A Metric for Evaluation of Mapped QuikSCAT Wind Products

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The influence of SST and surface heat fluxes on midlatitude storms
J. F. Booth, L. Thompson, J. Patoux, K. A. Kelly

SST effects a storm’s warm sector and moisture fluxes feed the storm’s growth (Booth et al. 2010)

No correlation between a storm’s intensification and temporal variability of SST

Storm passing through the Gulf Stream region. Wind vectors, storm path (pink) and SST for a storm on Feb 24, 2001.
Assessment of Surface Heat Fluxes in Storms Modeled by WRF

QuikSCAT confirms that WRF:
• reproduces storm shapes and positions well
• underestimates wind speeds over unstable regions
• has flux biases from WRF boundary layer scheme
• air-sea temperature difference (not winds) are responsible for flux bias
Need for a Metric

• Users need ways to determine which product appropriate for their application.
• Maps made with same data (12.5 km QuikSCAT) have varying time and spatial grids (resolution?).
• Different maps have different strengths, purposes. Users need guidance from Science Team.
• Post-QuikSCAT there is even more of a need to evaluate products (not homogeneous over time).
Mapping Scatterometer Data

• Assimilate data into NWP
• Blend data with other sources
• Average data in time (reduce aliasing)
Taylor Diagram: evaluate correlation and magnitude

**Taylor diagram:** plot correlation and magnitude in polar coordinates.

Squared error

$$< \varepsilon^2 > = < d_m^2 > + < d_o^2 > - 2 < d_m d_o >$$  \hspace{1cm} (2)

From law of cosines

$$< \varepsilon^2 > = \sigma_m^2 + \sigma_o^2 - 2 \sigma_m \sigma_o \cos \theta$$  \hspace{1cm} (3)

By definition,

$$< d_m^2 > = \sigma_m^2, < d_o^2 > = \sigma_o^2$$

$$\rho = \cos \theta \quad \text{or} \quad \theta = \cos^{-1} \rho$$  \hspace{1cm} (4)

$$< \varepsilon^2 > = \sigma_m^2 + \sigma_o^2 - 2 \sigma_m \sigma_o \cos^{-1} \rho$$  \hspace{1cm} (5)

*Normalized Taylor diagram* gives relative error $\varepsilon / \sigma_o$

$$\frac{< \varepsilon^2 >}{\sigma_o^2} = \frac{\sigma_m^2}{\sigma_o^2} + 1 - 2 \sigma_m \cos^{-1} \rho$$  \hspace{1cm} (6)

“Normalized error” $\varepsilon$
Vector Correlations: use a version with compatible with scalar

Time series of observations $v_o(t) = u_o(t) + iv_o(t)$ and estimate $v_m(t) = u_m(t) + iv_m(t) + \varepsilon$

**Correlation of anomalies**

$$r = \frac{v_m^* v_o}{\sigma(v_m)\sigma(v_o)};$$

This version of complex correlation gives:

- magnitude of $r$: 0-1
- angle between vectors
In-situ Data – Open Ocean

Two research moorings located in Western Boundary Currents. These are regions of high currents and steep SST gradients.

CLIMODE Mooring: Nov ’05 – Jan ’07 (14 mos) sonic anemometer

CLlvar MOde Water Dynamics Experiment (NSF)

KEO Mooring: Jun ’04 – Jul ’08 (4 years with gaps) sonic anemometer

Kuroshio Extension Observatory Pacific Marine Environmental Lab (NOAA)
In-situ Data – Near Land

Five buoys located in the Aegean Sea. Land contaminates the scatterometer signal. Variable winds persist on scales on the order of the QuikSCAT footprint.

Aegean Sea Buoys: Jul ‘99 – May ’04 (5 years with gaps)

Poseidon System, Hellenic Centre for Marine Research (EFTA)

All in-situ winds converted to 10m in neutrally stratified atmosphere with COARE v3.0 algorithm.

- Metadata amended with ECMWF variables where needed.
- Used in-situ currents when available.

Winds below 3 m/s not included in analysis.
Mean Vectors at CLIMODE Mooring
Daily Wind Maps

- Kelly & Dickinson
  - daily, ½ degree

- Tang & Liu
  - 12-hourly, ½ degree

- Ifremer
  - daily, ½ degree

- NCEP2
  - daily, gaussian ~1.9 deg

- ECMWF
  - daily, gaussian, ~1.1 deg
Mean Vectors at CLIMODE Mooring
6-hourly Wind Maps

Cross-calibrated, multi-Platform
• 6-hourly, ¼ degree

Milliff (blended)
• 6-hourly, ½ degree

NCEP2-6h
• 6-hourly, gaussian, ~1.9 deg
Mean Vectors at CLIMODE Mooring Stress Maps

Kelly & Dickinson
• daily, ½ deg

Ifremer
• daily, ½ deg
Mean Vectors at CLIMODE Mooring
Pseudostress Maps

Center for Ocean-Atmosphere Predictions Studies
• 6-hourly, 1 deg
Taylor Diagram – CLIMODE Mooring Daily Winds

Daily Winds

Magnitude ratio: Mapped satellite data / Smoothed buoy data

Correlation

K & D = 0.36
T & L = 0.72
Freret = 0.38
NCEP2 = 0.83
ECMWF = 0.28
Taylor Diagram – CLIMODE Mooring
6-hourly Winds

Daily Winds
- K & D = 0.36
- T & L = 0.72
- Ifremer = 0.38
- NCEP2 = 0.93
- ECMWF = 0.28

6-hourly Winds
- CCMP = 0.34
- Milliff = 0.40
- NCEP2-6h = 0.61

Correlation

Magnitude ratio: Mapped satellite data / Smoothed buoy data
Estimate Temporal Resolution

Procedure:
1) Smooth buoy winds at various intervals (3 hr, 6 hr, 12 hr, etc)
2) Compute “normalized error” between gridded product and smoothed buoy winds
3) Nominal resolution is interval with minimum normalized error
Normalized Error vs Averaging Bin
CLIMODE Mooring – Daily Winds
Normalized Error vs Average Bin
CLIMODE Mooring – 6-hourly Winds
Stress and Pseudostress Maps
CLIMODE Mooring

NOTE:

$C_d$ for stress calculations at buoys and for Kelly & Dickinson maps, Large et al. 1994
Stress and Pseudostress Maps
CLIMODE Mooring
Taylor Diagram – KEO Mooring Daily and 6-hourly Winds

CLIMODE

Daily Winds
- K & D=0.39
- T & L=0.72
- HiTemer=0.36
- NCEP2=0.83
- ECMWF=0.28

6-hourly Winds
- CCM2=0.34
- MM5=0.64
- NCEP2 6h=0.61

Magnitude ratio: Mapped satellite data / Smoothed buoy data

Correlation

KEO

Daily Winds
- K & D=0.39
- T & L=0.69
- HiTemer=0.36
- NCEP2=0.62
- ECMWF=0.29

6-hourly Winds
- CCM2=0.32
- MM5=0.44
- NCEP2 6h=0.54

Magnitude ratio: Mapped satellite data / Smoothed buoy data

Correlation
Mean Vectors – Aegean Buoys

Daily Winds  
6-hourly Winds  
Stress  
Pseudostress
Taylor Diagram – Aegean Buoys
Daily and 6-hourly Winds

CLIMODE

Aegean

Daily Winds
K & D=0.35
T & L=0.72
Htrem=0.36
NCEP2=0.92
ECMWF=0.28

6-hourly Winds
CCMP=0.94
Marr=0.46
NCEP2 6h=0.61

Correlation

Magnitude ratio: Mapped satellite data / Smoothed buoy data

Daily Winds
K & D=0.49
T & L=0.43
Htrem=0.52
NCEP2=0.59
ECMWF=0.47

6-hourly Winds
CCMP=0.49
Marr=0.16
NCEP2 6h=0.69

Correlation

Magnitude Ratio: Mapped satellite data / Smoothed buoy data
Normalized Error – Aegean Buoys
Daily and 6-hourly Winds

CLIMODE

Aegean
Conclusions

- Taylor diagram to represent both energy levels and correlation
- Determine temporal resolution of a particular product
- Metric robust with respect to different locations
- Based on buoy comparisons:
  a) Best daily products: ECMWF, K&D, Ifremer
  b) CCMP for 3-6-hourly product
- Next: test other products?
- Need other metrics such as spatial structure and derived fields
Mean Vectors – KEO Mooring

KEO Mooring winds weaker than GCMs and CCMP winds, (where CLIMODE speeds comparable)
Stress Maps at Aegean Buoys

CLIMODE

Aegean

![Graphs showing stress maps and correlation data for CLIMODE and Aegean.](image-url)
Stress Maps at KEO Mooring

CLIMODE

KEO

Normalized Error:

CLIMODE

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Normalized Error – KEO Mooring Daily and 6-hourly Winds

CLIMODE

KEO