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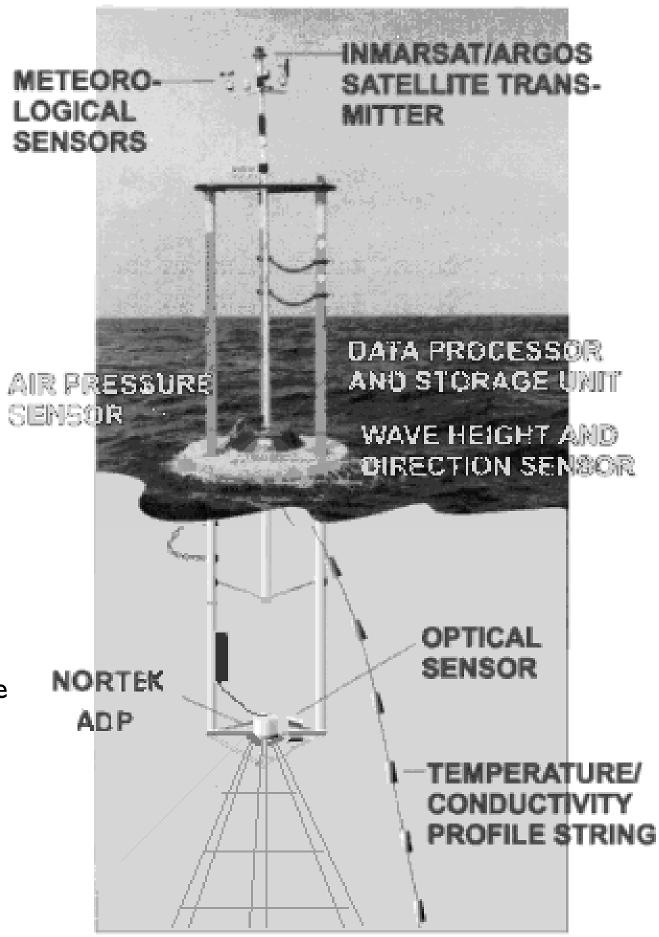
Comparison of buoy mounted NDP current velocity data with upward looking ADCP data

Data from "Kristin", April 3 - April 12, 1998

During the period April 3 - April 12, 1998, an experiment was conducted where a 500 kHz NDP was mounted on a Seawatch buoy manufactured by the Norwegian companyOceanor ASA. The experiment took place in the North Sea and included a bottom mounted 300 kHz WH ADCP for reference. The purpose of the experiment was to find out if buoy mounted NDPs could be used for routine current measurement in offshore areas. More specifically, the experiment aimed to find out if accurate measurements can be obtained without the need to compensate for the buoy motion. The results indicate that the answer is a partial yes. On one hand, there is no doubt that the buoy motion does indeed affect the NDP current measurements. On the other hand, the errors are not very large (less than 10 cm/s in the current experiment) and can be brought further down by introducing simple correction terms that do not require the use of additional motion sensors. The end result is an accuracy of a few cm/s which is sufficient for most engineering applications and also for many scientific purposes. When we also consider the many practical advantages of having the NDP mounted on a buoy, the result suggests that the mounting method is a suitable solution to the problem of monitoring the ocean current profile.

The Seawatch buoy consists of a transparent framework approximately 6 meters in height, surrounding the central buoyancy. It is commonly used in environmental data collection networks as a sensor carrier with a data acquisition system that can control and power a series of different sensor systems. The buoy is designed for offshore use. The 500 kHz Nortek NDP was mounted as a stand-alone unit about 3.2 meters below the surface (see picture) and data were recorded to the internal data logger.



The NDP was configured to measure the velocity every 10 minutes in 4-m depth cells down to about 80 m below the surface. For comparison, a 300 kHz WH ADCP was mounted at a depth of 120 meters at a distance of 200-1000 m from the buoy. The data collection period overlapped for about 9 days.

Buoy Motion

The wave regime during the deployment period was not measured independently. Fortunately, the NDP however, provides a wealth of information about the buoy motion, and the variation in the vertical velocity (stored in the NDP as the velocity standard deviation) can be used to estimate the significant wave height (Hs). The vertical velocity is directly controlled by the buoy motion and a function only of the wave height, the wave period and the buoy response. Since the vertical NDP component is independent of wave direction, the significant wave height can then be estimated if a wave period is assumed. For the 9-day period, the results are shown in Fig. 1, where Hs is plotted as a function time, assuming a mean wave period of 8 seconds. The data are not extremely precise since the wave period is not measured independently but the figure gives an idea of the sea state during the measurement period.

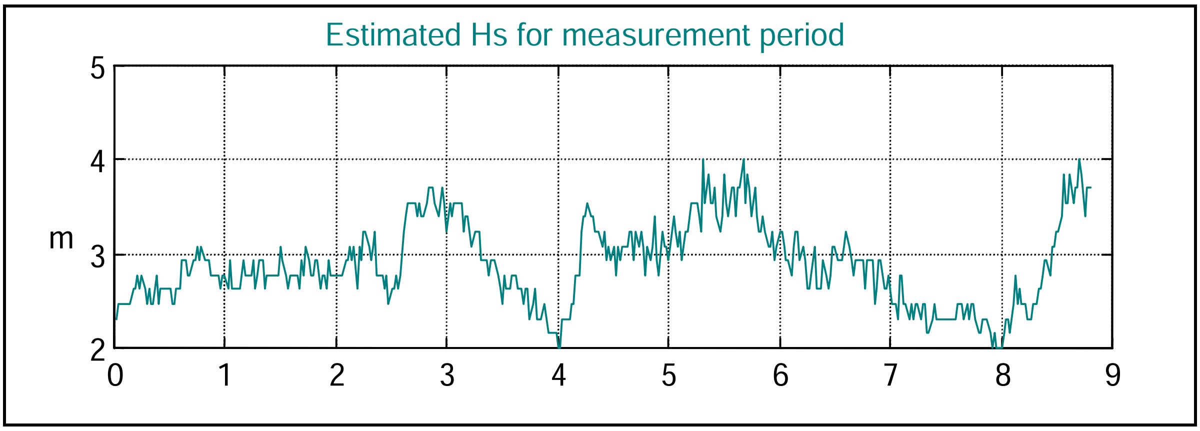


Figure 1 - Calculated wave-height based on vertical velocity variance and assume wave period of 8 seconds

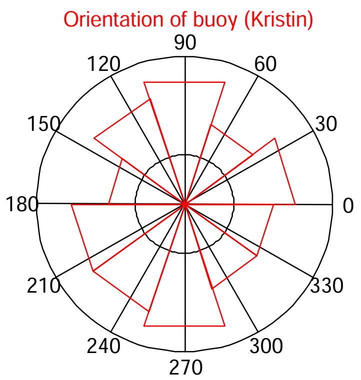


Figure 2 - A "histogram" of the buoy direction. The dominating wave direction during the deployment period is reported to have been toward the south

The buoy is dynamically more stable than anticipated. The average compass direction rarely moves more than 5 degrees from one 30-minute period to the next. The standard deviation of the heading data is of order 15-25 degrees and most of this variation is assumed to come from instability of the NDP compass in dynamic conditions. The internal NDP compass seemed to be adequate for the experiment, even though a compass better suited for dynamic conditions would provide more stable direction estimates. This would be especially true if the NDP was mounted on a smaller buoy where the accelerations are larger. The tilt sensor was disabled for the experiment because it will be inaccurate when large buoy accelerates.

Velocity Data

The uncorrected NDP and ADCP data collected 50 m below the surface generally match up (Fig. 3). Especially the east component is very close with a mean difference of only 0.7 cm/s. The standard deviation between the NDP and ADCP is about 5 cm/s, which was the same both for the east and the north component.

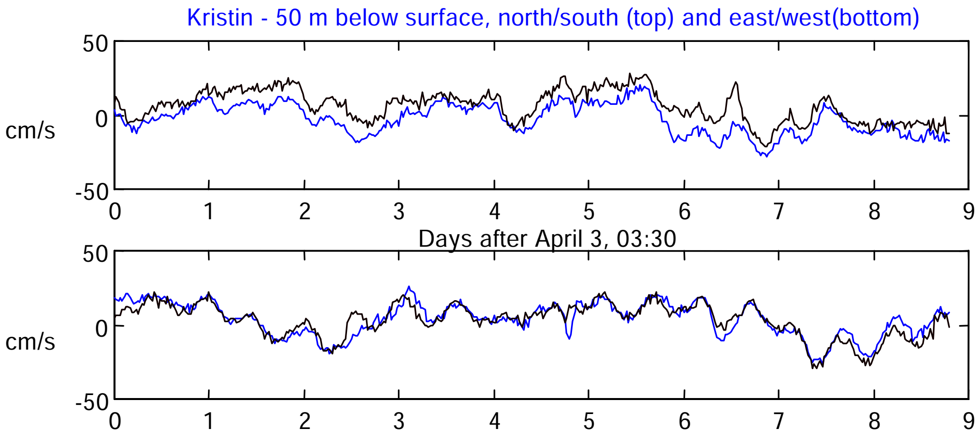


Figure 3 – Uncorrected NDP and WH-ADCP data for the deployment period. For the North/South component, the NDP velocity appears to be smaller than the bottom mounted ADCP velocity.

Even if the overall match is quite good, the differences require an explanation. The most striking mismatch is a difference in the north/south component of about 8 cm/s. The variability in the difference is about the same as for the east component, or about 5 cm/s.

After preliminary data analysis, it was clear that the differences were unlikely to be related to the performance characteristics of the NDP or ADCP. Data from the two current profilers have been compared in a number of bottom deployments and typical linear regressions show coefficients of 0.98-1.02, with correlation coefficients consistently exceeding 0.9. Also, several more complex aspects of the data suggested that data differences were related to the buoy motion and not aspects of the Doppler processing. The most important finding in this regard was that the offset between the NDP and ADCP was the same throughout the water column. This is important because errors introduced by the buoy motion affects the whole water column. Second, the error is along the same component as the predominant wave direction, again suggesting that we are dealing with buoy effects.

From analysis of vessel mounted systems, which in this case can be thought of as very large buoys, several mechanisms can be seen to generate velocity offsets when the complete system of motion is analyzed. Without getting into the algebra involved, the largest errors are generated when the buoy heave combines with rotation to generate a non-linear pumping effect. The net result is an apparent mean current that has the same sign as the wave direction. This non-linear pumping effect is consistent with the experimental data because a "false" mean current toward the south would make the NDP underestimate the North/South component.

To precisely determine the correction terms, it would be necessary to measure the detailed buoy motion. This has been tried in other projects but requires complex motion measurements that add significant cost to the current profiler. Using instead the wealth of information about the buoy motion that is recorded by the NDP, combined with knowledge about the functional forms involved, it is possible to derive correction terms which require no detailed knowledge about the buoy motion. Instead, the correction terms are derived directly from the NDP data and only assume external knowledge about the main wave direction, which incidentally also can be estimated from the NDP but would require additional internal processing that is not implemented.

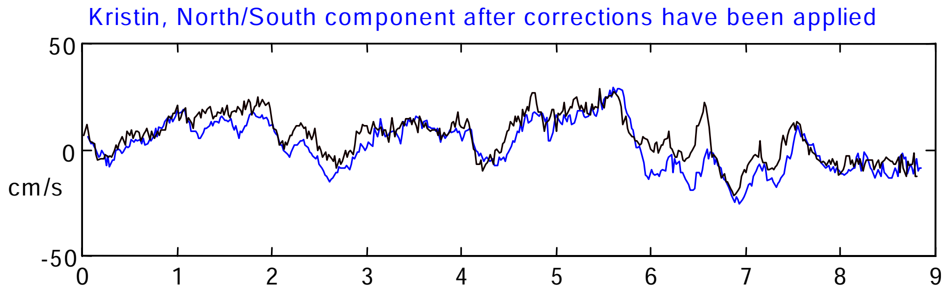


Figure 4 - North/South component after correction terms have been applied. The wave direction is assumed to be Southward

If the correction terms are added to the North/South Velocity component, the mean difference between the NDP and ADCP becomes negligible. The results are shown in Fig. 4 and in the table below. The correction terms do not reduce the short-term variations between the NDP and the ADCP, suggesting that there are also other mechanisms at play. Some of these are due to other non-linear buoy effects, the difference in the NDP and ADCP location can have an effect, and some of the difference can simply be due to the mean velocity of the buoy as the tidal current changes direction. The overall impression, however, is that the differences are small and that buoy mounted NDPs represent an effective alternative to bottom mounted systems.

	Uncorrected		Corrected	
	Mean	Std	Mean	Std
East/West	-0.8 cm/s	5.6 cm/s	'--------	'------
North/South	-8.8 cm/s	5.0 cm/s	2.7 cm/s	5.1 cm/s

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