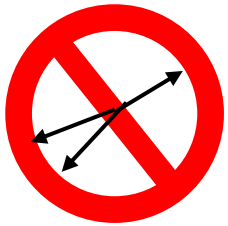
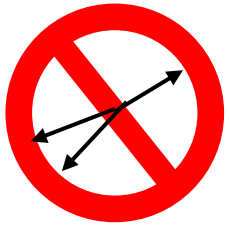
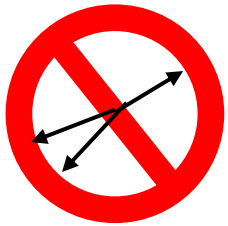

Remote Sensing Systems
www.remss.com

Two-Look Polarimetric (2LP) Microwave Radiometers for Ocean Vector Wind Retrieval

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Remote Sensing Systems

Shannon Brown

Jet Propulsion Laboratory

IOVWST Meeting

Brest, France

June 2-4, 2014

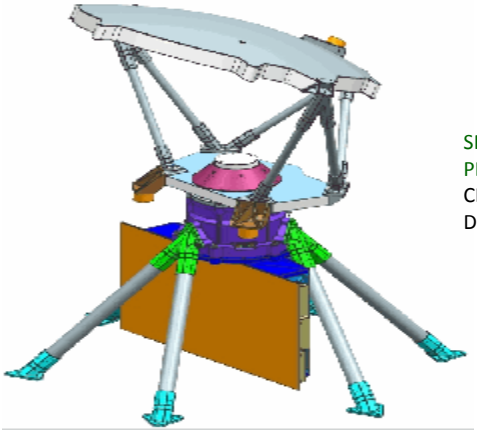
Introduction

- US Department of Defense (DoD) recently funded a number of studies to defined future MW Weather Sensors (follow-on to SSM/I and SSM/IS programs)
- This time, priority was given to Ocean Vector Wind Retrievals
- Low-Cost was also a major requirement
- At least two of these studies recommended a two-look polarimetric (2LP) microwave radiometer: full 360^{o} view, fully polarimetric.
- JPL's 2LP radiometer, called the Compact Ocean Wind Vector Radiometer (COWVR) is currently selected for a space demonstration in the 2016 timeframe.

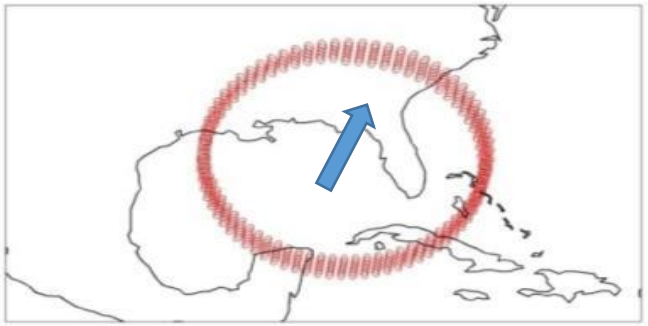
Jet Propulsion Laboratory
California Institute of Technology

COWVR Instrument Overview

- Fully polarimetric microwave radiometer (18 channels):
  - 18.7, 23.8, 33.9 GHz
  - V,H,+45,-45,LCP,RCP
  - < 0.3 K TB uncertainty
- 360^{o} conical imaging
  - Rotation rate: 30 RPM
  - Spatial resolution: < 35 km
    - 34x21 km@18.7 GHz; 18x11 km@33.9 GHz
  - Swath width: 1012 km
  - Earth Incidence Angle: 51.7^{o}
- Internal Calibration
  - Correlated noise sources
  - PIN-diode Dicke switches
- Resources
  - Data rate: 77 kbps
  - Mass: 58.7 kg
  - Avg. Power: 41 W (inst. power)
- Heritage
  - Jason-2/3 Advanced Microwave Radiometer
- EDRs
  - Wind vector, precipitation, sea ice, precipitable water, cloud liquid water, snow depth, tropical cyclone intensity



SRR - Aug 8, 2013
PDR – Jan 9, 2014
CDR - June 10, 2014
Delivery: September 2015



For information on COWVR contact Shannon Brown (PI) shannon.t.brown@jpl.nasa.gov

Predicting 2LP Performance with WindSat

- Predict the performance of 2LP radiometers using actual WindSat fore and aft observations.
- First Time (to our knowledge) WindSat fore and aft data have been simultaneously used for retrievals
- Focus on performance before ambiguity removal algorithm to look at inherent skill of sensor
  - Skill Rate: Percentage of time first-ranked ambiguity is closest to true direction
  - Standard Deviation of First-Rank Ambiguity relative to buoys

2LP OVW Chi-Squared Algorithm

$$\chi^2\left(\phi_{W,j}\right)=\sum_i \frac{\left[T_{B,meas,i}-T_{B,rtm}\left(T_S,W,\phi_{W,j},V,L,\theta_i,\varphi_i\right)\right]^2}{\mathrm{var}\left(T_{B,i}\right)}$$

- RSS RTM: *Meissner and Wentz* [2006]; *Meissner and Wentz* [2012]
- 18 'Flavors' of Observations provide a unique determination of wind direction.

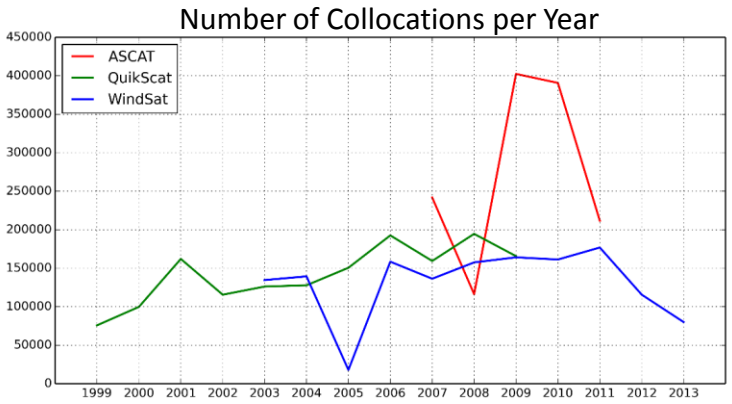
Frequency (GHz)	Channel Combination	Expected Error (K)
10.7 GHz	V for-aft	0.3
	H for-aft	0.4
	T3 for	0.3
	T3 aft	0.3
	T4 for	0.2
	T4 aft	0.2
18.7 GHz	V for-aft	0.4
	H for-aft	0.7
	T3 for	0.2
	T3 aft	0.2
	T4 for	0.1
	T4 aft	0.1
37.0 GHz	V for-aft	0.6
	H for-aft	1.0
	T3 for	0.2
	T3 aft	0.2
	T4 for	0.1
	T4 aft	0.1

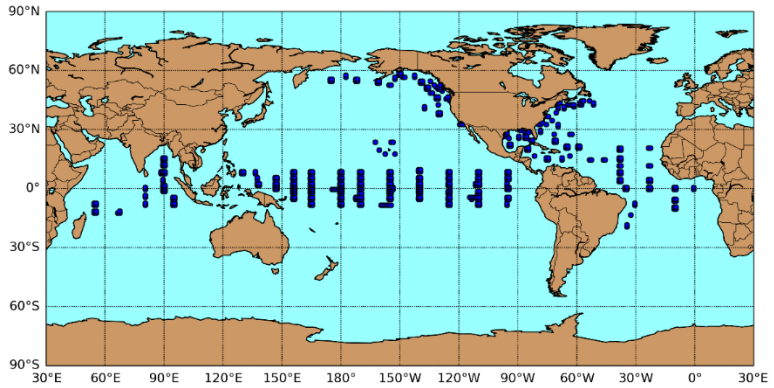
Satellite Datasets

- WindSat 2LP
  - *Hilburn* [2014] http://images.remss.com/papers/rsstech/2014_Hilburn_053014_WindSat_L2A_Product_Specification.pdf
  - *Hilburn, Meissner, Wentz, and Brown* [in preparation]
  - Time period: 2003-2014
- QuikScat (V4)
  - Ku-2011 GMF: *Ricciardulli and Wentz* [2011]
  - Time period: 1999-2009
- ASCAT (V1)
  - Consistent GMF for Ku- and C-bands: *Ricciardulli and Wentz* [2012]
  - Scatterometer Climate Data Records: *Ricciardulli and Wentz* [2014]
  - Time period of available data: 2007-2011
- Quality-control
  - "Rain free" requires radiometer rain = 0 mm/hour
  - Use sweet zone (3 or more flavors) for QuikScat, unless otherwise noted as full swath
  - Exclude retrievals with large sigma-0 residual (larger than 1.9)

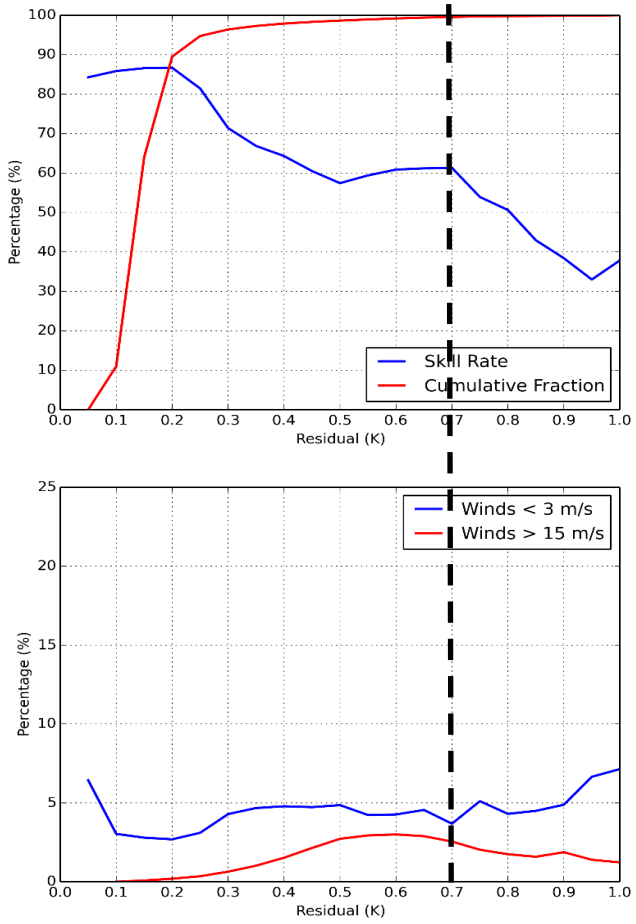
In Situ Datasets

- Buoys: NDBC, MEDS, TAO, TRITON, PIRATA, RAMA
- Spatial radius: 25 km
- Temporal radius: 30 minutes
- WindSat had significant data outages in 2005
- From 2012 onward, buoy collocations decrease due to NOAA budget cuts for annual servicing





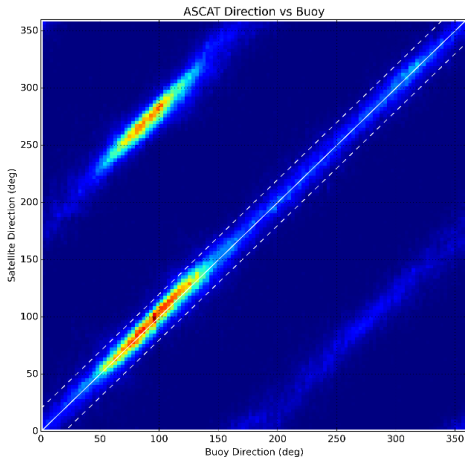
WindSat 2LP vs Chi-Square Residual



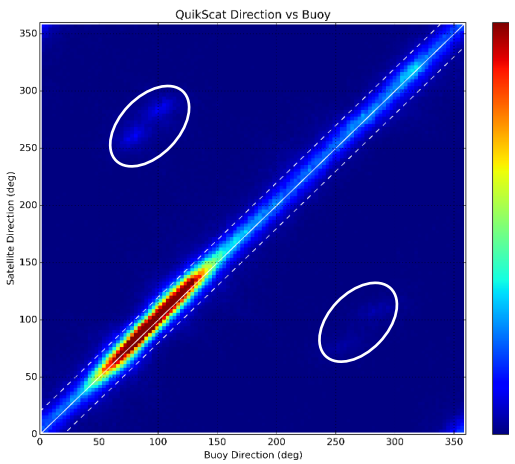
- The WindSat 2LP algorithm returns ambiguities ranked by sum of measured minus model TB difference squared, weighted by inverse of expected variance
- TOP:
  - The skill rate is better than 85% for residuals below 0.2 K, which is 90% of the vectors
  - The skill rate is better than 60% for residuals below 0.7 K, which is 99.6% of dataset
- BOTTOM:
  - Residuals above 0.7 K do not preferentially select either low or high winds
- Thus, using 0.7 K as q/c threshold for rest of the statistics in this presentation; removes 0.4% of data

First Ranked Ambiguity vs Buoy Direction

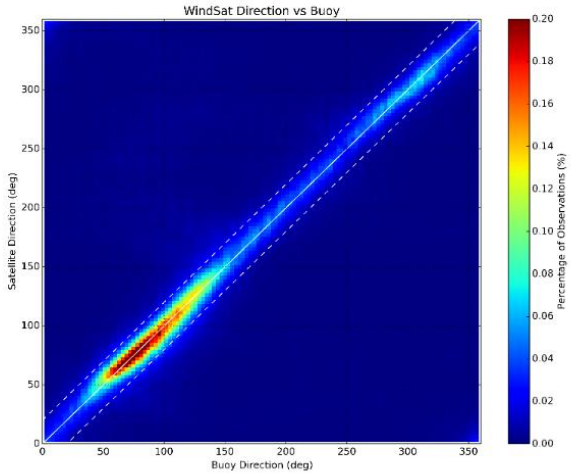
ASCAT



QuikScat



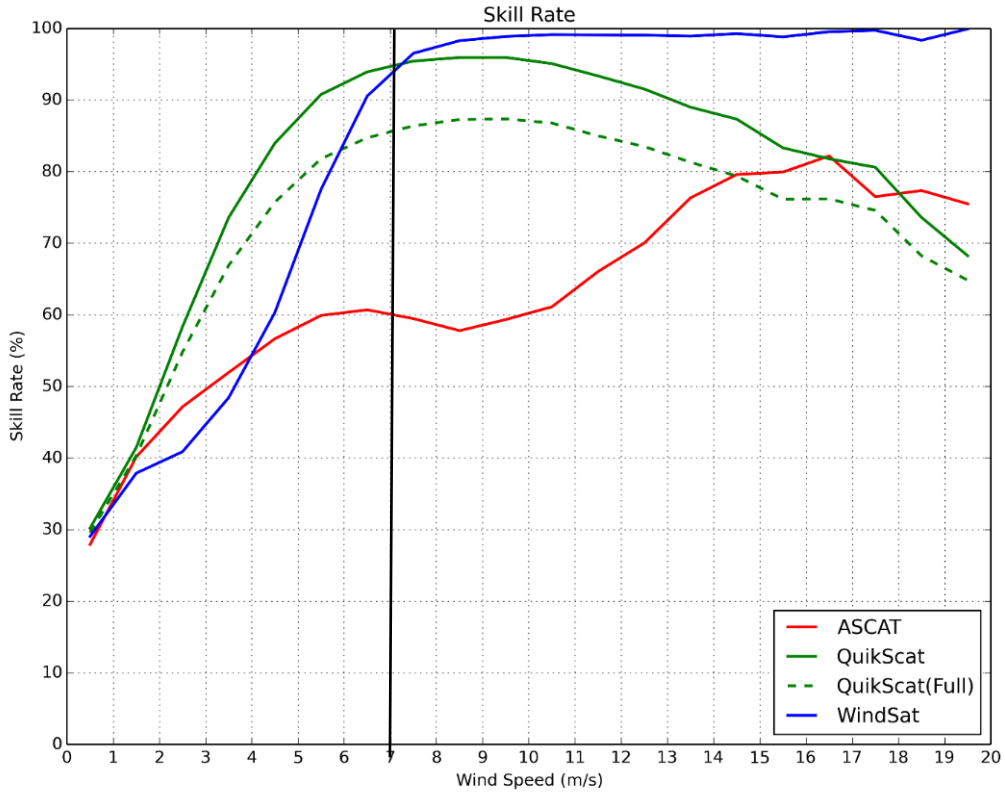
WindSat



- Shown: percentage of data in 3 deg by 3 deg bins of wind direction (meteorological)
- Rain free, buoy wind speeds > 3 m/s
- Dashed lines: +/- 20 deg

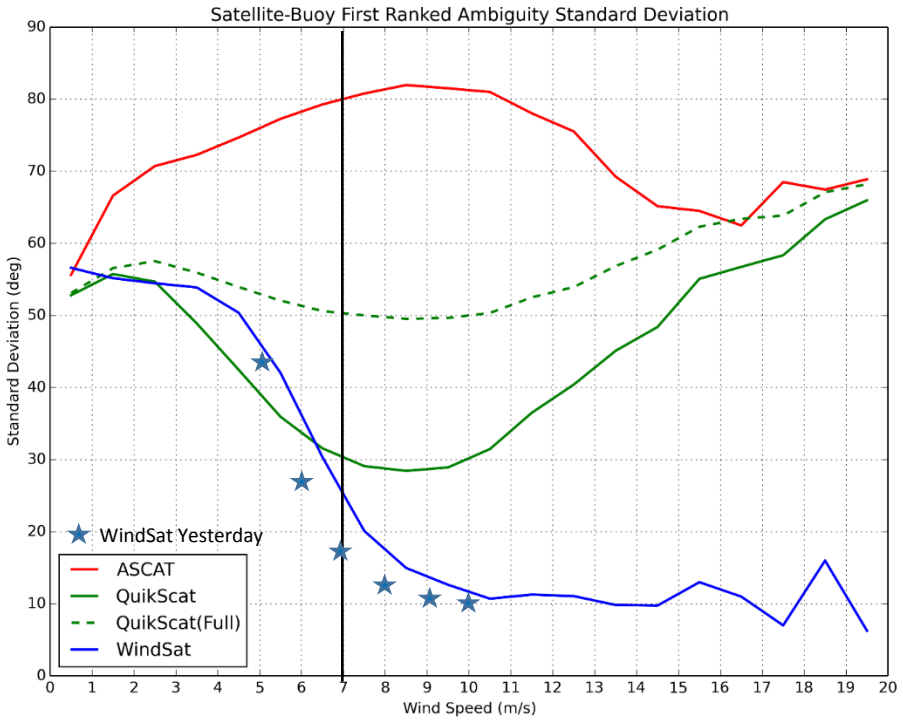
Dataset	% within 20 deg of buoy
ASCAT	54.45
QuikScat	82.18
QuikScat (full)	74.08
WindSat	72.90

Skill Rate vs Wind Speed



Dataset	Skill Rate (%)
ASCAT	58.7
QuikScat (full)	79.6
WindSat	85.3
QuikScat	87.6

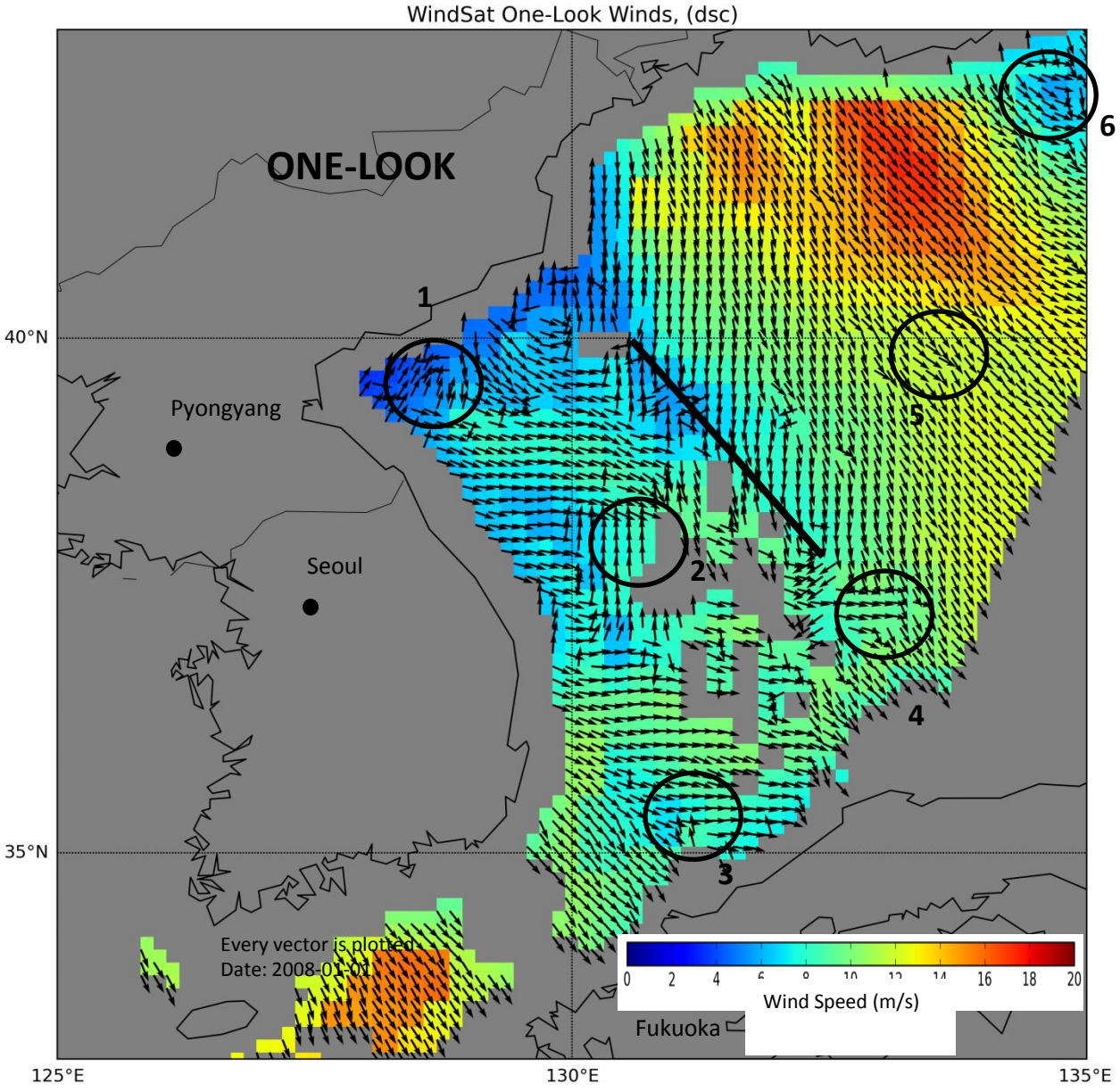
Directional Standard Deviation vs Wind Speed



- The only satellite to achieve better than 20 deg SD for FRA is WindSat, which does so for winds above 7 m/s
- WindSat achieves about 10 deg SD for winds above 10 m/s
- Understand that SDs > 50 deg (i.e. ASCAT) are due to relatively small number of very large differences (usually +/- 180 deg)
- QuikScat SD are slightly better than WindSat for winds below 6 m/s
- QuikScat full swath is considerably worse than sweet zone for most winds
- QuikScat SD increases for winds above 9 m/s

2LP radiometers do not require an ancillary wind field for ambiguity removal for winds above 6-7 m/s.

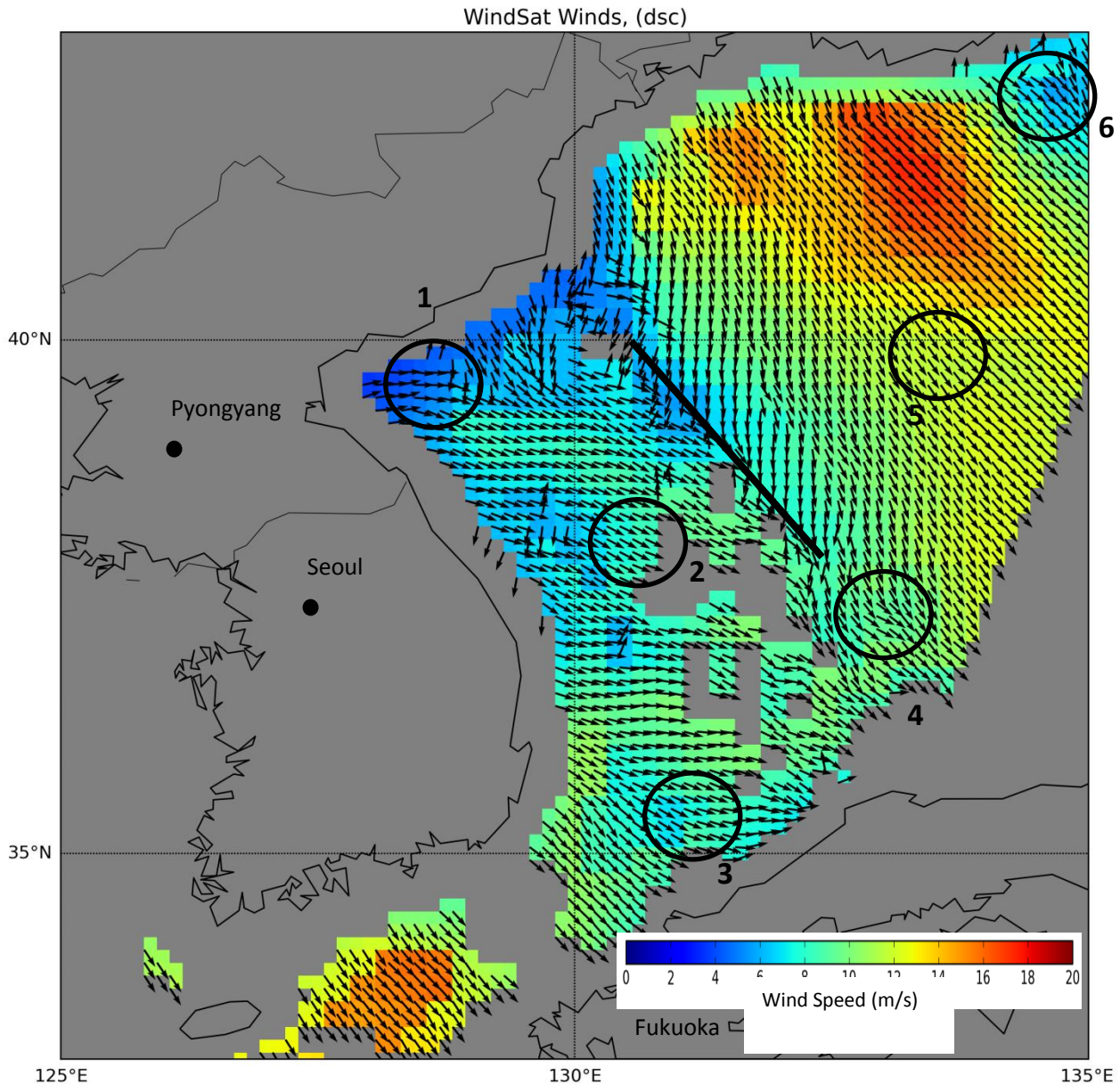
Sea of Japan: One-Look Example



<u>One-look has problems in:</u>

- Low wind speeds (1,3,6)
- Near rain (2,4)
- Moderate winds (5)
- Convergence zone (heavy black line) not clearly defined because of noisy vectors

Sea of Japan: Two-Look Example

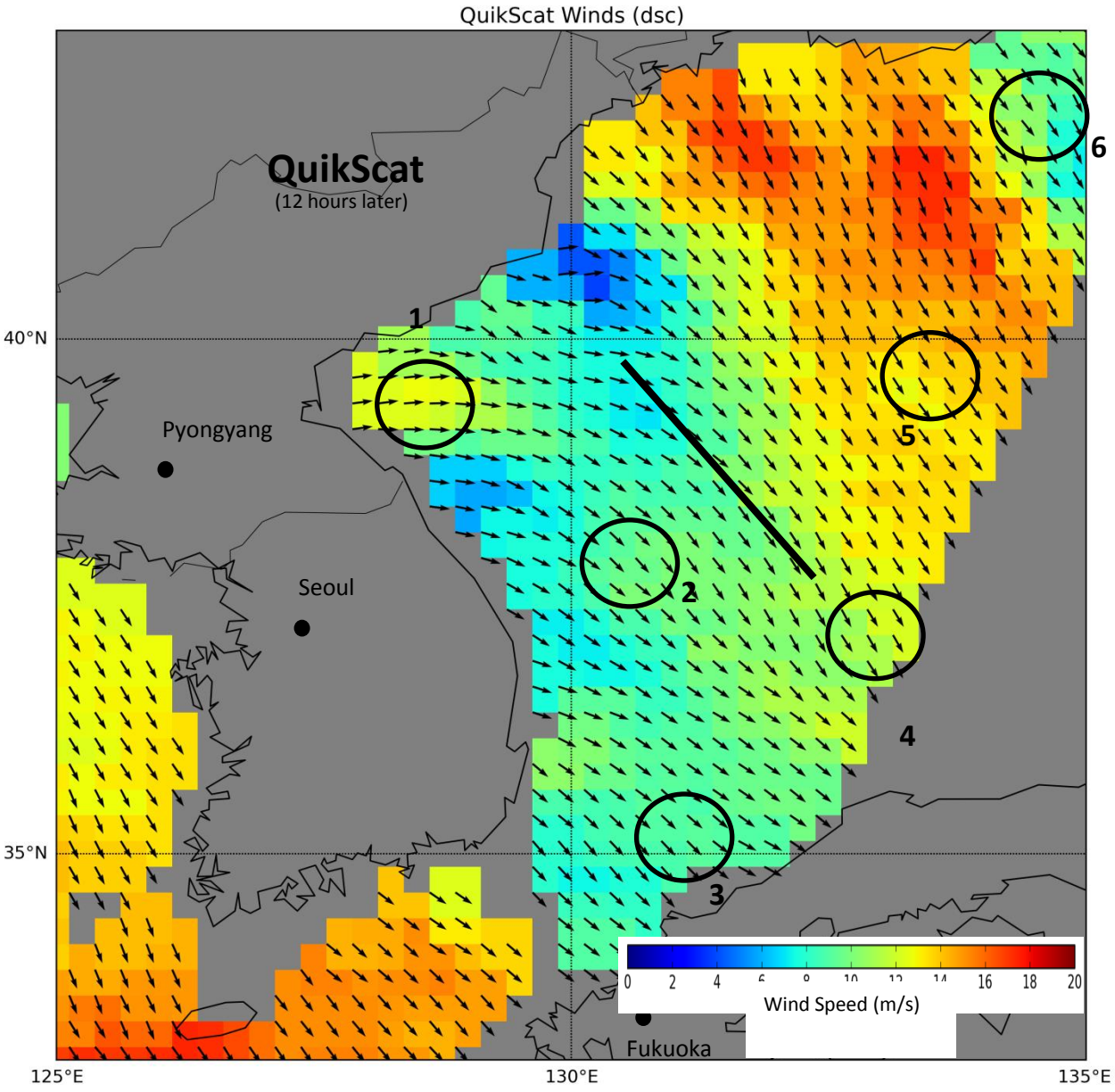


Two-look is better in:

- Low wind speeds (1,3,6)
- Near rain (2,4)
- Moderate winds (5)
- Convergence zone (heavy black line) is clearly defined

Every vector is plotted
Date: 2008-01-01

Sea of Japan: Quik-Scat Example



- Different time of day
- Convergence zone… what convergence zone?

Every vector is plotted
Date: 2008-01-01

Conclusions

- 2LP radiometers provide ocean surface vector winds of comparable accuracy to scatterometers
- Vector wind retrievals from 2LP radiometers do not require an ancillary wind field for ambiguity removal for winds above 6-7 m/s.
- 2LP radiometers can also provide a full suite of climate variables:
  - Sea surface temperature through clouds (C-band required)
  - Total water vapor
  - Cloud liquid water path
  - Surface rain rate
  - Sea-Ice and snow
- Performance in rain need to be investigated

2LP Radiometers Appear to be a Cost-Effective Alternative for Sustainable OVW Climate Measurements

Take A Look For Yourself: 11 Years of Retrievals – REMSS.COM