Geostrophic, Ekman and ADCP Volume Transports through CalCOFI Lines 67,77 and Line 77

Abstract. A set of OC3570 leg 1 cruise data was extracted for analysis to achieve the following objectives:

a. Compute and compare the ADCP, geostrophic and Ekman volume transport through the coastal box off California coast shown in figure 1 in page 2.

b. Verify whether Ekman divergence transport is balanced by Geostrophic convergence within the box.

c. Estimate the net velocity profile from the surface to a depth of – 20 m through the coastal box from the geostrophic and Ekman velocities.

Based on the extracted data collected from the cruise in July 2002, appropriate Matlab programs were written to analyze these data and compute the required volume transports. Matlab programs were also used to create plots to facilitate data analysis and presentation.

Submitted By:

MAJ Ong AhChuan

Republic of Singapore Navy

20 SEP 2002

OC 3570

Geostrophic, Ekman and ADCP Volume Transport computation

1. Introduction

The OC 3570 Summer Operational Oceanography Cruise (Leg 1) was successfully conducted from 15 to 18 July, 2002. Many meteorology and oceanography data were collected in the cruise. This report made use of some of the data, such as the wind speed and direction, air temperature, atmospheric pressure, CTD and Acoustic Doppler Current Profiler (ADCP) velocities recorded in the cruise to compute the volume transports through the coastal box. The coastal box was developed which encompassed California Cooperative Oceanic Fisheries Investigations (CalCOFI) line 67 (along course 240), line 70 (along course 130) and along CalCOFI line 77 (Course 060) to Port San Luis. The planned cruise track and hydrographic stations along the coastal box are shown in the figure 1 below.

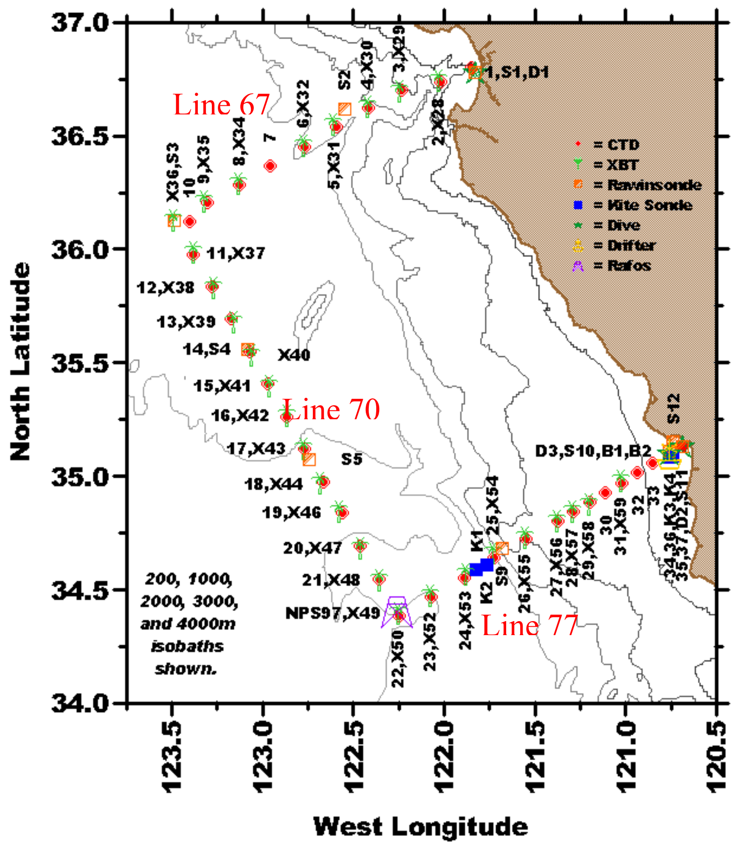


Figure 1: California Coastal Box

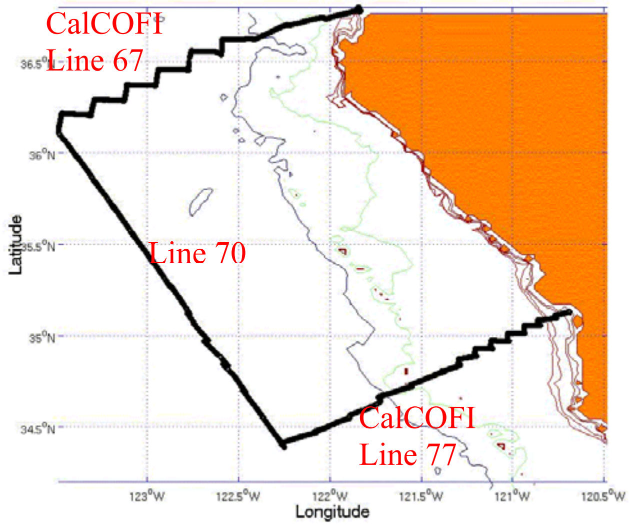
2. California Current System

The California Current System (CCS) extends up to 1000 km offshore from Oregon to Baja California and encompasses a southward meandering surface current, a poleward undercurrent and surface countercurrents. It exhibits high biological productivity, diverse regional characteristics, and intricate eddy motions. The California Current flows southward beyond the continental shelf throughout the year. It has a typical velocity of 10 cm/s and brings water low in temperature and salinity, with high oxygen and phosphate contents. The California Current is strongest in July and August in association with westerly to northwesterly winds. The California Undercurrent, a narrow (20 km) subsurface countercurrent, flows northward along the upper continental slope with its core at a depth of about 200 m. This current is also strongest in the summer with a mean velocity of about 10 cm/s. It brings warmer water with more saline, and less oxygen and phosphate. The poleward undercurrent has been observed as near as 10 km off the coast between Monterey Bay and Port San Luis. As a result, the geostrophic velocity calculated based on CTD stations from surface to a depth of 1000 m along CalCOFI Line 67, 77 and Line 70 would resemble the poleward undercurrent structure around 200 m depth. A good understanding of the CCS would facilitate the analysis of the oceanographic data collected in the OC3570 cruise.

3. Data Collection Process

During the OC3570 cruise (Leg 1), underway meteorological and oceanographic observations were recorded from the oceanographic cruise on the Research Vessel Point Sur. Data utilized for this study were wind direction, wind speed, position, time, relative humidity, sea surface and air temperature. These data were obtained from the Point Sur's Science Data Acquisition System referred to as the SAIL data. The data sampling rate was approximately every 53.7 seconds. In addition, CTD and ADCP data were also used to compute the volume transport associated with the geostrophic and ADCP velocities. The location of the study was along the coastal box off the central coast of California with the actual ship's tracked traveled in the cruise plotted in figure 2 (next page).

Figure 2: Coastal Box plotted with actual ship's track executed in Leg 1



4. Data Analysis

A raw data analysis was completed. Parameters were plotted versus time to assess for obvious errors. No observable errors were noted. This analysis also enabled us to compare the port and starboard wind anemometer readings. There were a few outliers but they were insignificant to affect the overall result. The windward side of the anemometer readings were used for the mass Ekman transport calculations, that is, starboard anemometer readings were used for line 67 and 70 and port anemometer readings were used for line 77. Another approach was to take the starboard anemometer readings to calculate wind stress but both approaches yielded similar results (shown in Appendix A). The following wind pattern was observed:

Table 1: Observed Maximum and Minimum wind pattern

True Wind Speed and direction	**Line 67**	**Line 70**	**Line 77**
Maximum starboard wind and corresponding direction **(knot / °)**	26.4 / 333.8	22.7 / 319.3	27.7 / 339.4
Maximum port wind and corresponding direction **(knot / °)**	27.5 / 333.7	22.9 / 319.2	26.9/ 318.0
Minimum starboard wind and corresponding direction **(knot / °)**	3.4 / 223.7	2.0 / 66.7	0.6 / 173.0
Minimum Port wind and corresponding direction **(knot / °)**	3.6 / 51.0	2.2 / 45.7	0.6/ 140.6
Percentage of samples with wind speed (%wd spd) < 10 kts	8%	0.6%	11%
14 <= %wd spd <= 20 kts	**51%**	**71%**	**53%**
%wd spd > 20 kts	15%	2%	28%

The vessel was sheltered by the mountains when it was proceeding from station 34 to 35 along line 77, the anemometer recorded a reduced wind speed to an averaged of about 6 knots. This effect is reflected in the following wind speed time series plot. Due to the relatively short duration between station 34 and 35 and the effect of averaging, this occurrence has little effect on the result of my analysis.

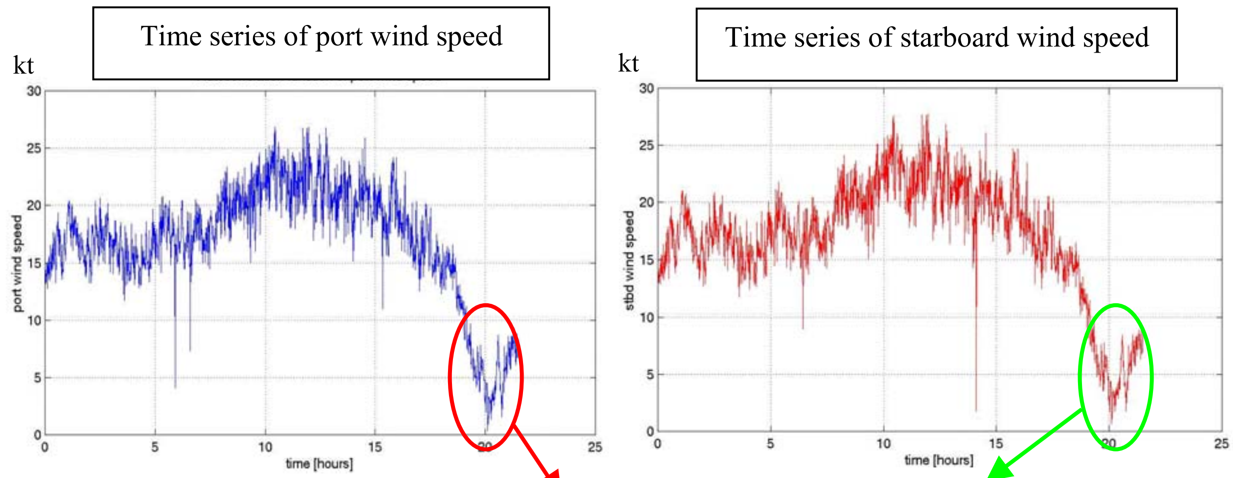


Figure 3: Time series of wind speed

Besides the above-mentioned observation, the wind data illustrates a relatively steady wind from the northwest for leg 1. Time series of wind direction, wind speed, air and sea surface temperature, pressure and humidity plots are given in appendix A of this report.

5. Geostrophic Volume Transport computation

Geostrophic velocities for the hydrographic stations were computed from the dynamic heights based on the CTD data collected. The dynamic height anomaly, $\Delta D = \int_{p_o}^{p_n} \delta dp$ where δ is the specific volume anomaly. Reference level for ΔD was set based on bottom of CTD cast. The dynamic height difference (dyndiff) between two stations was calculated to a depth of 1000 m or the deepest common depth between 2 stations. CTD data collected were entered into the Matlab specific volume anomaly subroutine to derive the dynamic heights. The distance (dist) between two stations was computed from the Matlab subroutine by entering the mean latitude and mean longitude. Sample Matlab programs to compute the geostrophic velocity (geovel) and volume transport through the coastal box are attached in Appendix E based on the following formula:

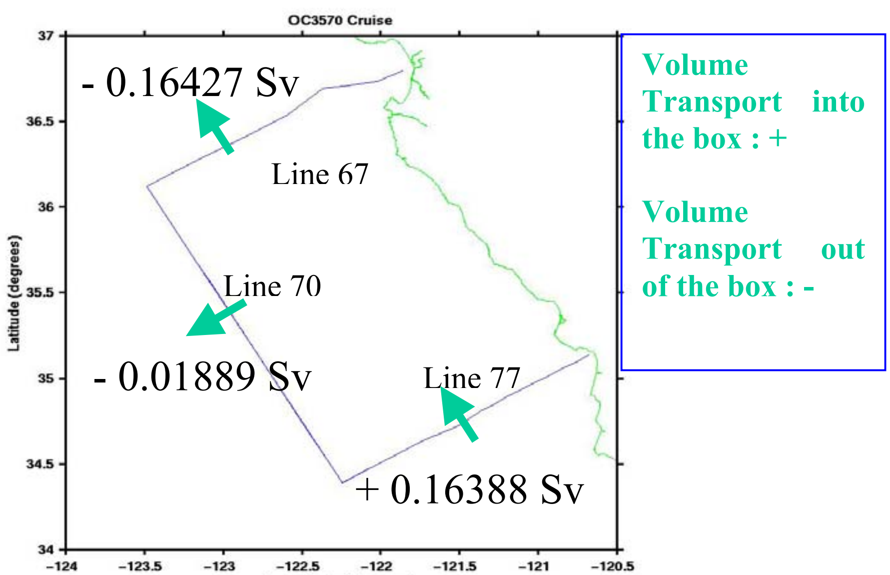
geovel[1] $= \mathbf{10 \times dyndiff \div (\mathit{f} \times 1000 \times dist)}$, f : coriolis parameter.

Where **geovel** is a column vector containing the gestrophic velocities from the surface to the deepest common depth between two appropriate CTD stations normal to the coastal line. Matlab subroutine was used to convert CTD cast pressure data in dbars to depth in meters before multiplied by the geovel and distance along the coastal line to obtain the volume transport. A sensitivity check was conducted using dbars instead of converting depth to meters and the result obtained is similar. Please refer to Appendix B for the result obtained using dbars.

Along line 67, the geostrophic volume transport was computed down to 1000 m depth except the first and second station. The lowest common depth of 200 m was used to compute the geostrophic transport between station one and two as the first CTD station was lowered to about 200 m. Along line 70, the geostrophic volume transport was computed down to a depth of 1000 m. There were numerous variations in the CTD cast depth from station 26 to station 35 along lone 77. As such, the geostrophic volume transport was computed to the lowest common depth between each pair of CTD station (from station 26 to station 35) before summing along the line. The result of the geostrophic volume transport through the coastal box is summarized as follows:

Figure 4:

Geostrophic Volume Transport through the coastal Box



[1] The factor 10 is to convert dynamic difference from dynamic meters to m^2/s^2. The factor 1000 is to convert distance from km to m.

Table 1: Summary of the Geostrophic Volume transport through the coastal box

	Pair of CTD Station	Volume Transport through pair of stations (Sv) –: out of the box +: into box	Volume Transport through the coastal line (Sv) –: out of the box +: into box
CalCOFI Line 67	1 - 2	– 0.00186208	
	2 - 10	– 0.16241164	**– 0.16427373**
Line 70	10 - 22	– 0.01888842	**– 0.01888842**
CalCOFI Line 77	22 - 25	+ 0.10219745	
	25 - 26	– 0.02938563	
	26 - 27	– 0.01932998	
	27 - 28	+ 0.00463704	
	28 - 29	+ 0.07044303	
	29 - 30	+ 0.01637260	
	30 - 31	+ 0.01378705	
	31 - 32	+ 0.00254251	
	32 - 33	+ 0.00566979	
	33 - 34	– 0.00303272	
	34 - 35	– 0.00002575	**+ 0.16387540**
Net transport through the coastal box			**– 0.01928675**

Plots of volume transport profile between each appropriate pair of CTD stations used to compute the geostrophic volume transport through the coastal lines are attached in Appendix C. The volume transport profile between station 2 and 10 shows a local maximum value at a depth of about 200 m is indicative of the core of the California undercurrent. This undercurrent flows northward along the upper continental slope with its core at a depth of about 200m (Hickey, 1979). Please refer to next page for a sample plot of the volume transport profile between station 2 and 10. This feature can also be seen in other plots of volume transport profile between each pair of CTD stations in Appendix C.

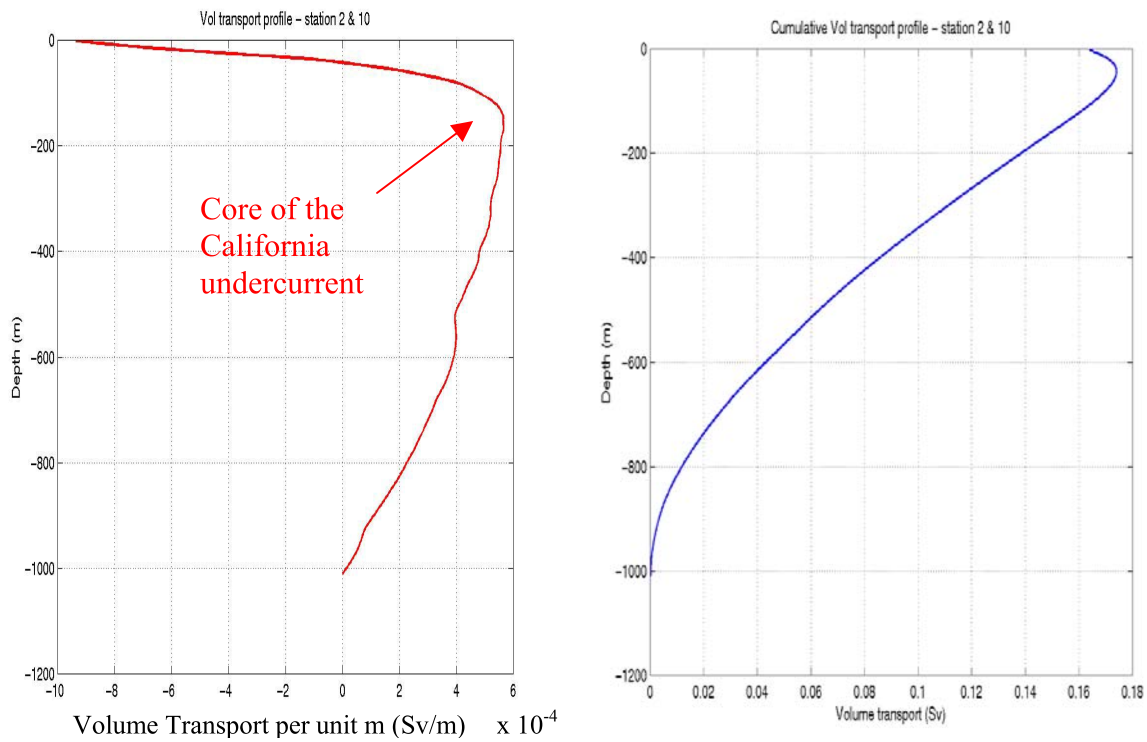


Figure 5: Volume transport profile between station 2 and 10 along CalCOFI line 67

6. Ekman Volume Transport Computation

Ekman Wind driven surface currents can be explained as the frictional wind stress that balances Coriolis force with a resultant mass transport at right angles to the wind direction. One of the objective of this paper is to analyze and evaluate shipboard wind data and calculate the Ekman volume transport using indirect methods since it is difficult to measure perturbations in the vertical momentum flux in equation (5). The momentum balance for Geostrophic and Ekman flow develops into the following equations. Here × refers to cross-product:

Total Current: $u = u_E + u_G$ (1)

Geostrophic flow: $2\Omega \times u_G = -\frac{1}{\rho}\nabla p$ (2)

Frictional Wind Driven (Ekman Flow): $2\Omega \times u_E = -\frac{1}{\rho}\frac{\partial \tau}{\partial z}$ (3)

Boundary Conditions: $\tau(z) = \tau_0$ @z = 0 (4)

$\tau(z) = 0$ @z ≤ -H

The raw SAIL data was partitioned into two-hourly segments (except the three corners of the coastal box, where the data were partitioned into approximately half-hourly segment). The bulk formulae from Smith's (1988) paper "Coefficients of sea surface wind stress, heat flux, and wind profiles as a function of wind speed and temperature" were used to calculate the momentum and heat fluxes. A program[2] written by Professor Peter Guest was used to calculate the wind stress and surface flux. The inputs required for this program are wind speed, air temperature, sea surface temperature, relative humidity, pressure, and height. The essential outputs were surface friction (u*) and wind stress (tau) at every data point.

It would difficult to measure the perturbation (u' and v') in the vertical momentum flux in equation (5), as such, indirect method is used by first solving for the surface friction velocity ($u_{*\,atm}^2$) based on the drag coefficient (c_d) and the mean velocity ($\bar{u}$). The reference height of the anemometer was 14 meters. For equations (5) to (8) given below, ρ_{atm} is the atmospheric density, f is the coriolis parameter and ρ_{ocean} is the ocean density.

Vertical Momentum Flux: $$\left.\begin{aligned}\tau &= \overline{-\rho u'w'}\\ \tau &= \overline{-\rho v'w'}\end{aligned}\right\} \qquad (5)$$

Stress (Momentum Flux): $$\tau = \rho_{ocean} u_{*\,\text{ocean}}^2 = \rho_{atm} u_{*\,\text{atm}}^2 \qquad (6)$$

Surface Friction Velocity: $$u_{*\,atm}^2 = c_d \bar{u}^2 \qquad (7)$$

Ekman Volume Transport: $$\text{Vx} = \int_{-H}^{0} u_E dz = \frac{\tau_0^y}{\rho f} \qquad (8a)$$

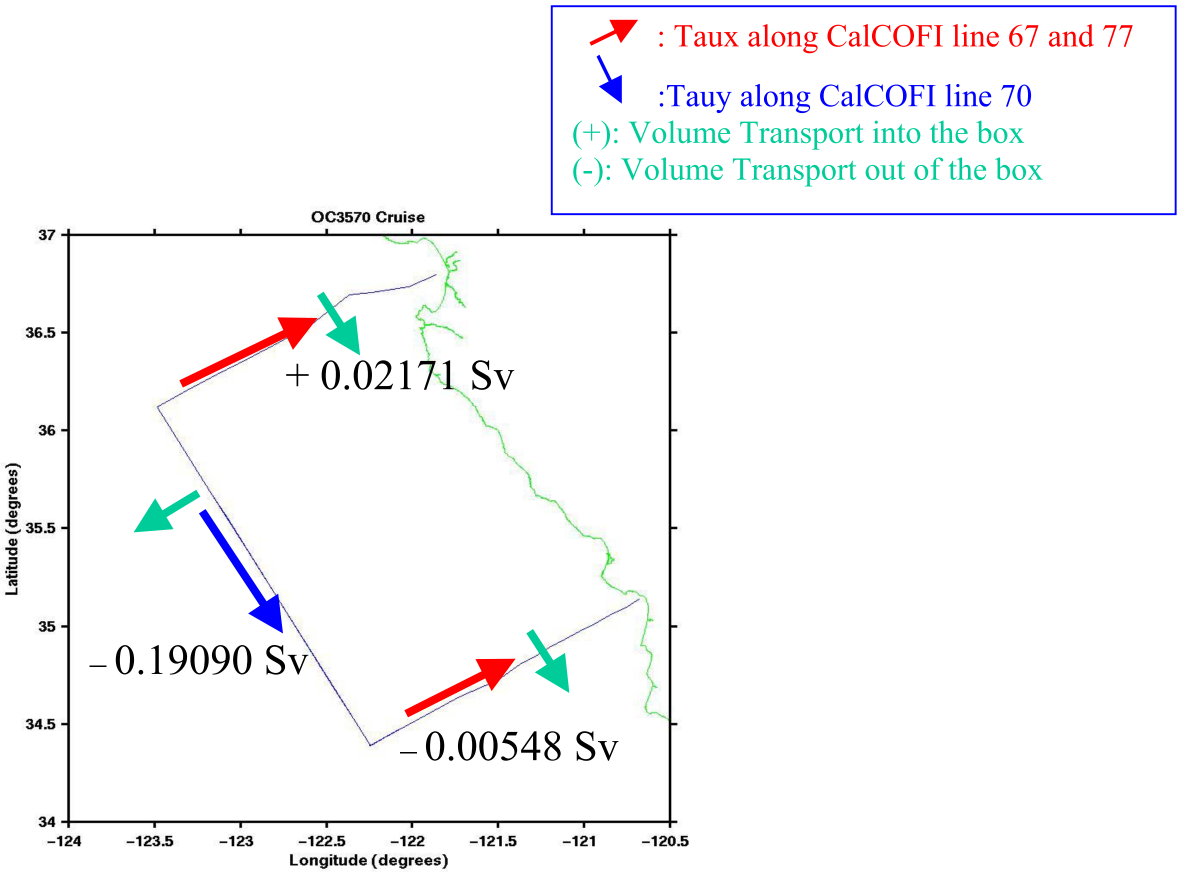
$$\text{V}_\text{y} = \int_{-H}^{0} v_E \partial z = -\frac{\tau_0^x}{\rho f} \qquad (8b)$$

The vector wind stress was then resolved into its x (taux) and y (tauy) components where x is along 060 and y is along 150. Thus, taux is acting along line 67 and line 77 while tauy is acting along line 70 (taux and tauy is perpendicular to each other). The volume transport per unit meter normal to each CalCOFI line was derived from equation (8a) and (8b). Two-hourly

[2] matlab programs are attached in appendix E.

average for taux and tauy was taken and multiplied by the distance traveled in each two-hourly segment. A smaller average was done around the corners (approximately half-hourly average).

Figure 6: Ekman Volume Transport through the coastal Box



Two hourly wind stress values along line 67, 70 and 77, distance traveled and the associated Ekman volume transport values are tabulated in Appendix D.

7. Compare Geostrophic Volume transport with Ekman Volume transport

To verify whether Ekman divergence transport is balanced by geostrophic convergence within the coastal box, the result of the geostrophic volume transport and Ekman volume transport are tabulated for comparison:

Table 2 Ekman Volume Transport (using windward side of the anemometer[3] data)

– : indicate volume transport out of the box

+ : indicate volume transport into the box

	Net volume transport into the box (Sv)	**Net volume out of the box (Sv)**	**Net transport (Sv)**
CalCOFI line 67	+ 0.0217098		
Line 70		– 0.1909018	
CalCOFI Line 77		– 0.0054774	
Total	**+ 0.0217098**	**– 0.1963792**	**– 0.1746694**

Table 3: Geostrophic Volume Transport

	Net volume transport into the box (Sv)	**Net volume out of the box (Sv)**	**Net transport (Sv)**
CalCOFI line 67		– 0.16427373	
Line 70		– 0.01888842	
CalCOFI Line 77	+ 0.1638754		
Total	**+ 0.1638754**	**– 0.18316215**	**– 0.01928675**

From table 2 and 3, it seems that Ekman divergence transport is not balanced by geostrophic convergence within the box. Some of the plausible explanations that resulted this unbalance are as follows:

a. Time-lagged in the data collection process – a total of about 3 days was taken to complete the entire data collection process. This could be the most likely and significant reason that caused the unbalance.

b. Geostrophic volume transport was not calculated to the full water depth and water could be escaped below the depth of – 1000 m, especially along line 70 where the water

[3] The result is similar when the starboard side of the anemometer readings were used. Please see Appendix A.

depth could be as deep as – 4000 m. The effect is expected to be small since the velocity below the depth of – 1000 m is very small.

c. Volume transport associated with inertial and tidal current was neglected in my calculation. The effect is expected to be small.

7. ADCP volume transport

The ADCP was used to measure the net current, primarily comprised of geostrophic current, Ekman surface current and tides. The calculated ADCP transport was **– 0.146715 Sv** based on the given box.dat data file where the depth of ADCP measurement was from – 20 m downward. The maximum depth of the ADCP readings ranged from about – 110 m near to the coast to about – 460 m in the deep waters. The sum of Ekman volume transport and geostrophic volume transport tabulated below gives the estimated net volume transport through the coastal box from surface to a depth of – 1000 m (or the deepest common depth between two CTD stations).

Table 4: Net volume transport (Geostrophic and Ekman volume transport)

– : Volume transport out of the box **+ : Volume transport into the box**

(E): Gesotrophic Volume Transport **(G): Ekman Volume Transport**

	Net volume into the box (Sv)	**Net volume out of the box (Sv)**	**Net Volume transport (Sv)**
CalCOFI Line 67	+ 0.0217098 (E)	– 0.1642737 (G)	– 0.1425639
Line 70		– 0.0188884 (G) – 0.1909018 (E)	– 0.2097902
CalCOFI Line 77	+ 0.1638754 (G)	– 0.0054774(E)	+ 0.1583980
Total Volume Transport	**+ 0.1855852**	**– 0.37954135**	**– 0.1939562**

The sum of Ekman and geostrophic transport through the coastal box (– **0.193956 Sv)** is bigger than the calculated ADCP volume transport (**– 0.146715 Sv**). The difference could be due to the following reasons:

a. The ADCP volume transport from the surface to – 20 m was not included in the calculation. This is because the ADCP velocity from the surface to – 20 m was not available due to technical constraint of ADCP. This resulted a significant portion of the volume transport due to Ekman wind stress not included in the ADCP volume transport.

b. ADCP volume transport was sum to a maximum available depth which ranged from –110 m to – 460 m. However, the maximum available depth used for geostrophic volume transport computation was as deep as – 1000 m.

c. Volume transport due to tides and inertial current was not included in the calculation, though the effect is expected to be small.

8 Net velocity from the surface to a depth of – 20 m through the coastal box

This objective was set as the net velocity from the surface to a depth of – 20 m could not be obtained directly from the ADCP. The Ekman depth D_e is calculated based on this formula taken from the Dynamic textbook:

$$D_e = 4.3*W/(\sin|\phi|)^{1/2}$$

where W is in the wind speed in m/s resolved in the direction of the coastal lines (line 67, 70 and 77) and ϕ is the latitude. After calculated the wind speed component along line 67, 70, 77 and D_e, the net Ekman velocity (V_o) can be derived from the following equation:

$$V_o = \sqrt{2}*\pi*1.8*10^{-3}*W^2/(D_e*1025*|f|)$$ f is the coriolis parameter

Ekman velocity normal (u_e) and along (v_e) the coastal box line 67, 70 and 77 can be calculated from the following equations:

$$u_e = V_o*COS(\pi/4 + \pi*z/D_e)*exp(\pi*z/D_e) \qquad v_e = V_o*SIN(\pi/4 + \pi*z/D_e)*exp(\pi*z/D_e)$$

The net velocity and Ekman velocity from the surface to a depth of – 20 m through line 67 and 70 are summarized in the following plots[4]:

Figure 7: Sum of Ekman and Geostrophic velocity normal to line 67

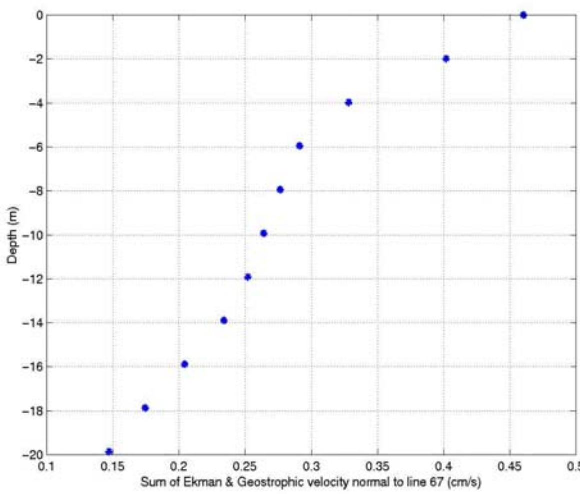
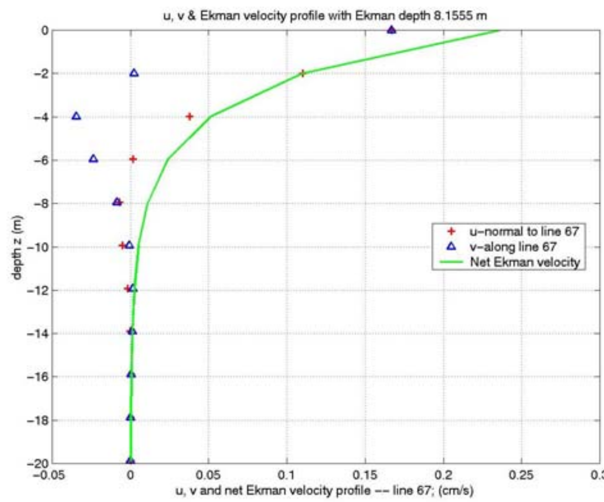
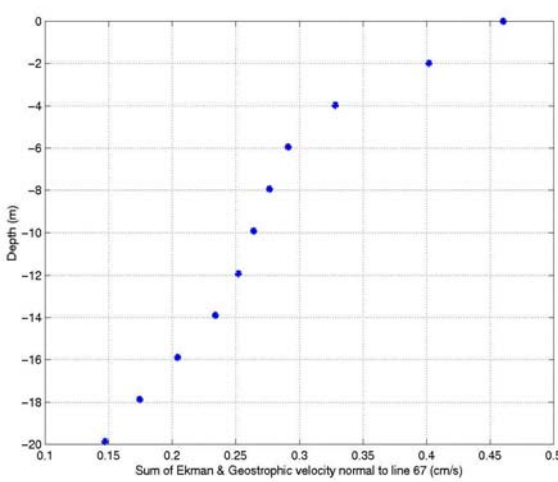


Figure 8: Ekman velocity profile (line 67)





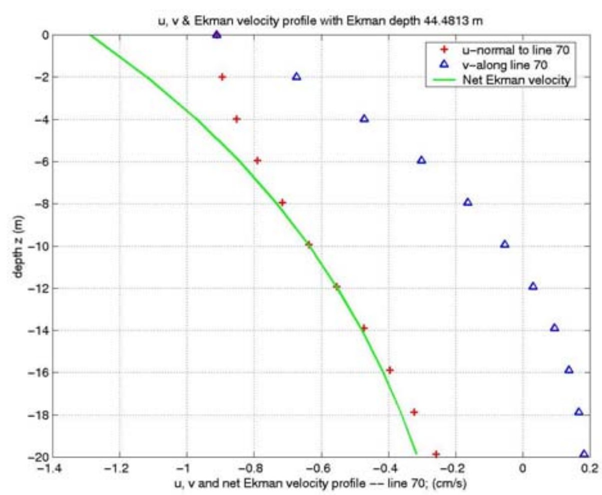


Figure 9: Sum of Ekman and Geostrophic velocity normal to line 70

Figure 10: Ekman velocity profile (line 67)

[4] Figures for line 77 are similar to those of line 67.

The sum of Ekman and geostrophic velocity profile (EGVP) normal to line 67 and 70 illustrated in figure 7 and 9 are the estimated net velocities normal to line 67 and 70. These net velocities are the estimates that the ADCP would measure. Along line 67 and 77, the sum of EGVP from surface to a depth of – 20 m normal to these lines is similar to the geostrophic velocity profile. This is because Ekman velocity is weak through line 67 and 77 since wind direction is predominantly from northwest and the steepest isopycnal lines are in the cross-shore direction. On the other hand, the sum of EGVP normal to line 70 is similar to the Ekman velocity profile normal to line 70.

Tides and inertial currents are neglected in my calculation but their effects are expected to be insignificant. As such, the sum of EGVP through the coastal box from surface to a depth of – 20 m is expected to be close to the net velocity.

9. Effect of averaging and Time Scale

Averaging was used in the data analysis to reduce random error. There were approximately 67 samples in a one-hour of data. Based on the normalized auto-correlation plot, the time scale for each of the coastal box line is about 5 hours based on zero-crossing method as shown in the following plot. Two-hourly average was chosen to remove some of the higher frequency variability. As the time taken to travel along each coastal line is about 24 hours, two-hourly average will enable us to have sufficient data points to represent the phenomenon adequately and also avoid aliasing.

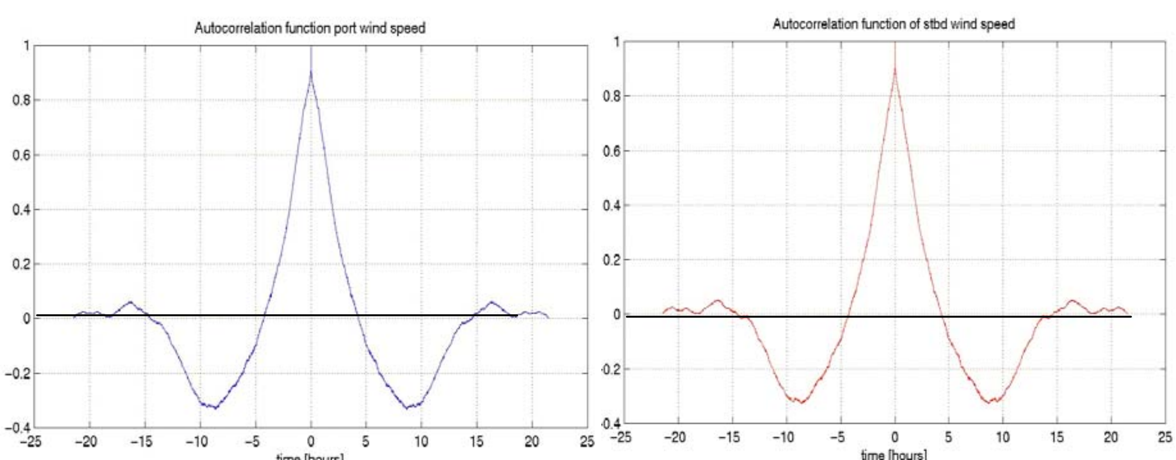


Figure 11: Auto-correlation plot for the port and starboard wind speed

Auto-correlation plots for other data used for my computations are attached in Appendix A.

10. Conclusion

The objectives of my study were carried out under some constraints, such as difficulty to meet all the Ekman assumptions, which are steady state, closure, vertical homogenous ocean, and away from horizontal boundaries. In addition, the level of no motion assumption was made for the bottom of CTD cast for my computation of the geostrophic velocities. This is a weak assumption when the depth is not deep enough, especially along line 77 where some of the CTD cast depths were only about - 500 m. The net Ekman volume transport out of the coastal box **(– 0.17467 Sv)** suggested that coastal upwelling occurred. This upwelling phenomenon was also reflected in the following chlorophyll disposition of the SEAWIFS picture taken on 18 July 2002.

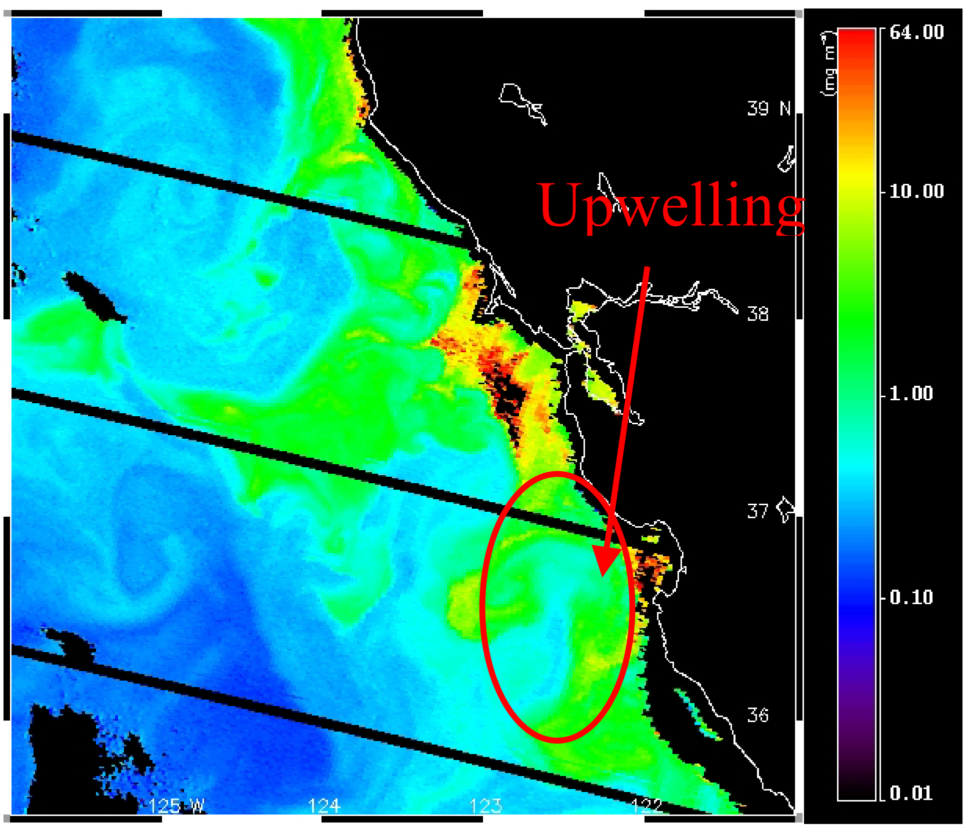


Figure 12: Chlorophyll disposition of the SEAWIFS picture taken on 18 July 2002

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http://www.ocnms.nos.noaa.gov/LivingSanctuary/wavescurrent.html

Appendix A

1. Sensitivity Analysis

As part of sensitivity analysis, starboard anemometer readings were used for coastal line 67, 70 and 77 and the result compare to that using windward side of the anemometer readings. Both approaches produced similar results for the Ekman volume transport through the coastal box.

Table 1: Ekman Volume Transport (using starboard side of the anemometer readings throughout the computation)

The result is similar to that using windward side of the anemometer readings given in the main paper.

– : Volume transport out of the box **+ : Volume transport into the box**

(E): Gesotrophic Volume Transport **(G): Ekman Volume Transport**

	Net volume transport into the box (Sv)	**Net volume transport out of the box (Sv)**	**Net volume transport (Sv)**
CalCOFI Line 67	+ 0.0217098		
Line 70		- 0.1909018	
CalCOFI Line 77		- 0.0004824	
Total	**+ 0.0217098**	**- 0.1913842**	**- 0.1696744**

Table 2: Net volume transport (Sum of Geostrophic and Ekman volume transport based on starboard side anemometer readings throughout Leg 1)

CalCOFI Line	**Net volume into the box (Sv)**	**Net volume out of the box (Sv)**	**Net transport**
CalCOFI Line 67	+ 0.0217098 (E)	- 0.1620891 (G)	- 0.1403793
Line 70		- 0.0190409 (G) - 0.1909018 (E)	- 0.2099427
CalCOFI Line 77	+ 0.1652725 (G)	- 0.0054774 (E)	+ 0.1597951
Total	**0.1869823**	**- 0.3775092**	**- 0.1905269**

2. Time series plots to facilitate raw data analysis

Time series of the data used for my computations were plotted to assess for obvious errors. No observable errors were noted. This analysis also enabled me to compare the port and starboard wind anemometer readings. There were a few outliers but they were insignificant to affect the overall result. The time 0 hour of the time-series plot correspond to the start time of the vessel at the beginning of each coastal line, namely, line 67, 70 and 77.

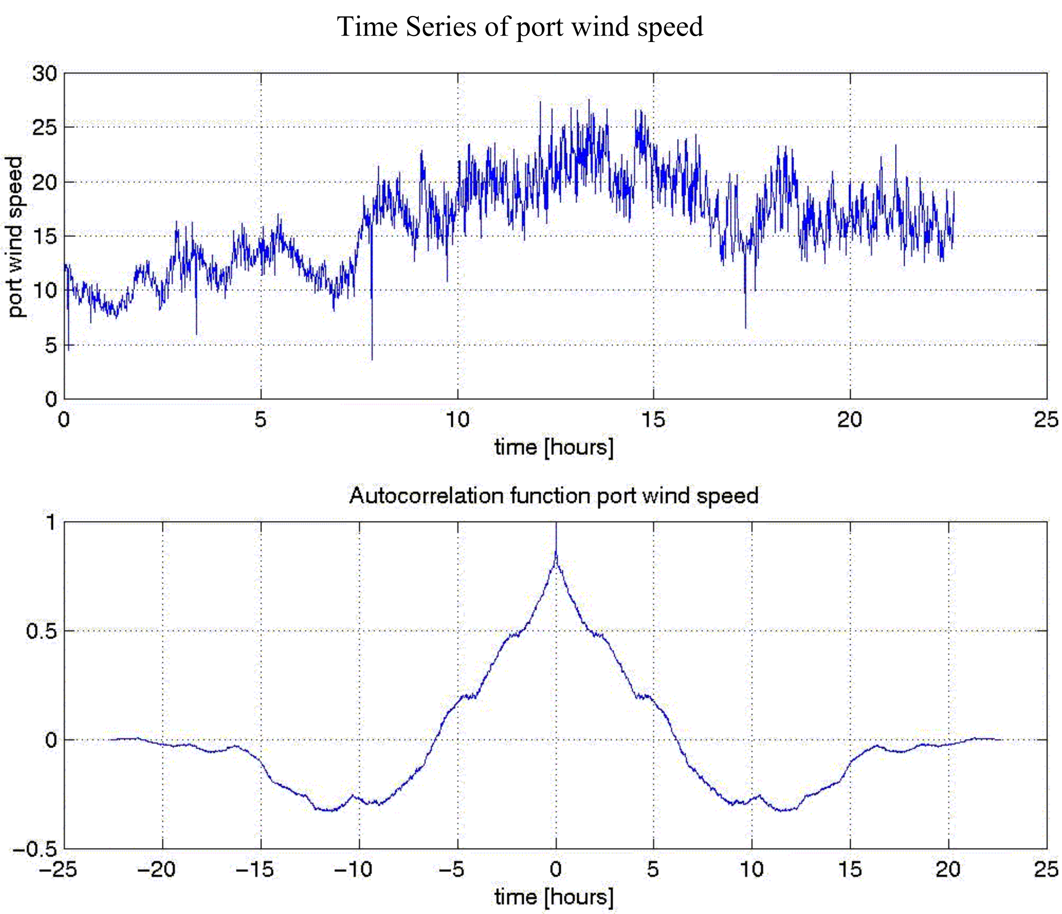


Figure A1: Time series and auto-correlation plot of port wind speed along line 67

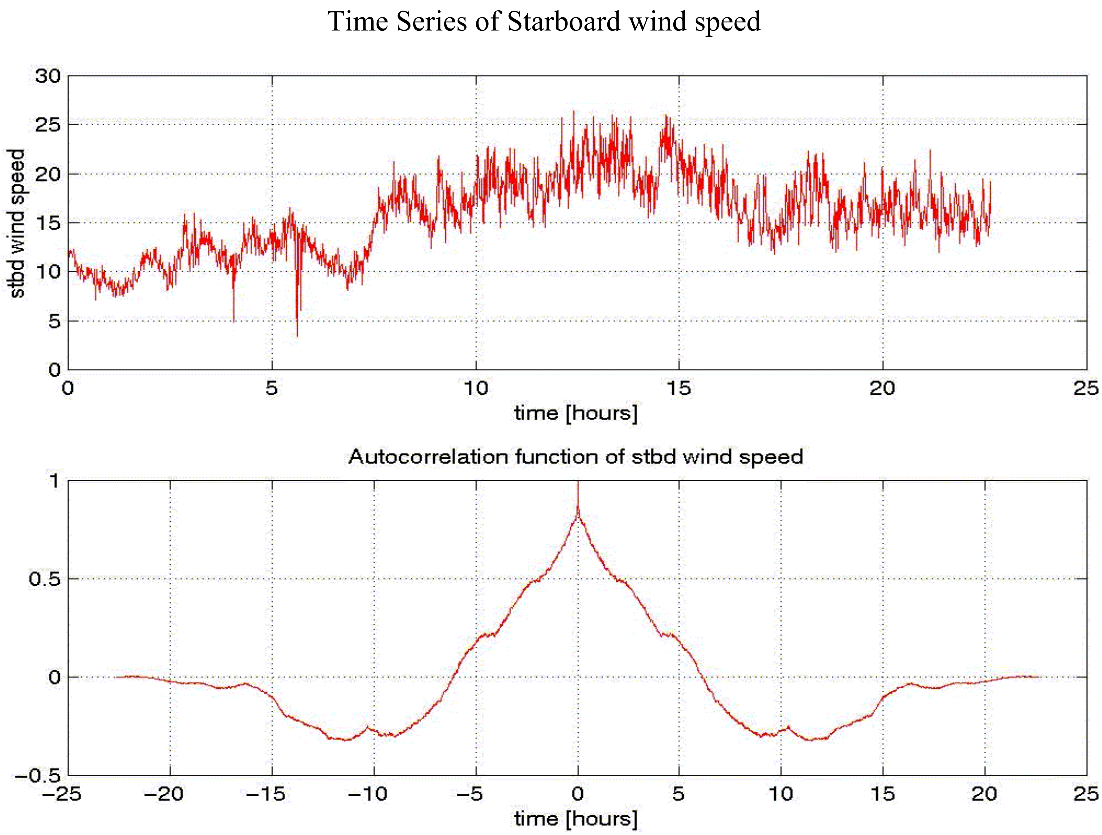


Figure A2: Time series and auto-correlation plot of starboard wind speed along line 67

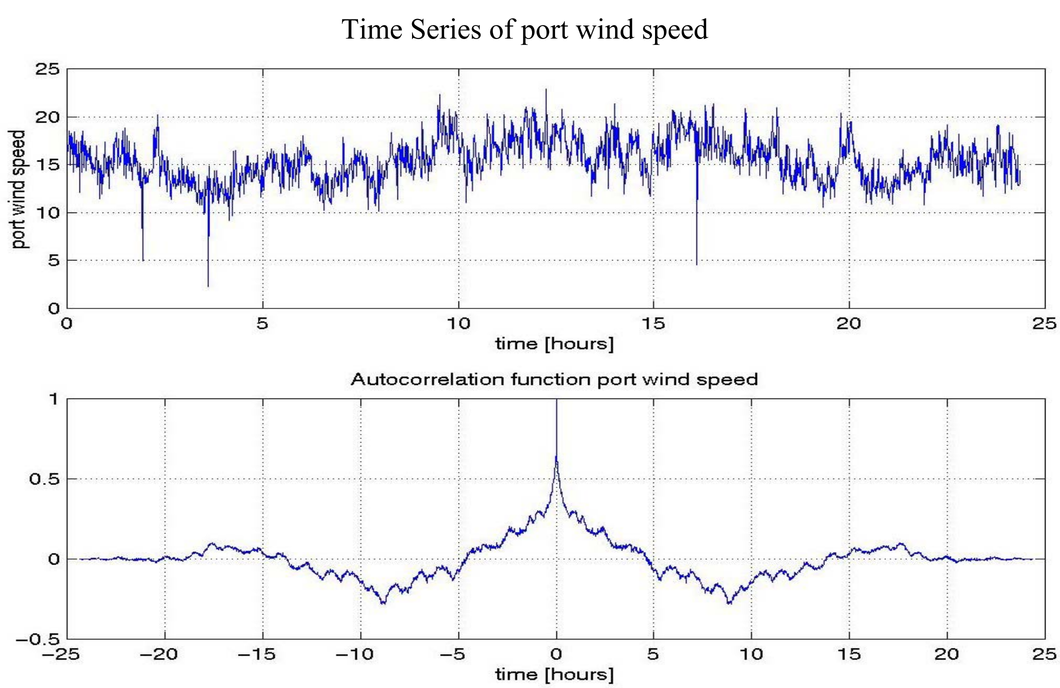


Figure A3: Time series and auto-correlation plot of port wind speed along line 70

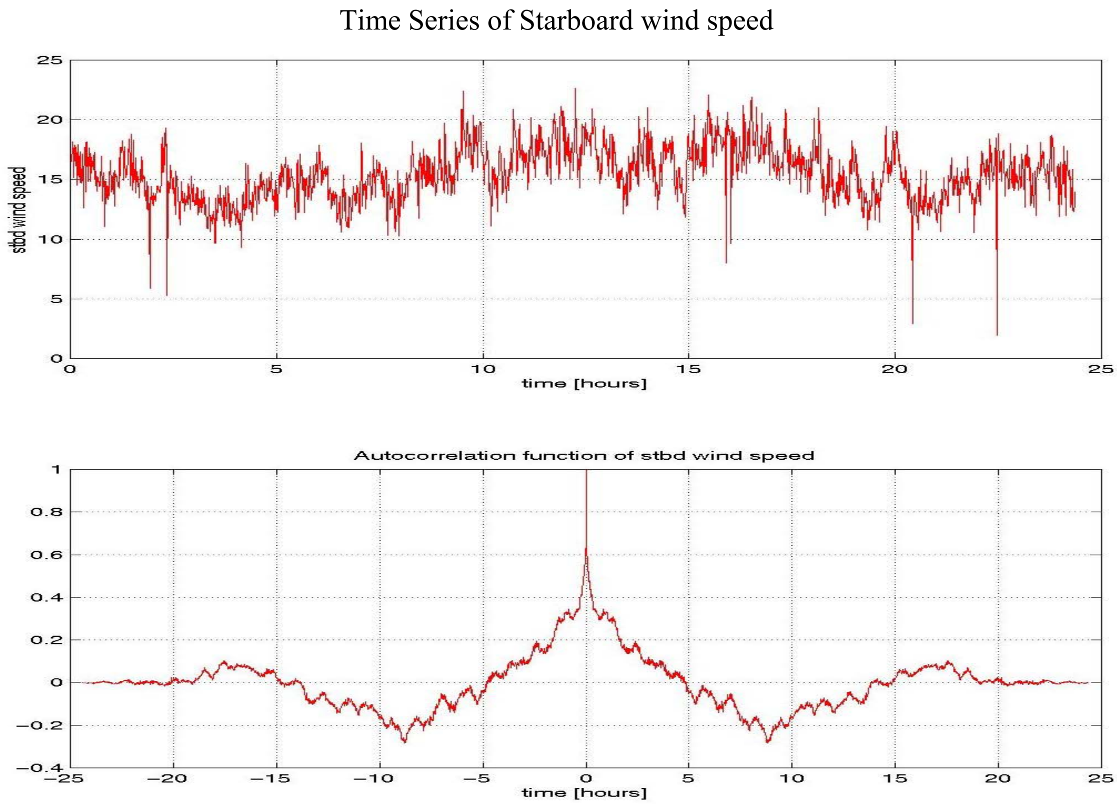


Figure A4: Time series and auto-correlation plot of starboard wind speed along line 70

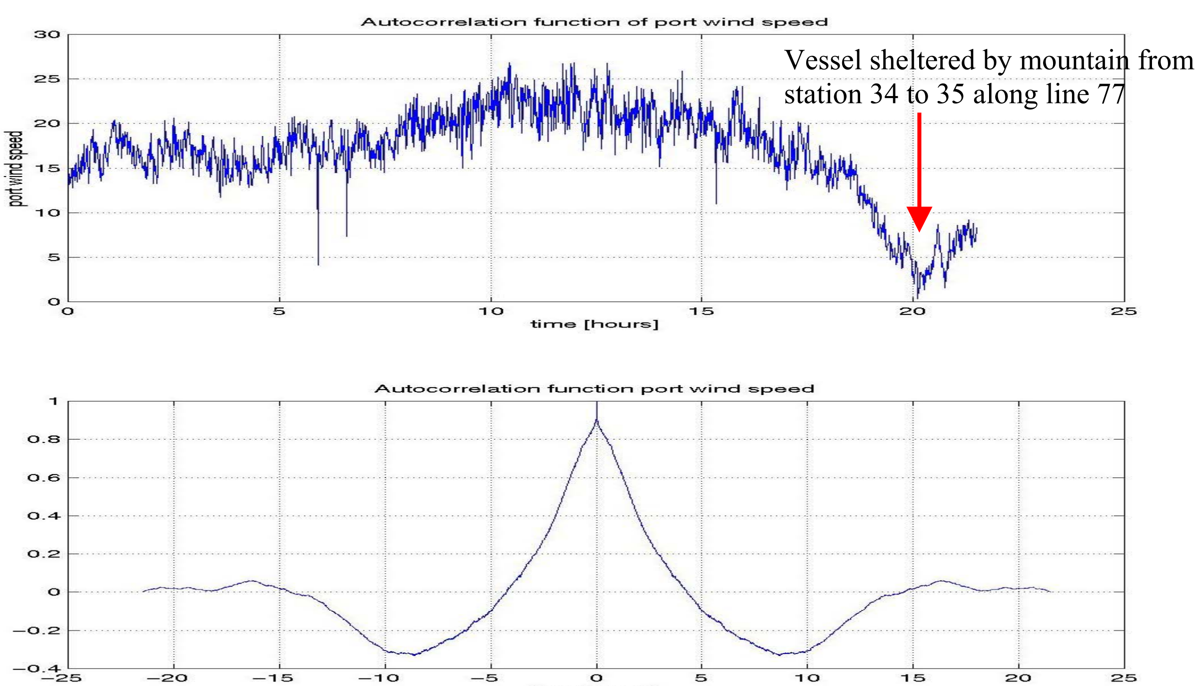


Figure A5: Time series and auto-correlation plot of port wind speed along line 77

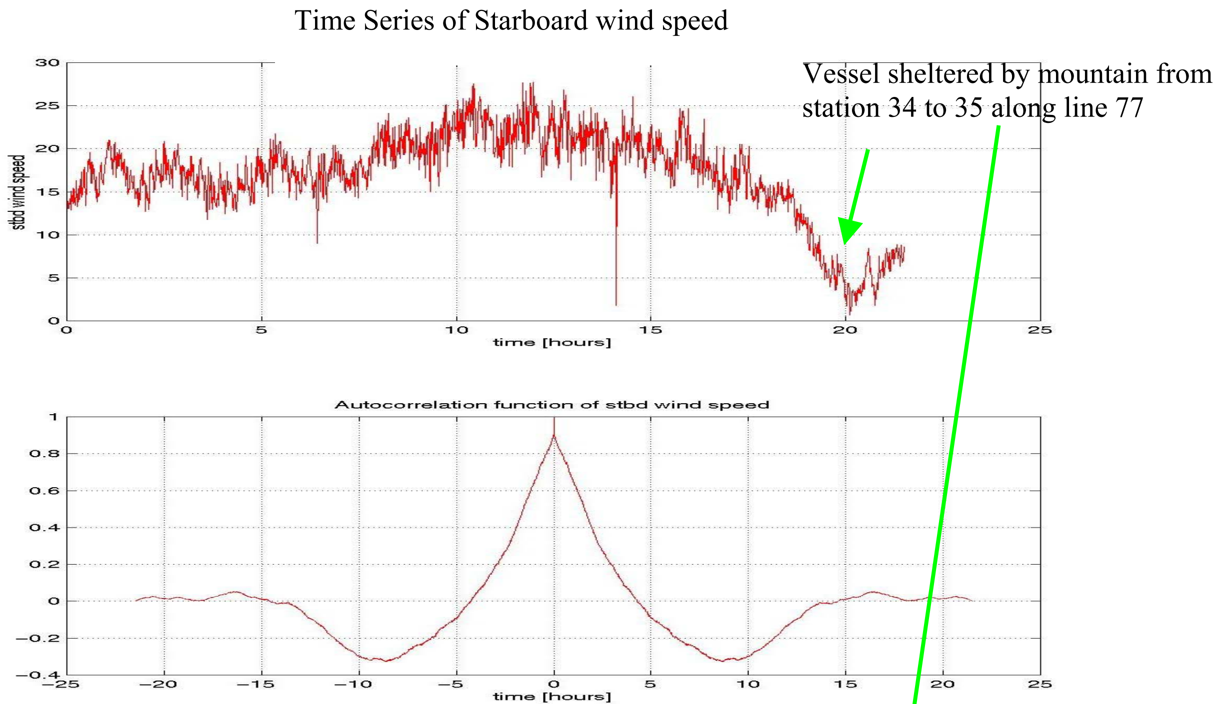


Figure A6: Time series and auto-correlation plot of starboard wind speed along line 77

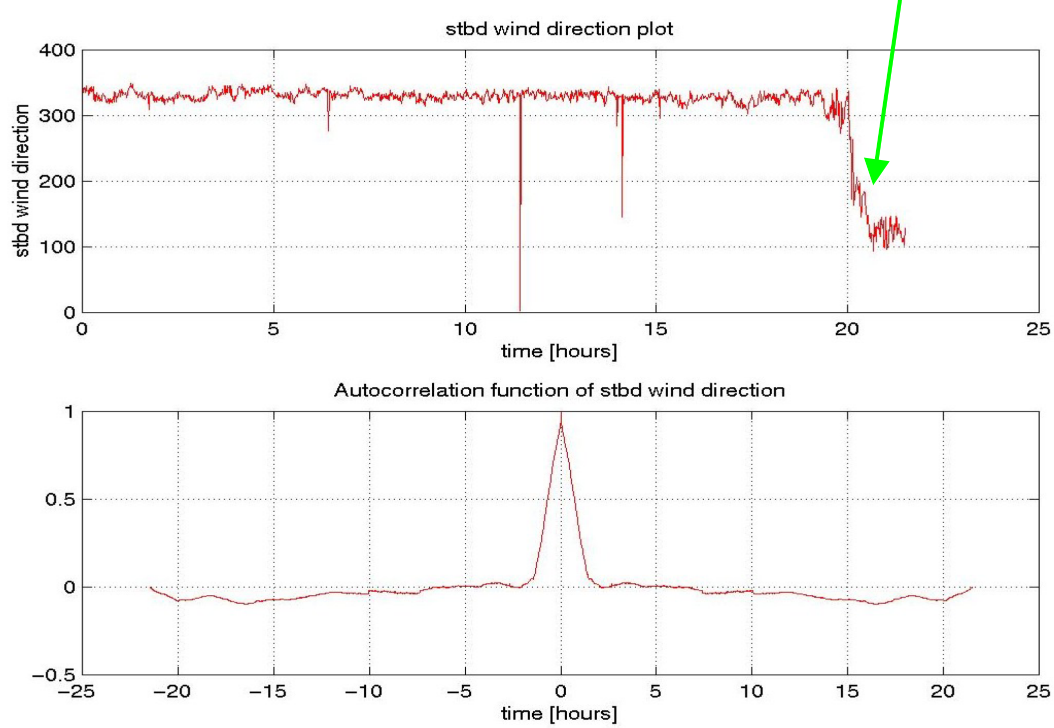


Figure A7: Time series and auto-correlation plot of starboard wind direction along line 77

Due to the variable wind direction when the vessel is sheltered by mountain from station 34 to 35, the time-scale is reduced to 2. 2 hour. However, it is still longer than the 2-hourly average that I have chosen.

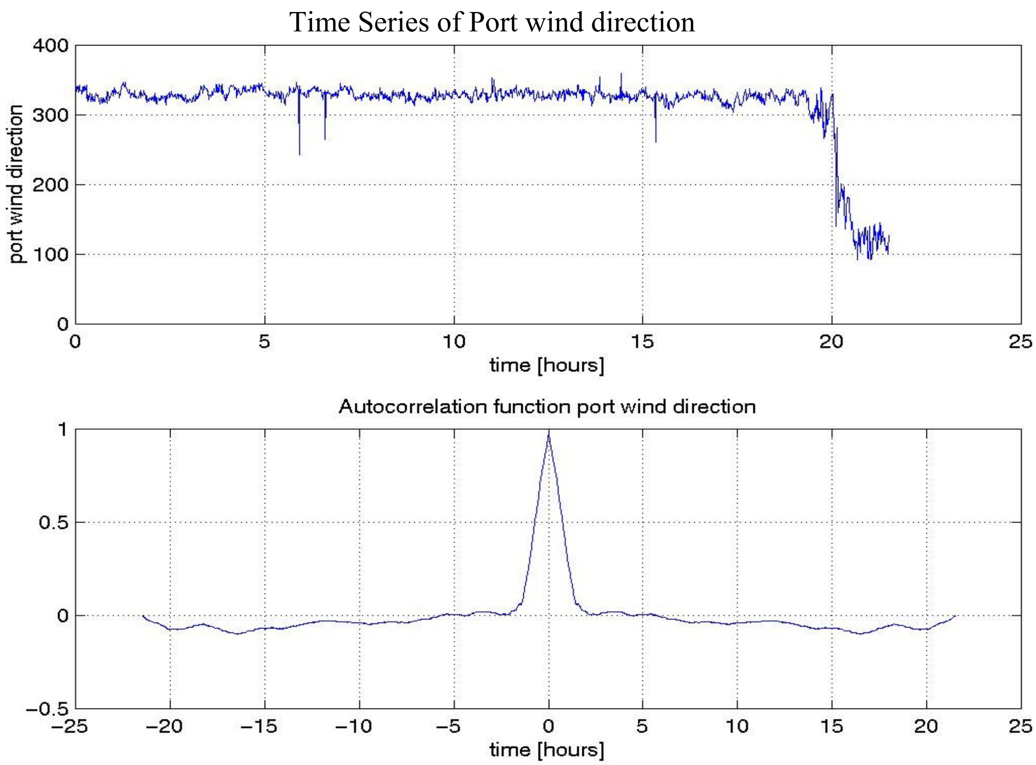


Figure A8: Time series and auto-correlation plot of port wind direction along line 77

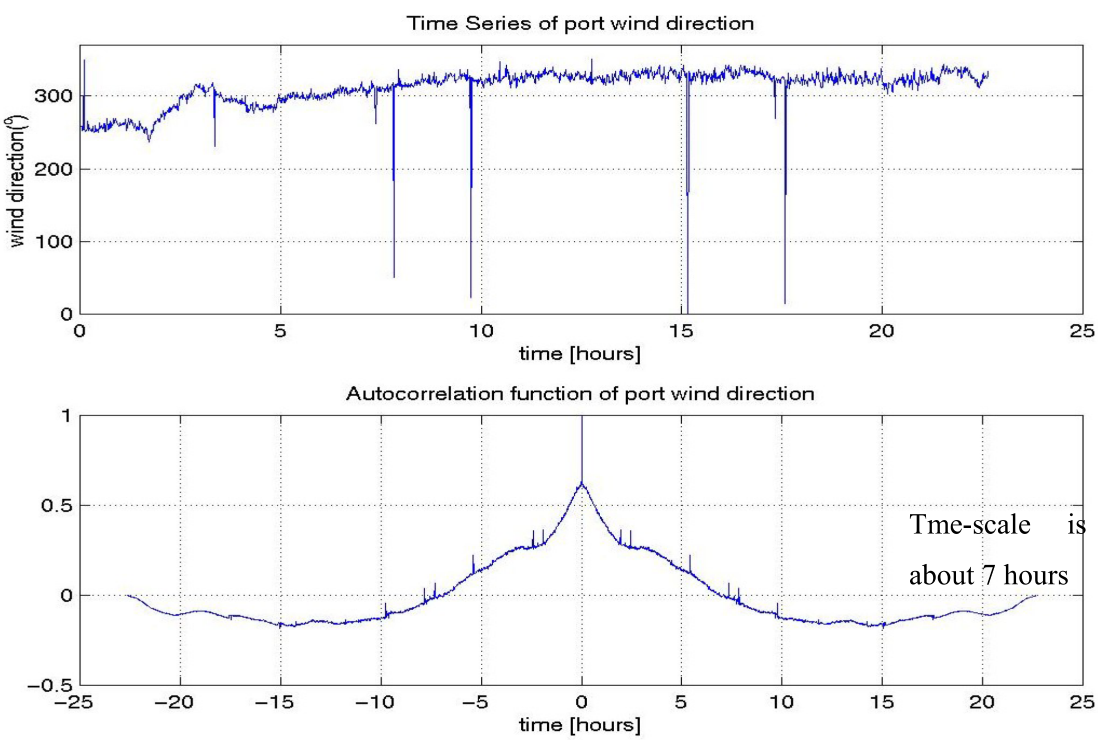


Figure A9: Time series and auto-correlation plot of port wind direction along line 67

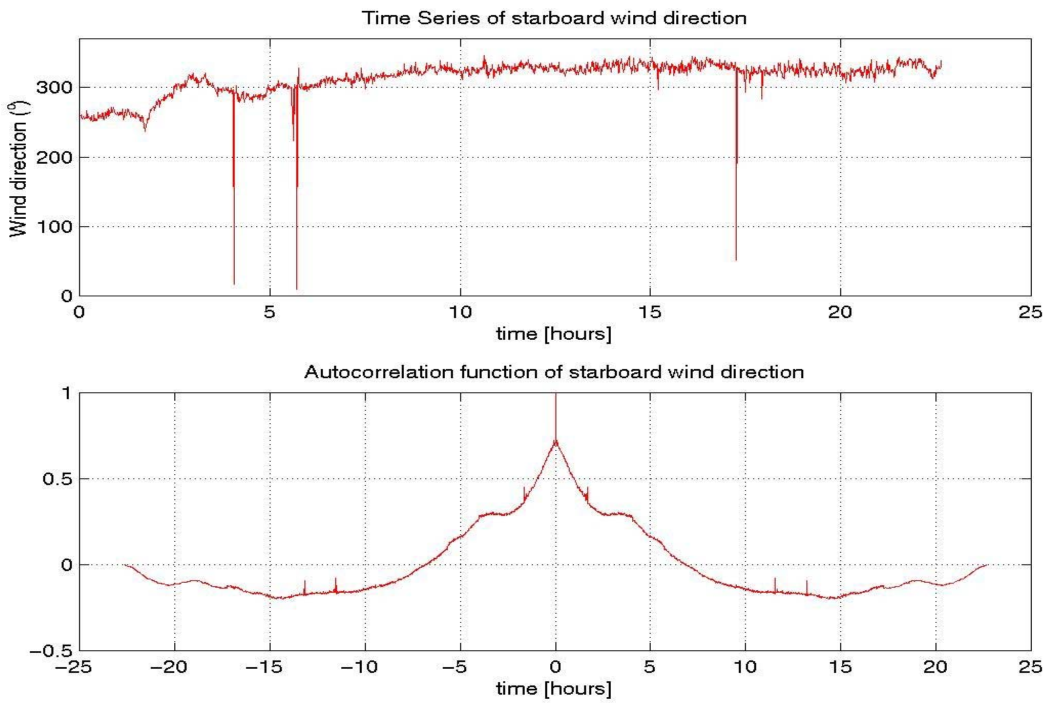


Figure A10: Time series and auto-correlation plot of starboard wind direction along line 67

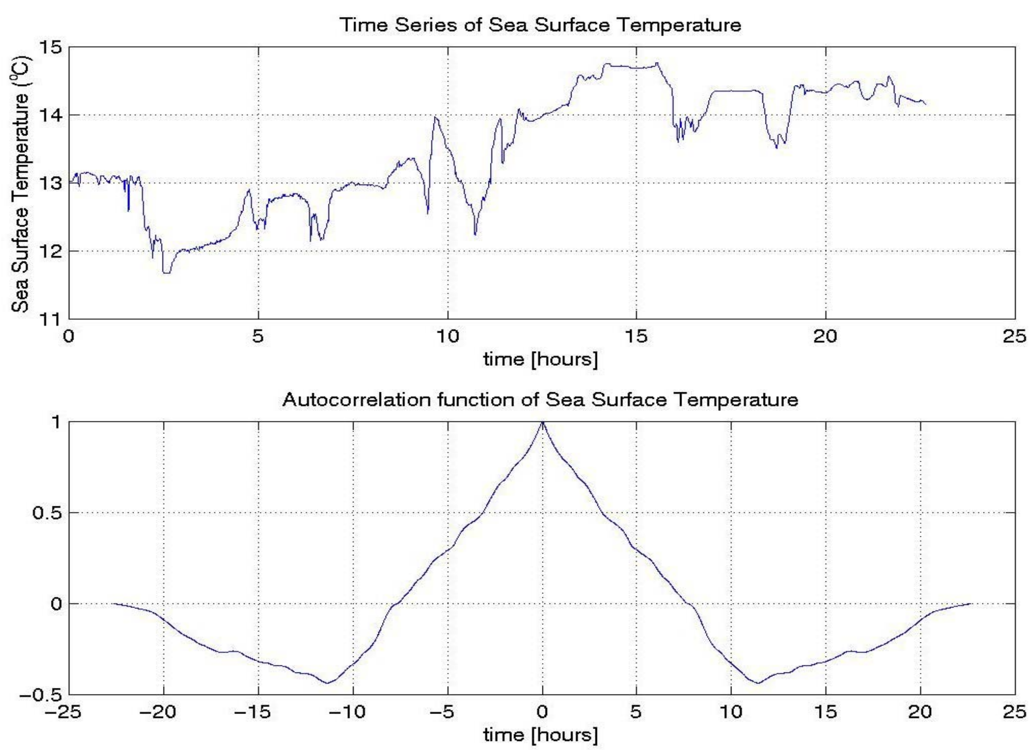


Figure A11: Time series and auto-correlation plot of Sea Surface temperature along line 67

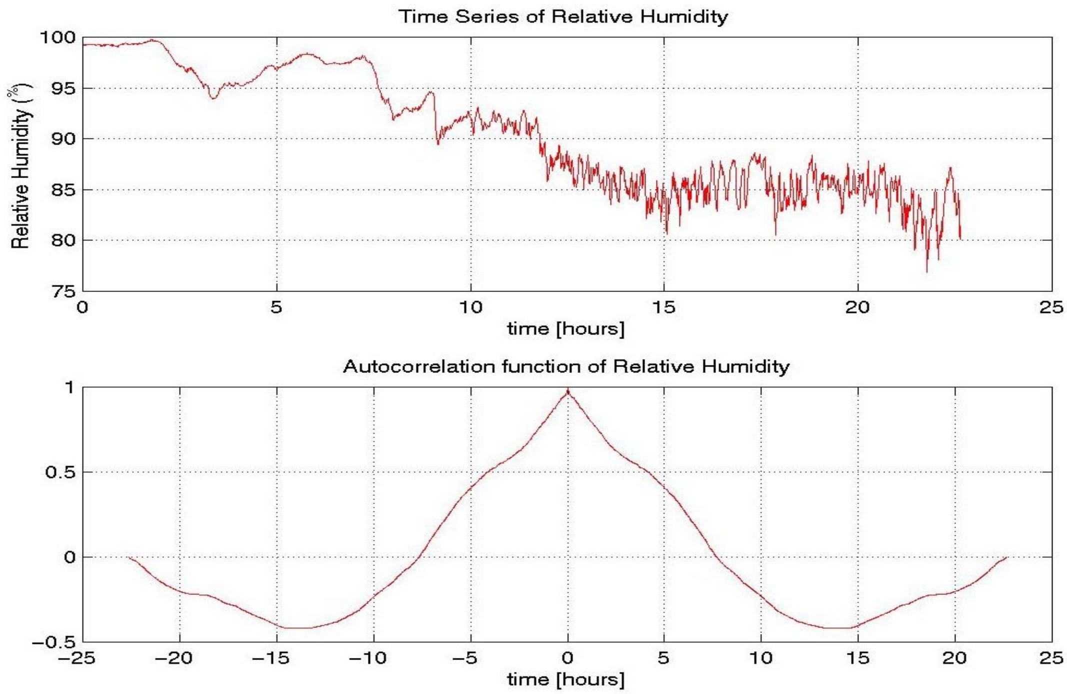


Figure A12: Time series and auto-correlation plot of Relative Humidity along line 67

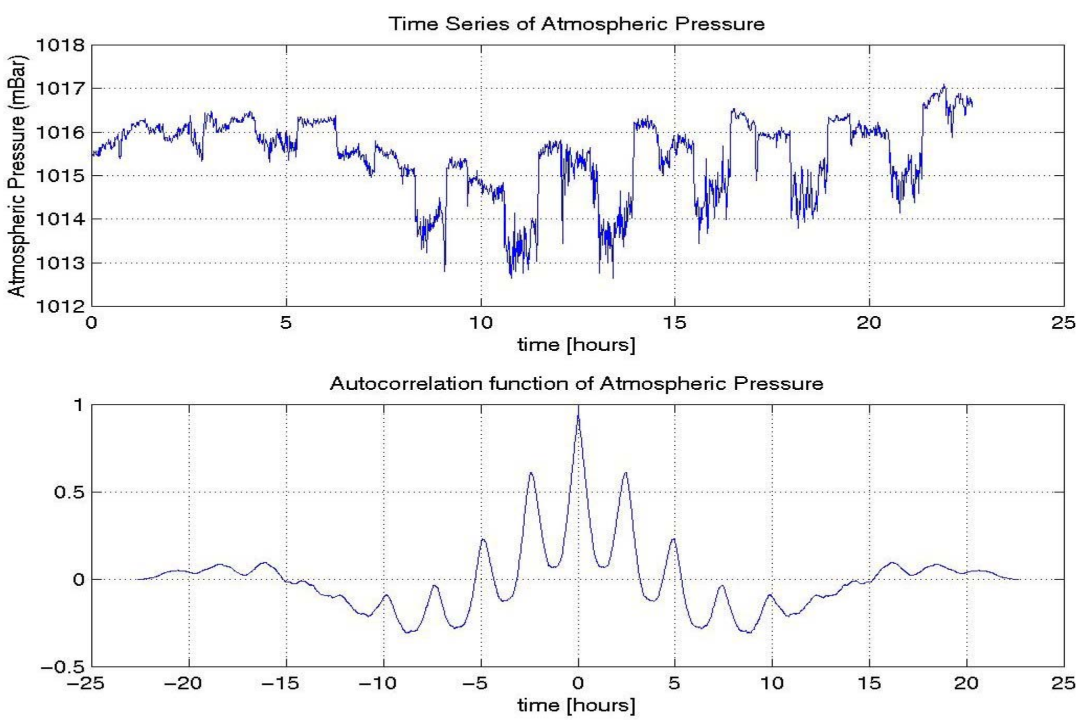


Figure A13: Time series and auto-correlation plot of Atmospheric Pressure along line 67

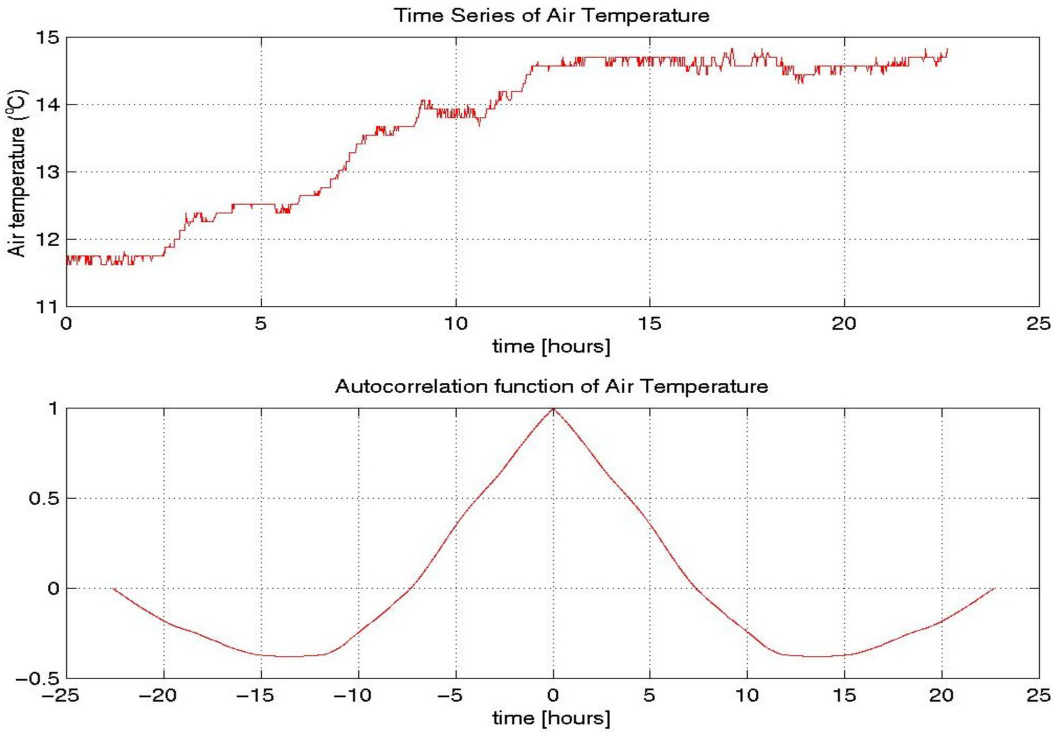


Figure A14: Time series and auto-correlation plot of Air temperature along line 67

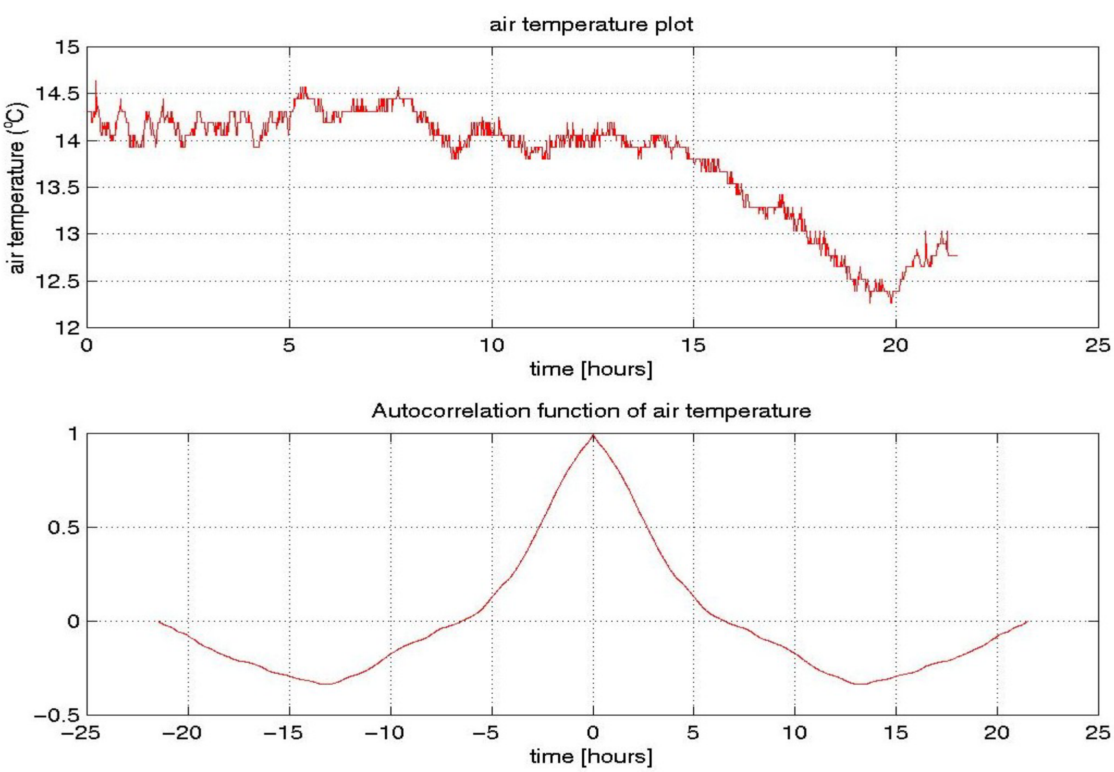


Figure A15: Time series and auto-correlation plot of Air temperature along line 77

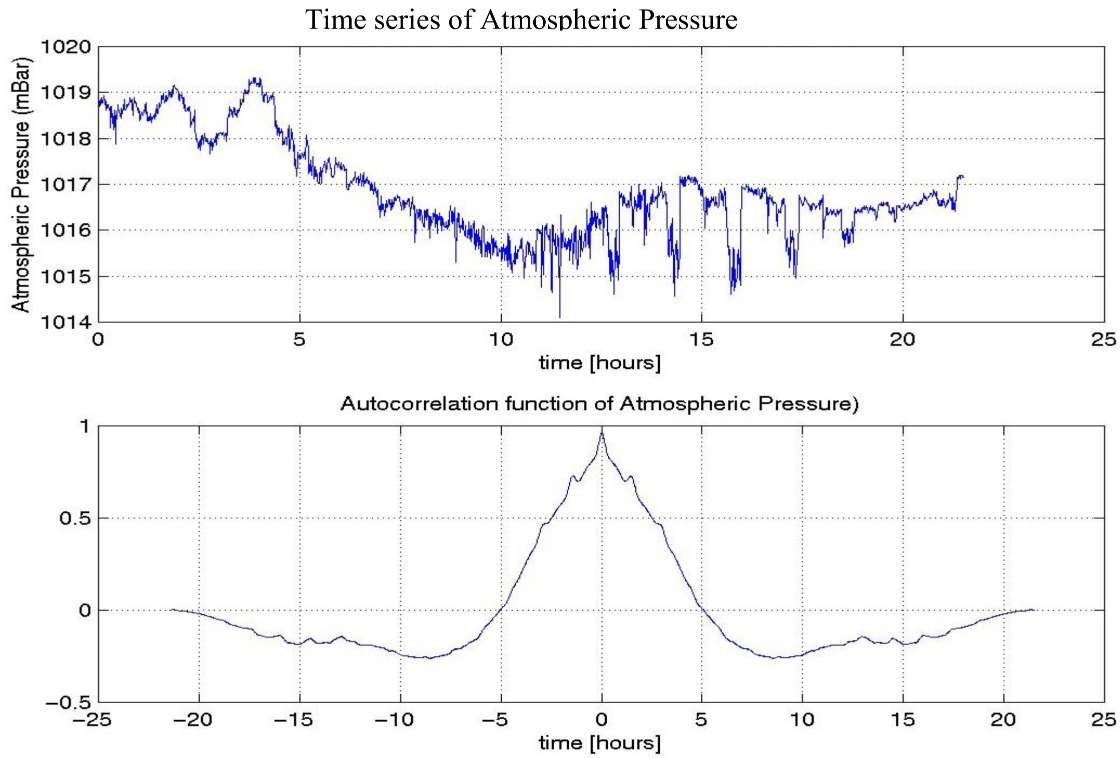


Figure A16: Time series and auto-correlation plot of Atmospheric Pressure along line 77

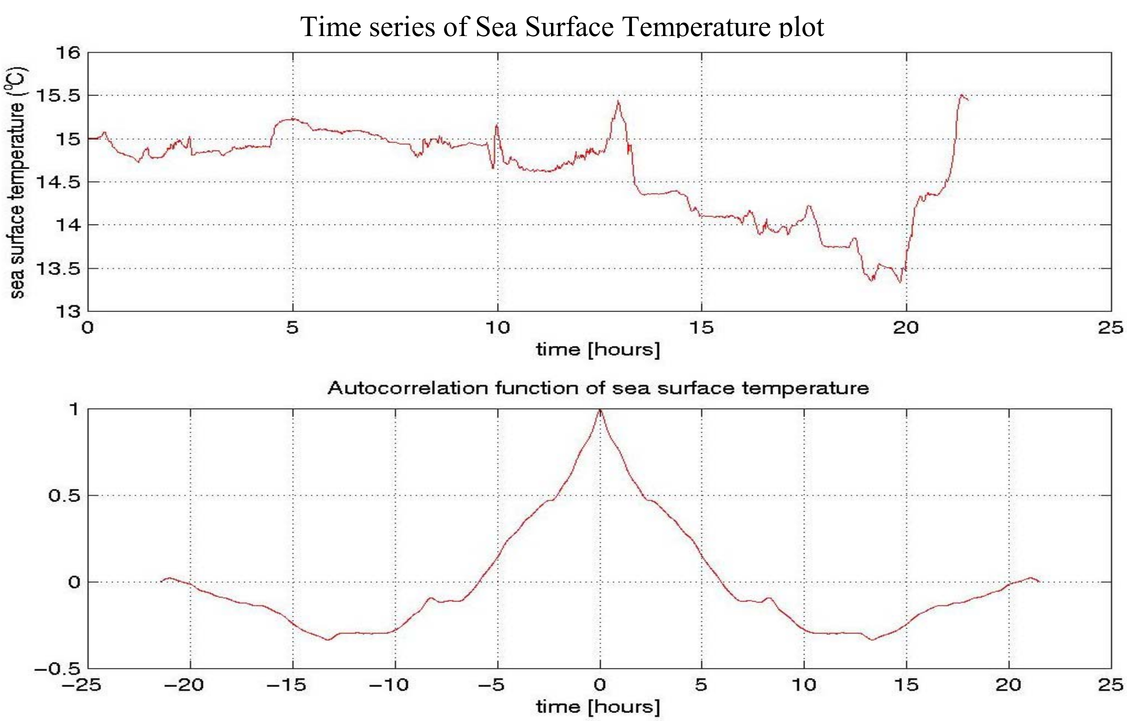


Figure A17: Time series and auto-correlation plot of Sea Surface Temperature along line 77

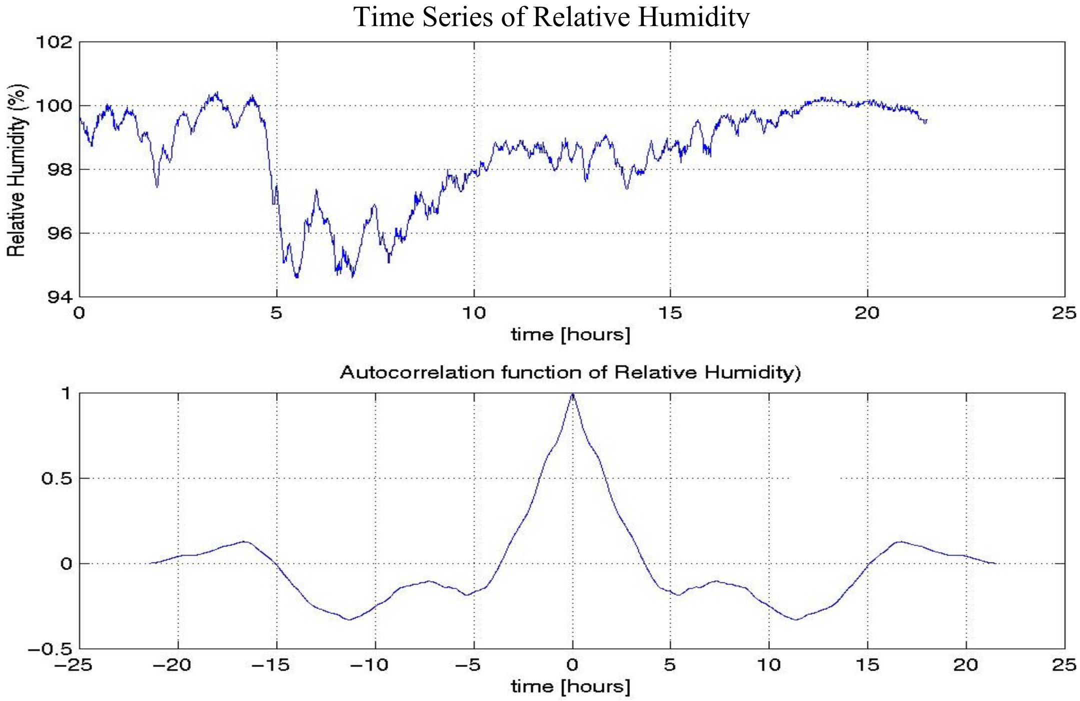


Figure A18: Time series and auto-correlation plot of Relative Humidity along line 77

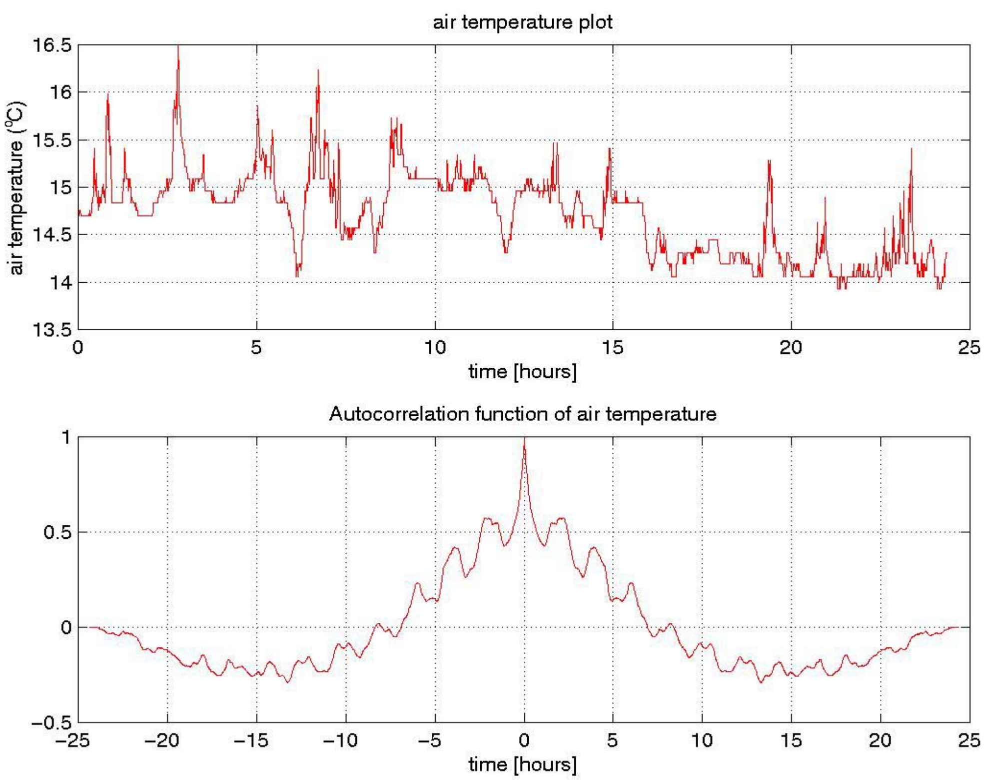


Figure A19: Time series and auto-correlation plot of Air temperature along line 70

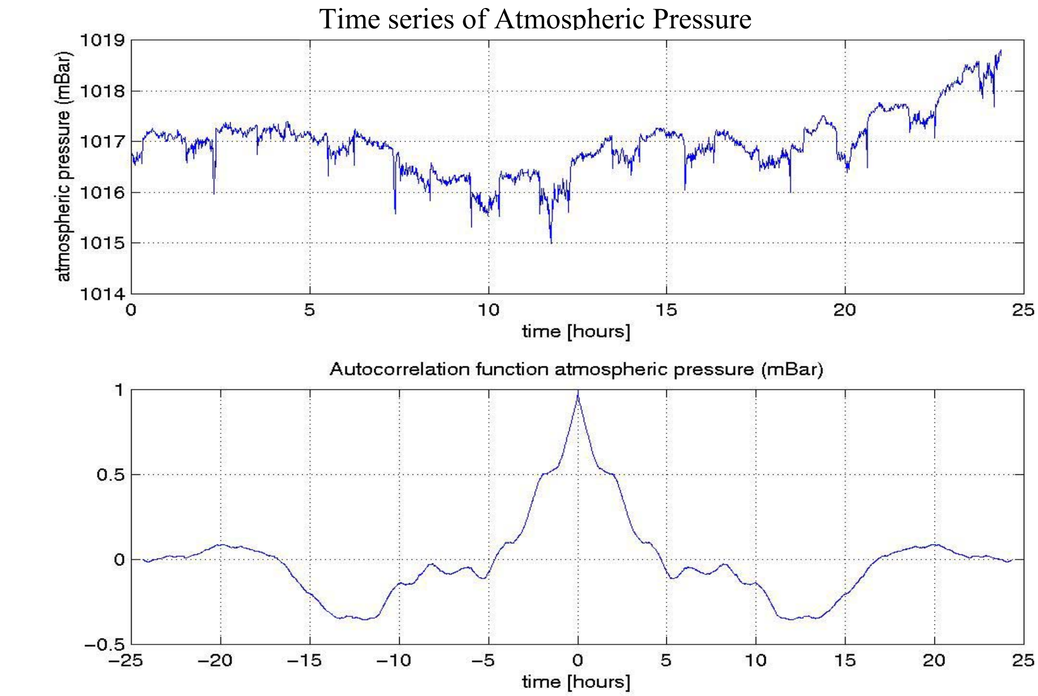


Figure A20: Time series and auto-correlation plot of Atmospheric Pressure along line 70

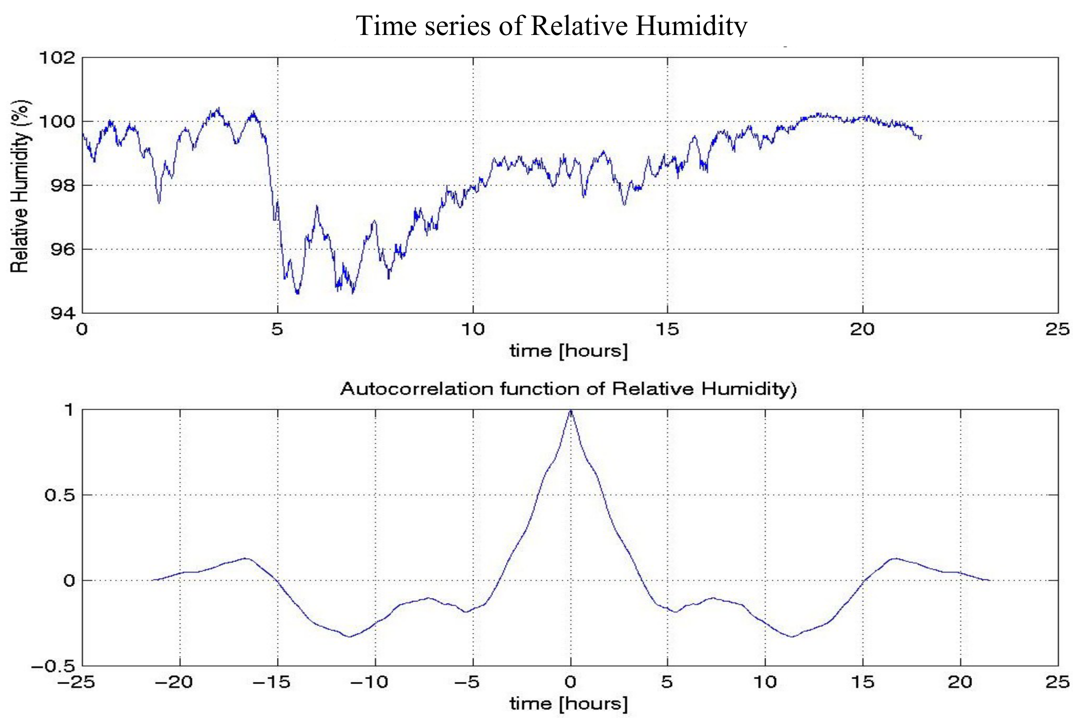


Figure A21: Time series and auto-correlation plot of Relative Humidity along line 70

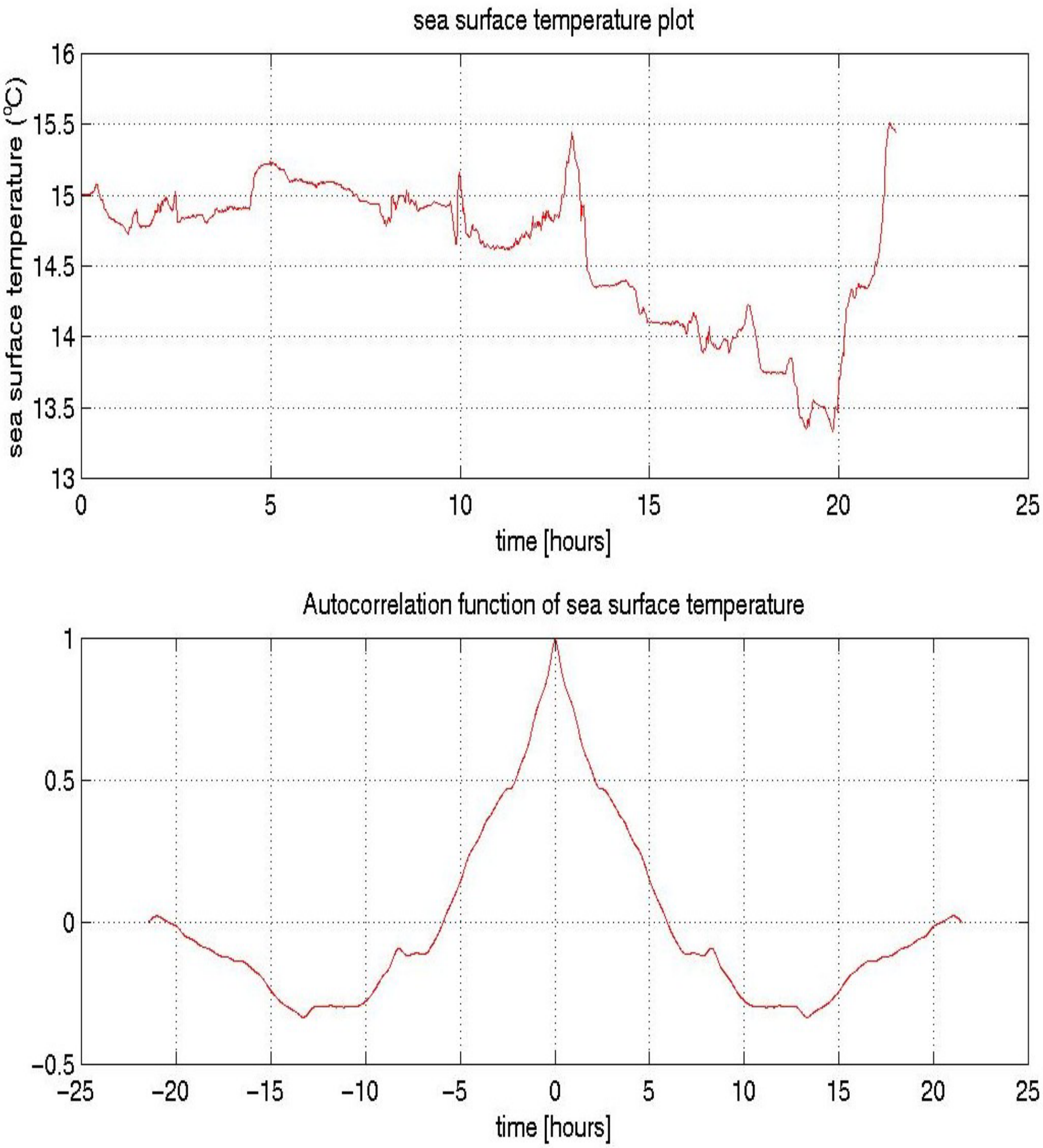


Figure A22: Time series and auto-correlation plot of Sea Surface Temperature along line 70

Appendix B

Sensitivity check conducted using dbars instead of converting depth to meters for the geostrophic volume transport.

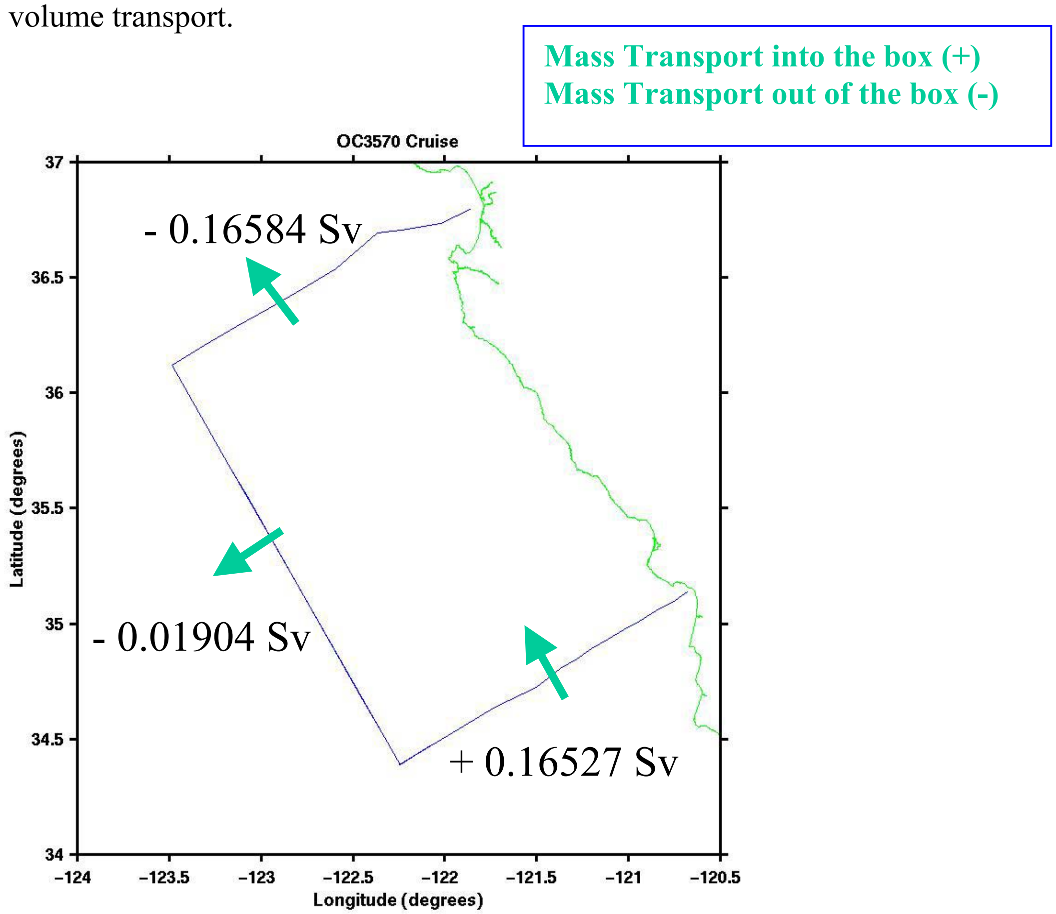


Figure B1: Geostrophic volume transport through the coastal box using dbars instead of converting to meters

Table B1: Geostrophic Volume Transport along Line 67 based on 2 dbars increment for depth

The result is similar to that obtained by converting dbar to meter in the main paper.

	Pair of CTD station	Volume Transport (Sv) - : out of the box + : into box	Net Volume Transport (Sv) - : out of the box + : into box
CalCOFI Line 67	1 - 2	- 0.0018767	
	2 - 10	- 0.1639658	**- 0.1658425**
Line 70	10 - 22	- 0.0190409	**- 0.0190409**
CalCOFI Line 77	22 - 25	+ 0.1030403	
	25-26	- 0.02956791	
	26-27	- 0.0194819	
	27-28	+ 0.0046747	
	28-29	+ 0.0710010	
	29-30	+ 0.0165138	
	30-31	+ 0.0138991	
	31-32	+ 0.0025624	
	32-33	+ 0.0057118	
	33-34	- 0.00305507	
	34-35	- 0.00002593	+ **0.1652725**
Net transport through the coastal box			**- 0.0196109**

Appendix C

1. Plots of volume transport profile between each appropriate pair of CTD stations used to compute the geostrophic volume through the CalCOFI line 67, 77 and line 70.

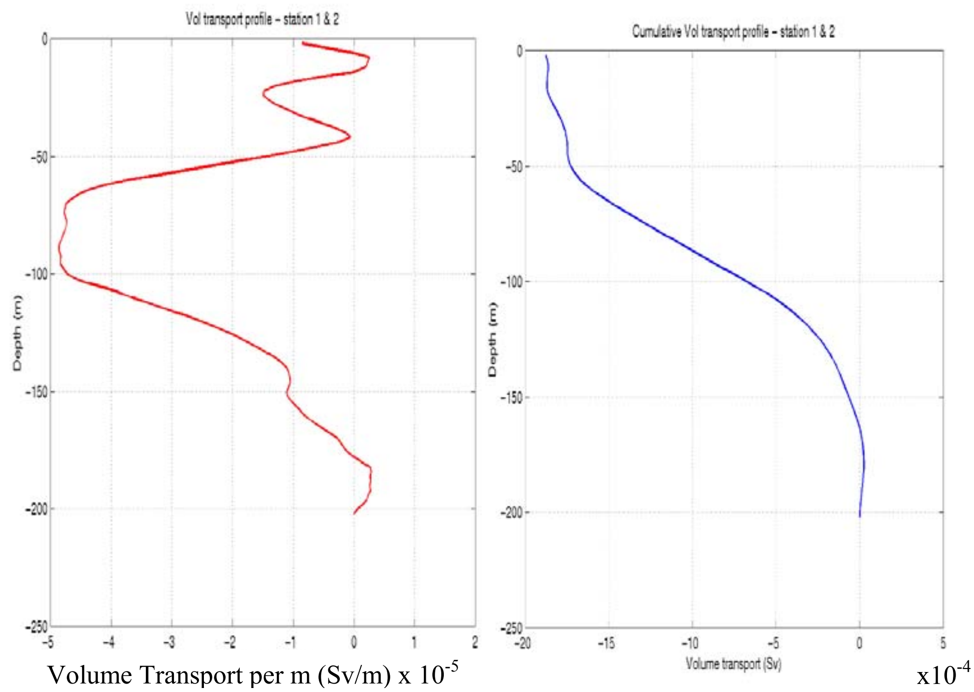
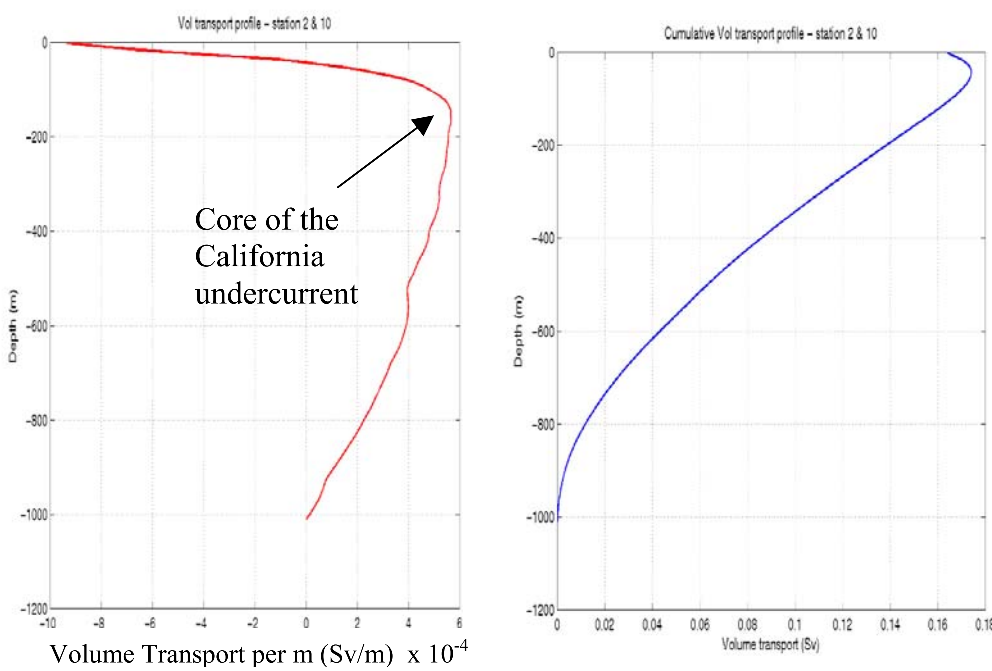


Figure C1: Geostrophic volume transport profile along Line 67



The volume transport profile between station 2 and 10 (figure C1 in page C1) has a local maximum at a depth of about 200 m which is indicative of the core of the California undercurrent. This similar feature is also observed between station 10 and 22 along line 70 in figure C2 below. This undercurrent flows northward along the upper continental slope with its core at a depth of about 200 m (Hickey, 1979). The feature of California undercurrent shown in figure C1 coincides with the observation that the poleward undercurrent can be detected as near as 10 km off the coast between Monterey Bay and Port San Luis.

Figure C2: Geostrophic volume transport profile along Line 70

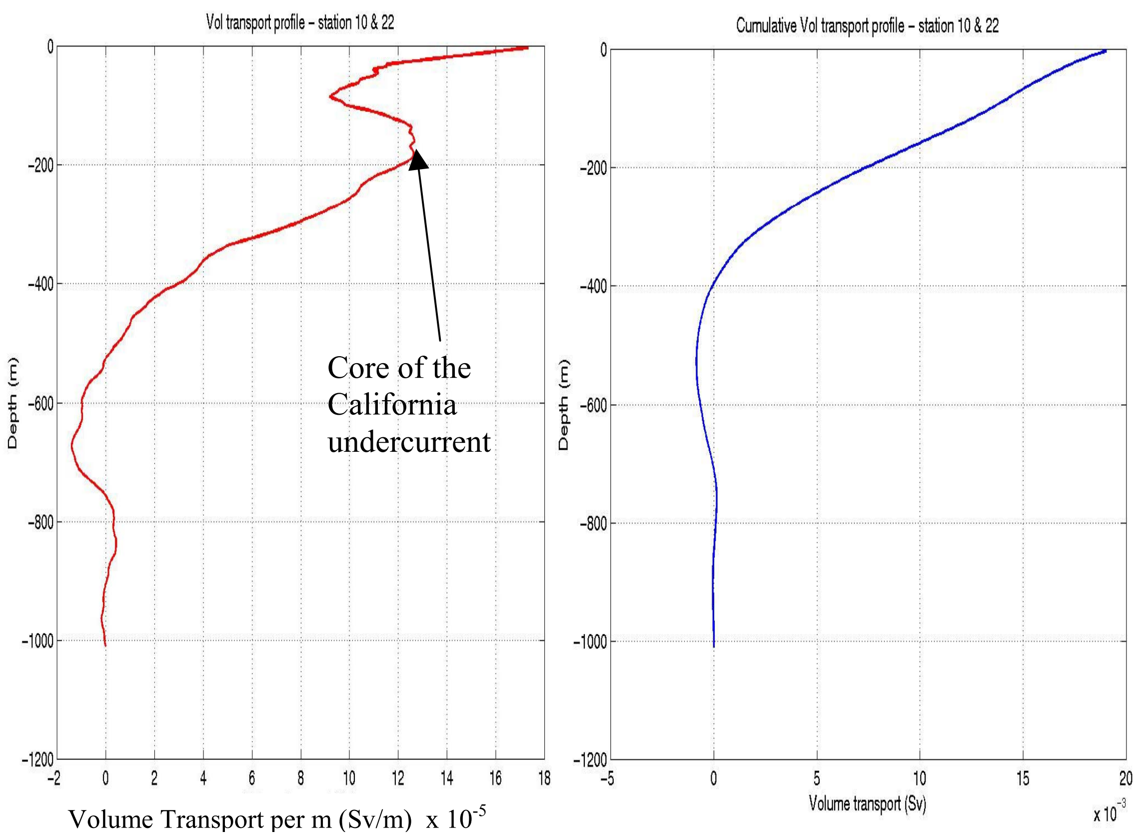
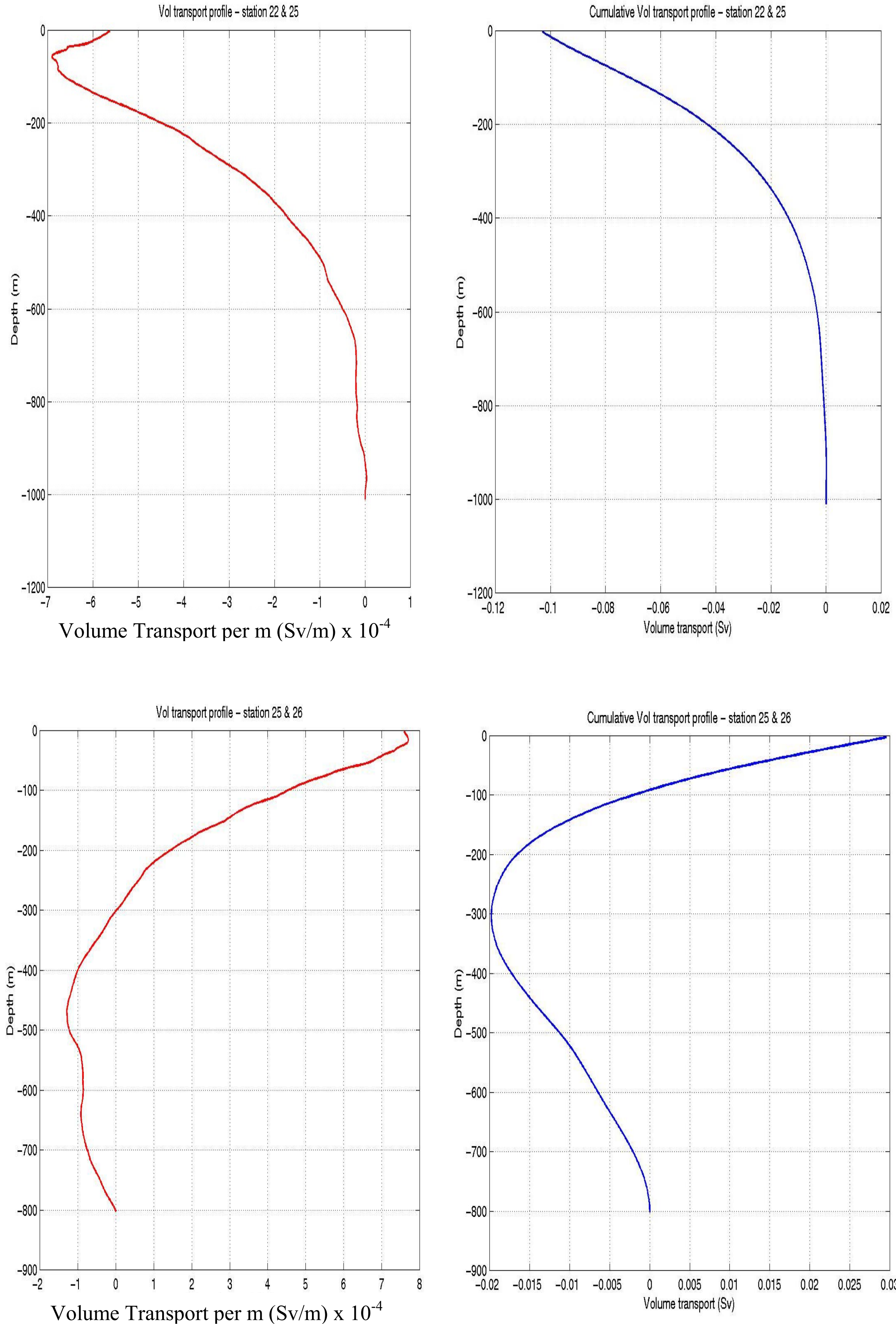
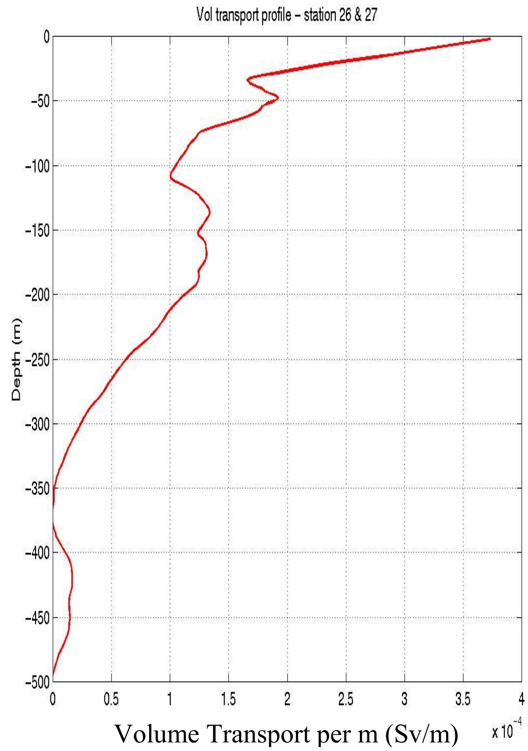
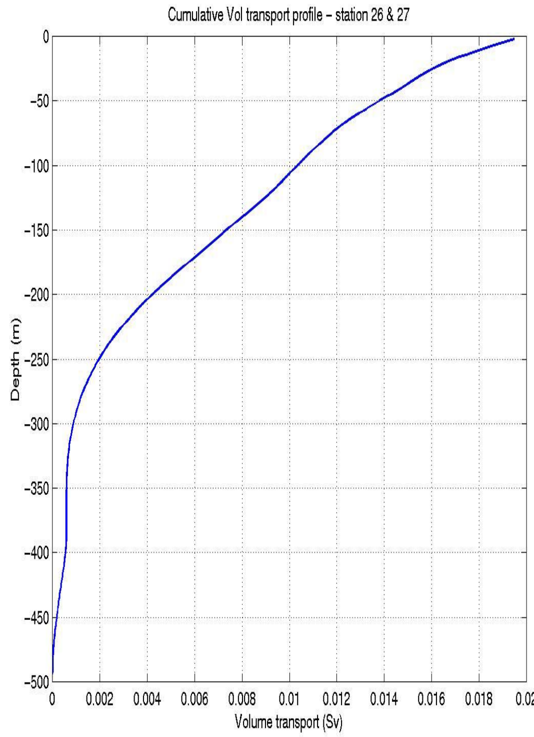
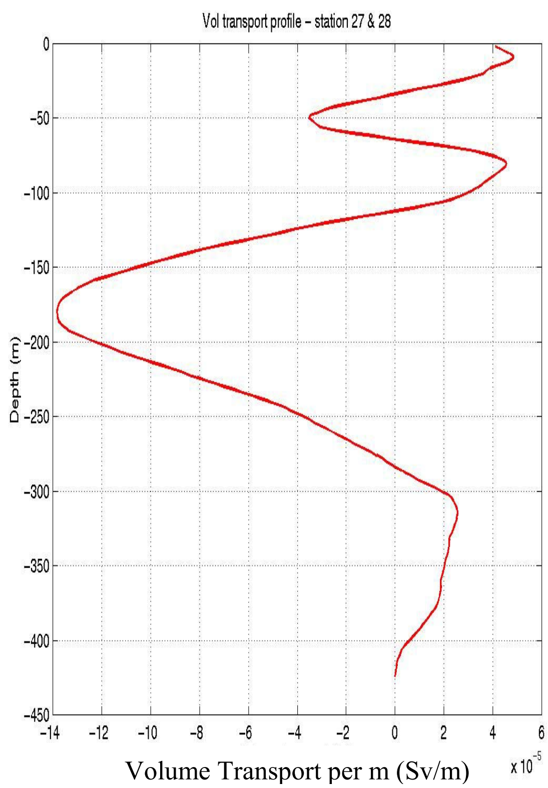


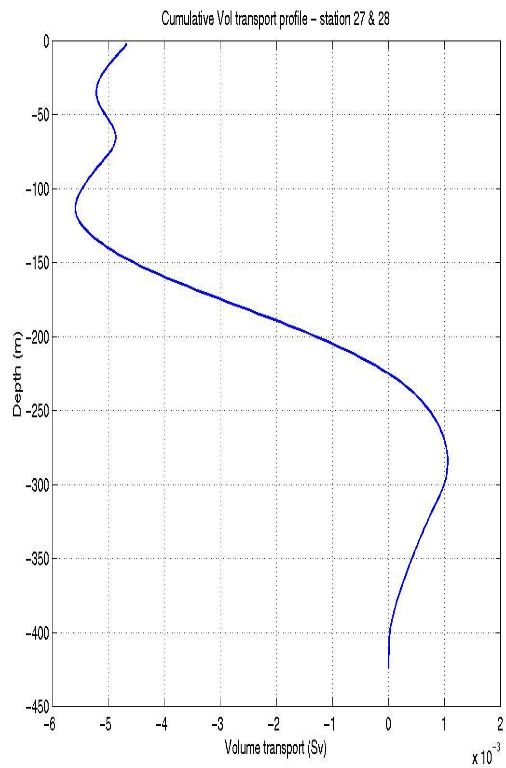
Figure C3: Geostrophic volume transport profile along Line 77

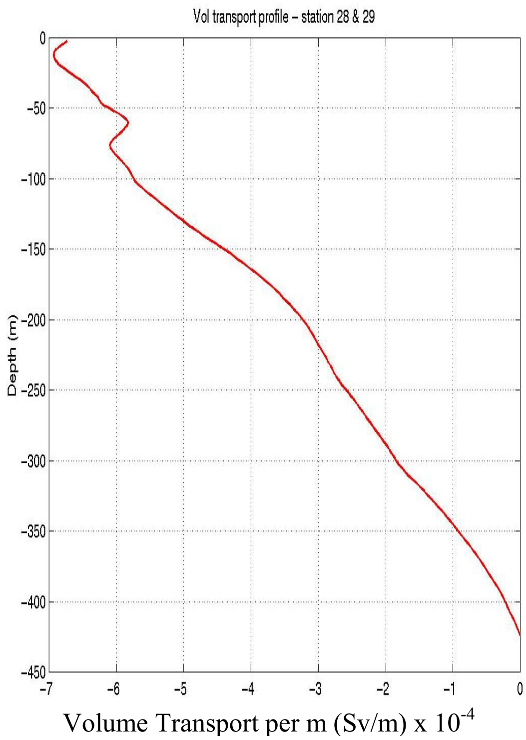


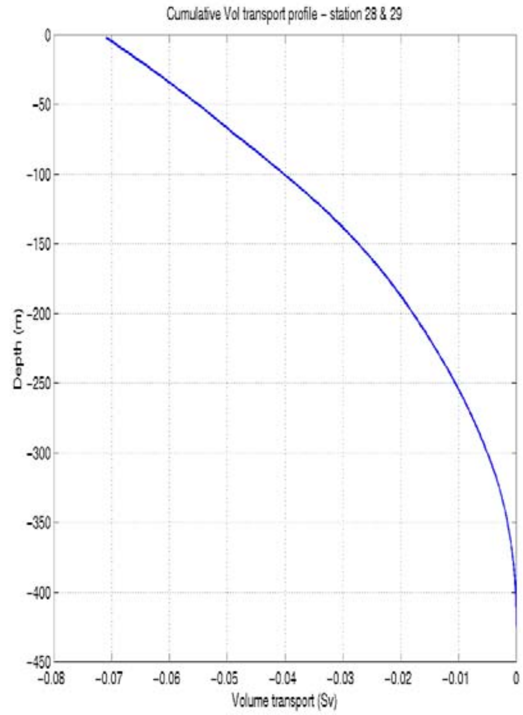

Vol transport profile – station 26 & 27
Depth (m)
Volume Transport per m (Sv/m)
x 10^-4

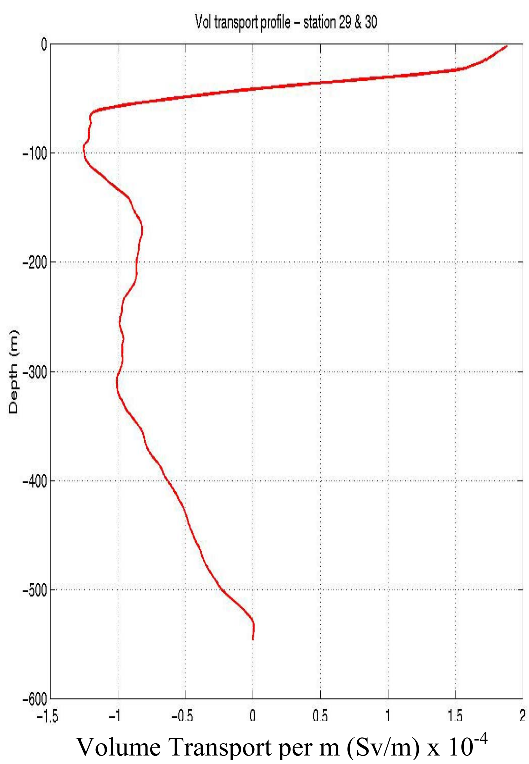

Cumulative Vol transport profile – station 26 & 27
Depth (m)
Volume transport (Sv)

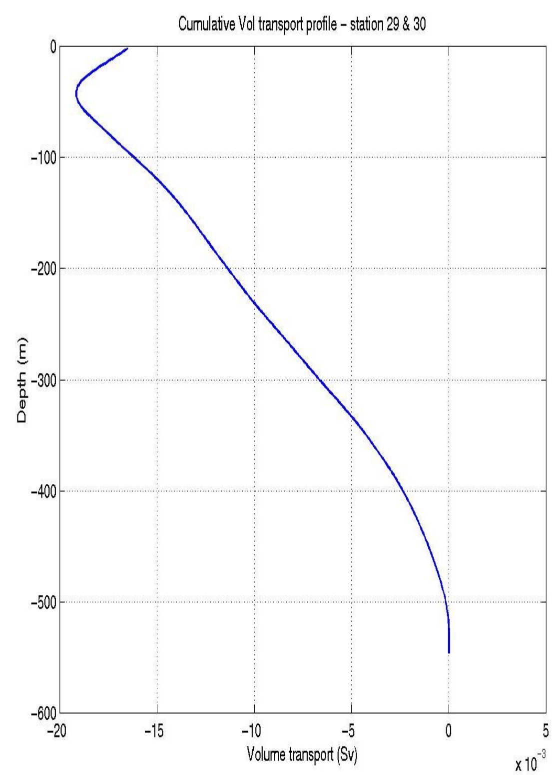

Vol transport profile – station 27 & 28
Depth (m)
Volume Transport per m (Sv/m)
x 10^-5

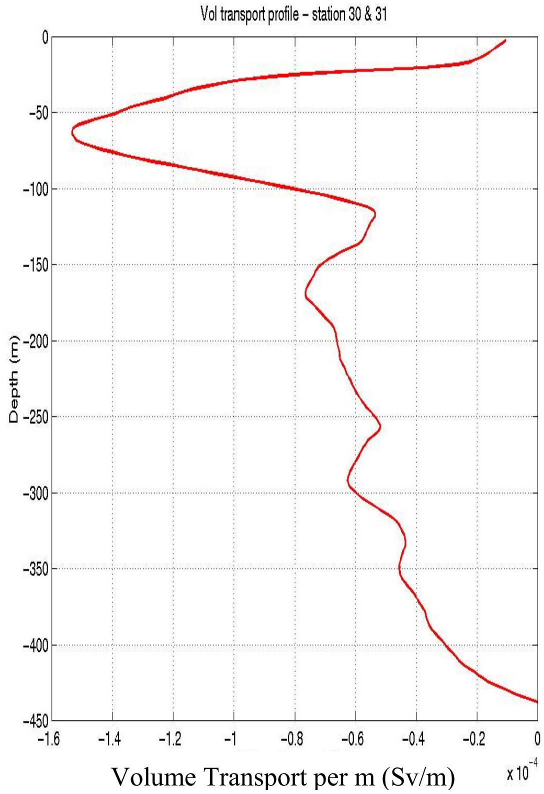

Cumulative Vol transport profile – station 27 & 28
Depth (m)
Volume transport (Sv)
x 10^-3

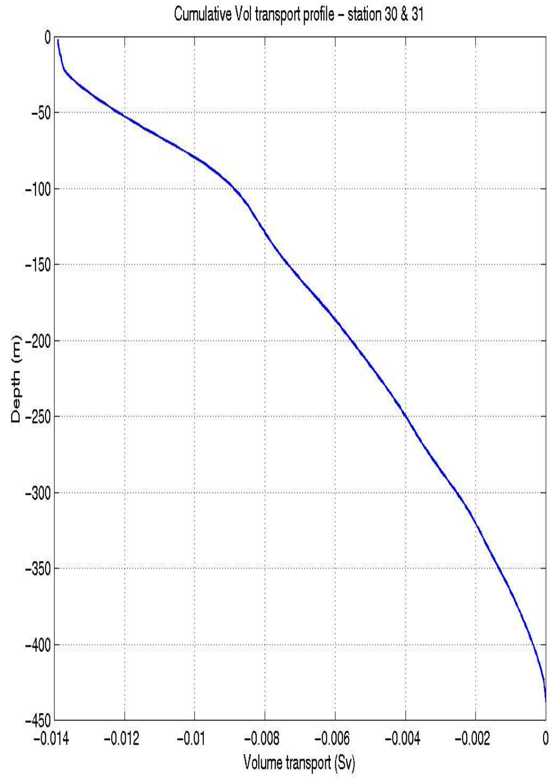

Vol transport profile – station 28 & 29
Depth (m)
Volume Transport per m (Sv/m) x 10-4

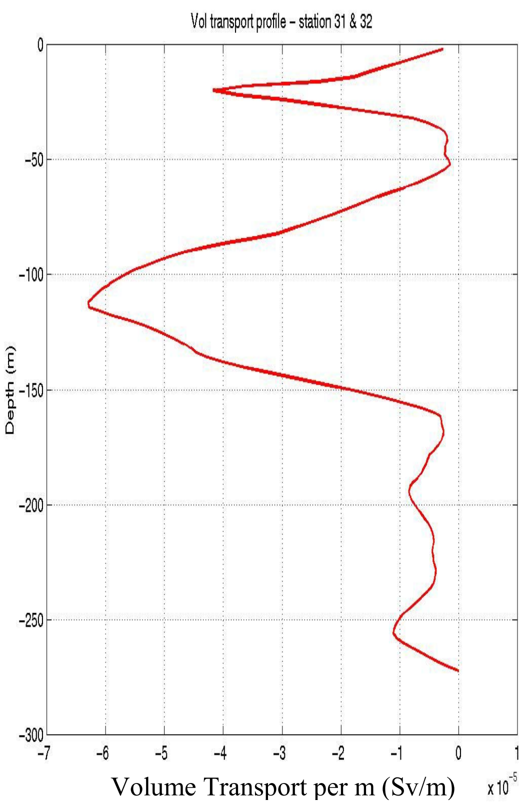

Cumulative Vol transport profile – station 28 & 29
Depth (m)
Volume transport (Sv)

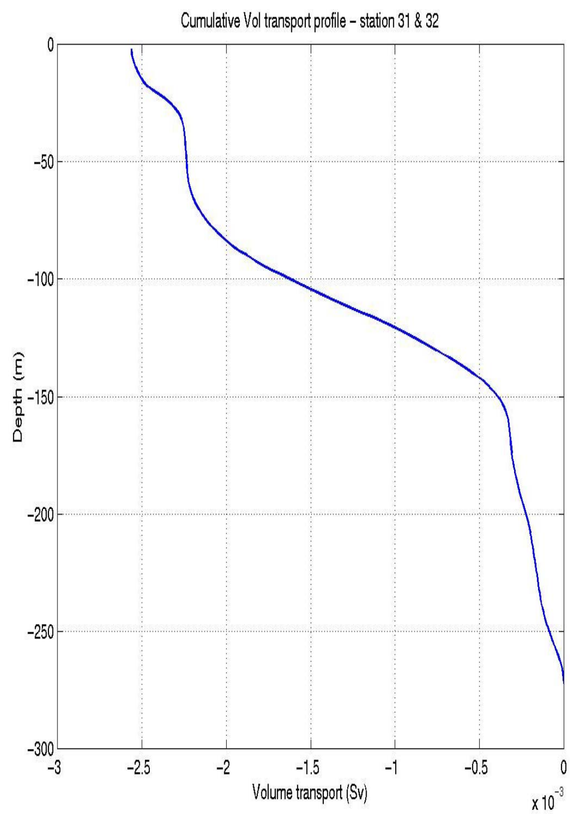

Vol transport profile – station 29 & 30
Depth (m)
Volume Transport per m (Sv/m) x 10-4

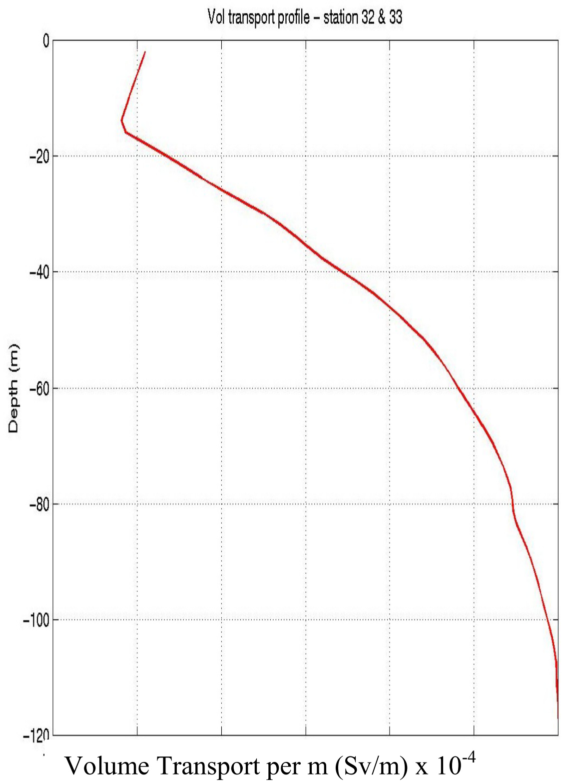

Cumulative Vol transport profile – station 29 & 30
Depth (m)
Volume transport (Sv)
x 10-3

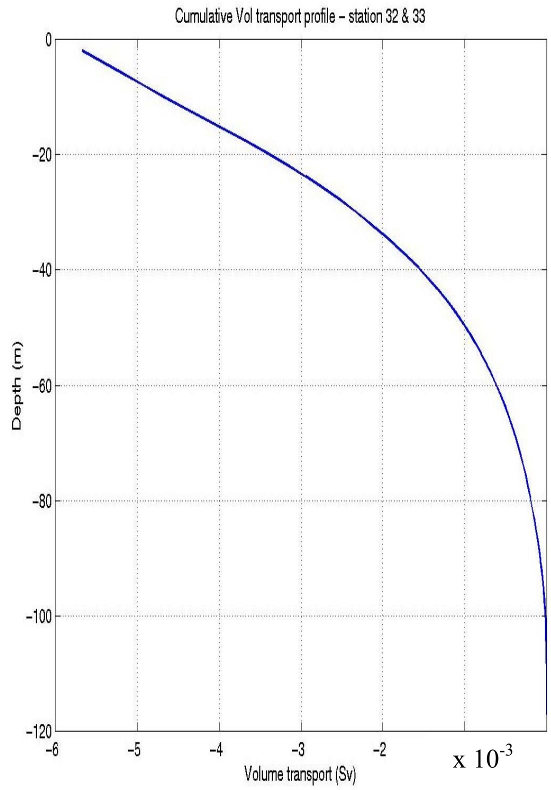

Vol transport profile – station 30 & 31
Depth (m)
Volume Transport per m (Sv/m)
x 10^-4

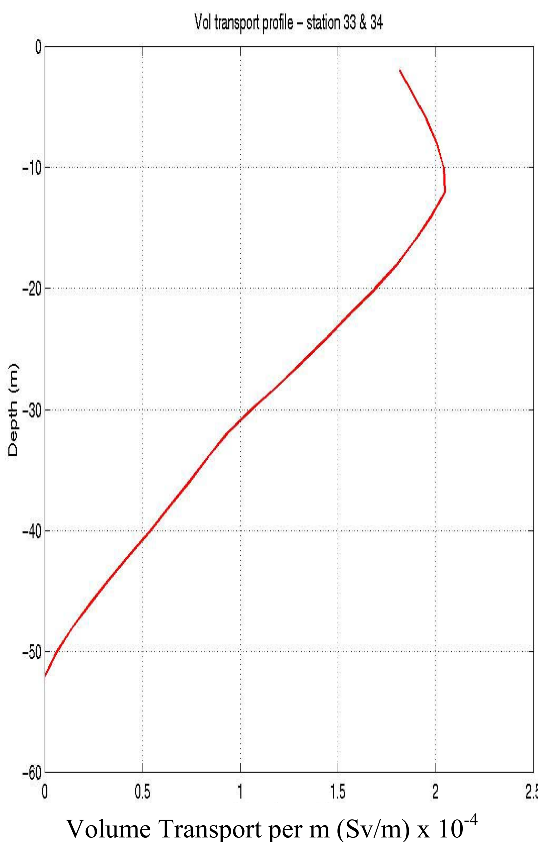

Cumulative Vol transport profile – station 30 & 31
Depth (m)
Volume transport (Sv)

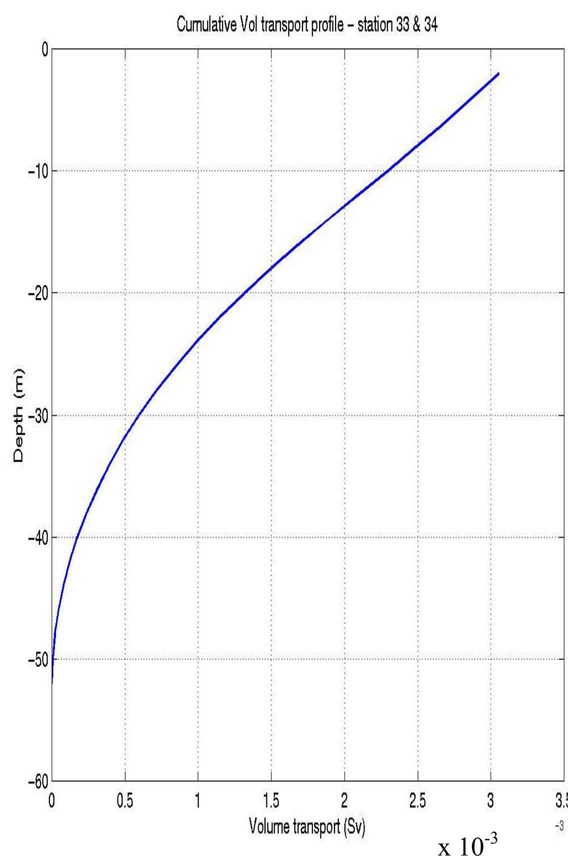

Vol transport profile – station 31 & 32
Depth (m)
Volume Transport per m (Sv/m)
x 10^-5

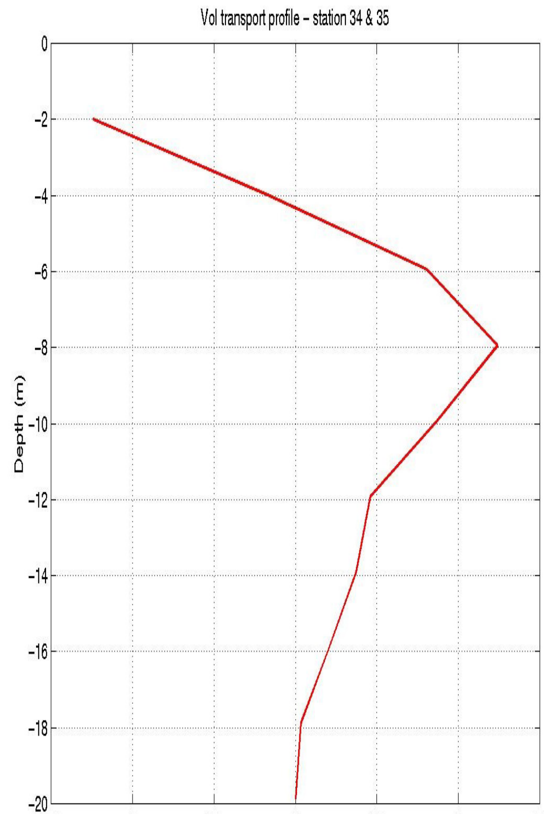

Cumulative Vol transport profile – station 31 & 32
Depth (m)
Volume transport (Sv)
x 10^-3


Vol transport profile – station 32 & 33
Depth (m)
0
-20
-40
-60
-80
-100
-120
Volume Transport per m (Sv/m) x 10^{-4}

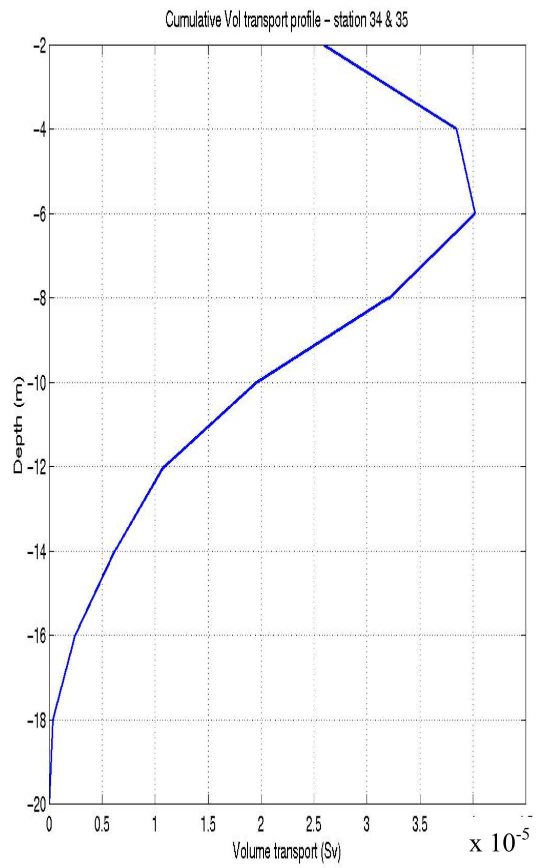

Cumulative Vol transport profile – station 32 & 33
Depth (m)
0
-20
-40
-60
-80
-100
-120
-6
-5
-4
-3
-2
Volume transport (Sv)
x 10^{-3}


Vol transport profile – station 33 & 34
Depth (m)
0
-10
-20
-30
-40
-50
-60
0
0.5
1
1.5
2
2.5
Volume Transport per m (Sv/m) x 10^{-4}


Cumulative Vol transport profile – station 33 & 34
Depth (m)
0
-10
-20
-30
-40
-50
-60
0
0.5
1
1.5
2
2.5
3
3.5
Volume transport (Sv)
x 10^{-3}



Volume Transport per m (Sv/m) x 10^{-5}



Appendix D

Table 1: Summary of the Ekman Volume Transport through the Coastal Box

CalCOFI Line 67 (course 240)

Date	**Time (GMT)**	**Distance traveled**	**Taux (kg/ms^2)**	**Volume transport (Sv)**
	(hr/min)	(km)	+: towards 060	+: into the box
			-: towards 240	-: out of box
15 July	1621-1821	4.490	+ 0.0310187	+ 0.0013604
	1821-2021	14.112	+ 0.0215373	+ 0.0029683
	2021-2221	19.524	+ 0.0328425	+ 0.0062622
16 July	2221-0021	17.633	+ 0.0171484	+ 0.0029530
	0021-0221	17.582	+ 0.0163819	+ 0.0028129
	0221-0421	14.903	+ 0.0098527	+ 0.0014339
	0421-0621	14.262	+ 0.0075119	+ 0.0010469
	0621-0821	13.401	- 0.0036634	- 0.0004794
	0821-1021	17.622	- 0.0027301	- 0.0004698
	1021-1221	17.997	+ 0.0104615	+ 0.0018387
	1221-1421	14.568	+ 0.0115017	+ 0.0016363
	1421-1511	9.240	+ 0.0038486	+ 0.0003473
Total		**175.339**		**+ 0.0217097**

CalCOFI Line 70 (course 150)

Date	Time (GMT)	Distance traveled	taux (kg/ms^2)	Volume transport (m^2/s)
	(hr/min)	(km)	+: towards 330	+: into the box
			-: towards 150	-: out of box
16 July	1512-1712	18.844	- 0.0839524	- 0.0154488
	1712-1912	18.250	- 0.0598813	- 0.0106724
	1912-2112	18.407	- 0.0691558	- 0.0124311
	2112-2312	18.330	- 0.0701232	- 0.0125520
17 July	2312-0112	18.464	- 0.0946159	- 0.0170608
	0112-0312	18.859	- 0.1037859	- 0.0191137
	0312-0512	18.070	- 0.1082984	- 0.0191108
	0512-0712	18.729	- 0.1054503	- 0.0192864
	0712-0912	17.956	- 0.1103035	- 0.0193422
	0912-1112	18.705	- 0.0768550	- 0.0140387
	1112-1312	18.748	- 0.0725887	- 0.0132903
	1312-1512	20.597	- 0.0886845	- 0.0178384
	1512-1539	0.796	- 0.0920848	- 0.00071582
Total		**224.755**		**- 0.19090176**

CalCOFI Line 77 (course 060)

Date	**Time (GMT)**	**Distance traveled**	**taux (kg/ms^2)**	**Volume transport (Sv)**
	(hr/min)	**(km)**	+: towards 060	+: into the box
			-: towards 240	-: out of box
17 July	1539-1739	18.71500	+ 0.0001800	- 0.0000329
	1739-1939	19.095	+ 0.0043669	- 0.0008143
	1939-2139	18.002	- 0.0064739	+ 0.0011381
	2139-2339	3.151	- 0.0019688	+ 0.0000606
18 July	2339-0139	20.470	+ 0.0110885	- 0.0022166
	0139-0339	19.286	+ 0.0003367	- 0.0000634
	0339-0539	12.702	+ 0.0002032	**- 0.0000252**
	0539-0739	11.809	+ 0.0139410	**- 0.0016077**
	0739-0939	15.853	+ 0.0111399	- 0.0017246
	0939-1139	11.691	+ 0.0041909	- 0.0004785
	1139-1315	15.662	- 0.00187733	+ 0.0002871
Total		**166.357**		**-0.0054774**

APPENDIX E: this section contains the sample matlab programs written to derive the various results for my report

```
%filename = tpt1022m
% calculate geostrophic volume transport using CTD data between station
10 & 22

close all;
clear all;

%  load first station file
addpath '/h/ochome1/acong/oc3570/CTD' -end
%  load second station file
dd1=load('dw010.asc');
dd2=load('dw022.asc');
p2=dd1(:,4);t2=dd1(:,5); s2=dd1(:,12);
lat2=dd1(:,2); lon2=dd1(:,3);
p10=dd2(:,4);t10=dd2(:, 5) ;s10=dd2(:,12);
lat10=dd2(:,2); lon10=dd2(:,3);

ii=10;                  %CTD station number
jj=22;                  %CTD station number
k2=length(p2);
k10=length(p10);
kk=min(k2,k10);
if kk >505
kk = 505
end

%  use seawater m files for derived properties
svan2=sw_svan(s2,t2,p2);      %  specific volume anomaly
svan10=sw_svan(s10,t10,p10);  %  note SI units m3/kg for svan
dyn2=cumsum(1000*svan2*2);    %  dynamic height for 2 dbar layers
dyn10=cumsum(1000*svan10*2);  %  integrate downwards;
dyn2=dyn2(kk)-dyn2;           %  set reference level to bottom of cast
dyn10=dyn10(kk)-dyn10;
for i=1:kk
dyndiff(i)=dyn2(i)-dyn10(i);  %  east is positive
end

la=[mean(lat2) mean(lat10)];
lo=[mean(lon2) mean(lon10)];
[dist,ph]=sw_dist(la,lo,'km');            %distance between stations in
km
la1=mean(la);
lo1=mean(lo);
zz=sw_dpth(p2,la1);                 % conversion from dbar to meters
la=0.5*mean(lat2)+0.5*mean(lat10);  % mean latitude
fcor=2*7.29*10E-05*sin(pi*la/180);  % coriolis parameter
geovel=10*dyndiff/(fcor*1000*dist); % 10 converts dyn m to m2/s2
                                          % 1000 converts km to m
```

```
% use geostrophic velocities to calculate transport
ll=dist*1000;
for nn=1:kk-1
zz1=ll*(zz(nn+1)-zz(nn));
veltra(nn)=geovel(nn)*zz1;    %depth diff*1000*dist
                                    % - as z upward is +
end
veltra(kk)=0;                 %make trans same dimension
                              %as vectra(note geovel(kk)=0)
sumvel=0;
for i=1:kk                      % integrate transports upward
    k=(kk+1)-i;                 % from reference layer
    trans(k)=veltra(k)+sumvel;
    sumvel=trans(k);
 end
trans=trans/1E06;                 % convert to Sv

figure
for i=1:kk              % Prep to plot graph
pp(i)=-zz(i);
lattt(i)=la1;
lonnn(i)=lo1;
end
h=plot(trans,pp,'b-');
set(h,'LineWidth',1.5);
ylabel('Depth (m)')
xlabel('Volume transport (Sv)')
title(['Cumulative Vol transport profile - station ',num2str(ii),' &
',num2str(jj)]);
grid on
figure
h=plot(veltra/1E6,pp,'r-');
set(h,'LineWidth',1.5);
ylabel('Depth (m)')
xlabel('Volume transport (Sv/m)')
title(['Vol transport profile - station ',num2str(ii),' &
',num2str(jj)]);
grid on

%Prep output file
output1=[-geovel' pp' lattt' lonnn'];     %assign -ve to indicate out
of box
tvol2=trans(1)                            %This –ve sign make heading
north -ve
vol1022=[ ];
save vol1022.data vol1022 -ascii;
load vol1022.data
vol1022=[vol1022 output1];
save vol1022.data vol1022 -ascii;
clear vol1022;
```

```
% filename=cov67wd.m
% Plot the time-series and auto-correlation function of selected data
% along line 67

clear all
close all
win1=load('w67.dat');
stbdr1=win1(:,22);            %load data
portr1=win1(:,26);
stbdwd1=win1(:,24);
stbdws1=win1(:,25);
portwd1=win1(:,28);
portws1=win1(:,29);
airt1=win1(:,31);
atmp1=win1(:,32);
hum1=win1(:,34);
sst1=win1(:,36);

day1=win1(:,[2]);
day1=day1*100;
GMTH=win1(:,[4]);
GMTM=win1(:,[5])/60;
GMTS=win1(:,[6])/3600;
GMT1=day1+GMTH+GMTM+GMTS;
lat1=win1(:,10)+win1(:,11)/60;
lon1=win1(:,12)+win1(:,13)/60;

dat=hum1;
dat2=sst1;
xx=length(dat);
xx2=length(dat2);
x1=(1:xx)/67;
x2=(1:xx2)/67;

subplot(2,1,1)
plot(x1,dat,'-r')
grid on
xlabel('time [hours]')
ylabel('Relative Humidity (%)')
title('Time Series of Relative Humidity')
subplot(2,1,2)
cov1=xcov(dat,'coeff');
ll=[1:1:length(cov1)]-2878/2;
plot(ll/67,cov1,'-r')
grid
xlabel('time [hours]')
title('Autocorrelation function of Relative Humidity')

figure
subplot(2,1,1)
plot(x2,dat2)
grid
xlabel('time [hours]')
ylabel('Sea Surface Temperature (^oC)')
title('Time Series of Sea Surface Temperature')
subplot(2,1,2)
```

```
cov2=xcov(dat2,'coeff');
plot(ll/67,cov2), grid
mm=max(cov2);
ii=find(cov2==1);
xlabel('time [hours]')
title('Autocorrelation function of Sea Surface Temperature (^oC)')
```

```
% filename=sfcfluxoc77.m
% calculates wind stress and surface fluxes and other parameters
% used for open water or open lead calculations
% based on ustar, tstar, qstar and L
% Peter Guest 4/3/97 modified for input  8/1/2001

% This program is being modified to calculate wind stress along line 77
echo off
%
%  Input:
%          utrue   wind speed (m/s) at z(1)
%          tair    air temperature (Centigrade) at z(2)
%          rh      relative humidity (%) at z(3)
%          tsfcsea    surface temperature (Centigrade)
%          p       atmospheric pressure at z(4) (mb)
%          z      measurement level (can be vector)
%
%  stars output:
%        ustar   friction velocity (m/s)
%        tstar   scaling temperature (k or c)
%        qstar   scaling specific humidity (g/kg)  not (g/g)!!!!
%        L       monin-obukov length scale (m)
%
%  sfcfluxoc77 output:
%
%        shf    sensible heat flux (W/m2)
%        lhf    latent heat flux
%        hf     (total) heat flux
%        wstar   free convection scaling length (needs zi)
%        tau     wind stress  (N/m2)
%        Cd      drag coeff
%        Ce      Dalton number
%        Cdn     neutral drag coeff
%        Ch      Stanton number
%  plus a bunch of other stuff

%     lv    specific heat set constant at 1004 J kg-1 k-1
%     cp    latent heat of vaporization set constant at 2.50e+6 J kg-1


clear all
close all
addpath '/home/a4/oc4335/matmap' –end     %this program made use of
subroutine
                                          %in matmap to plot map
try77po=[  ];                             %prepare output file
save try77po.data try77po -ascii

%Extract SAIL data along line 67
win1=load('w77a.dat');
stbdr1=win1(:,22);
portr1=win1(:,26);
stbdwd1=win1(:,24);
stbdws1=win1(:,25);
portwd1=win1(:,28);
portws1=win1(:,29);
```

```
airt1=win1(:,31);
atmp1=win1(:,32);
hum1=win1(:,34);
sst1=win1(:,36);
day1=win1(:,[2]);
day1=day1*100;
GMTH=win1(:,[4]);
GMTM=win1(:,[5])/60;
GMTS=win1(:,[6])/3600;
GMT1=day1+GMTH+GMTM+GMTS;

lat1=win1(:,10)+win1(:,11)/60;
lon1=win1(:,12)+win1(:,13)/60;

%Initial parameters
c1=0;
yy=0;
m2=1;


for k1=1715.65:2:1811.65            %partition data into 2-hrly segemnt
if (k1 < 1723.65)|(k1>=1801.65)     %handle change of day
c1=c1+1;                            %count # of interval
[jj]=find((GMT1>=k1) & (GMT1<k1+2))
nn=length(jj);
for i=m2:m2+nn-1
yy=yy+1;
portwdh(yy)=portwd1(i);
portwsh(yy)=portws1(i);
airth(yy)=airt1(i);
atmph(yy)=atmp1(i);
humh(yy)=hum1(i);
ssth(yy)=sst1(i);
lon2(yy)=lon1(i);
lat2(yy)=lat1(i);
end
la=[lat1(m2) lat1(m2+nn-1)];
lo=[-lon1(m2) -lon1(m2+nn-1)];
m2=nn+m2;

elseif k1 == 1723.65
c1=c1+1
[jj]=find((GMT1>=k1) & (GMT1<k1+78))
nn=length(jj);
for i=m2:m2+nn-1
yy=yy+1;
portwdh(yy)=portwd1(i);
portwsh(yy)=portws1(i);
airth(yy)=airt1(i);
atmph(yy)=atmp1(i);
humh(yy)=hum1(i);
ssth(yy)=sst1(i);
lon2(yy)=lon1(i);
lat2(yy)=lat1(i);
end
la=[lat1(m2) lat1(m2+nn-1)];
lo=[-lon1(m2) -lon1(m2+nn-1)];
```

```
m2=nn+m2-1;
else
display(['Number of 2-houly inteval in Line 67 ', num2str(c1)]);
end

[dist,ph]=sw_dist(la,lo,'km');      % cal distance between stations in
km
dis(c1)=dist;
count(c1)=nn;                       %count no of elements in 2-hrly
vector
end

%plot map of path traveled
[lon,lat,topo]=opmcmap(-123.5,-120.5,34.2,36.8);
v=[-2000 -1000 -100 -80 -40 -20 0];
[c,h]=contour(lon,lat,topo,v);  %plot topo graph clabel(c,h);
%plot datapoints
lon3=lon2mapreg(-lon2,lon);
hold on;
plot(lon3,lat2,'ko','markersize',3);

% load data to Prof Peter Guest’s program
nn=0;
len=length(count);
for kk=1:length(count)        %perform iteration for each 2-hrly
interval
for i=1:count(kk)
nn=nn+1;
wd1(i)=portwdh(nn);
sp1(i)=portwsh(nn);
airt2(i)=airth(nn);
p2(i)=atmp1(nn);
rh2(i)=humh(nn);
tsf2(i)=ssth(nn);
dist(i)=dis(kk);                  %k need to increase for each iteration
lenn(i)=len;
end

utrue=sp1*.514444;            %convert to m/s
tair=airt2;
tsfcsea=tsf2;
rh=rh2;
p=p2;
z=[14];
%z=input('Measurement height(s)? m  ')
%utrue=input('Utrue? (m/s)  ');
%tair=input('Tair?  C  ');
%tsfcsea=input('SST? C  ');
%rh=input('rh? %  ');
%p=input('Pressure? mB  ');
%z=input('Measurement height(s)? m  ');

[ustar tstar qstar L] = stars(utrue,tair,tsfcsea,rh,p,z);
% Set some stuff again for later calcualtions
if isempty(p)  % Default pressure
  p = 1012;
end
```

```
pbad = find(isnan(p));
p(pbad) = 1012  * ones(size(pbad));



if length(z) == 0 % Default measurement heights
  zu = 10.;
  zt = 10.;
  zq = 10.;
  zp = 10.;
elseif length(z) == 1
  zu = z(1);
  zt = z(1);
  zq = z(1);
  zp = z(1);
elseif length(z) == 2
  zu = z(1);
  zt = z(2);
  zq = z(2);
  zp = z(2);
elseif length(z) == 3
  zu = z(1);
  zt = z(2);
  zq = z(3);
  zp = z(2);
elseif length(z) == 4
  zu = z(1);
  zt = z(2);
  zq = z(3);
  zp = z(4);
else
  disp ('Incorrect z array')
end

z10=10.0;      % reference height for Obukhov length scale
CHn10=1.0e-3;  % heat and buoyancy flux transfer parameter at z10=10
(Smith, 1988)
CEn10=1.2e-3;  % humidity flux transfer parameter at z10=10 (Smith,
1988)
gamma=0.00975; % adiabatic lapse rate
k=0.4;         % Von Karmen's constant
g=9.81;        % gravity


% Calculate mixing ratios
psfc = (p + 0.116*zp);   % surface pressure (mb) based on standard atms
ess = esat(tsfcsea);         % saturation vapor pressure wrt flat water
qsat = 622.0.*ess./(psfc - ess);  % saturation mixing ratio (g/kg)
%qsfc = qsat;             % mixing ratio at surface assumed staturated
qsfc = qsat .* 0.98;       % for salt water  (different from Smith)
esa = esat(tair);          % saturation vapor pressure wrt flat water
esair = (rh./100).*esa;
q = 622.0.*esair./( p - esair); % true mixing ratio at zt  (g/kg)
%q = 622.0.*(rh/100).*esa./( p - esa); % mixing ratio at zt  (g/kg)
%esai = esati(tair);
%rhi = rh.*esa./esai;
```

```
% potential air temperature (K) measured at zt
 theta=tair+273.15+gamma.*zt;
 thsfc=tsfcsea+273.15;

% virtual potential temp (K) based on Stull (1988)
 thetav=theta.*(1.0+0.61e-3*q);  % virtual potential air temp
 thetavsfc=thsfc.*(1.0+0.61e-3*qsfc); % virt pot temp at sfc
% find roughness lengths
  zo= zu.*exp(-utrue.*k./ustar - psimsmith(zu,L));
  zot = zt.*exp((thsfc-theta).*k./tstar - psitsmith(zt,L));
  zoq = zq.*exp((qsfc-q).*k./qstar - psitsmith(zq,L));
  zot1 = z10.*exp(-k.*k./(CHn10*log(z10./zo))); % Using constant CHn10
(Smith,1988)
  zoq1 = z10.*exp(-k.*k./(CEn10*log(z10./zo))); % Using constant CEn10
(Smith,1988)
% find reference height (usually 10 meters)  values
  u10=ustar./k.*(log(z10./zo)-psimsmith(z10,L));
  th10=thsfc+(tstar/k).*(log(z10./zot)-psitsmith(z10,L));  % Kelvin
  t10=th10-273.16-z10.*gamma;                          % C
  q10=qsfc+(qstar./k).*(log(z10./zoq)-psitsmith(z10,L));

% Calculate surface fluxes
  rho=psfc./(2.87.*thetavsfc); % calc density with ideal gas law
  shf=-rho.*1004.*ustar.*tstar; % sensible heat flux
  lhf=-rho.*2.5e3.*ustar.*qstar; % latent heat flux
  cd=(ustar./u10).^2;  % Drag Coeff
  cdn=(1./(cd).^(0.5)+psimsmith(z10,L)./k).^(-2); % neutral Drag Coeff
  ce=ustar.*qstar./(u10.*(q10-qsfc));  % Dalton number
  cen=k^2./(log(z10./zo).*log(z10./zoq)); % Neutral Z10 m moisture
transfer coeff.
  ch=ustar.*tstar./(u10.*(th10-thsfc));
  chn=k^2./(log(z10./zo).*log(z10./zot)); % Neutral Z10 m heat transfer
coeff.
  zl=z10./L;
  tau=rho.*(ustar.^2);   %wind stress
  taubad=find(isnan(tau));  % replacing any possible complex NAN
  tau = markbad(tau,taubad);
%calculating the Richardson Number
Ri=z10./L;
 j=find(z10./L>0);
   if ~isempty(j);
     Ri(j)=(z10./L(j)).*(0.74+(4.7 .*(z10./L(j))))./((1+(4.7
.*(z10./L(j)))).^2);
   end;
%calculating the free convection length scale (wstar)
zi = 500;
tstarv=tstar+(0.61e-3.*theta.*qstar);
 wstar=(-g./theta.*tstarv.*ustar*zi).^(1/3);
 j=find((tstarv) >= 0); % setting stable to NAN (wstar not applicable)
  if j ~isempty(j);
   wstar = markbad(wstar,j);
  end;
disp('  shf        lhf       tau');
disp([shf lhf tau]);
tauxout1=[tau' wd1' dist' lenn'];

% Prepare output file to be used by program Ek77po.m to compute
```

```
% volume transport through line 77
load try77po.data
try77po=[try77po tauxout1];
save try77po.data try77po -ascii;
end
clear try77po

% file=Ek77po.m
% Cal Ekman Transport along line77 based on output 'try77po.data'=
% [tau' wd1' dist' lenn'] obtained from sfcfluxoc77.m

clear all
close all

%f=coriolis parameter at midlat(s^-1)
%taux = wind stress along 240 degrees (kg/ms^2)
%mtauxxxx= ave of tauxx at beginning of hr to hr (kg/ms^2)
%volxxxx = hrly vol transport per unit width along line 67(m^2/s)

f=0.0001;
den=1024;         %density in kg/m^3

%Prepare output file for report

vol77a=[  ];
save vol77a.data vol77a -ascii
tpt77a=[  ];
save tpt77a.data tpt77a -ascii

%Extract taux and wind dir along line 77

dd=load('try77po.data');
len=dd(:,4);
aa=0;
for kk=1:len            %No. of 2-hrly interval along line 77
tau1=dd(:,1+aa);        %Read in data
dir1=dd(:,2+aa);
dist=dd(:,3+aa);
aa=aa+4;

%cal windstress along line 77
%Tpt right(east) is +

tt=length(dir1)
for t=1:tt
if (dir1(t)>=240) & (dir1(t) <330)
taux(t) = tau1(t)*cos((dir1(t)-240)*pi/180); %towards east is +
elseif (dir1(t)>=330) & (dir1(t)<=359.99)
taux(t) = -tau1(t)*sin((dir1(t)-330)*pi/180);  %towards west is -
elseif (dir1(t)>=0) & (dir1(t)<=060)
taux(t) = -tau1(t)*cos((60-dir1(t))*pi/180); %towards west is -
elseif (dir1(t)>=150) & (dir1(t)<240)
taux(t) = tau1(t)*cos((240-dir1(t))*pi/180);
elseif (dir1(t)>060) & (dir1(t)<150)
taux(t) = -tau1(t)*cos((dir1(t)-60)*pi/180);  %towards west is -
else
cc=1    % checking purpose
```

```
end
end


%cal volime transport along line 67

mtaux=mean(taux);                    %cal 2-hrly mean for taux
vol1=mtaux/(f*den*1*10^6);           %cal vol transport in Sv
mvol=mean(vol1);
vol2hr=dist(1)*mvol*1000 %km to m


%prepare output files

load vol77a.data
vol77a=[vol77a vol1];
save vol77a.data vol77a -ascii;

ttt=[vol2hr  dist(kk) mtaux];

load tpt77a.data
tpt77a=[tpt77a ttt'];

save tpt77a.data tpt77a -ascii;

end

clear vol77a;

p=load('tpt77a.data')
p(1,:)'
p(2,:)'
p(3,:)'
sumtpt=sum(p(1,:))
sumdis=sum(p(2,:))
sumtaux=sum(p(3,:))
```

```
% filename Ek70vb.m
% Cal Ekman velocity along line70 down to 20m
clear all
close all

%fcor=coriolis parameter at midlat(s^-1)
%taux = wind stress along 240 degrees (kg/ms^2)
%mtauxxxx= ave of tauxx at beginning of hr to hr (kg/ms^2)
%volxxxx = hrly vol transport per unit width along line 67(m^2/s)

den=1024;   %density in kg/m^3
Az=0.014;   %Eddy viscosity m^2/s recommended by Stephen Pond in Dy
Oceanography

% load first station file
addpath '/h/ochome1/acong/oc3570/CTD' -end
%Extract wind speed from SAIL data along line 77
win1=load('w70a.dat');

%Extract depth data for comparision
addpath '/h/ochome1/acong/oc3570' -end
dep=load('vol1022.data');
dep1=load('vol3435.data');
zz=dep1(:,2);
geo=dep(:,1);
ge0=-(geo(2)-geo(1))/(zz(2)-zz(1))*zz(1)+geo(1);
geo=[ge0 geo']*100;  %convert to cm/s
dir1=win1(:,24);                      %stbdwd1
stbdws1=win1(:,25)*.514444;           %convert to m/s

% load second station file
dd1=load('dw010.asc');
dd2=load('dw022.asc');
p2=dd1(:,4);t2=dd1(:,5); s2=dd1(:,12);
lat2=dd1(:,2); lon2=dd1(:,3);
p10=dd2(:,4);t10=dd2(:, 5) ;s10=dd2(:,12);
lat10=dd2(:,2); lon10=dd2(:,3);
%ii=10;
%jj=35;
la=0.5*mean(lat2)+0.5*mean(lat10);   % mean latitude

fcor=2*7.29*10E-05*sin(pi*la/180)  % coriolis parameter
len=length(stbdws1);

%resolve wind direction along line 77
for t=1:len                   %dir east is +
if (dir1(t)>=240) & (dir1(t) <330)
wx(t) = -stbdws1(t)*cos((dir1(t)-330)*pi/180); %towards south is -
elseif (dir1(t)>330) & (dir1(t)<359.99)
wx(t) = -stbdws1(t)*cos((dir1(t)-330)*pi/180);
elseif (dir1(t)>0) & (dir1(t)<=060)
wx(t) = -stbdws1(t)*sin((60-dir1(t))*pi/180);
elseif (dir1(t)>=150) & (dir1(t)<240);
wx(t) = stbdws1(t)*cos((dir1(t)-150)*pi/180);
else
cc=1
end
```

```
end

mwind=mean(wx);         %cal mean wind along 77

De2=abs(4.3*mwind/sqrt((sin(abs(la)*pi/180))))        %Ekman depth in
metres
v0=(sqrt(2)*pi*1.8E-3*mwind*mwind)/(De2*den*abs(fcor)); %surface Ekman
vel

%compute Ekman velocity
for nn=1:length(zz)
ue(nn)=v0*cos((pi/4)+(pi*zz(nn)/De2) )*exp(pi*zz(nn)/De2); %normal to
line 77
ve(nn)=v0*sin( (pi/4)+(pi*zz(nn)/De2) )*exp(pi*zz(nn)/De2); %along line
77
ekv(nn)=sqrt(ue(nn)*ue(nn)+ve(nn)*ve(nn));
tet(nn)=atan(ve(nn)/ue(nn));
fu1(nn)=cos(tet(nn))*ekv(nn);
end
ue0=v0*cos(pi/4);
ve0=v0*sin(pi/4);

zz=[0 zz'];
ekv=[v0 ekv]*-100; %convert to cm^2, into box is +ve
ve=[ve0 ve]*-100;  %convert to cm^2

uu=[ue0 ue]*-100;  %convert to cm/s
figure
h=plot(uu,zz,'r+',ve,zz,'b^',ekv,zz,'g-');
set(h,'LineWidth',1.5);
ylabel('depth z (m)')
xlabel('u, v and net Ekman velocity profile -- line 70; (cm/s)')
legend('u-normal to line 70','v-along line 70', 'Net Ekman
velocity',0);
title(['u, v & Ekman velocity profile with Ekman depth ',num2str(De2),'
m'])
grid


% sum of Ekman and Geostrophic velocities

for nn=1:length(zz)
sumv(nn)=uu(nn)+geo(nn);
end

figure
h=plot(sumv,zz,'b*');
set(h,'LineWidth',1.5);
ylabel('Depth (m)')
xlabel('Sum of Ekman & Geostrophic velocity normal to line 70 (cm/s)')
grid on

%prepare output files
vol7720=[ ];
save vol7720.data vol7720 -ascii;

load vol7720.data
```

```
vol7720=[vol7720 zz ue];
save vol7720.data vol7720 -ascii;
clear vol7720;
```

```
%file = adcp.m
%calculate ADCP volume transport based on the box data given by Prof
Collins

clear all
close all

ad=load('box.dat');
dist=ad(:,1)*1856;
dep=ad(:,2);
u1=ad(:,3)/100;
v1=ad(:,4)/100;
jj=0;
kk=0;
sum2=0;
sum1=0;

ll=length(dist);

for i=1:ll-1
if dist(i+1)-dist(i)==0
kk=kk+1                              %count levels
z1(kk)=dep(kk)-dep(kk+1);            %cal depth difference
sum1=z1(kk)*v1(i)+sum1;              %product of v & depth for station i
else
jj=jj+1                              %count no. of station
x1(jj)=dist(i+1)-dist(i)
sum2(jj)=sum1*x1(jj);
kk=0
sum1=0;
end
end
totaltpt=sum(sum2)/1E6               %Convert to Sv
```