THE GENERATION OF STRONG TURBULENCE OVER CONTINENTAL SLOPES

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The Meriodional Overturning Circulation (MOC), which represents the large scale oceanic circulation, requires a level of mixing almost 10 times more vigorous than that observed in the ocean interior; it is believed that instead enhanced mixing occurs at the oceans' boundaries. Such processes are yet to be fully understood however and until they are their impact on the oceans cannot be quantified. Our results show evidence of two processes that generate turbulence near the sea-bed and which have been essentially neglected in the scientific literature. The first is related to the asymmetric response of the bottom boundary layer to a variable flow along the continental slope, and the second to the response of the deep thermocline to strong winds at the sea surface. Their overall impact on boundary mixing could be significant when extrapolated to the continental slopes across the global ocean.

During 1999 two cruises were conducted in the Faeroe-Shetland Channel in which we measured currents, temperature, density and sediment transport over the continental slope. An initial inspection of data revealed spike-like reductions in current speed which appeared to reflect an instrumental deficiency. The search for an explanation however revealed that a physical process was actually responsible for generating turbulence to which the instrument couldn't respond. The current direction was found to rotate anticlockwise towards the seabed due to friction and the earth's rotation. Over the Shetland slope this results in downwelling at the seabed during periods when the current flows along the slope to the north-east, causing lighter water to be driven beneath heavier water lower down the slope (Figure 1). Such a situation is unstable and leads to turbulence, causing rapid fluctuations in the current direction which lead to the current meters under-reading the current speed. In contrast, during periods when the current flows to the south-east, heavy water flows up the slope, enhancing the stratification and inhibiting turbulence.

We also observed the thermocline rushing up the continental slope (Figure 2) in the form of a wave train which eventually breaks, very much like surface waves breaking on a beach, and causing vigorous mixing. We term such features 'solibores' because they appear both like internal bores and trains of 'solitons' (Figure 3), a particular type of wave. Our observations are unusual because of the depth of the solibores and the ori

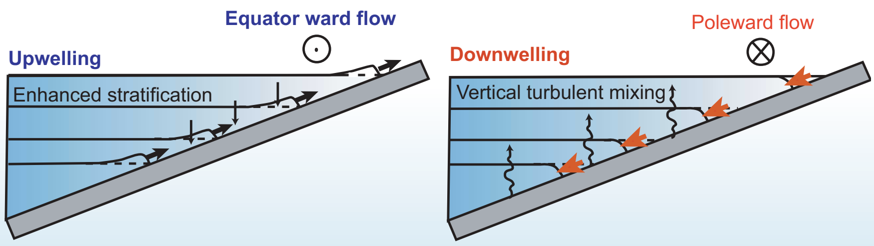

Fig. 1. The asymmetric response of the bottom boundary layer under contrasting long-slope flows and the consequences for turbulent mixing in the near-bed region.

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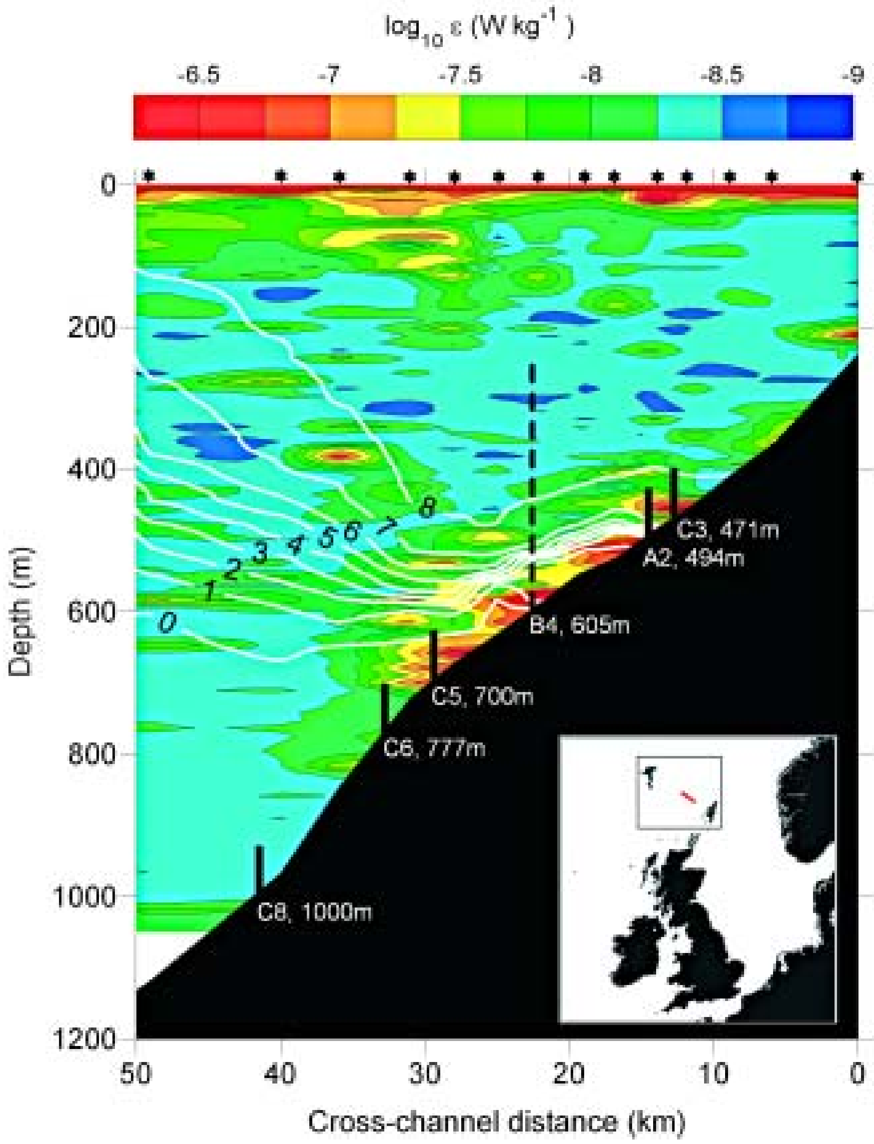

Fig. 2. Turbulence over the continental slope generated by a solibore passing up the slope and (inset) the location of the study region. The turbulence is expressed in terms of the energy dissipation rate ε. The white lines indicate the position of the isotherms from which the up-slope rushing nature of the solibore may be inferred.

gin of their forcing which is atmospheric rather than the usually considered case of tidal forcing. They cause mixing which is locally 100 times larger than the value supposedly required to maintain the MOC, and are furthermore able to resuspend exceptionally large amounts of sediment at the sea bed. This is the first time that the evolution of the permanent pycnocline has been observed to respond to the wind in this way, and it is suggested that such features could be much more commonplace throughout the world's oceans than previously thought.

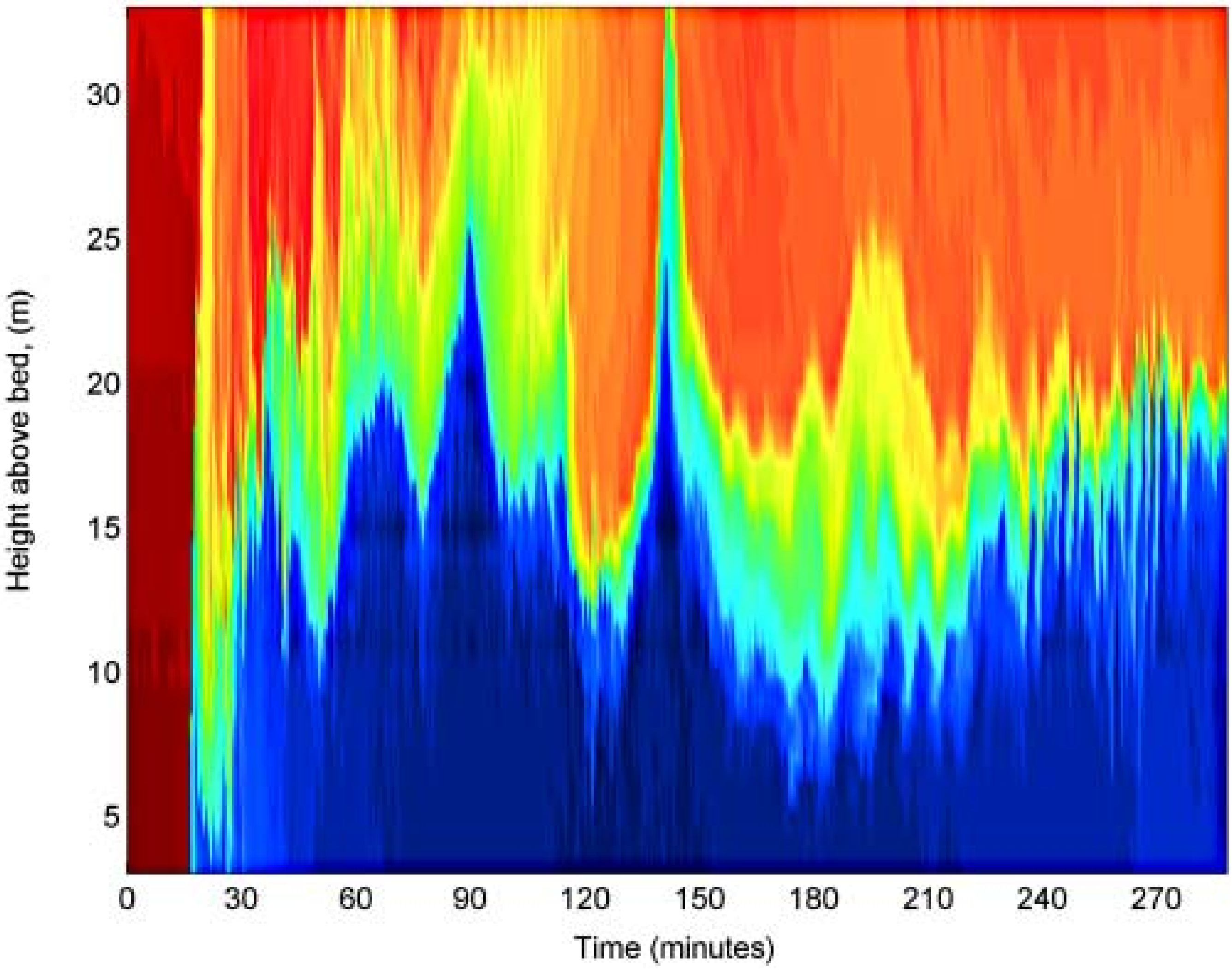

Fig. 3. Temperature during the passage of a large solibore when large sediment fluxes occurred.