Jill Lehn[1*], Aron Slabon[1], Dörthe Holthusen[1], Lorenzo Rovelli[1], Annika Fiskal[1], Thomas Hoffmann[1], Christine Borgsmüller[1]

[1]Federal Institute of Hydrology (BfG), Koblenz, Germany *Contact: Lehn@bafg.de

Spring-neap tidal variation of fluid mud occurrence in the hyper-turbid Ems estuary

Introduction

The Ems estuary is heavily impacted by human activities: Dredging of the fairway since the 1980s to accommodate the increasing draft of ships. This had negative effects on the sediment balance and ecology of the estuary. The fairway deepening strongly altered the tidal dynamics, such as tidal amplitude and duration. This leads to increased fine sediment input, and, at high suspended sediment concentrations, to the formation of fluid mud (FM)— a mixture of silt, clay, and organic matter that is impeded from settling. The most common lower suspended sediment concentration (SSC) threshold for FM occurrence is 10 g L^{-1} [1,2].

Aim

Fluid mud dynamics, particularly the differences between spring and neap tides, are not yet fully understood. This study aims to investigate the phases of fluid mud formation and breakup within the semidiurnal tidal cycle, the influence of current velocity and salinity, as well as the differences between spring and neap tides.

Methods

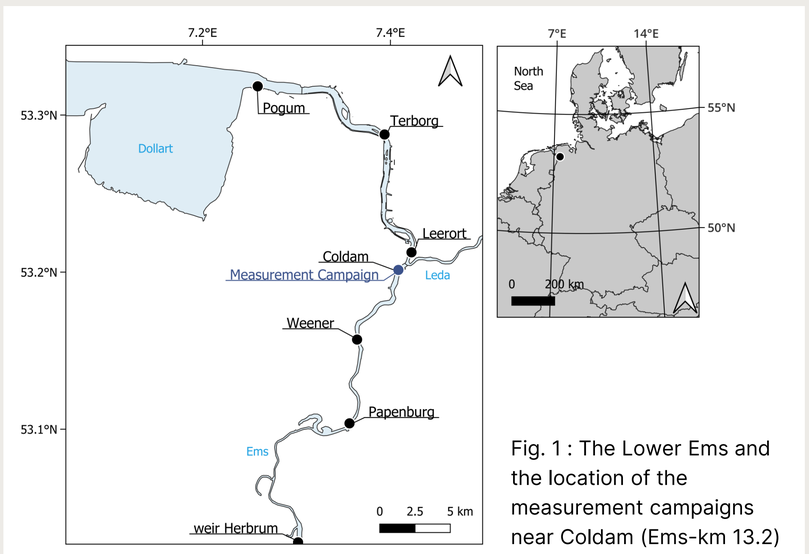

Fig. 1 : The Lower Ems and the location of the measurement campaigns near Coldam (Ems-km 13.2)

Fig. 2: SeaGuard (top) and RheoTune (bottom)

The River Ems is located in the northwest of Germany and constitutes part of the direct border with the Netherlands. The tidal zone of the Ems extends landwards until the tidal weir at Herbrum, while the Lower Ems begins in Papenburg (Ems-km 0) (Fig.1).

Two measurement campaigns were conducted in the Lower Ems River near Coldam in September 2023 with the RV “Friesland” (Fig.1). Each campaign included two days—one during spring tide and one during neap tide (06–07 and 19–20 Sept). Data collection focused on late ebb tide through to flood tide, including low water slack (LWS).

Vertical density profiles were measured with a RheoTune tuning fork probe (Stema Systems), while a multiparameter probe (SeaGuard RCM, Xylem/Aanderaa) recorded parameters such as current velocity and salinity. Profiles were taken approximately every 10 minutes using a sideboard winch (Fig. 2).

Results

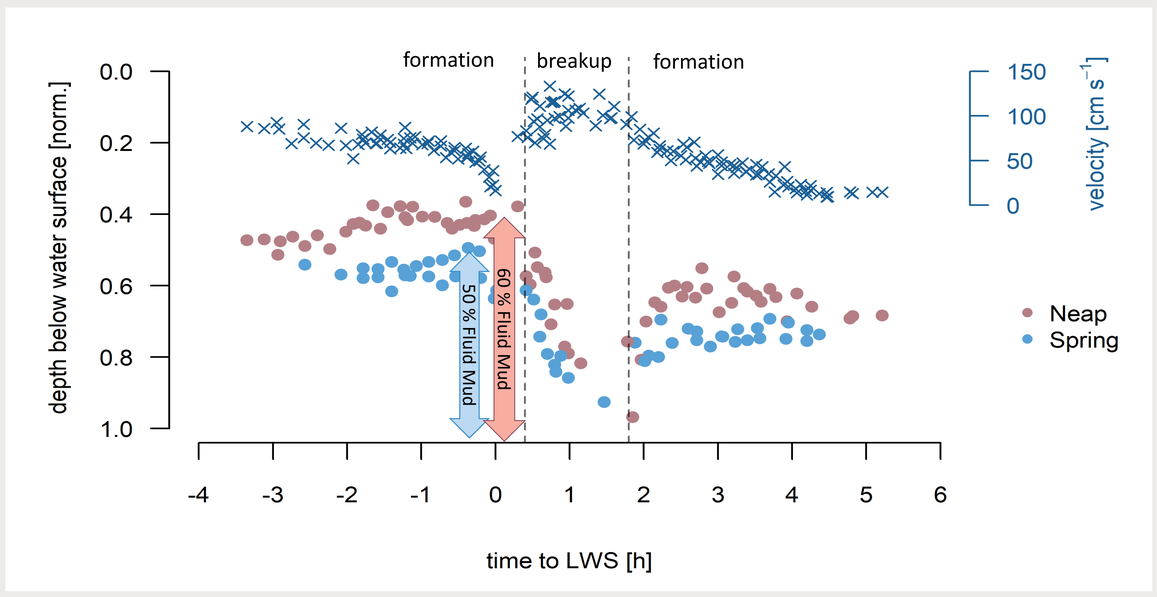

Fig. 3: Depth of 10 g L^{-1} lutocline for neap (red) and spring (blue) tide with mean current velocity (blue cross)

Fluid mud (FM) was present throughout most of the semidiurnal tidal cycle, except 1.5 – 2 h after low water slack (LWS) (Fig. 3–5). At ebb tide, multiple lutoclines with suspended sediment concentrations (SSC) up to 100 g L^{-1} were observed (Fig. 4, 5a). FM covered up to 60% of the water column during neap tide and 50% during spring tide (Fig. 3). Formation occurs during ebb and late flood, with breakup starting at flood onset. FM dynamics are influenced by current velocities: high velocities after LWS cause FM entrainment into the upper layer, while lower velocities promote FM formation and stratification (Fig. 3). A halocline at the height of the lutocline during late flood indicates vertical salinity stratification and the decoupling of the FM layer and the upper water column (Fig. 5c). Salinity is thus an indicator of stable stratification, with slightly higher values during neap tide (Fig. 5).

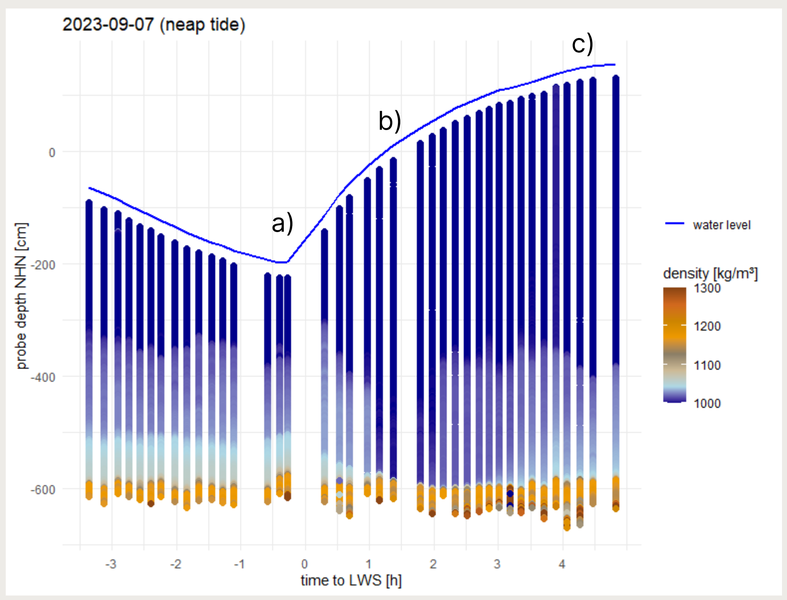

Fig. 4: Vertical density profiles from neap tide with extracted profiles 15 mins before LWS (a), 1,5 h after LWS (b) and 4,5 h after LWS (c)

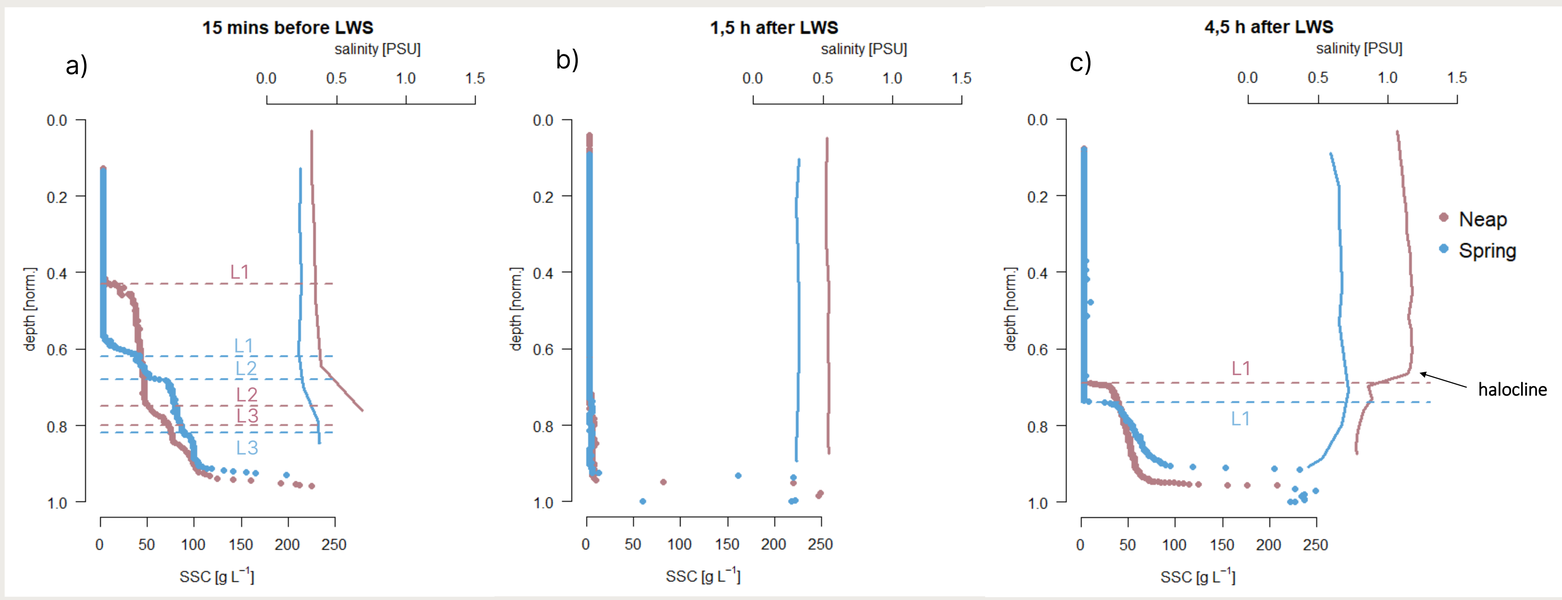

Fig. 5: Vertical profiles of suspended sediment concentration (points) and salinity (lines) at three selected time points within the observed tidal cycle (a–c) for neap (red) and spring (blue) tides. The corresponding timing within the tidal cycle is shown in Fig. 3. Position of lutoclines is shown by dashed lines (L)

Outlook

Our study reveals a distinct difference between spring and neap tides. The fluid mud layer is thicker during neap tide compared to spring tide, leading to a reduced flow cross section. Additionally, the study highlights the strong influence of current velocity on fluid mud dynamics, as well as the importance of salinity as an indicator of stable stratification. The findings emphasize the need to include spring-neap considerations for future sediment management plans for the Ems. To obtain deeper insights into fluid mud dynamics over extended timescales, future research should integrate measurement campaigns into long-term monitoring data.

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Abstract

Sharing is encouraged

Sources: [1] Manning, A. J., Langston, W. J., and Jonas, P. J. C. (2010): A review of sediment dynamics in the Severn Estuary: Influence of flocculation, Marine Pollution Bulletin, 61, 37-51, 10.1016/j.marpolbul.2009.12.012,. [2] Inglis, C. and Allen, F. (1957): THE REGIMEN OF THE THAMES ESTUARY AS AFFECTED BY CURRENTS, SALINITIES, AND RIVER FLOW, Proceedings of the Institution of Civil Engineers, 7, 827-868, 10.1680/iicep.1957.2705.

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