

# **Surface Geostrophic Circulation of the Mediterranean Sea Derived from Drifter and Satellite Altimeter Data**

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with contributions from: M. Menna & E. Mauri  
and many others who helped with instrument deployments/recoveries, who shared their  
data, etc.

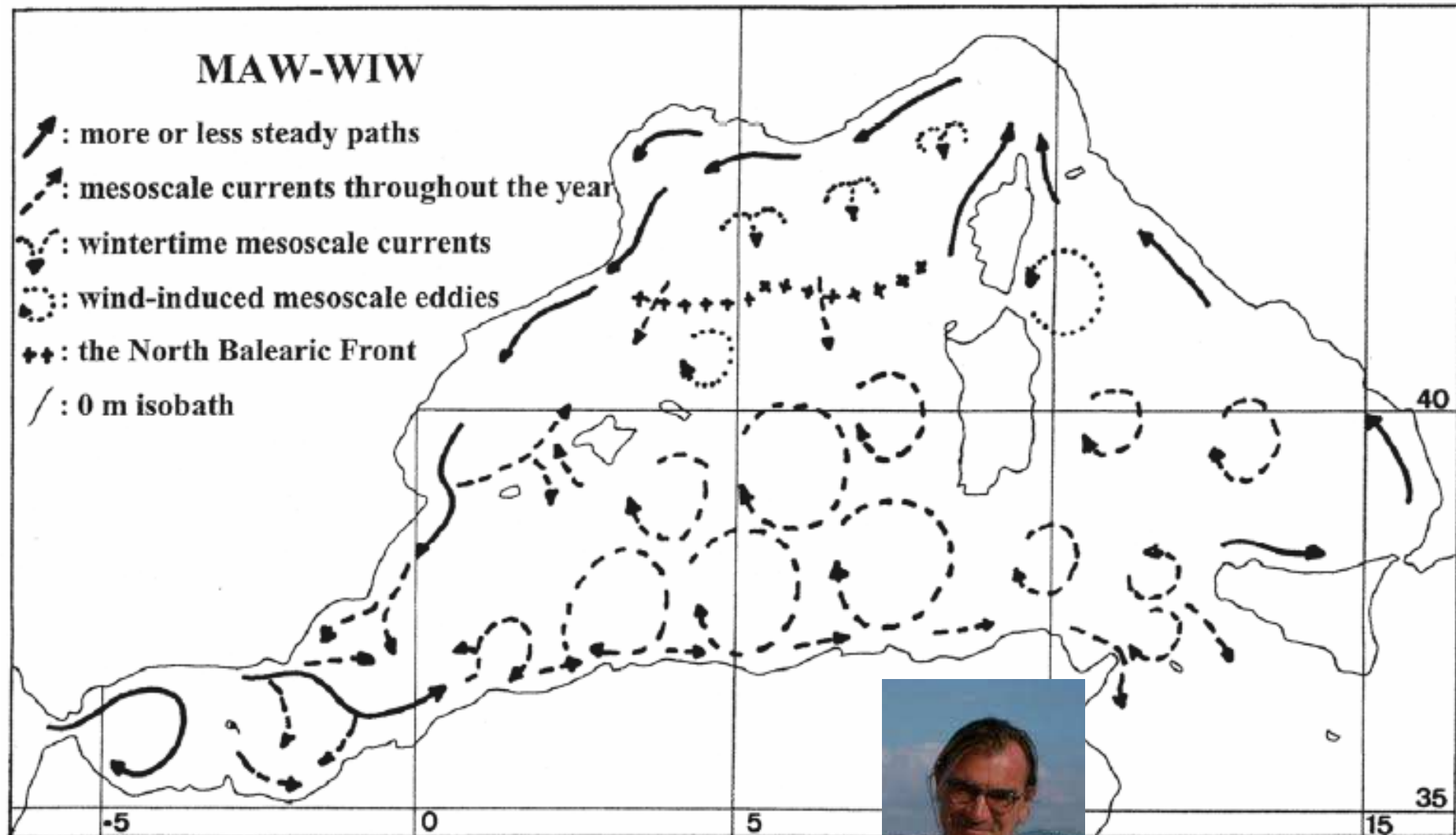
## Objective:

Describe the spatial structure and temporal variability of the surface throughout the entire Mediterranean Sea.

## Outline:

- Mediterranean circulation background
- Surface drifters
- Pseudo-Eulerian statistics of surface circulation
  - Mean flow and “eddy” variability in selected basins
- Combination with satellite altimetry data to obtain maps of unbiased mean geostrophic circulation of the Mediterranean:
  - statistical methods
  - results.

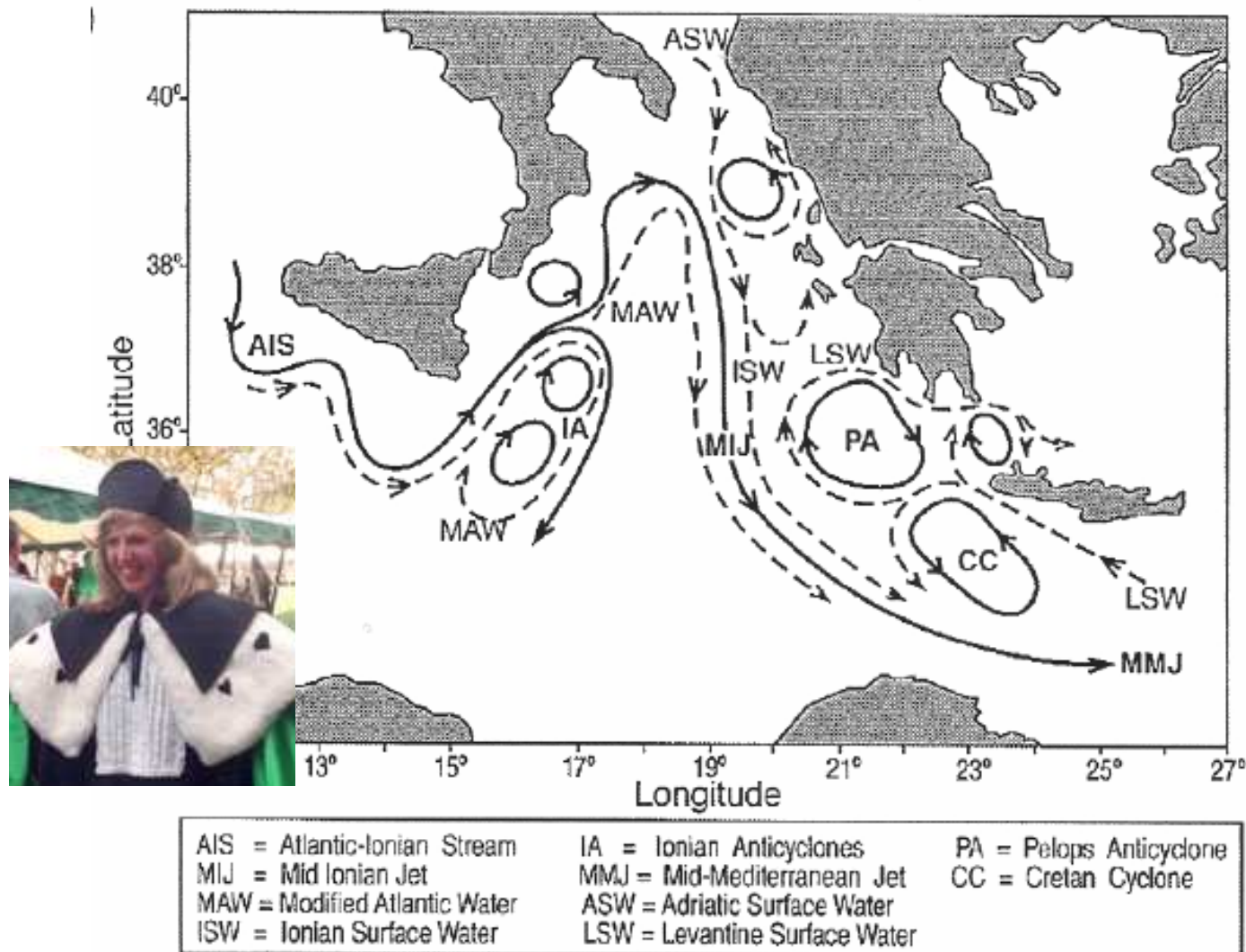
# Background



Millot (1999)



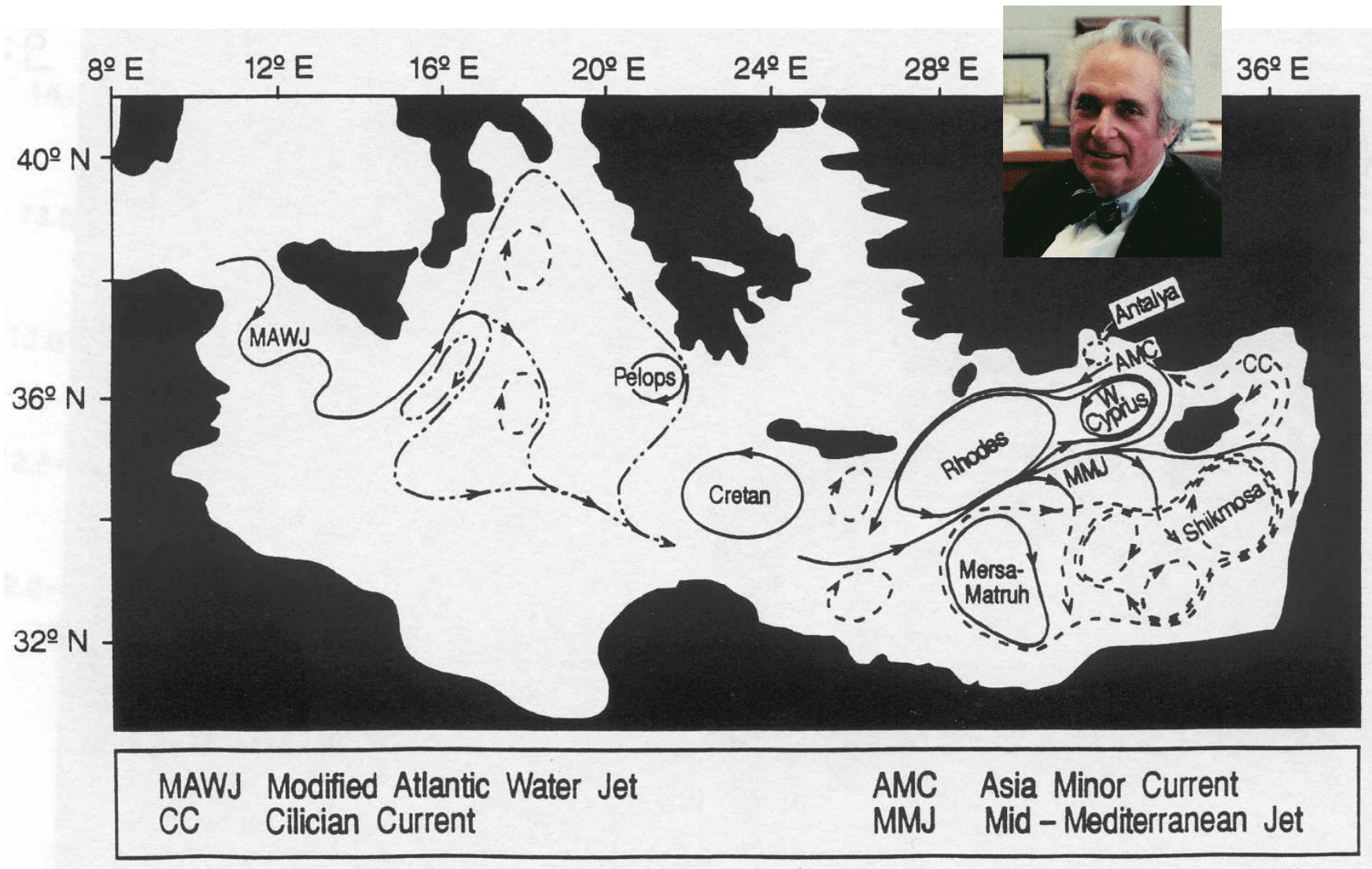
# Background



Malanotte-Rizzoli et al. (1997) - POEM

IMEDEA, Esporles, Spain, 4 July 2012

# Background



Robinson and Golnaraghi (1993) - POEM

IMEDEA, Esporles, Spain, 4 July 2012



# Surface Drifters



SVP

CODE

CMOD

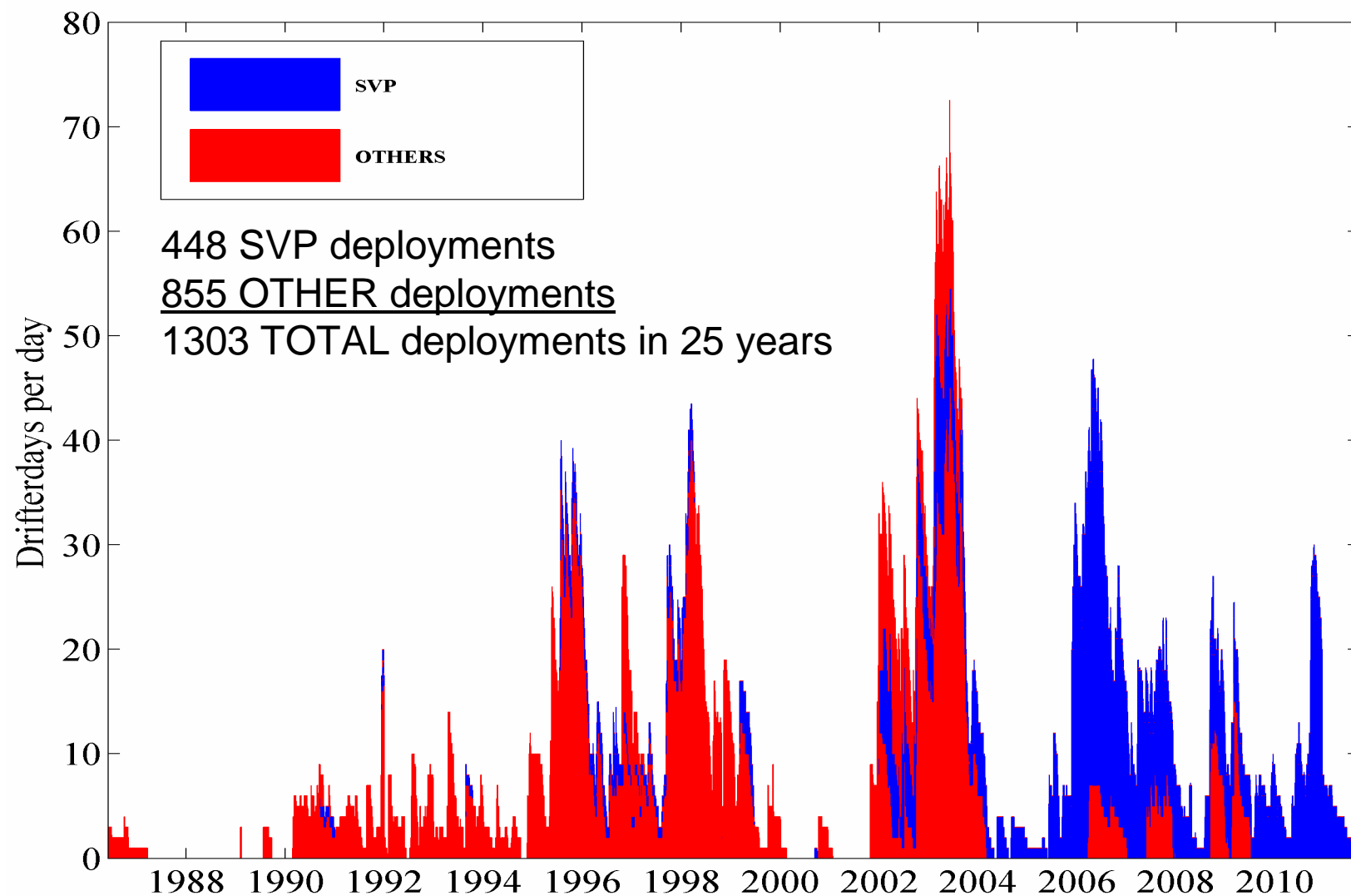


# Surface Drifters



IMEDEA, Esporles, Spain, 4 July 2012

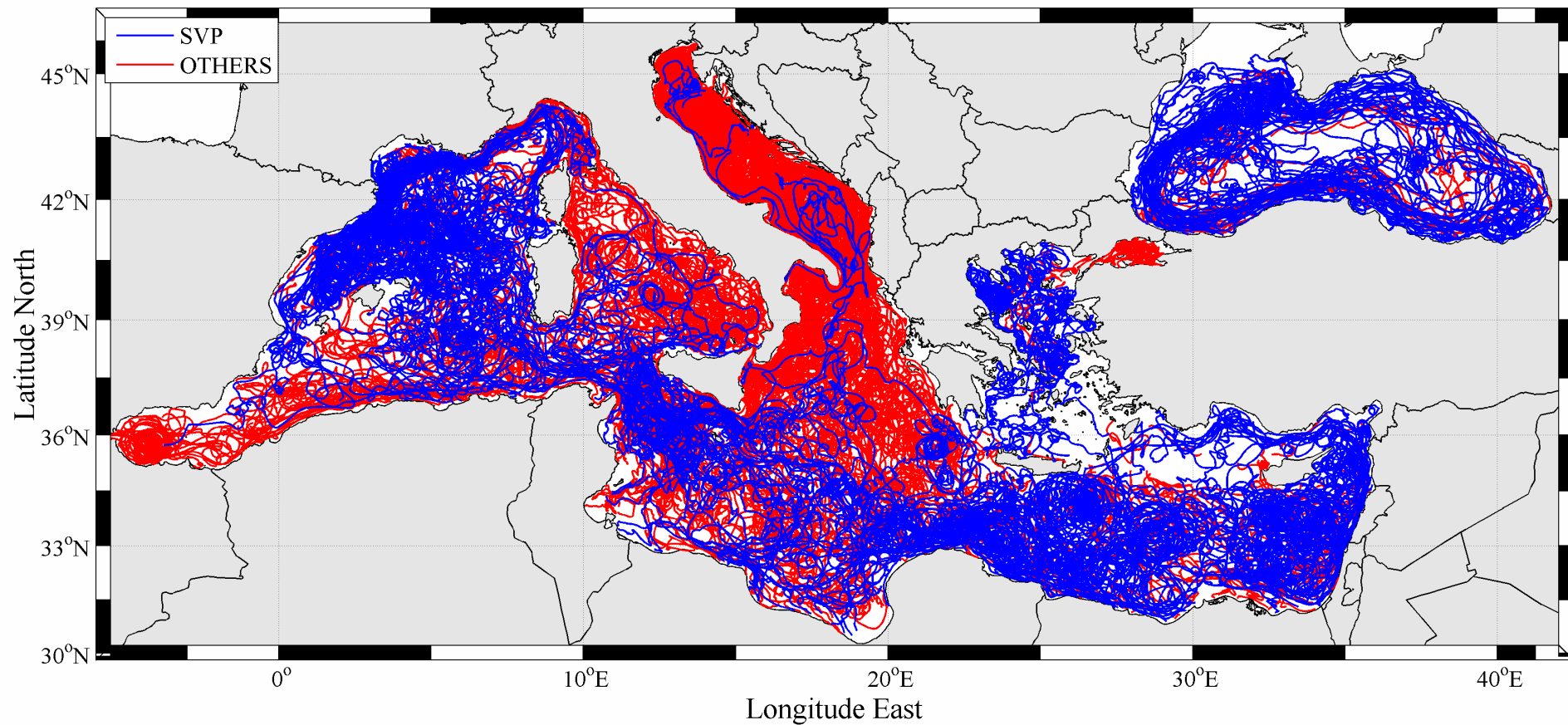
# Surface Drifters



Surface drifters in the Mediterranean and Black Seas



# Surface Drifters



Surface drifters in the Mediterranean and Black Seas

# Surface Drifters



**Only 1 drifter currently  
active in the Mediterranean  
& Black Seas!!!**

**See MedSVP web pages:**

<http://nettuno.ogs.trieste.it/sire/medsvp>

**MedSVP is part of the Global  
Drifter Program (GDP)  
See GDP web pages:**

<http://www.aoml.noaa.gov/phod/dac>

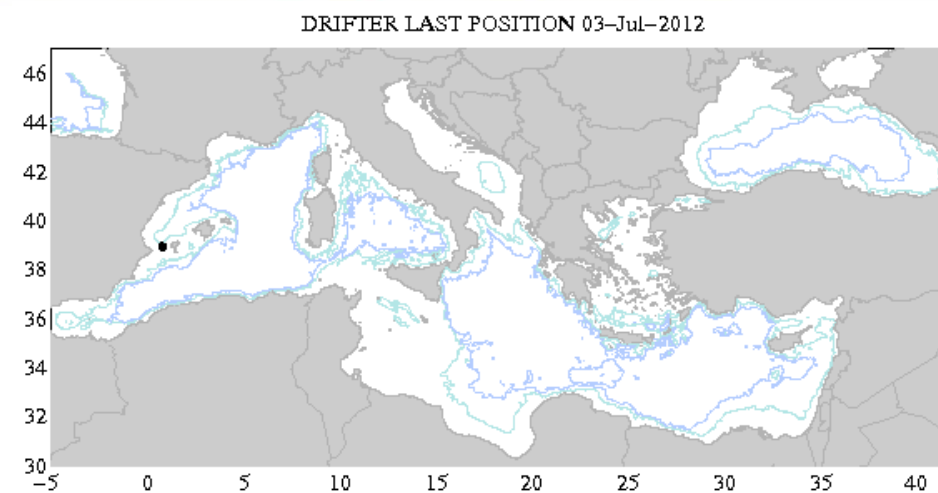
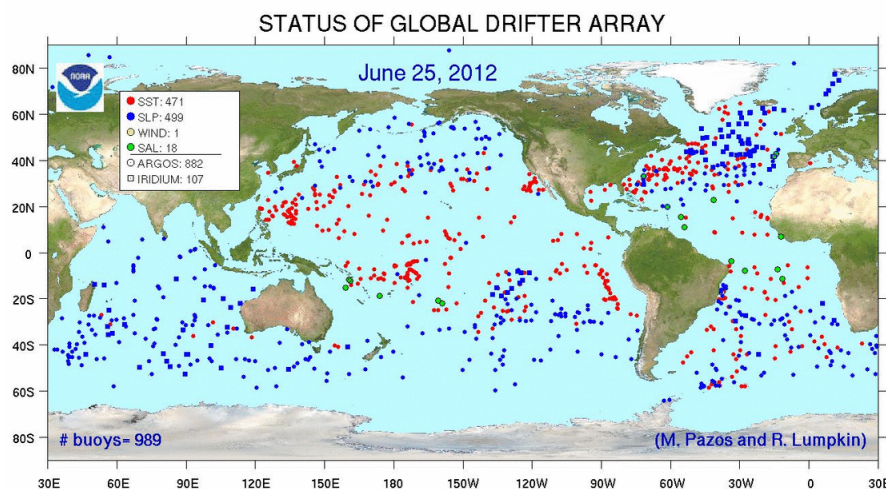


## *Mediterranean Surface Velocity Programme*

The Mediterranean Surface Velocity Programme (MedSVP) is responsible for the coordination of surface drifter operations at the Mediterranean level. This includes the following activities:

- 1) the coordination of drifter deployments in the Mediterranean;
- 2) the processing of the drifter data with specific QC tailored for the Mediterranean, both in NRT and delayed-mode;
- 3) the preparation and distribution of Mediterranean drifter products and services;
- 4) and the comparison of the Mediterranean drifter data with ancillary surface velocity data (e.g., HF radars) and model products.

MedSVP is part of the Italian "Gruppo Nazionale di Oceanografia Operativa" (GNOO) and of the Mediterranean Operational Oceanography Network (MOON). Partial support is provided by the MyOcean project.



## Surface drifters in the Mediterranean and Black Seas

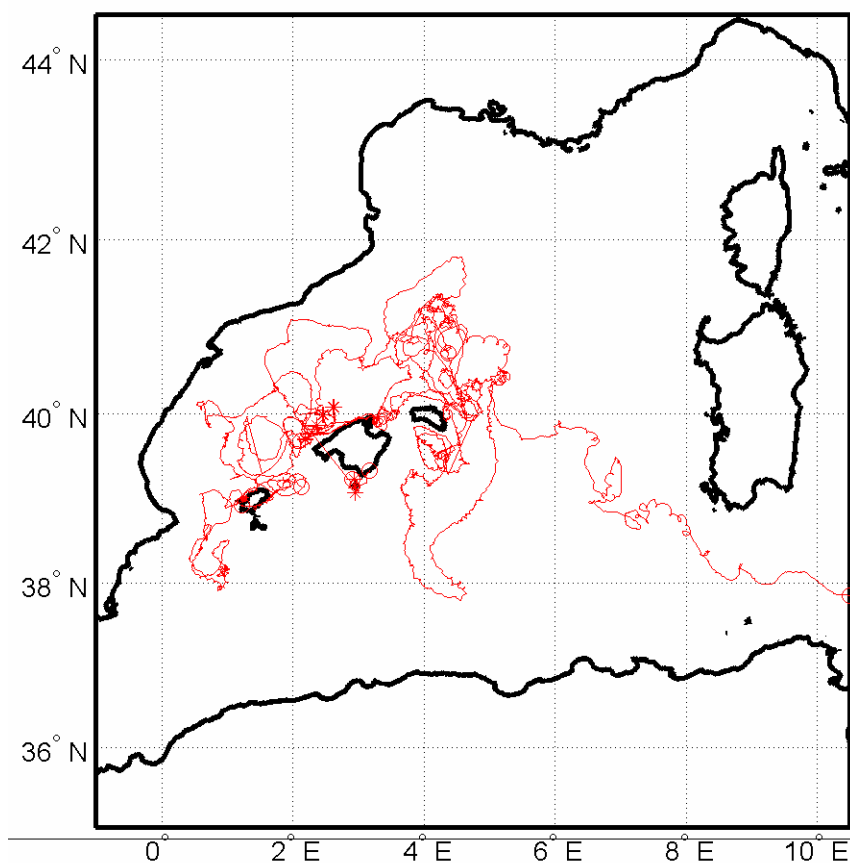
IMEDEA, Esporles, Spain, 4 July 2012

# Surface Drifters

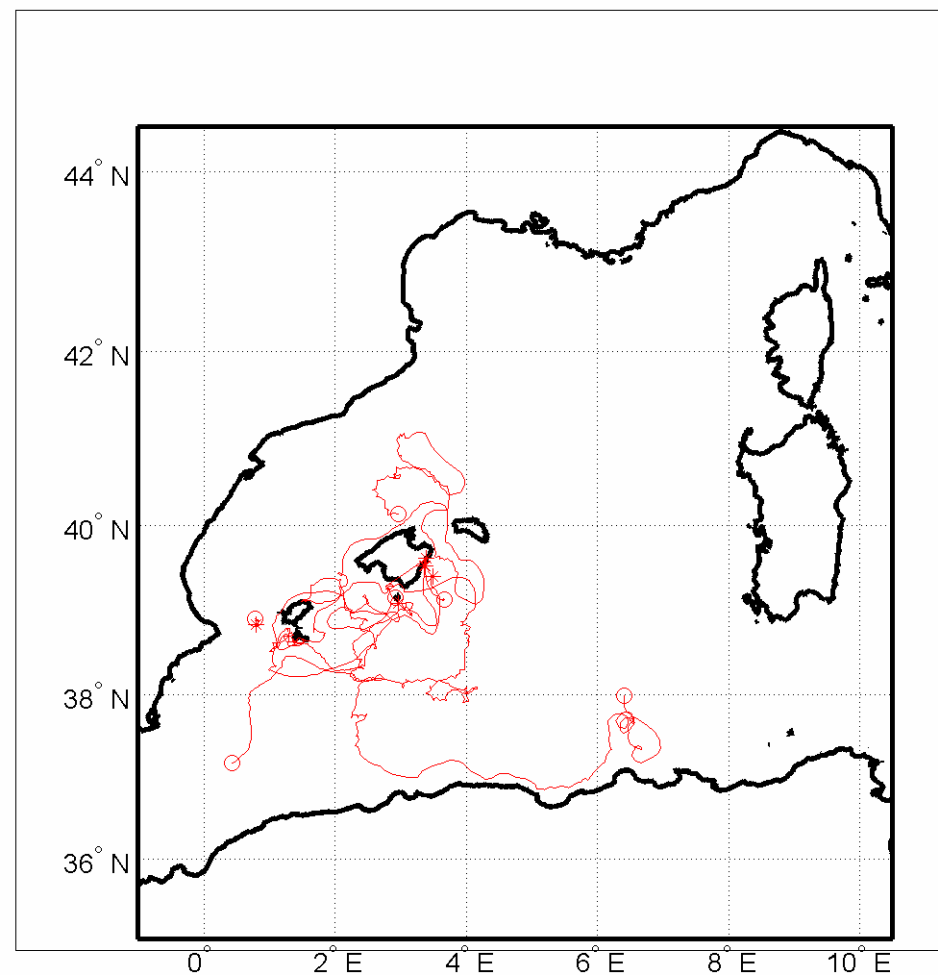


## Drifters deployed by IMEDEA/SOCIB (2009-2012)

9 IMEDEA SINOCOP Drifter Tracks: to



8 IMEDEA Kriged Drifter Tracks: 23-Jul-2009 18:00:00 to 03-Jul-2012 07:00:00



## Surface drifters in the Mediterranean and Black Seas

IMEDEA, Esporles, Spain, 4 July 2012

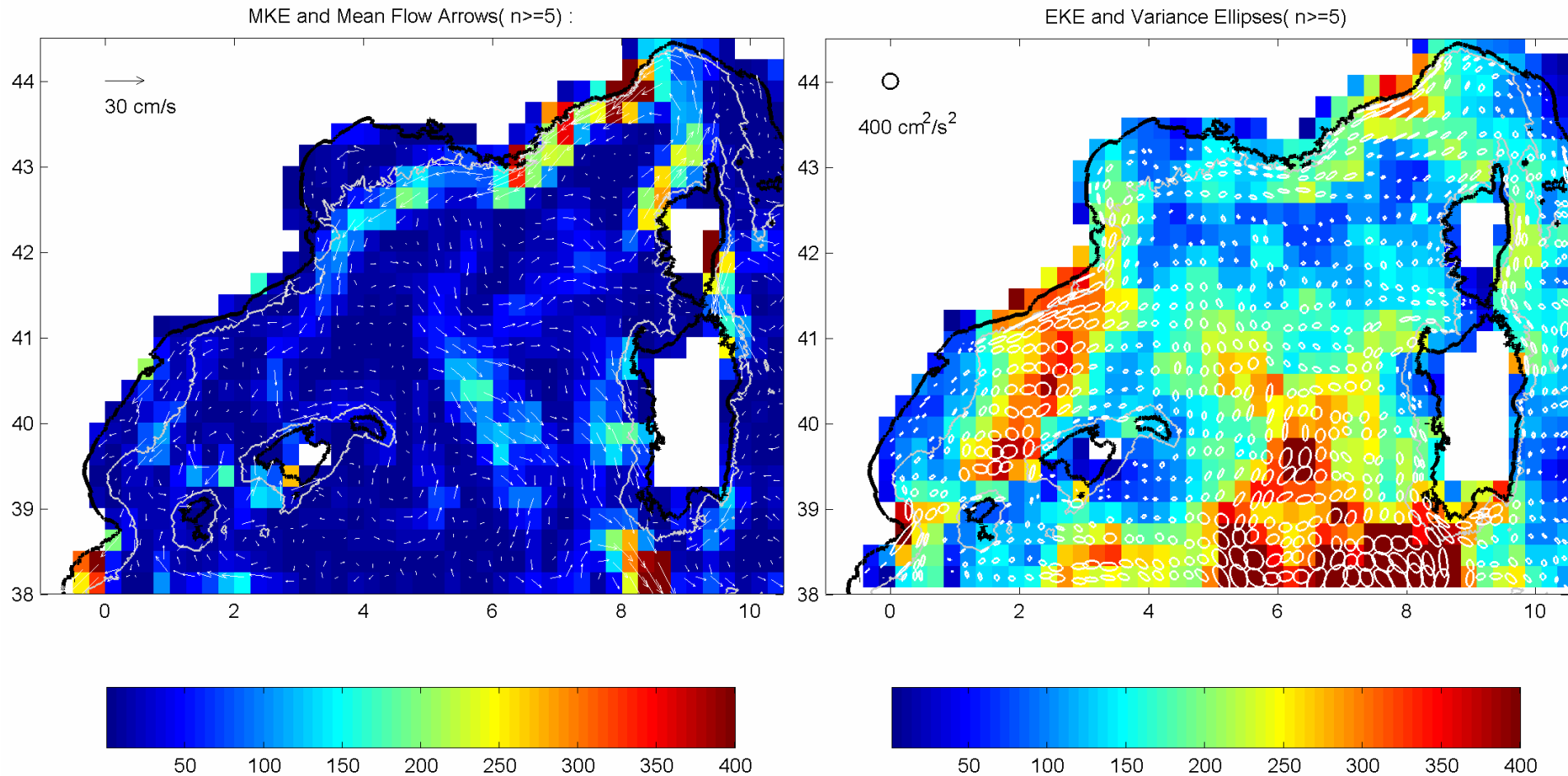


# Surface circulation



## Pseudo-Eulerian Statistics

Surface circulation in NW Mediterranean, grid of  $0.25^\circ$  and bins of  $0.5^\circ \times 0.5^\circ$



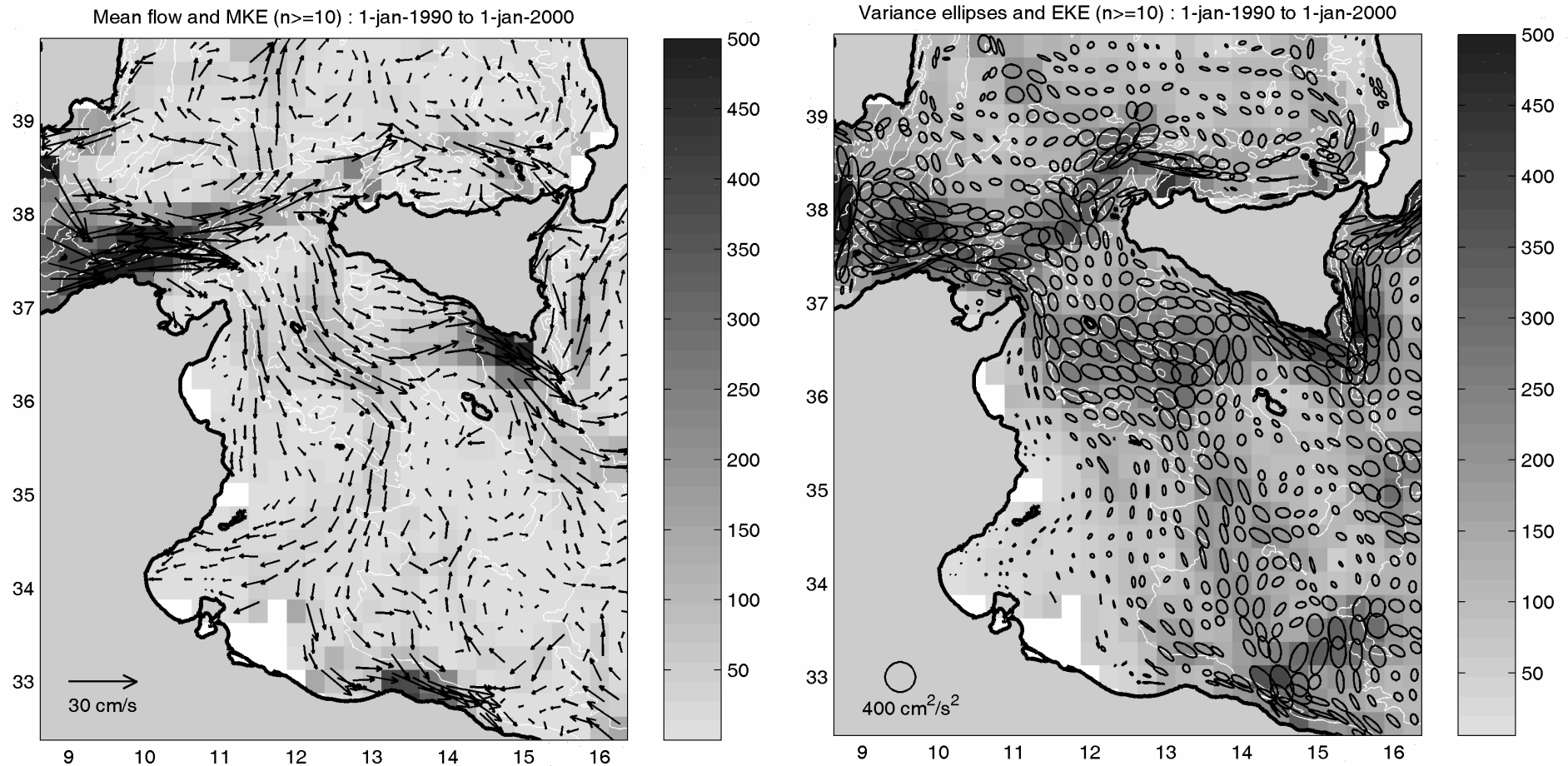
Circulation in selected basins: NW Mediterranean

# Surface circulation



## Pseudo-Eulerian Statistics

Surface circulation in Sicily Channel (Poulain and Zambianchi, 2007)



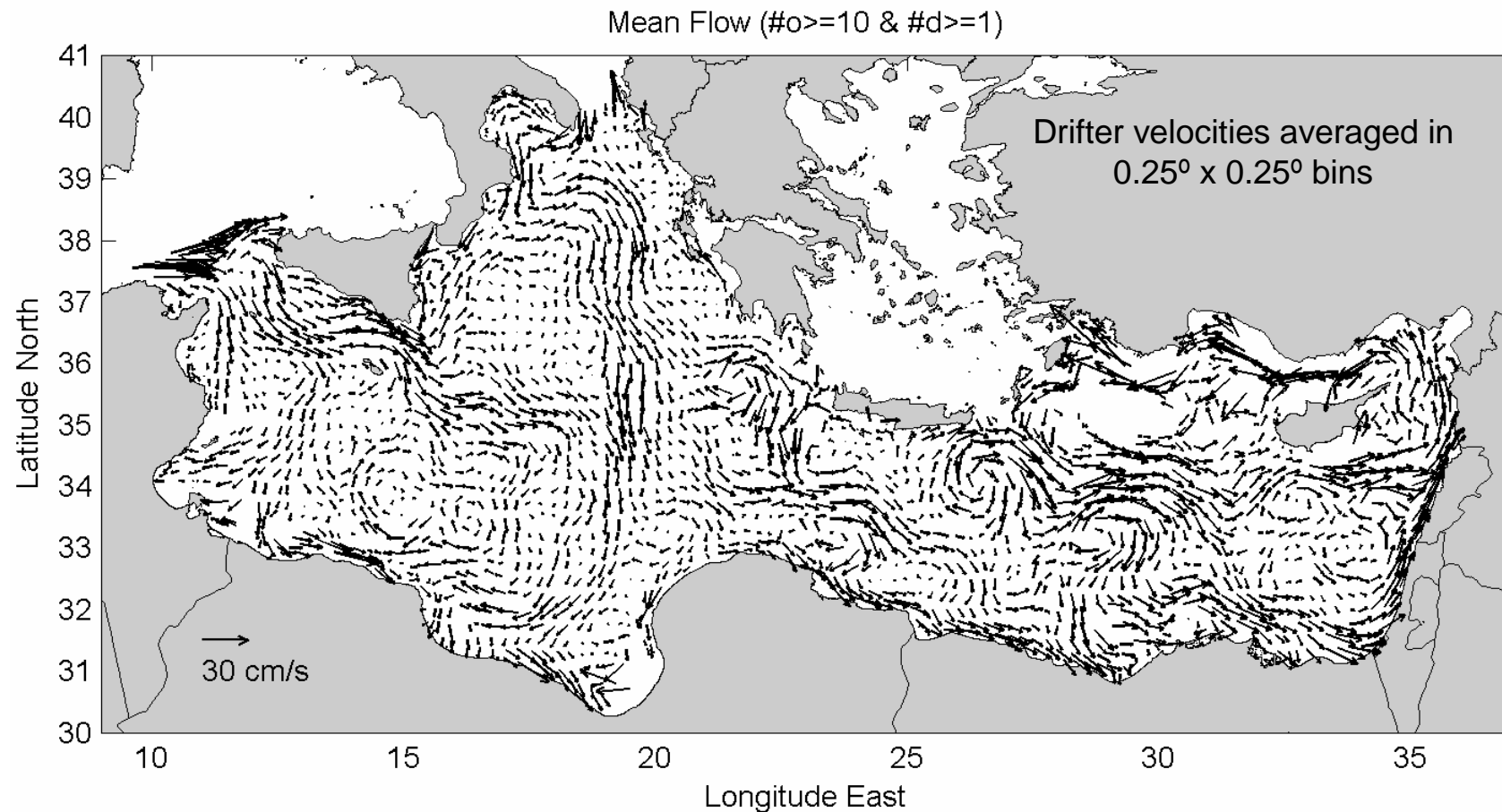
Circulation in selected basins: Central Mediterranean

# Surface circulation



## Pseudo-Eulerian Statistics

Surface circulation in Eastern Mediterranean (Gerin et al., 2009)



Circulation in selected basins: Eastern Mediterranean

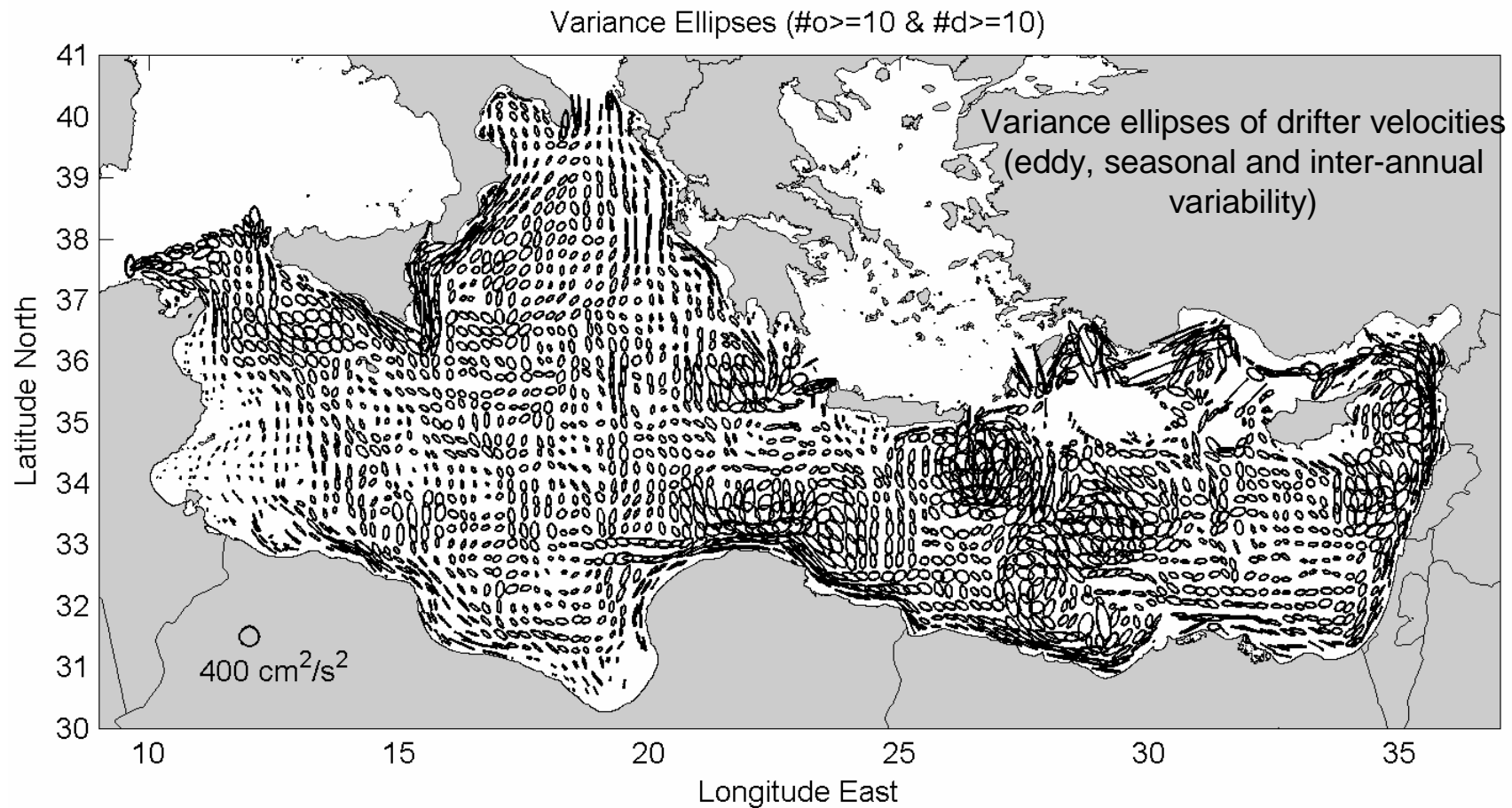


# Surface circulation



## Pseudo-Eulerian Statistics

Surface circulation in Eastern Mediterranean (Gerin et al., 2009)



Circulation in selected basins: Eastern Mediterranean

# Drifter & satellite altimeter data: method



Combining drifter and satellite altimetry data to estimate the mean surface geostrophic currents in the Mediterranean  
(Poulain et al., 2012)

## Drifter Data

- Period: October 1992-December 2010, 221 drifter-years, 1218 tracks.

Drifter Type	Number of drifter tracks	Drifter- days
CMOD	171	6845
CODE	567	40558
SVP drogued	145	9051
SVP undrogued	85	5106
SVP <u>unknown</u>	231	17826
A106/A111	19	1301
Total	1218	80687

- Interpolation (kriging), velocities from finite differences of positions, low-pass filtering (36 h), no correction for slippage due to wind/waves

# Drifter & satellite altimeter data: method



Combining drifter and satellite altimetry data to estimate the mean surface geostrophic currents in the Mediterranean  
(Poulain et al., 2012)

## Satellite Altimeter Data

- AVISO:

- weekly gridded SLA (multi-mission, delayed time, 14 Oct 1992- 31 Dec 2010).
- Corresponding anomalies of surface geostrophic velocities ( $\mathbf{U}_{SLA}$ ).
- Absolute dynamic topography and absolute surface geostrophic currents defined from the SLA and the SMDT of Rio et al. (2007).



# Drifter & satellite altimeter data: method



Combining drifter and satellite altimetry data to estimate the mean surface geostrophic currents in the Mediterranean  
(Poulain et al., 2012)

## Wind-driven Currents

- Within each spatial bin the following regression model was applied:

$$\mathbf{U}_D - \mathbf{U}_{AGRIO} = \beta e^{i\theta} \mathbf{W} + \text{error} ;$$

$\mathbf{U}_D$  = drifter velocities;

$\mathbf{U}_{AGRIO}$  = absolute surface geostrophic velocities;

$\mathbf{W}$  = CCMP wind velocities.

Drifter Type	$\beta$	$R^2$ (%)	RMSE (cm s <sup>-1</sup> )	N
CMOD	$0.02\exp(-18^\circ i)$	27	4.1	22353
CODE	$0.01\exp(-33^\circ i)$	11	4.7	160127
SVP drogued	$0.005\exp(-34^\circ i)$	1	4.8	32990
SVP undrogued	$0.01\exp(-26^\circ i)$	22	4.2	17855
SVP <u>unknown</u>	$0.007\exp(-32^\circ i)$	7	3.3	60176
A106/111	$0.007\exp(-21^\circ i)$	5	2.4	4456

# Drifter & satellite altimeter data: method



Combining drifter and satellite altimetry data to estimate the mean surface geostrophic currents in the Mediterranean  
(Poulain et al., 2012)

- Within each spatial bin the following regression model was applied:

$$\mathbf{U}_{\text{DG}} = \mathbf{A} \mathbf{U}_{\text{SLA}} + \mathbf{B} + \text{error} ;$$

$\mathbf{U}_{\text{DG}}$  = bin averaged ( $0.5^\circ \times 0.5^\circ \times 1$  week) drifter velocities from which the wind driven component were removed;

$\mathbf{U}_{\text{SLA}}$  = anomalies of surface geostrophic velocity from AVISO;

$\mathbf{A}$  = slope between  $\mathbf{U}_{\text{SLA}}$  and  $\mathbf{U}_{\text{DG}}$  ;

$\mathbf{B}$  = offset between  $\mathbf{U}_{\text{SLA}}$  and  $\mathbf{U}_{\text{DG}}$  (or mean surface circulation over period used to defined SLA).

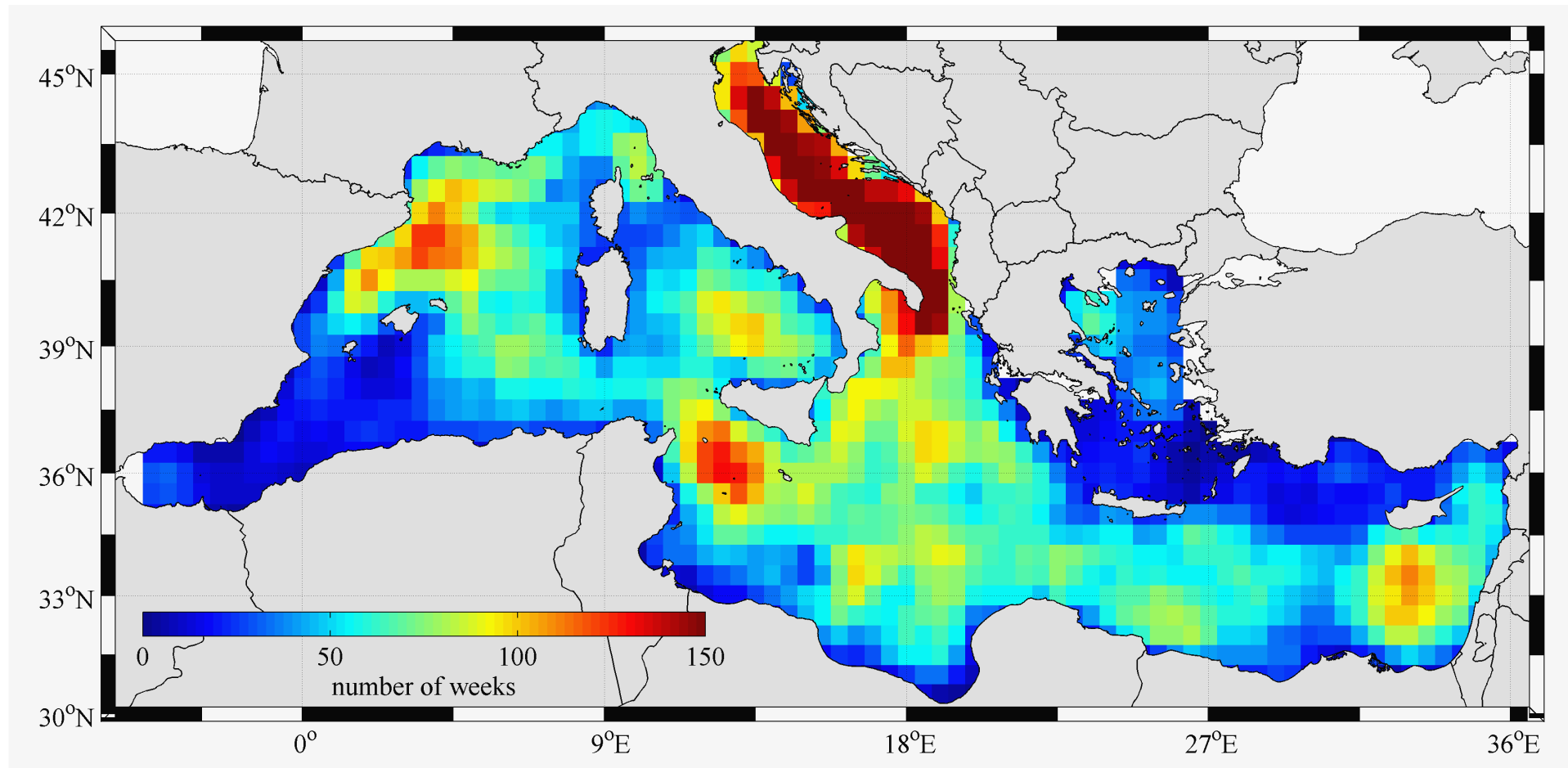
- The relationship between drifter velocities and satellite-derived anomalies of geostrophic velocities, estimated from 17 years of concurrent data, can be used to compute the unbiased geostrophic currents in the whole period in which  $\mathbf{U}_{\text{SLA}}$  is available.

# Drifter & satellite altimeter data: method



## Combining drifter and satellite altimetry data

Spatial distribution of the number of weeks worth of drifter data in bins of  $1^\circ \times 1^\circ$  for the period 14 Oct 1992 – 31 Dec 2010.



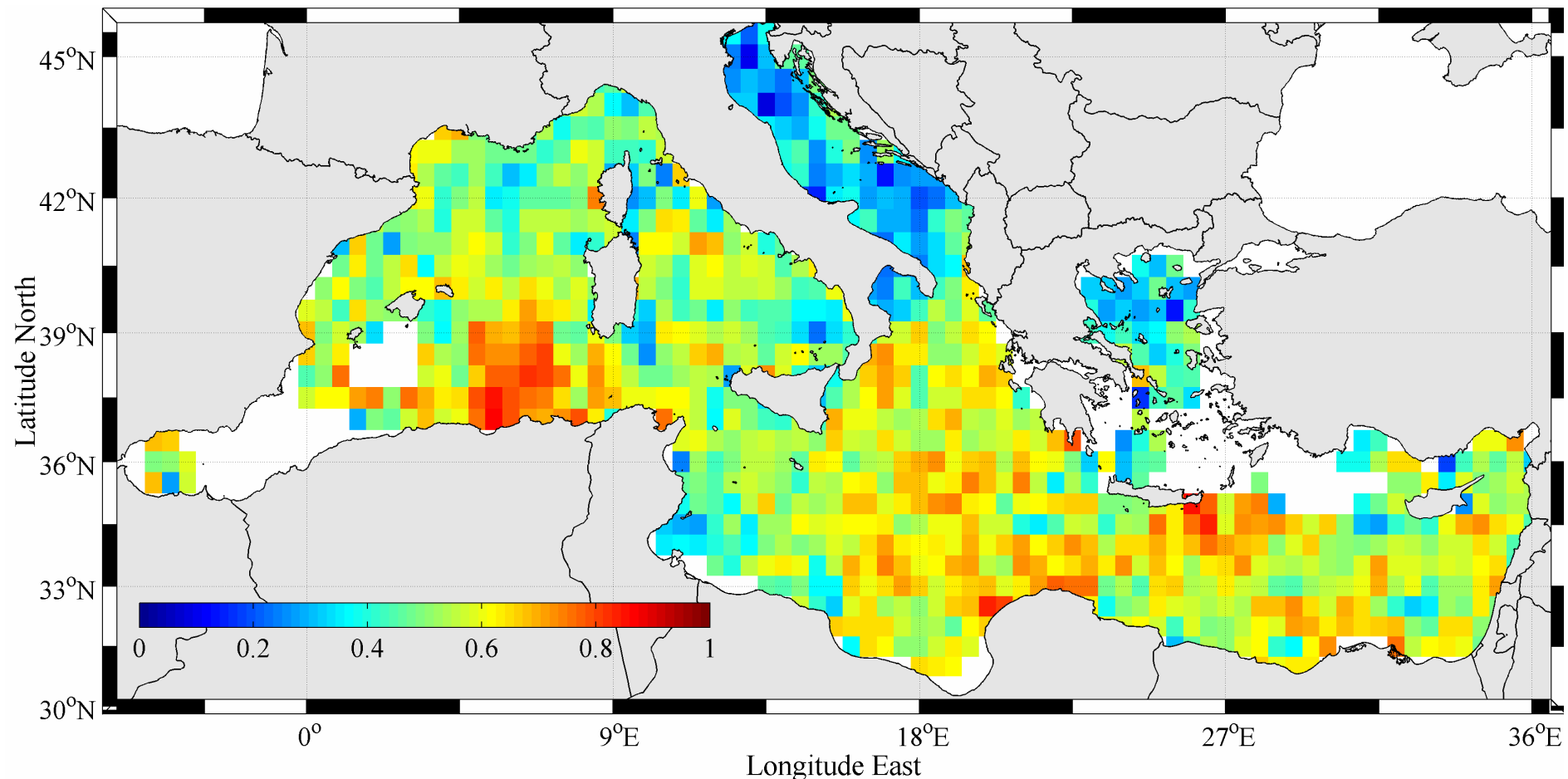


# Drifter & satellite altimeter data: method



## Combining drifter and satellite altimetry data

Spatial distribution of the correlation  $R$  between  $U_{DG}$  and  $U_{SLA}$

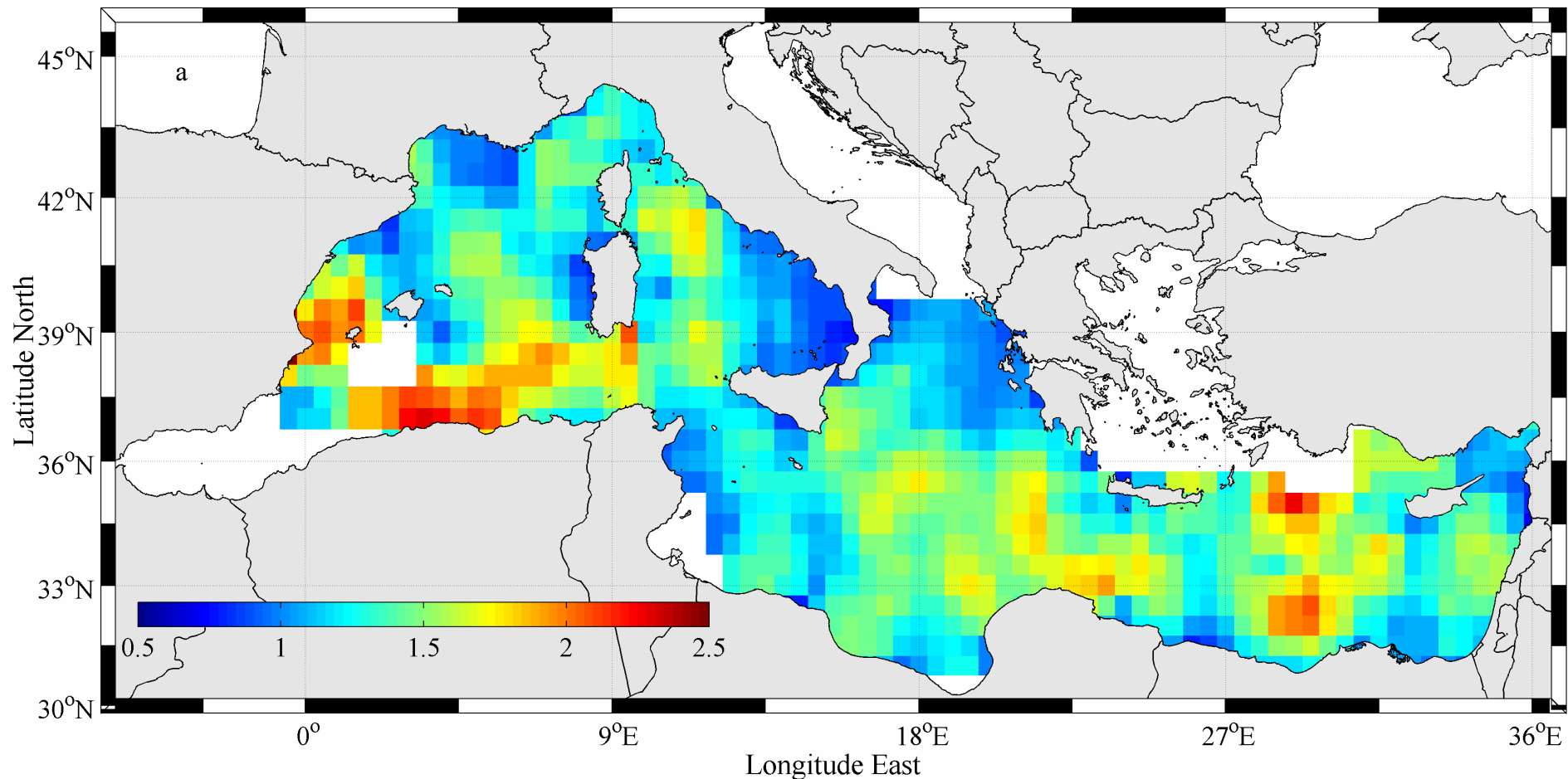


# Drifter & satellite altimeter data: method



## Combining drifter and satellite altimetry data

Spatial distribution of the magnitude of slope **A**

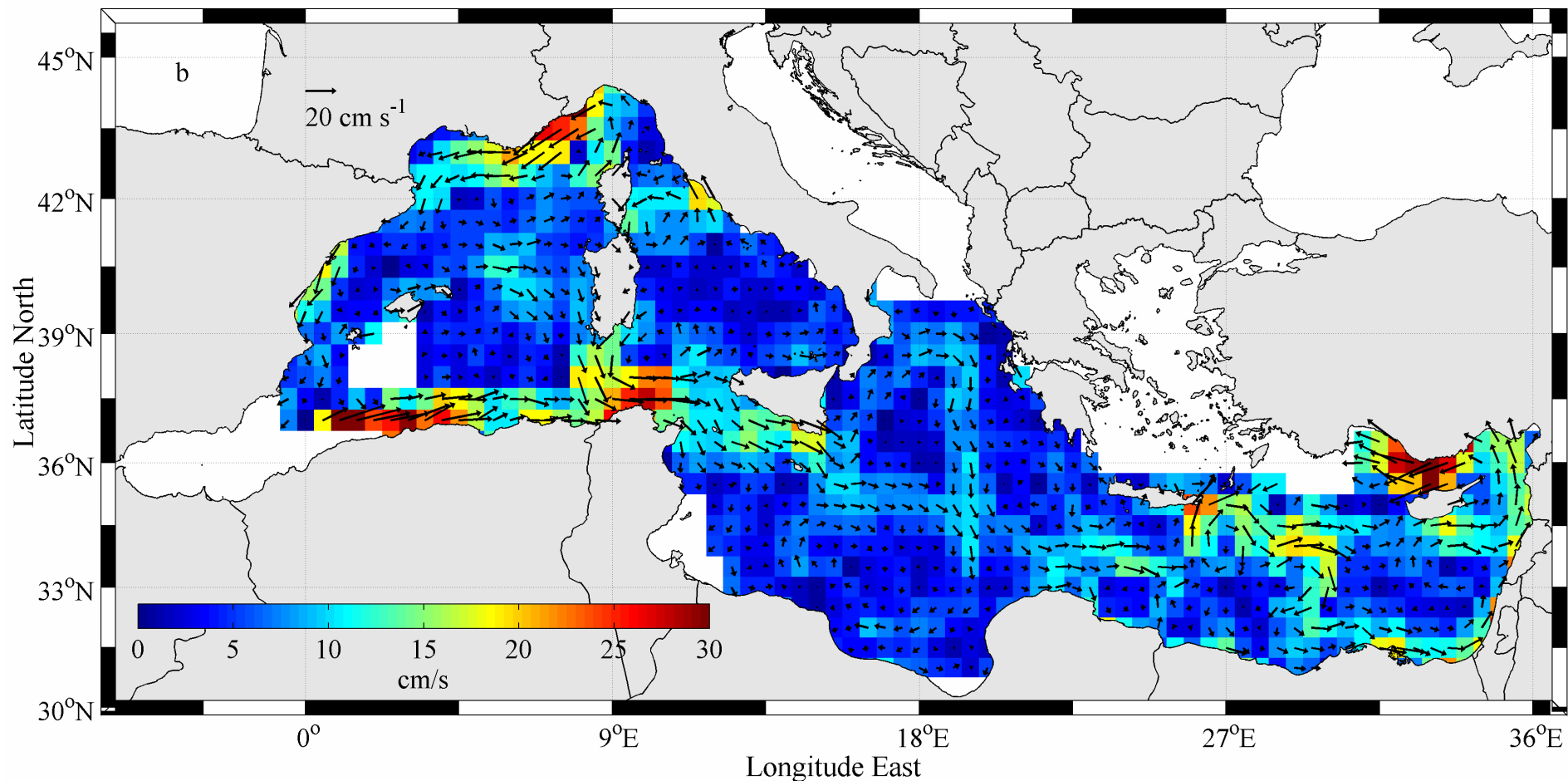


# Drifter & satellite altimeter data: method



## Combining drifter and satellite altimetry data

Spatial distribution of offset **B** ( $= \langle \mathbf{U}_{DG} \rangle_{93-99}$ )

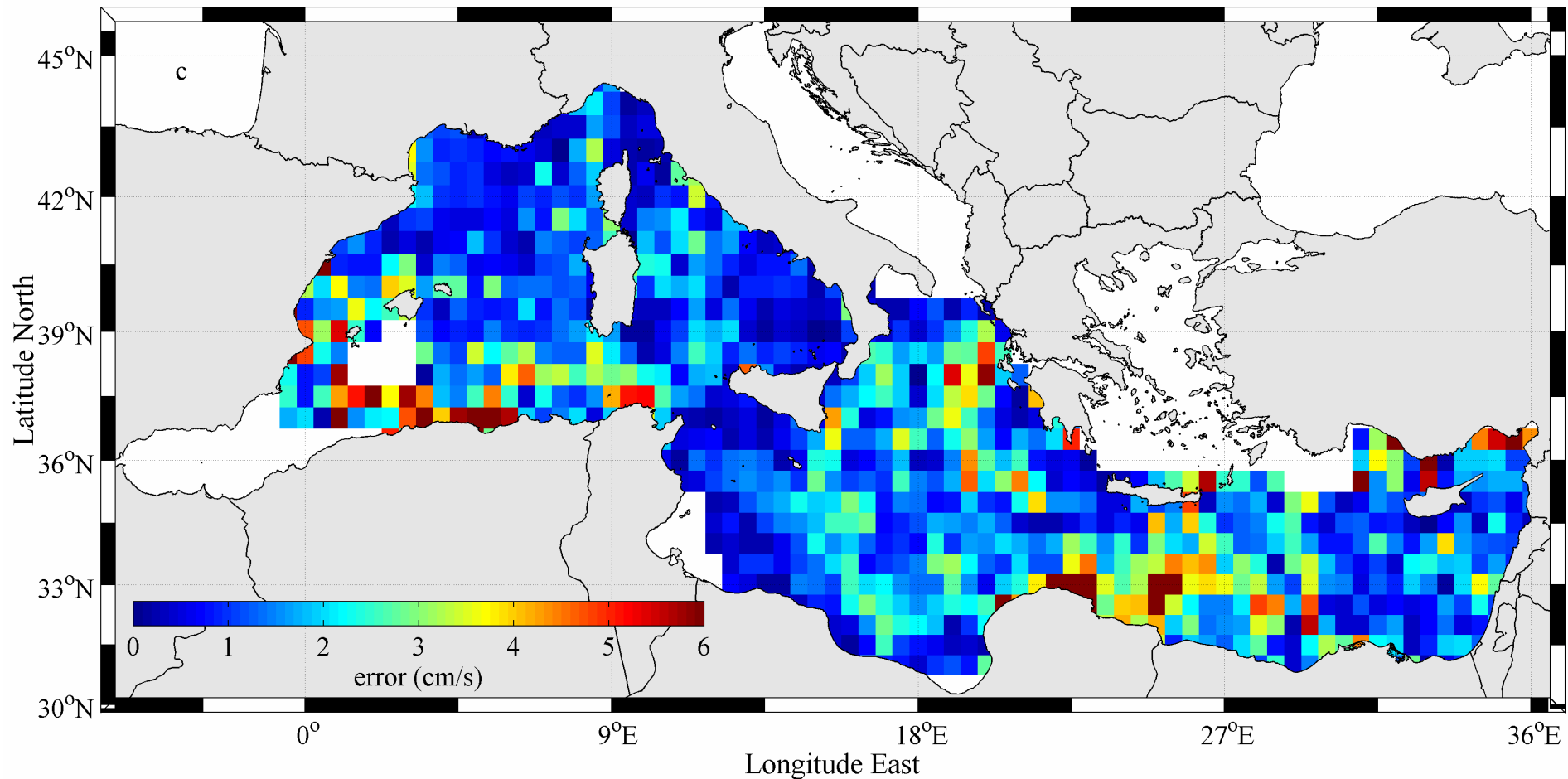


# Drifter & satellite altimeter data: method



## Combining drifter and satellite altimetry data

Spatial distribution of **RMSE** ( $= \sqrt{\langle \text{error}^2 \rangle}$ )



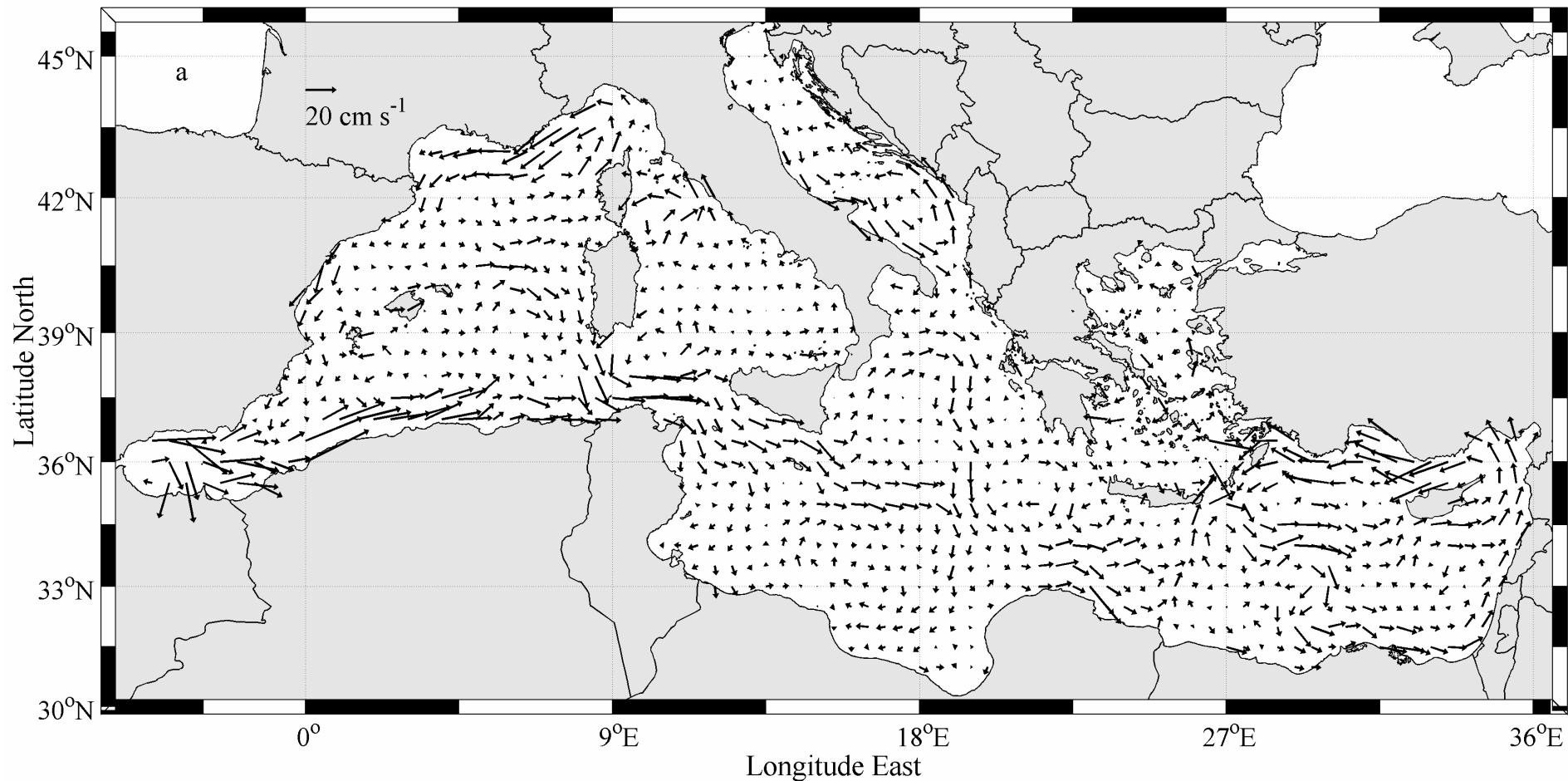


# Drifter & satellite altimeter data: results



Mean geostrophic currents in bins of  $0.5^\circ \times 0.5^\circ$  (B iased map)

14 Oct 1992 – 31 Dec 2010

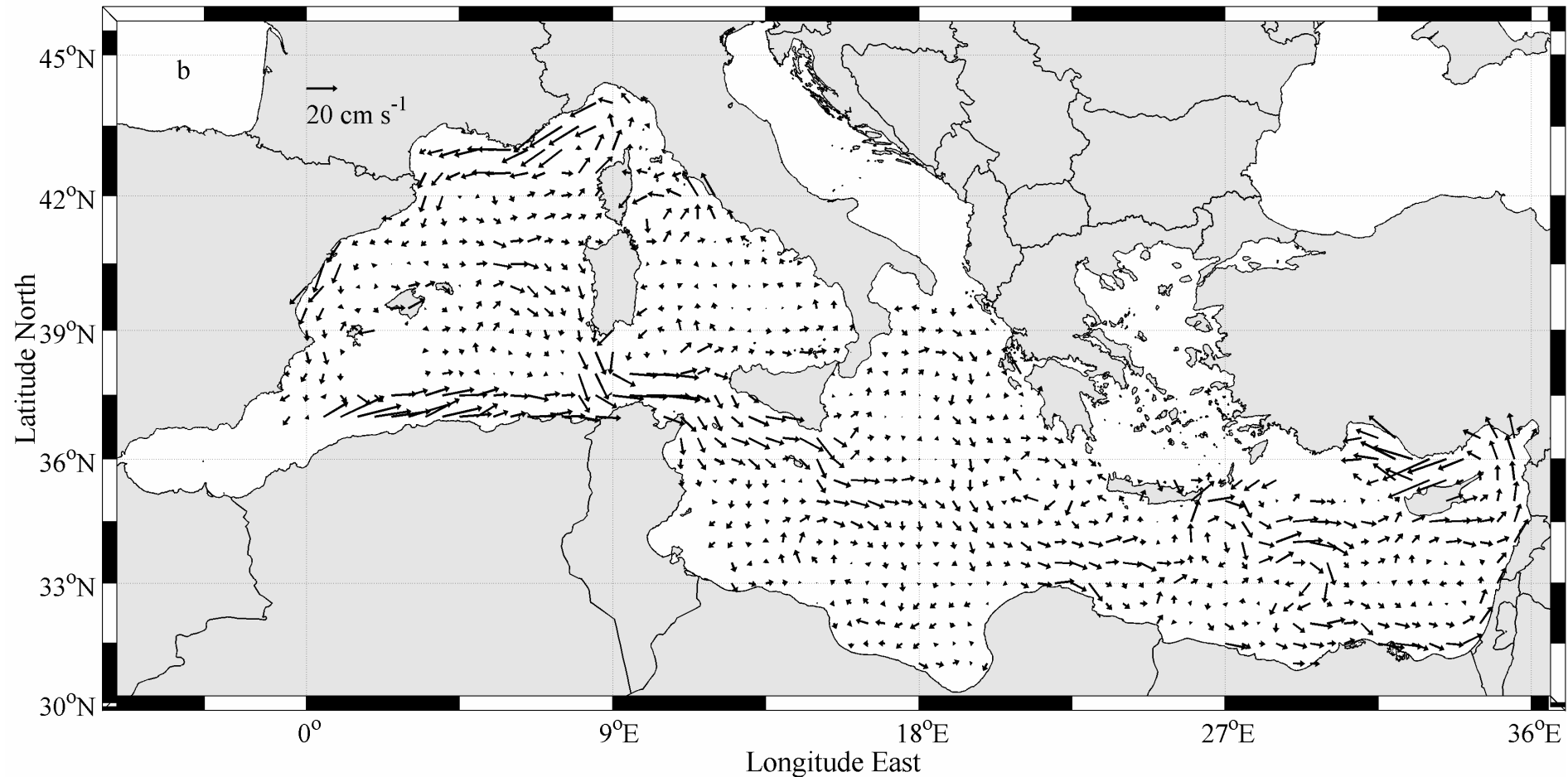


# Drifter & satellite altimeter data: results



Mean geostrophic currents in bins of  $0.5^\circ \times 0.5^\circ$  (U nbiased map)

14 Oct 1992 – 31 Dec 2010

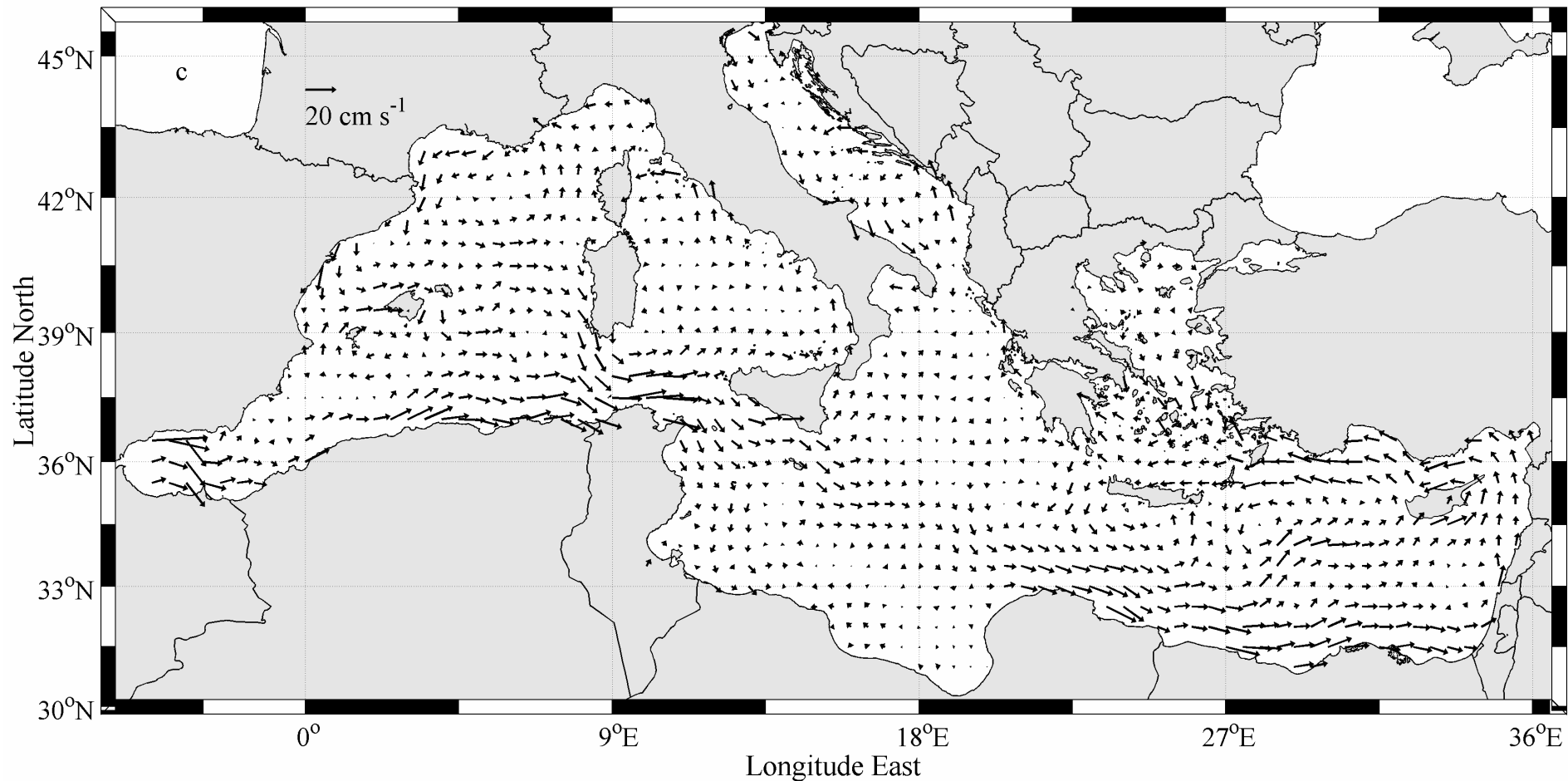


# Drifter & satellite altimeter data: results



Mean geostrophic currents in bins of  $0.5^\circ \times 0.5^\circ$  (using SMDT of Rio et al.)

14 Oct 1992 – 31 Dec 2010

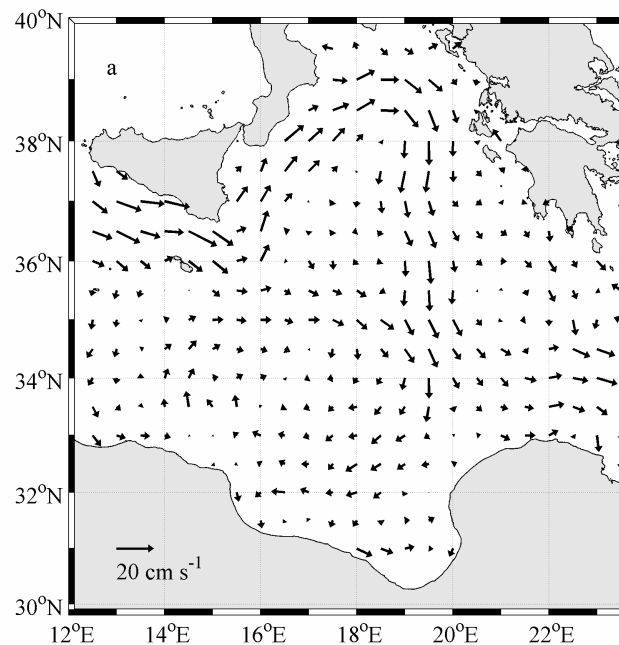


# Drifter & satellite altimeter data: results

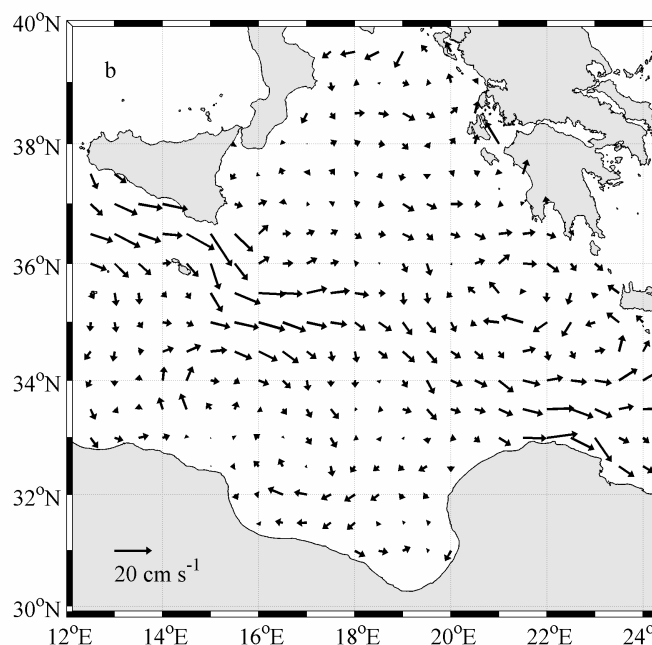


Unbiased mean maps of geostrophic circulation in the Ionian Sea  
with horizontal resolution of  $0.5^\circ$

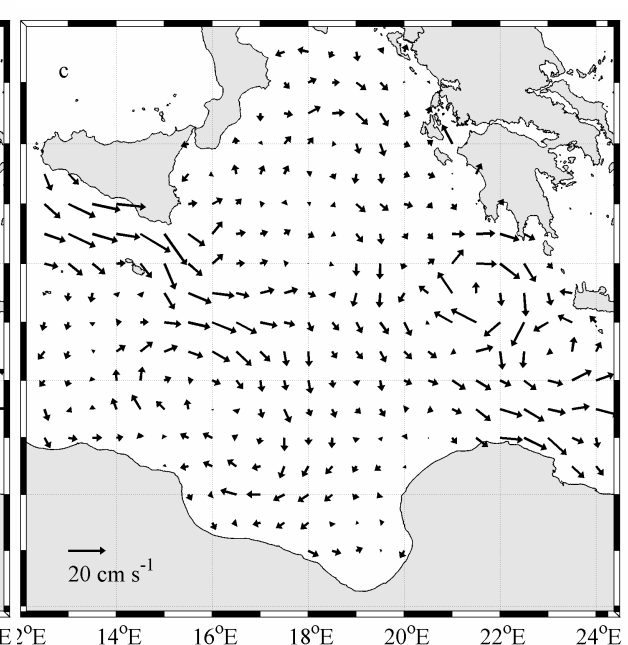
Oct 1992 - Jun 1997



Jul 1997 - Dec 2005



Jan 2006 - Dec 2009



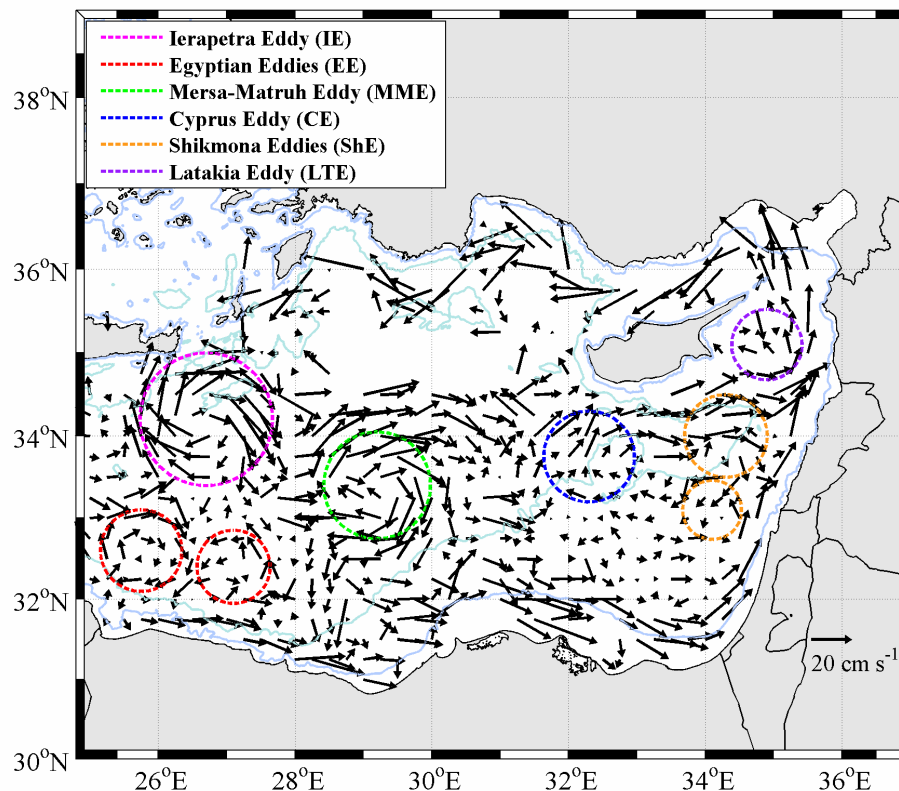


# Drifter & satellite altimeter data: results

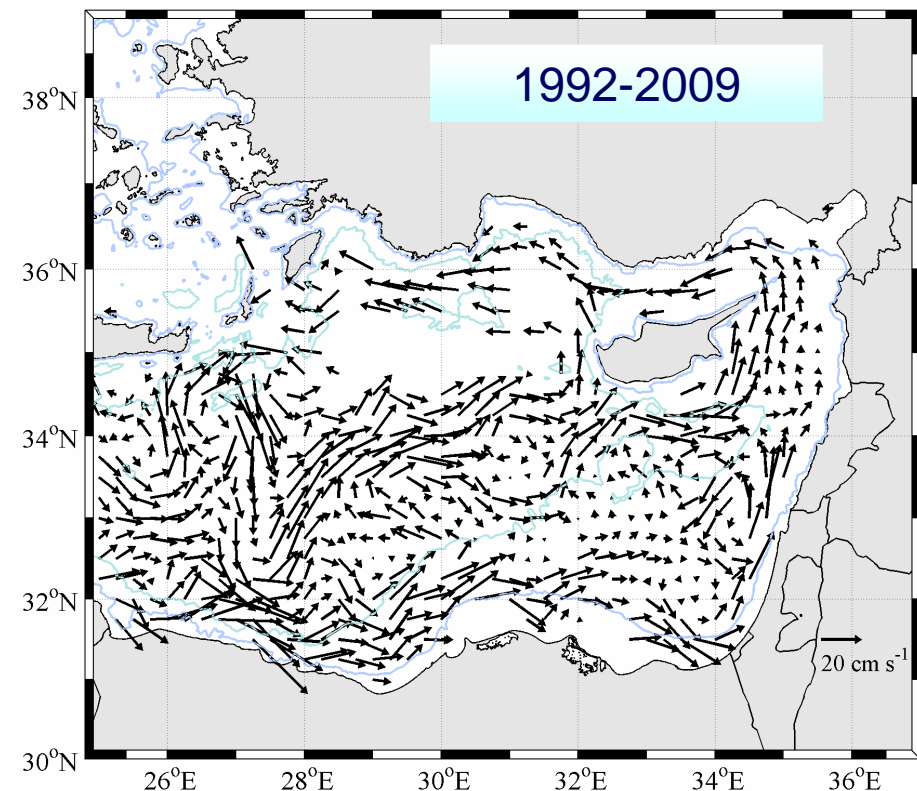


## Eastern Mediterranean circulation (Menna et al., 2012)

Unbiased mean velocity field  
obtained with our approach (1992-  
2009)



Absolute geostrophic mean velocities  
obtained from altimeter data and SMDT  
(Rio et al., 2007)



# Drifter & satellite altimeter data: results



Schematic diagram of the mean surface geostrophic circulation in the Mediterranean Sea derived from drifter and altimetry data in 1992-2009

