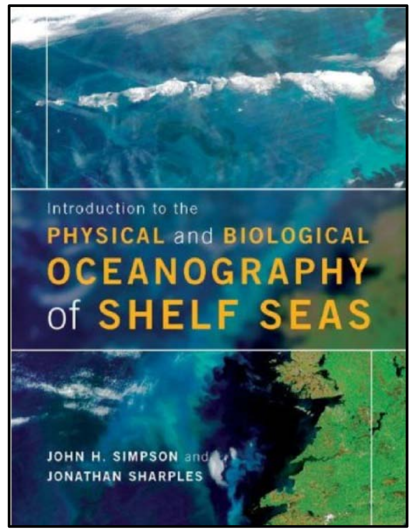
Observational Data

Shelf Edge



Data Source:

This data was collected off the NE shelf of New Zealand's North Island, during cruise CR3026 aboard RV *Tangaroa* in November 1995.

Data Acknowledgement:

Data is supplied courtesy of NIWA (National Institute of Water and Atmospheric Research Ltd., New Zealand). Funding for the project came from New Zealand's Foundation for Research in Science and Technology.

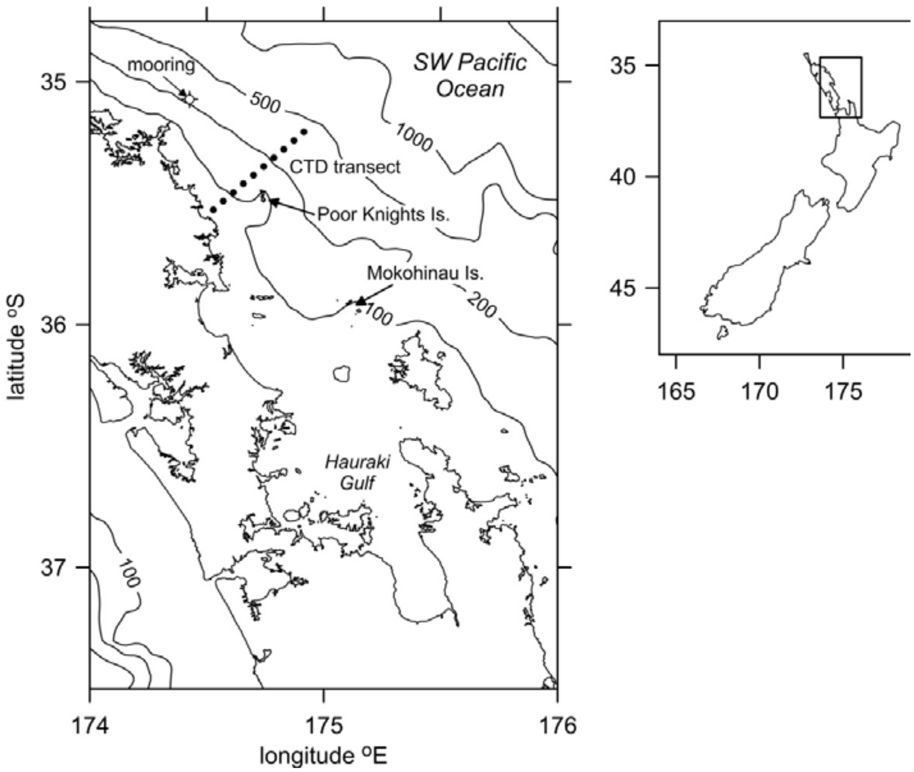
Summary of data uses:

Contoured sections of salinity, temperature, density and nutrients across a shelf edge; calculation of geostrophic current sections; identification of bottom Ekman layers at the shelf edge; tidal and mean flows at the shelf edge; upwelling events and estimating nitrate supply to the shelf.

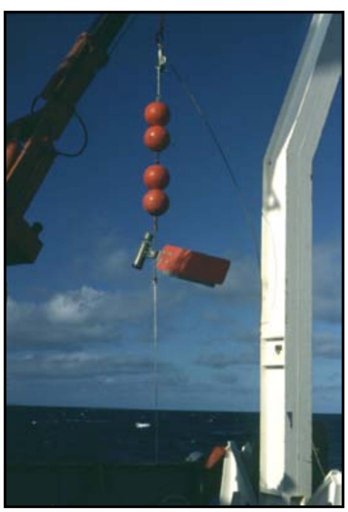
Oceanographic Background and Useful Papers:

New Zealand sits in the path of the SW Pacific sub-tropical gyre. The western boundary current of this gyre is the East Australia Current, which flows down the Australian coast and then heads eastward across the Tasman Sea. This current passes around the north of New Zealand, and flows as a re-attached western boundary flow southeastward along the slope of NE New Zealand. This sub-tropical surface water is warm and salty. It is usually constrained to follow the shelf slope, though summer stratification and strong northwestward winds have been shown to lead to sub-tropical water crossing onto the shelf. Barotropic tides on the NE shelf of New

Zealand tend to be very weak. However, there is a large internal tide that is a significant source of vertical turbulent mixing.



Location map for the CTD stations (●) and the mooring site (⌖).



An Aanderaa recording current meter being deployed

RV *Tangaroa* by the Poor Knights Islands, NE New Zealand

Useful papers:

Sharples, J., 1997. Cross-shelf intrusion of subtropical water into the coastal zone of Northeast New Zealand. *Continental Shelf Research*, **17(7)**, 835-857.

Sharples, J., & M. J. N. Greig, 1998.Tidal currents, mean flows, and upwelling on the northeast shelf of New Zealand. *New Zealand Journal of Marine and Freshwater Research,* **32(2)**, 215-231.

Sharples, J., C. M. Moore, E. R. Abraham. 2001. Internal tide dissipation, mixing, and vertical nitrate flux at the shelf edge of NE New Zealand. *Journal of Geophysical Research*, **106 (C7)**, 14,069-14,081.

Zeldis, J. R., 2004. New and remineralised nutrient supply and ecosystem metabolism on the northeastern New Zealand continental shelf. Continental shelf Research, 24(4-5), 563-581.

Data:

1. A cross-shelf transect of CTD stations, including nitrate and phosphate concentrations from analysis of bottle sample.
2. Time series of near-surface and near bed currents and temperatures from moored Aanderaa current meters.
3. Wind speed and direction time series covering the time of the mooring.

Data Files:

CTD data:

10 files `V556pro.dat - V565pro.dat`.

The transect of stations began on November 18th 1995, and was completed on November 19th 1995.

Data columns are:

pressure (dbar), depth (metres), temperature (ºC), salinity (PSS), σ_t (kg m^{-3})

Data were collected with a Seabird 911 plus CTD system, and post-processed to 1Hz averages. Salinity accuracy is ±0.002, temperature accuracy is ±0.002 ºC.

CTD positions are spaced approximately 6.7 km apart.

Each CTD profile reached to approximately 10 metres above the seabed.

CTD Positions:

CTD file	Latitude (ºS)	Longitude (ºE)
V556pro.dat	35.206	174.917
V556pro.dat	35.243	174.872
V556pro.dat	35.278	174.830
V556pro.dat	35.313	174.787
V556pro.dat	35.348	174.744
V556pro.dat	35.384	174.701
V556pro.dat	35.420	174.657
V556pro.dat	35.457	174.615
V556pro.dat	35.491	174.571
V556pro.dat	35.527	174.528

Nutrient data:

The spreadsheet `NZ_nutrient_data.xlsx` contains the results of chemical analyses for nitrate and phosphate (both mmol m^{-3}) carried out on bottle samples collected during the CTD profiles.

Mooring data:

A mooring was deployed at 35.071 ºS, 174.427 ºE, 10 nautical miles NE of Cape Brett early in the morning of November 18th 1995. Total water depth was 211 metres. The mooring consisted of 2 Aanderaa recording current meters (RCM7), one 5 metres above the seabed and one 175 metres above the seabed. Sample interval was 30 minutes between 0600 NZST 18th November 1995 to 0900 NZST 31st January 1996.

`CapeBrettCurrentmeter_surface.dat` contains the data from the RCM 175 metres above the bed.

`CapeBrettCurrentmeter_bed.dat` contains the data from the RCM 5 metres above the bed.

Data columns are:

time (decimal days from 0000 hrs 1st January 1995), current direction (º from N), current speed (cm s^{-1}), temperature (ºC).

Wind data:

Wind speed and direction data were acquired from an automatic weather station on the nearby Mokohinau Islands.

`MokohinauWinds.dat` contains hourly wind speed and direction information from 0000 hrs NZST 13th November 1995 to 0000 hrs NZST 1st February 1996.

Data columns are:

Time (decimal days from 0000 hrs NZST 1st January 1995), wind direction (º from N), wind speed (m s^{-1}). Note that the wind direction is that *towards* which the wind blows.

Note: NZST (New Zealand Standard Time) is used as the common time reference for the current meter and the wind data. NZST is UTC + 12 hours.

Possible Analyses:

1. *Contouring a CTD and nutrient section.[Textbook Sections 10.3.2, 10.4].*
   There are several software packages available that can be used to plot a section of CTD data, including Matlab (www.mathworks.com), Surfer (www.goldensoftware.com), and Ocean Data View (odv.awi.de). Students would need to collate the data into a suitable file, including specifying the x-coordinate (cross-shelf). Starting simply by getting the students to contour data by hand on some graph paper is often very instructive as it encourages students to be more critical of the interpolated grids of data produced by software mapping tools. The nutrient data is good for the manual contouring as there is only a limited amount of it. The CTD data is suitable, but requires some sub-sampling in the vertical. The basic results across this section show the along-shelf edge (southeastward) flow of warm, salty sub-tropical water (the East Auckland Current). Isopycnals are all upwelling onto the shelf, which is a common feature of this region arising from upwelling under the along-shelf edge flow. The nitrate section is interesting as it shows the transfer of deep nitrate onto the shelf.

2. *Calculation of geostrophic flow through the CTD section. [Textbook Sections 3.3.2, 10.3.2].*

   A first estimate of the along-shelf edge flow in the East Auckland Current can be made by looking at the extent of the bottom Ekman layer in the CTD profiles. Determine the thickness of the bottom Ekman layer in each CTD profile by assessing the thickness of the bottom mixed layer. The current can be calculated following the method in problem 10.2. This can be further developed by calculating the Ekman flux and, using the nitrate data, estimating the supply of nutrients to the shelf.

   The geostrophic method (see Section 3.3.2 in the textbook) can be used to produce a section of along-shelf flow corresponding to the density section provided by the CTD profiles. Assume a level of no motion at the seabed. The calculated current field can then be compared to the estimates based on the Ekman layer thickness (see above), or to the current meter record (see below).

3. *Extraction of tidal and mean flows from current meter records. [Textbook Sections 2.5.1, 10.4].*

   Both the near-surface and near-bed current records show significant tidal variability, superimposed on a more slowly varying mean flow. Separating the tidal and mean components of the flow is useful, particularly if the current records are first rotated so that the y-axis is aligned with the shelf edge. The mean flows at the upper current meter correspond well with the estimates made in 2 above. Extracting the barotropic tide could utilise the simple harmonic analysis Matlab script (see end of this document), or a tidal analysis package (e.g. http://www.psmsl.org/train_and_info/software/analysis.php). The minimum tidal constituents to analyse for would be M2, S2, N2, O1, K1. Applying harmonic analysis to a whole time series of current data will quantify the barotropic tidal contributions. If these are then removed from the original data there will still be a lot of what looks like tidal variability left. This is the internal tide; because its phase does not remain constant, it is not picked out by a harmonic analysis of the whole time series. The vertical range of the internal tidal oscillations can be estimated by using the tidal oscillations in the near-surface current meter temperature record and an estimate of the vertical temperature gradient at the current meter from one of the nearby CTD profiles.

Removing the tidal variability completely, leaving the mean flow, can be done using a filter (e.g. in Matlab, or get the students to write their own script using, for instance, the Doodson X0 filter).

Note in the surface current record that there is a short period of suspiciously low flow around time=355 days. This occurs at the same time as a pulse of wind along the shelf that is down-welling favourable and which would counter the normally southeastward along-shelf edge flow. A sharp rise in surface temperature at this time suggests sub-tropical water has been advected past the mooring towards the shelf. I am not sure whether this is a real signal, or if something got caught briefly in the rotor on the current meter. Get the students to form their own, evidence-based, opinion.

4. *Analysis of upwelling of deep water and/or analysis of surface water transport onto the shelf. [Textbook Sections 3.5.3, 10.3.1, 10.6.1].*
Rotate the current reference frame to align along the shelf (e.g. positive y-axis to the northwest). Filter out the tidal variability in the currents and in the temperatures from both current meter records. Similarly rotate the wind reference frame to align with the shelf edge, so that the v-component can be easily interpreted as either upwelling (southeastward) or downwelling (northwestward).

First look at the along-shelf wind component and the near-bed temperature. There are several clear upwelling-favourable wind events which can be visually correlated quite easily with decreases in water temperature. Then have a look at the near-bed currents to see if there is an on-shelf component associated with the temperature drop. What is the time delay between the initiation of upwelling-favourable wind and development of the on-shelf flow? How does the surface mean flow respond over the wind event? You could also try a basic temperature-nitrate relationship from the nitrate data collected on the CTD transect (choose data below the surface layer) and get the students to think about the role of these events in supplying the shelf with nitrate.

A similar analysis can be carried out on the surface current meter record, looking this time for rapid rises in surface temperature associated with downwelling-favourable winds (e.g. look around days 355, 370 and 387). These temperature increases reflect the

Ekman transport of surface water towards the shelf (the sub-tropical water in the East Auckland current is warm).

```
function S=harmonic(time,data,w1)

% S=harmonic(time,data) fits a single tidal constituent to a time
% series of data.
% "time" = array of times associated with data (N rows x 1 column)
% "data" = array of observational data to be fitted (N rows x 1 column)
% "w1" = frequency (radians per unit time) to be analysed for in "data"
%
% Data is fitted to:
%       predicted = S(1)+S(2)*cos(w1*time)+S(3)*sin(w1*time)
%
% A solution is found to the matrix problem
%                               A.S=C
% where A is an array of cos, sin, and cross terms, C is the array made  %
up of combinations of the constituent terms and observations,
% and S is the array of estimated amplitudes for the tidal constituent.
%
%
N=length(data);                        % N is the number of data points
%
%
A1(1:N,1)=1;
A1(1:N,2)=cos(w1*time(1:N));
A1(1:N,3)=sin(w1*time(1:N));
%
A2=A1';        % A2 is the 3xN transpose of A1 (rows and columns swapped).
%
A=A2*A1;       % A is the 3x3 array required for the analysis procedure.
%
C=A2*data;     % C is the 3x1 righthand array of the problem.
%
S=A\C          % S is the 3x1 answer, which can be used to calculate the
%              predicted tidal variability.
%
% end of function
```