VALIDATION REQUIREMENTS FOR THE TOPEX/POSEIDON ALTIMETER MISSION

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ABSTRACT

The joint NASA/CNES Topex/Poseidon mission will be mainly dedicated to the large scale oceanic circulation observation. The satellite payload will include two altimeters, one radiometer and two precise orbit determination systems, Doris and GPS. Such system will provide sea level measurements with an absolute decimetric accuracy. The satellite will be launched in June 92 for a 3 to 5 years long mission. Previous studies, based on Geosat data, have shown that a large scale signal as the seasonal signal of the tropical Atlantic can be well recovered by altimetry. Comparisons with models and in-situ data emphasize the consistency of the altimetric results. However, local differences are observed which can be due to real oceanographic effects or to imperfections in the altimetric data. In order to discern and to characterize the various error sources, a careful validation of altimetric data is required. For the Topex/Poseidon mission a complete verification plan has been proposed by CNES. First, a single-point system verification will be achieved at a site located in the Mediterranean Sea, the Italian Lampedusa island, instrumented with tide gages, laser station and other adequate sensors. Additional verification activities will include regional verification experiments, meteorological model comparisons and statistical analysis. This verification effort will be specially intense during the first 6 months of the mission but it will be extended overall the mission to ensure a permanent control of the system and cross-calibrations with other satellite systems.

Keywords: Altimetry, Topex/Poseidon, Tropical Atlantic, seasonal cycle, validation.

1. THE TOPEX/POSEIDON MISSION

The altimetric Topex/Poseidon (T/P) mission was born from two separate projects, TOPEX which started to be studied by NASA in 1979 and Poseidon which was declared as a priority project by CNES in 1981. The two projects were reunited in a joint NASA/CNES project in 1983. The project was approved by both agencies in 1987, the satellite will be launched in July 1992.

The T/P mission will be following the GEOS (75-78), SEASAT (June-September 78), GEOSAT (85-89) and ERS1 (to be launched in April 91) altimetric missions. It will be optimized for the large scale circulation study thanks to a complete and performing altimetric system (Ref.1). The main satellite package will include the bifrequency NASA TOPEX altimeter plus the experimental solid state CNES Poseidon altimeter. The NASA three channel microwave radiometer, the CNES DORIS system, the experimental GPS receiver and the laser retroreflectors are the additional equipment which will provide an accurate orbit (within 10 cm) and precise geophysical corrections. Such system will be able to measure the sea level with an absolute accuracy of 14 cm and a relative precision of 3 to 4 cm.

The mission will be 3 to 5 years long and will be part of a long term observation program of the oceanic circulation starting with the WOCE international program in 91. About 40 Principal Investigators (PI) were selected by NASA and CNES to support, through their proper investigations, the T/P mission development. All the T/P data will be distributed to these PI and other interested scientists after a careful validation process, specially active during the first 6 months of the mission. This verification effort is particularly important for large scale ocean study which is considered as the main objective of the T/P mission.

2. AN EXAMPLE OF LARGE SCALE SIGNAL OBSERVED BY ALTIMETRY: THE SEASONAL CYCLE IN THE TROPICAL ATLANTIC

Using two years of Geosat data, from November 86 to November 88, the seasonal variability of the Tropical Atlantic circulation was described in terms of sea level anomalies. About 100 Geosat tracks are covering the domain between 20° S and 20° N in latitude and 70° W and 15° E in longitude (Fig. 1). These Geosat passes are repetitive every 17 days (the repeat cycle of the satellite orbit). The data were corrected from atmospheric effects (troposphere and ionosphere) and from tides. Then the collinear method was applied to the data: each repetitive pass was referenced to the mean pass to provide along track sea level anomalies by respect with the mean sea level. An objective analysis was performed, integrating all the sea level anomaly data, to produce monthly sea level anomaly maps (Ref. 2).

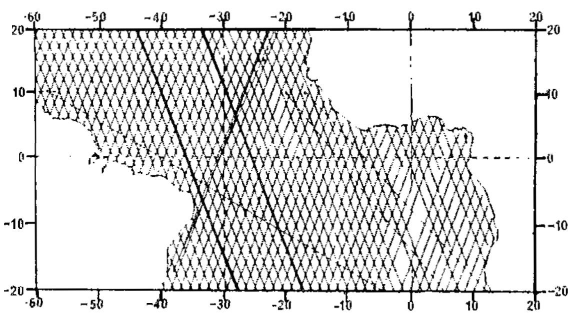


Figure 1: Geosat data coverage between 60°W-20°E and 20°N-20°S

One of the first concern was to verify the consistency of the altimetric results by comparison with independent results: climatology, in-situ data and oceanic circulation models. As an example, two monthly situations are presented in figure 2. The May 88 map shows a strong signal in the west of the basin, one zonal negative anomaly (around -9 cm) along 2° N corresponding to a weak North Equatorial Counter-current (NECC) and a positive anomaly along 10° N in the North Equatorial Current (NEC). The equatorial upwelling creates a negative anomaly along the equator. In September, the map shows a reversed situation, with a high positive anomaly along 4° N when the NECC is reaching a maximum. The equatorial upwelling has disappeared. In this west part of the basin, there is a good agreement of altimetry with climatology and models. This is confirmed by comparison of time series computed in a point located in the NECC, at 0°-2° N and 40°-44° W (Fig.3). The only notable difference

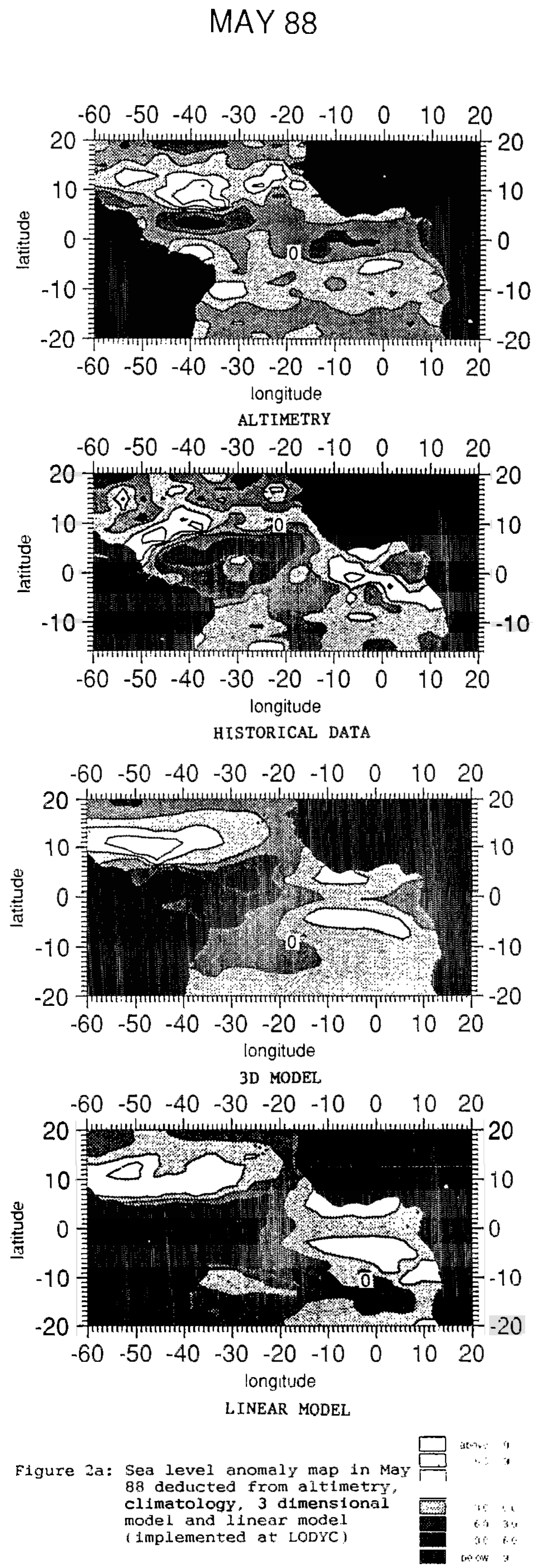
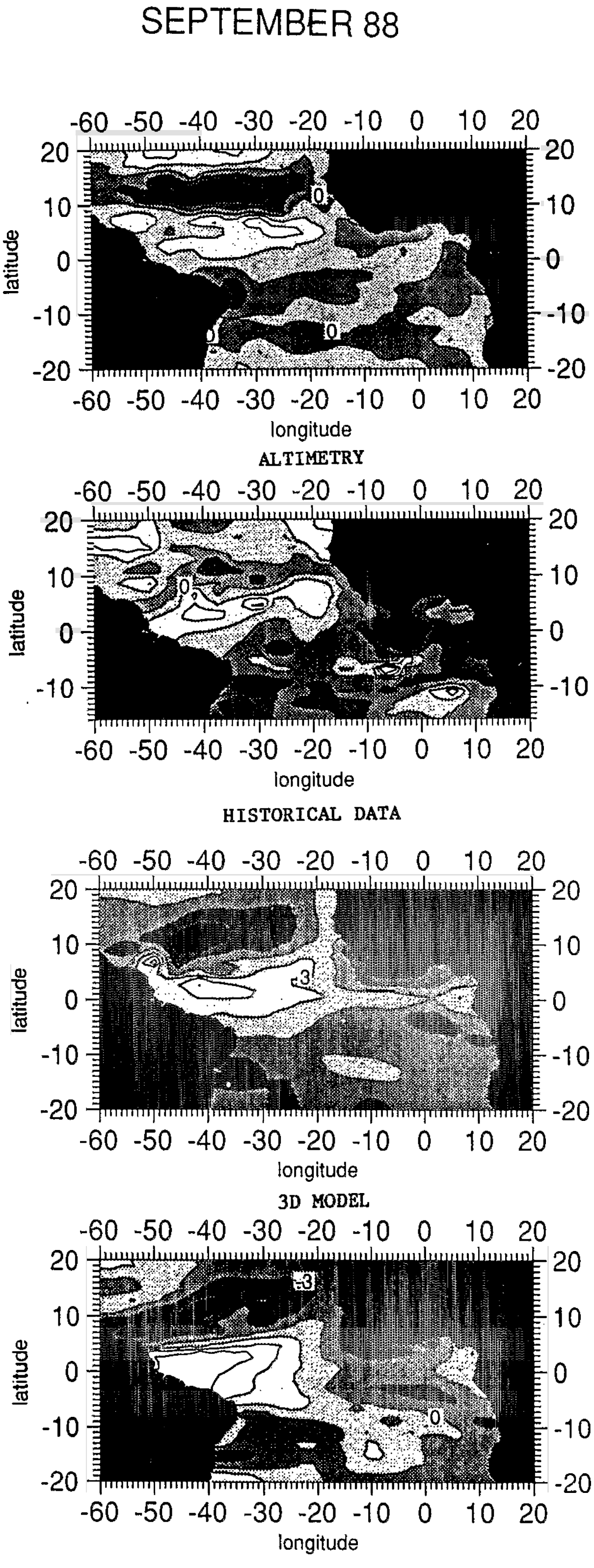


Figure 2a: Sea level anomaly map in May 88 deducted from altimetry, climatology, 3 dimensional model and linear model (implemented at LODYC)



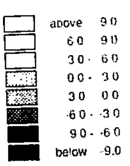


Figure 2b: Same as figure 2a, but for September 88

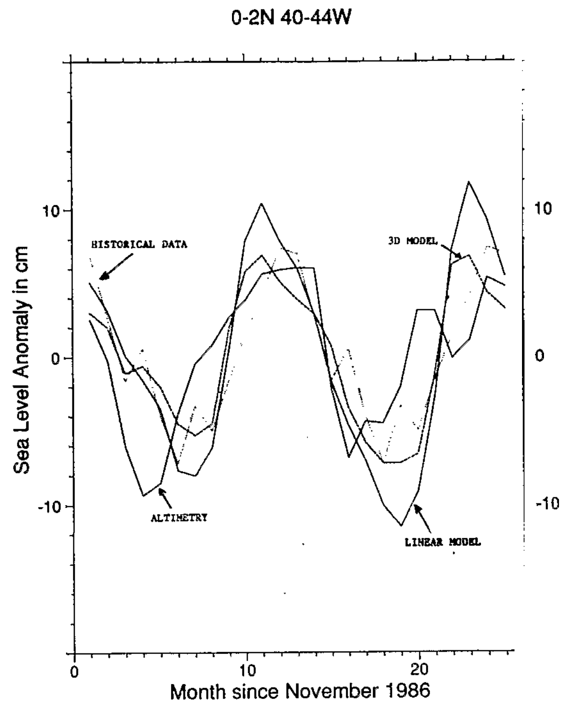


Figure 3 : Time series from Nov 86 to Nov 88 computed at 1° N-42° W for altimetry, climatology, 3 dim model and linear model

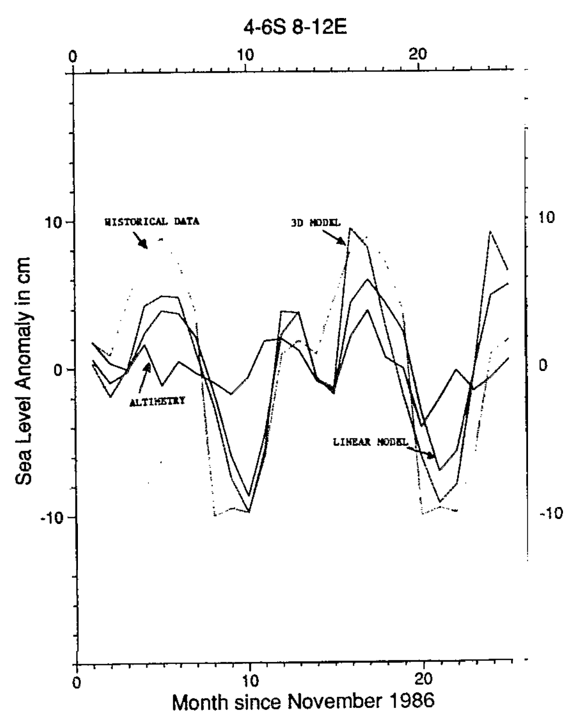


Figure 4 : Same as figure 3 at 5° S and 10° E.

is a time lag of about 2 months observed in March-May 87 and 88 in the NECC which could be due to interannual events not well recovered by models. In the eastern basin, the altimetry shows a signal weaker than models and climatology (Fig. 4). This apparent deficiency of altimetry could be due to the weakness of altimetric corrections. However more investigations are needed to better understand such difference.

Another "scientific" validation experiment was achieved along a Geosat track crossing the Tropical Atlantic from France to Brasilia (Ref. 3). This track was exactly superimposed on the line of a commercial ship going from Le Havre to Rio de Janeiro (Fig. 5). During the cruise of September 9 to October 5, 1988, about 300 XBT were dropped between 35 N and 20 S, with an intense sampling between 10 N and 3 S. Thus, a quasi time-space collocation was obtained between the ship measurements and the Geosat along track data of the same period. XBT data were transformed in dynamic height anomalies, using surface salinity data collected during the campaign and a mean T-S relation, and then compared to the sea level anomalies deducted from altimetric data (figure 6). The comparison emphasizes the good correlation of both data sets, specially north of 5 S where it reaches 0.87. South of 5 S, the agreement is not so good, due probably to high mesoscale variability (in the Brasilia current vicinity) not well sampled by the XBT.

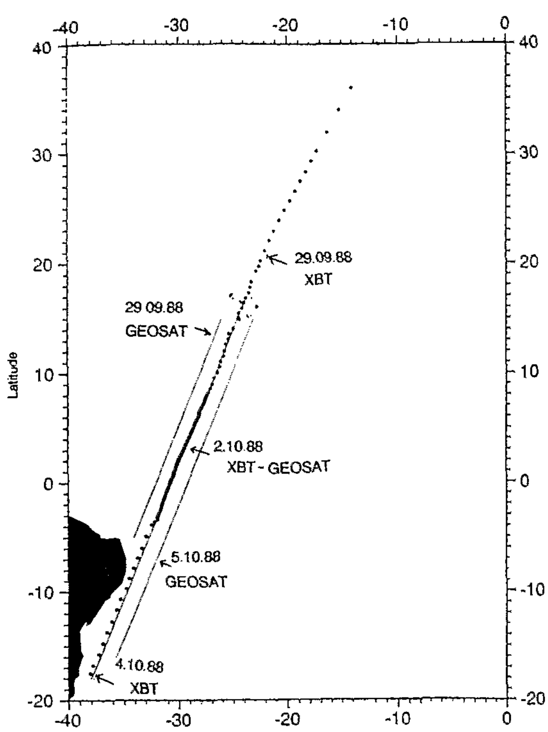


Figure 5: XBT SAMPLING AND GEOSAT TRACKS

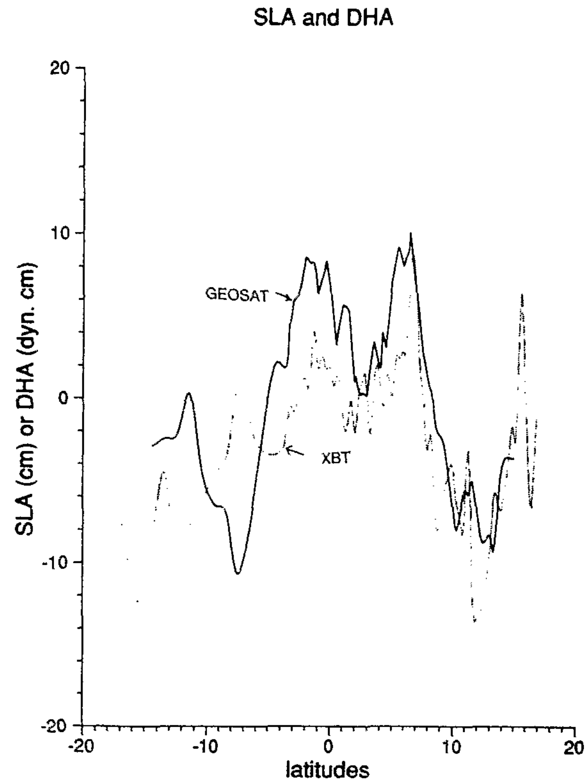


Figure 6 : Comparison of Geosat sea level anomaly with XBT dynamic height anomaly along the ship line.

These results show the general good agreement of altimetry observations with external data. However some discrepancies exist which need to be explained. They can be due to real oceanographic effects, they also can be due to imperfections in the reference data or in the altimetric data. For instance, atmospheric altimetric correction residuals may have time-space scales which can mask part of the searched oceanic signal. In order to better understand these differences, to distinguish between the various error sources and to characterize them, it is necessary to plan adequate verification operations of the altimetric data at the initial geophysical level. Thus, a complete verification plan has been initiated for the T/P mission.

3. THE CNES T/P VERIFICATION PLANS

The engineering assessment of the altimetric system will be first performed at a single-point verification site, equipped with all the required instrumentation to provide an optimal control of the parameters interfering in the system. The dedicated site chosen by CNES is the Lampedusa island in the Mediterranean Sea which is located mid-way between Tunisia and Malta. The principle of the engineering verification is based on the comparison of the sea level altimetric measurement made at the vertical of the site with an equivalent range deducted from tide gage sea level measurements and laser tracking data. This Italian island is a small, flat tableland of 7 km by 3 km large and 100 meter high. Several advantages were preponderant in this choice: the small geographic extension which reduces the perturbation of the satellite data when overflying the land, the relatively quiet oceanographic and meteorological conditions which reduce the atmospheric errors on the altimeter measurements and ensure a good success in the laser satellite tracking. Lampedusa is also part of the Wegener-Medlas geodetic program network and periodically, a mobile laser station is installed on the site to track geodetic satellites as Lageos. Thus, there are potential opportunities to have a laser on Lampedusa during T/P verification campaigns. Finally, there is a small islet 18 km west of Lampedusa, which will be overflight by T/P and will serve as the main calibration point (Fig. 7).

To realize a performing verification of the altimetric system, the site will be equipped with the following instrumentation: Two coastal tide gages will be installed in Lampedusa, one at the south-west and another one at the south-east of the island. An additional tide gage will also be put at the Lampione rock, considered as the main calibration point. This tide gage network along with local oceanographic models will provide a monitoring of the sea level around Lampedusa with a centimetric accuracy (Ref. 4). In order to refer this sea level to the reference ellipsoid, a GPS campaign will be carried out to tie the three tide gages with the laser station in Lampedusa. This laser station (one of the Wegener-Medlas mobile station or the french mobile station actually being developed) will track the satellite to provide the altitude of the satellite above the calibration point. This tracking will be completed by surrounding doppler and laser stations (Grasse, Matera...). The combination of both sea level tide gage measurements and laser tracking data will give the satellite-sea level range directly comparable to the altimeter measurement (Fig. 8). Additional instrumentation will allow an accurate correction of the altimeter data: an upward looking radiometer to correct the troposphere range delay, a GPS receiver to correct the ionosphere range delay, a wind-wave buoy to correct the sea-state electromagnetic bias.

The main goals of these verification campaigns are to provide an assessment of the entire altimetric system, a calibration of the altimeters including the measure of bias and drift of the instruments. A pre-launch Lampedusa campaign is scheduled during the summer

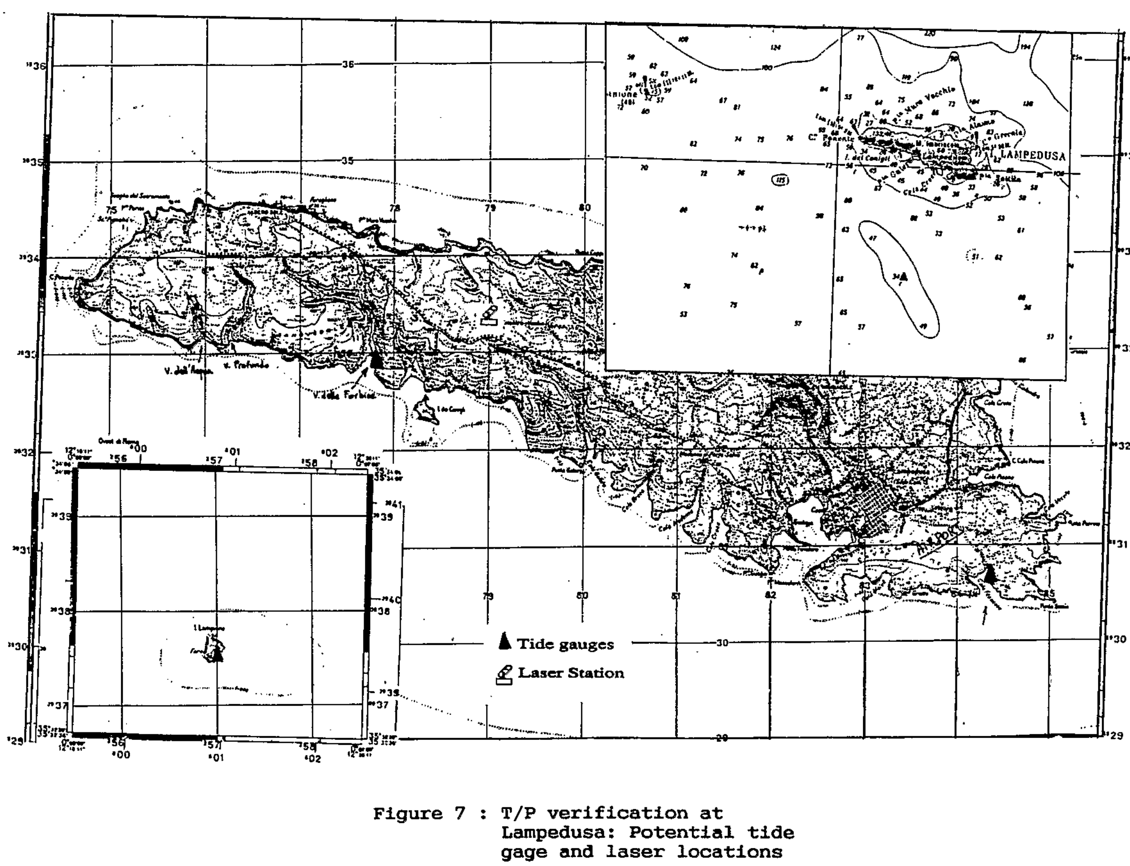


Figure 7 : T/P verification at Lampedusa: Potential tide gage and laser locations

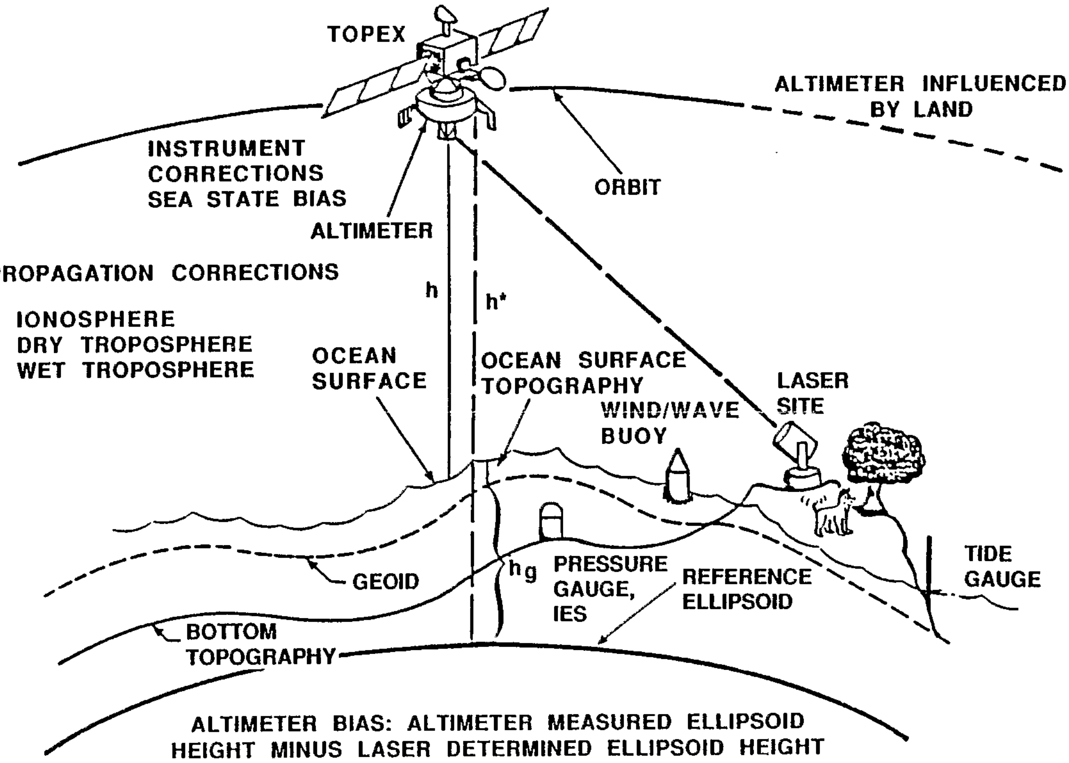


Figure 8 : Altimeter calibration geometry using tide gage sea level data and laser tracking.

91 to test and adjust all the instrumental and data processing system. The operational campaign is planned for the first 6 months of the mission which is devoted to an intense verification of the system before the delivery of the data to the scientists. However, other Lampedusa campaigns will be held in 93 and 94, in accordance with the laser station availability to allow a long term control of the system. NASA has also instrumented an oil platform near the Californian coast, the Harvest platform, to perform the same kind of single-point verification.

Other verification activities (Ref. 5) will complete the single-point verification sites in order to characterize on a more global scale the system performances. Regional verification experiments have been proposed in the Mediterranean Sea and the Norwegian Sea. The Mediterranean Sea experiment includes a large scale verification of the altimetric system based on a comparison of mean sea surface obtained from altimetry with mean sea level deducted from tide gage data. The dense satellite tracking station network and the GPS collocated tide gage network will efficiently constraint the problem. The Norwegian Sea experiment will be more concentrated on the sea-state related algorithm verification, taking into account the high variability sea-state conditions of this region. In-situ and air-borne data will be used there to validate the altimetric measurements. Other regional verification opportunities exist specially those proposed by the T/P PI.

Statistical analysis will also be performed to assess the system performances and to characterize the error sources. They include systematic comparison with meteorological models for the wave-height, wind speed, water vapor content (tropospheric correction) validation, along track analysis for noise level measure, cross-over point analysis for orbit accuracy verification, global statistics to show the space-time distribution of altimetric data and associated corrections.

4. CONCLUSIONS

The requirement for a careful assessment of satellite altimetric data, at the geophysical level, before their distribution to the users, has been clearly demonstrated through previous scientific analysis of Geosat altimetric data. This preliminary step includes the verification of the system performances, the determination of instrument bias and drift, the validation of the geophysical algorithms applied to altimetric data, the evaluation and the spectral characterization of the error sources. This last point is specially important for the implementation of new techniques of altimetric data analysis, inverse methods, objective analysis, assimilation in the models. To fulfill these objectives, a T/P verification plan has been proposed by CNES which comprises verification campaigns at dedicated sites, regional verification experiments, model comparisons and statistical analysis. The intense verification period of the first 6 months of the mission will be followed by continuous verification activities all along the mission in order to affine the first validation results and to ensure a permanent control of the system.

It must be noted that this verification effort, along with the improvement of correcting models, is essential to permit a thorough analysis of satellite data. Verification plans need to be settled for all the future space oceanic missions. This will be very helpful specially to cross-calibrate the different sensors being on-board separate satellites (ex: T/P and ERS1) and thus, to generate a continuous homogenized data set over several years.

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