Progress in Coastal Altimetry: the experience of the COASTALT Project

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+ the whole COASTALT crew!

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UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

COASTALT - a Coastal Zone Product Study

- At end of 2007 ESA launched an ITT for a research and development activity in **Coastal Altimetry**
- Winning proposal is **COASTALT** lead by NOCS, with CNR-IBF/Pisa, NERC/POL, Univ. of Cadiz, Starlab, Univ. Porto and HIDROMOD Lisbon
- COASTALT started in Jan 2008, will last until late 2009
- It is done in coordination with CNES which is funding a parallel study in France, named PISTACH.
  - PISTACH consortium lead by CLS

COASTALT

www.coastalt.eu

PISTACH

COASTALT - objectives

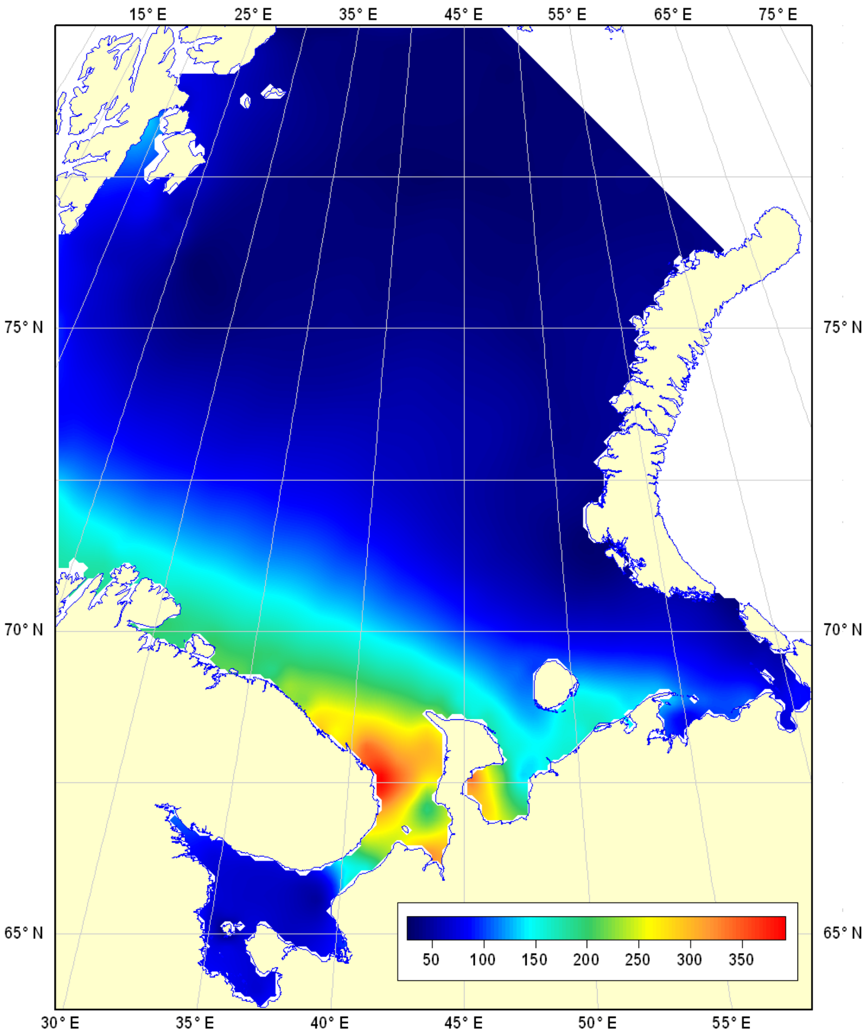
- COASTALT aims to lead to the definition, specification and prototyping of a **new pulse-limited radar altimetry coastal zone product**.
- In COASTALT this is done over a number of study regions:
  - NW Mediterranean (incl Corsica Channel)
  - West Britain
  - Portugal Coast
- The new product is eventually destined to become operationally processed by ESA
  - including the reprocessing of all the ESA Radar Altimetry archive (ERS-1, ERS-2, ENVISAT)
  - exploitation of CryoSat and Sentinel-3 over the coastal zone
  - PISTACH focuses on NASA/CNES Jason-1, Jason-2 instead

COASTALT - structure

Six Work Packages:

1. user **requirements** for a pulse-limited radar altimetry product (user survey)
    - Completed and issued **recommendations** – available on web site
2. improvement of **corrections**
3. development of **ad-hoc retracking** model and processor prototyping
4. specification of Level 2 output coastal product **format and contents**, and a product user handbook,
5. **validation** and performance assessment,
6. **outreach**.

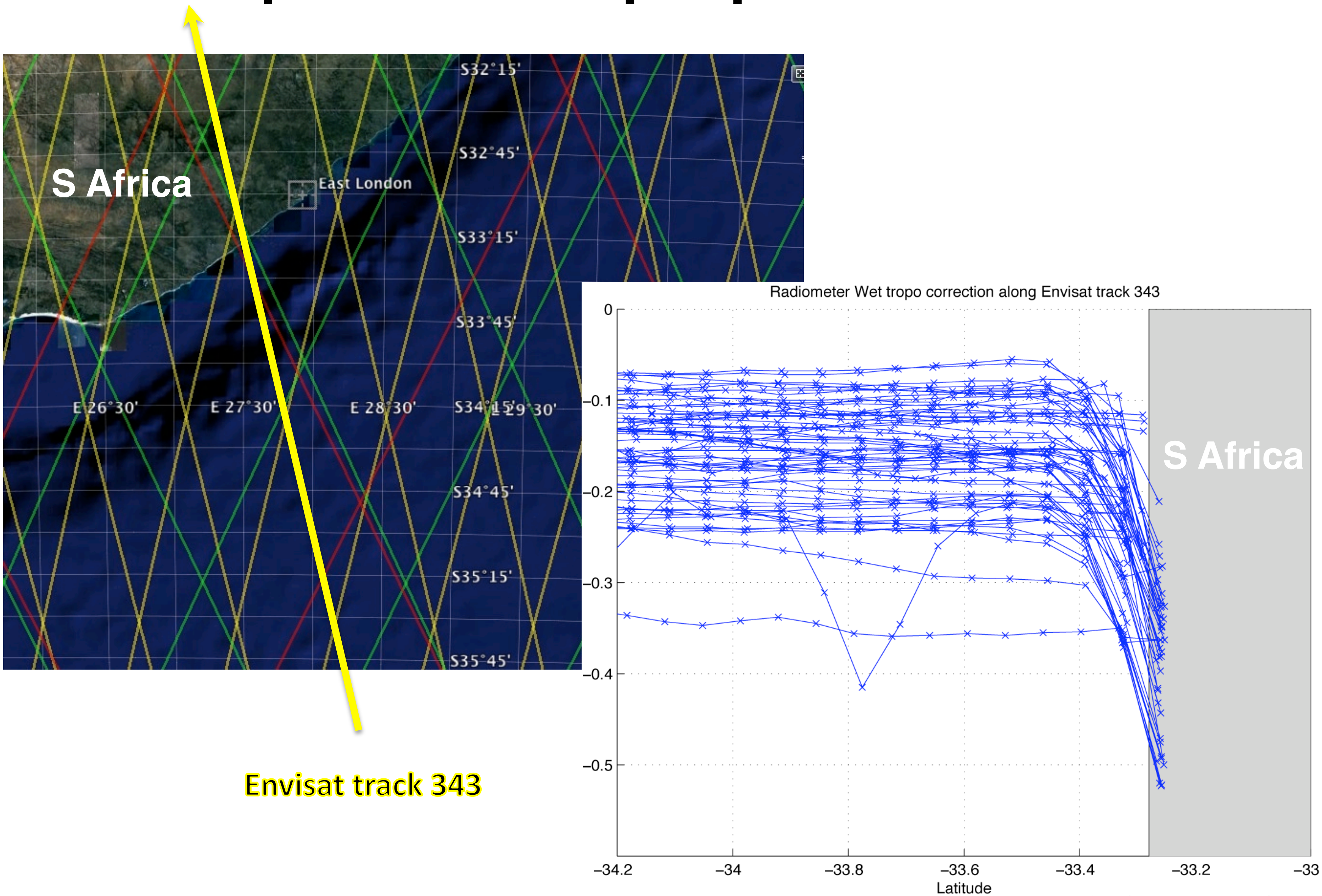
WP2 - improving corrections



Example: Difference between a local tidal model and a global one (GOT00) over the White Sea (courtesy of S. Lebedev / A. Sirota for ALTICORE)

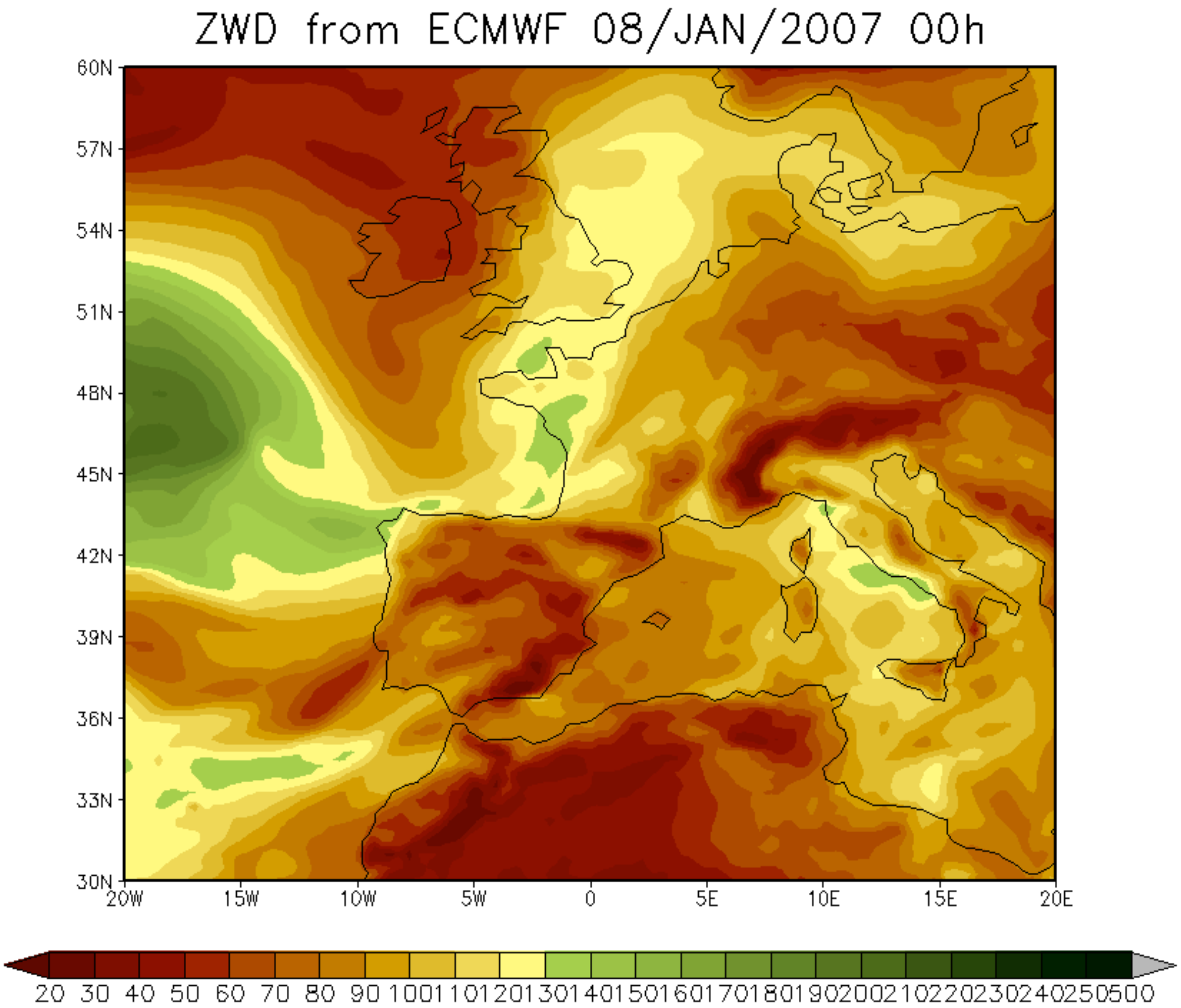
- **Wet Tropospheric** correction:
  - Extending (linking) models with radiometer observations
  - Modelling/removing land effect (being developed by PISTACH)
  - GPS-based wet tropo
- **Dry Tropospheric** correction:
  - Investigate specialized models like ALADIN (Météo-France)
- **Ionospheric corrections**
  - Extend dual-freq open ocean corrections using GIM model (based on GPS)
- **IB and HF dealiasing**
  - Investigate and use local models
- Also need better **data screening and editing**

Example - Wet Tropospheric correction



J. Maina Mbui for ALTICORE-Africa

Wet Tropo Model



U Porto (Fernandes/Nunes/Lazaro/Pires)

Linking radiometer and model: DLM approach

- DLM = ‘Dynamically Linked Model’
- Simple method requiring only GDR fields:
  - Radiometer and NWM derived wet corrections
  - MWR flags (LAND flag + MWR QUAL flag for Envisat)
- Optional information: distance to land

- Data are split into segments
- In each segment identifies “land contaminated zones”

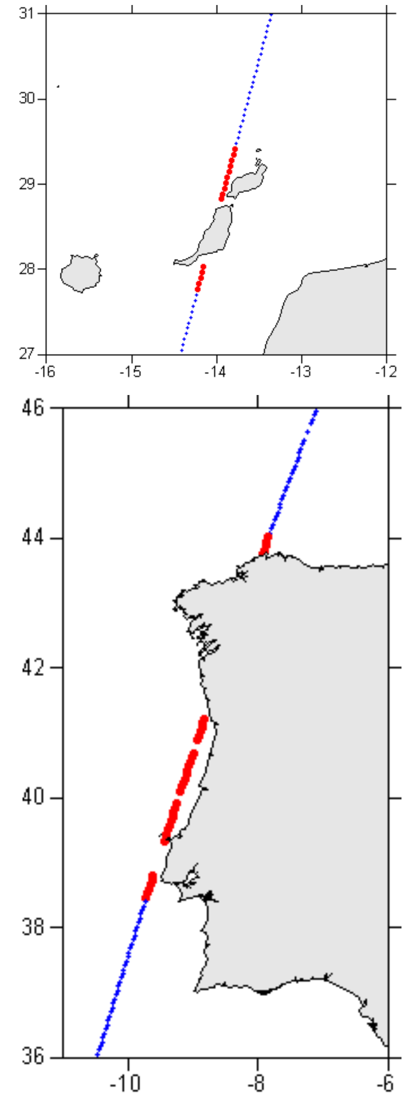
- Identification of “land contaminated zones”
  - Flags only
  - Flags + distance to land

DLM approach

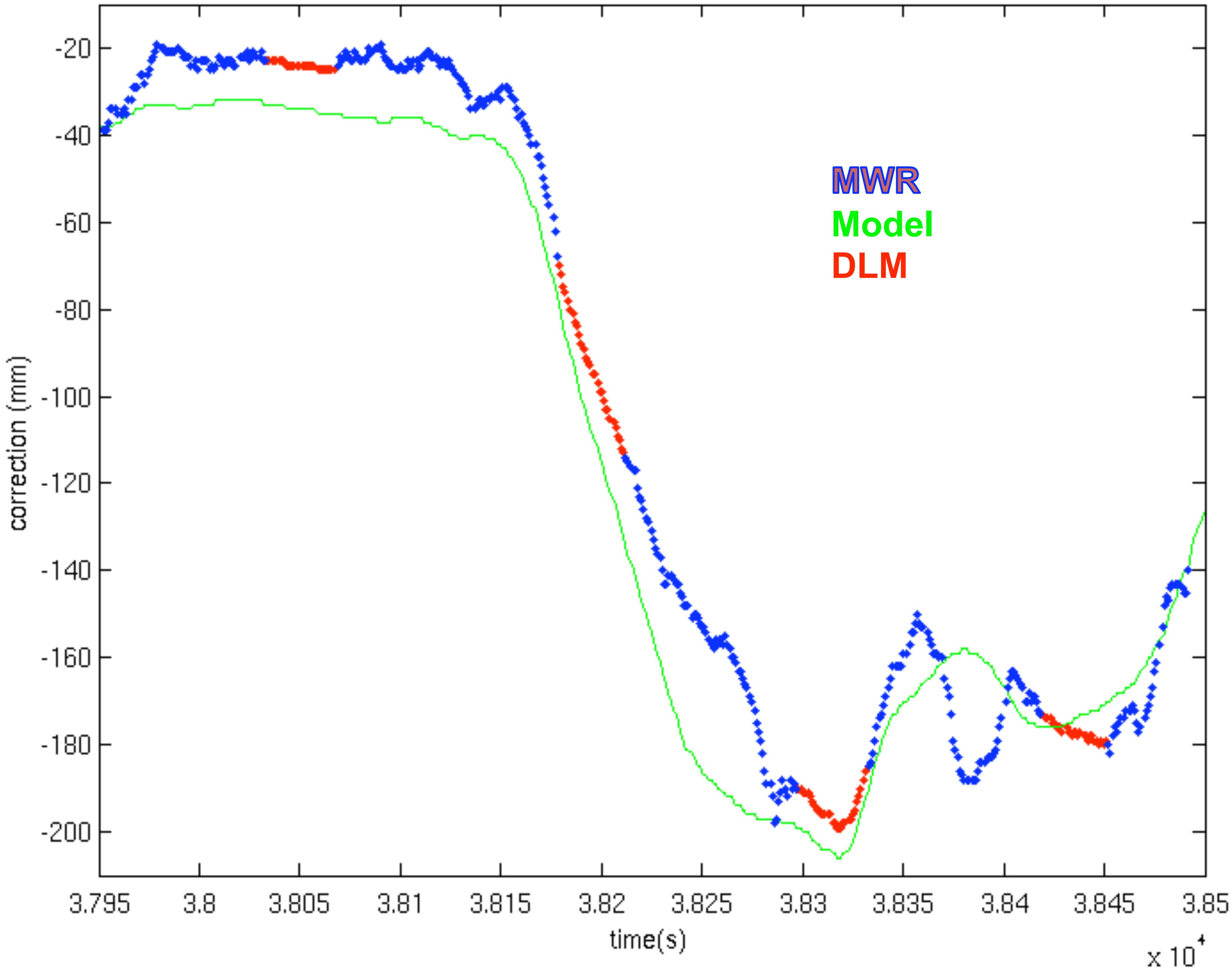
Two types of algorithm

- Island type or ‘double-ended‘ algorithm
  - valid radiometer points on each side of the segment
  - Model field is adjusted to the radiometer field, at the beginning and end of the land contaminated segment, by using a linear adjustment (using time as interpolation coordinate)

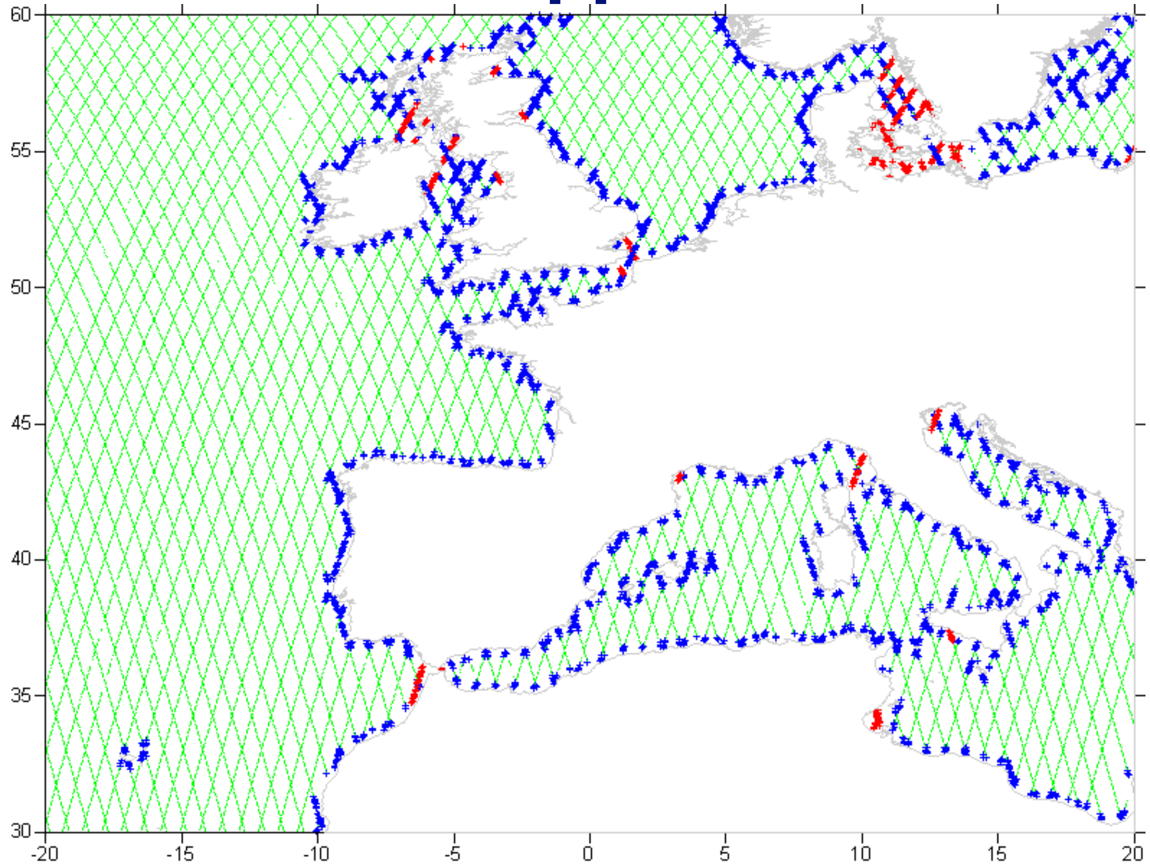
- Continental coastline type algorithm (‘single-ended’)
  - only valid radiometer points on one side of the segment
  - Model field is adjusted to the radiometer field, at the beginning or at the end of the land contaminated segment, by using a bias correction



U Porto (Fernandes/Nunes/Lazaro/Pires) + NOCS


MWR
Model
DLM
correction (mm)
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
3.795
3.8
3.805
3.81
3.815
3.82
3.825
3.83
3.835
3.84
3.845
3.85
time(s)
x 10⁴

DLM approach



- Bue – corrected points
- Red - uncorrected points

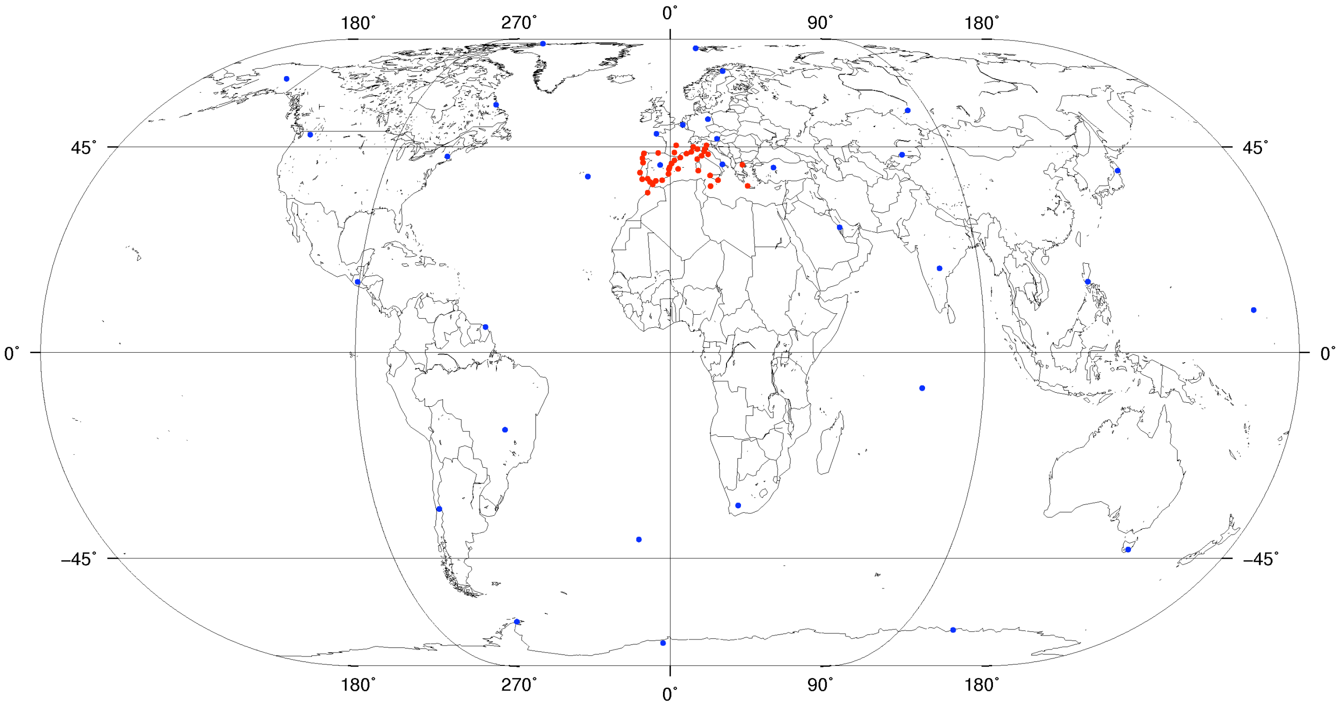
U Porto (Fernandes/Nunes/Lazaro/Pires)

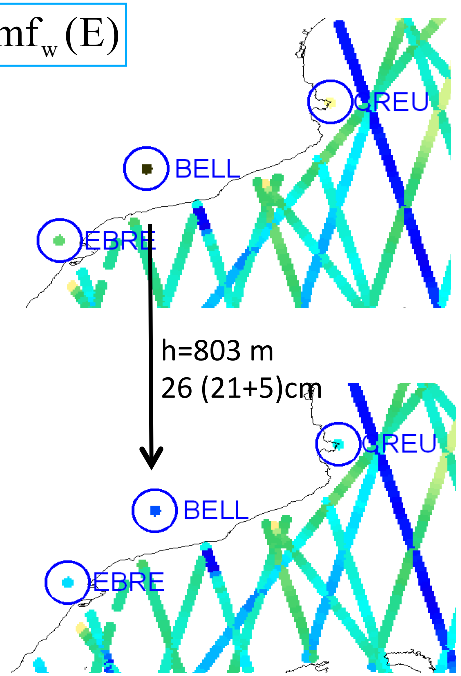
GPD Approach: Determination of Tropospheric Path Delays at GNSS stations

Software and processing strategies:

- GAMIT: allows estimation of ZWD from GNSS STD
- Vienna -1 Mapping Functions: ECMWF-based ‘slant’ to ‘zenith’ delays
- Network design: regional (**EPN**) + global (**IGS**)
- Data reduction to sea level: separate corrections for ZWD and ZHD

$$\boxed{\mathrm{STD}\,(E) = \mathrm{ZHD} \times \mathrm{mf}_h\,(E) + \mathrm{ZWD} \times \mathrm{mf}_w\,(E)}$$





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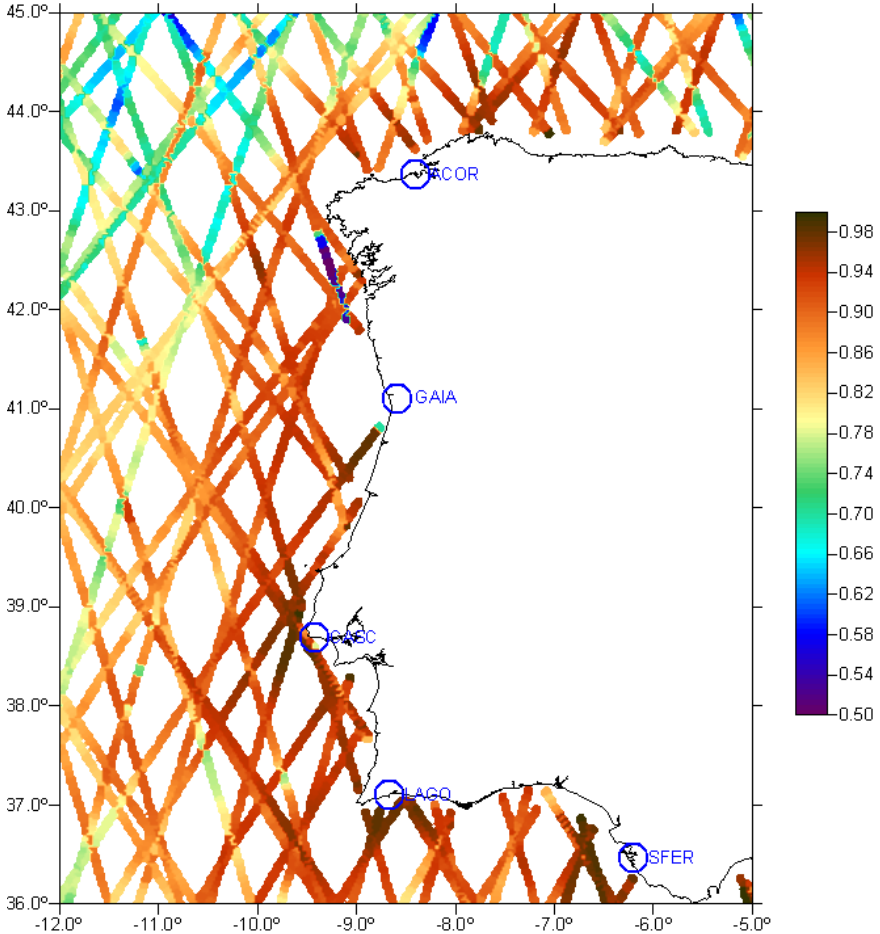
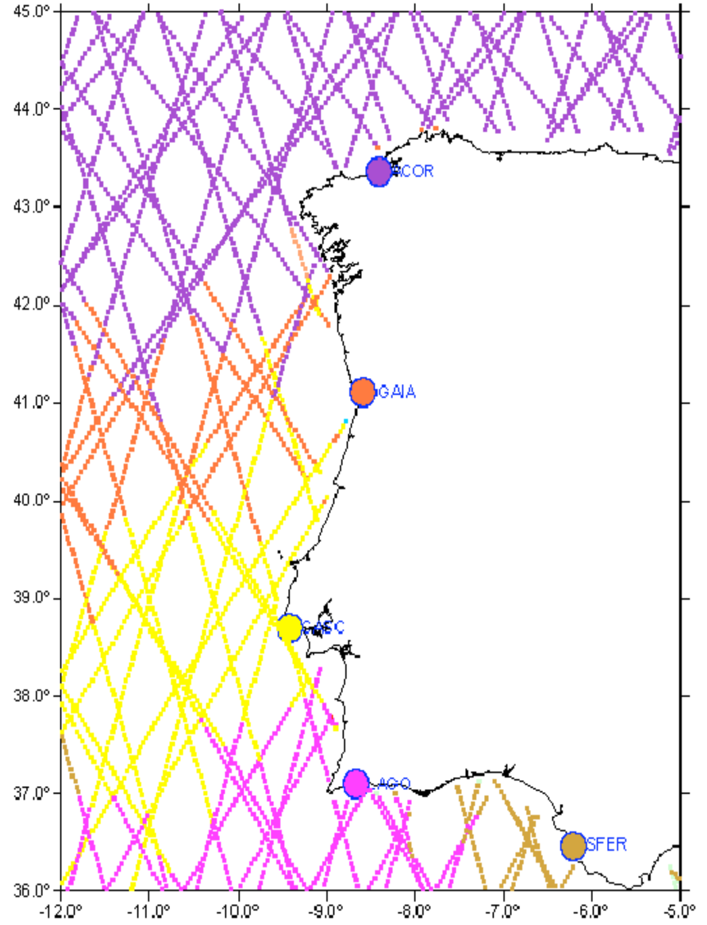
Analysis of GNSS derived tropospheric fields and corresponding altimeter fields

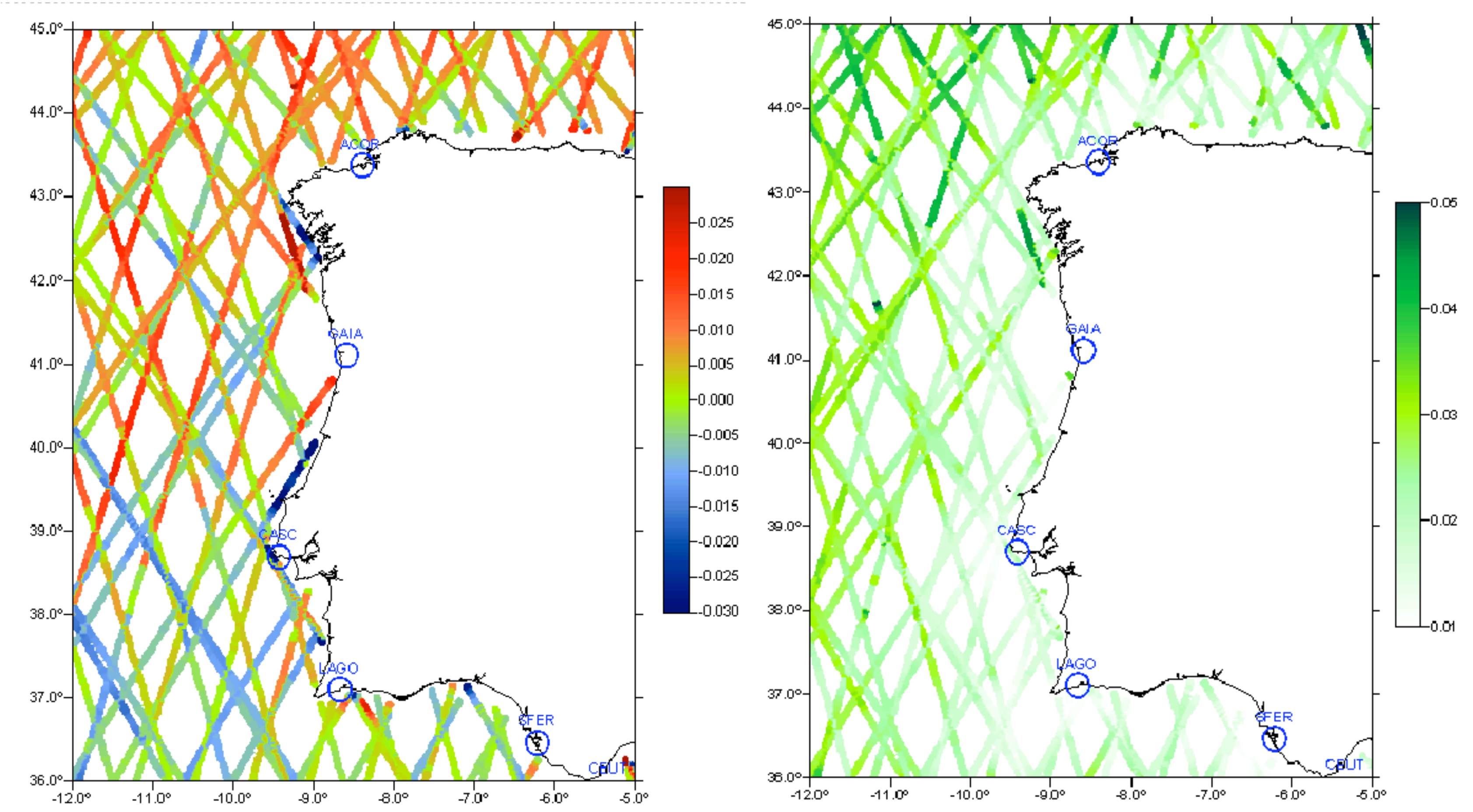




Maximum correlation (left) and station with maximum correlation (right) between GNSS-derived and altimeter MWR wet correction
Period A: September 2002 to August 2005

U Porto (Fernandes/Nunes/Lazaro/Pires)

Analysis of GNSS derived tropospheric fields and corresponding altimeter fields

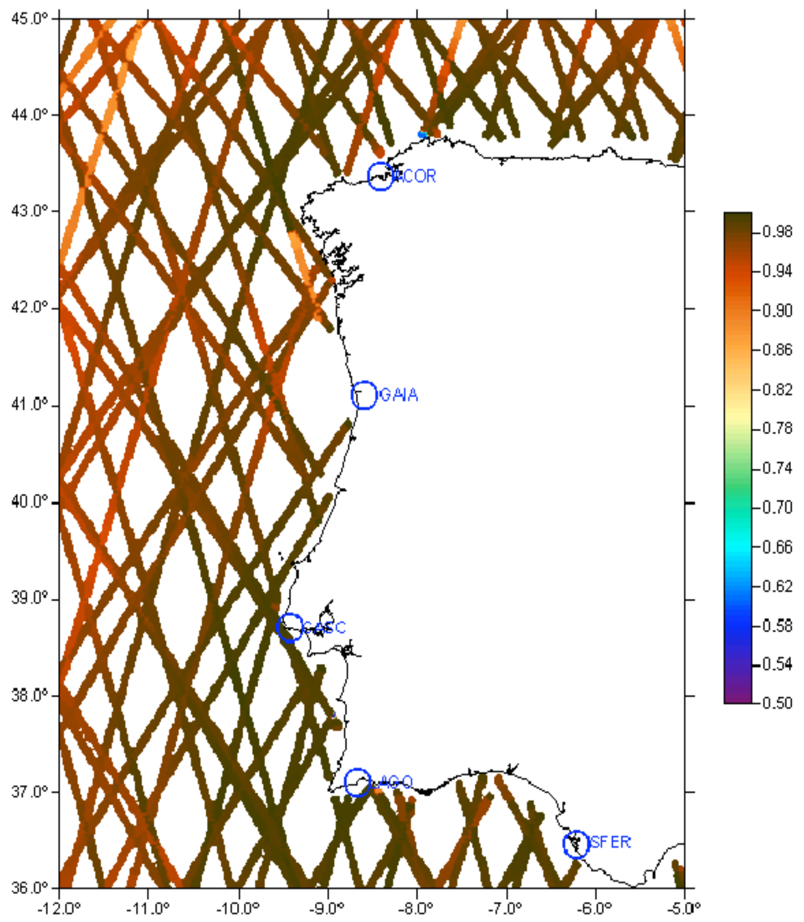


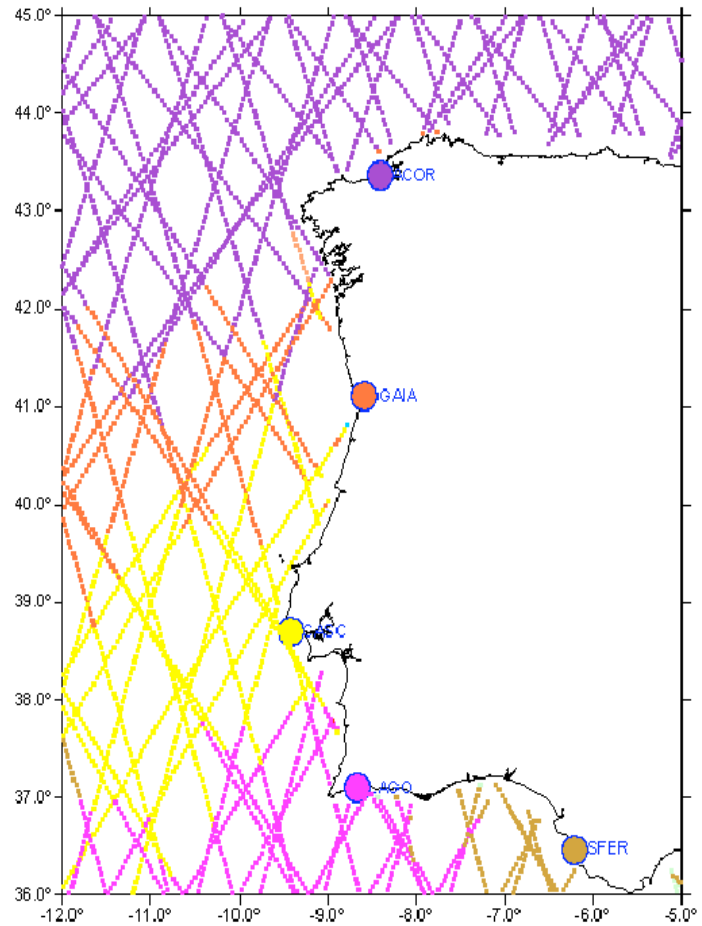
Mean (left) and standard deviation (right) of the difference between GNSS-derived and altimeter MWR wet correction

Period A: September 2002 to August 2005

U Porto (Fernandes/Nunes/Lazaro/Pires)

Analysis of GNSS derived tropospheric fields and corresponding altimeter fields





Maximum correlation (left) and station with maximum correlation (right) between GNSS-derived and altimeter ECMWF dry correction
Period A: September 2002 to August 2005

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WP 3 - Retracking

- WP3.1 Coastal waveform analysis (UCadiz, NOCS)
- WP3.2 Software Processor Design and Development (NOCS, UCadiz)
- WP3.3 Validation Plan (UCadiz, NOCS)
- WP3.4 Software Testing & Validation (Starlab, NOCS, UCadiz)
- WP3.5 Innovative Retracking (NOCS)

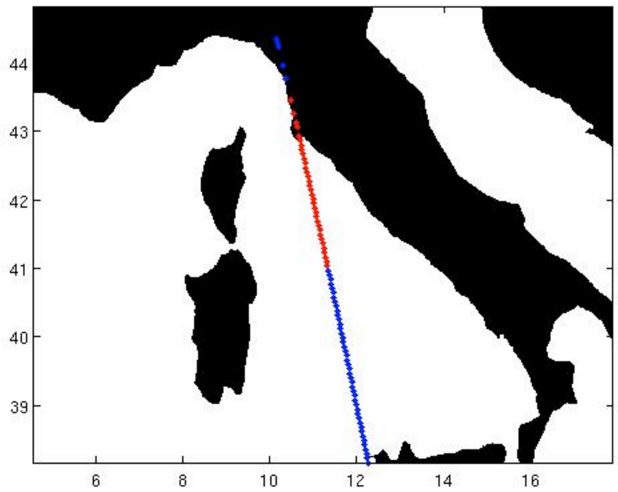
The COASTALT Processor - Coding

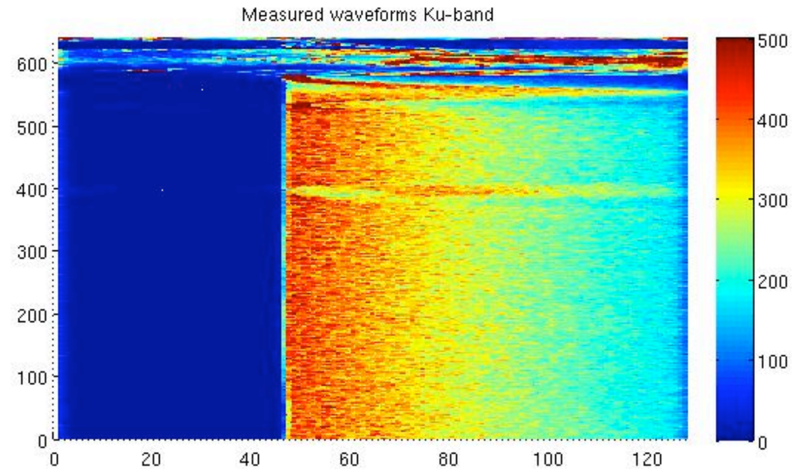
- Coded in C and Fortran
- I/O in C
  - Read L2 SGDR files
  - Generate netcdf output files
- NAG fitting in Fortran
  - Least-square fitting (weighted or unweighted)
  - **Brown, Specular and Mixed** waveform models
- Open-source/GSL fitting in C

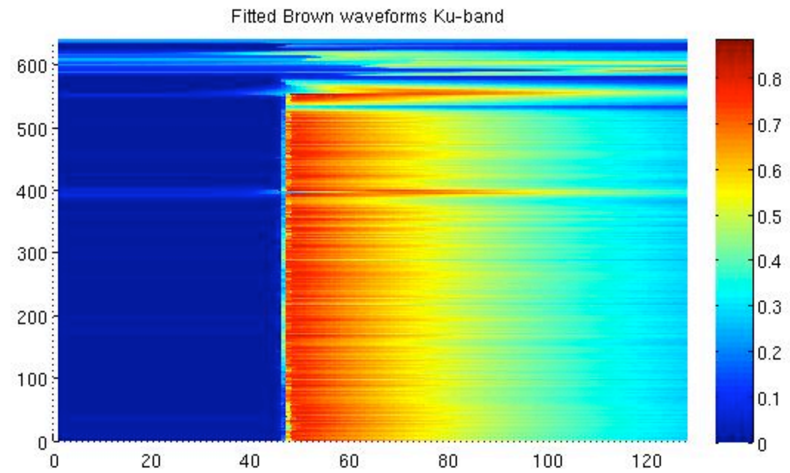
- **Output in NetCDF**
  - Now being tested/validated, will be made available via web pages in near future

Brown retracker behaviour

Orbit 357

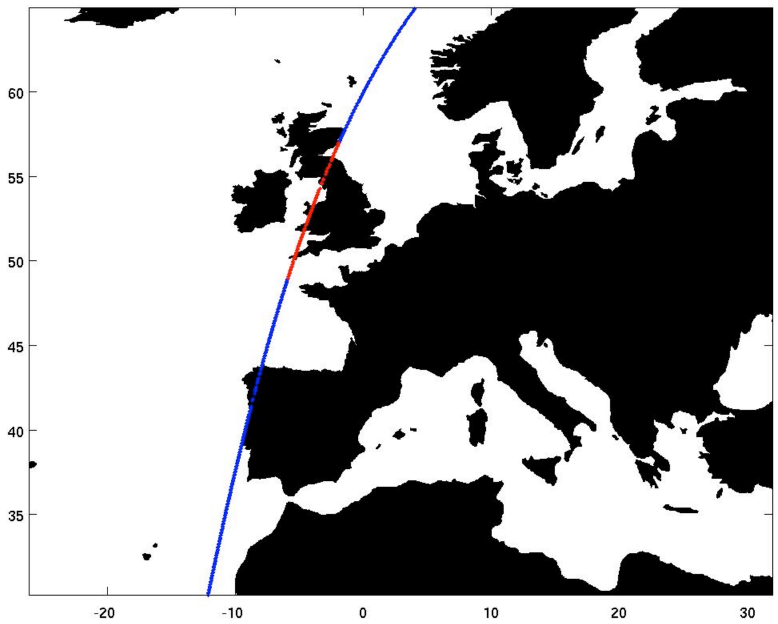


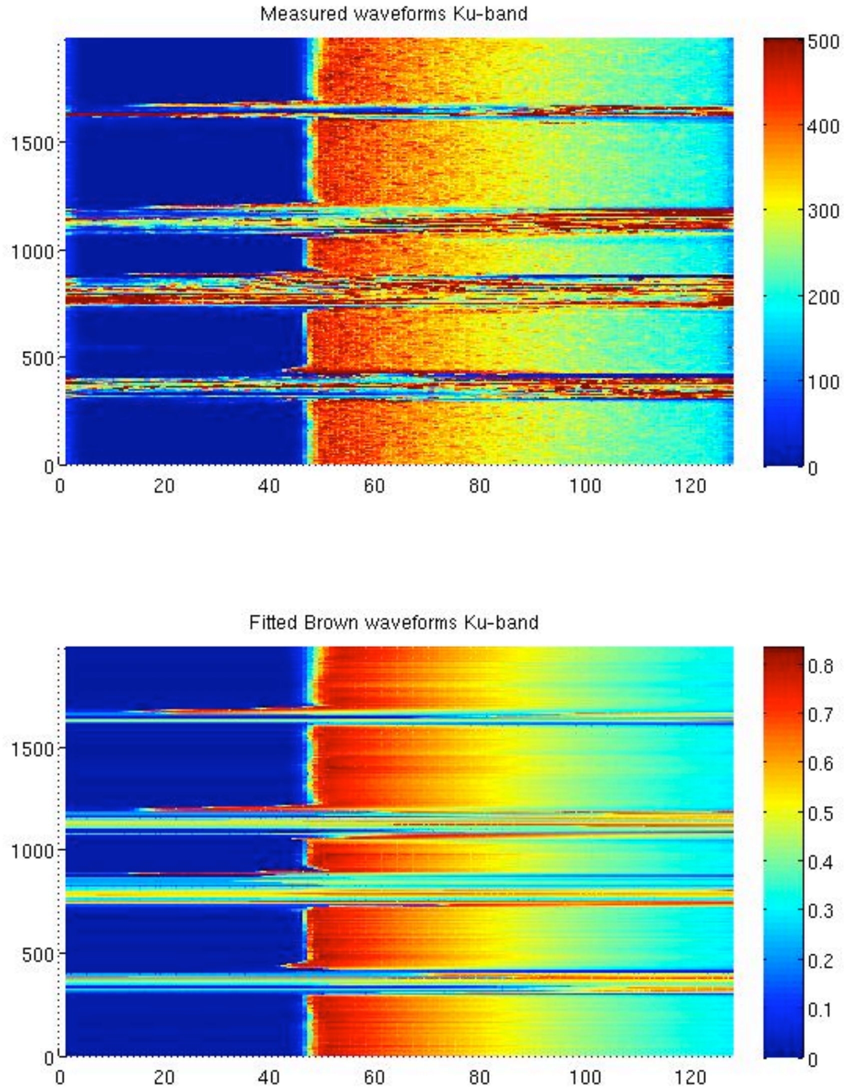




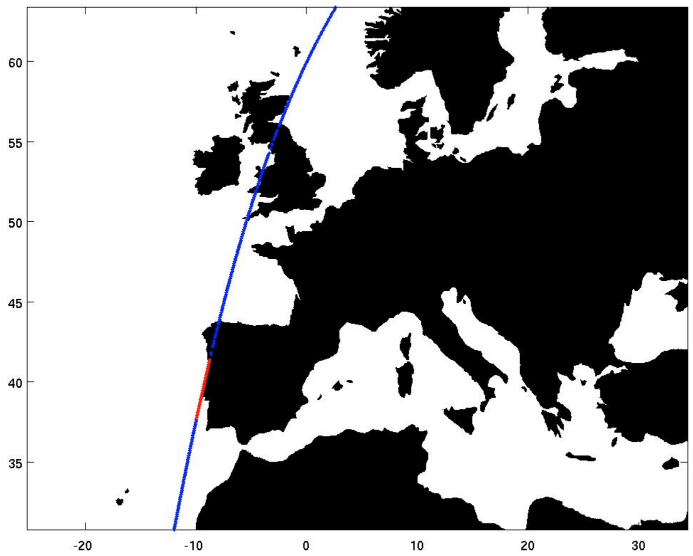
Brown retracker behaviour

Orbit 080 W. Britain

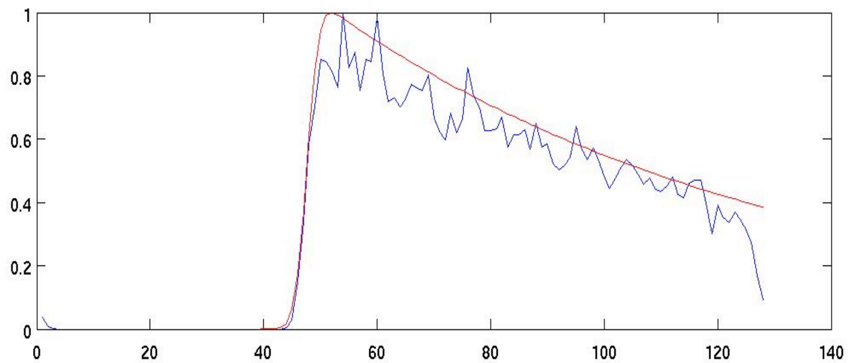




Brown retracker behaviour

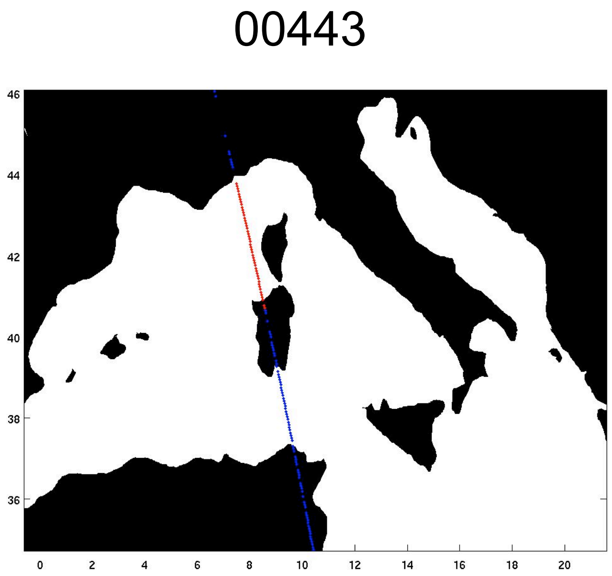


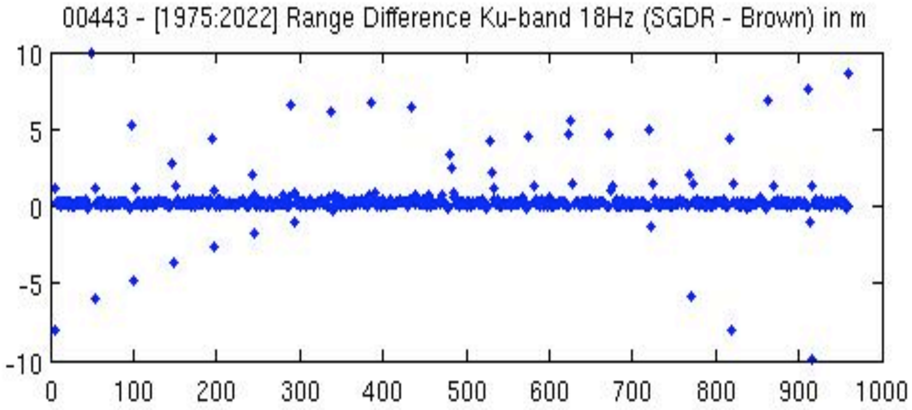
Ku-band

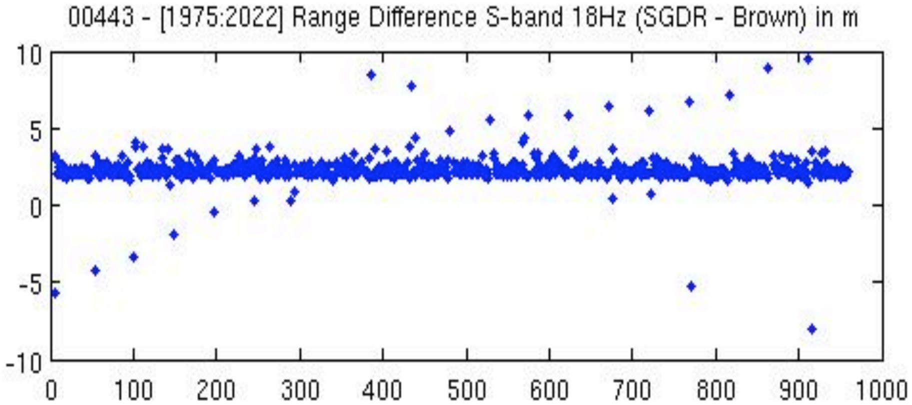


S-band still needs adjustment
(we’re working on it)

Validation - Brown retracked range v SGDR



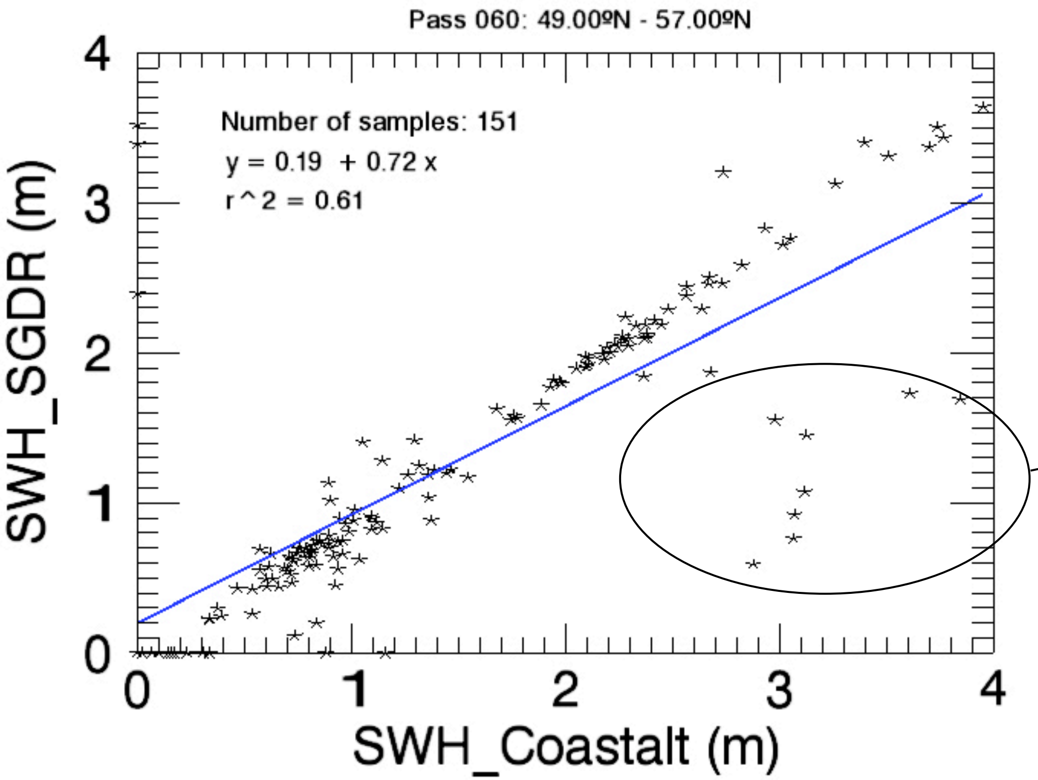


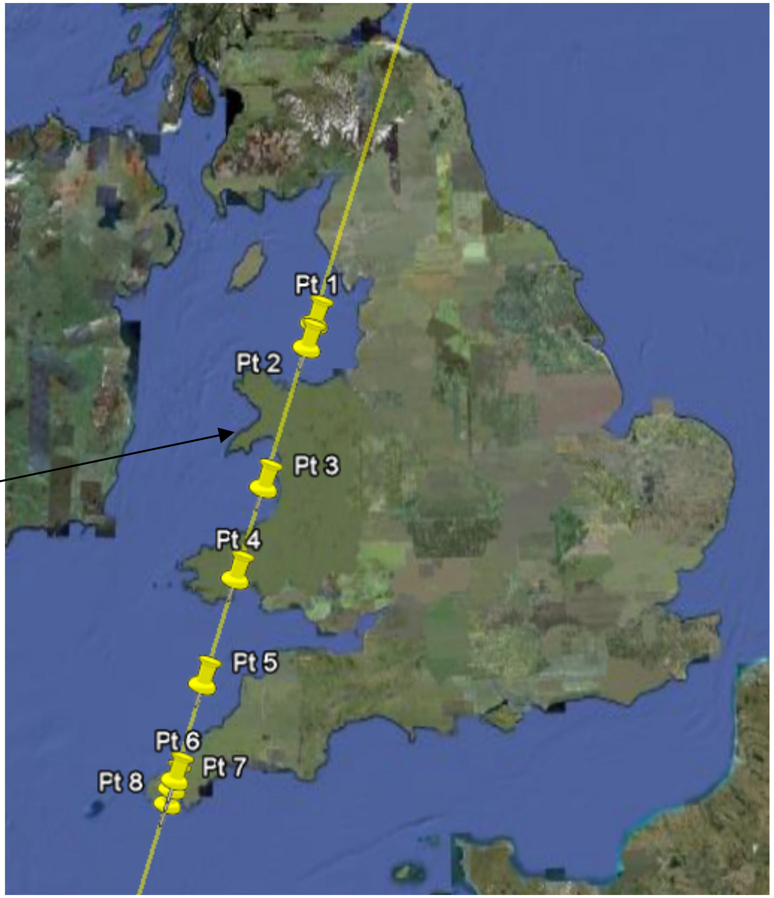


SWH Validation: Descending Track Number 00080 (West Britain): [49.0° N – 57.0° N]

Cycles analyzed: 26 - 39

18-04-2004 / 17-07-2005



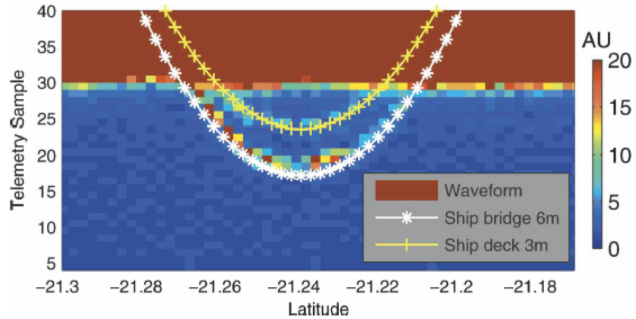


$SWH_{Coastalt}$>2.7 and SWH_{SGDR}<2.0

Innovative retracking - Bright targets

- A bright target in the footprint follows a quadratic path through successive pulses

$$\tau^2 = \tau_0^2 + \left[\frac{2v}{c}(t - t_0)\right]^2$$

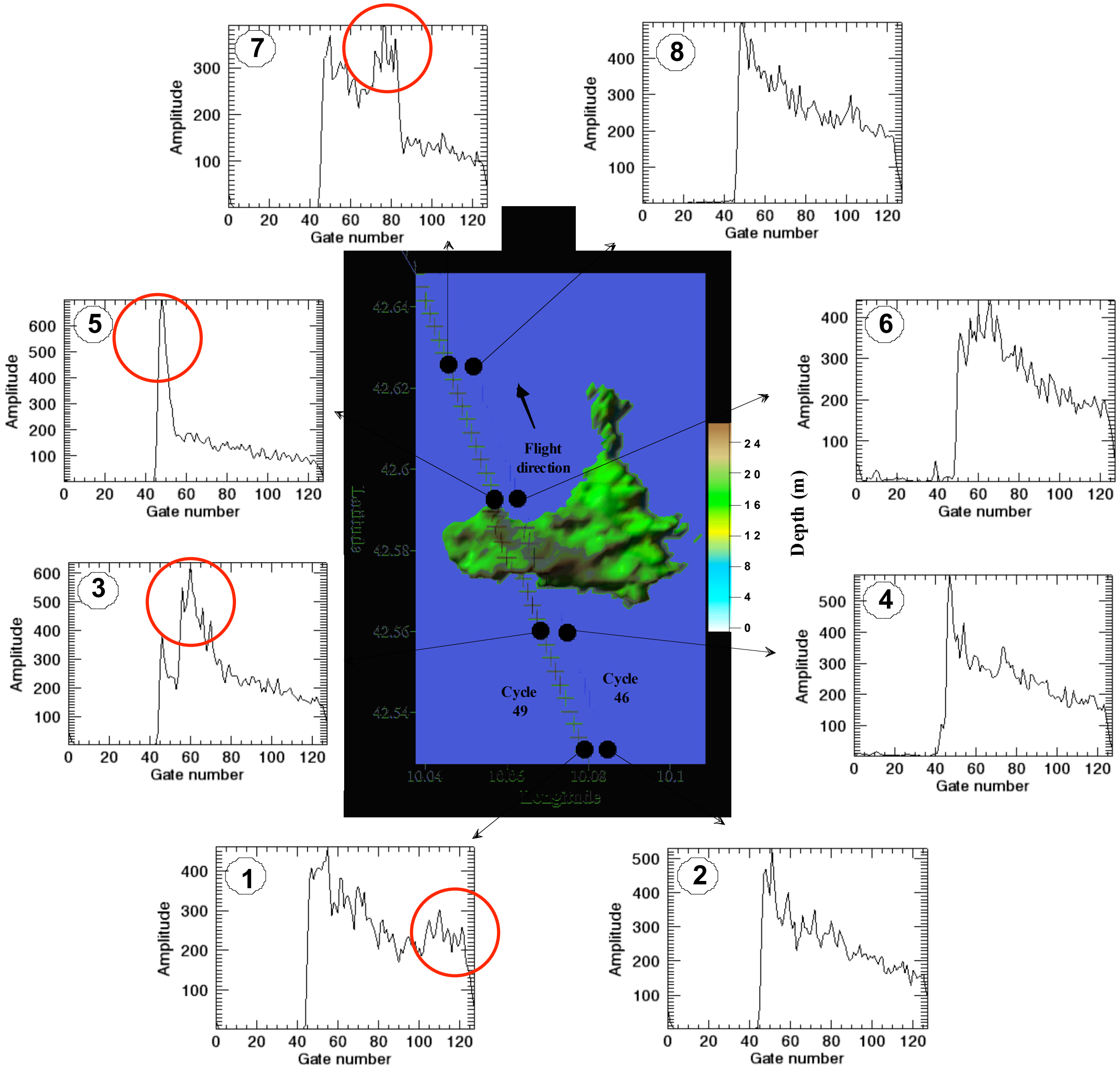


- where $v = \sqrt{Rz\omega}$
- R is the radius of the satellite orbit
- z is the radius vector from the target to the centre of the Earth projected onto the orbit plane
- ω is the orbit angular velocity
- The nadir distance is given by $D = \sqrt{\left(H_{eff}^2 + \rho^2\right)} - h$

Tracking Bright Targets

- The bright targets can confuse conventional retrackers
- Because we know the form of the hyperbola (the speed of the satellite) we can accurately predict its position across a set (batch) of waveforms
- ‘Dark’ targets (e.g. rain cells) can be handled similarly

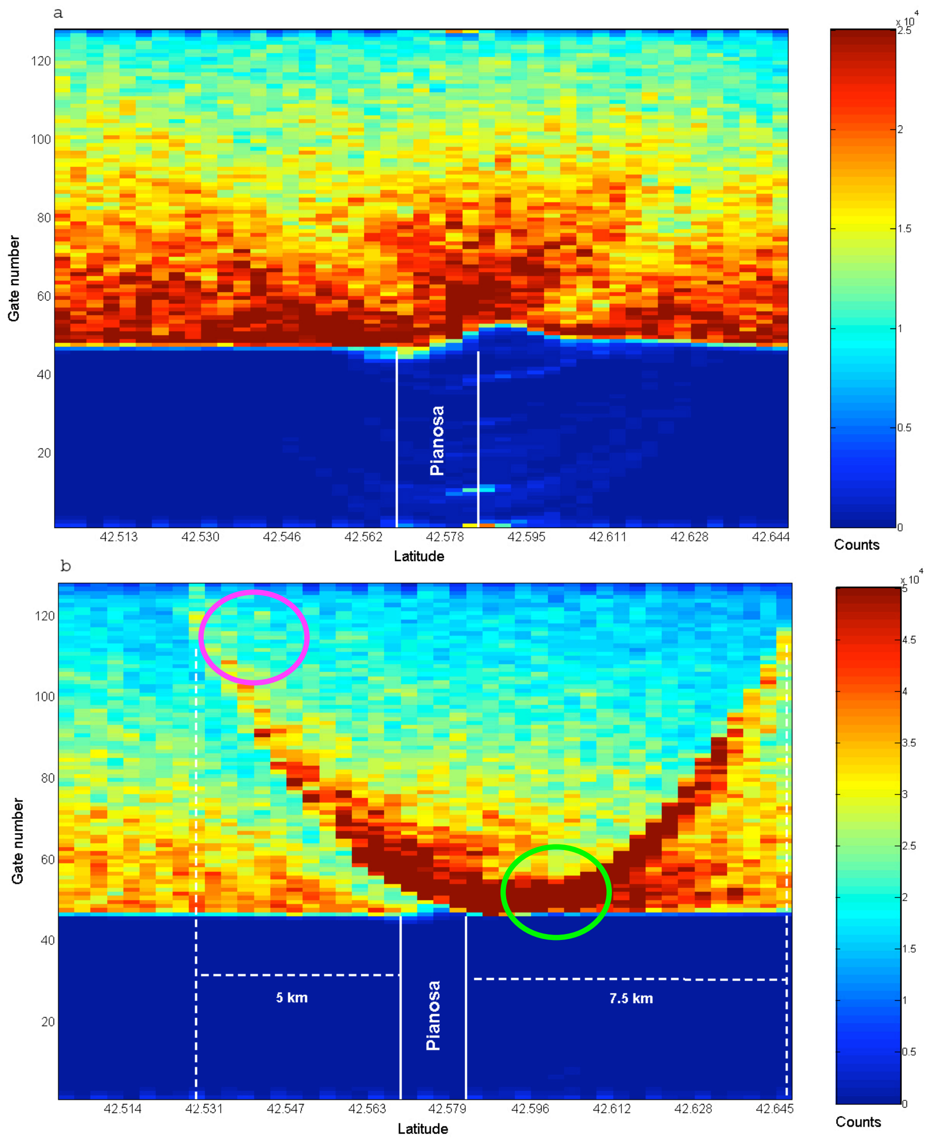
Example - Pianosa Island



Waveform shapes

- Shapes are similar to cycle 46 in most of the cycles
- But… Something happens in about 20% of the cases (cycle 49)
- For cycle 46 the echo returns are “Brown-like” (similar to that expected from a uniform sea surface)
- In contrast, the waveforms for cycle 49 show a complex structure (peak superimposed to the ocean-like returns)

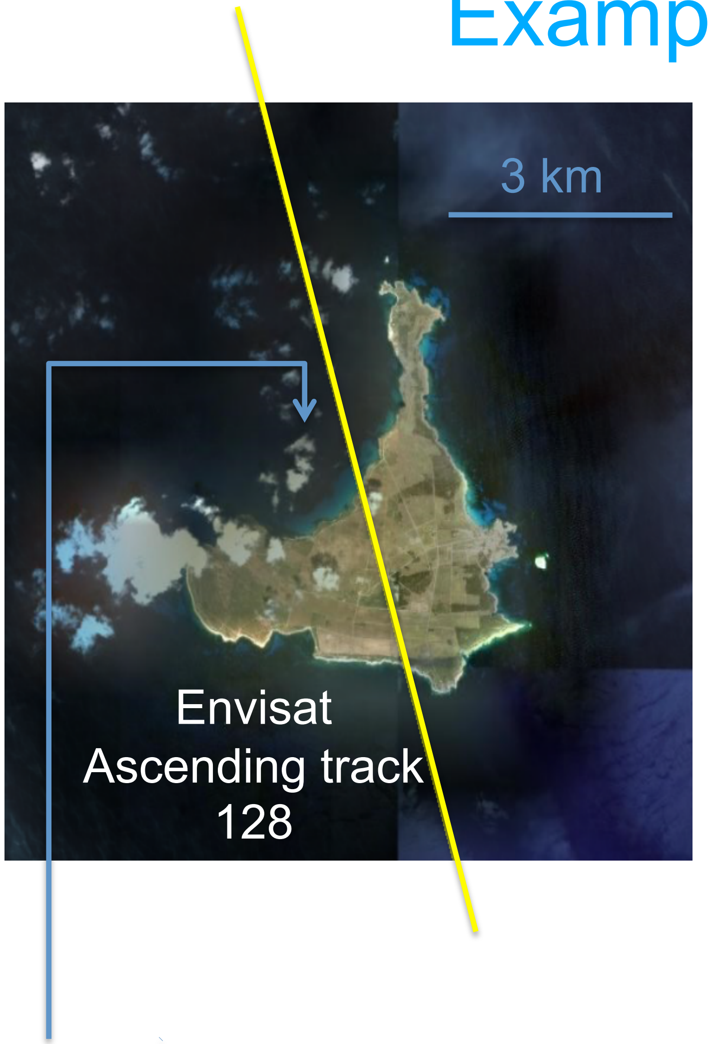
Example - Pianosa Island

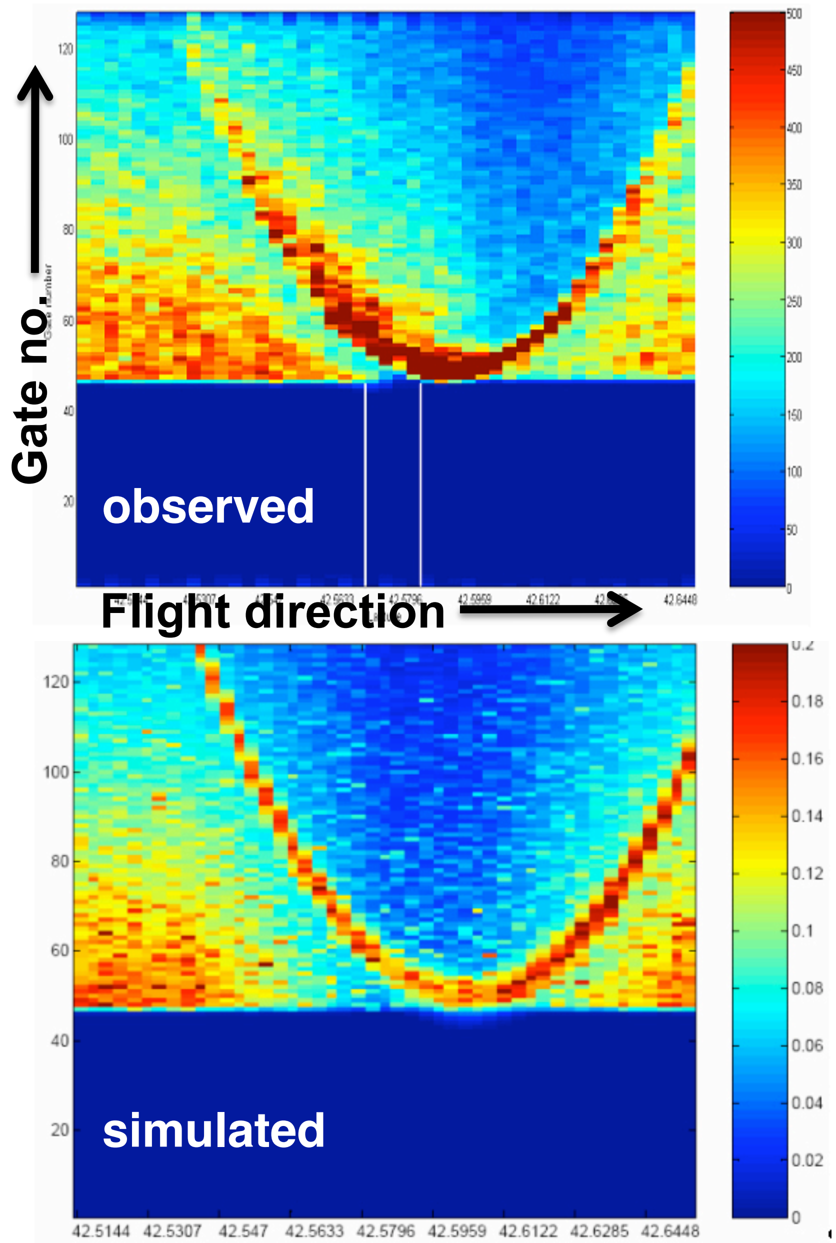


Peak migration

- 'Small' influence of the island observed in cycle 46 (most of the waveforms are 'Brown-like')
- Hyperbola found in cycle 49: the appex of the feature corresponds to the north of the island (known as Golfo delle Botte)
- The radar 'senses' the change in ocean reflectance 7-8 km before the satellite overpasses the batch.

Example - Pianosa Island





In cycle 49, bright target due to wave sheltering in NW bay (Golfo della Botte)

Retracking Summary

- The presence of exposed sandbanks, coastal flats and calm waters act as reflectors (bright targets), although the return from the open water portion is still Brown-like.
- These bright targets usually contaminate the shape of the waveforms in the Coastal zone and complicate the retracking of the waveforms.
- If these effects can be tracked and modeled and then removed during the re-tracking fitting process, the accuracy in the retrieval of geophysical parameters should improve.

Summary

- There is ample scope for developing altimetry in the coastal zone (users, many applications, etc)
- Space Agencies (ESA, CNES) are funding R&D in field
- COASTALT: development of an Envisat RA Coastal Product (to be extended to other ESA missions)
- Significant work done on user requirements (WP1) and corrections (WP2), with recommendations
  - Innovative approach to Wet Tropo correction: GPD
- Now working on development of prototype processor, including Brown, specular and mixed retrackers
- Also pioneering innovative retracking techniques, that account for migration of targets in sequential echoes
- **Bottom line: with projects like COASTALT and PISTACH, coastal altimetry should be accepted widely as a legitimate component of coastal observing systems**