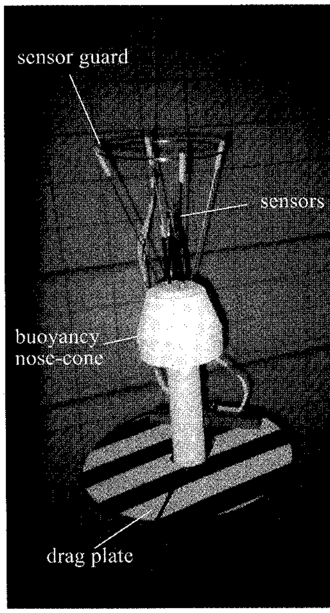
INSTRUMENTS / OCEANOGRAPHY

SCAMP: measuring turbulence in estuaries, lakes and coastal waters



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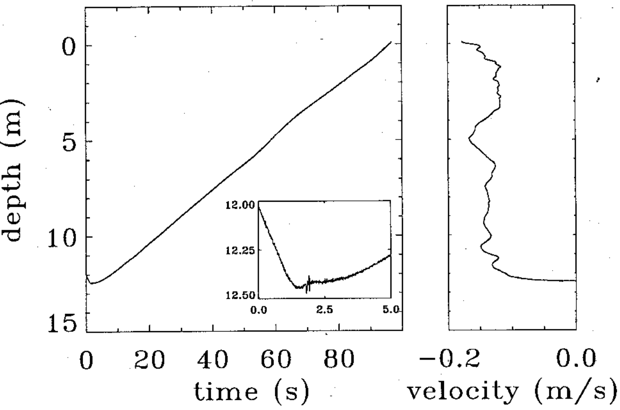
Measuring turbulence in large water bodies requires an approach different from that used in rivers. A new instrument seems to fit the bill.

TURBULENCE refers to the irregular variations over time in the movement (both speed and direction) of fluids. Turbulent mixing is very important in controlling how materials are transported in almost all fluid environments. It is also very difficult to measure. In water, "acoustic doppler velocimeters" can provide useful measurements at single points (e.g., in rivers, see *Water & Atmosphere* 5(3): 22–24). However, in big water bodies such as estuaries, lakes and coastal waters, "vertical density stratification" – the formation of water layers as a result of density differences caused by temperature and salinity variations – is known to cause turbulence to vary dramatically. Thus, point measurements recorded even a small distance apart can return very different answers. So, in these situations, how can we obtain an accurate picture of turbulence that will allow us to learn more about the mixing process?

One way is to use profiling methods that can capture minute temperature variations over equally tiny distances. The resulting profiles can be used to calculate turbulence through the water column.



SCAMP's depth vs. time trajectory on a profile in Akaroa Harbour. The inset shows the initial turnaround when the profiler stops sinking and starts its ascent. The right-hand panel shows the calculated rise velocity.

above right: *The SCAMP underwater in a dive pool. The sensors are hidden within the sensor guard. The yellow and black disk is a drag plate and the white collar is a buoyancy element.*

A new profiler for ocean research

NIWA has recently purchased a SCAMP – Self Contained Autonomous MicroProfiler – for temperature and conductivity measurements. This is a "free fall/rise" profiler that can be deployed from small boats. Its speed of descent or ascent is controlled only by drag and buoyancy, using a drag-plate in combination with floats and ballast. The photograph (above) shows the SCAMP rising to the surface in a 5-m-deep dive pool.

Originally developed by the Centre for Water Research (www.cwr.uwa.edu.au) at the University of Western Australia, SCAMP is now manufactured by a Californian company, Precision Measurement Electronics (www.pme.com). The profiler is essentially a high-precision conductivity–temperature–depth (CTD) device. The data it generates complement those from more traditional devices used aboard NIWA's research vessel *Tangaroa*, such as the SeaBird CTD, which is more stable in its absolute calibration. The SCAMP records data every millimetre whereas a SeaBird has a spatial resolution of perhaps hundreds of millimetres.

The very small-scale measurements of the SCAMP make it possible to estimate very precisely how stable a vertical water column is, as well as the amount of mixing and energy dissipation occurring in various regions of the profile. A drawback of the technique is that the profilers are very delicate with sensor tips that are viewable only under a microscope. This delicacy leads to elevated activity in the equipment operator's nervous system when playful dolphins come around to see their new toy!

Near-surface measurements

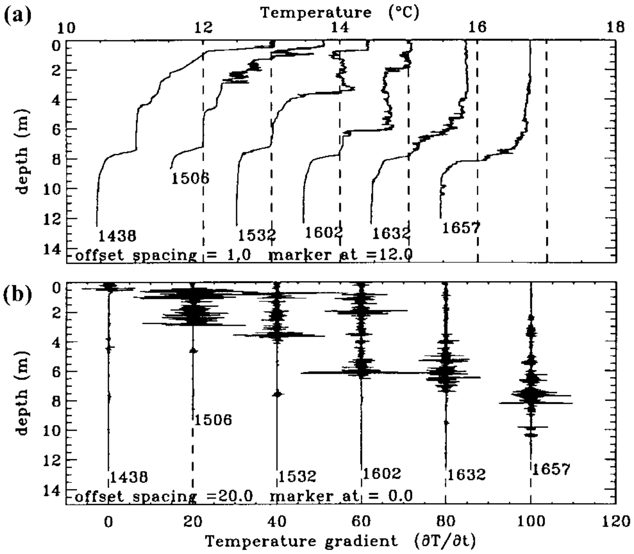
Mixing and energy dissipation within the water column are often driven by wind and waves at the surface. Therefore it is best to make measurements as close to the surface as possible. This is difficult with the traditional CTD because of the arrangement of the sensors. But with the SCAMP we can place the sensors at the top of the profiler and use the instrument in a rising motion so that it slowly approaches the surface from below.

The operator launches the probe with only a thin kevlar tether. The probe then sinks to a pre-programmed depth where it releases an expendable ballast weight and starts to rise at a speed of around 10 cm/s. Data can be returned to the operator via a cable or stored in the profiler for later downloading.

The figure left shows the depth time-series from a profile in Akaroa Harbour. The profiler released its ballast at a depth of 12 m and simultaneously started to measure. The measurements captured the final phase of the sinking and the subsequent acceleration period as the instrument started to rise. The profile is broken up into many sections for analysis and, while a constant velocity is desirable for good results, the SCAMP needs to hold this velocity only over the duration of each of these segments. Thus the many bumps and wiggles in the velocity profile shown in the figure are not detrimental to the observations.

Ocean–Atmosphere Interactions

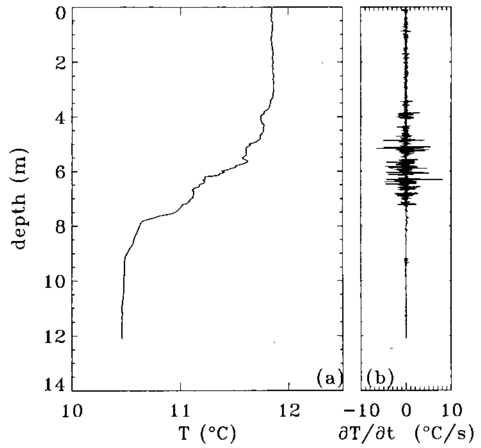
THE "OCEAN–ATMOSPHERE INTERACTIONS" programme, funded by the Public Good Science Fund (PGSF), includes experiments designed to determine the link between wind conditions and air–sea gas and heat exchange. A vital component of this is the mixing of surface waters caused by surface waves. This energy is significantly enhanced by the presence of deep-water wave breaking. This type of wave breaking occurs naturally in oceans, lakes and estuaries and is not related to the shallowing of a beach but to unstable growth of the waves – they simply get too steep and break. The overturning plume of water rushing down the face of the wave injects bubbles and energy into the near surface region of the water column.



A sequence of microstructure profiles. The panels show (a) temperature and (b) temperature gradient profiles recorded at one location in Akaroa Harbour at about half-hour intervals as the wind increased from around 5 to nearly 20 knots. The warm fluid in the near-surface layer gradually mixes down over this time. An interesting point is that the turbulent mixing identified by two-sided gradient data is not confined to above the shallowest region of thermal stratification. In other words, the present situation is not determined solely by top-down mixing. Some internal process, possibly shear-related, may be introducing turbulence at depth, many metres away from the surface where the wind and waves are acting. However this shear is most likely wind-driven.

The sequence of SCAMP profiles shows how the temperature and temperature-gradient profiles develop. The temperature profiles show how the sharp thin surface layer caused by the warm morning sun in the absence of any significant breeze is gradually eroded until it is mixed down to the pre-existing thermocline (at a depth of about 8 m). The temperature-gradient profiles give a direct picture of temperature variations and show where light and heavy fluids are mixing. Once this is adjusted to take background stratification into account, turbulent energy dissipation can be determined from segmented versions of these profiles.

The initial strong surface stratification is especially important to the Ocean–Atmosphere programme. Temperature variations such as this affect the solubility of gases at the water surface. These types of detailed near-surface observations need to be recorded to reduce the present uncertainty in our understanding of air–sea gas exchange. The Ocean–Atmosphere programme seeks to link the changes in near-surface turbulent levels with changes in the waves and wind and from this improve our understanding of mass and momentum exchange between the atmosphere and the oceans.



left: *Vertical profiles of (a) temperature and (b) the "temporal gradient" of temperature.*

The figure above shows a SCAMP temperature profile. The key difference between this profile and one recorded at the same time with a traditional CTD are that the SCAMP data are much higher resolution and the profile goes right to the surface. Another difference is the SCAMP's ability to record a plot of temperature changes over time vs. water depth. This can be translated into the distribution of different-sized turbulent fluctuations and used to generate an estimate of turbulent energy dissipation. Application of this technique provides many opportunities for scientific development. For example we have recently trialled the NIWA SCAMP in a cross-comparison with colleagues from the Southampton Oceanography Centre (SOC), UK.

At the time of writing there are only 13 SCAMPs worldwide and they have successfully been deployed in many estuaries, coastal regions and lakes. Locations include Lake Kinneret (Israel), Mono Lake (California), Lake Biwa (Japan), Maracibo estuary (Venezuela), Venice Lagoon (Italy), and recently in New Zealand, at Akaroa (deployed by NIWA) and the Hauraki Gulf (deployed by SOC).

The first job for the NIWA SCAMP will be to look at surface mixed-layer energetics as part of the Ocean–Atmosphere programme. This PGSF programme seeks to link variations in near-surface mixing (see panel) to breaking-wave occurrence determined by microwave radar (*Water & Atmosphere* 6(2), 26–27). The SCAMP will also play a support role in another PGSF programme aimed at describing the mixing habitats of coastal embayments such as Pelorus Sound and Akaroa Harbour. ■

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Acknowledgements

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Further reading

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