Advances in coastal altimetry: the COASTALT Project outlook

Paolo Cipollini[1] + the COASTALT crew

[1]National Oceanography Centre, Southampton, UK
cipo@noc.soton.ac.uk

Rationale for Coastal Altimetry

- Altimetry: **most successful technique** for ocean remote sensing
  - To study/monitor the open ocean dynamics
  - large-scale & meso-scale phenomena (currents, Rossby waves, eddies), Niños, etc.
  - open ocean sea level change
  - Great “give & take” with tidal science
- **Now we need to extend it to the Coastal Zone!**
- Unlikely to be used in isolation, but great synergies with in situ and modelling systems, for:
  - sea level, currents, waves - not only long term studies and climatologies, but also specific hazardous events
  - Assimilation into coastal models
  - Fisheries, shipping, sediment transport, erosion

Coastal Altimetry: the context

ALBICOCCA
France-Italy-UK 2001/04
Feasibility

ALTICORE-EU
EU/INTAS 2006/08
Capacity building

ALTICORE-India
ALTICORE-Africa

MAP/XTRACK/MARINA
CNES/LEGOS/CTOH
Integrated approach

PRODUCT DEVELOPMENT STUDIES INCLUDING RETRACKING

PISTACH
CNES 2007-present
For Jason-2

COASTALT
ESA 2008-present
For Envisat

…plus several OSTST Projects funded by NASA and CNES

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
  - West Britain
  - Portugal Coast

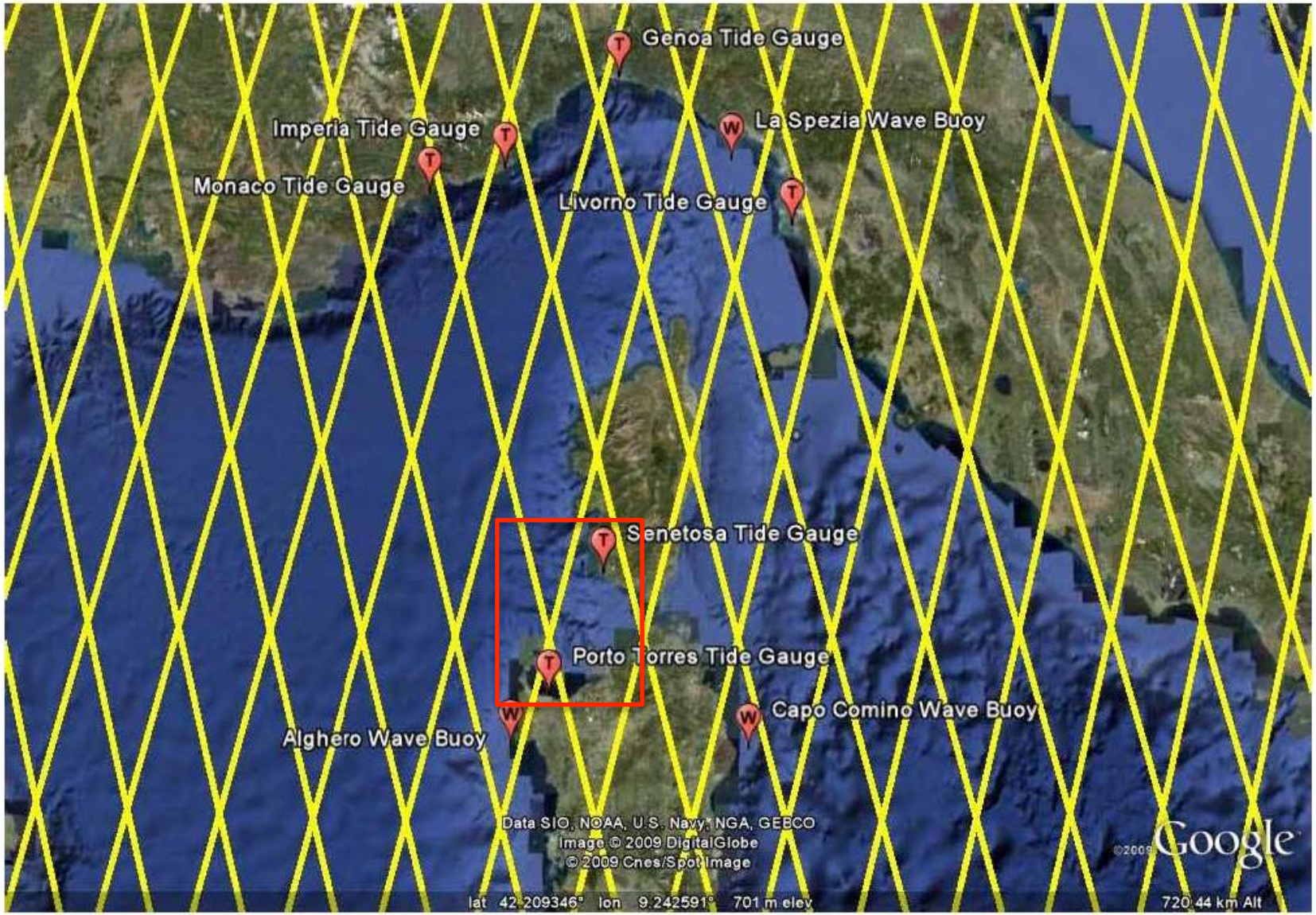
COASTALT
www.coastalt.eu

- 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

Sorting out coastal altimetry – in three steps!

- On the Shelf (100-0 km): main problem is the correction of **tides** (and HF atmospheric effects)
  - NEED **GOOD TIDAL & HF MODELS**
- Coastal strip (30-0 km): radiometer-derived **wet tropospheric correction** affected by land vicinity
  - NEED GOOD TIDES/HF + SOME **OPTIMIZED COASTAL WET TROPO** (a few ideas around…)
- Up to the shore (10-0 Km): the altimetric echoes **waveforms** affected by land & specular reflections
  - NEED TIDES+WET TROPO+ **DEDICATED WAVEFORM RETRACKING**

Tides/HF: validation on NW Med



Comparison of model-derived and tide gauge constituents

- We assume as measure of confidence the modulus (cm) of the complex difference between significant tidal constituent at tide gauges and available models

Tidal Model	Porto Torres		Senetosa	
	M2	K1	M2	K1
Mog2D-Medsea	**0.6**	1.7	3.6	**1.2**
FES2004	1.2	1.2	**3.3**	1.7
GOT4.7	0.8	**0.7**	4	1,5

Surprisingly, the best tidal correction should be generated from a composite spectrum

L.Roblou (LEGOS) – S. Vignudelli (CNR)

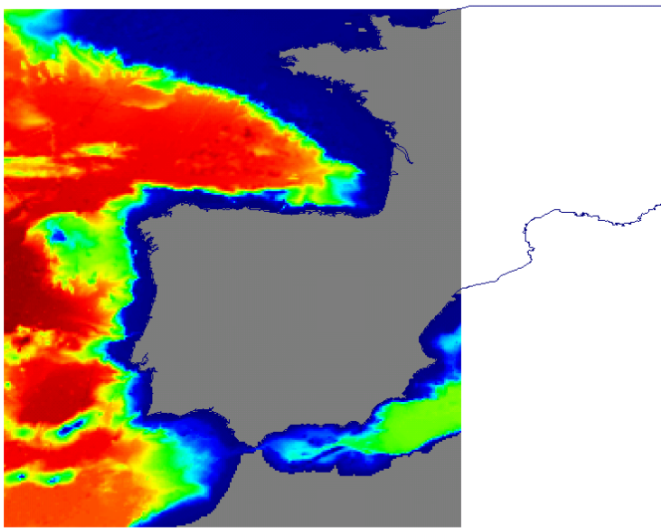
Tides: MOHID model on West Iberia

- One way multi-nesting levels:
  - Level 1 (domain of the pre-operational model of the Portuguese coast) – spatial step = **0.06º** (two implementations with SRTM30 and ETOPO1);
  - Level 2 (shelf area of interest to the COASTALT project) – spatial step = **0.016º** - (two implementations with SRTM30 and ETOPO1);
  - Level 3 (high resolution models focused in specific points - e.g. areas with tidal gauges, intersection points of satellite tracks)– spatial step ~ **0.003º** ;

H. Coelho (Hidromod)

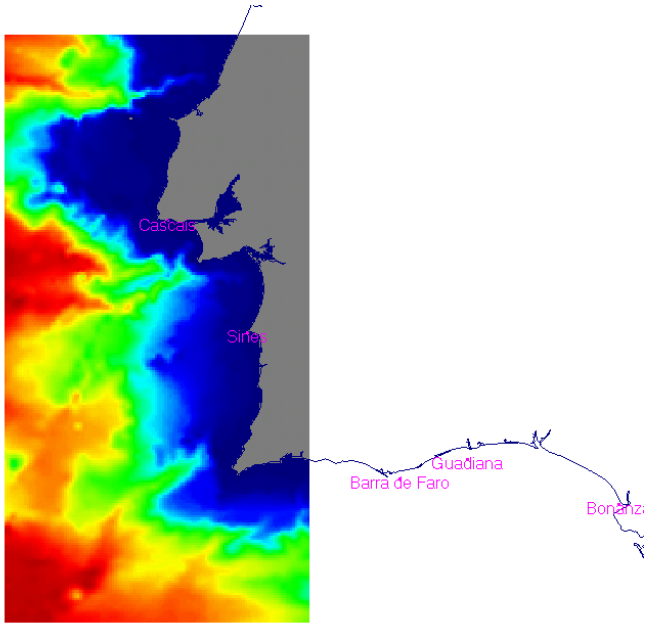
3 nested levels

1



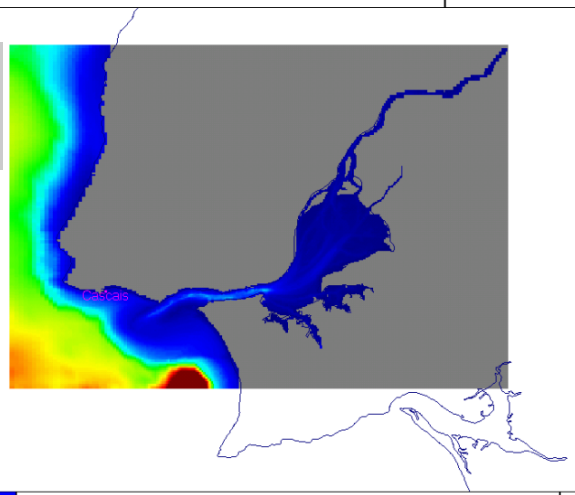
MOHID Water Modelling System | Level 1 - 0.06º

2



MOHID Water Modelling System | Level 2 - 0.016º

3



MOHID Water Modelling System | Level 3 - 0.003º

H. Coelho (Hidromod)

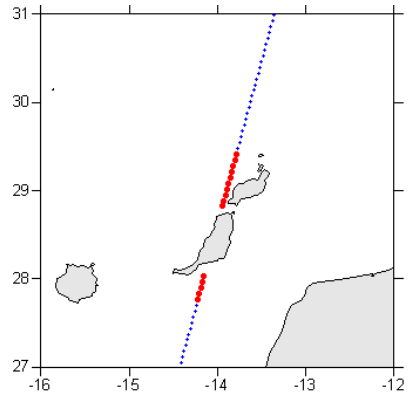
Wet Tropo - DLM approach

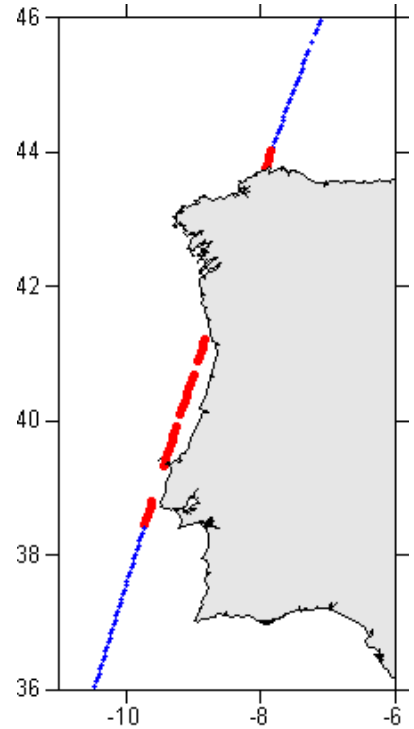
”Dynamically Linked Model”

- Two types of algorithm

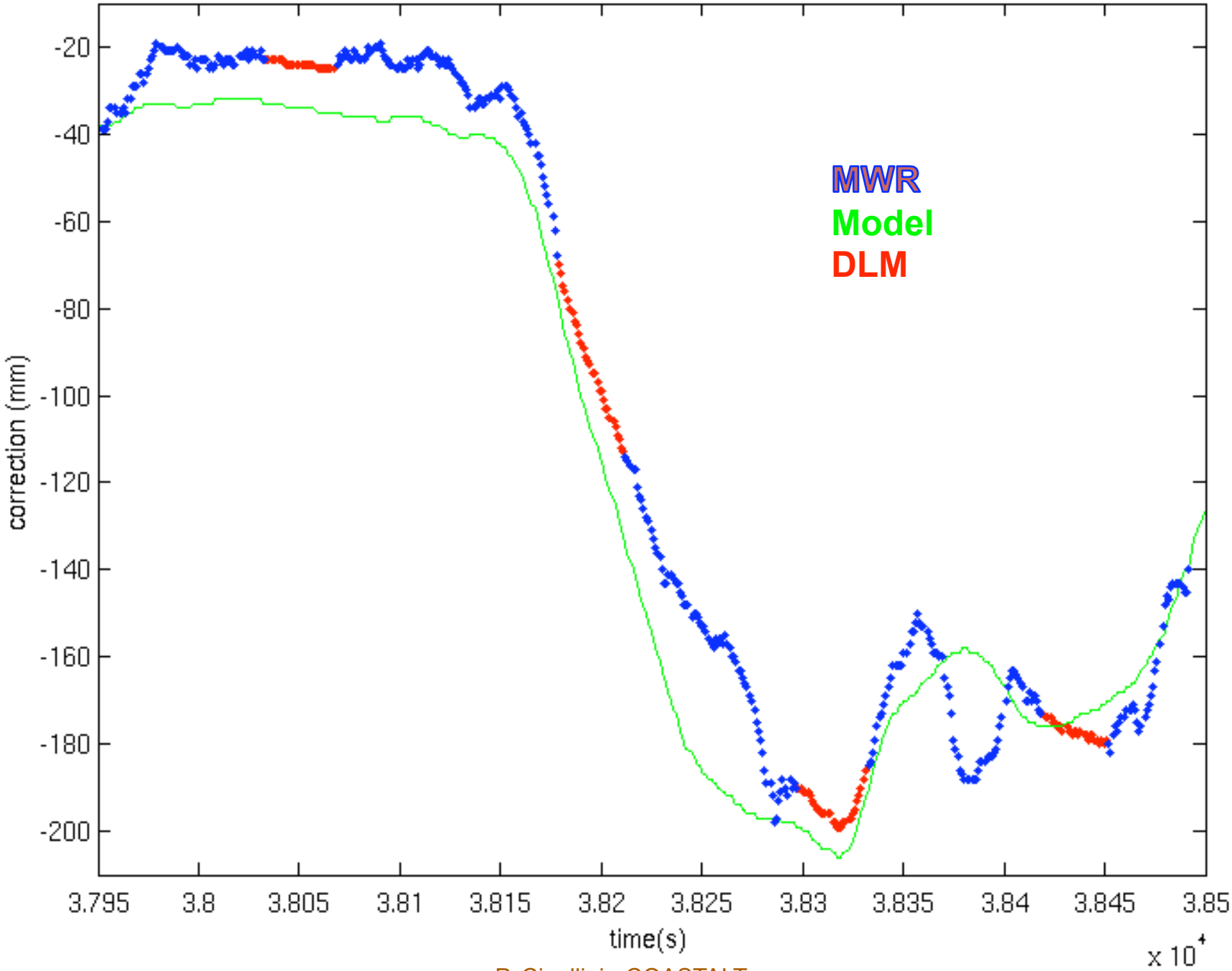
- Island type or ‘double-ended‘ algorithm
  - valid radiometer points on each side of the segment
  - Model field is adjusted to the radiometer field, at the beginning and end of the land contaminated segment, by using a linear adjustment (using time as interpolation coordinate)

- 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





J. Fernandes/ A.Nunes/C. Lazaro/ N. Pires (Univ. Porto) – P. Cipollini (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 10^4

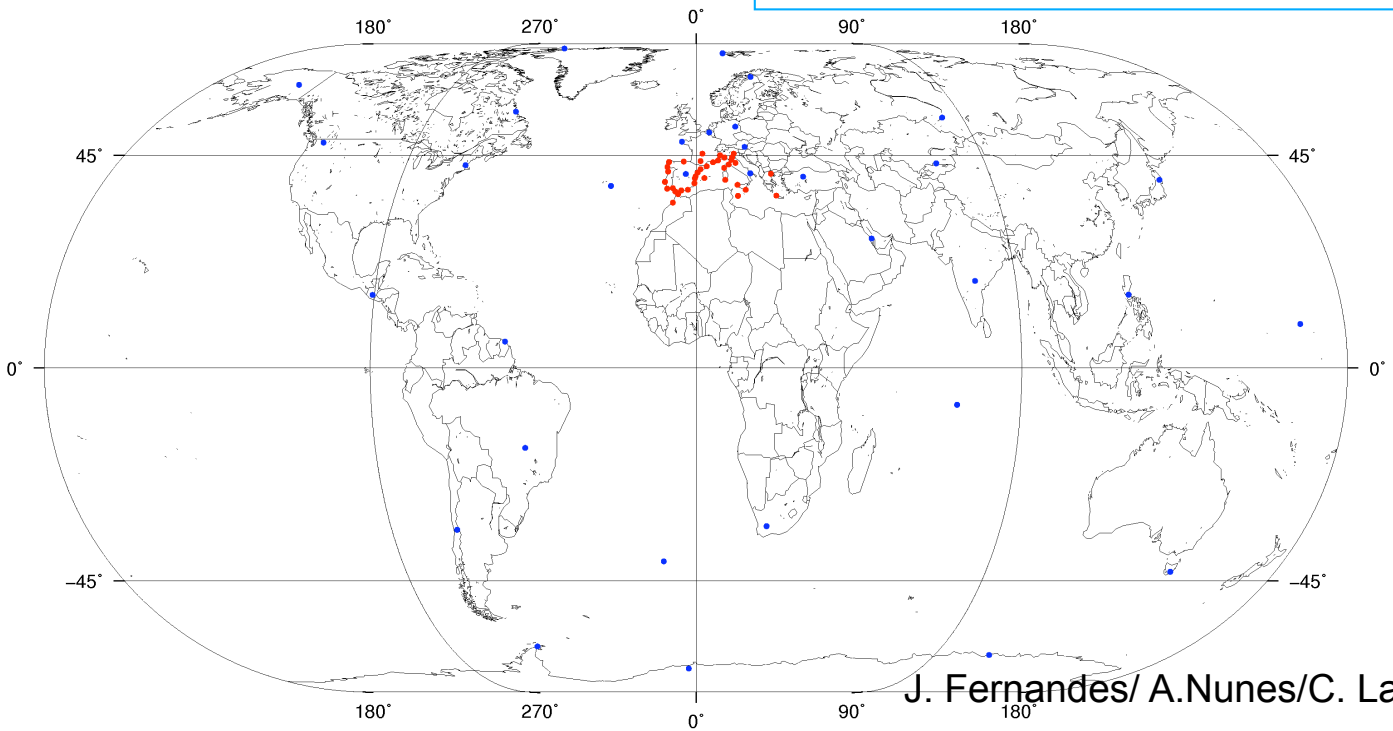
Wet tropo: GPD Approach - 1

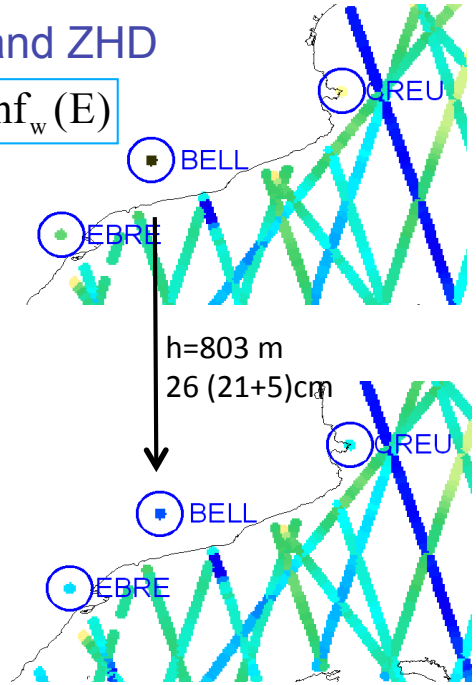
"GNSS-derived Path Delay"

Software and processing strategies:

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

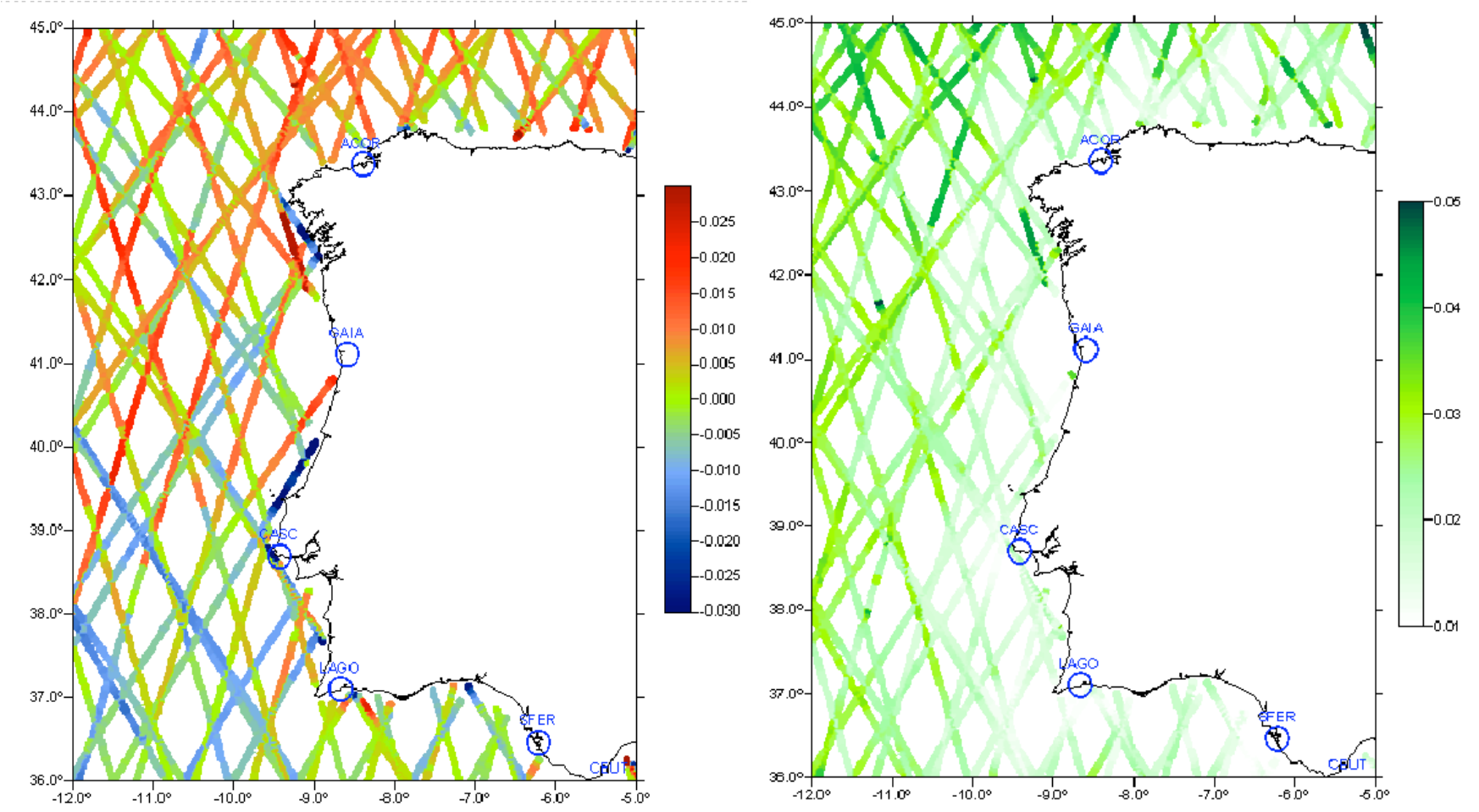
$$STD(E) = ZHD \times mf_h(E) + ZWD \times mf_w(E)$$





J. Fernandes/ A.Nunes/C. Lazaro/ N. Pires (Univ. Porto)

Wet Tropo – GPD approach (cont.)



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

J. Fernandes/ A.Nunes/C. Lazaro/ N. Pires (Univ. Porto)

Retracking: the COASTALT processor

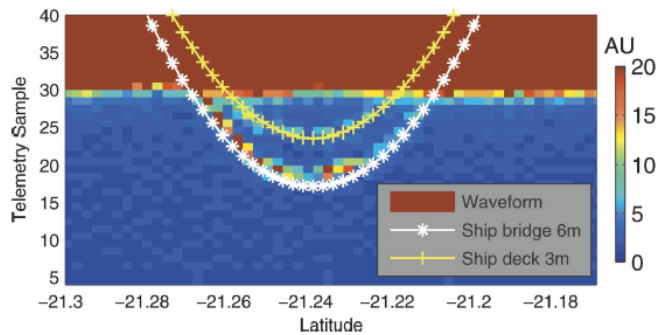
- Coded in C and Fortran: I/O in C
  - Read L2 SGDR files
  - Generate NetCDF output files
- waveform fitting in Fortran
  - Least-square fitting (weighted or unweighted)
  - **Brown, Specular and Mixed** waveform models
- **Output in NetCDF**
  - Over selected tracks in pilot regions
  - Software being tested/validated (By Starlab, UCadiz, NOCS); pilot reprocessed tracks will be made available on www.coastalt.eu in near future
- Includes a separate module to append to the NetCDF any custom correction (so fully flexible+expandable)

C. Gommenginger/ S. Gleason/ H. Snaith (NOCS)

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 $v = \sqrt{R}z\omega$
- 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 $D = \sqrt{\left(H_{eff}^2 + \rho^2\right)} - h$

P. Challenor/G. Quartly (NOCS)

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

A good case study: Pianosa Island

Pianosa

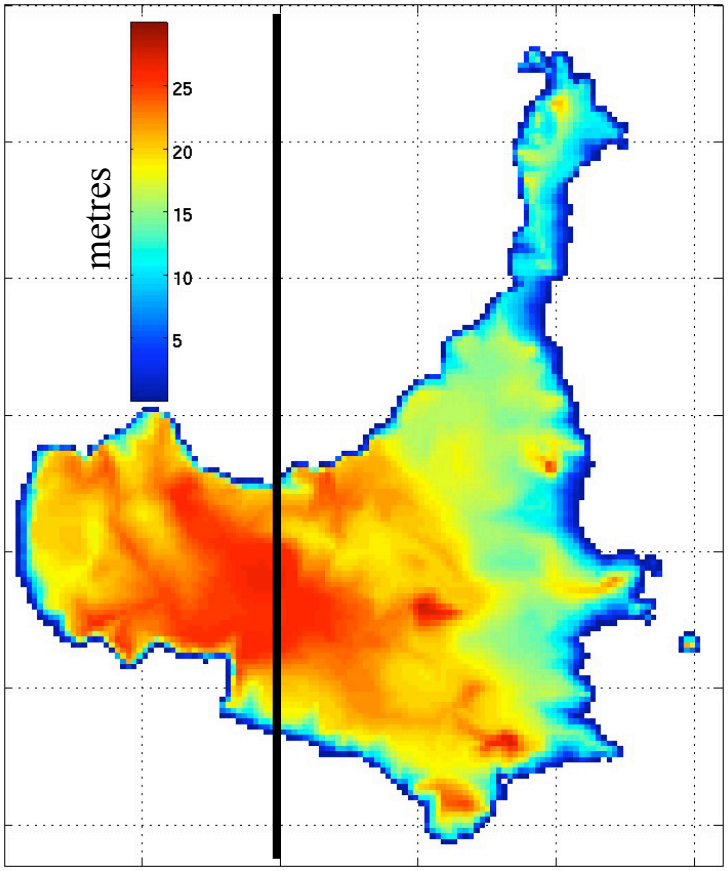
Small island (~10 km^2)

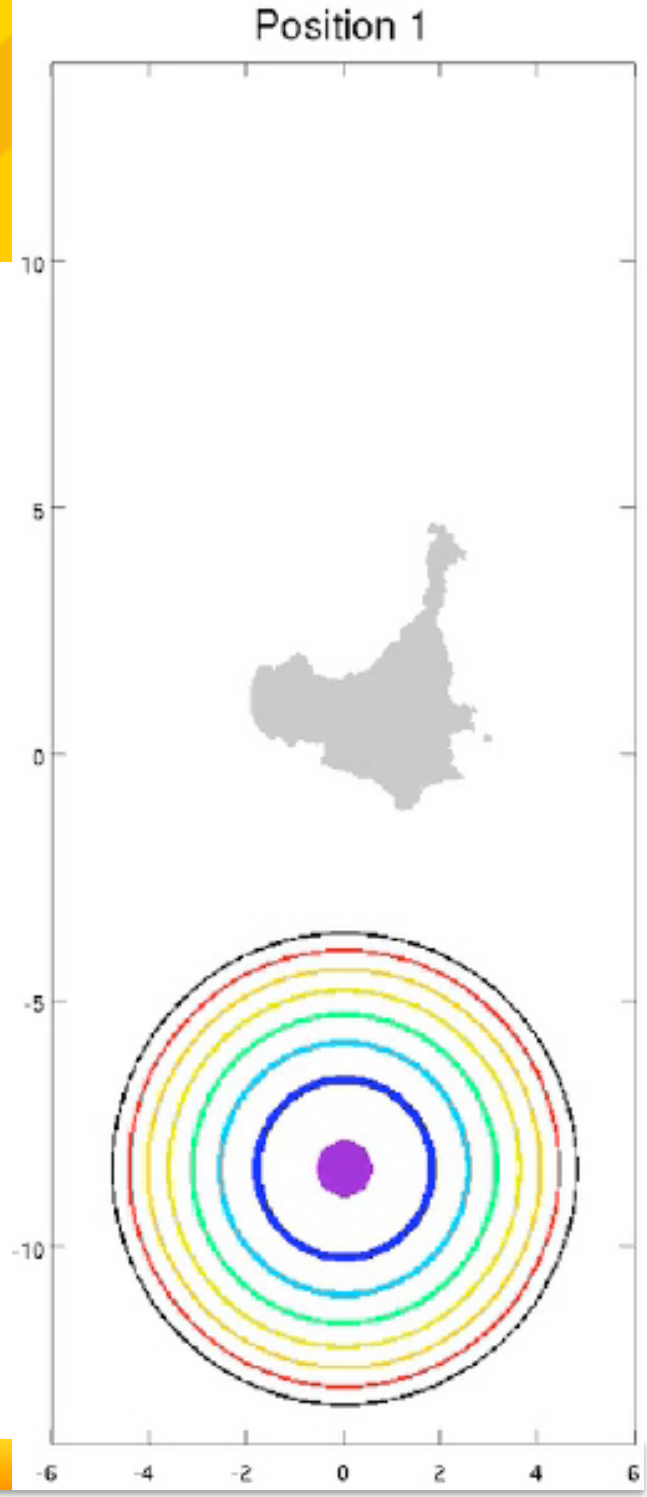
Known DEM

Flat (peak ht=28m)

Met. station

Envisat fly by





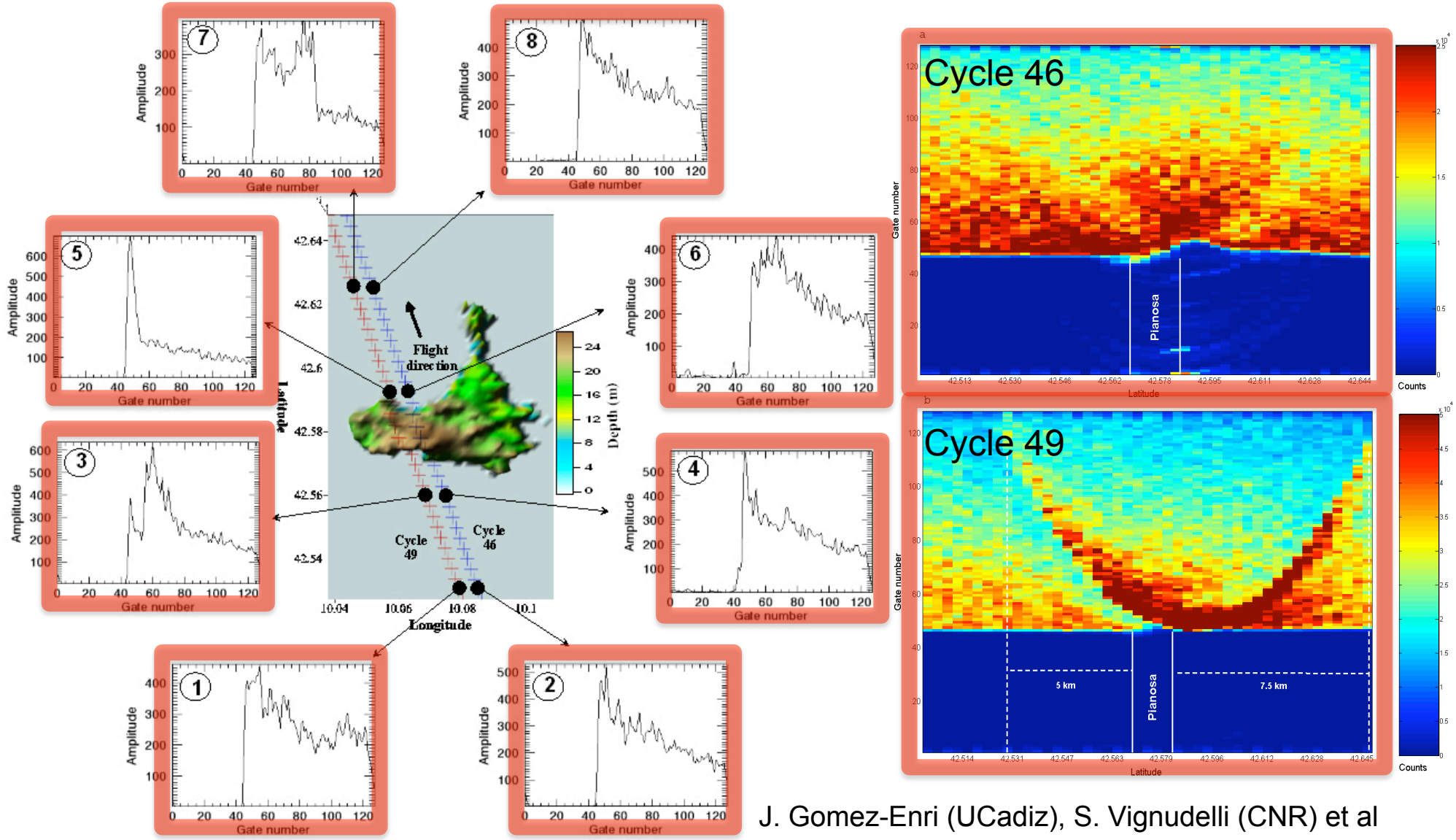
Expected effects on altimetry:

Weaker over land -> power loss for where no sea

Land higher -> Return before track point

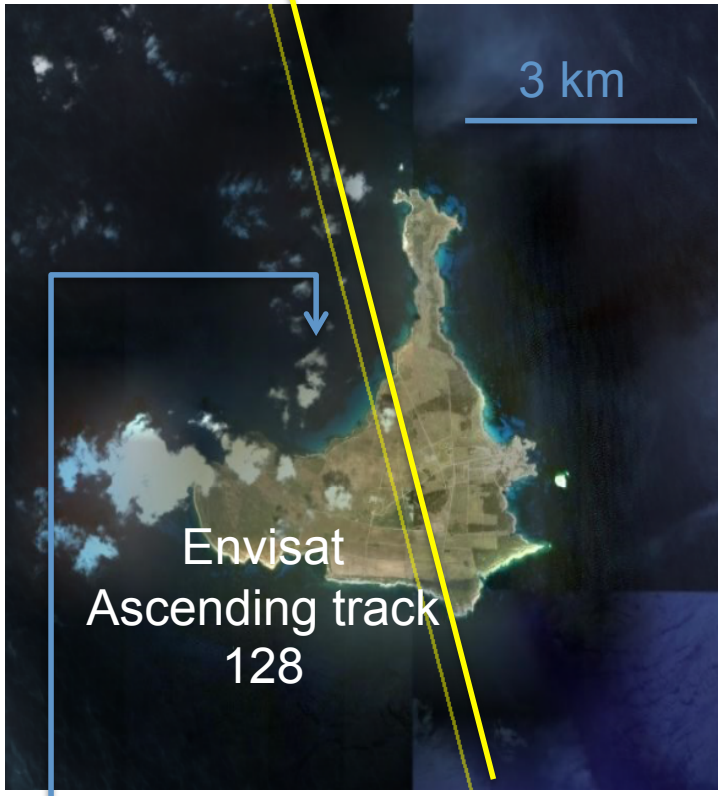
G. Quartly (NOCS)

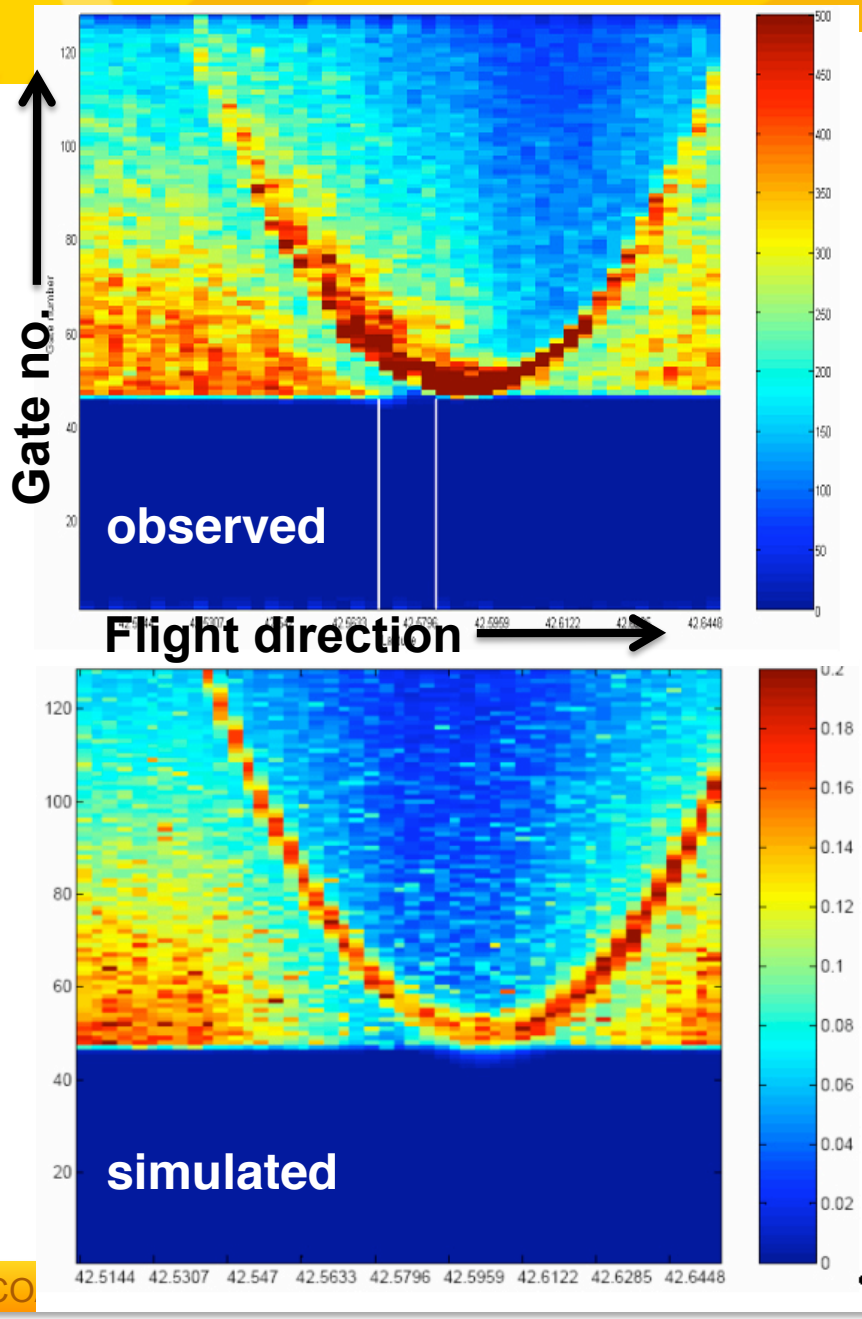
Waveform analysis



J. Gomez-Enri (UCadiz), S. Vignudelli (CNR) et al

Pianosa 2: model



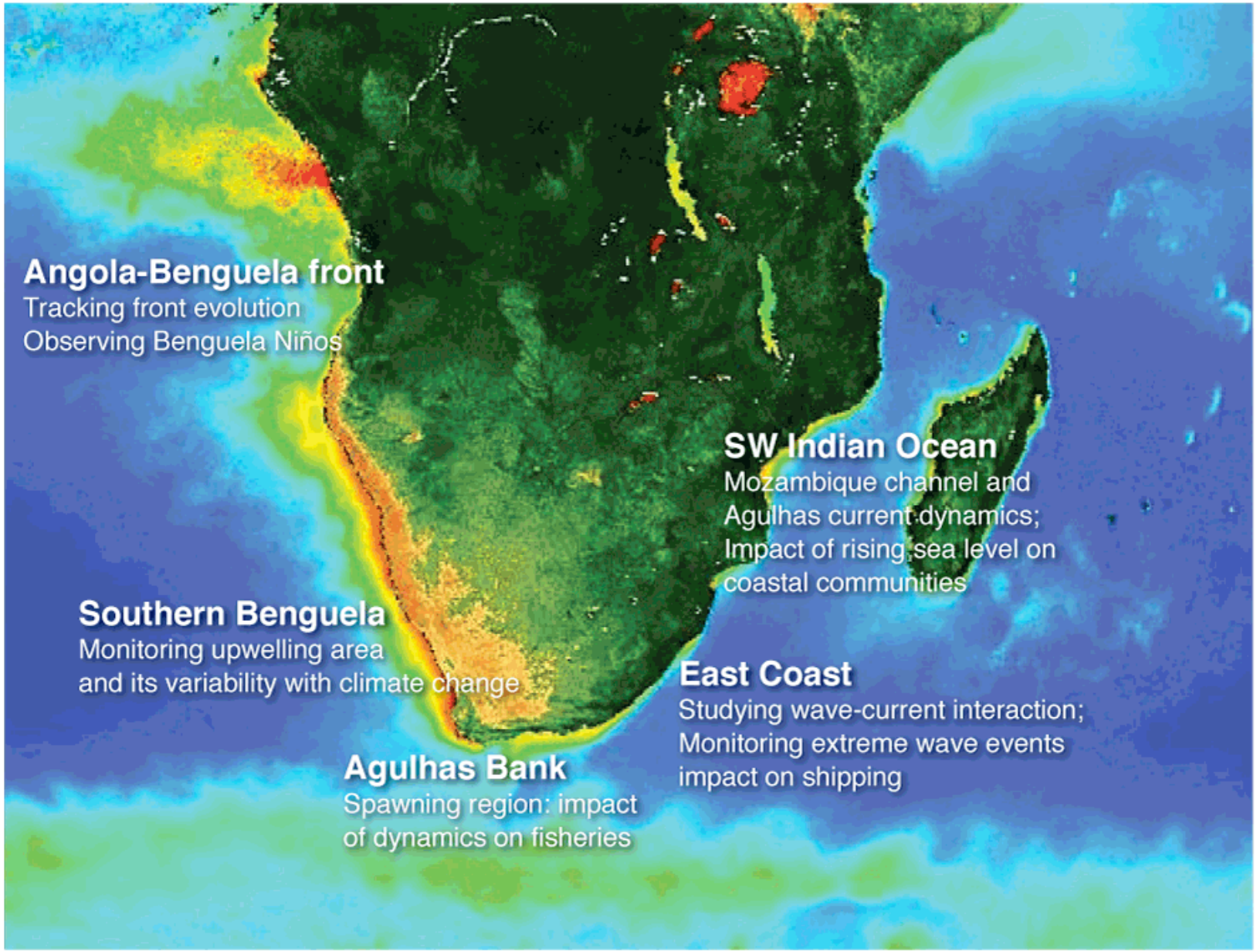


In cycle 49, bright target due to wave sheltering in NW bay (Golfo della Botte)

COASTALT: next

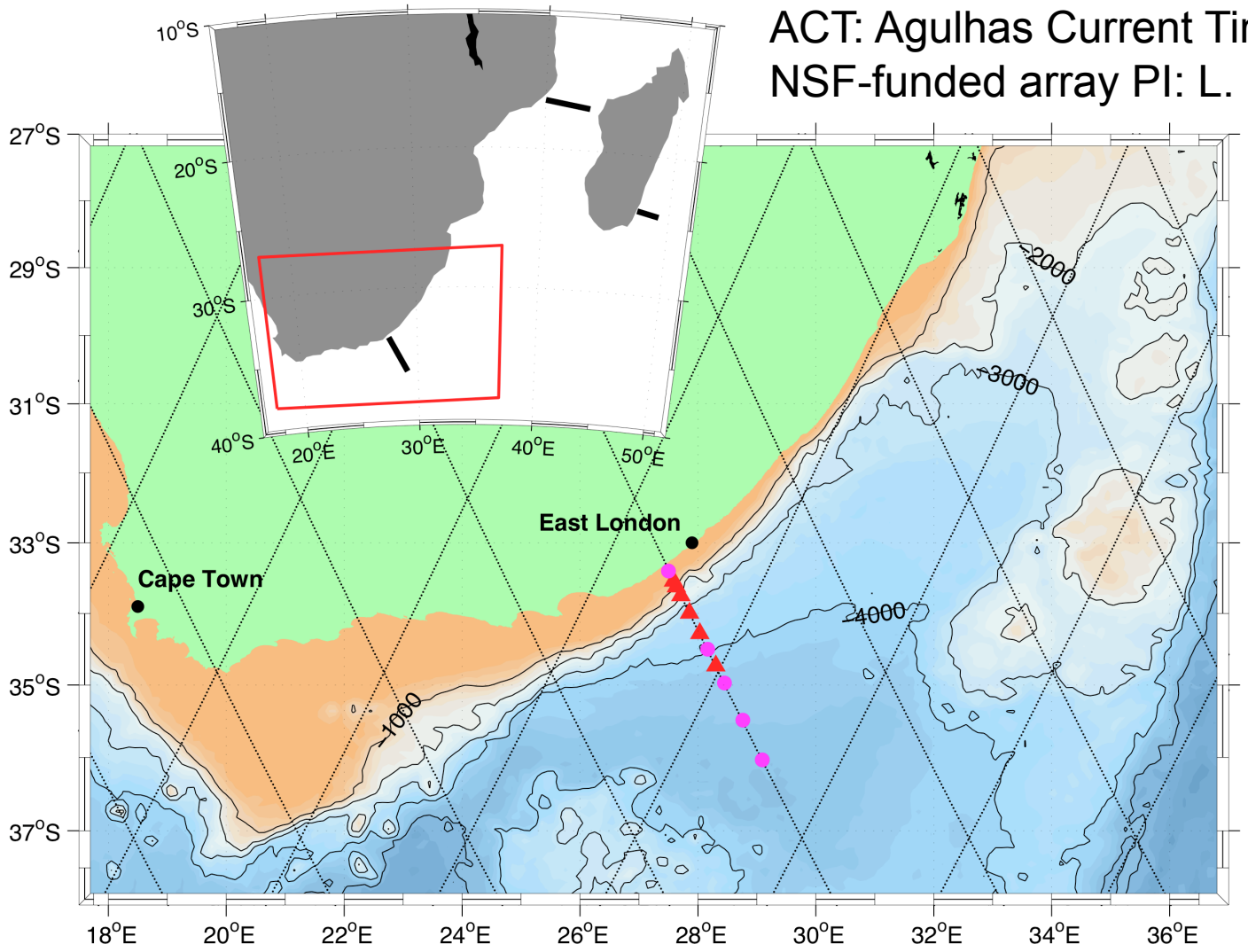
- **Test products** out
- User **Handbook** (H. Snaith, NOCS)
- **Outreach**: selection of case study examples and implementation of a tutorial module for BRAT http://earth.esa.int/brat/ (V. Byfield, NOCS)
- Extending the work to **other areas**…..

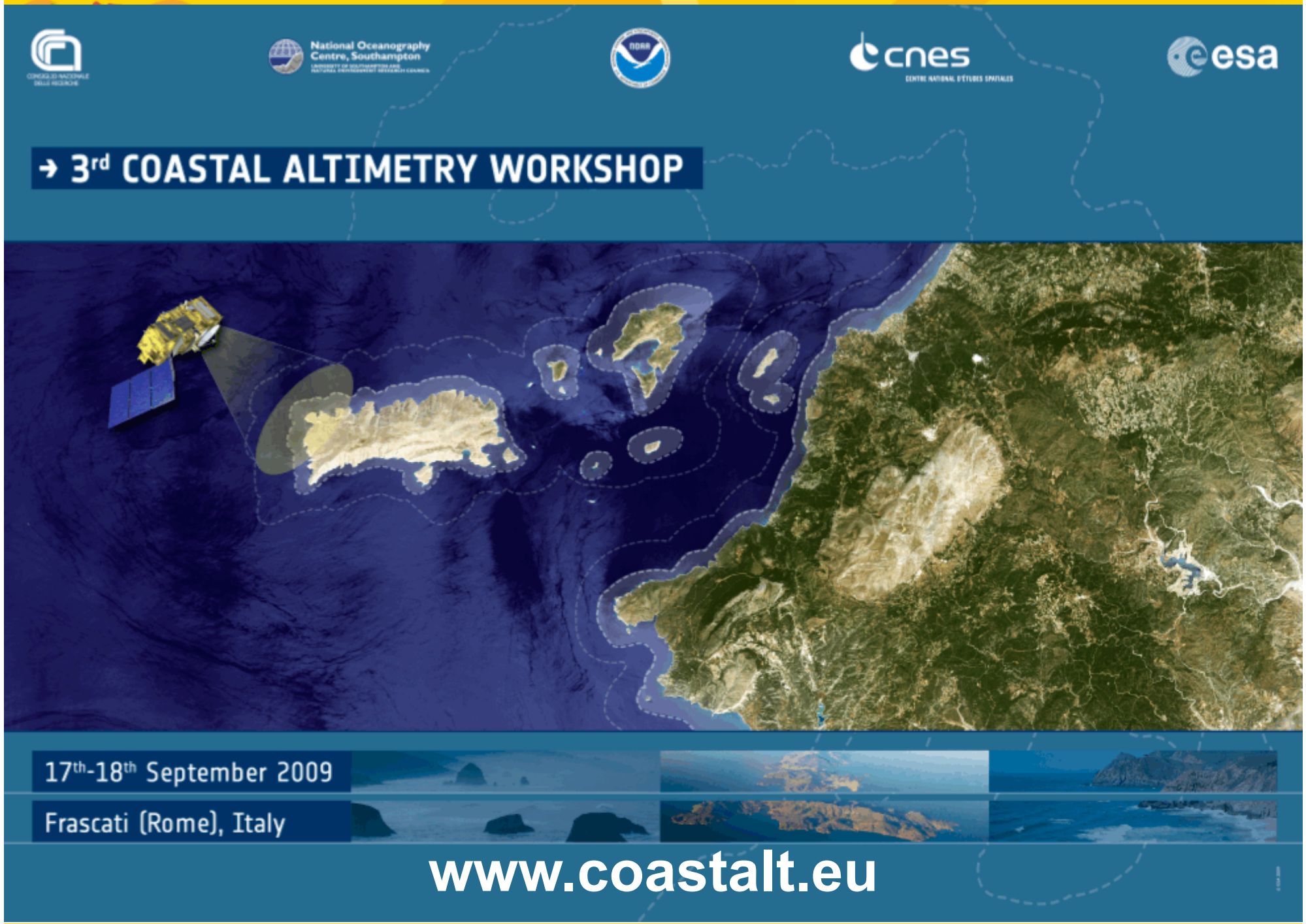
COASTALT for ALTICORE-Africa



Natural laboratory: the ACT area

ACT: Agulhas Current Time-series
NSF-funded array PI: L. Beal (Miami)




National Oceanography Centre, Southampton
cnes
esa
→ 3rd COASTAL ALTIMETRY WORKSHOP
17th-18th September 2009
Frascati (Rome), Italy
www.coastalt.eu