shelves at the western entrance behave differently than the rest of the SBC due to wind stress. Just north of San Miguel the currents are directed southeast year-round rather than east like the rest of the southern SBC in response to windstress at that location. In spring, just south of Pt. Conception on the northern SBC shelf, the flow turns southwest to south in response to upwelling-favorable wind stress at that location. In the summer, and throughout the rest of the year, the mean flow at that location is westward in response to the alongshore pressure gradient set up along the coastal shelf. The flow at the eastern SBC entrance is southeast out of the SBC during the spring, and is northwest (poleward) the remainder of the year. Anticorrelated events between the SBC shelves occur only when the flow at the eastern SBC entrance is poleward into the SBC.

Currents at depth in the western and eastern portions of the SBC along its central axis were measured at NDBC Buoys 54 and 53 respectively at downward looking APCD bins between 24 m and 328 m (fig. 4.4-6). In the early spring, vertical profiles directed eastward at both locations are strongly sheered in the top 100 m with maximum velocities at the surface. Minimum velocities occur at mid-depth. From late spring to winter similarities between the two profiles disappear. In the western central SBC the maximum currents remain at the surface, but the vertical shear is sharply reduced. The major portion of the profile, including the surface currents, rotate clockwise towards the west as the year progresses. In the eastern central channel, the flow is stronger than in the west with its vertical profile directed westward with maximum currents at approximately 140 m in late spring to early fall, shifting to the surface in mid to late fall. Unlike the flows at depth in the western and eastern central basin, the 100m flow at the SBC eastern entrance does not change direction seasonally but remains poleward throughout the year.

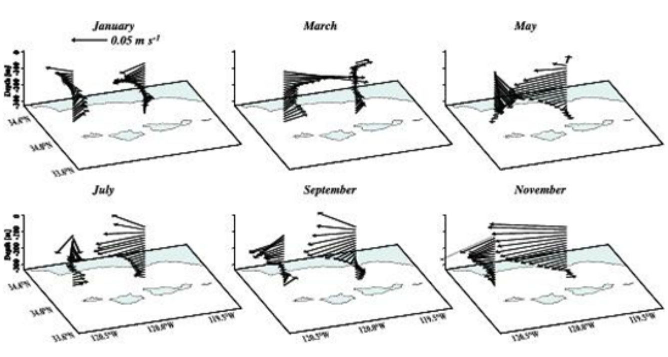

Figure 4.4-6. Seasonal fluctuations in the vertical structure of currents at NDBC buoys 53 and 54. Monthly averaged ADCP velocities between 24-m and 328-m depths are shown for every other month. Vertical resolution is 16 m. Arrows are proportional to the current magnitude in units m s^{-1} (Harms 1996).

4.4.4.3.3 SURFACE WATER TEMPERATURE

Figure 4.4-7 depicts monthly averaged contour maps of water temperatures in the central California coast to the Southern California Bight. The coldest temperatures are found along the central California coastline near Pt. Arguello in the spring due to the persistent upwelling of cold nutrient rich water to the surface caused by strong equatorward winds in that region. The warmest waters are found in the Southern California Bight in the summer due to the wind sheltering by the coastline mountain ranges and local solar heating cycles.

Inside the SBC the temperatures typically increase from the southwest corner to the northeast. The temperature gradient between these two regions varies due to the seasonal variation of the balance between the two oceanic circulation forcing mechanisms: the upwelling favorable winds along the central California coastline and the poleward alongshore pressure gradient caused by temperature driven surface pressure increases in the Southern California Bight. In the spring when the upwelling favorable wind forcing is dominant, cold water is upwelled at Pts. Arguello and Conception and cold water spreads eastward into the SBC with the coldest water appearing along the southern SBC shelf. In the late spring and summer the alongshore pressure gradient builds up, the currents at the eastern SBC entrance (ANMI) reverse to the poleward direction and warmer Southern California Bight water is introduced along the northern shelf of the SBC continuing to Pt. Conception. Temperature gradients between the colder waters at the southwest region of the SBC and the warmer waters in the SBC's northeast region are at a maximum during the summer (June to September). In mid-fall temperature gradients decrease as warmer Bight water replaces the cold waters offshore Pts. Conception and Arguello and the southern central California coast. Temperature gradients decrease further as SBC surface water temperatures decline to their winter values.

4.4.4.3.4 SURFACE PRESSURE FIELD

Surface pressure (SSP) at various stations is directly related to bottom and baroclinic pressures, the latter of which is derived from temperature measurements (Harms and Winant; 1994). Computed surface pressure values are compared to monthly fluctuations in measured bottom pressure, computed baroclinic pressure, and measured wind stress for southern and northernmost current stations, and the monthly wind stress differences between NDBC Buoys 53 and 54 in figure 4.4-8. Figure 4.4-9 illustrates monthly differences between the northernmost and southernmost stations in surface, bottom, and baroclinic pressure.

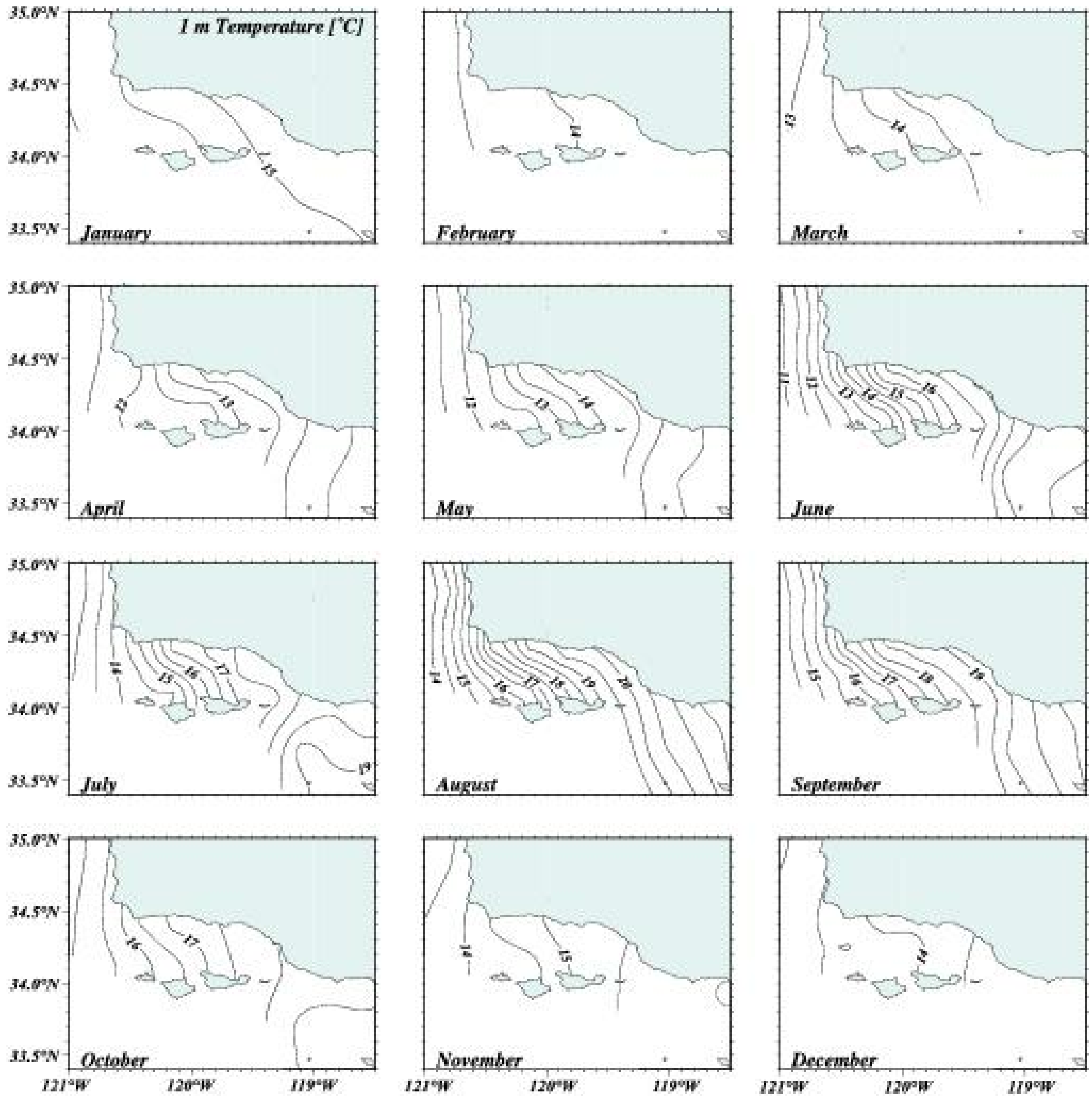

Figure 4.4-7. Contour maps of monthly average 1-m temperatures. Temperature unit are °C. Contour interval is 0.5 °C (Harms 1996).

Minimum surface pressure occurs everywhere in April, while maximum surface pressures occur in the late summer and early fall. Surface pressure decreases to its minimum in the spring with the onset of equatorward wind stress. In late spring the surface pressure begins to steadily increase until fall despite the fact that the upwelling favorable winds continue to blow strong off Pt. Conception throughout the summer. Part of this increase is due to bottom pressure which increases uniformly to approximately the same values everywhere. Baroclinic pressure, on the other hand, is always at higher values in the Southern California Bight than offshore the central California coast and increases at a faster rate in the Southern California Bight than in the Santa Maria Basin. The increase in baroclinic pressure begins and reaches its annual maximum at the southernmost station, BARB, one month before the northernmost station, PAIN. Its these differences between these two regions in the rate and degree of increase in baroclinic pressure, which is temperature driven, that causes the poleward alongshore pressure gradient in the region. As we see in Figure 4.4-9, the maximum poleward surface pressure gradient occurs in August during a period of strong wind stress gradient between the western and eastern SBC regions (fig. 4.4-8).

4.4.4.4 BALANCE OF ALONGSHORE WIND STRESS AND PRESSURE GRADIENTS IN EFFECTING THE CIRCULATION

The alongshore momentum balance between upwelling-favorable wind stress and the alongshore pressure gradient at any particular location in the SBC largely determines the surface currents at that location. The relative importance of these two major forcing mechanisms can be determined at any particular location in the SBC by evaluating the momentum equation which balances the alongshelf acceleration term with the alongshelf pressure gradient term and the local wind stress term. Using the right-handed Cartesian coordinate system (x,y,z) where "+ y" is alongshelf in the poleward direction and (u,v,w) are the corresponding velocity components:

$$\partial v/\partial t = -1/\rho\,(\partial p/\partial y) + 1/\rho\,(\partial \tau/\partial z)$$

acceleration term = - (alongshore pressure gradient) + (surface wind stress & linear drag @ surface layer bottom)

where p is the surface pressure, D is the reference density, J is the surface wind stress, and z is the affected layer depth.

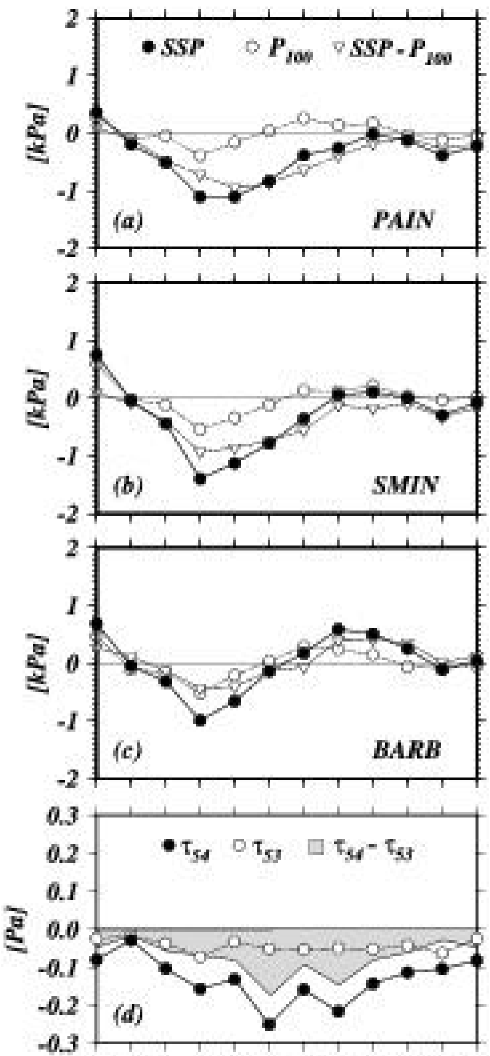

Figure 4.4-8. (a)-(c) Seasonal variability of synthetic subsurface pressure (SSP) bottom pressure (P_{100}) at selected stations. Mean values are relative to the 3-year mean. Units are kilopascals. (d) Seasonal fluctuations in alongshelf wind stress at NDBC buoys 54 and 53 in pascals. The difference between both time series is shaded (Harms and Winant 1998).

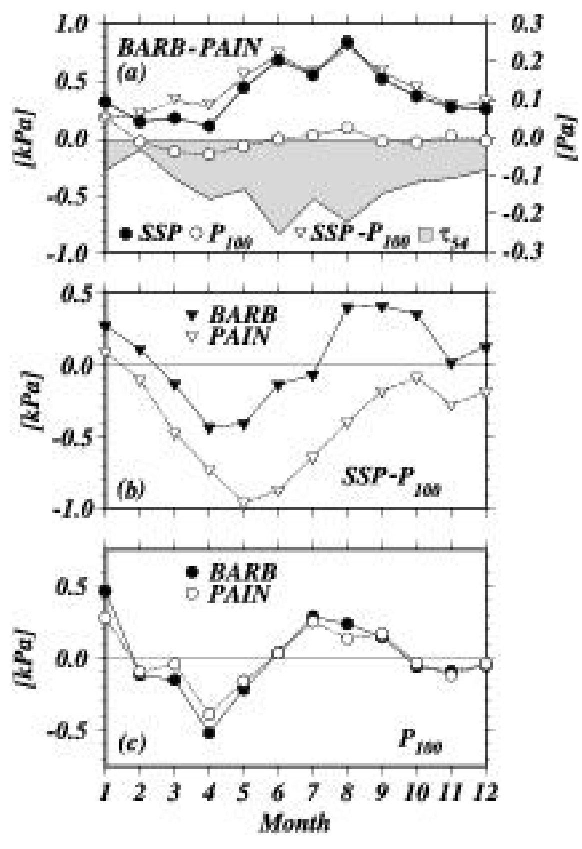

Figure 4.4-9. (a) SSP , bottom pressure (P_{100}) and baroclinic pressure (SSP-P_{100}) differences between BARB and PAIN. A positive pressure difference corresponds to a poleward pressure gradient. Units are kilopascals. The shaded time series represents seasonal variations in the alongshelf (304°N) wind stress at NDBC buoy 54 in units Pa. Note that the along-channel SSP difference opposes the wind stress year round. (b) Baroclinic pressure (SSP-P_{100}) at BARB and PAIN. (c) Bottom pressure (P_{100}) at BARB and PAIN. (Harms and Winant 1998).

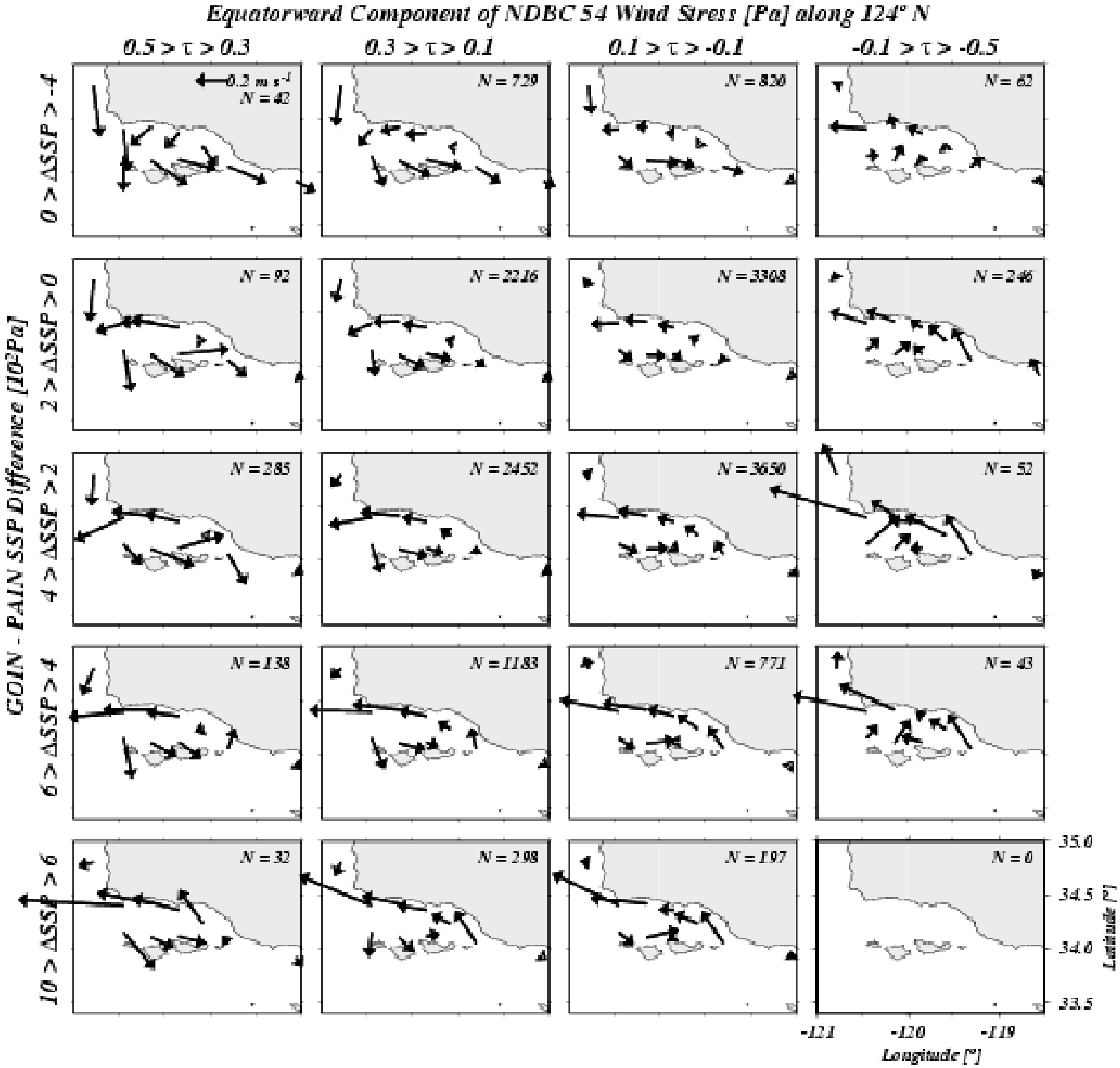

Figure 4.4-10. Average 5-m current velocity (mS^{-1}) as a function of equartorward wind stress (in pascals) at NDBC 54 along 124° N and the along-channel SSP difference (10^{2}Pa) between GOIN and PAIN. The analysis period is January 1, 1994, to December 31, 1995. The ranges for the wind stress and the SSP difference, displayed along the top for wind stress and along the left for the SSP difference, span all values observed during the years 1994 and 1995. The number of realizations (i.e., hours) of each combination of forcing is shown in the upper right corner of each panel (Harms and Winant 1998).

The otherwise typical coriolis term is not included with the acceleration term on the left hand side of the equation. This is because observations indicate that the coriolis term represents motions that are on shorter length scales than the other terms, and therefore, exhibits no correlation with them. The resultant current patterns for various values of wind stress and alongshore pressure gradient is illustrated in figure 4.4-10. Analysis of time series of both forcing mechanisms indicate that upwelling-favorable wind stress and the alongshore pressure gradient:

- oppose each other year-round going equatorward and poleward respectively,
- are seasonal, and that they are both strongest in the summer and fall and weakest in winter,
- in summer and fall are dominated by fluctuations of time scales longer than 10 days,

- are strongly anticorrelated with each other with the alongshore pressure gradient lagging the upwelling favorable wind stress by one day.

This last bullet strongly suggests that the alongshore pressure gradient is a response to this mesoscale upwelling favorable wind stress forcing. Observations strongly indicate that for both larger and smaller than SBC length scales, spatial variation in the upwelling favorable wind stress is responsible for establishing the poleward alongshore pressure gradient.

The simple momentum balance equation above can be used to determine the degree of dominance of one forcing agent over another in eliciting alongshore flow in three major regions of the SBC: the southern shelf, the northern shelf, and the eastern entrance.

The southern shelf of the SBC is exposed to the upwelling favorable winds off the central California coast where the surface wind stress is 2 to 3 times smaller just north of Santa Cruz island (GOOF) than that at the western entrance (NDBC Buoy 54). This amount of wind stress however, is much greater than anywhere along the northern SBC shelf. Not surprisingly, the acceleration term is strongly correlated with the wind stress term, and has negligible correlation with the opposing (to wind stress), but much smaller, alongshore pressure gradient term calculated for this area. Fluctuations of correlated wind stress and acceleration terms are on the order of days.

In the vicinity of GOIN on the northern shelf of the SBC the wind stress is weak to negligible and the currents flow westward year round. The largest calculated term in the right hand side in the momentum equation is the alongshore pressure gradient which is characterized by low frequency fluctuations on the order of a month. The second largest calculated term is the local acceleration term which is characterized by higher frequency fluctuations on the order of days. These two forcing terms are highly correlated with the respective low and high fluctuations in current flow at this location. There is no correlation between the surface stress (the smallest term in the equation) and the currents. Together the alongshore pressure gradient and acceleration terms exclusively predict the current flow at GOIN.

The current flow at the eastern SBC entrance (ANMI) is polarized in the alongshelf direction. In the spring the current flow is equatorward out of the SBC, and the rest of the year the flow is poleward into the SBC. Superimposed on this seasonal pattern are fluctuations lasting on the order of days to weeks that are strong enough at times to reverse the flow. These higher frequency fluctuations occur many times throughout the year. The annual mean surface flow, however, is poleward into the SBC.

The surface wind stress at the eastern entrance of the SBC is weaker than it is at GOOF on the southern shelf, but stronger than what occurs on the northern shelf. All terms on the right hand side of the momentum equation are similar in magnitude. The surface stress and the alongshore pressure gradient are significantly anticorrelated when both exhibit low frequency fluctuations on the order of weeks to months. Surface stress also exhibits higher frequency fluctuations on the order of days as dose the local acceleration term. The correlation between calculated and observed currents at ANMI is strong when both the surface stress and the alongshore pressure gradient is taken into account. This suggests that, unlike the northern and southern SBC shelves, both alongshore pressure gradient and wind stress play an important role in determining the flow at the eastern SBC entrance.

4.4.4.5 CHARACTERISTIC SYNOPTIC PATTERNS OF THE CIRCULATION

The different patterns of current flow in the SBC-SMB are largely determined by the upwelling favorable wind stress (and its gradients) and the opposing alongshore surface pressure gradient. Hendershott and Winant, 1996, Harms 1996, and Harms and Winant 1998 through much collaborative effort, subjectively deduced six flow regimes characteristic of the SBC-SMB area from inspecting synoptic displays of daily averages of near-surface current, wind, temperature, and pressure observations. The flow regimes are called Upwelling, Cyclonic, Relaxation, Propagating Cyclones, Flood East, and Flood West and are illustrated in figure 4.4-11. These regimes were later objectively verified by subjecting the 5 and 45 meter current observations to empirical orthogonal function (EOF) analysis. Three (two) EOF modes described 50% (53%) of the 5m (45m) current fluctuations, which when combined with their respective mean current fields depict spatial current patterns similar to the six flow regimes determined by more subjective means. The EOF analyses of the 5 m current observations also indicated that from late spring through the fall there is a repeating sequence of four flow states: Upwelling-Cyclonic-Relaxation-quiescent period, that cycles approximately every 16 days. A brief summary of the six flow regimes are given below.

When the equatorward upwelling-favorable winds are strong off the central California coast and the poleward alongshore pressure gradient is weak, the flow everywhere except possibly in the northeast corner of the SBC is south to southeastward (including the flow at the eastern SBC entrance). This flow regime is called Upwelling, and is characteristic of what we see in the early spring.

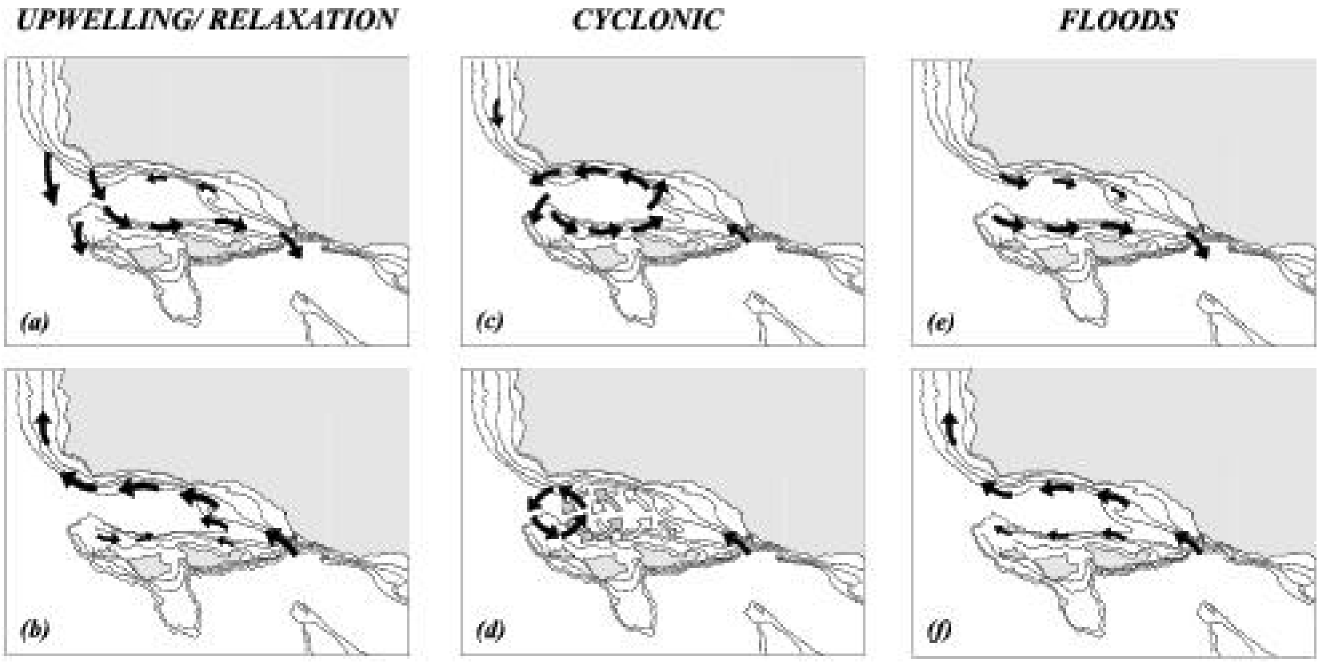

Figure 4.4-11. Synoptic views of the circulation in the Santa Barbara Channel: (a) Upwelling, (b) Relaxation, (c) Cyclonic, (d) Propagationg Cyclones, (e) Flood East, (f) Flood West (Harms and Winant 1998).

When the equatorward upwelling-favorable winds are strong, but we now have a strong poleward alongshore pressure gradient established, we have poleward flow into the eastern entrance of the SBC, strong westbound currents over the northern SBC shelf, strong eastbound flow over the southern SBC shelf. There is strong cross basin shear in this case and this flow condition is called Cyclonic. The Cyclonic flow regime is found to occur most frequently in the late spring through the summer.

When the poleward alongshore pressure gradient is still strong, but the upwelling favorable winds have significantly weakened (relaxed) we have strong poleward flow into the eastern SBC entrance, strong westerly flow along the northern SBC shelf, strong westerly flow at the northwest SBC corner (SMIN), and poleward flow along the central California coast (usually as far offshore as PAIN). The flow along the southern SBC shelf is weak, but continues to be eastward. The Relaxation flow regime occurs most prominently in the early fall to early winter.

There are times when the alongshore pressure gradient and the wind stress are acting in the same direction, or one of these forcing agents simply does not exist, and we get either a Flood East or Flood West where the flow everywhere in the SBC flows in either one of these directions. These two flow regimes do not last very long, are not particularly strong flows, and typically occur in the winter.

During a time when the shear between the alongshelf flows on the northern and southern shelves is strong and we have

- significant anti-correlation between the currents at stations along the same longitudinal transect within the SBC,
- the signal at current stations at both shelves lead their western neighbor by a lag time of 4 to 5 days, and
- the current fluctuations on the southern shelf lead current fluctuations on the northern shelf, we get smaller-than SBC scale cyclones that originate in the eastern SBC and propagate westward.

When this occurs we have what is known as a Propagating Cyclone flow regime. Table 4.4-1 summarizes these flow regimes along with a description of the relative strengths of their forcing agents.

4.4.4.6 AVHRR SATELLITE IMAGERY AND FREE FLOATING SURFACE DRIFTER DATA

AVHRR satellite imagery and free floating surface drifter deployments give information about the synoptic surface currents, synoptic surface temperatures, and general movement of water masses for not only the SBC-SMB area and the SCB, but the entire California coastal area. Daily AVHRR satellite images of the SBC-SMB area and surrounding area can be found on the MMS/Scripps website: www-ccs.ucsd.edu/oilspill/. Black and white and color im-

Table 4.4-1. Relation between the current patterns and the forcing terms. *Due to the absence of a pressure gauge in the center of the SBC, the measurements do not resolve the cross-shelf distribution of the surface pressure when the Cyclonic flow regime prevails. During Cyclonic flow events we expect suface pressure to be low in the center of the SBC and higher over the shelves.

Current Pattern	Upwelling	Relaxation	Cyclonic	No Flow	Flood East	Flood West
Wind Stress	strong upwelling favorable	weak upwelling favorable	strong upwelling favorable	weak upwelling favorable	strong upwelling favorable	strong downwelling favorable
	strong gradients	weak gradients	strong gradients	weak gradients	weak gradients	weak gradients
Surface Pressure	weak poleward alongshelf gradient	strong poleward alongshelf gradient	strong poleward alongshelf gradient	weak poleward alongshelf gradient	equatorward alongshelf gradient	poleward alongshelf gradient
	onshore cross-shelf gradient	offshore cross-shelf gradient	*no cross-shelf gradient	no cross-shelf gradient	onshore cross-shelf gradient	offshore cross-shelf gradient

ages depicting the meso-scale, and some finer scale, oceanographic processes occurring on a particular day of interest can be found. Water masses from different sources have different salinity and temperatures, and they leave their temperature signatures on the ocean surface. Consequently, their location and general movement can be tracked by AVHRR satellite imagery. This information supplied a visual ground-truth to what other observations were indicating to Scripps scientists. "A typical image of the SBC-SMB area includes upwelling of water along the southern central California coastline and the southwestern corner of the SBC (deep blue), warmer water entering the eastern SBC entrance and moving westward along the northern SBC coast to Pt. Conception (yellow to deep orange), and a temperature gradient between these two water masses in the central portion of the SBC (yellowish-green)" (Browne 2001).

Free-floating drifters designed to follow the top meter in the water column were constructed and deployed in support of the SBC-SMB Circulation Study. Twenty-nine drifter deployments either from 12 or 24 locations in the SBC and SMB were conducted from 1993 to 1999 in a manner that would allow a reasonable sampling over the four seasons. Three major flow regimes are easily defined by these drifter data: Upwelling, Convergent, and Relaxation. Dever (2000) renames the Cyclonic flow regime as "Convergent." This was done because remnants of the western SBC cyclone exist during many of the flows and the word Convergence more aptly defines the resulting condition of an equally strong poleward alongshore pressure gradient and an equatorward upwelling-favorable wind stress existing simultaneously in the SBC. Figures 4.4-12 through 4.4-14 illustrate surface drifter tracks representing these three flow conditions. All drifter tracks depicted in these figures represent drifter travel over 40 days. Drifters have traveled as far north as San Francisco and as far south as the Baja over a 40 day period. Figures 4.4-12 and 4.4-14 depict drifters striking the coastline of northern San Diego county and inside Monterey Bay respectively. A description of the surface drifter's construction, the entire drifter data set for the study, and graphical interactive displays of surface drifter tracks can be found at the website: www-ccs.ucsd.edu/oilspill/ under "Surface Drifter Tracks."

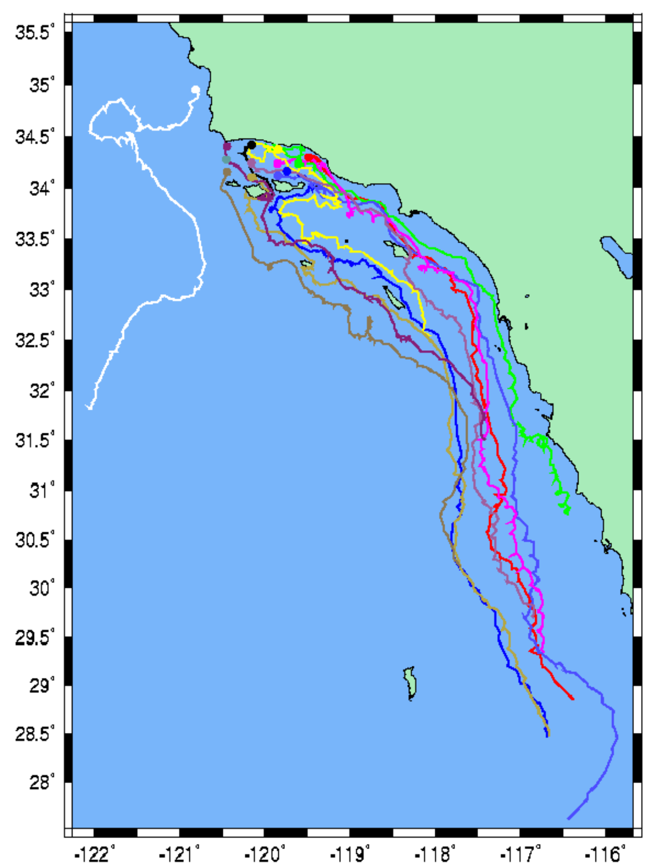

Figure 4.4-12 (a). Free-Floating drifter tracks from March 1995 deployment in the Santa Barbara Channel primarily depicting the upwelling flow regime (http://www.ccs.ucsd.edu/oilspill/ - click "Interactive Drifter Track Plotting").

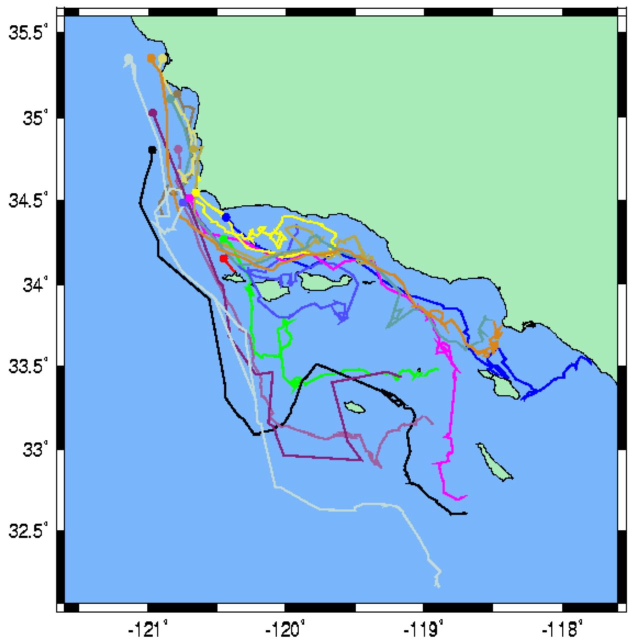

Figure 4.4-12 (b). Free-Floating drifter tracks from April 1998 deployment in the Santa Maria Basin depicting the "upwelling" flow regime. Note that many drifters traveled south-east through the Santa Barbara Channel to get into the southern portion of the Southern California Bight (http:/ www.ccs.ucsd.edu/oilspill/ - click "Interactive Drifter Track Plotting").

4.4.4.7 APPLICATIONS OF SBC-SMB OCEANOGRAPHIC RESEARCH: DETERMINING THE SYNOPTIC FLOW STATE FOR THE SBC-SMB FROM REAL-TIME DATA PRESENTED ON THE MMS/SCRIPPS WEBSITE

The SBC-SMB Circulation study, with its comprehensive field program and rigorous analysis and modeling effort, adequately fulfills the research requirements necessary to allow a small array of moored instruments, strategically located, to effectively monitor the oceanographic conditions in the SBC-SMB area in near real-time. Through a new cooperative agreement between the MMS and Scripps and an interagency agreement with NOAA, a monitoring array for the SBC-SMB area was deployed in the fall of 1999 and will be in place until September 2004. It consists of four current and temperature observation moorings reporting surface currents in near real-time, three NDBC Buoy stations reporting near surface winds in near real-time, daily satellite imagery, and a cache of drifters ready for deployment to observe special oceanographic phenomena upon short notice of their occurrence. The near real-time observations can be found both in data stream and in graphical format at the MMS/Scripps website: www-ccs.ucsd.edu/oilspill/

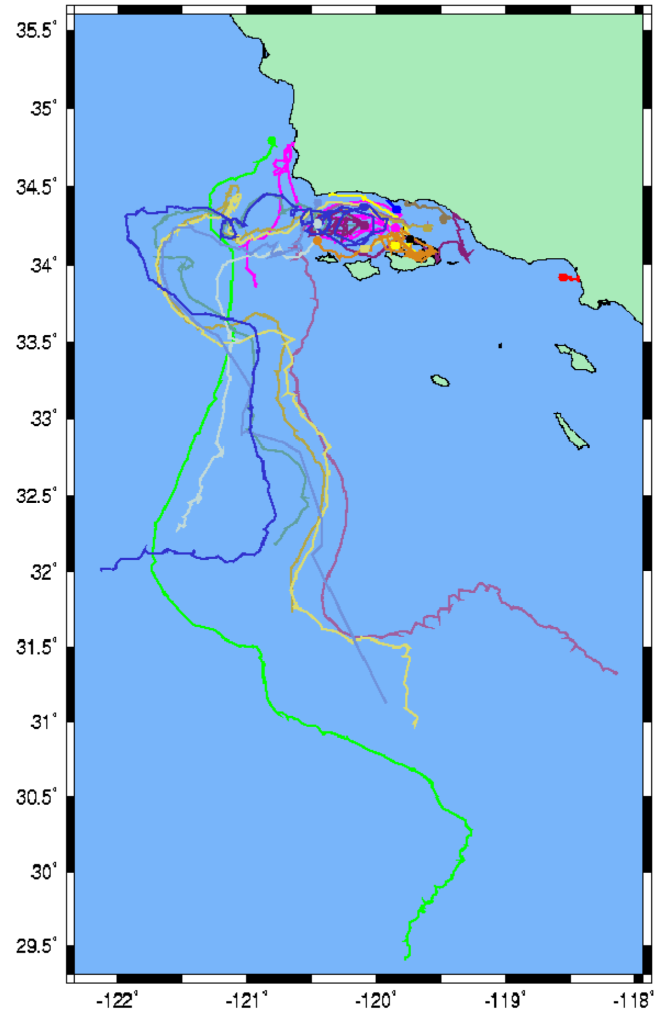

Figure 4.4-13 (a). Free-Floating drifter tracks from September 1994 deployment primarily in the Santa Barbara Channel depicting the "cyclonic," also called "convergent," flow regime (http:// www.ccs.ucsd.edu/oilspill/ - click "Interactive Drifter Track Plotting").

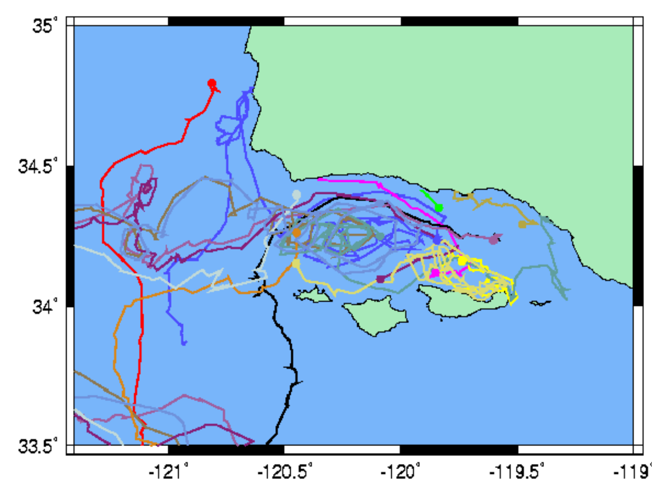

Figure 4.4-13 (b). Enlargement of Santa Barbara Channel portion of Figure 4.4-13 (a): "cyclonic," also called "convergent," flow regime (http:/ www.ccs.ucsd. edu/oilspill/ - click "Interactive Drifter Track Plotting").

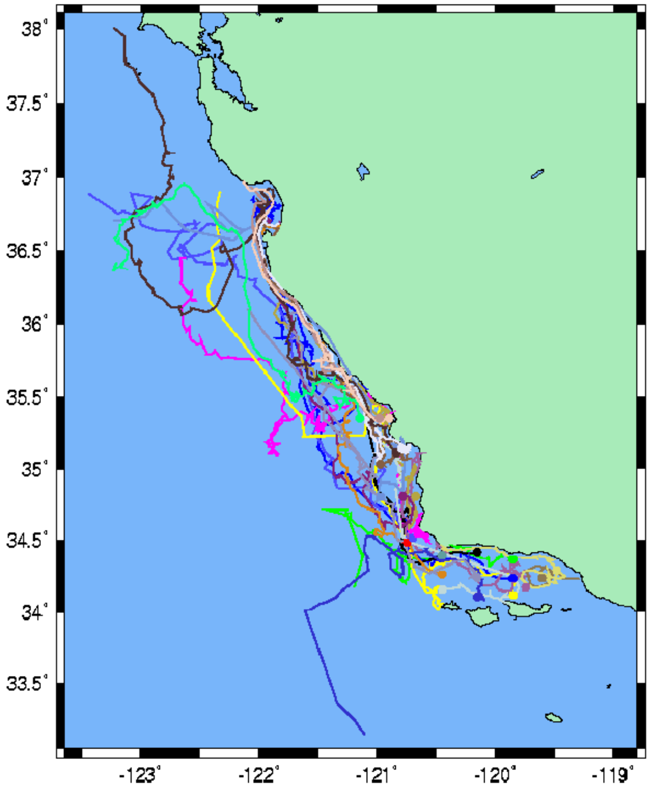

Figure 4.4-14 (a). Free-Floating drifter tracks from December 1996 deployment in the Santa Barbara Channel depicting the "relaxation" flow regime (http://www.ccs.ucsd.edu/oilspill/ - click "Interactive Drifter Track Plotting").

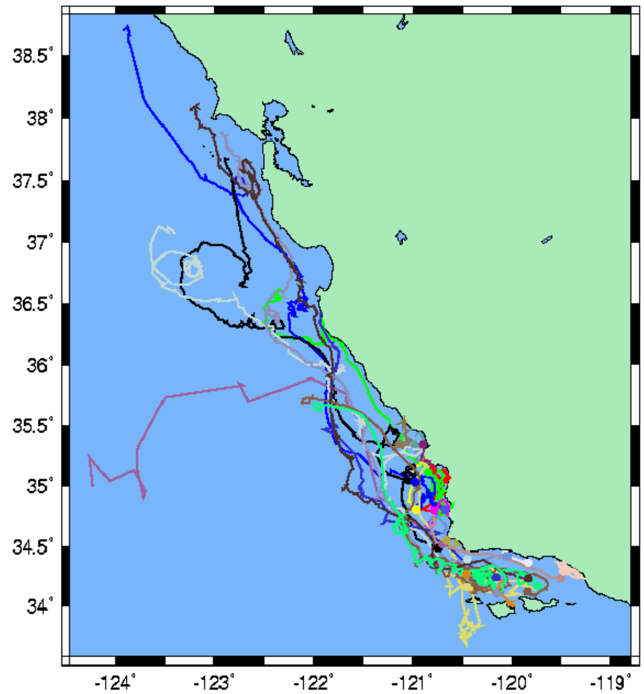

Figure 4.4-14 (b). Free-Floating drifter tracks from November 1997 deployment in both the Santa Barbara Channel and the Santa Maria Basin depicting the "relaxation" flow regime (http://www.ccs.ucsd.edu/oilspill/ - click "Interactive Drifter Track Plotting").

At any time, a trained user can determine the particular flow regime, and get a fair idea of its intensity, by looking at the near real-time wind and current data reported on the MMS/Scripps website. This information can be used for marine biological research as well as studying the physics of the ocean. It can also be used in time of crisis, such as an oil spill event, whether it be from a tanker in the area or from an offshore platform or pipeline. In the particular event of an oil spill, this information can be used to determine oil spill trajectory by subjective calculation or by inputting the near real-time current and wind data directly into an oil spill trajectory model. However we do this, there is certain information that a person attempting to predict oil spill trajectory in the SBC-SMB area must know to be successful. They must know the fundamental causes and spatial variation of the Upwelling, Convergent, and Relaxation flow regimes that are characteristic to the SMB-SBC area, and how to read the near real-time current and wind data to determine what particular flow regime is occurring at the advent of an oil spill crisis.

"When faced with an actual oil spill, or oil spill alert, the trained oceanographic forecaster will then use (1) the basic knowledge learned from the Santa Barbara Channel-Santa Maria Basin Circulation Study, (2) real-time oceanographic and meteorological data obtained from monitoring stations, (3) the latest satellite imagery of the area, (4) knowledge of drifter trajectory statistics, (5) results from the latest numerical circulation and oil-spill trajectory model runs, and (6) personal ability to synthesize the results of these analyses and background knowledge into accurate estimates of surface trajectories of water/pollutant particles" (Browne 1994).

4.4.4.7.1 THREE PRIMARY SYNOPTIC FLOW REGIMES USED IN REAL-TIME APPLICATIONS

Dr. Ed Dever of Scripps (Dever 2000) describes these three flow regimes in a bit more detail than what was provided in the description of the characteristic synoptic flow regimes above. He also provides rules of thumb, based on strong statistics, on how to read the near real-time current and wind data provided on the MMS/Scripps website.

"The synoptic flow states described below are a compact way of describing certain commonly-observed features of the large-scale circulation in the Santa Barbara Channel-Santa Maria Basin (SBC-SMB) region. Though they are subjectively defined, statistical descriptions of the near-surface circulation demonstrate similar spatial structures.

These descriptions are intended to be used with information available from the MMS oil spill response page(http://www-ccs.ucsd.edu/oilspill/) maintained by the Center for Coastal Studies, Scripps Institution of Oceanography. Each synoptic flow state is described in terms of its diagnostic features in the observed surface currents off Purisima Pt., Pt. Conception, San Miguel Island, and the eastern entrance to the Santa Barbara Channel. Ancillary information such as regional winds and satellite sea surface temperature imagery are also described as a function of synoptic flow state.

It is important to remember the synoptic flow states are merely a conceptual model. They can be unambiguously identified about 60% of the time. Small-scale features, transitions between different synoptic states and uncommon patterns can make it difficult to identify the observed flow with a single synoptic state. Therefore, variations on the basic synoptic states will also be described.

Upwelling: The upwelling state gets its name from upwelling of cold (approximately 11° C) subsurface waters near Pt. Conception which often occur during it. The upwelling state occurs primarily in spring, though it has also been observed in other seasons. In terms of the conceptual models of the momentum balance, it occurs when strong (10 m/s or more) persistent (several days or more) upwelling favorable (equatorward) winds overwhelm any poleward along-shelf pressure gradient.

The most characteristic feature of the resulting flow field is southward flow at the western entrance to the SBC which continues eastward from San Miguel to Santa Cruz and out the eastern SBC entrance. However, even during upwelling the flow can be weakly (10 cm/s) westward on the mainland coast of the SBC. While there can be a cyclonic (counterclockwise) recirculation in the western channel during upwelling, the southern limb of the circulation is almost always stronger than the northern limb. Weaker velocities tend to occur in the eastern SBC over the broad shelf between Port Hueneme and Santa Barbara and in the SMB within 5 km of the coast. Within the SMB the strongest (20 cm/s) velocities are observed over the 100 m isobath between Purisima Pt. and Pt. Arguello. Very weak (<10 cm/s) velocities are often observed within 5 km of the shore in San Luis Obispo Bay and between Pt. Sal and Purisima Pt. During upwelling, velocity fluctuations (relative to the mean upwelling state) are strongest southwest of Pt. Conception. This may be an expression of the tendency for an upwelling jet to fluctuate in direction and speed during upwelling. The weakest fluctuations are found over the northeast SBC shelf between Santa Barbara and Ventura as well as the above-mentioned nearshore regions (within 5 km) of the SMB.

Convergent: The convergent state gets its name from the convergence of southward flow west of Pt. Arguello with westward flow south of Pt. Conception. The convergent state occurs primarily in summer, though it has also been observed in other seasons. In terms of the conceptual models of the momentum balance, it tends to occur when upwelling favorable winds and a strong poleward along-shelf pressure gradient exist.

The most characteristic feature of the resulting flow field is a strong (with velocities often 40 cm/s or more — velocities of 70 cm/s are not unheard of) cyclonic recirculation in the western SBC with about equal strength in the northern and southern limbs of the recirculation. While northwestward flow at the eastern entrance to the SBC often occurs during the convergent state, northeastward flow across the eastern entrance to the SBC can also occur. The convergent synoptic state averages are accompanied by southward flow in the SMB near the shore and offshelf flow further away from the coast. The combination of westward flow at the northeast SBC entrance and southward flow along the SMB coast is associated with convergence and offshore flow southwest of Pt. Conception. Relative to the upwelling state, stronger velocities are observed in the western SBC and in most of the SMB. The highest velocity fluctuations are observed at the western entrance to the SBC The lowest velocity fluctuations are again found between Santa Barbara and Ventura and in San Luis Obispo Bay.

Relaxation: The relaxation state gets its name from the fact that it generally occurs when winds off Pt. Conception "relax" from their usual equatorward direction. The relaxation state occurs primarily in fall and early winter. In terms of the conceptual models of the momentum balance, it occurs when poleward along-shelf pressure gradients overwhelm upwelling favorable or weak winds.

The most characteristic feature of the resulting flow field is a strong westward flow (50 cm/s or more) through the SBC and into the SMB. Flow in the SMB is strongest along the mainland coast. Cyclonic recirculation in the western SBC is often present, but with a northern limb strengthened with respect to the southern limb. Poleward flow continues out the western entrance to the SBC into the SMB. Within the SMB the strongest poleward averages are found offshore of the 100 m isobath where there is generally an offshore in addition to a poleward component of flow. Closer to shore in the SMB averages are weaker and in some nearshore locations, southward.

The highest velocity fluctuations occur west of Pt. Conception in the region where the westward flow from the SBC is turning poleward into the SMB. There is a secondary maximum in the western SBC where recirculating cyclonic flow rejoins the westward flow along the mainland coast. The lowest velocity fluctuations are again found between Santa Barbara and Ventura and in San Luis Obispo Bay" (Dever 2000).

4.4.4.7.2 REAL-TIME DATA CRITERIA USED TO DETERMINE SYNOPTIC FLOW STATE

A trained user can easily obtain surface current data from three to four moorings, winds from NDBC Buoy 46054 and others in the area, and at times AVHRR satellite imagery, which, when combined with the knowledge from the greater field program, will indicate which of the three major synoptic flow regime states is occurring that very hour (Browne 1994). The criteria that indicate which flow regime is actually occurring are summarized below by Dever 2000.

4.4.4.7.2.1 "UPWELLING CRITERIA

Surface Currents: Upwelling occurs when (subtidal) flow in the Santa Maria Basin (PAIN) is southward and flow at the eastern entrance to the Santa Barbara Channel (ANMI) is southeastward (fig. 4.4-15a).

Winds: During upwelling, the wind field tends to show strong velocities (averaging above 8 m/s) to the southeast, south of Pt. Conception at NDBC 46054. Within the SMB winds are generally onshore and equatorward. Within the eastern SBC winds can be relatively weak.

Satellite Imagery: When available, satellite sea surface temperature images often show cold water (11°-12° C) between Pt. Arguello and Pt. Conception. Cooler water can be seen spreading southwards from Pt. Conception past San Miguel Island and eastwards from San Miguel towards the eastern entrance to the Santa Barbara Channel.

4.4.4.7.2.2 CONVERGENCE CRITERIA

Surface Currents: Convergence occurs when (subtidal) flow in the Santa Maria Basin is southward, flow at the eastern entrance to the Santa Barbara Channel is northwestward, and flow at Pt. Conception (SMIN) is westward (fig. 4.4-15b).

Winds: In the convergent state, the wind field can resemble the upwelling wind field although this is not diagnostic in the sense that weak winds can sometimes accompany the convergent state. The average winds at NDBC 46054 during convergence are nearly equal to those observed in upwelling, above 7 m/s to the southeast.

Satellite Imagery: In the convergent state, satellite sea surface temperature images often show warm water (17°-20° C) extending from the eastern Santa Barbara Channel north and westwards along the mainland coast. South of Pt. Conception, this warm water turns south and in exceptionally clear images a counterclockwise recirculation of warm water can often be discerned. Cold upwelled waters are still present between Pt. Conception and Pt. Arguello, often with tongues of cold water reaching westwards or southwestwards.

4.4.4.7.2.3 RELAXATION CRITERIA

Surface Currents: Relaxation occurs when (subtidal) flow in the Santa Maria Basin is northward, flow at the eastern entrance to the Santa Barbara Channel is northwestward, and flow at Pt. Conception (SMIN) is westward (fig. 4.4-15c).

Winds: Winds during a relaxation event tend to be weak equatorward or poleward at NDBC 46054 at the western entrance to the Santa Barbara Channel. The average winds at NDBC 46054 during relaxation are under 4 m/s (to the southeast).

Satellite Imagery: Satellite sea surface temperature images during relaxation will often show warm water (17°-20° C) extending from Pt. Conception northwestwards into the Santa Maria Basin" (Dever 2000).

4.4.4.7.3 MONTHLY, SEASONAL, AND ANNUAL FREQUENCY OF OCCURRENCE OF SYNOPTIC FLOW REGIMES

Using the criteria above, the SBC-SMB moored current data is characterized into "Upwelling," "Convergence," and "Relaxation" flow regimes or "other" for December 1993 to November 1999 in table 4.4-2. "Other" occurs when flow conditions did not satisfy any of the criteria for the three flow regime states. Only days with good velocity data at ANMI, SMIN, and PAIN are considered.

"From table 4.4-2 we can easily see a seasonal preference of occurrence for the synoptic flow regimes: upwelling occurs primarily in Feb-June, convergence throughout the year (except April), and relaxation from September through January" (Dever 2000). "By looking at the number of days of occurrence for each flow regime in each month, as is detailed in the last four columns of the table, we can determine the annual percentage of occurrence of each flow regime by dividing the annual totals of days for each flow re-