

# Responses of coastal processes to multiple drivers in the Baltic Sea

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Visible by naked eye:

Baltic Sea coasts under pressure





Southern coast of Saaremaa

Eroding Järve beach, Saaremaa, 30.04.2006



# Gulf of Riga



23.04.2012

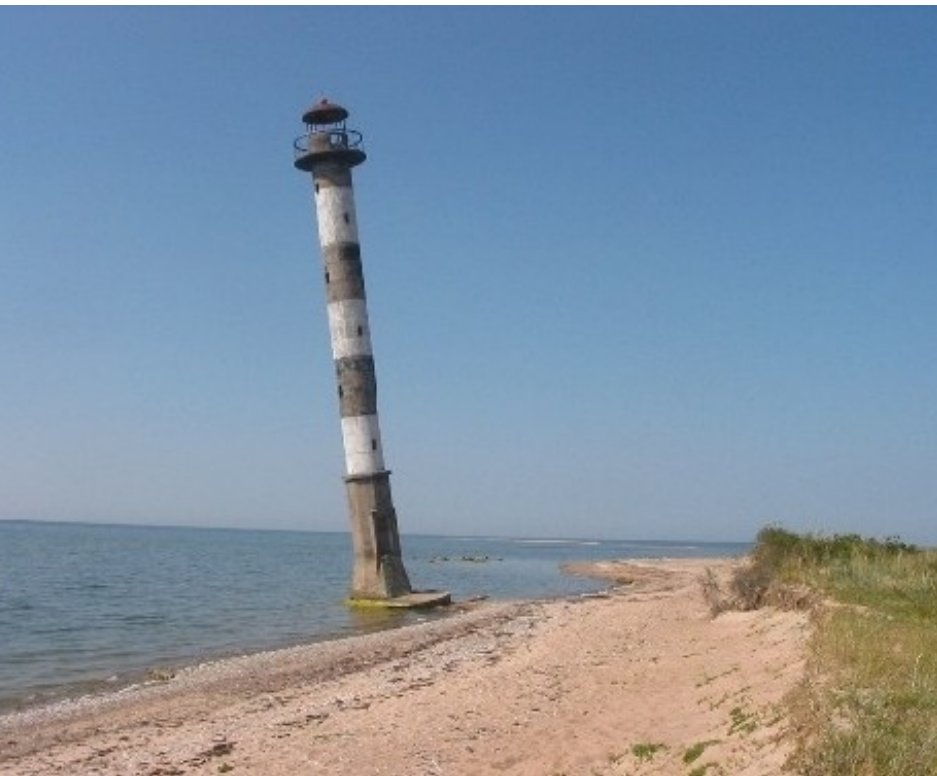


# The reason to worry

- Rapid coastal retreat along several eastern Baltic Sea coasts since the 1990s:

2009

Kiipsaare lighthouse, Estonia, 2004

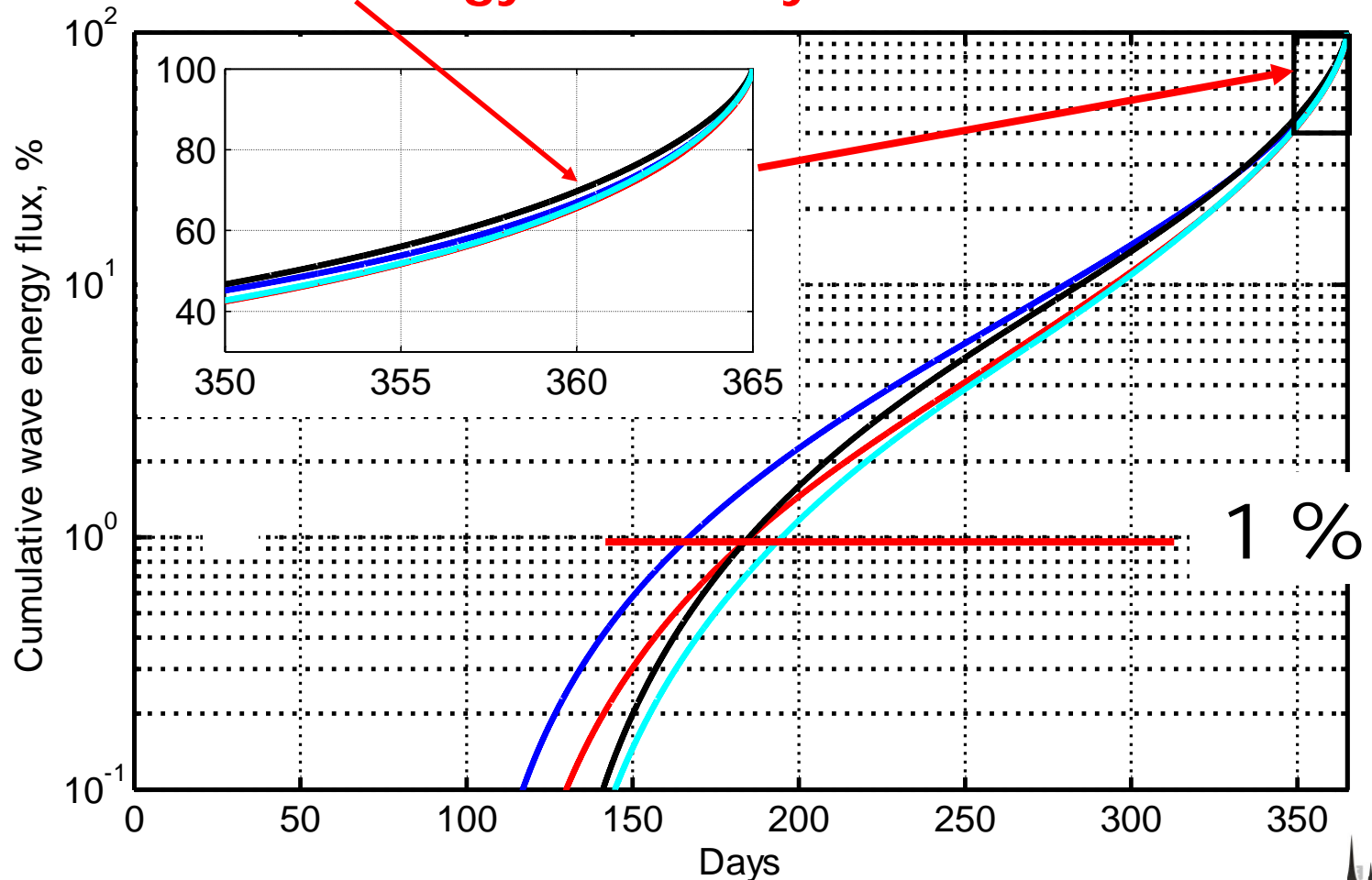


# Intense coastal processes: only if several conditions are met

- Strong waves
  - Unfortunate approach angle
- High water level
- Finer sediment available
- Unprotected sediment
  - No ice cover, mangrove forest, reed field or similar

# Baltic Sea wave climate: intermittent

- ~ 1% of the total annual energy arrives within 170-200 days
- ~ 60 % of the annual energy arrives within 20 days
- ~ **30 % of the energy: ~ 3-4 days**

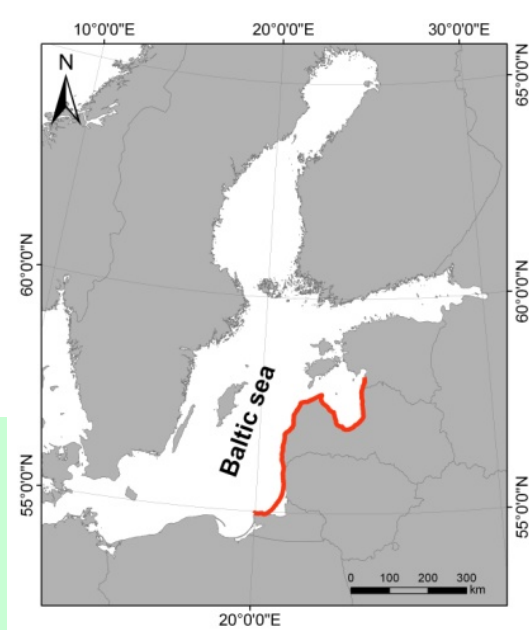




A simple consequence  
from **intermittency** (of wave fields)  
and **geometry** (of the coast)

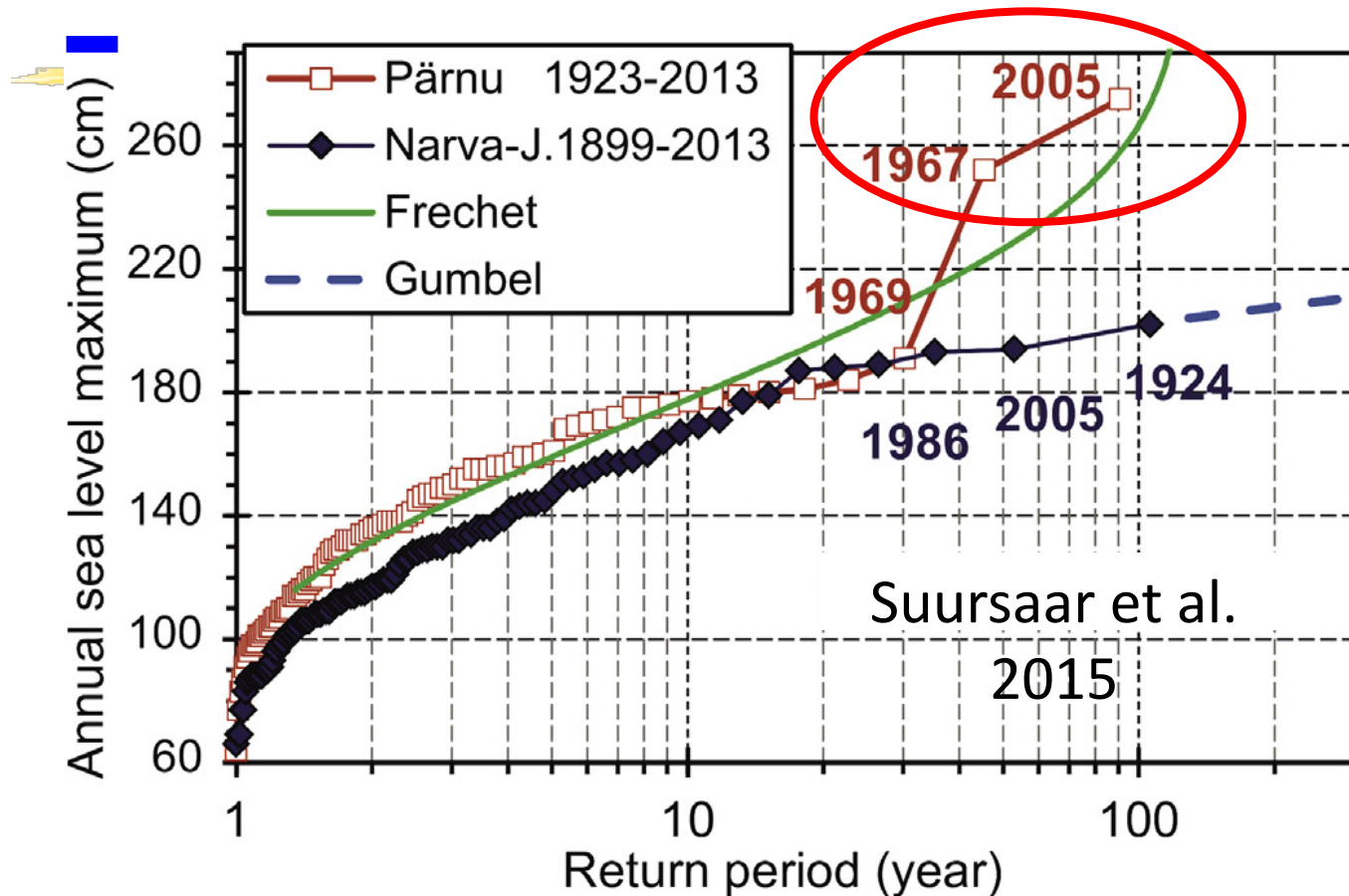
Evolution of the Baltic Sea shores  
is a step-like process

- A few events of rapid changes
  - when strong waves arrive from a specific direction during high water level events
- Most of the time: very slow changes
  - Require high-resolution measurements to detect





# Extreme water levels: The complicated future of the Baltic Sea coastal nations?

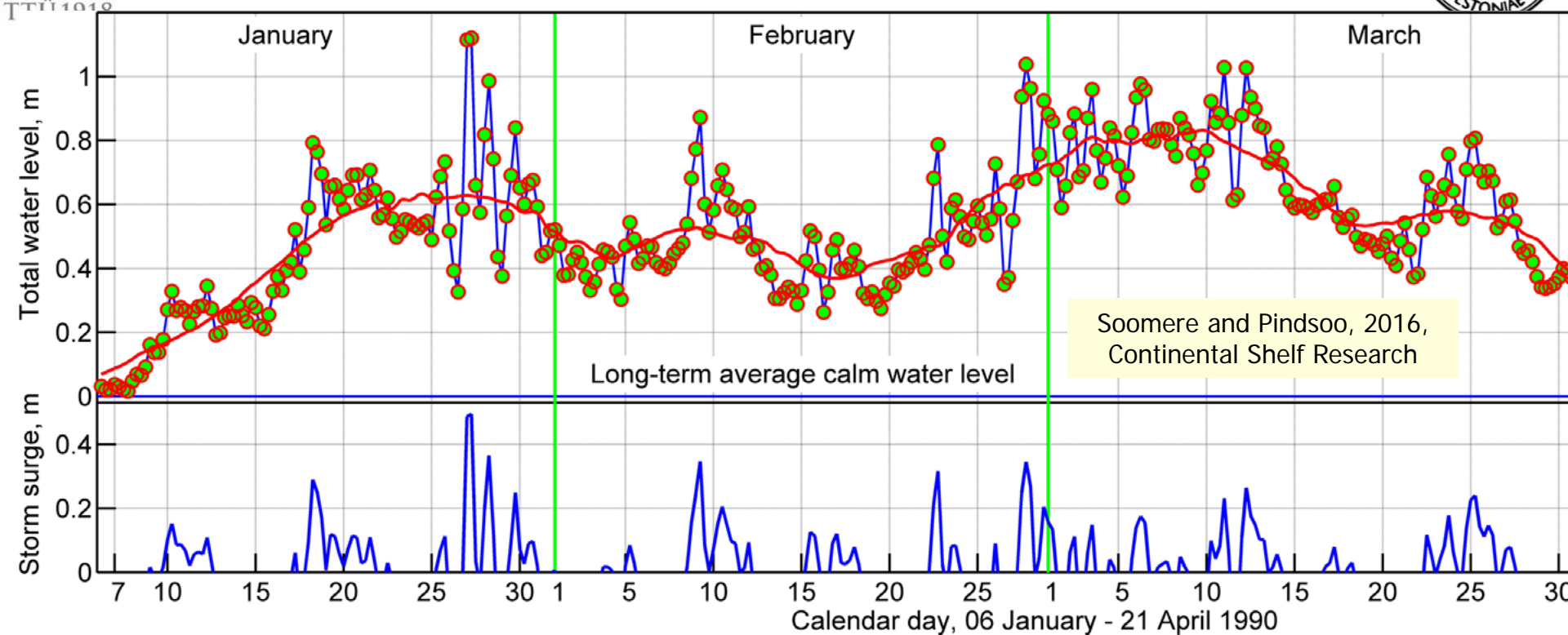


The problem (e.g. Suursaar and Sooäär 2007; Suursaar et al. 2015):

- extremely high sea level values (e.g. at Pärnu)
- which statistically appear as unpredictable outliers
- but are nevertheless caused by 'normal' storms

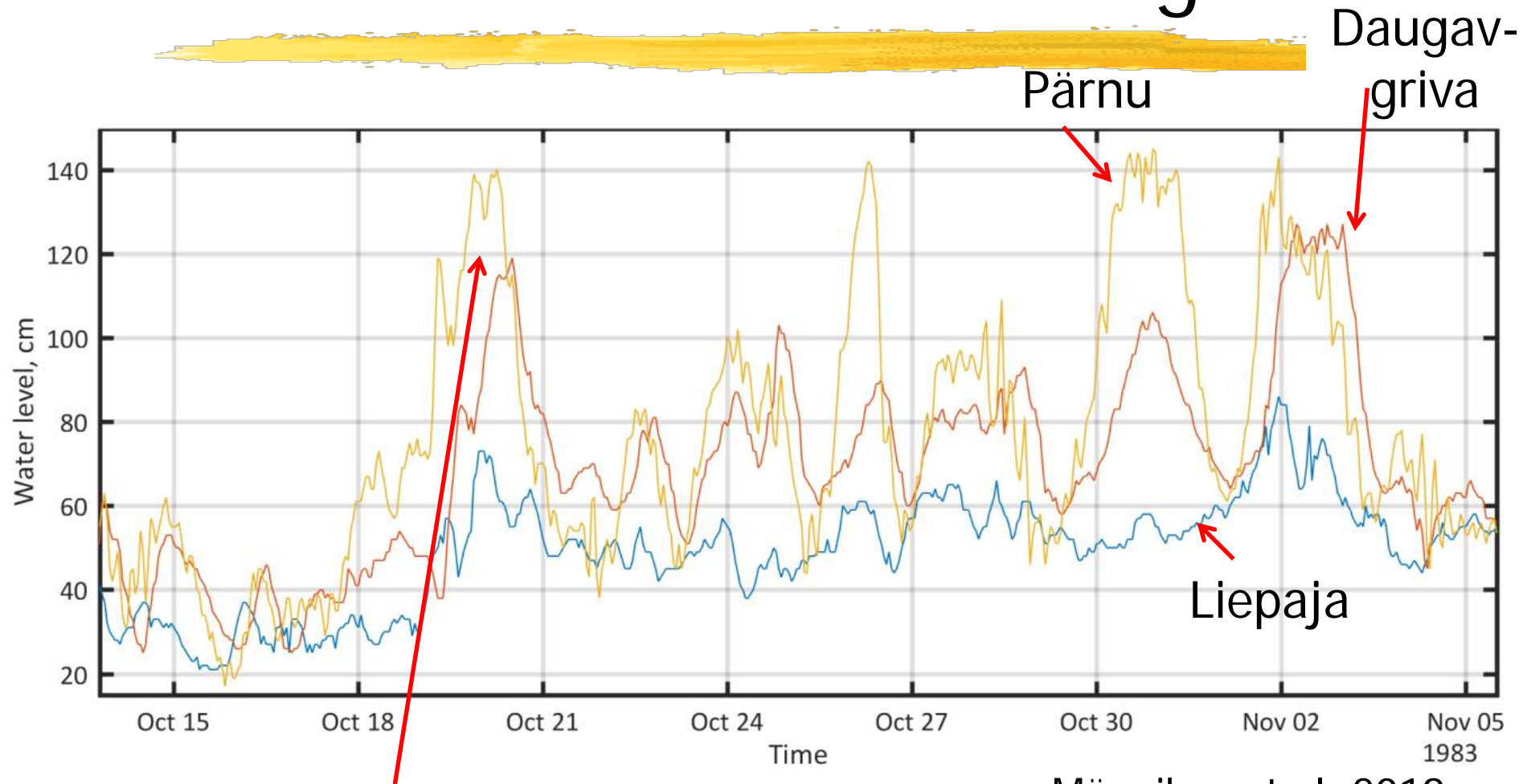


# Water volume of the Baltic Sea varies



- ## Specific feature of the Baltic Sea
- Events of increase in the water volume of the entire sea
    - High water level events over a few weeks, ~1 m
  - Different mechanisms: work basically independently
  - Challenge: single out the response to each driver

# Multi-step process: super-elevations in the Gulf of Riga



Up to +1m once in 7-10 years

Männikus et al. 2019,  
submitted



Wave approach direction:  
usually directly towards the coast





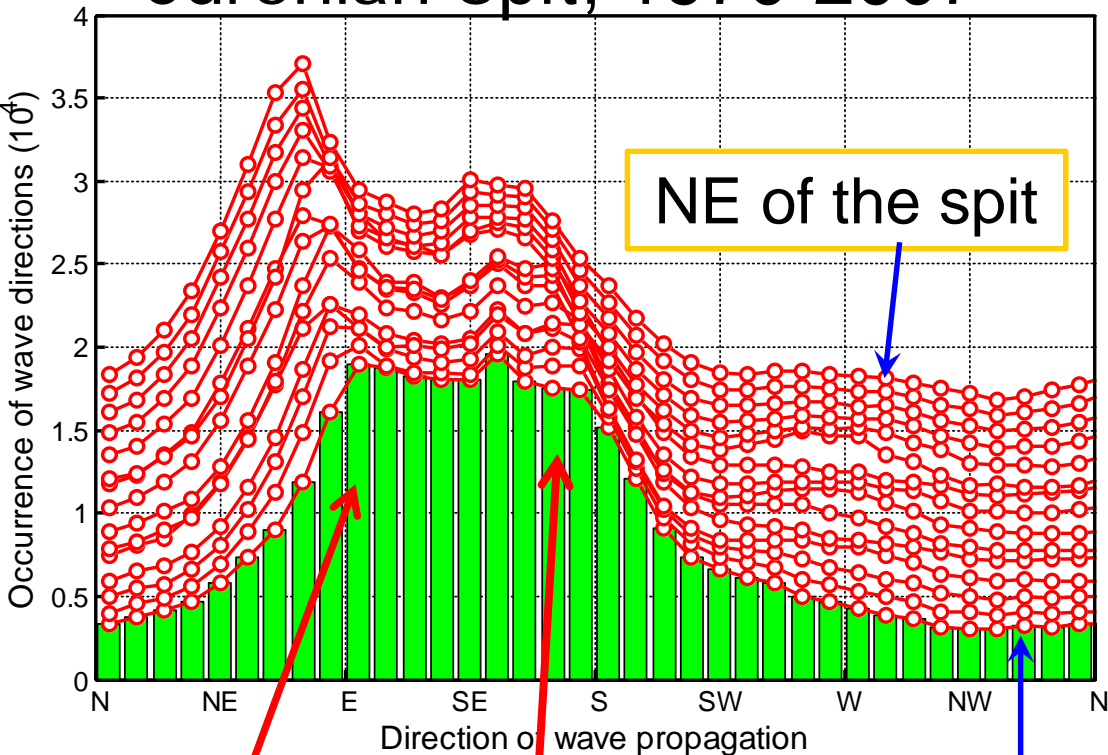
Wave approach direction in the Baltic Sea:  
often under large angle with respect to the coast





# Directional wave climate at the Curonian Spit

## Curonian Spit, 1970-2007

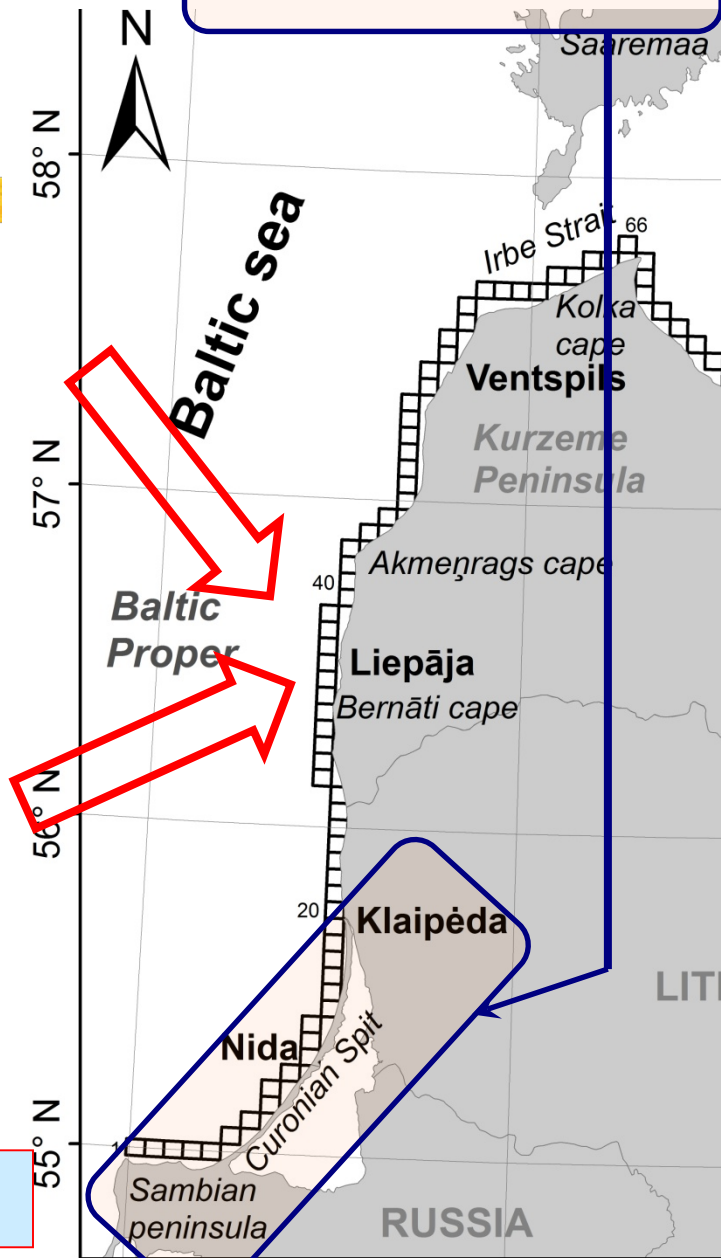


From WSW

From NNW

SW of the spit

Which direction dominates the transport?





# Consequences of large approach angle

- Sensitivity with respect to particular approach direction
- Comparatively large sediment transport rate
  - Proportional to  $\sin(2 \times \text{angle})$
- Classic cut-and-fill process does not close the loop
  - Mobile sediment moved along the shore to another location
- Small proportion & intensity of swells: natural beach refill slow or missing

The properties of single storms and the timing of storms in sequences become decisive

# Valgerand, Pärnu Bay, Estonia: it seems that there is enough sand



The appearance  
of coasts mirrors  
the wave regime



In reality, only thin sand sheet covers clay and pebbles





# Asymmetry of sediment flux

- Often limited by the availability of fine sediment
  - Overall sediment deficit on the Baltic Sea shores
  - Real sediment flux only a few % of the potential flux
  - Slow accumulation in flux convergence areas
- Accumulation features may be easily destroyed
  - Sediment transport in single storms from unexpected direction can be much more intense

Again:

The properties of single storms and the timing of storms in sequences become decisive



The impact of ice  
Ristna (Ristinina) harbour  
April 2006





# A problem for navigation



# Damaging houses (Komarovo, Neva Bay, 2008)



Ryabchuk et al., 2011 BER



# The problem for sedimentary beaches:

**No ice == no protection** against severe waves and high water level

- Storm surges much higher than for ice-covered sea
- Wave energy reaches mobile sediment
- Particularly dangerous: **high surge + strong waves + mobile sand**

(Komarovo, Neva Bight, 29 October 2006

11 January 2007 )

Ryabchuk *et al.* 2009, 2011





# Many Baltic Sea shores should be very vulnerable:

- Small amount of sand
- Young coasts
- Open to hydrodynamic loads
- Overall fine sediment deficit

Still they are explicitly or implicitly stabilized by

- Short waves → surf zone narrow
- Geometry: stable sections in bayheads
- Infrequent hits by storms
- Postglacial rebound ~ = sand accretion

Consequence:

Almost equilibrium state of many beaches with very small amount of sand

Thank you  
for your attention

