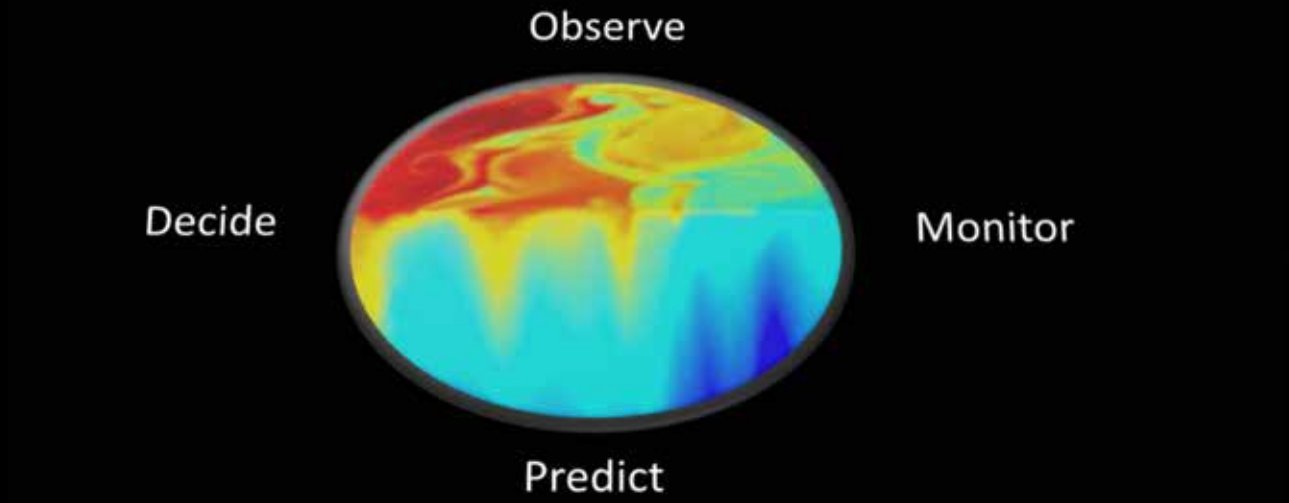
Jerome Bouffard

CryoSat Mission Geophysicist

Coastal Altimetry

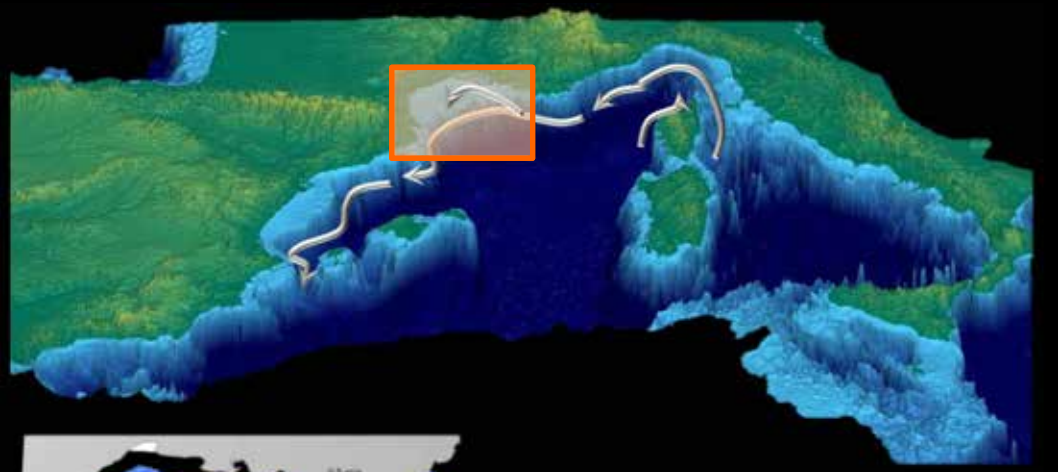
A review of applications & synergy with complementary measurements

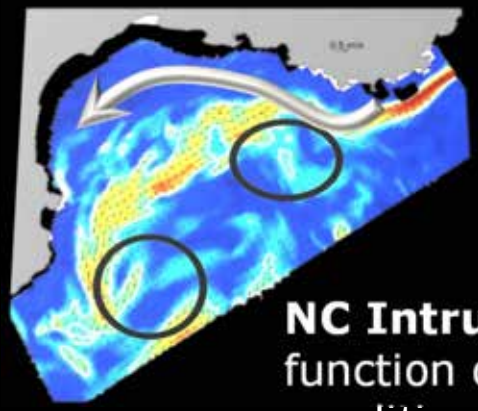


The North Western Mediterranean Sea

Complex dynamics, wide spectrum of variability

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





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

Observing small-scales with conventional alti. challenging

Conventional Altimetry … ~ 20 years ago

Open Ocean: Adapted

Large scale Currents (e.g. Gulf Stream), El Niño/ La Niña , Global Sea level Changes, Open-ocean Large Eddies (>O(100 km))

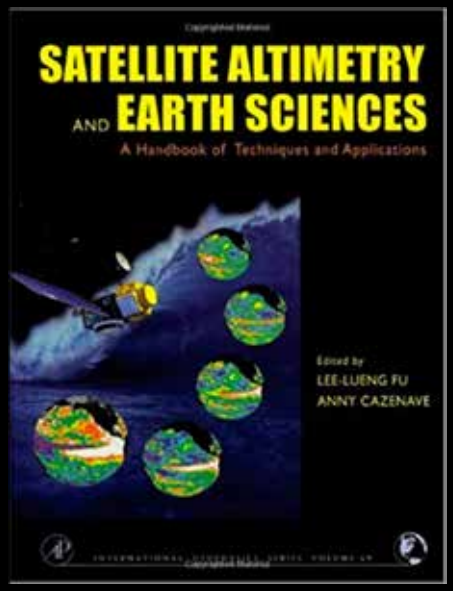
Coastal Ocean: inadapted

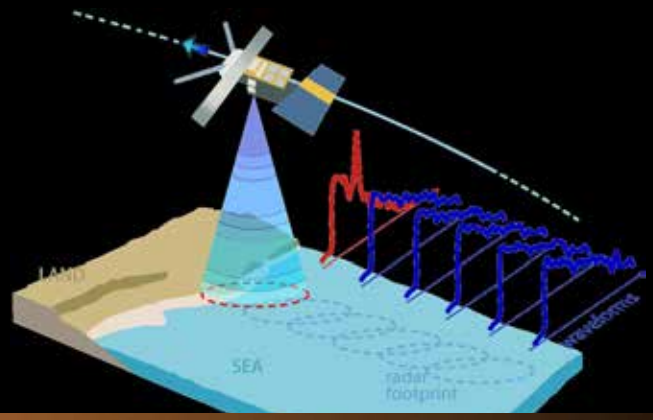
Low SNR and non-optimized instruments, geo-corrections/post-processing

Lack of ***on-purpose* validation** approaches dedicated HR coastal altimetry

Poor knowledge of **oceanographic features hidden** behind the raw signals …

Fu and Cazenave 2000





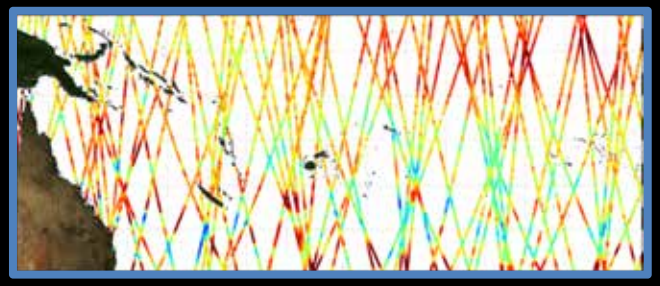
Need of new strategies to resolve small–scale coastal signals

Two decades of R&D in Coastal Altimetry

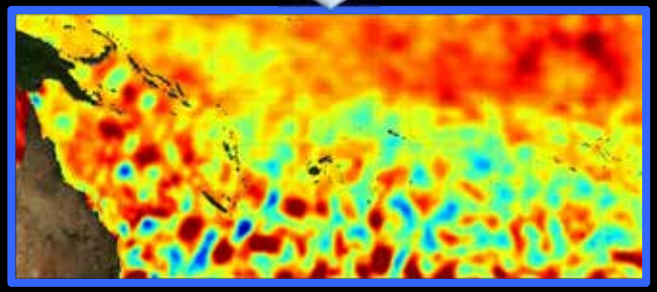
Improved characterization of small-scale coastal dynamics

Surface Observation improvement → **Surface detection and tracking** → **Sub-surface Characterization**

Improve along-track altimetry



Improve 2D HR map of SLA



New **processing technics** for **conventional Ku, Ka** (SARAL), **SAR** (CS2,S3) & **SARIN** (CS2)

Cross-compare / Optimize algo based on surface and sub-surface *in situ* observations

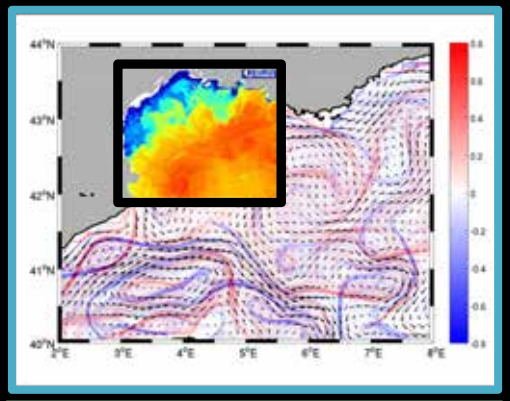
Use new Optimal Interpolation methods

Two decades of R&D in Coastal Altimetry

Improved characterization of small-scale coastal dynamics

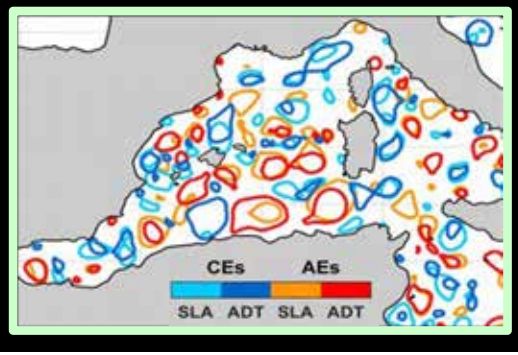
Surface Observation improvement → **Surface detection and tracking** → **Sub-surface Characterization**

Lagrangian analysis of surface 2D fields



© Francesco Nencioli

Eddy detection and tracking



Escudier et al., 2016

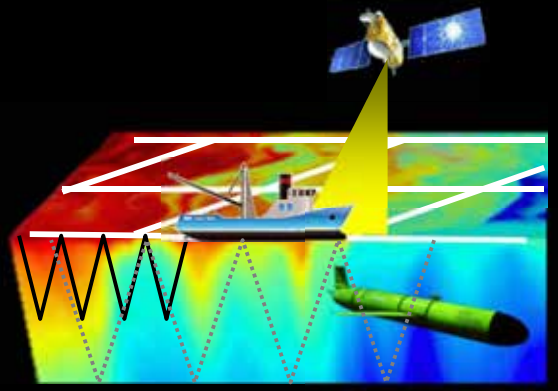
- Detection of Lagrangian Coherent Structures (FSLE)
- Comparisons with Ocean Color / SST and in situ (e.g. drifters)
- Analysis/use of different Eddy tracking approaches

Two decades of R&D in Coastal Altimetry

Improved characterization of small-scale coastal dynamics

Surface Observation improvement → **Surface detection and tracking** → **Sub-surface Characterization**

Small-scale gradients vs *in situ* profiles (CTD, ADCP, Gliders, MVP)



- Deployed **along altimetry** tracks
- Assess **physical content** (geo. Vs ageostrophy) , spot issues (Ref. Level & Synopticity)
- Representation error of observations

Coastal Altimetry from conventional missions

Pionner developments of coastal post-processing technics

ALBICOCA

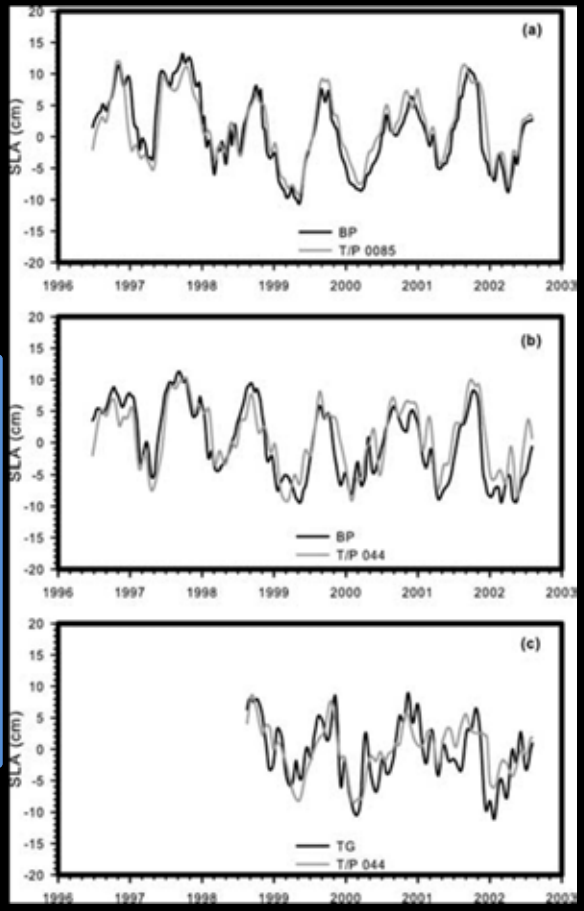
1Hz - Topex/Poseidon

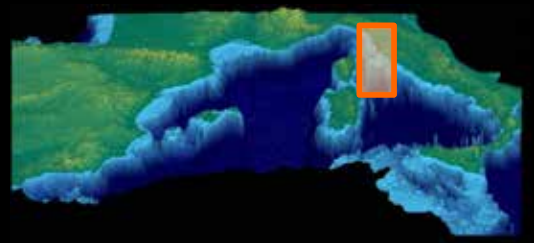
Project over the Corsica Channel (CNES, ASI)

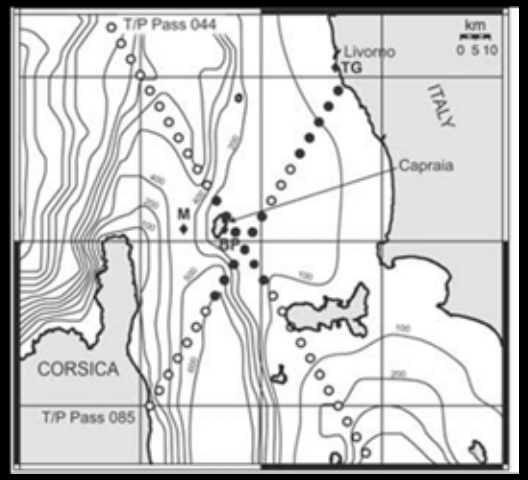
New **Editing** + **Filtering** & **Reconstruction** of geo corrections (Bezier Poly)

High Resolution local de-aliasing (MOG2D Tides + DAC)

High Resolution local MSS







Vignudelli et al., 2005

More data close to the coast with good agreement with TG

Coastal Altimetry from conventional missions

Pionner developments of coastal post-processing technics

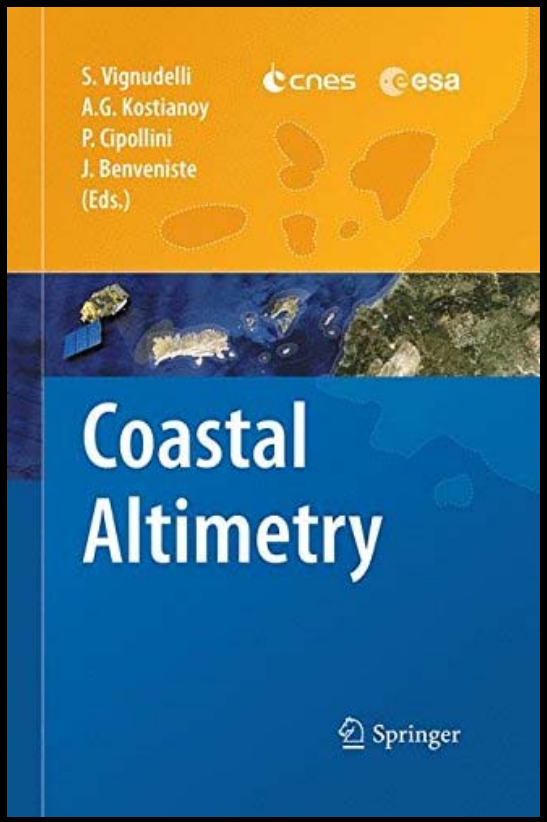
Several valuable datasets …

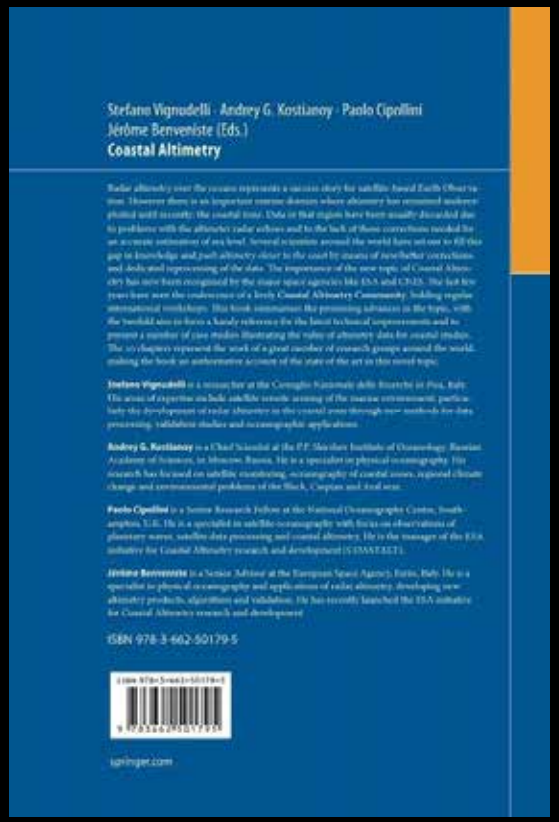
as shown in *Vignudelli et al 2011*

and recent literature:

- ✓ **RADS** *(Scharroo et al,2016)*
- ✓ **ALES** *(Passaro et al.,2014)*
- ✓ **PEACHY** *(Valladeau et al.,2015)*
- ✓ **SARVATORE** *(Dinardo et al.)*

Etc.





It is now time to exploit them to study coastal dynamics

Coastal Altimetry from conventional missions

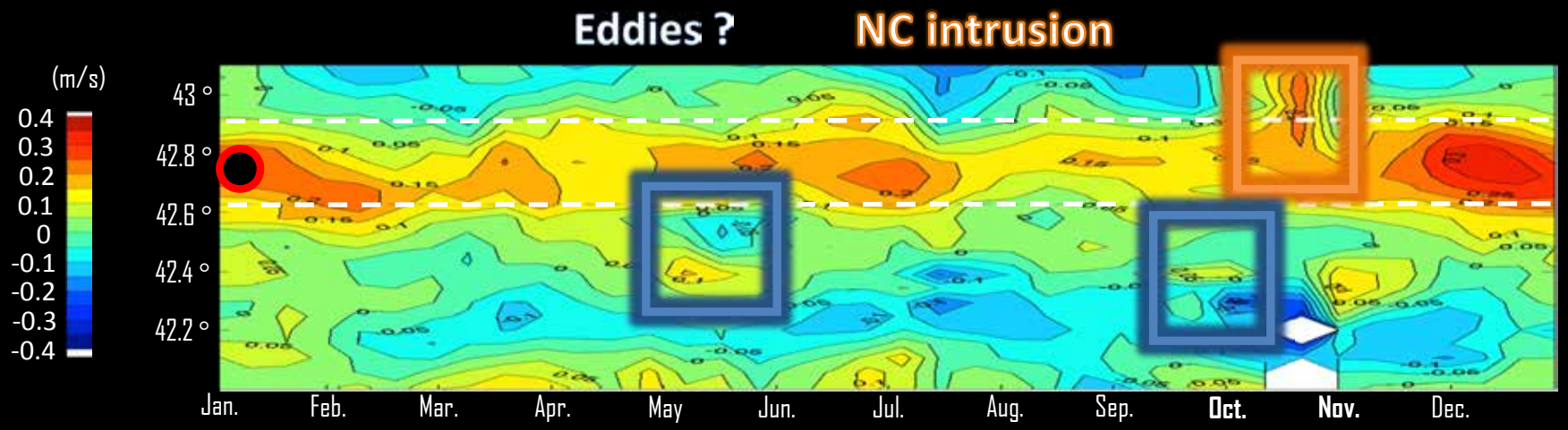
Application to monitor variations of Coastal Density Currents

Several studies focused on the **North Current**

Bouffard, 2007; Bouffard et al, 2011; Birol et al. 2010; Birol & Delebecque 2014

Observe **seasonnal** and **interannual** variations of the NC position/intensity

High Frequency signals such as automnal NC **intrusions** over the GoL and small-scale and rapidly evolving **eddy**-like structures



Approach transposable to other study areas ?

Coastal Altimetry from conventional missions

Variability over the Tunisian coastal area

Shallow water (<200 m) and Macro tidale zones (> 2 m)

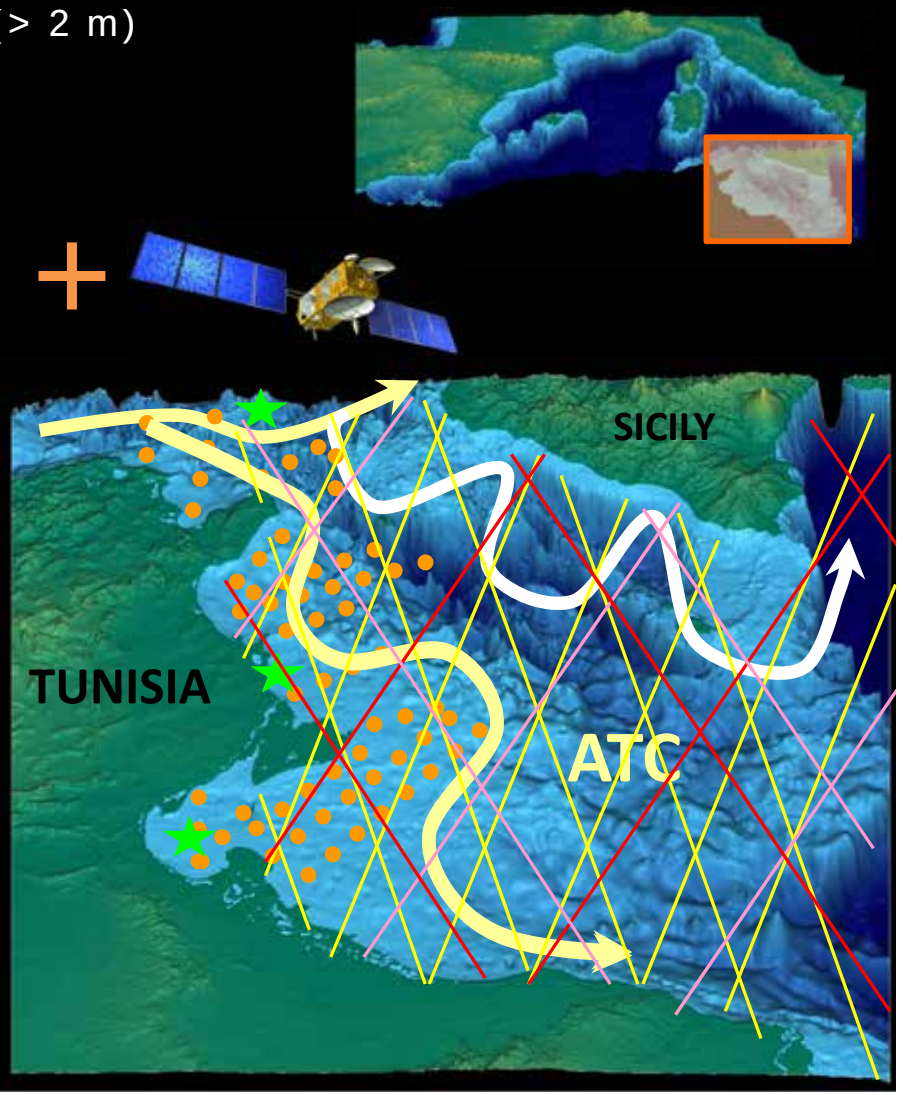
Main feature: ATC dynamics poorly documented

Modeling: North Part. Need to be valided

Campaigns (CTD) Focus on the ATC 3D structure but short period & limited areas

Mooring & Tide Gauges
Long time series but limited coverage

Coastal Altimetry
Free / global but requires optimization & provide only surface information

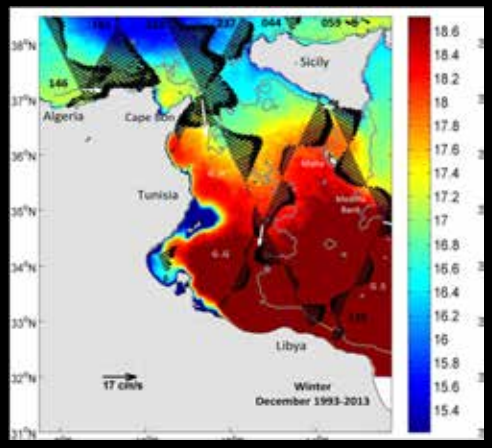


Coastal Altimetry from conventional missions

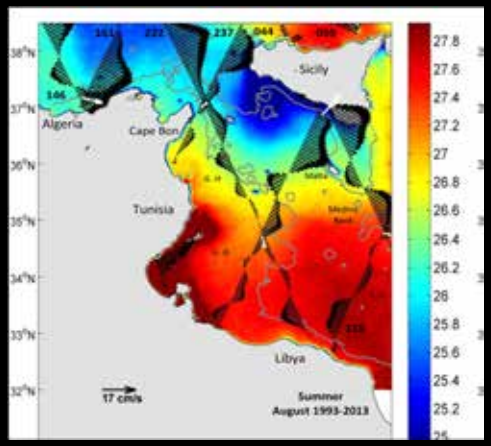
Seasonal evolution of surface circulation over Tunisia

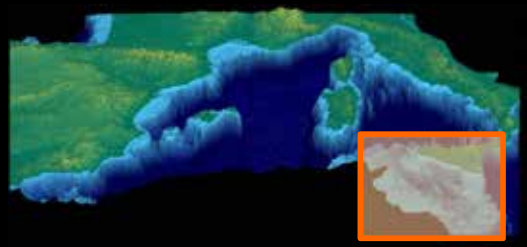
Jebri et al., 2016

SUMMER



WINTER

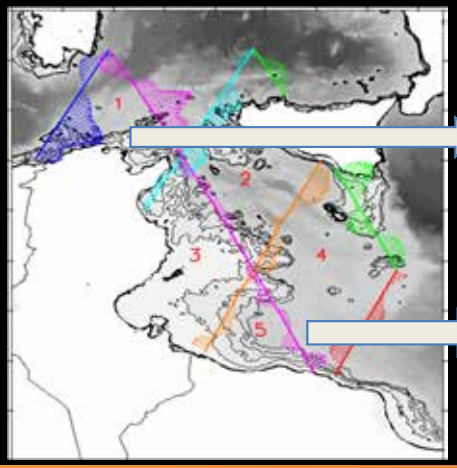


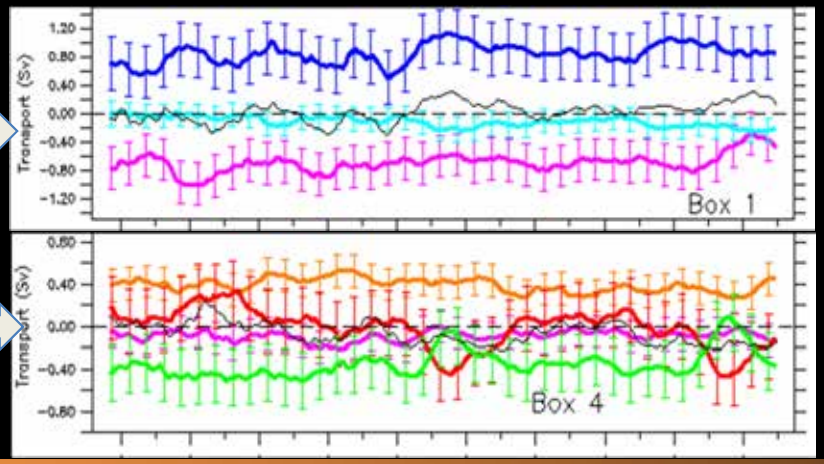


Using XTRACK SST & ADCP

New circulation Scheme

Interannual transports variations & Volume budget *Jebri et al., 2017*





From empirical altimetry-based techniques

Show variation unequally shared the ATC & AIS

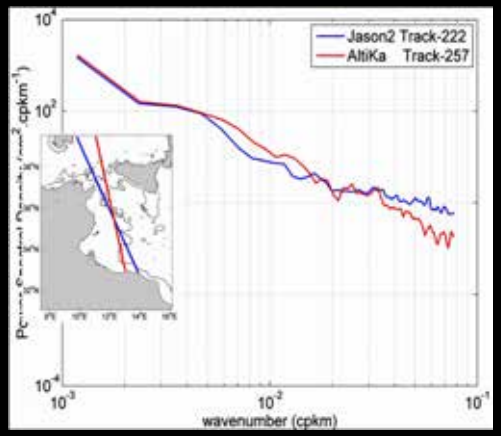
Good results for LF signals but SNR not optimun to resolve mesoscale

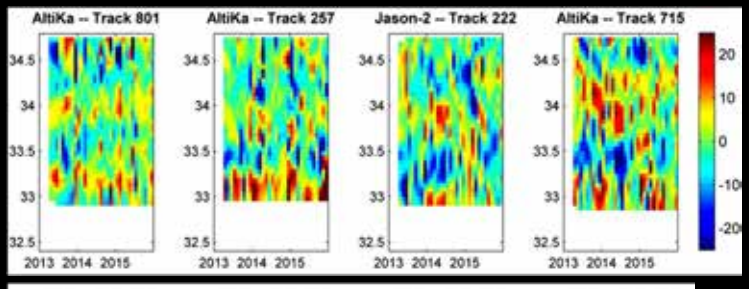
Coastal Altimetry from a Ka-Band Mission

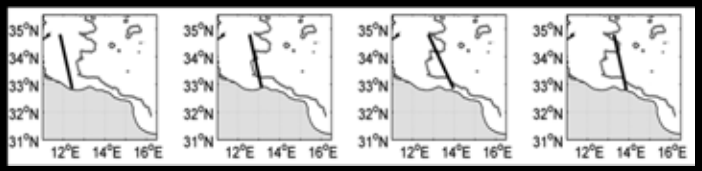
Scale resolving from smaller Ka Footprint

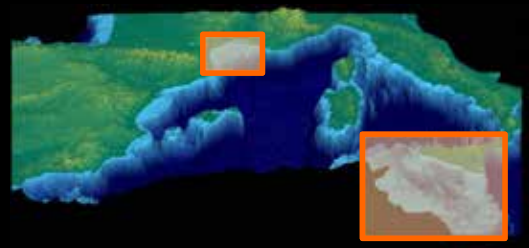
Tunisian Coast

Jebri et al., 2016







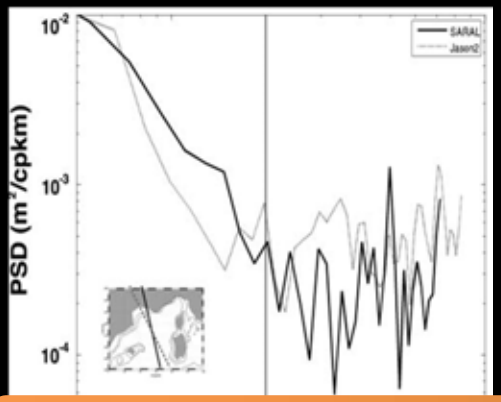


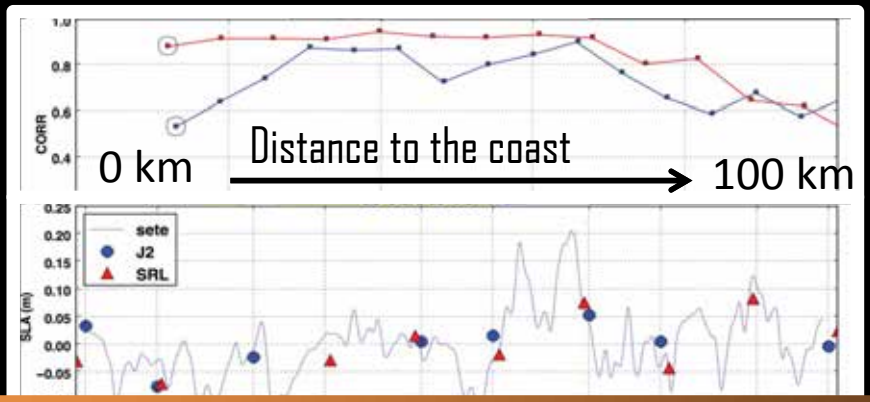
AltiKa less noisy and resolve oceanic smaller scale than J-2

AltiKa shows higher variation with increased coverage at coast

Gulf of Lion

Birol et Nino., 2015; Morrow et al.,2017





Comparisons at Tide Gauge show higher corr. With AltiKa than J-2

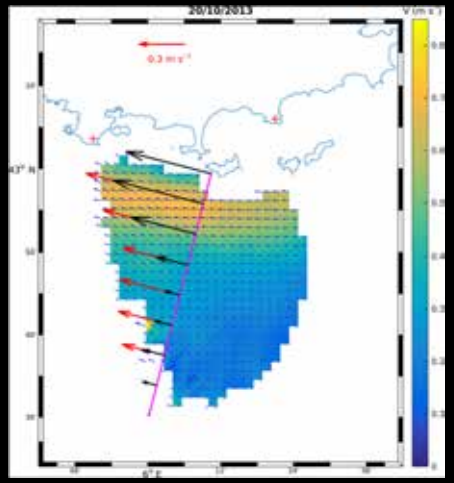
Encouraging results requiring to be confirmed in terms of gradient

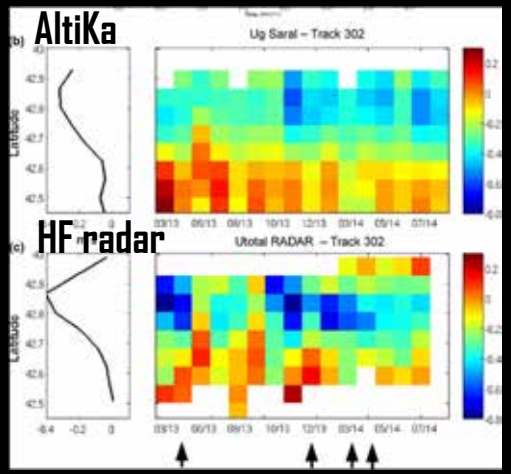
Coastal Altimetry from a Ka-Band Misson

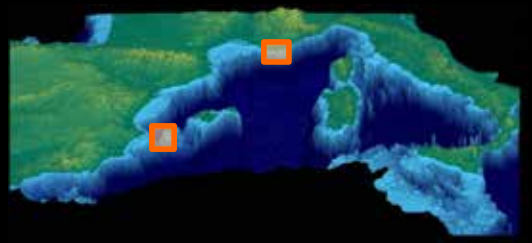
Comparisons to High Frequency Radars

Ligurian Sea

Morrow et al., 2017





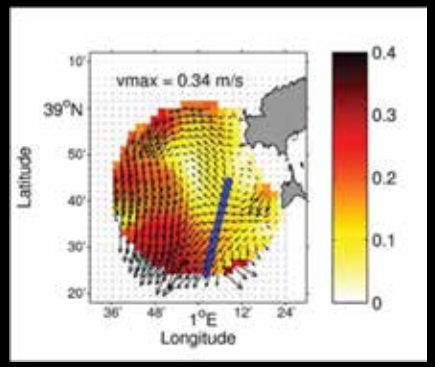


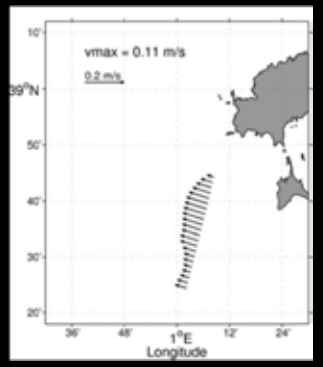
AltiKa velocities reveal the NC & mesoscale signals in agreement with HF radar fields

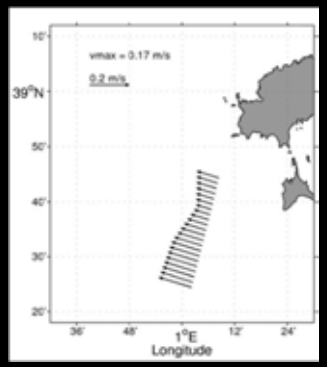
Differences due instrumental radar errors, non- geostrophic signals & low SNR in alti.

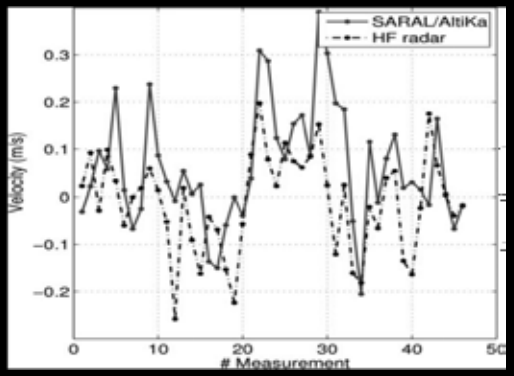
Ibiza Channel

Pascual et al., 2017; Troupin et al. 2015







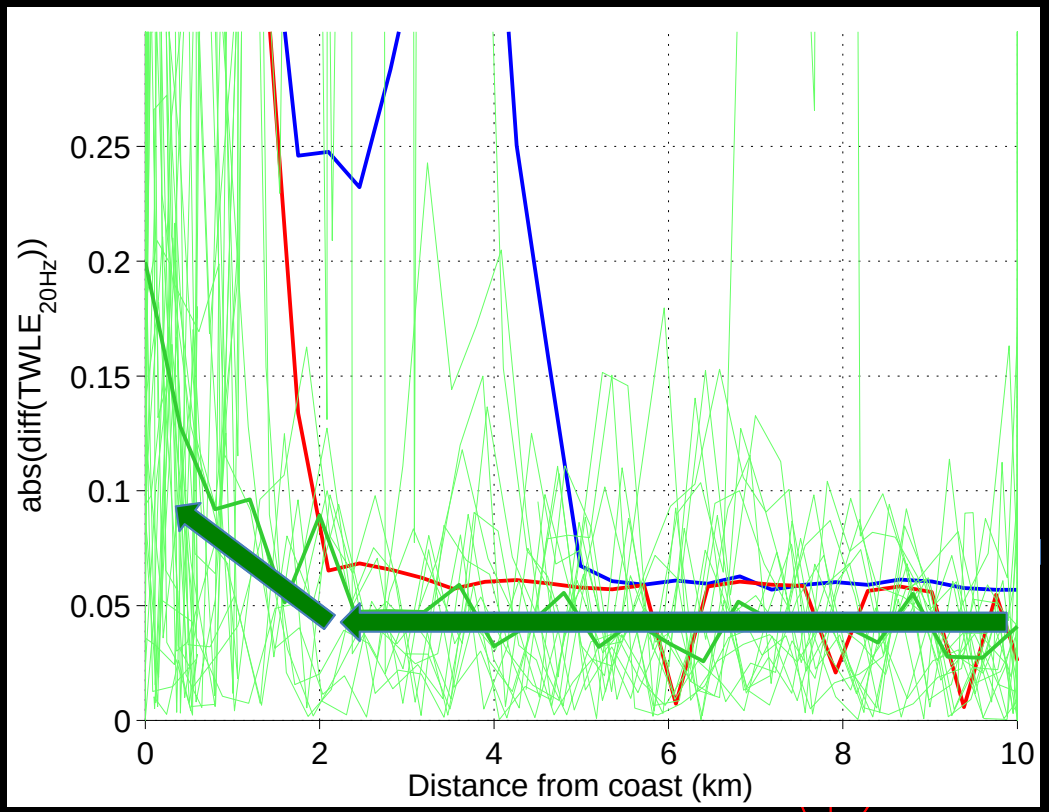


Still possible to enhance the spatial resolution ?

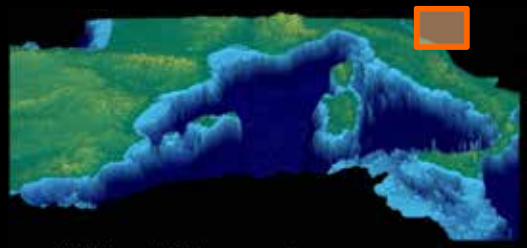
Coastal Altimetry from SAR Missions

SAR: Better adapted to monitor coastal small-scale dynamics

ENVISAT vs CryoSat noise in Coastal North Adriatic



Lower noise, and gets closer to coast



Cipollini, Passaro & Vignudelli, paper in prep.

Envisat p0543 SGDR
(median of 76 passes)

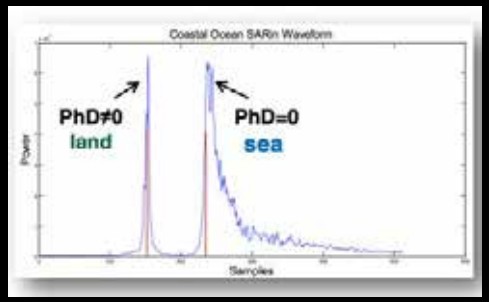
Envisat p0543 ALES
(median of 76 passes)

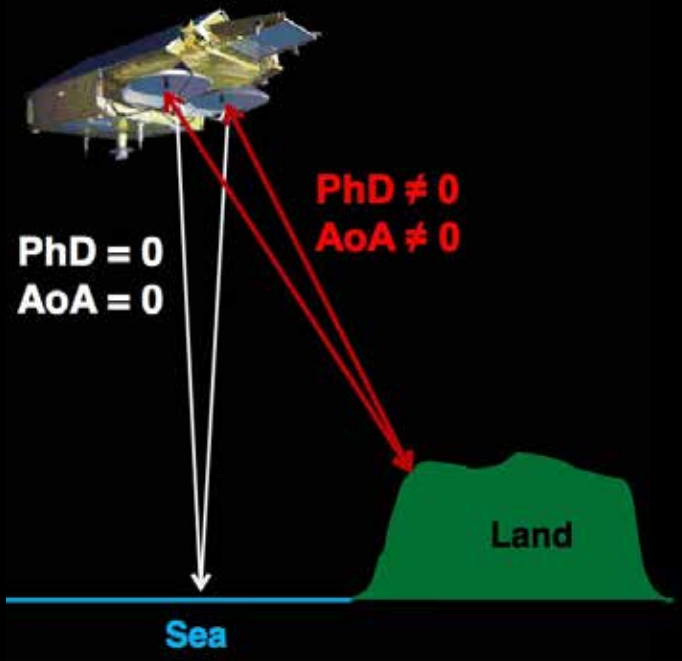
CryoSat–2 SAMOSA
(single passes)

(median of 11 passes)

Coastal Altimetry from a SARin Mission

SARIn: Allow to discriminate Coastal echoes between land & Sea

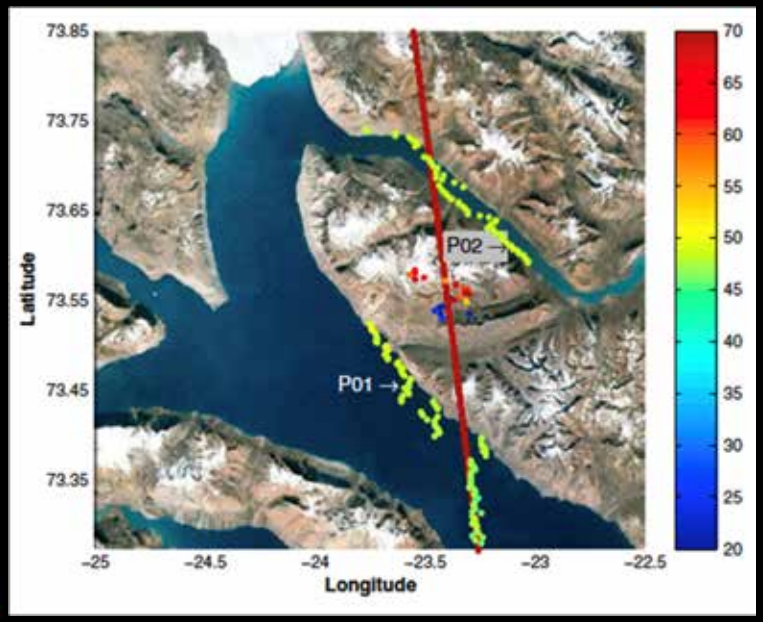




Particularly relevant over complex coastal areas

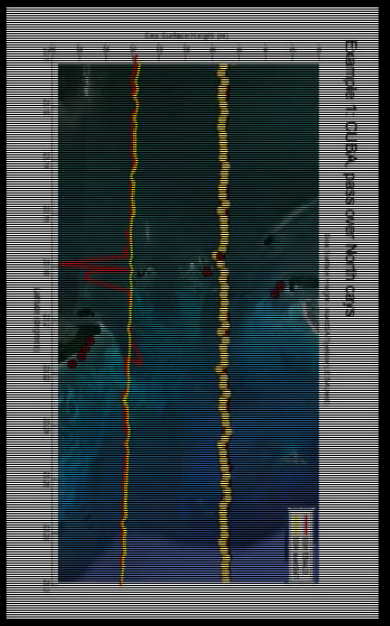
Fjords

Abulaitijiang et al (2015)



Lagoon

CP4O © IsarSat



Require *had-hoc* processing technic to retrieve optimal SSH

Coastal Altimetry from Multi-mission fields

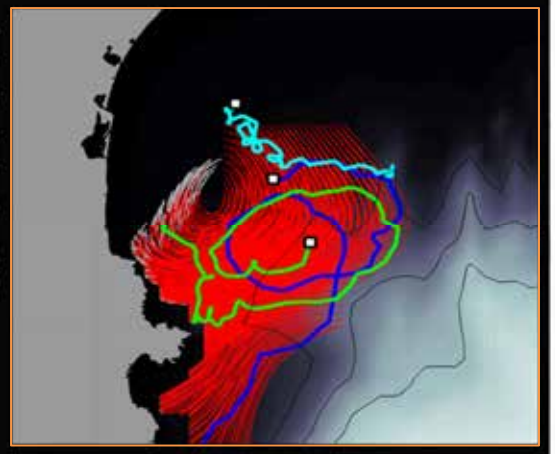
Observe 2D surface signatures of coastal eddies

Escudier at al., 2013 (GRL)

Lagrangian Analysis

New validations with drifters from LATEX Campaigns (MIO)

Bouffard et al, 2014 (ASR)



+ Vertical profiles / Modeled EOF

Monitoring transports of bio species

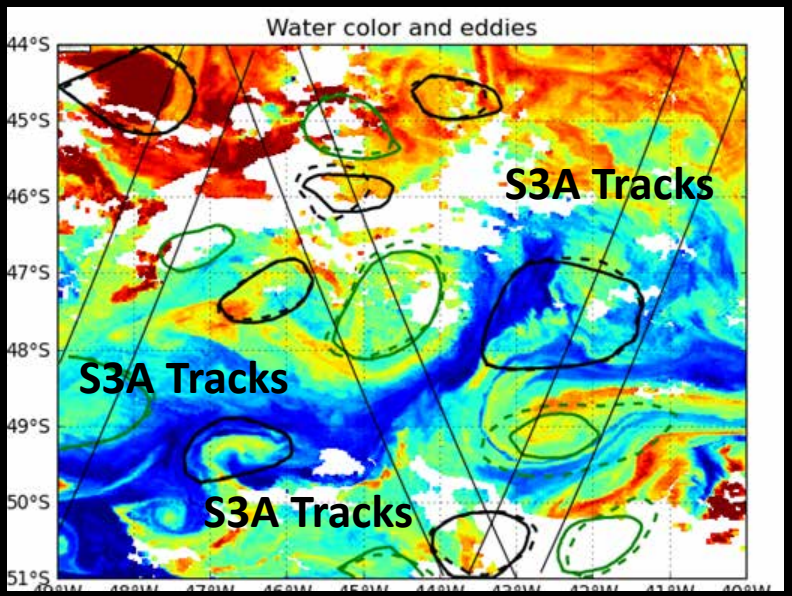
Still possible to increase the resolution & temporal continuity ?

Coastal Altimetry from Multi-mission fields

Recent developpments to improve gridded products

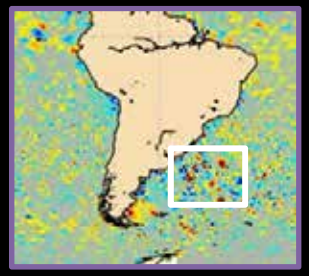
Using inversion of submesoscale tracer fields *(Gaultier et al., 2013)*, or based on PV conservation *(Ubelmann et al., 2015)*

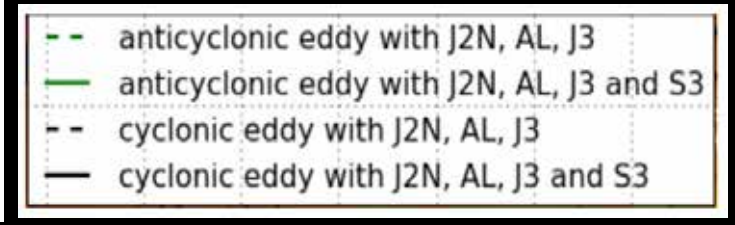
Positive impacts of including new altimetric missions



Contribution of S-3 from eddy tracking technics

(Mason et al, 2017)





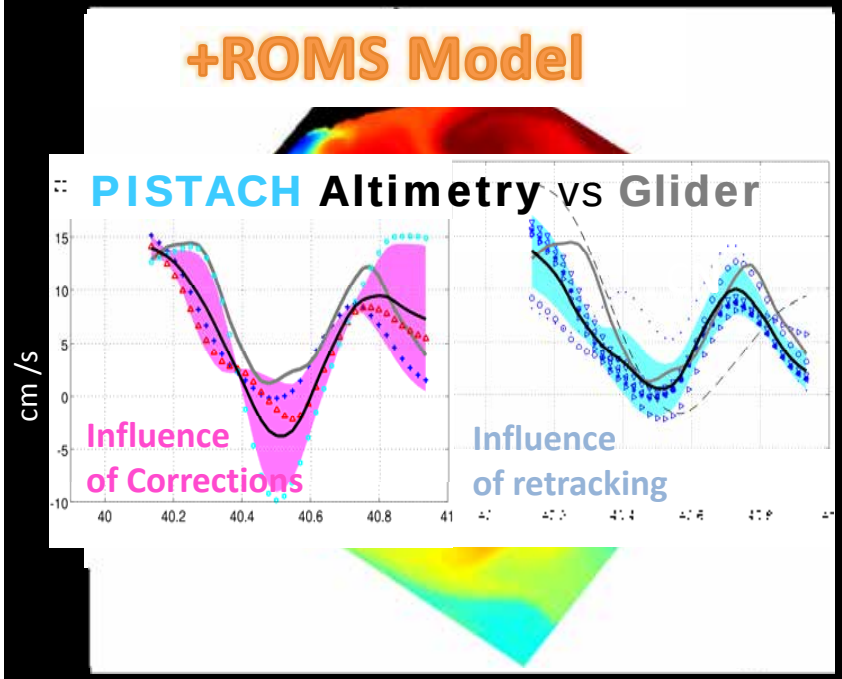
Better match w.r.t. surface Ocean Color images

What about the link to sub-surface signals ?

Coastal Altimetry & Multi-platform approaches

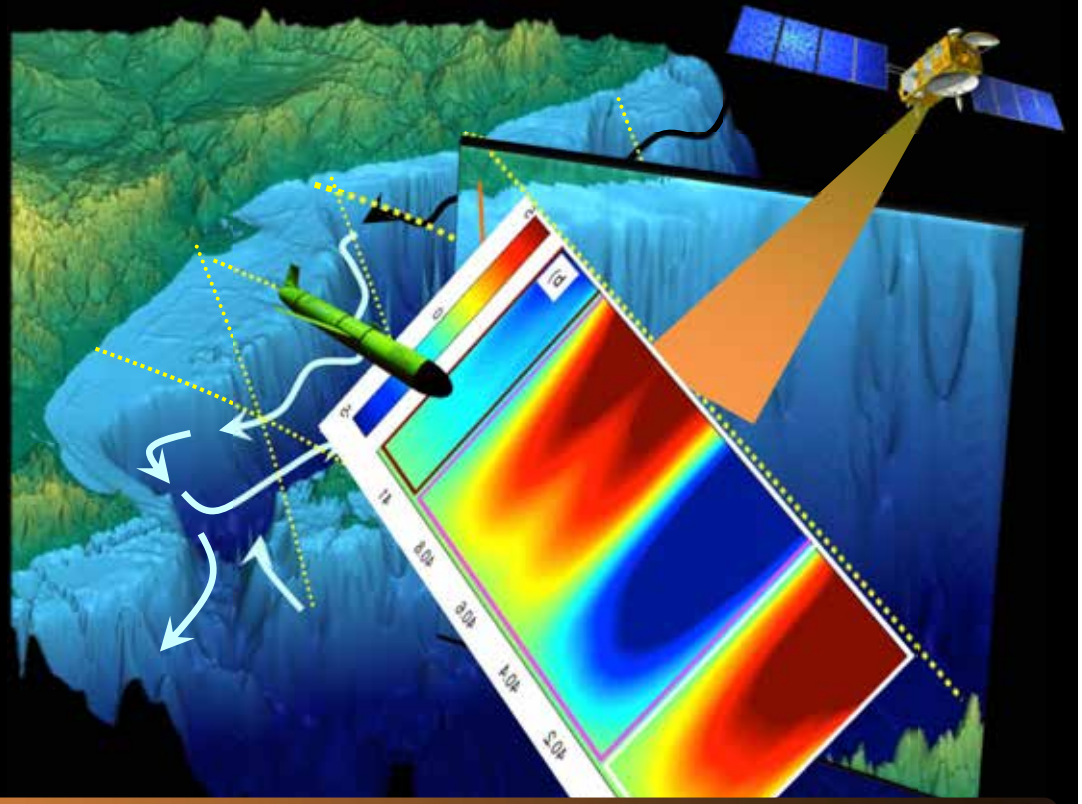
Exploitation of *on-purpose* campaigns & underwater vehicule

Several experiments conduced by IMEDEA over the past few years



Bouffard et al., 2010 (JGR)

Bouffard et al., 2012 (PIO)



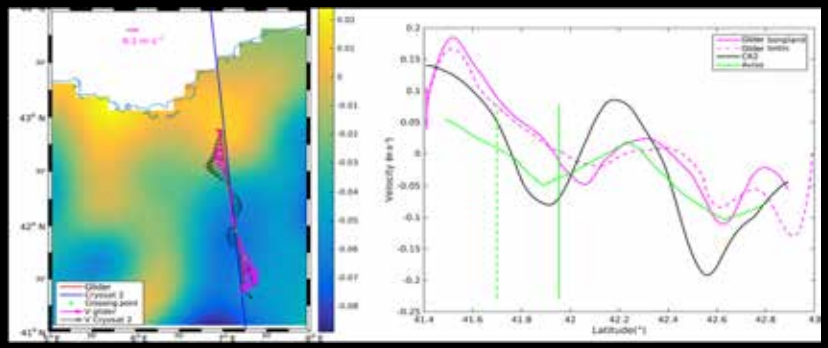
Validation & Tuning of new glider and altimetry technics

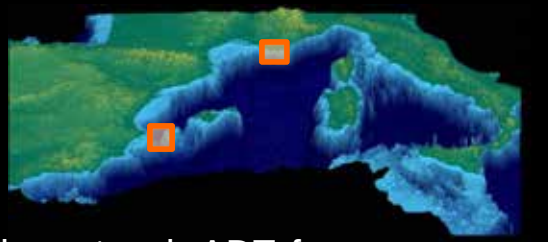
3D characterizations and physical content assessement

Coastal Altimetry & Multi-platform approaches

Widely used by several groups to assess SAR /Ka Altimetry

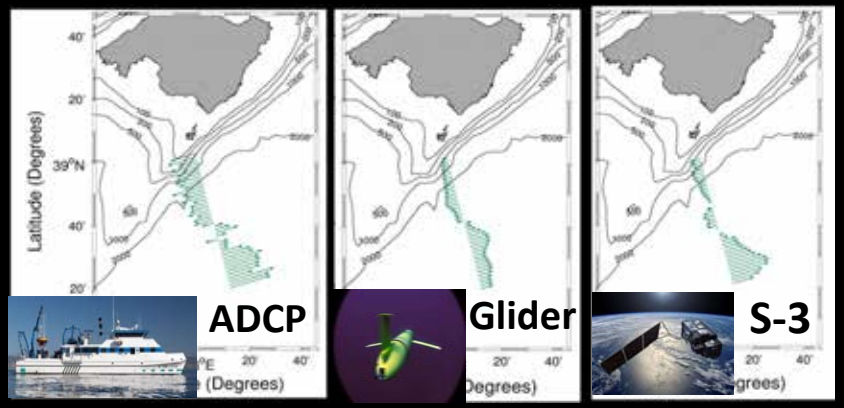
CS-2 vs Glider over the Ligurian Sea *Morrow et al., 2017*





Better agreement with along track ADT from CryoSat than with AVISO (too smoothed)

S-3 vs Glider & ADCP (May 2016) *Pascual et al., 2017, see also Borrione et al (CAWI7)*



Better agreement with ADCP (RMSE = 9.7 cm/s | R = 0.87) than with Glider

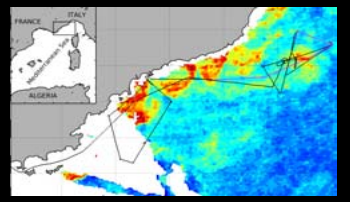
not very clear why … but

In situ shall not be considered as perfect reference for Coastal Altimetry

Need to further investigate alti. signals & *in situ* limitations

Coastal Altimetry & Multi-platform approaches

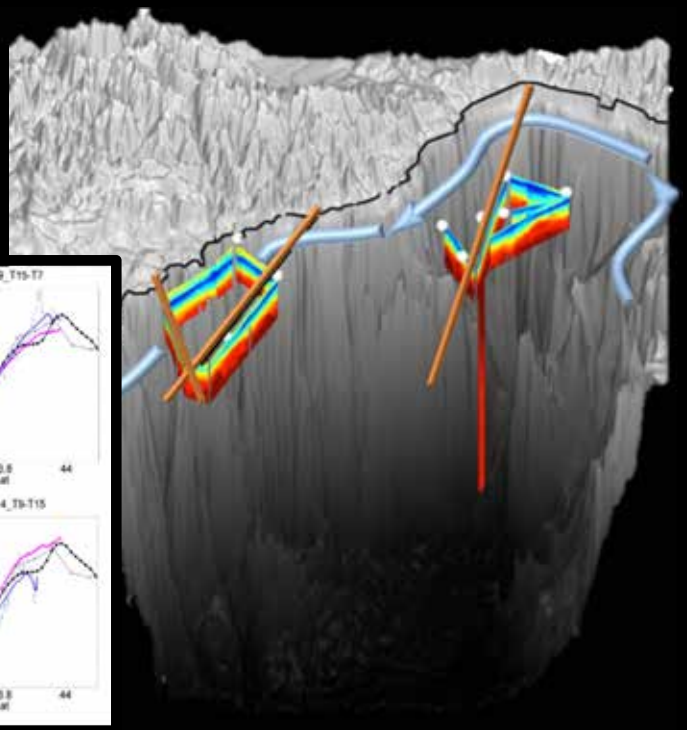
2015 OSCAHR campaign *(A. Doglioli & A. Petrenko – M.I.O.)*

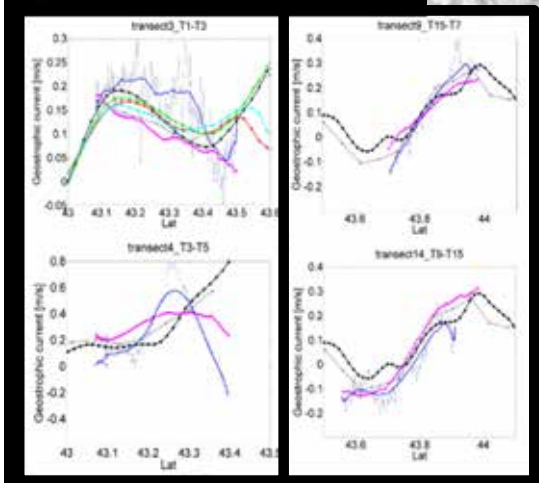


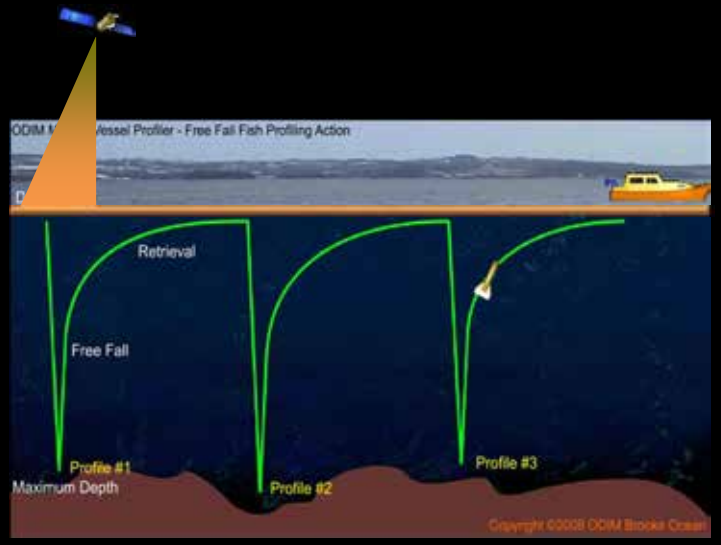
Explore link between fine-scale physics & phytoplankton diversity

Assess impacts of processing (PEACHI), Editing, Corrections when compared to **non perfect** *in situ (synopticity, reference level, ageostrophy)*

Meloni and Bouffard (in preparation)







ADCP & MVP (Moving Vessel Profiler) deployed along AltiKa & J-2 tracks

More details in the OSTST2017 poster by Meloni et al.

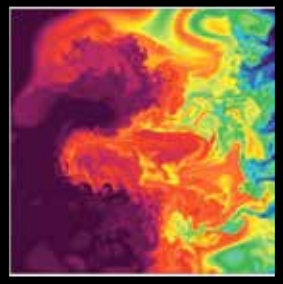
How continue to progress in Coastal Altimetry?

- ✓ Not only develop processing algo. & make statistics but also **Exploit** Altimetry & *in situ* to improve our knowledge of coastal processes

NEW CRYOSAT OCEAN PRODUCT AVAILaBLE NEXT WEEK

- ✓ Assess the **real** added-value/ weaknesses of coastal Altimetry processing for new (CS2, S-3) and future mission (J-CS, SWOT)

- ✓ Use models & develop *had-hoc* **science**-oriented diagnostic to better asses small-scale **gradients** & understand the physical content





Thank you for your attention