Sub-daily Variation of Ocean Surface Wind and Stress

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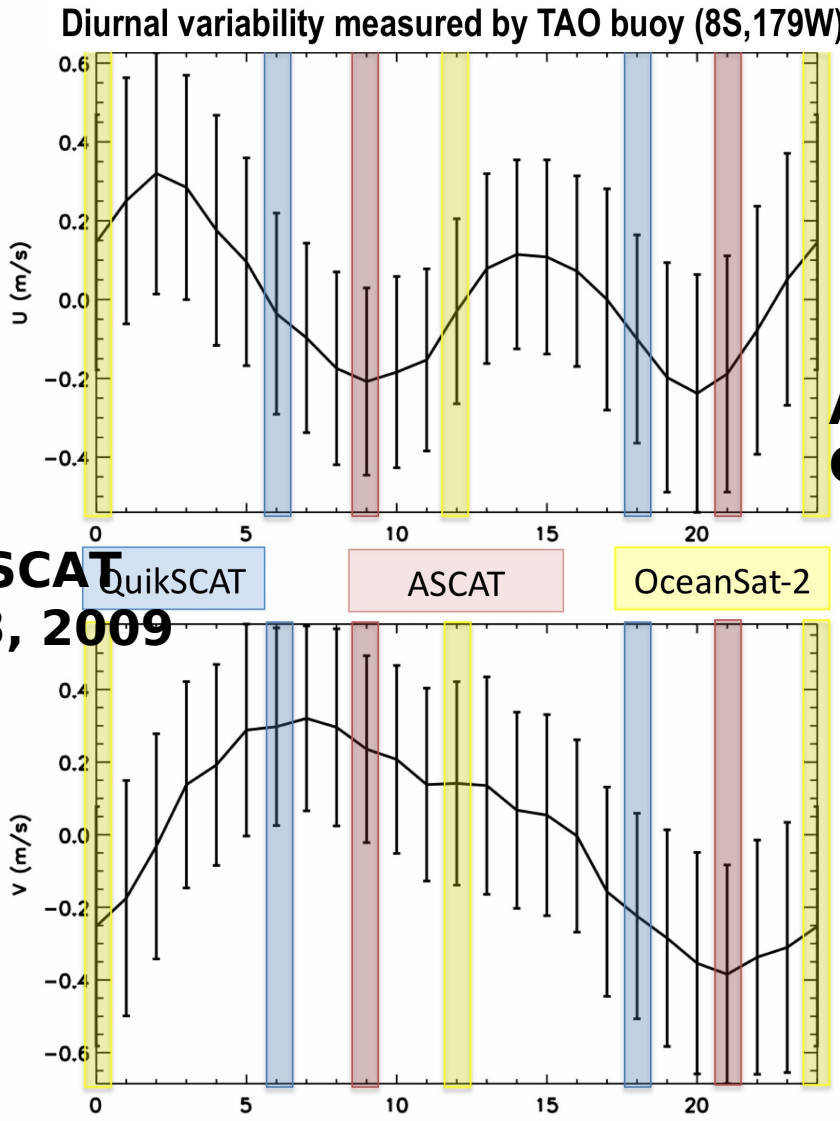
Perspective

- **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**

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

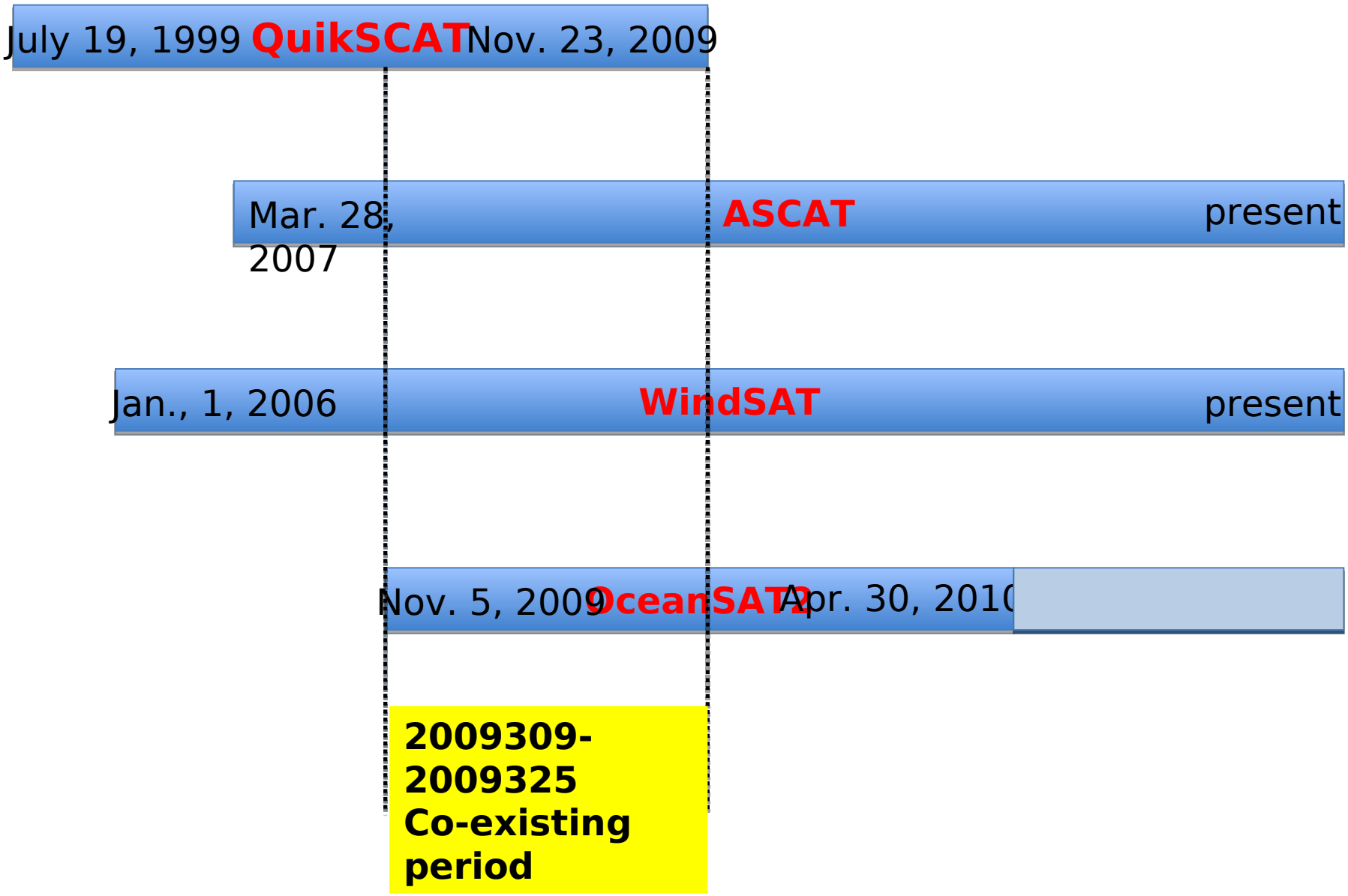


Local time of satellite passing

ASCAT/EUMETSAT Met
Oct. 19, 2006-present

ndSAT/NPOESS Coriolis
n.6, 2003-present

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

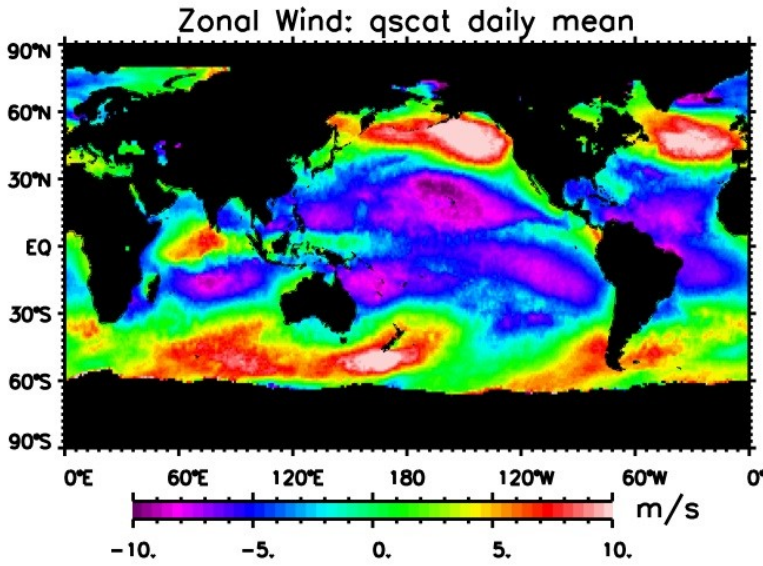

July 19, 1999
QuikSCAT
Nov. 23, 2009
Mar. 28, 2007
ASCAT
present
Jan., 1, 2006
WindSAT
present
Nov. 5, 2009
OceanSAT2
Apr. 30, 2010
2009309-2009325 Co-existing period

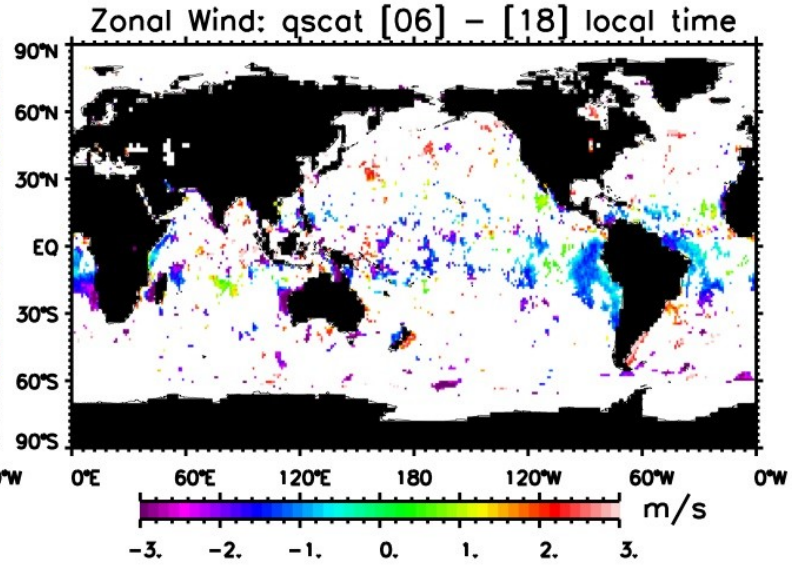
ikSCAT 2009 309-325

Mean

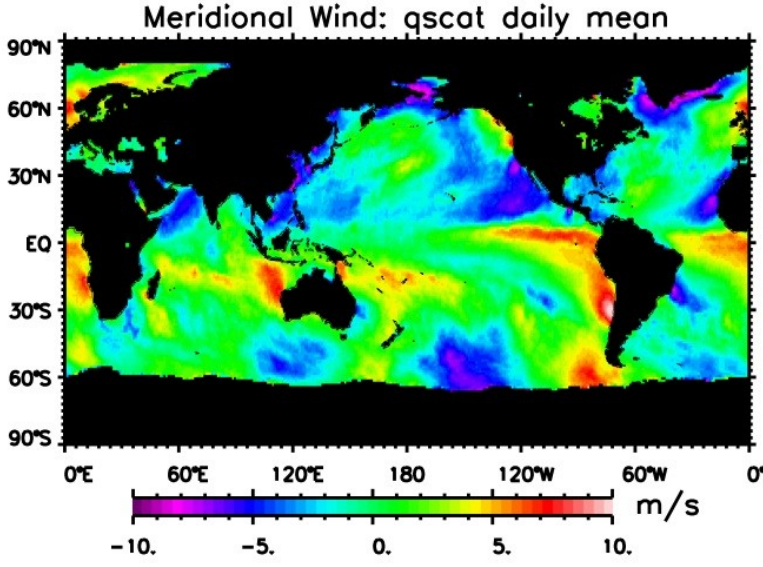
Difference between passes

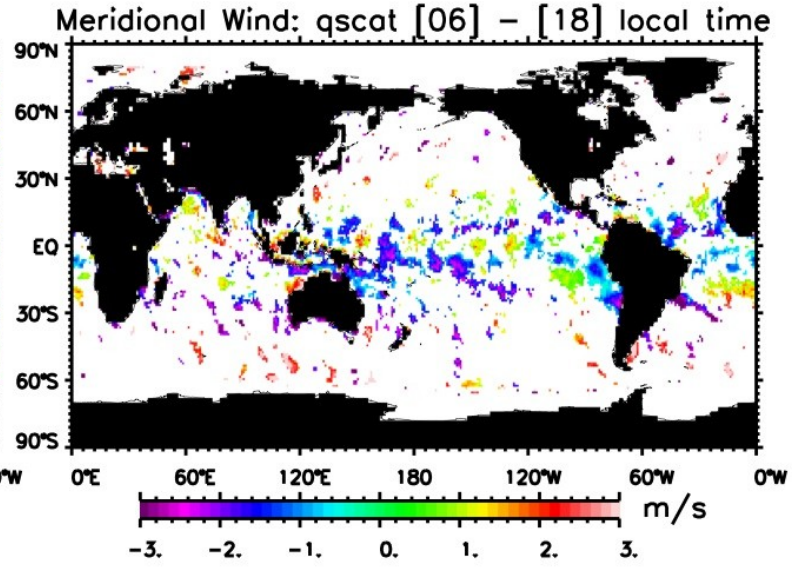
Zonal Wind





Meridional Wind





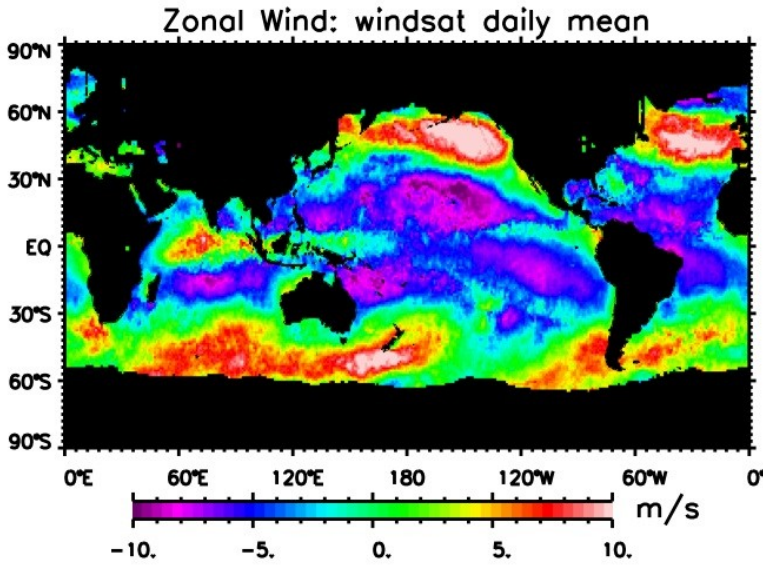
T-test with 70% significance

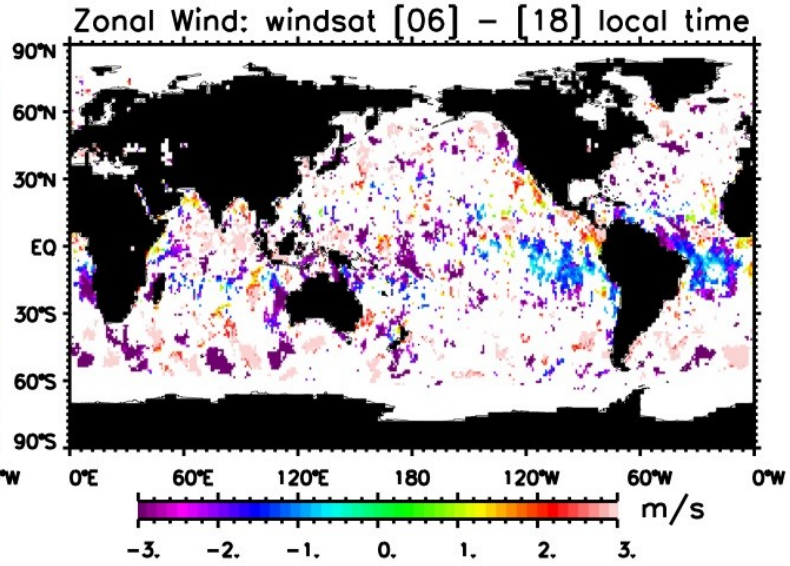
ndSAT 2009 309-325

Mean

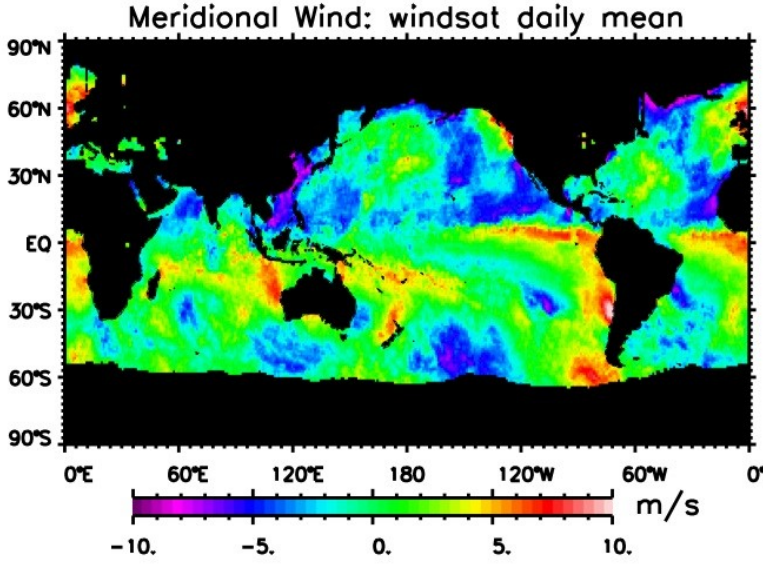
Difference between passes

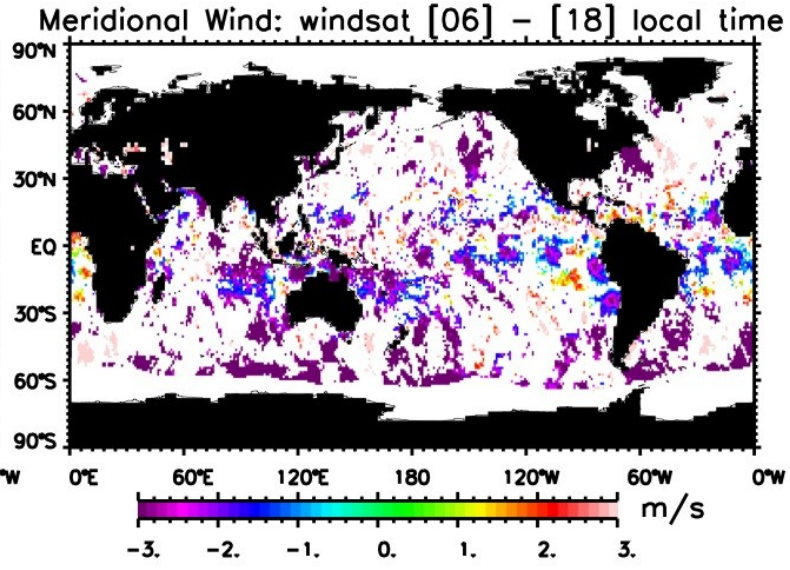
Zonal Wind





Meridional Wind





T-test with 70% significance

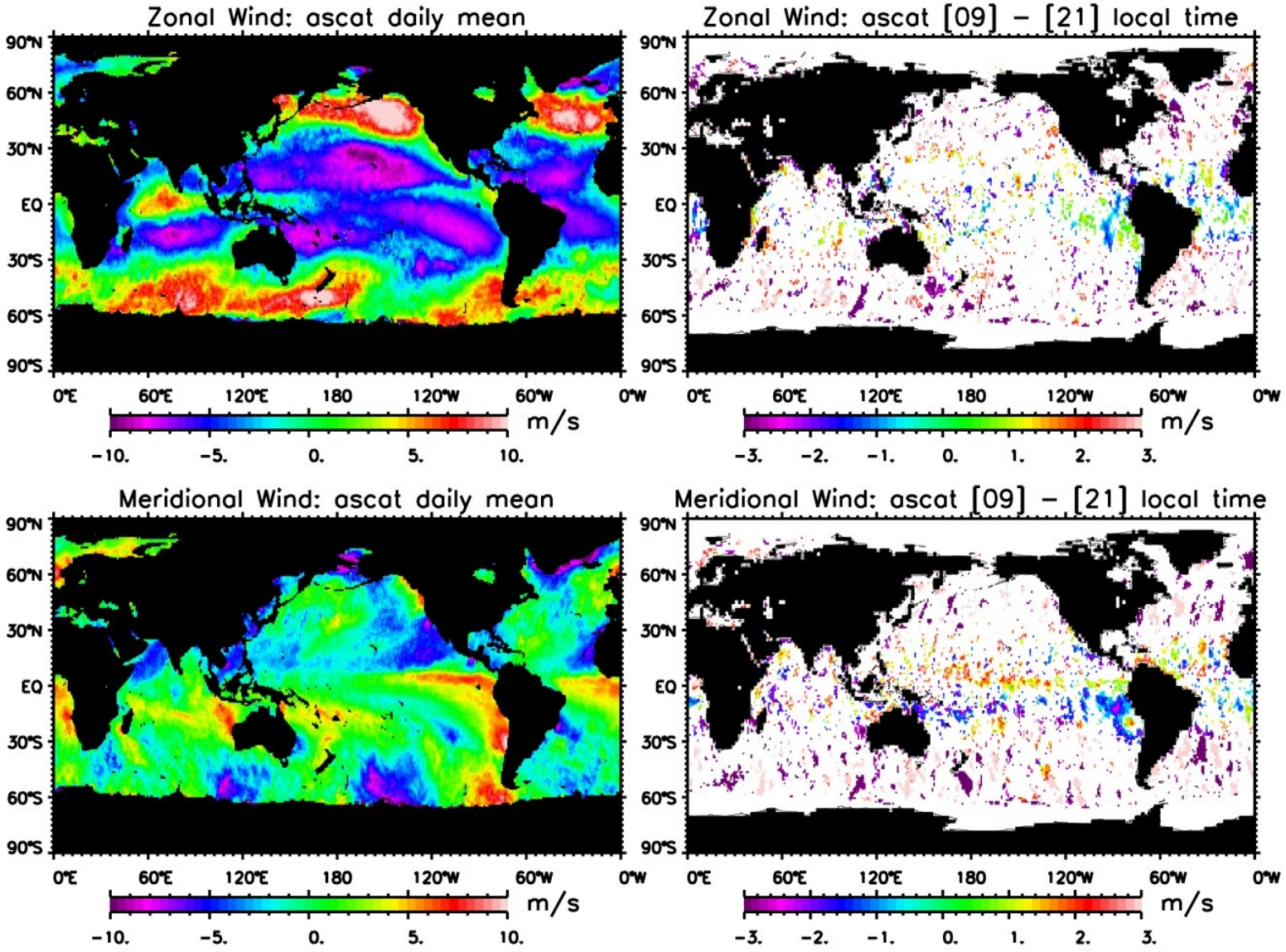
SCAT 2009 309-325

Mean

Difference between passes

Zonal Wind

Meridional Wind



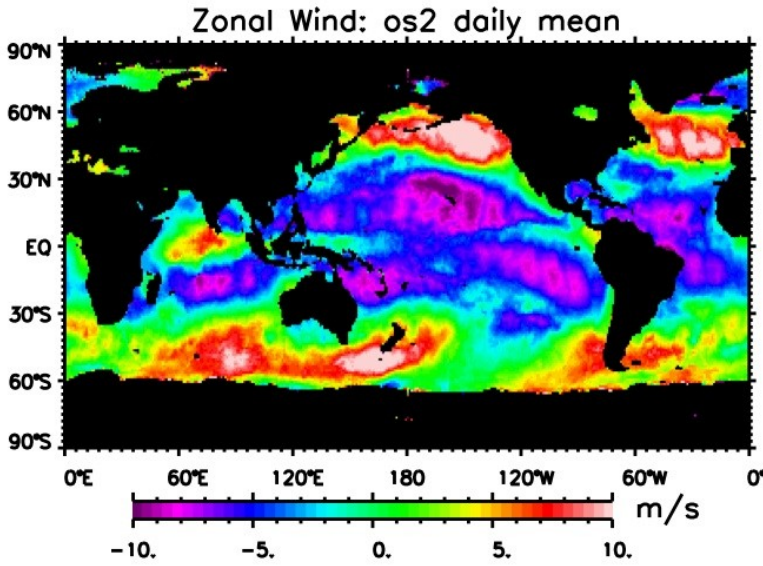
T-test with 70% significance

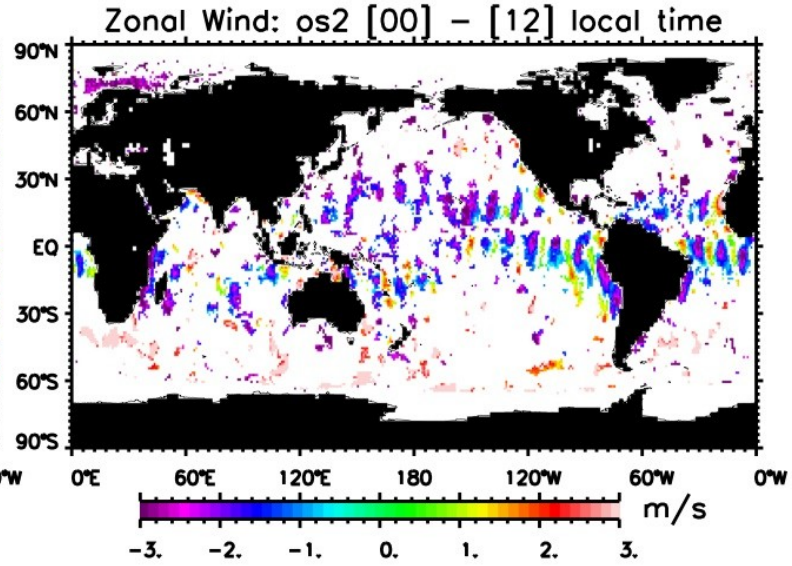
eanSAT-2 2009 309-325

Mean

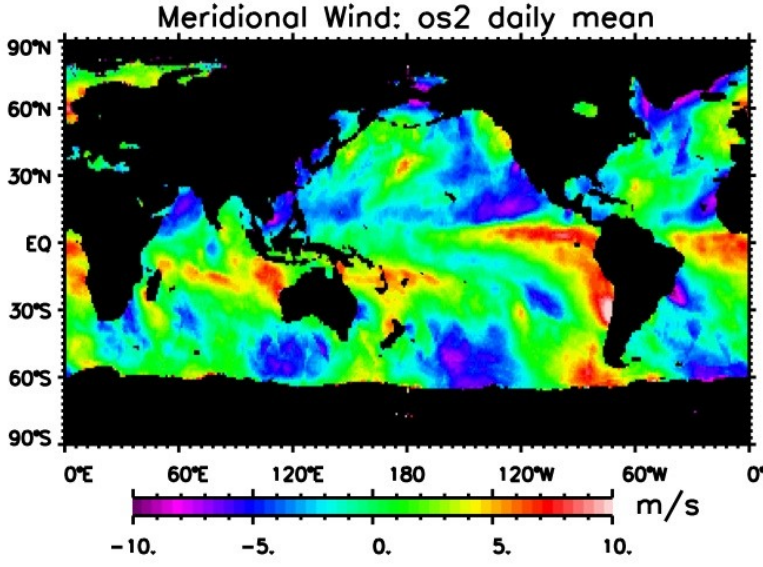
Difference between passes

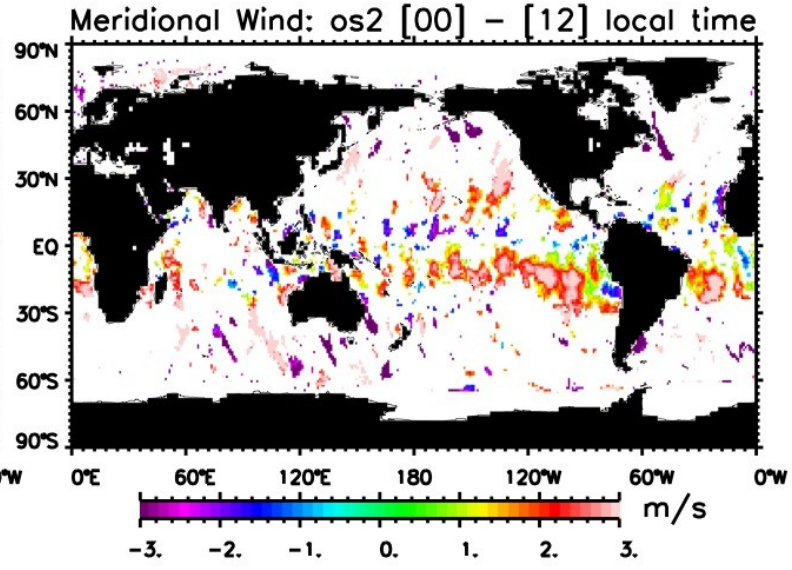
Zonal Wind





Meridional Wind





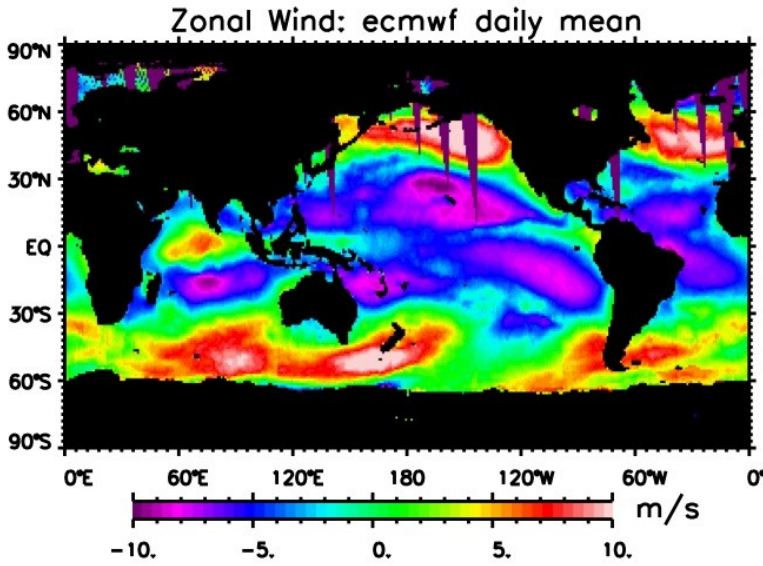
T-test with 70% significance

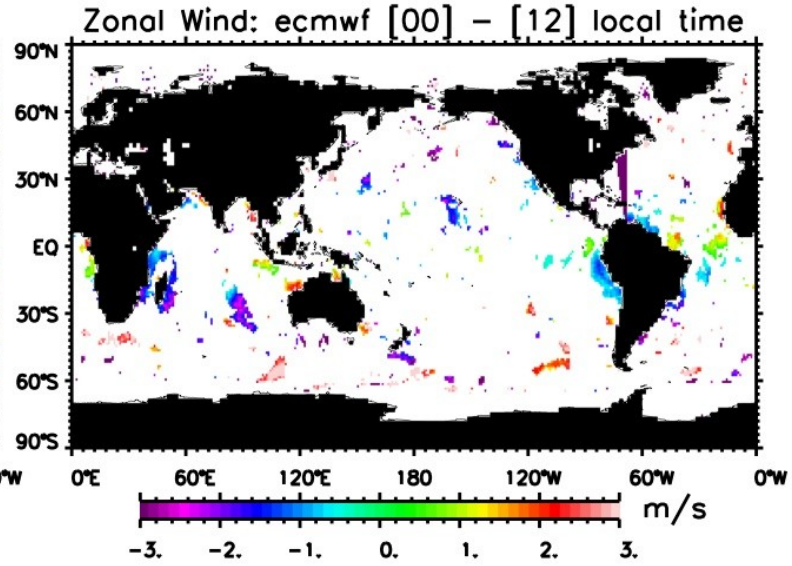
/F (along OceanSAT-2 swath) 2009 309-325

Mean

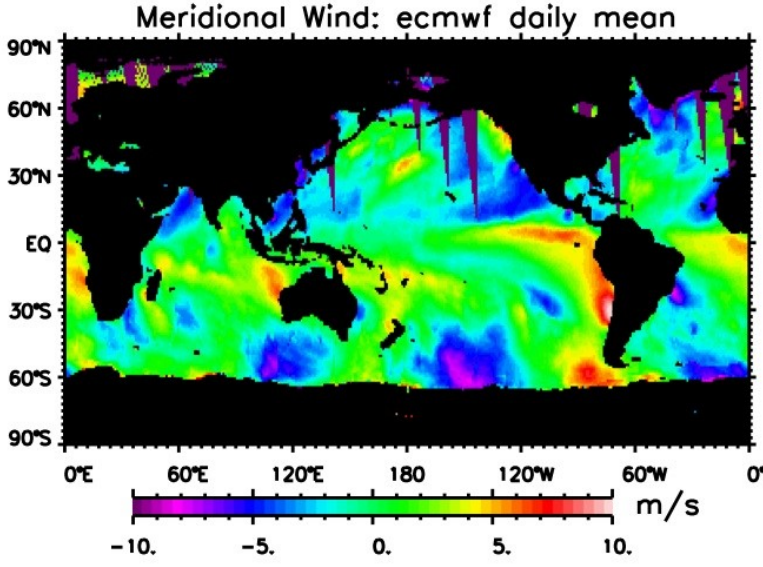
Difference between passes

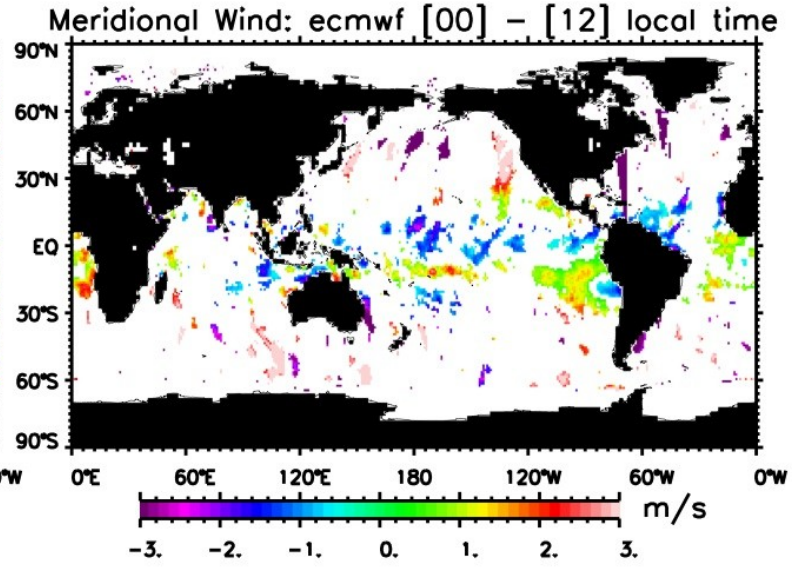
Zonal Wind





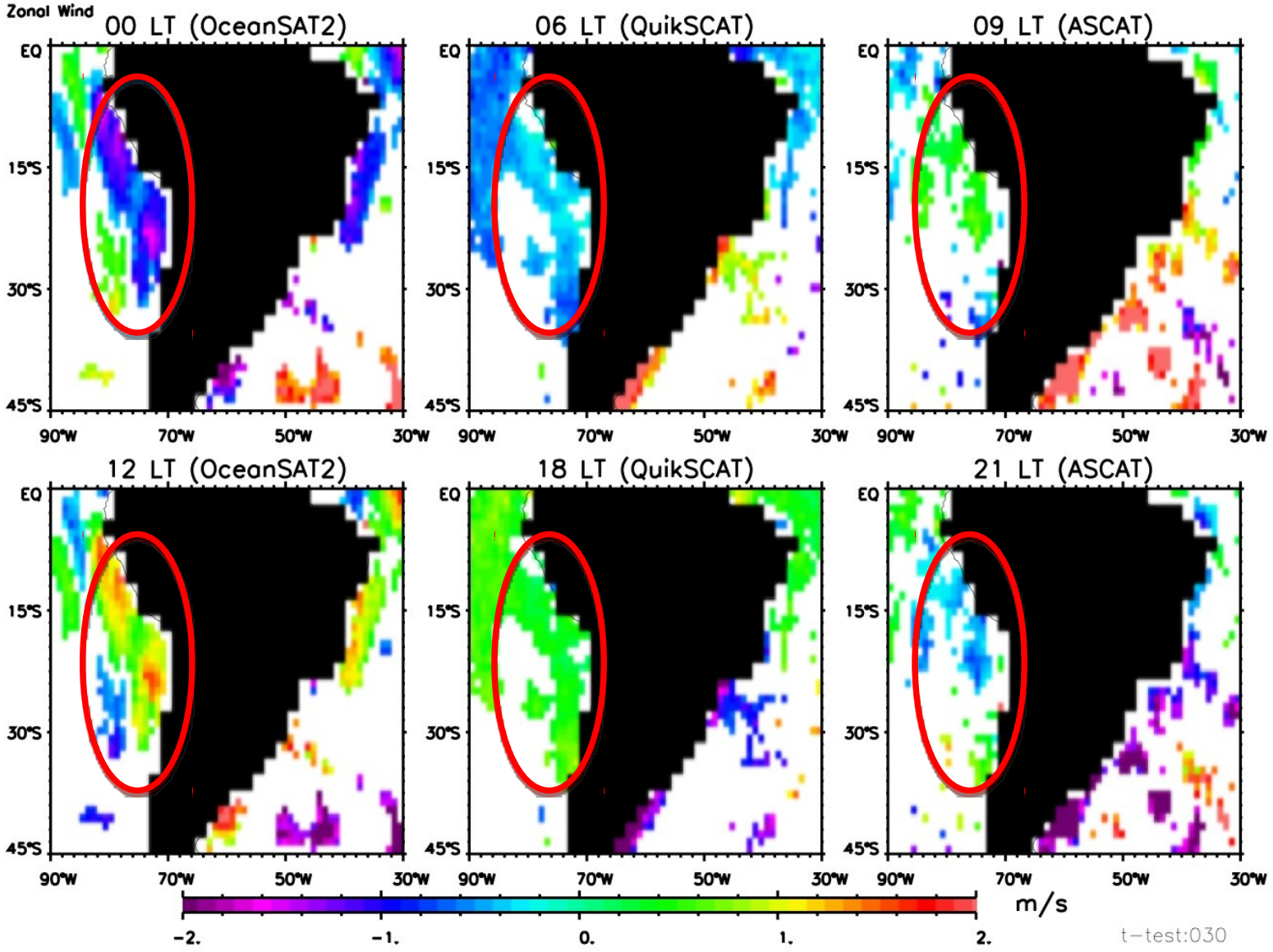
Meridional Wind



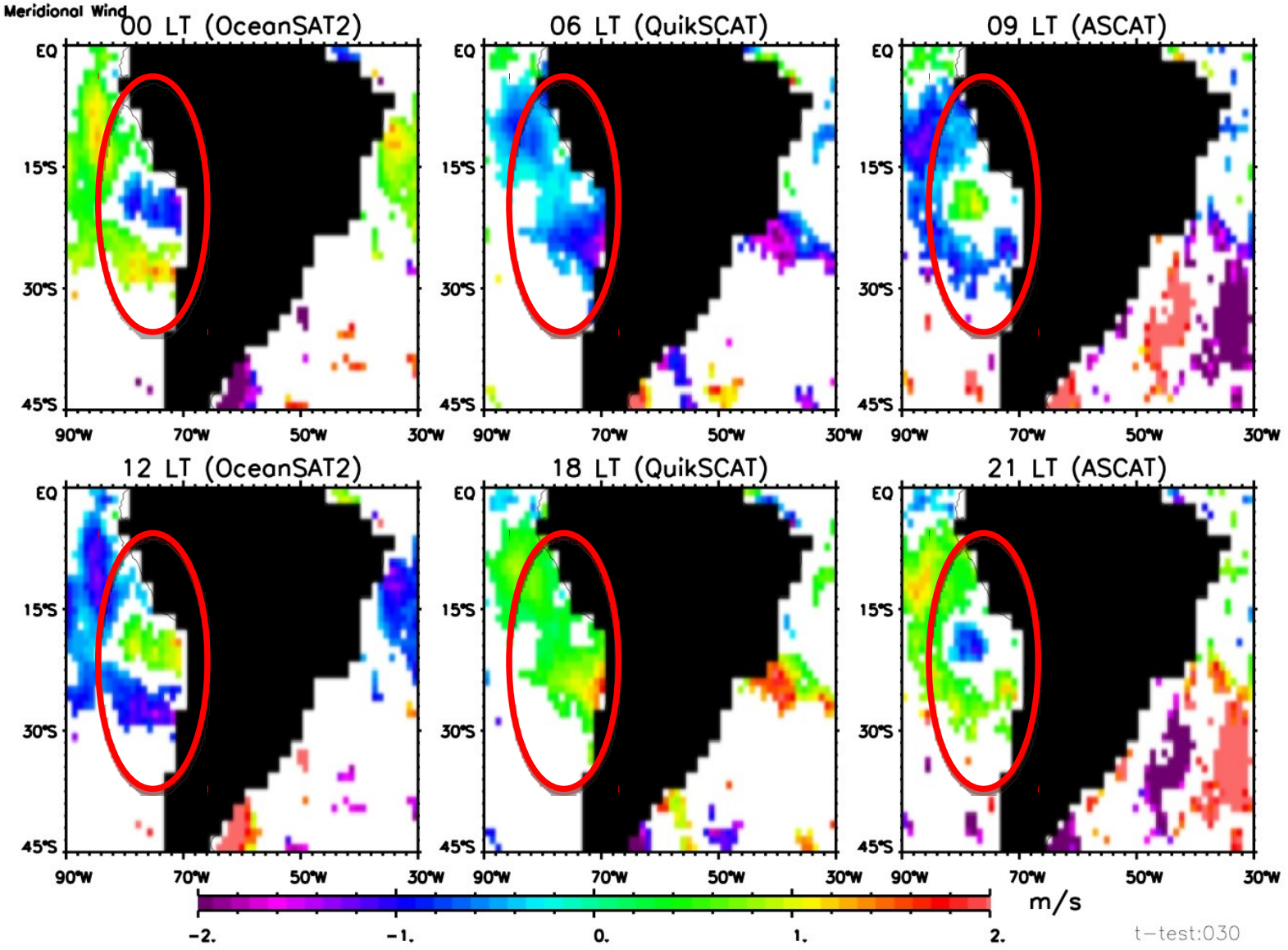


T-test with 70% significance

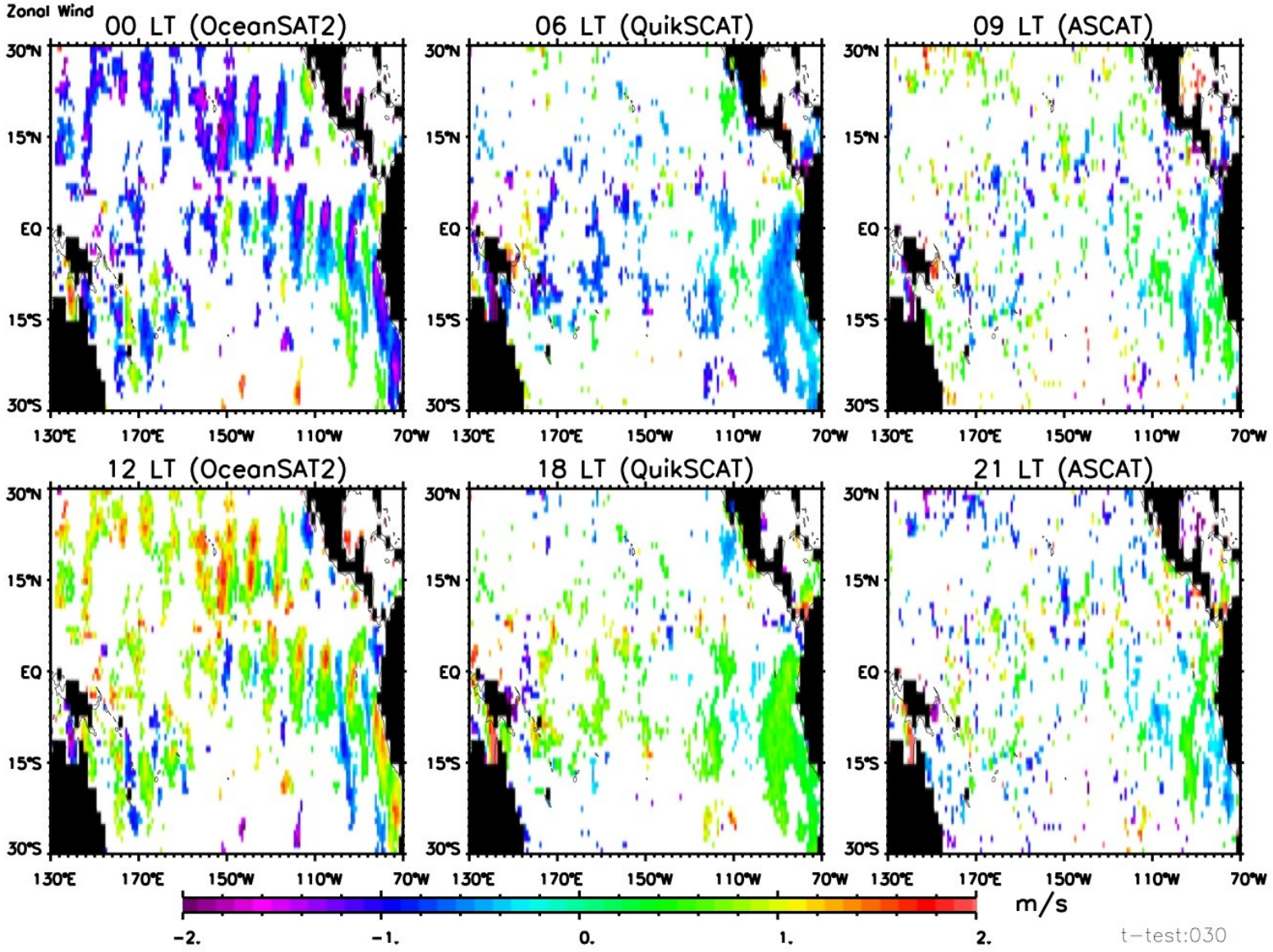
Zonal WInd


Zonal Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
EQ
15°S
30°S
45°S
90°W
70°W
50°W
30°W
m/s
-2.
-1.
0.
1.
2.
t-test:030

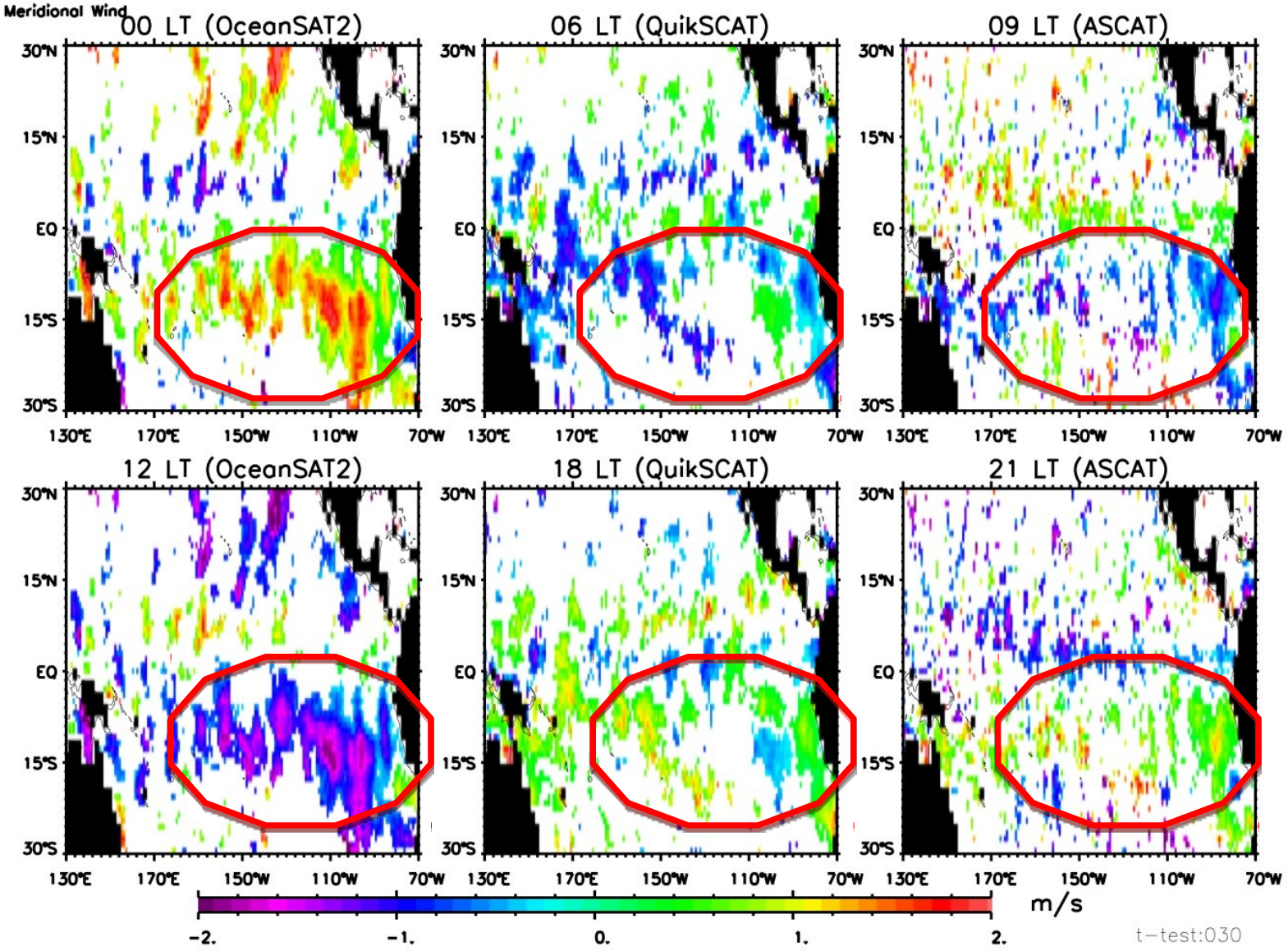
Meridional WInd



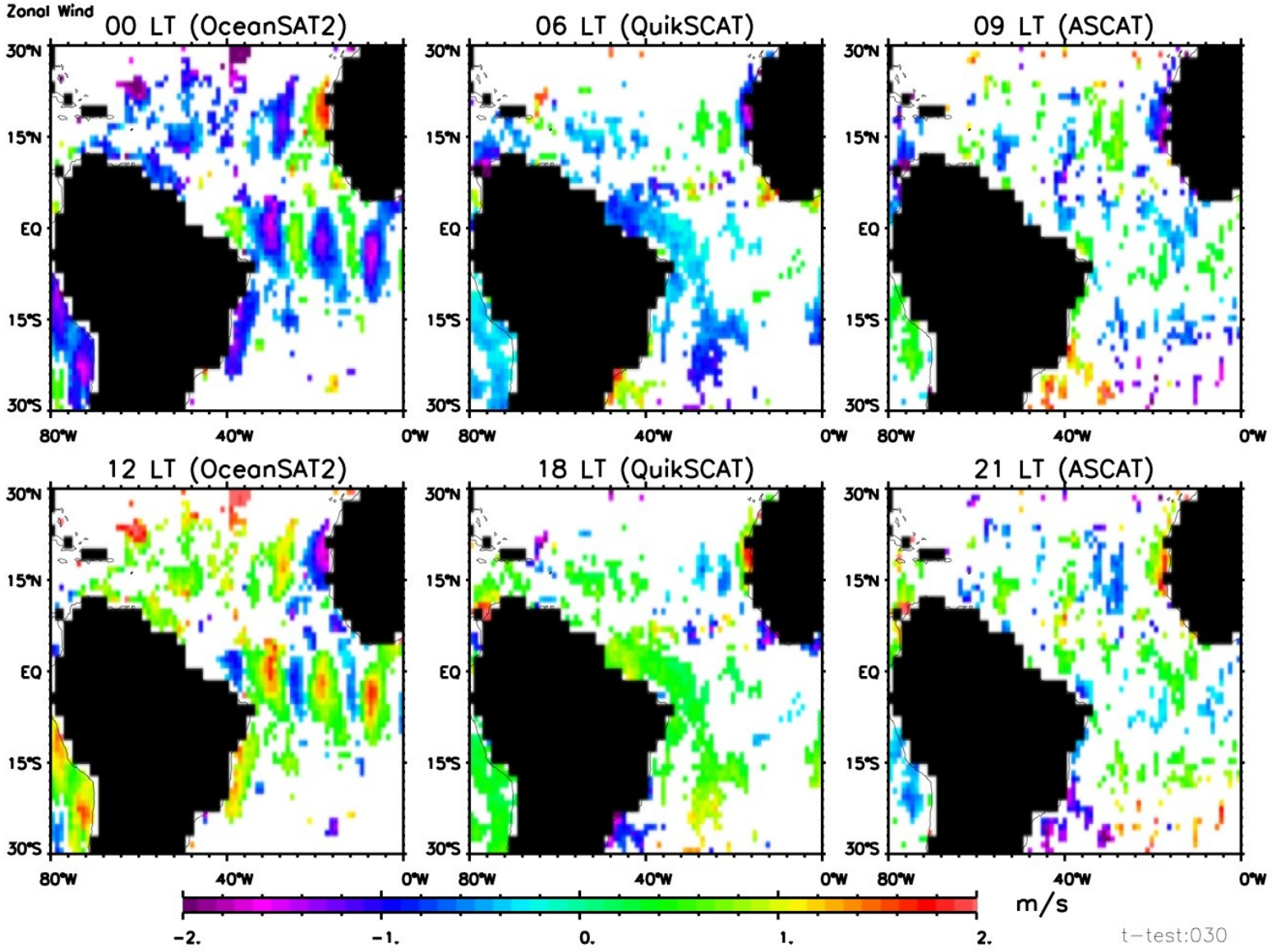
Zonal WInd


Zonal Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
30°N
15°N
EQ
15°S
30°S
130°E
170°E
150°W
110°W
70°W
m/s
−2.
−1.
0.
1.
2.
t−test:030

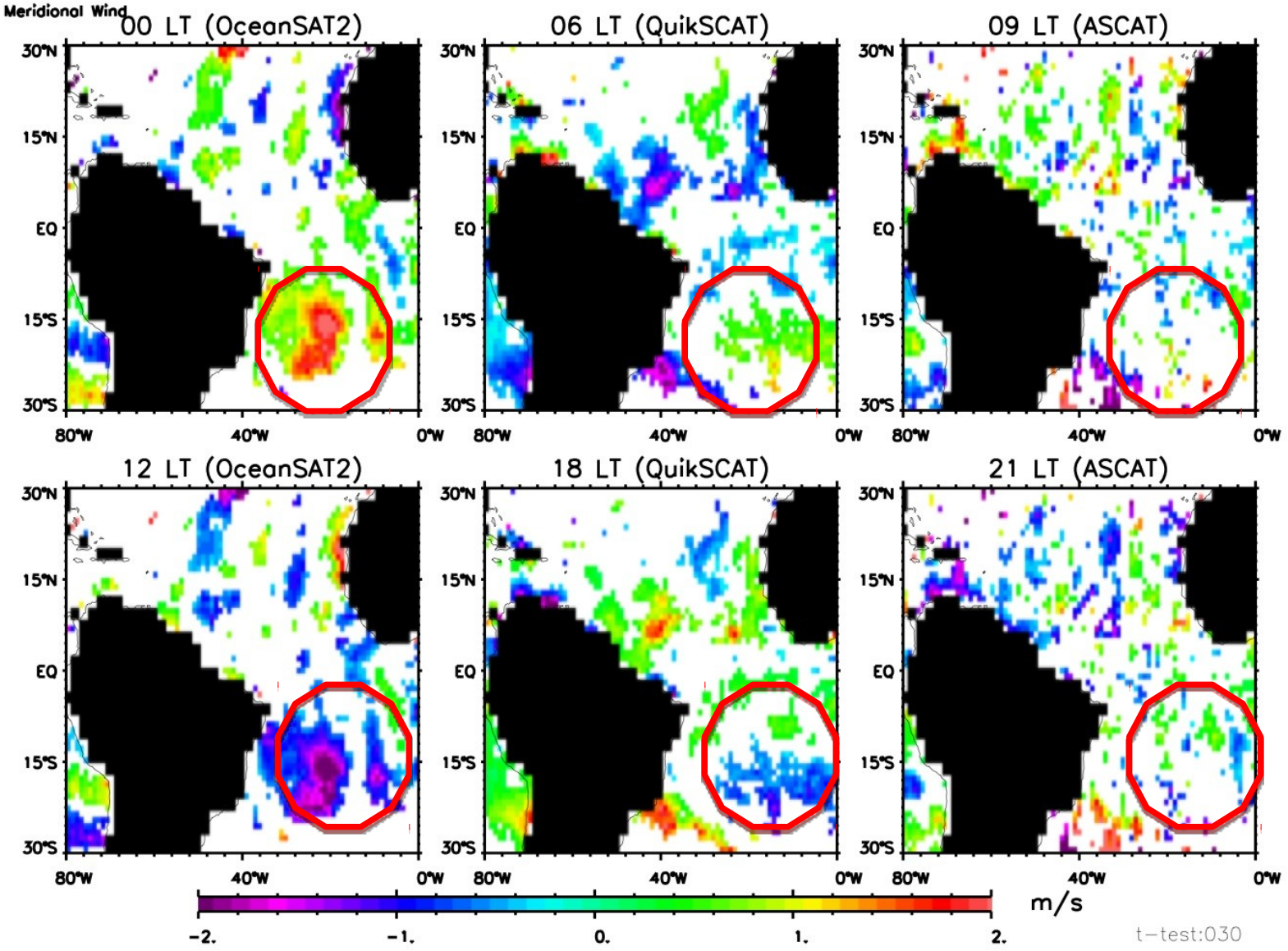
Meridional WInd

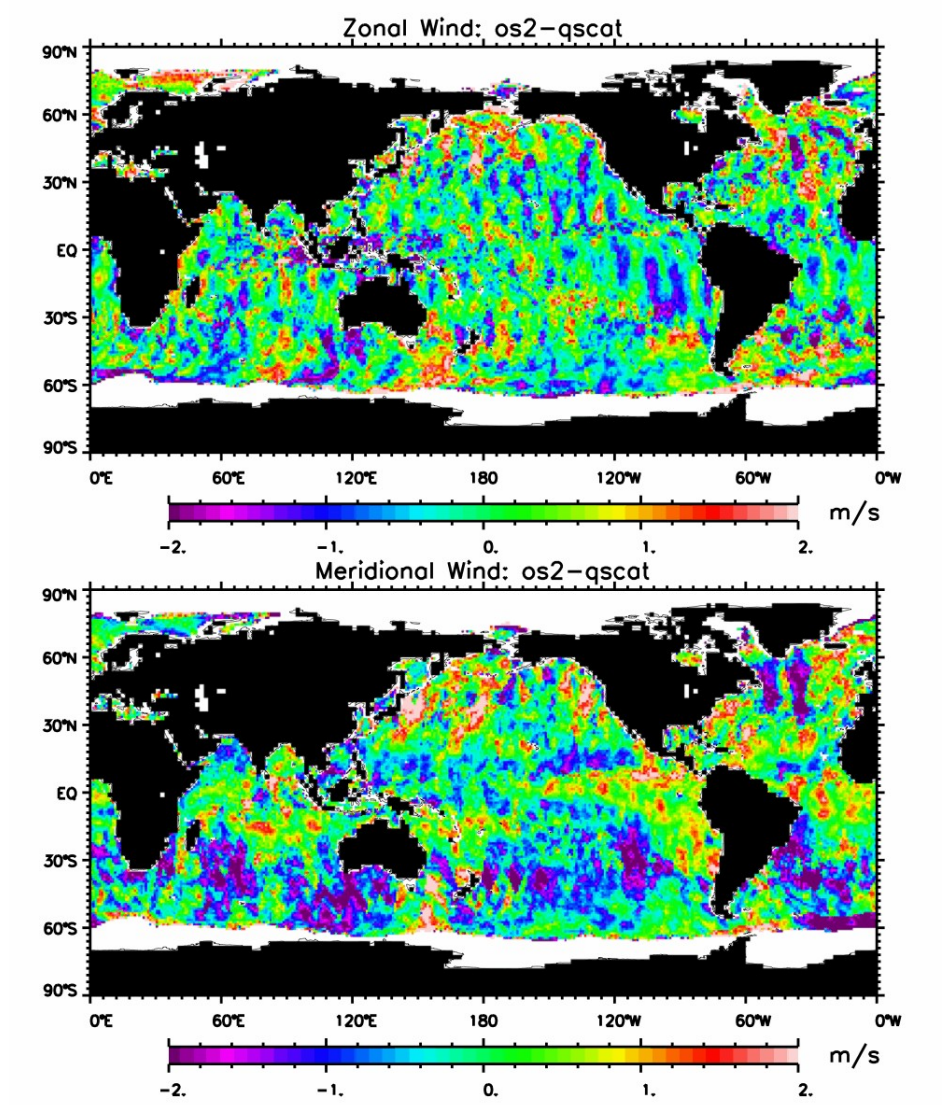


Zonal WInd

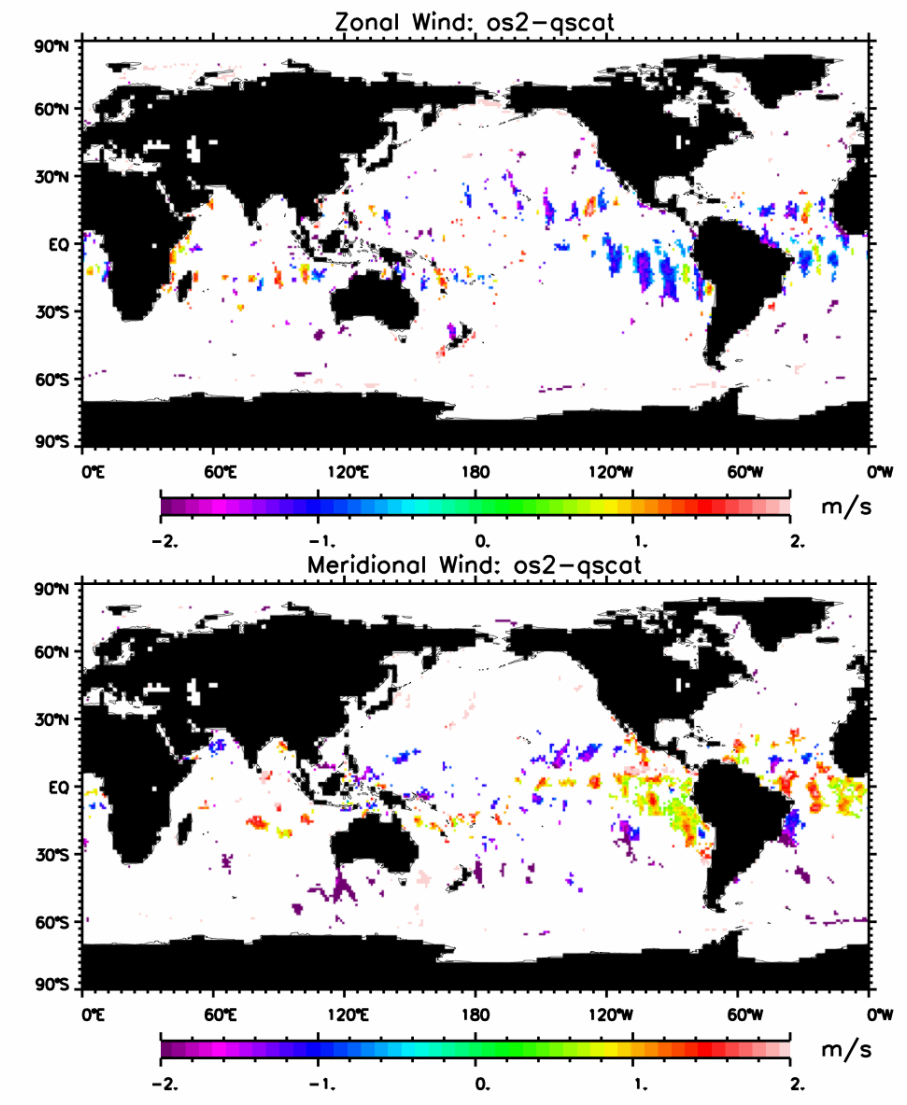

Zonal Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
30°N
15°N
EQ
15°S
30°S
80°W
40°W
0°W
m/s
-2.
-1.
0.
1.
2.
t-test:030

Meridional WInd





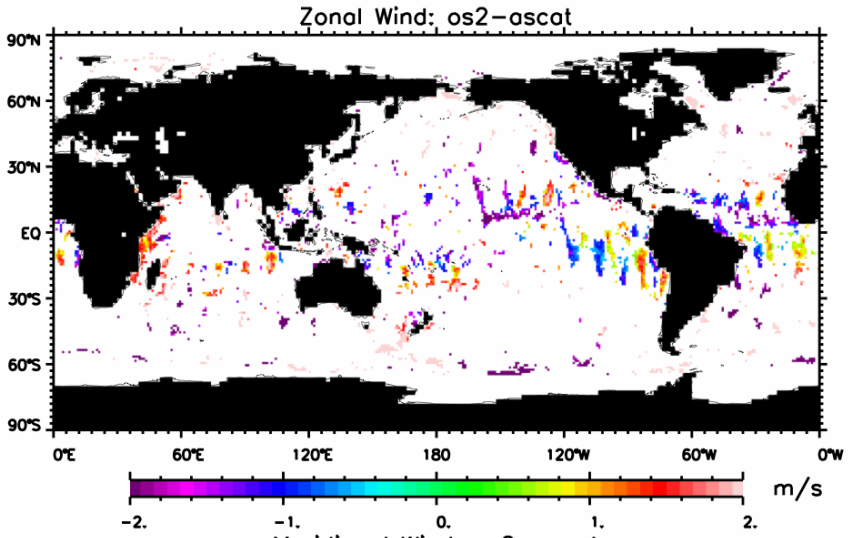
Differences between OceanSat-2 and QuikSCAT measurements averaged over the two weeks of coincidence for zonal (upper) & meridional (lower)



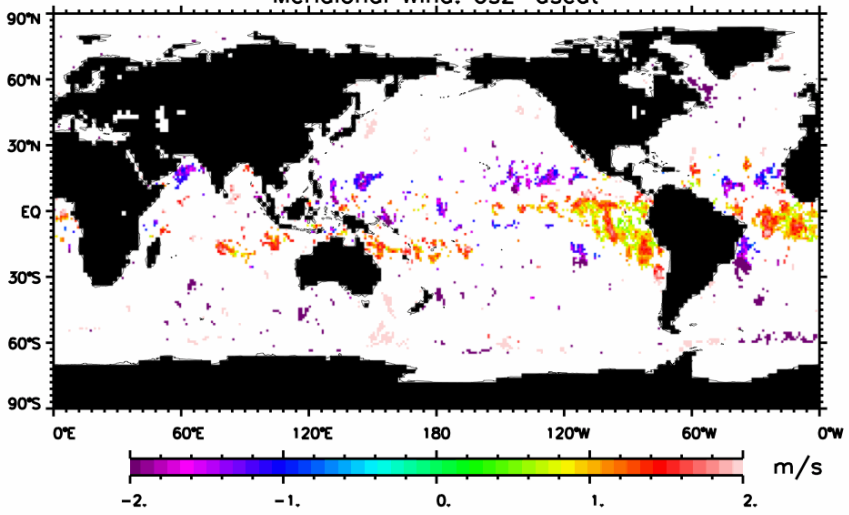
Significant (90%) difference observed in tropical oceans, where strong diurnal variability of ocean wind were

OceanSAT-2 - ASCAT

U

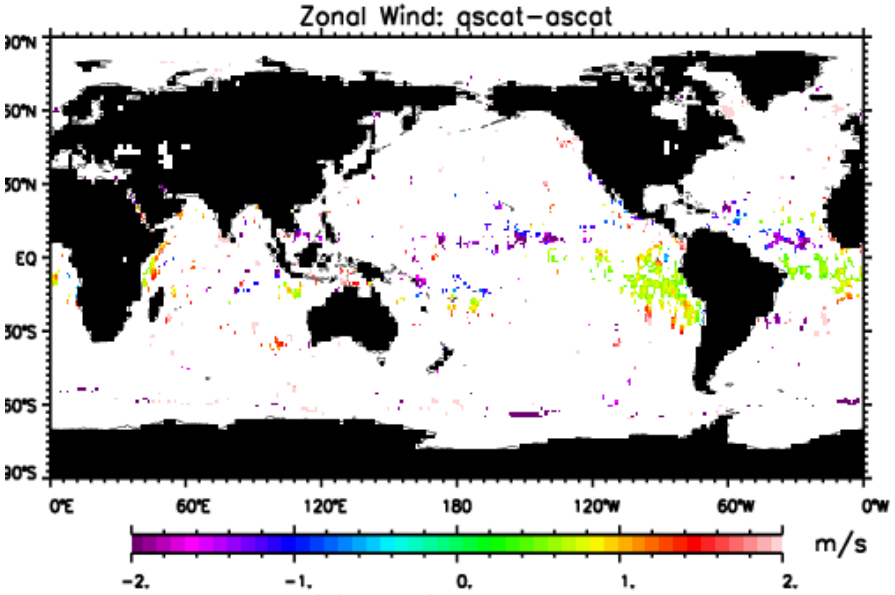


V

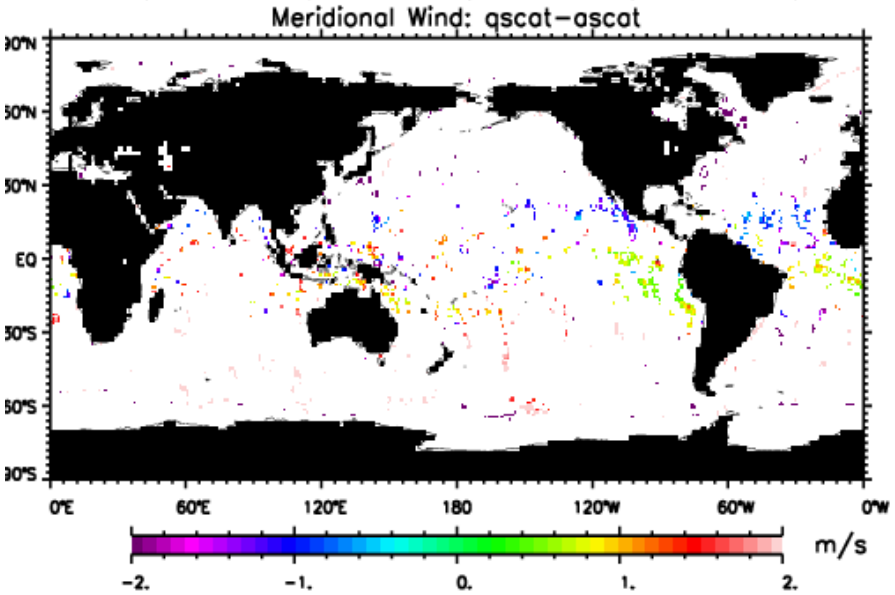


QuikSCAT - ASCAT

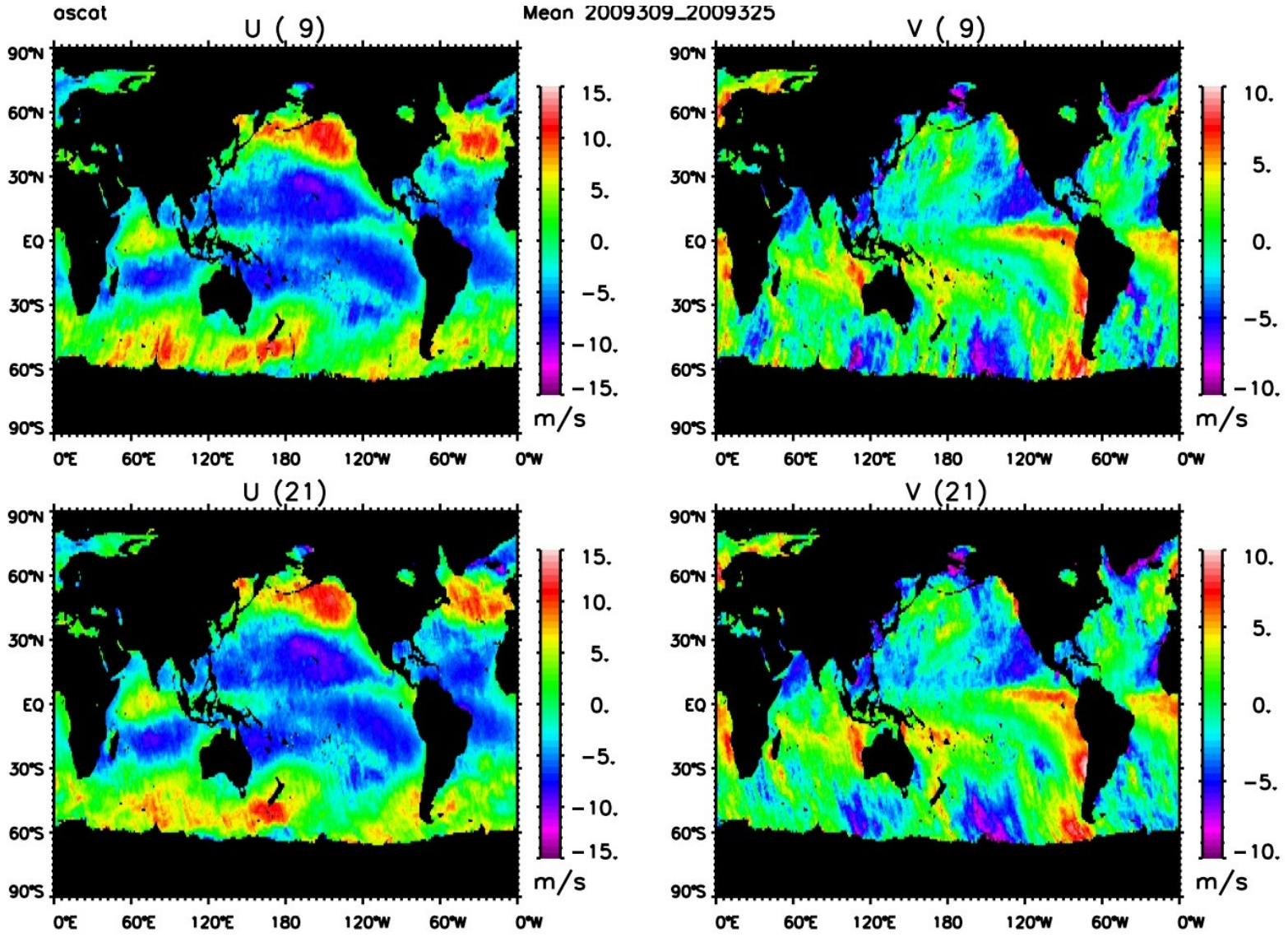
U



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.

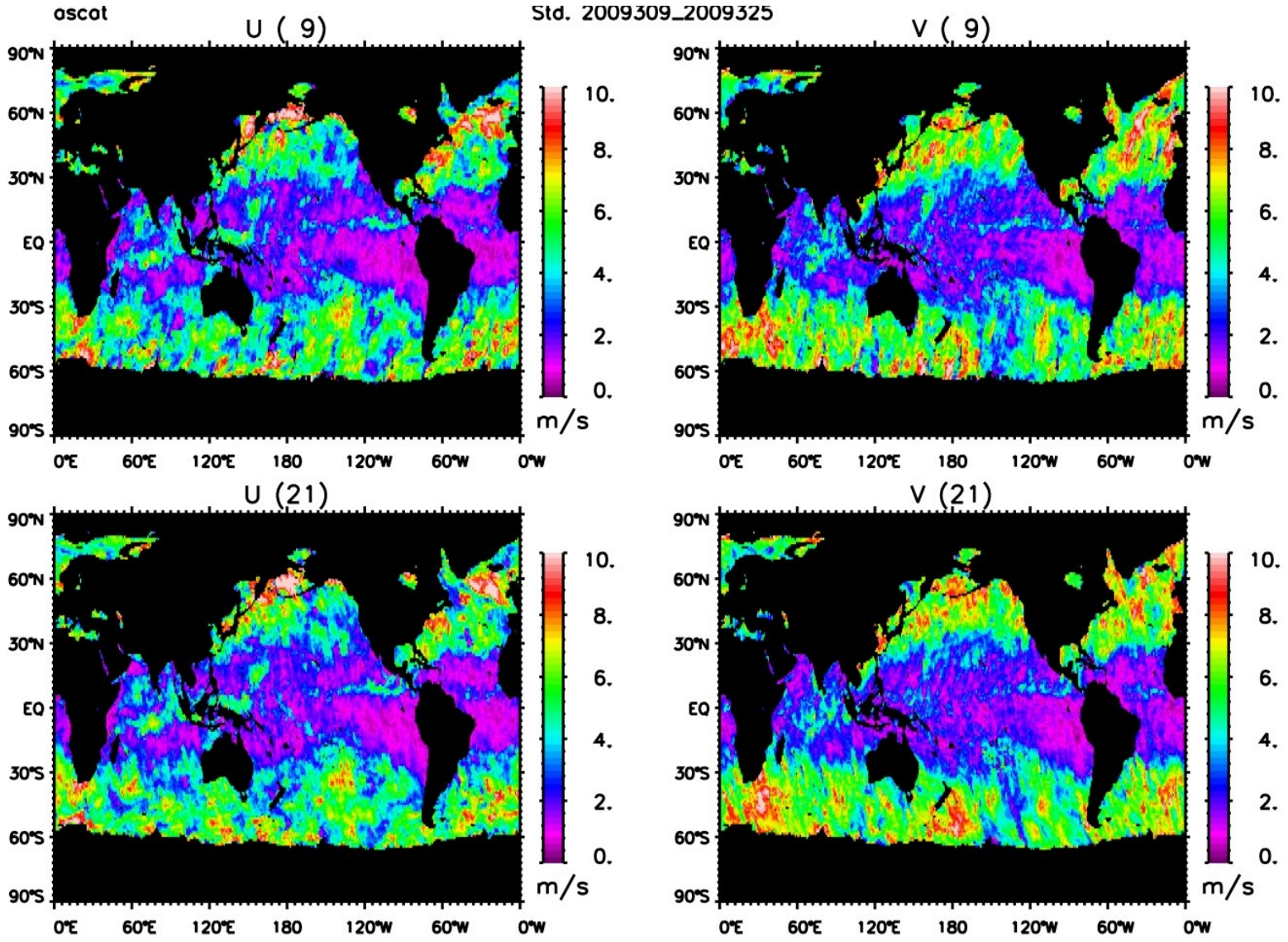
The zonal and meridional components are fitted to a second order harmonic function to obtain the amplitude (A1, A2) and phase (p1, p2) of the diurnal and semidiurnal cycles,

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

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

Uncertainties are derived using stardard errors and random noises

ASCAT: Standard deviation of U & V for ascending/descending passes



Uncertainty estimated via Monte Carlo simulation

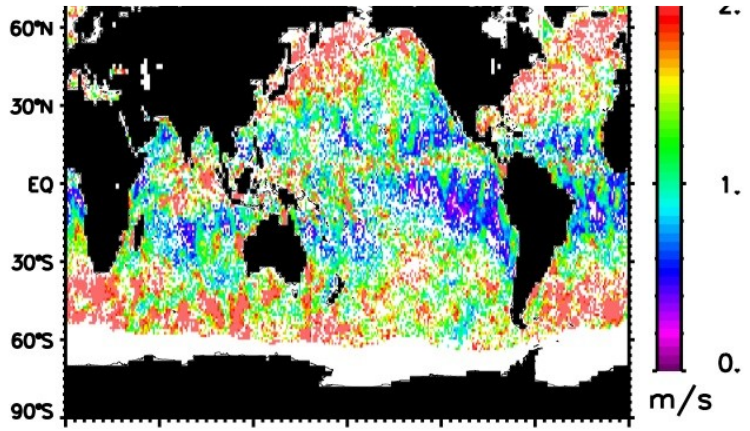
(1) Perturb the original 6 data values by adding random numbers with a Gaussian distribution and a variance equivalent to the standard error of measurements; and re-derive A_1, p_1 and A_2, p_2;

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

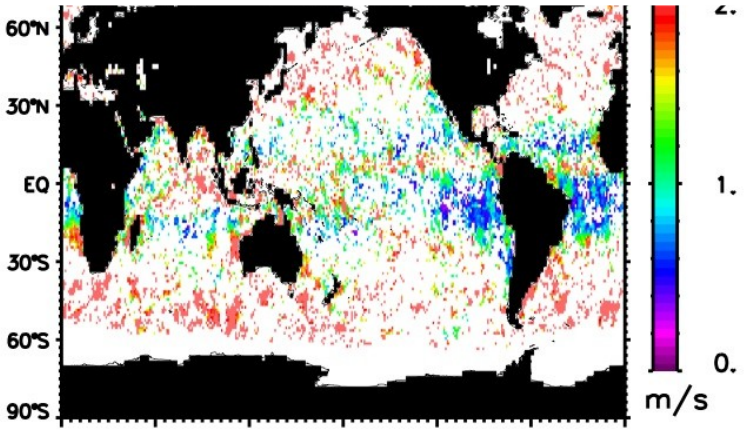
(3) Uncertainties of A_1, p_1 and A_2, p_2 are determined from the standard deviation of the 100 realizations, i.e. the uncertainty of A_1 is the standard deviation of 100 A_1 computed

ude (A1) of the diurnal cycle of Zonal Wind (where A1

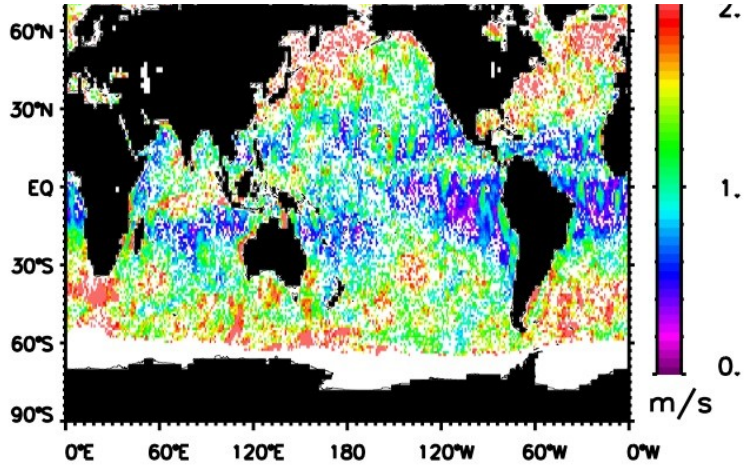
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



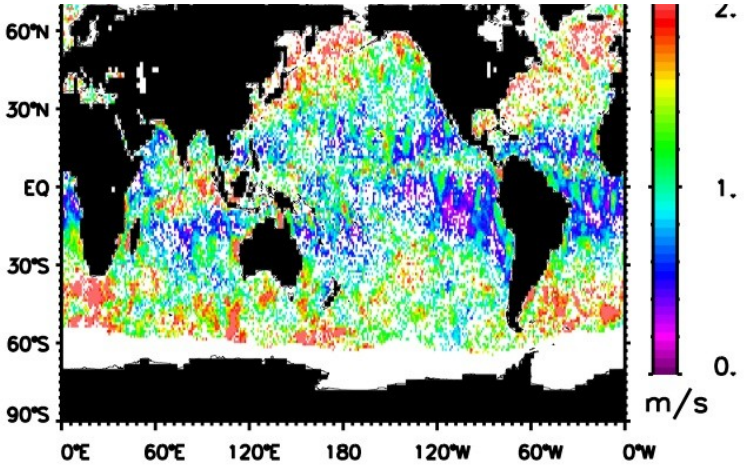
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+Oc eanSAT2



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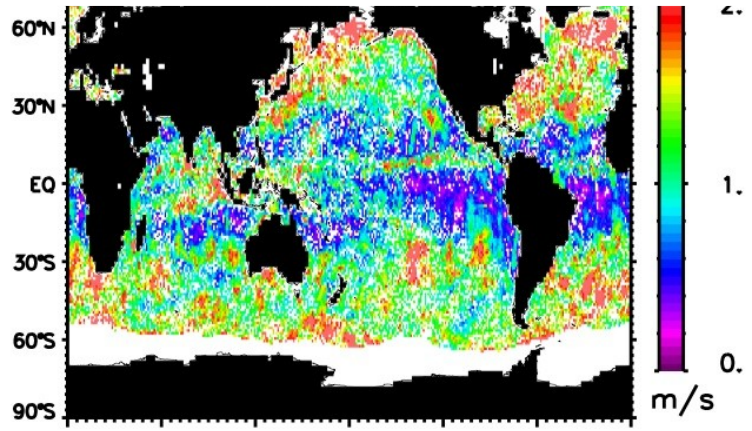
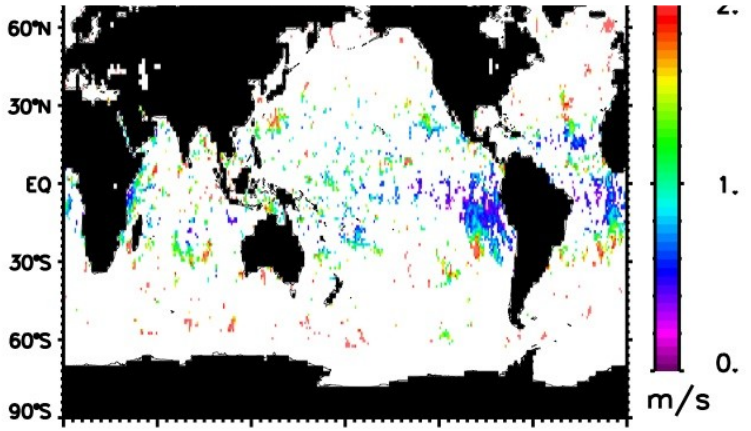
data over two weeks period (Nov. 5-21, 2009) when all four ser

(A2) of the semi-diurnal cycle of Zonal Wind (where A

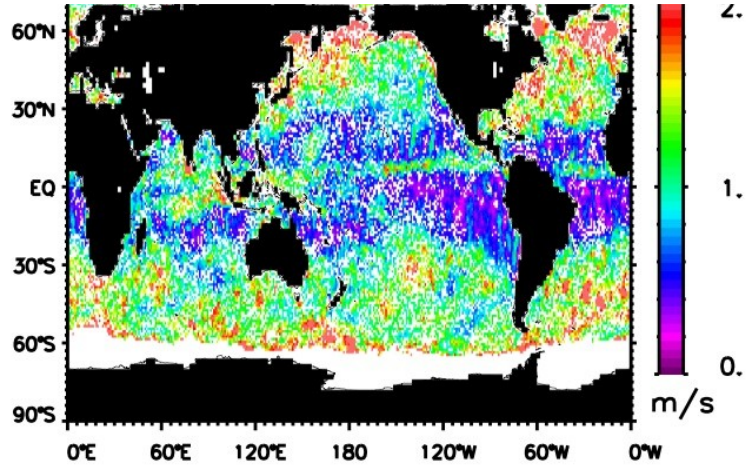
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



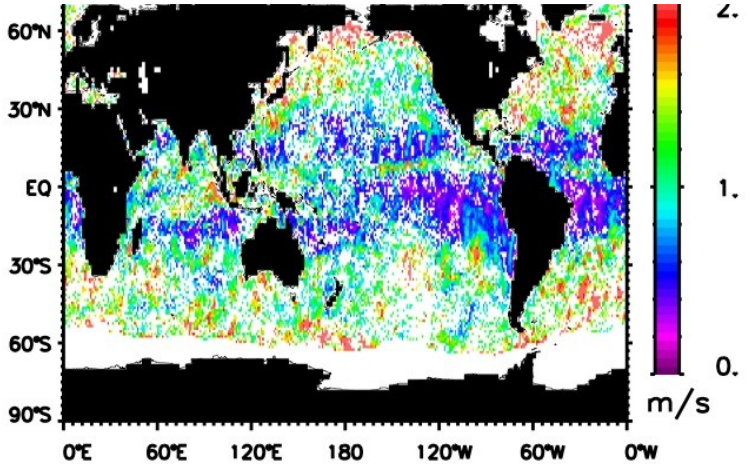
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+OceanSAT2



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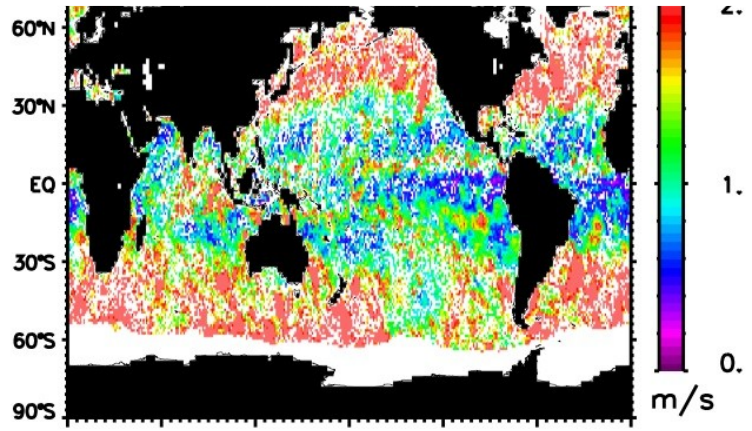
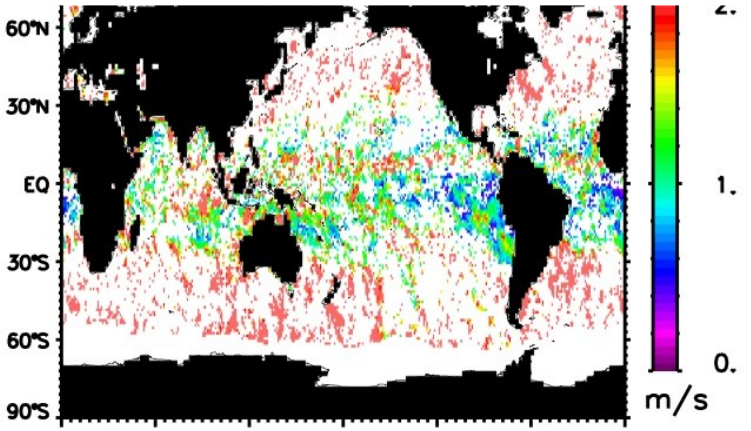
data over two weeks period (Nov. 5-21, 2009) when all four ser

de (A1) of the diurnal cycle of Meridional Wind (where

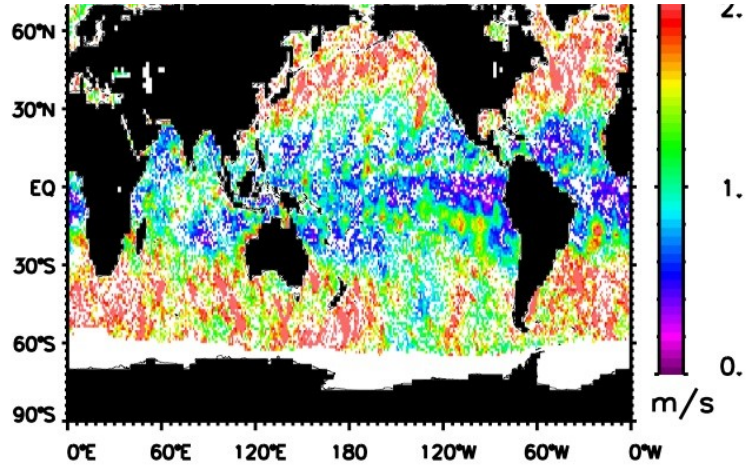
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



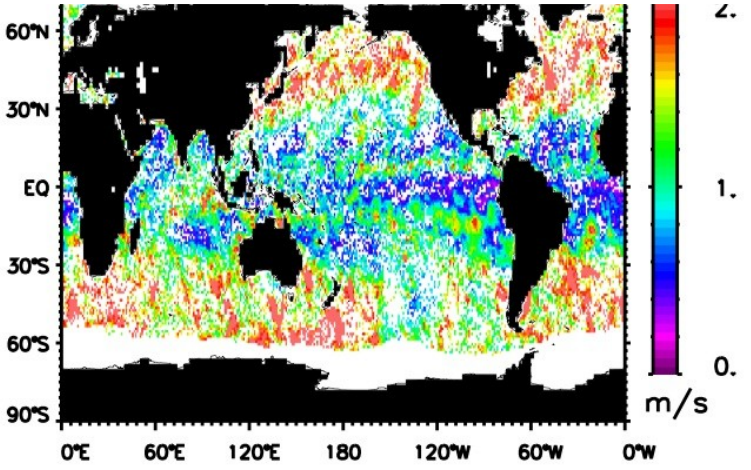
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+Oc eanSAT2



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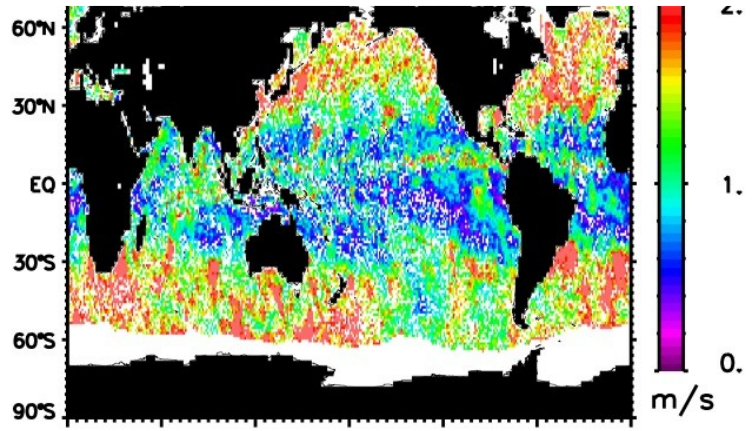
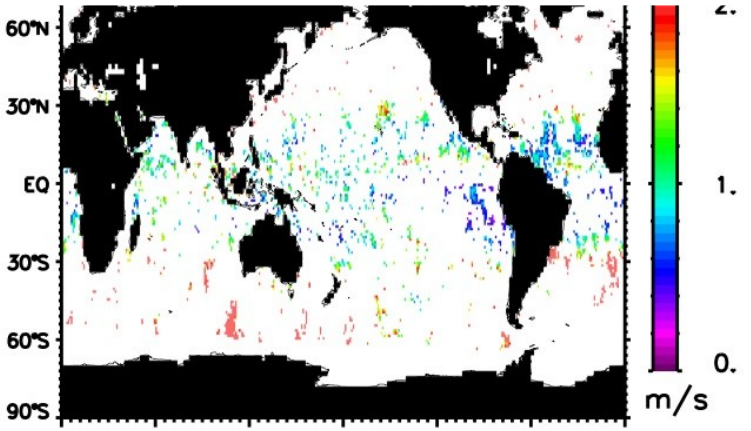
data over two weeks period (Nov. 5-21, 2009) when all four ser

(A2) of the semi-diurnal cycle of Merid. Wind (where

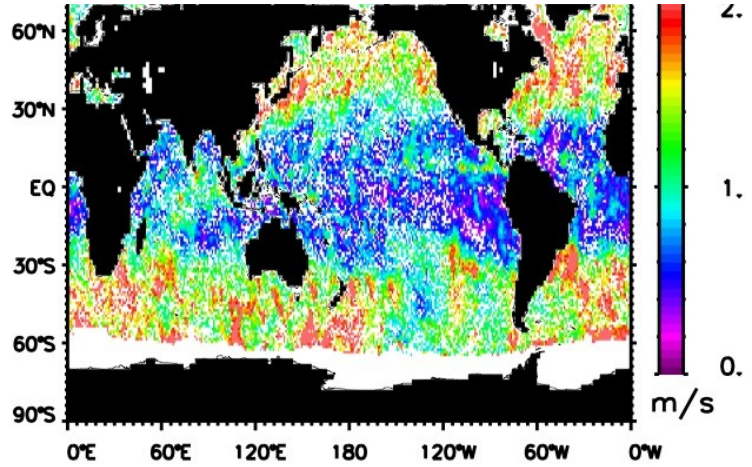
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



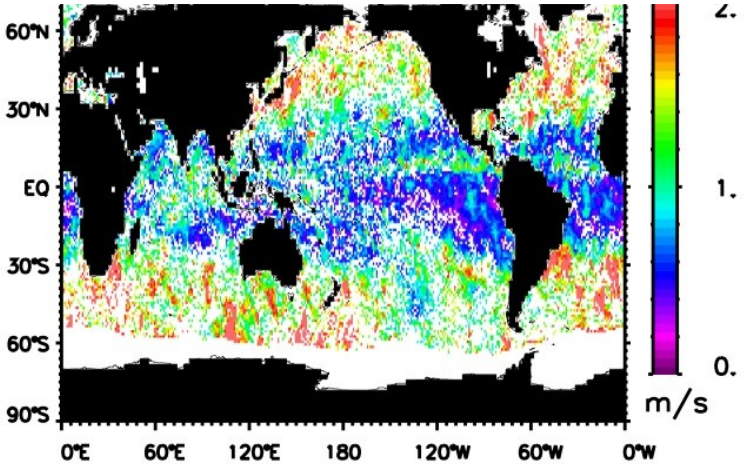
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



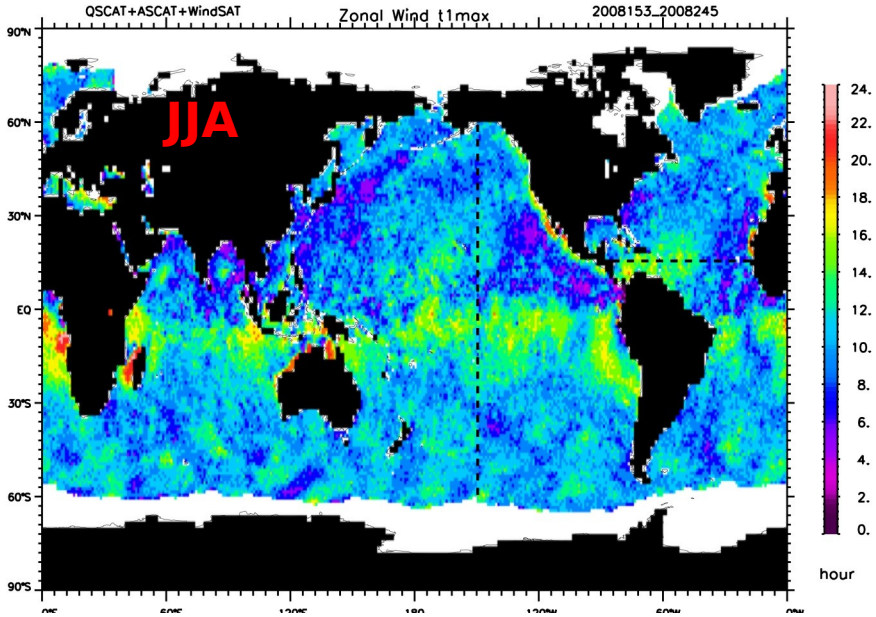
QSCAT+ASCAT+WindSAT+OceanSAT2

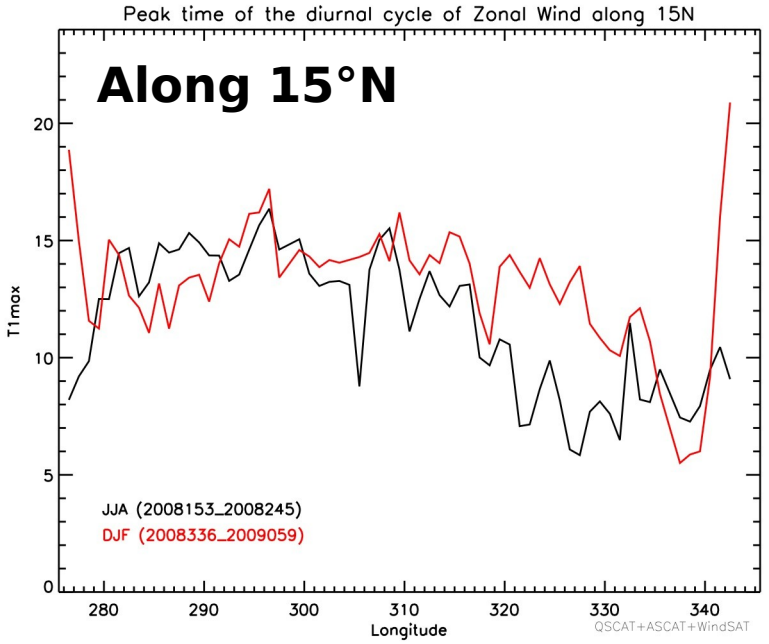


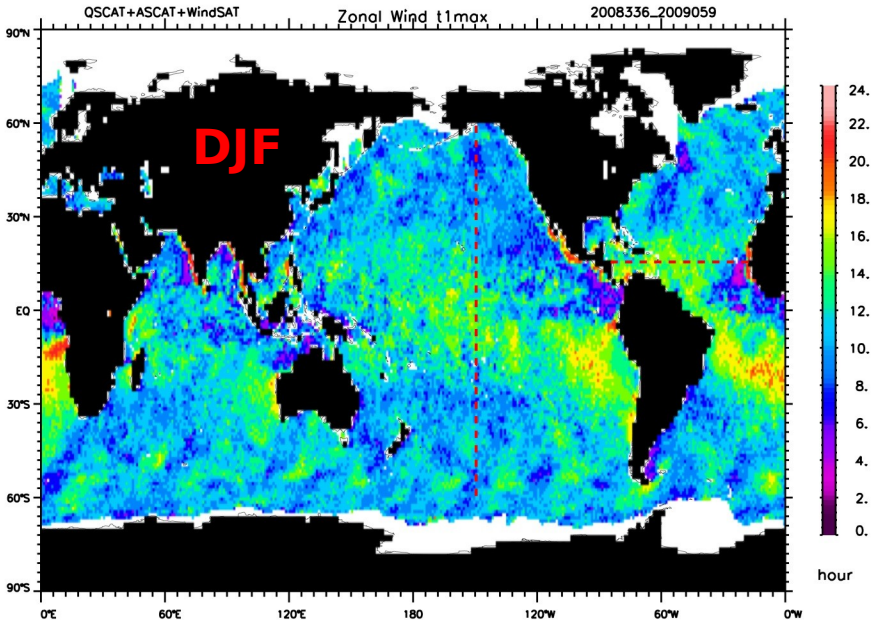
2009309_2009325

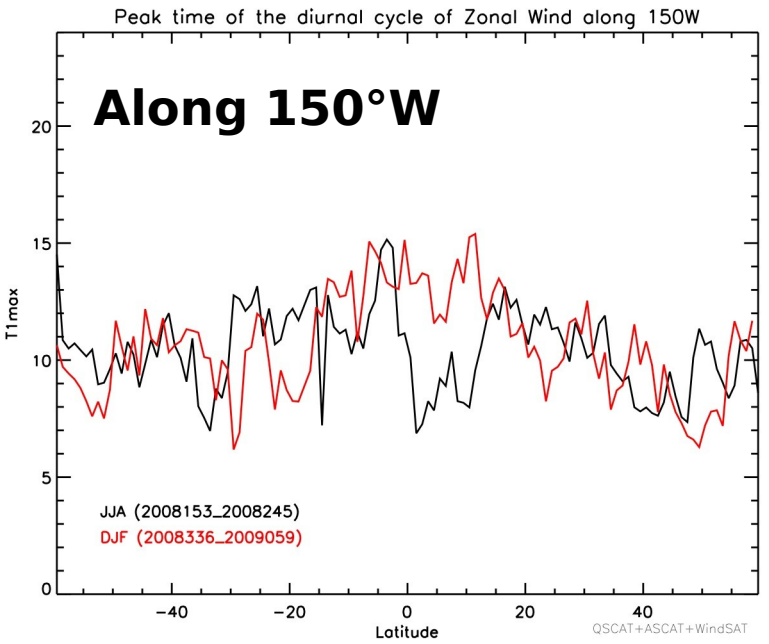
data over two weeks period (Nov. 5-21, 2009) when all four ser

ak time of the zonal Wind diurnal cycle in summer an

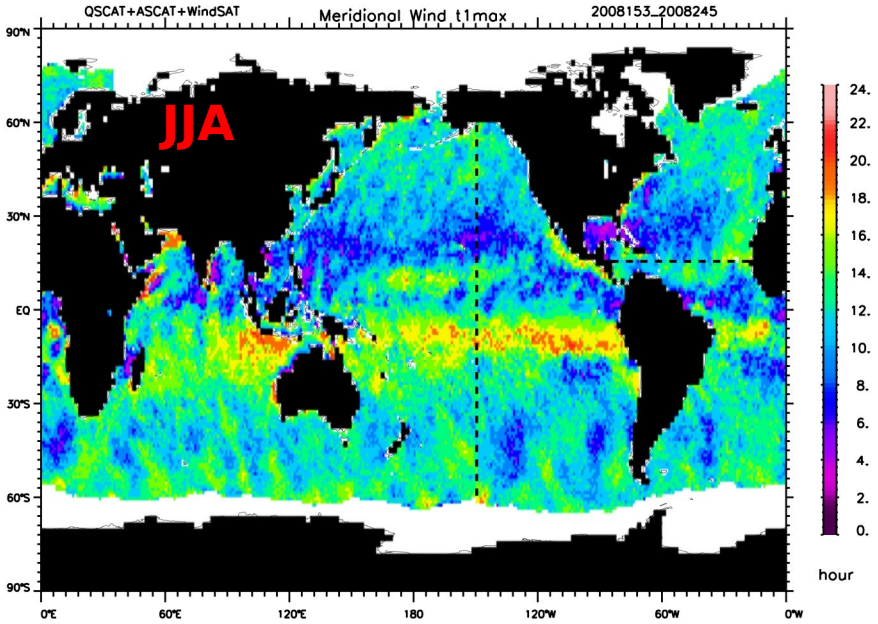


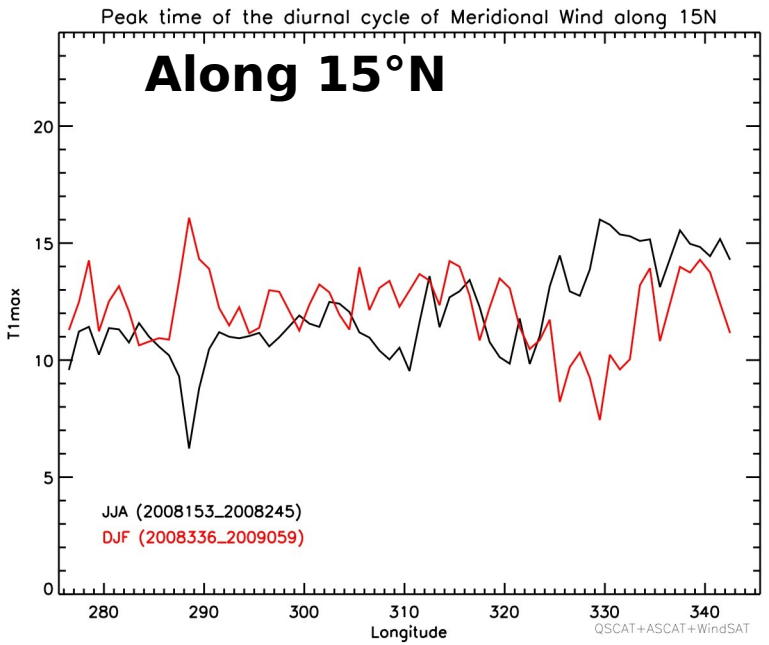


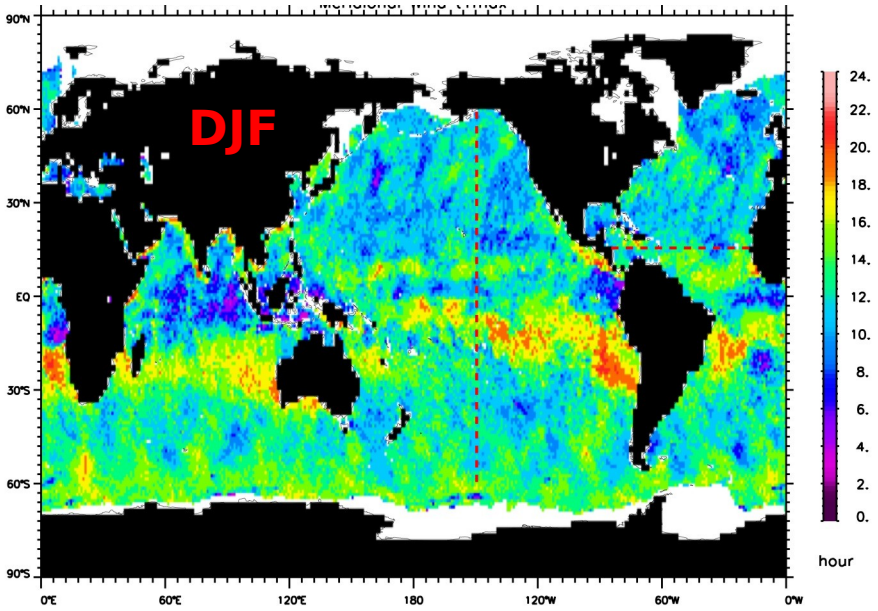


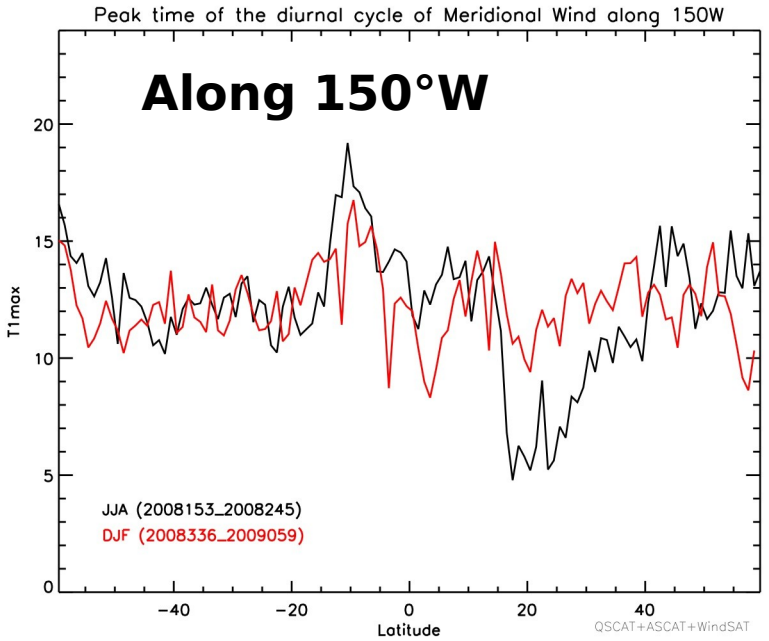


ak time of the merid. Wind diurnal cycle in summer a





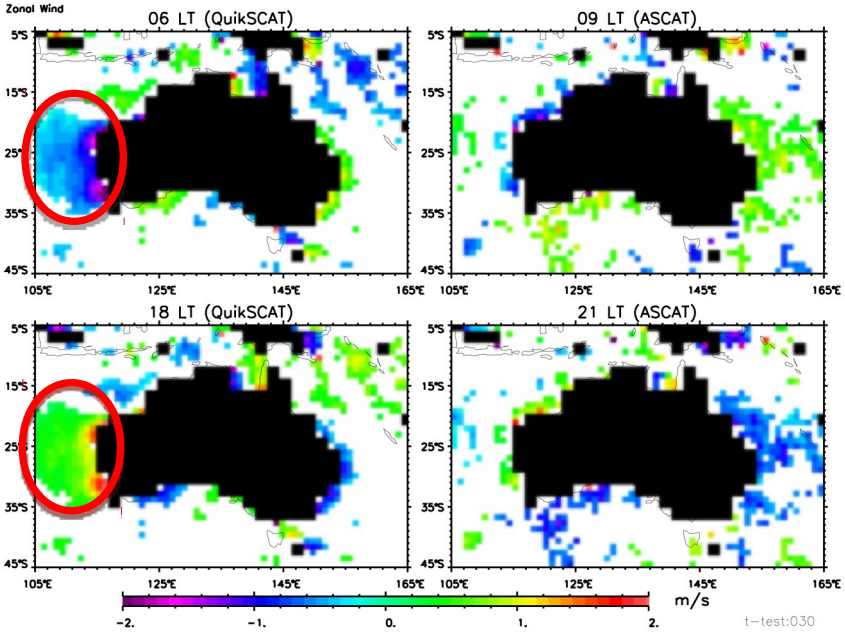


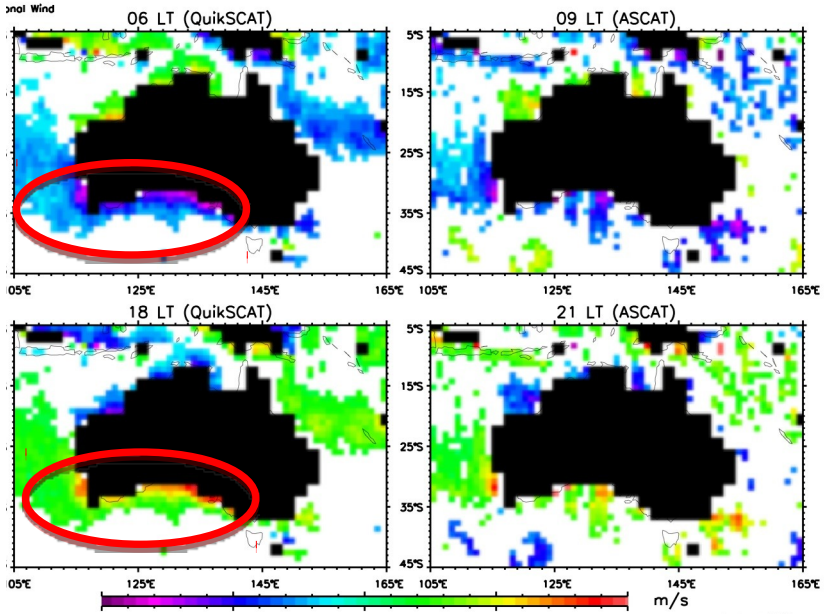


Zonal Wind Comp.

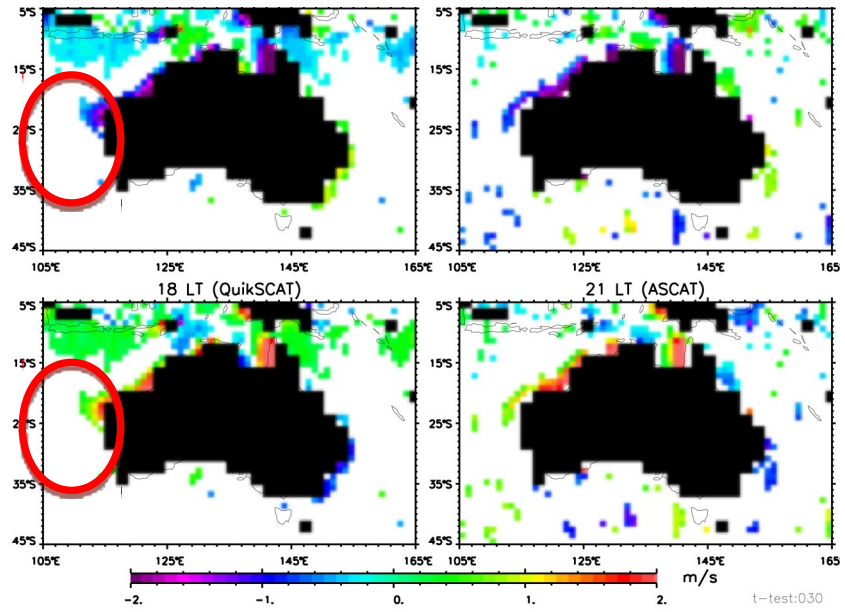
Meridional Wind Comp.

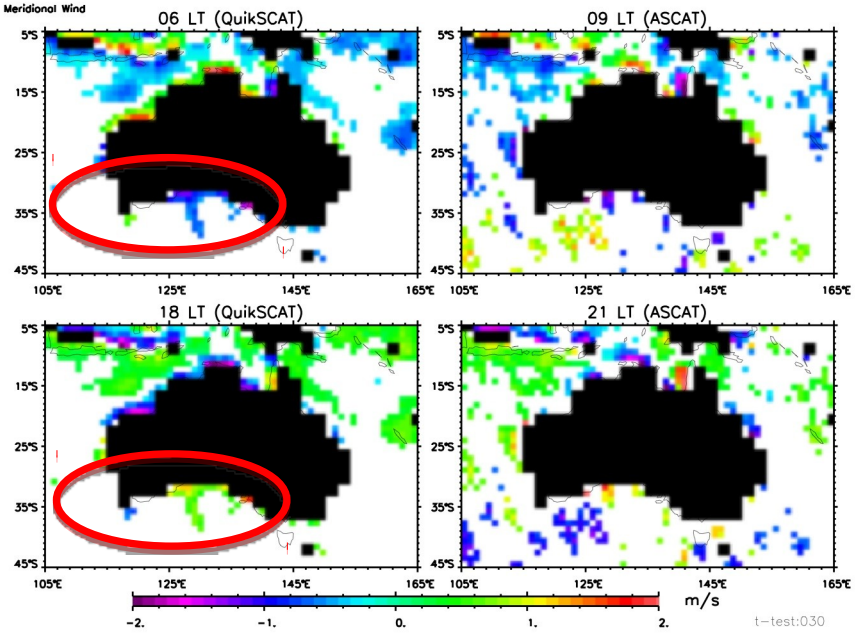
S.H. Summer

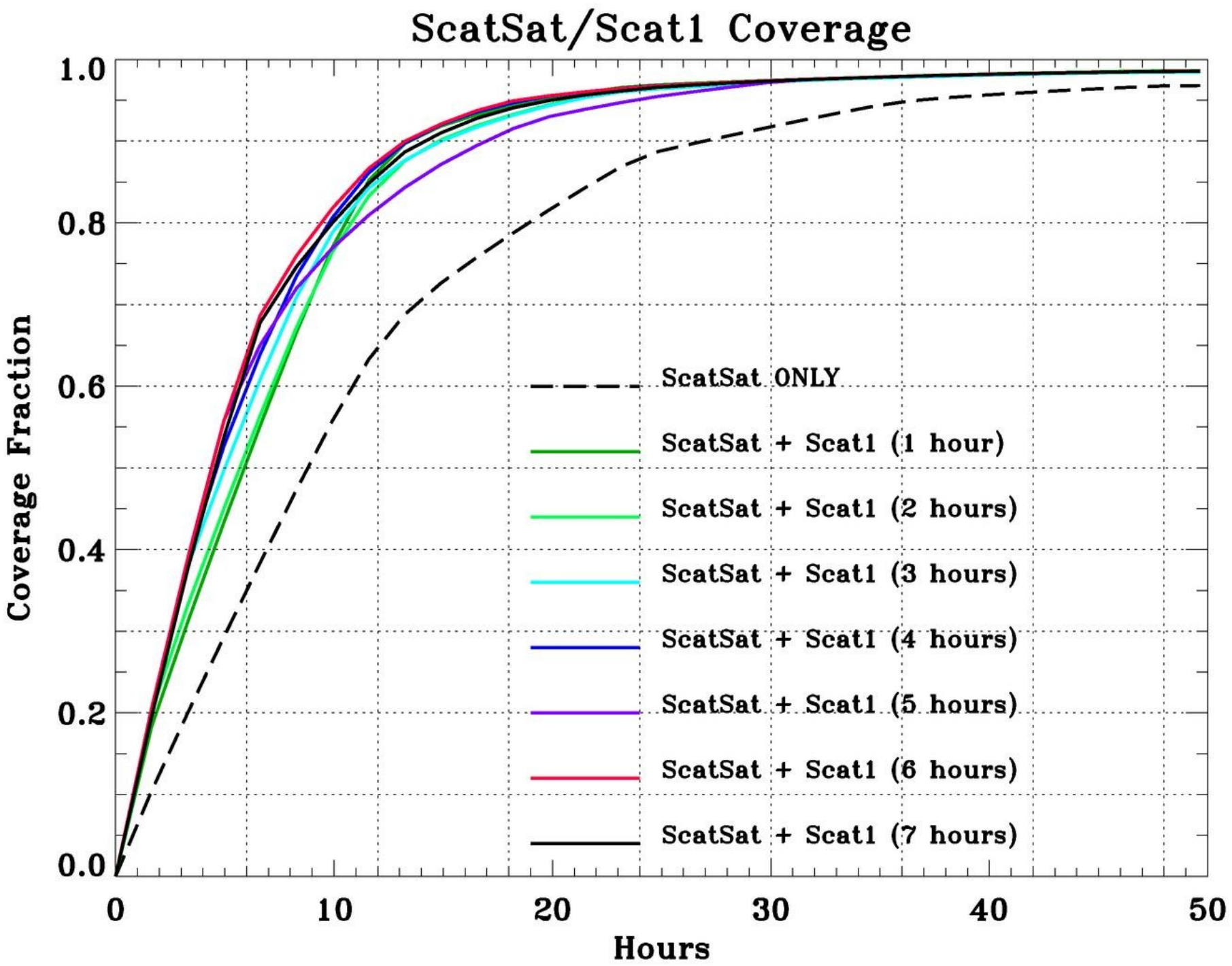




S.H. Winter






ScatSat/Scat1 Coverage
Coverage Fraction
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Hours
ScatSat ONLY
ScatSat + Scat1 (1 hour)
ScatSat + Scat1 (2 hours)
ScatSat + Scat1 (3 hours)
ScatSat + Scat1 (4 hours)
ScatSat + Scat1 (5 hours)
ScatSat + Scat1 (6 hours)
ScatSat + Scat1 (7 hours)

Summary

Significant regional day and night difference in scatterometer data

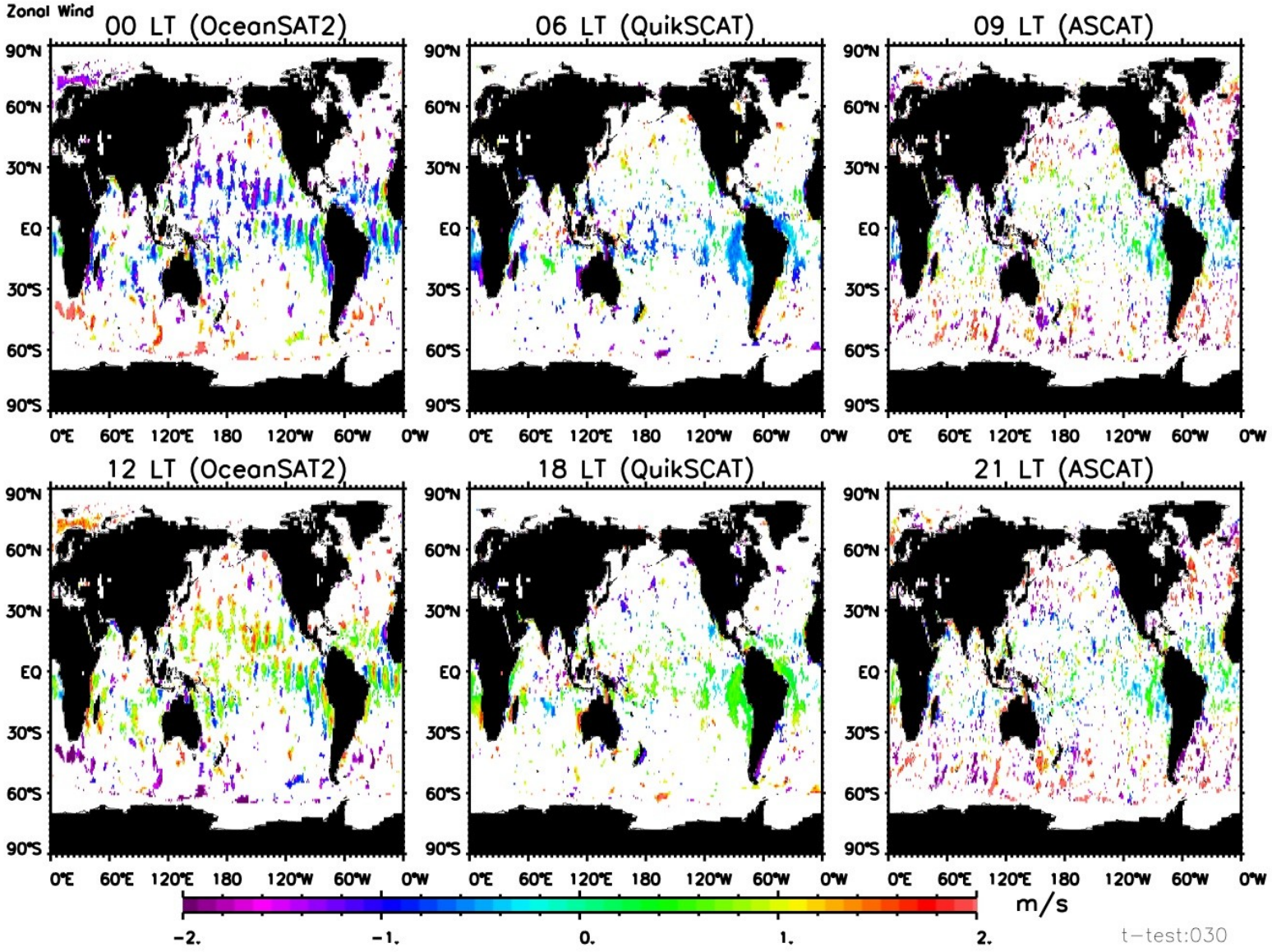
Extend our knowledge of diurnal and sub-daily variation from mooring locations
To open ocean

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

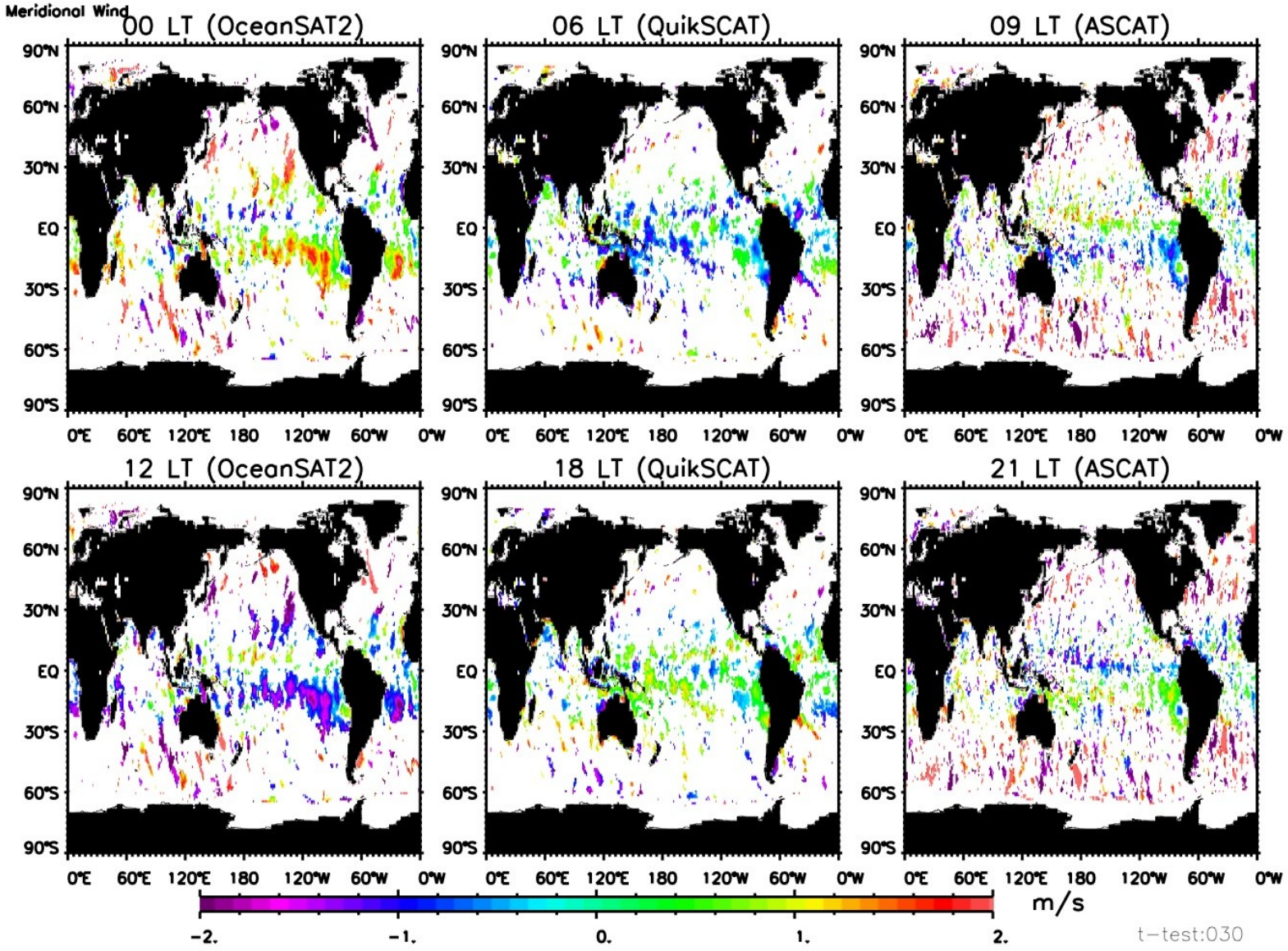
Future optimal spacing of satellite orbit will help avoid aliasing of subdaily variation into climate record.

backup

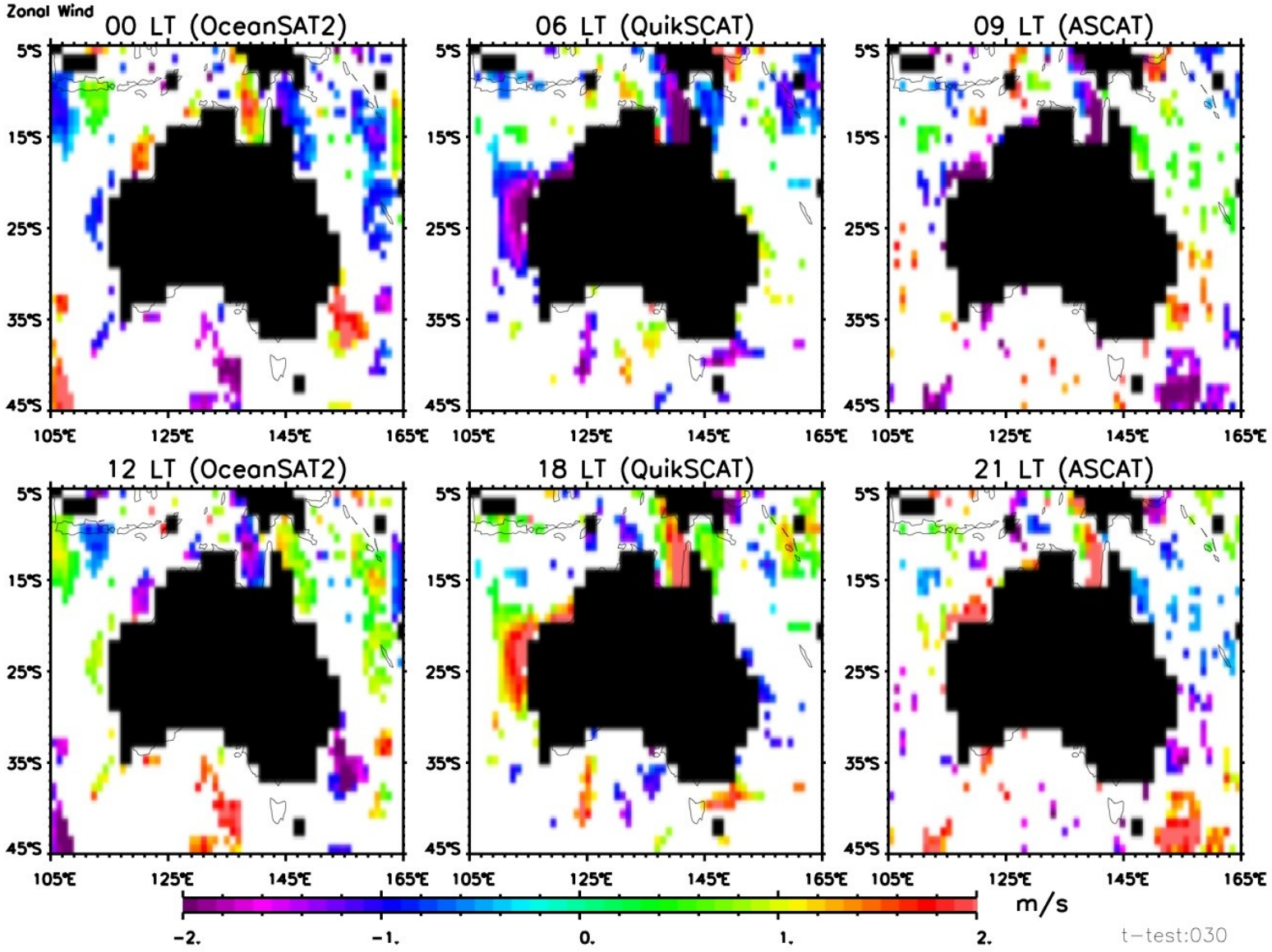
Zonal WInd


Zonal Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
90°N
60°N
30°N
EQ
30°S
60°S
90°S
0°E 60°E 120°E 180 120°W 60°W 0°W
m/s
−2. −1. 0. 1. 2.
t−test:030

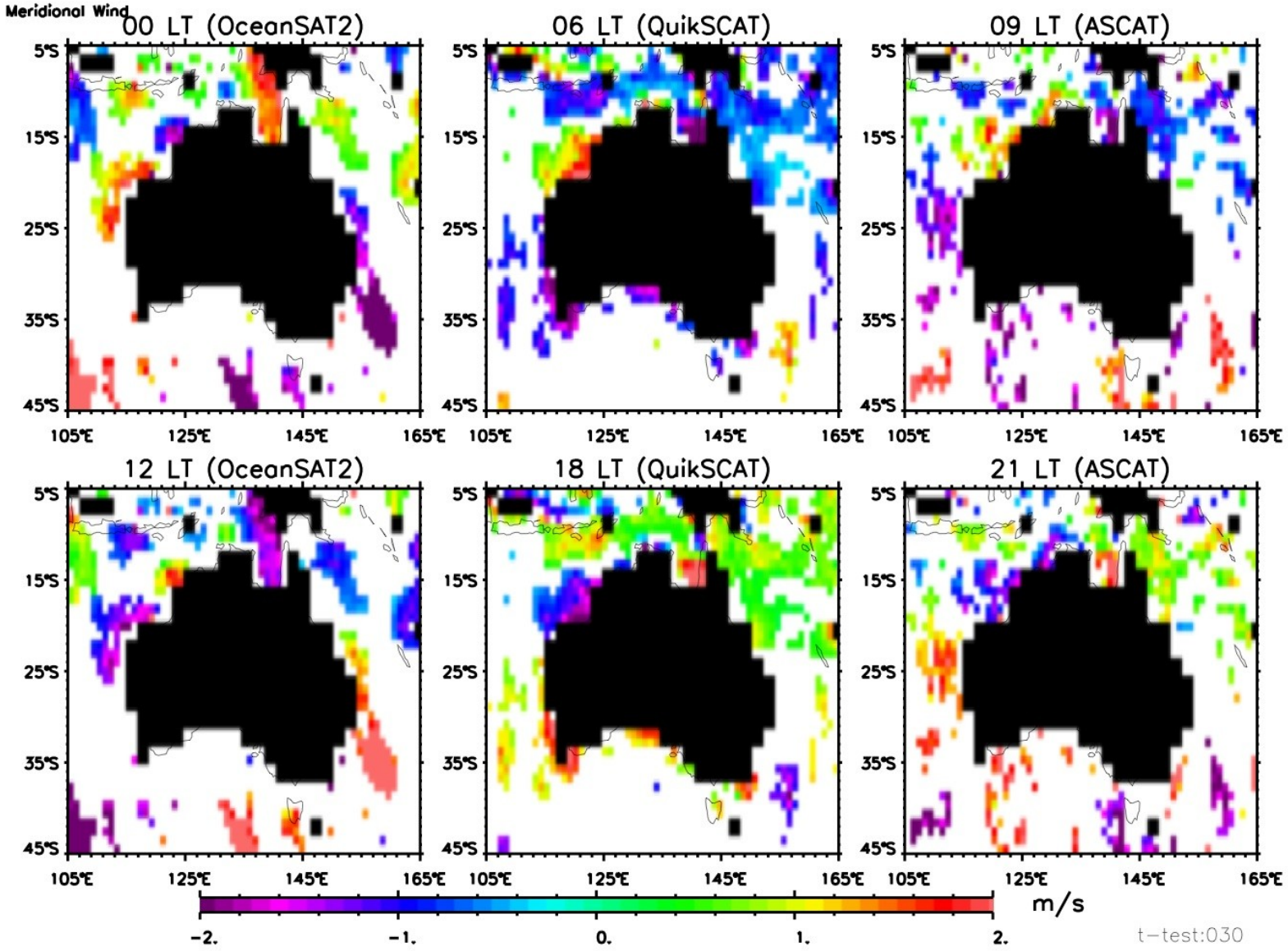
Meridional WInd



Zonal WInd

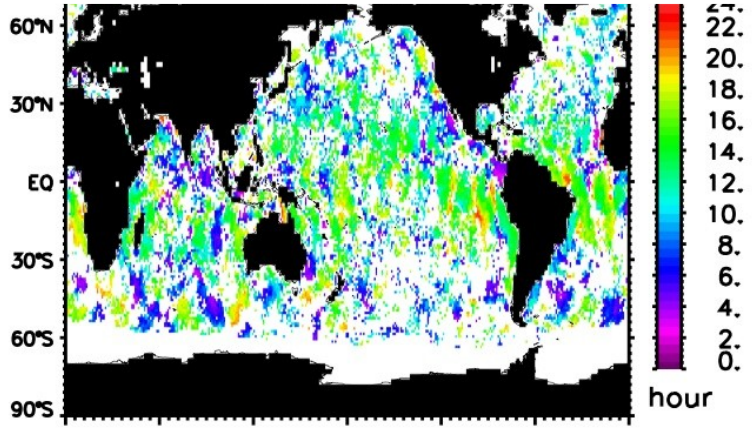

Zonal Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
5°S
15°S
25°S
35°S
45°S
105°E
125°E
145°E
165°E
m/s
-2.
-1.
0.
1.
2.
t-test:030

Meridional WInd

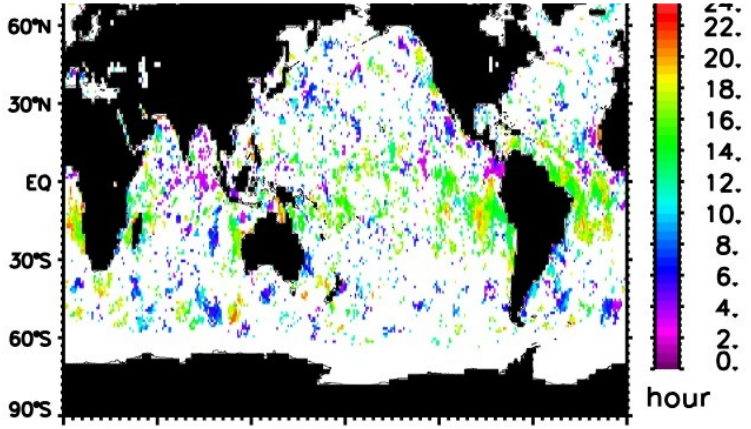


hase ($T1_{max}$) of the diurnal cycle of Zonal Wind (A1 > 2

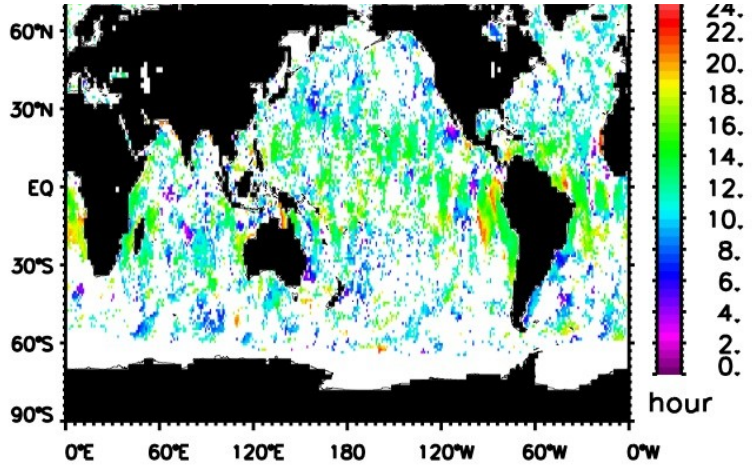
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



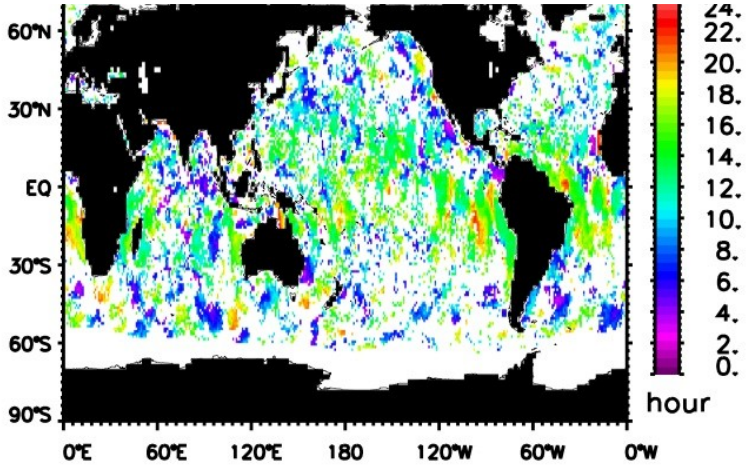
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+OceanSAT2

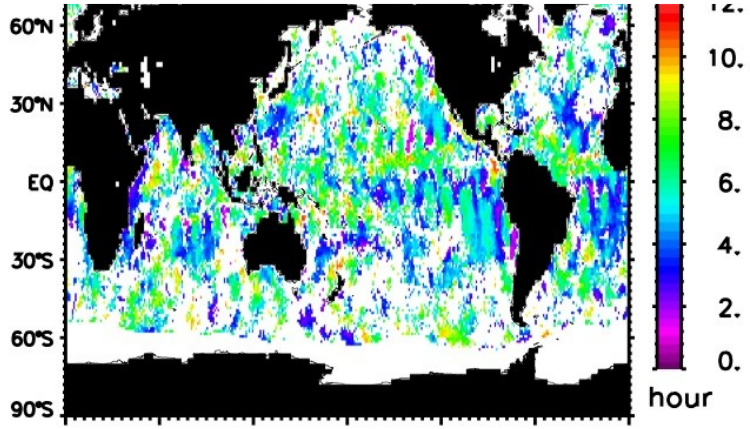


2009309_2009325

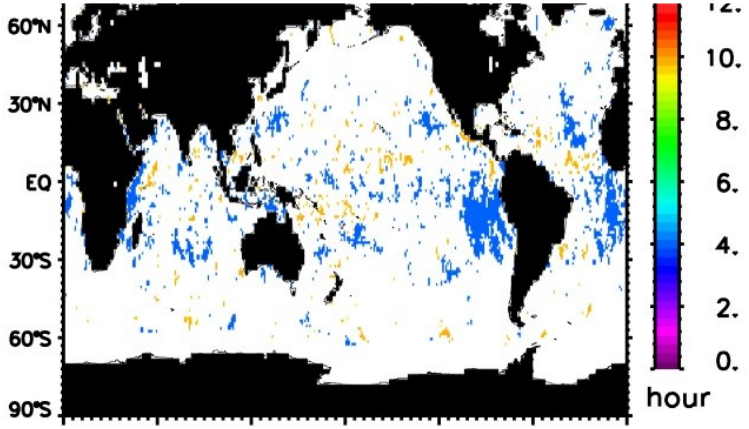
data over two weeks period (Nov. 5-21, 2009) when all four ser

2_{max}) of the semi-diurnal cycle of Zonal Wind (where A

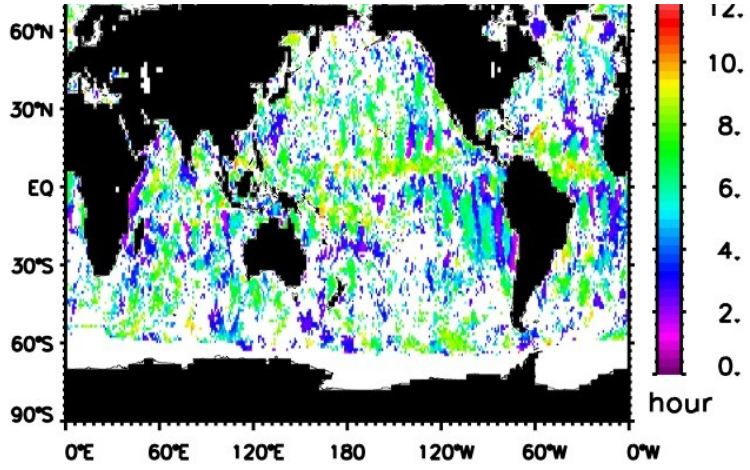
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



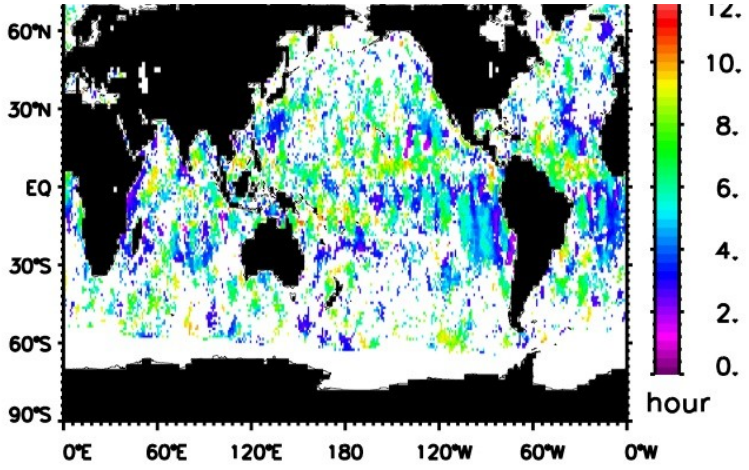
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+OceanSAT2

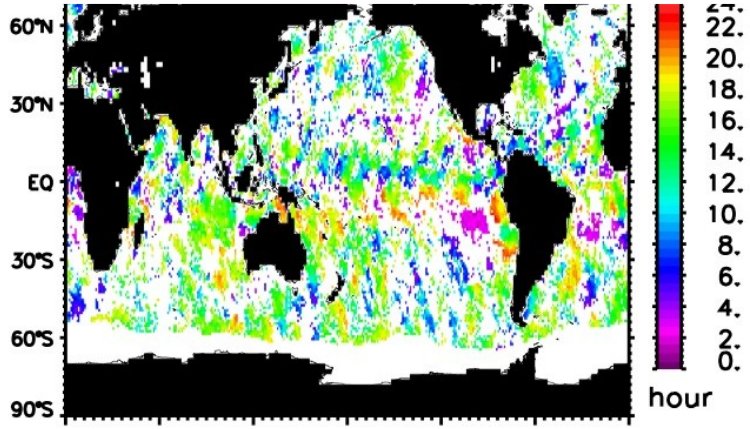


2009309_2009325

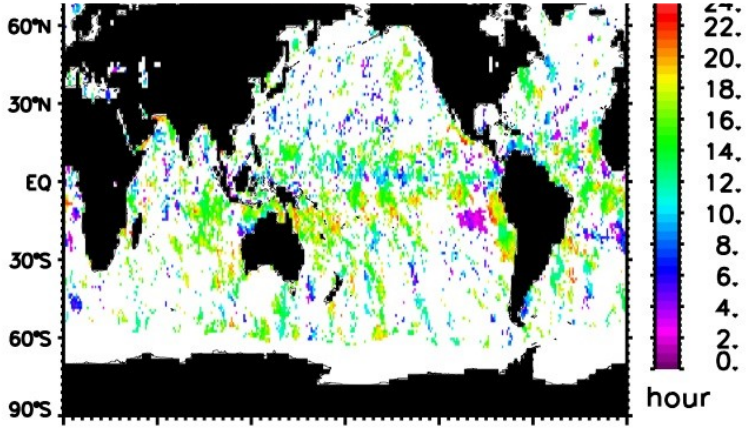
data over two weeks period (Nov. 5-21, 2009) when all four ser

T1$_{max}$) of the diurnal cycle of Meridional Wind (where A

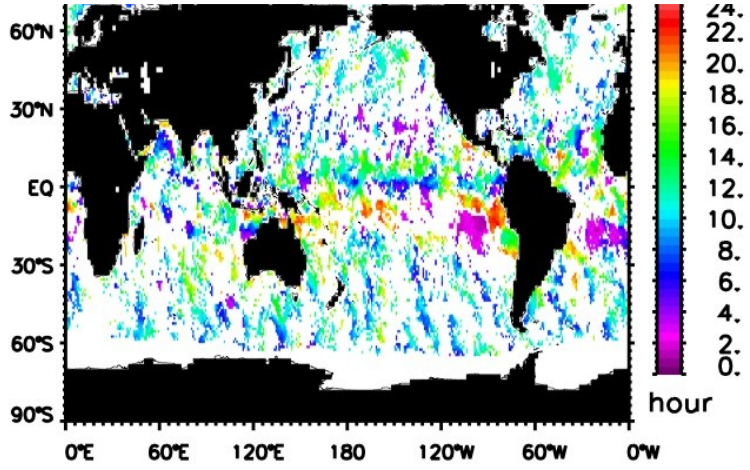
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



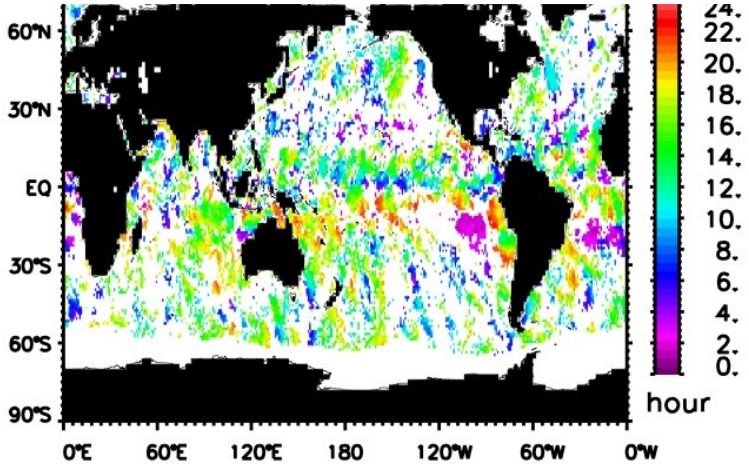
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+OceanSAT2

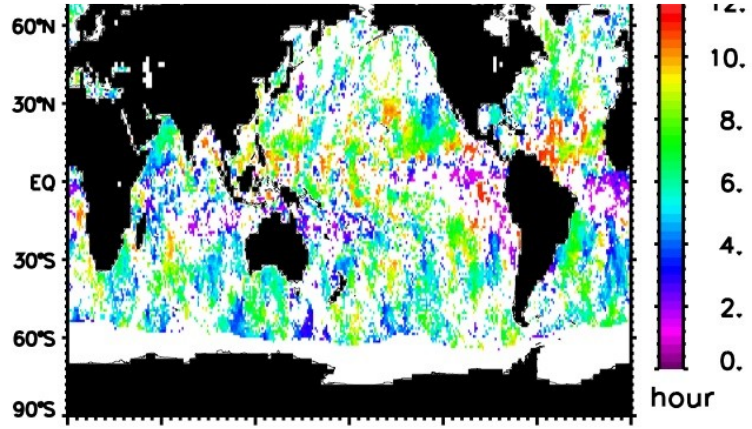


2009309_2009325

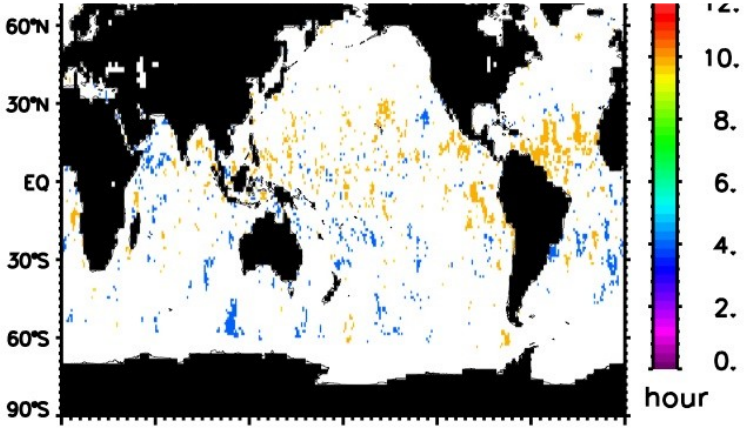
data over two weeks period (Nov. 5-21, 2009) when all four ser

ϕ_{max}) of the semi-diurnal cycle of Merid. Wind (where A

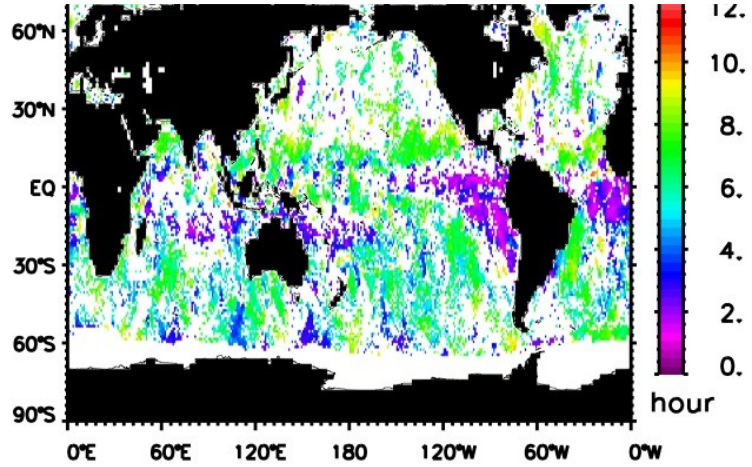
OceanSAT2(0,12)+ASCAT(9,21)+ WindSAT(6,18)



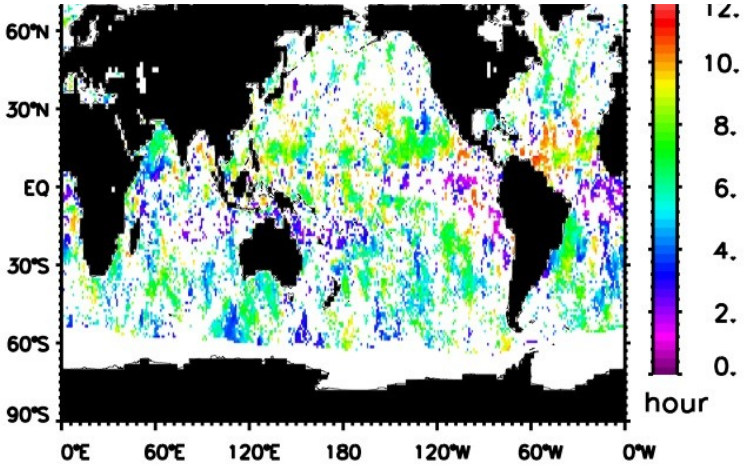
QSCAT(6,18)+ASCAT(9,21)+ WindSAT(6,18)



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



QSCAT+ASCAT+WindSAT+OceanSAT2

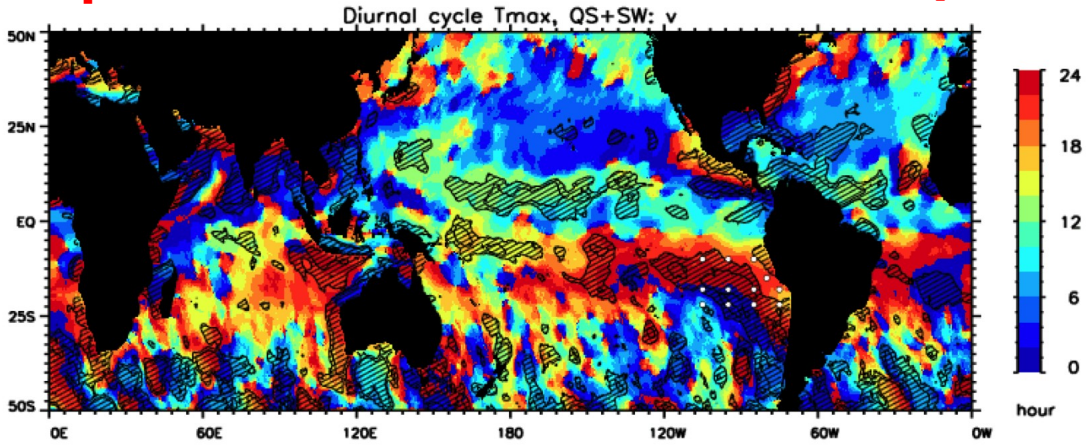


2009309_2009325

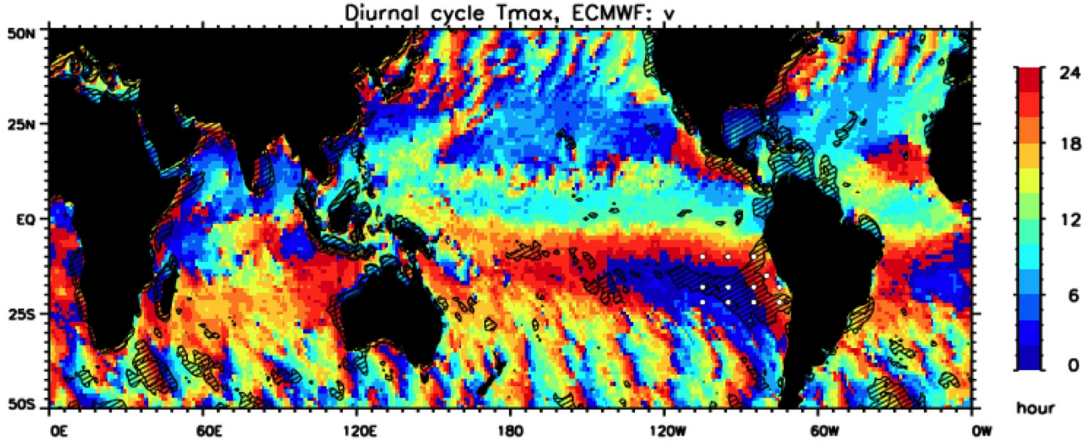
data over two weeks period (Nov. 5-21, 2009) when all four ser

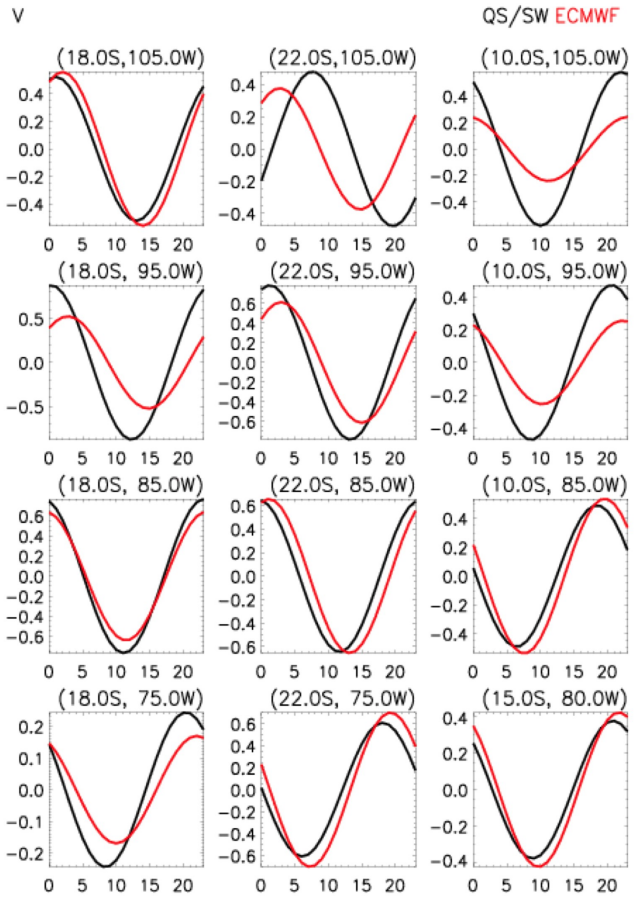
rnal cycle derived from SeaWinds tandem mission compared wit

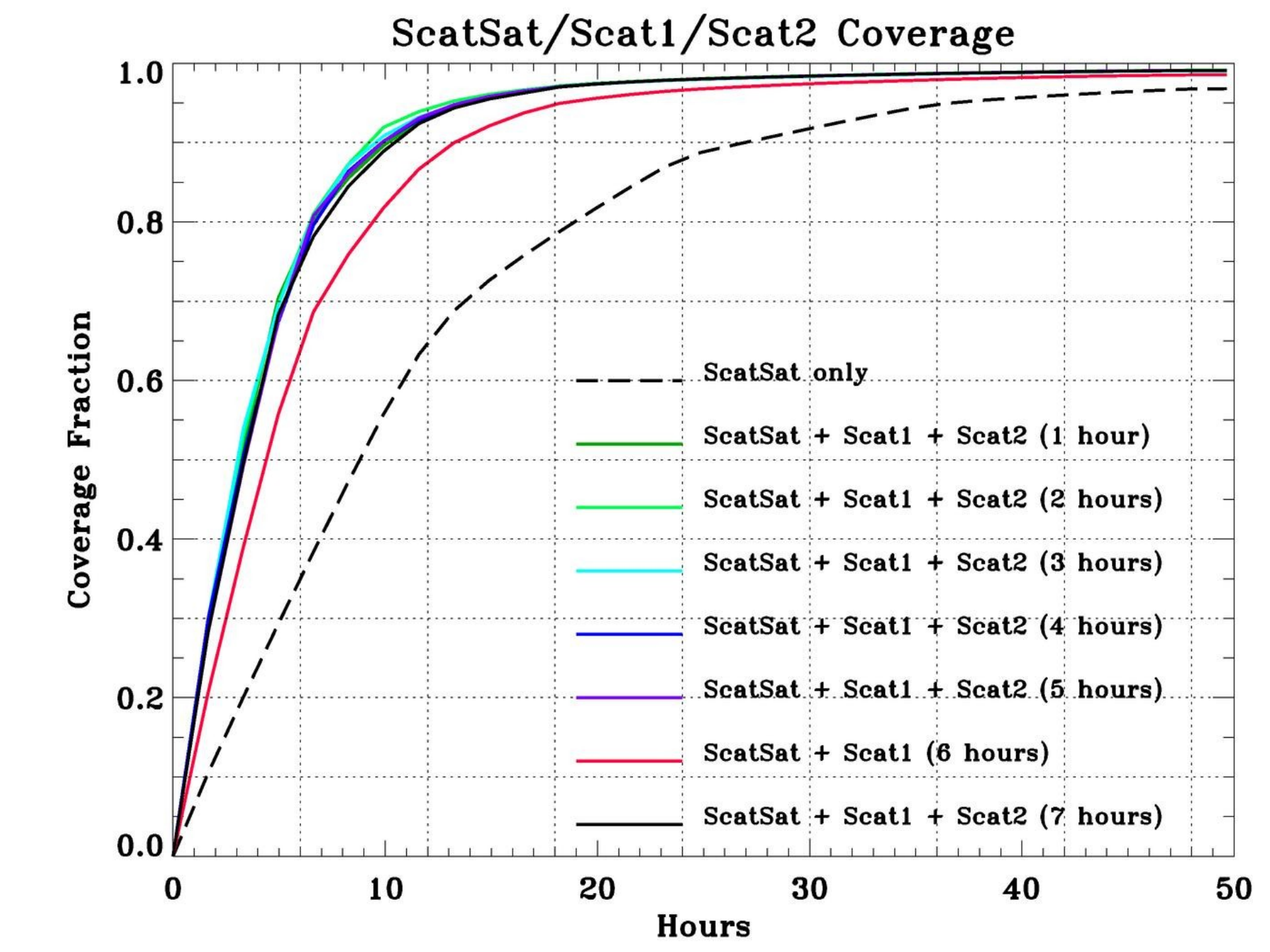
Local peak time of meridional wind (QS/SW)



ocal peak time of meridional wind (ECMWF)

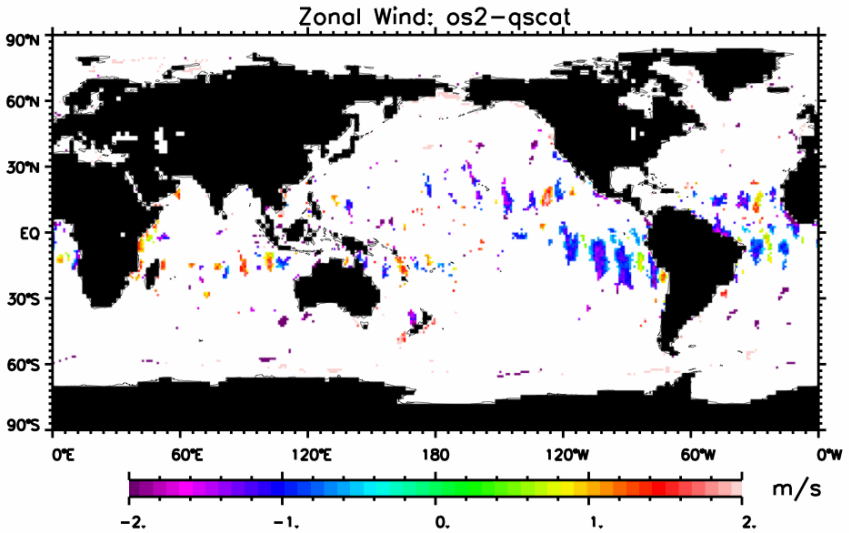




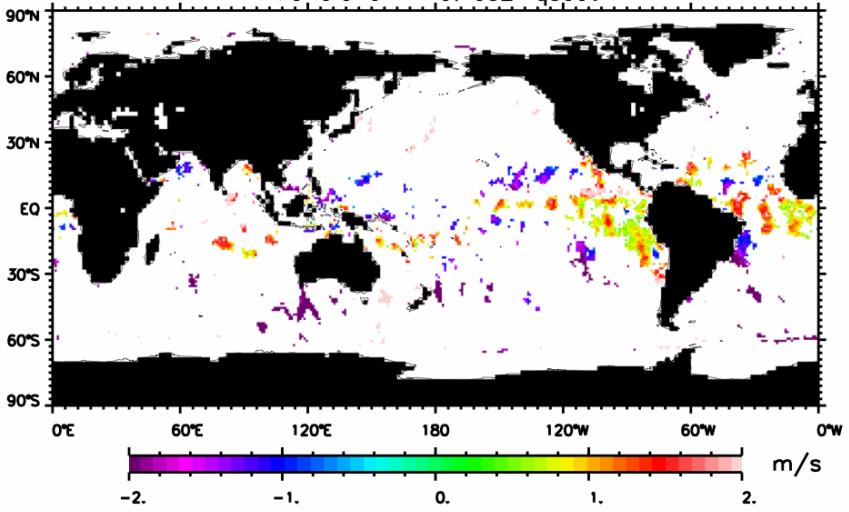

ScatSat/Scat1/Scat2 Coverage
Coverage Fraction
Hours
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
ScatSat only
ScatSat + Scat1 + Scat2 (1 hour)
ScatSat + Scat1 + Scat2 (2 hours)
ScatSat + Scat1 + Scat2 (3 hours)
ScatSat + Scat1 + Scat2 (4 hours)
ScatSat + Scat1 + Scat2 (5 hours)
ScatSat + Scat1 (6 hours)
ScatSat + Scat1 + Scat2 (7 hours)

OceanSAT-2 - QuikSCAT

U

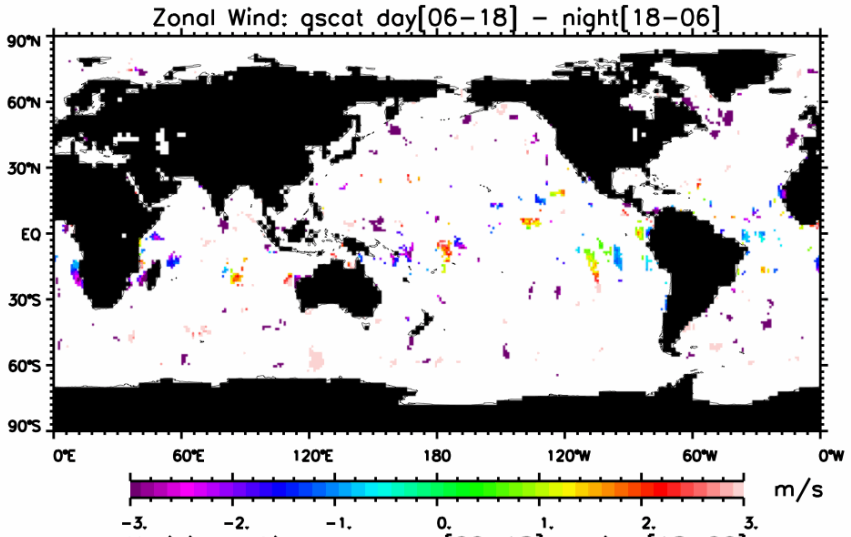


V

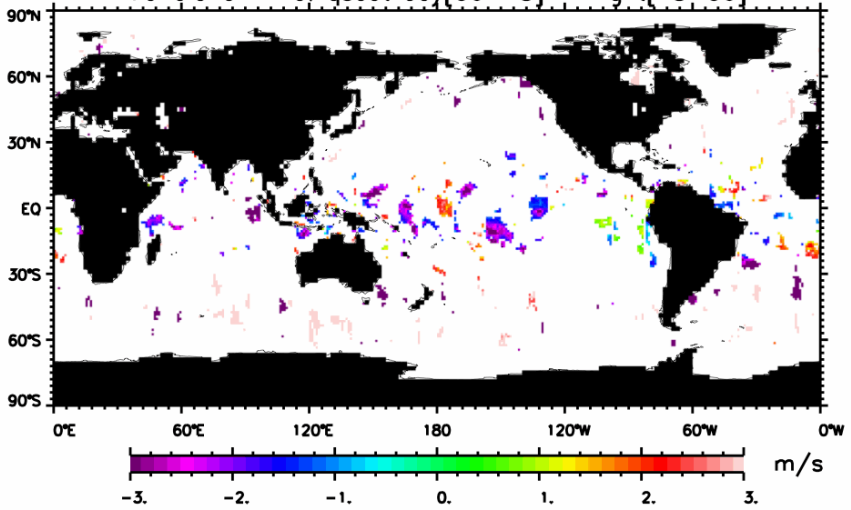


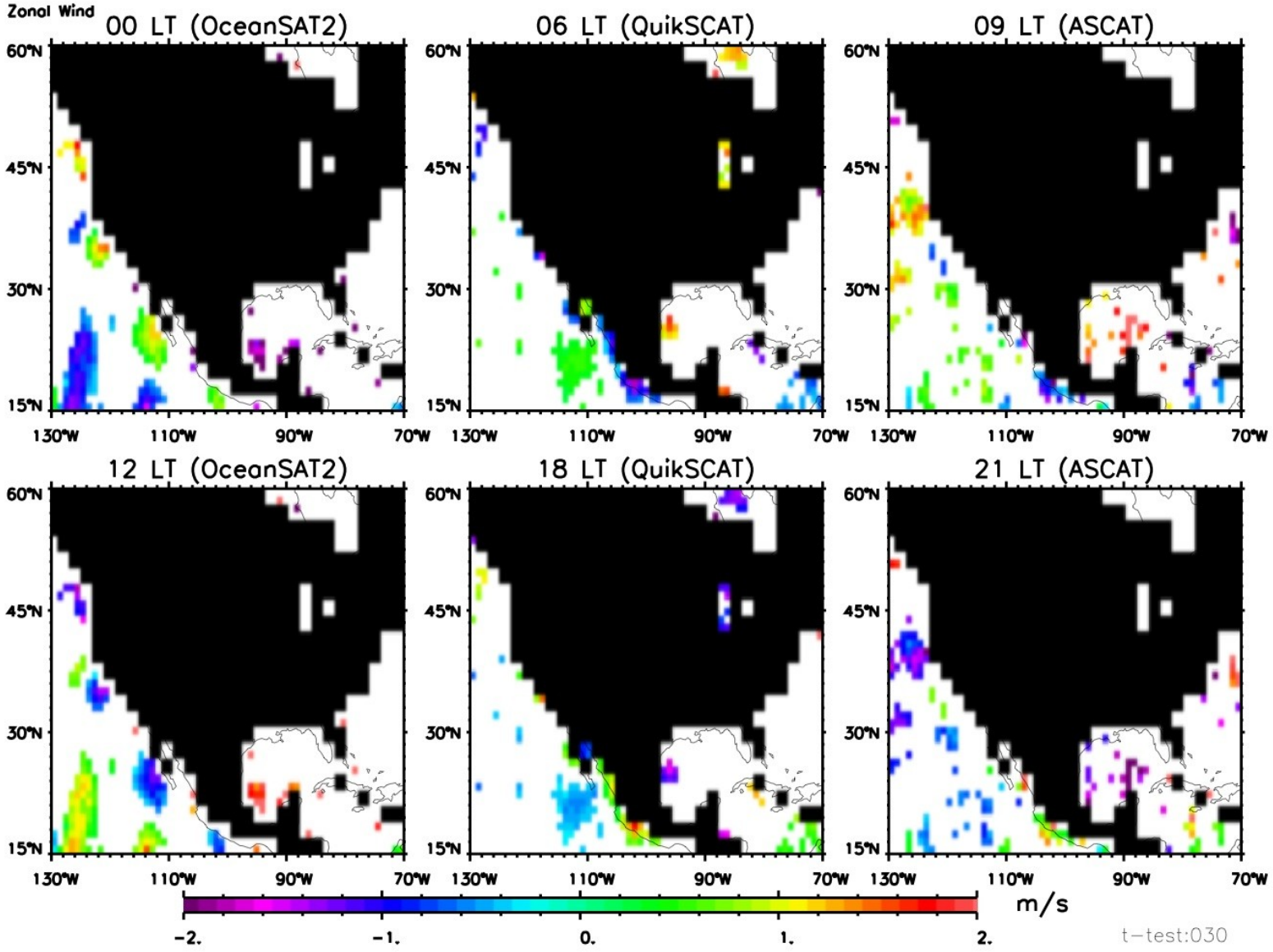
QuikSCAT day-night difference

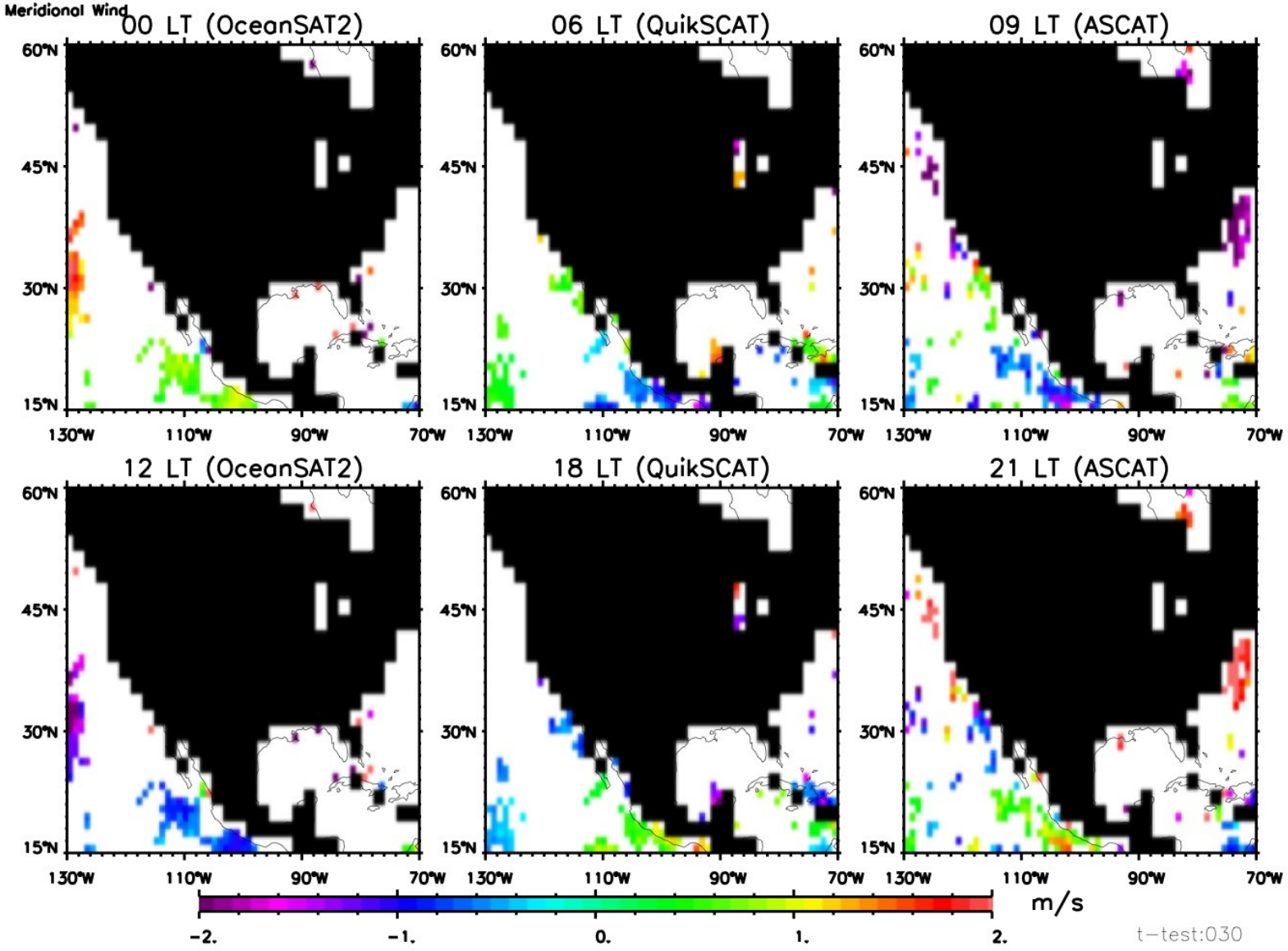
U



V

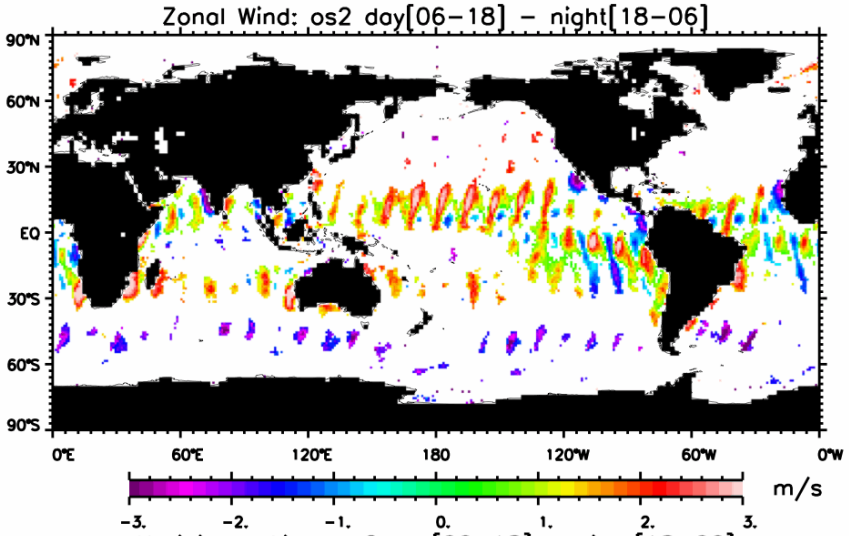



Zonal Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
60°N
45°N
30°N
15°N
130°W
110°W
90°W
70°W
m/s
−2.
−1.
0.
1.
2.
t−test:030

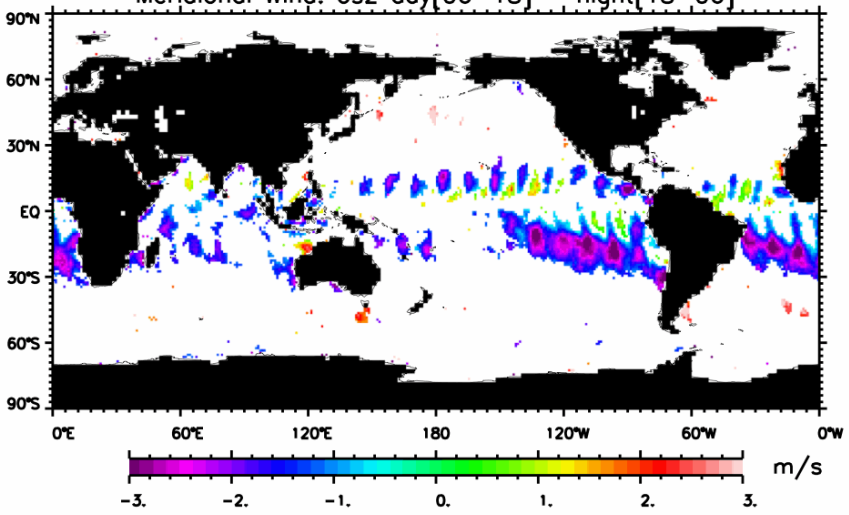

Meridional Wind
00 LT (OceanSAT2)
06 LT (QuikSCAT)
09 LT (ASCAT)
12 LT (OceanSAT2)
18 LT (QuikSCAT)
21 LT (ASCAT)
60°N
45°N
30°N
15°N
130°W
110°W
90°W
70°W
m/s
-2.
-1.
0.
1.
2.
t-test:030

OceanSAT-2 day-night difference

U

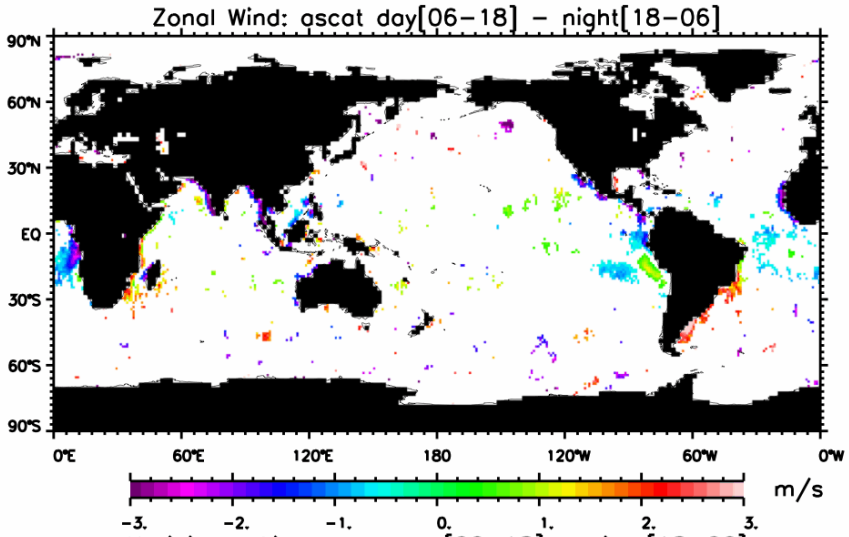


V

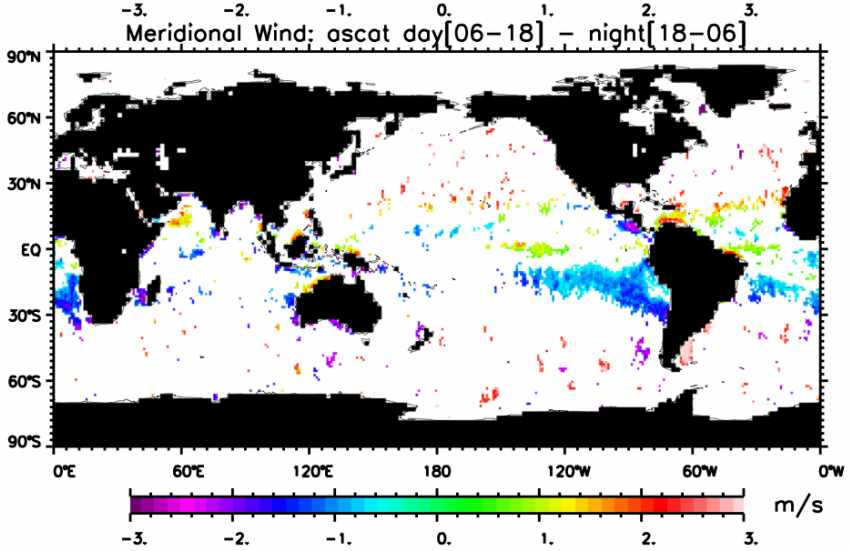


ASCAT day-night difference

U

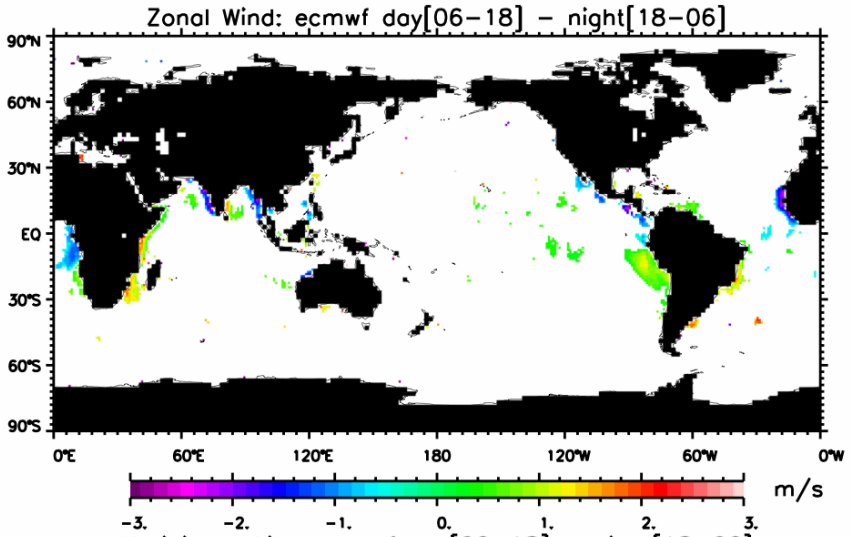


V

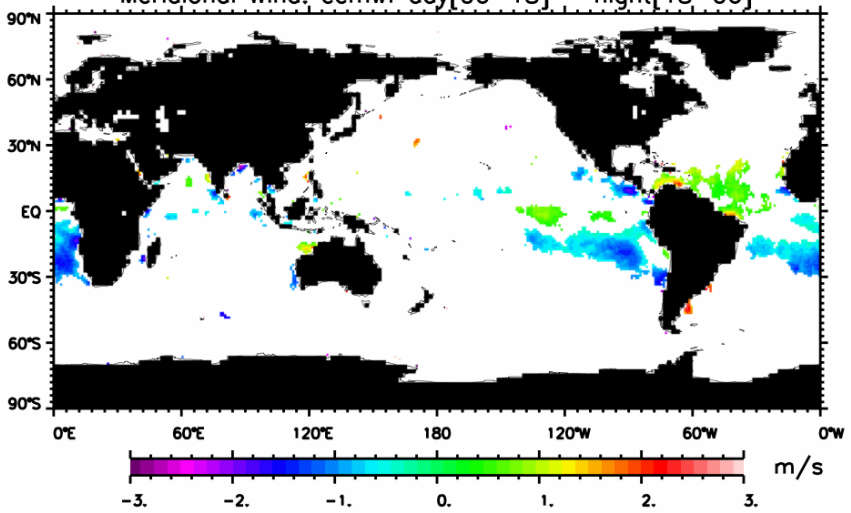


ECMWF day-night difference

U



V



(along OceanSAT-2 swath)