

Priorities in coastal protection due to extreme sea levels under sea-level rise

Christian Jordan¹, Torsten Schlurmann^{1,2}, Leon Scheiber³, Nils Goseberg^{2,4}, & C. Gabriel David^{4,5}
¹Ludwig-Franzius-Institute, Leibniz Universität Hannover
²Coastal Research Center, Joint Research Facility of Leibniz Universität Hannover and Technische Universität Braunschweig
³Climate Service Center Germany (GERICS), Helmholtz-Zentrum Hereon
⁴Leichtweiß-Institute, Division of Hydromechanics, Coastal and Ocean Engineering, Technische Universität Braunschweig
⁵Junior Research Group "Future Urban Coastlines", Technische Universität Braunschweig

Motivation

- Protection levels of coastal infrastructure decline earlier than anticipated as sea level-rise (SLR) compresses extreme sea level (ESL) return periods
- We ask whether engineered coastlines lose protection lifetimes uniformly or fragment under SLR, revealing where adaptation is needed first**

Methods

- Adapting the TimingAFs amplification and timing framework [1] to kilometer scale, we link ESL statistics from a 66-year hydrodynamic hindcast [2, 3] with IPCC AR6 SLR projections [4] (see Fig. 1)
- Applied to the highly engineered yet hydrodynamically diverse German Bight, **we map where and when protection lifetimes are lost along a contiguous coastal system under broadly similar design paradigms**

Results

- The SLR needed to turn a 100-year ESL event into a 10-year event can differ by up to a factor of two between nominally similar locations
- Amplification intensifies sharply between 2 °C and 3 °C warming and peaks where natural water-level variability is low
- Strong spatial contrasts in amplification open decade-scale timing gaps between neighboring sites** along the same engineered coastline (see Fig. 2); see [5] for more details

Implications

- With neighboring sites facing starkly different, sometimes unprecedented, intervention frequencies (see Fig. 3), **SLR fragments protection lifetimes even along a single coastline**
- Spatial contrasts break the logic of uniform safety margins and episodic upgrades, **demanding spatially differentiated, more continuous adaptation**
- Amplification-based timing thresholds can guide future adaptation planning

References

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Sea-level rise fragments protection lifetimes, creating uneven adaptation demands along a single engineered coastline

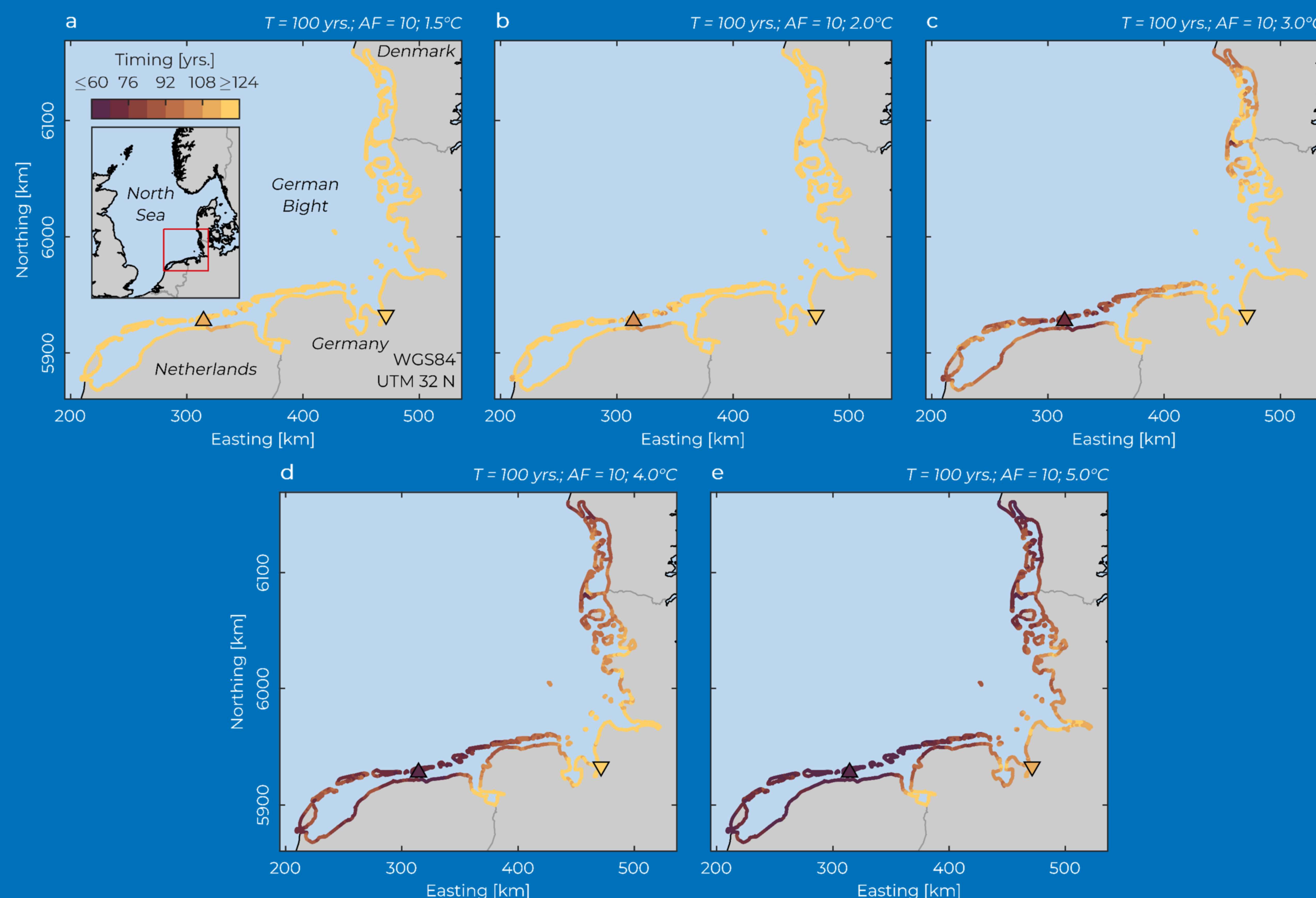


Fig. 2: Timing of tenfold amplification in the German Bight. Panels (a–e) show central estimates of the timing at which the baseline 100-year ESL event reaches a tenfold amplification (AF = 10) under global warming levels of (a) 1.5°C, (b) 2.0°C, (c) 3.0°C, (d) 4.0°C, and (e) 5.0°C under late-century conditions (2080–2100). Bremerhaven and Schiermonnikoog are marked by downward- and upward-pointing triangles, respectively.

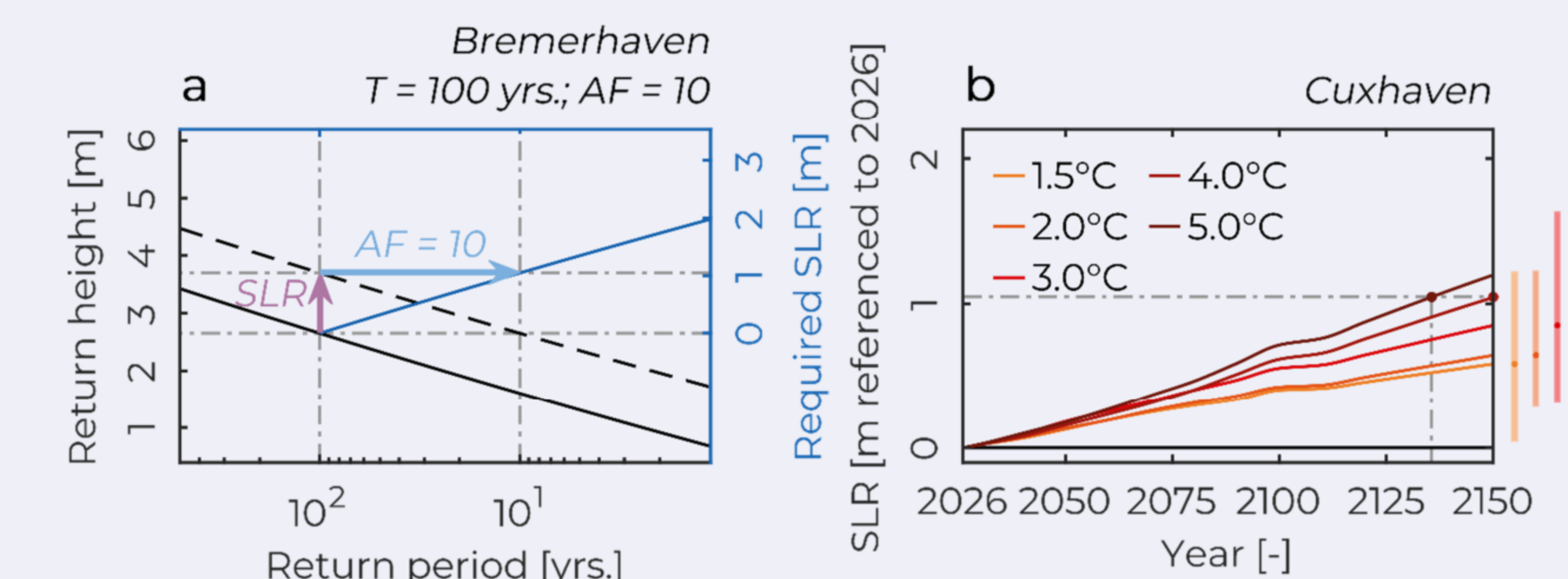


Fig. 1: Return heights, required SLR, and timing. (a) Return curve and SLR required for a tenfold amplification (AF=10) of the baseline 100-year ESL event at Bremerhaven. (b) Timing based on regional SLR trajectories at nearby Cuxhaven for five global warming levels. Bremerhaven is marked in Fig. 2 by a downward-pointing triangle.

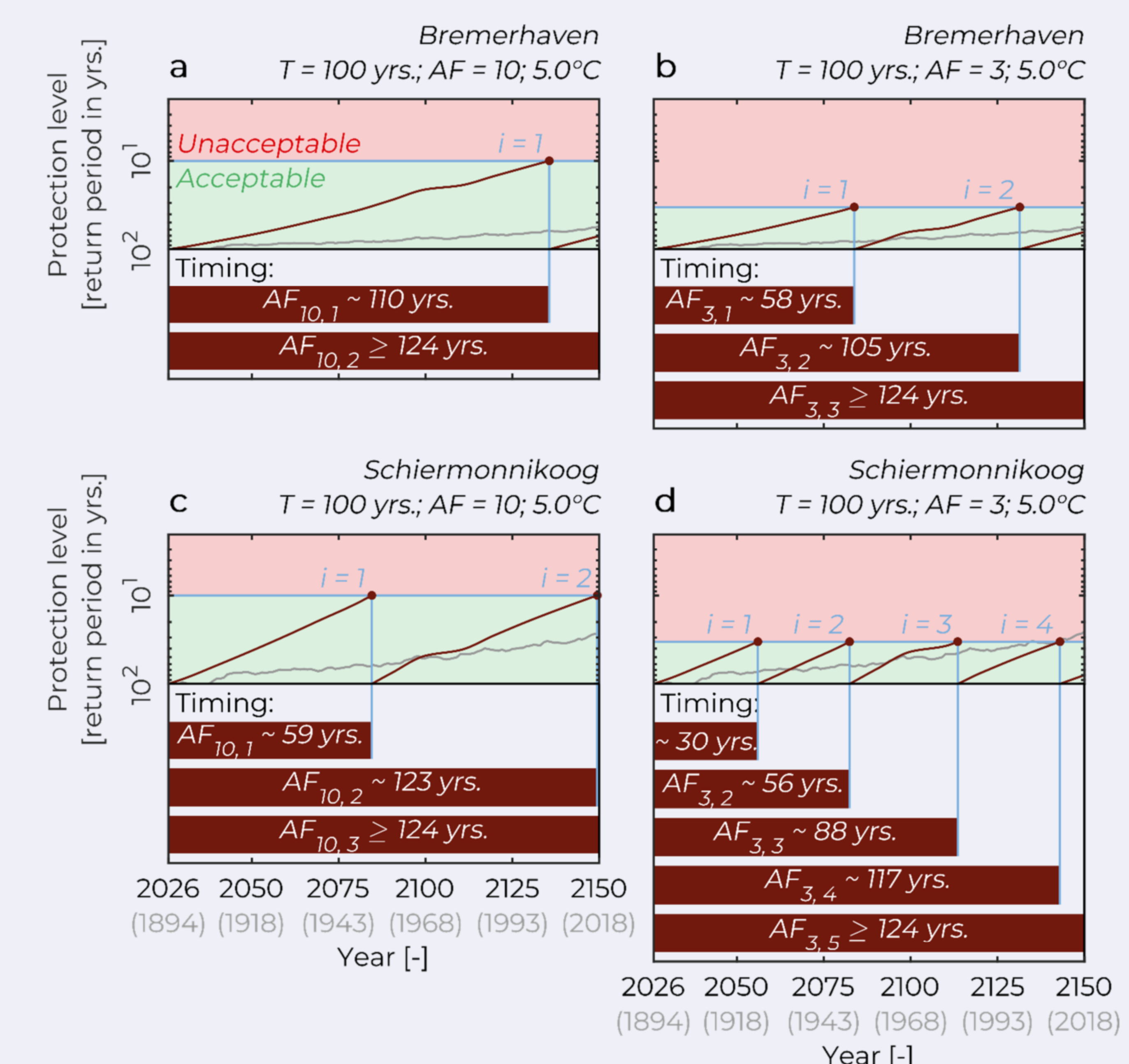


Fig. 3: Amplification thresholds and intervention timing under 5.0 °C warming (late-century conditions; 2080–2100). Timing of the 100-year ESL event reaching tenfold (AF = 10; a, c) and threefold amplification (AF = 3; b, d) at Bremerhaven (a, b) and Schiermonnikoog (c, d). Gray lines show 11-year running means of observed SLR (1894–2018) at nearby stations Cuxhaven (a, b) and Delfzijl (c, d). Bremerhaven and Schiermonnikoog are marked in Fig. 2 by downward- and upward-pointing triangles, respectively.

