A Comparison of ADCP and Geostrophic Current Profiles Referenced to Fixed Depths or Isopycnals at the Entrance to the Gulf of California

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Non-technical summary

Geostrophic currents are a balance of a pressure gradient force and the Coriolis force (due to the Earth's rotation). They are inferred by recording salinity and temperature at a number of depths at different locations, from which horizontal density gradient profiles are estimated. These are integrated vertically to obtain geostrophic shear, the variation of current with depth. An independent measurement or an assumption is required to convert relative geostrophic current profiles to absolute current referenced to Earth axes. Scientists historically have used a variety of assumptions to reference geostrophic current profiles, often a particular depth or density. An alternative is to use directly measured currents from an Acoustic Doppler Current Profiler, together with ship speed measured from GPS navigational fixes, to provide a reference for geostrophic currents. In this study the geostrophic currents are compared, using different reference depths, with the ADCP recorded currents.

Abstract

Absent of an ADCP, past studies have used hydrographic profiles to characterize geostrophic currents near the Gulf of California, but using various reference depth assumptions. This study compares using ADCP currents to assumed levels of no motion at 1000m depth, 500m depth, or the 1027kgm^{-3} density surface, finding that currents at 500m and 1027kgm^{-3} were almost identical in this region. Geostrophic profile shapes deviated from those of the ADCP at most stations. Tide filtering was an issue, and where a greater length of time was spent at a station interval (26-27) results were considerably improved. Calculated between 12-hour station intervals, the geostrophic currents and ADCP currents were in far better correlation, though there magnitudes were far smaller due to averaging out most of the variation.

Introduction

Ocean circulation controls the distribution of most water mass properties, including pollutants. The presence of a subsurface deoxygenated zone is a significant feature of the Eastern Tropical North Pacific (ETNP), particularly at the mouth of the Gulf of California. Its position, size and mixing are influenced by the current velocities, their origins and shear between depths. Thus determining which calculation methods provide accurate current velocities is crucial.

However despite their importance, currents in the region are relatively unstudied. When Kessler published his paper 'The Circulation of the Eastern Tropical Pacific' in 2006, he left a question mark in the region just south of the Baja peninsula. Kessler's work was based on historical hydrographic data and surface drifters. Roden (1971, 1972) carried out one of the first hydrographic surveys in the study area but he had only an STD (a precursor to the modern Conductivity-Temperature-Depth (CTD) instrument widely used for hydrographic studies) with a salinity accuracy of only 0.03%. Conclusions have since been made by more recent studies but still the accuracy of the assumptions used to infer current remains open to question. Most studies have used hydrographic data (often with sparse data), satellite altimetry and surface drifters. Making conclusions from these require multiple assumptions, from which the degree of disagreement is made apparent by scientists varied choices in fixed reference depths (the presumed level of no motion) for the same phenomena in the same region. Lavin et al. (2006) used a reference depth of 1000m, Strub and James (2002a, 2002b) used 500m ad Kessler (2006) used 450m. Godinez et al. suggest that to use a fixed reference depth at all is inaccurate, claiming an improvement would be to reference to an isopycnal (σ=27kgm^{-3} in their case). Here, ADCP currents are used to compare currents inferred geostrophically according to various assumptions. Having taken measurements and analysed them using each of the methods I had expected to find that both the fixed depth and fixed isopycnal techniques will be inaccurate due to variations in density profiles at different stations. My hypotheses were:

- Hypothesis 1: The geostrophic current calculations will be significantly (>0.01ms^{-1}) different using a fixed reference depth to the ADCP-recorded currents.
- Hypothesis 2: The geostrophic current calculations will be significantly (>0.01ms^{-1}) different using a fixed reference isopycnal to the ADCP-recorded currents.

- Null hypothesis: There will be no significant difference (<0.01ms^{-1}) in geostrophic current calculations using each of the fixed depth and fixed isopycnal methods, with ADCP-recorded currents.

Testing the accuracy of geostrophic current calculations will be relevant not just to this specific region but also to current measurements worldwide, potentially setting a standard for future surveys. If hypotheses 1 and 2 are found to be true it would cast doubt on most previous circulation findings and make ADCP-recorded currents a necessity in all modern current calculations.

<u>Methods</u>

Measurements were taken from the R/V Thompson from the 17th to 27th March 2012. The instruments used were the Seabird SBE-911+ CTD, and the Teledyne RD current profiler, Ocean Surveyor 75kHz ADCP. The ADCP recorded currents while transiting as well as on station by compensating for the vessel's velocity, allowing it to record for the entire ship track (Figure 1). It recorded 5minute averages in 5m depth bins to about 300m though this varied depending on the ship's speed and suspended particles in the water column.

a)

b)

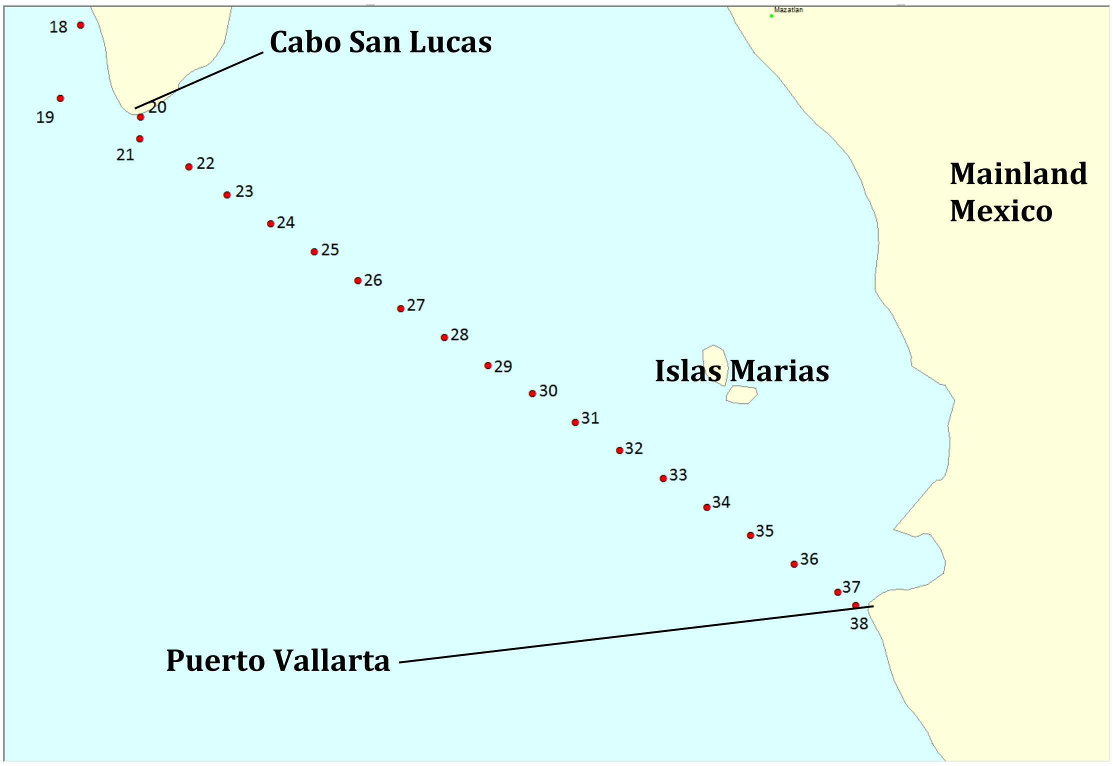

Figure 1: a) Map of stations along entire ship track

b) Map of station locations in transect (21 – 38)

Temperature, salinity and pressure profiles were acquired from the CTD at 18 stations along the transect (Figure 1: Station 21 [22.75111°N, 109.918°W] to Station 38 [20.41806°N, 105.760°W]), to 1000m depths (occasionally greater) or the max depth allowed due to the seafloor's proximity. The seafloor depth was established using the ship's acoustic depth sounder. The CTD casts were chosen to be along a transect from the southern tip of the Baja California Peninsula at Cabo San Lucas to Puerto Vallarta on the Mexican mainland, closing off the Gulf of California. Water samples were also taken at 10 of the stations using Niskin bottles generally fired at 200m intervals from 200-1000m deep. These were used to ensure the accuracy of the CTD salinity sensor and calibrate it if necessary.

From the pressure, salinity and temperature values, density profiles were produced in Matlab. From these density gradients, geostrophic currents were calculated from a balance of the pressure gradient and the Coriolis force.

The ADCP data was plotted in Matlab in a plot with the geostrophic current profiles for each pair of stations for stations 21-37. Stations 20 and 38 were too shallow to reference to depth, so instead were referenced to the surface. The mean current for each depth bin was plotted to reduce the scatter. It was noted that semidiurnal tidal currents were prominent in the ADCP records (Figure 2). Hence tides were filtered from the results using a triangular average filter with a 12-hour half-width. This had the effect of reducing the spatial resolution of the ADCP currents, but was an unfortunate necessity. A correction was then applied plotting the geostrophic currents so that its mean best fitted the mean ADCP data. The correction value was plotted to compare the corrections between stations.

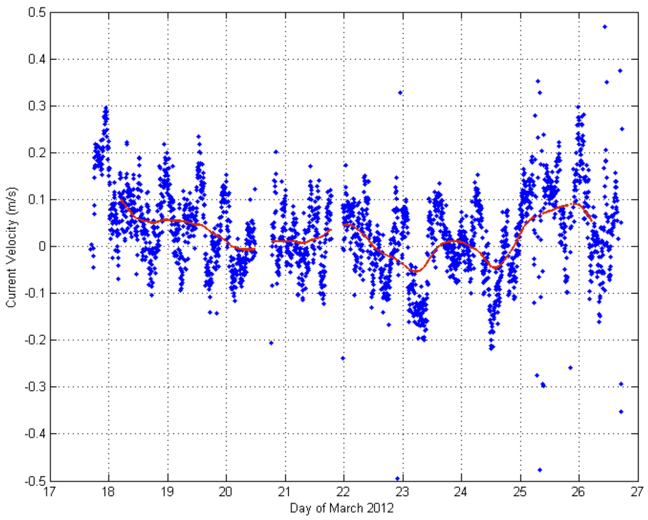

Figure 2: Plot of ADCP Current Velocities over Time for the 19th Depth Bin

Blue Dots – Plots of Raw Current Velocity
Red Line – Current Velocity after tidal filtering by a 12-hour triangular average

The main hypotheses were tested by calculating geostrophic currents based on a 500m reference depth, a 1000m reference depth, and a σ=27kgm^{-3} reference isopycnal. The magnitude difference between each of these and the ADCP-fitted currents were calculated.

Results

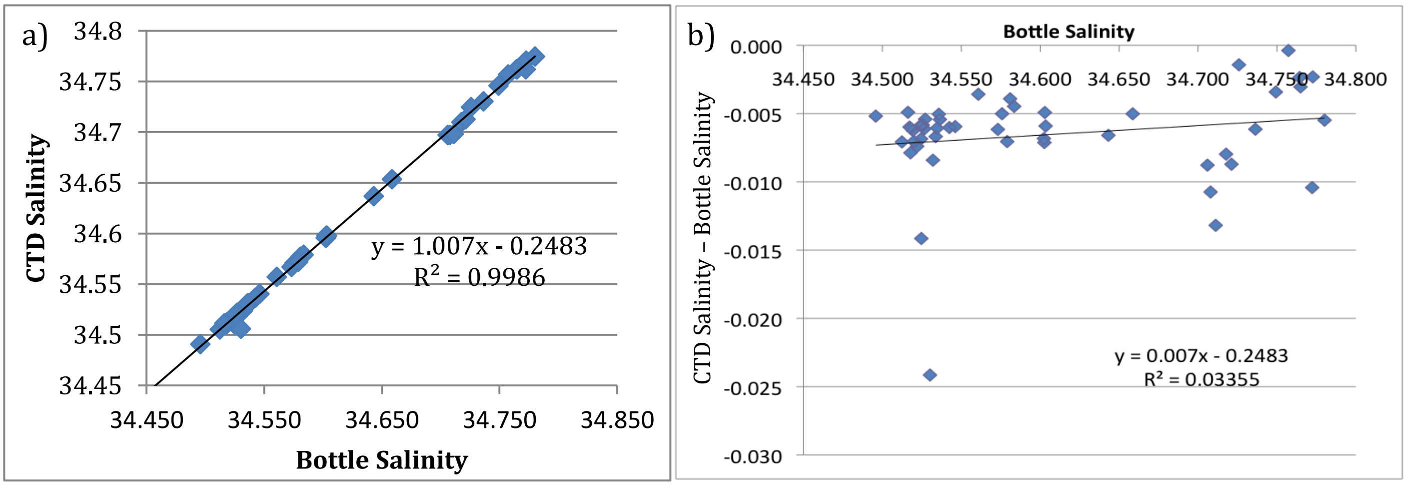

Figure 3: a) Plot of the CTD Salinity Readings against the corresponding Salinometer measurements.
b) Plot of (CTD Salinity – Bottle Salinity) over the Bottle Salinity

The R^2 value showed that the trendline equation was statistically significant at the 99.86% level. This trend had a small enough variation from the y=x line that a salinity calibration was deemed unnecessary. The difference between the two salinity readings over salinity showed very little statistical significance and had a shallow gradient. Thus no relationship was evident between variations at certain salinities. However it was noted that in all cases the bottled salinity was higher than the CTD salinity by (≈0.006)

From the initial plots (Appendix, Set 1) of ADCP across-track current component versus pressure (proxy for depth) there was a large amount of scatter in the results. Thus a time average was taken at every depth bin for which no NaN values were encountered in a CTD station pair interval. This average was more representative of the entire dataset for the particular station in some plots than others. Stations 24-25 (Figure 4a) in particular seemed to have a transition from one regime to another partway through transit. Therefore its average hides the complexity of the real data. 35-36 too had particularly high variation in the surface values. Besides these two cases the mean was roughly representative of the trend in the profiles (e.g. Figure 4b).

a) b)

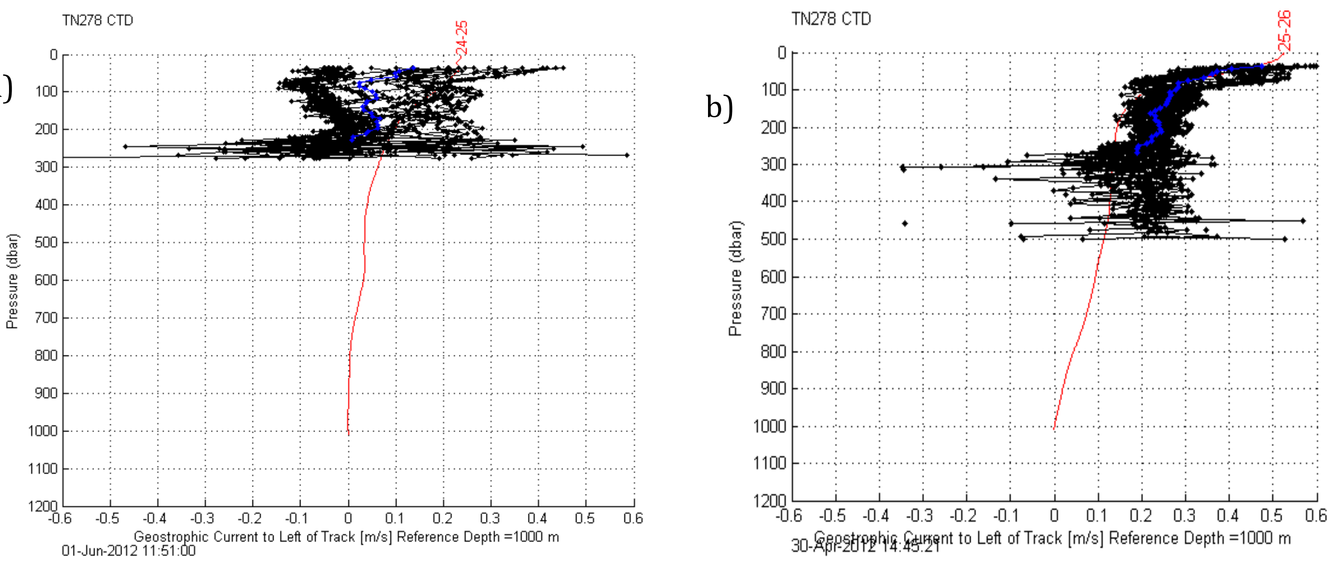

Figure 4: Plots of Across-track Current Component (m/s) against Pressure (dbar)
a) Station Pair 24-25
b) Station Pair 25-26

Black – ADCP Currents for all 5-minute intervals in a CTD pair interval
Blue – Time average of ADCP Currents at each depth bin for which no NaN values were encountered in a CTD station pair interval
Red – Geostrophic Currents referenced to 1000m
Dashed Red – Geostrophic Currents referenced to the surface when the stations were not deep enough to reference to 1000m

A time series of ADCP current at a given depth reveals a semidiurnal cycle (Figure 2) suggesting there was a strong tidal component to the directly measured currents. By filtering these records with a 12-hour triangular filter, much of the semidiurnal signal is suppressed (Appendix, Set 2). This can be seen to greatly reduce the variation at each station interval as well as between them. Few of the results fit the geostrophic (1000m) calculation well, so plots were produced plotting a profile where a correction had been applied to fit the geostrophic average close to the ADCP mean (Appendix, Set 3). Most geostrophic profiles over adjacent CTD station pairs, even once corrected, did not fit the shape of the ADCP profiles adequately. The exception, that matched up extremely well, was the 26-27 station interval. This particular station interval covered roughly 12 hours, far longer than all other intervals, due to a geophysical survey carried out between them. This meant that the tidal filtering was far less detrimental to the results of this station interval. Upon this realization, station intervals were broadened to cover roughly 12 hours (Figure 5) so that the new intervals became: 21-26, 26-27, 27-31, 31-33, 33-37. This had the effect of reducing spatial resolution to only 100km on average but this was unavoidable.

For individual station pairs there was a spread of correction values from -1.0574m/s to +0.15207m/s resulting in a mean of +0.003214m/s. After the new intervals were defined, the correction values were reduced to a range of -0.041 to +0.079m/s though this was influenced by the varying spatial resolution.

The magnitude difference between the mean currents of all of the 16 station intervals were classed as significant (>0.01ms^{-1} difference). After broadening to 12 hour intervals though, 21-26 and 27-31 did not classify as significant by the original criteria, although this was likely a result of averaging out much of the variation between the profiles. To test whether the 500m or σ=27kg/m^3 reference depths were improvements on the 1000m, plots were made of each of these on each station interval (Appendix, Set 4). It was clear from the plots that the 1027kg/m^3 isopycnal often occurred close to 500m depth in this region therefore they could almost be used interchangeably, at least at this time of year, though this would not be the case in other regions. There was a great degree of variation in these results likely due to the tidal influences and most profiles did not correlate well. Hence analysis was focused on the 12 hour station intervals (Figure 5).

Generally the profiles over these new intervals correlated far better than the profiles of the original intervals and the 1000m, 500m, and 1027kg/m^3 reference depth profiles were in far closer agreement.

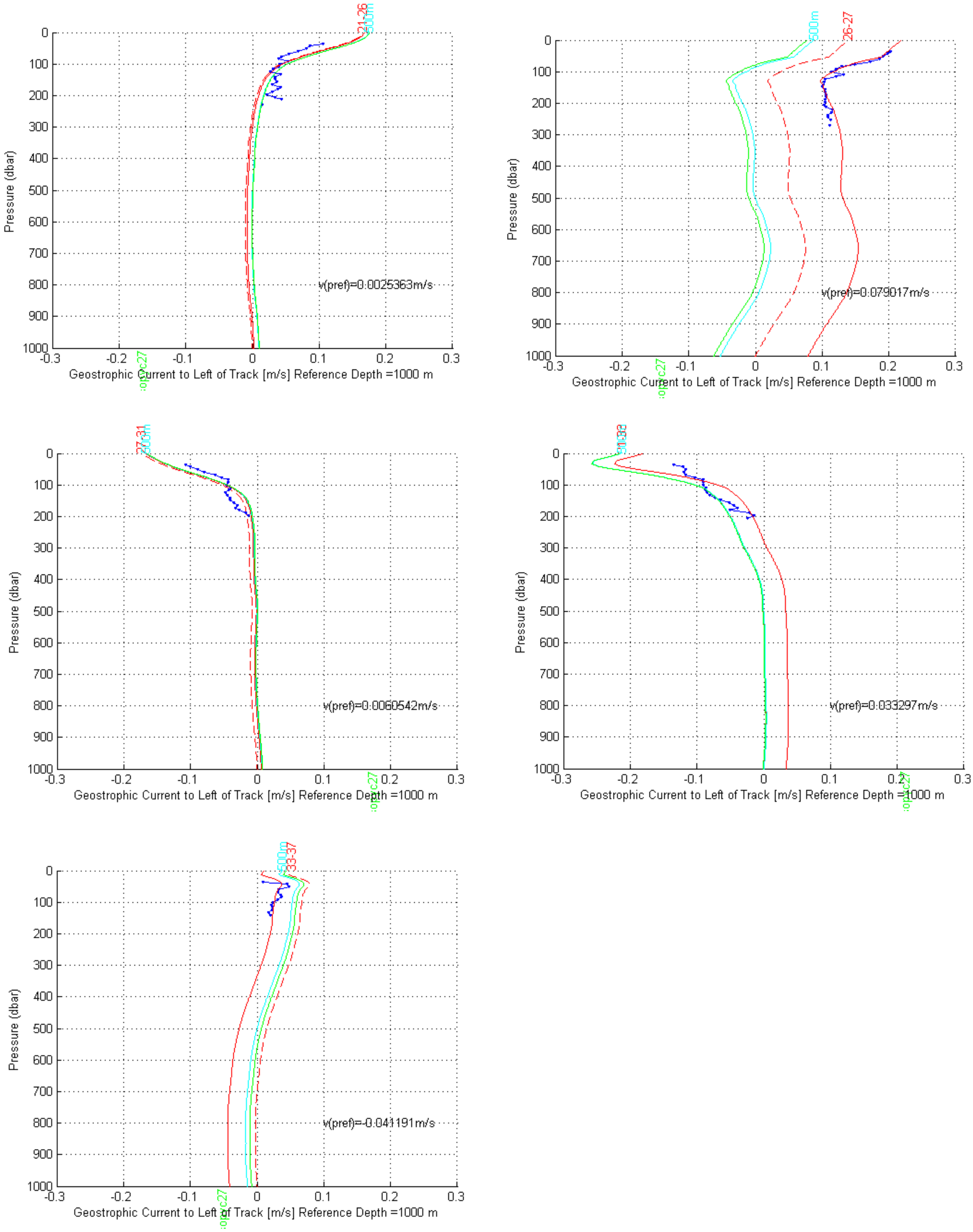

Figure 5: Plots of Current Speed (m/s) against Pressure (dbar) for the ≈12hour separated station intervals

Blue – Time average of ADCP across-track current component at each depth bin for which no NaN values were encountered in a CTD station pair interval

Dashed Red – Geostrophic Currents referenced to 1000m

Red – Geostrophic currents with correction

Cyan – Geostrophic currents referenced to 500m

Green – Geostrophic currents referenced to the 27kg/m3 isopycnal

V(pref) – Velocity at reference depth (according to correction)

However there was still no consistently good reference depth. Surprisingly 300m appears to be the best choice of reference depth for these profiles fitting the corrected geostrophic profile closely for 4 of the 5 intervals. For the exception (interval 26-27) though, a 300m reference depth was significantly worse than the 1000m reference. The effect of the variation in spatial averaging seems evident in the results. It could be that variations in surface waters tend to be at 300m upwards and through conservation of mass the barotropic flows below 300m average to zero over broad enough distances.

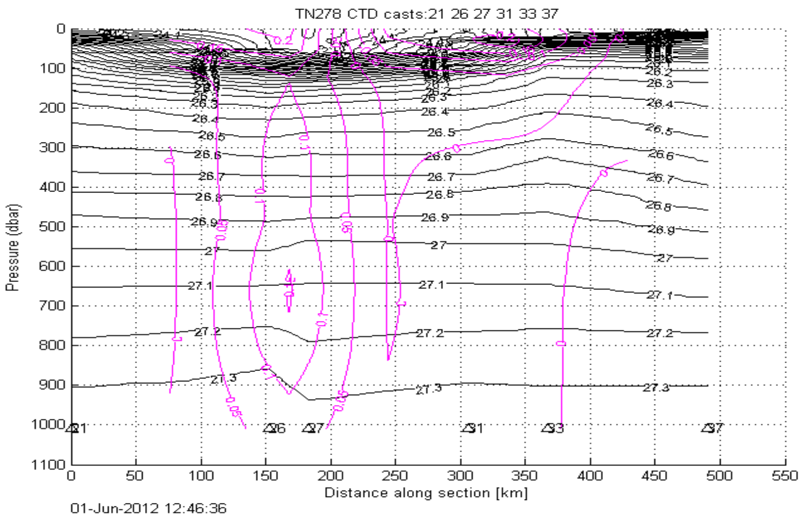

Figure 6: Plot of Density (Black) and Geostrophic Velocity (Purple) Profiles along the transect

The conflict between those stations averaged over a large spatial distance to those over much smaller distances is clear in Figure 6 where the geostrophic velocities between 26-27 dominate the transect. A lowering of the pycnocline between 100 and 300km is bounded by zones of greater surface geostrophic currents, as would be expected, where the isopycnals are tilted.

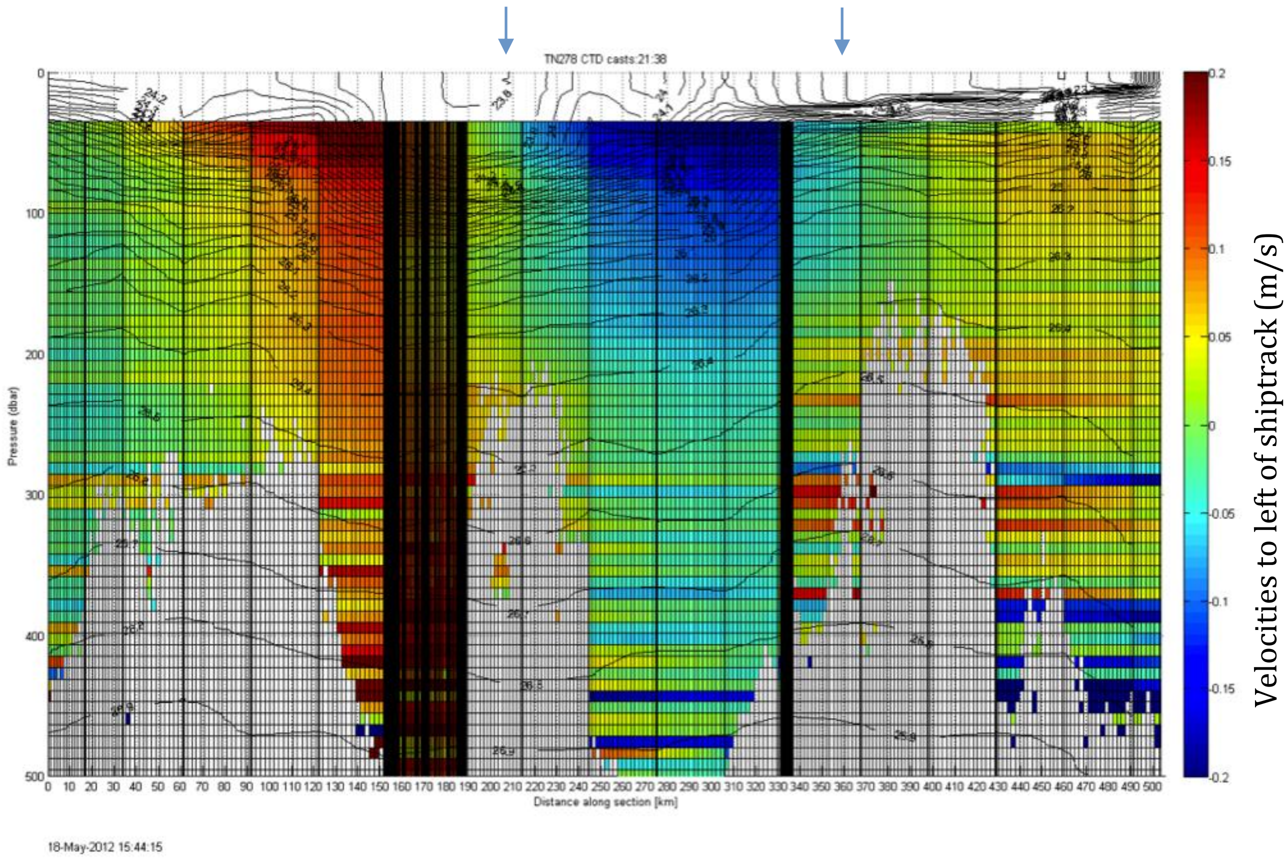

Figure 7: Plots velocities to the left of the shiptrack on a section of distance along the transect and pressure.

Since the transect was in a SE direction positive velocities are in the NE direction and negative is in SW direction

Vertical black lines mark the section lines

Horizontal black lines show the depth range over which the currents have been integrated

Arrows mark the section lines where a distinct change can be seen on either side

Finally a section plot of the transect (Figure 7) shows the overall trends. It is obvious, as expected, that the surface currents are a lot stronger than the deeper ones. Progressing along the transect, there is initially low current velocities close to the tip of Baja. This moves into an increasing current heading NE, into the Gulf of California. Moving past the geophysical survey area (concentrated black vertical lines due to ship's slow velocity) is an area of a strong Southwestward flow out of the Gulf of California. Towards the Manzanillo end of the transect the current's trend again becomes a Northeastward flow though at a lower velocity. This Northeastward flow closer to this coastline fits with Godinez et al.'s (2007, 2010) observations. This is also in general agreement with the surface flows of the broad station intervals in Figure 5. Here it too can be seen that there is a Northeastward flow in 21-26 and 26-27. There is then a transition to Southwestward flow for intervals 27-31 and 31-33. 33-37 then switches to a coastal Northeastward flow again.

A diurnal cycle of reduced ADCP depth penetration can be seen (Figure 7) with patchy areas of high velocity values adjacent to them. These are likely strips of bad data.

<u>Discussion</u>

The transition from strong Northeastward to strong Southwestward velocities was likely due to the spatial and temporal transition over an eddy (Figure 8).

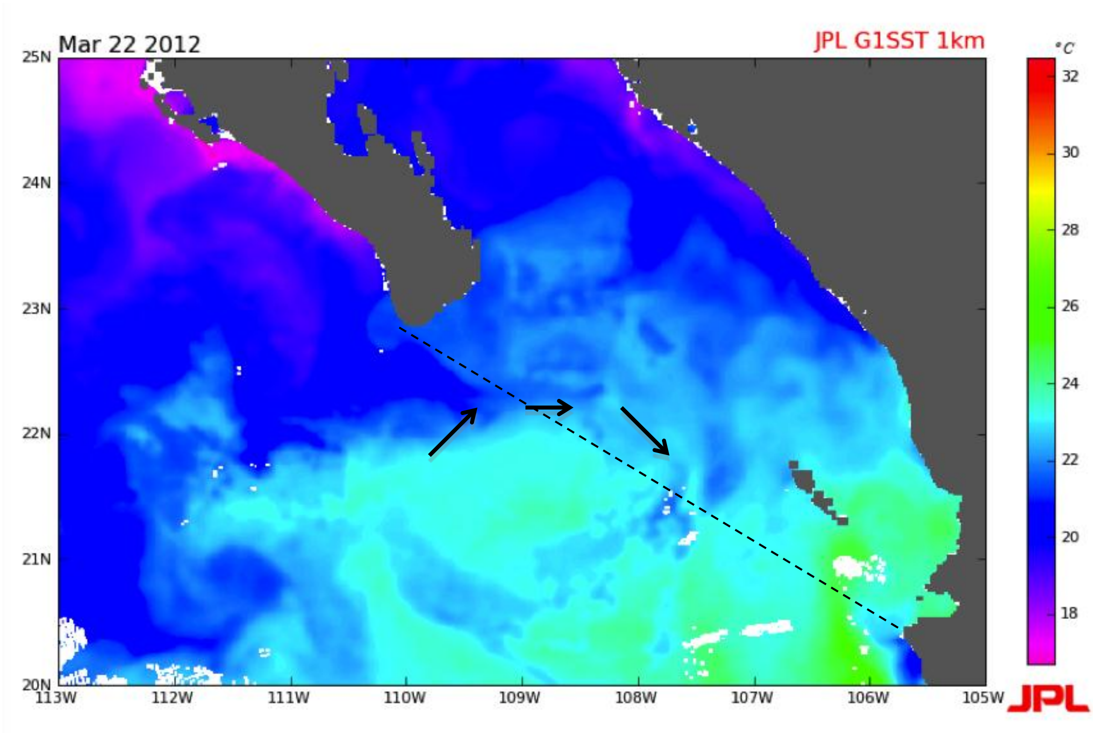

Figure 8: Satellite Image of Sea Surface Temperature (NASA, 2012). Arrows mark circulation pattern where an eddy is evident. The dashed line marks the transect

The greater degree of scatter in currents at the extremes of the profiles (deepest and shallowest depths recorded) was expected and likely due to a lower percentage of reflected signal being received from the deeper depths, and due to issues with the speed of the ship over the water and it's turbulent influence on the surface waters for shallow depths.

Due to the tide filtering method used there was a low resolution after averaging over 12hours. Unfortunately since the ship continued along its course during this time, this 12hour period spanned approximately 3 stations each time. Thus as well as reducing our ability to identify shorter temporal variations in the currents, it also blurred together the spatial variation. This reduced the apparent ADCP variation between stations despite the geostrophic being predicted to vary significantly. Also what appears to be a good pattern in the section (Figure 7), could be due to the influence of a few large anomalous velocities that then have their influence spread over the 12hour averages making them appear as larger scale trends. Evidence that the data might not be reliable can be seen by the distinct changes in velocities at each vertical black section line (Arrows on Figure 7). The variation in penetration depth, though influenced by ship speed, seems to be dominated by a diurnal cycle that is likely due to the vertical migration of zooplankton (Zhu et al. 2000) increasing the concentration of biological reflectors.

The reason for station interval 26-27's success over the other individual station pairs was due to a geophysical survey carried out between these two stations. As a result the ship remained between 26 and 27 for about 12hours, thus the tidal averaging would not have had such a detrimental effect on the results due to our limited spatial transition. It was calculated that to have 12 hour intervals between each station the ship would have to have transited at only 1.3knots. Since being allowed the ship time to carry out just this in future cruises is unlikely, I recommend collaborative efforts where other studies are carried out during these station intervals. This would alleviate the issue in this study that by taking 12-hour intervals the spatial resolution was reduced to an average of over 100km.

An additional source of error was that when converting the ADCP data over to matlab, current velocities that had lower than a 95% reflective certainty were deemed unreliable and so for data processing were converted into NaN's (not valid values). It was then necessary to interpolate between cases where there were NaN's surrounded by real values. In some cases these values adjacent to the NaN's quite clearly deviated from the normal distribution (Figure 9), but the method used would have interpolated between these inaccurate results resulting in the 12hour averages incorporating these points being skewed.

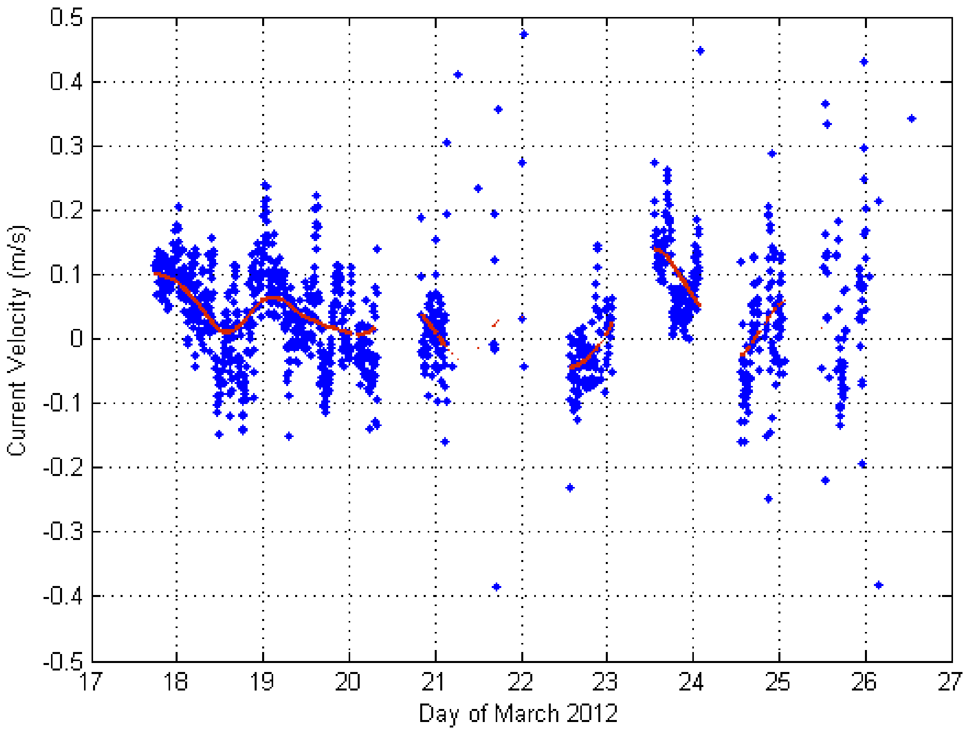

Figure 9: Plot of ADCP Current Velocities over Time for the 50th Depth Bin
Blue Dots – Plots of Raw Current Velocity
Red Line – Current Velocity after tidal filtering by a 12-hour triangular average

According to the hypotheses the differences between the 1000m reference and the corrected profile for intervals 21-26 and 27-31 are not significant since they are less than $0.01ms^{-1}$. However it should be argued that relative to the small magnitude of the current velocities the differences are significant. The small magnitudes are likely an artefact of the processing technique, where 12hour averages followed by averaging over a 12-hour station interval, would have reduced the spread and variation significantly.

A number of different timescale variations in currents was evident, from the geostrophic, to tidal, to eddies to even shorter scales. Hence when trying to look at the geostrophic trends the shorter timescales acted as noise. This was improved by averaging over the 12hours but was also skewed and reflected spatial variation as well as temporal. Longer-scale seasonal, annual, decadal variations should also be investigated in future longer term studies.

This data could also lead to the conclusion that using geostrophic predictions at all is unreliable and that an ADCP is essential for any current circulation studies. Certainly, for any future studies, increased ship time and further resources must be put into the investigation. Primarily this would allow improved tidal filtering. More boat time at each station would reduce the negative impact of this method of tidal filtering. Alternatively if tidal currents are well characterized in a region this could allow for them to be filtered out simply from subtracting the predicted velocities so that a 12hour averaging can be avoided. A far greater station density, over a far larger area should be aimed for, as well as deploying moorings and drifters to increase the available data. Having additional transects would also allow geostrophic current components in the SE/NW direction to be characterized which was not possible with this data set.

Future studies should utilise reliable satellite SSH altimetry in combination with hydrographic profiles for improved geostrophic current predictions. This may result in vertical shifts allowing better fits between the profiles.

The method of averaging to eliminate spurious values at all should be avoided when time is less of an obstacle. Averaging, results in a skew, whereby anomalies, rather than being eliminated, are simply being hidden amongst the rest of the data. A time-consuming but greatly improved method would be to look at each case step-by-step and judge their reliability and then remove those anomalies deemed unreliable.

Conclusions

The results suggest that the choice of reference depth must be chosen with care, ideally from prior research in the particular area, as they cause significant variation. It seems to be the case that the 500m/1027kgm^{-3} reference depths match each other closely, but none of the proposed reference depths are reliable every time. It could be worth further looking into the effectiveness of a 300m reference depth, however for referencing geostrophic currents to either depths or densities there will never be an all-encompassing rule. Hydrographic profiles vary spatially and temporally so that a correlation between a depth or density and a level of no motion will not remain consistent. A number of components influence current velocities simultaneously but on different spatial and temporal scales thus interfering with geostrophic current calculations. Tidal and eddy currents were the two components identified to most strongly impact the currents in this investigation. No suitable correction value could be identified to consistently improve the 1000m referenced depth. An ADCP should always be used to substantiate inferred geostrophic profiles when available.

Acknowledgements

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Appendix

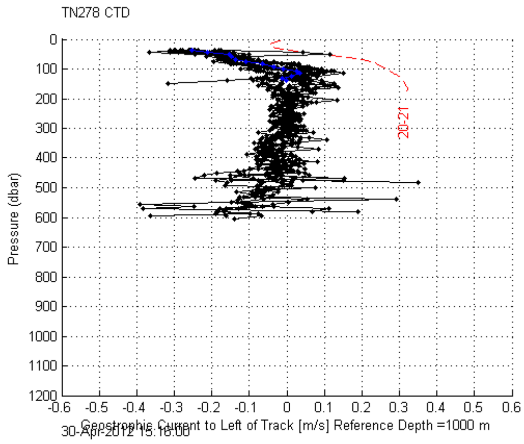
Set 1: Plots of Current Speed (m/s) against Pressure (dbar)

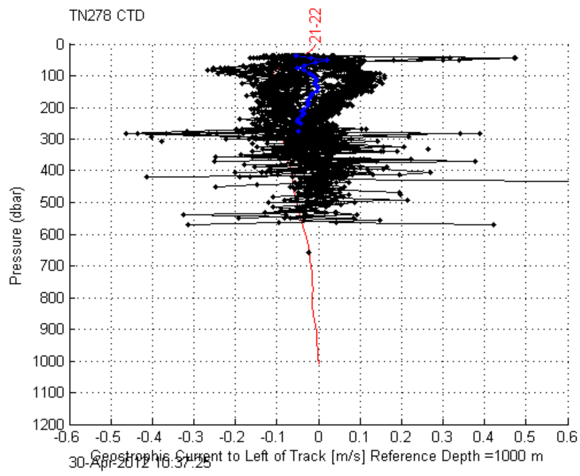
Black – ADCP across-track current component for all 5-minute intervals in a CTD pair interval

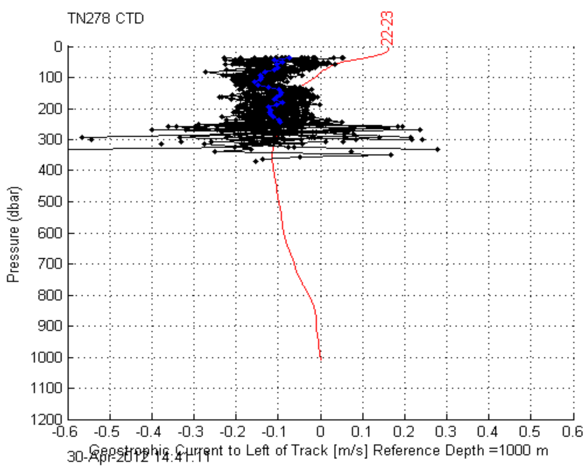
Blue – Time average of ADCP across-track current component at each depth bin for which no NaN values were encountered in a CTD station pair interval

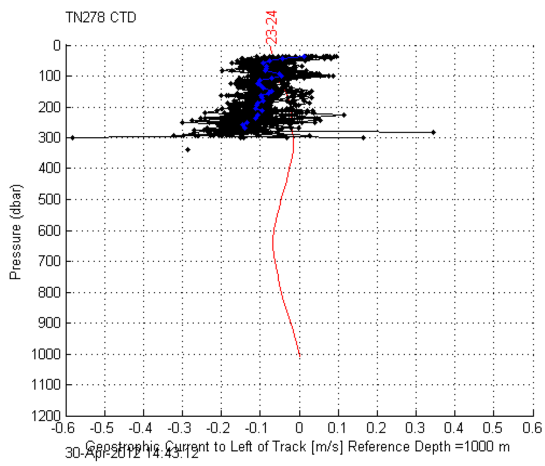
Red – Geostrophic Currents referenced to 1000m

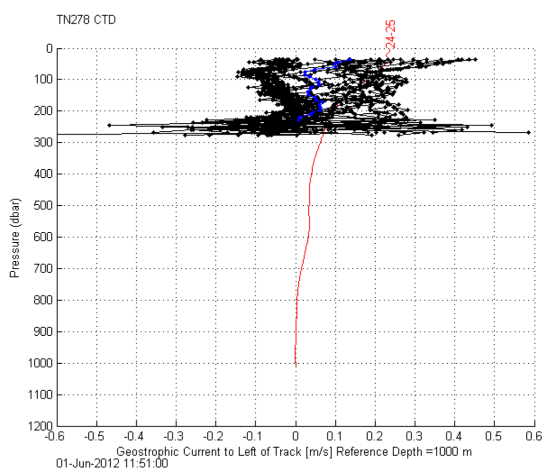
Dashed Red – Geostrophic Currents referenced to the surface when the stations were not deep enough to reference to 1000m

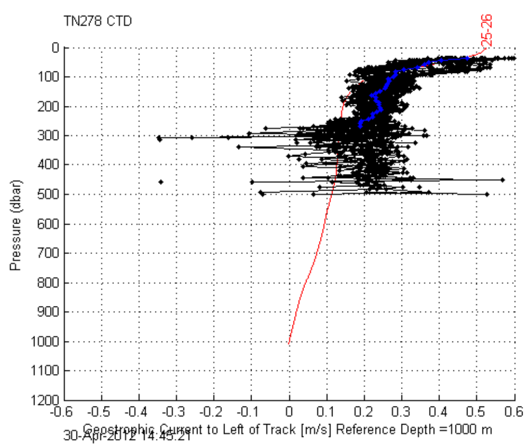


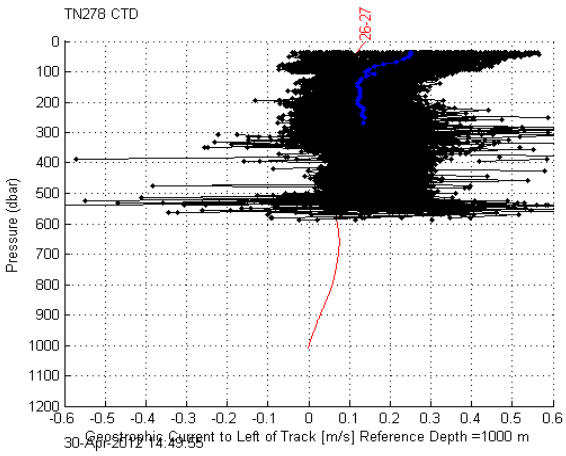








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Pressure (dbar)
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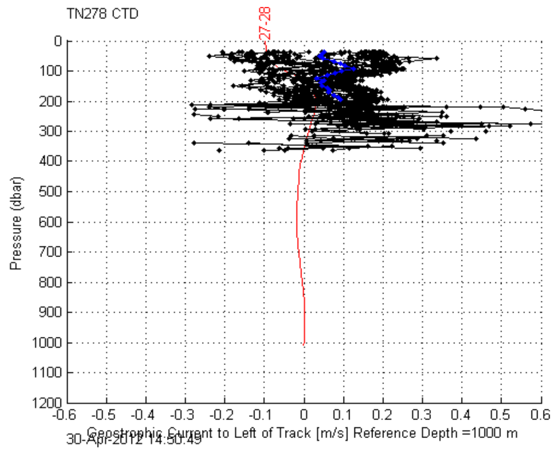
30-Apr-2012 14:49:55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27-28
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
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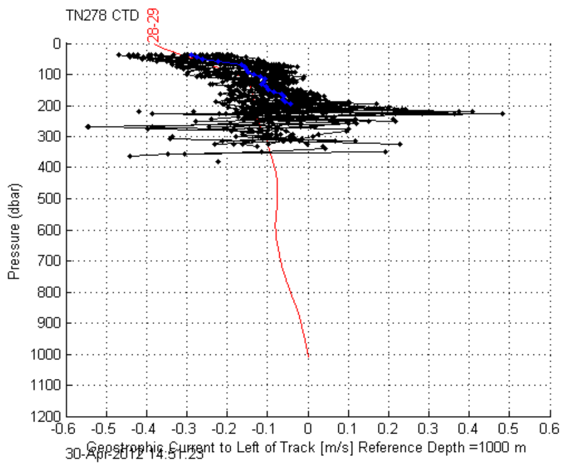
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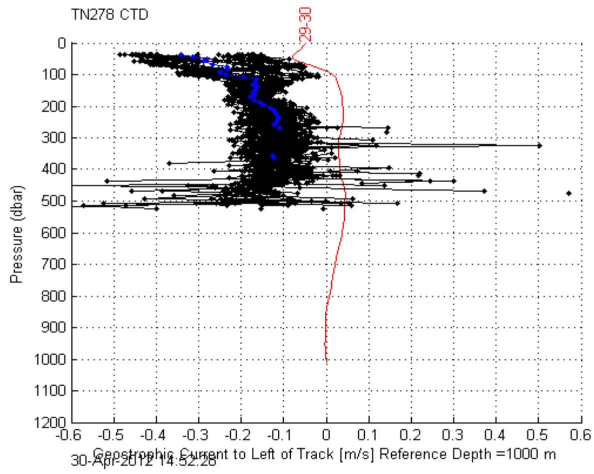
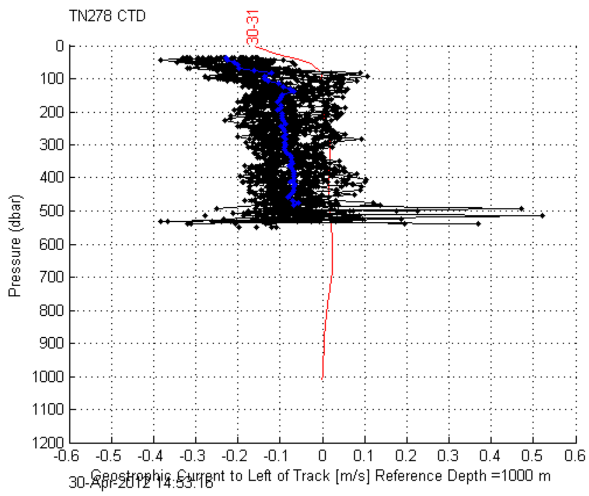
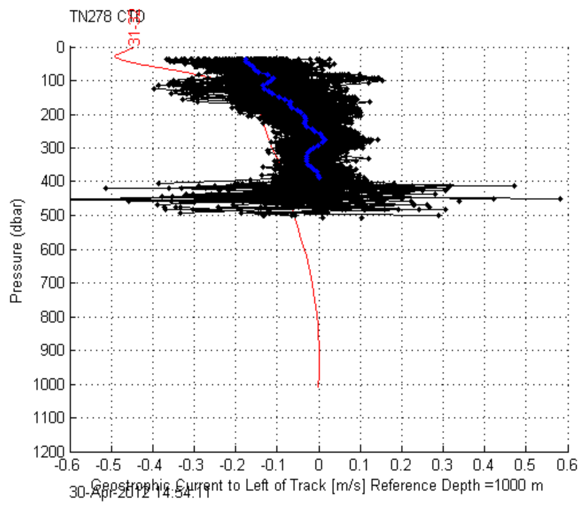
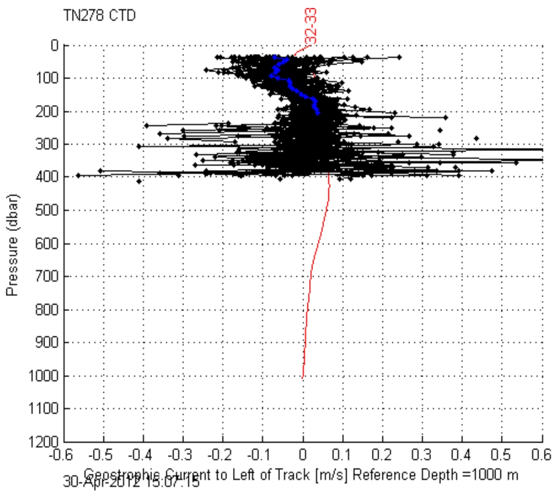
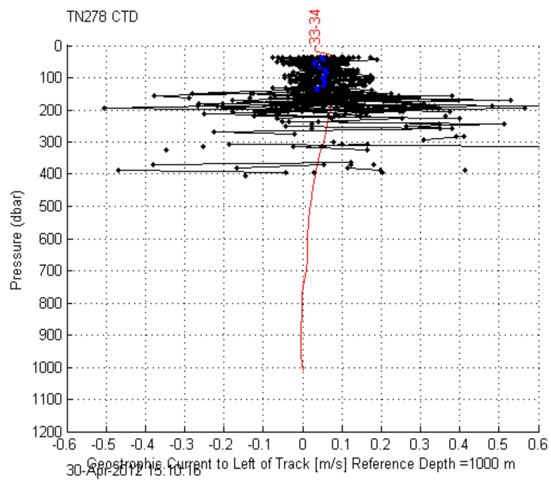
28-29
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 14:51:23

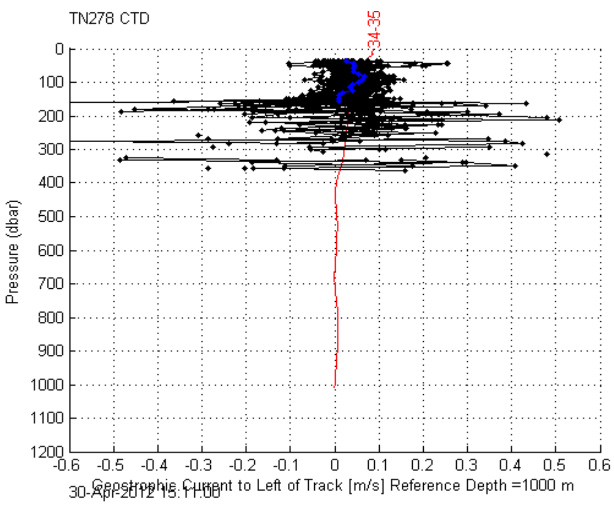

TN278 CTD
29-30
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 14:52:28

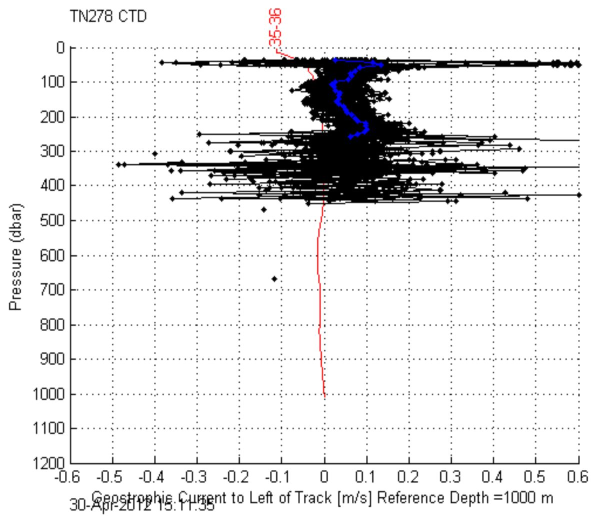

TN278 CTD
30-31
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 14:53:16

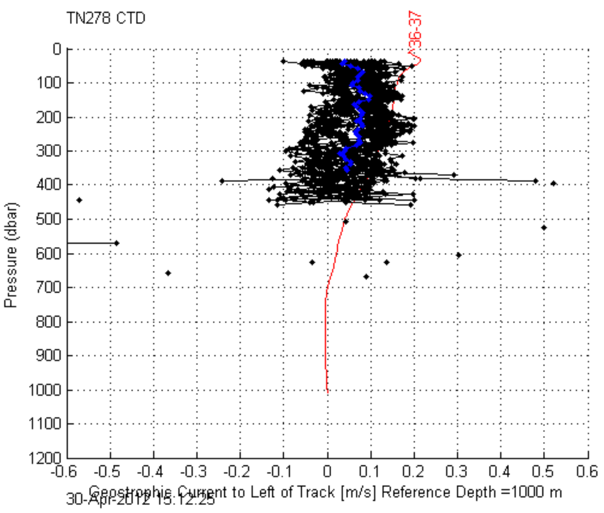

TN278 CTD
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 14:54:11

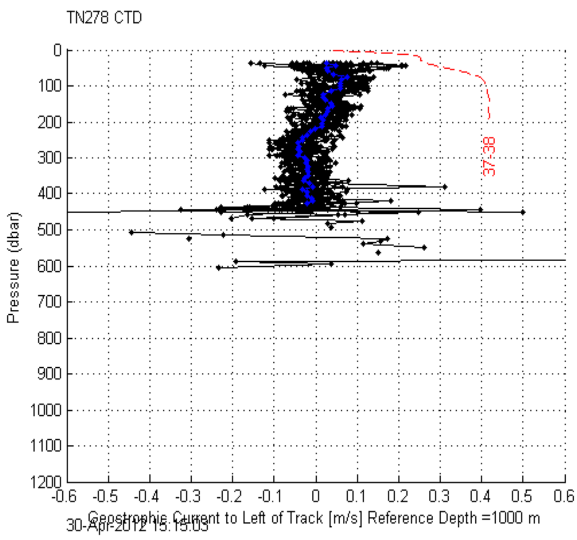

TN278 CTD
32-33
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 15:07:15


TN278 CTD
33-34
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 15:10:16


TN278 CTD
34-35
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 15:11:08


TN278 CTD
35-36
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 15:11:35


TN278 CTD
36-37
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 15:12:25


TN278 CTD
37-38
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
30-Apr-2012 15:15:03

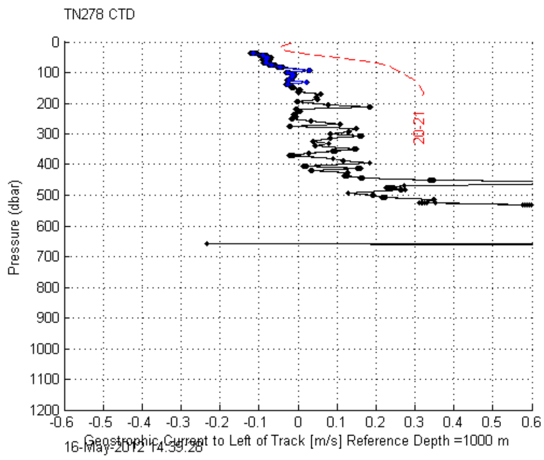
Set 2: Tidally Filtered (12hour triangular average) plots of Current Speed (m/s) against Pressure (dbar)

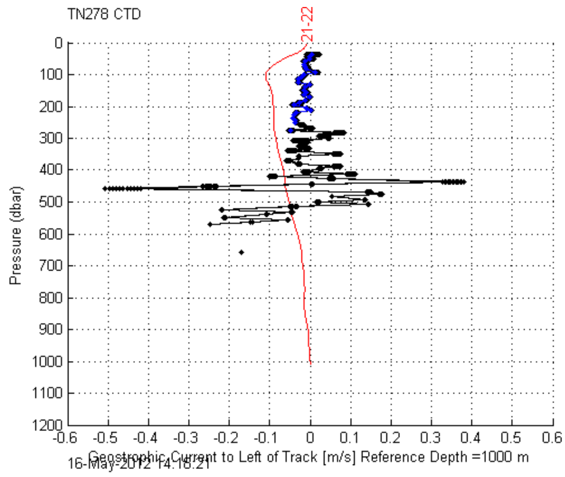
Black – ADCP across-track current component for all 5-minute intervals in a CTD pair interval

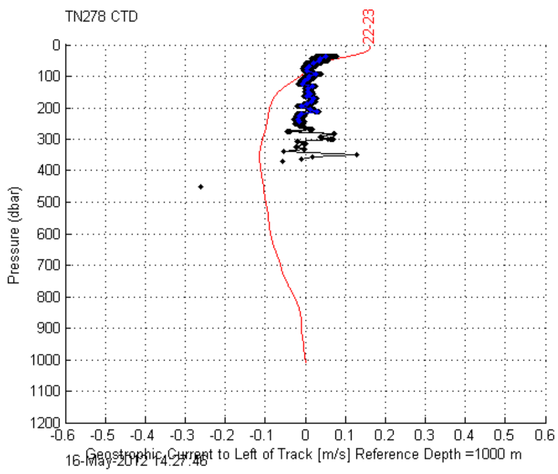
Blue – Time average of ADCP across-track current component at each depth bin for which no NaN values were encountered in a CTD station pair interval

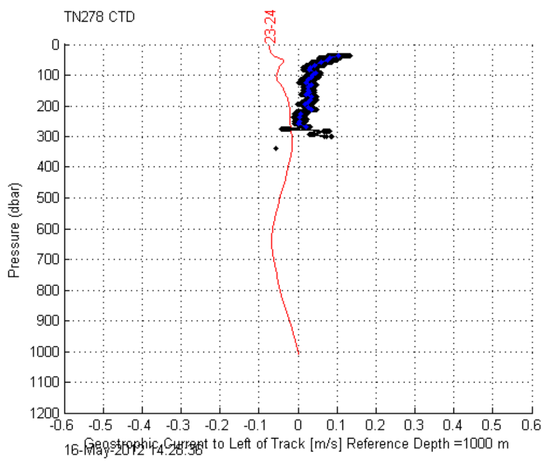
Red – Geostrophic Currents referenced to 1000m

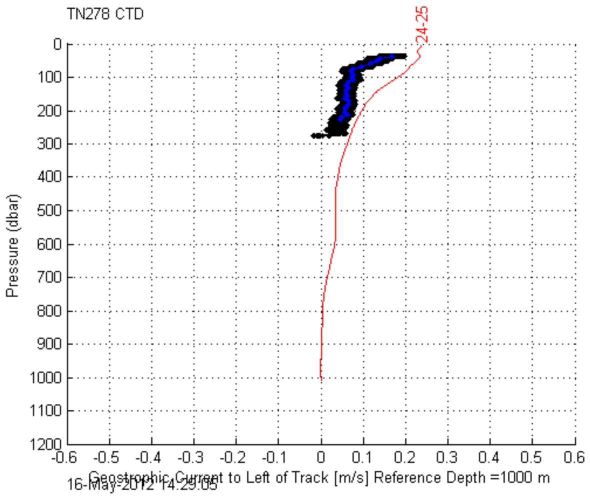
Dashed Red – Geostrophic Currents referenced to the surface when the stations were not deep enough to reference to 1000m

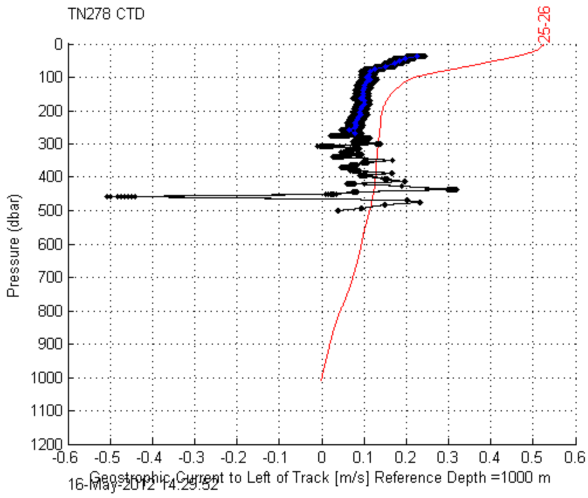


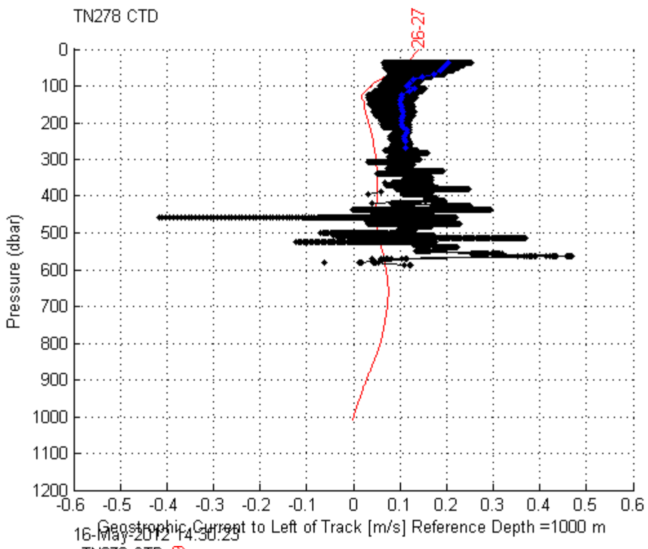


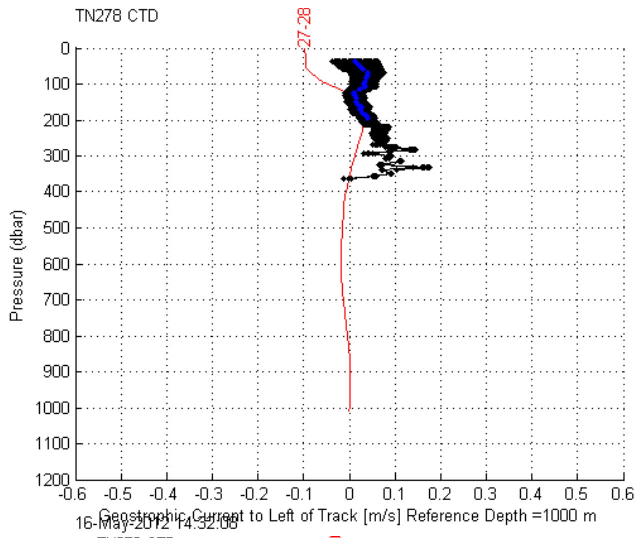


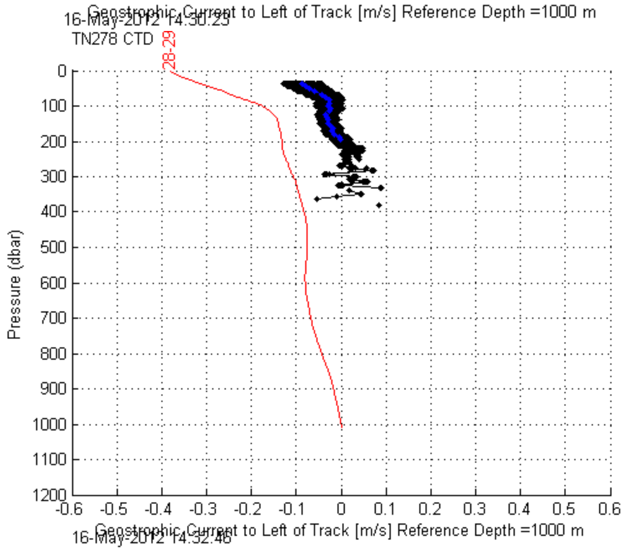


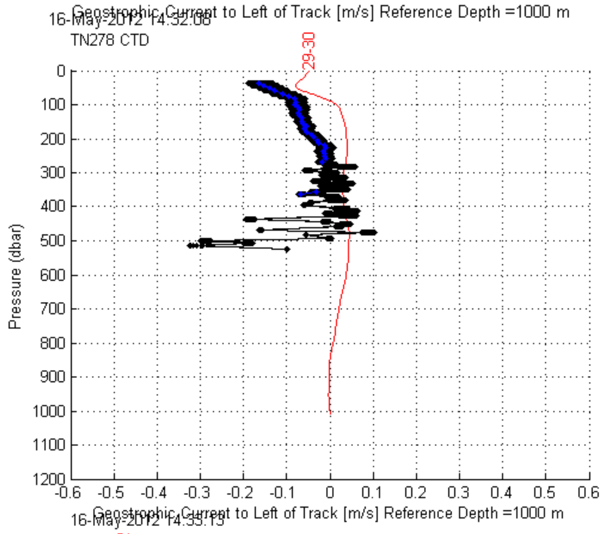

TN278 CTD
24-25
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:29:05

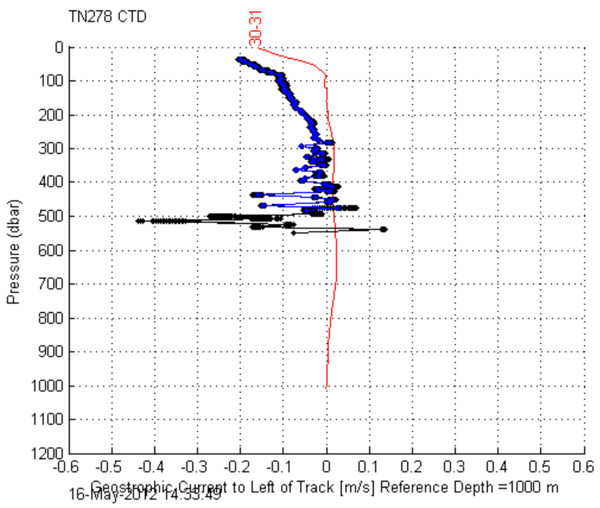

TN278 CTD
25-26
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:29:52

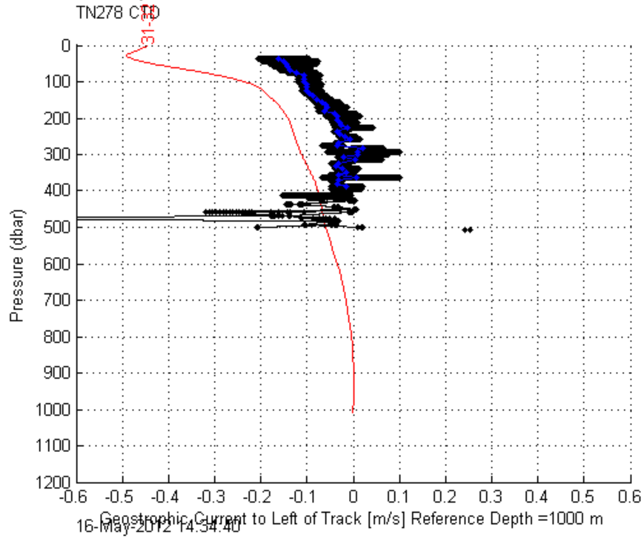

TN278 CTD
26-27
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:30:25

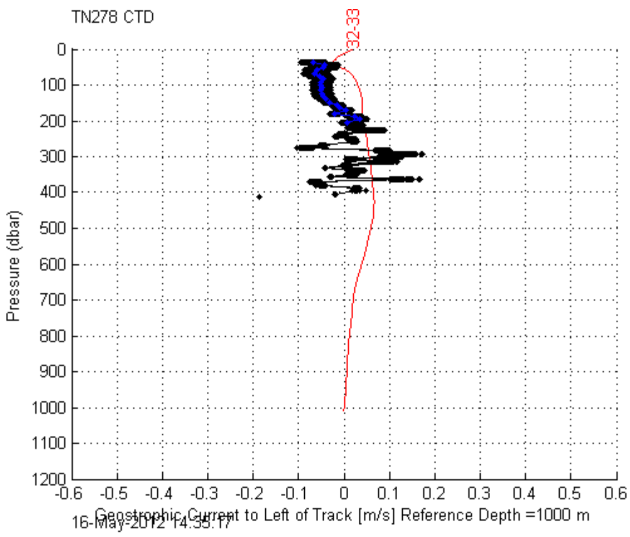

TN278 CTD
27-28
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:32:08

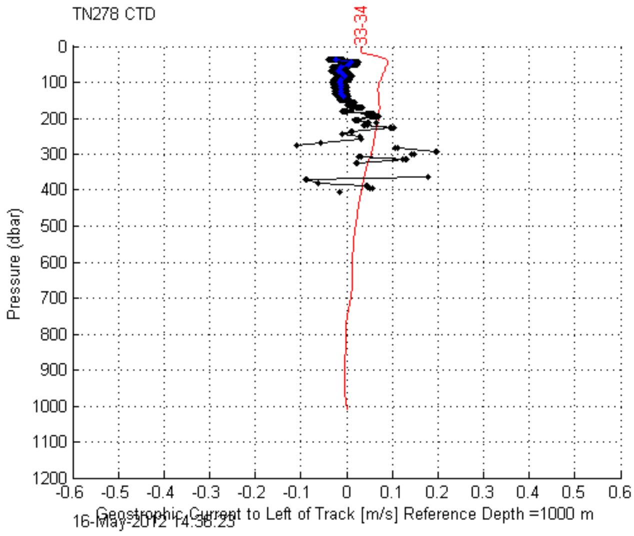

TN278 CTD
28-29
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:32:46

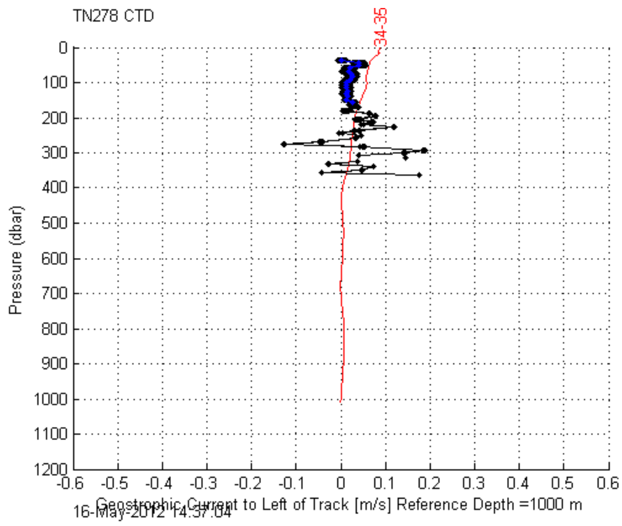

TN278 CTD
29-30
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:33:13

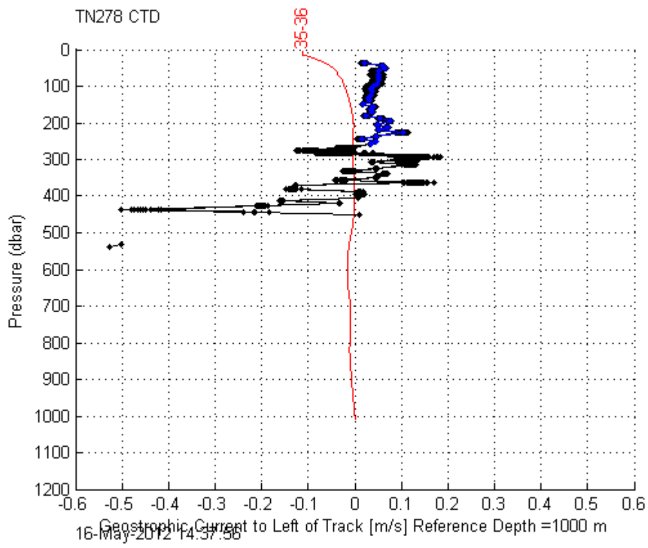

TN278 CTD
30-31
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:33:49

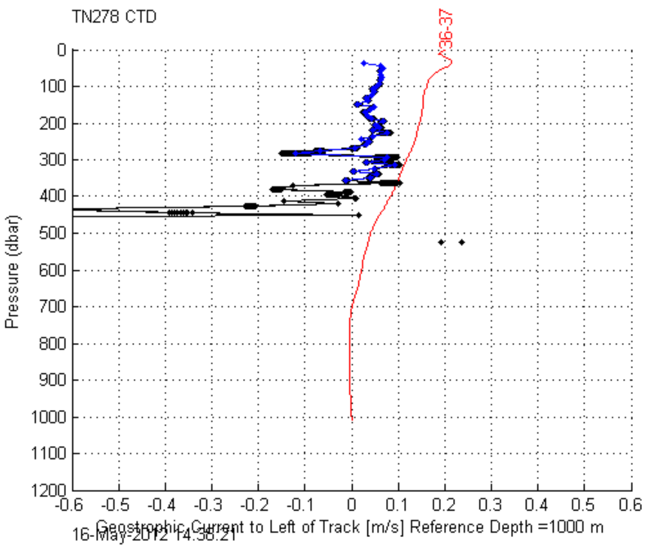

TN278 CTD
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:34:40

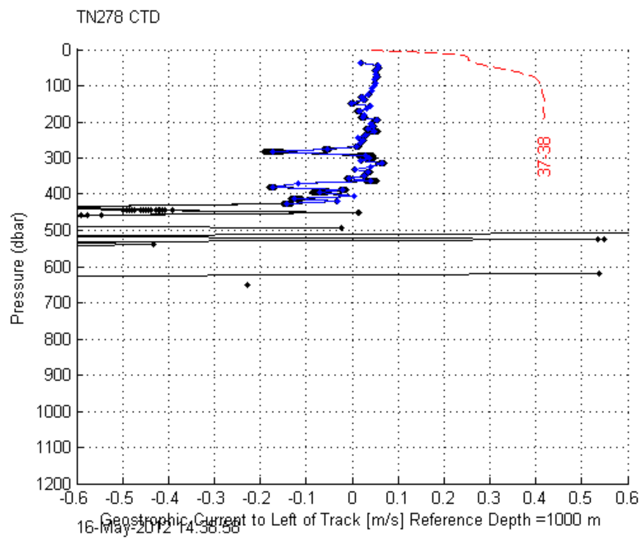

TN278 CTD
32-33
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:35:17


TN278 CTD
33-34
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:36:23


TN278 CTD
34-35
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:37:04


TN278 CTD
35-36
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:37:56


TN278 CTD
36-37
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:38:21


TN278 CTD
37-38
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
16-May-2012 14:38:58

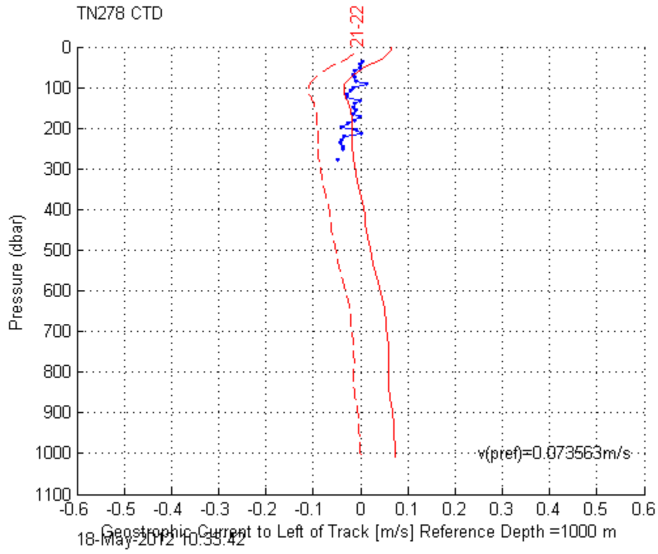
Set 3: Plots of Current Speed (m/s) against Pressure (dbar)

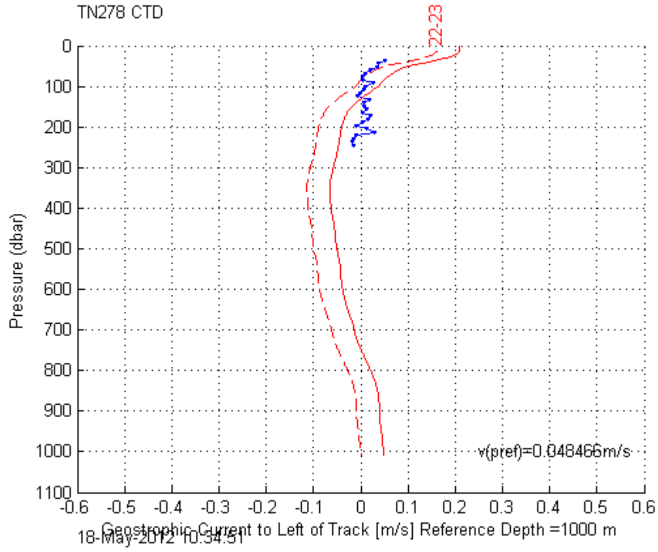
Blue – Time average of ADCP across-track current component at each depth bin for which no NaN values were encountered in a CTD station pair interval

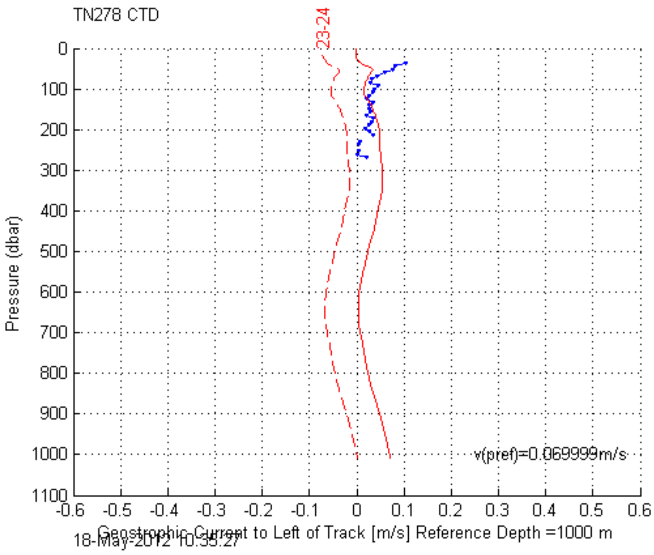
Dashed Red – Geostrophic Currents referenced to 1000m

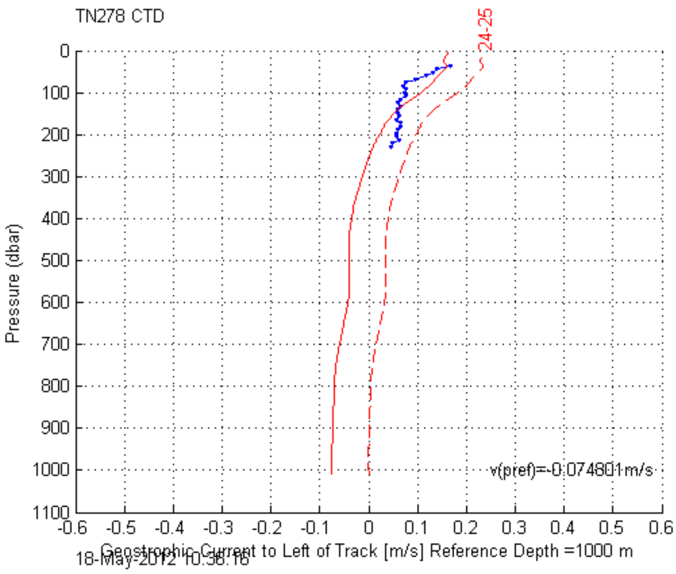
Red – Geostrophic currents with correction

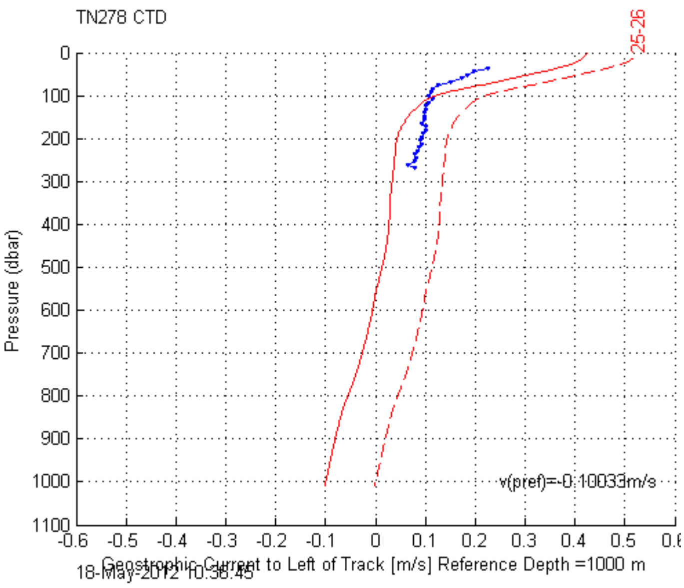
V(pref) – Velocity at reference depth (according to correction)

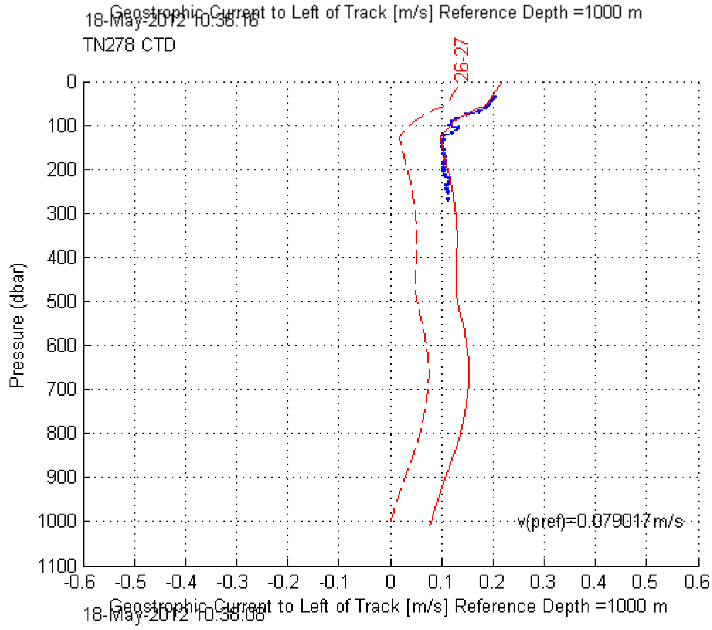

TN278 CTD
21-22
Pressure (dbar)
v(pref)=0.073563m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

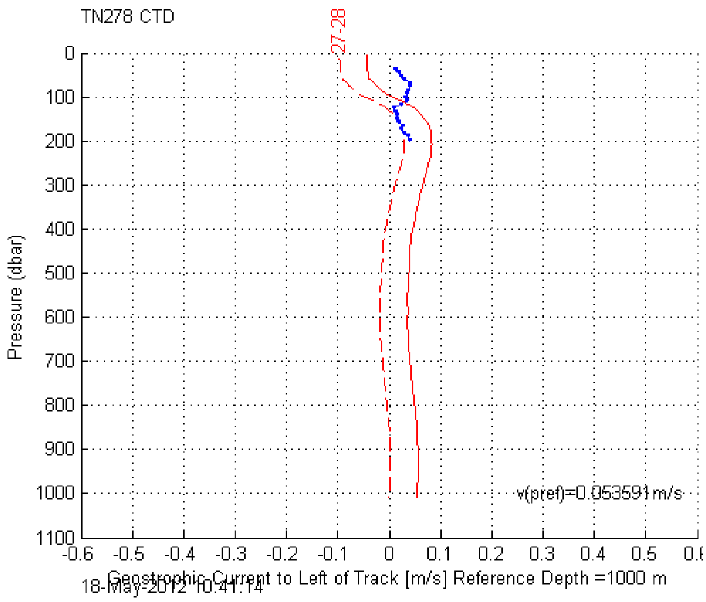

TN278 CTD
22-23
Pressure (dbar)
v(pref)=0.048466m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

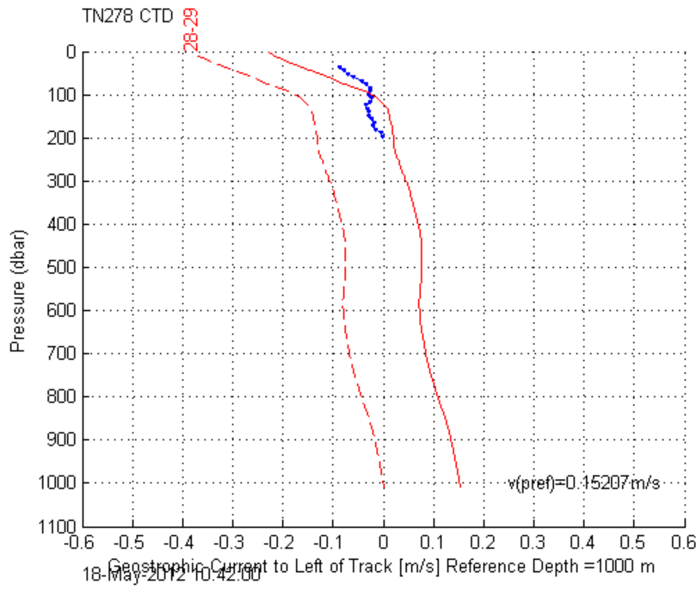

TN278 CTD
23-24
Pressure (dbar)
v(pref)=0.069999m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

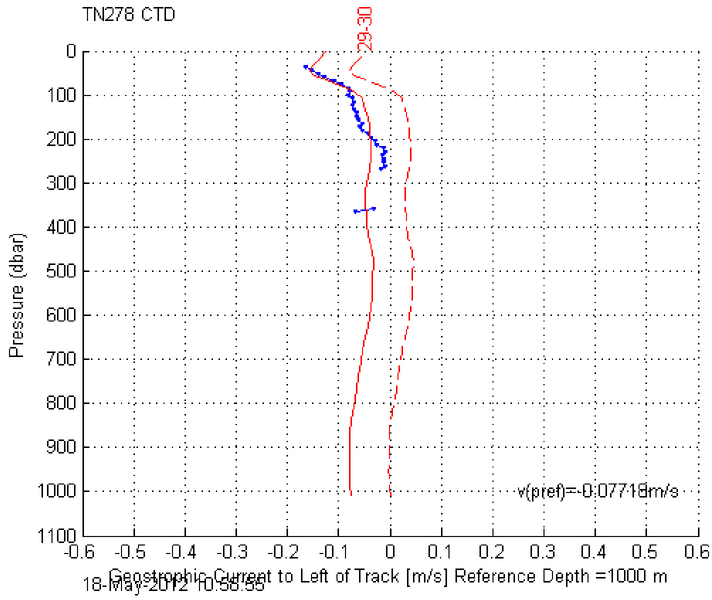

TN278 CTD
24-25
Pressure (dbar)
v(pref)=-0.074801m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

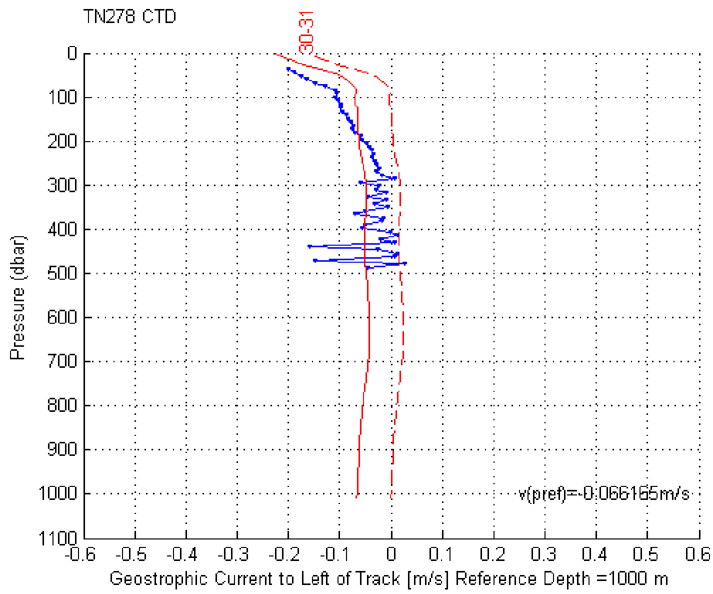

TN278 CTD
25-26
Pressure (dbar)
v(pref)=-0.10033m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

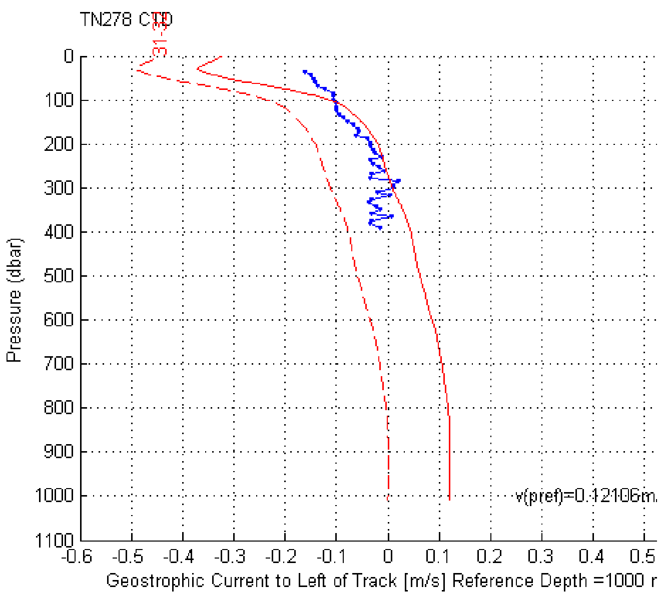

TN278 CTD
26-27
Pressure (dbar)
v(pref)=0.079017m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

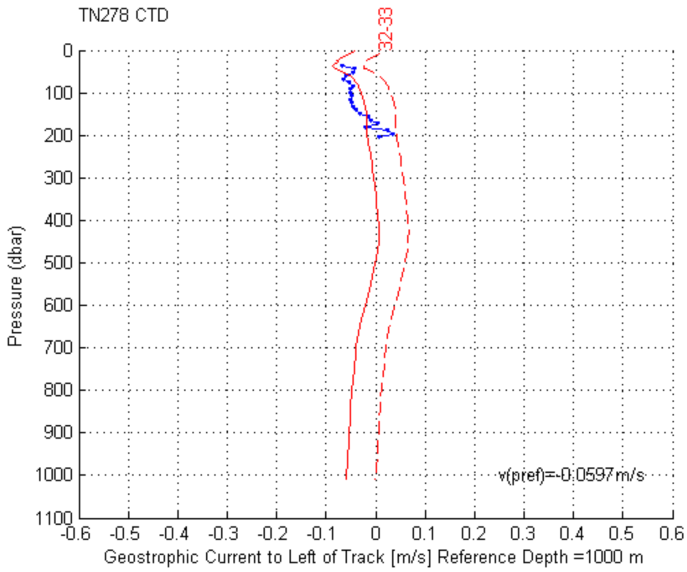

TN278 CTD
27-28
Pressure (dbar)
v(pref)=0.053591m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
18-May-2012 10:41:14

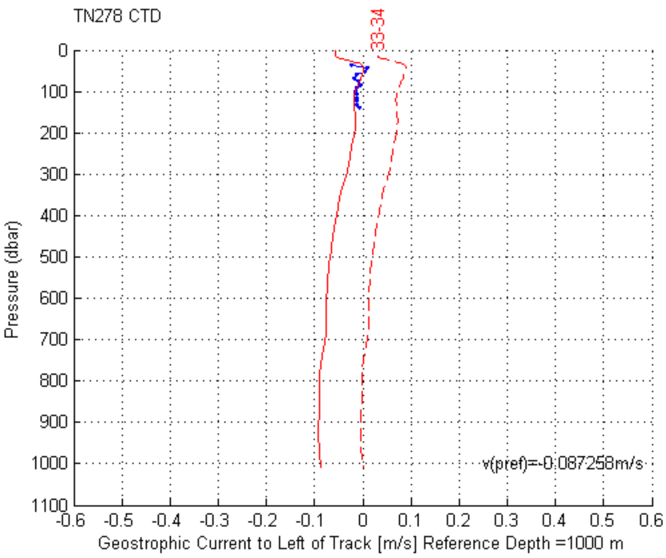

TN278 CTD
28-29
Pressure (dbar)
v(pref)=0.15207m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
18-May-2012 10:42:00

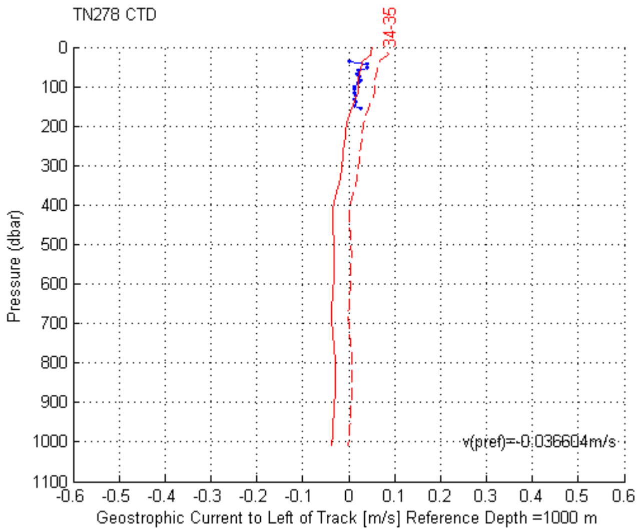

TN278 CTD
29-30
Pressure (dbar)
v(pref)=-0.07718m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
18-May-2012 10:58:55

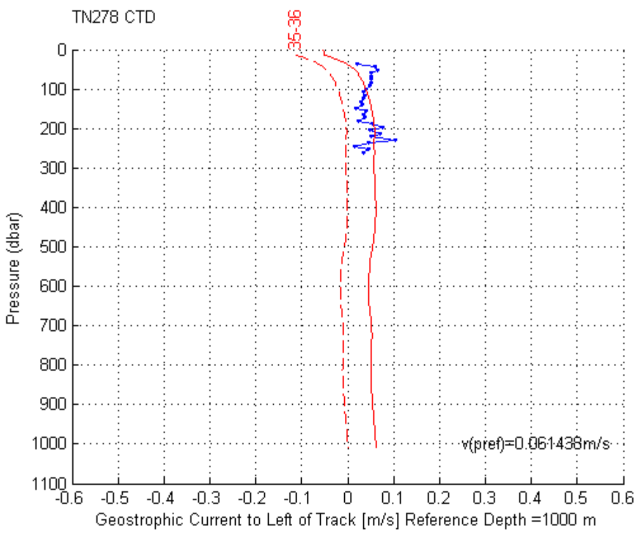

TN278 CTD
30-31
Pressure (dbar)
v(pref)=-0.066165m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

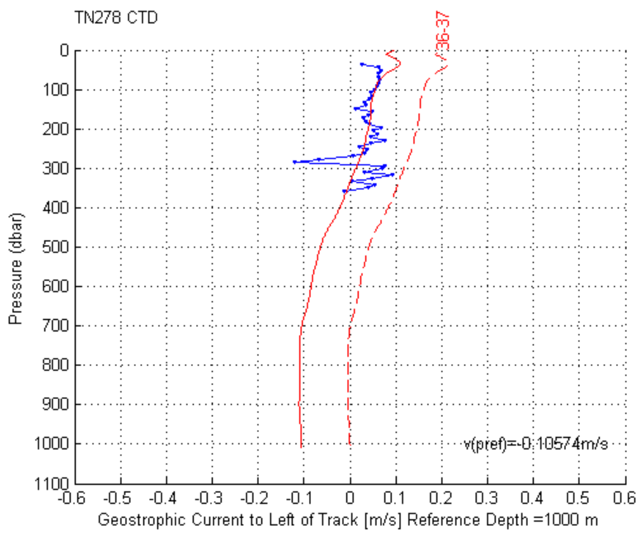

TN278 CTD
31-32
Pressure (dbar)
v(pref)=0.12106m
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 r


TN278 CTD
32-33
Pressure (dbar)
v(pref)=-0.0597m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m









<u>Set 4:</u> Plots of Current Speed (m/s) against Pressure (dbar)

Blue – Time average of ADCP across-track current component at each depth bin for which no NaN values were encountered in a CTD station pair interval

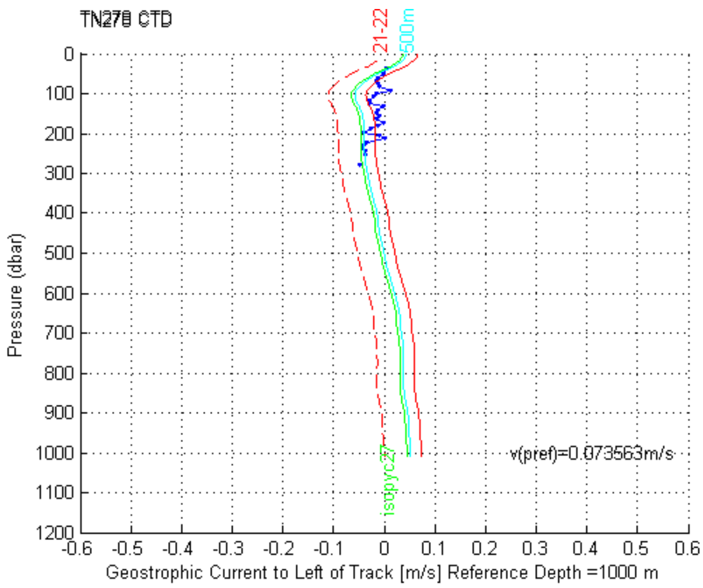
Dashed Red – Geostrophic Currents referenced to 1000m

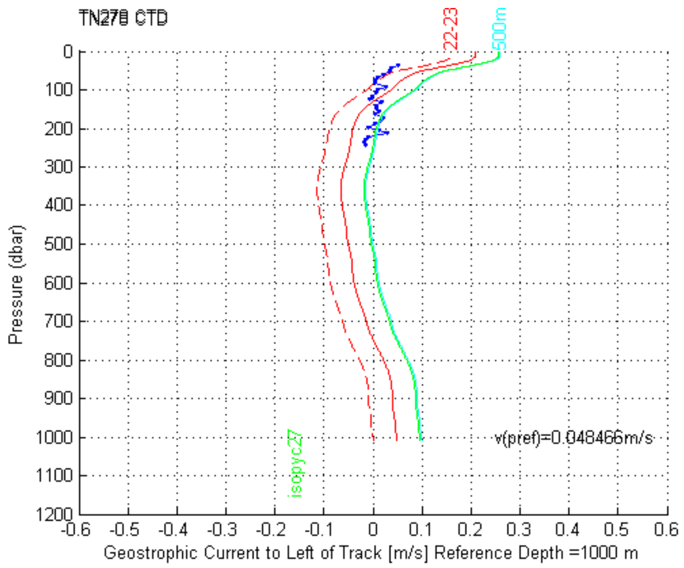
Red – Geostrophic currents with correction

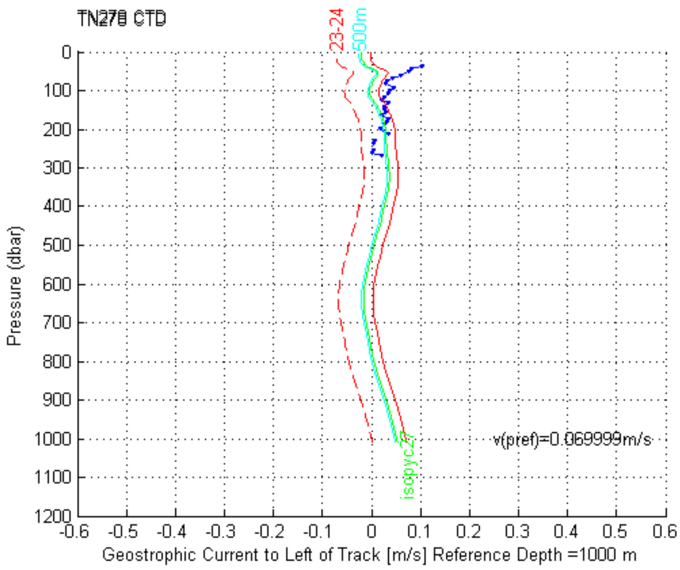
Cyan – Geostrophic currents referenced to 500m

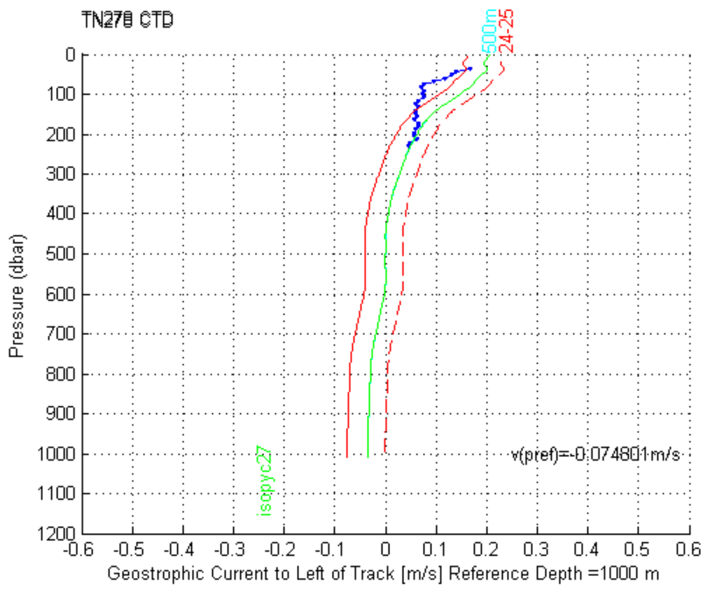
Green – Geostrophic currents referenced to the 27kg/m^3 isopycnal

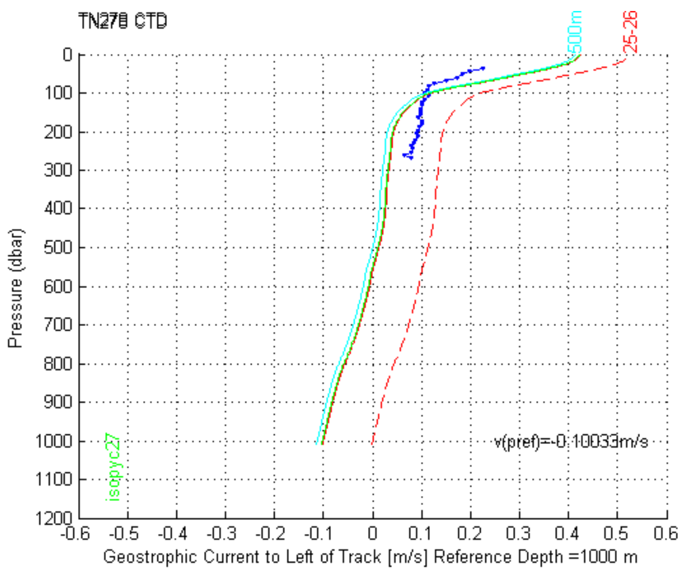
V(pref) – Velocity at reference depth (according to correction)

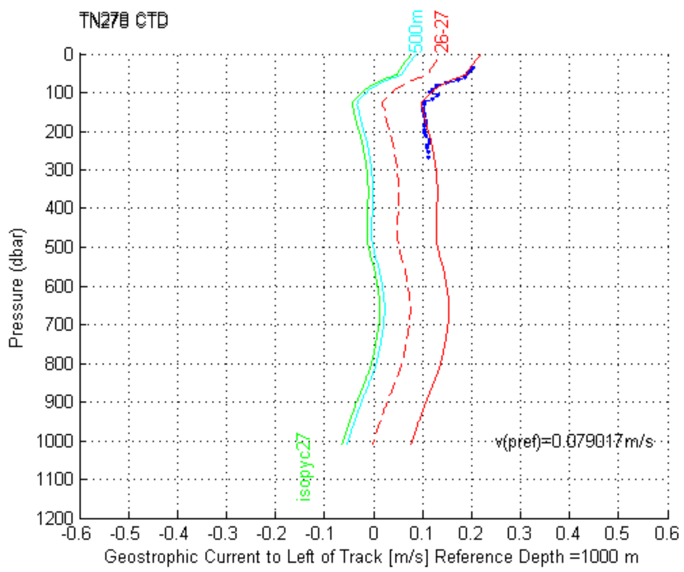

TN278 CTD
21-22
500m
isopyc27
v(pref)=0.073563m/s
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

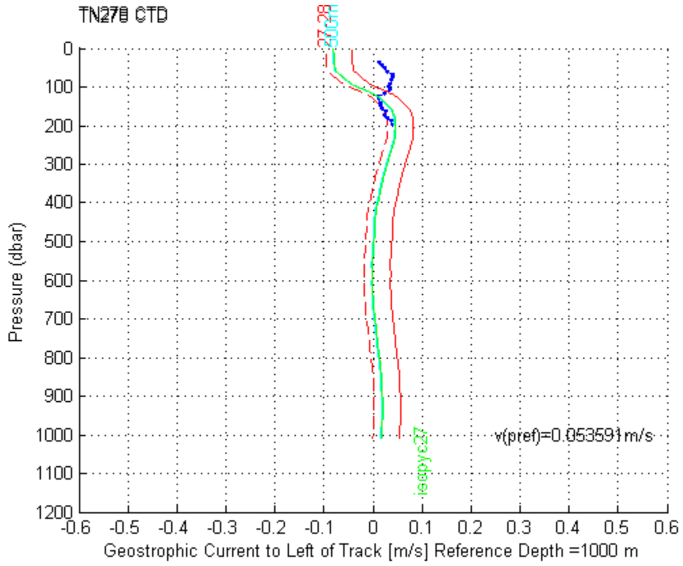

TN278 CTD
22-23
500m
isopyc27
v(pref)=0.048466m/s
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

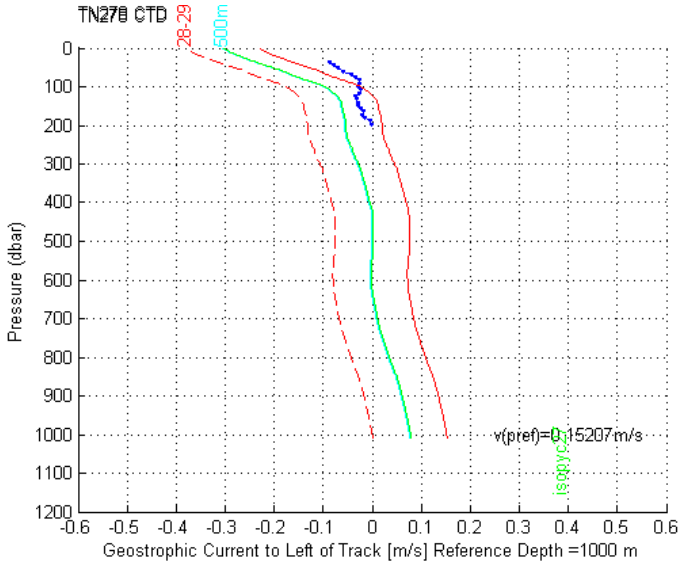

TN278 CTD
23-24
500m
isopyc27
v(pref)=0.069999m/s
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

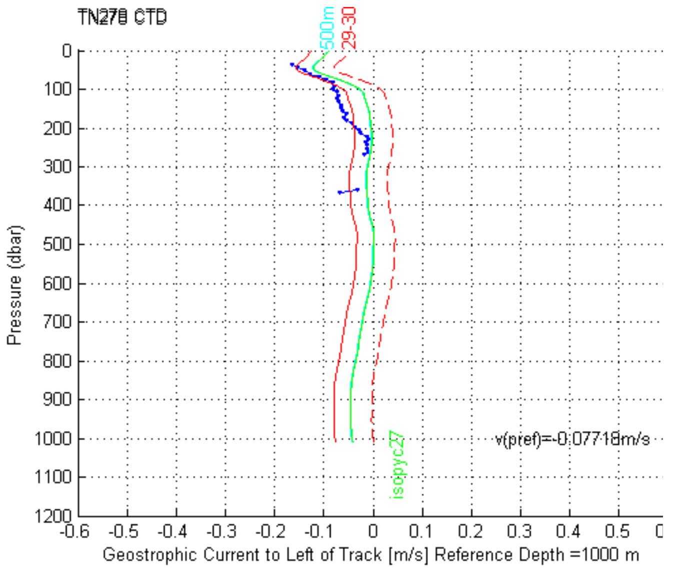

TN278 CTD
500m
24-25
isopyc27
v(pref)=-0.074801m/s
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

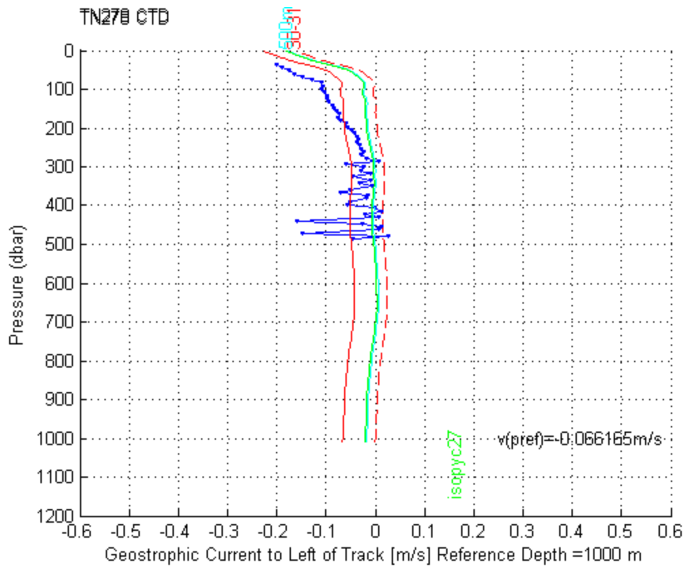

TN278 CTD
500m
25-26
isopyc27
v(pref)=-0.10033m/s
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

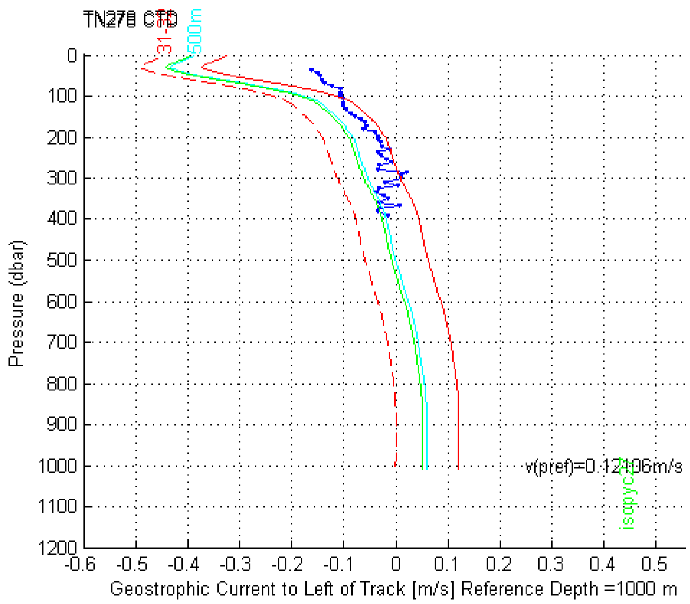

TN278 CTD
500m
26-27
isopyc27
v(pref)=0.079017m/s
Pressure (dbar)
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

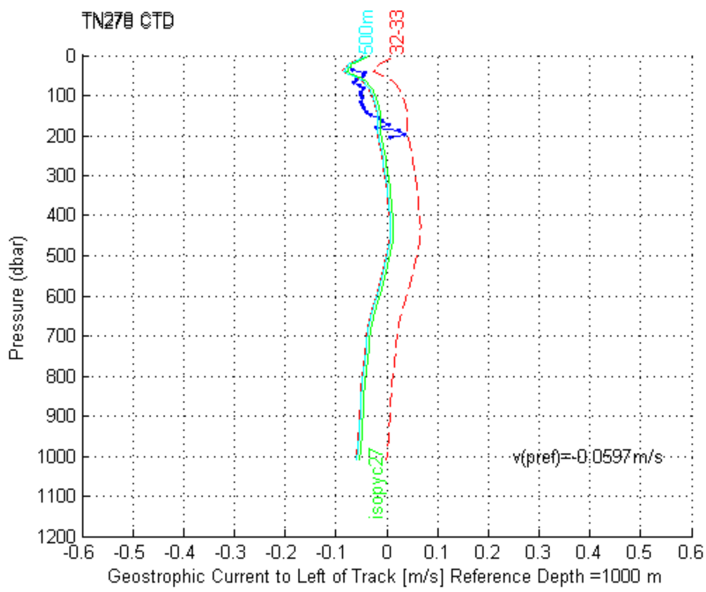

TN278 CTD
27-28
500m
Pressure (dbar)
v(pref)=0.053591m/s
isopyc27
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m

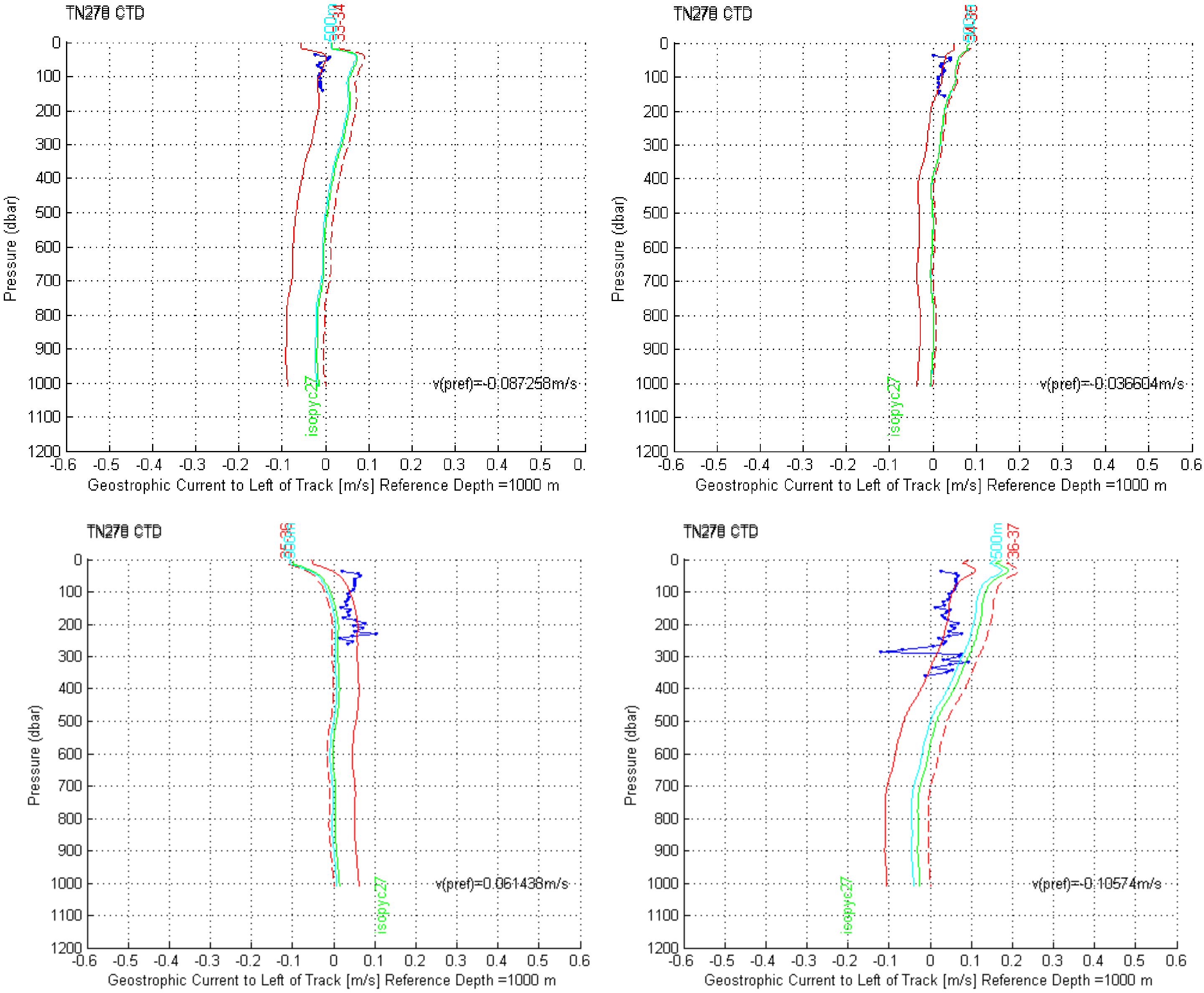

TN278 CTD
28-29
500m
Pressure (dbar)
v(pref)=0.15207m/s
isopyc27
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m


TN278 CTD
500m
29-30
Pressure (dbar)
v(pref)=-0.07718m/s
isopyc27
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m


TN278 CTD
500m
30-31
Pressure (dbar)
v(pref)=-0.066165m/s
isopyc27
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m


TN278 CTD
500m
Pressure (dbar)
v(pref)=0.12106m/s
isopyc27
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m


TN278 CTD
500m
32-33
Pressure (dbar)
v(pref)=-0.0597m/s
isopyc27
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m



Set 5 Plots of Current Speed (m/s) against Pressure (dbar) for the ≈12hour separated stations

Blue – Time average of ADCP across-track current component at each depth bin for which no NaN values were encountered in a CTD station pair interval

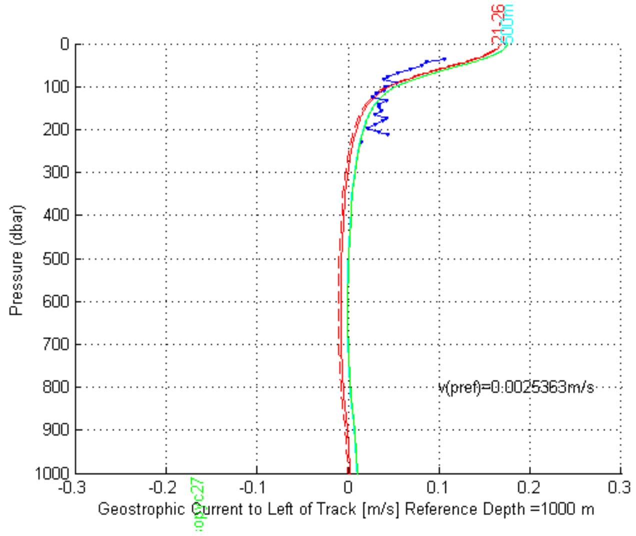
Dashed Red – Geostrophic Currents referenced to 1000m

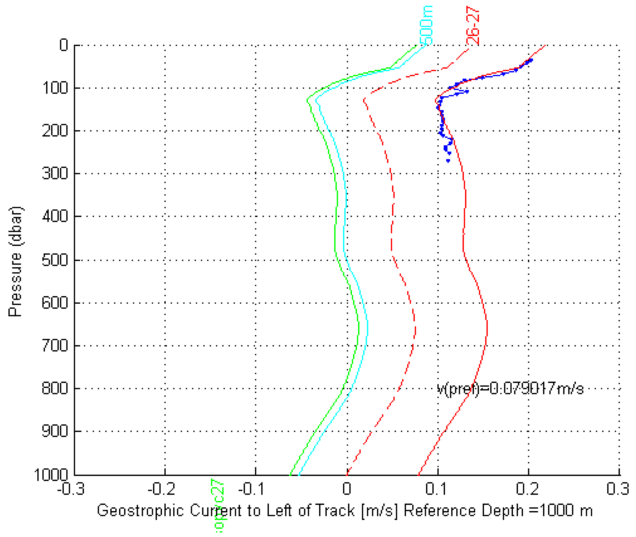
Red – Geostrophic currents with correction

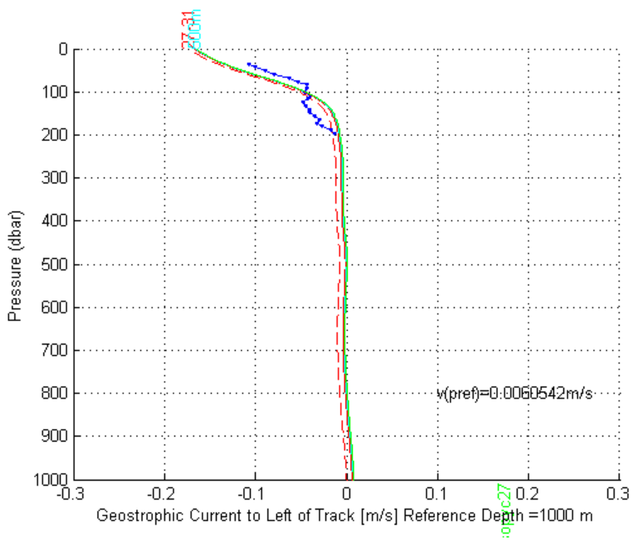
Cyan – Geostrophic currents referenced to 500m

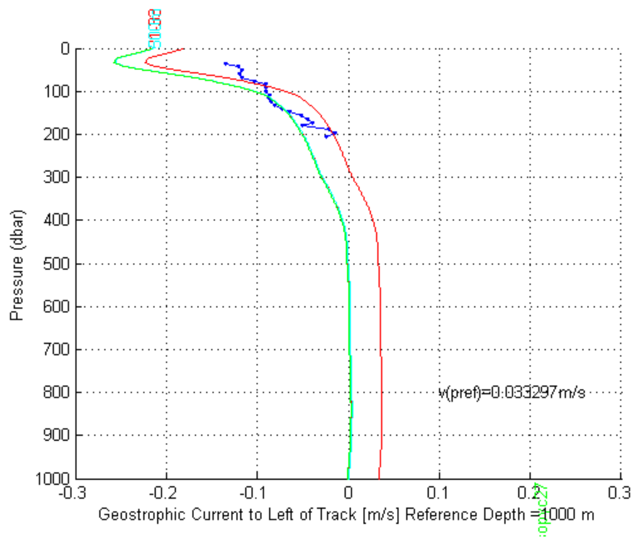
Green – Geostrophic currents referenced to the 27kg/m^3 isopycnal

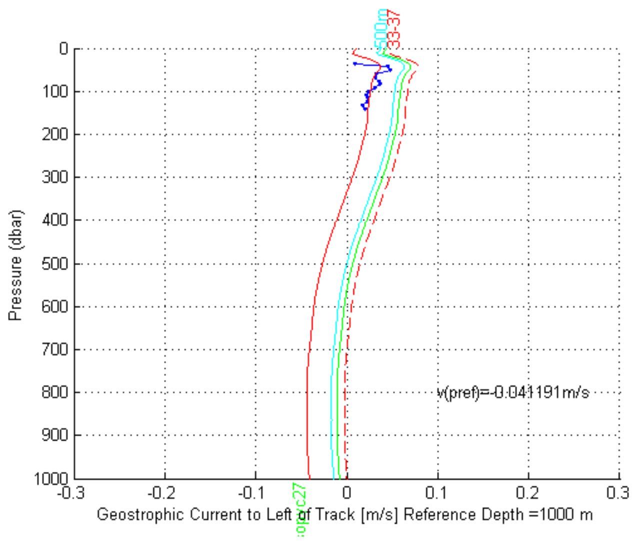
V(pref) – Velocity at reference depth (according to correction)


21-26
500m
Pressure (dbar)
v(pref)=0.0025363m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
oprc27


500m
26-27
Pressure (dbar)
v(pref)=0.079017m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
oprc27


27-31
500m
Pressure (dbar)
v(pref)=0.0060542m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
oprc27


Pressure (dbar)
v(pref)=0.033297m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
oprc27


500m
33-37
Pressure (dbar)
v(pref)=-0.041191m/s
Geostrophic Current to Left of Track [m/s] Reference Depth =1000 m
oprc27