SMAP Observations of Extreme Ocean Winds

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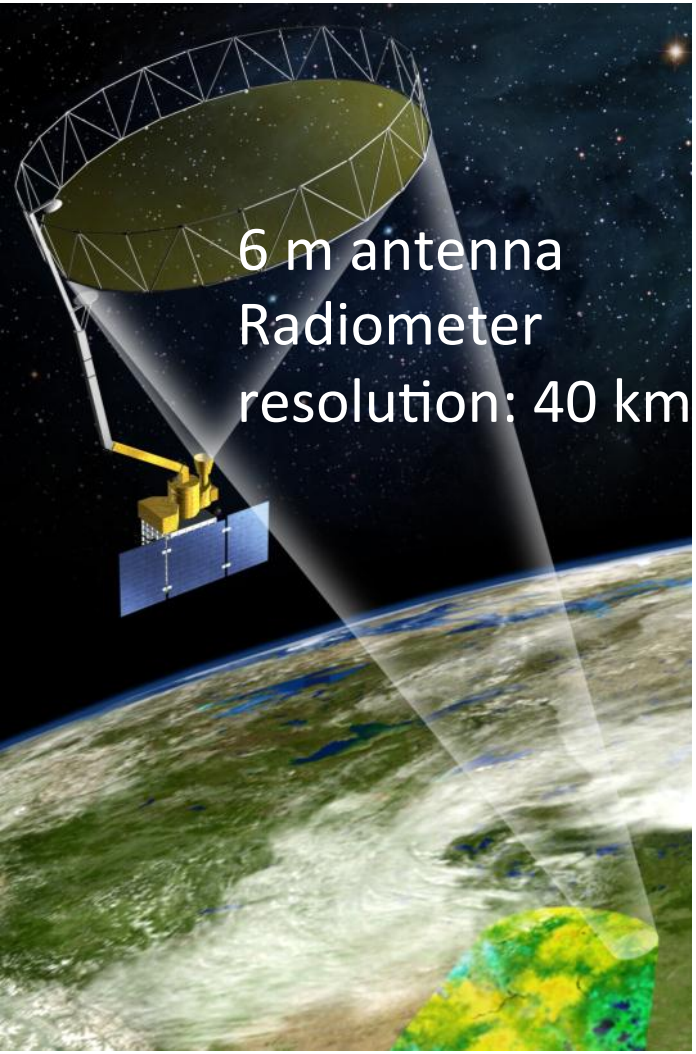
SMAP Overview



http://smap.jpl.nasa.gov/

Primary Science Objectives

- Global, high-resolution mapping of soil moisture and its freeze/thaw state to
  - Link terrestrial water, energy, and carbon-cycle processes
  - Estimate global water and energy fluxes at the land surface
  - Quantify net carbon flux in boreal landscapes
  - Extend weather and climate forecast skill
  - Develop improved flood and drought prediction capability

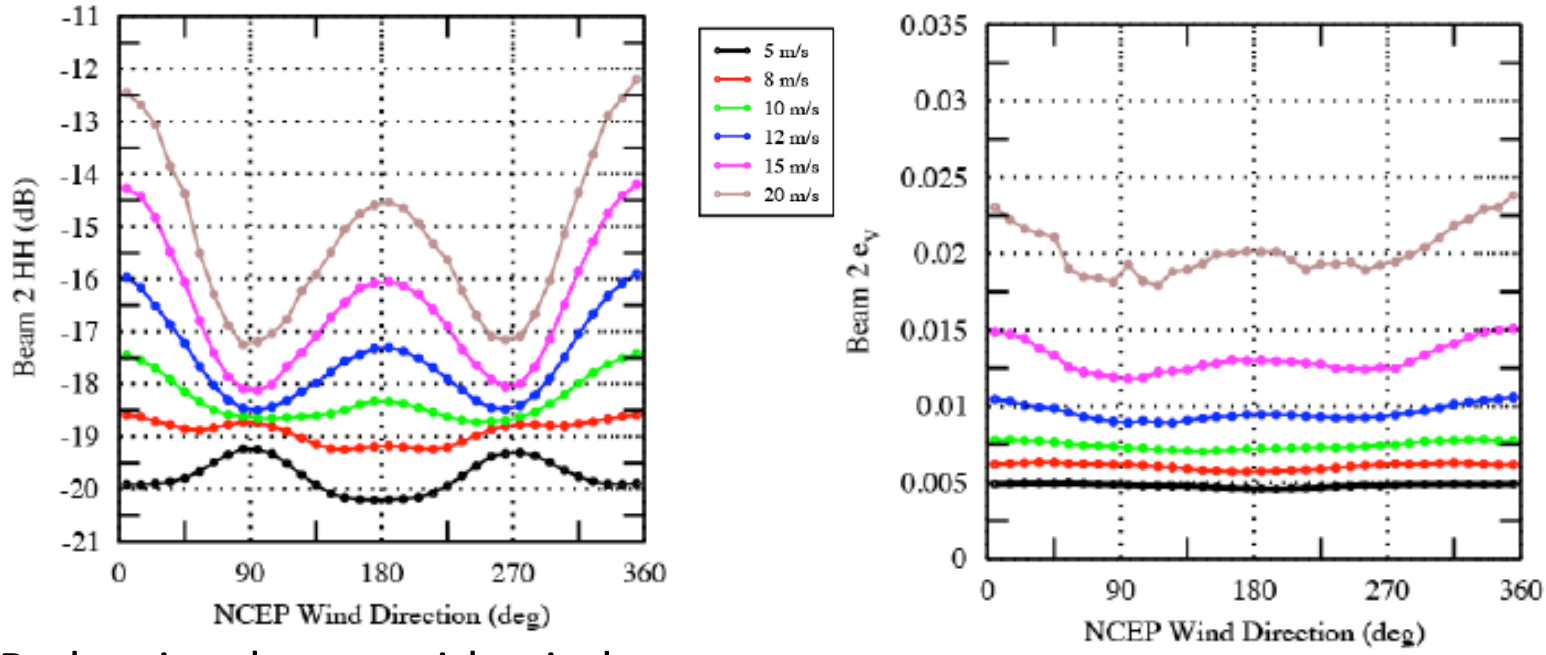
Mission Implementation

Partners	• JPL (project & payload management, science, spacecraft, radar, mission operations, science processing) • GSFC (science, radiometer, science processing)
Launch	• January 31, 2015 on Delta 7320-10C Launch System
Orbit	• Polar Sun-synchronous; 685 km altitude
Duration	• 3 years
Payload	• L-band (non-imaging) synthetic aperture radar (JPL) • L-band radiometer (GSFC) • Shared 6-m rotating (13 to 14.6 rpm) antenna (JPL)

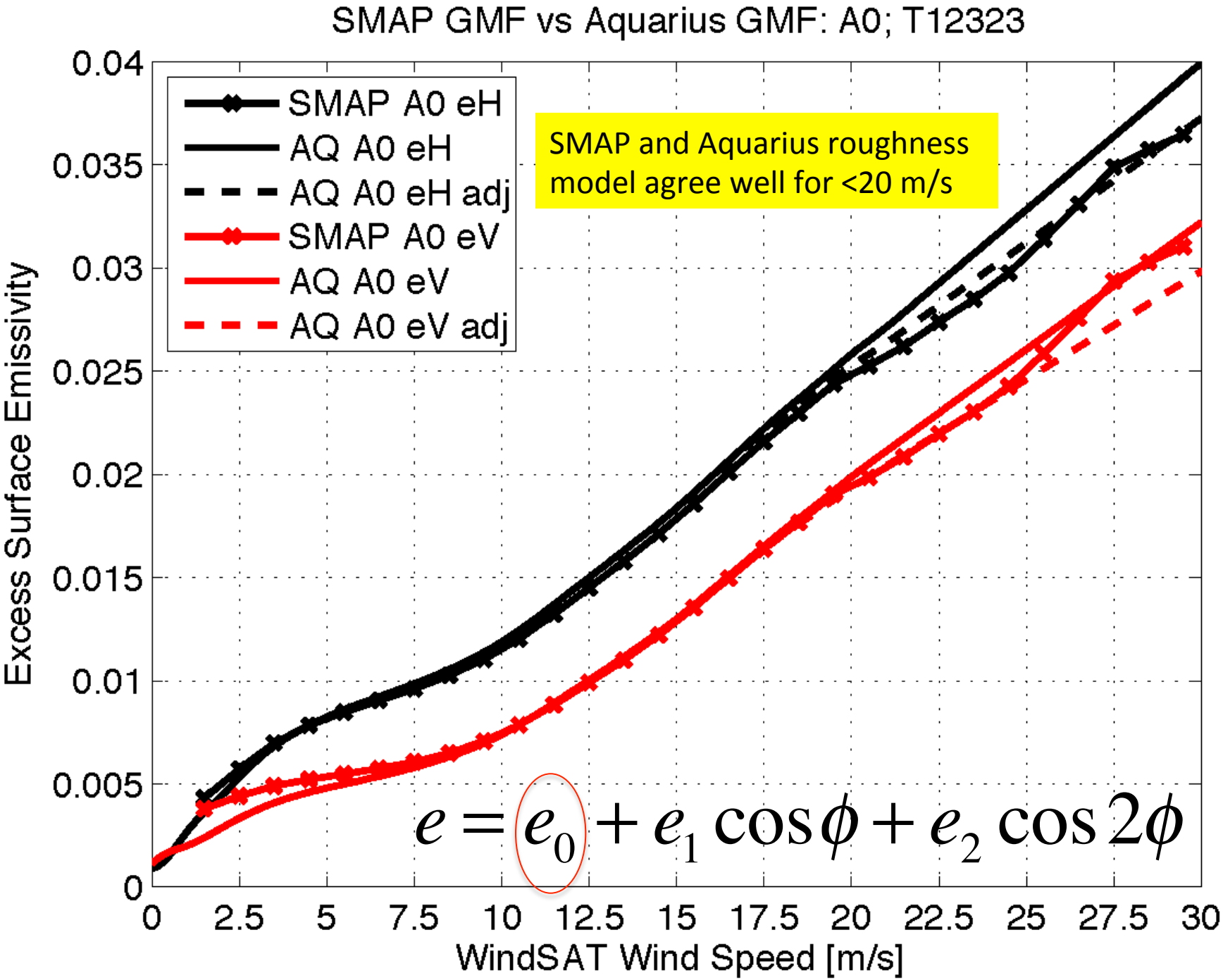
NRC Earth Science Decadal Survey (2007) recommended SMAP as a Tier 1 mission

Effects of Wind/Wave on Radar and Radiometer Signals Observed by Aquarius

- The matchup of Aquarius data with NCEP wind direction, SSMIS wind speed indicates impact of ocean wind on radar and radiometer signals.
  - The charts below indicate the signal sensitivity for the data from Aquarius beam# 2 (~39 deg incidence angle)



- Radar signals vary with wind speed and wind direction
  - Cosine signal changes sign at about 8 m/s
- Radio emissivity (TB/Ts) varies with wind speed and wind direction


SMAP GMF vs Aquarius GMF: A0; T12323
SMAP A0 eH
AQ A0 eH
AQ A0 eH adj
SMAP A0 eV
AQ A0 eV
AQ A0 eV adj
SMAP and Aquarius roughness model agree well for <20 m/s
$e = e_0 + e_1 \cos\phi + e_2 \cos 2\phi$
Excess Surface Emissivity
WindSAT Wind Speed [m/s]
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30

Radiometer TB SSS and Wind Processing

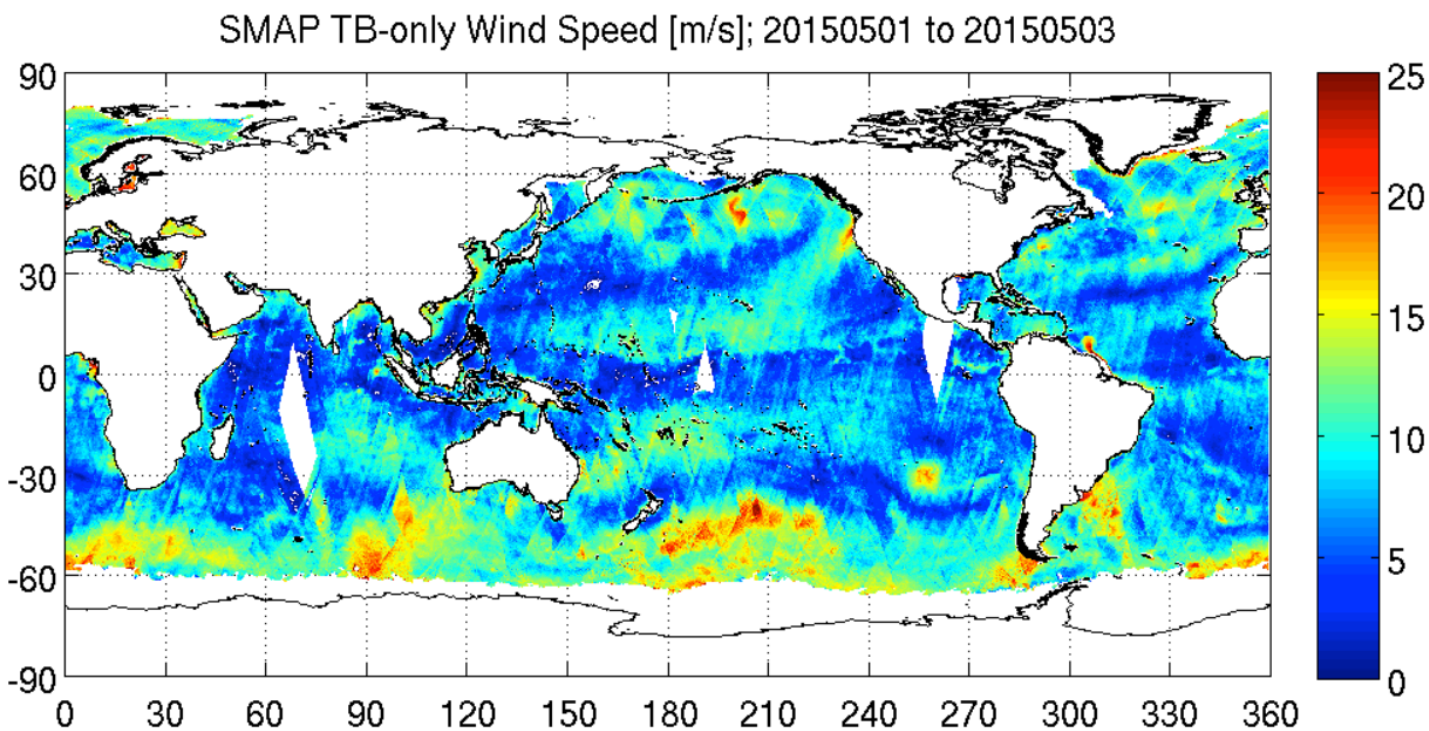
- Compute delta TB using ancillary data and model
  - Average over each day; use 8 day median filtered value
  - Decimated by fore/aft x asc/dec
- Grid into a 25 km L2A swath grid a la RapidSCAT
  - Gridding method oversamples observations onto the grid.
  - Effective resolution is somewhat larger than 40 km
- Estimate wind speed and salinity using constrained objective function minimization

$$F(spd, sss) = \sum_i \left[\frac{T_{B,i} - T_{B,i}^m \left(spd, sss, anc_dir, anc_swh, anc_sst \right)}{NEDT_i} \right]^2 + \left(\frac{spd - spd_anc}{1.5 m/s} \right)^2,$$

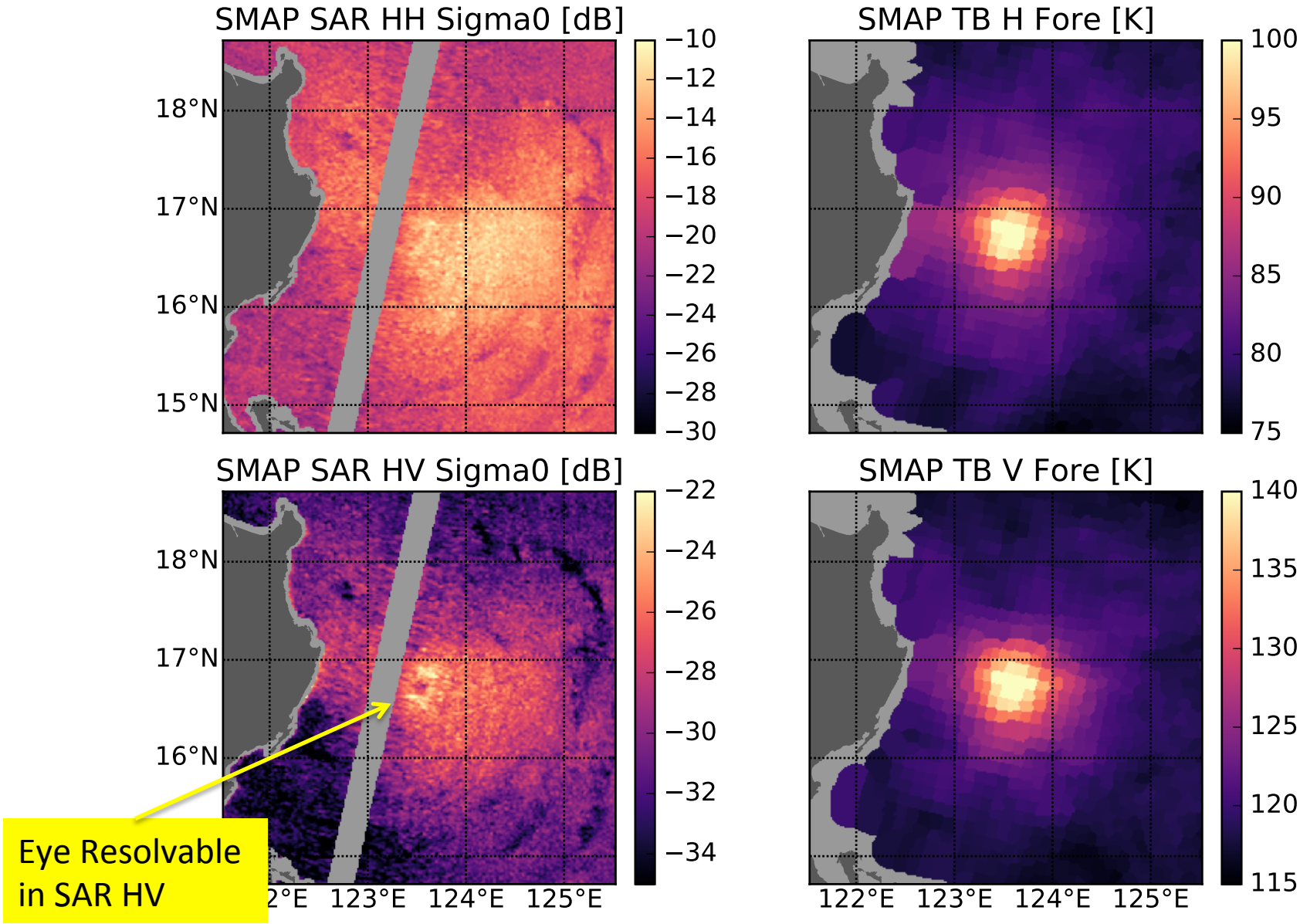
SMAP L-band Radiometer Data For Severe Weather – Ocean Vector Wind

- L-band brightness temperature useful for hurricane wind speed retrieval using two looks, dual-pol TB
- Using HYCOM SSS as ancillary

$$C(w,\phi) = \sum_{i=1}^{2} \frac{(T_{BVi} - T_{BVMi})^2}{\Delta T^2} + \sum_{i=1}^{2} \frac{(T_{BHi} - T_{BHMi})^2}{\Delta T^2}$$

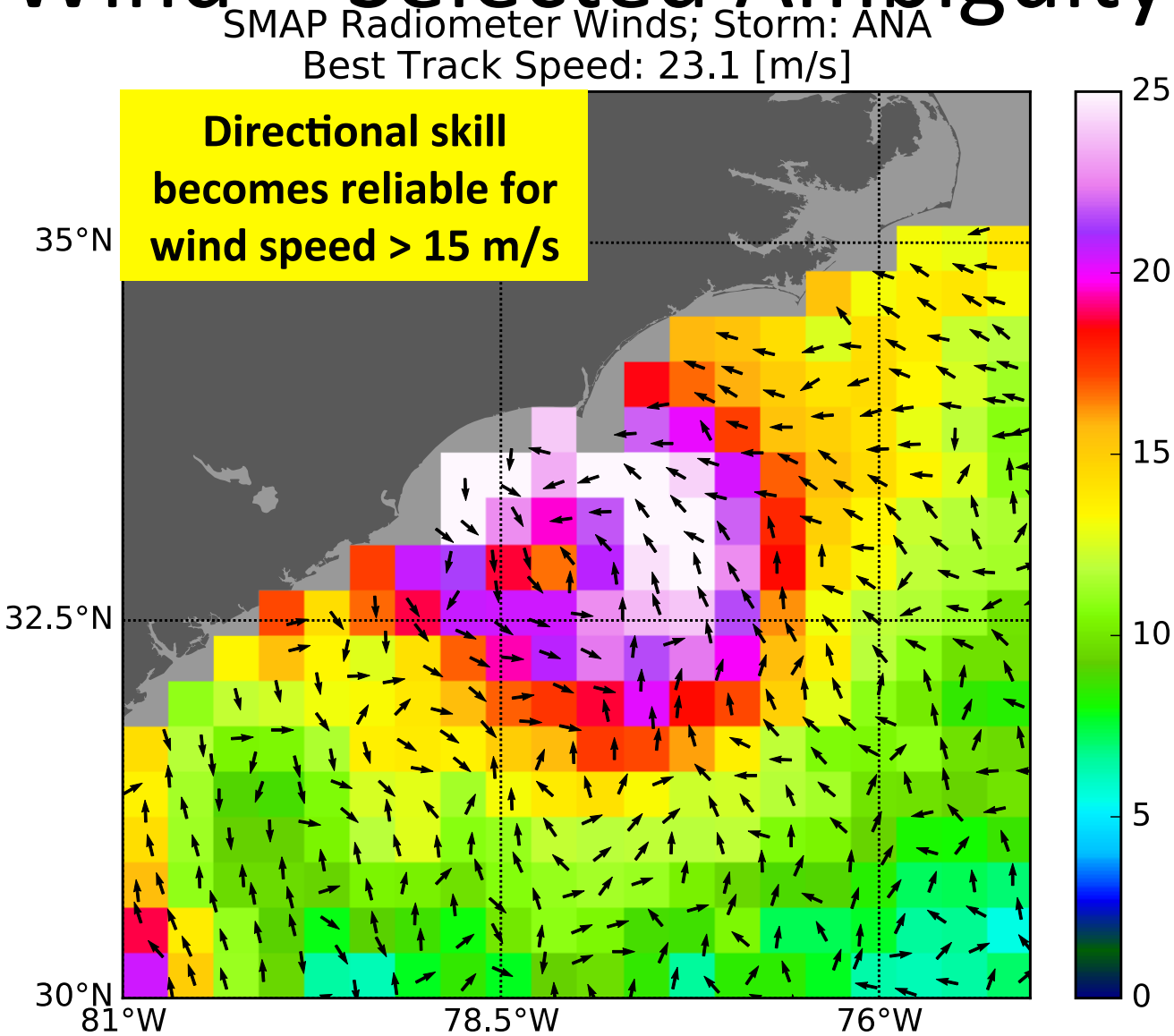


Noul, cat 5, best track ~ 71 m/s

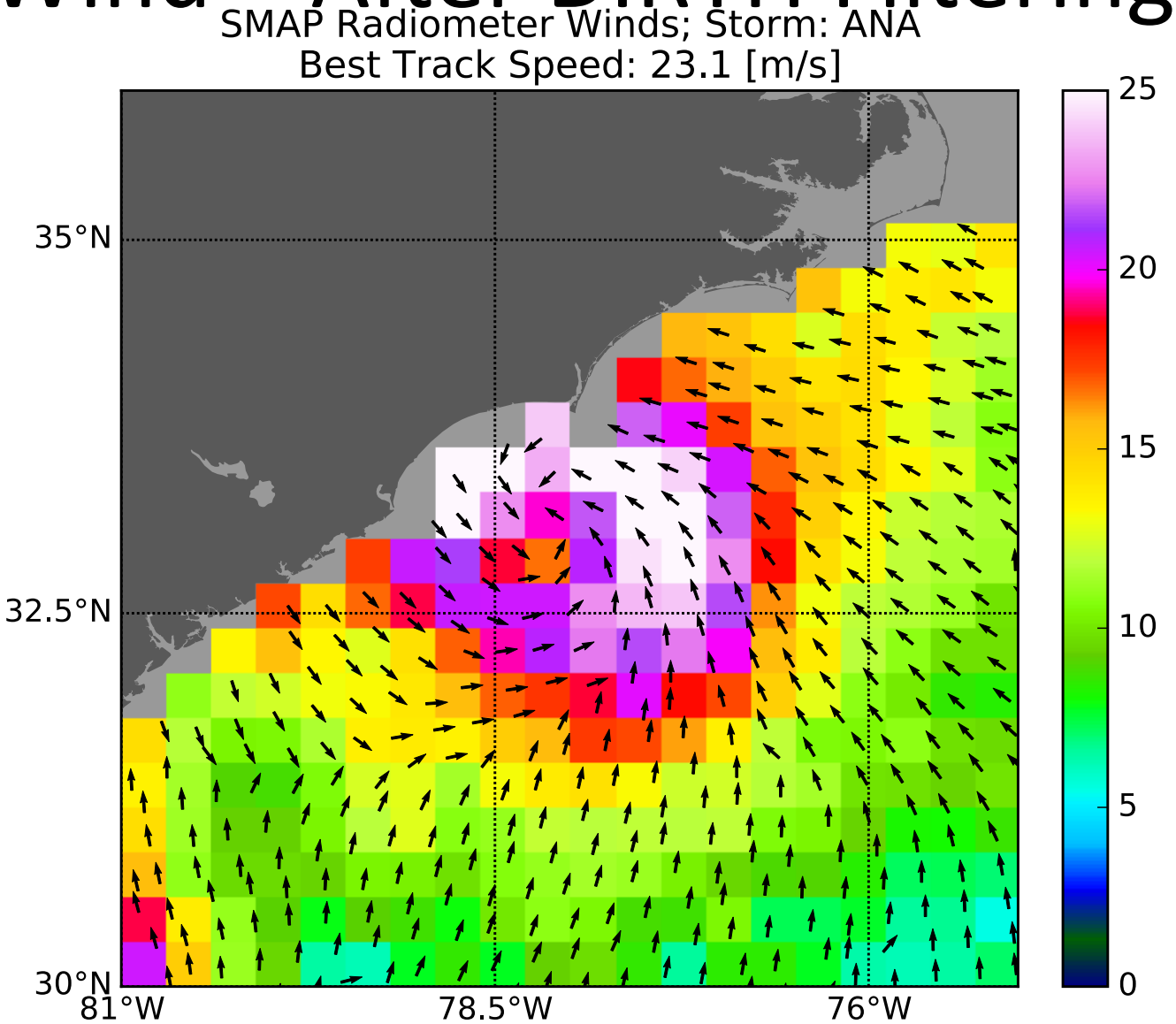


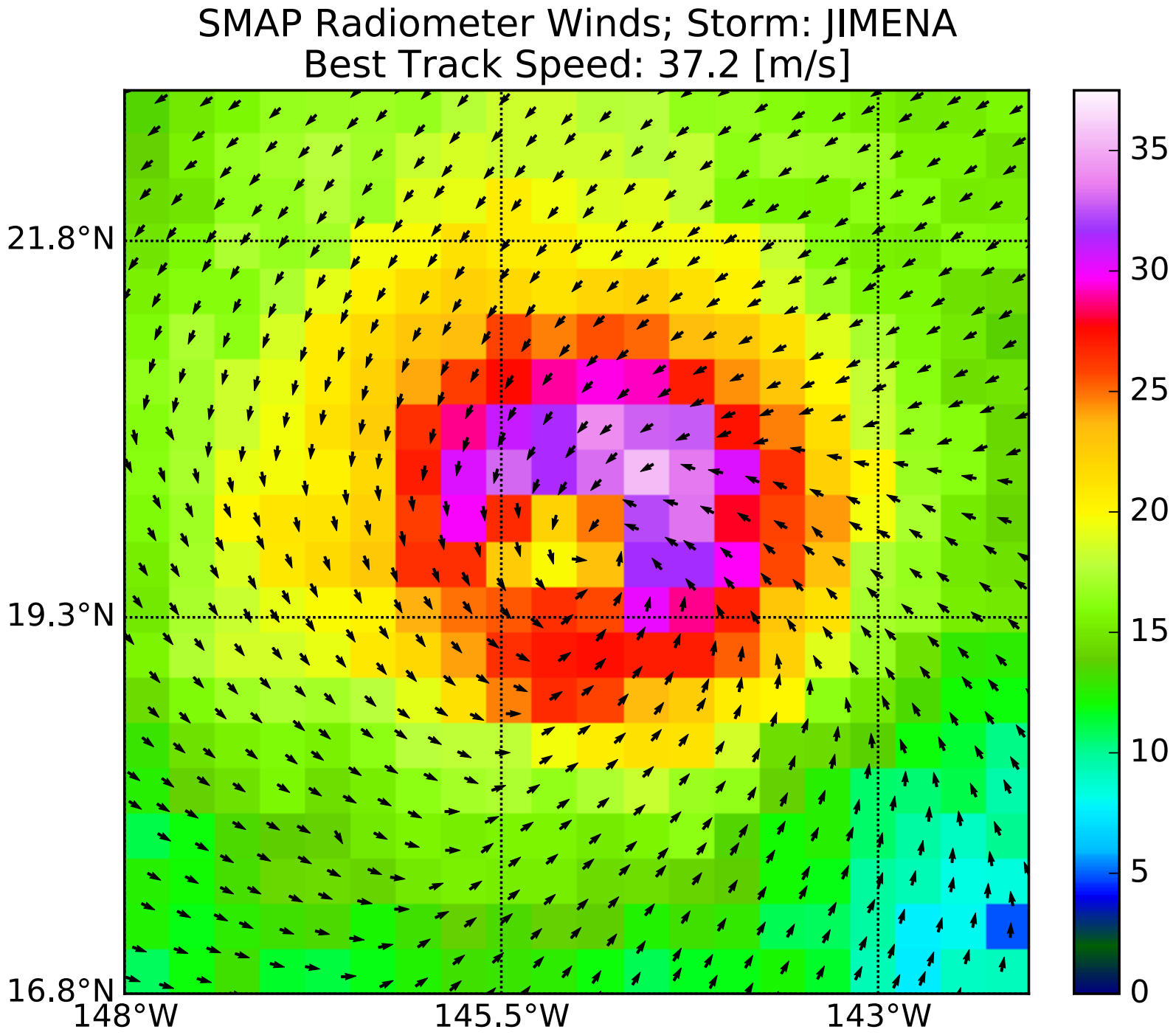
SMAP TB can't resolve fine structure but can get intensity

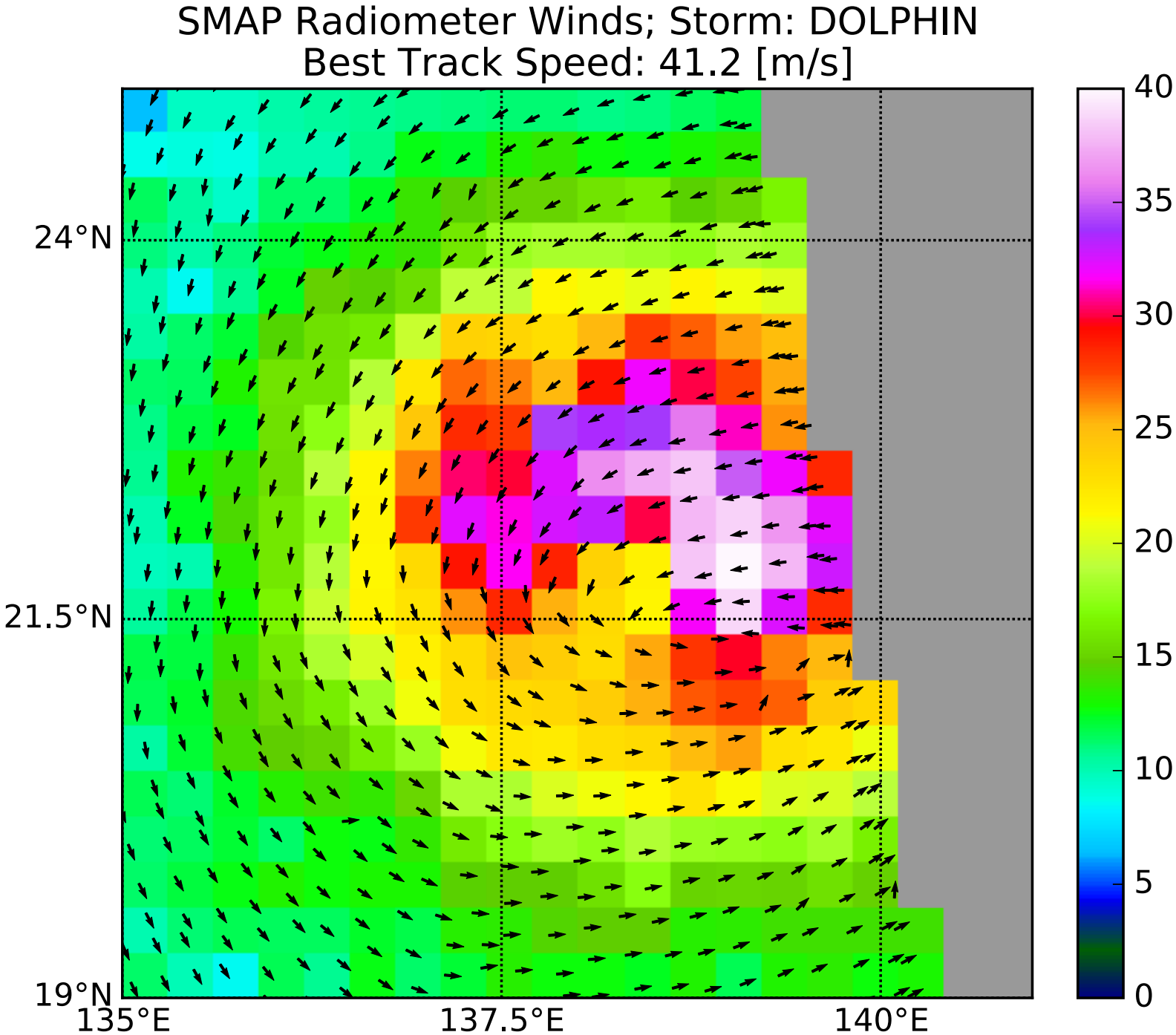
SMAP L-band Radiometer Vector Wind -- Selected Ambiguity

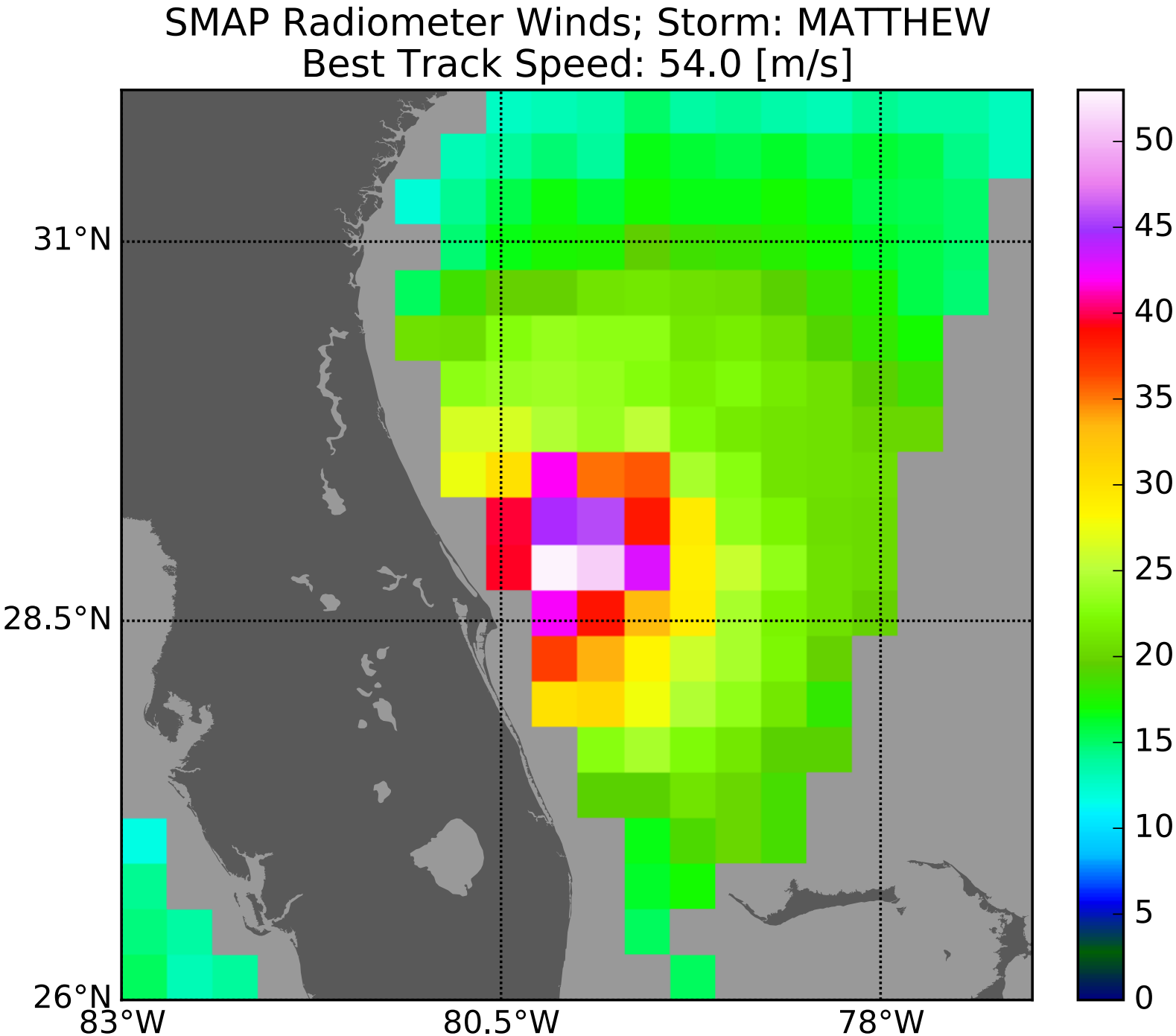


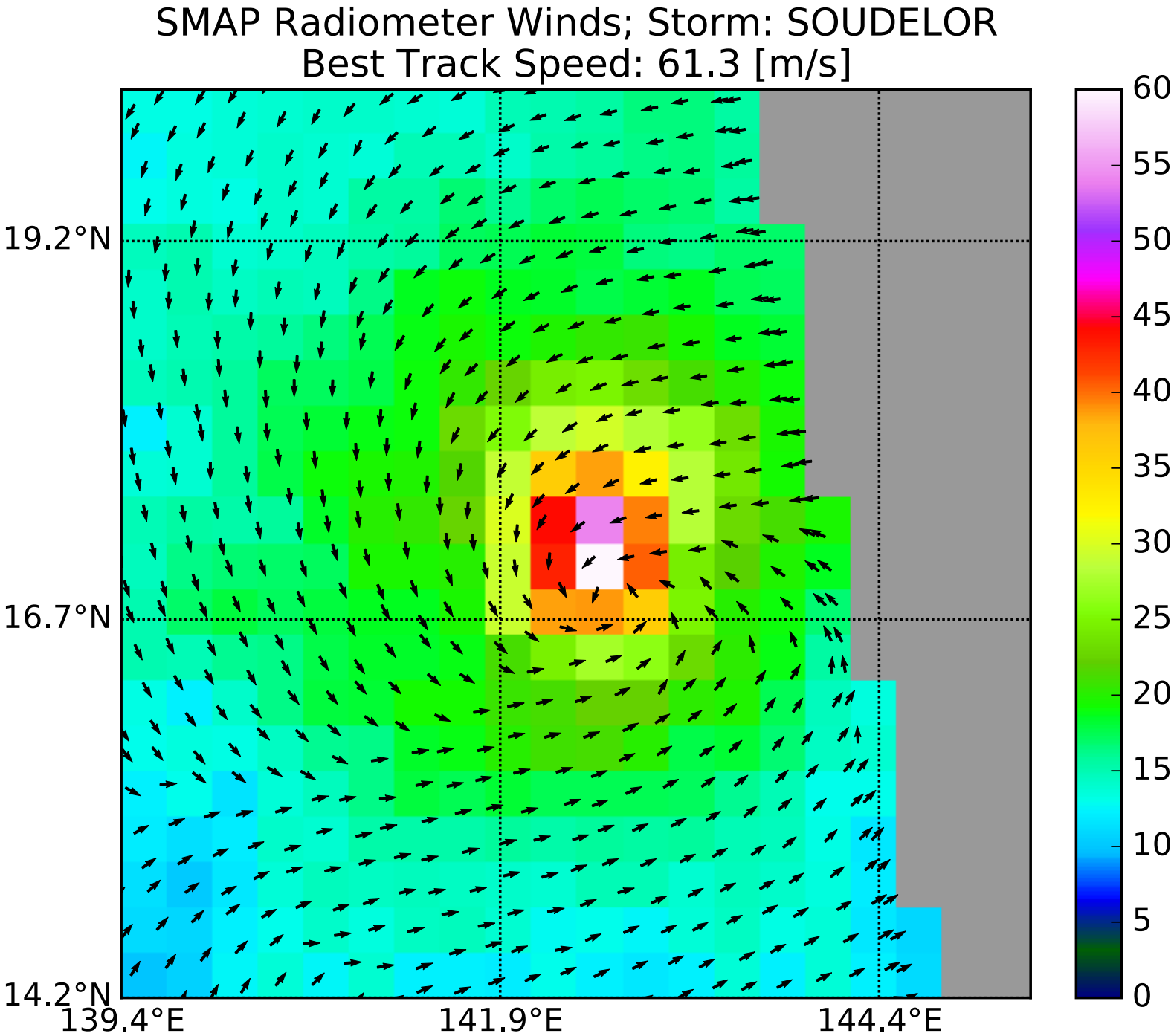
SMAP L-band Radiometer Vector Wind – After DIRTH Filtering

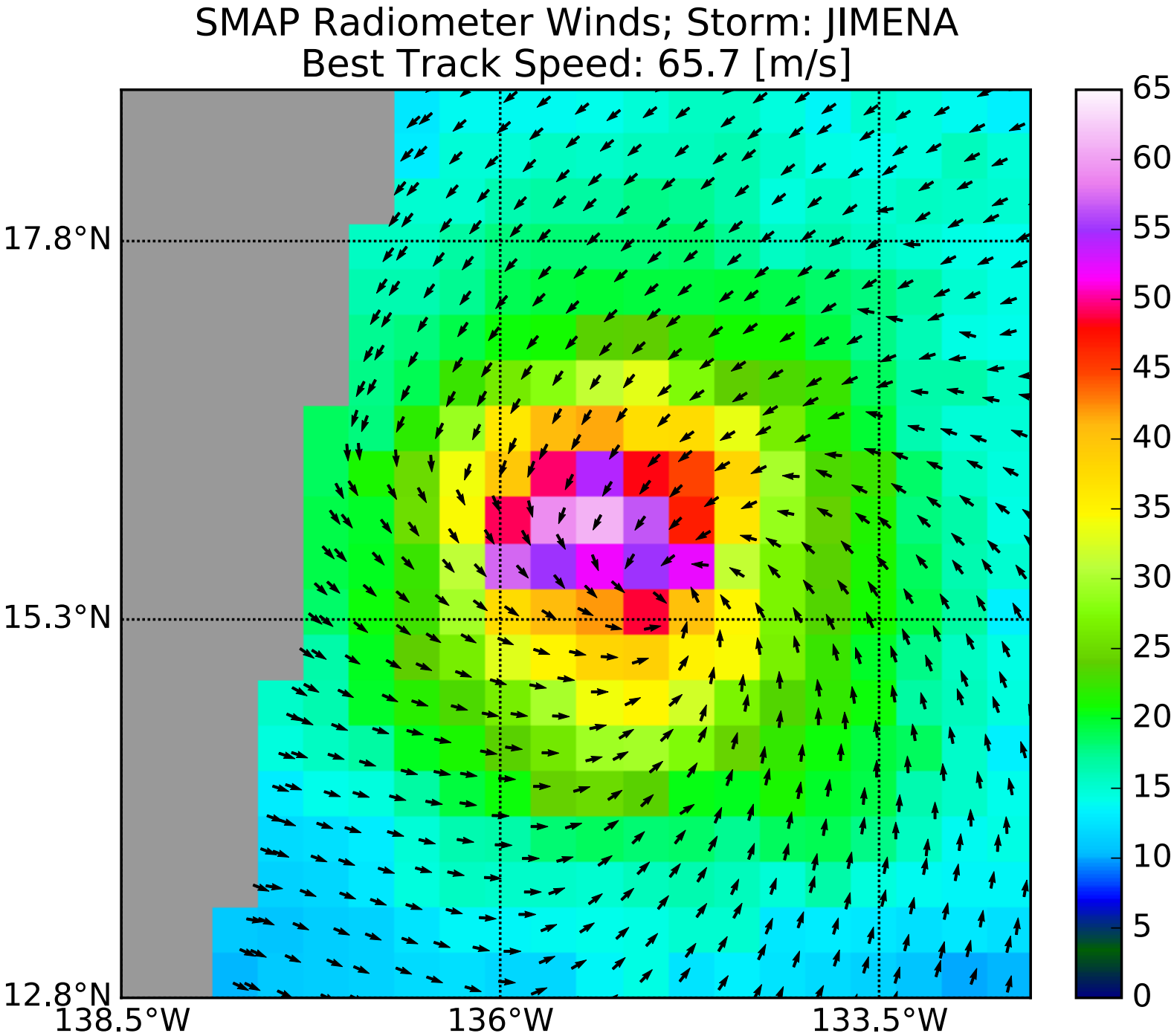


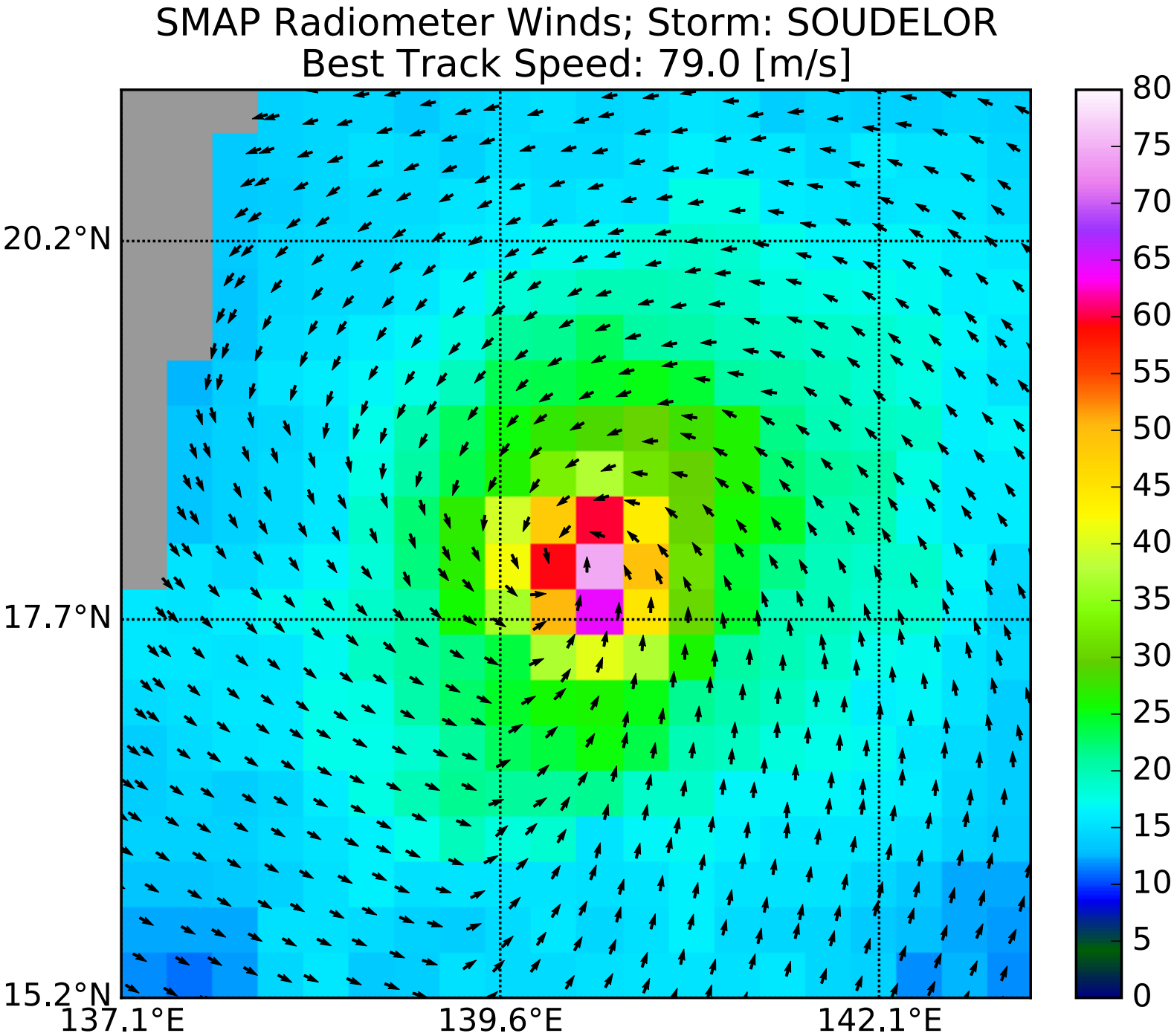

SMAP Radiometer Winds; Storm: JIMENA
Best Track Speed: 37.2 [m/s]
21.8°N
19.3°N
16.8°N
148°W
145.5°W
143°W
35
30
25
20
15
10
5
0

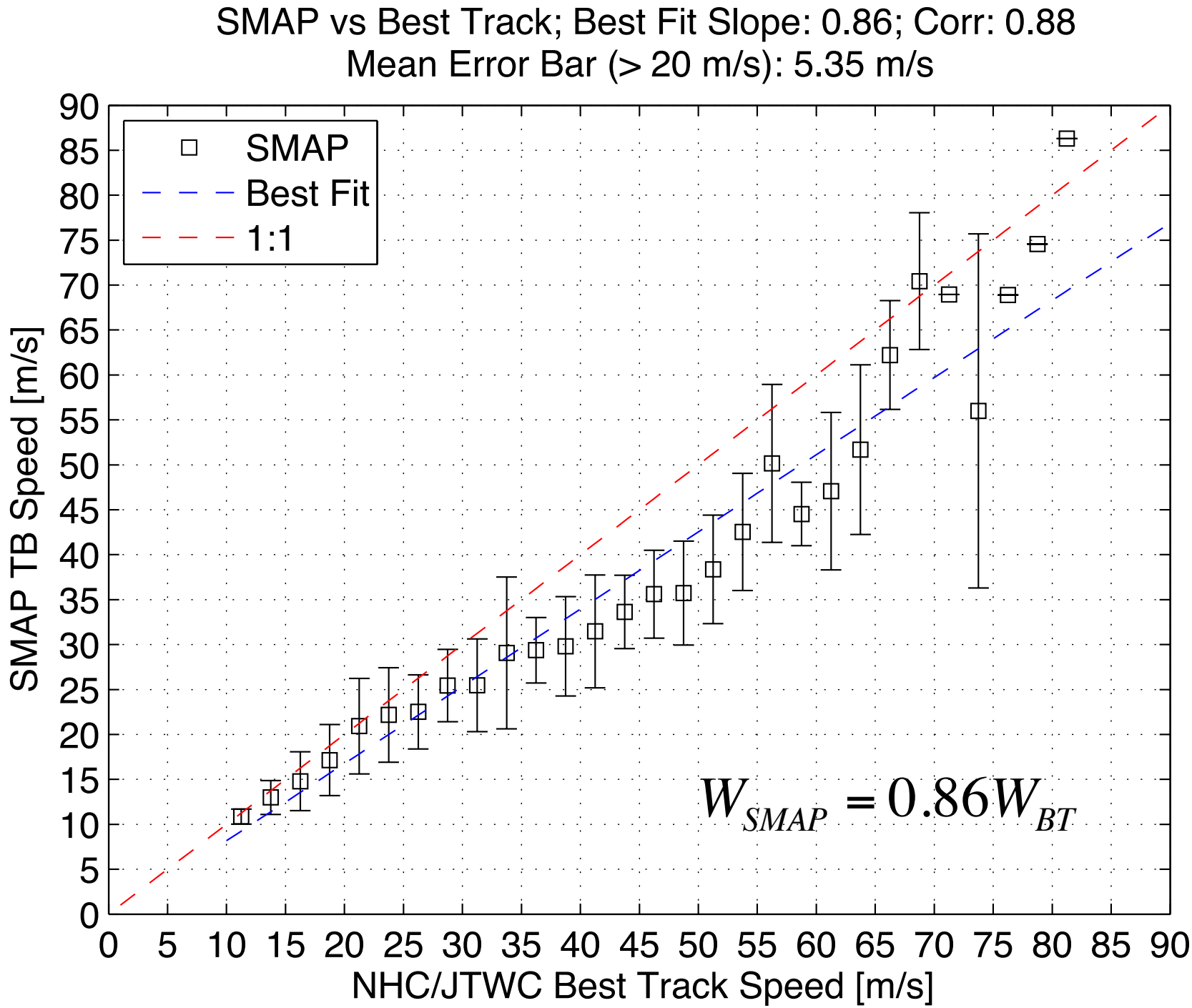

SMAP Radiometer Winds; Storm: DOLPHIN
Best Track Speed: 41.2 [m/s]
24°N
21.5°N
19°N
135°E
137.5°E
140°E
40
35
30
25
20
15
10
5
0


SMAP Radiometer Winds; Storm: MATTHEW
Best Track Speed: 54.0 [m/s]
31°N
28.5°N
26°N
83°W
80.5°W
78°W
50
45
40
35
30
25
20
15
10
5
0

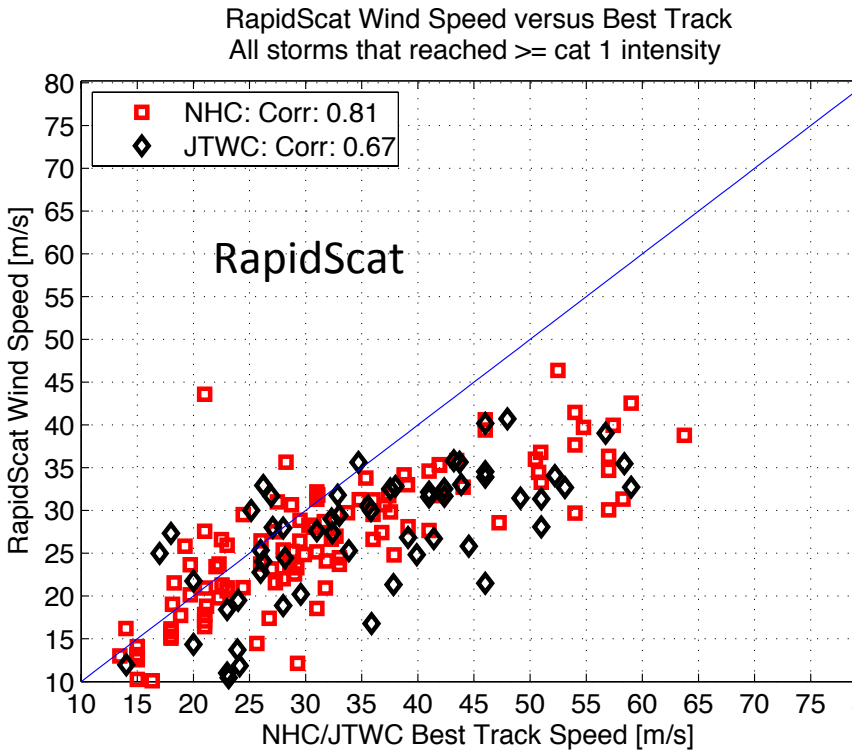

SMAP Radiometer Winds; Storm: SOUDELOR
Best Track Speed: 61.3 [m/s]
19.2°N
16.7°N
14.2°N
139.4°E
141.9°E
144.4°E
60
55
50
45
40
35
30
25
20
15
10
5
0

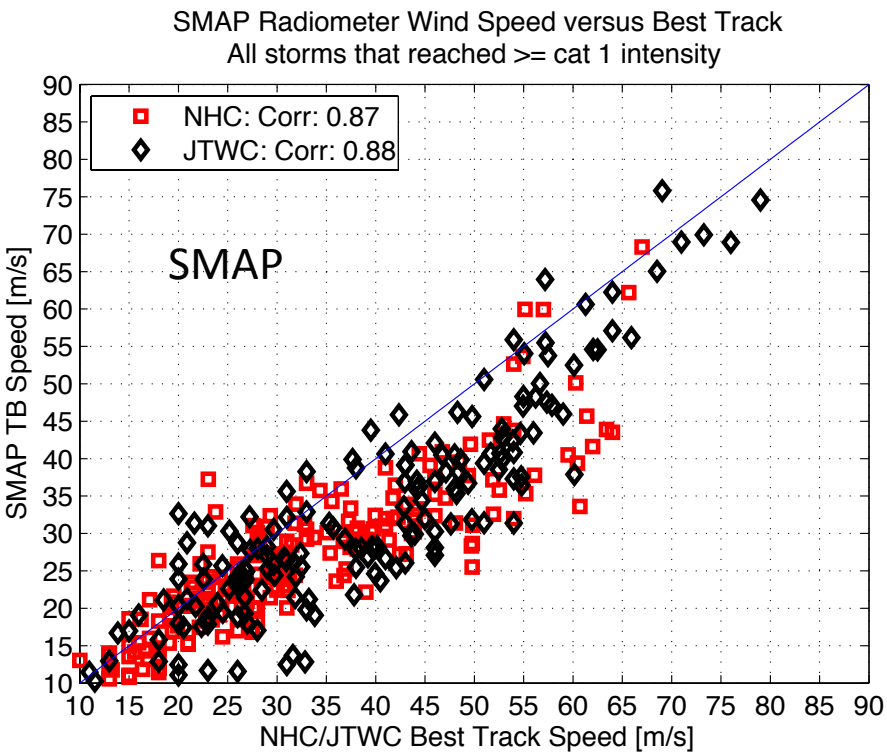

SMAP Radiometer Winds; Storm: JIMENA
Best Track Speed: 65.7 [m/s]
17.8°N
15.3°N
12.8°N
138.5°W
136°W
133.5°W
65
60
55
50
45
40
35
30
25
20
15
10
5
0


SMAP Radiometer Winds; Storm: SOUDELOR
Best Track Speed: 79.0 [m/s]
20.2°N
17.7°N
15.2°N
137.1°E
139.6°E
142.1°E
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0


SMAP vs Best Track; Best Fit Slope: 0.86; Corr: 0.88
Mean Error Bar (> 20 m/s): 5.35 m/s
SMAP
Best Fit
1:1
$W_{SMAP} = 0.86 W_{BT}$
SMAP TB Speed [m/s]
NHC/JTWC Best Track Speed [m/s]
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

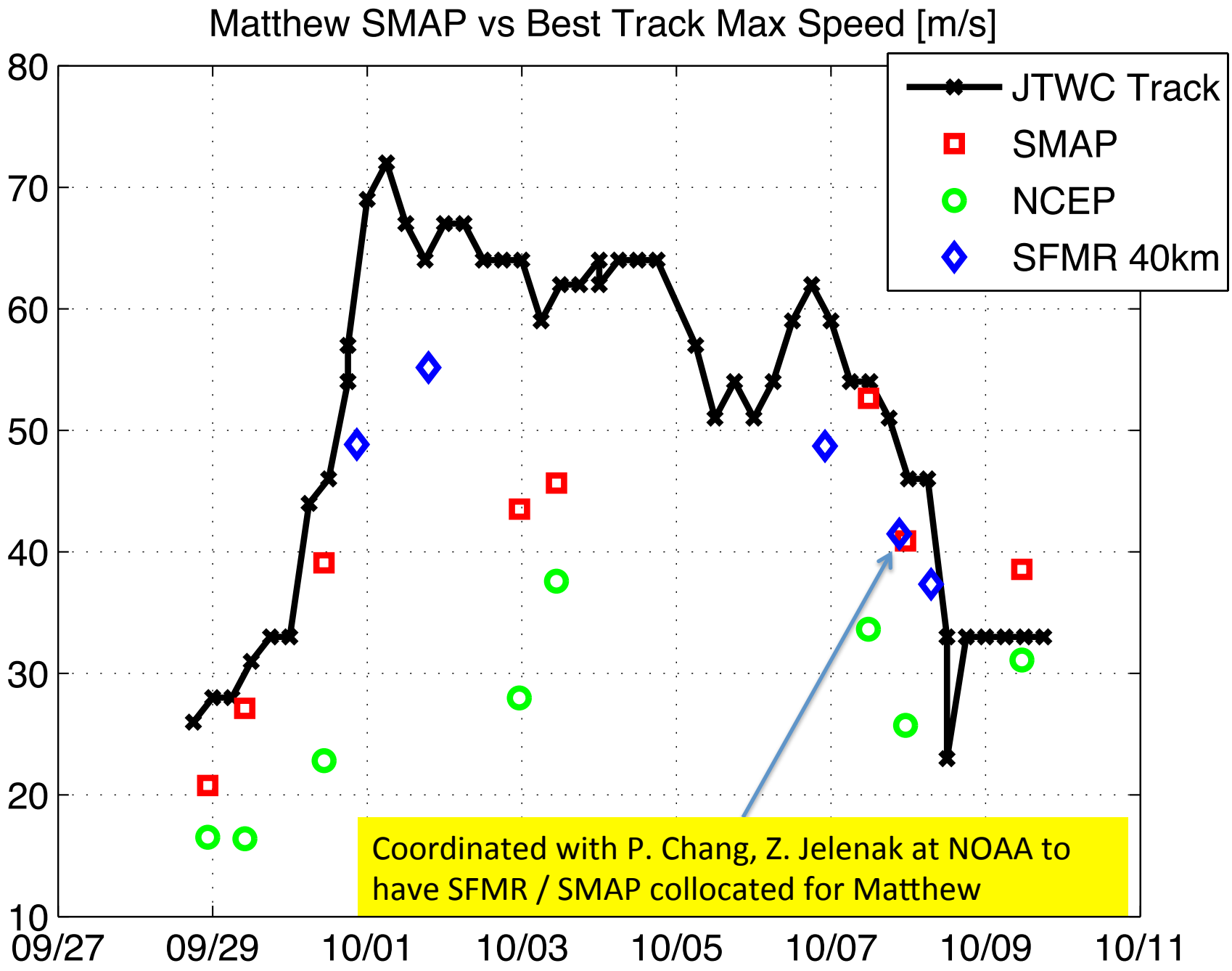
SMAP and RapidSCAT Max Wind vs. Best track (All data)



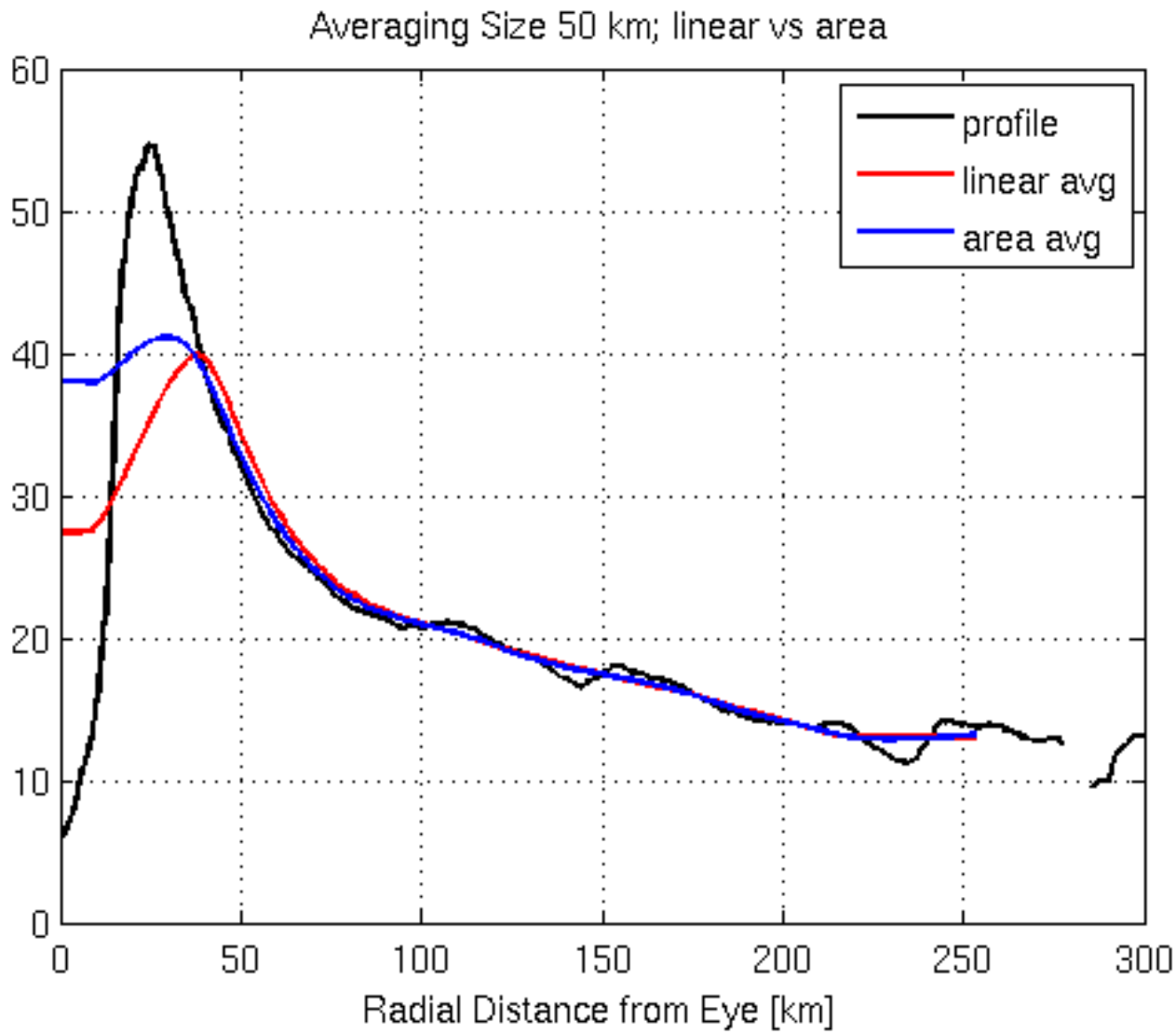


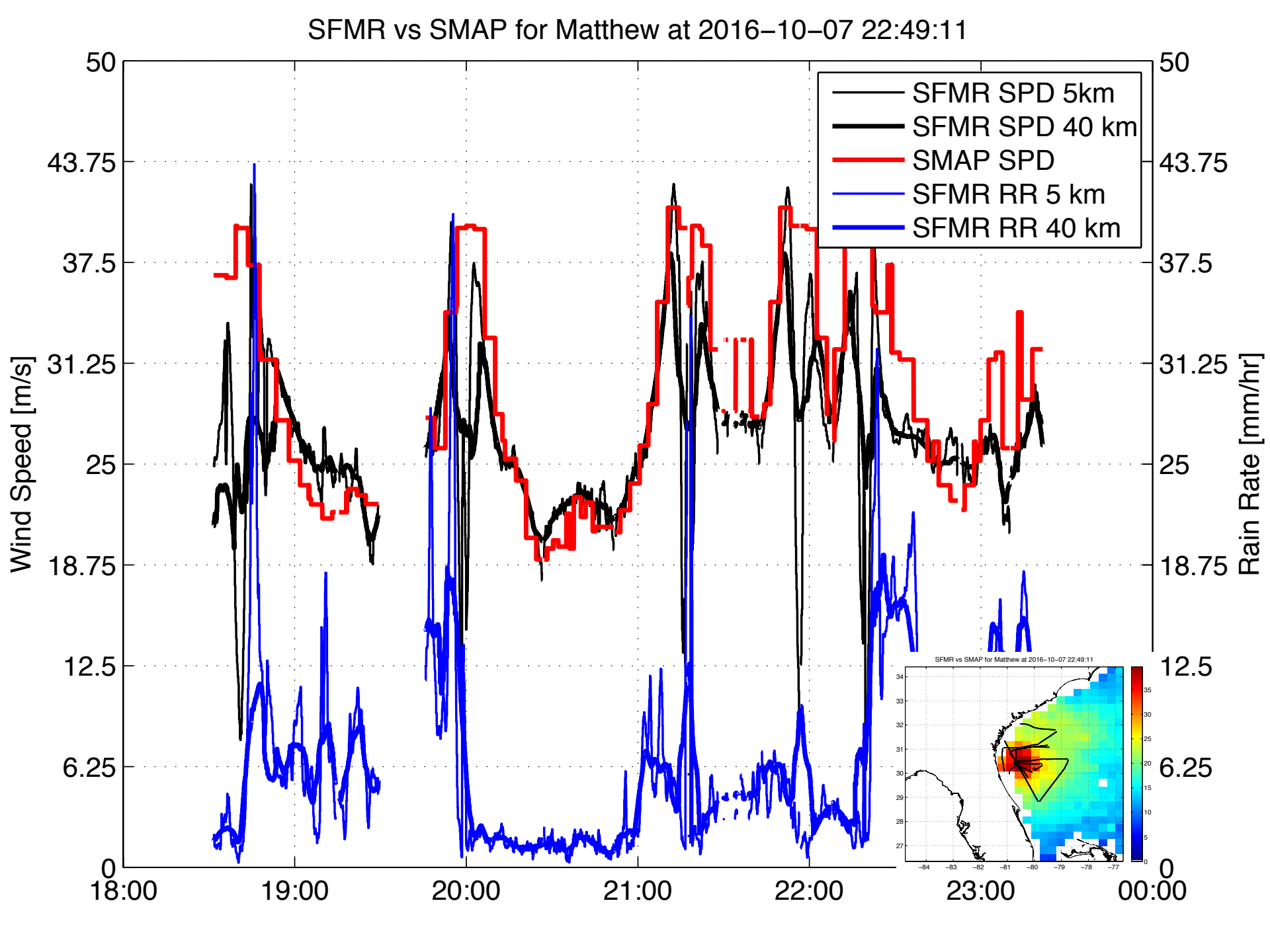
The L-band passive signal does not show any saturation for any wind speed regime.

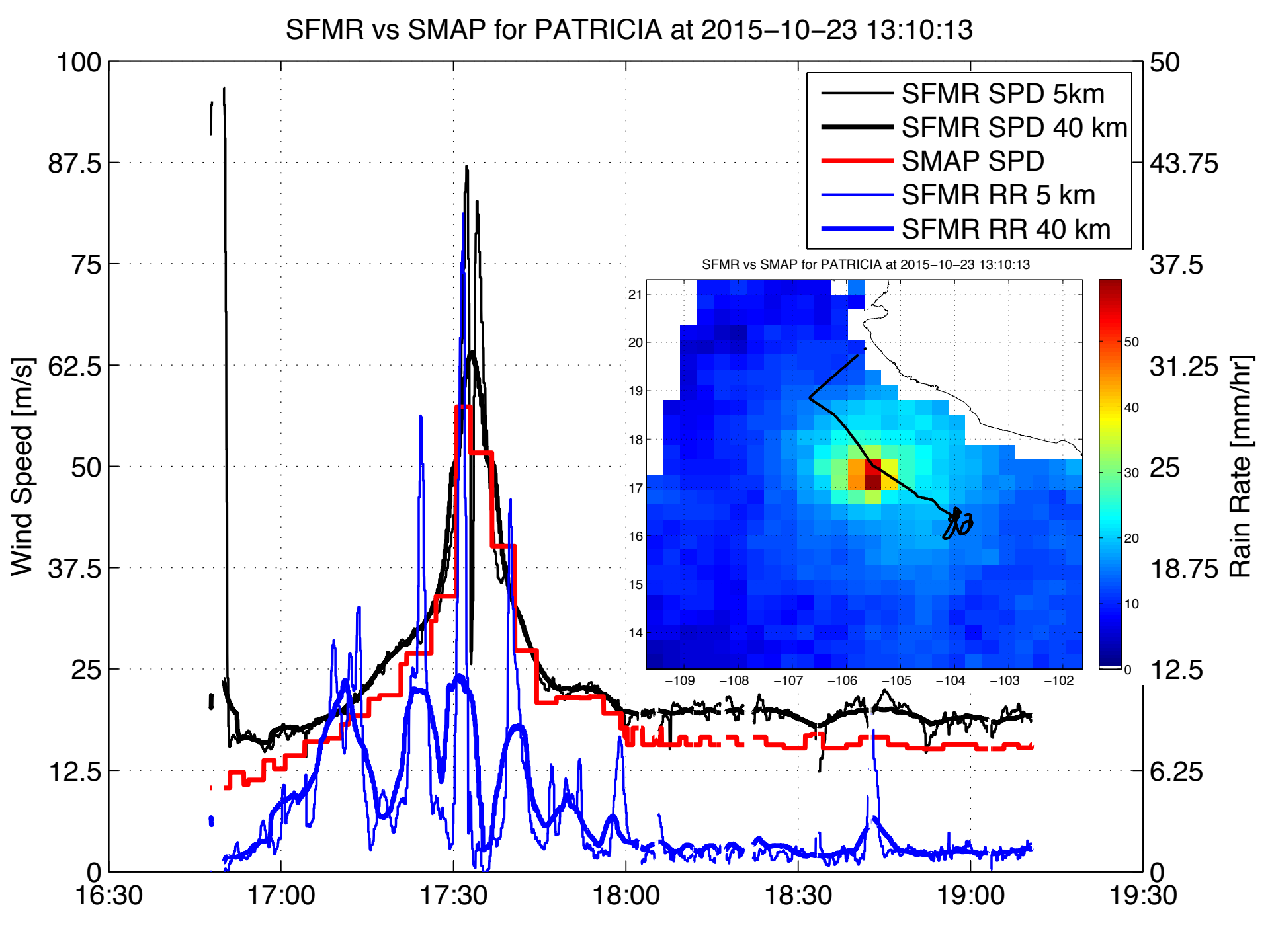
All traditional scatterometers so far are not capable of sensing extreme winds (perhaps ASCAT with HV will).

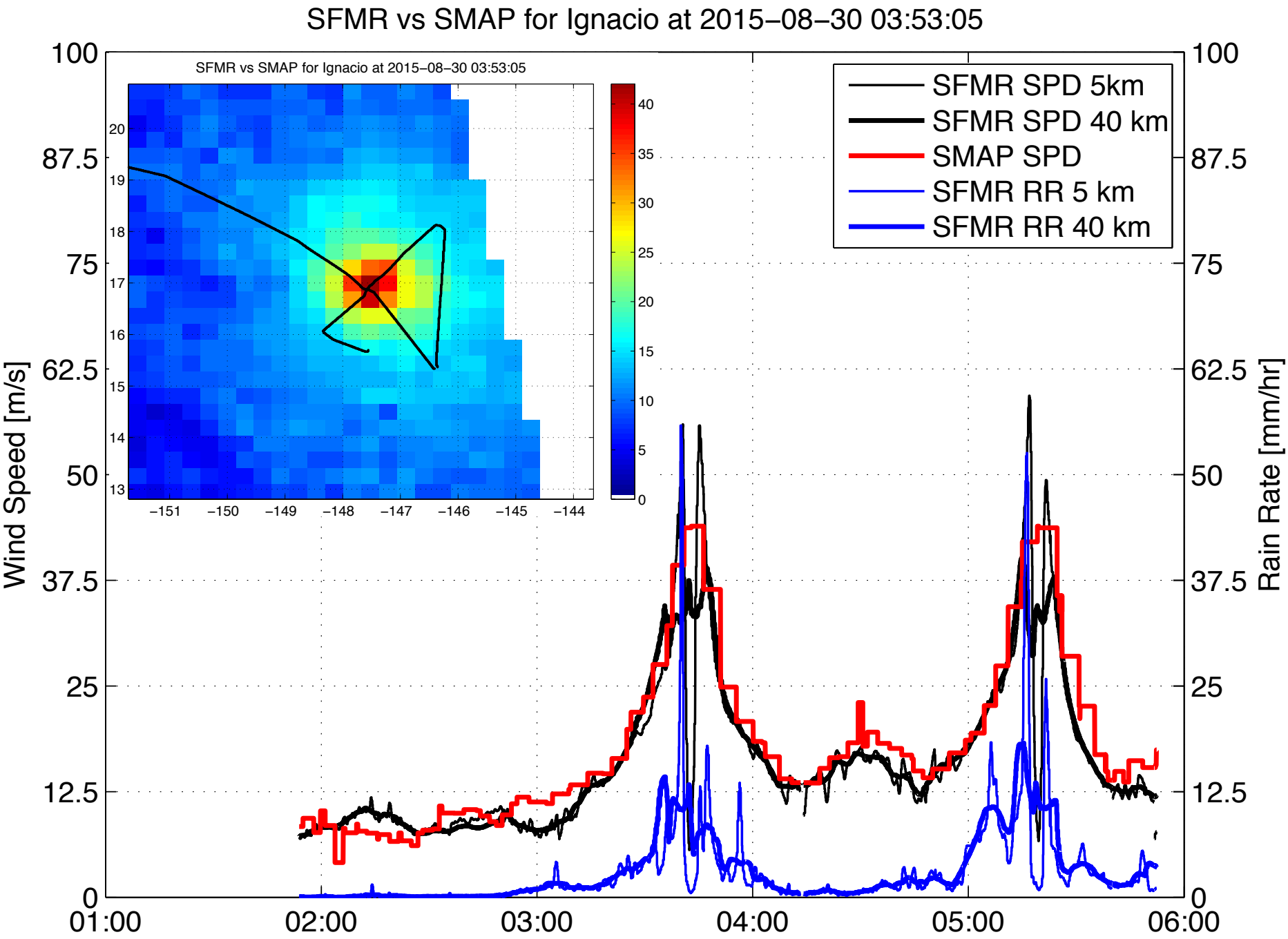

Matthew SMAP vs Best Track Max Speed [m/s]
80
70
60
50
40
30
20
10
09/27
09/29
10/01
10/03
10/05
10/07
10/09
10/11
JTWC Track
SMAP
NCEP
SFMR 40km
Coordinated with P. Chang, Z. Jelenak at NOAA to have SFMR / SMAP collocated for Matthew

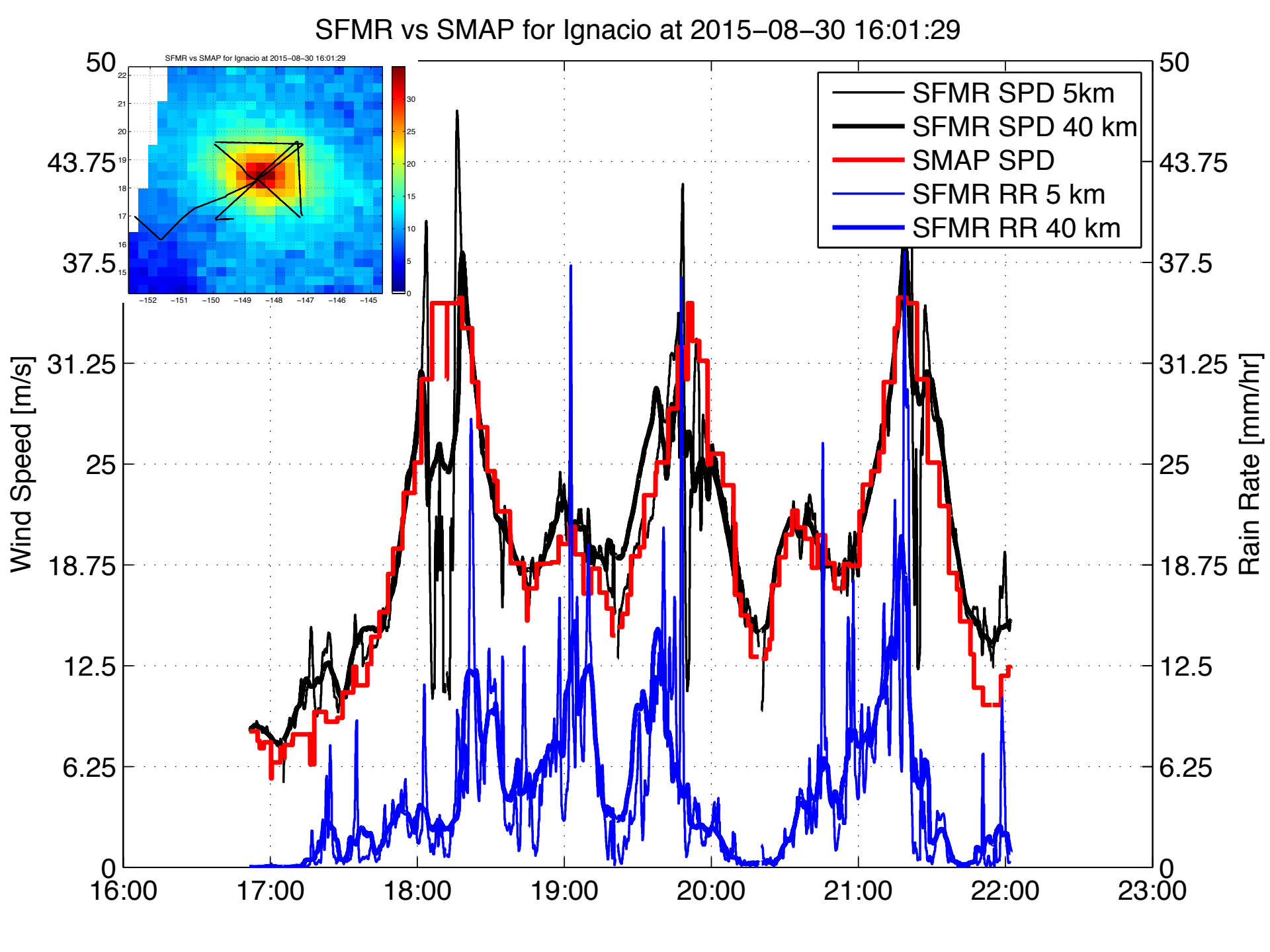
SFMR Averaging Effects Linear versus Area

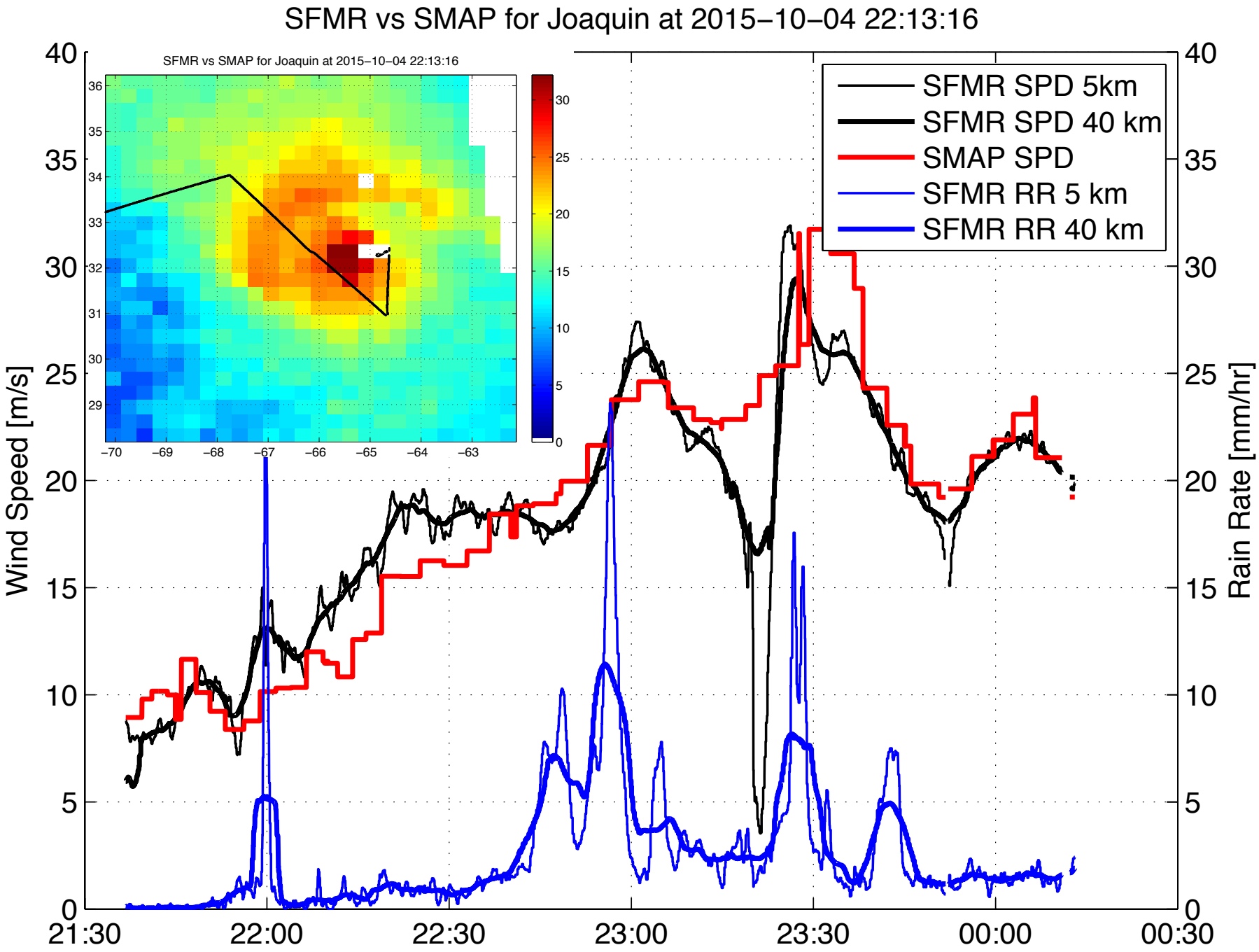


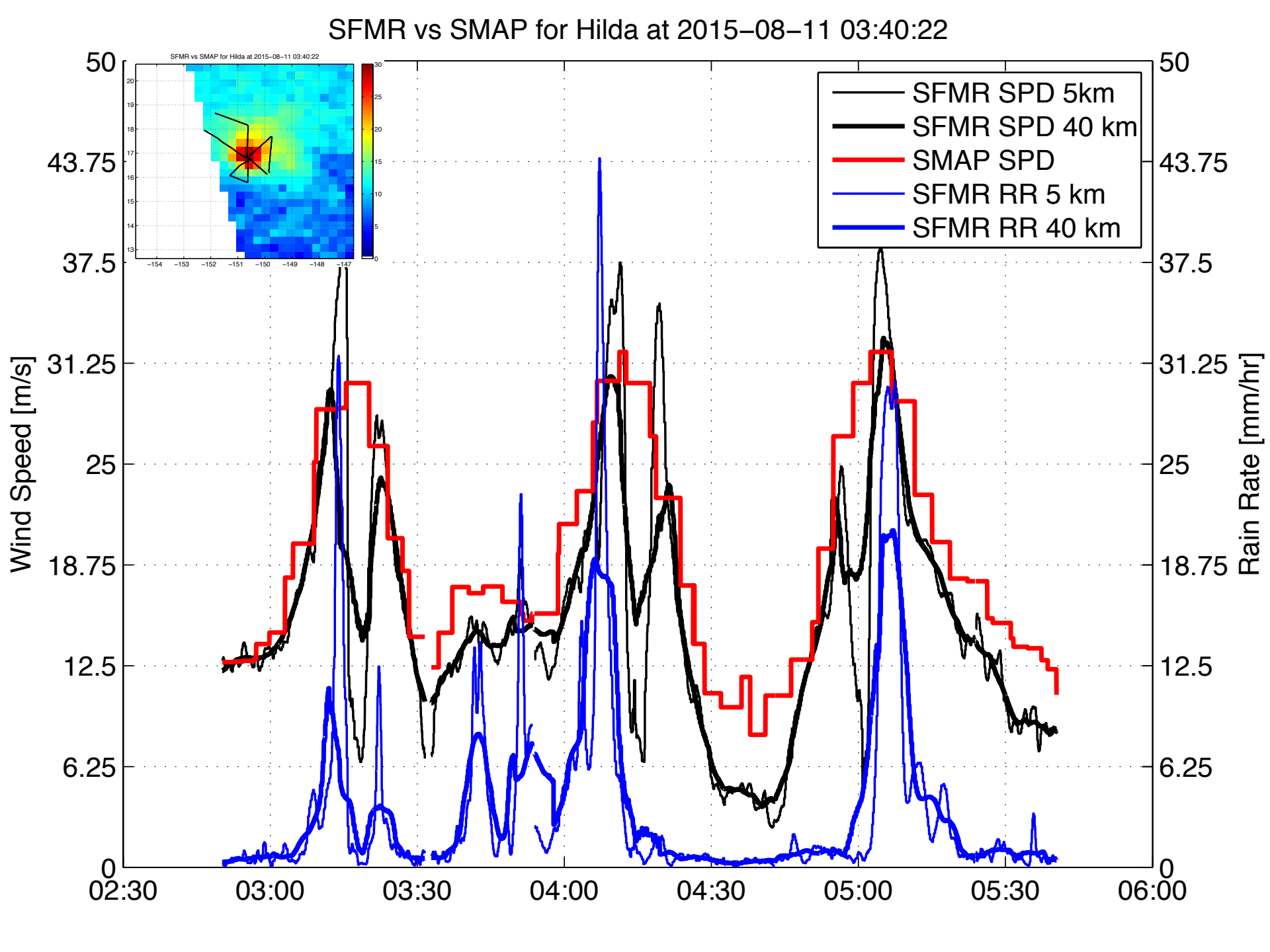

SFMR vs SMAP for Matthew at 2016−10−07 22:49:11
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
50
43.75
37.5
31.25
25
18.75
12.5
6.25
0
18:00
19:00
20:00
21:00
22:00
23:00
00:00
SFMR vs SMAP for Matthew at 2016−10−07 22:49:11


SFMR vs SMAP for PATRICIA at 2015−10−23 13:10:13
Wind Speed [m/s]
Rain Rate [mm/hr]
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
100
87.5
75
62.5
50
37.5
25
12.5
0
50
43.75
37.5
31.25
25
18.75
12.5
6.25
0
16:30
17:00
17:30
18:00
18:30
19:00
19:30
SFMR vs SMAP for PATRICIA at 2015−10−23 13:10:13
21
20
19
18
17
16
15
14
−109
−108
−107
−106
−105
−104
−103
−102
50
40
30
20
10
0


SFMR vs SMAP for Ignacio at 2015−08−30 03:53:05
SFMR vs SMAP for Ignacio at 2015−08−30 03:53:05
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
100
87.5
75
62.5
50
37.5
25
12.5
0
01:00
02:00
03:00
04:00
05:00
06:00
20
19
18
17
16
15
14
13
−151
−150
−149
−148
−147
−146
−145
−144
40
35
30
25
20
15
10
5
0


SFMR vs SMAP for Ignacio at 2015−08−30 16:01:29
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
50
43.75
37.5
31.25
25
18.75
12.5
6.25
0
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
SFMR vs SMAP for Ignacio at 2015−08−30 16:01:29


SFMR vs SMAP for Joaquin at 2015−10−04 22:13:16
SFMR vs SMAP for Joaquin at 2015−10−04 22:13:16
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
21:30
22:00
22:30
23:00
23:30
00:00
00:30


SFMR vs SMAP for Hilda at 2015−08−11 03:40:22
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
50
43.75
37.5
31.25
25
18.75
12.5
6.25
0
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00

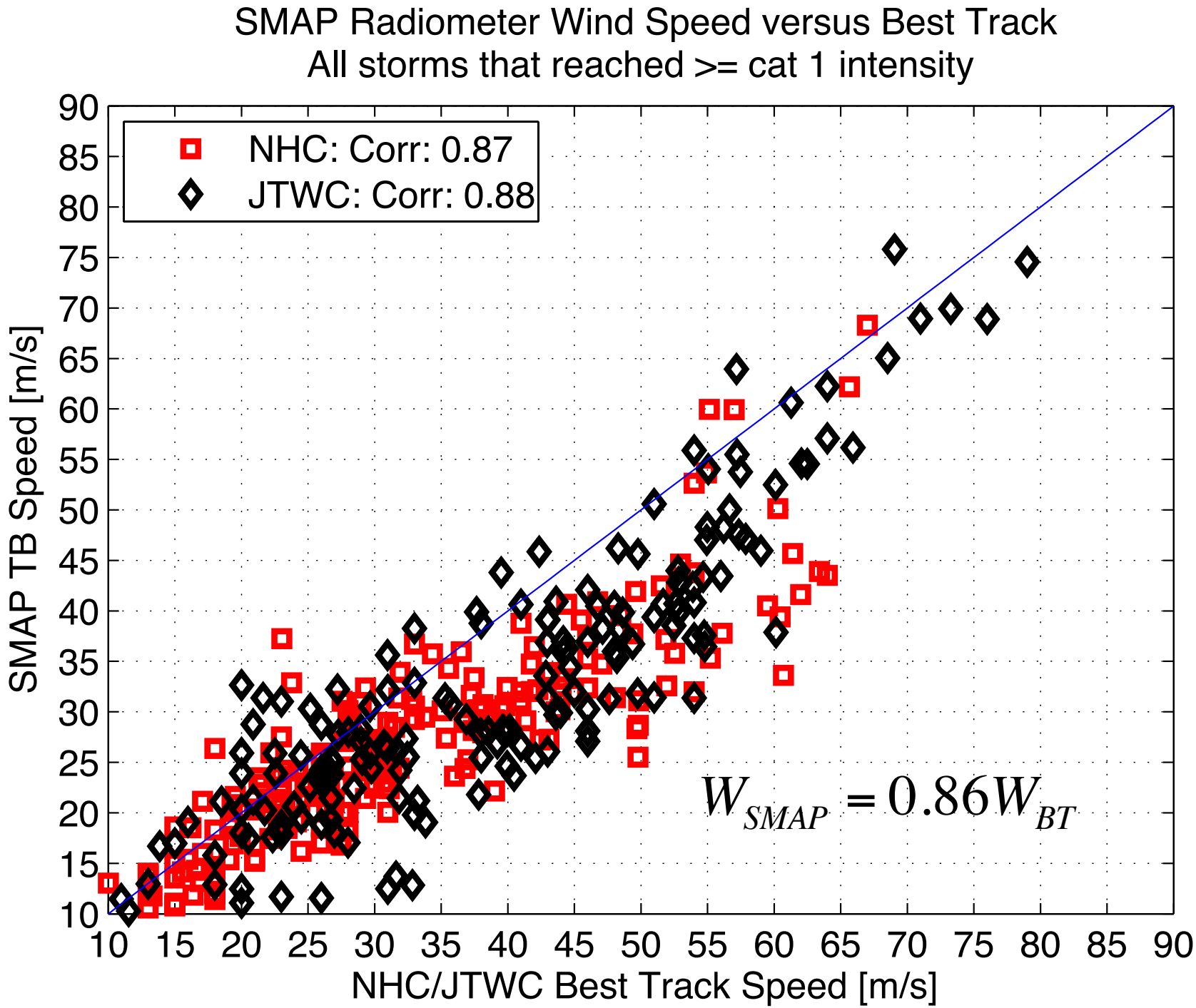
SFMR Matchups for 2015-2016

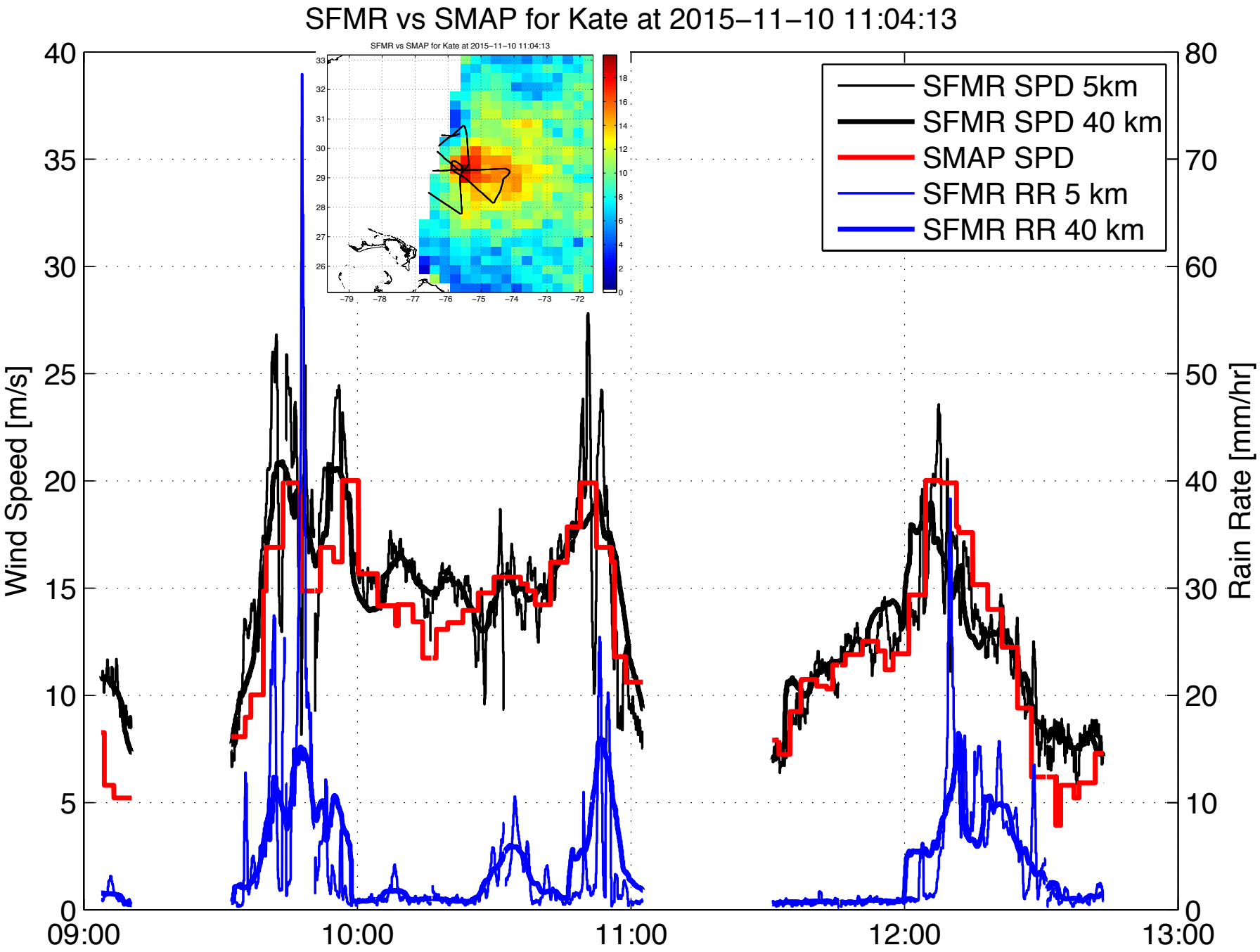
Matchup Time [min]	Counts >15m/s	Bias [m/s] >15 m/s	STD [m/s] > 15 m/s	Counts > 25 m/s	Bias [m/s] > 25 m/s	STD [m/s] > 25 m/s
15	35	1.49	2.97	4	3.26	2.44
30	75	1.60	2.99	10	1.89	2.19
45	111	1.70	2.89	10	1.89	2.19
90	229	2.01	6.17	30	3.13	3.53
180	412	1.69	5.07	58	2.69	3.60
240	509	1.52	4.77	70	2.28	3.82
300	655	1.43	5.60	89	1.50	4.63
360	771	1.24	5.39	95	1.22	4.93

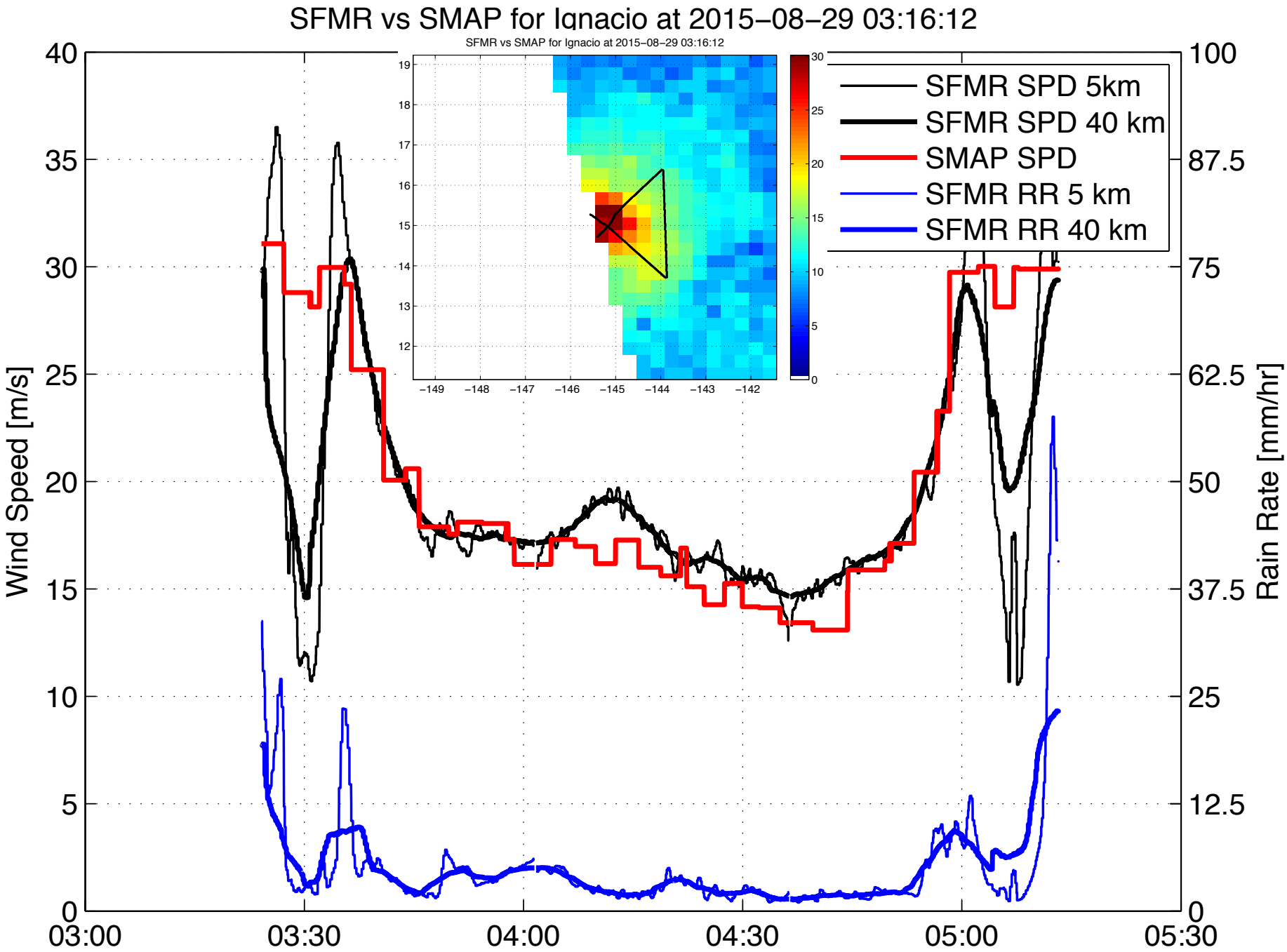
- Average SFMR within +/- 25 km of SMAP L2B grid cell.
- Use best-track to shift SFMR tracks to SMAP observation time.

Summary

- *SMAP radiometer is capable of providing a ocean vector wind product with unprecedented sensitivity to extreme winds!*
  - Direction signal becomes significant above 15 m/s.
  - Strong scaling with wind speed appears to extend up 70-80 m/s.
- Capable of resolving 40 km length scales and above.
  - Structure at scales < 40 km not resolvable.
  - Can track intensity, size, and location even if cannot resolve structure.
- Data are available at: http://ourocean.jpl.nasa.gov/ (version 3 just released)
  - L2B science data with 3 day delay.
  - L3 data with one week delay.
- SMAP winds overlaid on Google Earth online at: http://wow.jpl.nasa.gov/smap/
- Peer-reviewed publications:
  - S. H. Yueh et al., "SMAP L-Band Passive Microwave Observations of Ocean Surface Wind During Severe Storms," in IEEE Transactions on Geoscience and Remote Sensing, vol. 54, no. 12, pp. 7339-7350, Dec. 2016.
  - A. G. Fore, et al., "Combined Active/Passive Retrievals of Ocean Vector Wind and Sea Surface Salinity With SMAP," in IEEE Transactions on Geoscience and Remote Sensing, vol. 54, no. 12, pp. 7396-7404, Dec. 2016.
- Contact: Alexander.fore@jpl.nasa.gov


SMAP Radiometer Wind Speed versus Best Track
All storms that reached >= cat 1 intensity
NHC: Corr: 0.87
JTWC: Corr: 0.88
$W_{SMAP} = 0.86 W_{BT}$
SMAP TB Speed [m/s]
NHC/JTWC Best Track Speed [m/s]
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90


SFMR vs SMAP for Kate at 2015−11−10 11:04:13
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
09:00
10:00
11:00
12:00
13:00
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
SFMR vs SMAP for Kate at 2015−11−10 11:04:13

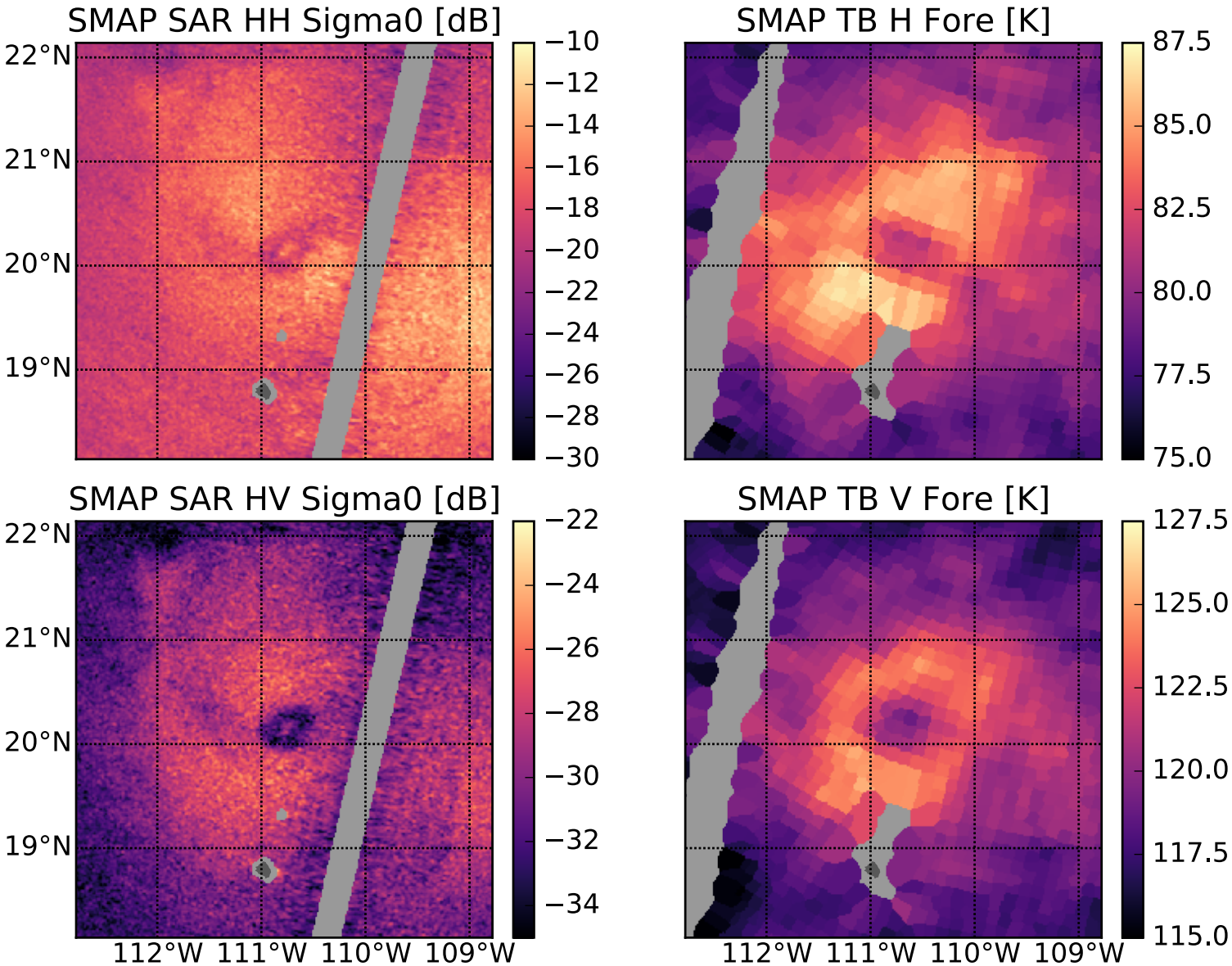

SFMR vs SMAP for Ignacio at 2015−08−29 03:16:12
SFMR vs SMAP for Ignacio at 2015−08−29 03:16:12
SFMR SPD 5km
SFMR SPD 40 km
SMAP SPD
SFMR RR 5 km
SFMR RR 40 km
Wind Speed [m/s]
Rain Rate [mm/hr]
03:00
03:30
04:00
04:30
05:00
05:30

SFMR Matchups for 2015-2016

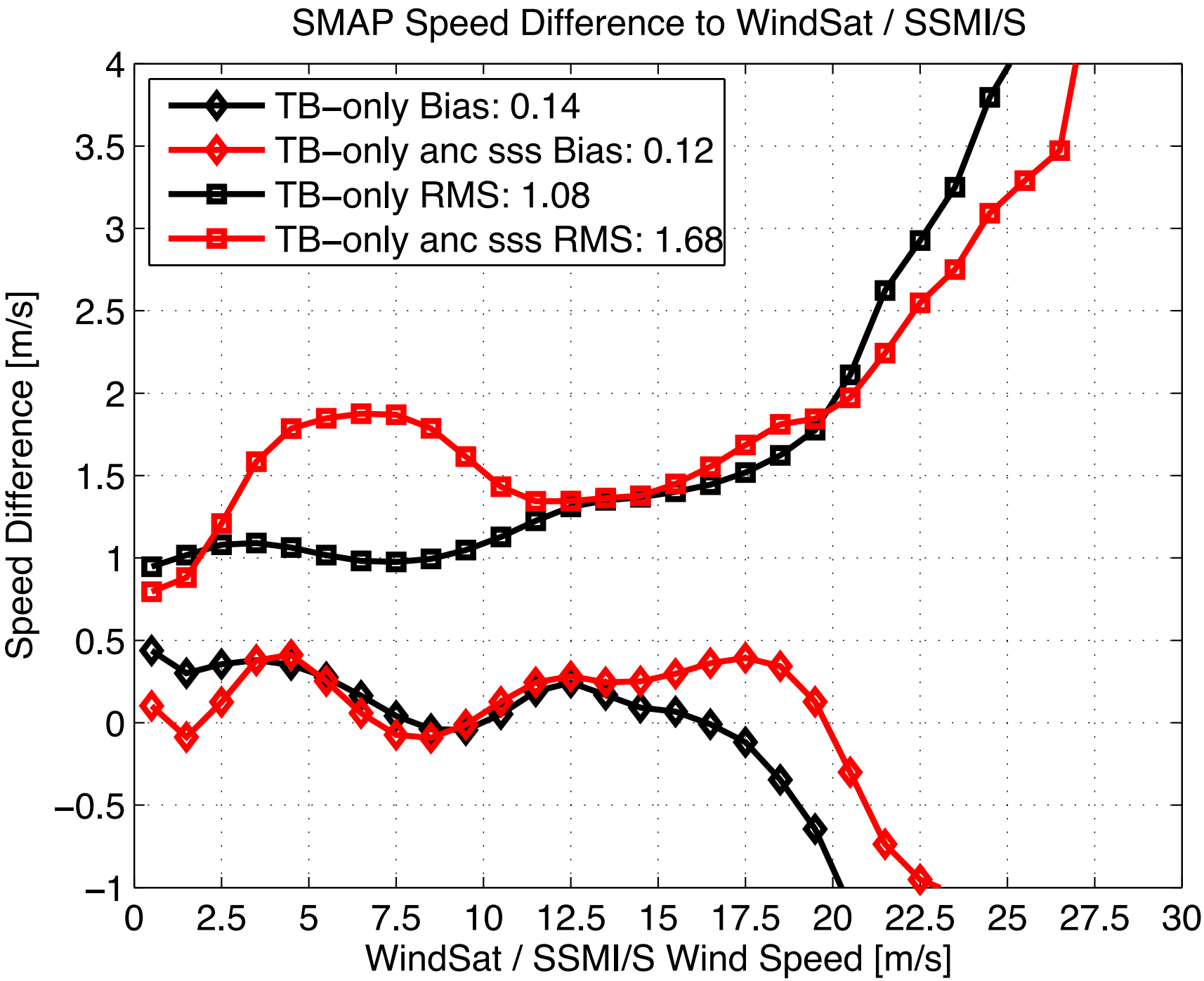
Matchup Time [min]	Counts >10m/s	Bias [m/s] >10 m/s	STD [m/s] > 10 m/s	Counts > 20 m/s	Bias [m/s] > 20 m/s	STD [m/s] > 20 m/s
15	120	1.12	2.47	9	2.01	4.05
30	220	1.29	2.45	18	2.32	4.36
45	319	1.26	2.42	23	2.90	4.37
90	580	1.41	4.24	64	2.46	3.80
180	993	1.37	3.69	136	1.97	3.71
240	1161	1.42	5.07	174	1.90	3.81
300	1303	1.38	6.41	237	1.20	4.18
360	1377	1.22	6.36	292	1.21	4.23

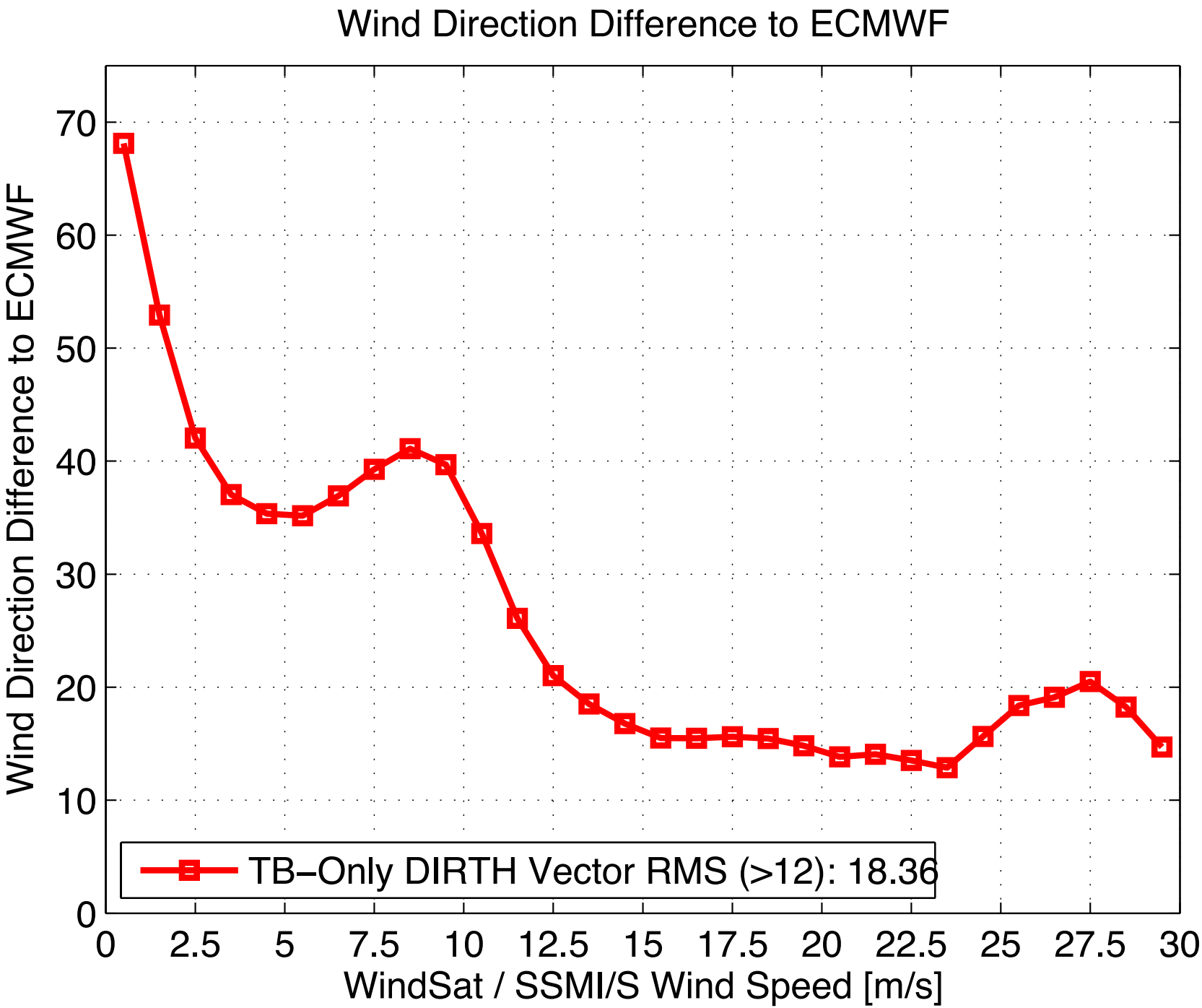
- Average SFMR within +/- 25 km of SMAP L2B grid cell.
- Use best-track to shift SFMR tracks to SMAP observation time.

Blanca, cat 2, best track ~44 m/s

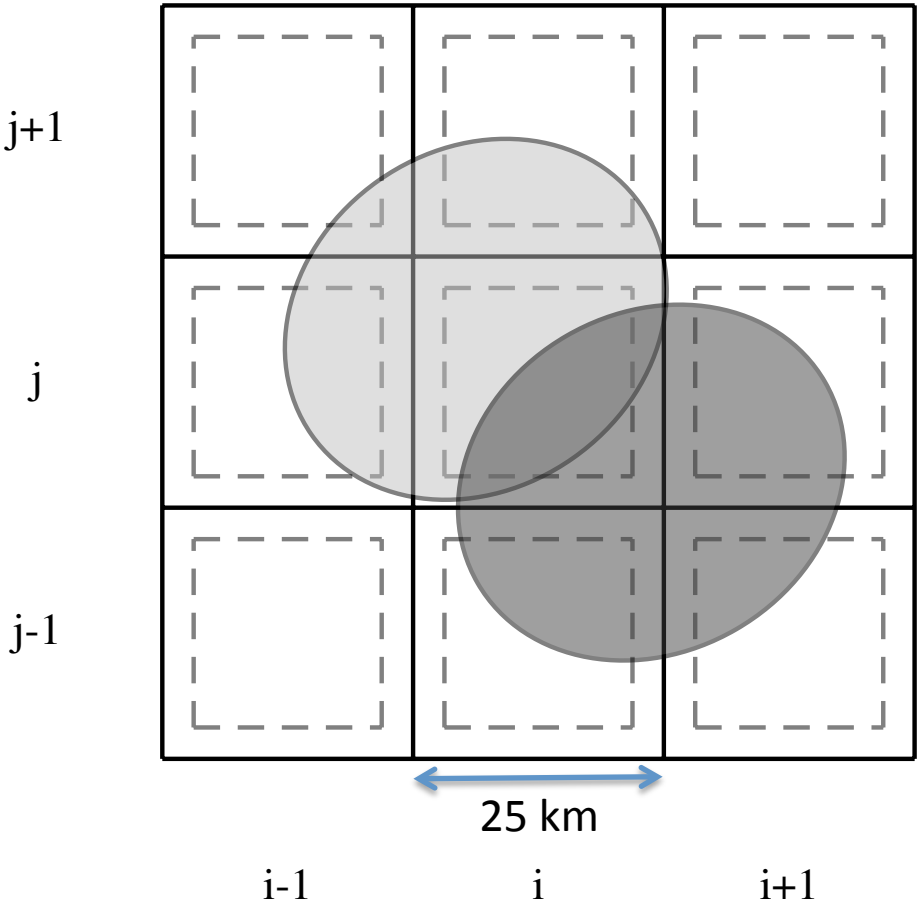


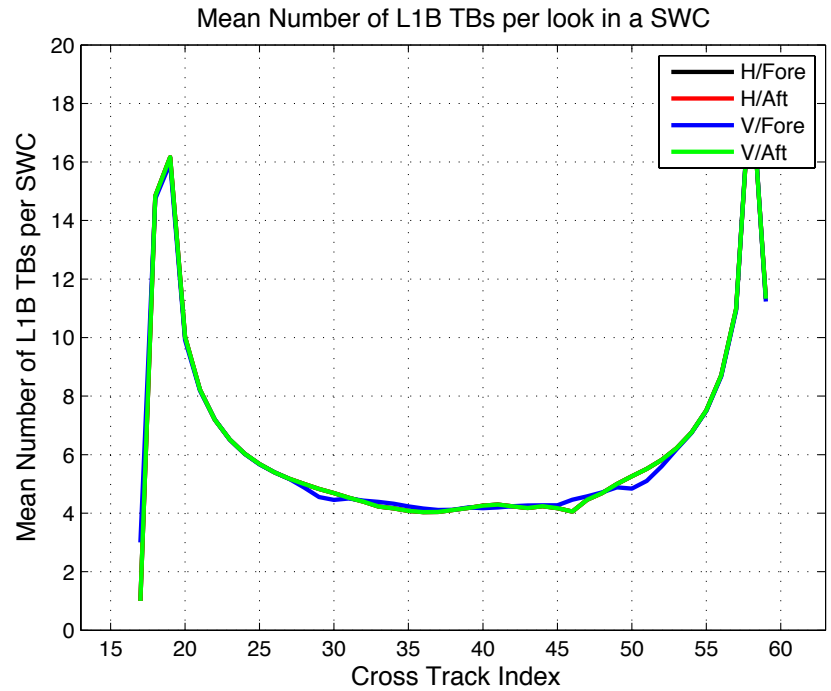
SMAP TB can resolve some structure here since it is much larger

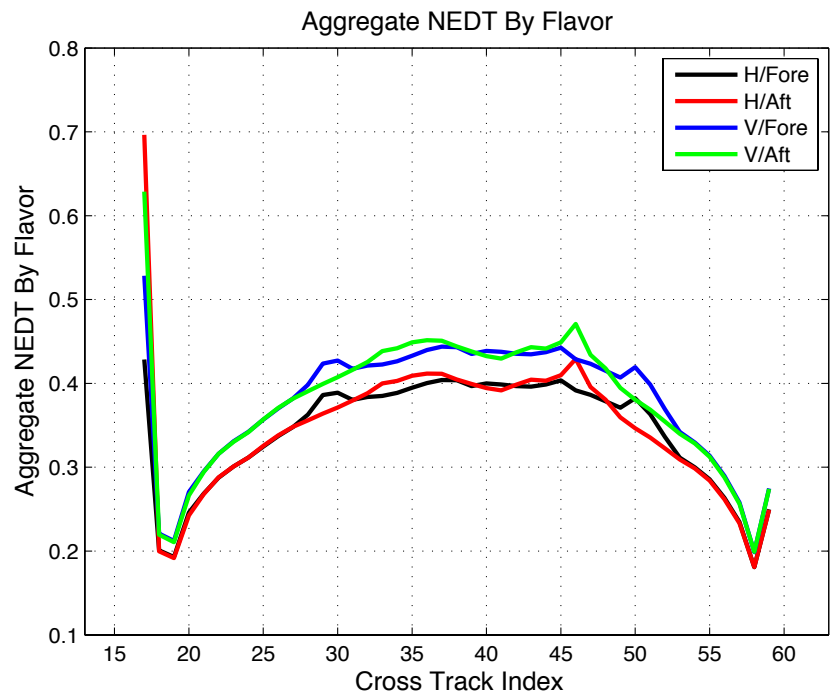

SMAP Speed Difference to WindSat / SSMI/S
TB−only Bias: 0.14
TB−only anc sss Bias: 0.12
TB−only RMS: 1.08
TB−only anc sss RMS: 1.68
Speed Difference [m/s]
WindSat / SSMI/S Wind Speed [m/s]
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30


Wind Direction Difference to ECMWF
Wind Direction Difference to ECMWF
WindSat / SSMI/S Wind Speed [m/s]
TB–Only DIRTH Vector RMS (>12): 18.36
0
10
20
30
40
50
60
70
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30

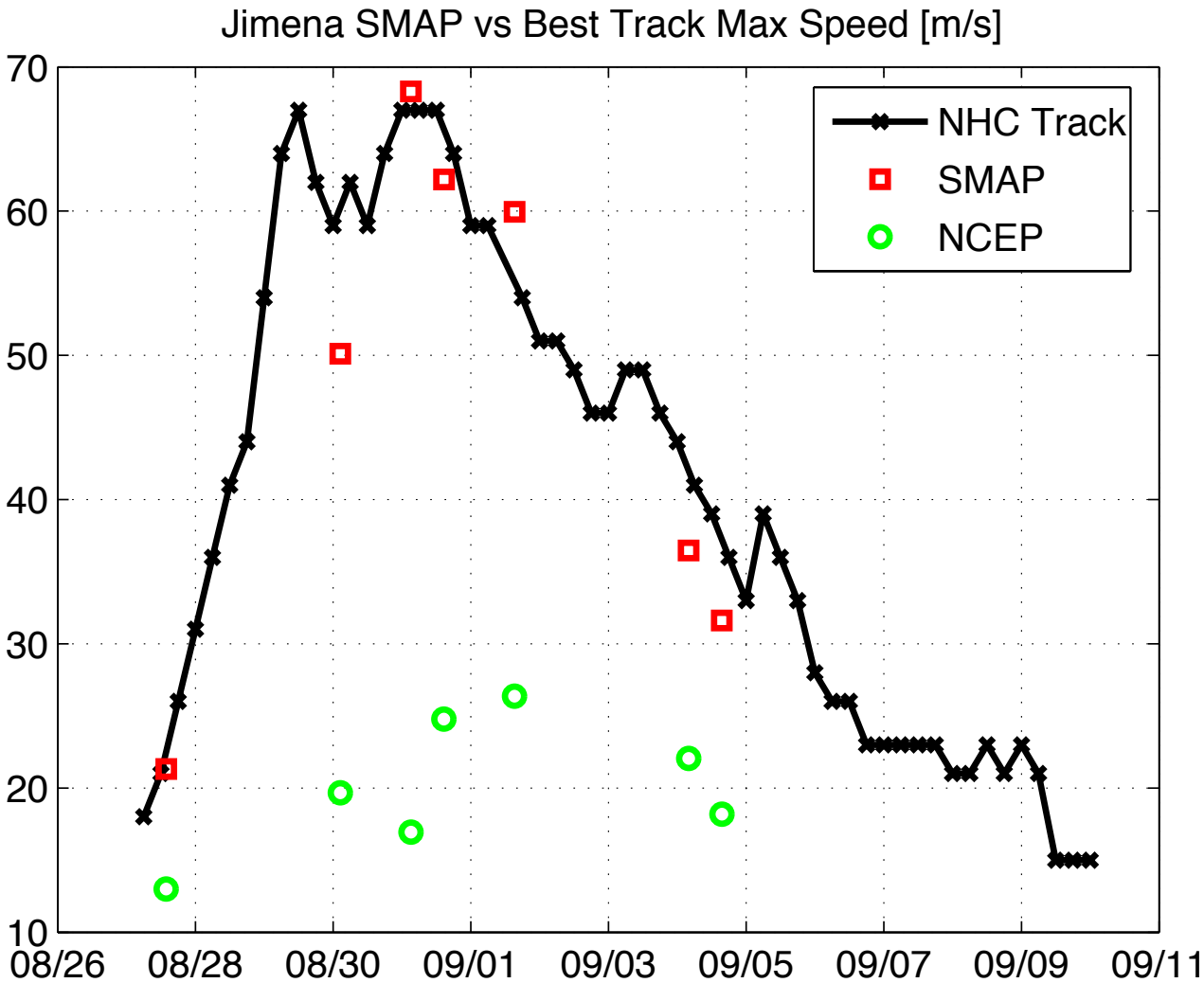
L2A Gridding

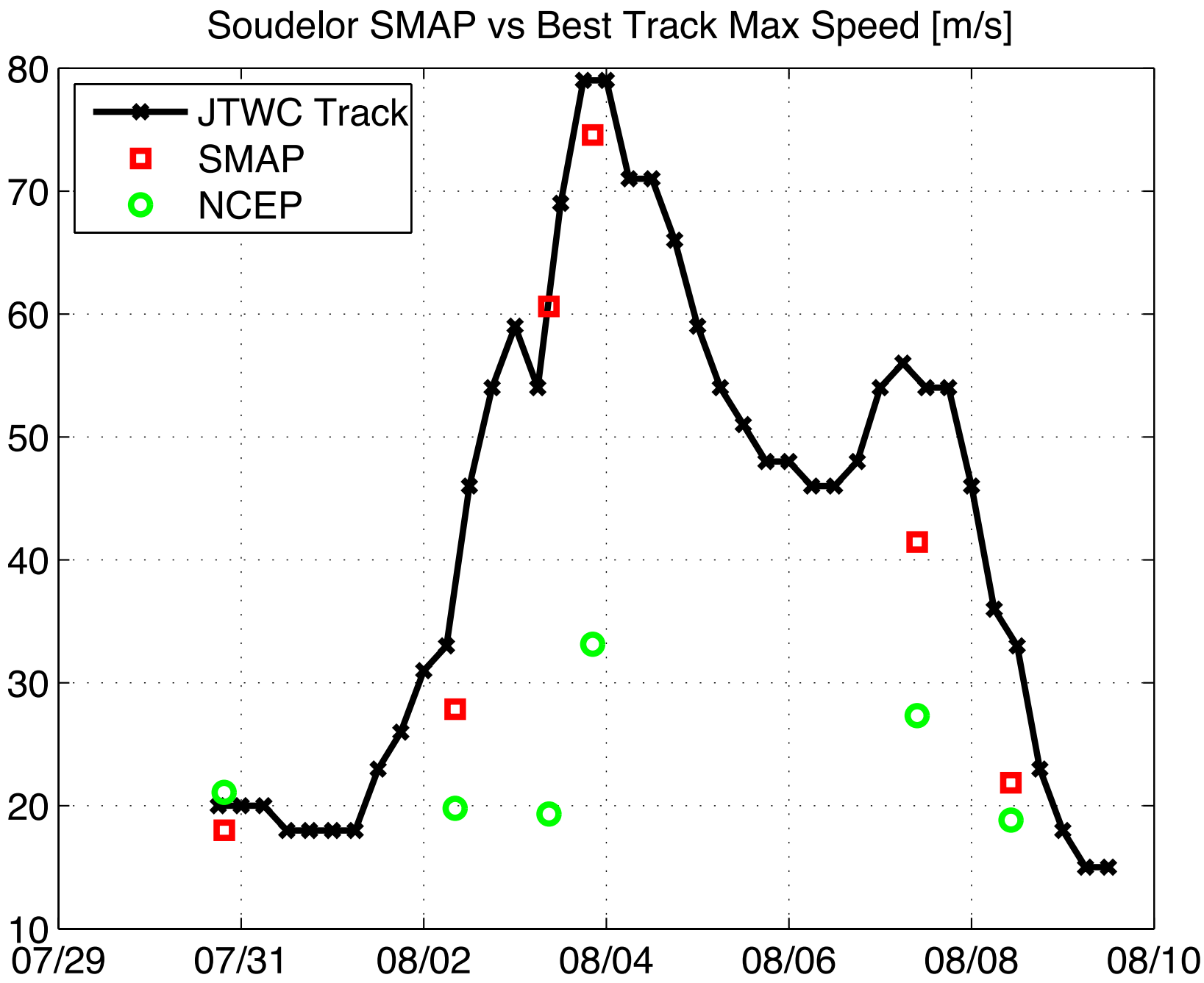


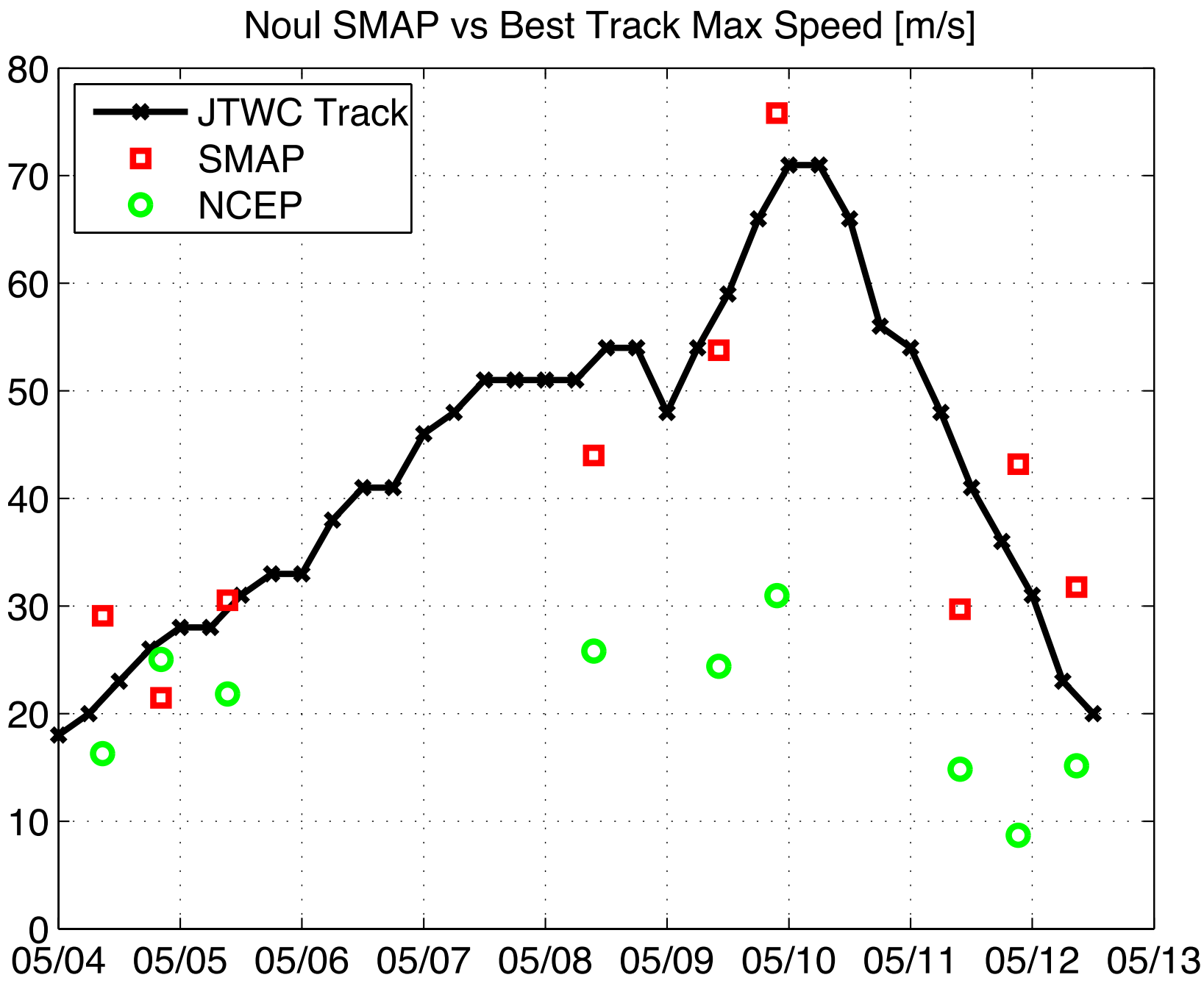


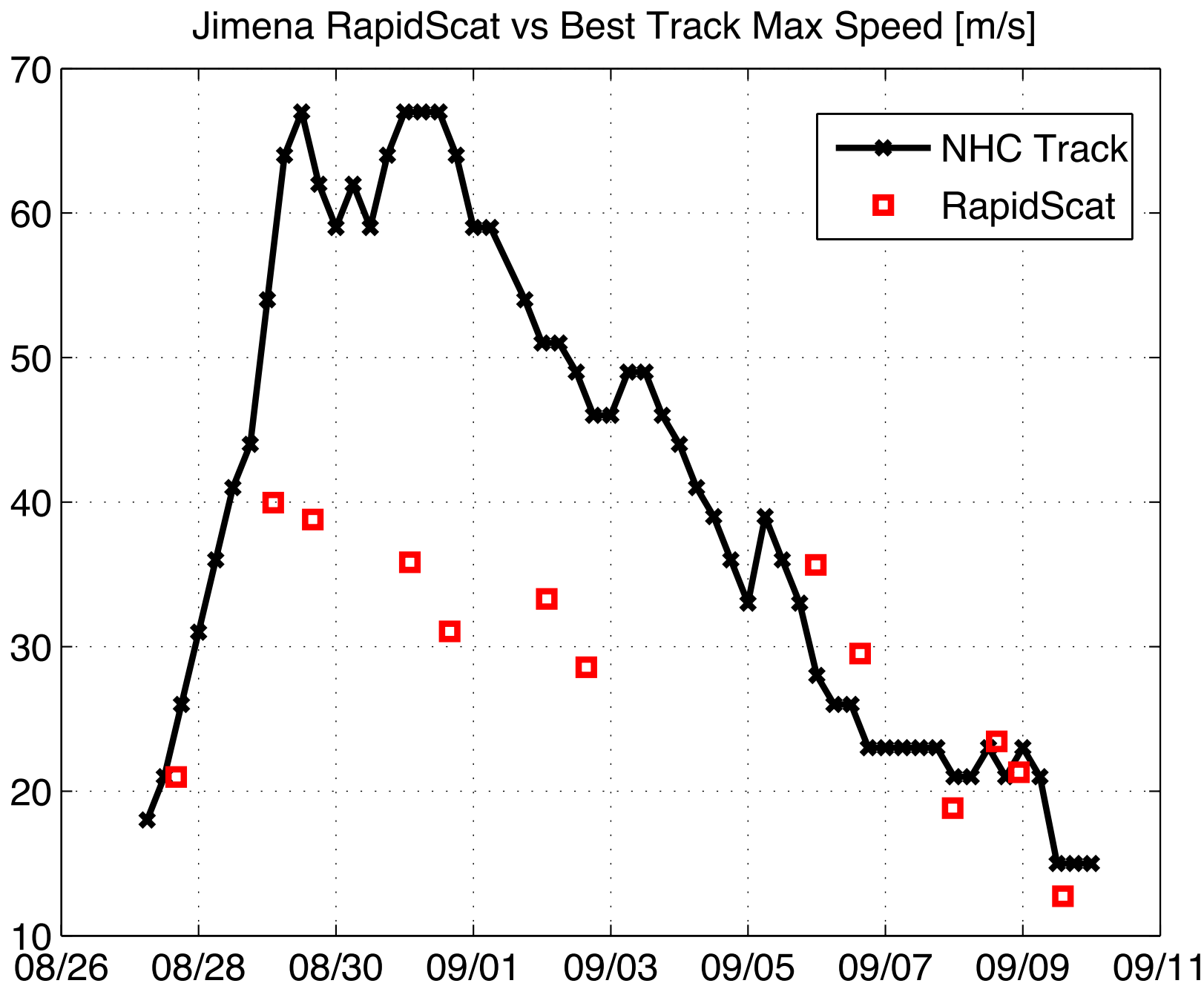


Maximum Jimena Wind Speed (Cat 4)
August-September 2015
SMAP radiometer wind speed can reach 70 m/s




Soudelor SMAP vs Best Track Max Speed [m/s]
JTWC Track
SMAP
NCEP
80
70
60
50
40
30
20
10
07/29
07/31
08/02
08/04
08/06
08/08
08/10


Noul SMAP vs Best Track Max Speed [m/s]
JTWC Track
SMAP
NCEP
0
10
20
30
40
50
60
70
80
05/04
05/05
05/06
05/07
05/08
05/09
05/10
05/11
05/12
05/13


Jimena RapidScat vs Best Track Max Speed [m/s]
NHC Track
RapidScat
70
60
50
40
30
20
10
08/26
08/28
08/30
09/01
09/03
09/05
09/07
09/09
09/11