TKE dissipation and turbulent mixing in the Northern Benguela

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- *Introduction and motivation*
- *Observations*
- *Discussion of results*
- *Summary*

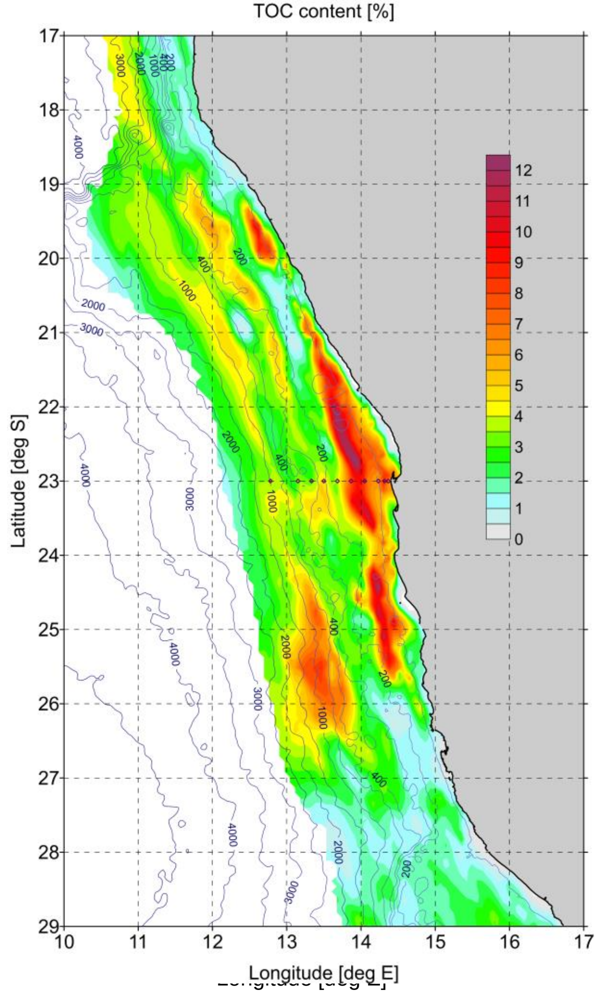
Upwelling and sediment distribution

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

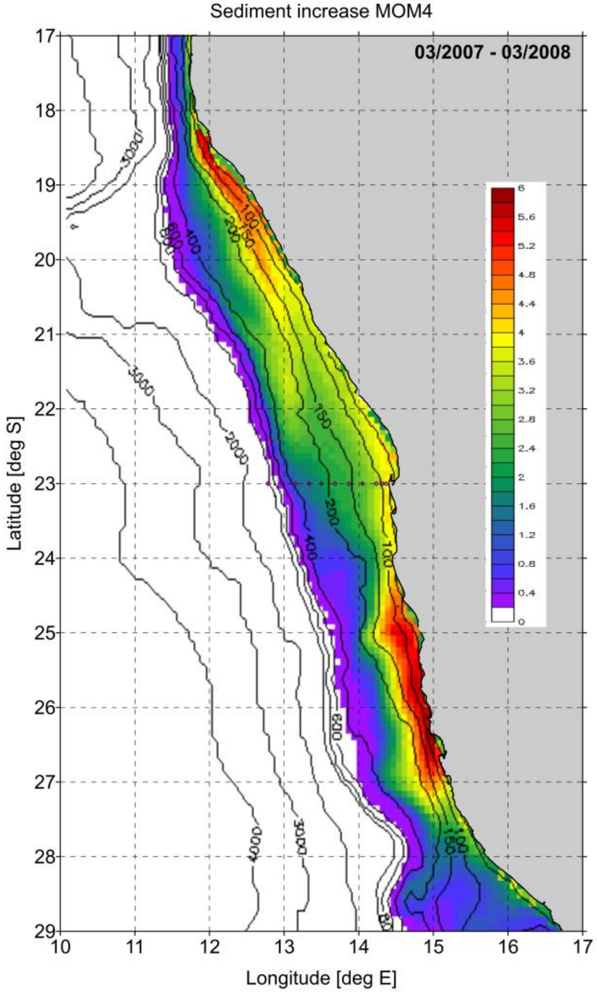
What causes the belt-like sediment distribution?

Currents, Plankton succession, enhance TKE?

observations



model



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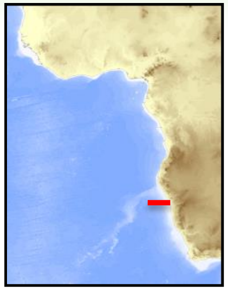
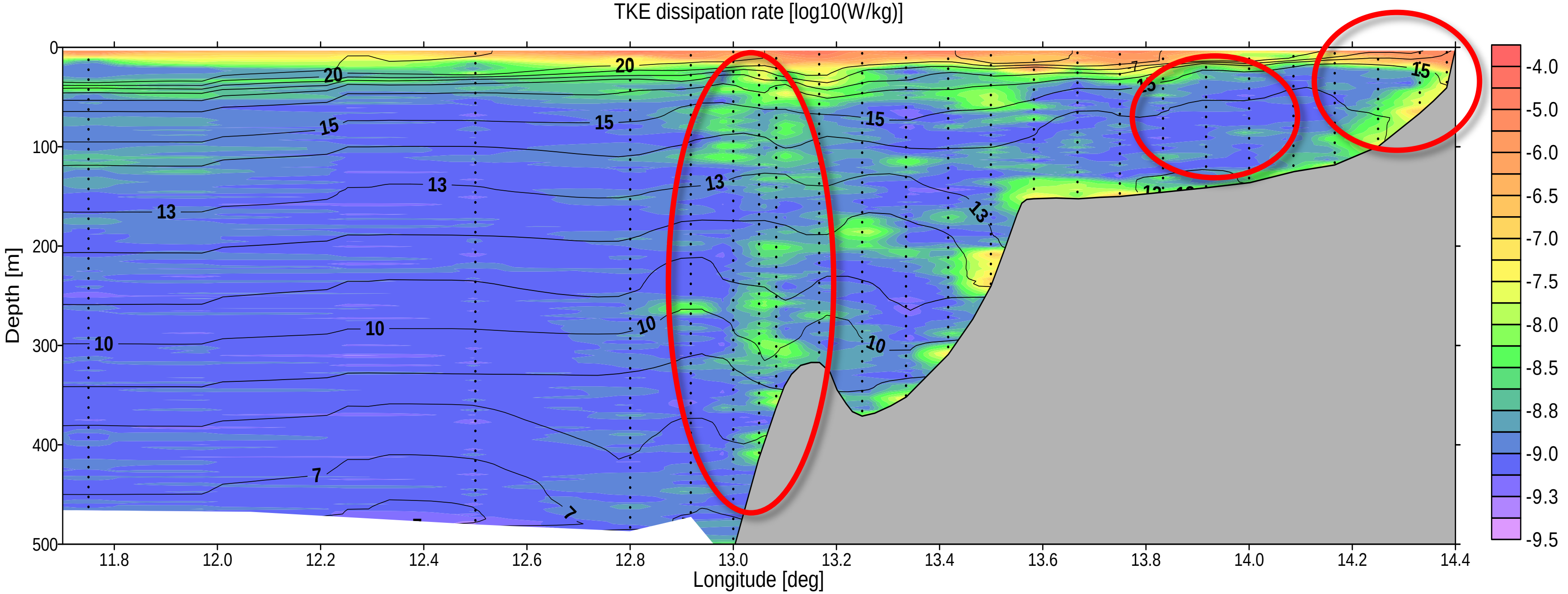
TKE dissipation across the shelf

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

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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

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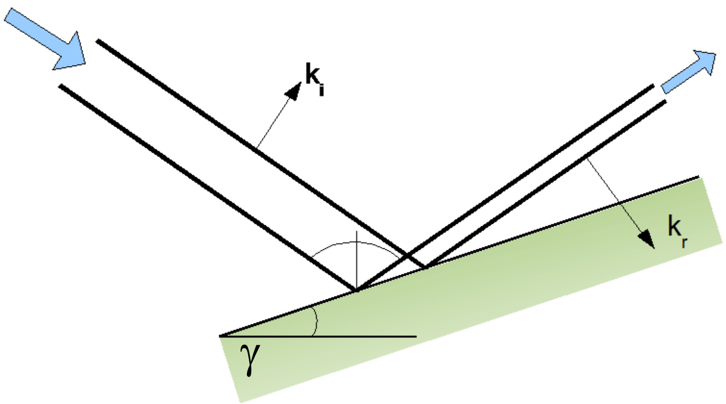
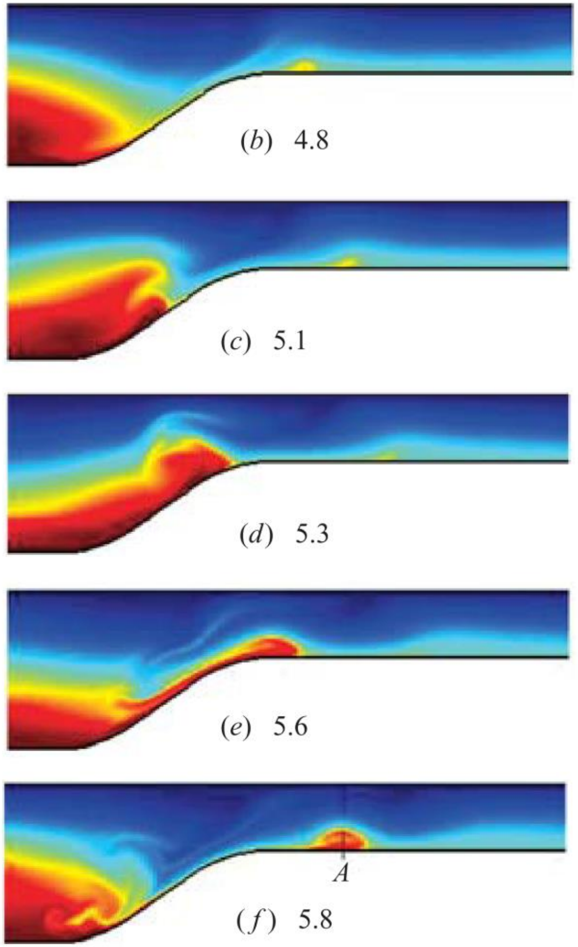
Internal waves and slope angle

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

$$\gamma = bathymetric\ slope$$



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



Venayagamoorthy and Fringer (2007)

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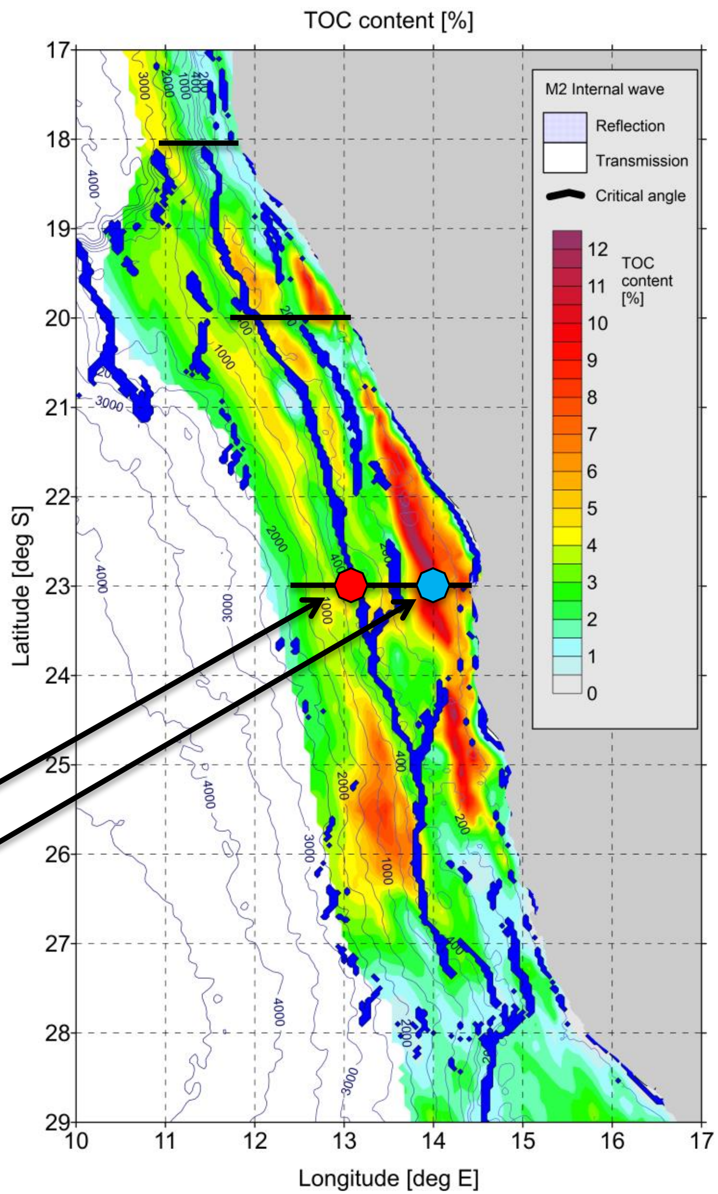
Critical slope angle

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



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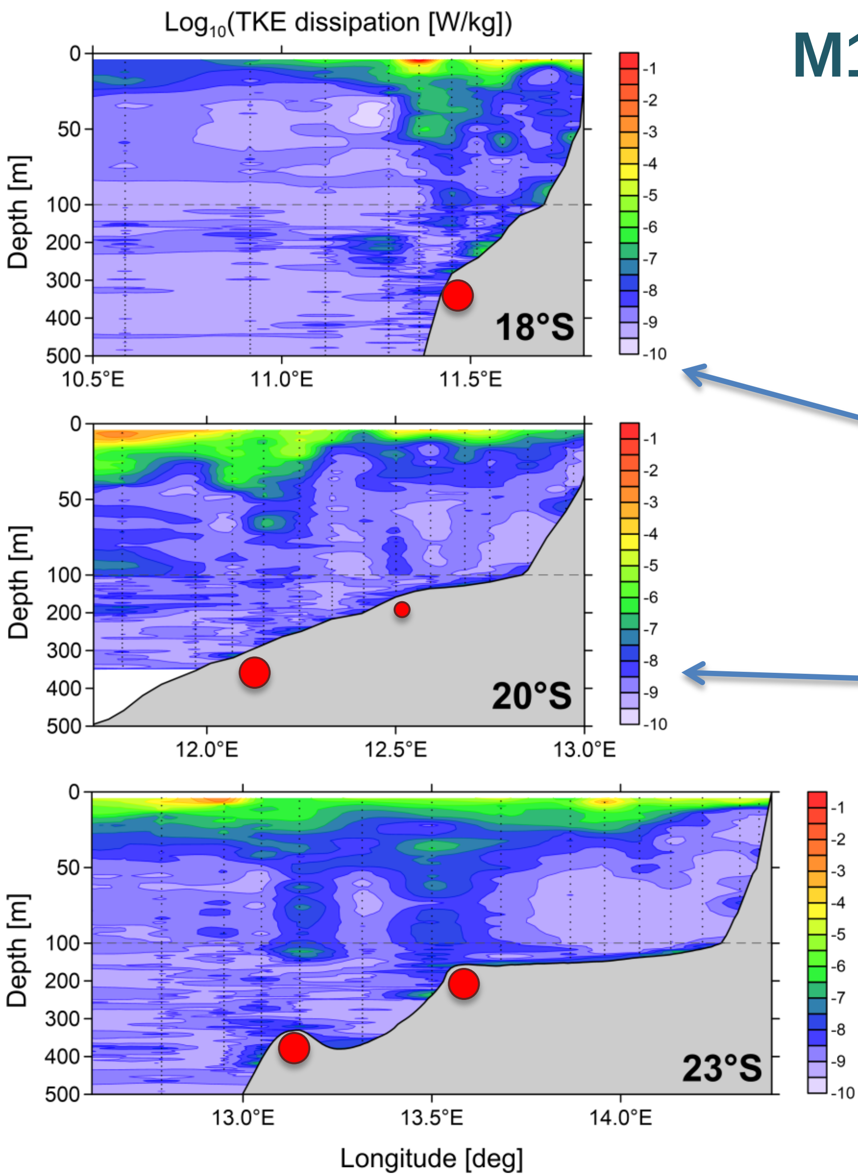
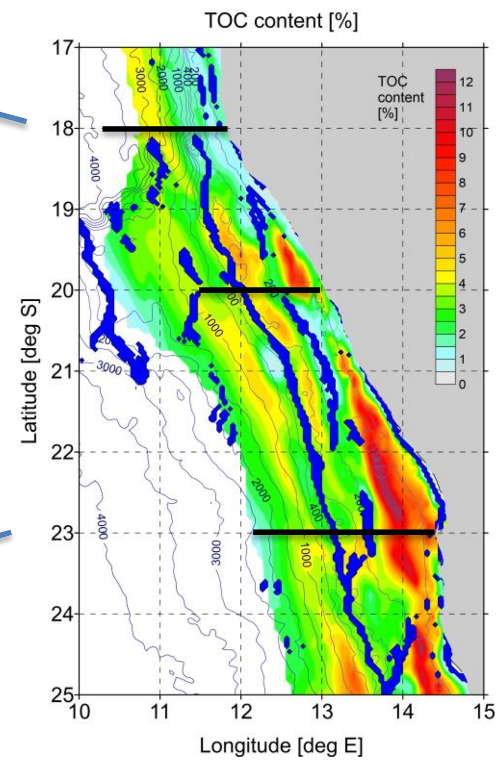
M131 – cross shelf transects

- Enhanced TKE dissipation at critical angles
- Internal wave braking is a transient process





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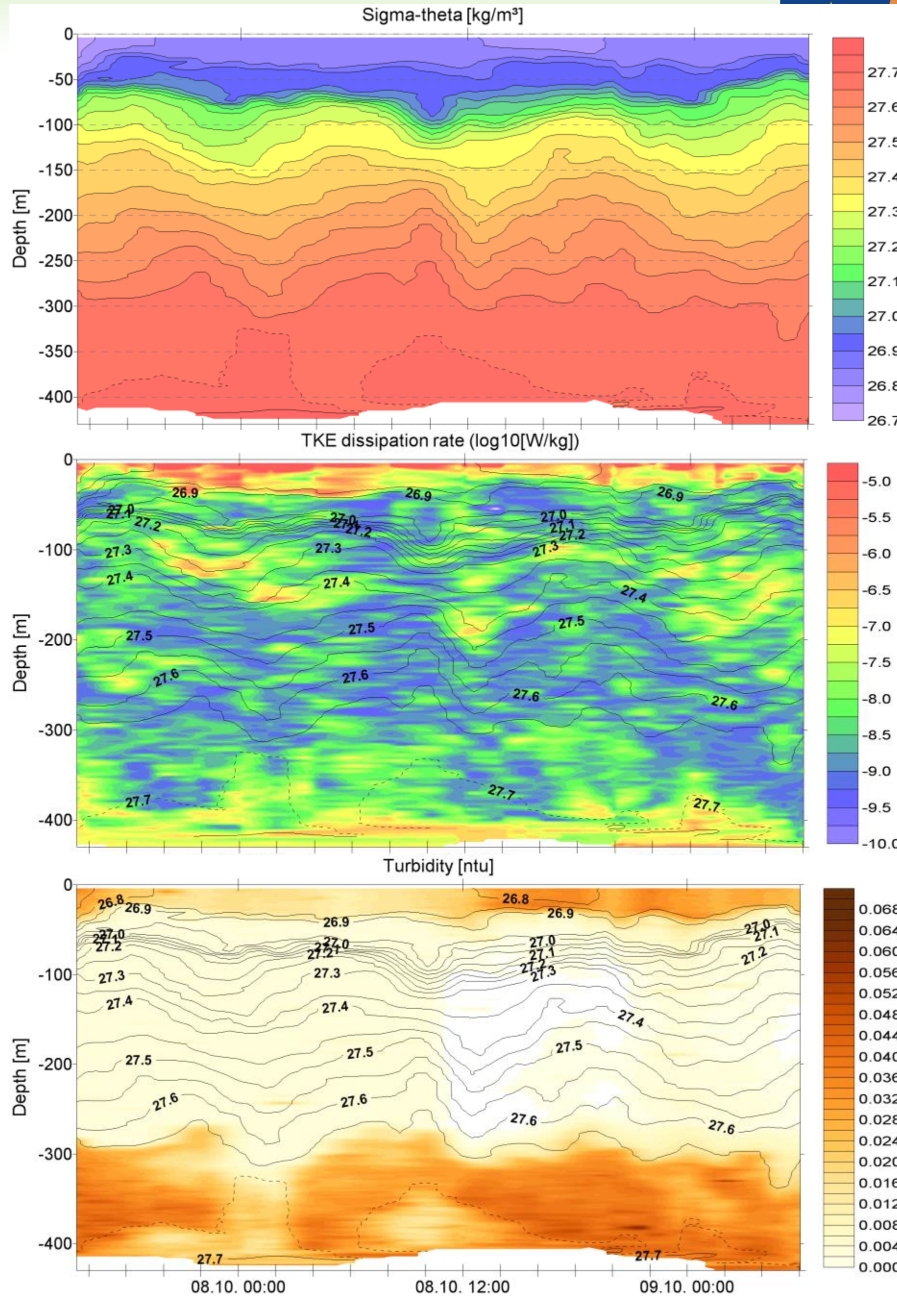
TKE dissipation time series at the shelf edge

(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 → resuspension

Hotspot of mixing



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Satellite observations of NLIW

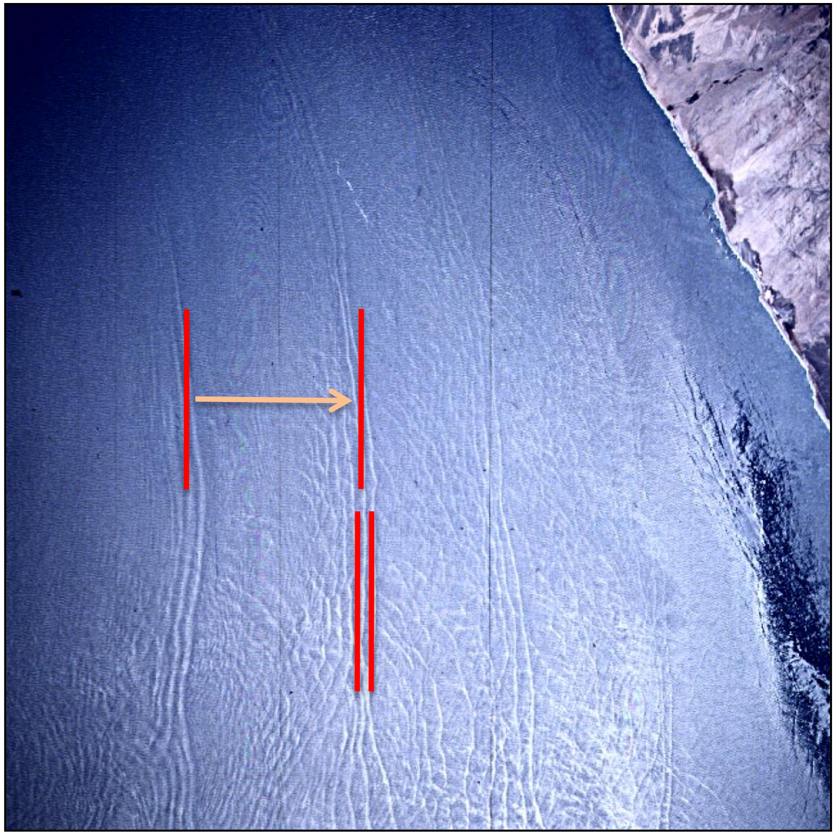


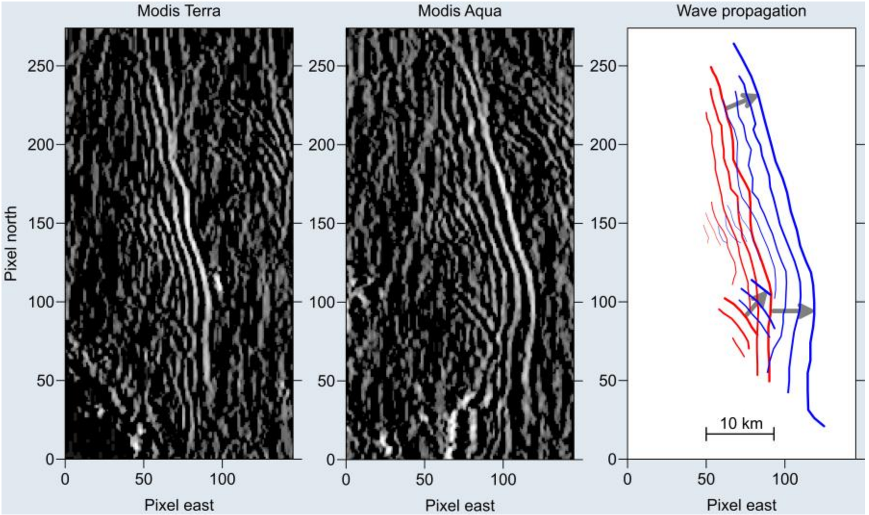
Foto: NASA STS035-74-19,
03. December 1990

- 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

$Time_{diff}$ = 165 min

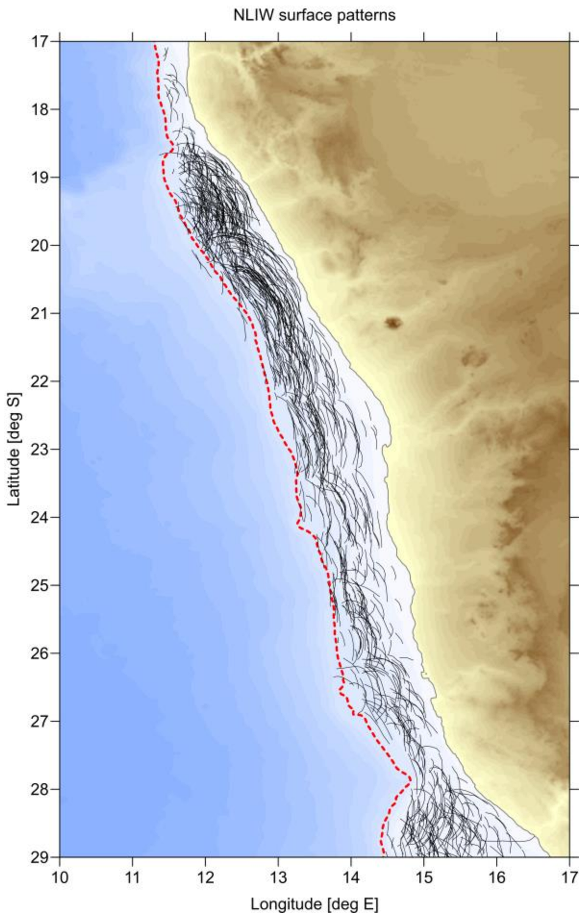
Distance = 6 442 m

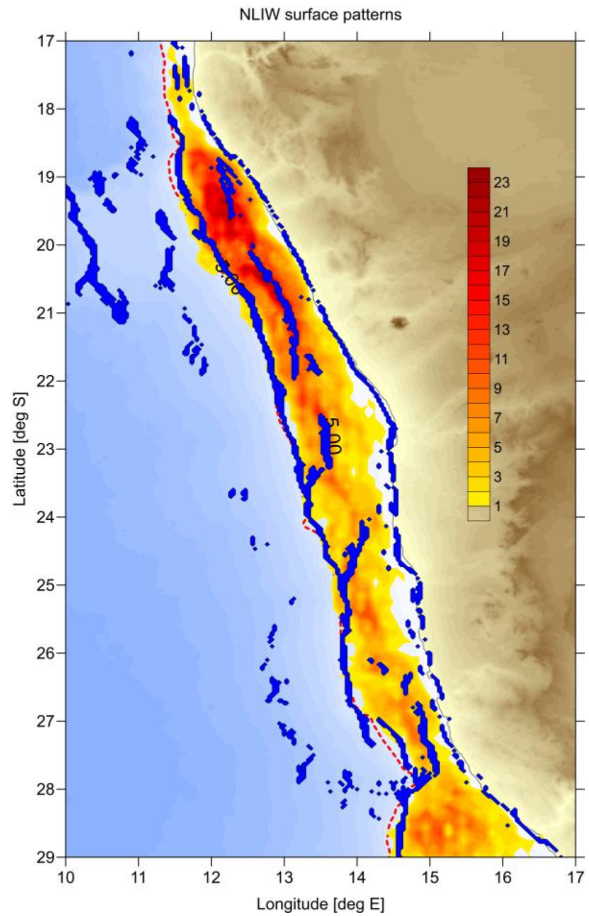
Group velocity = 0.65 m/s



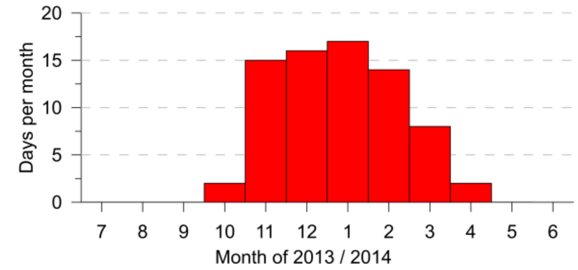
Spatial distribution of NLIW

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





Monthly frequency



- 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

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Long term variability

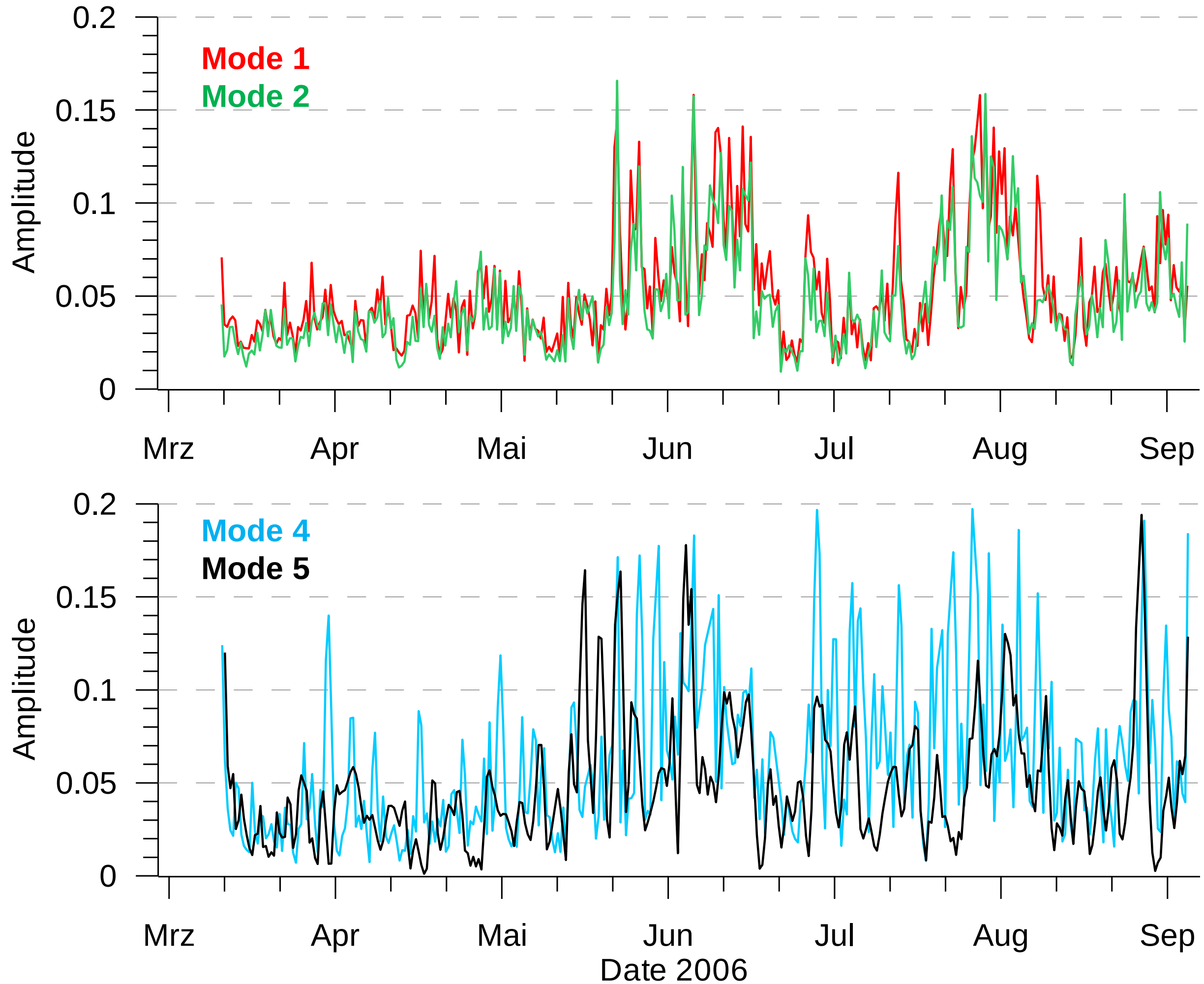
- EMD
- Hilbert transformation

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: $r^2 = 0.31$



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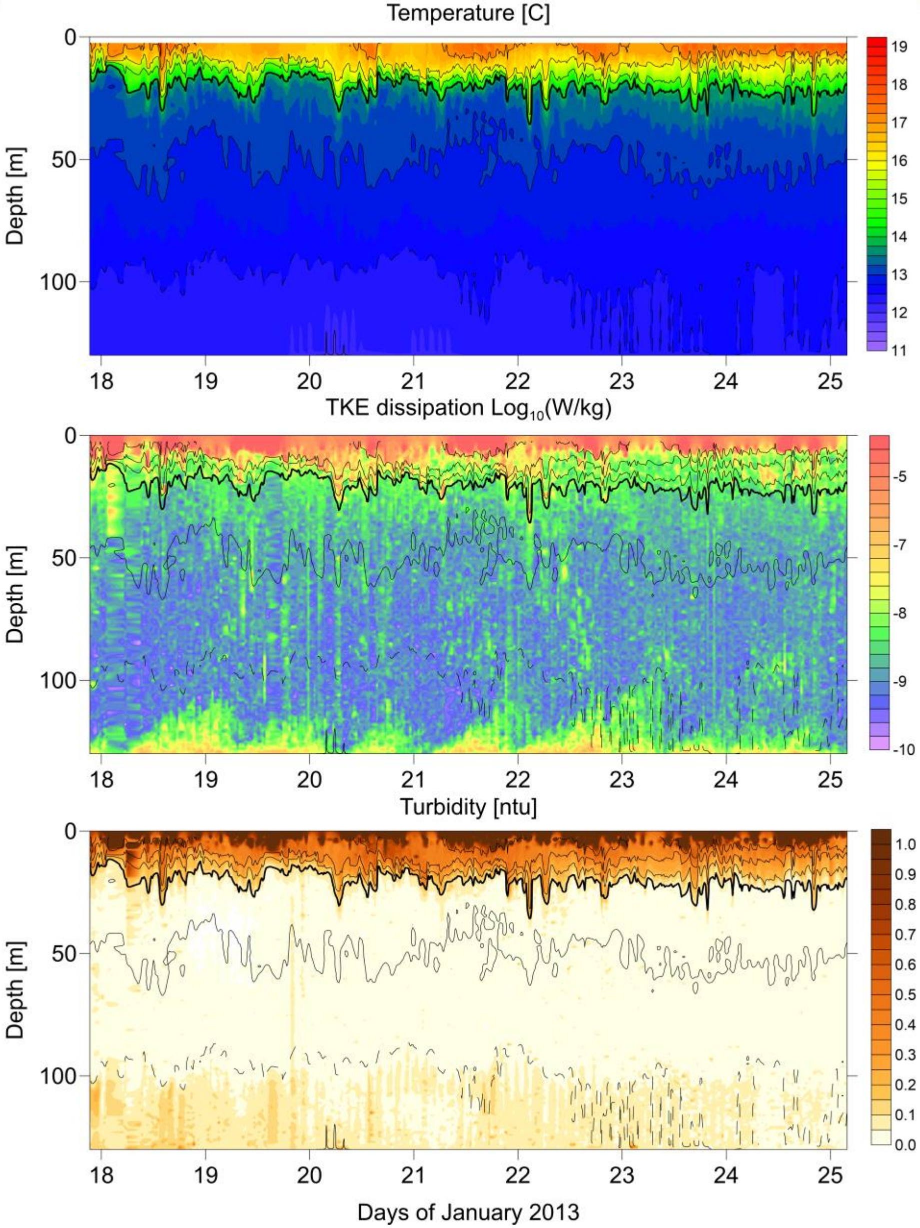
TKE dissipation time series on the inner shelf

(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 → resuspension

Shadow area



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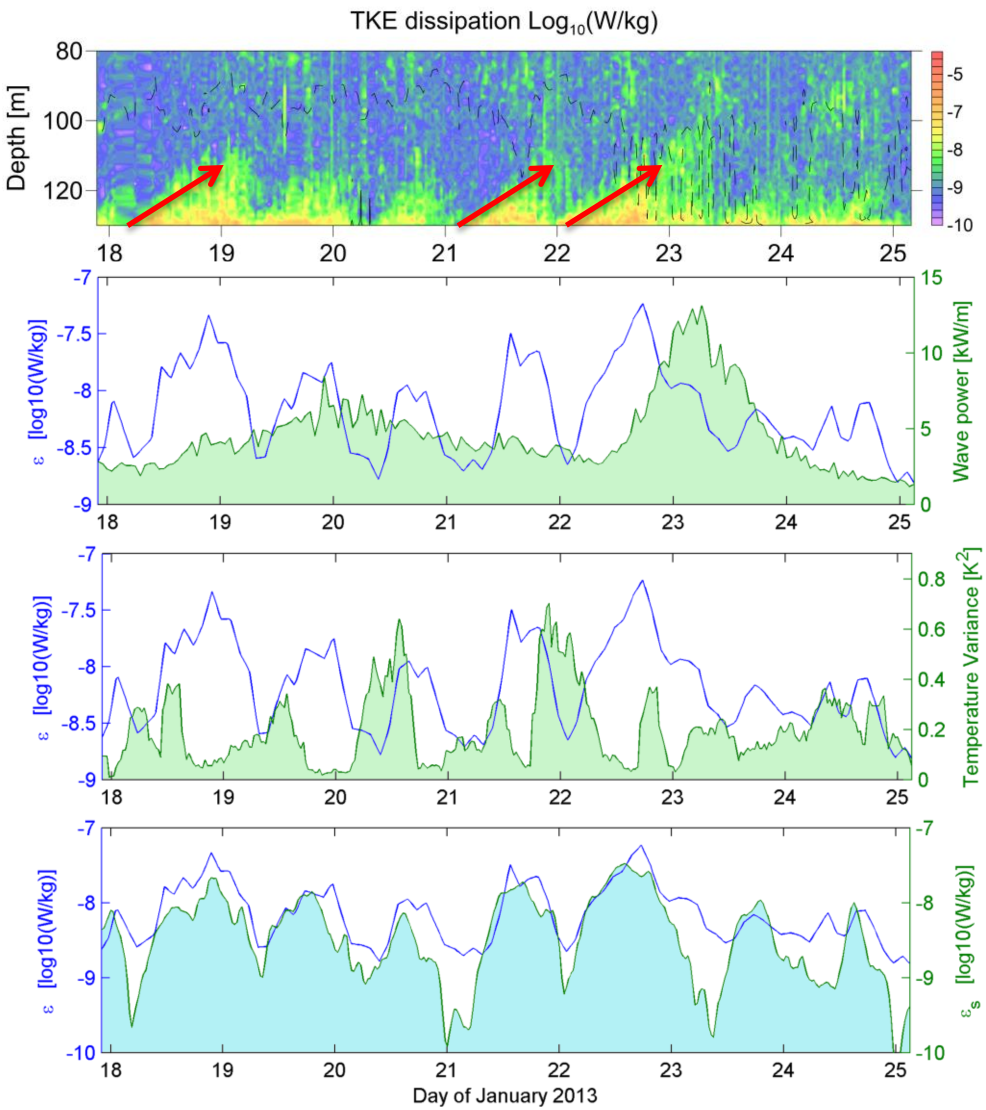
Correlation analysis (inner shelf)



- 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)

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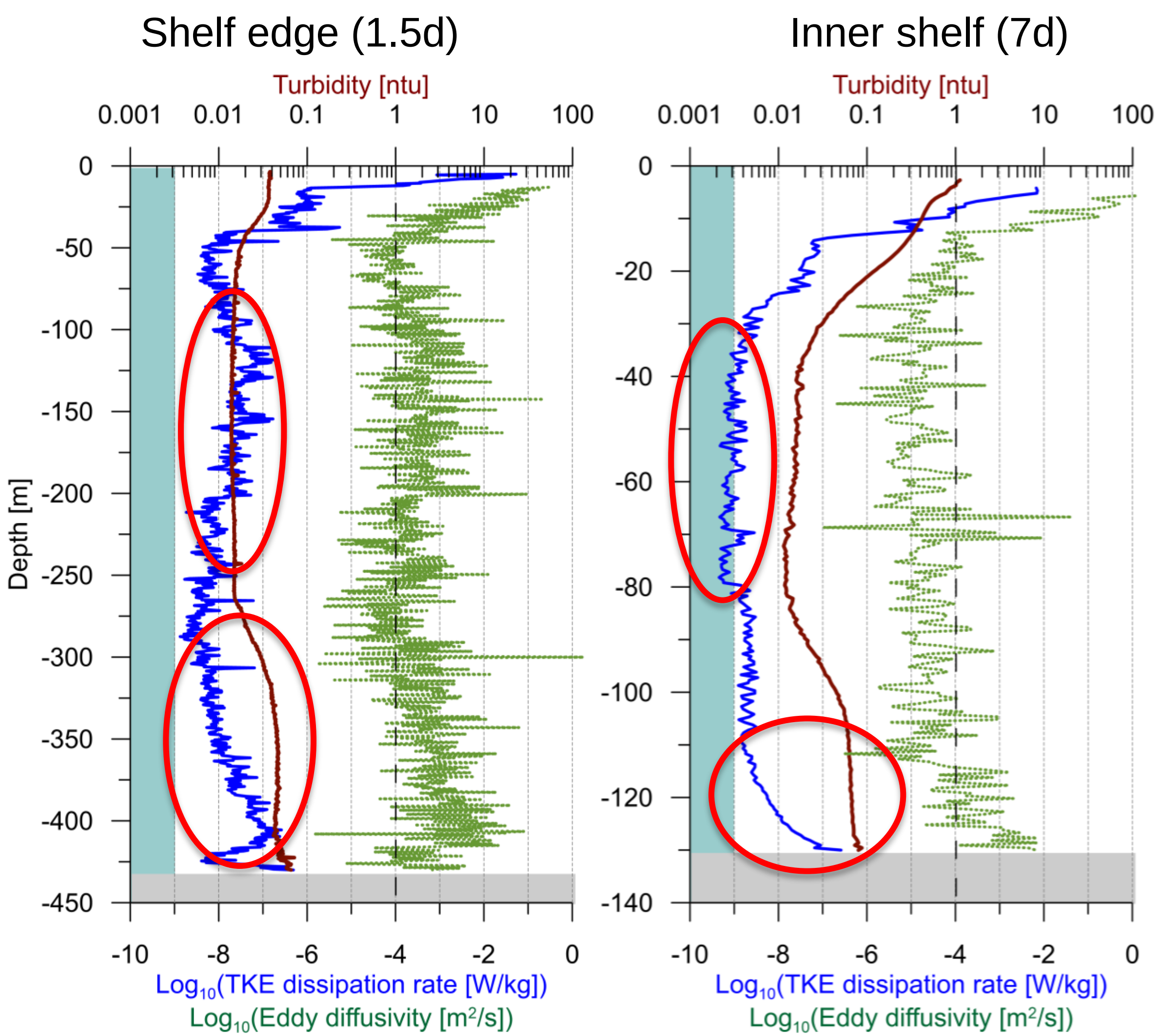
Time series mean profiles



Schelf edge

- TKE dissipation in mid water enhanced by 1 to 2 magnitudes
- Extended mixed layer thickness at the bottom

Inner shelf

- TKE dissipation in midwater at noise level
- Logarithmic boundary layer

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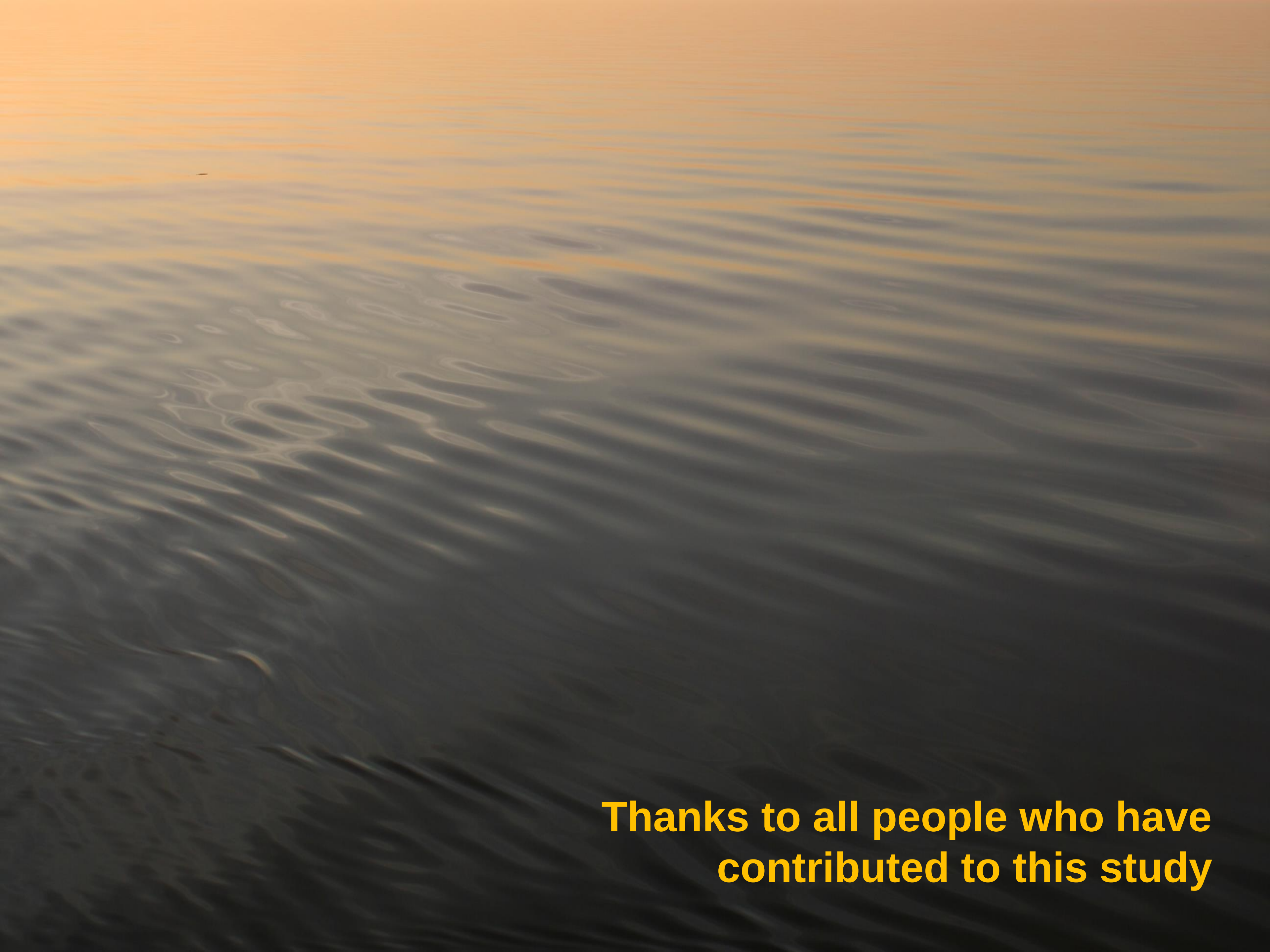
Conclusions

- 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 schelf. 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 paramerization of mixing caused by subgrid processes (NLIWs, boluses, swell).


Thanks to all people who have
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