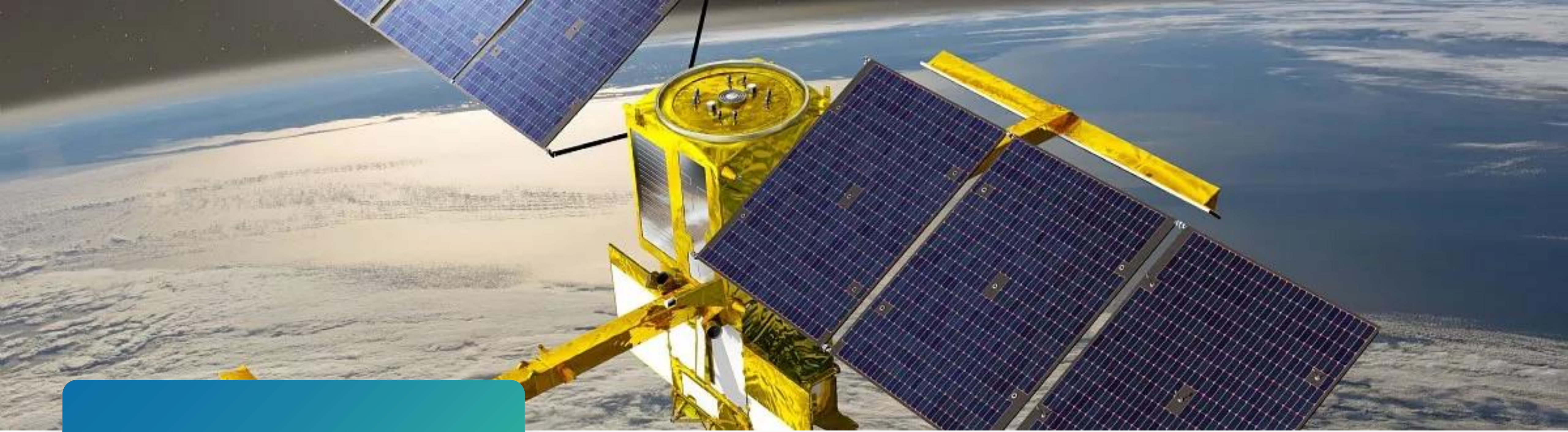


Strengths and limitations of SWOT geophysical corrections

Francesco Nencioli[1], Matthias Raynal[2], Pierre Prandi[1]

[1] Collection Localisation Satellites,Toulouse, France
[2] Centre National d'Etudes Spatiales, Toulouse, France

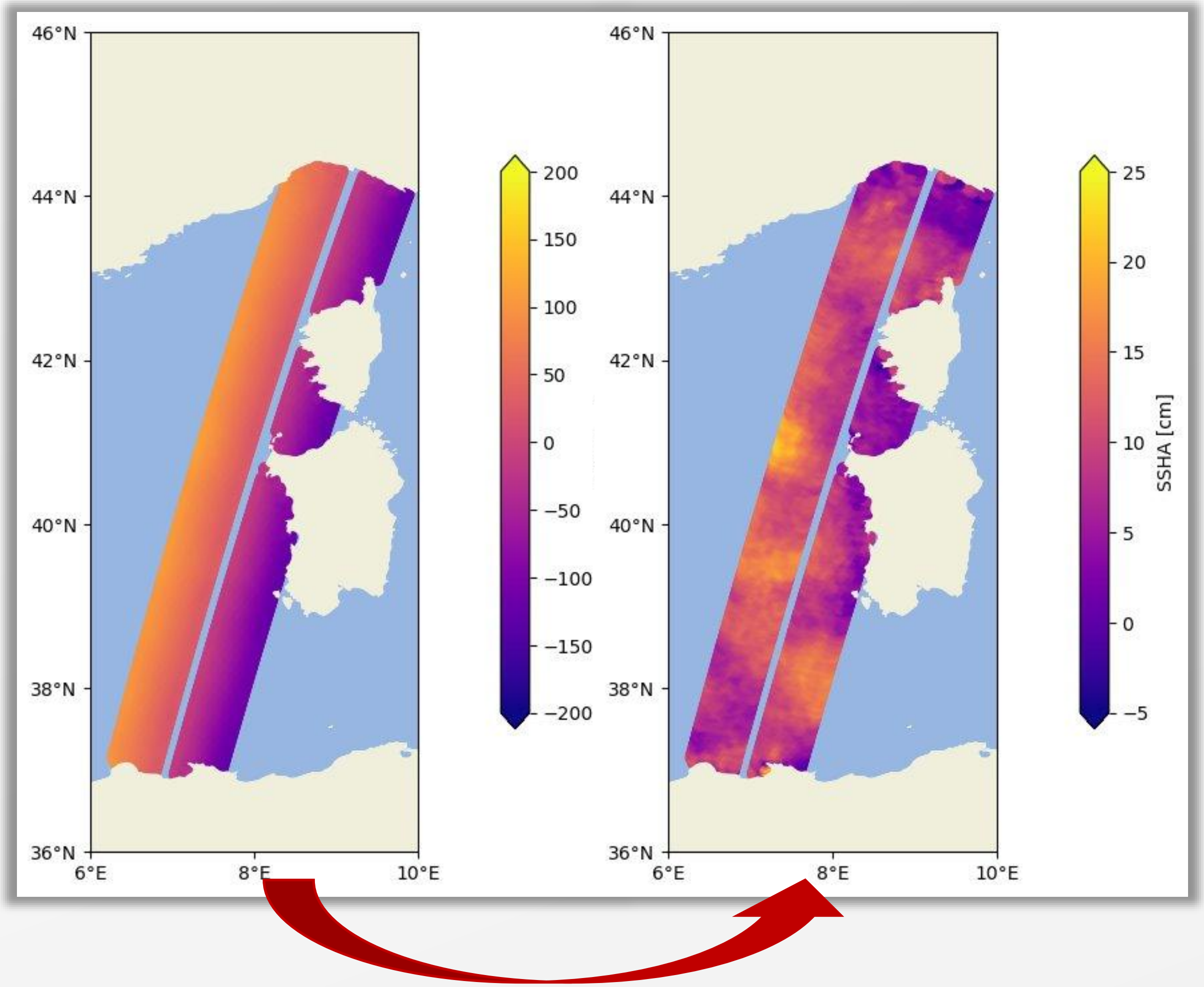
fnencioli@groupcls.com

COLLECTE LOCALISATION SATELLITES
CENTRE NATIONAL D'ÉTUDES SPATIALES

SWOT geophysical corrections

- ➢ Needed to obtain ssha from KaRIn observations
- ➢ Measured, modelled or empirical

- Atmospheric corrections:
  - Ionospheric correction
  - Wet tropospheric correction
  - Dry tropospheric correction
- Sea Surface corrections:
  - Tides
  - Sea state bias
  - Mean Sea Surface
  - Dynamic atmospheric correction
- Non-geophysical correction:
  - Cross-over correction



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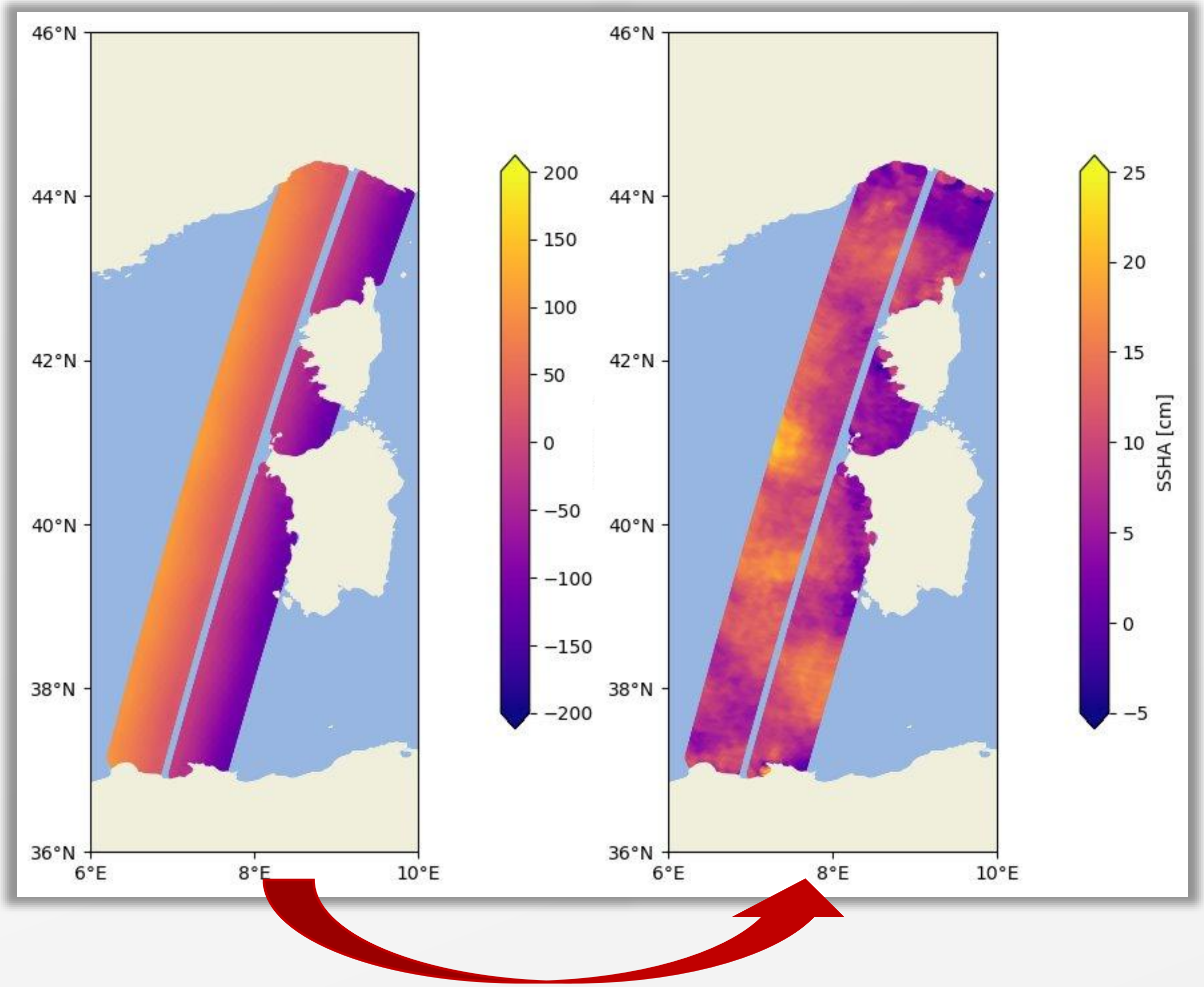
- 2 corrections focus of this presentation



SWOT corrections

Goal: Evaluate correction performance

- Quantify **variance reductio**n of corrected SSHA compared to the uncorrected one (underlying hypothesis: geophysical corrections reduce variance of SSHA signal)
  1. Impact at different wavelengths
  2. Geographical distribution

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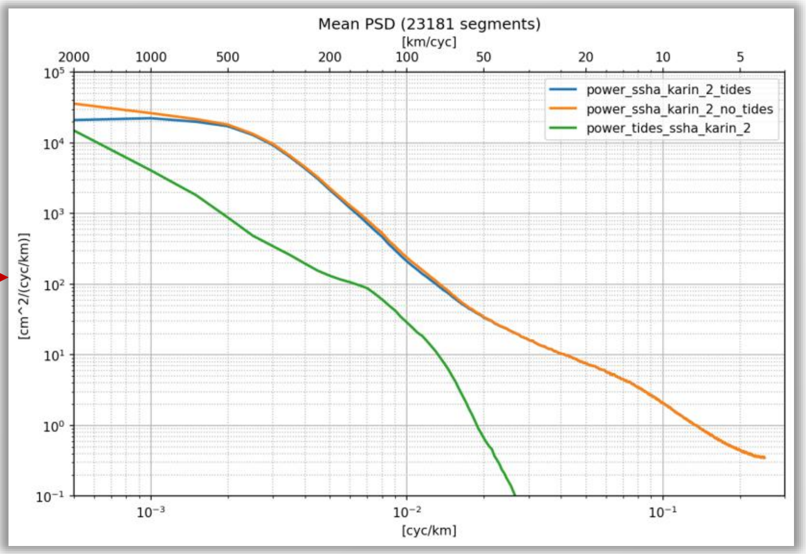

Spectral analysis

- Spectra of SSHA_no_corr, SSHA, Correction
- Computed over 2000 km segments
- Middle of left swath observations

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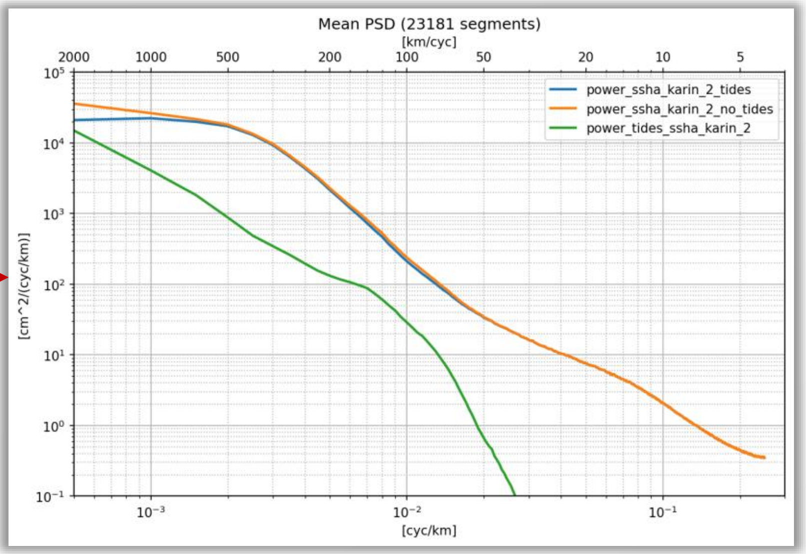

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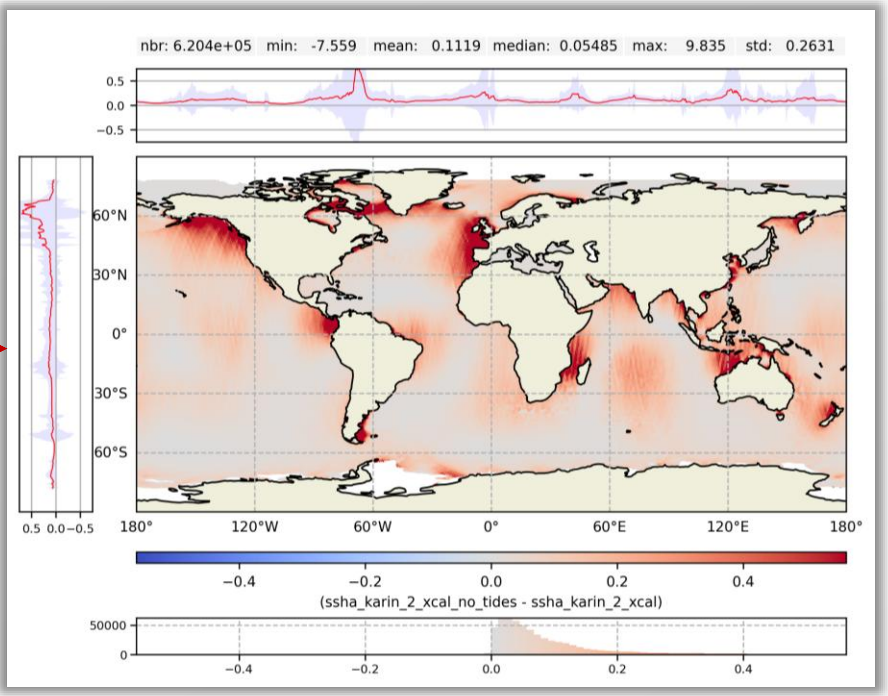


Red is good (i.e. variance reduction!)

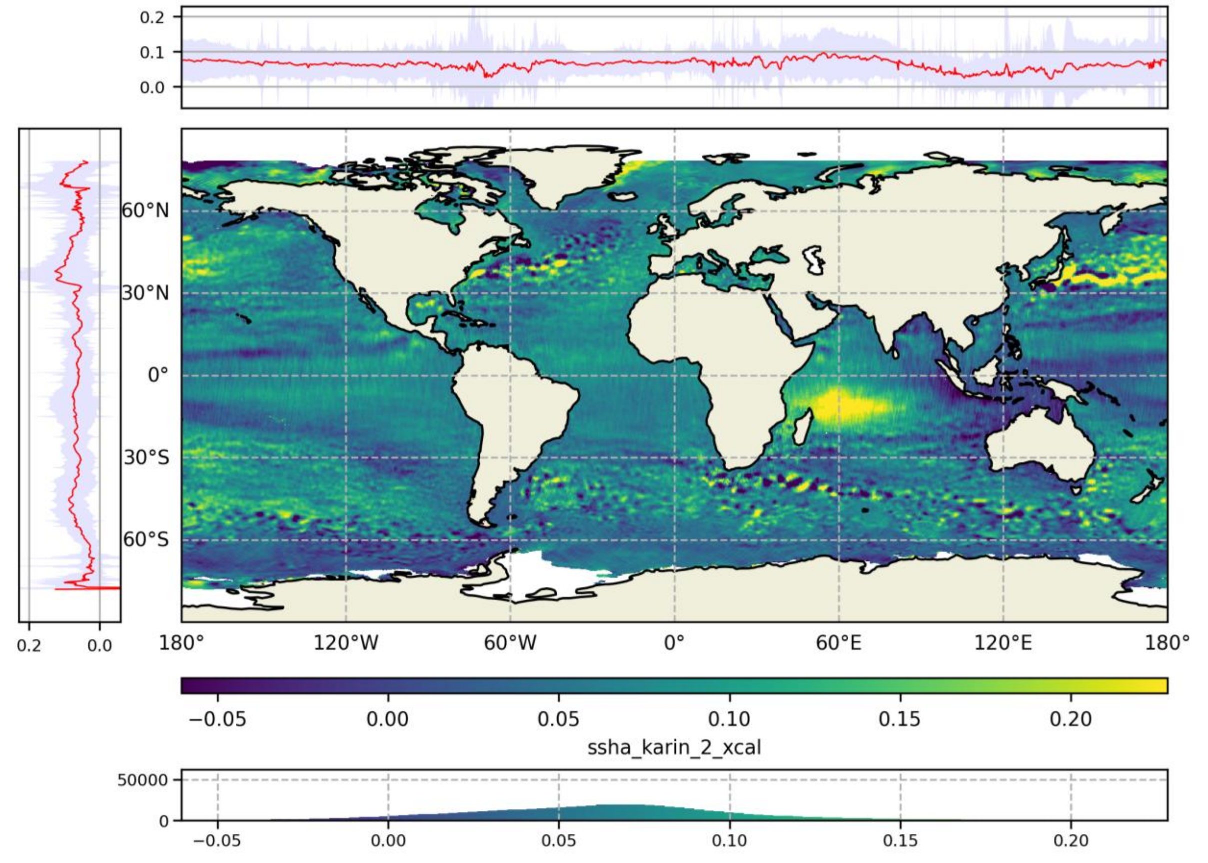
Maps of Variance difference

- Variance(SSHA_no_corr) – Variance(SSHA)
- Computed over 0.25°x 0.25° boxes
- Full swath observations

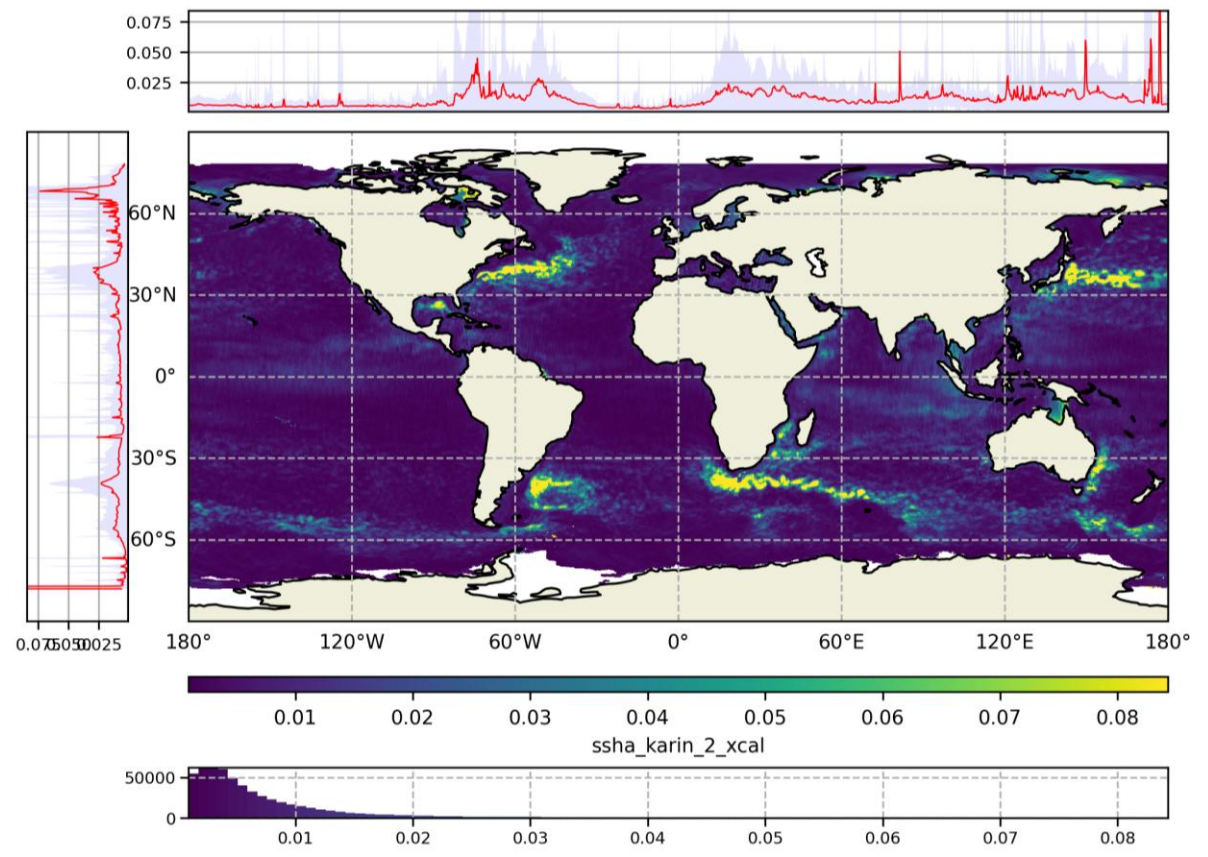
CLS

Data: L2 PGC0 L3 product (2 km resolution)

- September 2023 to September 2024 (Science Orbit cycles 3 to 20)
  - ssha_ karin _2: waves and wet troposphere from model
  - ssha_karin : waves from nadir, wet troposphere from MW radiometer



SSHA Mean



SSHA Variance

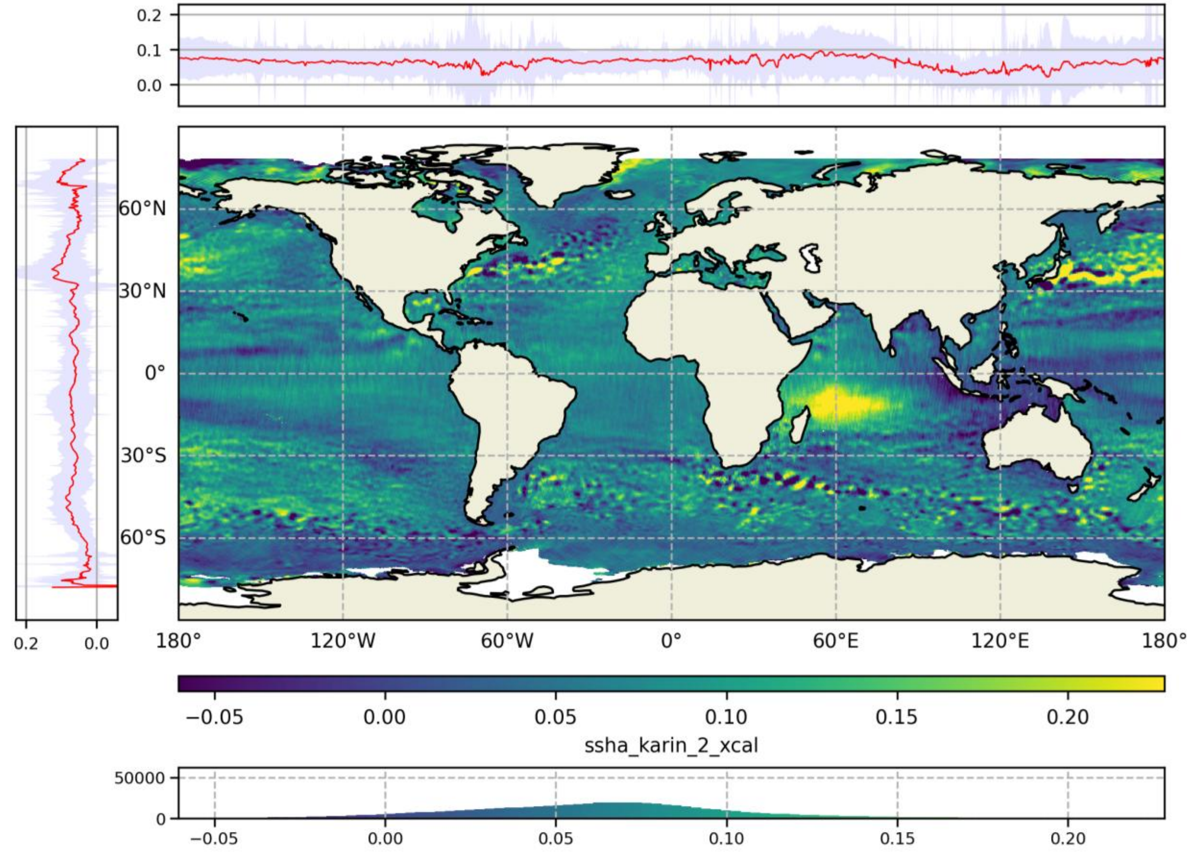
Tide correction

- Good global performance at wavelengths > 30 km
- No impact at wavelengths < 30 km

Wet tropospheric correction

Wet tropospheric correction: mean distribution

- ➢ Correct for signal propagation delay due to water vapor in the atmosphere
- ❑ Smaller values than SSHA (largest along the equator)



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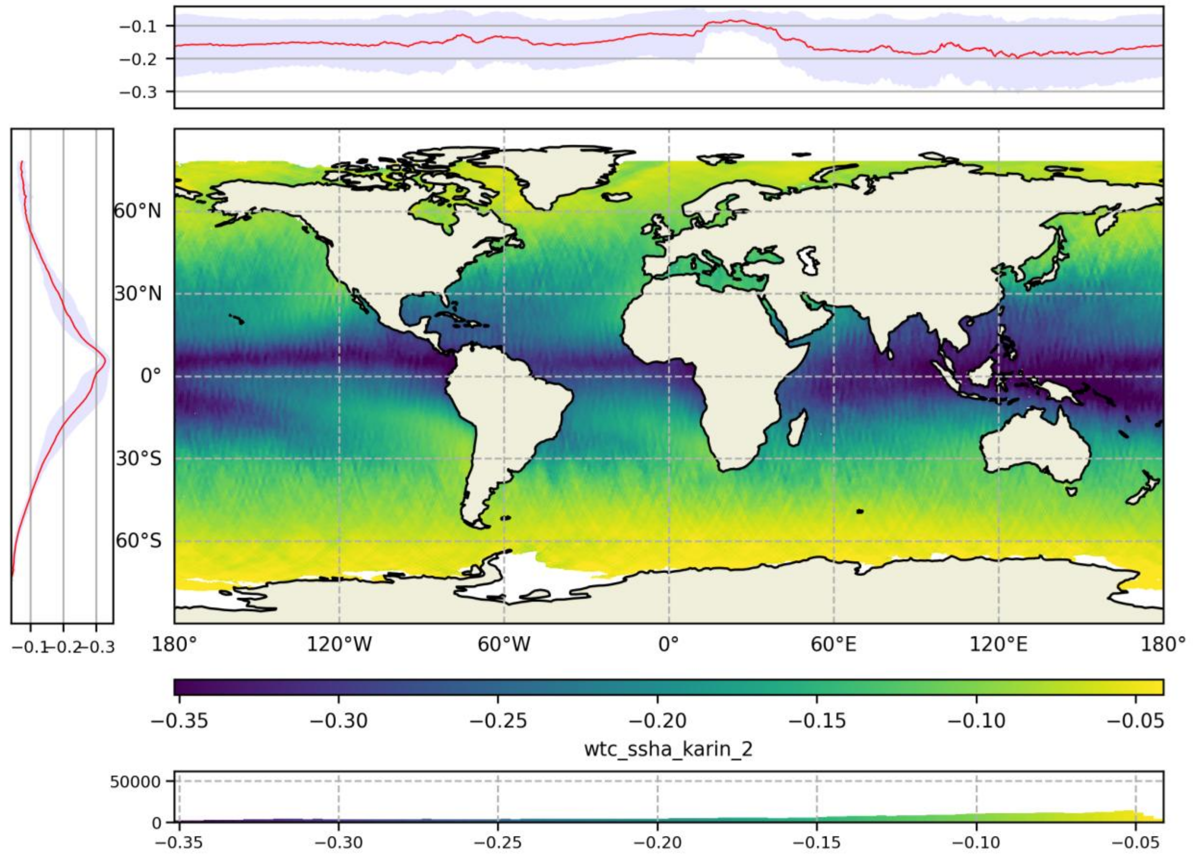

Model WTC Mean

Wet tropospheric correction: variance distribution

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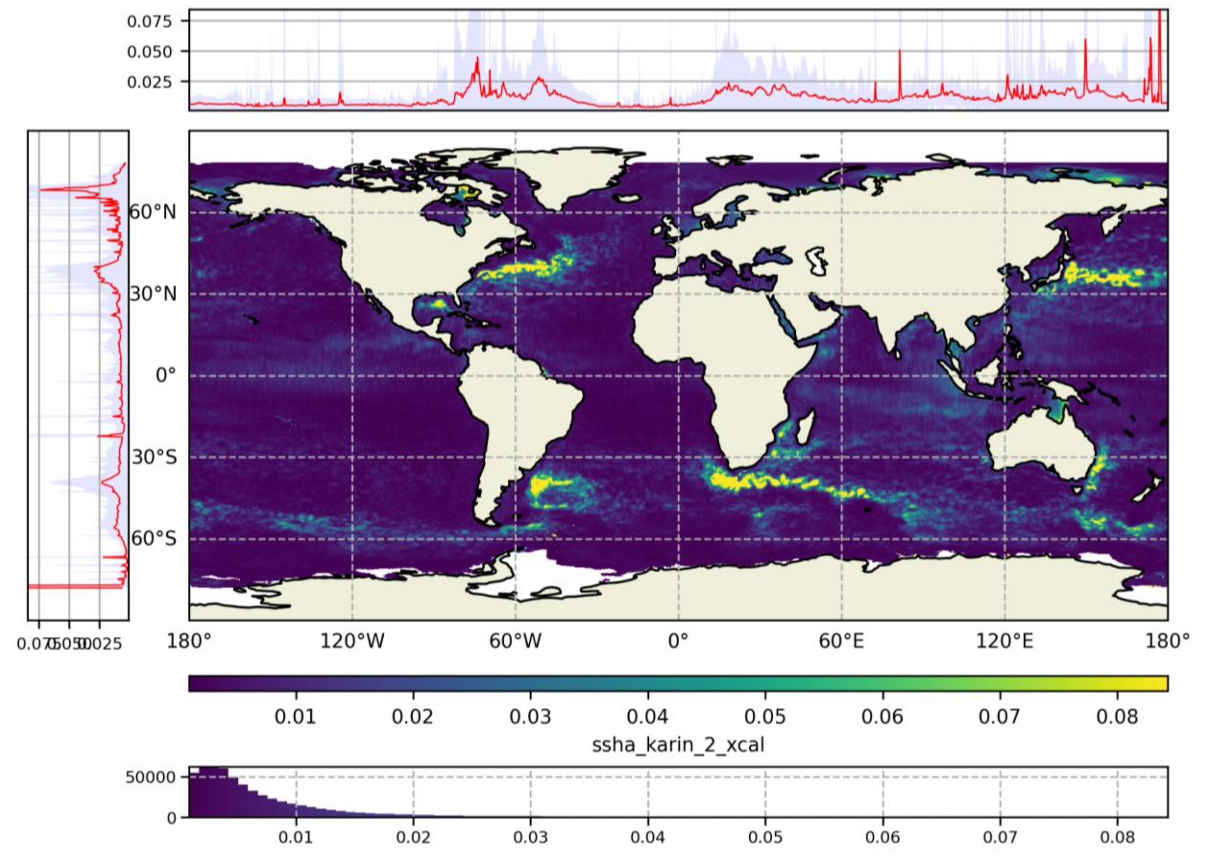
- ❑ Smaller values than SSHA (largest along the equator)
- ❑ Largest variance at mid latitudes (smaller than for SSHA)



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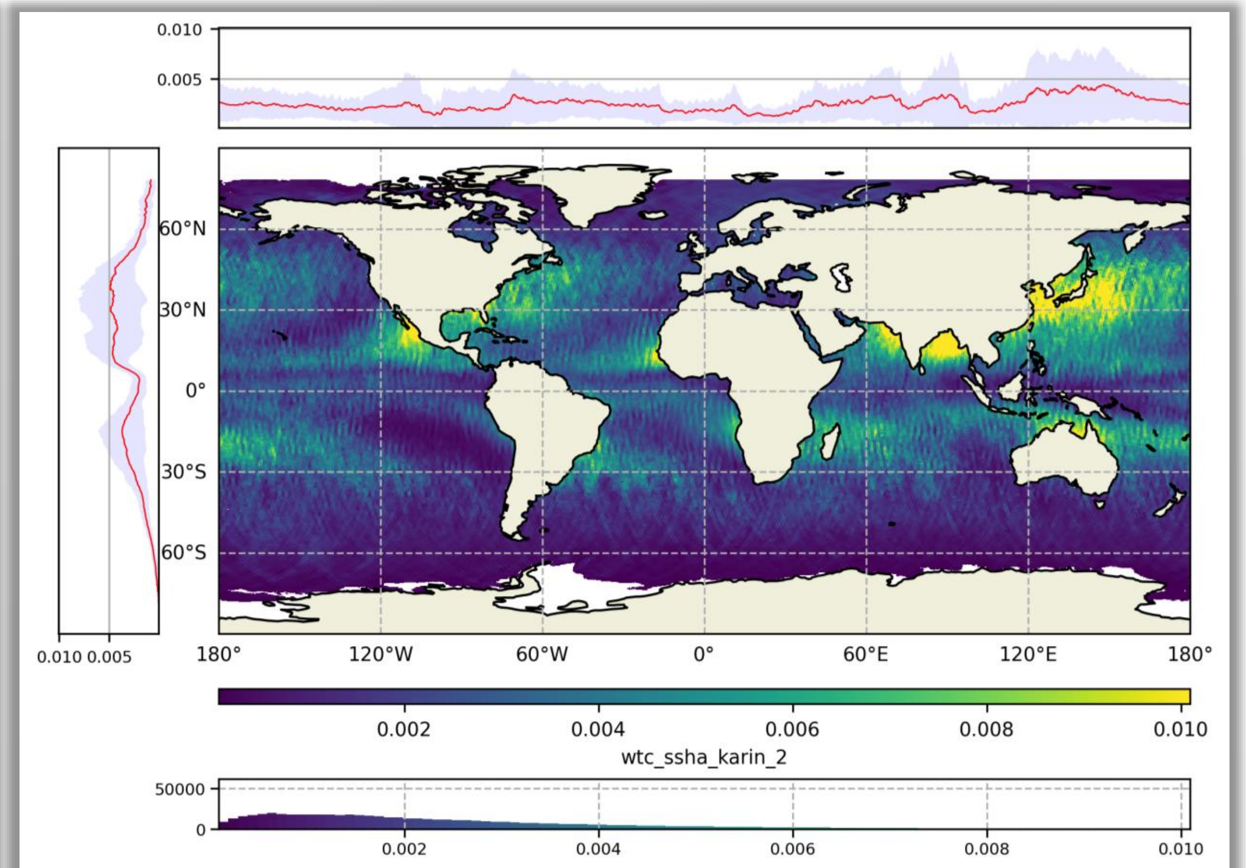

Model WTC Variance

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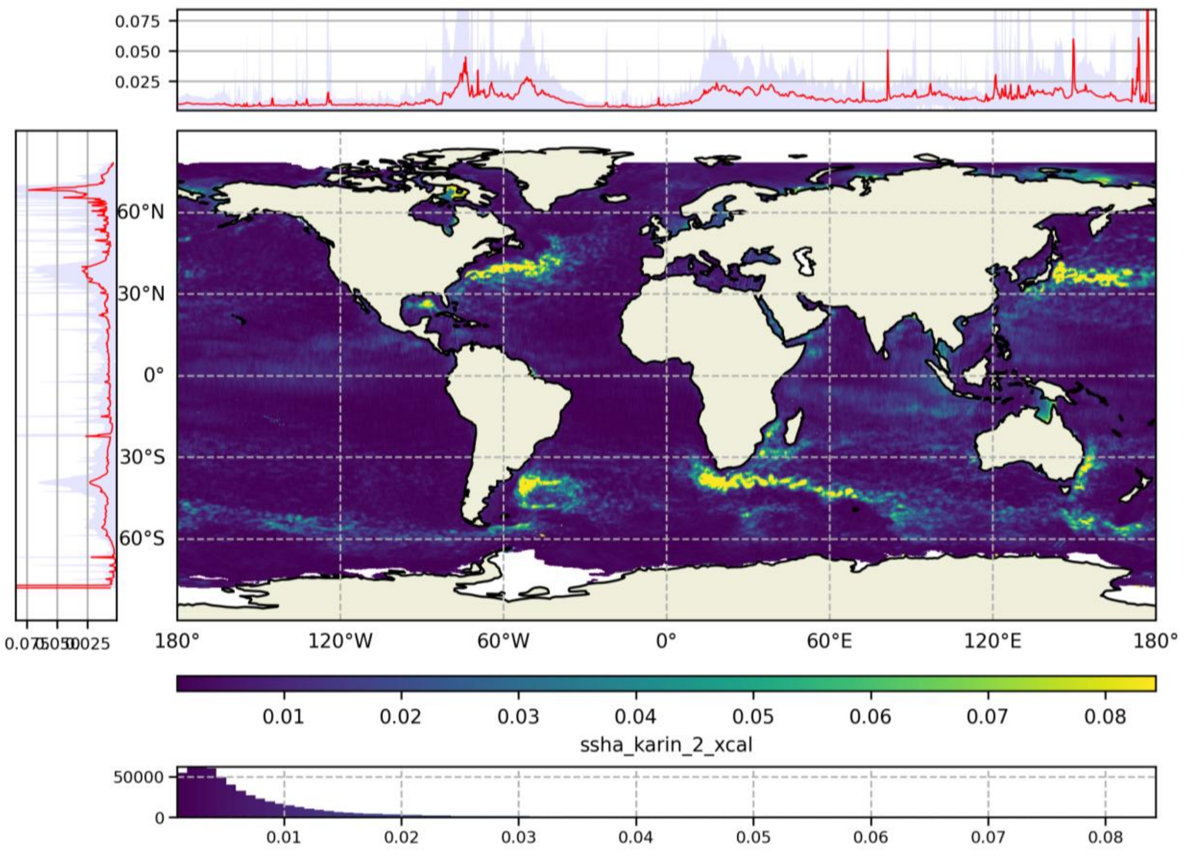
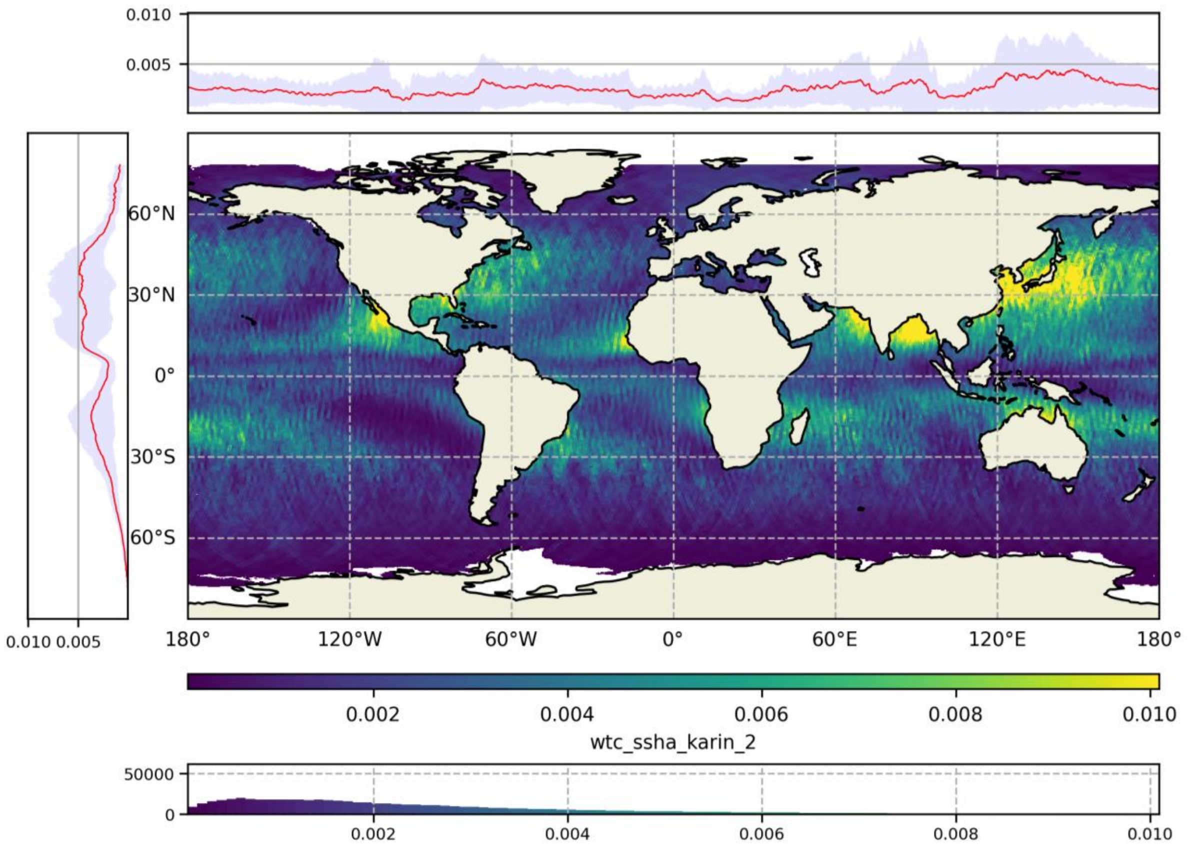
Almost identical maps for MW Radiometer WTC

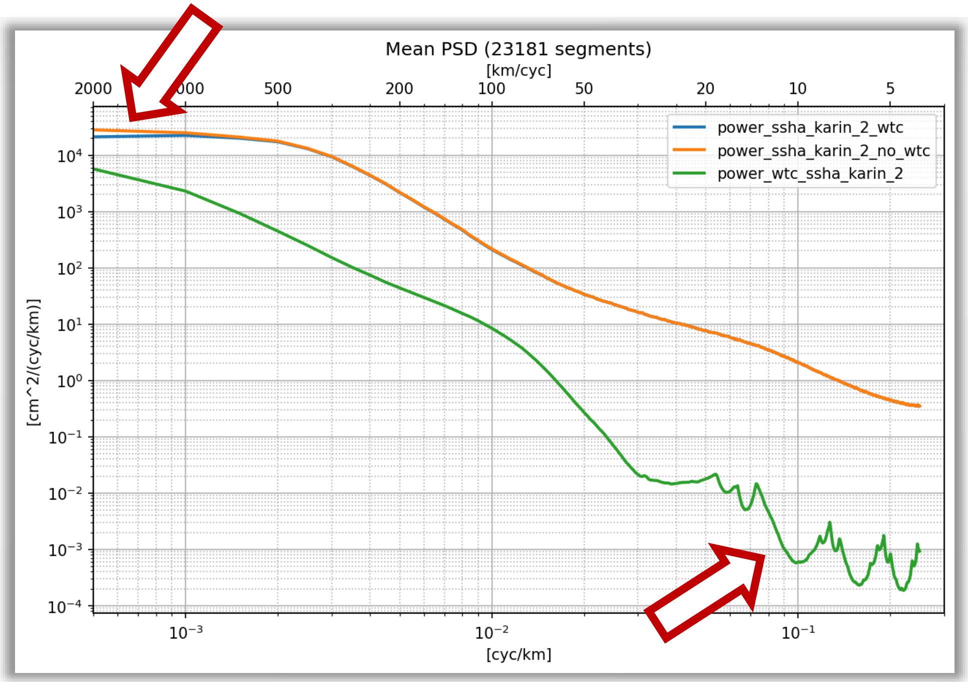


SSHA Variance



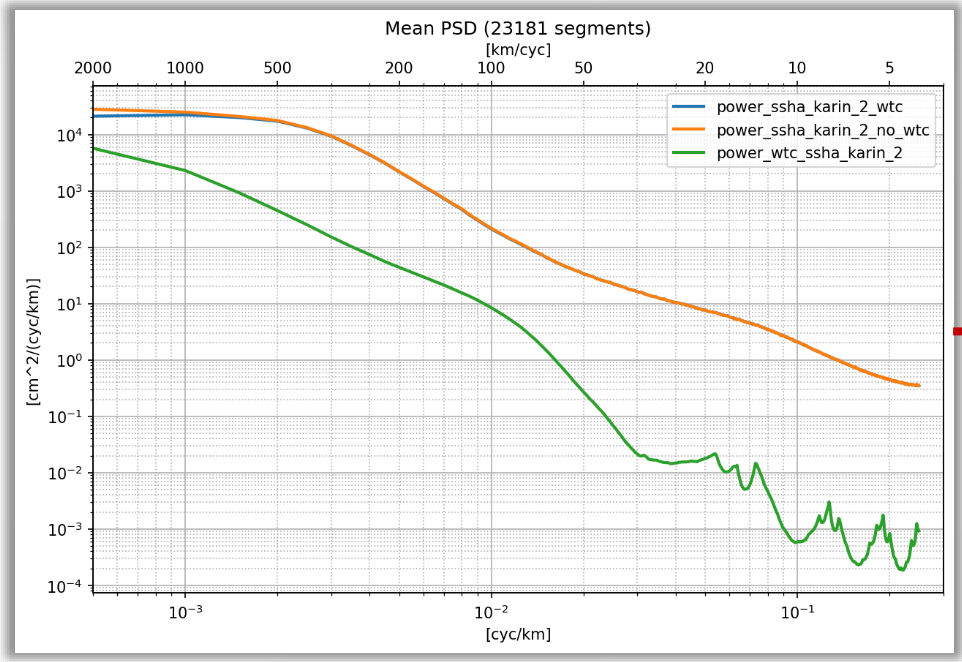
Model WTC Variance

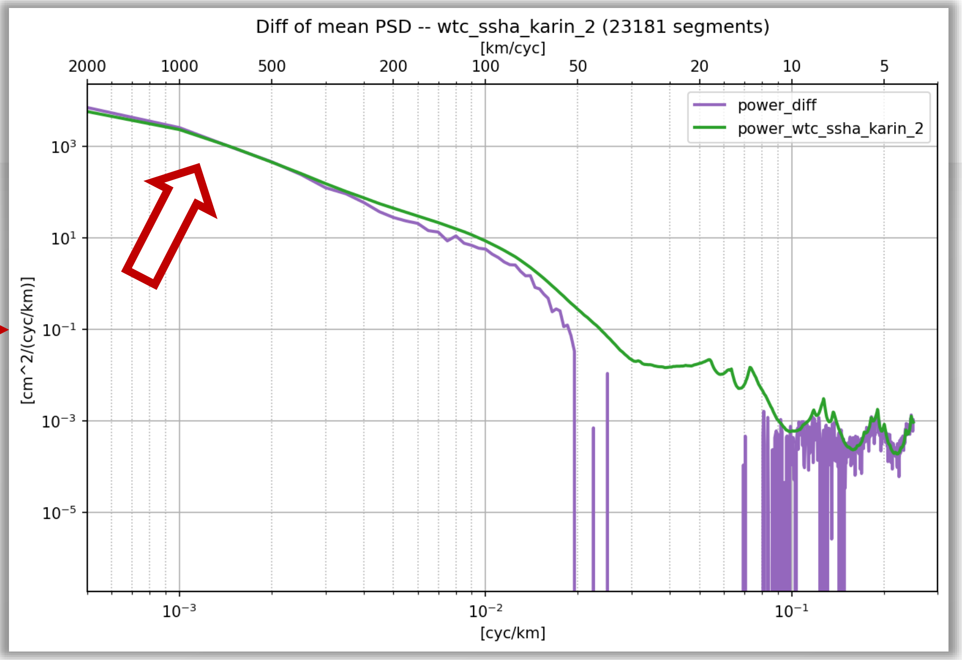
WTC: spectral analysis Model



- Impact of correction mostly at scales > 1000 km
- At wavelengths <30 km artifacts due to interpolation from model grid

WTC: spectral analysis **Model**





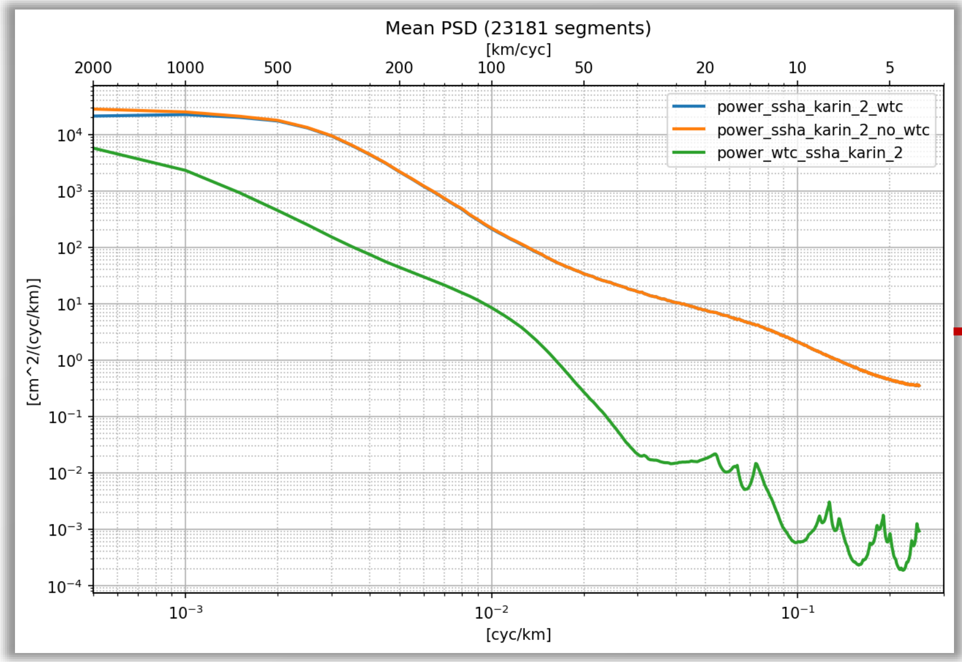
Var(ssh_no_corr) – Var(ssha) = Var(corr) – 2 Cov(SSHA, corr)

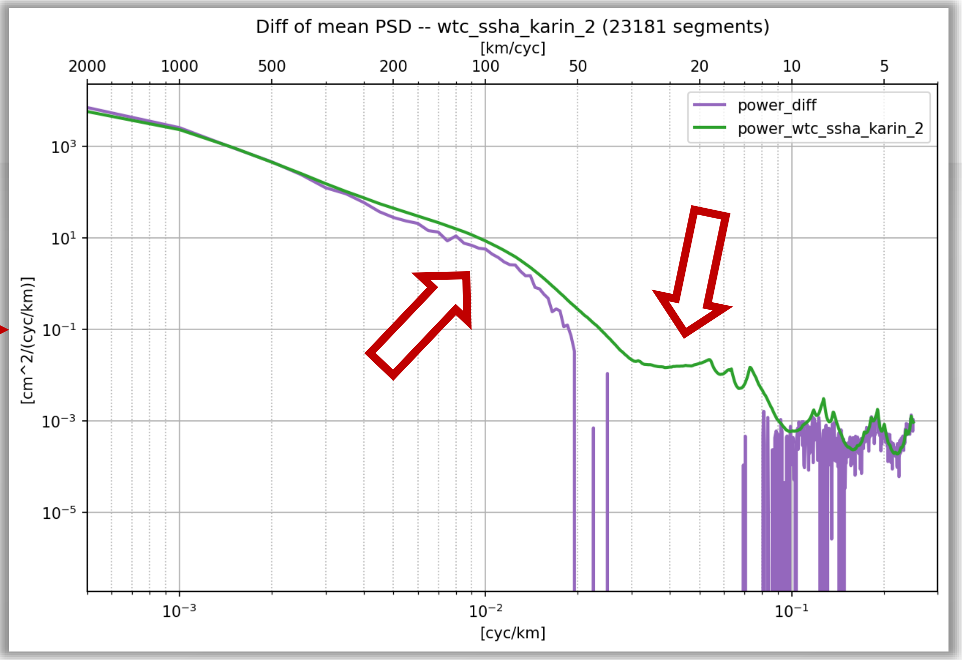
- WTC model effective at scales >250 km (no residual covariance)

Comparison between

- spectral difference of SSHA_no_corr and SSHA (violet)
- spectrum of correction (green)

WTC: spectral analysis **Model**





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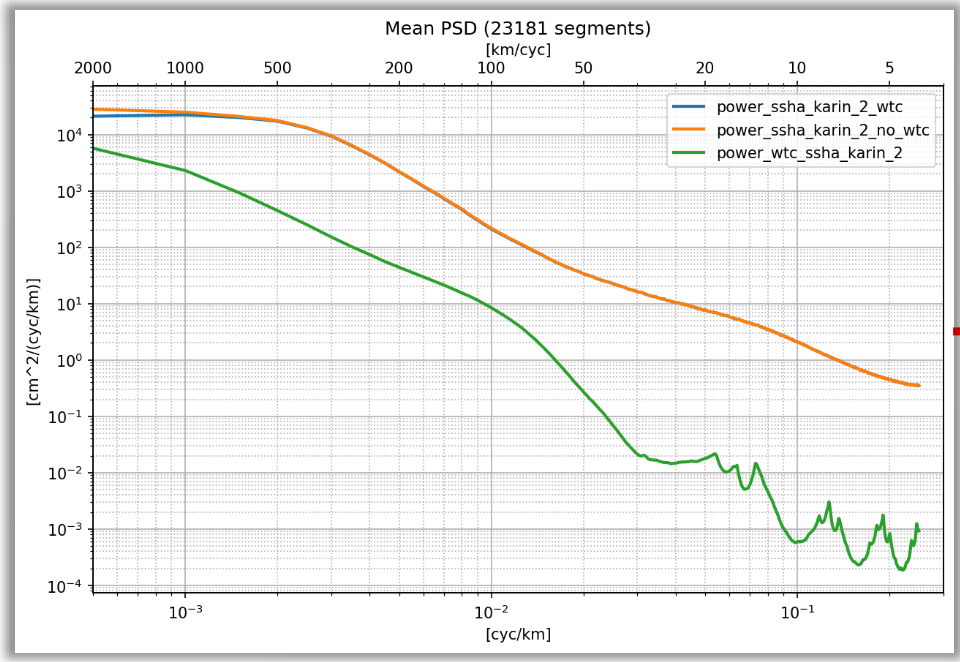
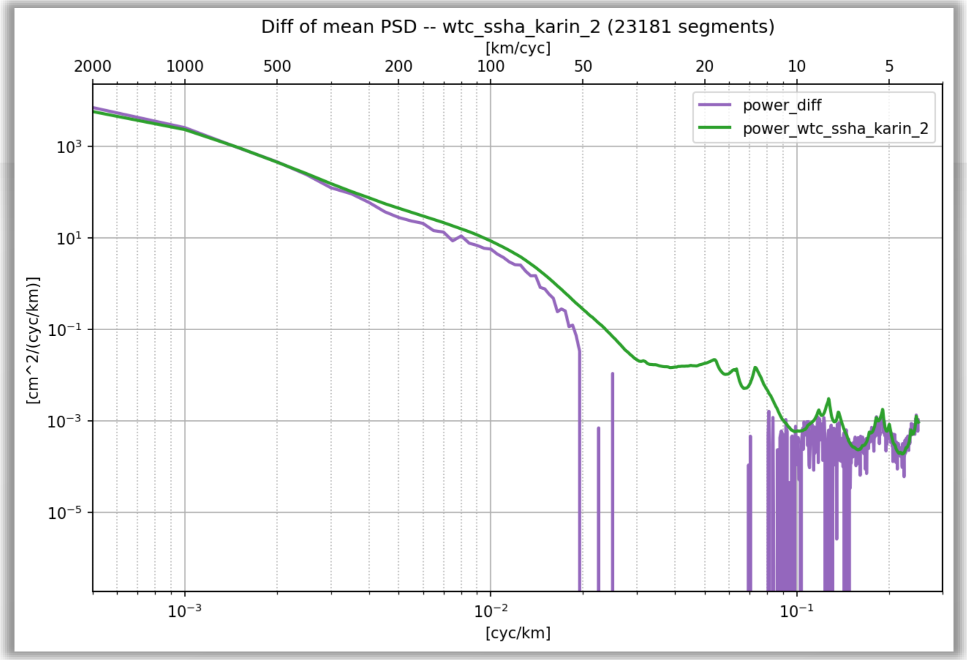
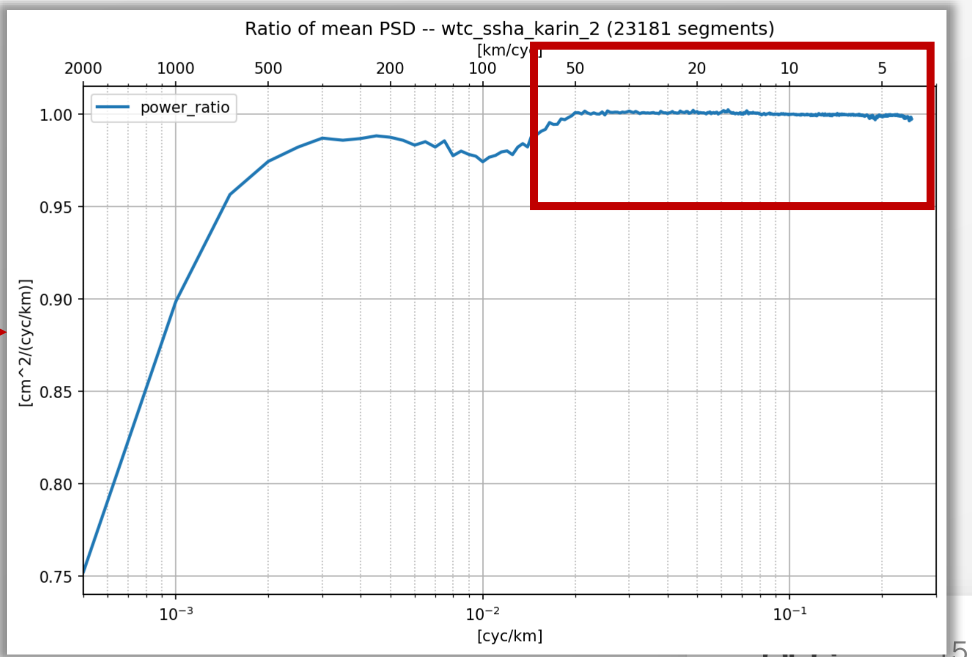
- ❑ SSHA variance injected between 20 and 10 km

WTC: spectral analysis **Model**







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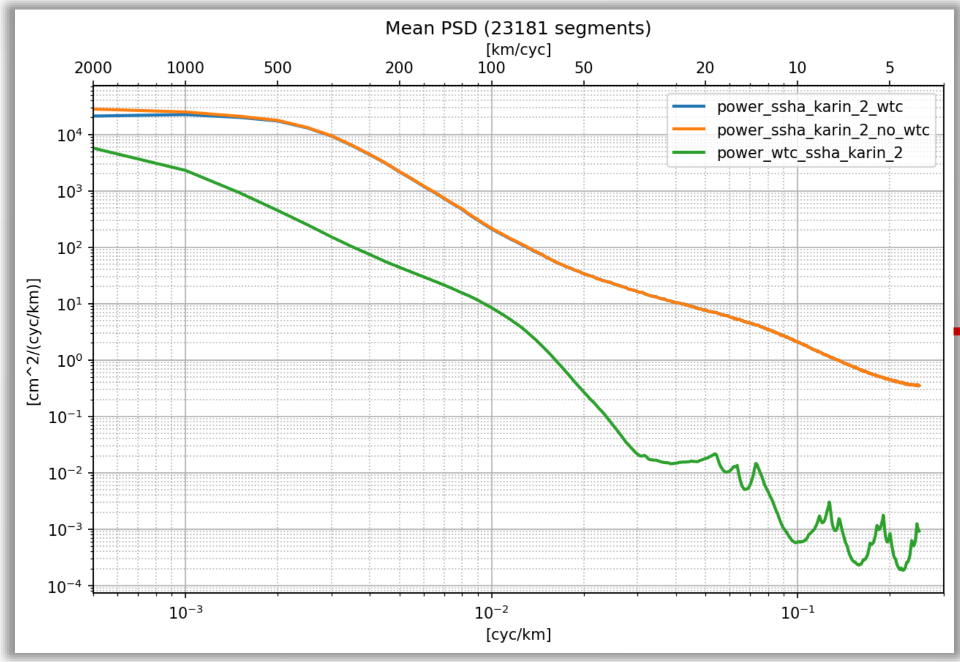

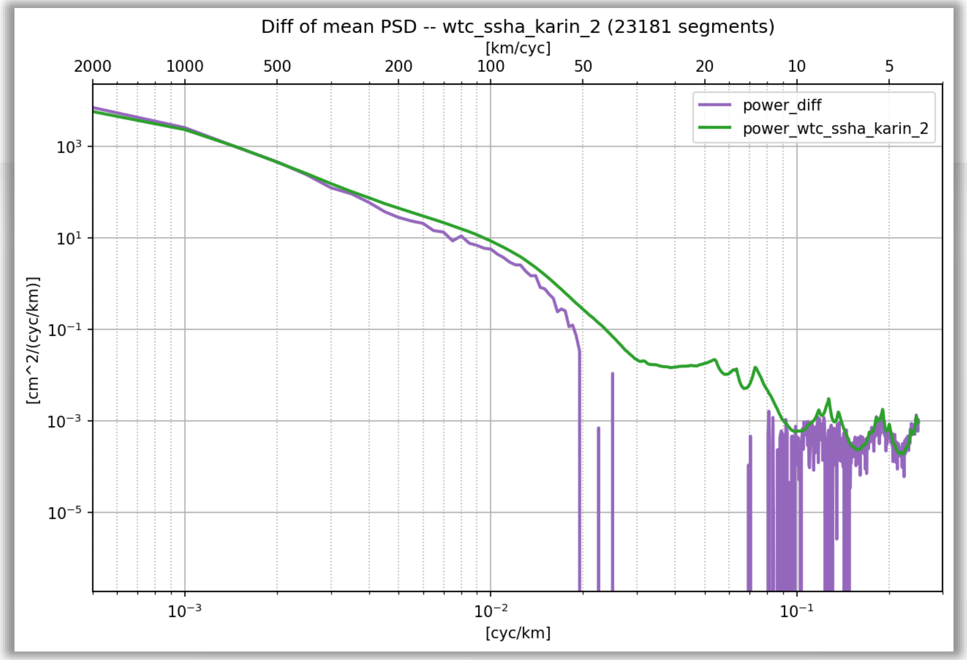

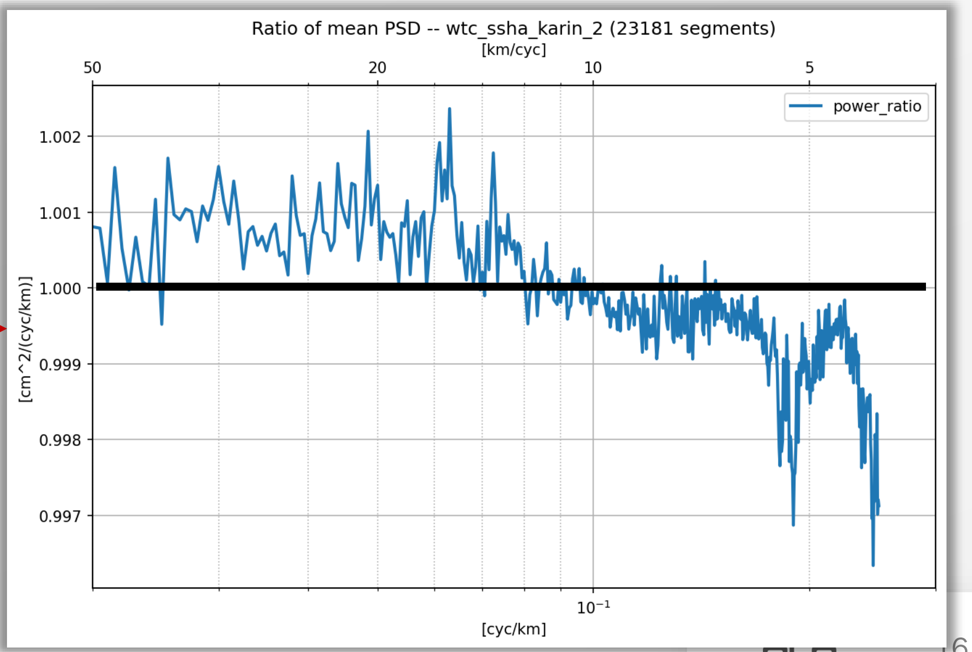

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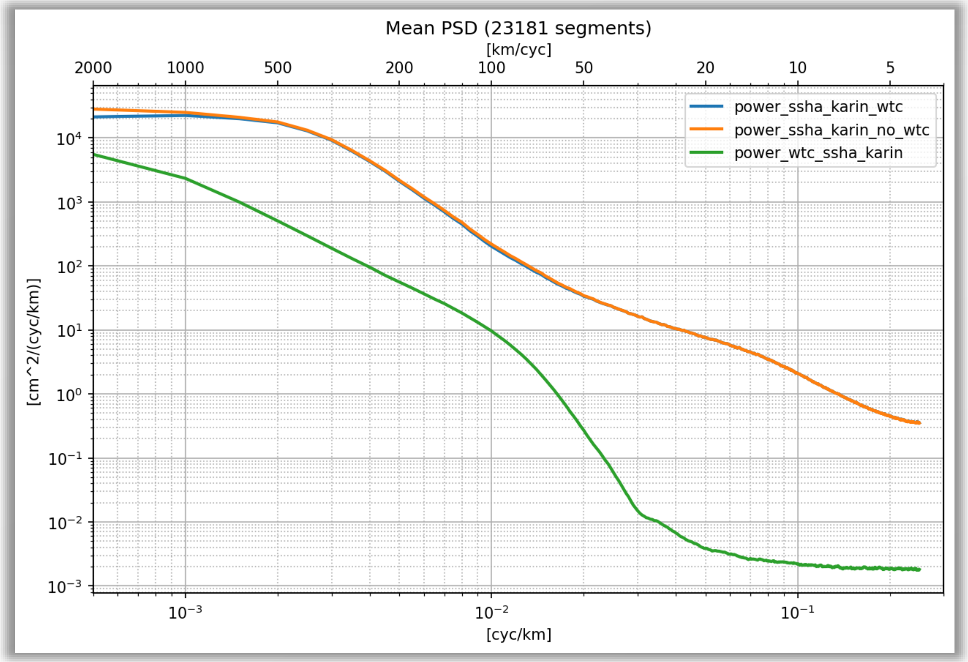
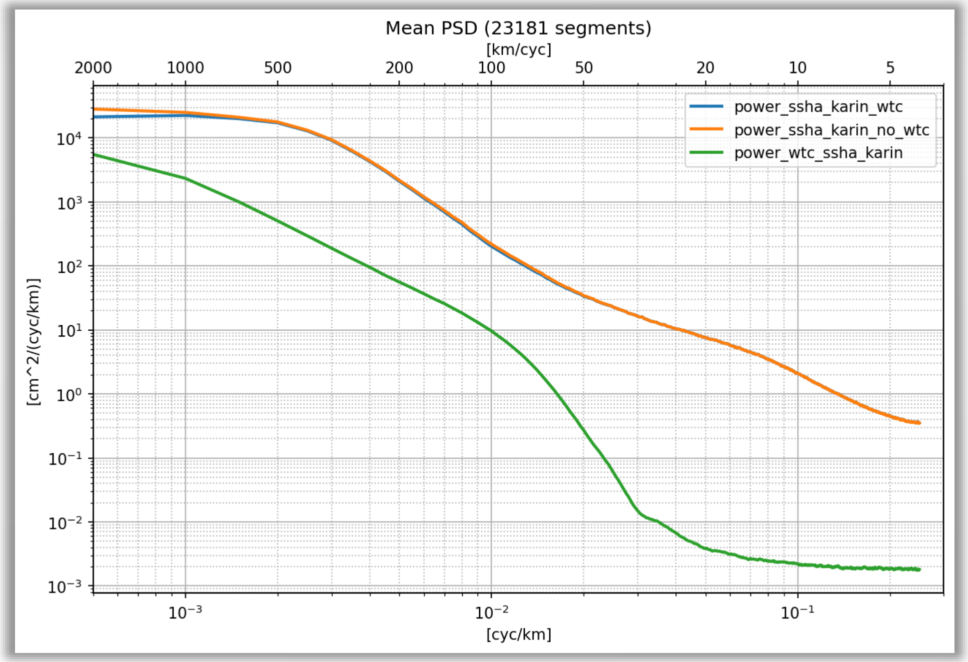
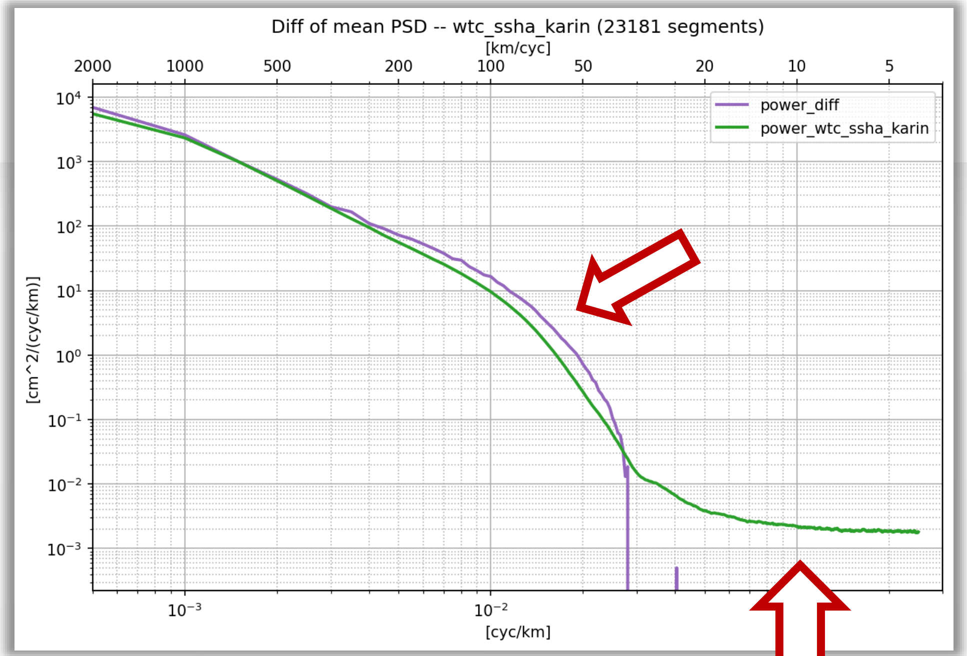
CLS

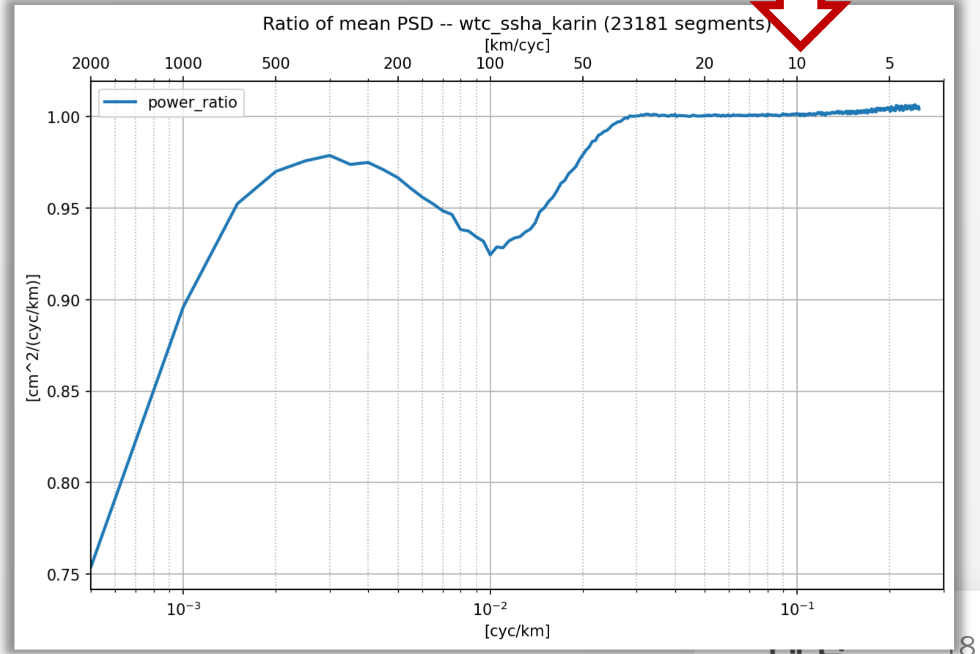
WTC: spectral analysis MWR



WTC: spectral analysis **MWR**







- ❑ WTC model effective at scales >250 km
- ❑ SSHA overcorrected between 250 and 50 km
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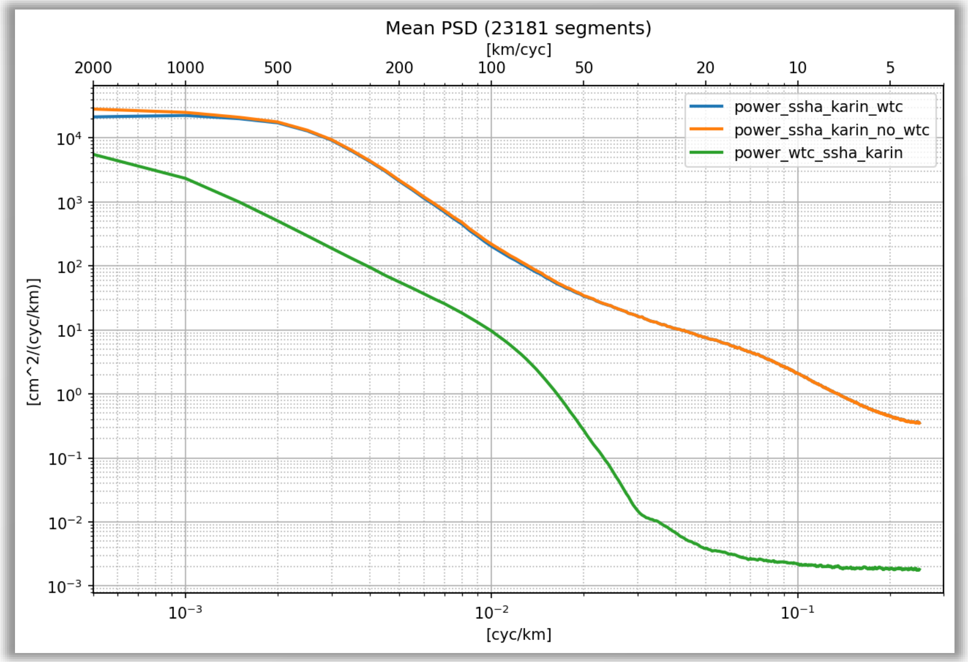

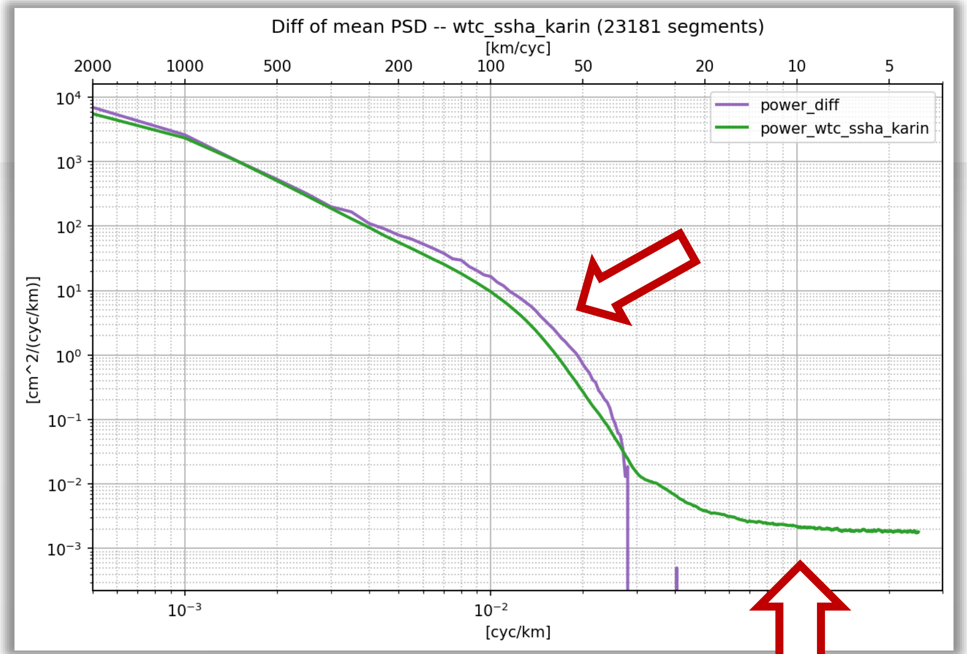

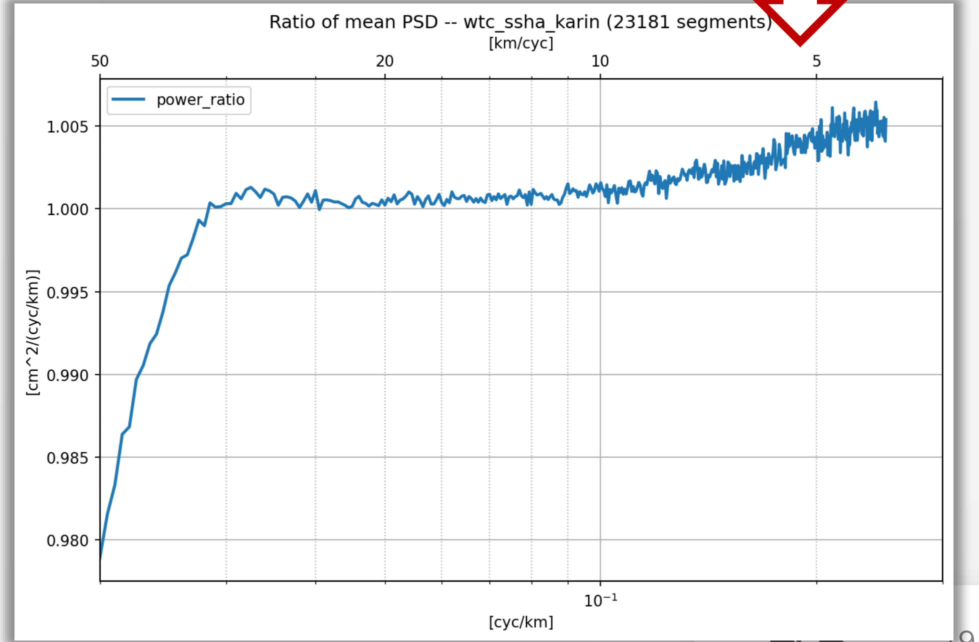

- ❑ WTC model effective at scales >250 km
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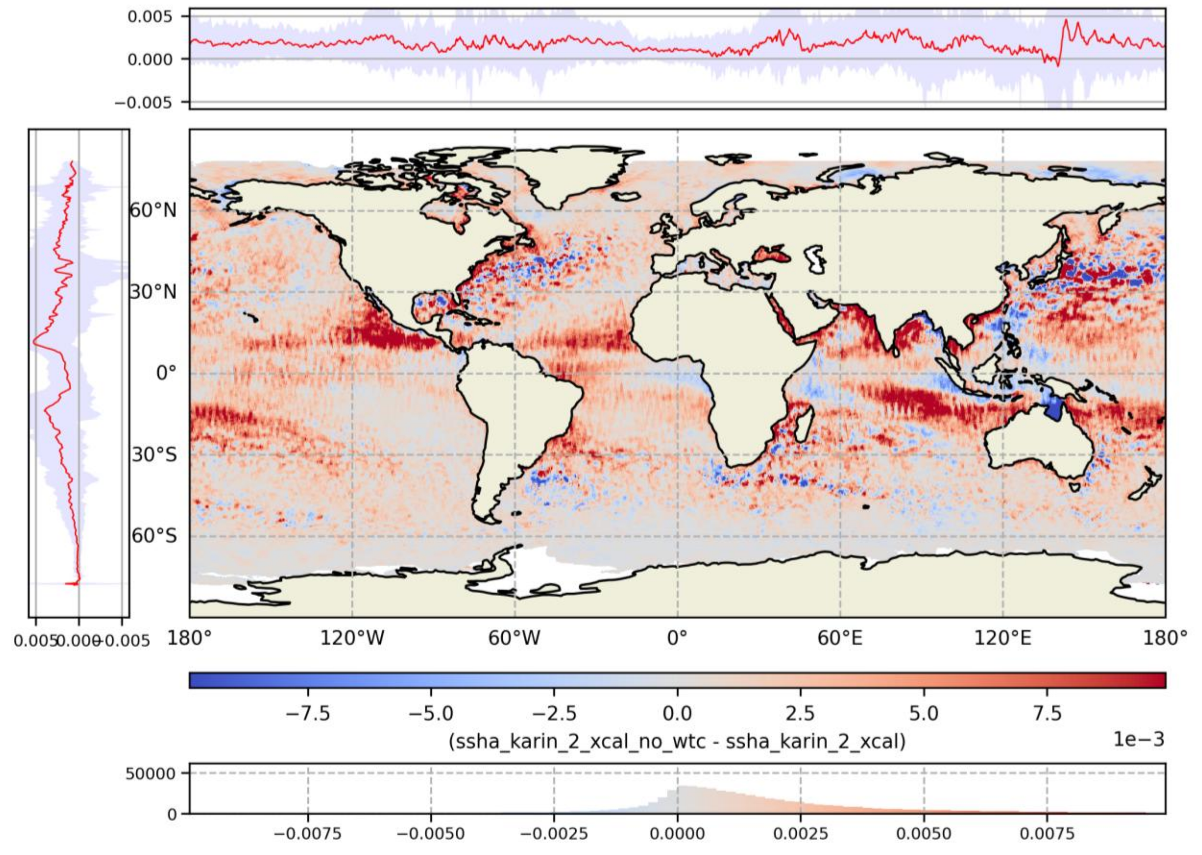
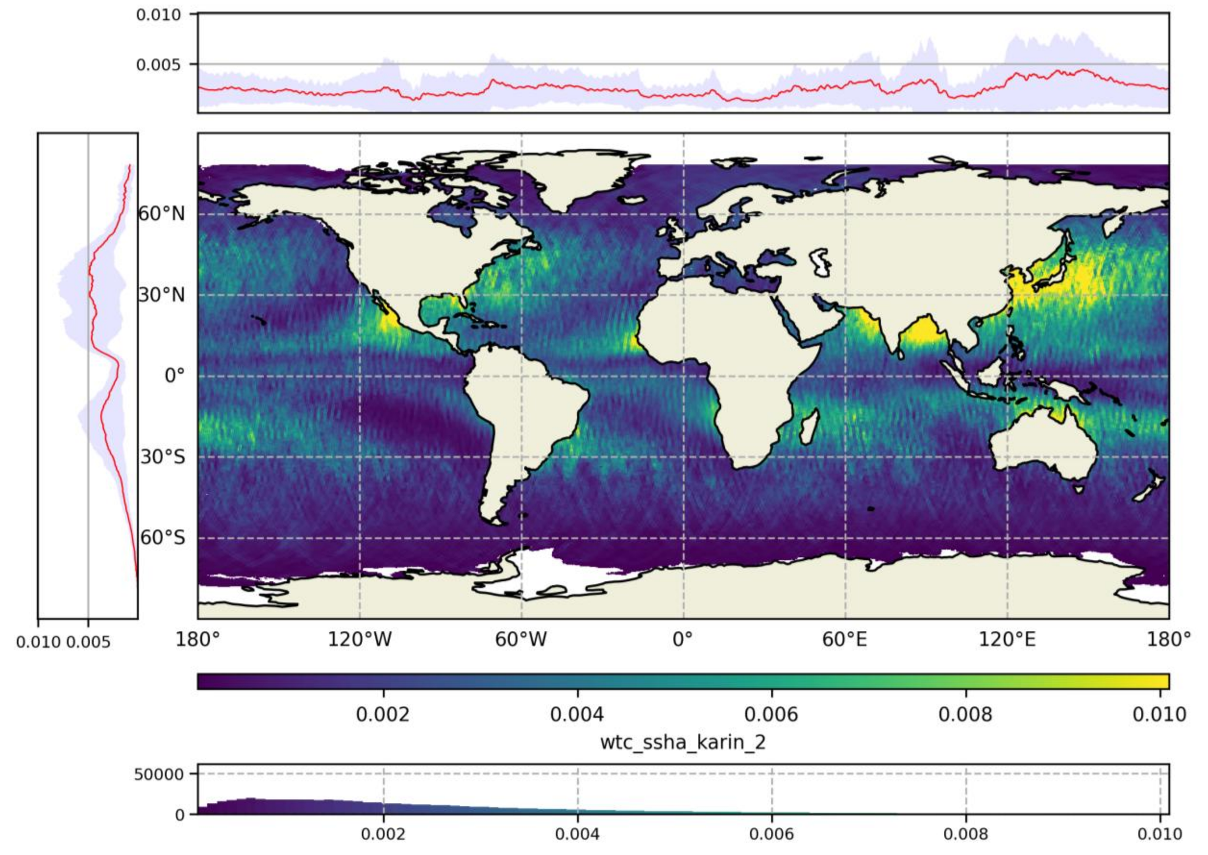
CLS

WTC: maps of variance difference

- Variance overall reduced globally (i.e. red)
- Strong alternating patterns in high energy ocean regions



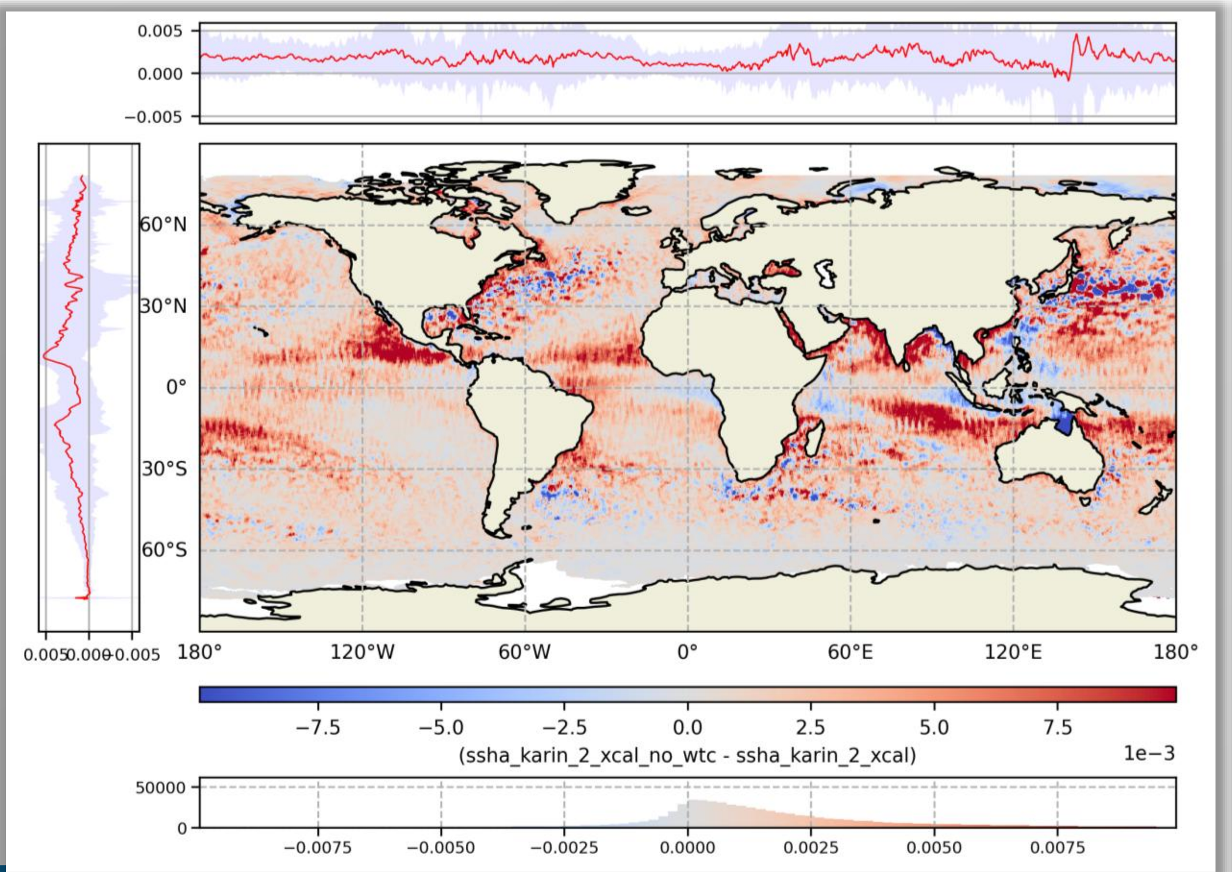
Variance difference SSHA_no_corr vs SSHA



WTC variance

WTC: maps of variance difference

- Variance overall reduced globally (i.e. red)
- Strong alternating patterns in high energy ocean regions
- Patches of over- and undecorrection (red-blue) near the equator (where correction variance is weak)



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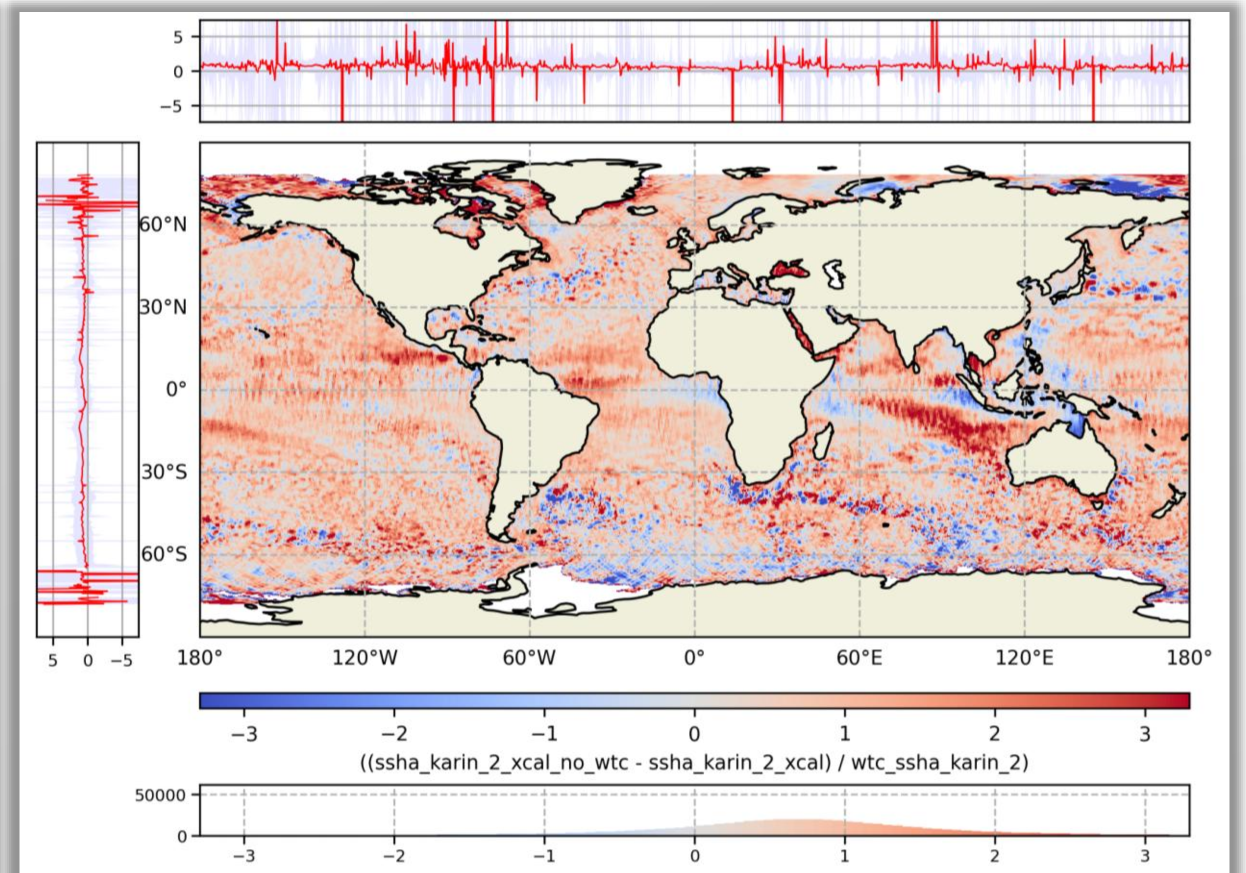

% of variance difference wrt WTC variance

Tide correction

- ❑ Good global performance at wavelengths > 30 km
- ❑ No impact at wavelengths < 30 km

Wet tropospheric correction

- ❑ Good performance for wavelengths > 250 km (both MWR and model)
- ❑ Sub-par performance for scales < 250 (MWR slightly worse than model)

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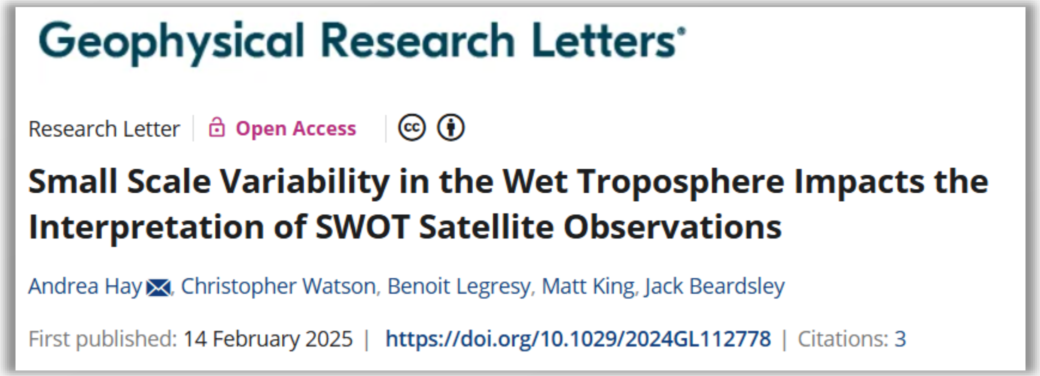
For an example of WTC limitations approaching the coast


Geophysical Research Letters

Research Letter | Open Access

Small Scale Variability in the Wet Troposphere Impacts the Interpretation of SWOT Satellite Observations

Andrea Hay, Christopher Watson, Benoit Legresy, Matt King, Jack Beardsley

First published: 14 February 2025 | https://doi.org/10.1029/2024GL112778 | Citations: 3

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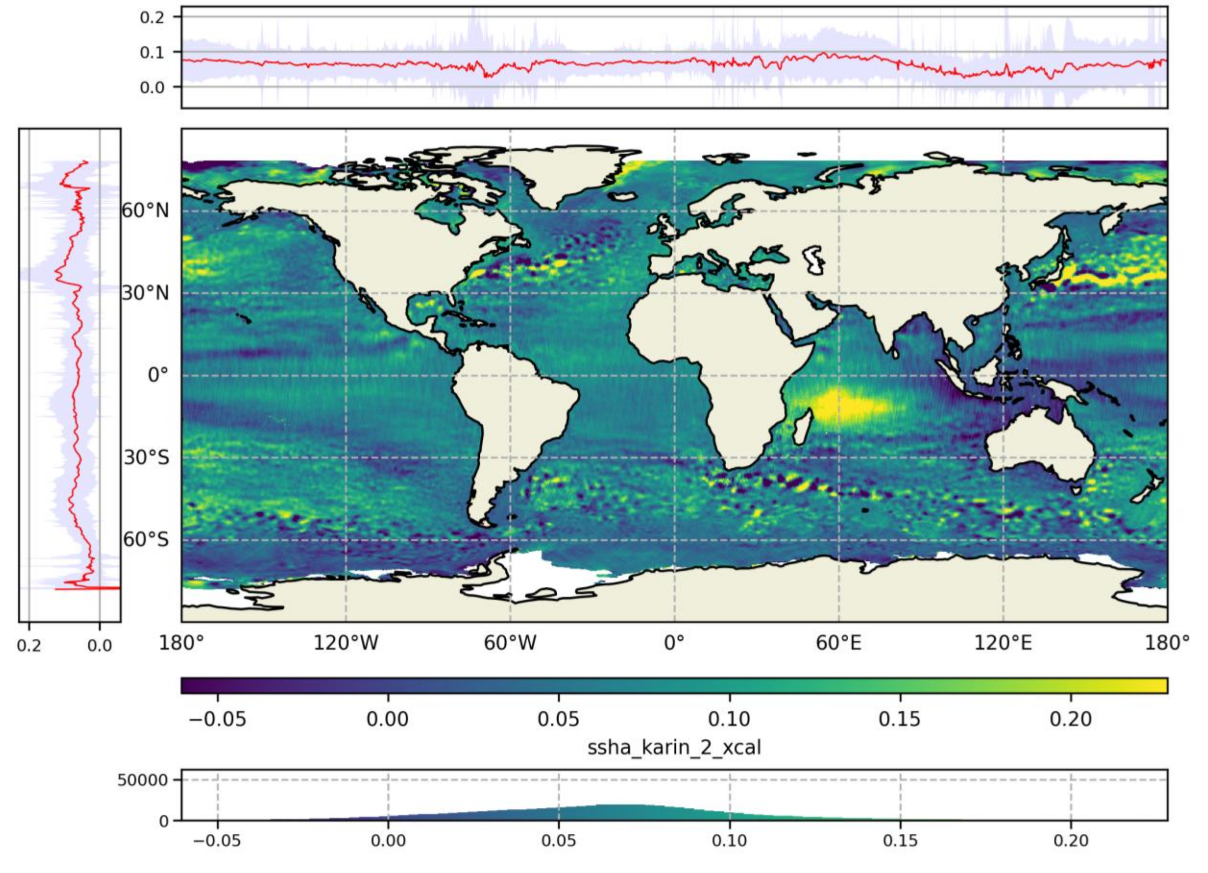
Sea State Bias

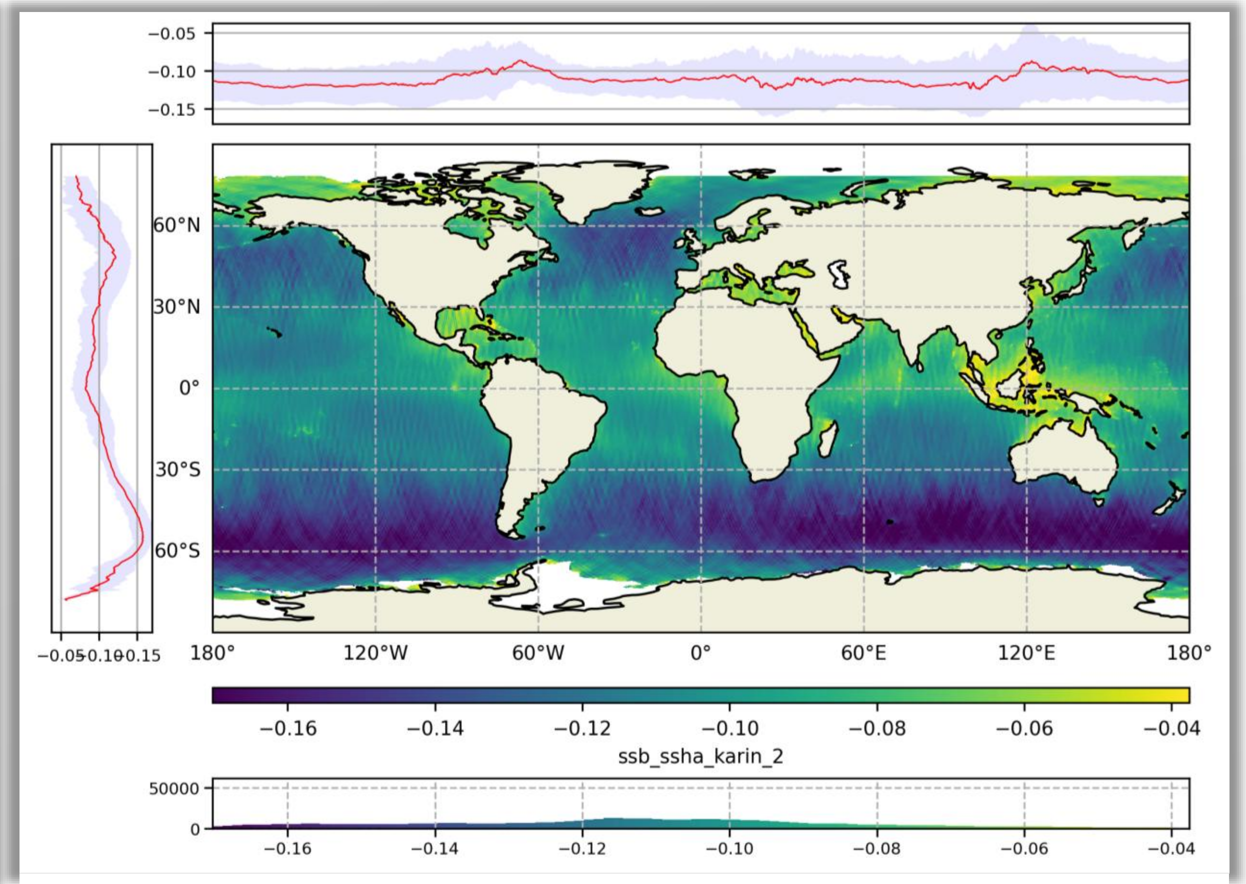
Sea State Bias: mean distribution

- Correct for impact of surface wave on signal reflection (Parametrized: LUT based on wind and waves)

- Smaller values than SSHA (largest at high latitudes)



SSHA Mean



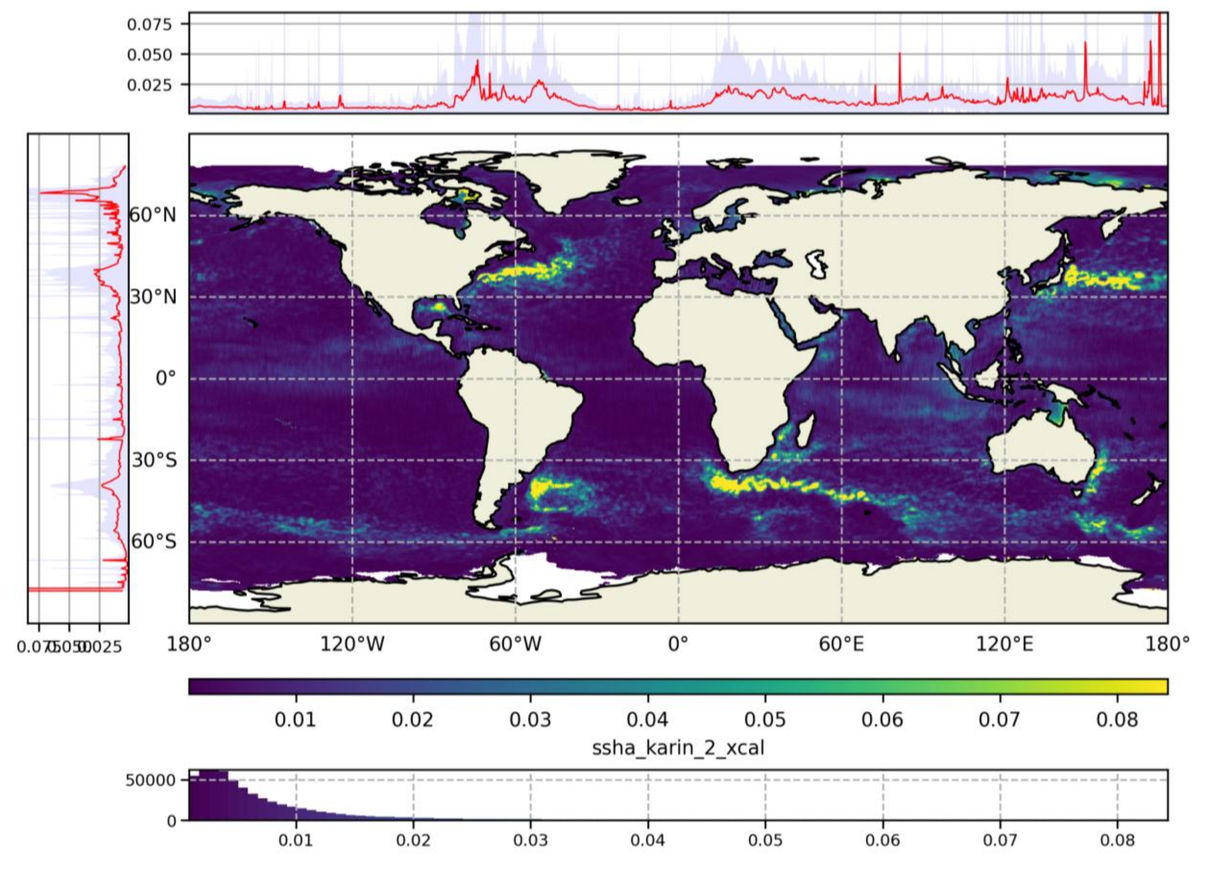
Model SSB Mean

Sea State Bias: variance distribution

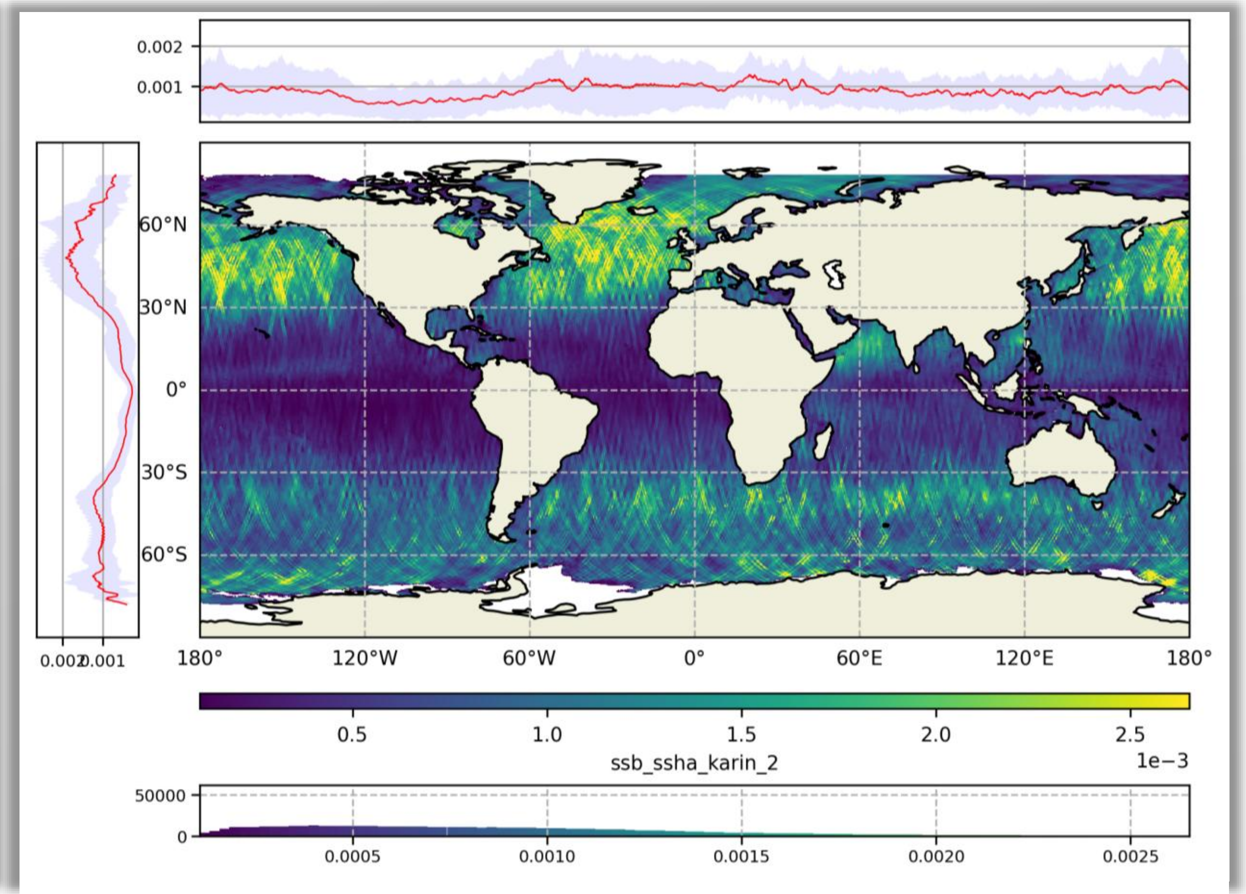
➢ Correct for impact of surface wave on signal reflection (Parametrized: LUT based on wind and waves)

❑ Smaller values than SSHA (largest at high latitudes)
❑ Largest variance also at high latitudes

Almost identical maps for Nadir-based SSB

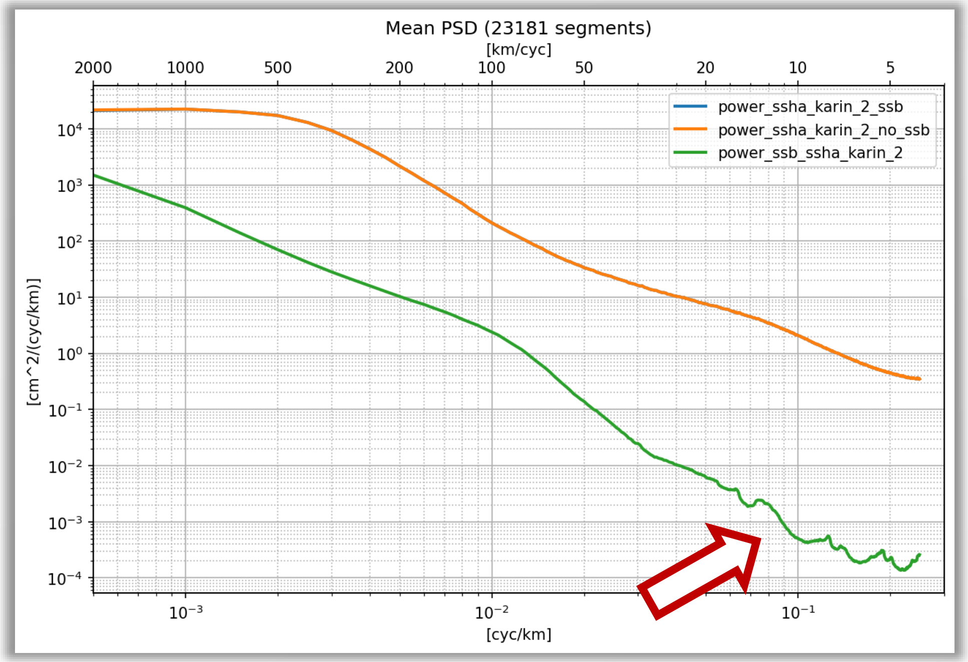


SSHA Variance



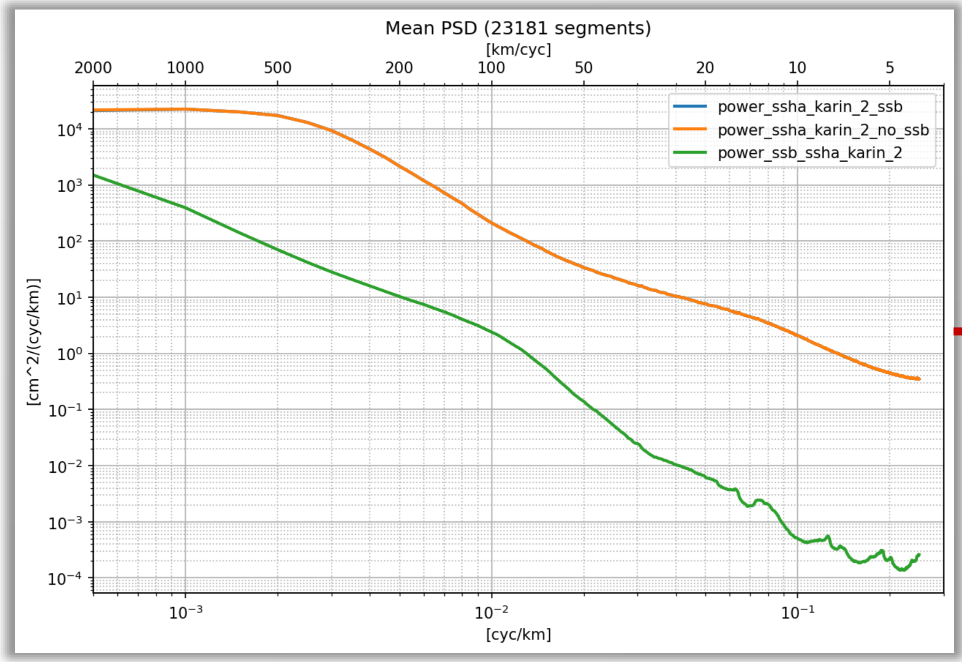
Model SSB Variance

SSB: spectral analysis **Model**



- ❑ Correction variance much smaller than SSHA at all wavelengths < 2000 km
- ❑ At wavelengths <20 km artifacts due to interpolation from model grid

SSB: spectral analysis **Model**

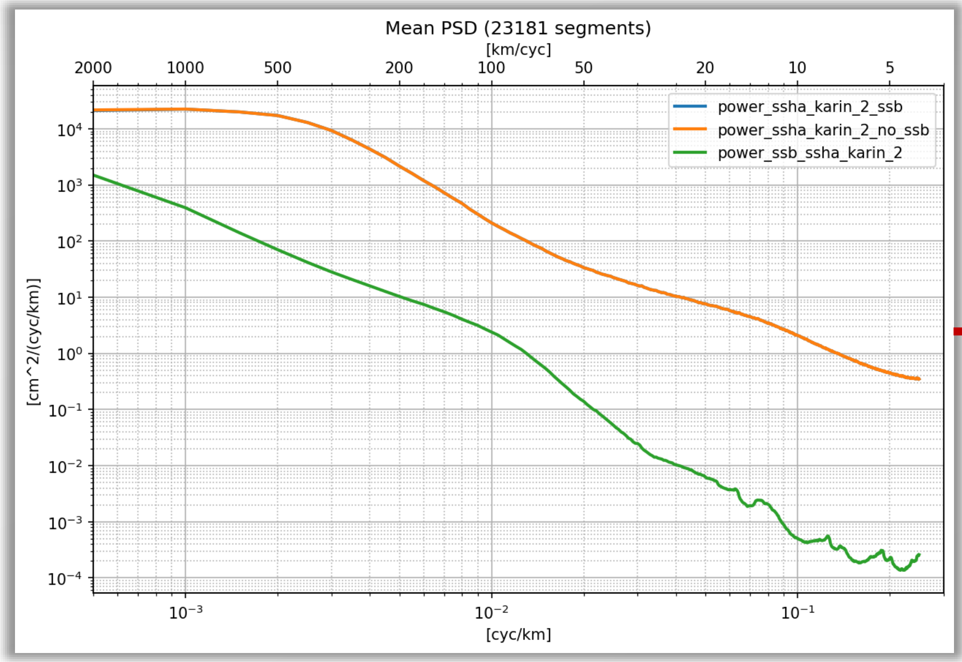


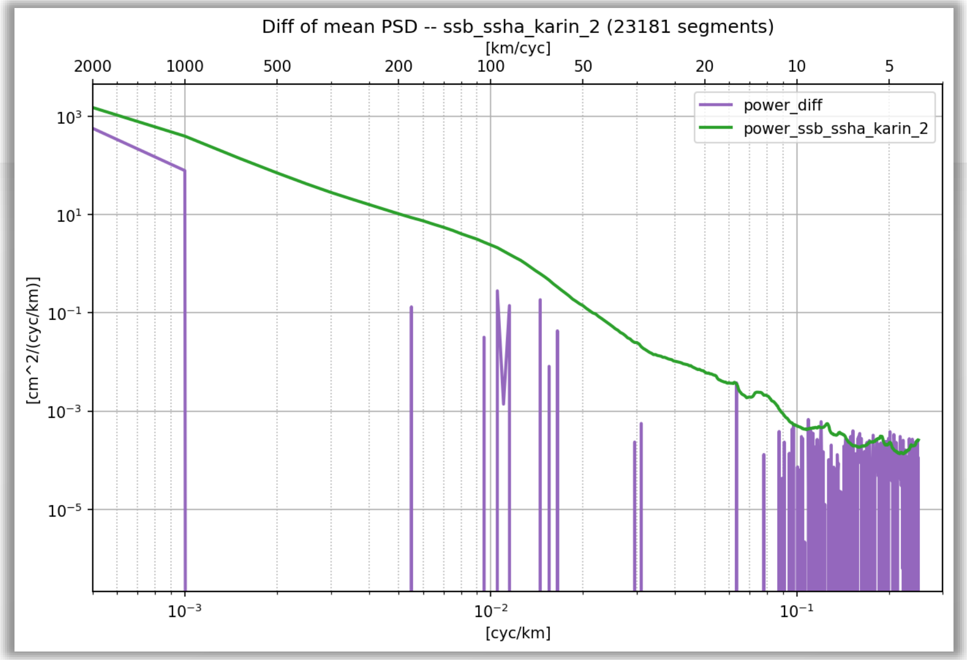
Var(ssh_no_corr) – Var(ssha) = Var(corr) – 2 Cov(SSHA, corr)

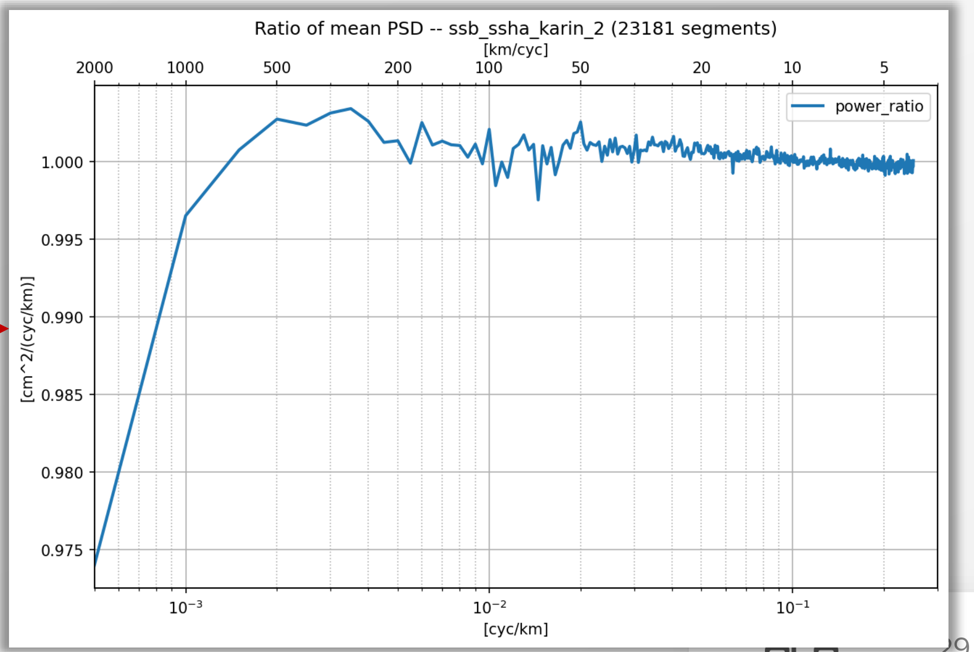
Sub-par performances (model limits? Inaccurate LUT?)

- ❑ Variance reduction only for scales > 1000 km
- ❑ Variance injection between 1000 and 10 km wavelength

SSB: spectral analysis Model







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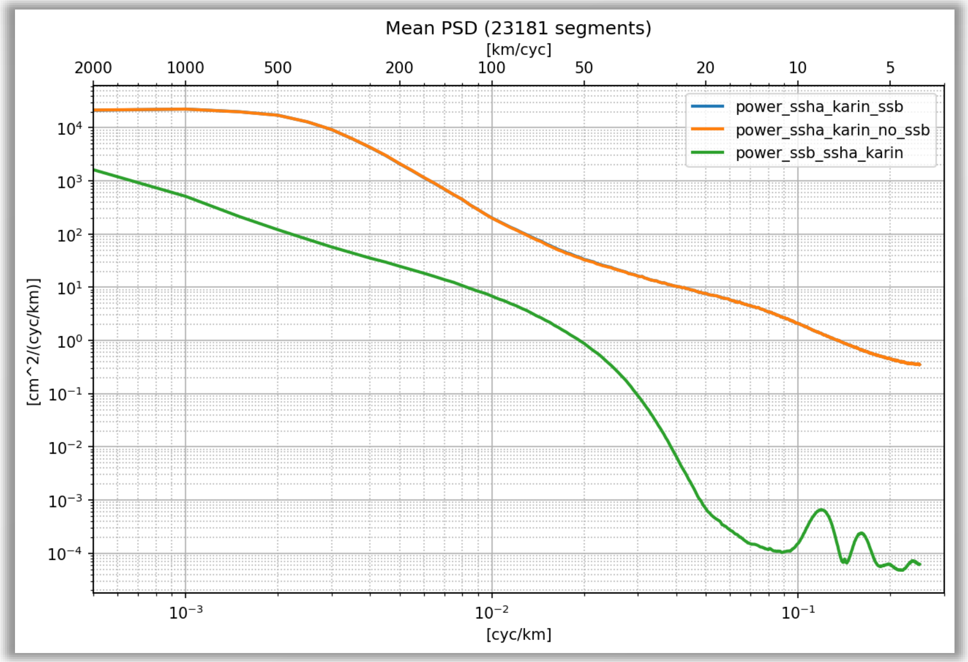
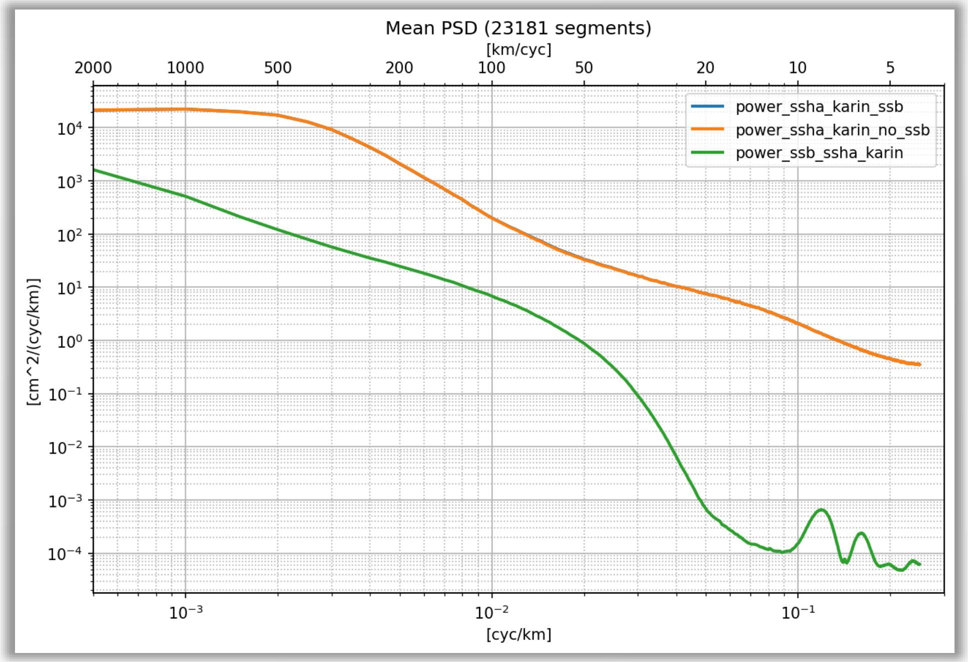
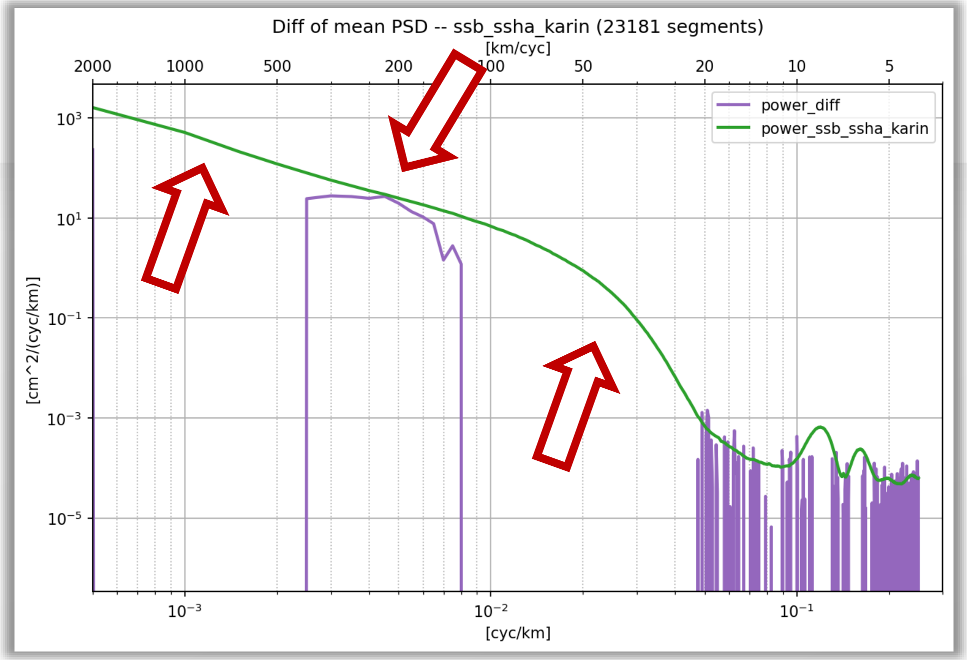
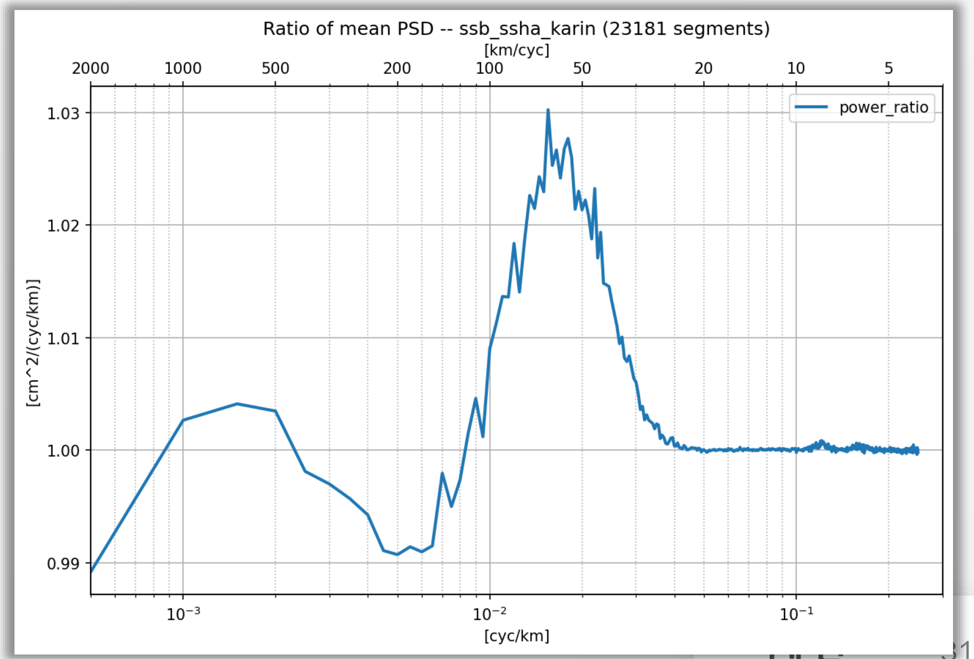
SSB: spectral analysis **SWH SSB**



SSB: spectral analysis **SWH SSB**



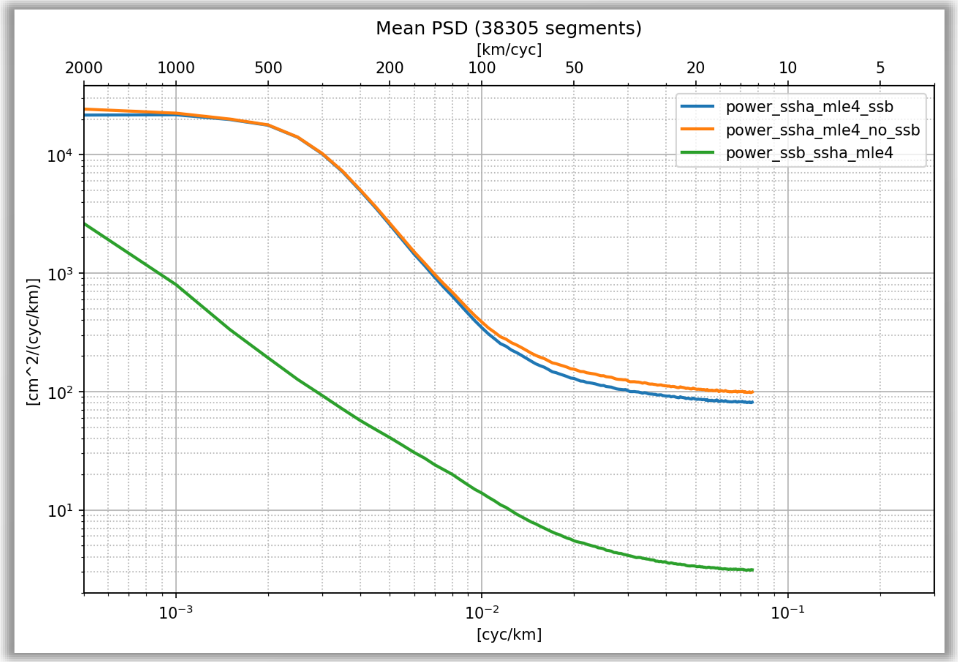




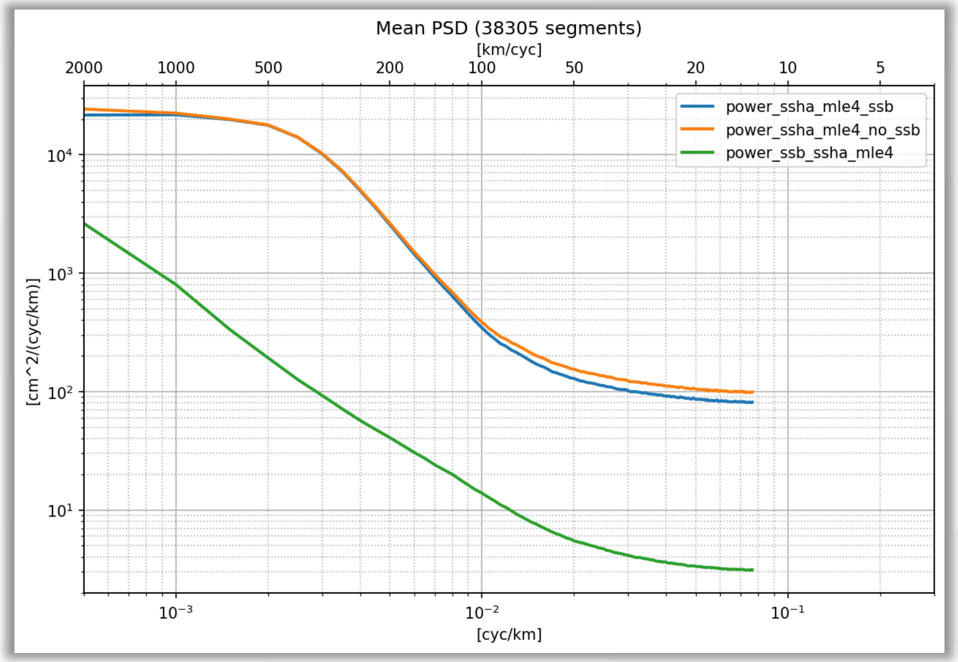
Also sub-par performance (Variability from nadir to mid-swath?)

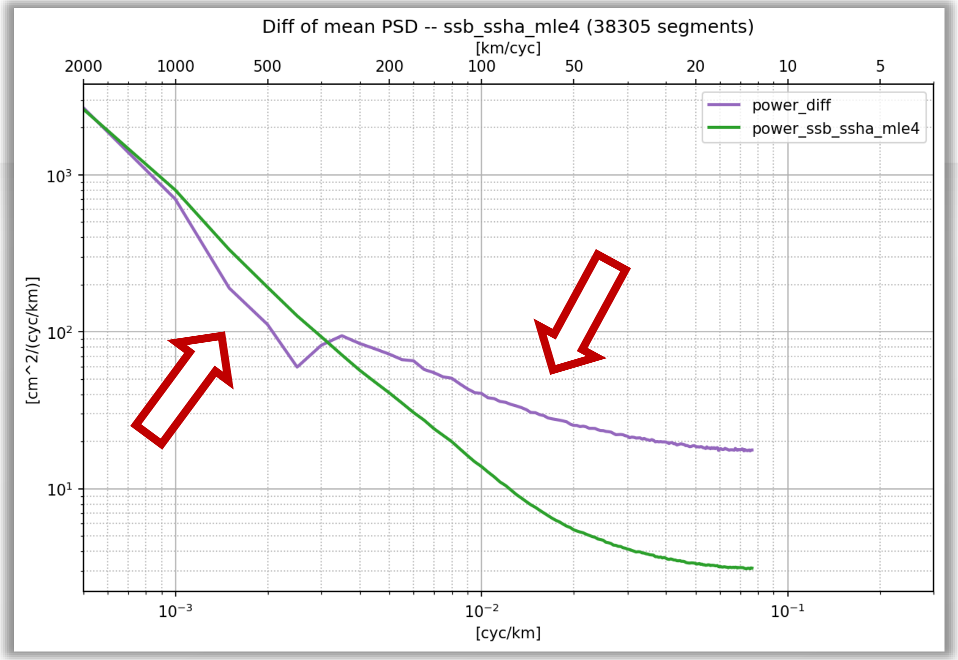
- ❑ SSHA reduced 400 and 150 km
- ❑ SSHA variance injected at all other wavelengths > 25 km
- ❑ Impact of bump artefacts (nadir interpolation) at small scales
- ➢ Confirmed by variance ratio

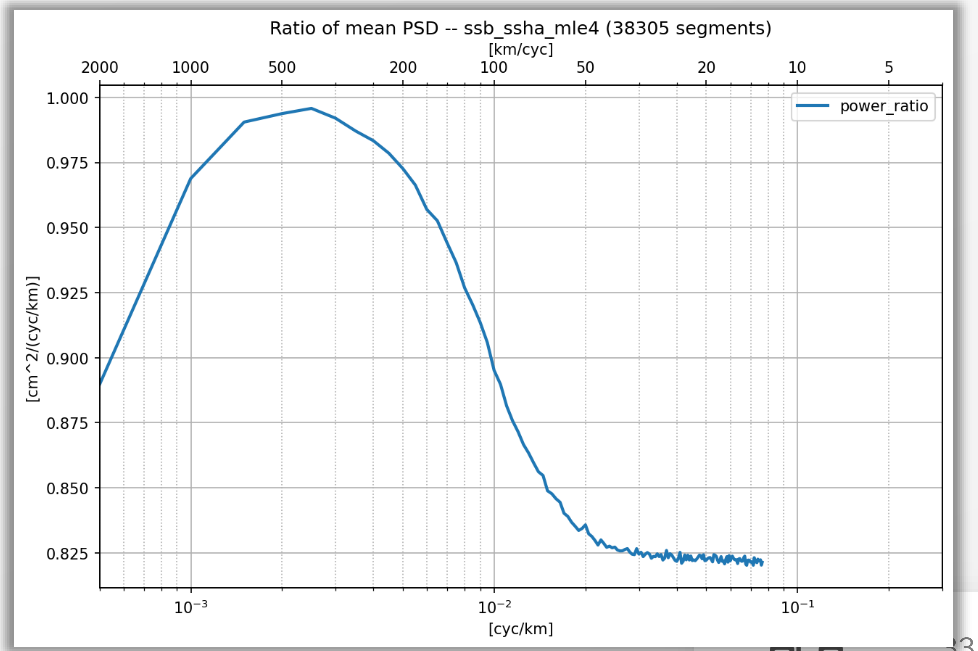
SSB: spectral analysis Nadir



SSB: spectral analysis **Nadir**





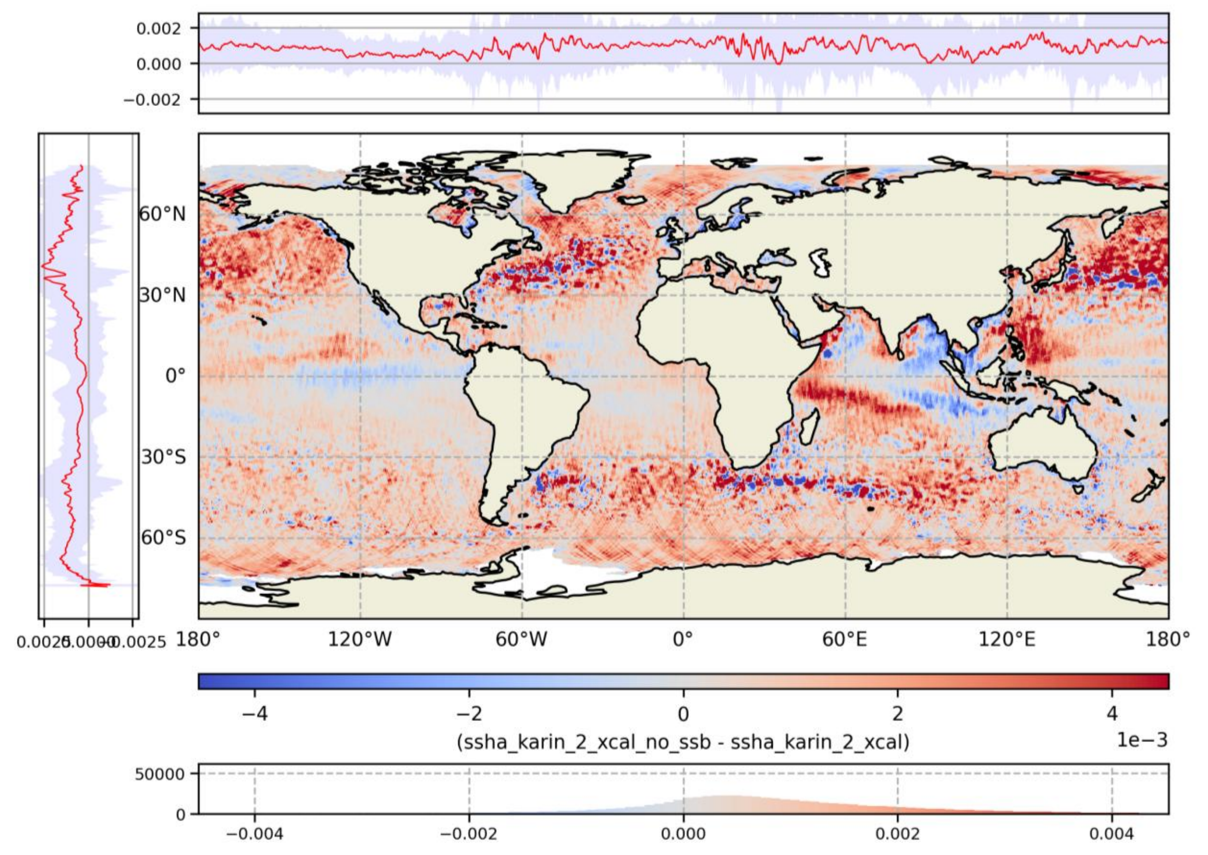


Sub-opar performance also for Nadir SSB (but better than KaRIn)

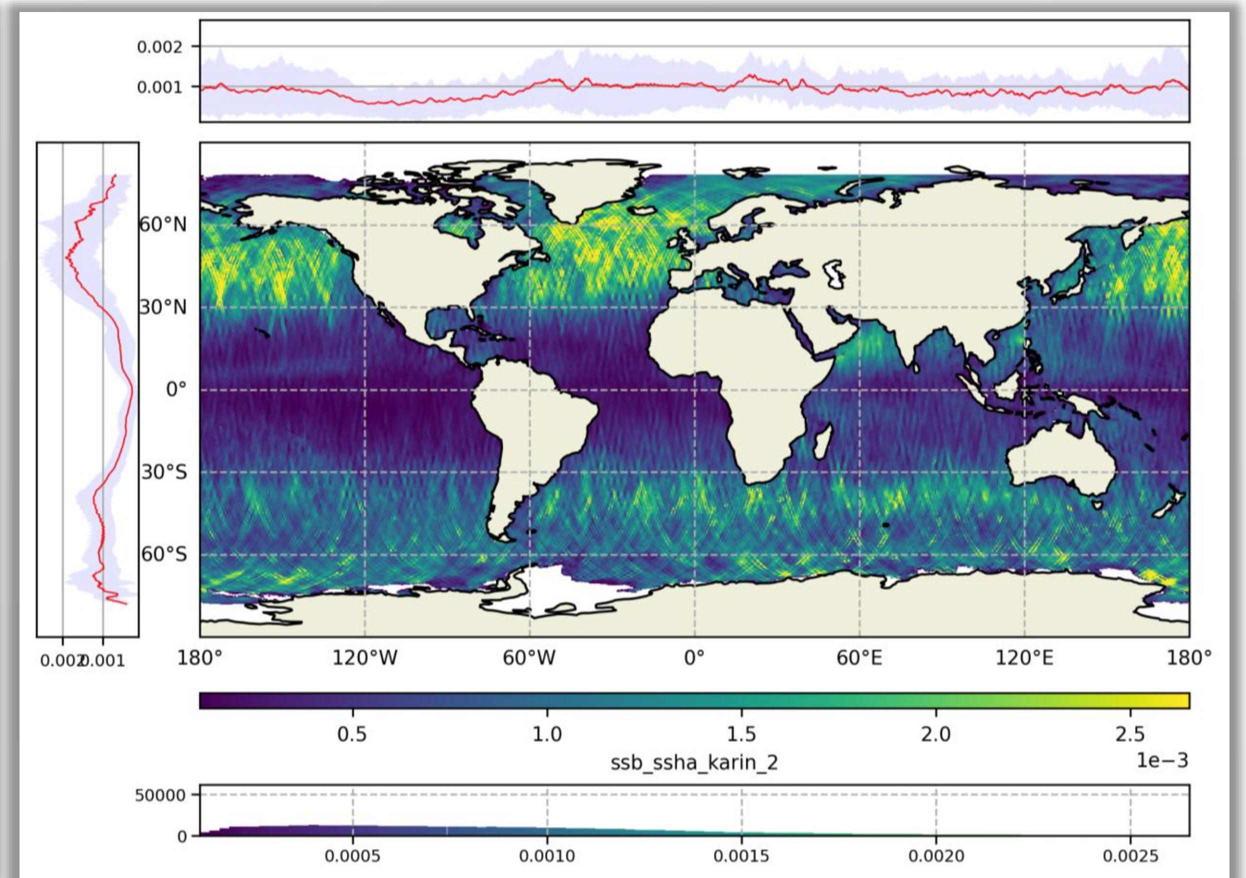
- ❑ Overcorrection at scales < 300 km
  (covariance between SWH and range noise from the retracker)
- ❑ Undercorrection between 1000 and 300 km

SSB: maps of variance difference

- Variance overall reduced globally (i.e. red)
- Strong alternating patterns in high energy ocean regions



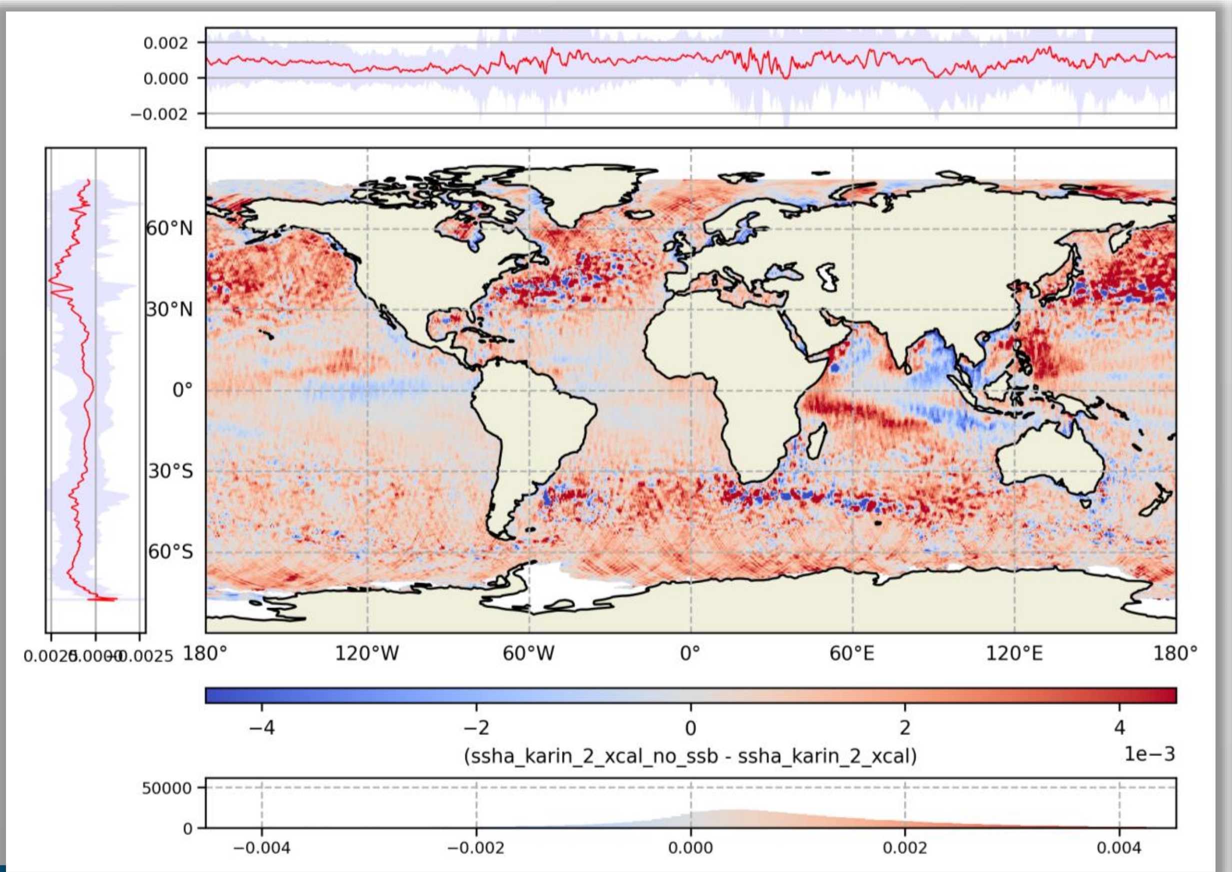
Variance difference SSHA_no_corr vs SSHA



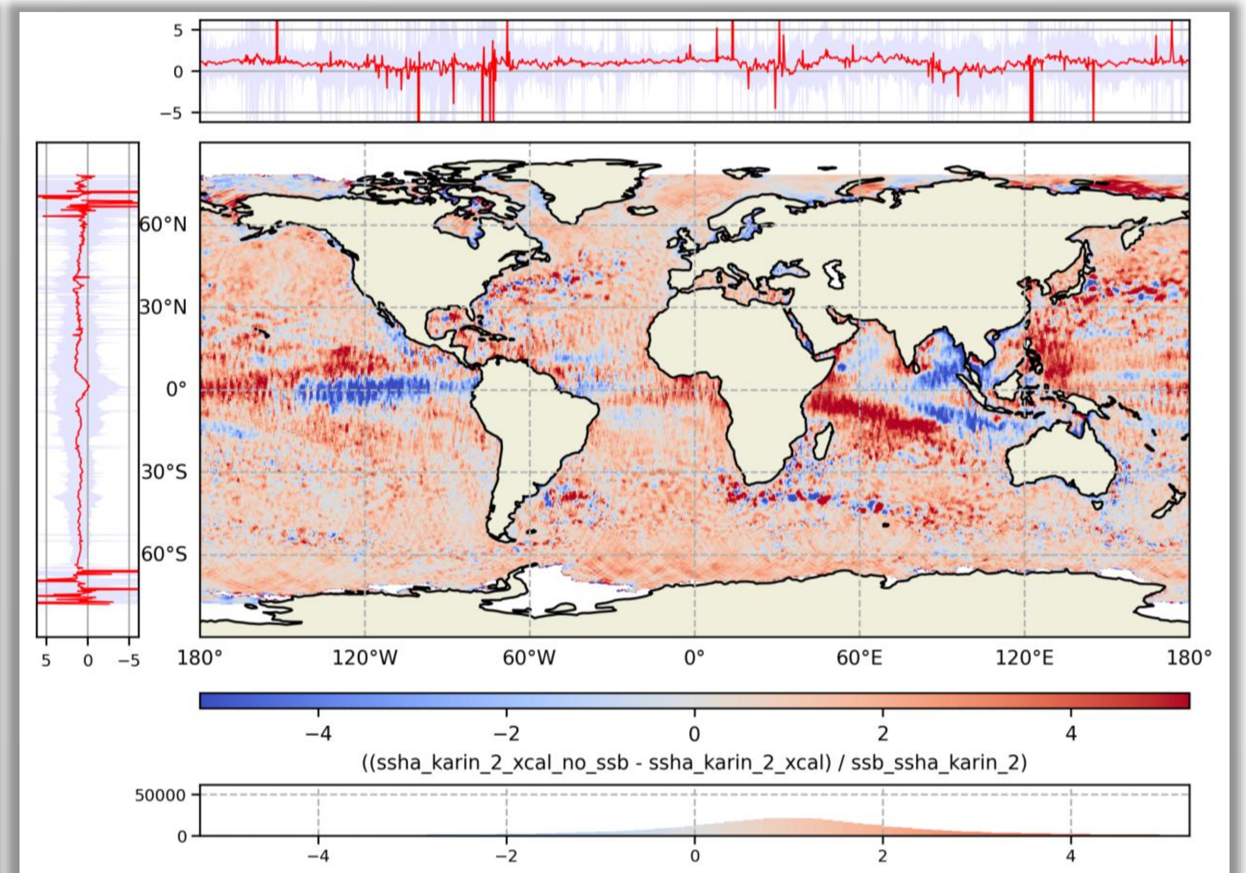
Model SSB Variance

SSB: maps of variance difference

- Variance overall reduced globally (i.e. red)
- Strong alternating patterns in high energy ocean regions
- Patches of over- and undecorrection (red-blue) near the equator (where correction variance is weak)



Variance difference SSHA_no_corr vs SSHA



Model SSB Variance

Conclusions

Tide correction

- Good global performance at wavelengths > 30 km
- No impact at wavelengths < 30 km

Wet tropospheric correction

- Good performance for wavelengths > 250 km (both MWR and model)
- Sub-par performance for scales < 250 (MWR slightly worse than model)

Sea State Bias

- Sub-par performance at all wavelengths for all versions (model, SWH as well as Nadir)
- Time to rethink the way we tackle the correction?

Conclusions

Tide correction and Dynamic Atmospheric Correction

- Good global performance at wavelengths > 30 km
- No impact at wavelengths < 30 km

Wet tropospheric correction

- Good performance for wavelengths > 250 km (both MWR and model)
- Sub-par performance for scales < 250 (MWR slightly worse than model)

Sea State Bias

- Sub-par performance at all wavelengths for all versions (model, SWH as well as Nadir)
- Time to rethink the way we tackle the correction?

Overall

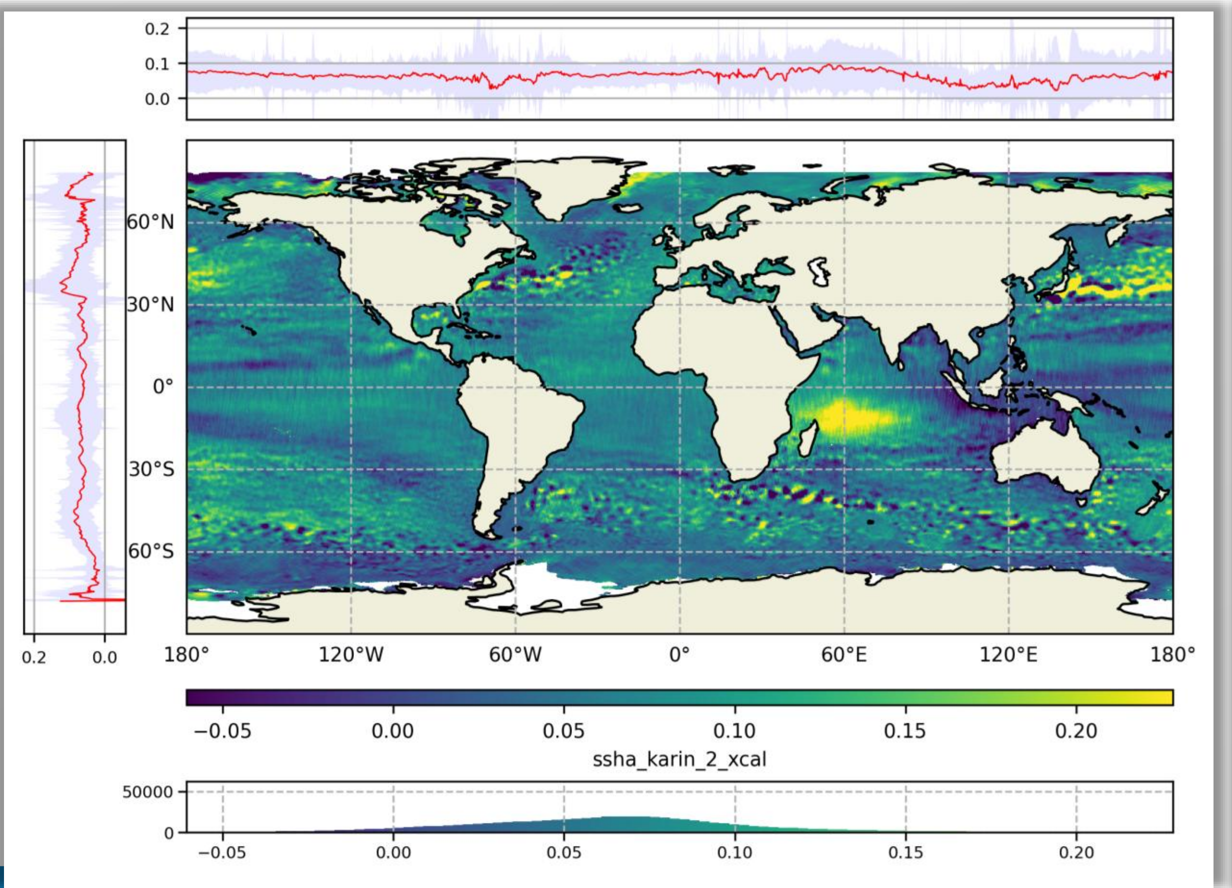
- All corrections seems to underperform in the equatorial band (especially in the Indian ocean)
- Hard to assess performance in high energy regions based on current diagnostics

Extra slides

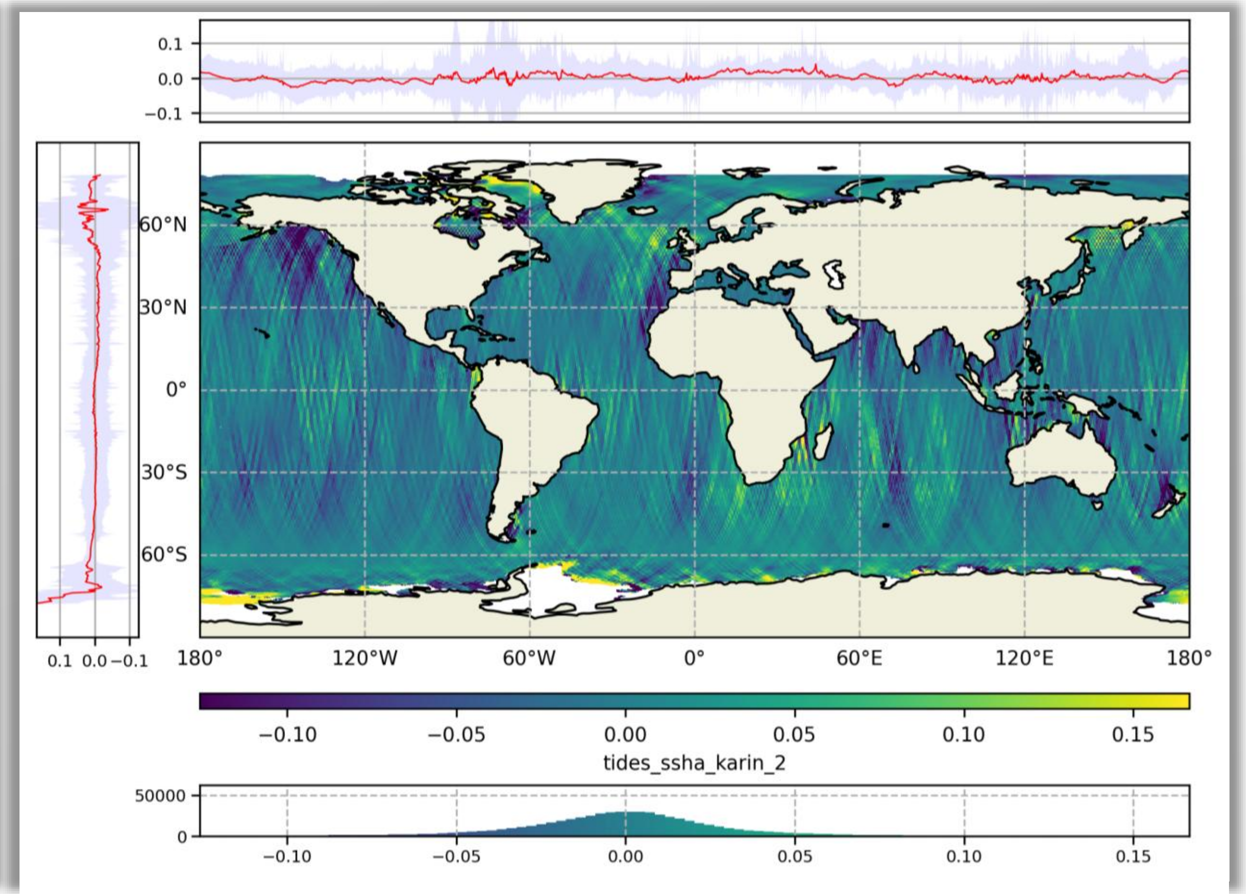
Tide correction

Tide correction: mean distribution

- ➢ Include solid Earth, ocean, load, coherent internal, and pole tides
- ❑ Same order of magnitude as SSHA but with larger scale patterns



SSHA Mean

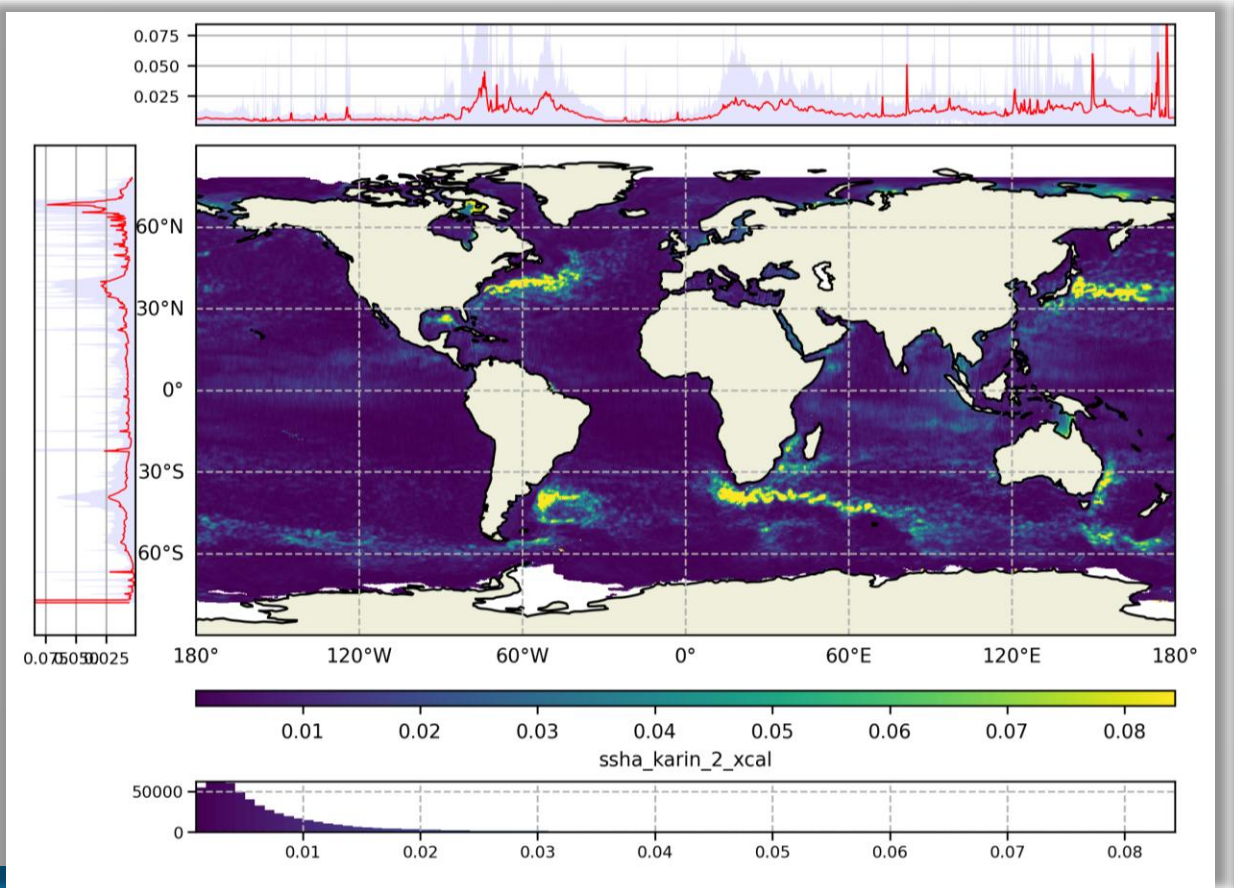


Tide Mean

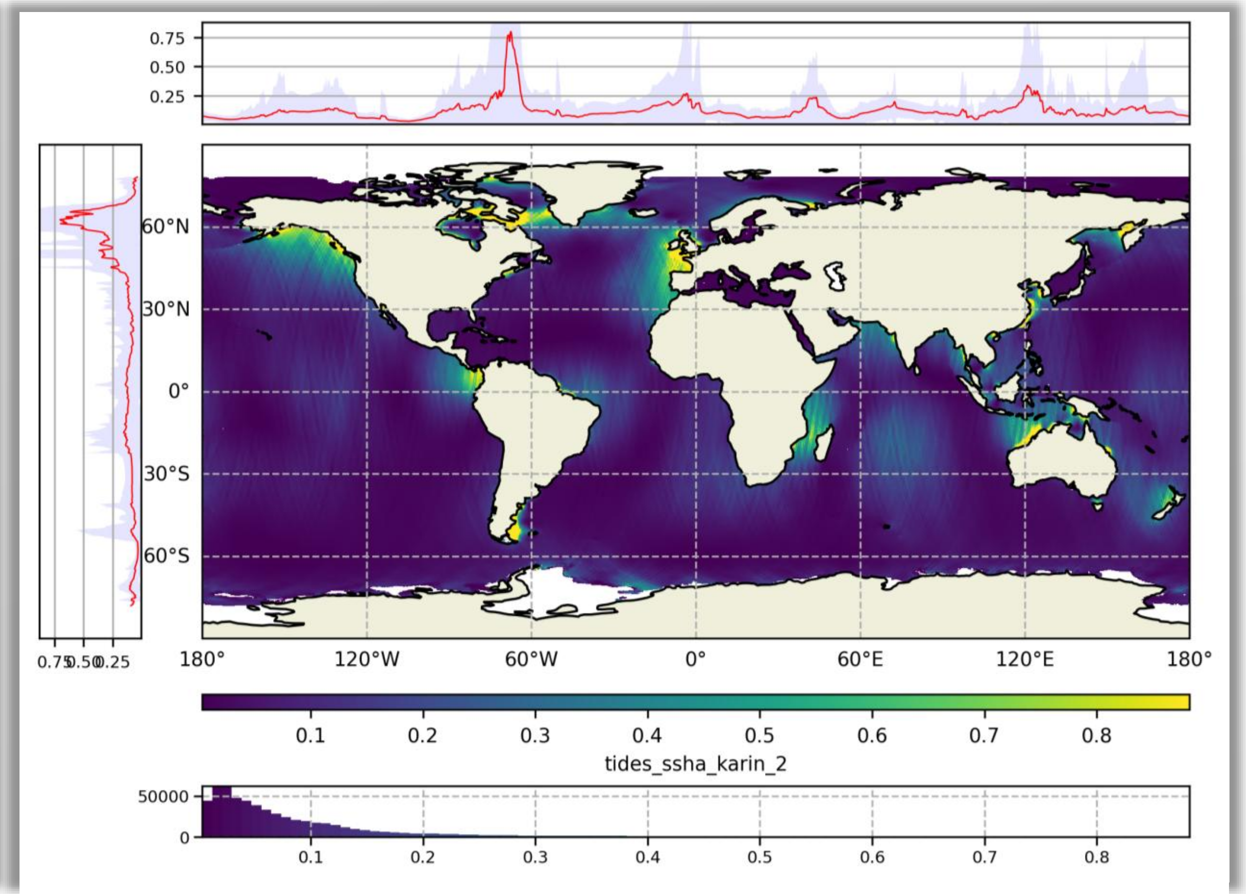
Tide correction: variance distribution

- ➢ Include solid Earth, ocean, load, coherent internal, and pole tides

- ❑ Same order of magnitude as SSHA but with larger scale patterns
- ❑ Much larger variance than SSHA and different spatial distribution

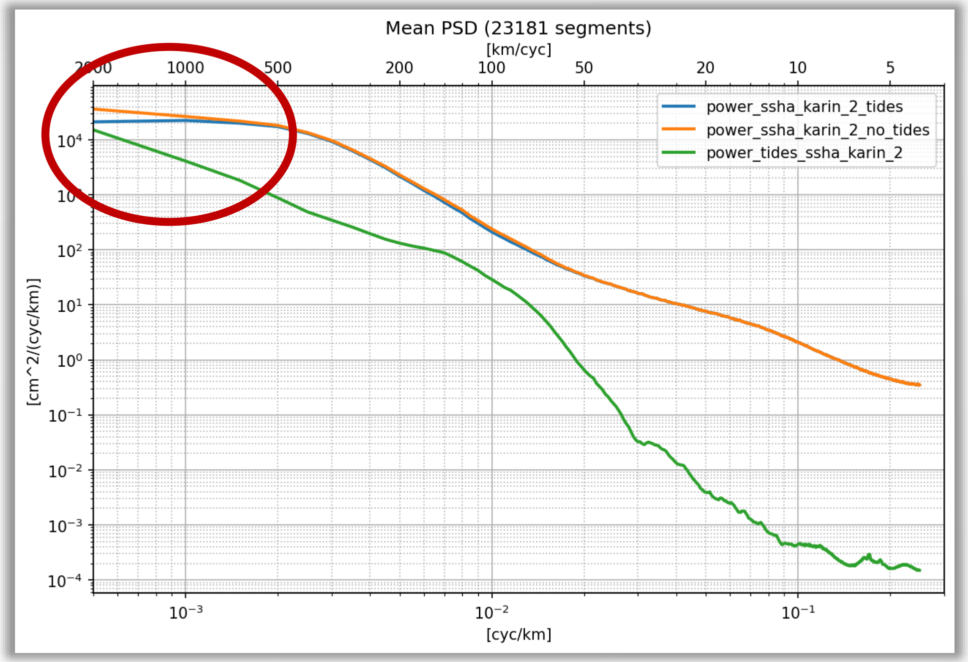


SSHA Variance



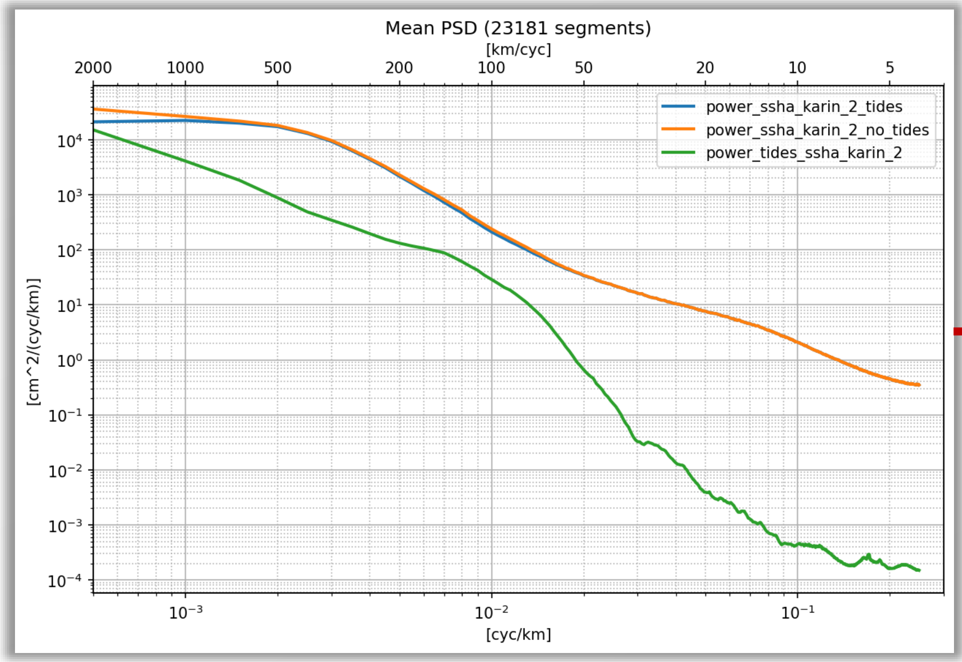
Tide variance

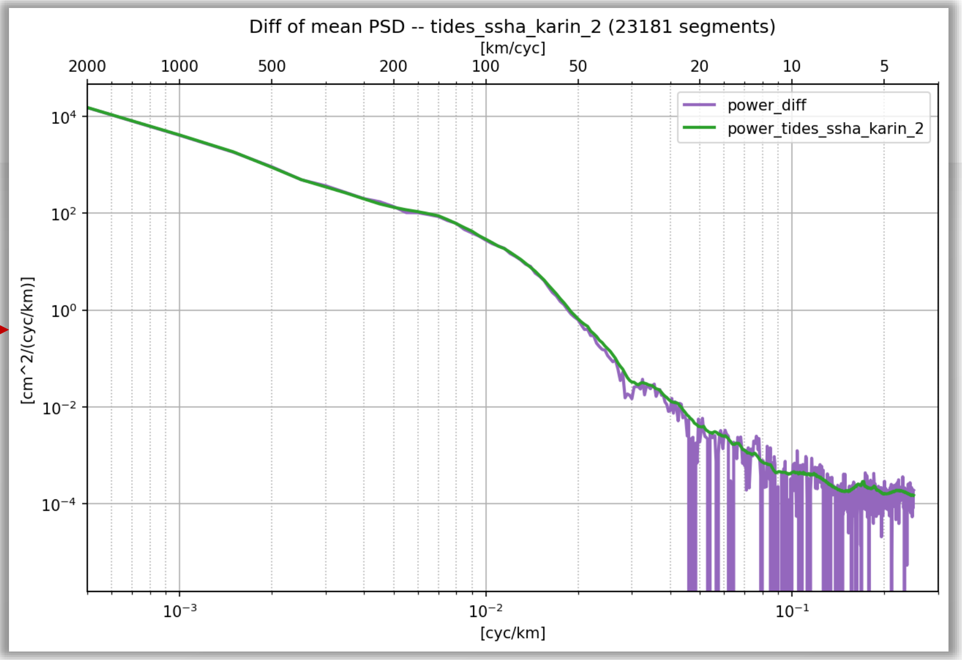
Tide correction: spectral analysis



- ❑ Tide variability concentrated at large scale
- ❑ Impact of correction mostly at scales > 1000 km
- ❑ SSHA variability larger than tide variability for wavelengths < 2000 km

Tide correction: spectral analysis



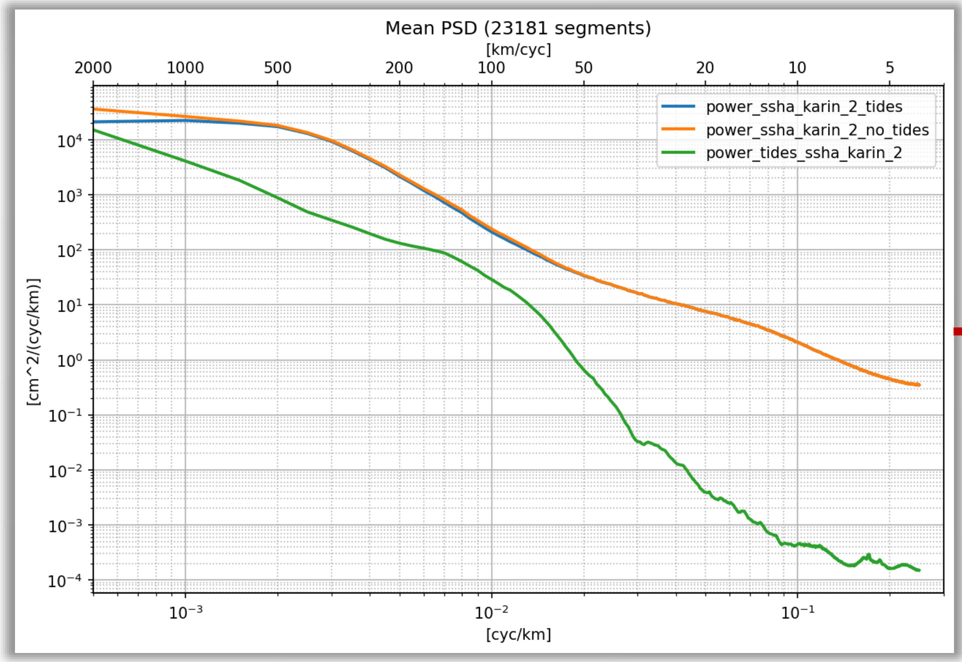


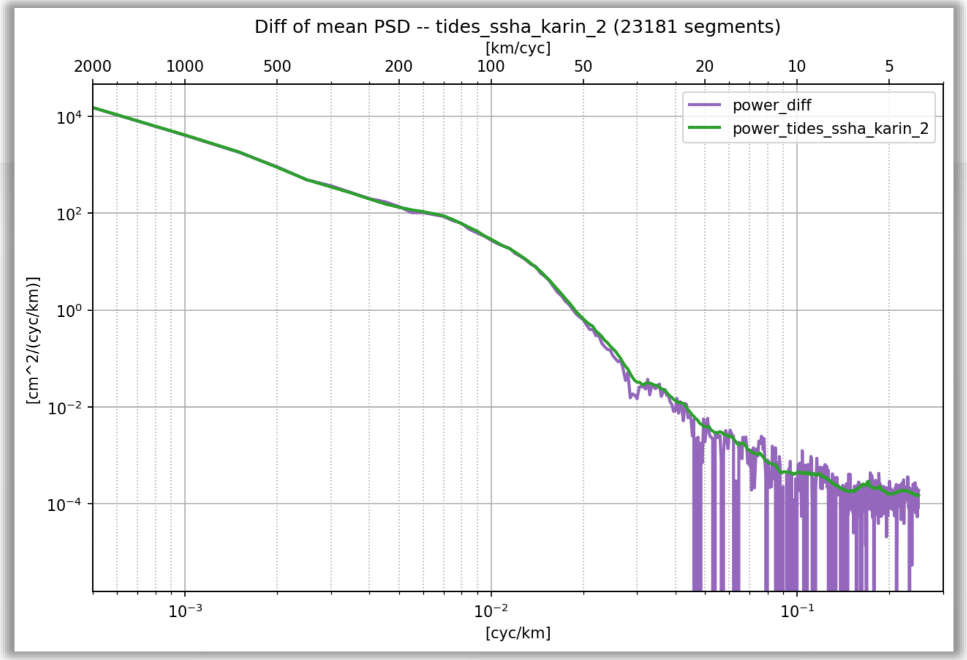
Var(ssh_no_corr) – Var(ssha) = Var(corr) – 2 Cov(SSHA, corr)

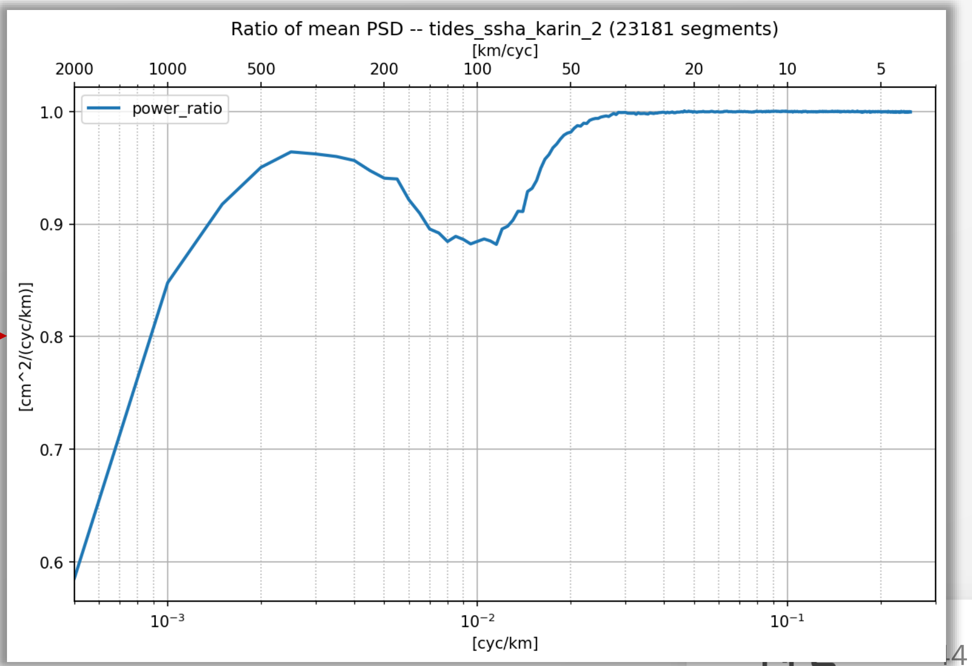
Comparison between SSHA_no_corr and SSHA spectral difference (violet) and spectrum of correction (green)

- ❑ The two curves are superposed down to ~20 km wavelength =>
  - ➢ **Excellent performance of the correction** (i.e. all tidal signal removed; no residual covariance)
- ❑ Correction too small below 20 km wavelength

Tide correction: spectral analysis





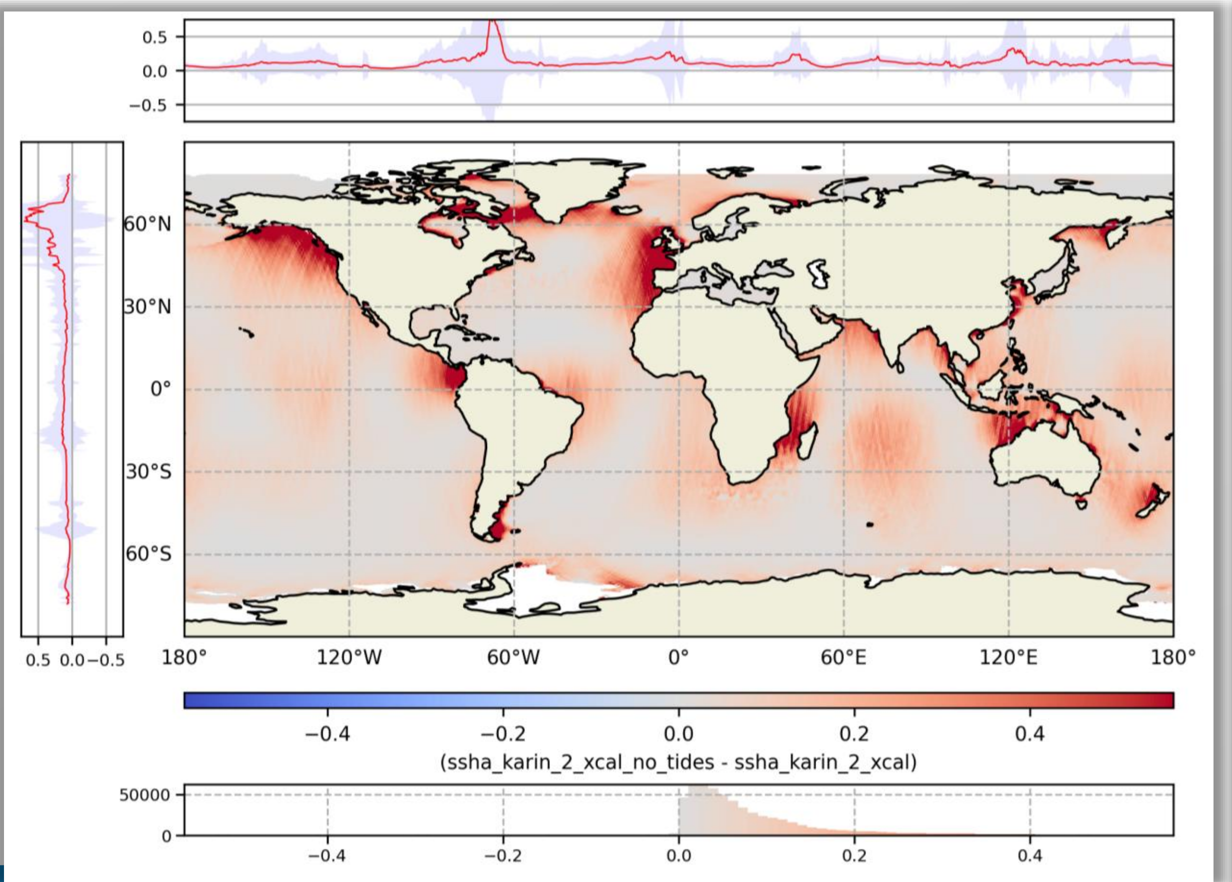


Ratio between SSHA_no_corr and SSHA spectra (**blue**)

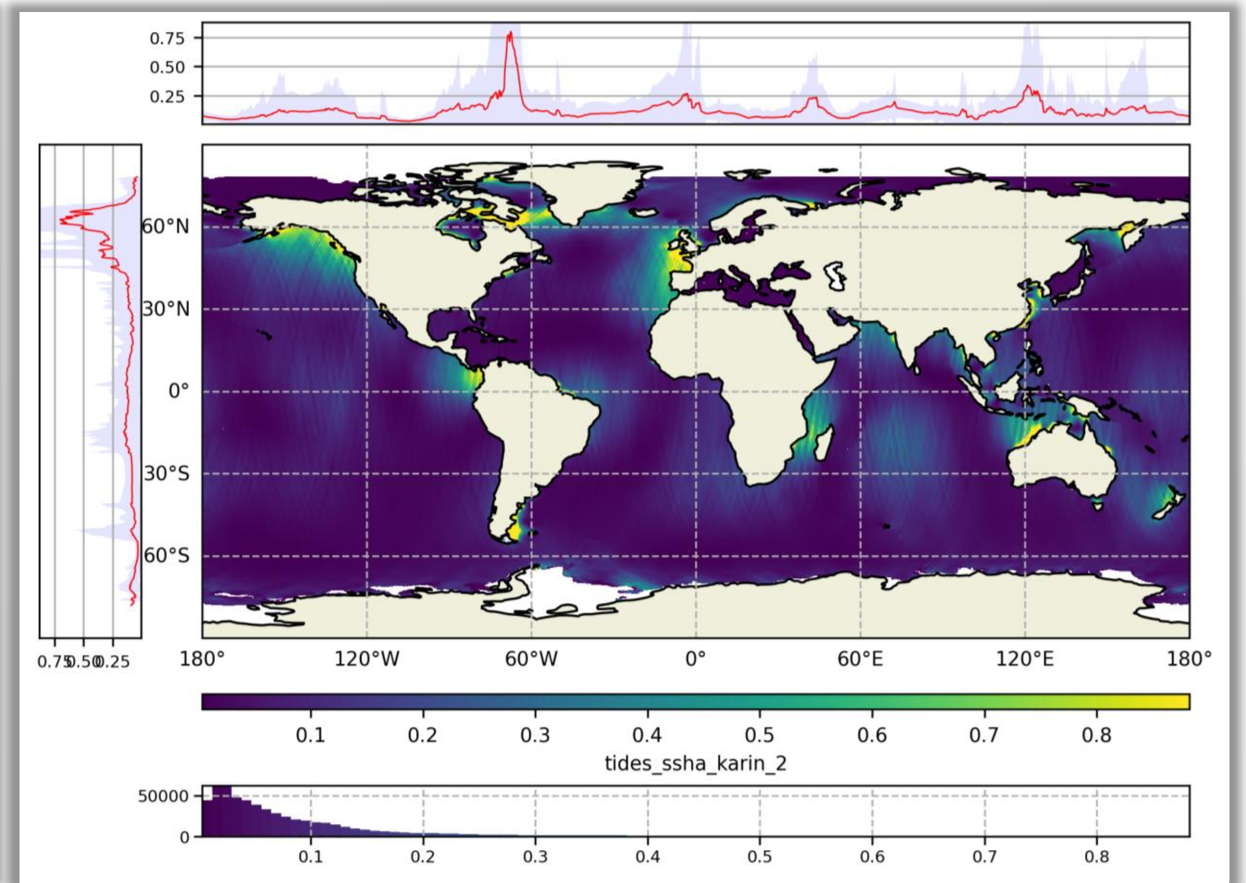
- ❑ Largest impact at large scales
- ❑ Effective around 100 km wavelengths
- ❑ No impact on SSHA variance below 30 km wavelength (common to most corrections !!!)

Tide correction: maps of variance difference

- Patterns of reduced variance consistent with tidal correction variance



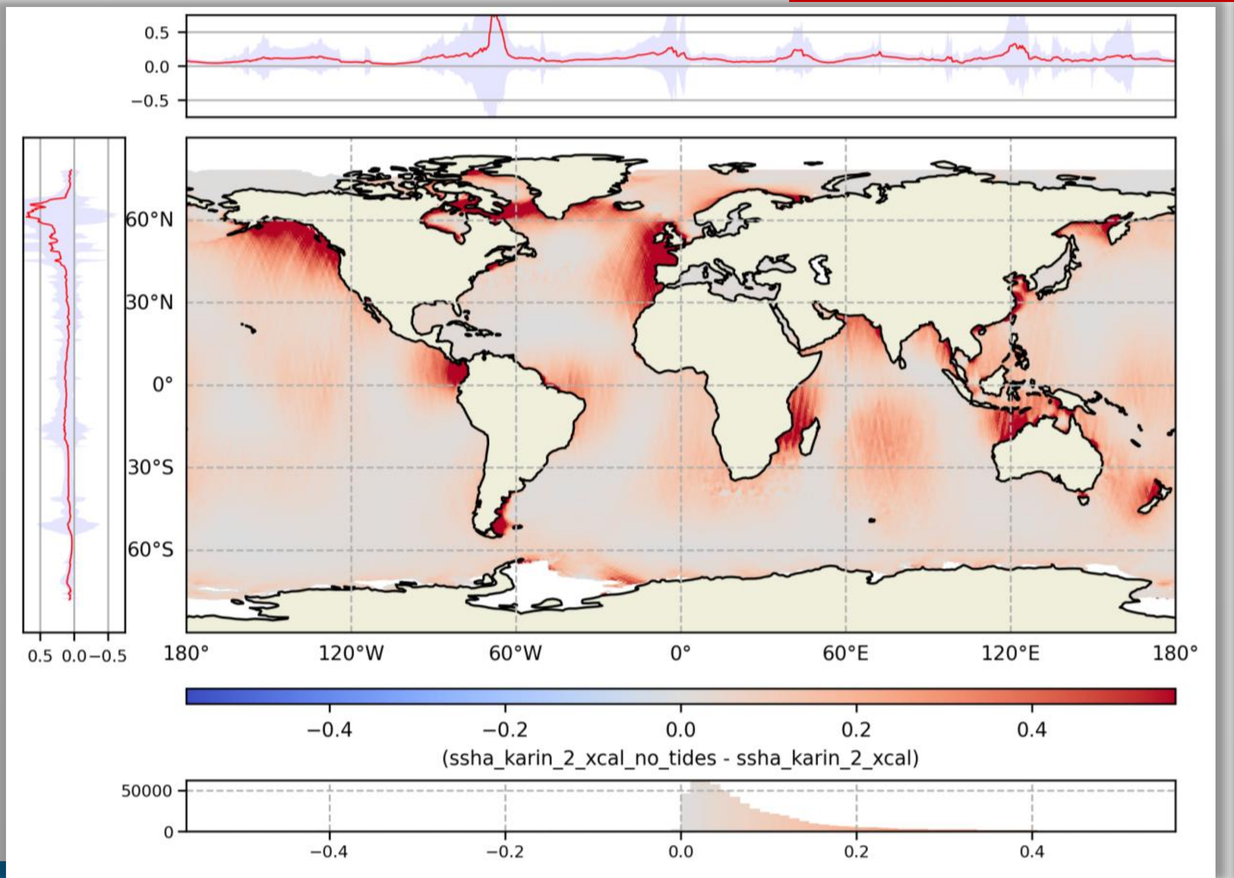
Variance difference SSHA_no_corr vs SSHA



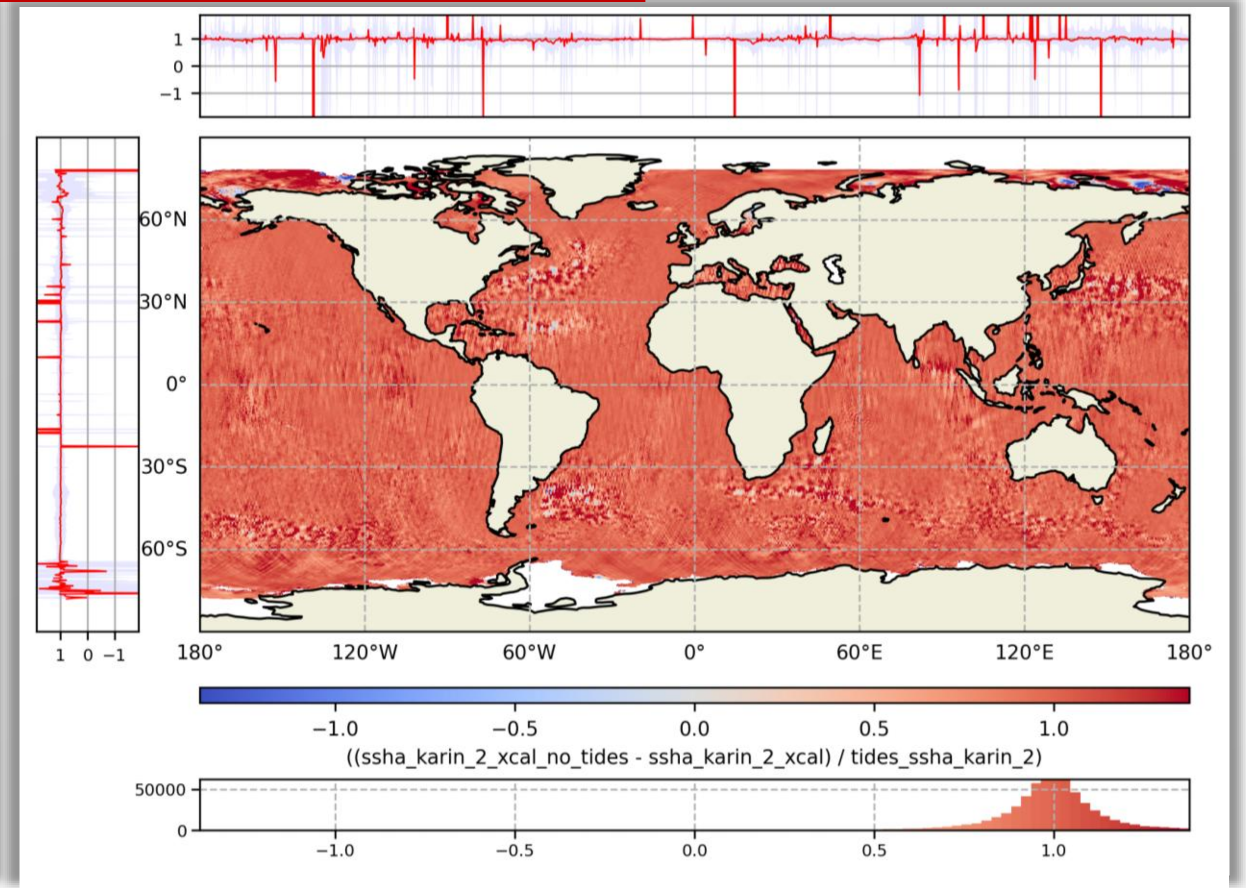
Tide variance

Tide correction: maps of variance difference

- Patterns of reduced variance consistent with tidal correction variance
- % of variance difference centered around 1 (no residual covariance)
- Homogeneous spatial distribution (but patterns emerge on high energy ocean regions)



Variance difference SSHA_no_corr vs SSHA



% of variance difference wrt tide variance

Tide correction

- ❑ Good global performance at wavelengths > 30 km
- ❑ No impact at wavelengths < 30 km