

Long-term variations of simulated sediment transport along the eastern Baltic Sea coast as a possible indicator of climate change

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Outline

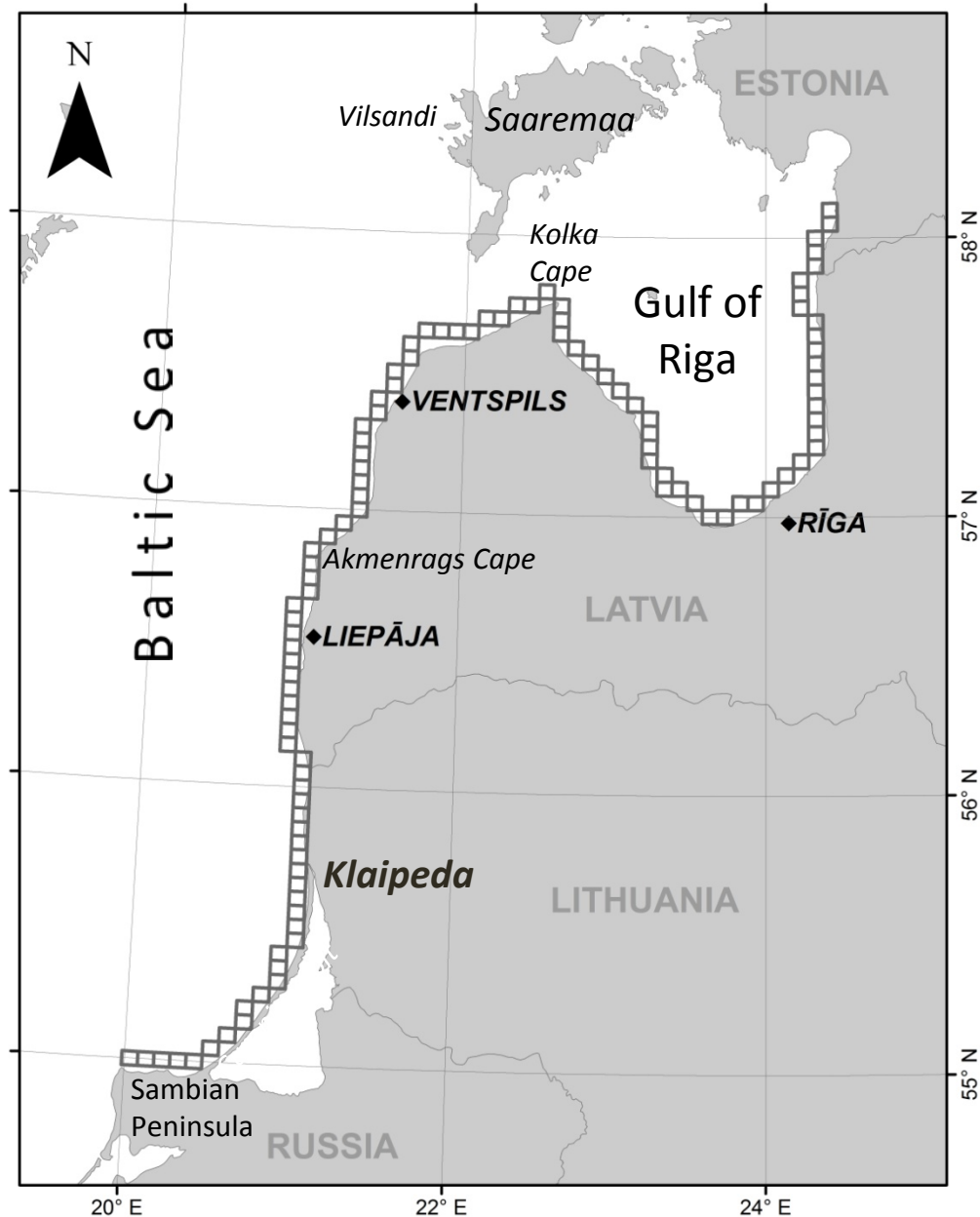
- Objectives
- Introduction
- Wave time series
- CERC method
- Results
 - Bulk sediment transport
 - Net sediment transport
- Conclusions

Objectives

- How do coastal processes reflect variations in wind and wave properties?
- How does the longshore sediment flux vary along the coastline over a 30-year period?
- Are there any long-term trends in bulk and net transport changes over the years?

Introduction

- Study area – approximately 700km from Sambian peninsula until Pärnu Bay
- Eastern coasts of the Baltic sea mainly consists of relatively soft and easy erodable sediment
- Sensitive to large hydrodynamic loads
- Exposed to winds from SW, W and N-NW
- Generally sediment deficit



Wave time series

- third-generation spectral wave model WAM
- spatial resolution of 3' along latitudes and 6' along longitudes (about 3x3 nautical miles)
- 1 hour temporal resolution
- calculated for 38 years (1970–2007)
- forced by adjusted geostrophic winds from the Swedish Meteorological and Hydrological Institute
- Idealized ice-free conditions

(Andrus Räämet)

Wave driven potential longshore sediment transport

- Simulated for 38 years (1970-2007)
- For simulation used CERC (Coastal Engineering Research Council) formula with spatial resolution 3 nautical miles
- Based on numerically simulated long-term time series of wave properties along the beach

Basic ideas/assumptions

- Look at **longshore transport only**
 - Especially its variation along the beach
- **Assume:** sediment flow driven exclusively by waves
- **Idealized case:** no longshore variations of sediment properties (fixed grain size)
- Sediment flow at each time instant : proportional to wave energy flux (CERC method, used worldwide)
- Major simplification from the above: very few information needed:
 - **Wave time series (H, T, direction)**
 - **Orientation of coastline**

Transport intensity from properties of waves and sediment

CERC method (Coastal Engineering Research Council)

Potential longshore transport

acceleration due to gravity

water density

wave height at breaking

CERC coefficient

sediment density

sediment porosity

breaking index/depth

$$Q_t = K \frac{\rho}{16(\rho_s - \rho)(1 - p)} \frac{\sqrt{g}}{\sqrt{\kappa}} H_b^2 \sqrt{H_b} \sin 2\alpha_b$$

$\kappa = H_b / d_b$

Wave-driven longshore sediment transport is proportional to the wave energy flux (wave power)

angle between the wave crests and the isobaths at the breaking (includes information about wave period via refraction)

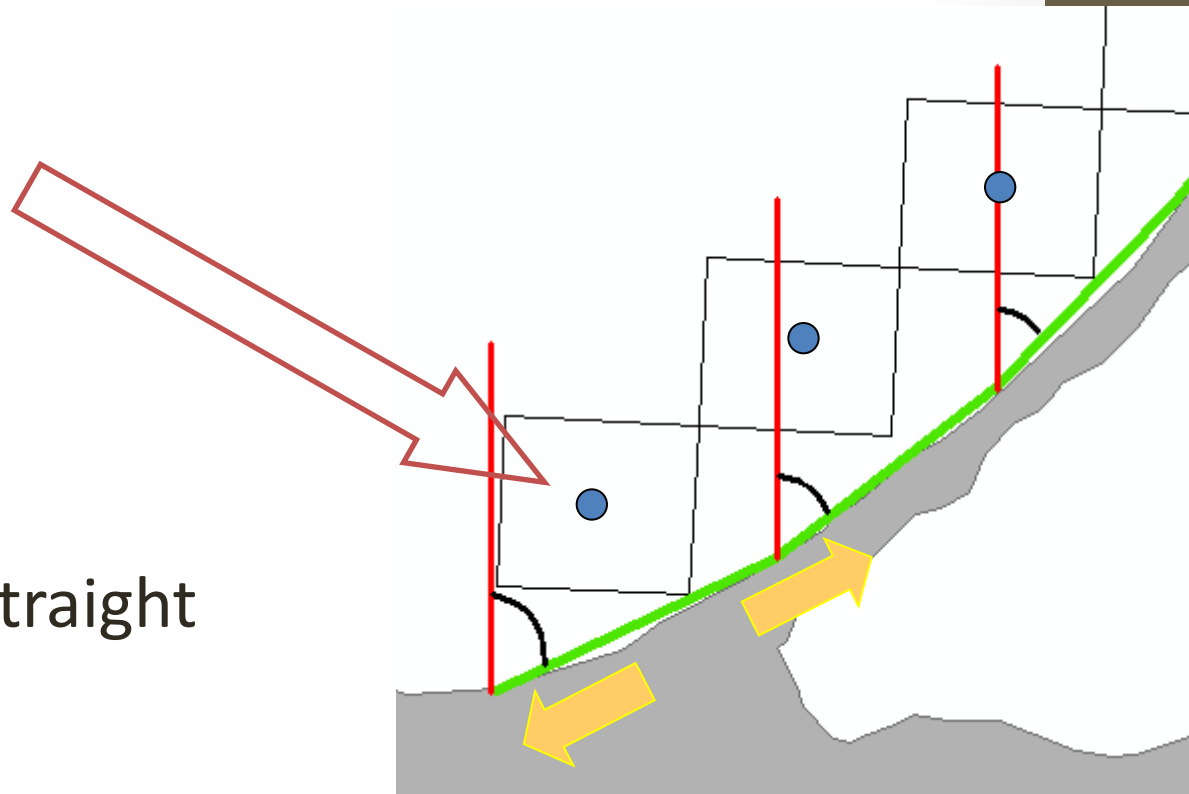
Waves driving the sediment in each sector

Changing in time and space:

- Wave height
- Wave direction
- Wave period

Fixed

- Depth of sectors
- Direction of coast approximated by straight lines



Net transport at each sector: summing up hourly transport (with sign!) over 38 years of wave data

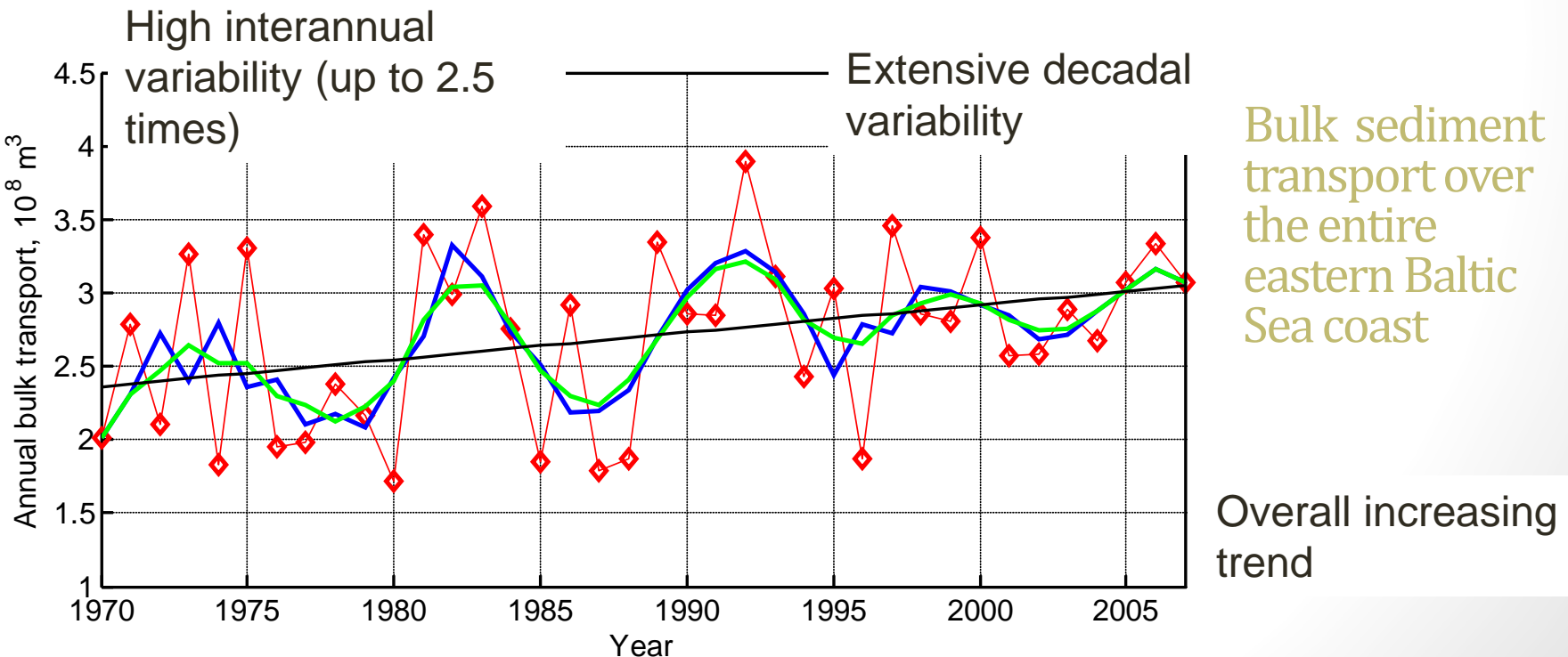
Results

- Bulk transport – the total amount of sediment brought into motion (moved in any direction, back and forth) by waves alongshore
- Net transport – the residual sediment motion in some direction

Model overestimates the actual transport rate but the *variation* of sediment flux (i) along the coast and (ii) in time is reliable

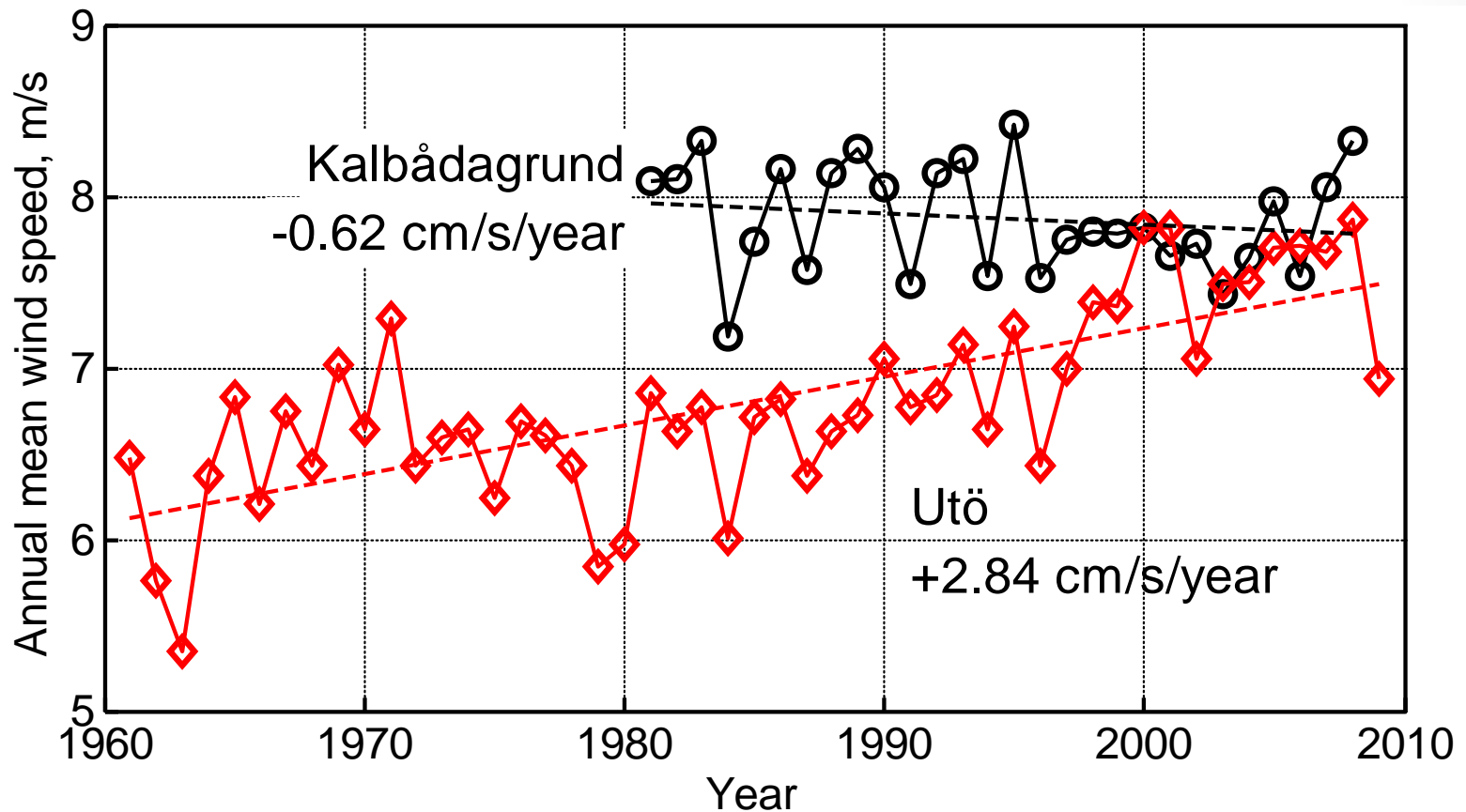
Bulk potential alongshore transport

- Transport increases considerably since 1970s (about 25%)
- Increase is mostly concentrated along the eastern coast of Baltic Proper (not evident in the Gulf of Riga)
- Clearly identifiable 10 years cycles of low and high values

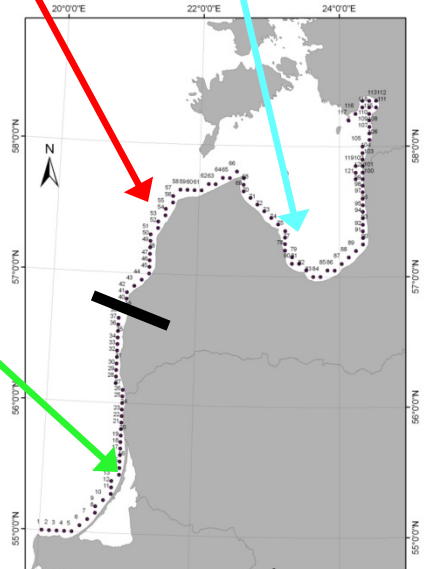
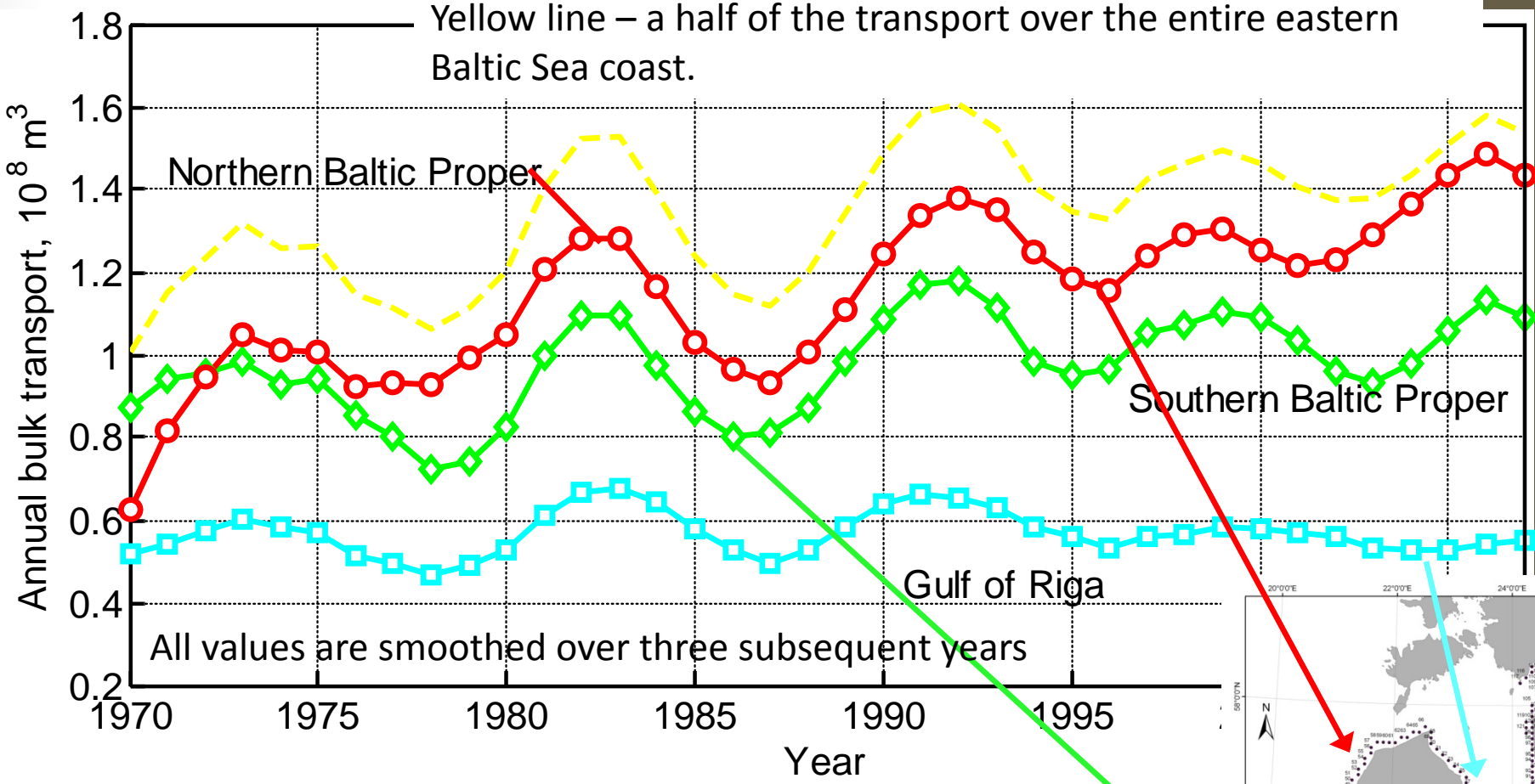


Long-term variations in the wind speed Utö (1961–2009)

- Overall increase in the transport rate matches well the increase in the wind speed over the northern Baltic Proper



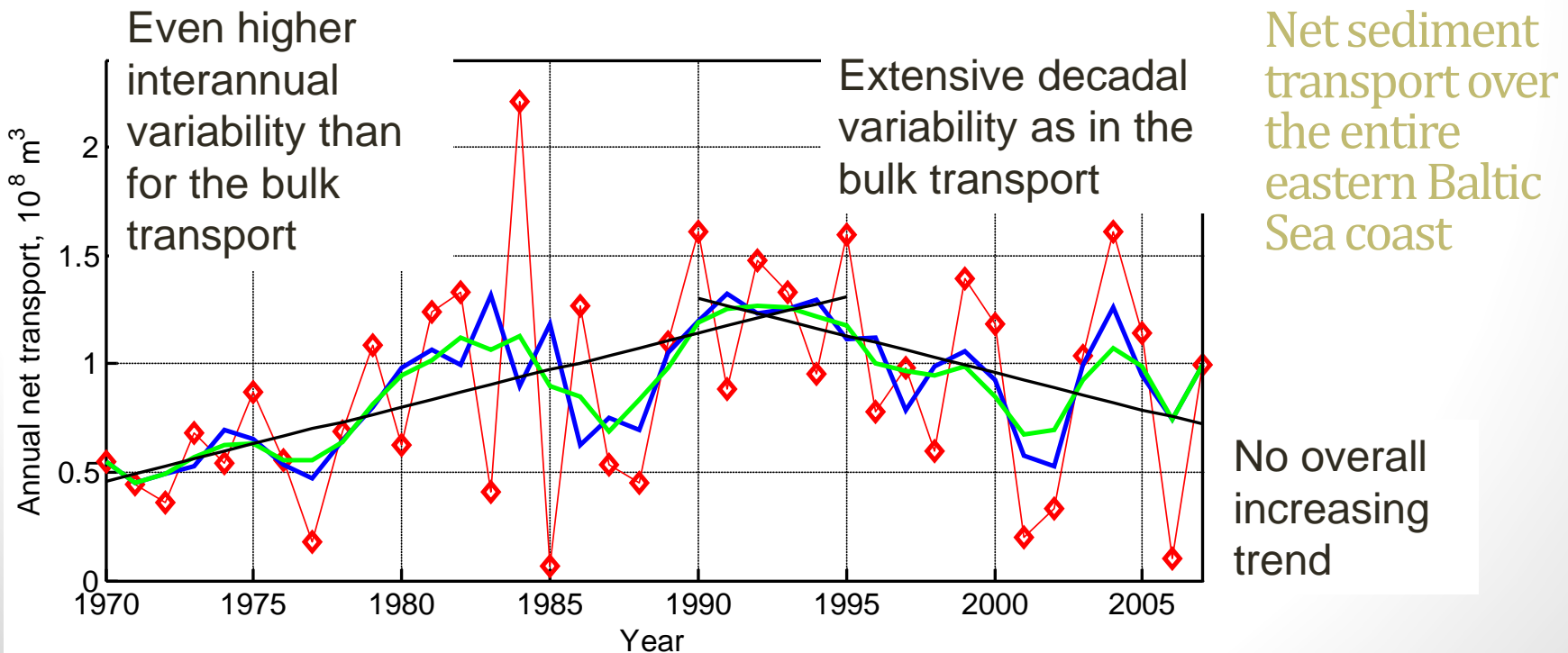
Bulk sediment transport for single compartments



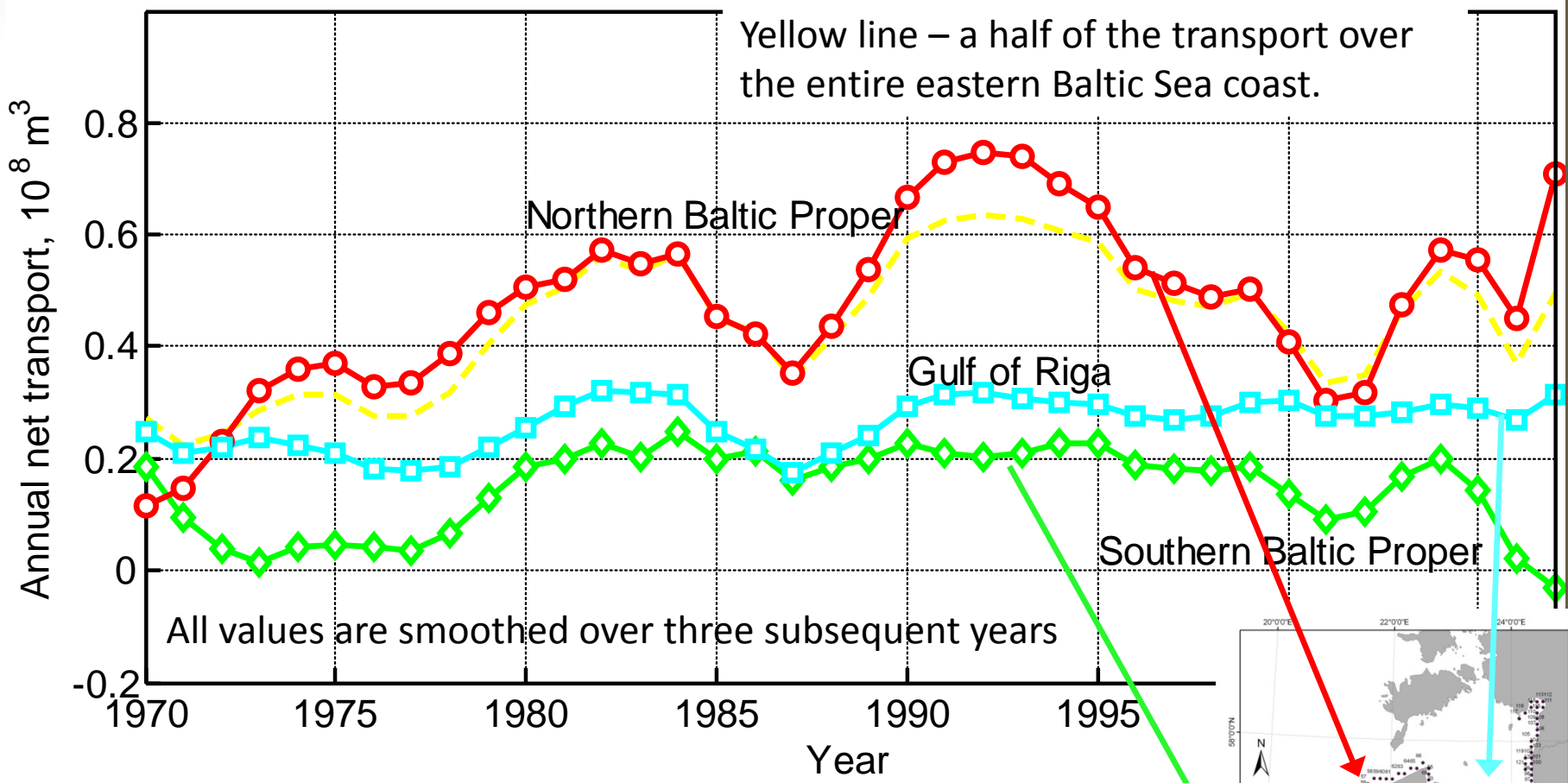
- Almost perfect match in decadal variations in three regions
- Except Gulf of Riga from 1995 onwards: behaves in a different way

Net potential alongshore transport

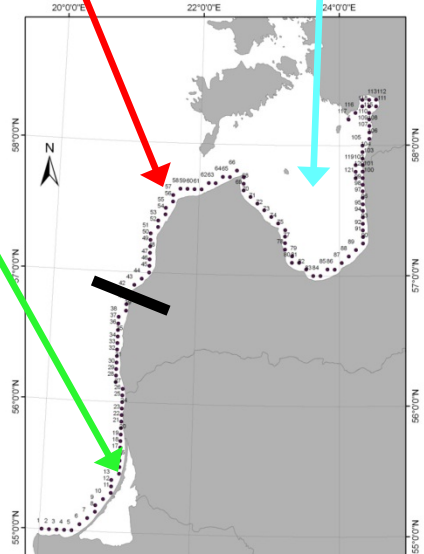
- Net potential transport does not follow trend of the bulk potential transport
- Increased in the 1970s and 1980s and **decreased with the same rate since the mid-1990s**
- Not so clear but still evident cyclic nature – typical time scale between high and low net transport varies from 10-20 years



Net sediment transport for single compartments



- Very limited match in decadal variations in 3 regions
- Net transport in the Gulf of Riga > in the SE Baltic;
- from 1995 onwards behaves in a different way
- Most of the entire Baltic variability: in the NW Latvia



Conclusions

- The **reaction of sedimentary** coasts to the wind and wave climate changes are extremely complicated
- Sedimentary coasts of Baltic Proper and in sub-basins of the Baltic Sea may **react differently with changing wind and wave properties**
- Since ~1990: the storms that impact the coast of Baltic Proper seem to have **less impact on the Gulf of Riga** and vice versa
- This feature might **reflect certain changes** in the trajectories of storm cyclones crossing the Baltic Sea
- Coasts of the Gulf of Riga develop under much **lower wave activity** differently from the southern Baltic Proper coasts
- Coasts in the gulf are still **far from the equilibrium** and thus host higher net transport even under relatively low waves

Thank you!

