The Credibility of Extrapolated Geostrophic Currents

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Background

In 1976, Reid and Mantyla (JGR 81:3100-10) demonstrated that the elevation of the sea surface measured by coastal tide gages agrees with the steric height (geopotential anomaly). Their results depend on two factors: the use of a reference level sufficiently deep to have negligible variability, and a procedure for extrapolating steric heights relative to the deep reference level into the shallow waters of the inner shelf.

The agreement between extrapolated steric height and coastal sea level is demonstrated here for data from the 1981-1984 CODE and SuperCODE experiments, which obtained time-series of 40-hour low-passed coastal sea level data from tide gages at Charleston, Crescent City, and Pt. Arena, and CTD sections along the FM, CR and COC lines (Figure 1). For each CODE and SuperCODE CTD section we used the Reid and Mantyla extrapolation technique (see Figure 2) to calculate geopotential anomalies for upper slope and shelf stations relative to 500 dbar.

Figure 3 shows the importance of shelf and upper slope waters in determining steric height at the coast. The steric height at the station just offshore of the 500 m isobath is only weakly or moderately correlated with coastal sea level and regression coefficients are much less than one. The steric height at the inner shelf station is highly correlated with sea level, and regression coefficients are very close to one. Thus we are confident that the Reid and Mantyla extrapolation technique captures important density variations over the shelf and upper slope.

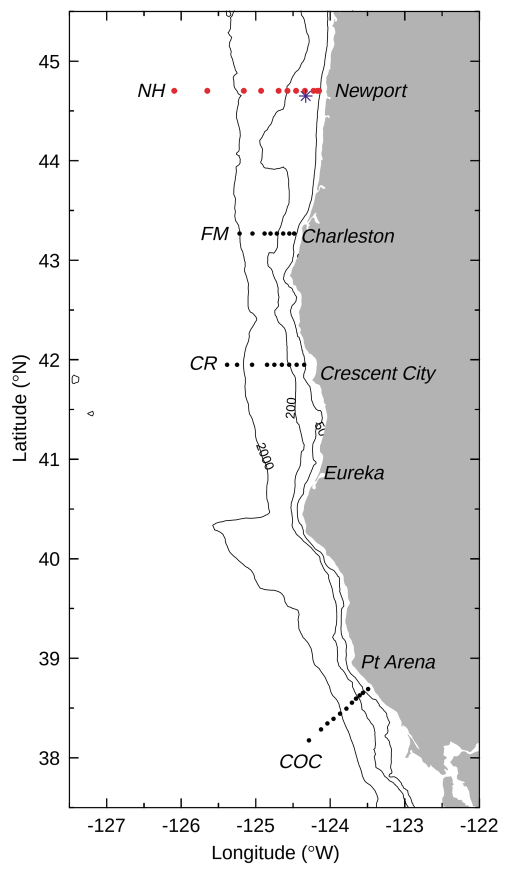

Figure 1. CTD stations in CODE and SuperCode (1981-1984, black) and in GLOBEC NEP (1997-2000, black and red). Also shown is the GLOBEC bottom-mounted ADP mooring at NH-10 (blue asterisk). Coastal tide gages at Charleston, Crescent City and Pt. Arena were operating during the 1981-84 period.

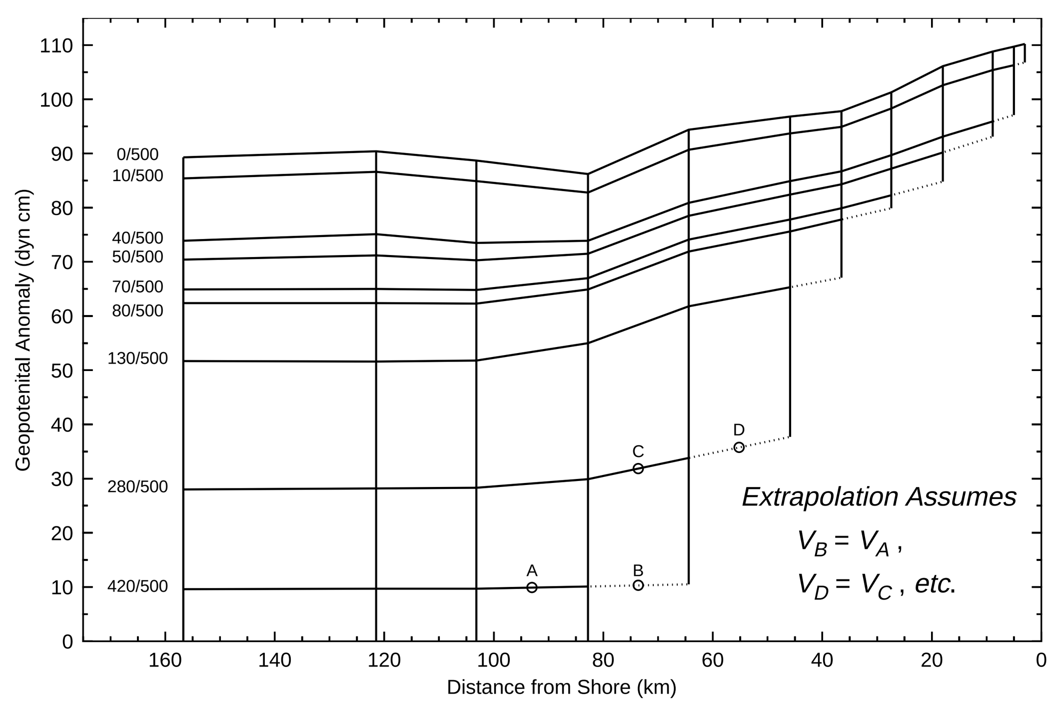

Figure 2. Sample of extrapolation of geopotential anomaly relative to 500 dbar from offshore deep water across the upper continental slope to the inner shelf using CTD data from the Newport Hydro Line, November 1997. Vertical lines represent CTD profiles; horizontal and oblique lines represent isobars. Dashed lines represent the extrapolated portions of isobars. For further details on extrapolation technique see Reid and Mantyla (1976, JGR, 81:3100-3110).

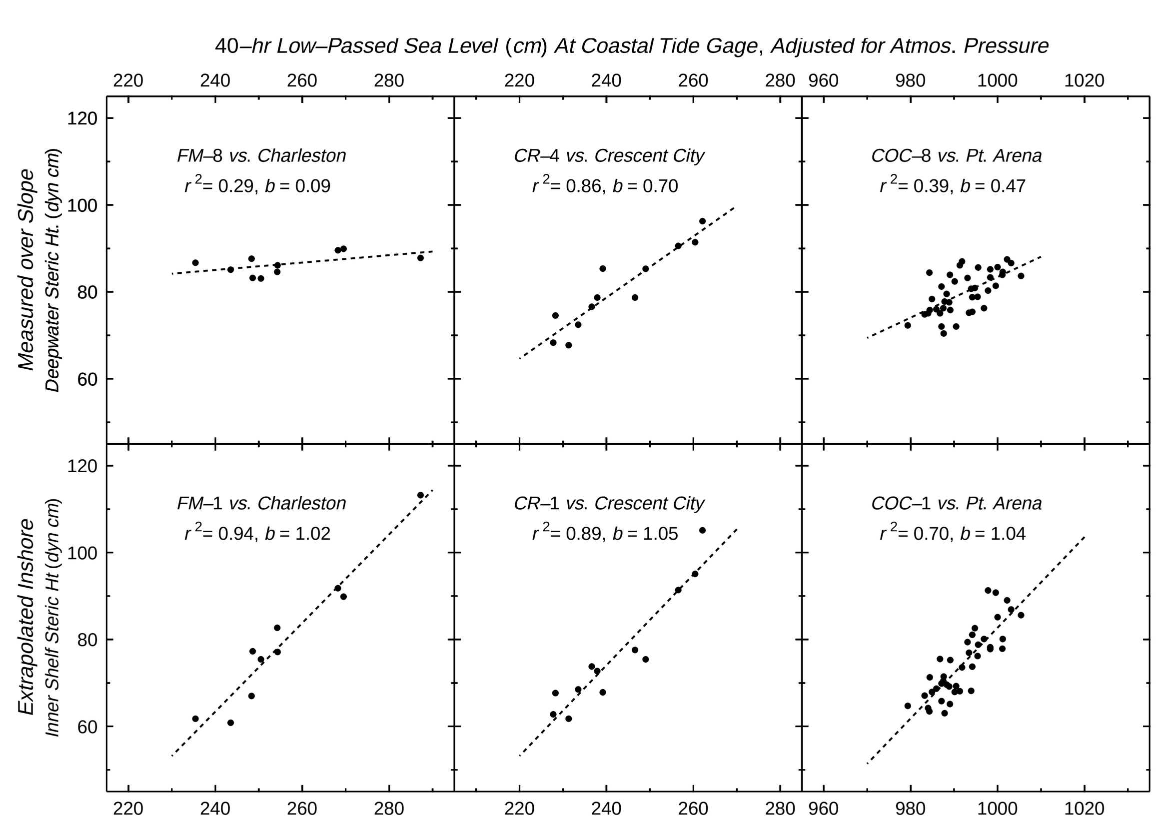

Figure 3. Comparison of surface steric heights (0/500) with 40-hour low-passed coastal tide gage data during CODE and SuperCode. Top row shows the deep-water steric height measured at stations just offshore of the 500 m isobath. Bottom row shows the steric height calculated for the inner shelf by extrapolation (see Figure 2). The slopes (b) of the regression lines in the lower panels are nearly exactly one.

Recent GLOBEC Sampling of the Newport Hydrographic Line

Since July 1997, the Newport Hydrographic Line (red dots in Figure 1) has been sampled seasonally from the inner shelf to 160 km offshore. Each section includes conventional CTD casts and continuous operation of the ship's Acoustic Profiler (150 kHz ADCP). Standard CTD station spacing is 9 km or less over the shelf, 18 km over the slope, and 36 km offshore. CTD casts sampled 90 percent of the water column over the shelf and upper slope, and sampled to 1000 dbar offshore. Using CTD data, geostrophic velocities in water shallower than 500 m were calculated relative to 500 dbar by extrapolating the offshore reference level into shallow water (Figure 2).

Vertical sections of extrapolated geostrophic velocities (Figure 4) and shipborne ADCP data (Figure 5) show broad similarities on the large cross-shelf scales – and both reveal anomalously strong poleward flow over the shelf during the fall and winter of El Niño 1997-98.

For most of the time there has also been a moored Acoustic Doppler Profiler (ADP) at mid-shelf providing a continuous record of currents (Figure 6). Comparisons of the mid-shelf extrapolated geostrophic current profiles with those from both the contemporaneous ship-borne ADCP and the moored ADP show reasonable agreement (Figure 7).

A quantitative comparison of the extrapolated geostrophic currents at "NH-12" (i.e., between CTD stations NH-10 and NH-15) with the ship-borne ADCP data averaged between NH-10 and NH-15 and low-pass filtered data from the moored ADP at NH-10 shows very good agreement in the upper half of the water column (Figure 8).

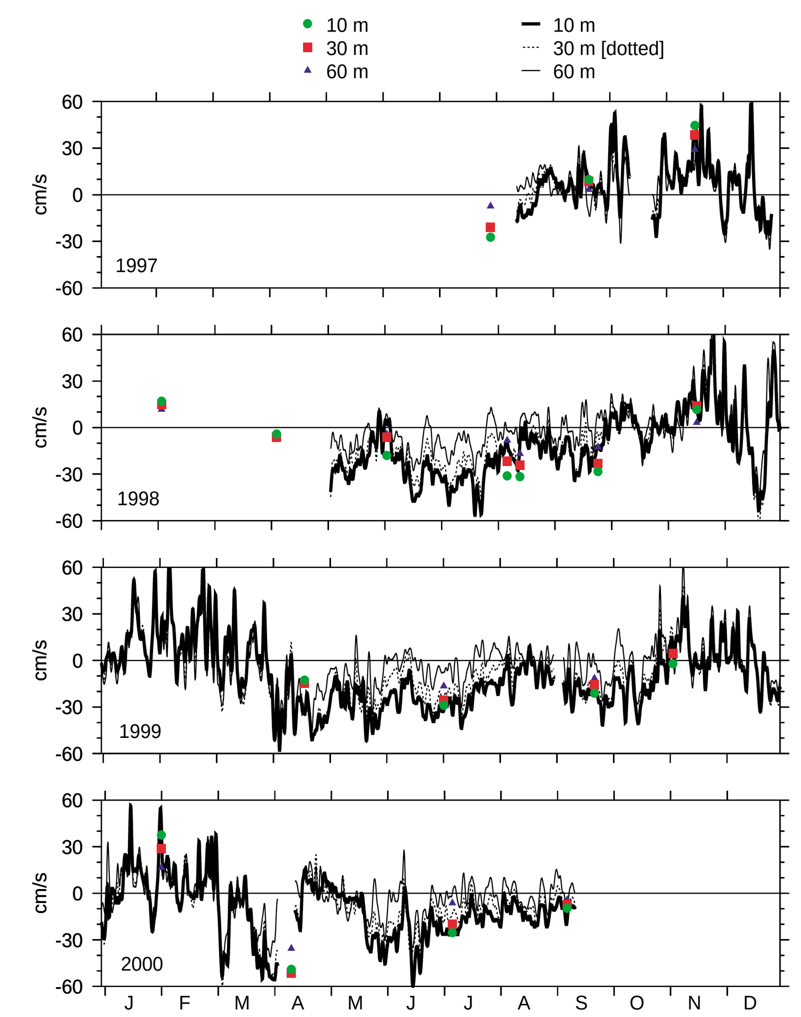

Figure 6. Low-passed (40-hr) time series of north-south (alongshore) current at depths of 10, 30 and 60 m from the ADP mooring at NH-10. Superimposed are the corresponding geostrophic velocities at the midpoint between NH-10 and NH-15.

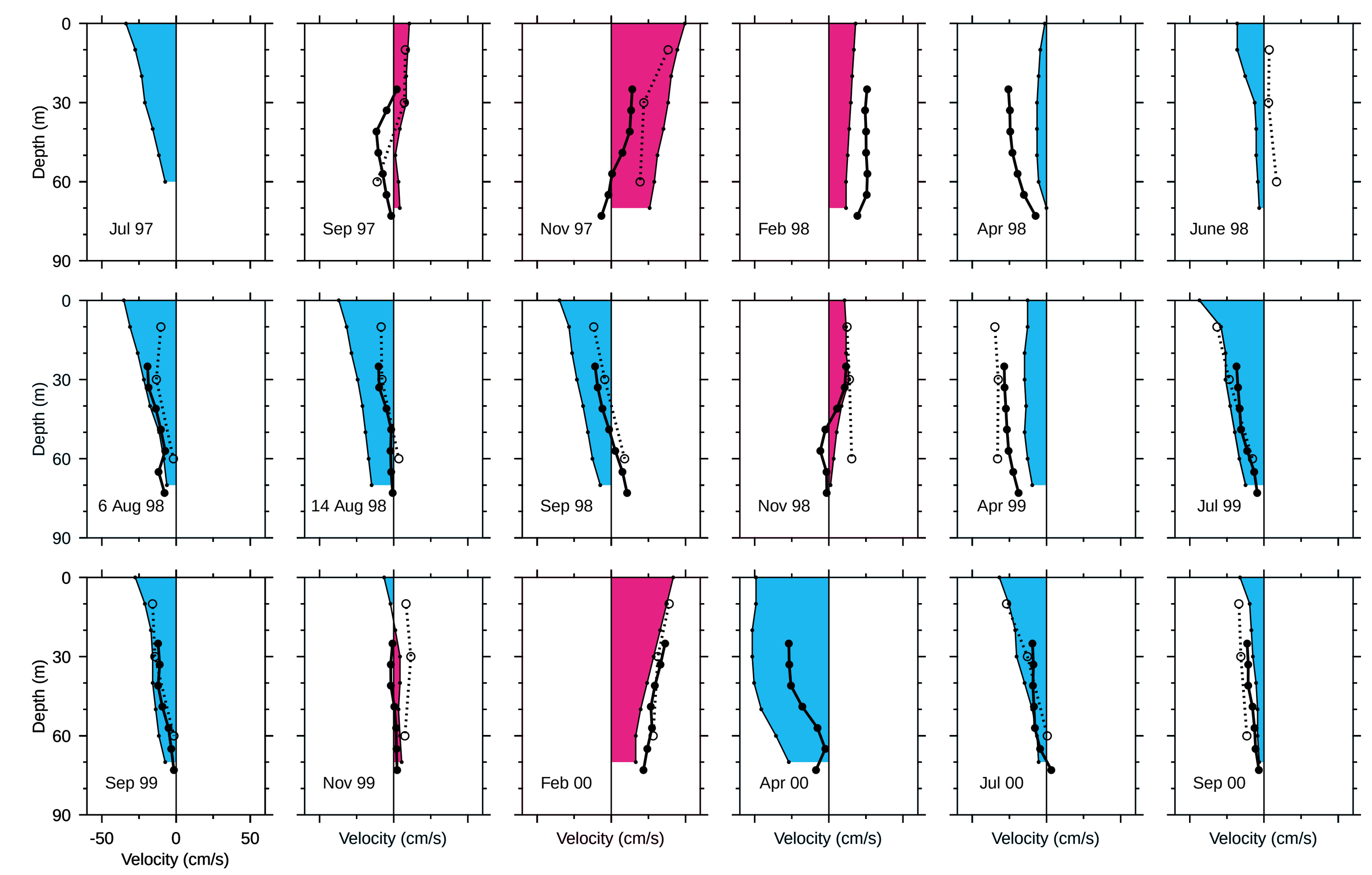

Figure 7. Vertical profiles of the north/south (alongshore) geostrophic current (filled) between NH-10 and NH-15, the north-south component of the gridded ship-borne ADCP data (solid dots, heavy curve), and the north-south component of the 40-hr low-passed current at the NH-10 ADP mooring (open dots, dashed curve).

Geostrophic Velocity Across the NH-Line

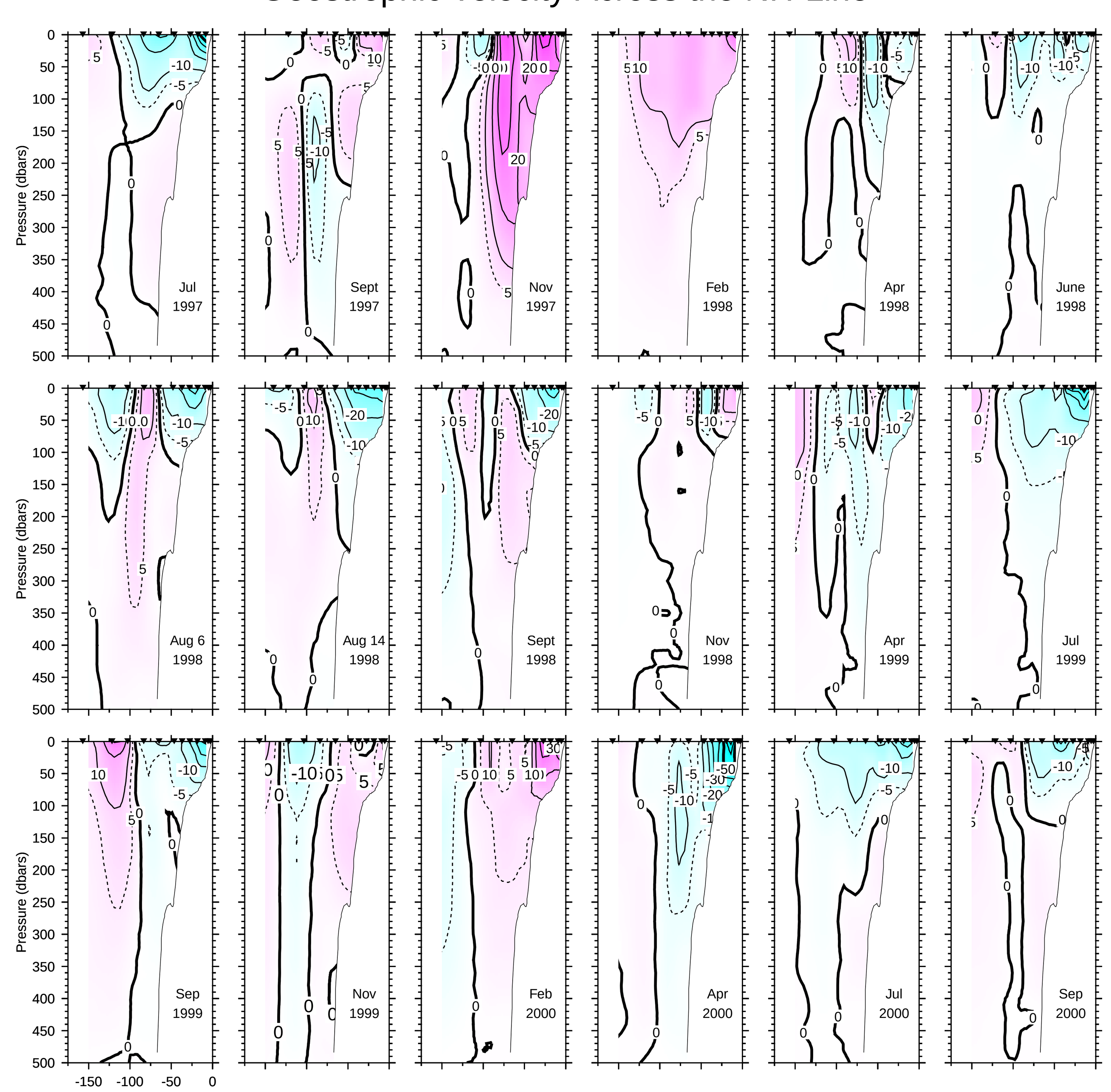

Figure 4. Geostrophic velocity (relative to 500 dbar) along the Newport Hydrographic Line, 1997-2000. Magenta indicates northward flow, cyan indicates southward flow. Normal contour interval is 10 cm/sec; dashed curves indicate the +5 and -5 cm/sec contours. Inverted triangles indicate CTD station postions.

North/South ADCP Velocity on the NH-Line

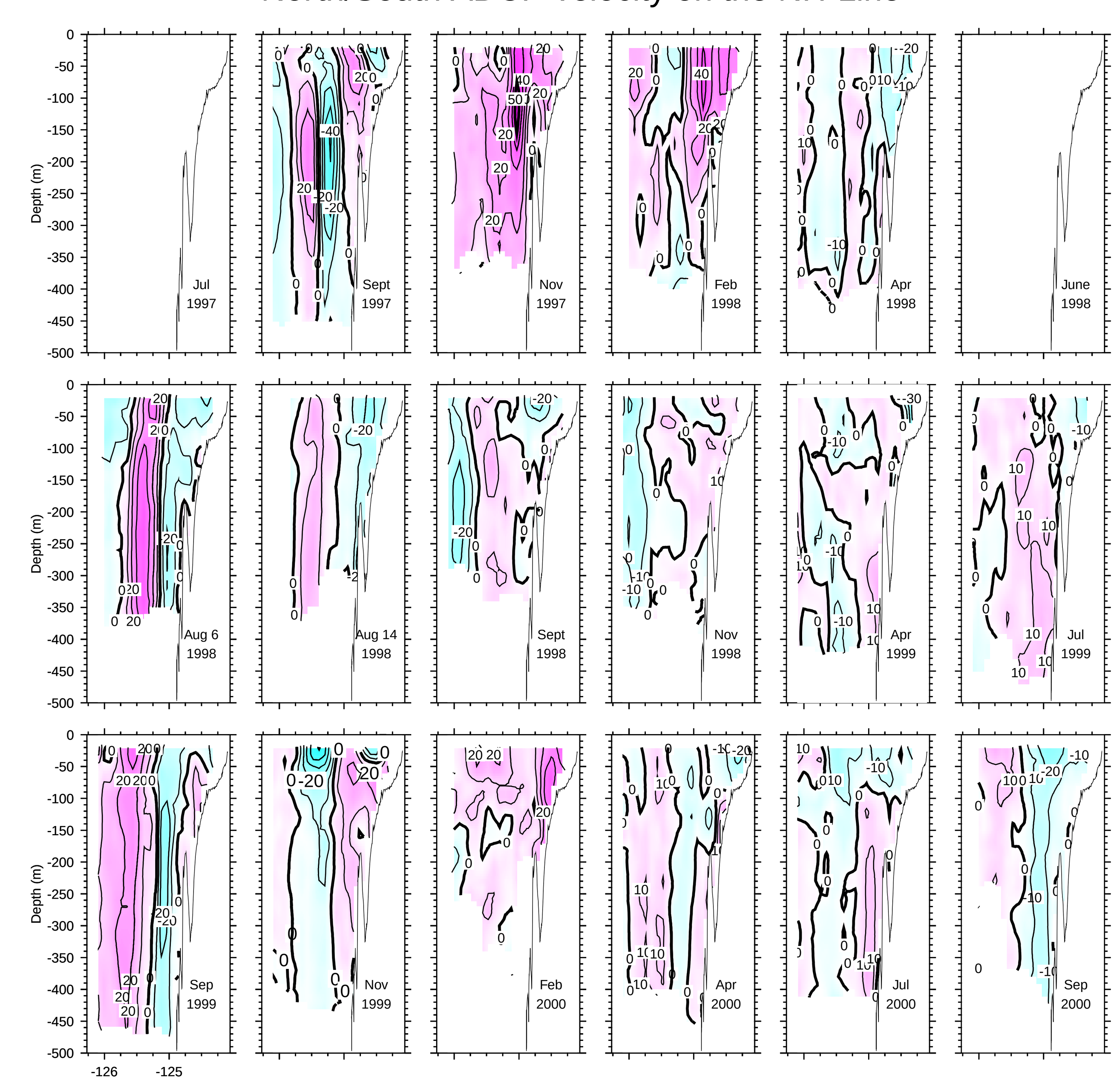

Figure 5. Alongshore velocity measured by ship's ADCP along the Newport Hydrographic Line, 1997-2000. Magenta indicates northward flow, cyan indicates southward flow. Contour interval is 10 cm/sec.

Comparisons of Midshelf Geostrophic and Measured Velocity

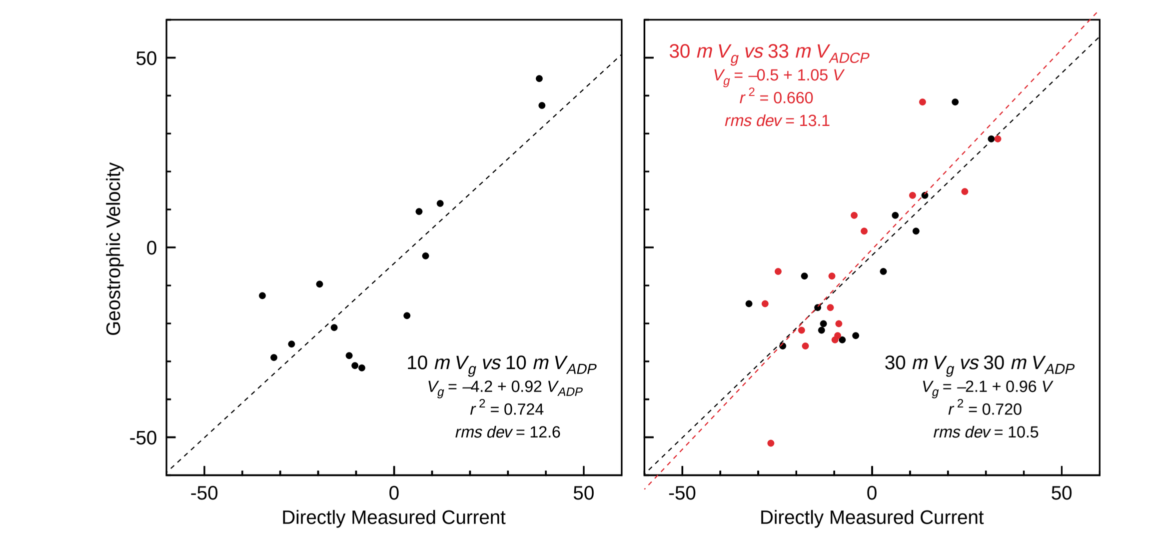

Figure 8. The comparison between the extrapolated geostrophic current at "NH-12" and the along-shore current from the moored ADP at NH-10 (black dots), and from ship-borne ADCP averaged between NH-10 and NH-15 (red dots) shows very good agreement. (The data points are the upper water column subset of those shown in Figure 7.)

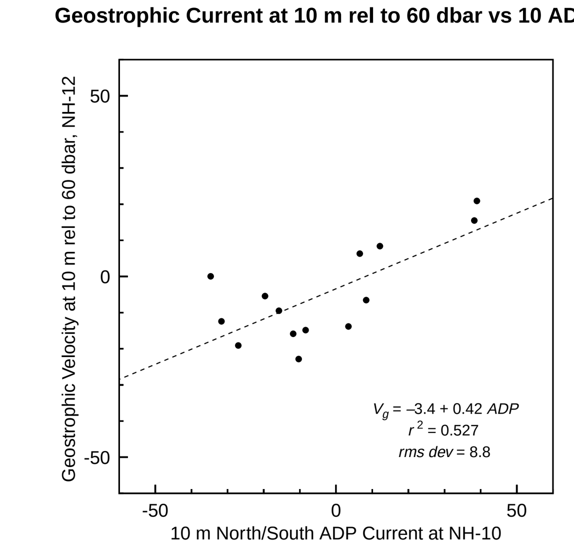

Figure 9. If, instead of using extrapolated geostrophic currents referenced to 500 dbar, we simply use a shallow reference level of 60 dbar, the results are not as good. This shows the importance of the upper slope waters in estimates of the currents over the shelf.

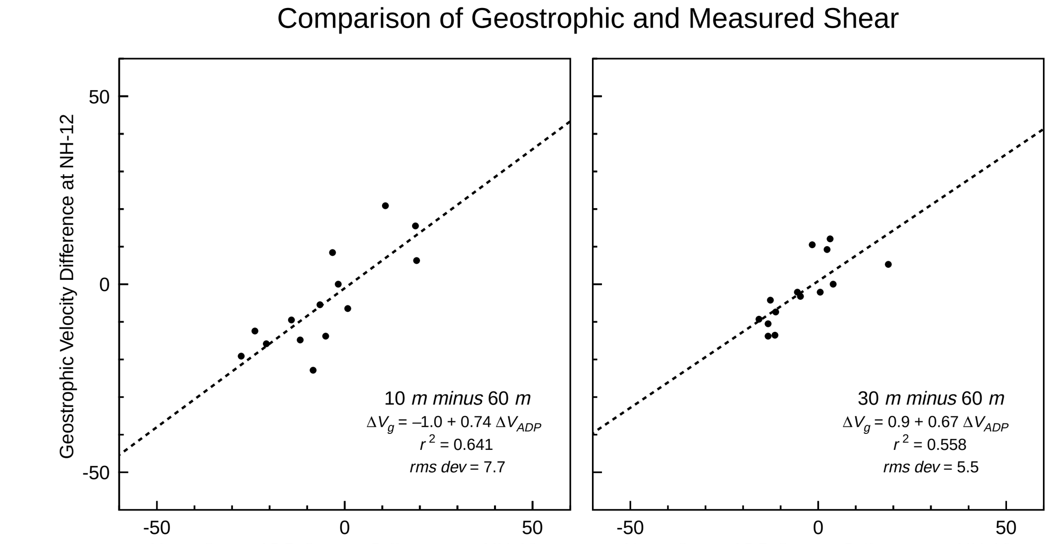

Figure 10. The geostrophic shear between 10 m and 60 m at "NH-12" is in very good agreement with the ADP shear at NH-10.

Conclusions

Vertical sections of extrapolated geostrophic velocities and shipborne ADCP data show broad similarities on large cross-shelf scales: Summer sections show equatorward flow over the shelf, and a poleward undercurrent over or near the upper slope. Winter sections show broad poleward flow over the shelf and upper slope, particularly during the El Niño fall and winter of 1997-98. Spring sections show equatorward flow over the inner shelf and poleward flow offshore.

Comparisons between mid-shelf geostrophic velocities show very good agreement with measured currents in both direction and magnitude, with regression slopes close to 1.0 and intercepts close to 0. RMS deviations of mid-shelf geostrophic currents from measured currents are about 10 cm/sec, much smaller than the seasonal range of the along-shore current, and much smaller than the day-to-week variations in winter, but similar in magnitude to the day-to week variations during summer.

We conclude that extrapolated geostrophic velocities can be used to study interannual variations of shelf currents for periods when hydrographic observations, but no direct current measurements, are available (e.g., off Newport, 1961-1971).

Acknowledgments

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