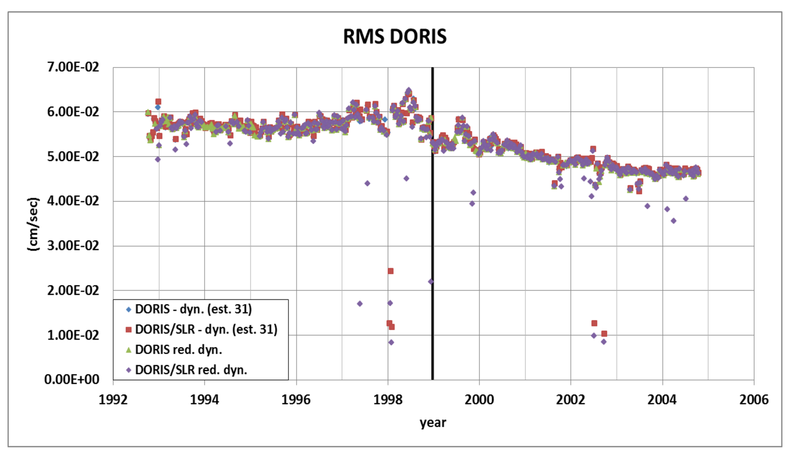


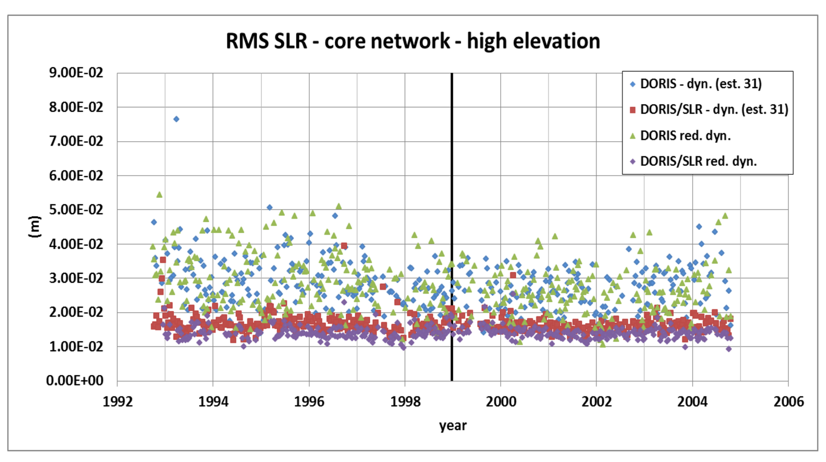
The orbit differences over ocean give the errors affecting the final altimetry products.

- Since the DORIS-only and DORIS+SLR solutions differ by less than 5 mm, the contribution of SLR data slightly improves the radial orbit error.
- The difference in RMS between the GSFC and CNES orbits is less than 1.5 cm. The mean radial differences are millimetric with a bias of -0.5 mm.

DORIS and SLR residuals

Mean of cycles 001-445	Std1504 dyn.	DORIS-only dyn.	DOR+SLR dyn.	DORIS-only red. dyn.	DOR+SLR red. dyn.
RMS DORIS (mm/s)	0.4953 *[2]*	0.5382	0.5473	0.5352	0.5217
RMS SLR (cm)	1.553 *[2]*	2.785	1.643	2.717	1.403





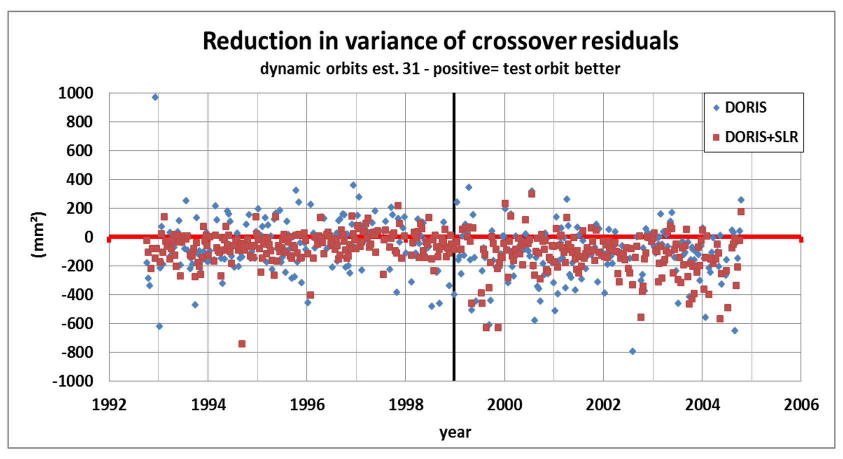
- **DORIS residuals**

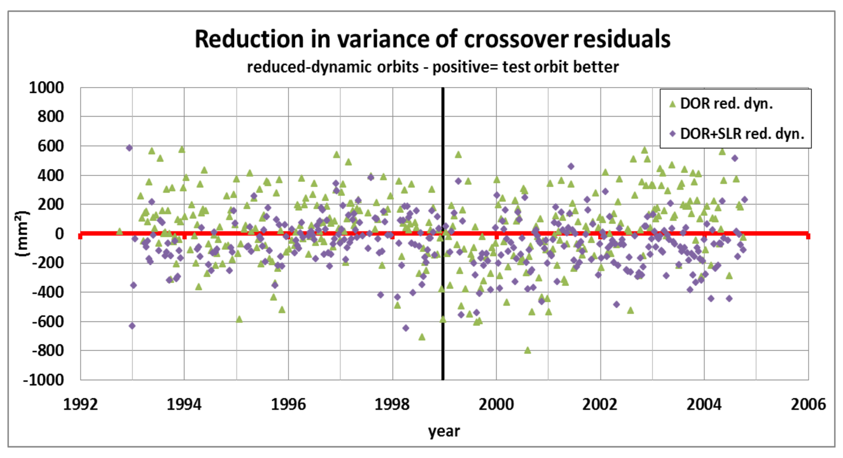
  The residuals are stable with respect to the strategy used to compute the orbit. However, a decrease of RMS is visible resulting from both the change of the DORIS on-board receiver used in late 1998 (bold line) and the improvement of the DORIS network starting in 2000 *[3]*.
- **SLR residuals**

  The SLR residuals significantly differ between the DORIS-only and DORIS+SLR orbits. However, the two types of orbits are quite similar in terms of orbit differences, which shows the importance of a means of orbit validation independent of the orbits. Indeed, the SLR RMS on a DORIS+SLR orbits are artificially better than those on the DORIS-only orbits.

Altimeter crossover residuals

The altimeter crossover residuals and in particular the reduction in variance compared to the GSFC orbits were analyzed.





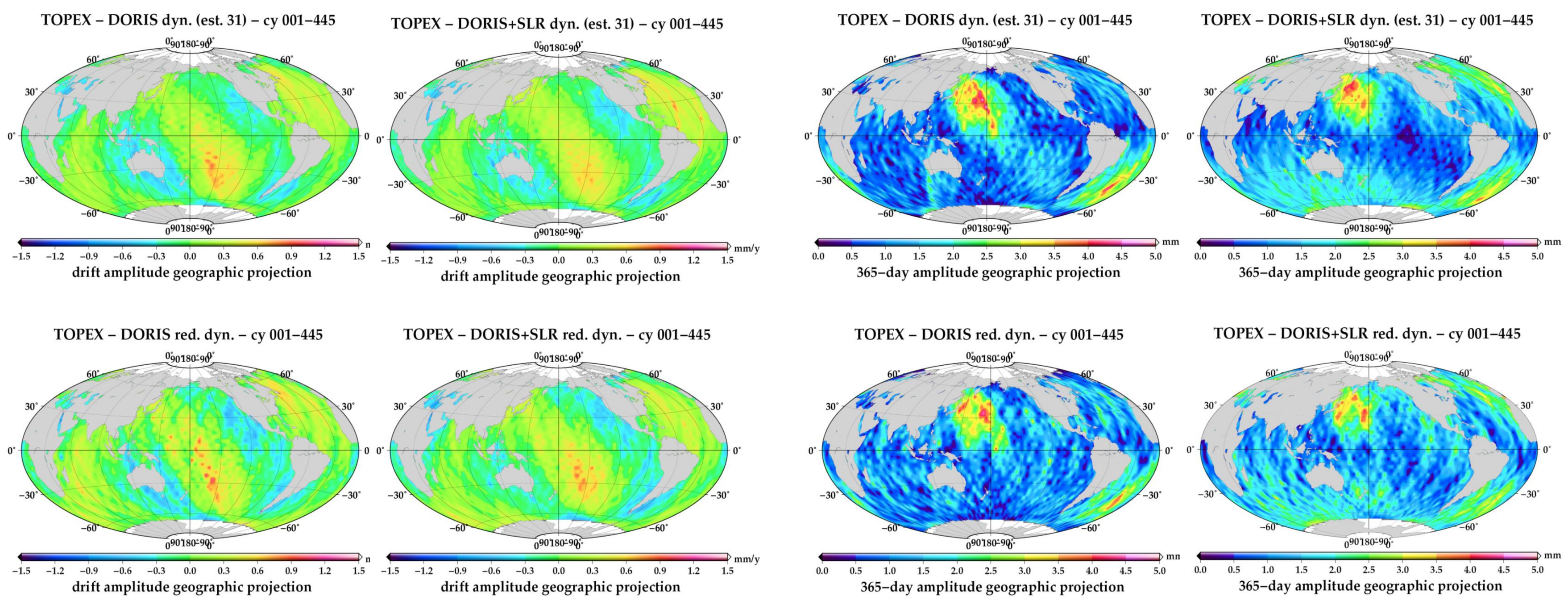
- There is a slight difference between the dynamic orbits, and the reference orbits tend to be better.
- The performances of the DORIS-only reduced-dynamic solutions seem to be better at the beginning and at the end of the considered period, whereas they are similar for the rest of the period.

Geographically correlated errors : drift and annual signal amplitudes

The altimeter crossover residuals do not enable to assess the errors due to the gravity fields, that are cancelled at the crossover points; that is the reason why the GCE were considered.

In the upper row, the graphs shows the results of the dynamic orbits, and in the lower those of the reduced-dynamic orbits.

Drift amplitudes | **Annual amplitudes**



DORIS-only | **DORIS+SLR** | **DORIS-only** | **DORIS+SLR**

- Compared to the GSFC orbits, the drift amplitudes between +/- 1,2mm/y show that both strategies enable to recover the errors due to TVG.
- High annual signals (amplitude of 4-4.5 mm) are observed over the North Pacific and the South Atlantic, which may be explained by errors on the orbit centering differences along the X and Z axes. Indeed, analyzing the orbit difference in a terrestrial frame shows that the annual signal of these two components are predominant.

Perspectives

- The annual signals over the North Pacific and the South Atlantic need more investigation.

References

[1] Couhert et al. "Towards the 1mm/y stability of the radial orbit error at regional scales." *Advances in Space Research* 55.1 (2015): 2-23

[2] Lemoine et al. "New POD Standards (std1504) ", OSTST 2015, Reston, VA, U.S.A

[3] Fagard, H. "Twenty years of evolution for the DORIS permanent network: from its initial deployment to its renovation." *Journal of Geodesy* 80.8-11 (2006): 429-456.