The impact of internal waves on sediment distribution at the Namibian shelf

V. Mohrholz | T. Heene | A.A. Muller

Baltic Sea Research Institute Warnemünde, Germany

Introduction

At the central Namibian shelf the sediment distribution depicts an accumulation of carbon rich sediments in three belt like patterns parallel to the isobaths. This structure was often discussed in terms of strong long shore currents or phytoplankton succession in upwelling filaments. More recently, it was also hypothesized that shoaling internal waves may generate for this sediment pattern. Satellite images have shown that surface expressions of internal soliton-like waves are a very common feature at the shelf off southwest Africa (see Figure 1), but in situ data were rare and ambiguous.

Time series measurements and transect data with a microstructure profiler (MSS), gathered during two GENUS-expeditions in October 2010 and February 2011, support the internal wave hypotheses.

Using Etopo 2 bathymetry data critical slope angles for internal wave reflection were calculated. They are located in water depth between 100 and 500m (Figure 2), pointing to a close correlation between the sediment distribution and internal wave breaking.

Along the cross shelf MSS transect at 23°S there are three locations of high TKE dissipation, where resuspension of particulate matter is supported by enhanced bed stress (Figure 3). At the shelf edge the breaking internal M2 tide causes intensified mixing in the entire water column (Figure 4) and generation of soliton like internal waves (NLIW) with a mean wave period of about 40min. The NLIWs spread towards the coast. Their interaction with the topography forces strong bottom mixing at the inner shelf break and at the coast. In the shadow of the outer shelf break and between the inner shelf break and the coast, "calm" zones are observed where the accumulation of sinking organic matter maintains the anoxic mud belt.

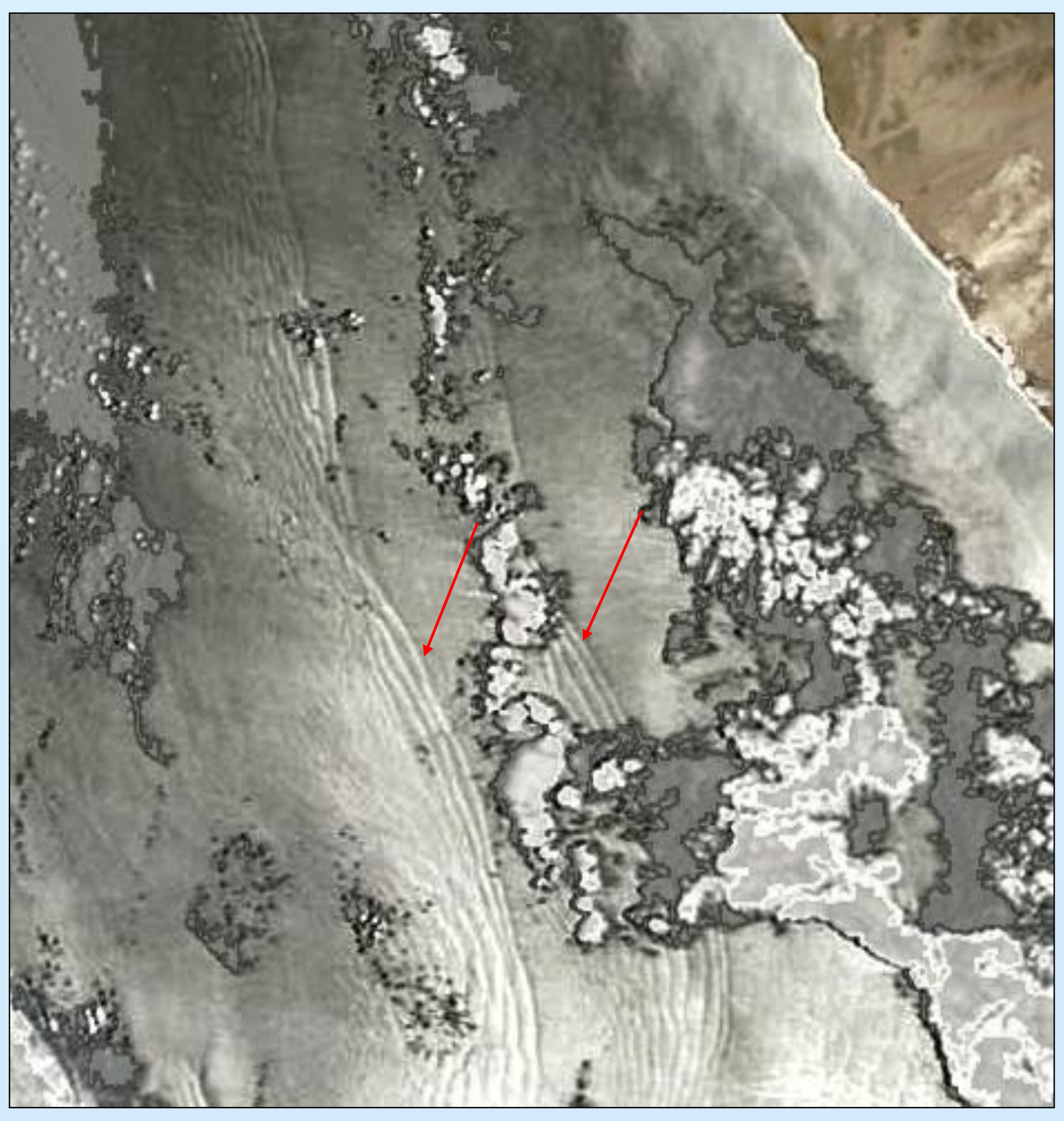


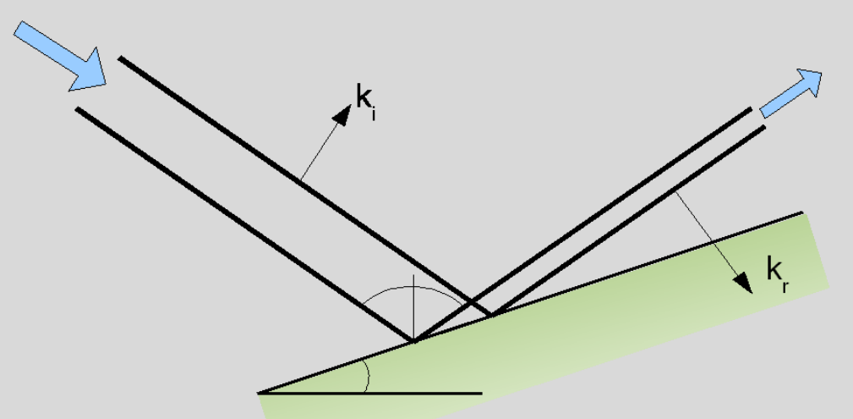
Figure 1: Surface expression of NLIW off central Namibia. The wave packages have a distance of approximately 18km. The wave length inside a package is about 1000m. (MODIS-Terra, 29.12.2008 09:35 UTC http://rapidfire.sci.gsfc.nasa.gov)

Internal waves (IW) are an ubiquitous feature in stratified fluids. They account for the major part of vertical mixing in the ocean interior and contribute to the global thermohaline circulation.

There are several mechanisms that generate internal waves, eg. Tides, inertial oscillations, flow over sills and other topographic obstracles.

The frequency ω of the internal waves cover the range from the inertial frequency f to the Brunt-Vaisälä frequency N, determined by local stratification. Depending on their frequency the wave energy spreads with a certain angle θ, determined by the dispersion law of internal gravity waves.

Internal waves are reflected at the bottom. The reflection becomes critical if the bathymetric slope γ is close to the spreading angle of the IWs. In this case the waves tend to break and release their energy to small scale turbulence and the generation of IW with higher frequencies.



$$s = \tan\theta = \frac{k}{m} = \sqrt{\frac{\omega^2 - f^2}{N^2 - \omega^2}}$$

$$\gamma = bathymetric\ slope$$

$$\gamma/s \begin{cases} <1 & : \text{subcritical} \\ =1 & : \text{critical} \\ >1 & : \text{supercritical} \end{cases}$$

Non linear internal waves (NLIW) are internal waves with low wave dispersion, thus they are also called soliton-like waves.

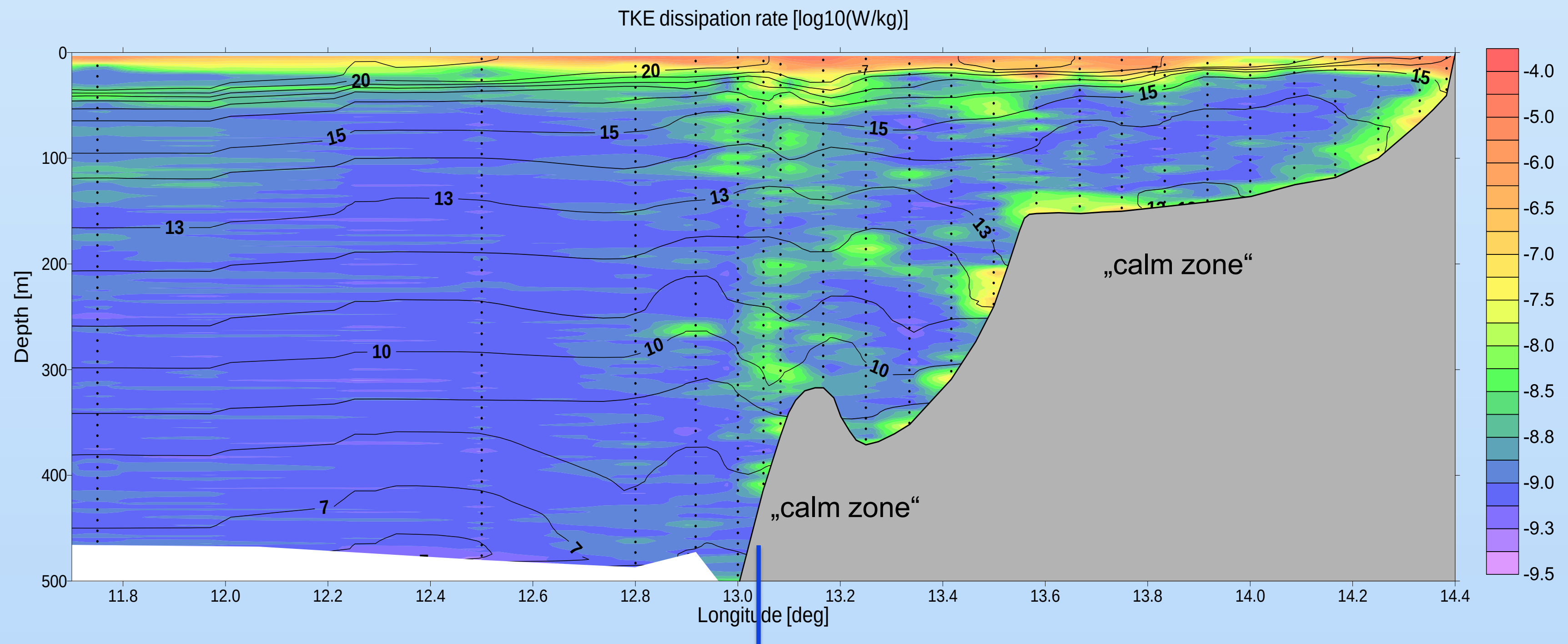


Figure 3: Hot spots of TKE dissipation at the Walvis Bay transect across the Namibian Shelf at 23°S (contour plot) and vertical displacement of isothermes (black lines) at the shelf edge.

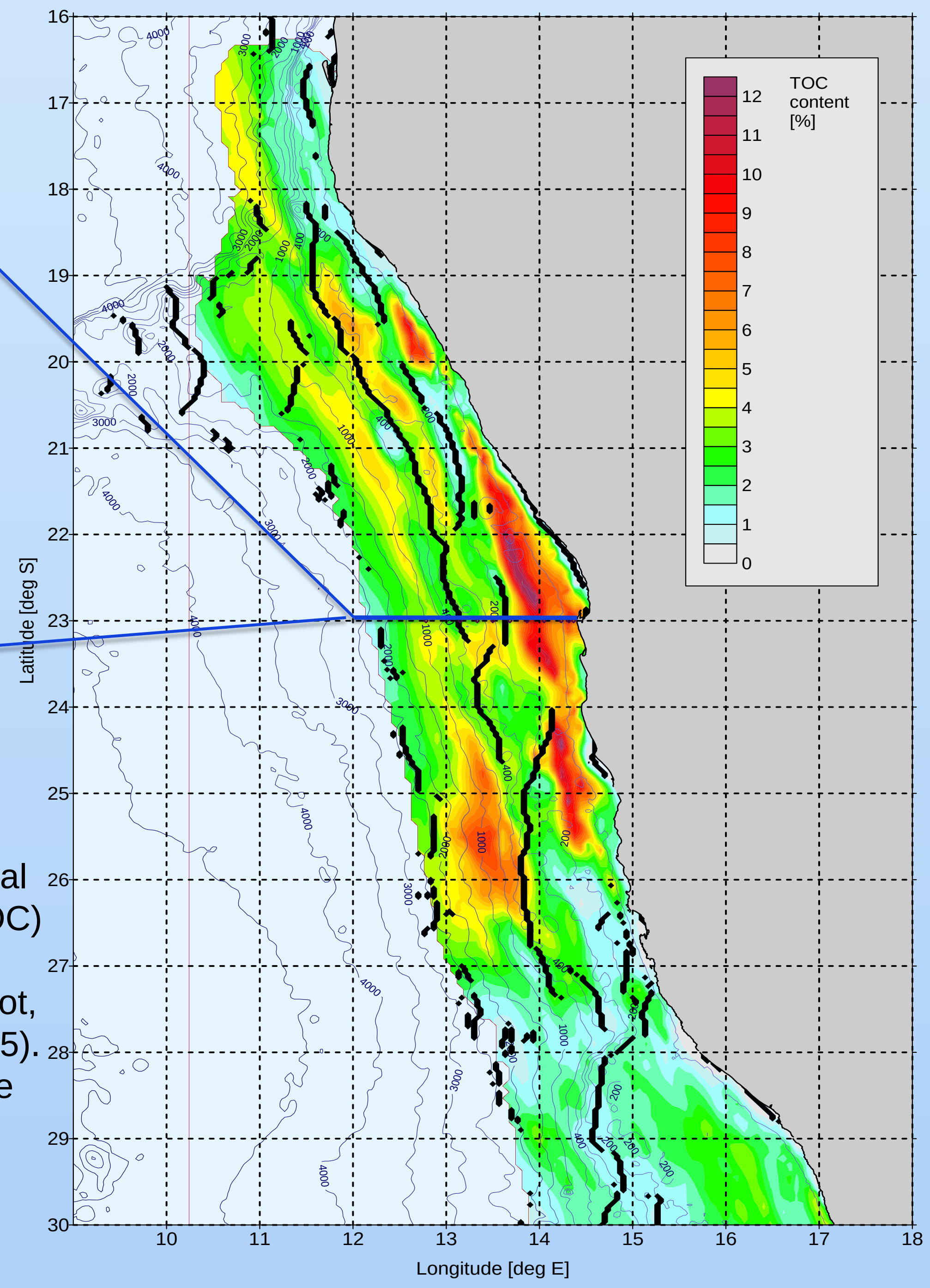


Figure 2: Distribution of total organic carbon content (TOC) in surface sediments off central Namibia (contour plot, data from Inthorn et al. 2005). And location of critical slope angles for internal M2 tide according to etopo2 bathymetry (black lines)

36 hours
time series
at the shelf edge

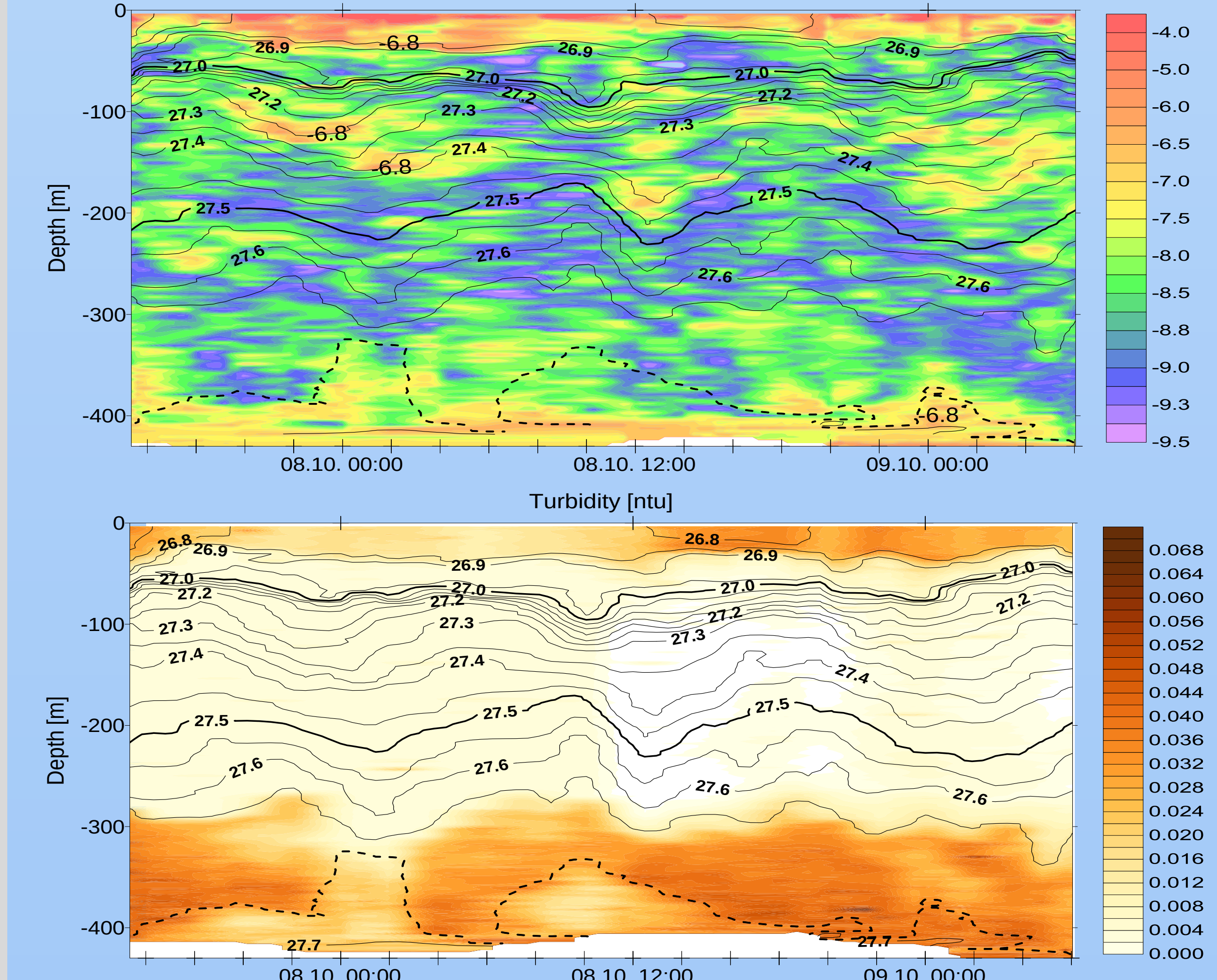


Figure 4: Time series of TKE dissipation (upper panel), and turbidity (lower panel) at the shelf edge of central Namibia (23°S). The isolines depict the density distribution. The internal M2 tide caused vertical isopycnal displacements of about 40m. The enhanced TKE dissipation at the shelf edge caused a 100m thick well mixed and turbid bottom layer

Results

- **The locations of critical slope angles for M2 tide coincide with the areas of low TOC content in surface sediments.**
- **At the shelf edge the shoaling internal M2 tide causes enhanced mixing in the entire water column and the generation of NLIWs that spread onto the shelf.**
- **At the shelf edge a mixed bottom layer of about 100m thickness, with high turbidity, points to resuspension and lateral transport of SPM.**
- **Hot spots of TKE dissipation in the bottom layer were found also at the inner shelf break and at the coast.**
- **On the shelf calm zones with low TKE dissipation in the bottom layer exist, where particulate organic matter can accumulate in the sediments.**