

Evolution of secondary cellular circulation flow above submarine bedforms imaged by remote sensing techniques

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Highlights

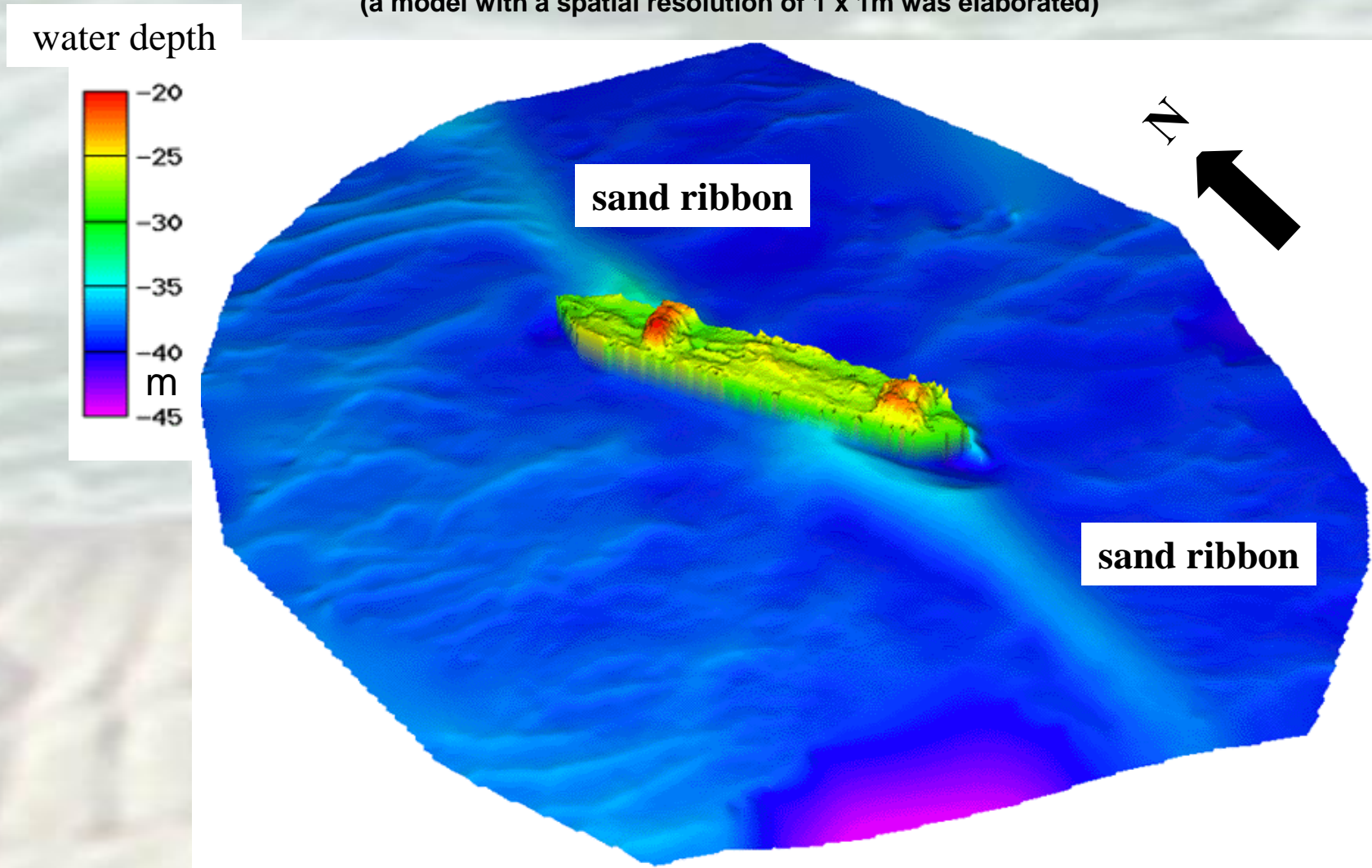
- Near water surface strain rate characterizes submerged sand ribbons and sand waves
- Active up- and downwelling effects play a significant role
- Both types of cellular circulations (perpendicular as well as parallel to the dominant tidal current direction) obey the Hamiltonian principle of classical mechanics

1.) Sand ribbons associated with secondary circulation flow

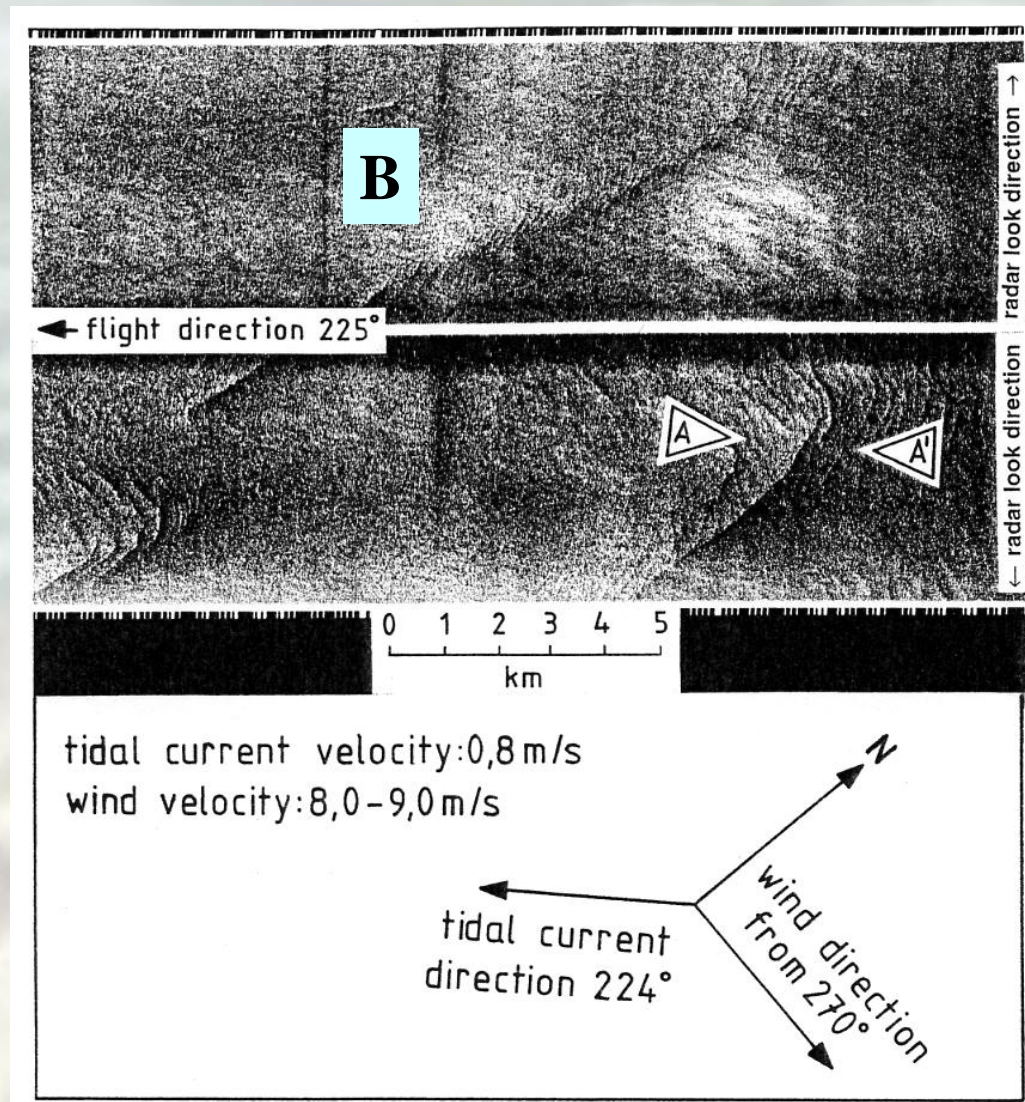
Multibeam echo sounding image of the M.V. *Birkenfels* wreck in the southern North Sea

Kongsberg EM1002 multibeam echo sounding data collected during a survey with the *Belgica* in May 2001

(a model with a spatial resolution of 1 x 1m was elaborated)

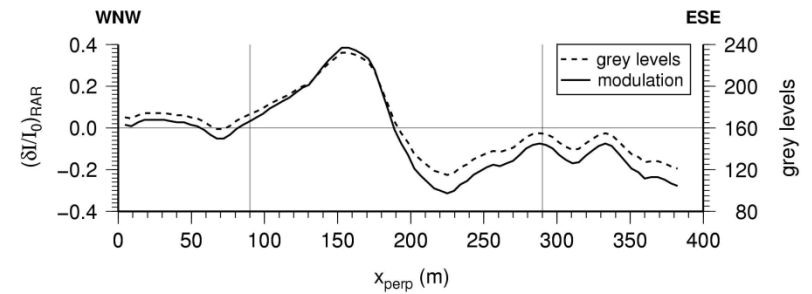
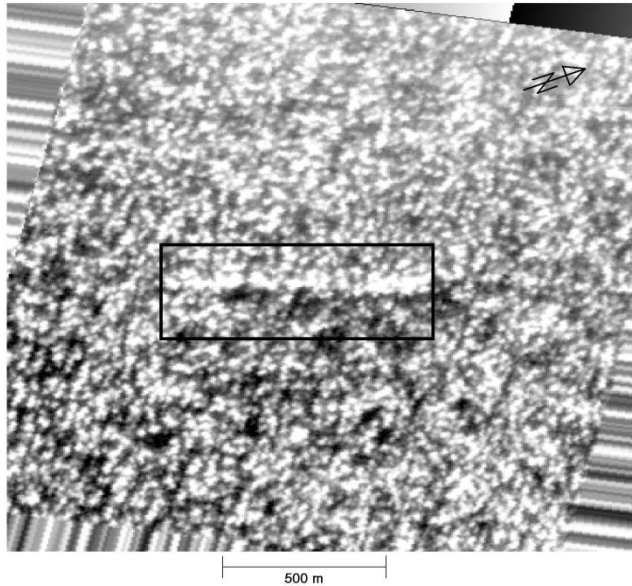


Airborne K_a -band real aperture radar (RAR) image shows radar signature of M.V. *Birkenfels* wreck indicated by B



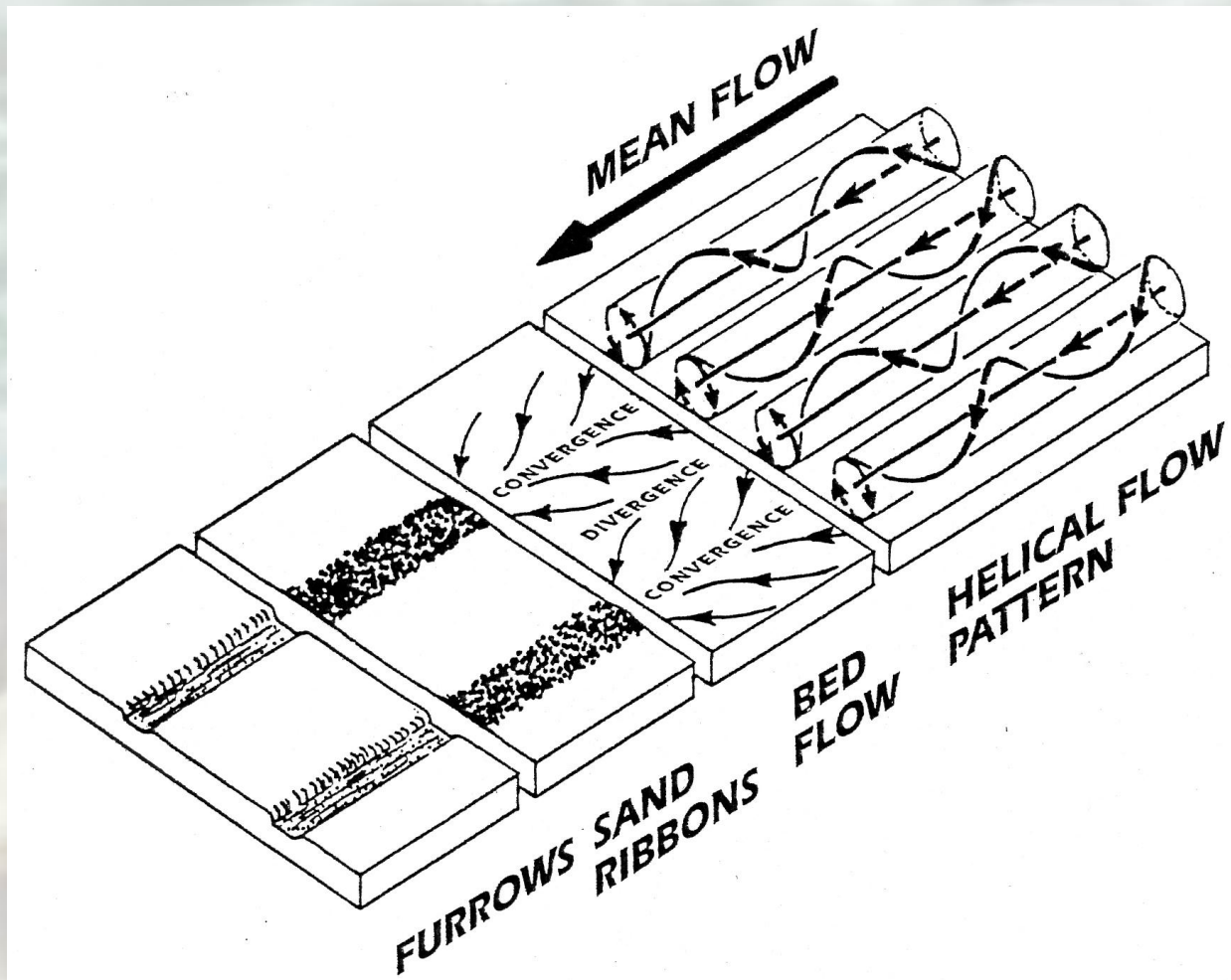
Enlarged RAR image section
around the sea area of the

Birkenfels wreck

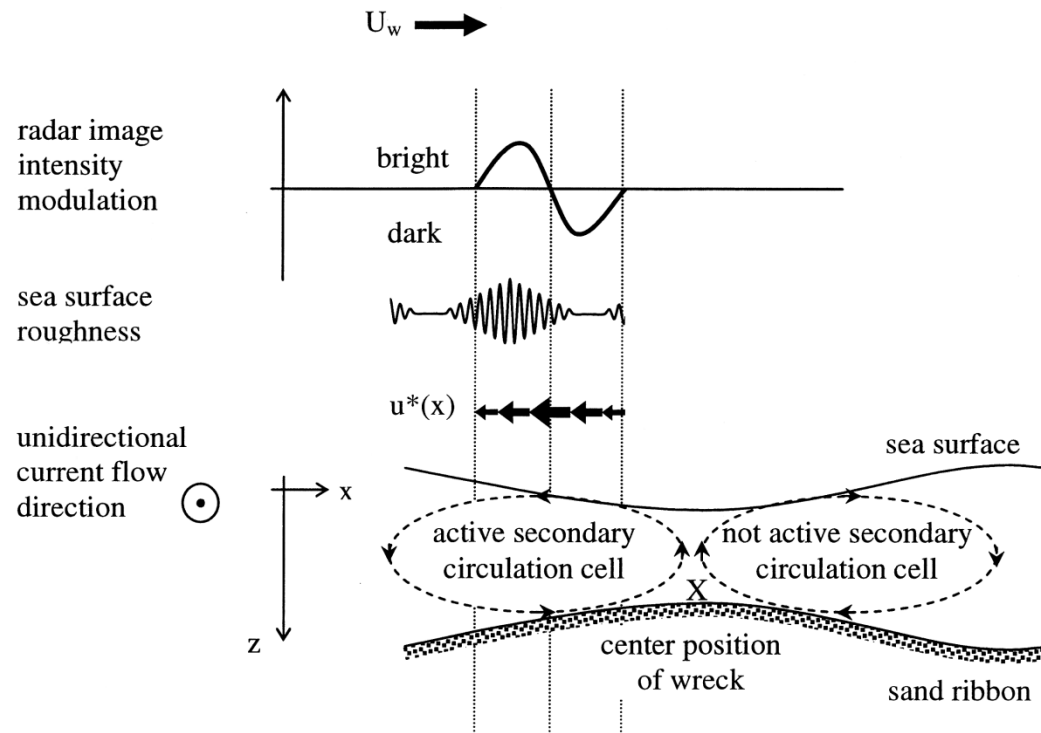


Mean RAR grey level or
intensity profile and image
intensity modulation of the
Birkenfels wreck signature

Schematic representation of the relationship between secondary circulations of the boundary layer, zones of convergence and divergence on the sea bed, sand ribbons, and sedimentary furrows
(Viekman et al., 1992)

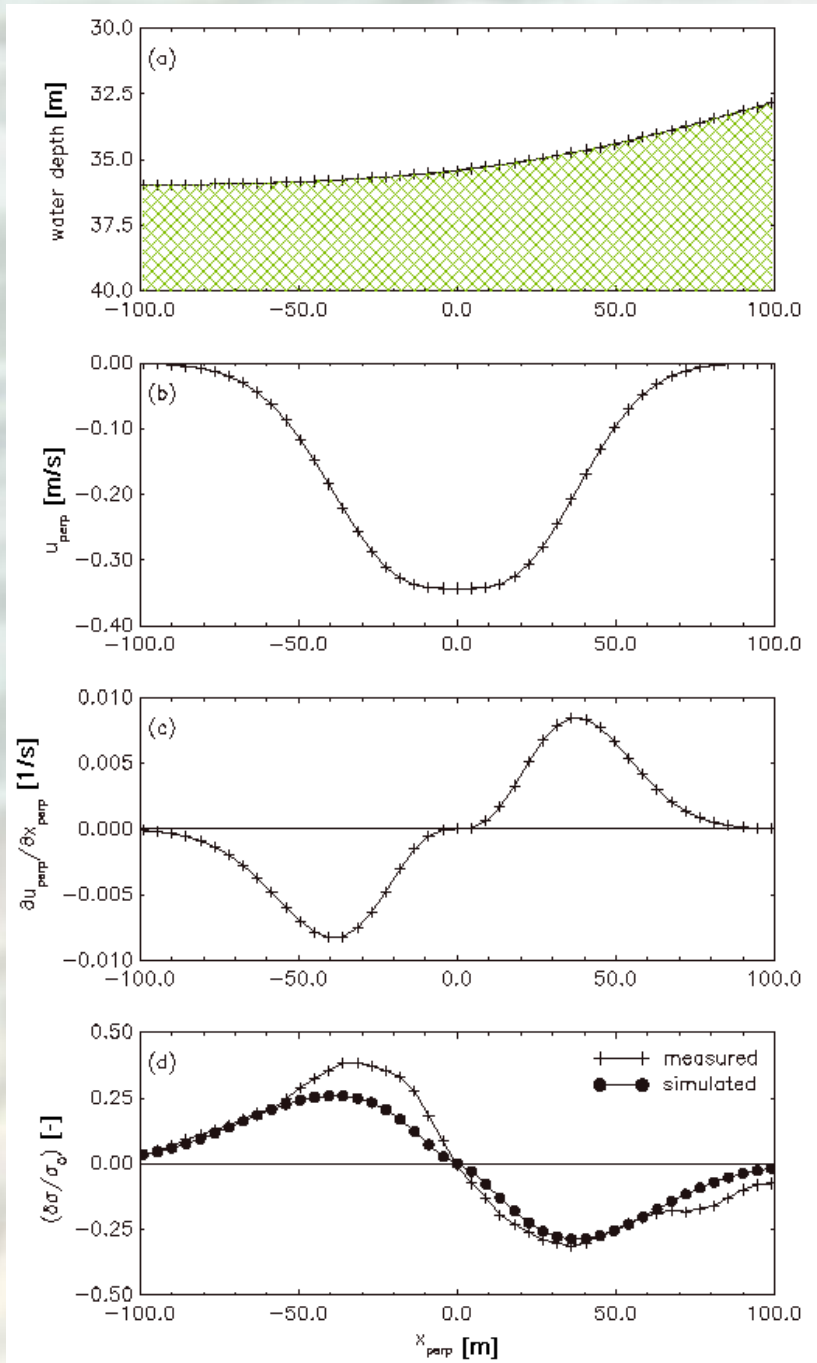


Schematic sketch of the unidirectional current flow, cross structure residual flow above sand ribbons, horizontal component of the tangential current of the secondary circulation cell at the sea surface, center position of wreck marked by the capital letter X, associated sea surface roughness, and radar image intensity modulation



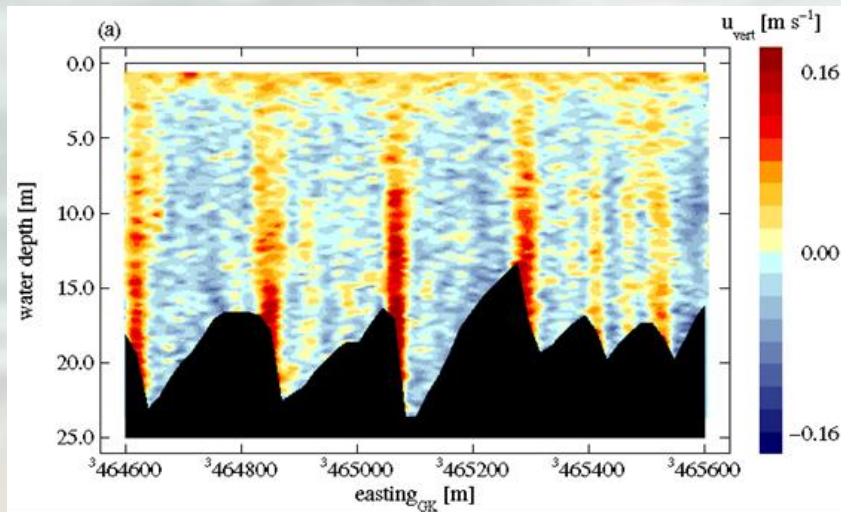
Results of simulations:

- (a) water depth as a function of x_{perp} ,
- (b) perpendicular residual current speed relative to the unidirectional tidal current flow U_0 ,
- (c) strain rate or gradient of the perpendicular component relative to U_0 of the residual current velocity, and
- (d) comparison of simulated and measured NRCS modulation

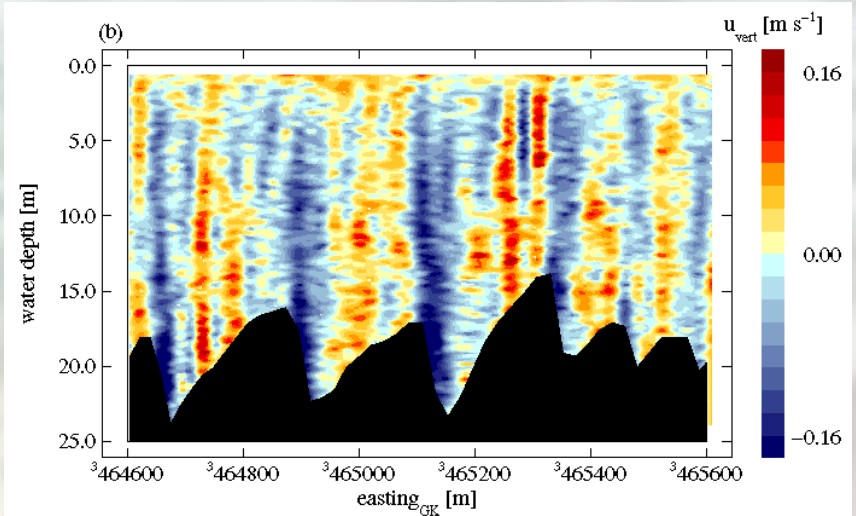


2.) Sand waves associated with secondary circulation flow

Ebb tidal current phase



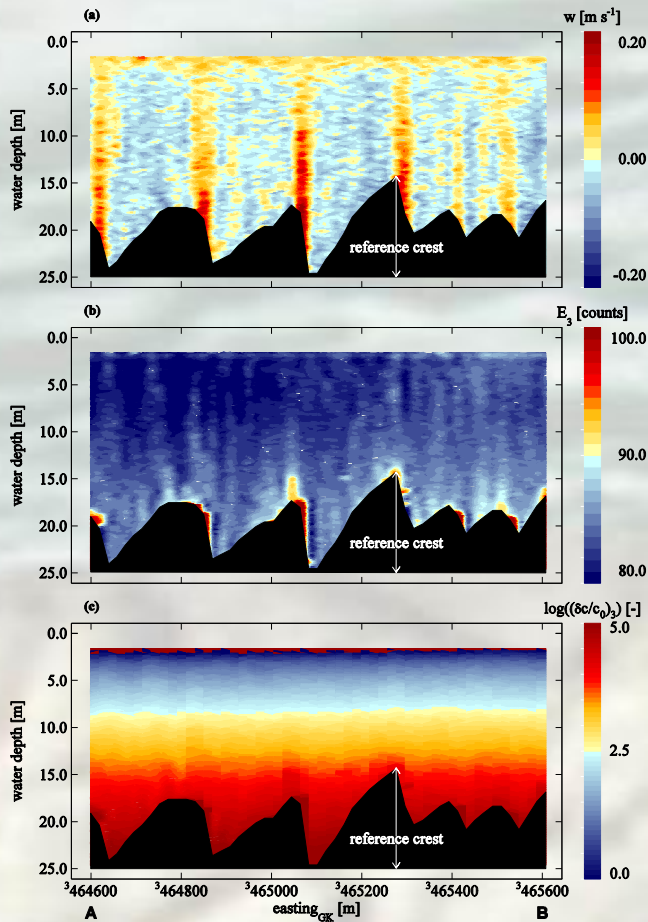
Flood tidal current phase



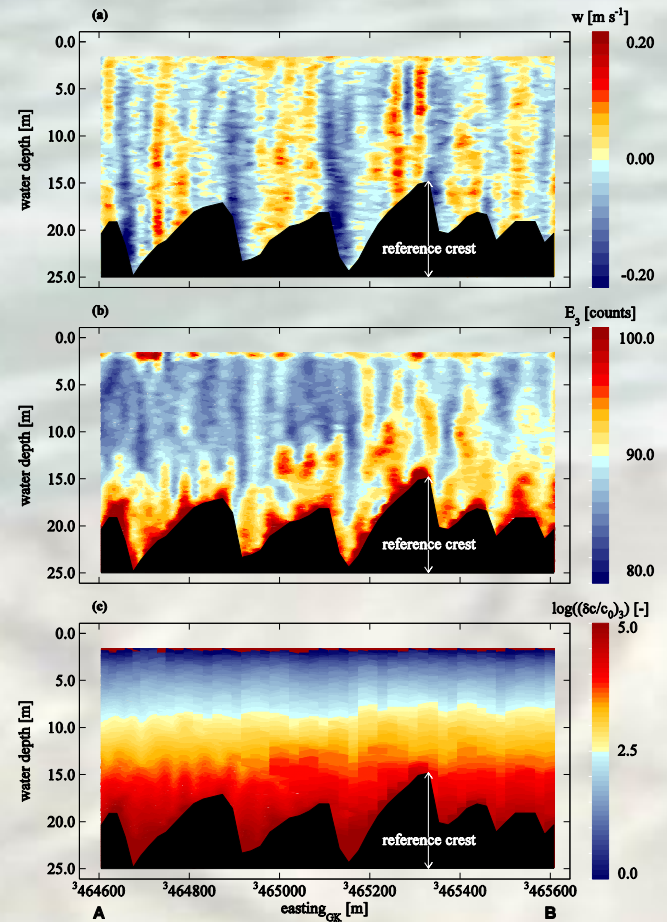
Vertical component of the current velocity field measured by acoustic Doppler current profiler (ADCP) in the Lister Tief, German Bight of the North Sea, on 10 August 2002.

Outlook

a) Vertical component of the current velocity field, b) echo intensity and c) calculated logarithmically modulation of suspended sediment concentration in the Lister Tief, German Bight of the North Sea, measured by ADCP on 10 August 2002.



Ebb tidal current phase



Flood tidal current phase