Wind Measurements from Combined Active and Passive L-Band Sensors

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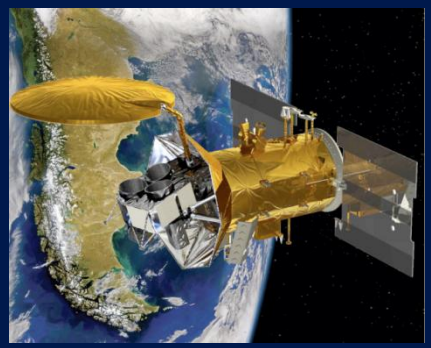
NASA

Spaceborne L-Band Missions (1)

- AQUARIUS
  - NASA instrument on board of CONAE SAC-D (Argentina).
  - Launched June 2011.
  - Science data since August 2011.
  - Radiometer (1.413 GHz) to measure sea surface salinity SSS.
    - V-pol, H-pol, 3rd Stokes.
  - Scatterometer (1.26 GHz) to correct ocean surface roughness.
    - VV, HH, VH, HV.
  - 3 feed horns shared by radiometer and radar.
    - Earth Incidence Angles: 29 ,38 45 deg
  - Pushbroom design:
    - 350 km swath.
    - 7-day global coverage.
    - 100 km resolution.



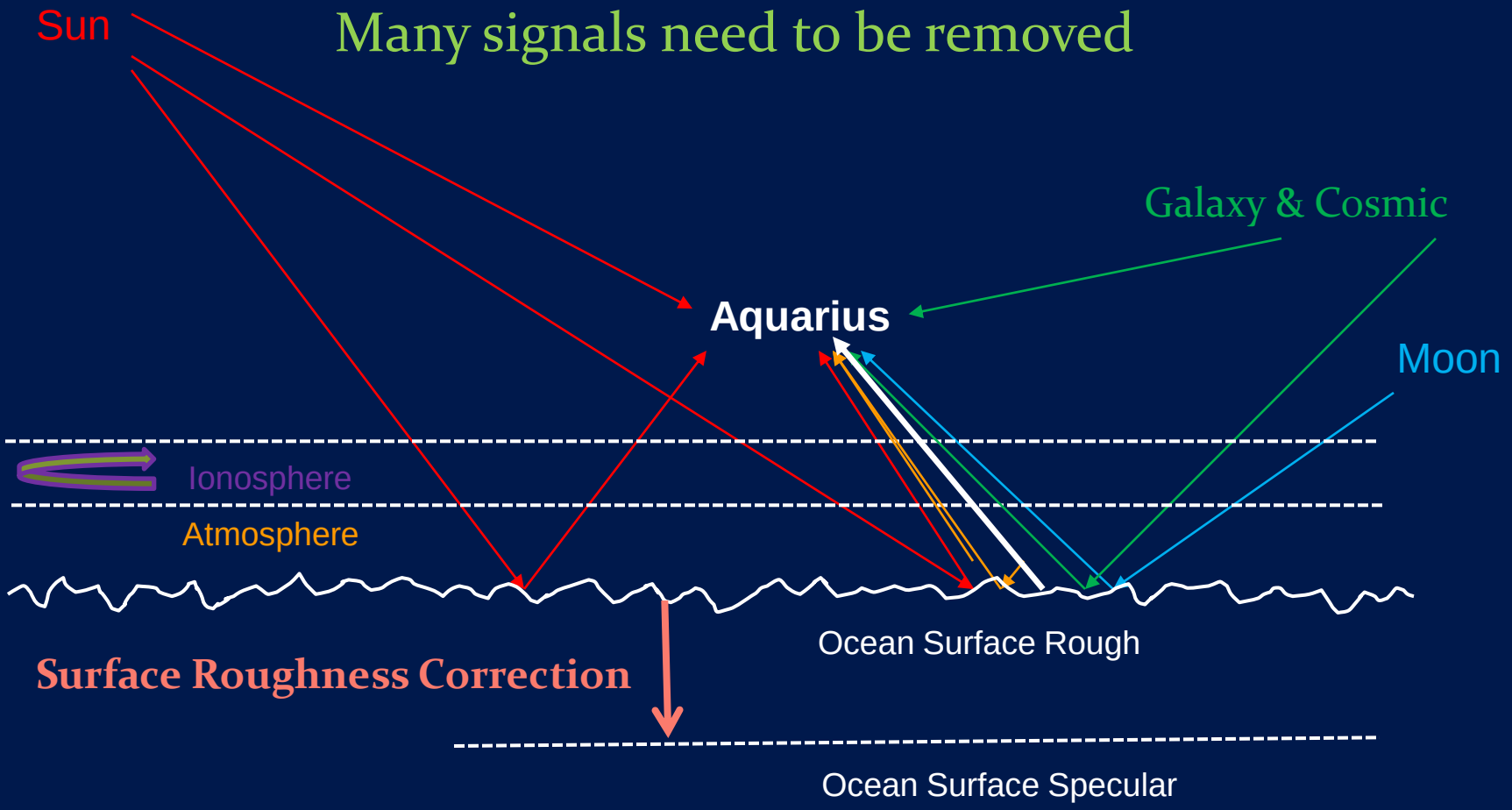
Spaceborne L-Band Missions (2)

- SMOS (Soil Moisture and Ocean Salinity)
  - ESA
  - Synthetic aperture radiometer.
  - Soil Moisture (SM) + Sea Surface Salinity (SSS).
  - 600 km swath width.
  - Launched November 2009.
- SMAP (Soil Moisture Active Passive)
  - NASA mission.
  - Synthetic aperture radar combined with scanning real aperture radiometer.
    - 1000 km swath.
    - 35 km resolution for combined active passive observations.
  - Designed to measure SM but also has SSS and wind speed capability similar to AQUARIUS.
  - Launch date October 2014.

Aquarius Ocean Salinity Retrieval (1)

- Challenge
  - High accuracy required: 0.2 psu (SSS) ≡ 0.1 K (TB)
  - Many spurious signals / effects need to be removed or corrected:
    - Drift of internal calibration system (noise diode).
    - Antenna Pattern Correction (spillover, x-pol).
    - Celestial signal (galaxy, sun, moon): large at L-band.
    - Faraday Rotation (ionosphere): large at L-band.
    - RFI: Radiometer and scatterometer.
    - Surface Roughness.
- Ocean Surface Roughness Correction
  - Uses scatterometer.
  - Wind speed is byproduct in roughness correction.
  - Excellent accuracy as stand alone product.

Aquarius Ocean Salinity Retrieval (2)

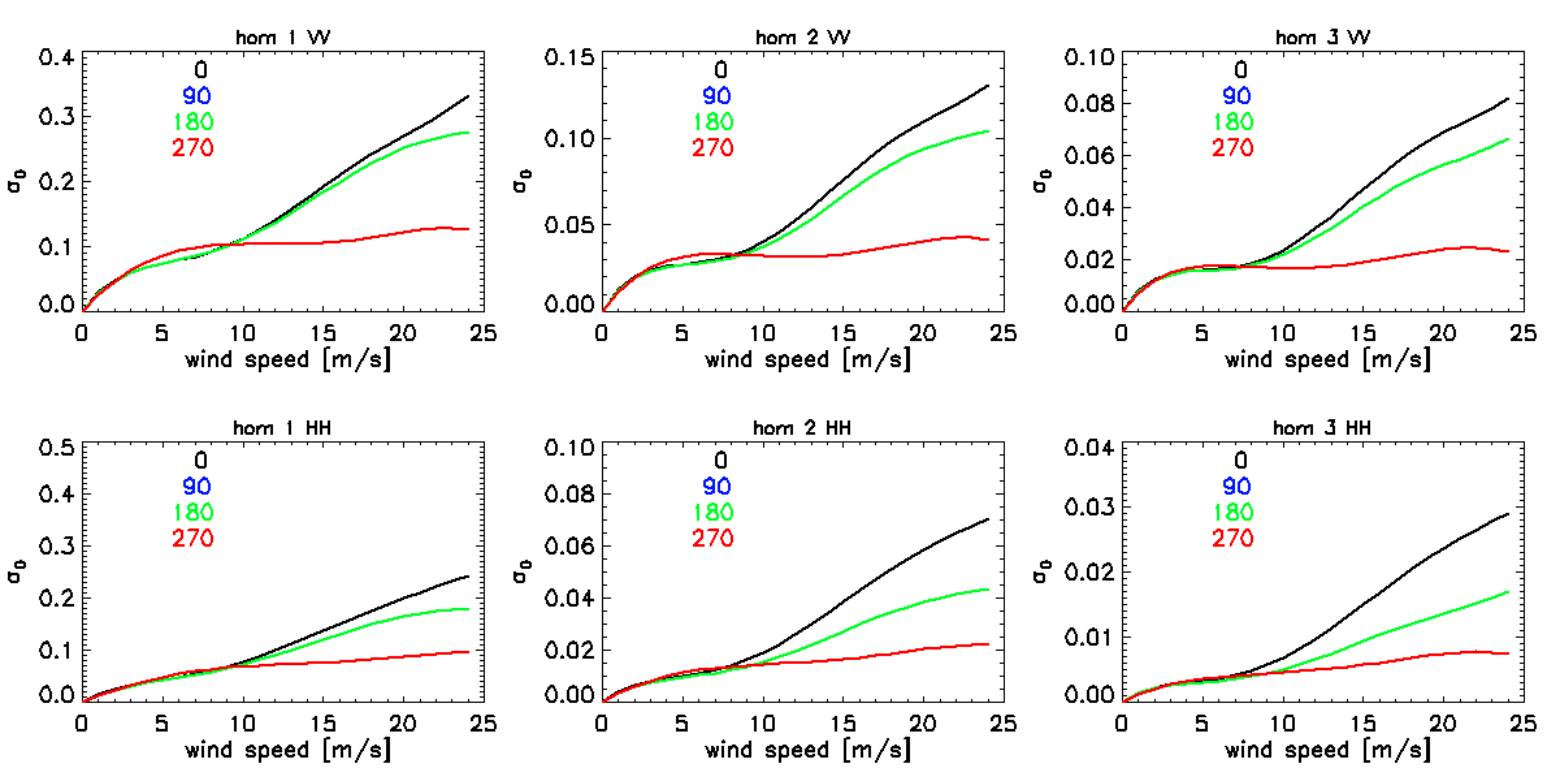


Meissner – Wentz Model for Permittivity of Sea Water → **Salinity**

Scatterometer GMF

VV

HH



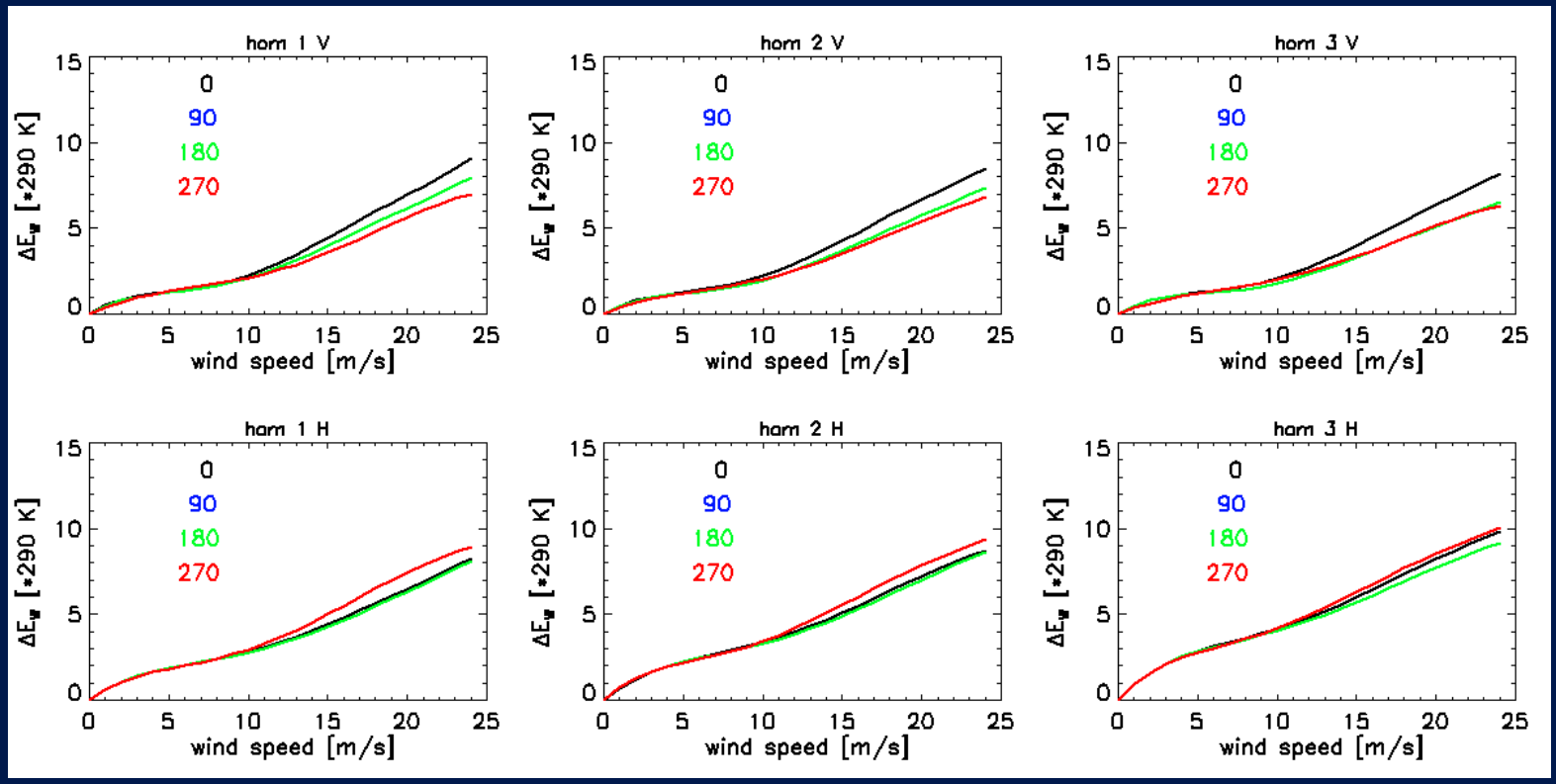
- GMF derivation uses WindSat / SSMIS F17 wind speeds.
- Scatterometer looses sensitivity to wind speed:
  - X-wind (unique feature of L-band).
  - At high wind speeds.

up-wind
down-wind
x-wind

Radiometer Emissivity Signal

V

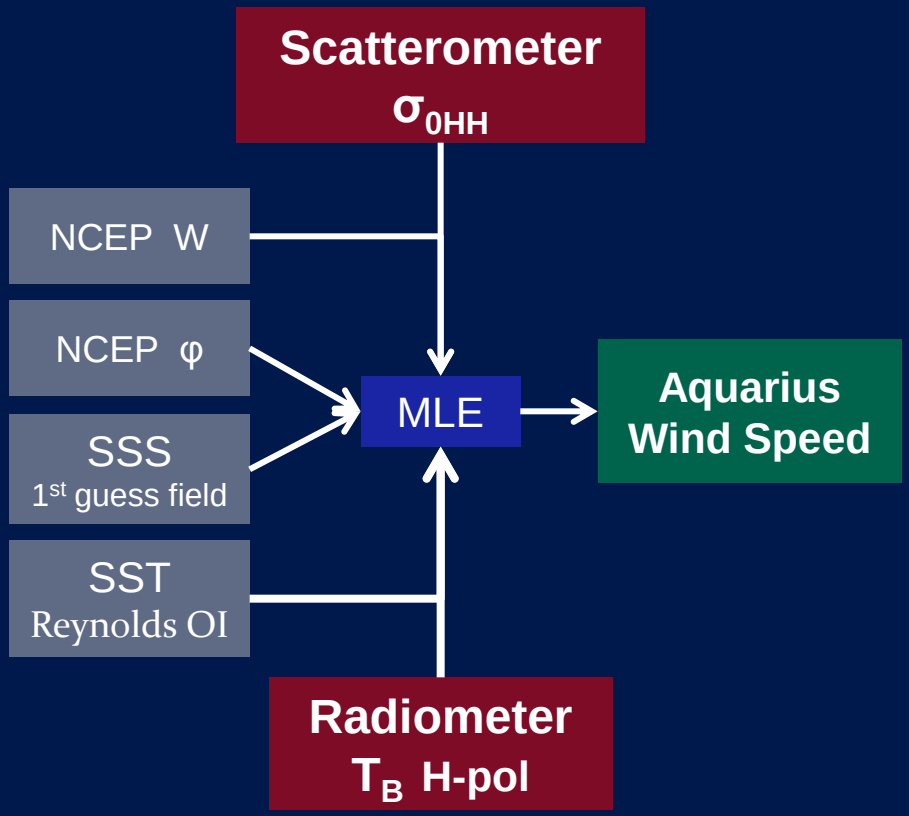
H



- Radiometer retains good wind speed sensitivity in all cases.
- Suggests appropriate combination of radar + radiometer channels (dating back to SEASAT)

up-wind
down-wind
x-wind

Aquarius Wind Speed Algorithm: Flow



- No improvement of wind speed performance if adding scatterometer VV-pol or radiometer V-pol.
- Radiometer V-pol more sensitive to SSS than H-pol.
  - V-pol is used in SSS retrieval.
- Scatterometer VV-pol can be used for correcting roughness effects that are orthogonal to wind speed.

Aquarius Measurement | Auxiliary Input | Output | Process

Aquarius Wind Speed Algorithm: MLE

$$\chi^2(W) = \frac{\left[\sigma_{0HH,meas} - \sigma_{0HH,mod}(W)\right]^2}{Var(\sigma_{0HH})} + \frac{\left[T_{BH,meas} - T_{BH,mod}(W)\right]^2}{Var(T_{BH})} + \frac{\left[W - W_{NCEP}\right]^2}{Var(W_{NCEP})}$$

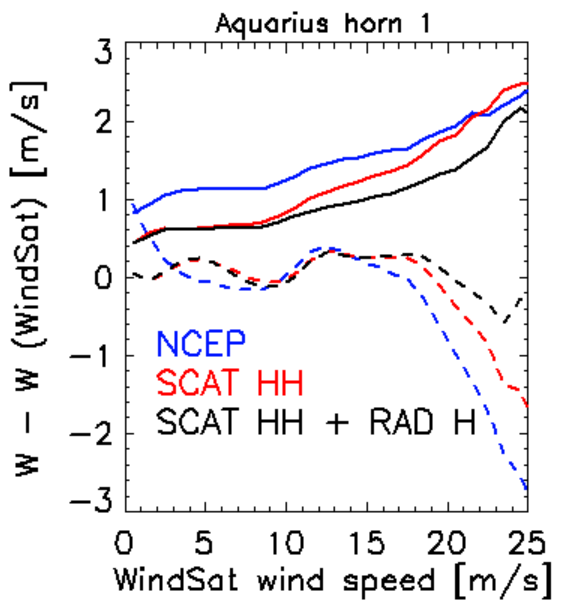
- Use total expected variances as relative channel weights.
- Use NCEP wind speed as background field.
  - Improves performance for x-wind observations.
- Wind direction signal removed from both radiometer and scatterometer measurements.
  - Use NCEP wind direction φ as auxiliary input.
- Radiometer model function $T_{BH,mod}$ needs auxiliary input.
  - SSS (1st guess)
    - E.g.: World Ocean Atlas climatology, HYOCM salinity field, AQUARIUS monthly averages.
  - SST: E.g.: Reynolds OI

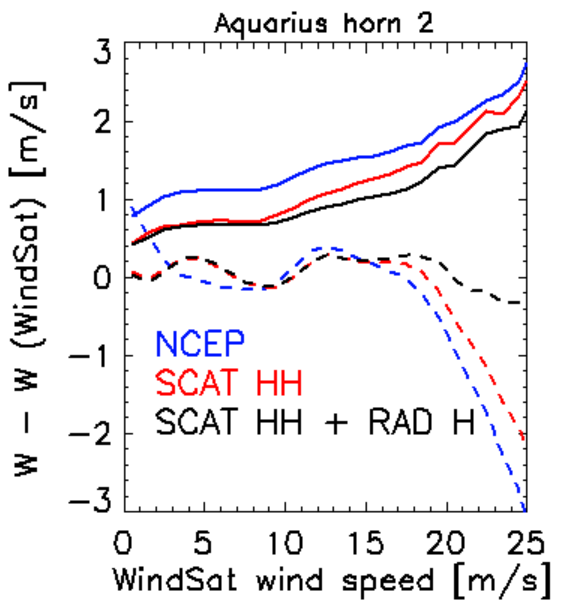
Aquarius Wind Speed Performance (1)

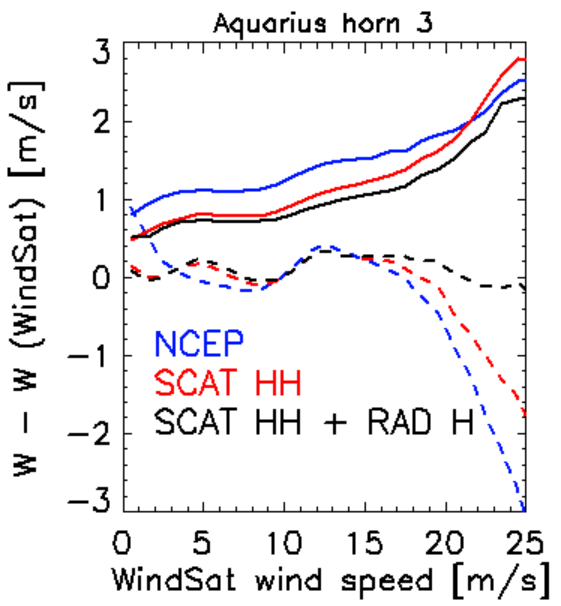
RMS [m/s] Evaluated against WindSat, 1hour, rain-free		
NCEP	HH scatterometer	HH-H scatterometer + radiometer
1.24	0.86	0.77

Aquarius wind speed accuracy matches that of WindSat, SSM/I, QuikSCAT, ASCAT

Aquarius Wind Speed Performance (2)



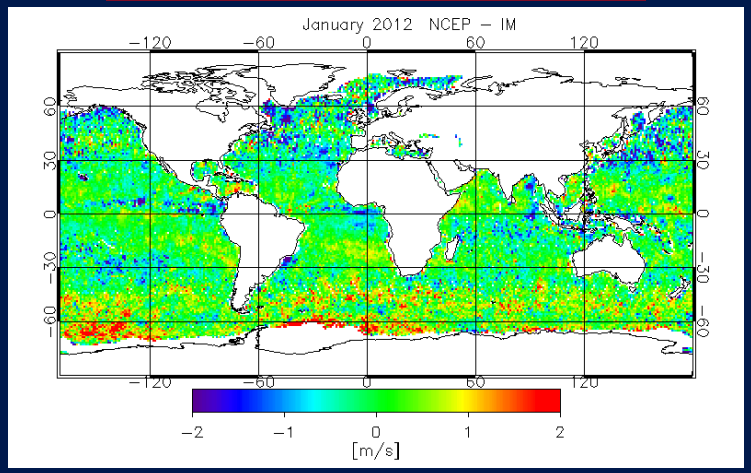




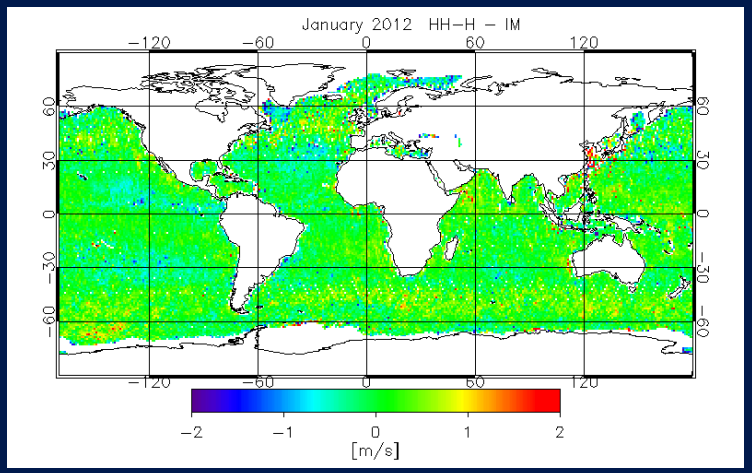
Dashed lines = BIAS
Full lines = standard deviation

Aquarius Wind Speed Performance (3)

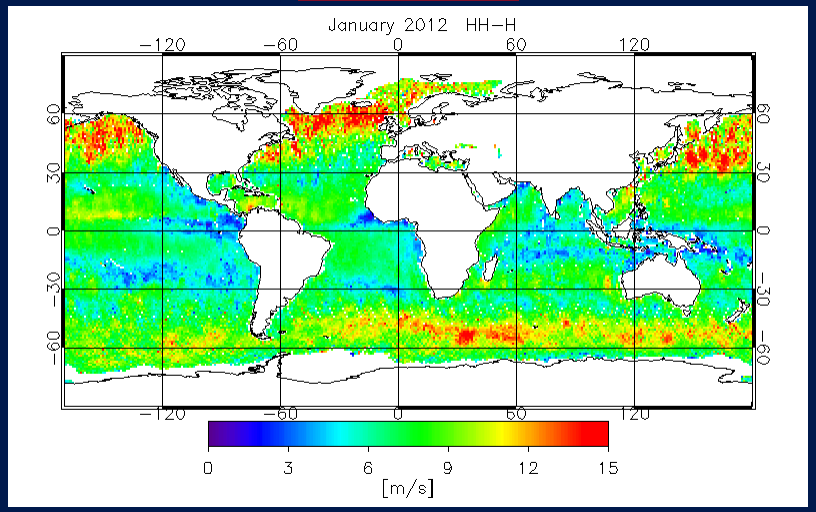
NCEP — WindSat



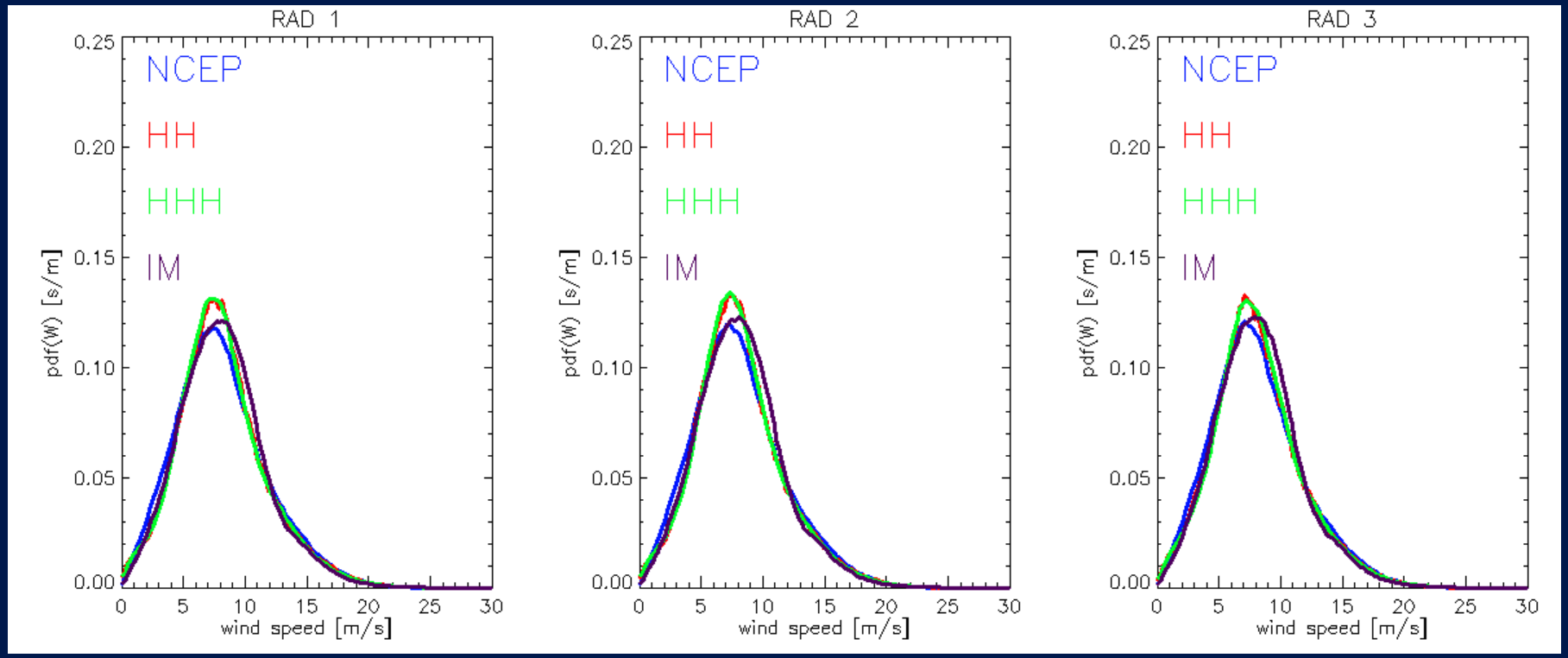
AQUARIUS (HH-H) — WindSat



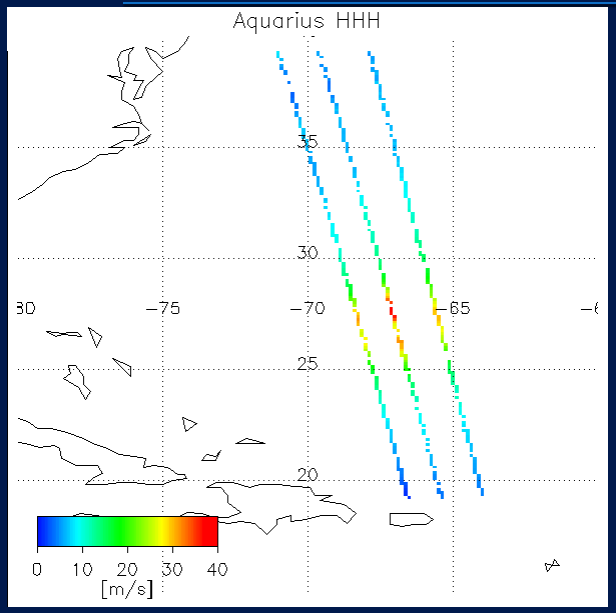
HH-H



Aquarius Wind Speed Histograms

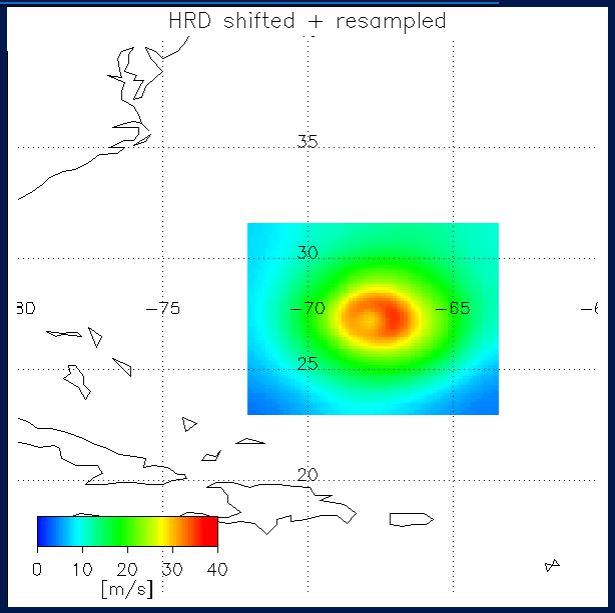


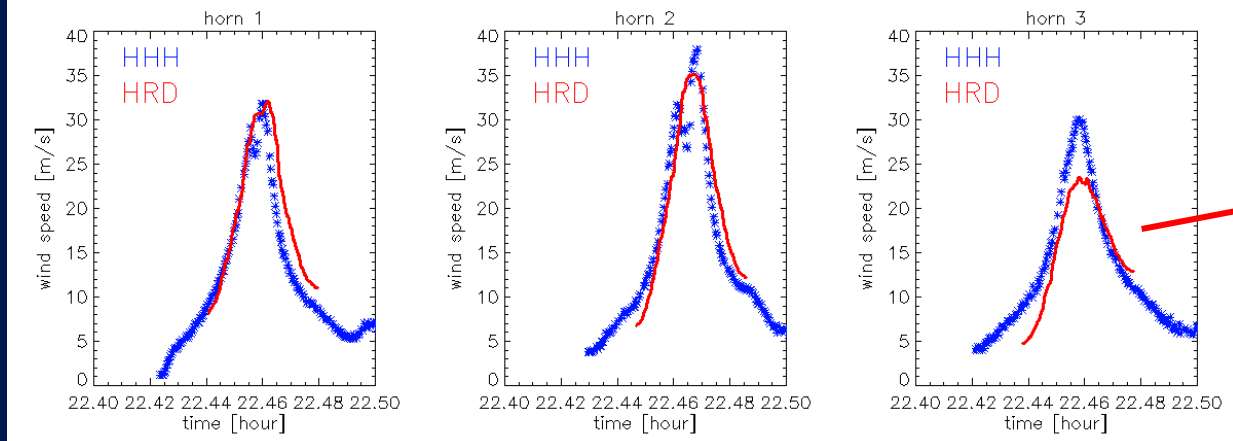
High Wind Speeds



Hurricane KATIA

- 09/06/2011
- AQ overpass ≈22:30 h UTC
- NOAA HRD Analysis from 19.:30 h shifted along track and resampled onto AQ resolution.

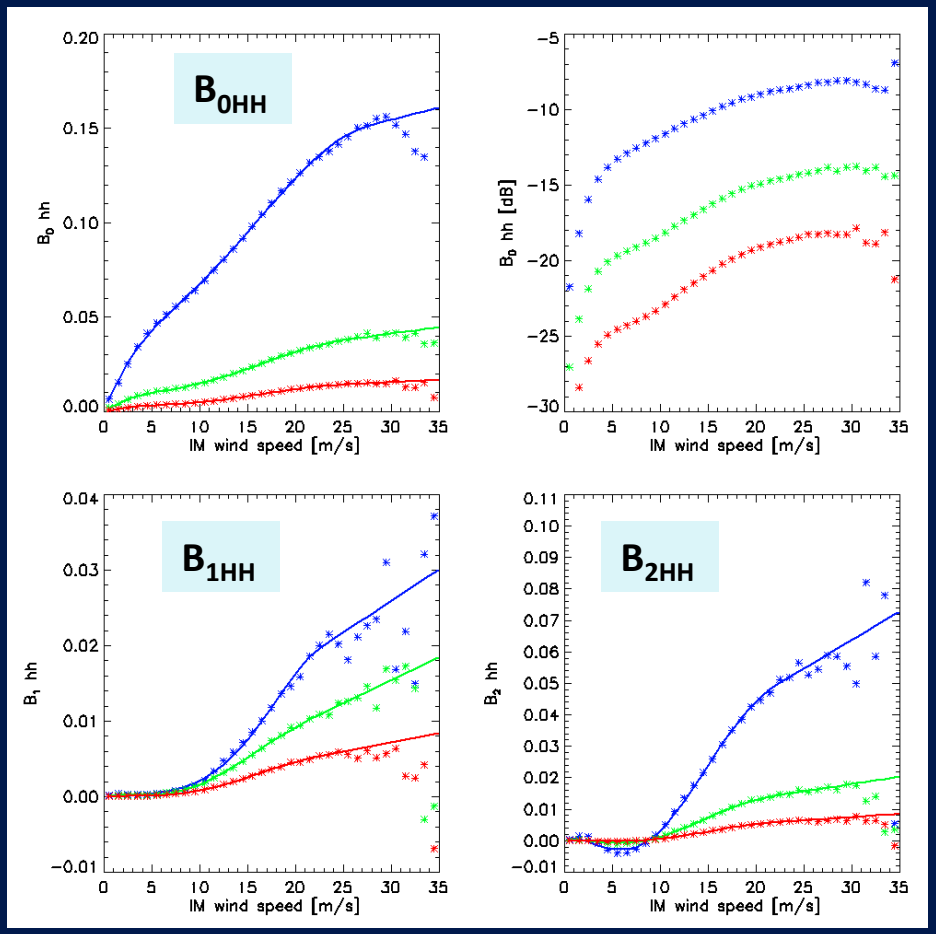




Possibly sampling mismatch between AQ horn 3 overpass and HRD field.

Wind Direction Capabilities

$$\sigma_0(W, \varphi_{rel}) = B_0(W) + \left[B_1(W)\cdot\cos(\varphi_{rel}) + B_2(W)\cdot\cos(2\varphi_{rel})\right]$$



- Needs further investigation.
- VV, HH, T_{BV}, T_{BH} directional signals are all very small below 8 m/s.
- 3rd and 4th Stokes ?
- SMAP: for/aft look.

horn 1
horn 2
horn 3

Summary and Outlook

- AQUARIUS demonstrates capability of retrieving wind speeds with L-band sensors.
  - By-product of ocean surface roughness correction of sea surface salinity retrieval.
  - Quality of AQUARIUS wind speed is comparable with WindSat, SSM/I, QuikSCAT, ASCAT.
- *Intelligent combination* of active/passive channels.
- Product available:
  - RSS Aquarius L2 Testbed Data.
  - ftp://Aquarius:saltyH2O@ftp.remss.com/Aquarius.
  - Is getting integrated into official GSFC Aquarius L2 data set.
- Anticipate useful wind speed product for SMAP
  - 35 km resolution, 1000 km swath.