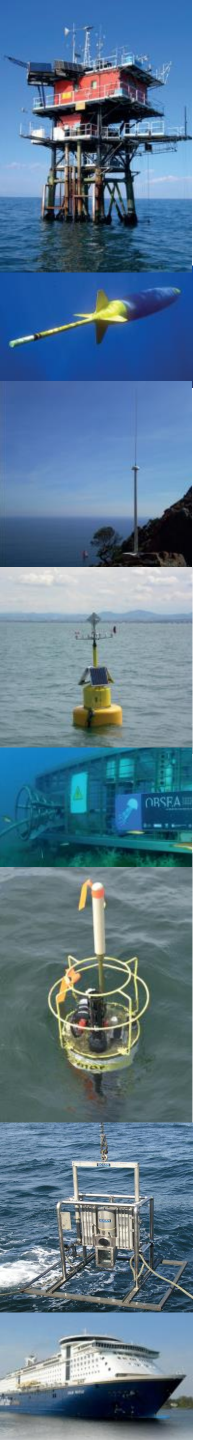


WP5, T5.6 : Definition of Quality Control procedures for HF Radar data

(M1-M42) - AZTI, SOCIB, HCMR,
HZG, SMHI, CNRS, EUROGOOS, ETT

JERICO-NEXT HF Radar workshop / San Sebastian / SPAIN / 9th – 11th March 2016

OBJECTIVE: Definition of shared Quality Control procedures for HF Radar data

- **Data model**
  - Standardization
  - Different levels of data products:
    - Quality controlled radial currents plus error (Level 1)
    - Gridded total vector velocities (Level 2)
    - Objective analysis of gridded surface current maps (Level 3)
  - Suitable temporal (hourly, daily…) and spatial (grids) scales for the provided data need to be defined.
  - User-driven

- **Quality Control**
  - Standardized QC procedure at European level will be defined for the coordinated implementation of delayed-mode and near real time HF Radar data access.
  - Two steps:
    1. Recovering outputs from the harmonization task performed in WP2, task 2.3
    2. Including Joint Research Activities performed in Task 3.2 of WP3.

Deliverables and milestones

D5.13 : Recommendation Report 1 for HFR data implementation in European marine data infrastructures (M16), including recommended common metadata and data model for HF radar
D5.14 : Recommendation Report 2 on improved common procedures for HFR QC analysis (M36)

Main intermediate actions for the first 18 months to reach Milestones and associated agenda (including meetings, workshops)

→ Participation in Workshop of Task 2.3: Harmonizing new network systems (Milestone MS9): M6 Feb2016 in San Sebastian → review of existing procedures
→ Coordination at Global level (IOOS, ACORN,…); GEO support
→ M12: first draft for D5.13 and distribution in EuroGOOS HFR Task Team and DATAMEQ WG.
→ M16: D5.13 delivery

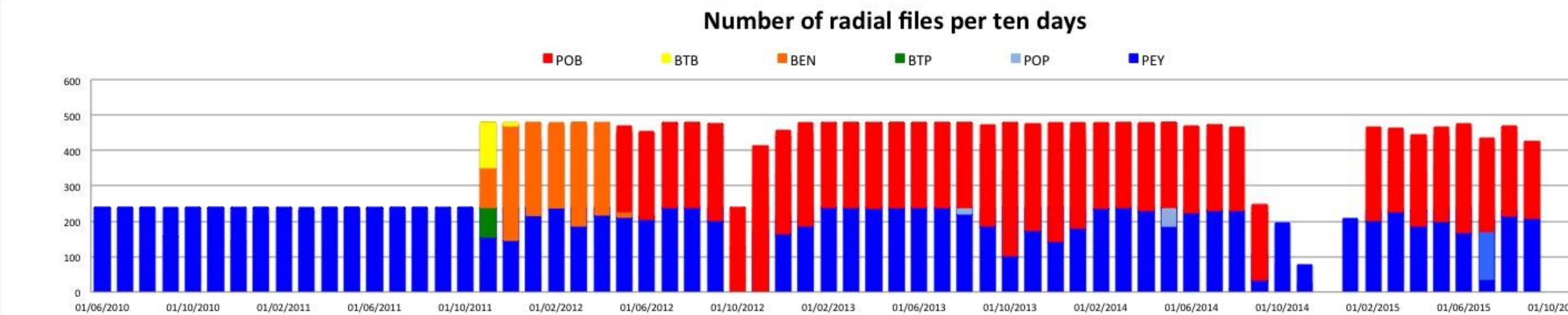
From the WP2 presentations

Task 2.3: Harmonizing new network systems: HF Radars

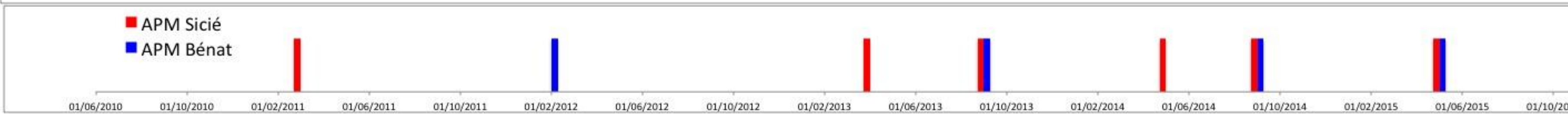
4. Quality assessment

Level 0 - Availability of the instruments (and data)

from june 2010 to october 2015 (in real time since 2012)



Level 1 - Control of the instrument by Antenna Pattern Measurement



Level 2 - Scientific performances on radial velocity

by statistics on radial data, a self-sufficient method

- first outlier removal by using the histogram of the temporal gradient of the current
- Forget, P. (2015), Noise properties of HF radar measurement of ocean surface currents, *Radio Sci., 50,* doi:10.1002/ 2015RS005681

and by comparison with in-situ instrument as:

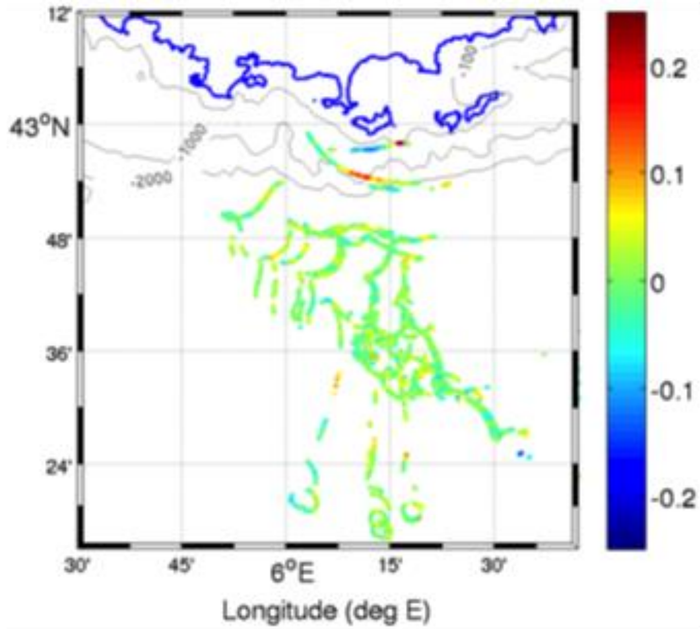
- lagrangian drifters during specific campaigns : TOSCA (dec 2011, aug 2013) , SUBCORAD (sep 2013)
- ADCP (moored or tracked): SUBCORAD (sep 2013), BOMBYX (dec 2013 - mar 2014)

Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment

TOSCA drifters

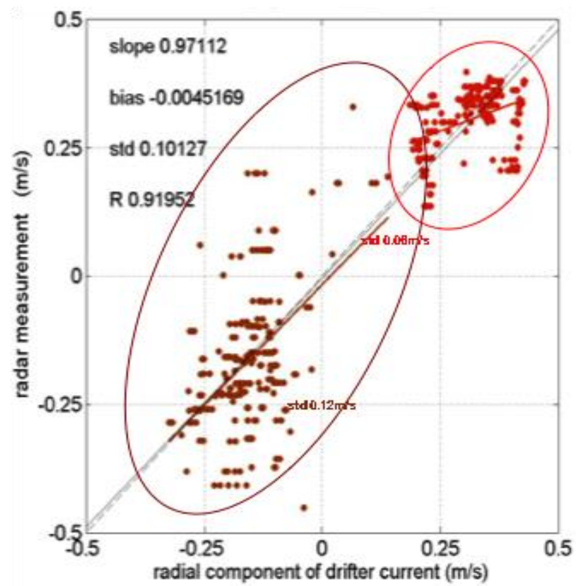
comparison between the radial velocities measured by the radar and the projection of the current in the same direction as it has been deducted by the drifters displacement during the TOSCA experiment



Bellomo, L. et al., Toward an integrated HF radar network in the Mediterranean Sea to improve search and rescue and oil spill response : the TOSCA project experience, accepted *in Journal of Operational Oceanography*.

SUBCORAD drifters

comparison between the radial velocities measured by the radar and the projection of the current in the same direction as it has been deducted by the drifters displacement during the SUBCORAD experiment



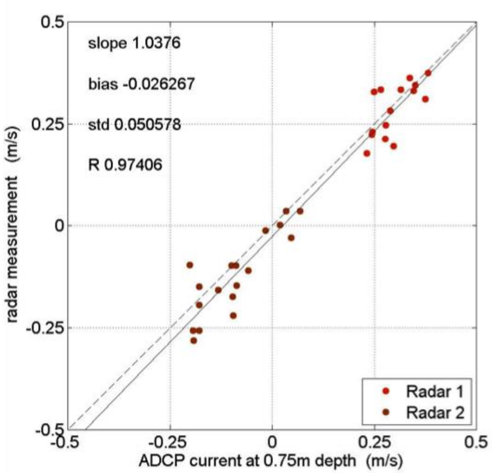
Fraunie, P. et al., Experimental investigation of the relationship between HF radar measurements of currents and the dynamical properties of the upper ocean, *EGU2014-13078*

Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment

SUBCORAD tracked ADCP

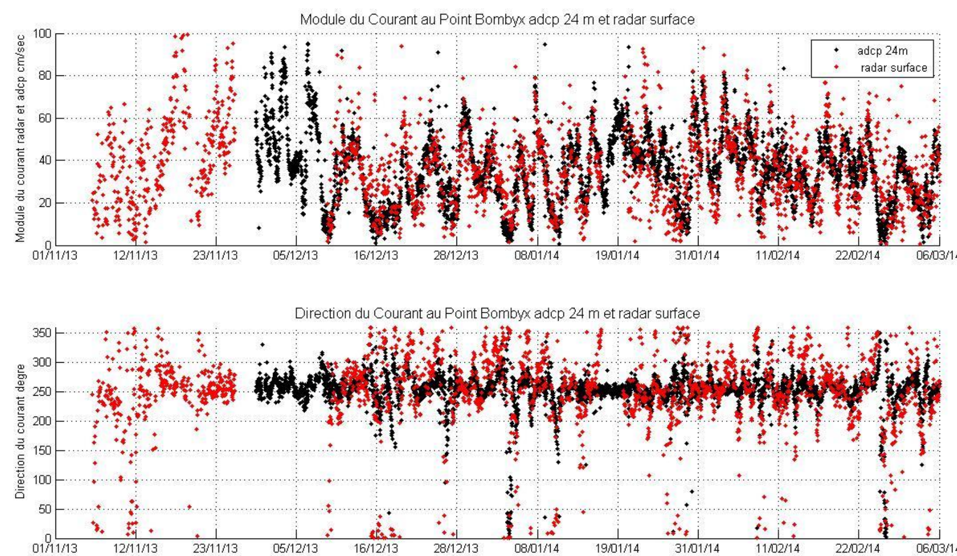
comparison between the radial velocities measured by the radar and the projection of the current in the same direction as it has been measured by a tracked ADCP at the surface level (-0.75 meter) along the radar cell



Fraunie, P. et al., Experimental investigation of the relationship between HF radar measurements of currents and the dynamical properties of the upper ocean, EGU2014-13078

BOMBYX moored ADCP (nov. 2013 - mar 2014)

comparison on a local point between the radial velocities measured by the radar and the projection of the current in the same direction as it has been measured by the ADCP at deeper level (-24 meter)



Rougier, G. et al., Wave-current interactions in deep water conditions : field measurements and analyses, EGU2015-4719

Task 2.3: Harmonizing new network systems: HF Radars

5. Data management

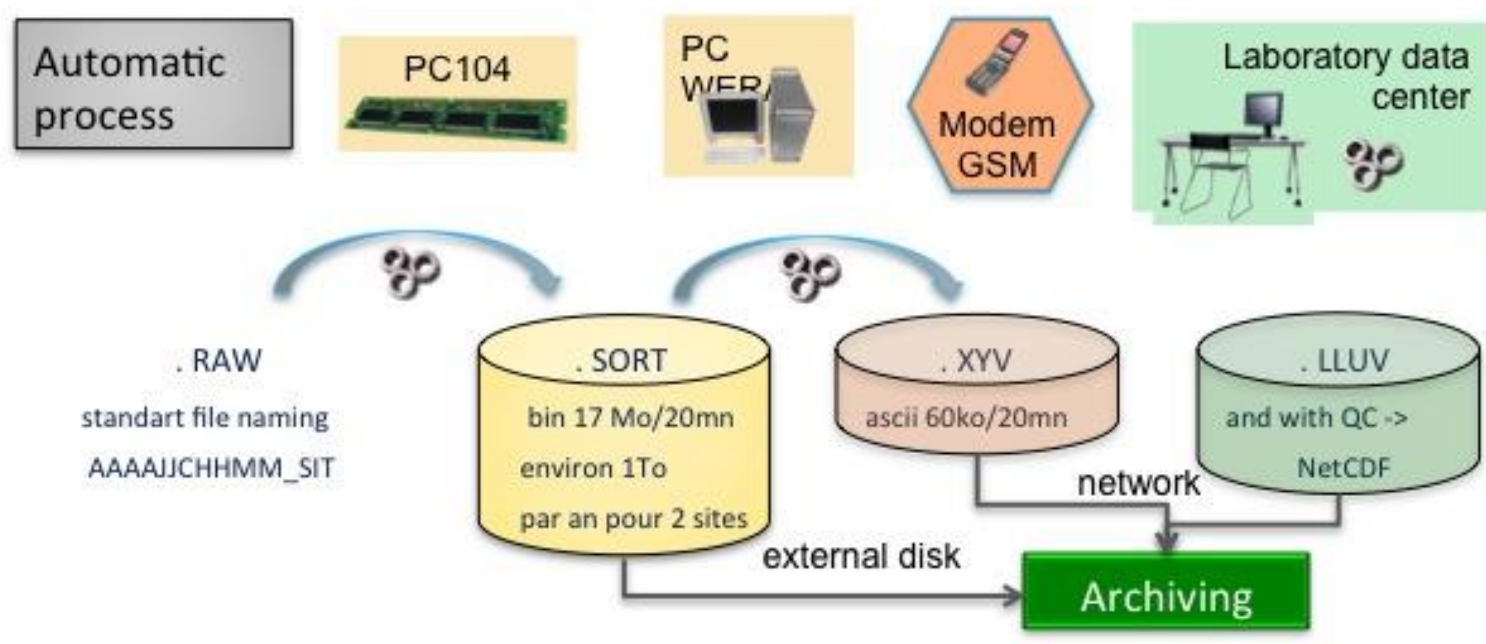
Data Flow

every station performs its diagnostics and send the radial files to the data server

Even if there is not a full link with the radar station to control it, we control

- if no radial file get -> alert
- if radial file is empty -> alert
- if antenna diagnostics failed -> alert

Radial files are then filtering to remove outliers, and a combination is made



4. Quality assessment

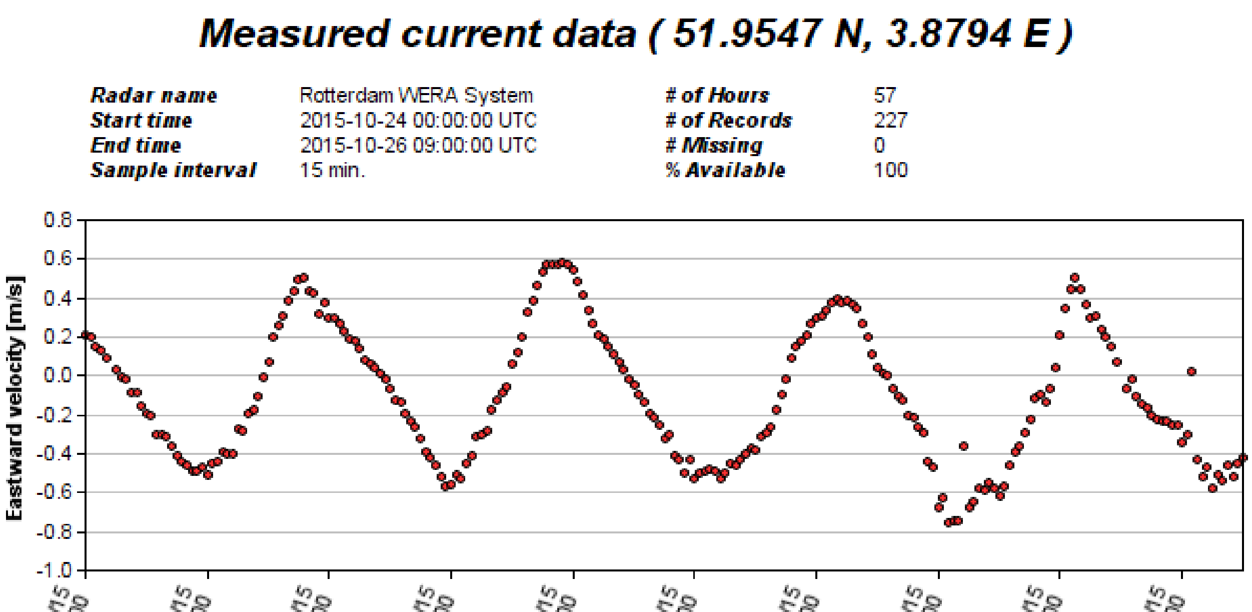
Contractor has to maintain the data availability for 5 years (Automated quality checks in place)

Quality checked at start-up period (contract) using ADCP data.

- Tidal components analysis
- Correlation with wind
- consistency

Some artifacts are artifacts, but some are physics!

- currents near shore (6m)cut off

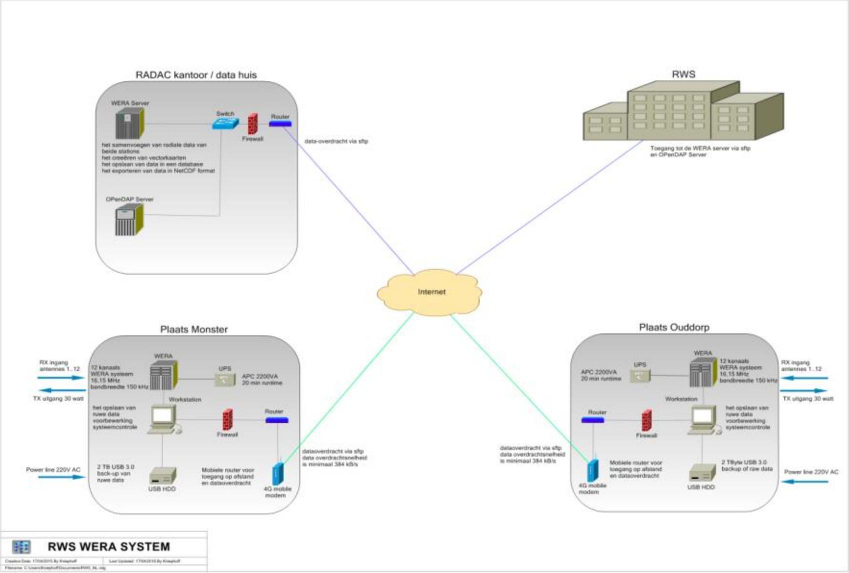


Task 2.3: Harmonizing new network systems: HF Radars

5. Data management

Format: NetCDF
Quality control: Standard by WERA software module by contractor
Data processing:
Both radials of separate stations and combined vectors available.

Data flow for dissemination: data on OpenDAP server. Access and products under discussion.

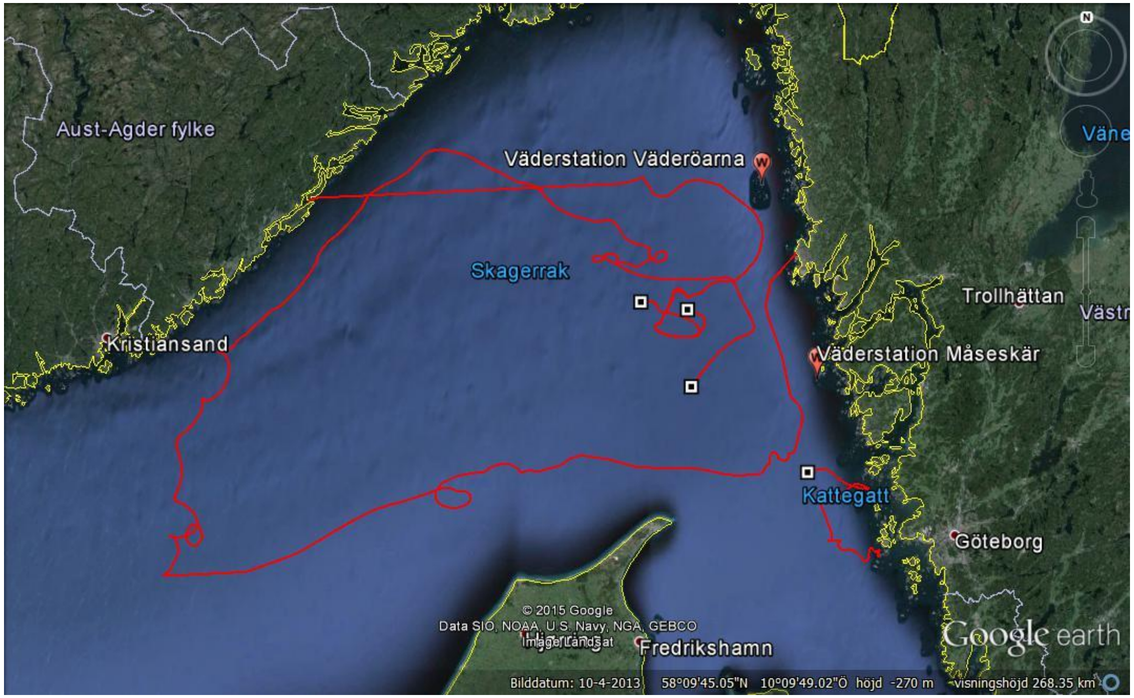


Deltares

Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment

- Close contact with Qualitas
- Minor quality control made by SMHI
- Some visual comparisons with drifters



Task 2.3: Harmonizing new network systems: HF Radars

5. Data management

- Historical HF radar data stored at SMHI:
    - 9 MHz: Nov 2014 – Jan 2015 (bad quality).
    - 13.5 MHz: Feb 2015 – Dec 2015.

- Drifter data stored at SMHI

Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment

CODAR QC procedures **[L0]**

- Threshold for radial (80 cm/s), total vectors (70 cm/s)
- Angle between radial in the range 30°-150°
- First Order Limit settings
- (prevent interferences and errant high radial velocities)
- Antenna pattern calibration → Last APM in July 2015.

SOCIB Data Centre procedures and flags **[L1]**

Battery of tests for individual total vector

- (range, gradient, spike for module and direction).
- System functioning diagnostic parameters at each radial station:
- signal-to-noise ratio
- radial vector count,
- average radial bearing
- comparison of averaged radial bearing for the measured and ideal patterns

Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment : validation

Comparison exercise in the Ibiza Channel:

3h averaged U, V velocities from
- HF radar (0.9m),
- Currentmeter (1.5m)
- ADCP (5m)

Period: 2013/09/27 to 2015/01/22
QC flags: 1, 2 (good and probably good data)

Results:
- 7cm/s < RMSE < 13cm/s
- 0.6 < correlation < 0.73
- Good agreements with previous studies
- (recently Lorente et al., 2014, Cosoli et al., 2010 or Rubio et al, 2011)
- Good agreement in reproducing the strongest velocities events
- Better agreement for the U component
- (geometric effect + higher variability for V)
- Improvement due to APM (July 2015)
-

Task 2.3: Harmonizing new network systems: HF Radars

5. Data management

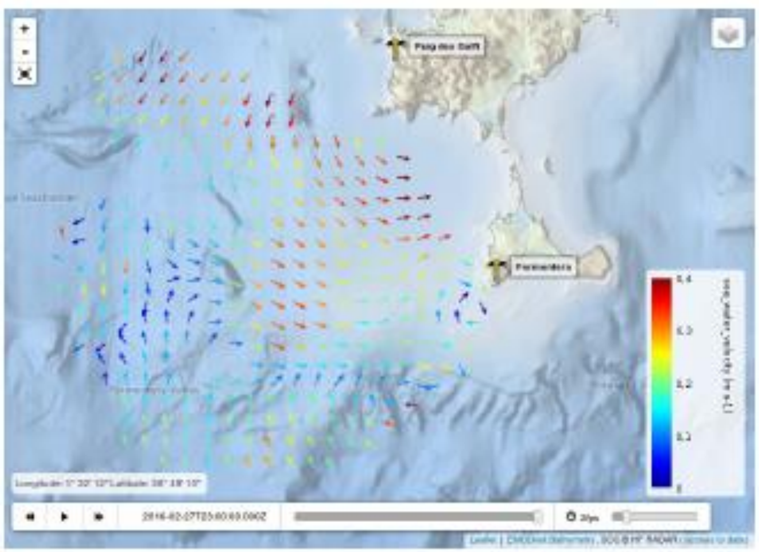
Thredds data server:

http://thredds.socib.es/thredds/catalog/hf_radar/hf_radar_ibiza-scb_codarssproc001/catalog.html

- One file per month
- L0 and L1

Visualisation:

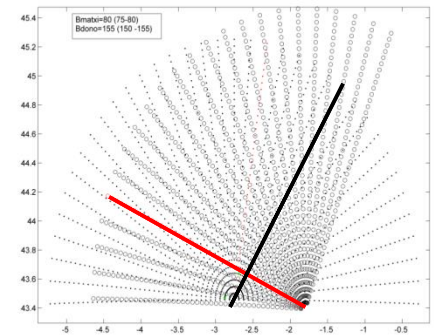
- ✓ Leaflet TimeDimension: https://github.com/socib/Leaflet.TimeDimension
- ✓ Lightweight for NetCDF: http://thredds.socib.es/lw4nc2/?m=radar



Task 2.3: Harmonizing new network systems: HF Radars

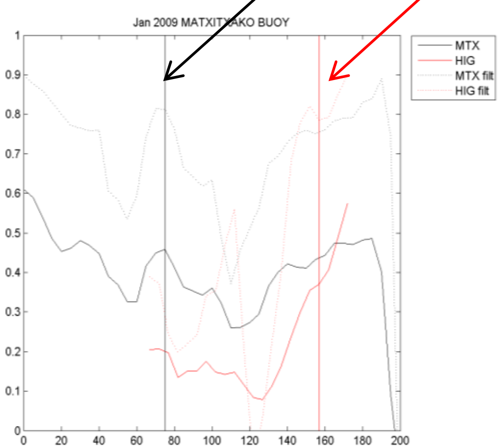
4. Quality assessment

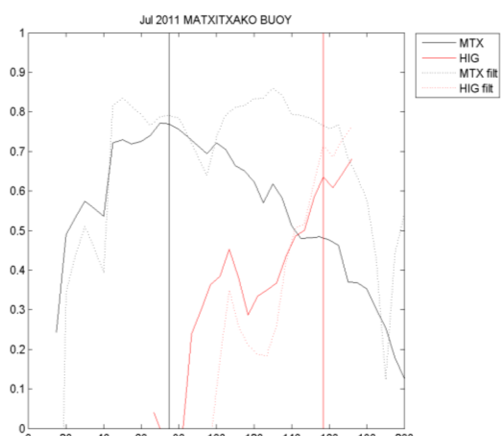
RADIALS R	BIMEP 11 m 2009 -2011		MATX 12 m 2009 -2011		HIGER 12 m 2009 -2011	
vs.	NON FILT	FILT (48h)	NON FILT	FILT (48h)	NON FILT	FILT (48h)
MATX SITE	0,72	0,91	0,46	0.60	0,14	0,24
HIGE SITE	0,48	0,77	0,35	0.54	0,29	0,48

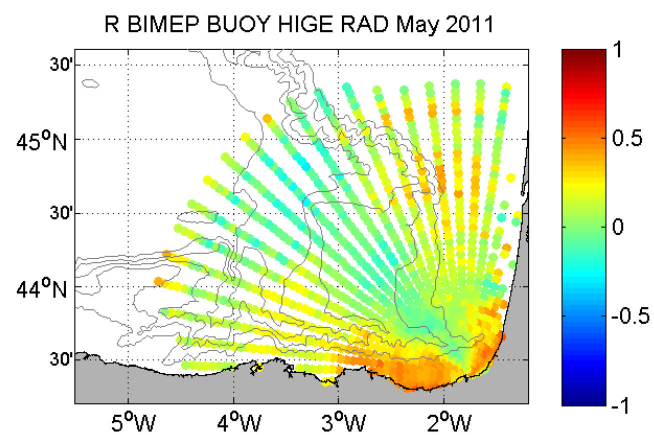


Bearing angle nearest MATXI RADIAL

Bearing angle nearest HIGE RADIAL



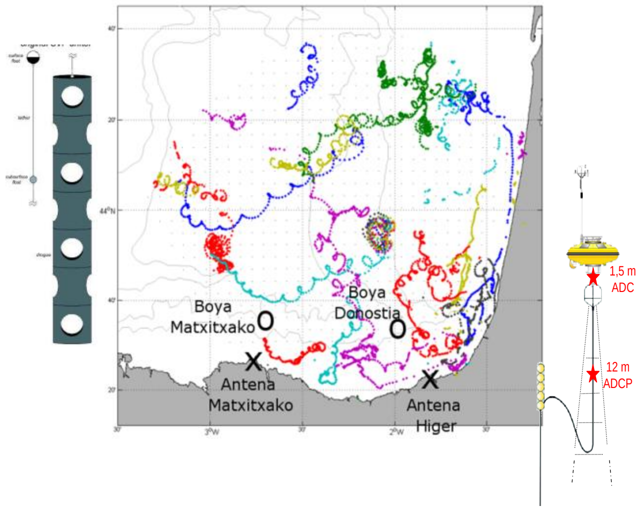




Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment

Eulerian comparisons



- RMS and R between HF radar and insitu data: slope buoys (from EUSKALMET) and drifters (Charria et al. 2013).

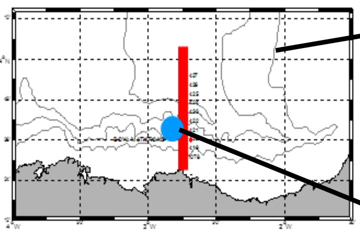
- RMS ~ 8-14cm/s depending on in-situ measurements depth, stratification conditions, current regime.

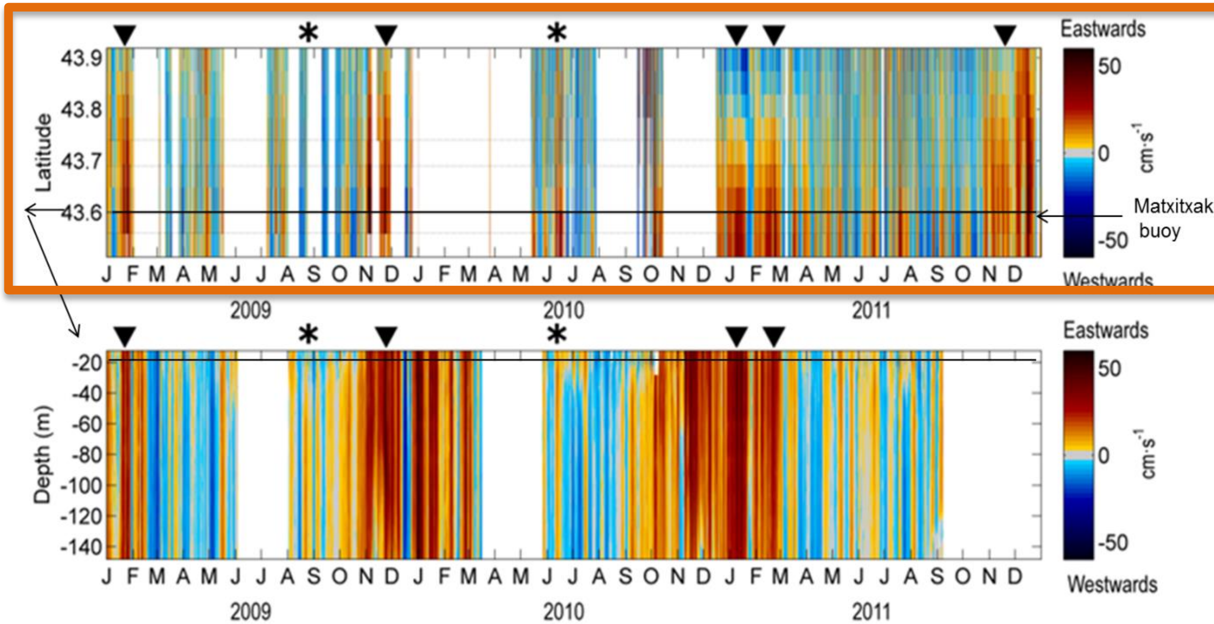
- *Rubio et al. 2011 GRL; Solabarrieta et al. 2013, CSR

In-Situ Data	Measurement depth (m)	Time period	RMS ($cm\ s^{-1}$) In-Situ data u	RMS In-Situ data v	RMS Radar node u	RMS Radar node v	Mean Speed In-Situ data u	Mean Speed In-Situ data v	Mean Speed Radar node u	Mean Speed Radar node v	Corr-u In-situ-Radar data	Corr-v In-situ-Radar data	RMSd-u ($cm\ s^{-1}$) In-situ-Radar data	RMSd-v ($cm\ s^{-1}$) In-situ-Radar data
Matxitxako	1.5	2009	16	10	13	8	-	-	-	-	0.86	0.64	8.09	8.12
Donostia	1.5	2009	12	11	11	12	-	-	-	-	0.53	0.34	10.38	12.88
Matxitxako	12	01-Jan-2009 /07-Sep-2011	13.88	8.20	14.3	9.21	5.30	-2.28	4.09	0.22	0.66	0.50	11.12	8.97
Donostia	12	01-Jan-2009 /15-Oct-2010	9.72	6.84	12.4	13.0	2.75	-0.01	3.84	4.20	0.49	0.27	10.95	13.09
Matxitxako	12	Well mixed months	20.03	8.98	18.5	8.69	13.3	2.05	11.1	0.62	0.67	0.46	12.38	9.46
Donostia	12	Well mixed months	13.23	7.79	14.7	16.4	5.84	1.03	6.06	9.27	0.59	0.20	11.49	16.41
Matxitxako	12	Stratified months	9.03	8.58	11.8	9.73	1.14	2.57	0.31	0.31	0.51	0.57	10.70	8.89
Donostia	12	Stratified months	8.77	6.76	11.9	11.6	1.67	0.28	2.66	2.51	0.44	0.32	11.07	11.52
Drifters	15	May-Sep-2009	13.99	13.6	13.7	13.8	-0.88	-0.33	-1.49	-1.14	0.42	0.46	14.85	14.30

Task 2.3: Harmonizing new network systems: HF Radars

4. Quality assessment –process oriented

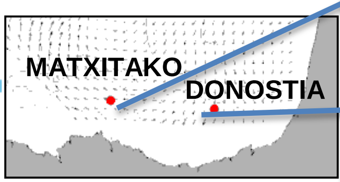


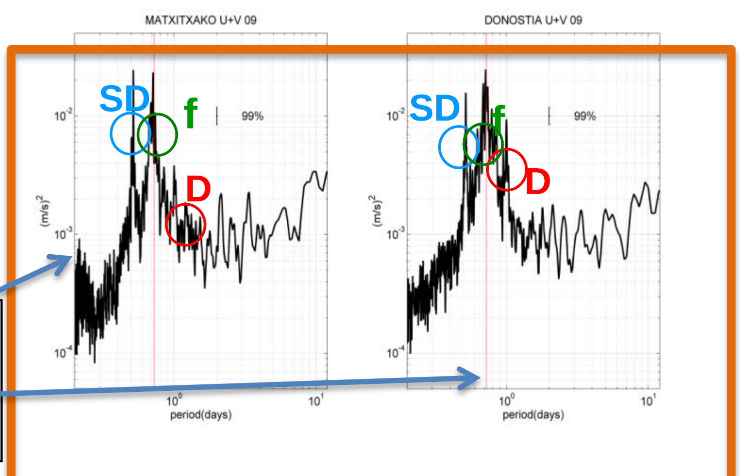


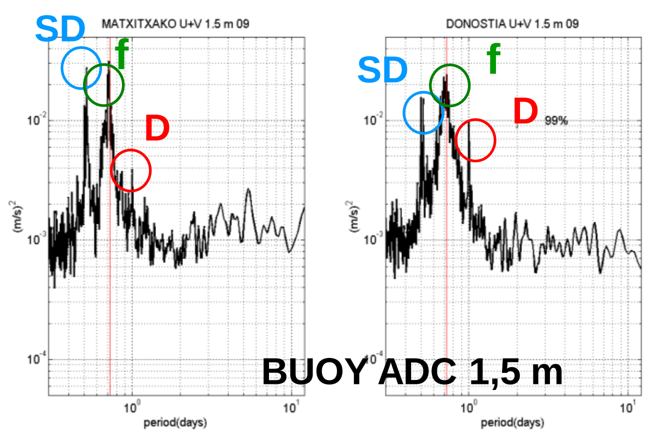
BUOY ADCP
15-200 m

MAIN LOCAL PEAKS

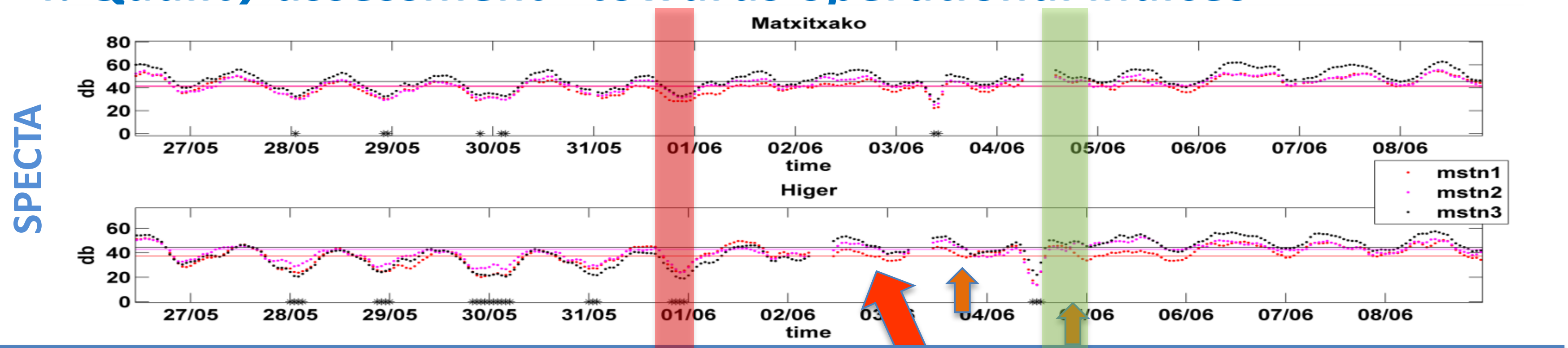
- **D**: diurnal
- **SD**: semidiurnal
- **f**: inertial

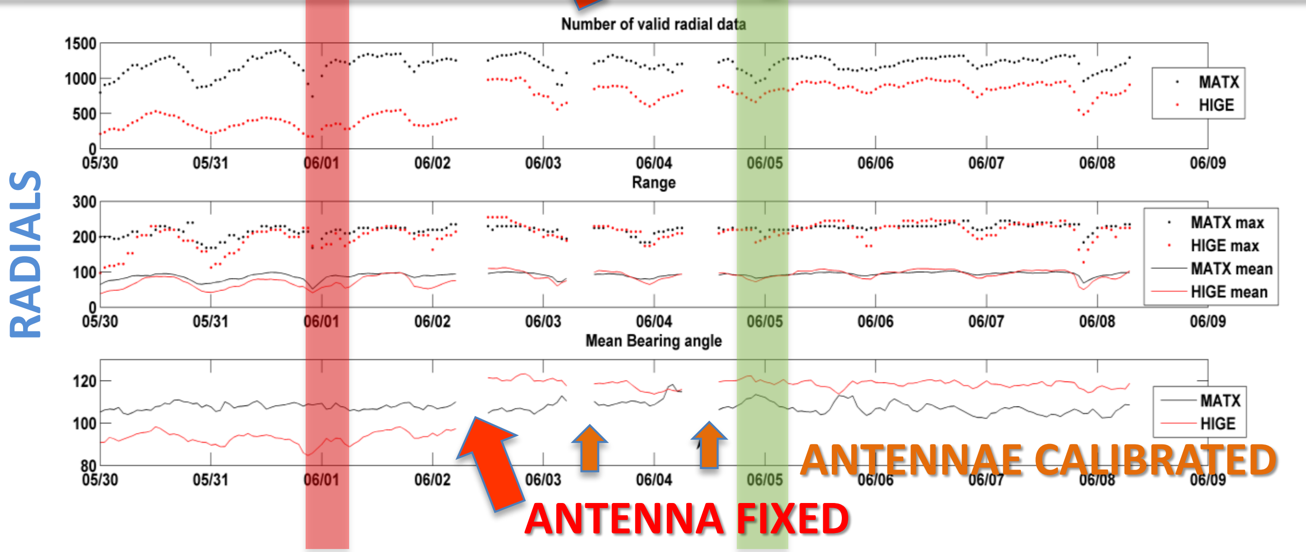






4. Quality assessment –towards operational indices

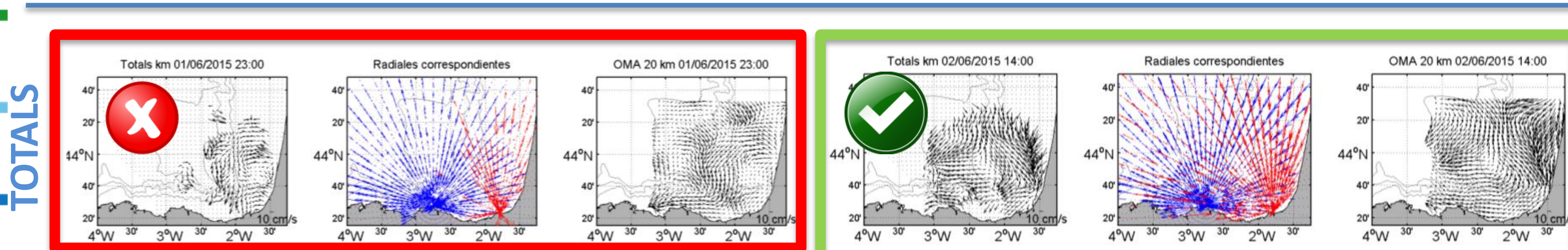




EXAMPLE of 3 LEVEL QA/QC procedure

1) Signal 2 noise ratios
2) Radial coverage
3) Total field coherence

All parameters contained in hourly total fields



4. NetCDF filename

use a standard file name coding like
<RR_HFR_Code_TimeStep_YYYYMMDD.nc>
Example:
IR_HRF_Basque_Hourly _20160307.nc

- RR: region bigram
- Code: platform code
- TimeStep: time step of data
- YYYYMMDD: year month day of data

5. NetCDF Metadata

use a minimum set of common metadata fields

- acknowledgement
- creator
- creator_email
- description
- institution
- institution_references
- license

<u>Example from Basque NetCDF file</u>

acknowledgement: These data have been generated …
creator: Yolanda Sagarminaga; Anna Rubio
creator_mail: ysagarminaga@azti.es, arubio@azti.es
description: The data set consists of maps of …
institution: Euskalmet, Basque Government
institution_reference: http://www.euskalmet.euskadi.net/; http://www.azti.es
license: Currently data, products and services are provided "as is", without any warranty.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654410.

WP 6: Virtual Access (HFR)

Unregistered anonymous access logging

- **Setup of a secondary THREDDS server for testing purposes**:
  - Replication of the dissemination THREDDS catalog.
  - Setup of test catalogs for demo dataset of total and radial velocity data.
  - Activation of the distribution protocols to be used in the project: OpenDAP, WMS, WCS, NetCDF Subset, HTTPS.

- **Access count on the test THREDDS server**:
  - Configuration of the THREDDS server to generate the “access log” file in the proper format.
  - Installation of a log analyzer (in our case open source perl program called AWSTATS.
  - Activation of Google analytics (by inserting a tracking code in the THREDDS server configuration file.
  - Automatic generation of access statistics in html graphical format.

- **Have a tour and rise the count**:
  - http://150.145.136.27:8080/stats/awstats.thredds-radarHF.html

JERICO-NEXT

HORIZON 2020

JOINT EUROPEAN RESEARCH INFRASTRUCTURE NETWORK FOR COASTAL OBSERVATORIES

WP3 : Innovations in Technology and Methodology

Task 3.2 Developments on current observations from HF radars (M0-M46)

CNR-ISMAR

SubTask: 3.2.1 Description

New HF radar procedures for current retrievals and data quality control (HZG leader, MIO, CNR-ISMAR, AZTI, EuroGOOS)

1. **Investigation of variability of currents and bathymetry in space and time on HF-measurements in**
   - **shallow water environments (<10 m)**
   - **close to river outflow**
   - **high sea state conditions**
2. **Improvement of algorithms**
3. **Improvement of error estimates and quality control**
4. **Joint validation surveys**
5. **Common protocols**

SubTask: 3.2.1: Progress and work planned in the next 6 months

- **Investigation of current variability**
  - Effects of small scale fluctuations of currents and bathymetry on beam forming HF-radar systems (HZG)
  - Study in progress on noise impacting HFR velocities (SOCIB)

- **Error quantification**
  - HF radar total and radial velocities have been compared with moored point-wise current meter and ADCP velocities and with drifter derived velocities (Lana et al., Ocean Dynamics, in press; Corgnati et al., Oceans, 2015) (SOCIB, CNR-ISMAR).
  - Use of moored instruments (currentmeters, ADCPs) to monitor HF radar "health" (alert in case of high deviation) (SOCIB)

- **Common formats**

Definition and implementation of netCDF formats for HF radar radial and total data compliant with CF-1.6, Attribute Catalog Dataset Discovery (ACDD), INSPIRE, Unidata Dataset Discovery conventions and with ROWG recommendetions: in synergy with the Italian RITMARE project and EuroGOOS HF Radar Task Team (CNR-ISMAR, AZTI, EuroGOOS)

- **QA/QC procedures for HF radar data.**

- Work in progress on the definition of common QA/QC procedures to become a European standard.

QA procedures are based on IOOS best practices and QC methods are based on SNR, spatial geometry (GDOP) and statistics: in synergy with the Italian project RITMARE and with the EuroGOOS HF Radar Task Team (CNR-ISMAR, AZTI, EuroGOOS)

SubTask: 3.2.2. Description

HF radar network developments ***(AZTI LEADER,*** *CNR-ISMAR, HZG, MIO)*

- Improvements on HF radar network design. Based on the analysis of existing systems and future developments scenarios (new antenna locations, data processing, baseline gaps methods), guidelines will be produced for optimizing and developing HF radar systems at regional scales.

- For this assessment, different combinations of technological hardware solutions will be analysed (including different method of angle determination, direction finding versus beam forming).
    - A test area will be the SE BoB – Installation of a non-comercial phased array system (covering the footprint area of the direction finding existing system).
    - Other test areas?

SubTask: 3.2.2: Progress and work planned in the next 6 months

STRATEGICAL APPROACH

- Definition of different scenarios of development
  - Optimal coverage of HF Radars (combination of long-range and higher frequencies systems)
  - Combination of more distant radial stations
  - Integration with other platforms
  - Use of baseline gaps methods
  - How to take into account the local current dynamics in the design
  - Contribution of OSSEs?

→ Contribution in deliverable D3.3, first report (M24 - SEP2017): description of the different types of scenarios could be defined with different methodological approaches.
→ Methodological approaches could be fed by reviewing bibliography and specific works
→ To be discussed: Contribution of each partner and when?

- Scenarios for Case studies:
  - BoB, IBIROOS?
  - NW MED? Other?

→ Contribution in deliverable D3.4, second report (M46 – JUL2019): Network design in case studies.
→ To be discussed: Contribution of each partner and when?

TECHNOLOGICAL INPUTS FROM DEMOSTRATION WORKS

- For this assessment, different combinations of technological hardware solutions will be analysed
  - ➢ Two test areas (other to be defined):

    I - SE BoB – Installation of a non-commercial phased array (PA) system covering the footprint area of the cross-loop (CP) existing system. Intercomparison of system performances (AZTI)

    → Contribution in deliverable D3.3, first report (M24 - SEP2017): description of Material and Methods; third station in French coast operating during 2017.
    →Contribution in deliverable D3.4, second report (M46 - JUL2019): Results and discussion.
    →To be discussed: Contribution of each partner and when?

    II – NW Med (Toulon) A real-time Direction Finding method for PA systems is aplied in real-time. (Method to be tested also in SE BoB , depending on the radar deployment) (MIO)

    →Contribution in deliverable D3.3, first report (M24 - SEP2017):
    →Contribution in deliverable D3.4, second report (M46 - JUL2019):
    →To be discussed: Contribution of each partner and when?

SubTask: 3.2.3. Description

*New products for 4D characterization of shelf/slope hydrodynamics and transport (**CNR ISMAR LEADER,** Mio, UIB-CSIC, SMHI, HZG, AZTI)*

- Integration of surface HF radar currents with water column information (ADCPs, buoy, drifters, gliders, numerical models.)
- Improvements of Lagrangian products for tracking biological and pollution quantities from HF radar fields
- Improvements in short term prediction using ocean observation and meteo forecasting, and trajectory error maps

SubTask: 3.2.3: Progress and work planned in the next 6 months

- **Review of background studies and data inventory**

– Review of previous woks on combining HF radar and other data and models from the partners (Solabarrieta et al, 2014, 2015: Berta et al., 2014, 2015)

- Gathering and inventory of available data for analysis and method testing (ALL)

- **Dynamical studies in the study areas**

  - Analysis of HF radar and other in situ instruments to identify main processes and scales of motion to guide the choice of the methods to estimate 4D transport.

  - Study of Ibiza Channel circulation with HF radars and gliders, ADCP, and satellite altimeter (SOCIB)

  - Work in progress on a data set in the N.W. Med including radar, glider, CTD, ADCP, drifters (CNR-ISMAR, MIO)

SubTask: 3.2.3: Progresses and work planned in the next 6 months

- **Synergy with assimilation efforts in WP3.7**

  - Collaboration with CMCC to provide 4d estimates of velocity and transport using an ensemble Kalman Filtering method (EnKF). Historical HF radar data provided by CNR-ISMAR for testing (CNR-ISMAR, HZG, SOCIB, SMHI)

  -

- **Improvements of Short Time Prediction (STP) methods.**

- Applications and assessment in the Bay of Biscay (Solabarrieta et al., 2016) (AZTI, UIB-CSIC)
- Work in progress on improvements of existing capabilities exploring: parametric statistical models, empirical and lagrangian models (UIB-CSIC, AZTI)

- **Improvements of HF radar particle tracking for biological applications**

- Work in progress on applications to larvae retention and fishery application using historical HF radar data in Manfredonia Gulf (CNR-ISMAR)

2016 Plans

- Participation to the JERICO_NEXT HF radar meeting in S.Sebastian, March 9-11. The meeting will be crucial for comunication and planning of all the subtasks and partners

- Some partners will participate to OI London (e.g. AZTI), but no plan for Task 3.2 meeting

- AZTI is planning to submit an abstract to ISOBAY (XV Intern. Symp. Oceanogr. Bay of Biscay)

Investigating transport by ocean currents using drifters, HF radars and models, and applications to Marine Protected Areas and fishery management

(CNR – ISMAR, La Spezia, Italy)

Goal and approach

- Transport by ocean currents plays an important role in physical connection between ecological locations and in retention properties
- How can we measure transport? Lagrangian pathways (i.e. trajectories of quantities advected by currents) are chaotic, i.e. they are very sensitive on current details.
- Introduce a methodology based on drifters (drifting buoys), HF radars and models. Each platforms have strength and weaknesses and their joint use is most effective.
- Applications to larvae connections between Marine Protected Areas (MPAs) and between fish spawning and nursery areas in the Adriatic Sea (Mediterranean Sea)

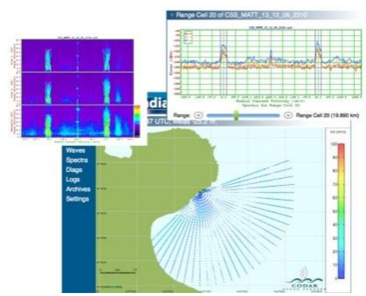
Strength and weaknesses of the different methods to assess transport

- Drifters

+ Direct measure of transport

– Few instruments, scarce data

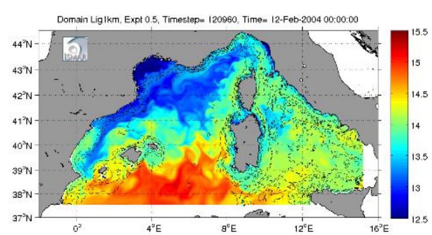
- Radars



+ High-resolution, uniformly gridded data

– 2D data, only at the surface, not always available

- Numerical models



+ 3D data on unform grid, also at different depths

– Need validation and calibration, are based on parameterizations

Data sets

• Drifter data in the Adriatic Sea:

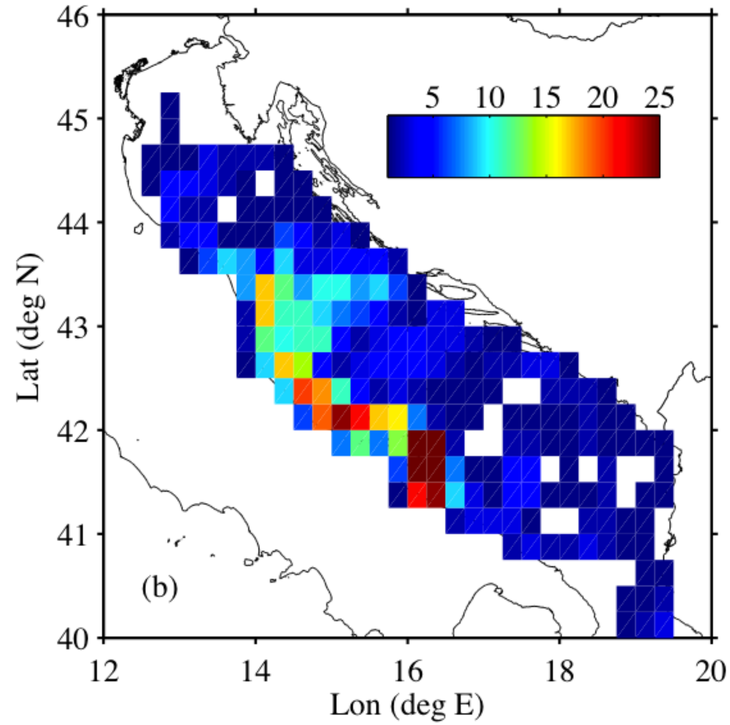
- the historical data set (Poulain 2001): 363 drifters deployed during 1990-2011

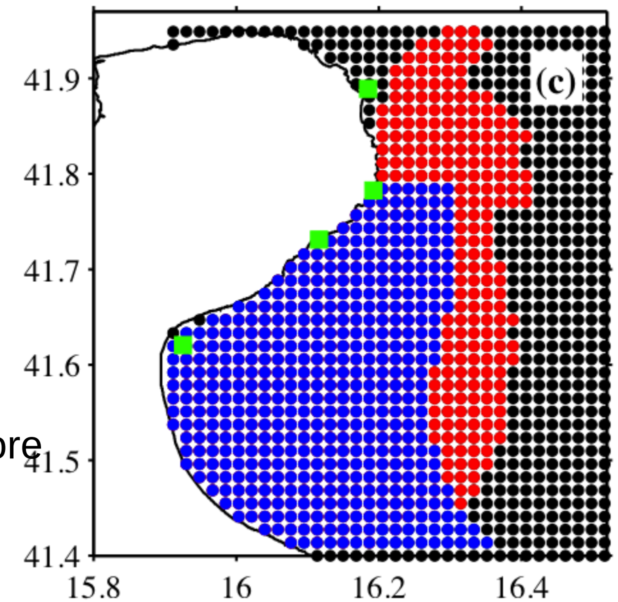
- more recent experiment data : 30 drifters deployed in 2013

- total of 393 drifters

• HF radar surface velocity:

- 4 CODAR SeaSonde 25 MHz in the Gulf, August 2013- April 2015.

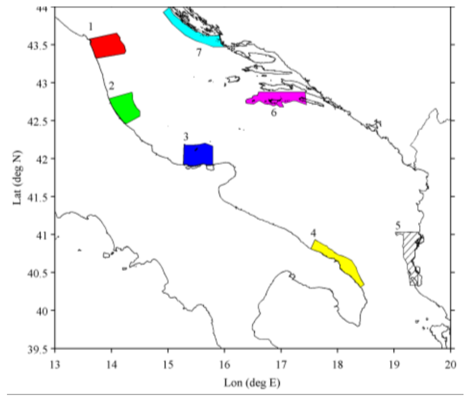




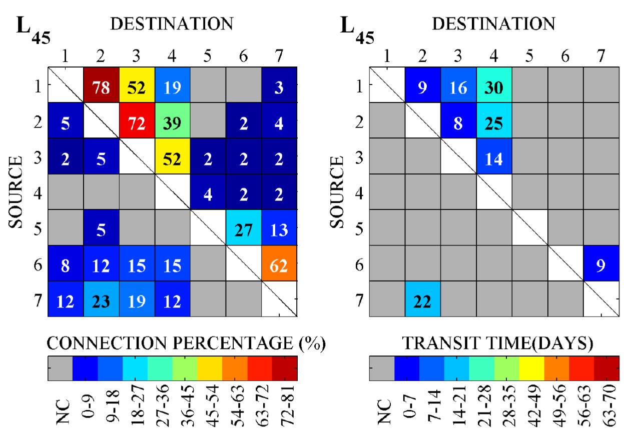
Concentration of drifter data before entering the Gulf (upper); Radar network and data grid (lower)

Application to Marine Protected Areas (MPAs)

We compute transport between 7 regions centered around MPAs using trajectories from 386 historical drifters and a ROMS ocean model.



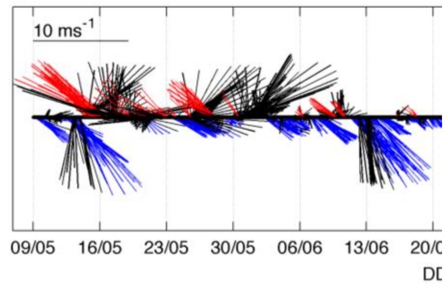
Main results:
•Strong along-shore connections and swift transit times (8-14 d)
•East to west cross basin connections stronger than west to east



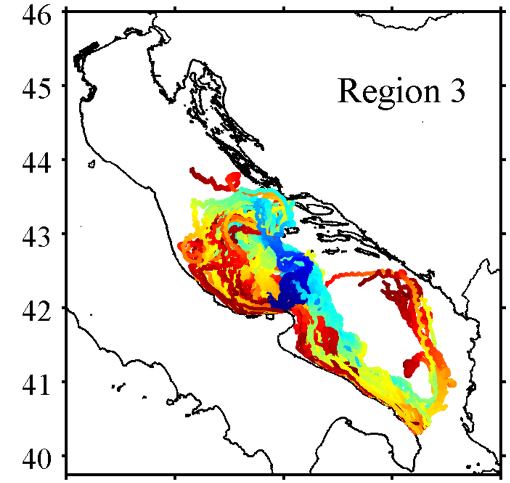
•Strong wind dependence over time scales of 3-30 days

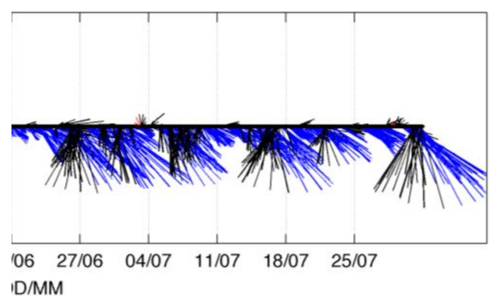
•Southeasterly winds increase west to east transport and weakens Western Adriatic Currents (WAC)

•Northwesterly winds reinforce WAC and inhibit west to east transport

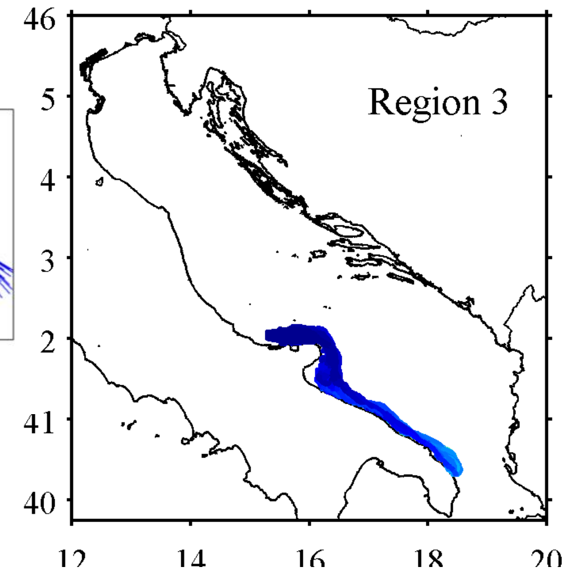


Dominant southerly winds



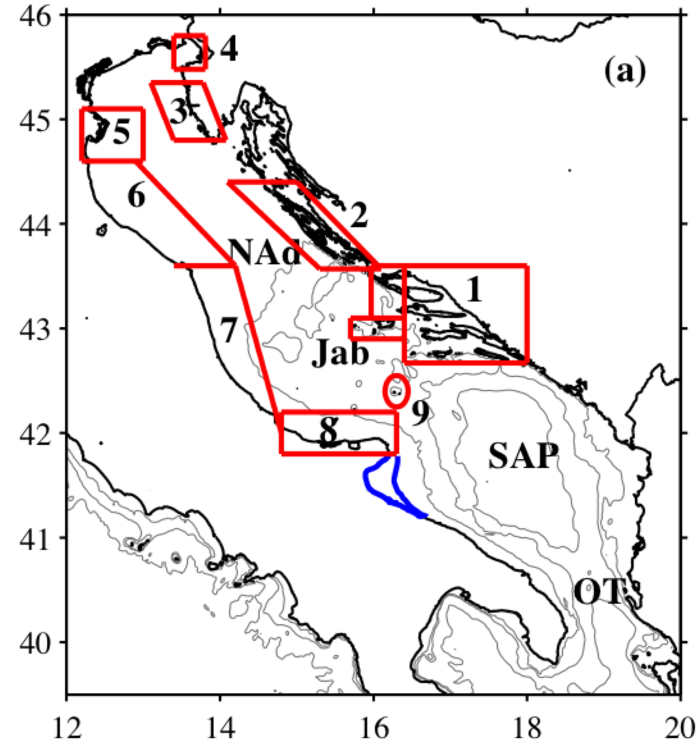


Dominant northerly winds



Application to fishery

- The Gulf of Manfredonia in the Adriatic Sea is a nursery area of anchovies and sardines
- Important question for fishery management
- Where do larvae come from? Locally spawned or advected from large spawning areas in the Adriatic?



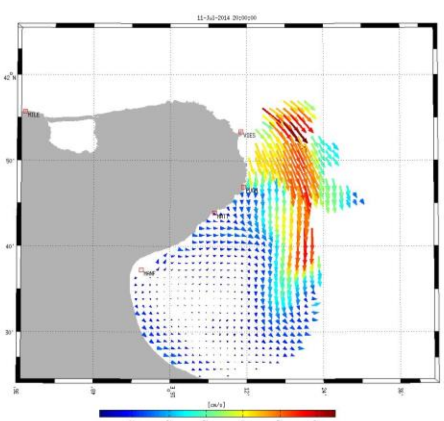
Blue (red) lines indicate the boundaries of the Manfredonia Gulf (spawing areas)

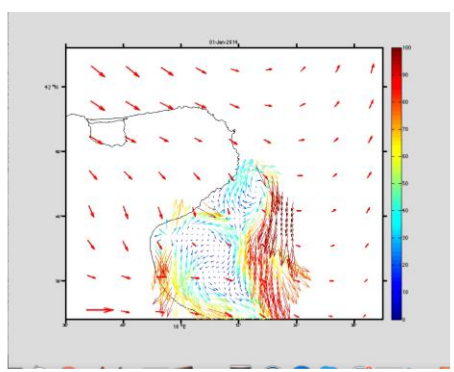
Velocity field in the Gulf from HF radar

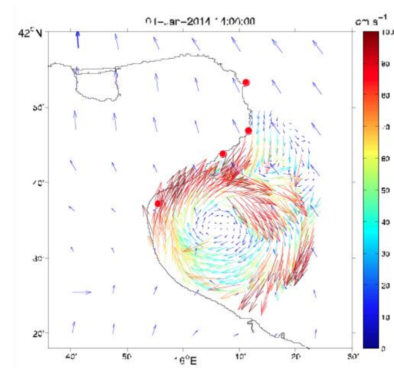
Velocity field in the Gulf is characterized by:

- WAC flowing southward and detaching at the Gargano Cape. Occasional reversal with southeasterly wind

- Complex and highly variable velocity within the Gulf, with recirculations at various scales and different rotation sense



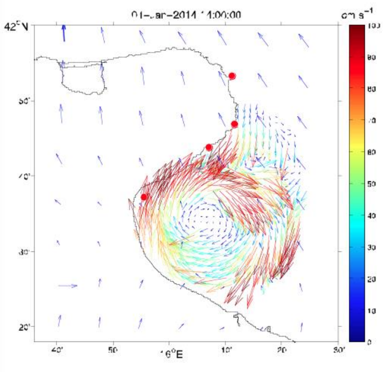


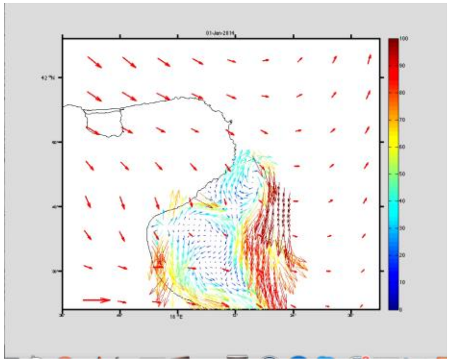


Examples of velocity fields in the Gulf of Manfredonia. Superimposed arrows indicate wind

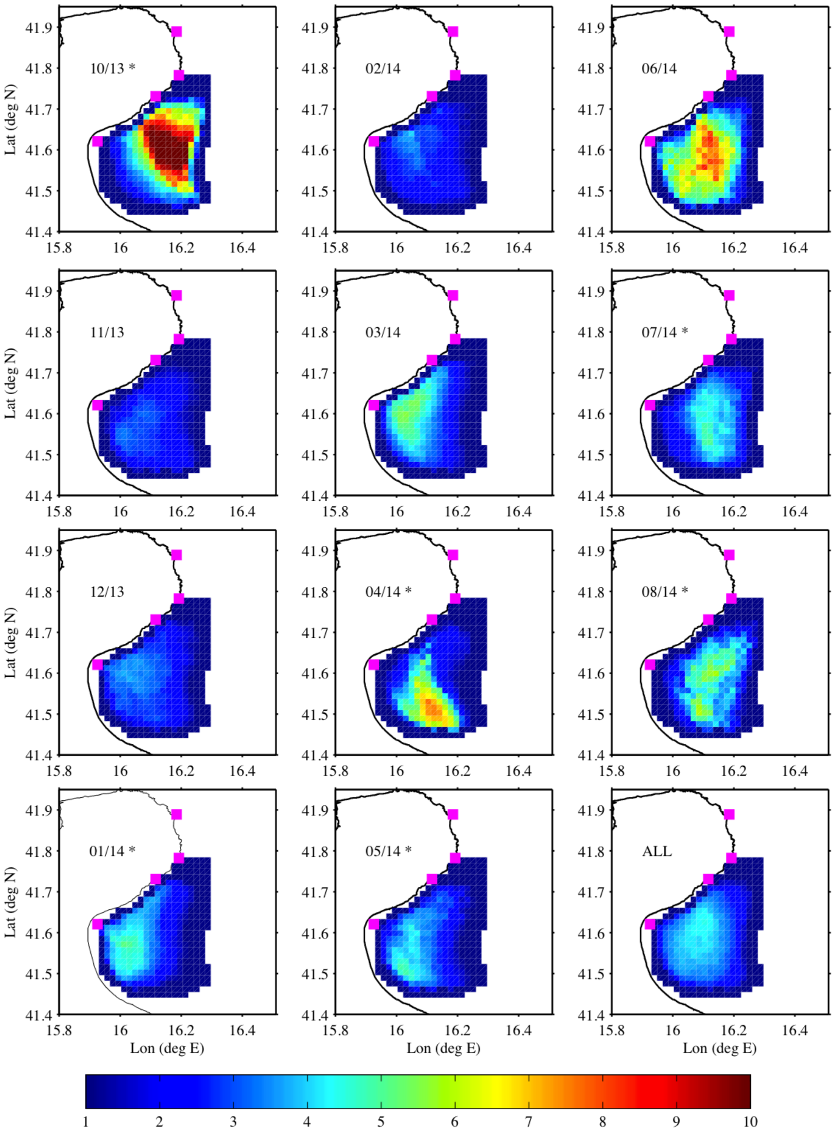
Main results:

•Typical local retention in the Gulf is < 10 days





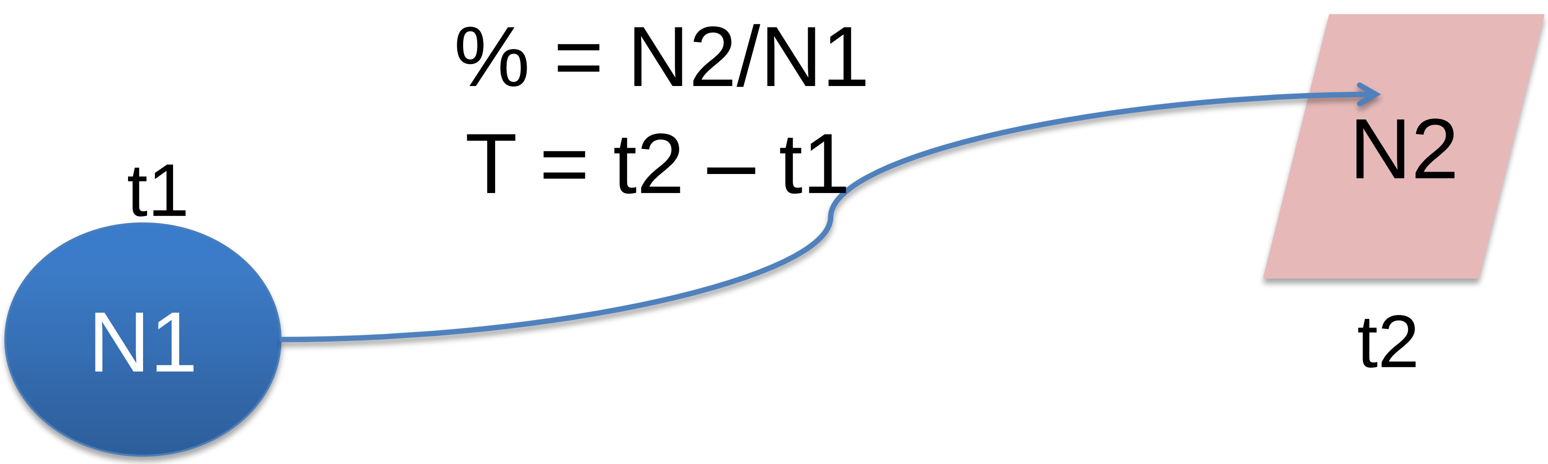
Examples of circulation in Gulf of Manfredonia from HF radar



Monthly means residence times from trajectories computed from HF radar velocities

Hydrodynamic Connectivity Between Regions

Historical Drifters
CoCoPRO 2013 & 2015 Drifters
Compute Connection Percentage & Transit Times

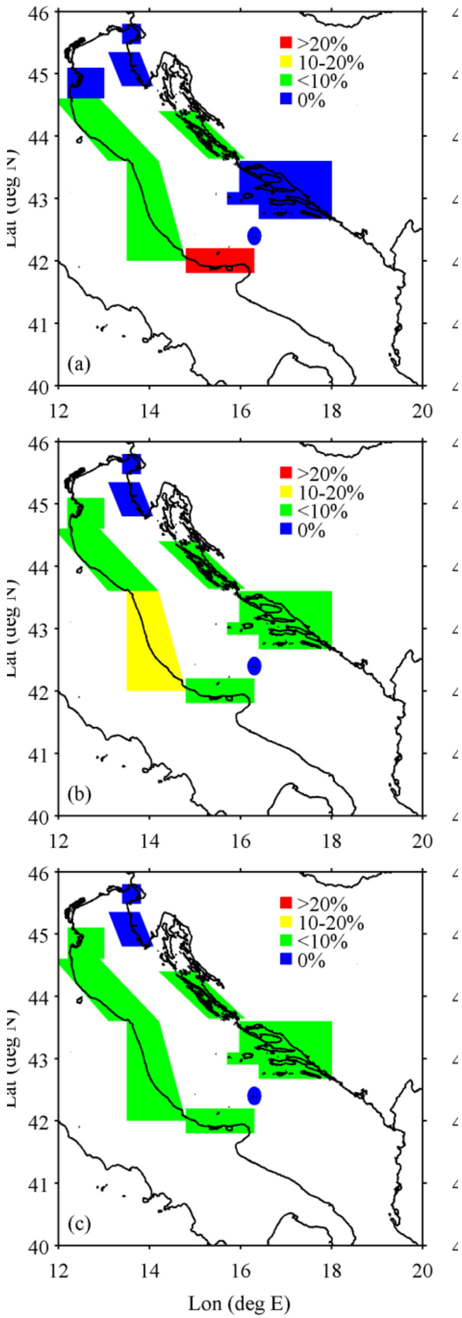


Drifters

393 Total CODE Surface Drifters
Historical and CoCoPRO
1990 – 2015

Minimum drifter lifetime = 10 d
Maximum drifter lifetime = 30 d (L_30); 45 d (L_45); total lifetime (L_0)

Hydrodinamic connectivity at different time scales



Results for conditional sets

Percentage of drifters reaching the Gulf during winter-spring (sardine spawning time) for:

- PLD= 0-20 d
- PLD = 20-40 d,
- PLD =40-60 d.

Conclusions

- Retention in the Manfredonia Gulf is typically less than 10d from HF radar data

- Comparison with ADCP data suggests high correlation in the vertical during winter months (sardine spawning time). Interior velocity could be smaller of about 30%

- Connections between spawning areas and Manfredonia Gulf computed from historical drifters occurs over times 10-60 d

- Since Pelagic Larval duration (PLD) is typically greater than 10 d, larvae are more likely to come from external spawning areas

Skill assessment of HF radar–derived products for lagrangian simulations in the Bay of Biscay

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(work submitted to JAOT)

Outline

i. Data set and approach
ii. Method used for STP
iii. Comparison to real trajectories
iv. STP spatio-temporal performance
v. Conclusions and future work

i. Data set and approach

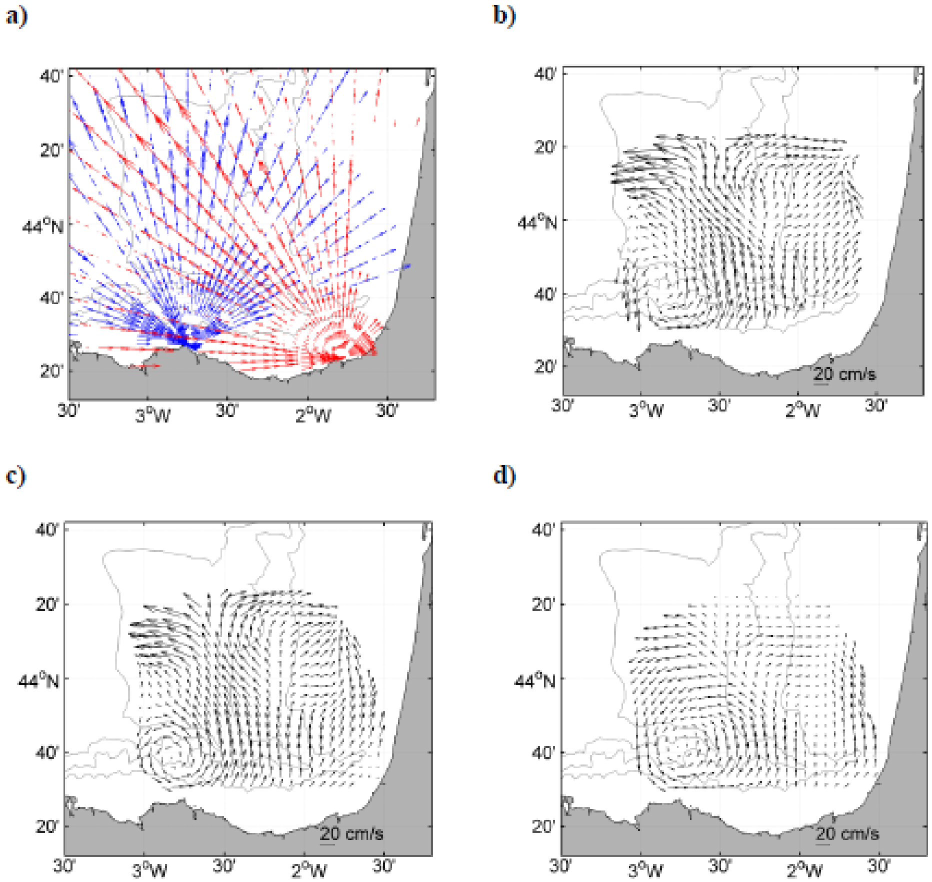
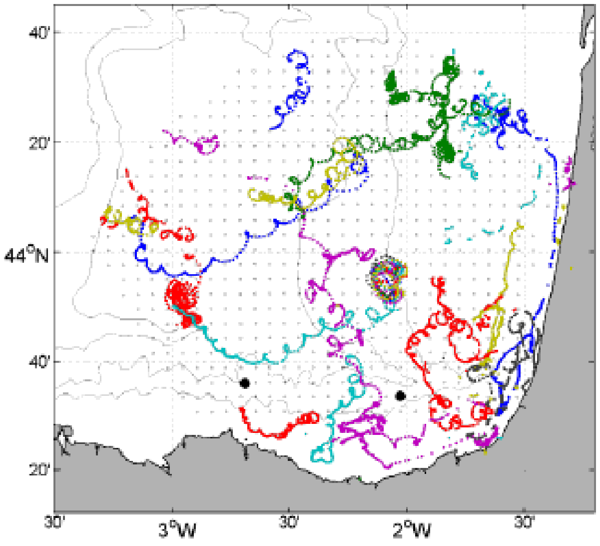


Figure 1. Snapshots of the surface currents February 13th 2011 at 13:00 for: (a) radial currents from the 2 radar sites, (b) total currents, generated from radial currents, (c) currents generated by OMA analysis, and (d) 24-h forecast currents for the same date (i.e. calculated starting on February 12nd 2011 at 13:00).

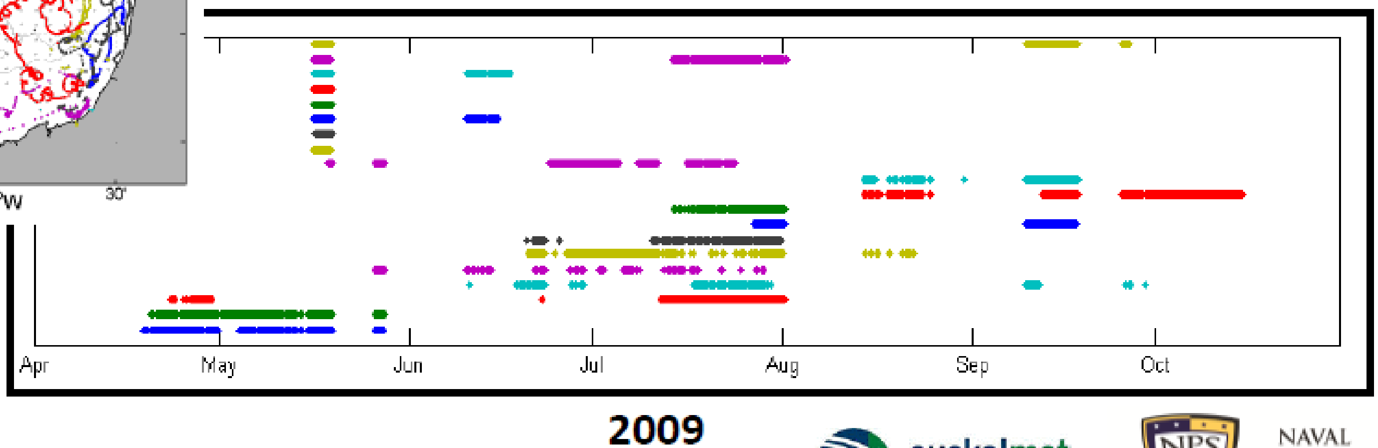
- Two Seasonde CODAR systems 4.5 MHz frequency, 200 km range with 5 km radial and 5º angular resolutions.
- Hourly radials (from MUSIC) are QC and converted to total fields, using the HFR Progs MATLAB package , gridded into a 5 km resolution regular orthogonal mesh (1416 nodes, LMS algorithm R=10 km) → TOTALS and OMA FIELDS
- A STP Method is used to obtain forecasts

i. Data set and approach

- 22 trajectories from several campaigns within the Bay of Biscay (Charria et al. 2013)
- Surface float linked to a long holey sock drogue (~10 m) centered at 15 m depth (hourly ARGOS positioning)



- Eulerian correlations of buoys comparable to those obtained for slope moorings 12.5 m data for stratified conditions and significantly higher that those for mooring data at 1.5m (*Rubio et al. 2011, Solabarrieta et al., 2013)

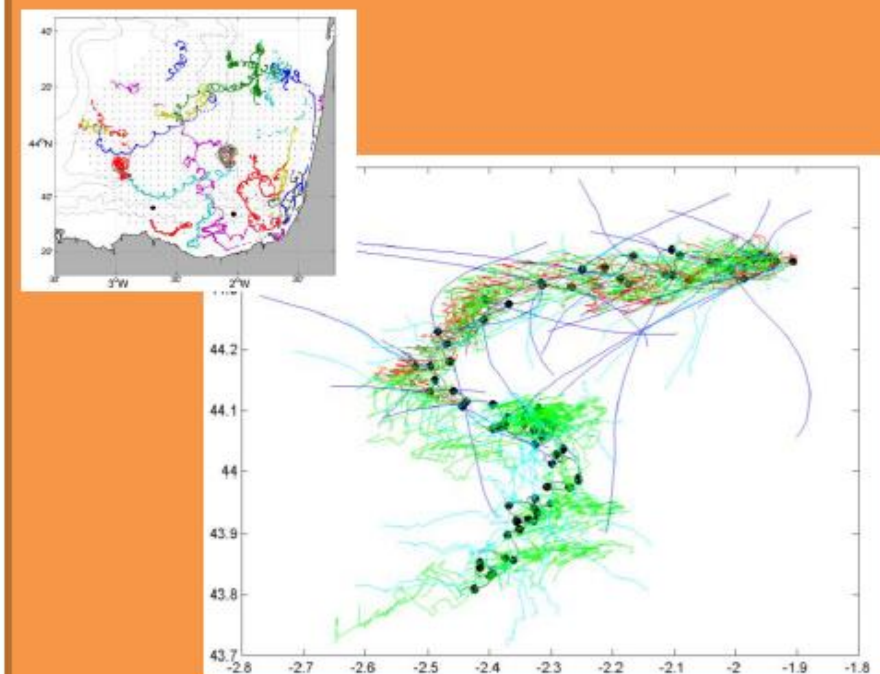


i. Data set and approach

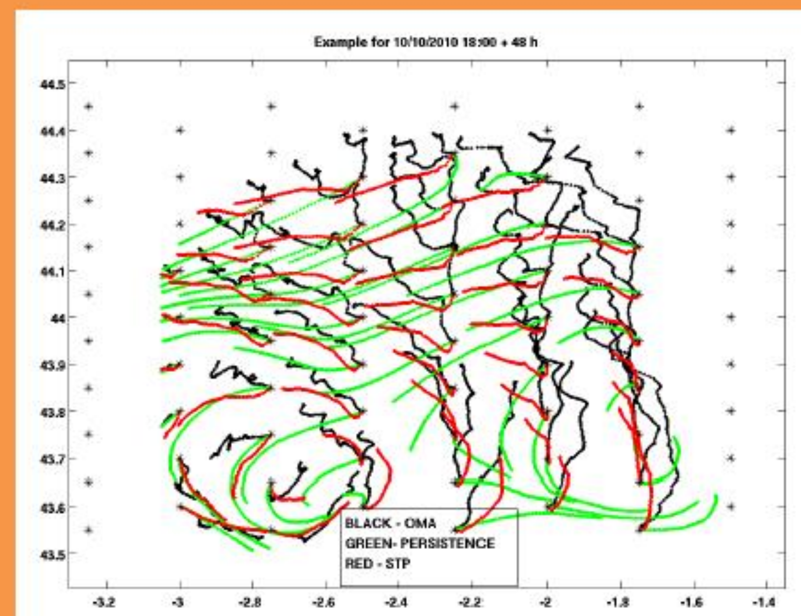
Transforming Science into Business

May 2010 - Dec 2012 → Training of the STP model

2009→ Comparison of TOTALs, OMA, PRESIS. and STP and real trajectories (1 trajectory /6h along the real track)



2009-2012 → Further evaluation of STP results, prediction vs. persistence (1 trajectory/ 1h using a regular grid)



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ii. Method used for the STP

WE use the linear autoregressive models described in Frolov et al., 2012.

MAIN STEPS

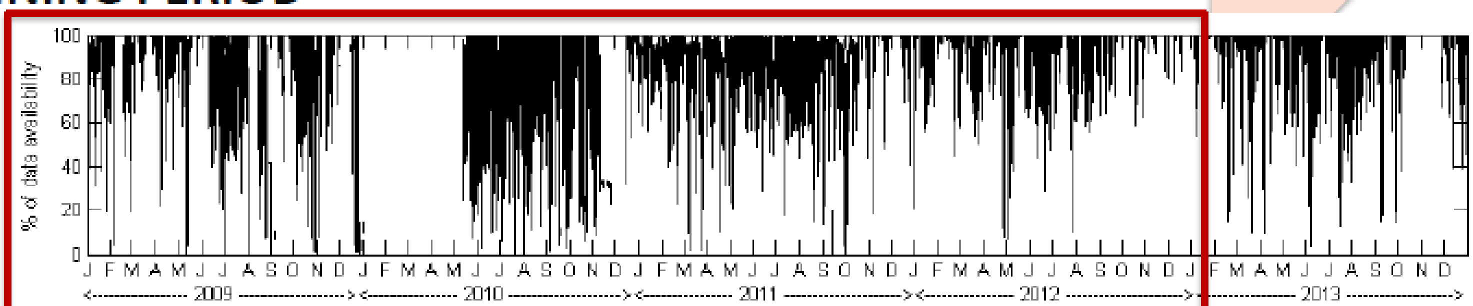
OMA analysis is applied to hourly HF radar data

Empirical Orthogonal Function (EOF) of OMA gridded fields

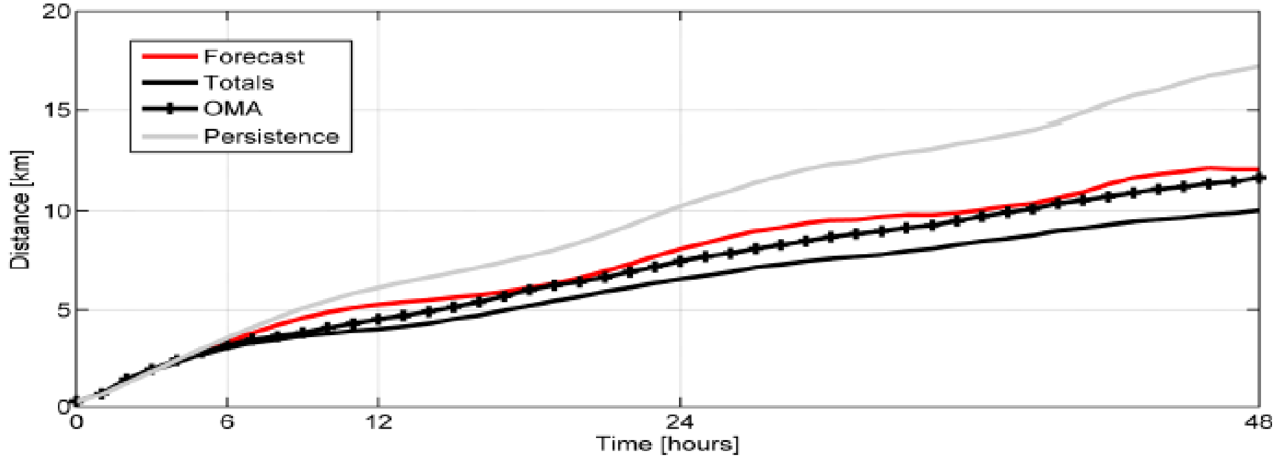
Retained the 50 leading EOF modes

For the time-series of these modes, construct a vector autoregressive model used for prediction.

TRAINING PERIOD



iii. Comparison to real trajectories

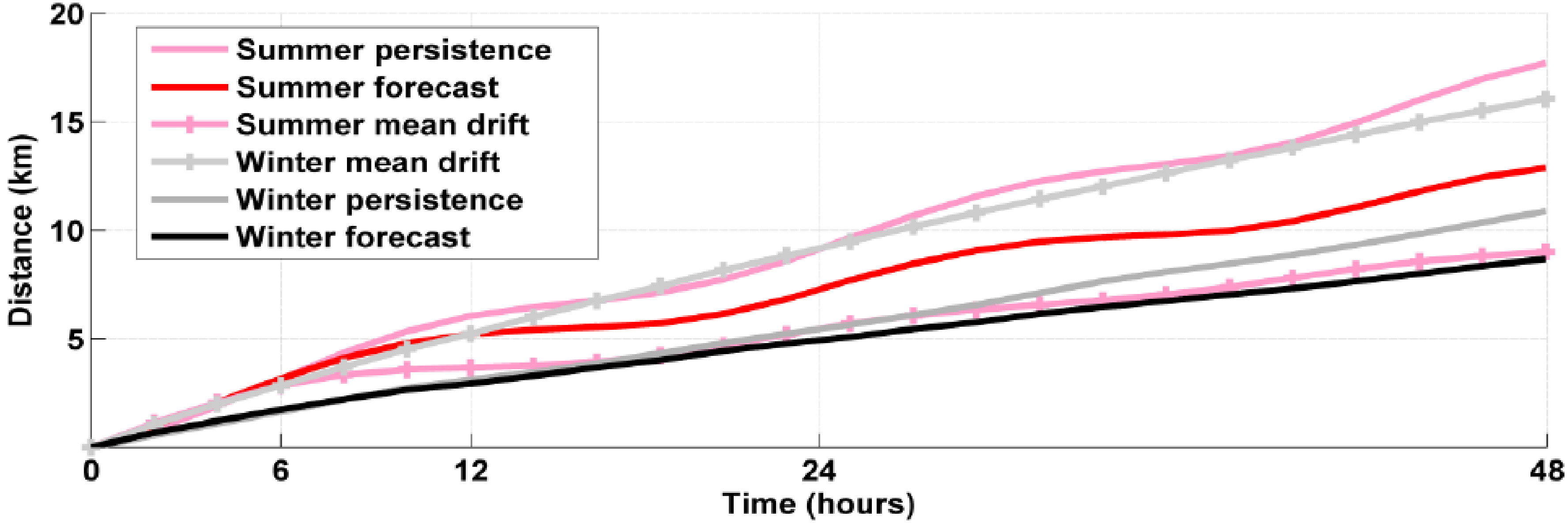


Time (h)	Main statistical parameters [km]							
	(a) TOTALS		(a) OMA		(a) PERSISTENCE		(a) FORECAST	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
6	2.85 [2.61, 3.14]	2.01 [1.69, 2.42]	2.91 [2.65, 3.21]	2.14 [1.081, 2.58]	3.15 [2.85, 3.49]	2.51 [2.09, 3.05]	2.98 [2.69, 3.34]	2.24 [1.85, 2.77]
12	4.07 [3.68, 4.54]	3.19 [2.65, 3.91]	4.47 [4.01, 4.96]	3.61 [2.99, 4.43]	6.048 [5.44, 6.77]	5.08 [4.20, 6.24]	5.29 [4.74, 5.95]	4.12 [3.37, 5.14]
24	6.59 [5.92, 7.38]	5.25 [4.32, 6.49]	7.42 [6.66,8.33]	6.13 [5.03, 7.59]	10.23 [9.08, 11.64]	9.47 [7.68, 11.93]	7.93 [7.06,9.00]	6.36 [5.13,8.05]
48	10.29 [9.28,11.51]	7.51 [6.17, 9.31]	12.16 [10.68,14.01]	11.16 [8.88, 14.37]	17.65 [15.7, 20.04]	14.74 [11.92, 18.62]	12.59 [10.98,14.65]	10.87 [8.50, 14.31]

Skill assessment of differently processed methods at the SE BoB

iv. STP spatio-temporal performance

azti tecnalia Transforming Science into Business



Time (h)	May 2009	all the period	Summer	Winter
12	12.5%	15.1%	13.6%	4%
24	22.5%	20.9%	20.9%	8%
48	28.6%	28.4%	27.2%	19.9 %

STP vs. PERSISTENCE

Skill assessment of differently processed methods at the SE BoB

euskalmet agencia vasca de meteorología euskal meteorologia agentzia

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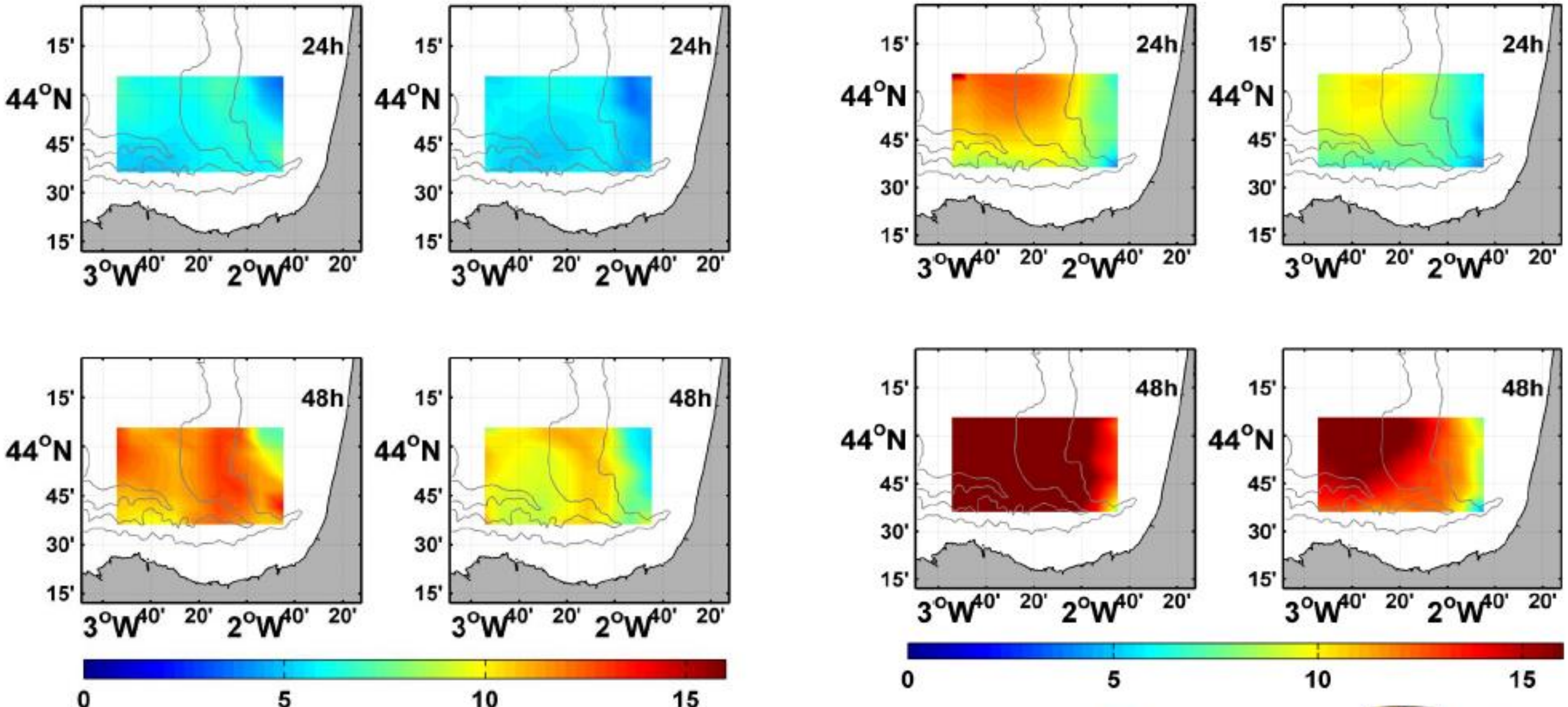
iv. STP spatio-temporal performance

WINTER

PERSITENCE FORECAST

SUMMER

PERSITENCE FORECAST

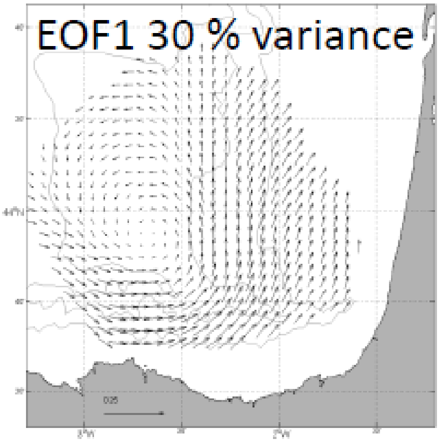


Skill assessment of differently processed methods at the SE BoB

iv. STP spatio-temporal performance

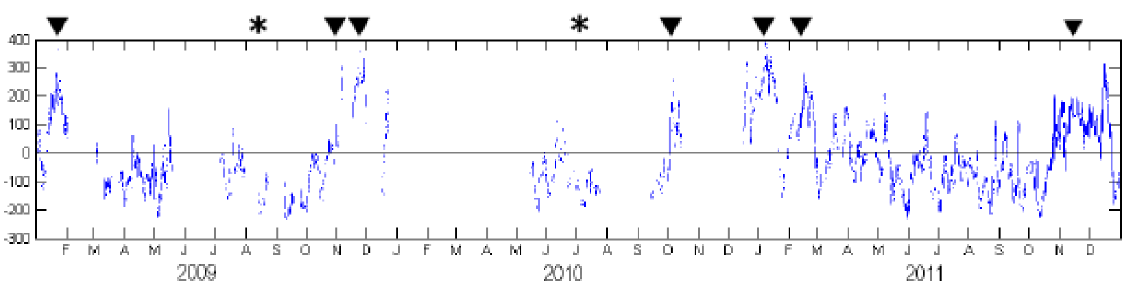
SE Bay of Biscay dynamics...

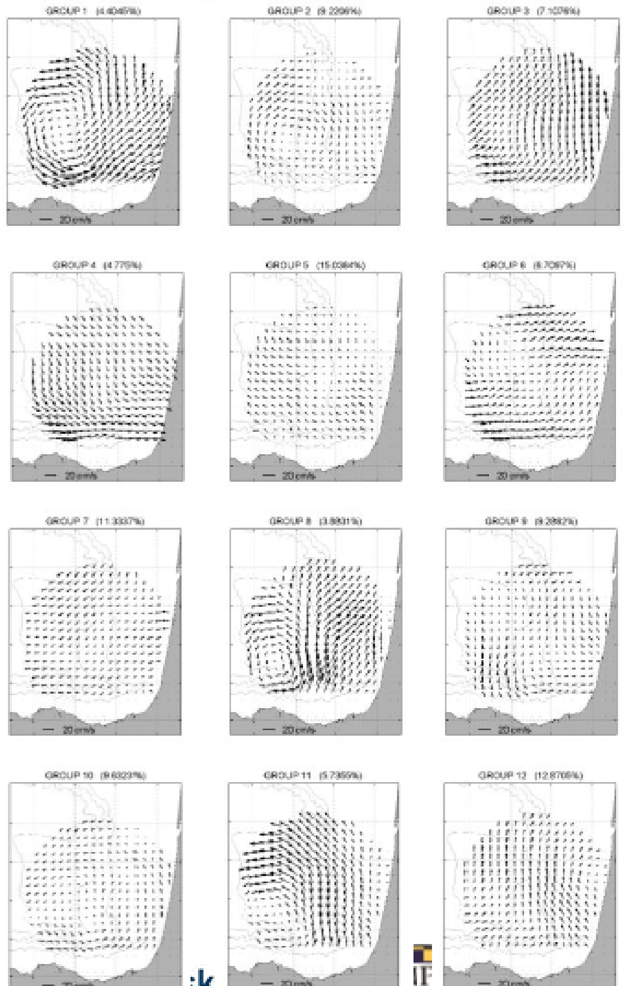
- *Seasonal slope current and seasonal winds*
- *Recurrent observation of mesoscale features*



EOF and K-means analysis

* Solabarrieta, et al. 2013, Cont Shelf Res; Solabarrieta, et al. 2015 Oc Dyn.





Skill assessment of differently processed methods at the SE BoB

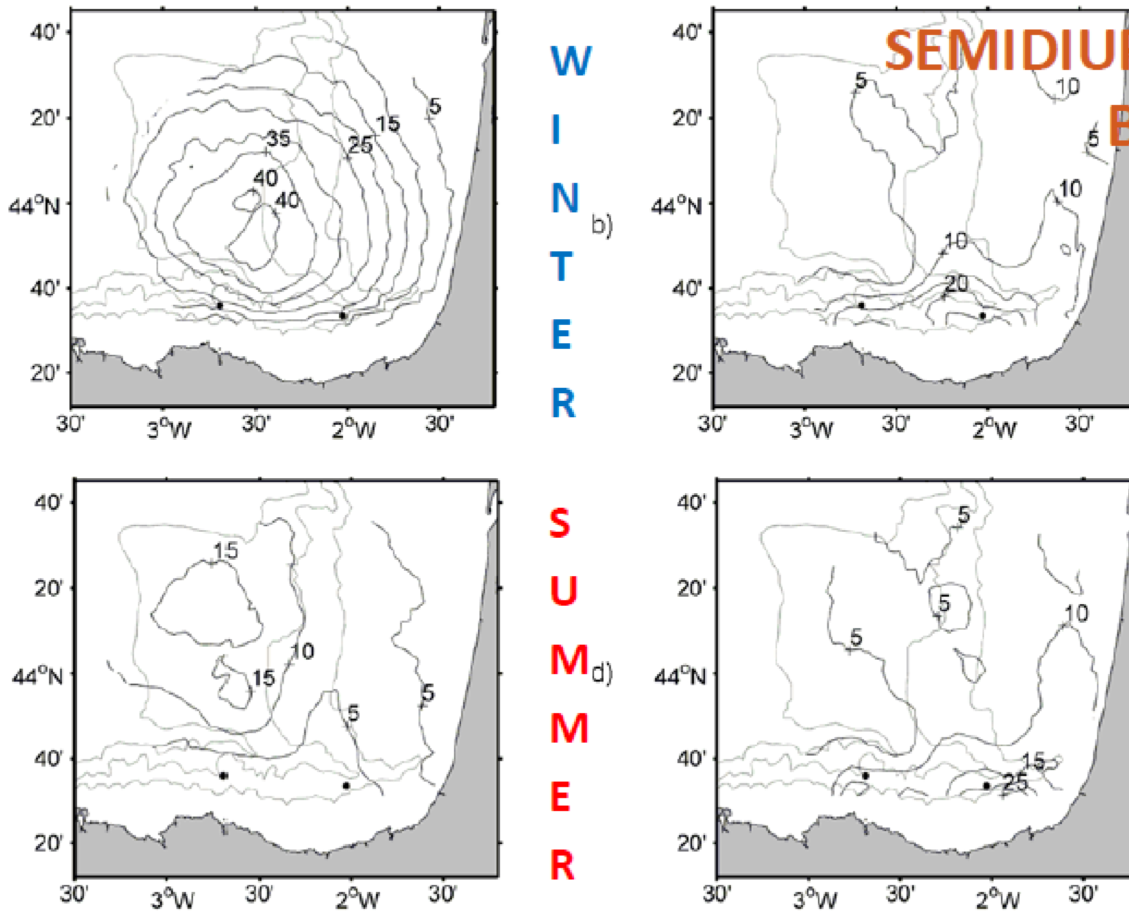
iv. STP spatio-temporal performance

SE Bay of Bscay dynamics...

❖ *Seasonal distribution of energy at high-frequency bands*

INERTIAL BAND

SEMIDIURNAL BAND



Contribution (%) to the total KE (2009-2011)

* Solabarrieta, et al. 2013, Cont Shelf Res; Rubio et al. 2011 GRL

iv. Conclusions and future work

- ✓ The **differences between real trajectories and simulated trajectories** obtained using HF radar total ***(and OMA)*** currents show values between 3 km and 7after 6 and 24 h of simulation, respectively. Different issues can contribute to these differences.

- ✓ In terms of **forecast currents the comparison with real trajectories leads to mean differences under 3 km at 6 h** (i.e. is not adding significant error) **and under 8 km within a forecast horizon of 24 h**.

- ✓ The **benefit of the forecast method** with respect to persistence **is of 12.5 % after 12 h and 28.6% after 48 h. The performances of the STP vary seasonally and spatially** (in agreement with the persistence). Different local processes which modulate the local circulation may be responsible of this variability

- ✓ **Improvement** could expected by seasonally conditioned learning periods or by separating the different contributions of the different physical processes (which have both different spatial and temporal variability scales) to the total variability before applying EOF decomposition (and thus forcing EOFs to split correctly different physical signals).

Thank you for your attention!

AKNOWLEDGEMENTS

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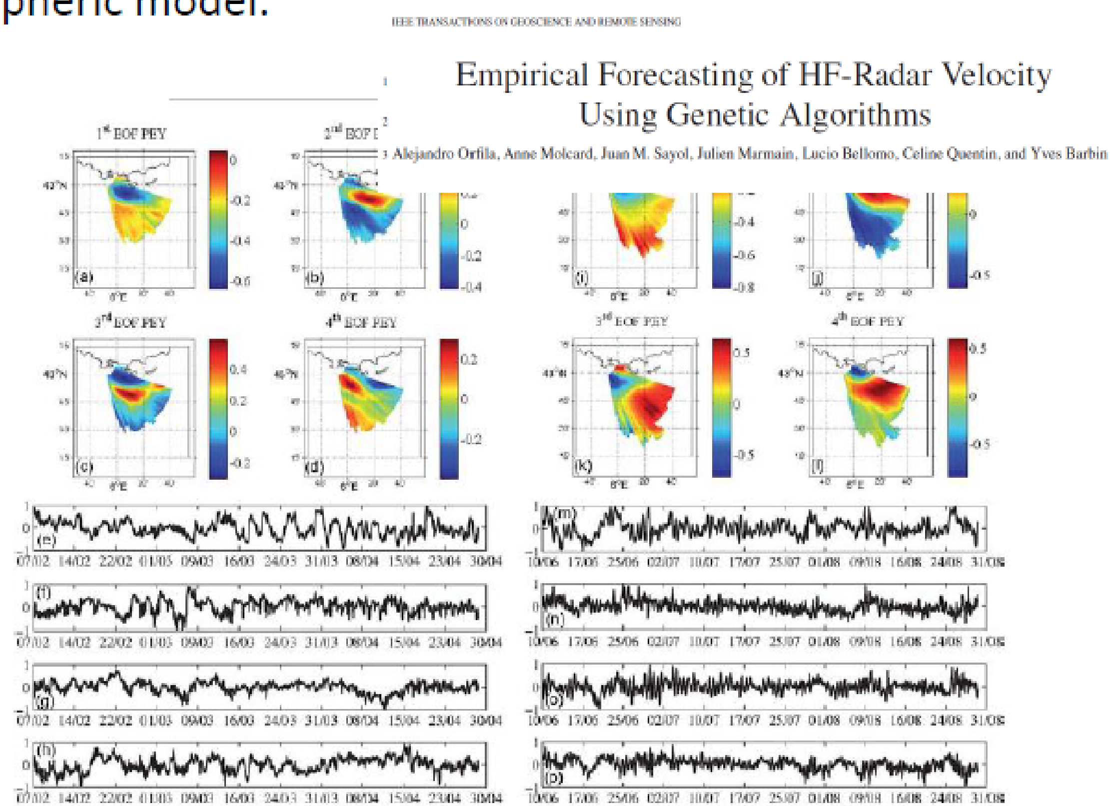
VERY BRIEF background on STP applied to HFR

- **Barrick, et al. 2012** used OMA decomposition (Lekien et al., 2004) and then a set of temporal modes was fitted to the time series of OMA coefficients over a short training period.

- **Frolov et al. 2012** used EOF decomposition and applied a vector autoregressive model on the leading EOFs time series for prediction, **incorporating wind stress forecasts** from a regional atmospheric model.

- **Orfila et al. 2014**, the spatial and temporal decomposition of current variability is also performed using **EOFs on RADIALS**, then the forecast approach relies on a **Genetic Algorithm (GA) (using only past observations)** to identify mathematical expressions that best forecast the evolution of the amplitudes associated with statistically significant EOF modes.



(A. Orfila) STP in T3.2.3 and JRAP#4 (already included in D4.1 FIRST DRAFT)

I. ***Parametric statistical models: Regression and Autoregressive models***. Use of statistical approaches to link independent variables (such as the wind speed at the ocean surface) in order to predict the radial velocities.

II. ***Empirical models based on the CCA of HFR and wind fields***. Use of EOF and CEOF to explore the possibility of deriving a 2-d predictor of (u,v) velocities using past measurements of HFR velocities and 2-d fields of surface wind forecasts.

III. ***Lagrangian models from FSLE.*** Lyapunov exponents of finite size (FSLE) are very well suited to study the Lagrangian Coherent Structures organizing the fluid motion, being also able to reveal oceanic structures below the nominal resolution of the velocity field. We propose to use the total HFR velocity fields to compute de FSLE to provide a STP of certain surface patterns.

IV. ***Models on analogous***. Neural network methods have several advantages in clustering and feature extraction compared to EOFs (e.g., Liu et al. 2006). These non-linear methods have been widely applied in meteorology and oceanography (Liu et al. 2006; Camus et al. 2011; Espejo et al. 2014, Solabarrieta et al. 2015) to improve the characterization of surface ocean dynamics and can provide a basis for STP.

Synergies with methodologies towards 4D transports to be explored further…