Processing and Validation of the ERS-1 Radar Altimeter data at the Italian PAF

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Abstract

In the frame of the realization of the Italian Processing and Archiving Facility (I-PAF), Nuova Telespazio developed, under ASI (Italian Space Agency) contract, a processing chain for ERS Radar Altimeter data based on new reconstruction algorithms of sea surface height corrected from geophysical effects, wind speed at nadir and significant wave height.

As a result of this activity, the off-line product ERS-1.ALT.MPR (Mediterranean ERS-1 Radar Altimeter Product) has been defined.

The procedure used to extract the quantities stored in the MPR product is tailored for closed seas (like the Mediterranean Sea), where the occurrence of areas where the sea is almost flat is frequent: the algorithm used to exploit the altimetric data needs special care in the satellite-sea surface distance computation and in the SWH extraction. Moreover the weakness of the oceanographic signal to be detected implies a full exploitation of the spatial resolution of the Radar Altimeter measurement (20 Hz data).

In order to validate this product different case studies have been defined using the Radar Altimeter data over the Mediterranean Sea in January 1993.

In this paper we present the results obtained by the processing chain exploiting these data. Moreover the comparison of these data with the corresponding ones stored in the ERS-1.ALT.OPR altimetric product is shown. Finally the altimetric wind speed data have been compared with the collocated data provided by the ECMWF analysis and the altimetric significant wave height data have been compared with the collocated data provided by the WAM model developed at ECMWF.

Keywords: Radar Altimeter, Sea Surface Height, Significant Wave Height, Geophysical corrections, Mediterranean sea, I-PAF

1. Introduction

The problem of processing the ERS Radar Altimeter (R.A.) data over the Mediterranean Sea has been approached by the authors for the realization of the Italian Processing and Archiving Facility (I-PAF). This facility is a part of the ERS ground segment and was realized by Nuova Telespazio under contract of the Italian Space Agency (ASI).

The result of this activity is the generation of the I-PAF product ERS-1.ALT.MPR, which contains the following quantities relative to the Mediterranean Sea and with a time coverage of one month:

☐ 20 Hz and 1 Hz satellite range data;

☐ 20 Hz and 1 Hz satellite range geophysical corrections;

☐ 20 Hz and 1 Hz satellite orbital height data over a reference ellipsoid;

☐ 1 Hz Significant Wave Height (SWH);

☐ 1 Hz sigma-naught and wind speed at nadir;

☐ 1 Hz sea specular points elevation probability density function.

Fig.1 shows the plot of a sample of some geophysical quantities contained in the MPR product.

One of the main problems for the Radar Altimeter data processing over closed seas, like the Mediterranean Sea, is the frequent occurrence of areas where the sea is almost flat. As a consequence the algorithm used to exploit the Radar Altimeter data needs special care in the satellite-sea surface distance (i.e. satellite range) computation and in the SWH extraction. Moreover the weakness of the oceanographic signal to be detected in such a condition implies a full exploitation of the spatial resolution of the Radar Altimeter measurement (20 Hz data).

In previous works (Bartoloni, 1993a), (Bartoloni, 1993b) we described a method for the reconstruction of these geophysical quantities. The method exploits heavily the properties in the Fourier domain of the convolution Brown model, which is the mathematical representation of the altimetric echo waveform stored in the telemetry (see Brown, 1977): the reconstruction procedure consists in the inversion of the Brown model using the Fast Fourier Transform (FFT) algorithm and its properties.

In order to asses the quality of the ERS-1.ALT.MPR product we chose the Mediterranean January 1993 data set, i.e. the Radar Altimeter telemetry relative to January 1993 over the Mediterranean Sea was processed and analyzed. The aim of this activity was

☐ to extract and compare the 1 Hz wind speed and the Significant Wave Height (SWH) stored in the MPR with the corresponding analyzed data delivered by ECMWF (European Center for Medium-range Weather Forecasts); the validation data set was built by a spatial and temporal collocation process between the ECMWF data and the ERS-1 Radar Altimeter wind speed and SWH measurements;

☐ to extract and compare the MPR quantities with the corresponding ones stored in the F-PAF (French PAF) altimetric product ERS-1.ALT.OPR (version 3.0).

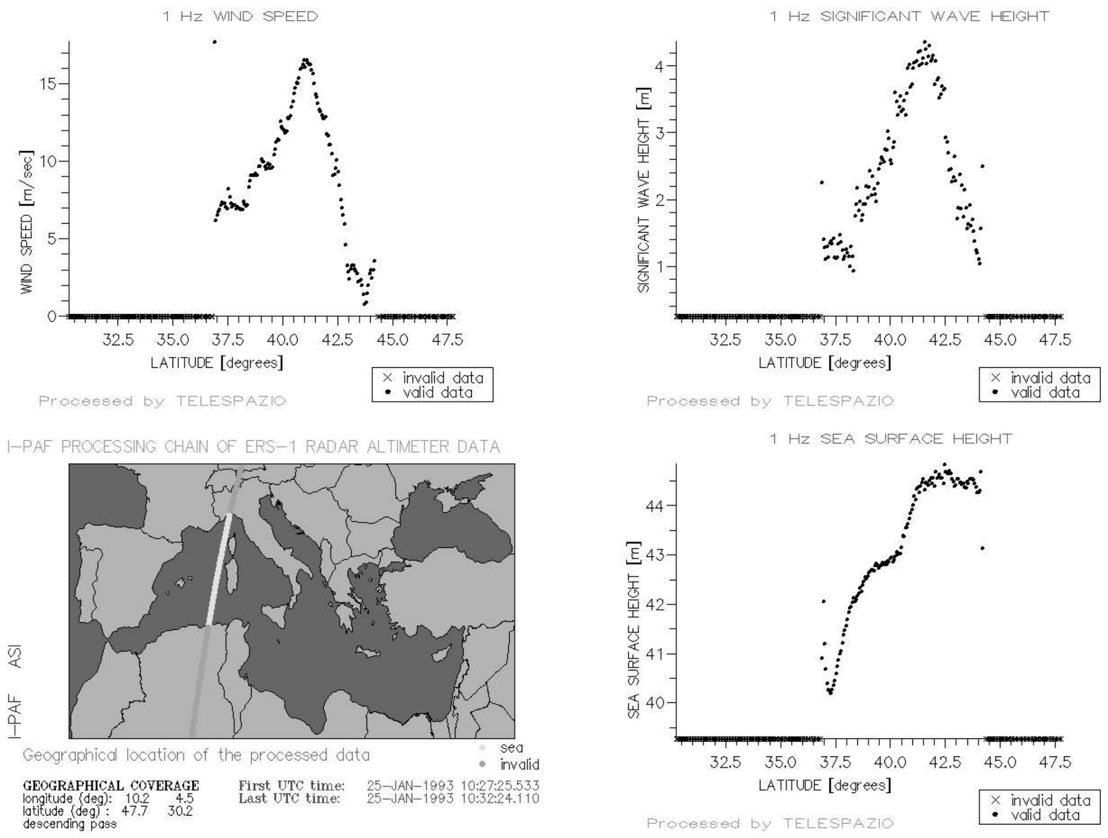

Fig.1. Graphical Display of the Most Relevant Quantities Contained in the MPR Product

2. ECMWF Data Comparison

Concerning the ECMWF and MPR wind speed data comparison, table 1 shows the results we found after that data were collocated.

# OF MATCHED WIND SPEED DATA	11343
MPR WIND SPEED MEAN VALUE [m/sec]	5.03
ECMWF WIND SPEED MEAN VALUE [m/sec]	5.52
WIND SPEED MEAN DIFFERENCE (ECMWF-MPR) [m/sec]	0.49
RMS DIFFERENCE [m/sec]	1.90
BIAS [m/sec]	1.88
TILT	0.72

Table 1. MPR-ECMWF 1 Hz Wind Speed Data Comparison

From the table we can deduce that the linear relation (in the least squares sense) between the two wind speed data sets is such that the ECMWF wind speed data are overestimated in correspondence of small values of the corresponding MPR data (i.e. for wind speed values less than 6.7 m/sec) and are underestimated for large wind speed values.

The same trend in the behavior of low values of the wind speed was found also in (Guillame, 1992). Also the rms difference (1.90 m/sec) and the mean difference ECMWF-MPR (0.49 m/sec) between the matched data is reasonable: very good results were found also in (Guillame, 1992).

Table 2 show the results obtained from ECWMF SWH data derived from WAM (WAve Model: see Cavaleri, 1991) and MPR SWH data comparison after the collocation procedure.

# OF MATCHED SWH DATA	6623
MPR SWH MEAN VALUE [m]	1.54
ECMWF SWH MEAN VALUE [m]	0.97
SWH MEAN DIFFERENCE (ECMWF-MPR) [m]	-0.56
RMS DIFFERENCE [m]	0.40

BIAS [m]	-0.37
TILT	0.88

Table 2. MPR-ECMWF 1 Hz SWH Data Comparison

From the table we can notice that the linear relation (in the least squares sense) between ECMWF SWH data and MPR data is such that the ECMWF SWH data are lower than the corresponding MPR SWH data. The same trend was found also in (Guillame, 1992). Also the mean difference ECMWF-MPR (-0.56 m) and the rms difference (0.40 m) shown in table 2 are very similar to the ones described in (Guillame, 1992): this is an indirect confirmation of the effectiveness of the SWH retracking algorithm implemented at I-PAF.

3. OPR (version 3.0) Data Comparison

Many quantities contained in the MPR product were compared with the corresponding ones stored in the OPR. In the following paragraphs we show the most meaningful results obtained from MPR-OPR data comparison.

3.1. 1 Hz SSH Data and Geophysical Corrections

Table 3 summarizes the results relative to the comparison between the MPR and OPR 1 Hz SSH data uncorrected from geophysical effects. We can notice that also in this case (like in the Venice data set) the agreement between the SSH data is good: in particular the high values of the significance of the mean difference implies that no bias between the OPR and MPR SSH data is present.

About the satellite range geophysical corrections, table 4 shows the results that we obtained.

# OF MATCHED 1 Hz SSH	11935
SSH MEAN DIFFERENCE (OPR-MPR) [cm]	1.48
SSH MEAN DIFFERENCE SIGNIFICANCE	0.93
RMS DIFFERENCE [cm]	9.65

Table 3 : OPR-MPR 1 Hz Uncorrected SSH Data Comparison

We remark that the electromagnetic bias correction is not reported in the table because the F-PAF and the I-PAF use the same mathematical model (see Barrick, 1985): the differences are only due to the fact that the SWH data (the main input for the e.m. bias correction computation) contained in the MPR and in the OPR data are different (see section 3.3).

Concerning the sea tide correction, at the moment the I-PAF processor computes it using preliminary tidal constituents (O_1, K_1, M_2 and S_2) evaluated on a gridded geographical map. In the very near future these maps will be updated with the tidal constituents delivered by the Proudman Oceanographic Laboratory (see Tsimplis, 1995) where a very precise Mediterranean sea tide model over a finely gridded geographical map was developed.

DRY TROPOSPHERIC CORRECTION MEAN DIFFERENCE [cm]	-0.50
WET TROPOSPHERIC CORRECTION (BY METEO) MEAN DIFFERENCE [cm]	-1.13
IONOSOPHERIC CORRECTION MEAN DIFFERENCE [cm]	0.30
BODY TIDE CORRECTION MEAN DIFFERENCE [cm]	-0.01

Table 4 : OPR-MPR 1 Hz Geophysical Corrections Comparison

From table 4 we can notice in general that in OPR-MPR satellite range geophysical corrections comparison there are not remarkable differences.

The 1 Hz SSH data were investigated together with their corrections also by the crossover analysis. We applied this technique on the SSH data corrected from the following geophysical effects: body tide, dry tropospheric correction, ionospheric correction, electromagnetic bias correction, wet tropospheric correction by meteorological data, OPR sea tide correction. The analysis was performed on 108 crossover points. Table 5 shows the results relative either to MPR or to OPR SSH crossover differences. From the table we can notice that there are not remarkable differences in OPR and MPR rms crossover difference.

MPR SSH crossover differences		OPR SSH crossover differences	
MEAN [cm]	RMS [cm]	MEAN [cm]	RMS [cm]
-9.39	18.92	-11.07	19.61

Table 5 : Crossover Analysis Results

3.2. 1 Hz Wind Speed data

Table 6 summarizes the statistical parameters that were found in OPR-MPR wind speed data comparison.

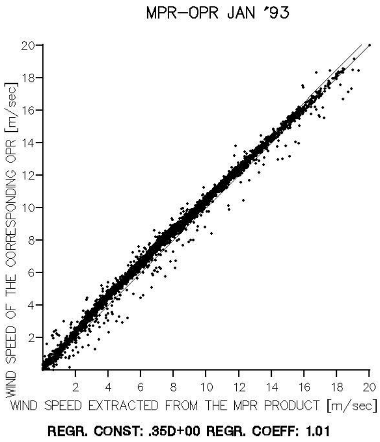

Fig.2. JAN '93 Wind Speed Data

Scatterplot (OPR vs MPR)

From the table and from the scatterplot shown in fig.2 we can not observe remarkable differences: this means that the F-PAF and I-PAF altimetric processors retrack the sigma-naught data with small differences and therefore the resulting wind speed data (obtained using the same model: see Witter, 1991) are very similar.

# OF MATCHED WIND SPEED DATA	11965
MPR WIND SPEED MEAN VALUE [m/sec]	5.39
OPR WIND SPEED MEAN VALUE [m/sec]	5.79
WIND SPEED MEAN DIFFERENCE (OPR-MPR) [m/sec]	0.39
RMS DIFFERENCE [m/sec]	0.25
BIAS [m/sec]	0.35
TILT	1.01

Table 6 : OPR-MPR 1 Hz Wind Speed Data Comparison

3.3. 1 Hz SWH data

Concerning the 1 Hz SWH comparison, we observed the presence in the OPR product of many outlaiers (i.e. SWH data whose values are greater than 5 meters until to 18 meters): this phenomenon is probably related to problematic performances of the F-PAF retracking algorithm (the so-called slope saturation).

# OF MATCHED SWH	9687
MPR SWH MEAN VALUE [m]	1.81
OPR SWH MEAN VALUE [m]	1.27
SWH MEAN DIFFERENCE (OPR-MPR) [m]	-0.55
RMS DIFFERENCE [m]	0.36
BIAS [m]	-0.90
TILT	1.19

Table 7 : OPR-MPR 1 Hz SWH Data Comparison

After that the OPR SWH outlaiers were discarded, the statistical parameters that we found are shown in table 7 and in fig.3.

We can notice that the OPR and MPR data have a good agreement in correspondence of SWH values larger than 1.5 meters, while there are large differences in correspondence of small SWH values. The origin of these differences have to be further investigated.

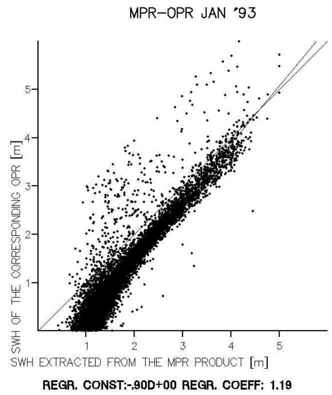

Fig.3. JAN '93 SWH Data

Scatterplot (OPR vs MPR)

4. Conclusions

After the analysis of the geophysical quantities stored in the ERS Mediterranean altimetric product MPR and after the comparison of these parameters with external data (ECMWF data, OPR data), we found that the MPR data quality assessment performed good results: the agreement between the MPR data and the collocated external data is reasonable and the results we found are similar to the ones described by different authors in the comparison of altimetric data with meteorological data or data derived from mathematical models.

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