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Spring-neap variability of tidal current velocity in the Emder Fairway (Ems estuary) derived from moored ADCP

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Motivation

- Approaches which aim explaining upstream increase of sediment concentration, as observed in the Ems estuary, are among others based on the principle of tidal asymmetry. Residual flux of suspended sediment is often classified by the difference in maximum velocities (peak currents) of flood to ebb [1].
- Here, we **evaluate velocity variability on spring-neap scales** from measurements and **compare peak currents to durations of high velocities**.

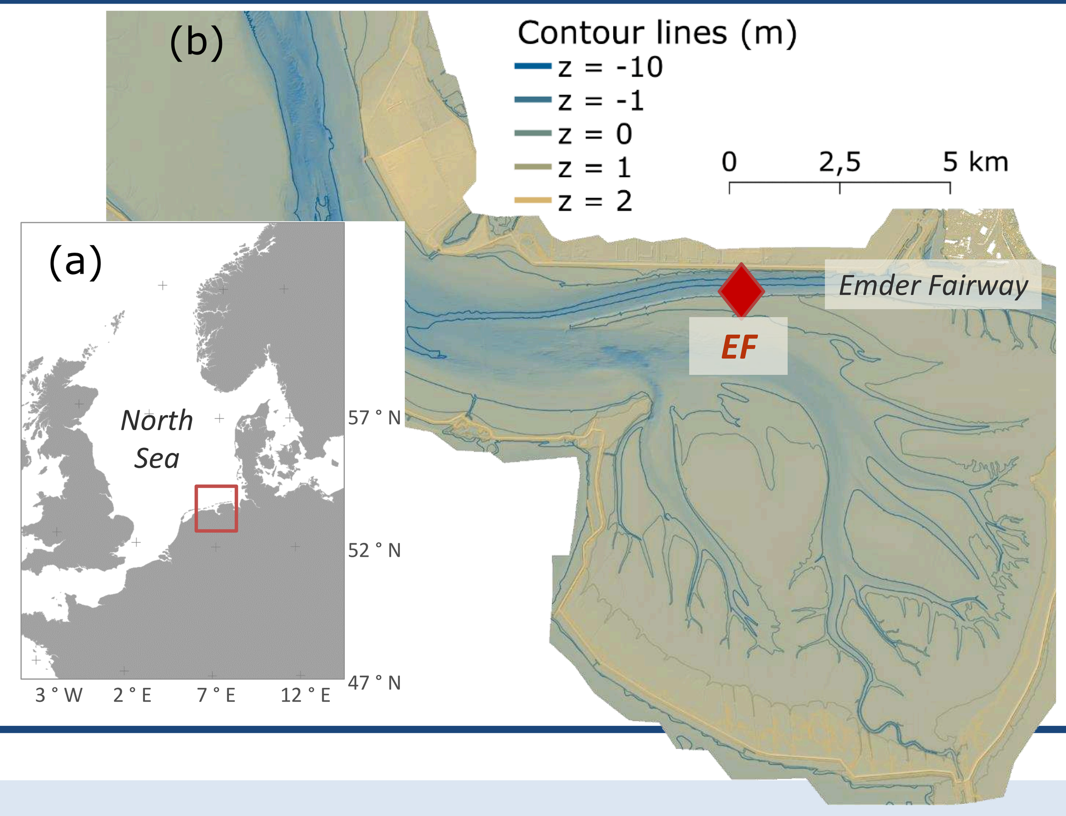


Figure 1: Study region Ems estuary (a) and zoom in showing bathymetry and contours (b) [2,3,4]. Location of the moored ADCP *EF* (red diamond).

1 Data

- Moored ADCP from the Ems Dollard Measurement campaign (EDoM), located in the Emder Fairway (at EF, Fig. 1b)
- Coverage of 25 days in August 2018 (Fig. 2)
  - Select four consecutive days (8 tidal cycles) to represent each period: Spring A, Neap and Spring B

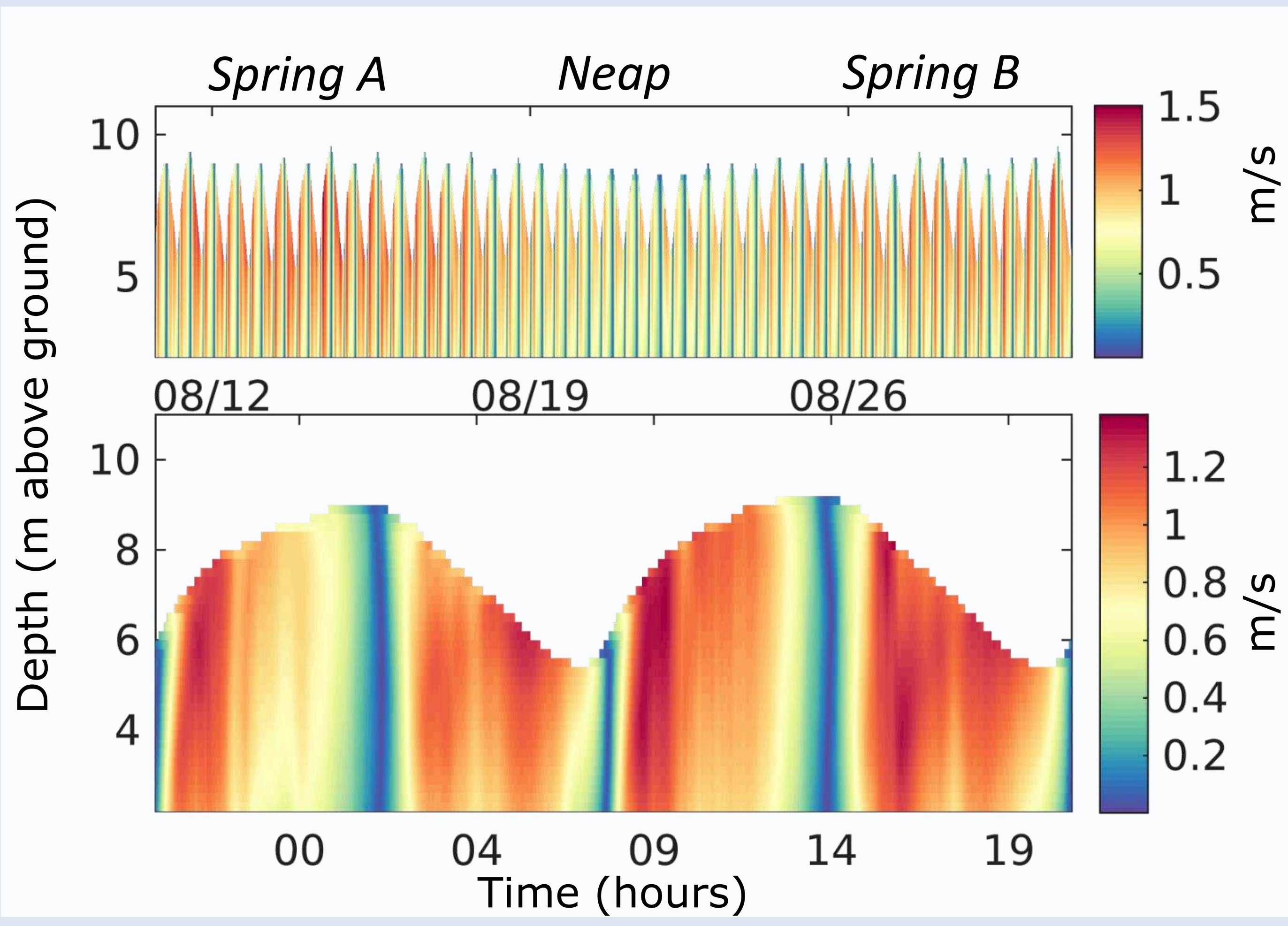


Figure 2: Velocity magnitude (m/s) from moored ADCP measured at EF for the period of the evaluated full spring-neap cycle and its subsequent spring period (upper panel) and a zoom into two tidal cycles, starting at 12 August, 20:06 (CET) (lower panel).

2 Methods

- Analyze time series for <u>each period</u> (Spring A, Neap and Spring B) of
  - Depth-averaged velocity magnitude u_{av}
  - Local maximum velocity magnitude u_{max}
    - Compute respective median $\langle\cdot\rangle$

Note: In the following methods denoted as U

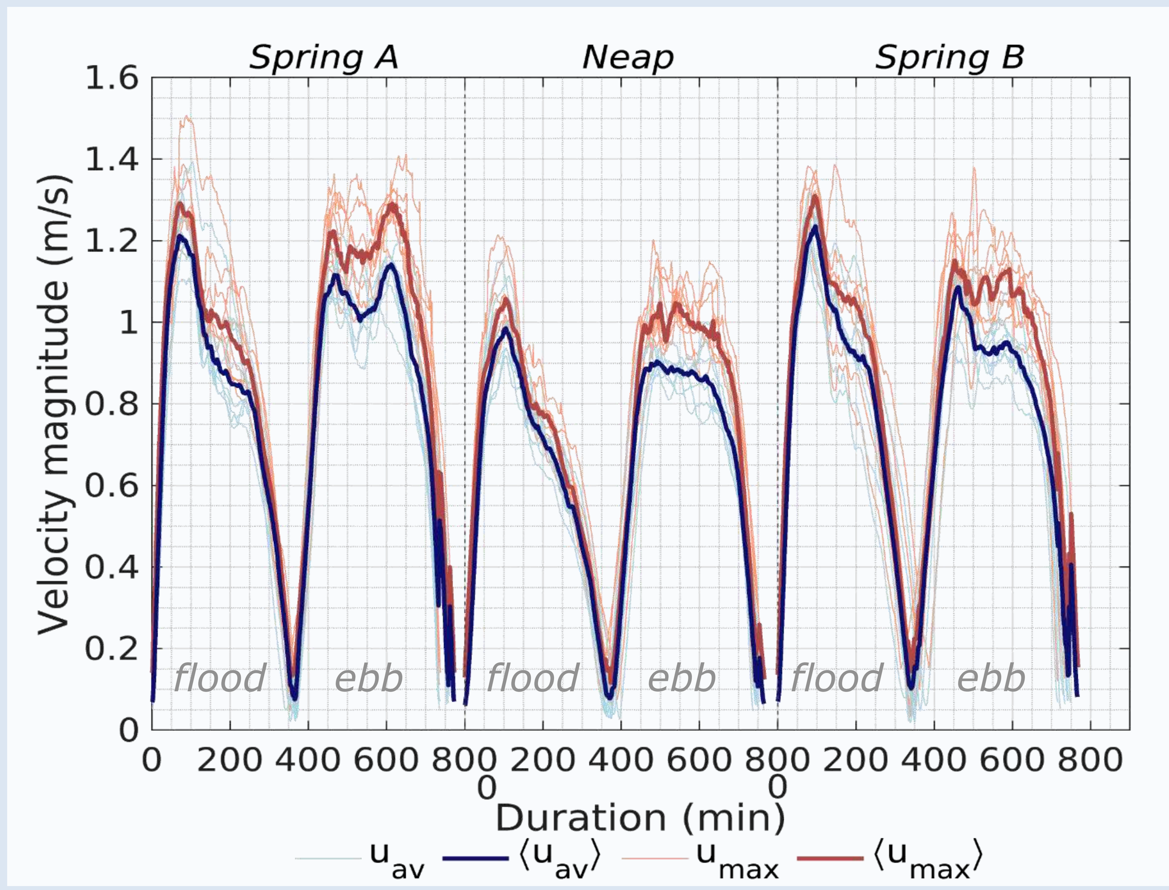
- **Peak current** asymmetry (PCA): $\max(U_{flood})/\max(U_{ebb})$:
  - $PCA > 1: \max(U_{flood}) > \max(U_{ebb})$
  - $PCA < 1: \max(U_{flood}) < \max(U_{ebb})$
- Ratio of **duration of high velocities** $t_{f,utr}/t_{e,utr}$:
  - Threshold velocity u_{tr}: median tidal current velocity
  - Get $[U_{flood}\ U_{ebb}] > u_{tr}$
  - $t_{f,utr}/t_{e,utr} > 1$: high U_{flood} outlast high U_{ebb}
  - $t_{f,utr}/t_{e,utr} < 1$: high U_{ebb} outlast high U_{flood}

- Evaluate spring-neap variability
- Compare peak current to duration of high velocity

3 Results

- Variability is visible on period-internal (i.e. Neap) and period-to-period scales (Spring A vs. Spring B) (Fig. 3).
  - Strongest at high magnitudes and at slack

Figure 3: Depth-averaged velocity magnitudes u_{av} (light blue line), their median $\langle u_{av}\rangle$ (dark blue, bold line) and maximum velocity magnitudes u_{max} (light red line), and their median $\langle u_{max}\rangle$ (dark red, bold line) (m/s) of the periods Spring A, Neap and Spring B. Labels at the x-axis indicate durations in minutes.



- Choice of depth-averaged or maximum velocity determines results of peak current ratio PCA (Fig. 4a).
- Durations of high velocities during ebb exceed those during flood ($t_{f,utr}/t_{e,utr}$ <1) even when PCA suggests stronger flood than ebb currents (Fig. 4).

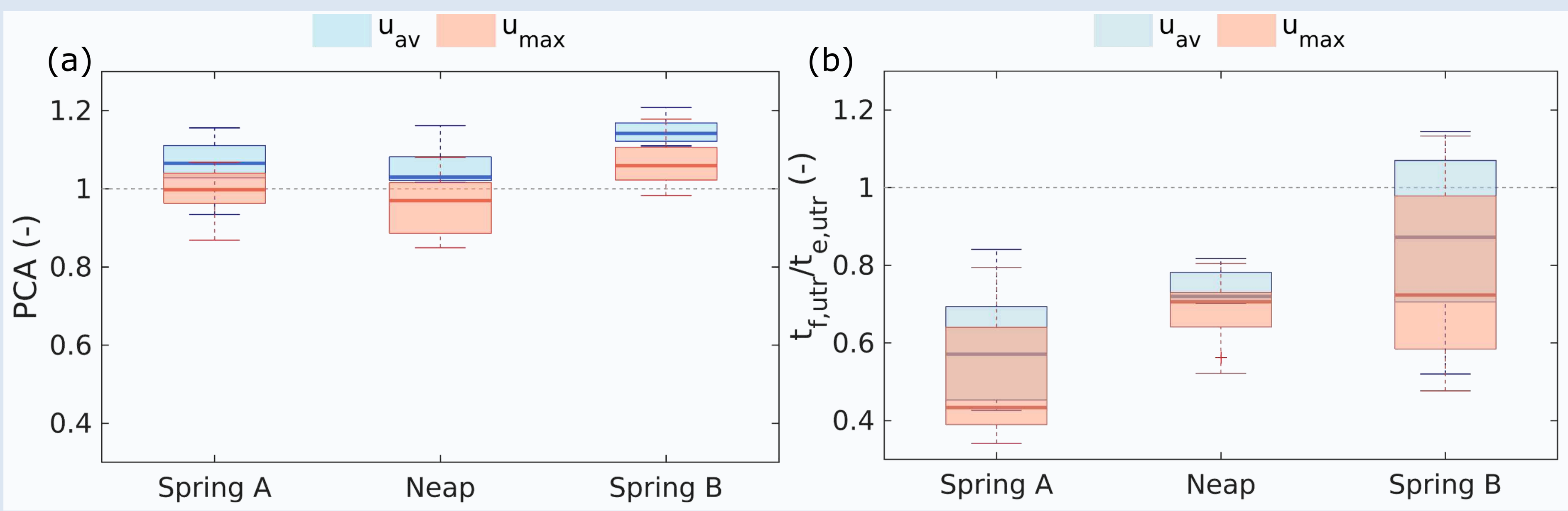


Figure 4: PCA (a) and ratio of duration of velocity magnitude exceeding critical value ($t_{f,utr}/t_{e,utr}$) (b) from depth-averaged velocity magnitudes u_{av}(blue) and maximum velocity magnitudes u_{max} (red) of the periods Spring A, Neap and Spring B.

4 Take home messages

- Variability of velocity magnitudes results in variability of derived peak currents and duration of high velocities.
- Classification of an estuary based on current velocity from short time series (e.g. one tidal cycle) is inapplicable.
- Peak currents may underestimate the impact of durations of high velocity magnitudes for possible sediment transport.

References:
[1] Dronkers, J. (1986). Tidal asymmetry and estuarine morphology. *Netherlands Journal of Sea Research*, *20*(2-3), 117-131.
[2] Sievers, J., Rubel, M., Milbradt, P.: EasyGSH-DB: Themengebiet – Geomorphologie, Bundesanstalt für Wasserbau, https://doi.org/10.48437/02.2020.K2.7000.0001, 2020
[3] Bathymetry adapted from the EasyGSH-DB data collection [4] Made with Natural Earth.

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