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Bringing Consistency into High Wind Measurements with Spaceborne Microwave Radiometers and Scatterometers

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in print

Photo courtesy: Seychelles Islands Development Company

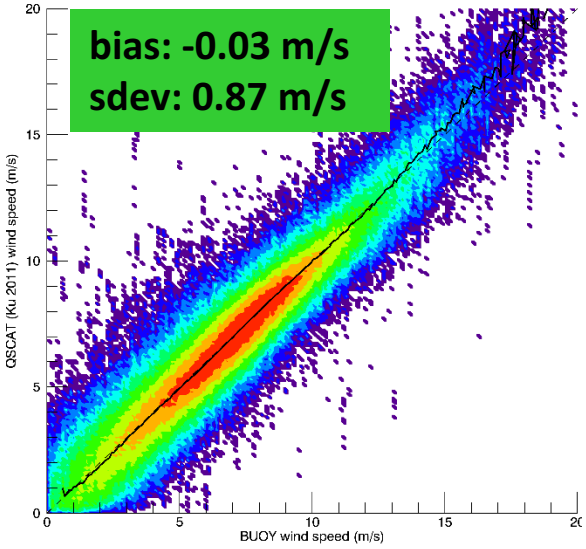
Goals + Outline

- Challenges of High Wind Measurements:
  - Sparse ground truth.
  - Rain: Error source for most radiometers + scatterometers.
  - Sensitivity (signal) at high wind speeds.
- Goal: Develop concept for **inter-calibrating and validating** high wind speed measurements for various spaceborne sensors.
  - WindSat (radiometer 7 - 37 GHz, V + H-pol).
  - QuikScat (Ku-band scatterometer, VV-pol + HH-pol).
  - ASCAT (C-band scatterometer, VV-pol).
  - SMAP (L-band radiometer, V + H-pol).
- Major validation source: SFMR (NOAA HRD).
- Key technique: **Utilize strengths of each instrument** where appropriate:
  - Sensitivity to wind speed ranges.
  - (Non-) degradation in rain.

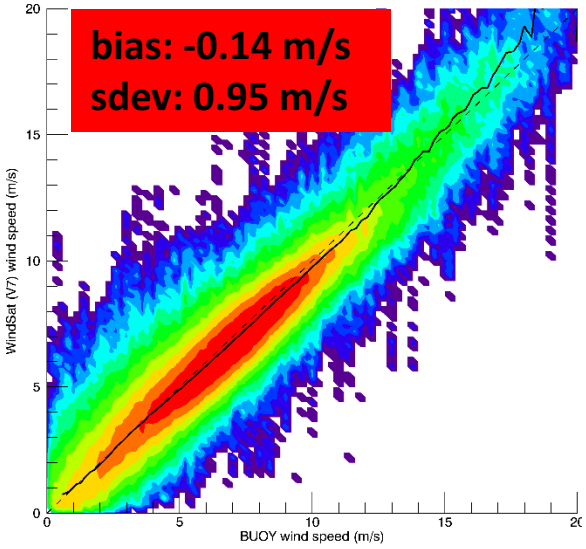
Low - Moderate Wind Speeds

Buoys Ground Truth Below 15 m/s

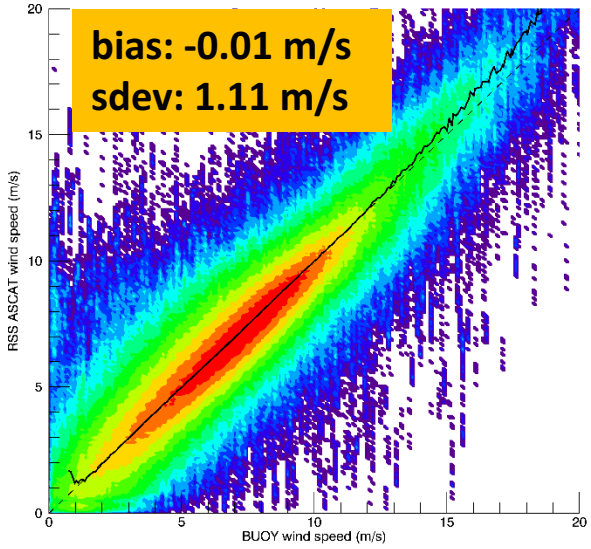
QuikScat (Ku 2011) – BUOYS



RSS WindSat (V7) – BUOYS



RSS ASCAT (V2.1) – BUOYS



- Excellent correlation between satellite (QuikScat, WindSat, RSS ASCAT) and buoy wind speeds below 15 m/s.
- Buoys observations are sparse and unreliable above 15 m/s (high waves, tipping over, …).
- NWP (ECMWF, NCEP) are not reliable in very high winds (> 20 m/s).

L-Band Radiometers

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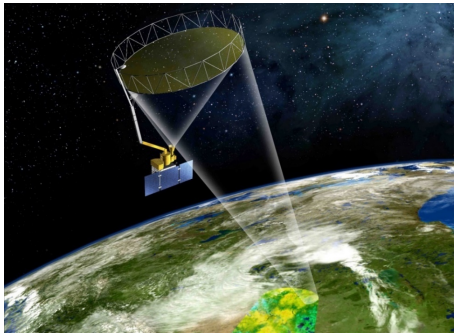
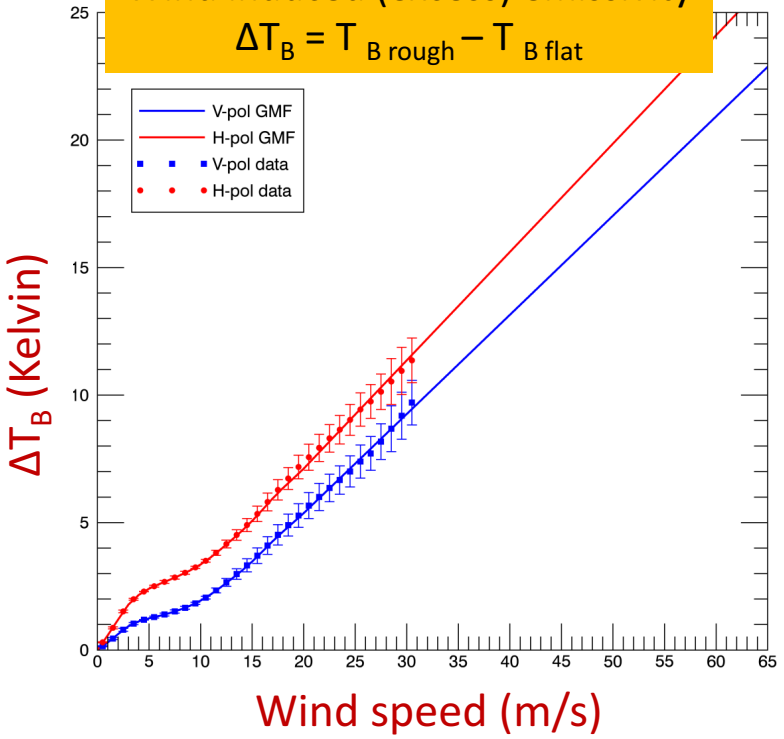
SMAP (**S**oil **M**oisture **A**ctive **P**assive) + SMOS



Wind response =

Wind induced (excess) emissivity

$\Delta T_B = T_{B\ rough} - T_{B\ flat}$



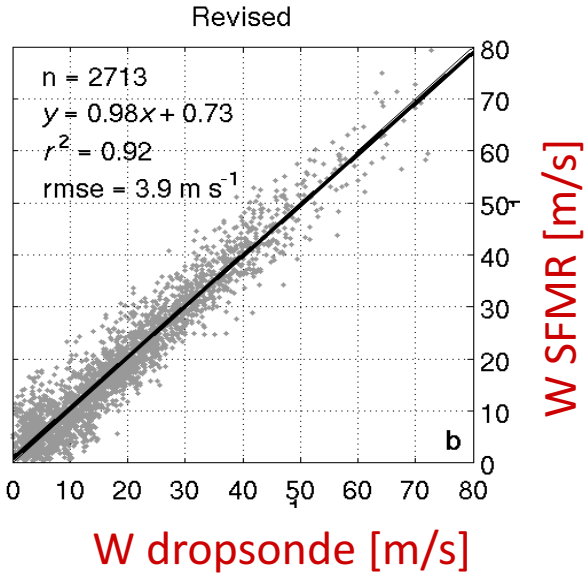
- First results were presented at IOVWST 2016 + Exeter workshop.
- L-band radiometer wind response does not saturate even at very high winds.
- L-band radiometer is **unaffected by precipitation** (< 25 mm h^{-1}).
- Extended to study of intense TC in 2015 + 2016 including intensity and wind radii.
- **T. Meissner, L. Ricciardulli + F. Wentz: BAMS 09/2017 in print. http://journals.ametsoc.org/doi/10.1175/BAMS-D-16-0052.1.**
- Data available at www.remss.com/smap.
- We started to create **microwave database of SMAP** maximum sustained winds and wind radii for NOAA and NRL.

Main Validation Source for High Winds

Stepped **F**requency **M**icrowave **R**adiometer **SFMR**

SFMR has **not** been used in deriving GMF. Provides independent source for validation for satellites that can see through rain (SMAP, ASCAT).

B. Klotz and E. Uhlhorn, *JAOT,* 2014, 41, 2392 – 2408.
Data provided by NOAA AOML HRD.
Reprocessed release.



SFMR correlate well with dropsonde wind speeds.

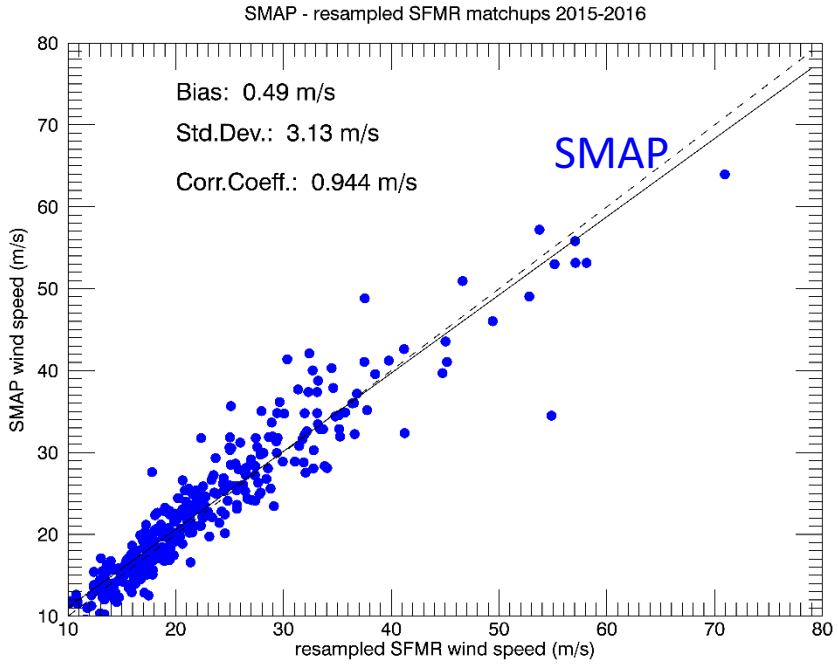
Satellite – SFMR Match-Ups

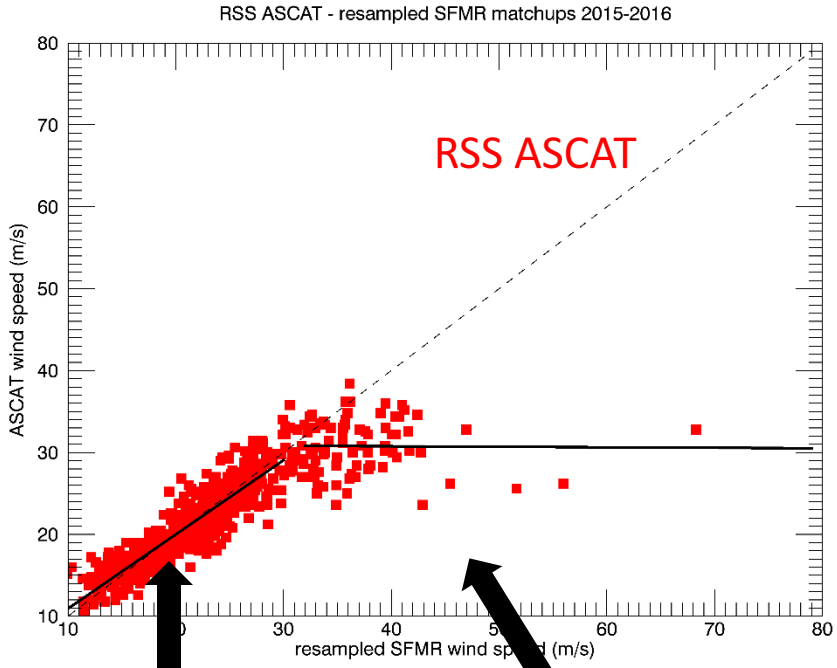
requires careful editing of each storm

- SFMR observations (3 km resolution) need to be resampled along-track to satellite resolution (25 – 40 km).
- Need to limit intensity changes.
  - Time match < 5 hours.
  - Use Best Track data to limit intensity change.
- Shift in location.
- Avoid eye/eyewall (discussion at Exeter High Winds Workshop)
- Need sufficient number of match-ups, not only one or two flights.
- Assessment possible within uncertainty limits (about 3 m/s).

SMAP/ASCAT vs resampled SFMR

Match-Ups for 2015 + 2016





- **Very good correlation + agreement between SMAP and resampled SFMR over whole wind speed range up to 70 m/s.**
- No degradation in rain.
- L-band radiometer signal does not saturate at high winds.

Very good correlation + agreement between RSS ASCAT and resampled SFMR below 30 m/s.

Very poor - no correlation above 35 m/s. C-band VV-pol scatterometer signal saturates.
Cannot be cured by scaling/adjusting GMF.

SMAP/ASCAT in TC Fantala

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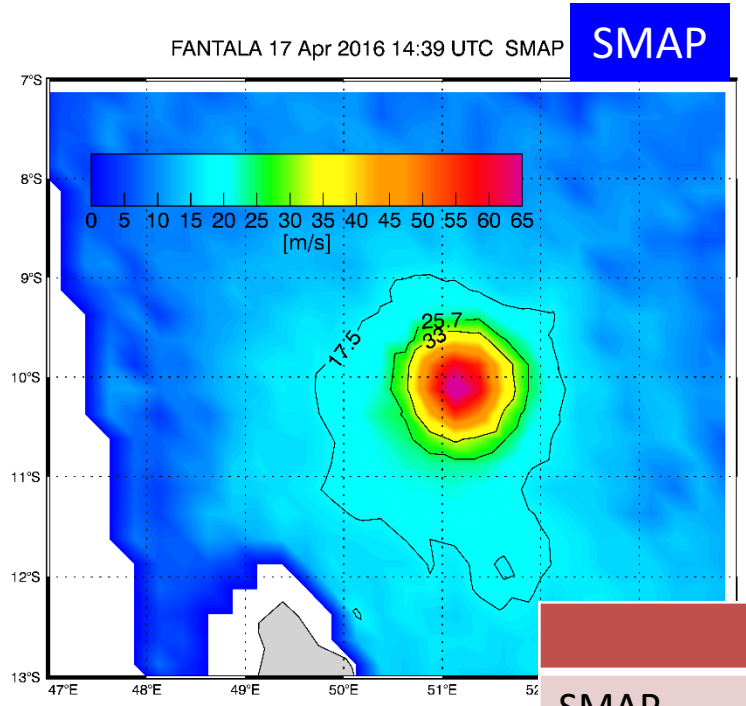
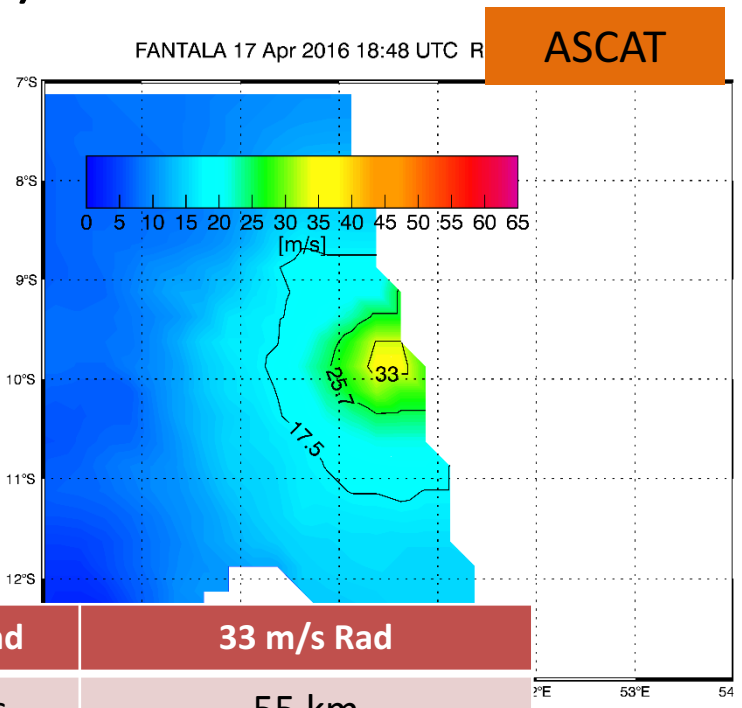
strongest observed cyclone in Indian Ocean (Seychelles)





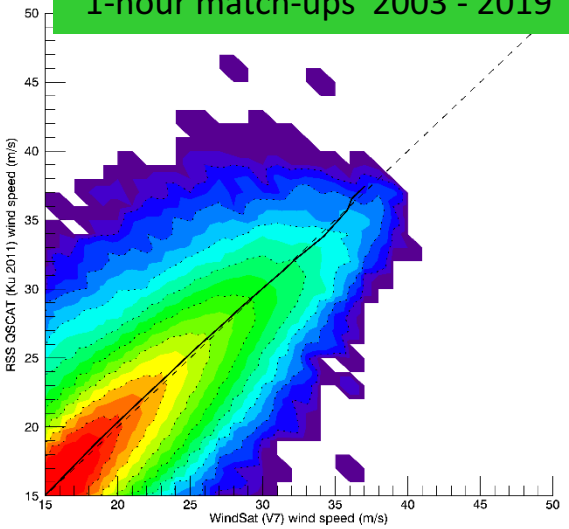
	Max wind	33 m/s Rad
SMAP	70 m/s	55 km
ASCAT	35 m/s	10 km
Best Track 10-min sustained	69 m/s	63 km

April 17, 2016.
Estimated max. 10-min sustained winds: 69 m/s.

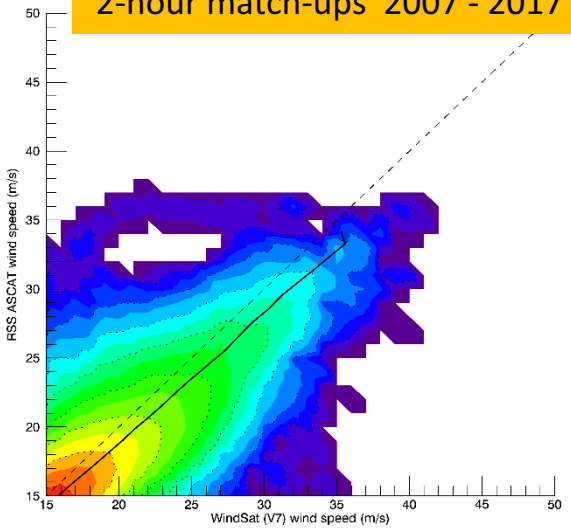
SMAP – ASCAT – QuikScat vs WindSat

Extratropical Cyclones. Strict Rain Filter.

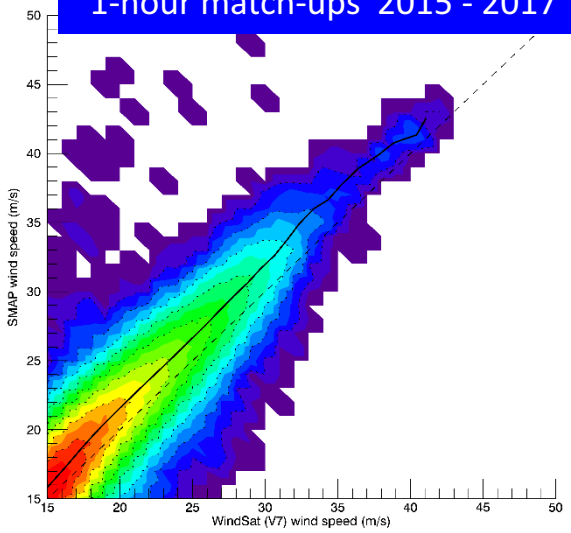
QuikScat (Ku 2011) vs WindSat
1-hour match-ups 2003 - 2019



RSS ASCAT (V2.1) vs WindSat
2-hour match-ups 2007 - 2017



SMAP vs WindSat
1-hour match-ups 2015 - 2017



- Almost **perfect line-up of QuikScat (Ku 2011), SMAP and WindSat up to 40 m/s.**
  - Expect little changes in updated Ku-band scatterometer GMF at high winds.
- SMAP has a small positive constant bias (+ 1 m/s) compared to WindSat up to 40 m/s.
- RSS ASCAT has small negative (- 1 m/s) bias compared to WindSat. Bias increases at high winds (saturation).
- **Demonstrates consistency between RSS radiometer and scatterometer winds in extratropical cyclones (rain free).**

Intra-Satellite Consistency

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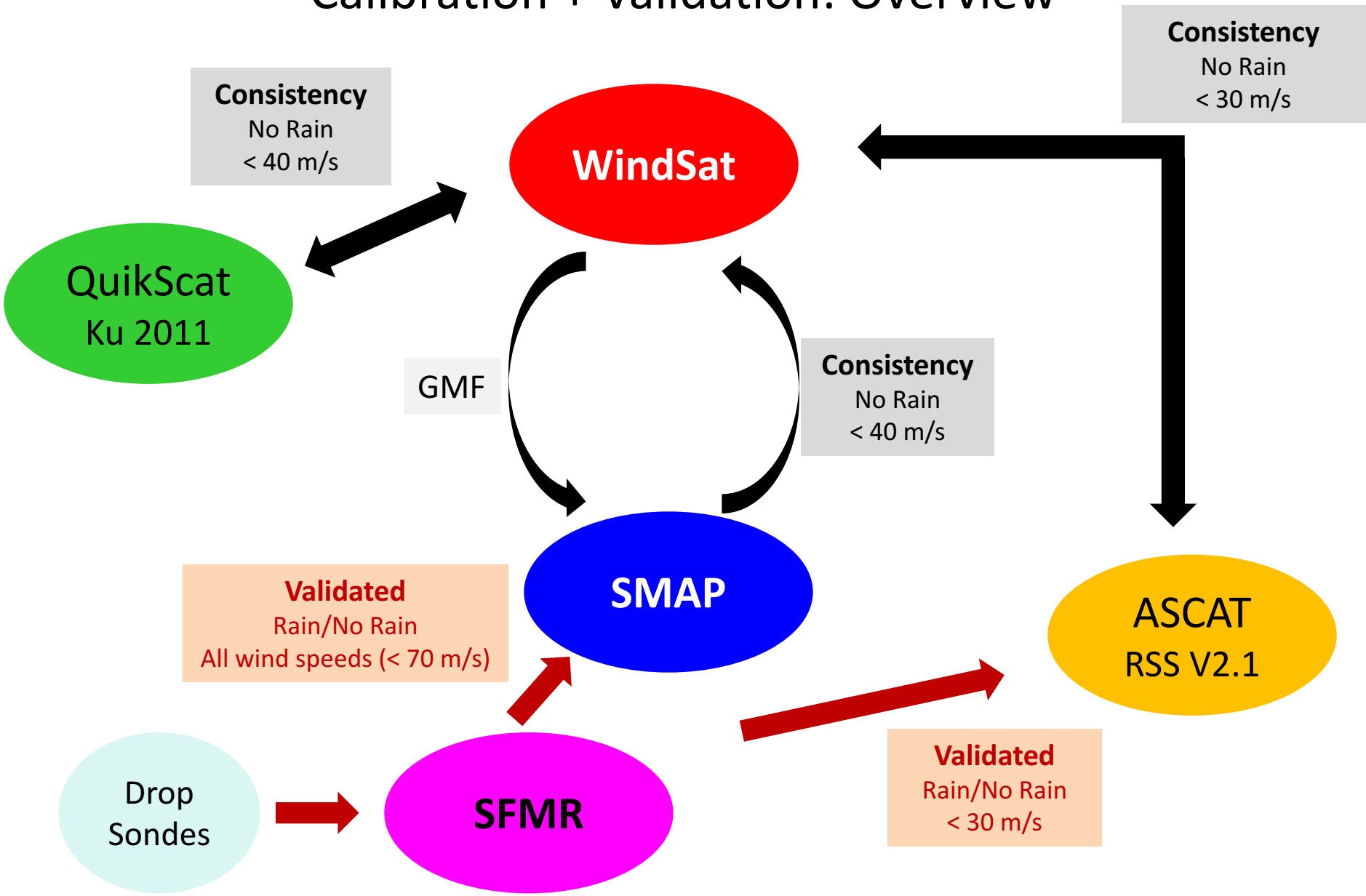
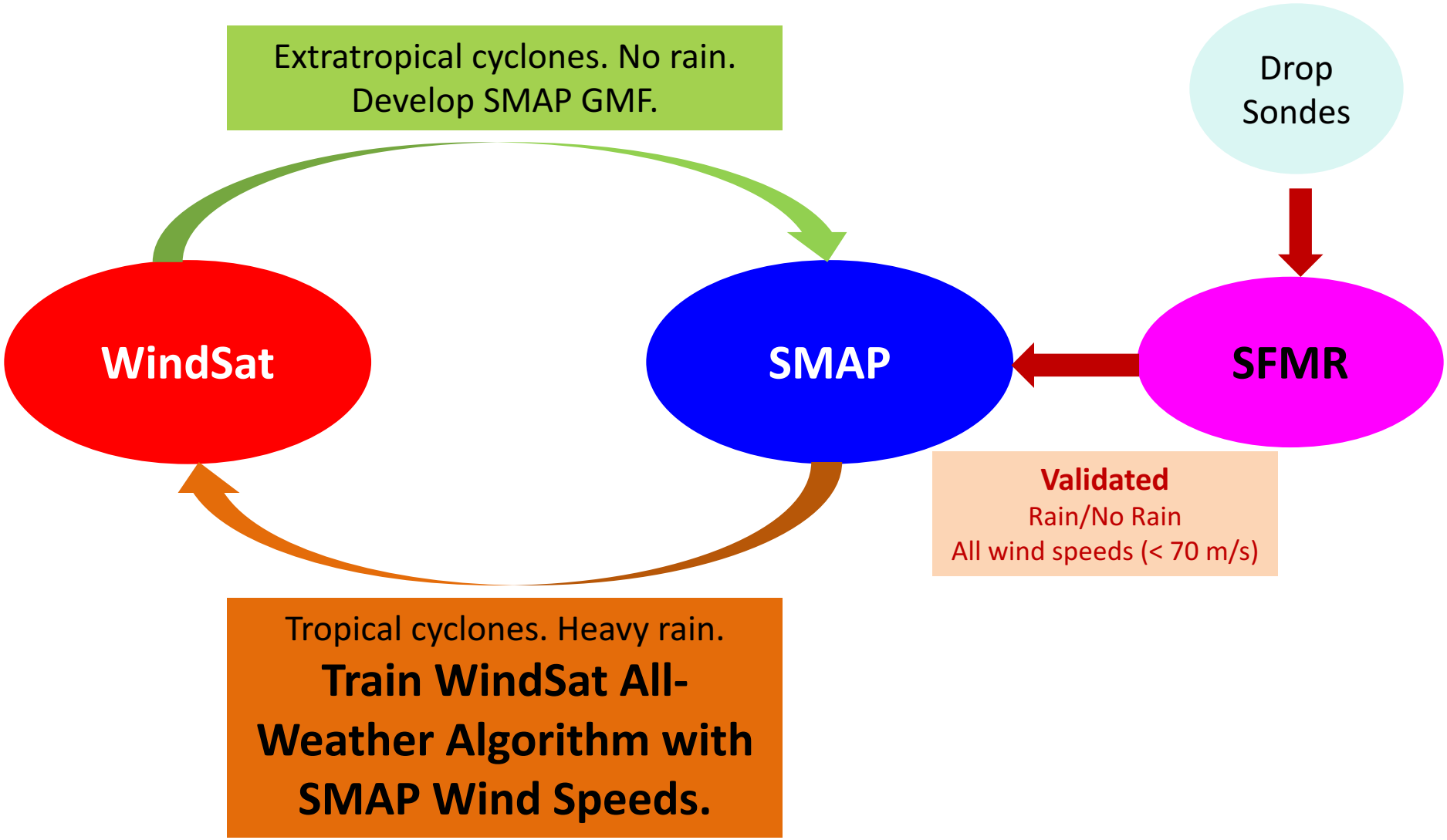
Calibration + Validation: Overview



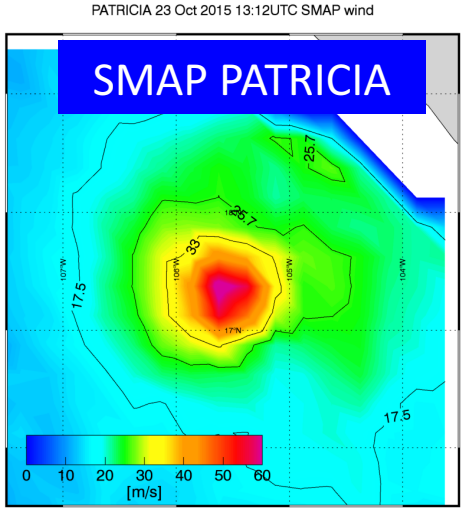
SMAP – WindSat: The Ideal Couple

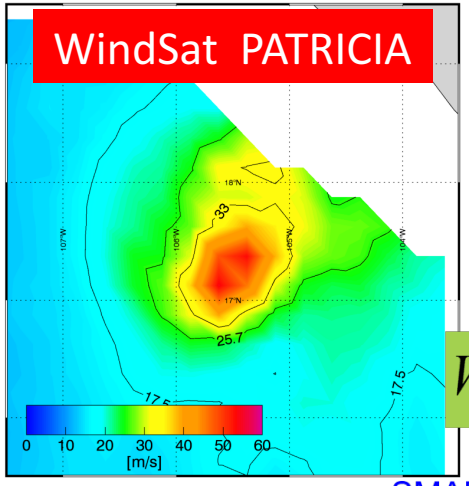
Same ascending node time. Mutual benefit.



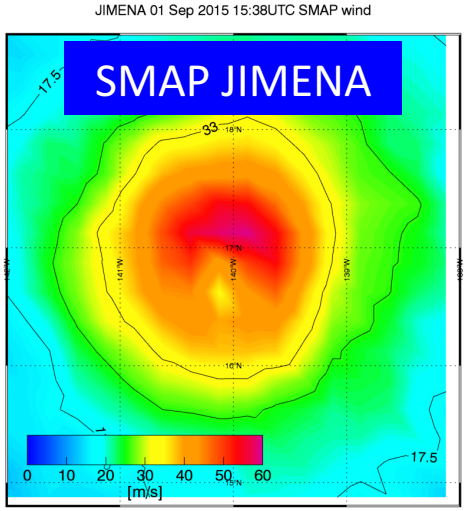
WindSat Wind Speeds in Rain

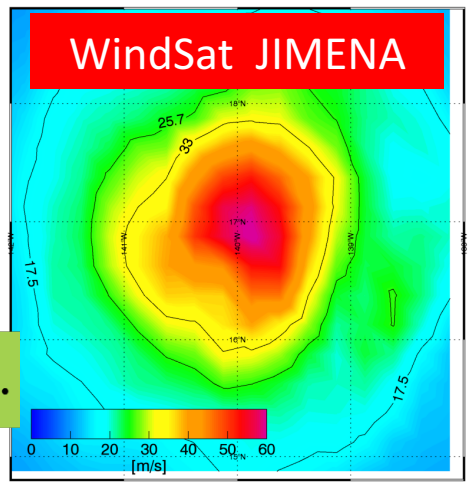
Training: PATRICIA Testing: JIMENA





- Current RSS WindSat all-weather algorithm had been trained up to 40 m/s.
- Train WindSat in rain retrieval algorithm with SMAP winds.
- Statistical algorithm.
  - Different from standard physical WindSat wind speed retrieval algorithm.
- Combine WindSat C-band and X-band channels to take out rain (SFMR-like).





WindSat TB

$$W_{reg} = c_0 + c_1 \cdot T_B^{C-band} + c_2 \cdot T_B^{X-band} + \ldots$$

SMAP wind speed

linear regression

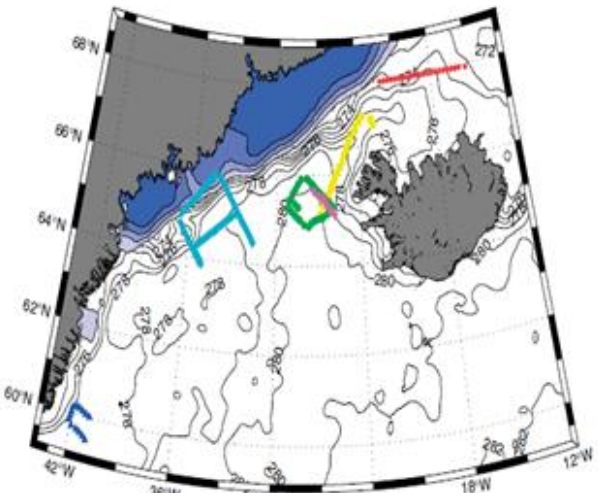
Summary + Outlook

- **SMAP** wind speeds validated with **SFMR**.
  - Range: 15 m/s to at least 70 m/s. No saturation.
  - Not affected in precipitation, even in heavy rain.
  - **Very valuable spaceborne sensor for assessing intensity and size of TC.**
  - Cal/Val source for CYGNSS at high winds.
- **RSS ASCAT** winds validated with **SFMR**.
  - Agree very well below 30 m/s.
  - Demonstrate sensitivity loss and saturation of ASCAT wind speed response.
- Very good consistency between RSS radiometer (**WindSat**, **SMAP**) and scatterometer (**QuikScat**, **ASCAT**) in extratropical cyclones.
  - Particular: **QuikScat** / **WindSat** **agreement** to 40 m/s (no rain).
  - Need careful rain filter and go through many storms.
- First results indicate capability to train **WindSat** winds in rain (C/X-band channels) using **SMAP**.
  - Up to TC with intensity 4 – 5.
  - Can be extended to other C/X-band radiometers (**AMSR-E, AMSR2**).

Backup Slides

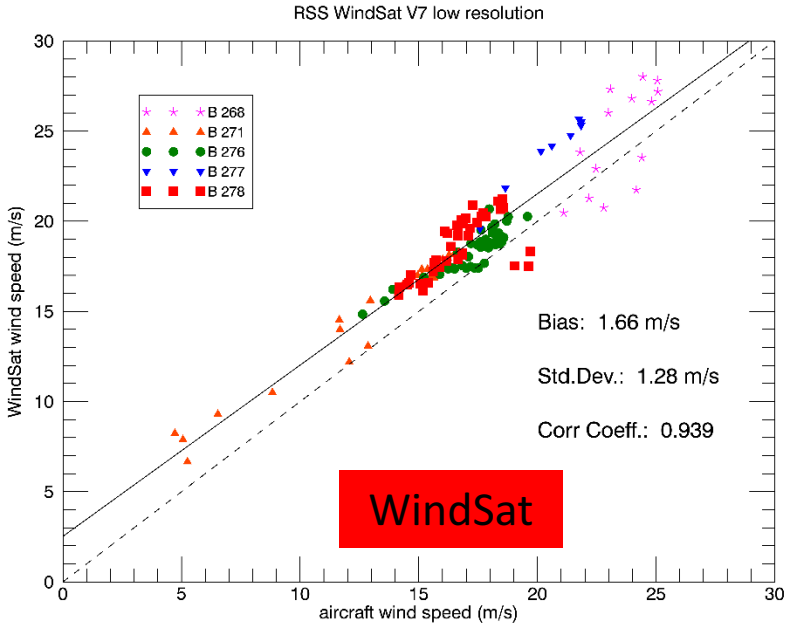
Greenland Flow Distortion Experiment

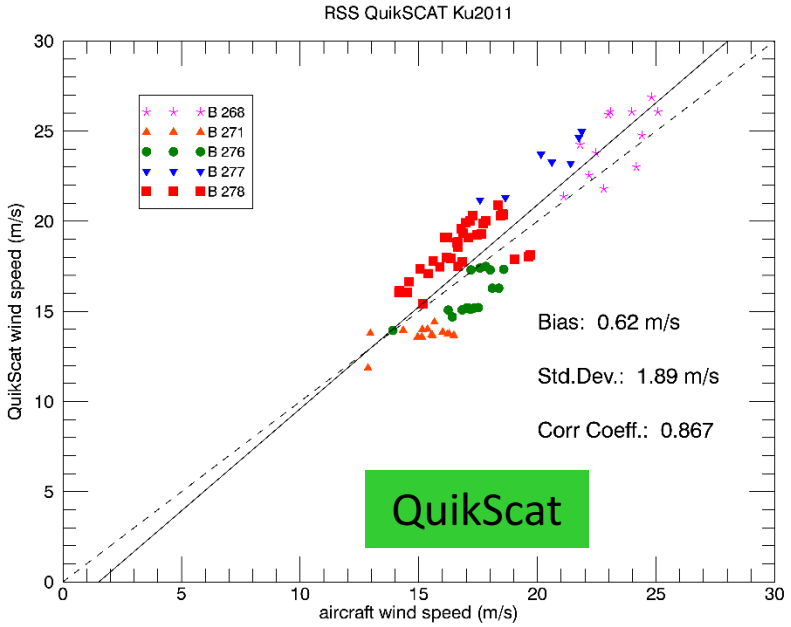
Up to 25 m/s



Renfrew et al. QJRMS 135, 2009, 2046 – 2066.

- Aircraft observations during Feb + Mar 2007.
- 150 measurements during 5 missions.
- Wind vectors measured by turbulence probe.
- Adjusted to 10m above surface.
- Contamination from land and sea ice. Makes satellite wind speeds systematically high. Radiometer most affected.





WindSat Wind Speeds in Rain

Use SMAP wind speeds as "truth"

- Current RSS WindSat all-weather algorithm had been trained up to 40 m/s.
- Train WindSat in rain retrieval algorithm with SMAP winds.
- Statistical algorithm.
  - Different from standard physical WindSat wind speed retrieval algorithm.
- Combine WindSat C-band and X-band channels to take out rain (SFMR-like).

Linear Regression

WindSat TB

$$W_{reg} = c_0 + c_1 \cdot T_B^{C-band} + c_2 \cdot T_B^{X-band} + \mathrm{K}$$

SMAP wind speed

$$\frac{c_1}{c_2} \approx -\frac{5}{2}$$

T. Meissner + F. Wentz
IEEE TGRS, 47(9), 3065 – 3083, 2009