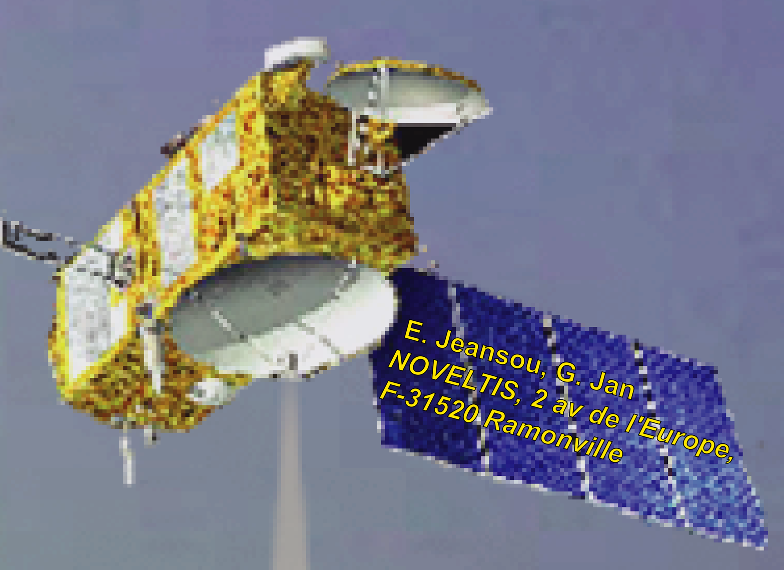
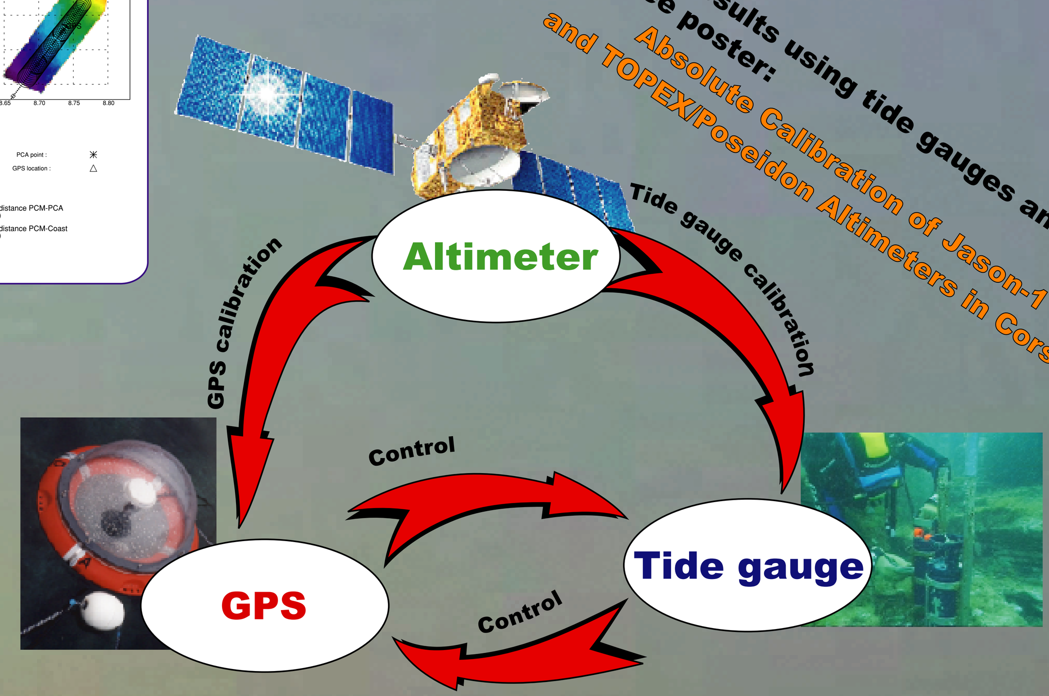
Radar Altimeter Calibration using a GPS-buoy in Corsica

P. Bonnefond, P. Exertier, O. Laurain
OCA/CERGA, avenue N. Copernic, F-06130 Grasse
Y. Ménard
CNES, avenue E. Belin, F-31055 Toulouse
A. Orsoni
IGN-CNES, avenue E. Belin, F-31055 Toulouse
E. Jeansou, G. Jan
NOVELTIS, 2 av de l'Europe, F-31520 Ramonville



For calibration results using tide gauges and description of the method see poster:
Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica

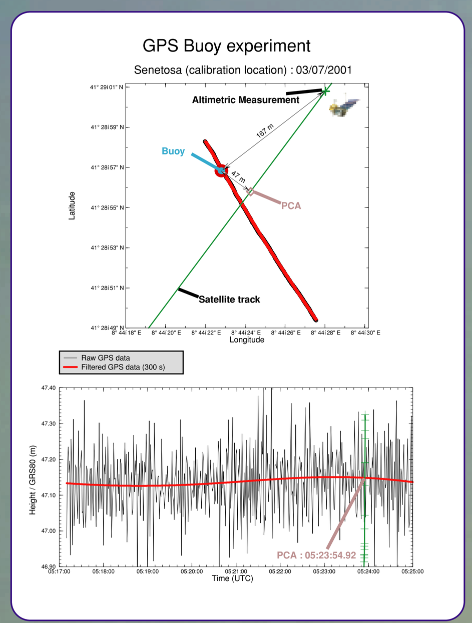


Abstract

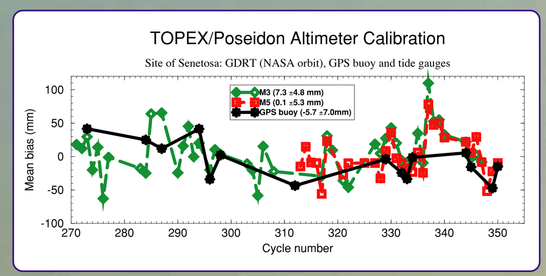
The Absolute calibration site of Corsica is working operationally for calibrating TOPEX/Poseidon and Jason-1 altimeters, using comparisons with tide gauges data. Taking the advantage of this site, a new experiment has been performed to calibrate altimeters: it uses kinematic GPS technique to monitor sea level heights. A reference receiver is placed at a geodetic point (near the lighthouse) while the other is on the sea.

Since February 2000, for each overflight a GPS buoy is placed under the ground track about 10 km off-shore, whenever sea state conditions are not too harsh to ensure safe navigation. GPS and altimetric sea heights are then compared to deduce altimeter biases. Systematic controls are also performed using measurements above the three tide gauges before and after the overflight. Results in the altimeter bias determination is at the same level considering buoy or tide gauges, the GPS data (buoy) also providing an estimation of the wet tropospheric path delay and Significant Wave Height; these parameters are then compared to T/P and Jason-1 measurements

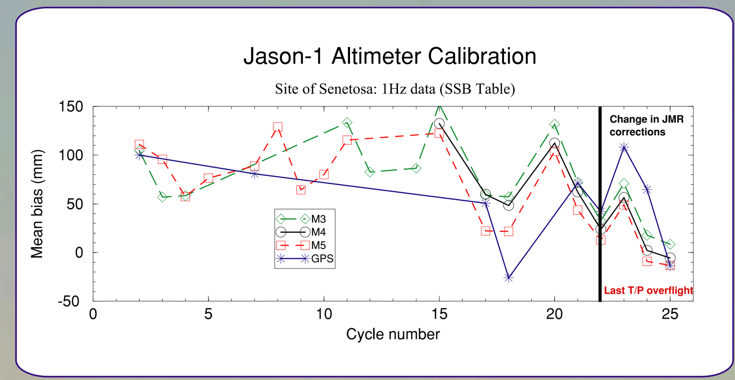
ALTIMETER CALIBRATION WITH GPS BUOY

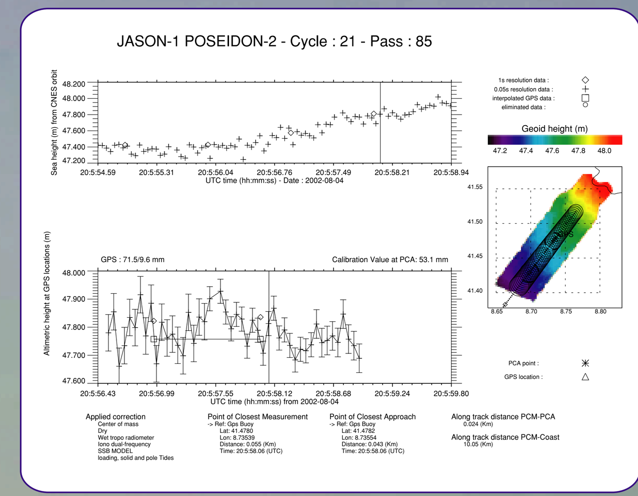


Since 2000, a GPS buoy is also used in the calibration process (GPS buoy are deployed at sea whenever sea state conditions are not too harsh to ensure safe navigation). Results show a good consistency between tide gauges and GPS buoy altimeter calibration even if GPS results have not the same statistical significance due to the lower number of determination.

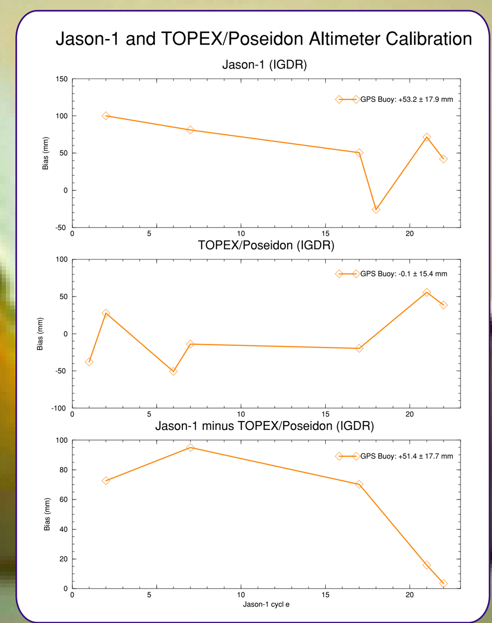


TOPEX / Poseidon and Jason-1 altimeter biases



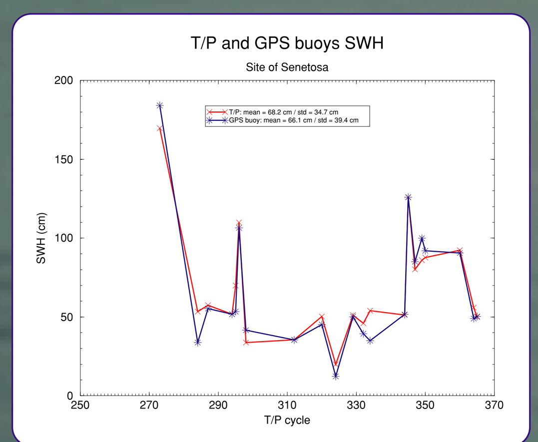


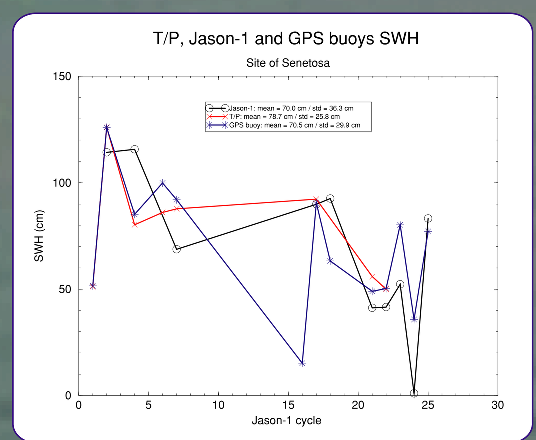
The above Figure show Jason-1 altimeter bias determination from cycle 2 to cycle 25 for the three tide gauges settled at Senetosa Cape and for the GPS buoy. Cycle 22 corresponds to the last T/P over flight (365, 14th august 2002) but also to a change in the JMR corrections. Cycles 23 to 25 will then be removed from the statistics in order to work on a consistent set of data. The Figure below shows Jason-1 and T/P altimeter biases time series as well as their differences. While the mean bias estimated for T/P is very close to the one obtain from the beginning of ALT-B altimeter, Jason-1 altimeter bias is lower by about 30mm. However, this set of data is not really statistically significant and we are confident that continuing the GPS buoy experiment will provide results at the level of those obtained for T/P.

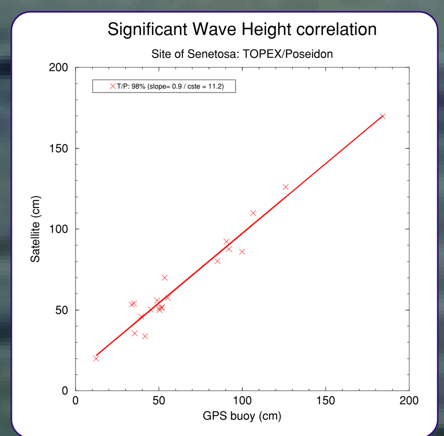


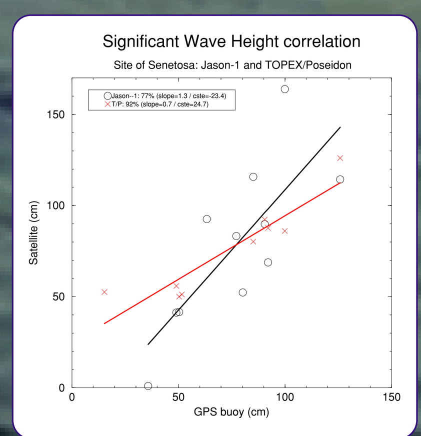
The GPS buoy experiment conducted on the Corsica calibration site provide an independent determination based on a very promising technique. It also provides a control of tide gauges behaviors. Moreover, this experiment allows the validation of the wet troposphere path delay and the Significant Wave Height estimated by the satellites. It has permitted to show that SWH from Jason-1 have a higher standard deviation than for T/P and that Jason-1 Microwave Radiometer seems to be biased by about 12mm.
Results will be continuously updated through Jason-1 validation phases and are available on the web site:
http://grasse.obs-azur.fr/cerga/gmc/calval/alt/

GPS BUOY "BY-PRODUCTS" Significant Wave Height









GPS buoy measurements also provide the sea height variations due to waves. Because GPS buoy is drifting during the calibration pass (about 1 hour of measurement centered on Time of Closest Approach) filtered sea height is removed to avoid sea height variations due to geoid slope. Standard deviation on the GPS buoy sea height residuals is then computed (σ_{shr}). GPS buoy measurements have also their internal error which have been estimated during quasi-static session to be at the level of 2.6cm (σ_{gps}). The Standard deviation on the GPS buoy sea height residuals is then the root square sum of σ_{gps} and σ_{wave} (where σ_{wave} is the standard deviation of GPS buoy measurements due to waves):

$(\sigma_{shr})^2 = (\sigma_{gps})^2 + (\sigma_{wave})^2$ where $\sigma_{gps} = 2.6cm$

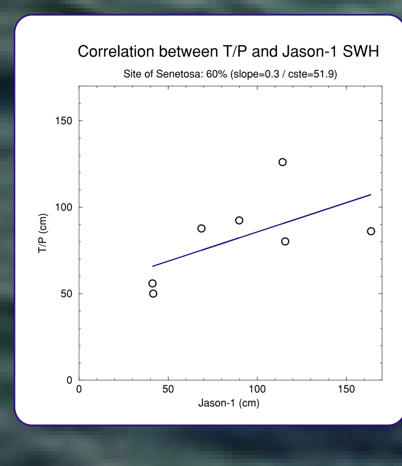
So, $\sigma_{wave} = SQRT((\sigma_{shr})^2 - (\sigma_{gps})^2)$

SWH (or $H_{1/3}$) is then deduced from the formula below (Stewart R., [2001], Introduction to physical oceanography)

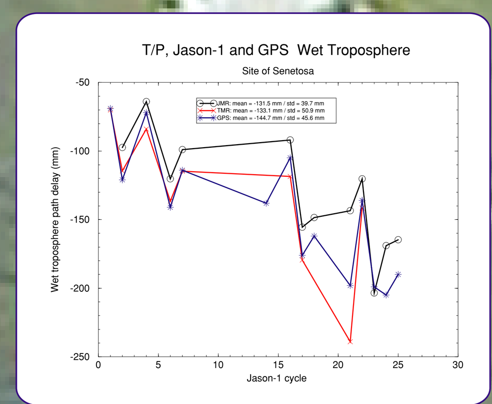
$SWH_{buoy} = 4.\sigma_{wave}$ where SWH_{buoy} is the resulting significant wave height deduced from GPS buoy measurements.

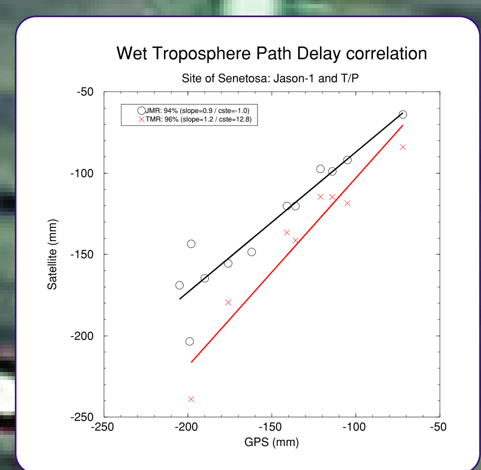
The analysis covers more than two years of T/P data sampled by about 20 over flights where SWH have been deduced from the GPS buoy. This has allowed to obtain various kind of sea states from very flat to relatively rough seas. Over this time period results show a very good correlation between both sets of SWH (98%) with a mean difference of about 2cm.

Since the beginning of Jason-1 mission SWH deduced from GPS buoy have also been compared to Jason-1 determination. While the correlation with T/P remains relatively good (92%) over the common observed period, the correlation with Jason-1 is lower (77%). No clear bias has been observed but the SWH coming from Jason-1 have higher standard deviation than T/P ones (36cm and 26cm respectively) and the correlation of the two sets is about 60%. Because the SWH is used to compute the Sea State Bias, a "poor" determination may affect it and then the deduced sea height. In our poster "Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica" we have shown that this effect can reach 20mm in the bias determination.



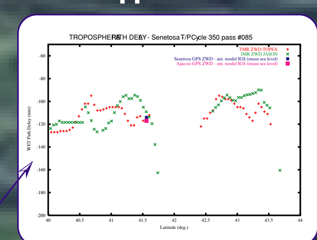
GPS BUOY "BY-PRODUCTS" Wet Troposphere

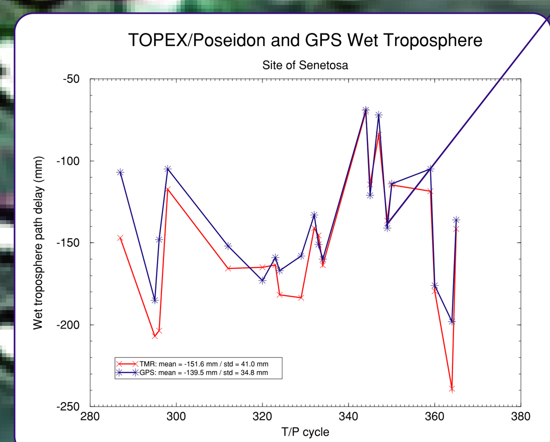


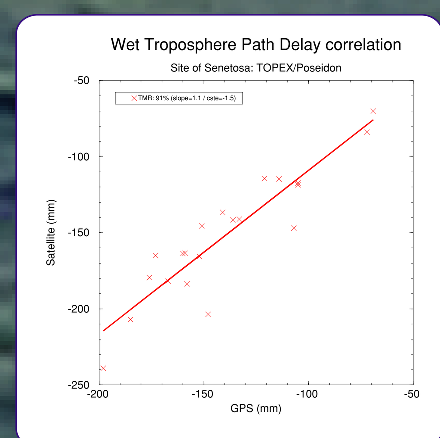


Using GPS data from the geodetic reference point (Lighthouse) the wet troposphere path delay is computed with GAMIT software using the following methodology:

- Computation of a one per hour troposphere path delay constraint by a piecewise linear model (0.02m/sqrt(hour)). The Senetosa station is determined relatively to the European network using the stations of Grasse, Ajaccio, Cagliari, Zimmerwald, Wettzell, Matera, Roquetes-Torto. Low constraints are applied to the coordinates and the precise ephemeris (GAMIT relax mode). An elevation cutoff of 10 is used and the fixed ambiguities solution is considered.
- The dry contribution is computed from Saastamoinen model using local meteorological data (lighthouse meteorology station) and is removed from GPS determination
- The resulting wet troposphere path delay is then computed by a linear interpolation at the time of closest approach.

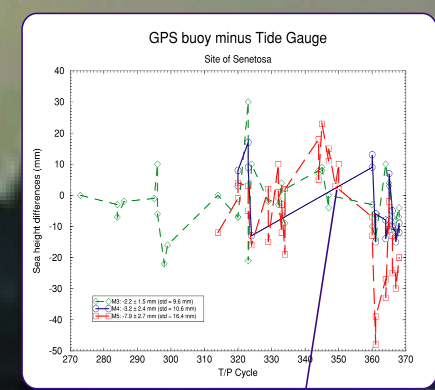






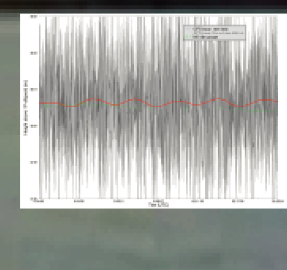
The time series of wet troposphere path delays determine by GPS in comparison to TMR determination show a good correlation (91%). Since cycle 330, the permanent GPS receiver settled at Ajaccio permits to better constrain the solution and the GPS and TMR solutions are then closer. Concerning the common period between T/P and Jason-1, correlations with GPS determination are respectively 96% and 94%. On common observed cycles, the differences in term of path delay correction (negative) are:
GPS - JMR = -20.1 mm
GPS - TMR = -8.1 mm
The resulting 12mm difference between JMR and TMR means that JMR "under-estimates" the wet troposphere path delay: Jason-1 bias should then be higher by about 12mm (see "Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica" poster).

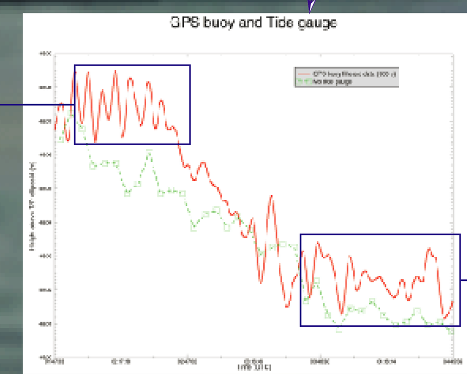
GPS BUOY AND TIDE GAUGES COMPARISONS

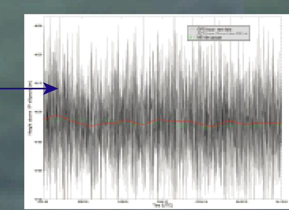


The problem encounter with M5 data is clearly evidenced in the comparisons with GPS buoy. See "Absolute Calibration of Jason-1 and TOPEX/Poseidon Altimeters in Corsica" poster for more details.

Before and/or after each calibration passe the GPS buoy is deployed at tide gauges locations to make direct comparisons of sea level determination. Differences for the three tide gauges (M3, M4 and M5) is at the millimeter level. During, each control phase tide gauge and GPS buoy seal level have a different behavior due to measurement process. An example is given for T/P cycle 350 where we can see undulations on the sea level deduced from GPS which seems to be linked to GPS data and/or kinematic process.



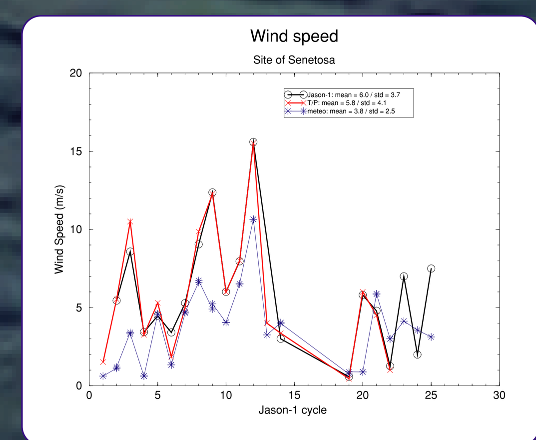


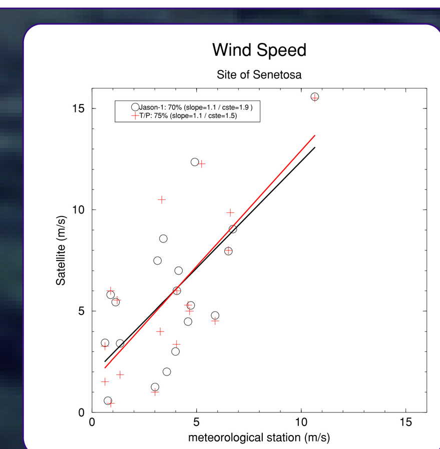


WIND SPEED CALIBRATION

Wind Speed from meteorology station has been compared to T/P wind speed values in IGDR (using Wind Speed from Witter and Chelton (1991) formulation, AVISO standards)

Results shows a good agreement with T/P and Jason-1 of the IGDR products: the main part of differences may be linked to the location of the meteorology station (altitude ~90m near the light house) where winds can be different than off-shore. Correlations are 70 and 75% respectively for Jason-1 and T/P with very similar time series between both satellites.





Pascal.Bonnefond@obs-azur.fr