Multi-Scale analysis of coastal altimetry data, multi-sensor observations and numerical modelling over the NWMed sea

1 Serco, Italy; 2 Rhea c/o ESA; 3 MIO(Mediterranean Institute of Oceanography), France,
4 CLS, France
Generality - Altimetry

A wealth of applications are possible using radar altimetry measurements:

- Geoscience fields
- 'Historical' applications (geodesy, general ocean circulation)
- Developing ones (solid Earth and coastal applications, etc)
- Ocean variability,
- Ice topography,
- Hydrology

Corrections for the various components of the atmospheric refraction

\[
R = \bar{R} - \sum_j \Delta R_j \quad \bar{R} = \frac{ct}{2} \quad \Delta R_j \quad j = 1, \ldots, n
\]

Heights

\[
h = H - R = H - \bar{R} + \sum_j \Delta R_j
\]

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Where altimetry is problematic (~CZT concept): Coastline / Open-Ocean Transition including the continental shelf and extending over few tens km:
- Contamination of altimetric footprints
- Sub-sampling of coastal dynamics
- Inaccuracy of corrections (e.g. Wet Tropospheric Corrections ...)

International active community

Technical Issues in CA altimetry data

Applications of coastal altimetry data

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Project Overview

WP3327-1: Management of the Project
Company: RHEA System SA
WP Manager: J. Bouffard

WP3327-2: Processing and validation of improve altimetry-derived parameters over the coastal NWMed
Company: RHEA System SA
WP Manager: J. Bouffard

WP3327-3: Methodology assessment and scientific analysis of in situ data and circulation model outputs
Company: SERCO/MIO
WP Manager: M. Meloni

WP3327-4: Contribute to the definition, development and validation of a new AIRWAVE-derived WTC for coastal altimetry
Company: SERCO
WP Manager: S.Casadio

WP3327-5: Contribute to the definition, development and validation a new Wet Tropospheric correction for coastal altimetry applications
Company: UoP
WP Manager: J. Fernandez
Challenge

- **Context**
  - Slope current and coastal mesoscale plays a key role on the across-shore transport and mixing of natural and anthropogenic elements.
  - Critical importance to monitor and forecast the variability of regional dynamics.

- **Challenges for Coastal Altimetry**
  - Isolate small scale signals wrt Altimetric noise.
  - Develop relevant diagnostics to properly evaluate new CA processing and corrections.
Objectives

**OSCAHR Campaign**
Submesoscale/Mesoscale dynamics characterisations
Coastal altimetry processing validation and fine tuning Ligurian sea
Better assess the physical content and limitations of each observing system.

**SYMPHONIE Model**
Model Validation
NC Variability (position and intensity) over the NWMed

**Coastal Altimetry vs JULIO**
Monitoring of NC intrusion over the continental shelf (GoL)
Study area ... from global to med to ligurian sea

- Marked by **Energetic processes**: slope current, eddies, filaments ...

- Complex hydrodynamical features of **smaller scale**

**New observational and high resolution approaches**
Complex dynamics, wide spectrum of variability (Send et al., 1999).

Northern Current: strong seasonal variability with maximum flux in winter (Gostan, 1967)

NC Intrusions over the GoL shelf function of stratifications and wind conditions (Gati et al., 2006)

Observing such regional dynamics with coastal altimetry is possible but very challenging.
Data set and methods – Technical issues

Limitations

- **Low SNR** and Non-optimized geo-corrections/post-processing
- Lack of **on-purpose validation** approaches dedicated HR altimetry
- Poor knowledge of **oceanographic features hidden** behind the raw signals ...

Strategies

- Improve continuously CA **processing** algorithms & corrections (*Vignudelli et al 2005 ...*)
- Develop **multi-platform** validation approaches (*Cipollini et al., 2009, Bouffard et al, 2010 ...*)
- Discuss results wrt **physical content & limitations** of each observing system

Validating Coastal Altimetry is not “statistics” ...
... but rather a matter of Physical Oceanography
Datasets and Methods - Altimetry

- **Study Areas**
  - GULF OF LION
  - LIGURIAN SEA

- **Datasets Altimetry**
  - AVISO 1Hz Data
  - PEACHI 40Hz Data

Extract from Bouffard et al., 2013

Extract from Bouffard et al., 2013

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Datasets and Methods – *In Situ*

- **2015 OSCAHR campaign** (A. Doglioli & A. Petrenko – M.I.O.): Explore the link between fine-scale physics and phytoplankton diversity

- **ADCP** and **MVP** (Moving Vessel Profiler) sampling along AltiKa and J-2 altimetry tracks

Impact analysis of new CA processing & parameters

Assess the Physical Content and Reference Level issues
Comparisons between several kinds of altimetry ADT, MVP DH derived current and ADCP.

- MVP Dynamic Height / 360 m
- AVISO SLA 1 Hz + OLD MDT Rio + NEW MDT Rio

ADCP Post-processed Edited / Filtered

Impacts of MDT? Processing? Ref Depth?
Multi-platform approaches: Ligurian Sea

- Impacts of the MDT on the retrieved elevations

**MVP AVISO PEACHI**

**NO MDT**

**OLD MDT**

**NEW MDT**

Altika Track429

R = 0.3

R = 0.5

R = 0.8

Altika Track674

R = 0.3

R = 0.4

R = 0.9

Good agreement between the altimetric & MVP elevations

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Multi-platform approaches: Ligurian Sea

- Impacts of the MDT on the retrieved elevations

### MVP AVISO PEACHI

#### NO MDT

- **Altika Track674**
  - Back travel
  - \( R = 0.3 \)

#### OLD MDT

- **Jason2 Track09**
  - \( R = 0.4 \)

#### NEW MDT

- \( R = 0.8 \)
  - \( R = 0.5 \)
  - \( R = 0.7 \)

Clear improvements from the New AVISO MDT (STD + Mean)
Multi-platform approaches: Ligurian Sea

- Impacts of the Post-Processing on the retrieved currents

**MVP vs Altimetry**

- **AVISO**
- **PEACHI**

Altika Track429

Altika Track674

Go travel

Relatively good agreement between altimetric & MVP current
Multi-platform approaches: Ligurian Sea

- Impacts of the Post-Processing on the retrieved currents

MVP vs Altimetry

Altika Track674
Back travel

Jason2 Track09

No clear improvement from PEACHI... Can we trust in the MVP?
Multi-platform approaches: Ligurian Sea

- Impacts of the Reference Depth and Physical Content

(ADCP – MVP) Surface Current VS Deep ADCP Current (>360 m)

Important differences over areas of strong deep currents (not seen by MVP)

Difficult to derive quantitative budget error but ...
Multi-platform approaches: Ligurian Sea

- Oceanography features observed from optimized Remote-sensing data and the in situ campaigns

In-situ MVP SST and ADCP currents

Satellite SST and PEACHT currents
+ MVP across track current
+ ADCP across track current

... Qualitative agreement and ... Good synergy for observing coastal features
SYMPPHONIE model description

- Symphonie, is a 3D primitive equation, free surface, sigma coordinate ocean model.

- Components of current, temperature and salinity are computed:
  - Arakawa-C grid using a classic finite difference method detailed in Marsaleix et al. (2006) and Marsaleix et al. (2008).

- Model validated in different studies: Hu et al. (2009), Bouffard et al. (2008, TAO), Kersale et al. (2013), Gatti et al. (2006) etc.

> 10 years of model outputs (from 2001 to 2011) have been acquired from MIO during the collocation meeting.

Heights and currents extracted and interpolated to satellites tracks for comparison:
- Daily-averaged current (Uavg, Vavg) at the surface.
- 3 Km resolution
SYMPHONIE model vs. Altimetry - Methodology

- Along – track altimetry ADT (SLA+MDT)
- Interpolated model elevation
- Temporal statistics per tracks
- Spatial statistics per tracks
- Model/altimetry agreement

Across track geostrophic current
SYMPHONIE model vs. Altimetry - Results

Jason-2
Track #146

Model time series

Satellite current time series

Mean value

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Conclusions

- Multi scale analysis of Coastal Altimetry focusing on Small-Scale Dynamics:

  - Compare multi-mission coastal altimetry with coincident in situ measurements (OSCAHR Campaign) and numerical model (SYMPHONIE):
    - Understand/Discriminate disagreements due to measurement/correction errors w.r.t. physical content, non collocations, reference level.
  
  - Analyse coastal altimetry (standard/experimental) data in order to assess the impact of altimetry processing.

Define new science-oriented diagnostics targeted to high resolution coastal altimetry

Validations/Improvements of coastal altimetry require knowledge of ocean processes behind the raw signals