Energy release through large internal wave breaking in the ocean.

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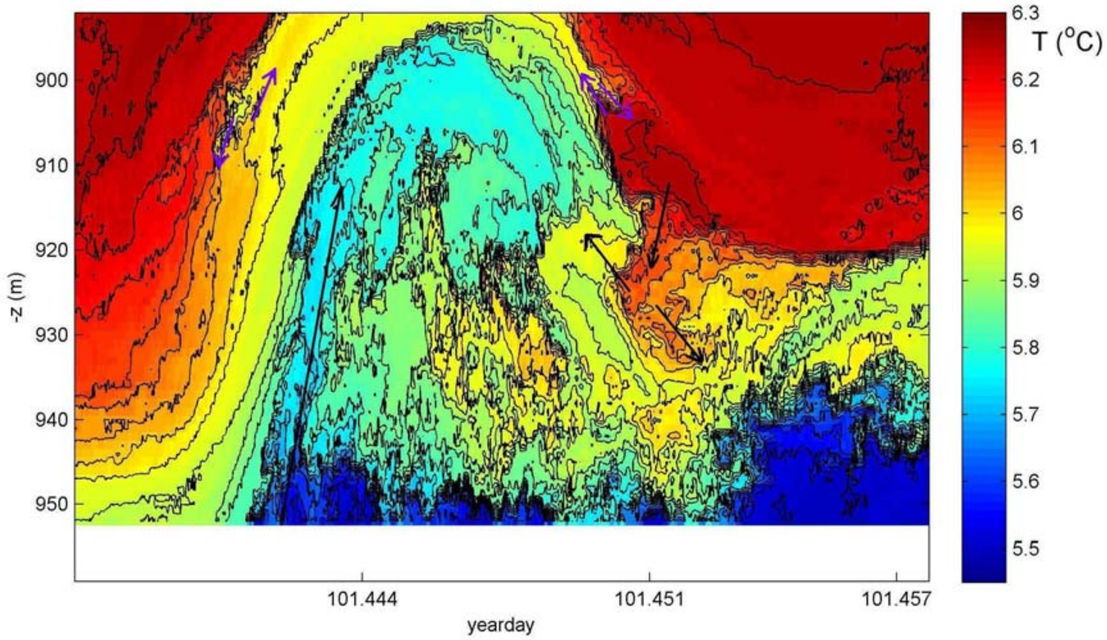
The sun stores huge amounts of heat in the ocean, but this heat would stay near the ocean surface if it were not mechanically mixed into the deep. Warm water is less dense ("lighter") than cold water, so that heated surface waters "float" on top of the cold deep waters. Only active mechanical turbulent mixing can pump down the heat. Such mixing requires remarkably little energy, about one-thousandth of the heat stored, but it is crucial for ocean life and for the transportation of nutrients and sediment. Several mechanisms for ocean mixing have been researched in the past. The dominant mechanism seems mixing through breaking of internal waves above underwater topography. Here we quantify the details of the transition from internal waves to strong turbulent mixing using 1-Hz high sampling rate temperature sensors. The sensors were moored above different sloping bottoms, varying from a large guyot in the Canary Basin -- North-Atlantic Ocean, a methane seep site of Opouawe Bank off New Zealand – Southern Ocean, a cold-coral site of Rockall Bank NE Atlantic Ocean. Over a tidal period, most mixing occurs in two-three periods of less than half an hour each. During such periods, a frontal 'bore' is seen to overturn and break backwards. Such a bore reaches tens of meters high from the bottom, see for instance the example in the Figure attached. During the passage of the bore, turbulence parameter values peak about 10,000 times higher than the open ocean mean values. Here, turbulence parameter values are estimated using 'Thorpe-displacements' that follow after re-ordering every 1-Hz observed temperature profile, which may contain statically unstable portions, into stable profile. The high-precision ($<5\times10^{-4}$°C) and low noise ($<6\times10^{-5}$°C) of the sensors allow quite precise determination of turbulence parameters, provided the density-temperature relationship is known. The observed 'boundary mixing' induced by internal wave breaking dominates sediment resuspension and is 100 times more turbulent than in the open ocean, when averaged over a tidal period. Extrapolating, the mixing may be sufficiently effective to maintain the density stratification in the ocean.



Time-depth image of 1800 s horizontally by 67 m vertically. It details a large backwards breaking internal wave. This was observed using 61 high sampling rate temperature sensors between 7 and 67 m above the bottom at 959 m, above a slope of Opouawe Bank, off New Zealand, Southern Ocean. Contour intervals every 0.04°C(black).