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Analysis of Remotely Sensed Ocean Data by the Optimal Spectral Decomposition (OSD) Method

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References

- Chu, P.C., L.M. Ivanov, T.P. Korzhova, T.M. Margolina, and O.M. Melnichenko, 2003a: Analysis of sparse and noisy ocean current data using flow decomposition. Part 1: Theory. Journal of Atmospheric and Oceanic Technology, 20 (4), 478-491.

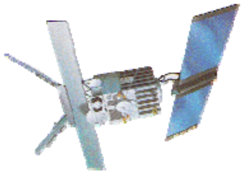
- Chu, P.C., L.M. Ivanov, T.P. Korzhova, T.M. Margolina, and O.M. Melnichenko, 2003b: Analysis of sparse and noisy ocean current data using flow decomposition. Part 2: Application to Eulerian and Lagrangian data. Journal of Atmospheric and Oceanic Technology, 20 (4), 492-512.

- Chu, P.C., L.M. Ivanov, and T.M. Margolina, 2004: Rotation method for reconstructing process and field from imperfect data. International Journal of Bifurcation and Chaos, 14(8), 2991-2997.

- Chu, P.C., L.M. Ivanov, and O.M. Melnichenko, 2005: Fall-winter current reversals on the Texas-Lousiana continental shelf. Journal of Physical Oceanography, 35, 902-910

- Chu, P.C., L.M. Ivanov, O.M. Melnichenko, and N.C. Wells, 2007: On long baroclinic Rossby Waves in the tropical North Atlantic observed from profiling floats. Journal of Geophysical Research – Oceans, 112, C05032, doi:10.1029/2006JC003698

- These papers can be downloaded from:
- http://faculty.nps.edu/pcchu



How can we effectively use remotely observed data to represent and to model/predict the ocean state?

Outline

- (1) Theory and Methodology

- (2) Application

  - ARGO Data: Baroclinic Rossby Waves in Tropical Atlantic

  - CODAR Data: Monterey Bay Surface Circulation

Part-1
Theory and Methodology

Spectral Representation - a Possible Alternative Method

Theoretical Base: Fourier Series Expansion

$$c(\mathbf{x}, z_k, t) = A_0(z_k, t) + \sum_{m=1}^{M} A_m(z_k, t)\ \Psi_m(\mathbf{x}, z_k),$$

Basis Functions (Closed Basin)

$$\triangle\Psi_k = -\lambda_k\Psi_k, \quad \Psi_k|_\Gamma = 0, \qquad k = 1, ..., \infty$$

$$\triangle\Phi_m = -\mu_m\Phi_m, \quad \frac{\partial\Phi_m}{\partial n}|_\Gamma = 0, \qquad m = 1, ..., \infty.$$

Eremeev et al. (1992 JGR)

Basis Functions (Open Boundaries)

(Chu et al., 2003 a,b JTECH)

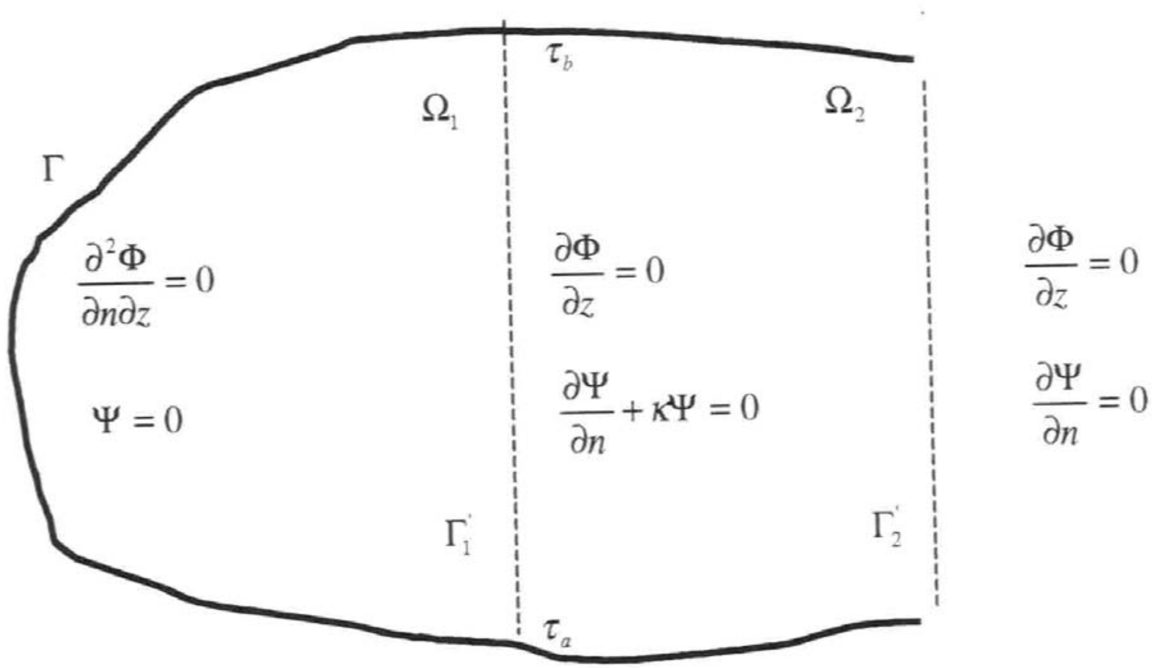
$$\Delta \Psi_k = -\lambda_k \Psi_k,$$

$$\Delta \Phi_m = -\mu_m \Phi_m,$$

$$\Psi_k|_\Gamma = 0, \quad \frac{\partial \Phi_m}{\partial n}|_\Gamma = 0,$$

$$\left[\frac{\partial \Psi_k}{\partial n} + \kappa(\tau)\Psi_k\right]|_{\Gamma_1'} = 0, \quad \Phi_m|_{\Gamma_1'} = 0,$$

Boundary Conditions



Benefit of Using OSD

- Ocean Topographic Configuration →

  Basis Functions (Pre-Determined)

Optimal Mode Truncation

$$J(a_{1,\dots,}a_K, b_{1,\dots,}b_M, \kappa, P) = \frac{1}{2}\left(\left\|u_p^{obs} - u_{KM}\right\|_P^2 + \left\|v_p^{obs} - v_{KM}\right\|_P^2\right) \to \min,$$

Vapnik (1983) Cost Function →Optimal Mode Truncation

$$J_{emp} = J(a_{1,\ldots,}a_{K,}b_{1,\ldots,}b_M, \kappa, P).$$

$$\mathrm{Prob}\left\{\sup_{K,M,S} |\langle J(K,M,S)\rangle - J_{emp}(K,M,S)| \geq \mu\right\} \leq g(P,\mu)$$

$$\lim_{P\to\infty} g(P,\mu) = 0$$

Optimal Truncation

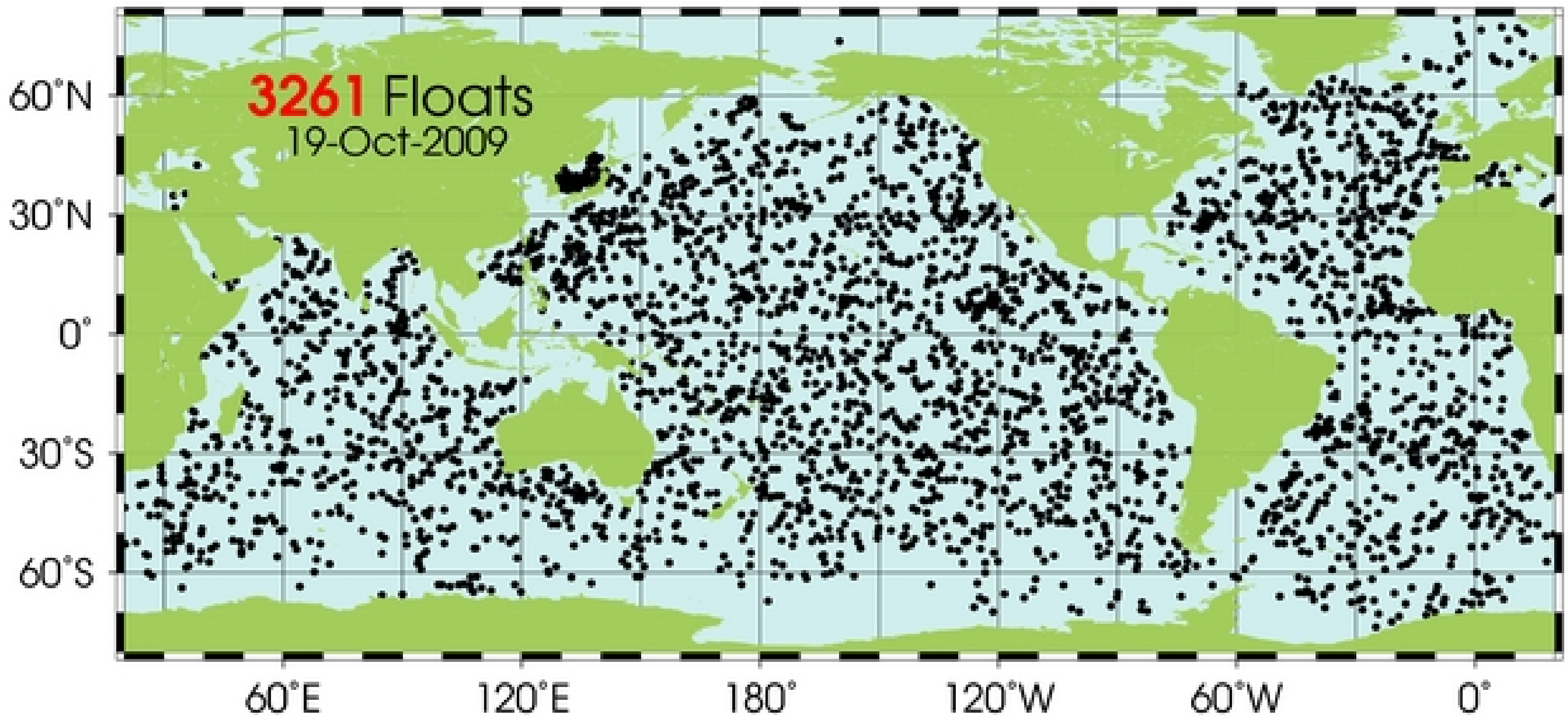
- Gulf of Mexico, Monterey Bay, Louisiana-Texas Shelf, Tropical Atlantic
- $K_{opt} = 40$, $M_{opt} = 30$

Determination of Spectral Coefficients
(Ill-Posed Algebraic Equation)

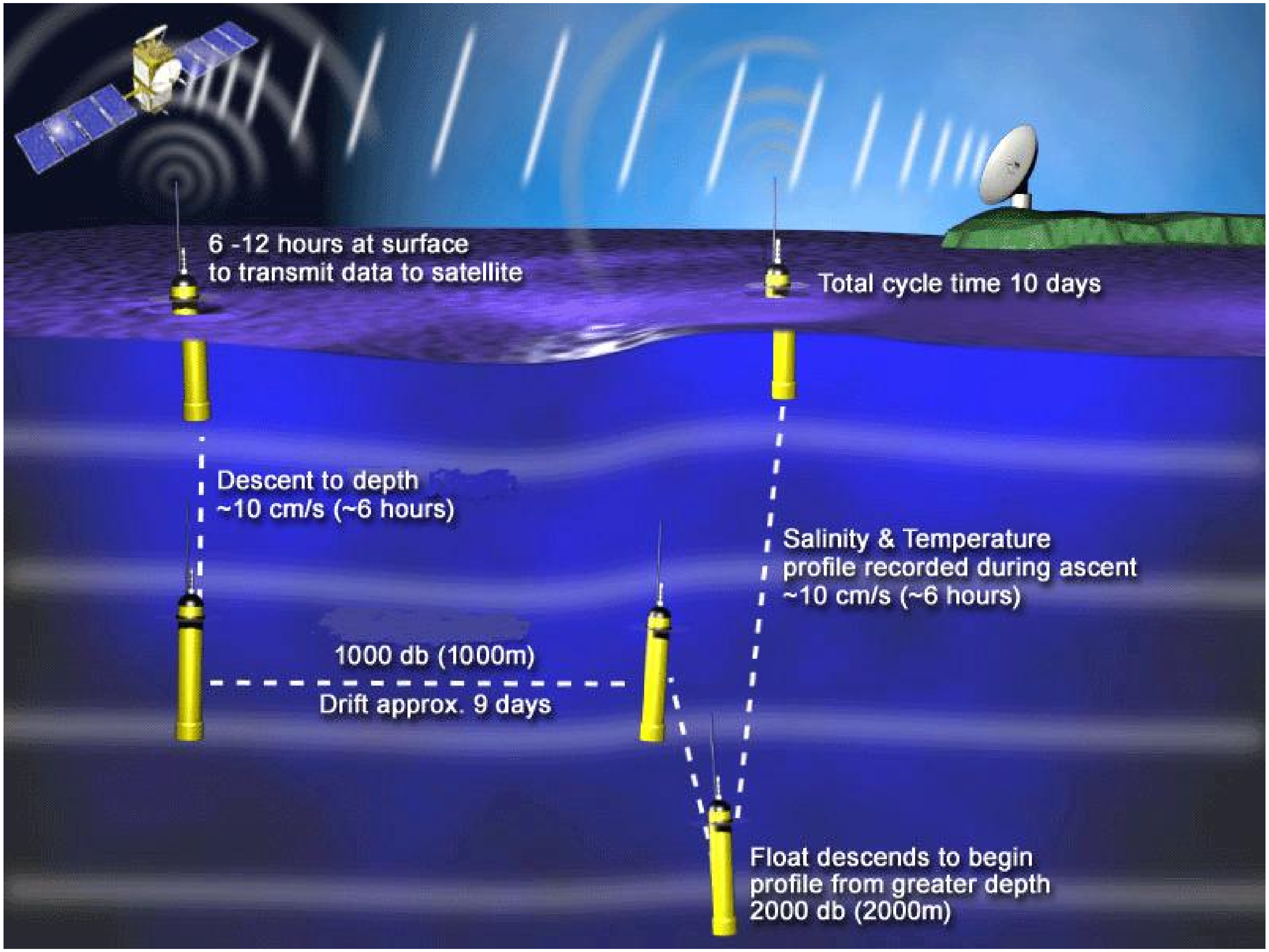
$$\mathbf{A}\hat{\mathbf{a}} = \mathbf{Q}\mathbf{Y},$$

Part 2 Applications

2.1. Argo Drifters



- http://www.argo.net/index_flash.html
- 3000 Argo drifters → Sampling the Global Ocean



Opportunities

- (1) 4D (T, S) fields
- (2) Deep ocean currents
- (3) Physical phenomena → Rossby wave propagation in mid-depth, …

Challenges

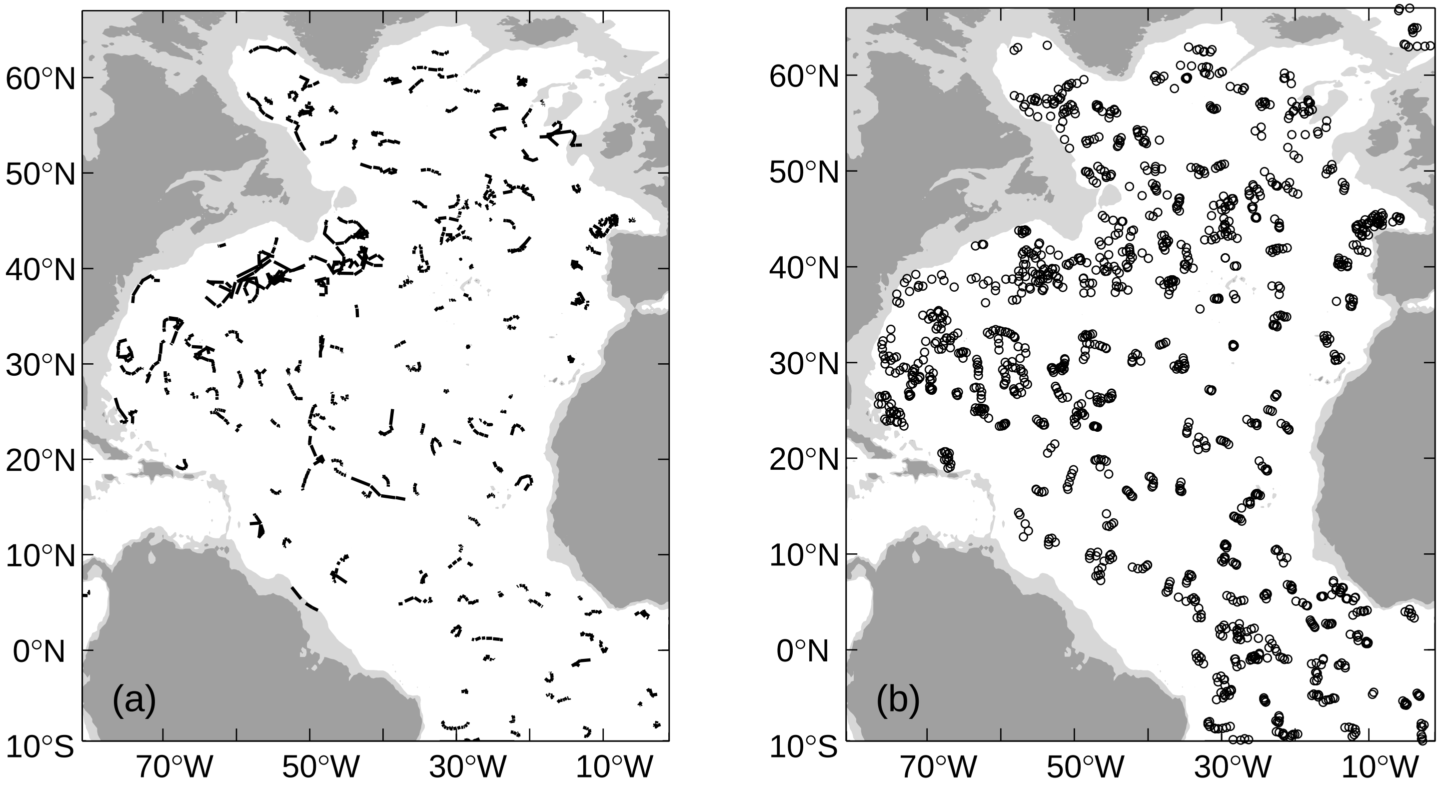
- Argo (T, S) profile and drift data

→ Noisy and inhomogeneously distributed

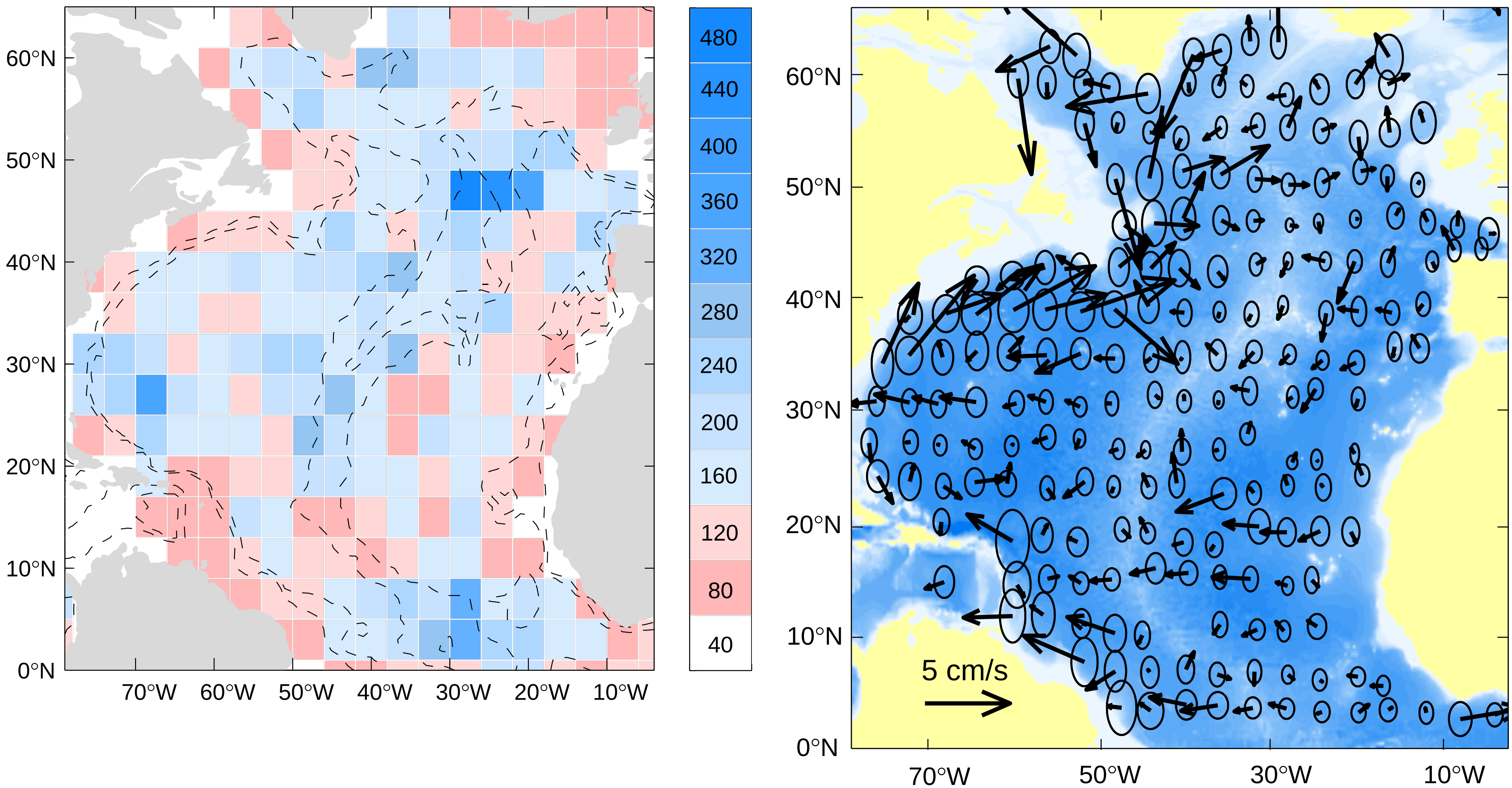
ARGO Observations (Oct-Nov 2004)

(a) Subsurface tracks

(b) Float positions where (T,S) were measured

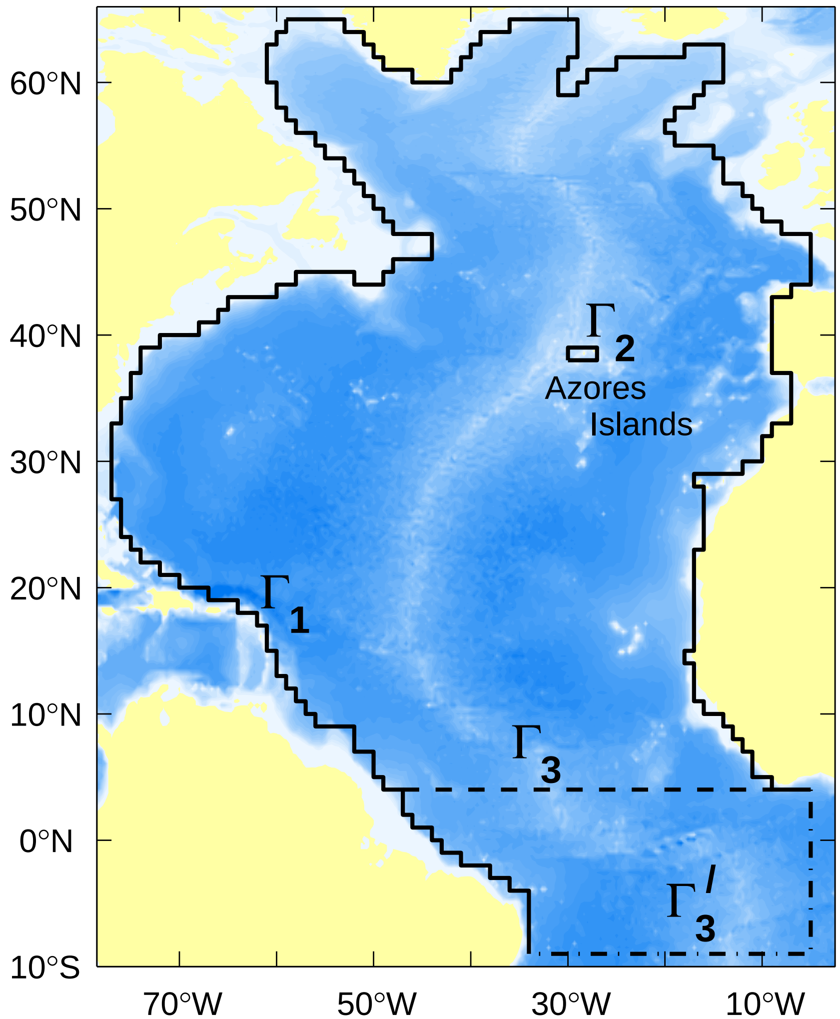


Circulations at 1000 m estimated from the original ARGO float tracks (bin method) April 2004 – April 2005

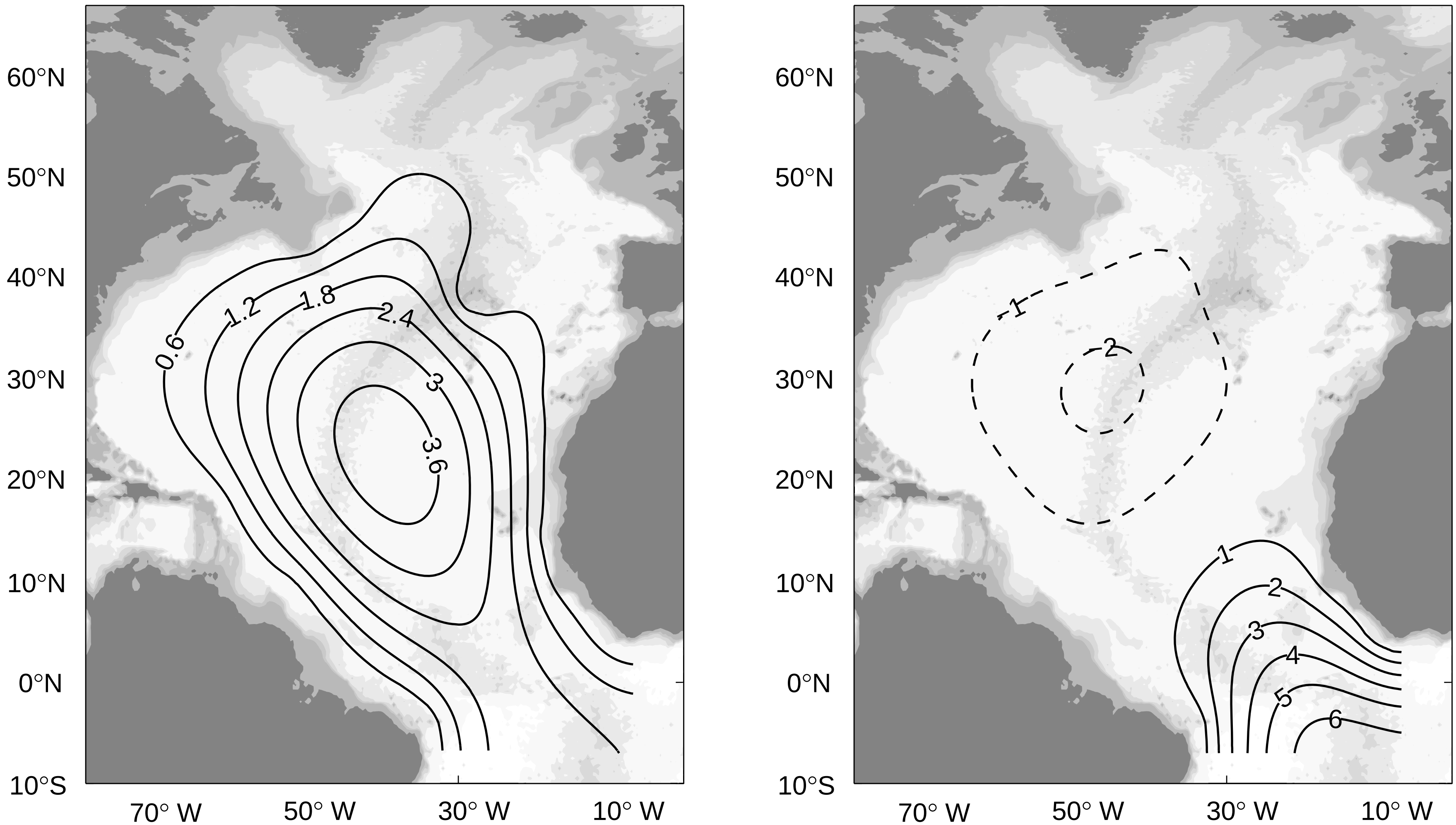


It is difficult to use such noisy data into ocean numerical models.

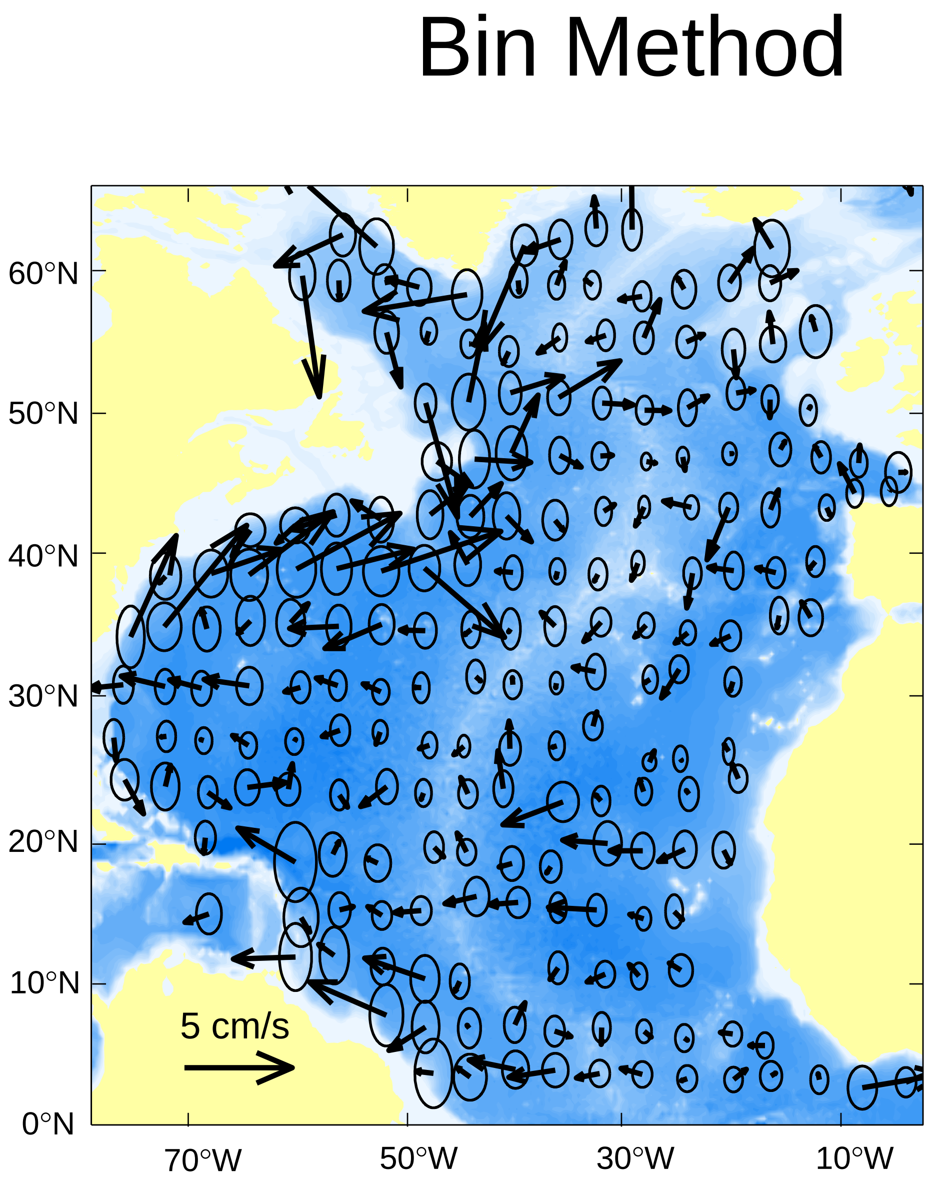
Boundary Configuration → Basis Functions for OSD

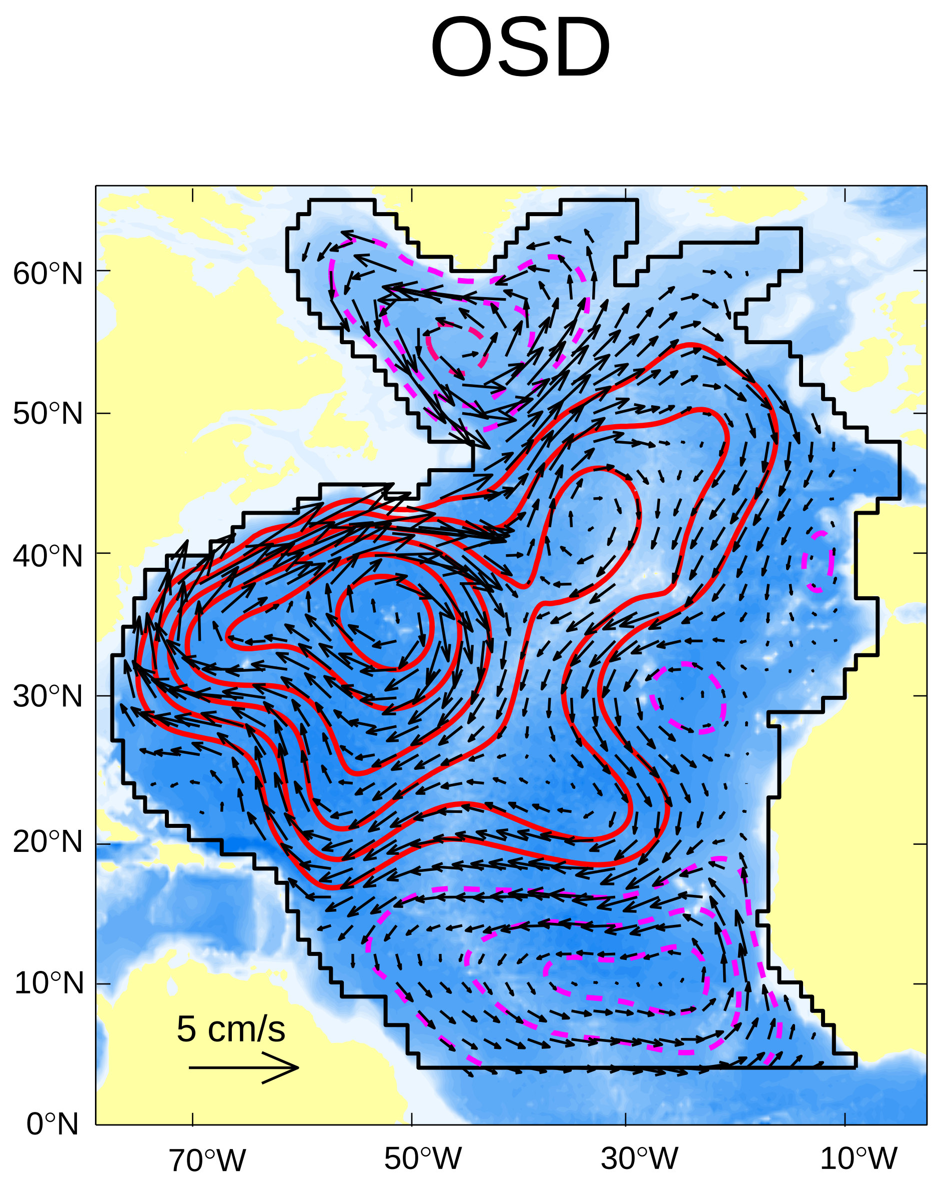


Basis Functions for Streamfunction Mode-1 and Mode-2



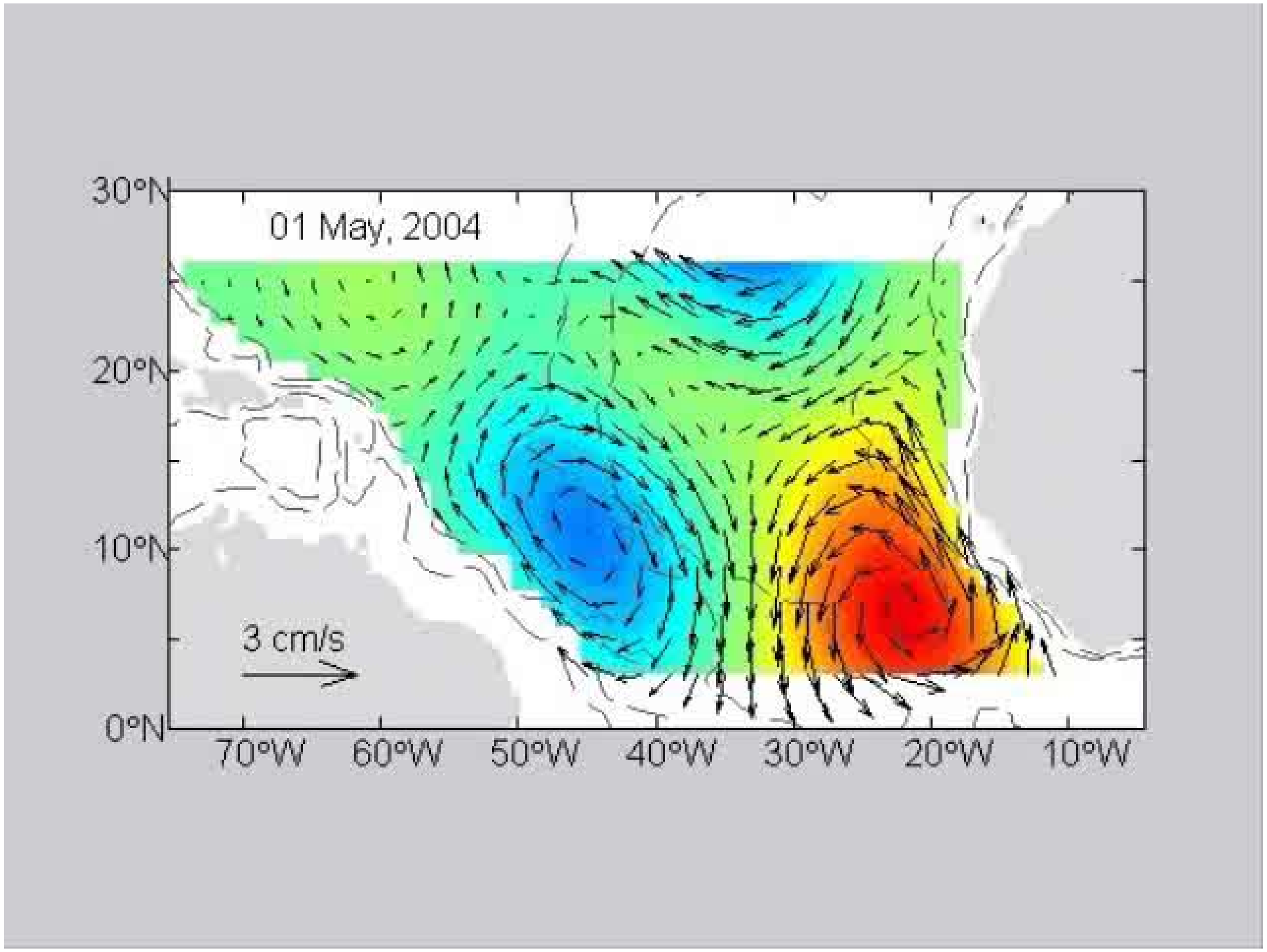
Circulations at 1000 m (March 04 to May 05)



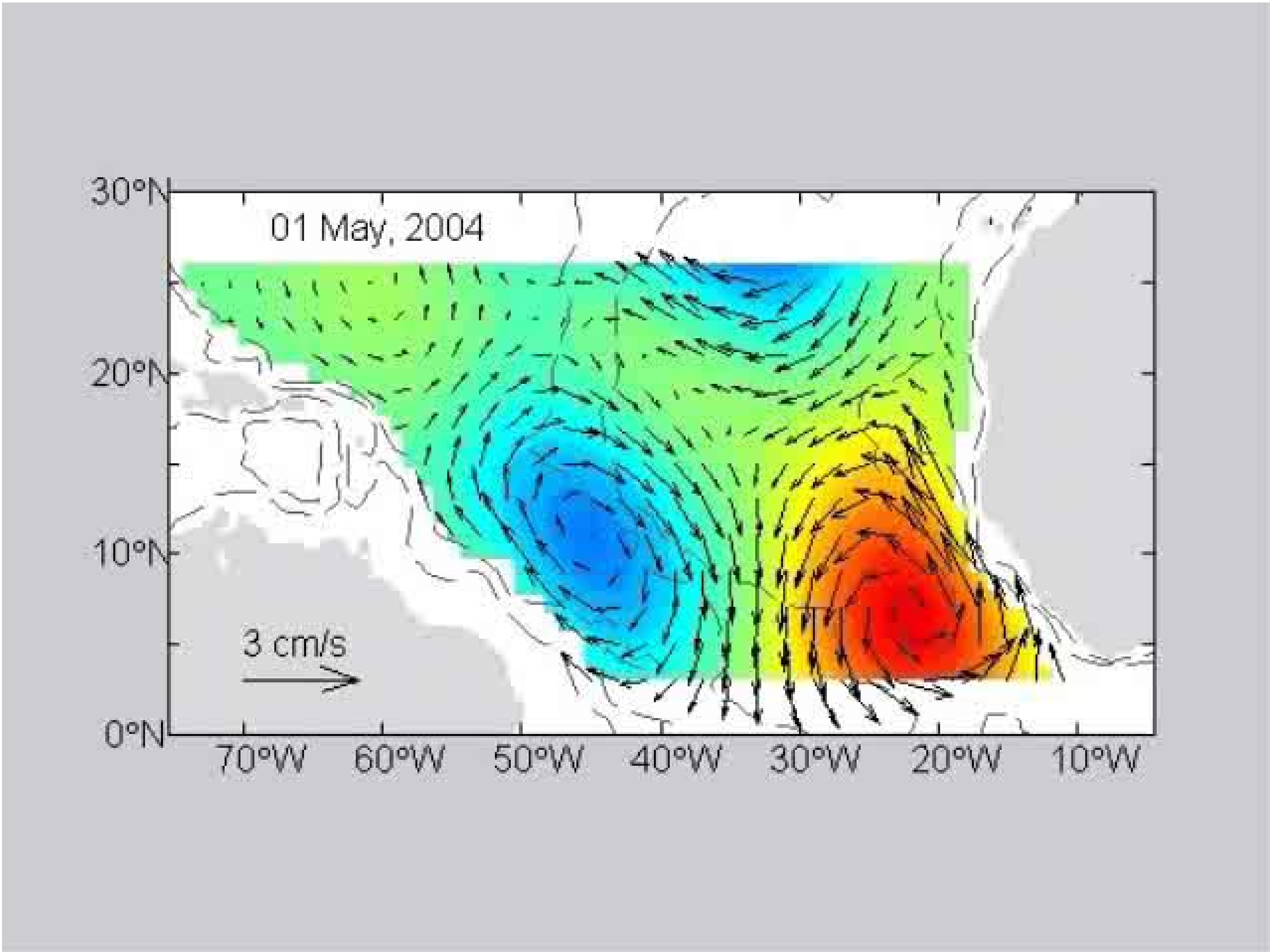


Baroclinic Rossby Waves in Tropical North Atlantic

Annual Component



Semi-annual Component

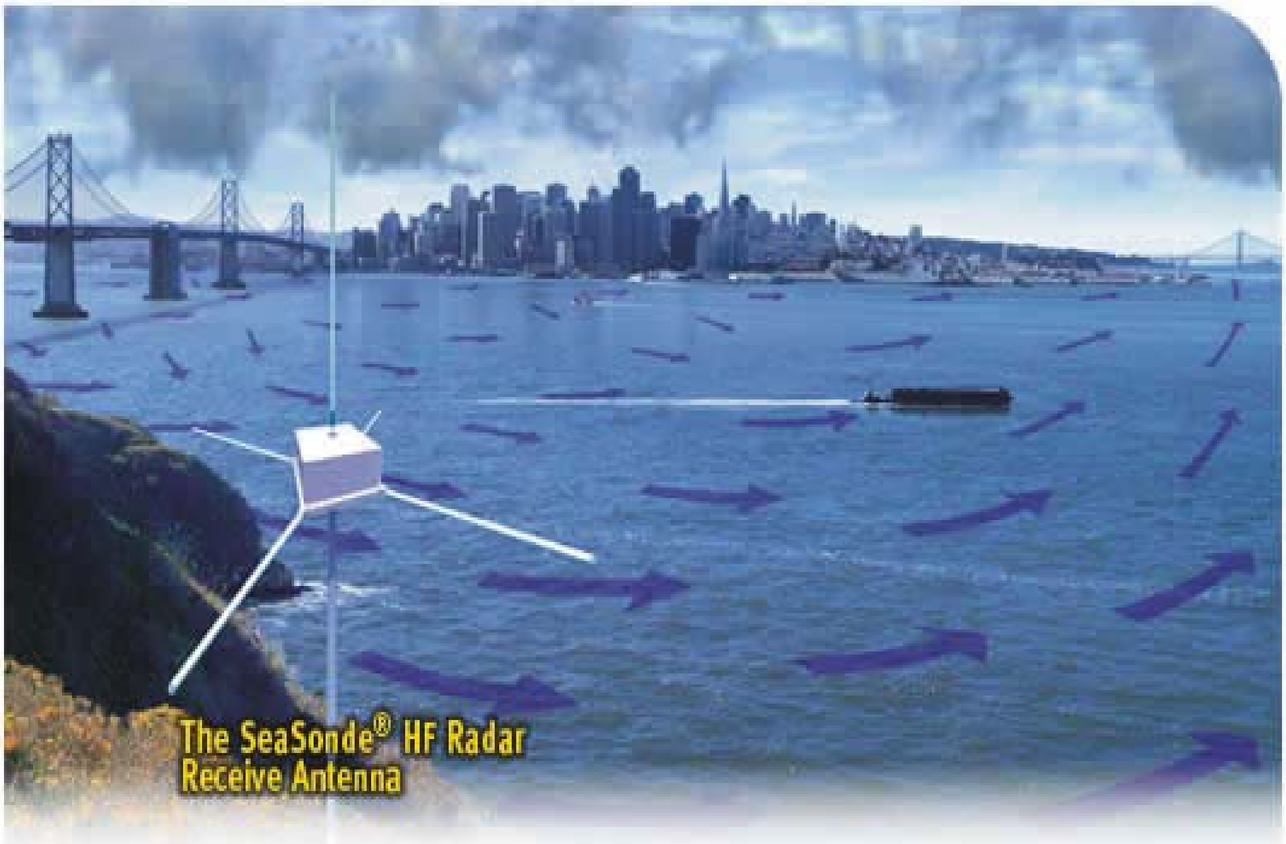


Characteristics of Annual Rossby Waves

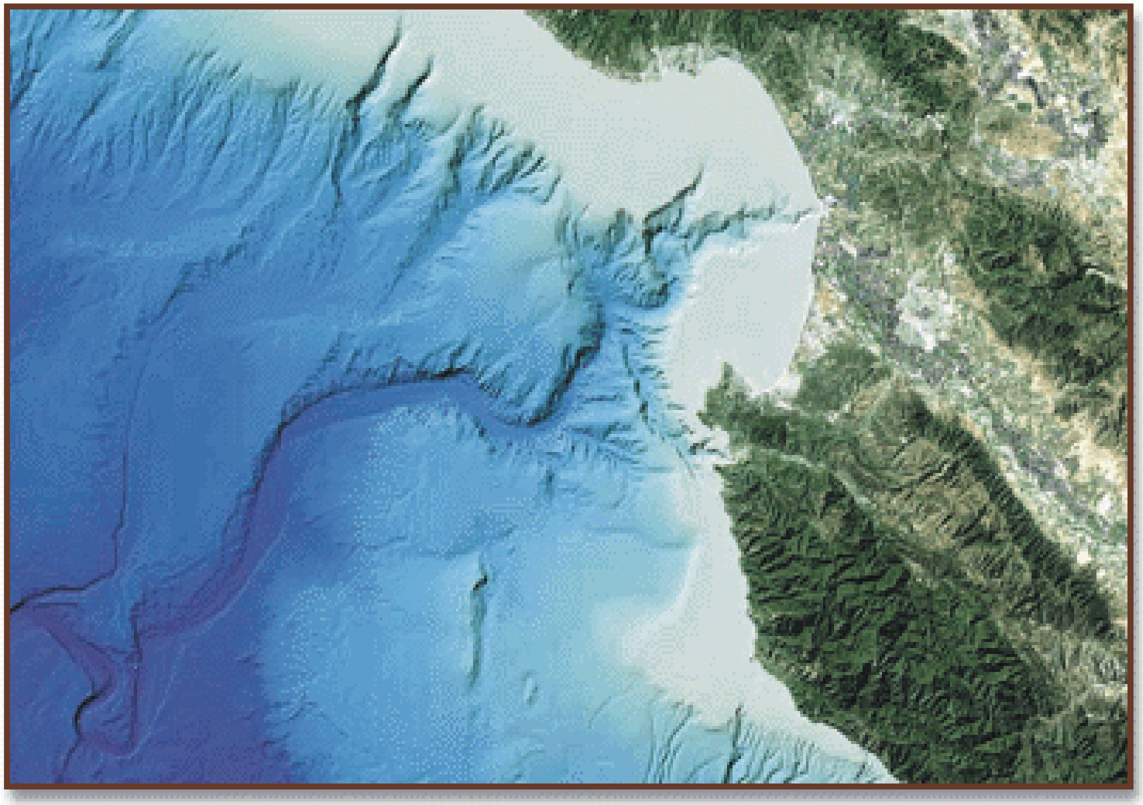
	March, 04 – May, 05 float data			March, 04 – May, 06 float data		
Latitude	c_p (cm/s)	L_1 (km)	L_2 (km)	c_p (cm/s)	L_1 (km)	L_2 (km)
5^0N	12	1200	1100	12	1300	900
8^0N	16	2500	1400	12	2100	1100
11^0N	14	2200	1400	11	1900	1100
13^0N	11	2100	1500	10	2300	1500

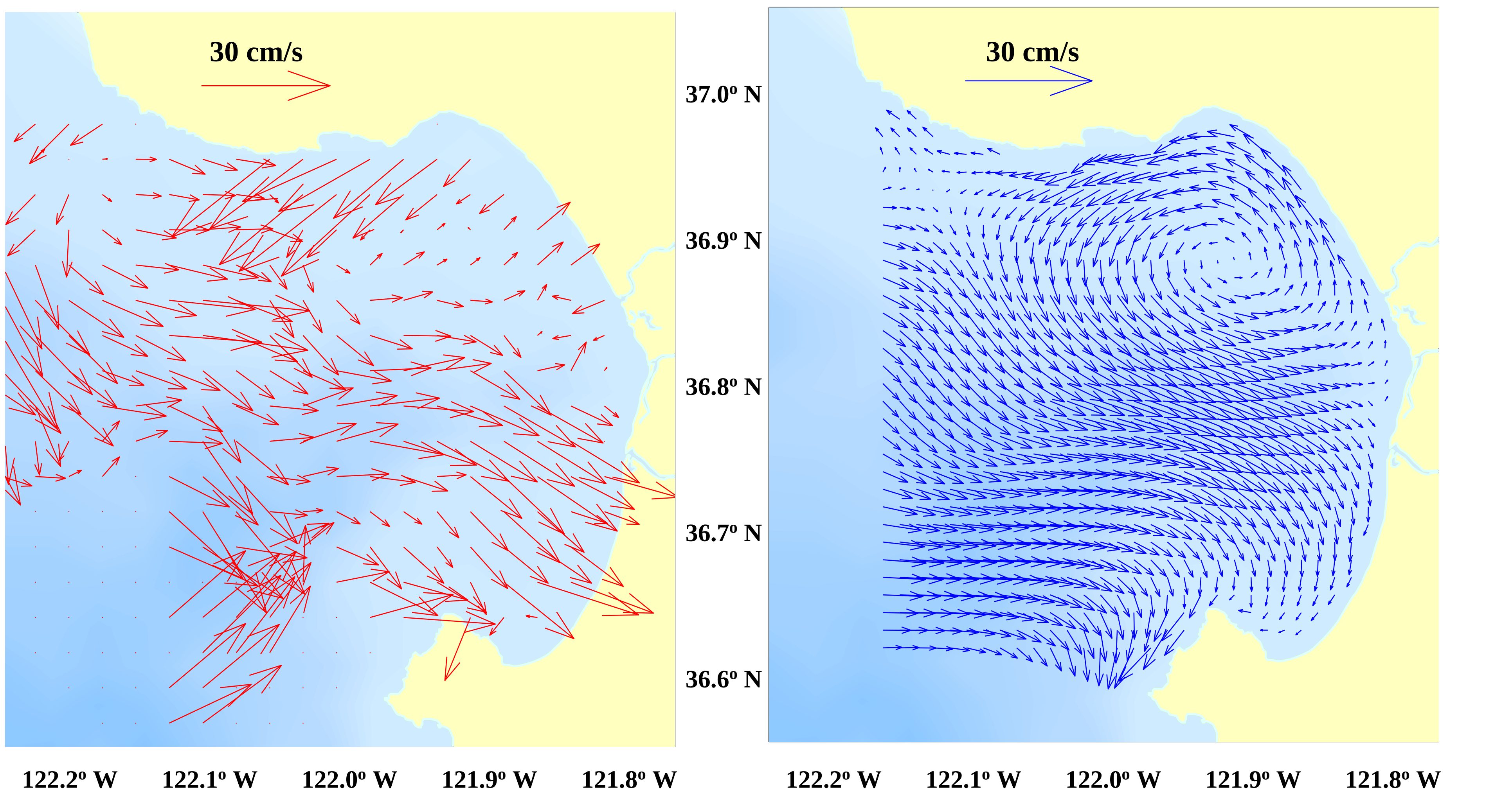
		Western Basin	Eastern Basin		Western Basin	Eastern Basin

CODAR



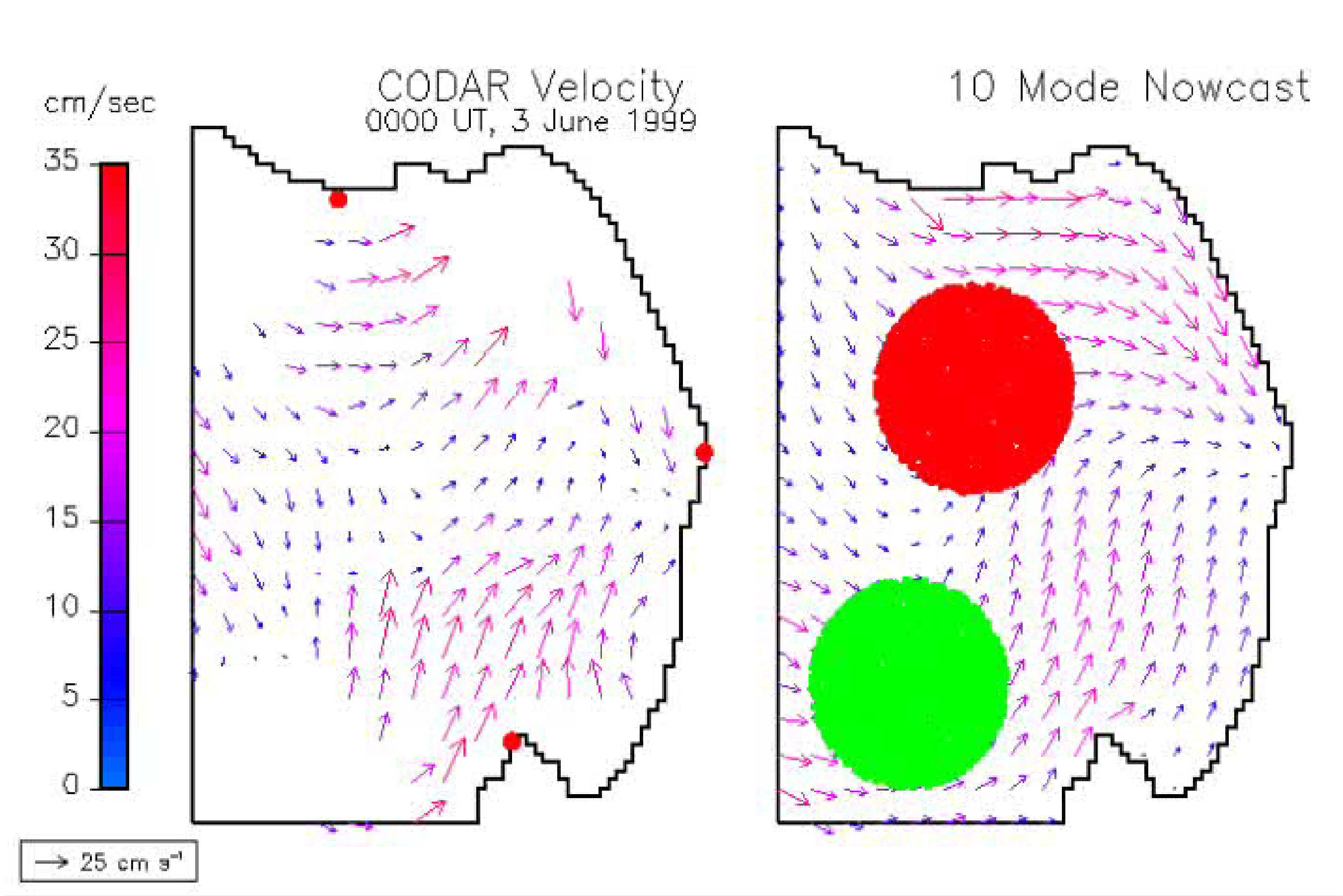
Monterey Bay





Place for comments: left - radar derived currents for 17:00 UT December 1, 1999

right – reconstructed velocity field.


CODAR Velocity
0000 UT, 3 June 1999
10 Mode Nowcast
cm/sec
35
30
25
20
15
10
5
0
→ 25 cm s⁻¹

Conclusions

- OSD is a useful tool for processing real-time velocity data with short duration and limited-area sampling.
- The scheme can handle highly noisy data.
- The scheme is model independent.
- The scheme can be used for velocity data assimilation.
- Phase space consideration