One & Two-Dimensional Wind Speed Models for Ka-Band Altimetry

John Lillibridge

NOAA Laboratory for Satellite Altimetry

<u>Remko Scharroo</u>

EUMETSAT

Saleh Abdalla

ECMWF

Doug Vandemark

University of New Hampshire

Outline

1. *Motivation*
2. *Applications*
3. *Backscatter (σ^0) Attenuation*
4. *One-Dimensional WS model: f (σ^0)*
5. *Two-Dimensional model: f (σ^0, SWH)*
6. *Conclusions*

Motivation

Initial Cal/Val Products:

- Attenuation correction = 0
- Ku wind speed model inappropriate for Ka-band

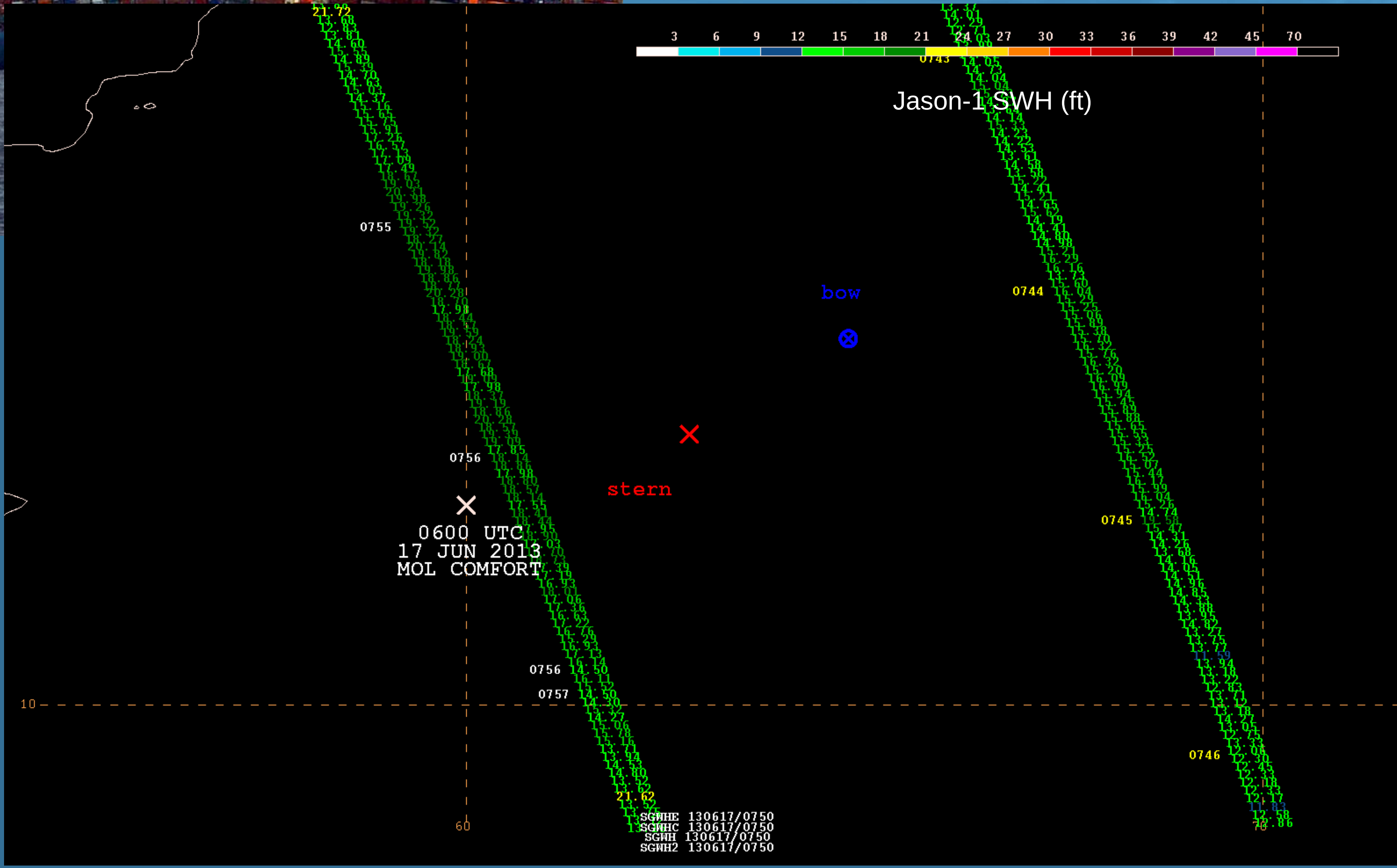
Preliminary 1D model of Abdalla (2013):

- Adjust σ^0 histogram to match Ku distribution
- Utilize existing Ku wind speed model

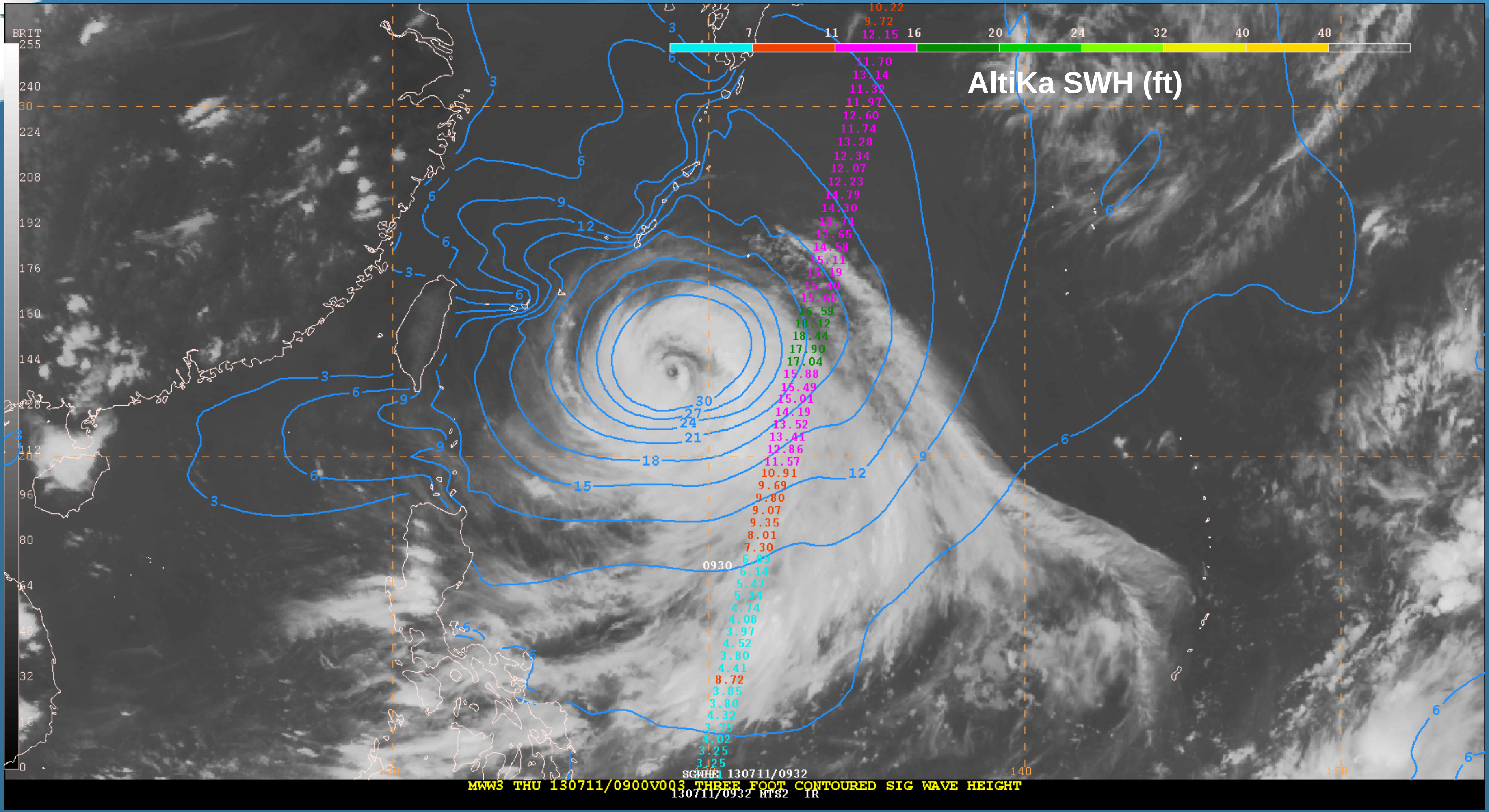
Our improved formulation:

- Physically based attenuation correction
- 1D and 2D models tuned to Ka backscatter
- Important for SSB models based on WS

Maritime Monitoring



Applications: Typhoon Soulik



NOAA/NWS utilizing AltiKa Wind/Wave information in 2013 Hurricane Season

Backscatter Attenuation Correction

Based on ITU radar propagation algorithms

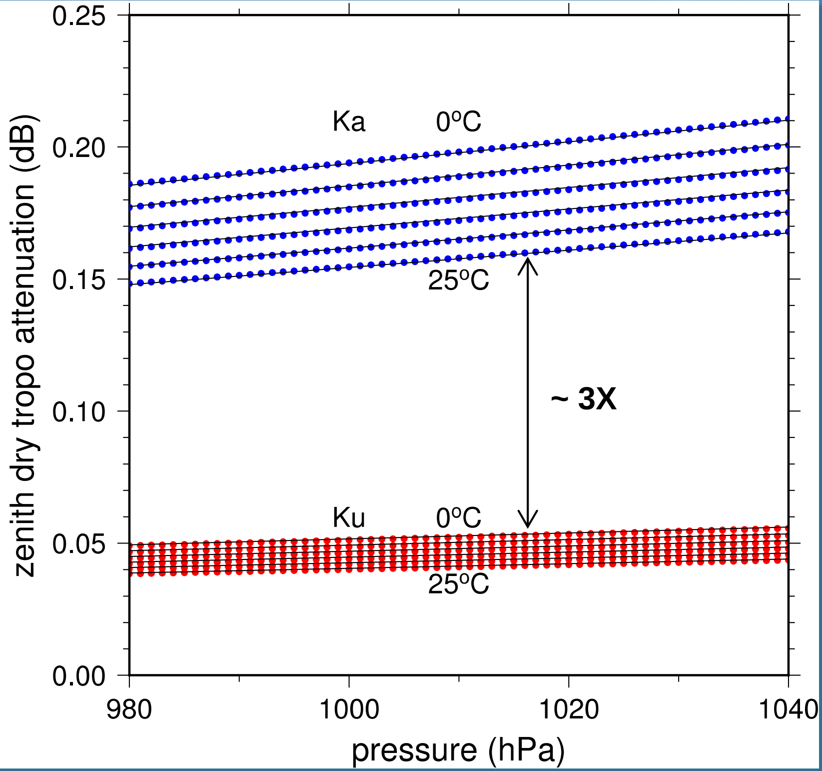
- **Dry troposphere (oxygen) = f (Press, Temp)**
- **Wet troposphere = f (Water Vapor Content)**
- **Rain / Fog = f (Liquid Cloud Water)**

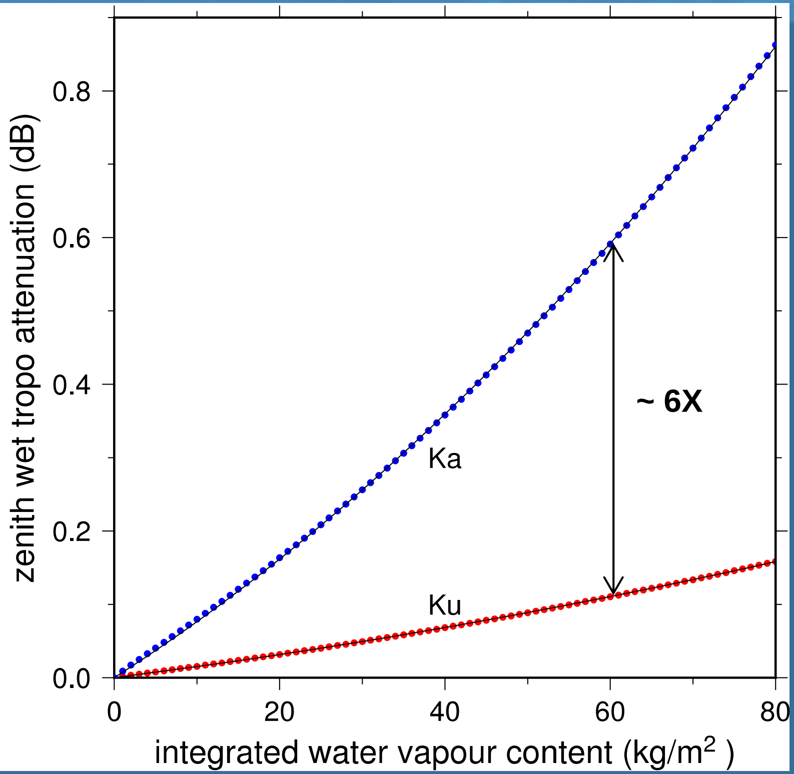
Polynomial fits to Ka-band frequency results

Driven by NOAA/NCEP GFS model grids

Double correction to account for round trip…

Backscatter Attenuation Correction





$$\Delta\,\sigma^{o}_{\text{dry}} = \begin{cases} 0.094 - 0.177\,p' - 0.145\,t' + 0.274\,p't' & \text{for Ku-band} \\ 0.310 - 0.593\,p' - 0.499\,t' + 0.956\,p't' & \text{for Ka-band} \end{cases}$$

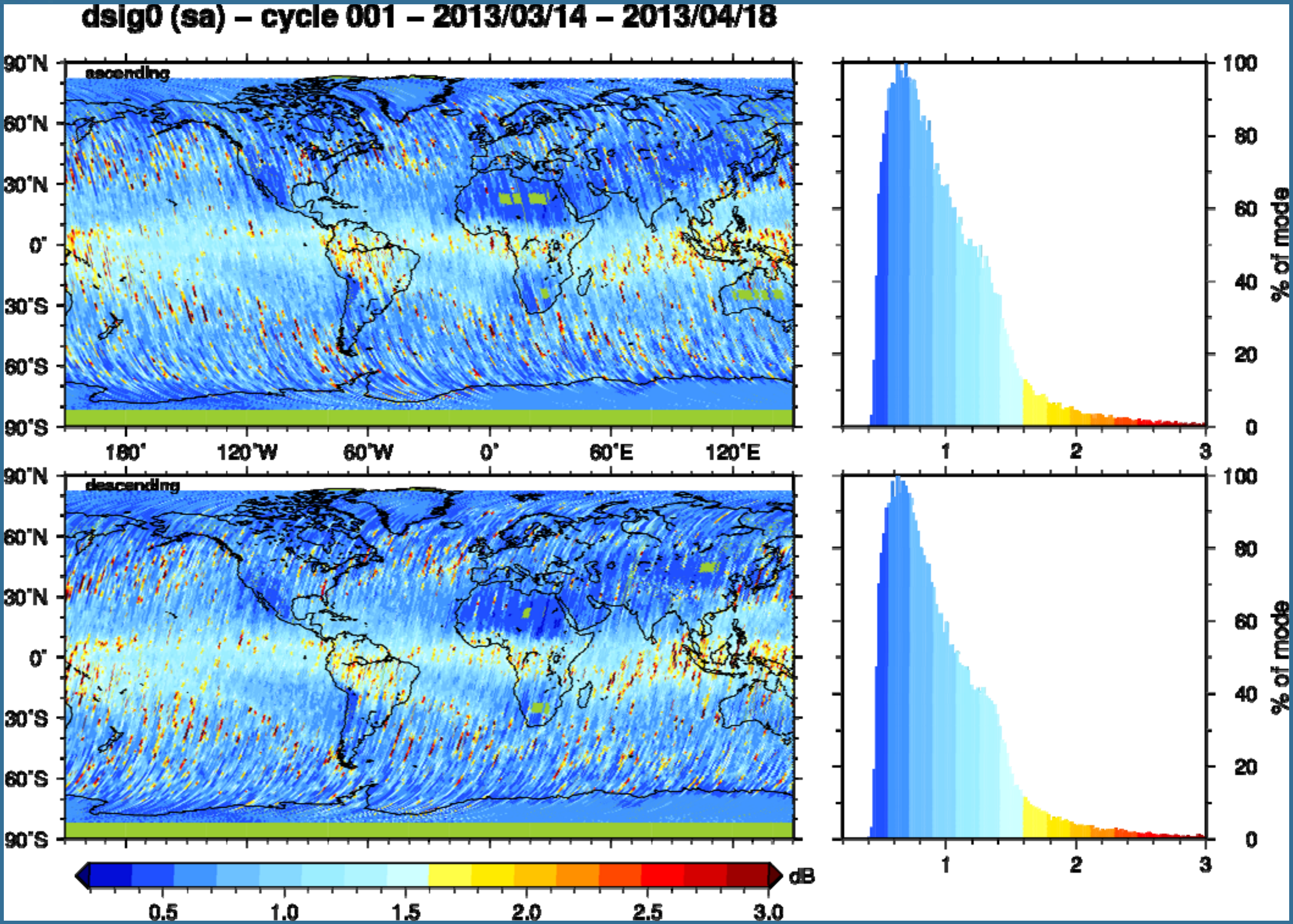
$$p' = p/1013 \qquad p = \text{ pressure in hPa}$$
$$t' = 288.15/t \qquad t = \text{temperature in K}$$

$$\Delta\,\sigma^{o}_{\text{wet}} = \begin{cases} 1.45\times10^{-3}\,w + 0.66\times10^{-5}\,w^2 & \text{for Ku-band} \\ 7.21\times10^{-3}\,w + 4.43\times10^{-5}\,w^2 & \text{for Ka-band} \end{cases}$$

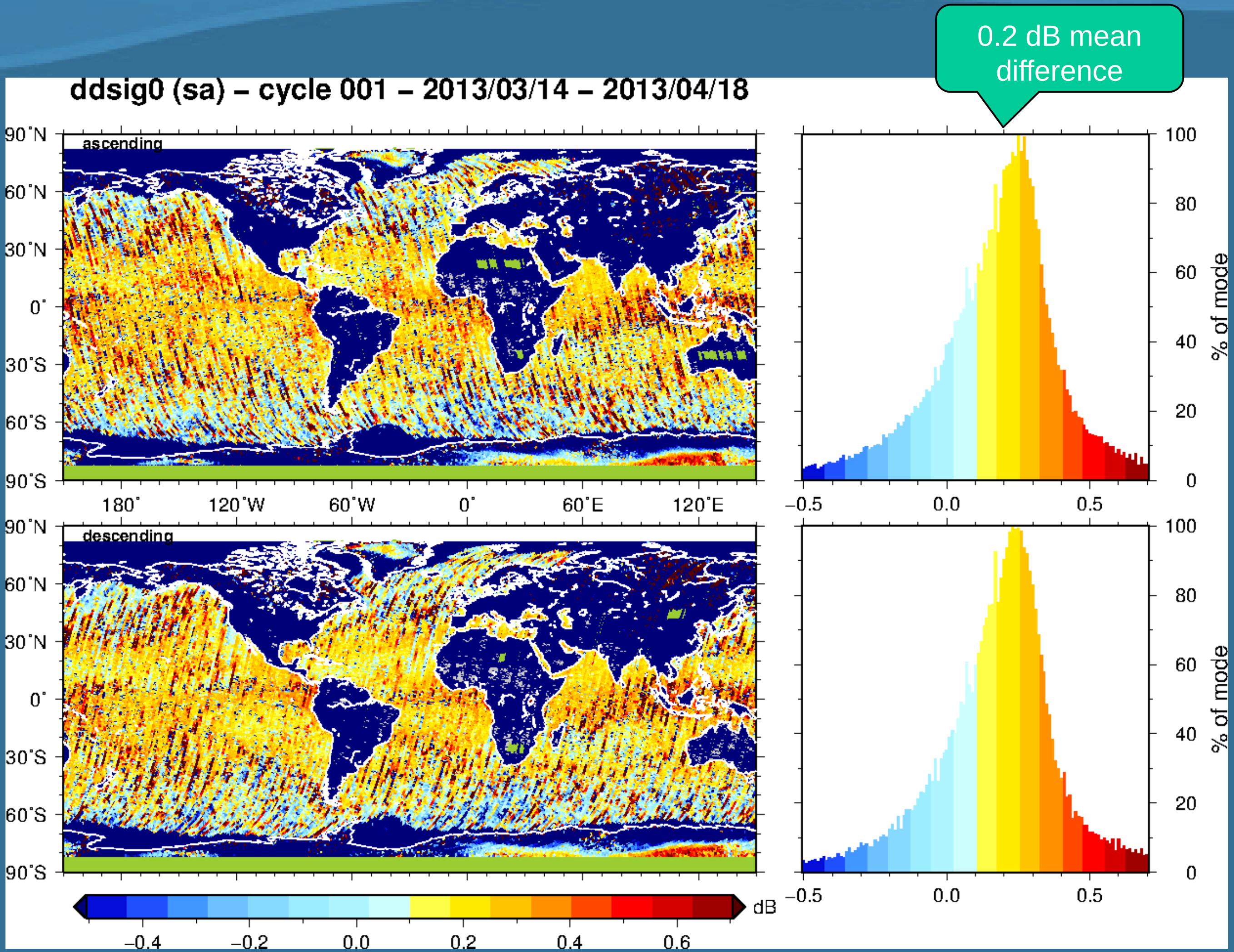
$$\Delta\,\sigma^{o}_{\text{rain}} = \begin{cases} 0.169\,L & \text{for Ku-band} \\ 1.070\,L & \text{for Ka-band} \end{cases}$$

~ 7X

Backscatter Attenuation Correction

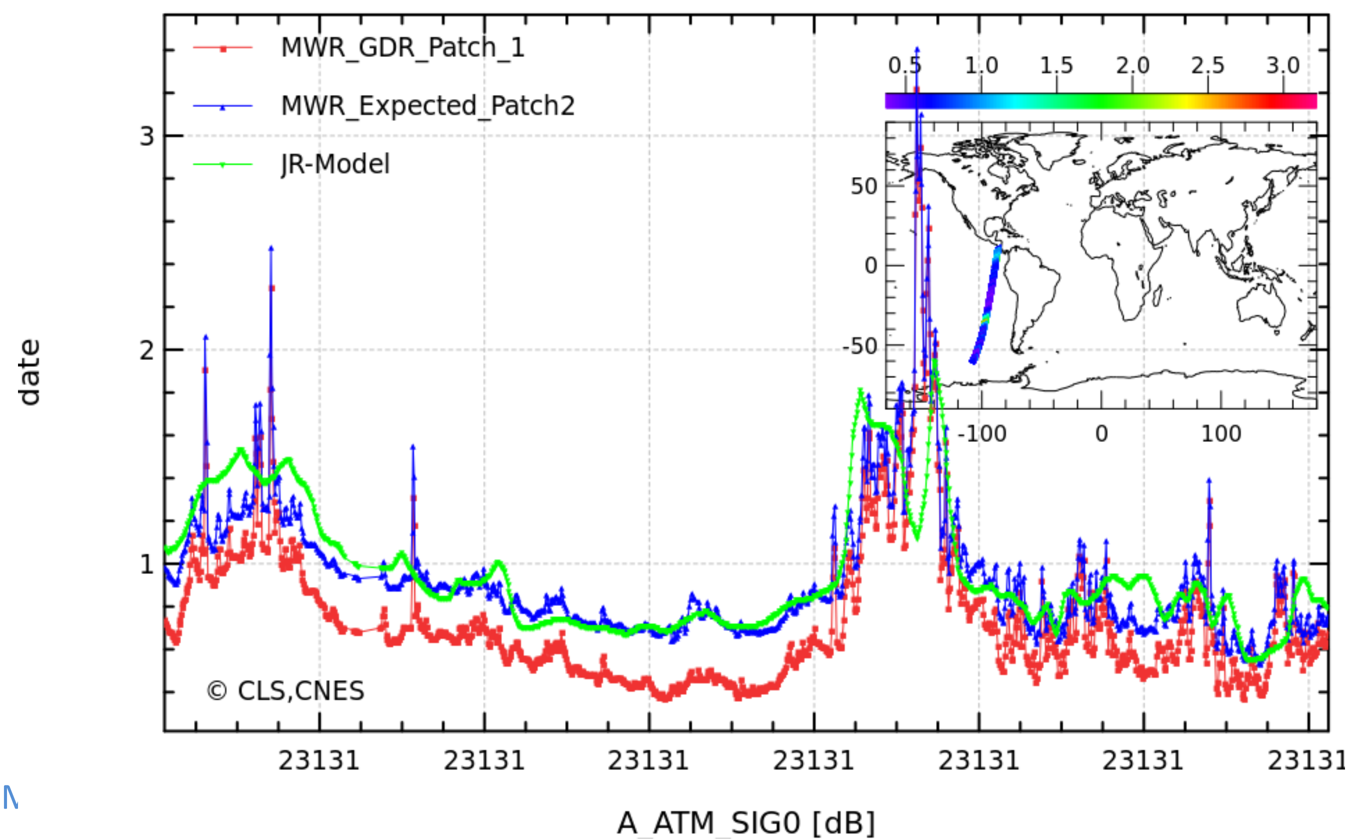


Backscatter Attenuation Correction (difference ITU – GDR patch 1)



Atmospheric attenuation

- Retrieval algorithm similar to the wet tropo one Att_Ka=NN(TB23.8,TB37, sigma0Ka)
- Comparison with Lillibridge-Scharroo model attenuation :
  - After P1 adjustment no more bias between model and radiometer values
  - Model estimation is smoother than MWR one



Estelle Obligis

One-Dimensional Wind Speed Model

Follow formalism from Abdalla (2007)

- Originally Developed for Envisat's Ku-band altimeter
- Only dependent on backscatter
- Two-branch model: linear (low) + exponential (high)

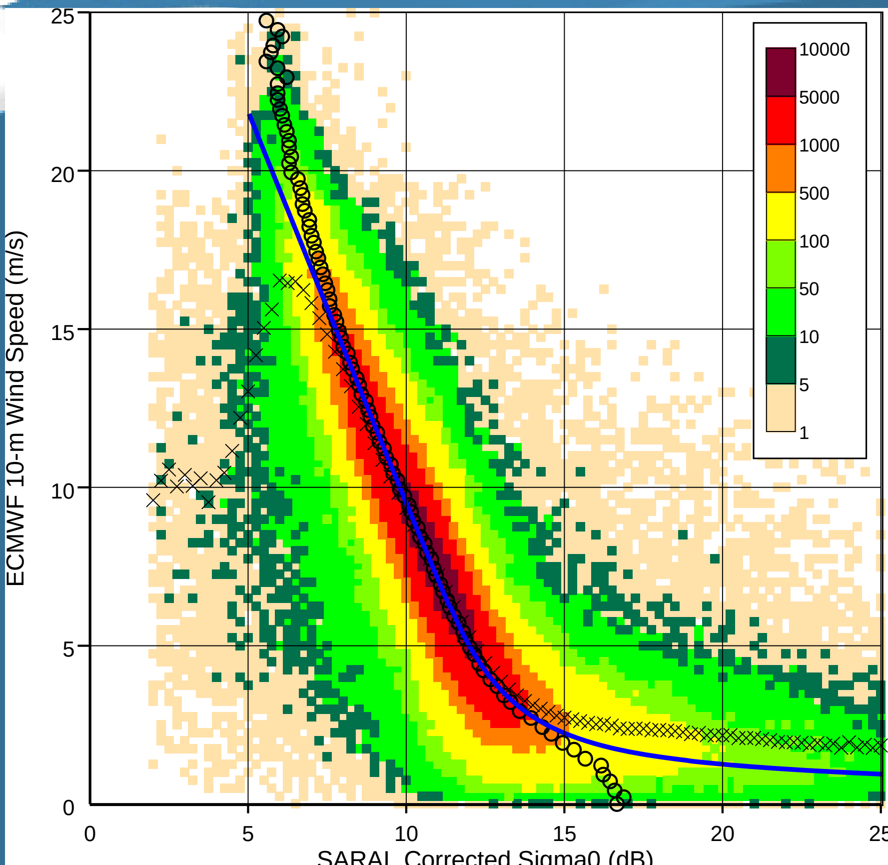
$$U_m = \begin{cases} \alpha - \beta\sigma^o & \text{if } \sigma^o \le \sigma_b \\ \gamma \exp(-\delta\sigma^o) & \text{if } \sigma^o > \sigma_b \end{cases} \qquad U_{10} = U_m + 1.4U_m^{0.096}\exp(-0.32U_m^{1.096})$$

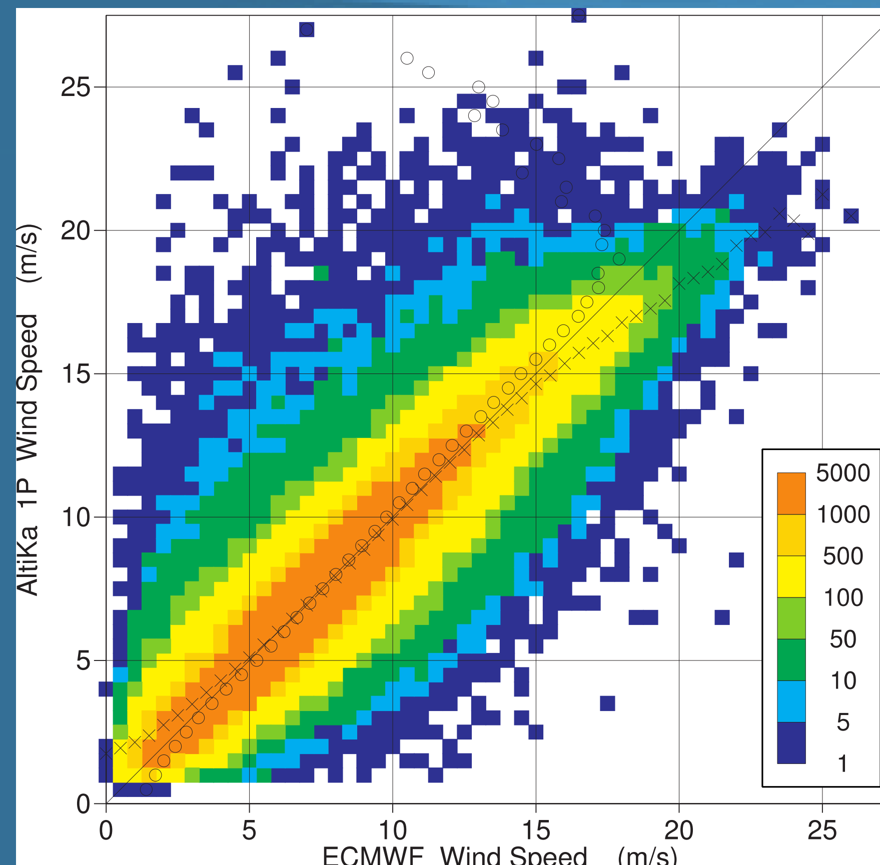
Correct AltiKa σ^0 for attenuation first

Fit model coefficients to ECMWF winds

Expect different linear slope at Ka vs. Ku

One-Dimensional Wind Speed Model

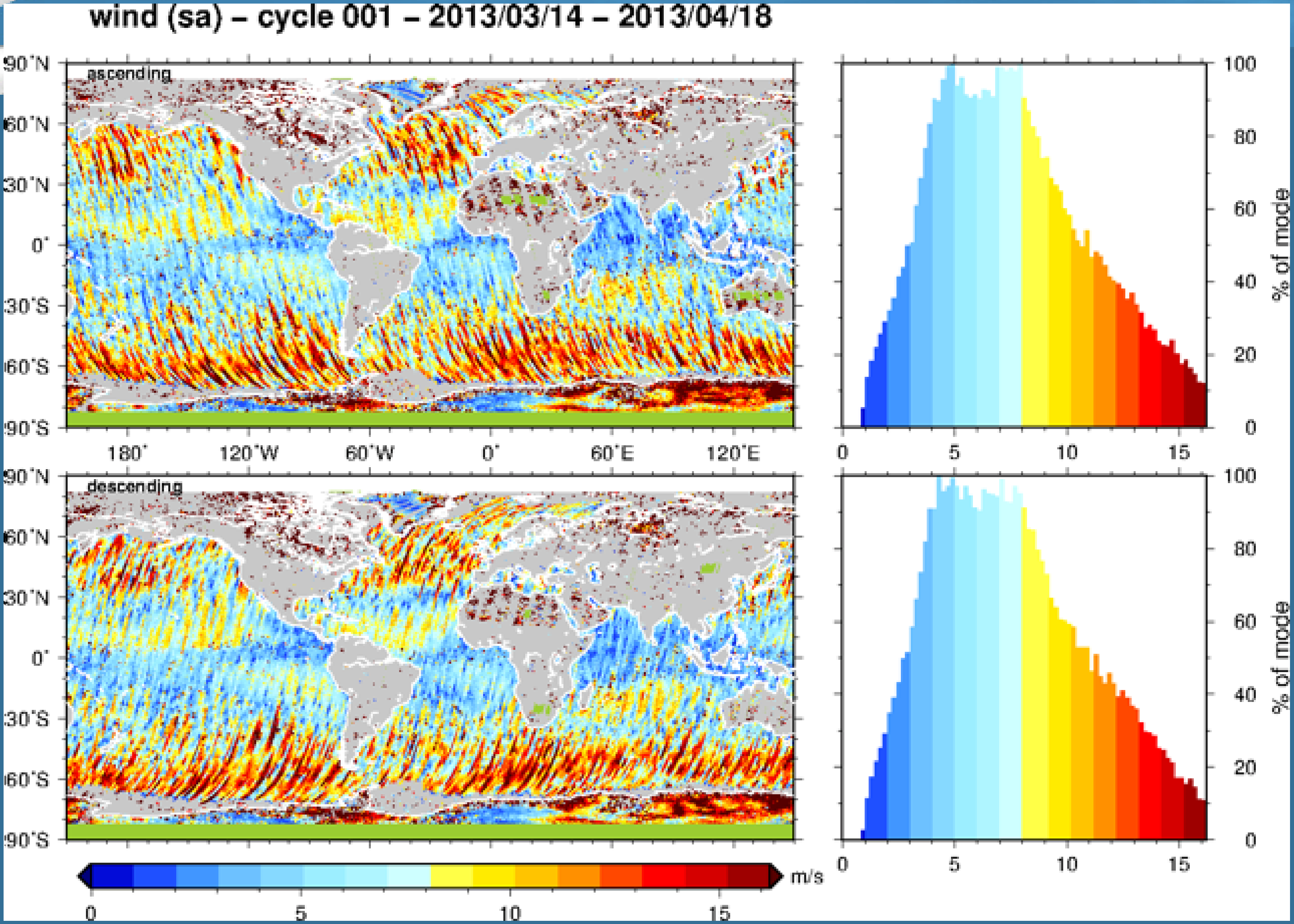




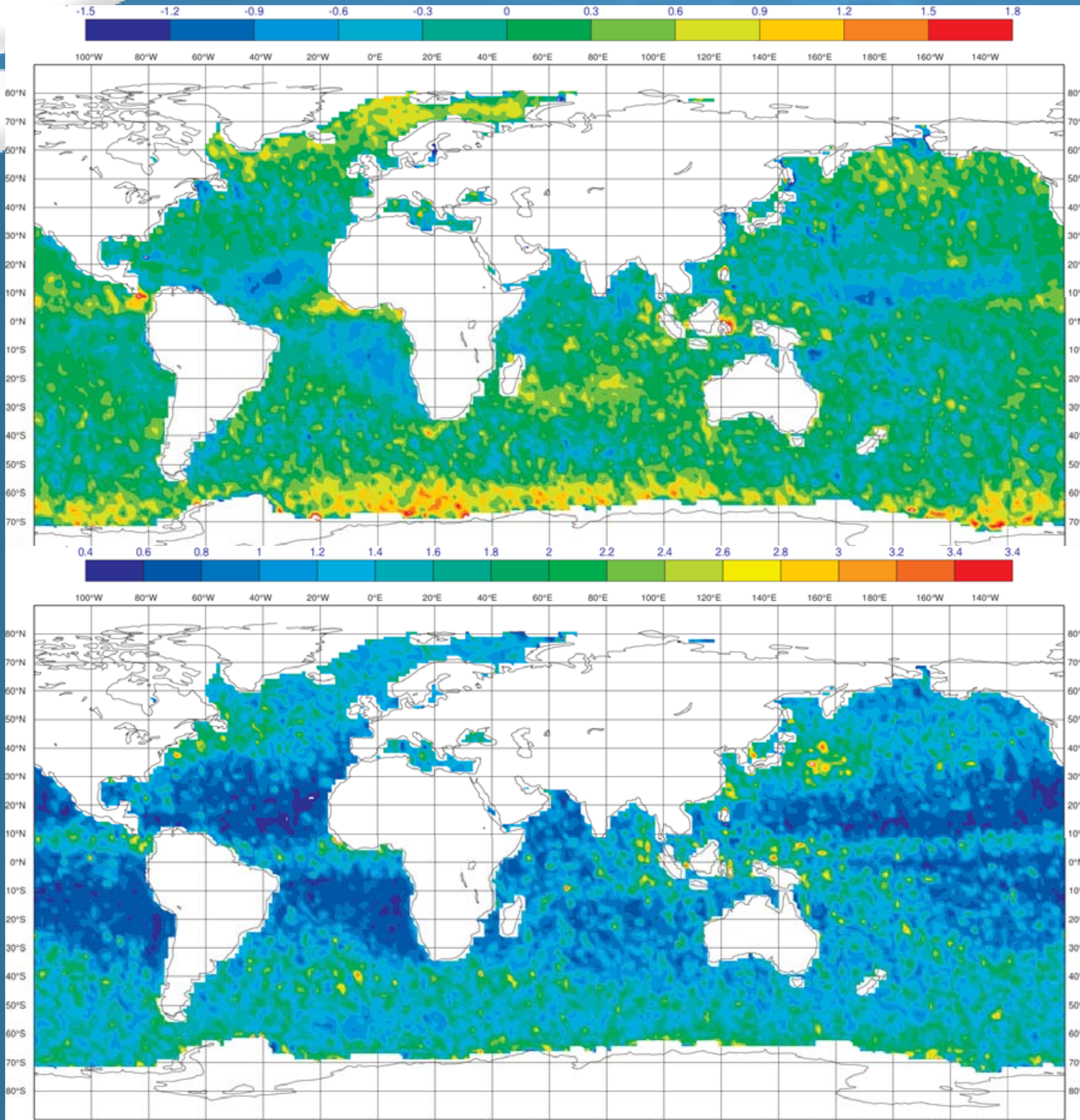
$\alpha = 34.2 \quad \beta = 2.48 \quad \sigma_b = 11.409$

$\gamma = 711.6 \quad \delta = 0.42$

One-Dimensional Wind Speed Model



One-Dimensional Wind Speed Model



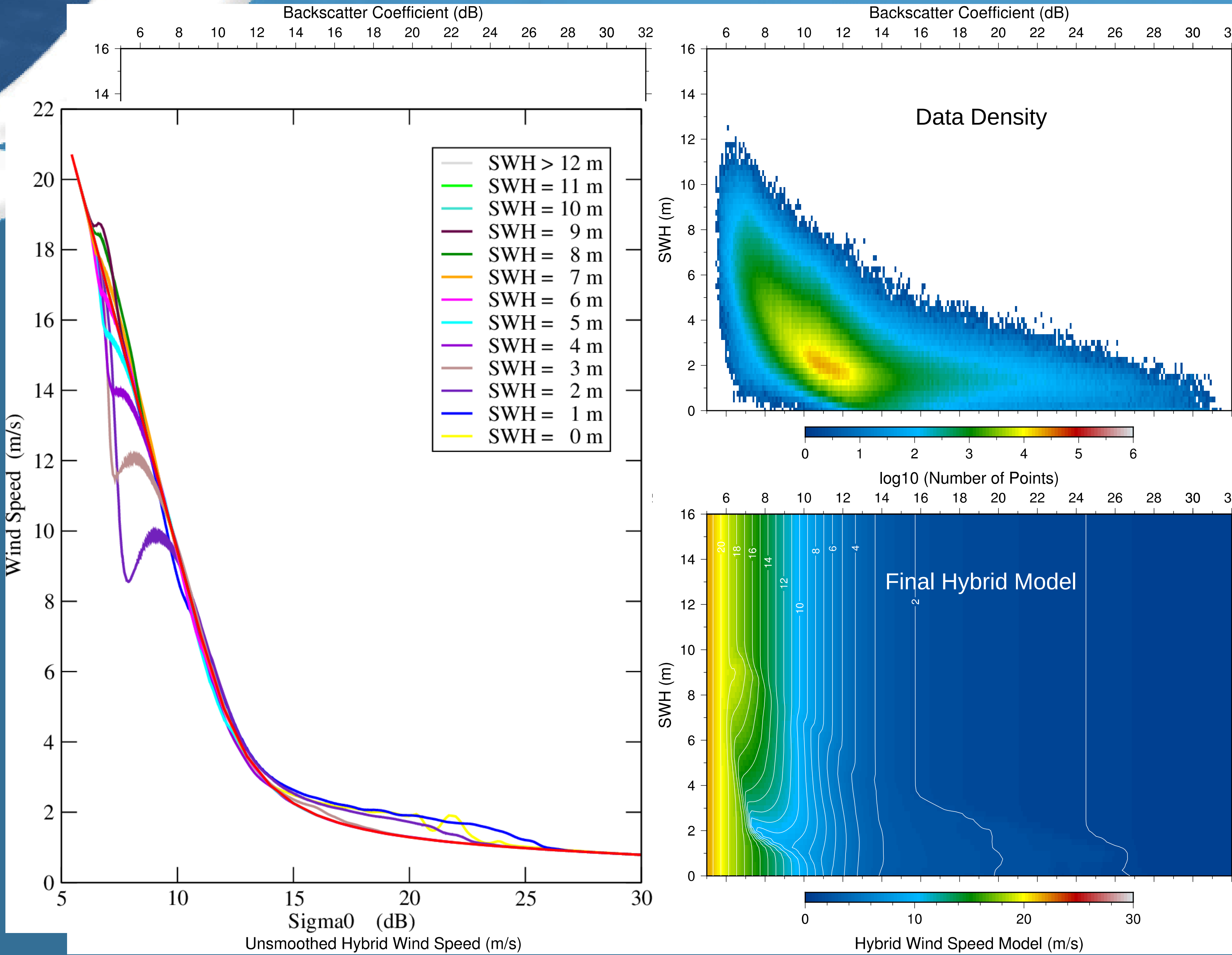
AltiKa - ECMWF Bias (m/s)

Standard Deviation of Differences (m/s)

Two-Dimensional Wind Speed Model

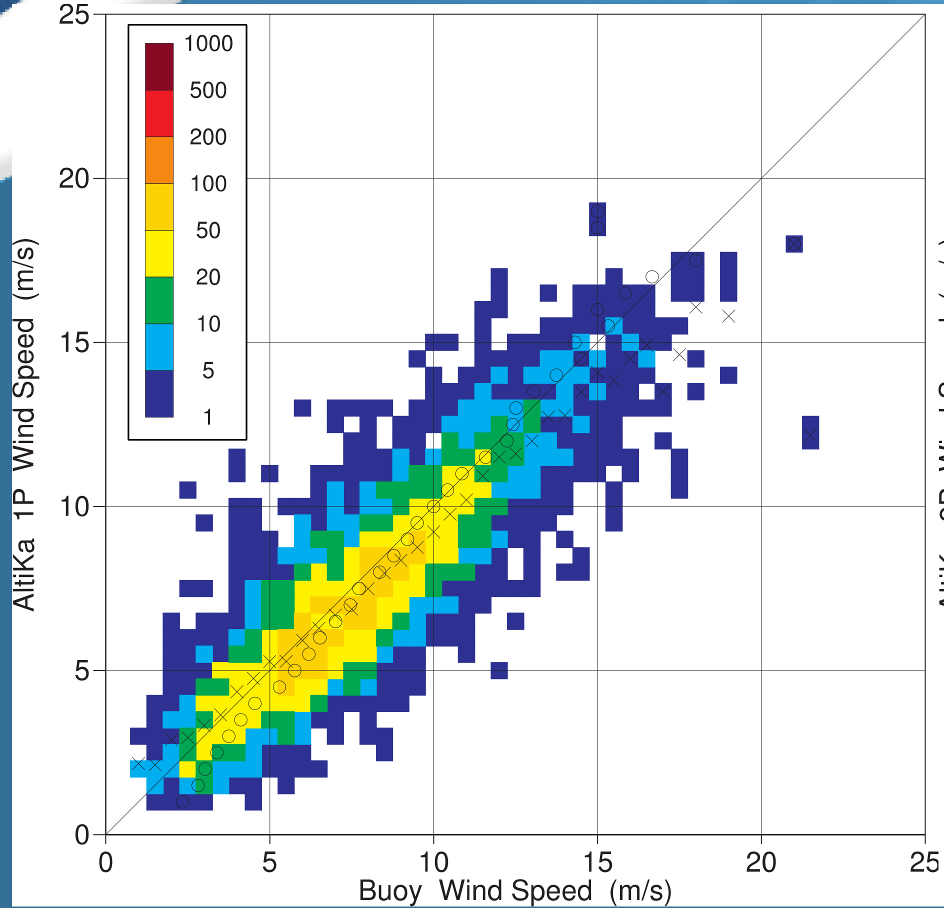
Use Direct Hybrid Method as done for SSB

1. **Bin ECMWF wind speed in σ^0 / SWH grid**
2. **Blend with background 1D parametric model**
3. **Smooth using data density to achieve hybrid model**

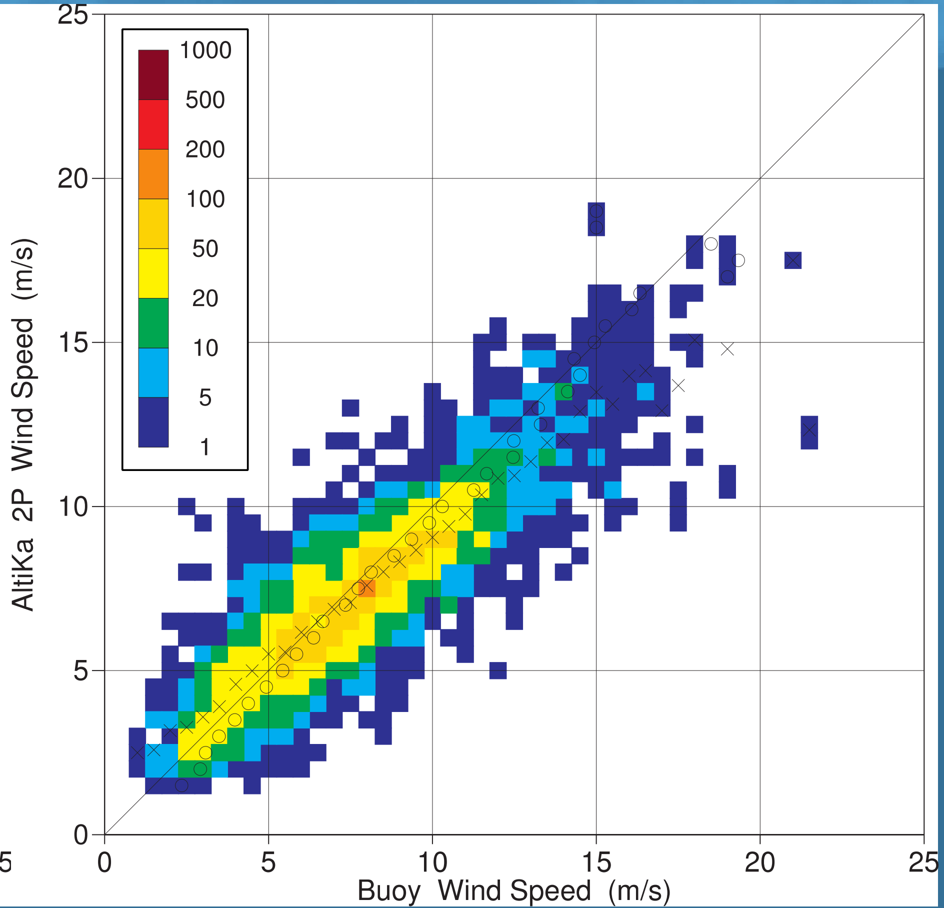


Backscatter Coefficient (dB)
SWH > 12 m
SWH = 11 m
SWH = 10 m
SWH = 9 m
SWH = 8 m
SWH = 7 m
SWH = 6 m
SWH = 5 m
SWH = 4 m
SWH = 3 m
SWH = 2 m
SWH = 1 m
SWH = 0 m
Wind Speed (m/s)
Sigma0 (dB)
Unsmoothed Hybrid Wind Speed (m/s)
Backscatter Coefficient (dB)
SWH (m)
Data Density
log10 (Number of Points)
Backscatter Coefficient (dB)
SWH (m)
Final Hybrid Model
Hybrid Wind Speed Model (m/s)

Validation with In Situ Buoys

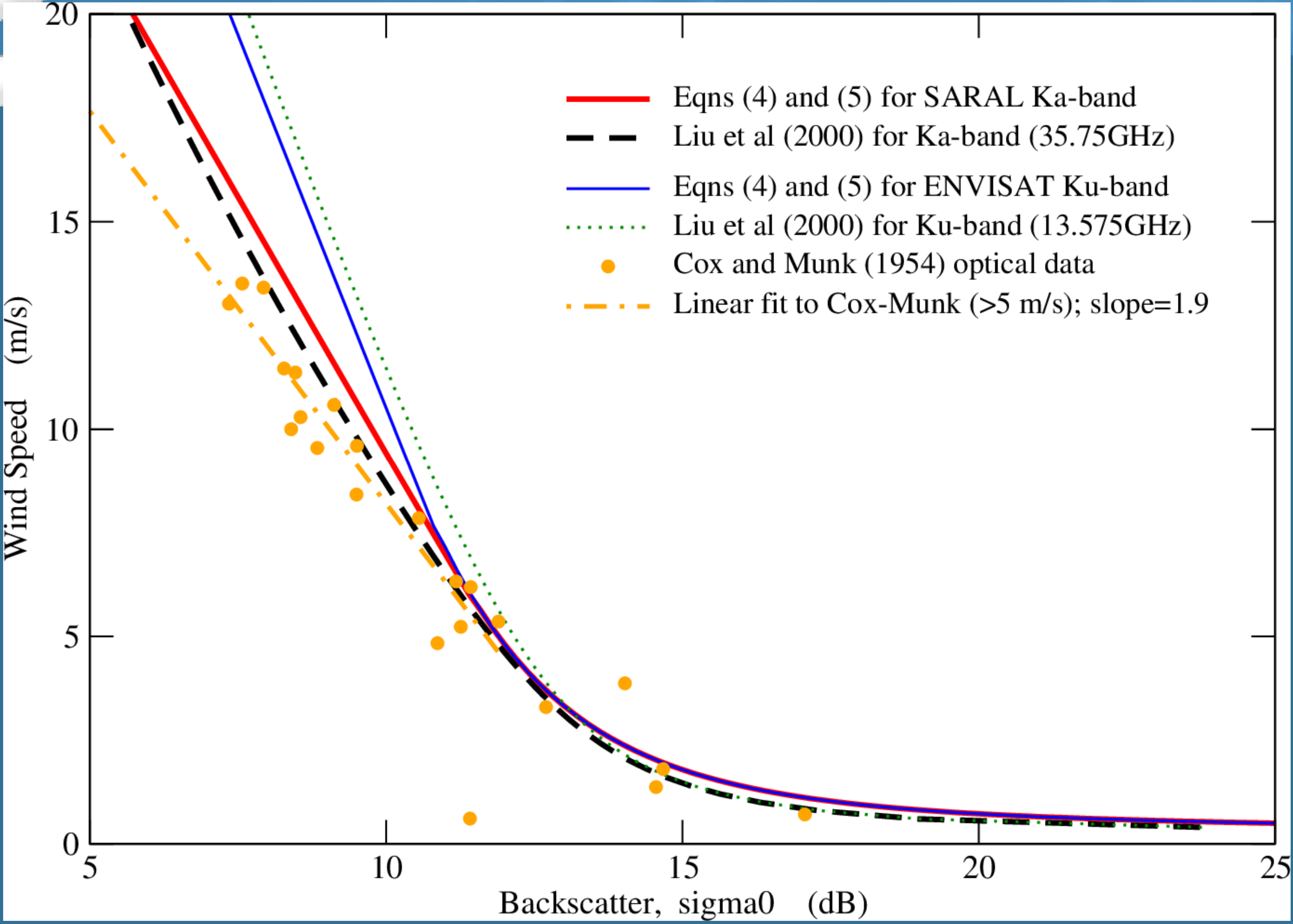


STATISTICS	
ENTRIES	5801
MEAN BUOY	7.7450
MEAN SARAL	7.3693
BIAS (SARAL - BUOY)	-0.3757
STANDARD DEVIATION	1.4805
SCATTER INDEX	0.1912
CORRELATION	0.8729
SYMMETRIC SLOPE	0.9549
REGR. COEFFICIENT	0.8535
REGR. CONSTANT	0.7591



STATISTICS	
ENTRIES	5801
MEAN BUOY	7.7450
MEAN SARAL	7.3842
BIAS (SARAL - BUOY)	-0.3608
STANDARD DEVIATION	1.4564
SCATTER INDEX	0.1880
CORRELATION	0.8713
SYMMETRIC SLOPE	0.9433
REGR. COEFFICIENT	0.7594
REGR. CONSTANT	1.5029

Validation of 1D-model with Theory



Conclusions

Physical model provides attenuation correction

- **Investigate using radiometer TPW and CLW**

One-dimensional wind speed model

- **Better approach to fit to Ka-band backscatter**
- **Slightly higher variability than historical Ku-band results**

Two-dimensional wind speed model

- **Reduced std. dev. of differences with ECMWF winds**
- **Scatterplot not symmetric (underestimates high winds)**

NOAA has embraced AltiKa NRT wind/wave data!

Conclusions

Thanks very much to the SARAL/AltiKa project teams at ISRO, CNES, and EUMETSAT for providing low-latency OGDRs, with very high quality, so quickly after launch!