NEAR-SURFACE DRIFTER TRAJECTORIES IN THE POINT CONCEPTION AREA

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ABSTRACT

Over 450 satellite-tracked drifters deployed near Point Conception provide insights into the near-surface circulation in the region. Drifters were seeded uniformly throughout the region and in all seasons. This was done in order to sample evenly in space and time minimizing bias towards any one circulation pattern. After deployment, drifters either exited the region or beached on an island or mainland coast. Typical residence times for drifters which exited were 10 days. The near-surface drifters exhibit a response to wind forcing and pressure gradients. South and east of Point Conception, in the Santa Barbara Channel, hydrographic cruises provide evidence that baroclinic pressure gradients are important in determining drifter trajectories. Local wind forcing is also important in the southwestern Santa Barbara Channel. North and west of Point Conception, in the Santa Maria Basin, the picture is more complicated. Though the baroclinic pressure gradient is sometimes important, the barotropic pressure gradient may also play a role. Local wind forcing can also be important here. The drifters were equipped with accurate temperature sensors. These indicate the amplitude of diurnal heating and cooling as well as giving insight into temperature mixing.

Keywords: Santa Barbara Channel, Santa Maria Basin, near-surface circulation, field observations

INTRODUCTION

To learn more about circulation within the Santa Barbara Channel and Santa Maria Basin and to better assess oil spill risks, the Minerals Management Service has funded an extensive oceanographic field program, the Santa Barbara Channel - Santa Maria Basin Coastal Circulation Study (Hendershott and Winant 1996; Harms and Winant 1998). The program included over 450 surface drifters deployed at 24 locations in a rough grid pattern within the Santa Barbara Channel and Santa Maria Basin (Figure 1). It also included an extensive moored current meter array with near-surface vector-measuring current meters (VMCMs) at 5 m depth. During mooring turnaround cruises, combined conductivity-temperature-depth, expendable bathythermograph, and acoustic Doppler current profiler (CTD/XBT/ADCP) surveys were also made.

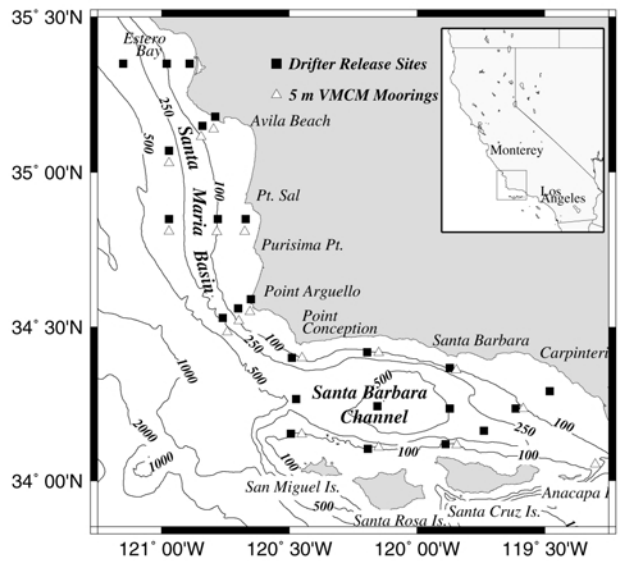

Figure 1. The Santa Barbara Channel and Santa Maria Basin, showing drifter deployment sites (solid squares) and vector-measuring current meter (VMCM) moorings (open triangles). Bottom bathymetry is also shown.

MATERIALS AND METHODS

The surface drifters used here are similar to the Davis (1985) Coastal Ocean Dynamics Experient (CODE) design. A central cylindrical case houses batteries and electronics. Four nylon sails are attached with fiberglass rods. Spherical styrofoam floats tied to the ends of the rods provide buoyancy. The nominal sampling depth of the drifters is 0.5 m. The primary difference between these drifters and the CODE type is the use of ARGOS satellite tracking rather than radio tracking. Positions were acquired for at least 40 days. Generally, four to five fixes per day are available with an accuracy of under 1 km (most often, under 300 m). Drifters and moored velocity measurements (Dever et al. 1998) compare well. Drifters also measured temperature (calibrated to 0.01°C) once per min and averaged them every hour.

Our data come almost entirely from drifters deployed on 25 occasions between May 1993 and July 1998. Additional data from a few drifters deployed in testing and for oil spill response drills also exist. To sample the seasonal variability, deployments were spaced about every 3 months. From 1993 to 1995, drifters were deployed mainly in the Santa Barbara Channel with only one or two drifters deployed in the Santa Maria Basin. Beginning in January 1996 the focus of the field effort shifted to the Santa Maria Basin with 12 drifters released there in each deployment.

During mooring turnaround cruises, drifters were deployed from the survey ship. In between these cruises, drifters were deployed from a small boat or helicopter. When survey data is available it greatly aids in interpreting the initial drifter trajectories. Ship surveys were generally completed in two days or less. To decrease survey time and increase synopticity, the primary survey method was XBTs. A temperature-salinity (T/S) relation based on historical CTD data was then used to estimate salinity from temperature. Underway velocity measurements were also acquired using a ship-mounted or towed ADCP.

Moored velocity and wind measurements also aid in the interpretation of drifter tracks. Between 1993 and 1995, eight moorings were in the Santa Barbara Channel with one or two moorings in the Santa Maria Basin. Since the beginning of 1996, 12 mooring sites within the Santa Maria Basin have been occupied along with sites at the eastern and western Santa Barbara Channel. Each mooring includes a near-surface vector-measuring current meter (VMCM) at 5 m. Winds from National Data Buoy Center (NDBC) buoys and meteorological stations on oil platforms and the coast were also acquired.

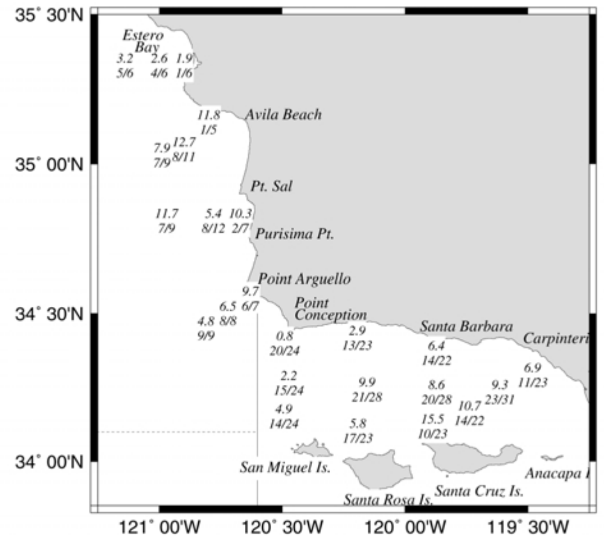

Figure 2. Residence times of drifters in the Santa Barbara Channel and Santa Maria Basin areas. The Santa Barbara Channel region considered here extends south along the solid line from the mainland between Point Arguello and Point Conception to the bottom of the map and east to the eastern boundary of the map. The Santa Maria Basin extends from the top of the map south to the dashed line west of San Miguel and east to the solid line marking the western boundary of the Santa Barbara Channel region. At each drifter launch point, the three numbers shown correspond to: median residence time of those exiting in days over the (number exiting)/(number deployed) e.g. at the northwest channel location 0.8 over 20/24 indicates a median residence time of 0.8 d with 20 exiting the Channel region out of 24 deployed.

RESULTS

Residence Times and Beaching

The residence time is defined here as the length of time a drifter spends in a specified region. Two regions are considered. The first is the Santa Barbara Channel, and the second is the Santa Maria Basin. The Santa Barbara Channel has well defined boundaries consisting of the eastern and western entrances and the Channel Islands. The Santa Maria Basin has more nebulous boundaries. Here we consider it to extend from Estero Bay south to a latitude near the Channel Islands and from the coast to 121.25°W. The Santa Barbara Channel and Santa Maria Basin regions considered here are indicated on Figure 2 and are roughly equal in area.

Within the Santa Barbara Channel, relatively large temperature gradients and spatially variable wind forcing exist (Harms and Winant 1998). The combination of wind and temperature forcing leads to a commonly-observed vigorous anti-clockwise (cyclonic) feature in the western channel with weaker circulation in the east. These characteristics affect the residence time and likelihood of beaching. In the Santa Barbara Channel, drifters launched in the western channel exited most rapidly (Figure 2) and had the lowest likelihood of beaching. Several of the beached drifters launched in the northwest channel actually were caught up in the cyclonic circulation, transported south and beached on the Channel Island coasts. Drifters launched in the eastern channel had longer residence times with an increased likelihood of beaching. These drifters generally beached near their launch points.

The Santa Maria Basin shelf is generally broader than that in the channel (approximately 20 km), while the coast is distinguished by Point Arguello, Purisima Point, and Point Sal. Within the Santa Maria Basin, wind forcing is more uniform and temperature gradients arise largely due to coastal upwelling. Most drifters deployed in the Santa Maria Basin exited within 10 days. Drifters deployed in the north across Estero Bay exited the region most rapidly. Drifters launched at the inshore locations near Avila Beach and Point Sal were the most likely to beach and beached near their launch point. Interestingly, few of the drifters launched at the Point Arguello line beached. Initial offshore movement was usually followed by southward flow west of San Miguel Island in summer or northward flow through the Santa Maria Basin in fall and winter. In only one deployment (April 1998) were drifters observed to transit into the Santa Barbara Channel from the Point Arguello line.

The Roles of Baroclinic Pressure Gradients and Wind Forcing

Despite the fact that drifters sample at a depth of less than 1 m, their trajectories can show effects of both subsurface baroclinic pressure gradients and surface wind forcing (local Ekman transport). Baroclinic pressure gradients are derived from horizontal gradients of density (temperature and salinity) as measured during CTD/XBT ship surveys. When pressure gradients act to balance the acceleration due to the Earth's rotation (Coriolis force), flow tends to occur along lines of constant pressure (geostrophic flow). Likewise, direct wind forcing of near-surface flow is affected by the Coriolis force such that wind-forced flow tends to be directed to the right of the wind in the northern hemisphere (Ekman flow). The effects of both geostropic and Ekman flow are seen when the drifter trajectories are examined in light of measured wind stress and the ship survey baroclinic pressure field (dynamic topography).

The effect of the baroclinic pressure gradient is seen most clearly in the western Santa Barbara Channel where a large low exists (Figure 3). Flow tends to be cyclonic (counterclockwise in the northern hemisphere) around this low. It is evidenced both by the drifters as well as by moored current meter and ship-survey ADCP measurements, and the magnitude of the flow as estimated by the baroclinic pressure gradient is approximately that observed.

Elsewhere, the consistency of the observed flow with the dynamic topography varies. In the southwest Santa Barbara Channel, where winds tend to be strong, wind forcing tends to force drifters in a southwest direction across lines of constant pressure. In the eastern Santa Barbara Channel the flow often bears little resemblance to that implied by topography while in the Santa Maria Basin, the baroclinic pressure gradient tends to have a smaller effect on the flow. Occasionally, as in Figure 3, it can be quite large in the Santa Maria Basin, but generally the flow implied by the dynamic topography is weaker than the observed flow. The strength of the observed flow relative to the dynamic topography may in part be due to a large contribution by the barotropic pressure gradient which is not included in the dynamic topography.

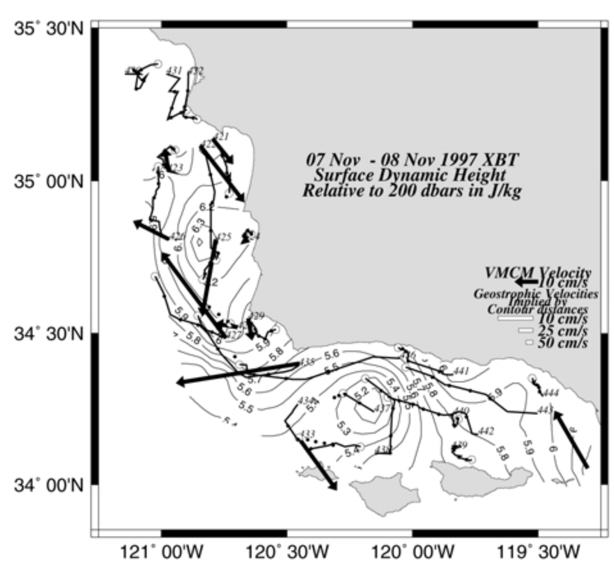

Figure 3. Surface dynamic topography with drifter trajectories and near-surface current meter vectors superimposed. The drifter trajectories are shown for approximately one day after deployment. Numbers indicate the start position of drifters are connected by solid lines to the open circles which indicate the last fix received on 8 November. Solid dots indicate drifter positions interpolated every six hours. In some cases they extend beyond the open circle to give a qualitative indication of drifter movement. VMCM velocity arrows are scaled such that their length corresponds to the distance a particle with that velocity would travel in one day.

Drifter Temperature Variability

Drifter temperature variability occurs on both diurnal and lower frequency time scales. Diurnal temperature variability occurs due to daytime near-surface warming and nighttime cooling. The magnitude of the diurnal cycle is affected by the wind stress as well as the solar radiation received during the day. High wind stress causes vertical mixing of heat input by the sun down to 10 m or more and a smaller near-surface temperature change than if solar heating were confined to the top couple of meters. Thus the amplitude of the diurnal heating cycle is primarily a function of the local wind conditions rather than the seasonal variation of solar radiation. Its amplitude generally ranges from about 0.5 to 2°C.

Averaged over time scales of several days, the net surface heat flux has a relatively small effect on drifter temperatures and on these time scales temperature variability occurs primarily due to horizontal and vertical mixing. The paths of the drifters in combination with the observed surface temperatures give some insight into temperature mixing. For example, in summer temperature isolines trend roughly southeast to northwest in the Santa Barbara Channel. The warmest temperatures are found along the mainland coast while the coldest temperatures are found in the southwest and in the center of the cyclonic circulation cell. Drifters often transit around the circulation cell with periods of several days. As a drifter moves from the north coast south towards the Channel Islands its temperature almost always decreases by several degrees. Either vertical mixing with colder subsurface water or horizontal mixing with colder surface water can cause this. Later it may head east and north to complete the cyclonic circulation. During this time its temperature generally increases. This increase is probably due to horizontal mixing only as mixing with colder subsurface water can only decrease its temperature further.

The drifter trajectories complement moored measurements and provide the most direct insights into water parcel movement available. They can be used qualitatively to gauge the likelihood of pollutants released at different locations impacting the coast. In the Santa Maria Basin, drifters released near the shore had the highest likelihood of beaching. They generally beached near their release points. In the Santa Barbara Channel, drifters released in the eastern channel were the most likely to beach. They too usually beached near their release point. Drifters released in the northwest channel were less likely to beach, but those which did often traveled south and beached on the Channel Islands.

Trajectories indicate that drifter movement in the Santa Barbara Channel results largely from subsurface baroclinic pressure gradients. These pressure gradients are consistent with the observed vigorous cyclonic circulation in the western Santa Barbara Channel. In the channel, wind forcing is important mainly in the southwest and results in a tendency for southwest flow. In the Santa Maria Basin, wind stress forcing is also important while subsurface pressure gradients are weak. Though wind stress and dynamic topography influence the drifter paths, trajectories often exhibit a smaller-scale structure than either the measured wind stress or dynamic topography. In some cases this may be due to limits on our ability to resolve dynamic topography and wind stress. In other cases it clearly indicates the importance of dynamics other than geostrophy and surface Ekman flow. These processes may also influence the temperature variations observed by the drifters.

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