

MAPPING CURRENTS IN CHANNELS AND FJORDS

Towed Current Profilers

Over the past decade, acoustic current profiling instruments have proven to be a powerful tool in measuring currents in the ocean, obtaining direction and magnitude of currents in a vertical profile. These instruments use high frequency acoustic backscatter and the Doppler principle to obtain detailed measurements of current velocity profiles. Suspended particles carried by currents in the water produce echoes that are “listened to” by the current profilers in order to obtain current magnitude and direction.

The application of this instrument has not been confined to coastal environments; it has been widely accepted within the marine science community. The instruments are used in studies on the continental shelf, in coastal plain estuaries and in fjords, among other coastal systems.

Although there are several combinations and sampling strategies, these may be easily grouped under three modes:

1. Vessel-mounted, where the transducer is permanently or temporarily installed on the hull
2. Self-contained, mounted in moorings or in frames on the sea bottom
3. Towed current profilers installed in a catamaran or other device towed from a boat

The present work presents and discusses the applicability of a towed current profiling method in estuarine systems, including fjords and channels. It is here used as a tool for mapping currents on nautical charts, showing examples of its application and justifying the use of spatial and time scales on the basis of the dynamics of these systems and other practical considerations.

Why Current Profilers?

Traditional methods used to measure currents in the ocean include drifters, current meters and current profilers. The use of surface drifters as indicators of current field in channels and fjords still represents a cheap way to obtain currents for mapping and is still used by several Hydrographic Services all around the world to solve contingency situations. However, this method requires at least three people to support the coastal tracking of the drifter and a boat supporting the operation. Weather conditions and visibility introduce an impediment to the work of the people on land, making the operation less straightforward. Also, this method is less accurate than direct data collection as observations are not direct and current velocity has to be calculated from successive positions, with a strong dependence on the precision of human observations. This method will thus become increasingly less used for mapping currents.

On the other hand, current meters, or single point measurements of currents, have provided valuable information over the years, being one of the most reliable systems used by researchers and surveyors for obtaining velocities at selected depths. Current meters are still widely used but their operation in coastal regions and inland seas carries the risks of many other moored arrangements. Dragging the mooring with fishery nets is one of the most frequent risks. Missing recovery of the array by bad functioning of the acoustic release also introduces uncertainty for the success of the operation. Weather conditions could also make difficult the deployment and recovery of the mooring.

Although current profiling devices are expensive compared with the instruments indicated above, they can provide a more convenient way to measure currents in these systems. Their capacity to measure currents in different cells of the vertical profile, instead of the single point of current meters, and their versatility in capturing data in different sampling strategies are among their main advantages. When mounted in a catamaran the stability of the platform is one of the main factors of superiority compared to current meters. It is known that under strong current velocities current meters tilt from the vertical to an angle at which they cannot take measurements. Current profilers measure regardless of current velocities.

Data Collection

The sampling strategy proposed uses a 307.2kHz RD Instruments ADCP and a Global Positioning System (GPS) interfaced to a laptop computer to obtain velocity profiles in the sampling area during two complete semidiurnal tidal cycles, preferably during spring tides (the strongest tides of the month). The current profiler is mounted in a catamaran about 3m in length (Figure 1) which is towed from the side of a boat at approximately 5 knots (Figure 2). An average current profile consists of eight pings averaged every 30 seconds. Vertical cell sizes of 1, 2, 4 or 8m may be selected for sampling.

The greater the cell size, the greater the range, with a maximum range of about 170m in this model of current profiler. An across-fjord transect (Figure 3) is traversed twenty times during the 24.5 hours of data collection. The number of repetitions shall be variable according to the width of the channel or fjord. A minimum of fifteen repetitions in the 24.5 hours period is recommended for optimum fit in the subsequent least square analysis.

Data Processing

Current profiler data is calibrated according to Trump and Marmorino [1997] and bad data removed following the procedure explained by Valle-Levinson and Atkinson [1999]. After applying the heading correction, data is rotated in a clockwise angle to an along (u flow) and across (v flow) channel coordinate system. This is the direction of greatest variability of tidal currents and weakest across-channel tidal flows. To obtain residual flows in the section (or mean flows), the semidiurnal tide (represented by the M2 constituent) is separated from the observed flow components using sinusoidal least squares regression analysis [e.g. Lwiza et al., 1991].

Results

To illustrate the results that may be obtained with this method I have chosen an example of a sampling made at the entrance of a Chilean fjord, the Aysen fjord. Its transect was previously shown in Figure 3. The mean flow observed in Figure 4 represents an average of the currents of the along-fjord direction in the transverse section. In addition to providing interesting information for scientific purposes, it shows an approximation for the net transport as well. There is net inflow (blue tones) between 20 to 60m depth associated with the effect of the tides and net outflows (red tones) near the surface associated with river flow, and near the bottom, probably associated with a compensatory flow set up by the wind.

From the point of view of the usefulness for nautical chart and navigation purposes, the surface values may be useful for navigators and some selected vectors may be picked up and considered as representatives of the mean currents. A couple of these vectors may be laid out on the nautical charts, as shown in the example in Figure 5. The subsurface distribution is useful for submarines and for the deployment of any device towed into the water column. The influence of bathymetric features on the flow in the section under study will also be reflected in the data. They may provide valuable insights for navigators and submariners.

The same sectional representation of Figure 4 could be obtained for the maximum currents during ebb, during flood or under specific magnitudes of wind or other selected conditions. An animation of the currents obtained during the repetitions could also be illustrative of changes in time.

Discussion

I have proposed a means to capture current data in order to represent it on nautical charts or in navigational aids. The considerations taken into account to select the timeframe of 24.5 hours are based on simple analysis of the main forcing of the dynamics in channels and fjords. River flow, tides and wind are known to be the main external “forcing” features determining the dynamics in estuaries and fjords. As the semidiurnal type of tide is dominant in many places around the world, including Chile, the M2 constituent (period = 12.4 hours.) is the most representative of the tidal energy.

But a period of 24.5 hours captures two cycles of tides, which is explained by two considerations. First, in this way we capture the strongest tide of the diurnal inequality and if we are in spring tides we are close to observing the maximum energy that tides may provide in that place. Secondly, there is the effect of the sea breeze (period=24 hours), an important forcing agent in coastal systems the effect of which could also be estimated in the sampling. Besides, if we sample two times in the year, during the highest and lowest river discharge, we will cover the extreme conditions of the main forcing features in the area of study, allowing for representative currents.

The spatial considerations are related to the influence of the coastline geometry and bathymetric features, which may produce accelerations to the flow that modify the effect of the forcing previously indicated.

I have also shown a method that is far less risky than mooring systems. Its advantages are increasing its potential as a flexible tool in obtaining a fast characterisation of the current field in different places within a short time, which is necessary for navigators. Their ability to capture the vertical current profile, regardless of the magnitude of the current, is one the main advantages of towed current profiling systems.

References

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