

CP40 CCN1 WP4000: Extended evaluation of CryoSat-2 SAR data in the Coastal Zone

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**National
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NATURAL ENVIRONMENT RESEARCH COUNCIL

Preamble: Coastal zone benefits from SAR mode

- Higher SNR
 - can detect small signals in 'noisy' (from the point of view of altimetry observables) coastal zone
- Much higher along-track resolution
 - part of it can be traded off, if not needed, in change for further noise reduction
- Reduced contamination by land and coastal targets (depending on their position)
- Access to individual echoes allows editing out affected echoes or doppler bins

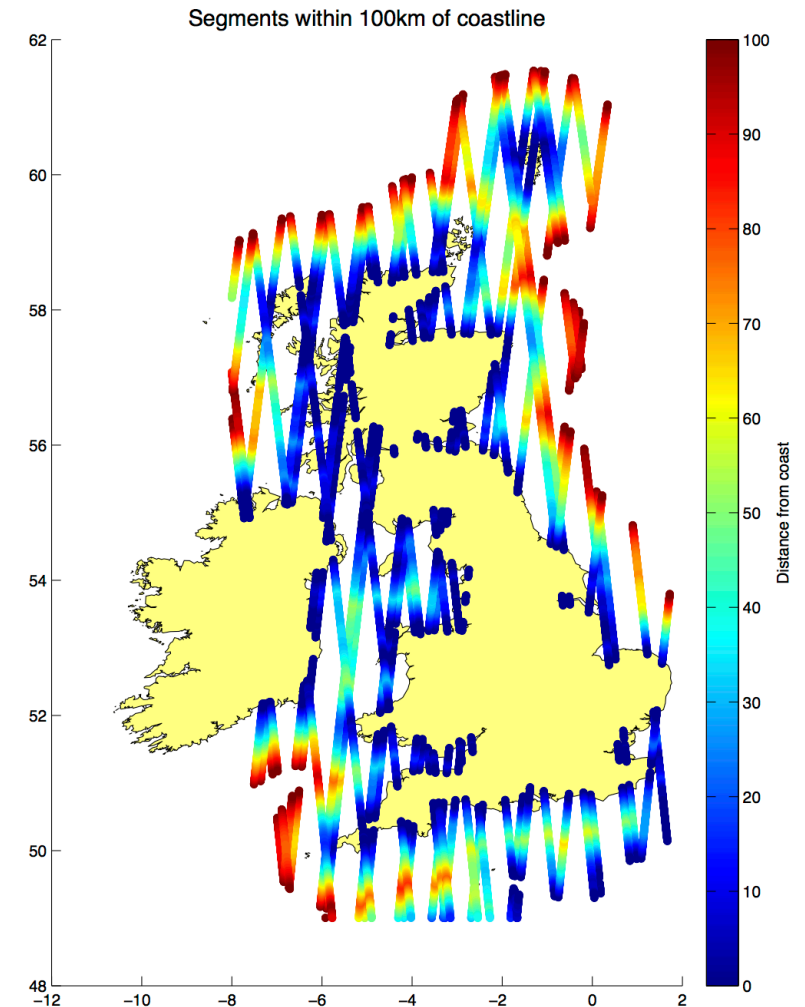
The first question is how precise and accurate are the measurements in the coastal zone? And how close to the coast can we get within a given level of precision?

verification

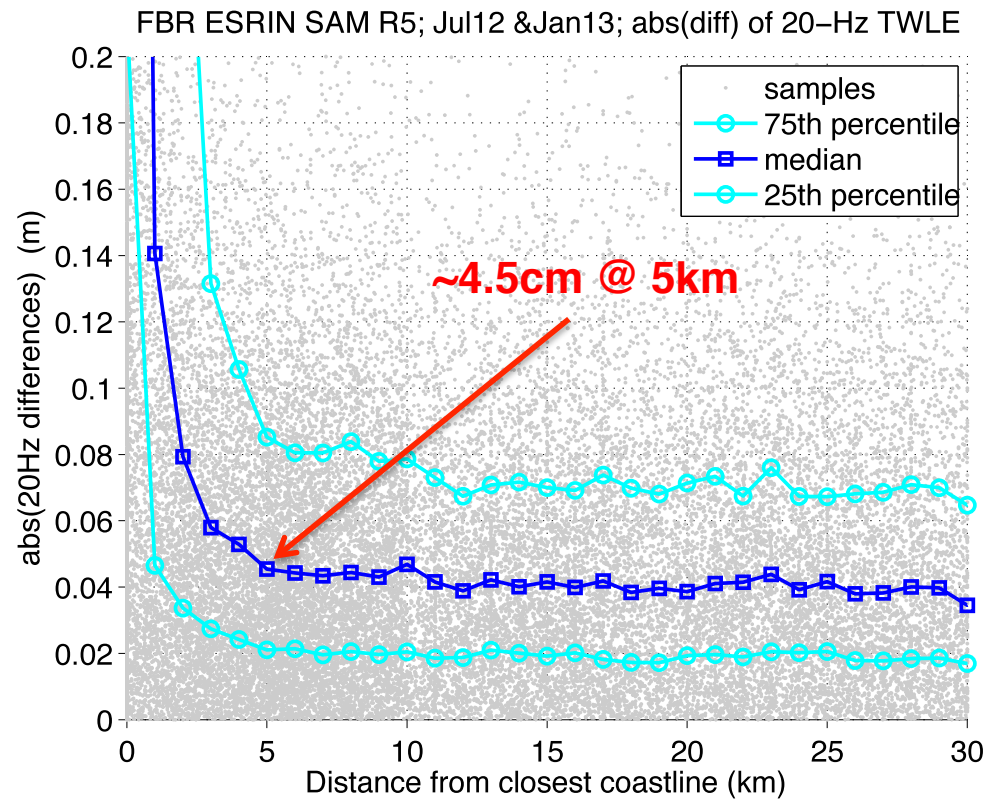
validation

Recap from CP4O main contract

- We had carried out a preliminary assessment (verification) of Cryosat-2 SAR mode data carried out within the ESA CP4O Project
 - UK coastline only
 - using 2 months of data from SARvatore processor run at ESRIN
- Results were encouraging in terms of performance (precision)
- ...but puzzling in terms of '**angle to coast**', i.e. direction of approach of the satellite with respect to the coast
- We had also tried a **validation against UK tide gauges** but had found **very large biases** (likely coming from L1 data as also observed in RADS at the time)

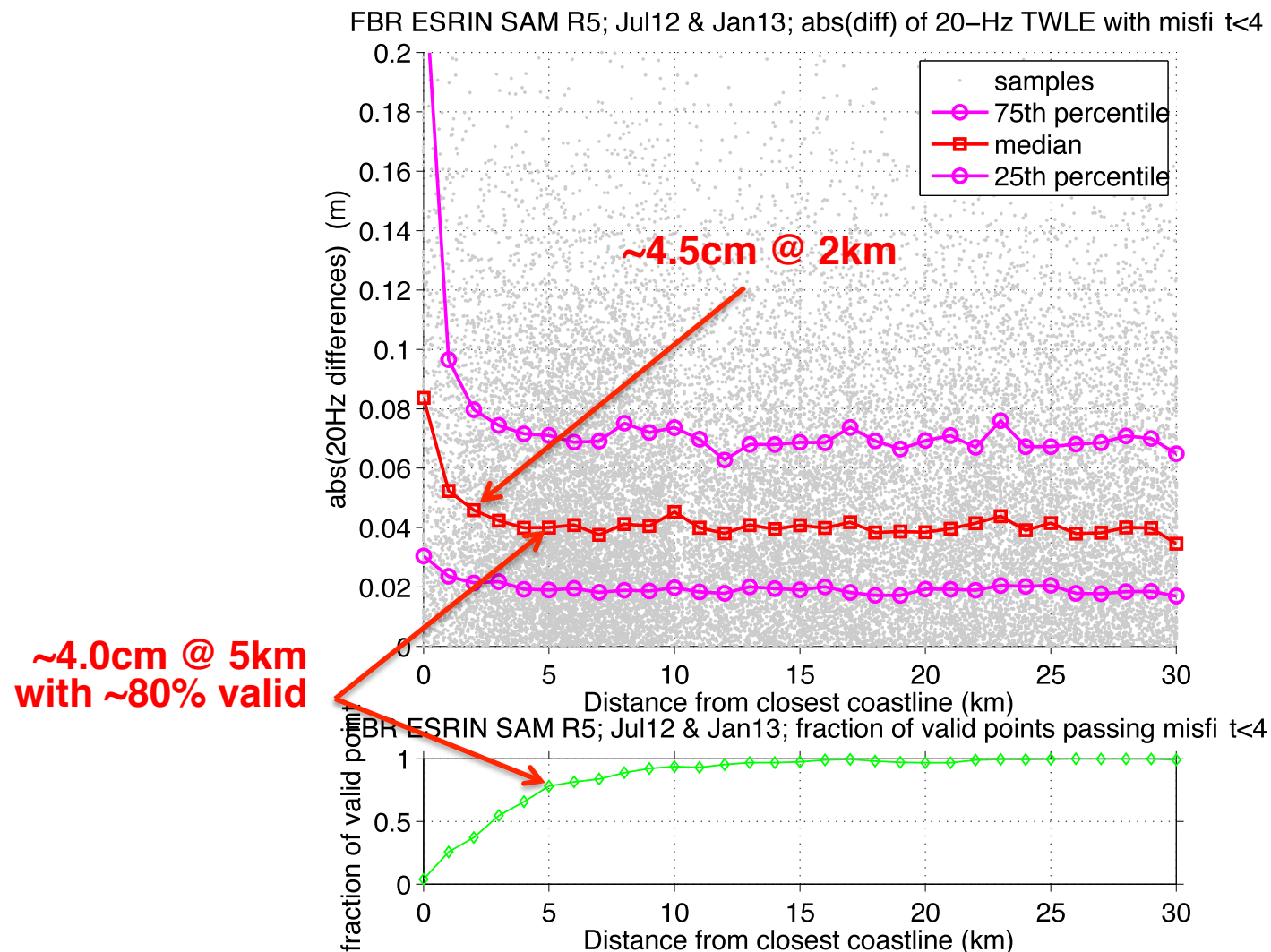


Previous results: noise vs distance

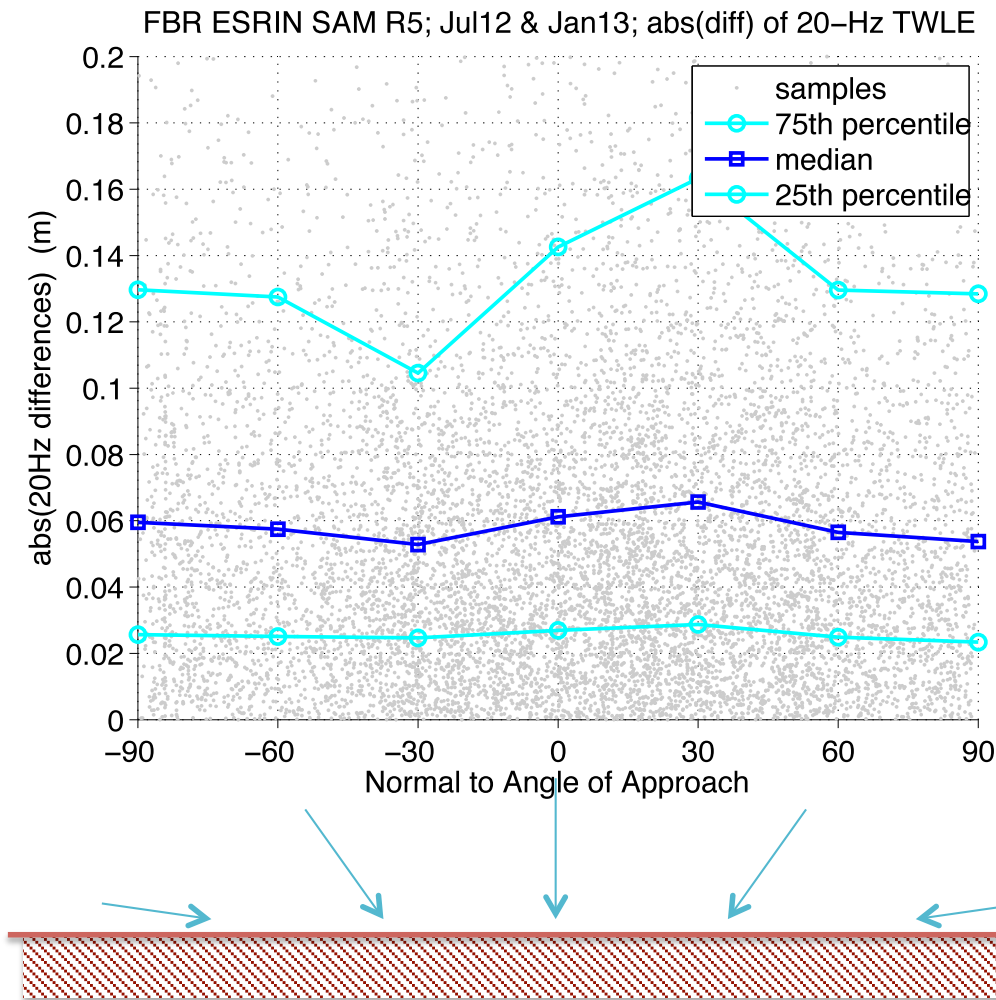


Previous results: noise vs distance

With additional screening based on retracking misfit



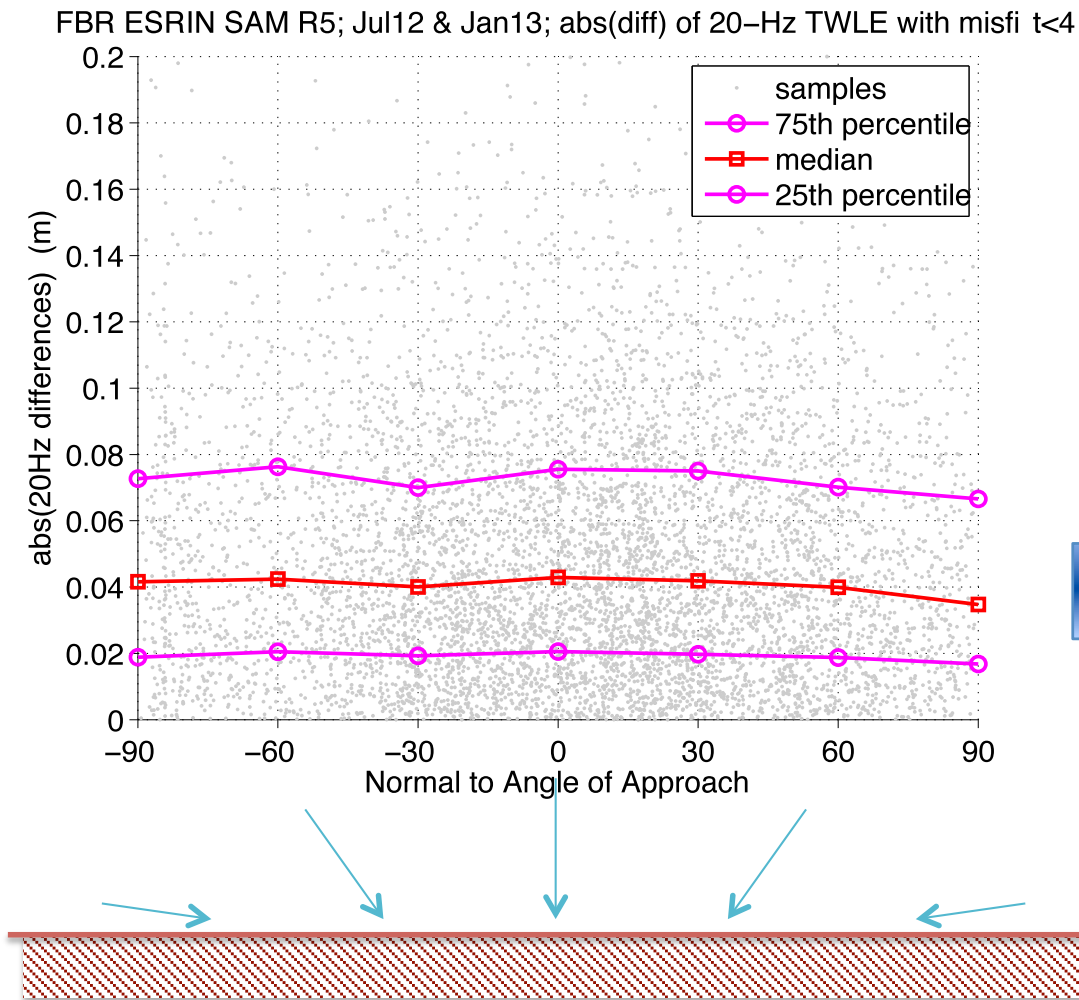
Previous results: noise vs angle



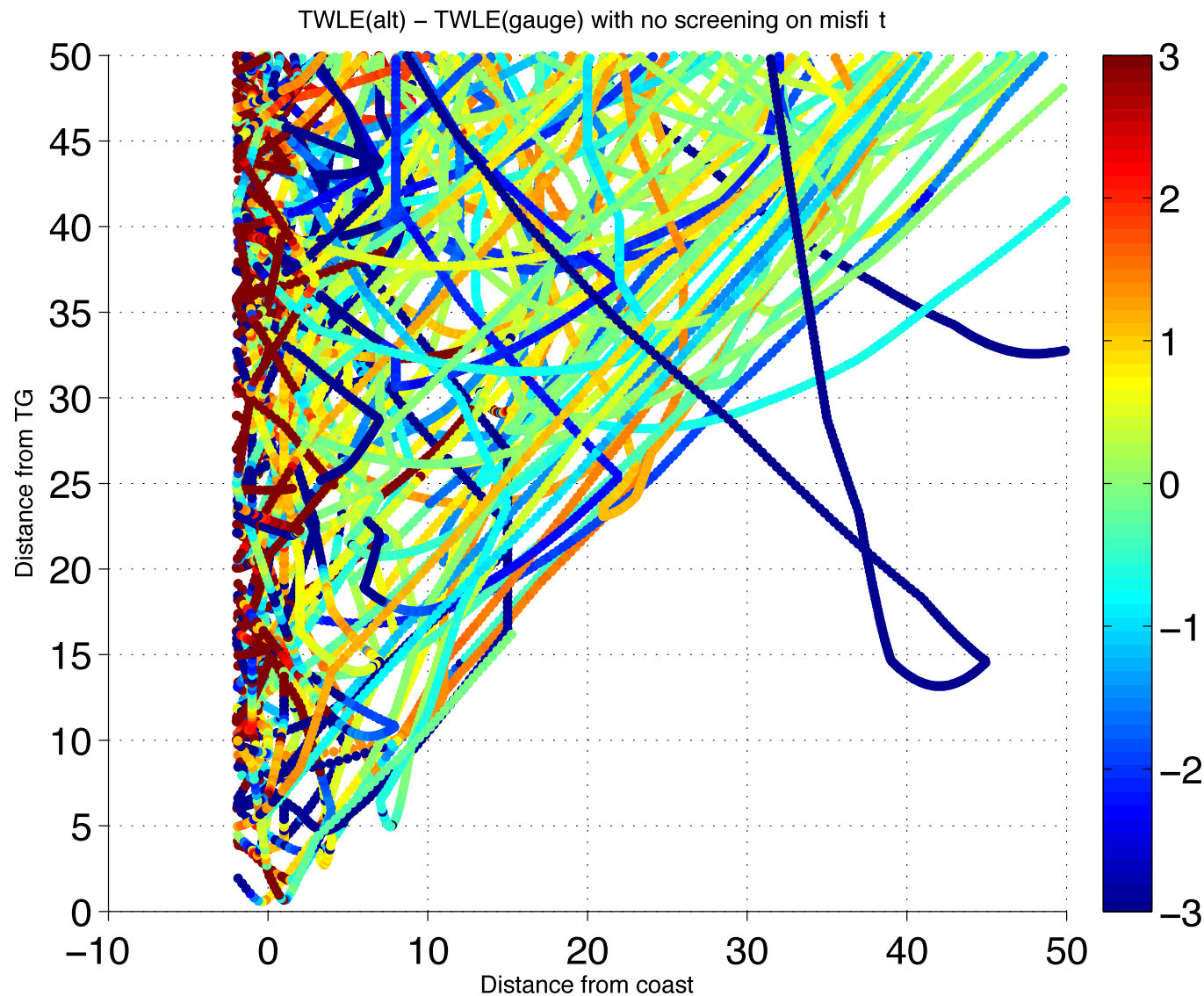
??

Previous results: noise vs angle

With additional screening based on retracking misfit



Previous results: validation wrt UK TGs



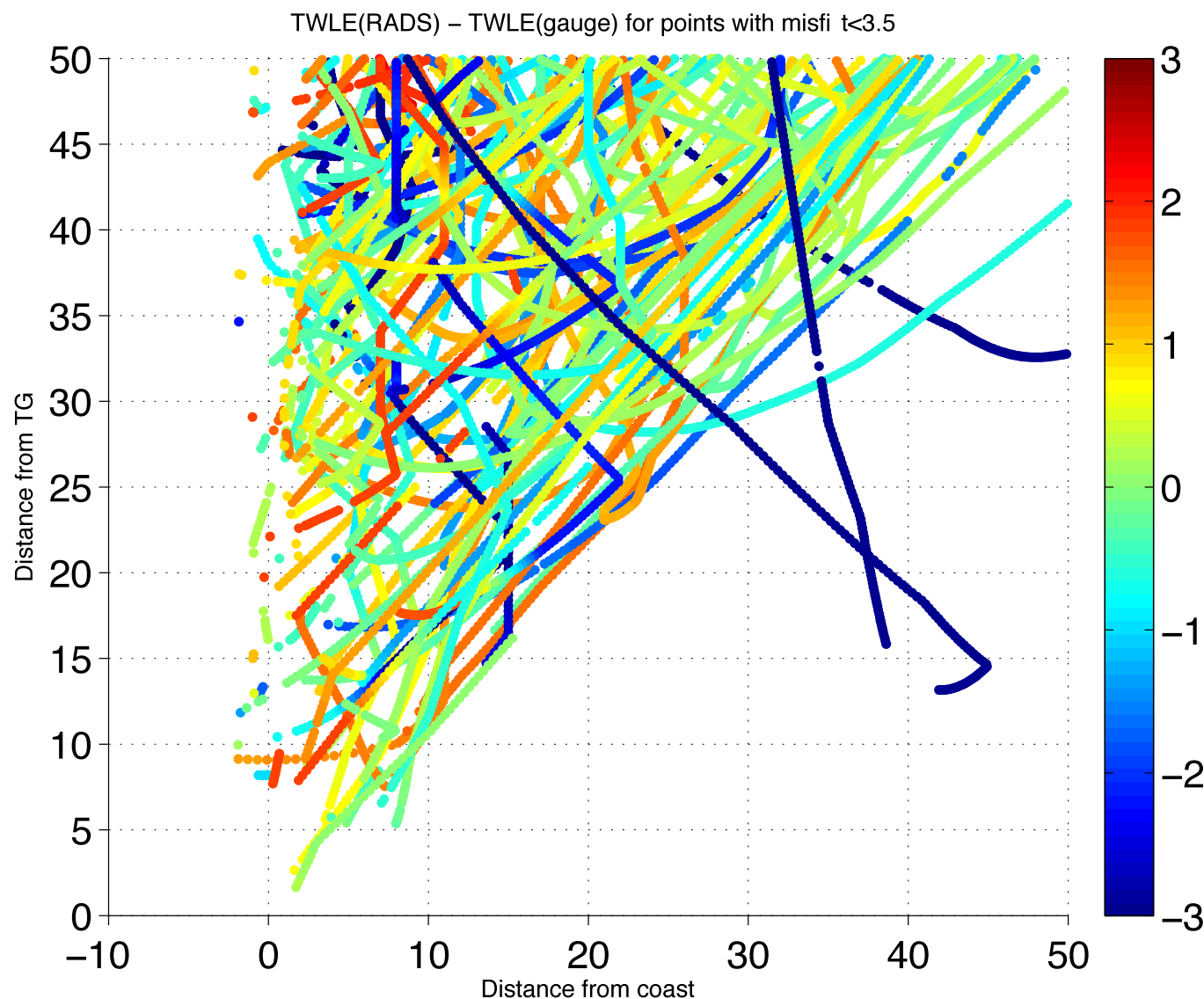
Validation is done using Total Water Level Envelope (TWLE) – i.e. sea level with tides and atmospheric forcing left in

Previous results: validation wrt UK TGs



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Previous results: validation wrt UK TGs



→ These large biases were coming from L1 data available at the time!

Extended study in the CCN

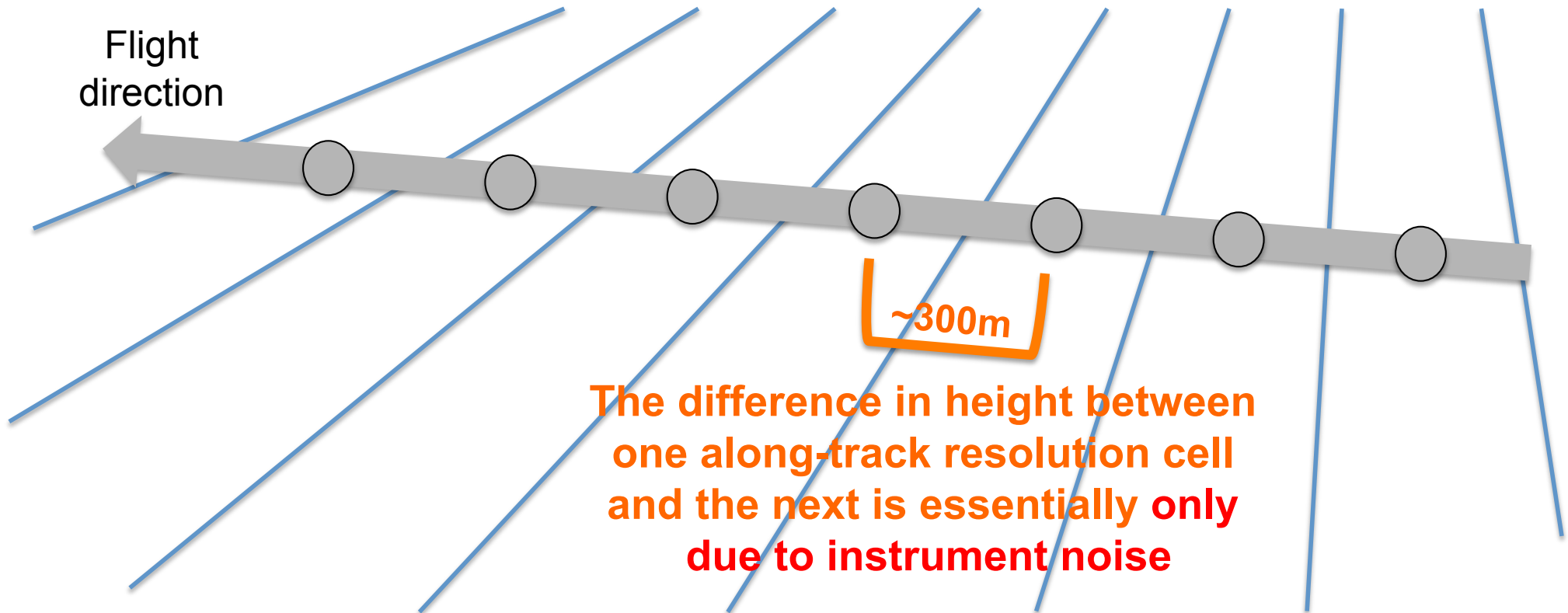
- One full year of data (1 Nov 12 to 31 Oct 13)
- 50-km coastal strip around all of British Isles
- Two processors:
 - **CNES CPP**: numerical retracker, very efficient, but not optimized for coastal zone (thanks to F. Boy for providing the data)
 - **ESRIN GPOD** (based on SARvatore) in a configuration optimized for coastal zone (Hamming weighting, extended range window, FFT zero padding)

SAR processors configuration

SAR L1b Processing Options	CPP	GPOD
Hamming Weighting Function	Not Applied	Applied only in Coastal Zone
Beam Steering	Approximated	Approximated
Radar Window Size	Normal (128 bins)	Extended (256 bins)
Range pre-FFT Zero Padding	Not Applied	Applied

SAR L2 Processing Options	CPP	GPOD
SAR Return Waveform Model	Numerical Solution with real antenna pattern & real PTR	SAMOS 2 with LUT for alpha_p (PTR width)
Delay Doppler Map (DDM) Masking	Applied	Applied

Assessing SAR mode performance



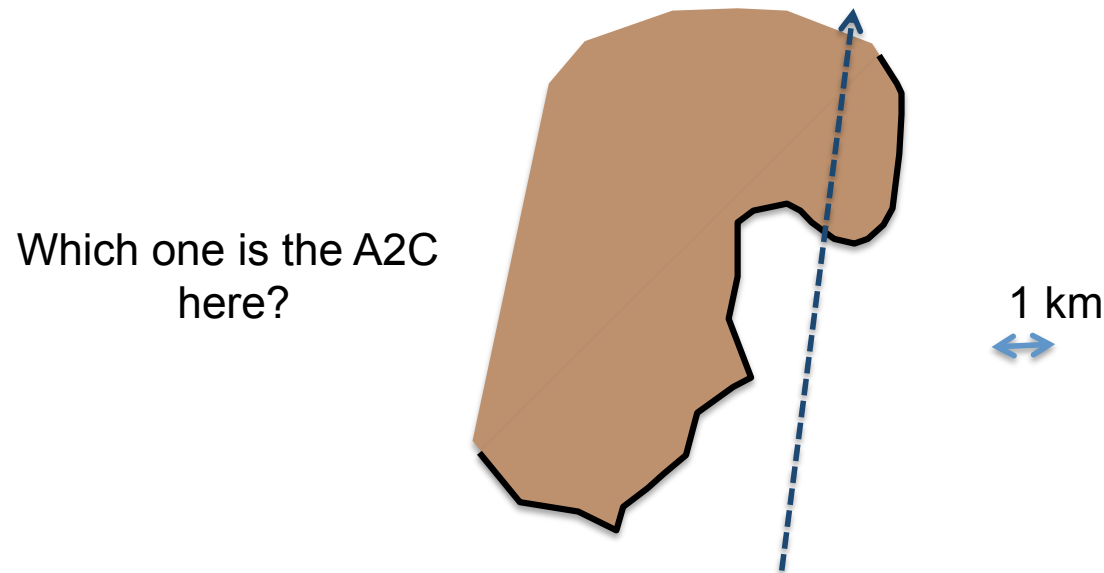
We use the absolute value of this difference as an indication of noise in that particular location along the track

Differences as estimates of noise

- We can safely assume that SSH does not change significantly over ~ 300 m
- **→ difference between adjacent 20-Hz SSH values is essentially a measure of the noise**
- if noise were gaussian:
 - $\text{noise} = \text{std}(\text{diff}(\text{SSH})) / \sqrt{2}$
- in practice outliers in $\text{diff}(\text{SSH})$ cause problems; a more robust estimate is
 - $\text{noise} = \text{median}(\text{abs}(\text{diff}(\text{SSH})))$

Which independent variable?

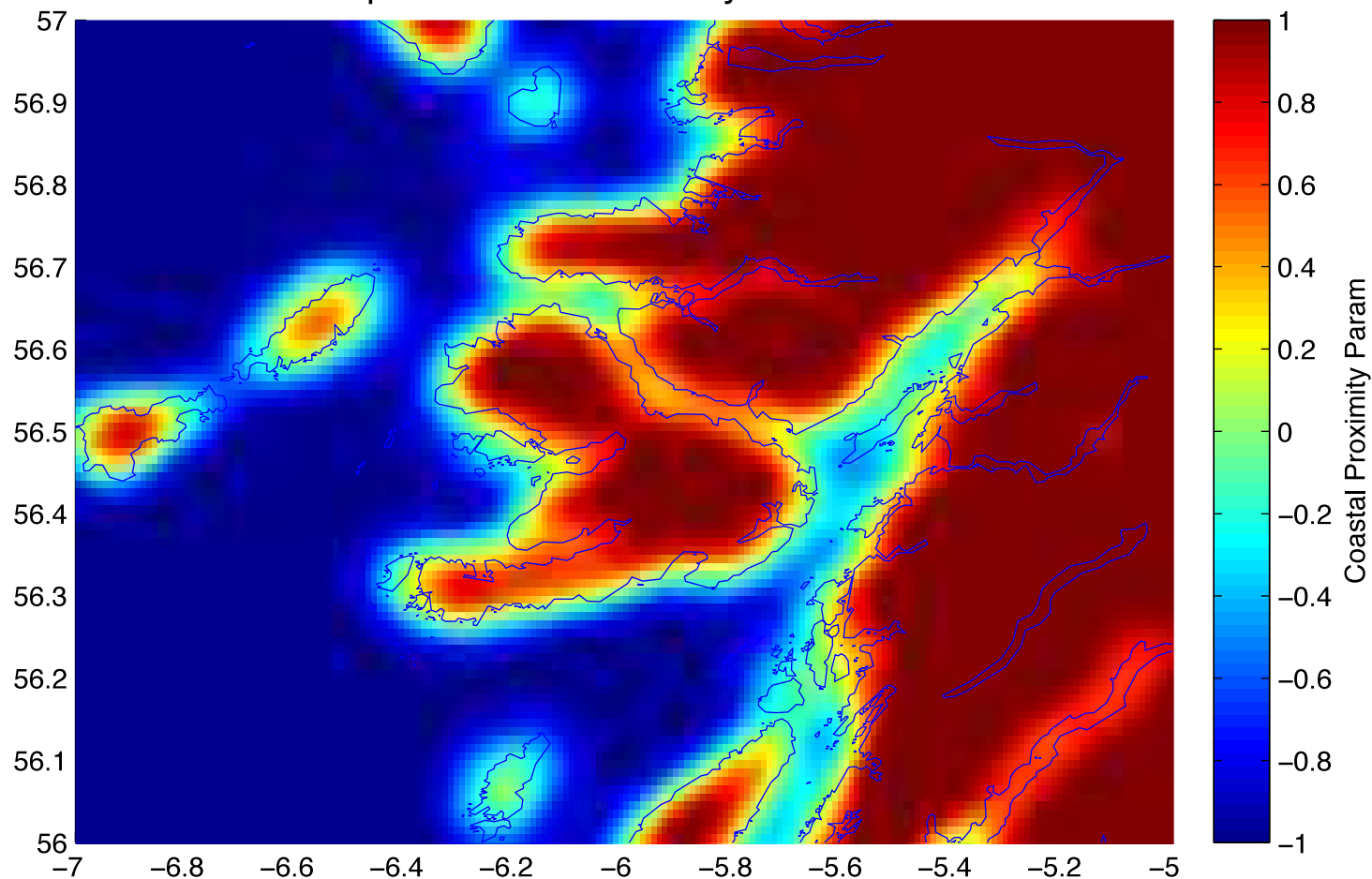
- Across-track distance is not much ambiguous (narrow SAR footprint well approximated by a line)
- “Angle to Coast” (A2C) is much more ambiguous
- For instance:



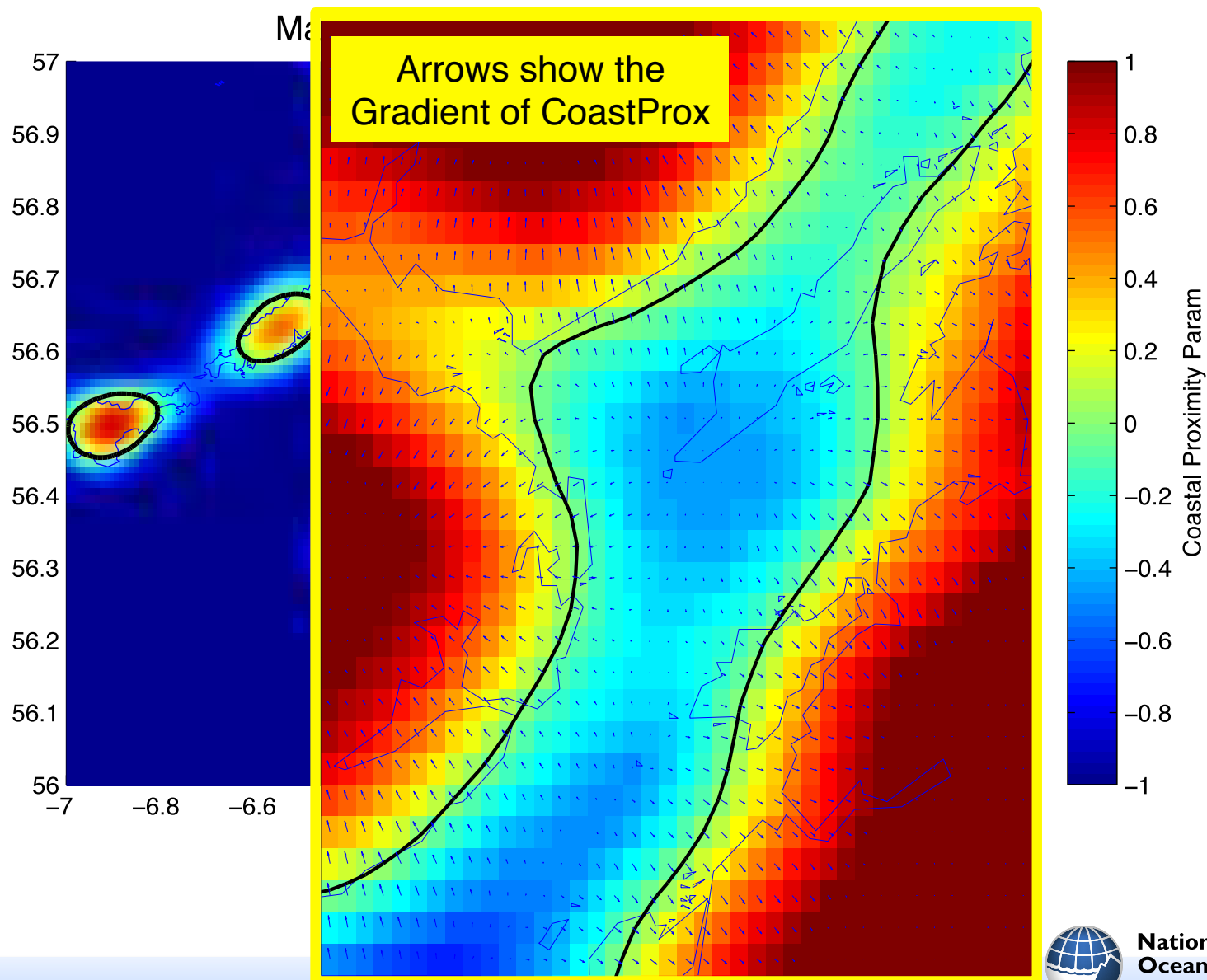
- (we now use an objective definition based on the gradient of the coastal proximity parameter, which was presented last year)

Example off W Scotland

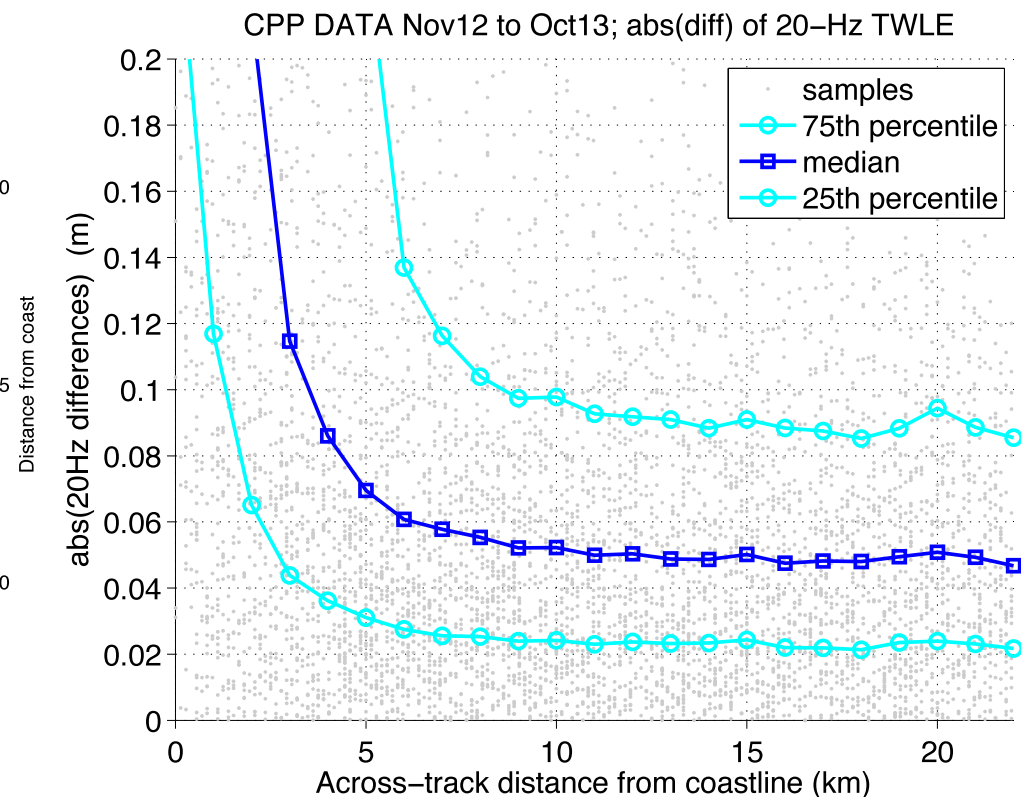
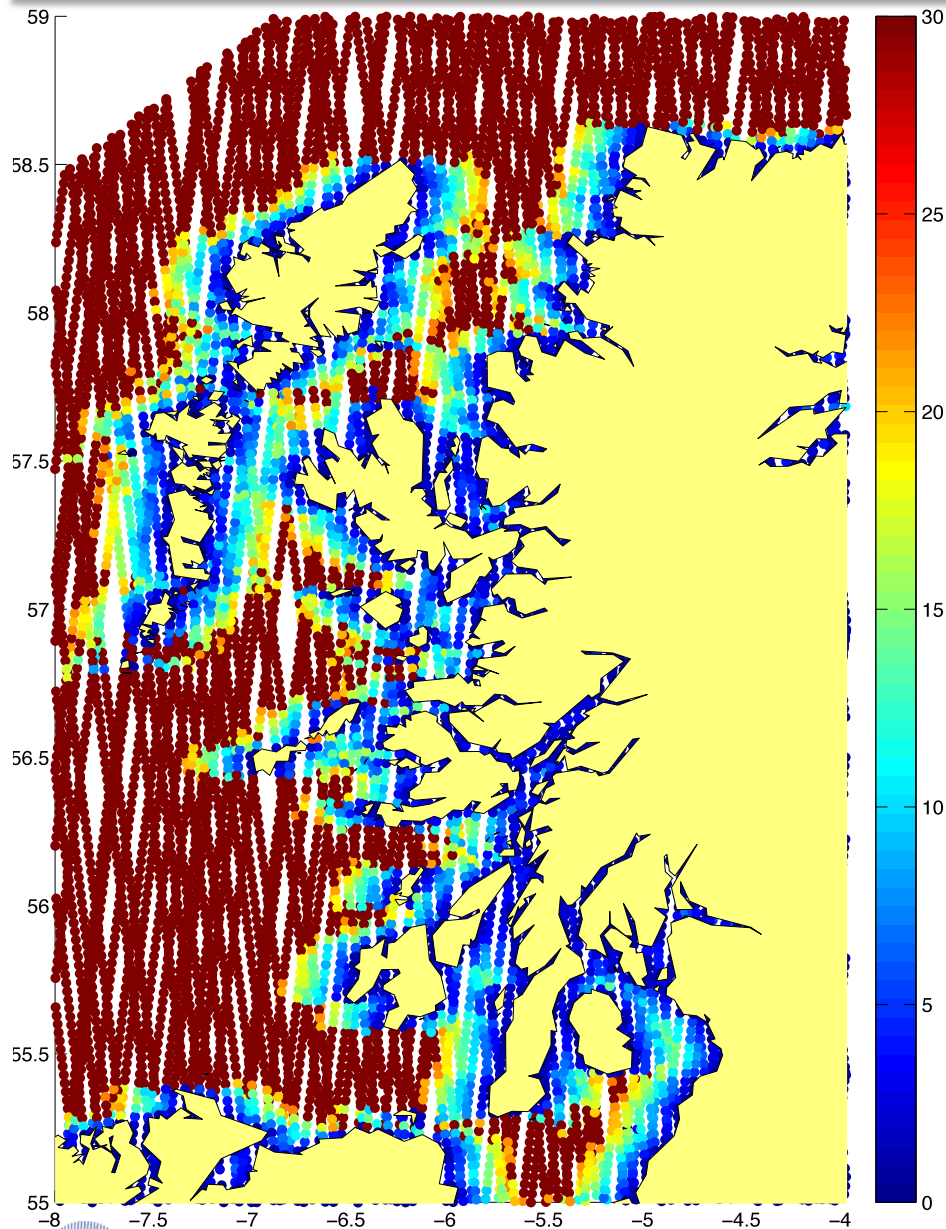
Map of Coastal Proximity Parameter



Example off W Scotland



Across-track distance from coast



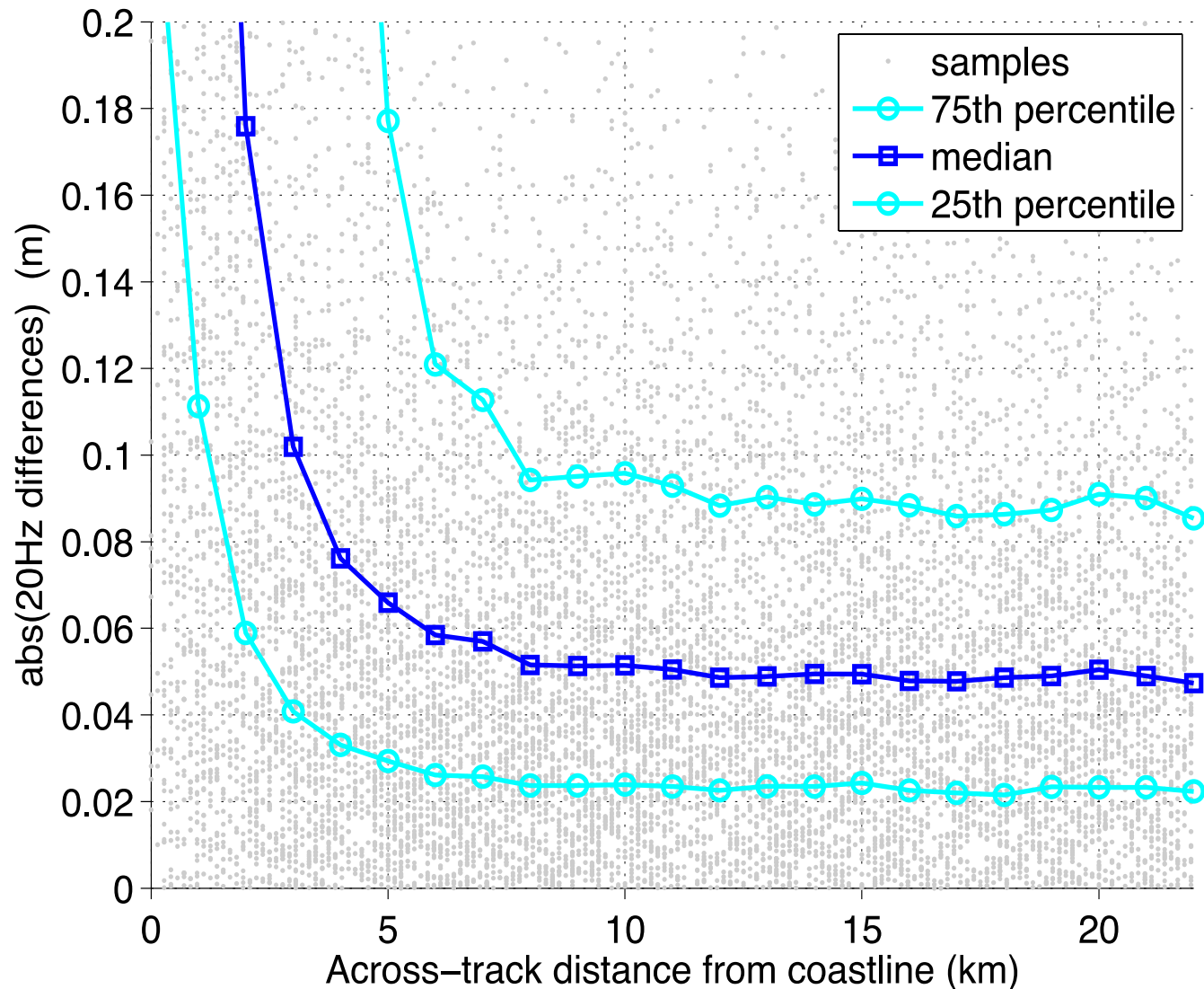
CP40 - CryoSat Plus for Oceans Project
C2 data from CPP processor (1 full year around UK)
provided by F. Boy, CNES

Results – Verification

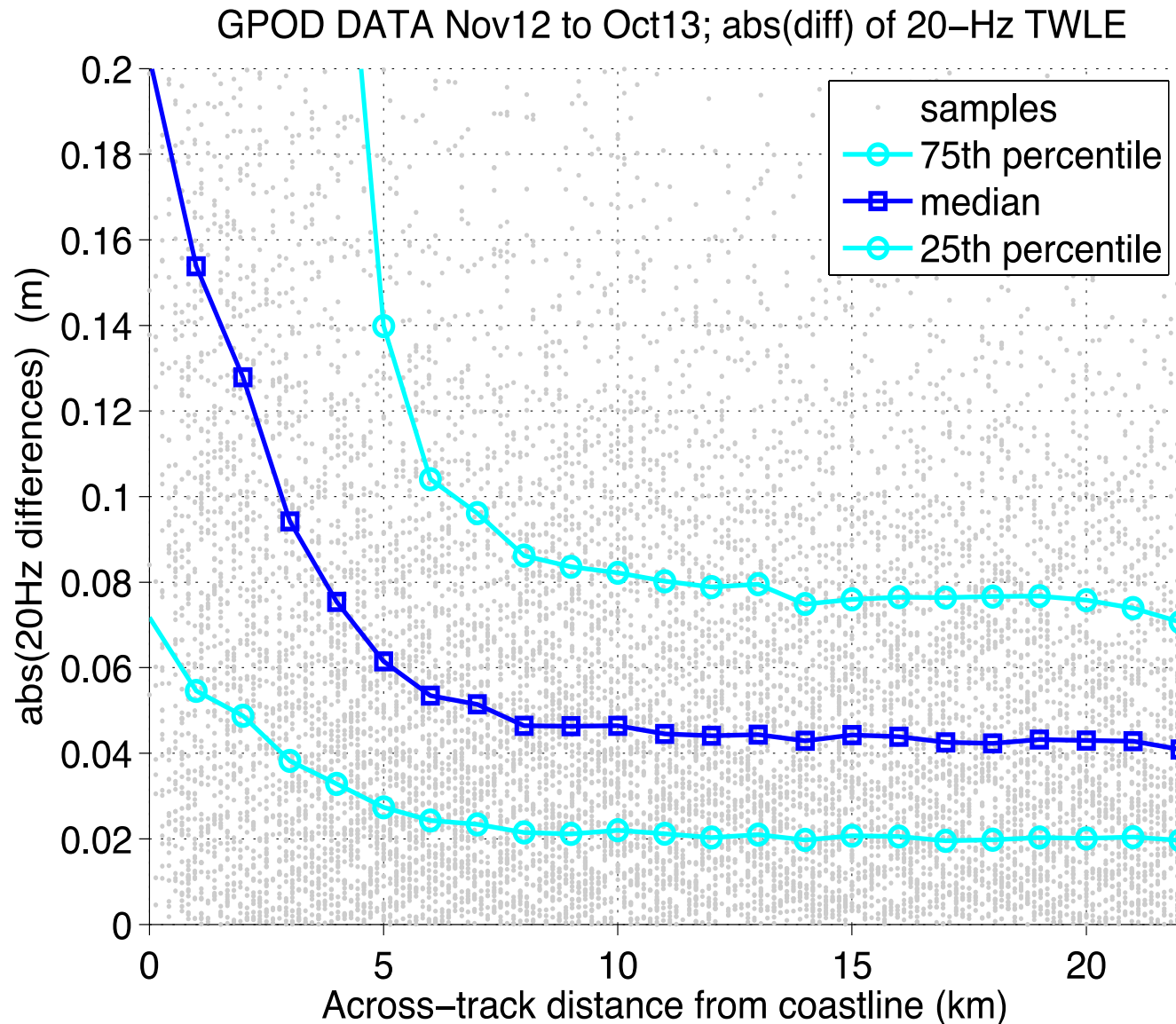
(assessment of precision / instrumental noise)

CPP – vs across-track distance

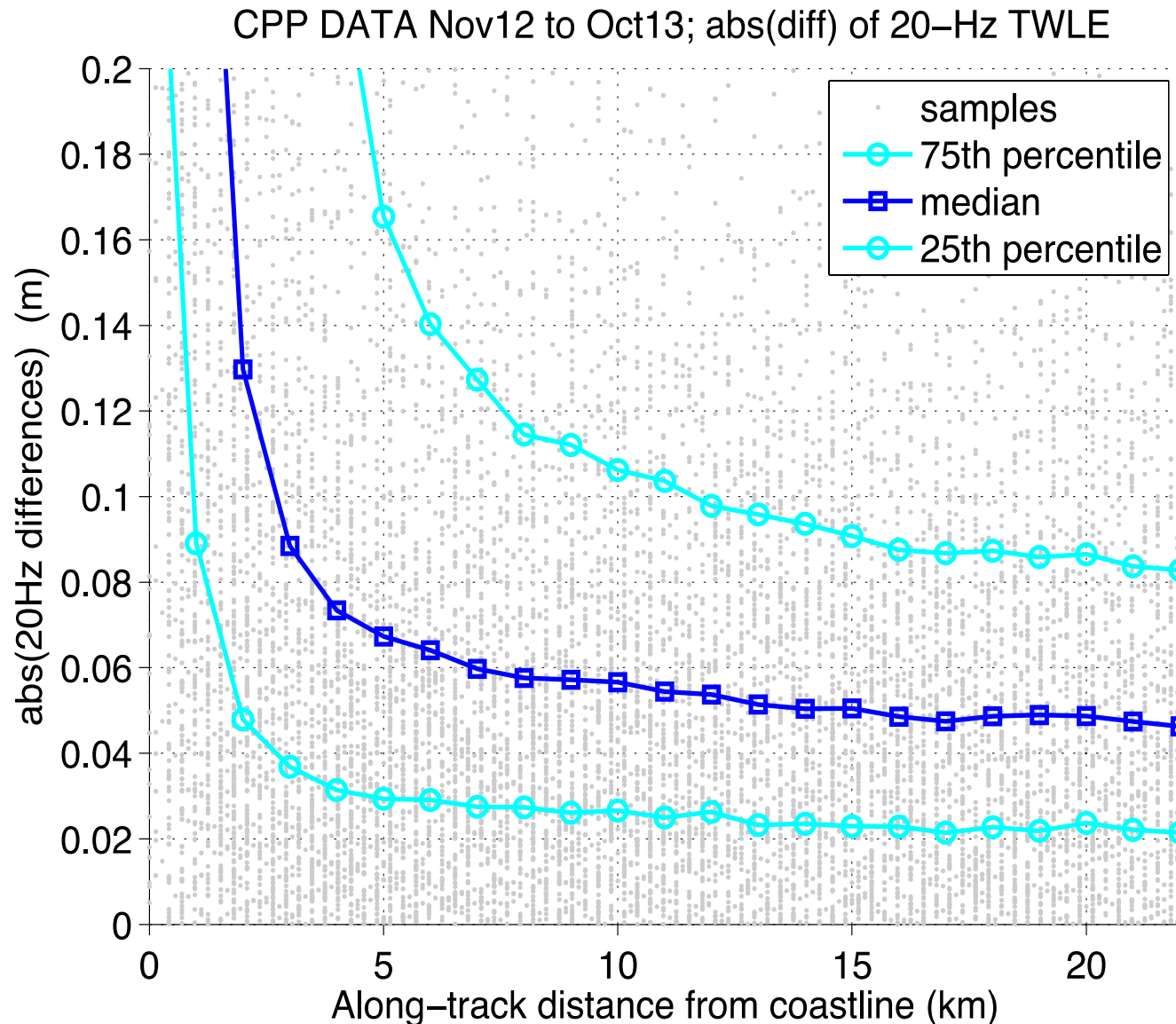
C-2 SAR is pulse-limited across-track → plot is similar to what we get from Envisat
CPP DATA Nov12 to Oct13; abs(diff) of 20-Hz TWLE



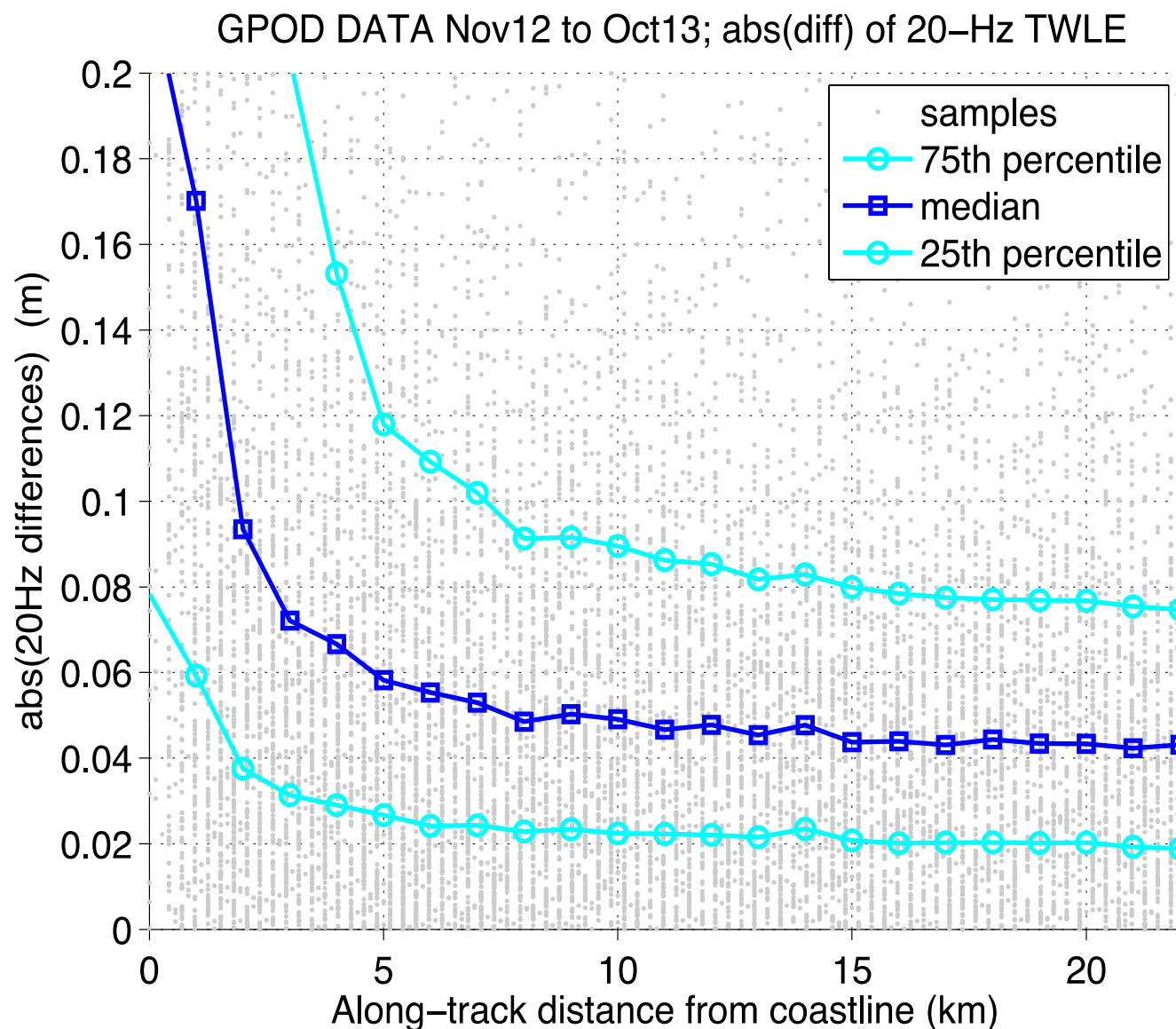
GPOD – vs across-track distance



CPP – vs along-track distance



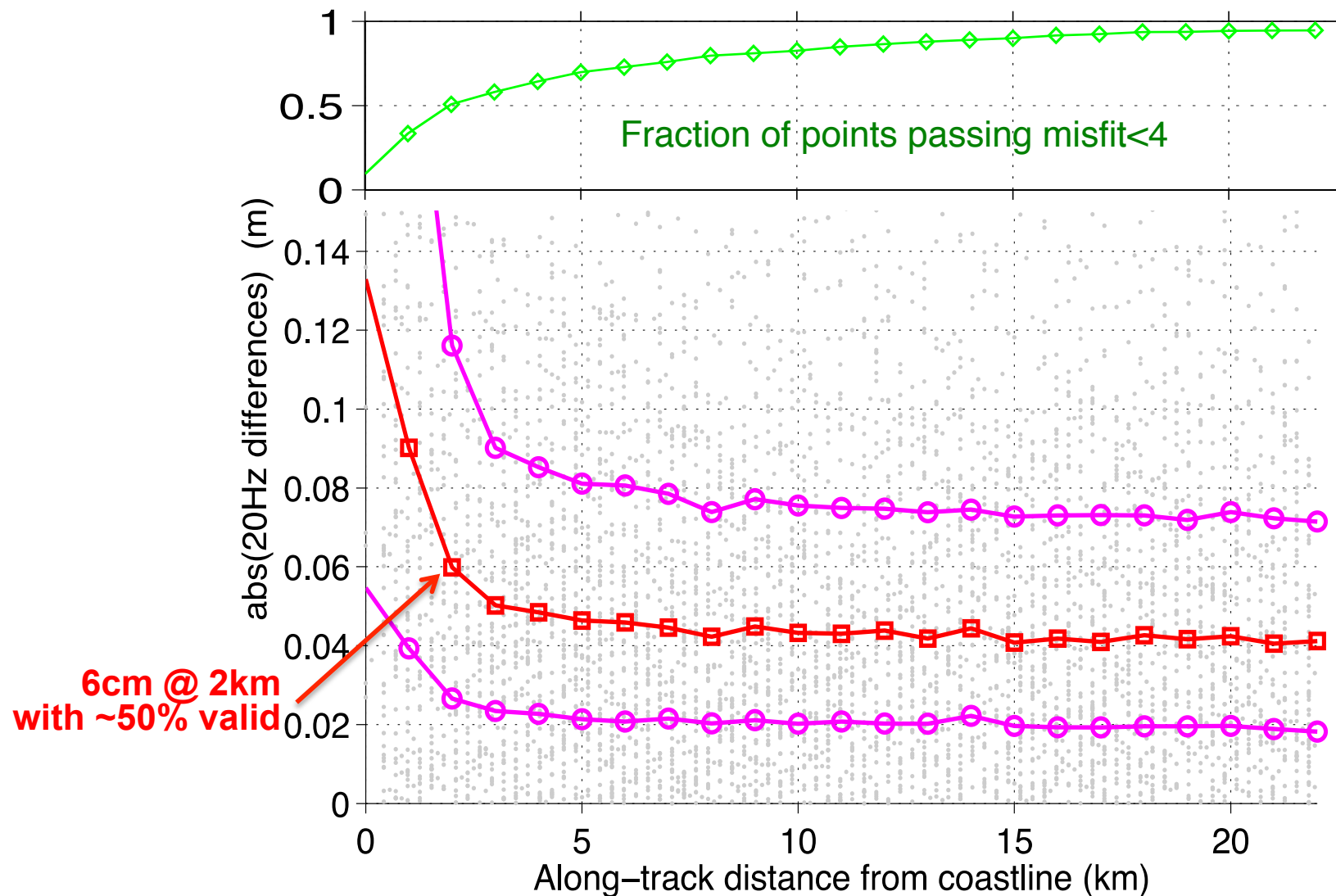
GPOD – vs along-track distance



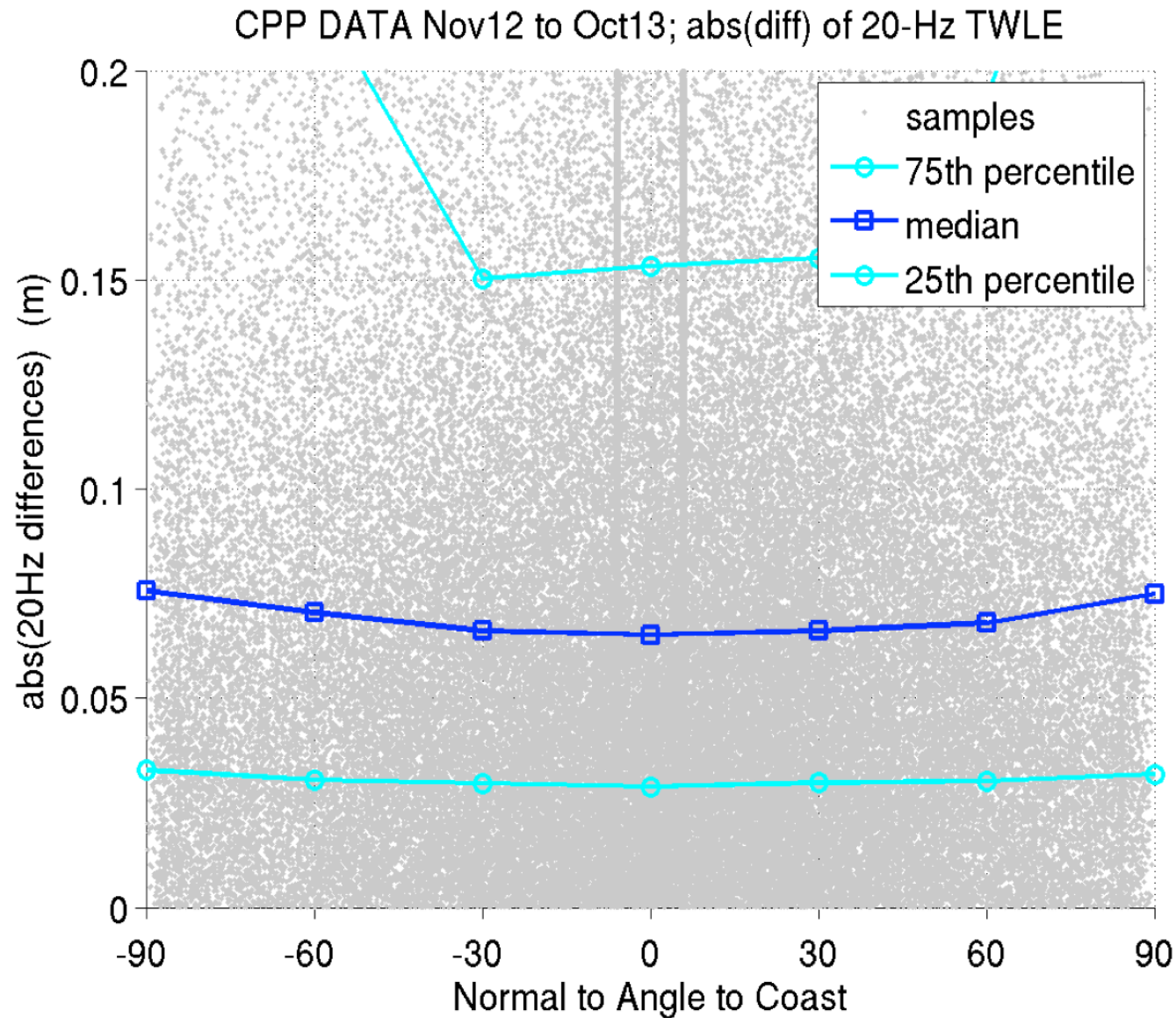
GPOD – vs along-track distance

With additional screening based on retracking misfit

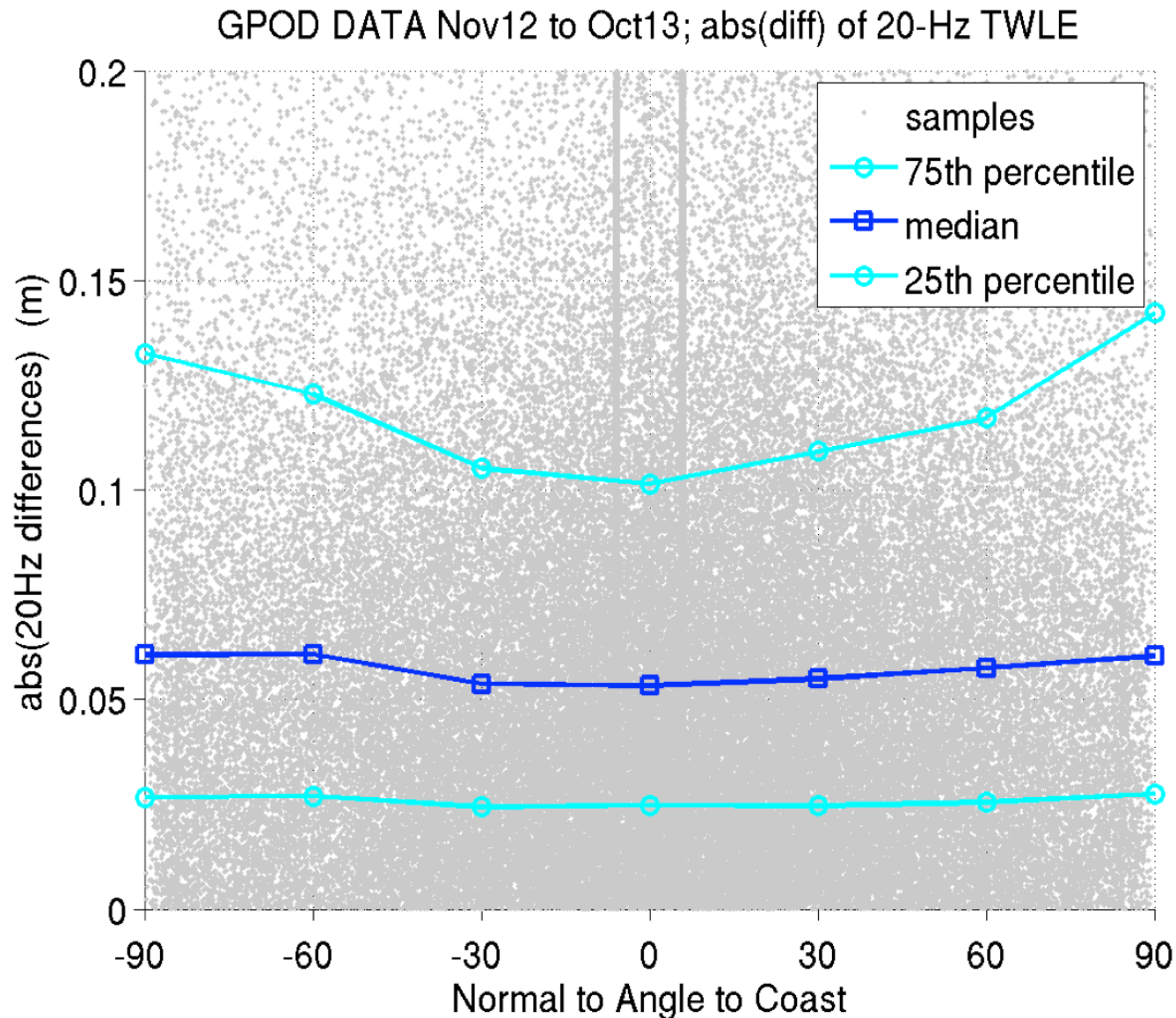
GPOD DATA Nov12 to Oct13; abs(diff) of 20-Hz TWLE with misfit<4



CPP – vs angle to coast

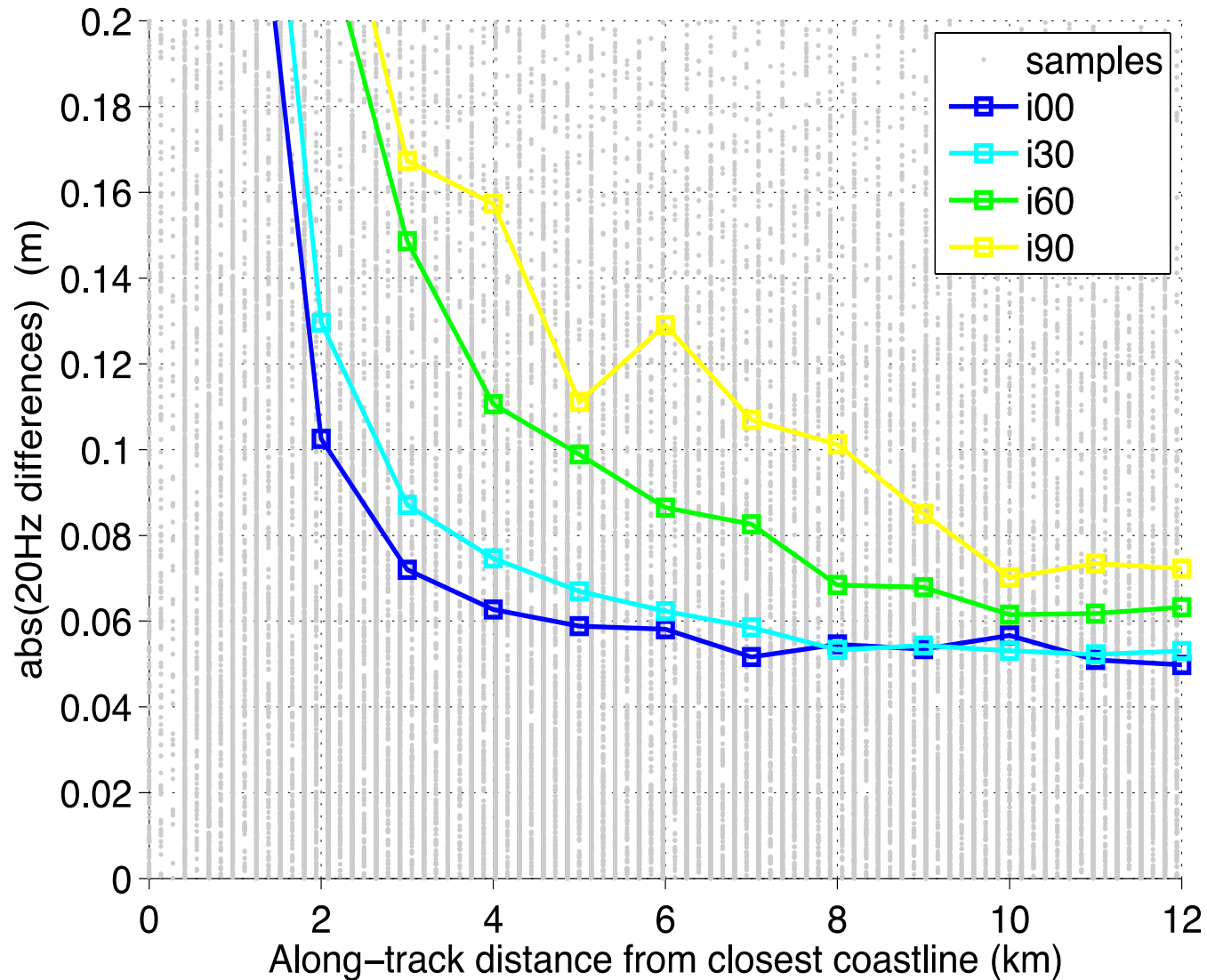


GPOD – vs angle to coast



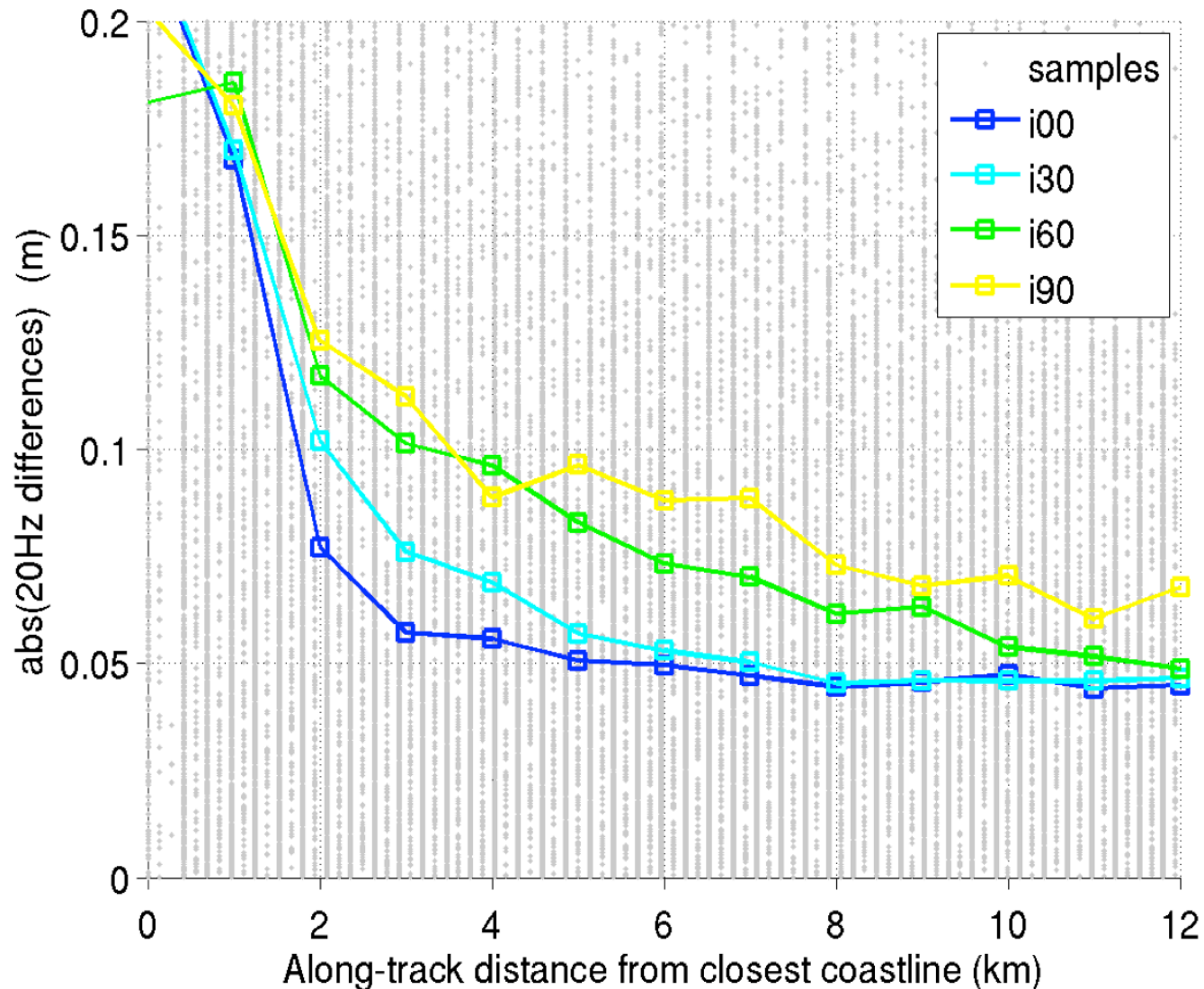
CPP in angle ranges

CPP DATA Nov12 to Oct13; abs(diff) of 20-Hz TWLE

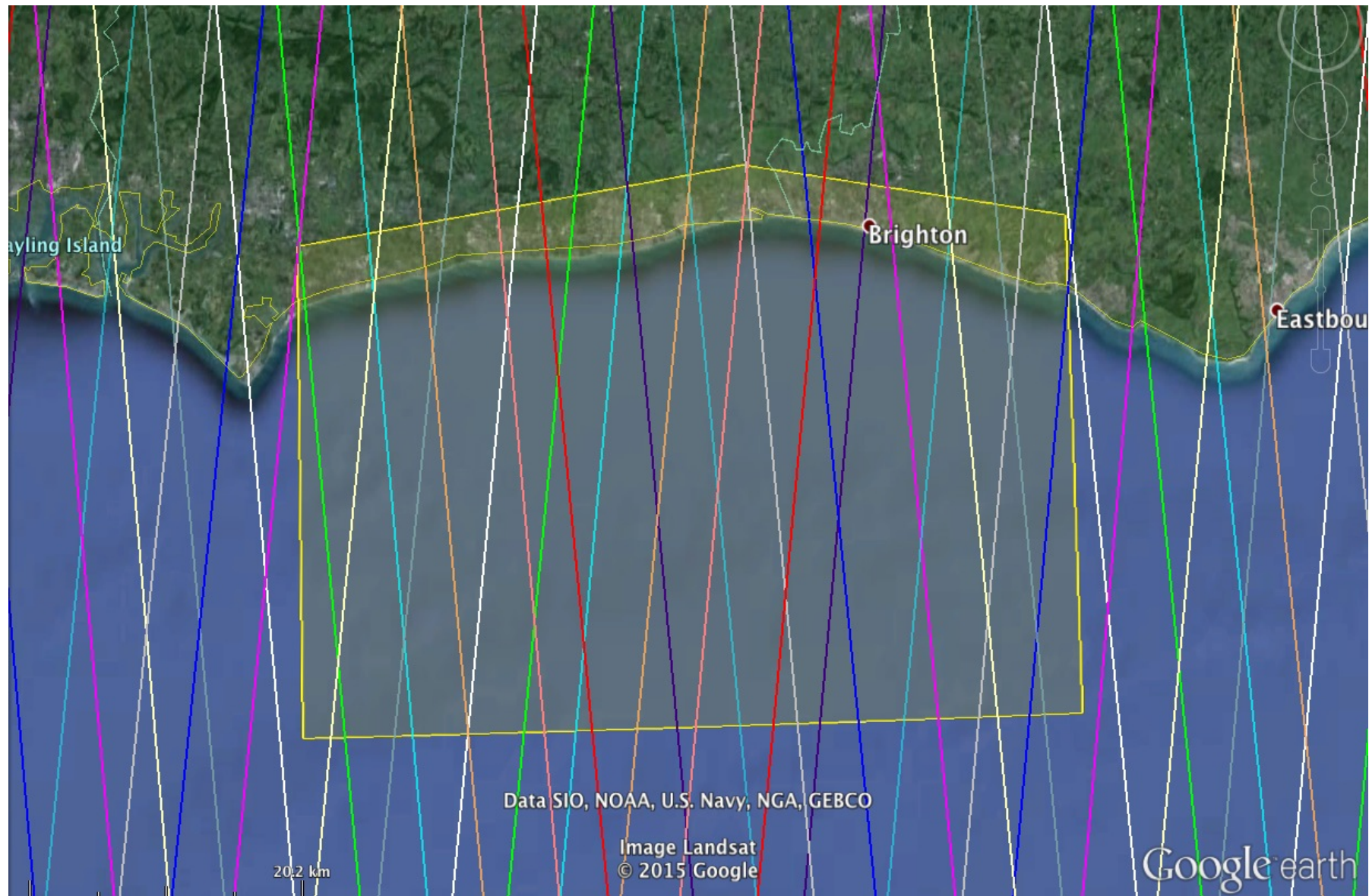


GPOD in angle ranges

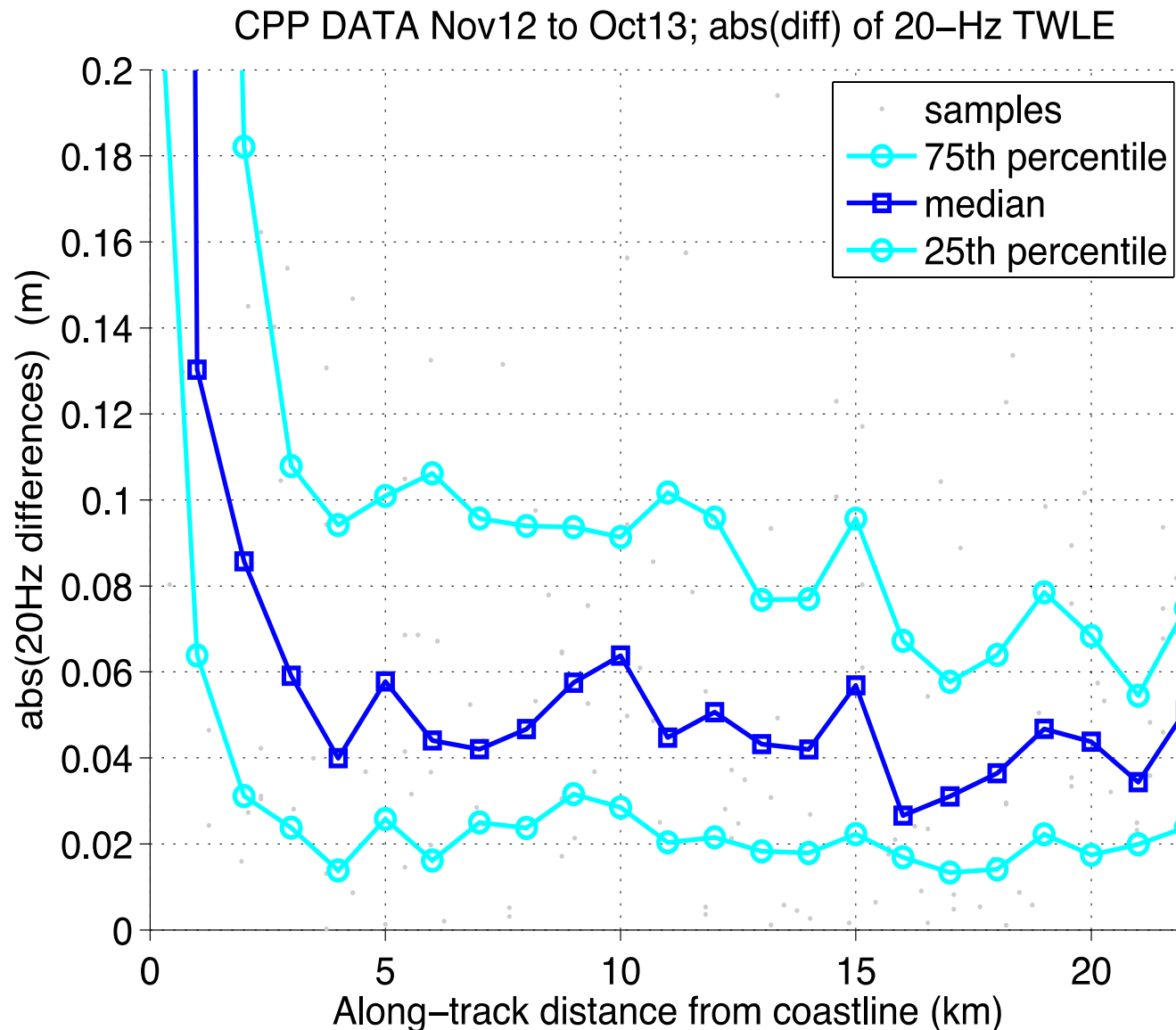
GPOD DATA Nov12 to Oct13; abs(diff) of 20-Hz TWLE



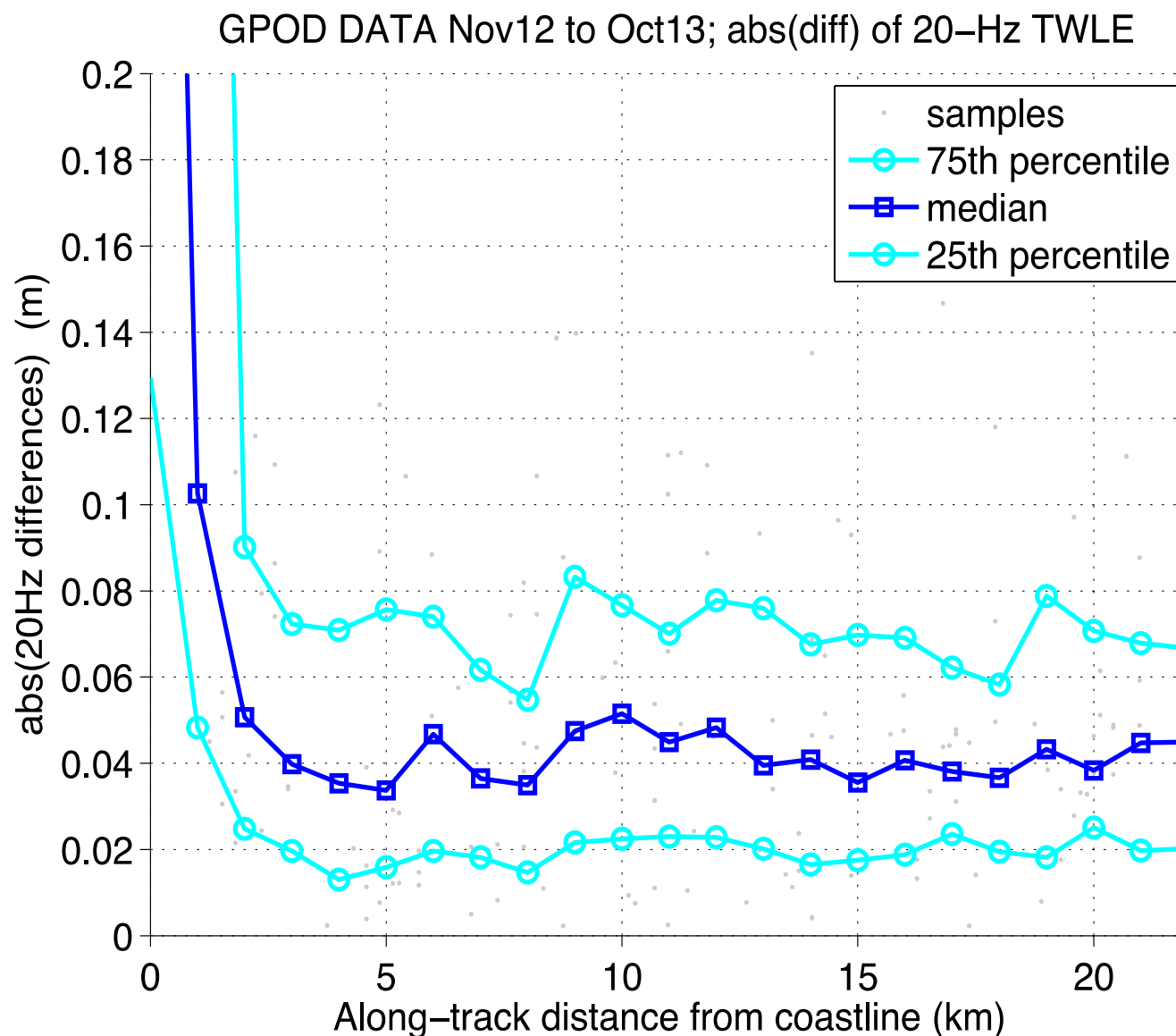
A good case study: Brighton Box



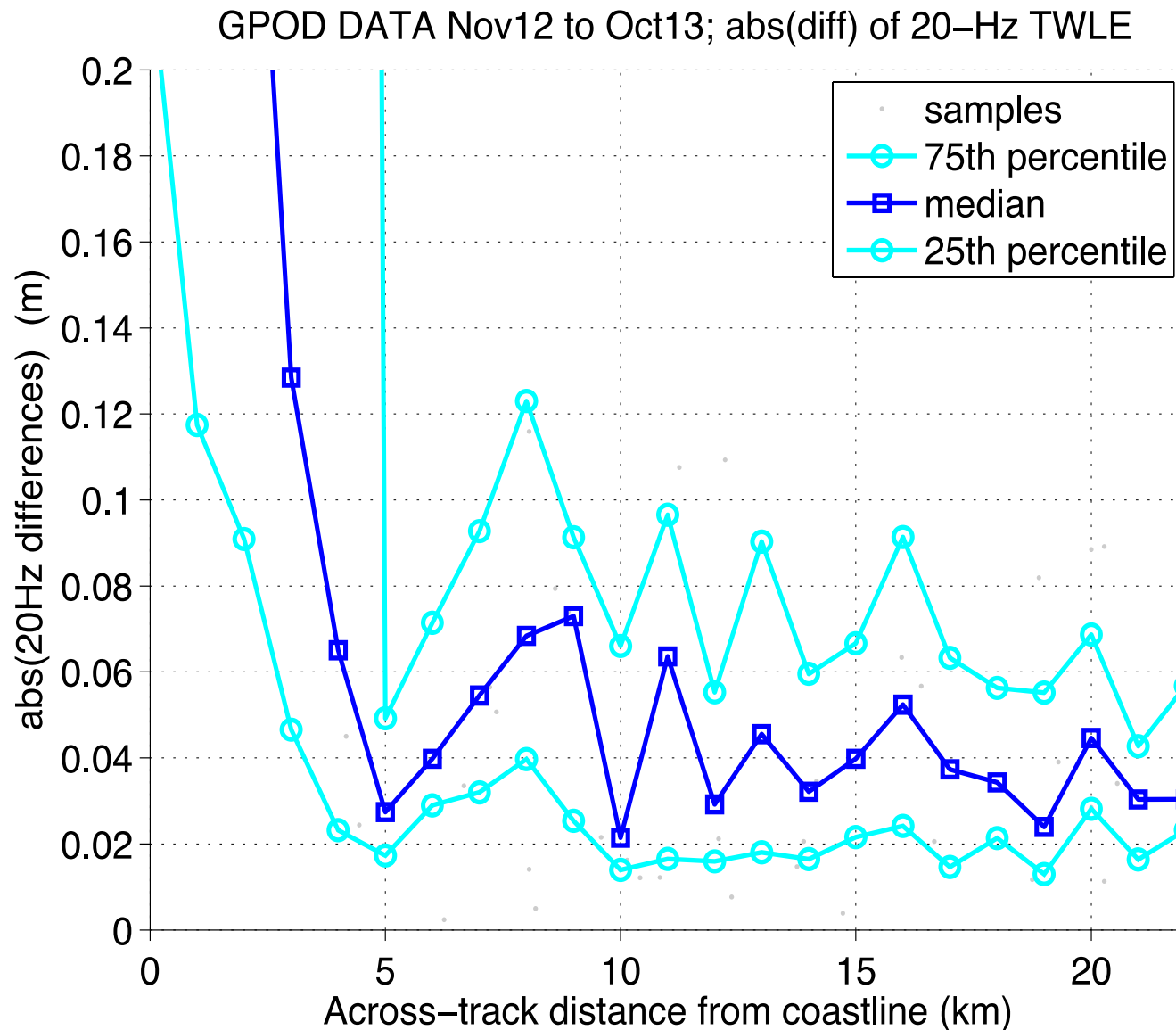
CPP on Brighton Box vs along-track d



GPOD on Brighton Box vs along-track d



GPOD on Brighton Box vs across-track d



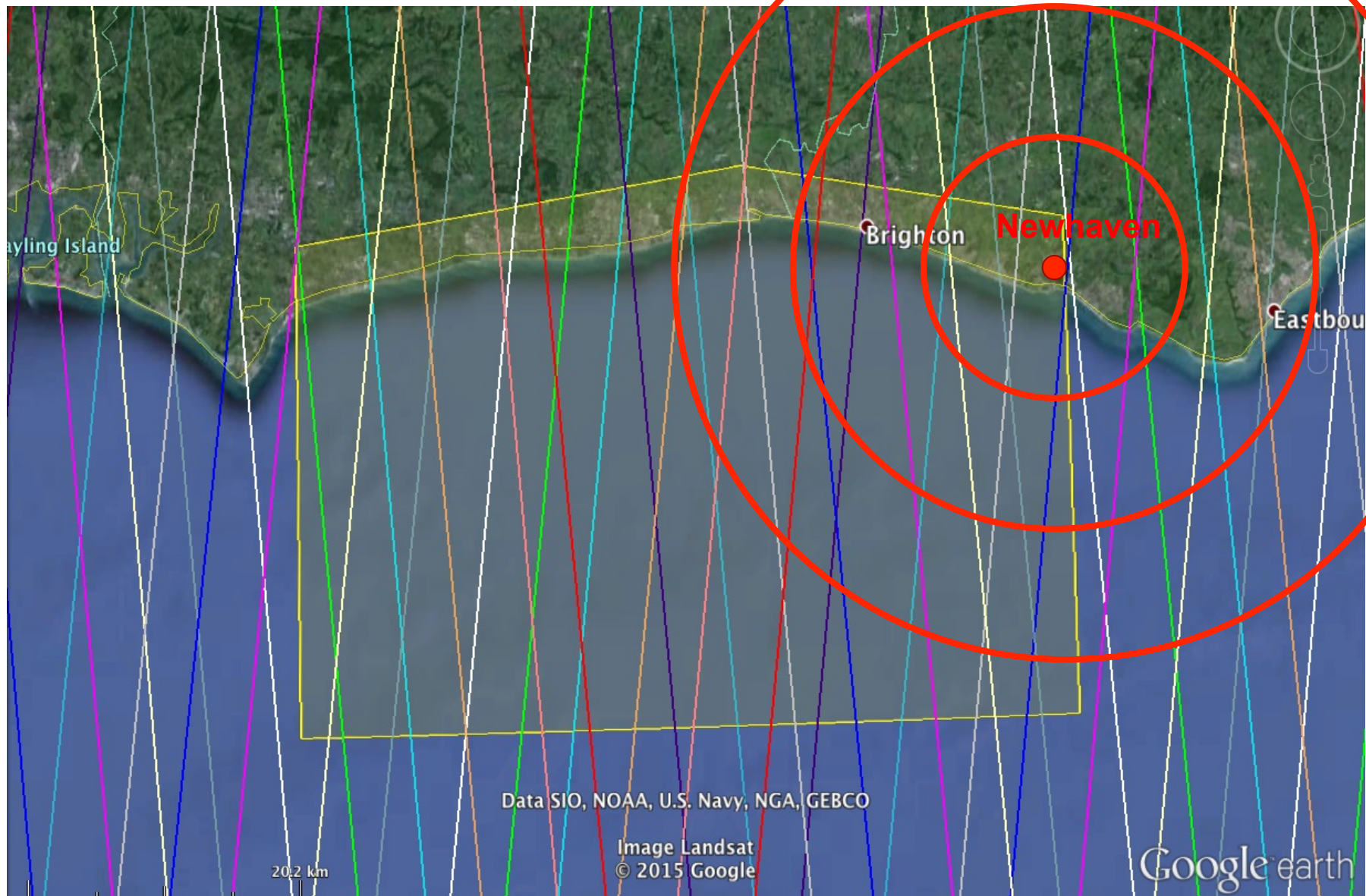
Results – Validation

(accuracy w.r.t. tide gauges)

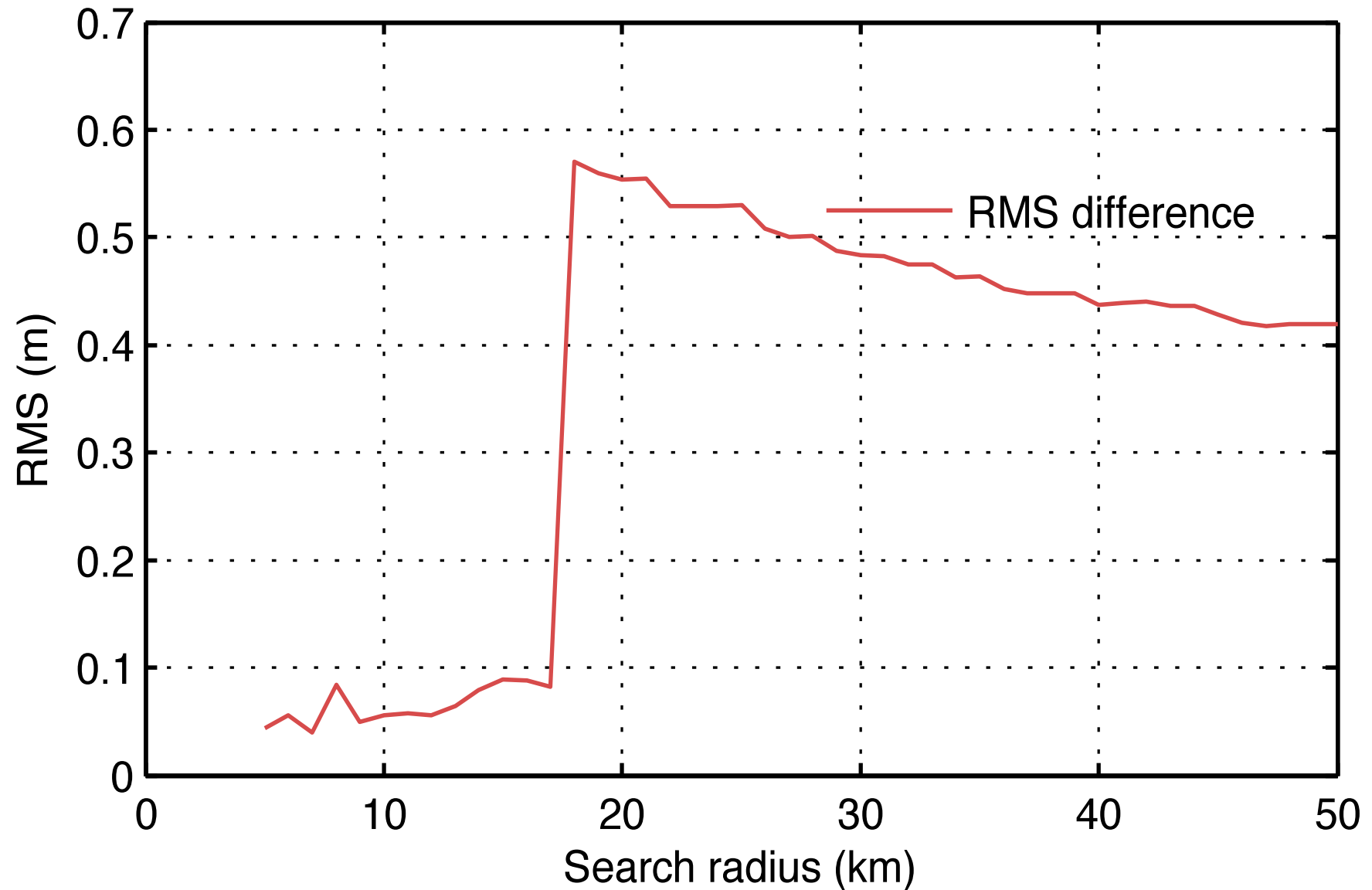
Validation against TG

- We compare Total Water Levels (i.e. we leave tides and atmospheric signals in)
- Validation of non-repeat altimetry against Tide Gauges presents an interesting problem:
 - **how far away from the tide gauge should we go in selecting the altimeter data?**
- We consider a 'search radius' around the TG and see how the rms difference varies when this radius is changed

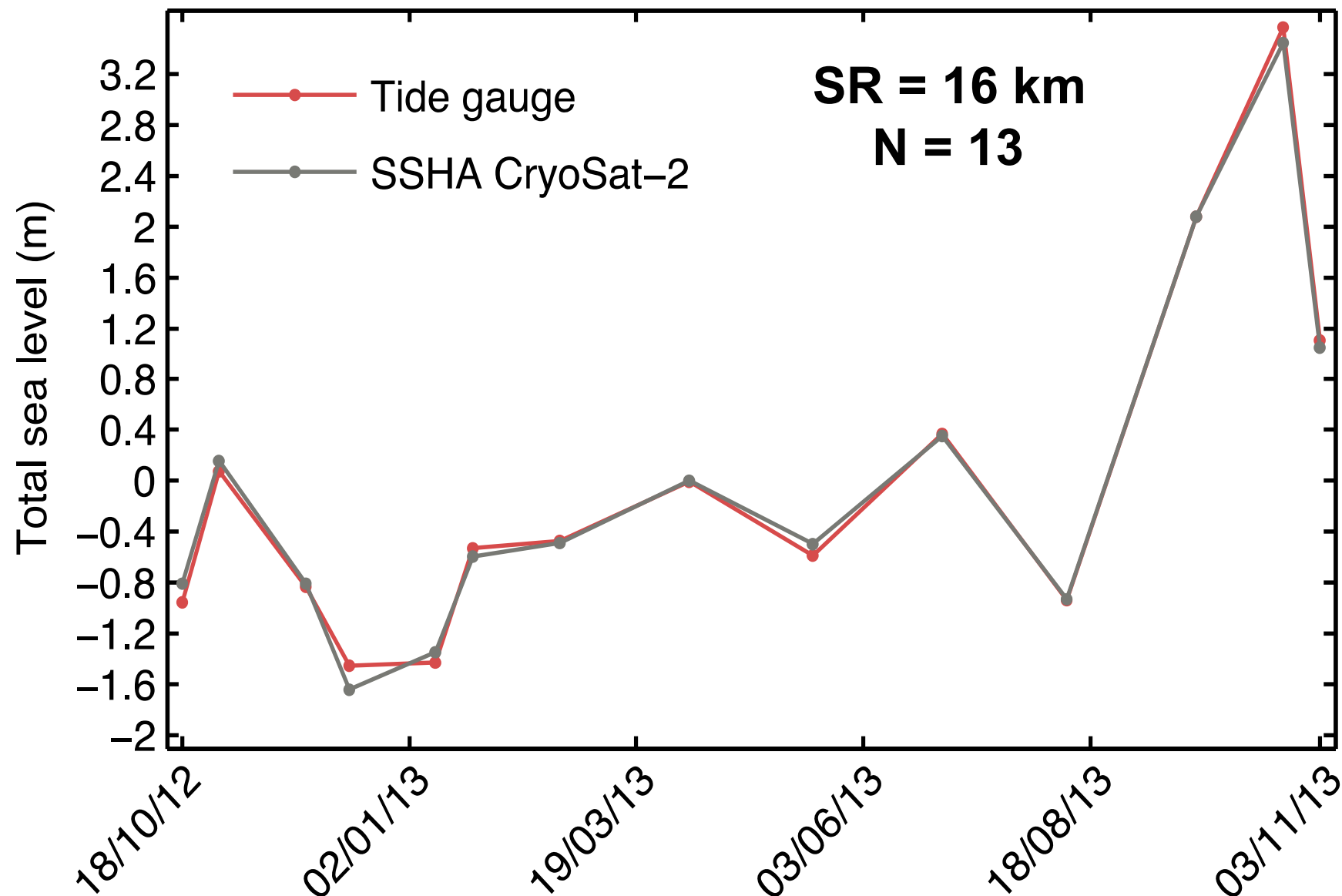
Newhaven TG



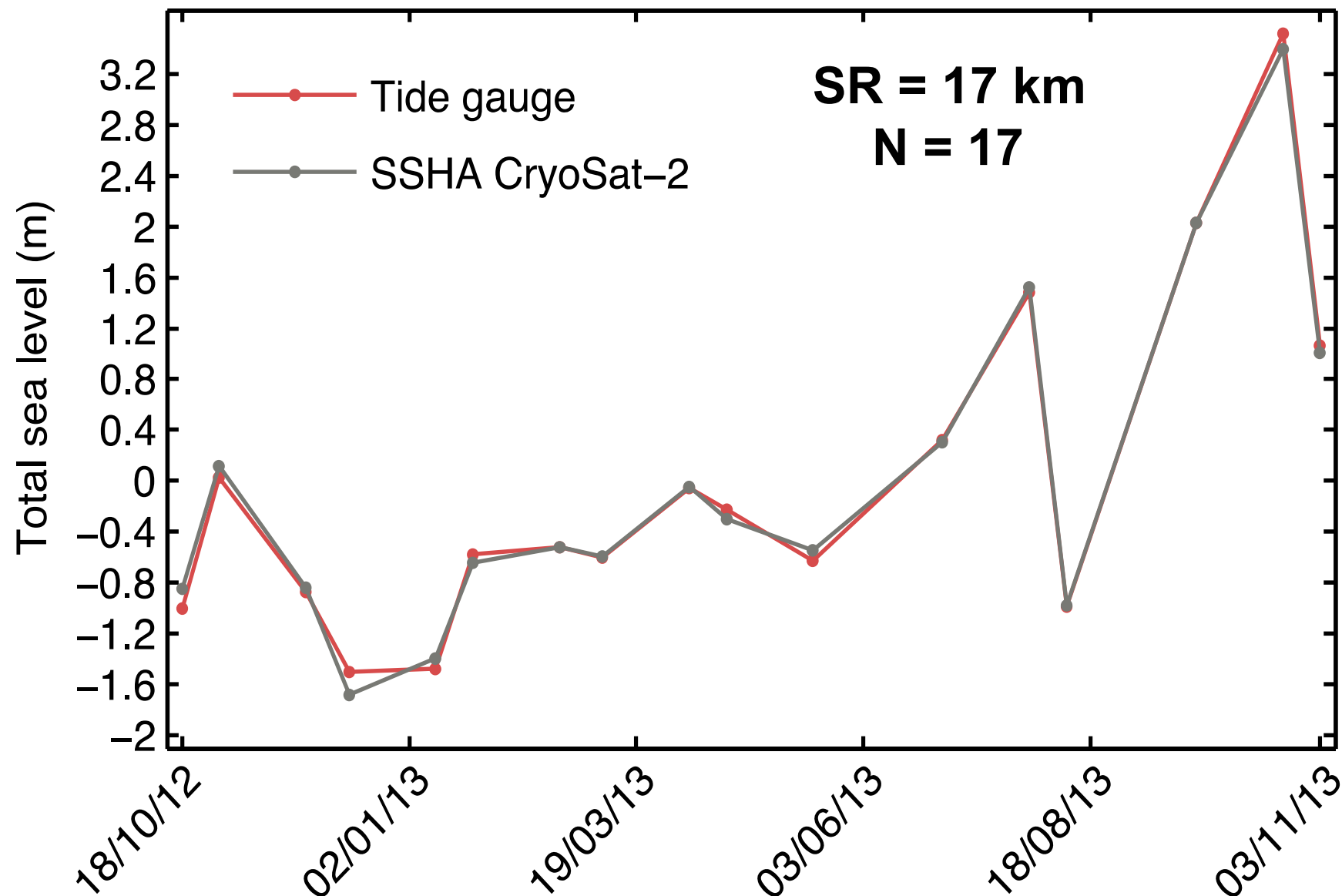
Newhaven



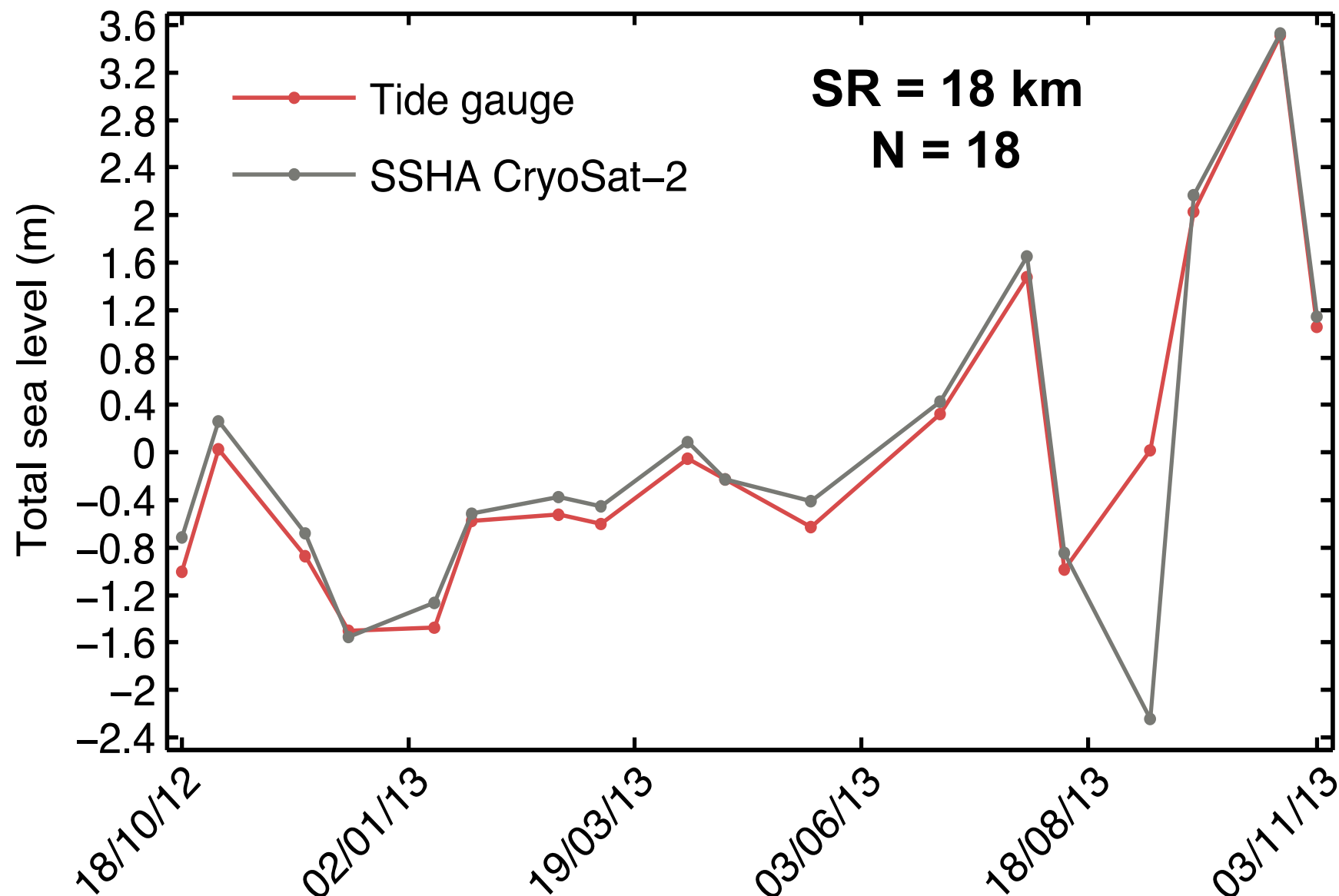
Newhaven



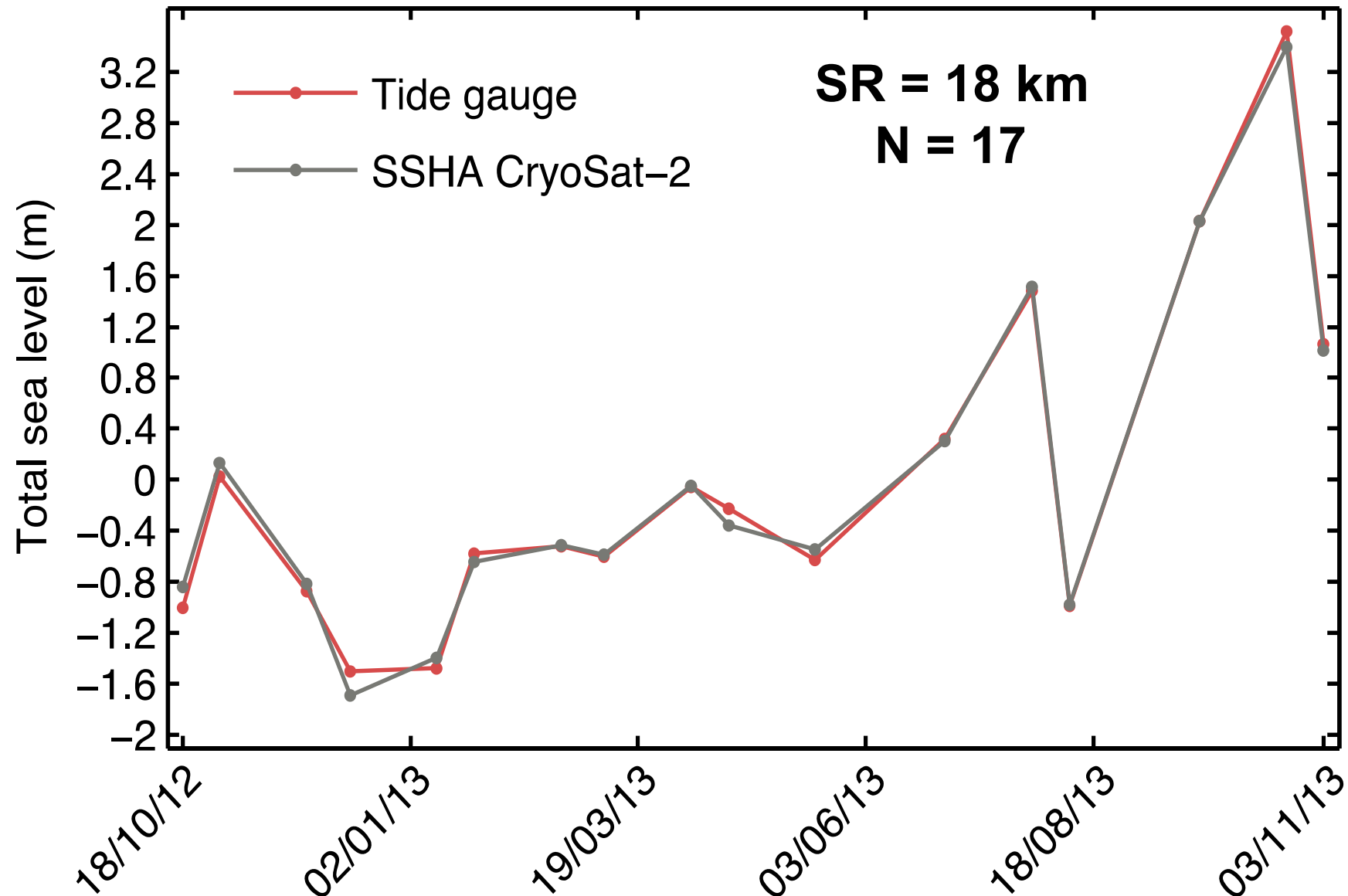
Newhaven



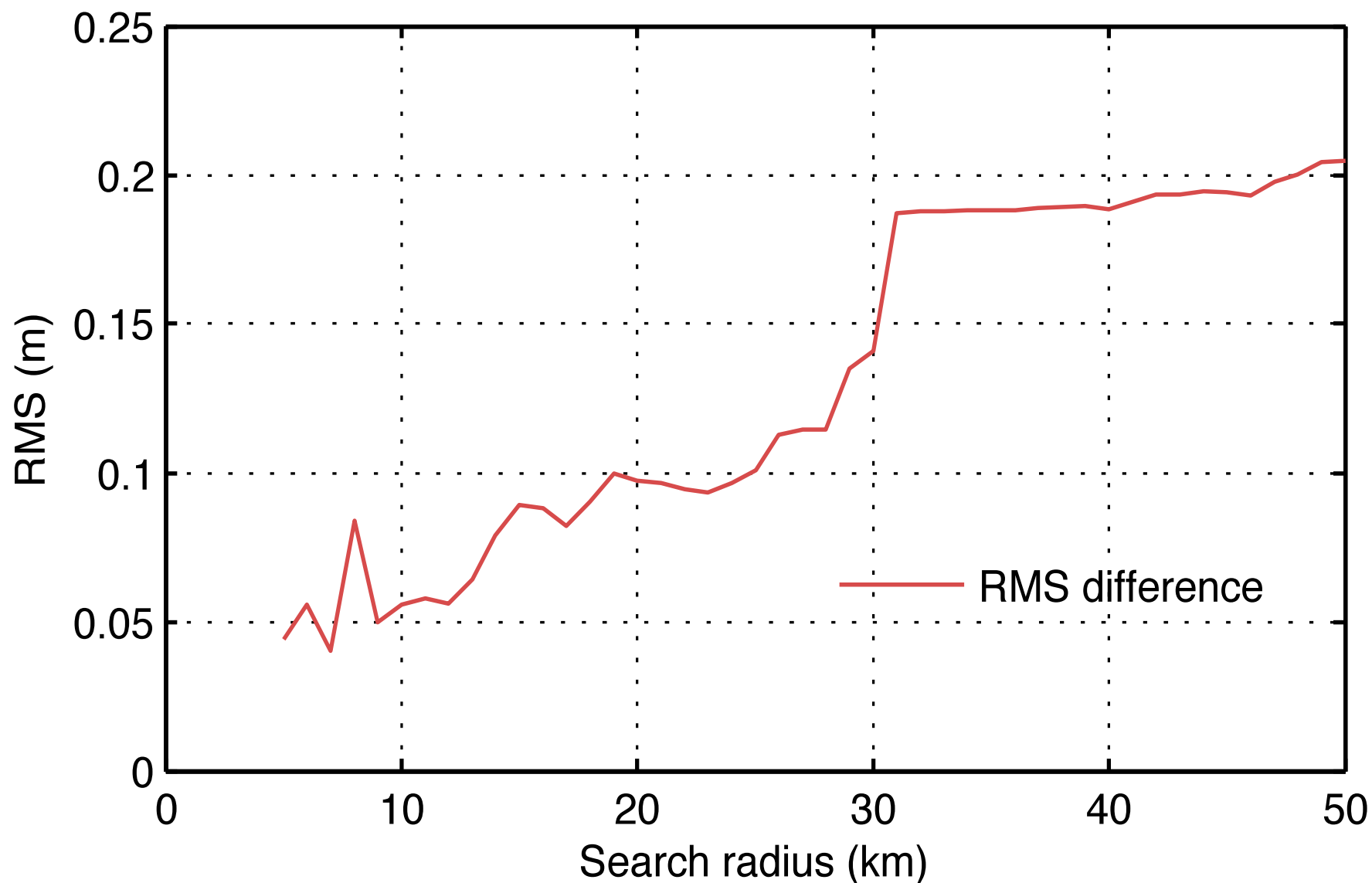
Newhaven



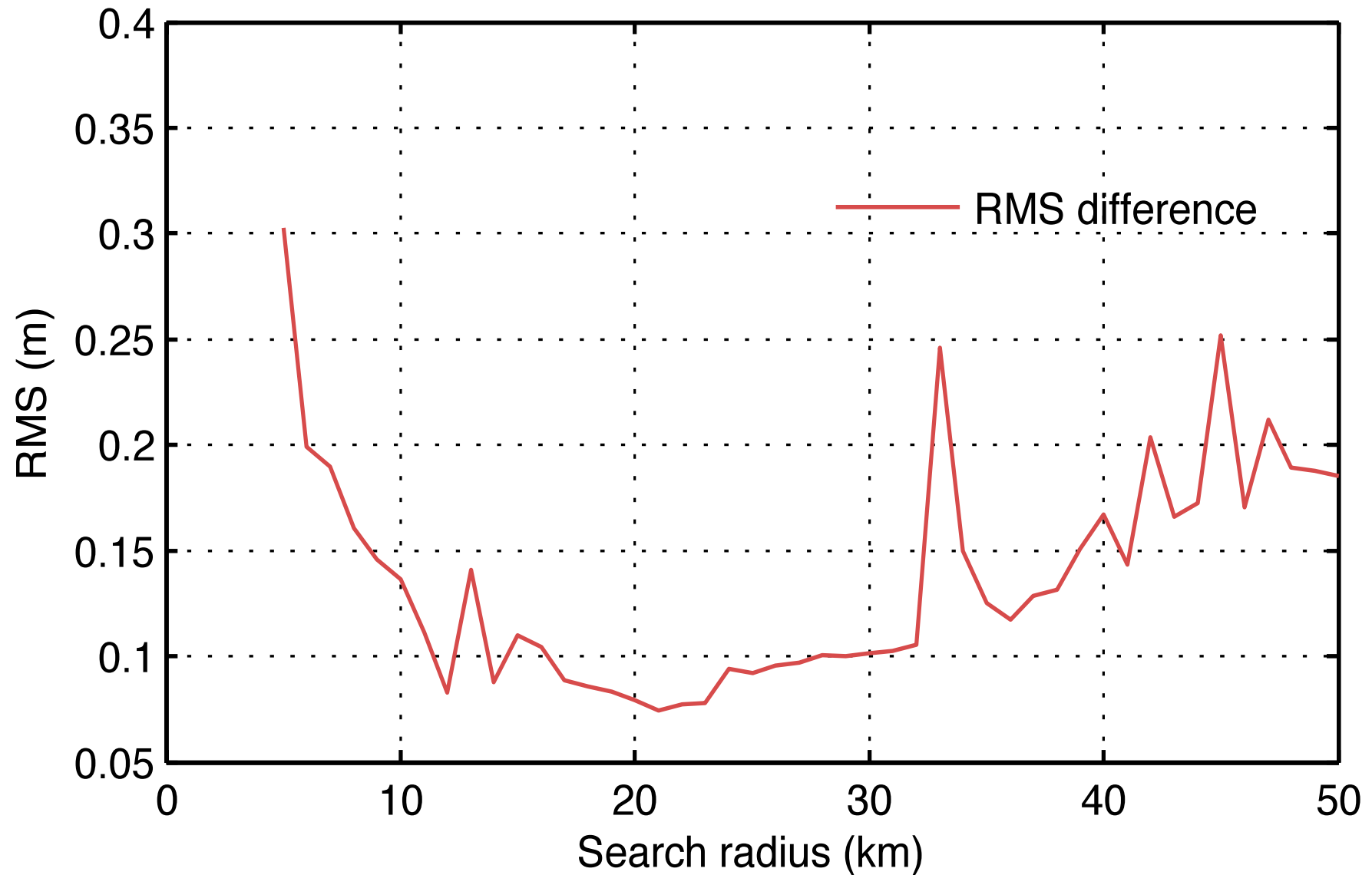
Newhaven, 1 outlier removed



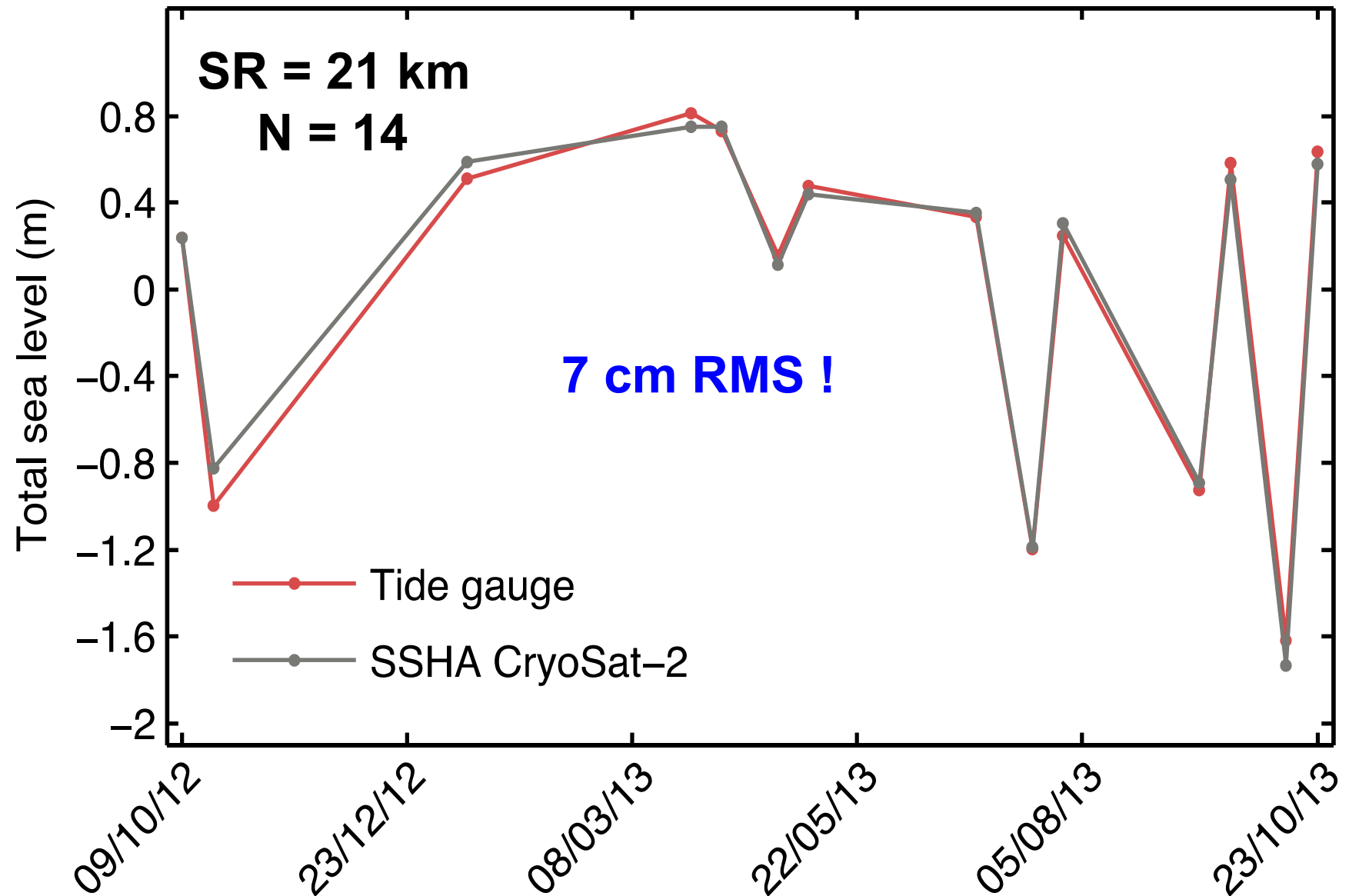
Newhaven, 1 outlier removed



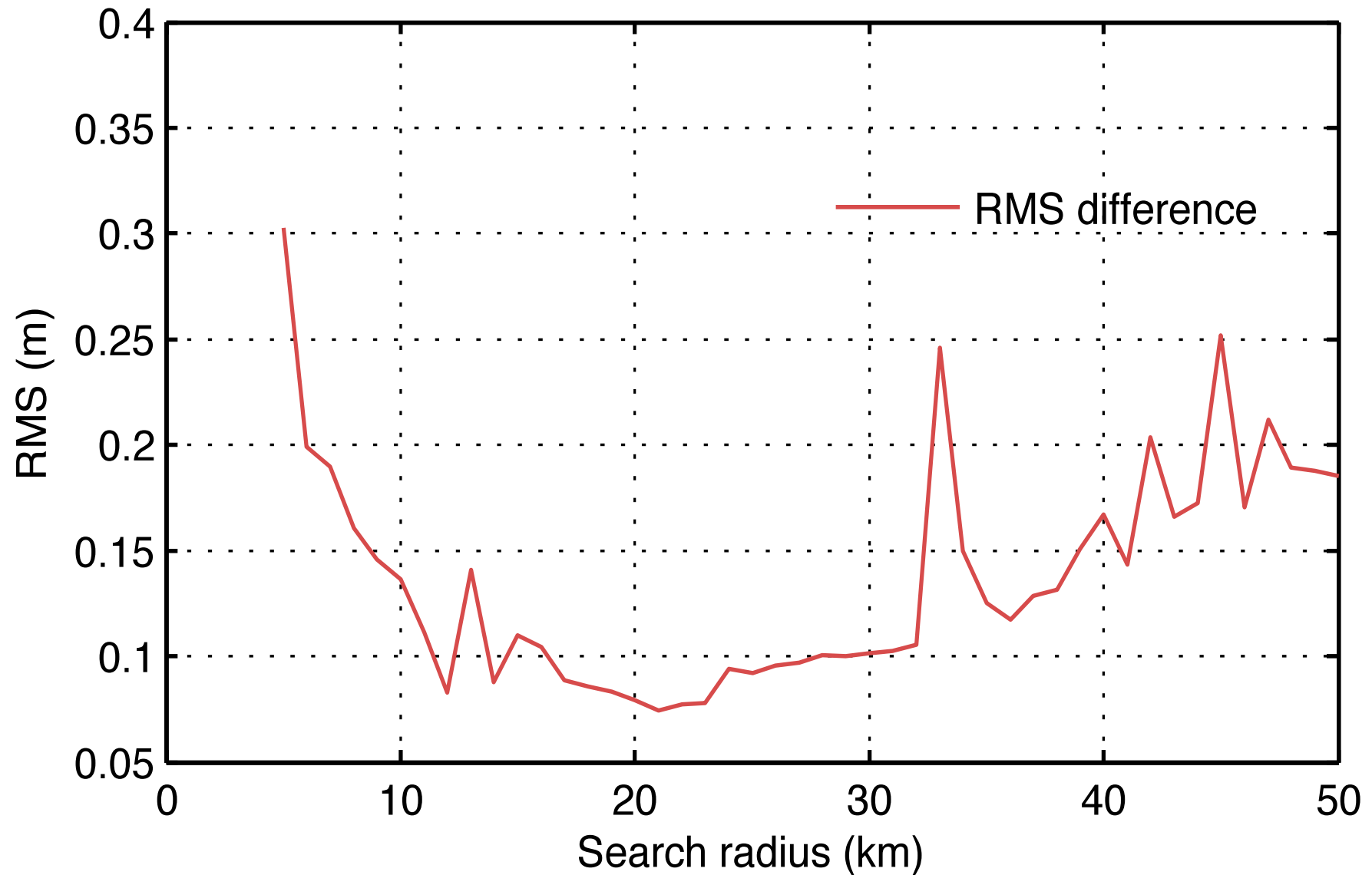
Aberdeen



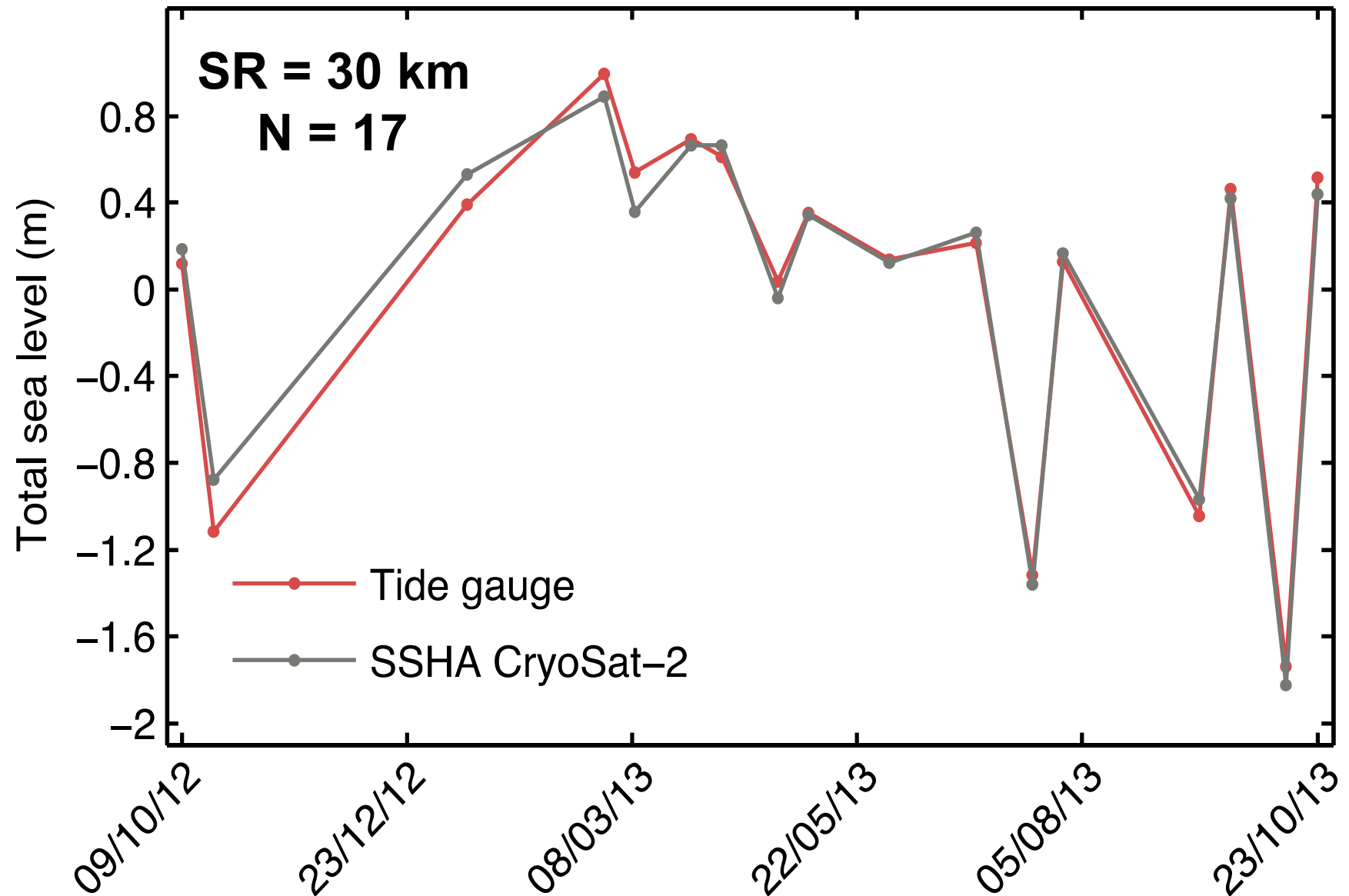
Aberdeen



Aberdeen



Aberdeen



Conclusions

- With CryoSat-2 in favourable conditions, measurements **at 2 km from the coast** display the same level of noise as over the open ocean
- Adoption of specific processing configuration (Hamming filter, Zero padding) improves the noise characteristics especially in the “last few kms”
- Validation against tide gauges is ongoing and results are encouraging - with fine tuning of search radius (and sometimes outlier removal) we can get **RMS < 10 cm with search radii around ~20 km**

More R&D to come

- ESA SEOM (Scientific Exploitation of Operational Mission) **SCOOP** study just started, to look at:
 - **exploiting the ‘stack’** of delay/doppler waveforms
 - stack wrt mean square slope/wind/wave direction
 - deriving a **global solution for SAR Sea State Bias** (and one for the coastal zone); a complementary study has been commissioned by EUMETSAT.
 - continuing to look at effects of **land morphology/orientation/proximity** on the SAR waveforms
 - **This paves the way to the exploitation of Sentinel-3 data in the coastal zone**