TKE dissipation and turbulent mixing in the Northern Benguela

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• Introduction and motivation
• Observations
• Discussion of results
• Summary
Upwelling and sediment distribution

- Intensive upwelling, generation of filaments
- Phytoplankton blooms
- Accumulation of carbon rich sediments off Namibia
- Significant differences between modelled and measured distribution

What causes the belt-like sediment distribution?

Currents, Plankton succession, enhance TKE?

TKE dissipation across the shelf

Transect at 23°S off Walvis Bay (MSS observations)

- At the outer shelf edge enhanced mixing throughout the water column
- Turbulent shadow zones above the inner shelf
- Enhanced mixing near the coast
Particular processes, which contribute to enhanced mixing on the Namibian shelf

- Shoaling internal tide at the shelf edge
- Soliton like internal waves (NLIW)
- Boluses, generated by breaking internal waves
- Current shear in the bottom boundary layer
- Incoming swell from the west wind belt
- ...  

Subgrid processes in regional numerical models
Internal waves and slope angle

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

\( \gamma = \textit{bathymetric slope} \)

\[ \frac{\gamma}{s} \begin{cases} < 1 : \text{subcritical} & \rightarrow \text{transmission} \\ = 1 : \text{critical} & \rightarrow \text{NL interaction} \\ > 1 : \text{supercritical} & \rightarrow \text{reflection / bolus generation} \end{cases} \]

Venayagamoorthy and Fringer (2007)
Critical slope angle

Estimation of critical slope areas using
- Etopo2 data
- Late summer stratification
- M2 internal tide as forcing

Low carbon fraction in sediment is correlated with location of critical slope angle areas.
- TKE dissipation observations at three cross shelf transects
- TKE dissipation time series at the shelf edge
- and on the inner shelf at 23° S
M131 – cross shelf transects

- Enhanced TKE dissipation at critical angles
- Internal wave braking is a transient process
TKE dissipation time series at the shelf edge

*(RRV Discovery cruise Oct. 2010)*

- Internal M2 causes up to 50m vertical displacements of isopycnals
- Patchy distribution of TKE dissipation, but enhanced throughout the entire water column
- Increased dissipation rates near surface and bottom
- Mixed bottom layer with enhanced turbididy $\rightarrow$ resuspension

Hotspot of mixing
Satellite observations of NLIW

- First observations in Space Shuttle pictures (1990)
- Area appr. 100 x 100 km
- Package distance: ~ 18km
- Wave length: 0.7-1.4 km
- Wave speed: 0.4 m/s (assuming M2)
- Along crest length: 75-100 km

Time$_{\text{diff}}$ = 165 min
Distance = 6 442 m
Group velocity = 0.65 m/s

*Foto: NASA STS035-74-19, 03. December 1990*
Spatial distribution of NLIW

Observations of NLIW surface signatures from July 2013 to June 2014 (MODIS aqua/terra VIS)

- Exclusively inshore of the 500m isobath
- Ubiquitous on the entire shelf
- Higher frequency between 19° S and 22° S
- Few observations near the coast between 22° S and 26° S
Long term variability

- EMD
- Hilbert transformation

**Mode**  mean period
1  0.607 h  (NLIW)
2  1.341 h  (NLIW)
3  3.979 h  (??)
4  12.73 h  (M2)
5  31.15 h  (f)
6  125.7 h  (CTW)

**Correlation**
1,2 with 4:  \( r^2 = 0.44 \)
1,2 with 5:  \( r^2 = 0.31 \)
TKE dissipation time series on the inner shelf

*(RV Mirabilis cruise Jan. 2013)*

- Internal M2 not pronounced
- Patchy distribution of TKE dissipation in midwater
- Mixing events near the thermocline due to NLIW
- Bottom TKE maxima not correlated with a distinct frequency
- Mixed bottom layer with slightly enhanced turbidity \(\rightarrow\) resuspension

**Shadow area**
Correlation analysis (inner shelf)

- TKE dissipation maxima spread from the bottom upward into the water column

Swell
(r = 0.16)

NLIW
(r = -0.20)

Bottom shear of current
(r = 0.78)
Time series mean profiles

**Shelf edge (1.5d)**
- TKE dissipation in mid water enhanced by 1 to 2 magnitudes
- Extended mixed layer thickness at the bottom

**Inner shelf (7d)**
- TKE dissipation in midwater at noise level
- Logarithmic boundary layer
Conclusions

• The location of critical slope angles at the Namibian shelf correlates with gaps in the mud belt.

• The shoaling of M2 internal tide generates enhanced mixing in the entire water column at the shelf edge. It generates "solitary internal waves" at the Namibian shelf.

• NLIW are ubiquitous on the Namibian shelf. Their intensity undergoes long term variations.

• Turbulent mixing in the "shadow zone" on the inner shelf can be attributed to current shear in the bbl.

Overall goal: Establishing a parameterization of mixing caused by subgrid processes (NLIWs, boluses, swell).
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