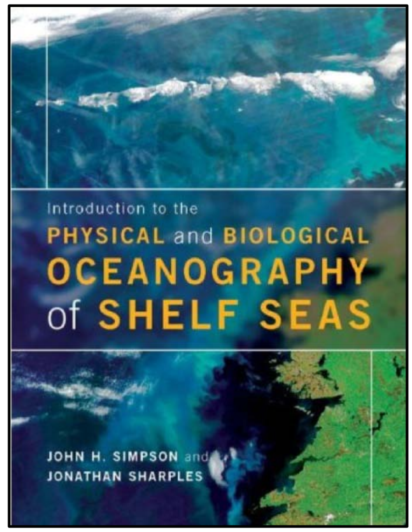
Observational Data

Stratification and flow in a ROFI



Data Source:

This data was collected from a long-term seabed ADCP mooring in Liverpool Bay as a part of the Liverpool Bay Coastal Observatory maintained by the UK National Oceanography Centre (see: http://cobs.pol.ac.uk/).

Data Acknowledgement:

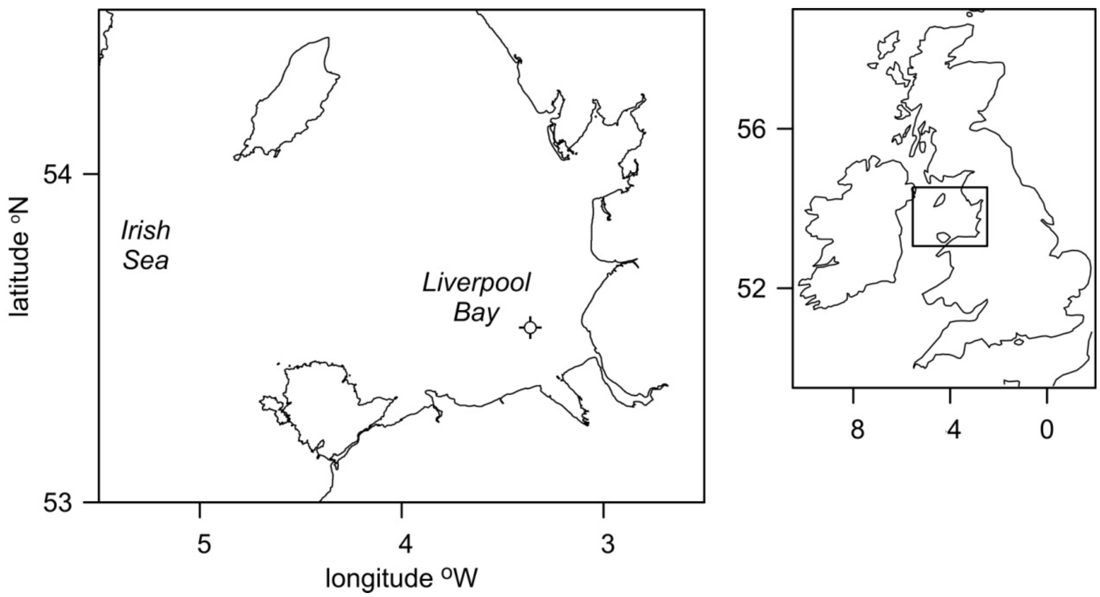
Data is supplied courtesy of the UK National Oceanography Centre. Processing carried out by Matthew Palmer and Juliane Wihsgott. Funding for the Coastal Observatory is provided by the UK Natural Environment Research Council.

Summary of data uses:

Calculation of tidal (via harmonic analysis) and residual flows; near-surface and near-bed mean flows in a ROFI; residual flow vertical profiles in a ROFI; cycles of stratification in a ROFI.

Oceanographic Background and Useful Papers:

Liverpool Bay is a ROFI (Region of Freshwater Influence) on the west coast of the United Kingdom. Freshwater inputs from rivers along the NW coast of England maintain a horizontal density gradient, with salinity increasing from the coast westward towards the Irish Sea. The density gradient drives a mean circulation, with denser, bottom water moving towards the coast and the less dense, surface water moving approximately seaward. The system is analogous to an estuary, but with the larger horizontal scale allowing significant influence of the Earth's rotation.



Location map for the mooring site (⌖).

Bed frame and ADCP ready for deployment in Liverpool Bay. The 600 kHz ADCP, with yellow protective cover, is on the left. The white and blue cylinder to the right contains the ADCP batteries. The yellow tubes provide the buoyancy to return the frame to the sea surface when the anchor weights are released for recovery. The weights are then recovered via a line spooled out of the brown cylinder on the far right of the frame.

Useful papers:

Polton, J. A., M. R. Palmer and M. J. Howarth, 2011. Physical and dynamical oceanography of Liverpool Bay. *Ocean Dynamics*, **61(9)**, 1421-1439.

Sharples, J. and J.H. Simpson. 1995. Semi-diurnal and longer period stability cycles in the Liverpool Bay region of freshwater influence. *Continental Shelf Research* **15(2/3)**, 295-313.

Verspecht, F., T. P. Rippeth, J. H. Simpson et al., 2011. Residual circulation and stratification in the Liverpool Bay region of freshwater influence. *Ocean Dynamics*, **59(5)**, 765-779.

Data:

All data is from a mooring at 53˚ 32' N 3˚ 21.8' W. Mean depth is 23.5 metres.

1. Time series of near-surface and near-bed currents recorded by a 600 kHz ADCP moored on a bed frame on the seabed.
2. Time series of vertical profiles of current velocity recorded by a 600 kHz ADCP moored on a bed frame on the seabed.
3. Time series of near-surface and near-bed temperature and salinity recorded by Seabird microcats, one attached to the ADCP bed frame and one beneath a surface buoy.

Data Files:

<u>ADCP data:</u>

All ADCP data are 10-minute averages with a vertical bin size of 1 metre. Positive flow is eastward or northward.

`A_2009_profile_array.dat`

Time series of vertical profiles of east and north velocity components. Each line of data is one complete profile. Note that the tide causes large variations in sea level; the height of the upper current measurement therefore varies, with NaN in regions of no data (i.e. above the sea surface).

Data columns are:

Time (decimal days, UTC, 2009), total depth (metres), followed by pairs of east and north velocity (cm s^{-1}) from the lowest depth bin to the highest depth bin. The height of the centre of the first (lowest) depth bin is 2.7 metres above the seabed.

`A_2009_nearbed_surf.dat`

Time series of near-bed and near-surface currents. These currents have simply been extracted from the file of vertical profiles of currents. The near-bed current is that in the bottom depth bin, centred 2.7 metres above the bed. The near-surface current is that of the last good data bin before the sea surface; this is approximately 2 metres below the sea surface.

Data columns are:

time (decimal days, UTC, 2009), near-bed east and north velocity (cm s^{-1}), near-surface east and north velocity (cm s^{-1}).

<u>Temperature and salinity time series:</u>

Over the same times as the ADCP data, time series of near-surface and near-bed temperature and salinity are also available.

`T_S_bed.dat`

10 minute temperature (ºC) and salinity (PSS) recorded by a SeaBird SEACAT logger attached to the ADCP bed frame (nominally 0.5 metres above the seabed).

`T_S_surf.dat`

10 minute temperature (ºC) and salinity (PSS) recorded by a SeaBird SEACAT logger attached below a surface buoy (nominally 5 metres below the seabed).

Data columns are:

Time (decimal days, UTC, 2009), temperature (ºC), salinity (PSS)

Possible Analyses:

1. *Near-bed and near-surface mean flows in a ROFI. [Textbook Sections 9.1, 9.2].*
   Use the current time series in `A_2009_nearbed_surf.dat` to calculate the mean, non-tidal flows near the seabed and near the sea surface. Simply calculating the averages of each data column yields the expected onshore near-bed flow and offshore near-surface flow. A more sophisticated analysis could involve harmonic analysis to remove the tidal part of the flow (e.g. adapting the script at the end of this document). Tidal constituents M2, S2, N2, O1, K1, and M4 would need to be considered. Power spectrum analysis could be used to determine which tidal frequencies are present in the

data. The effect of Coriolis is seen in the surface flow being diverted north of due westward.

2. *Vertical profiles of non-tidal currents in a ROFI. [Textbook Sections 9.2].*
   Analysis of the mean flow, similar to that in 1 above but calculating a full vertical profile of mean circulation. The large tidal variation in sea level, and therefore in the number of current measurements in each profile, causes a small problem. One solution is to interpolate the current profiles onto a uniform depth co-ordinate (e.g. $z' = z/h$, see textbook section 9.1.1). The resulting vertical profile of mean east and north velocity components can be compared to the Heaps solution (textbook section 9.2.2, and Fig.9.5a) by tuning the appropriate value of the vertical eddy viscosity.

3. *Cycles of stratification and tidal currents in a ROFI. [Textbook Sections 9.3, 9.4].*
   Use the near-bed and near-surface temperature and salinity (`T_S_bed.dat`, `T_S_surf.dat`) to calculate density time series and a time series of bed – surface density difference as a measure of stratification. Identify the straining and more enduring stratification, and compare with the surface and near-bed currents (`A_2009_nearbed_surf.dat`) to see the roles of shear and mixing in controlling the different components of stratification.

4. *Non-tidal transport variability in a ROFI. [Textbook Sections 9.4, 9.5].*
   This would be a challenging project for a good student. Calculate time series of non-tidal near-bed and near-surface flows, and compare them with the time series of stratification. Are there instances when the residual flow appears to respond to changes in stratification? For instance, enduring stratification de-couples the surface and bottom waters which could lead to acceleration in the surface and bed residual currents. In addition, is it possible for reduced mixing over slackwater to generate a short pulse in residual flows? Analysis similar to 2 above, but calculating mean current profiles over a series of short (1 – 2 day) windows through the data set could be used to yield a time series of the effective vertical eddy viscosity (by fitting to the Heaps solution).

Note that the data used here is all from the NERC-funded Liverpool Bay Coastal Observatory. If you have ideas to investigate other avenues which require additional data (e.g. longer time series, meteorological data, wave data), then go to the Observatory website (http://cobs.pol.ac.uk/).

```
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
```