Characterization of hurricane structure from satellite-derived wind fields

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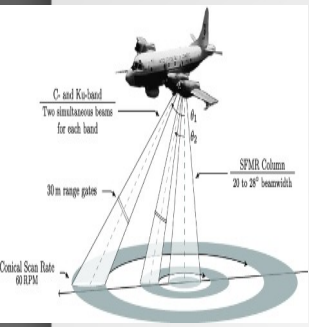
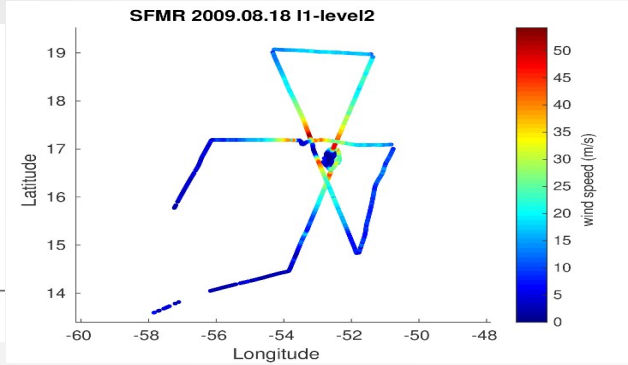
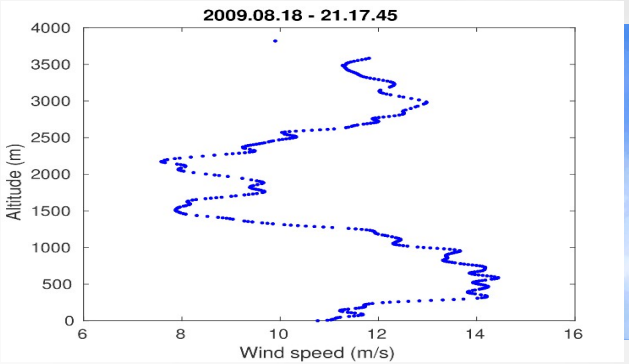
ESA MAXSS project:
Extreme wind inter-calibration & validation

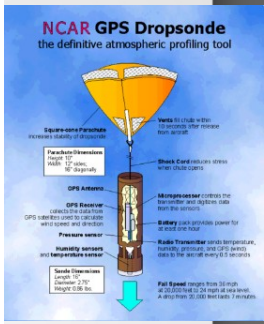
- Aim: To adjust radiometers & scatterometers high & extreme winds using SFMR (2010-2020)
  - **OSI SAF**: ASCAT-A, -B & -C, Rapidscat, OSCAT, OSCAT2, HY-2A & -2B
  - **REMSS**: Windsat (v7), AMSR-2 (v8), SMAP (v1)
  - **Ifremer**: SMOS (v2)
- Assess spatial representativeness, QC & SFMR calibration effects
- Ensure inter-calibration among all satellite systems
- To adapt triple collocation analysis for extreme wind error characterization of the different wind datasets

SFMR & GPS Dropsonde









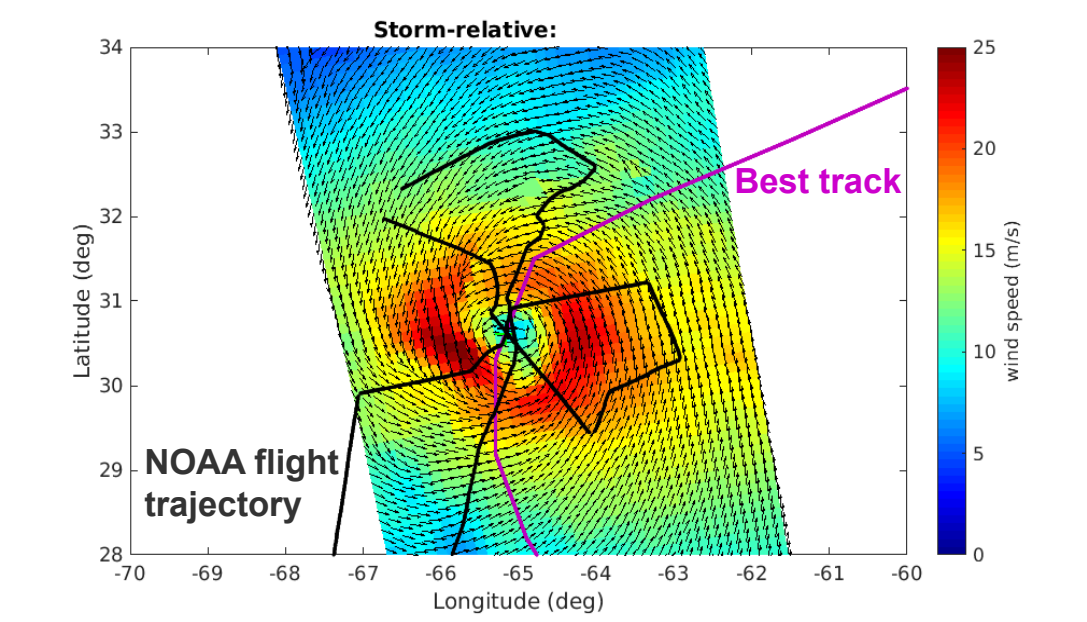
SFMR:

- Nadir-pointing radiometer at C-band.
- The equivalent neutral surface wind speed retrieved by inversion of a Geophysical Model Function.
- Surface wind retrieval are provided in **1-sec sampling** and the **aircraft position** is assigned to each wind retrieval.

Dropsondes:

- They provide the wind profile
- The 10m equivalent neutral surface wind speed and direction *empirically derived* by the **WL150 algorithm.**
- Surface wind value consists in an **height-weighted average** of the dropsonde readings available within the lowest **150m-layer** between 10m and 350m.

Triple collocations SFMR-SAT-Model

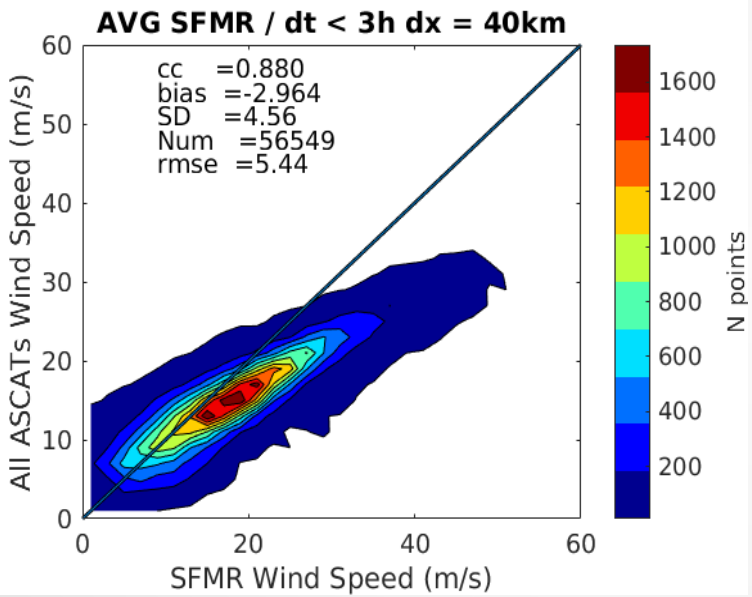


ASCAT wind field over Hurricane Karl on September 23rd, 2016

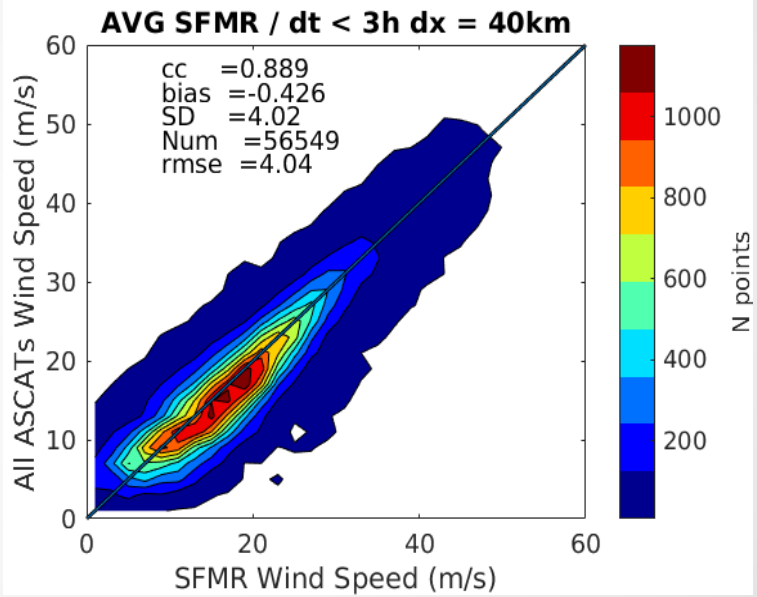
- All SFMR wind data available within a 10ºx10º box around TC centre
- SFMR collocations in storm-motion centric coordinates
- Model (ECMWF/MM) spatially and temporally interpolated to the Satellite wind field

Extreme wind adjustment using SFMR as reference

Original ASCAT winds

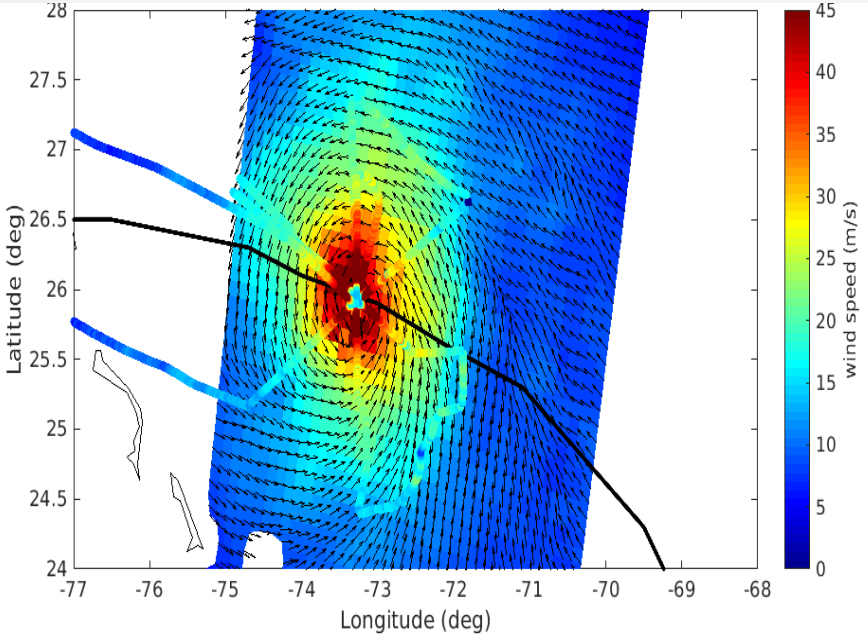


Adjusted ASCAT winds



- ***All scatterometer & radiometer winds adjusted using SFMR as reference***
- ***A similar exercise is done with ERA5***

ASCAT extreme wind adjustment



ASCAT adjusted wind field over Hurricane Dorian using SFMR winds as calibration reference

Objectives

- Develop algorithms for estimating hurricane structure parameters
- Compare estimates from multiple satellite and hurricane hunter data against reference best track data
- Confront different satellite data products to show which one best reflects the true nature of tropical cyclones

Radial Wind Profile Calculation

- Radial wind profiles interpolated from wind speed field along radial lines (length 500 km)
- Regular intervals of radials (15° spacing) ensure representative sampling

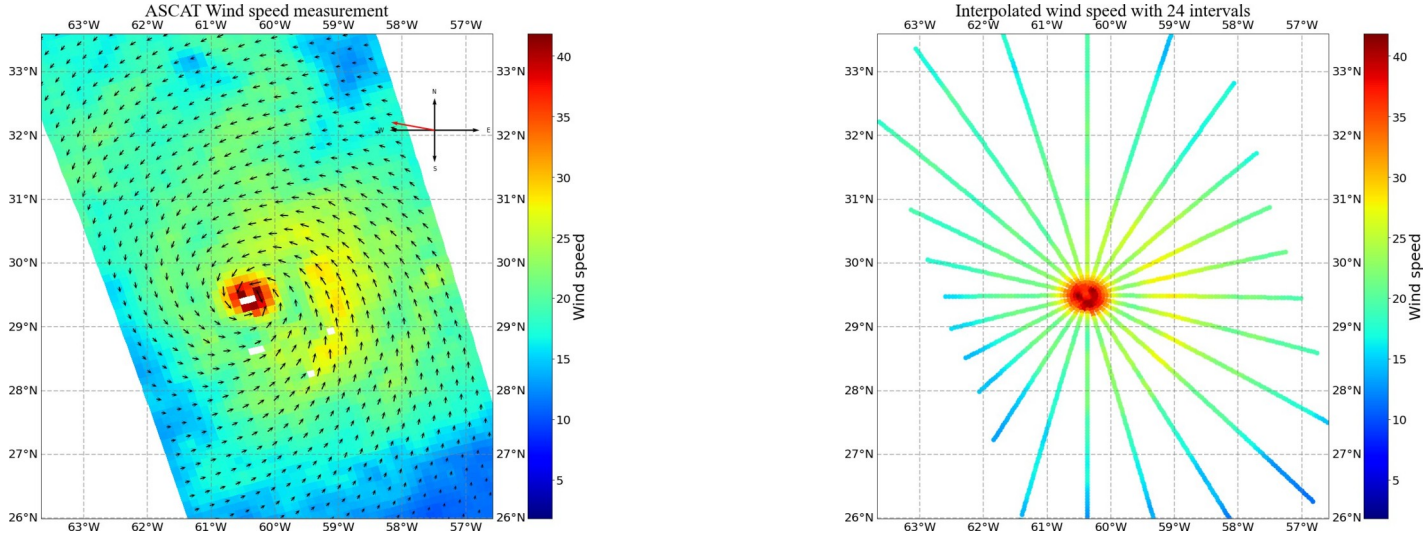


Figure: ASCAT wind field and interpolated profiles for Hurricane Epsilon

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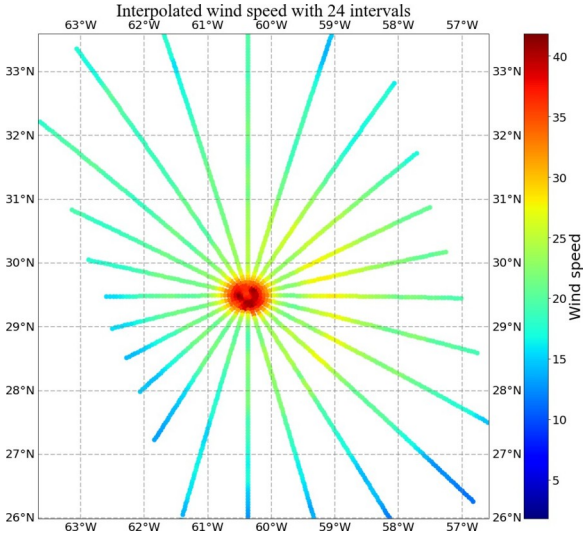


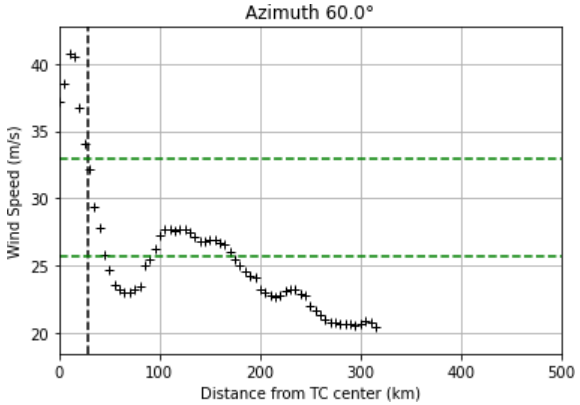


Figure: Interpolated wind profile from ASCAT wind field for Hurricane Epsilon

Wind Speed Profile Intersections

Several intersection selection techniques:

- **Closest/Farthest Method**
- **Sector-average Method:** Uses closest to averaged valid intersections within a TC sector (adopted from Lin et al., 2022)
- **Adjacent Method:** Uses closest to averaged neighboring valid intersections
- **Variance Method:** Selects intersection minimizing variance of valid intersections within a TC sector

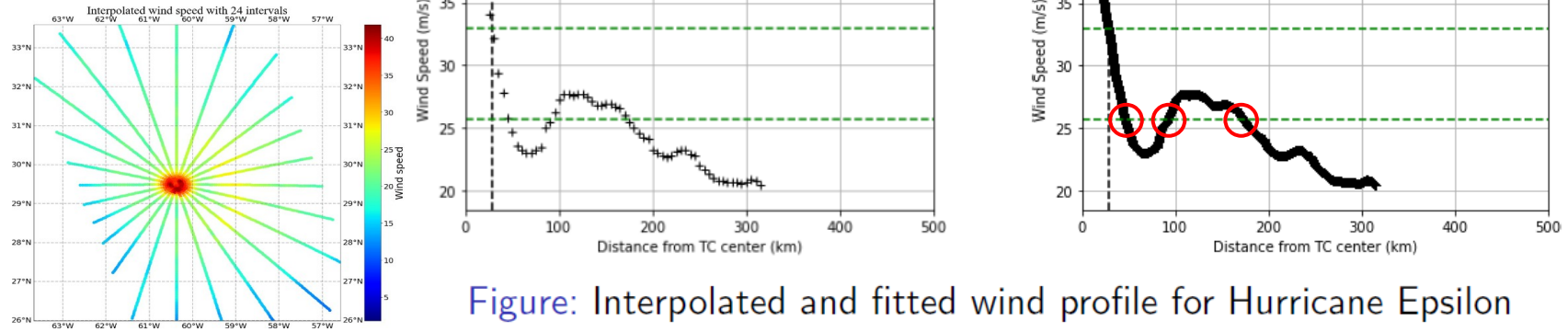


Figure: Interpolated and fitted wind profile for Hurricane Epsilon

Wind Radii Estimation Methods

Two methods for calculating wind radii:

- **Mean Method:** Averages all valid intersections within each sector
- **MAXSS-derived Method:** Selects the value closest to 90% of sorted intersection values

75°	30°	0°	60°	**15°**	45°	Mean
44.2	44.24	44.72	45.52	**46.17**	46.44	45.22

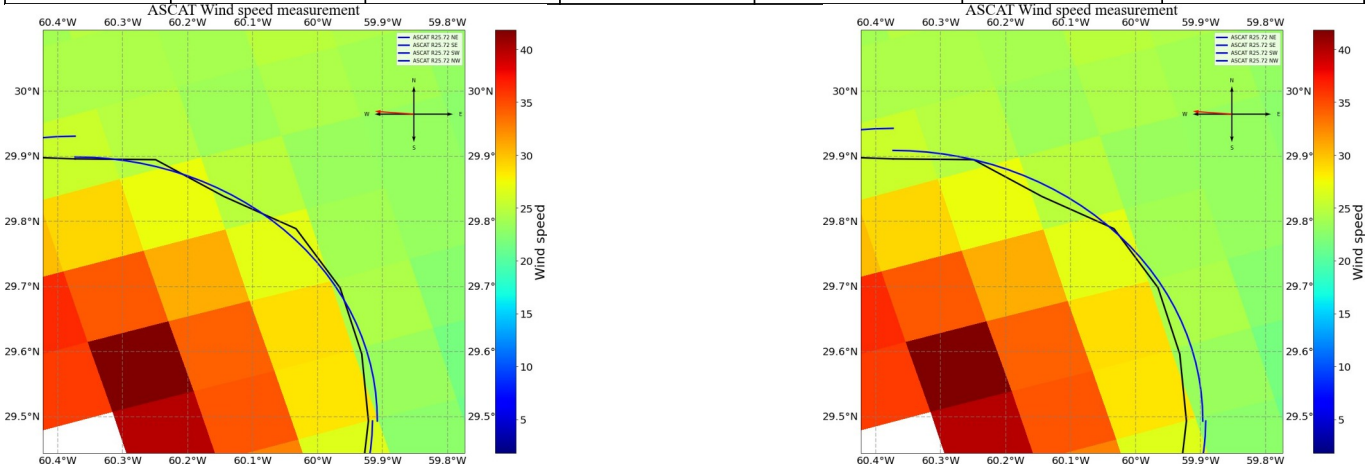


Figure: NE R50 estimates using the mean method (left) and the MAXSS-derived method (right)

Analyses of the Methods Used

Several methods for selecting intersection points or estimating wind radii were analyzed, using scatter plots and several statistical parameters:

- Bias: μ *or* $\langle x - y \rangle$
- Standard Deviation: σ *or* *SD*
- Pearson Correlation Coefficient: ρ

ASCAT vs BT wind radii

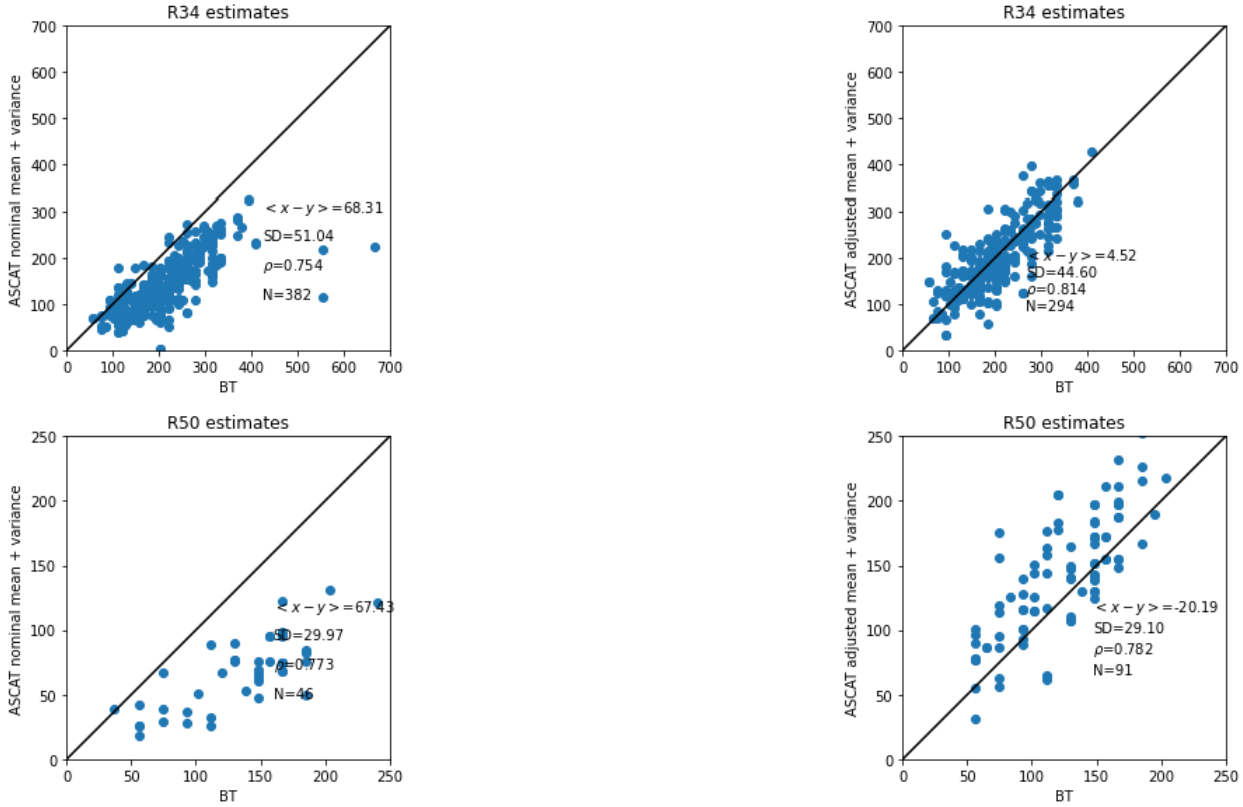


Figure: Scatter plots of R34 (top) and R50 (bottom) estimates for ASCAT vs BT using nominal (left) and adjusted (right) ASCAT data

Adjusted ASCAT vs BT Comparison

Table: Statistical performance of the R34 (top) and R50 (bottom) derived from adjusted ASCAT wind data with different methods, using BT data as reference

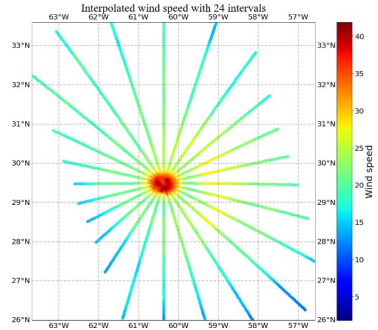
N = 294		closest	farthest	variance
MAXSS	μ	-1.67	-15.12	-3.32
	σ	48.83	58.39	49.04
	ρ	0.789	0.75	0.789
Mean	μ	6.98	-3.6	4.52
	σ	43.5	46.86	44.6
	ρ	0.821	0.809	0.814

N = 91		closest	farthest	variance
MAXSS	μ	-23.48	-26.33	-24.27
	σ	31.43	31.29	31.6
	ρ	0.778	0.774	0.774
Mean	μ	-18.67	-22.1	-20.19
	σ	29.66	28.65	29.1
	ρ	0.773	0.787	0.782

Mean method:

- slightly outperforms MAXSS-derived method
- is less impacted by the intersection choice method

Increasing the Number of Intervals



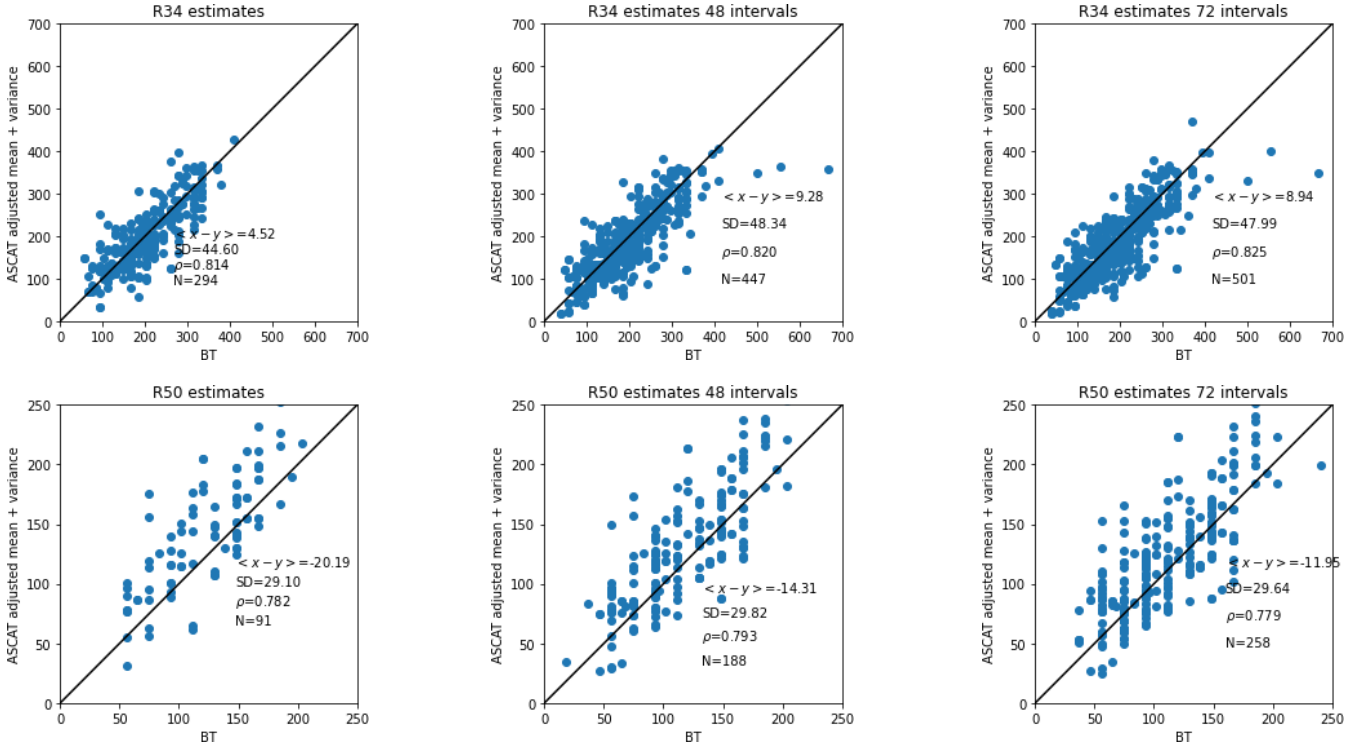


Figure: Adjusted ASCAT vs BT estimates of R34 and R50, using the variance and mean methods, with 24, 48 and 72 intervals

Study of Outliers: Hurricane Close to Land

The land impact invalidate the assumption of steady structure.

Possible solution:

- Flag cases with a lot of missing data close to the TC

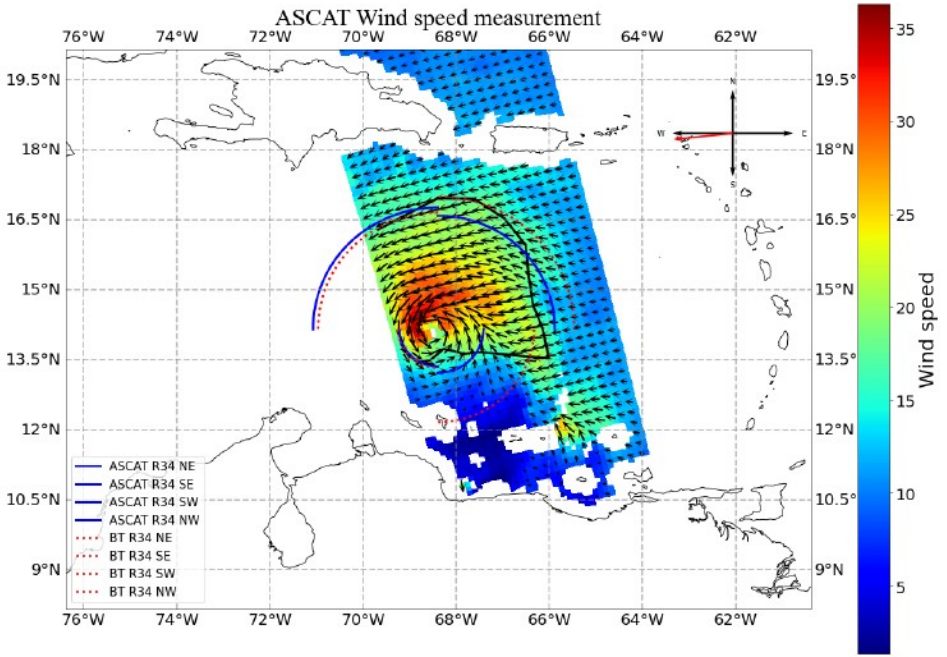


Figure: Adjusted ASCAT wind radii estimations of Hurricane Matthew on 30/09/2016

Summary of Key Points

- **Methods Comparison:**
  - Mean method slightly outperforms MAXSS-derived method
- **ASCAT Winds:**
  - Adjusted ASCAT more consistent with BT data than nominal ASCAT
  - Valuable information for hurricane advisories
- **Outliers and Improvements:**
  - Better dataset filtering
  - TC center estimation from ASCAT
  - Flag dataset to avoid comparison with BT (e.g., land impact)

Study of Outliers: Partially Caught Hurricane

Possible solutions:

- Improve filtering during the collocation process
- Estimate the TC center location from ASCAT data

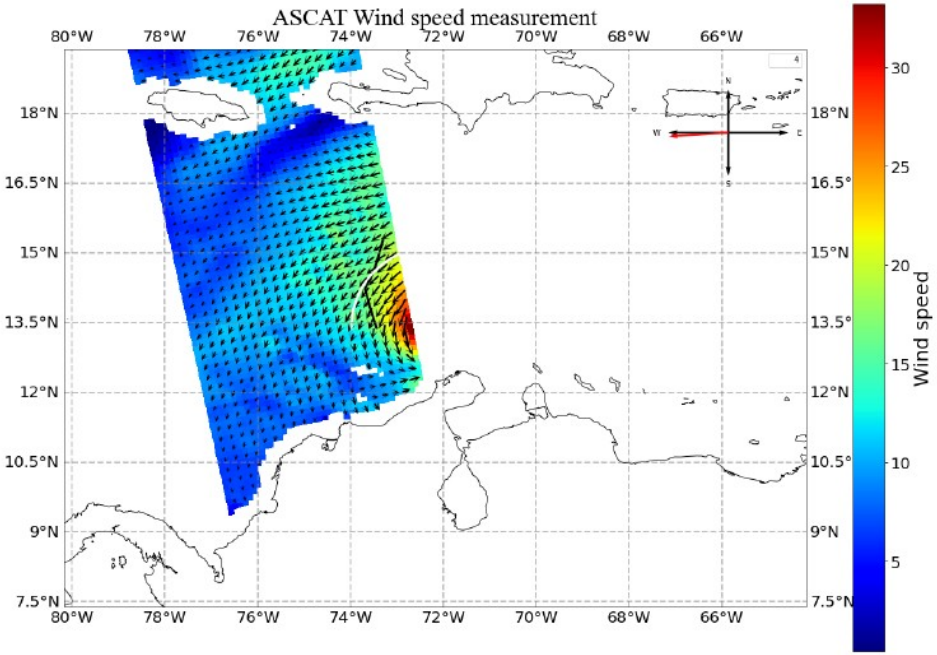


Figure: Adjusted ASCAT wind radii estimations of Hurricane Matthew on 01/10/2016

Study of Outliers: Very Large Hurricane

Possible solutions:

- Increase the amount of points necessary for the estimation
- Flag datasets with high maximum wind speed

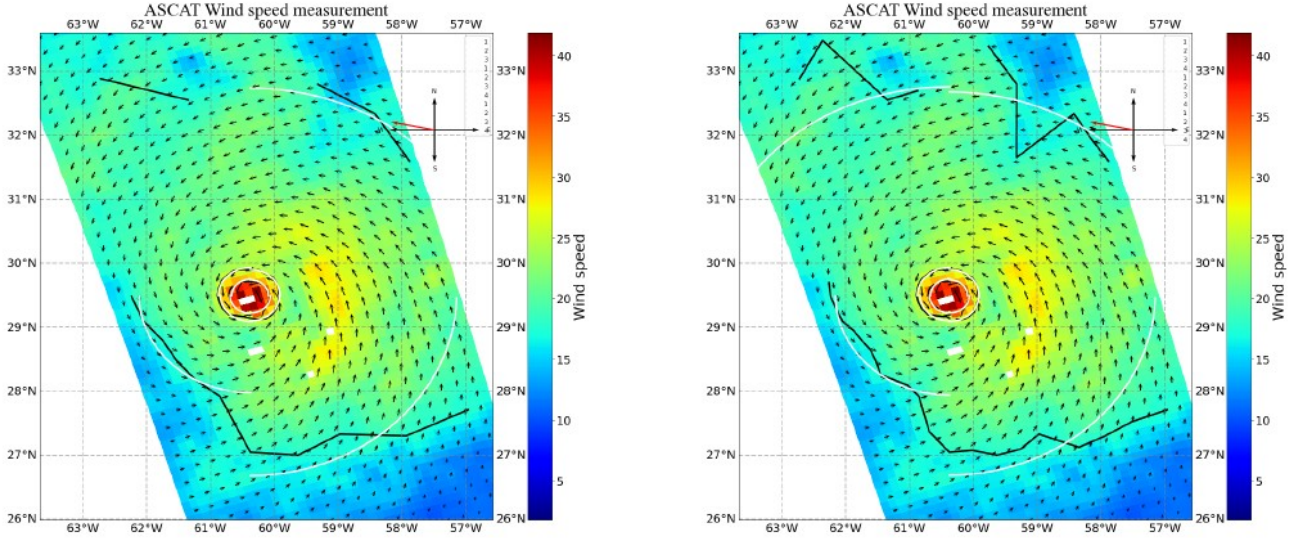


Figure: Adjusted ASCAT wind radii estimations of Hurricane Epsilon on 21/10/2020, using 24 (left) and 48 (right) intervals