Compounding Effects of Riverine & Coastal Floods and its Implications for Coastal-Urban Flood Resilience

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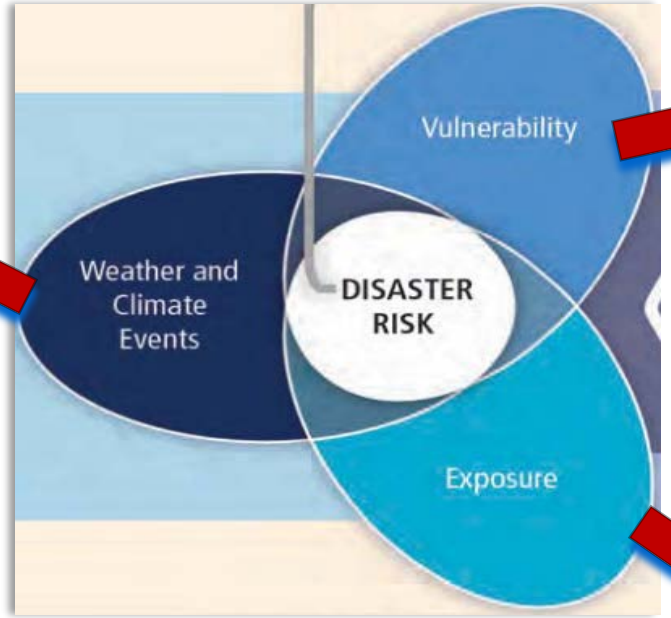
Compound Floods: National & Regional Impacts

Increase in Relative Sea Level: EU

downward

upward

European Env. Agency, 2017

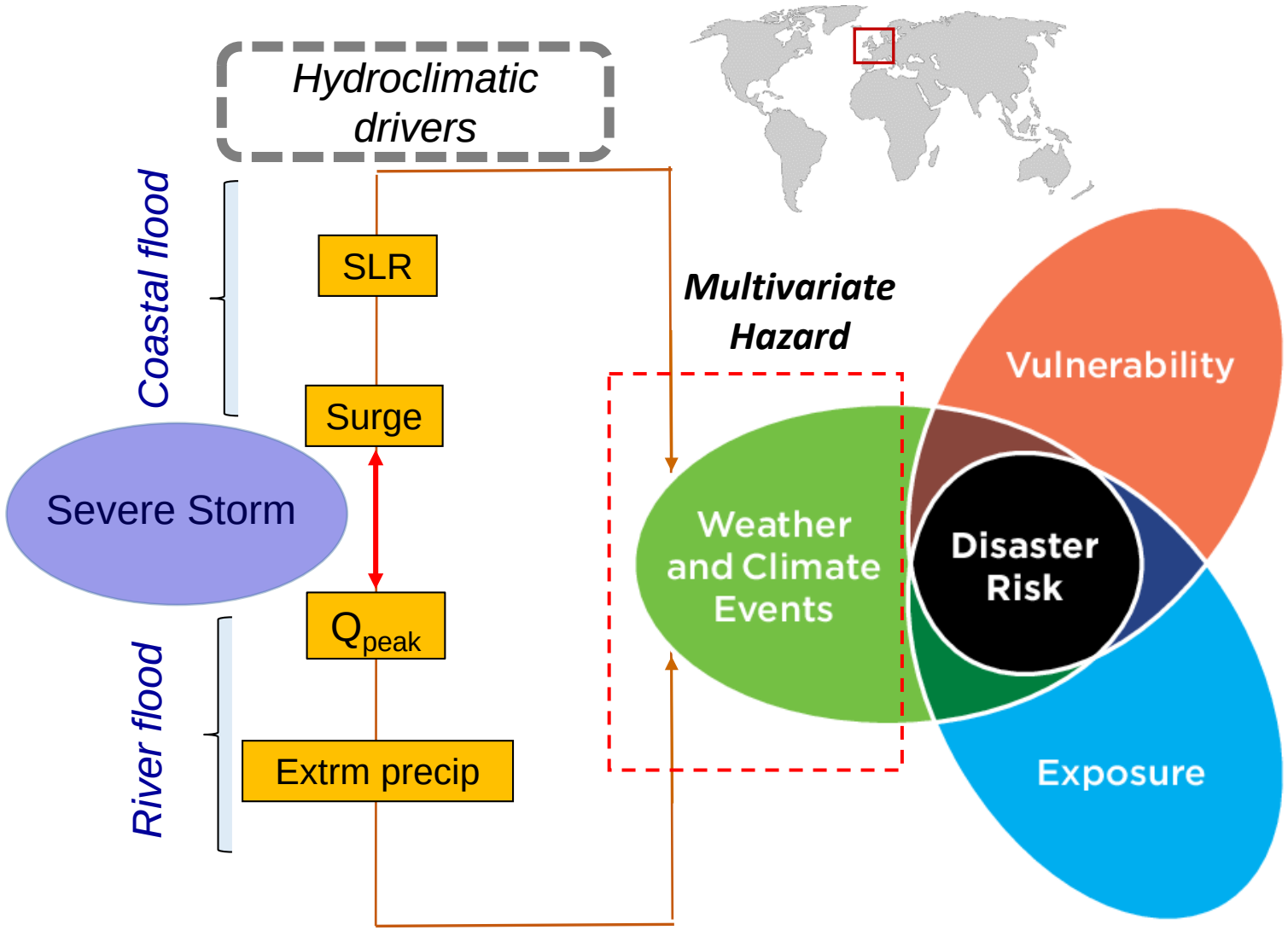


IPCC SREX Framework of Risk (2012)

Nuisance Floods: Florida coast, USA

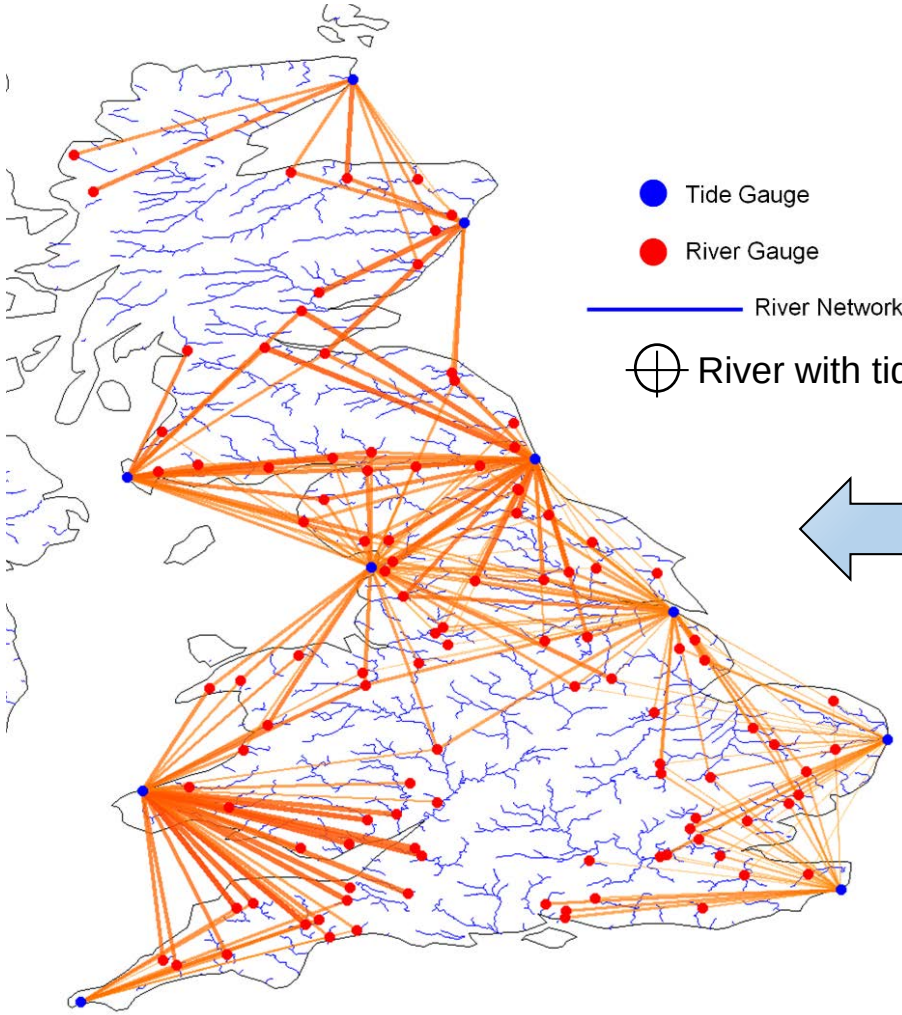
Compound floods in German city Hamburg: storm surge at coast and high discharge of river Elbe, source: *compidoc, www.flickr.com*

Holistic Hazard Framework: Single vs Compound Floods



Zscheischler et al., 2018, Nature Climate Change

Physical Connection: (Annual Maxima) Coastal Flood Height vs *d*-day Lagged Peak Discharge within ±7-day of Coastal Flood

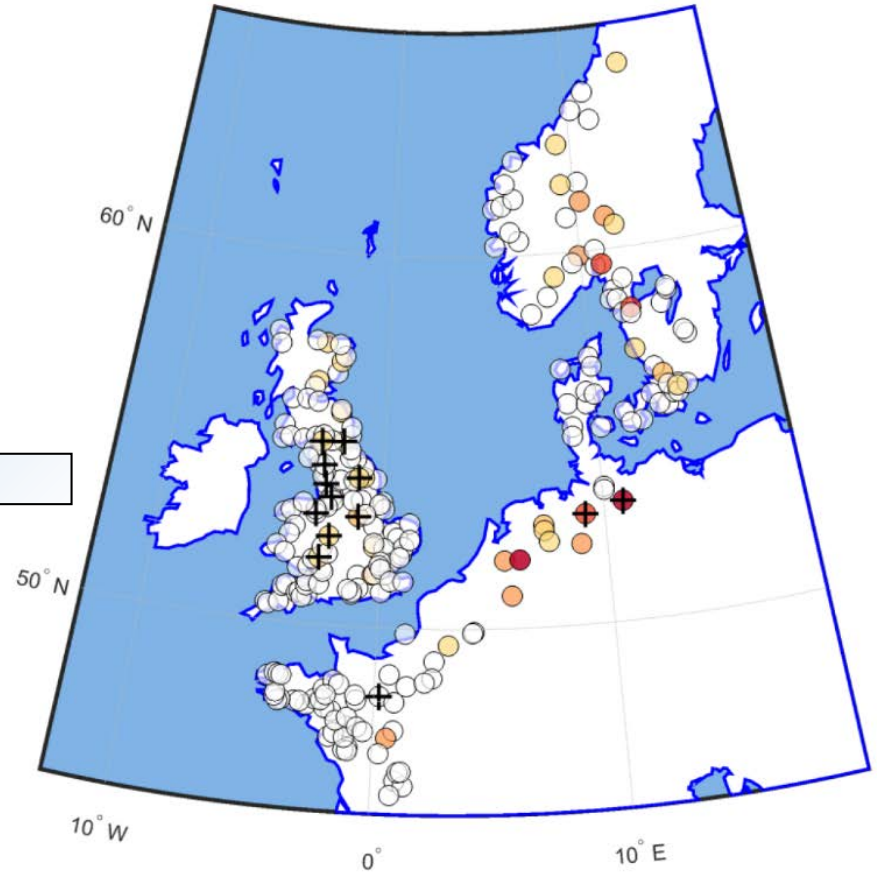


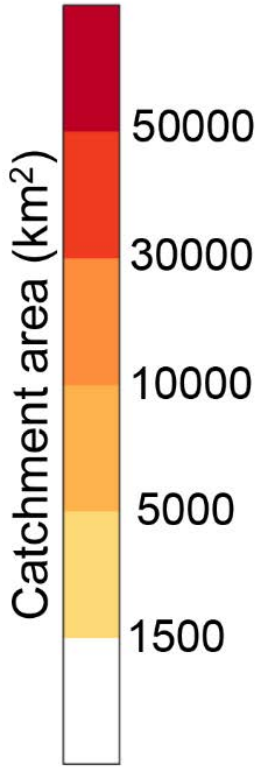
Tide Gauge

River Gauge

River Network

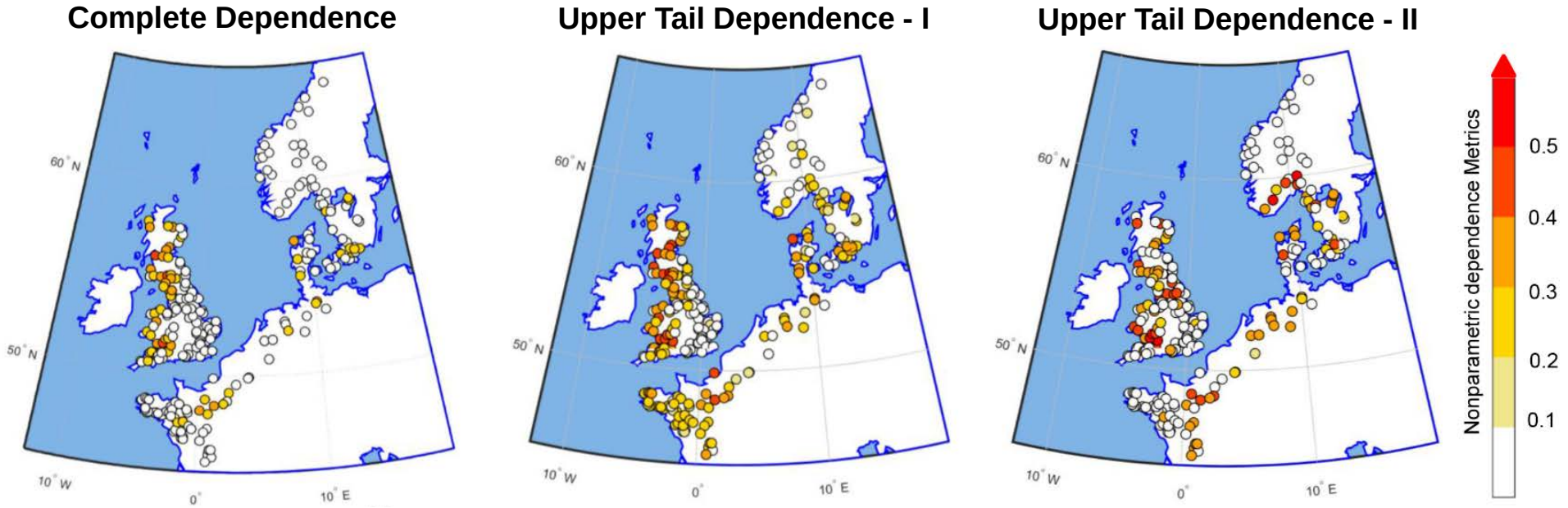
River with tidal influence

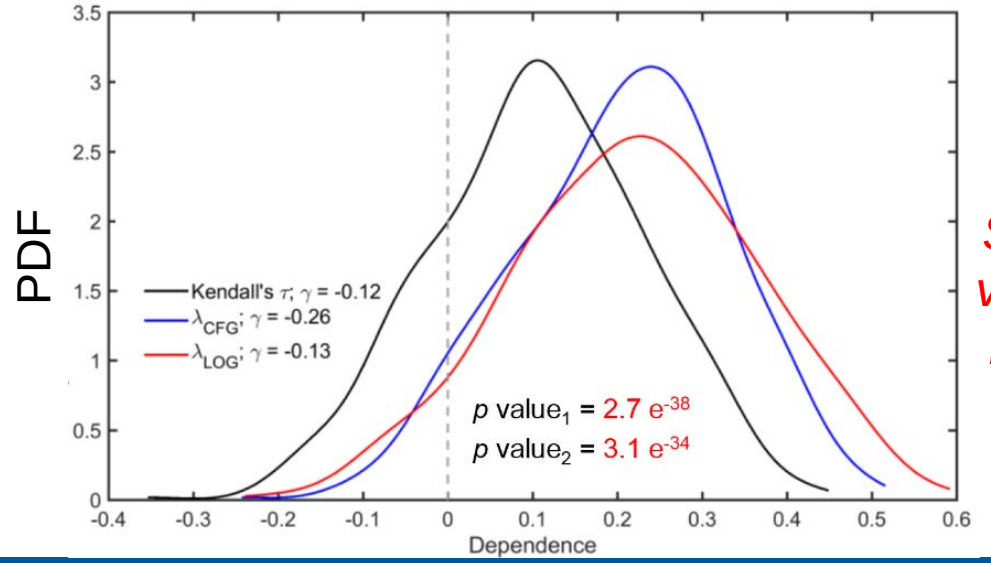




Ganguli, P., Merz, B. (2019a), Extreme coastal water levels exacerbate fluvial flood hazards in northwestern Europe. Scientific Reports, 13165.

Complete Dependence Does Not Provide Enough Information for Low Probability-High Impact Events…

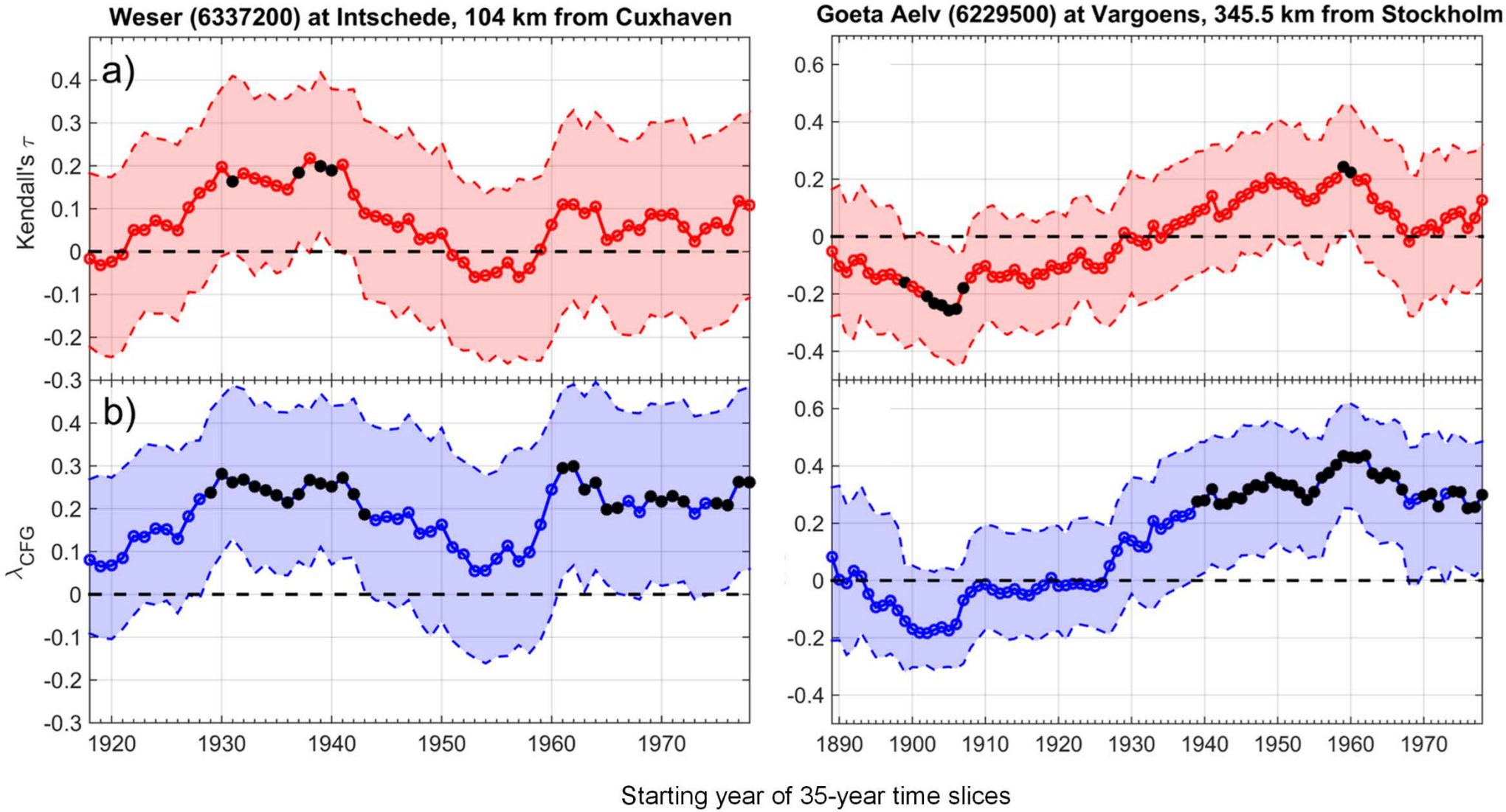




Shifts between complete vs upper tail dependence is significant at 5% level

Ganguli and Merz (2019a), Scientific Reports

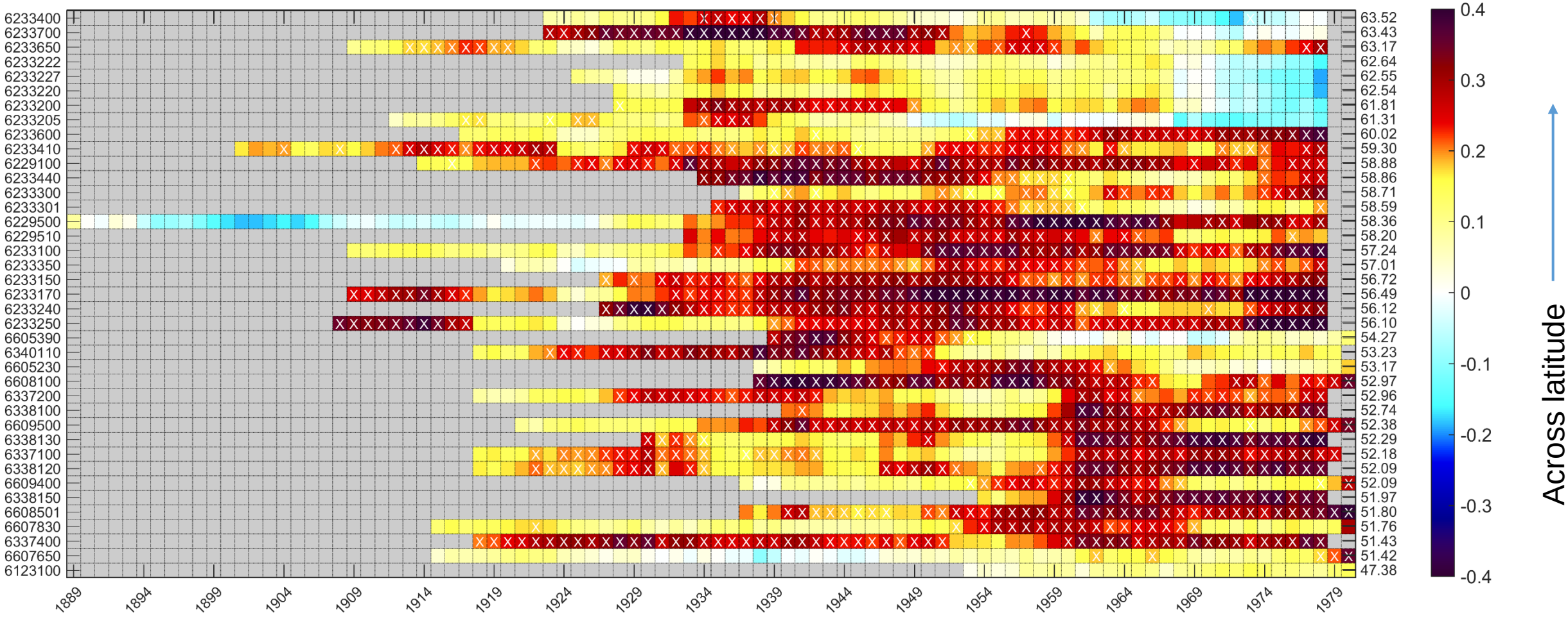
Temporal Evolution of Dependence Pattern of Compound Floods



Ganguli and Merz (2019b), GRL

- Statistically significant at 5% significance level

Synchronicity in the Upper Tail Dependence over Space & Time



Ganguli and Merz (2019b), GRL

× Statistically significant at 5% significance level

Assessment of Compound Flood Severity using Compound Hazard Ratio [CHR]

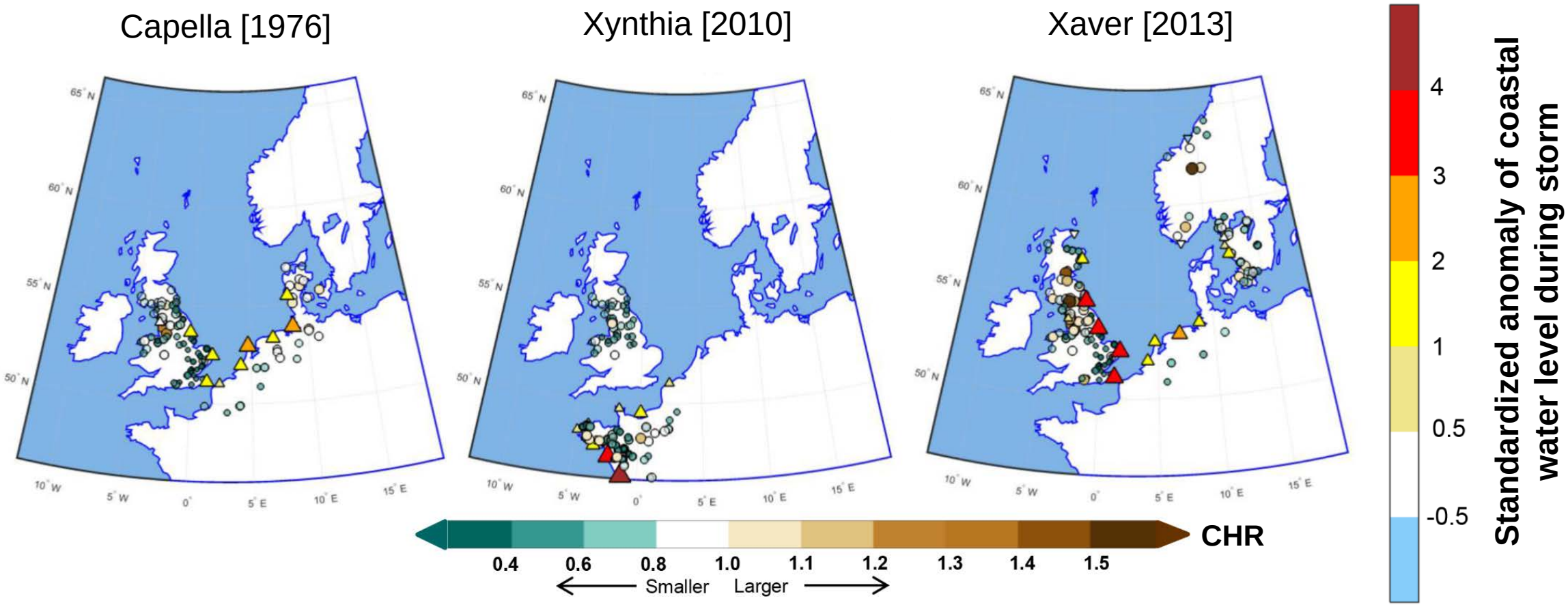
CHR is the ratio of severity of a *T*-year compound event assuming annual maxima coastal water level as the covariate to at-site *T*-year seasonal peak river discharge (Ganguli and Merz, 2019a,b).

$$CHR = \frac{Q'_T}{Q_T} = \frac{C^{-1}_{Q|CWL=cwl}\left[1 - \frac{1}{T_{Q|CWL}\left(q \mid cwl\right)}\right]}{F^{-1}_{Q}\left[1 - \frac{1}{T_Q\left(q\right)}\right]}$$

where $T_{Q|CWL}\left(q \mid cwl\right) = \frac{1}{1 - C_{Q|CWL=cwl}}$

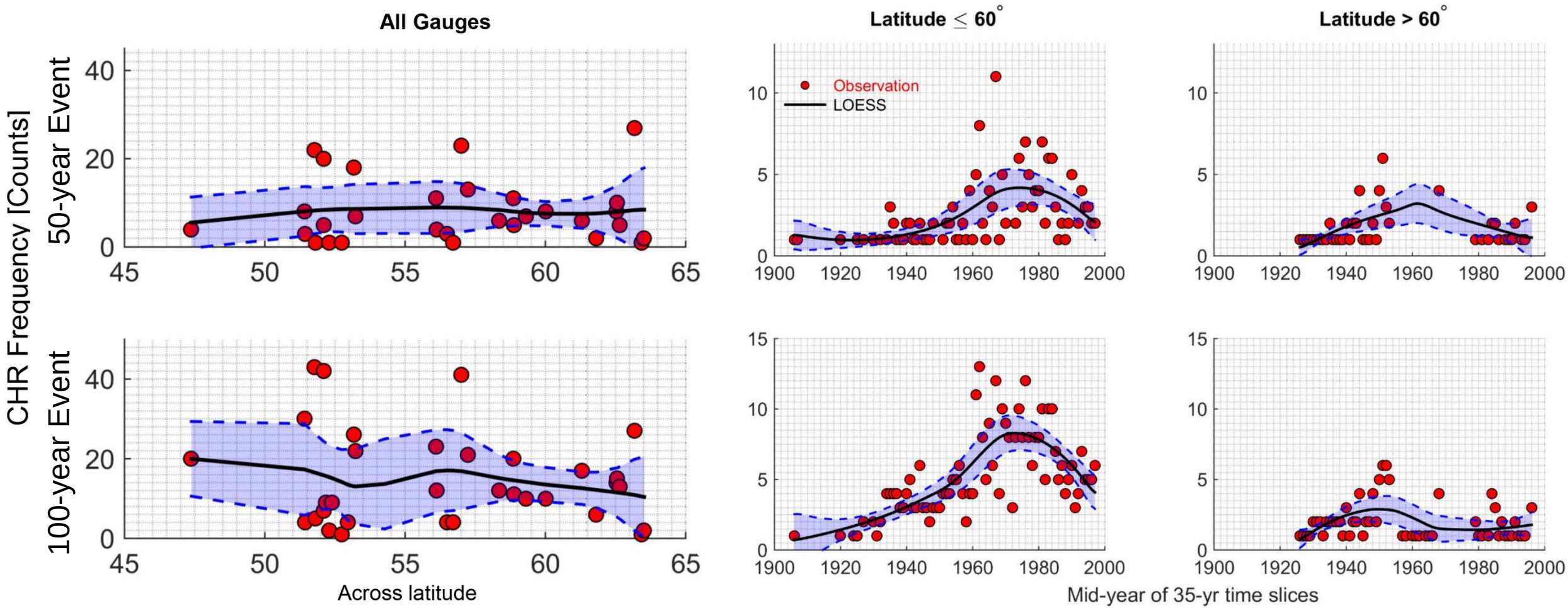
CHR > 1 shows hazard associated with compound flood is larger than that of the seasonal at-site peak discharge.

Event-Specific Assessment of CHR for 50-yr Compound Events



Ganguli and Merz (2019a), Scientific Reports

Compound Flood Frequency in Mid vs High Latitudes



Ganguli, P., Merz, B. (2019b), Trends in compound flooding in northwestern Europe. Geophysical Research Letters, 46, 10810-10820.

Summary: Key Insights

- Variations of upper tail dependence show a distinct patterns over space and time, which index based on complete dependence fails to produce, hence extremes may be underestimated using only complete dependence metric.

- A spatially coherent pattern in dependence between annual maxima coastal water level and river peaks – and its frequency.

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