1. Abstract

Winds for climate research: Here we describe recent progress in bringing consistency to satellite observations of ocean vector winds from several space-based sensors, with an accuracy required for climate analyses. Surface wind speed and direction are identified as one of the essential atmospheric Environmental Parameters, as they drive atmospheric and oceanic processes with impact on long term global climate variability.

Objective: Most of the space-based wind vector observations are from scatterometers, which started in 1991 with ERS, followed by QuikSCAT, ASCAT and recently by RapidScat, and by the polarimetric radiometer WindSat. Our main goal is to intercalibrate all these measurements, in order to develop a 25-yr Climate Data Record (CDR) of ocean vector winds.

Approach: Our approach is to intercalibrate all the scatterometer wind speeds to those from microwave radiometers. We first reprocessed all the radiometer data starting from 1988 with a common Radiative Transfer Model, the RSS V7, and then used those wind speeds as reference target to develop the model function (GMF) for each scatterometer type, at three frequency bands and for a wide range of incidence angles. The following intercalibrated scatterometer datasets have been reprocessed at RSS and are available to the public: ASCAT, QuikSCAT, RapidScat, and Aquarius.

Next, we plan to process the ERS data, in order to complete the timeseries starting from 1991. Data available at www.remss.com.

Summary: Here we discuss our methodology, present results on the consistency of all these wind datasets among themselves and versus buoy data, show examples on how they are already used for climate research, and discuss other issues that need to be addressed before merging all the data into a unique CDR, like diurnal variability aliases, and other spurious biases that might affect the data.

Finally, we introduce a newly reprocessed satellite-based wind vector analysis dataset, the Cross-Calibrated Multi-Platform (CCMP) winds Version 2. They have been recently reprocessed at RSS using consistent winds as input from the V7 radometers and the QuikSCAT and ASCAT scatterometers. The CCMP V2 dataset additionally uses buoy data as input, and ERA-Interim surface winds as a background field for the variational analysis that leads to the final product. The CCMP V2 consists of 6-hourly global vector winds gridded at 0.25 degrees, starting from 1988 until 2015.

2. Methodology for Cross-Calibration

Steps

• Inter-Calibrate radiometer winds by using the same Radiative Transfer Model (RTM) RSS V7 and removing all biases and drifts. Emissivity model is linear and reliable at least up to 40 m/s.
• Careful validation of radiometer wind speeds (rain-free) at all wind regimes versus in-situ, aircraft, and other space-based observations.
• Develop scatterometer Geophysical Model Functions (GMFs) using the rain-free radiometer winds for calibration. Three GMFs: L-band, C-band, and Ku-band
• Careful validation of scatterometer winds
• Understanding and removing sources of sensor bias

Challenges:

• Each sensor observes the Earth at different time of the day -> diurnal variability must be taken into account when comparing or merging them
• Each sensor has different sources of bias (atmospheric/ocean surface effects, rain impact, imperfect GMFs, sensor drifts and biases...)
• Cross-Calibration has to be within 0.1 m/s (global, monthly scales) for Climate-Quality dataset

3. Challenge: Diurnal Variability

Sun-Synchronous: Fixed Local Time of Observation (Figure on right) SMMI, SSMS, AMSR-E, AMSR2, GSAT, ASCAT, WindSat, Aquarius

TMI/AMSR E: Fixed Local Time of observation very useful for CROSS-CALIBRATION

4. Cross-Calibration: Global Scales

CDRs require a demanding intercalibration standard that has to be met by all teams, we promote joint regional scales, and at all wind regimes. Here we show the level of consistency of pairs of scatterometer and radiometer winds speeds, tightly colocated in space (25 km) and time (0-90 min) over the globe. The figure on top shows the normalized joint Probability Distribution Functions of the scatterometer winds speeds (QuikSCAT, ASCAT, Aquarius and RapidScat) versus the radiometers (TMI, WindSat, GMI). All datasets are consistent with each other within 0.1 m/s in the range 0-30 m/s, with a standard deviation less than 1 m/s. The figure on the left shows the wind speed PDFs for RapidScat and colocated AMSR2, WindSat and ASCAT, and for the scatterometers (QuikSCAT, ASCAT and Aquarius) versus buoys.

5. Diagnosing problems with sensors

Since August 2015 RapidScat (scatterometer on the International Space Station) is experiencing some anomalies in the received echo power, causing at first some data disruption and later some small jumps in the calibration of the received signal and, as a result, of the wind measurements.

As part of the RapidScat Cal/Val team, we promptly used our suite of cross-calibrated scatterometers to estimate the jumps in the calibration during the anomaly states. We closely collocated RapidScat wind measurements in time and space with other available satellite winds, and estimated a general bias of ~0.3 m/s during the anomaly states with reduced echo power. The data quality is slightly affected, mostly at low wind speeds. For climate-quality, the RapidScat will need to be adjusted (re-calibrated) during the anomaly states. Continuous monitoring is still in progress.

6. Timeseries Stability

ASCAT/QSCAT/WindSat/TMI/GMI/AMSR global wind anomaly timeseries are very stable
• Differences within 0.1 m/s
• V1.1 RapidScat in line with others, hardware anomaly in Aug 2015 caused ~0.3 m/s bias
• Drift with SSMIS F17 in mid 2011 emerges
• Confirmation that ASCAT slightly dropped recently (~0.1 m/s, September 2014)

7. Merged Winds: CCMP V2

The Cross-Calibrated Multi-Platform (CCMP) wind product consists of 6-hourly gridded analyses of surface vector winds produced using satellite, in-situ, and model data. This Version-2 CCMP (to be released Jan 2016) combines all Version-7, and higher, RSS radiometer wind speeds, scatterometer wind vectors, in situ wind data. The observed data are combined using the ERA-Interim model as background wind fields and performing a Variational Analysis Method (VAM) to produce four daily (6-hourly) maps of 0.25 degree gridded ocean vector winds, from 1988 to 2015.

8. Examples of climate research using intercalibrated ocean winds

Satellite wind time series consistently processed for 25+ years can be used for climate studies. Here we show how they were used for looking at Westernly Wind burst events as precursors of El Nino (Capotondi and Ricciardulli, OS51C-08). Another example using these winds for El Nino research is [Halpern, OS51C-07].

Related presentations:
• OS51C-08: Precursors of ENSO Events from 27 Years of Satellite Data by Capotondi and Ricciardulli.
• ASTH-04: Inter-calibrating Multi-instrument Microwave Ocean Data Records over Three Decades by Smith and Wentz

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