Evidence of tidal straining in well-mixed channel flow from micro-structure observations[1]

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ECOWS - Project

ECOWS (Role of Estuarine Circulation for Transport of Suspended Particulate Matter in the Wadden Sea)

The aim of this project is to investigate the role of estuarine circulation for suspended particulate matter (SPM) transport in the Wadden Sea. Major hypotheses are that (i) estuarine circulation is relevant to SPM transports in the Wadden Sea, that (ii) tidal straining (i.e. the correlation between vertical shear and eddy viscosity due to tidal asymmetry caused by horizontal density gradients) is the major process contributing to estuarine circulation, and (iii) that wind straining (i.e. the subtidal vertical shear generated by surface wind stress) is an important episodic contribution to estuarine circulation. These hypotheses will be tested by means of targeted field observations in three tidal channels (Hörnum Deep, Jade Bay and Otzumer Balje), idealised process-oriented numerical model simulations and realistic hindcast simulations for the focal areas and for the entire Wadden Sea. Confirmation of these hypotheses will lead to a paradigm shift in understanding Wadden Sea dynamics which so far has been widely assumed to be unaffected by density gradients.

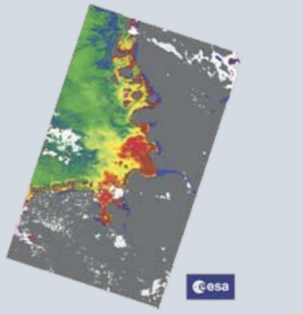


Fig. 1 Total suspended matter in the German Bight taken by the Medium Resolution Imaging Spectrometer (MERIS) on board the European Space Agency (ESA) satellite *Envisat 12 Aug 2003. (Burchard et al. 2008)* [2]

Tidal Straining

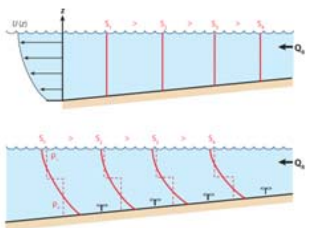
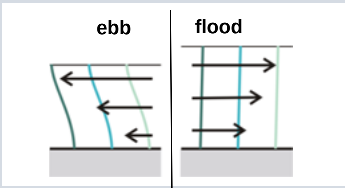


Fig. 2 Schematic of the tidal-straining mechanism *(based on Simpson et al. 1990* [4]*, reprinted by MacCready and Geyer 2010* [3]*). The* top panel illustrates well-mixed conditions at the end of the flooding tide and the vertical profile of ebbing velocity. The solid lines in the second panel show the distortion of the salinity contours by the ebb, and the dashed lines indicate the influence of mixing.



ebb	flood
• current increases vertical stratification	• current decreases vertical stratification
• suppressed vertical mixing	• increased vertical mixing
• smaller near bottom velocities	• larger near bottom velocities
• SPM trapped near the bottom	• SPM homogeneously distributed over the whole water column

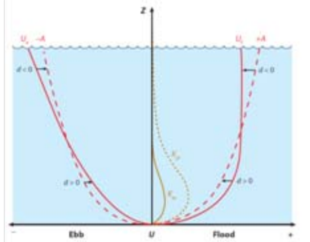


Fig. 3 Vertical profiles of velocity and eddy mixing coefficients, demonstrating tidal asymmetry (based on *Jay & Musiak 1994* [5] ,reprinted by *MacCready and Geyer 2010* [3]*).* The thick solid lines (U_f and U_e) are the ebb and flood velocity profiles, and the thick dashed lines (−A and +A) indicate the semidiurnal velocity structure. The thin solid and dashed lines are eddy viscosity profiles for flood and ebb, with stronger mixing during the flood. The difference ± between the semidiurnal and actual velocity is the signal of tidal asymmetry. This is made up of a quarterdiurnal component and the mean (landward near the bottom and seaward near the surface.)

Observational Evidence for Tidal Straining

The major objective of the present study[1] is to directly confirm, by means of a variety of independent field observations, the significance of the tidal straining mechanism for driving estuarine circulation. In order to obtain some insight into the tidal straining process, a short ship campaign was carried out in the Lister Deep during April 15–17, 2008. During that ship campaign a vessel-mounted ADCP as well as an MSS (MicroStructureSonde) were deployed to measure high-resolution velocity-, CTD-, turbulence-, and SPM-profiles.

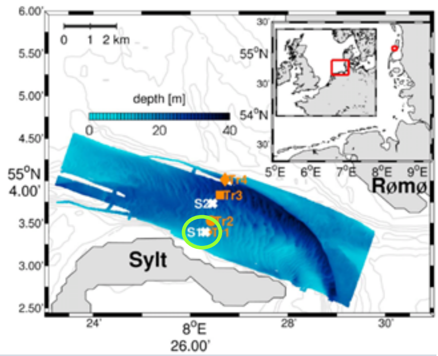
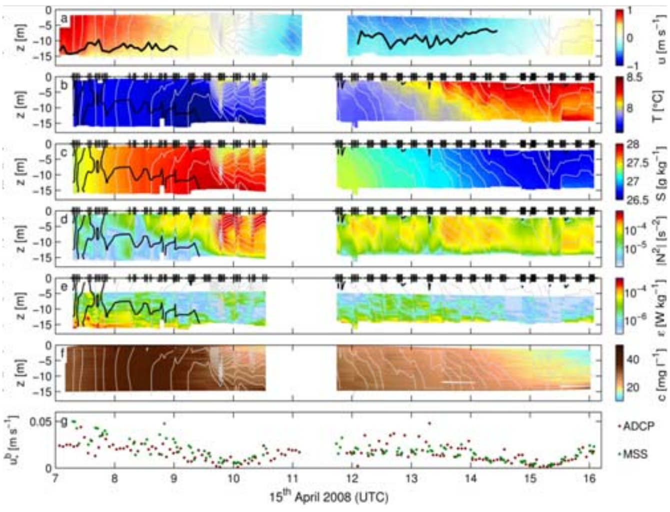


Fig. 4 Map of the study - site showing water depth from multi - beam soundings (gray scale) and bathymetric charts (gray lines). S1 and S2 mark the measurement positions on April 15 and 17, respectively, and the transect stations Tr1–Tr4 (symbols) on April 16. The inserted maps show the coastlines of the North Sea (smaller map) and the German Bight areas (larger map) [1].

Fig. 5 Observed profiles on April 15, 2008 at station S1 (see Fig. 4), (a) the current velocity. (b and c) The temperature and salinity, respectively, (d) the buoyancy - frequency, N^2, and (e) the dissipation - rate of TKE. Fig. 5b–5e are based on MSS - profiles, which are marked by black crosses atop the panels. (f) The SPM concentration. The bold black line in Fig. 5a shows the depth level at which 75% of the velocity maximum in each profile is obtained. The light - gray lines, occurring in each panel, are isopycnals and the black line shown in Fig. 5b–5e encloses areas of unstable vertical stratification ($N^2 < 0.$). (g) The temporally resolved bottom friction velocity, based on ADCP - data (red) and dissipation rates from the MSS (green). [1]



Tidal straining directly seen from 5 independent profiling observations:

1.velocity is mixed downwards significantly deeper during flood than during ebb

2.temperature and

3.salinity are well mixed during flood and significantly stratified during ebb, with a maximum stratification during the slack tide in between, as indicated by N^2

4.SPM concentration profiles show strong homogenisation during flood and stably stratified profiles during ebb, with substantial sedimentation during slack tides

5.turbulent dissipation rates are large throughout the water column during flood, but restricted to near - bottom turbulence during ebb, with decreased values during slack.

With the data set presented here, the dynamics of tidal straining have been directly shown for the first time in a tidally energetic, weakly stratified regime. For such regimes Burchard et al. (2011)[6] predicted it to be the major contributor to estuarine circulation.

References

[1] Becherer, J., H. Burchard, G. Flöser, V. Mohrholz, and L. Umlauf (2011), Evidence of tidal straining in well - mixed channel flow from micro - structure observations, *Geophys. Res. Lett.*, **38**, L17611, doi:10.1029/2011GL049005.

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Acknowledgements

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