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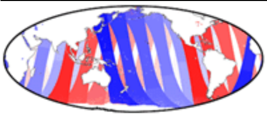

SCATTEROMETRY & OCEAN VECTOR WINDS
Satellite Studies

Overview

What is Scatterometry?

Scatterometers are unique among satellite remote sensors in their ability to determine the wind direction over water. Scatterometers can provide a wealth of wind velocity observations over the earth's bodies of water. These wind observations have a wide variety of applications including weather forecasting, marine safety, commercial fishing, El Nino prediction and monitoring, and long term climate studies. The exceptional accuracy of the recent NASA Scatterometer (NSCAT) is leading to development of new applications.

At COAPS, we have found that examining animations of scatterometer winds can inspire new scatterometry applications. We have generated wind animations (NSCAT, QSCAT) for 37 overlapping regions spanning the global oceans.

How Scatterometry Works

To date, all scatterometers have been active microwave sensors: they send out a signal and measure how much of that signal returns after interacting with the target. Microwaves are Bragg scattered by short water waves; the fraction of energy returned to the satellite (backscatter) is a function of wind speed and wind direction. The wind speed can be determined from the strength of the backscatter signal.

The wind direction is found by determining the angle that is most likely to be consistent the backscatter observed from multiple angles. In roughly 5 minutes, a satellite in a low polar orbit will move far enough to view a point on water surface from angles spanning 90º. The mathematical function describing the fit of the observed backscatter (as a function of the wind direction) usually has multiple minima (ambiguities). Ideally, the best fit corresponds to the true direction of the wind. Typically, the next best fit is in approximately the opposite direction, and the next two minima are in directions roughly perpendicular to the wind direction. The process of selecting the direction from among the multiple minima is called ambiguity selection. Noise in the observations can change the quality of fit and thereby cause incorrect directions (also known as aliases) to be chosen. NSCAT ambiguity selection has proven to be much better than previous scatterometers, with roughly 90% successful selection of the correct ambiguity. Most of the problems with ambiguity removal occur for low wind speeds, where the signal is weak and easily confounded by noise. For wind speeds greater than 8 ms^{-1} successful ambiguity removal is near certain.

NSCAT provided wind observations with a superb combination of unprecedented coverage, spatial and temporal resolution, and ease of processing. However, many applications require these winds in a regular grid, without gaps in coverage (see example of daily coverage over the Indian Ocean). The pattern of wind observations follows the satellite orbits rather than a regularly patterned grid. Therefore, the winds from orbital swathes have to be transferred to a grid, and gaps in the observations have to be filled in a reasonable manner. COAPS has produced several of these gridded products, as well as gridded products from other observations.

Table of Previous and Ongoing Satellite Scatterometers

Short Background	Period in Service	Spatial Resolution	Product Grid Spacing	Scan Characteristics	Operational Frequency	Detailed Background
SeaSat-A Scatterometer	1978/7/7 - 1978/10/10	50 km	100 km	Two sided Double swath	Ku band (14.6 GHz)	Background
ERS-1 Scatterometer	1991/7 - 1997/5/21	50 km	50 km	One sided Single swath	C band (5.3 GHz)	Background
ERS-2 Scatterometer	1997/5/21 - 2011/7	50 km	50 km	One sided Single swath	C band (5.3 GHz)	Background
NSCAT	1996/9/15 - 1997/6/30	25 km	25 km	Two sided Double swath	Ku band (13.995 GHz)	Background
SeaWinds on QuikSCAT	1999/7/19 - 2009/11/23	25 km	12.5 km	Conical scan One wide swath	Ku band (13.4 GHz)	Background
SeaWinds on ADEOS II	2002/12 - 2003/10	25 km	12.5 km	Conical scan One wide swath	Ku band (13.4 GHz)	Background
ASCAT-A	2006/10 - Present	50 km	12.5 km	Two sided Double swath	C band (5.255 GHz)	Background
ASCAT-B	2012/10/29 - Present	50 km	12.5 km	Two sided Double swath	C band (5.255 GHz)	Background
OCEANSAT2	2009/9/23 - 2014/	25 km	25 km	Conical scan One wide swath	Ku band (13.5 GHz)	Background
HY-2A	2011/9? - Present	25 km	25 km	Conical scan One wide swath	Ku band (13.256 GHz)	Background
ISS RapidSCAT	2014/09/20 - Present	25 km	12.5 km	Conical scan One wide swath	Ku band (13.4 GHz)	Background

ERS Scatterometers

The scatterometers on ERS-1 is the same design as the scatterometer on ERS-2. The data gathered by these scatterometers covers almost a decade of vector winds. One use of this data results in improved weather forecasts. The ERS scatterometers differ from others in that they operate on C-band (which has longer waves than Ku-band), they cover less area (one 500km wide swath), and they are not always in operation.

The NASA Scatterometer (NSCAT)

The NASA Scatterometer (NSCAT) was launched on the polar orbiting ADEOS satellite and measured wind speeds from Sept. 15, 1996 to June 30, 1997. The observational coverage was 600 km wide swaths on both sides of the satellite. The resolution within the swaths was approximately 25 km. Each swath was sampled by fore, mid, and aft beams; each of which sampled from different directions. One beam had two polarizations, which provided another independent backscatter observation that could be used in ambiguity selection. Wind speeds and directions are calculated where there were observations from each of these beams. Cloud cover has little impact on the backscatter, so there were few instances of dropout over water.

QuikSCAT

QuikSCAT was a new design of scatterometer developed for the SeaWinds project. It was tentatively scheduled to be launched on May 23, 1999. The ocean vector wind record begins on the 200th day of 1999, and extends to the 324th day of 2009: a greater than 10 year record. QuikSCAT accuracy characteristics were similar to NSCAT, and roughly it had double the coverage. QuikSCAT's coverage will extend an additional 100 km to each side of the NSCAT swaths, and the gap between the NSCAT swaths will be filled.

SeaWinds on ADEOS II

ADEOS II was the originally proposed platform for a SeaWinds scatterometer. A goal of this mission is much higher resolution winds. The observation density for SeaWinds is much greater than for NSCAT. However, the increased observation density is mostly in one dimension; consequently, the improved resolution is in only one dimension. The footprint used to determine the winds changes from 25 x 25 km to 25 x 6 km.

ASCAT-A

The Advanced SCATterometer (ASCAT) is a real aperture radar operating at 5.255 GHz (C-band) and using vertically polarised antennas. It transmits a long pulse with Linear Frequency Modulation ('chirp'). Ground echoes are received by the instrument and, after de-chirping, the backscattered signal is spectrally analysed and detected. In the power spectrum, frequency can be mapped into slant range provided the chirp rate and the Doppler frequency are known. The above processing is in effect a pulse compression, which provides range resolution.

ASCAT-B

This dataset from the ASCAT-B operational near-real-time Level 2 ocean surface wind vector retrievals from the Advanced Scatterometer (ASCAT) on MetOp-B at 25 km sampling resolution (note: the effective resolution is 50 km). ASCAT is a C-band dual swath fan beam radar scatterometer.

ISRO Scatterometer on OCEANSAT2

The ISRO scatterometer is similar to QuikSCAT; however, it is in a much lower orbit (720km) and has greater incidence angles to match QuikSCAT's 1800km swath. It is currently in a calibration/validation phase.

HY-2A Scatterometer

The HY-2A scatterometer is similar to QuikSCAT; however, it is in a higher orbit (963km) and has smaller incidence angles. It is currently in a calibration/validation phase.

ISS RapidSCAT

The RapidSCAT instrument replaced NASA's QuikScat Earth satellite. The instrument is currently on board the International Space Station. 900-kilometer swath during each orbit provides coverage of the majority of the ocean between 51.6 degrees north and south latitude in 48 hours.

Table of Future Satellite Scatterometers

Short Background	Intended Period of Service	Spatial Resolution	Product Grid Spacing	Scan Characteristics	Operational Frequency	Detailed Background
HY-2B Scatterometer	2015 - 2018+	25 km	12.5 km	Conical scan one wide swath	Ku band	
SCATSAT	2016 - 2021	25 km	12.5 km	Conical scan one wide swath	Ku band	
FY-3E	2016 - 2020	25 km	12.5 km	Conical scan one wide swath	C and Ku band	
Meteor-M N3	2017 - 2020	25 km	12.5 km	Conical scan one wide swath	Ku band	
METOP-C Scatterometer	2017 - 2023+	50 km	12.5 km	Two sided Double swath	C band	
Oceansat-3	2018 - 2023	25 km	12.5 km	Conical scan one wide swath	Ku band	
CFOSAT	2018 - 2021	25 km	12.5 km	Conical scan one wide swath	Ku band	Background

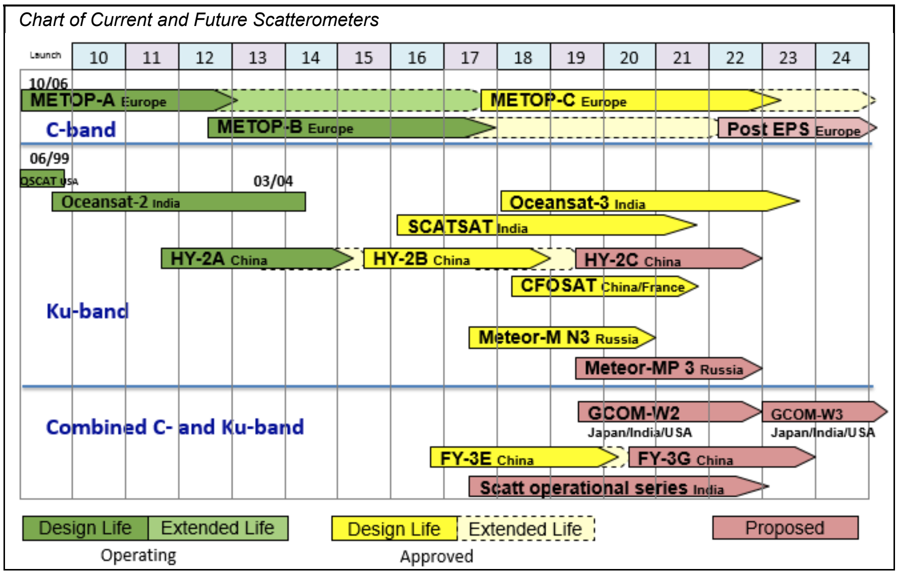
Chart of Current and Future Scatterometers
Launch
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
10/06
METOP-A Europe
METOP-C Europe
C-band
METOP-B Europe
Post EPS Europe
06/99
QSCAT USA
03/04
Oceansat-2 India
Oceansat-3 India
SCATSAT India
HY-2A China
HY-2B China
HY-2C China
CFOSAT China/France
Ku-band
Meteor-M N3 Russia
Meteor-MP 3 Russia
GCOM-W2
Japan/India/USA
GCOM-W3
Japan/India/USA
Combined C- and Ku-band
FY-3E China
FY-3G China
Scatt operational series India
Design Life
Extended Life
Operating
Design Life
Extended Life
Approved
Proposed