Combining land-based HF radar data with in-situ and satellite data for studying coastal mesoscale processes in the south-eastern Bay of Biscay

Anna Rubio*, Ainhoa Caballero, Ivan Manso and Julien Mader

AZTI, San Sebastian, Spain
arubio@azti.es

Outline

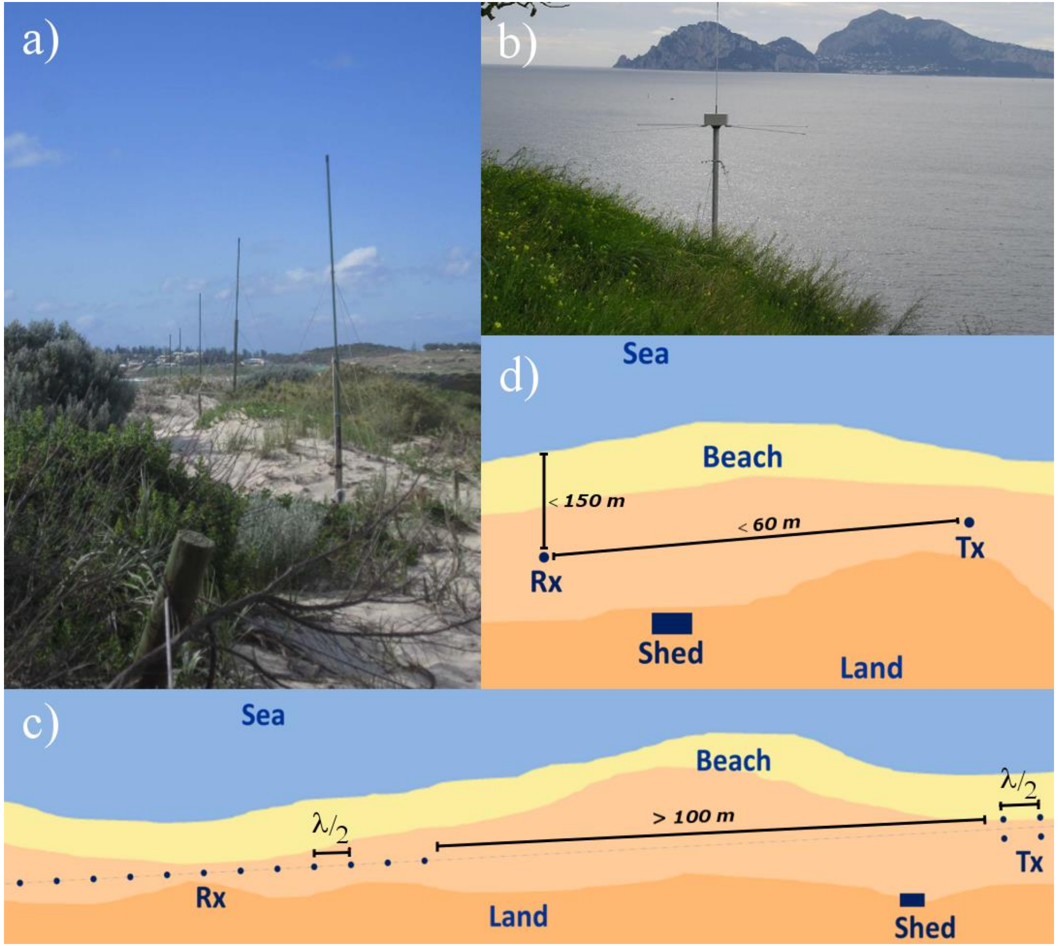
1- Land-based radar: main characteristics of the measurements and scales/processes resolved

2- Ocean processes in the SE Bay of Biscay from remote sensing

3- Data blending (work in progress)

4- Ongoing examples of HF radar applications

5- Status of the EU HF radar network



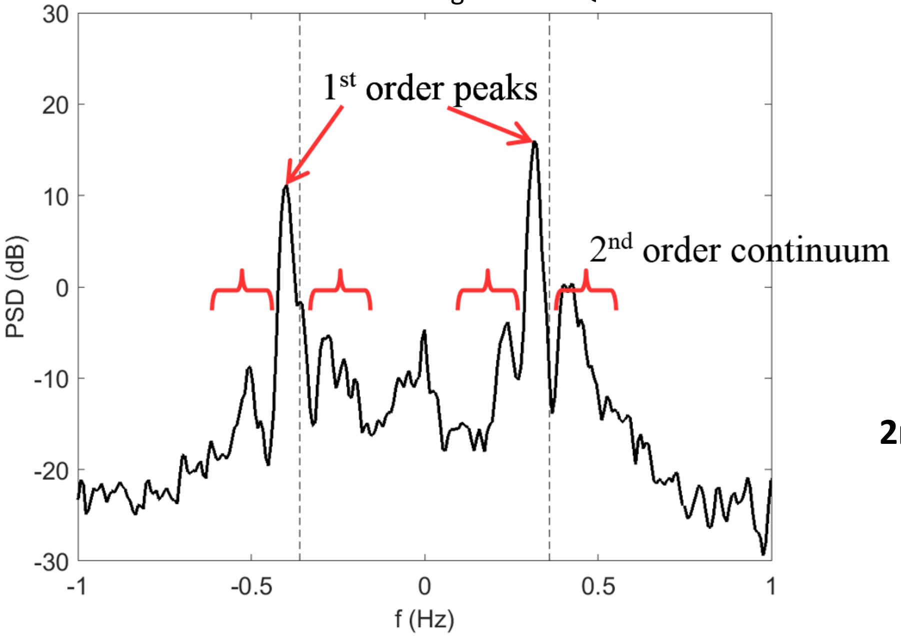
Examples of characteristic HF radar installations

a-c Phased Array system
b-d Direction Finding system

Rx: receive antenna
Tx: Transmit antenna
Shed: represents typical shed setting for hosting the HFR electronics.

Figure from Rubio et al. 2017

Figure from Quentin et al. 2017



Typical Doppler spectrum of the signal back-scattered from a single range/azimuth cell (1st order peaks: coherent reflection of the transmitted wave (λ) by the ocean waves whose wavelength is λ/2)

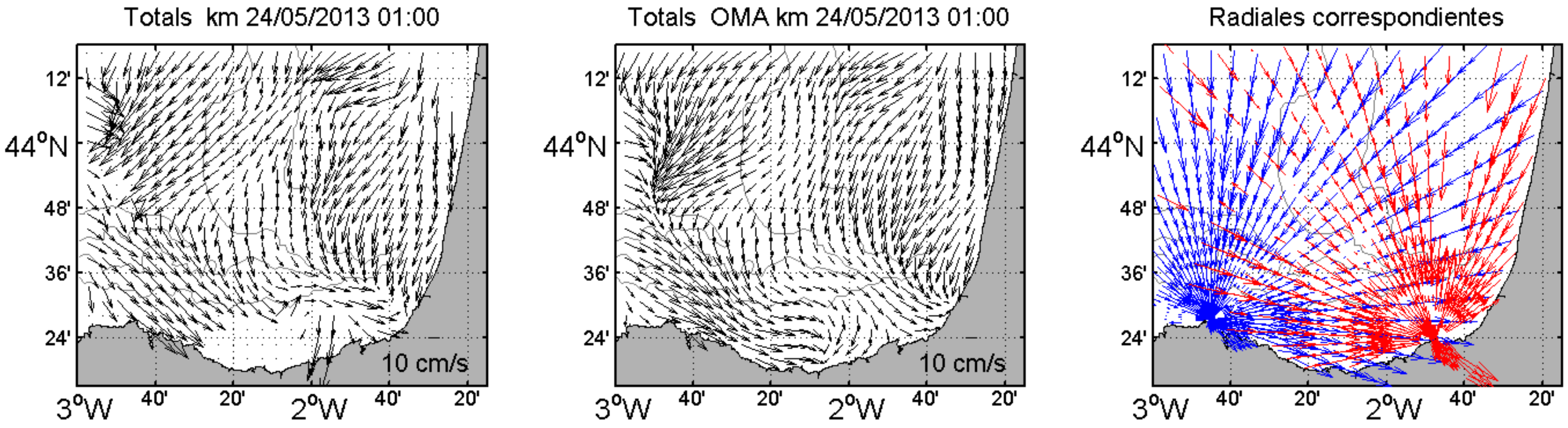
1st Order peak

- Velocity of the **radial component of the surface ocean current** (radar look direction)
- Includes the **wave-induced Stokes drift** (Graber et al., 1997; Law, 2001; Ardhuin et al., 2009)
- 2 sites at least to retrieve **the total surface ocean current**
- Also used to estimate **wind direction** (under the assumption that the Bragg waves are locally wind driven and aligned with the wind).

2nd Order signal

- Mostly generated by **non-linear waves**, it can be used to retrieve properties of the sea state such as **significant wave height** (e.g. Wyatt et al. 2006)
- **Potential use for ship detection** (Dzvonkovskaya et al., 2008) and tracking (Maresca et al., 2014).

➢ Comparisons of the power spectra of the backscattered signal at different radar frequencies has been used to study **sea surface shear** (Ivonin et al, 2004).



Totals km 24/05/2013 01:00
Totals OMA km 24/05/2013 01:00
Radiales correspondientes
12'
44°N
48'
36'
24'
3°W
40'
20'
2°W
40'
20'
10 cm/s
10 cm/s

Typical temporal / spatial scales resolved

	ITU frequency bands	Radar wavelength	ocean wavelength	ocean wave period	Equivalent integration depth for current	Typical minimum acquisition time	Typical range resolution	Typical maximum range for current analysis	Upper Significant Wave Height Limit
	f_{em}	λ	Λ	T	Λ/8	>= (1/δf *3)	dr	R_{max}	$H_{1/3}$
	(kHz)	(m)	(m)	(s)	(cm)	(minutes, 60s)	(km)	(km)	(m)
Long Range	4.438 4.488	67	34	4,6	420	35	12	220	25
	5.250 5.275	57	28	4,3	356	30	12	175	25
Medium range	9.305 9.355	32	16	3,2	201	16	12	80	13
	13.450 13.550	22	11	2,7	139	11	3	60	13
	16.100 16.200	19	9	2,4	116	9	3	60	13
High Resolution	24.450 24.600	12	6	2,0	76	6	1	30	7
	26.200 26.350	11	6	1,9	71	6	1	30	7
	39.000 39.500	8	4	1,6	48	4	300 m	20	3
	42.000 42.500	7	4	1,5	44	4	250 m	15	3

Depend mainly on the operation frequency and available bandwidth.

Range resolution O(100) m – O(12) km

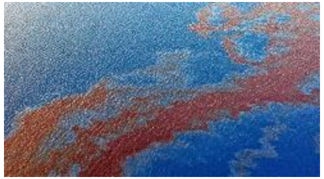
Max range O(200) km

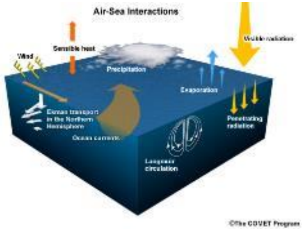
Integration depth ranging O(10) cms - O(1–2) m

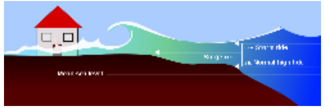
Examples on the observation of small scale eddies:

Park *et al.* (2009) and Archer *et al.* (2015): O(10-20) km eddies along frontal regions of the Florida Current using a 16 MHz.

Kim, 2010 or Kirincich, 2016: O(2-3) km vortices over the shelf in different areas with a VHF.







Near Real Time Products

- Support Coast Guard **search and rescue** operations
- Increase efficiency and safety of **maritime shipping**
- Plot **routes** for recreational sailing and boating

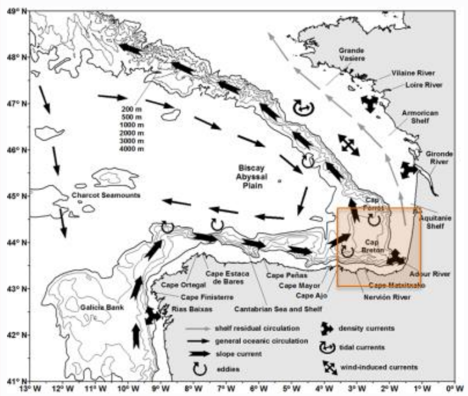
- Track oil and other **pollutants** (e.j. marine litter)
- Improve coastal **water quality** and reduce human exposure to pollutants

- Manage marine **fisheries**
- Design marine **parks and conservation areas**
- Assess the potential of **ocean energy**

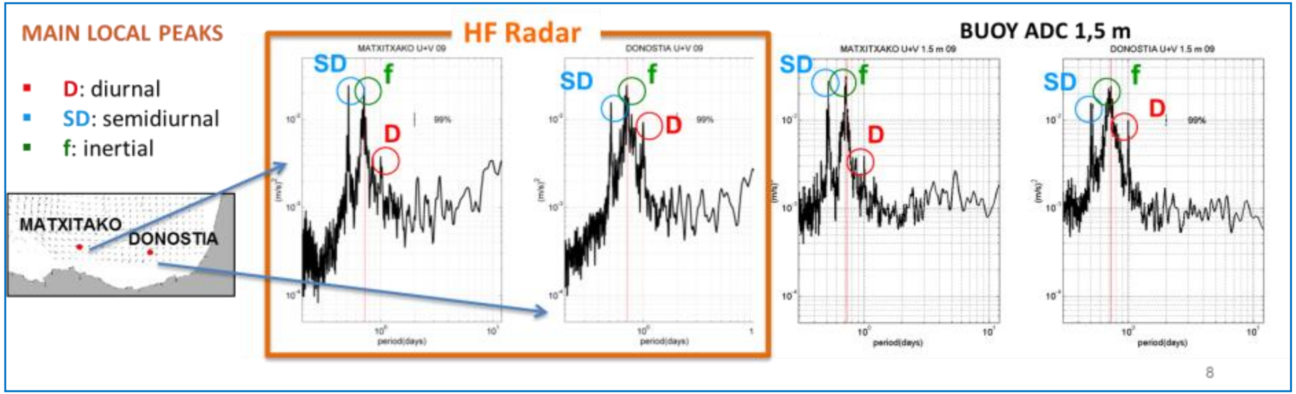
Multi Year Products

- Monitor **seasonal and interanual variability**
- Increase precision in **weather and climate forecasts**
- Predict **storm surge**
- Mitigate coastal **erosion**

Tidal (semidiunal and diurnal) and **intertial oscillations**

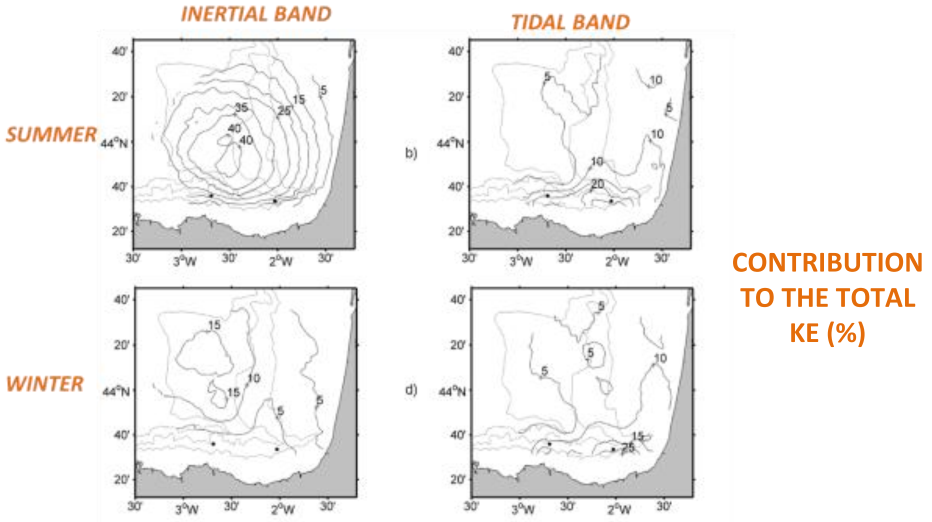


- ✓ High frequency processes
- ✓ Shelf slope regime
- ✓ Mesoscale eddies



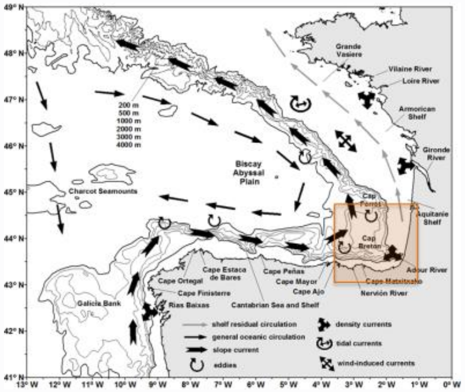
Their contribution to the total KE is **spatially and seasonally modulated**

(Solabarrieta et al., 2014; Rubio et al. 2011)

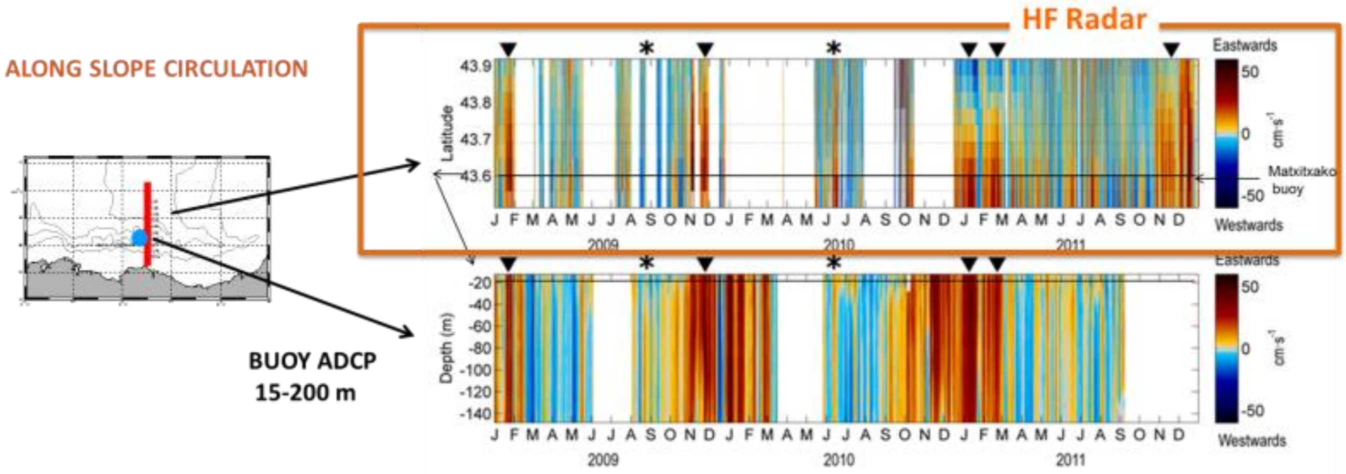


Iberian Poleward Current – EBCS seasonal poleward flow

(Solabarrieta et al 2015)

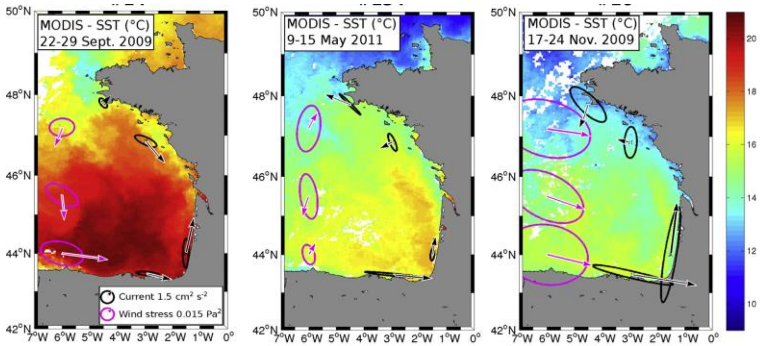


- ✓ High frequency processes
- ✓ **Shelf slope regime**
- ✓ Mesoscale eddies

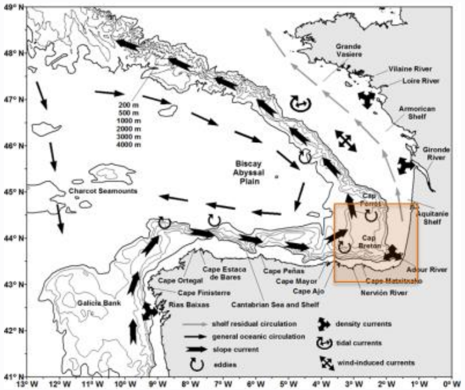


Wind induced currents & strong (> 50 cm s^{-1}) inner shelf poleward subinertial currents

(Kersalé et al., 2016,
Solabarrieta et al. 2015)



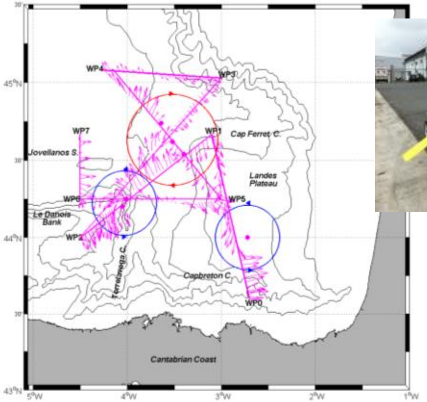
SWODDIES. Seasonal generation: IPC instabilities and bathymetric irregularities (Pingree and Le Cann, 1992).



- ✓ High frequency processes
- ✓ Shelf_slope_regime
- ✓ Mesoscale eddies

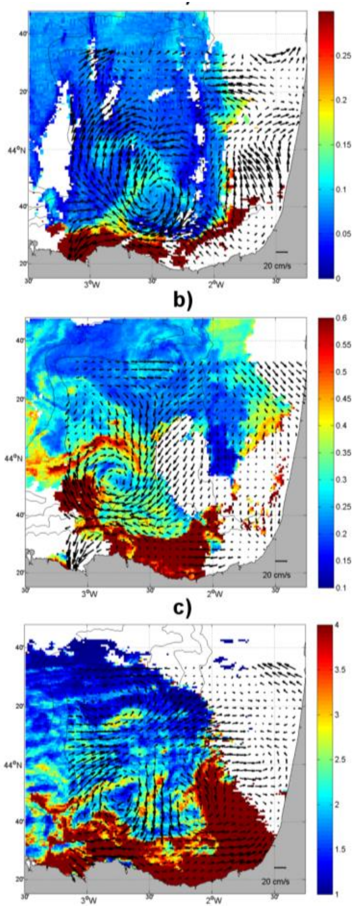
Stationary 4W eddy (glider+SST+SSH)

(Garcia-Soto et al., 2002; Caballero et al., 2014)



2W eddies – identified by HF radar

(Rubio et al. 2013, 2018; Solabarrieta et al 2014, 2015)

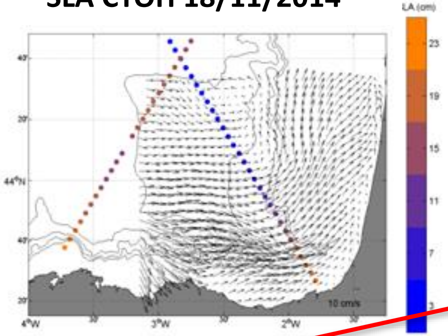


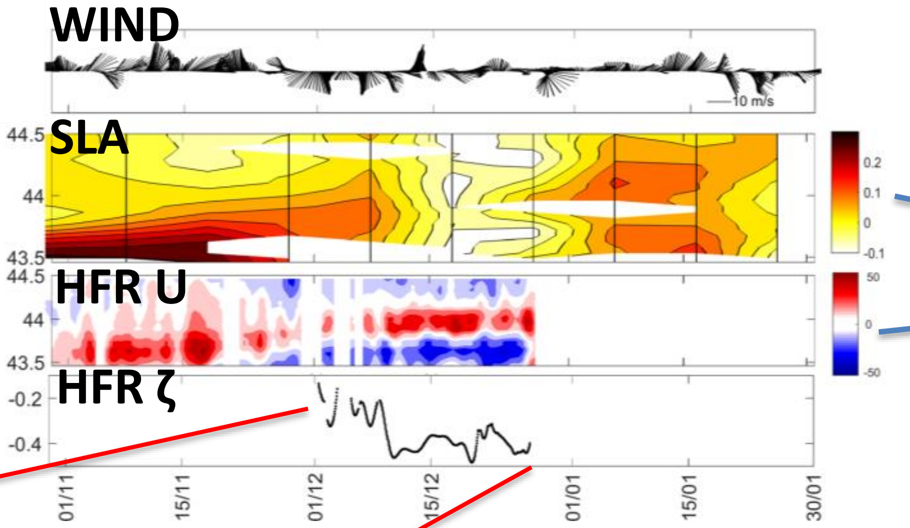
MODIS-Aqua derived Chl-a (mg m−3), from Rubio et al. 2018

Eddy-induced cross-shelf transport

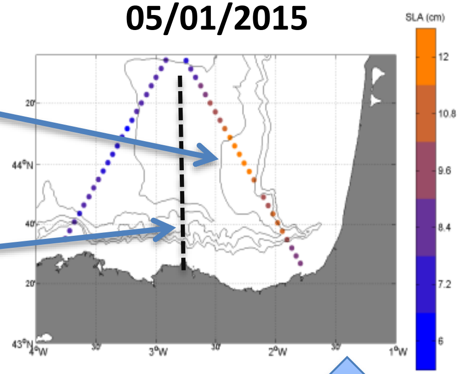
~2 months lifetime; D= 50 km
Umax=50 cm s^{-1} ; RV= -0.45f

SLA CTOH 18/11/2014

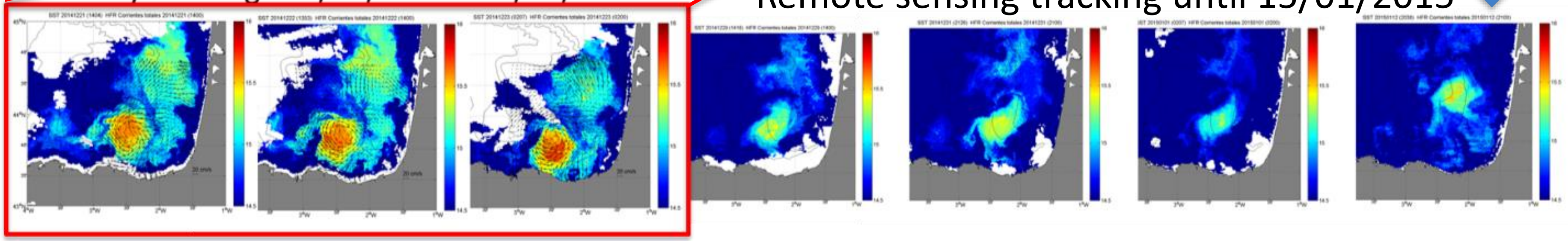


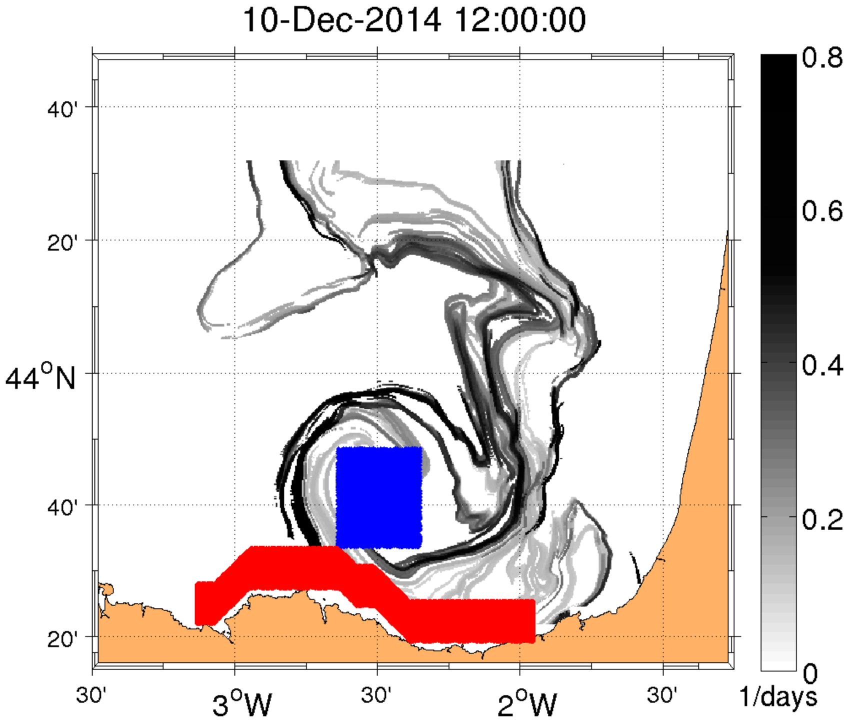


SLA COTH 05/01/2015



Remote sensing tracking until 15/01/2015

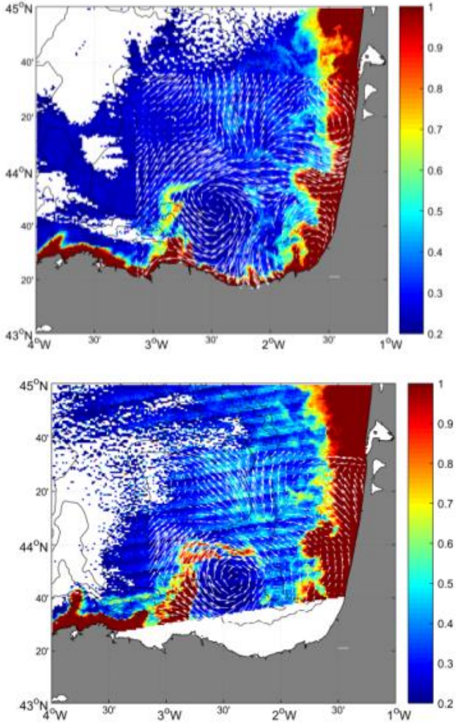




Shelf particles

Core partcles

MODIS Chl-a 21-22 Dec

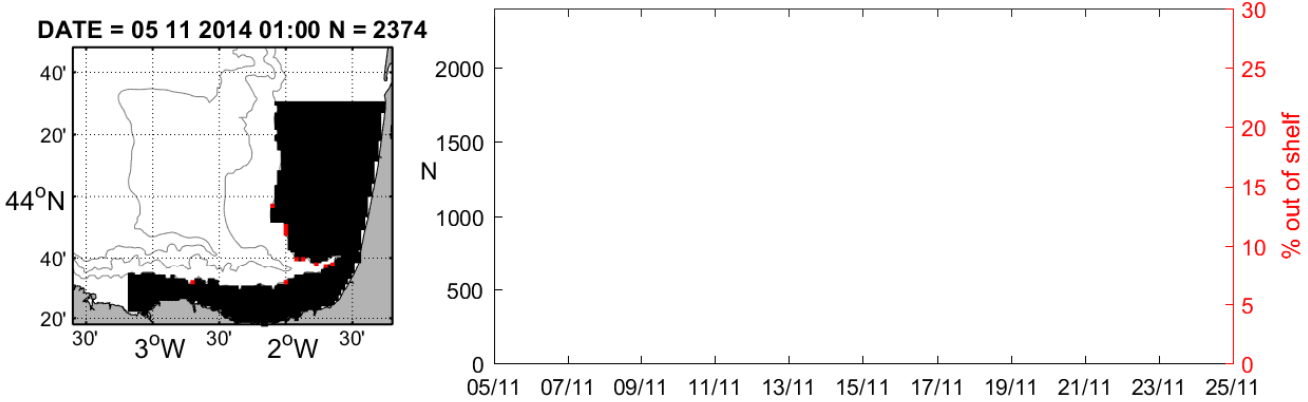


Rubio A., Caballero A., Orfila, A.,Hernández-Carrasco, I., Ferrer L., González M., Solabarrieta, L, Mader, J. (2018). Eddy-induced cross-shelf export of high Chl-a coastal waters in the SE Bay of Biscay. Remote Sensing of Environment, 205, 290-304, doi: 10.1016/j.rse.2017.10.037

November

Typical winter regime

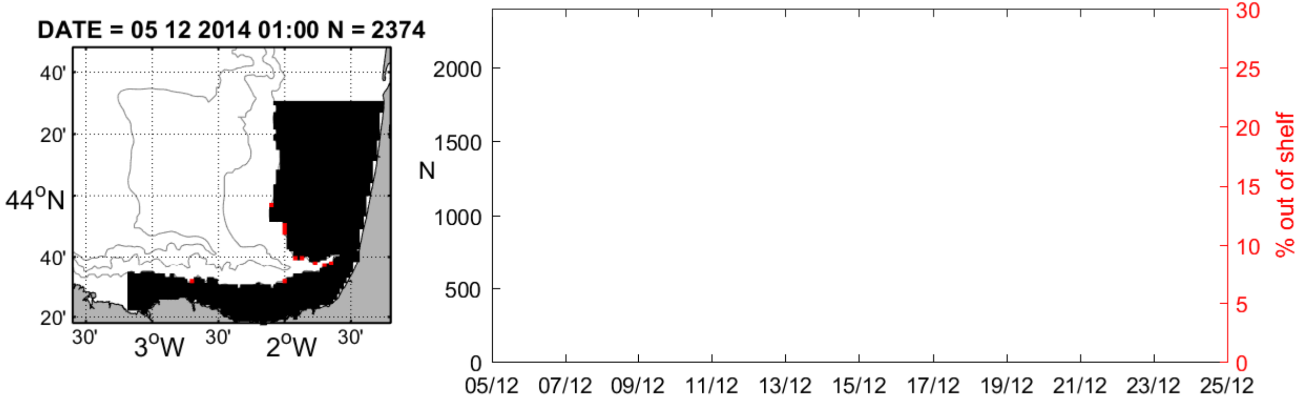
e-folding -0.16



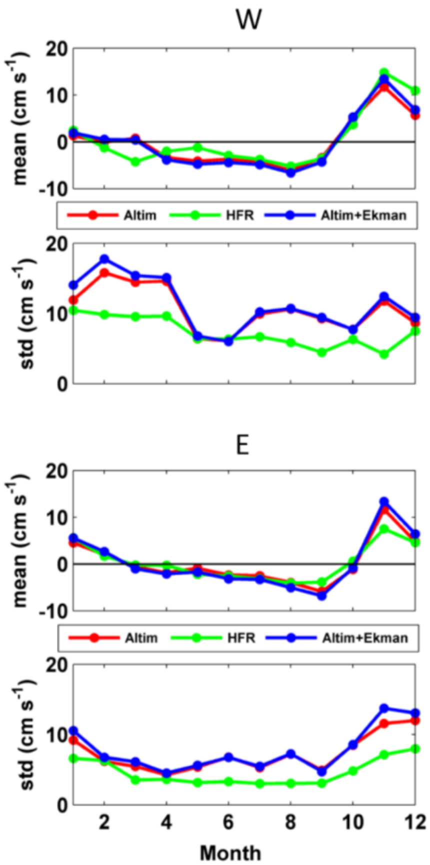
December

Anticyclone

e-folding -0.05



Joint analysis of coastal altimetry and HF radar data

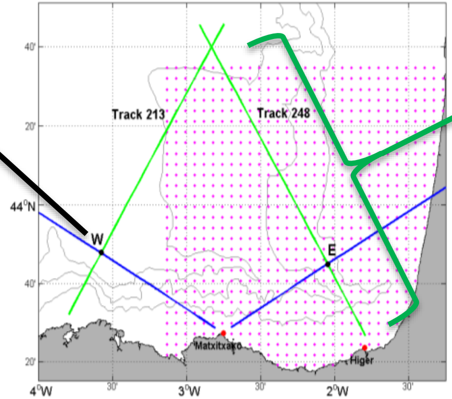


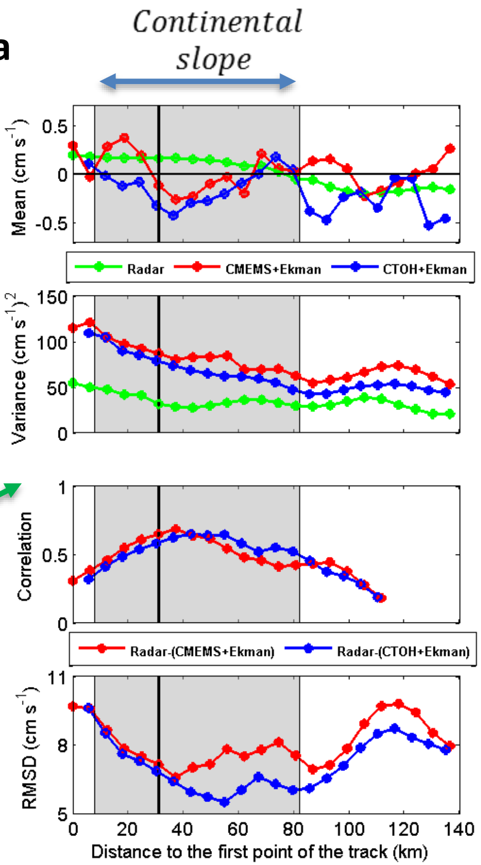
$$AC_{HFR} = V - \langle V \rangle_{t1-t2}$$

$$SLA' = SLA - \langle SLA \rangle_{t1-t2}$$

$$AC_G = -\frac{g}{f}\frac{\Delta SLA'}{\Delta x}$$

t1 = 1 January 2009 t2 = 24 July 2015



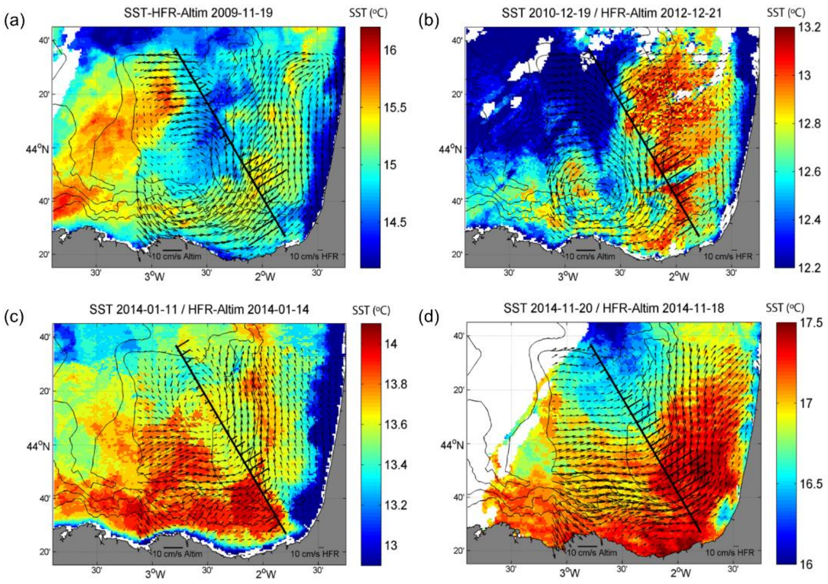


Manso-Narvarte, I., Caballero, A., Rubio, A., Dufau, C., Birol, F. (2018). Joint analysis of coastal altimetry and HF radar data: observability of seasonal and mesoscale ocean dynamics in the Bay of Biscay. Ocean Science, doi: 10.5194/os-2018-33

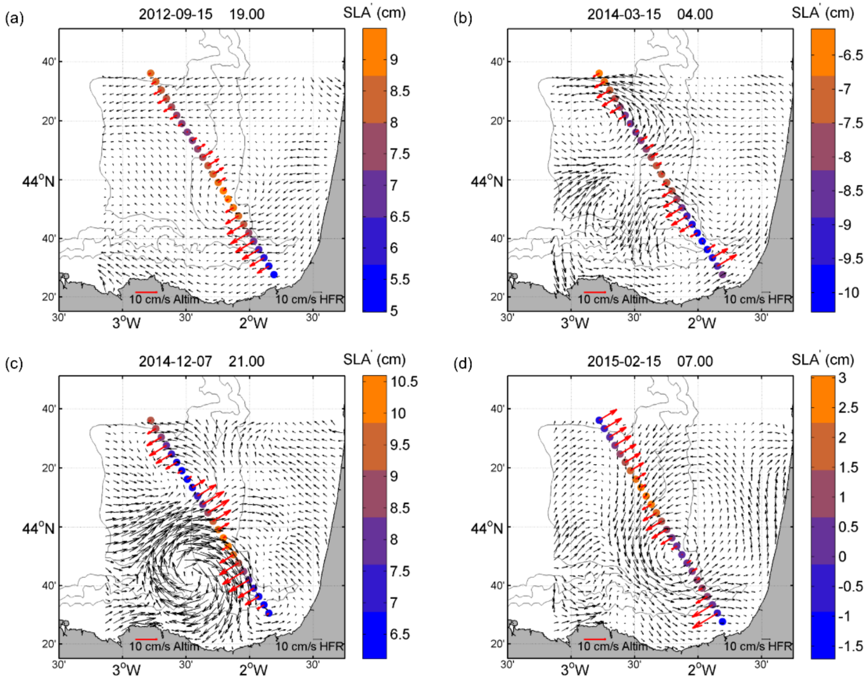
JERICO next

Joint analysis of coastal altimetry and HF radar data

IPC



Mesoscale eddies



Manso-Narvarte, et al. (2018), doi: 10.5194/os-2018-33

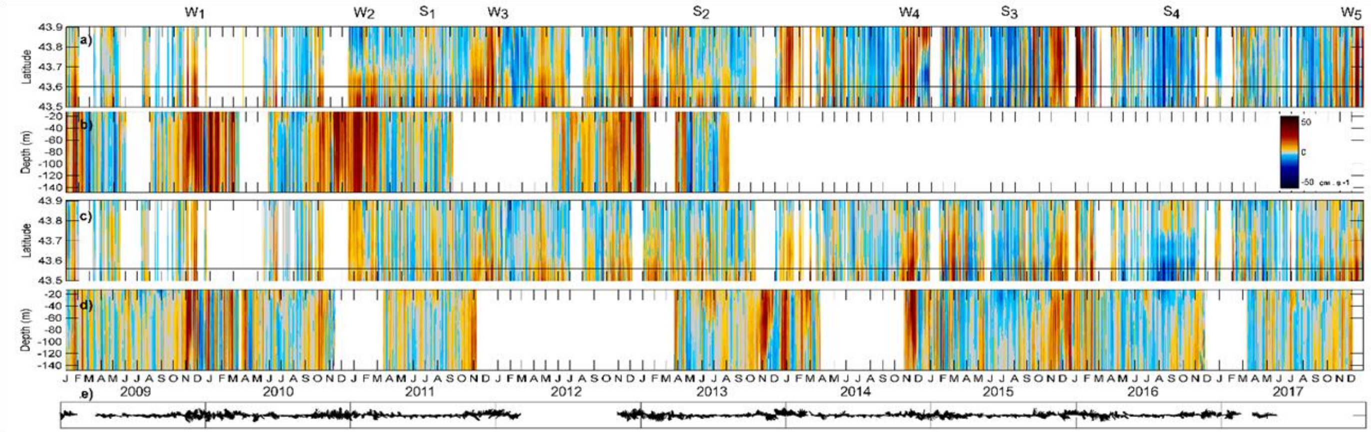
Joint analysis of in-situ ADCP and HF radar data (in progress)

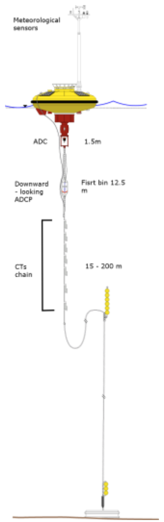
HFR -W

ADCP

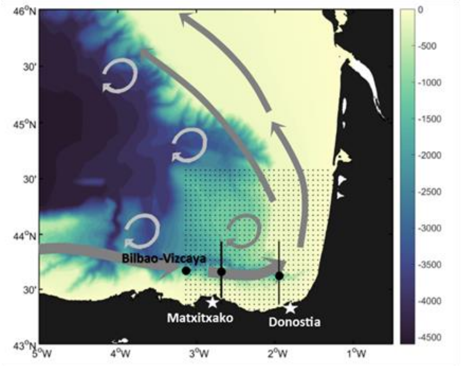
HFR - E

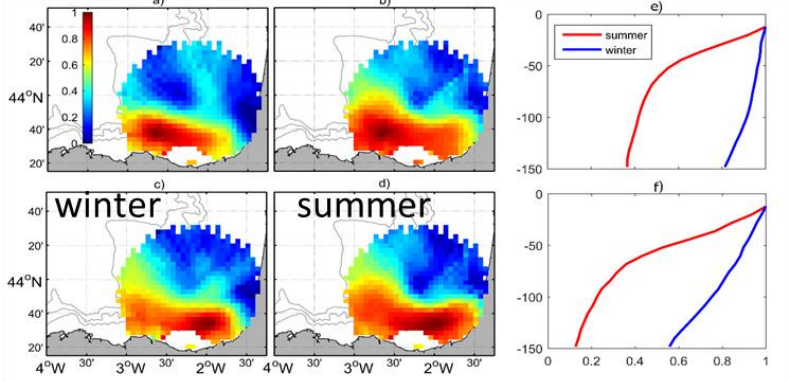
ADCP





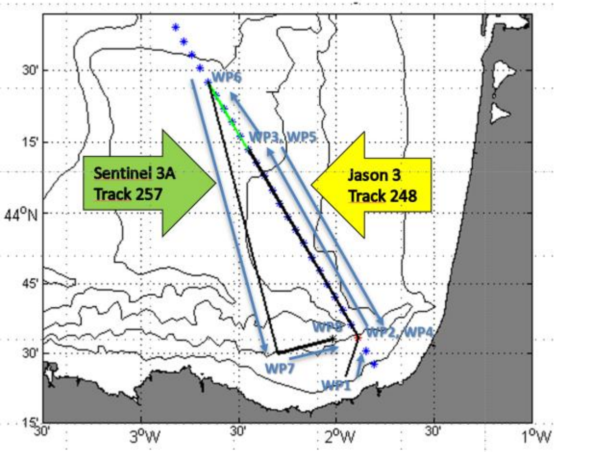
Maps and profiles of temporal correlation





Testind data blending methods in collaboration with A. Griffa (CNR, Italy) ,E. Fredj (Univ. Jerusalem) and G. Jordà (IEO)

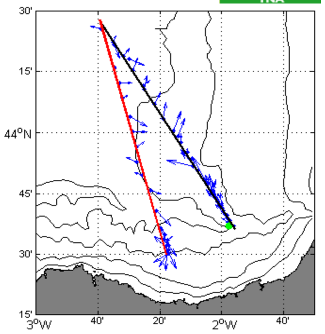
Joint analysis of in-situ GLIDER, SLA and HF radar data (in progress)



Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

JERICO next

TNA



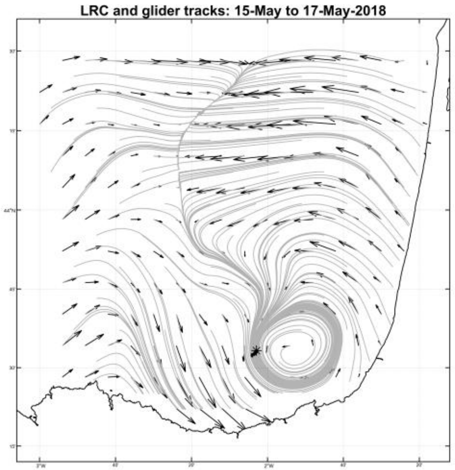
BB-TRANS glider mision (May 2018)

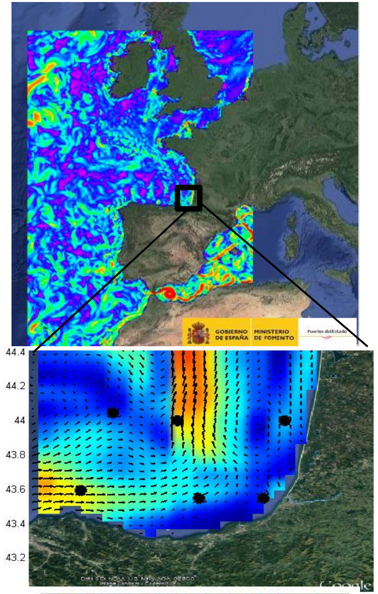
✓A **deep** and a **shallow** gliders in the area covered by the HF radar.

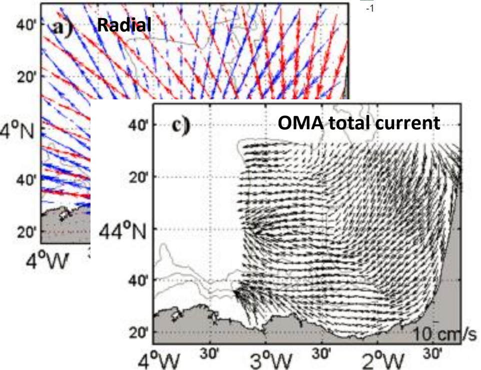
✓Equipped with CTD, ADCP, microstructure, fluorescence-turbidity sensors

The aim is:

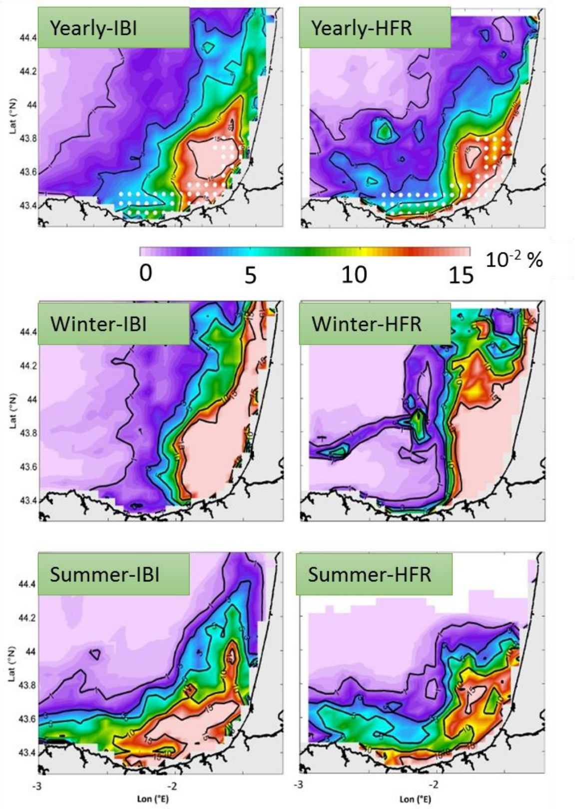
- ✓ to study the 3D circulation and transport in the within the area covered by the coastal HF radar system.
- ✓ Validate the accuracy of coastal altimetry along-track data within the HFR footprint area.
- ✓ Evaluate different methodologies for data blending







FML transport forecast in the SE Bay of Biscay with CMEMS IBI model and HF radar data



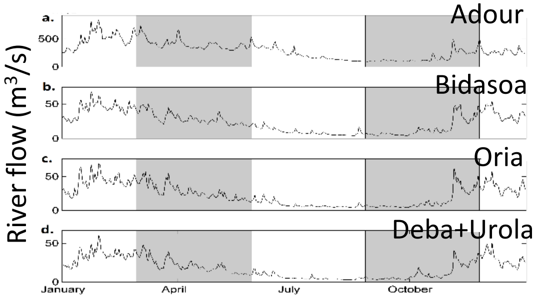
Normalized densities of particles: IBI model vs. HF radar

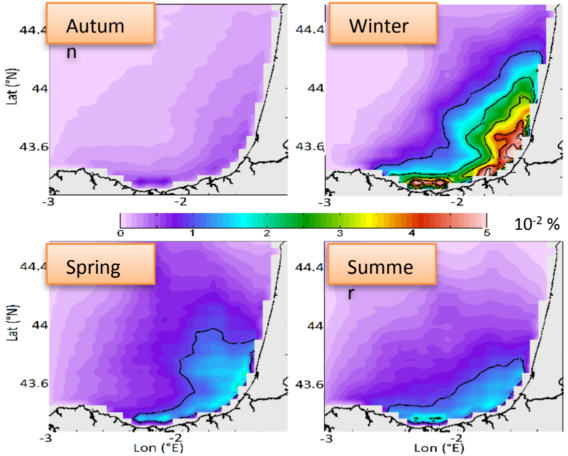
- Yearly averaged in good agreement for both runs
- Particle **transport** is **northward in winter // southwestward in summer**

*Transport of Floating Marine Litter in the coastal area of the south-eastern Bay of Biscay: a Lagrangian approach using modelling and observations. A. Declerck, M. Delpey, A. Rubio, L. Ferrer, O. Cabezas, J. Mader and M. Louazo submitted to Journal of Operational Oceanography

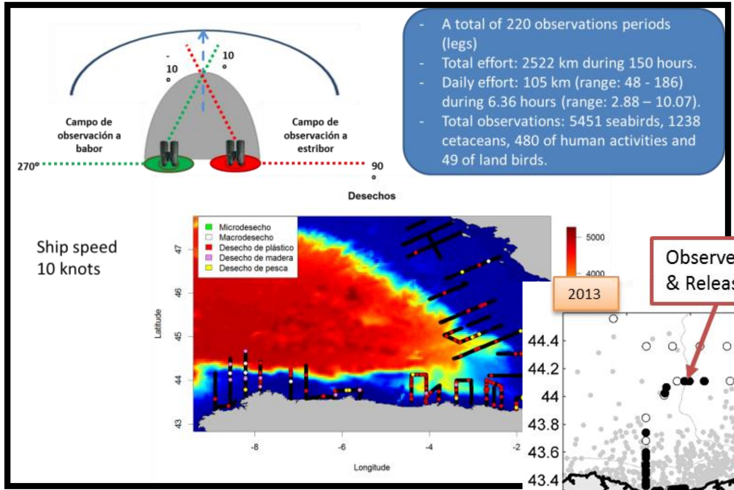
Characterization of surface transport patterns for FML

Introduced with continental outflow

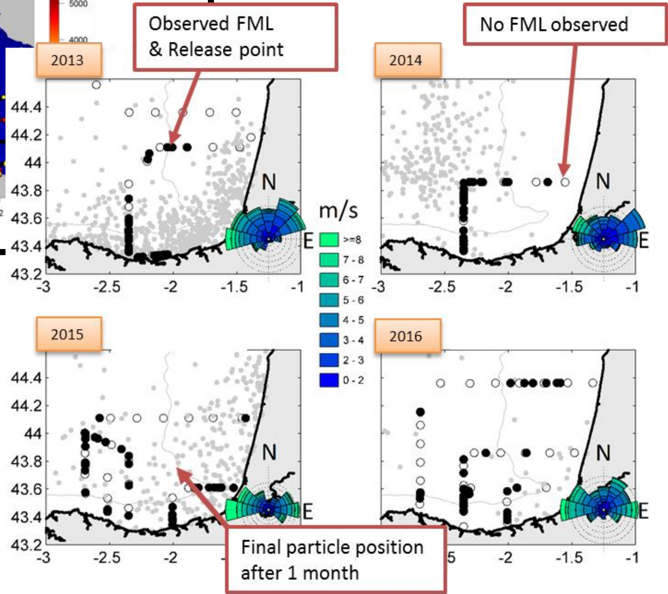




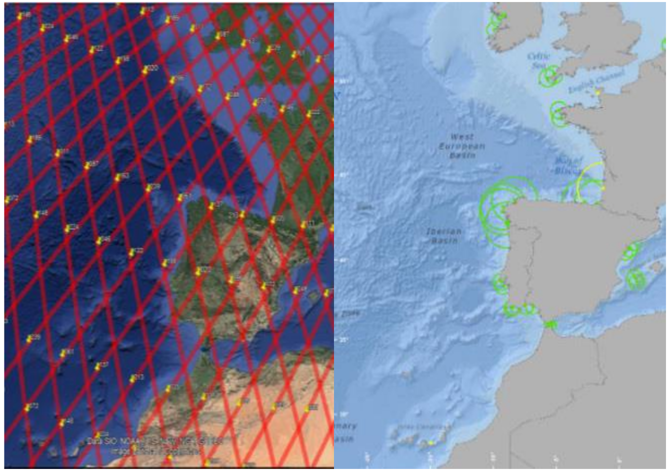
From summer macroplastic observations



- A total of 220 observations periods (legs)
- Total effort: 2522 km during 150 hours.
- Daily effort: 105 km (range: 48 - 186) during 6.36 hours (range: 2.88 – 10.07).
- Total observations: 5451 seabirds, 1238 cetaceans, 480 of human activities and 49 of land birds.



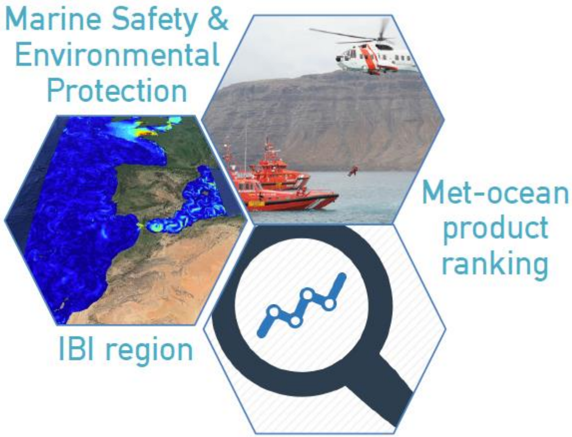
Declerk, et al. (under review for JOO)



Two additional CMEMS HFR-related projects recently started:

- **COMBAT** (2018-2010, CMEMS Service Evolution)

HFR data products will be used to improve coastal altimetry (CMEMS SE COMBAT) (AZTI, CLS, LEGOS)



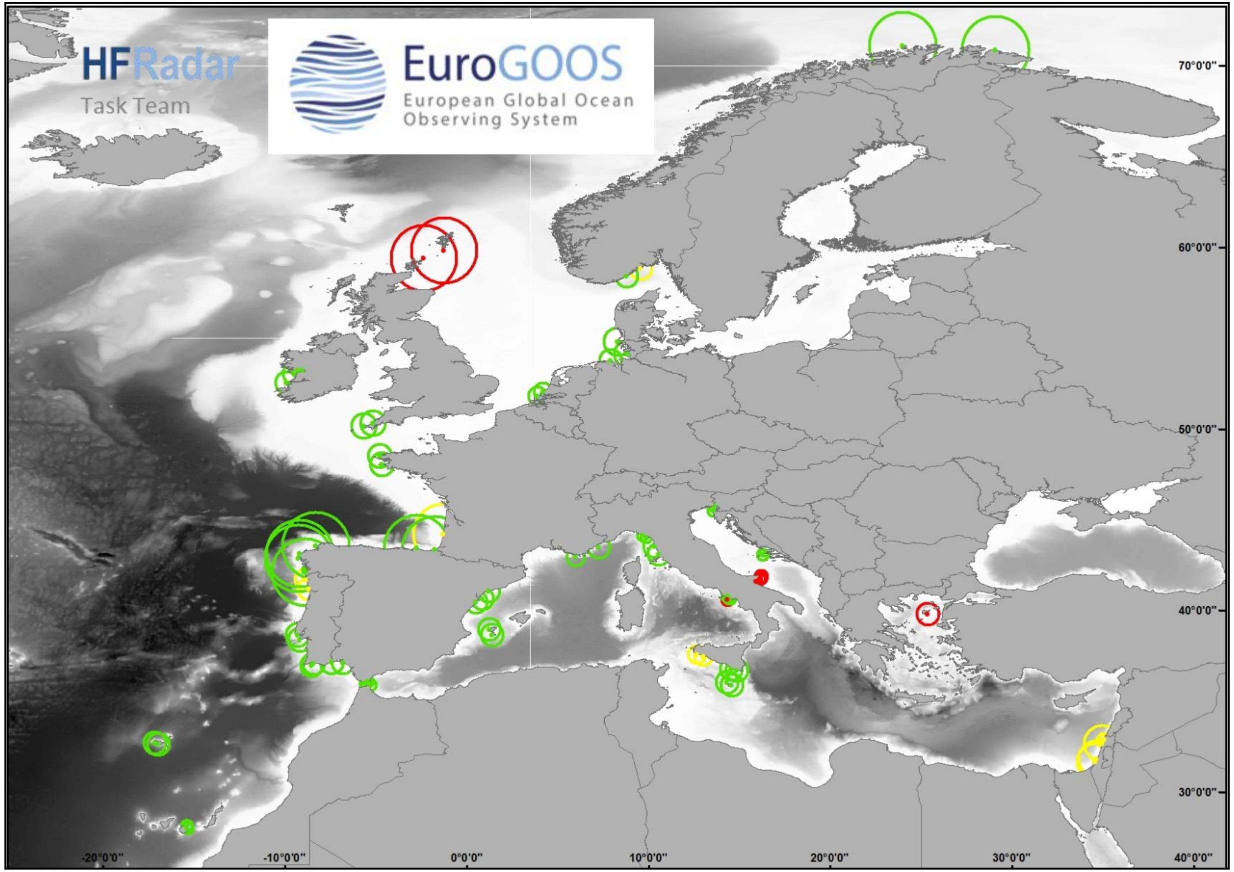
- **IBISAR** (2018-2010, CMEMS User Uptake)

Demonstrate the potential of CMEMS products and HFR for SAR operations. (SOCIB, RPS, AZTI)

www.ibisar.es

COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE – CMEMS DEMONSTRATION COASTAL - IBI – Contract 31-DEM1-L7 Until 30 September 2018

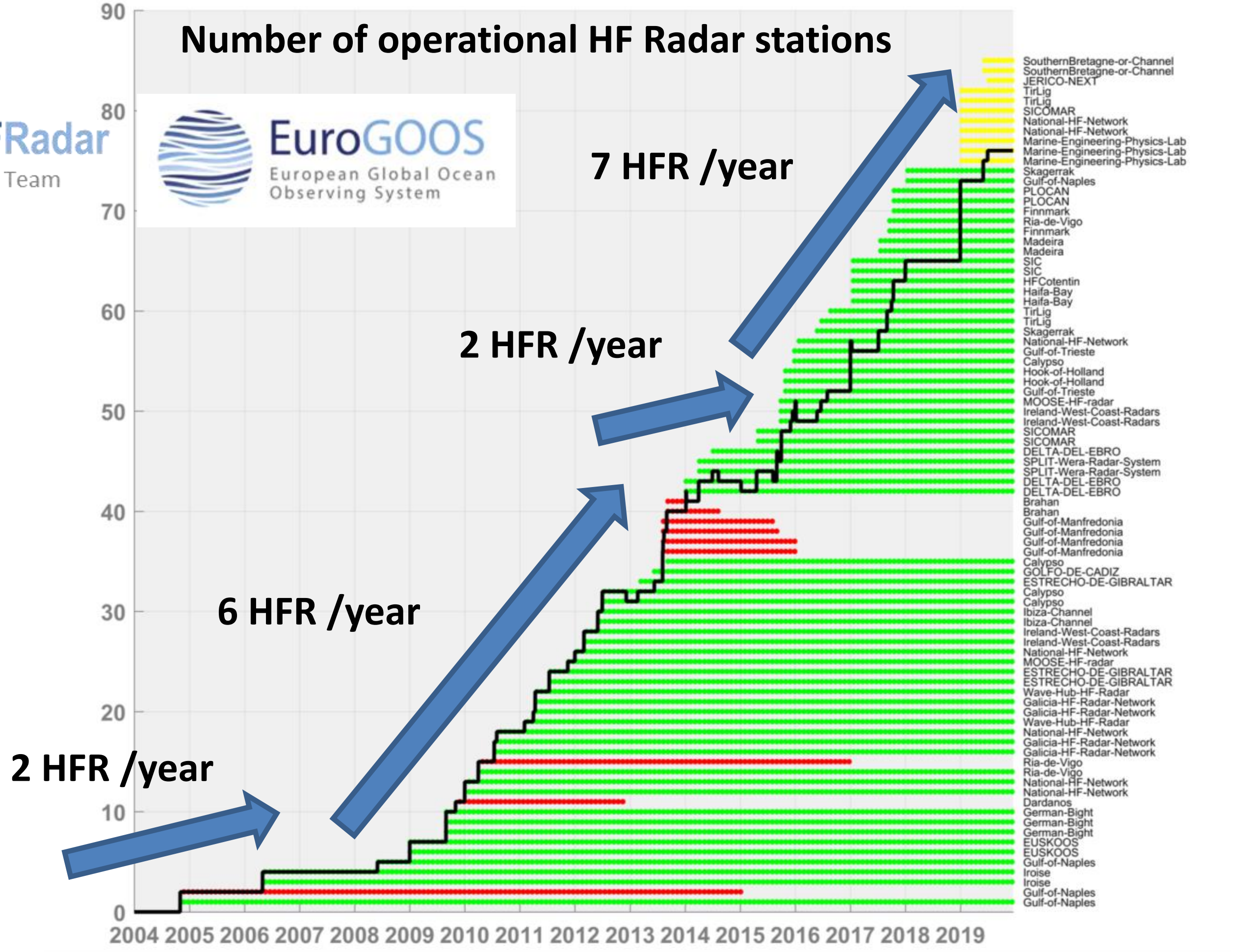
SOCIB Balearic Islands Coastal Observing and Forecasting System



EU HFR Inventory (Update Apr 2018): 58 operational (green); 12 future (yellow); 9 past (red)

Scottish Government
Riaghaltas na h-Alba
gov.scot
marine scotland
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung
UNIVERSITY OF PLYMOUTH
UNICAEN
Ifremer
SHOM
euskalmet
agencia vasca de meteorologia
azti tecnalia
intecmar
INSTITUTO TECNOLÓXICO PARA O CONTROL DO MEDIO MARIÑO DE GALICIA
UNIVERSIDADE DE VIGO
hidrográfico
Puertos del Estado
PLOCAN
Observatório Oceânico da Madeira
SOCIB
mio
Institut Méditerranéen d'Océanologie
ISMAR
OGS
NIB
NATIONAL INSTITUTE OF BIOLOGY
INSTITUT ZA OCEANOGRAFIJU I RIBARSTVO SPLIT
CALYPSO
UNIVERSITÀ DEGLI STUDI DI PALERMO
hcmr

HFRadar Task Team



HFRadar Task Team

EuroGOOS European Global Ocean Observing System

Copernicus The European Earth Observation Programme

CMEMS Service Evolution INCREASE — Copernicus Marine Environment Monitoring Service — Contract until February 15 2018

CMEMS IN SITU OCEAN TAC — Copernicus Marine Environment Monitoring Service — Contract 82-CMEMS TAC INSITU Until March 31 2021

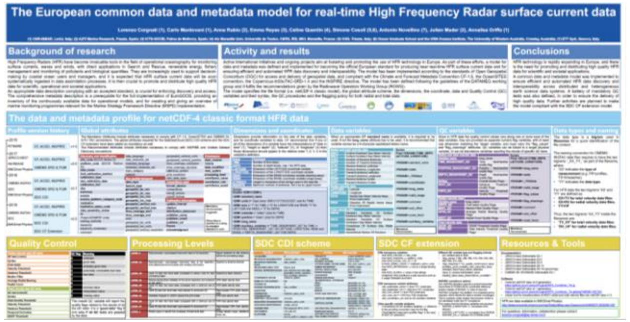
EU HFR data

EMODnet European Marine Observation and Data Network Physics

JERICO next

SeaDataNet

European common data and metadata model Reference Card (by Corgnati et al.)


The European common data and metadata model for real-time High Frequency Radar surface current data

https://presentations.copernicus.org/EGU2018-13317_presentation.pdf

- Tentative date
- Specified in the CMEMS Development Plan

U.S. HFR data

IOOS Integrated Ocean Observing System

IMOS Integrated Marine Observing System

Rowg

thank you
danke
謝謝
ngiyabonga
شكراً جزيلاً
teşekkür ederim
спасибо
dank je
gracias
tapadh leat
mochchakkeram
dziękuję
bedankt
go raibh maith agat
obrigado
sukriya
kop khun krap
arigatô
dakujem
grazie
terima kasih
мерси
감사합니다
merci
ευχαριστώ