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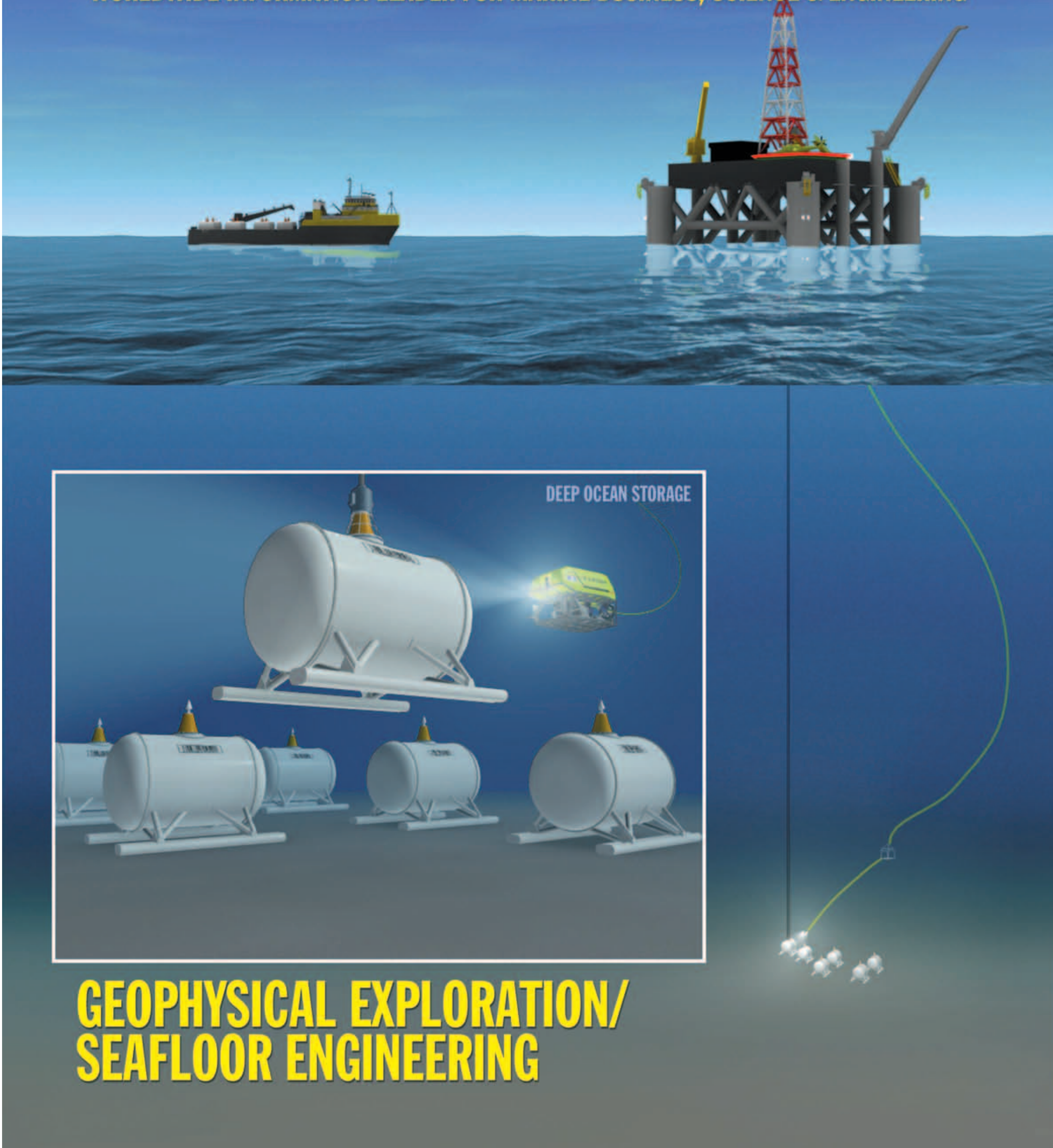

GEOPHYSICAL EXPLORATION/ SEAFLOOR ENGINEERING

Belinda Lipa has a Ph.D. in theoretical physics and worked at Stanford University before forming a private company in 1980 that develops software to provide ocean surface information from high-frequency radar sea echo. Since 1986, she has been vice president of Codar Ocean Sensors, a small company that develops and markets the SeaSonde.

In undergraduate physics labs, we are taught that no measurement is complete without its error bars, but in the real world of engineering, uncertainties often do not seem to get the respect they deserve. It is difficult to deny that uncertainty estimates are indispensable when comparing different data sets. For example, as a postdoctorate I was assigned to investigate the rather outlandish claim that heart attacks were caused in part by sunspot activity. This entailed calculating the correlation coefficient between heart attack mortality and the sunspot index. The enthusiasm generated when the correlation coefficient turned out to be positive faded somewhat reluctantly when the value turned out to be less than its error bar. Therefore, the result was entirely consistent with no correlation at all. Such results can be unpopular, but, hey, that's science. What is important is to understand the data, and that includes its uncertainties.

This understanding is certainly necessary when comparing ocean current measurements from different instruments such as high-frequency (HF) radar systems and acoustic Doppler current profilers (ADCPs). HF radar devices operate from shore and provide a convenient way to measure surface currents over a large area. A single radar measures the component of the current velocity radial to the radar site; radial velocities from two or more separate radars can be combined to give total current velocities. One HF radar system is the SeaSonde, which employs broad-beam antennas and direction-finding to produce maps of radial current velocity vectors. Each vector produced is the average over a radar cell, which is typically a circular band three kilometers wide with a 5° angular width. Phased array radars also produce area-averaged currents, as their radar beamwidth theoretically exceeds 10° and, in practice, can be much larger.

Many sources of uncertainty in SeaSonde velocities are familiar, such as statistical variation, non-optimal analysis parameters, etc. In addition, each radar cell contains different current velocities due to velocity shear on the ocean surface. The SeaSonde averages over these velocities, so at a single point within the radar cell, any of the values may apply. I will refer to the standard deviation of these individual velocities as "spatial uncertainty." When SeaSonde and buoy measurements are compared, discrepancies are bound to exist in the presence of current shear.

Fortunately, this spatial uncertainty in the SeaSonde average can be estimated. During data-processing, the radial velocity value is defined by the signal frequency; analysis of the antenna voltage signals yields the corresponding direction-of-arrival. Usually, several velocities fall within a radar cell, and their standard deviation is a measure of the spatial uncertainty, which tends to increase with range from the radar along with the size of the radar cell.

Even if the spatial uncertainty is high, the uncertainty in the average can be low. Thus, SeaSonde measurements appear stable from time to time, and two SeaSondes operated side-by-side will produce similar results. It can be a different matter when a Seasonde area measurement is compared with an ADCP point measurement. In the presence of sizeable velocity shear, good agreement can be expected only if the radar cell size is small. Poor agreement does not necessarily indicate inconsistency if the differences are less than the error bars.

When comparing SeaSonde and ADCP data, it is best to compare radial velocities, resolving the ADCP velocities into components radial to the radar site. Then, differences between measurements can be compared with the radar uncertainties, which are different for each radar. Individual uncertainties are lost when radial velocities from two sites are combined to form total velocities, so comparing total velocities is not as informative.

Another example of SeaSonde velocity comparisons is the so-called baseline test, which is a consistency check on radial velocities from two SeaSondes at points on the baseline joining the two sites. As the Sea Sondes "see" the same radial current along the baseline, the two systems will ideally give the same estimates of radial velocity. However, at all baseline points except the mid point, the sizes of the radar cells differ, and spatial uncertainty may play a role.

Baseline tests were performed on SeaSondes at Montauk and Misquamicut on the Long Island Sound and it was found that the Montauk and Misquamicut rms radial speeds differed by as much as 40 percent on the baseline near Montauk. This discrepancy was found to be due to the different radar cell sizes and the large velocity shear close to Montauk, where the current swirls around the Montauk Point. As the radar cell size is proportional to the distance from the radar, the cell sizes for Montauk in this region are much smaller than for Misquamicut. A smaller cell size results in less averaging-down of the velocity. Thus, the Montauk site produces current velocities with higher values and lower spatial uncertainties. The large baseline deviations are completely accounted for by the large spatial uncertainties in the Misquamicut data.

To conclude, when comparing current velocity measurements, it is not sufficient to simply compare the values, one must also consider the uncertainties. For the area-averaged measurements produced by HF radar systems, uncertainty estimates should include uncertainties due to horizontal velocity shear on the ocean surface. Current velocity measurements from two instruments can be considered to be consistent if the differences are within the uncertainty limits. So, those uncertainties are important—it's good to know we learned something useful in college. /st/