Assessment of Saildrone extreme wind measurements in Hurricane Sam using MW satellite sensors

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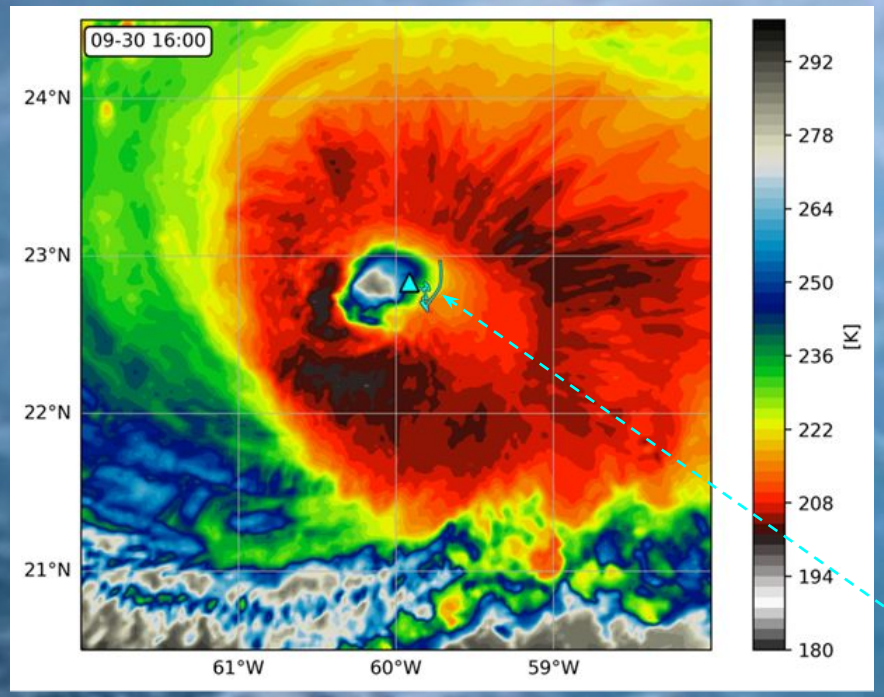
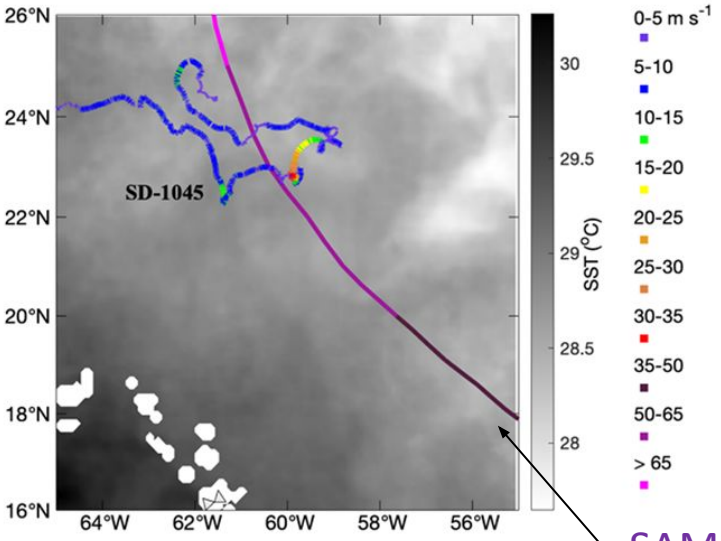


▲ Saildrone 1045 position

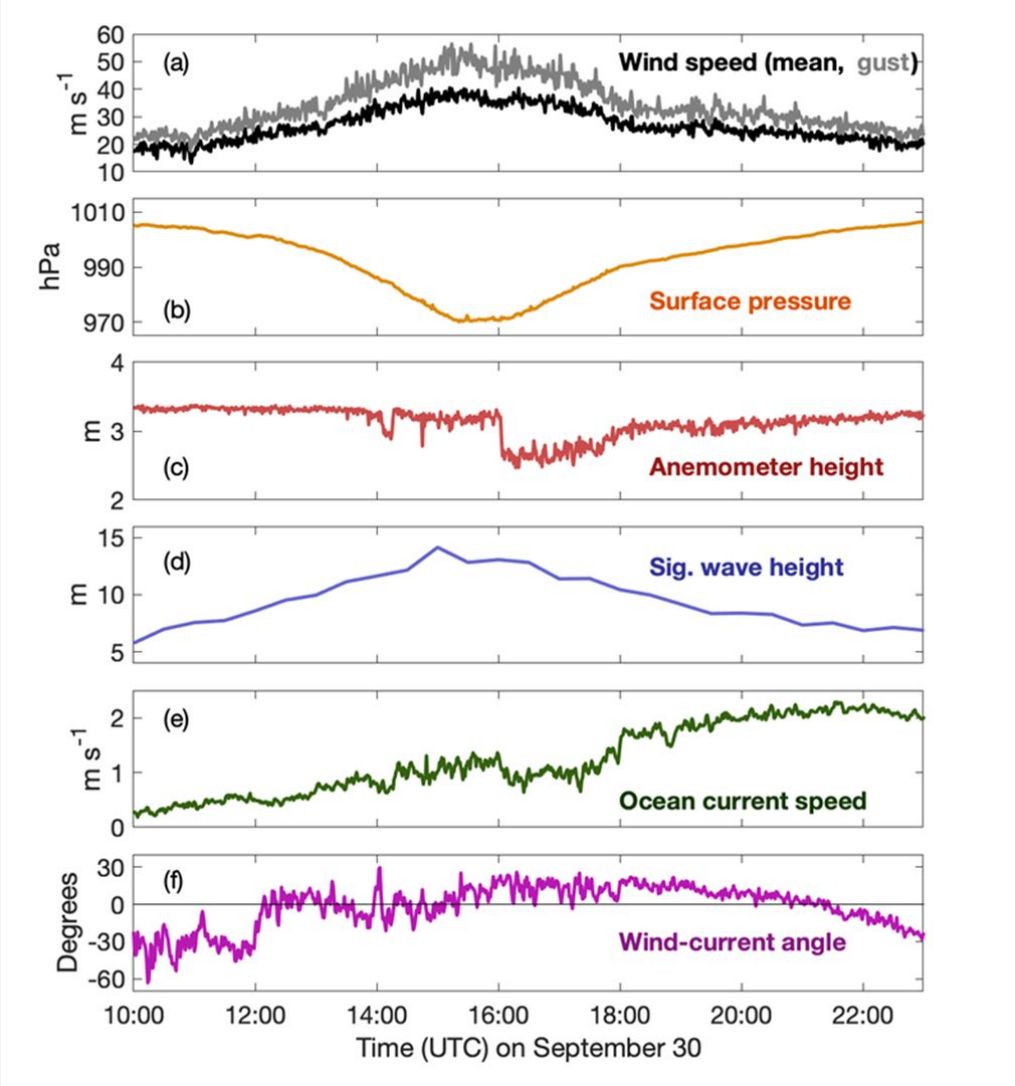
Acknowledgment: This analysis was supported by NASA OVWST

Saildrone (SD) mission in Hurricane SAM

- **NOAA/SD project** (summer 2021): 5 unmanned solar/wind powered Saildrones to monitor Tropical Atlantic/Caribbean, deployed in areas with high probabilities of storms.
- **SAM**: long lasting major Atlantic hurricane, Cat. 3-4 for 8 days (Sep/Oct 2021)
- **On Sep 30, 2021, SD-1045 was in the core of Hurricane Sam**
- Unprecedented observations of ocean surface variables within a major hurricane: winds, SLP, SHW, SST, RH, currents



SAM track



More details at www.pmel.noaa.gov/saildrone-hurricane2021/ and Foltz et al, 2022, *EOS*, under review

Objective

Assess accuracy of SD extreme wind measurements, using many datasets:

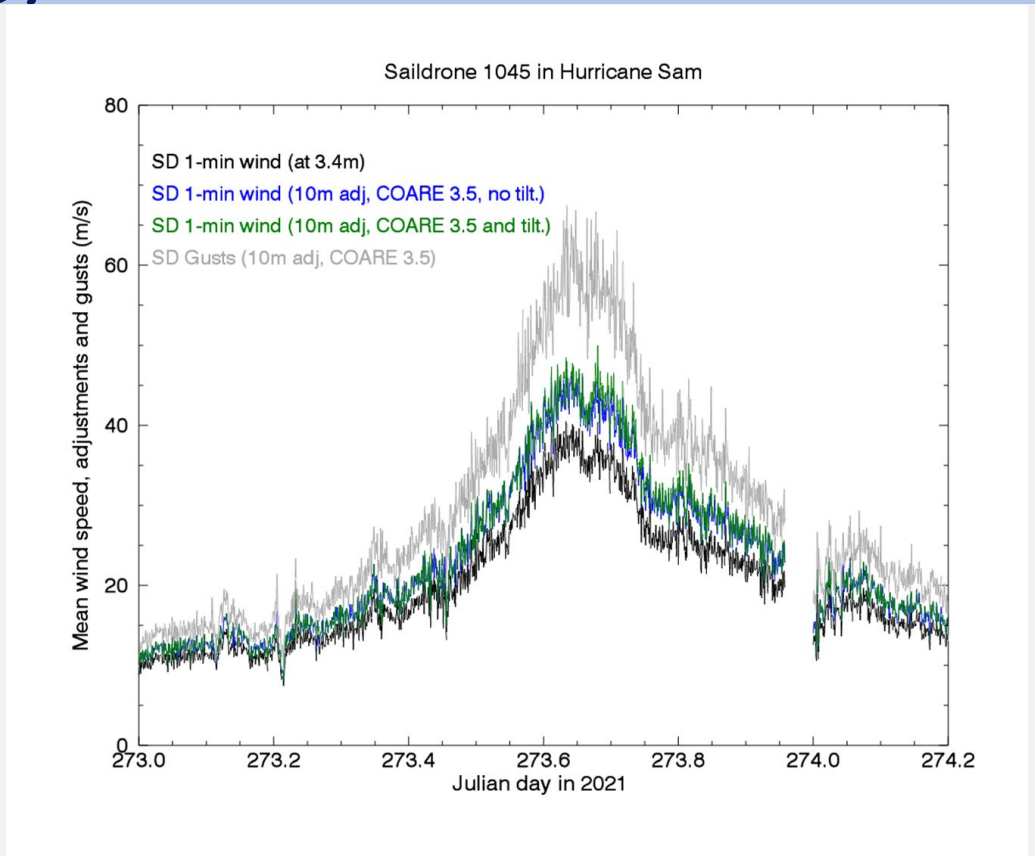
- MW Satellite Sensors: radiometers (SMAP, AMSR2), scatterometers (ASCAT) , SAR
- NDBC Buoy 41044
- HWRF model.

Methodology

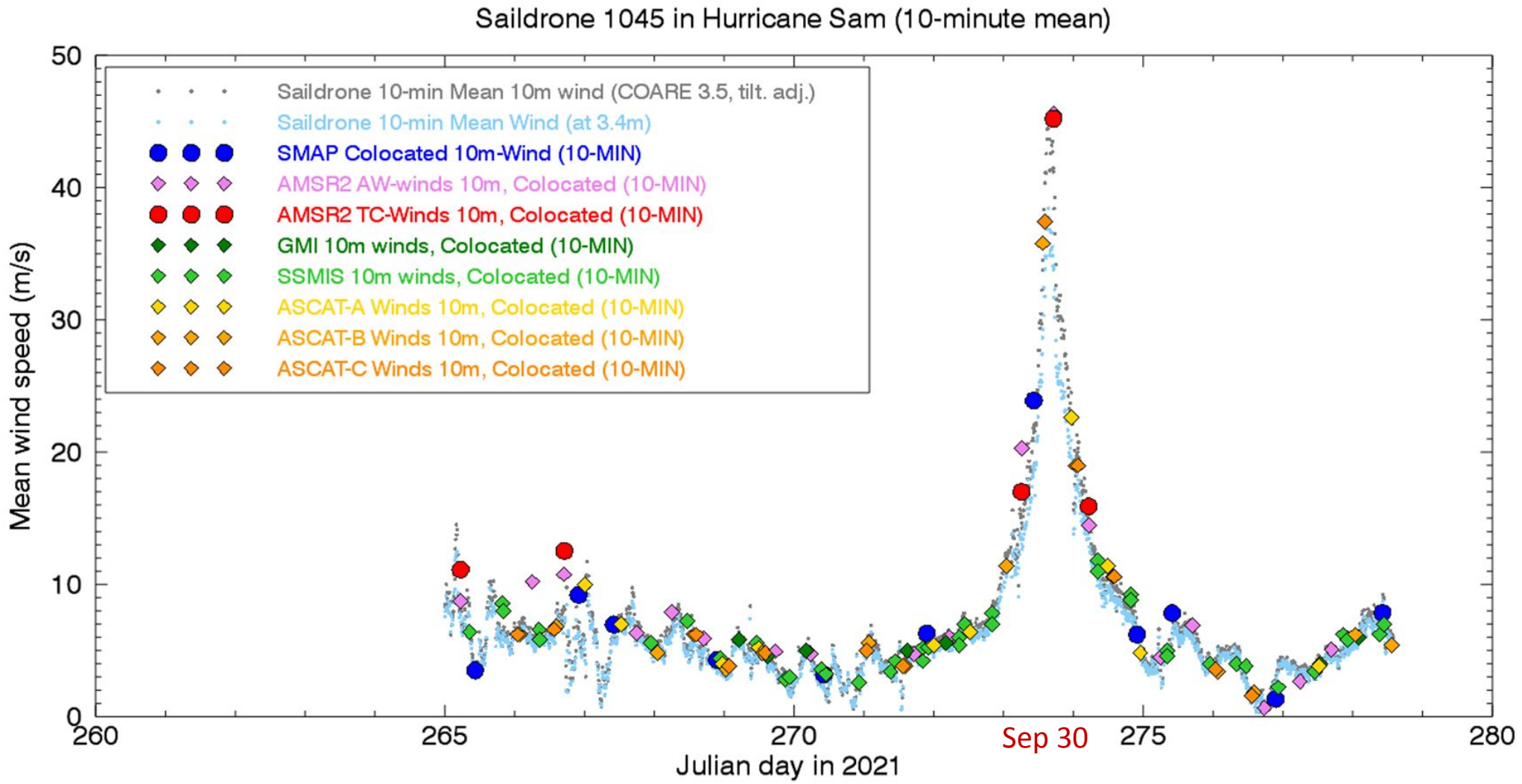
Homogenize the observations to common height (10m) and account for differences in observed spatial/temporal scales

Approach:

1. Conversion to 10 m reference height in unusually extreme conditions: Use COARE 3.5 algorithm for 10 m adjustment (Fairall et al, 2003; Edson et al, 2013); adjust for tilting.
2. Time average SD to 10-min when comparing to low resolution (25-40 km) satellite
3. Tight co-location between SD, Buoy, and satellites: 10 minutes, 25 km
4. Apply similar adjustments to buoy data
5. Not possible to compare SD and Buoy directly use Sat and HWRF for cross-comparisons.



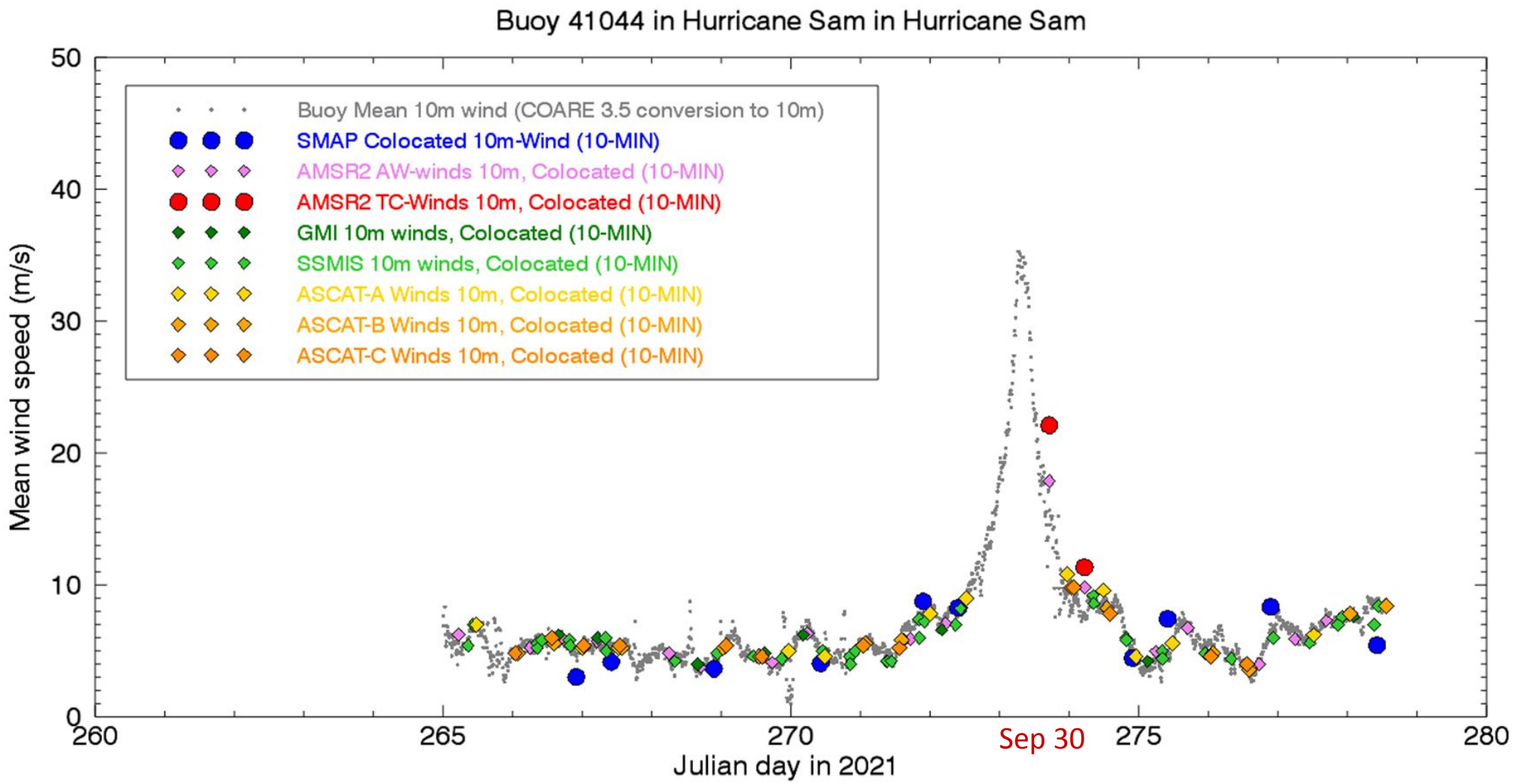
SD-1045 vs Satellite Winds



(Sep 22-Oct 5)

SD peak winds at ~15 UTC

Buoy 41044 vs Satellite Winds



Buoy peak winds ~6 UTC

AMSR2 TC-Winds at 17 UTC

AMSR2 TC- wind product:

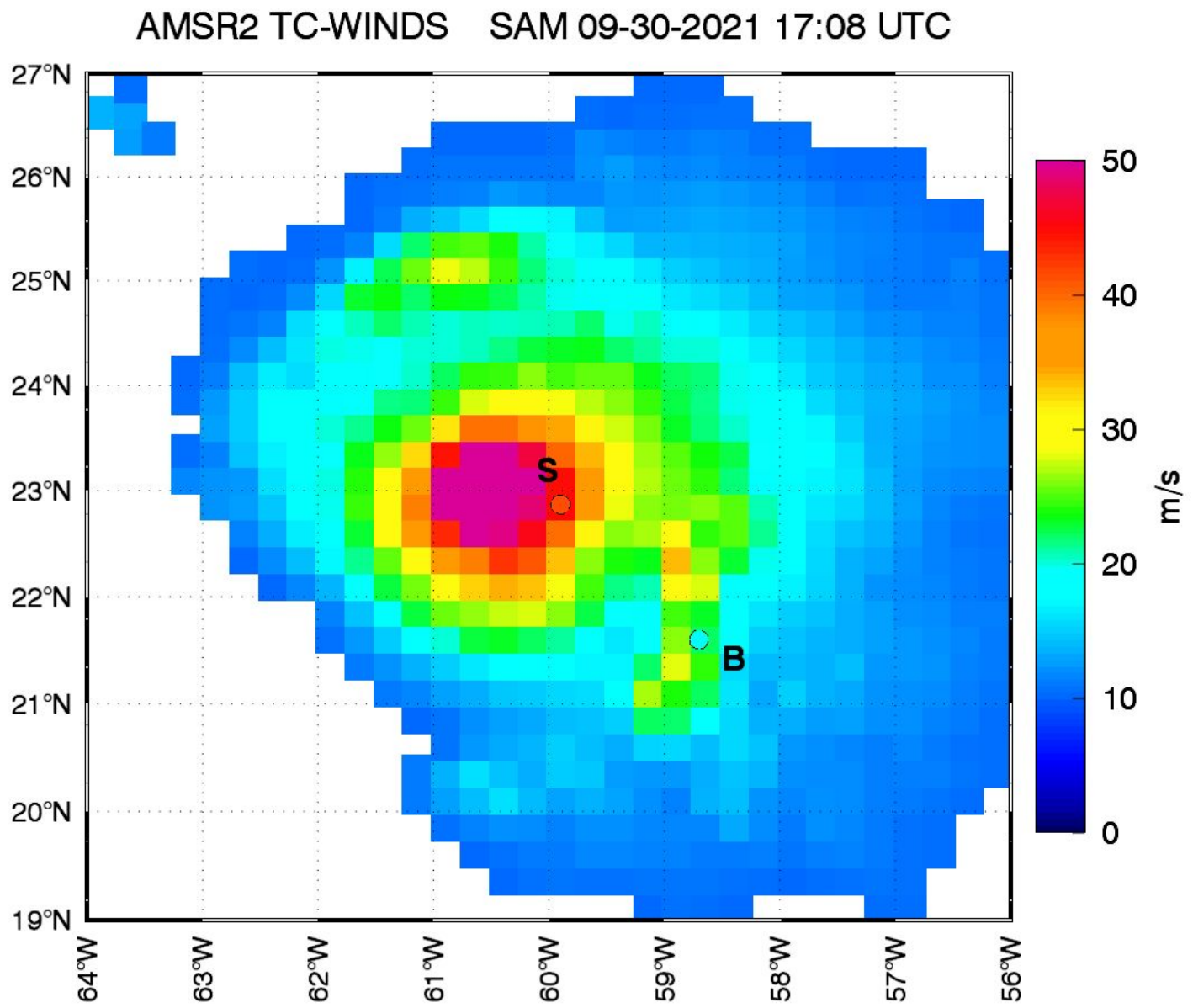
- Specifically trained for storm conditions and in rain
- 25 km grid; considered ~10-min winds
- ~10% uncertainty
- Processed at RSS in NRT:

https://www.remss.com/tropical-cyclones/tc-winds/

(Meissner et al, 2021; Manaster et al, 2021)

AMSR2 TC-WINDS SAM 09-30-2021 17:08 UTC
Max AMSR2 Wind speed (m/s) 60.6

SD vs	**AMSR2** Wind speed (m/s)	**41.5**	**45.2**
Buoy vs	**AMSR2** Wind speed (m/s)	**17.7**	**22.1**



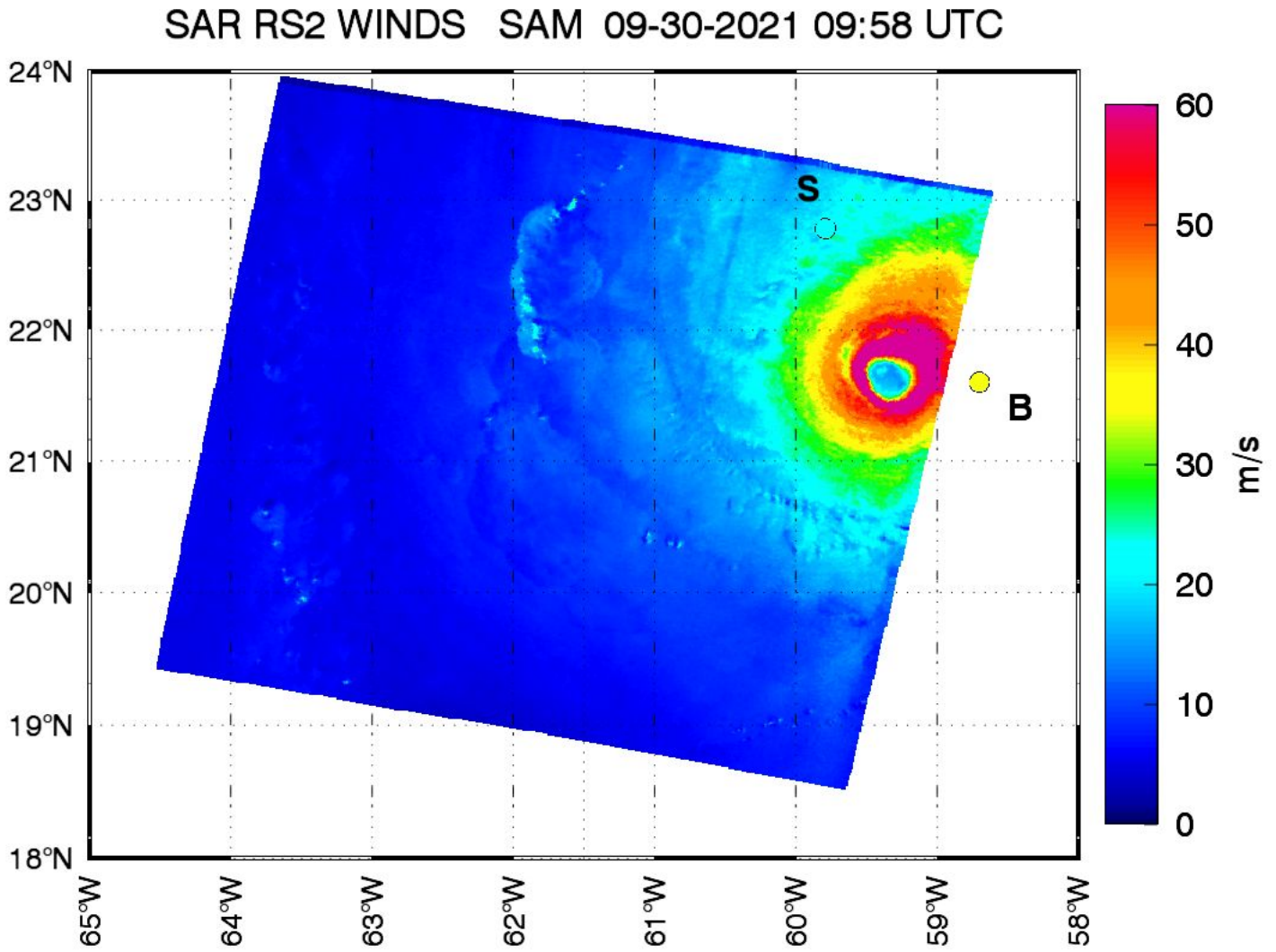
SAR (RadarSat-2) ~10 UTC

SAR wind products:

- We used SAR winds from Ifremer
- Accurate in TCs up to Cat. 5
- 3 km grid, considered ~ 1-min winds
- Processed at Ifremer in NRT:

https://cyclobs.ifremer.fr/app/tropical.

(Mouche et al, 2019; Combot et al, 2020)



SAR RS2 WINDS SAM 09-30-2021 09:58 UTC

Max SAR Wind speed (m/s)	80.0	
SD vs **SAR** Wind speed (m/s)	**20.7**	**20.3**
Buoy vs **SAR** Wind speed (m/s)	**32.4**	**n/a**

HWRF 15 UTC

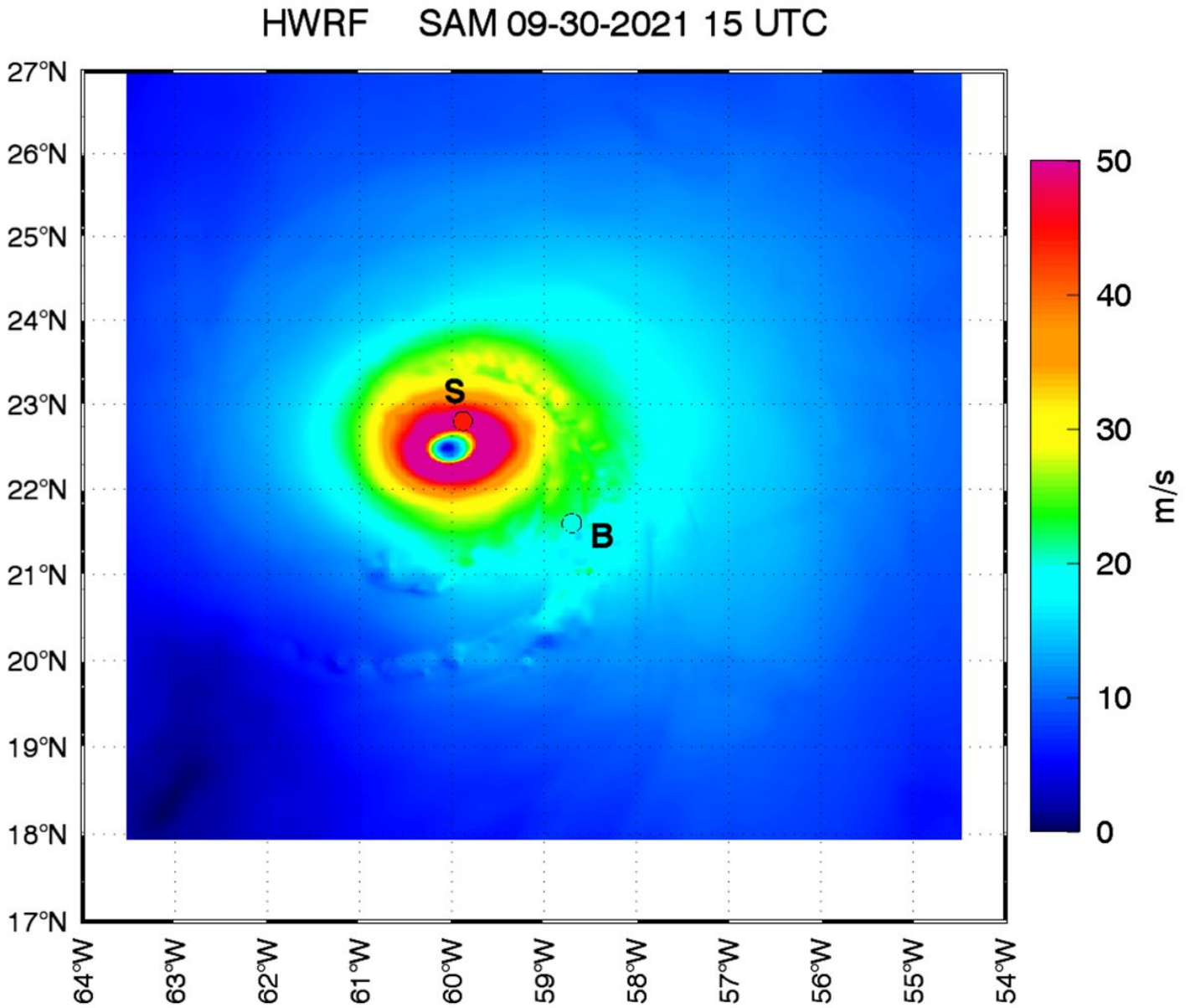
HWRF wind products:

- We used 0-hour analyses at 0,6,12,18Z and 3-hr forecast at 15Z
- 10 m winds
- 1.5 km grid, considered ~ 1-min winds
- Later resampled at Sat resolution
- Processed at NOAA/NWS/NCEP:

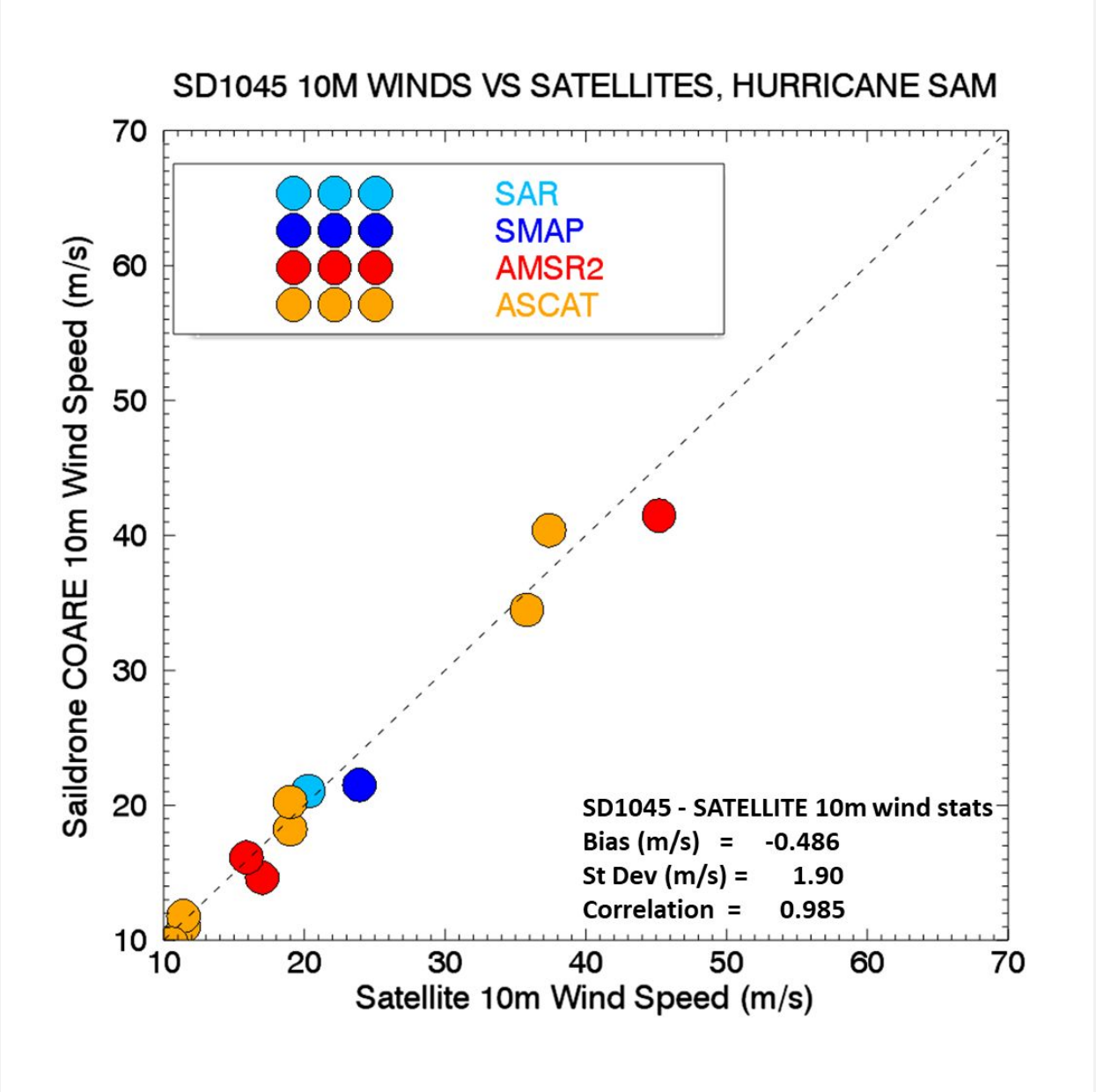
(Biswas, 2018)

HWRF WINDS SAM 09-30-2021 15 UTC

Max HWRF Wind speed (m/s)	67.9	
SD vs **HWRF** Wind speed (m/s)	44.4	**59.3**
Buoy vs **HWRF** Wind speed (m/s)	19.8	**20.3**
Max Resampled HWRF Wind speed (m/s)	52.2	



Summary Scatterplot of SD vs Satellite, 30 Sep 2021



SUMMARY

Saildrone SD-1045 mission in Hurricane Sam (Sep 2021) exceeded expectations
Great potential for monitoring storms in remote locations

- SD observed peak winds of 40.5 m/s at a nominal height of 3.4m
- When converted to 10 m □ SD_{10m} ~ 50 m/s
- Conversion to 10 m winds performed using sophisticated algorithm for atmospheric boundary layer: COARE 3.5
- SD winds here were compared to all available MW Satellite passes for Sep 30
- Remarkable agreement between SD-1045 and Satellite at all winds (0-46 m/s)
- Indirect comparisons with buoys using satellite and HWRF as third-party data
- First and only assessment so far in hurricane
- Here we developed a methodology for comparisons with satellite winds
- More missions are planned for 2022
- SD data simultaneous with SAR and SMAP would be an ideal configuration
- This analysis □ Ricciardulli et al, being submitted to *Remote Sensing* in April 2022

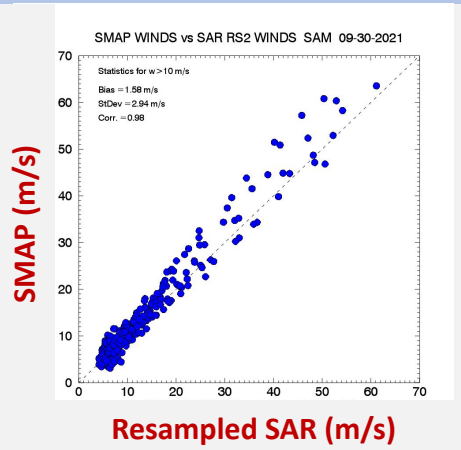
Extra slides

SAR vs SMAP vs HWRF: 10-12 UTC

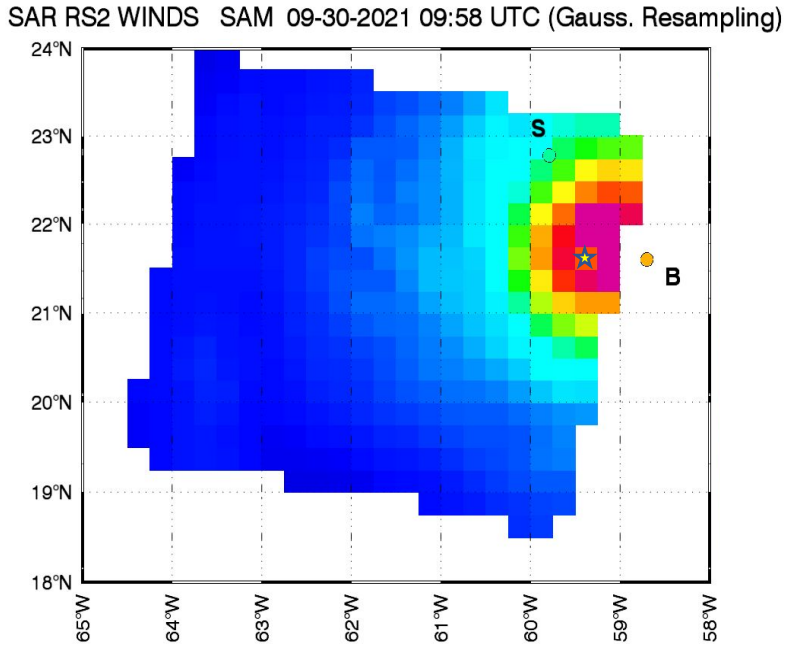
Homogenizing spatial scales:

In order to compare high-resolution SAR (3 km) or HWRF (1.5 km) to low-resolution SMAP (25 km grid), we performed a resampling of the SAR and HWRF grids using a Gaussian weighted window (40 km half-power width) resembling the SMAP signal distribution within a satellite footprint. (methodology in Manaster et al, 2021)

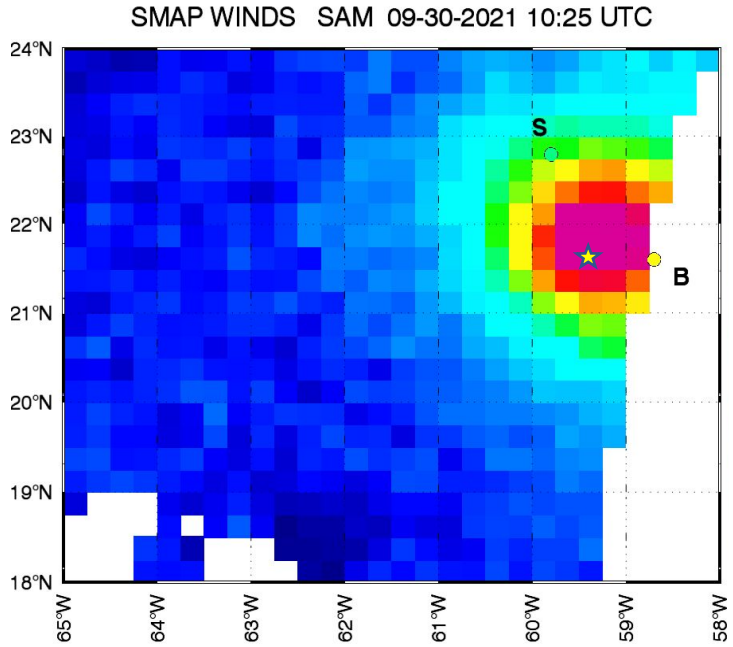
The resampled SAR and HWRF wind fields are consistent with SMAP.



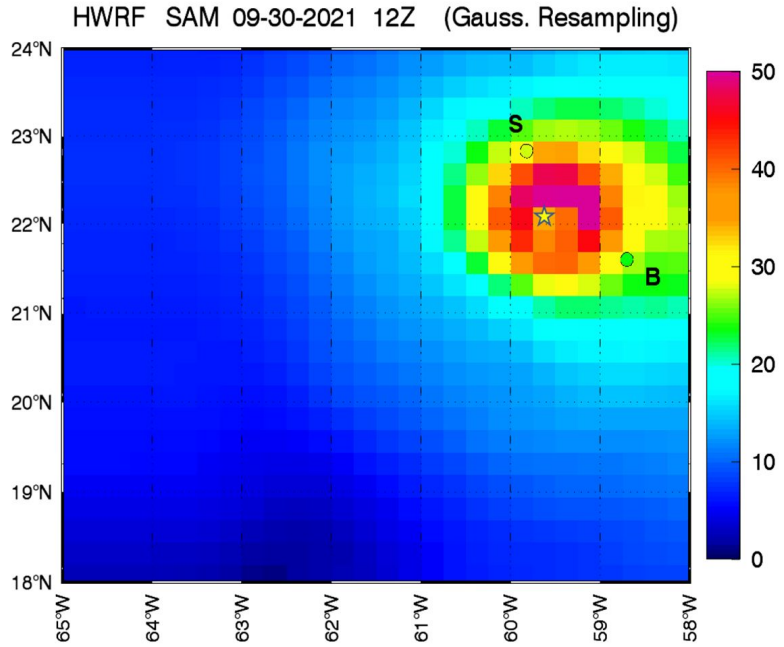
Resampled SAR ~10 UTC



SMAP ~10:30 UTC



Resampled HWRF ~12 UTC

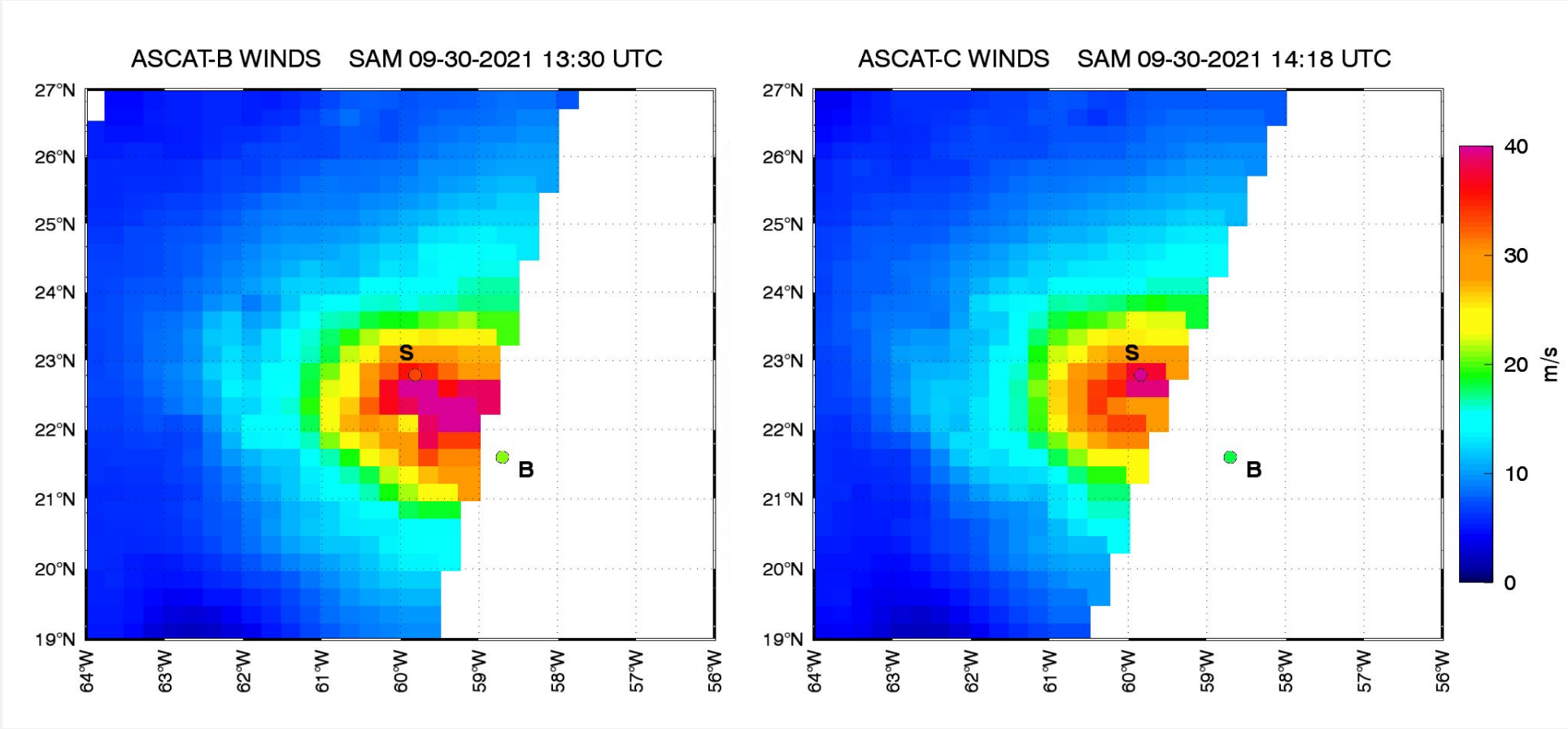


ASCAT-B and -C TC-Winds at 13-14 UTC

ASCAT -B and -C: Processed at RSS, latency ~ days

- Global winds (25 km grid), ASCAT-A,B,C developed as Climate Data Record (Ricciardulli and Manaster, 2021);
- Not significantly affected by rain in storms; Decreased signal sensitivity above 35 m/s, might be biased low > Cat 1

www.remss.com/ascat



ASCAT-B WINDS SAM 09-30-2021 13:30 UTC

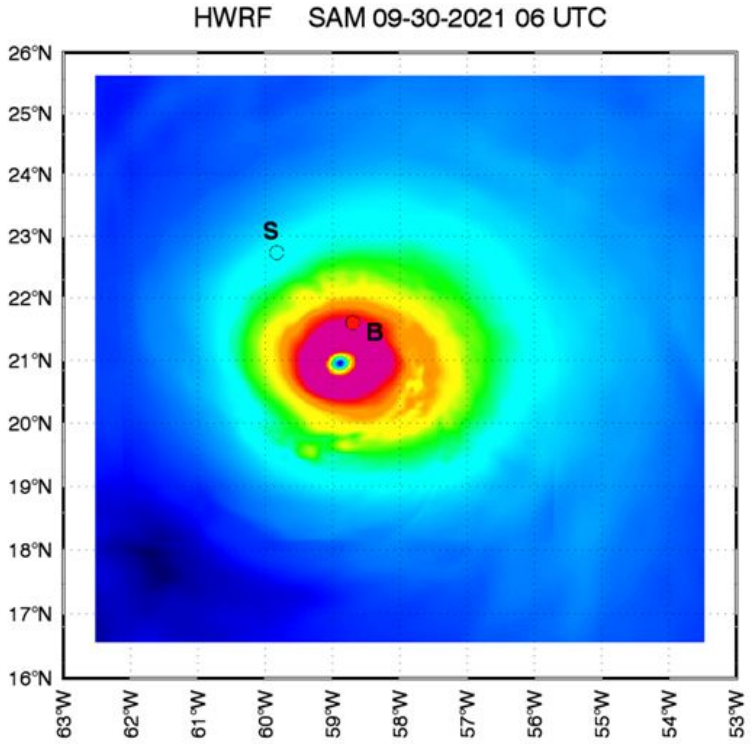
Max ASCAT-B Wind speed (m/s)	47.2	
SD vs **ASCAT-B** Wind speed (m/s)	**33.7**	**35.8**
Buoy vs **ASCAT-B** Wind speed (m/s)	**20.9**	**n/a**

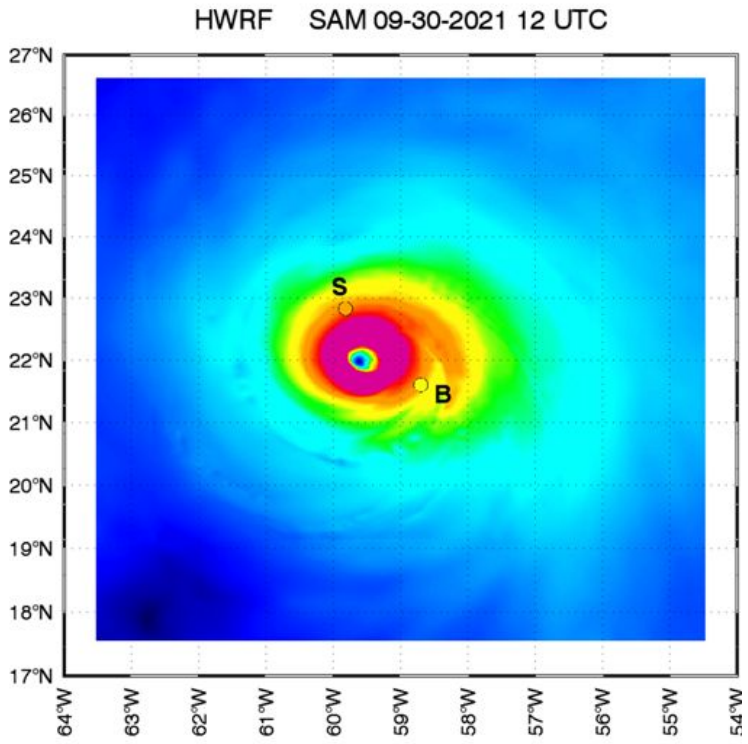
ASCAT-C WINDS SAM 09-30-2021 14:18 UTC

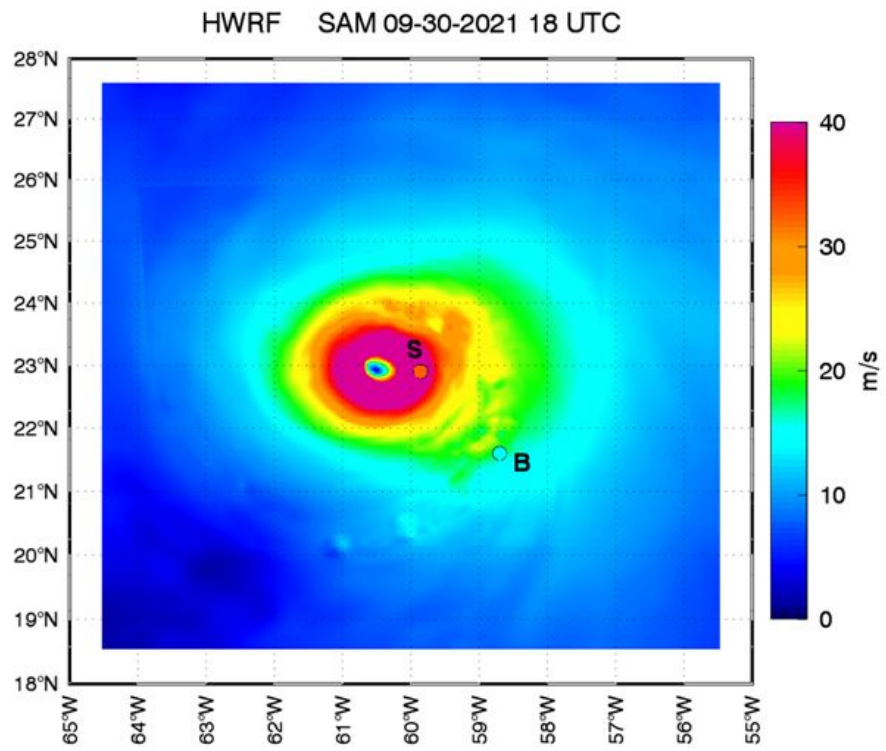
Max ASCAT-C Wind speed	39.4	
SD vs **ASCAT-C** Wind speed	40.4	**37.4**
Buoy vs **ASCAT-C** Wind speed	**18.1**	**n/a**

OTHER HWRF SCENES: 06,12,18 UTC

Sharp wind gradients and even small inaccuracies in the storm center position in the HWRF model make a comparison with SD or buoy in-situ data very challenging







HWRF WINDS 06 UTC

Max HWRF Wind speed (m/s)	65.0	
SD vs **HWRF** Wind speed (m/s)	**15.1**	**14.5**
Buoy vs **HWRF** Wind speed (m/s)	**35.6**	**43.7**

HWRF WINDS 12 UTC

Max HWRF Wind speed (m/s)	69.4	
SD vs **HWRF** Wind speed (m/s)	**27.7**	**31.7**
Buoy vs **HWRF** Wind speed (m/s)	**23.6**	**28.3**

HWRF WINDS 18 UTC

Max HWRF Wind speed (m/s)	65.0	
SD vs **HWRF** Wind speed (m/s)	**32.6**	**55.5**
Buoy vs **HWRF** Wind speed (m/s)	**15.3**	**18.4**

Hurricane Sam wind cross-section, 30 Sep 10-12 UTC

High resolution data (solid lines)

- Small eye (~ 50 km)
- Very sharp eyewall
- SAR minimum winds ~ 14 m/s
- HWRF minimum winds ~ 1 m/s !

Resampling to a low resolution:

- Challenging resampling due to very small size of eye and core of the storm
- Resampled SAR consistent with SMAP
- HWRF resampled minimum is much lower than satellite.