The Potential of Polarimetric Radiometry for Numerical Weather Prediction

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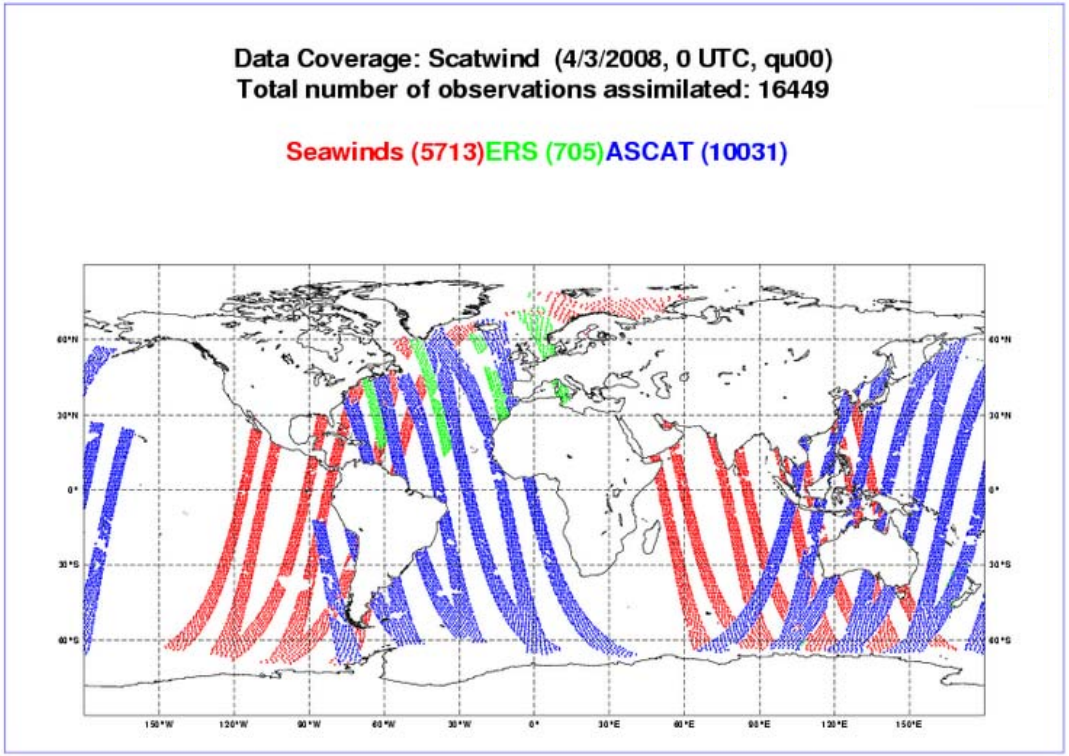
Contents

An overview of the work performed to examine both the expected and actual performance of wind vectors from the WindSat radiometer

- The existing use of satellite surface wind vectors at the Met Office
- Expected WindSat Error Characteristics
- Forecast impact of synthetic WindSat obs
- Evaluation of real WindSat retrievals
- Forecast impact of Windsat retrievals
- Summary

Current use of satellite wind vectors

- Three scatterometers in space (most recent is ASCAT – first assimilated in November 2007).



- We deal with the directional ambiguity within our assimilation scheme

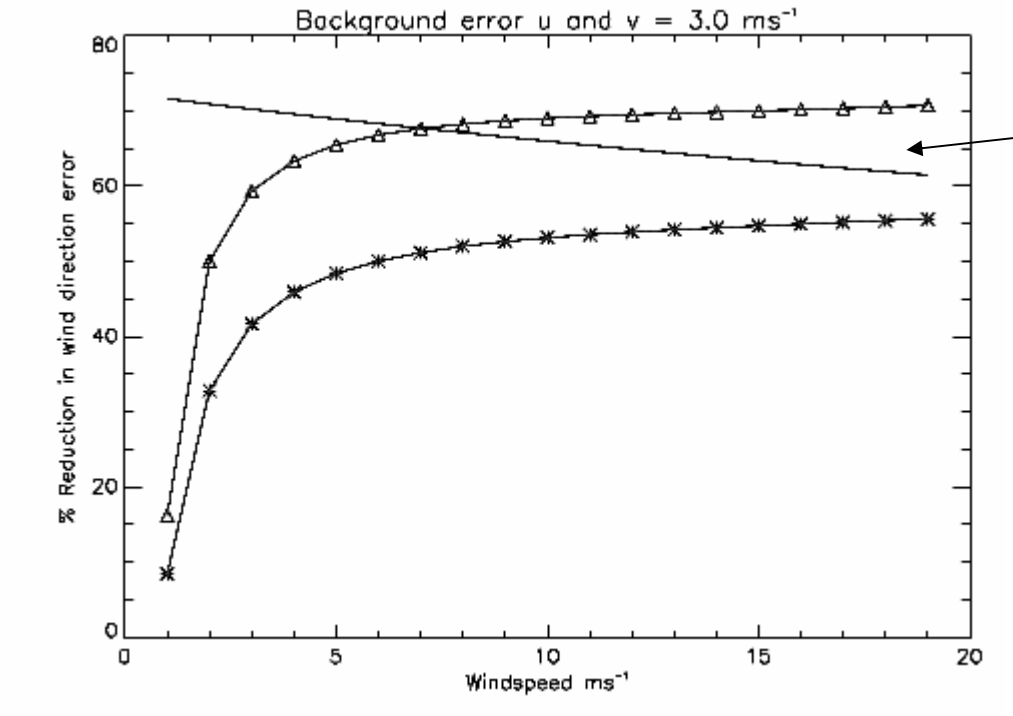
Current use of satellite wind vectors

- The introduction of Seawinds into our assimilation scheme and ASCAT both gave significant forecast impact.
- Impacts observed both in extra-tropical regions and in the forecast tracks of tropical cyclones.
- Our latest assimilation scheme (4D-Var) uses a linearised version of the forecast model – surface wind information can be propagated aloft.
- WindSat – of interest to us as
  - Robustness (QuikScat backup)
  - Early look at the type of data we may well receive in NPOESS area
  - Also Sea Surface Temperature and moisture information…

Information content Study

Use Observation-Modelled differences to evaluate "Worst Case" for WindSat

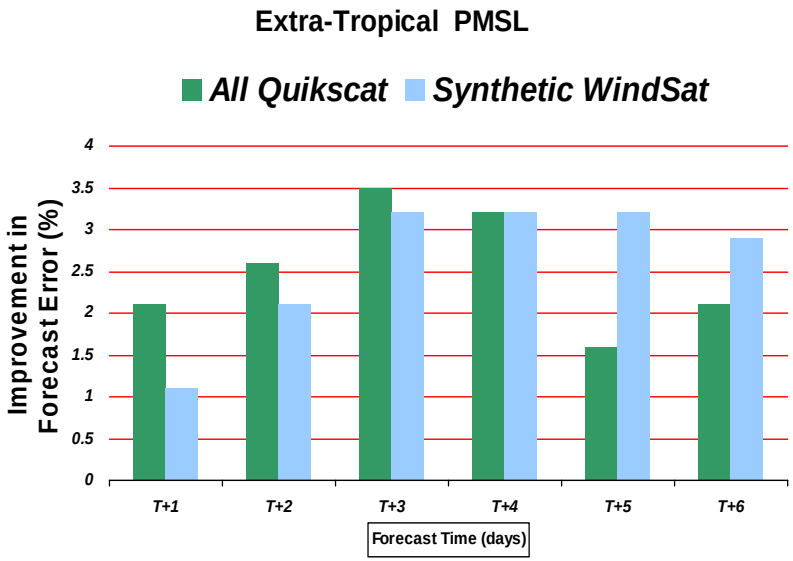
Traingles: dual view, Asterixs: single view



Scatterometer performance

Using QuikScat to simulate WindSat vectors

- Compare Forecast impact of assimilating QuikScat wind vectors in two modes:
  - All QuikScat – WindSpeed Range 2-25 ms^{-1}
  - High WindSpeed – “Synthetic” WindSat 8-25 ms^{-1}



- Larger analysis increments in the vicinity of Tropical Cyclones for All QuikScat

Evaluation of Real WindSat Retrievals

- Source: Environmental Data Records (EDRs) supplied by NRL. Retrieval uses scheme by Bettenhausen et al. (2005)
- Period: August/September 2005 (forecast impacts)

Real Time data from 2006 onwards.

Follow strategy for Scatterometers – compare wind retrievals with six hour forecast wind from Met O operational NWP model

WindSat Quality Control:

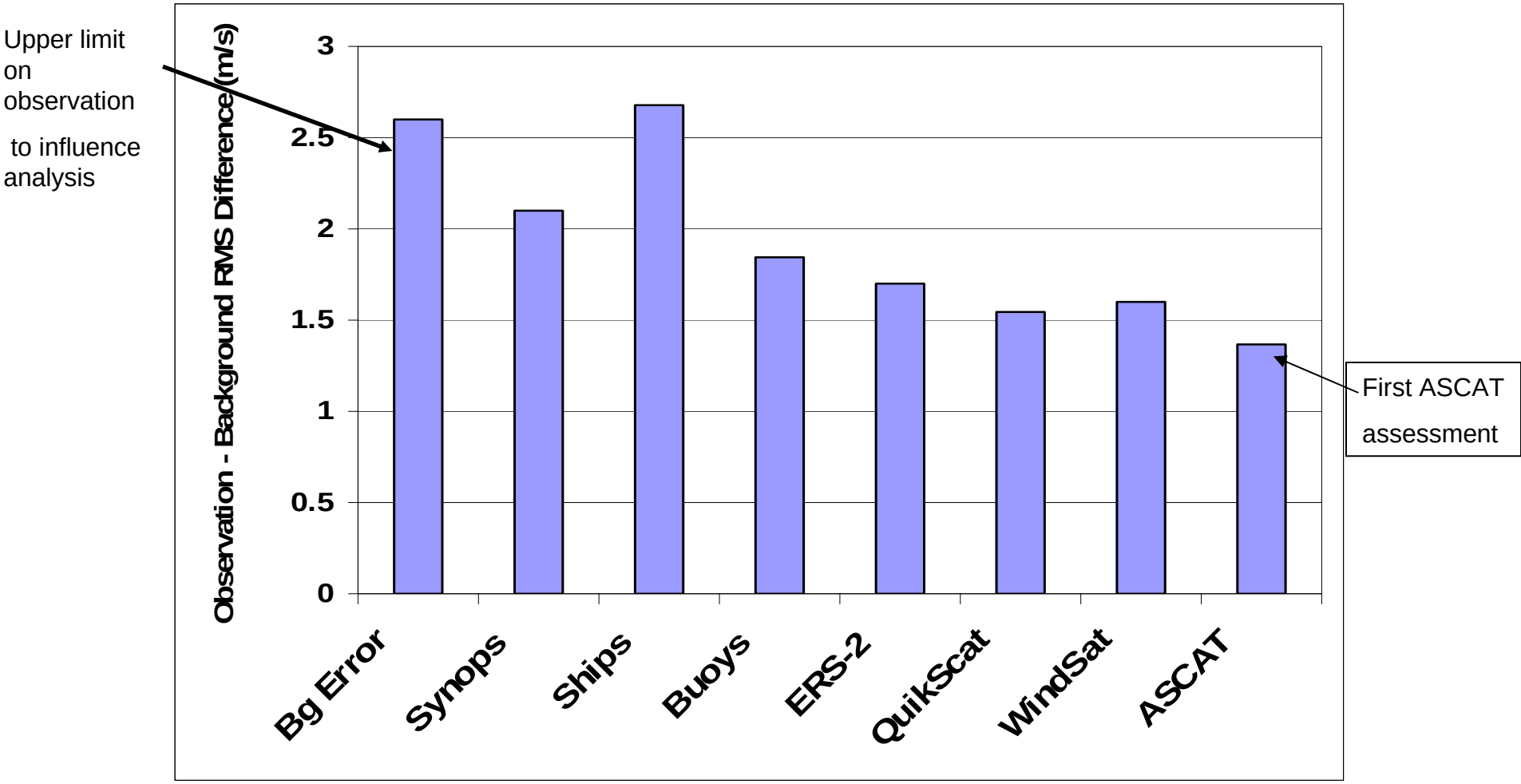
- Rain in field of view
- Retrieved LWP exceeds 0.1 mm
- Observation over sea-ice or close to coast
- Poor final fit of forward model to observed radiances

Evaluation of Real WindSat Retrievals

Wind Speed Range (m/s)	Standard Deviation of Observation – Background	
	Wind speed (m/s)	**Wind Direction (°)**
5-6	1.26 *1.29* **B**	21.0 *17.2*
6-7	1.20 *1.26* **B**	16.8 *14.2*
7-8	1.19 *1.24* **B**	13.9 *12.1*
9-10	1.34 *1.33*	10.5 *9.8*
10+	1.42 *1.49* **B**	8.6 *9.0* **B**

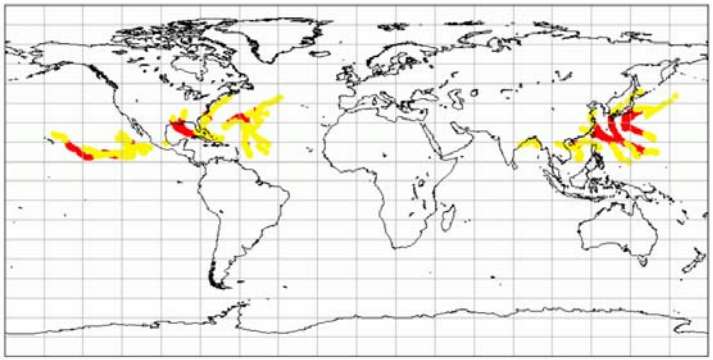
WindSat QuikScat

How does this compare to other observing systems?



Forecast Impact Evaluation

- Period mid-August 2005 – mid-Sept 2005



- Assimilation / Forecast system based on operations from mid -2005

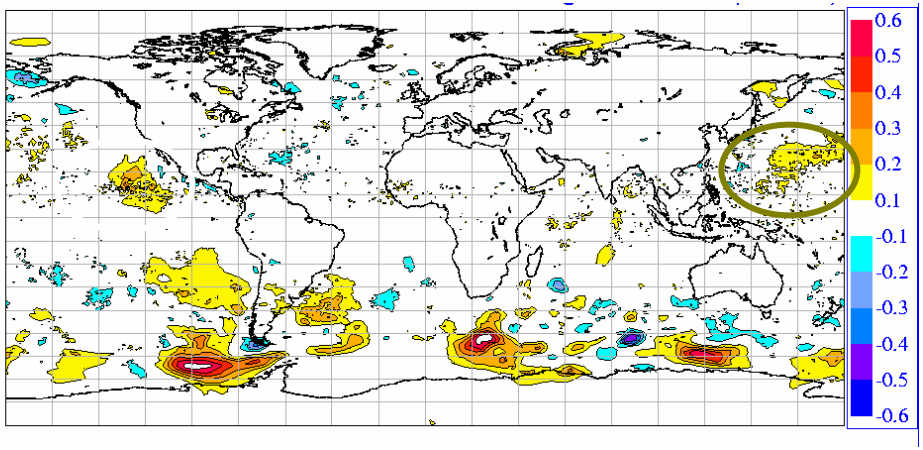
  Model Resolution horizontally ~60km, model top at 40km

  4D-Variational assimilation scheme – 4 analyses per day with data windows of 6 hours

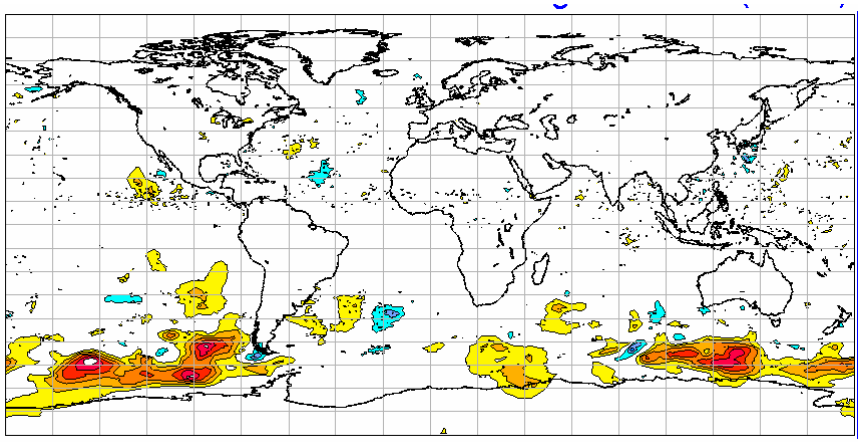
- *Control run* - operational assimilation (sounding data, station reports, etc) minus scatterometer
- *QuikScat run* – QuikScat on top of control
- *WindSat run* – WindSat on top of control

Analysis Increments

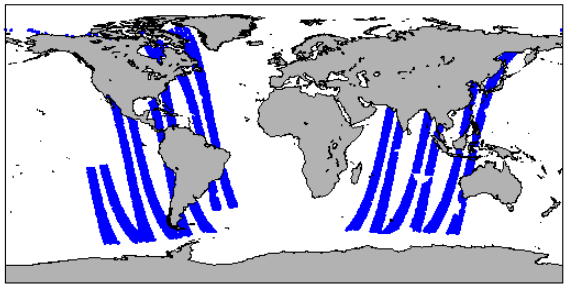
QuikScat

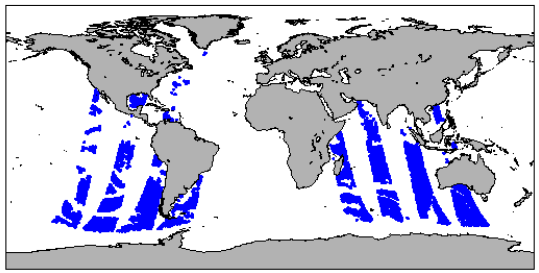


WindSat

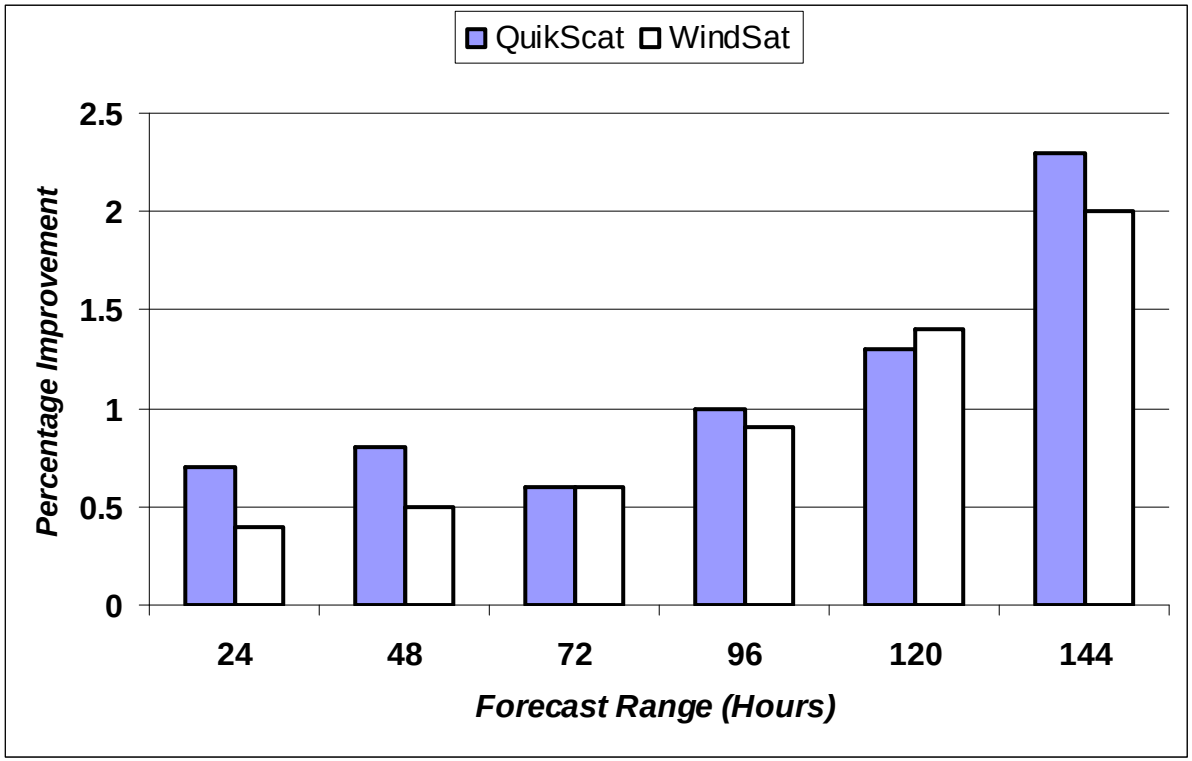


Pressure Increments (hPa)





Forecast Impact on Sea Level Pressure Forecasts

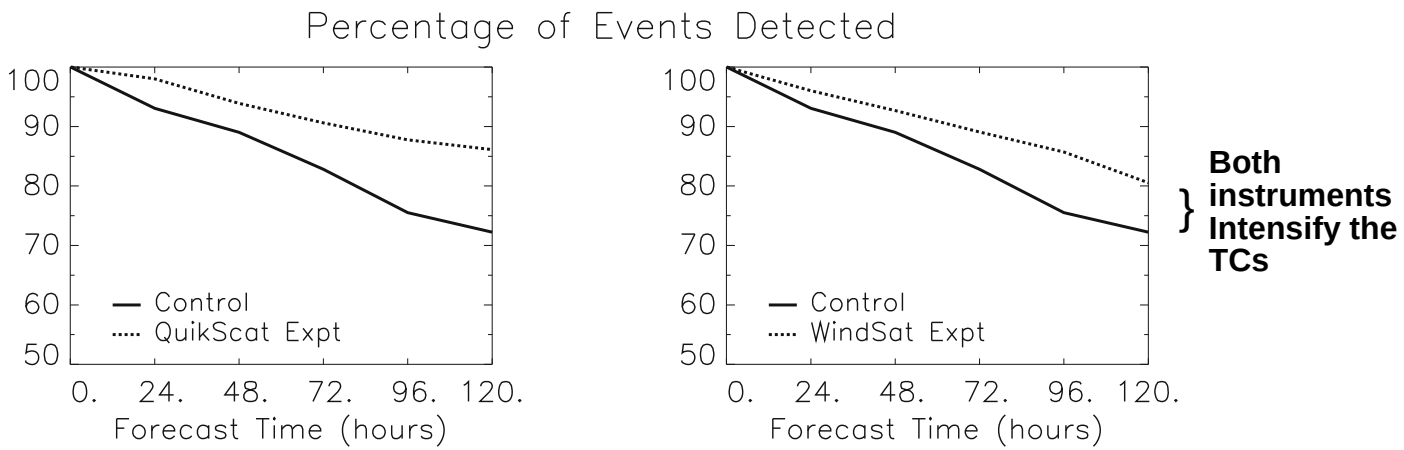


Tropical Cyclone Impacts

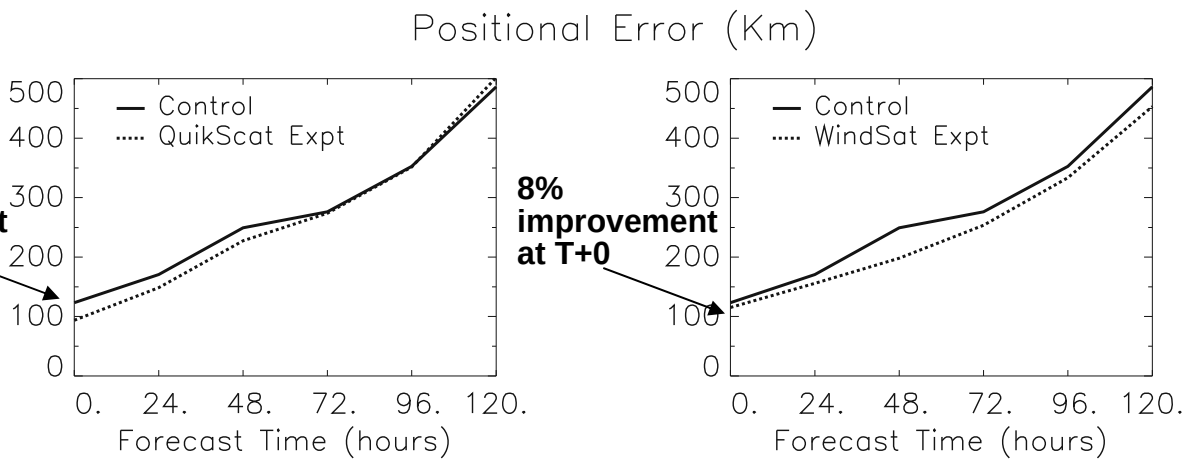
21 cyclones examined

QuikScat return time to a cyclone 0.8 days

WindSat 1.4 days



Both instruments Intensify the TCs



~25% improvement at T+0

8% improvement at T+0

Summary

- Error analysis suggested that the WindSat directional information will be useful down to wind speeds of ~8 ms^{-1}. For global numerical weather prediction the majority of the scatterometer forecast impact comes from high wind speed observations.
- Real Windsat data has comparable observation errors to scatterometer missions down to around 6 ms^{-1}
- Impact of the WindSat data is very encouraging:
  - Comparable impact to QuikScat in extra-tropics
  - Intensifies Tropical Cyclones in a similar manner to QuikScat, with smaller short range impact, but performs better at long range.
  - Overall results suggest a useful addition to current scatterometer missions
  - There is the potential for further exploitation of information – moisture, low wind speeds.

Spare Slides

Expected WindSat Error Characteristics

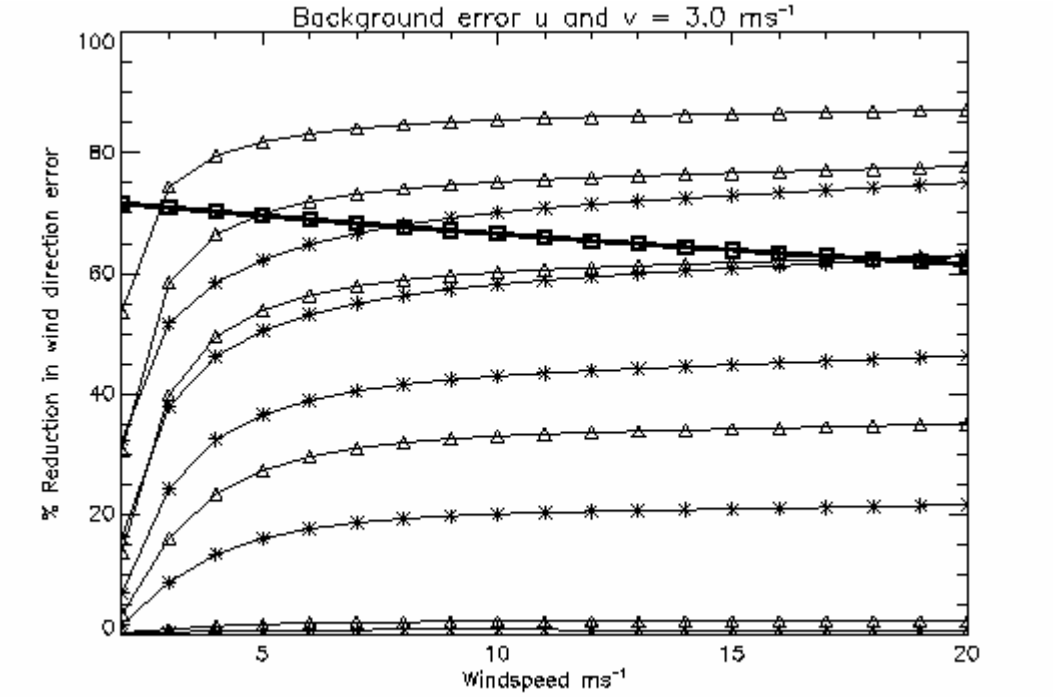
- At what wind speed can we expect directional sensitivity to drop?
- Estimated this using linear error framework (Eyre, 1990)

$$A^{-1} = B^{-1} + H^T R^{-1} H$$

- A – analysis error, B – background error matrix, *H* gradient of the observation operator, R observation error matrix
- Observation operator: fast radiative transfer model , RTTOV (operationally used at MetO, coupled to the Liu & Weng (2002) fast emissivity model, which includes the azimuthal variation.

Single view - asterisk Dual view – triangles Scatterometer - squares

Lines assume observation error of 2 K for 1st two elements of Stokes vector and 0.05 K, 0.1 K, 0.2 K, 0.5 K, 1.0 K for 3rd and 4th elements from top to bottom.



Assimilation and dealiasing

We can deal with the directional ambiguity associated with WindSat directly in the assimilation scheme as is already performed for Scatterometer data

$$J(x) = J^B + J^O + J^{Constrain}$$

Typically a conventional wind vector ob is treated as having a Gaussian error structure:

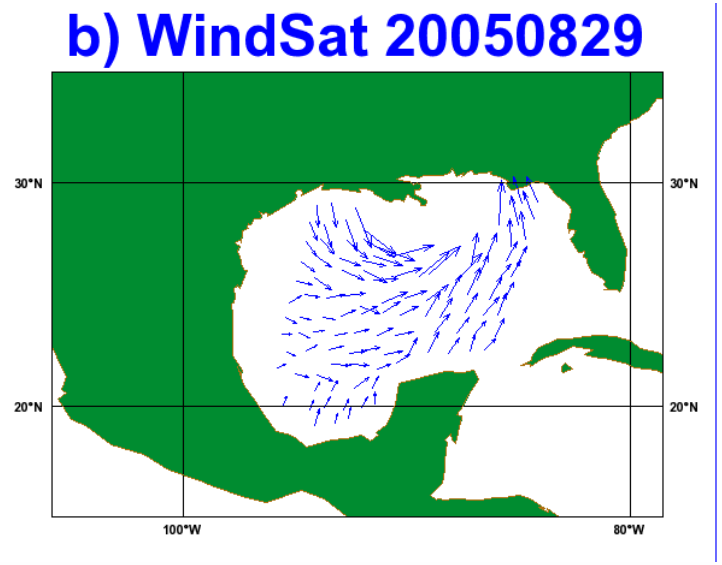
$$J^o_{ship} = \frac{\left(\mathrm{u} - \mathrm{u}^o\right)^2 + (v - v^o)^2}{2\varepsilon^2}$$

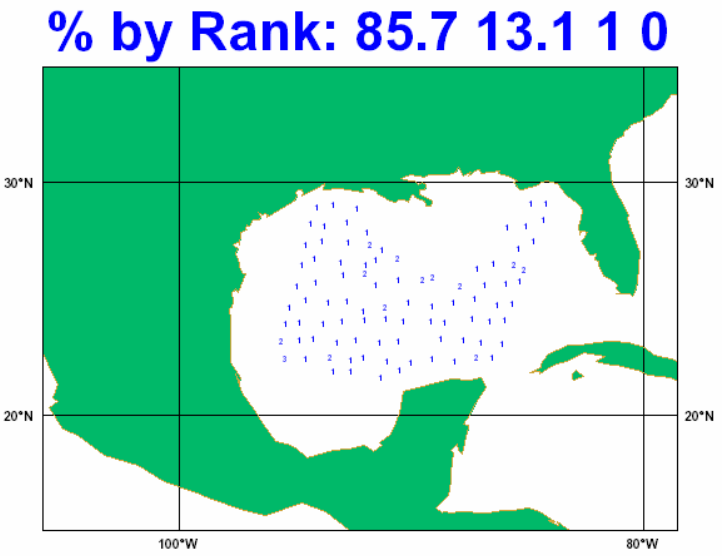
For an observation with several wind ambiguities:

$$J^o_{scat} = -\ln\left(\sum_{i=1}^{N} P_i^o e^{-j_i}\right)$$

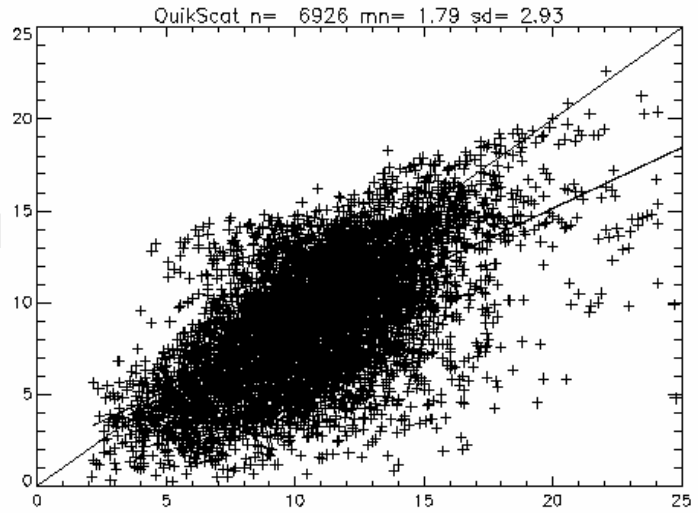
with

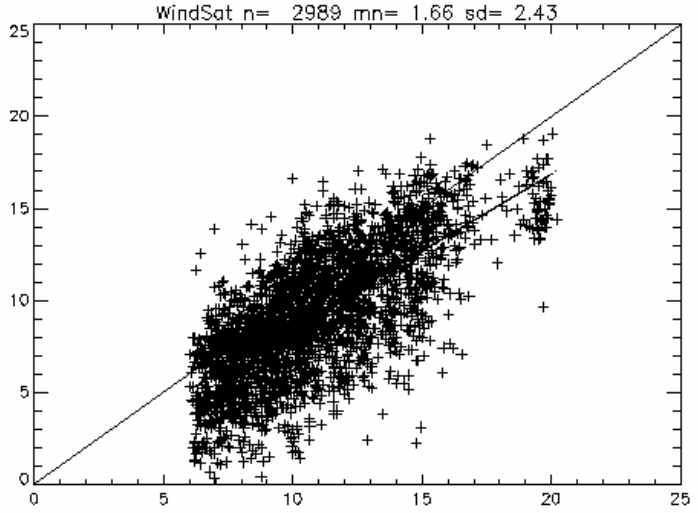
$$j_i = \frac{(u - u_i^o)^2 + (v - v_i^o)^2}{2\varepsilon^2}$$

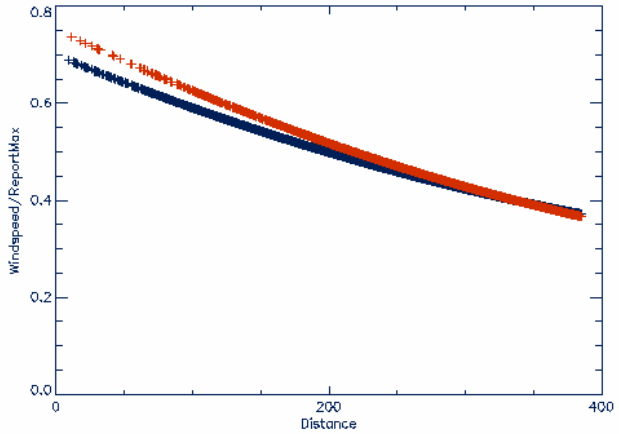




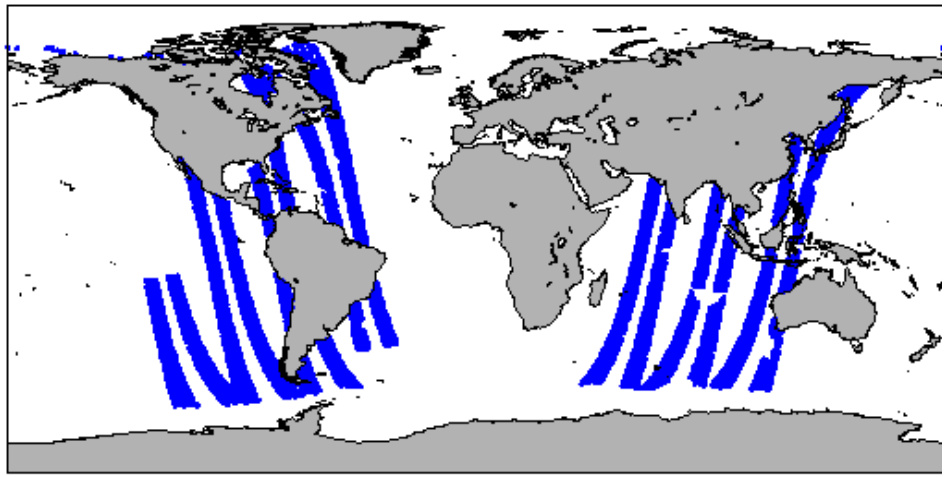
Fit to model in vicinity of TCs

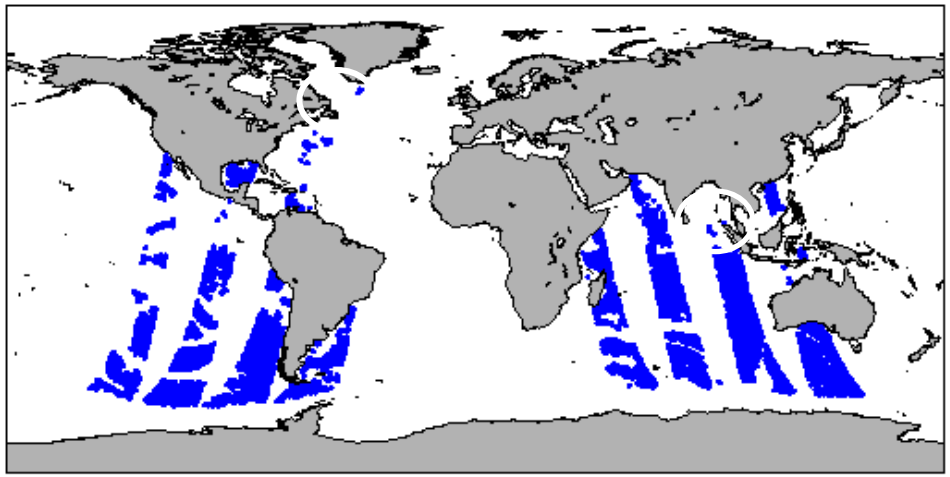




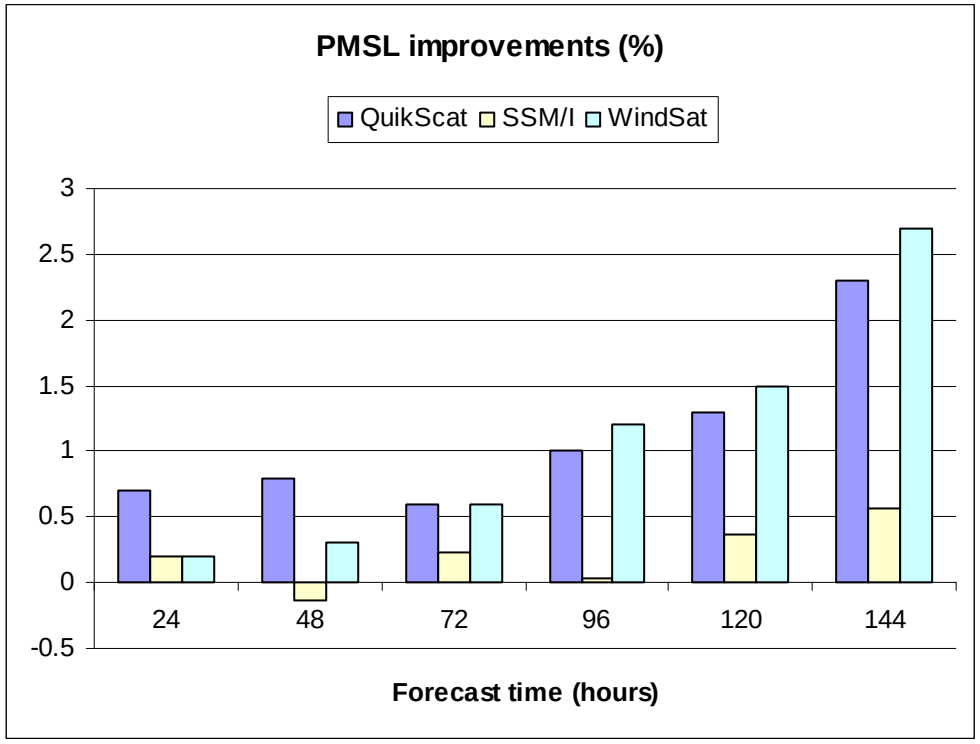


Observations passed to assimilation step

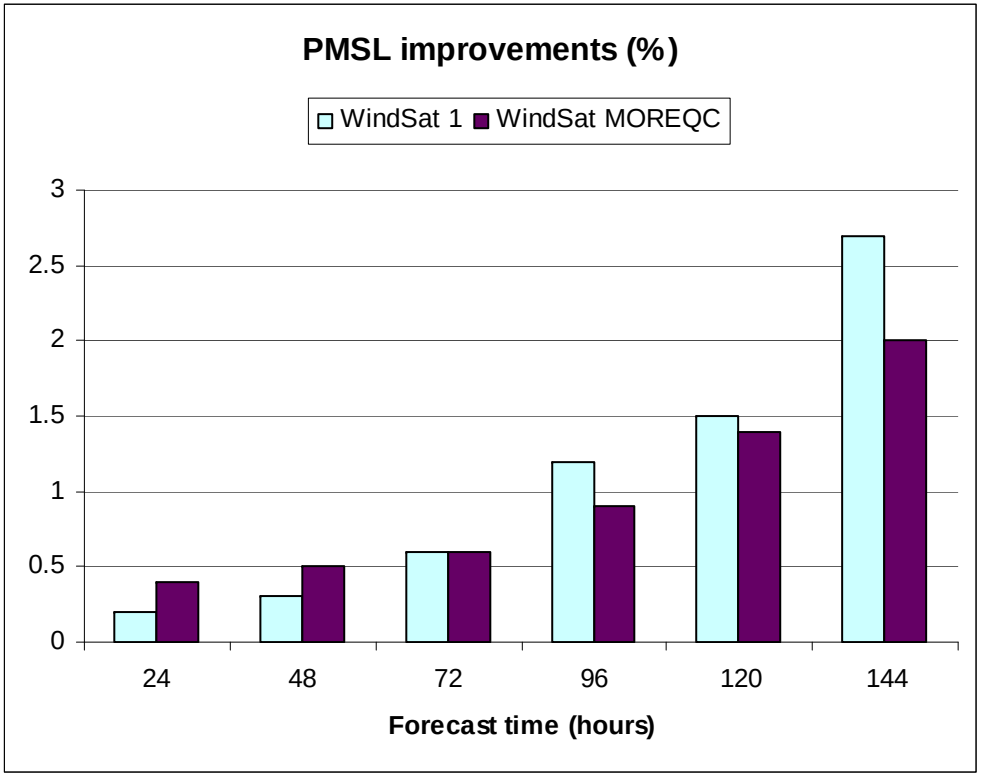




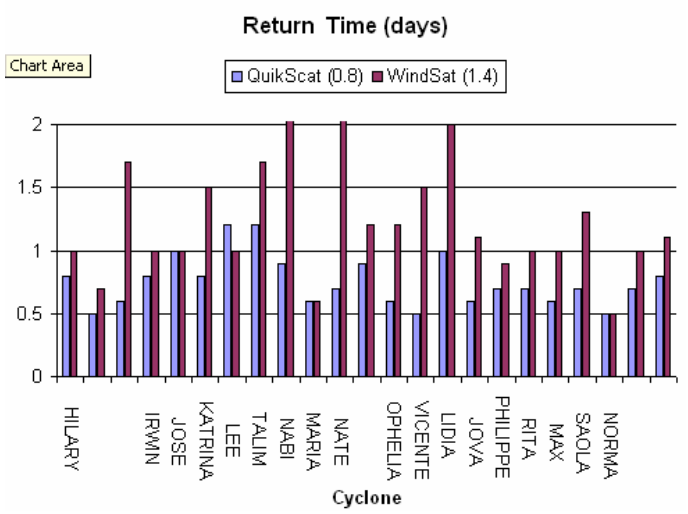
C.f. SSM/I wind speed impact

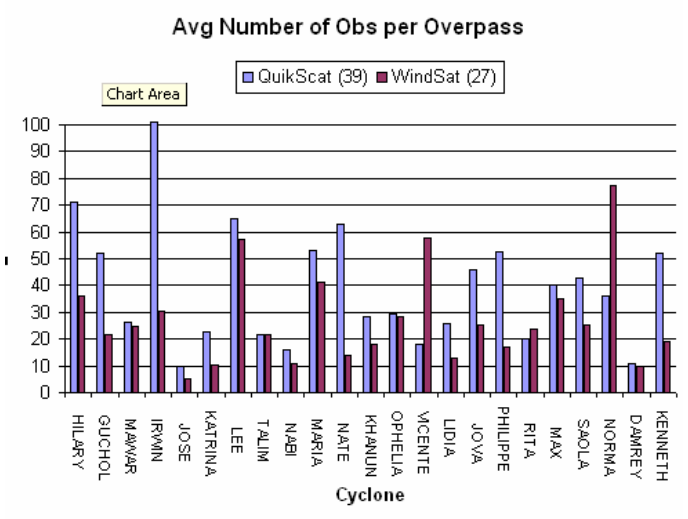


WindSat sensitivity to QC



TC Overpass comparisons

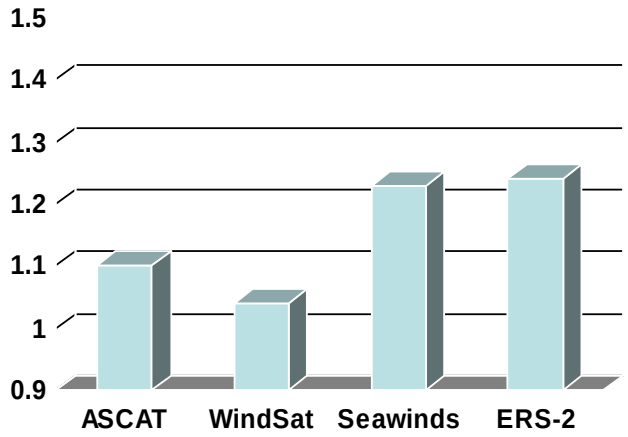




Most Recent Comparisons

Fit to Background 07/03/2008

Wind Speed (m/s)



Direction (°)