4.1 VALIDATION OF WIND RETRIEVAL ALGORITHMS FROM SPACEBORNE SAR.

E. Arabini(1)*, G. De Carolis(2), F. Parmiggiani(1) and A. Siccardi(3)
(1) ISAO-CNR Bologna (Italy), (2) ITIS-CNR Matera (Italy), (3) IAN-CNR Genoa (Italy)

The exploitation of Synthetic Aperture Radar (SAR) imagery as a tool to obtain geophysical information of the marine environment has been object of intense studies by the scientific community in the recent years. Several methods have been proposed in the last few years to retrieve quantitative estimates of ocean wave spectra and of wind speed and direction at a given reference height from SAR imagery. These tools appear very interesting in view of the future dual-polarised ASAR instrument onboard the European ENVISAT satellite, whose launch is planned for June 2001.

An ERS-2/SAR scene of March 30, 2000, over an area of the North Tyrrhenian Sea off–shore from La Spezia, shown in Figure 1, was selected as case study. A number of instrumented sites operate in this area at different locations and provide regular measurements of the wave spectrum and of the wind vector. Directional wave spectra for the area were available every three hours from the buoy of the Italian Wave Measurement Network (RON, Rete Ondametrica Nazionale) located at 43.92 N and 9.82E. Other reference data are provided by the buoy ODAS Italia 1, located at 43.8 N and 9.1 E, which is an open sea facility for multidisciplinary research, equipped with a full set of geophysical and biochemical instruments (Siccardi et al., 1996). All the relevant meteorological parameters (wind intensity, wind direction, air/sea temperature) are collected by ODAS Italia 1 during a total of 1 hour of acquisition, centered around the time of satellite pass.

The empirical backscatter model CMOD4 (Stoffelen and Anderson, 1997) was used to retrieve the wind velocity, once the wind direction had been estimated. The latter was determined as average direction of the atmospheric boundary layer rolls detected on the SAR image. The inherent 180° direction ambiguity was resolved by available in situ observations and/or by the the output of ECMWF atmospheric model. CMOD4 analysis was performed on a strip 512 pixels wide in azimuth, spanning the whole SAR swath. The strip had been previously calibrated, with corrections for antenna gain pattern, range losses and ADC saturation. The backscatter value as a function of the incidence angle value was computed by averaging over range lines.

The measured wave spectra revealed steady state conditions during six hours since 06:00GMT. In fact, the peak period was constant at 9.1s with propagation direction also constant within 11° (from 55°N at 06:00GMT to 66°N at 12:00GMT) and wave heights ranged from 3.7m at 06:00 to 3.8m at 12:00GMT. No swells are present in the wave spectra. These surface conditions apply to a steady state frequency spectrum as required for reliable application of the wave distribution proposed by Donelan et al. (1985) as a function of the inverse wave age $\Omega=U_{10}/c_p$. The wave frequency spectrum collected at 09:00GMT (H_s=3.6m), one hour before the ERS pass, is shown in Figure 2. The same plot reports the best fit with the parametric spectrum from Donelan et al., (1985). The estimated inverse wave age Ω was 0.84, a value corresponding to fully developed wave spectrum and U_{10}=11.9m/s; in addition, the fully developed condition can be compared to Pierson and Moskowitz (1964) wave distribution for which U_{10} should be 11.5±0.2m/s to satisfy the variability in H_s. The SAR atmospheric boundary layer rolls are oriented at about 38° relative to azimuth direction which means 65°N after compensating for SAR image rotation. This value is in good agreement with wave peak direction by considering that fully developed waves are aligned with wind vector. ECMWF atmospheric model predicts an average wind velocity of about 12 m/s and mean direction of about 52°N over the SAR imaged area (corresponding to the part delimited by the dotted line in Figure 3). The value is consistent with wave observation although the model output refers to two hours later than SAR acquisition, a result explained by wave stationariness. Wind velocity and direction time series of about one hour around the SAR overpass were collected by ODAS anemometer. The wind vector resulted almost constant at about 14 m/s from 200°N. Compared to other data sources, the wind direction shows a bias of about 40°, anyway it results consistent with values from ECMWF and from SAR image analysis.

The plot of the SAR normalised radar cross section as a function of the incidence angle shows that the CMOD4 model predicts a wind velocity of 12-13m/s to account for the backscatter variability (see Figure 4). This value is in good agreement with wind velocity obtained both from La Spezia wave buoy and ECMWF prediction and slightly lower than that measured by ODAS. It has to be considered that ODAS buoy is located just outside the area covered by the SAR frame.

For the near future, we plan to install an ondametric buoy in the vicinity of ODAS Italia 1 in order to have a complete system for the validation of ENVISAT/ ASAR products.

* *Corresponding author address:* Elena Arabini,
ISAO – CNR, v. Gobetti 101, 40129 Bologna, Italy;
e-mail: e.arabini@isao.bo.cnr.it

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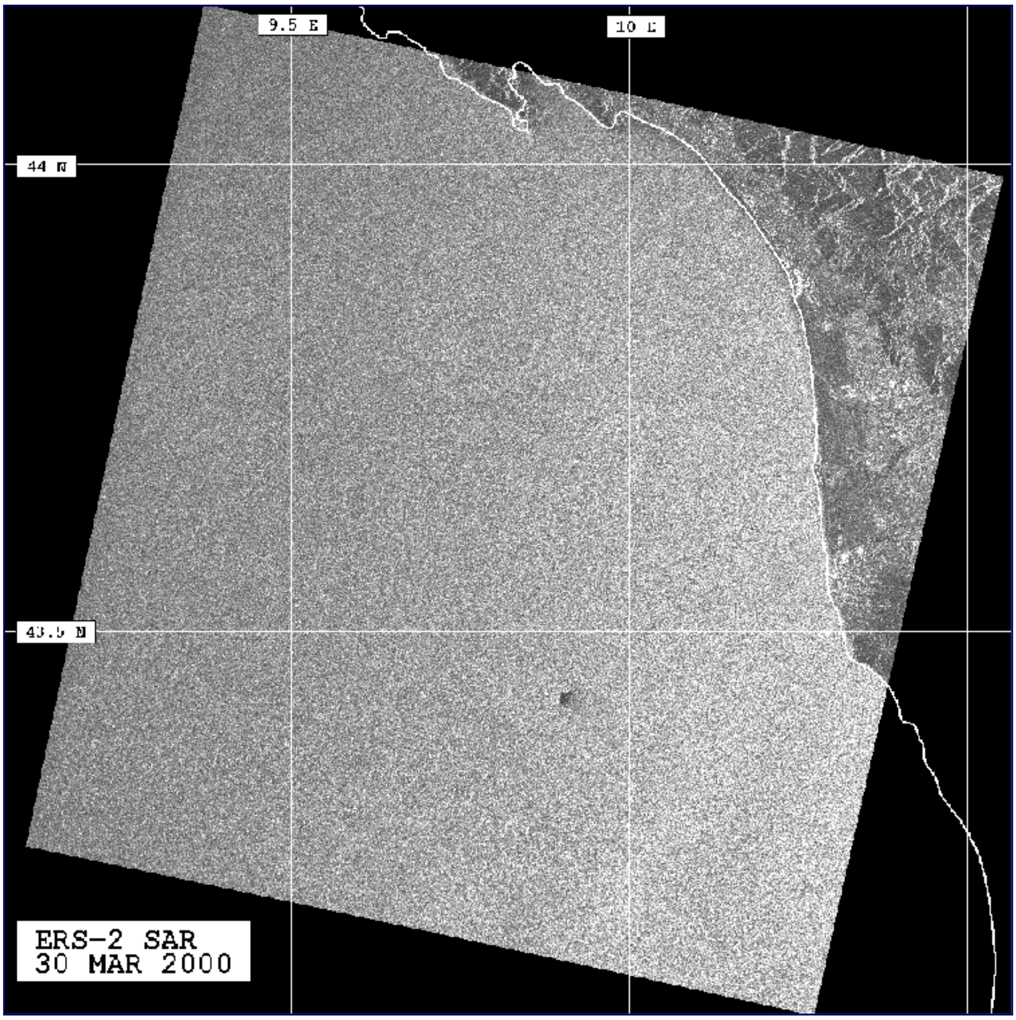

Figure 1. ERS-2/SAR scene of March 30, 2000 (orbit: 25842 frame: 2727).

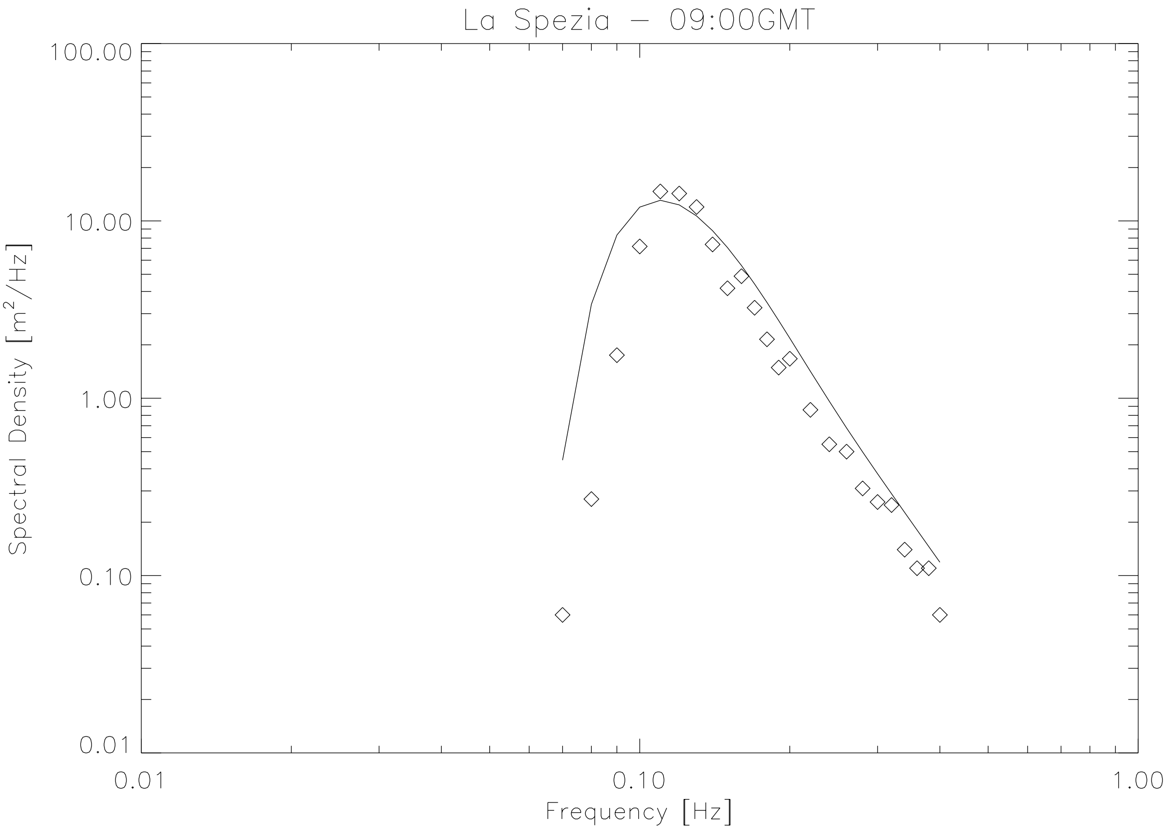

Figure 2. Wave frequency spectrum collected by the RON buoy in the Gulf of La Spezia.

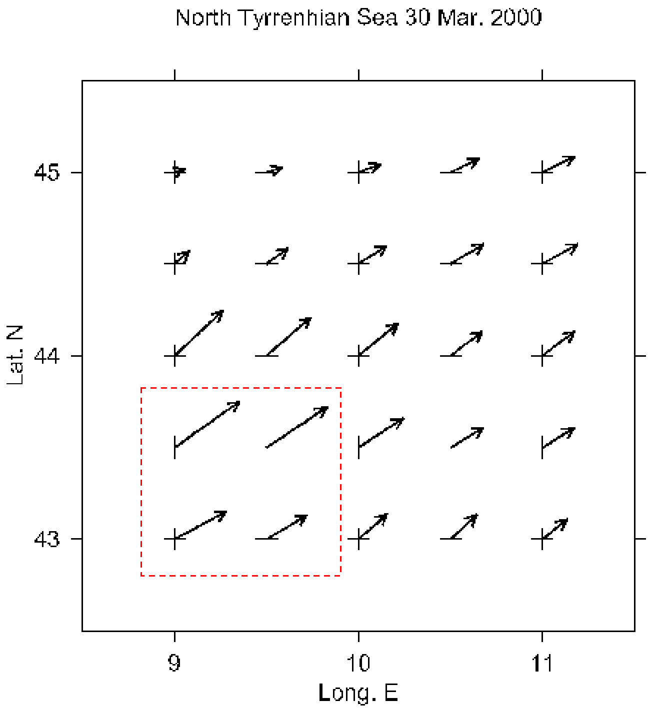

Figure 3. Wind vector map obtained from ECMWF.

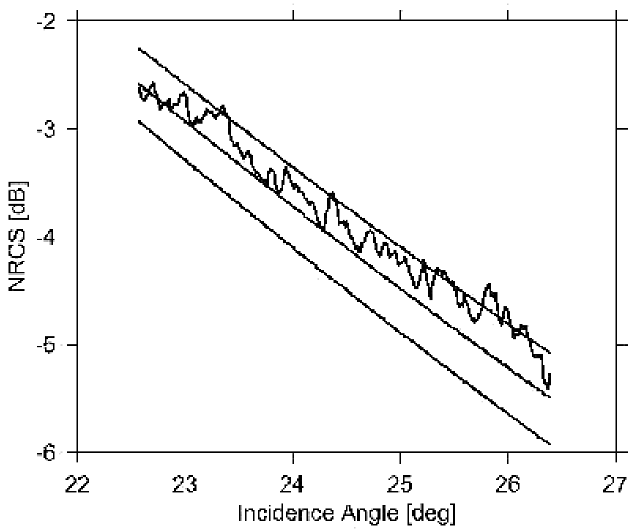

Figure 4. CMOD4 wind velocity estimation.