NAVAL POSTGRADUATE SCHOOL.

OC 3570. OPERATIONAL OCEANOGRAPHY AND METEOROLOGY.

ANALYSIS OF MOORED RECORDING CURRENT METER (RCM8) DATA AT S2.

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A. INTRODUCTION.

In early 1998, a data collection project was started in order to observe currents and sediments transport at two sites over the continental slope off Monterey, California. The study was originally designed to measure currents and across slope transport of sediments during the occurrence of the phenomena El Nino. The data collection has been extended since then and until March 11, 2003; ten data collections have been done (Table 1).

Data collection has been accomplished with two moorings of the intermediate type place offshore of the Monterey bay, in two sites designated S2 and S3 (Figure 1), and located in 1800 m. and 3200 m. of water at 36°-40' N., 122°-25' W., and 36°-20' N.123°-10'W. respectively. Data collection at mooring S3 was stopped right after its recovery in July 27, 2000.

Both moorings have common instruments (Figure 2), that include an upward looking Acoustic Doppler Current Profilers (ADCP) at 300 m., Aanderaa RCM-8 current meters at 305 m. and IRSC sediment trap just below. Both S2 and S3 moorings contain also an Aanderaa RCM8 at 1200 m. and 2400 m. and a Honjo sediment trap just below.

Means of flotation consist of glass balls as well as subsurface spheres, photocell activated flashing lights, radio direction finders, and ARGOS transmitters are mounted on the upper flotation unit to facilitate the recovery.

At the location of mooring S2, currents are typically poleward, while S3 is located in a transition zone between the poleward inshore current and the equatorward flow associated with the California Current.

The California Current System (CCS) is the eastern limb of the large-scale, anticyclonic North Pacific gyre (Lynn and Simpson, 1987) that has three major domains; oceanic, coastal and an intervening transition zone.

The CC is an offshore (850-900 km.), near-surface (0-300 m.) equatorward flow characterized by low salinities, low temperatures, and high dissolved oxygen, with average speeds of 25 cm/s. Near the coast (within 150 km.), there is a seasonal change in the direction of this surface flow. Throughout the fall and winter, the direction of this narrow zone of coastal surface flow is often poleward (Reid and Schwartzlose, 1962), and is refer as the Inshore Countercurrent(IC). North of Point Conception the IC is often referred to as the Davison Current.

The California Undercurrent originates in the eastern equatorial Pacific a flow poleward along the North American coast (Sverdrup and Fleming, 1941). It has a high velocity core (100-300m.), and an average speed of 2-10 cm/s. the CU shows considerable seasonal variability in position, strength, and core depth (Hickey, 1979).

B. PURPOSE.

The purpose of this project is the analysis of Aanderaa current meter data collected from March 1998 to March 2003, at S2 (Table 1).

Time series of currents (tick plots), time series of temperature observation, and scatter-plot of daily 300 m. analysis for the entire period 1998-2003 was performed, and with the exception of the second half of 2000 whose RCM8 failed, in order to provide a basic description of the annual variability of currents at the location of S2.

C. DATA COLLECTION, POST-PROCCESING, AND METHODS.

On both moorings, S2 in 1800m. and S3 in 3000m., Aanderaa (RCM-8), current meters has been place normally at 300m. depth and at 615m. above the bottom respectively. The recording Current Meters internally recorded vector-averaged speed and direction, temperature, and pressure at 30 minute sampling intervals. The deployments ranged in duration from five to six months, this due to the six month sample capacity of the sediment trap.

The raw data for each sensor is stored in the current meter's Data Storing Unit (DSU), as a bit number ranging from 0 to 1023. During the post-processing, the bit numbers are converted to scientific units by applying calibration coefficients or by comparing the bit number to a table of corresponding physical units.

For the temperature sensors, a relationship between raw bit numbers and scientific values is determined by calibrating raw data to a known standard. The calibration is restricted to measurements at two different temperatures; this measurement is performed with the instrument immersed in a temperature-stabilized bath that is stirred to avoid temperatures gradients.

For the pressure sensor the calibration is performed by means of dead-weight tester covering the range 0 to 600 kh/cm^2.

For the compass, a checking procedure is performed to ensure that the compass readings are within the limits of tolerance. A table of bit numbers versus degrees is prepared by use of a compass stand survey to true north.

Current speed is measure by rotations of a shrouded paddle type rotor magnetically linked to an electronic counter. The counter is tested for accuracy and proper operation in the laboratory by using a modified rotor with known rotation rate.

Once the raw Aanderaa recording current meter data file has been converted into engineering units and ASCII flat file, data is filtered by means of LP and LLP filters.

The present work is mainly based on Principal axes analysis and Time series of currents (stick plots); here is briefly the description of both methods.

Principal axes analysis is a common technique that improves the Empirical Orthogonal Functions (EOF) by rotating its principal axes. For a set of vector time series, in this new coordinates system most of the variance or maximum amount of data scatter is associated with the major axis, and the remaining variance, or minimum scatter is associated with the minor axis. The usefulness of principal component analysis is that it can be used to find the main orientation of fluid flow at any current meter site (Emery and Thomson, 1997).

Time series of currents. Vector quantities require a plot of two parameters against time, "stick plots", are a common practice to represent current vector, by convention in Oceanography current vectors are plotted as the direction the current is toward.

D. RESULTS.

Figure 3 is the scatter diagram formed by the daily average of the u and v components of the current for the entire 300 m. set of current observation. Since mooring S2 is placed in a relatively shallow waters, the mean currents generally flow parallel to the coastline, but the N-W elliptical shape direction is due to currents that flow offshore as will be corroborate by the tick plots analysis and estimates of statistic for the entire data set (Table 2). The mean current was directed toward 335.6° (true North), with a mean speed of 4.0 cm/s.

Daily currents and temperatures are shown in figures 4 and 5, and are used to quantify the annual variability of currents at the S2 site. Since the depth of this current meter is below the main thermocline over the continental slope, a strong poleward flowing CUC is expected to influence the data set more than any other large-scale feature of the California Current System.

In the present paper, the term "spring jet", used by Collins et all: Ocean Currents Off Point Sur, California, is used to differentiate the strong poleward flow that occurs in spring and summer from shorter period poleward flows.

1998. The observation began on March 24, during the spring transition that extended through April with Southeast flow and velocities of approximately 7-8 cm/s. The spring jet started on April 27, and it extended until late August, with a maximum velocity of 21 cm/s. The temperature minimum, 6.2° C. registered in early May, the lowest temperature registered in this study, coincided with the developed of the spring jet. From that minimum the temperature increased for the entire period of the spring jet reaching a maximum of 8.7 ° C. A strong equatorward offshore flow occurred in late June early July with a velocity maximum of 19 cm/s.

Equatorward flow occurred in September and mid October, the temperature cooled from 8.4° C. to a minimum of 6.7°C. November and December were characterized by variable flows and temperatures, from a minimum of 7.1° C. to 7.8° C.

1999. Poleward offshore flow occurred through January and late February. The spring transition was characterized by short period of weak poleward and equatorward flow with the temperature cooling from 7.5° C. in early March to 6.7° C. in late April. The spring jet developed in April 14 and extended until the early July, with maximum velocities of 26 cm/s. and was accompanied by warming from 6.7° C. in early March, to 7.7 °C. in late April.

The spring jet was interrupted twice by equatorward and offshore flow on May 17 and June 3. This offshore flow coincided with a decrease in temperature from a maximum of 7.3° C. and 7.5° C. to a minimum of 6.7° C. and 6.8° C. respectively. A long period of equatorward flow began on September 23 that lasted until November 27, this period shown the second strongest equatorward flow observed in the record and occurred on October 6, with a velocity maximum of 21 cm/s.

In December the temperature began to increase steadily from 6.8° C. to 8.1° C, with poleward flow and a strong squirt of offshore flow.

2000. A failed in the alignment of the Aanderaa recording current meter during its deployment, did not allow the measurement of currents in second half of this year although the temperature sensor was not affected. Analysis of the first half (From February 7 to July 20), will be describe in this segment.

Pulses of equatorward and poleward flow occurred in January, February and early March. A strong poleward offshore pulse occurred on March 28, but the spring jet developed until May 18, with velocities maximum of 31 cm/s. (the greatest velocity registered during this study). The temperature cooled steadily from 8.1° C. in late January to 6.7° C.

in mid May. At the beginning of the spring jet an increased of temperature began reaching a maximum of 8.3°C. in late July.

2001. A strong poleward pulse of 22-cm/s. was observed on March 7, but the spring jet began on May 4 and extended until October 9. The temperature minimum of 6.4°C. occurred on May 23 beginning to warm, reaching a temperature maximum of 8.3° C. on September 9. The flow was poleward the entire cycle with the exception of two shot equatorward squirts in mid June, and mid July. Poleward flows and warm temperatures remained until the end of the year.

2002. Equatorward flow occurred in late January through February, but the spring jet developed until May 2, and extended until late September, with maximum velocity of 25 cm/s. The temperature decreased steadily from 8.3° C. on March 14 to 6.4° C. on May 22, and began to increase reaching a maximum of 8.5° C. on September 10. A strong equatorward flow was observed through October with maximum velocity of 26 cm/s. reaching temperatures of 8.8° C. the warmest observed during this study. After this strong equatorward flow, variable flow was observed for the period November-December, with temperatures remaining warm between 8.2°-8.4° C.

E. DISCUSSION.

Poleward flow prevailed at all deployments, except deployment number four whose mean flow was equatorward, from March 24, 1998 to March 11, 2003. Table 2 shows the current meter statistics where the u and v velocity components were rotated 30^0 counterclockwise in order to define the new components in the along and across shore directions. The mean flow for the v component was toward the north at all deployments with velocity maximum of 31 cm/s. (May 18, 2000). The mean flow for the u component was westward (offshore), also at all moorings (the exception was deployment four who showed an equatorward and onshore flow).

The most obvious feature seen in the currents at S2 is the spring jet with Poleward flow, but also distinct equatorward events interrupted this strong Poleward flow, which occurred in late June-early July 1998, two similar events occurred in mid May and early June 1999, one in late June-early July 2000, two events in early June and mid July 2001, and finally two events in late June and early August. The structure of vectors in the stick plot for this equatorward flow exhibited a smooth counterclockwise rotation that could be explained by an anticyclonic eddy passing by the mooring. The satellite sea surface temperature (SST), data collected near the two events on June 26,1998 and June 07, 1999 (Figure 8), support this idea. Previous work (Rosenfeld et al.,1994), has shown that warm features of this type are common off the mouth of Monterey Bay.

A spring transition marked the beginning of the spring jet with variable flow direction, low velocities, and a decrease in temperatures. Temperature during the spring jet increased reaching a maximum of 8.5^0C.

The annual cycle appears well defined; figure 6 shows the scatter plot of daily average u and v velocity components for the entire study period. Northward flow begin on April 23, that is follow by an increase in temperature that begin on April 30, reaching a velocity peak of 21 cm/s. and a maximum temperature of 8.2^0C. Spring jet extended from early May to late September.

The period November, December and sometimes part of January showed variable velocity currents with temperatures remaining warm.

The spring transition showed also variable flow, although the temperature decreased from 8.1° C. in early January until it reached minimum temperatures of 6.8° C. in middle April.

F. CONCLUSSION.

The annual cycle at S2 appears well defined:

- Spring transition characterized by variable flow in velocity and direction, with decrease of temperature.
- Spring jet characterized by strong Poleward flow, but also with distinct Equatorward events, explain by an anticyclonic Eddy passing by the Mooring.
- Autumn-Winter time characterized by variable flow in velocity and direction, with temperatures remaining warm after the spring Jet occurrence.

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Emery, W.J. and R.E. Thomson. 1997: Data analysis methods in physical oceanography. Gray Publishing, Kentucky.

Ramp, S.T, L.K. Rosenfeld, T.D. Tisch, and M.R. Hicks, Moored observations of the current and temperature structure over the continental slope off central California, J Geophys. Res.102: 22,877-22,901.

Rosenfeld, L.K., F.B. Schwing, N, Garfield, and D.E. Tracy: Bifurcated flow from en upwelling center: A cold water source for Monterey Bay, Cont. Shelf Res., 14, 931-964,1994.

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Mooring.	Date Deployment.	Latitude.	Longitude.	Bottom Depth.	Date Recovered.
S2	03/24/98	36 40.016	122 22.523	1800m.	08/20/98
S3	03/24/98	36° 29.9909	122° 56.008	3000m.	08/21/98
S2	08/26/98	36° 39.953	122° 22.536	1800m.	01/27/99
S3	08/25/98	36° 29.996	122° 56.005	3000m.	01/28/99
S2	02/04/99	36° 39.920	122° 22.482	1790m.	07/21/99
S3	02/05/99	36° 29.972	122 56.050	2997m.	07/21/99
S2	07/27/99	36° 39.920	122° 22.448	1809m.	01/27/00
S3	07/28/99	36° 29.978	122° 56.067	2998m.	01/26/00
S2	02/05/00	36° 39.925	122° 22.448	1801m.	07/20/00
S3	02/06/00	36° 29.995	122° 56.155	2980m.	07/21/00
S2	07/29/00	36° 39.884	122° 22.374	1792m.	01/25/01
S2	01/25/01	36° 39.932	122° 22.399	1797m.	08/09/01
S2	08/16/01	36° 39.929	122° 22.381	1785m.	02/01/02
S2	02/08/02	36° 39.971	122° 22.463	1802m.	08/28/02
S2	02/08/02	36° 39.971	122° 22.449	1792m.	03/11/03

Table 1. Position and Date information on MBARI S2 and S3 Moorings.

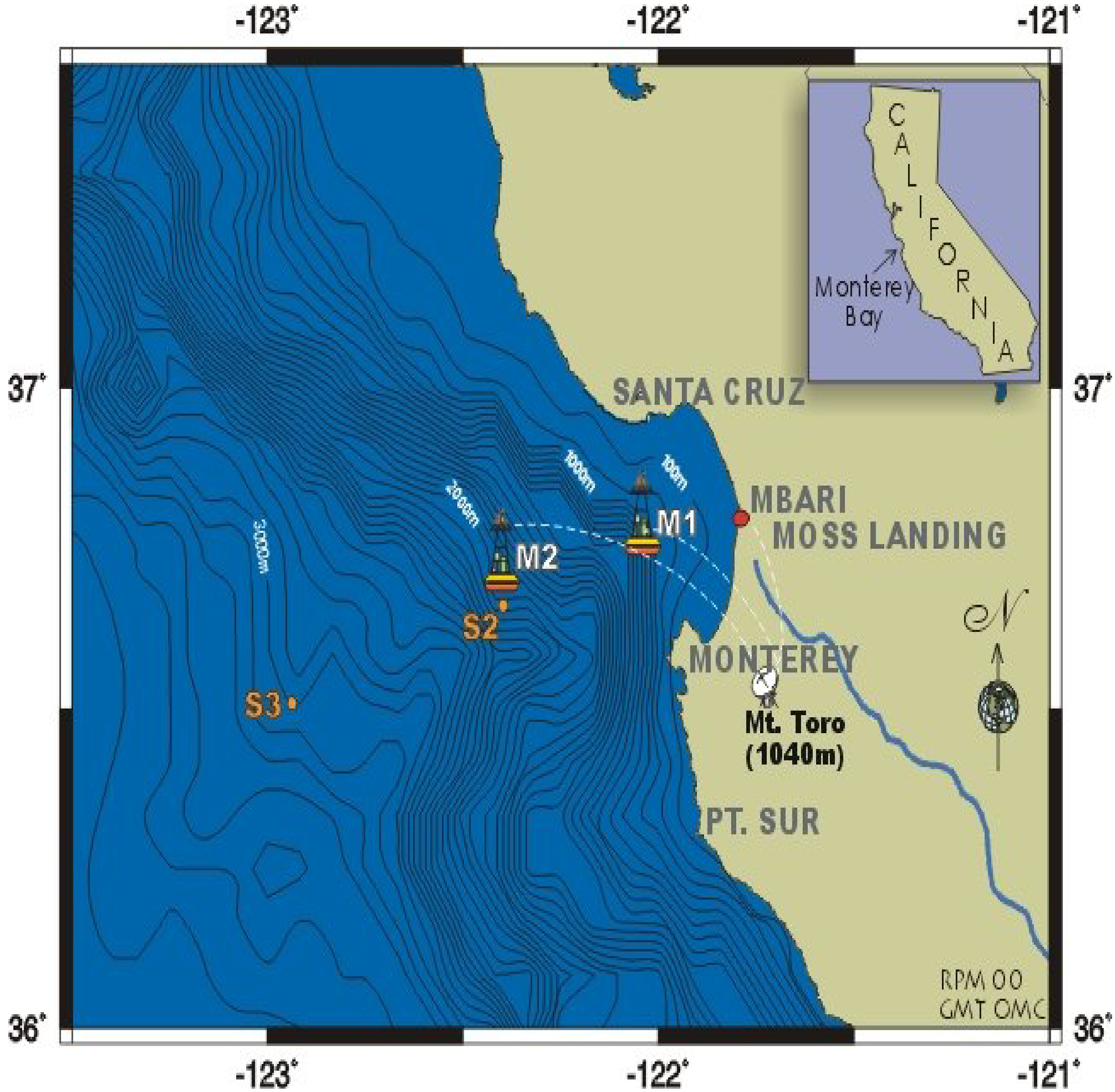

Figure 1. Position of MBARI S2 and S3 Moorings.

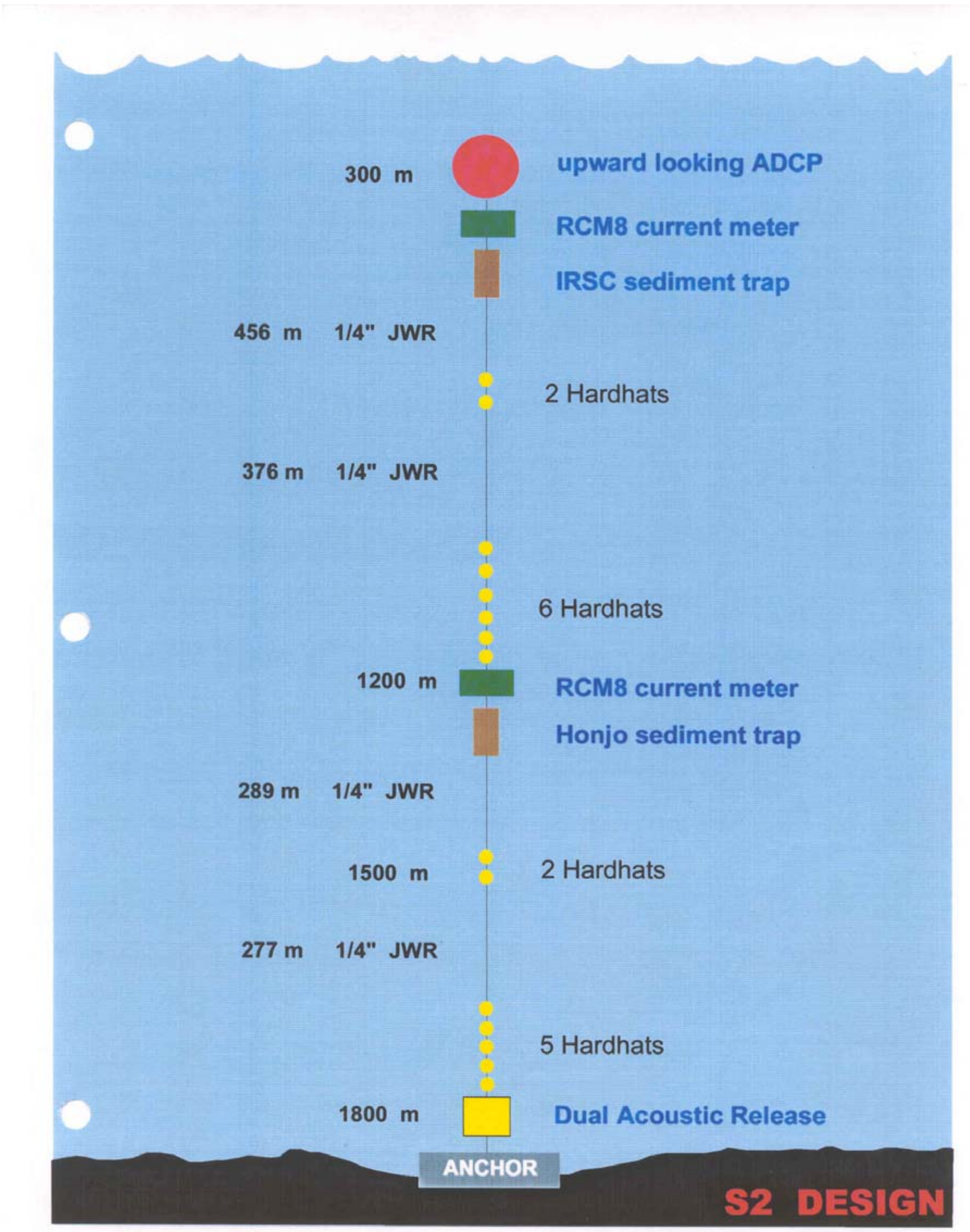

Figure 2. Mooring S2 design.

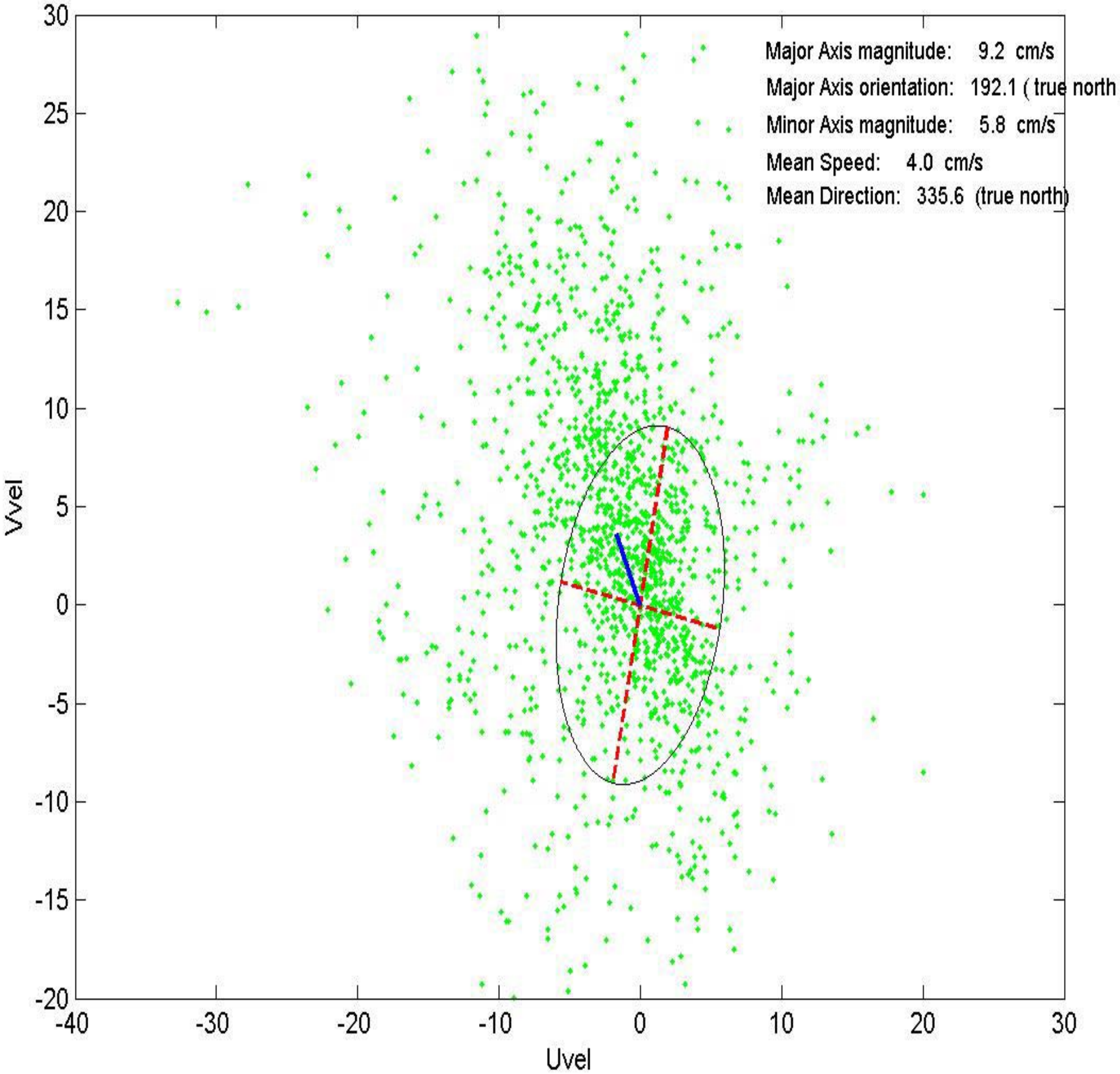

Figure 3. Scatter plot of Daily 300 m. current observations.

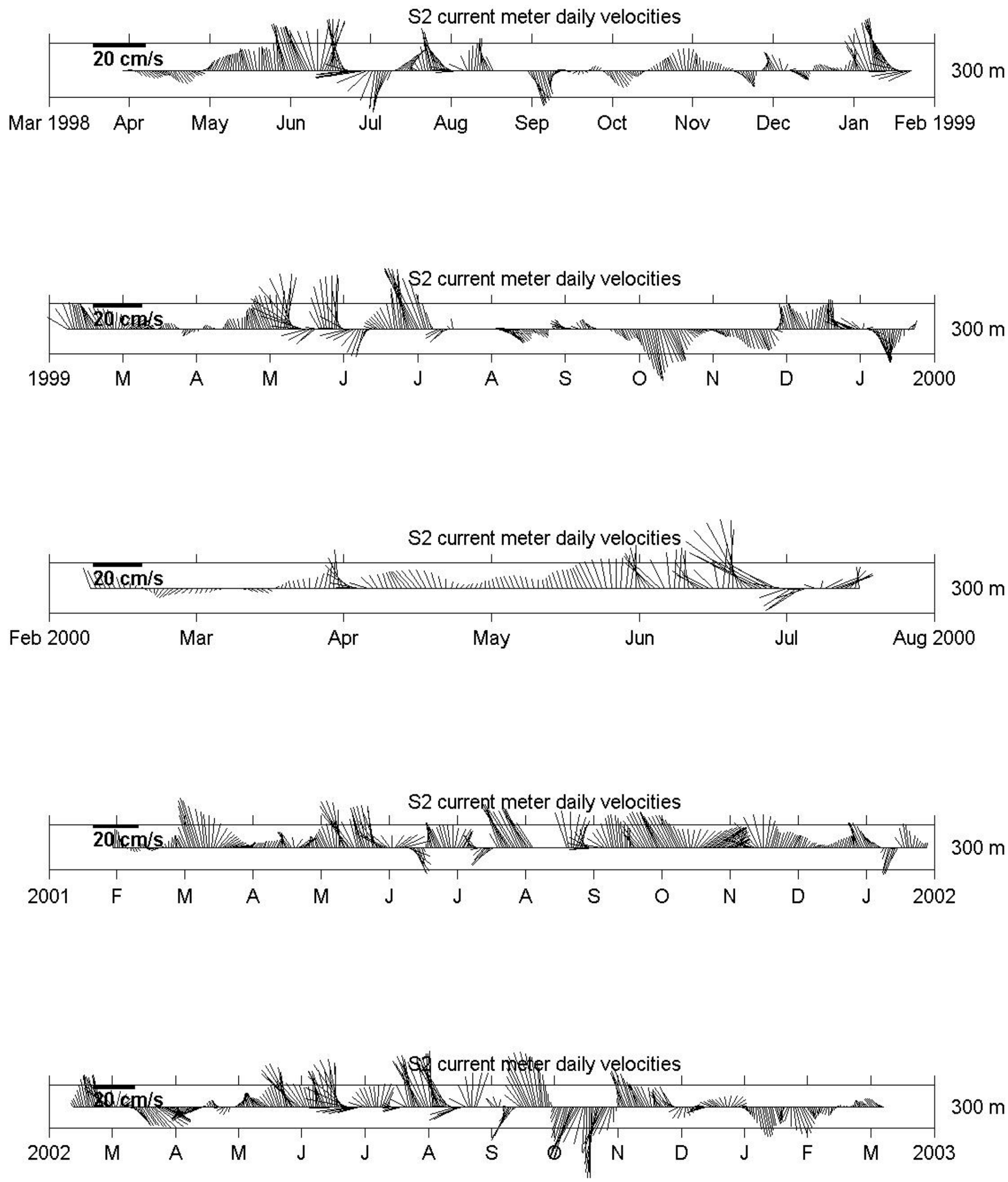

Figure 4.Time series of currents at 300m. depth.

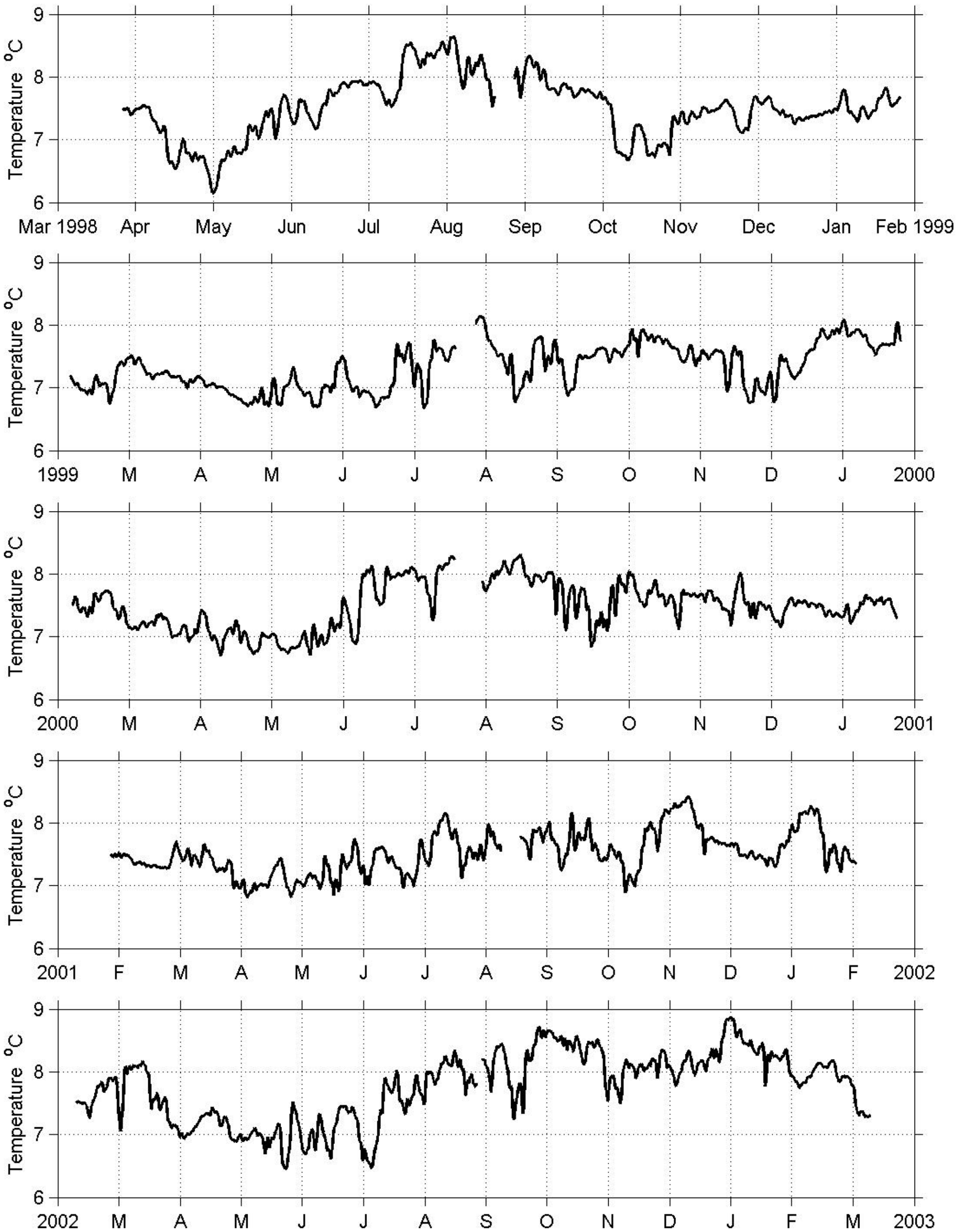

Figure 5. Time series of Temperature observations at 300m. depth.

	U Velocity		V Velocity		Temperature		Pressure	
Deploy	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
1	-3.5	40.12	3.50	62.08	7.53	0.35	294.68	0.01
2	-0.95	37.67	0.67	26.87	7.47	0.11	303.30	0.112
3	-5.71	45.71	3.80	65.68	7.09	0.07	308.37	0.39
4	2.05	38.79	-1.13	32.80	7.52	0.10	292.82	0.14
5	-5.44	60.08	3.32	55.47	7.33	0.18	294.65	0.23
6	--	--	--	--	--	--	--	--
7	-4.36	55.86	4.82	35.87	7.35	0.07	306.65	0.15
8	-4.12	40.27	5.28	36.68	7.7	0.01	298.38	0.19
9	-5.91	80.28	3.76	73.20	7.38	0.21	302.66	0.28
10	-1.15	55.80	-2.73	108.44	8.14	0.11	295.86	2.41

Table 2. Combined Statistics for Mooring S2.

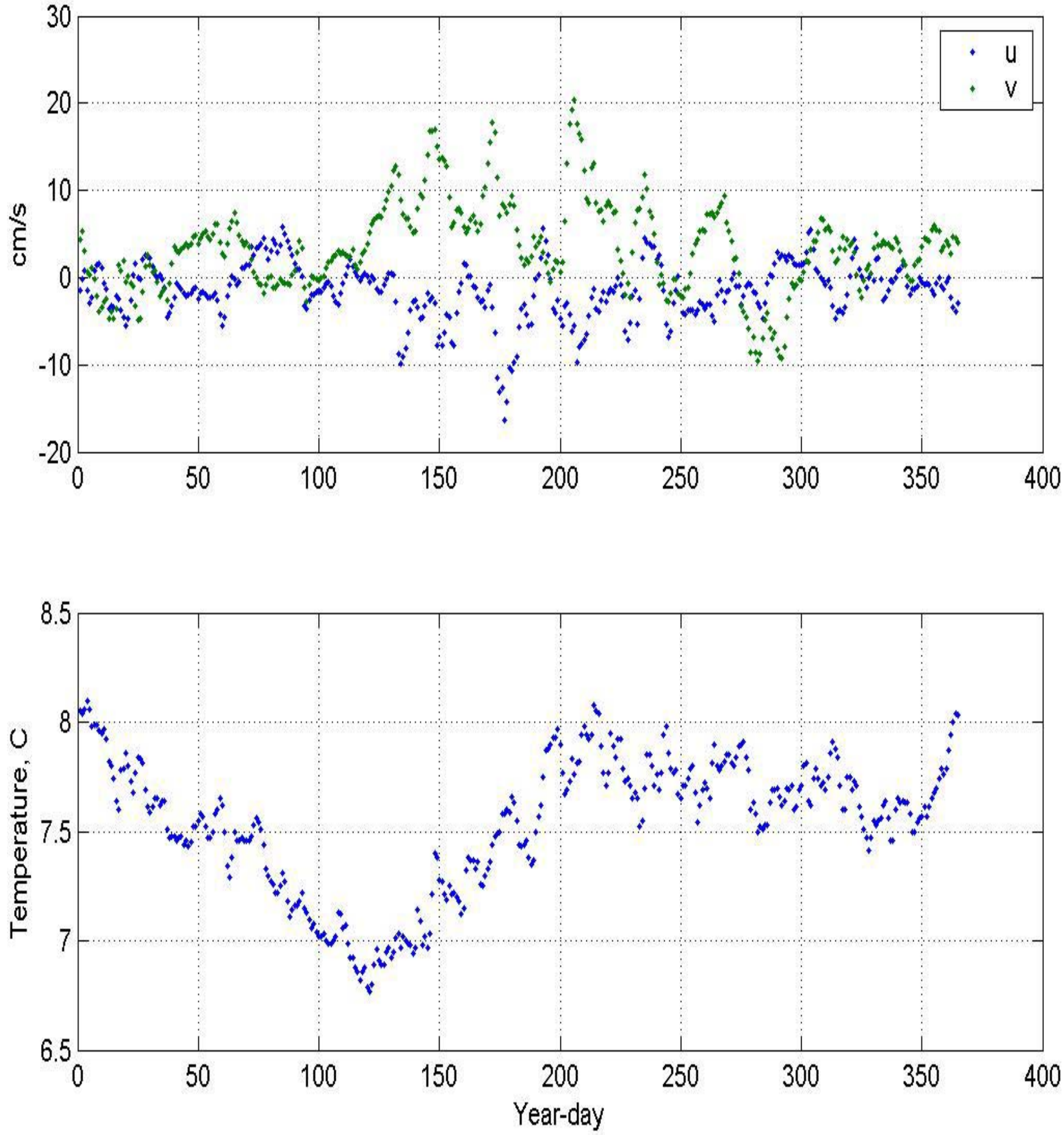

Figure 6. Daily average of u and v Velocity components and Temperature.

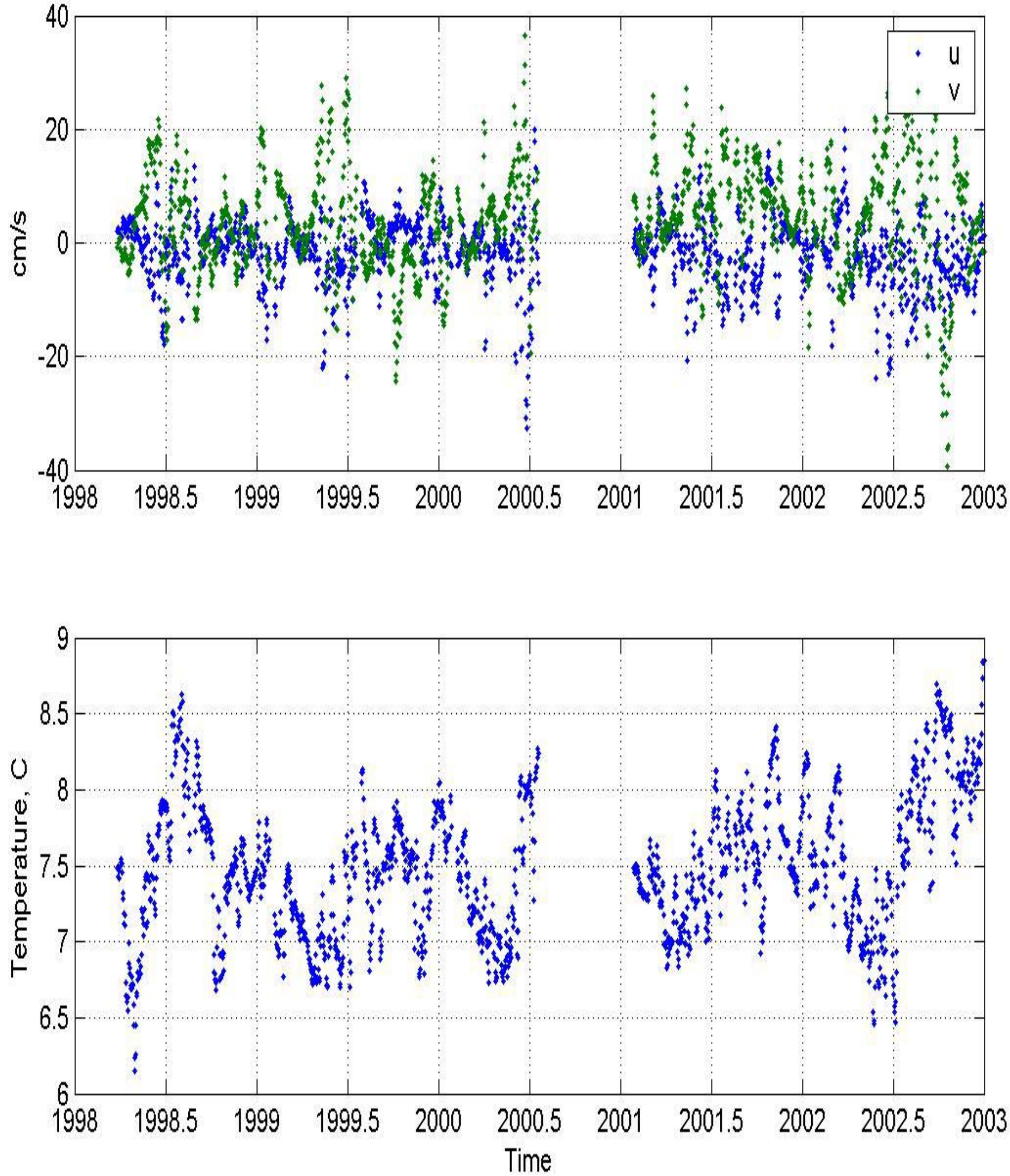

Figure 7. Annual average of u and v Velocity components and Temperature.

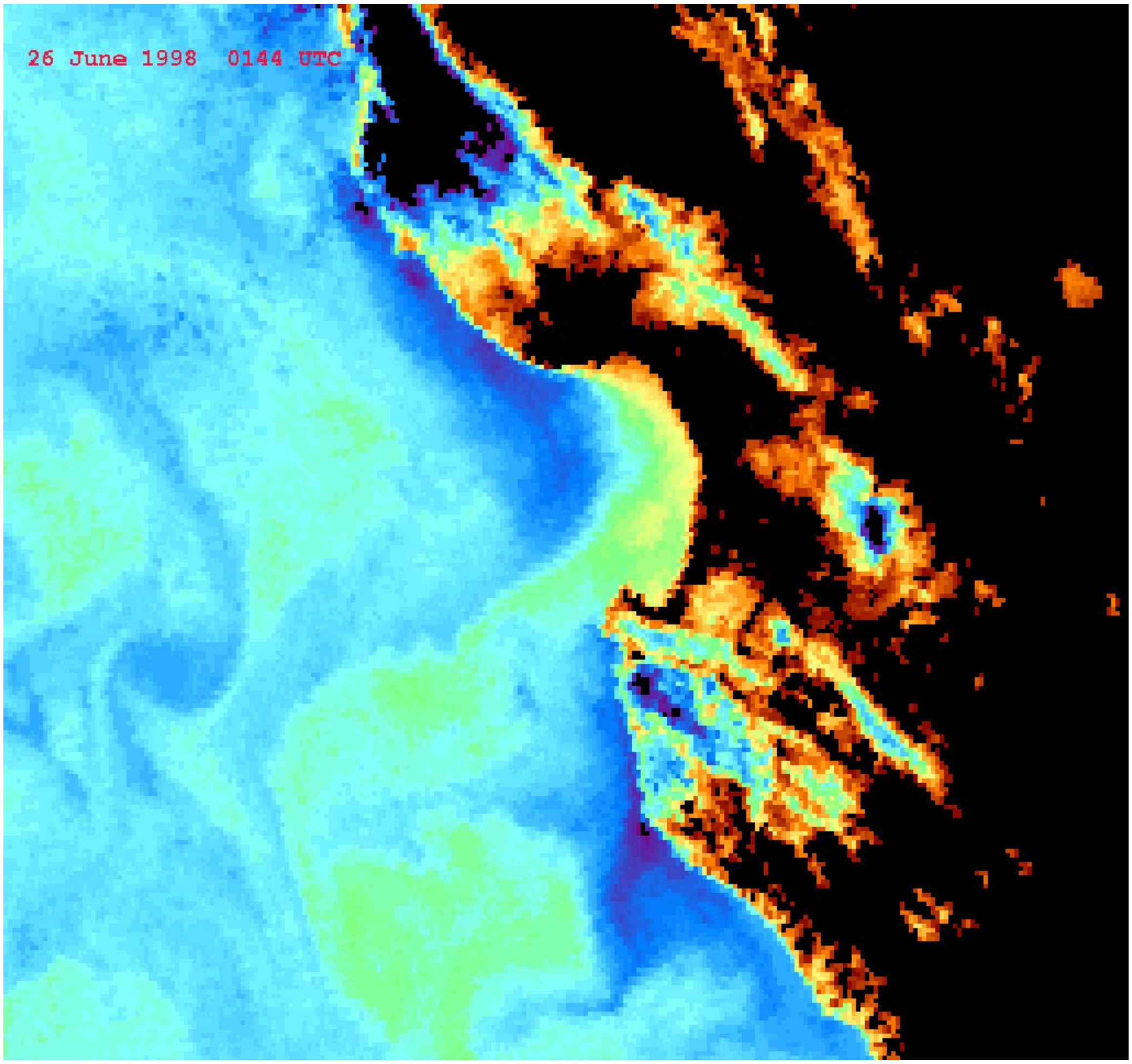

Figure 8. Satellite Sea Surface Temperature (SST).

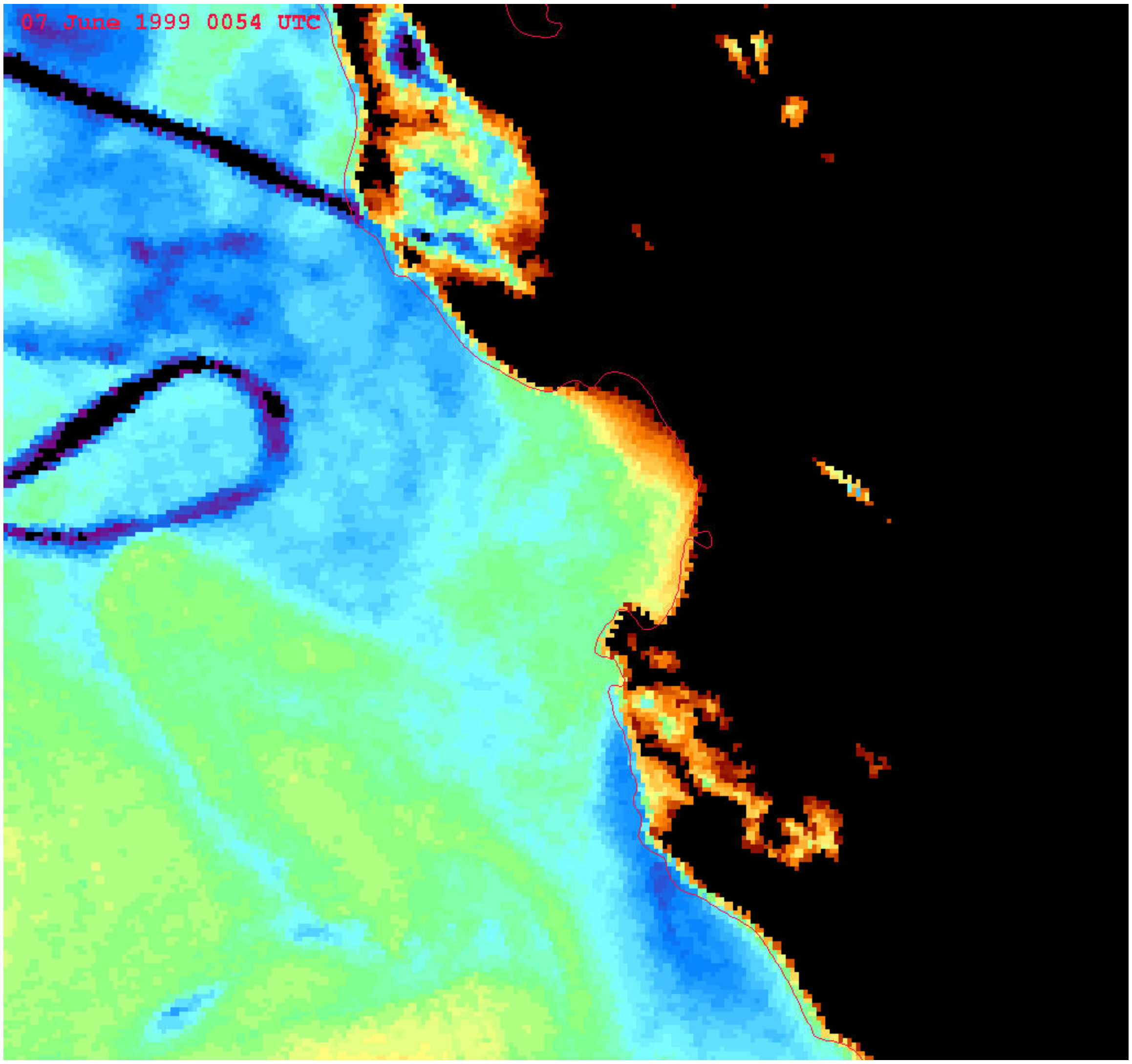

Figure 9. Satellite Sea Surface Temperature (SST).