→ SAR ALTIMETRY TRAINING COURSE

SAR Altimetry in the Coastal Zone

Performance evaluation and applications

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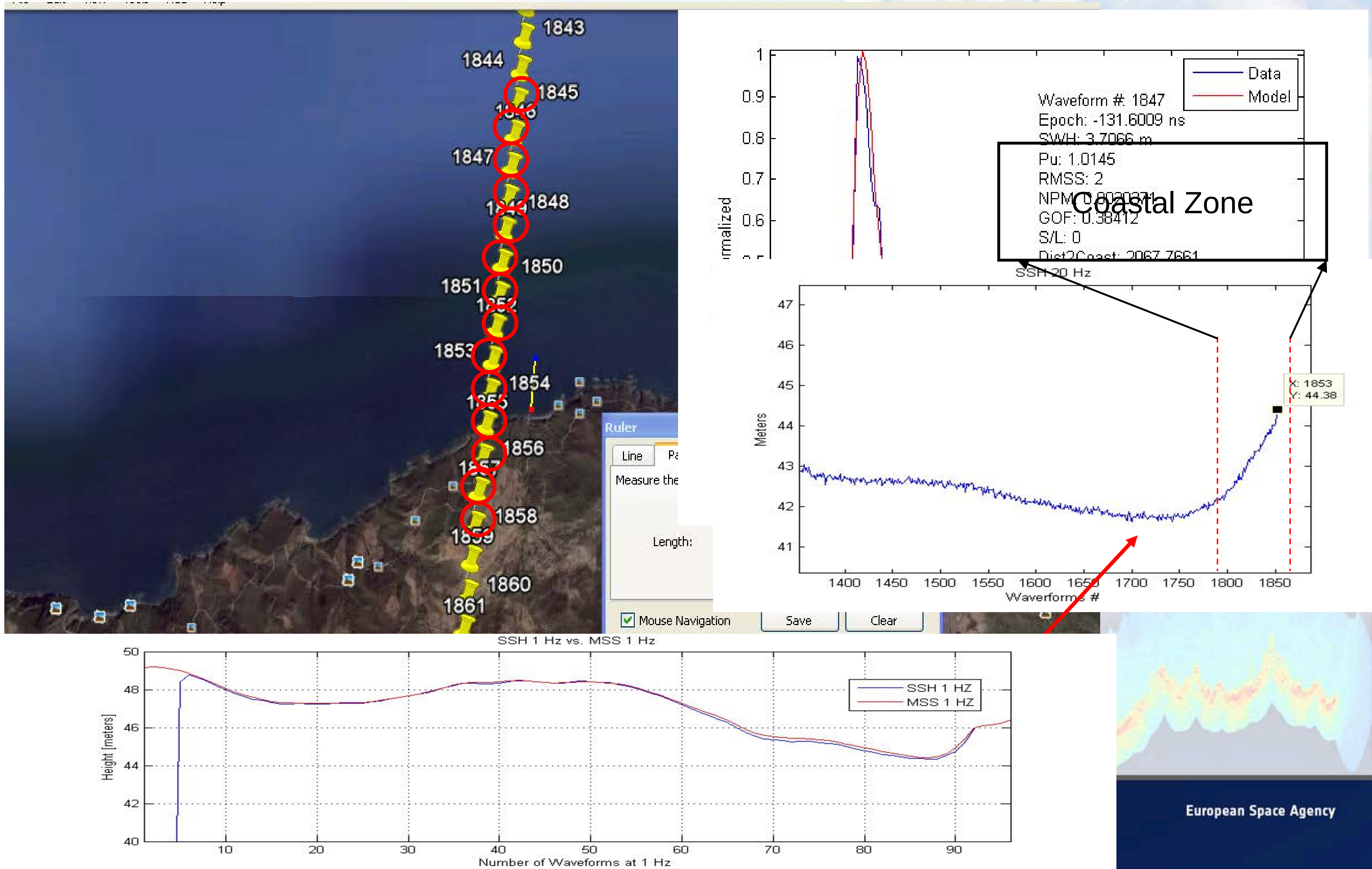
Outline

- What we expect from SAR altimetry in the coastal zone
- Assessment of performance (precision)
- Does the 'angle of approach' matter?
- Applications? → see during the next two days!

Approaching coast in SAR mode – S. Dinardo 2011

Waveforms at 20 Hz, one waveform each 300 meters – Optimal Conditions

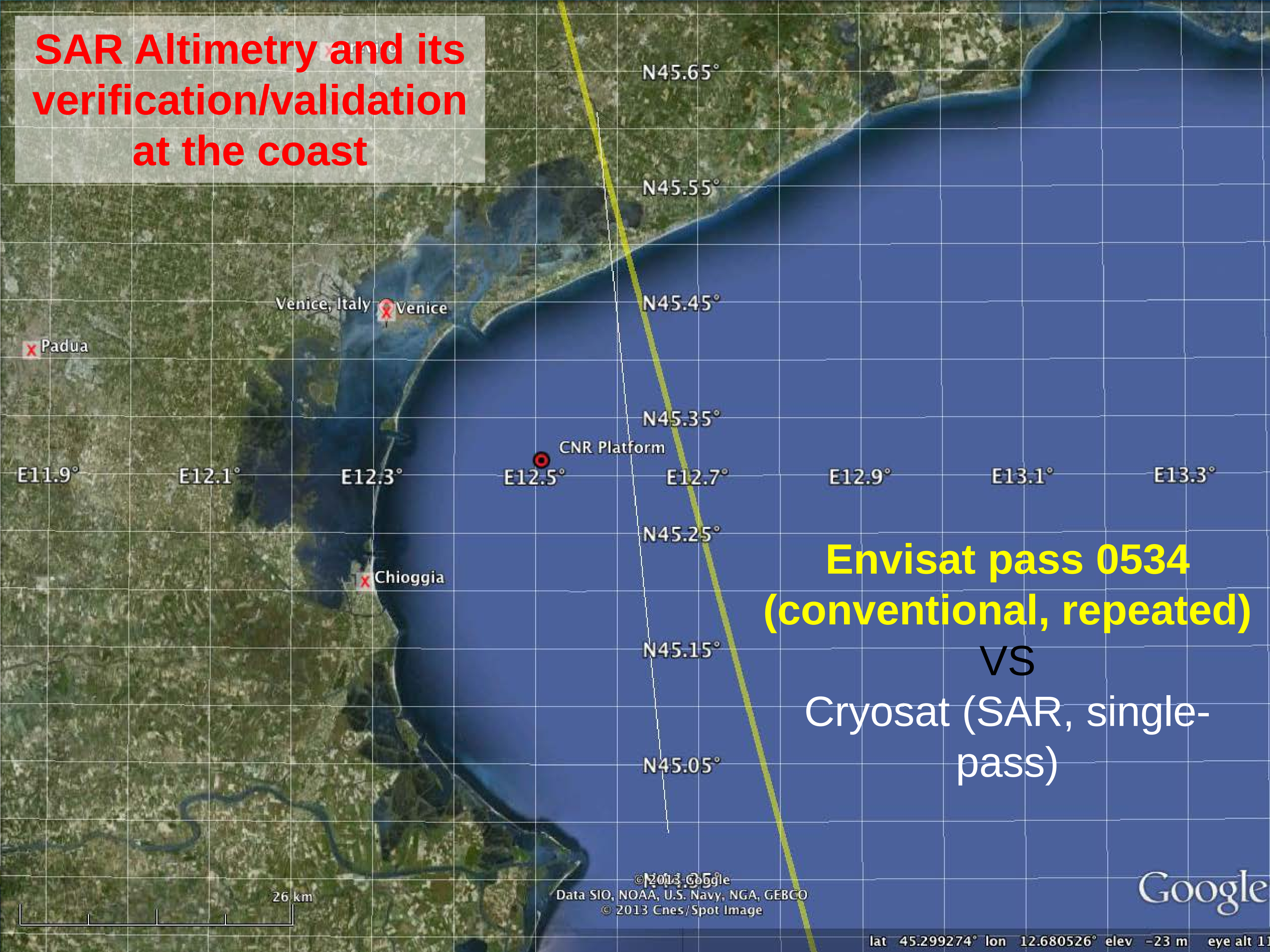


European Space Agency

In essence…

- …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) not good as it spans ~7km
- Let’s see another example

SAR Altimetry and its verification/validation at the coast

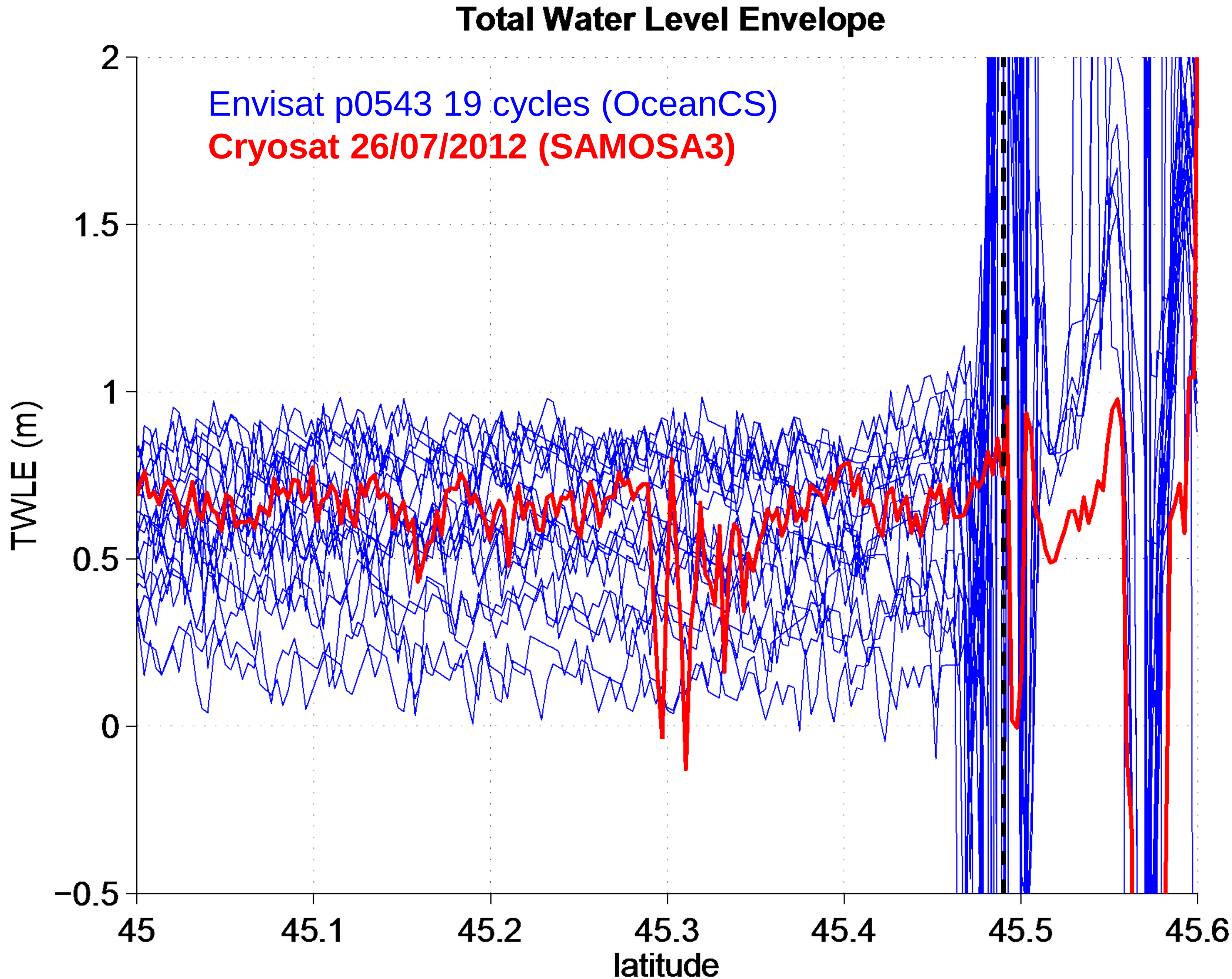


Envisat pass 0534 (conventional, repeated)

VS

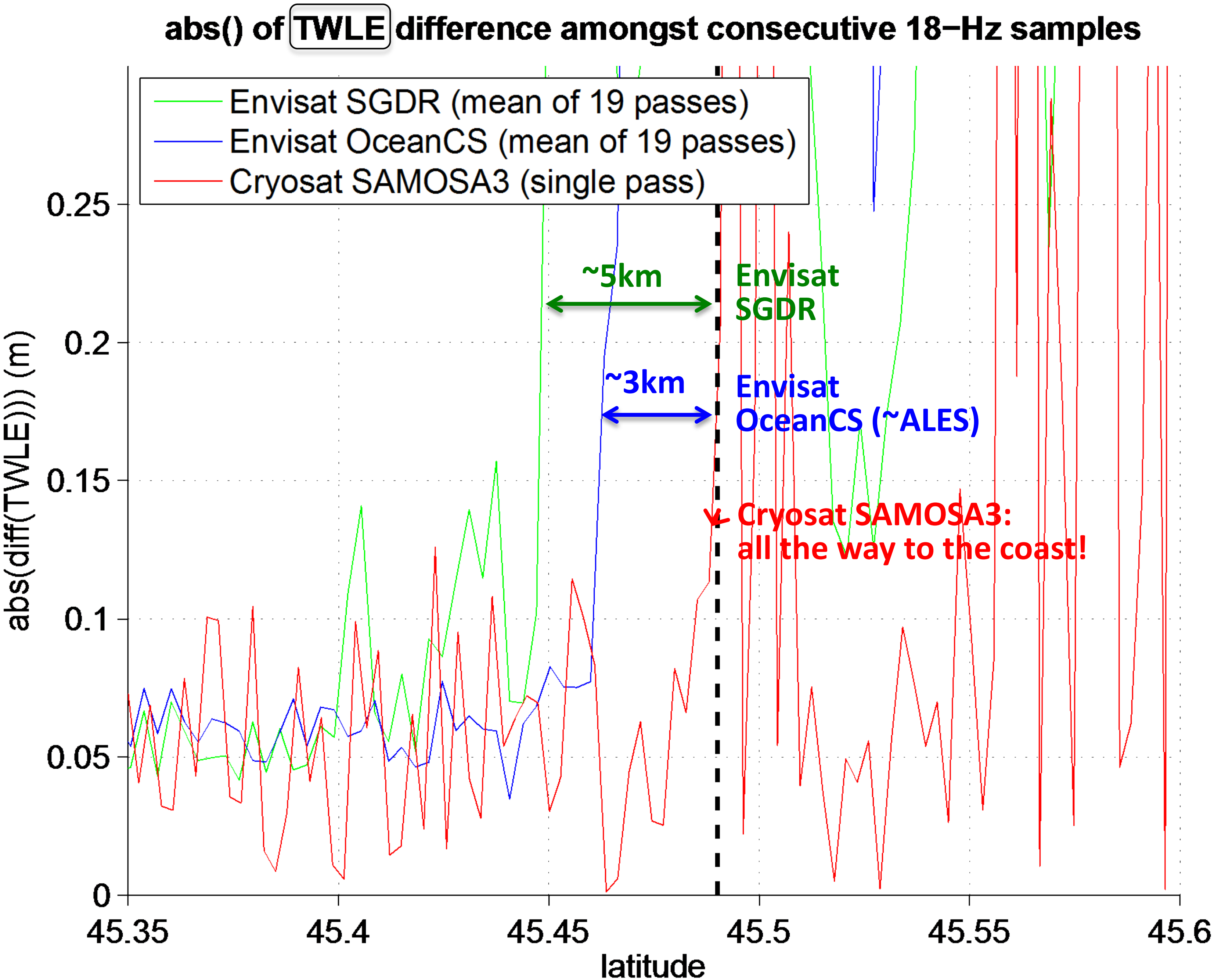
Cryosat (SAR, single-pass)

Total Water Level Envelope – sea level inclusive of tides and pressure/wind effects



OceanCS retracker (subwaveform retracker): Yang et al, 2012

Total **W**ater **L**evel **E**nvelope – sea level inclusive of tides and pressure/wind effects

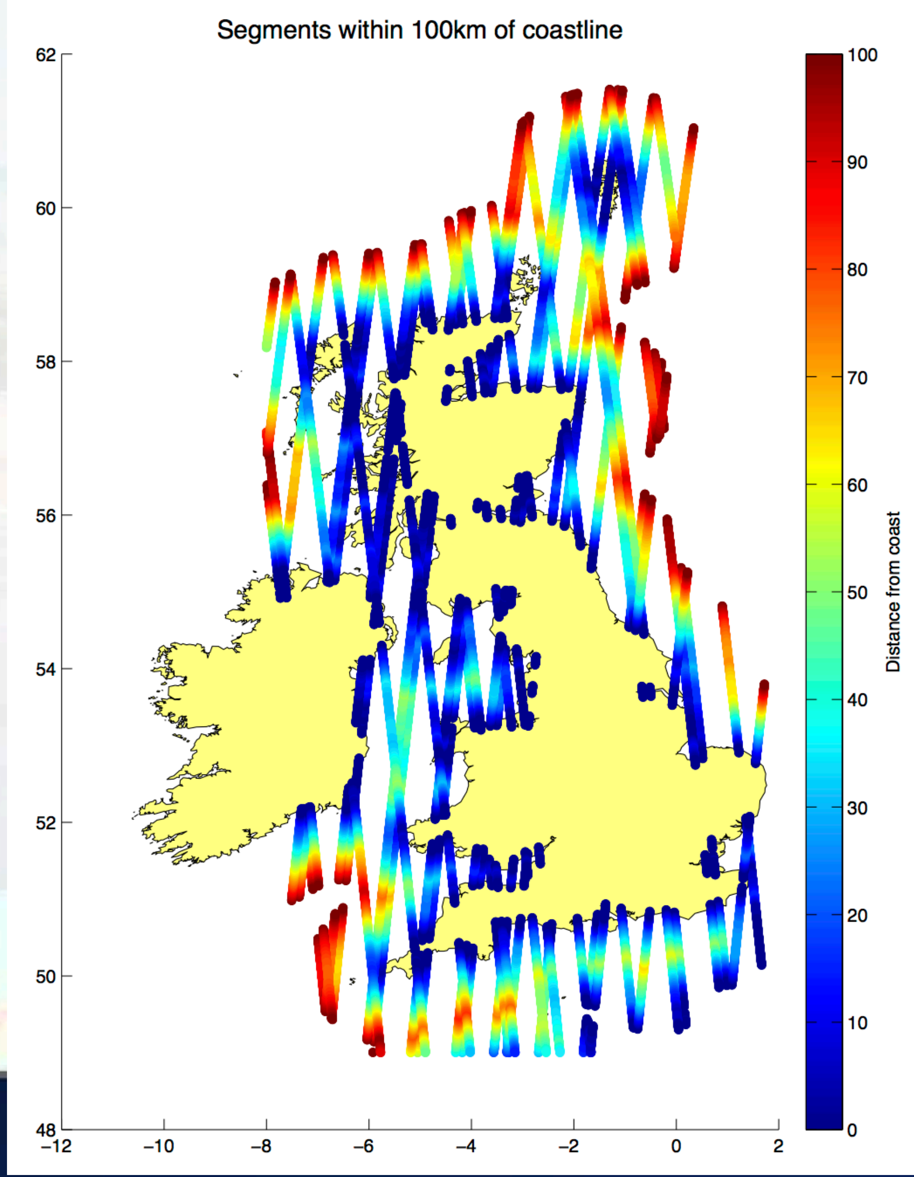


Differences as estimates of noise

- We can assume that SSH does not change significantly over 350 m
- → difference between adjacent 20-Hz SSH values is essentially due to the measurement 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)))

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'

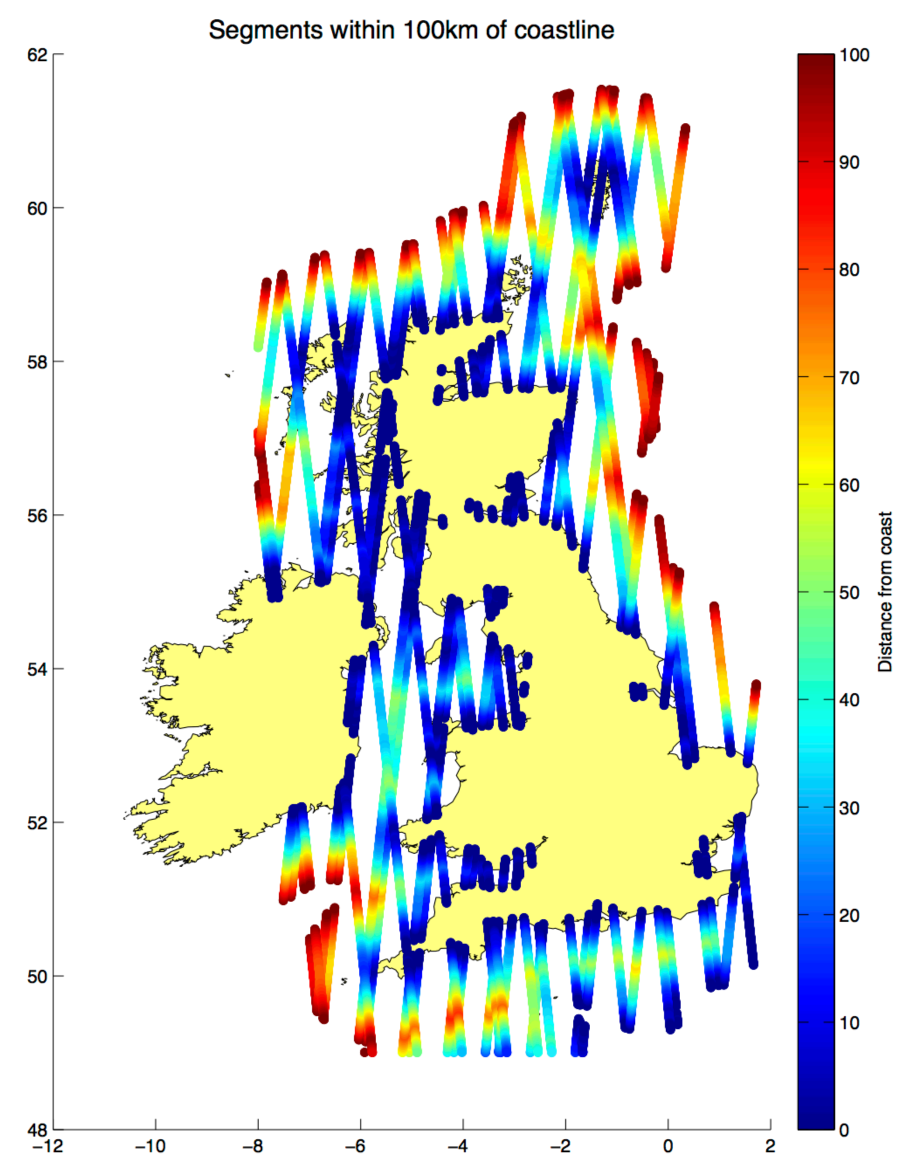


CP40 Run R5

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

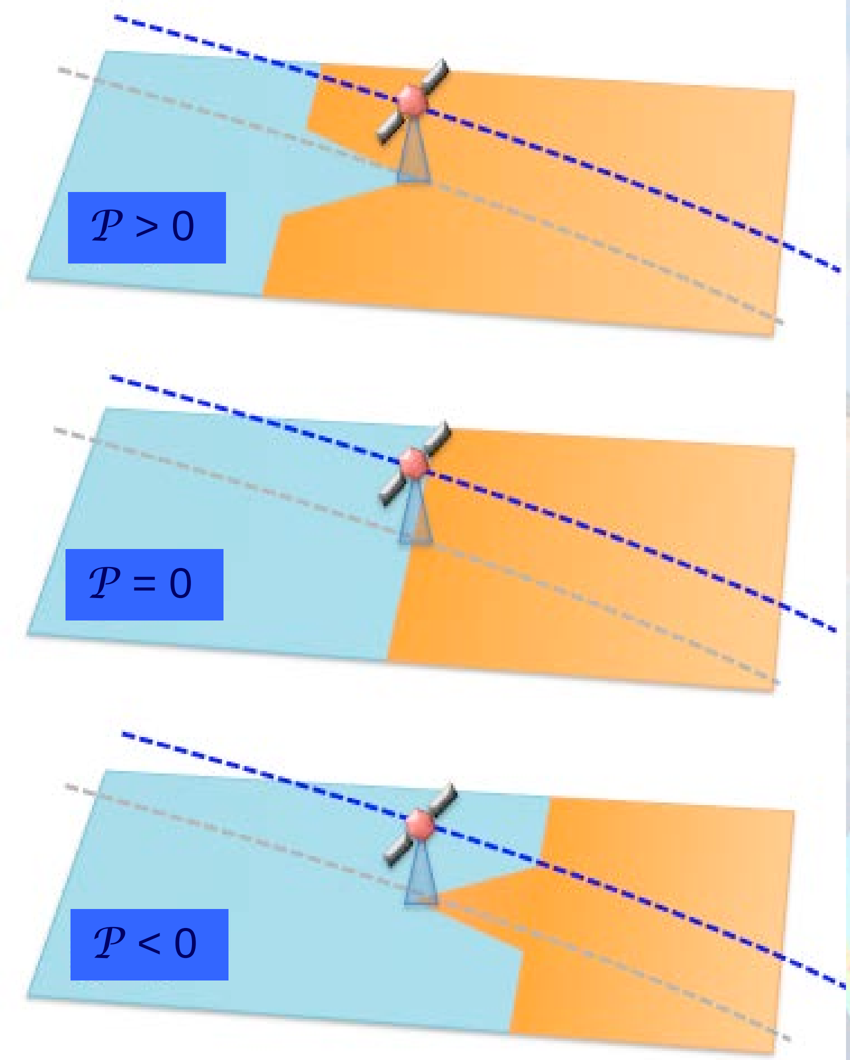


Coastal Proximity $\mathcal{P}$

- 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

Defining $\mathcal{P}$

- increasing from ocean → land
- smaller over tips/peninsulas, larger in recessed bays
- for easier comparison with distance (which is zero at coastline), $\mathcal{P}$ can be remapped
  - -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 any location 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 $\mathcal{P}$

Computing $\mathcal{P}$ - parameterise the two contributions

We assume them to be independent and parameterise them as ‘worst cases’, and compute, *gate by gate* :

1. power deficit due to “missing ocean”: assume $sigma0_{land}=0$ for this effect

$$P_1 = \frac{n_{ocean0} - n_{ocean}}{n_{ocean0}}$$

where n_{ocean} is the return from the ocean elements only; and n_{ocean0} the return from ocean elements if there was no land at all

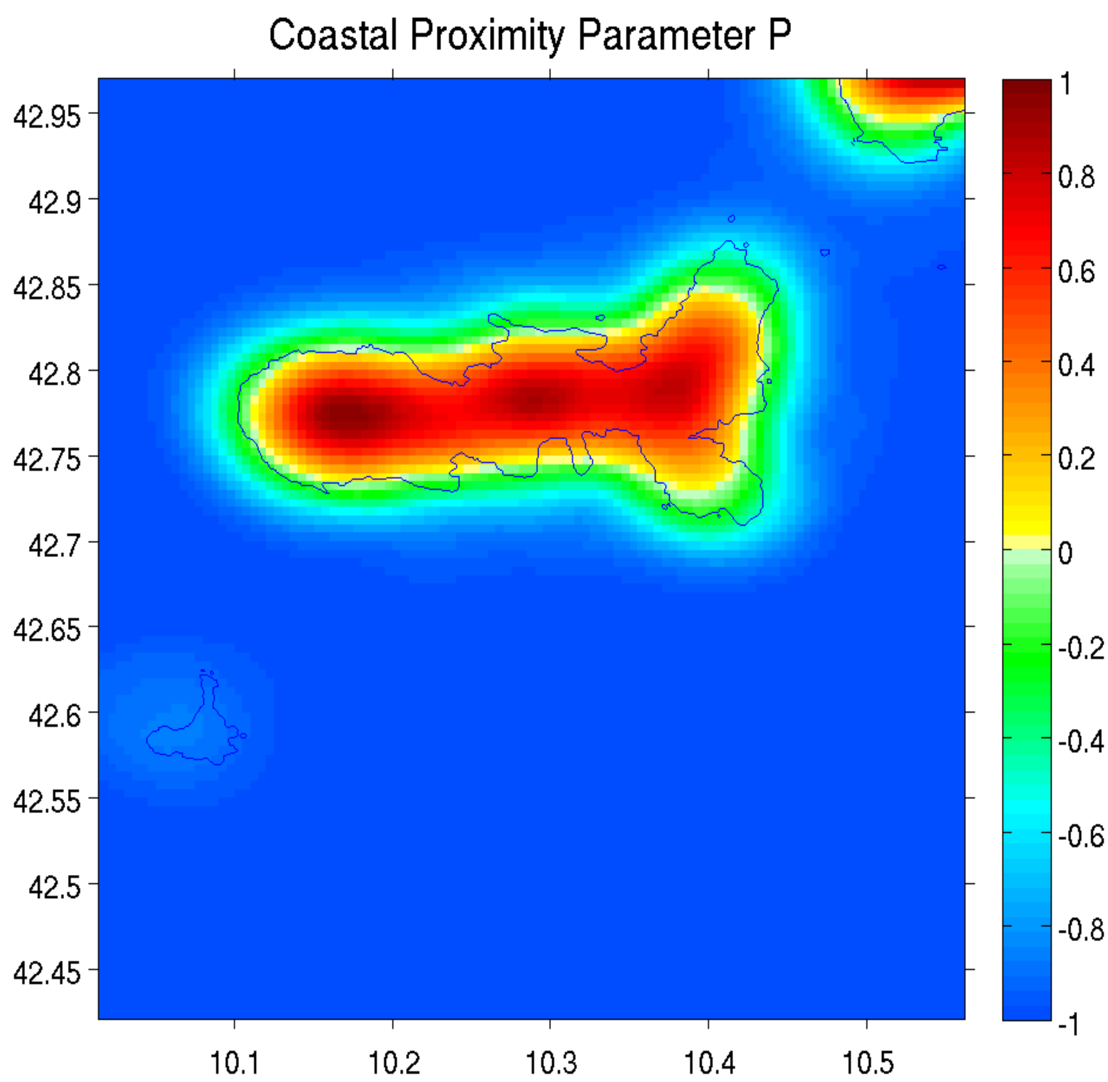
2. land returns in various gates depending on land elevation: assume $sigma0_{land}=sigma0_{ocean}$ for this effect

$$P_2 = \frac{n_{land}}{\max\left(n_{ocean0}\right)}$$

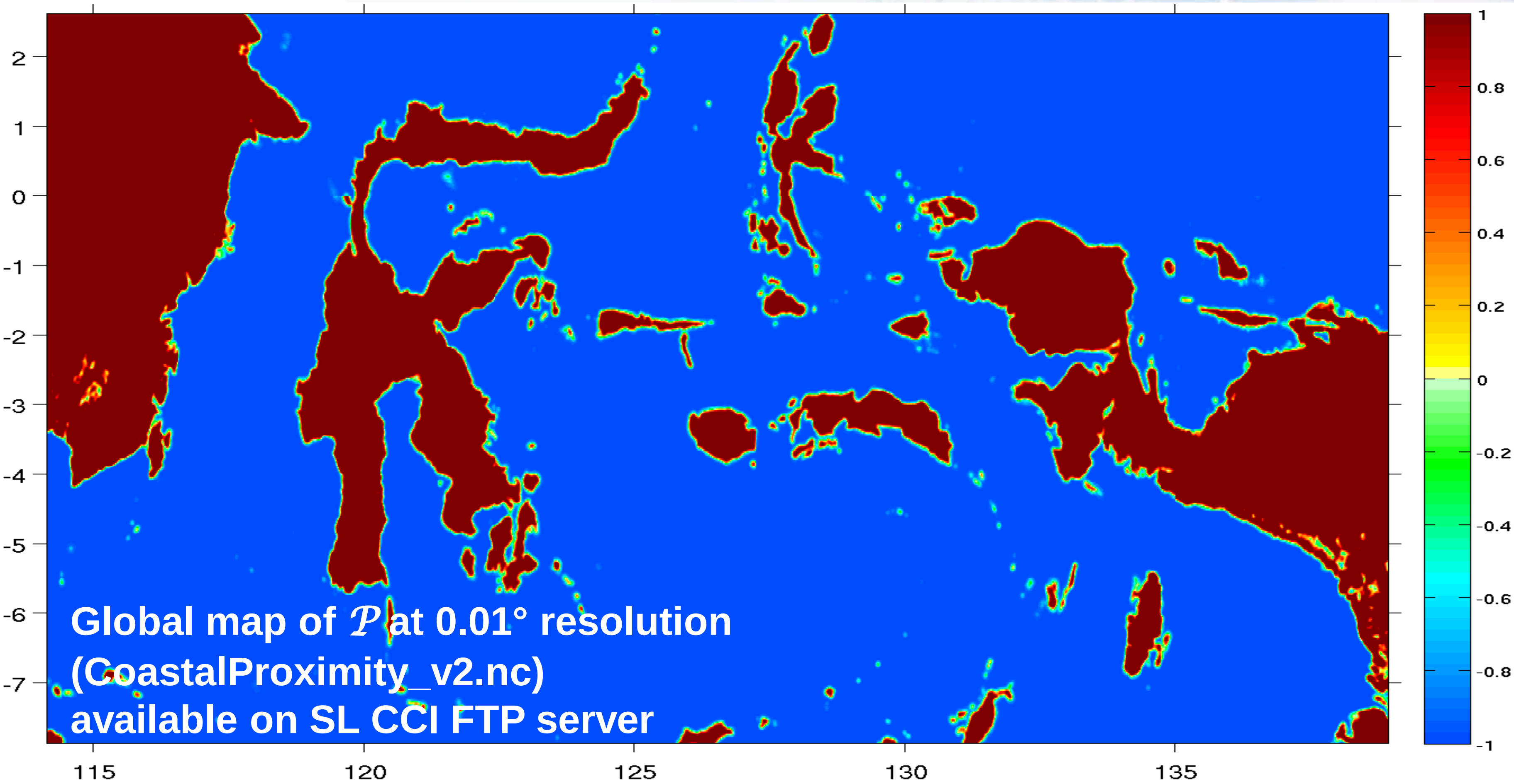
where n_{land} is the return from the land elements only

Finally we weight $\mathcal{P}_1$, $\mathcal{P}_2$ by gate position, sum them and rescale them to [-1,1]

Example of $\mathcal{P}$

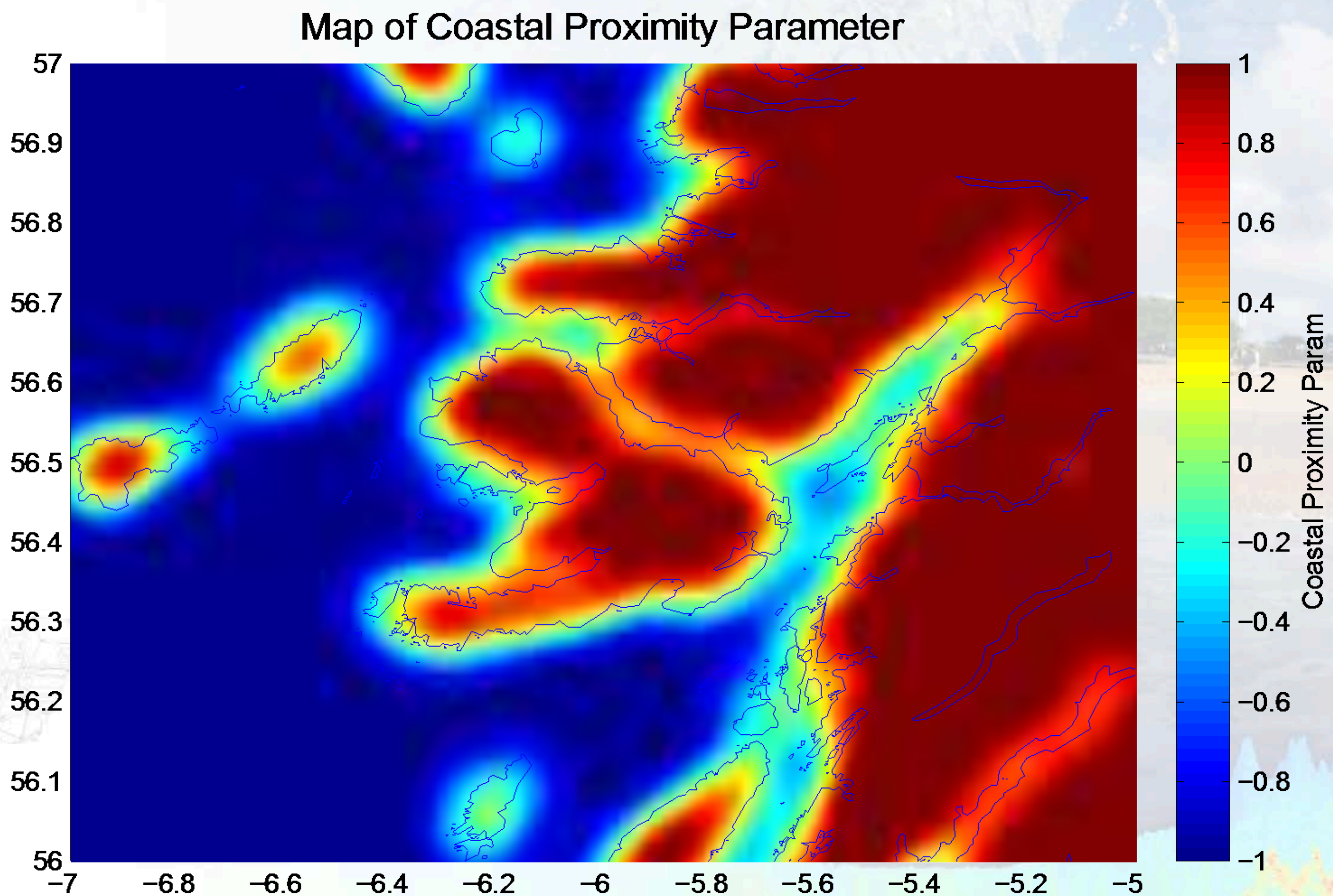


Example of $\mathcal{P}$

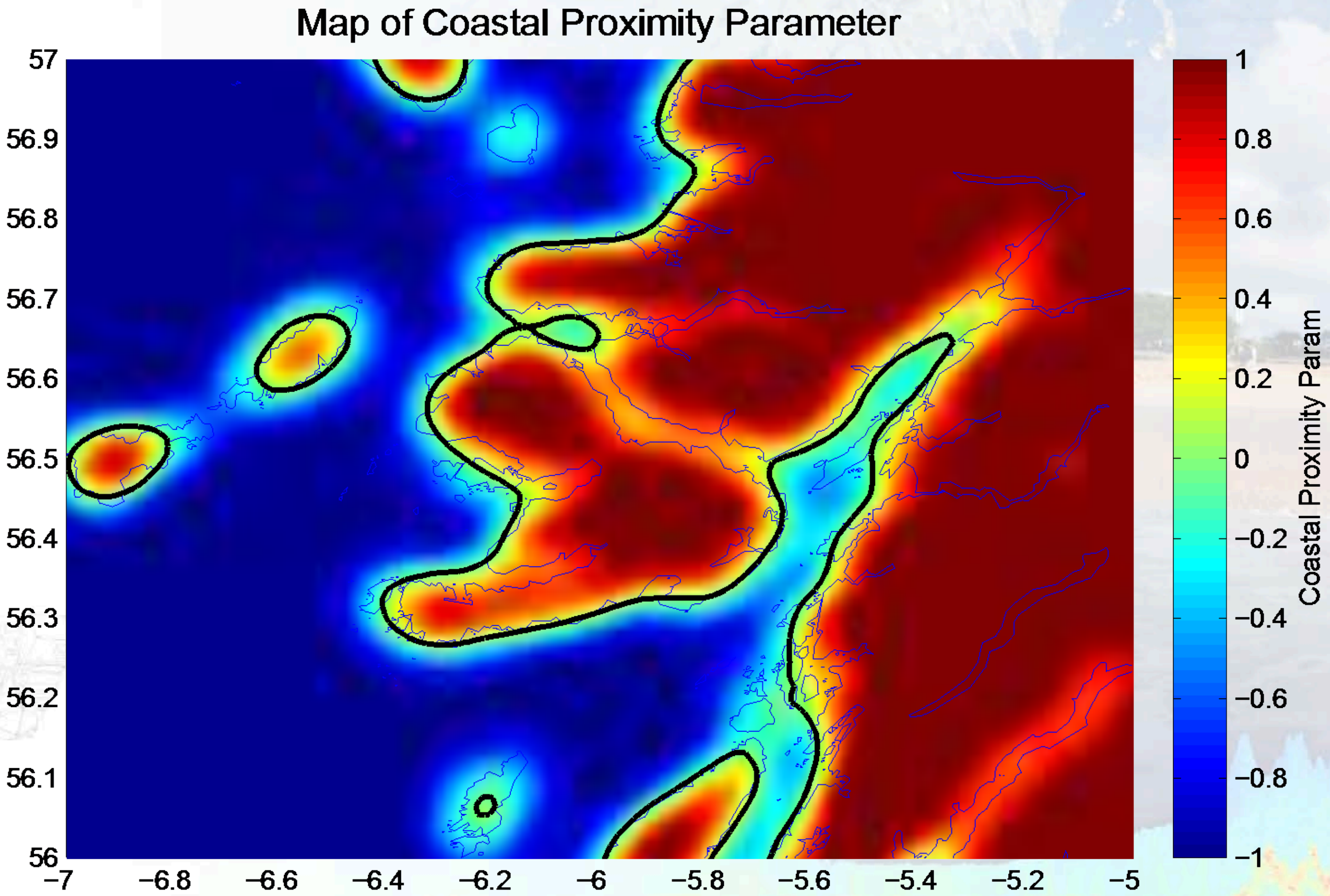


Global map of $\mathcal{P}$ at 0.01° resolution (CoastalProximity_v2.nc) available on SL CCI FTP server

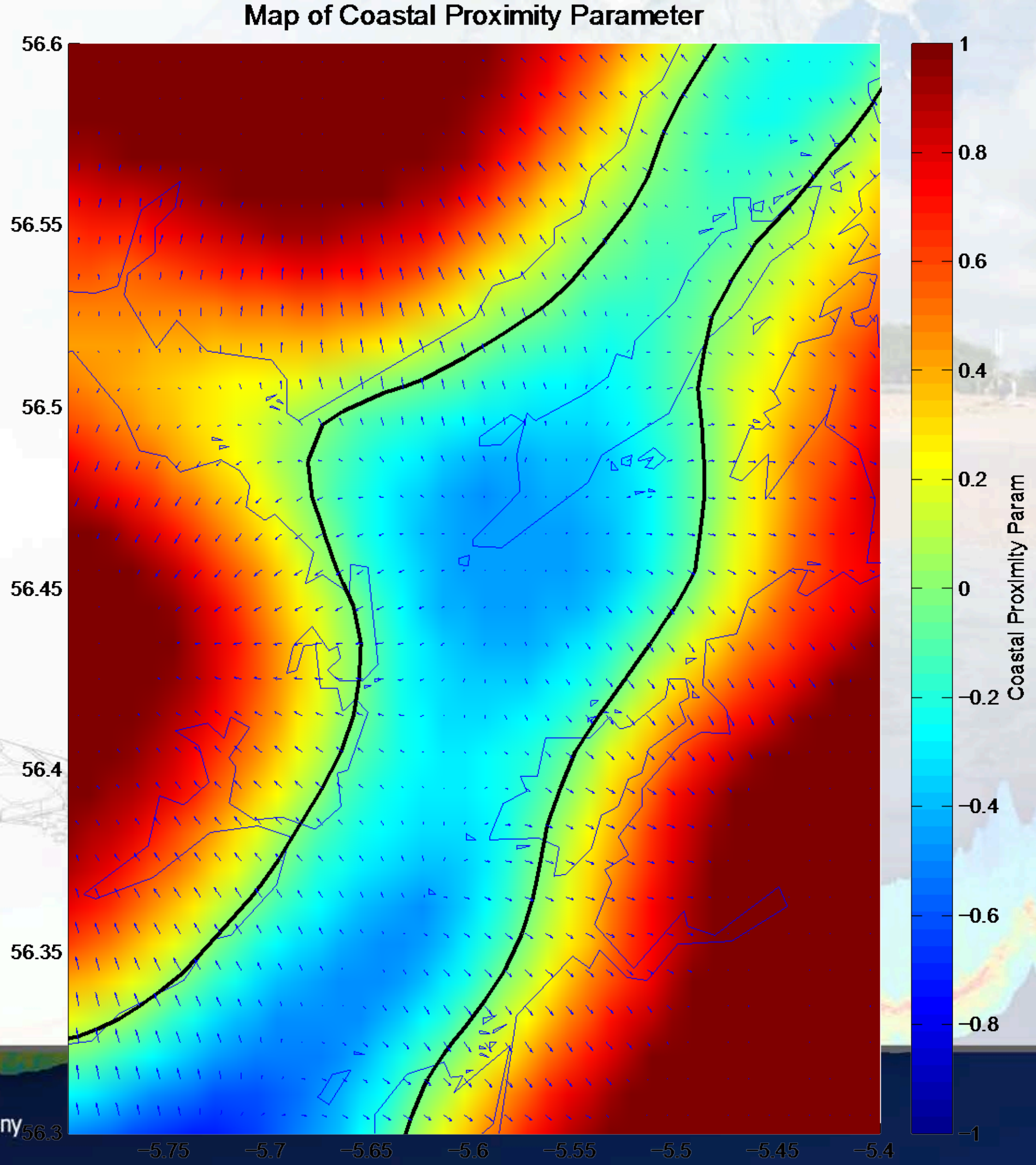
Example off W Scotland



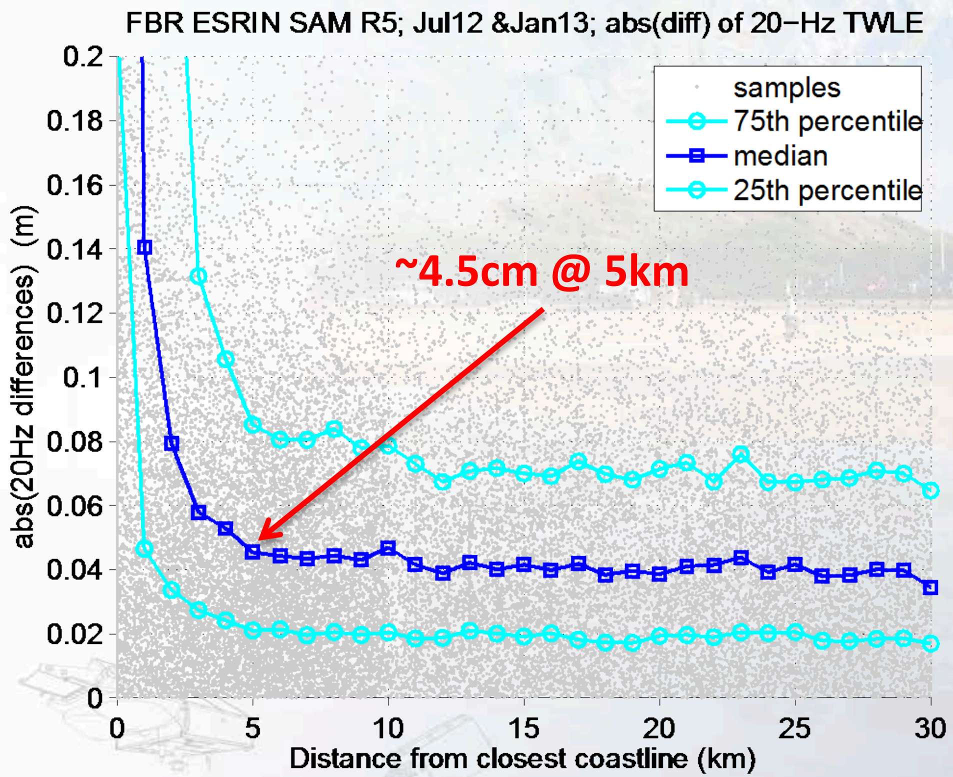
Example off W Scotland



Gradient of $\mathcal{P}$

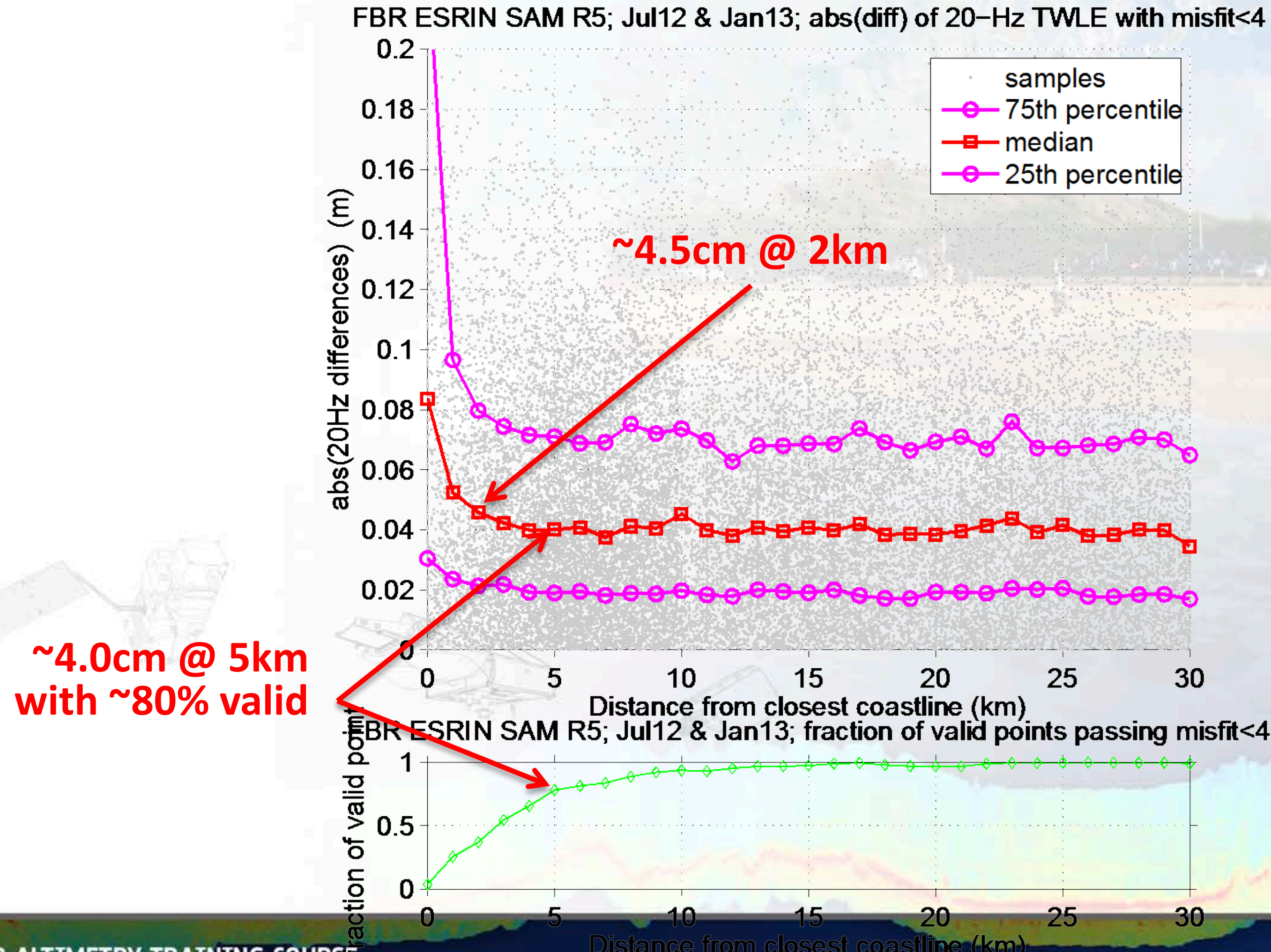


Results: noise vs distance

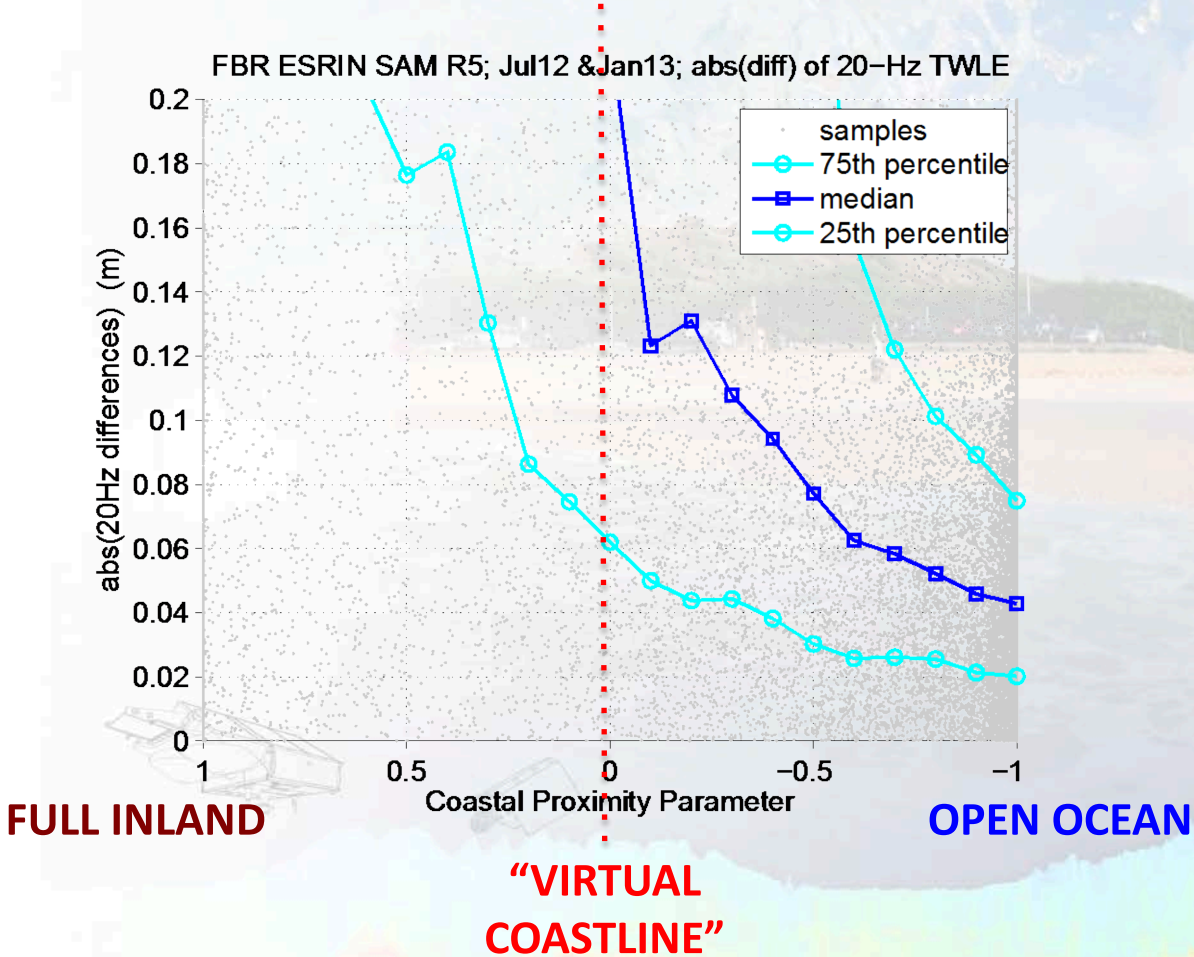


Results: noise vs distance

With additional screening based on retracking misfit



Results: noise vs $\mathcal{P}$



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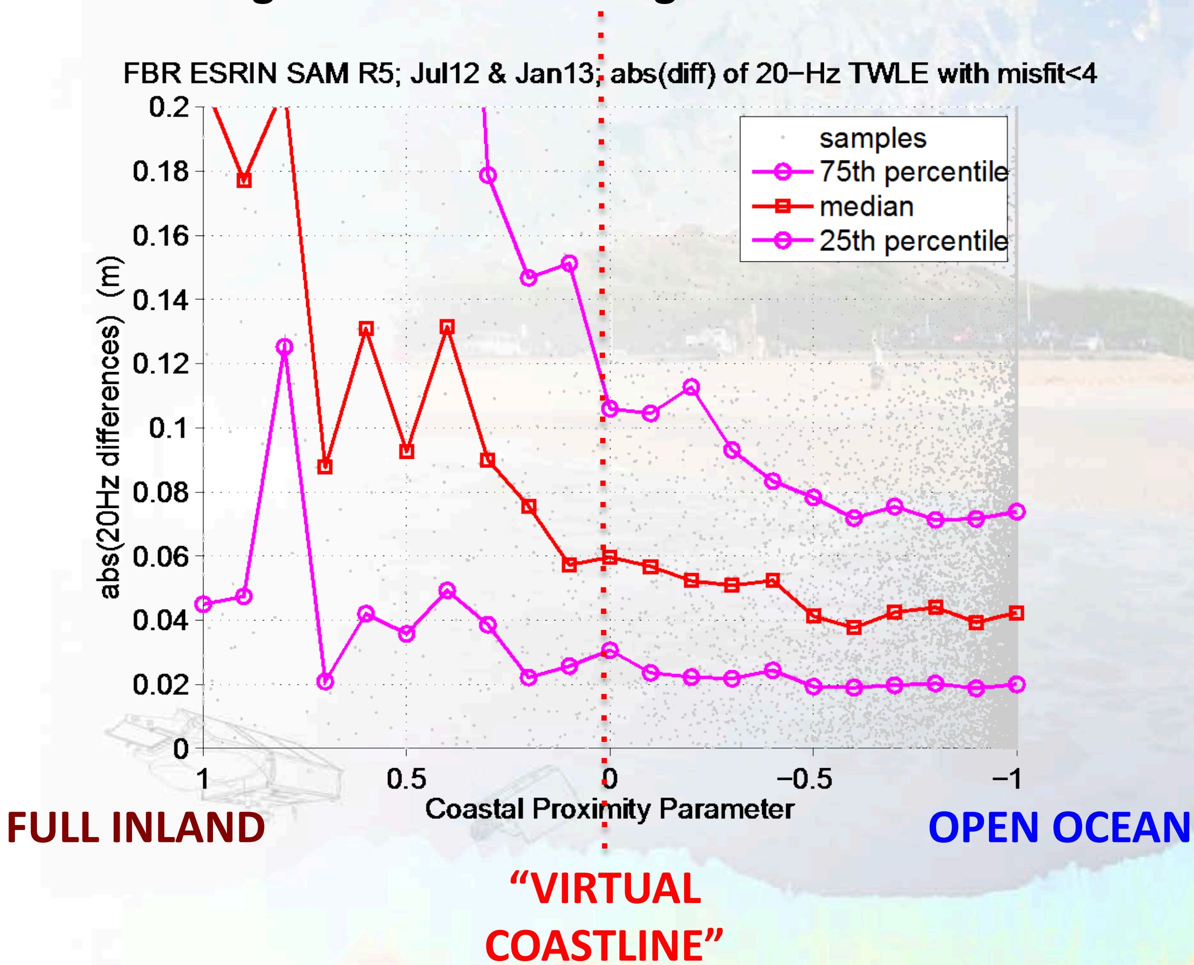


An interesting question:

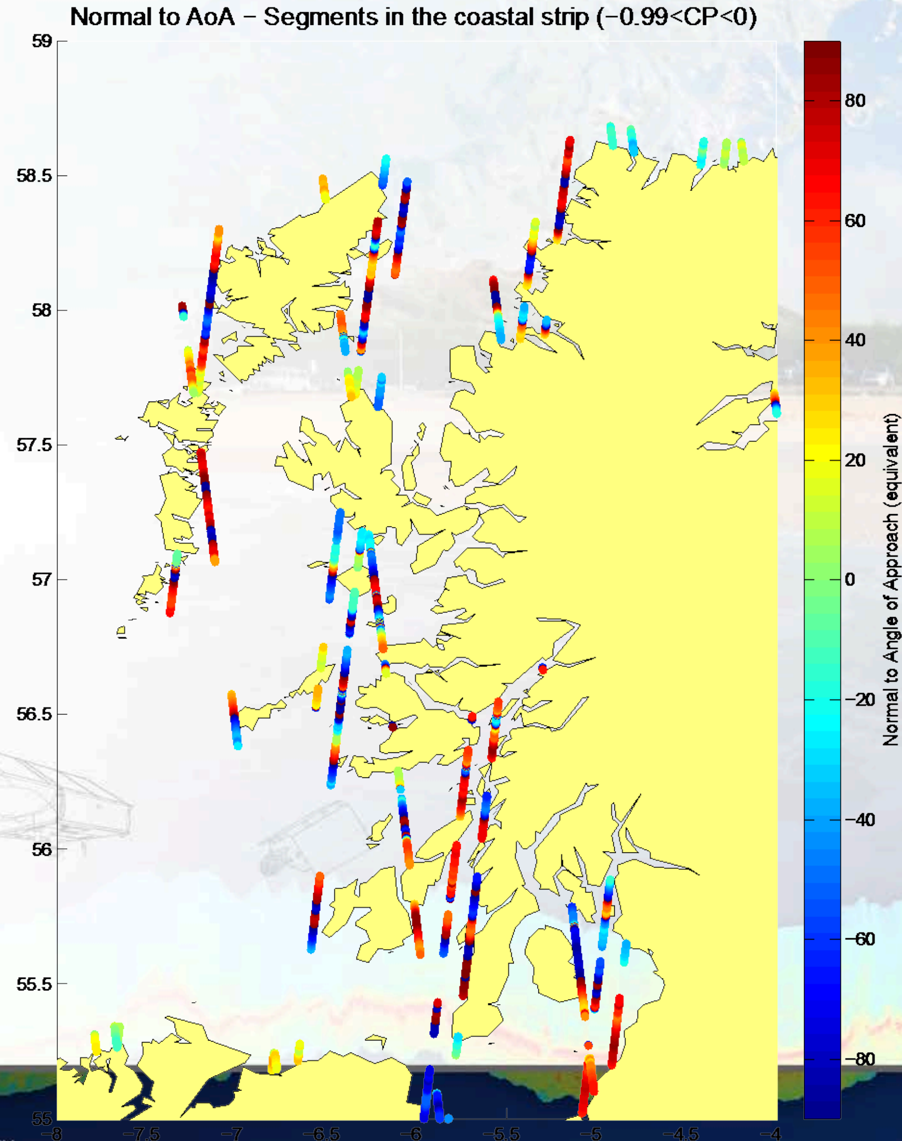
DOES PRECISION REALLY DEPEND ON ANGLE OF APPROACH TO COAST?

Angle of approach

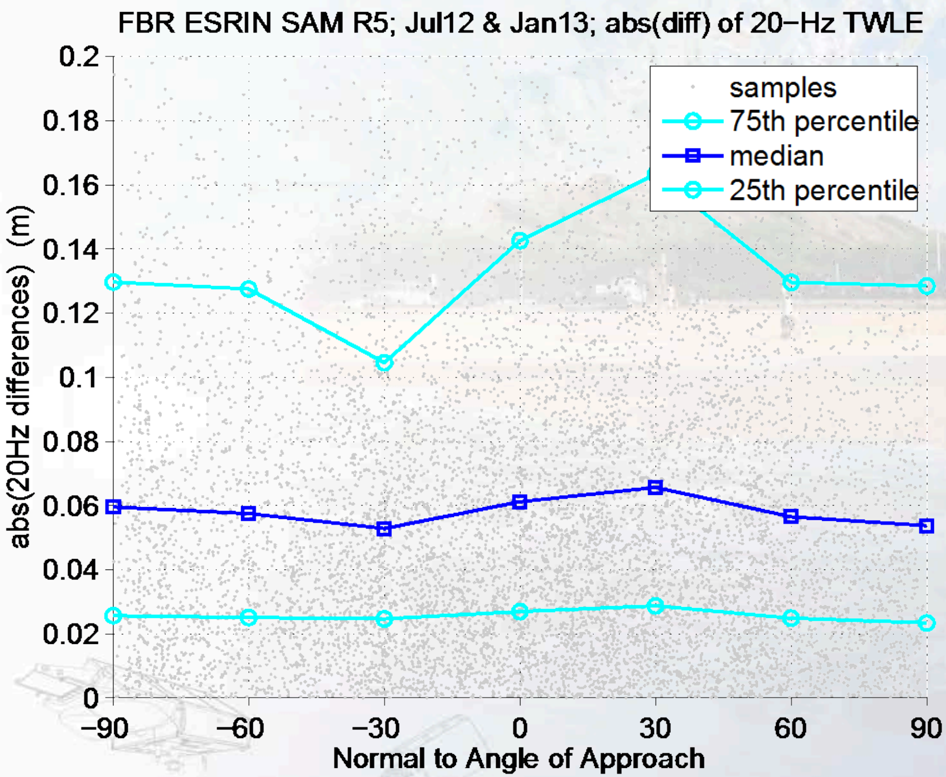
- Can be computed for each along-track point as difference between track orientation and orientation of coastal proximity gradient

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



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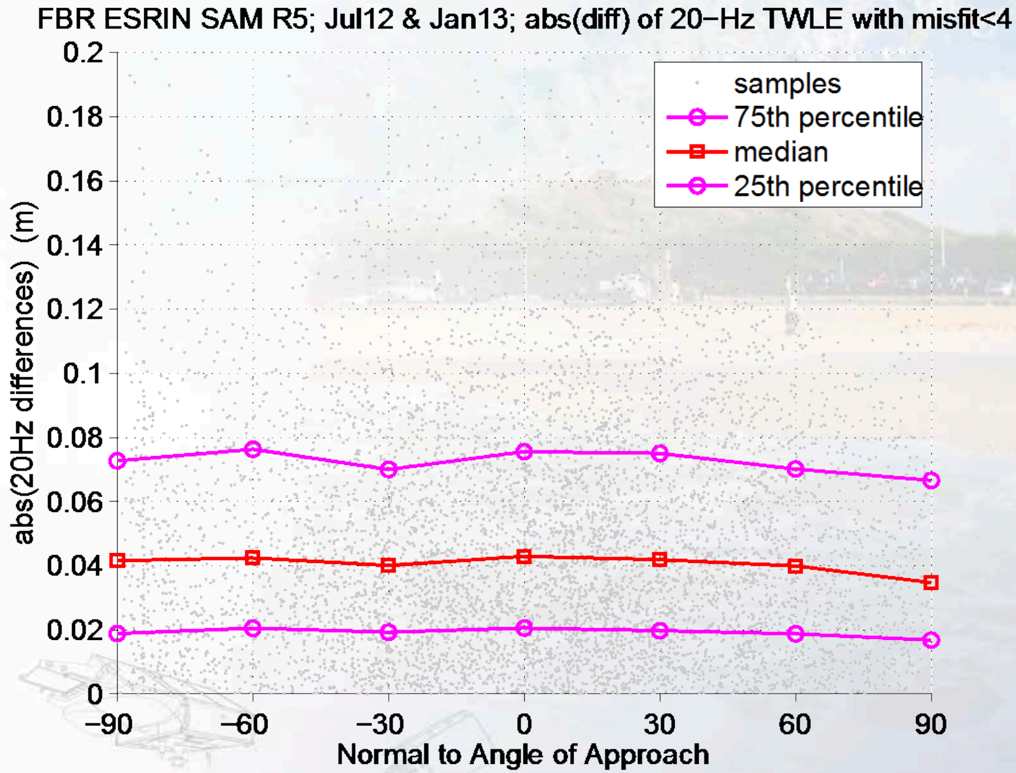
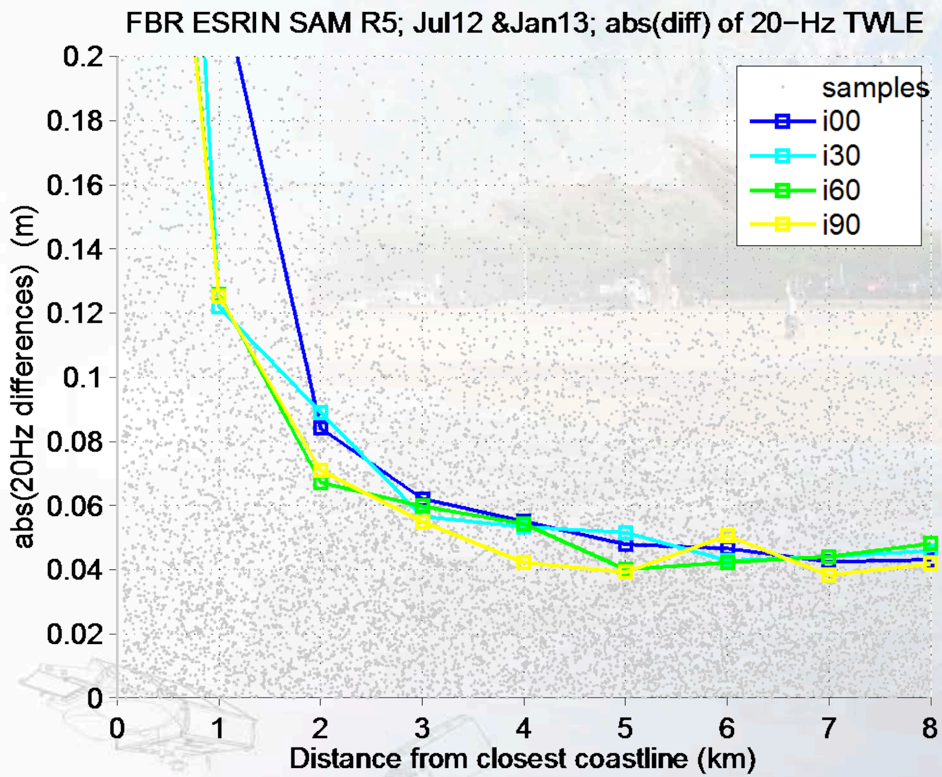
Results: noise vs AoA

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!

Conclusions

- SAR waveforms from CryoSat-2 tend to 'behave' in the coastal zone
- Precision can be studied both as function of distance to coast and 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 points. Or 4.5cm@2-3km with 40-50% valid points
- Dependence on angle of approach needs more investigation, results are not conclusive.