(Brief update on) Near-Surface Inflow in Tropical Cyclones from Satellite Scatterometers

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Science Goal

- Understand the relationship between the near-surface inflow, upper-level outflow and Tropical Cyclone intensity
- 1st step: near-surface inflow from scatterometers
  - Neural Net wind *speeds*
  - Need directions

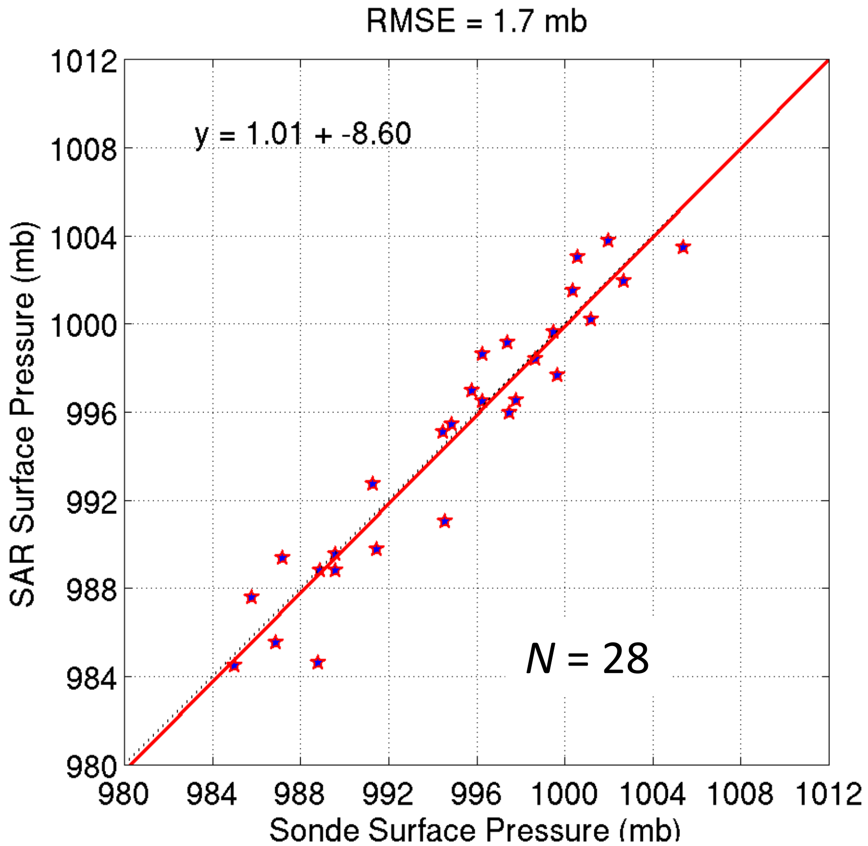
TC SLP Retrieval

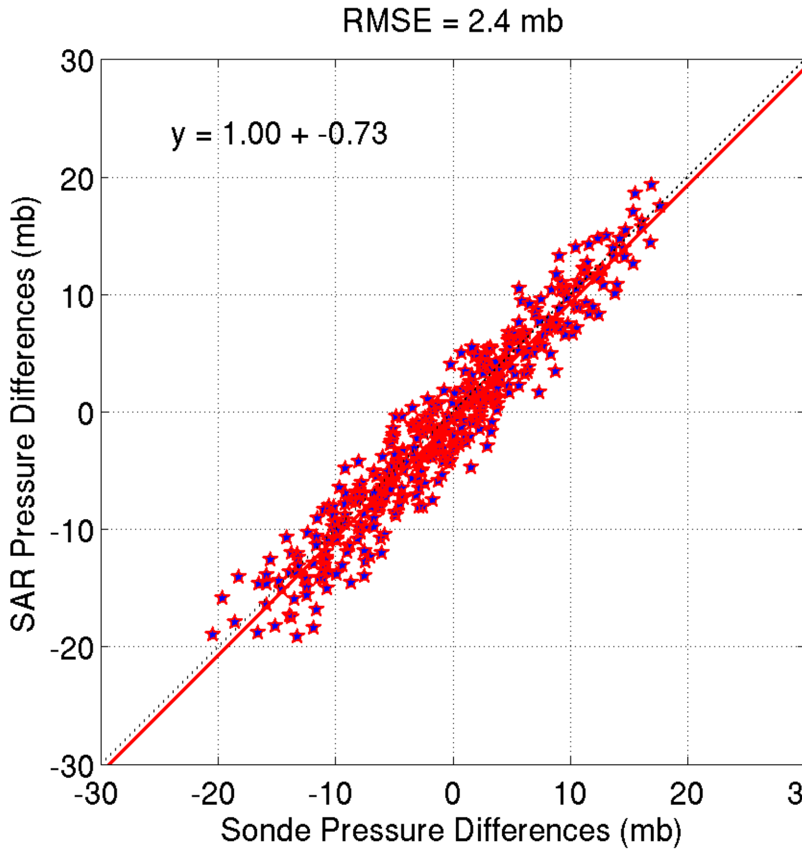
- New TCBL parameterization developed for 1km resolution SAR OVW retrievals
  - CBLAST-like Cd
  - Storm-relative nonlinear mean flow dynamics
  - Dynamic shallowing of TCBL due to vortex inertial stiffness
- Method developed for 1-km resolution SAR OVW
  - Transfer (back) to scatterometer (~12 km)

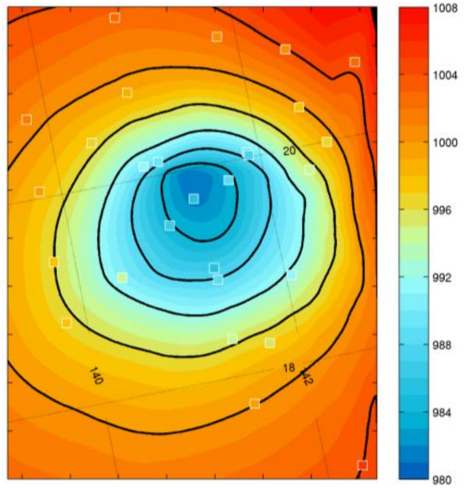
SAR TC Performance

- (Repeated from last meeting – breeze through)

Malakas 22 Sep: Drop Sonde Surface Pressure



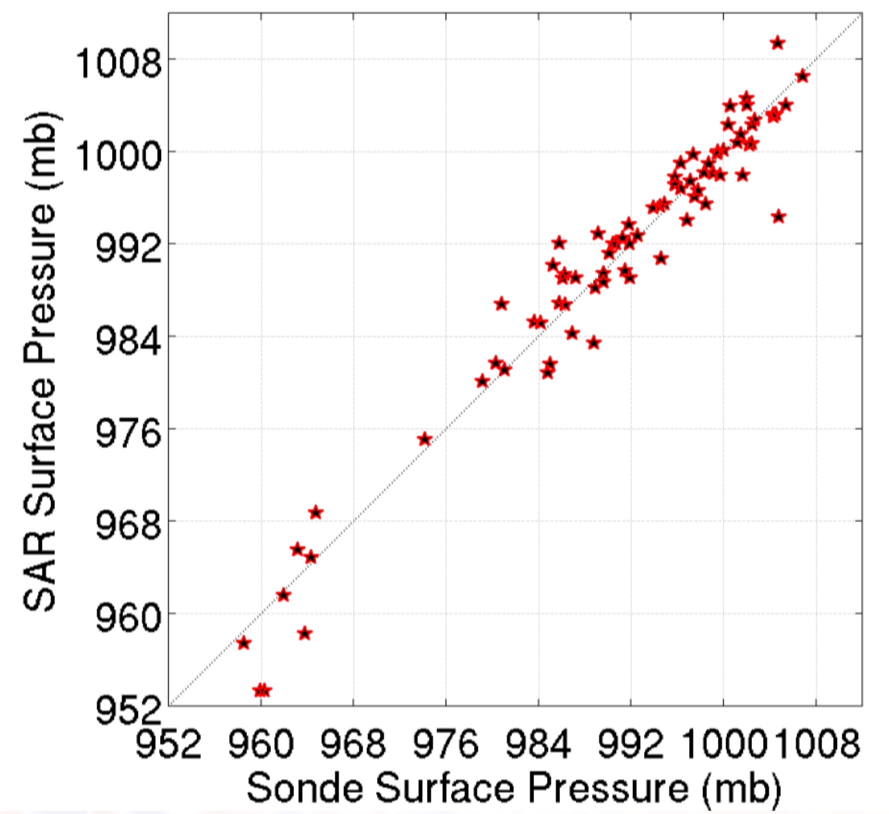


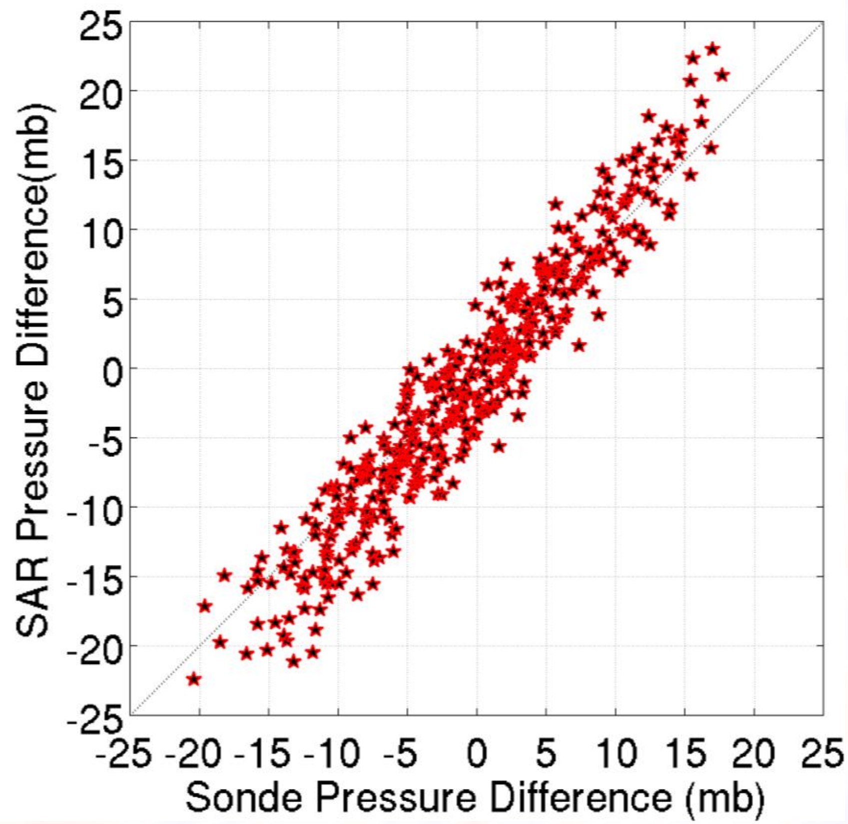


- $\frac{N(N-1)}{2} = 378$ pairs of sondes
- SLP pair-wise differences (PWD) give sense of SLP pressure shape retrieval

- SLP RMS < 2 mb
- SLP Pair-Wise Difference (PWD) RMS < 2.5 mb

Five SAR Scenes Compared to Drop Sonde Surface Pressure



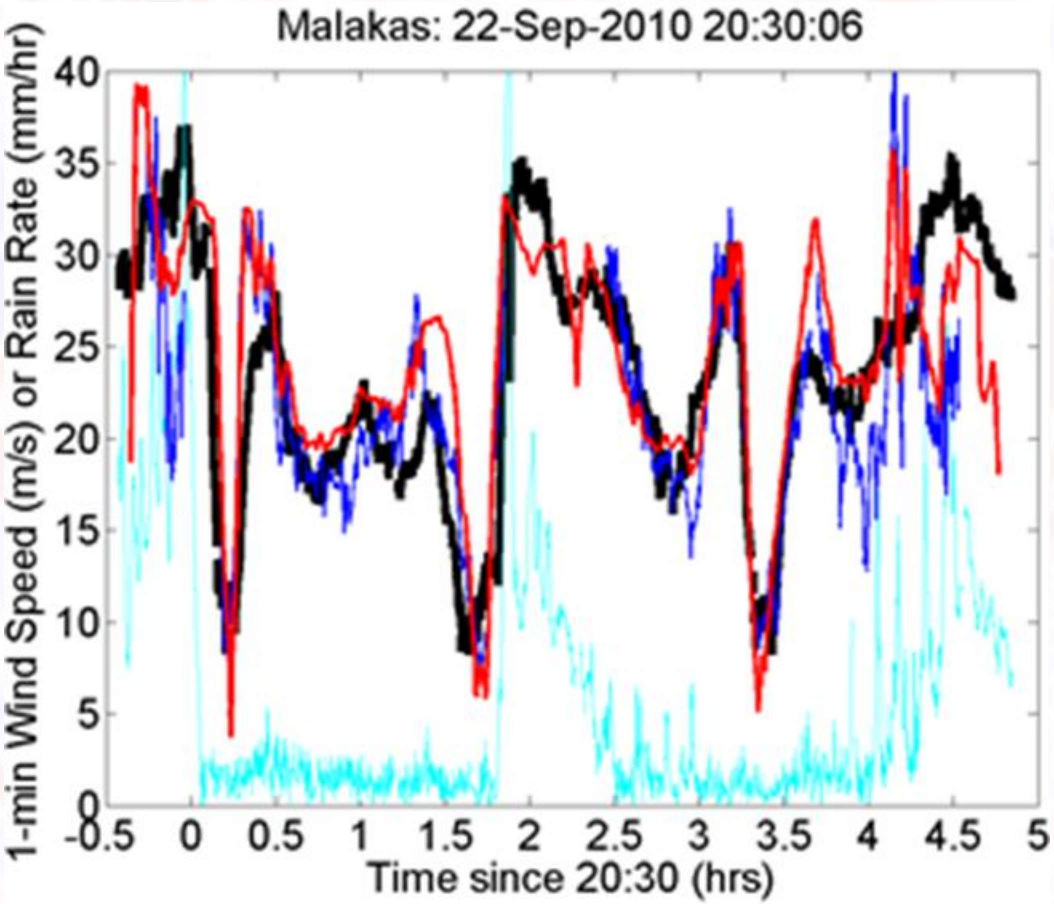


	SLP Bias (mb)	SLP RMS (mb)	PWD Bias (mb)	PWD RMS (mb)
SAR	0.1	2.8	0.6	2.9

Lili	30 Sep, 2002
Katrina	27 Aug, 2005
Helene	20 Sep, 2006
Ike	13 Sep, 2008
Malakas	22 Sep, 2010

- Overall ~3 mb RMS compared to drop sondes

Malakas 22 Sep, 2010 20:30: SFMR



Good Only N = 5,454	RMS (m/s)
RAW	3.4
SLP-Filter	3.4

Masked Only N = 4,427	RMS (m/s)
RAW	6.1 ← Not plotted
SLP-Filter	4.9

All Data N = 9,881	RMS (m/s)
RAW	7.8
SLP-Filter	4.2

Black: SFMR wind speed
Blue: RAW input wind (unmasked)
Red: SLP-filtered
Cyan: SFMR Rain Rate

- SLP-filtered and RAW winds are equal quality in good region
- SLP-filtered winds are better quality than RAW winds in masked region
- SLP-filtered winds have overall lower RMS

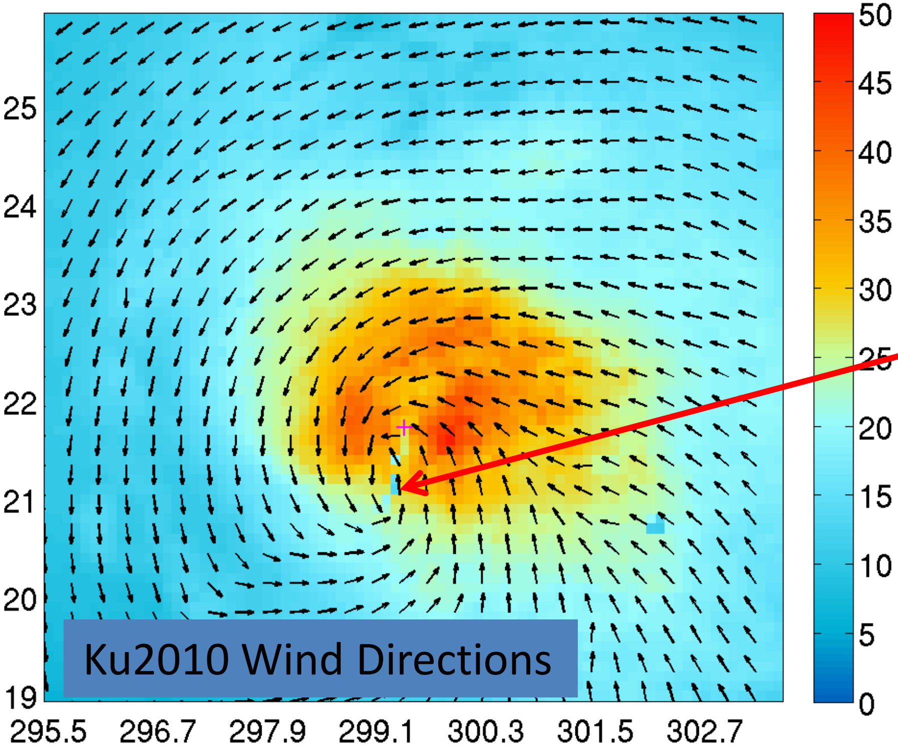
QuikSCAT/OSCAT/RapidSCAT Neural Net GMF

- Speed-only TC Geophysical Model Function
  - http://tropicalcyclone.jpl.sa.gov/hurricane/gemain.jsp
  - NN trained against 2005 H*WIND
    - Stiles BW, RE. Danielson, W. Lee Poulsen, M J. Brennan, S. Hristova-Veleva, T-P.J. Shen, and A. G. Fore: 2013: Optimized Tropical Cyclone Winds from QuikSCAT: A Neural Network Approach, *TGARRS*, (2013), Doi 10.1109/TGRS.2014.2312333
  - ~12.5 km pixels
- Scatterometer wind directions are bad in high rain rates
  - Iterate directions ***only*** for best agreement between scatterometer and drop sondes
  - Develop improved wind direction parameterization for NN winds
    - First guess:
      - Zhang, J. A., and E. W. Uhlhorn, 2012: Hurricane sea surface inflow angle and an observation-based parametric model. *Mon. Wea. Rev.*, **140**, 3587-3605

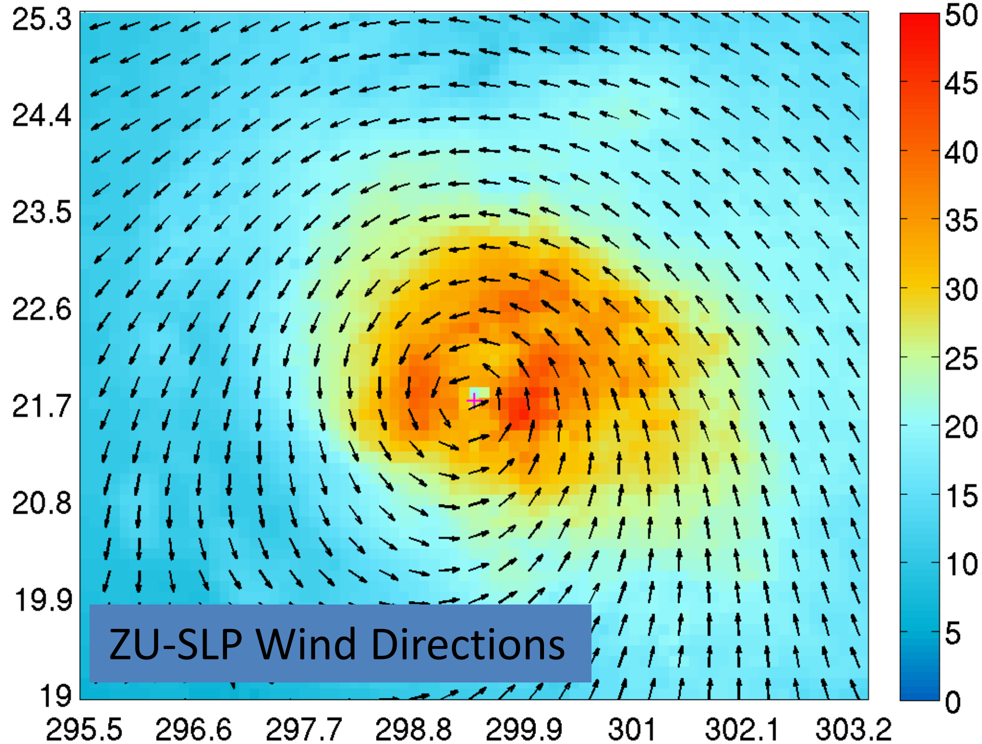
Year	Month	Day	Hour	Min	Name	Scatterometer	Flight	Approx. NHC Category
2003	9	13	9	39	Isabel	QuikSCAT	N42: 15:15 to 22:30	H4 (130 kt)
2004	8	30	9	40	Frances	QuikSCAT	N43: 13:20 to 22:45	H3 (100 kt)
2004	9	1	10	29	Frances	QuikSCAT	N43: 14:15 to 23:00	H4 (120 kt)
2004	9	7	9	31	Ivan	QuikSCAT	N43: 13:55 to 21:23	H2 (95 kt)
2004	9	9	10	20	Ivan	QuikSCAT	N43: 14:50 to 23:20	H4 (140 kt)
2004	9	12	10	45	Ivan	QuikSCAT	N43: 09:00 to 17:00; N42: 14:00 to 23:00	H4 (135 kt)
2005	8	25	11	4	Katrina	QuikSCAT	N43: 13:10 to 21:15	TS (55 kt)
2005	8	28	11	26	Katrina	QuikSCAT	N43: 16:21 to 01:40	H5 (145 kt)
2005	9	21	11	3	Rita	QuikSCAT	N43: 14:00 to 21:00	H4 (120 kt)
2005	9	23	11	53	Rita	QuikSCAT	N43: 13:13 to 22:12; N42: 15:30 to 23:37	H3 (115 kt)
2007	9	2	10	24	Felix	QuikSCAT	N43: 08:23 to 14:40; N42: 21:00 to 02:35	H2 (90 kt)
2008	8	31	11	20	Gustav	QuikSCAT	N43: 08:00 to 16:00	H3 (100 kt)
2009	8	20	9	45	Bill	QuikSCAT	N43: 07:41 to 14:47	H3 (105 kt)
2010	6	30	7	18	Alex	OSCAT	AF 306: 06:05 to 14:45	H1 (70 kt)
2010	8	27	16	44	Danielle	OSCAT	AF305: 13:23 to 20:40	H3 (115 kt)
2010	8	28	4	52	Danielle	OSCAT	AF305: 01:05 to 08:27	H2 (95 kt)
2010	8	31	5	36	Earl	OSCAT	N43: 20:00 (30) to 04:00	H3 (115 kt)
2010	9	1	17	35	Earl	OSCAT	N42: 08:00 to 16:00; N43 20:00 to 04:00	H3 (115 kt)
2010	9	2	5	42	Earl	OSCAT	N43: 20:00 (1) to 04:00; N42: 08:00 to 16:00	H4 (125 kt)
2010	9	18	4	36	Igor	OSCAT	AF309: 01:30 to 08:15	H2 (85 kt)
2010	9	18	16	45	Igor	OSCAT	AF309: 13:07 to 19:55	H1 (80 kt)
2010	9	16	18	28	Karl	OSCAT	N42: 15:00 to 23:50	H1 (70 kt)
2011	10	24	17	38	Rina	OSCAT	AF306: 14:16 to 21:49	H1 (65 kt)
2011	10	26	6	23	Rina	OSCAT	N42: 08:00 to 16:00	H3 (100 kt)

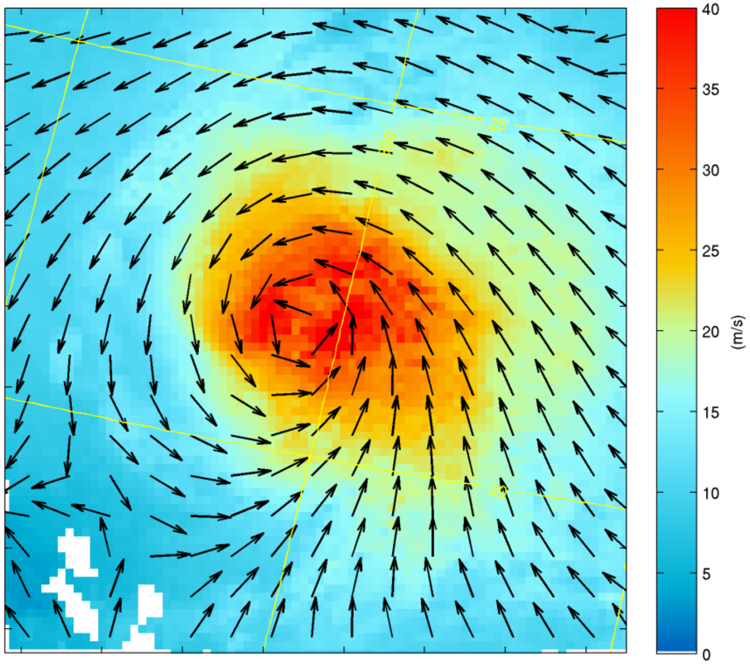
Scatterometer NN Co-locations with research flights

Hurricane Bill
20 Aug 2009, 09:45
QuikSCAT NN

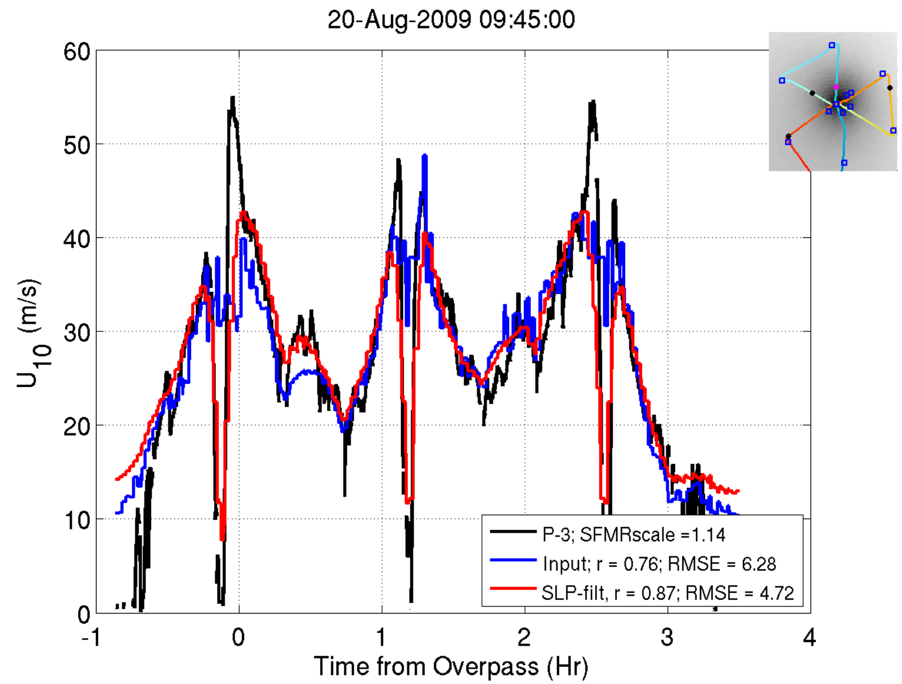


Note: “squared-off” vortex shape & misplaced storm center

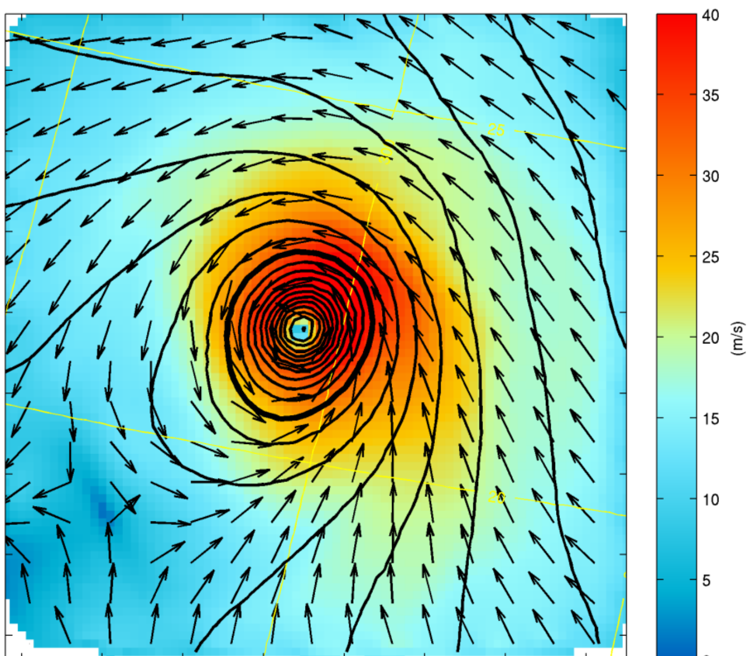




40
35
30
25
20
15
10
5
0
(m/s)
25



20-Aug-2009 09:45:00
U_{10} (m/s)
Time from Overpass (Hr)
P-3; SFMRscale =1.14
Input; r = 0.76; RMSE = 6.28
SLP-filt, r = 0.87; RMSE = 4.72



40
35
30
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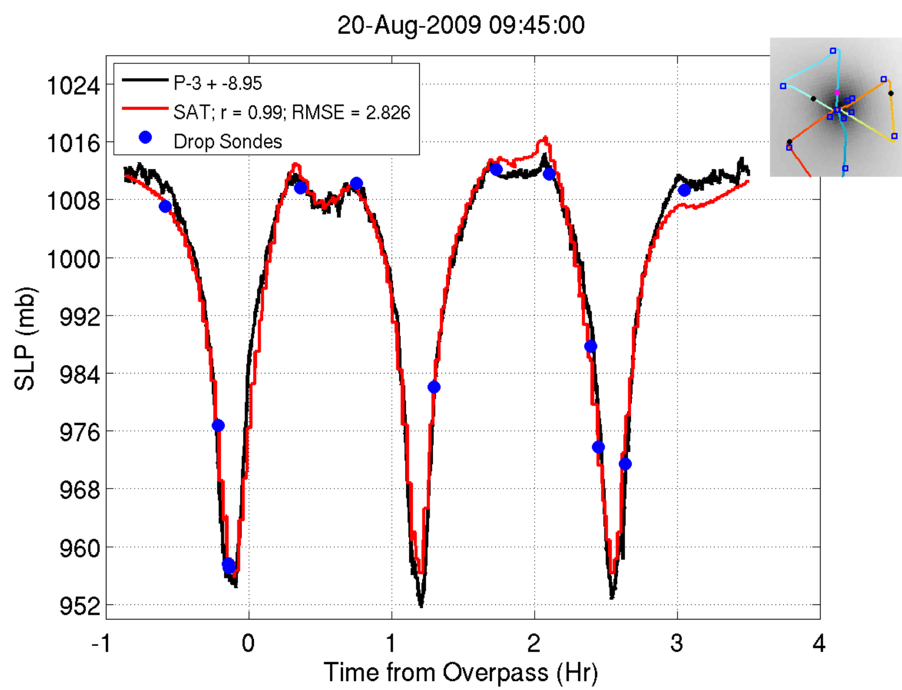
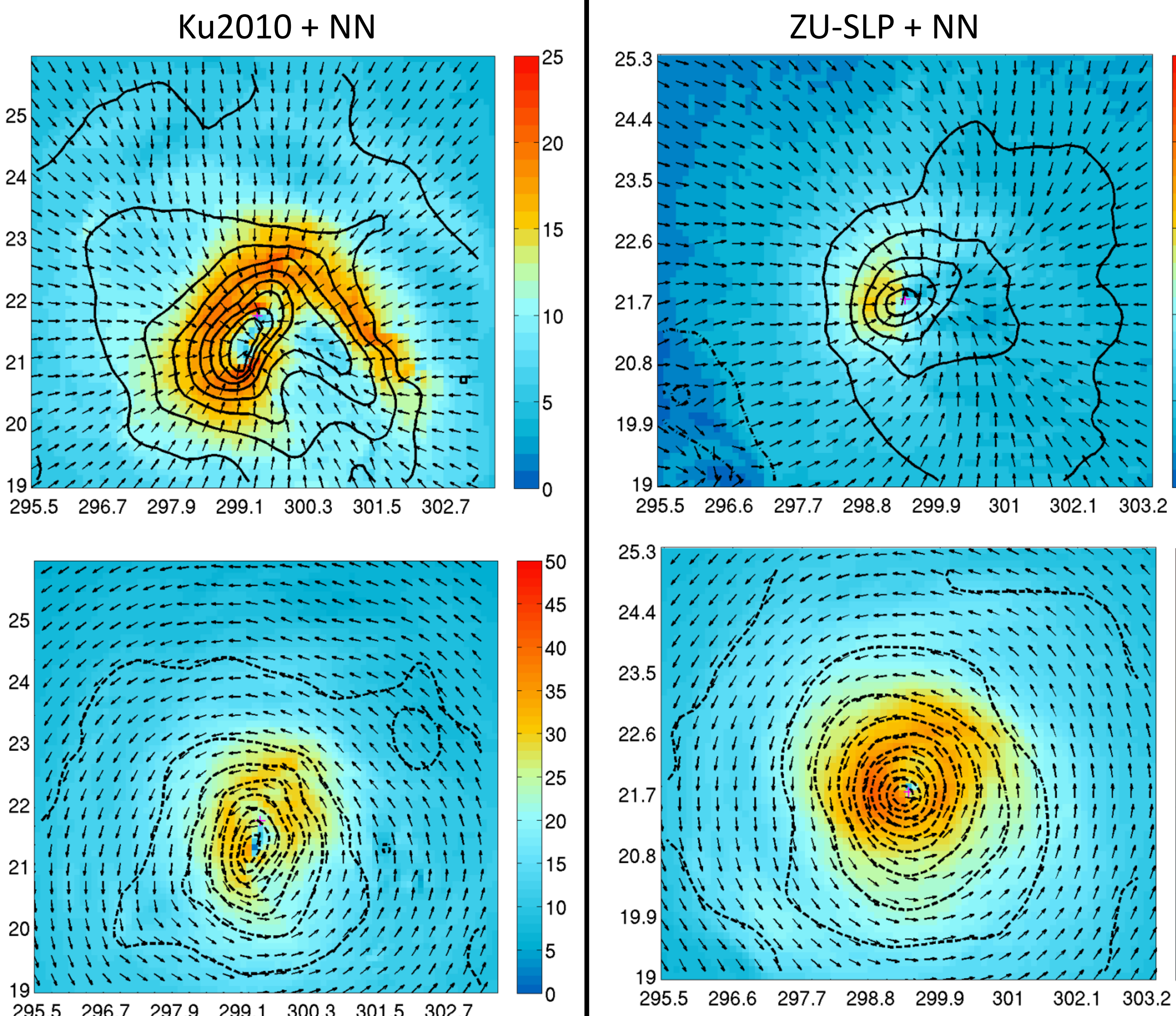
20
15
10
5
0
(m/s)
25



20-Aug-2009 09:45:00
SLP (mb)
Time from Overpass (Hr)
P-3 + -8.95
SAT; r = 0.99; RMSE = 2.826
Drop Sondes

Wind Direction Assumption (All use QSNN speed)	SFMR (SLP-filtered) ($m\ s^{-1}$)	P-3 Flight-Level SLP Calculation (mb)	Sonde SLP (mb)	Sonde SLP pair-wise pressure differences (mb)
Ku2010	6.2	10.0	8.6	12.2
H*WIND	4.9	3.4	4.3	6.0
Zhang-Uhlhorn	4.9	3.1	4.7	6.7
SLP-filter Directions	**4.7**	**2.8**	**3.5**	**5.0**

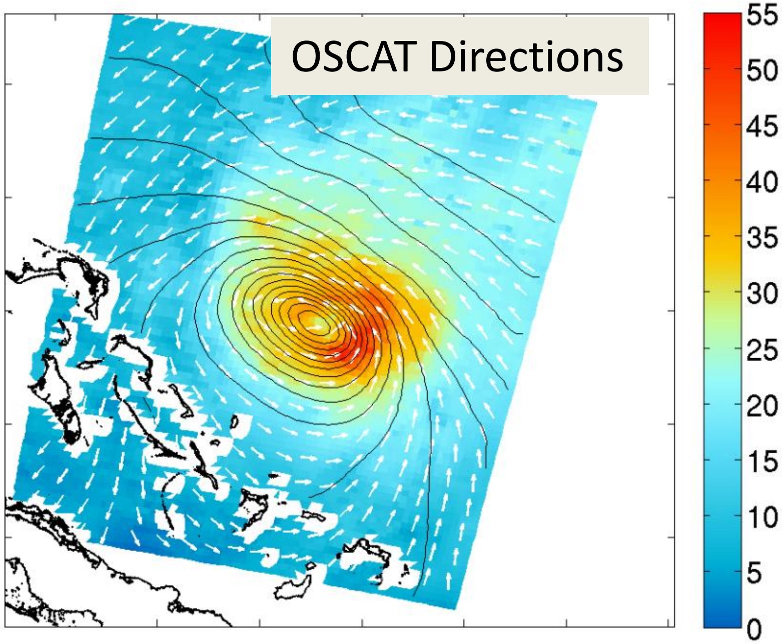


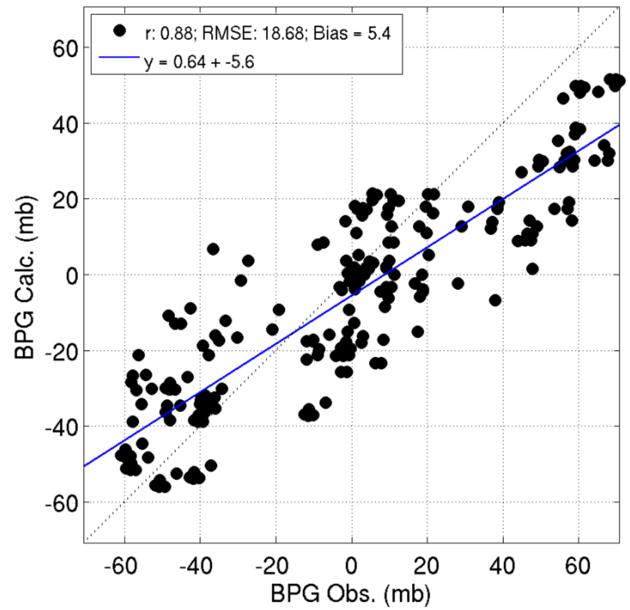
Irrotational Flow (Lower branch of the Secondary Circulation)

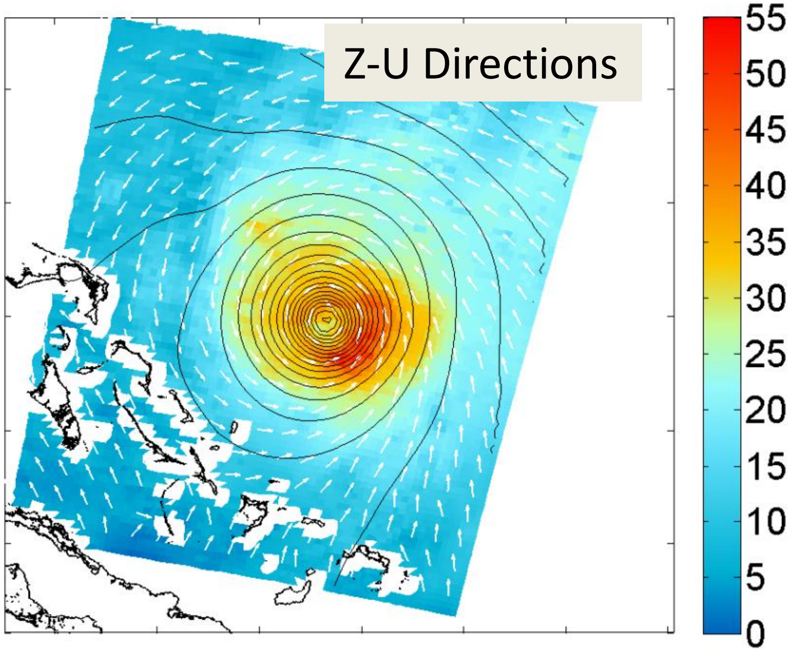
Nondivergent Flow (Surface imprint of the Primary circulation)

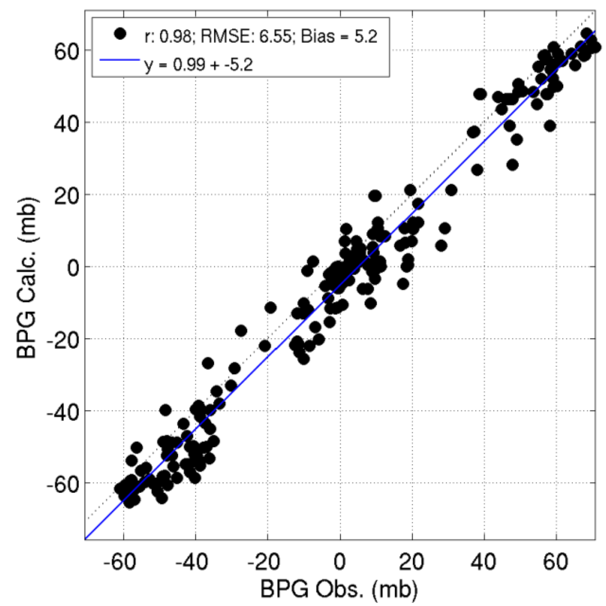
Bishop, C H., 1996: Domain-Independent Attribution. Part I: Reconstructing the Wind from Estimates of Vorticity and Divergence Using Free Space Green's Functions. *J. Atmos. Sci.*, **53**, 241–252.

Hurricane Earl, 1 Sep, 2010





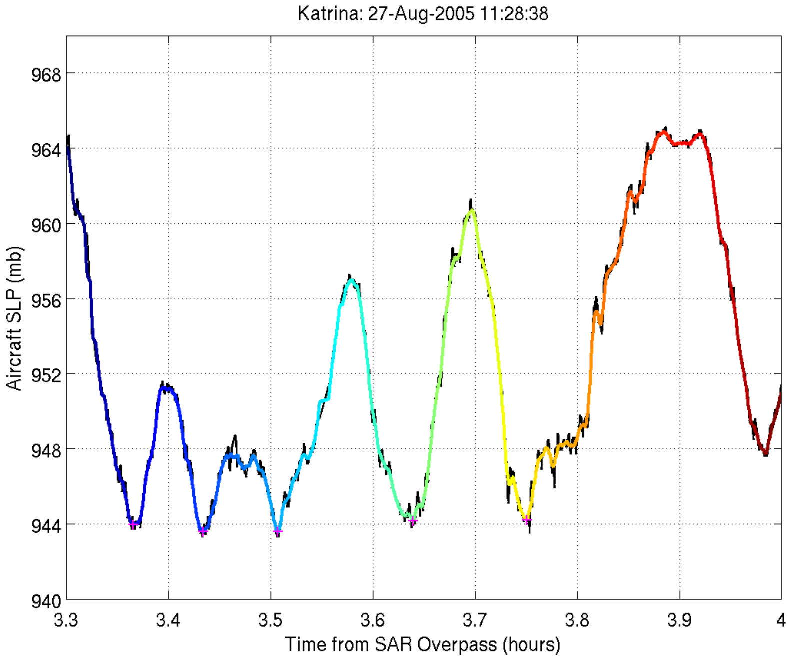


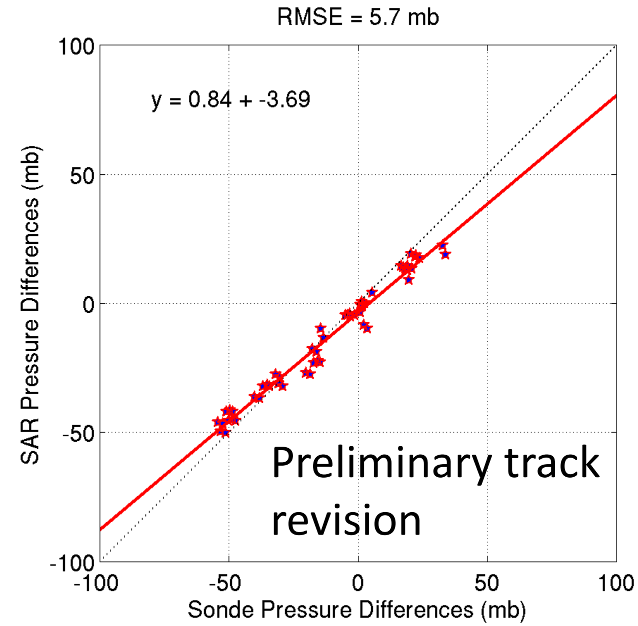


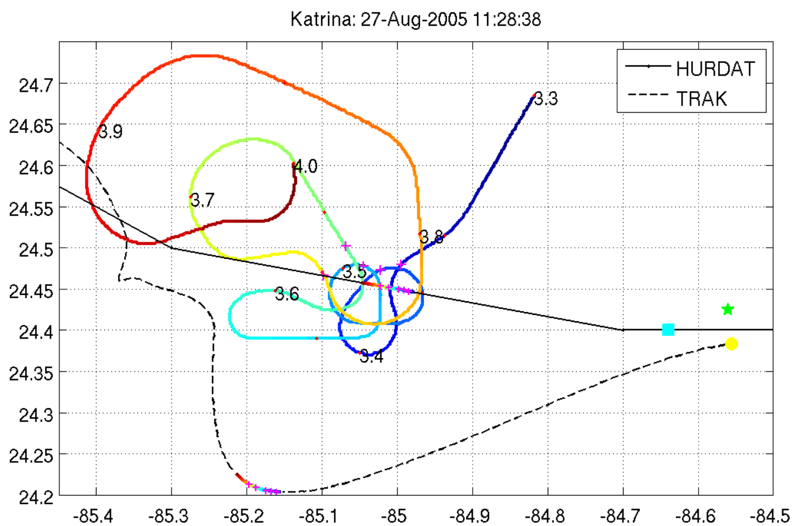
Preliminary navigation of drop sondes

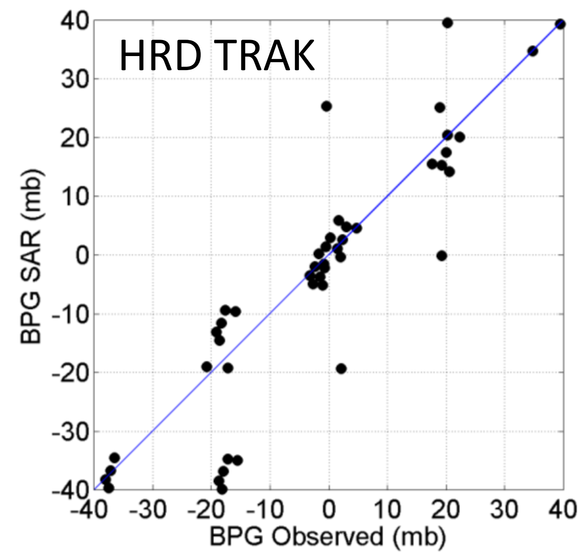
Location mapping to overpass is a significant contribution to RMS

Katrina 27 August



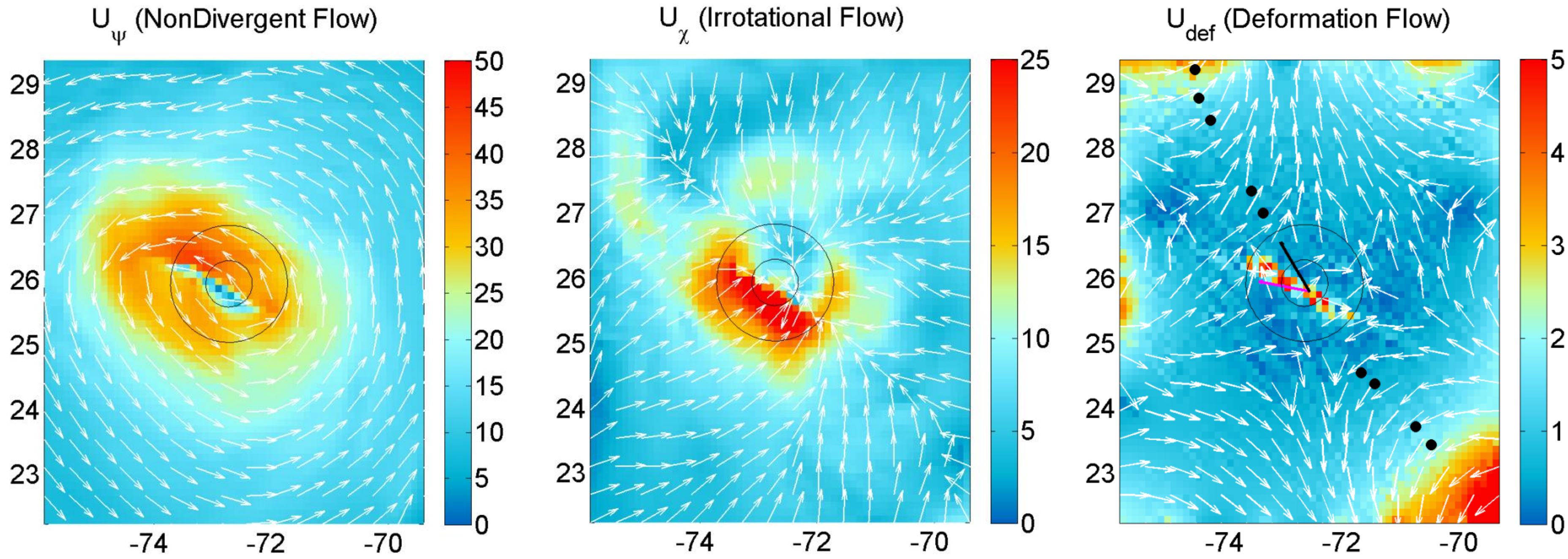




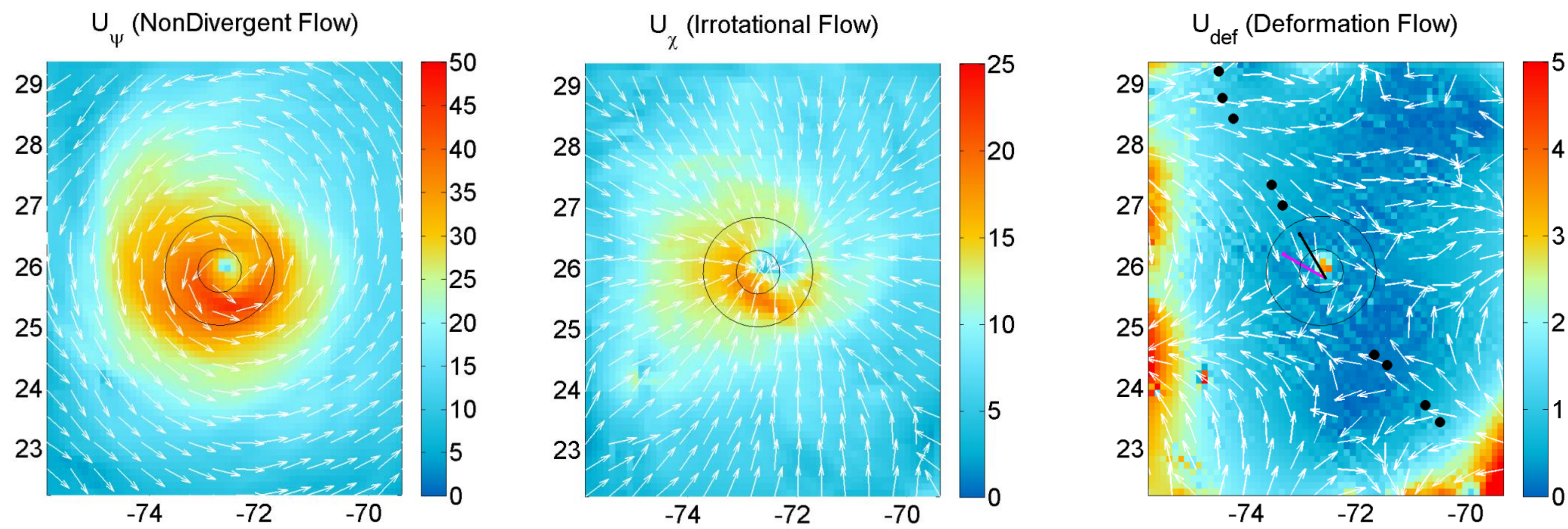


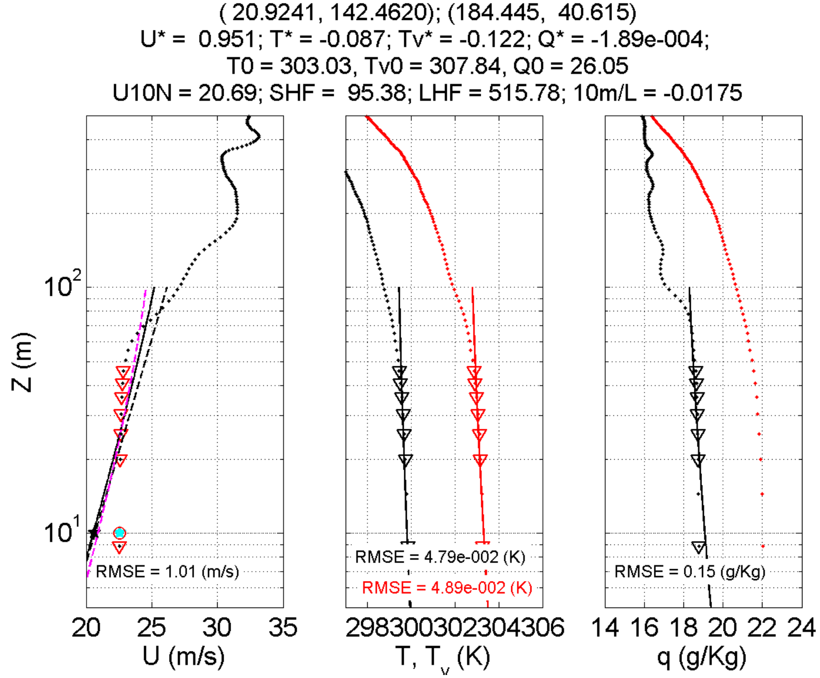
OSCAT Directions

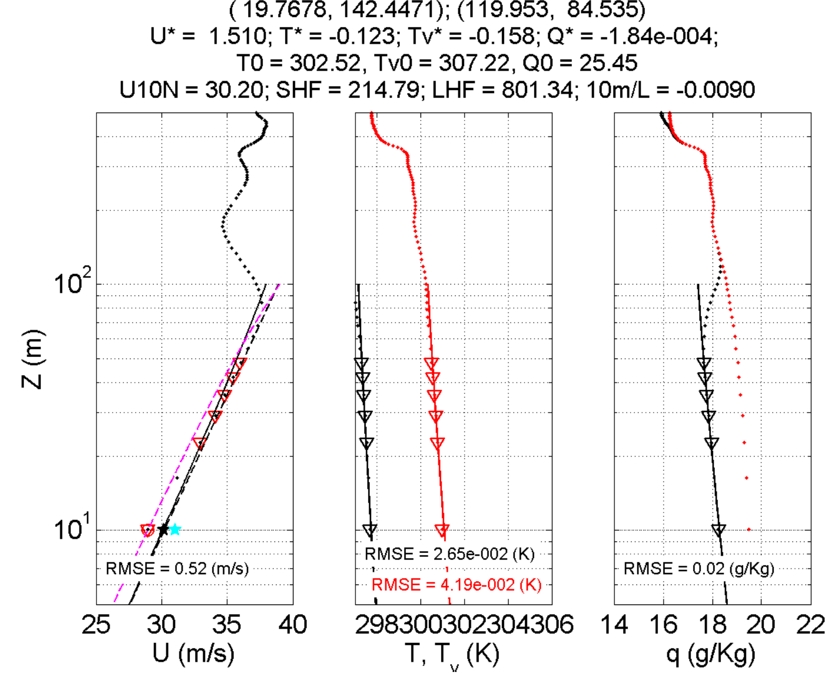
Hurricane Earl, 1 Sep, 2010

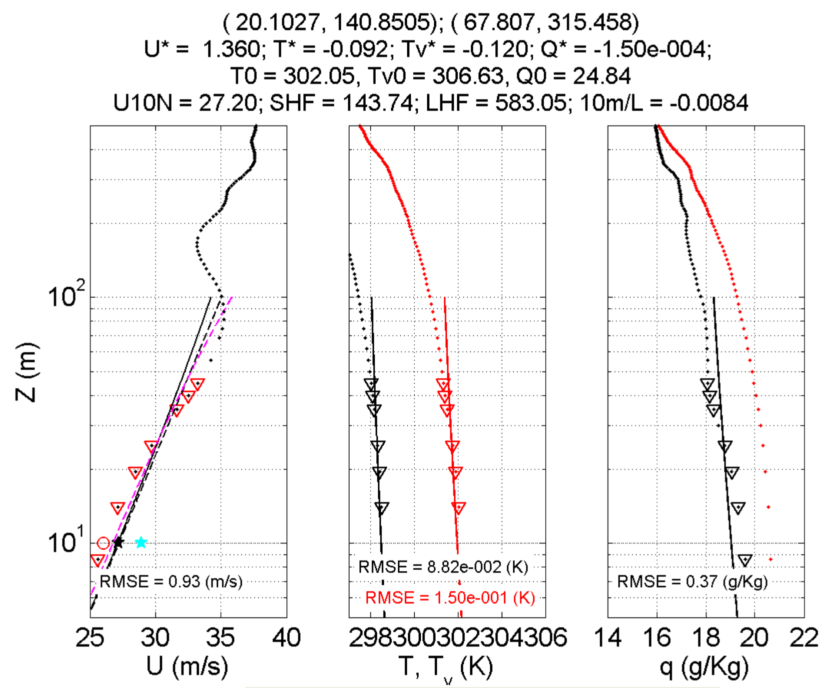


ZU Directions

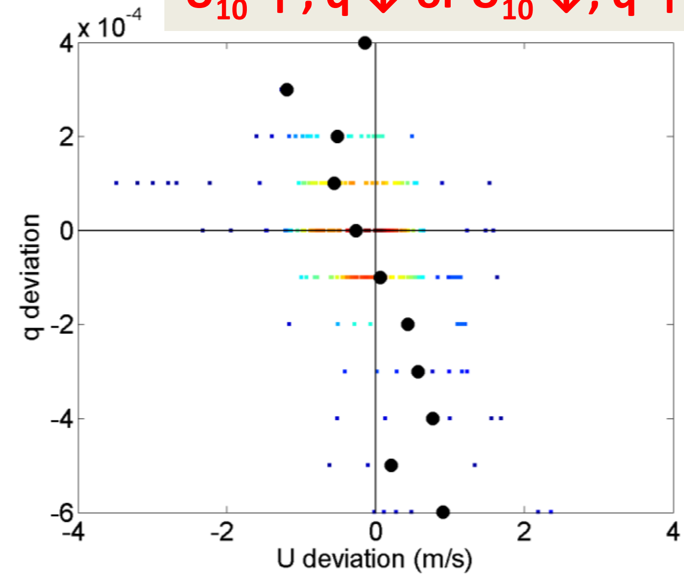








Overturning Roll Signature:
U_{10} ↑, q ↓ or U_{10} ↓, q ↑



T always follows MOS

Summary

- Given accurate wind directions, accurate SLP patterns can be derived from TC NN wind speeds
  - Use collocations to develop inflow angle parameterization
- Correct location of in situ data is crucial
- Flow partitioning extracts surface signature of TC secondary circulation
- Deformation “col” location may help identify TC surface circulation center

Major Focus

- Developing “research-quality” tracks for collocations
  - ARCHER & aircraft fixes
- Evaluate existing methods, and, continue developing new method for extracting surface layer properties from drop sondes
- Ensure collocated SFMR is latest processing
- Continued evaluation & improvement of TCBL model
- Set up wind direction optimization code