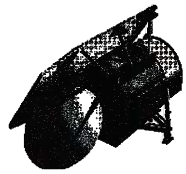

GFO contribution to multi-satellite applications and statistical performance assessment

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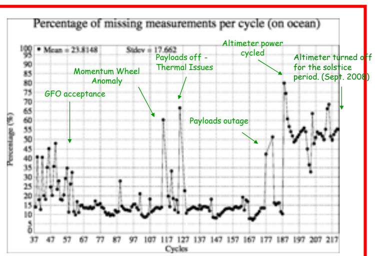
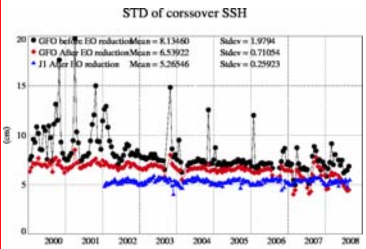
Abstract

Geosat Follow-On (US Navy) is in orbit for now almost 11 years. For more than 7 years, it has been used in the CNES multi-altimeter system (DUACS). Despite its age and the consequent incidents or uneven quality (radiometer shut off, eclipse mode), and despite the reduced data coverage (batteries), GFO still contributed to the DUACS product accuracy until September 2008. GFO is now unlikely to be available in 2009.

GFO Statistical quality assessment

Data availability: Since its acceptance for operational applications, GFO endured various anomalies inducing variations of the number of data available. Last important event was the passage to the eclipse mode in January 2007. It induced a ~50% fall of the number of measurement until the recent shutdown in last September for solstice period while nominal value is around 15% missing measurements.

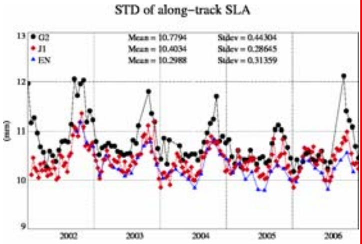




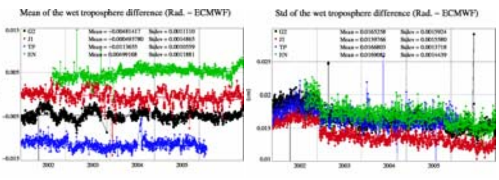
SSH Crossover analysis : SSH cross track analyze give us information about GFO data consistency. Mean SSH standard deviation at cross track location is about 8 cm and is reduced to near 6.5 cm after Orbit error reduction. These values are lightly higher than results obtained with Jason-1 and reveals the differences in ground processing method as well as orbit determination performances.

Standard deviation of GFO SSH crosover, with (red) and without (black) orbit error reduction.

SLA along-track analysis : In the same way, along track Sea Level Anomaly (SLA) analyze underlines the data quality and consistency. SLA standard deviation computed for each cycle presents high value during autumn/winter period. Although natural sea level variability contributes to these values, GFO statistics are higher than for Jason-1 and Envisat for these seasons.



Standard deviation of along-track SLA for GFO (black), Jason-1 (red) and Envisat (blue)



Radiometer performances : GFO radiometer allows a quite good estimation of the wet troposphere. Differences with ECMWF model shows an good long-term stability but with a significant annual signal.

Mean differences (left) and standard deviation (right) between wet troposphere deduced from radiometer and ECMWF model. GFO (black), Jason-1 (red), Topex/Poseidon (blue) and Envisat (green)

GFO impact on the Near Real Time system's resilience and accuracy

The timeliness of satellite altimeter measurements has a significant impact on their value for operational oceanography. Delayed Time (DT) or GDR products benefit from the best accuracy but with a delay that is not compatible with requirements of operational oceanography. Near Real Time (NRT) (or IGDR) and Real Time (RT) (or OGDR) products delay delivery respond to these requirement but on the other hand they involve additional sources of errors induced by lower precise measurement (mainly for orbit determination) and non-centered processing time windows.

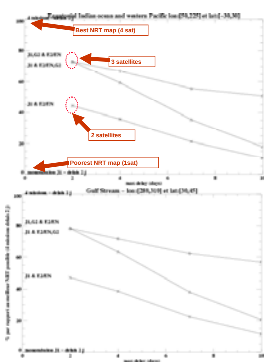
However, NRT products accuracy is improved when more and more altimeter data are merged. In this way 4-satellite NRT products can reach the same performances as the 2-satellite DT products in term of accordance with in-situ data (tide gauge and drifter data) (Pascual and al, 2008). In this way GFO is a key component for NRT system accuracy since it was used as third operational altimeter.

	2 missions	4 missions
DT	36.7	29.7
NRT	45.2	37.1

Mean square differences between tide gauges and altimeter sea level (in % of the tide gauge variance)

	DT		NRT	
	2 missions	4 missions	2 missions	4 missions
U	26.6	24.2	31.0	26.9
V	33.1	28.1	41.2	33.4

Mean square differences between drifter and altimeter velocities (in % of the drifter variance)



NRT indicator (0 to 100%) as a function of the IGDR delivery delay in the Equatorial Indian (top) and in the Gulf Stream (bottom). Assessing the performance loss when IGDR data are temporary unavailable

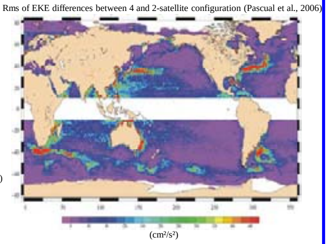
The quality of simulated NRT maps quickly deteriorates when altimeter data are delayed or missing. The comparison of "optimal" NRT maps with degraded NRT maps (as a function of the number of days of delivery delay) shows a linear trend which is used to define a NRT performance indicator. It shows how good the NRT configuration is, and how sensitive to data gaps and delays it can be. For a two satellites configuration, there is a 5% error increase per day of missing data, and only 4% for a three satellites configuration. Not only is a three satellites configuration better in a nominal case, but it is also more resilient to data gaps and delays. GFO thus provides not only an important source of data in term of accuracy, but also a better resilience against temporary anomalies on others missions.

GFO contribution to the restitution of mesoscale activity and local phenomena

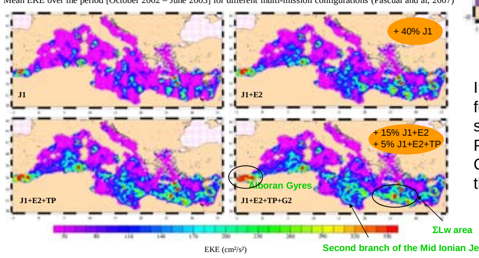
Multi-mission merging process considerably improve the accuracy of altimeter gridded products. The more complementary satellites are added, the best is the accuracy of multi-mission mapping process (Le Traon and Dibarboure. 1999). Combination of two altimetrer missions gives an important estimation of the mesoscale and surface ocean circulation (Ducet and al, 2000; Chelton and schlax, 2003; and others). However, largely improved results are obtained when merging information from more than two satellites.

Eddy Kinetic Energy (EKE) is a good indicator of mesoscale activity level and variability. Contribution of a third and forth altimeter is especially visible at mid and high latitudes where the rms differences between 2 and 4-satellite configuration can reach more than 400 cm²/s² (Pacual and al, 2006).

Rms of EKE differences between 4 and 2-satellite configuration (Pascual et al., 2006)

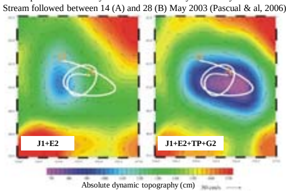


Mean EKE over the period [October 2002 – June 2003] for different multi-mission configurations (Pascual and al, 2007)

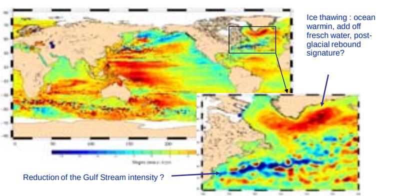


In this way, GFO contributes to the fulfillment of all the structures as showed in the Mediterranean Sea by Pascual and al. (2007). In this basin, GFO data allow a EKE level 5% higher than for the 3-satellite configuration.

Comparison of altimetry and drifter data in a cyclonic eddy of the Gulf Stream followed between 14 (A) and 28 (B) May 2003 (Pascual & al, 2006)



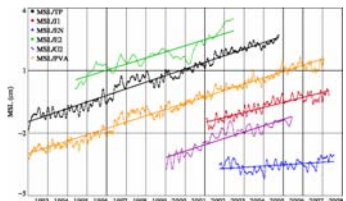
GFO improves the recovery of mesoscale structures that are not properly sampled with a 2-satellite configuration. This is clearly evidenced thanks to a direct comparison with in-situ measurements that show a significant improvement of the correspondences with altimetry when 3 or 4 satellites are used rather than 2.



More globally, GFO's contribution to merged products allowed a significant reduction of the mapping error and thus strongly contributed to a finest restitution of local phenomenon. An example is given here with sea level trend observation in North Atlantic area.

GFO : a reference dataset from offline studies

GFO proved to be a significant asset for offline scientific studies when multiple altimeters are required. With spatial and temporal coverage different than for the other satellites, as well as different processing centre, GFO is an independent source of data that is used as a reference or comparison point.



Global Mean Sea Level Trend observed by each satellite and with the DUACS multi-missions merged product (annual, semi-annual and 60-day signals were removed)

An example is given with Mean Sea Level (MSL) monitoring. Although intra-annual Mean Sea Level variability reported by GFO was more pronounced than for others satellites (TP, EN or J1), Mean Sea Level Trend observed by GFO during its nominal phase was in the same order than the one reported by TP and Delayed time multi-mission products (PVA) : ~3 mm/year. GFO thus allows to complete the cross-calibration processing and contribute to the precision of the measurement.

Conclusions:

Lunched in February 1998, GFO is now arriving at the programmed end of the mission. Since 2001 it was integrated in SSALTO/DUACS operational system and was proved to strongly contribute to improve the quality and precision of multi-mission altimetric products.

Combined with the others altimeters, GFO contributed to the improved spatial and temporal sampling of the ocean signal. In this way, its contribution to improved restitution of local phenomena and mesoscale structure restitution was essential.

GFO's contribution was especially important for the real time system's resilience and accuracy. GFO measurements largely contributed to maintain a minimum quality level of the products when the others satellites were temporally missing. Even with a partial coverage induced by the eclipse configuration and battery status, GFO data were representing near 20% of the total altimeter data involved in the system and contributed to longer maintain NRT services during Jason-1 absence in last August. Without GFO, the minimum quality level would not be reached when either Jason or Envisat is down, and in the worst case, the near real time service would not be provided to operational applications.

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