VALIDATION AND ANALYSIS OF OCEAN PARAMETERS USING ASCAT DATA

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Abstract

This project aims to investigate the quality of ASCAT measurements as well as their use for oceanographic purposes. The accuracy of ASCAT retrievals will be mainly based on the use of collocated data from moored buoys, numerical weather prediction models, and satellites. The resulting collocated data will be used to explore the accuracy of the geophysical model function which relates the backscatter coefficients to surface wind vectors, as well as to assess the quality of ASCAT vector winds at global and local scales. Once this objective reached, it will enable to fully utilize the MetOp data for oceanographic applications. They will contribute to evaluate various estimates of ocean surface flux parameters required to force ocean general circulation models. The estimation of global vector wind fields and wind stress, latent and sensible heat fluxes and ocean precipitation with both high spatial resolution and time sampling will be given special attention. Also, scatterometers have demonstrated their ability to monitor sea ice coverage, age and drift. ASCAT backscatter coefficient will be processed for sea ice geophysical interpretation in order to increase the long time series of ice parameters already available.

I. Calibration and validation of ASCAT measurements

I.1 Collocated data system

The project will set-up an operational system to collocate data from various sources at global and regional scales.

I.1.1 Moored buoy data

Near surface observations of wind speed and direction, air and sea surface temperatures and, on some platforms, relative humidity (or dew point), will be provided by five buoy networks: the National Data Buoy Center (NDBC) buoys off the U.S. Atlantic, Pacific, and Gulf coasts maintained by the National Oceanic and Atmospheric Administration (NOAA); the European ODAS buoys in Mediterranean sea and in the eastern Atlantic, maintained by the United Kingdom's Meteorological Office and Météo-France; the Tropical Atmosphere Ocean (TAO) buoys located in the tropical Pacific Ocean and maintained by NOAA's Pacific Marine Environmental Laboratory (PMEL); the PIlot Research moored Array in the Tropical Atlantic (PIRATA) moored in the tropical Atlantic ocean and maintained by the Institut pour la Recherche et le Développement (IRD) and PMEL. The number of moored buoys will be approximately 120.

The collocation procedure is similar to the one developed and successfully used for ERS-1/2, ADEOS-1, and QuikSCAT (Bentamy *et al.*, 2002). It will be achieved by selecting ASCAT cells (25km×25km), which fall within a 50km×50km square centered around the buoy location. Temporal collocation is achieved by choosing the buoy observation closest to the time of the ASCAT wind cell. For comparison with ASCAT remotely sensed winds, the Liu-Katsaros-Businger (LKB) model (Liu *et al.*, 1979) and Fairall *et al*. (1999) will be used first to calculate 10-m wind speeds and humidity at neutral conditions from mast measurements at 4-m height. Only validated remotely and buoy data, based on the use of quality flags included in the products, will be compared. The influence of environmental factors on the difference between scatterometer and buoy data will be investigated.

I.1.2 Satellite data

During ASCAT calibration/validation period, several satellite-borne microwave instruments will provide surface parameter estimates such as surface wind and sea state. ERS-2 and QuikSCAT will enable the estimation of 10-m height wind speed and direction over cells of 50kmx50km and 25kmx25km. SSM/I series will provide an estimation of surface wind speed and atmospheric data such as water liquid, water vapor contents, and precipitation. Wind speed and significant wave height parameters will be derived from ERS-2, Jason and Envisat altimeters. WindSat will provide wind speed and direction estimates.

The collocation of ASCAT data is achieved by selecting, for each ASCAT cell, all other remotely sensed surface parameters with a temporal separation less than 1 hour, and a spatial separation less than 100km. On average, 18 pairs ASCAT/QuikSCAT per each 0.5 degree grid point are expected, with a maximum located in the high latitudes and especially in the southern hemisphere and in the Atlantic Ocean. Their total number during the first ASCAT three month of operation is expected to be about 850 000.

I.1.3 NWP data

The third surface wind data products will be derived from the European Center for Medium-Range Weather Forecast (ECMWF) at global scale and at synoptic time, and from Météo-France NWP model ARPEGE over the North Atlantic and the Mediterranean seas. Both NWP data will provide a quick estimate of the validity of ASCAT wind retrievals over large ocean areas.

We will mainly emphasize the use of NWP wind data to assess the intercomparisons between ASCAT and other scatterometer data (ERS-2, QuikSCAT). Therefore, the resulting collocated sets ASCAT/NWP will be further collocated with other scatterometer surface winds. These triple collocation sets will be used through this study.

I.2 ASCAT data validation

The remotely sensed, in situ, and model data collocated with ASCAT measurements (backscatter coefficient measurements and wind vector estimates) will provide the opportunity to validate MetOp scatterometer measurements. The main scientific and operational goals of this study are :

1. To resolve the spatial and temporal averaging issue
2. To validate the ASCAT model geophysical function over the full incidence angle and wind speed and direction (scatterometers, buoys)
3. To estimate the local accuracy of ASCAT winds. The primary analysis method which will be used is least square orthogonal regression. The influence of environmental factors upon the differences between satellite and in-situ data will be examined.
4. To estimate the global accuracy of ASCAT winds. Even if C-band backscatter coefficient measurements are mainly related to short capillary-gravity waves through Bragg mechanisms, wave interactions at different scales modulate the short wave spectrum and therefore σ^0. The dependency of ASCAT σ^0 and the related wind vector on sea state will be investigated through the behavior of the difference between ASCAT and altimeter wind speeds as a function of significant wave height for several incidence angles and wind speed ranges.
5. To provide a quick estimate of the validity of ASCAT wind retrievals over large areas through a comparison with ECMWF and ARPEGE wind analysis.

Figure 1 illustrates the use of collocated scatterometer and buoy measurements to assess the quality of GMF.

In order to achieve the operational and scientific goals within ASCAT calibration/validation period, we plan to start during the IOP period, the development of the data base containing satellite and in-situ data, the development and test of the analysis methods, the validation of all tools which will be used for calibration/validation issues, and the collaborations with the institutes involved in the MetOp program.

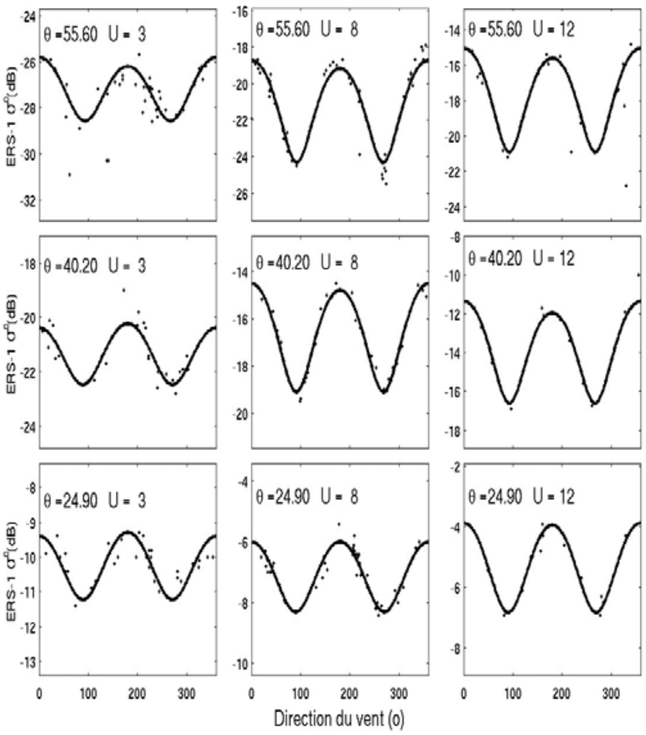

Figure 1 : Behavior of backscatter coefficient (σ°) as a function of relative wind direction for three incidence angles (row) and three wind speed (column) ranges. Surface winds are derived from buoys. Heavy line and dots indicate estimated (through GMF) and measured σ°, respectively.

II. Use of ASCAT measurements

Several European and international scientific programs require high accurate surface parameters at global or regional scales, of which turbulent fluxes and sea ice are needed to determine an oceanic forcing function for ocean circulation, wave, and sea ice models.

II.1 Estimation of turbulent fluxes

The project will focus on satellite estimates of the wind field (speed and direction), wind stress, latent and sensible heat fluxes, and oceanic precipitation which are the dominant surface forcing terms for ocean circulation. The work will attempt to evaluate the models and methods used to estimate ocean surface fluxes from satellite observations.

II.1.1 Ocean surface wind vector

The results derived from study related to comparisons with other sensors between wind vectors will be used. Biases between the different data sources will be evaluated and removed so as data from the various sensors can be merged in the analysis processes. Most of the inter-comparisons will be performed over regions with in-situ data.

II.1.2 Surface wind stress

Following the wind vector evaluation, the project will focus on the computation of ocean surface wind stress for each three hour period from available satellite wind observations on a grid of 0.5°x0.5° in longitude and latitude. The global gridded daily, weekly, and monthly wind stress values will be derived from these instantaneous wind stress estimates. The wind stress computations will use bulk aerodynamic formulation. Variations in the efficiency of turbulent exchange (therefore affecting the bulk exchange coefficients) are most strongly due to atmospheric stratification influences as buoyancy forces contribute to or diminish the turbulence generated by the wind shear. For our calculation and with regard to previous estimation (Bentamy *et al.*, 1999) of satellite-derived momentum flux, we shall employ the formulation of Smith (1988) for the drag coefficient appropriate for open ocean and deep waters, valid for wind speeds between 6 m/s and 25 m/s. For low wind speed, we shall apply the formula of Liu *et al.* (1979), which considers the effect of free convection at wind speeds close to zero. The formulation proposed by Fairall *et al*. (1999) will be tested.

II.1.3 Latent and sensible heat fluxes

The aim of this activity is to continue estimation of the latent heat and sensible flux derived from several satellite sensors (Bentamy *et al*., 2003). The global latent and sensible heat flux calculations will be based on the combination of brightness temperature measurements from SSM/I, SST analysis data (SAF Ocean /Sea Ice, NCEP/NCAR data bases), and surface winds from scatterometers. Two temporal resolutions will be available : weekly and monthly. The flux estimates will be calculated using the bulk aerodynamic formulation developed by Bentamy *et al.* (2003). However, comparison with other satellite products (HOAPS, GSSTF) will be performed and statistical parameters will be provided.

II.2 High spatial and temporal surface winds

The ASCAT retrievals will be used to enhance the spatial and temporal resolutions of surface parameters over the global ocean.

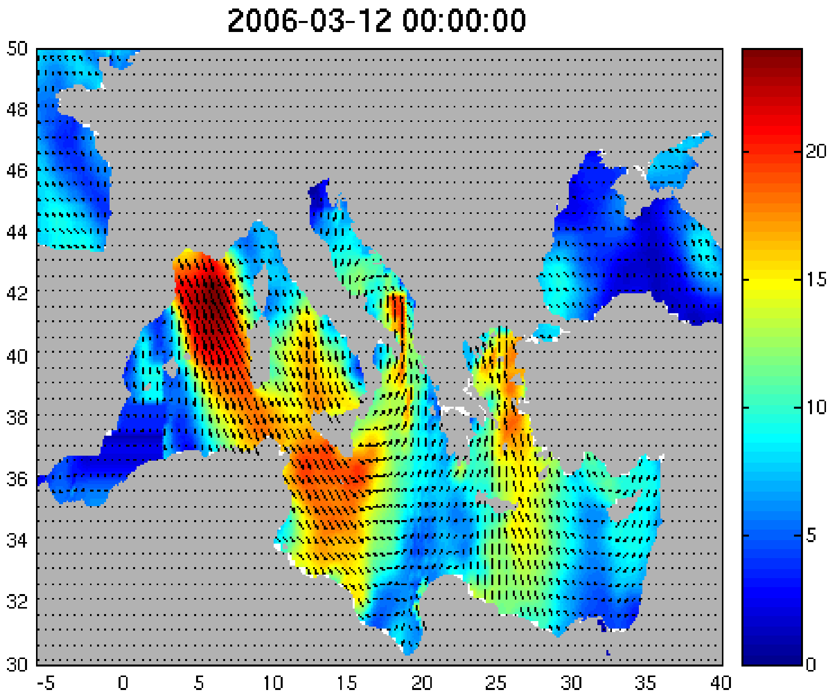

Figure 2 : Example of blended wind field estimated from merging QuikSCAT, SSM/I, and ECMWF wind estimates over the Mediterranean Sea for 12th March 2006 at 00h :OO epoch. The spatial and temporal resolution is 0.25° in longitude and latitude and 6 hours, respectively.

The purpose of this study is to focus on the estimation of the blending near real time remotely sensed wind observations and operational ECMWF wind analysis. Ocean surface wind observations will be retrieved from ASCAT scatterometer as well as from QuikSCAT scatterometer and from SSM/I. The analysis will be performed by optimum interpolation based on the kriging approach. The needed covariance matrixes will be estimated from the satellite, zonal and meridional component of wind speeds. The quality of the 6-hourly resulting blended wind fields on 0.25° grid will be investigated through comparisons with the remotely sensed observations as well as with moored buoy averaged wind estimates. Figure 2 shows an example of such calculation merging QuikSCAT, SSM/I and ECMWF wind estimates over the Mediterranean Sea. The blended wind data and remotely wind observations, occurring within 3 hours and 0.25° from the analysis estimates, compare well over the global basin as well as over the sub-basins. Using measurements from moored buoys, the high-resolution wind fields are found to have similar accuracy as satellite wind retrievals. Blended wind estimates exhibit better comparisons with buoy moored in open sea than near shore.

II.3 Sea ice

Since 1979, buoys are moored on ice each year in the framework of the IABP, providing continuous local measurements of drift on the Arctic. Since the 1990's, satellites data enable daily and global coverage of the polar oceans, providing an unique monitoring capability of sea ice dynamics over Arctic and Antarctic. Available geophysical parameters are sea ice concentration and extent (from radiometers) and sea ice type and drift (from scatterometers).

Since 1991, IFREMER-CERSAT developed a strong knowledge of using scatterometer data to generate geophysical sea ice products. This capability relies on previous scatterometer missions ERS, NSCAT, and QuikSCAT. IFREMER-CERSAT will work on ASCAT data for several sea ice projects.

II.3.1 Backscatter maps

Backscatter values over oceans are used to estimate wind field. Over sea ice, this parameter can be related to sea ice age and enables the discrimination of multi year ice (the ice which has not melt during summer) from first year ice. Backscatter maps are also used as a basic product for sea ice drift estimation (see §II.3.2).

Nowadays, daily QuikSCAT backscatter maps are estimated at a pixel resolution of 12.5 km. Because of conical revolving antennas, QuikSCAT does not require any incidence angle corrections whereas ASCAT needs such correction. IFREMER-CERSAT will construct ASCAT backscatter maps at 40° incidence, daily and for the Artic and the Antarctic. This will increase the IFREMER-CERSAT backscatter time series over sea ice :

- 1991-2001 with ERS-1 and ERS-2
- 1996-1997 with NSCAT
- 1999-present with QuikSCAT.

Figure 3 is an example of backscatter map from QuikSCAT in February, blue color are weak backscatter (first year ice, near Siberia) and red are strong backscatter (multi year ice, North of Canada). The backscatter threshold to distinguish first year from multi year is complex to determine. If the Ku-band QuikSCAT (14 GHz) and the C-band ASCAT (6 GHz) data are simultaneously available, the ice type discrimination will be greatly improved (example of ERS-2 –C band- and NSCAT –Ku band- during winter 1996-97, Ezraty and Cavanié, 1999).

II.3.2 Sea ice drift

Backscatter maps from SeaWinds/QuikSCAT (since 1999) and brightness temperature maps from the Special Sensor Microwave Imager (SSM/I) (since 1992) are available with a pixel resolution of 12.5 km from which ice drift can be estimated for each sensor (Ezraty *et al.*, 2006ab). Since 1999, IFREMER-CERSAT produces a "Merged" sea ice drift data set based on the combination of these drifts. Drifts are estimated for 3, 6 and 30-day lags during the winter period at the grid resolution of 62,5 km. It has been demonstrated that combining these drifts increases the number of valid vectors (Ezraty *et al.*, 2006c). Figure 4 is an example of "Merged" drift over a 3-day period for the whole Arctic. The strong southward drift in Fram strait, ice exit of Kara area, and drift from Laptev sea to central Arctic can be seen.

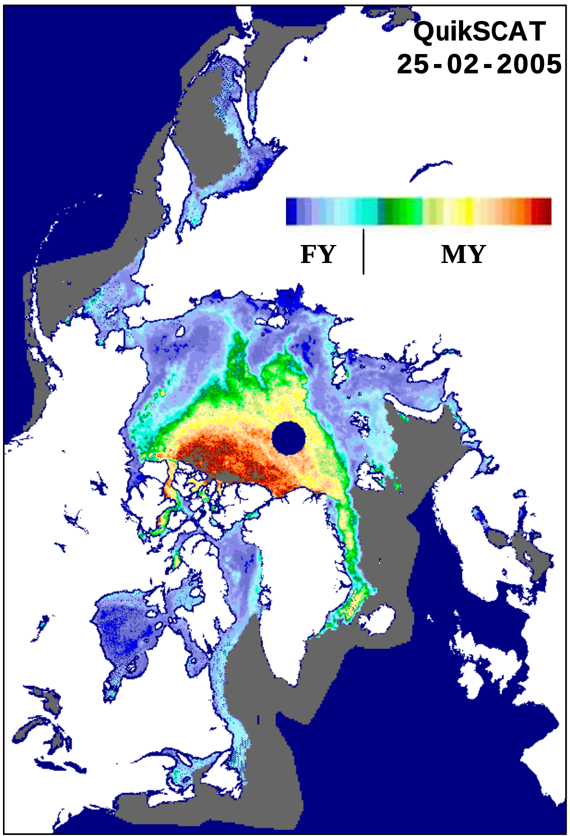

Figure 3 : Backscatter map from QuikSCAT for the 25th February, 2005 over the Arctic. Colors from blue to green are first year ice (FY), green to red are multi year ice (MY).

Similarly to QuikSCAT backscatter processing, drift maps will be estimated from ASCAT backscatter maps. The continuous time series of drift maps since 1992 will be extended. The same grid resolution will be used (one drift vector each 62.5 km). Given ASCAT geometry and MetOp orbit parameters, it might be inferred that drift data will be more noisy.

II.3.3 ASCAT sea ice product applications

ASCAT sea ice drift and sea ice age maps are used by the scientific community. Backscatter maps will be used to discriminate first year from multi year ice. Our continuous time series from 1992 will be extended, it can be expected that adding data will make the time series of backscatter more useful for climatological studies. IFREMER-CERSAT distributes these data as inputs for ocean, wave, sea ice and climate change models (Mercator, FOAM UK Met Office, AWI, NERSC…). Sea ice parameters assimilation in the models greatly improved models results (example with the UK MetOffice FOAM model with application for oil spill drift and sediment transport, Girard-Ardhuin et al., 2006). Future work could combine CryoSat 2 (?) and drift data for ice volume flux.

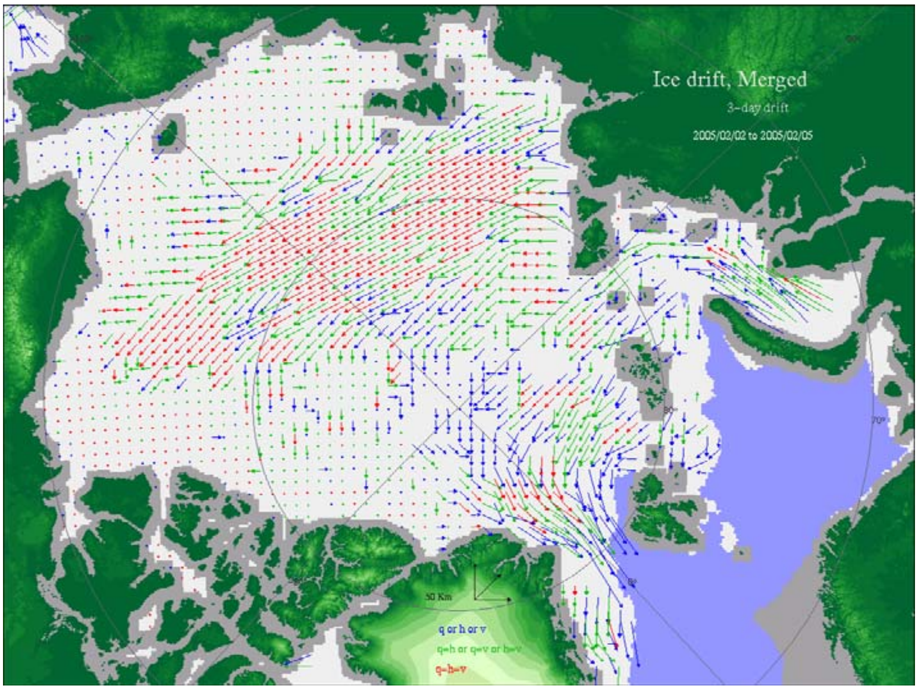

Figure 4 : Arctic sea ice drift from the combination of SeaWinds/QuikSCAT scatterometer data and SSM/I data (h and v polarizations) over 3 days (February 2nd-5th, 2005). Drift vectors less than one pixel are marked with a cross. In red : identical drift for the 3 vectors, in green : identical drift for any pair of vectors, in blue : selection or validation of single value.

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