WP 5000
Assessment of SAR ocean waveform retrackers

T. Moreau, M. Raynal, S. Labroue, F. Boy, N. Picot

ASSESSMENT OF SAR RETRACKERS

Assessment will focuss on the following retrackers:

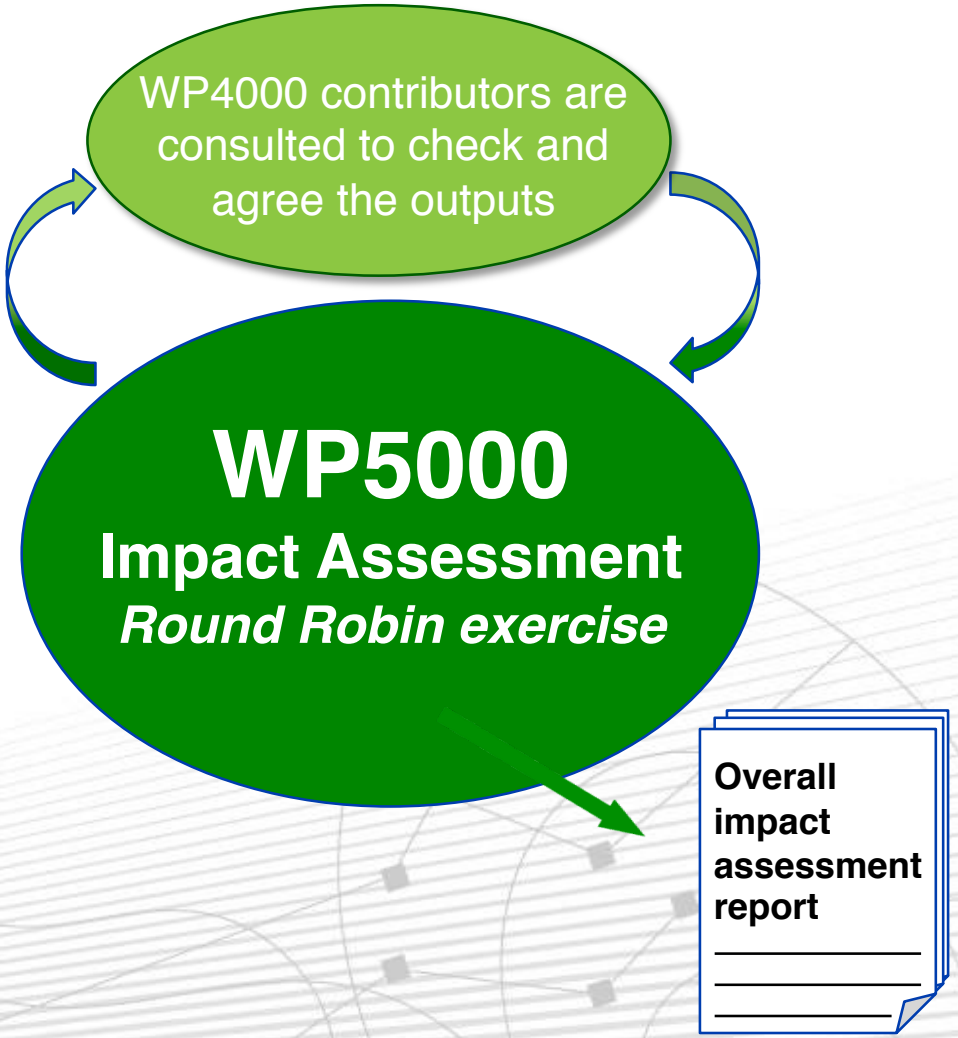
- ESRIN SAR solution retracker
- SAMOSA3 SAR retracker which is the basis of the ocean waveform retracking for Sentinel-3 STM (S3 DPM 2.3.0)
- SAR CPP retracker from CNES

SAR retracker outputs will be compared to the collocated SAR CPP products

WORK PLAN

INPUTS

- WP2000 recommandations
- WP4400 data set
- Data set user manual
- WP4000 Product validation report
- WP4000 ATBDs
- CNES/CLS database (L2 CPP SAR/RDSAR)
- CNES/CLS database (other EO satellite data and geophysical corrections)



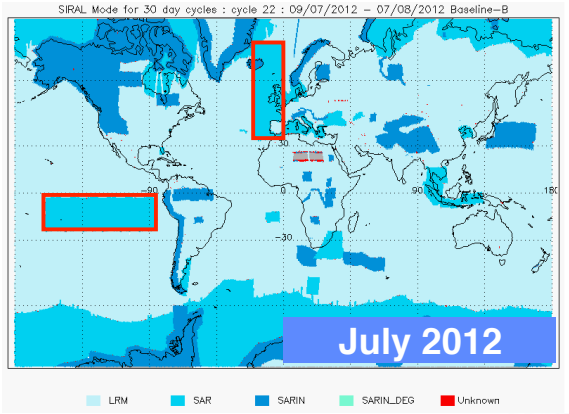
ZONES AND PERIOD

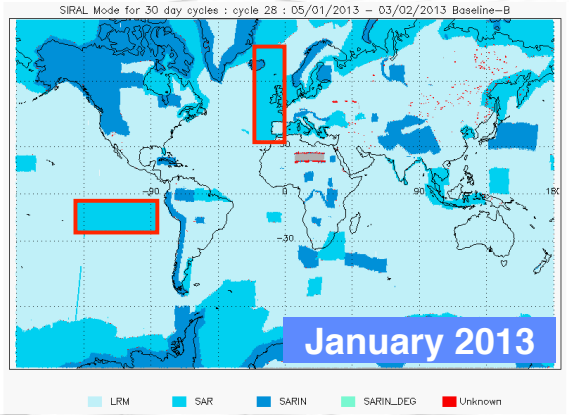
- Time period
  - 2 months of data: July 2012 and January 2013

- Equatorial Pacific SAR-mode area
  - low ocean variability stable in time (easing the inter-mission calibration with conventional altimetry satellites),
  - few occurrences of rain and sigma0 blooms events,
  - mean SWH around 2 meters and mean wind around 7 meters (sea state is close to the mean conditions).

This site was used for successfully validating CPP SAR data in comparison with CPP RDSAR data

- North-East Atlantic SAR-mode area
  - seasonal variation (with bloom events in summer time)
  - high waves in winter time





METHODOLOGY

Assessment of SAR retracker performances @20-Hz:

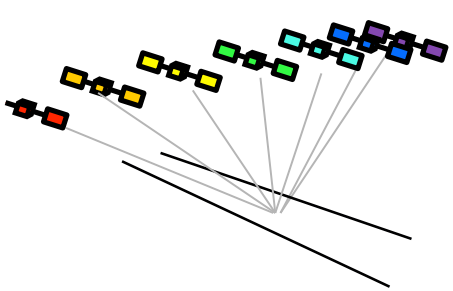
- Analysis of differences between retracker outputs (direct comparisons of the collocated SLA, SWH, Sigma-0)
  - Analysis of the parameters differences (histograms, maps, scatter-plots)
  - Detection of dependencies in the difference (sentivity to radial velocity, roll/ pitch angles, SWH, calms or sigma-0 blooms or rain areas) done separating ascending and descending passes
- Other diagnoses
  - Analysis of the retracking misfit
  - Along track profiles
  - Spectral analysis of SLA, SWH, Sigma-0
  - Statistics at crossovers (C2/C2)
  - Cross-calibration with Jason-2 data
  - Analysis of parameters wrt to coastal distance

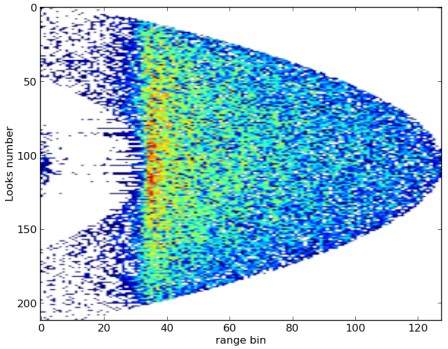
WP 5000
Assessment of ESRIN SAR solution vs SAR CPP retracker

T. Moreau, M. Raynal, S. Labroue, F. Boy, N. Picot, S. Dinardo, B. Lucas

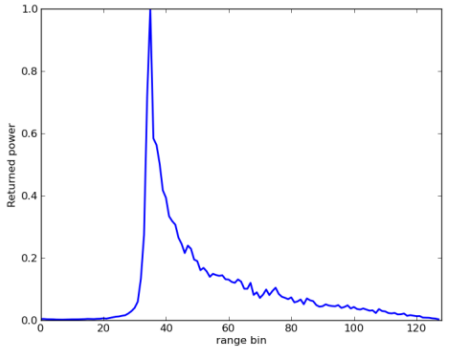
SAR OCEAN WAVEFORM RETRACKER DESCRIPTION

- Same Level-1B multilooked SAR echo power (from CPP)





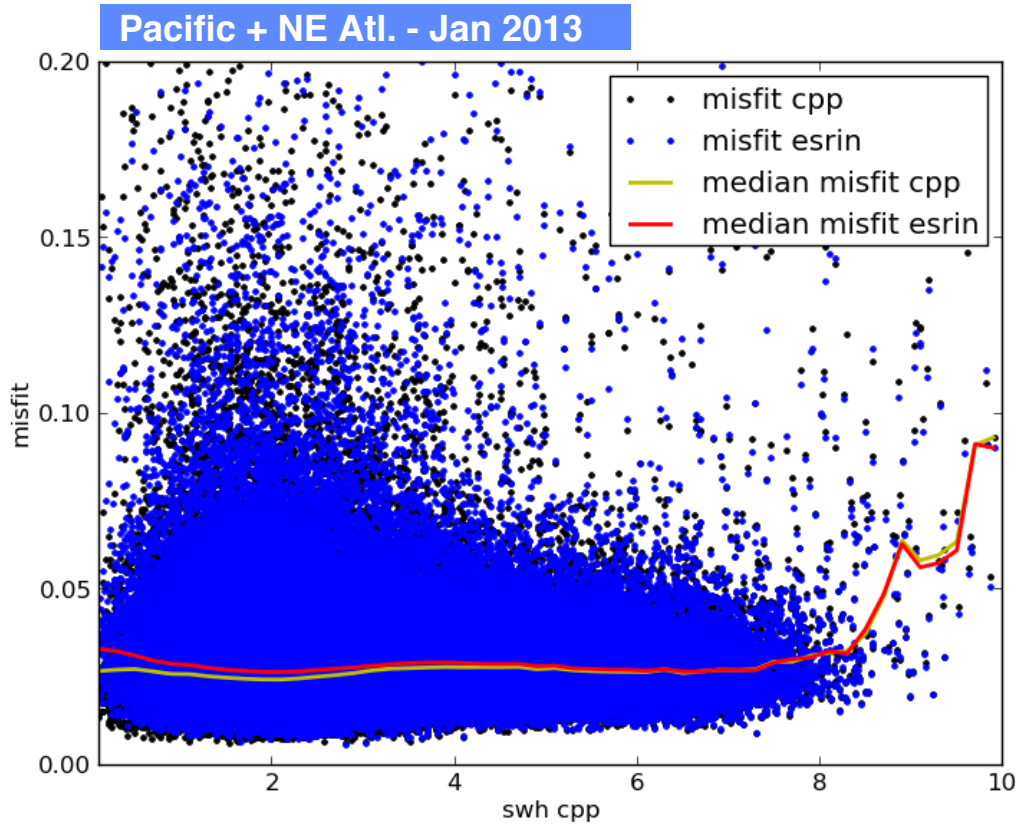
SUM ➔



SAR ESRIN solution retracker	**CPP CNES SAR retracker**
Analytical retracker	***Numerical retracking***
3-parameters estimated (range, SWH, amplitude)	3-parameters estimated (range, SWH, amplitude)
SAMOSA2 analytical model	pre-computed multilooked waveform models
Levenberg-Marquardt least square estimator	unweighted least square estimator (MLE3)
LUT applied to correct approximations for the PTR	No LUT

- Along/cross off-nadir angles (from star-tracker) used as input parameters of retrackers
- **Instrumental corrections**: (no timing-bias, no internal-path delay correction, constant bias applied to 20-Hz range and sigma0 after cross-comparisons with Jason-2 data)
- **Atm/Geo Corrections**: same corrections, same MSS (and same altitude)

MISFIT ANALYSIS



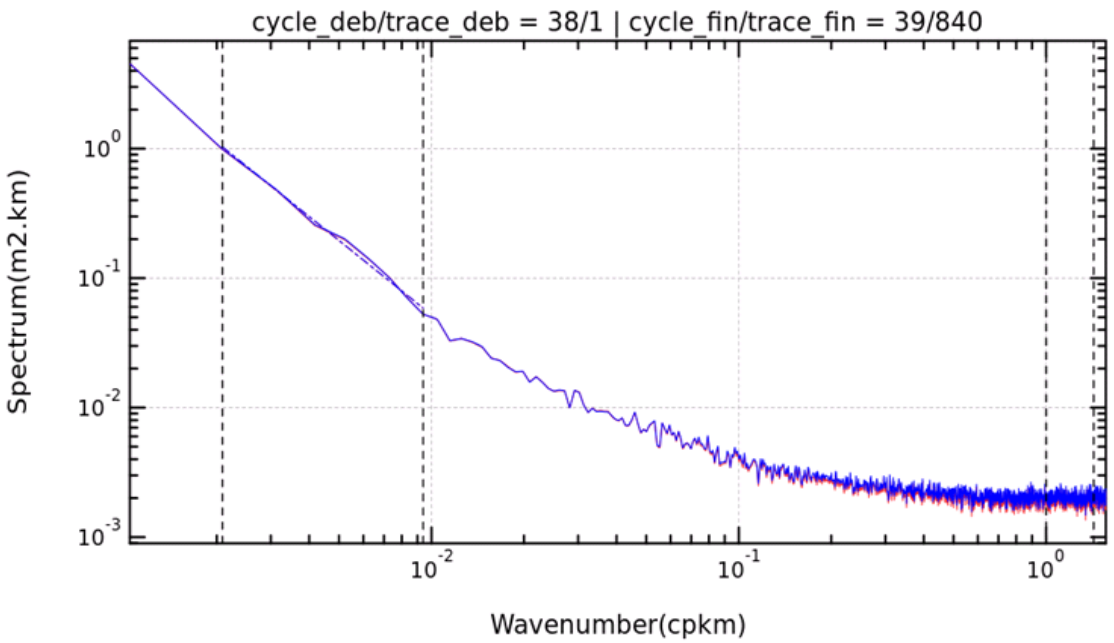
- Very similar behaviour
- Good agreement of the averaged misfit

  - Lower misfit for the CPP at low wave height

  - Tend to coincide at high wave height (where the approximation of the PTR has negligible impact)

SLA ANALYSIS

Pacific + NE Atl. - Jan 2013

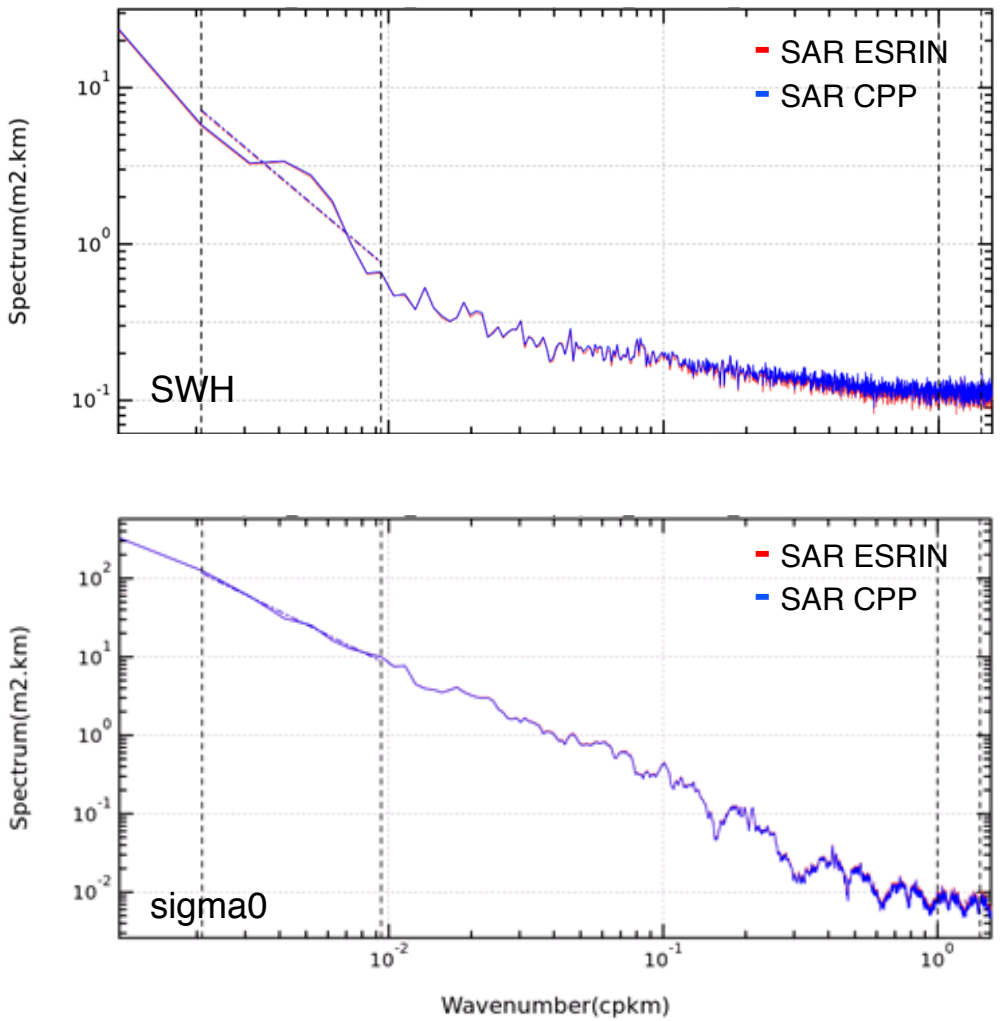


- Sea level spectrum performed at all spatial scales:
  - Same oceanic signal content measured by both retackers
  - Both perfectly follow the slope of the oceanic signal up to 50 km whereas the RSAR SLA spectrum breaks off the signal at around 100 km
  - No correlated errors for scales between 10 and 80 km with the SAR retrackers whereas a « spectral hump » is detected with the LRM
  - SAR noise level close to 5.5 cm at 20-Hz

➔ **Both SAR retrackers allows 1-Hz product users to recover smaller wavelengths (10-80 km) of interest for oceanography**

SPECTRAL ANALYSIS OF SWH/SIGMA0

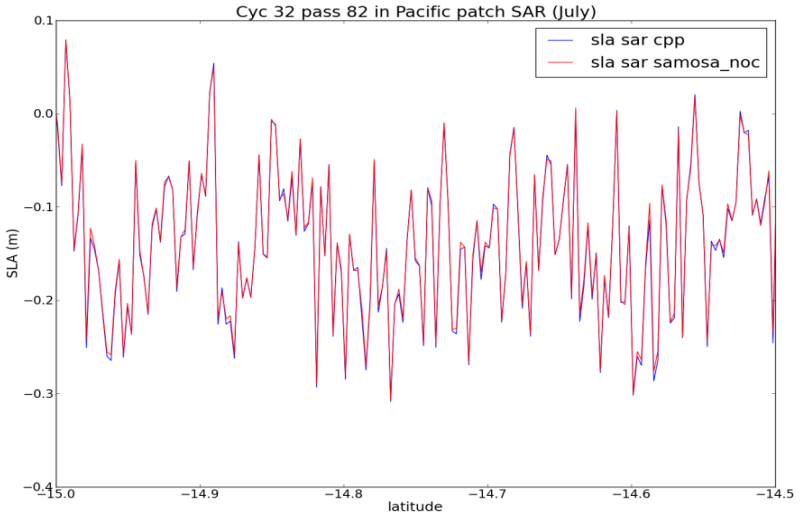
Pacific + NE Atl. - Jan 2013

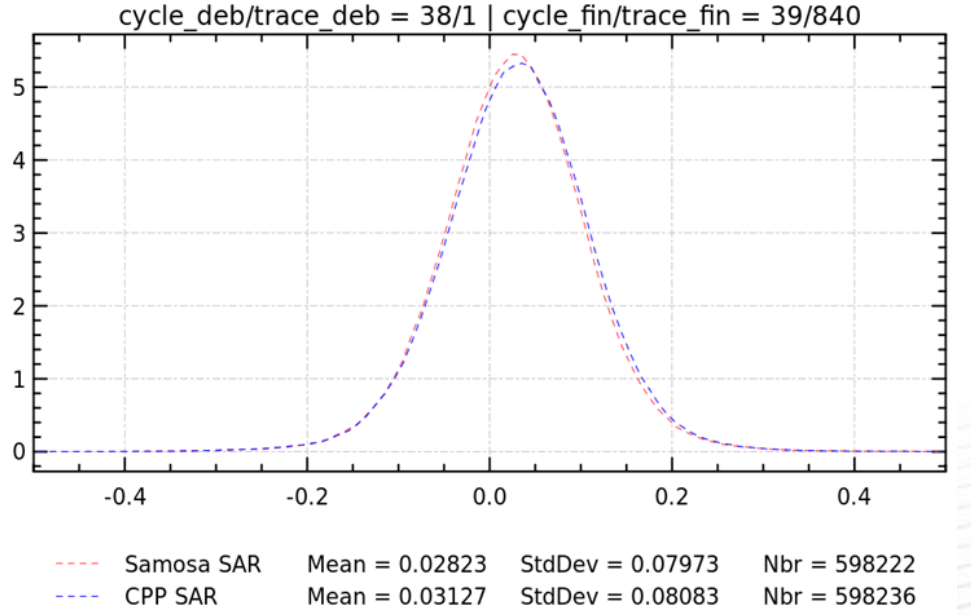


- Spectra well overlapped with each other
- Same noise levels for SWH (around 42cm @20-Hz) and Sigma0

➔ **Very similar behaviour of the retrackers on geophysical signals from high to low wavelengths in open ocean**

PLOTS OF 20-Hz SLA

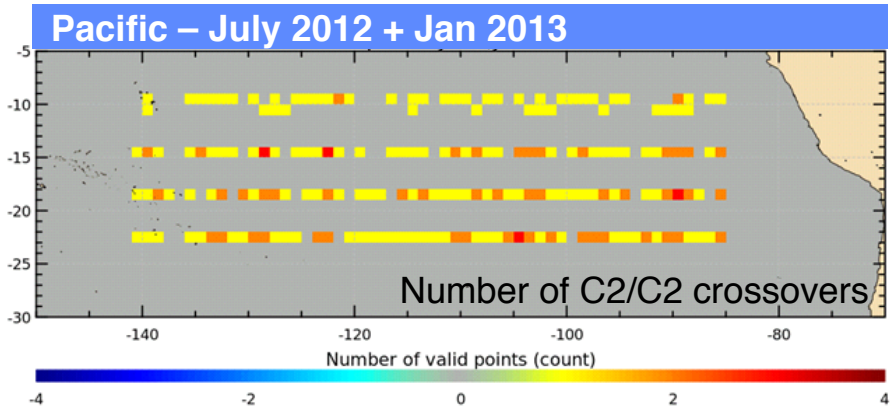


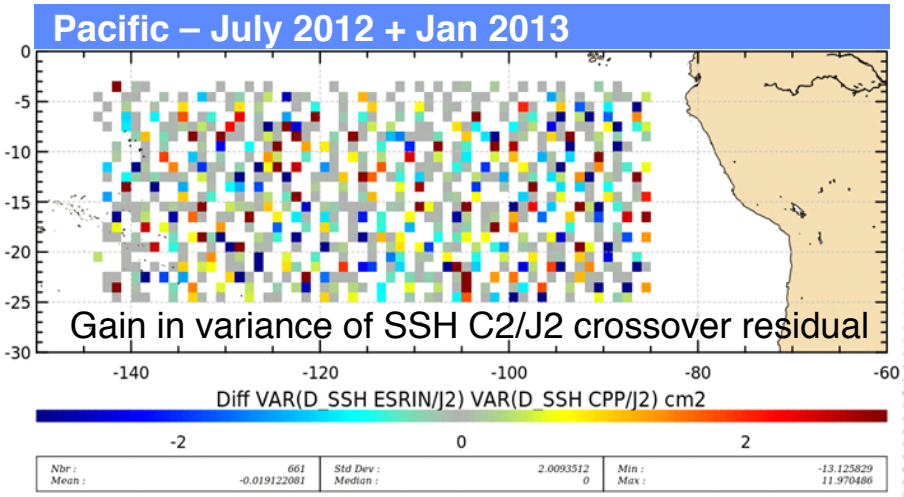


- SLA profiles are « overlapped »
- Mean SLA difference is of few mm

➔ **Very consistent retrackers**

GAIN OF VARIANCE OF SSH





- Too low statistic of C2/C2 and C2/J2 (with same geophysical corrections) crossovers ($\Delta t<10$days) in 1°x1° bins

  ➔ **No apparent pattern in the maps**

- But same global precision of the SSH residual at crossovers is computed

  $\Delta VAR = (\sigma_{\Delta SSH\ ESRIN})^2-(\sigma_{\Delta SSH\ CPP})^2 = 0$

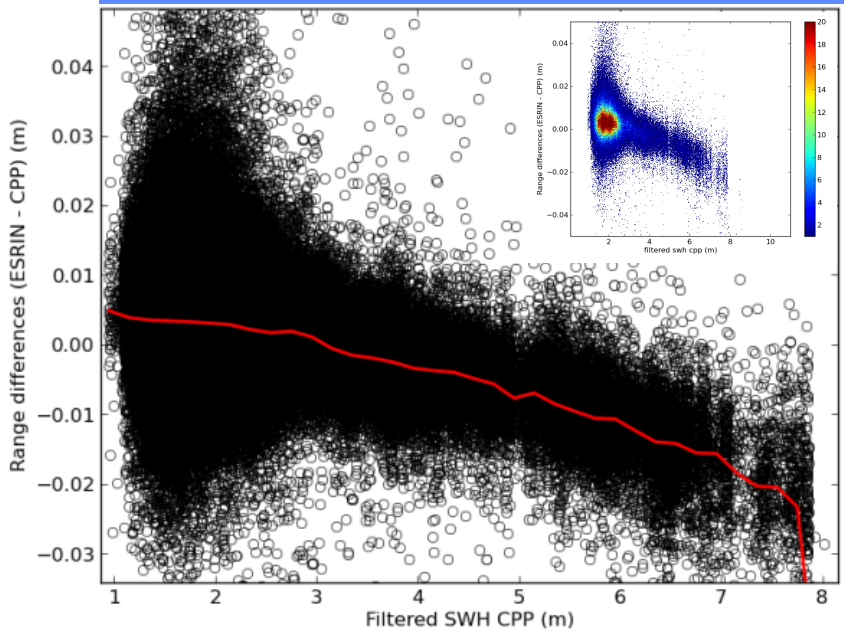
  ➔ **No gain in SSH variance between both retrackers at C2/C2 and C2/J2**

  ➔ **Equivalent retracking in open ocean**

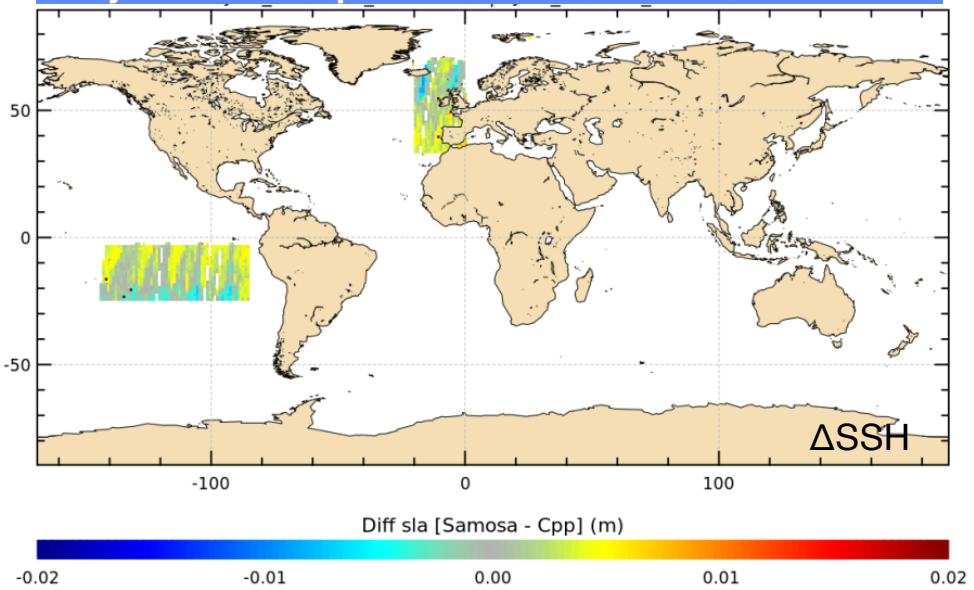
- Note that the gain of SWH/Sigma0 variance is not relevant since lower $\Delta t<1$day is required

DEPENDENCIES OF SSH DIFFERENCE

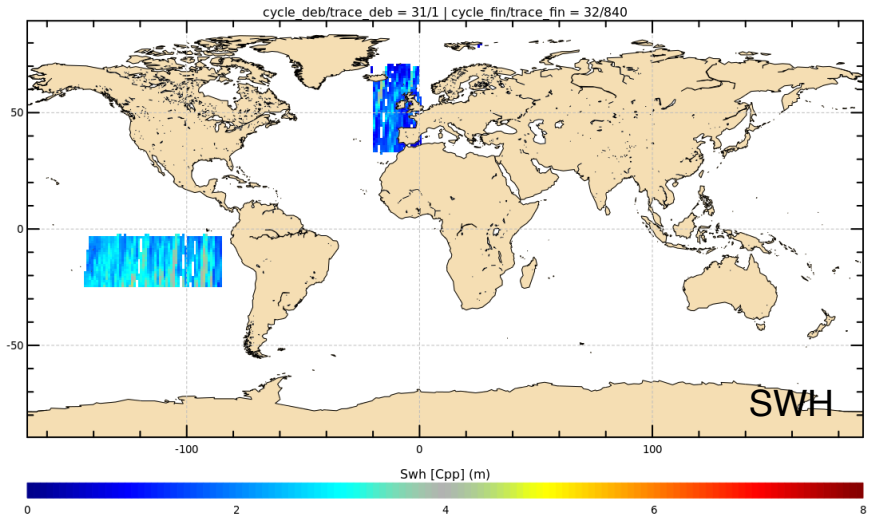
Pacific + NE Atlantic – Jan 2013 – Dsc



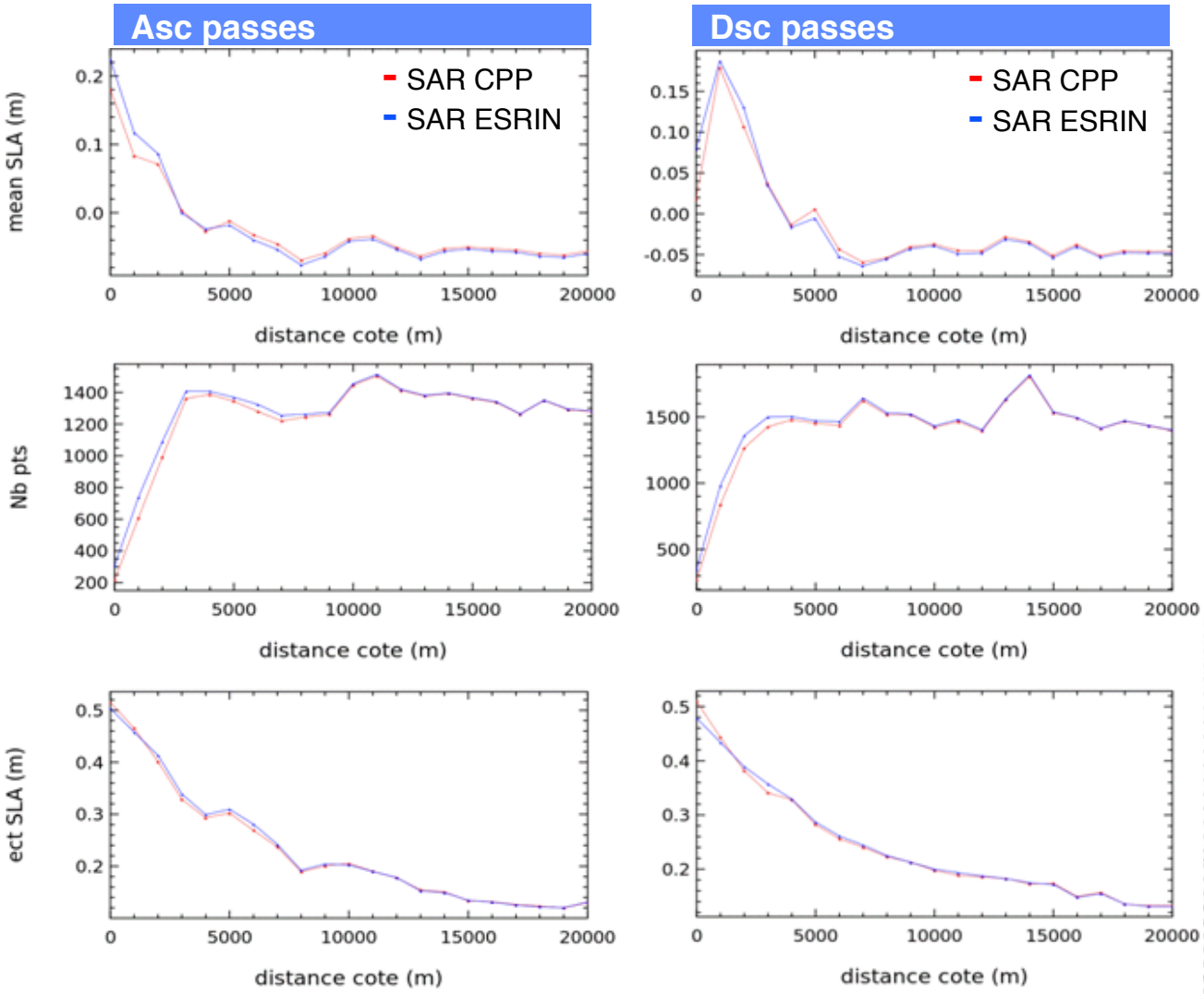
July 2012 – Dsc passes



- SSH residual depends on SWH though quite low (between ±5mm for SWH up to 4m)
- No apparent impact on the dependencies wrt mispointing angles and radial velocity



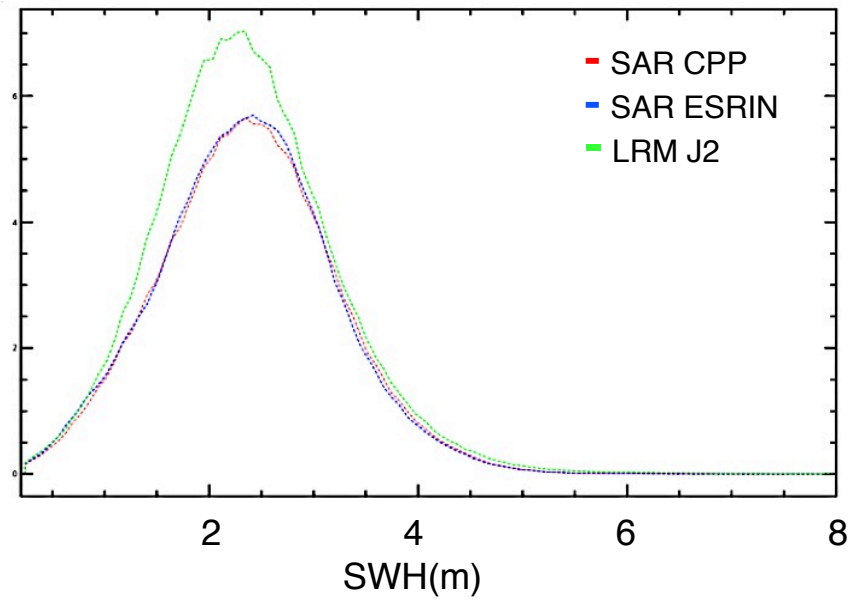
SLA ANALYSIS IN COASTAL OCEAN

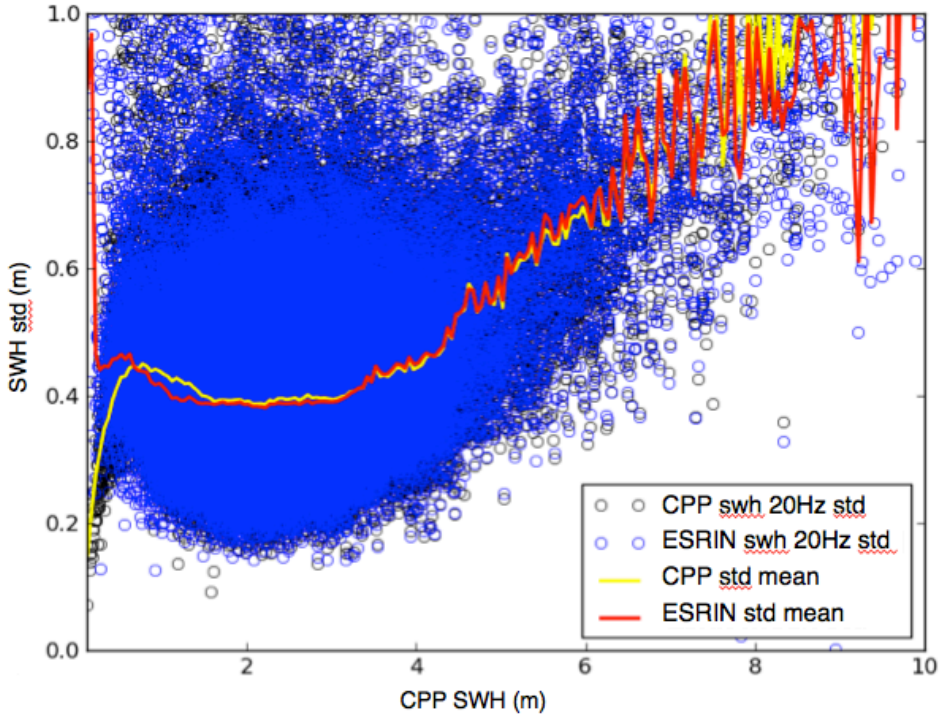


- Averaged SLA in 1km distance-to-coast bins (with different incident angle relative to the shoreline)
- Quite similar statistics near the coast (mean SLA, std SLA, density of point):
  - Number of points drop below 3km from the coast
  - Averaged SLA increases <5km
  - Precision slightly increases from 20km

PLOT OF 20-Hz SWH AND NOISE

Pacific + NE Atlantic - July 2012



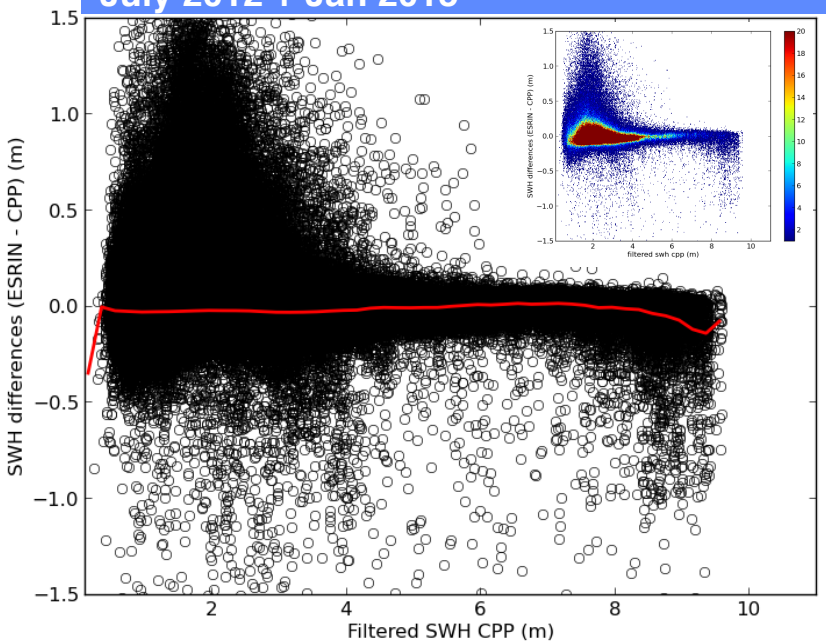


- Mean SWH difference <5cm with J2 LRM
- Similar noise performances with around 40cm of SWH noise at 2-3m wave height, … except at very low wave height

➔ **Need particular investigations to better understand this behaviour**

DEPENDENCIES OF SWH DIFFERENCE

July 2012 + Jan 2013



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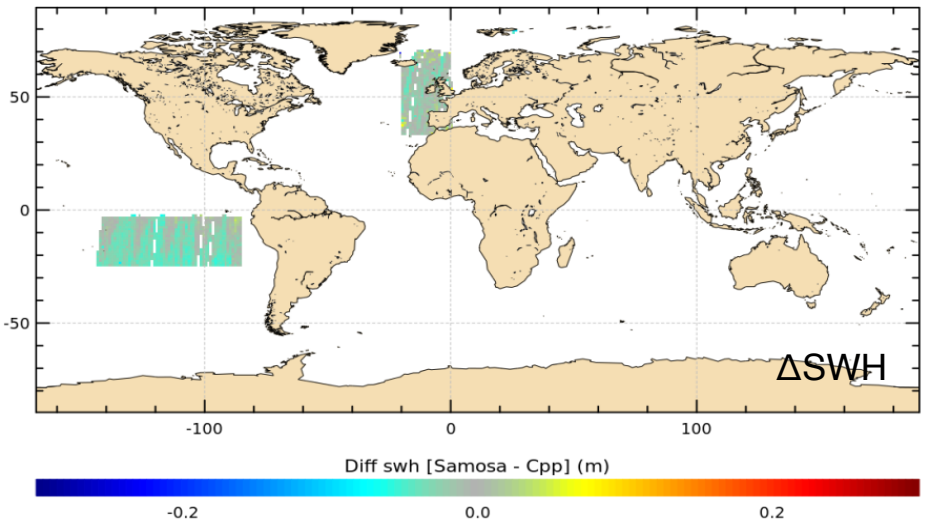
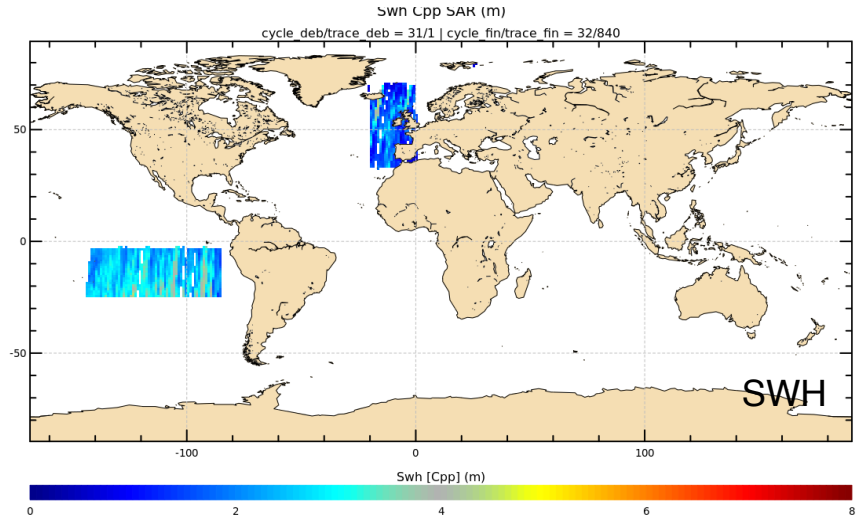
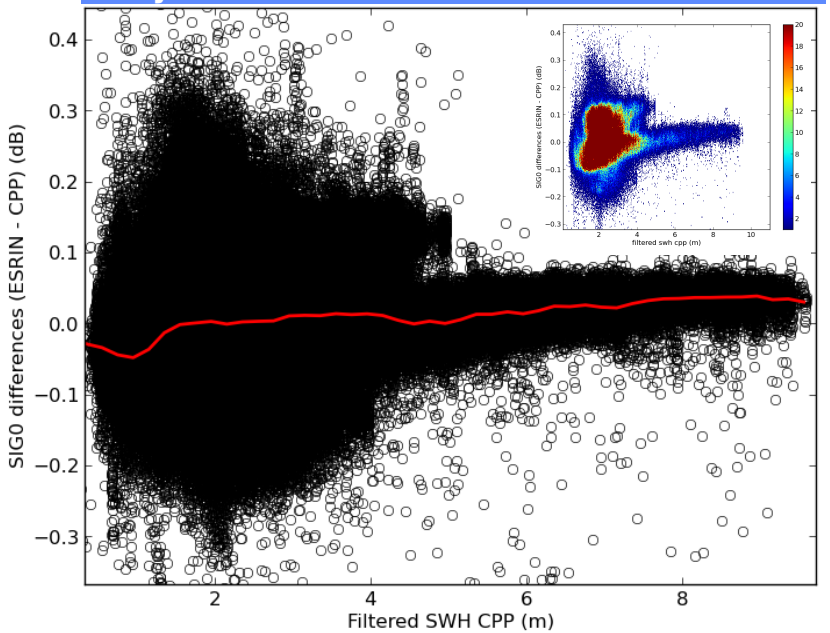




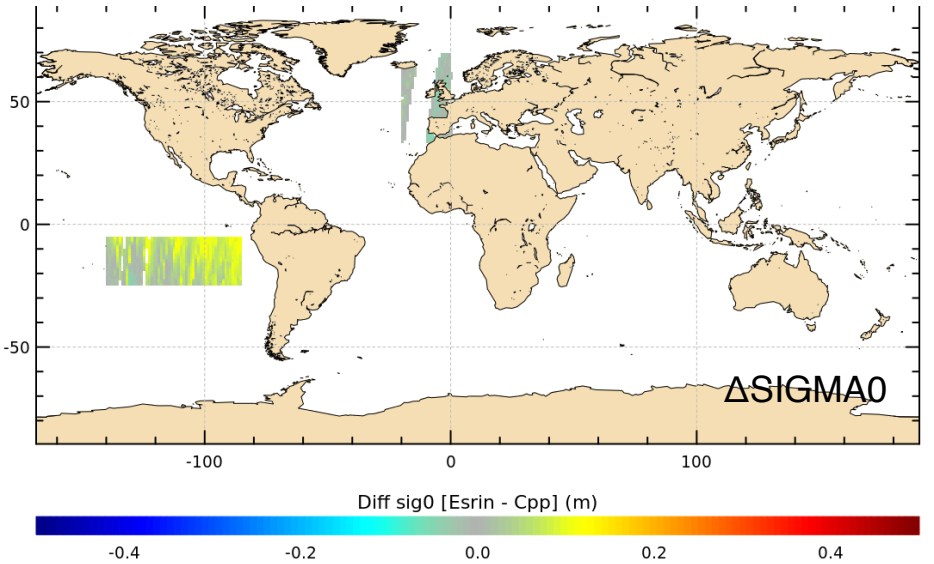
- Very good agreement between SWH
- No significant dependence with SWH
- Averaged SWH residual quite low (<5cm at 4m wave height)
- No dependence of the residual on other parameters (mispointing angles and radial velocity) is reported

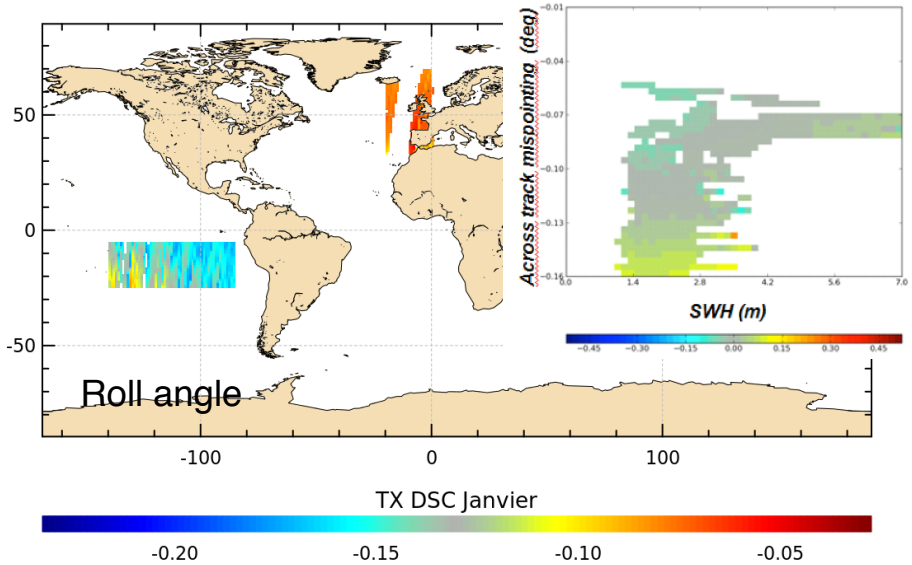
DEPENDENCIES OF SIGMA0 DIFFERENCE

July 2012 + Jan 2013



Jan 2013 – Dsc passes

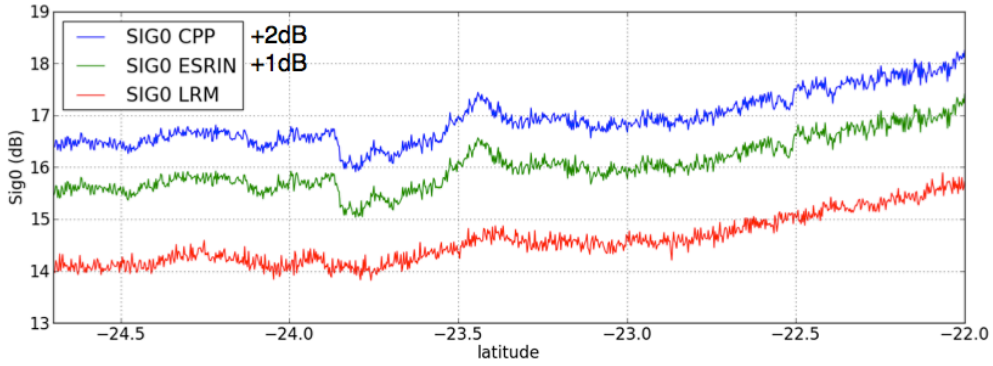


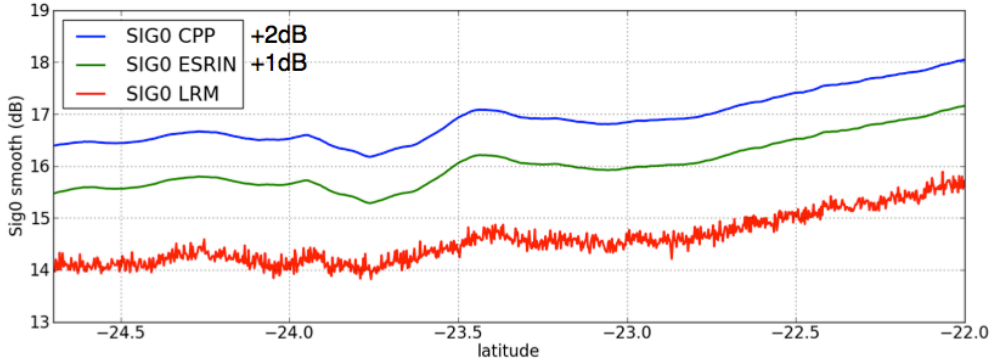


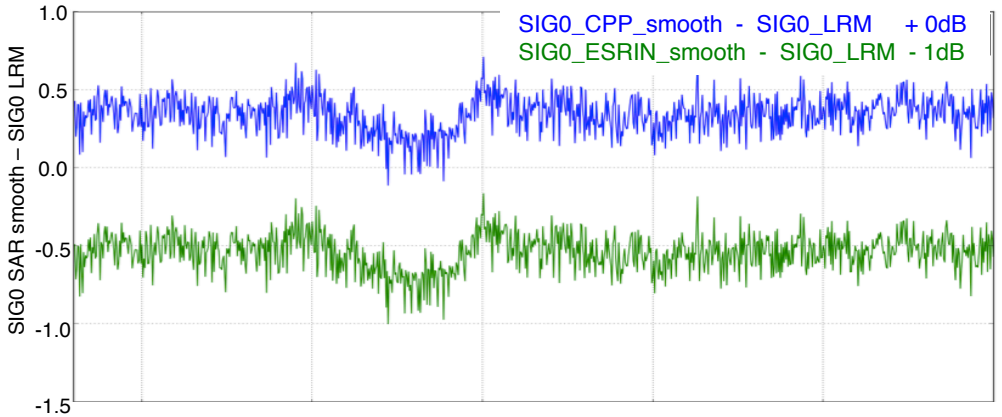
- Good agreement in Sigma0 estimates
- Sigma0 residual varies slightly with SWH
- Quite low difference between ±0.1dB
- Noticeable dependence of the residual on roll

➔ To be precisely evaluated with larger set of data

COMPARISON WITH RDSAR SIGMA0







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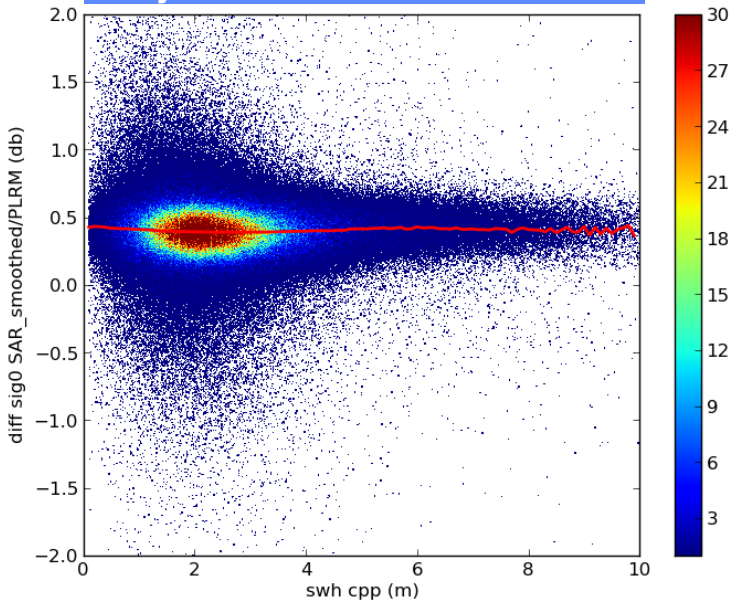

- Smaller scale structures seen in SAR
- SAR Sigma0 is smoothed to artificially make its footprint comparable to LRM one
- Degraded Sigma0 consistent with RDSAR

  ➔ **Same ocean structures captured**

However few discrepancies are observed where SAR sigma0 exhibits quick drop

CONCLUSIONS

- Both estimates are in a very good agreement with differences up to:
  - few mm in range
  - few cm in wave height
  - one tenth of dB in sigma0 (correlated notably to roll angle)

➔ **Very close behaviour and very similar performances**

- Longer time series with more relevant statistics will allow to better detect dependencies and confirm outputs of this study

- This assessment raised however two remaining issues:
  - The sigma0 residual dependency on roll angle (as low as it is)
  - The difference of SWH noise performance at very low wave height

➔ **Simulations and real data investigations with much larger time period are needed to draw some conclusions**

WP 5000
Assessment of SAMOSA3 SAR retracker (S3 DPM 2.3.0) vs SAR CPP

T. Moreau, M. Raynal, S. Labroue, F. Boy, N. Picot, S. Dinardo, B. Lucas

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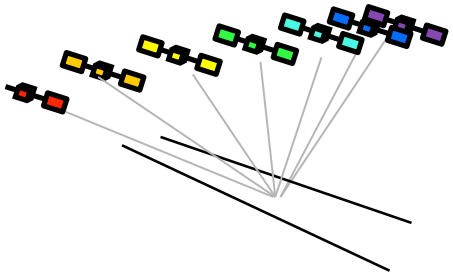
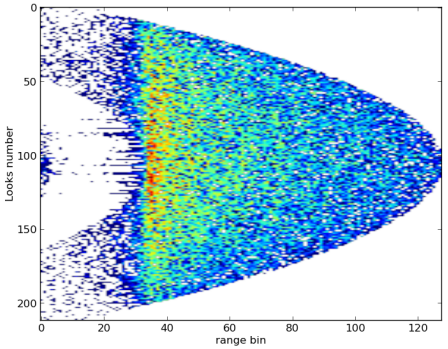
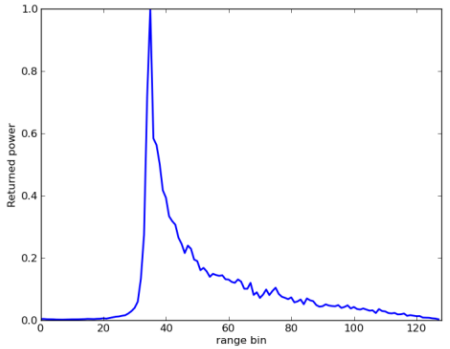




SUM ➔



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Levenberg-Marquardt least square estimator	unweighted least square estimator (MLE3)
No LUT to correct approximations for the PTR	No LUT

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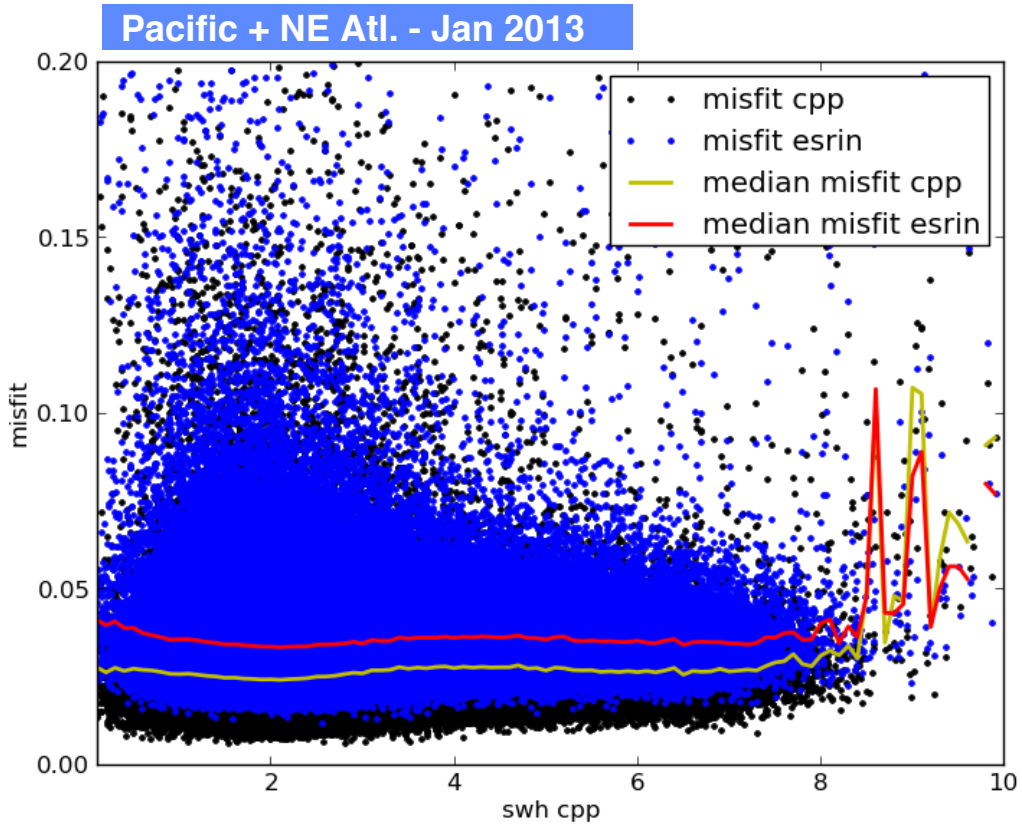
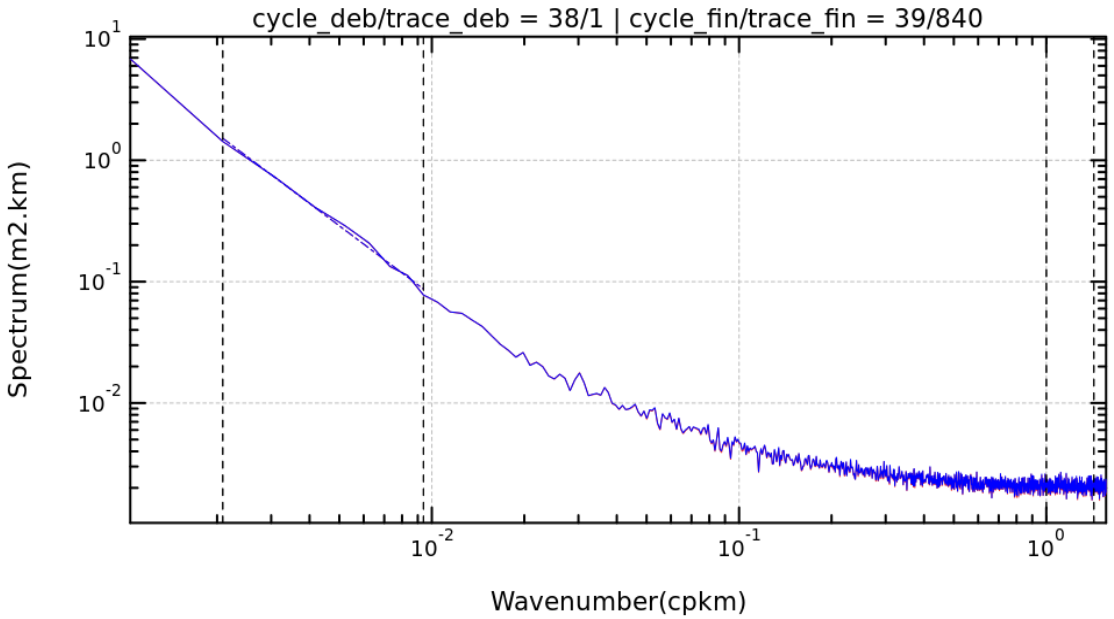
MISFIT ANALYSIS



- As expected, lower misfit for CPP, thanks to a better model-echo fitting
- SAMOSA3 model approximation (i.e., Gaussian approximation for the PTR) may lead to residual waveform misfit and possible errors of estimates

SLA ANALYSIS

Pacific + NE Atl. - Jan 2013



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  - Same oceanic signal content measured by both retackers
  - Both perfectly follow the slope of the oceanic signal up to 50 km whereas the RSAR SLA spectrum breaks off the signal at around 100 km
  - No correlated errors for scales between 10 and 80 km with the SAR retrackers whereas a « spectral hump » is detected with the LRM
  - SAR noise level close to 5.7 cm at 20-Hz

➔ **Both SAR retrackers allows 1-Hz product users to recover smaller wavelengths (10-80 km) of interest for oceanography**

SPECTRAL ANALYSIS OF SWH/SIGMA0

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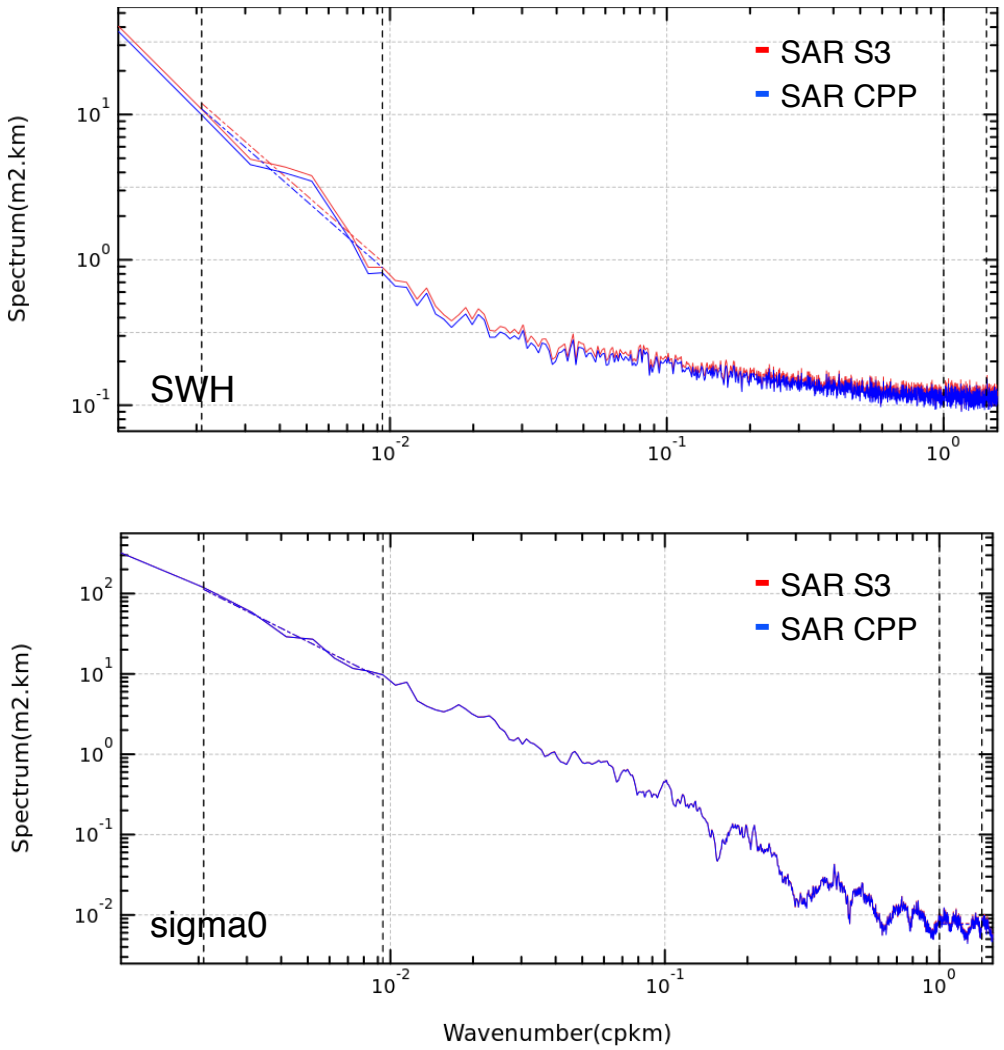


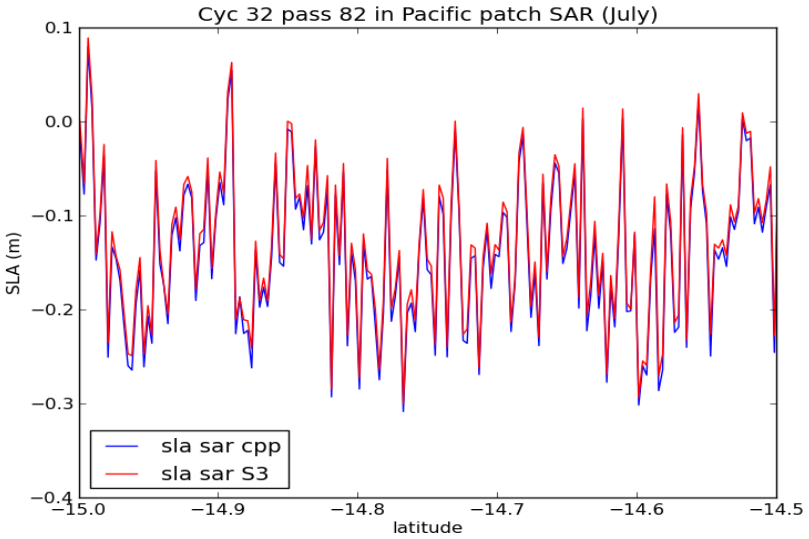
- S3 SAR SWH spectrum is however slightly higher than the one for the CPP

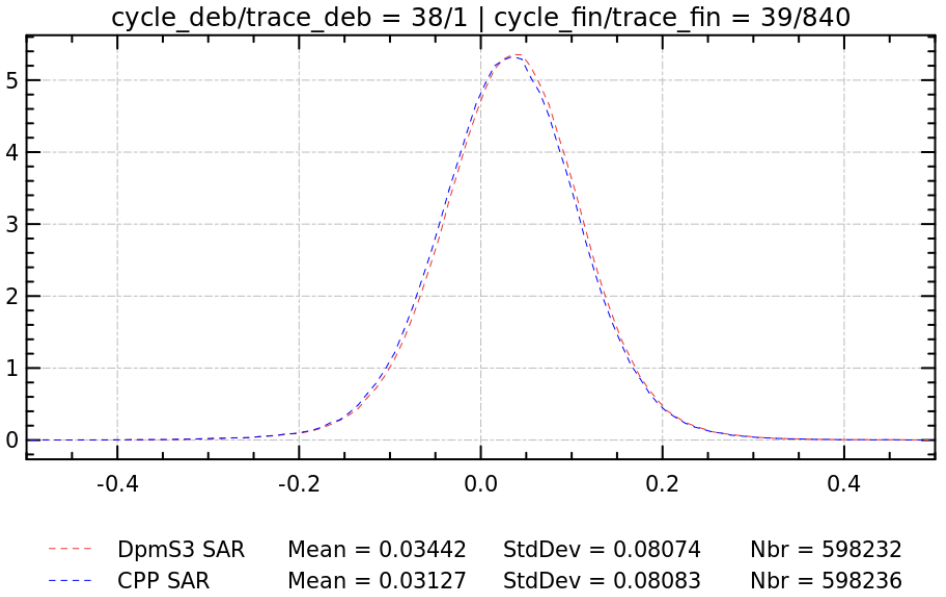
➔ S3 SAR SWH PSD is a little bit higher in amplitude

- Sigma0 spectra well overlapped with each other
- Same noise levels for SWH (42cm @20-Hz) and Sigma0

➔ Comparable behaviour of the retrackers on geophysical signals from high to low wavelengths in open ocean

PLOTS OF 20-Hz SLA



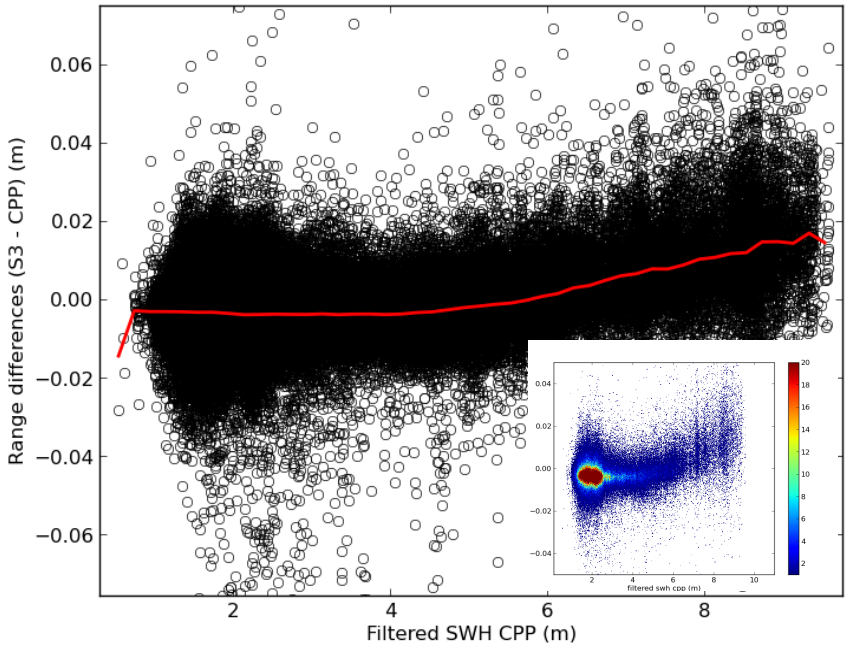


- SLA profiles and mean SLA are in good agreement (few mms of difference at maximum)

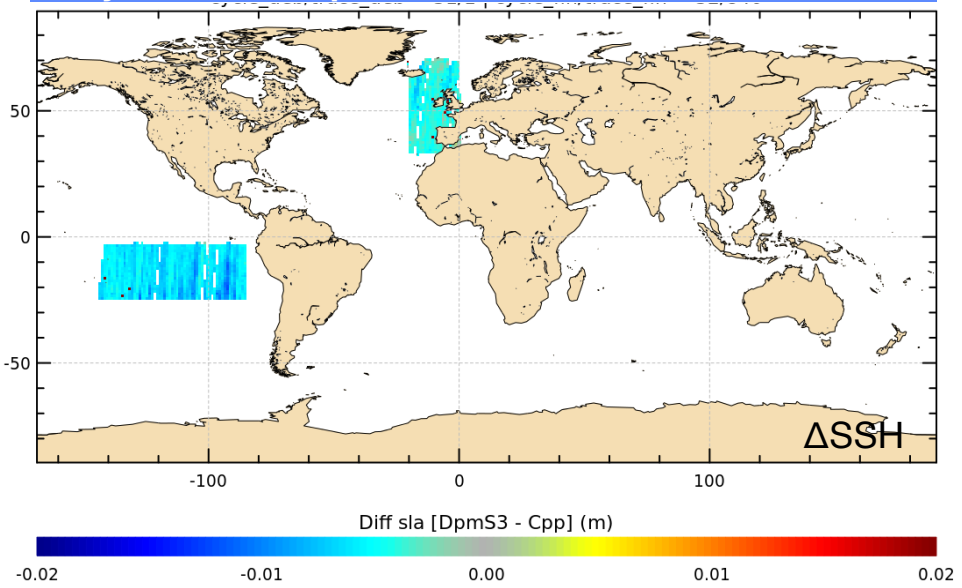
➔ **Very consistent retrackers in SLA estimates**

DEPENDENCIES OF SSH DIFFERENCE

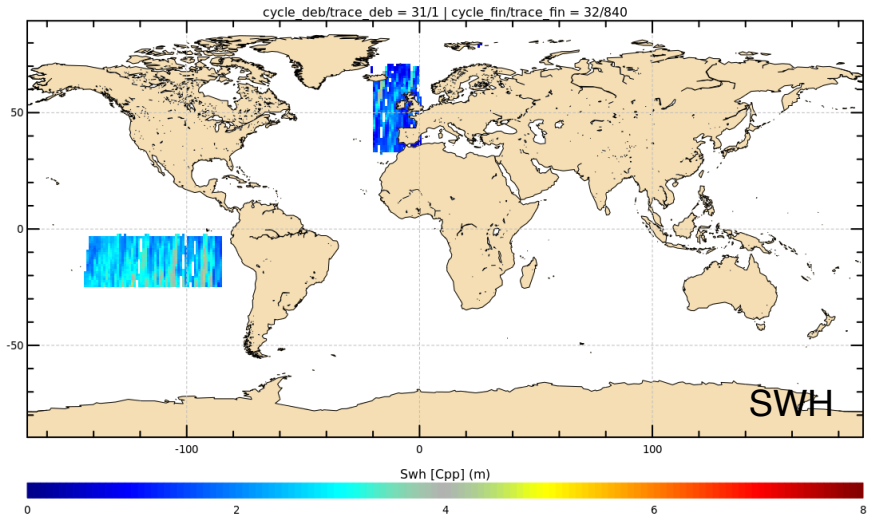
Pacific + NE Atlantic – Jan 2013 – Asc



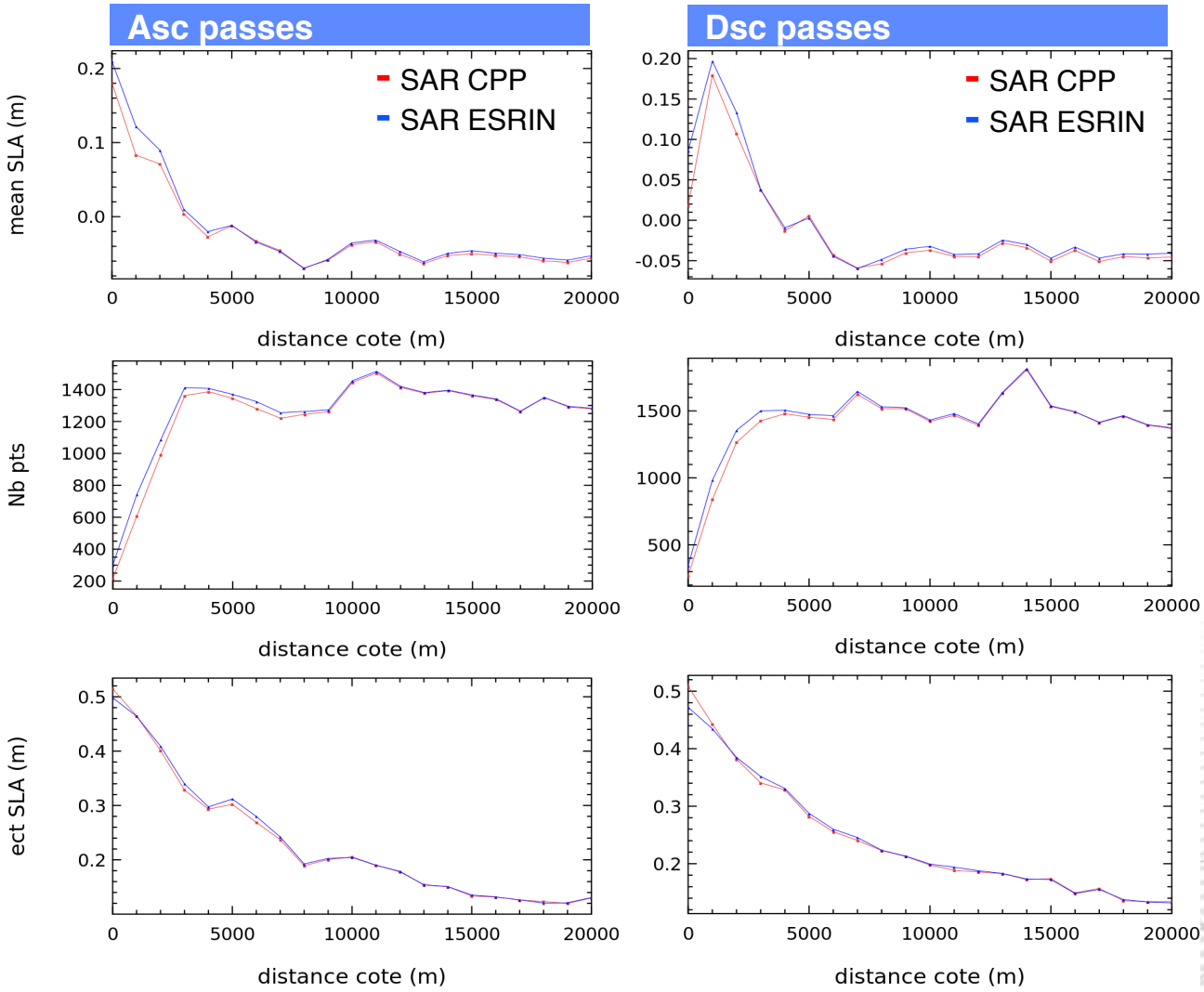
July 2012 – Dsc passes



- SSH residual depends on SWH though quite low (lower than 5mm for SWH up to 4m)
- No apparent impact on the dependencies wrt mispointing angles and radial velocity



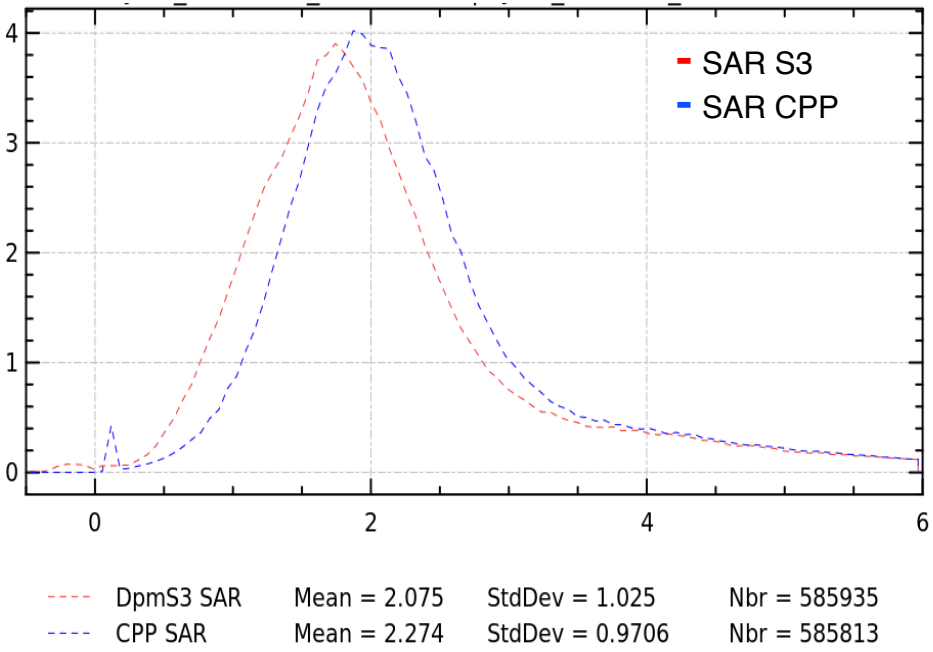
SLA ANALYSIS IN COASTAL OCEAN



- Averaged SLA in 1km distance-to-coast bins (with different incident angle relative to the shoreline)
- Quite similar statistics near the coast (mean SLA, std SLA, density of point):
  - Number of points drop below 3km from the coast
  - Averaged SLA increases <5km
  - Precision slightly increases from 20km

PLOT OF 20-Hz SWH

Pacific + NE Atlantic - July 2012

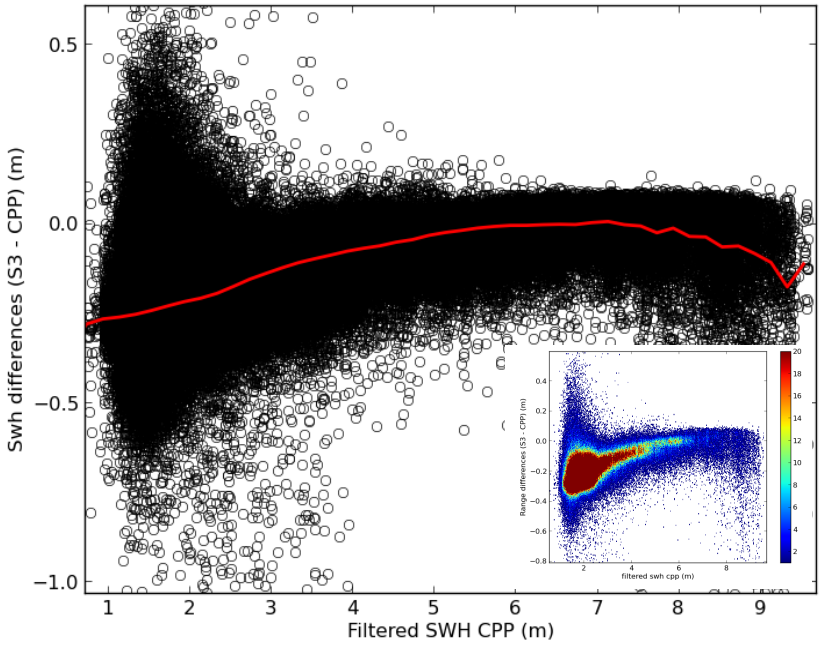


- Significant SWH difference with a bias of around 20cm

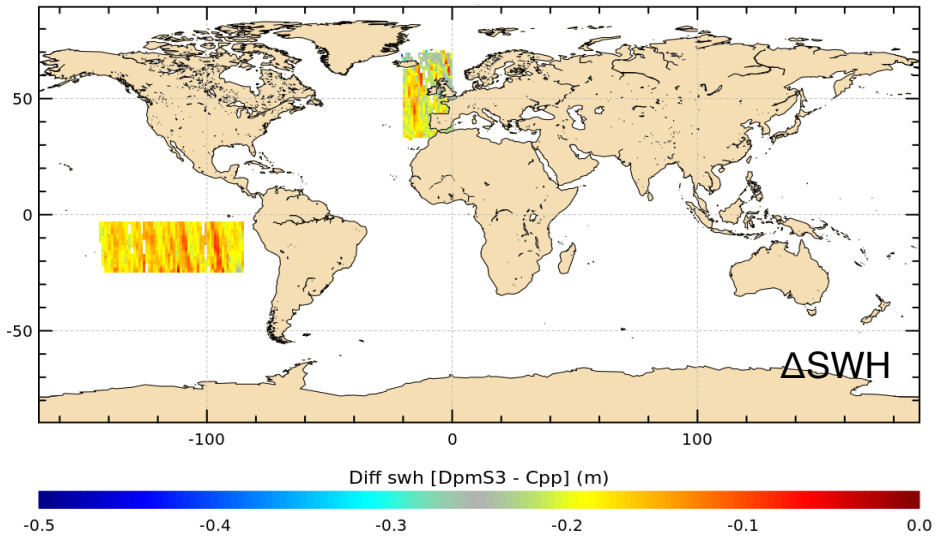
➔ **Need to better characterize this difference**

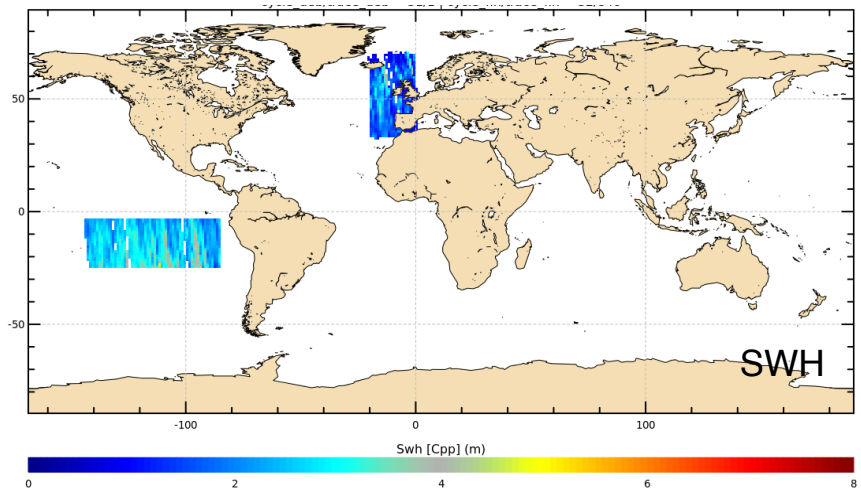
DEPENDENCIES OF SWH DIFFERENCE

July 2012 + Jan 2013



July 2012 – Asc passes

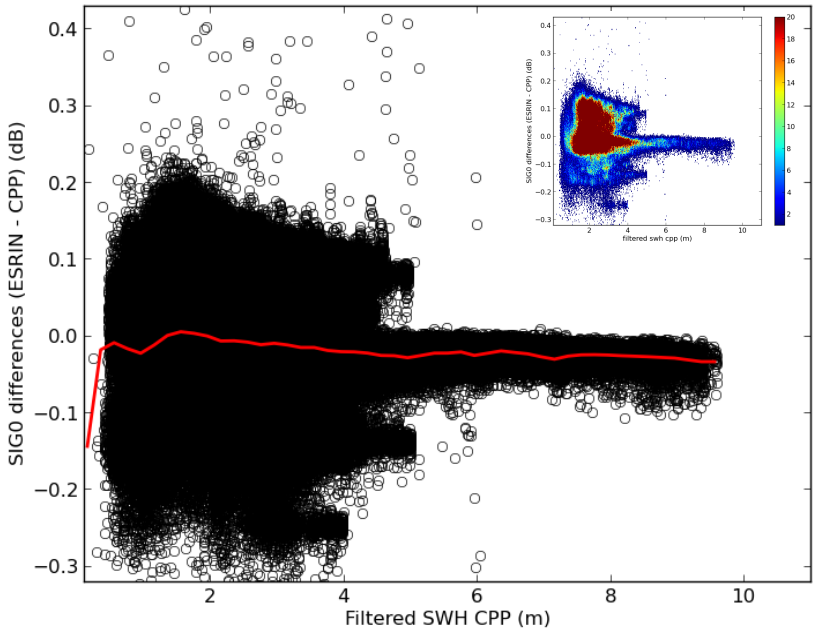




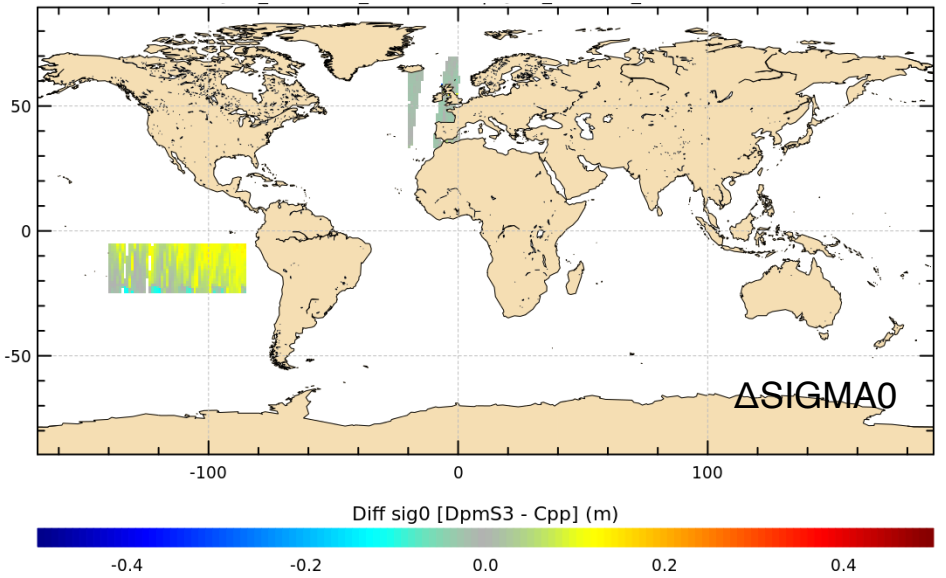
- SWH residual depends strongly on wave height (up to 25cm at very low swh) that could be due to the Gaussian approximation for the PTR in the SAMOSA3 model
- No dependence of the residual on other parameters (mispointing angles and radial velocity) is reported

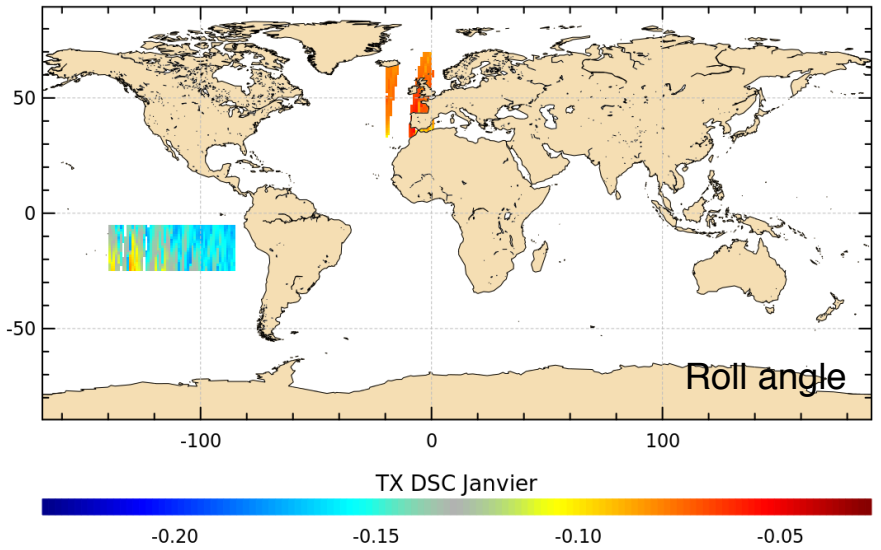
DEPENDENCIES OF SIGMA0 DIFFERENCE

July 2012 + Jan 2013



Jan 2013 – Dsc passes

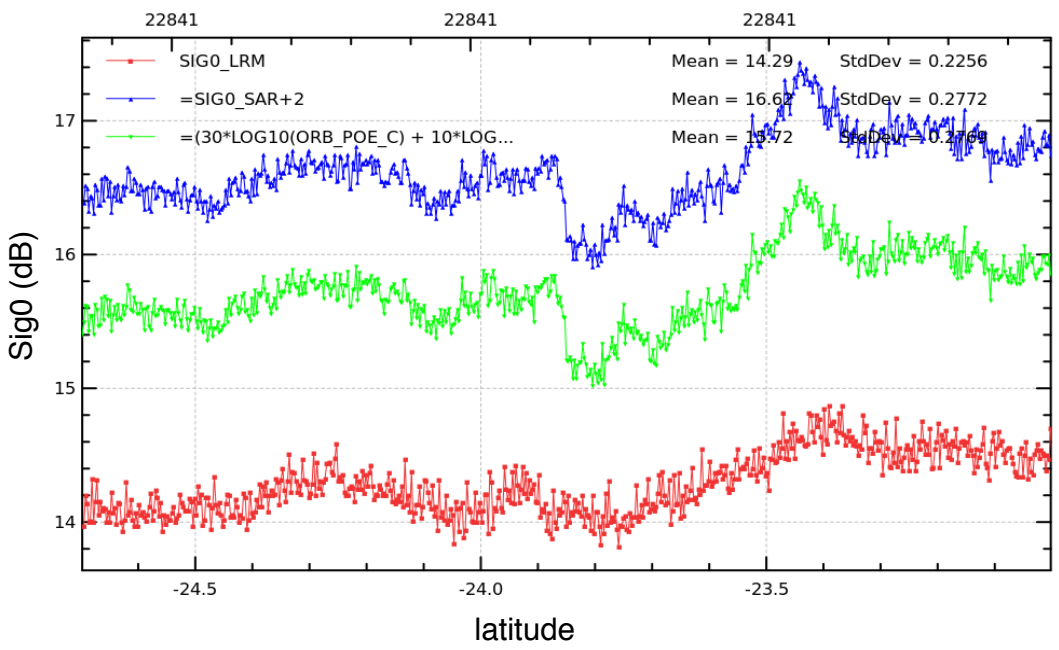


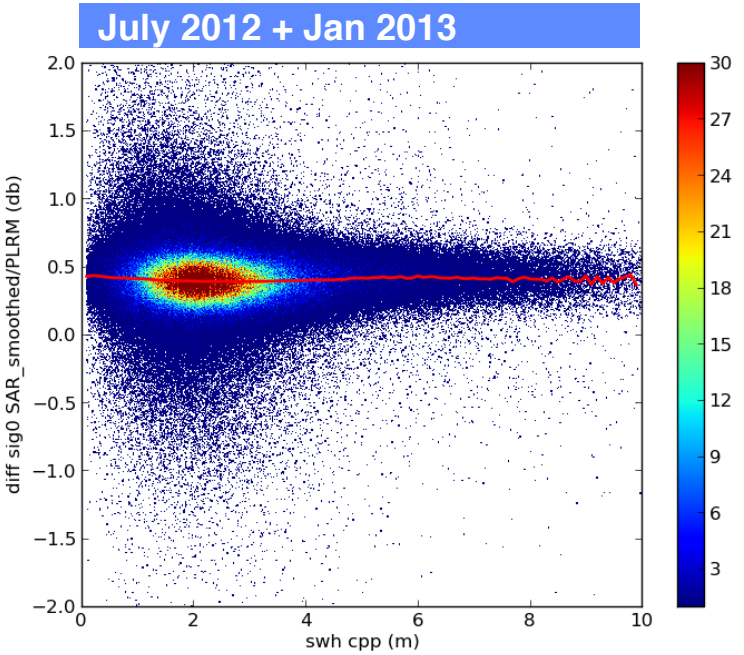


- Good agreement in Sigma0 estimates
- Sigma0 residual varies slightly with SWH
- Quite low difference between ±0.1dB
- Noticeable dependence of the residual on roll

➔ To be precisely evaluated with larger set of data

COMPARISON WITH RDSAR SIGMA0





- Smaller scale structures seen in SAR
- SAR Sigma0 is smoothed to artificially make its footprint comparable to LRM one
- Degraded Sigma0 consistent with RDSAR

  ➔ **Same ocean structures captured**

However some discrepancies are observed where SAR sigma0 exhibits quick drop

CONCLUSIONS

- Good agreement in term of range and sigma0 with differences up to:
  - few mm in range
  - one tenth of dB in sigma0 (correlated notably to roll angle)

➔ **Very close behaviour and very similar performances**

➔ **Longer time series with more relevant statistics will allow to better detect dependencies and confirm outputs of this study**

- However S3 SAR SWH exhibits significant errors that could be related to the Gaussian approximation of PTR in the SAMOSA3 ocean model. Errors might be corrected applying a dedicated correction Lookup Table to the SWH estimates.

- This assessment raised also the sigma0 residual dependency on roll angle (as low as it is)

➔ **Simulations and real data investigations with much larger time period are needed to draw some conclusions on this point**

TO CONLUDE

S3 SAR retracker vs SAR CPP	ESRIN SAR solution vs SAR CPP
• few mm in range correlated to SWH	• few mm in range correlated to SWH
• Significant SWH differences correlated to wave height due to the approximations in SAMOSA3	• Few cm in wave height • Different SWH noise performance at very low wave height
• One tenth of dB in sigma0 correlated to roll	• One tenth of dB in sigma0 correlated to roll