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Round Robin Assessment of Radar Altimeter LRM and SAR Retracking Algorithms for Significant Wave Height

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Motivation

Goals of the ESA project Sea State Climate Change Initiative (SeaState_CCI)

- Estimation/exploitation of consistent climate-quality time-series of significant wave height (SWH)
- Improvement and development of novel retracking algorithms for estimating SWH:
  - Better signal-to-noise ratio (SNR) and performance in the coastal zone
  - Precision and accuracy of satellite altimetry data of the past 25 years
- Two novel retracking algorithms shall be selected for production
  - 1x for low resolution mode (LRM) and 1x synthetic aperture radar mode (SARM)

For evaluating the performance of retracker algorithms a Round Robin exercise is conducted to select two algorithms for both conventional, pulse-limited, low-rate-mode (LRM) and synthetic aperture radar mode (SARM) altimetry

- Open to both internal and external teams
- Test datasets for both Jason-3 and Sentinel-3A covering up to 21 months of data
- Different open-ocean and coastal scenarios with various sea state conditions are selected

Round Robin Data

Level-1 Datasets to be retracked

- Jason-3 (J3)
  - 16 half-orbit, pole-to-pole tracks
  - 73 cycles (covering 21 months)
  - 1162 netCDF files in total
  - L1B waveforms available
- Sentinel-3A (S3A)
  - 30 half-orbit, pole-to-pole tracks
  - 17 cycles (covering 13 months)
  - 512 netCDF files in total
  - L1A and L1BS waveforms available (L1BS including PLRM)

Reference Output used for Validation

- 2x Models: ERA5, ERA5-based hindcast, each for Jason-3 and Sentinel-3A (PLRM and SAR)
- L2 SGDR datasets: MLE-4 (Jason-3) and SAMOSA (Sentinel-3A)
- In-situ buoy data

Methods

Outlier Analysis

- **is_nan:** original NaN value, qual_flag, or sea_ice_flag set
- **Not_in_range:** Sample is out of range [0.25, 25] m
- **Median absolute deviation (MAD):** Per-sample: (SWH – median_closest_20 > 3 * MAD_closest_20)
  - **Three sigma:** The difference between the sample and the expectation value of the closest 20 points > 3*sigma

Noise Analysis

Definition of noise: A noise value is defined as the standard deviation of the 20-Hz SWH within a 1-Hz distance.

Comparison with Model

Model grid points and altimetry are coupled by considering the median of the SWH 20-Hz measurements from altimetry within the grid point.

Comparison with In-situ Data

Definition: buoys are grouped into "open ocean buoys" and "coastal (but exposed) buoys". Statistics are separated accordingly.

Representation of Scales of Variability

Along-track spectra of SWH are calculated for open ocean segments of track of at least 1024 points (~330 km length) using Welch's method.

Retracker validation framework: retrackval

- Fully-automated scripts, written in Python 3.x
- Hosted on TUM-GitLab
- Python package
- Python dependencies managed by conda environment
- Unit-tests
- Platform-independent
- Easy-to-use: About 10 commands → validation can be run
- Computational speed: 8 hours @30 cores, 2.20GHz
- Source is available on request

Outlier Analysis

- Distance-to-coast dependent analysis

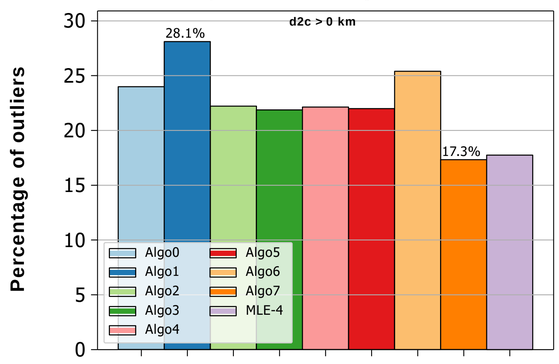

Figure 1: Percentage of outliers w.r.t. distance-to-coast, comparison of all retrackers (J3)

- Types of outliers

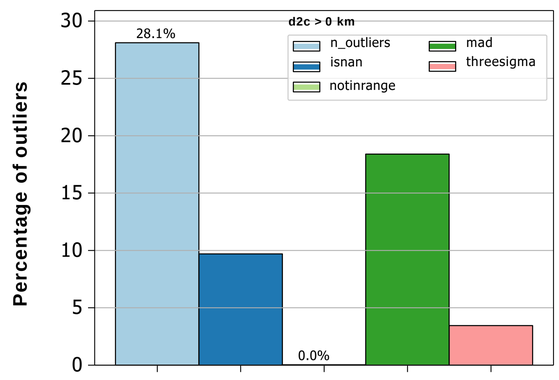

Figure 2: Percentage of outliers w.r.t. distance-to-coast (J3)

Noise Analysis

- Noise vs. SWH

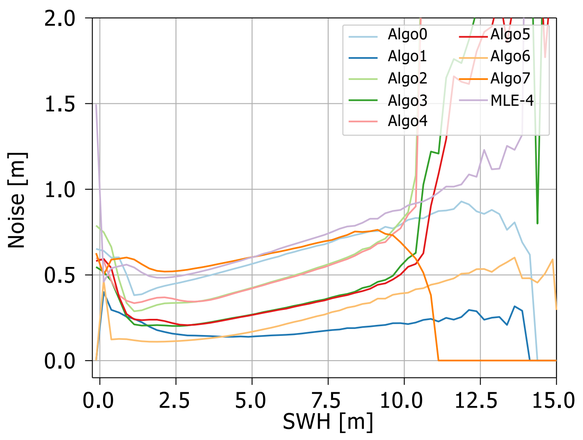

Figure 3: Noise w.r.t. SWH, comparison of all retrackers (J3)

Correlation with Model

- Correlation coefficient as a fct. of dist2coast/SWH

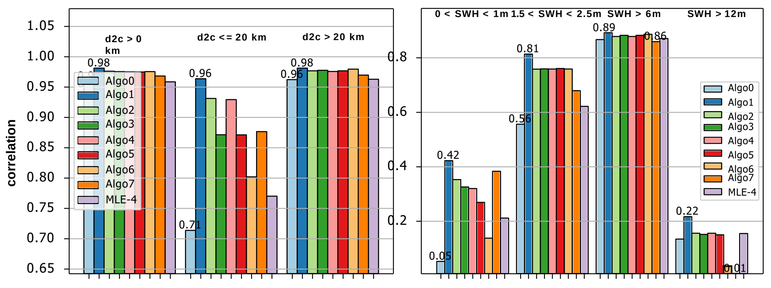

Figure 4: Correlation coefficient of retracked time-series vs. model data against ERA5-based hindcast model (J3)

Comparison with In-situ Data (buoys)

- Standard deviation of the differences (SDD)

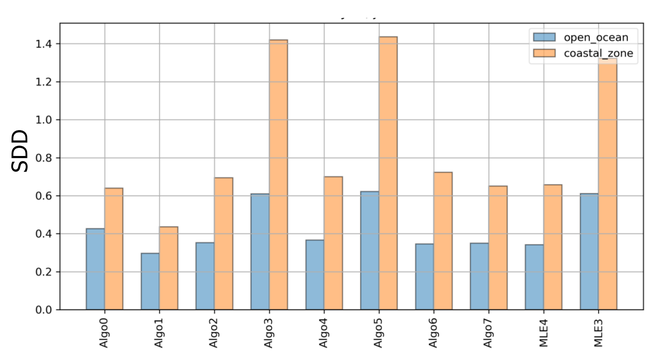

Figure 5: Comparison of altimeter-derived values (median of nearest 51 points) with buoy data interpolated to the overpass time. Many algorithms have a r.m.s. mismatch with open ocean in situ data of ~35 cm, but fare worse in the coastal zone, due to the effects of land and small-scale inhomogeneities within the altimeter footprint. (J3)

Representation of Scales of Variability

- Spectral analysis of SWH

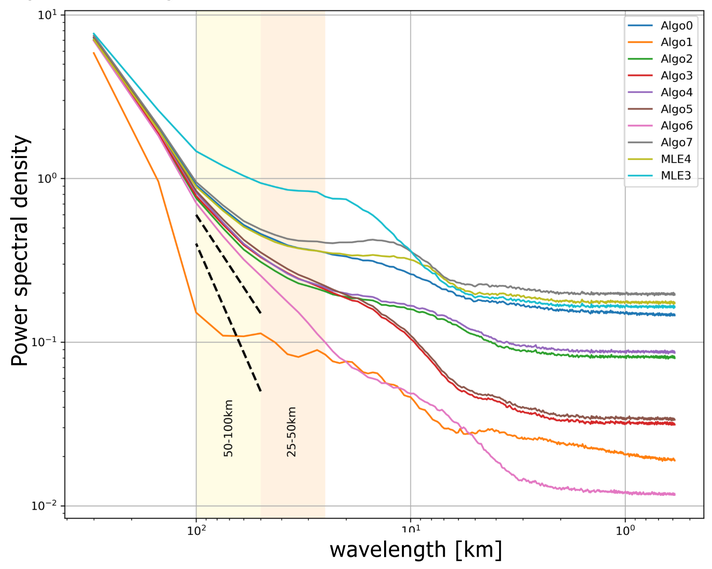

Figure 6: Along-track spectra of wave height according to the various algorithms. Spectra are averages of all open ocean near-continuous passes of 1024 points or more, using a Hanning window. The far right of the plot shows the immediate along-track variation due to response to fading noise, whilst the far left corresponds to the large-scale geophysical variation. The dashed lines indicate the range of spectral slopes expected at the mesoscale from a modelling study by Ardhuin et al. (2017). (J3)

Results and Conclusion

- Outliers: Mostly NaNs, increasing in coastal area
- Noise: Improved by most of the novel retracker algorithms
- Correlation with model/buoy data: Significant improvement against standard retracker algorithms
- Representation of scales of variability: Some retrackers are not able to model spectral power at mesoscale
- Interpretation is ongoing and participants will be provided with the full analysis

Round Robin Assessment → excellent opportunity for:

- Objective comparison of state-of-the-art retracking algorithms
- Harmonisation of algorithm evaluation process
- Reusability for other projects that involve satellite altimetry

References and Acknowledgements:

- ESA Climate Change Initiative Sea State Project, http://cci.esa.int/seastate
- Ardhuin, F et al. (2017): Small-scale open ocean currents have large effects on wind wave heights, J. Geophys. Res. Oceans,122, 4500-4517, doi:10.1002/2016JC012413
- Ardhuin, F et al. (2019): Observing Sea States. Frontiers in Marine Science, 10.3389/fmars.2019.00124

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