Analysis of Co-Located Synthetic Aperture Radar and QuikSCAT Neural-Net Surface Wind Vectors Retrieved in Tropical Cyclones

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Motivation

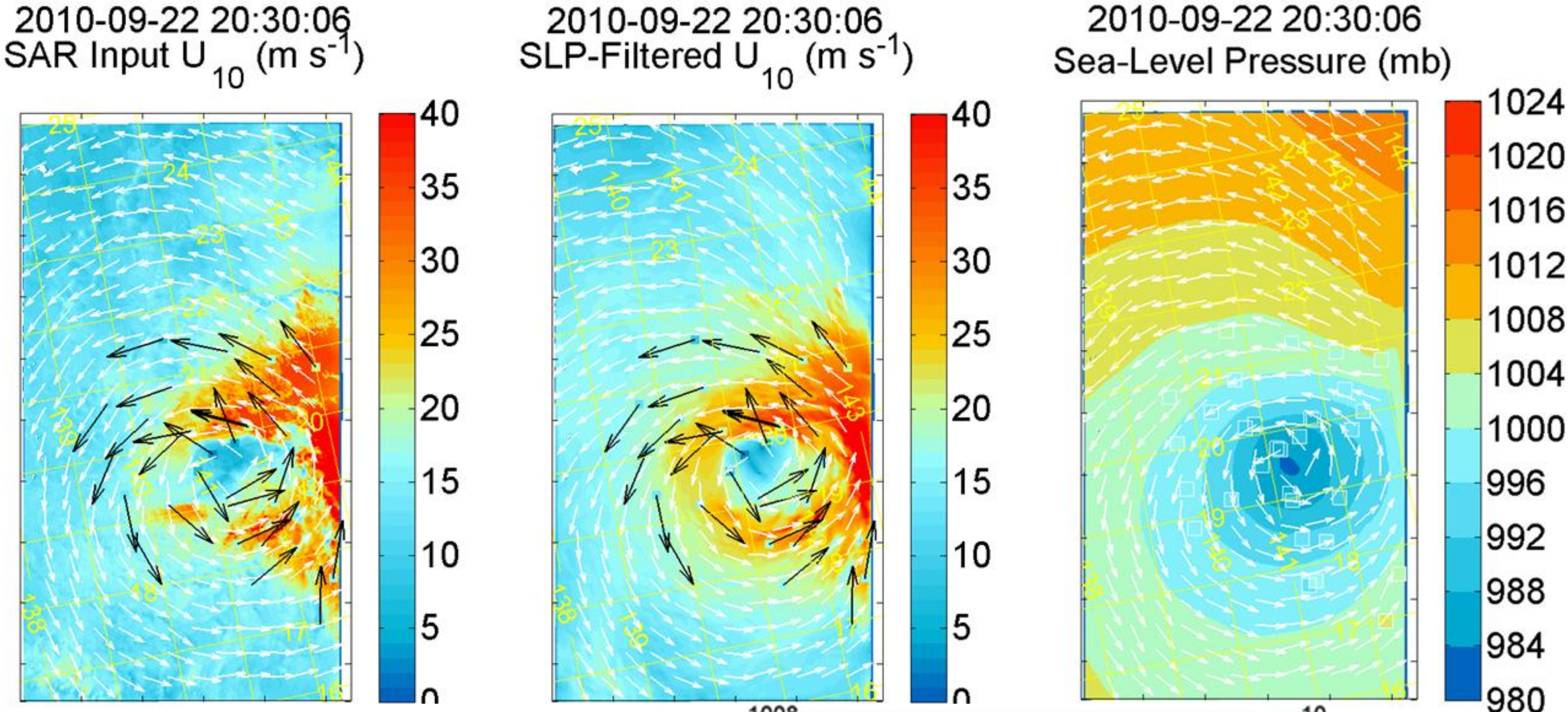
- We have demonstrated that our Sea-Level Pressure (SLP) retrieval methodology can adapted and applied to SAR Tropical Cyclone (TC) data.
  - SAR: limited data/often high cost
- Long, freely available, extensive scatterometer record
  - QuikSCAT/UHR possible
  - ASCAT/UHR possible
  - RapidSCAT
- New QuikSCAT TC Neural Net (QS_NN) product
  - Can we address the "Pressure-Wind" relationship?
    - Used in Dvorak estimates
  - Synergy between products (different views of same processes)

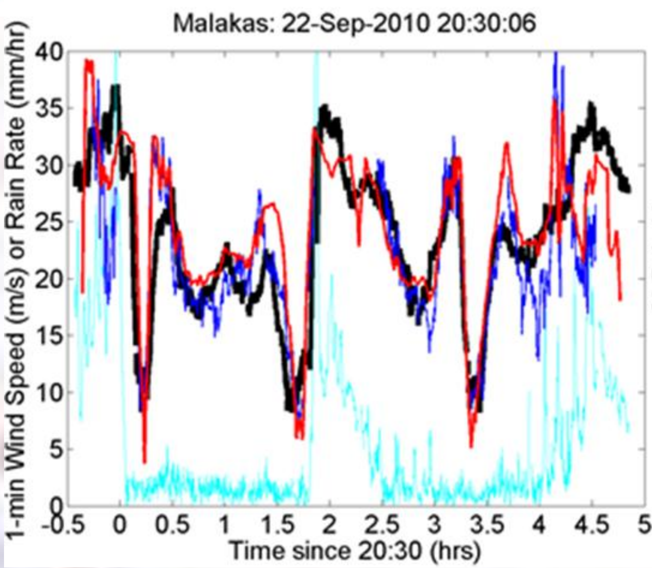
Basic SAR Winds Processing Steps

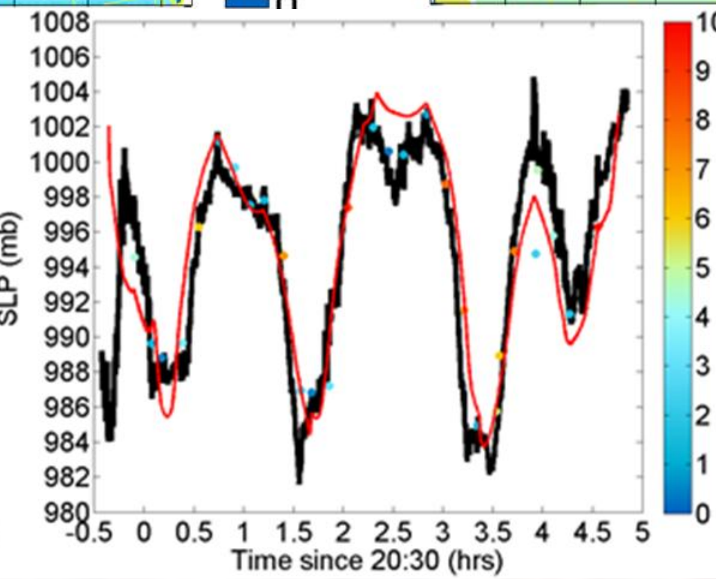
- De-beaming: remove “seams” in ScanSAR (Wackerman)
- Remove “Venetian Blind” noise (Romeisser)
- Estimate wind directions
  - Based on “linear features” (PBL rolls/streaks)
    - Wackerman: maximum contrast $\lambda > \sim 2$ km
    - Horstmann: maximum gradient $\lambda \sim 0.5$ km
    - Reconcile & adjust inflow
    - (Foster: iterate w/PBL model)
- Polarization ratio (HH/VV) Thompson, $\alpha = 0.8$
- CMOD5N 1-km pixels (or experimental X-band GMF)

Typical SAR-SLP Results

- Typhoon Malakas 22 Sep, 2010, 20:30
  - Cat 1, weak typhoon
  - Co-Pol image


2010-09-22 20:30:06
SAR Input U10 (m s-1)
2010-09-22 20:30:06
SLP-Filtered U10 (m s-1)
2010-09-22 20:30:06
Sea-Level Pressure (mb)
40
35
30
25
20
15
10
5
0
1024
1020
1016
1012
1008
1004
1000
996
992
988
984
980

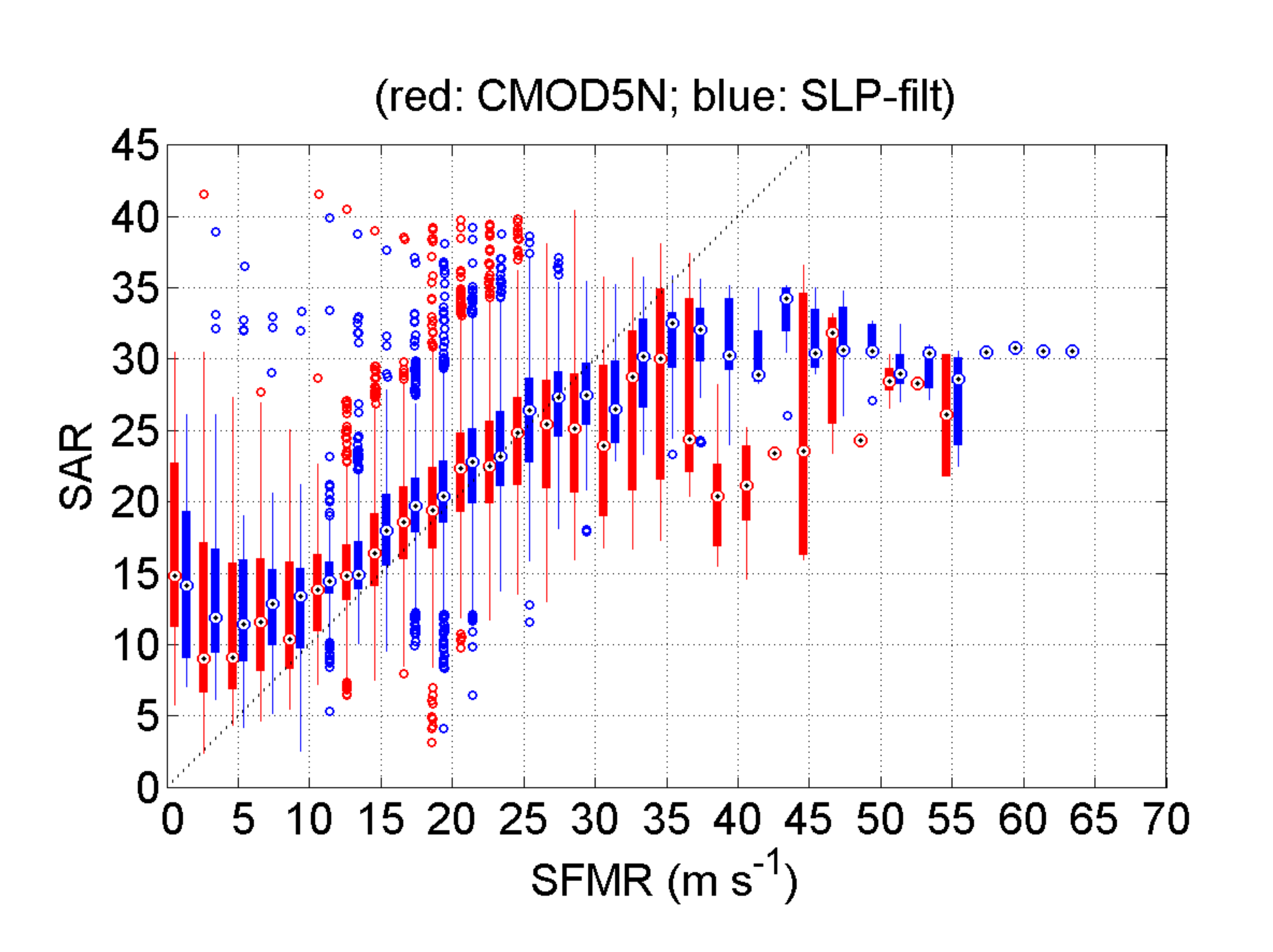

Malakas: 22-Sep-2010 20:30:06
1-min Wind Speed (m/s) or Rain Rate (mm/hr)
Time since 20:30 (hrs)


SLP (mb)
Time since 20:30 (hrs)

C130 SLP

Evaluating Wind Fields

- Historic W. Pac. storms: compare with QuikSCAT
- ATL storms & ITOP storms: SFMR & QuikSCAT
- Drop sondes
  - mainly to assess Sea-level Pressure
    - Indirect Cal/Val of winds ala scatterometer
  - Proper surface wind is very difficult to estimate from drop sonde
- Time-averaging considerations
  - Best track (Dvorak) varies between centers:
    - 1-min (JTWC)
    - 10-min (JMA)
  - HWIND 1-min
  - CMOD5N ~ 10 min
  - SFMR ~ 1-min ("~$0.8*U_{150}$")
    - Bruce Harper: 1-min ~ 1.2(10-min) – for the higher winds
    - Empirically we find factor is 1.1 to 1.2 → very difficult to pin down

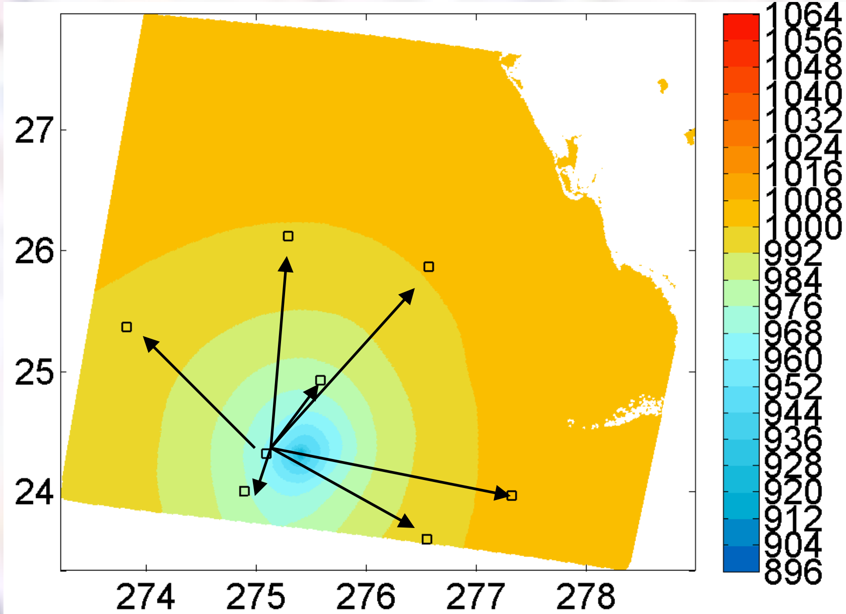


SFMR good ~> 5 to 10 m/s
SAR good to ~ 30 m/s
Fair 30 to 35 m/s
Improvement possible (ambiguity selection, GMF and/or PBL model improvement)

Eight SAR scenes (8428 data points)
C-band, mostly RSAT-1

Katrina,
27 Aug, 2005

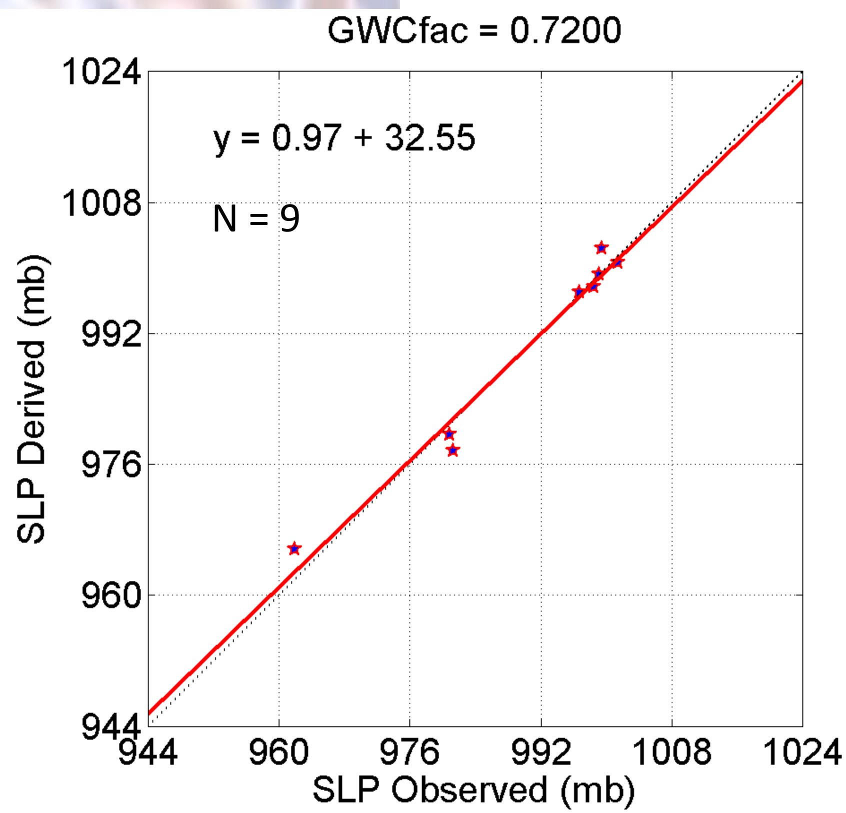
GPS Drop Sondes

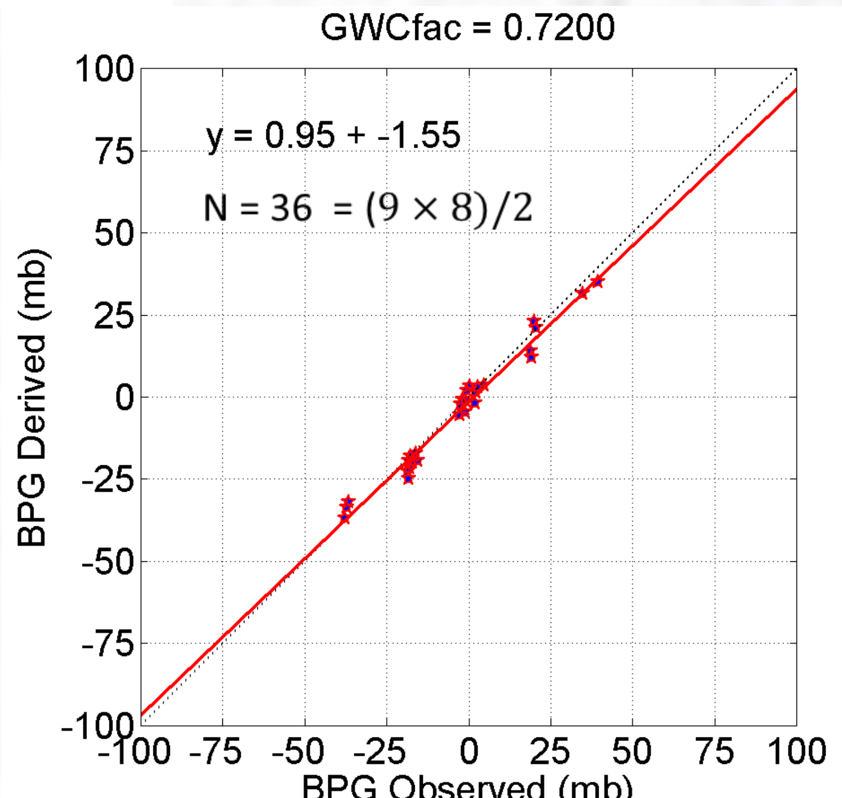


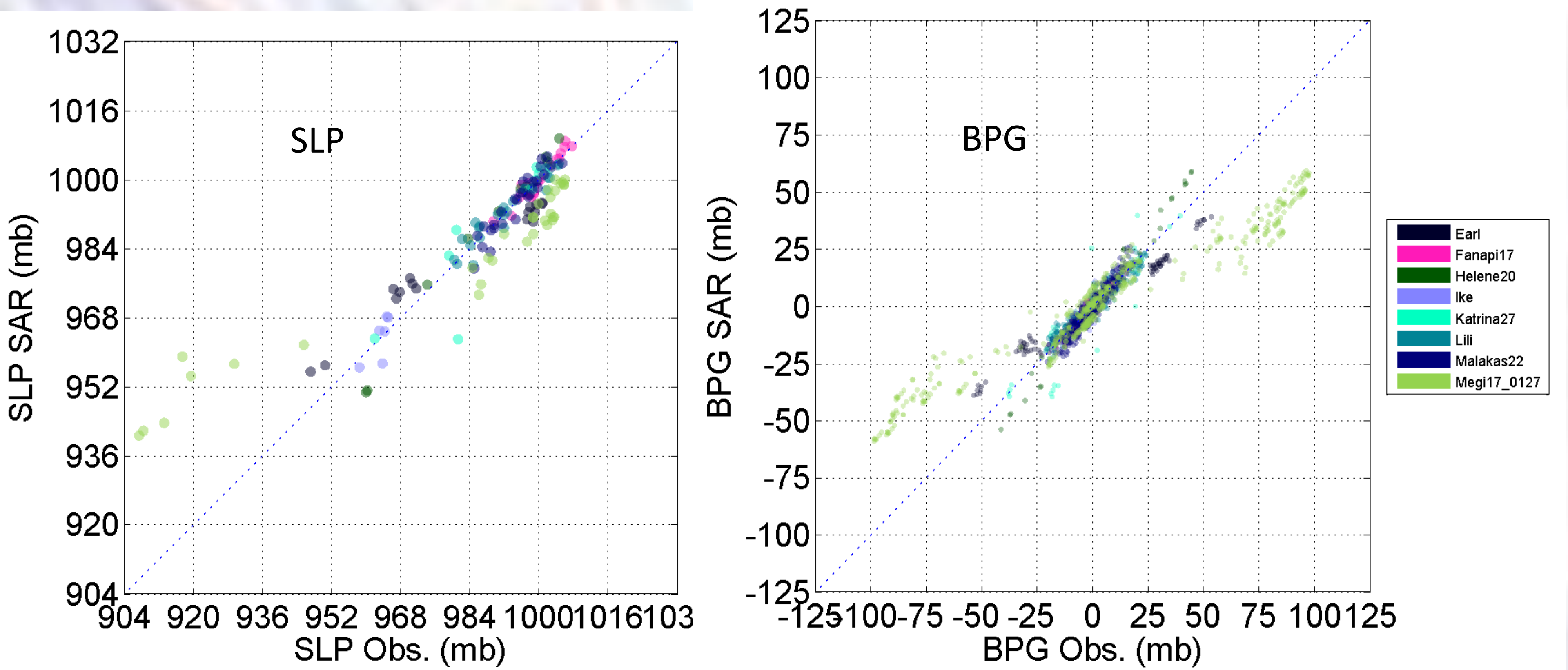
N sondes

$$\frac{N(N-1)}{2} \quad \text{pairs}$$

Bulk Pressure Gradient (BPG)



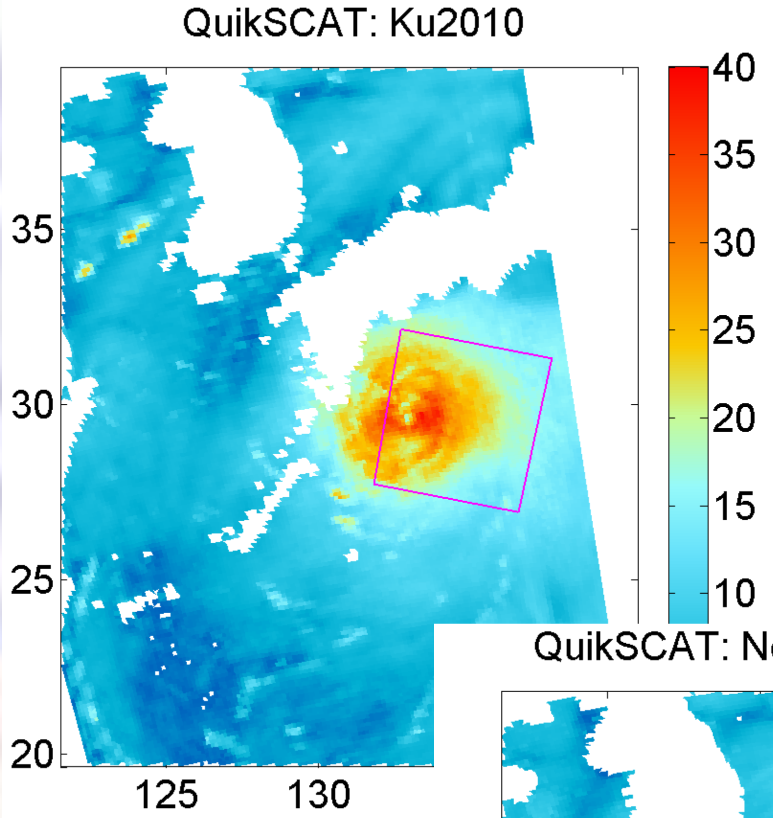


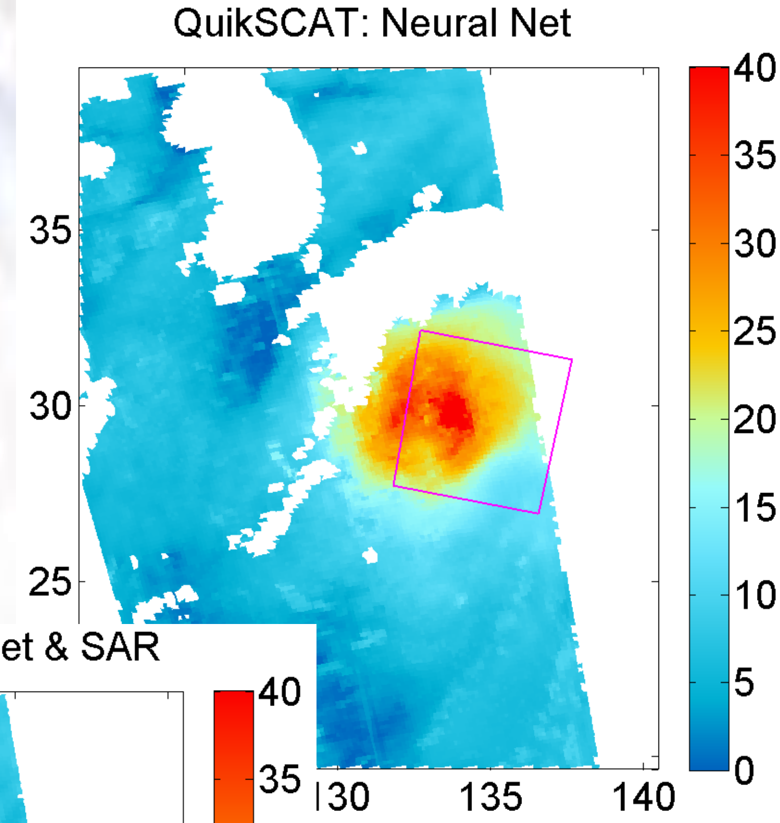


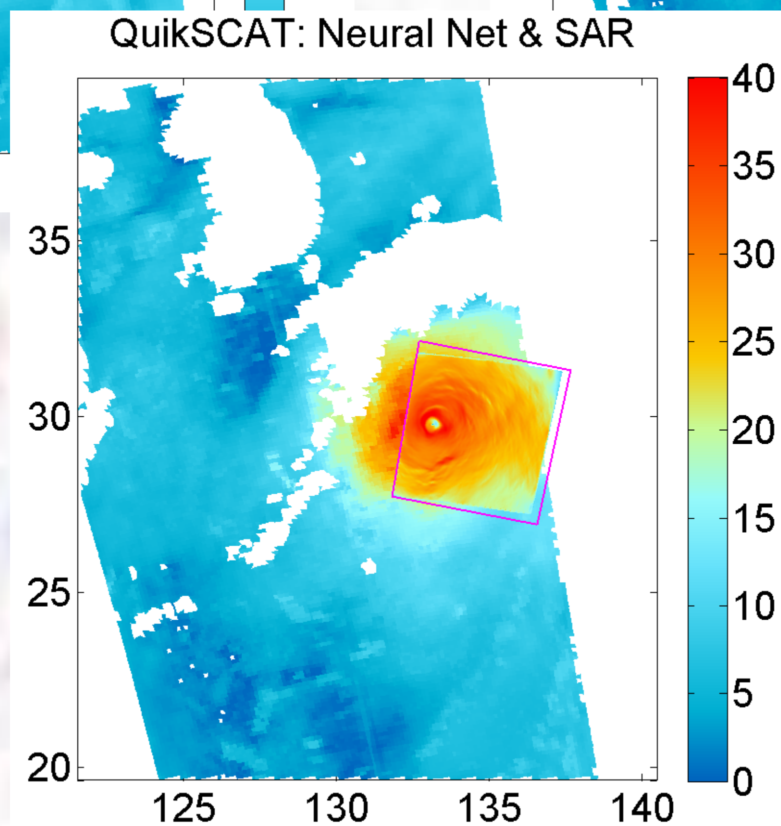
- Super-Typhoon Megi was an anomalous storm
  - ~160 kt winds (85 m/s drop sonde on 17 Sep)
  - Record low MSLP (885 mb)
  - Very small RMW (~10 to 15 km)
- Long time between aircraft and SAR (+8 hr)
  - Still deepening

JPL QuikSCAT Neural Net Winds

- Speed only
  - Directions from JPL Ver. 3 processing
- Trained using 2005 season data
  - NOAA/HRD HWIND analyses (1-min winds)
- Srad, 8 sigma0s input all the time
- Retrieves ~1-min winds at 12.5 km pixel
  - SAR/CMOD5N: ~10 min winds at 1 km pixel
- Close in time match-ups: QS/RSAT-1

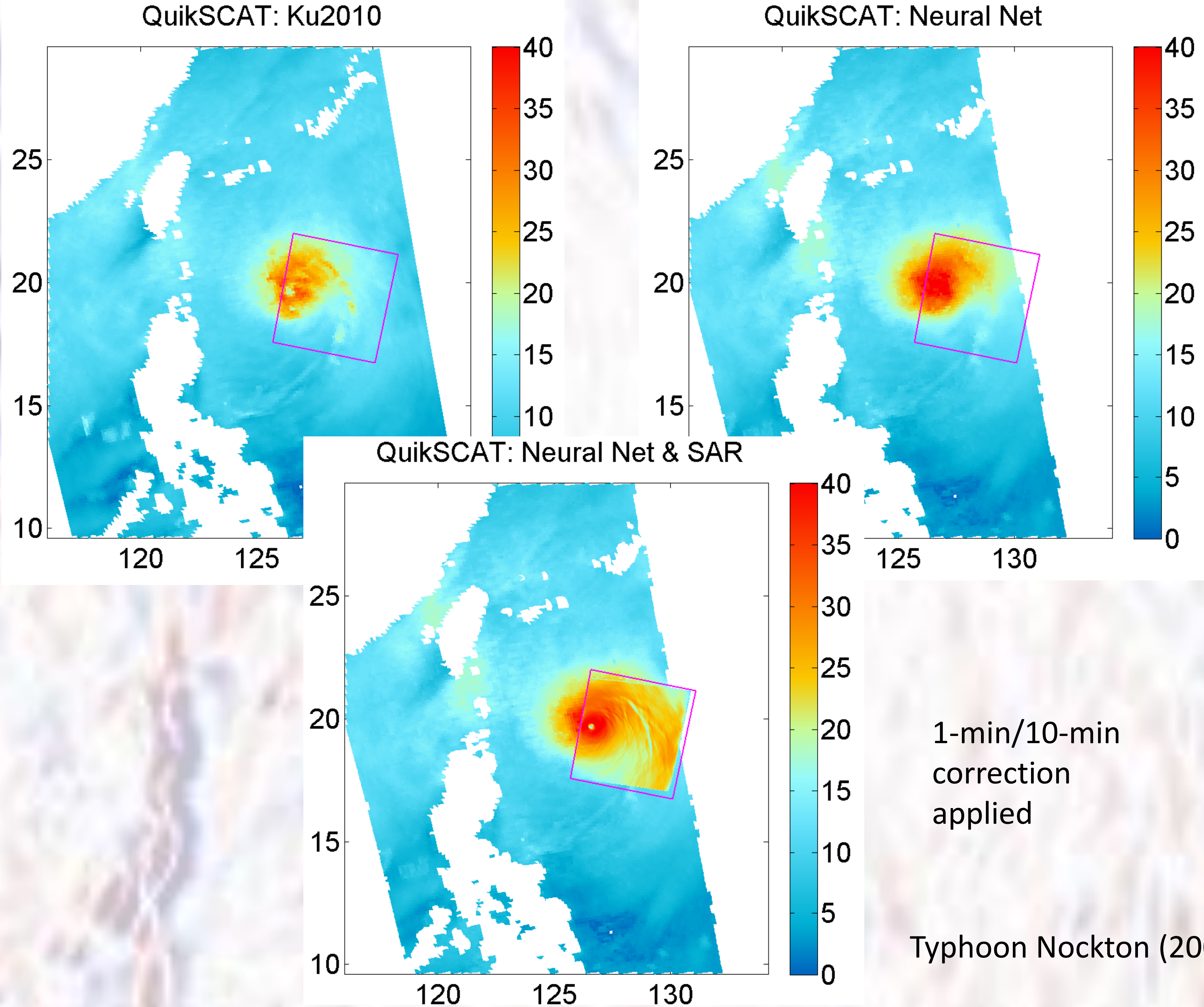






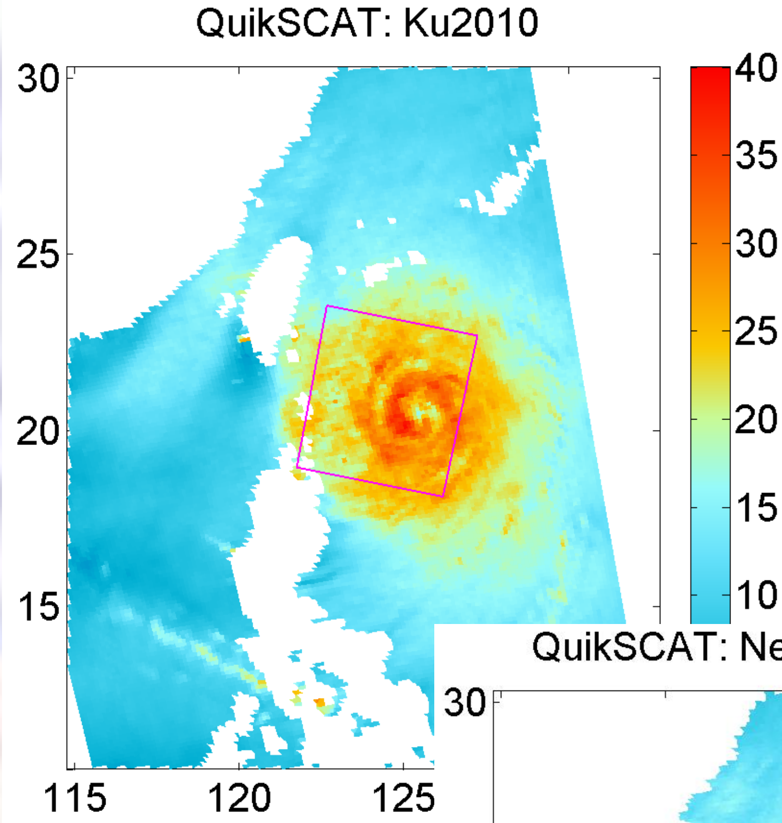
1-min/10-min correction applied

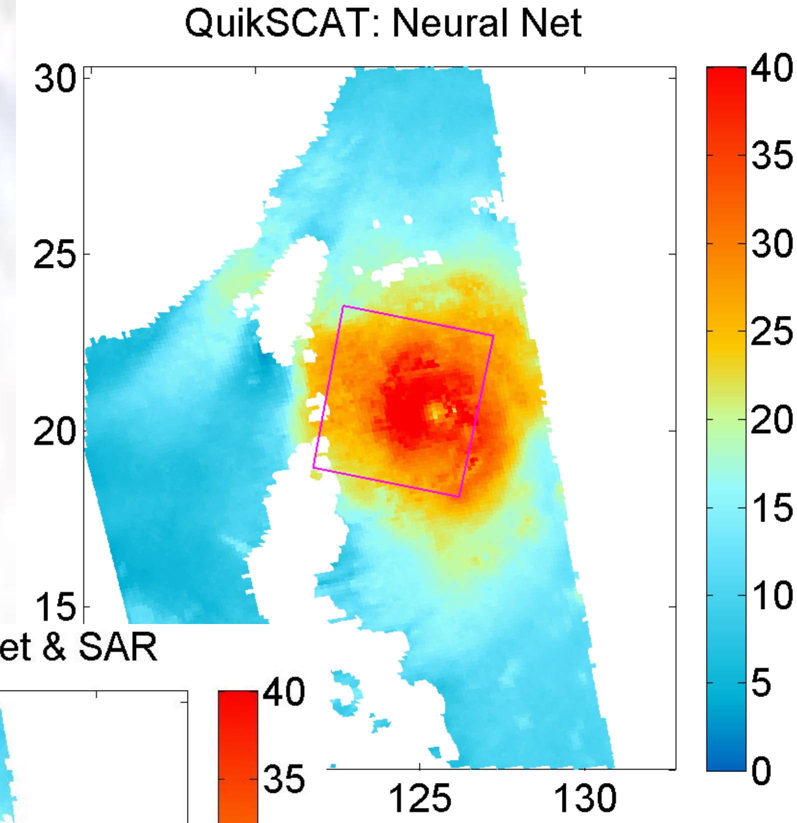
Typhoon Usagi (2007)

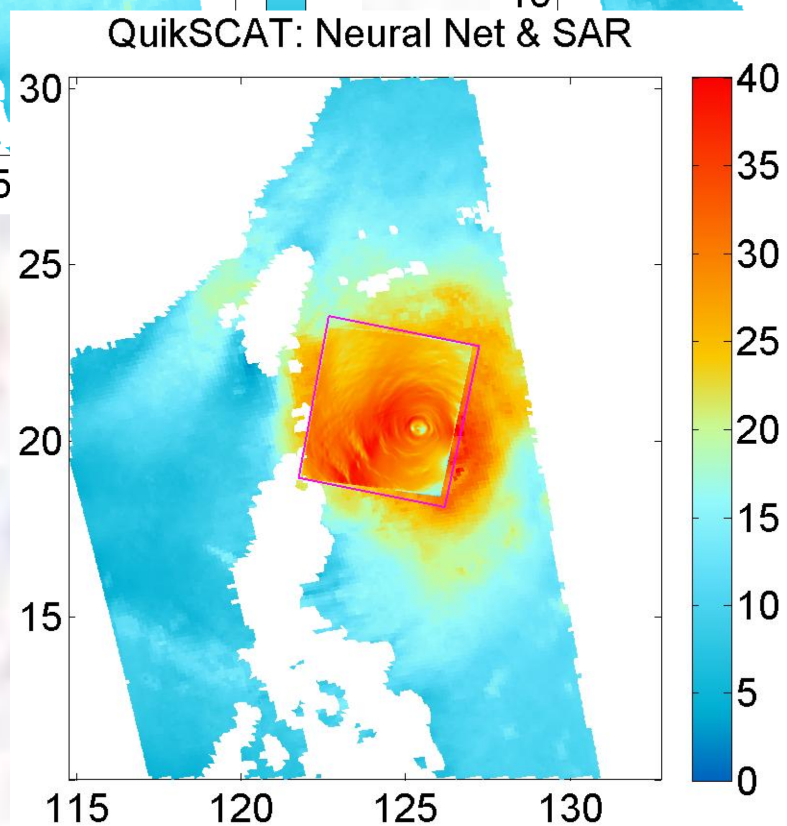


1-min/10-min correction applied

Typhoon Nockton (2004)



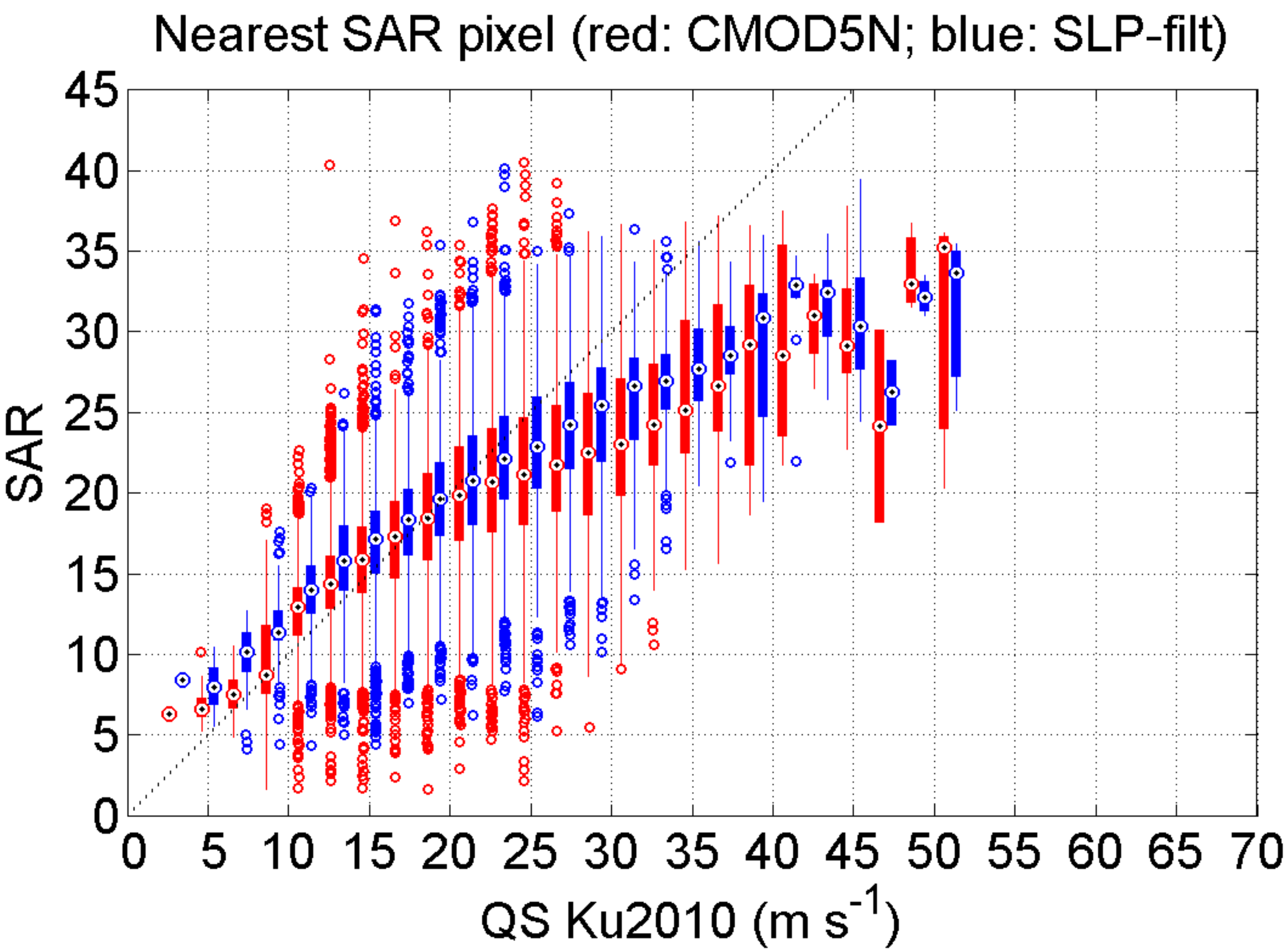




1-min/10-min correction applied

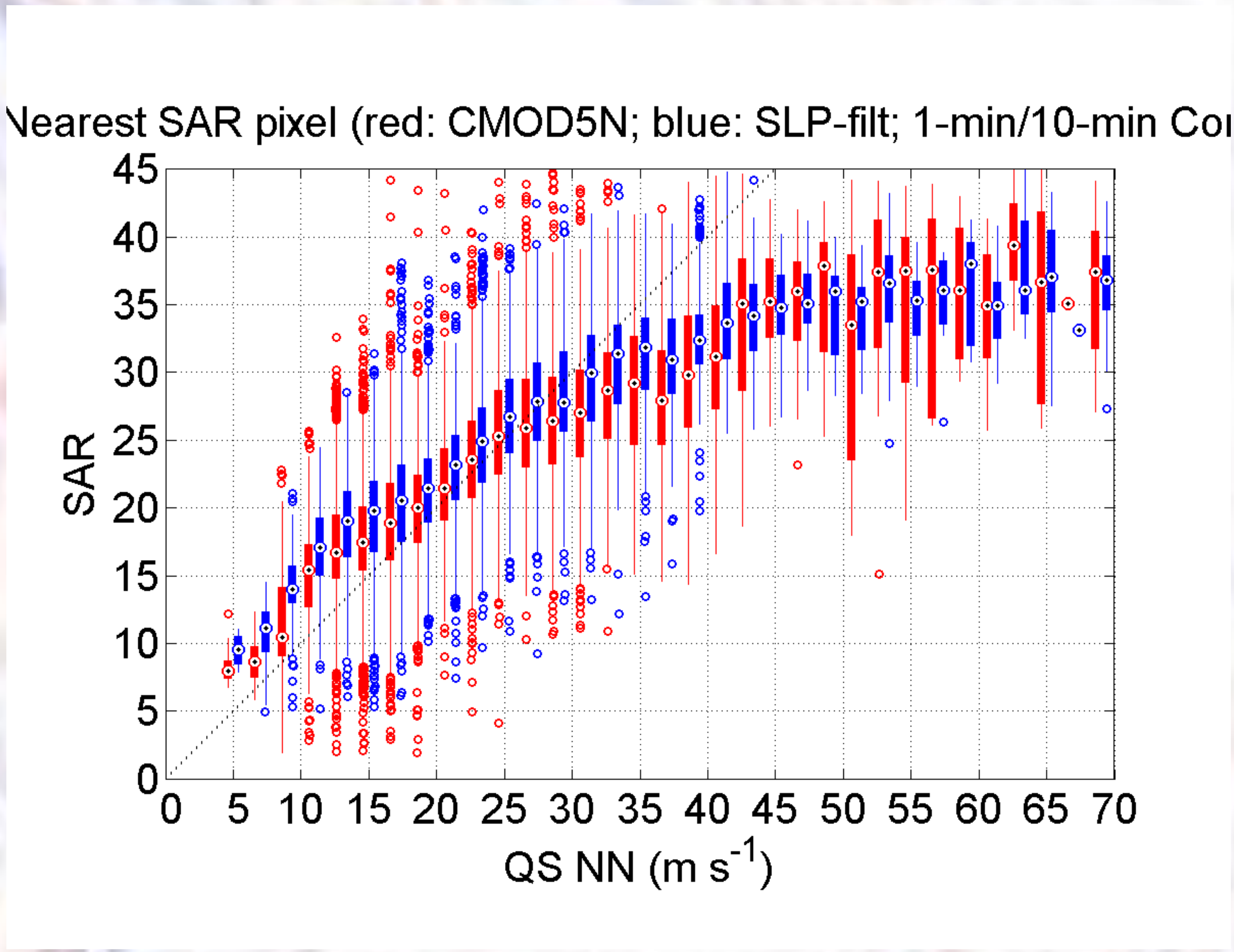
Typhoon Krosa (2007)

QuikSCAT

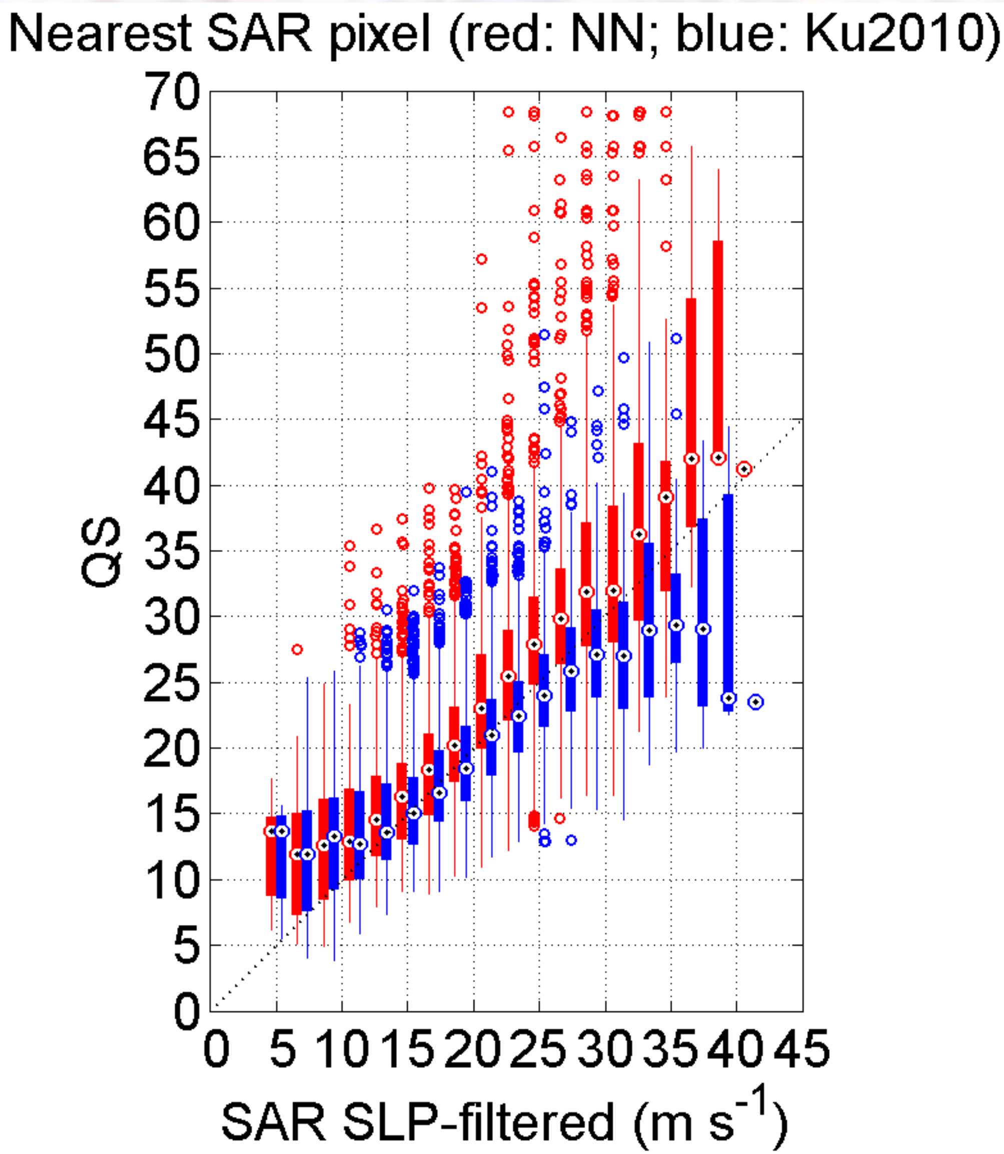


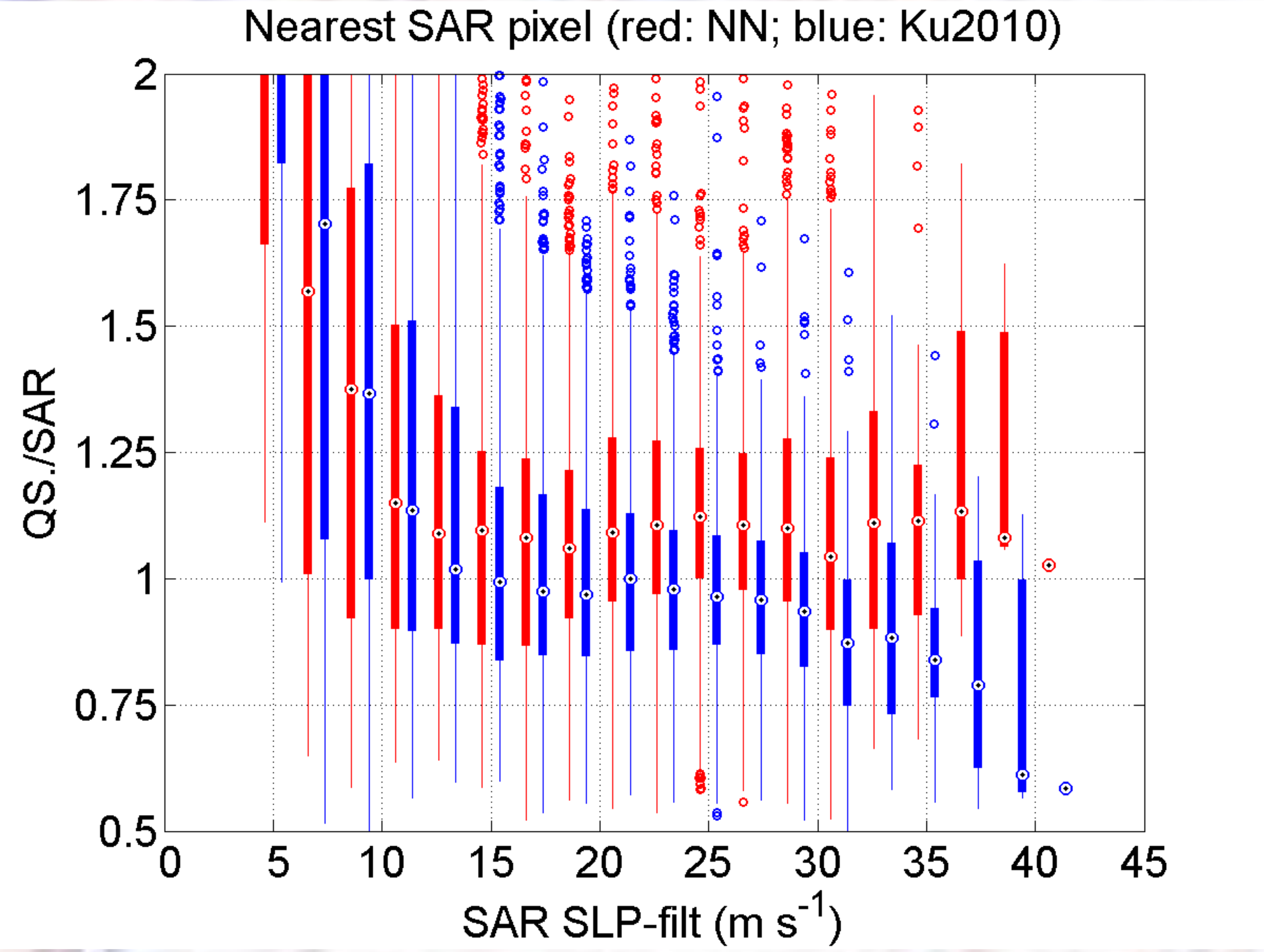
Rain flags ignored

QuikSCAT



Neural Net Product

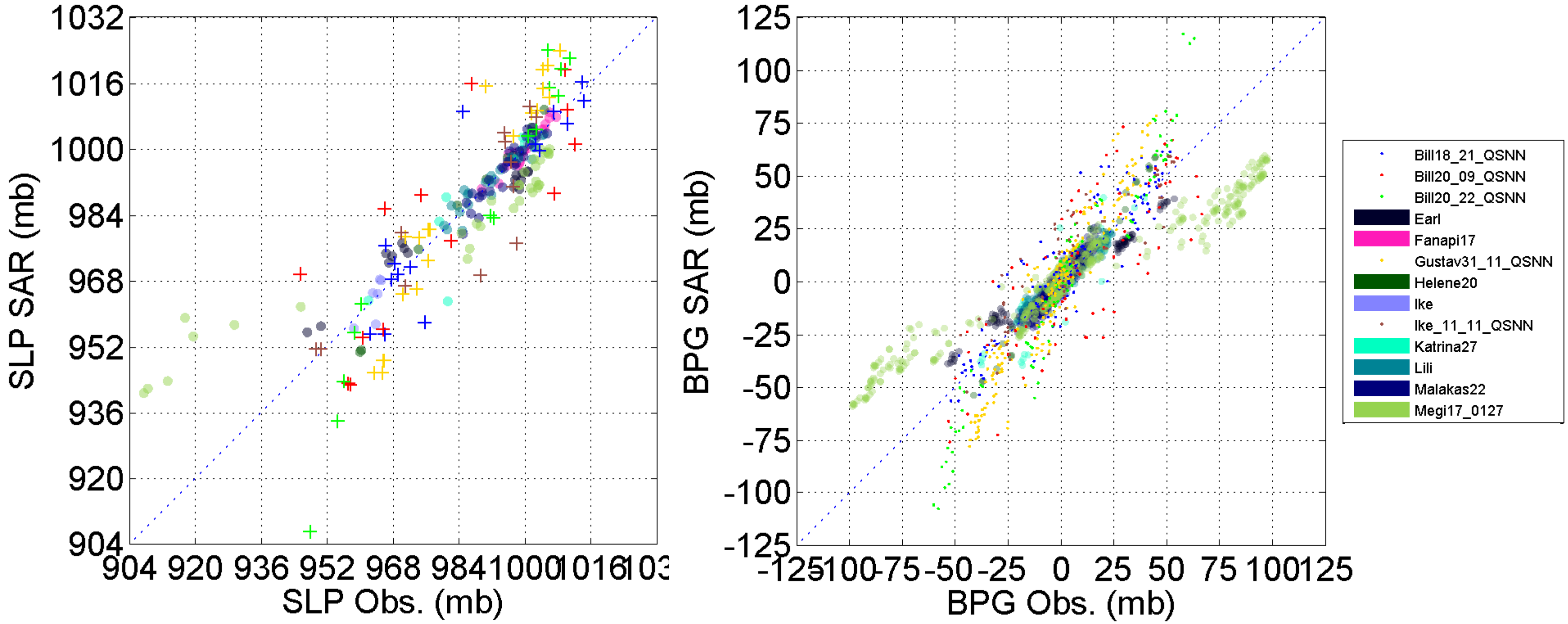

Nearest SAR pixel (red: NN; blue: Ku2010)
QS
SAR SLP-filtered (m s-1)
0 5 10 15 20 25 30 35 40 45
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70



Nearest SAR pixel (red: NN; blue: Ku2010)
QS./SAR
SAR SLP-filt (m s-1)
2
1.75
1.5
1.25
1
0.75
0.5
0
5
10
15
20
25
30
35
40
45

Adapting SLP retrieval to QS_NN

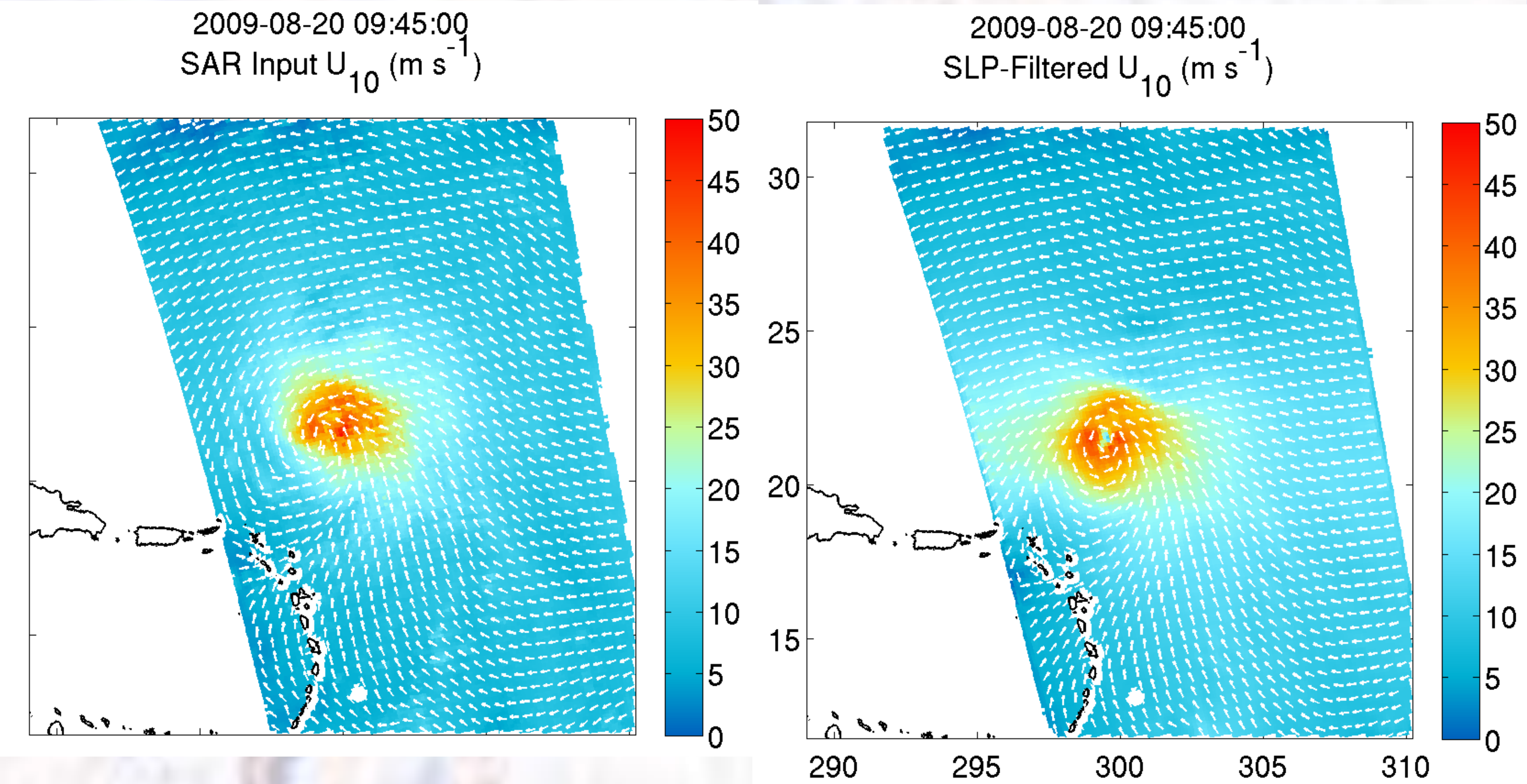
- Collecting swaths and NOAA/HRD overlaps
- Initial results (5 swaths)
  - Quality of SLP fields from QS_NN is much worse than for SAR
  - Possible problems:
    - Further improvements needed for TC PBL model?
    - Bad input wind directions?

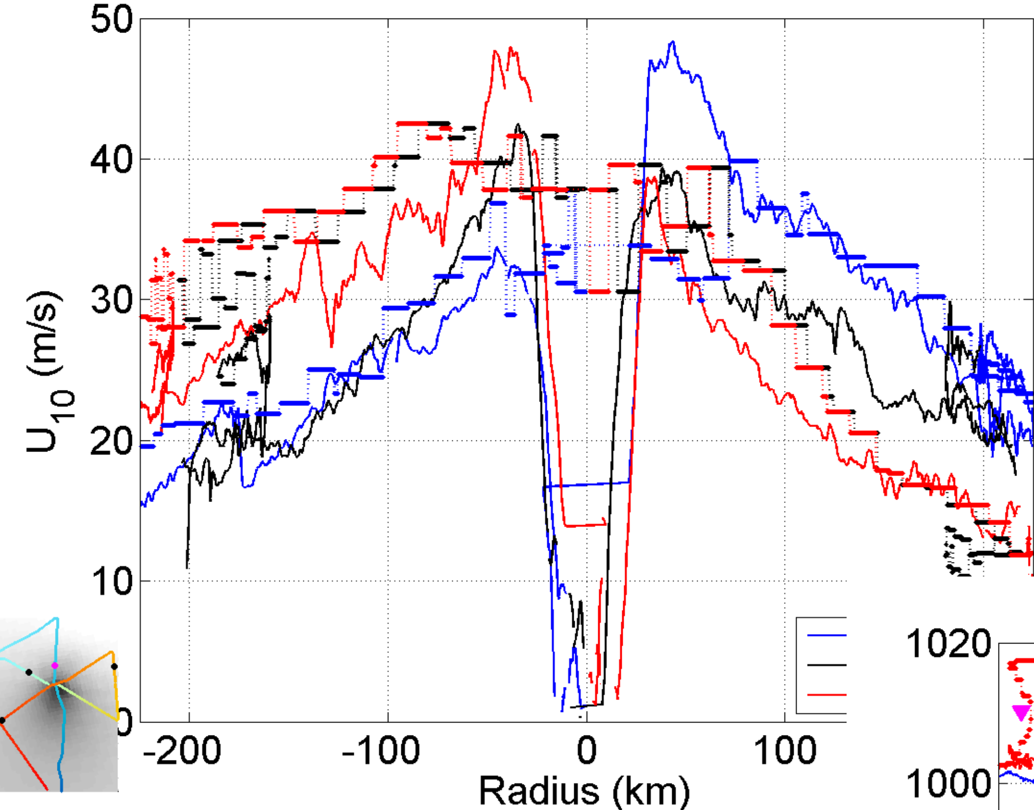


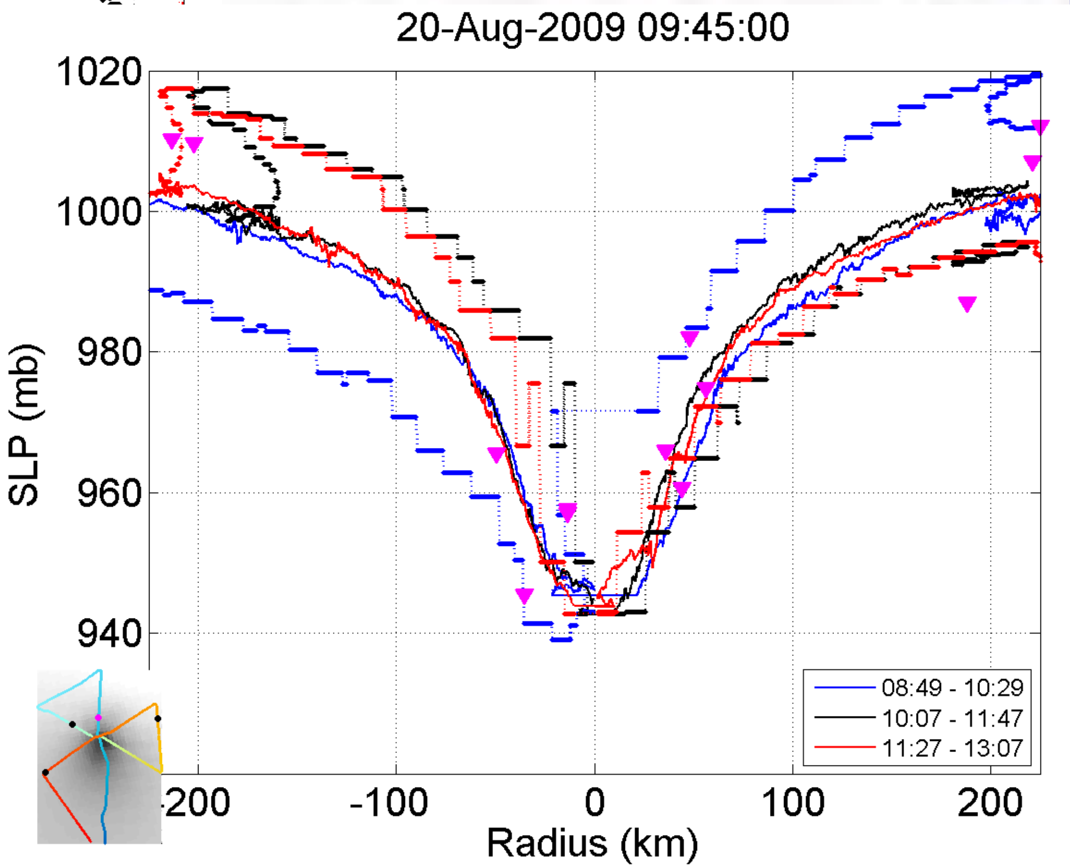
SLP SAR (mb)
SLP Obs. (mb)
BPG SAR (mb)
BPG Obs. (mb)
Bill18_21_QSNN
Bill20_09_QSNN
Bill20_22_QSNN
Earl
Fanapi17
Gustav31_11_QSNN
Helene20
Ike
Ike_11_11_QSNN
Katrina27
Lili
Malakas22
Megi17_0127

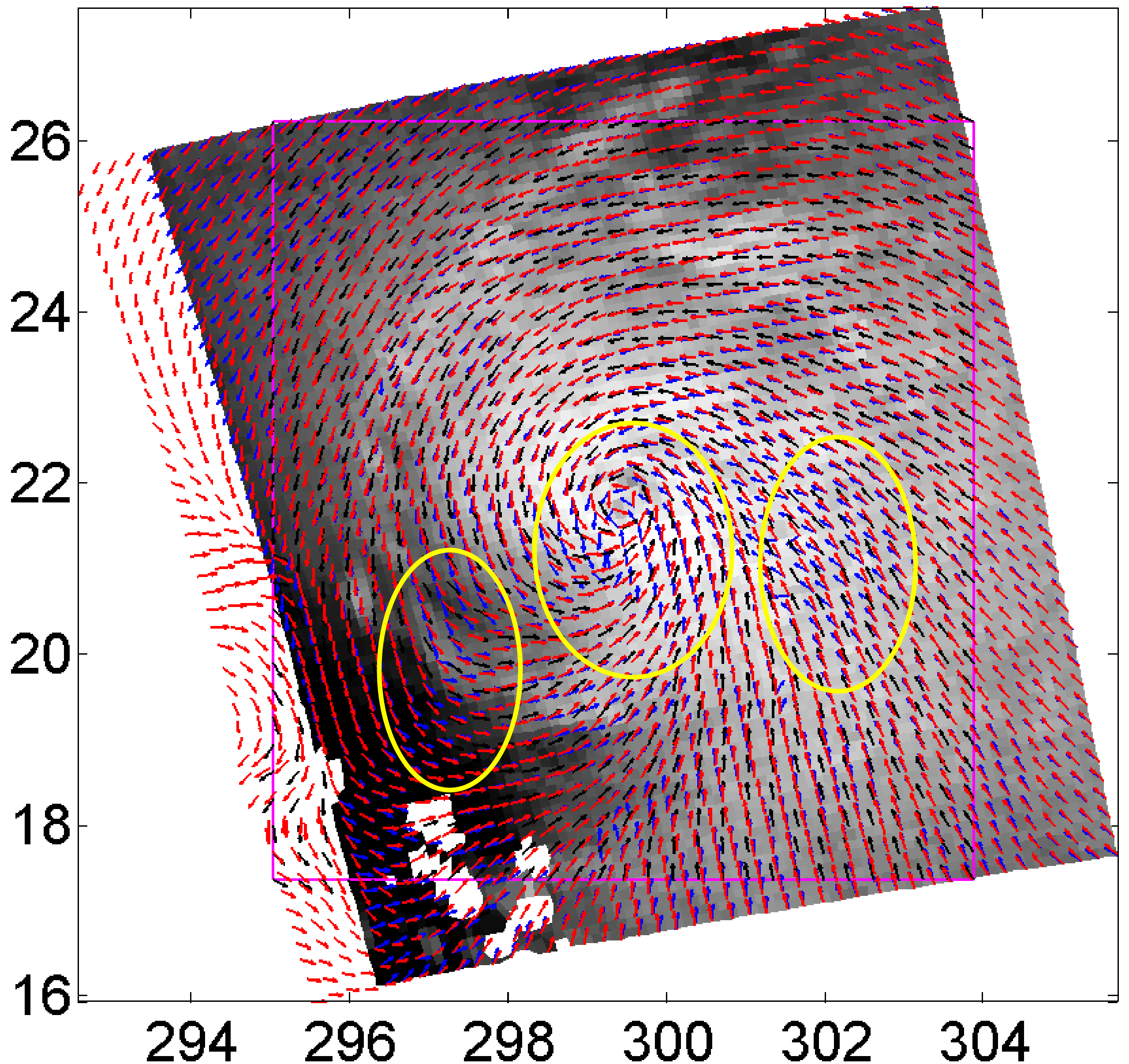
Hurricane Bill (2009)

- Example swath: 20 Aug, 09:45
  - P-3 sampled inner core -1 to +3.5 hours
  - 13 drop sondes
  - SFMR
  - Data adjusted to overpass using HRD flight-level (Willoughby) trak file


2009-08-20 09:45:00
SAR Input U_{10} (m s^{-1})
50
45
40
35
30
25
20
15
10
5
0
2009-08-20 09:45:00
SLP-Filtered U_{10} (m s^{-1})
30
25
20
15
290
295
300
305
310
50
45
40
35
30
25
20
15
10
5
0


50
40
30
20
10
0
-200
-100
0
100
Radius (km)
U_{10} (m/s)

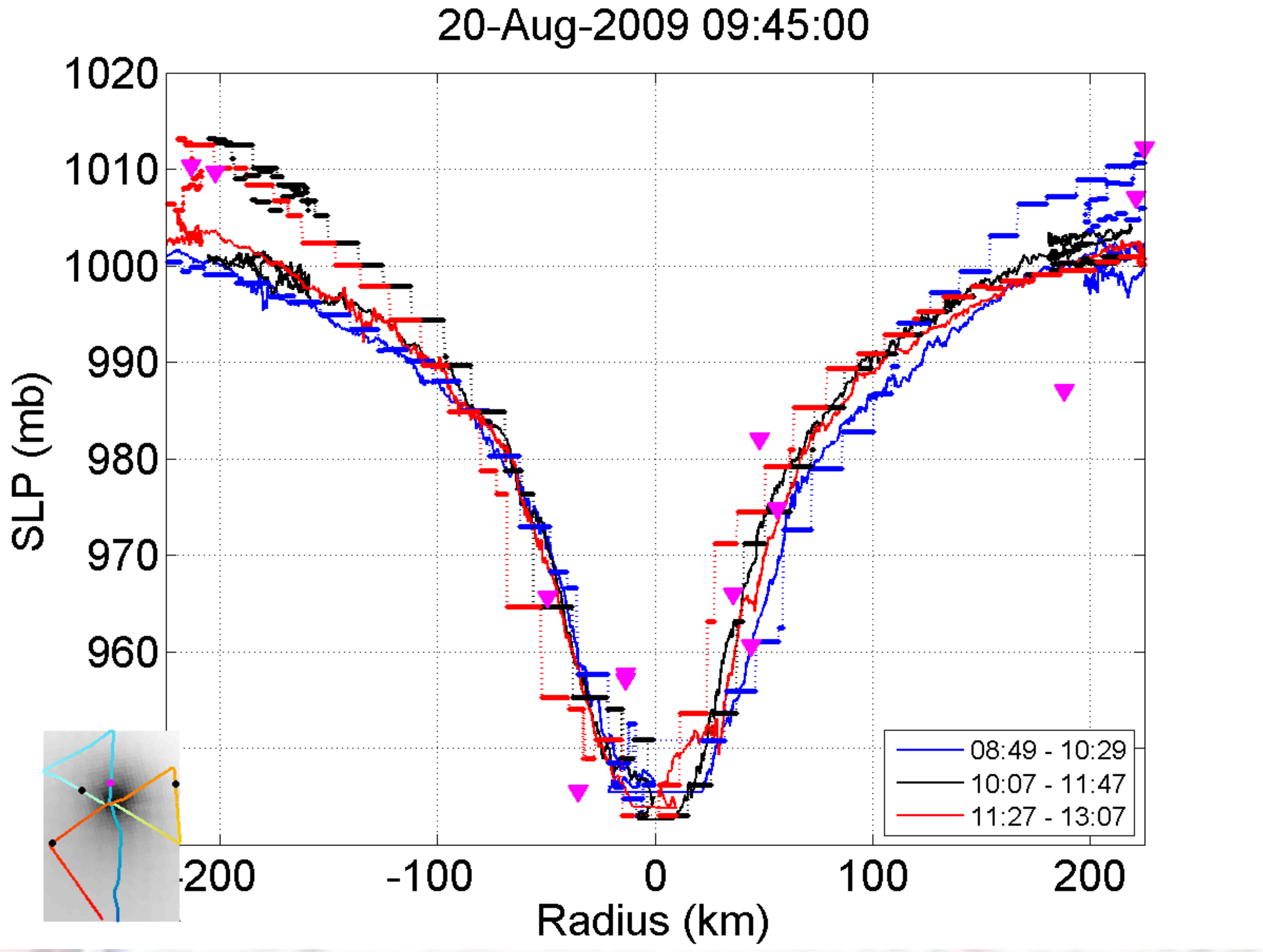

20-Aug-2009 09:45:00
1020
1000
980
960
940
-200
-100
0
100
200
Radius (km)
SLP (mb)
08:49 - 10:29
10:07 - 11:47
11:27 - 13:07

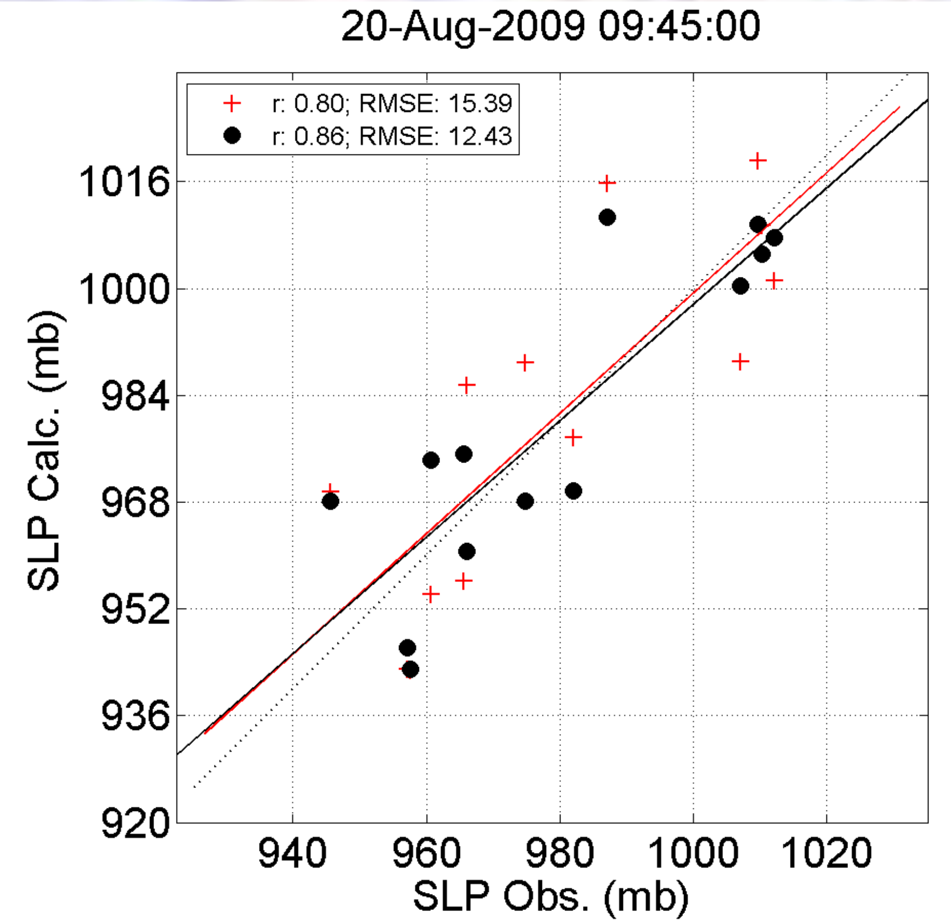


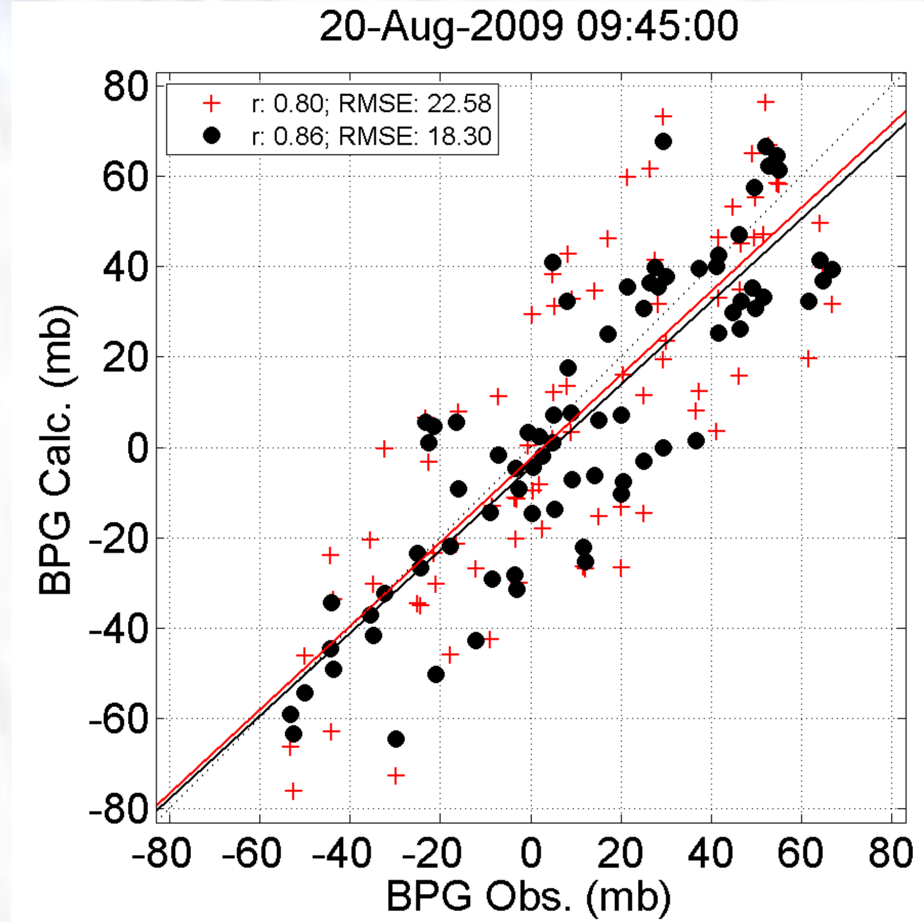
- Are QS wind directions are affecting results?
- Use HRD/HWIND analysis (with P-3 data included) to replace QS directions
- Effectively FL minus 10 to 20 deg
- ***No change to QS_NN speed***

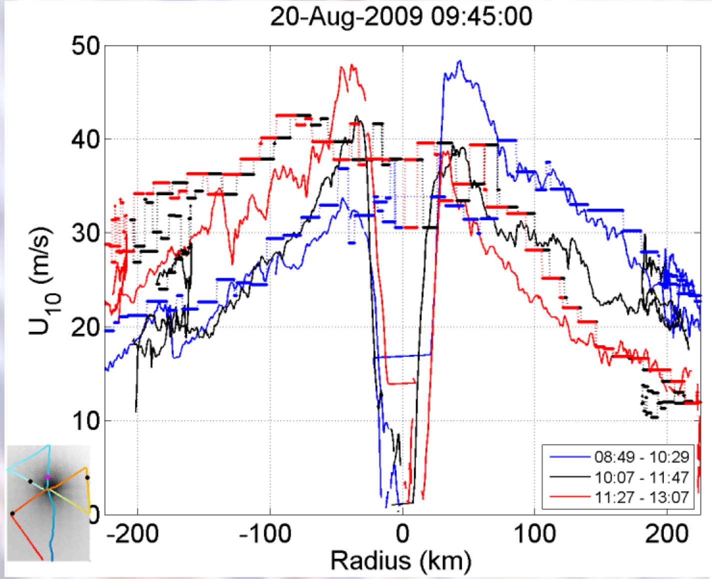
Blue: QS directions
Black: HRD directions
Red: HRD mapped to QS

Background: σ_0

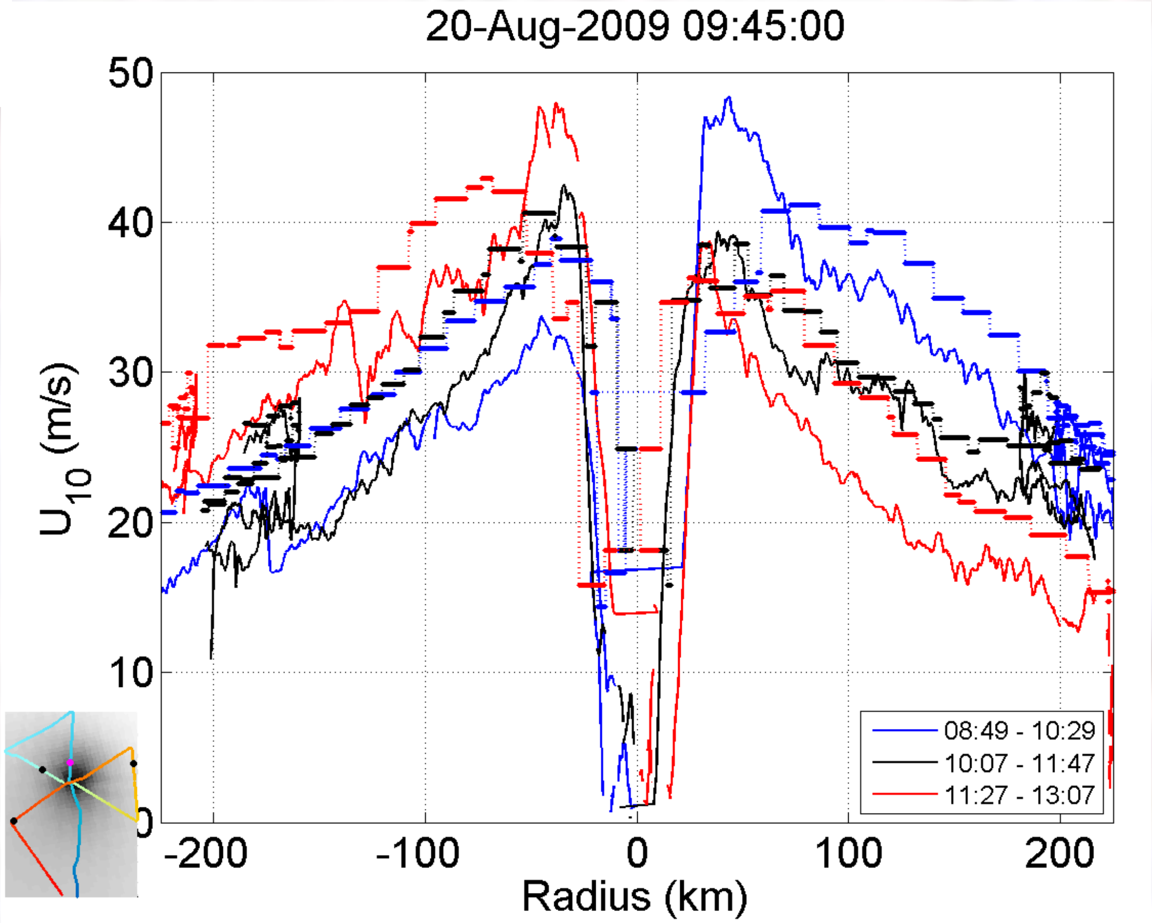

20-Aug-2009 09:45:00
SLP (mb)
Radius (km)
08:49 - 10:29
10:07 - 11:47
11:27 - 13:07
1020
1010
1000
990
980
970
960
-200
-100
0
100
200


20-Aug-2009 09:45:00
r: 0.80; RMSE: 15.39
r: 0.86; RMSE: 12.43
1016
1000
984
968
952
936
920
940
960
980
1000
1020
SLP Calc. (mb)
SLP Obs. (mb)


20-Aug-2009 09:45:00
r: 0.80; RMSE: 22.58
r: 0.86; RMSE: 18.30
80
60
40
20
0
-20
-40
-60
-80
-80
-60
-40
-20
0
20
40
60
80
BPG Calc. (mb)
BPG Obs. (mb)



Input QS_NN Speed

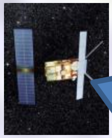


Output SLP-filtered speed

Conclusions & What's Next

- First look at QS_NN wind speeds suggests they have good potential for TC research
  - Good stress test of PBL model & SLP methodology
    - Look for ways to improve PBL model
  - Role of coarse (12.5 km) resolution?
- QS Ver 3 wind directions have remaining problems in TC inner cores
- It appears likely that we will be able to pursue Pressure-Wind relationship
- Planned future collaborations with Jun Zhang (HRD) & Pete Black (SAIC) on TC wind fields & PBL processes using OVW
  - RapidSCAT/SAR/QS (NN& UHR)/ASCAT (UHR)
- Can SLP methodology help improve direction retrieval in TC inner cores?
  - TC inner core: SLP retrieval sensitive to direction errors

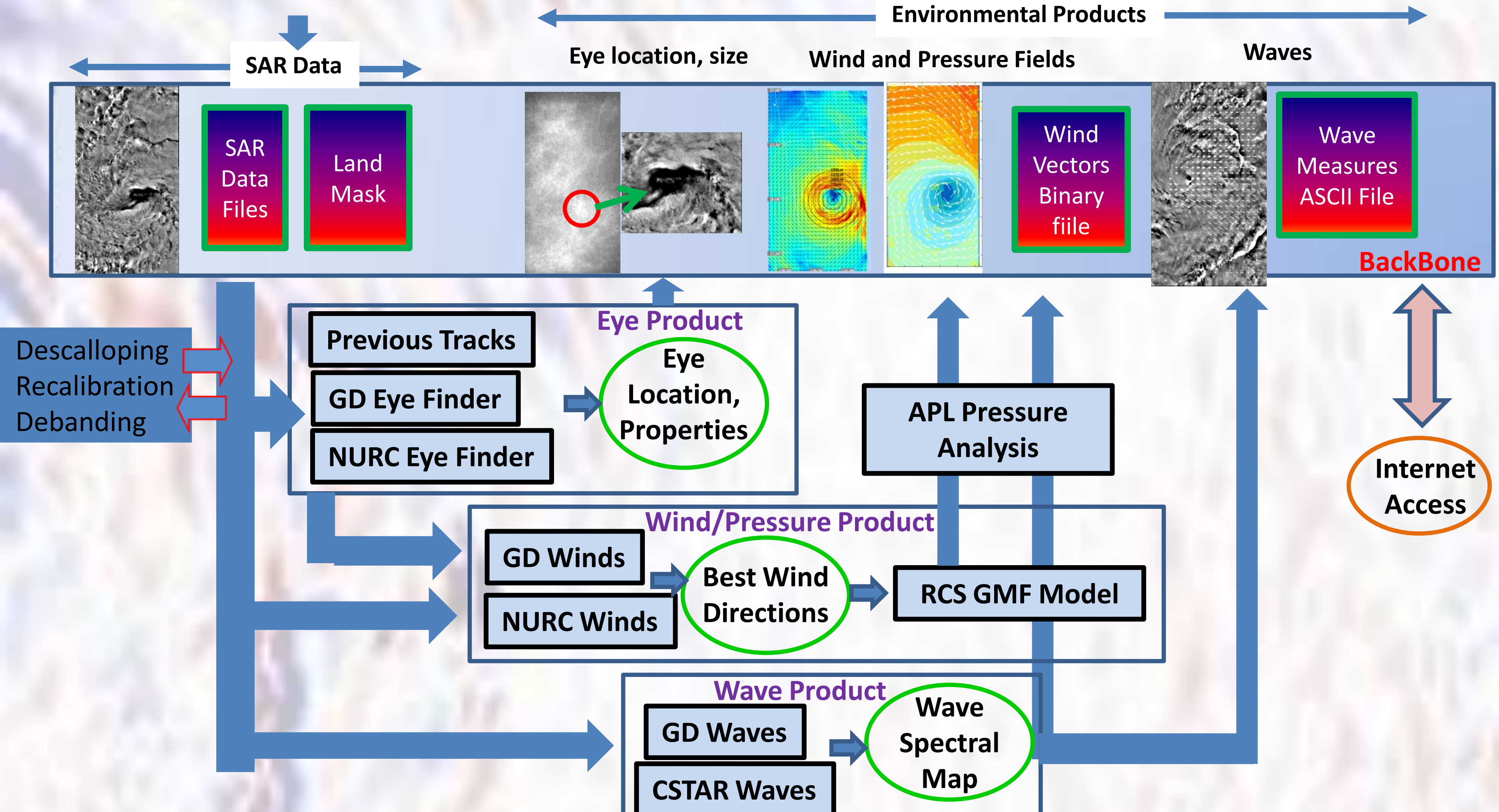
Extra Slides



SAR Typhoon Processing System (SARTyPS)

CSTARS SAR BackBone Processing System

Real-time SAR environmental product generation system being built at CSTARS to support field deployment

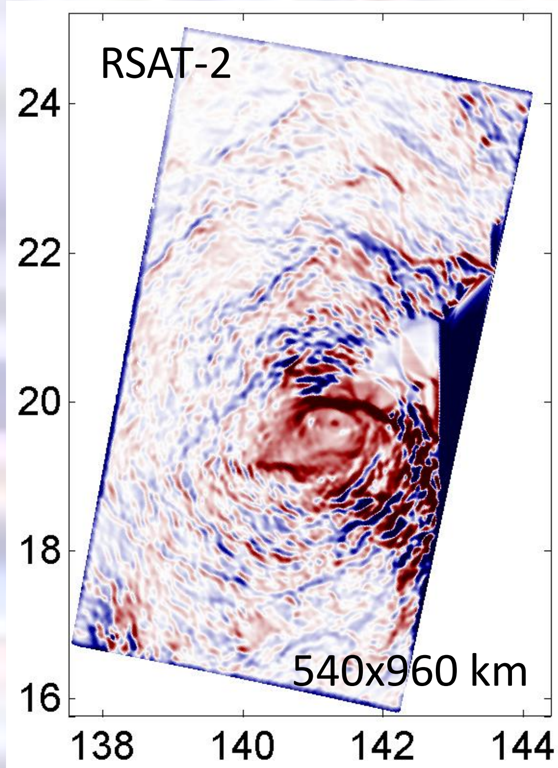


Tropical Cyclone SAR Working Group

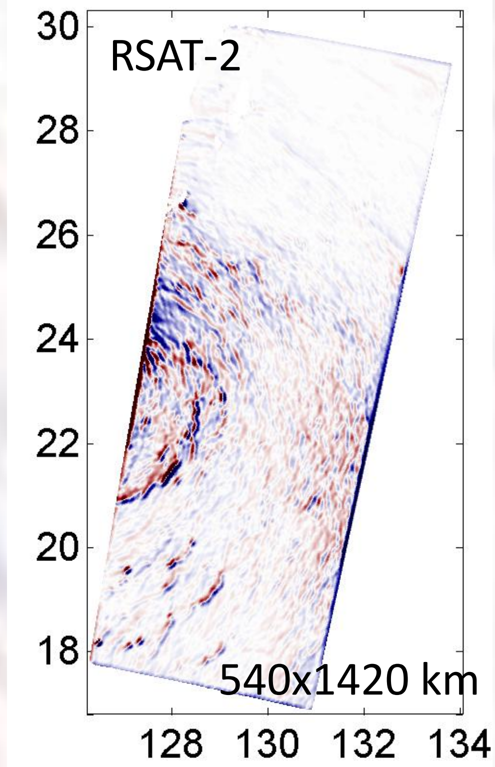
Dr. Hans Graber – CSTARS UoM; SAR Tasking, Processing
Mr. Mike Caruso – CSTARS UoM: SAR Tasking, Processing
Dr. Roland Romeiser – CSTARS UoM: Wave Estimation
Dr. Jochen Horstmann – NATO/NURC: Wind Estimation
Dr. Ralph Foster – APL/UW: Wind, Pressure Estimation
Dr. Chris Wackerman – GDAIS: Wind, Wave Estimation

Why Are SAR Wind Direction Estimates Pretty Good?

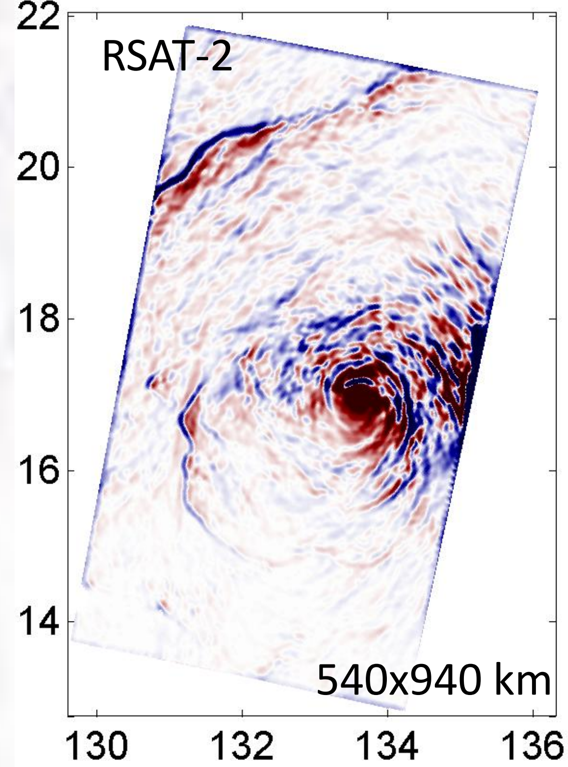
- SAR resolves PBL rolls at a variety of scales
  - Sub-km to multi-km wavelengths
- Rolls are approximately aligned with the mean surface wind
- Rolls are strong perturbation of mean surface wind



Malakas 22 Sep 2010



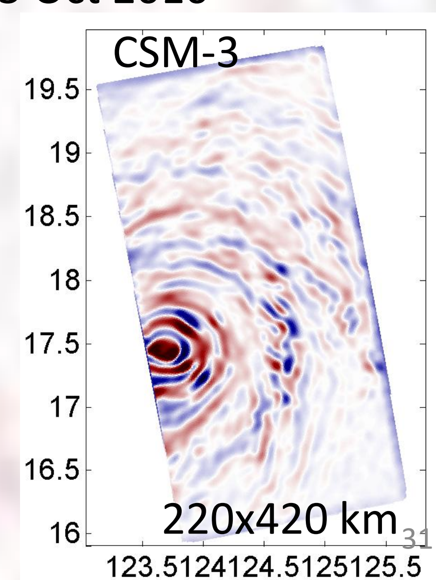
Fanapi 17 Sep 2010



Megi 15 Oct 2010

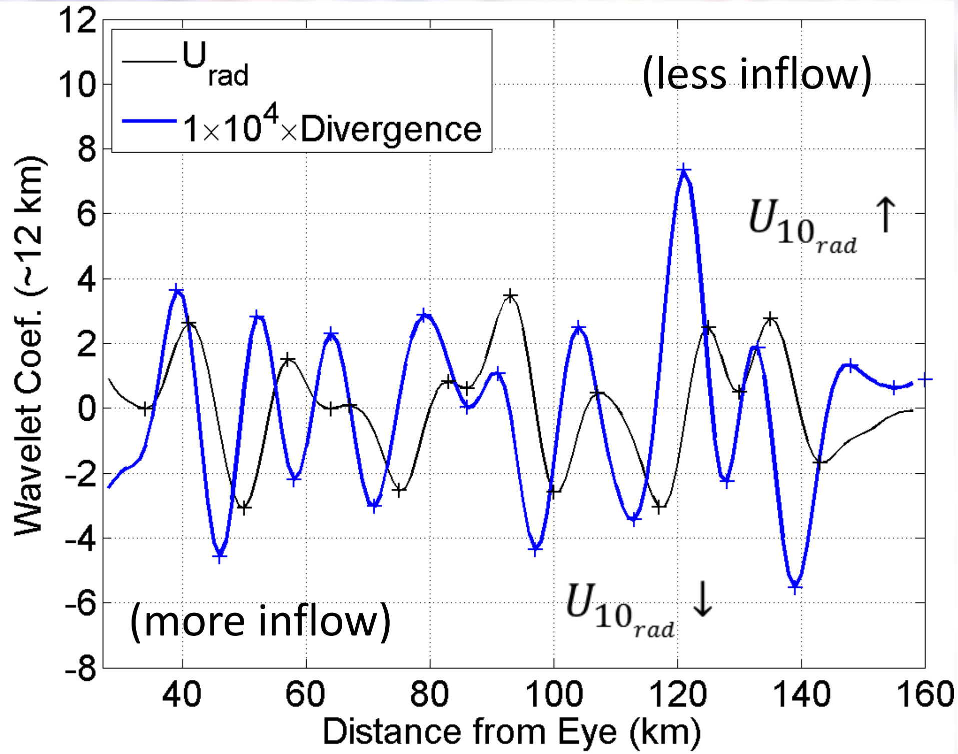
Kinematic Surface Wind Stress Curl

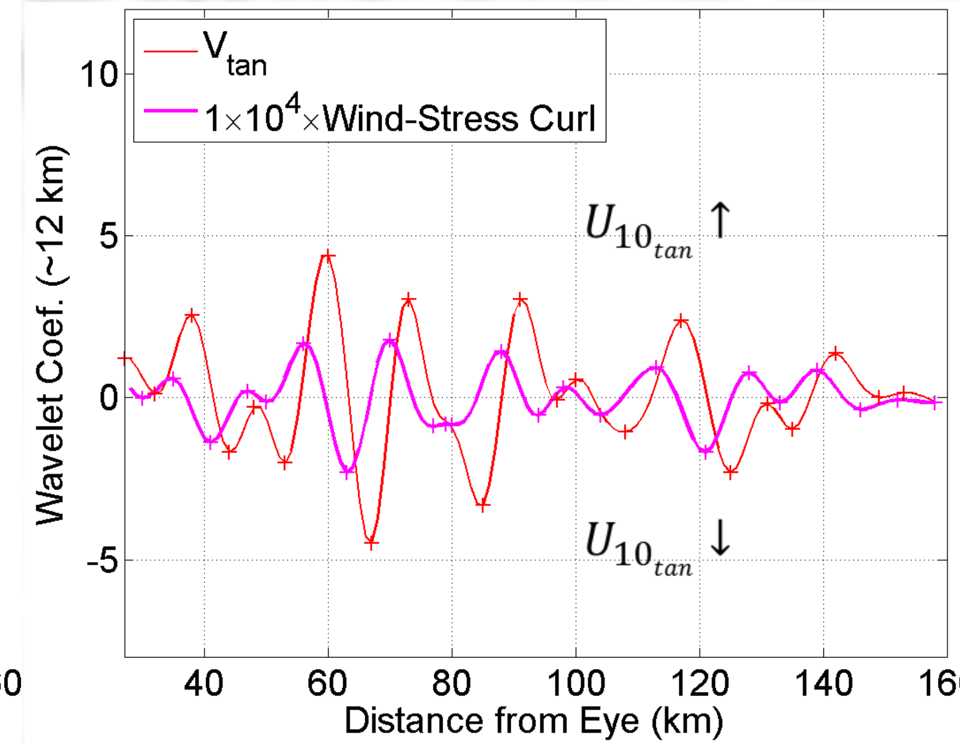
$\lambda \approx 10\ km$



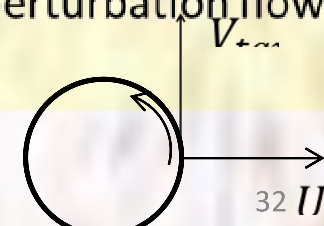
Megi 17 Oct 2010
(X-band)

Katrina 27

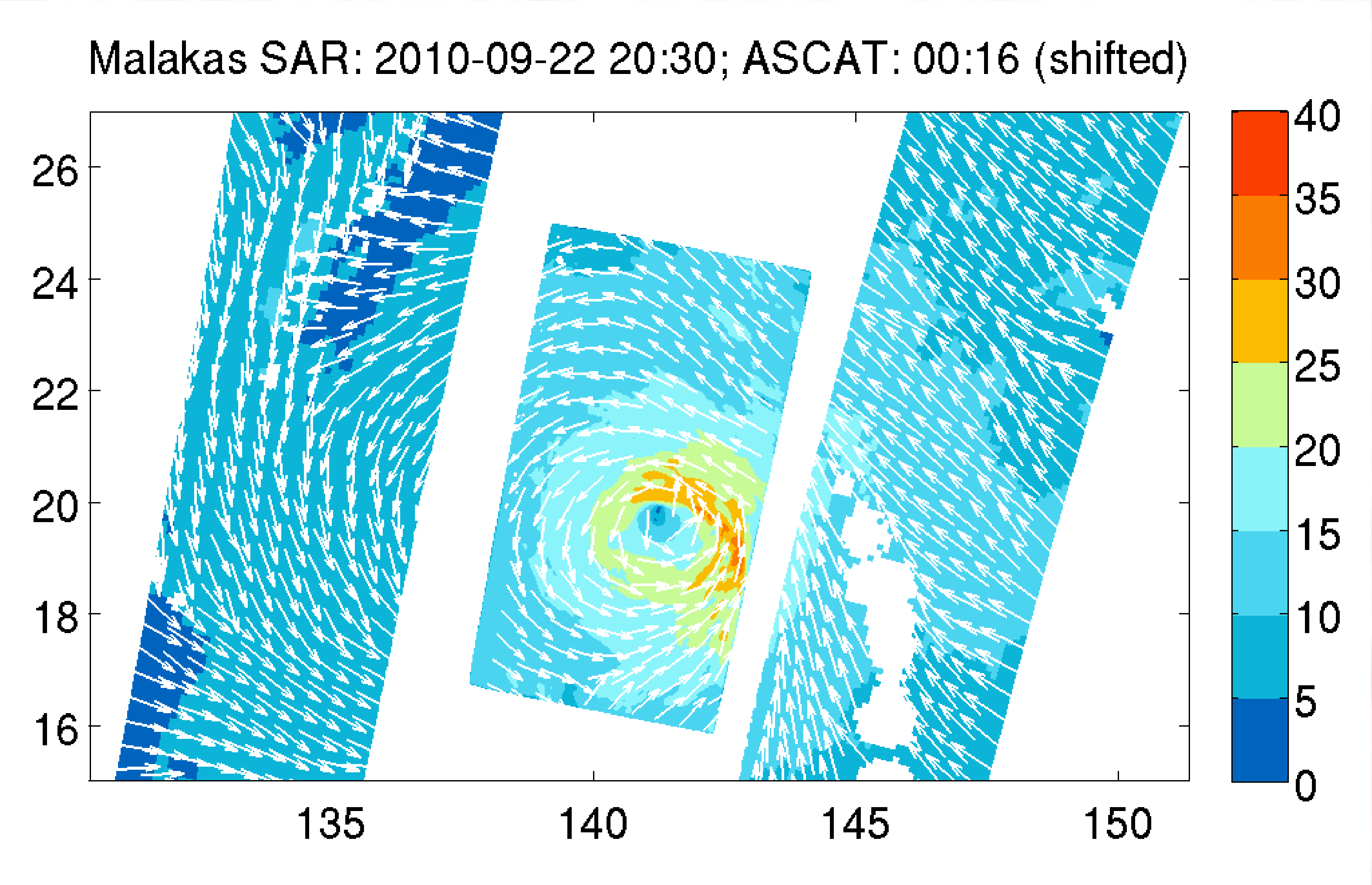




- ~10 km $(\nabla \cdot \boldsymbol{U})'$ approx. associated with enhancement and reduction of inflow
- ~10 km $(\nabla \times C_D|\boldsymbol{U}|\boldsymbol{U})'$ approx. associated with enhancement and reduction of azimuthal wind
- $(U_{rad}, V_{tan})'$ perturbations not aligned with each other
- OLE *not aligned* with azimuthal wind, so (U_{rad}, V_{tan}) not aligned with OLE perturbation flow.
  - Some of the stronger azimuthal wind aliased into radial wind



Consistency ASCAT vs. RSAT-2



ASCAT RSAT-2 ASCAT