SOCIB Sistema de Observación y Predicción Costero de las Illes Balears

European high-frequency radars as a valuable asset to validate and improve ocean prediction in coastal areas

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EuroSea/OceanPredict Workshop - Ocean Prediction and Observing System Design
29 Jun 2022 - 1 Jul 2022, Met Office, Exeter (UK)

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Outline

1. Coastal areas
2. Coastal high-frequency radars (HFRs)
3. HFR applications: model assessment and improvement
4. Forecasting systems: WMOP & COSYNA
5. HFR data assimilation in WMOP & COSYNA
6. Conclusions & remarks

01 Coastal areas

Land-sea-atmosphere interface

Most dynamic part of the oceans

High-productive areas

Anthropic activities & pressures

Climate change threats

Marine knowledge gaps

Observing & forecasting challenges

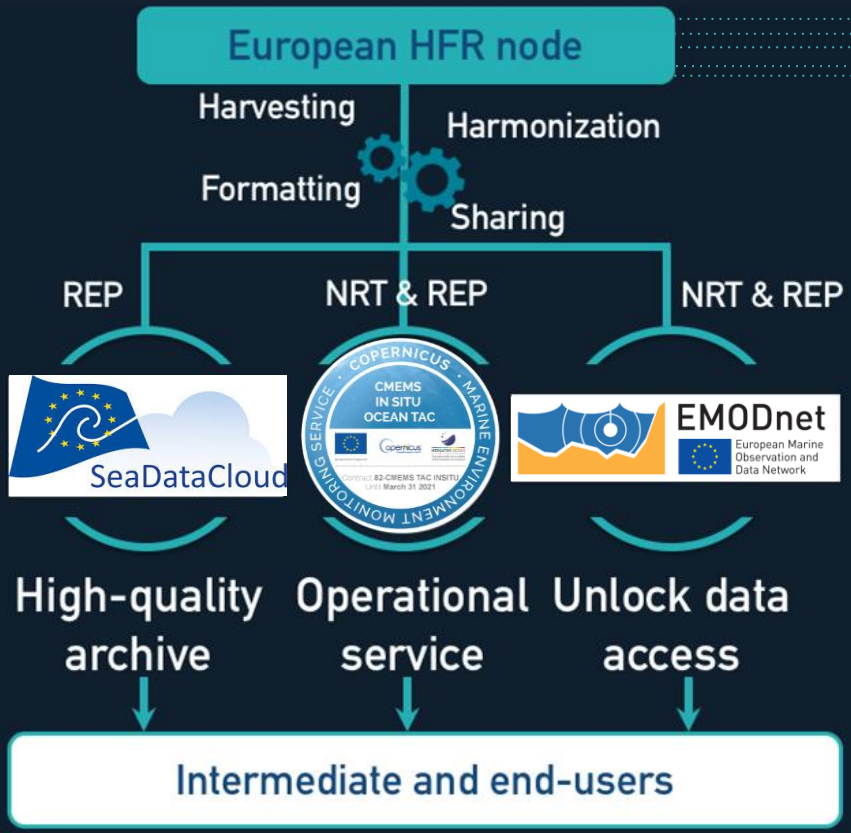
Accurate representation & prediction of coastal ocean processes is essential

Integration of high-resolution models & observations are required

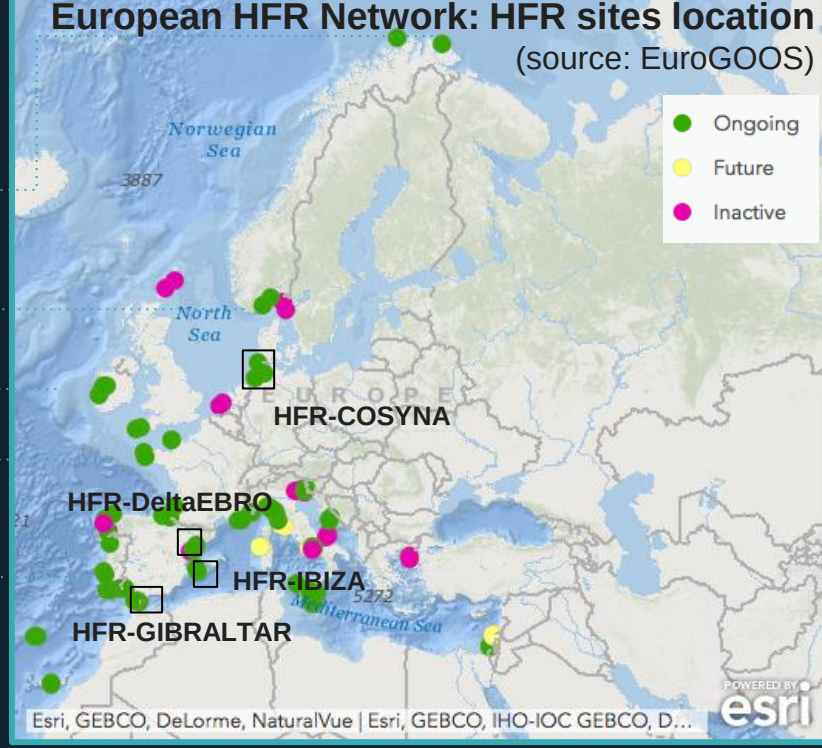
Capabilities are increasing:
- DA schemes improvement
- HFRs key features

© contains modified Copernicus Sentinel data (2017) processed by Sinergise/ESA

02 Coastal high-frequency radars



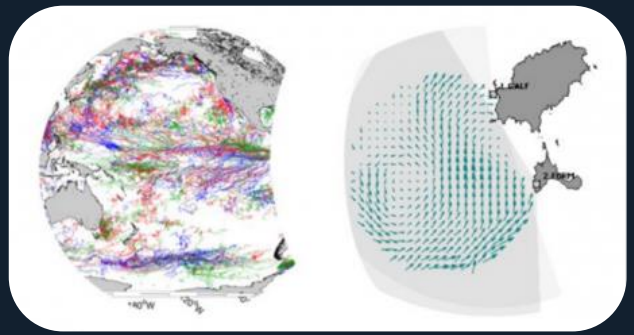
Mader et al., 2016; Rubio et al., 2017, 2020; Corgnati et al., 2018



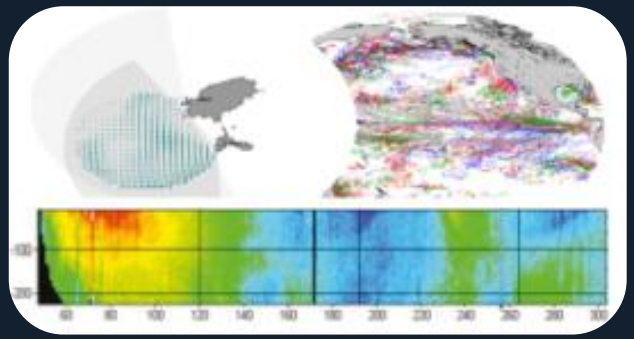
72 operational HF radar sites in Europe

- Operation principle: Bragg's theory
- 2D surface currents maps, waves & wind
- High spatial resolution (0.2-6km)
- High temporal resolution (15-60 min)
- Wide coastal coverage (up to 200 km)
- Complement coastal in-situ & satellite

02 Coastal high-frequency radars



Global Ocean In-situ NRT observations of Ocean Currents



Global Ocean delayed-mode In-situ Observations of surface and subsurface water velocity

HFRs Quality Control Tests

8 QC HFR_radial*	6 QC HFR_total*
Syntax check	Syntax check
Over-water	Data density threshold
Velocity threshold	Velocity threshold
Variance threshold	Variance threshold
Temporal derivative	Temporal derivative
Median filter	GDOP threshold
Average radial bearing	
Radial Count	

* CMEMS INSTAC QC for coordinate variables (TIME, POSITION, DEPTH) are also included.

Corgnati et al., 2018
Mantovani et al., 2020

HFRs Data Products @ https://marine.copernicus.eu/

02 HFR-Ibiza Channel

2 CODAR SeaSonde HF radar stations

- Frequency = 13.5 MHz
- Operational since June 2012

HF radar radial velocities

Settings

Output interval	1 h
Grid resolution	3 km
Averaging radius	6 km
Max. range rad/totals	88/65 km
Azimuth range	5º
Range cell/resolution	1.6 km
Average Depth	~0.9 m

Lana et al., 2016
Tintoré et al., 2020

02 HFR-Ibiza Channel

2 CODAR SeaSonde HF radar stations

- Frequency = 13.5 MHz
- Operational since June 2012

HF radar surface currents

Lana et al., 2016
Tintoré et al., 2020

Settings

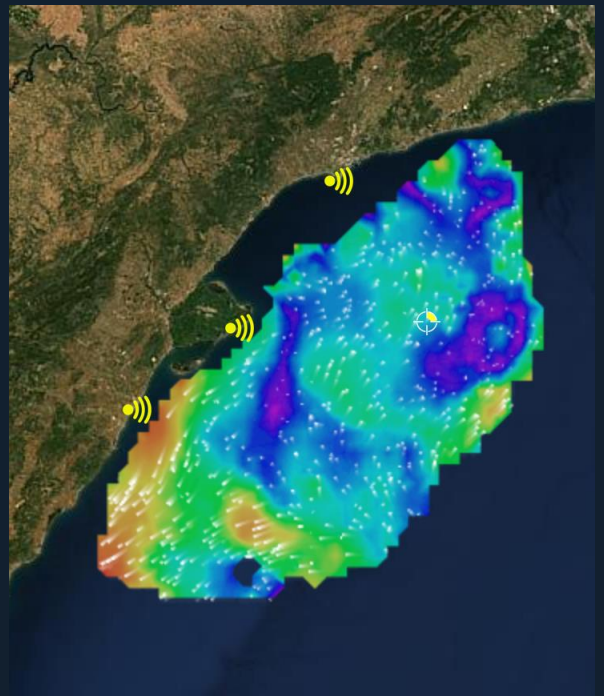
Output interval	1 h
Grid resolution	3 km
Averaging radius	6 km
Max. range rad/totals	88/65 km
Azimuth range	5º
Range cell/resolution	1.6 km
Average Depth	~0.9 m

02 HFR-DeltaEbro

3 CODAR SeaSonde HF radar stations

- Frequency = 13.5 MHz
- Operational since December 2013

HFRs pictures. Source: MONGOOS



HF radar surface currents

Screenshot of HFR-DeltaEbro surface currents available at https://portus.puertos.es/#/

Settings

Output interval	1 h
Grid resolution	3 km
Averaging radius	6 km
Max. range radials	80 km
Azimuth range	5º
Range cell/resolution	1.6 km
Average Depth	~0.9 m

Lorente et al., 2015

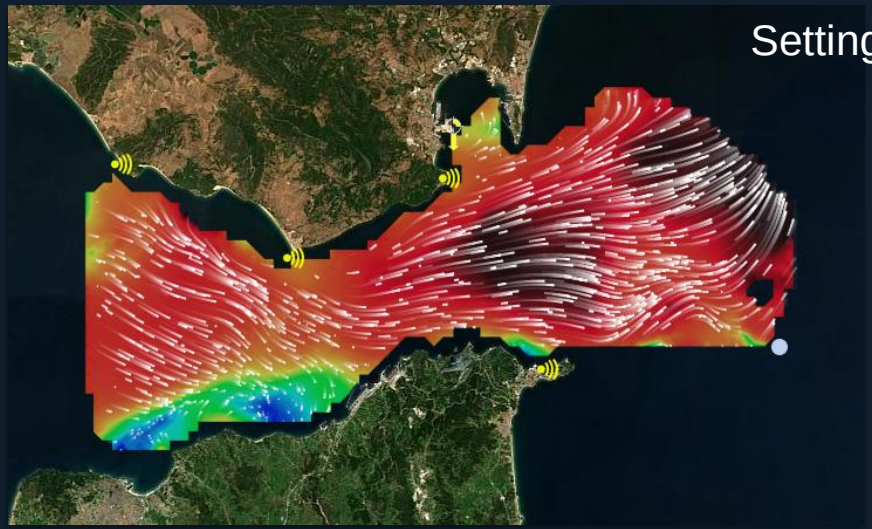
02 HFR-Gibraltar Strait

4 CODAR SeaSonde HF radar stations

- Frequency = 26.275 MHz
- Operational since May 2011

Camarinal HFR site. Picture: Marina Bolado

HF radar surface currents



Screenshot of HFR-Gibraltar surface currents available at https://portus.puertos.es/#/

Settings

Output interval	1 h
Grid resolution	1 km
Averaging radius	3 km
Max. range rad/totals	40 km
Azimuth range	5º
Range cell/resolution	0.99 km
Average Depth	~0.5 m

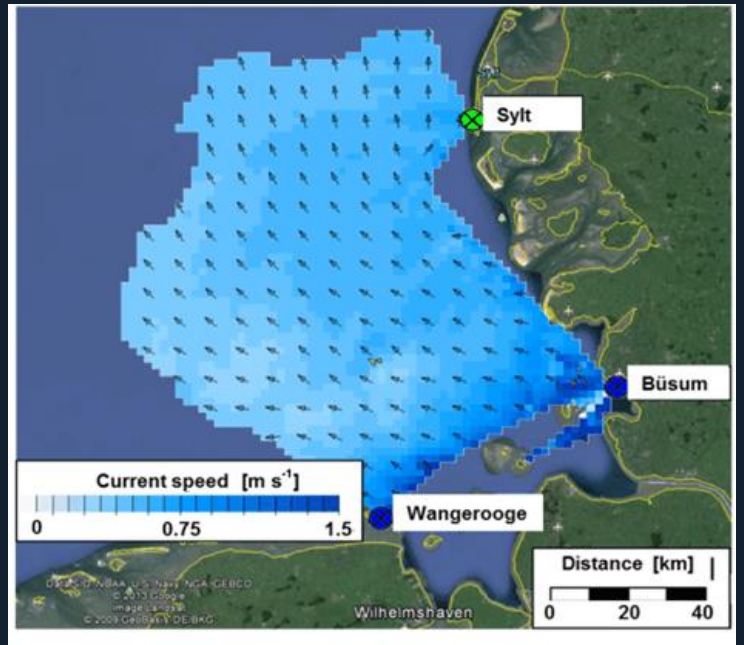
Soto Navarro et al., 2016

02 HFR-COSYNA: German Bight

3 WERA radar stations

- Frequency = 10.8 and 12.5 MHz
- Operational since Feb 2007

HF radar surface currents



Baschek et al., 2017

Baschek et al., 2017

Settings

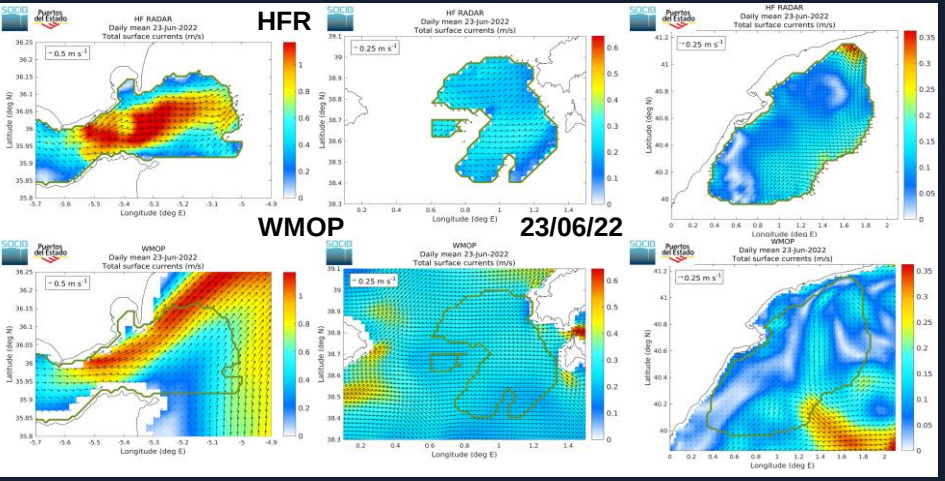
Output interval	20 min
Grid resolution	2 km
Range	120 km
Average Depth	~0.95-1.11 m

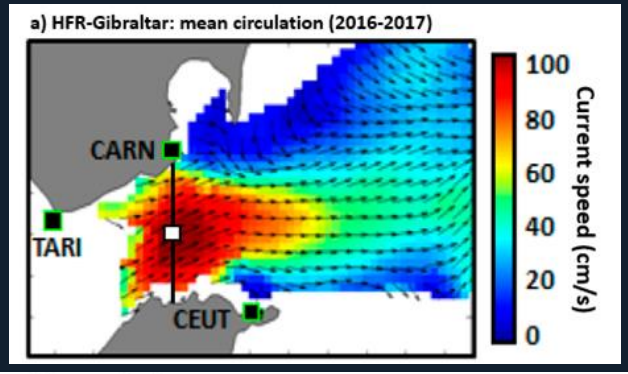
03 HFRs applications: model assessment & improvement

WMOP system vs HFRs

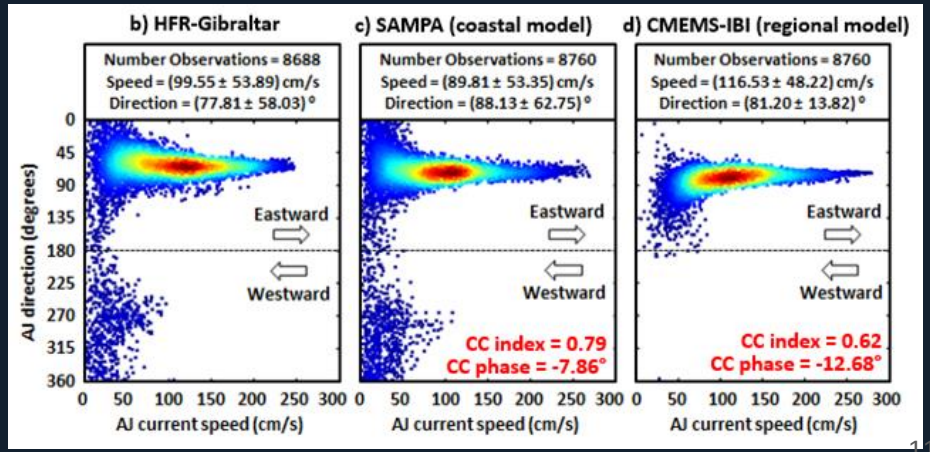
IBI-MFC and SAMPA (child) models vs. HFR-Gibraltar

HFR-Gibraltar HFR-Ibiza HFR-DeltaEbro





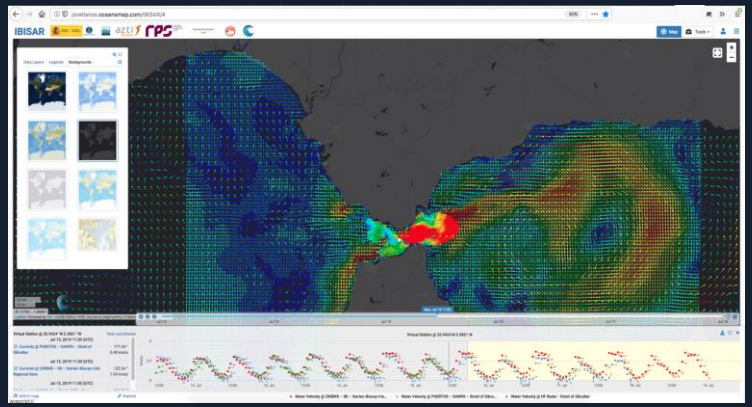
Lorente et al., 2019



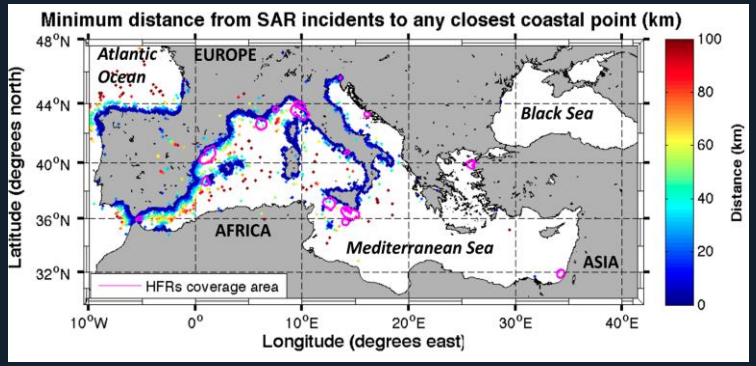
Mourre et al., 2018

03 HFRs applications: model assessment & improvement

IBISAR: Skill assessment services for Search and Rescue operators



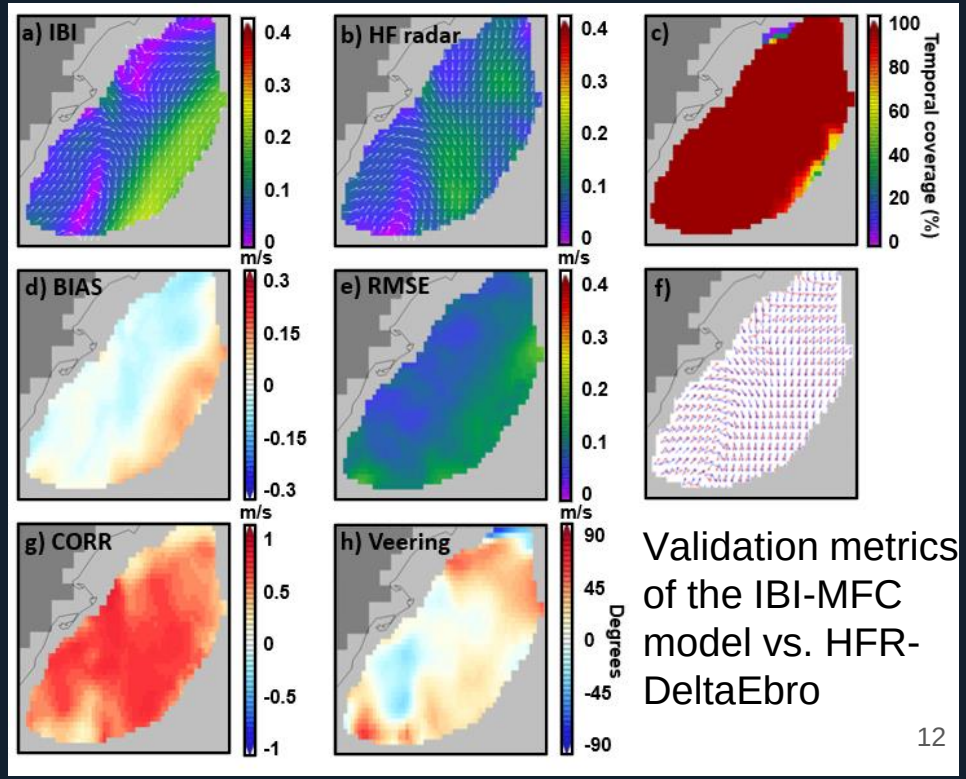
Reyes et al., 2020



Reyes et al., 2022

NARVAL: North Atlantic Regional VALidation
Regional and coastal models skill assessment tool

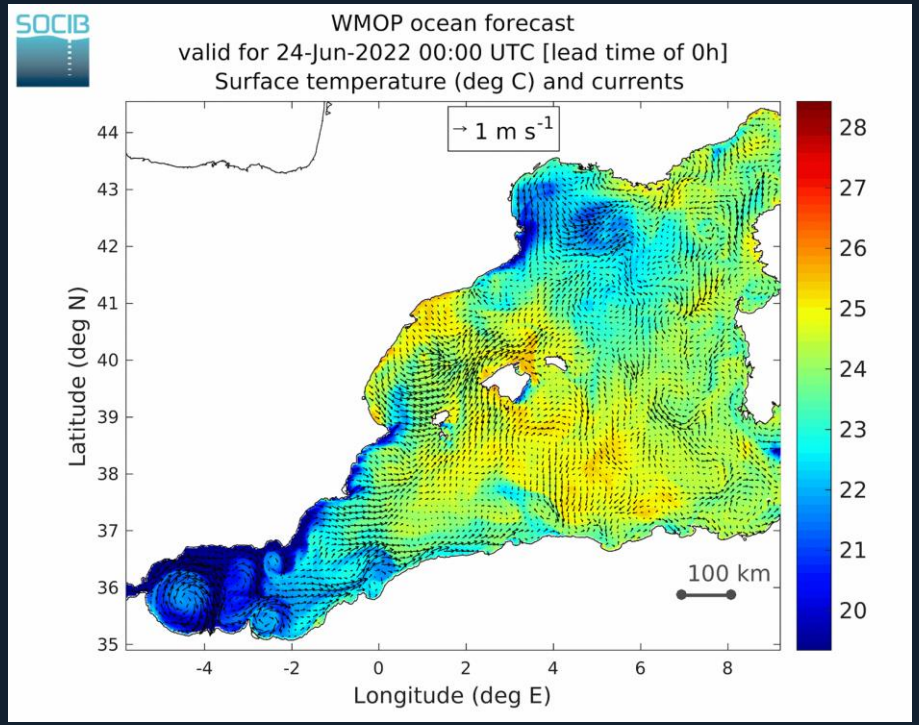
Lorente et al., 2019



Validation metrics of the IBI-MFC model vs. HFR-DeltaEbro

04 Forecasting systems: WMOP and COSYNA

WMOP: Western Mediterranean OPerational model System



Forecast available at www.socib.es

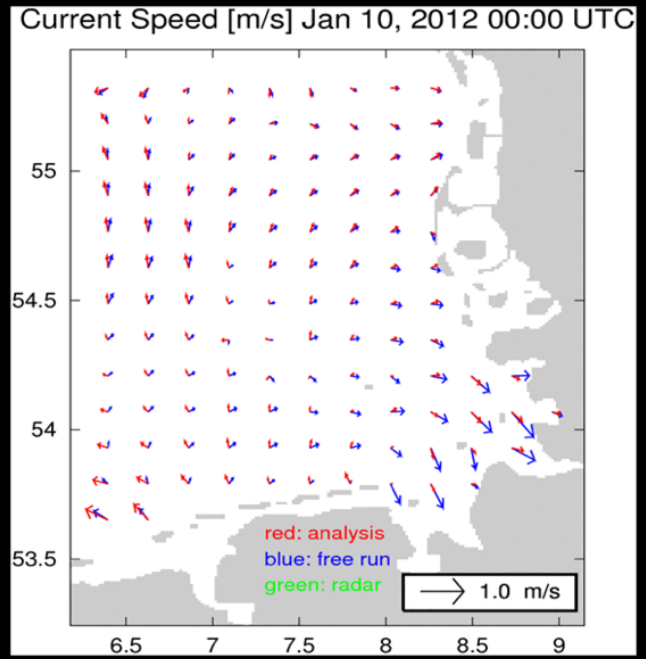
WMOP configuration

Spatial domain	Western Mediterranean (Gibraltar to Sardinia-Corsica)
Forecast length	72 hours
Horizontal resolution	~2 km (~1/50º)
Vertical resolution	32 σ-levels
Output resolution	3 h
Atmospheric forcings	AEMET Harmonie (1h/2.5km)
Initial & boundary conditions	CMEMS Med Forecast (1/24º, daily)
Data Assimilation	SLA along-track, L4 SST, Argo & gliders T-S profiles, HFR totals (daily)

Juza et al., 2016, Mourre et al., 2018

04 Forecasting systems: WMOP and COSYNA

COSYNA- IMCO: Coastal Observing System for Northern and Arctic Seas - Invertible Model for the Coastal Ocean



Forecast available at http://codm.hzg.de/codm/register.jsp

COSYNA-IMCO model configuration

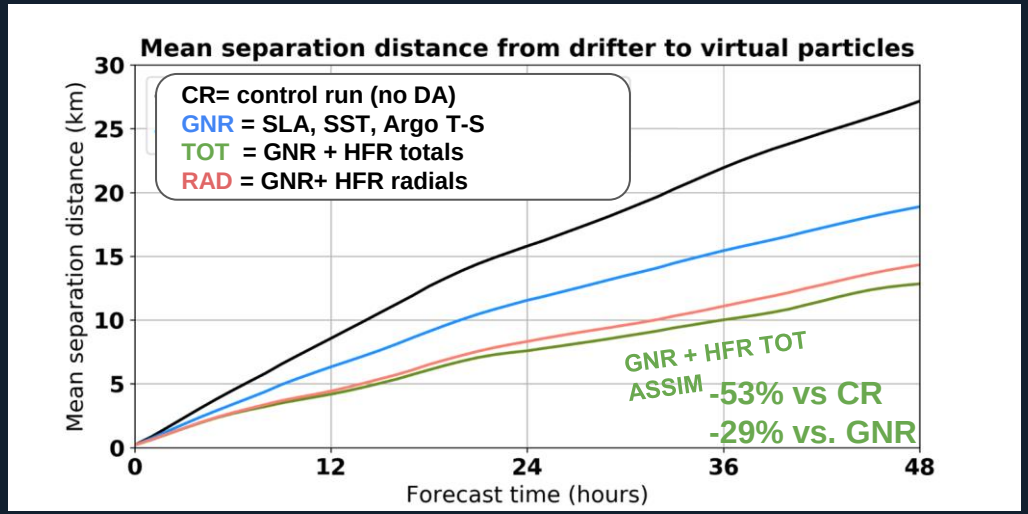
Spatial domain	German Bight (North Sea)
Forecast length	12 hours
Horizontal resolution	1 km
Vertical resolution	21 σ-levels
Output resolution	1 h
Atmospheric forcings	DWD* wind (1h/7km)
Initial & boundary conditions	North Sea 3NM model
Assimilation	HFR radial (20’, 2 km)

* Deutsche Wetterdienst

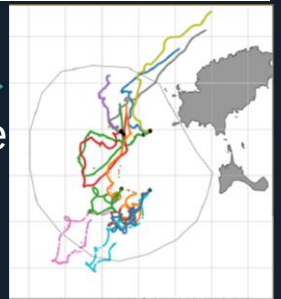
Schulz-Stellenfleth et al., 2022

05 HFR data assimilation in WMOP and COSYNA

WMOP Data Assimilation results



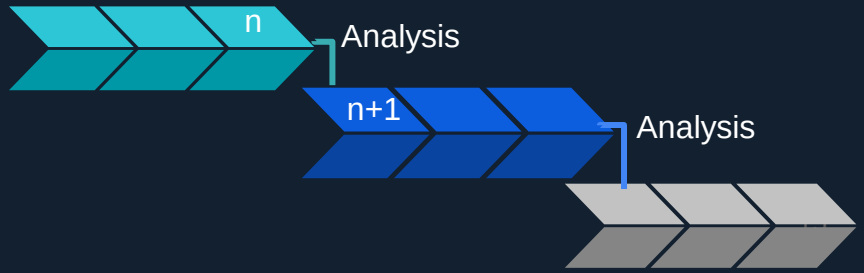
HFR DA improves the prediction of Lagrangian trajectories reducing the mean separation distance by 53% vs. CR and 29% vs. GNR.



Hernández-Lasheras et al., 2021

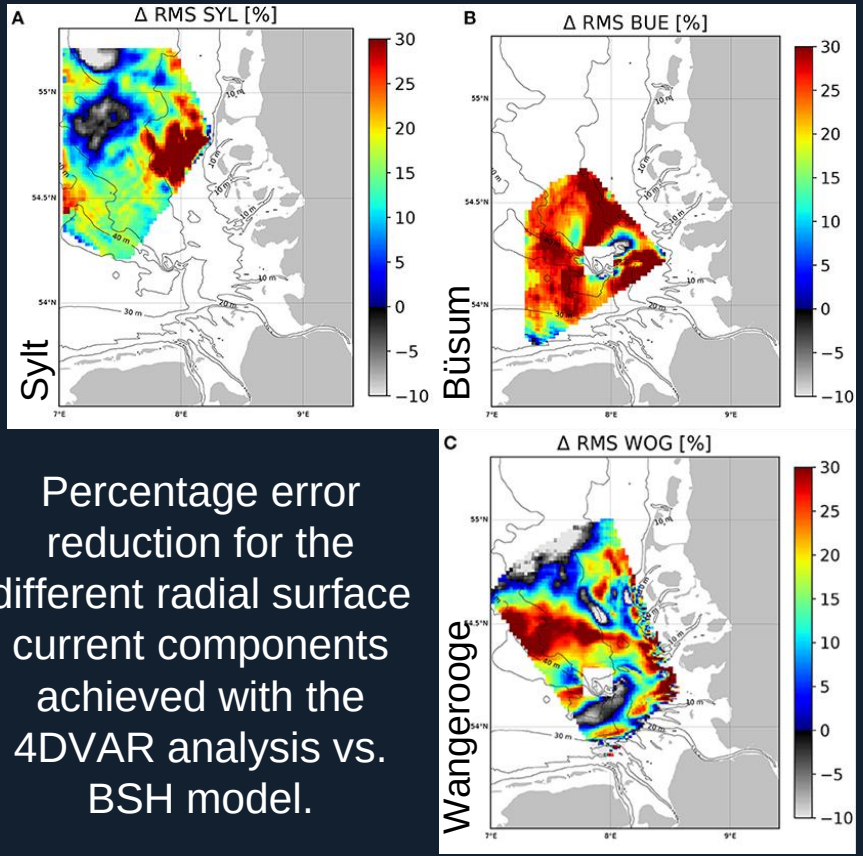
WMOP - DA System

Scheme	Local multi-model Ensemble Optimal Interpolation (EnOI)
HFR data	Radial /Total (daily mean)
Num. Ensemble	80
Domain localization	200 km radius
Backg. error cov.	Stationary ensemble
Initialization	analysis



05 HFR data assimilation in WMOP and COSYNA

COSYNA Data Assimilation Results



Schulz-Stellenfleth et al., 2022

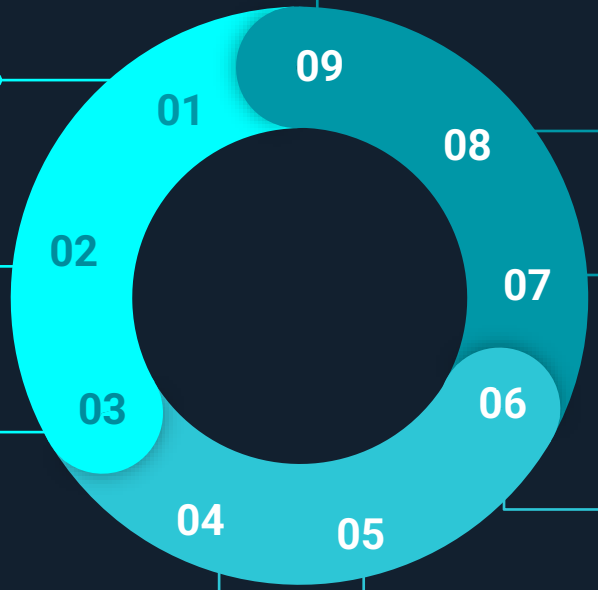
Percentage error reduction for the different radial surface current components achieved with the 4DVAR analysis vs. BSH model.

COSYNA - DA Scheme

Scheme	4DVAR variational optimisation
HFR data	Radials (hourly)
Other observations	Sea level, ADCP
Corrections included in the control vector	- Seafloor roughness, - open boundary forcing, - wind forcing, - turbulence and - vertical momentum diffusion.
Dynamics	Dominated by barotropic processes with short time scales.

Stanev et al., 2015, Schulz-Stellenfleth et al.,2021, 2022

06 Conclusions and remarks



01 HFRs DA helps to assess & improve the model performance

02 HFR radial DA: easier error characterization and higher coverage

03 Consensus needed about the Stokes contribution in the HFR data

04 HFR and tide gauges combination adds information on transport

05 DA dedicated approaches required for diverse coastal regions, processes & time-scales

06 HFR observation & model error covariances should be characterized and available

07 Robust operational DA schemes needed to exploit the HFR high-temporal resolution

08 Need to further analyze numerical approaches to minimize the cost function

09 HFR DA should be boosted to improve operational high-resolution coastal models

SOCIB Sistema de Observación y Predicción Costero de las Illes Balears

Thank you very much!

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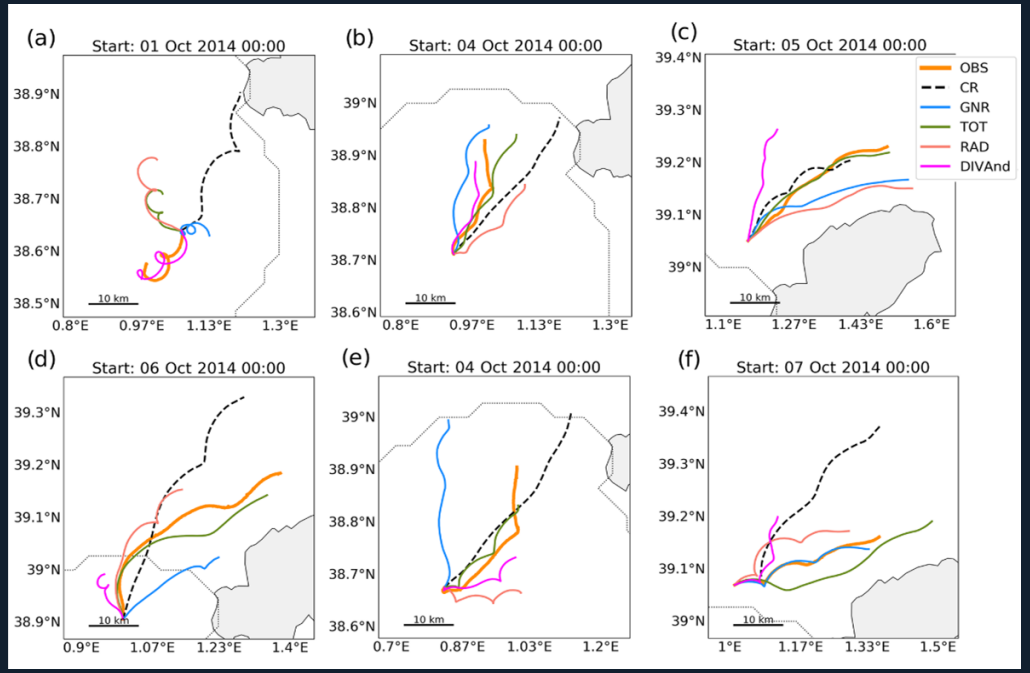
Supplementary material

Real.vs.simulated trajectories maps for different WMOP DA experiments



WMOP - DA System (nesting)