Eddy HF radar observations in the Gulf of Lions

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The geographical and scientific context

HF-radar system and observations

eddy characterization

numerical study of generation mechanism
North-Western Mediterranean

- Northern current following the continental slope in the Gulf of Lion from background surface cyclonic circulation
- Deep water formation
- Complex coastline
- High mesoscale activity

SAR detected vortices in the period between 1996 and 1998 (A. Platonov & al., 2007)

SeaWIFS Chl-a 08/06/1999
ECOLO French program (p nec/ ec2co) + COLARGOL (LEFE-IDAO)

- 2005-2007

- coastal-open ocean exchanges: controlling mechanisms (bathymetry, hydrology, wind-forcing, waves...)

- interactions between the Northern Current and the Rhone outflow => generation of secondary and sub-mesoscale structures

- response of the system to wind forcings

- annual and interannual budgets

- LSEET contribution: HF-radar experiment

(thanks to Yves Barbin, Philippe Forget, Joel Gaggelli)
Coastal radar WERA: how does it work?

Discretization:
1. Azimuthal range
2. Azimuthal resolution
3. Radial resolution

http://ifmaxp1.ifm.uni-hamburg.de/WERA.shtml
HF-radar observations in the Gulf of Lions
System capabilities and specifications
HF WERA radar

- 2 sites 40-km apart
- 16.2 MHz: spatial resolution 3km
- Reception 12-antenna (Salin)- 4-antenna (Frioul) linear array
- Emission 4-antenna rectangular array
- Available data: surface current maps from June 2005 to March 2007 over a 50X80 km2 domain.
- Every half hour radial maps combined for horizontal current maps.
- Direction Finding Method
Radar observations in the Gulf of Lions

Inertial circulation

14.05.2006 12:00

1 m/s

Anticyclonic circulation

29.12.2006 06:00

1 m/s
Eddy events and lifetime

- Maximum lifetime ~ 3 days
- Irregular event
  (5 times in December 2006)
Eddy characteristics

- Anticyclonic
- Core ~ (5°E, 43.15°N)
- Diameter ~ 40km
- Maximum speed ~ 0.4m/s

How do they form?
Why such a lifetime variability?
Why do/don't they migrate?
Other in-situ data evidence an eddy at same location at various depth

Petrenko & al, 2002 (ADCP)

Allou et al., 2010
(surface HF radars + ADCP, 50m)

Hull-mounted ADCP (Téthys II)
What are the possible driving mechanisms?

- Wind forcing: specific and strong, high temporal and spatial variability
- Bathymetric: Complex bathymetry and coastline, shallow (<100m)
- Intrusions of Northern Current
- Rhône outflow
- Buoyancy forcing
Wind forcing as driving mechanism for eddy generation: correlation between wind and eddy evidence?

Mean wind field

Buoy (4.7E, 42.1N)

Model at buoy location (4.7E, 42.1N)

Model at eddy location (5.1E, 43.1N)
EOF analysis of MM5 wind (dec2006)

Wind intensity comparison: MM5 / buoy

Mean wind field

First mode

First mode amplitude
Modelling

Hydrodynamic model: MARS3D (Model for Application at Regional Scale)
- PE, hydrostatic and Boussinesq approximation
- sigma coordinate, free surface (Blumberg and Mellor, 1987)
- resolution: \( dx = 1.2 \) km, 30 sigma levels

Realistic modelling (MENOR):
- Nesting by Mediterranean Forecasting System
- No data assimilation
- Wind from MM5 (NCAR, \( dx = 9 \) km, \( dt = 3 \) h)
  No reproduction of eddy events at right time

Eddies could result from the interaction between several forcings
- idealized study to better understand their relative influence
Process oriented study

test different idealized winds (from EOF analysis) & control all the different forcings & understand their relative influence

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<th>Configuration option</th>
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<th>2</th>
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<tr>
<td>Bathymetry</td>
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<td>realistic</td>
<td>Flat 200m-shelf</td>
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<td>Northern current</td>
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<td>Rhône river runoff</td>
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<tr>
<td>Wind forcing</td>
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<td>northerly</td>
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Different bathymetries
Initial homogeneous T,S distribution, with a vertical profile (from realistic model, central point of the domain)

Eastern BC: T,S signature (from realistic model)

1 month spin-up

« realistic NC »: ~500m depth ~ 35km wide at surface |u|max ~ 0.35m/s; weak intrusion into the gulf, follows the continental shelf

Density and current section at 6°E

Surface temperature and currents
Generation mechanism I

Strong northerly wind forcing & Wind relaxation

Eddy generated at depth by bathymetric constrain of a coastal south-easterward jet, apparent at surface after wind relaxation.

Only with realistic bathymetry and coastline; NC and river runoff not necessary, but reinforce the eddy in intensity.
Strong southerly & wind relaxation

Eddy generated at surface: by density gradient on a freshwater bulge on Marseille bay.

Only with Rhône river runoff and realistic coastline; NC not necessary, but reinforce the eddy in intensity.
... toward realistic modelled winds:

- Wind intensity underestimated?
  → MM5 intensity*1.5

- Wind relaxation underestimated?

Depth-averaged currents

Surface eddy
Realistic modelling: other dates, same mechanism

06/16/200 8 3h

05/03/200 8 15h
Conclusions

- The « ECOLO » campaign shows the existence of a strong, repeated & intermittent mesoscale structure with variable lifetime. The influence of wind forcing is analyzed using an academic numerical study, and ends to be certainly one of the generation mechanism.

- Numerical reproduction of the event depends on the temporal resolution (relaxation).

- HF-radar is a powerful surface current observation tool, for monitoring the coastal circulation and evidence dispersion/retention processes. Needs to be complementary to other measurements (drifters, ADCP).

- **Future plans**

  Amandine Schaeffer PhD: Study other forcings (northern current intrusion, Rhône plume, buoyancy) and interactions, as possible driving mechanisms; Improve wind forcing (spatial and temporal resolution) by using Arome (MeteoFrance).

  LSEET HF-radar experiments in the NW Med Sea:
  - VHF in 2007 in the Gulf of La Spezia (MREA),
  - summer 2010 permanent HF radar in the Var coast,
  - september 2010 HF western Gulf of Lions (LATEX ),
  - in the future a CODAR system in Nice.