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Regional changes in Ka-band SSH related to influence of SST and mean wave period on altimeter backscatter coefficient

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Motivation (1/3) → room for improvement

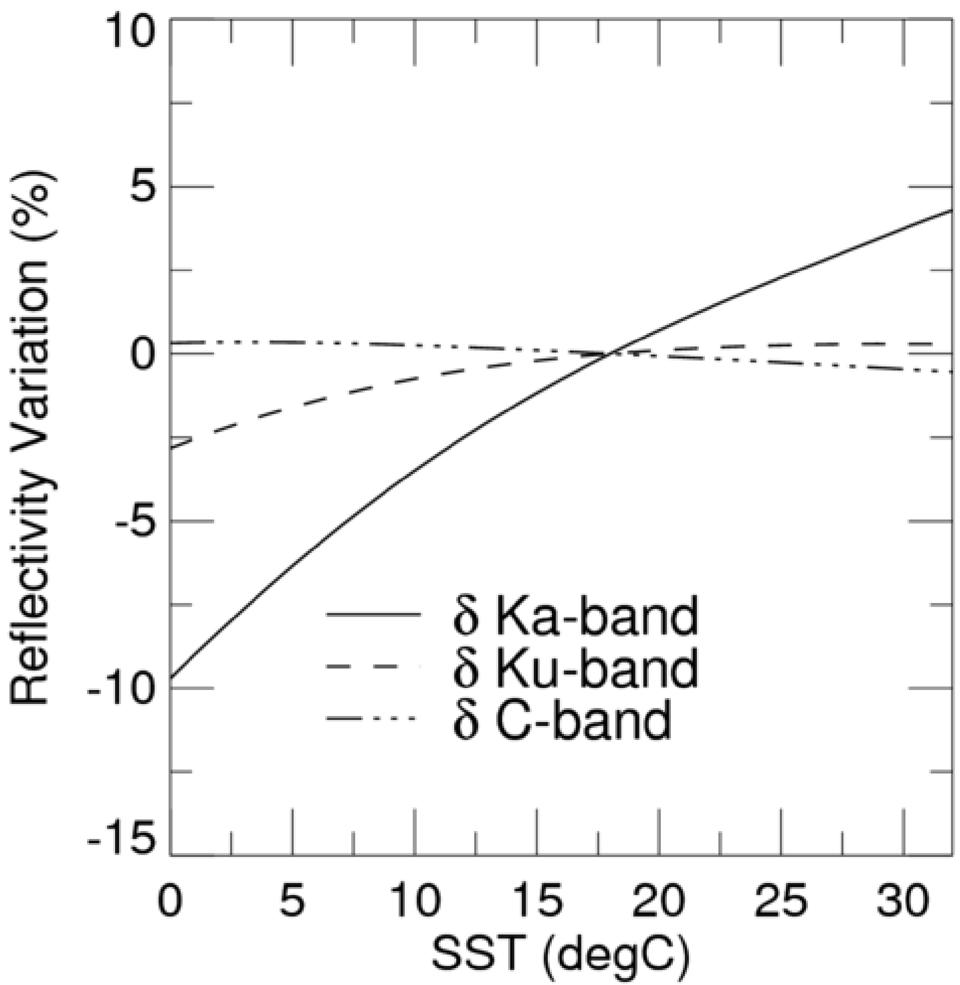
- In order to address one of the important questions concerning the sea level rise :

  "What are the potential causes of the regional and interannual variabilities?"

- The accuracy of altimetry-based sea level records at global and regional scales needs to be further improved to lower sea level trend uncertainties

- We focus here on modulations of altimeter backscatter coefficient (σ0) upon both sea surface temperature and mean wave period which affect the wind speed retrieval and by going through the Sea State Bias (SSB) correction would impact the SSH accuracy

Motivation (2/3) → published observations of correlated errors in wind retrieval with SST



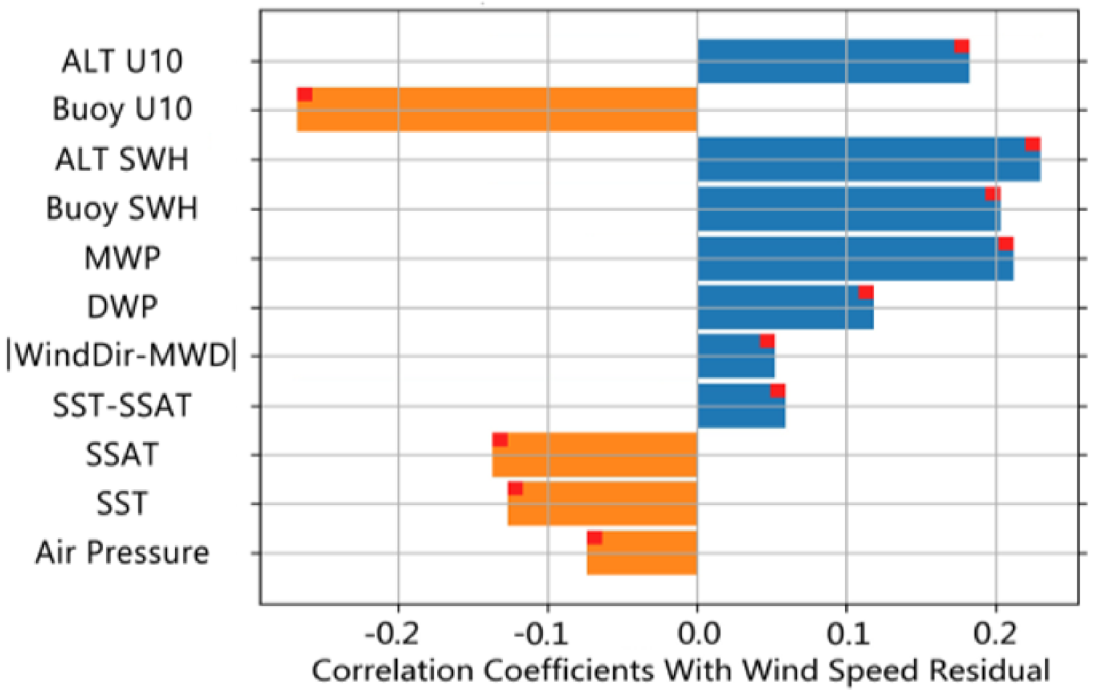
- Vandemark D., B. Chapron, H. Feng, Hui & A. Mouche (2016): "Sea Surface Reflectivity Variation With Ocean Temperature at Ka-Band Observed Using Near-Nadir Satellite Radar Data", IEEE Geoscience and Remote Sensing Letters, 13. 1-5, 10.1109/LGRS.2016.2520823.

  – Reported results clearly indicated that Ka-band retrieved wind speed estimation (from GDR-T products) carries an SST-dependent error. The differences between Altika and ECMWF estimations can reach 1 m/s in polar regions.

  – They linked this error with SST because under the geometrical optic theory, the nadir specular backscatter data can be well approximated as s0 ≈ ρ /mss; with ρ = $|R^2|$ and R being the nadir Fresnel reflection coefficient tied to dielectric constant of seawater e = f(frequency, SST, SSS) and mss representing the effective mean square slope.

  – The Fresnel reflectivity variation with SST (shown on the left) does impact Ka-band s0 significantly leading to the observation of an SST impact on wind that needs to be corrected for.

Motivation (3/3) → published observations of correlated errors in wind retrieval with mean wave period



- Jiang H., Z. Hao & M. Lin (2020): "Improving Altimeter Wind Speed Retrievals Using Ocean Wave Parameters", 10.20944/preprints202002.0319.v1.
  - The data from ten altimeters were collocated with buoys to investigate the error of the altimeter U10 retrievals.
  - The results indicated that significant wave heights and mean wave periods are effective in correcting U10 retrievals, probably due to the tilting modulation of long-waves on the sea surface.

OUTLINE → focus on Ka-band sigma0

- SST data and ALTIKA sampling
- SST correction for Ka-band sigma0
- 3D wind model development as WS(s0, SWH, mean wave period T02)
- Impact evaluation of both SST and mean wave period in wind speed retrieved with 2D (GDR-F version) or 3D models
- Impact evaluation of SST in SSB estimations (GDR-F 2D models for both wind speed and SSB)
- Conclusion and perspectives

SST data & ALTIKA sampling

- Use of L4 gridded SST data from CMEMS: Global Ocean OSTIA Diurnal Skin Sea Surface Temperature (SST_GLO_SST_L4_NRT_OBSERVATIONS_010_014) from year 2015 with reprocessed GDR-F ALTIKA data (cycles 21 to 30, 10-month period)

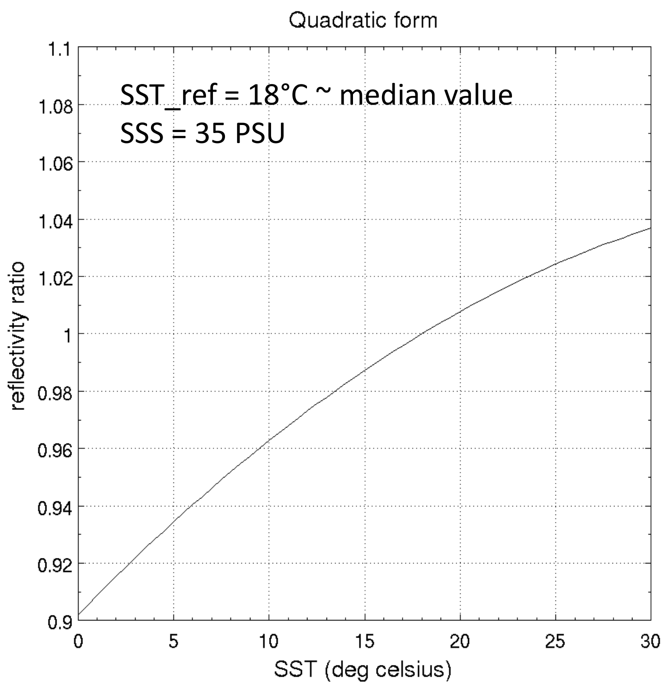
- Main SST variation is observed with respect to latitude between 0 to 30°C, then annual variation cycle can reach 10°C locally, diurnal variation related to local measurement time is up to 3°C, the SST variation with respect to depth below the surface is lower than 1°C during night-time

- With passes @ 6 and 18h local hours, the impact of diurnal SST variation is minimized for ALTIKA data, occurrences of warm SST condition (2° above SST_foundation) close to 18h or after are very small

- SST correction on sigma0 should display lower variations with hourly SST estimates than with daily data which display larger variations along passes. Differences between daily and hourly SST are between -2 and 1.5 °C

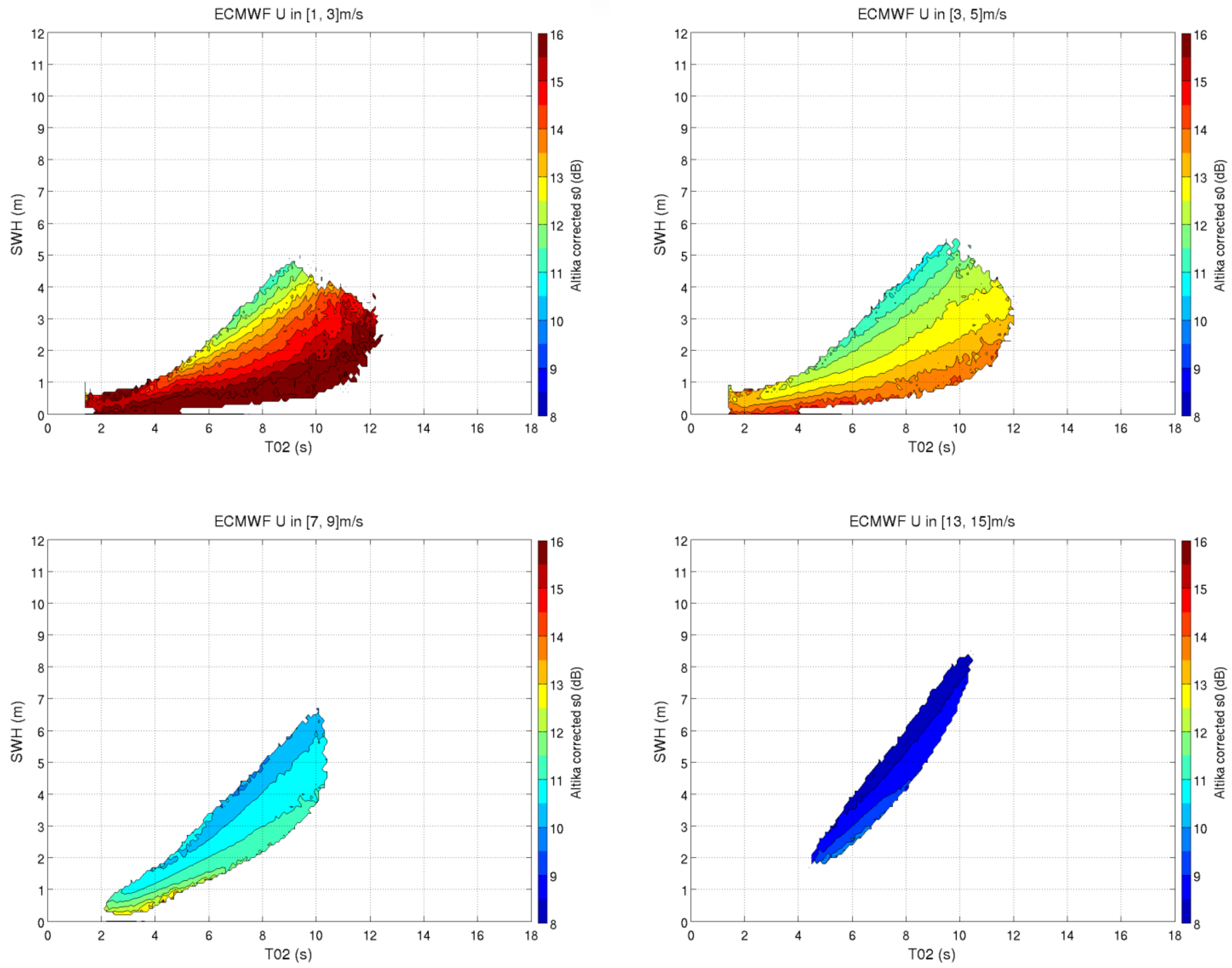
SST correction for Ka-band sigma0

- Use of the Vandemark et al [2016]'s point-by-point correction using collocated SST estimates
- Use of Meissner and Wentz [2004] seawater permittivity model for ρ → quadratic form fitting (Ka-band, SSS=35 PSU) for easier use (note the SSS impact is ~10 times lower than the SST effect)



1. To compute sigma0 in linear unit
2. To adjust each sigma0 value with the scaling factor
   $\beta = \rho(SST) / \rho(SST\_ref)$: $s0\_lin\_corr = s0\_lin / \beta$
3. To compute the corrected sigma0 in dB unit

Wind speed model, 3D model WS(corrected s0, SWH, T02) -8

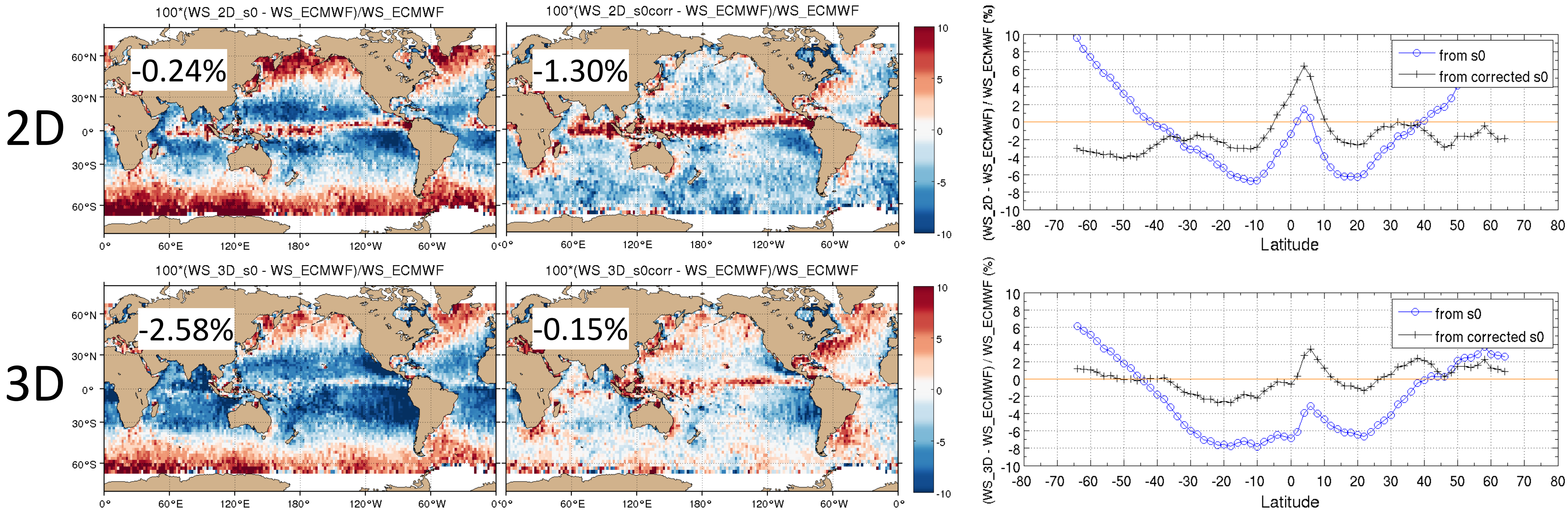


- SST and SWH data show anti-correlated variations but SWH impact on sigma0 is larger than SST effect
- Even after correcting sigma0 for SST impact, the corrected sigma0 behavior still displays some dependence on SWH
- It is observed that mean wave period (T02) also modulates the sigma0 values
- 3D model for wind speed retrieval was developed as a function of (SST corrected s0, SWH, T02)

Impact on wind speed estimation → biases (% of change)

Comparison with ECMWF winds

with SST corrected s0



- After correcting s0 for SST effect and the use of the 3D wind speed model, the ALTIKA estimation differences against ECMWF model ones are now closer to 0 and more homogeneously distributed geographically. This indicates that the global large-scale wind circulation is better retrieved. In the vicinity of the strong currents, it looks like we can see residual surface roughness modulation by currents in sigma0 that are not taken into account in the ALTIKA wind speed model.

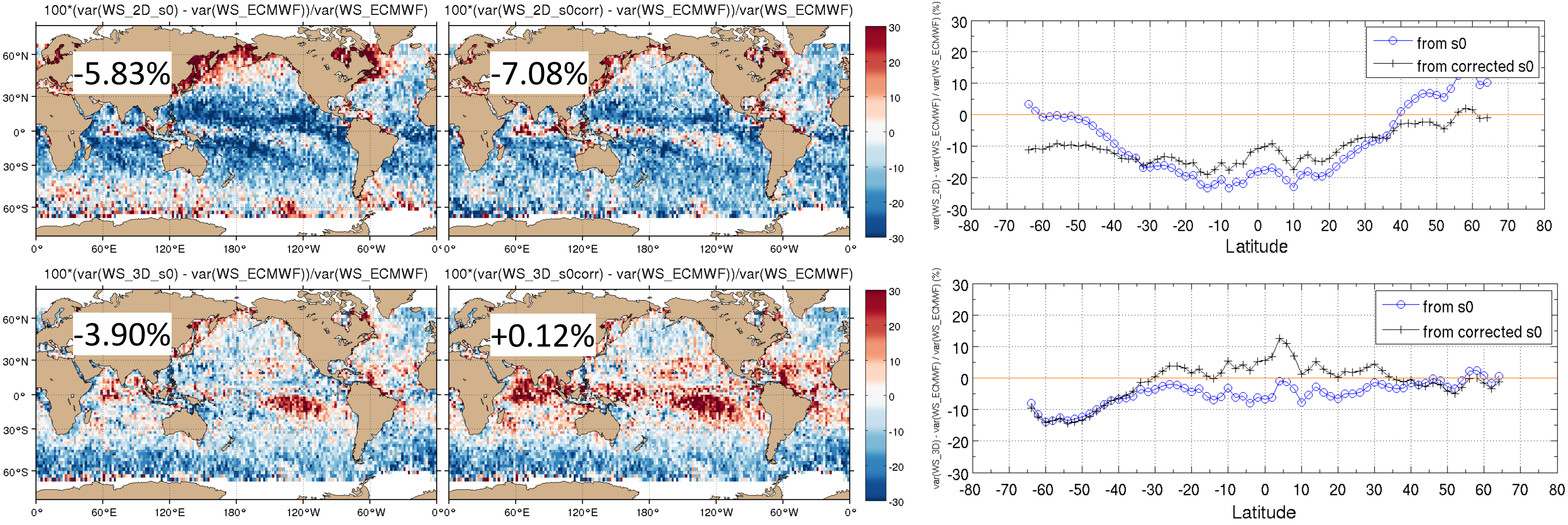
Impact on wind speed estimation → variance (% of change)

Comparison with ECMWF winds

with SST corrected s0

2D

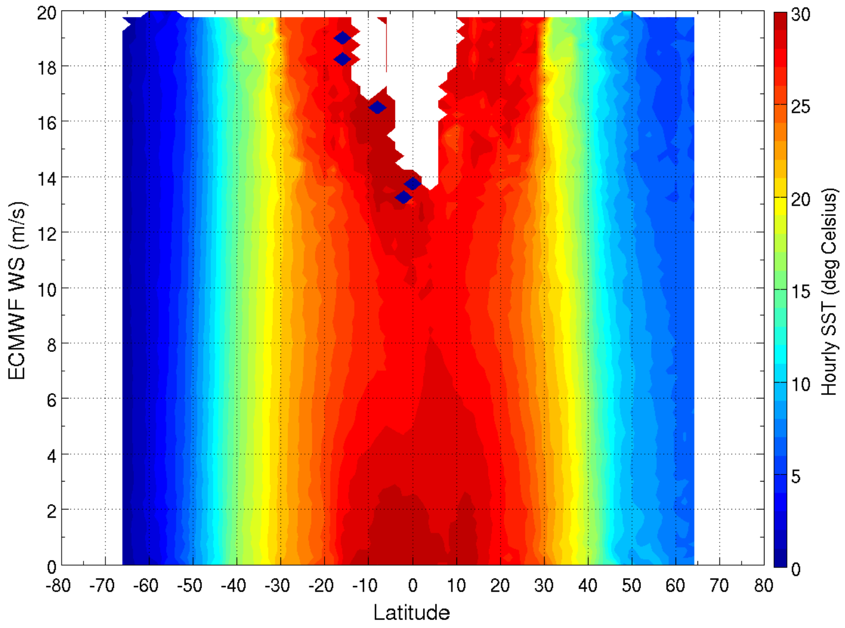
3D



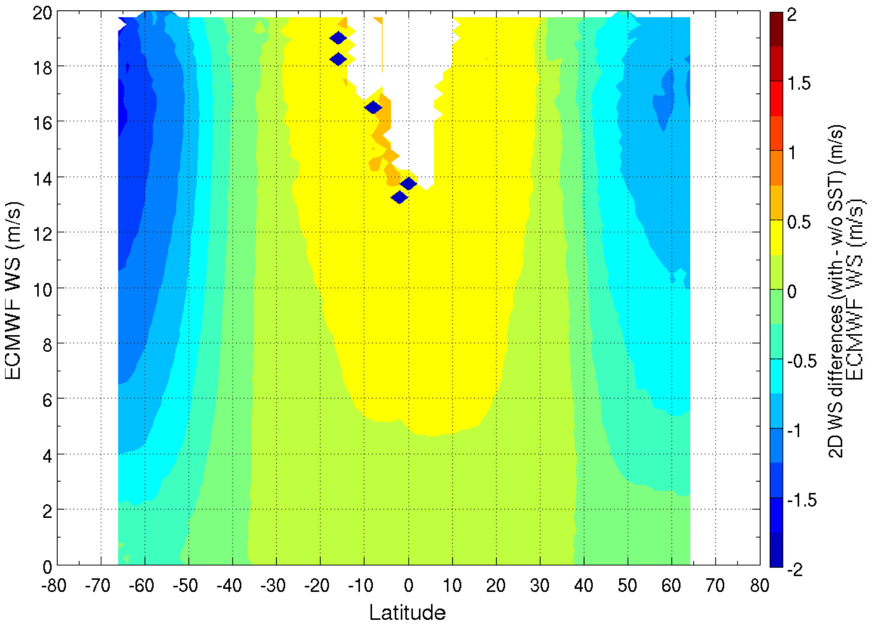
➢ After correcting s0 for SST effect and the use of the 3D wind speed model, we can see that the variance of the altimetric wind speed estimations is now larger than the model estimations variance except for latitude > 30°S. This indicates that the altimeter data may see shorter scale-features that were hidden before by the sigma0 signal modulation related to both SST and mean wave period effects.

Impact on SSB estimation,
GDR-F 2D models for both wind speed retrieval and SSB computation

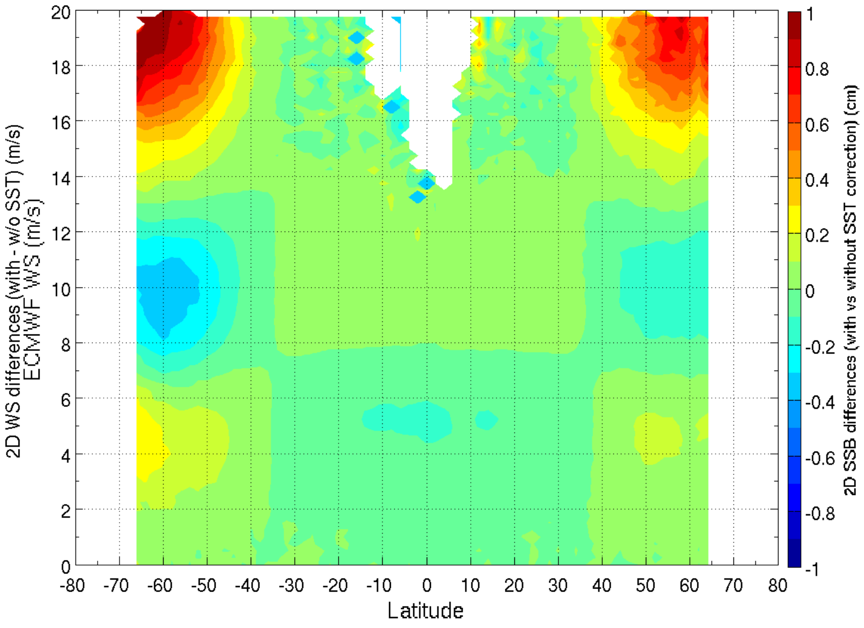
SST



ΔWS in [-1.8, 0.5] m/s



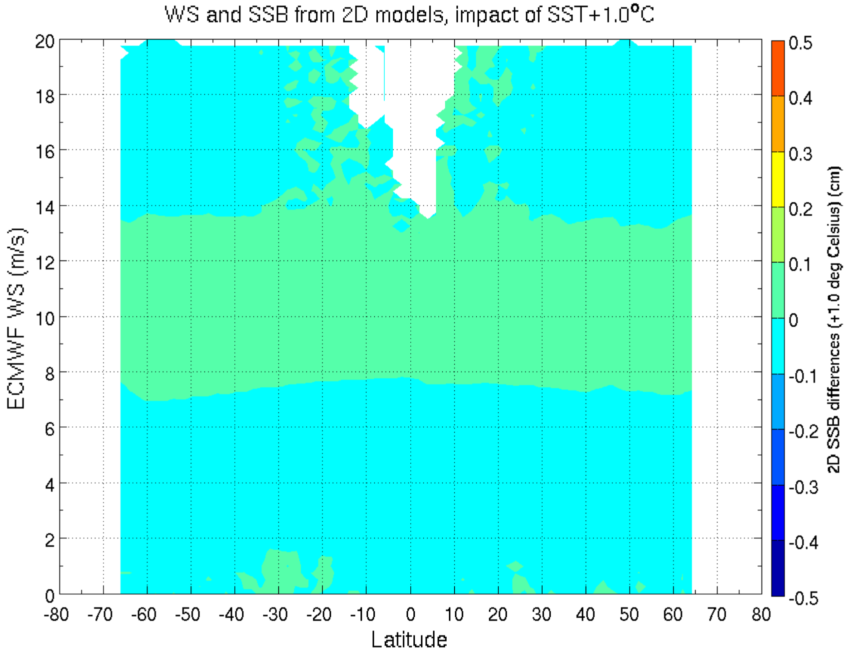
ΔSSB in [-0.4, 1.2] cm



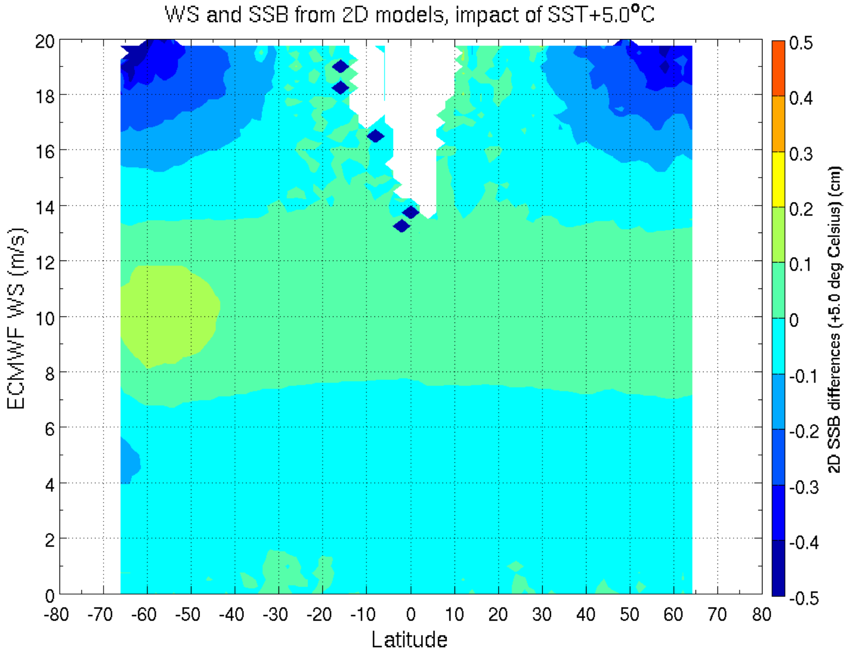
- Large impacts of SST on SSB estimations (>0.4 cm in absolute value) are observed for latitude higher than 40° in both hemispheres. The SSB estimation errors can reach ~1 cm under high wind conditions (>14 m/s) in polar regions.
- We can see here regional impact on the accuracy of altimetry-based SSH records that could be further improved to lower sea level trend uncertainties

Impact on SSB estimation of uniform SST increase,
GDR-F 2D models for both wind speed retrieval and SSB computation

SST+1°C



SST+5°C



- Test of uniform SST increase on SSB estimations to evaluate the effect of ocean warming confirms regional changes in SSH mostly in the polar regions. Because it is observed that during recent decades, the Arctic region has warmed at a rate about twice the rest of the globe, studies regarding the Arctic sea level trend may benefit from such SSH accuracy improvement to lower sea level trend uncertainties.

Conclusions

- In this analysis, we applied the correction developed for Ka-band sigma0 by Vandemark et al [2016] with SST data (diurnal skin SST) coming from CMEMS OSTIA products

- These differences are between -1.8 and 0.5 m/s when the wind speeds come from the 2D model used in GDR-F products (10% minimum of change at high latitudes).

- The 3D model better reduces differences between altimetric and model estimations; residual surface roughness modulation by currents can now be seen through wind speed map comparison against model since some larger variabilities have been removed through the wind speed model.

- Impact evaluation of the SST on the SSB estimations shows that changes as large as 1 cm can occur in polar regions. Such sigma0 correction should be further analyzed in the prospect of better understanding regional sea level climate change.

- SST correction on Ku-Band sigma0 and development of 3D wind speed model should be considered in the future.

Service Altimetrie & Localisation Precise

Thank you