Session 2 Presentation5 (pre-recorded interview)

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Application of DORIS for the geocenter

Definitions:
CF: Geometrical center of the Earth's surface, called Center of Figure.
CN: Center of Network accessible from the limited coverage of crust-fixed stations.
CM: Whole Earth's Center of Mass about which satellites naturally orbit.

1 - You have advocated in recent papers, and including in your Ph.D dissertation that DORIS could contribute to estimation of the geocenter. Before we delve into the details, for the benefit of the viewers of DORIS Days, could you explain what is the geocenter, and why is it important?

Major water and atmosphere mass transports occurring over large regions give rise to temporal variations of CM observed by satellites dynamical motion) with respect to CF (measurable from motions of stations tied to the crust). This motion is strongest at the annual frequency where it mostly reflects non-tidal fluid mass redistribution on the Earth's surface. This heartbeat of the Earth is called the "geocenter motion".

Why do such small changes matter?
Its expected annual amplitude is smaller than the size of a cherry (2-3 mm in the equatorial plane and up to 5 mm in the direction of the polar axis), yet it is now necessary to account for its perturbing effect on the modeling of ground station observations (tied to the crust), used to observe the natural orbital motion of the satellites.
Nowadays, we have new climate-driven precise monitoring of geocenter motion needs because the uncertainty in the trajectory of the geocenter motion is now the highest uncertainty in understanding the variations of the Regional Mean Sea Level and the global Earth energy-water cycle.
Indeed, if you want to answer the question "How much will sea-level rise at regional scales over the next decade and beyond?" you should be able to observe regional sea-level patterns driven by anthropogenic forcing which are within 0.5 mm/yr.
Thus, highly stable orbits of better than 0.1 mm/y decade at regional scales are required.
Given the fact that the geocenter motion is expected to vary by as much as 50 mm over the course of the century, not accounting properly for this motion will affect both satellite altimetry precise orbit determination and satellite-derived estimates of the change in regional mean sea level.
You also need a good modeling of the geocenter motion to assess the current status of climate change and its future evolution:
Indeed, it has a strong effect on measuring the change in the ice-sheets, and to understand their impact on sea level and global fluid mass redistribution or the Earth's energy imbalance, we must explore strategies to better observe and model these subtle variations in the Earth's geocenter.

2 - Currently, two methods to estimate a small signal like geocenter include Satellite Laser Ranging (through a kinematic technique or through direct estimation) or with GNSS (through a combination and inversion technique). How do you estimate the geocenter with DORIS?

DORIS observation of the geocenter motion is challenging because of the complex modeling of the non-gravitational forces of the DORIS satellites. Nevertheless, the DORIS tracking network is stable and uniquely well distributed geographically). This can be an asset to reduce network effects in DORIS-based geocenter time series. We yet have to consider the main source of beacon height inaccuracy.
Indeed, the Zenith Troposheric Delays (ZTD) is correlated with station heights (microwave measurements).
Vertical site displacement should be estimated (with the inclusion of low-elevation DORIS data). It is a sensible way to take into account the various error sources reducing the quality of station height estimates to better sense the motion of CF with respect to CM.
Draconitic effects should also be looked at.
Errors in the modelling of Solar Radiation Pressure (SRP) can alias directly into the annual sinusoidal Z geocenter coordinate.
SRP modelling error on the Jason-type satellites can be identified and mitigated, without compromising the Z geocenter estimate.
State-of-the-art gravity and troposphere models have also to be used.

3 - Over what time period have you estimated the geocenter, and how does it compare with other solutions?

With the contribution of Jason-2 & Jason-3, we are now able to derive a geocenter motion time series since mid-2008 with this approach. Unfortunately, the strong sensitivity of the DORIS receiver on board Jason-1 to radiations in the South Atlantic Anomaly area, as well as the lack of attitude measurements for the Topex satellite, make it currently difficult to start an earlier time series with these two preliminary missions.
Complementary solutions were obtained using either SLR-only or GPS-only data in two previous papers, with Jason-2/3. They both compare very well with the DORIS-based solution, especially for the main annual signal. Yet, biases, drift and interannual signatures remain difficult to compare between these independent estimates.

4 - A key point raised in your papers was the use of non-sun-synchronous satellites. You used the Jason satellites for your results so far? Have you tried other satellites either from actual data or simulation?

Indeed, Sun-synchronous satellites should be disregarded. Instead, data from Jason-like satellites should be used, since any potential errors in SRP modelling will have a distinct period of 118-days, which is the draconitic period of Jason-like satellites, and this one is independent of the annual component of the geocenter signal one wants to estimate.
More recent Sentinel-6 Michael Freilich and HY-2C/D missions, or the upcoming launch of SWOT, should also permit to derive the same type of geocenter solutions, provided their solar radiation pressure perturbations can be properly modelled. The HY-2C/D and Sentinel-6A satellites are all less than 1 year old thus it is still too early to look at their respective geocenter time series.

5 - You have proposed a working group on geocenter within the IDS. What are the short term goals of the WG?

Space-geodetic observation of the geocenter motion is still in its infancy. Estimating geocenter coordinates is one of the most demanding applications of high precision geodetic techniques due to the current precision of the geodetic data, and the nature and magnitude of different types of systematic error.
So we will first try to derive consistent DORIS-only time series in terms of biases, annual signatures, and drifts to be able to successfully combine them together, using Jason-2/3, soon Sentinel-6, HY-2C/D, and the SWOT satellite.
Independent solutions derived using different techniques have systematic differences as large as the signal level.
This is why future improvements of the precision and accuracy of the ITRF origin, which is the Earth's geocenter, will depend on the inclusion of additional geodetic techniques (such as DORIS & GNSS) to SLR and satellites, like the Jason "space ties" platform, which has on board all these tracking techniques. This could be very useful to validate independent geocenter solutions.