Transport in tidal channels: the Wadden Sea as an event-driven system

or:

recurring tides *versus* wind events

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recurring tides *versus* **wind events**

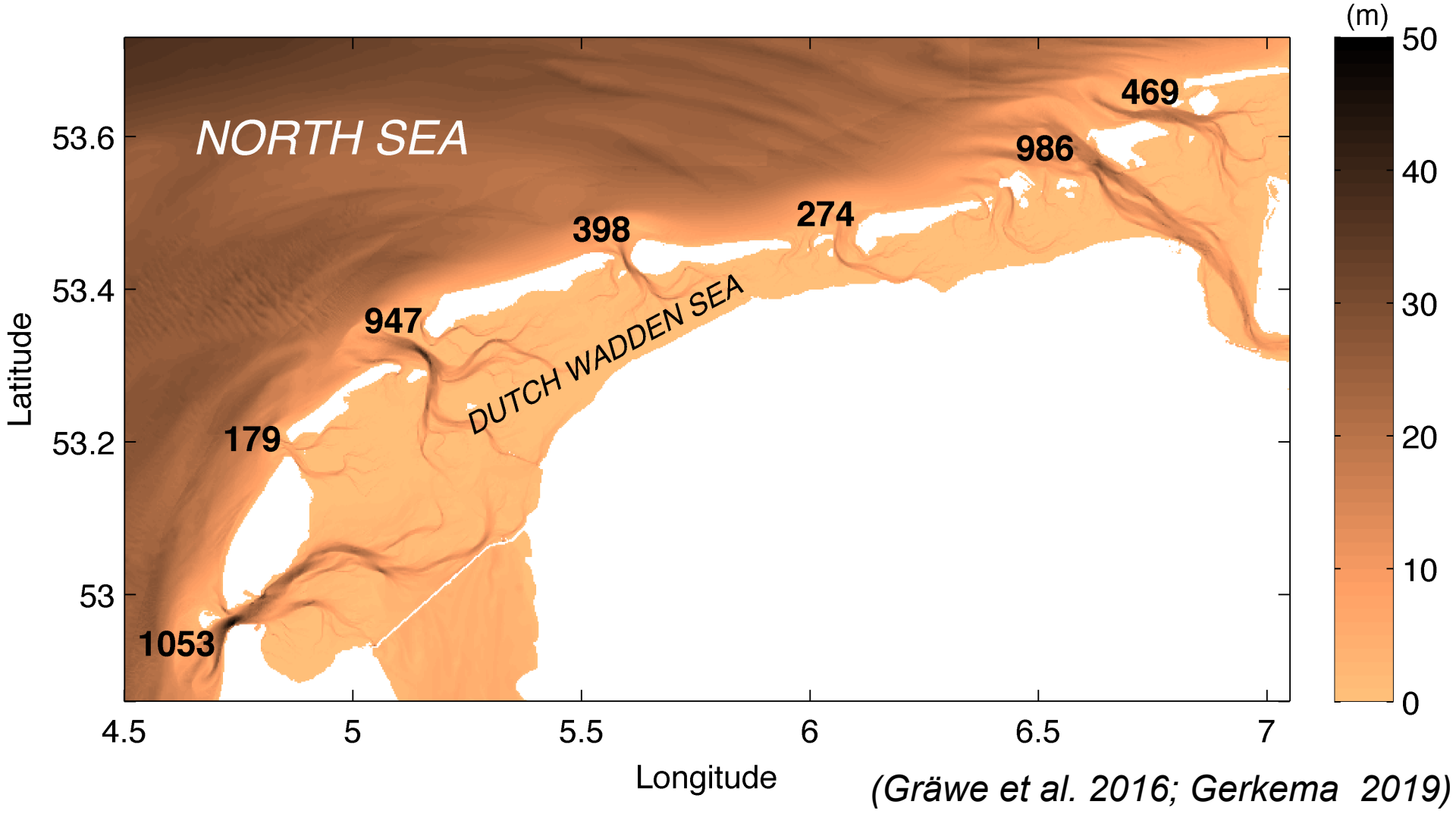
Two main drivers in the Wadden Sea for transport of (fresh)water, suspended sediment, organic matter etc:

① **Tides:** as such predictable, repetitive

② **Wind:** episodic, variable

Key of this talk: wind is a prevailing driver in transport
➔ episodic, event-driven, variable

Tidal exchange through inlets: mean **tidal prism** (10^6 m^3)

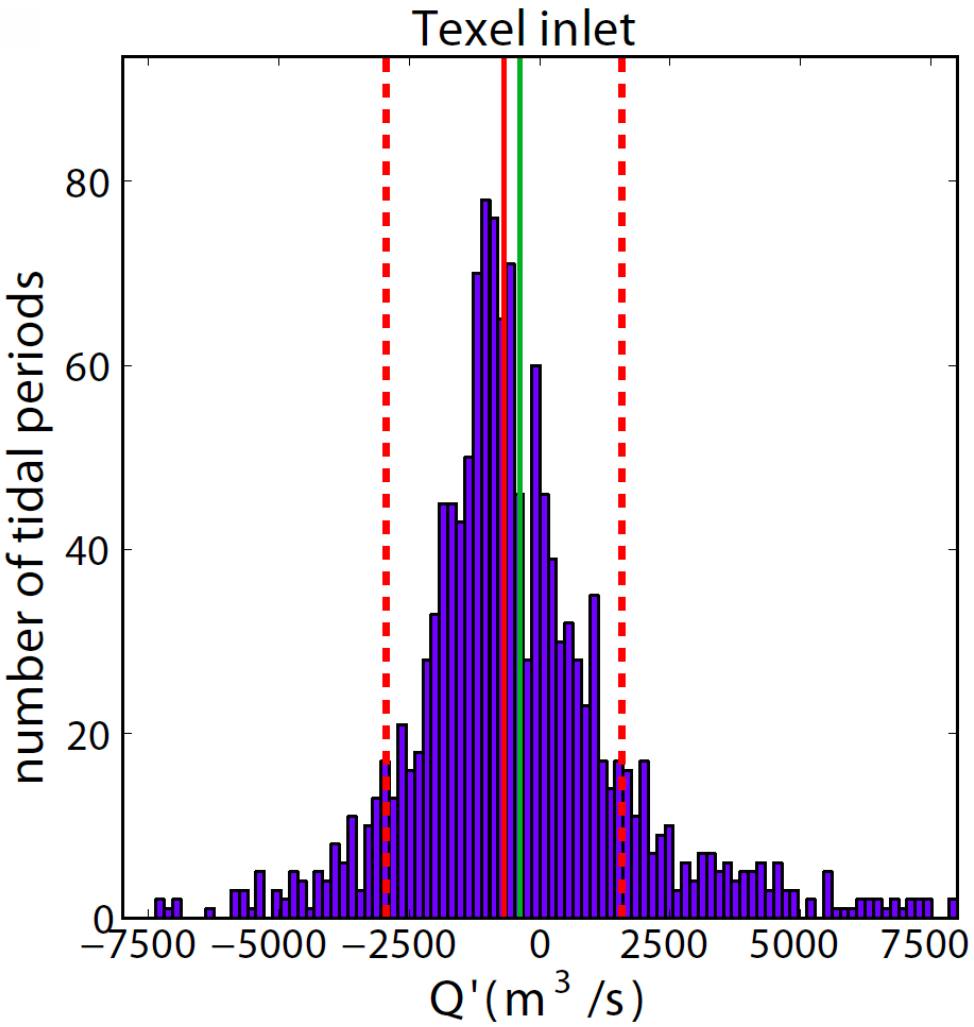


(Gräwe et al. 2016; Gerkema 2019)

Variability in tidal prism:
order 20% of mean (spring-neap, wind)

*What about **tidally averaged** (=net) fluxes?*

small difference of two large numbers: net is ~2% of tidal prism



Net values from two years of model data:

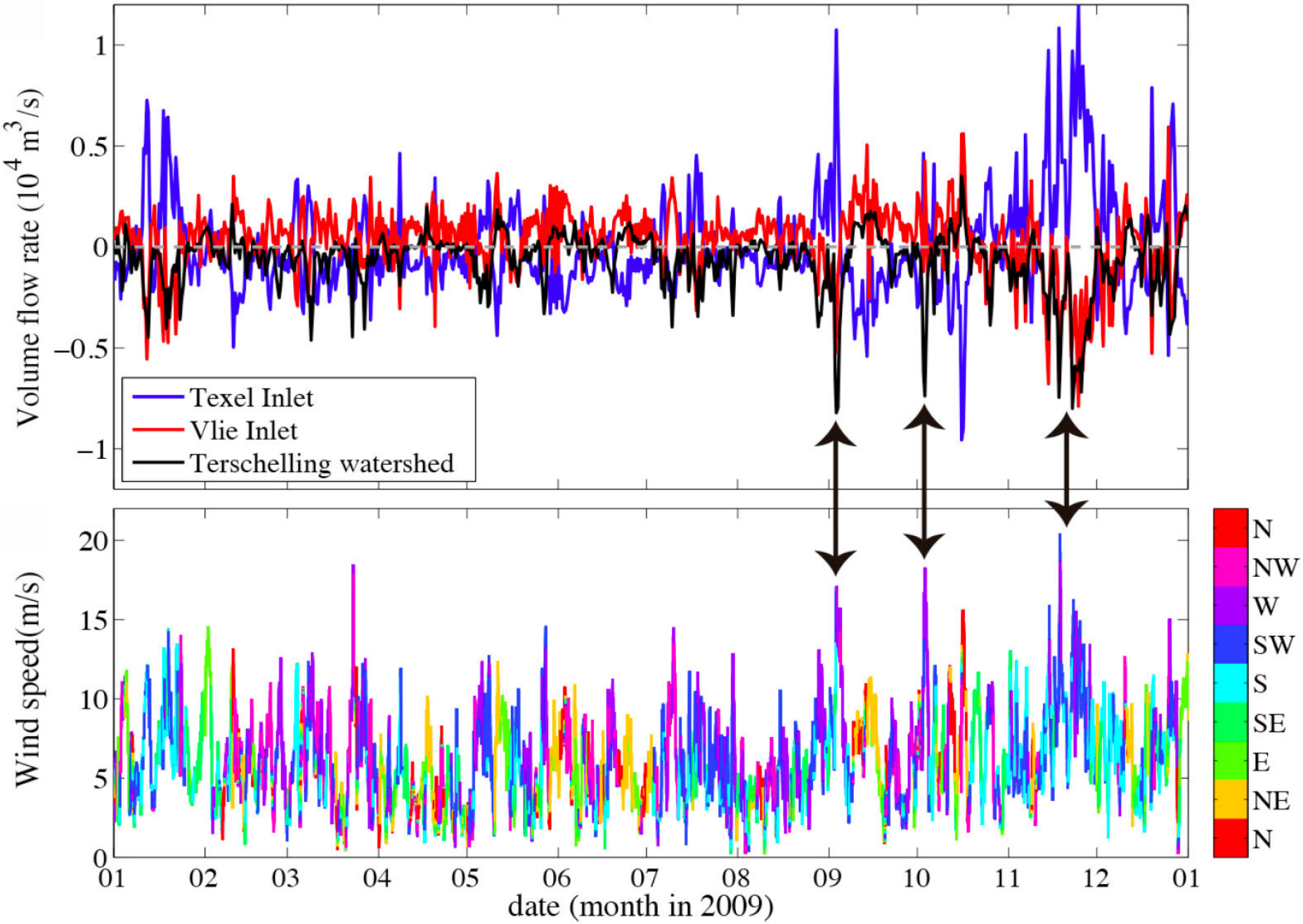
Standard deviation (dashed, ±2300 m^3/s)
order of magnitude larger than median (-700 m^3/s) and mean (-400 m^3/s)

➔ **Enormous variability!**

Cause?

(Duran-Matute et al. 2014)

Intermittency in net transport related to **wind events**



Inter-annual variability

Within a year, large variability. *Also between different years?*

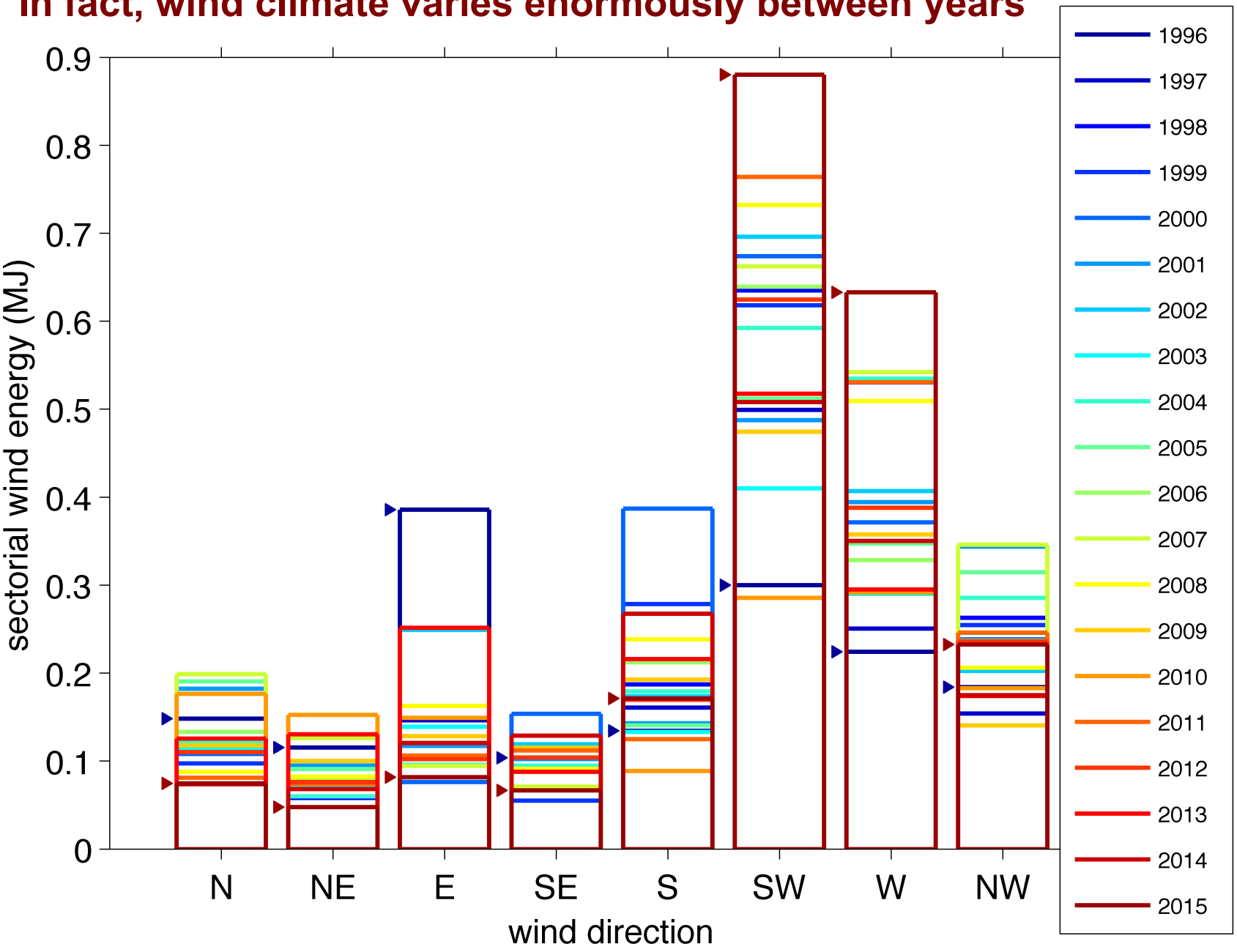
Example: tidal-averaged transports through Marsdiep (m^3/s)

Year	annual mean	annual median
2009	+3	−455
2010	−756	−903
2011	+1	−316

Again: caused by prevailing wind climate
(relatively much NE wind in 2010 ➔ export)

(Duran-Matute et al. 2015, 2016)

In fact, wind climate varies enormously between years



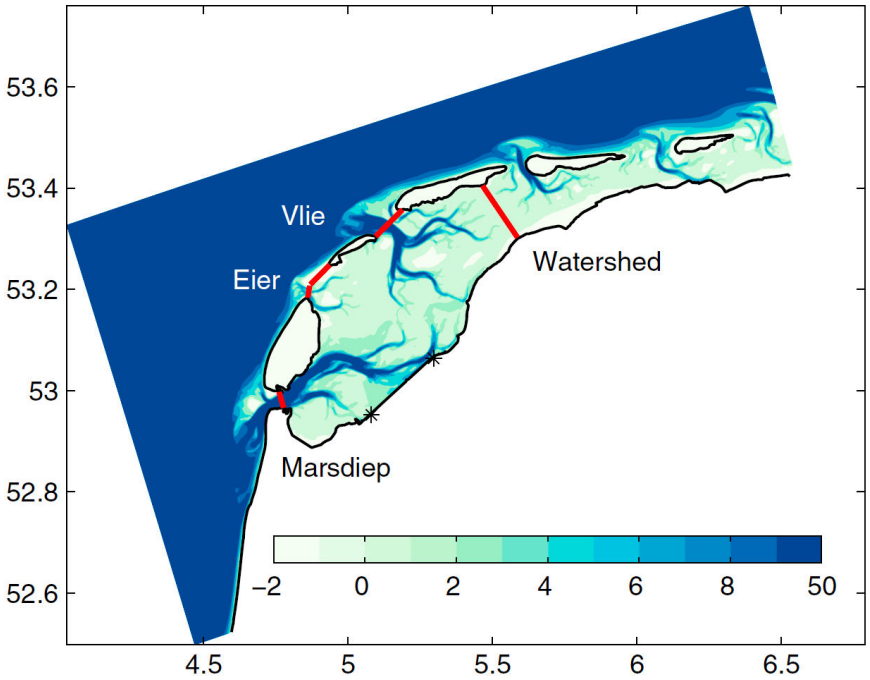
Example from Vliehors (KNMI weather station) *(Gerkema & Duran-Matute 2017)*

Upshot:

- Gross ebb and flood transports fairly predictable, as are the tides themselves. *However:*
- Tidally averaged transports vary strongly due to wind.
- Wind events cause episodic flushing through inlets or across watersheds.
- Even *inter-annual* variability in transports, due to variability in wind climate.

So far in this talk: about transport of **water.**

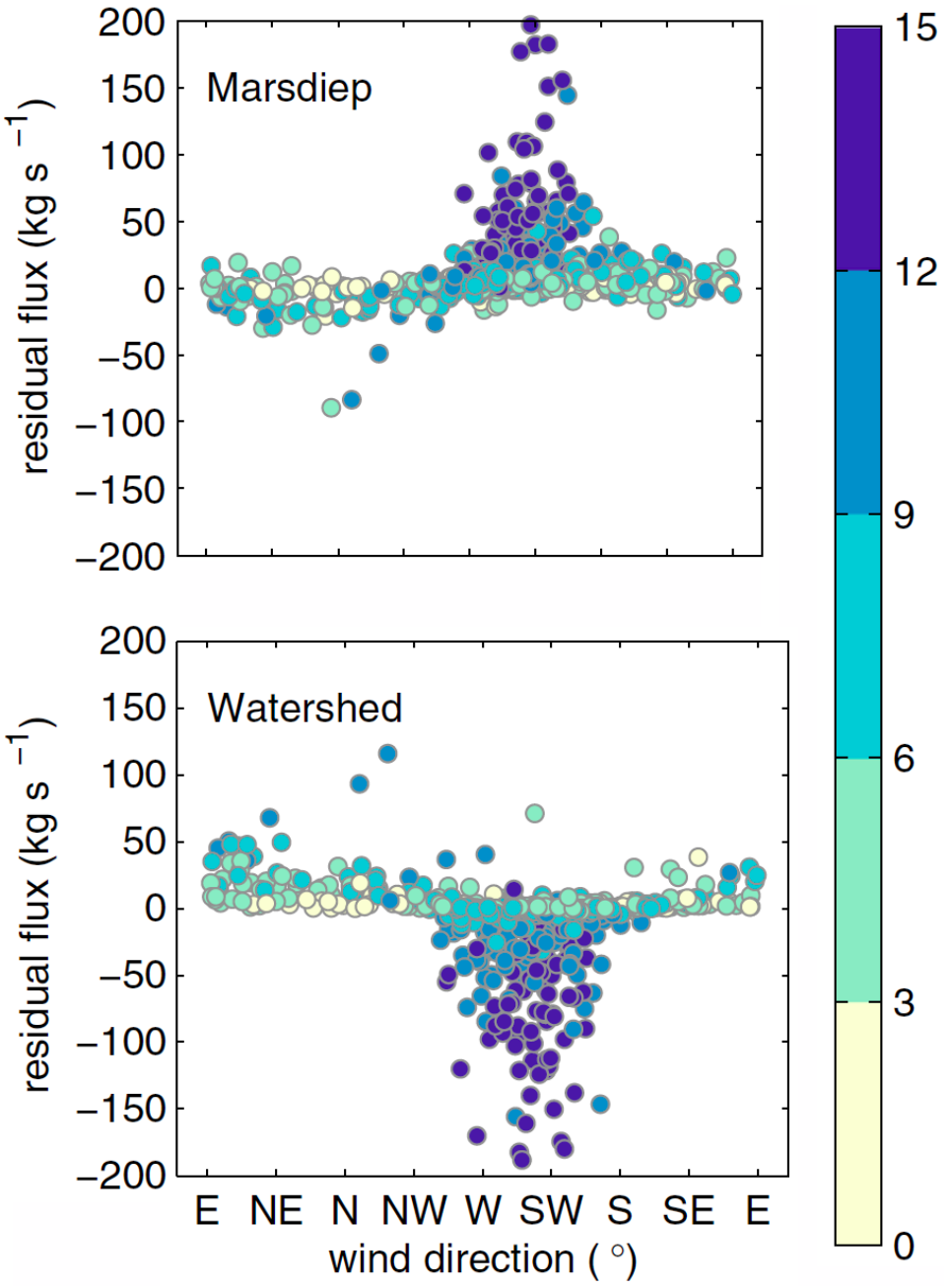
But this variability carries over to **sediment transport.**



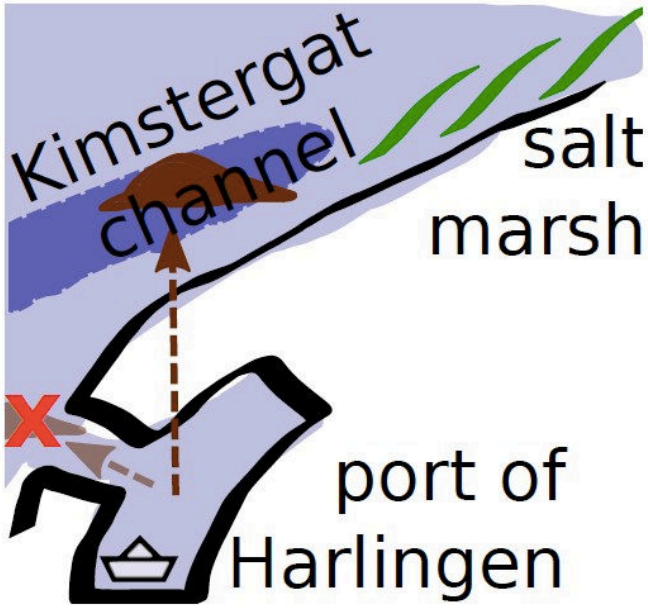
Wind effect on transport of suspended sediment (model results):

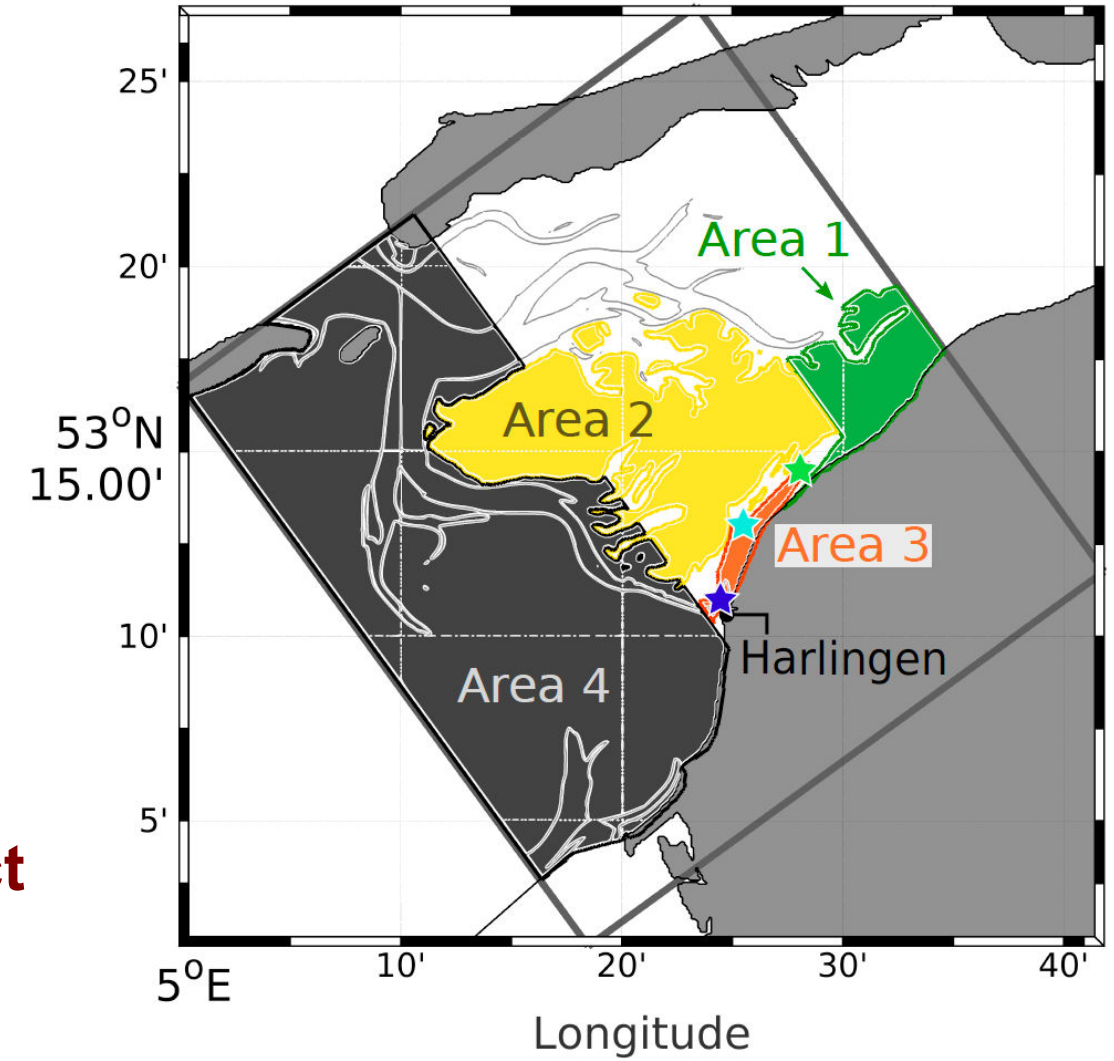
- Preferential wind direction
- Episodic fluxes for strong winds
- Large role for watershed

Colorbar: windspeed in m/s



(Sassi et al. 2015)



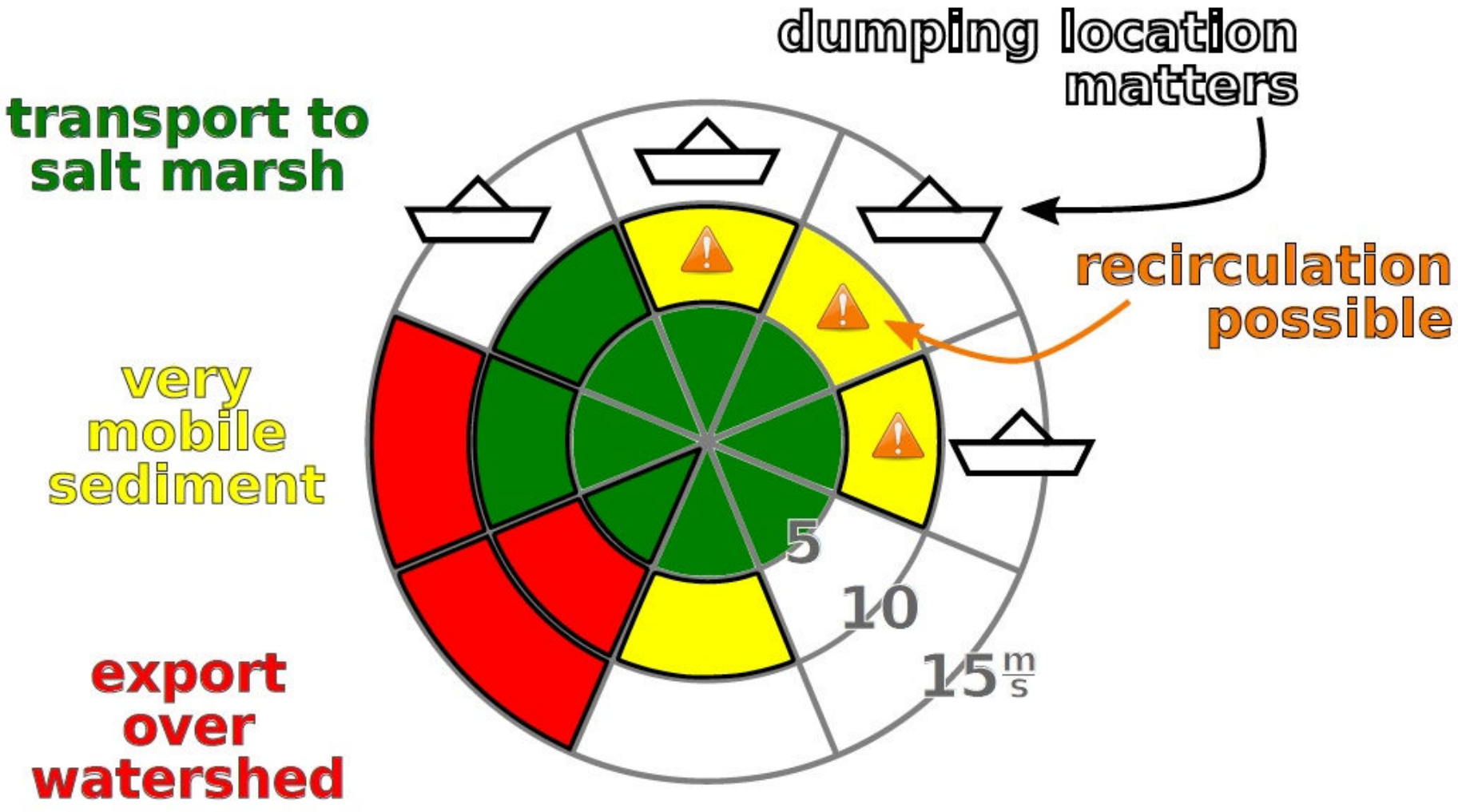


The “mudmotor” project

Model results on **alternative spreading locations** for mud from the harbour of Harlingen: *role of the wind?*

(Schulz et al. 2019)

Summary of results plotted in a wind rose:



(Schulz et al. 2019)

Conclusions

- Wind key factor in transport on a range of times scales.
- Wind introduces high variability: from daily to annual.
- Sediment dynamics in Wadden Sea strongly *event-driven,* especially across watersheds.
- *Long-term* measurements and modelling needed to get representative estimates of overall transports!

References:

- Duran-Matute et al., *Oc. Sci.*, 2014; *Oc. Dyn.*, 2015; *JGR*, 2016.
- Gräwe et al., *JGR*, 2016.
- Gerkema & Duran-Matute, *Earth Syst. Dyn.*, 2017.
- Sassi et al., *Oc. Dyn.*, 2015.
- Schulz et al., *Est. Coasts*, 2019 (subm).
- Gerkema, *An Introduction to Tides*, Cambridge University Press, 2019.