

# New Earth Observation products for Regional & Coastal Oceanography: the contribution of **Coastal Altimetry**

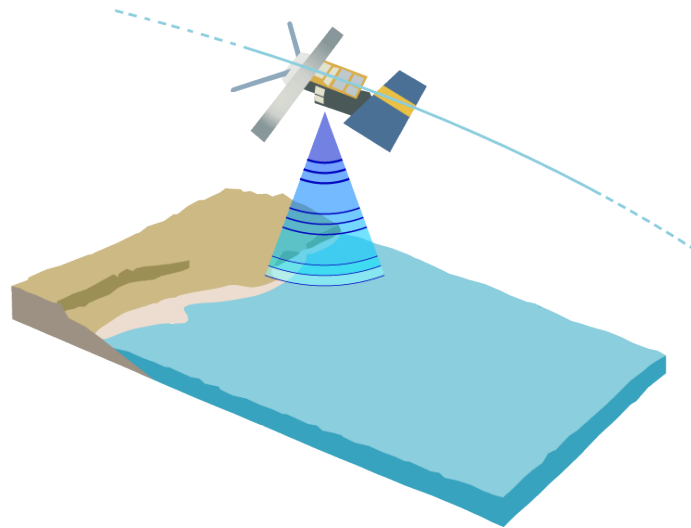
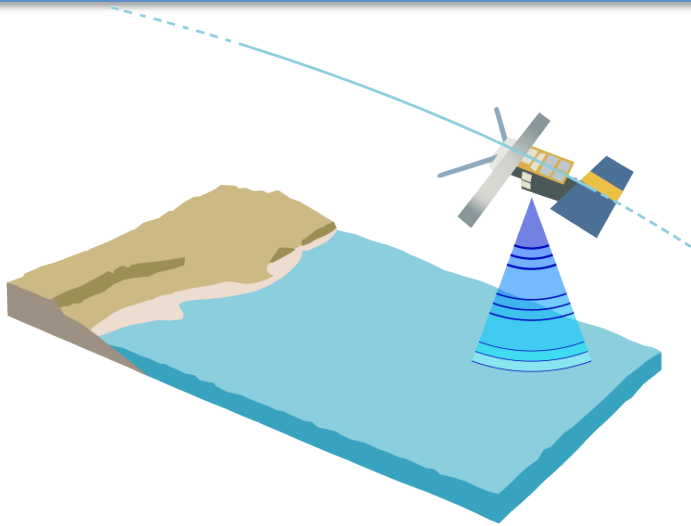
Paolo Cipollini *National Oceanography Centre, UK*



**National  
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NATURAL ENVIRONMENT RESEARCH COUNCIL



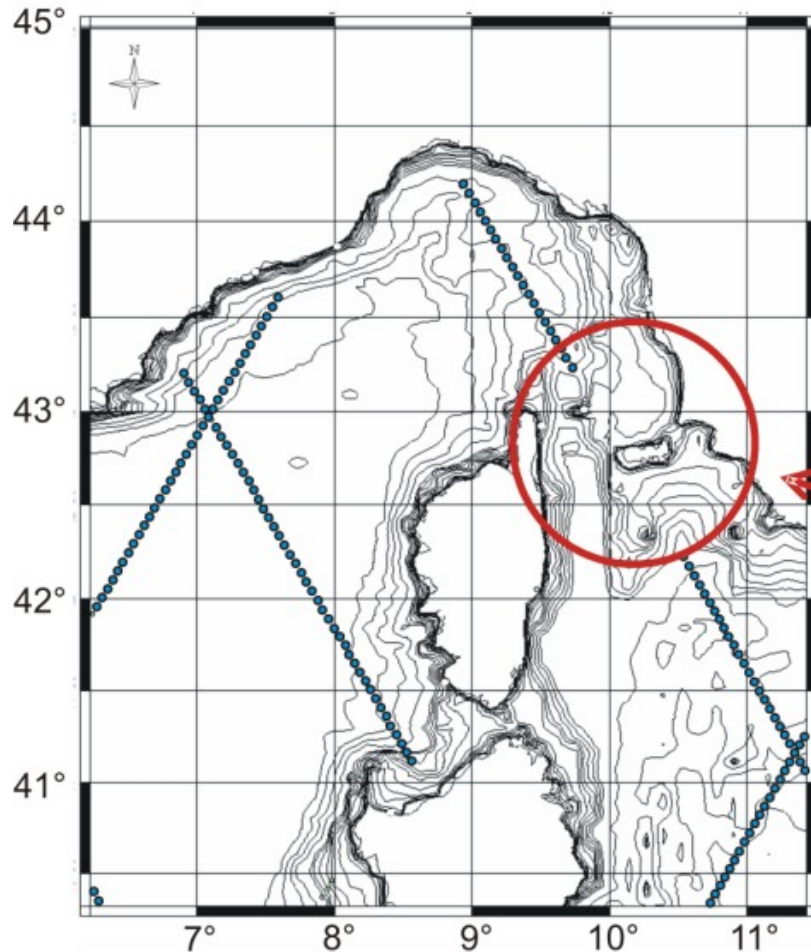
# Coastal altimetry - the concept



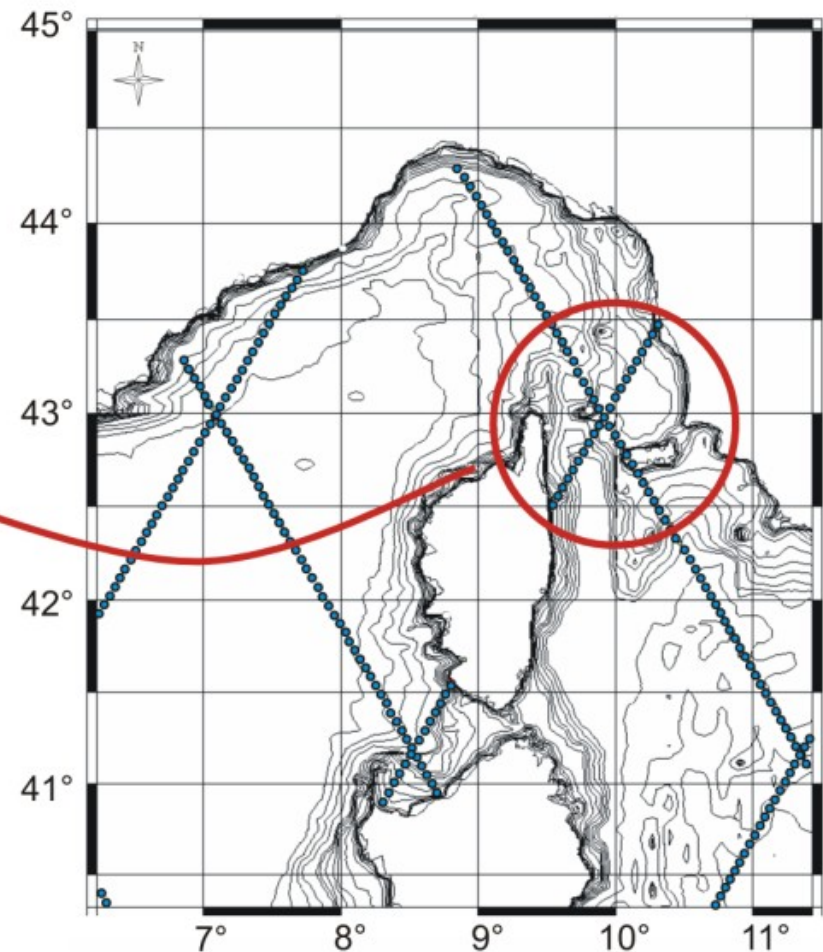
- Satellite altimetry designed for open ocean
- BUT coastal region has enormous strategic importance
- 20 years of data over the coastal ocean are still **underexploited**
  - normally flagged as ‘bad’ in the official products - but **they can be recovered!** (next slide shows example)
- Many possible uses
  - sea level, currents, waves - not only long term studies and climatologies, but also specific hazardous events (surges)
  - Assimilation into coastal models
  - Tides
- It is a **legitimate component of coastal observing systems**
  - *See Cipollini et al., OceanObs’09, Community White Paper, 2010*

# For instance - can we recover these?

TOPEX/Poseidon - Ground Track Reference Mask



Standard Product



Improved Product

**We believe so, with dedicated reprocessing and corrections.**

# Coastal Altimetry – the challenges

- Challenging **technological aspects**
  - Waveform retracking
  - Environmental corrections (radiometer or model path delay, altimeter or model ionospheric correction)
  - Geophysical corrections (coastal tides, Dynamic Atmospheric corrections)
  - Sea State Bias
  - Mean Reference Surfaces (Mean Sea Surface, Mean Dynamic Topography)
  - Both validation and applications require **exploitation of coastal models & in situ measurements**



# A bit of history (on the European side)

## ■ Some seminal papers

- Manzella et al. 1997 - custom wet tropospheric correction
- Crout 1998 - could recover data when coastal topography is flat
- Anzenhofer et al. 1999 – retracking waveforms
- Vignudelli et al. 2000 - Signal recovered consistent with in situ data

### **ALBICOCCA**

France-Italy-UK 2001/04  
*Feasibility*

### **ALTICORE-EU**

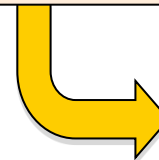
EU/INTAS 2006/08  
*Capacity building*



### **MAP/XTRACK/MARINA**

CNES/LEGOS/CTOH

*Integrated approach, Data editing and filtering, dissemination (ongoing)*



**ALTICORE-India**

**ALTICORE-Africa**



## **PRODUCT DEVELOPMENT STUDIES INCLUDING WAVEFORM RETRACKING**

### **PISTACH**

CNES 2007-present  
*For Jason-2*



### **COASTALT**

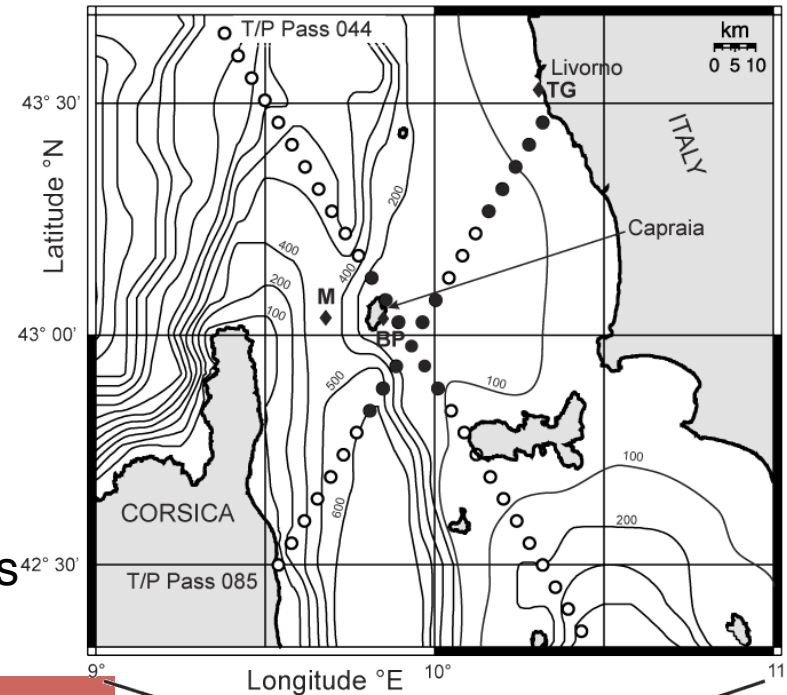
ESA 2008-2011  
*For Envisat*



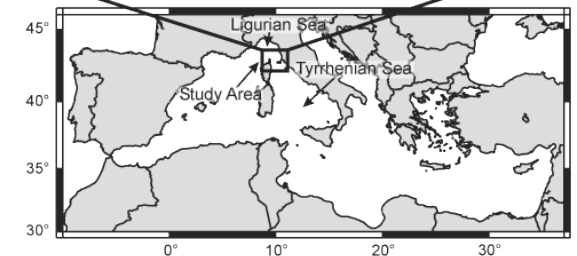
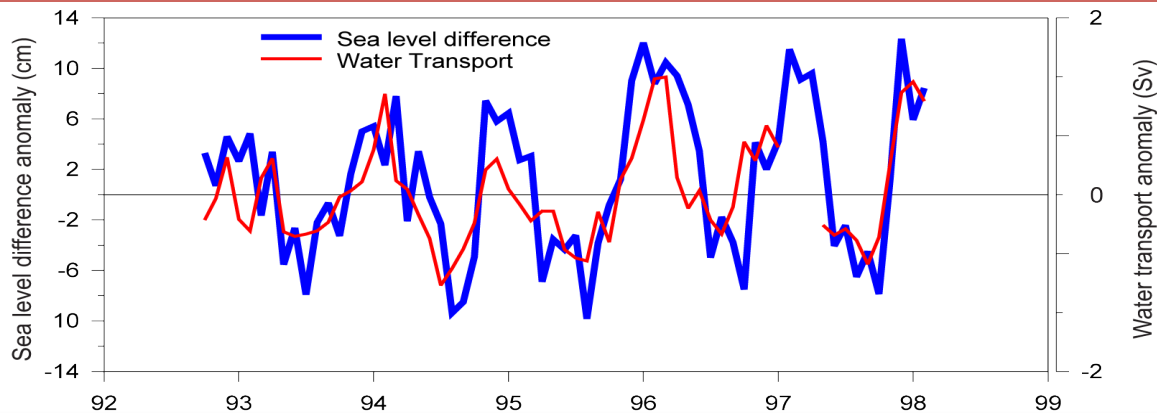
**...plus several OSTST Projects funded by NASA and CNES**

# Work in the Corsica Channel

- Vignudelli et al 2000
  - Simple improvement in tidal modelling
  - Signal recovered consistent with in situ data at seasonal time scales
- Area of Corsica Channel is an excellent pilot site for coastal altimetry
- ALBICOCCA Project in the area (2001-2004)
- ALTICORE Project (2006-2008)
- It is also one of the COASTALT validation sites

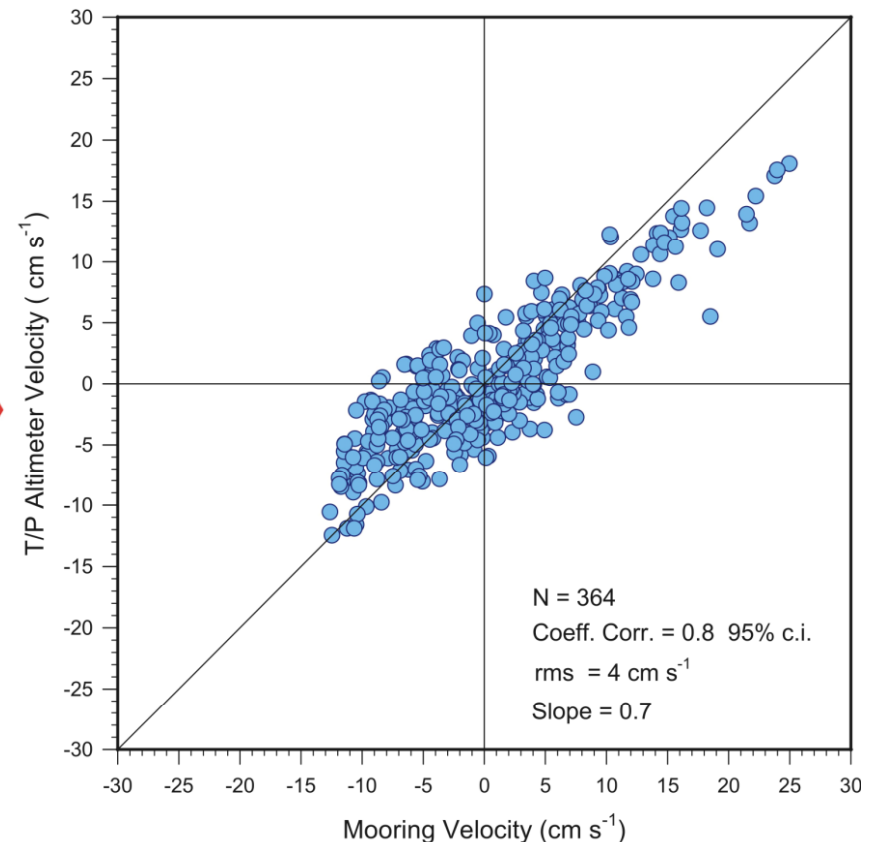
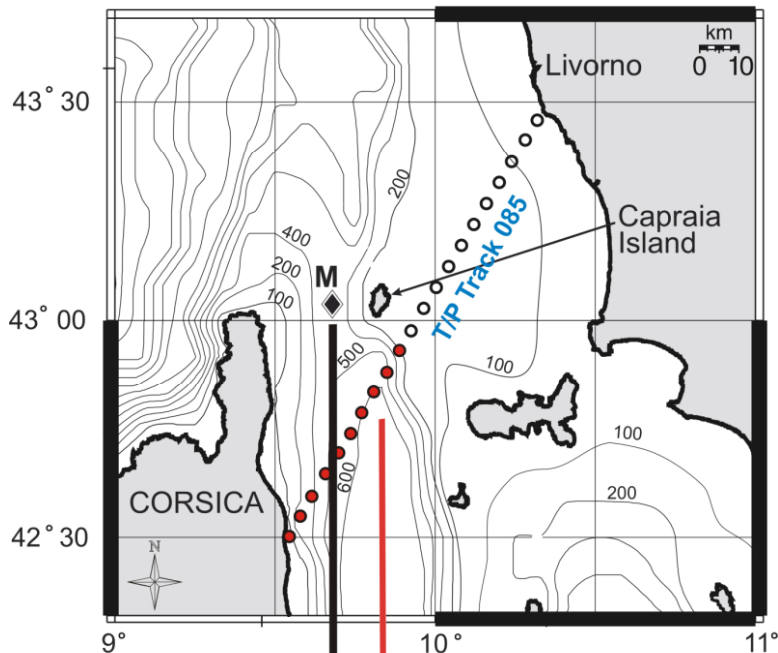


Comparison of **in situ water transport** with **altimetric Sea Level difference** between two ends of the Corsica channel



# Vignudelli et al 2005

- Recomputation of SLA along T/P track 085 with X-TRACK system
  - RMS difference 2-3 cm w.r.t. Capraia station at periods  $> 30d$
  - Speed anomalies:



# The International Framework

- **Space Agencies** are supporting Coastal Altimetry:
  - Also in preparation to new missions (**CryoSat-already showing excellent data**, AltiKa, Sentinel-3)
  - **COASTALT** (2008-2011): ESA-funded, for prototype Envisat Coastal Altimeter processor, NOC Southampton leading (Paolo Cipollini), 5 EU partners. Prototype data distributed from October 2011, see <http://www.coastalt.eu>
  - **PISTACH** (2007-2011): funded by CNES for Jason-2, see presentation by Dufau. Data available since Nov 2008 via AVISO: <http://www.aviso.oceanobs.com/index.php?id=1527>
  - **ESURGE** (2011-2013): ESA initiative for Earth Observation support to storm surge monitoring and forecasting, has significant coastal altimetry component. <http://www.storm-surge.info>
- **International coordination** via COASTALT-SWT (Science Working Team), and **Coastal Altimetry Workshops** (Silver Spring 2008, Pisa 2008, Frascati 2009, Porto October 2010, San Diego Oct 2011), reporting to OSTST.



# The Coastal Altimetry Community

5th Workshop, San Diego, 16-18 October 2011



[www.coastalaltimetry.org](http://www.coastalaltimetry.org)

**Next CA-WS: 20-21 Sept 2012, Riva del Garda, Italy.**

Stefano Vignudelli · Andrey Kostianoy · Paolo Cipollini  
Jérôme Benveniste (Eds.)  
**Coastal Altimetry**

Radar altimetry over the oceans represents a success story for satellite-based Earth Observation. However there is an important marine domain where altimetry has remained underexploited until recently: the coastal zone. Data in that region have been usually discarded due to problems with the altimeter radar echoes and to the lack of those corrections needed for an accurate estimation of sea level. Several scientists around the world have set out to fill this gap in knowledge and *push altimetry closer to the coast* by means of new/better corrections and dedicated reprocessing of the data. The importance of the new topic of Coastal Altimetry has now been recognised by the major space agencies like ESA and CNES. The last few years have seen the coalescence of a lively Coastal Altimetry Community, holding regular international workshops. This book summarises the promising advances in the topic, with the twofold aim to form a handy reference for the latest technical improvements and to present a number of case studies illustrating the value of altimetry data for coastal studies. The 20 chapters represent the work of a great number of research groups around the world, making the book an authoritative account of the state of the art in this novel topic.

**Stefano Vignudelli** is a researcher at the Consiglio Nazionale delle Ricerche in Pisa, Italy. His areas of expertise include satellite remote sensing of the marine environment, particularly the development of radar altimetry in the coastal zone through new methods for data processing, validation studies and oceanographic applications.

**Andrey G. Kostianoy** is a Chief Scientist at the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, in Moscow, Russia. He is a specialist in physical oceanography. His research has focused on satellite monitoring, oceanography of coastal zones, regional climate change and environmental problems of the Black, Caspian and Aral seas.

**Paolo Cipollini** is a Senior Research Fellow at the National Oceanography Centre, Southampton, U.K. He is a specialist in satellite oceanography with focus on observations of planetary waves, satellite data processing and coastal altimetry. He is the manager of the ESA initiative for Coastal Altimetry research and development (COASTALT).

**Jérôme Benveniste** is a Senior Advisor at the European Space Agency, Esrin, Italy. He is a specialist in physical oceanography and applications of radar altimetry, developing new altimetry products, algorithms and validation. He has recently launched the ESA initiative for Coastal Altimetry research and development.

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springer.com

Vignudelli · Kostianoy  
Cipollini · Benveniste (Eds.)

 Coastal Altimetry

S. Vignudelli  
A. Kostianoy  
P. Cipollini  
J. Benveniste  
(Eds.)



# Coastal Altimetry

 Springer

# Applications

- Multifold:
  - Sea Level, tides - not only long term studies and climatologies, but also specific hazardous/extreme events (storm surges)
  - Near-shore currents and waves
  - Assimilation into coastal models (see **Mediterranean example** in next slide)
  - Fisheries, shipping, sediment transport

Altimetry is a **legitimate component of any coastal observing systems...**

- See Cipollini et al OceanObs'09 Community White Paper
- ...of course, **in combination and synergy with in situ measurements and models!**

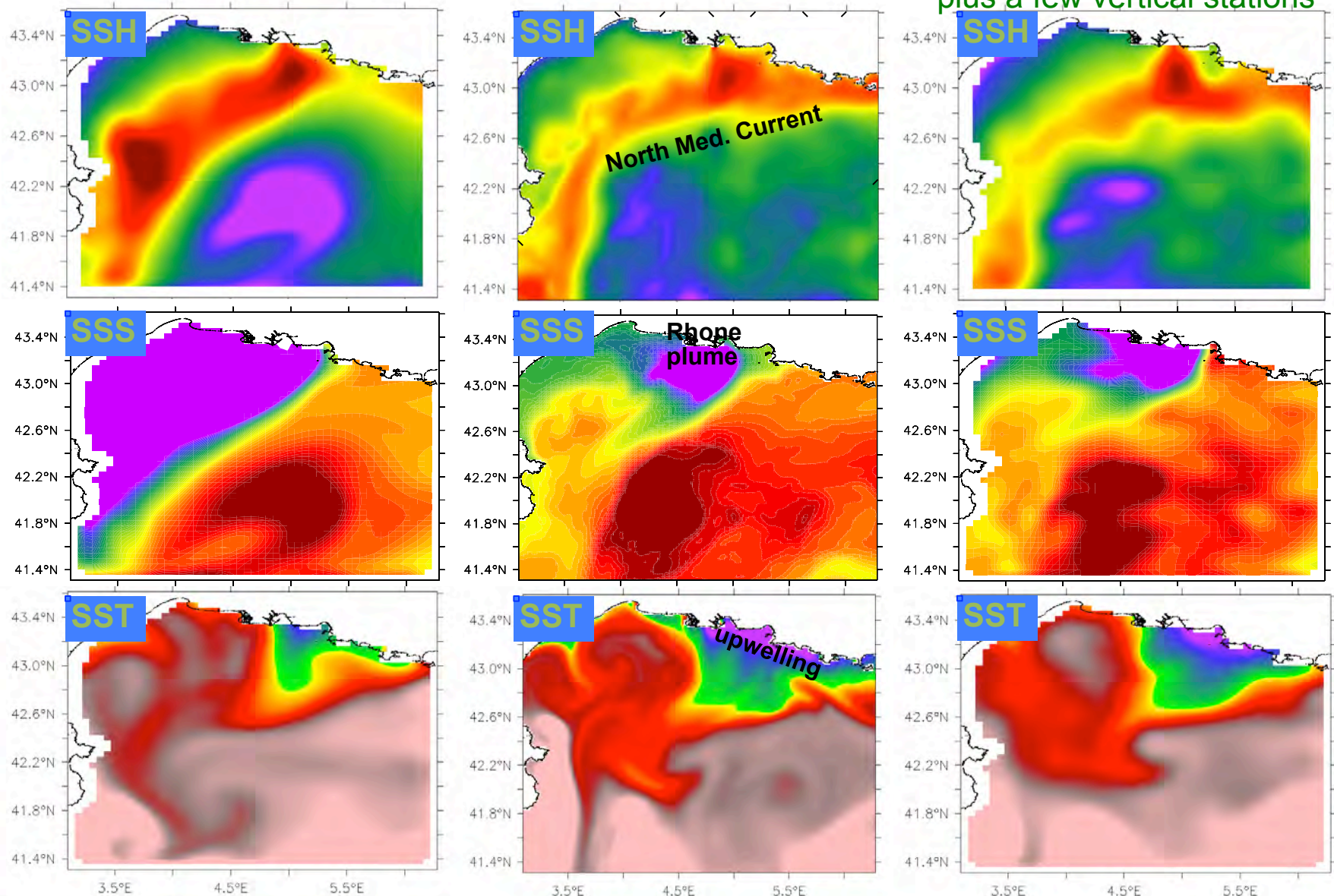


# Example of expected impact of coastal altimetry over Gulf of Lions, by Aurélie Duchez, LEGI Grenoble (now @ NOC), paper in prep.

lower-res model, 1/16°

“truth”: high-res model, 1/64°

lower-res model, 1/16°  
PLUS SSH on alt tracks  
plus a few vertical stations

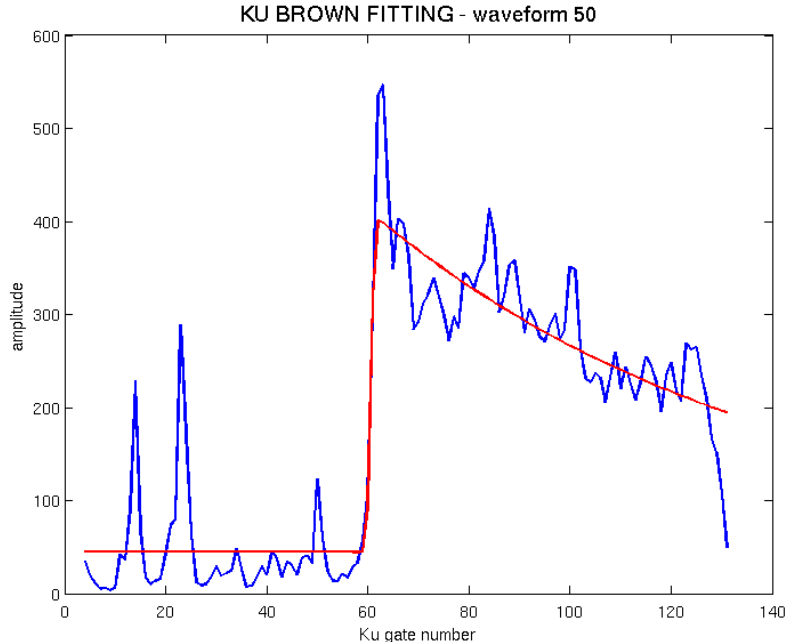


# How we recover more valid data

0-10 km

## A. Specialized **retracking**

- Use better waveform models, accounting for change of shape in coastal environment
- Use specialized (2-D or sequential) retracking techniques



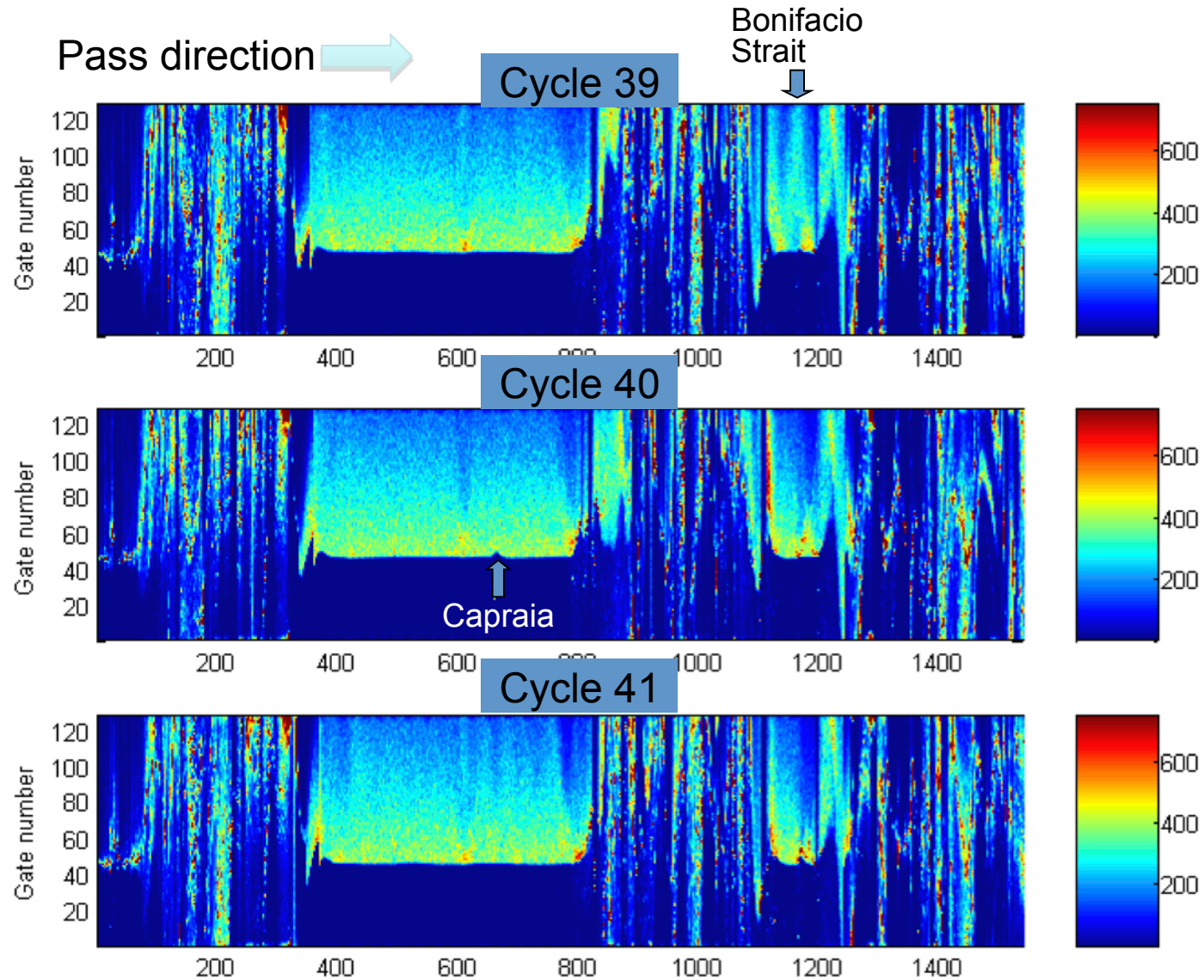
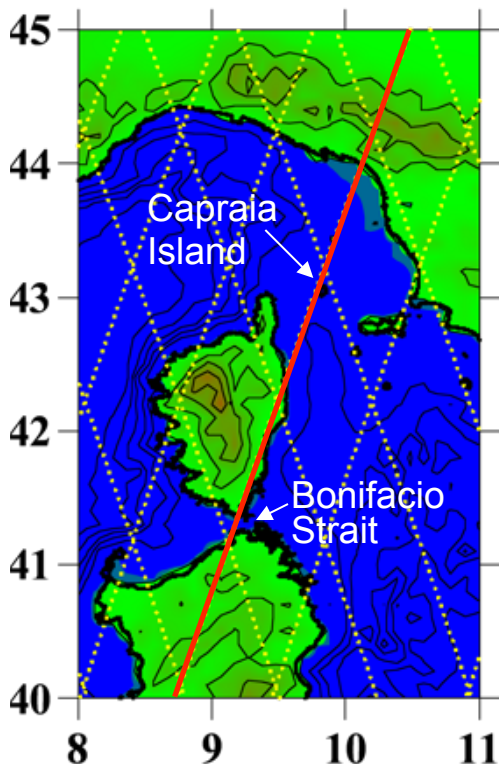
0-50 km

## B. Improved **Corrections**

- Most crucial is the correction of path delay due to **water vapour** (“wet tropospheric” correction)
- Some applications require correction of **tidal** and **high-frequency** signals, which are also difficult to model in the coastal zone

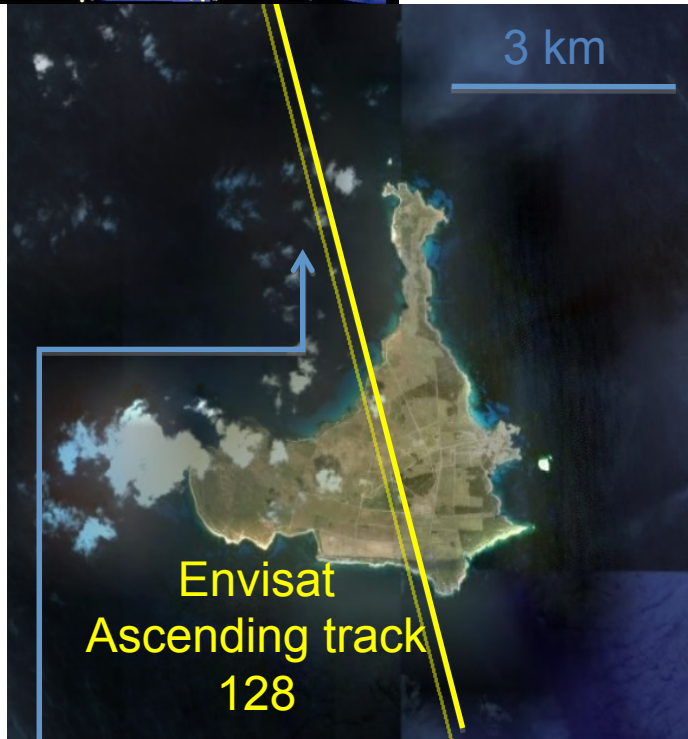
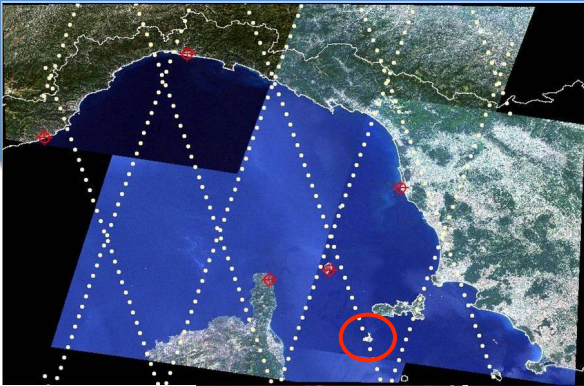
# Example of coastal waveforms

ENVISAT **pass 294**  
(descending)



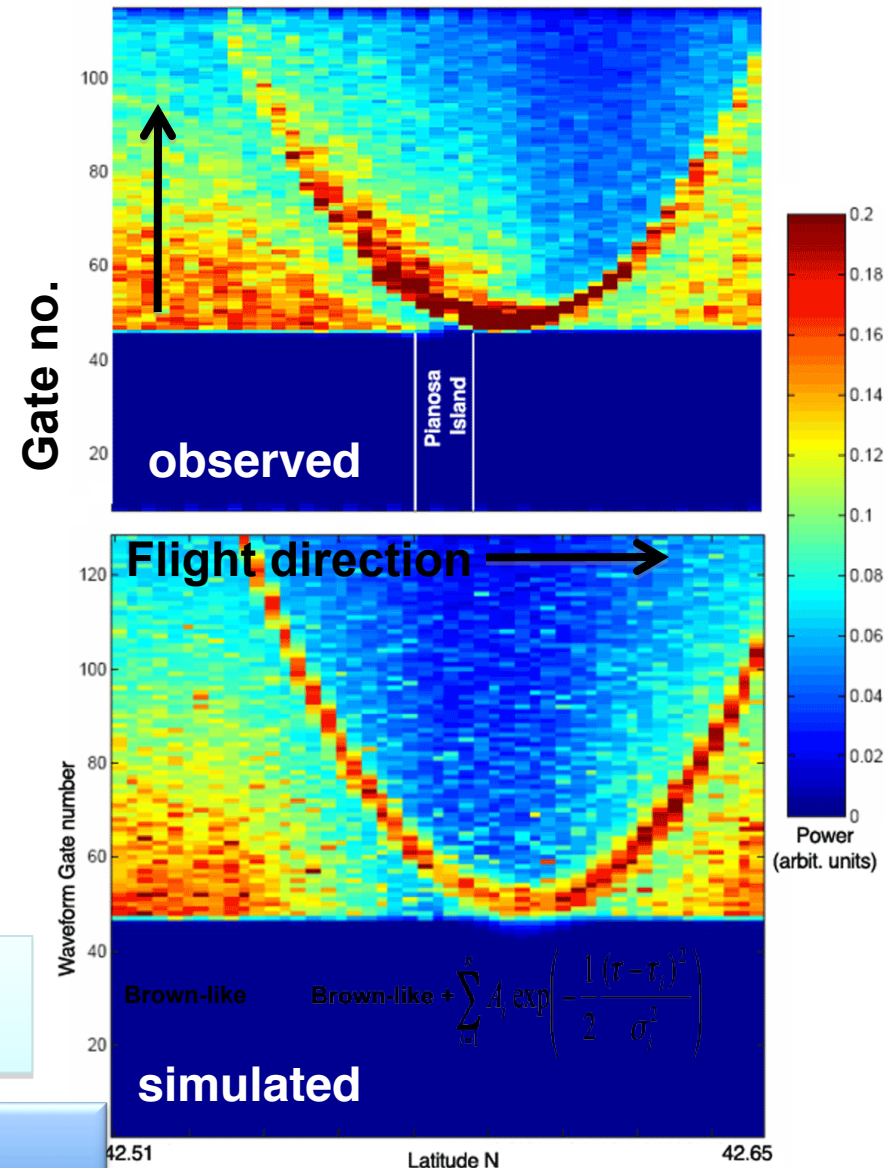


# Example – Pianosa Island



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

*J. Gómez-Enri et al., IEEE GRSL 2010*  
*Scozzari et al, GRL 2012*



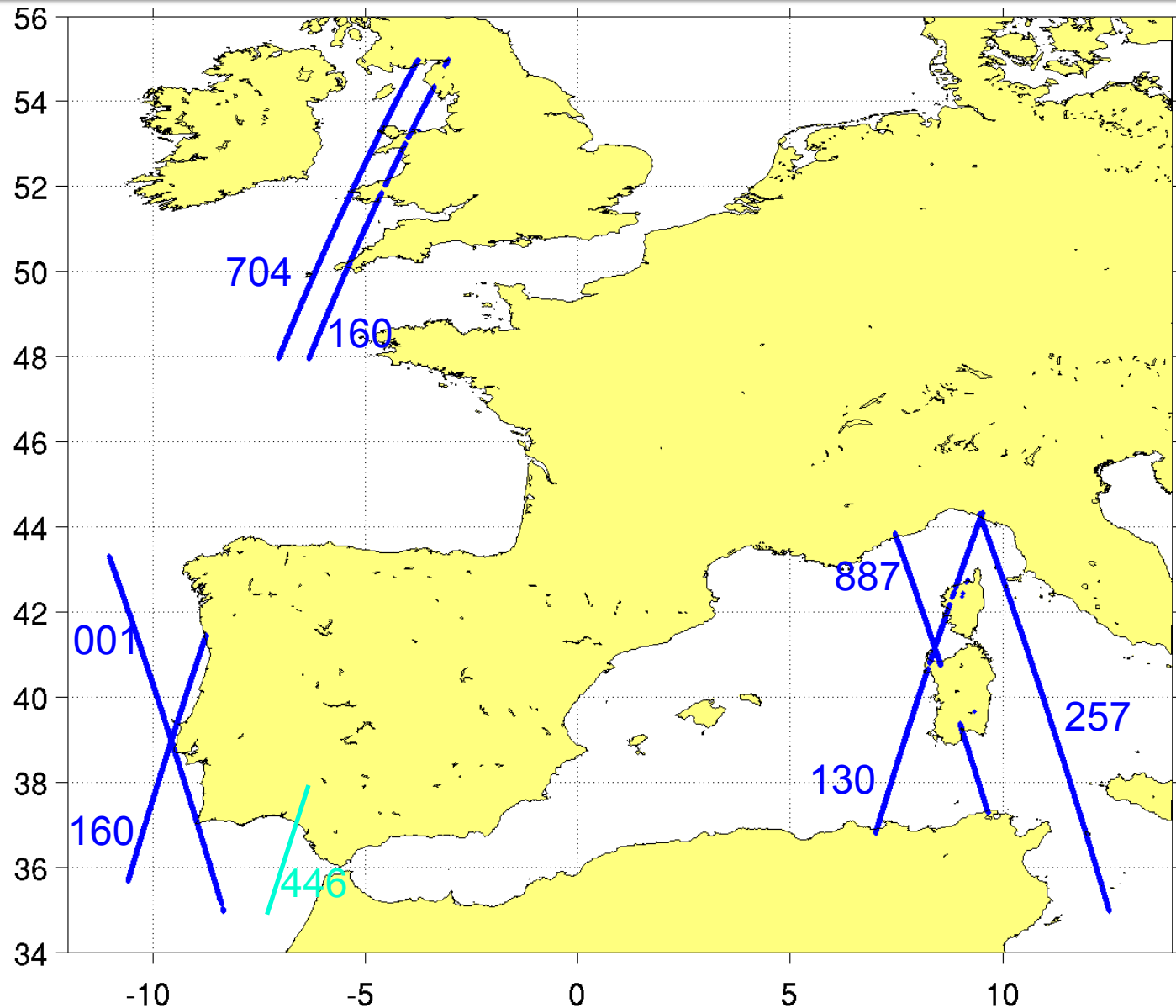
April 2012

# **Where to find coastal altimetry data**

# Data from COASTALT

- **COASTALT aimed at the definition, specification and prototyping** of a new pulse-limited radar altimetry coastal zone **product**.
- In COASTALT this has been done for a small number of track over **three study regions**:
  - NW Mediterranean (incl Corsica Channel)
  - West Britain
  - West Iberian Coast (and Gulf of Cadiz)
- This new product will hopefully be **the seed for future routine reprocessing** of coastal altimetry data by ESA
  - including the reprocessing **of whole ESA Radar Altimetry archive** (ERS-1, ERS-2, ENVISAT)
  - exploitation of **CryoSat** and **Sentinel-3** over the coastal zone
  - the R&D is already moving on within the **eSurge Project**

# COASTALT pilot tracks





# CGDRs – now available

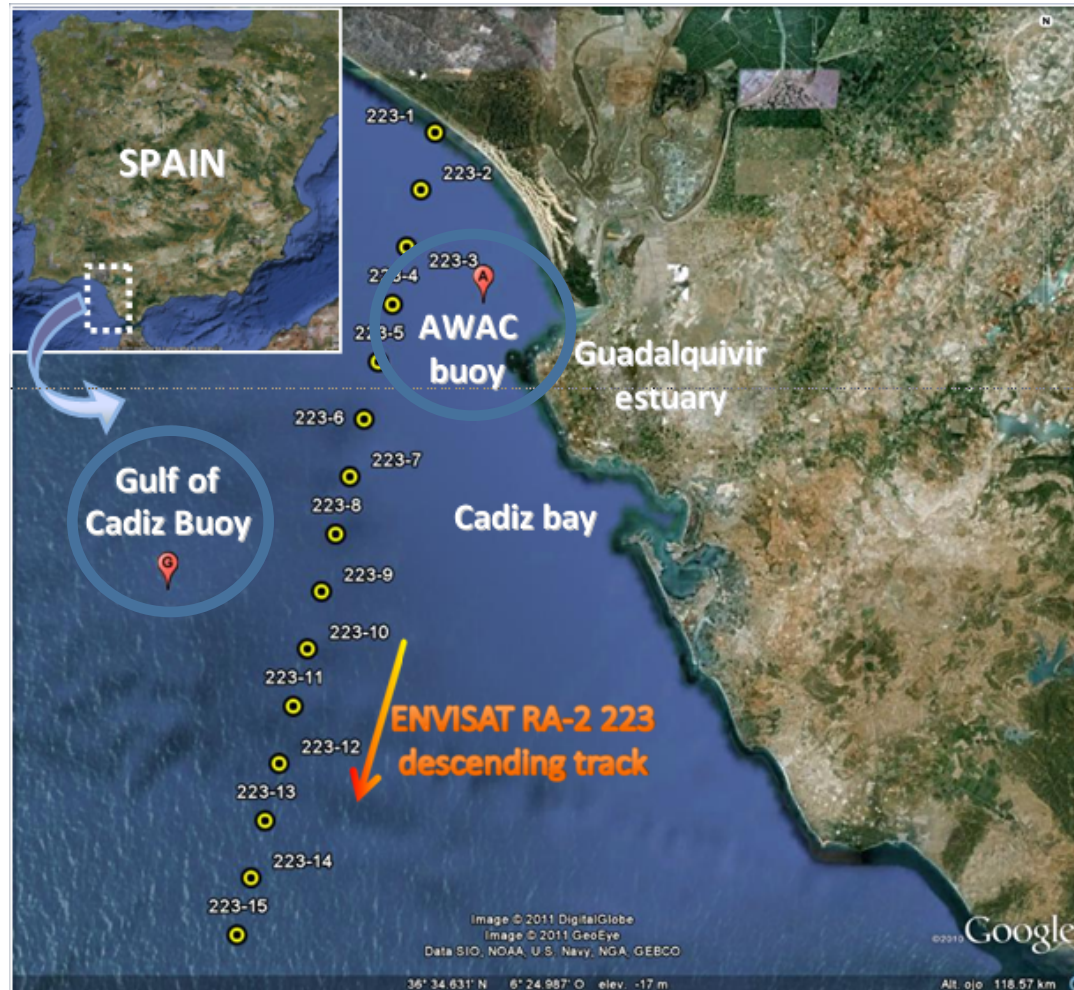
- The COASTALT processor produces Coastal Geophysical Data Records – CGDRs – over pilot tracks
  - contains output of all retrackers (h, swh, sigma0) and full range of corrections including the new GPD Wet Tropospheric correction by Univ. Porto
  - **v2.0r3 (latest) freely available from web site - [www.coastalt.eu](http://www.coastalt.eu)**
- Fully Documented:
  - Product Specification document
  - Product User handbook

See also COASTALT poster



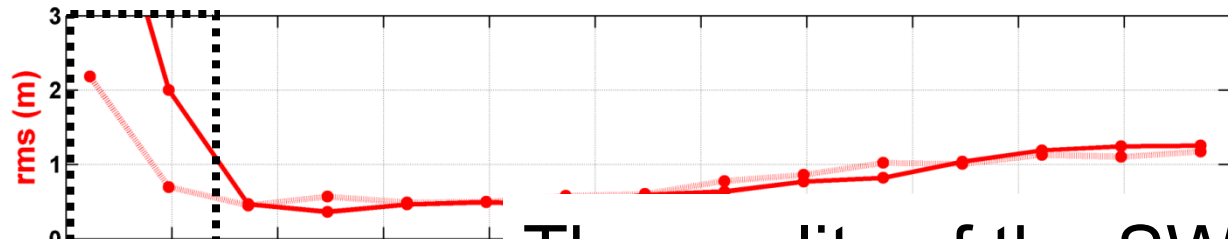
# Validation of COASTALT SWH

## STUDY AREA: THE GULF OF CADIZ

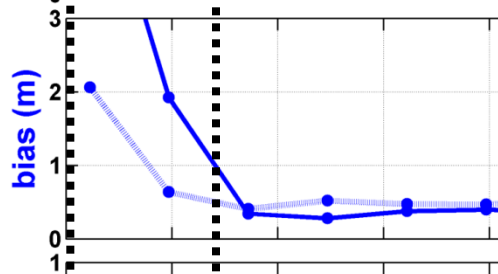


## VALIDATION WITH IN-SITU DATA: coastal buoy

**GDR**  
**Coastalt**

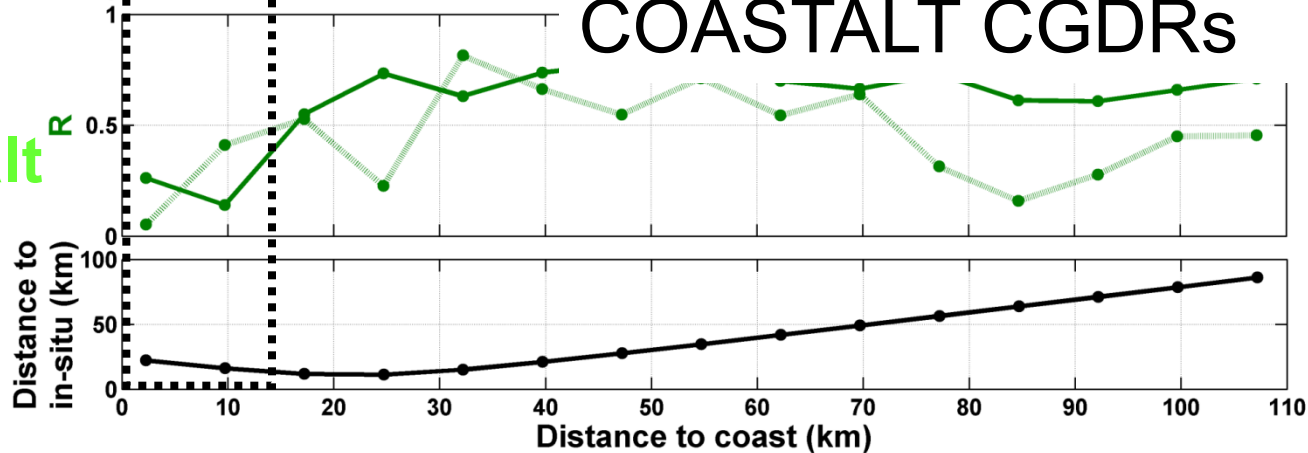


**GDR**  
**Coastalt**



The quality of the SWH when approaching the coast is better in the COASTALT CGDRs

**GDR**  
**Coastalt**



# Data from PISTACH

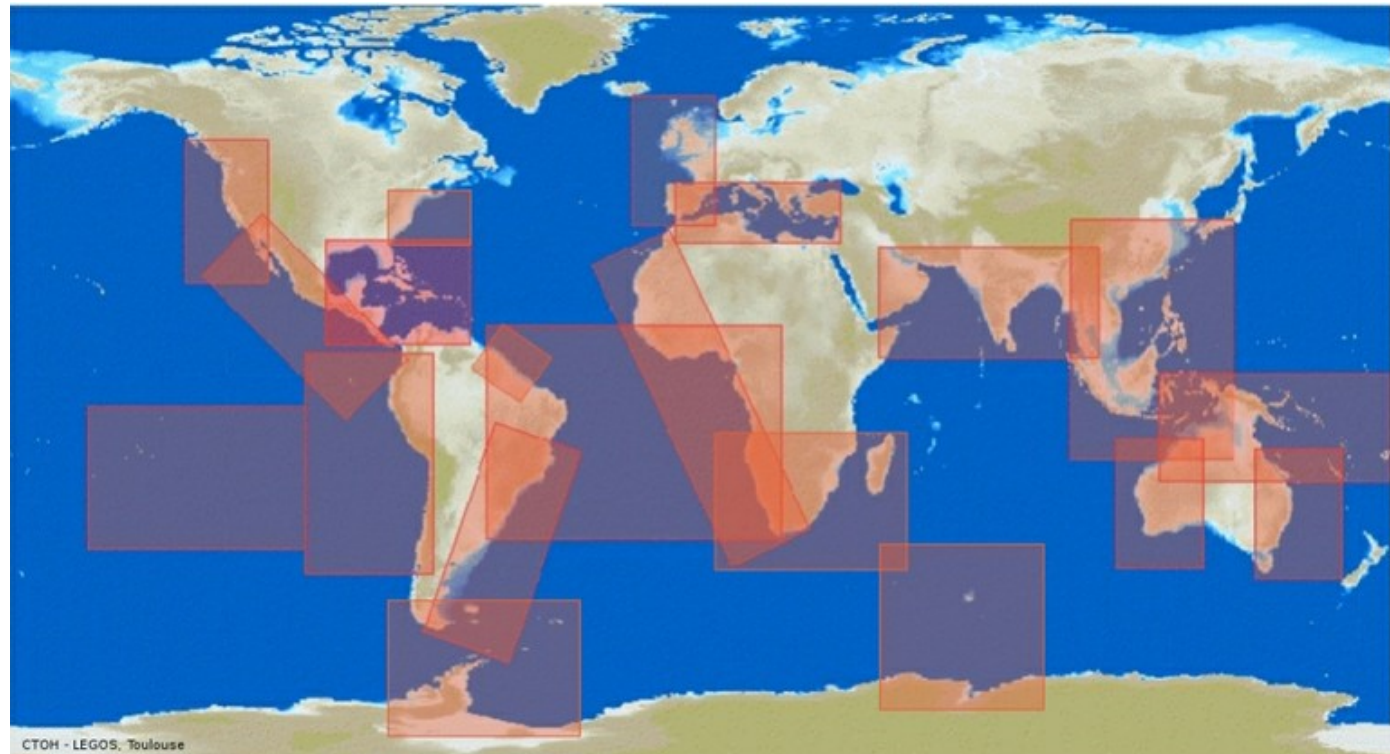
N. Picot et al

- The PISTACH project is funded by CNES
- Goal is to generate Along-track experimental product dedicated to coastal ocean and continental waters for altimetry-expert users (**Jason-2 mission only**)
- Production in Near Real Time (2 days) of an **updated level 2 product in NetCDF** with dedicated processing algorithms (retracking, tides, ....) and with an **along-track sampling of about ~300 meters** instead of the ~ 6 km
- Delivered freely through the AVISO website:  
<http://aviso.oceanobs.com>



- 1 Hz non-retracked product, NetCDF format:
  - SLA time series along a nominal ground-track,
  - MSSH consistent with SLA
  - geophysical corrections included
  - distance to nearest coast (Leuliette)

- **20 regions** available, T/P Jason-1,-2 everywhere, Envisat and GFO on request
- access to simple diagnostics
- **now available at 20 Hz** (experimental)





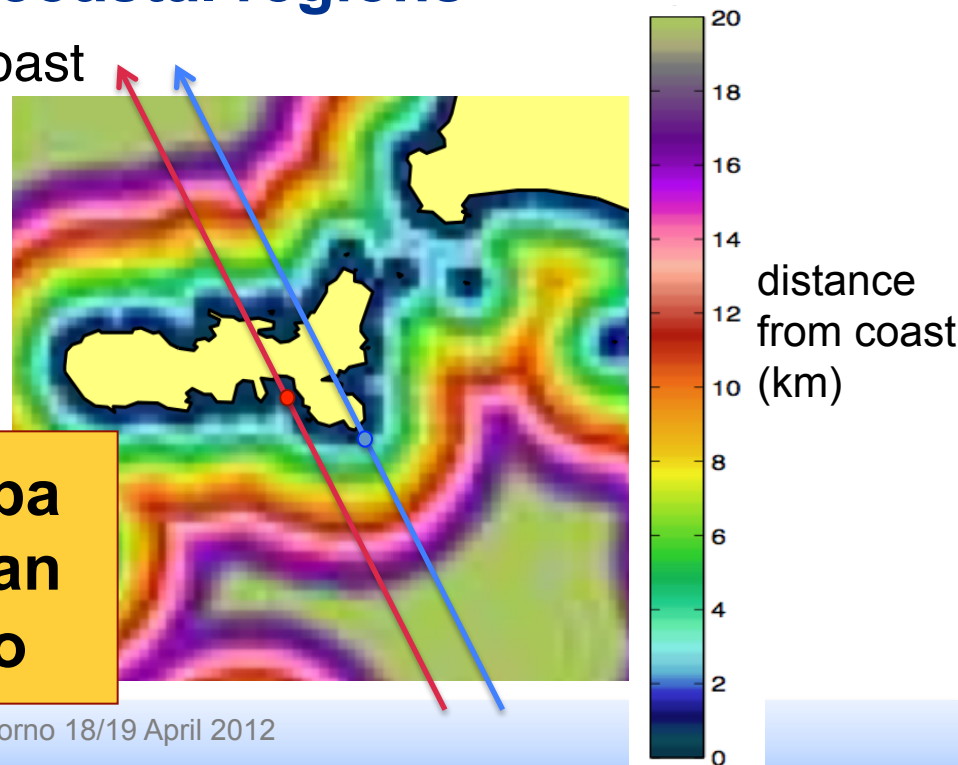
# Other: Coastal Proximity $\mathcal{P}$

- A new parameter to be used as independent variable
  - aims at capturing differences in coastal morphology
    - problem is well defined once geometry and instrumental params are fixed (orbital height, antenna beamwidth, pulse length, number of gates) and a good DEM is available
- **The  $\mathcal{P}$  parameter is expected to improve screening (impact on the regional variability in coastal regions)**
  - with reference to distance from coast

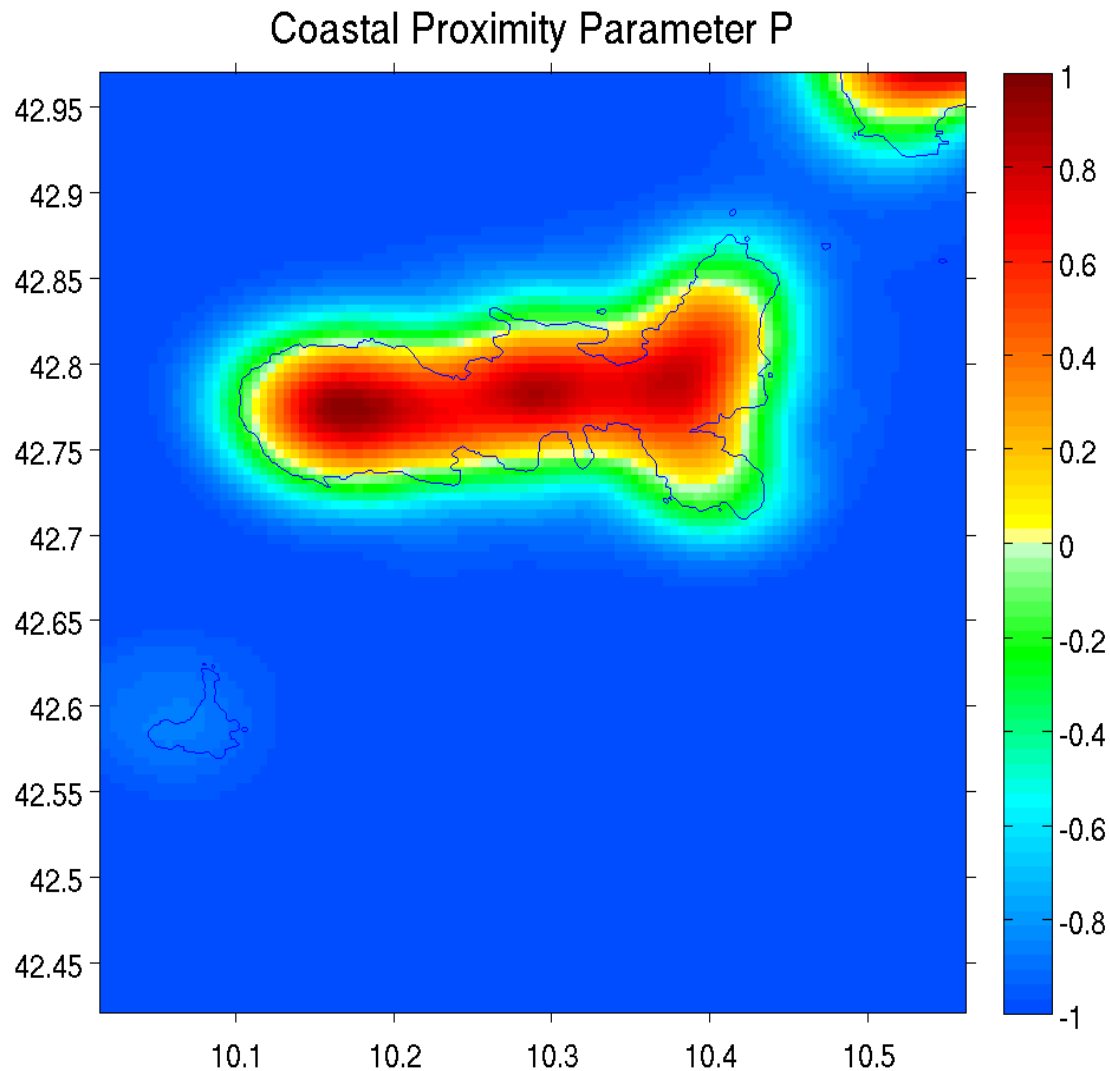
Developed within ESA Sea Level Climate Change Initiative

<http://www.esa-sealevel-cci.org/>

**Example: Elba Island, Tuscan Archipelago**



# Example of $\mathcal{P}$





# What we need now (ideas for discussion)

- Systematic **validation** of data
  - need consensus on **metrics** to measure improvement
- **Assimilation experiments** of coastal altimetry
- studies of the long term stability of data for climate-quality monitoring of trends
  - some work within the ESA Sea Level CCI Project
- More Applications/demonstration studies
  - coastal dynamics
  - fisheries
  - **storm surges (ESA eSurge project)**
- The Mediterranean remains an ideal laboratory for all these!!!

# eSurge Project

- New ESA-funded project, kick-off in Jun 2011, 30 months.
  - Logica UK (lead), NOC (UK), DMI (DK), KNMI (NL), CMRC (IE)
- Investigate contribution of EO data to monitoring and forecast of **storm surge events**.
- Coastal Altimetry recognized as one of the key datasets
- Will fund extension of COASTALT processor to other regions (**including whole Med**) and other missions
- Will also extend capabilities of processor to **Near-Real Time Data**.

# Conclusions

- Coastal Altimetry is a very worthwhile extension of altimetry
  - significant expected impact on several applications, all relevant to the Mediterranean
- COASTALT and other projects are **making coastal altimetry data available**
  - we need more validation – and to promote applications
- The Coastal altimetry community is very lively and the **6th<sup>th</sup> Coastal Altimetry Workshop** will take place in Riva del Garda, Italy, on 20-21 September 2012

[www.coastalt.eu](http://www.coastalt.eu)  
[www.CoastalAltimetry.org](http://www.CoastalAltimetry.org)



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## → 6th COASTAL ALTIMETRY WORKSHOP



20-21 September 2012 | Riva del Garda, Italy

Abstracts by 22 June (ORAL) / 7 Sept (POSTER)

[www.coastalaltimetry.org](http://www.coastalaltimetry.org)