APPLICATION OF A TOWED ADP SYSTEM

Shallow Water Current Measurements

Since the management of coastal areas came to the attention of marine science, much effort has been expended in applying originally ‘blue water’ measurement technologies to typical scientific problems in a shallow water environment. For hydrographic investigations in a large but shallow area of the Baltic Sea, a towed current meter system was designed and tested which minimises the limitations of standard vessel mounted ADP application in shallow water conditions.

The new system was successfully operated during several cruises in the Baltic Sea. It provides accurate current data in the near surface layer, normally disturbed by the ship induced wave field. Commercially available components were mainly used so as to reduce system costs.

Over the last decade the ADP (Acoustic Doppler Profiler) has been established as a standard instrument for en route measurements of currents with an ocean going vessel. Although its results are reasonable in most applications below a surface layer the thickness of which depends upon the length and speed of the vessel, the inherent limitations of the system in the bottom and surface layer become important when it comes to the special requirements of shallow water investigations. At the Baltic Sea Research Institute in Warnemünde, a towed system based on a small sailing catamaran was developed which minimises the shadow zone at the surface and the impact of ship-induced disturbances on the current field.

Shallow Water Requirements

Large areas of the Baltic Sea are shallow but strongly stratified. Therefore, many important advection processes are restricted to a surface layer of about 10 m depth. In 1993 a project on coastal and estuarine processes in the Pomeranian Bight, a large embayment of the western Baltic, was begun. The interdisciplinary approach, which included oceanographers, chemists and biologists, required the use of a research vessel of medium size. A Vessel Mounted Acoustic Doppler Current Profiler (VMADCP) was used for current measurements. However, with a mean water depth of 20 to 30m, the main part of the current, some degree of profile was lost by the distance of the ADP transducer from the surface but much more by disturbances to the flow field made by a moving ship, superimposed on the normal current field down to roughly half of the ships length. In detail, at the surface three metres were lost by the mounting depth of the transducer head; another two metres by the ‘blank after transmit’ range and, in the case of our 35 m research vessel, more than fifteen metres by the disturbed current field. An additional three metres are blanked out at the bottom due to the side lobe effect. This means that more than 65 per cent of the total water column and nearly the whole surface mixed layer could not be covered by reliable current measurements using a vessel-mounted ADP.

How could this problem be solved? The bottom blanking by the side lobe effects could not be reduced. A numerical correction of the measured current field by a calculation of the ship-induced flow field fails due to the lack of knowledge on the ship-induced flow field between the beams of the ADP. The solution could be to place the transducer as close as possible to the sea surface and to bring the system outside the vessel’s flow field. The idea of using a towed device which enables operating a direct reading ADP in an online data access mode outside the magnetic and hydrodynamic disturbances of the towing ship was developed by Hans Ulrich Lass and Thomas Schmidt.

The Towed System

An ADP was mounted on a small sport catamaran of 5m length. A conventional sport catamaran was chosen since it is able to develop the lateral force required to position the platform alongside of the ship track and to carry the necessary devices, even under raw sea conditions. The flow field induced by the catamaran is negligible during towing speeds of up to 10 knots. The ADP (BB-DR-ADP frequency depends on requested range and vertical resolution) was fixed between the hulls at the front spar. A particular problem was selection of an appropriate tow cable. The cable should allow power supply, direct data access and should be strong enough to be used for towing the system in rough seas. A 12 wire Kevlar armed cable with a working load of 10kN (breaking load of 30kN) was used. The cable was the most expensive part of the carrying system. To obtain better control of the catamaran’s navigation, the device was equipped with a radio-controlled helm. A passive radar reflector and a light signal mounted at the mast completed the carrier.
Operating Mode

During the measurements the catamaran was towed at the lee side, 150-200m behind the ship and outside of its magnetic field and the stern wave. The wake shelters the lee side from short wind waves. To prevent disturbances from the ship’s wake the device is towed at least 20m outside the wake, controlled by a helm slant. During calm conditions a tow speed of up to 8km could be achieved, depending on wave height. The system was tested in wind forces up to 7Bft. It works well even during rough sea conditions if the ship is going with the waves. The problem limiting operation of the system in rough sea was not the towing itself but safe deployment and recovery of the device. We operate with 4 pings per measuring ensemble and averaged the ensembles over 2 min to a single profile, which is equivalent to a horizontal resolution of some hundred metres.

System Test

To obtain information about system performance and accuracy we used a VMADCP and the towed system for simultaneous measurements during a cruise in the Mecklenburg Bight, which is part of the western Baltic Sea. The greater blanking range of the VMADCP in the surface layer hid a shallow jet-like structure in the component normal to the ship axes (Figure 4). The strong current speeds in this pattern contribute a significant amount to overall transport in the bight. Without this information the closing of mass balances was incomplete in this highly variable area. Whereas differences in the component normal to the ship axes seem to be due to the different transducer depth only, the impact of the ship's flow field on the along ship component is obvious. The flow field is disturbed down to 15m. As expected, a large backward directed current component is masking the natural current field in the upper layer. Data from the towed ADP was compared with that of a moored instrument to test a possible impact from the catamaran’s flow field. The mooring position was passed with the towed system at a distance of a few hundred metres. The measured profiles show the same patterns. No impact could be recognised of the catamaran’s flow field on the measurements of the towed device.

Advantages and Problems

The towed ADP system meets the requirements of shallow water current measurements. It allows near surface measurements without disturbances from the flow field of the vessel. The system operates with a high tow speed and reasonable horizontal resolution. It works during rough sea conditions, when smaller ships could not operate. The towed ADP system is mobile and may be used by the ship of opportunity. The instrument platform consists of standard elements and is economically priced. However, compared with a VMADCP, the towed ADP requires a higher level of effort for handling and transport, and it needs additional space on deck.

Deep Water Application

The near surface current field is not only important in shallow areas. The towed ADP was also used off the shelf of Southwest Africa in the Atlantic Ocean, where Ekman drift is required to be measured. Due to the ship’s length of nearly 100 m, the current field detected by a VMADCP is disturbed by the ship’s wave field down from 40 to 50 m depth, the main part of the Ekman layer. The water depth of more than 3,000 m allows no bottom tracking. The device was therefore equipped with an ADU2 attitude determination unit from Ashtech for the required accurate heading estimation. Reasonable results could be achieved with average intervals of 10 minutes. The measurements could be verified by comparing measurements over the shelf, where bottom tracking was available.

Summary

The towed ADP system has been successfully used in several projects in the Baltic and in ‘blue water’ over the past nine years. The results have increased our knowledge of processes in the wind driven surface layer and of coastal and shelf sea dynamics. Although more effort is required for handling this towed ADP system, its use is justified by the advantages it offers.

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