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Master Thesis

CHARACTERIZATION OF OCEAN WIND VECTOR RETRIEVALS USING ERS-2 SCATTEROMETER HIGH-RESOLUTION LONG-TERM DATASET AND BUOY MEASUREMENTS

EXECUTIVE SUMMARY

The scatterometer is an instrument on board satellite (or aircraft) able to measure wind speed and wind direction. It consists in a microwave radar designed to measure the Normalized Radar Cross Section NRCS of the sea surface and such section can be interpreted as a measure of the ability of the observed object (in this case the portion of the sea surface involved) to reflect the radar signal towards the radar receiver. Measurements of NRCS are obtained thanks to the scattering mechanism of the so-called capillary waves directly generated by the wind. This mechanism is known as Bragg scattering, which occurs from the capillary waves since they are in resonance with the microwaves. Therefore, the scatterometer does not directly perform measurements of wind, but is able to estimate its speed and direction from measurements of the NRCS provided by the capillary waves. To do so, it is necessary to have a Geophysical Model Function (GMF) able to relate the NRCS with these geophysical parameters, as well as inversion algorithms that allow retrieving the desired information. In this thesis the scatterometer on board the European Remote-sensing Satellite (ERS) -2 has been examined which was launched by the European Space Agency (ESA) in July 1995 as a follow-on mission to ERS-1. These satellites strongly contributed to the Earth Observation activities, since they were able to collect a large number of data necessary to monitor natural disasters, as well as to improve the scientific understanding of our planet and which are still used.

ERS-2 embarks several instruments including an Active Microwave Instrument, AMI, working at 5.3 GHz, where two radar instruments are incorporated: a Synthetic Aperture Radar, out of scope of this thesis, and the scatterometer. The latter consists of three different antennas looking at 45 ° forward, sideways and 45 ° afterward. Thanks to such antennas, the instrument is able to perform three different measurements of NRCS, which are essential to estimate both wind speed and direction. The geophysical model function used by ERS-2 scatterometer is called C-band geophysical model function for equivalent neutral wind, CMOD5.N.

One of the most important steps in remote sensing is the validation phase, which consists in investigating the accuracy of the data estimated by satellites as well as of the geophysical models used. The aim of this thesis is the validation of the long-term dataset of ERS-2 wind scatterometer using the so-called in-situ measurements provided by the buoys located in the Tropical Atlantic Ocean. In-situ measurements are direct measurements of the geophysical quantities, and since they do not involve any models, they can be considered as a "reference" sources to estimate the accuracy of the satellite data and to refine and improve, where necessary, the models used. According to our knowledge, there are not, in the literature, previous works about such in-situ validation of ERS-2 wind products, however, there are works on the soil moisture validation, but this is not the object of this work.

The long-term dataset of ERS-2 wind scatterometer involved in this analysis covers a very long period starting from 1995 up to 2003, hence, this means that such dataset is a huge amount of data. These data

are the result of a project called "Advanced Scatterometer Processing System" (ASPS), whose purpose is to provide, through the reprocessing of the entire ERS mission, a homogeneous and high quality measurements of the NRCS of Earth surface and high quality measurements of the wind field over Ocean. In particular, the data analyzed in this thesis are the High Resolution ASPS Level 2, which have a resolution of 25 km rather than 50 km as in the case of the Nominal Resolution.

The in-situ measurements are provided by one of the largest datasets of in situ wind speeds and wind direction called Prediction and Research Moored Array in the Atlantic (PIRATA). PIRATA is a program designed for studying the Ocean-atmosphere interactions which have shown to have a strong influence on climate variability in the Atlantic region. PIRATA is a network of twenty buoys in the Tropical Atlantic Ocean but in this thesis only thirteen of them are involved since the date of their first measurement refers to a period after the 2003. The first step necessary to begin the validation has been the extraction of the measurements from both the datasets. For this purpose, appropriate algorithms -with Matlab- which are able to read and process the data, have been realized, adopting different strategies in order to reduce the very long processing times caused by the big amount of the data involved.

The validation issue, using in situ buoy measurements, has been faced according to ASCAT (Advanced Scatterometer) scatterometer in situ validation [Bentamy et al., 2008]. The investigation of the ERS-2 wind quality is based on the use of data collocated in space and time, therefore, it is necessary identifying such pairs of measurements that could be effectively compared. To do so, a Matlab algorithm able to select pairs of measurements, whose spatial difference is less than 100 km and time difference less than 10 minutes has been created. Such large distance has been chosen in order to have a reasonable number of matches. Then, this distance has been reduced with the aim of understanding its effects on the final results and also to reduce the so-called *representativity error*. The validation has been carried out at two different levels of the scatterometer data processing, namely at Level 1 - NRCS measurements as acquired by the three antennas – and at Level 2 – wind speed and direction-. The purpose of the validation at Level 1 is to check, through the buoy measurements, the validity of the CMOD5.N function, while the purpose of the validation at Level 2 is to characterize the scatterometer wind retrievals. In both cases, a statistical analysis of the differences between both datasets has been carried out considering all wind ranges: low winds (wind speeds less than 5 m/s), medium winds (wind speeds between 5-10 m/s) and high winds (wind speeds greater than 10 m/s). In this way, a long-term characterization of the whole wind field over Ocean has been realized according to scatterometer and buoy measurements.

From the results obtained by the validation at level 1, it was found that the buoys are able to retrieve the main characteristics of the NRCS estimated by the satellite. This allowed to check the validity of the CMOD5.N function used to retrieve the measurements of wind speed and direction. This is true for all the wind ranges, however, the main discrepancies are found for high winds, according to the case of ASCAT. The results of the validation at Level 2 show that there is a very good agreement between the ERS-2 and buoys winds and also their seasonal trends compare well. The results suggests that wind speed misfit is less than approximately 1 m/s on average and the wind direction misfit is less than 30 °on average. However, analyzing the three different ranges of wind, it was found that the agreement between both winds is better for medium winds where there is also the greatest number of collocated available pairs. It can be noticed in fact, that ERS-2 tends to overestimate the lower winds and to underestimate higher winds. This behavior may be caused by calibration problems of the GMF as well as by calibration problems of the instrument. At the time, according to our knowledge, results in the literature in support of this claim were not found. Such behavior of ERS-2 wind scatterometer could be the starting point of future investigations, through, for example, the use of another database provided by the so-called European Center for Medium-range Weather Forecasts (ECMWF) in place of the buoy measurements.