Issues involved in global wave model application to routine SSB range correction

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Report on 3 topics related to SSB=f(SWH, σ^0(wind), *wave period*)

1.Multi-mission 3D sea state bias (SSB) correction models for altimeter Climate Data Record generation – **wave model data**
2.Revised and new Jason-2 wind models (from N. Tran)
3.New finding – SST impact on radar backscatter at Ka-band

Poster plugs

•Work on latest Topex retracked data incl. new 2 and 3D SSB models

•***!!! Whitewater investigation reopened !!!***
– breaking waves study using AMR and JMR + Jason radars

SSB using wave model data

Wave model outline

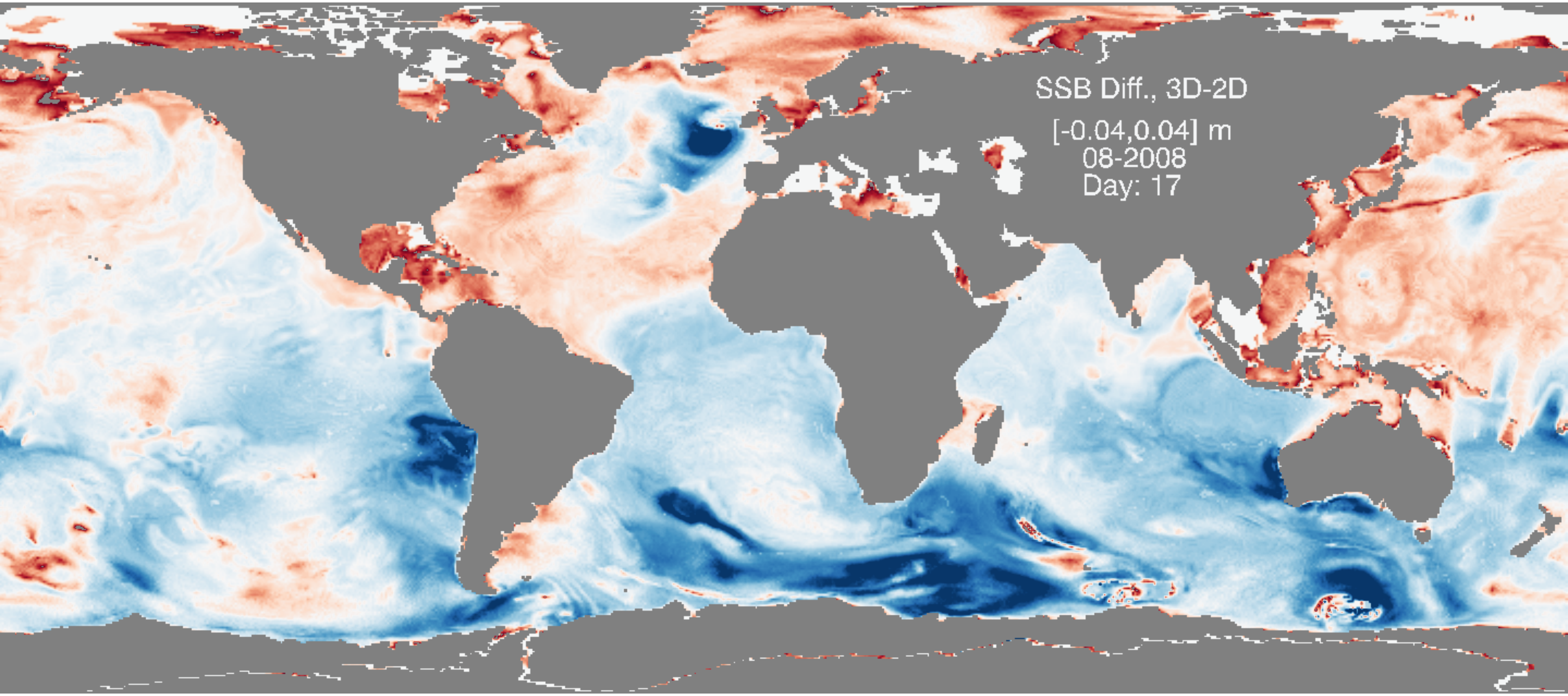
1. Problem defined – stable continuous wave model data; requires wind forcing and operational wave model; Focus on Tm02 spectral parameter
2. Options explored for simplicity, accuracy, availability
3. Solution :

    1992-2014 IFREMER wavewatch 3 with NCEP-CFSR forcing

    2015-forward Meteo-France WAM operational

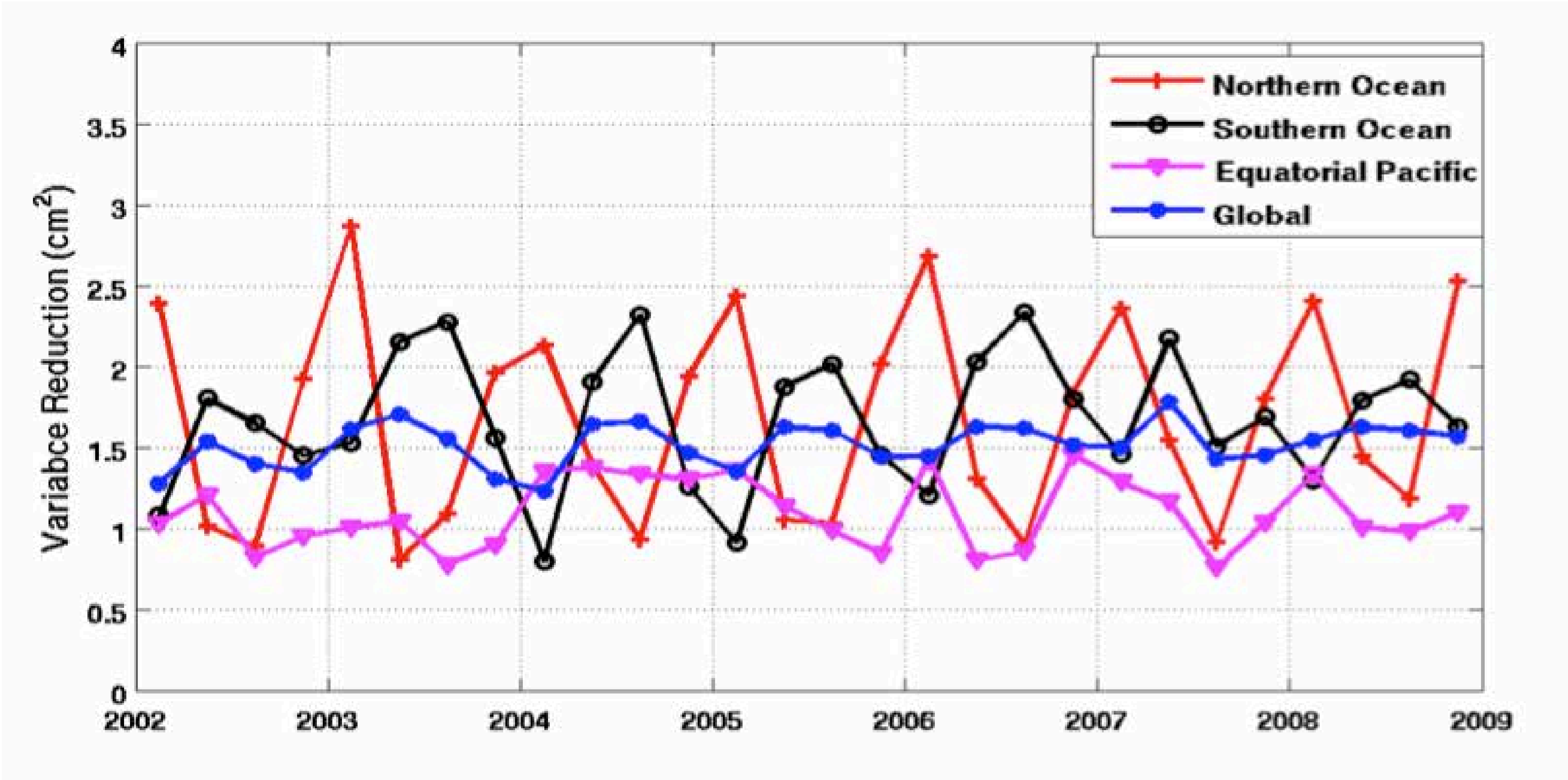
2. Today just bit of detail on the marriage…
3. Table slide, Eval_exampl slides(2), SSB PDF, SSB result, Status – ingesting MF since last Dec. NRT availability, CFSR should be updated from 2012-2014 this fall, we have thredds server in place with models and data in Brown CP format

Motivation: 1-2 cm^2 of gain still possible in sea state geophysical corrections (SSB) ?



- Example here: SSB with Wavewatch III global model input
- Difference Above = enhanced_SSB - GDR_SSB
- Earlier talk uses Alt-Only; Metrics should help choice.

Motivation: 1-2 cm^2 of gain?
2002-2009 Jason-1 example of zonal improvements



- Example here: SSB with Wavewatch III global model input
- Difference Above = enhanced_SSB - GDR_SSB

Problem to resolve: ocean wave model data for point-point SSB correction from 1992-present

Issues:

1. Drift (?): Wave model output dominated by wind model input
   Wind drift or discontinuity -> wave output drift -> SSB drift -> sea level error
2. Model options and availability: Wave models are many and varied
   - physics, metrics/tuning, numerics, resolution, sea ice, islands,…
   - Hindcast vs. operational for support of OSTST data processing
3. Proof of concept work used quite a few versions (e.g. Peachl talk, UNH in-house, etc..) working with F. Ardhuin (focus on T_{m02})

Our present solution/recommendation for T_{m02} data:

a. 1992-2014 IFREMER-Wavewatch 3 with NCEP-CFSR winds
b. 2015-forward Meteo-France WAM with ECMWF winds
c. Care taken to monitor and remove small wave period offsets at level sufficient to maintain stable SSB
d. Provide data to CLS, RADS, OSTST as netCDF correction products

	IFREMER (IFR)	Meteo France (MF)	Meteo France (MF)	ECMWF (EC)
MODEL	WW3-test471	WAM (~)Test471 Assimilation	WAM (~)Test 471 No Assimilation	WAM Assimilation
Abbr.	IFR:WW3	MF:WAM(A)	MF:WAM(NA)	EC:WAM
Grids	0.5-by-0.5 deg in lat/lon (77.5N to 77.5S)	0.5-by-0.5 deg in lat/lon (90.0N to 90.0S)	0.5-by-0.5 deg in lat/lon 90N to 90S)	0.5-by-0.5 deg in lat/lon 90N to 90S)
Winds	ECMWF	ECMWF	ECMWF	ECMWF
Outputs	3 hourly (Hs, T01,T02)	3 hourly (Hs, T01,T02)	3hourly (Hs, T01,T02)	6 hourly (Hs, T01,T02)

Notes:

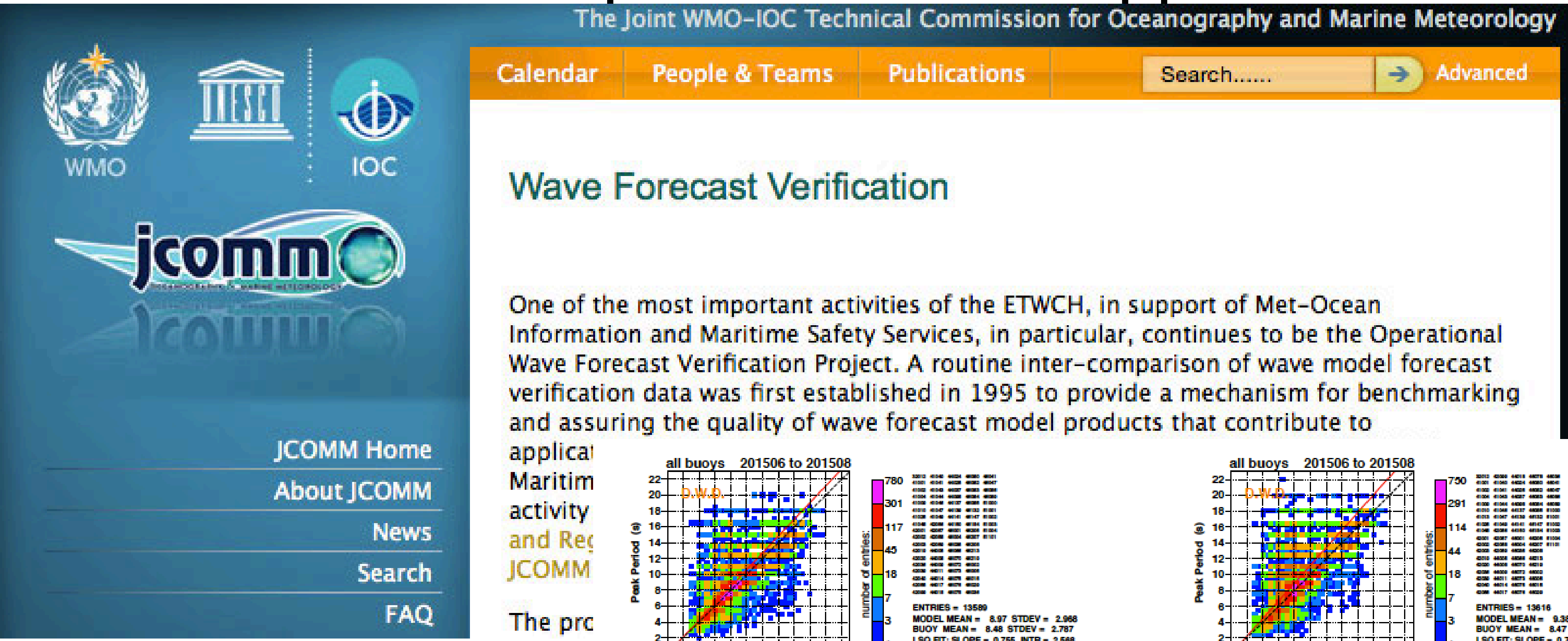
1) T_{01}=m0/m1 (mean wave period), T_{02}=sqrt(m0/m2)

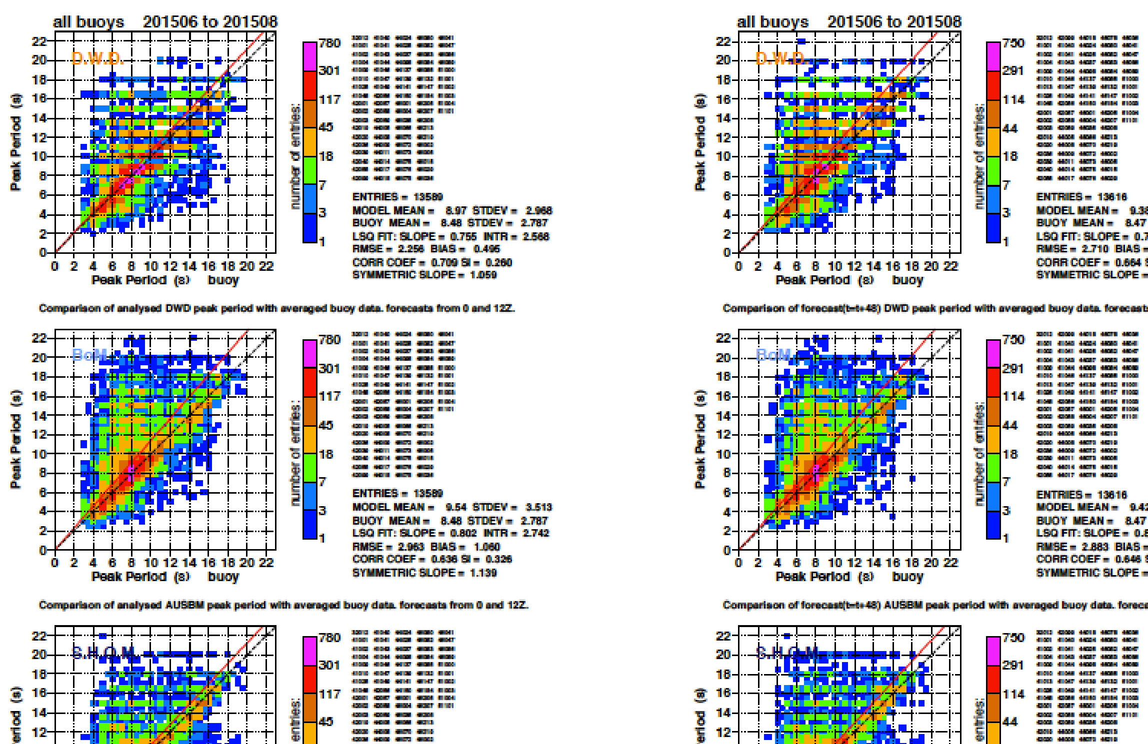
2) $m0=(Hs/4)^2$; m1=m0/T01; $m2=m0/(T02)^2$

3)Model runs for the period of Dec 2014, differences are computed pt by pt.

4) Several known differences between IFRWW3 and MFWAM, e.g. sheltering coeffs…

Model Wave period for SSB application



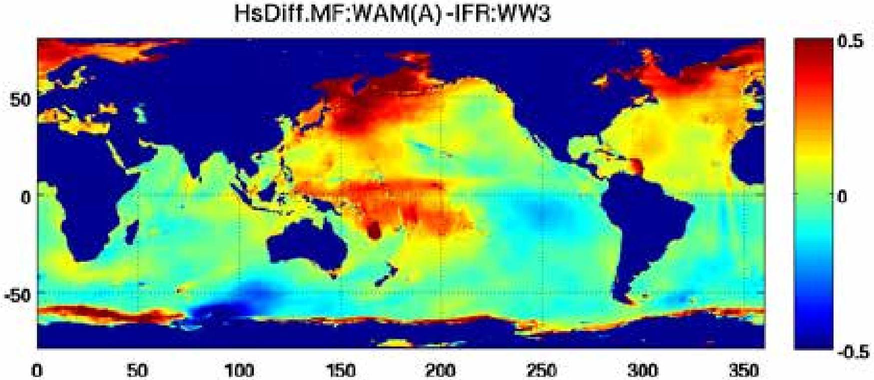


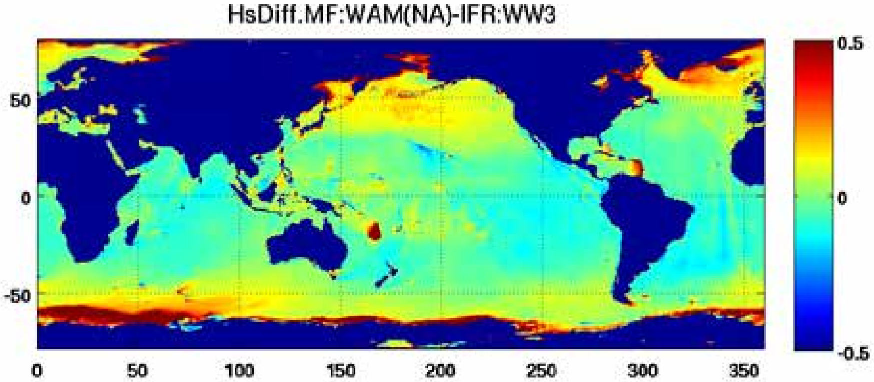
CLS

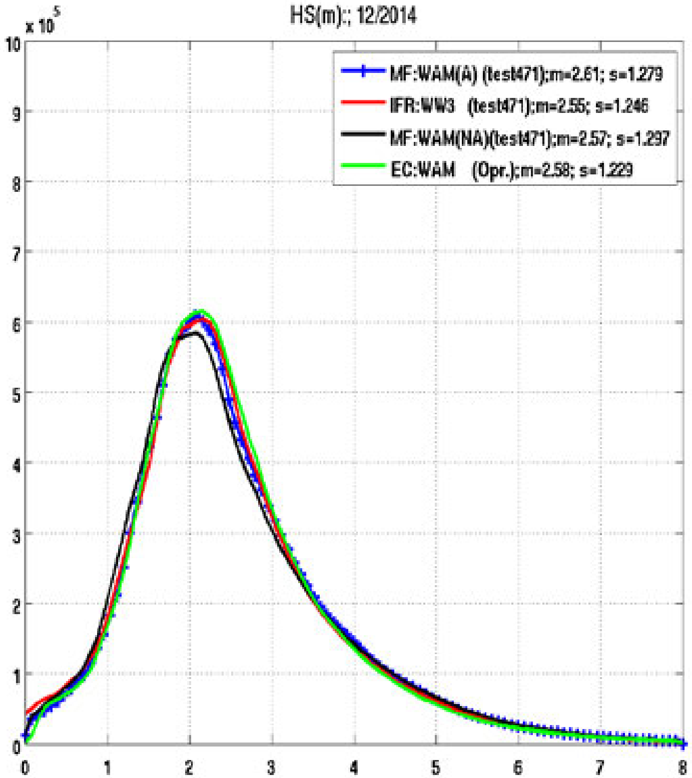
Ifremer

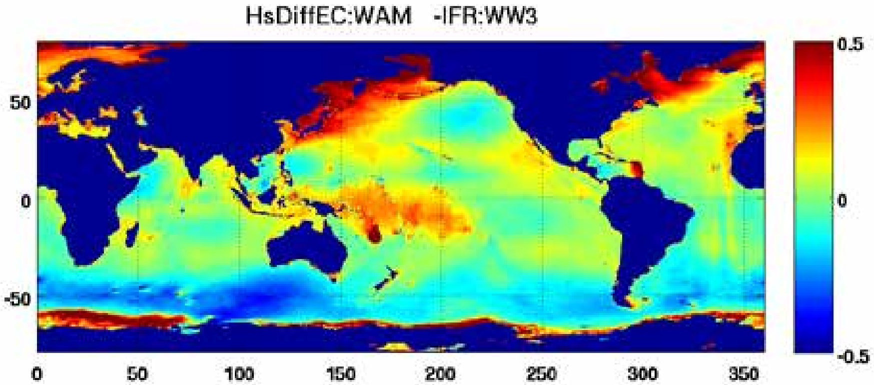
Figure 1 Hs

Below: pdfs
Right: Diff maps
(Relative to IFR-WW3)



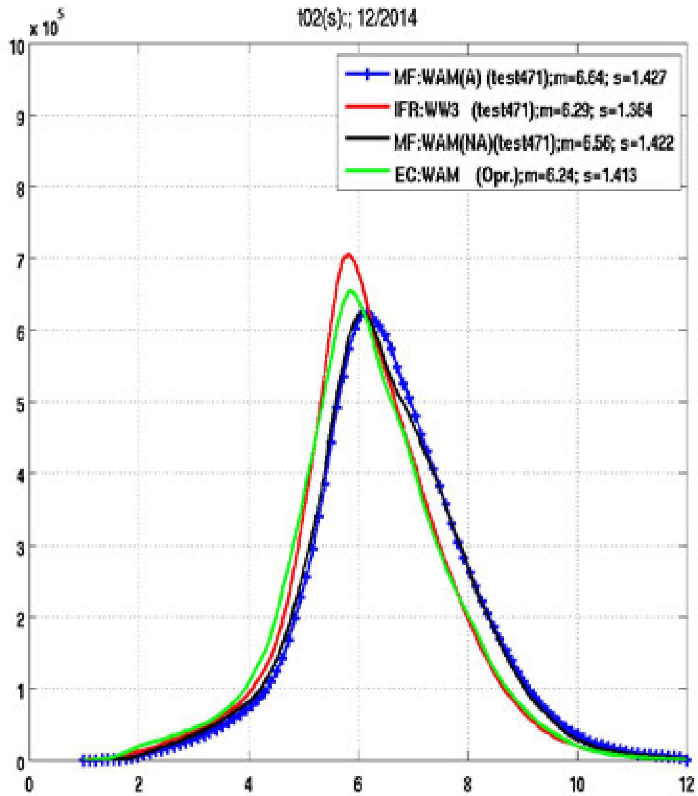






T_{m02} Comparisons

Below: pdfs
Right: Difference maps
(Relative to IFR-WW3)



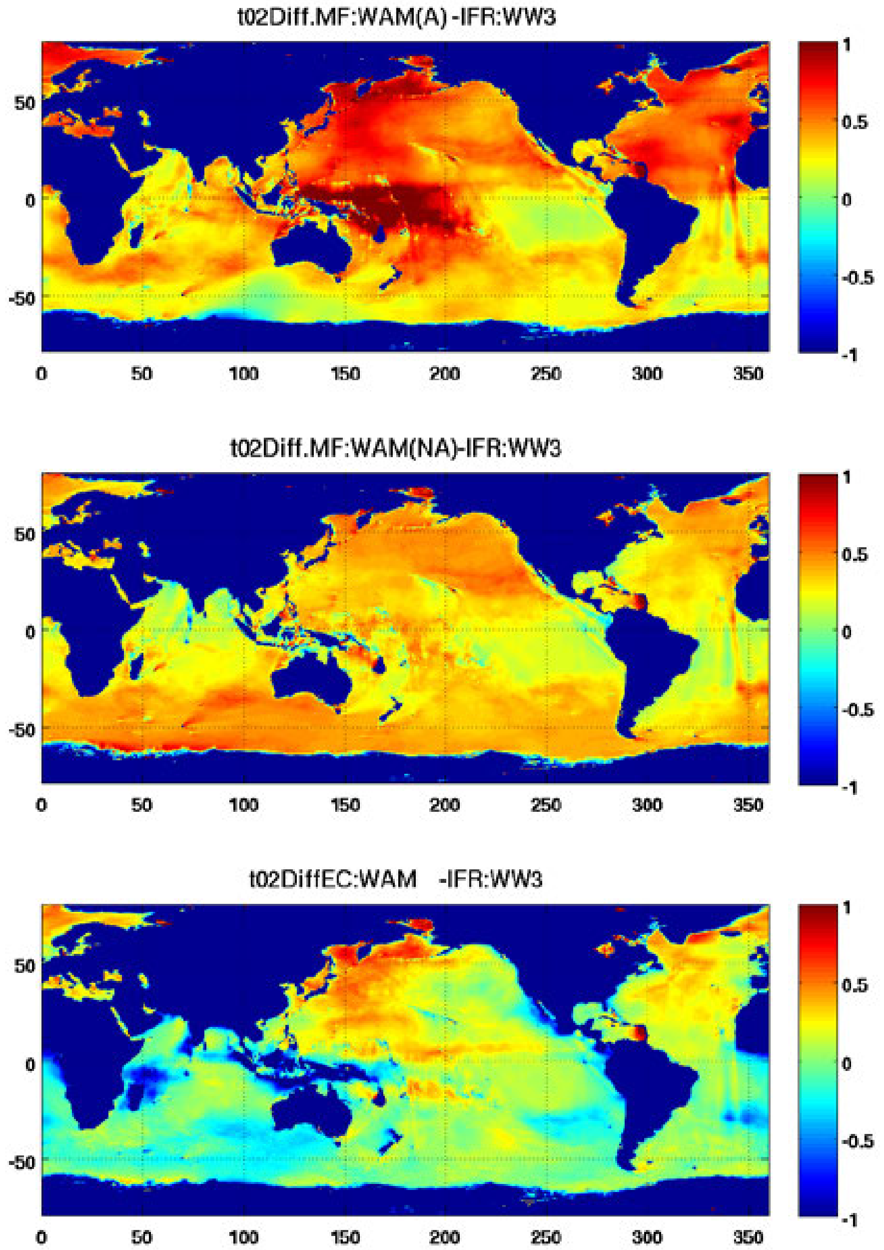
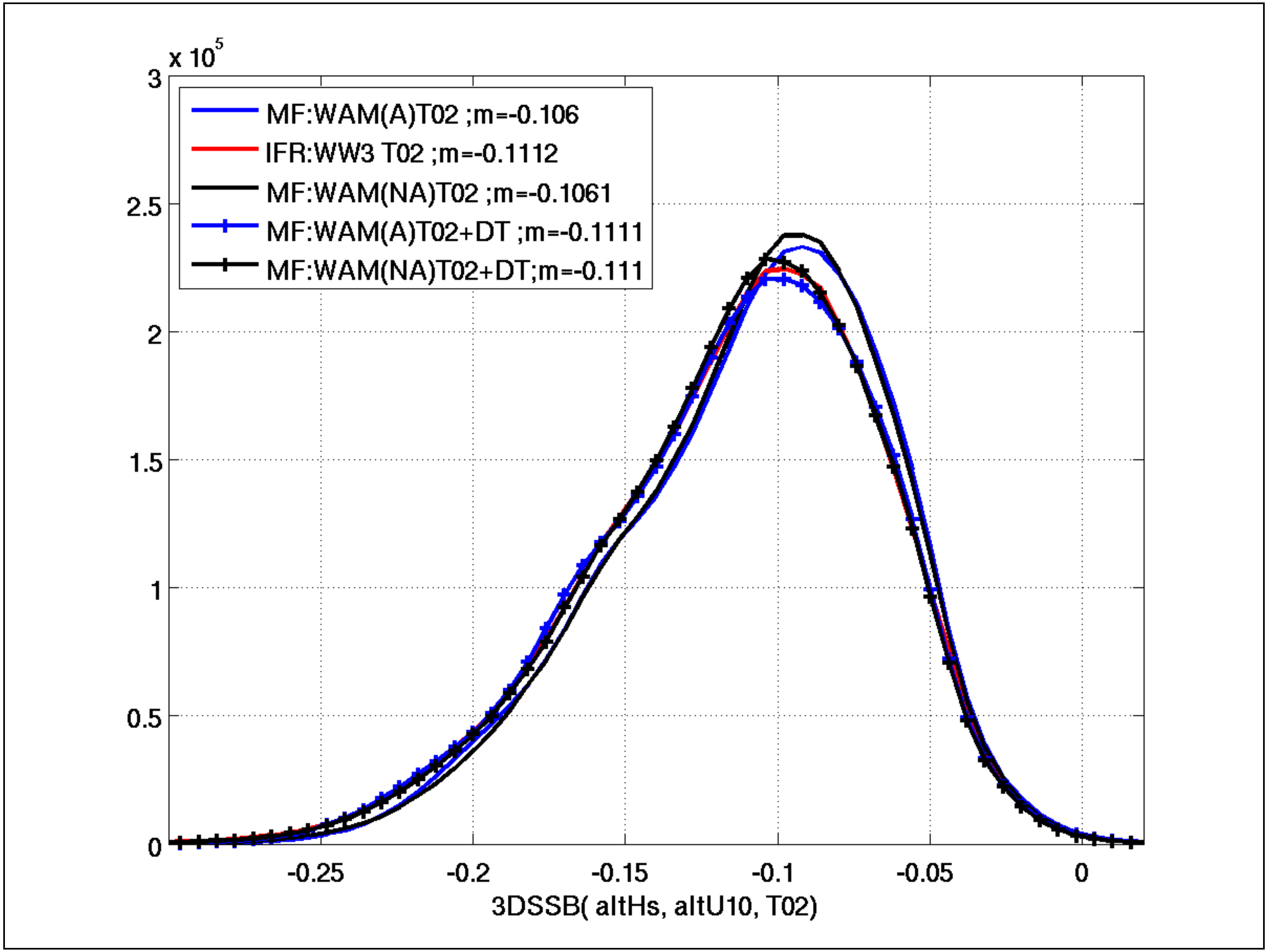
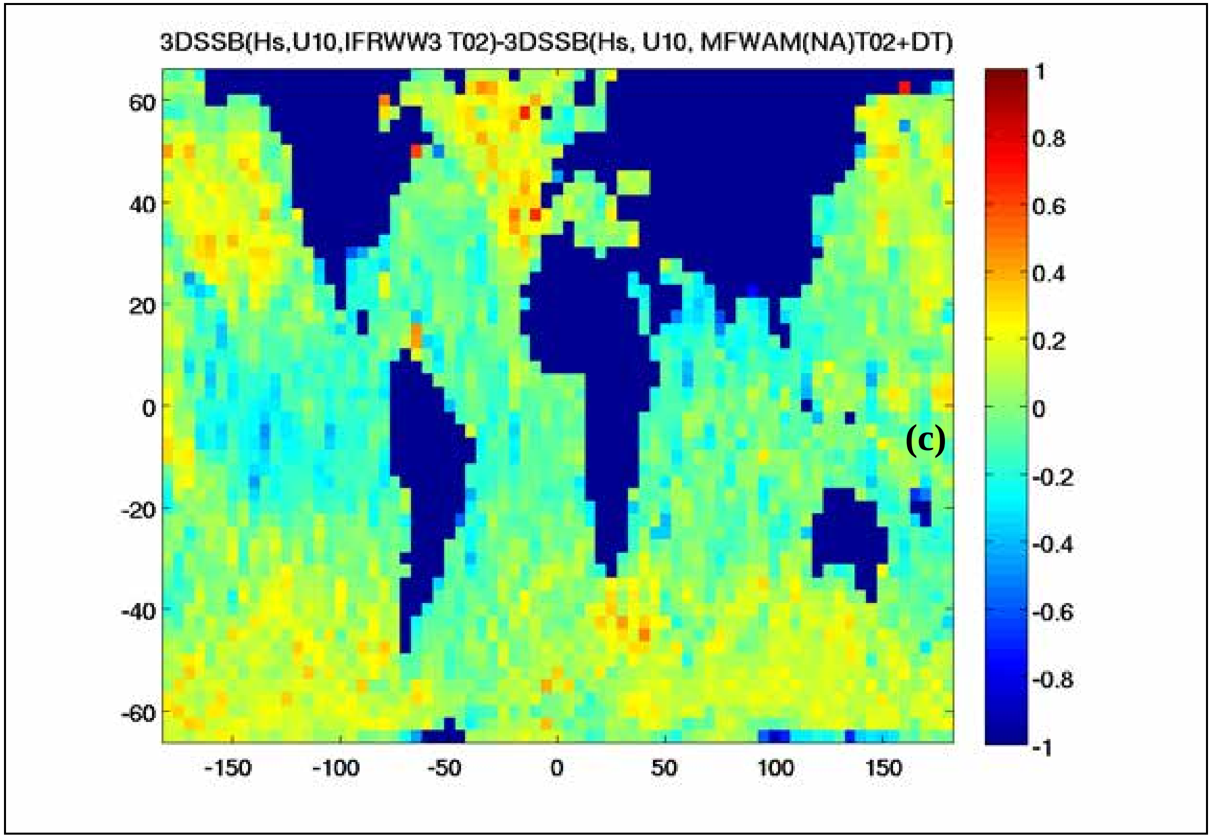


Figure 9 3D SSB (in m) distributions



There is a global bias, DT, of MF:WAM(A) or (NA) T02 related to IFR:WW3. Here 3DSSBs were also computed by using the bias DT corrected T02.

3D SSB correction difference due to wave model transition (IFR product -> Meteo-France product)



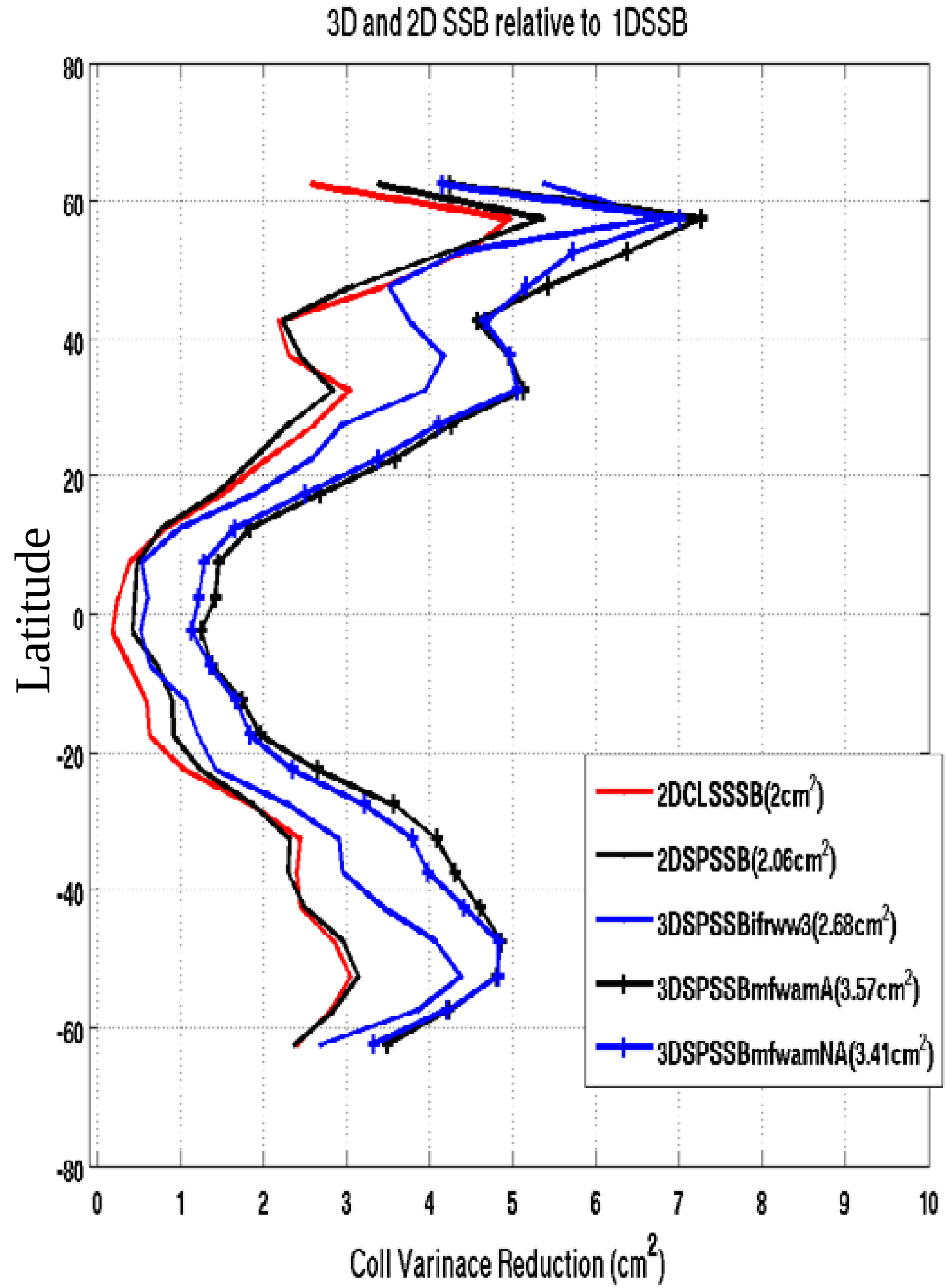
- Some geographical variation but < 2 mm in most cases
- Main source of difference is likely data assimilation in MF model (MF data simply a bit better?)

Zonal on-orbit J2 data SSB correction evaluation

Variation with latitude of **collinear** differed SSHA variance reduction obtained by
2D or 3D SSB models relative to a 1D SSB(-4% SWH)

- **Best result obtained using Meteo-France model with data assimilation**

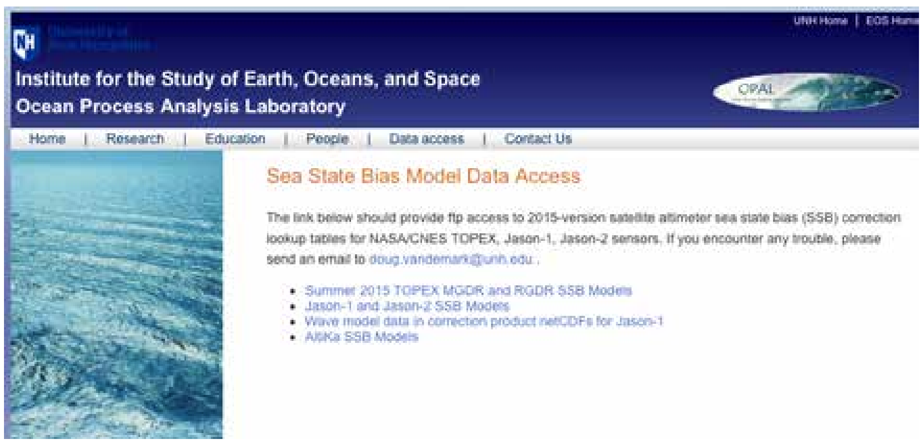
- **Overall plan to marry two model products appears to be viable to cover 1992-present**



Website for SSB look up table and Wave model data access and info

- All recent SSB models (2D and 3D) for Topex, Jason-1, Jason-2, Altika
- GDR formatted wave model data - Trial basis netCDF files to provide wave data after S. Brown JMR and AMR on UNH THredds (Jason-1)
- Waiting on IFR CFSR 2012-2014 data, then full access possible 1992-present

http://www.opal.sr.unh.edu/data/sea_state_bias.shtml



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Ocean Process Analysis Laboratory

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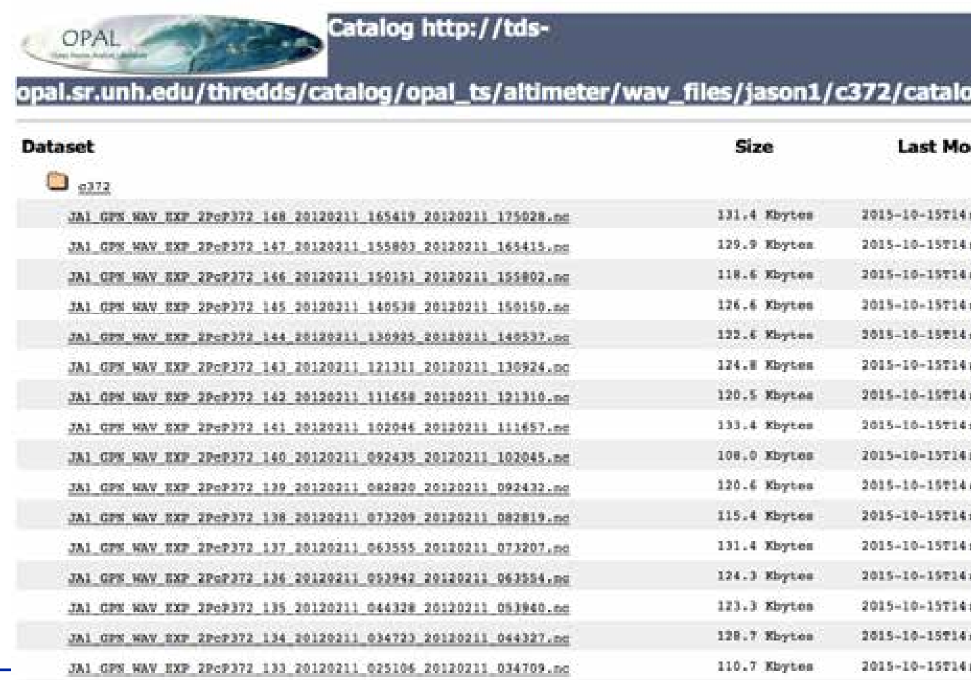
Sea State Bias Model Data Access

The link below should provide ftp access to 2015-version satellite altimeter sea state bias (SSB) correction lookup tables for NASA/CNES TOPEX, Jason-1, Jason-2 sensors. If you encounter any trouble, please send an email to doug.vandemark@unh.edu .

- Summer 2015 TOPEX MGDR and RGDR SSB Models
- Jason-1 and Jason-2 SSB Models
- Wave model data in correction product netCDFs for Jason-1
- AltiKa SSB Models



Catalog http://tds-opal.sr.unh.edu/thredds/catalog/opal_ts/altimeter/wav_files/jason1/c372/catalo

Dataset	Size	Last Mo
c372		
JA1_GPN_WAV_EXP_2PcP372_148_20120211_165419_20120211_175028.nc	131.4 Kbytes	2015-10-15T14
JA1_GPN_WAV_EXP_2PcP372_147_20120211_155803_20120211_165415.nc	129.9 Kbytes	2015-10-15T14
JA1_GPN_WAV_EXP_2PcP372_146_20120211_150151_20120211_155802.nc	118.6 Kbytes	2015-10-15T14
JA1_GPN_WAV_EXP_2PcP372_145_20120211_140538_20120211_150150.nc	126.6 Kbytes	2015-10-15T14
JA1_GPN_WAV_EXP_2PcP372_144_20120211_130925_20120211_140537.nc	122.6 Kbytes	2015-10-15T14
JA1_GPN_WAV_EXP_2PcP372_143_20120211_121311_20120211_130924.nc	124.8 Kbytes	2015-10-15T14
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Altimeter wind speed modeling for Jason-2

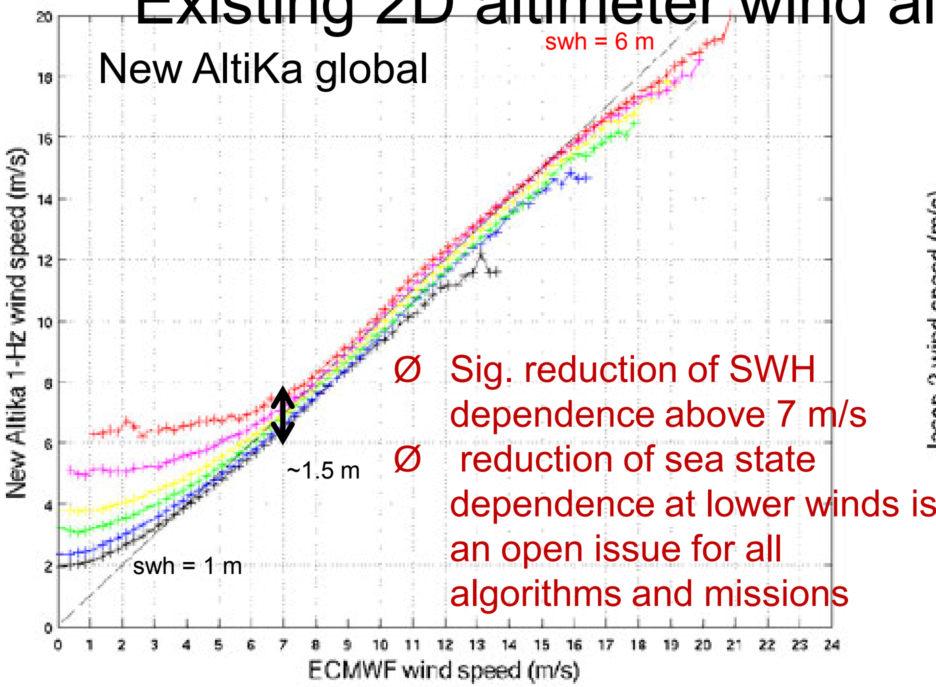
Ngan Tran and Hui Feng

Objectives:

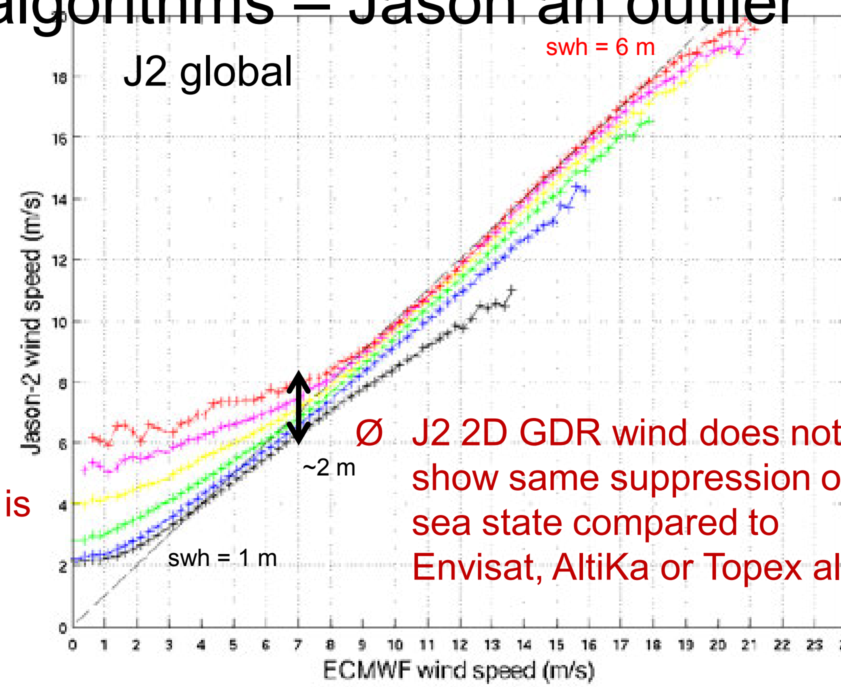
1) Use latest Jason-2 MLE4 NRCS and SWH data to compute new 2 input wind speed model
   - J2 inherited the J-1 Collard 2005 model
   - Since then bias issues, methods, and retracking suggest a revisit

2) Investigate the possibility of improving upon the 2 input wind model idea using additional global wave model data

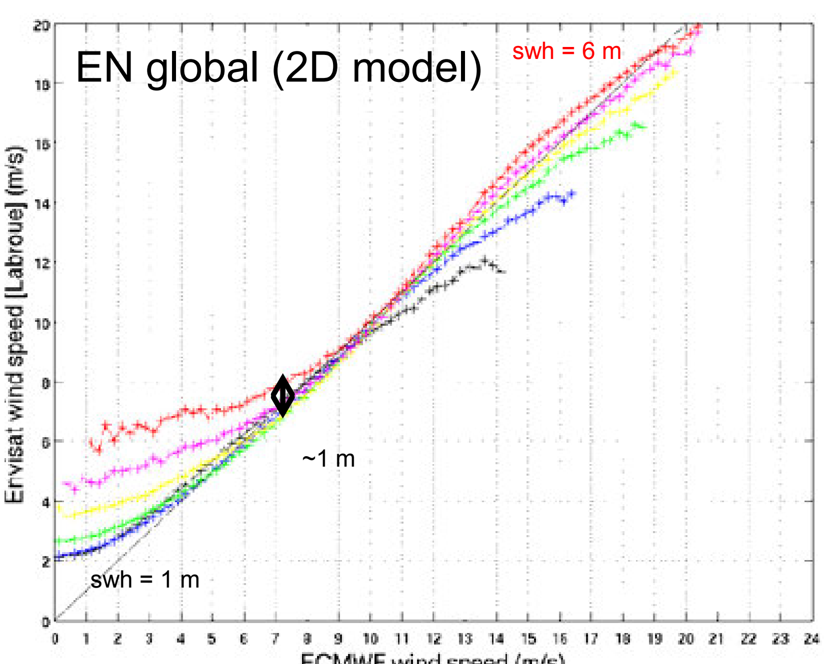
Existing 2D altimeter wind algorithms – Jason an outlier

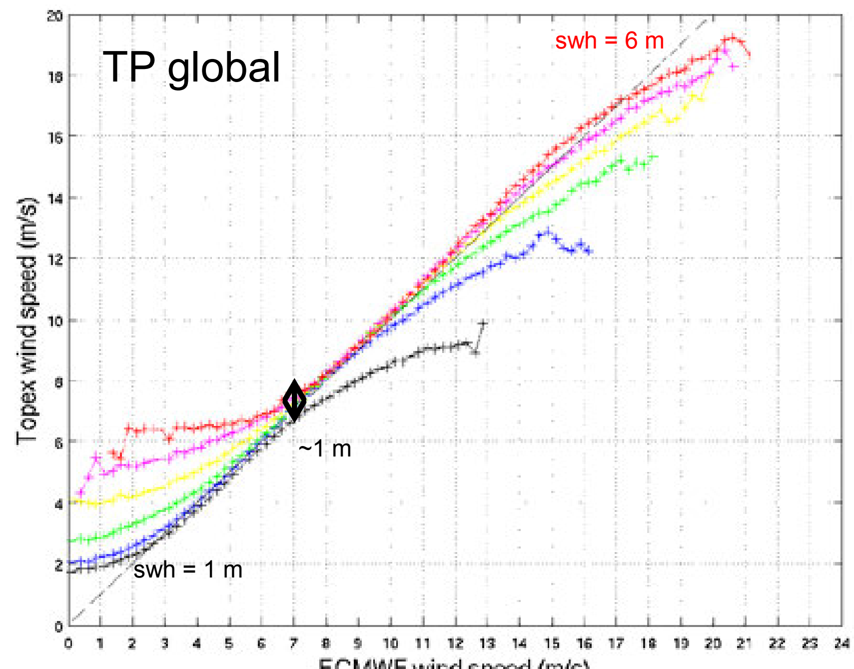


- Sig. reduction of SWH dependence above 7 m/s
- reduction of sea state dependence at lower winds is an open issue for all algorithms and missions



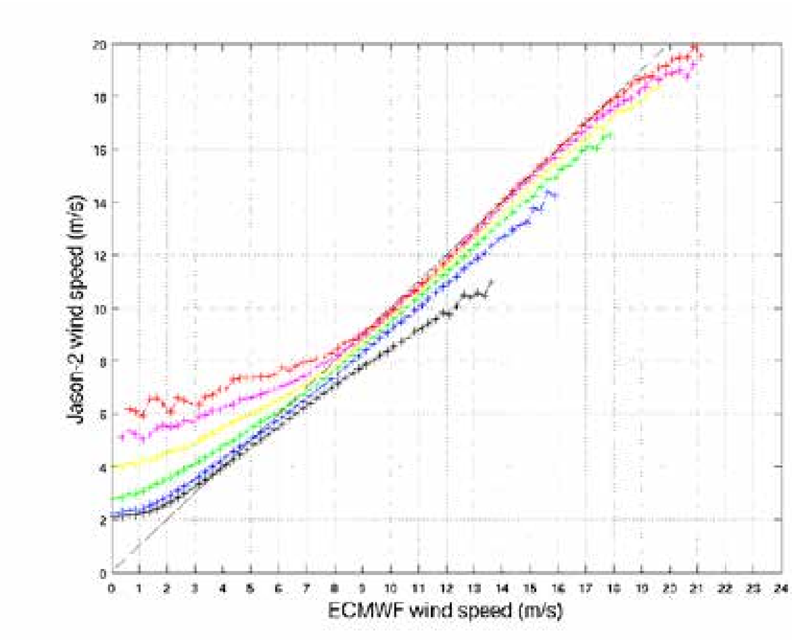
- J2 2D GDR wind does not show same suppression of sea state compared to Envisat, AltiKa or Topex algos



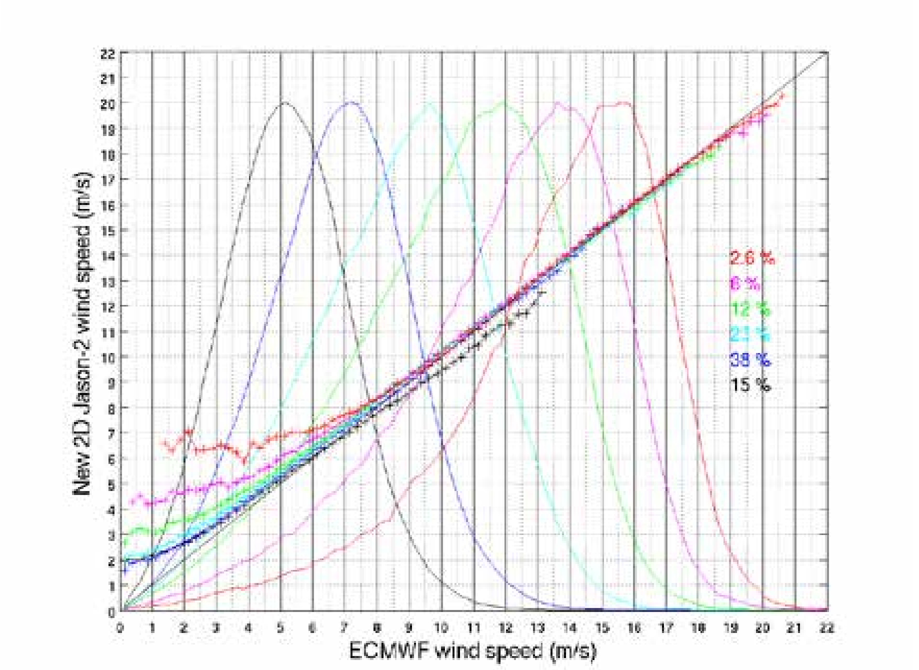


New J2 wind – much improved in SWH attenuation

J2 GDR



New J2

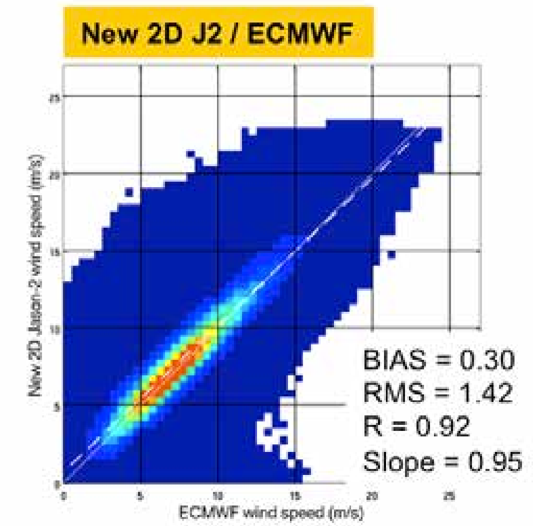


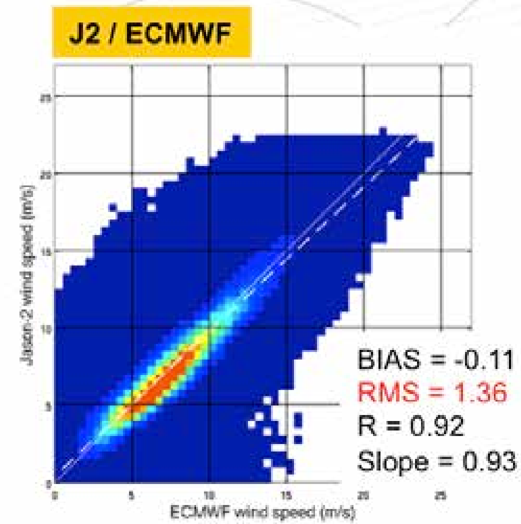
- Ø New 2D model
  - Ø Model based on Jason-2 data themselves MLE4 (sig0, SWH)
  - Ø Collocated ASCAT-A winds used as reference for its calibration

New Jason-2 2D wind – bias and pdf

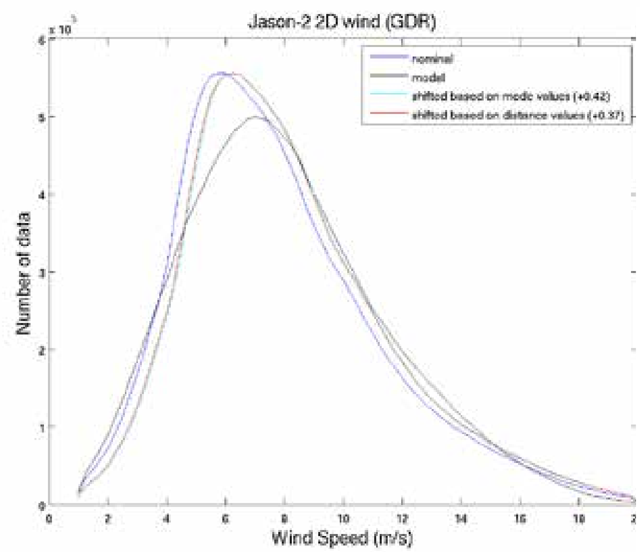
Similar mean bias and rms

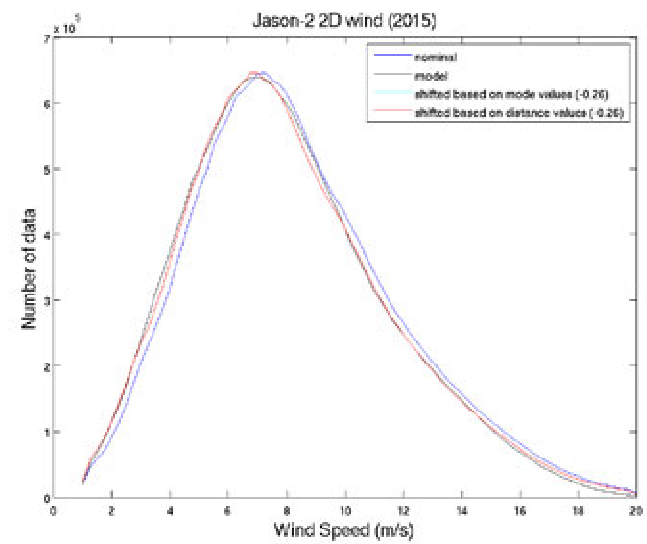
Strong improvement not obvious in bulk statistic





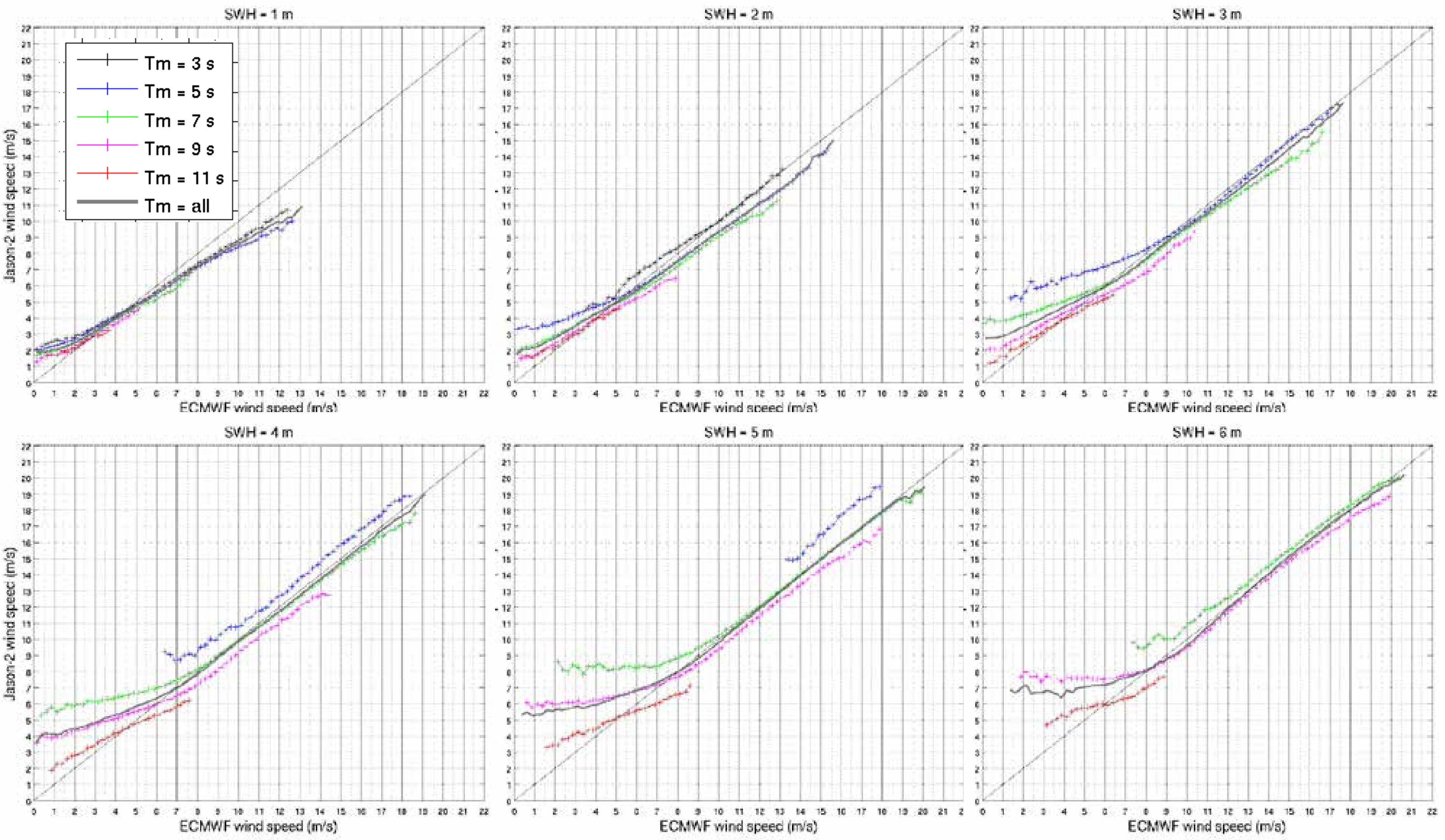
Significantly better agreement with global PDF of ocean wind (far right)





OBJECTIVE #2 – a 3D wind speed algorithm? $U_{GDR\ Jason\text{-}2}$ vs U_{ECMWF} (additional Tm dependence)

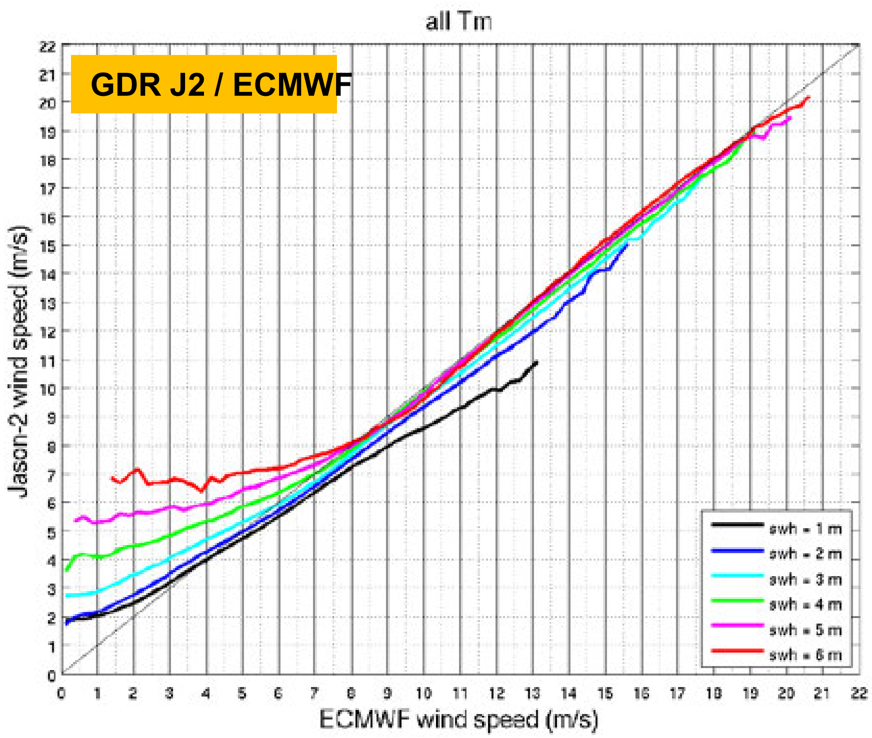
- Using same approach, now adding wavewatch model T_{m02} data

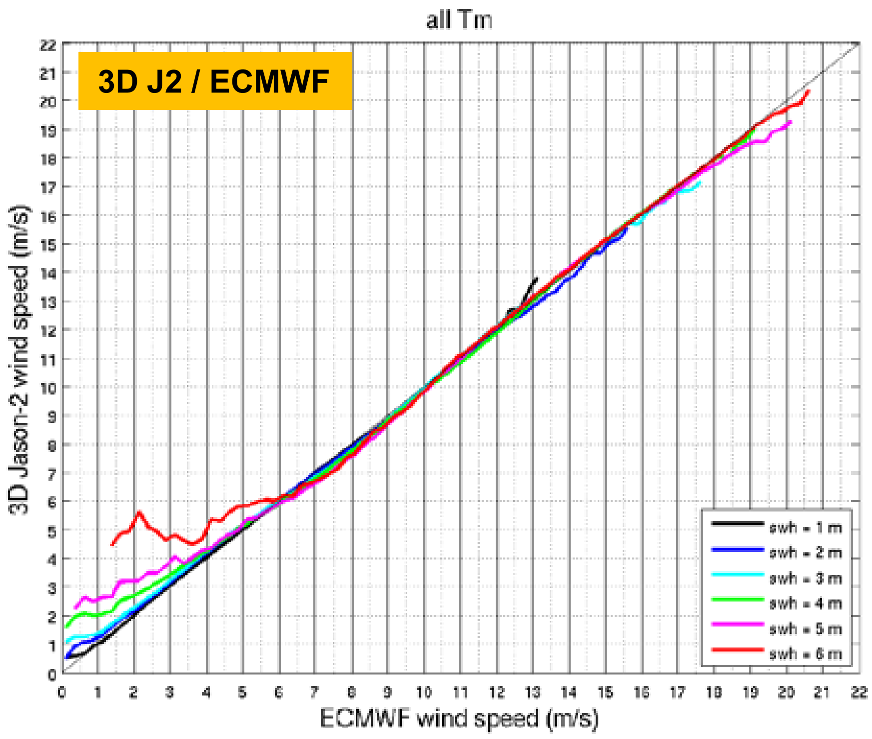


$U_{Jason\text{-}2}$ / U_{ECMWF} (SWH impact)

- Larger reduction of the wave impact with the new estimates when one compares with ECMWF winds

- Better improvement with 3D model since it uses ECMWF winds for its calibration

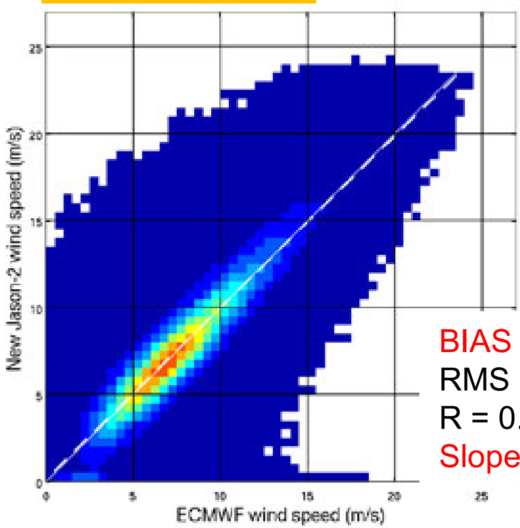




New Jason-2 WS = f(sigma0, SWH, T_{m02})

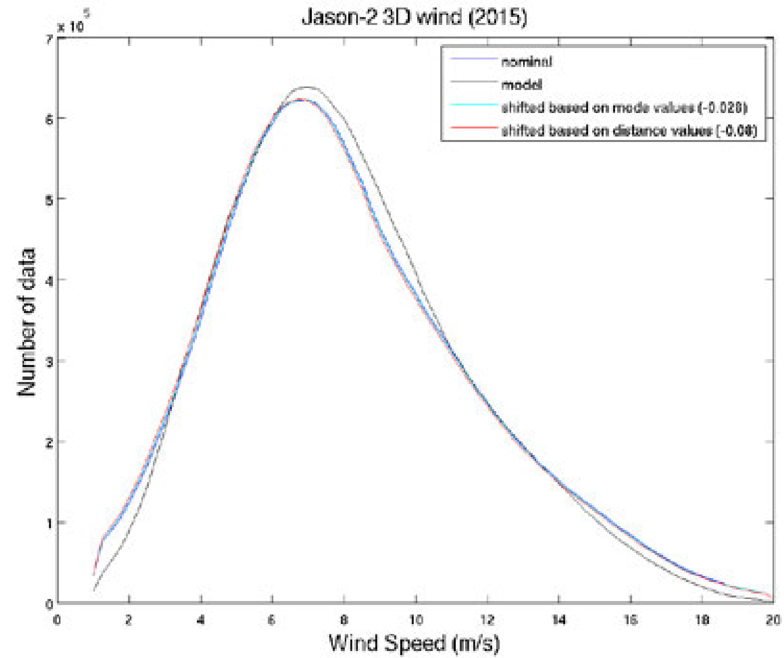
Scatter Comparison with ECMWF

3D J2 / ECMWF



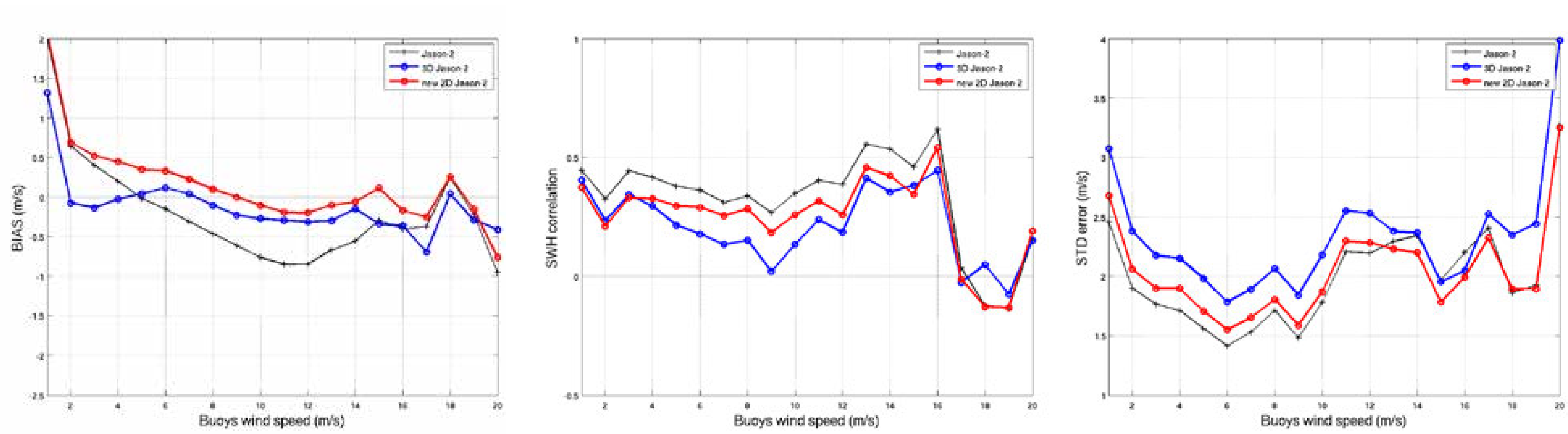
BIAS = 0.03
RMS = 1.63
R = 0.90
Slope = 0.98

Global PDF comparison to ECMWF



BUOY VALIDATION AT NDBC STATIONS

July 2008- April 2015, Dtime < 1 hour, Ddist < 50 km, 7275 valid samples



- Larger reduction of the biases with the 3D model for light to moderate wind speeds and of the correlation of the wind speed error with respect to SWH
- Slight increase of the STD and RMS of the errors due to the addition of the third dimension
- Some limited gain, TBD on pros/cons of promoting this towards operational

Conclusions of new Tran and co. wind speed work

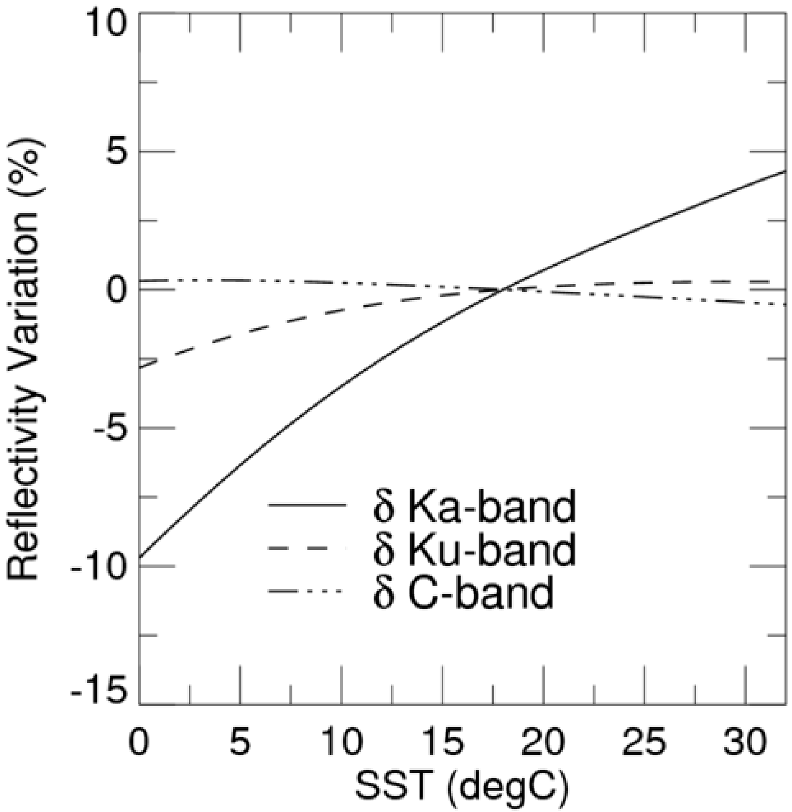
- The new developed models(using ASCAT) available as look up tables
- Better reduction of the SWH dependence is observed with the new J2 model regardless of the wind speed source used as reference
- 3D algorithm that uses additionally Tm helps to better reduce the sea state effects observed on retrieved winds when one compares to ECMWF winds as seen by the reduction of the biases, the lower SWH correlation and the reduction of the geographically-correlated differences
- 3D algorithm can/should be developed also for Altika mission
- TBD on pros/cons of moving towards operational (SSB, wave model, etc..)

next

Sea surface reflectivity variation with ocean temperature at Ka-band using near-nadir satellite radar data

Doug Vandemark, Bertrand Chapron, Hui Feng, and Alexis Mouche

draft submitted to IEEE TGRS



Near Nadir Geom Optics Backscatter

$$\sigma_0(\theta) \cong \rho / mss_{eff} \cdot \sec^4\theta \cdot \exp^{-\tan^2\theta / mss_{eff}}$$

ρ (θ, freq, polarization) = | **R**(θ) **R**(θ)*|
is the reflectivity (= 1 – emissivity)

And **R** is the Fresnel reflection coefficient tied to dielectric constant of seawater
ε = F(temperature, salinity, frequency)
Thus: ρ (θ, freq, polarization, sst, sss)

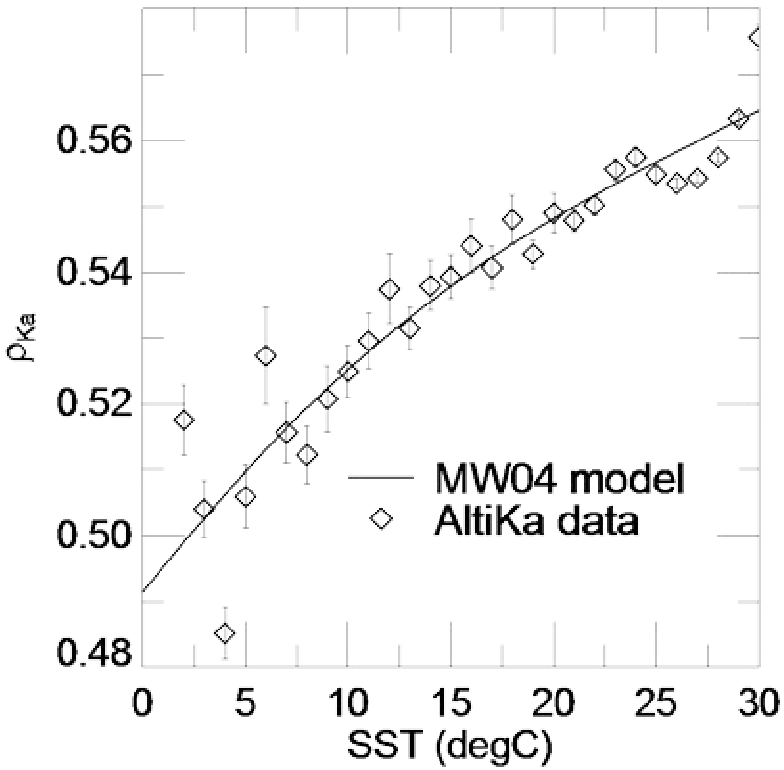
TO DATE - WE NEGLECT SMALL VARIATION IN REFLECTIVITY, BUT AT KA-BAND?

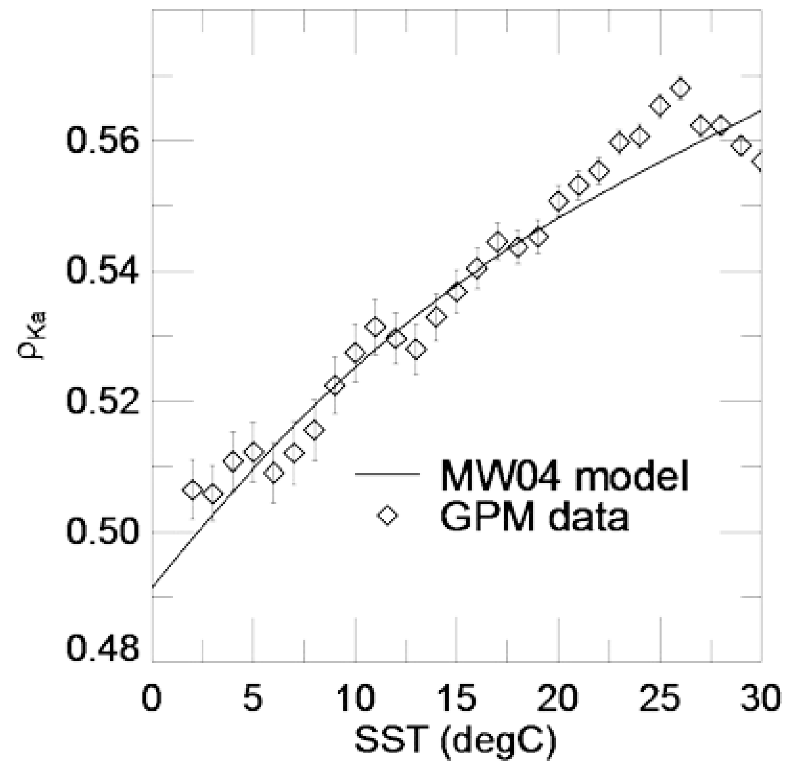
SST Impact on backscatter at Ka-band?

Can now evaluate globally using ALtiKa and using Global Precip. Mission Radar

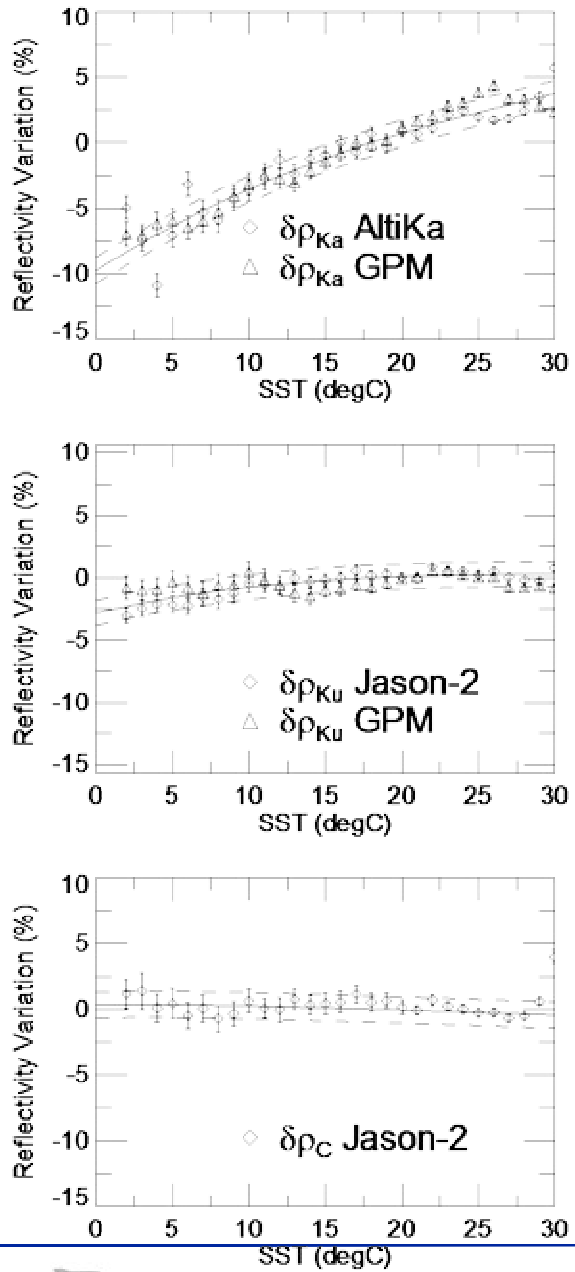
Methods:

- Use nadir backscatter data from GPM and ALtiKa matched to SST
- Invert backscatter equation at fixed wind speed assuming mss_{eff}~=wind to retrieve reflectivity (this at wind = 5 m/s)
- Compare to Meissner and Wentz dielectric model (2004)





SST Impact on Backscatter – Multi-Frequency Check



Assess data at C, Ku, and Ka-band

Here looking at ratio ρ / ρ(SST=18 degC)

•All 3 frequencies follow the MW04 model closely

•GPM and ALtiKa in close agreement, statistically congruent

•C and Ku impacts indeed low though some decrease at SST that could be notable (e.g. for scatterometry)

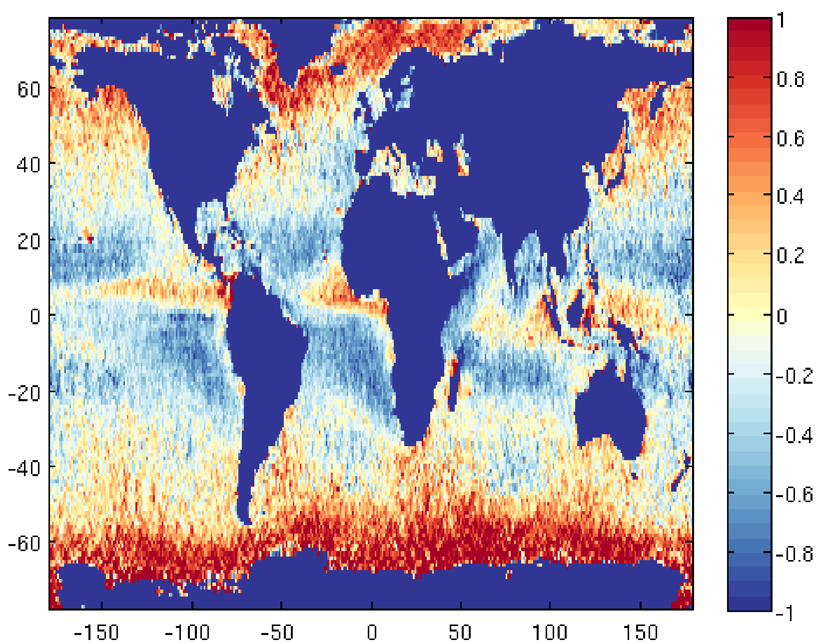
•Little doubt that SST significantly impacts at Ka-band

SST Impact on Wind at Ka-band – Global View Application

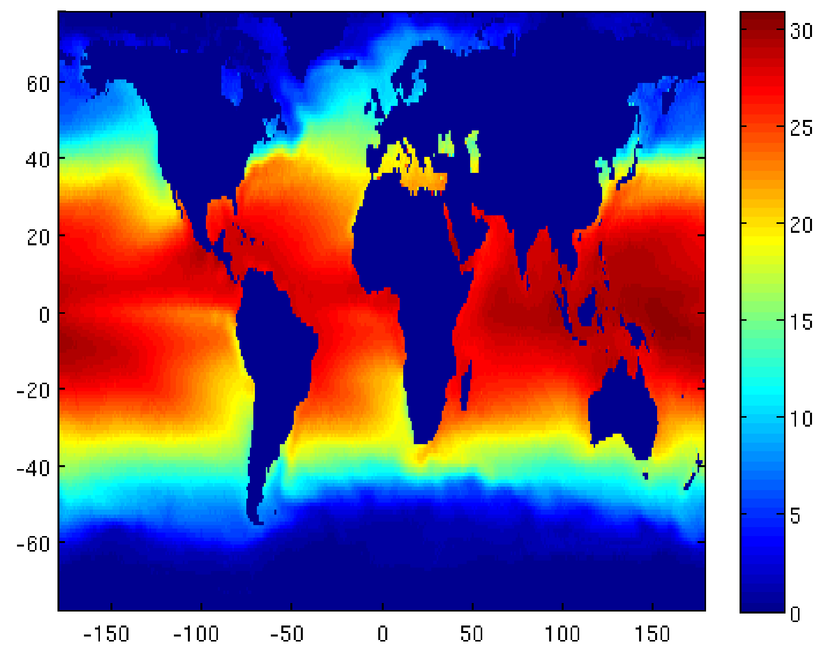
SARAL ALtiKa Ocean Wind Speed (algo: Lillibridge et al 2014)

•Significant geographical biases in altimeter vs. model (ECMWF) wind (e.g. > 1 m/s at high latitude)

U_AltiKa – U_ecmwf (1 year)



Corresponding SST (1 year)

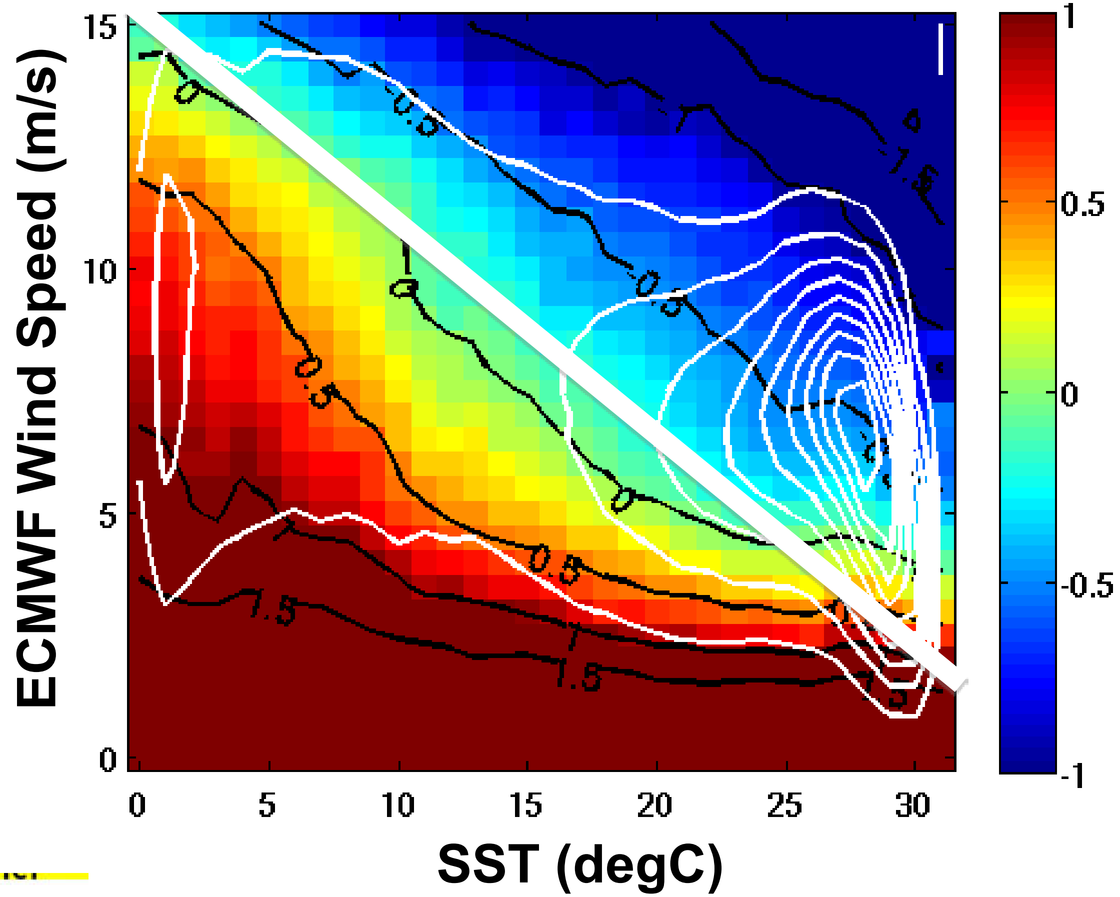


SST Impact on Wind at Ka-band – Global View Application

SARAL ALtiKa Ocean Wind Speed

•Bias change with SST apparent at most wind speeds
•Zero bias shifts to colder water at higher winds (training set)

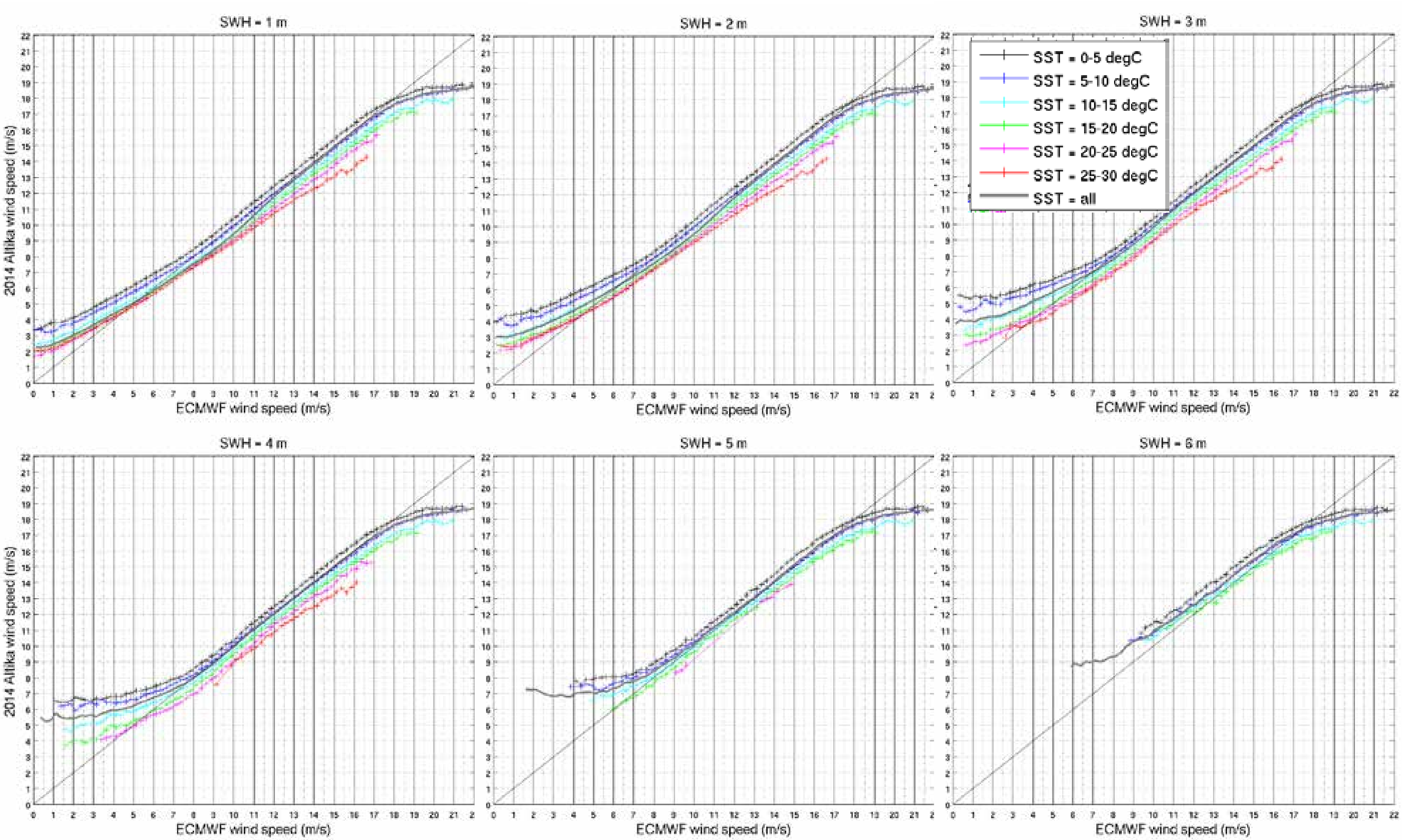
U_AltiKa – U_ecmwf (1 year)



SST Impact on Wind at Ka-band Largely Independent of Sea State

(Here wind-to-wind results giving for SWH = 1 to 6 m)

U_{ALTIKA_2014} vs U_{ECMWF} (from N. Tran)



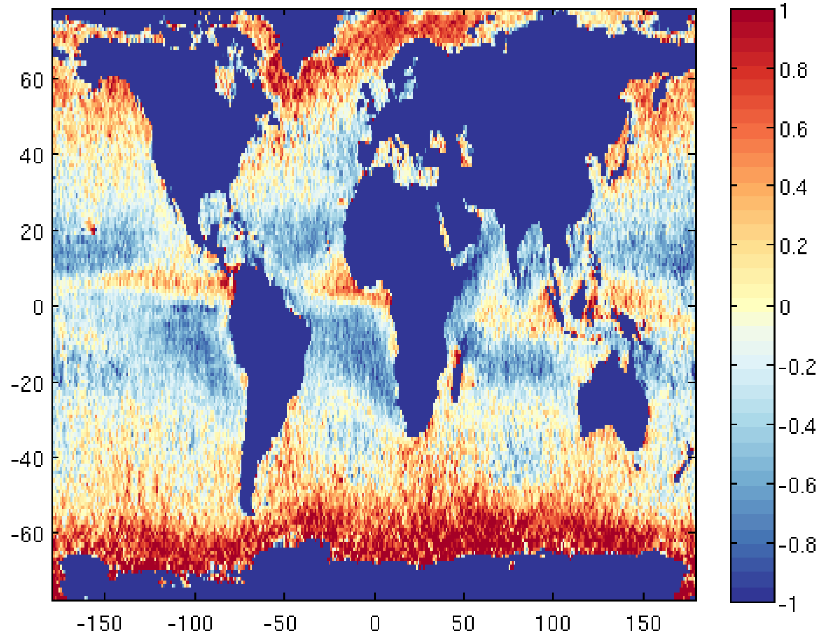
SST Impact on Wind at Ka-band – Global View

Preliminary and *ad hoc* correction approach:

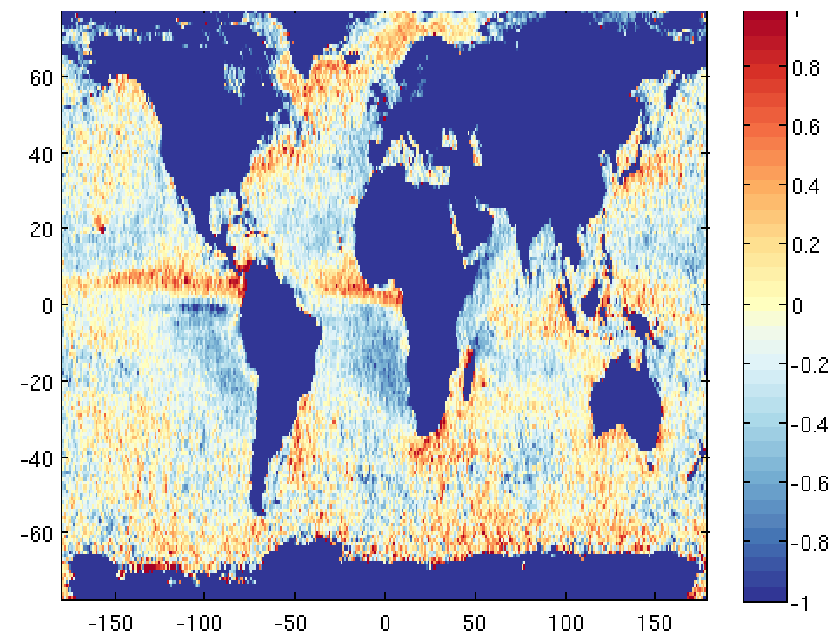
a) $\beta \cong \rho(SST)/\rho(SST_{ref})$ where $SST_{ref}=f(U)$ is the SST at each wind speed where $U_{altiKa} - U_{ecmwf} = 0$

b) $\sigma^0_{corrected} = \sigma^0/\beta$ prior to Lillbridge2014 AltiKa wind algorithm input

U_AltiKa – U_ecmwf (1 year)

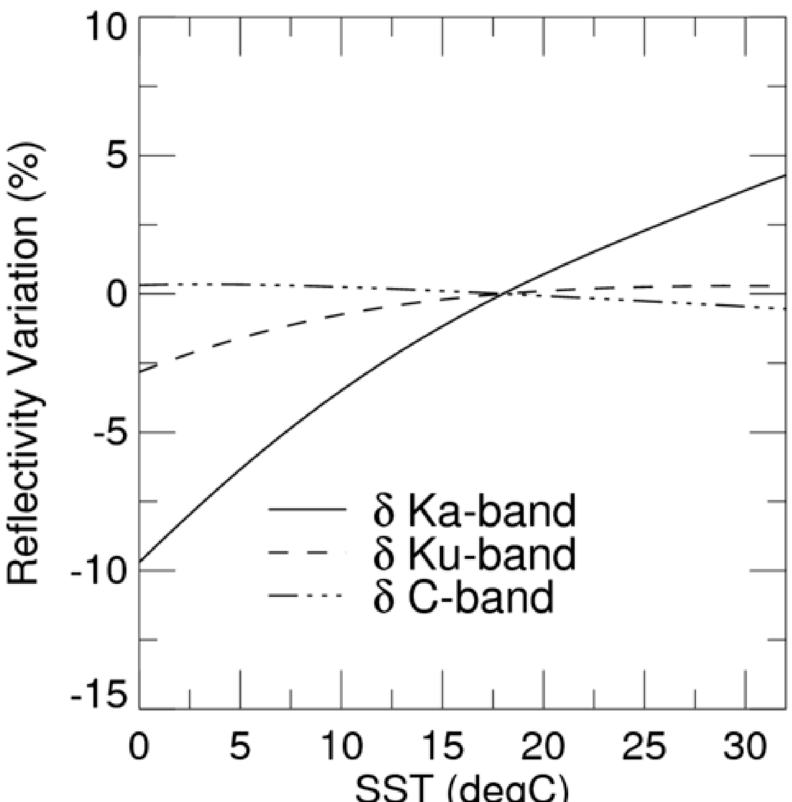


U_AltiKa – U_ecmwf (1 year)
***** after correction for SST*****



Sea surface reflectivity variation with ocean temperature at Ka-band using near-nadir satellite radar data

Doug Vandemark, Bertrand Chapron, Hui Feng, and Alexis Mouche



- Fresnel reflectivity variation with SST does impact ocean radar measurements at Ka-band
- Effect accords well with models developed using radiometry; thus path to 1st order correction is quite clear
- Numerous implications for altimetry (AltiKa (even wet tropo) and SWOT), GPM and scatterometry
- May even need to look back to cold water at Ku-band where climate data records are concerned

Thank you

and thanks to NASA and CNES for project support