Determination of the wind field from SAR in coastal areas

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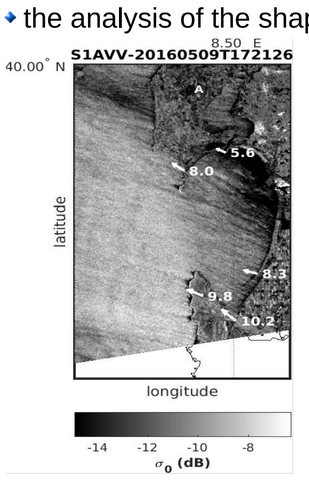
Summary

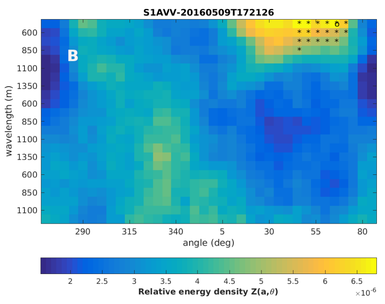
A method based on the 2D Continuous Wavelet Transform (2D-CWT) has been developed and applied to SAR images to retrieve the wind direction. The 2D-CWT is working well for any kind of SAR (Envisat ASAR, Sentinel-1a,b, Radarsat-2 and CosmoSkyMed), is reliable and provides wind direction fields without external information, making their variability similar to that of the in-situ data. This may be taken as a proxy to assess the reliability of the SAR computed wind directions. The problem of the wind direction determination from SAR is thus virtually solved by the 2D-CWT method: the resulting wind fields have been compared with those derived using WRF model and the OWI ESA wind directions. The results indicate discrepancies which should be investigated. In coastal areas exhaustive validation is very difficult due to the lack of suitable wind reports and local area atmospheric models.

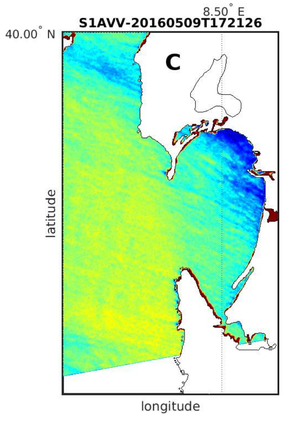
The 2D-CWT method 1

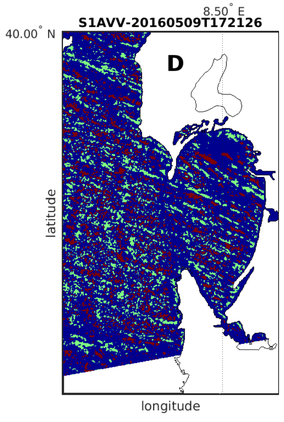
A fully 2-D Continuous Wavelet Transform (2D-CWT), a refinement of the quasi-2D method developed in the past (Zecchetto et. al., 2002, 2008) has been used to extract from the SAR images the aliased wind direction. The method is based on:

- the computation of the 2D-CWT spectrum of SAR image (A) to find the spatial scales and the angles where the energy related to the wind speed is located (B, stars);
- the reconstruction a SAR-like image only with selected scales and angles to evidence the shape of the backscatter structures related to the wind (C);
- the analysis of the shape of these structures (elliptic wind cells) to get the direction of their major axis (D)



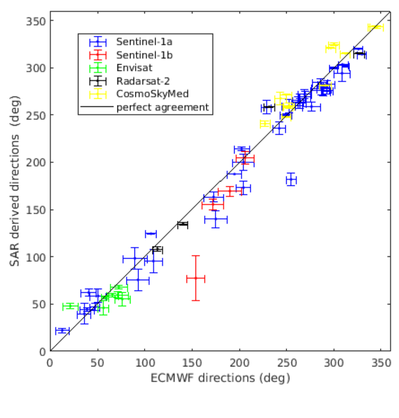


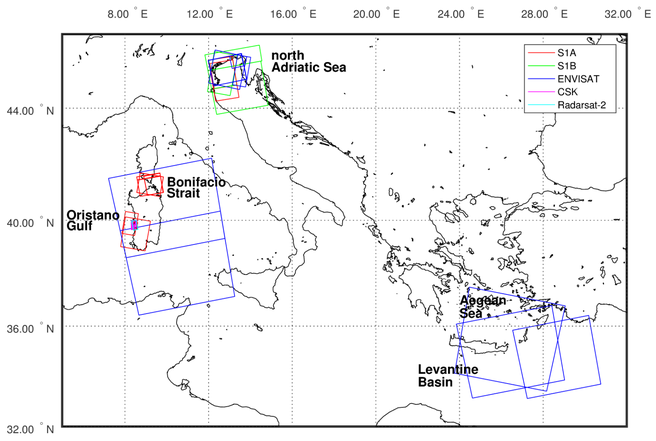




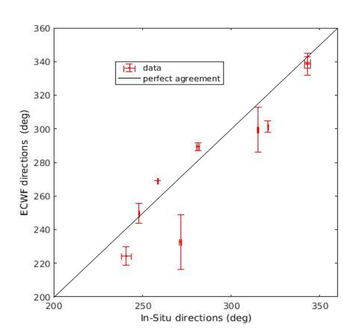
original image **2D-CWT power spectrum** **reconstructed image** **wind structures**

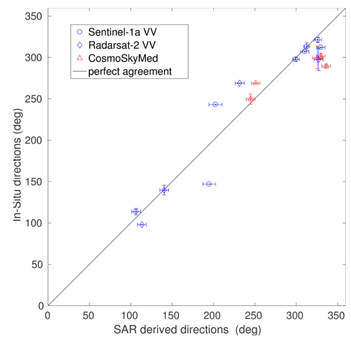
Global results of wind direction determination 2

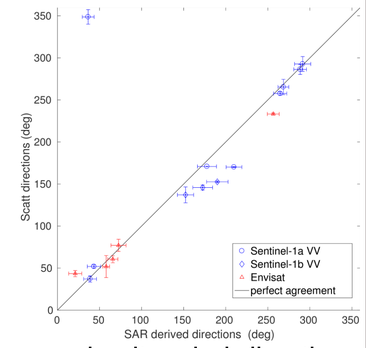




The left panel reports the scatterplot between the SAR mean wind directions obtained from the SAR images shown in the right pane and those from ECMWF along with their standard deviation: for 83% of cases, the difference is <20°, for 92%, <30°. Only for 5% the difference is >50°. It is important to remark that *this is only a proof of consistency, not a validation,* because often the model wind directions differ from those measured in coastal areas (left panel below) reporting in-situ vs ECMWF wind directions in the Oristano Gulf.

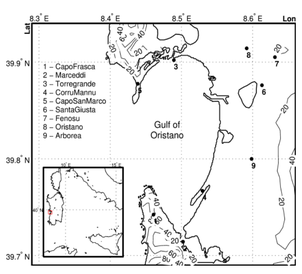


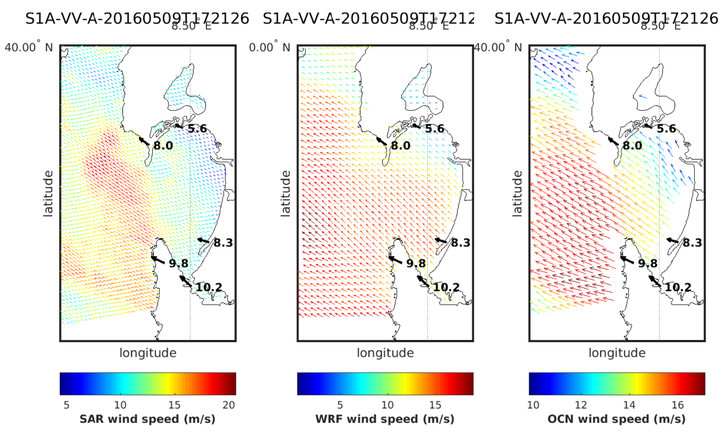


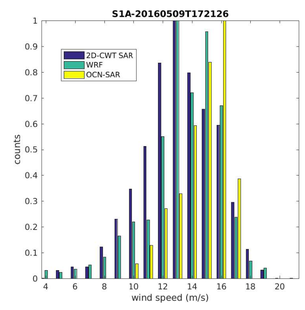


The middle and right panels report the 2D-CWT SAR versus in-situ wind directions for the Oristano Gulf area and versus scatterometer data in open ocean.

Wind fields from 2D-CWT, atmospheric model (WRF) and ESA-OWI in the Oristano Gulf 3



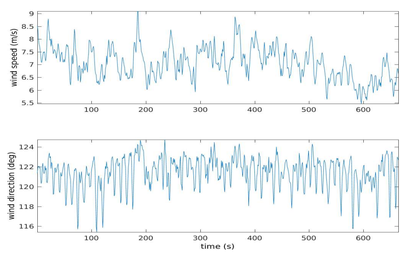


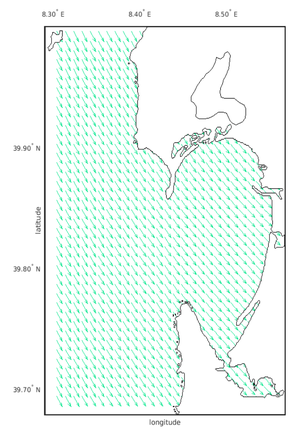


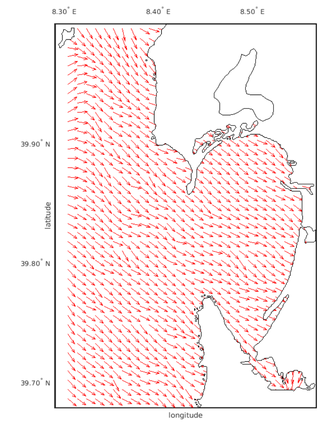
Oristano Gulf **2D-CWT SAR** **WRF model** **OWI-SAR** **wind speed distributions**

There are evident differences in the wind field spatial layout and in the wind speed distributions. In general the SAR derived winds are higher than the in-situ reports (not shown here).

Some consideration on wind direction validation 5



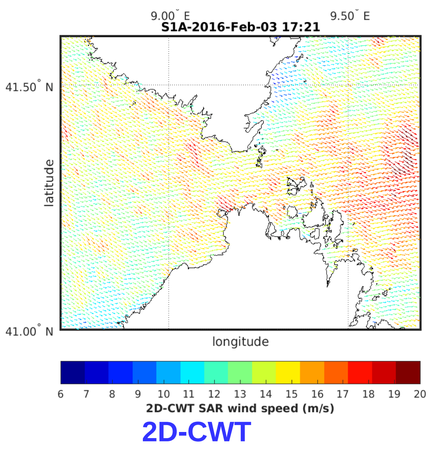


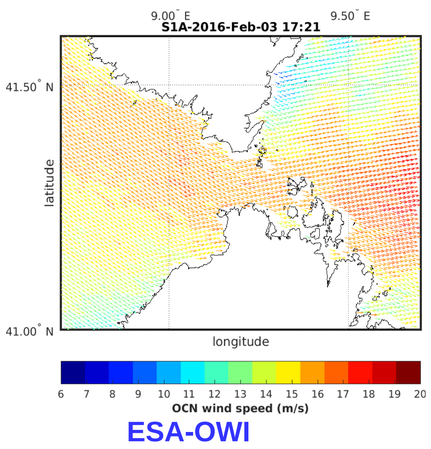


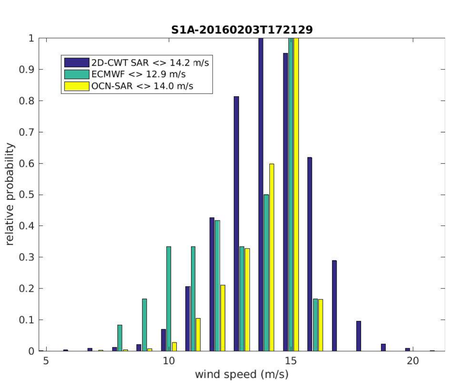
in-situ 600 s **WRF model** **2D-CWT SAR**

The in-situ wind shows a variability (left panel) which must reflect locally on the SAR image. The WRF model and 2D-CWT SAR fields (middle and right panels) show a different local spatial variability: which describes better the geophysical situation? There is *no way to answer to this question,* also because to the lack of offshore wind networks. The SAR wind direction standard deviation σ_{Sar}= 6° is closer to that of experimental data σ_{exp}=7.5° than to that of WRF σ_{wrf} =1° . This can be taken as an indication of suitability of the 2D-CWT SAR derived directions.

Wind fields from 2D-CWT and ESA-OWI in the Bonifacio Strait 4







2D-CWT **ESA-OWI** **wind speed distributions**

There are evident differences in the wind field spatial layout due both to the different spatial resolution and to the local wind direction variations in the 2D-CWT field (the OWI-SAR field results spatially flat, similar to those of the model). This is reflected in the different wind speed distributions even if the mean winds are similar. Note the differences close to coast, where the spatial resolution is crucial. The wind speed differences may be also due to the differences in the wind directions.

References

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Conclusions

In coastal areas the determination of the wind direction is crucial and should be analyzed with more attention.

The 2D-CWT method is working well for any kind of SAR (Envisat ASAR, Sentinel-1a,b, Radarsat-2 and CosmoSkyMed). It provides wind direction fields without external information with similar variability of the in-situ data.

Considering the problem of the wind direction determination from SAR virtually solved by the 2D-CWT method, the main issues are how to use the SAR wind fields for research and application (also accounting for the low revisiting time of SARs), and how to validate them. The ongoing research is focused

- to verify the SAR wind estimates which appear too high with respect to the in-situ
- to assess the validity of the Taylor hypothesis of frozen turbulence on short spatial and temporal scales given the availability of in-situ wind data at 1 Hz sampling
- to study the wind vorticity fields derived from the SAR wind fields