I. Background:

Fluid motion can best be depicted by marking a fluid parcel and tracking the movement of the parcel to show the pattern of flow. The Naval Postgraduate School embarked on a project to track flow in the Eastern Pacific using RAFOS floats. RAFOS is SOFAR, or Sound Fixing And Ranging, spelled backwards. This indicates the opposite direction of acoustic signaling. A SOFAR float sends out an acoustic signal that is picked up by a hydrophone array. A RAFOS float has a device onboard that listens for an acoustic signal produced by a moored sound source. RAFOS floats are quasi-isobaric floats having no pressure compensating devices. An isobaric float would sink to the programmed pressure and remain at that pressure. RAFOS floats cannot detect outside pressure accurately due to glass and end cap thermal expansions. They record latitude, longitude and in situ pressure and temperature. RAFOS floats are Lagrangian. They measure the time rate of change for a particular parcel of fluid and then evaluate this at the position of the parcel. Figure 1 is a diagram of the equipment onboard a RAFOS float.

The Naval Postgraduate School launched a total of seven RAFOS floats. Four of these floats were launched during the summer and three during the winter. Launch dates, latitudes and longitudes are listed in the Table 1.

The RAFOS floats were recovered by the Naval Postgraduate School approximately three months after deployment. RAFOS float recovery dates, latitudes and longitudes are listed in Table 2.

The RAFOS project also required the Naval Postgraduate School to deploy a series of sound sources, giving the RAFOS floats an acoustic signal to listen for. These sound sources transmitted 15 Watts of energy per day for eighty seconds twice a day. The floats were programmed to be able to listen to all four sound sources. The sound source latitudes, longitudes, depths, broadcast times and deployment dates are listed in Table 3. Figure 2 is a plot of the sound source locations.

Individual Float Data:

Data from float N062 showed an initial flow northwest along the coast. It then floats to the southwest, nearly perpendicular to the shore. The float seems to be caught in a series of cyclonic eddies. The path of float N062 is shown in Figure 3.

Data from float N063 showed an initial flow northwest along the coast, getting caught up in a cyclonic eddy. It then floats westward, following another small cyclonic eddy and then a larger, anticyclonic eddy, changing its path to the southeast. The path of float N063 is shown in Figure 4.

Data from float N064 showed northwest flow along the coast. The float is caught in a few cyclonic eddies as it flows northward. The path of float N064 is shown in Figure 5.

Data from float N065 showed an initial flow northwest along the coast. It is then caught in a cyclonic eddy, redirecting its flow to the southwest, nearly perpendicular to the shore. The float is then caught in an anticyclonic eddy, but continues to flow westward and perhaps into another cyclonic eddy. The path of float N065 is shown in Figure 6.

Data from float N066 showed an initial flow toward the southwest. The float is then caught in a series of anticyclonic eddies. These eddies direct the float back to the northeast. There the float begins to flow northward, following a path along the coast. It is then caught in another series of anticyclonic eddies that appear to have a larger diameter. The path of float N066 is shown in Figure 7.

Data from float N067 showed an initial flow northwest along the coast. It then floats westward. Next, the float gets caught in a series of anticyclonic eddies. For a period of time, the float is caught in a stationary anticyclonic eddy. The float is then directed southeastward, and is possibly caught in a cyclonic eddy. The path of float N067 is shown in Figure 8.

Data from float N068 is immediately caught in a cyclonic eddy. It is then pushed out of the eddy and flows northwest along the coast and then begins a path to the south. There, the float is caught in a large anticyclonic eddy. The path of float N068 is shown in Figure 9.

III. Flow Patterns:

Float N064 is the only float that almost exclusively exhibits a northward flow pattern following the coastline. Initially, floats N062 and N067 also displayed this behavior. Float N066 also shows this flow pattern for some time. During this flow pattern these floats are most likely caught in the California Undercurrent. The California Undercurrent flows to the north, adjacent to the continental slope. Figure 10 is an ensemble diagram of the paths of these floats caught in the California Undercurrent.

Floats N063 and N065 both exhibit westward flow and are primarily transported in anticyclonic eddies. Floats N062, N066, N067 and N068 are all also eventually caught this westward flow. Figure 11 is an ensemble diagram of the paths of these westward flow floats.

IV. Seasonal Float Data:

Floats N062, N063, N064 and N065 were all launched and released during the summer season. Only float N064 is caught solely in the California Undercurrent. Floats N062, N063 and N065 all have initial northward flow, but end up moving westward toward the interior of the Pacific Ocean. All of the winter floats also display a similar behavior, so perhaps there is no strong seasonal difference. Figure 12 is an ensemble diagram of the paths of these summer floats.

Floats N066, N067 and N068 were all launched and released during the winter season. Only float N067 has an initial northward flow. Floats N066 and N068 are immediately caught in a southward flow. All three floats eventually move westward toward the interior of the Pacific Ocean. All of the summer floats also display a similar behavior, so perhaps there is no strong seasonal difference. Figure 13 is an ensemble diagram of the paths of these winter floats.

V. Temperature and Pressure Data

Table 4 records the float launch and recovery dates and their individual initial depths (dbars).

Float N062 had an initial pressure of 391.8 dbar with a steady rise to 330 dbars, followed by a drop to 350 dbars for the final 50 records. It maintains a nearly constant temperature of 6.4 degrees C as it changes depth.

Float N063 had an initial pressure of 338.7 dbar, then dropped to 385 dbars, followed by a slow rise to 375 dbars. As this float gets deeper the temperature recorded gets colder.

Float N064’s pressure wavered between 360 and 400 dbars. This float remains at a relatively constant depth. When it does change depth, it shows the temperature decreasing as depth increases.

Float N065 held at a fairly steady pressure of 350 dbars until the 400th record, when it then showed a steady drop to 385 dbars. This float maintains a nearly constant temperature and depth.

Float N066 held steady at a pressure of 405 dbars until the 600th record, when it then showed a steady rise to 380 dbars. As this float changes depth it reports decreasing temperature as pressure increases.

Float N067 did not report pressure data. For the most part, this float shows decreasing temperature as pressure increases; however, for a time it gets much deeper and reports warmer temperatures.

Float N068 held steady at a pressure of 445 dbars until the 100th record, when it then rose to 420 dbars, dropped to 440 dbars, rose to 395 dbars and finally oscillated between 405 and 390 dbars. This float maintains a nearly constant temperature and depth.

Figure 14 is an ensemble diagram of the temperatures vs. pressures of the summer floats. Pressure on this figure is increasing along the y-axis, therefore depth is increasing in the y-direction. In general, these floats all show increasing temperature with increasing depth, opposite of what is expected. This phenomenon may be due to the upwelling that occurs in the summer months.

Figure 15 is an ensemble diagram of the temperatures vs. pressures of the winter floats. Pressure on this figure is increasing along the y-axis, therefore depth is increasing in the y-direction. All three floats here also show increasing temperature with increasing depth. Because these are winter floats, this unexpected increase of temperature with depth may not be attributed to upwelling. Float N067 shows some instances of increasing temperature with decreasing depth, indicating a possible grounding.

VI. Conclusions:

Comparing the flow patterns and temperatures vs. depths of these floats does not show any great seasonal differences. Both groups of floats have both

California Undercurrent and Westward flow. Therefore, no seasonally specific flow patterns can be determined. Both groups of floats also show an unusual increasing temperature with increasing depth. Summer upwelling or other seasonal temperature patterns cannot be determined from this data. The RAFOS floats are an excellent way to determine flow patterns at programmed depths.

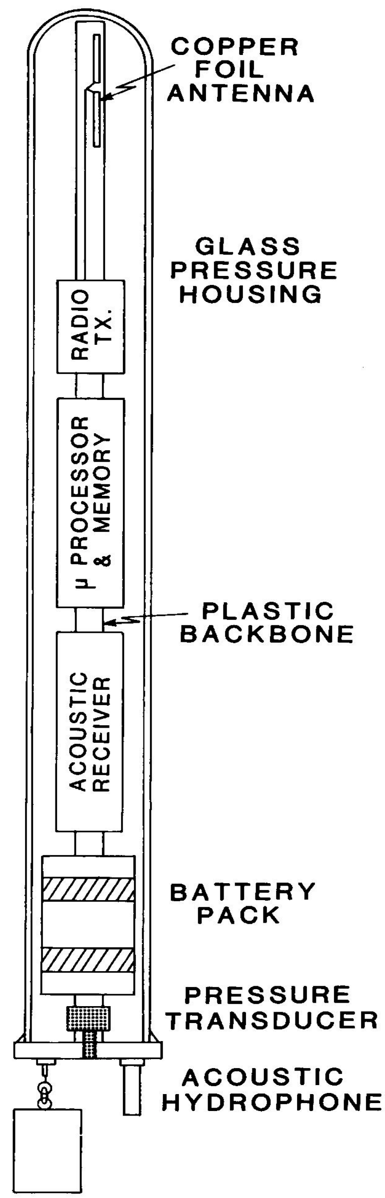

COPPER
FOIL
ANTENNA
GLASS
PRESSURE
HOUSING
RADIO
TX.
μ PROCESSOR
& MEMORY
PLASTIC
BACKBONE
ACOUSTIC
RECEIVER
BATTERY
PACK
PRESSURE
TRANSDUCER
ACOUSTIC
HYDROPHONE

Figure 1

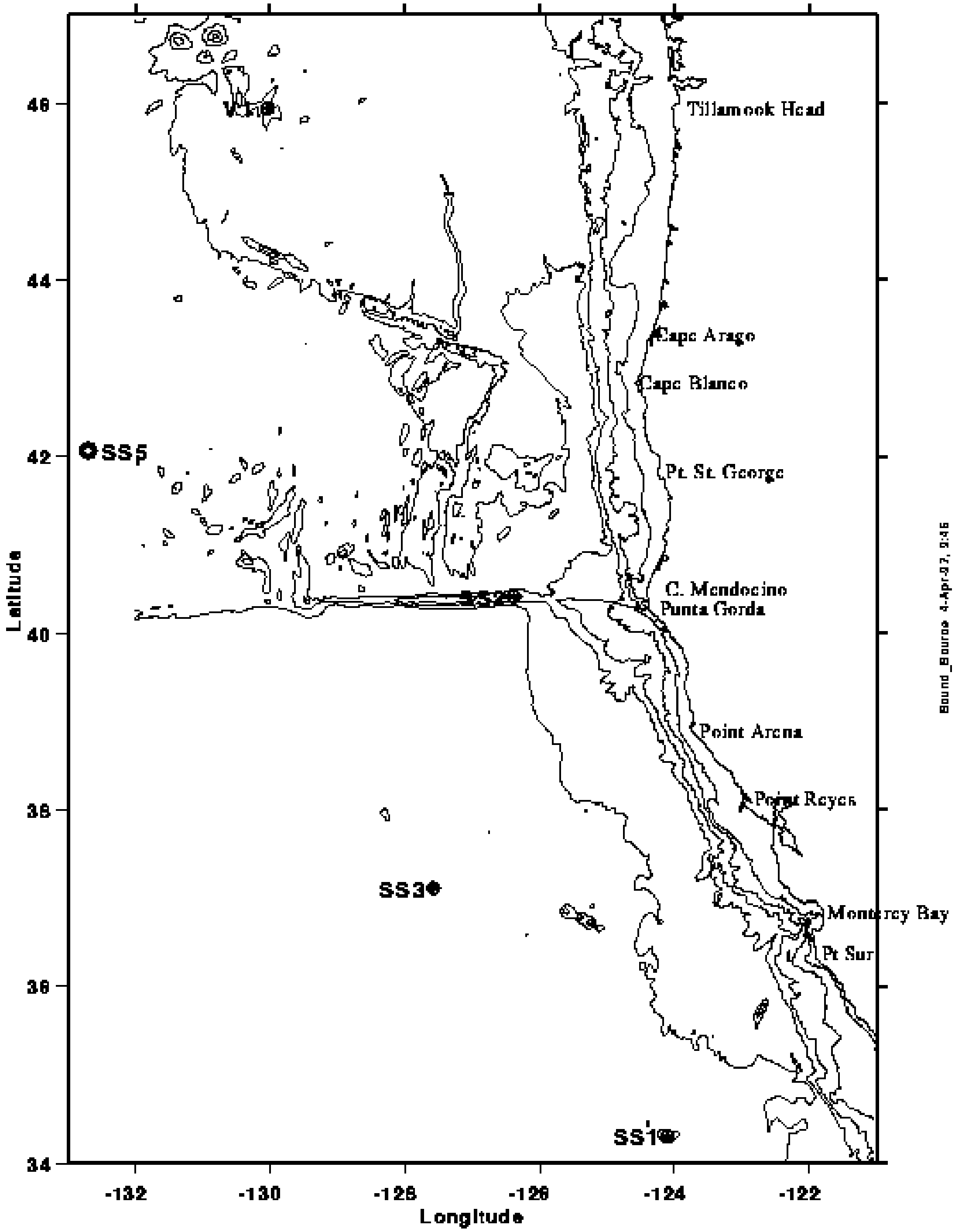
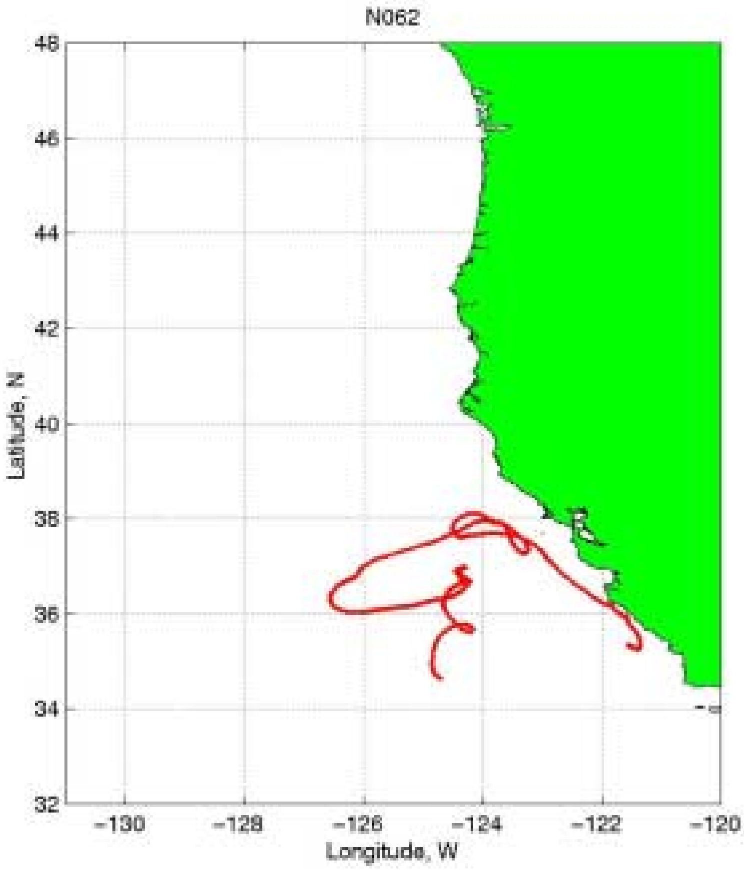

Tillamook Head
Cape Arago
Cape Blanco
Pt. St. George
C. Mendocino
Punta Gorda
Point Arena
Point Reyes
Monterey Bay
Pt Sur
SS5
SS2
SS3
SS1
46
44
42
40
38
36
34
Latitude
-132
-130
-128
-126
-124
-122
Longitude

Figure 2


N062
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

I. Figure 3

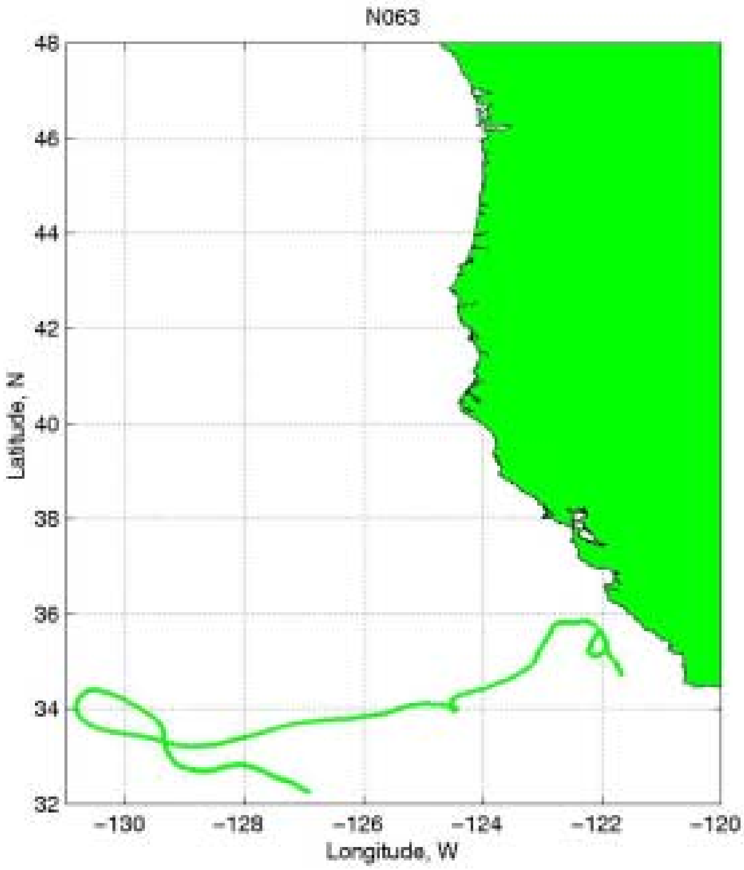

N063
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 4

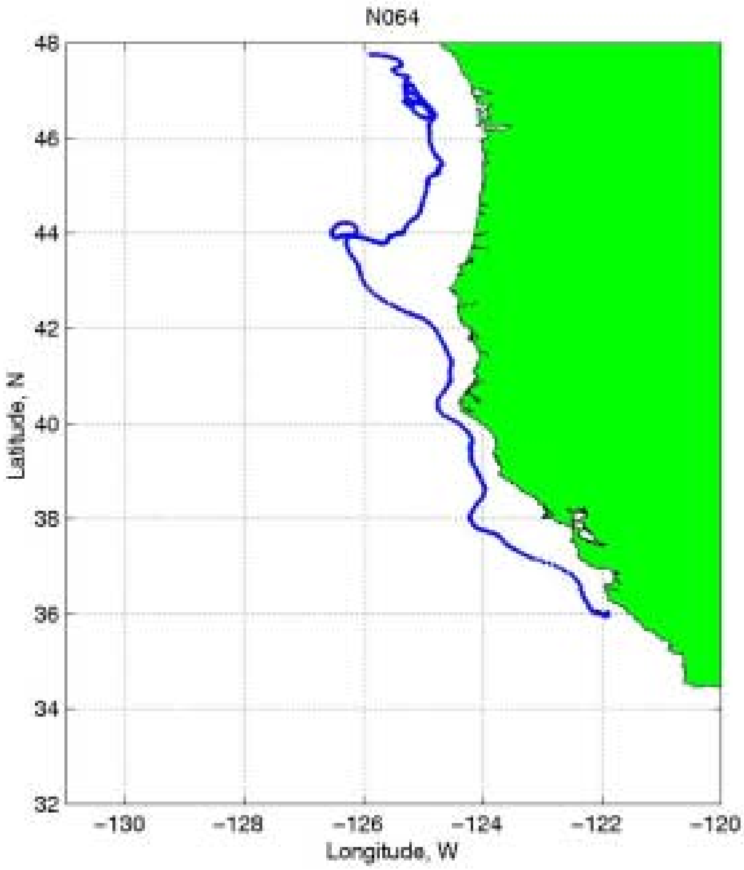

N064
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 5

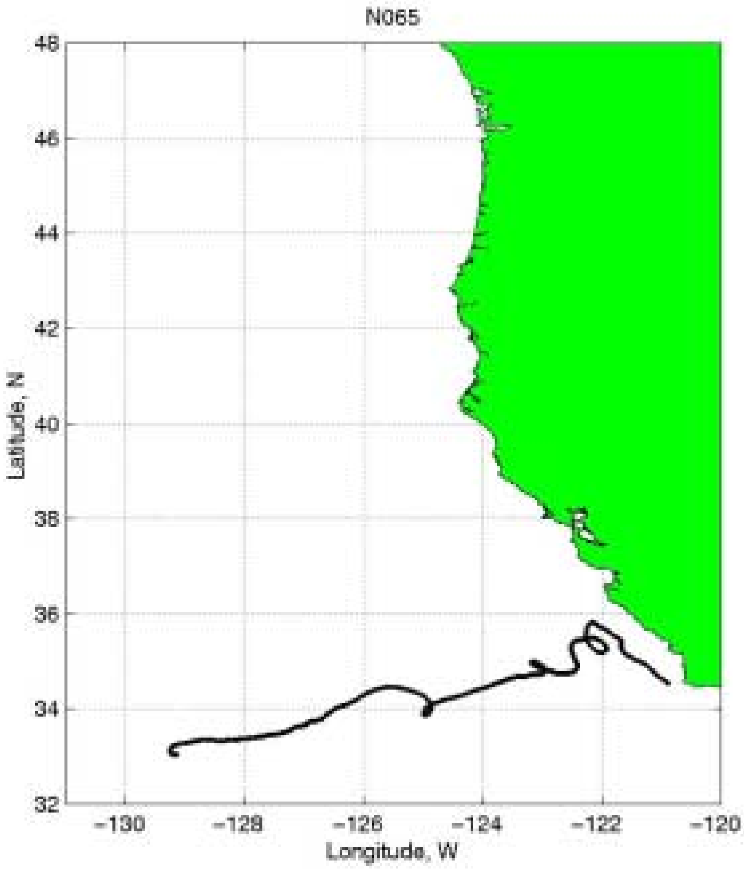

N065
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 6

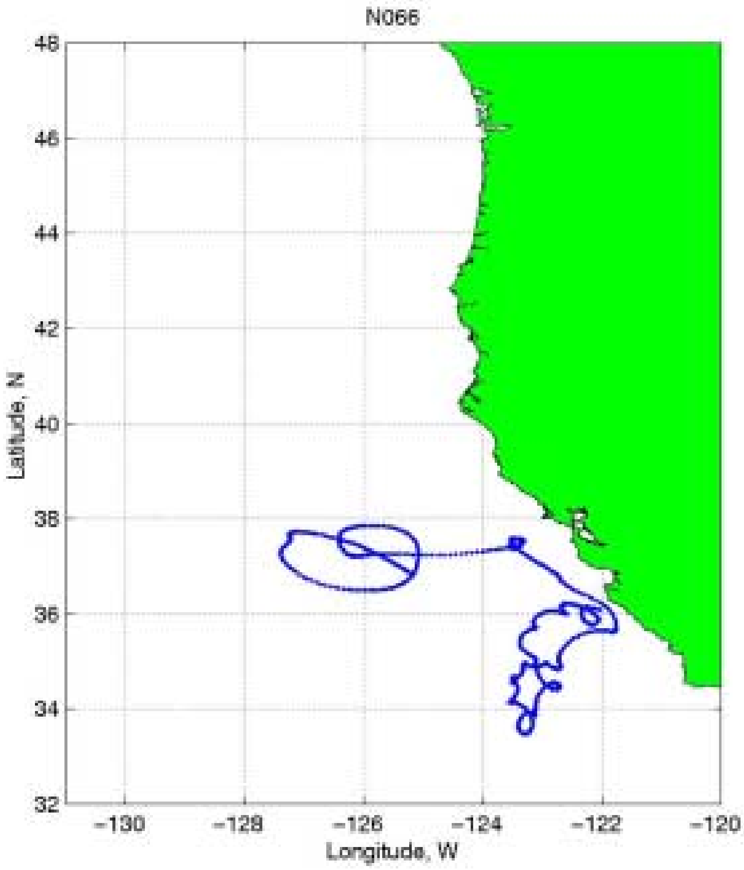

N066
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 7

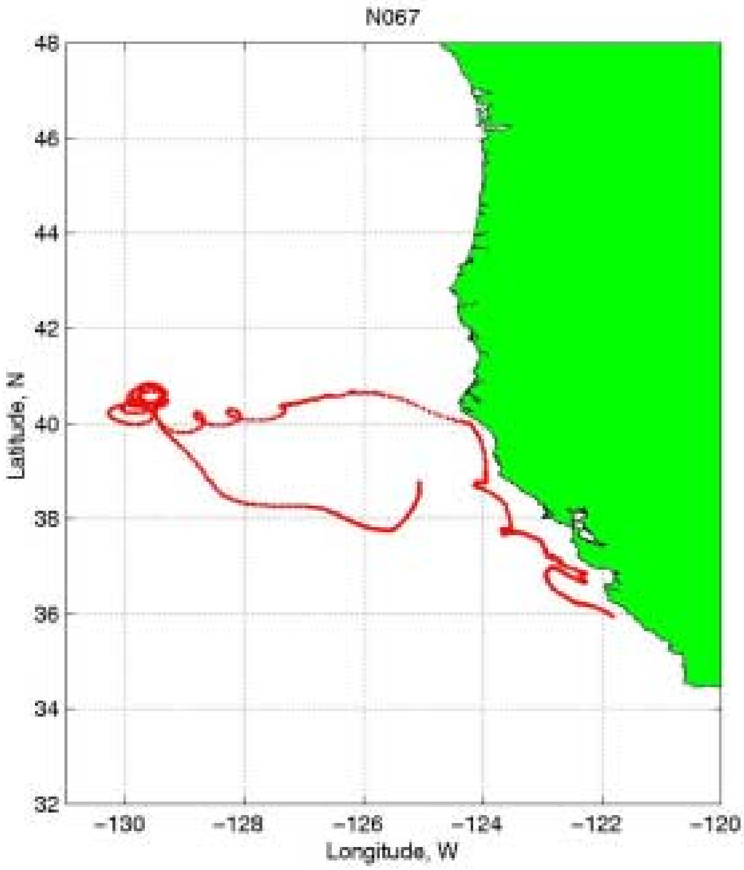

N067
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 8

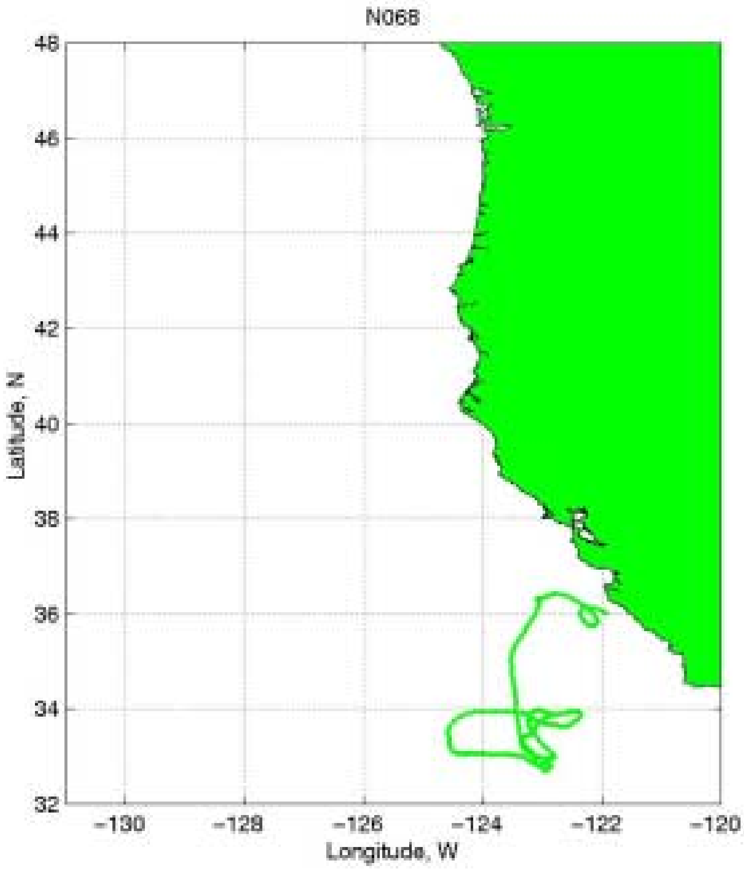

N068
Latitude, N
48
46
44
42
40
38
36
34
32
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 9

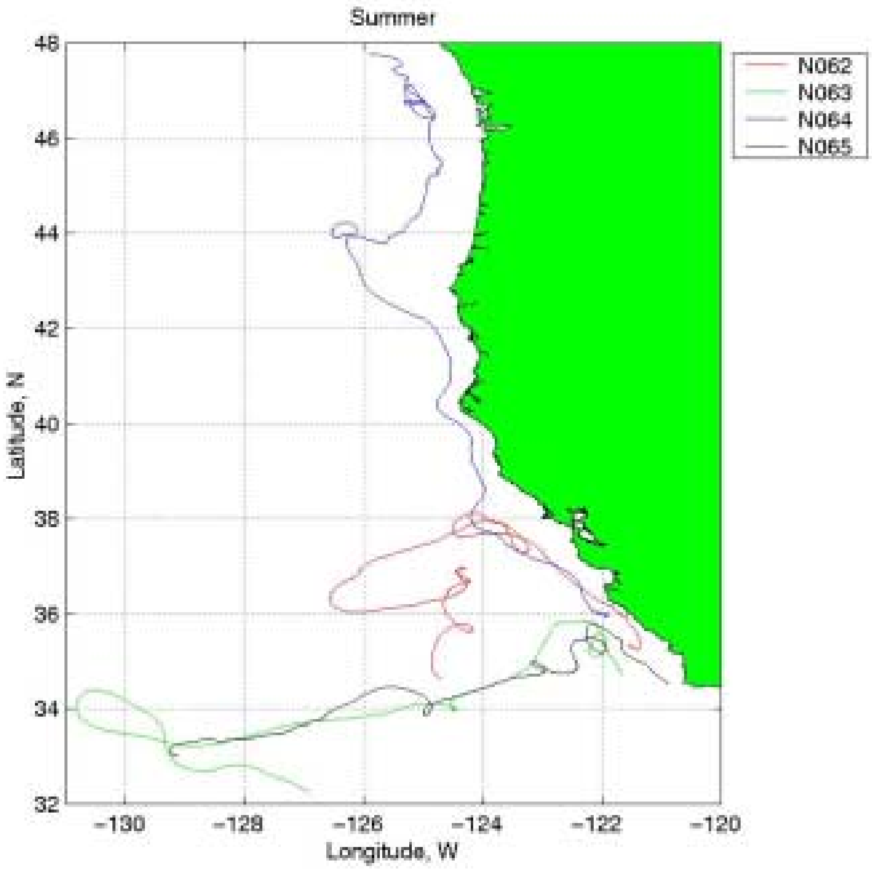

Summer
N062
N063
N064
N065
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 10

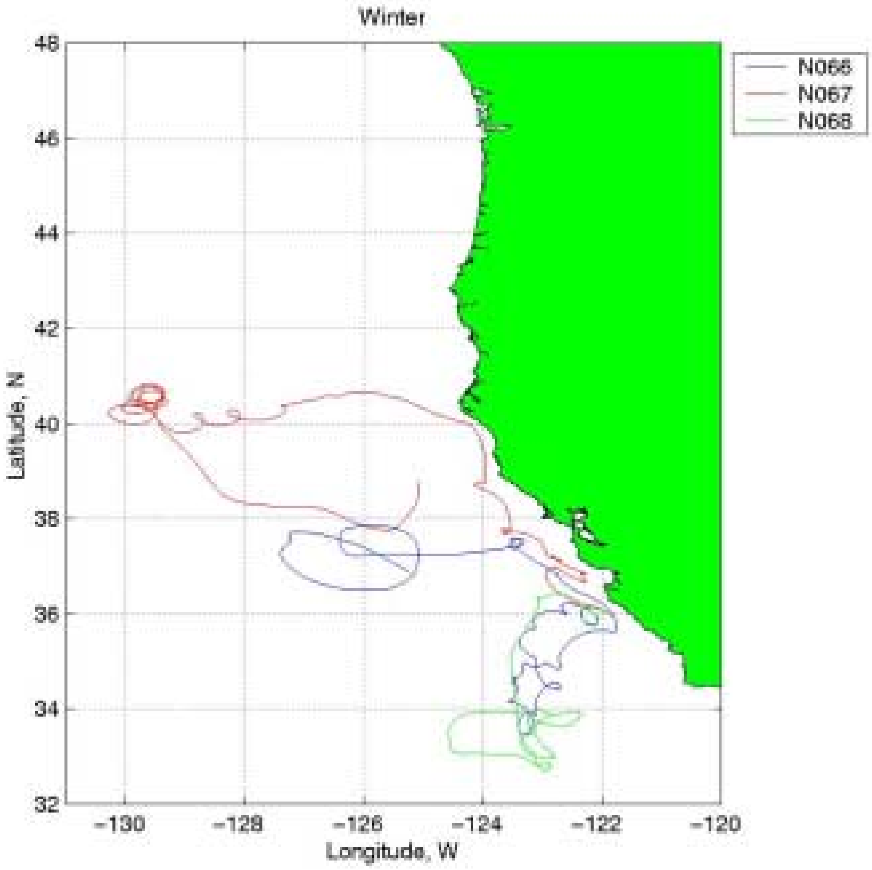

Winter
N066
N067
N068
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 11

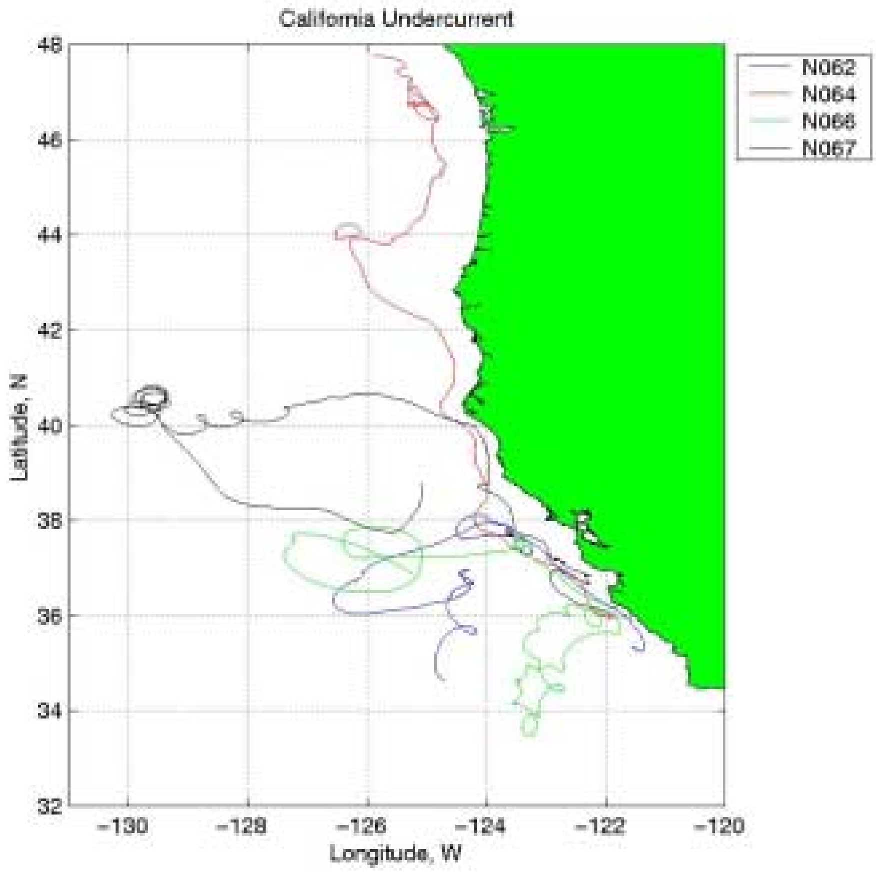
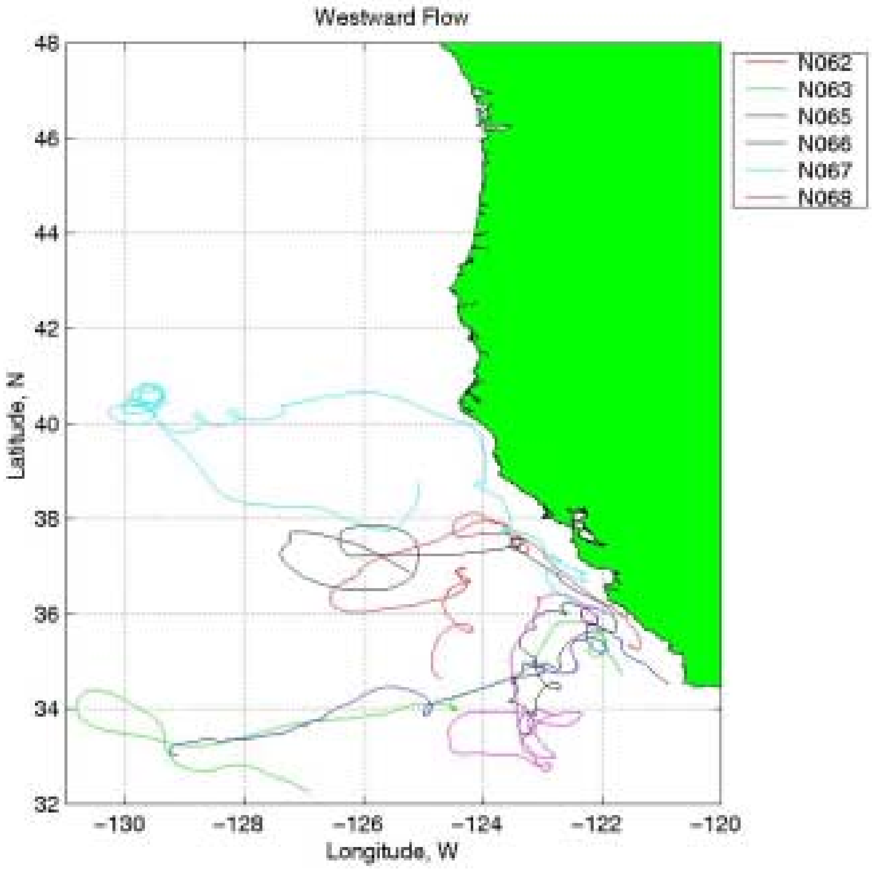
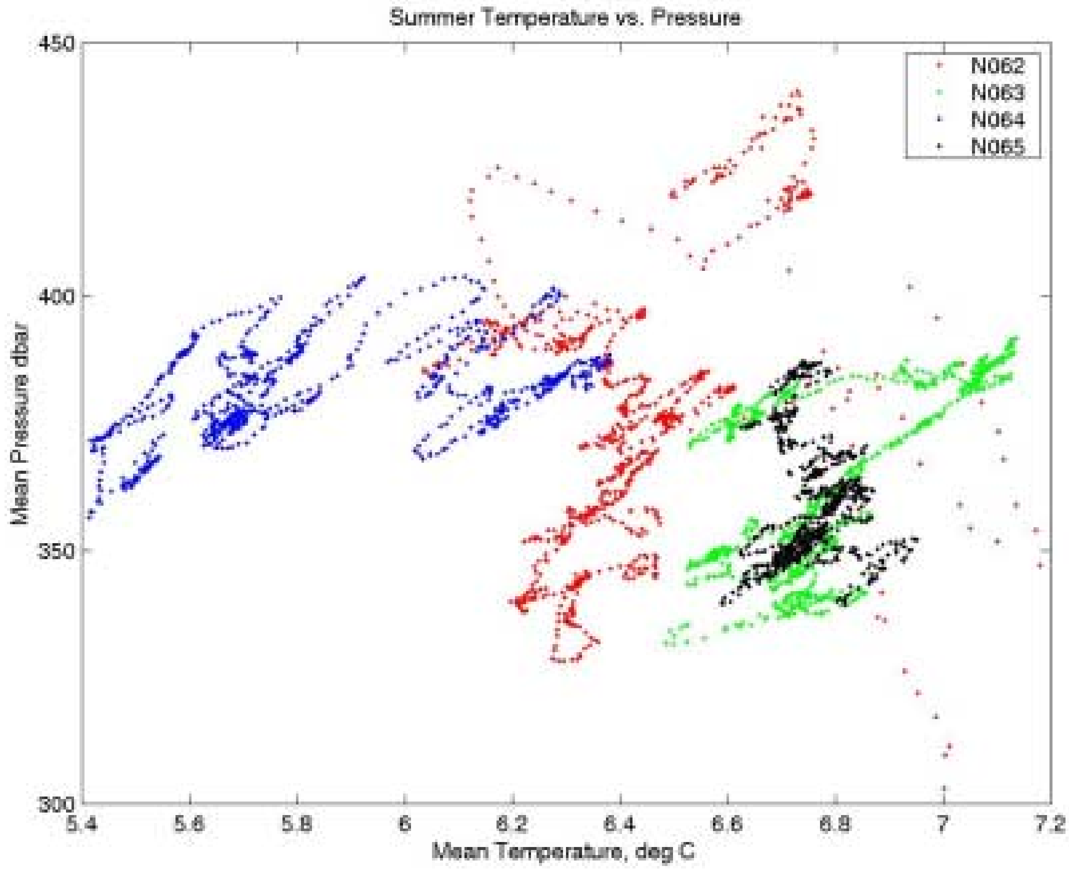

California Undercurrent
N062
N064
N066
N067
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W

Figure 12



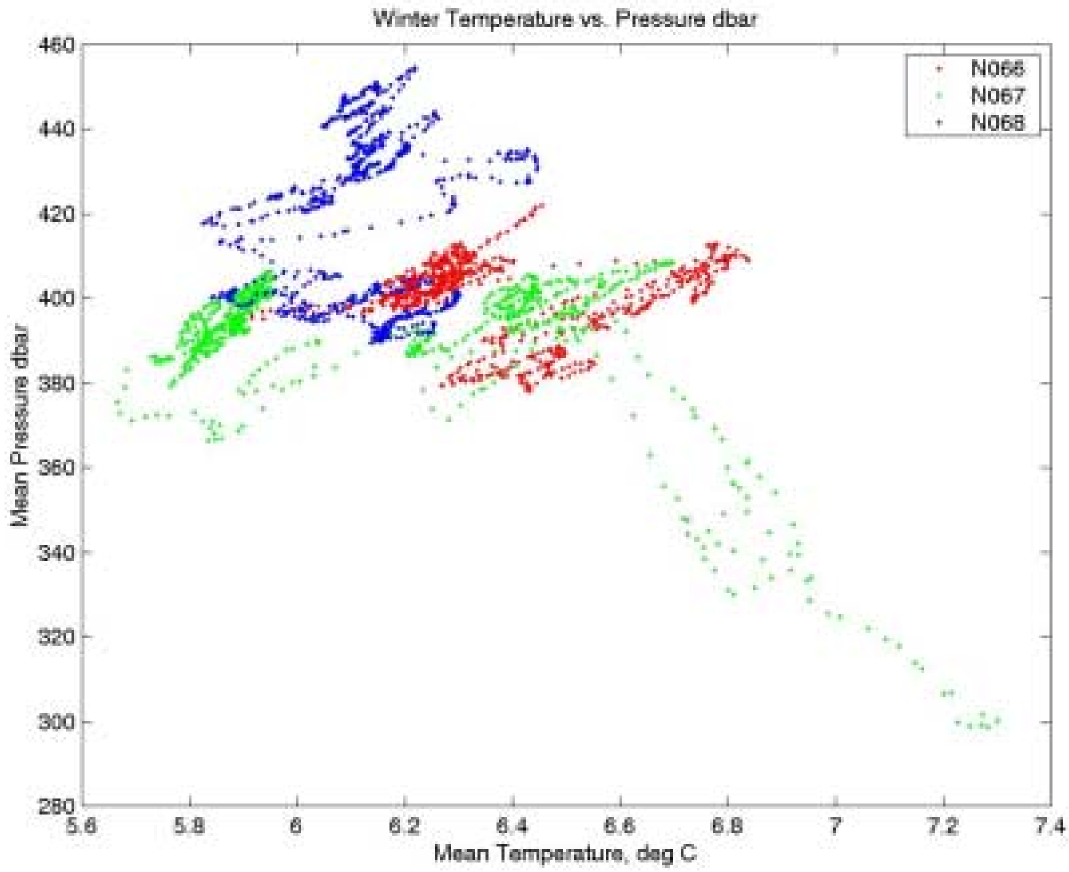
Westward Flow
48
46
44
42
40
38
36
34
32
Latitude, N
−130
−128
−126
−124
−122
−120
Longitude, W
N062
N063
N065
N066
N067
N068

Figure 13



Summer Temperature vs. Pressure
N062
N063
N064
N065
Mean Pressure dbar
Mean Temperature, deg C
450
400
350
300
5.4
5.6
5.8
6
6.2
6.4
6.6
6.8
7
7.2

Figure 14



Winter Temperature vs. Pressure dbar
N066
N067
N068
Mean Pressure dbar
460
440
420
400
380
360
340
320
300
280
5.6
5.8
6
6.2
6.4
6.6
6.8
7
7.2
7.4
Mean Temperature, deg C

Figure 15

Data Set	Float Name	Launch Date	Launch Latitude	Launch Longitude
N062	Kirk	29 APR 98	35-24.798 N	121-35.798 W
N063	Polaris	17 MAY 98	34-41.600 N	121-41.200 W
N064	Charlotte	29 APR 98	36-00.030 N	122-00.370 W
N065	Calypso	29 APR 98	34-26.882 N	120-55.493 W
N066	Pollux	27 OCT 98	36-00.610 N	121-50.050 W
N067	Castor	27 OCT 98	35-49.970 N	121-44.964 W
N068	Sirius	27 OCT 98	35-55.060 N	121-47.390 W

II. Table 1

Data Set	Float Name	Recovery Date	Recovery Latitude	Recovery Longitude
N062	Kirk	25 JUN 99	34-36.60 N	124-33.90 W
N063	Polaris	12 JUL 99	32-13.38 N	126-51.54 W
N064	Charlotte	25 JUN 99	47-43.74 N	126-09.84 W
N065	Calypso	24 JUN 99	33-02.88 N	129-09.66 W
N066	Pollux	23 DEC 99	36-43.74 N	125-09.54 W
N067	Castor	23 DEC 99	39-07.62 N	124-51.12 W
N068	Sirius	23 DEC 99	33-49.74 N	122-40.68 W

Table 2

Source	Latitude	Longitude	Instrument Depth (m)	Broadcast (GMT)	Date Deployed
SS1	34-18.0 N	124-06.2 W	605	0430, 1630	AUG 94
SS2	40-24.8 N	126-23.1 W	526	0500, 1700	AUG 94
SS3	37-06.6 N	127-34.6 W	642	0530, 1730	AUG 94
V1	45-56.5 N	130-02.0 W	700	0400, 1600	MAY 93

Table 3

Data Set	Float Name	Launch Date	Recovery Date	Initial Depth (dbars)
N062	Kirk	29 APR 98	25 JUN 99	391.8
N063	Polaris	17 MAY 98	12 JUL 99	338.7
N064	Charlotte	29 APR 98	25 JUN 99	376.9
N065	Calypso	29 APR 98	24 JUN 99	348.5
N066	Pollux	27 OCT 98	23 DEC 99	406.2
N067	Castor	27 OCT 98	23 DEC 99	Data not available
N068	Sirius	27 OCT 98	23 DEC 99	443.4

Table 4