Aquarius Pioneering the L-band Passive and Active Microwave Remote Sensing of Sea Surface Salinity and Wind

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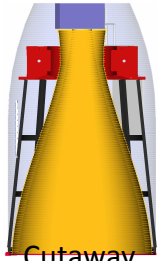
Background

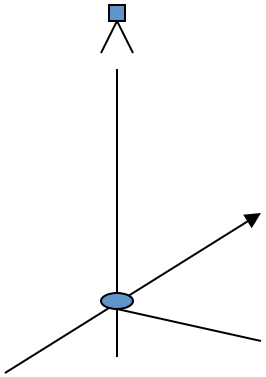
- Development of SSS remote sensing techniques started in 1980s.
- NASA flew ESTAR in 1980s
- The Salinity Sea Ice Working Group started to advocate the L-band passive-active remote sensing in 1998
- Surface roughness recognized as one of the key error sources (PALS, 2000 flights across the Gulf Stream)
- Aquarius/SACD – the first combined active-passive L-band remote sensing mission – selected by ESSP in 2002

Early ESSP SSS Mission Concepts

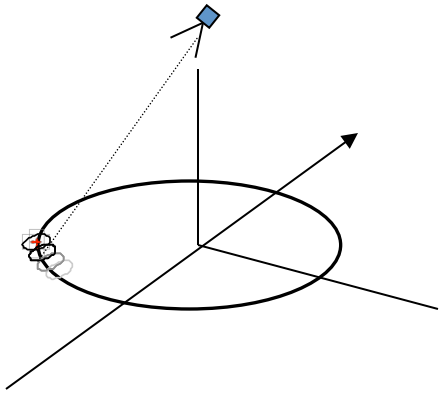
- Horn Antenna
  - Nadir looking horn antenna



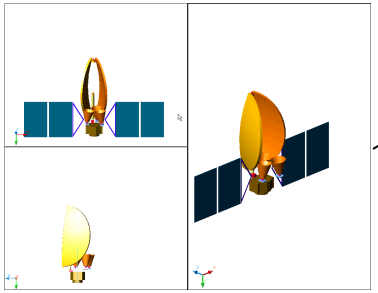
Cutaway View

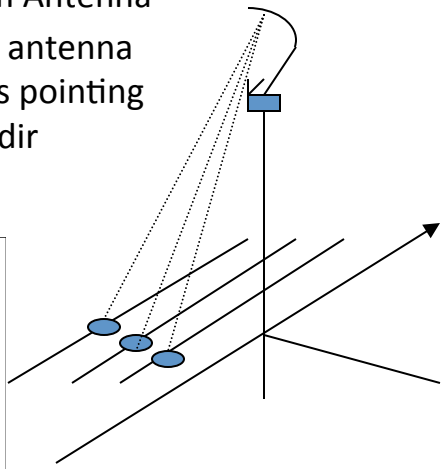


- Conical scanning horn
  - 20° incidence angle
  - 5 RPM
  - 480 km swath at 550 km orbit

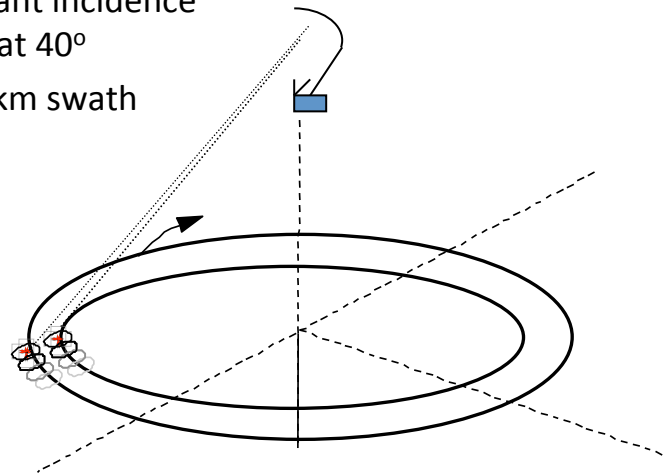


- Push-Broom Antenna
  - Three antenna beams pointing off nadir



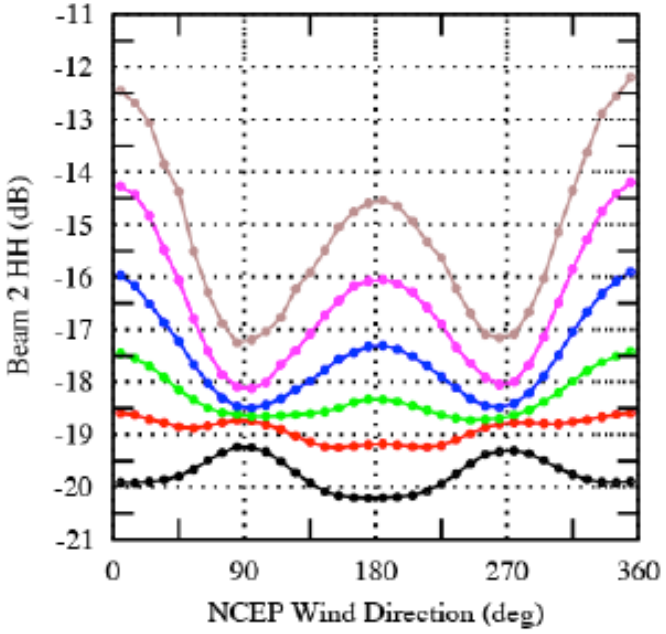


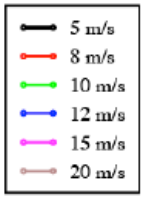
- Conical scanning reflector
  - Constant incidence angle at 40°
  - 1000 km swath

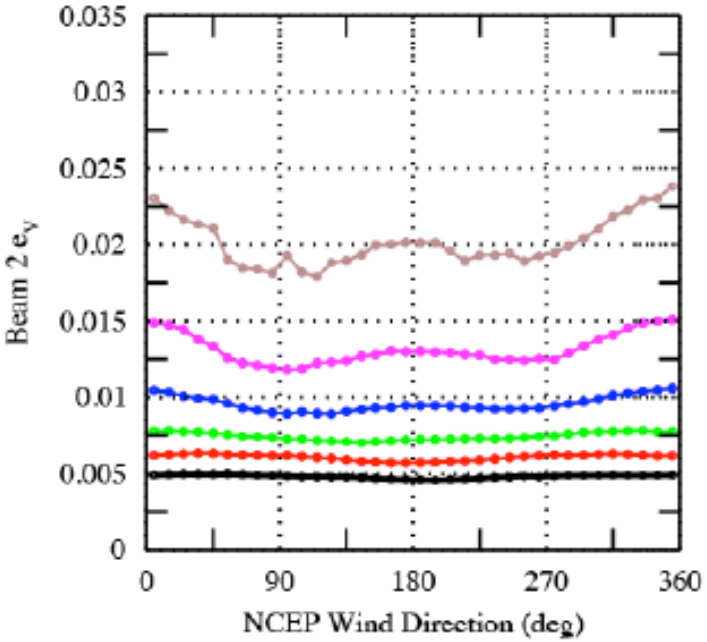


Effects of Wind/Wave on Radar and Radiometer Signals Observed by Aquarius

- 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

JPL's Aquarius Combined Active-Passive (CAP) Retrieval

- Combined Active-Passive (CAP) Algorithm – minimization of a quadratic cost function
  - Retrieve SSS, Wind Speed and Direction Using Combined Passive and Active Data

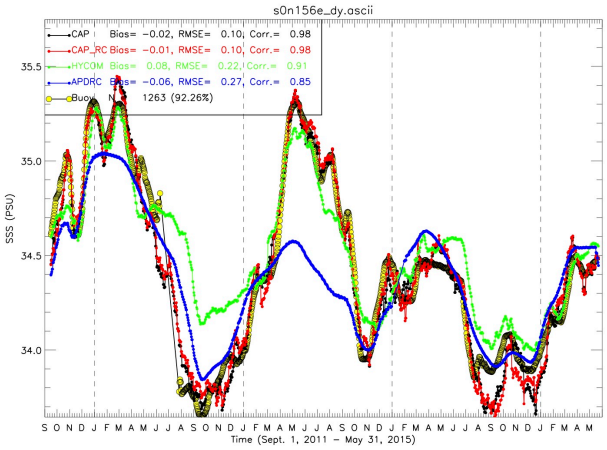
$$F_{ap}(SSS,w,\phi)=\frac{(T_{BV}-T_{BVm})^2}{\Delta T^2}+\frac{(T_{BH}-T_{BHm})^2}{\Delta T^2}+\frac{(\sigma_{VV}-\sigma_{VVm})^2}{k_p{}^2\sigma_{VV}{}^2}+\frac{(\sigma_{HH}-\sigma_{HHm})^2}{k_p{}^2\sigma_{HH}{}^2}+\frac{(w-w_{NCEP})^2}{\Delta w^2}+\frac{\sin^2((\phi-\phi_{NCEP})/2)}{\delta^2}$$

- CAP V4.0 includes two SSS outputs
  - SSS with no rain correction
  - SSS_rc with rain correction

Yueh, S. H., W. Tang, A. Fore, G. Neumann, A. Hayashi, A. Freedman, J. Chaubell, and G. Lagerloef (2013). *IEEE Trans. Geoscience and Remote Sensing*
Yueh, S. H., W. Tang, A. Fore, A. Hayashi, Y. T. Song, and G. Lagerloef (2014), *J. Geophys. Res. Oceans.*

Validation of JPL's Aquarius Combined Active-Passive (CAP) SSS Retrieval

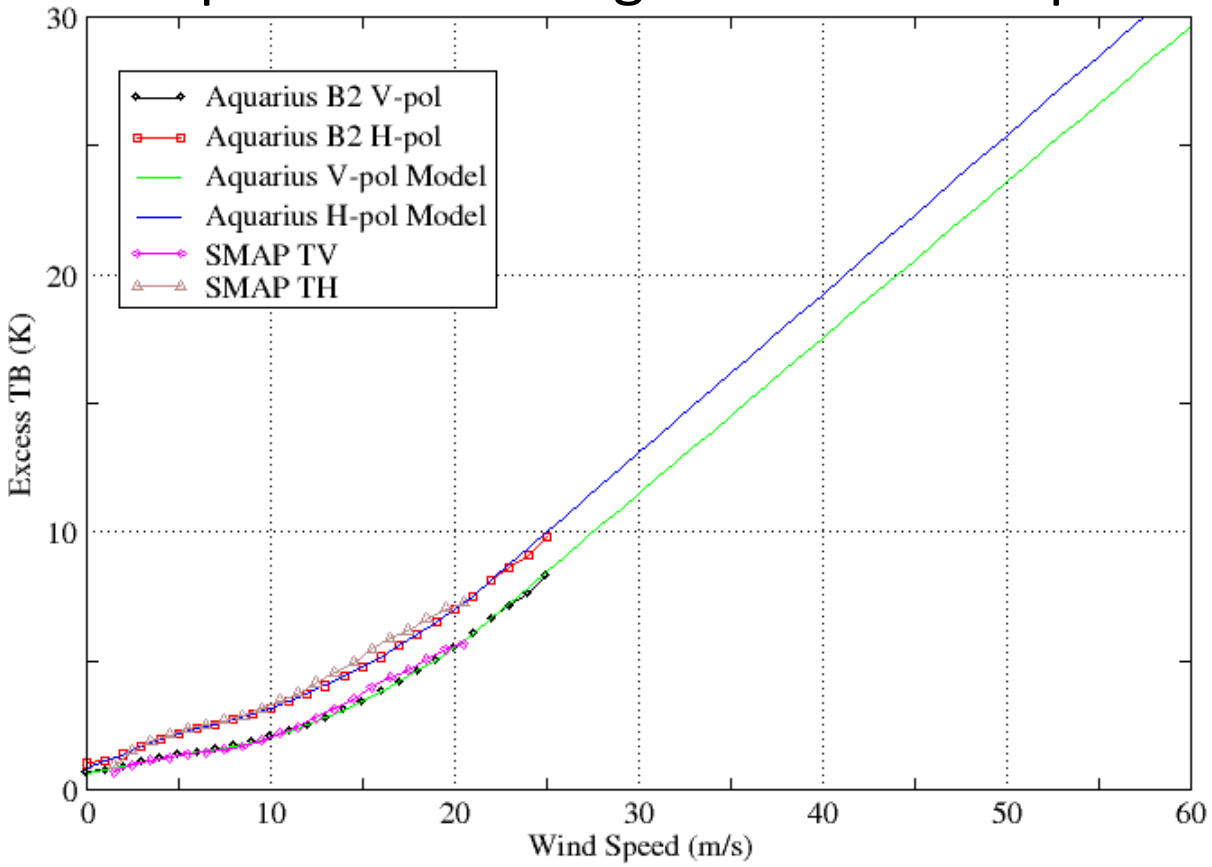
- 0.14 (RMSD) psu with respect to buoy data
- Better agreeemnt with buoy data than Hycom and APDRC (0.19 psu, RMSD)



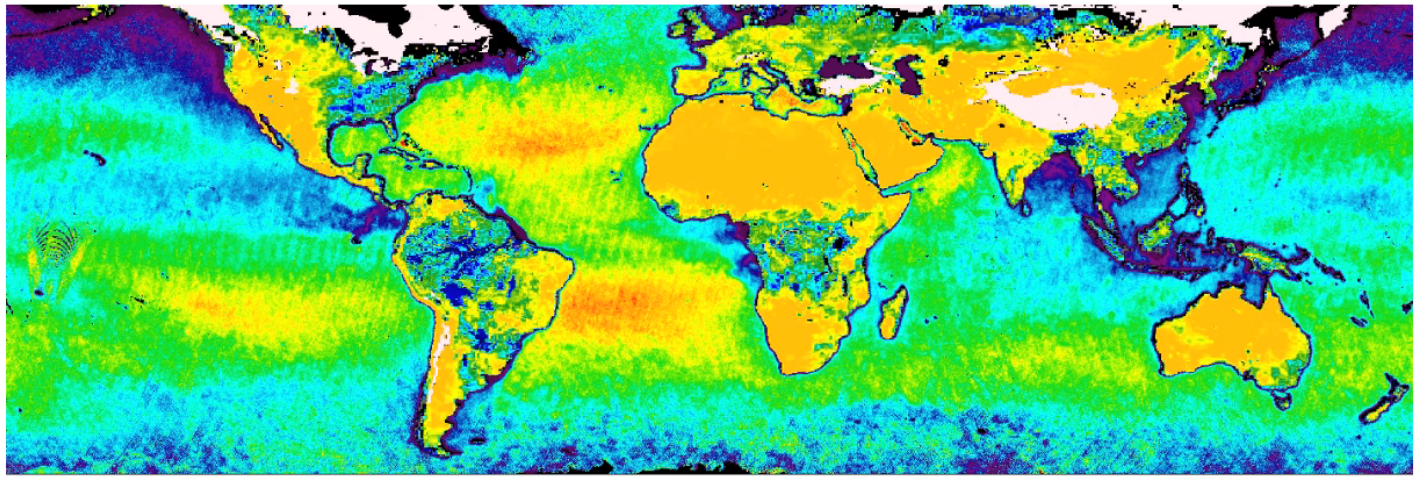
	CAP	CAP_RC	HYCOM	APDRC
Bias [PSU]	0.032	0.036	0.043	0.001
RMSD [PSU]	0.141	0.141	0.191	0.190
Correlation	0.710	0.711	0.611	0.600

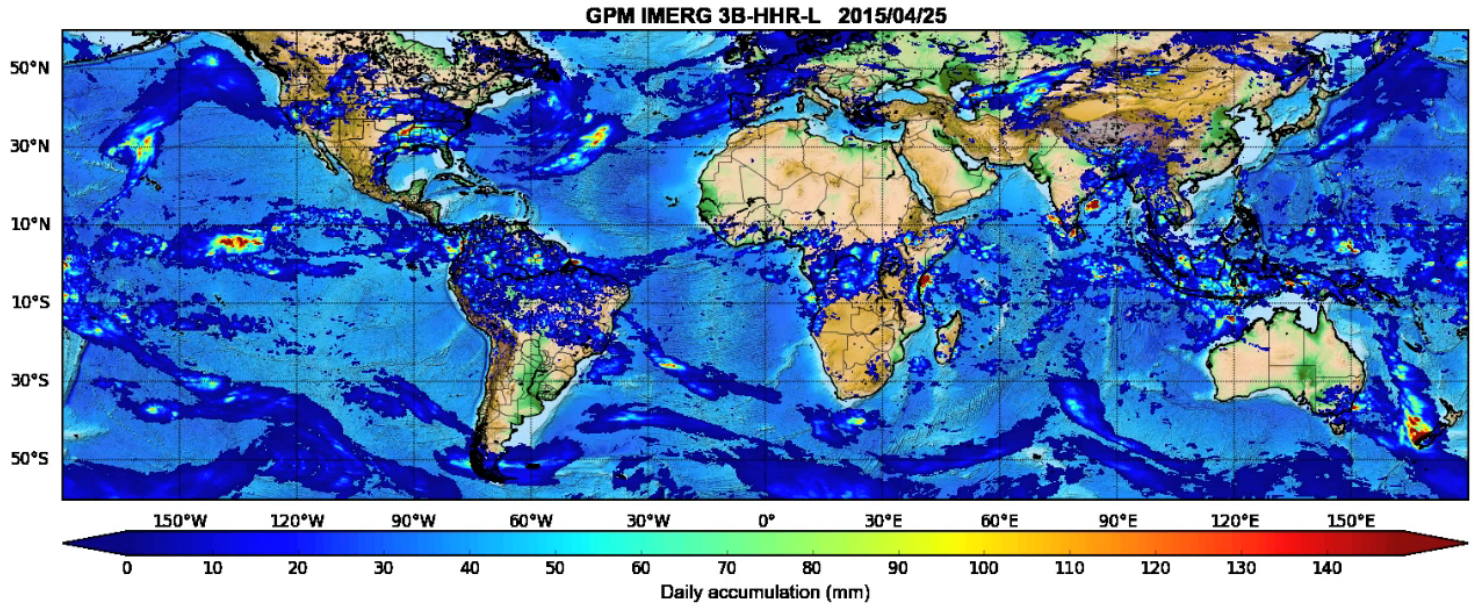
Aquarius/SACD Excess Brightness Temperature Model Applicable to SMAP

- Aquarius Model Function Derived from V.4 data
- SMAP data acquired to date agree with the Aquarius GMF.



SMAP Salinity + Soil Moisture and GPM Rain
(SMAP Salinity not yet as accurate as Aquarius)



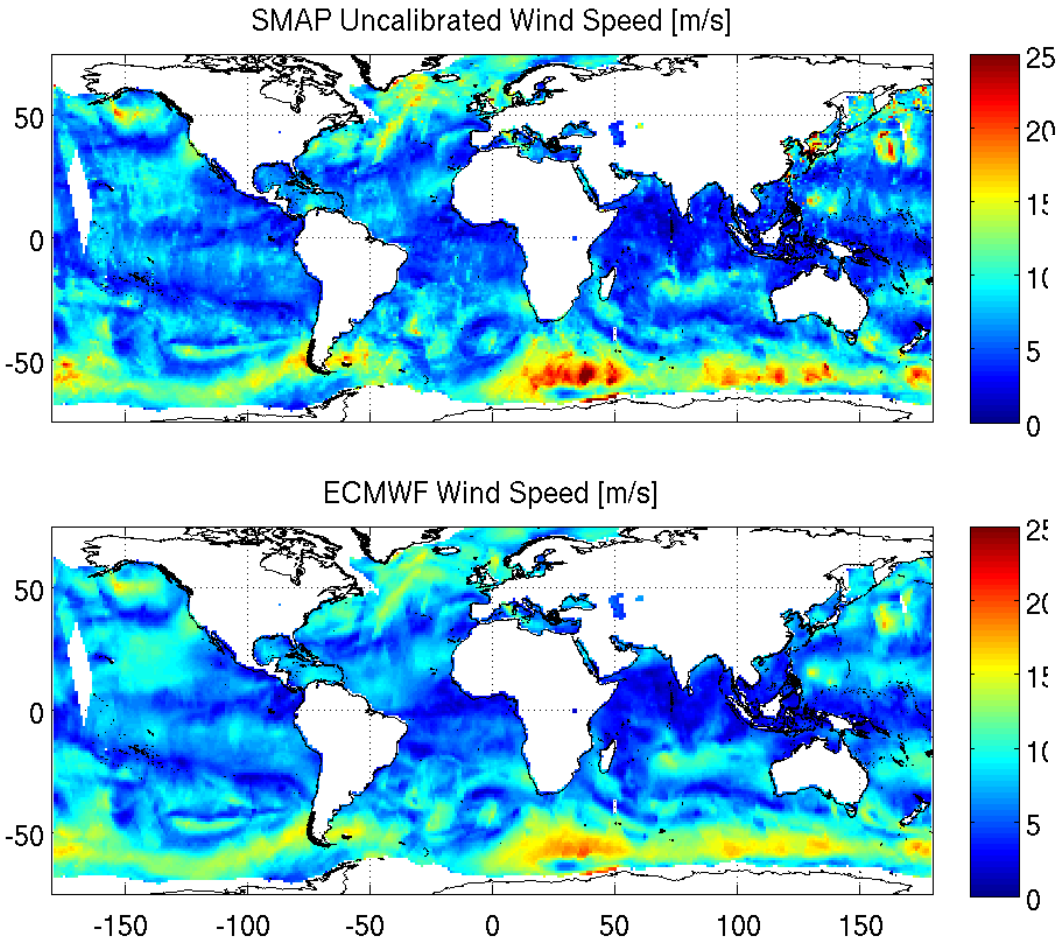


L-Band Remote Sensing of Severe Ocean Wind

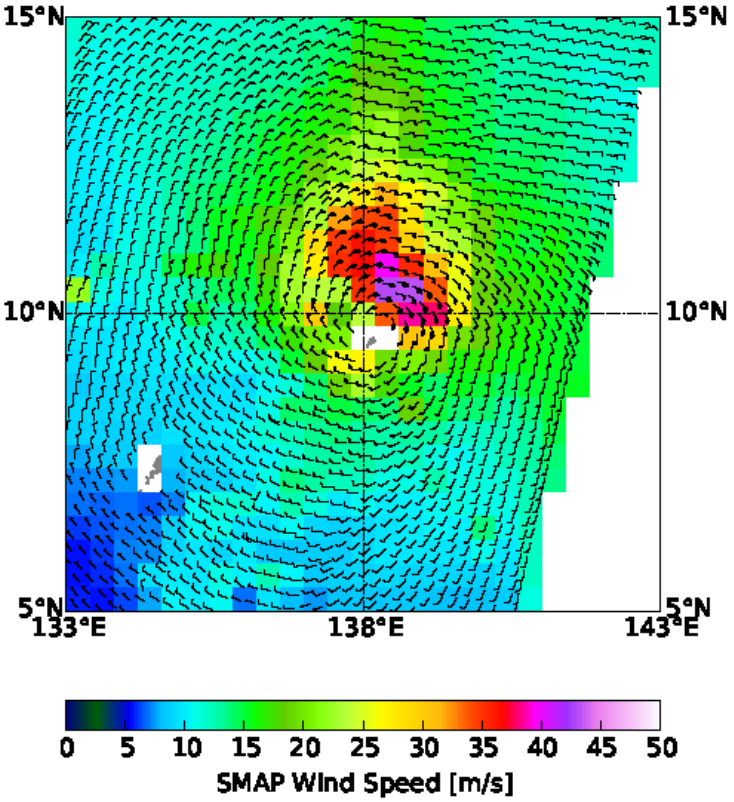
- Surface Roughness Impact on L-band Microwave: signal for severe ocean surface wind
  - Active -> vector
  - Passive only -> speed

L-band Radar Data for Ocean Surface Winds

- SMAP two look radar data used to produce ocean surface winds – good agreement with the ECMWF analysis
- Research effort supported by Oceanography program



SMAP radar wind for super typhoon Maysak on 2015-090

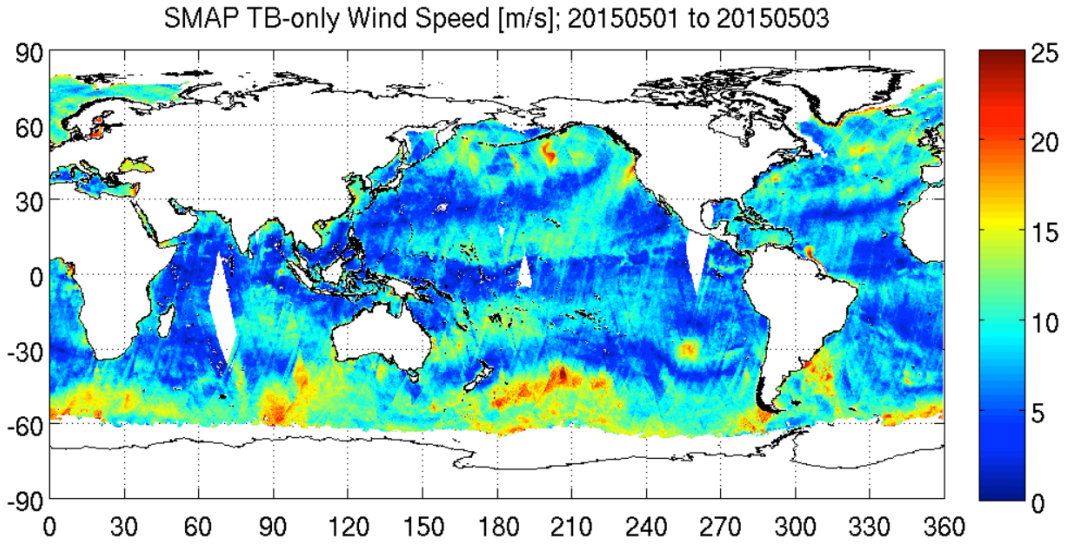


SMAP L-band Radiometer Data For Severe Weather

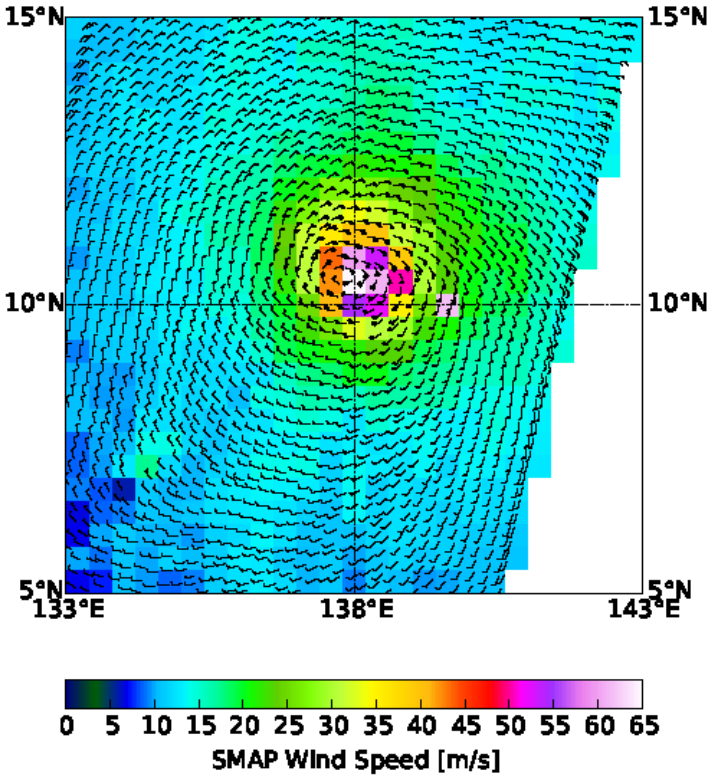
All Weather Ocean Surface Wind speed

- L-band brightness temperature useful for hurricane wind speed retrieval using two looks, dual-pol TB data given the NCEP wind direction

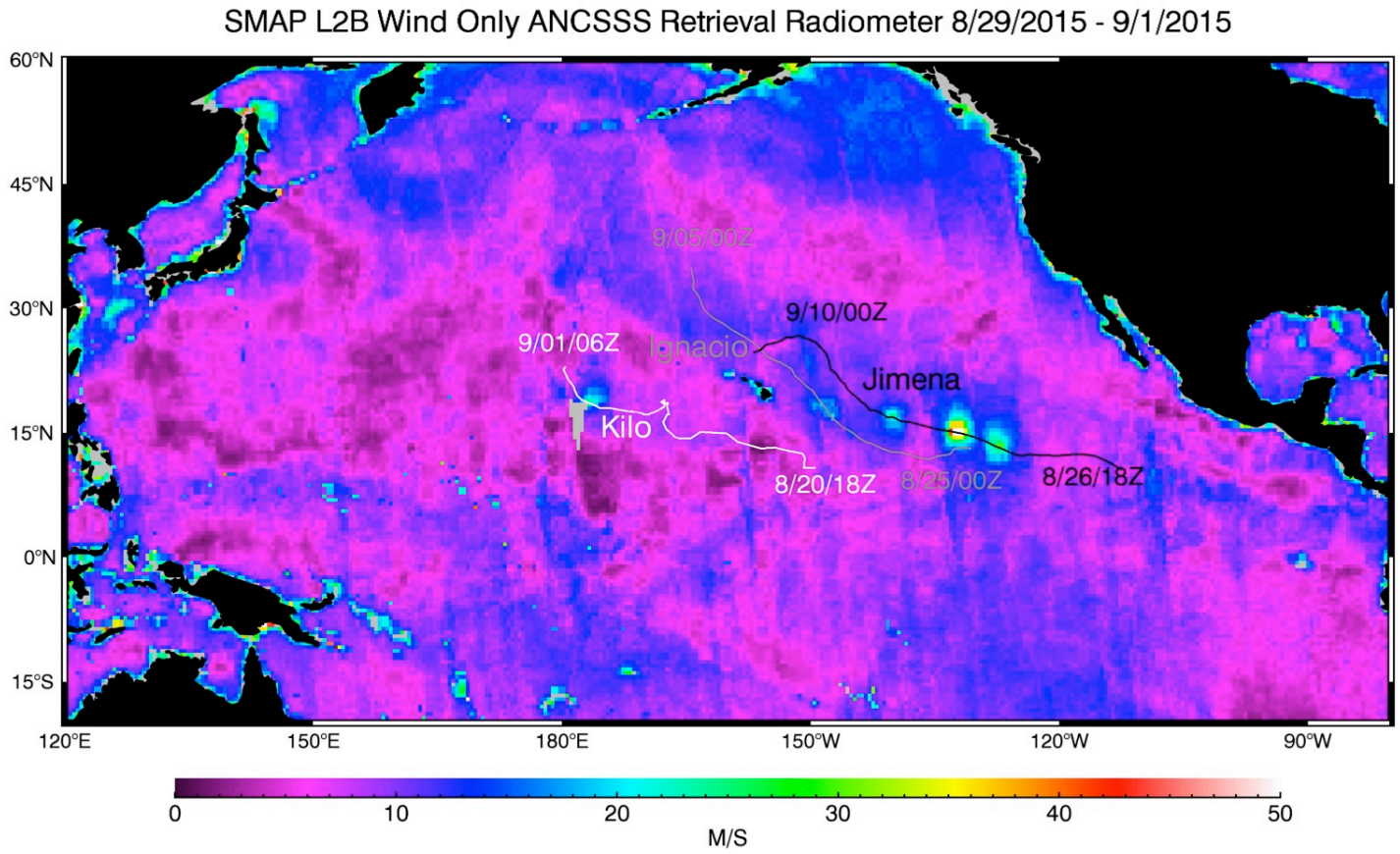
$$C = \sum_{i=1}^{2} \frac{(T_{BVi} - T_{BVMi})^2}{\Delta T^2} + \sum_{i=1}^{2} \frac{(T_{BHi} - T_{BHMi})^2}{\Delta T^2}$$



SMAP Wind for Super Typhoon Maysak on Mar 31, 2015 reached 120 knots



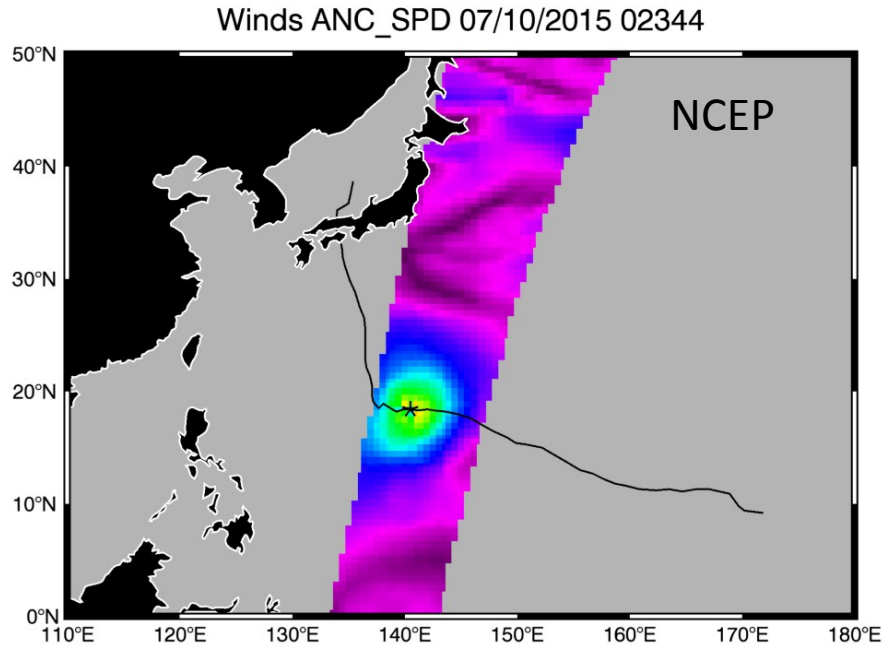
SMAP captured three C4 Pacific Hurricanes August-September 2015

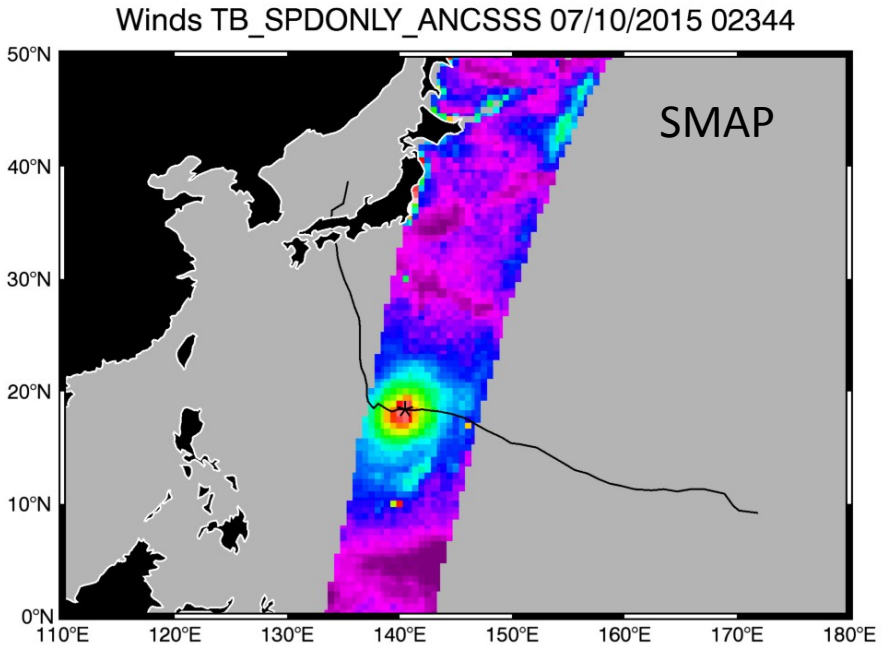


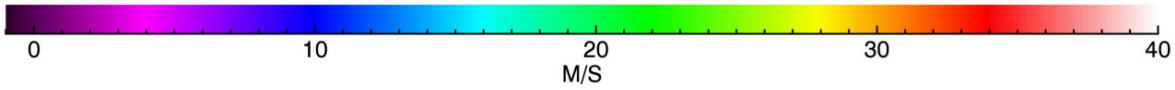
SMAP and NCEP Winds for Nangka

- **Both SMAP and NCEP captured the storms**
- **SMAP exhibited a much stronger intensity**

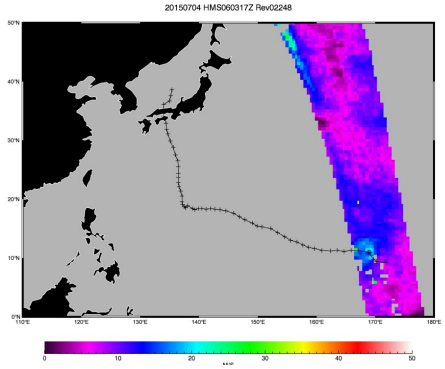
NANGKA

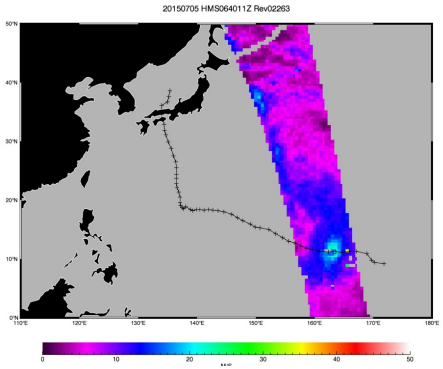


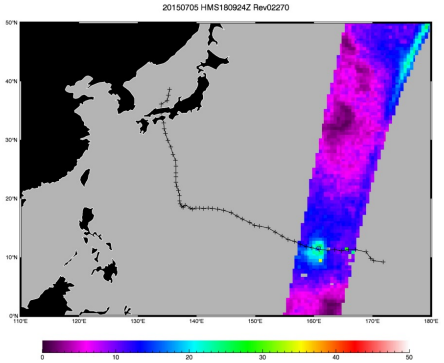


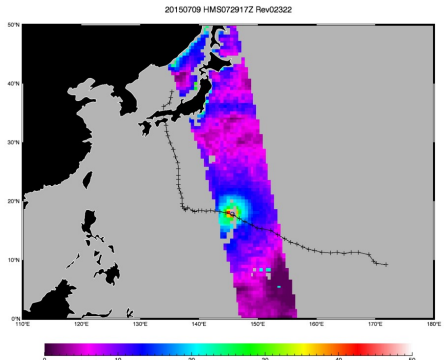


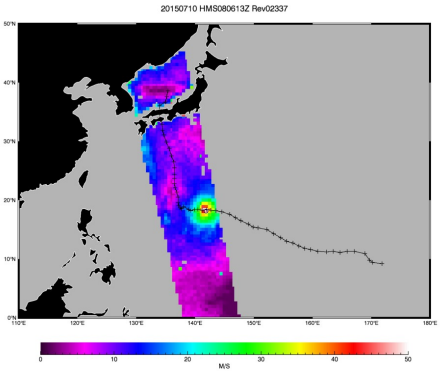
SMAP Wind Speed and Track for Typhoon NANGKA (Cat 4)

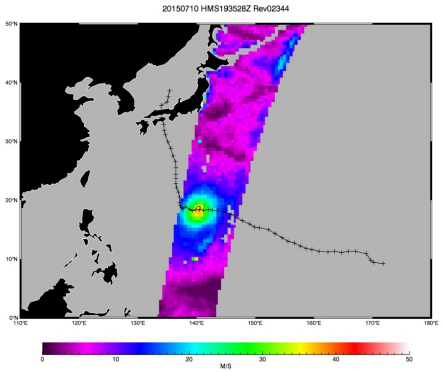


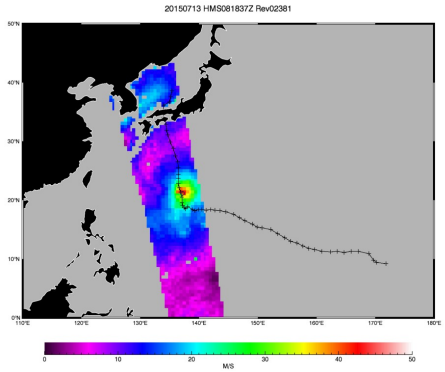






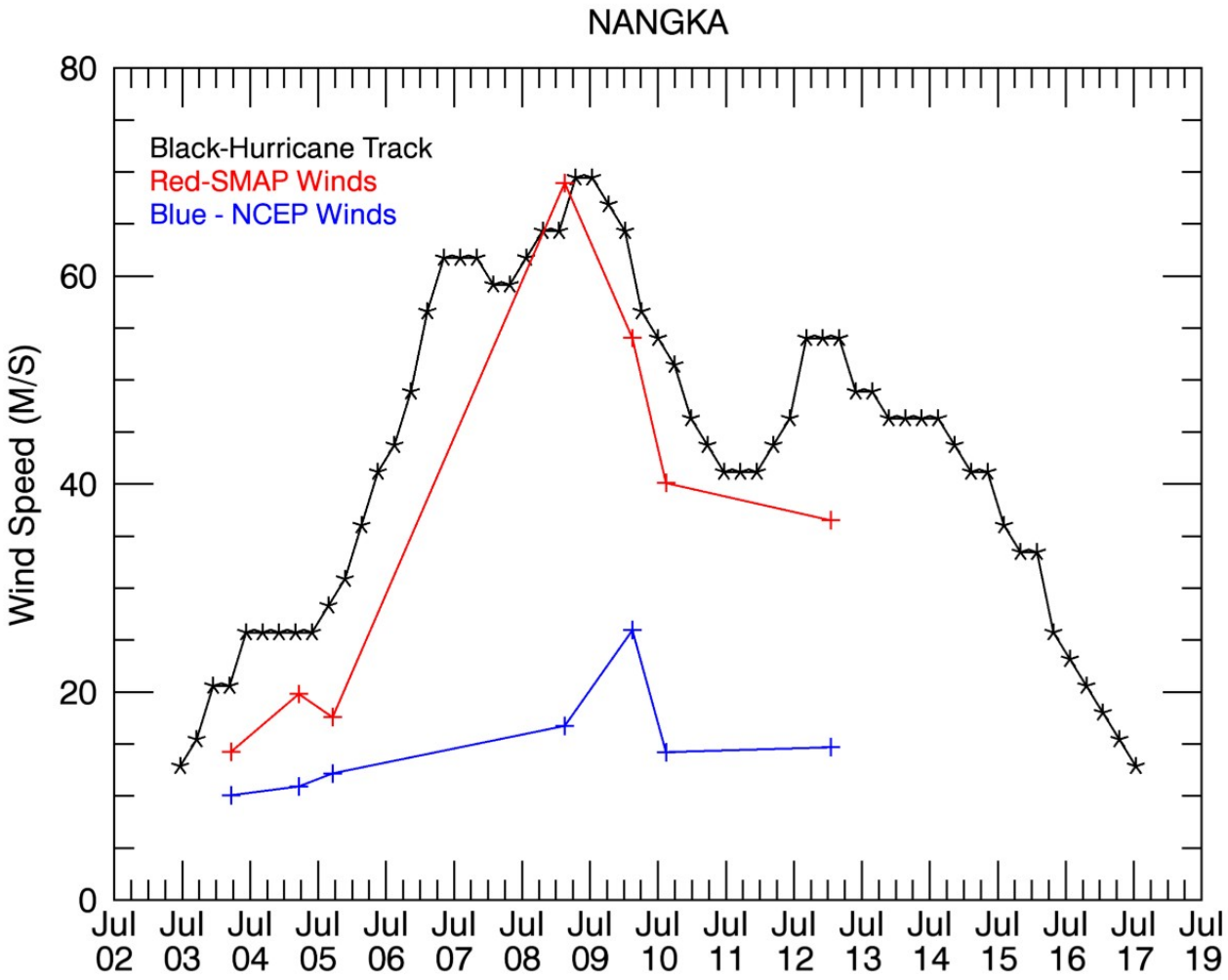






Maximum SMAP Wind Speed and Track analysis for Typhoon NANGKA (Cat 4)

Good Agreement with TPC's Best Track Analysis

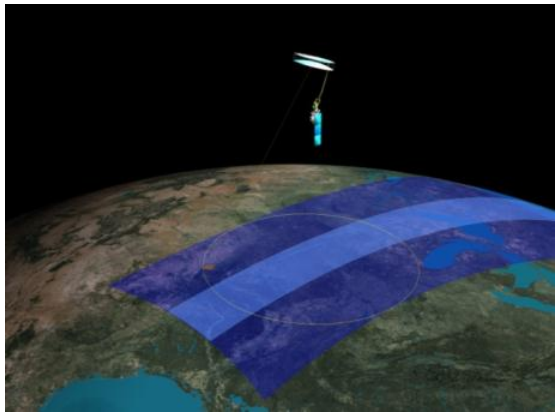


Summary

- Aquarius/SACD – the first L-band combined active-passive space mission – provided data for SSS research
- Aquarius/SACD data also provide rich information leading to new applications, inc. severe ocean wind remote sensing, land surface freeze/thaw detection, and so on.
- Provide the foundation for the next decadal Earth Science survey

Future - Decadal Survey Mission Concept

- 20 km spatial resolution -> Large 12 meter antenna
- 3-day revisit -> Conical scanning to produce > 1000 km swath



- Improved accuracy– Multi-frequency band
  - L+Active/passive (Continuity)
  - P passive (Cold water sensitivity/Sea ice)
  - C and/or S passive (SST and roughness)

Excess Brightness Temperature Due to Surface Roughness

- Discrepancy of the Aquarius and SMOS GMF for high winds to be resolved.