An evaluation of CryoSat-2 SAR mode performance around the UK coasts

P. Cipollini[1], C. Gommenginger[1], H.M. Snaith[2], D. Cotton[3], S Dinardo[4], J. Benveniste[5]

[1]NOC, [2]BODC, [3]SatOC, [4]SERCO/ESRIN, [5]ESA/ESRIN

National Oceanography Centre

NATURAL ENVIRONMENT RESEARCH COUNCIL

Outline

We present the result of an evaluation (verification) of Cryosat-2 SAR mode data carried out within the CP4O Project:

1. Assessment of performance (precision)
2. Does the 'angle of approach' of the satellite w.r.t. the coast matter?

We also discuss possible validation strategies w.r.t in situ data, given the non-repeat orbit of the instrument

CryoSat Plus for Oceans (CP4O)

Objectives:

- Build a sound scientific basis for new applications of CryoSat-2 data over the *open ocean*, *polar ocean*, *coastal seas* and for *sea-floor mapping*.
- Generate and evaluate new methods and products that will enable the full exploitation of the capabilities of the CryoSat-2 SIRAL altimeter, and extend their application beyond the initial mission objectives.
- Ensure that the scientific return of the CryoSat-2 mission is maximised. Preparation for Sentinel-3, Jason C-S.

Themes:

- **Open Ocean:** (sub)meso-scale, SAR retrackers, RDSAR processing.
- **Coastal Ocean:** Coastal features, land contamination, SARIN mode.
- **Polar Ocean:** Sea-ice effects, new mean sea surface, MDT models.
- **Sea Floor Topography:** Can SAR data resolve new features?
- **Geophysical Corrections:** Wet Troposphere, Ionosphere, regional tides

Verification of C2 SAR data

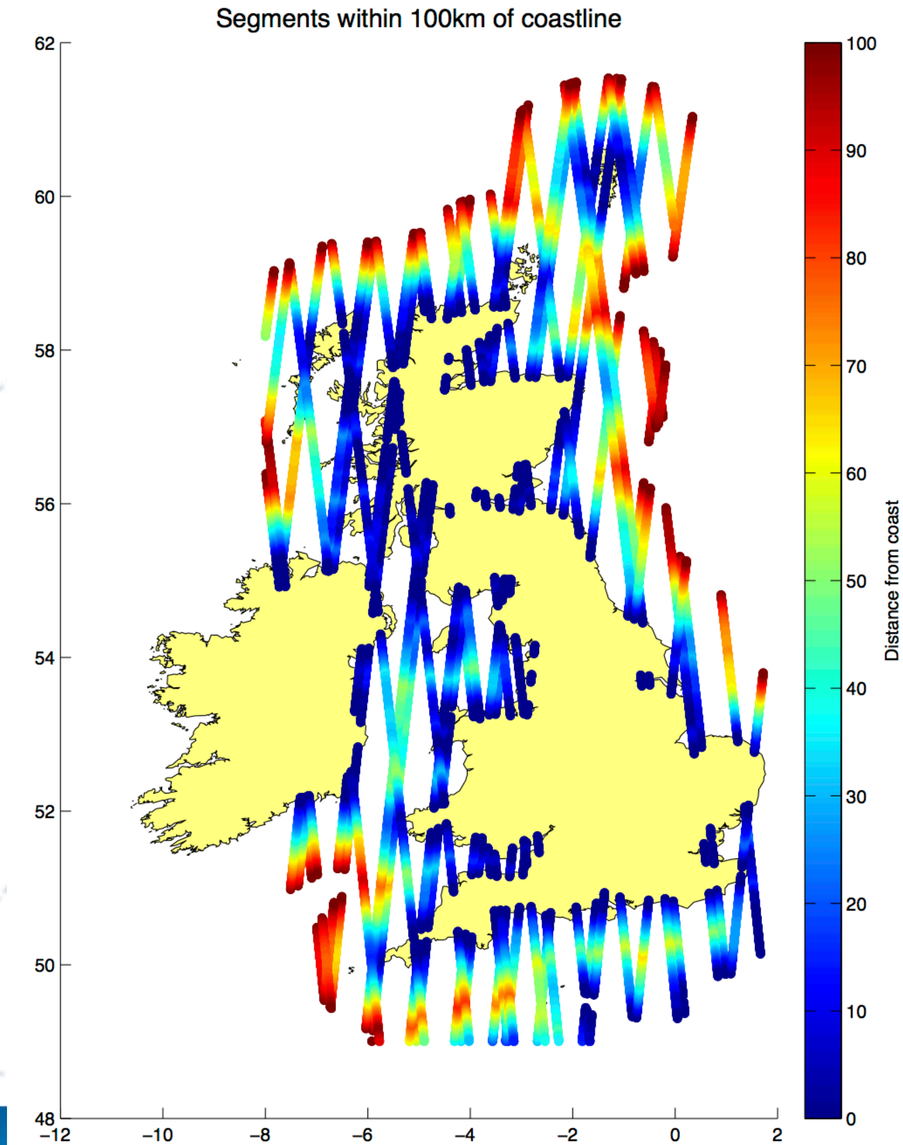
- …in 'the right conditions', we would expect a SAR altimeter to give a precise measurement all the way to the coast.
- We need a practical way of measuring this precision in the coastal zone
  - std of a 1-Hz block (20 samples) is not good as it spans ~7km -> we cannot 'localize' the estimate well enough
- We need a different statistics to capture the rapid variation of noise on approaching the coast

Differences as estimates of noise

- We can safely assume that SSH does not change significantly over 350 m
- → **difference between adjacent 20-Hz SSH values is essentially a measure of the noise**
- if noise were gaussian:
  - noise=std(diff(SSH))/sqrt(2)
- in practice outliers in diff(SSH) cause problems; a more robust estimate is
  - noise=median(abs(diff(SSH)))

Perfomance around UK coast

- Done for ESA CP4O (CryoSat Plus for Ocean) project
- All CryoSat-2 passes around UK in July 2012 and January 2013
- Data from ESRIN SARvatore run 'R5'

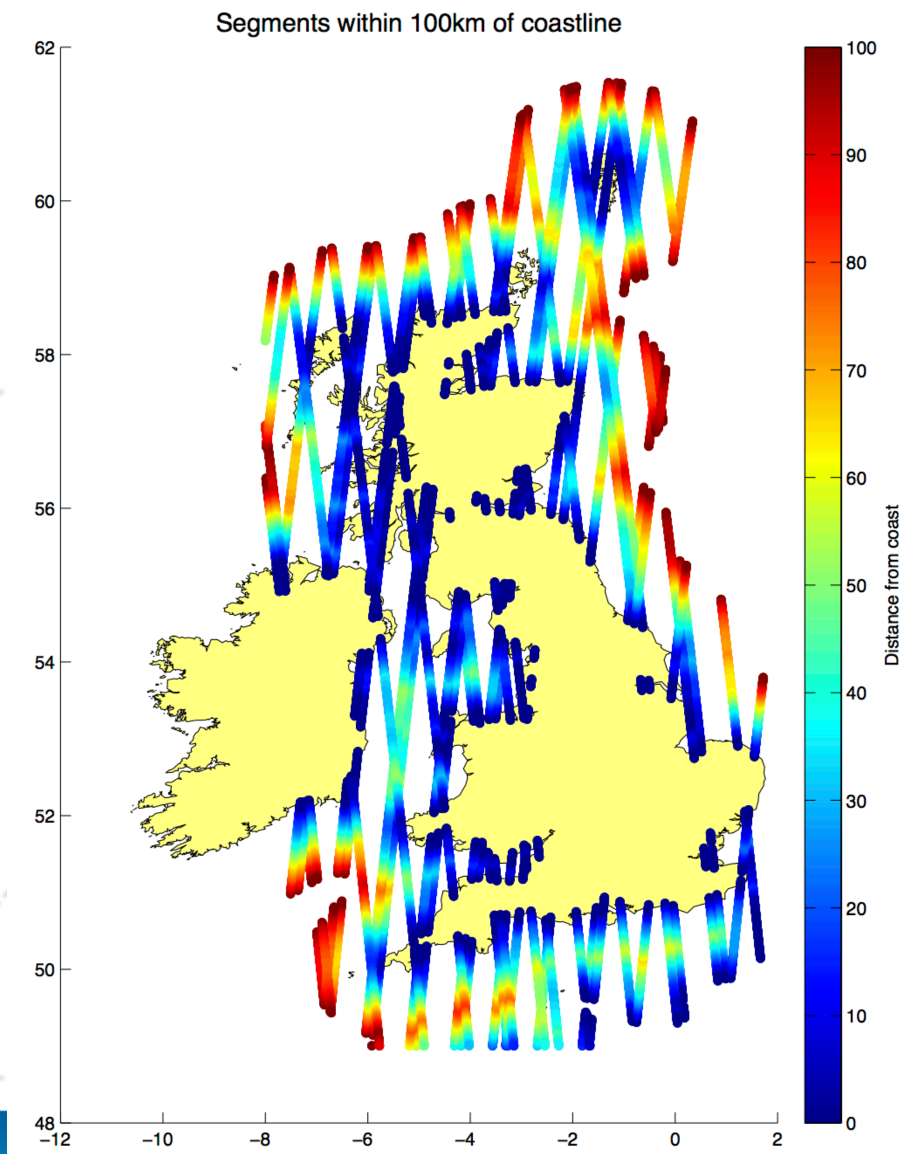


CP40 Run R5

Run reference	C2 L1B product	L2 SAR retracker model	Alpha_p LUT	Peel effect applied	Motivation
ESRIN R5	ESRIN FBR	ESRIN SAM2	Yes	Yes	To explore impact at L2 of L1B processing choices

Assessment of performance around UK coast

- Done for ESA CP4O (CryoSat Plus for Ocean) project
- All CryoSat-2 passes around UK in July 2012 and January 2013
- Data from ESRIN SARvatore run 'R5'
- **See how precision varies wrt:**
  - **Distance from coast**
  - **"coastal proximity"**
  - **possibly, angle of approach**



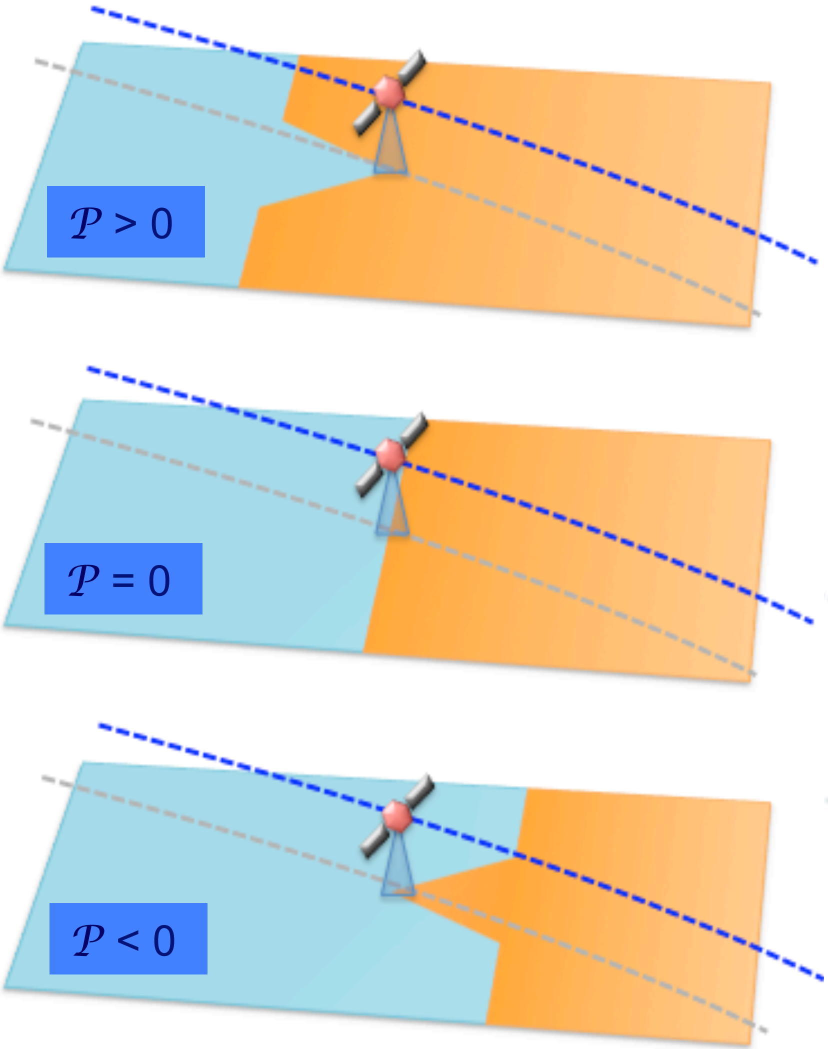
Coastal Proximity $\mathcal{P}$

- A new parameter defined within ESA Sea Level CCI Project, to be used as independent variable instead of (or together with) distance from coast
- aims at **capturing differences in coastal morphology "as seen by the altimeter"**
    - problem is well defined once geometry and instrumental params are fixed (orbital height, antenna beamwidth, pulse length, number of gates) and a good DEM (such as **ACE2**) is available
- In practice tells how 'coastal' (='affected by land') a waveform is, and therefore how difficult it is to retrack it

Defining $\mathcal{P}$

- increasing from ocean → land
- lower over tips/peninsulas, higher in recessed bays

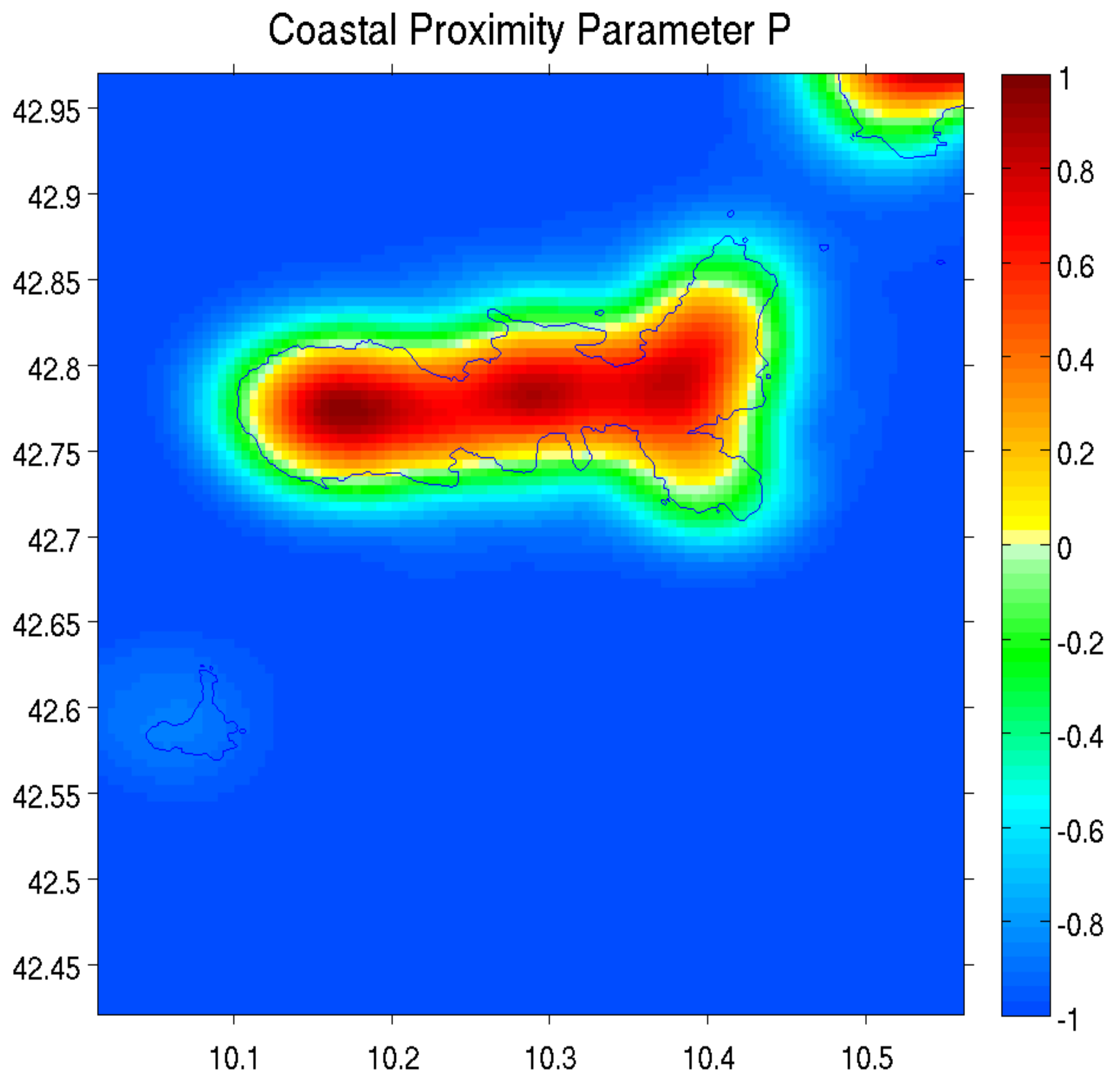
- for easier comparison with distance (which is zero at coastline), $\mathcal{P}$ is defined to be:
  - **-1 over open ocean**
  - **0 at idealized, straight coastline**
  - **1 inland**



Computing $\mathcal{P}$

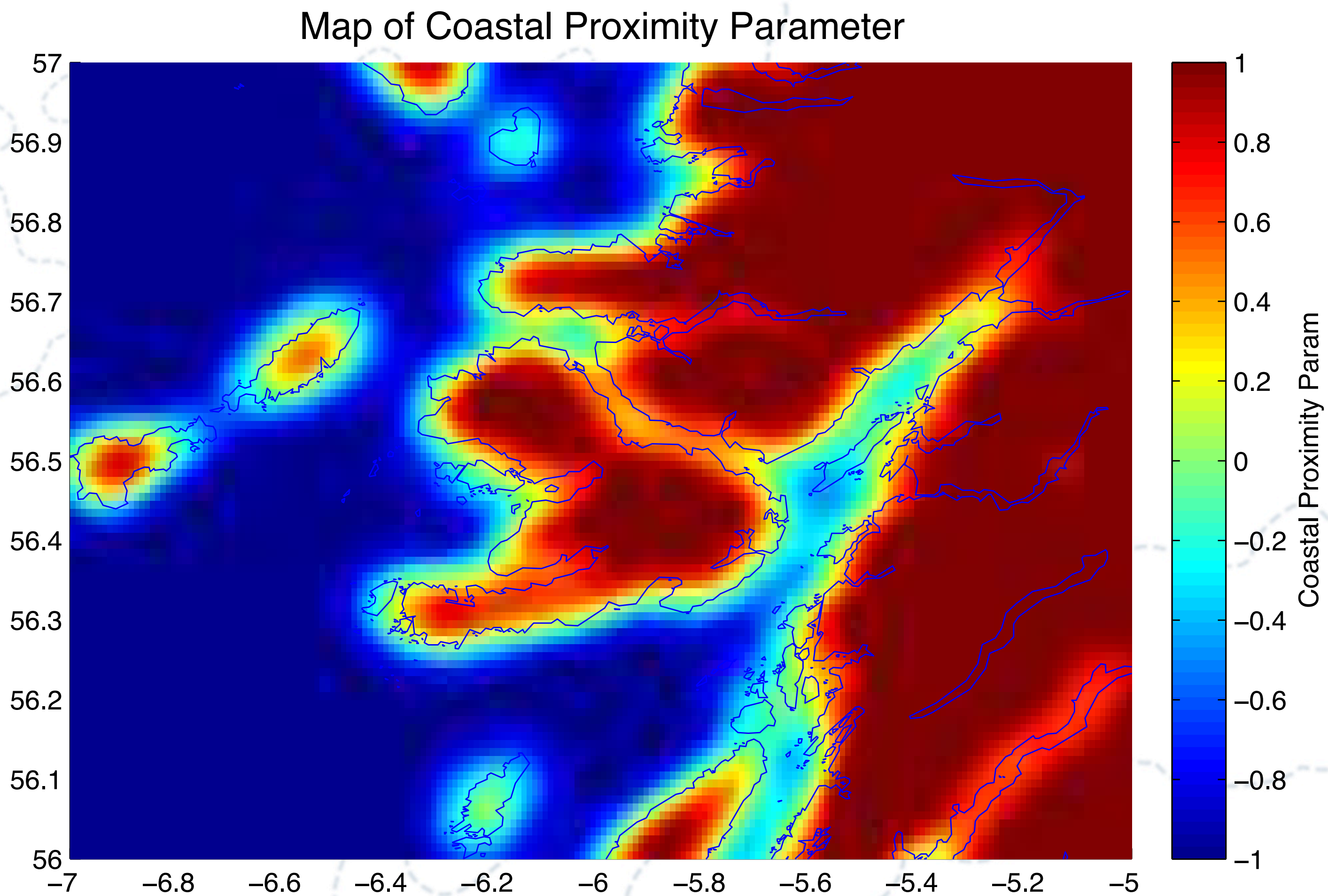
- We need to simulate the effects of land on waveforms
- → we fly a virtual altimeter over a good DEM (ACE2 produced by De Montfort University, 3 arcmin) and in every gridpoint we model two effects:
- **Contribution 1: power deficit due to "missing ocean"**
  - land, even if it is at z=0, will usually have much lower backscatter than ocean (there are exceptions, but they are difficult to model!)
- **Contribution 2: land returns in various gates** depending on land elevation
  - i.e. we get echoes from land elements in various gates (before and after leading edge) depending on the land height
- Combining them we obtain $\mathcal{P}$

Example of $\mathcal{P}$

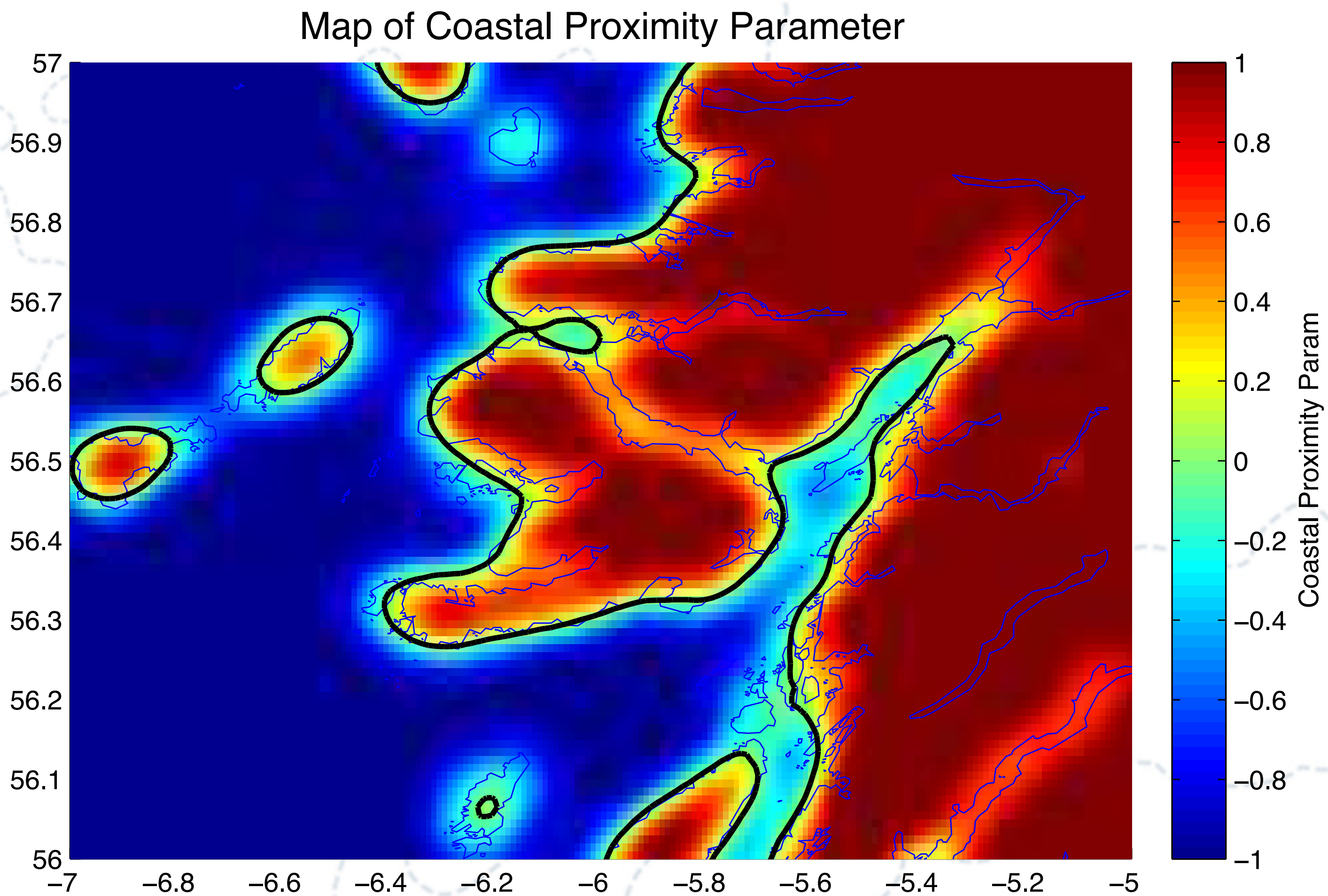


Global $\mathcal{P}$ dataset at 0.01° resolution is available on SL CCI FTP server

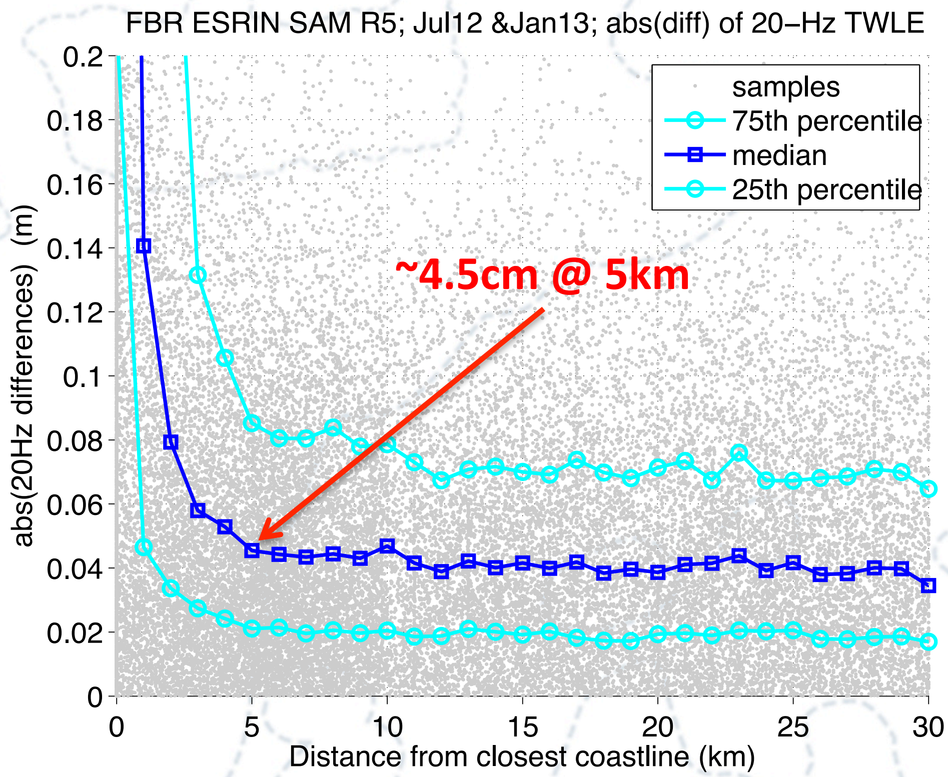
Example off W Scotland



Example off W Scotland

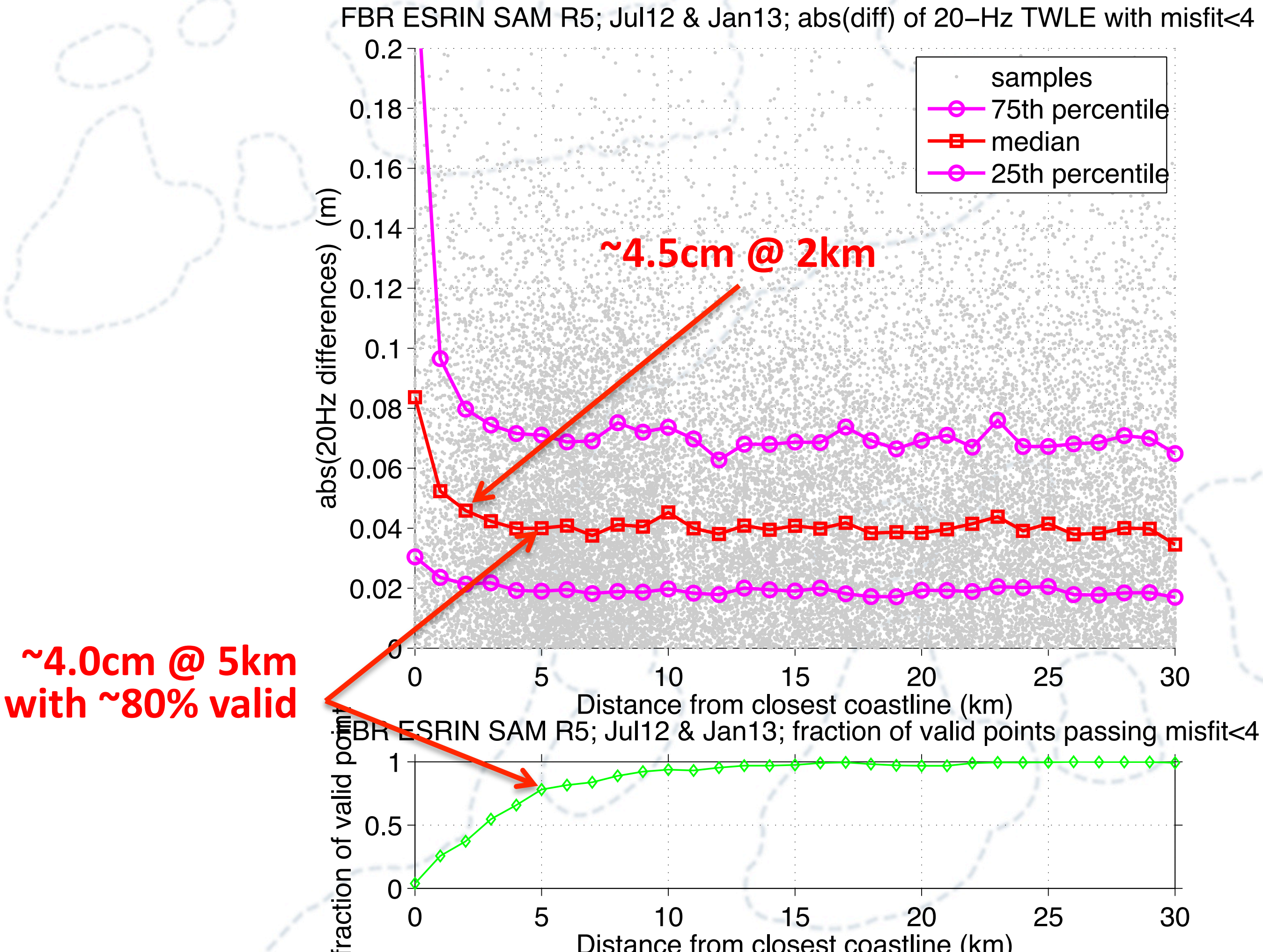


Results: noise vs distance

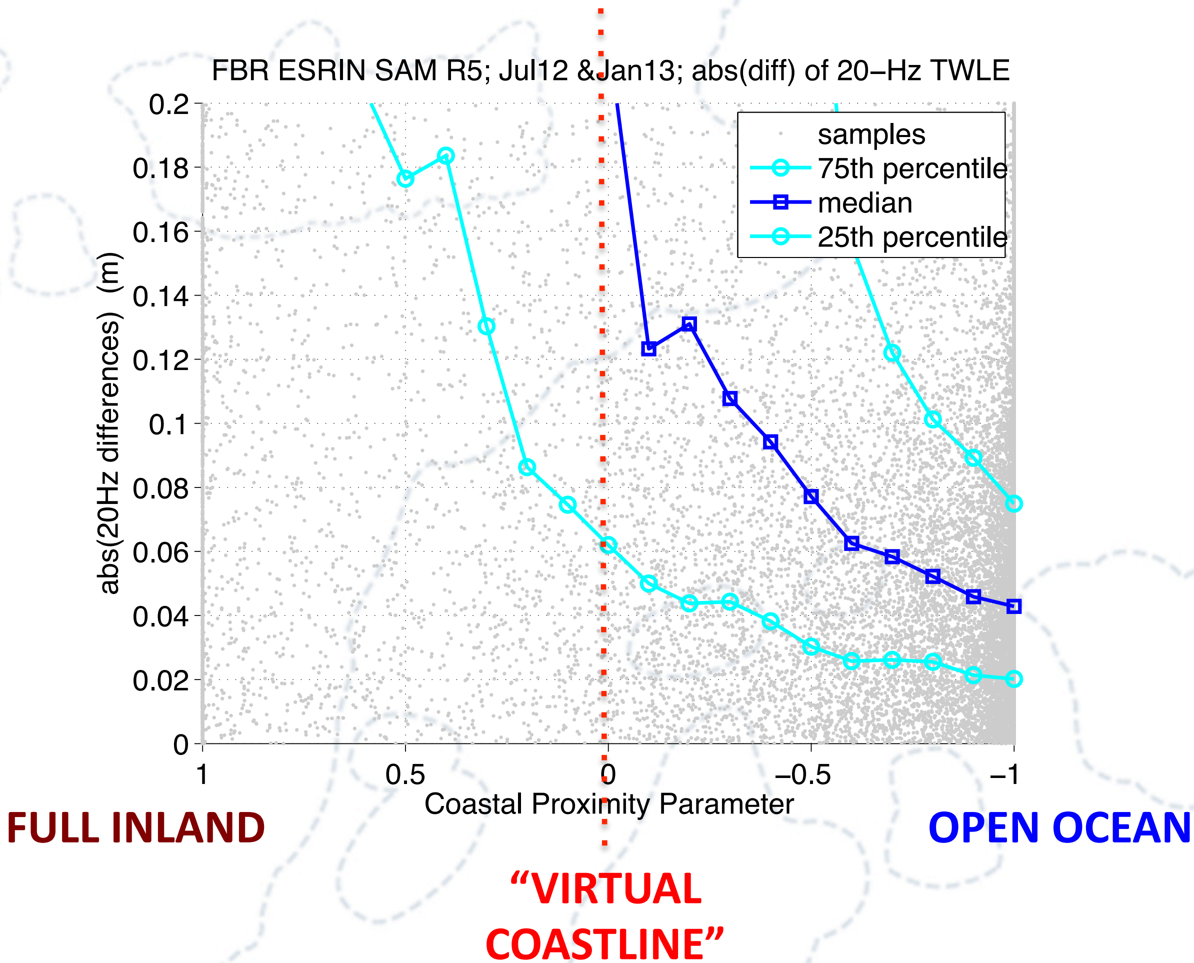


Results: noise vs distance

With additional screening based on retracking misfit

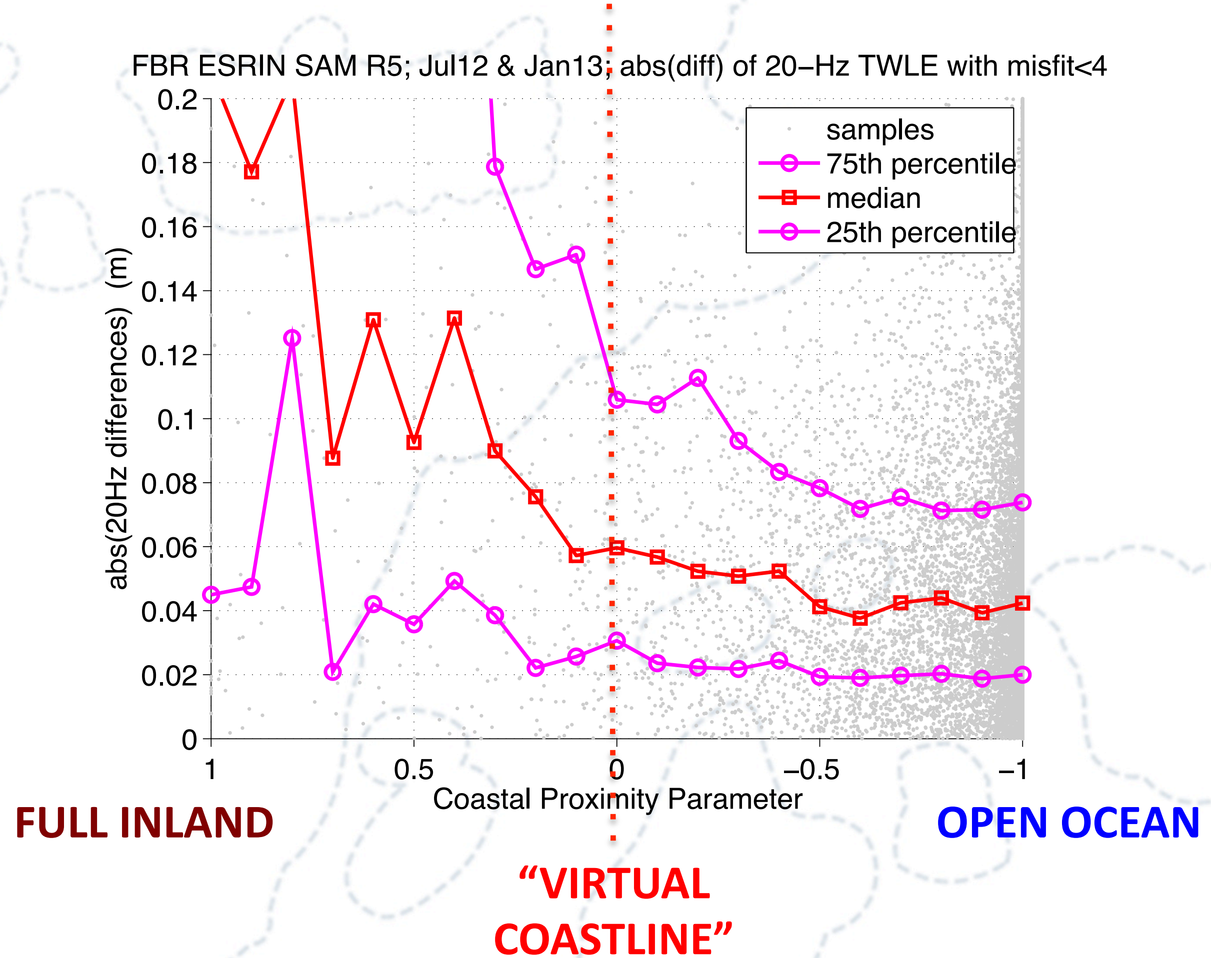


Results: noise vs $\mathcal{P}$



Results: noise vs $\mathcal{P}$

With additional screening based on retracking misfit

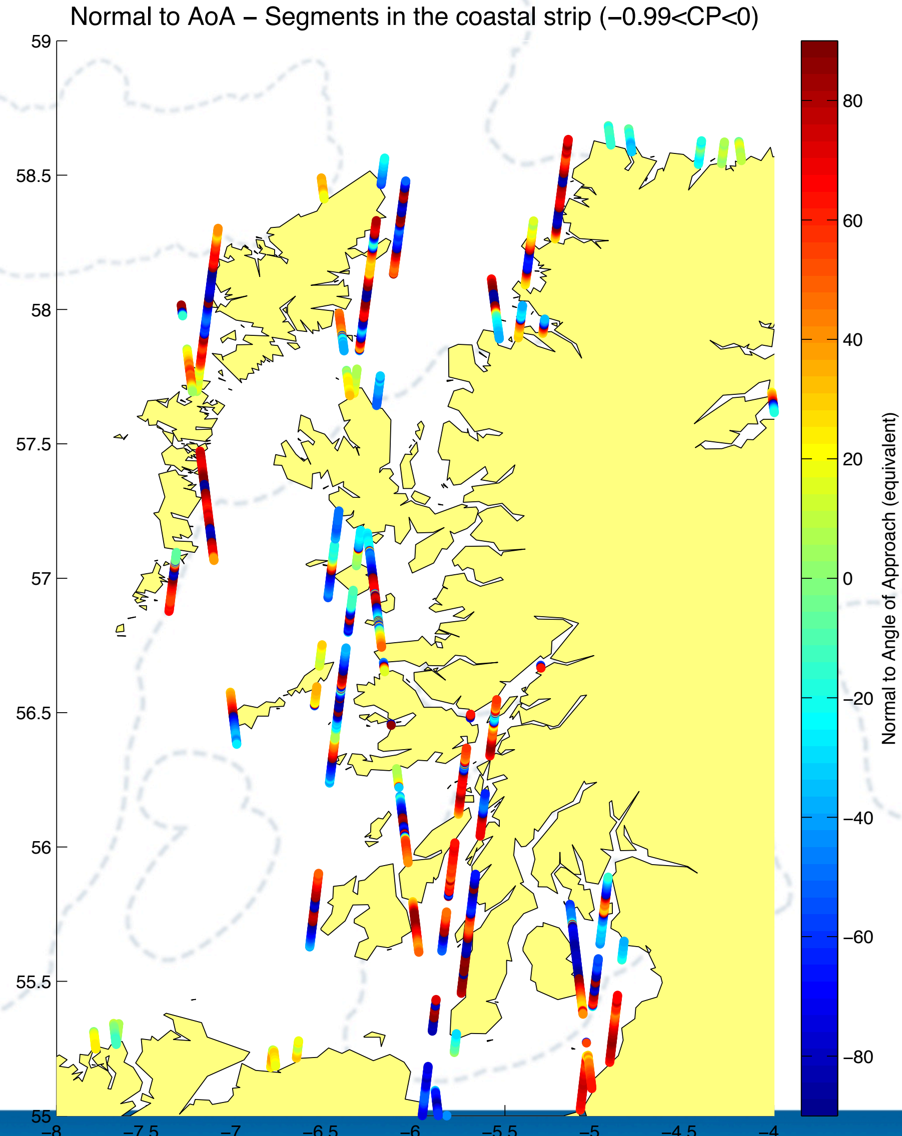


Dependence on Angle of Approach?

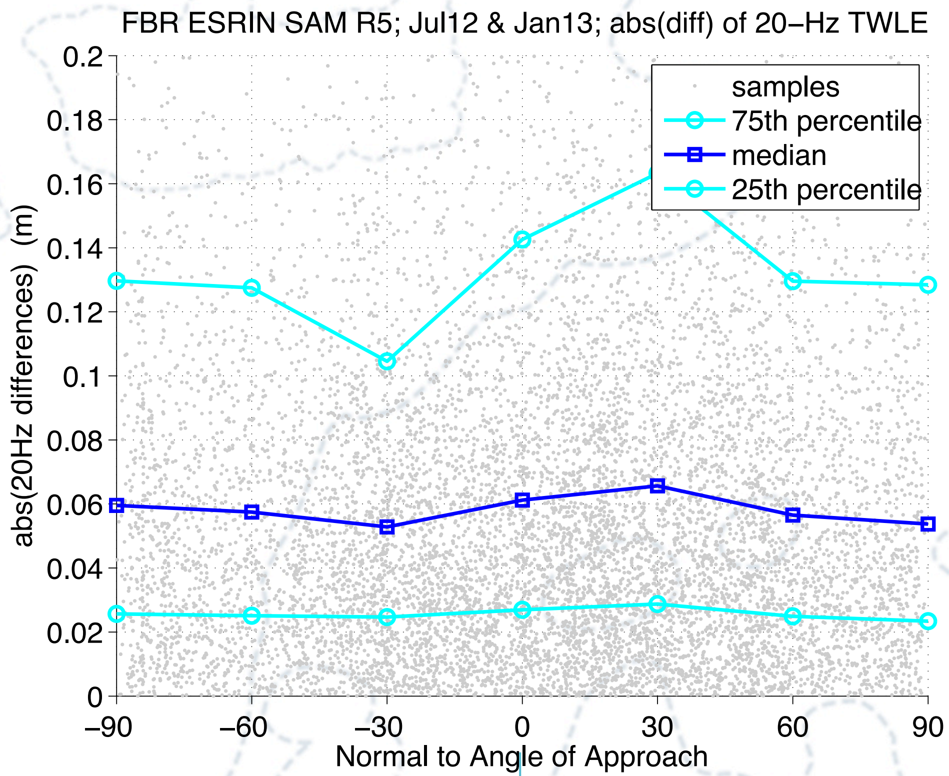
Angle of Approach can be computed for each along-track point as difference between track orientation and orientation of coastal proximity gradient

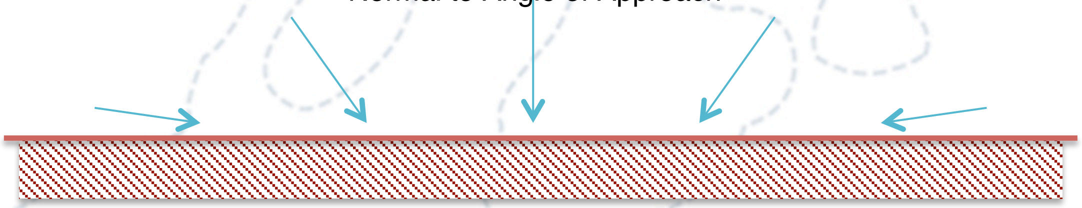
NOTE: we will plot results in terms of “Normal to angle of approach”: 0° means track orthogonal to coast, ±90° means track parallel to coast

Example: AoA over West scotland



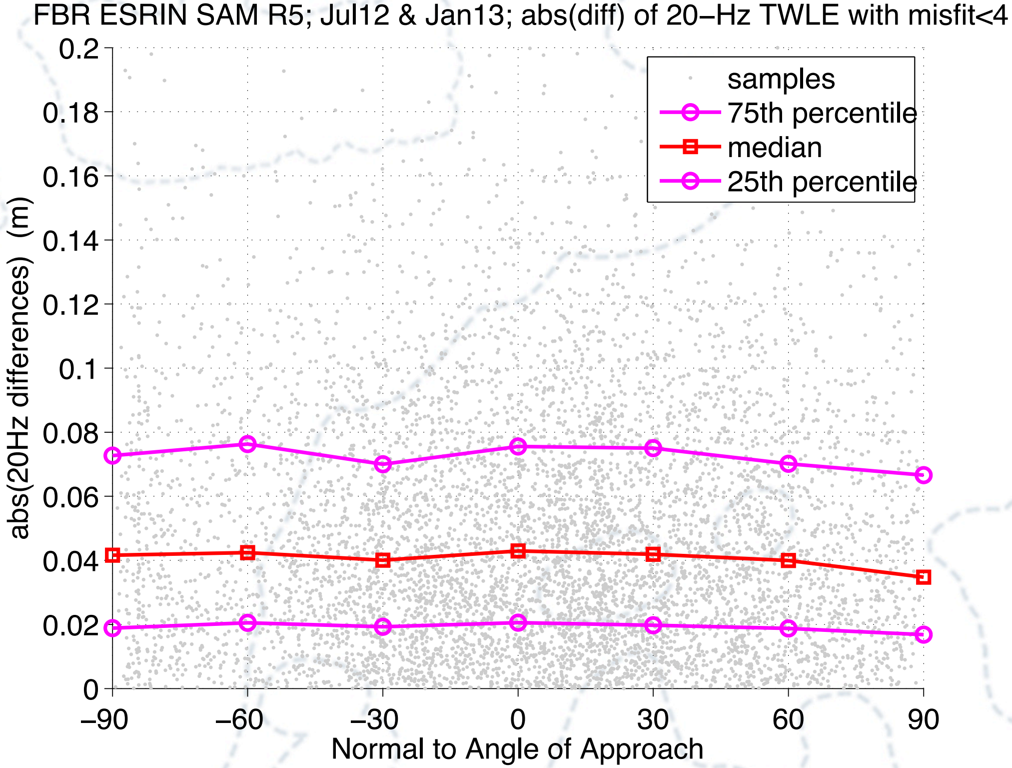
Results: noise vs AoA





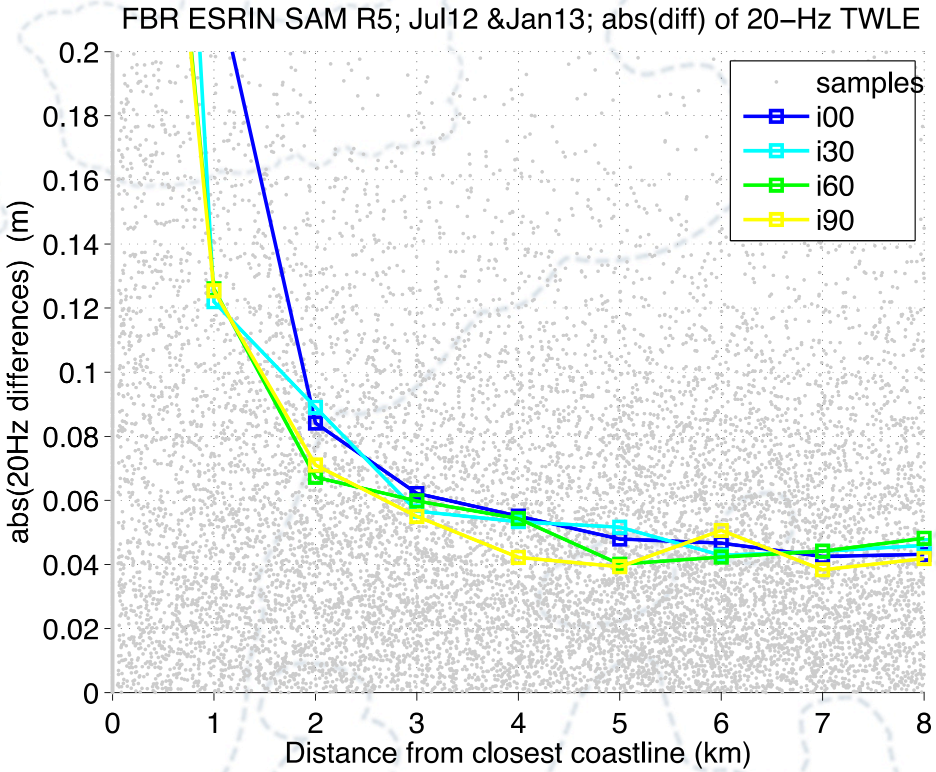
Results: noise vs AoA

With additional screening based on retracking misfit



Flat!

Noise vs distance for various AoA



NO clear dependence!!

If anything, shallow angles of approach seem to perform better!

How to validate C2 data vs in situ?

- For Cryosat-2, (369 day, essentially a non-repeat orbit from the point of view of ocean and coastal dynamics) it is not possible to build time series in a fixed location.
- IF lots of passes are available over a small area (i.e. at least several months of data, if not years) we could use the methodology presented by Jesus Gomez-Enri in his talk(next): grouping data according to distance from coast.
- Which strategy would be appropriate for smaller datasets? We tried to use all available altimeter/tide gauge measurement pairs (match-ups) over a wide geographical area (whole UK) while disregarding the time information, but results (not shown) are not convincing. → need more discussion

Conclusions

- SAR waveforms from CryoSat-2 tend to 'behave' in the coastal zone
- Precision can be studied as function of distance to coast and/or coastal proximity parameter
- Retracking misfit is very good for screening purposes
- Noise levels (on the high-rate data):
  - 4.5cm @5km
  - with screening, 4.0cm @5km and ~80% valid samples. Or 4.5cm@2-3km with 40-50% valid points
- Dependence on angle of approach needs more investigation, results are not conclusive.
- Which validation strategy vs in situ data? needs discussion.

Thanks

Questions/suggestions welcome!