Sub-daily Variation of Ocean Surface Wind and Stress

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Perspective

• Current knowledge is based on moorings, with limited geographical coverage [Deser and Smith, 1998]
• Spacebased data may extend it to global coverage
• A polar-orbiting scatterometer can sample at one location only twice a day.
• NASA tandem scatterometer missions (QuikSCAT and ADEOS-II) provide 4 views a day to study diurnal variations over the ocean [Liu and Tang, 2004; Gille et al., 2005]
• 3 to 4 wind sensors have operated together for various periods and are used to improve our knowledge of the diurnal and sub-daily variations over open oceans
Diurnal variability measured by TAO buoy (8S, 179W)

Local time of satellite passing

ASCAT/EUMETSAT Metop
Oct. 19, 2006-present

OceanSAT-2/ISRO
Sep. 23, 2009-present

Winds/NASA QuikSCAT
June 19, 1999-Nov. 23, 2009

WindSAT/NPOESS Coriolis
Jan. 6, 2003-present
QuikSCAT: July 19, 1999 - Nov. 23, 2009

ASCAT: Mar. 28, 2007 - present

WindSAT: Jan. 1, 2006 - present

OceanSAR: Nov. 5, 2009 - Apr. 30, 2010

2009309-2009325 Co-existing period
**QuikSCAT 2009 309-325**

**Mean**

**Zonal Wind: qscat daily mean**

**Difference between passes**

**Zonal Wind: qscat [06] - [18] local time**

**Meridional Wind: qscat daily mean**

**Meridional Wind: qscat [06] - [18] local time**

T-test with 70% significance
T-test with 70% significance
ASCAT 2009 309-325

Mean

Zonal Wind: ascat daily mean

Difference between passes


Meridional Wind: ascat daily mean


T-test with 70% significance
MeanSAT-2 2009 309-325

Mean
Zonal Wind: os2 daily mean

Difference between passes

Meridional Wind
Zonal Wind: os2 daily mean


T-test with 70% significance
ECMWF (along OceanSAT-2 swath) 2009 309-325

Mean

Zonal Wind: ecmwf daily mean

Difference between passes


Meridional Wind: ecmwf daily mean


T-test with 70% significance
Zonal Wind

00 LT (OceanSAT2)

06 LT (QuikSCAT)

09 LT (ASCAT)

12 LT (OceanSAT2)

18 LT (QuikSCAT)

21 LT (ASCAT)

m/s

-2.  -1.  0.  1.  2.

T-test: 0.30
Zonal Wind

00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)

m/s

-2. -1. 0. 1. 2.

t-test: 0.30
Meridional Wind
Zonal Wind

00 LT (OceanSAT2)  |  06 LT (QuikSCAT)  |  09 LT (ASCAT)

12 LT (OceanSAT2)  |  18 LT (QuikSCAT)  |  21 LT (ASCAT)

m/s

-2.  |  -1.  |  0.  |  1.  |  2.

t-test: 0.30
Meridional Wind

00 LT (OceanSAT2)

06 LT (QuikSCAT)

09 LT (ASCAT)

12 LT (OceanSAT2)

18 LT (QuikSCAT)

21 LT (ASCAT)

m/s

-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0

t-test: 0.030
Differences between OceanSat-2 and QuikSCAT measurements averaged over the two weeks of coincidence for zonal (upper) & meridional (lower) components.

Significant (90%) difference observed in tropical oceans, where strong diurnal variability of ocean wind were documented by in situ measurements.
OceanSAT-2 - ASCAT

Zonal Wind: os2-ascat

U

Meridional Wind: os2-ascat

V
ASCAT: U & V means averaged over two weeks period (Nov. 5-21, 2009)
Fitting

The temporal means of 3 sensors at two overpasses (6 values) are used to derive diurnal/semidiurnal cycles at each location.

The zonal and meridional components are fitted to a second order harmonic function to obtain the amplitude ($A_1$, $A_2$) and phase ($p_1$, $p_2$) of the diurnal and semidiurnal cycles,

$$F(x,t) = A_1 \sin(x+p_1) + A_2 \sin(2x+p_2)$$

where $x = \pi t/12$, and $t$ is the local time (0-24 hour)

Uncertainties are derived using standard errors and random noises
ASCAT: Standard deviation of U & V for ascending/descending passes
Uncertainty estimated via Monte Carlo simulation

(1) Perturb the original 6 data values by adding random numbers with a Gaussian distribution and a variance equivalent to the standard error of measurements; and re-derive $A_1$, $p_1$ and $A_2$, $p_2$;

(2) Repeat (1) 100 times for the Monte Carlo simulation of uncertainty analysis;

(3) Uncertainties of $A_1$, $p_1$ and $A_2$, $p_2$ are determined from the standard deviation of the 100 realizations, i.e. the uncertainty of $A_1$ is the standard deviation of 100 $A_1$ computed.
Amplitude ($A_1$) of the diurnal cycle of Zonal Wind (where $A_1 > 2\sigma$)

OceanSAT2(0,12) + ASCAT(9,21) + WindSAT(6,18)

Derived from data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist.

OceanSAT2(0,12) + ASCAT(9,21) + QSCAT(6,18)

QSCAT + ASCAT + WindSAT + OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist.
Amplitude ($A_2$) of the semi-diurnal cycle of Zonal Wind (where $A_2 > 2\sigma$)

OceanSAT2(0,12) + ASCAT(9,21) + WindSAT(6,18)

QSCAT(6,18) + ASCAT(9,21) + WindSAT(6,18)

OceanSAT2(0,12) + ASCAT(9,21) + QSCAT(6,18)

QSCAT + ASCAT + WindSAT + OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist
Amplitude ($A_1$) of the diurnal cycle of Meridional Wind (where $A_1 > 2σ$)

OceanSAT2(0,12)+ASCAT(9,21)+WindSAT(6,18)

QSCAT(6,18)+ASCAT(9,21)+WindSAT(6,18)

OceanSAT2(0,12)+ASCAT(9,21)+QSCAT(6,18)

QSCAT+ASCAT+WindSAT+OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist.
Amplitude ($A_2$) of the semi-diurnal cycle of Merid. Wind (where $A_2 > 2\sigma$)

OceanSAT2(0,12) + ASCAT(9,21) + WindSAT(6,18)

QSCAT(6,18) + ASCAT(9,21) + WindSAT(6,18)

OceanSAT2(0,12) + ASCAT(9,21) + QSCAT(6,18)

QSCAT + ASCAT + WindSAT + OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist
Peak time of the zonal Wind diurnal cycle in summer and winter

JJA (Along 15°N)

Along 15°N

DJF (Along 150°W)

Along 150°W
Peak time of the meridional Wind diurnal cycle in summer and winter (JJA and DJF) along 15°N and 150°W.
Summary

Significant regional day and night difference in scatterometer data

Extend our knowledge of diurnal and sub-daily variation from mooring locations
To open ocean

On-going effort to relate the high frequency variation to those of other atmospheric and oceanic parameters

Future optimal spacing of satellite orbit will help avoid aliasing of subdaily variation into climate record.
backup
Zonal Wind

00 LT (OceanSAT2)

06 LT (QuikSCAT)

09 LT (ASCAT)

12 LT (OceanSAT2)

18 LT (QuikSCAT)

21 LT (ASCAT)

m/s

-2.0 -1.0 0.0 1.0 2.0

t-test: 030
Meridional Wind

00 LT (OceanSAT2)

06 LT (QuikSCAT)

09 LT (ASCAT)

12 LT (OceanSAT2)

18 LT (QuikSCAT)

21 LT (ASCAT)
Meridional Wind

00 LT (OceanSAT2)

06 LT (QuikSCAT)

09 LT (ASCAT)

12 LT (OceanSAT2)

18 LT (QuikSCAT)

21 LT (ASCAT)

m/s

-2. -1. 0. 1. 2.

t-test: 0.30
Phase \((T_{1\text{max}})\) of the diurnal cycle of Zonal Wind \((A1 > 2\sigma)\)

OceanSAT2(0,12)+ASCAT(9,21)+WindSAT(6,18)

QSCAT(6,18)+ASCAT(9,21)+WindSAT(6,18)

OceanSAT2(0,12)+ASCAT(9,21)+QSCAT(6,18)

QSCAT+ASCAT+WindSAT+OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist.
Phase $T_{2\text{max}}$ of the semi-diurnal cycle of Zonal Wind (where $A^2 > 2\sigma A^2$)

**OceanSAT2(0,12)+ASCAT(9,21)+WindSAT(6,18)**

**QSCAT(6,18)+ASCAT(9,21)+WindSAT(6,18)**

**OceanSAT2(0,12)+ASCAT(9,21)+QSCAT(6,18)**

**QSCAT+ASCAT+WindSAT+OceanSAT2**

Data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist.
$T_{1_{\text{max}}}$ of the diurnal cycle of Meridional Wind (where $A_1 > 2\sigma$)

OceanSAT2(0,12) + ASCAT(9,21) + WindSAT(6,18)

QSCAT(6,18) + ASCAT(9,21) + WindSAT(6,18)

QSCAT + ASCAT + WindSAT + OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist
$T_{max}$ of the semi-diurnal cycle of Merid. Wind (where $A_2 > 2\sigma$)

OceanSAT2(0,12)+ASCAT(9,21)+WindSAT(6,18)

QSCAT(6,18)+ASCAT(9,21)+WindSAT(6,18)

OceanSAT2(0,12)+ASCAT(9,21)+QSCAT(6,18)

QSCAT+ASCAT+WindSAT+OceanSAT2

data over two weeks period (Nov. 5-21, 2009) when all four sensors co-exist.
The diurnal cycle derived from SeaWinds tandem mission compared with ECMWF.

Local peak time of meridional wind (QS/SW)

Local peak time of meridional wind (ECMWF)
OceanSAT-2 - QuikSCAT

**Zonal Wind:** os2-qscat

**Meridional Wind:** os2-qscat

- **U** and **V** components are shown.
- The maps display wind speed in m/s across the globe.
QuikSCAT day-night difference
OceanSAT-2 day-night difference
ASCAT day-night difference

Zonal Wind: ascat day[06–18] – night[18–06]

Meridional Wind: ascat day[06–18] – night[18–06]
ECMWF day-night difference

Zonal Wind: ecmwf day[06-18] – night[18-06]

Meridional Wind: ecmwf day[06-18] – night[18-06]

(along OceanSAT-2 swath)