Improvements & Advances to the Cross-Calibrated Multi-Platform (CCMP) Ocean Vector Wind Analysis (V2.0)

Joel P. Scott (RSS, scott@remss.com), Frank J. Wentz (RSS), Ross N. Hoffman (AER), & Robert M. Atlas (NOAA)
Remote Sensing Systems, Santa Rosa, CA

PO54F - 3322

Remote Sensing Systems
www.remss.com

Introduction

Ocean vector wind is a valuable climate data record (CDR) useful in observing and monitoring changes in climate and air-sea interactions. Ocean surface wind stress influences such processes as heat, moisture, and momentum fluxes between the atmosphere and ocean, driving ocean currents and forcing ocean circulation.

The Cross-Calibrated Multi-Platform (CCMP) ocean vector wind analysis is a quarter-degree, six-hourly global ocean wind analysis product created using the variational analysis method (VAM) [Atlas et al., 2011; Atlas et al., 1996; Hoffman et al., 2003].

The CCMP V1.1 wind product is a highly-esteemed, widely-used data set containing the longest gap-free record of satellite-based ocean vector wind data (July 1987 to June 2012). CCMP V1.1 was considered a "first-look" data set that used the most-timely, albeit preliminary, releases of satellite, in situ, and modeled ECMWF-Operational wind background fields.

The authors have been working with the original producers of CCMP V1.1 to create an updated, improved, and consistently-reprocessed CCMP V2.0 ocean vector wind analysis data set. With Remote Sensing Systems (RSS) having recently updated all passive microwave satellite instrument calibrations and retrievals to the RSS Version-7 Ocean Radiative Transfer Model (RTM) standard, the reprocessing of the CCMP data set into a higher-quality CDR using inter-calibrated satellite inputs became feasible.

In addition to the use of SSM/I, SSMIS, TRMM TMI, QuikSCAT, AMSRE, and WindSat instruments, AMSR2, GMI, and ASCAT have been also included in the CCMP V2.0 data set release, which has now been extended to the beginning of 2015. Additionally, the background field has been updated to use six-hourly, quarter-degree ERA-Interim wind vector inputs, and the quality-checks on the in situ data have been carefully reviewed and improved.

CCMP V2.0 Data Inputs

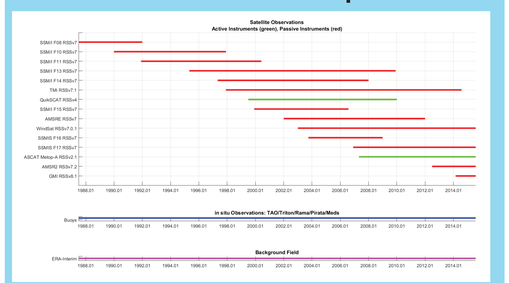


Figure 1: The CCMP vector wind analysis product applies a VAM minimization technique to solve for 6-hourly global wind fields using a variety of wind observations from satellite and in situ sources.

The CCMP methodology solves for these wind field solutions using a first-guess model background wind. This figure highlights the varying active (green lines) and passive (red lines) microwave satellite, in situ (blue line), and model (purple line) data used in CCMP V2.0.

All satellite inputs have been consistently processed and intercalibrated using RSS's V7 (and higher) RTM. The in situ observations are sourced from highly quality-controlled moored buoys in five major buoy network systems, known for their stability in time. The model background field used in CCMP V2.0 is 10-meter, 6-hourly, 0.25-degree ERA-Interim model wind vectors.

CCMP V2.0 Changes & Upgrades

CCMP V2.0 Product Details

- CCMP's original objective: create a level-3 global wind vector product that combines passive and active microwave satellite wind observations in a physically consistent manner.
  - To have consistency between satellite observations, intercalibrated satellite data inputs must be used. (RSS V7 and higher Ocean RTM)
- The objective begs the question: what to do when no satellite measurement exists?
  - Between swaths, near heavy rain, when time gaps are too far apart, etc.
  - Solution: use a model wind product as a first-guess wind solution to be nudged up or down by weighted in situ and satellite observations.
- To properly handle the differences between model, in situ, and satellite wind inputs, the VAM minimization technique [Atlas et al., 2011; Atlas et al., 1996; Hoffman et al., 2003] is used to solve for a global vector wind analysis solution that best fits all the varying, weighted inputs.
  - This method also allows constraints to be set on divergence, conservation of mass, etc.
- The result is CCMP 6-houly, 0.25-degree global vector-wind analysis fields for the span of the microwave satellite era (1987-present).

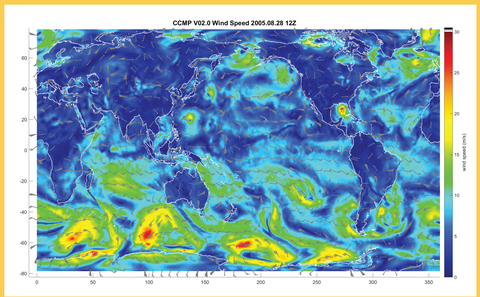


Figure 2. This figure depicts the newly re-processed CCMP V2.0 vector-wind analysis product for August 28th 2005. This is the 12Z map showing global wind speed in meter per second as the background color map and wind barbs depicting the wind direction field. This time was chosen to demonstrate an example of CCMP V2.0's wind analysis shortly before Hurricane Katrina made landfall, while the storm was still situated in the Gulf of Mexico. Wind direction is according to the oceanographic convention.

Table 1. CCMP V2.0 Product

Product	Cross-Calibrated Multi-Platform Ocean Winds
Version	2.0
Spatial Coverage	Region: Global Northernmost Latitude: 80 degrees Southernmost Latitude: -80 degrees Westernmost Longitude: 0 degrees Easternmost Longitude: 360 degrees
Temporal Coverage	1987-Jul-10 to 2015-Jul-30
Spatial Resolution	0.25 degrees (Latitude) x 0.25 degrees (Longitude)
Temporal Resolution	6 Hour
Latency	< 6 month lag (updated twice yearly)
Input Data Platform / Sensor / Data Version	AQUA / AMSR-E V7.0 GCOM-W1 / AMSR2 V7.2 TRMM / TMI V7.1 GPM / GMI V8.1 QUIKSCAT / SEAWINDS V4.0 (Ku-2011) METOP-A / ASCAT V2.1 DMSP-F08 / SSM/I V7.0 DMSP-F10 / SSM/I V7.0 DMSP-F11 / SSM/I V7.0 DMSP-F13 / SSM/I V7.0 DMSP-F14 / SSM/I V7.0 DMSP-F15 / SSM/I V7.0 DMSP-F16 / SSMIS V7.0 DMSP-F17 / SSMIS V7.0 Coriolis / WindSat V7.0.1
Data Format	NetCDF-4, CF-1.6 compliant
File Size	~25 Mb per file
Parameter	ocean surface vector winds at 10 meters height
Parameter Range	0 to 50 m/s
Unit of Measurement	meters/second

CCMP V2.0 Data Access & Use

- CCMP V2.0 can be accessed here:
  - http://remss.com/ccmp
  - ftp://ftp.remss.com/ccmp

Data Use Warnings:
- CCMP V2.0 is not suitable for studying global trends.
- CCMP V2.0 is biased low at high wind speeds (>20 m/s).
- CCMP V2.0 is NOT an extension of CCMP V1.1.

Table 2. CCMP Version Changes

	CCMP V2.0	CCMP V1.1 First Look
Satellite data	RSS RTM V7 and higher	RSS RTM pre-V3 to V7 (depending on year and instrument)
Number of instruments	15, added F16, AMSR2, ASCAT-A, GMI; removed SeaWinds	12
Model background	0.25-deg ERA-Interim Wind Re-Analysis	1-deg ECMWF-Operational Wind Analysis (1999-2011) 1-deg ERA-40 Wind Re-Analysis (1987-1999)
In situ data	Quality-filtered moored buoy data from PMEL, NDBC, & MEDS	GTS buoy and ship data
Years of coverage	1987.07 to 2015.07	1987.07 to 2011.12
Products	L3.0 daily file	L2.5 orbital L3.0 daily L3.5 5-day and monthly
Data format (Level 3)	netCDF 4 CF-1.6 compliance	netCDF 3
Data Producers	RSS	AER / GSFC
Data access	RSS FTP	PODAAC

CCMP V2.0 versus V1.1 Firstlook

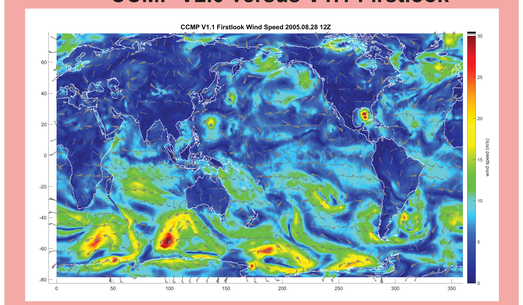
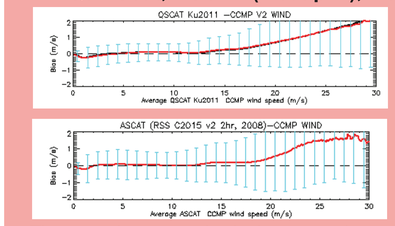


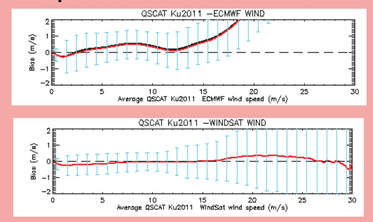
Figure 3. This figure depicts the older CCMP V1.1 firstlook vector-wind analysis product for August 28th 2005. This is the 12Z map showing global wind speed in meter per second as the background color map and wind barbs depicting the wind direction field. This figure serves to highlight the newly reprocessed CCMP V2.0 (Figure 2) vector-wind map's improved resolving of high-wind features in a more physically-consistent manner. Notice V1.1's bimodal structure of Hurricane Katrina. V2.0 benefits from the higher-resolution background model wind and improved scatterometer wind retrievals and rain flagging.

CCMP V2.0 Validation & Comparison

Wind Speed Validation: QuikScat, ASCAT (MetOp-A), ECMWF-Operational vs CCMP V2.0

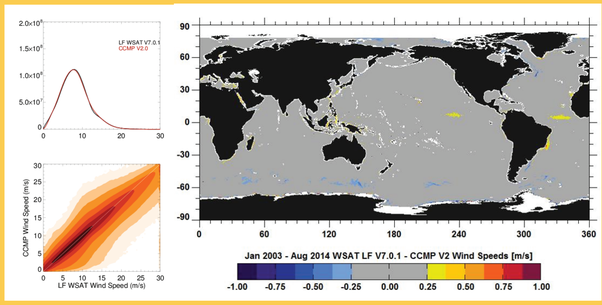


The two above panels depict comparisons of collocated and spatio-temporally interpolated CCMP V2.0 to RSS's QuikScat (Ku-2011) and ASCAT (C2015) on MetOp-A. The plots show good agreement (within 0.5 m/s) between the active microwave scatterometer wind speed retrievals up to ~20 m/s. At higher winds, the model background is bringing CCMP V2.0 down and this CCMP V2.0 is biased low at high wind.



The two above panels depict comparisons of collocated and spatio-temporally interpolated RSS's QuikScat (Ku-2011) to ECMWF-Operational Analysis model product and RSS's WindSat V7.0.1 low-frequency wind speed product. The plots show that QuikScat and WindSat have good agreement (within 0.5 m/s) at nearly all wind speeds. However, comparison of the ECMWF wind product shows model winds are biased low at high wind speeds (above 15 m/s).

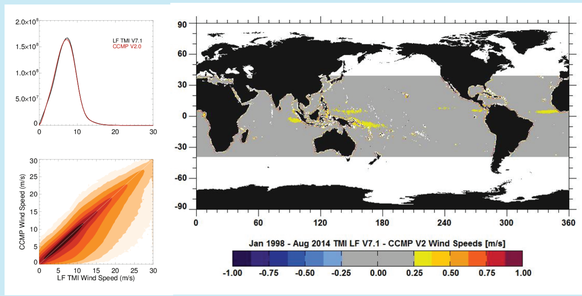
Wind Speed Comparison: WindSat V7.0.1 vs CCMP V2.0



These figures depict a comparison of RSS's WindSat V7.0.1 low-frequency (LF) wind speed retrieval. WindSat is collocated with spatio- temporal interpolation to the CCMP V2.0 wind analysis for the period from 2003 to 2014. The LF wind retrieval from WindSat is a passive microwave retrieval of wind speed using the following channels (in GHz): 10.7 V&H, 18.7 V&H, 23.8 V&H, and 37.0 V&H.

The comparison shows good agreement between to the two datasets with a bias of -0.01 m/s and a standard deviation of 0.67 m/s (WindSat - CCMP). The differences are coming from regions of persistent clouds and large wind events.

Wind Speed Comparison: TMI V7.1 vs CCMP V2.0



These figures depict a comparison of RSS's TRMM Microwave Imager (TMI) V7.1 low-frequency (LF) wind speed retrieval. TMI is collocated with spatio-temporal interpolation to the CCMP V2.0 wind analysis for the period from 1998 to 2014. The LF wind retrieval from TMI is a passive microwave retrieval of wind speed using the following channels (in GHz): 10.65 V&H, 19.35 V&H, 21.3 V&H, and 37.0 V&H.

The comparison shows good agreement between to the two datasets with a bias of 0.04 m/s and a standard deviation of 0.59 m/s (TMI - CCMP). The differences are coming from regions of persistent clouds and rain.

References & Acknowledgements

Atlas, R., R. N. Hoffman, J. Ardizzone, S. M. Leidner, J. C. Jusem, D. K. Smith, D. Gombos, 2011: A cross-calibrated, multiplatform ocean surface wind velocity product for meteorological and oceanographic applications. Bull. Amer. Meteor. Soc., 92, 157-174. doi: 10.1175/2010BAMS2946.1

Atlas, R., R.N. Hoffman, S.C. Bloom, J.C. Jusem, and J. Ardizzone, 1996: A multiyear global surface wind velocity dataset using SSM/I wind observations. Bull. Amer. Meteor. Soc., 77, 5, 869-882.

Hoffman, R. N., M. Leidner, J. M. Henderson, R. Atlas, J. V. Ardizzone, and S. C. Bloom, 2003: A two-dimensional variational analysis method for NSCAT ambiguity removal: methodology, sensitivity, and tuning. Journal of Atmospheric & Oceanic Technology, 20, 585-605.

The authors acknowledge Deborah K. Smith (RSS) and Dr. Lucrezia Ricciarduli (RSS) for their contributions to the Validation and Comparison section of this work. The authors would also like to acknowledge Mark Leidner (AER) and Joe Ardizzone (NASA GSFC) for their assistance in coding and porting the CCMP project for operation at RSS.