## **Engineering 101**

## **Considerations for CTD Spatial** and Temporal Resolution on Moving Platforms

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When making measurements in a temporally and spa- only be assumed from the transit speed of the package tially variable marine environment, especially from a as it travels through the water. It is nearly impossible to moving platform, instrument limitations in conjunction achieve a constant velocity for a moving platform due with the sampling methodology need to be considered to ship heave and accelerations, drift, and currents in when choosing the right tools for the measurements.

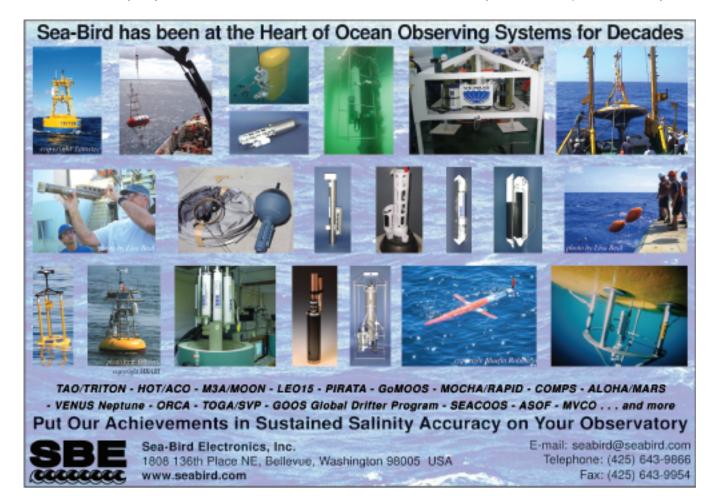
Oceanographic conductivity, temperature, and depth (CTD) instruments are used to collect high resolution platforms (shipboard profiling, towed vehicles, and AUVs). Obtaining accurate measurements is more difficult when moving either vertically (profiling) or horizontally (surface mapping), or both vertically and horizontal- For these reasons, accurate and stable pumped CTD ly simultaneously (AUVs, towed vehicles). The combination of platform velocity, sensor response time, and quality and resolution of the final data set. For example, faster responding sensors allow for faster moving plat- Many platforms and/or applications require a smaller forms, but are possibly limited by sampling frequency. Faster sampling frequency instruments also allow for sensor response time.

Many commercially available conductivity sensors cies and are sometimes equipped with slower specify response times dependent on flow rates past response time sensors. Continuous sampling with an the sensor. For unpumped sensors, the flow rates can instrument that samples too slowly or has a response

the environment. Therefore, unpumped sensors can experience variable response times while in transit. This complicates post-processing of data and will result in uncorrectable, mismatched sensor measurements data from stationary (moored observations) and moving caused primarily by a response time disparity between temperature (not flow dependent) and conductivity measurements (flow dependent).

sensors that have very fast response times and that sample at rapid and constant frequencies are preferred. instrument and platform data acquisition traits (including These CTDs offer the most flexibility in application and sampling frequency) all play a part in determining the can accommodate most moving platform technologies.

instrument, which usually has less sampling power than a larger CTD package can offer, including auxiliary faster moving platforms, but are possibly limited by sensors. For instance, towed platforms and slow moving AUVs, including gliders, utilize individual sensors or smaller "hand-held" CTDs with lower sampling frequen-



**54** Volume 15 • Issue 6 ON&T September, 2009 time inadequate for the speed of the As with temporal sampling, in order vessel may result in a data set that lacks the resolution necessary to resolution of 1 m (for example), the clearly map the attributes of interest. The "smoothed" result may appear as if a heavy-handed low-pass filter at least one-half the wavelength of was applied to the data, potentially masking important yet smaller scale features. With unpumped sensors, Table 1 provides simple examples the quality of the data is worsened and virtually uncorrectable due to pling frequency combinations with variable speeds of the platform. To resultant realized spatial resolution further complicate matters, some for a towed undulating vehicle. The commercial gliders and AUVs do results provide an estimate of the not acquire data at a constant sam- maximum spatial resolution for an pling frequency, making it difficult to evenly spaced feature that can be align data streams during post processing. All of these issues will tow speed, sampling frequency and restrict the spatial and temporal res- sensor response times. The true olution in a moving application, sampling resolution will likely be even at speeds as slow as 1 m/s (2 more complicated in reality, as graknots). However, data can be great-dient features in the marine environly improved by pumping or by slow- ment are rarely evenly spaced. As ing the transit speed to give sensors can be surmised, moving faster time to respond.

to resolve features with a spatial sample rate and sensor response times must be adequate to resolve the feature, in this case 0.5 m.

of sensor response time and samwith slower sampling instruments

equipped with slower response time sensors will limit the accuracy and spatial reliability of a mapped

To ensure the best data product for any project, it is important that the data quality objectives and the deployment method be compatible with the capabilities of the instrumentation.

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Limiting Sensor Response Time*	Instrument Sample Frequency (delta t)	Measurement Spatial Resolution	Realized Spatial Resolution (2X Measurement Resolution)
0.060 s	8 Hz 0.125 s	0.45 m	0.90 m
0.060 s	24 Hz 0.042 s	0.15 m	0.30 m
0.1 s	1 Hz 1 s	3.6 m	7.2 m
0.1 s	4 Hz 0.25 s	0.9 m	1.8 m
0.1 s	8 Hz 0.125 s	0.45 m	0.9 m
0.5 s	4 Hz 0.25 s	1.8 m	3.6 m
1 s	1 Hz 1 s	3.6 m	7.2 m
5 s	8 Hz 0.125 s	18.0 m	36 m
30 s	1 Hz 1 s	108.0 m	216 m
60 s (1 min)	8 Hz 0.125 s	216.0 m	432 m
180 s (3 min)	1 Hz 1 s	648.0 m	1296 m

<sup>\*</sup> Assumes a constant flow rate past conductivity and oxygen sensors (i.e., steady response time)

Table 1. Sensor response time and sampling frequency combinations and expected spatial resolution. Results assume that the stated response times are met by the given suite of sensors, as in a pumped system or a constant tow speed application. Resolution estimates are for a towed instrument package that is moving through the water at a constant speed of 7 knots (3.6 m/s). Limiting factor noted in bold italics.

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