Do all altimeters contribute equally to DUACS/AVISO maps ?

...and how DFS techniques give the answer on-the-fly and in near real time

G.Dibarboure, MI.Pujol, CLS
PY.LeTraon, Ifremer
N.Picot, CNES

1 - Abstract

To estimate the impact of additional observations in a mapping or assimilating system, the traditional approach is to perform Observing System Experiments (OSEs). An alternative is now used in the atmospheric and ocean modeling communities: the Degrees of Freedom of Signal (DFS).

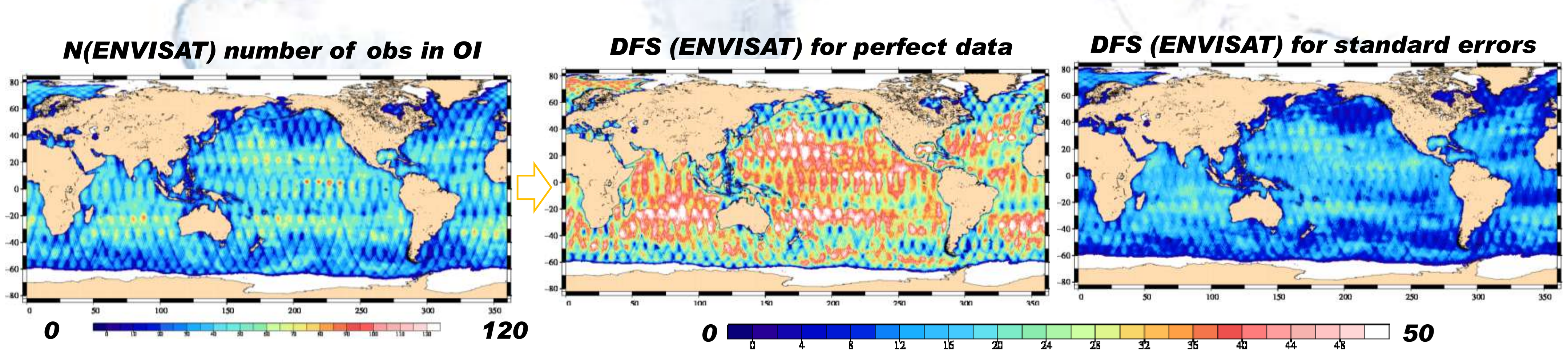
This work illustrates how this technique can measure the contribution of a sensor to multi-mission products from within the constellation and in Near Real Time. Error budget changes and sampling duplicates are observed on-the-fly from within the constellation and during operational computations.

2 - Degrees of Freedom of Signal

DFS are the trace of the HK matrix where K is the Kalman gain matrix. The objective analysis can provide a direct access to HK as it is explicitly computed with the error covariance matrix (or formal mapping error). DFS are computed on each matrix, i.e. each grid point.

Partial Degrees of Freedom of Signal DFS(i) are associated with a particular subset of observations (e.g. a given satellite i), and computed from the partial trace of the HK matrix, taking only elements associated with the subset to be analyzed.

Partial DFS can be normalized to the number of observation locally available in this dataset or N(i). The ratio is 100% for error-free data if their content is independent. It decreases with observation error and redundant observations.



F1: Number of observations from ENVISAT locally used by the OI for the computation each pixel (left), and degrees of freedom of signal for error-free data (middle) or standard error budget (right)

3a – Fraction of information actually used from each sensor

The ratio E(sat) = DFS(sat) / N(sat) is the fraction of the content from a given satellite actually exploited by the objective analysis, i.e. the amount of information not lost to redundant data and measurement errors: if E(i) is 0.5, half the information from a satellite "i" is lost to data redundancy and measurement errors.

Maps of E(sat) give a synoptic view (F3) of the areas where each satellite is exploited to its full extent (e.g. strong currents), and where the observations' value is suboptimal (e.g. ENVISAT sub-cycles). The information is dynamic and moving with time dictated by sampling patterns.

This metric is also strongly affected by the error budget set to each mission in the OI. The type of error (noise, correlated) have a different impact for zones of intense mesoscale activity and zones of lower oceanic variability (F2).

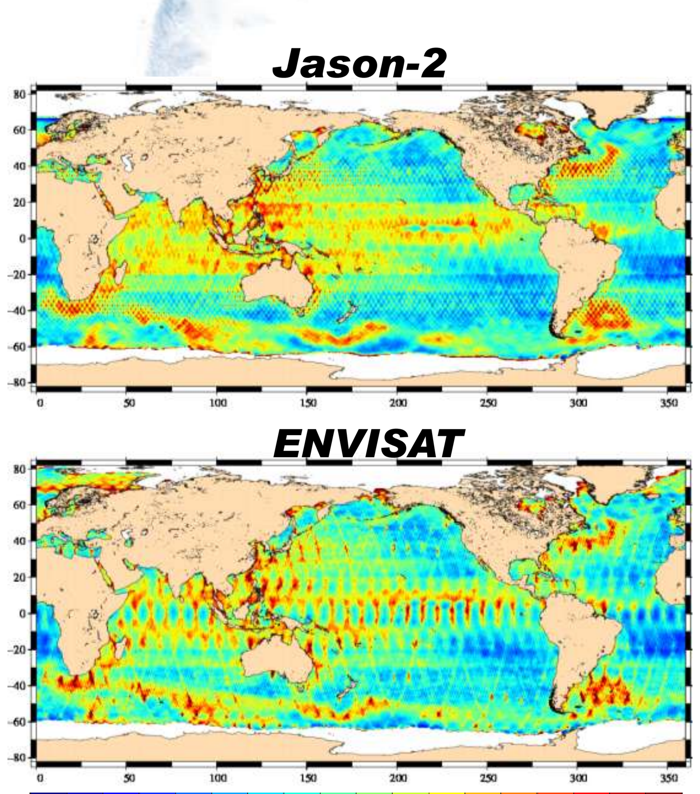
Oceanic variability > 15cm — Fraction the satellite information actually used

	Jason2	ENVISAT
No error (perf. obs.)	96%	95%
Standard error	42%	45%
LWER+2cm on ENVISAT	42%	37%
Noise+2cm on ENVISAT	42%	42%

Oceanic variability < 10cm — Fraction the satellite information actually used

	Jason2	ENVISAT
No error (perf. obs.)	82%	81%
Standard error	32%	34%
LWER+2cm on ENVISAT	32%	29%
Noise+2cm on ENVISAT	32%	27%

F2: Global averages from DFS analysis for four 2-satellite maps: fraction E of mission-specific content actually exploited by the OI. Top panels are for zones where the oceanic variability is higher than 15cm, and bottom panels for zones of oceanic variability lower than 10cm.



F3: Fraction of the satellite-specific information content actually used by the OI for a Jason1+Jason2+ENVISAT map. Top map is E(Jason-2) and bottom map is E(ENVISAT)

3b – Fraction of multi-mission map coming from each sensor

The ratio C(sat) = DFS(sat) / Σ_i(DFS(i)) is the sensor's contribution to the multi-satellite map: if C(i) is 0.5, half the local map content comes from sensor i.

Maps of C(sat) give a synoptic view (F5) of the areas where each satellite contributes to the merged map. In a 3-satellite map, C(sat) highlights the cycle or sub-cycle sampling patterns similarly to OSSE reconstruction errors. This technique highlights the excellent sampling of the Jason coordinated tandem and the relative weakness of ENVISAT's sampling (except at higher latitudes where the tandem is blind).

Although more than 30 days of altimetry are used by the mapping process, Near Real Time maps are dictated by data from the last 10 days, as expected from the short correlation function.

Running a DFS analysis for various error budgets underlines that noise and correlated errors impact differently multi-mission maps (F4): zones of intense mesocale activity are more affected by correlated errors, while uncorrelated noise has more impact else. A measly 2cm of additional error on a satellite (here ENVISAT) can decrease its global contribution from 49% to 42% and much less wherever Jason2 is usable.

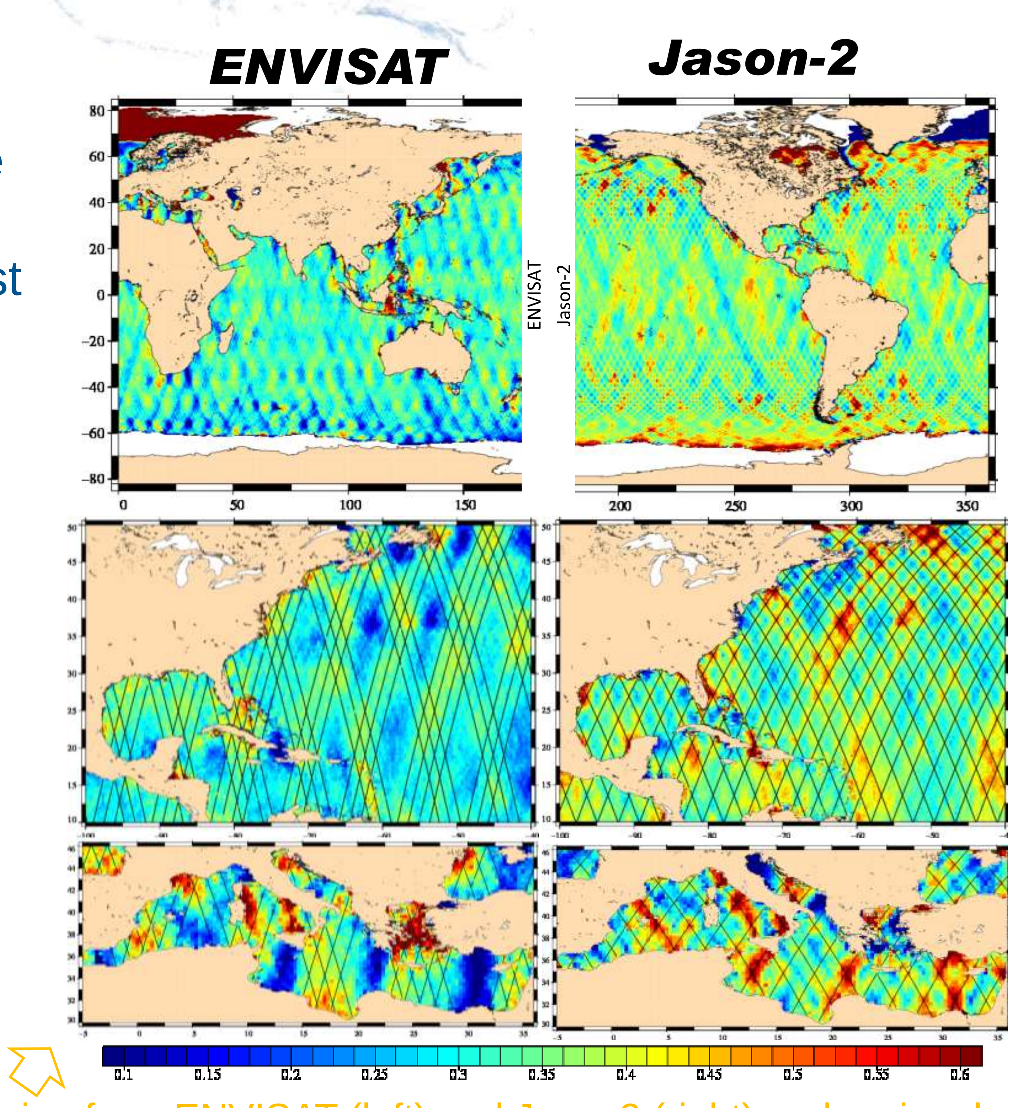
Oceanic variability > 15cm — Fraction of the map coming from a satellite

	Jason2	ENVISAT
No error (perf. obs.)	53%	47%
Standard error	51%	49%
LWER+2cm on ENVISAT (Correlated error)	55%	45%
Noise+2cm on ENVISAT (Noise error)	53%	47%

Oceanic variability < 10cm — Fraction of the map coming from a satellite

	Jason2	ENVISAT
No error (perf. obs.)	52%	48%
Standard error	51%	49%
LWER+2cm on ENVISAT (Correlated error)	55%	45%
Noise+2cm on ENVISAT (Noise error)	58%	42%

F4: Global averages from DFS analysis for four 2-satellite maps: fraction of multi-mission map coming from each satellite. Various error budgets are used.



F5: Fraction of the 3-satellite map information coming from ENVISAT (left) and Jason2 (right) and regional zooms (middle & bottom). Computed as the ratio of DFS (i) / Sum(DFS(i)) on each point of a Jason2+Jason1+ENVISAT near real time map. Satellite tracks of the last 10 days of NRT data of each satellite are superimposed as black lines (out of an analysis window as large as 30 days).

4 – Third satellite in Near Real Time mapping: impact on DFS metrics

When Jason1 is added to Jason2+ENVISAT in the mapping process, the multi-satellite map is built from all satellites almost evenly: contribution C(sat) is almost 33% for each satellite. Jason2 is slightly higher thanks to a more favorable error budget.

Furthermore, although Jason1 is added, the fraction of information actually used by the OI from each satellite barely decreases on Jason2 and ENVISAT (from 41% to 39%). Adding the Jason1 interleaved provides more data actually exploited by the OI in addition to Jason2 and ENVISAT (read: not instead of).

The level of content duplication (oversampling) between the third satellite and the first two is only a few percents. The DFS analysis confirms results from [Pascual et al, 2008] : DUACS' NRT mapping is actually exploiting the full extent of all three satellites. The third one is not competing with the others. The DFS is significantly more efficient than OSSEs to do this, because they provide an on-the-fly estimate of the contribution of each satellite, and from within the constellation (as opposed to twin experiments).

Oceanic variability > 15cm

	Fraction of the multi-satellite map coming from a satellite: Jason2	ENVISAT	Jason1	Fraction the satellite information actually used: Jason2	ENVISAT	Jason1
Jason1+Jason2+ENVISAT	36%	32%	32%	39%	39%	39%
Jason2+ENVISAT	51%	49%	0%	41%	44%	0%

F6: Averages from DFS analysis for two DUACS NRT maps: 3 satellites and 2 satellites. The left panel shows the fraction of the multi-satellite information coming from each mission, and the right panel shows the fraction of mission-specific content actually exploited by the OI.

CLS cnes Ifremer OSTST Meeting 2010 SSALTO DUACS SALP