Surface current reconstruction from single HF/VHF coastal radar site

Julien Marmain, Philippe Forget, Anne Molcard
LSEET-CNRS (UMR 6017), Sud Toulon-Var University , France

Introduction

Surface current mapping from HF/VHF coastal radars needs two distant stations to reconstruct the current field from radial velocity data. However, it can happen that only one radar is available, e.g. due to failure of the other one.

Here, we try to reconstruct the current vector field from a single radar station. We assume non divergence of the surface flow as in Frish and Leise (1981), Lipa and Barrick (1983) and Liu et al. (1999).

The method (CMVR: Characteristics Method for Vector Reconstruction) consists in solving the partial differential equation governing the stream function.

The method is tested on modeled current off Provence coasts, on VHF data collected in Italy and on recent data acquired by a single HF station near Toulon.

Method

The reconstruction method CMVR uses radial velocity data measured by a single station (Vr). Vr represents the projection of the horizontal Cartesian current field (u,v) along the radial axis. θ being the angle between zonal and radial axis, Vr is expressed as

$$Vr = u\cos\theta + v\sin\theta \quad (1)$$

The 3-D incompressibility condition is $\vec{\nabla}.\vec{V} \equiv \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$

If the surface flow is non divergent, *i.e.* there is no acceleration on the vertical, this condition writes

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (2)$$

(2) allows to introduce the stream function (ψ) defined by

$$u = -\left(\frac{\partial \Psi}{\partial y}\right)_{x=cte} \quad , \quad v = \left(\frac{\partial \Psi}{\partial x}\right)_{y=cte} \quad (3)$$

Using cylindrical coordinates, the total differential of the stream function writes

$$d\psi = \left(\frac{\partial \psi}{\partial r}\right)_{\theta} dr + \left(\frac{\partial \psi}{\partial \theta}\right)_{r} d\theta = V_\theta dr - rV_r d\theta \quad (4)$$

For a constant radius / range, (4) writes $d\psi = -rV_r d\theta \quad (5)$

This PDE is solved by the characteristics method. The PDE's characteristics are concentric circles centered at the radar location. At each range, ψ is computed along the characteristic starting from coasts where ψ = cste = ψ_0.

$$\psi(r,\theta) = -r\int_{\theta_0}^{\theta} V_r d\theta \quad (6)$$

The numerical scheme is at first-order of discretization and writes

$$\psi(r,\theta+\Delta\theta) = \psi(r,\theta) - rV_r(r,\theta)\Delta\theta \quad (7)$$

This method involves a boundary condition and implicitely requires that the radar coverage intercepts the coast at one of its lateral extremities.

Generally, it is convenient to set the value of ψ on the coast. For a continuous coast, ψ_0 is constant due to impermeability condition.

Note that the stream function homogeneity between continental coasts and islands is not expected.

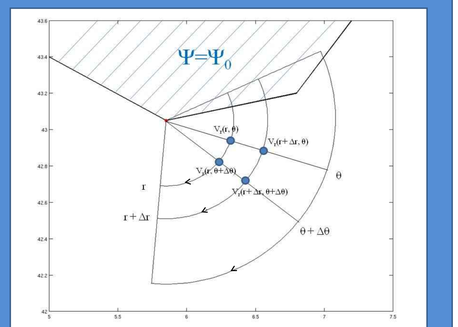


Fig. 1: Implementation scheme of CMVR

Application to modeled data (NEMO)

NEMO (Nucleus for European Models of the Ocean) is an ocean general circulation model based on the free surface primitive equations. A high resolution configuration of NEMO, GLAZUR 64, was developed by LSEET to study circulation in the North Western Mediterranean basin. It extends from Spanish coasts to French Riviera (Fig. 2) and has a horizontal resolution of 1/64° on a regular Mercator mesh (~1.25 x 1.25 km²). There are 130 z-levels in the vertical with spacing ranging from 1 m in the first 35 m to 30 m near the bottom in the abyssal plain (2665 m) (Langlais et al., 2009).

We use NEMO results to obtain synthetic surface radial velocities which we suppose to represent radar observations. No noise was introduced in these data.

Two distinct typical regions are investigated. The first one, gulf of Lion, presents smooth coastlines. The second one, Provence coastal zone, is characterized by complex coastlines, including islands, peninsulas and capes.

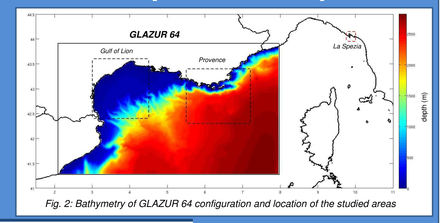
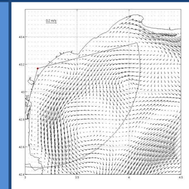
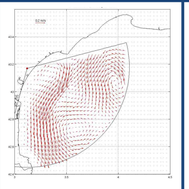
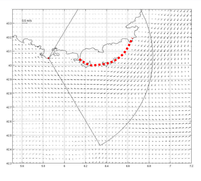
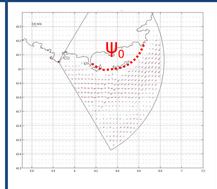
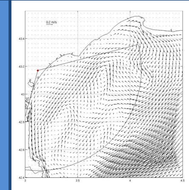
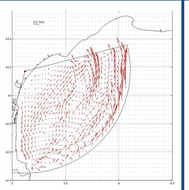
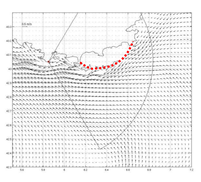
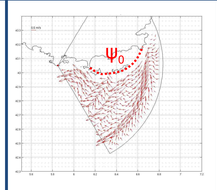


Fig. 2: Bathymetry of GLAZUR 64 configuration and location of the studied areas

Divergence	gulf of Lion		Provence	
	modeled surface current	reconstructed	modeled surface current	reconstructed
weak				
high				

➔ As expected, the quality of the reconstruction is highly dependent on the degree of divergence.

➔ The reconstructed current field can be locally satisfactory.

➔ For the Provence case, the complexity of coasts needs to consider a fictitious boundary. This affects the accuracy of the method.

Application to real data: La Spezia

Table1: Main radar characteristics

Central frequency (MHz)	45,25
Bragg wavelength (m)	3,31
Bandwith (kHz)	500
Processed range resolution (m)	600
Azimuthal resolution (°)	5
Radial speed resolution (cm/s)	1,5

The data were acquired in the framework of the Marine Rapid Environment Assesment exercise LASIE in the Ligurian Sea, and as part of the coastal component experiment POET focused on the Gulf of La Spezia. A dual station of VHF WERA was deployed in june 2007 (Fig. 3, Table 1) [Molcard & al. ,2009].

We compare results of the CMVR method applied to the single site radar ENEA to surface current fields obtained by combination of measurements from both radars. Note the quasi-straight coastline delimiting ENEA radar's coverage.

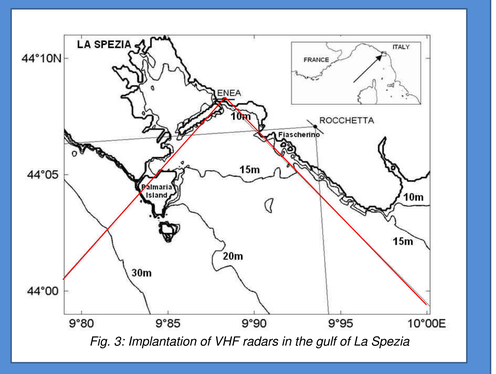
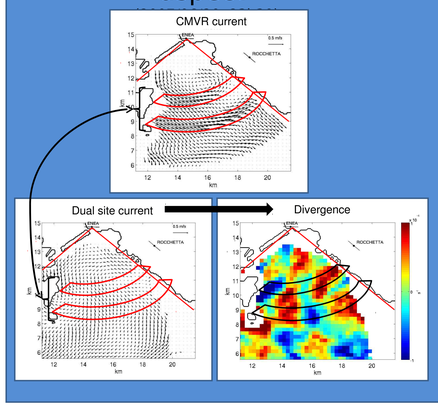


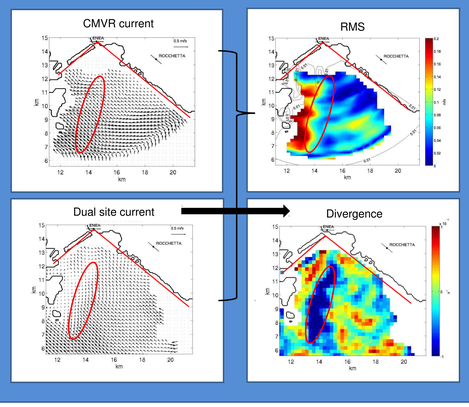
Fig. 3: Implantation of VHF radars in the gulf of La Spezia

Qualitative aspect



Quantitative aspect

(2007/06/22, 01h30)

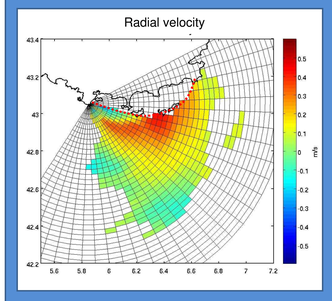


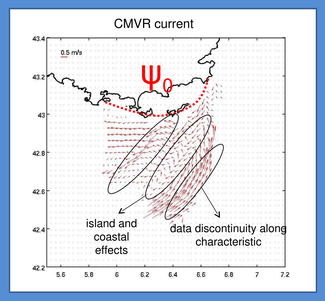
➔ Reconstruction is satisfactory (small RMS) in regions of weak divergence.

➔ Interception of divergence patches by characteristics involves typical circular features which delimit regions of bad values.

➔ These features are hardly distinguishable for radially extended patches.

Application to a single site radar: Toulon





To study the coastal Provence circulation, LSEET is currently deploying a dual station of HF WERA. At the moment, only one site is available since May 2010. CMVR method is applied to this single site radar configuration. Raw data are smoothed. Land is assumed to extend up to the dotted red line.

On this example, we can see a background coastal current. However, currents calculated along characteristics starting between the islands seem wrong.

➔ Irregular coastlines and islands constitute an environment which seems too far from the conditions required by CMVR method (straight coastline).

Conclusion

The quality of the inverted current field from single site radar using CMVR is quite good for low divergent flows and for simple coastline (gulf of Lion, gulf of La Spezia).

In the Provence zone, in addition to the possible influence of divergence zones, the validity of the method seems penalized by the complex coastline geometry, especially due to presence of islands. This problem is still under investigation using interpolation/extrapolation methods to fill the radar data gaps near the coast.

References

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