LAGRANGIAN OBSERVATIONS IN THE IBERIAN COASTAL TRANSITION ZONE

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Abstract. Satellite-tracked drifters deployed in the Iberian coastal transition zone were gradually carried northward in a poleward flowing continental slope current between September 1986 and March 1987 in convoluted trajectories which revealed the ubiquitous presence of mesoscale eddies. We estimate the rate of dispersion from the Lagrangian statistics of the drifting buoys and present a comparison of the results with those obtained from other oceanic regions. The dispersion of the drifters is well modelled by a simple description of eddy diffusion assuming homogeneous isotropic turbulence (Taylor's theory). The assumption of homogeneity and stationarity facilitated the derivation of stable Lagrangian statistics. After correction for non stationarity, the diffusivities obtained were $K_{11} = 3.4 \times 10^6 \text{ cm}^2 \text{ s}^{-1}$ in the zonal direction and $K_{22} = 2.5 \times 10^6 \text{ cm}^2 \text{ s}^{-1}$ in the meridional direction. The Lagrangian integral time scales were respectively $T_{11} = 1.25$ days and $T_{22} = 1.9$ days. Our results and those of other authors, in environments ranging from truly oceanic to eastern boundaries, have all indicated that Taylor's theory fits the observations well. As a first order approximation the assumption of a homogeneous and stationary field would appear quite robust.

1. Introduction

In recent years there has been an increase in the use of Lagrangian devices to provide a quantitative as well as qualitative picture of the ocean's current field. In particular, a number of recently published papers describe the nature of oceanic eddy fields and their associated Lagrangian statistics [e.g., Krauss and Böning 1987; Colin de Verdière, 1983]. In this paper, we use the Lagrangian properties of satellite tracked drifters to gain some understanding of the complex current field and of the dispersion and the diffusion which exist in the Iberian coastal transition zone (CTZ). This zone can be defined as the region where continental waters and open ocean waters interact. It encompasses the region of cold upwelled "filaments" observed in satellite imagery [Flament *et al.*, 1985]. The transition zone is complex, associated with intense mesoscale activity which is still poorly studied.

Our description of the surface circulation is based on satellite tracked drifters deployed in September 1986 and tracked until March 1987.

The drifters generally were gradually carried northward in a poleward flowing surface current along the Iberian Peninsula (Figure 1) during these winter months, while their convoluted trajectories revealed the ubiquitous presence of mesoscale eddies. This is described in more detail by Haynes and Barton [1990]. Independent observations of this flow are reported by Frouin *et al.* [1990].

The rate of dispersion (diffusion) in this little-studied region is estimated from the Lagrangian statistics of the drifting buoys, and a comparison of the results with those obtained from other oceanic regions is presented. The rate of dispersion in the ocean depends on the scale of the dominant processes [e.g. Okubo 1971]. The exact relationship between scale and rate is not established, although there have been various attempts to relate the two. It is likely that there exists no simple relationship and that the rate of dispersion, characterized by the corresponding horizontal diffusion coefficient (K_H), is a function of the scale of the "turbulence" [Bowden, 1972]. It is important for the study of pollutant dispersion, plankton dynamics, and numerical modelling, which depend critically on an assumed value of K_H , that as many observational estimates of K_H as possible be made in different marine environments [Booth 1988]. From a theoretical stance, the Lagrangian viewpoint allows diffusion to be examined more realistically since it is the concentration in the neighborhood of a particular element of fluid, or the separation of a pair of particles which is of interest [Bowden, 1972].

The drifter data set and its subsequent processing are first described in section 2, where the ability of the drifters to behave as true Lagrangian particles is also discussed. In section 3, a summary of the basic statistics and their spatial and temporal distribution is given. This is followed in section 4 by a brief discussion on Lagrangian statistics. Single-particle properties and their comparison with Taylor's [1921] theorem are given in section 5. Section 6 discusses the diffusivities calculated from the dispersion of the drifters. The main results of the statistical analysis are discussed in section 7 and summarised in section 8.

2. Drifter Data and Processing

Six satellite-tracked drifters drogued at a nominal depth of 5 m were released in September 1986 as part of a study of the circulation of the Iberian coastal transition zone. Two provided records of insufficient length to be useful for subsequent statistical analysis. The drifters were of the TRISTAR-II design, which have excellent water-following characteristics

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Fig. 1. Bathymetry of the Atlantic Ocean west of Iberian Peninsula.

[Niiler et al., 1987]. No determination of the behavior of the drifter under the winter conditions specific to the study area has been possible. However, wind slip estimated during spring and summer tests in the California Current was $O(0.02 \text{ m s}^{-1})$, which may be taken as the best possible performance to be expected. While actual slippage rates may have been worse, it is believed that the TRISTAR drogue is superior to traditional (cruciform and window shade) designs in this respect [Niiler et al., 1987].

The drifters should be regarded as only pseudo-Lagrangian particles, as they do not truly follow the path of the water parcels into which they were seeded. This non-Lagrangian behavior is the result of (1) wind, wave, and current shear on the drifter which leads to "slippage" of the drifter relative to the water parcel, (2) drift along horizontal surfaces (in regions of convergence or divergence water particles may move vertically, whereas the

drifter is constrained to move horizontally), and (3) random errors in the velocity estimates, introduced by satellite location tracking.

The drifters were tracked by the Argos system, and position fixes were obtained on average every 3-4 hours, although there were several periods when position updates were not obtained for 12 hours or more because of operating problems. The Argos system at the latitude of interest gives position fixes to an accuracy of $O(250 \text{ m})$. The record lengths of the various drifters are given in Table 1. The data were interpolated to 1-hourly intervals by use of a cubic spline. The data were then filtered using a cosine Lanczos filter, with a half-power point at 40 hours to remove tidal and inertial currents, and sub sampled to 6 hourly values. The drifter positions are referenced to a Cartesian coordinate system with the positive x direction towards the east (subscript 1), and the positive y direction towards the north (subscript 2), the origin being at 40°N , 10°W .

3. The Temporal and Spatial Distribution

The filtered drifter tracks shown in Figure 2 illustrate the general northward meandering associated with the presence of a poleward flowing continental slope current off Iberia during the winter months. The drifters also reveal the complex and intense mesoscale activity associated with the numerous eddies in this flow.

As the drifters were only observed for a relatively short time $O(\text{months})$ during the autumn and winter of 1986, we are unable to construct a "snapshot" of the mean wintertime circulation. However, it is observed that during the winter months, flow is poleward along the continental slope off Iberia. It appeared stronger within 100 km of the coast and flowed around Cape Finisterre into the Bay of Biscay and along the northern Spanish coast. These observations of the current provide an estimated alongshore mean flow of the order of $0.1\text{--}0.2 \text{ m s}^{-1}$. A similar speed was indicated by current meter data discussed by Haynes and Barton [1990], who also showed that the drifter tracks closely follow the thermal signature of the current as it advects relatively warm and saline water poleward.

TABLE 1. Primary Statistics and Lagrangian Time Scales and Length Scales as Derived From the Autocorrelation Functions

Buoy No.	Record Length Days	Mean Velocity, cm s^{-1}		Time Scale, days		Length Scale, km	
		$\bar{u}$	$\bar{v}$	τ_u	τ_v	L_u	L_v
6220	178	0.4	2.4	1.1	2.0	9.1	12.1
6222	149	2.4	1.8	2.7	3.3	21.5	16.9
6227	165	0.1	0.5	1.5	3.4	8.2	18.5
6234	95	0.8	-0.3	1.1	6.7	4.5	20.8
Mean		0.8 ± 0.5	1.1 ± 0.6	1.6 ± 0.8	3.8 ± 2.0	10.9 ± 7.4	17.0 ± 3.7
Mean from 52 segments		0.8	1.3	1.3	1.9	9.2	11.2

Fig. 2. Drifter trajectories of four triangles. The duration of the drifters is given satellite-tracked buoys. The launch position is indicated by squares and the end point by triangles.

4. Lagrangian Statistics and Turbulent Diffusion

In order to obtain meaningful Lagrangian statistics on the diffusion within an oceanic eddy dominated environment it is usual to apply the theory of homogeneous isotropic turbulence [Taylor, 1921]. However, as the buoys are in a complex coastal transition zone where the mean flow is inhomogeneous, it cannot necessarily be assumed that the buoy position $\mathbf{r}(t)$ at time t is the result of a stationary process. For a limited period it is, however, possible to approximate the non stationarity of the buoy position $\mathbf{r}(t)$ by a linear function and hence the increments of $\mathbf{r}(t)$ form a stationary random process [Panchev, 1971].

If $\mathbf{u}(t)$ is the velocity at time t of a drifter and $\bar{\mathbf{u}}$ is the mean velocity of the drifter, the residual velocity can be defined as $\mathbf{u}'(t) = \mathbf{u}(t) - \bar{\mathbf{u}}$, where an overbar represents a mean value. The normalized autocorrelation function $R(\tau)$ is defined as

$$R(\tau) = \frac{1}{\bar{\mathbf{u}}'^2 T_{\max}} \int_0^{T_{\max}} \mathbf{u}'(t) \mathbf{u}'(t+\tau) dt \quad (1)$$

The Lagrangian integral time scale T and space scale L are a measure of the time scale during which the drifter "remembers" its path (i.e., correlates with itself) and are defined as

$$T = \int_0^{\infty} R(t) dt \quad (2)$$

$$L = \sqrt{\bar{\mathbf{u}}'^2} \int_0^{\infty} R(t) dt = \sqrt{\bar{\mathbf{u}}'^2} T \quad (3)$$

The finite length of the time series $T_{\max}$ leads to problems when determining the integral time scale T . The autocorrelation functions consist of a decaying and oscillatory component, and as the integration in (2) cannot be extended to infinity the oscillatory component can falsify T . The method chosen to minimize the effect of the oscillatory component was to integrate from zero to the time of the first zero crossing. This is the usual practice and corresponds to the first maximum of the integral scales and the results obtained can be regarded as upper bounds to the true scales [Poulain and Niiler, 1989].

If we assume homogeneous isotropic turbulence, the single-particle dispersion (i.e., the dispersion of a particle from its origin) is related, according to Taylor [1921], to the autocorrelation function as

$$\overline{\mathbf{x}'^2(t)} = 2\bar{\mathbf{u}}'^2 \int_0^t (t-\tau) R(\tau) d\tau \quad (4)$$

where $\mathbf{x}'(t)$ is the displacement due to $\mathbf{u}'$. Equation (4) reaches two limits independent of the form of $R(\tau)$: Initial dispersion, as $t \rightarrow 0$, $t < T$ ($R(0)=1$ at $\tau=0$),

$$\overline{\mathbf{x}'^2} = \bar{\mathbf{u}}'^2 t^2 \quad (5)$$

Fig. 3. (a) The number of artificially generated releases, produced by restarting the trajectories at 10-day intervals as a function of time. (b) Time series of the mean displacements (motion of the center of gravity)

in the zonal and meridional directions for the 52 segmented drifter tracks. The straight lines correspond to global mean velocity computed from the entire data set.

and random walk regime, for $t \gg T$ ($R(\tau) \rightarrow 0$, as $\tau \rightarrow \infty$),

$$\overline{x'^2} = 2\overline{u'^2}Tt \quad (6)$$

The Lagrangian diffusivity K_{ii} , where $i = 1$ for the zonal direction and $i = 2$ for the meridional direction, is defined as half the rate of change of dispersion. During the random walk regime the diffusion is proportional to time, and so it is given by

$$K_{ii} = \frac{1}{2} \frac{d\overline{x'^2}}{dt} = \overline{u'^2} \int_0^t R(\tau) d\tau = \overline{u'^2} T \quad (7)$$

The number of drifters available (four), is small and does not approach the large number of realizations required to determine diffusion and dispersion by the approach of single-particle dispersion. Utilisation of the data base was increased by taking advantage of stationarity and homogeneity in a method first described by Colin de Verdière [1983]. Since the decorrelation time scale will be shown to be of the order of 2 days, any two locations of the same drifter separated in time by more than 2-3 days, longer than the Lagrangian integral time scale T should be uncorrelated. Hence it should be possible to increase the data set substantially by restarting the drifters every 3 days. In reality Colin de Verdière showed that the expected increase in the number of degrees of freedom is less than theory predicts, and so to avoid the possibility of unwanted correlations between drifter segments which would lead to spurious statistics, a new buoy data segment was

started every 10 days. The original four drifter tracks therefore yielded 52 drifter segments. It was necessary to limit the length of the composite data set to 60 days, as after this time the number of contributing observations (the number of artificially generated releases) is less than 30, which is insufficient to provide reliable statistics (Figure 3a).

To test Taylor's theory it is necessary to separate the motion of the center of gravity of the drifters, $\bar{x}$ (i.e., the instantaneous mean of the drifter positions), and the dispersion, caused by turbulence, away from that center of gravity. The drifters tend to disperse by the action of velocity features over a range of scales within the ocean. The background circulation was effectively removed from the analyses, leaving the dispersion to be estimated as the cumulative effect of the smaller scale processes both random and non random. Figure 3b shows that up to approximately 60 days, mean displacements of the segmented data and the values of the global mean flow ($0.84, 1.27 \text{ cm s}^{-1}$) are in good agreement. The data, therefore, satisfy the relationship

$$\frac{d}{dt} \bar{x} = \bar{u} \quad (8)$$

and so Taylor's theorem can be applied to periods of less than 60 days. The assumption of independent data segments is important in the procedure, since if independence is not achieved, the observed correlation function will not fall to zero at large time lags. This procedure has the disadvantage that it puts

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Fig. 3. (continued)

extra emphasis on the middle portion of each drifter record, which is the portion most frequently sampled by the segmentation of the tracks. In our case, as the drifter records are relatively short, $O(\text{months})$, we may be biasing the Lagrangian results toward time and length scales that predominated for only a short time during the middle of the drifter deployment. However, the segmentation of the drifter records does enhance a limited data set, and this outweighs the possible risk of bias.

5. Single-Particle Dispersion

In this section we explore the absolute dispersion of particles from a fixed origin using the theory of Taylor [1921] and assuming homogeneity and stationarity of the underlying turbulent field. Under these assumptions, the estimated Lagrangian dispersion should closely resemble the dispersion of an instantaneous release of dye about its center of gravity computed after a large number of releases (or restarts). To illustrate the diffusive character of the currents within the Iberian coastal transition region the segmented drifter tracks are shown in Figure 4, as the displacement of each of the segments versus time after deployment or restarting. The figure has the appearance of a diffusing dye plume from a continuous source and illustrates the dispersion and advection of particles by the assumed homogeneous turbulent field.

Figure 5 shows the rms dispersion of the drifters calculated from the residual velocity $u'(t)$ as a function of time for a range up to 60 days. After this time the number of data points becomes too small, and random fluctuations become dominant. It is possible to distinguish the two distinct regimes predicted by Taylor's

small time and large time approximations (equations (5) and (6)). The first is the rapid increase in dispersion during the initial time after deployment; this corresponds to Taylor's small-time approximation where dispersion is proportional to the square of time after release. The second regime is a region of reduced but linear increase in dispersion between days 20 and 60 which corresponds to Taylor's large-time approximation (equation (6)), where the increase in dispersion is directly proportional to time. In the following subsections we attempt to fit our observations to Taylor's theory and show that the theory and observations agree reasonably well.

5.1. Initial Dispersion

If Taylor's theory is applicable to the situation observed off Iberia, then the initial dispersion should increase as t^2 in the limit as $t \rightarrow 0$ (equation (5)). Figure 6 shows the good agreement between Taylor's small-time approximation and the observed rms dispersion. The observed and theoretical curves follow closely up to $1\frac{1}{2}$ days in the zonal direction and $2\frac{1}{4}$ days in the meridional direction. After these periods the observed increase in the rate of dispersion slows down in accordance with Taylor's theory. The transition period between the two limiting cases of Taylor's theory (i.e., initial dispersion and random walk) is from equation (4) dependent on the autocorrelation function $R(\tau)$. Krauss and Boning [1987] examined the deviation of their observed curves from theoretical dispersion curves and showed that the smaller the integral time scale T , the shorter is the initial time range before the observed curves deviate from Taylor's small-time approximation. As the zonal integral time scale

Fig. 4. (a) Zonal and (b) meridional for the segmented drifter tracks, showing the displacement plots versus time after deployment dispersing "plume" revealed by the drifters.

Fig. 5. Dispersion plotted as a function of time, showing the rapid initial dispersion and the near-linear increase in the rate of dispersion from days 20 to 60.

is shorter than the meridional time scale, we observe the zonal dispersion deviating from the theoretical curve prior to the meridional dispersion in Figure 6.

5.2. Random Walk (Taylor's Large-Time Approximation)

As was previously noted, Figure 5 shows that after a time $O(10)$ days the rate of dispersion has slowed down to a random walk i.e. a linear

increase with time. Log-log plots of the dispersion versus time (Figures 7a and 7b) show that there is good agreement between the observed dispersion curves and Taylor's theory both for the initial dispersion, as was already discussed, and for the random walk regime. The straight lines on Figures 7a and 7b are calculated from Taylor's large-time approximation (equation (6)) using the Lagrangian integral time scale T calculated from

Fig. 6. The rms displacement versus time for the initial dispersion regime. The symbols represent the observations, the straight lines show the initial linear regime predicted by Taylor's theorem (equation(5)). Error bars represent 67% confidence limits of the rms displacement.

Fig. 7. A log-log plot of the dispersion (displacement variance) versus time for (a) the meridional direction and (b) the zonal directional. The symbols show the observations and the solid lines represent Taylor's theorem for initial dispersion (equation (5)) and random walk regime (equation (6)). Error bars represent 67% confidence limits of the displacement variance.

the autocorrelation function of the segmented drifter tracks. The Lagrangian integral time scale estimated from Figures 7a and 7b by a least squares analysis of the dispersion curves between days 20 and 60 agrees closely with the time scale calculated below by integrating the autocorrelation function.

6. Diffusivities

The close agreement between the observed dispersion curves and Taylor's two approximations is consistent with the hypothesis that homogeneity and stationarity are appropriate for the Iberian coastal transition

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Fig. 7. (continued)

Fig. 8. The mean Lagrangian autocorrelation time lag for the zonal (solid) and meridional functions and diffusivities as a function of (dashed) directions.

zone. Hence estimates of diffusivities (diffusion coefficient) obtained should be valid. As dispersion curves showing a linear relationship between the horizontal scatter variance $\overline{x^2}$ and time indicate a constant diffusion coefficient, it would be expected that for times between 20 and 60 days (i.e., at mesoscale periods) a constant horizontal diffusion coefficient K_H is appropriate. Figures 6 and 7 both show a linear relationship between the dispersion and time in that time range.

The Lagrangian diffusivity can be evaluated by any of the definitions of equation (7). It was here calculated by integrating the

autocorrelation function. To compute the needed autocorrelation function, the overall mean was first subtracted from the velocity time series of each drifter. The mean Lagrangian autocorrelations are shown in Figure 8 and have zero crossing points at 5 and 7 days in the zonal and meridional directions respectively. The associated Lagrangian time scales are $(T_{11}, T_{22}) = (1.25, 1.9)$ days by (equation (2)), and the Lagrangian length scales are $(L_{11}, L_{22}) = (9.2, 11.2)$ kms from equation (3). The mean Lagrangian scales calculated from the 52 drifter segments are smaller than those calculated from the individual drifters (Table 1) probably as a

result of the subtraction of different means. The observed autocorrelation function (Figure 8) falls to near zero at lags approaching 60 days. This indicates that the procedure of restarting the drifters every 10 days is a valid one, as for large lags the drifter segments are uncorrelated. The correlation between the drifter segments in our processing is much less than that reported by other authors [Poulain and Niiler, 1989; Colin de Verdière, 1983; Krauss and Böning, 1987; Booth, 1988]. This probably results from our segmenting the data at time periods approximately 5 times longer than the Lagrangian integral time scale, thus ensuring that there is no possibility of correlations due to having too short a segmentation time interval.

As the dispersion $\overline{x^2}$ increases linearly with time in the random walk regime, the diffusivity according to equation (7) reaches a constant level in that regime. This constant level is observed in Figure 8 from day 20 to day 60. The mean value in this interval gives the random walk diffusivity, which is calculated in the zonal direction as $K_{11} = 3.4 \times 10^6 \text{ cm}^2 \text{ s}^{-1}$ and in the meridional direction as $K_{22} = 2.5 \times 10^6 \text{ cm}^2 \text{ s}^{-1}$.

7. Discussion

In the above sections we have shown that by assuming a homogeneous and stationary oceanic field there is excellent agreement between the theoretical results of Taylor [1921] and our observations. This is quite surprising in view of the fact that the drifters obviously sampled a very inhomogeneous velocity field, from eddies of different scales to low frequency, near-linear, topographically guided currents. These must have different Lagrangian time and length scales associated with them, and so for a simple theory that assumes one time and length scale to fit observations so well is remarkable. It would thus appear that as a first-order approximation the assumption of a homogeneous and stationary field is quite robust. Indeed, the recent papers of Poulain and Niiler [1989], Krauss and Böning [1987], and Colin de Verdière [1983], in environments ranging from truly oceanic to eastern boundaries, have all shown that Taylor's theory fits the observations well.

If we compare the different scales of diffusion observed by other authors we find as expected that the rate of dispersion depends on the scale of the dominant processes (Table 2). In the open ocean where large mesoscale ($O(100$

TABLE 2. A Comparison of Lagrangian Length and Time Scales and Diffusion Coefficients for Different Oceanic Regions Obtained Using Drifting Buoys

Region	Author	Time Scale	Length Scale	Diffusion Coefficient
		T days	L km	$K, \text{ cm}^2 \text{ s}^{-1}$
N.E. Atlantic	Booth [1988]	$O(3-4)$		$3-4 \times 10^7$
E.N. Atlantic (Bay of Biscay)	Colin de Verdière [1983]	$T_{11} 2.5$		$K_{11} 2.3 \times 10^7$
		$T_{22} 2.0$		$K_{22} 1.7 \times 10^7$
N.N. Atlantic	Krauss and Böning [1987]	$T_{11} 2.8$	$L_{11} 40$	$K_{11} 6.6 \times 10^7$
		$T_{22} 2.1$	$L_{22} 30$	$K_{22} 4.5 \times 10^7$
E. Pacific (California Current)	Poulain et al. [1989]	$T_{11} 4.2$	$L_{11} 40$	$K_{11} 3.4 \times 10^7$
		$T_{22} 4.7$	$L_{22} 48$	$K_{22} 4.3 \times 10^7$
California CTZ	Davis [1985]	$O(1.5)$	$O(40)$	
10 km				$K_{11} O(10^6)$
Offshore				$K_{22} 3 \times 10^7$
Offshore				K_{11} increases K_{22} decreases
Iberian CTZ	this paper	$T_{11} 1.3$	$L_{11} 9.2$	$K_{11} 3.4 \times 10^6$
		$T_{22} 1.9$	$L_{22} 11.2$	$K_{22} 2.5 \times 10^6$
Oregon coastal region	Stevenson et al. [1974]			1.24×10^4

km)), eddies dominate, typical diffusivities are $O(10^7 \text{ cm}^2 \text{ s}^{-1})$, Lagrangian time scales $O(2-4 \text{ days})$ and Lagrangian length scales $O(40 \text{ km})$. In coastal transition zones where eddies of $O(30 \text{ km})$ and topographically guided flows are common, the typical diffusivities are $O(10^6 \text{ cm}^2 \text{ s}^{-1})$, Lagrangian time scales are $O(1-2 \text{ days})$ and length scales are $O(10-40 \text{ km})$. In shallow coastal shelf seas the scale of the dispersive processes are correspondingly smaller and typical diffusivities are $O(10^4 \text{ cm}^2 \text{ s}^{-1})$.

In the case of the Iberian coastal transition zone the character of the flow is related to the close proximity of the coastline, to localized sources of mesoscale variability associated with eastern boundary processes, and to annual variations in the current regime. Davis [1985] showed that on the continental shelf off central California the diffusivity is anisotropic, with the zonal diffusivity being suppressed within 40 km of the coast owing to the nearly two-dimensional flow parallel to the coast. This may be the case off Iberia, but the lack of sampling nearshore precludes any discussion of nearshore variability. There is a marked seasonality in the current regime in the Iberian coastal transition zone. During the winter months, when the drifters were deployed, a poleward flowing continental slope current is dominant. This is a relatively weak phenomenon with surface currents $O(0.1-0.2 \text{ m s}^{-1})$. The most energetic features are therefore the small mesoscale eddies $O(20-30 \text{ kms})$ which are observed in advanced very high resolution radiometer (AVHRR) infra red satellite imagery. The direct effect of these eddies on large-time dispersion is probably small, as they tend to stir rather than mix. However, the indirect contribution can be important because they introduce shear, and their kinetic energy may be shed to smaller scales where it contributes to mixing [Booth, 1988].

In summer, the Iberian coastal transition zone is a region of active upwelling. Satellite imagery indicates the zone is dominated by energetic features such as cool filaments, similar to the California Current region where offshore flowing current jets with speeds $O(1 \text{ m s}^{-1})$ have been reported [e.g., Kosro and Huyer, 1986]. The marked seasonality of the dynamical processes must lead to differences in the diffusivities and the Lagrangian length and time scales throughout the year. In the summer, when the Iberian coastal transition zone is more energetic, the scales of the dominant physical processes are larger, and we would therefore expect the corresponding diffusivities and Lagrangian length and time scales to be bigger. It is important for the study of pollutant and plankton dispersion and numerical modelling that as many observational estimates of the diffusivity K_H be made as possible. In complex regions such as coastal transition zones, these must encompass the seasonal evolution of diffusivity as well as the nearshore cross-shelf variations due to the proximity of the coast and the presence of the continental shelf.

8. Summary

Satellite tracked drifters deployed in the Iberian coastal transition zone during the

autumn and winter of 1986 sampled a very inhomogeneous velocity field with weak mean flow and eddies of different scales. The observed surface circulation represents a weak continental slope current which flows northward along the Iberian peninsula into the Bay of Biscay. The dispersion of the drifters is well modelled by a simple description of eddy diffusion assuming homogeneous isotropic turbulence [Taylor, 1921]. The assumption of homogeneity and stationarity facilitated the derivation of stable Lagrangian statistics. After correction for non stationarity, the diffusivities obtained were $K_{11} = 3.4 \times 10^6 \text{ cm}^2 \text{ s}^{-1}$ and $K_{22} = 2.5 \times 10^6 \text{ cm}^2 \text{ s}^{-1}$. The Lagrangian integral time scales were respectively $T_{11} = 1.25 \text{ days}$ and $T_{22} = 1.9 \text{ days}$.

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