Surface Wind/Stress Structure under Hurricane

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Asymmetry
Relating wind to stress

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Asymmetry

♣A complete map of surface wind-stress almost does not exist

♣Surface wind/stress measurement depends on vertical extrapolation of dropsonde data along flight paths or point measurement of opportunity

♣Horizontal distribution of wind stress need high confidence in extrapolation scheme or numerical models.

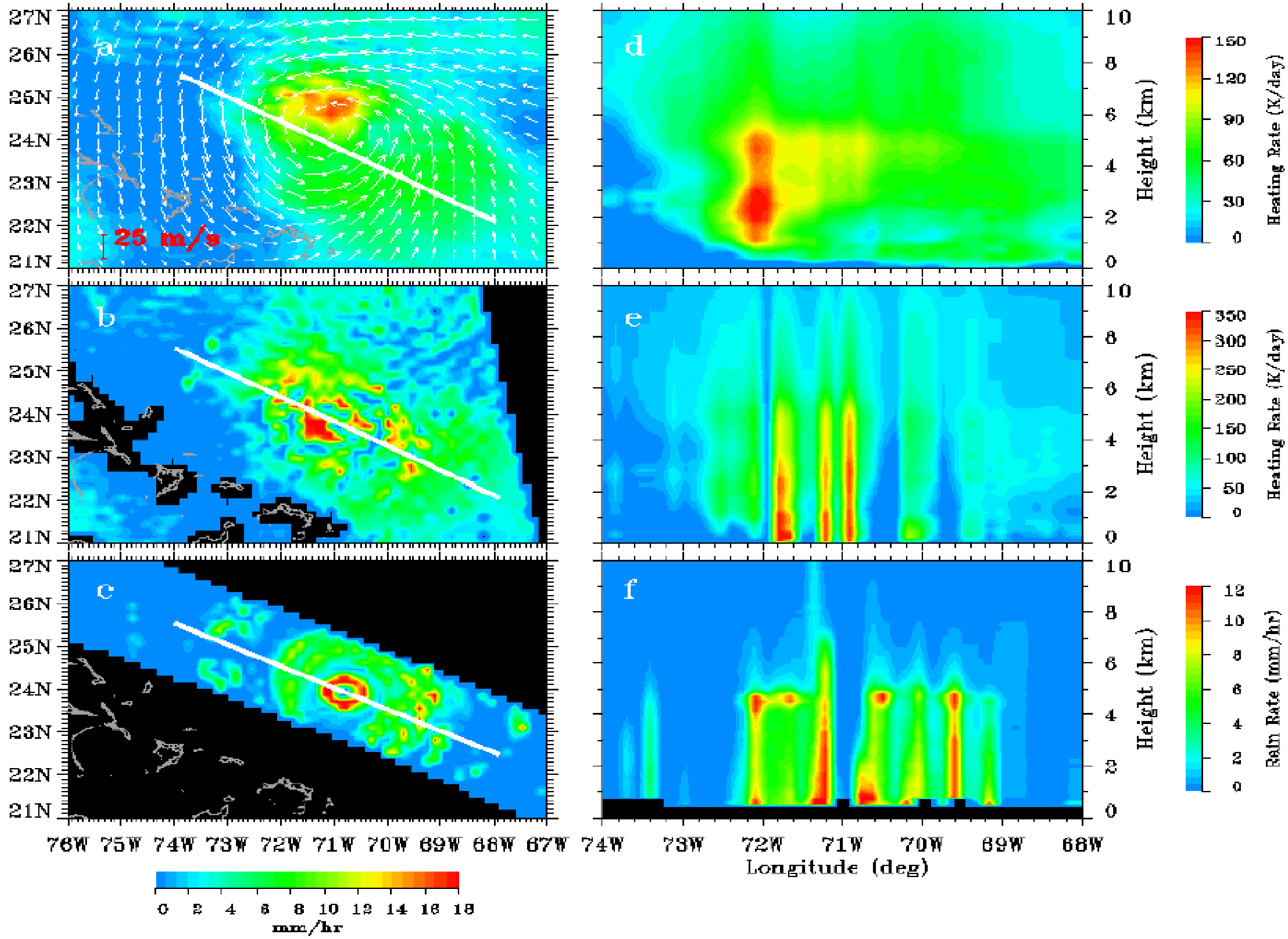
Scatterometer may give a map, but it is not designed for hurricane conditions.

- Rain contamination
- Flow separation at strong wind
- Coarse resolution

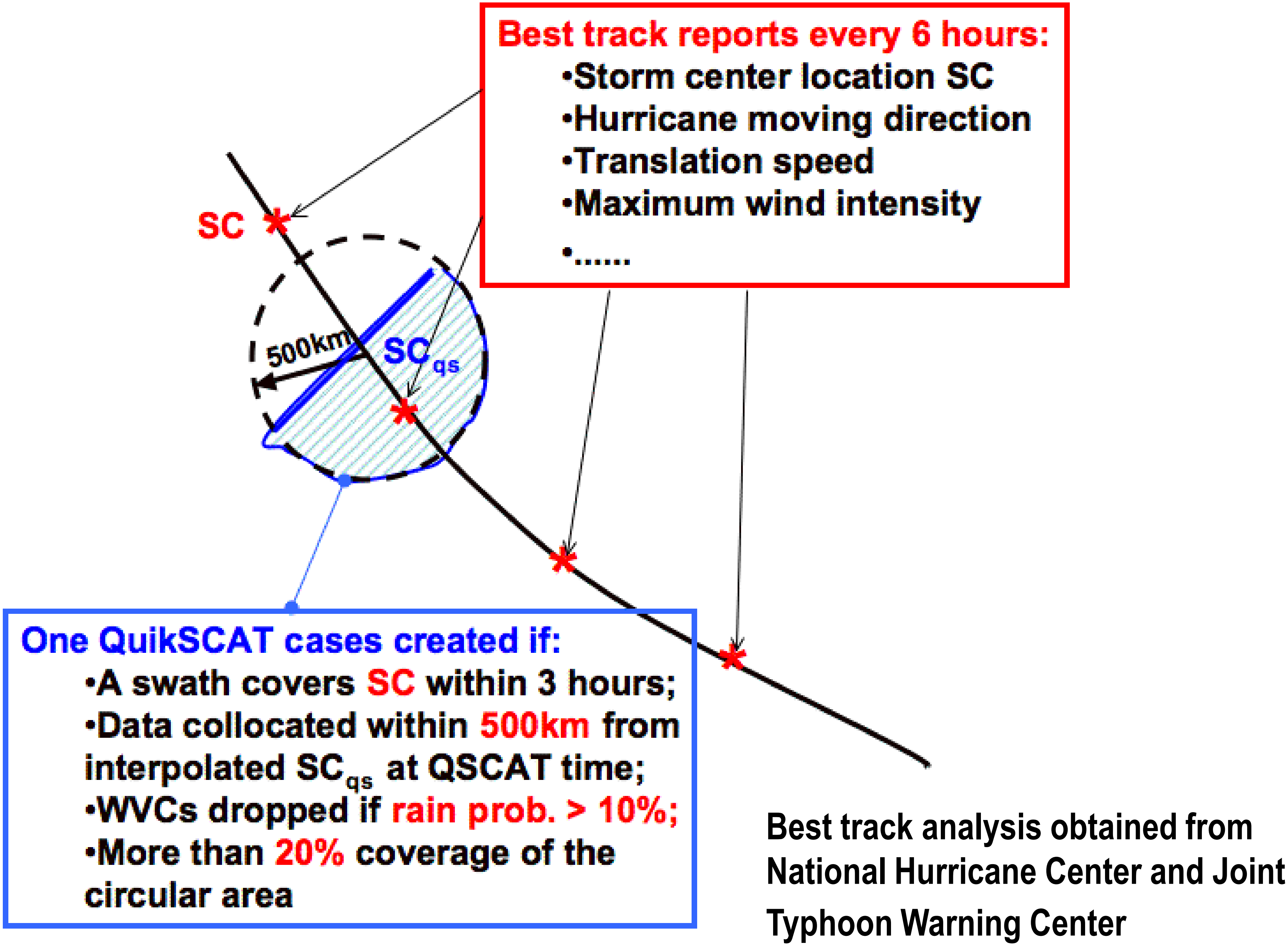
We will show you advances could still me made with scatterometer............

Interplay Between Wind and Rain Observed in Hurricane Floyd

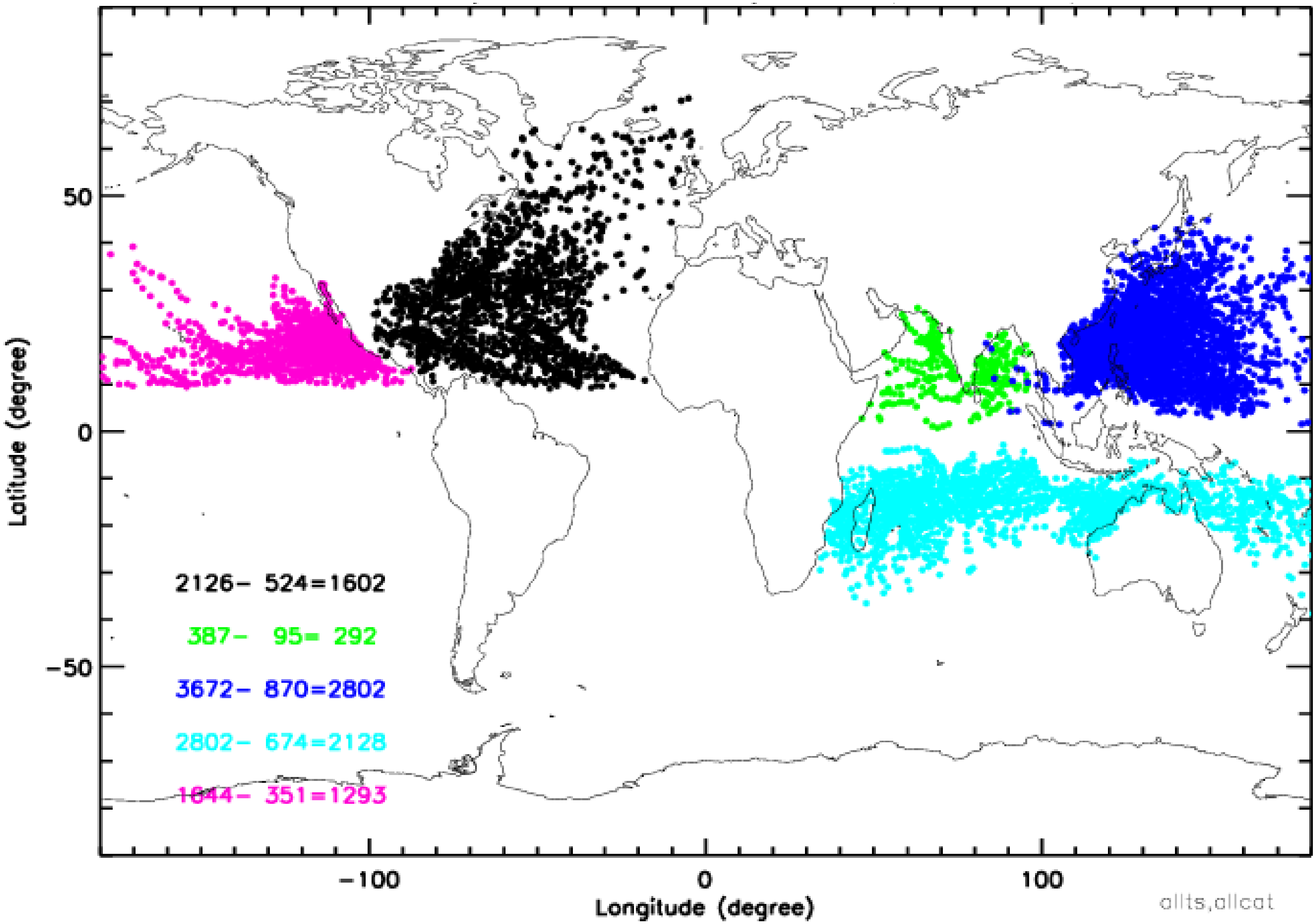
- W. Timothy Liu, Hua Hu, and Simon Yueh (EOS, 23, 254 & 257, 2000)



The surface wind and fresh water flux of the operational numerical weather prediction model with the highest spatial resolution (EDAS) cannot resolve the rain bands of Hurricane Floyd [upper left]. By simply replacing the surface level EDAS wind divergence with QuikSCAT data, the fresh water flux [middle left] became more realistic compared with observations by the TRMM Radar (PR) [lower left]. The vertical profiles of heating and rain rate [right panels] show that QuikSCAT data help to reveal the eye and precipitation walls, in agreement with PR obervations.


Best track reports every 6 hours:
•Storm center location SC
•Hurricane moving direction
•Translation speed
•Maximum wind intensity
•......
SC
500km
SCqs
One QuikSCAT cases created if:
•A swath covers SC within 3 hours;
•Data collocated within 500km from interpolated SCqs at QSCAT time;
•WVCs dropped if rain prob. > 10%;
•More than 20% coverage of the circular area
Best track analysis obtained from National Hurricane Center and Joint Typhoon Warning Center

Tropical storm activities captures by QuikSCAT (2000-2007)



Each dot indicates storm center location for one QuikSCAT case collocated with best track report, total number over global ocean is 8008.

Basic structure of hurricane wind fields

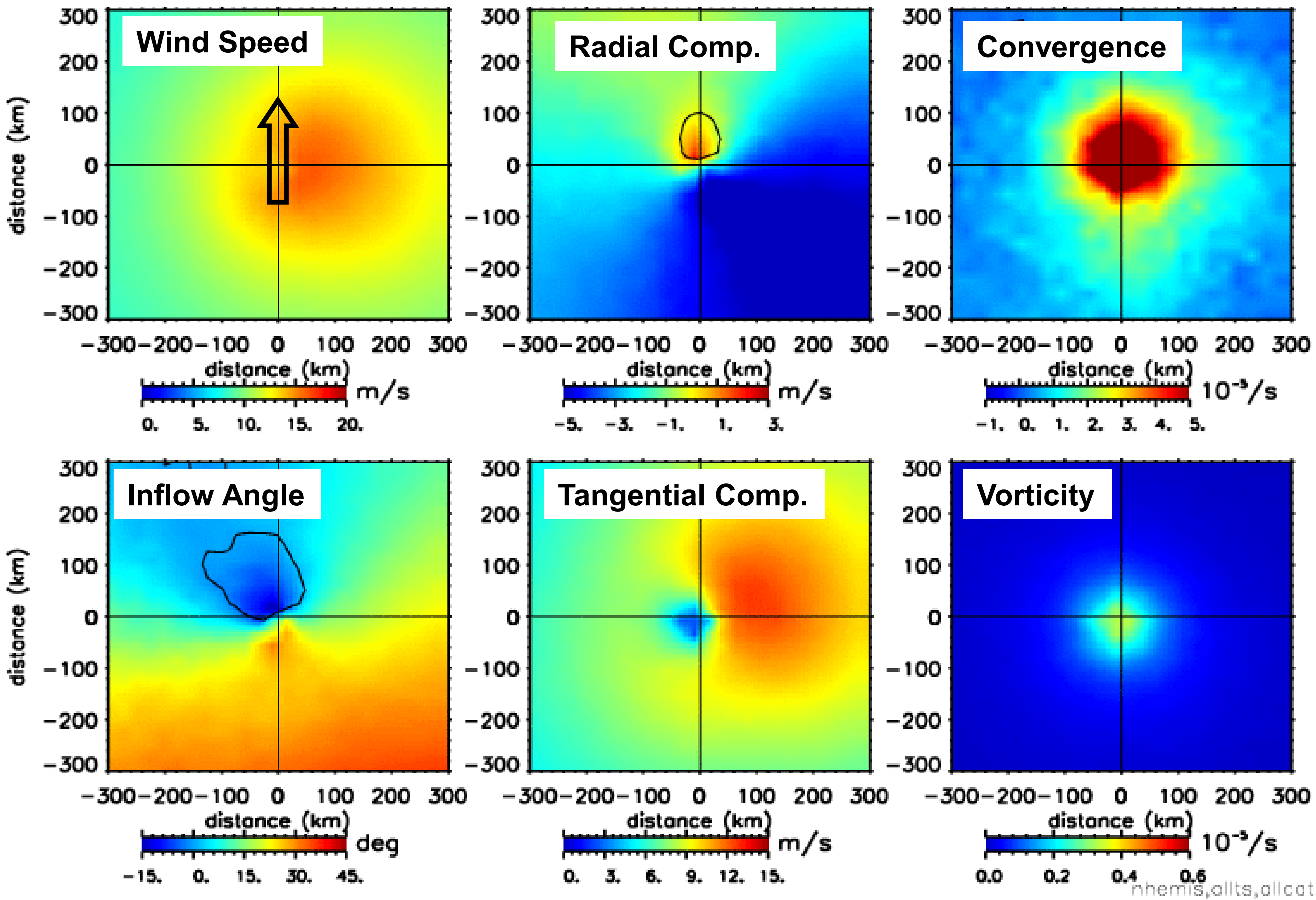
Composite of

- Wind speed (spd)
- Inflow angle (inc)
- Radial component (rad)
- Tangential component (tan)
- Divergence (div)
- Vorticity (vor)

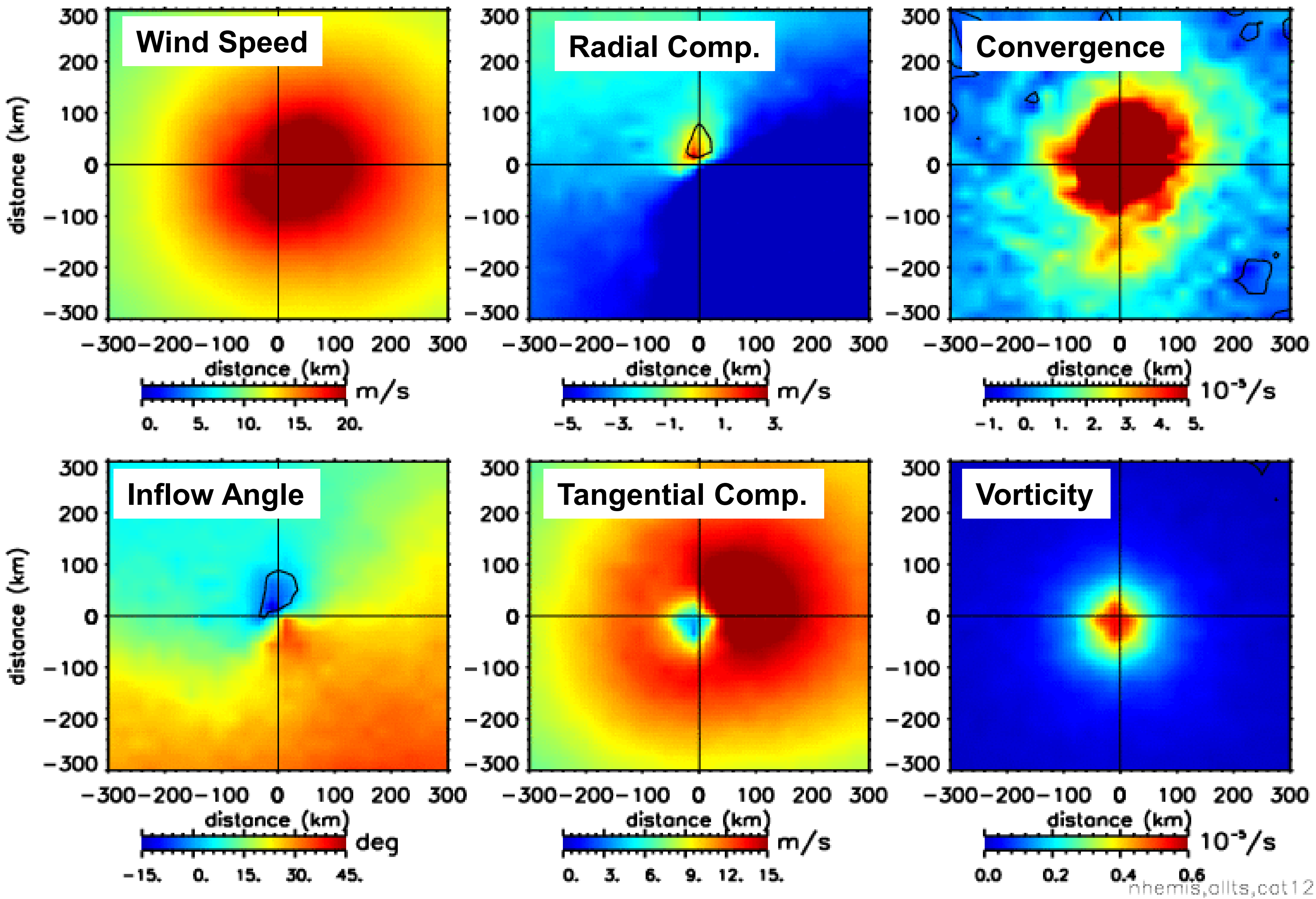
Sorted according to :

- hurricane intensity
- ocean basins (best track)
- Translation speed

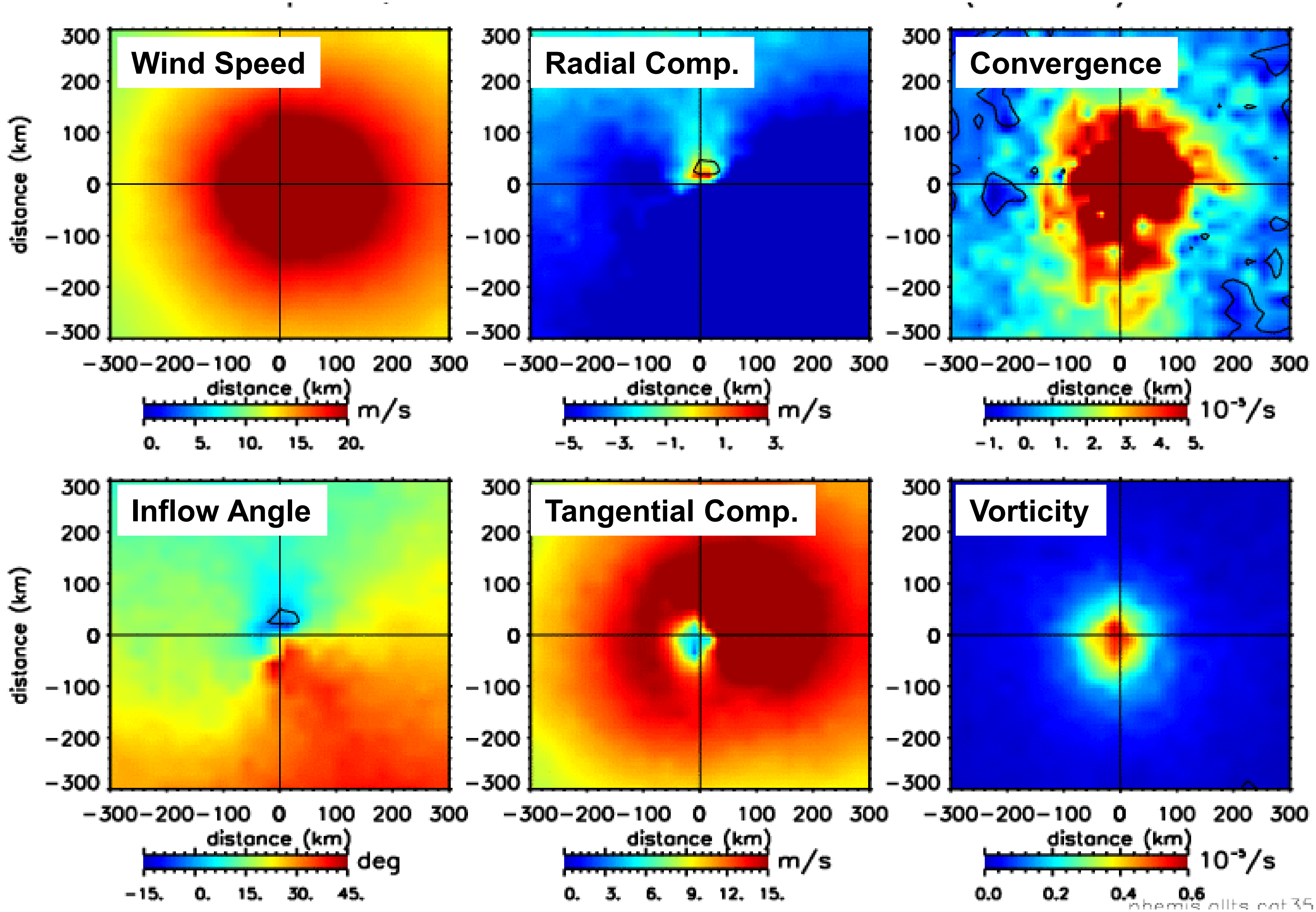
QuikSCAT Composite (2000-2007) in **Northern Hemisphere** collocated with best track for **All Categories,** total no. of cases:**5906**, **storm moving in y-axis**



QuikSCAT Composite (2000-2007) in **Northern Hemisphere** collocated with best track at all translation speed for **Categories 1&2,** total no. of cases:**1190**

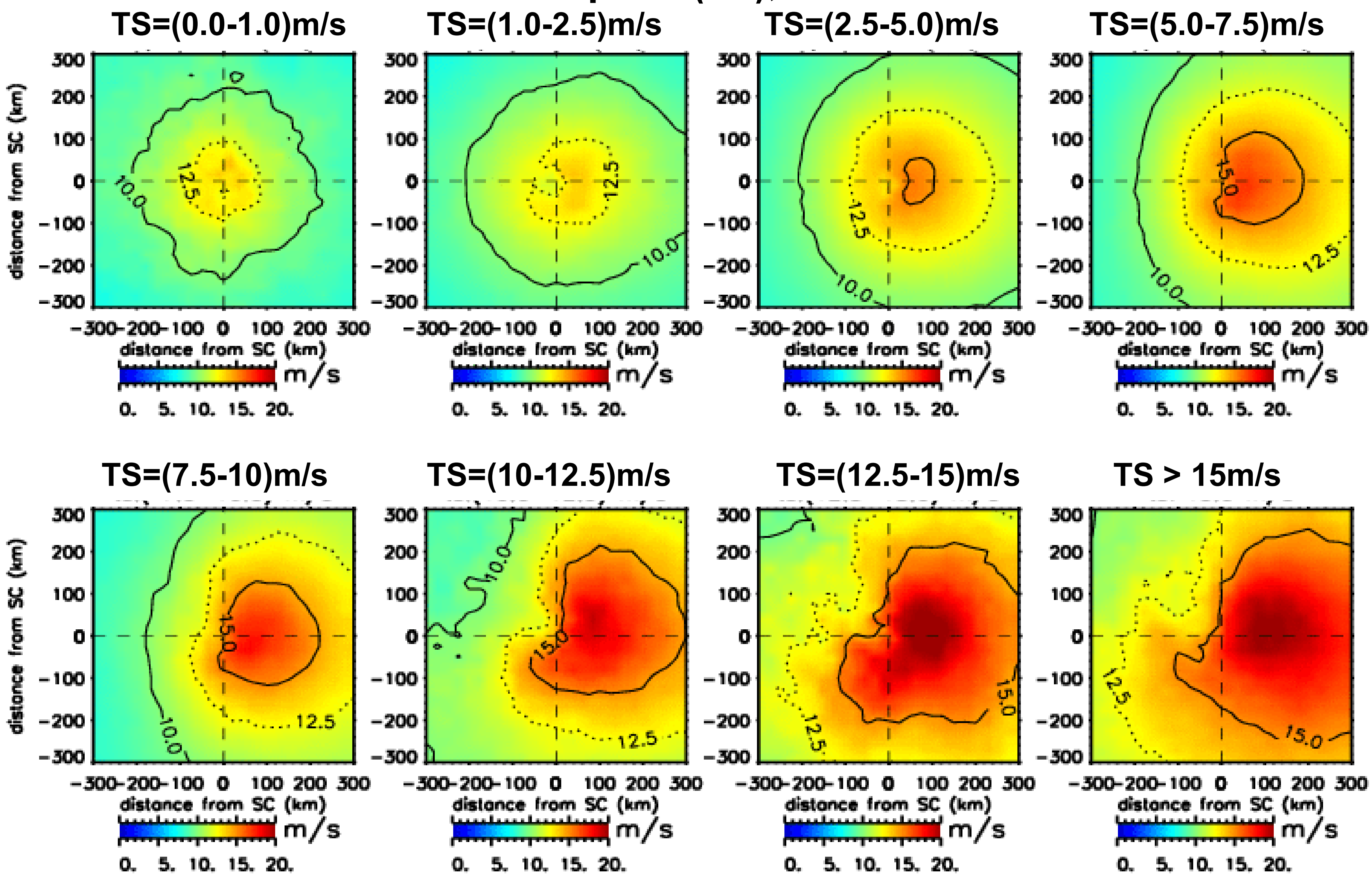


QuikSCAT Composite (2000-2007) in **Northern Hemisphere** collocated with best track at all translation speed for **Categories 3-5,** total no. of cases:**664**



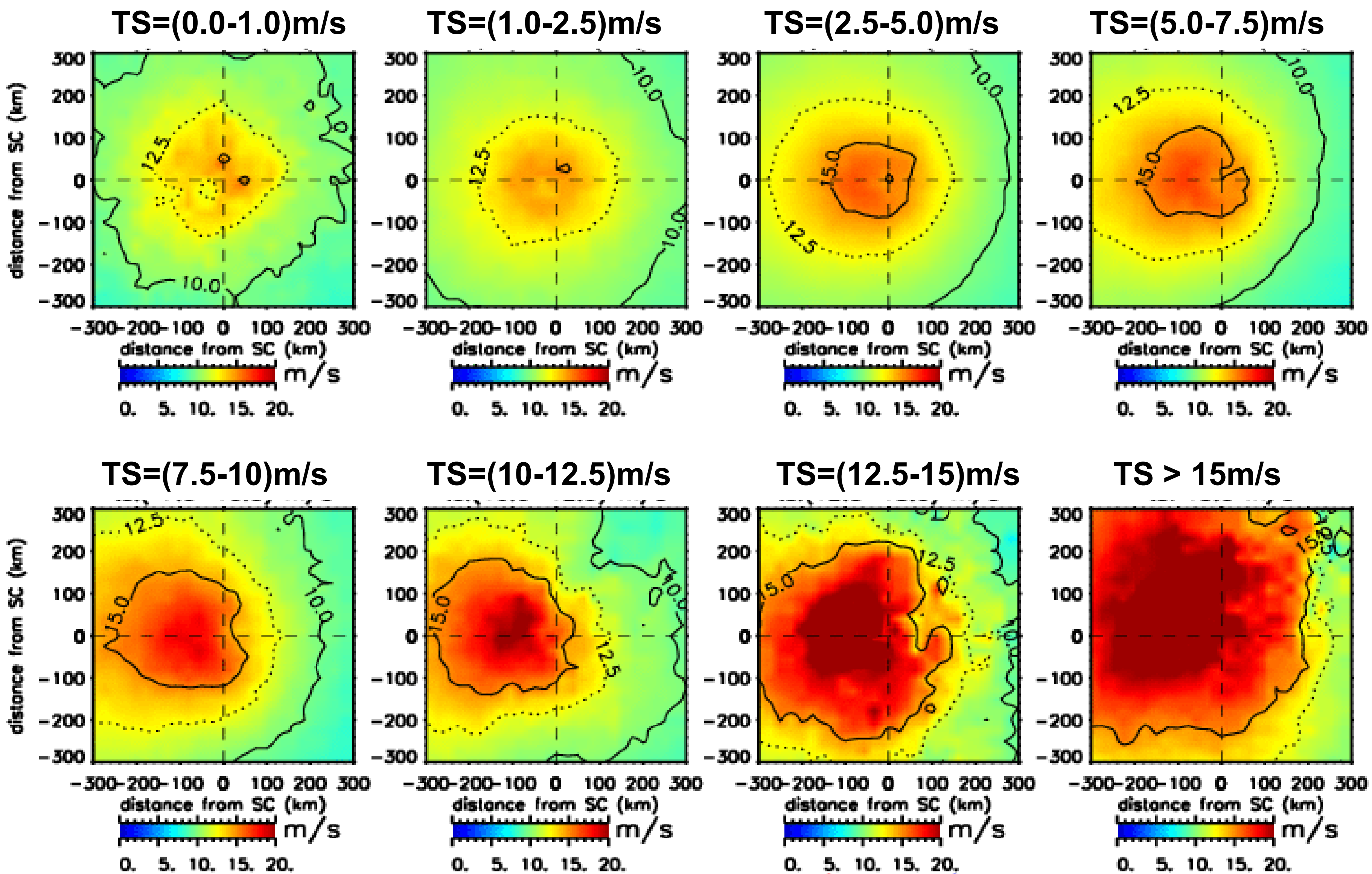
Translation Speed (m/s)	(a) QSCAT N. Hemis	(b) QSCAT S. Hemis
0.0-1.0	89	42
1.0-2.5	735	395
2.5-5.0	2172	944
5.0-7.5	1661	500
7.5-10.0	687	143
10.0-12.5	228	49
12.5-15.0	108	11
>15.0	226	18
Total	**5906**	**2102**

Composites of QuikSCAT wind speed in Northern Hemisphere, in terms of storm translation speed (TS), 2000-2007



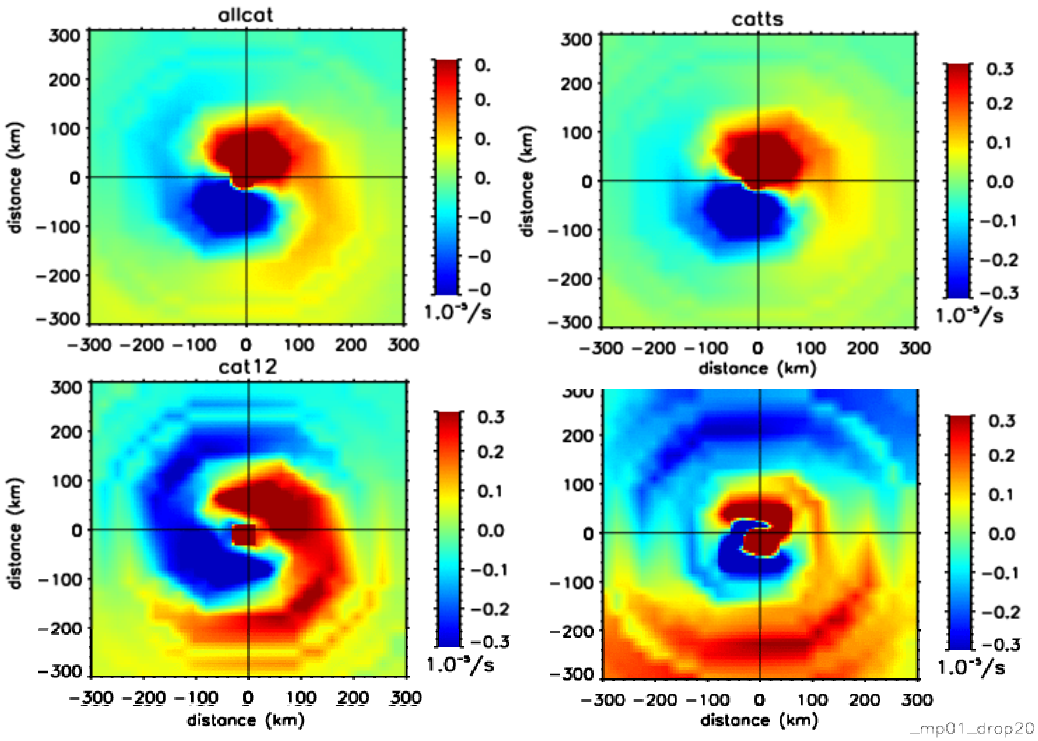
Asymmetry induced by moving storm: wind on the right side of the track gradually becomes stronger with increasing translation speed.

Composites of QuikSCAT wind speed in Southern Hemisphere, in terms of storm translation speed (TS), 2000-2007



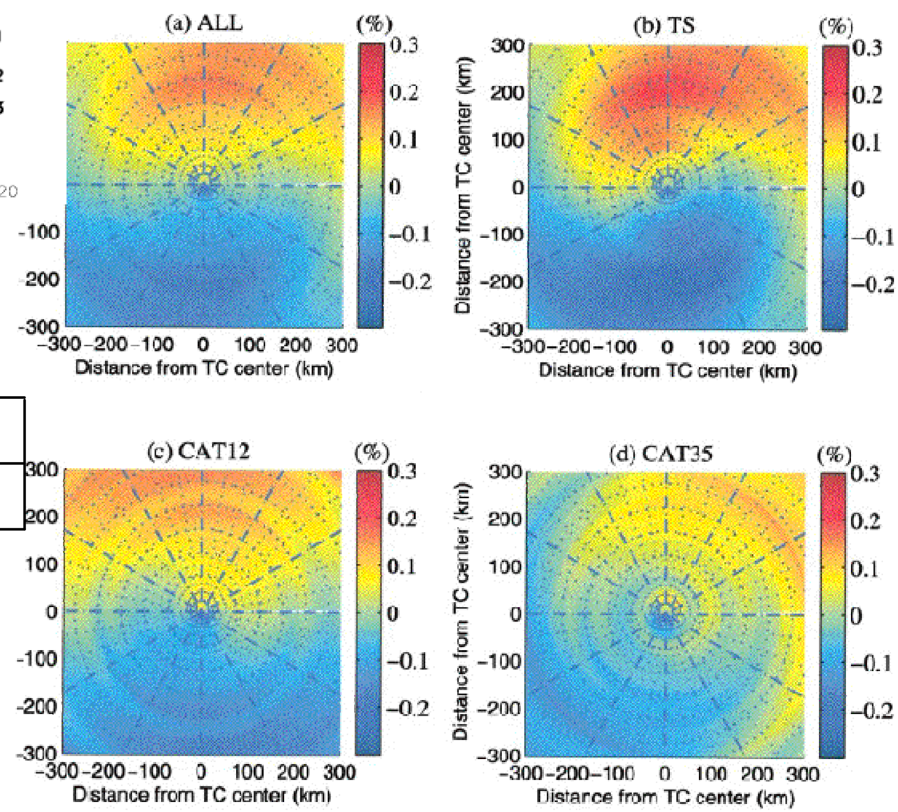
Asymmetry induced by moving storm: wind on the left side of the track becomes stronger with increasing translation speed, where translation enhance the circulation

QuikSCAT Wind Convergence Asymmetry



At hurricane intensity, a pattern of strong convergence located ahead of strong precipitation, indicating the role of wind in organizing convection and supply the moisture to fuel the hurricane intensification.

TRMM precipitation Asymmetry



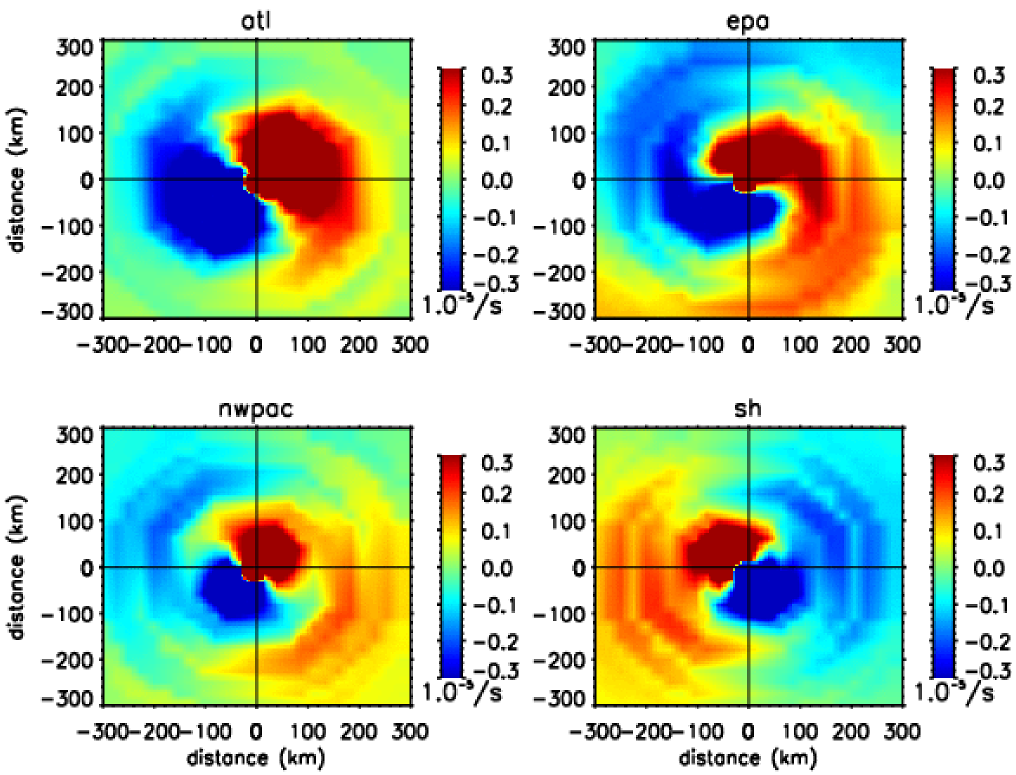
Storm Intensity

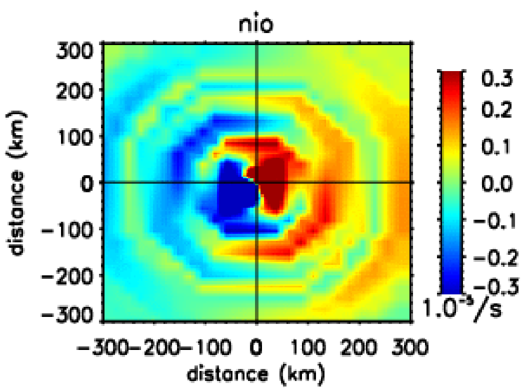
All categories	**Tropical storm**
Category 1&2	**Categories3-5**

Storm moving direction

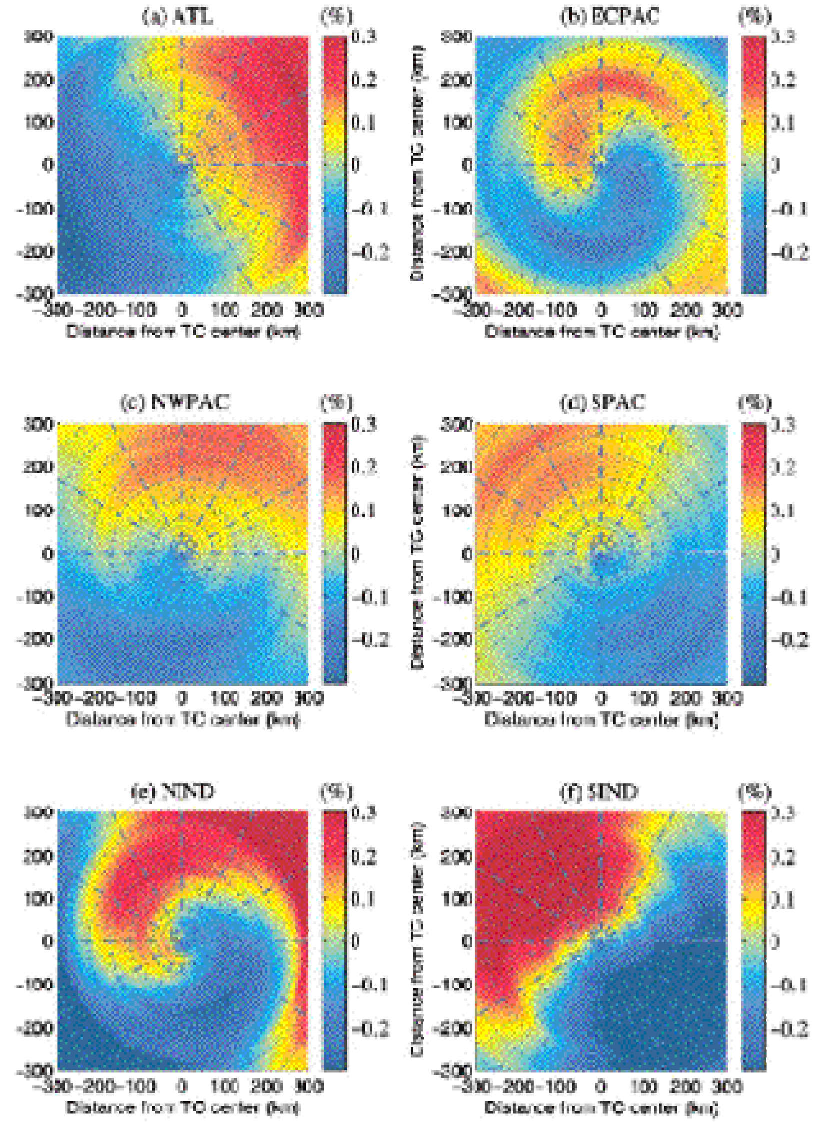
Lonfat et al, 2004

Convergence asymmetry by QSCAT





Rain asymmetry by TRMM



Lonfat et al, 2004

Ocean Basins

Atlantic	E Paci
NW Pacific	S Paci
N Indian	S Indi

The distinct difference between northern and southern hemisphere is consistent with TRMM observed precipitation. Convergence ahead of precipitation.

Conclusion

- Wind speed is higher on right side in N. Hemisphere
- Wind moves out in the front, steered slight to the left, but converge in from all other directions
- Asymmetry intensifies with strength of hurricane
- convergence collocated closely with rain

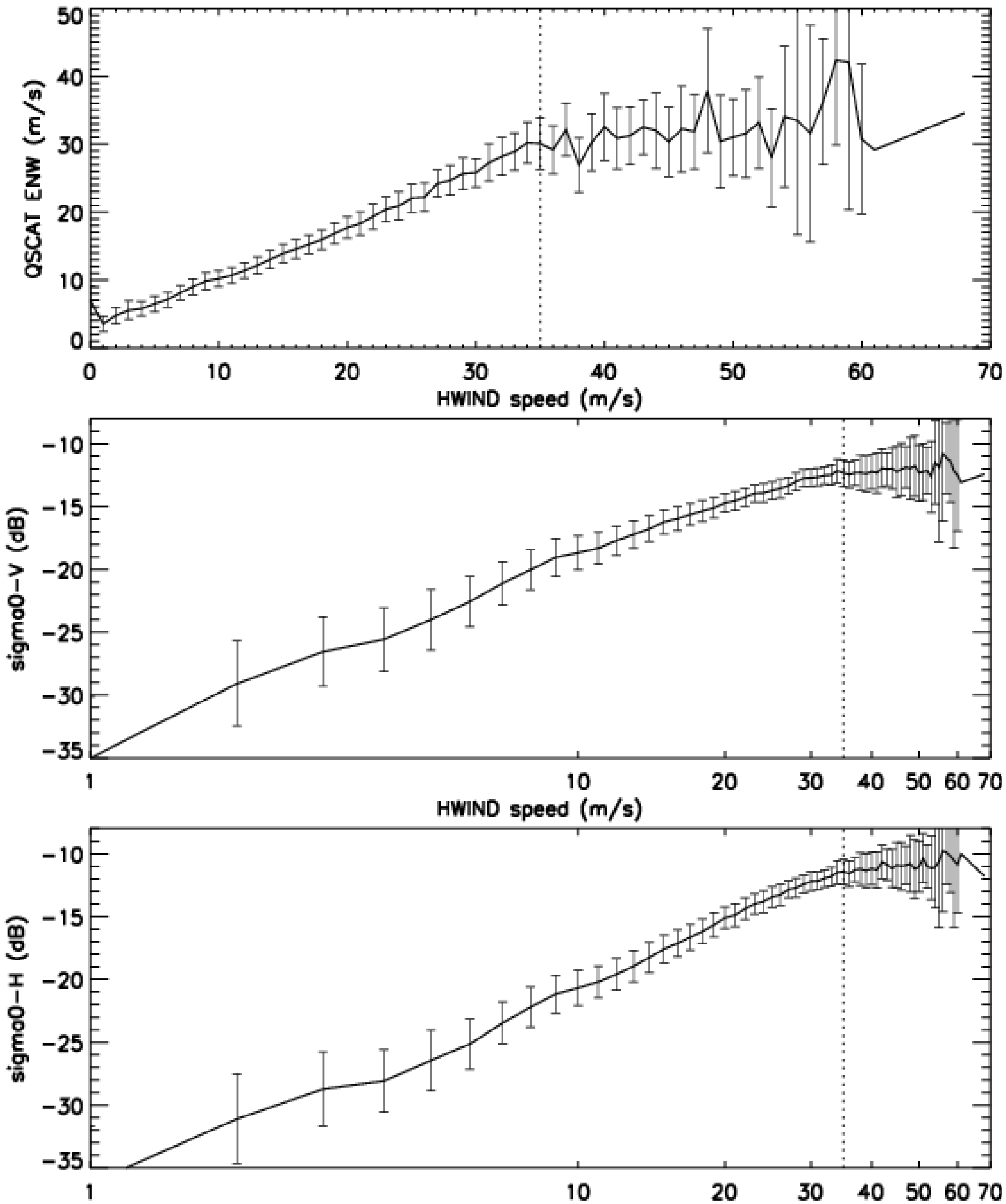
Relating wind to stress

QuikSCAT and Hwind

QSCAT U_{ENW}

QSCAT σ_o-V

QSCAT σ_o-H



Collocated **Hwind Speed (m/s)** p=0.5

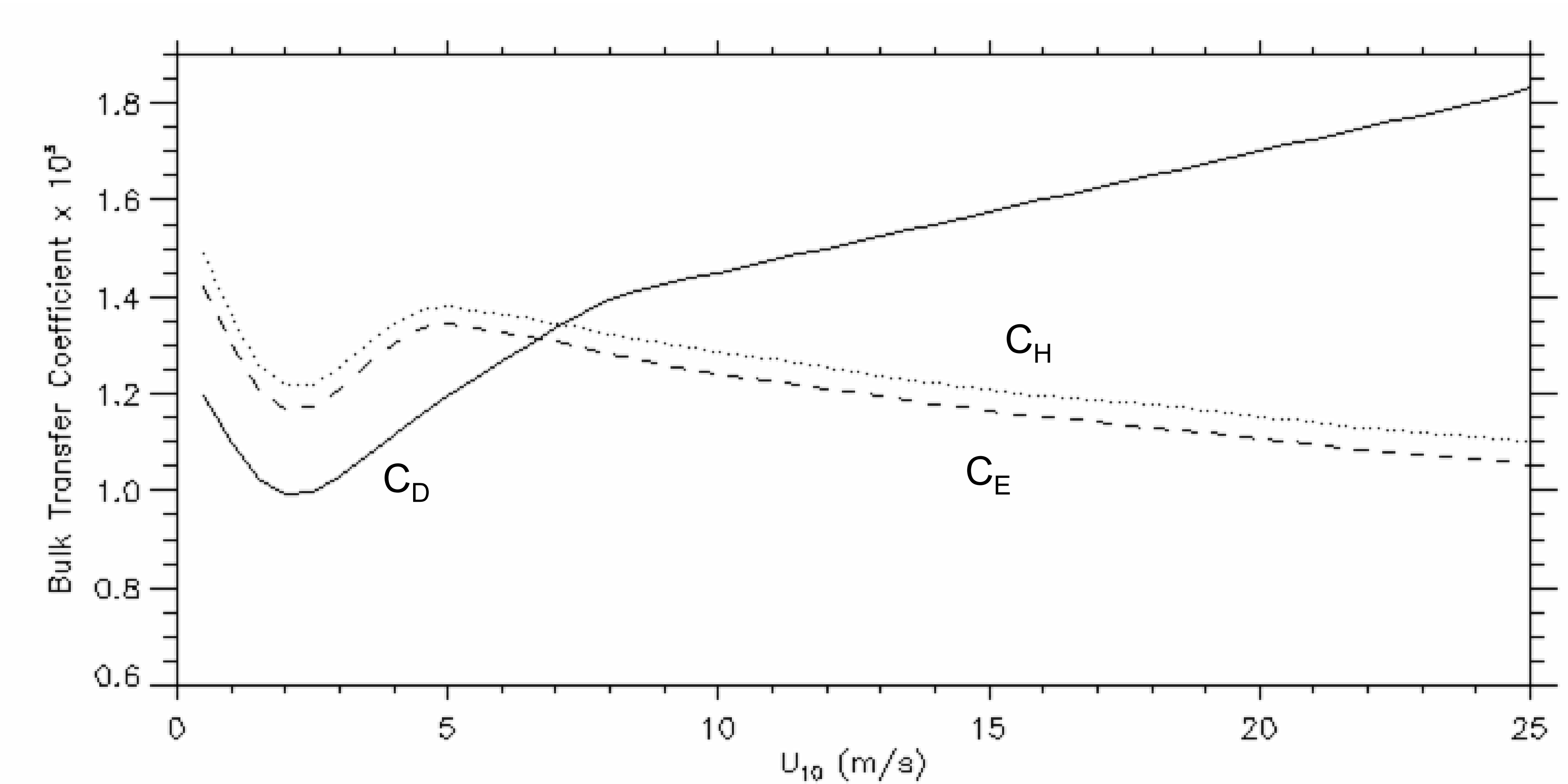
12 Hurricanes in 2005 were used. Those with more than 50% chance of coincident rain occurrence were removed.

BULK FORMULA

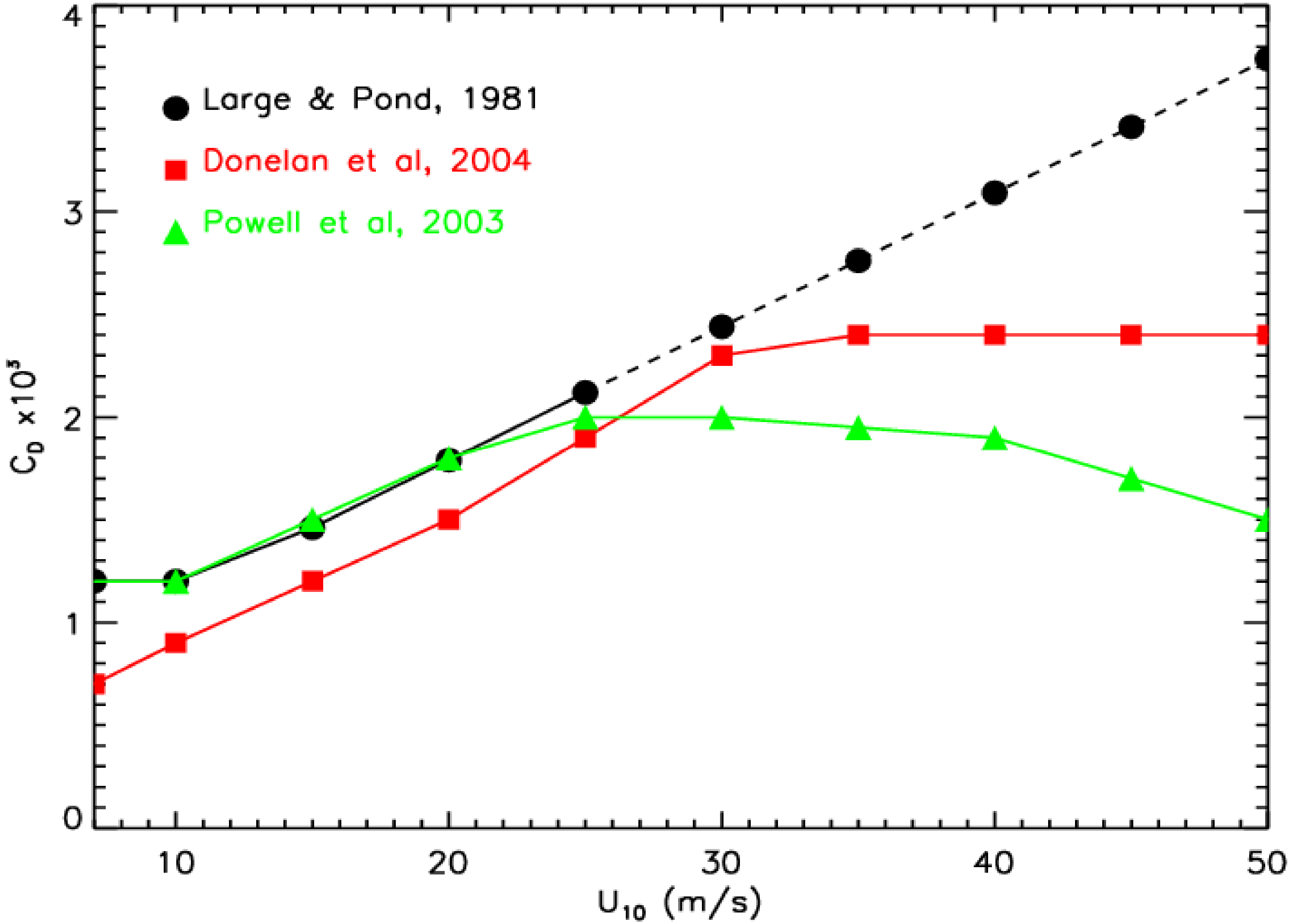
$$\tau = \rho \quad C_D (u-u_s)^2$$

$$H = \rho \, C_P \, C_H (T-T_s)(u-u_s)$$

$$E = \rho \quad C_E (Q-Q_s)(u-u_s)$$



Liu et al, 1979



Large & Pond, 1981
Donelan et al, 2004
Powell et al, 2003
$C_D \times 10^3$
U_{10} (m/s)
0
1
2
3
4
10
20
30
40
50

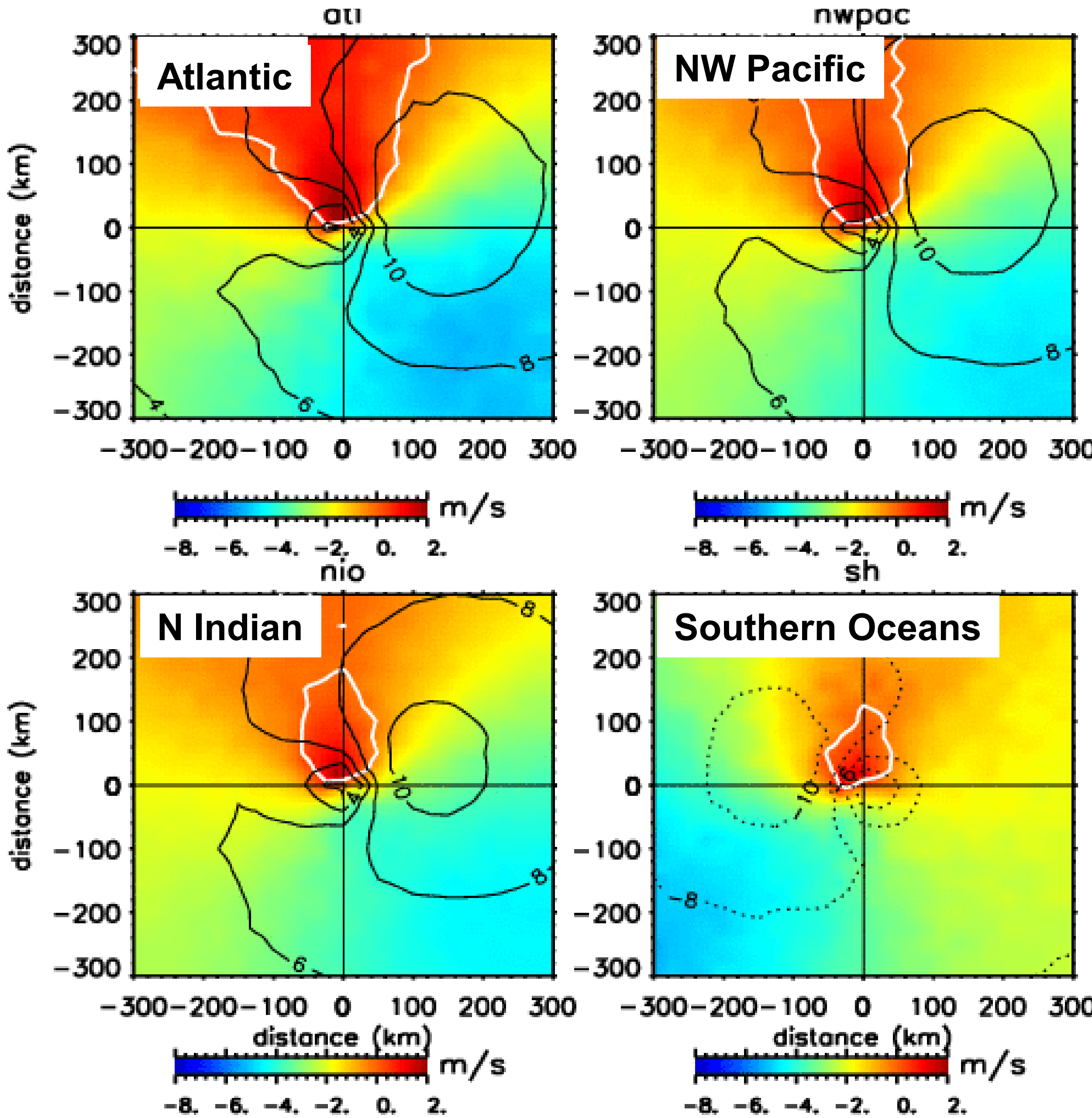
Backup

In different ocean basins

- Atlantic
- Northwestern Pacific
- Eastern Pacific
- North Indian Ocean
- Southern Oceans

Hurricane Intensity	**Atlantic**	**NW Pacific**	**E Pacific**	**N Indian**	**S. Oceans**	**TOTAL**
TS	1127	1689	986	250	1491	**5543**
Catogery-12	331	637	200	22	369	**1559**
Catogery-35	132	429	93	10	242	**906**
TOTAL	**1590**	**2755**	**1279**	**282**	**2102**	**8008**

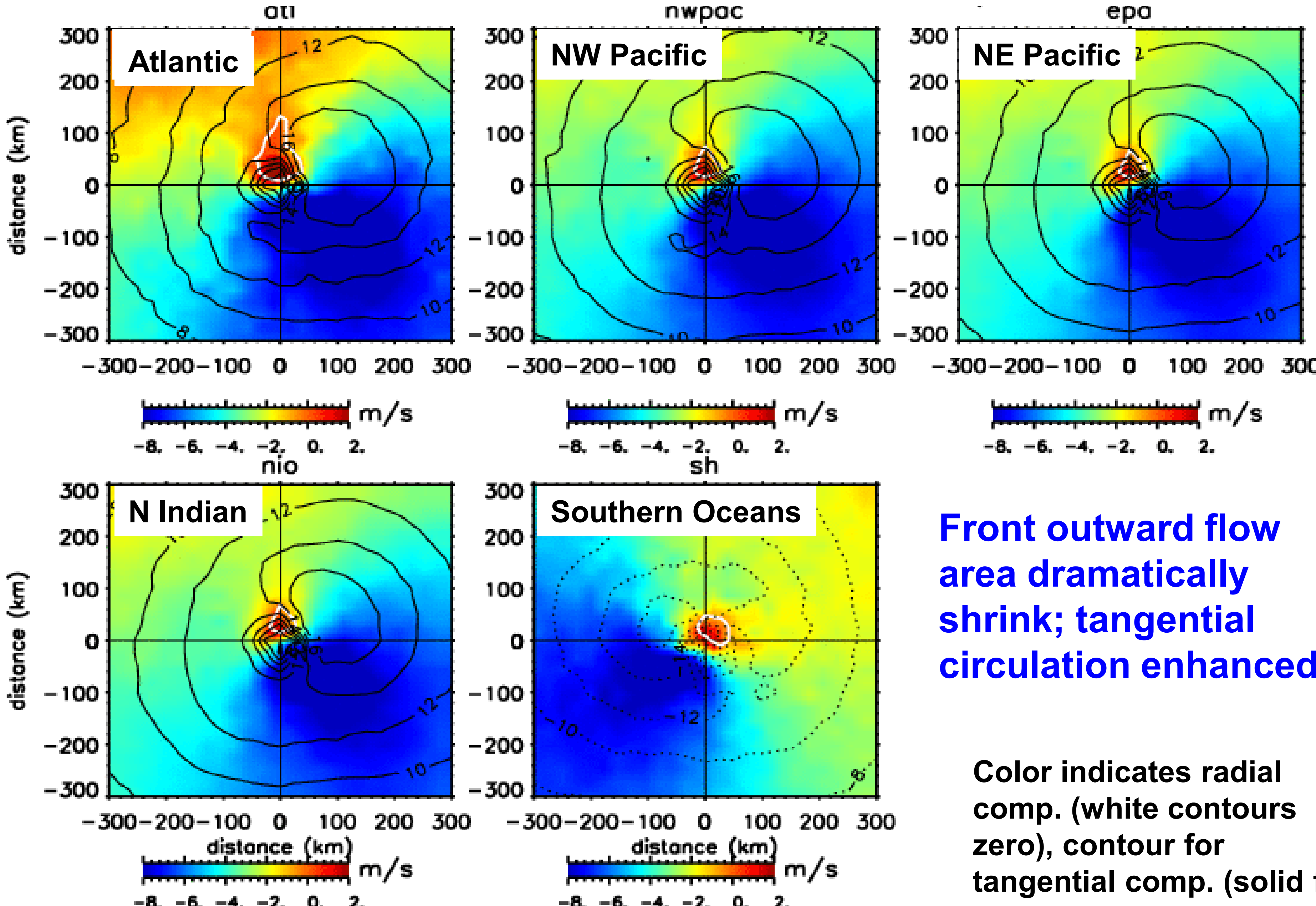
QuikSCAT composite in ocean basin (2000-2007) Tropical Storm (Vmax<64 knot)



Stronger circulation right (left) of track in north (south) hemisphere; Inward flow towards storm center from all quadrants except a small portion in front.

Color indicates radial comp. (white contours zero), contour for tangential comp. (solid for counterclockwise)

QuikSCAT composite in ocean basin (2000-2007) Categories1-5 (Vmax>64 knot)



Front outward flow area dramatically shrink; tangential circulation enhanced.

Color indicates radial comp. (white contours zero), contour for tangential comp. (solid for counterclockwise)

Physical model:

In cylindrical coordinates translates with the hurricane vortex with velocity c, the radial and tangential momentum equations are:

$$u\frac{\partial u}{\partial r}-\frac{v^2}{r}-fv+\frac{v}{r}\frac{\partial u}{\partial \lambda}+\frac{\partial \phi}{\partial r}-K(\nabla^2 u-\frac{u}{r^2}-\frac{2}{r^2}\frac{\partial v}{\partial \lambda})+\boxed{F(\vec{c},u)}=0$$

$$u(\frac{\partial v}{\partial r}+\frac{v}{r})+fu+\frac{v}{r}\frac{\partial v}{\partial \lambda}-K(\nabla^2 v-\frac{v}{r^2}+\frac{2}{r^2}\frac{\partial u}{\partial \lambda})+\boxed{F(\vec{c},v)}=0$$

The frictional drag F is quadratic and parallel to the total wind u+c relative to the earth:

$$F(\vec{c},\vec{u})=\frac{C_D}{h}\left|\vec{u}+\vec{c}\right|(\vec{u}+\vec{c}\,|)$$

The drag C_D is assumed linear, $$C_D=(\alpha+\beta\left|\vec{u}+\vec{c}\right|)\times 10^{-3}$$

[Shapiro, 1983]

The first-order Fourier coefficients:

$$a_1 = \sum_i [P_i \cos(\theta_i)] \qquad b_1 = \sum_i [P_i \sin(\theta_i)]$$

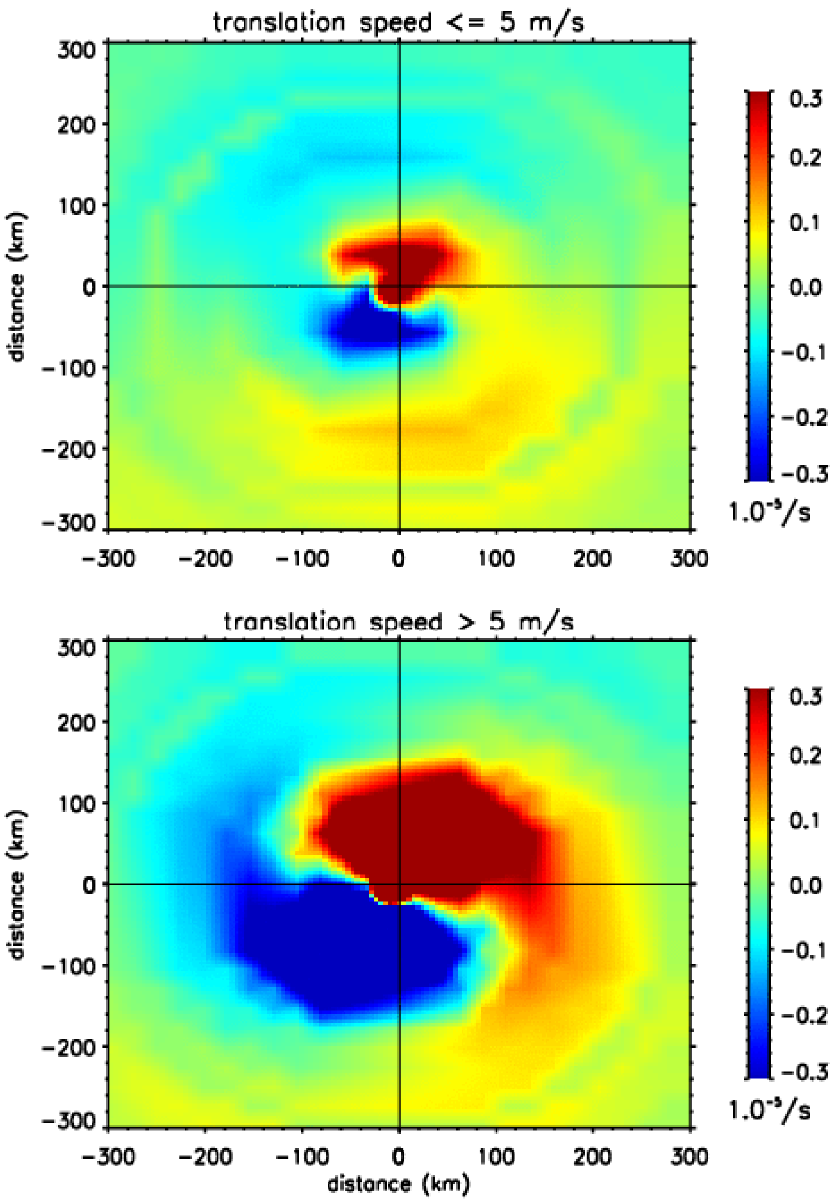
where P_i is each individual estimate of parameter P.

Wavenumber-1 asymmetry:

$$M_1 = [a_1 \cos(\theta) + b_1 \sin(\theta)] / P$$

where P is the mean around 25km-wide annuli around the TC center, and θ is the phase angle relative to the storm motion.

Convergence asymmetry by QSCAT

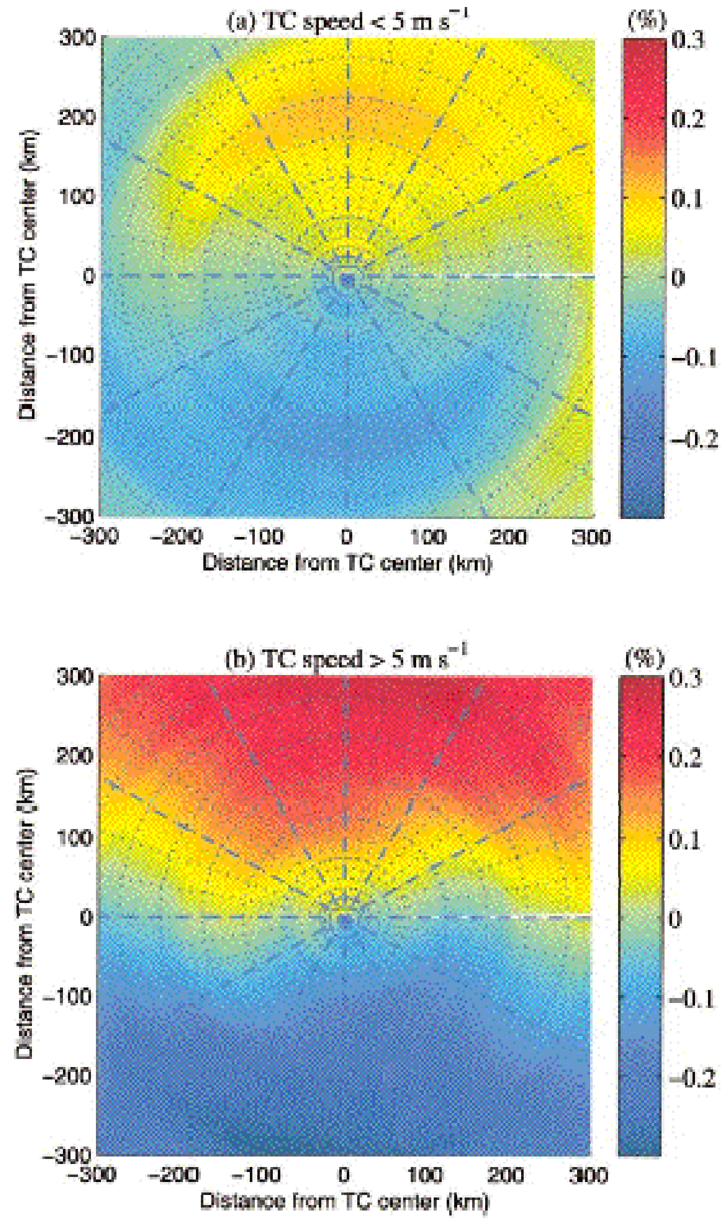


Storm translation speed (TS)

TS<5m/s

TS>5m/s

Rain asymmetry by TRMM



Maximum wind convergence in front right quadrant; fast moving storms generate much stronger convergence and cover larger radius.