Some evidence about climate changes and shifts in the Baltic Sea

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Outline

- The Baltic Sea
- Motivation
- The water body
  - Stability of circulation
- Surface effects
  - Water level
  - Waves
  - Ice
- Response

Baltic Sea: a strange water body

Inner sea of the EC

Relatively shallow: S=380,000km2, V=21,000km3, mean depth ~**55**m

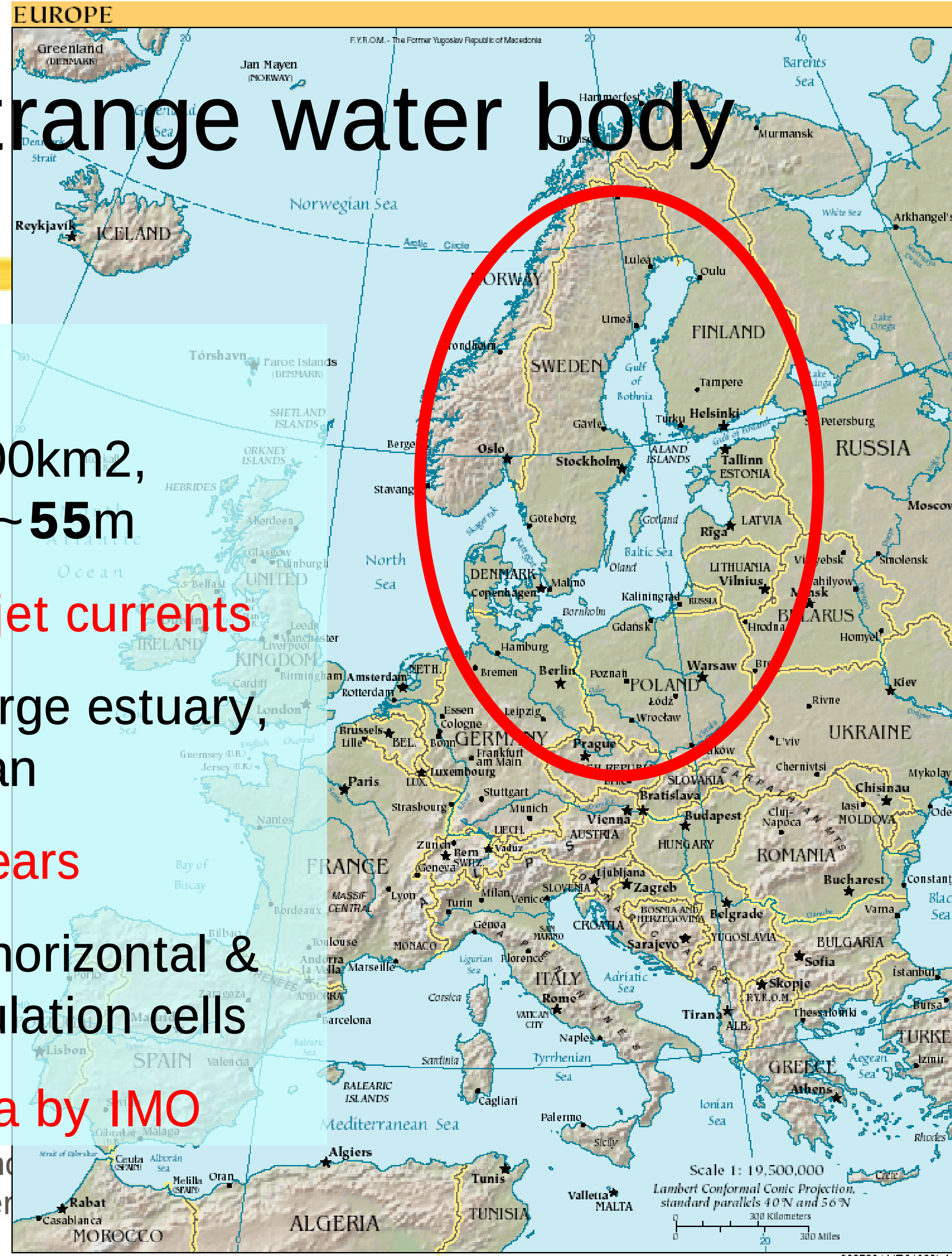
Long coastline, no tides, no jet currents

Combines properties of (i) large estuary, (ii) large lake, (iii) small ocean

Water exchange time ~25 years

Brackish water, with strong horizontal & vertical gradients, small circulation cells

Particularly sensitive sea area by IMO



Motivation: drastic changes in many sea state parameters

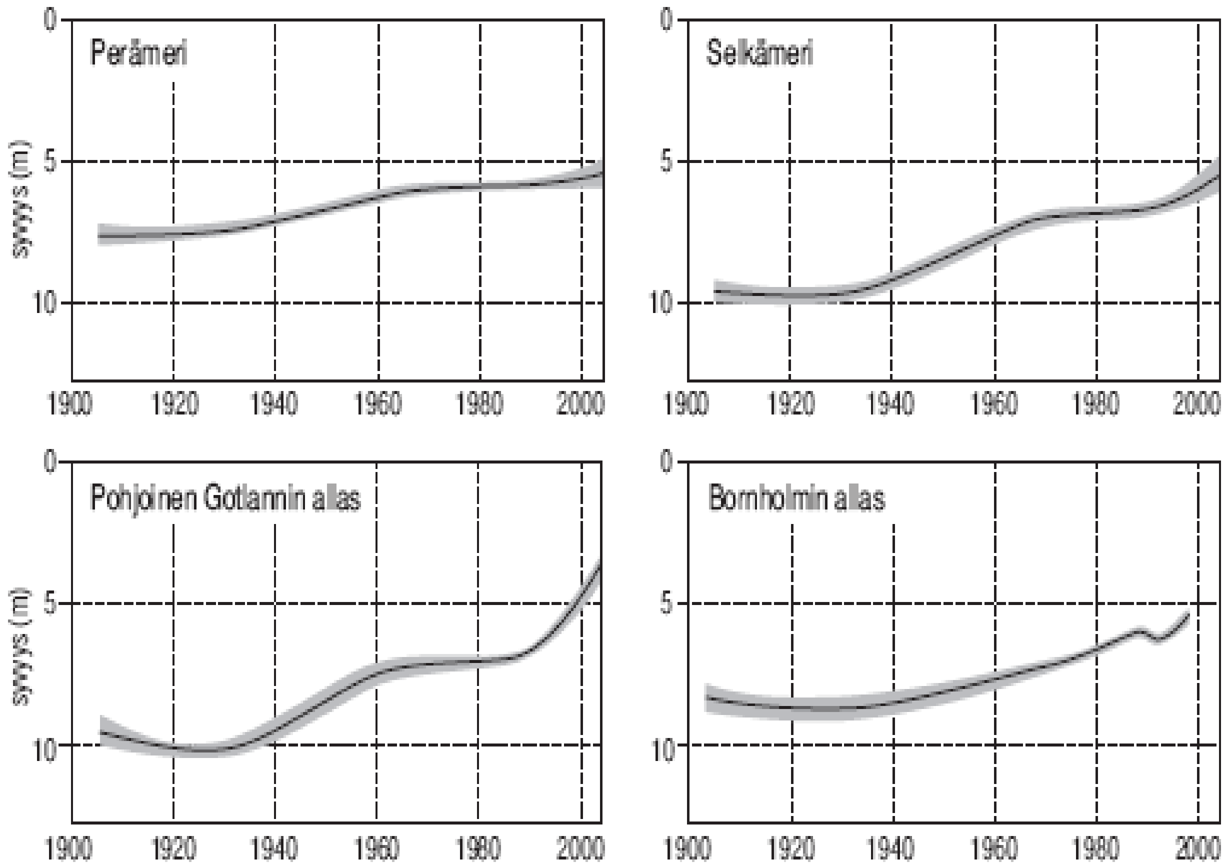
Secchi depth 1900 – 2000 in the Baltic Sea

Bay of Bothnia 7→5m

Sea of Bothnia 10→5m

Gotland Sea, North 10→4m

Bornholm Basin 8→5m



Courtesy to Matti Leppäranta, University of Helsinki

The sea-surface temperature has increased in 50 years by about 0.5 degrees

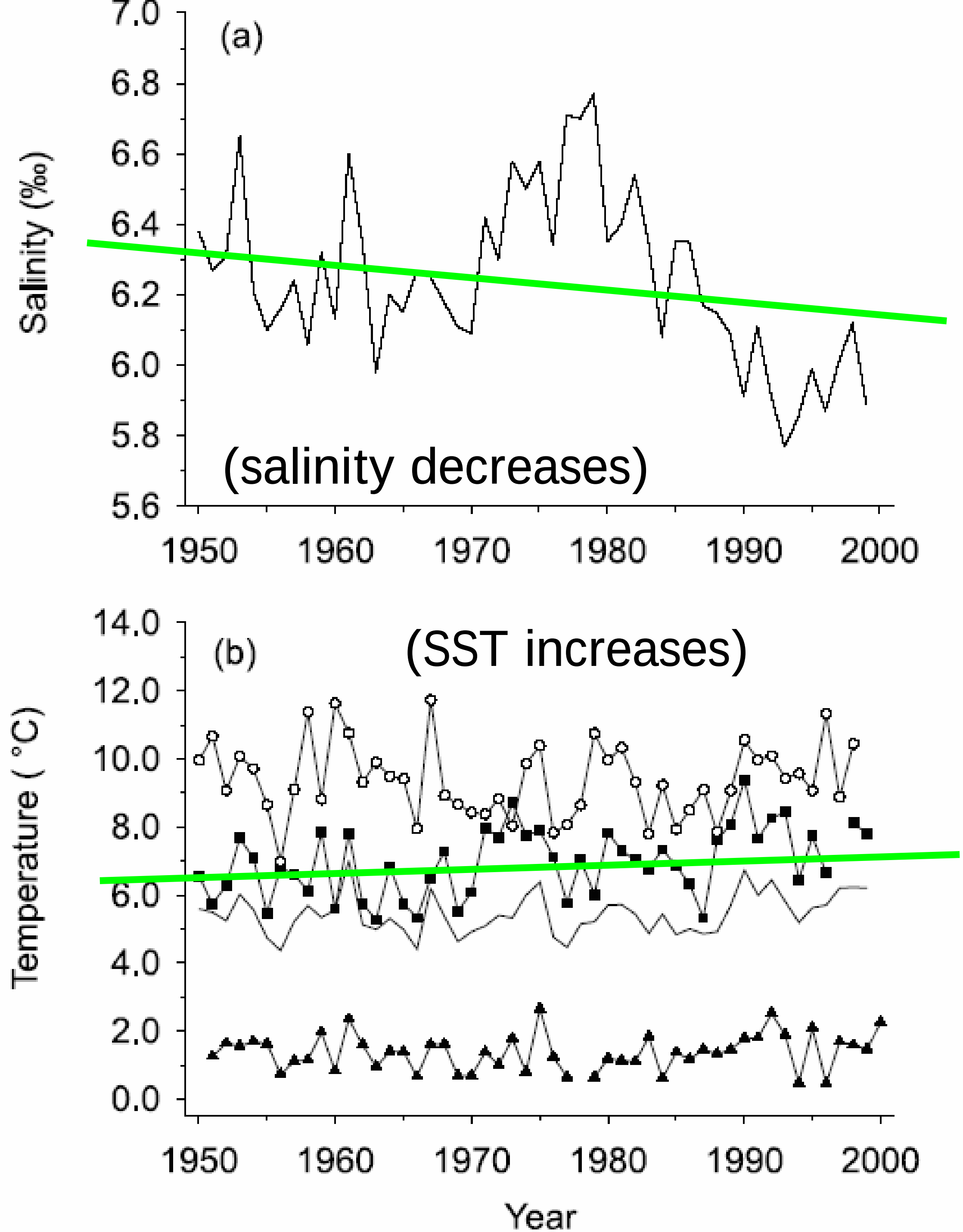


Fig xx. Annual averages of surface water 0-30 m) (a) salinity and (b) temperature at Utö , Tvärminne and Harmaja in the years 1950-1999. Seasonal averages of temperature (May-July (■), August-November (O), and December-April (▲)) are shown in (b)

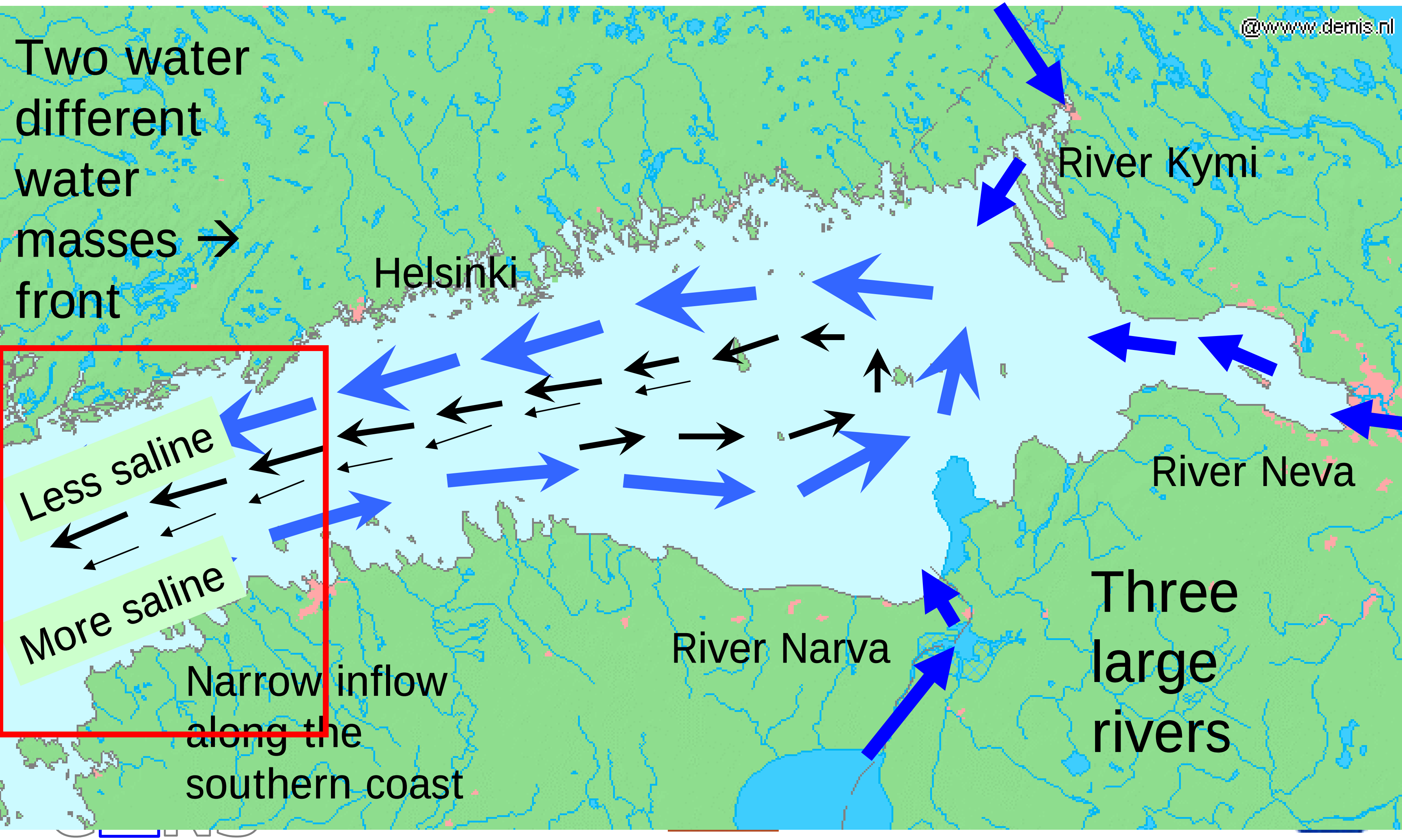
Variability *versus* long term changes: Baltic Sea as a test area

- relatively small size: susceptibility with respect to the external forcing factors
- mostly separated from the rest of the World Ocean
- forcing factors easy to identify & measure
- basin-wide studies within a reasonable budget
- numerous changes of the forcing conditions and of the reaction of the water masses already identified during the latter decade

Part I

The water body

Classical circulation pattern: estuarine transport combined with front development



Estuarine transport:

may be reversed

the entrance to the Gulf may serve as a “chimney” for ventilation of deep water of the Baltic Sea

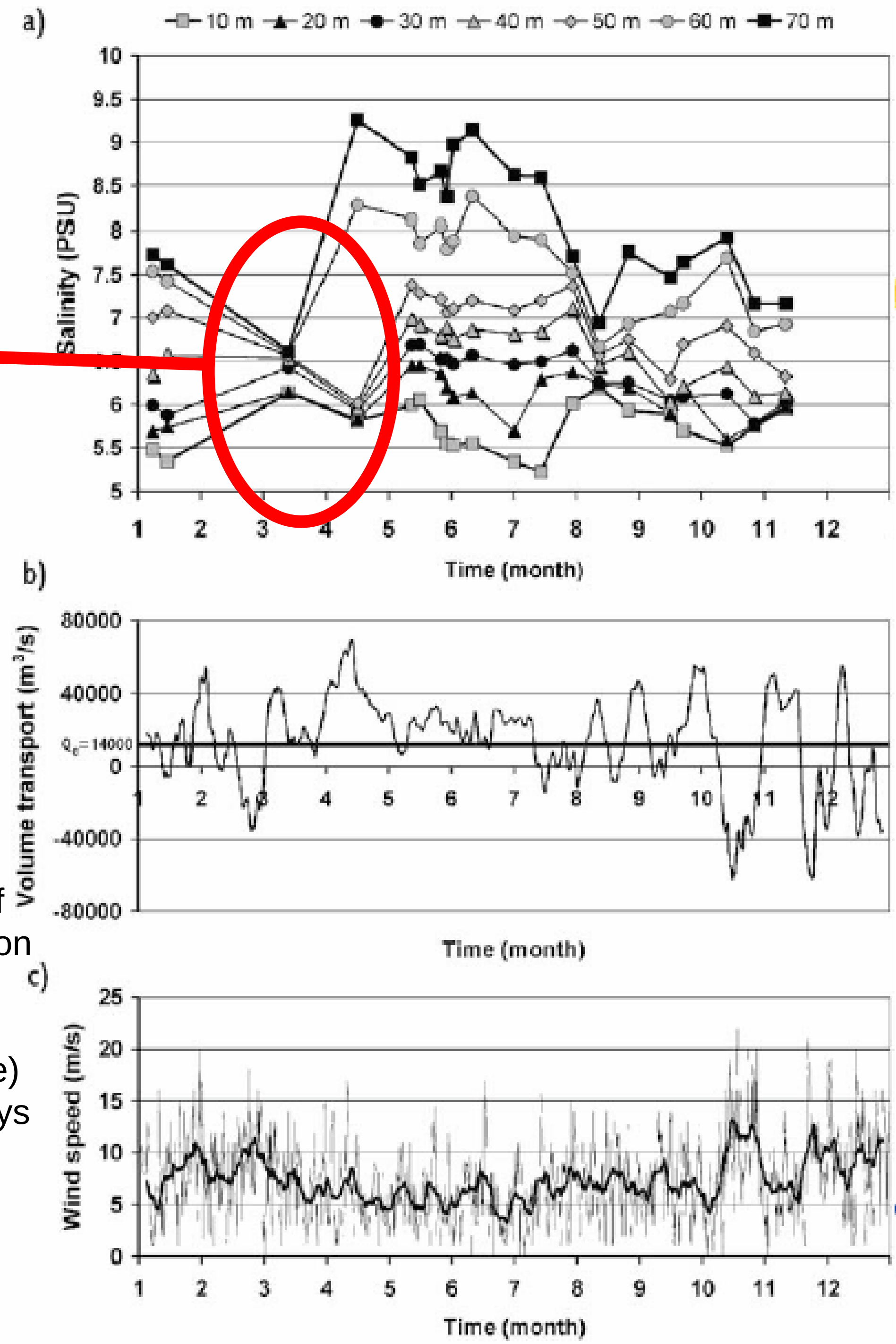
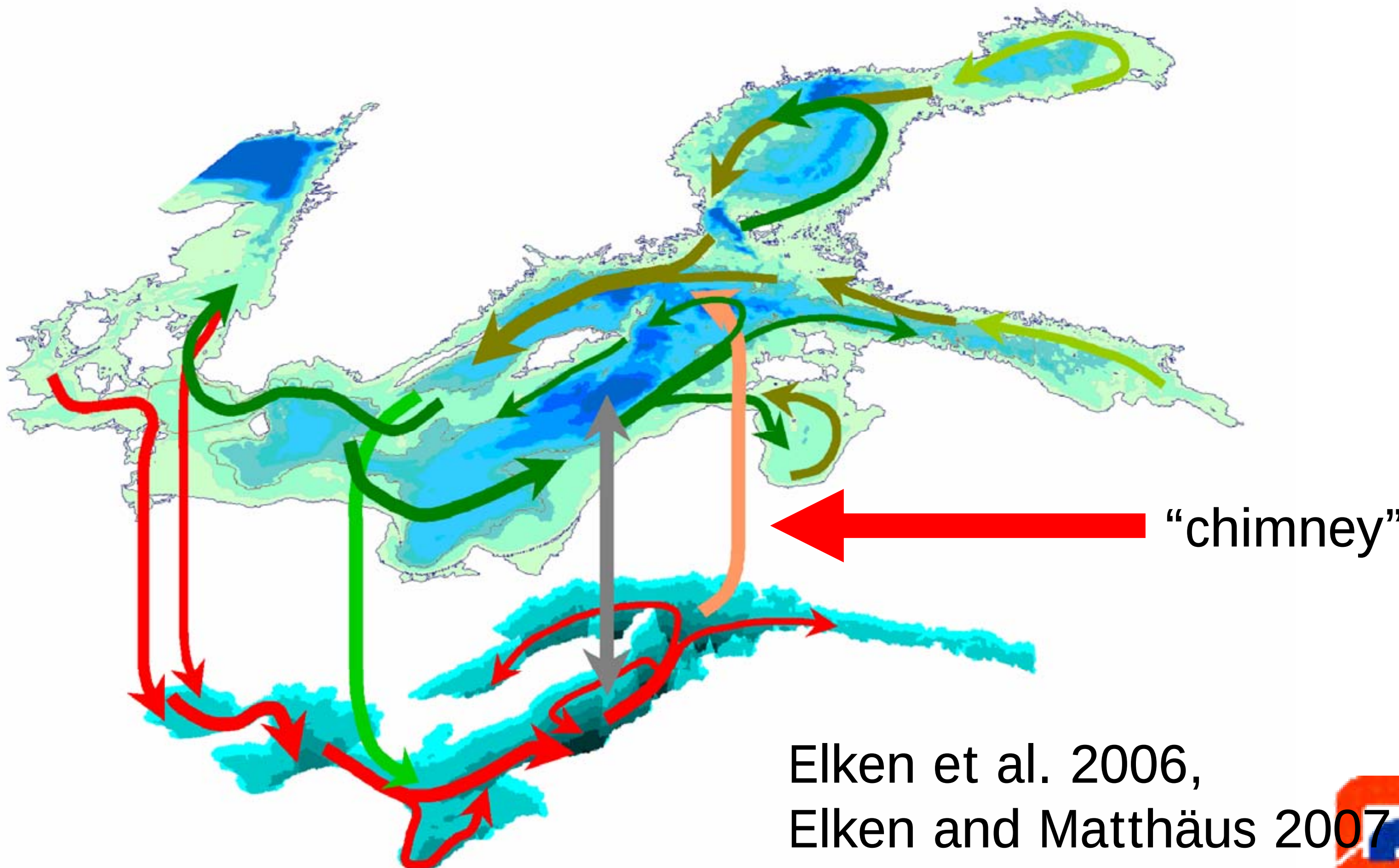


Fig. Xx. Time series in the western part of the Gulf of Finland during 1998: (a) salinity observations at station F3 on the levels from 10 to 70 m, (b) deep-layer volume transport calculated from the wind measurements at Utö island (7-days moving average) (c) the wind seep at Utö (original data, thin line, 7-days moving average (thick line).(Elken, Raudsepp, Lips, 2003)

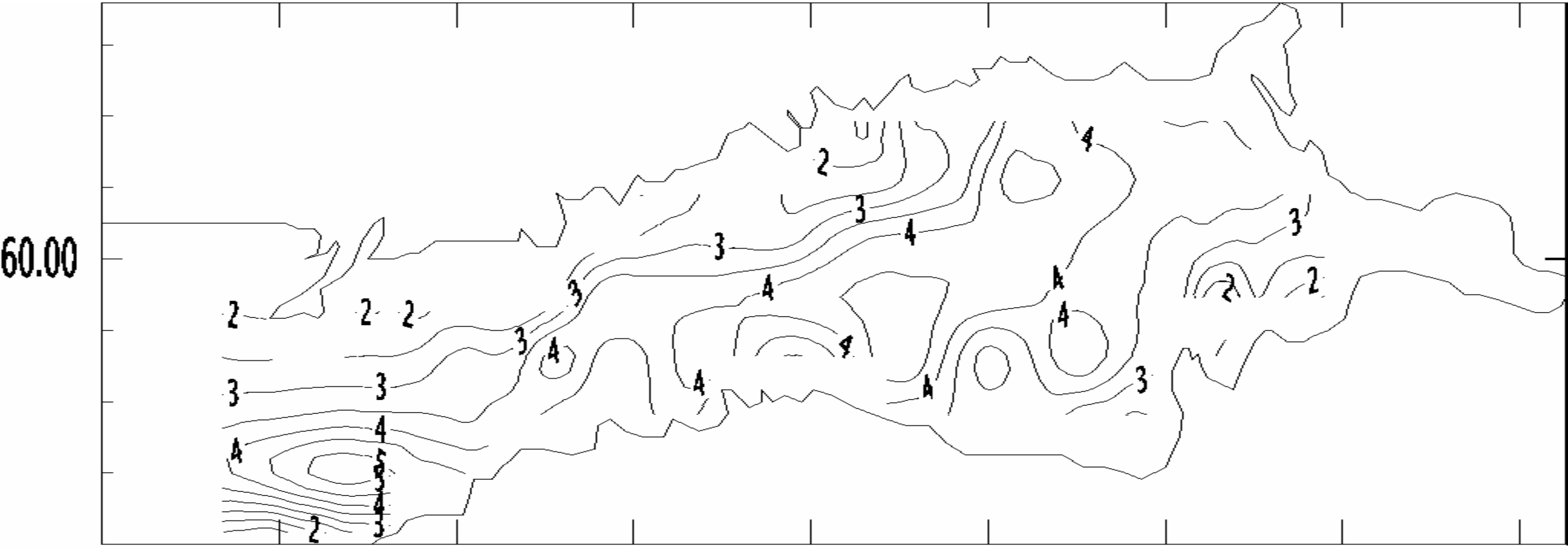
Conveyor belt: does it exist? Is it stable?



Elken et al. 2006,
Elken and Matthäus 2007

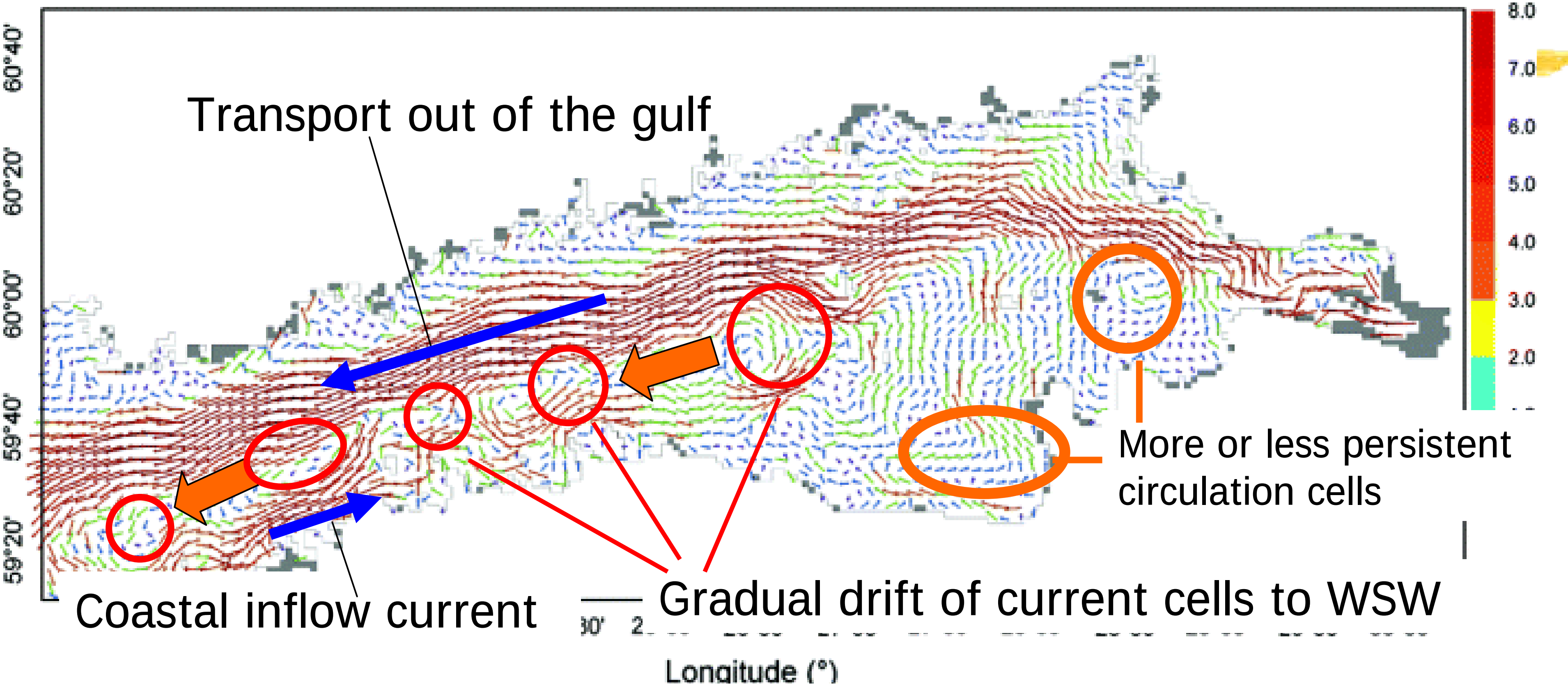
Rossby radius – “measure” of size of structures in the water body

✓Affects (the size of) mesoscale features → transport properties, water age pattern etc. etc.



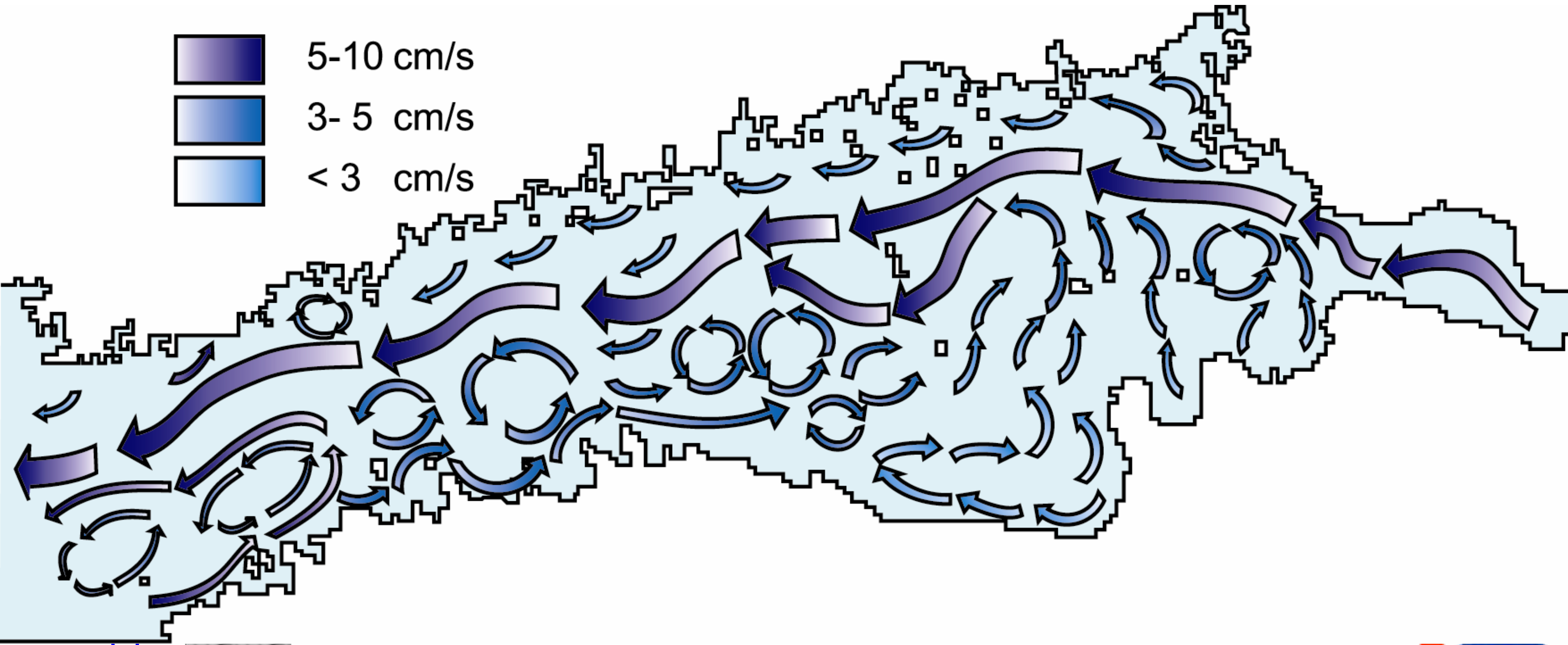
Average baroclinic Rossby radius in the Gulf of Finland based on nearly 2000 CTD-cast in 1990’s (Alenius,Myrberg, Nekrasov, 2003).

Patterns: clear structure in the subsurface layer (average 1987-1992)



The simulated mean circulation in the subsurface layer between 2.5 and 7.5 m from 31 August 1987 to 31 August 31 1992. OLEG ANDREJEV, KAI MYRBERG & PETER A. LUNDBERG.
Age and renewal time of water masses in a semi-enclosed basin application to the Gulf of Finland. - *Tellus A* **56** (5), 548-558, 2004.

Climate change: does it involve change of current patterns?
(just because of change of the Rossby radius?)



... Or the water age (~measure of water quality, pollution level etc.)

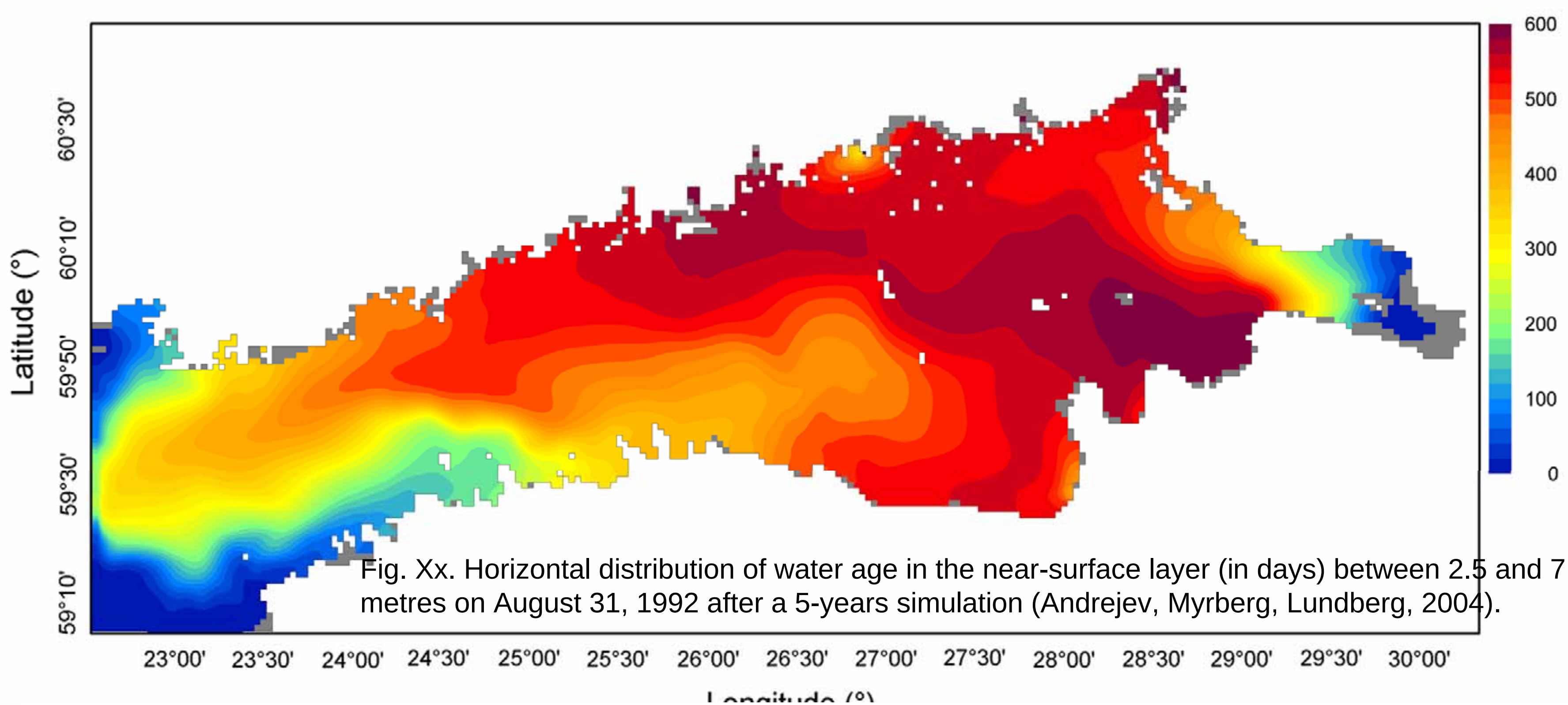


Fig. Xx. Horizontal distribution of water age in the near-surface layer (in days) between 2.5 and 7.5 metres on August 31, 1992 after a 5-years simulation (Andrejev, Myrberg, Lundberg, 2004).

The oldest bottom water -- about 8.3 years

Water renewal time – 5 years (river discharge only: 10 years)

Part II

Forcing factors and reaction of sea surface

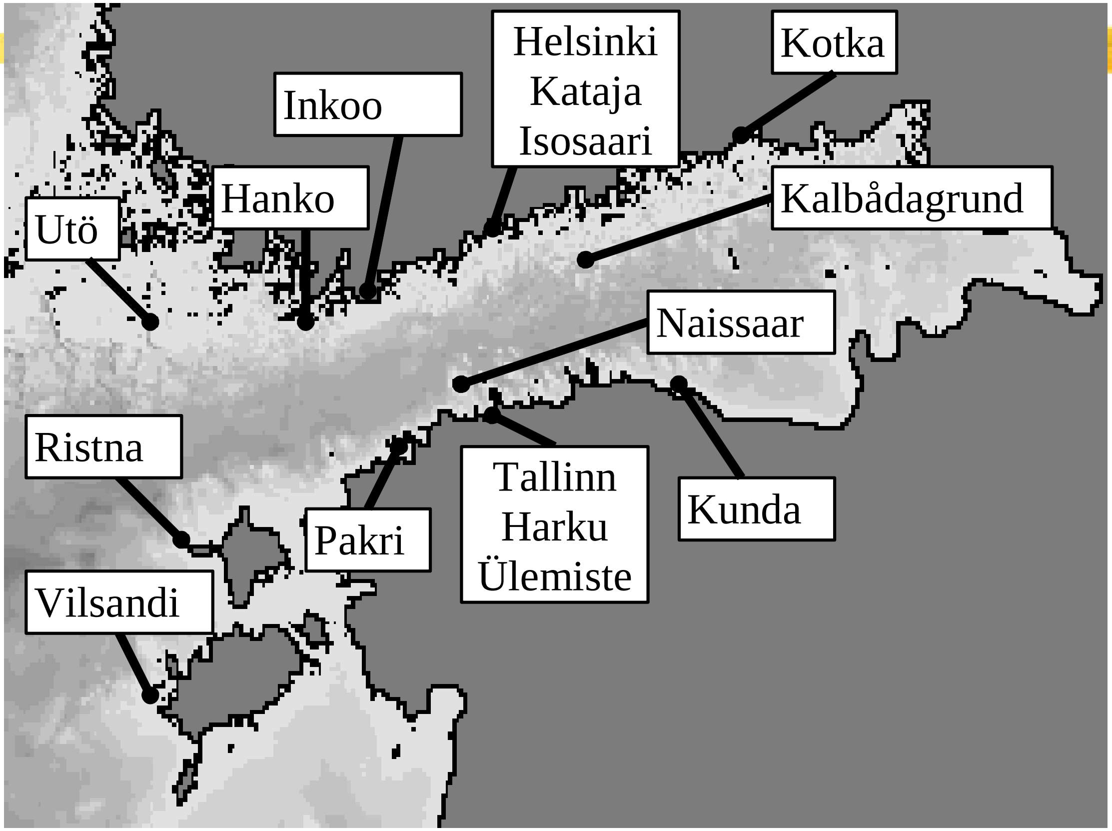
Wind structure

Surface waves

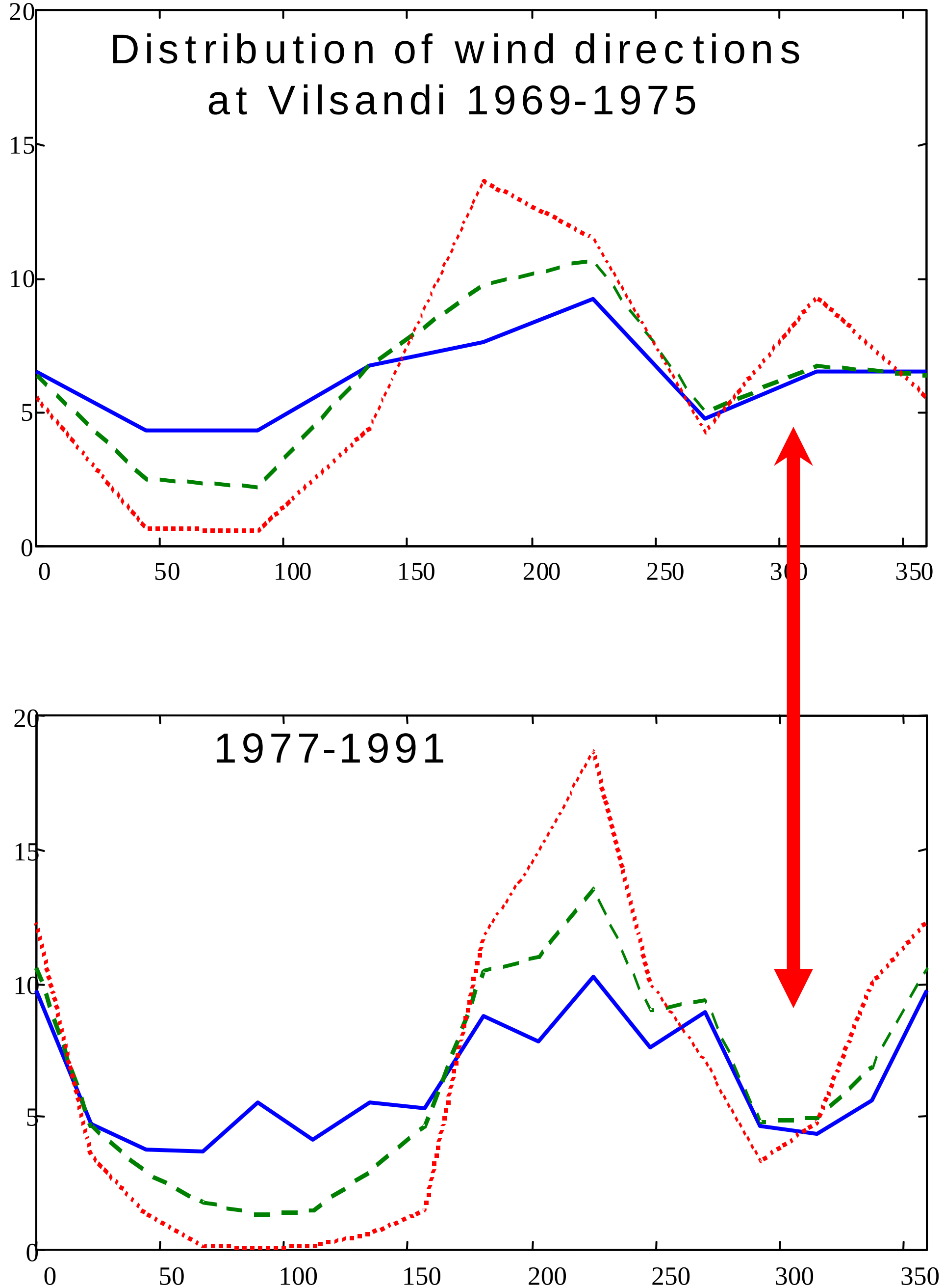
Water level

Sea ice

Wind data: from NE Baltic Sea

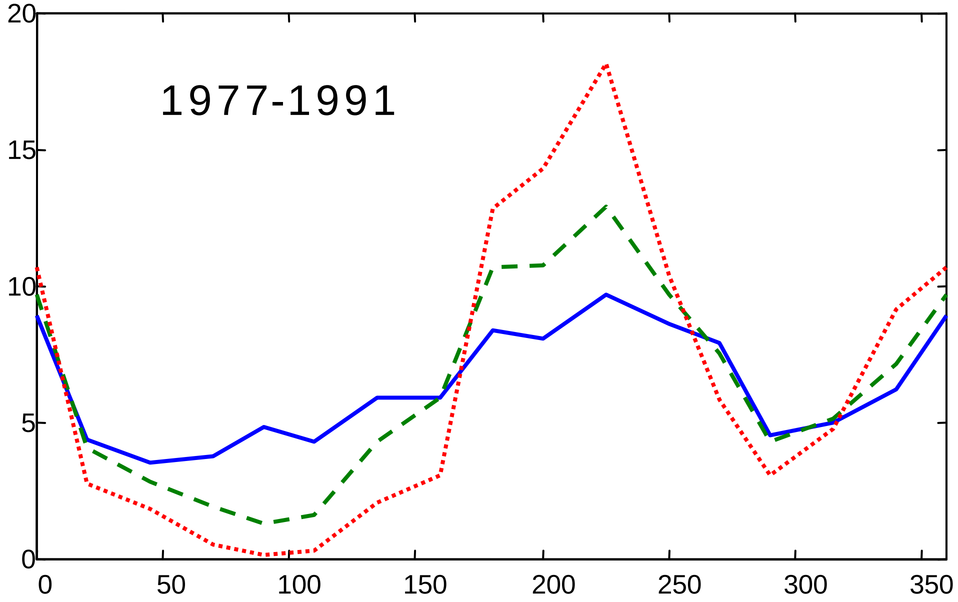


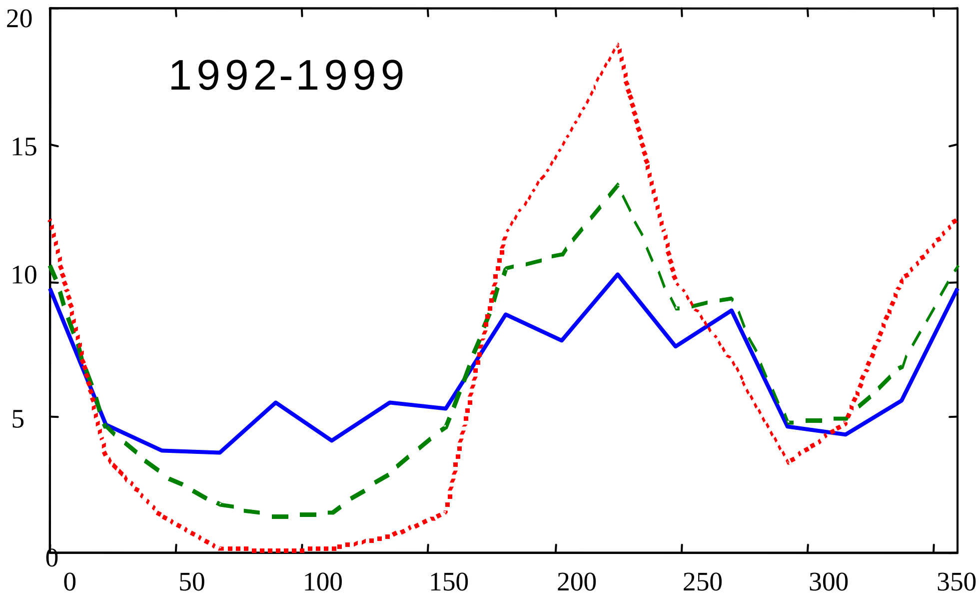
Wind rose: changes shape



Vilsandi,

Once each 3 hours





No changes in the 1980s and the 1990s

Response I: upwelling patterns strongly wind-structure-dependent

UPWELLING INDEX, %

GULF OF FINLAND

Upwelling & description of vertical mixing: still a challenge for circulation models

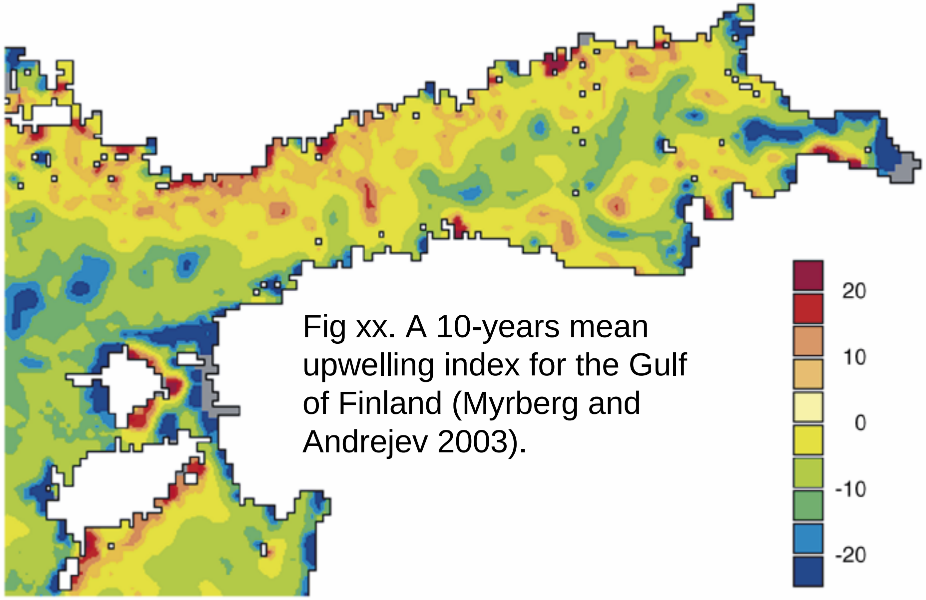


Fig xx. A 10-years mean upwelling index for the Gulf of Finland (Myrberg and Andrejev 2003).

Response II: coastal processes

Pirita Beach near Tallinn: usually a nice beach

After a storm from a “wrong” direction

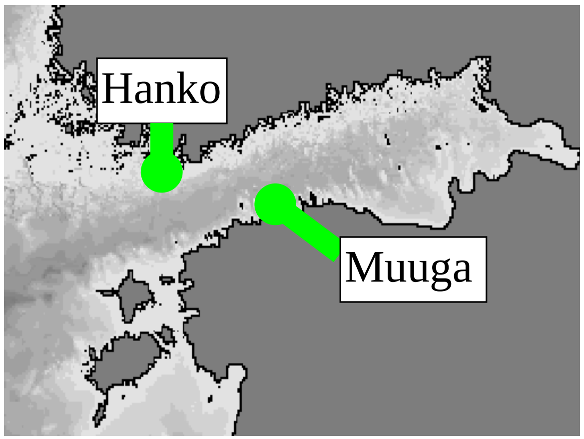
Photo: Kaarel Orviku

Photo: Kaarel Orviku

… While storms from "correct" direction cause "reasonable" damage

Photo I.Kask

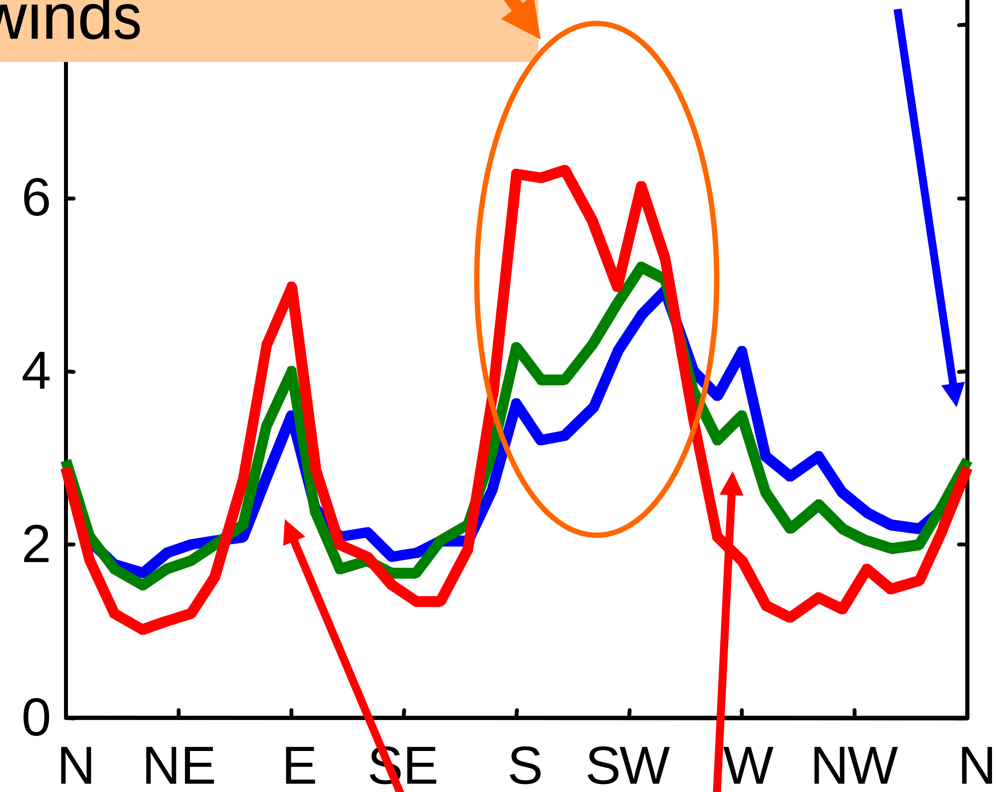
Possible background: strongest winds come from unexpected directions



Also in the Baltic Proper

Dominating south and southwest winds

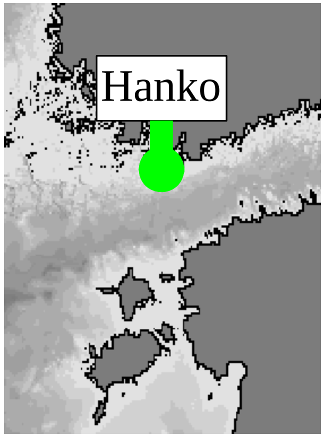
North winds: also present

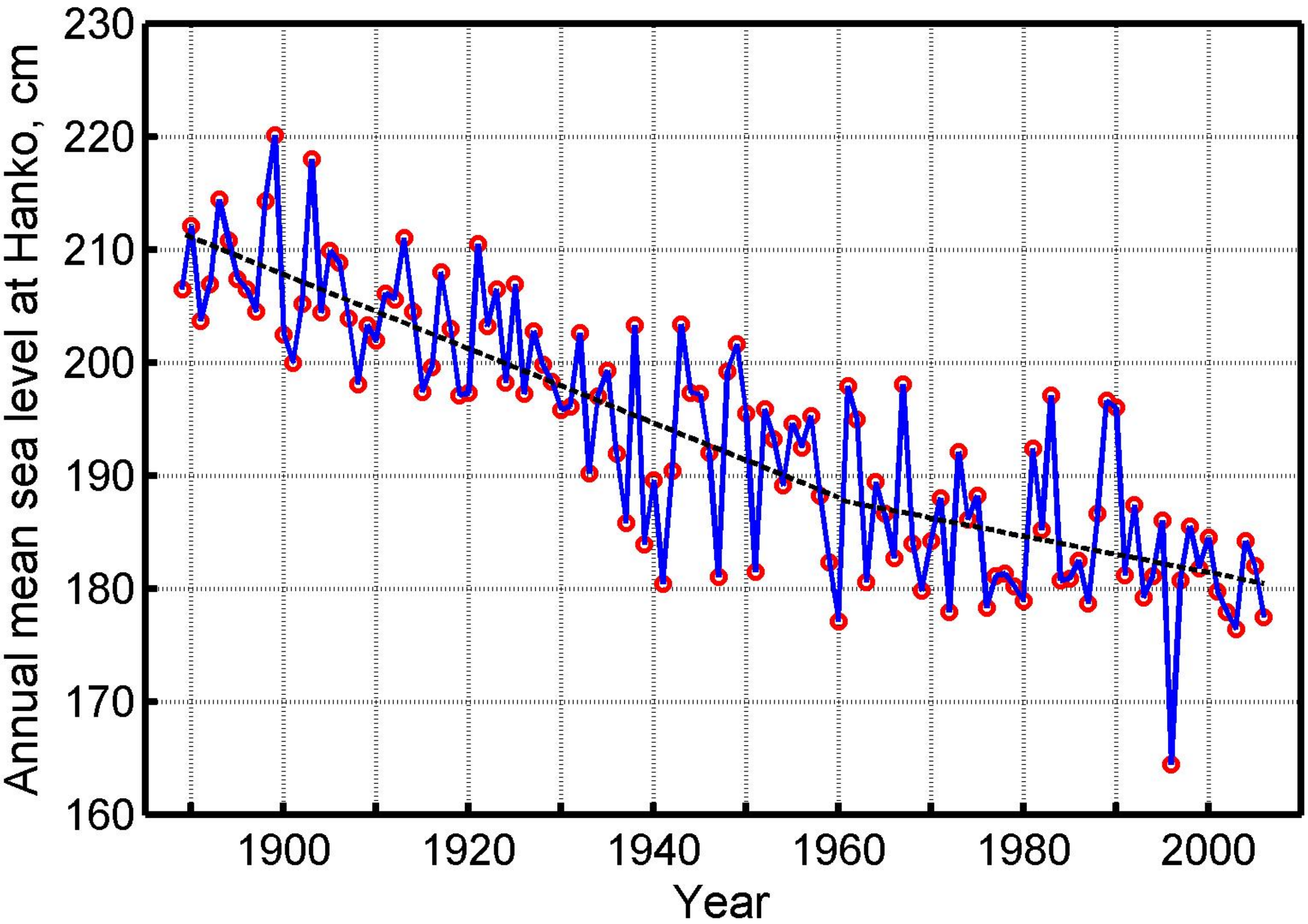


Blue: all winds
Green: winds >5 m/s
Red: winds >10 m/s

West and east winds blowing along the gulf axis (specific to the Gulf of Finland)

Sea level at Hanko: change of uplift rate?

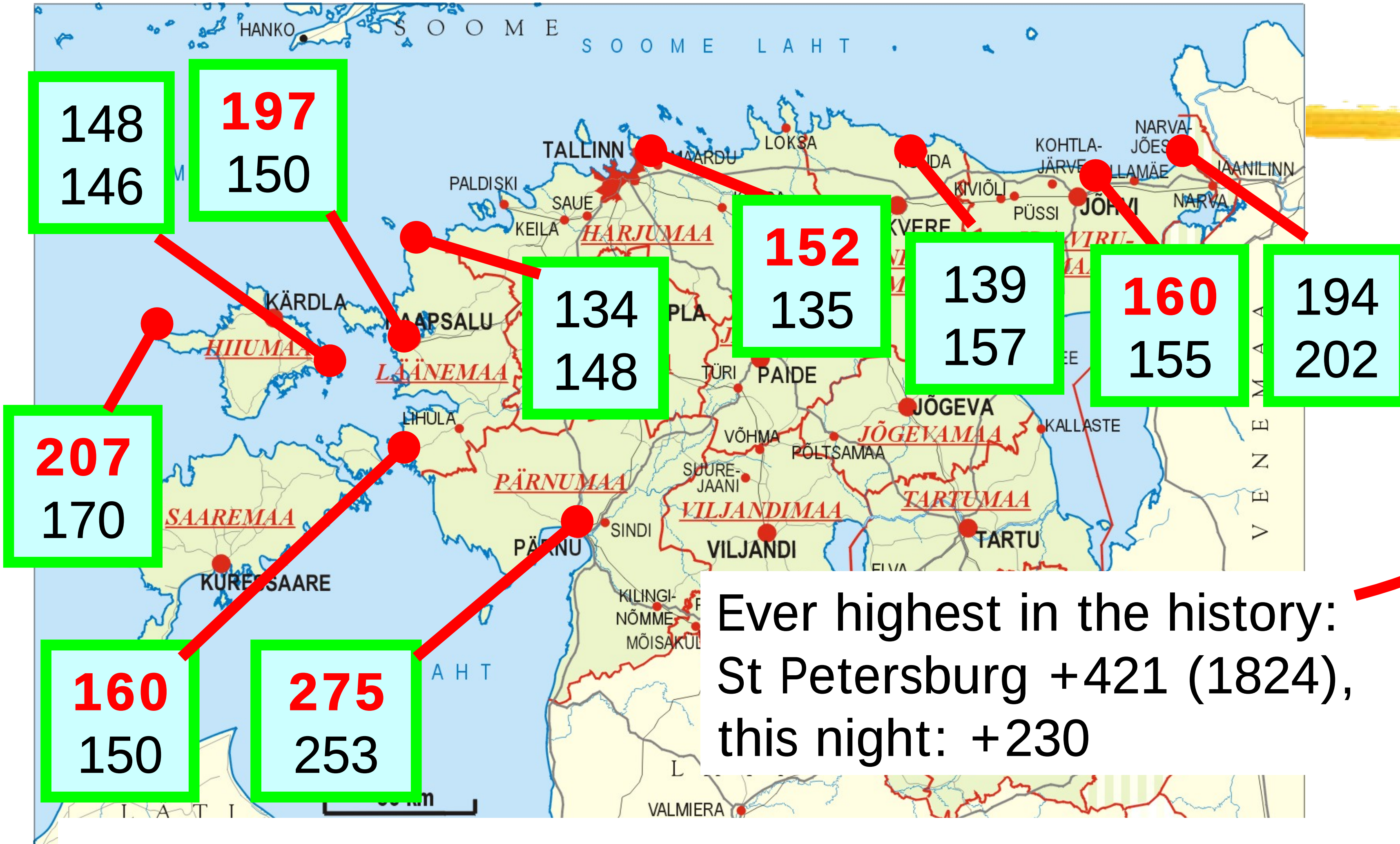




Data: Finnish Institute of Marine Research

Turku (**130** cm) Helsinki (**151** cm) Hamina (**197** cm)

Hanko (**132**)

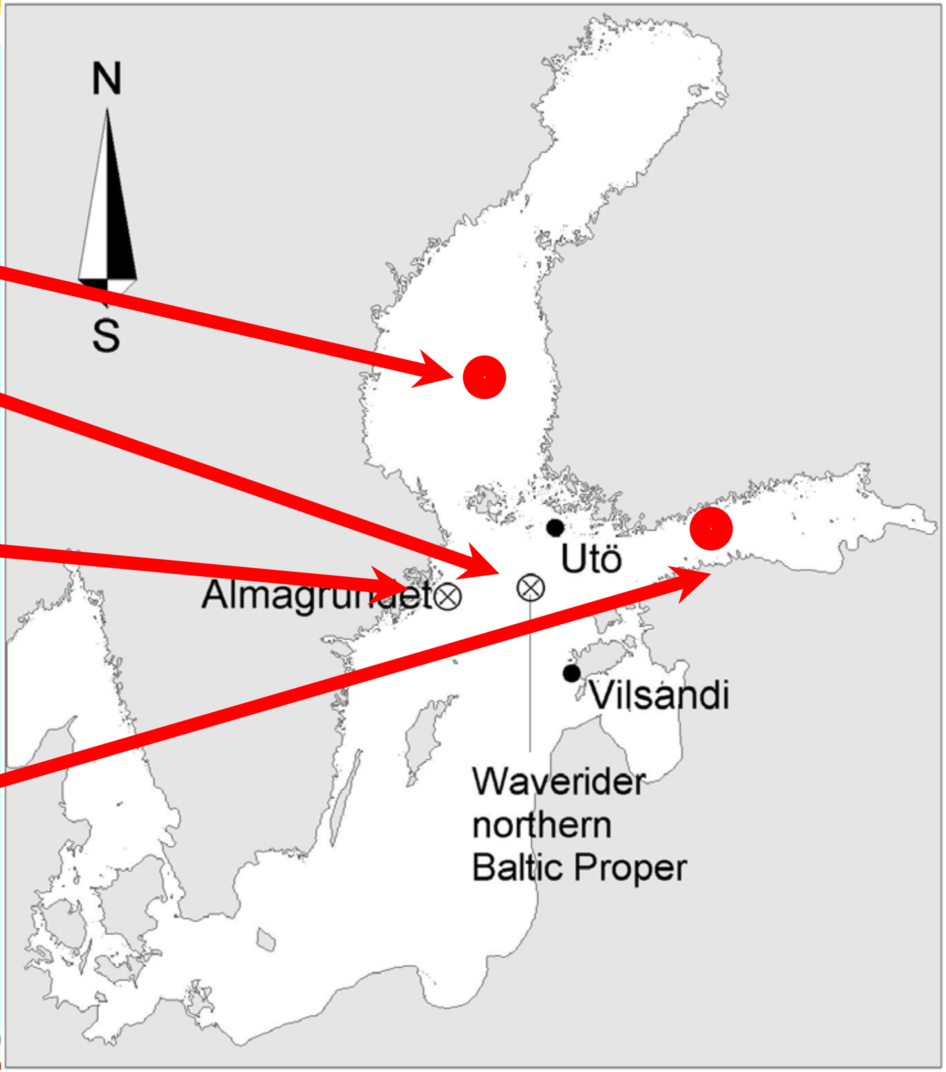


Sea level: unexpected maxima (red: new maxima in January 2005)

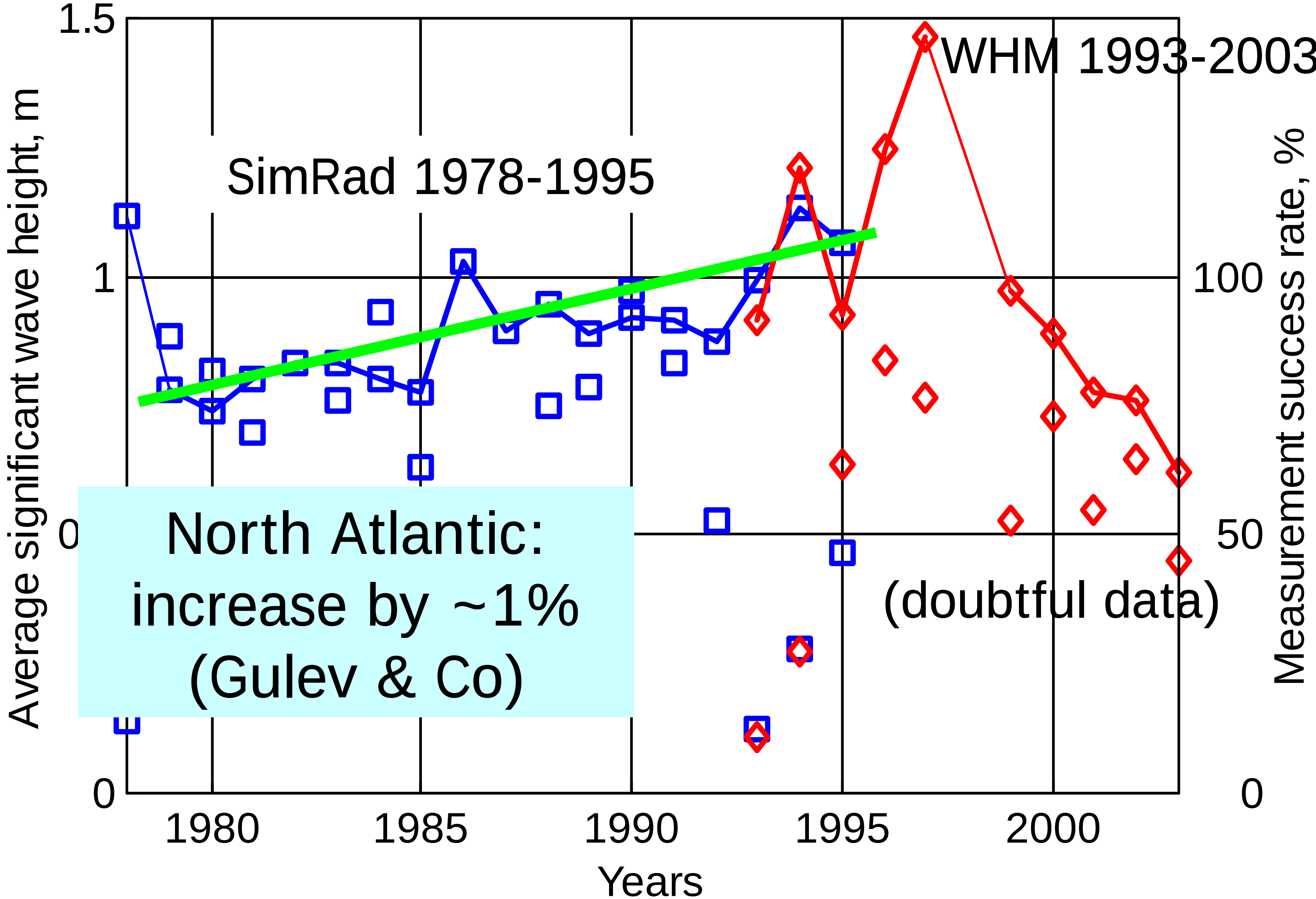
Long-term wave statistics in the northern part of the Baltic Sea

At a few locations

- Bothnian sea:
- Open sea: 1996→ (Kahma et al. 2003)
- Almagrundet 1978-2003 (Broman et al. 2006)
- Gulf of Finland 1991→ ice-free time (Pettersson 2001 & 2004)

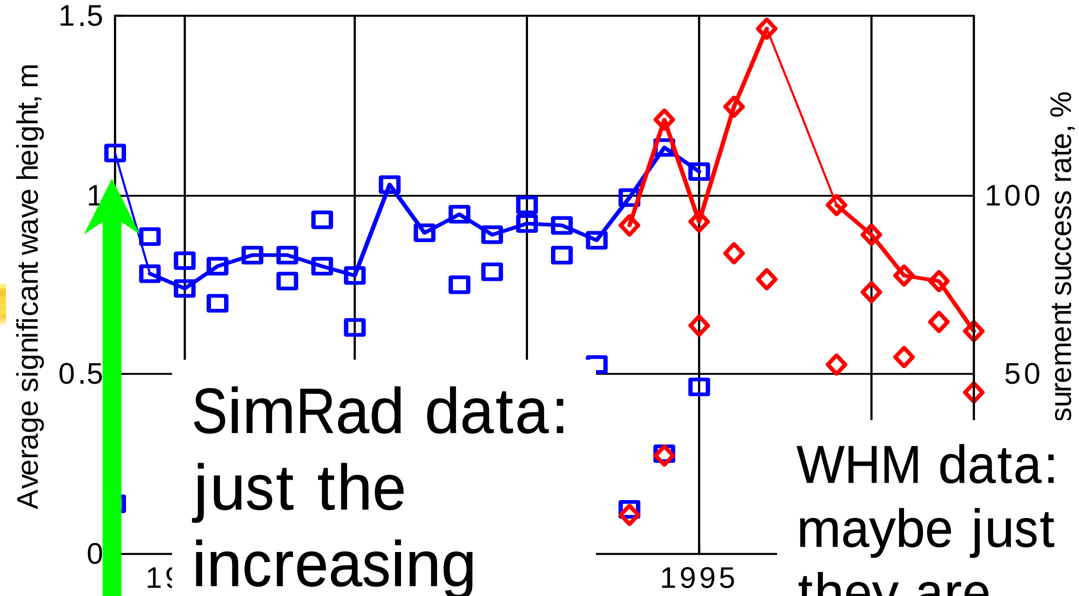


Long term trend: wave heights seem to increase by 1.8%/year (Almagrundet)



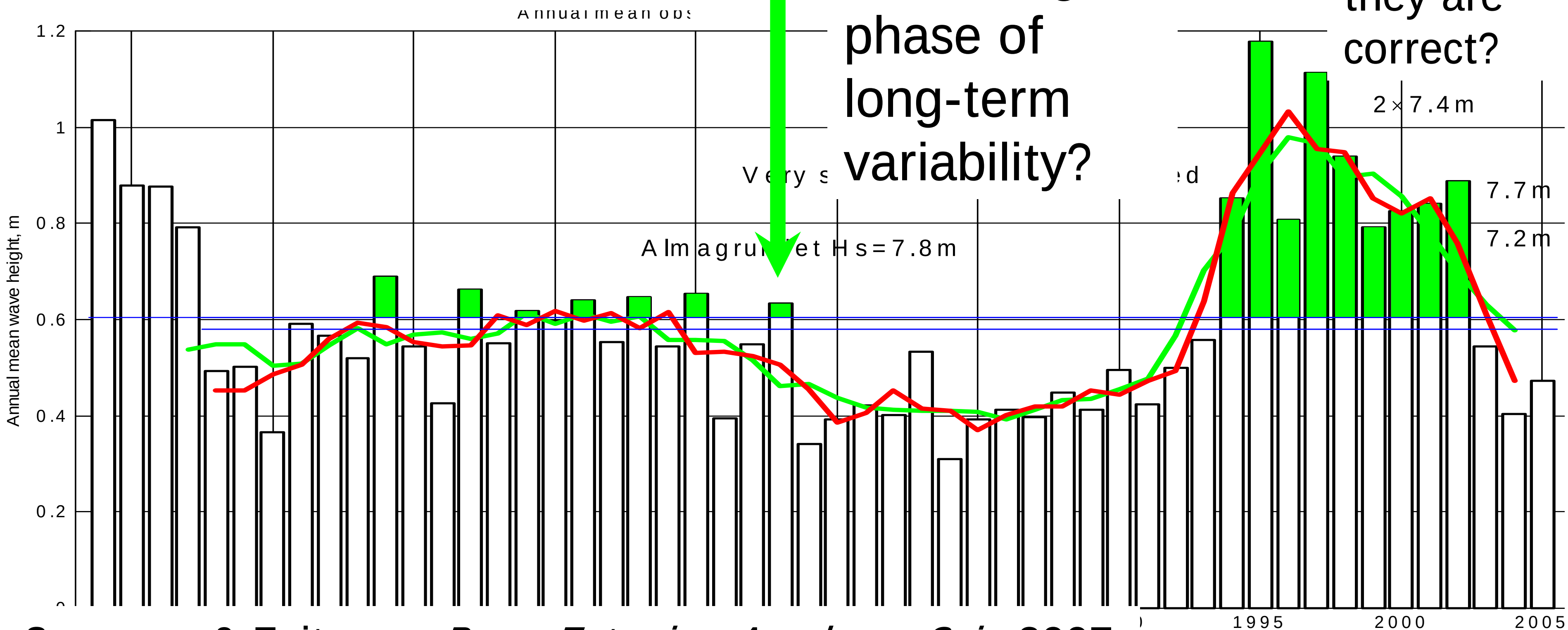
North Atlantic: increase by ~1% (Gulev & Co)

Long-term variation of annual mean wave heights: Two Almagrundet data sets fit perfectly



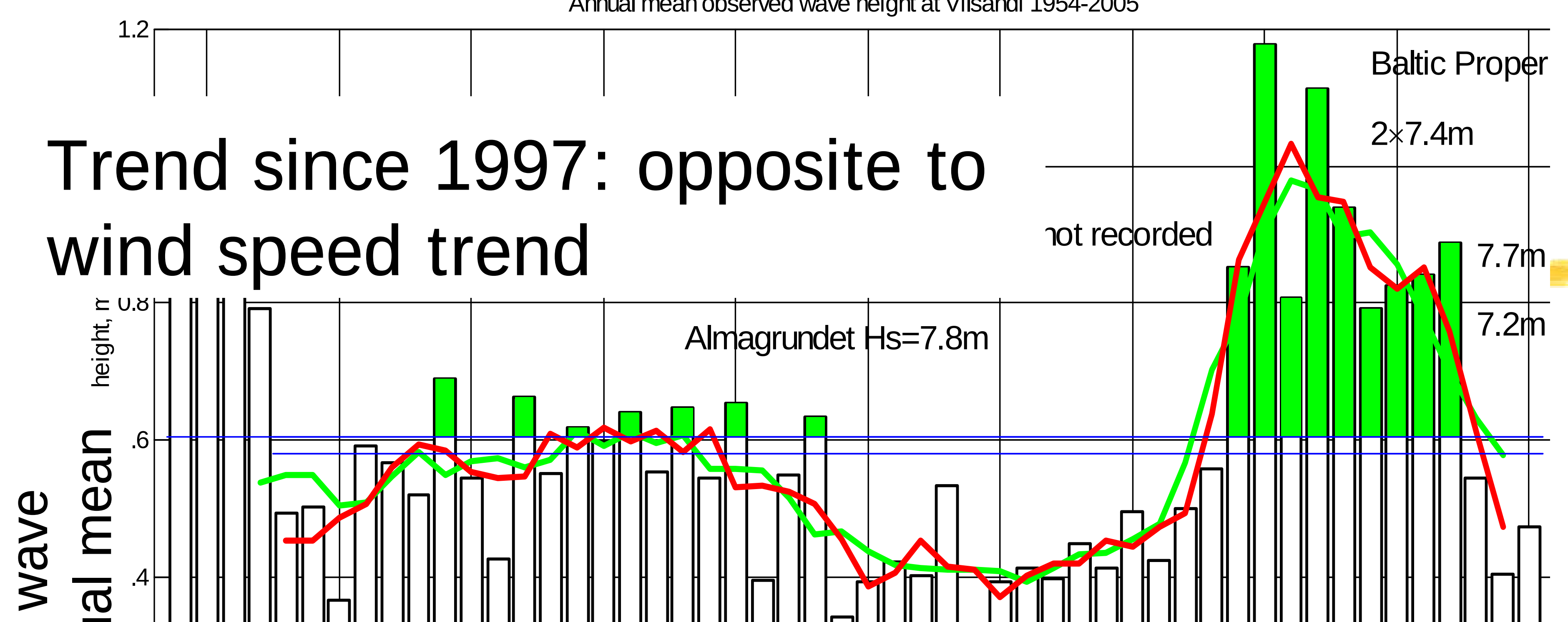
SimRad data: just the increasing phase of long-term variability?

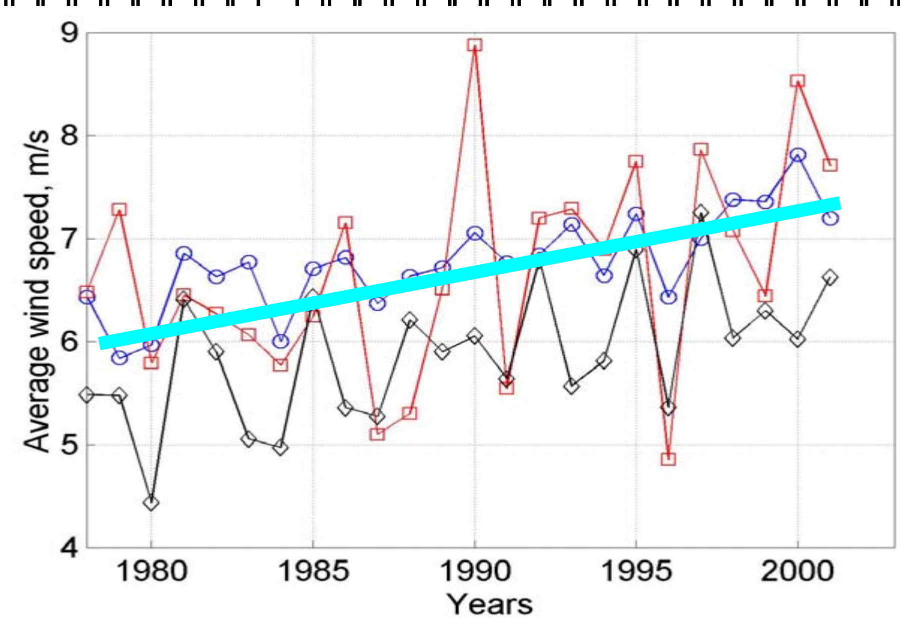
WHM data: maybe just they are correct?



Soomere & Zaitseva, *Proc. Estonian Academy Sci.* 2007

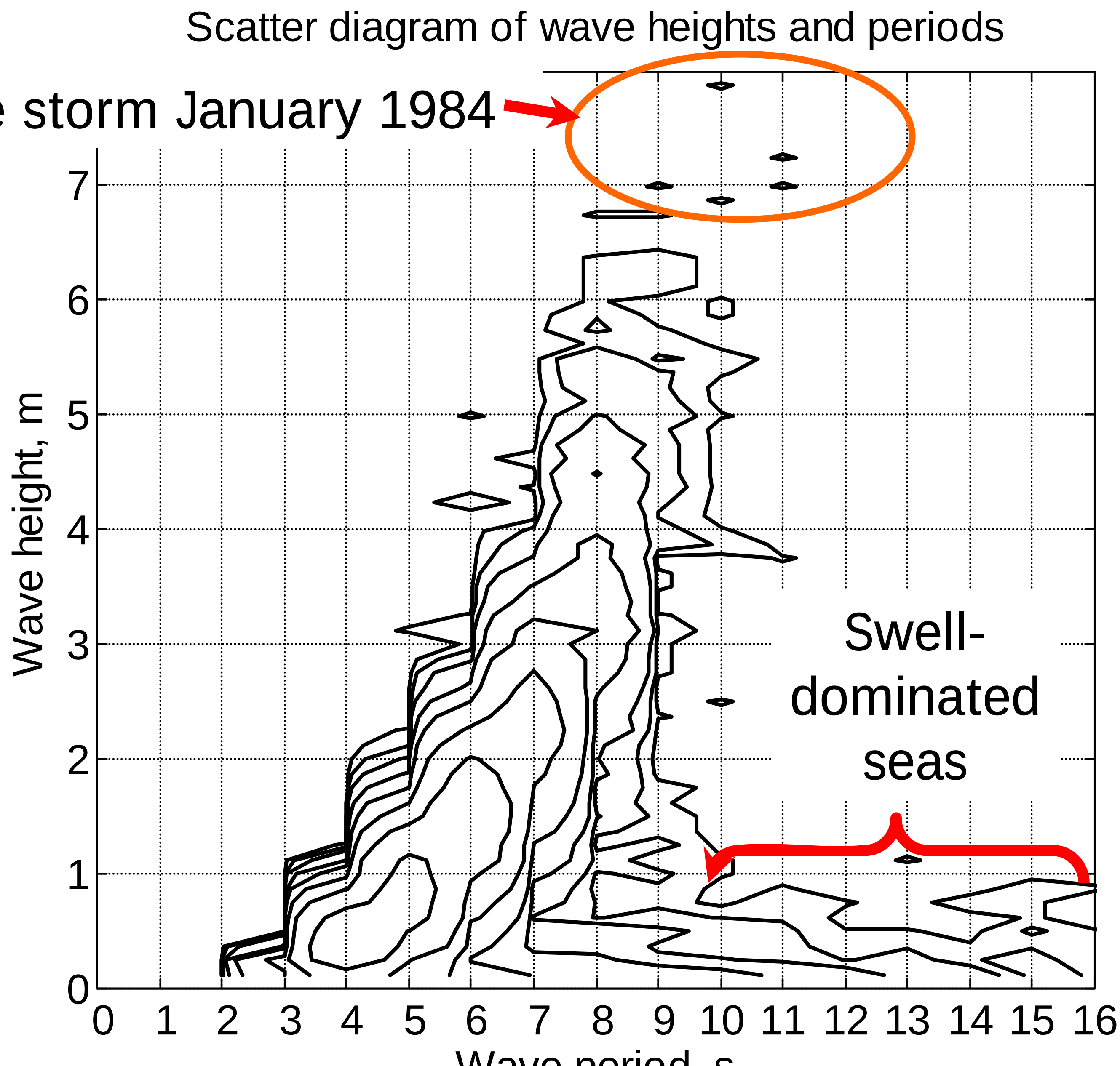
Trend since 1997: opposite to wind speed trend





Wave heights and periods: reasonable

Isolines for 1, 3, 10, 33, 100, 330, 1000 and 3300 cases, 1978-1995



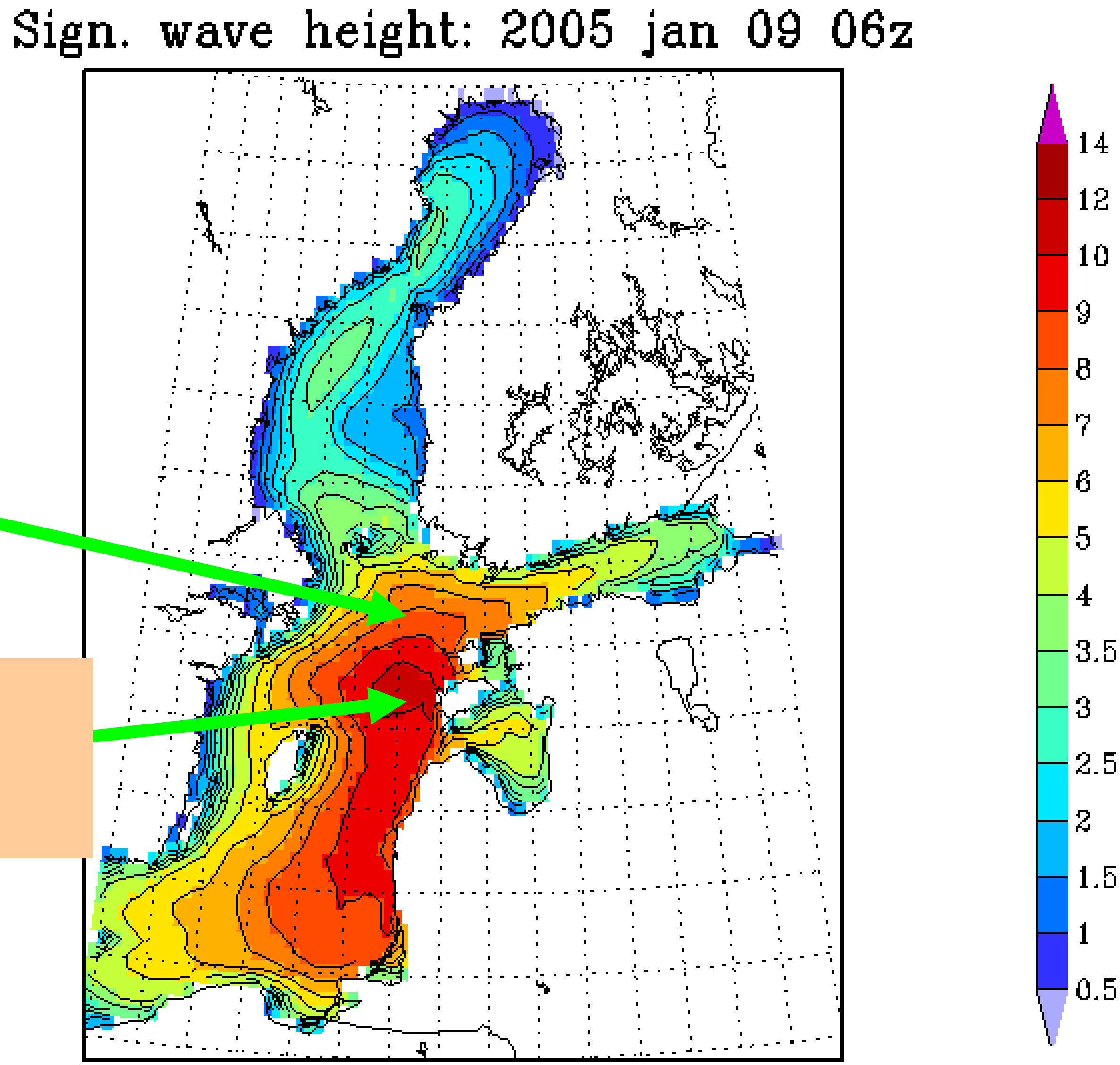
Broman et al. (2006) *Oceanologia* 48 (S)

Unexpectedly high: 09 Jan 2005

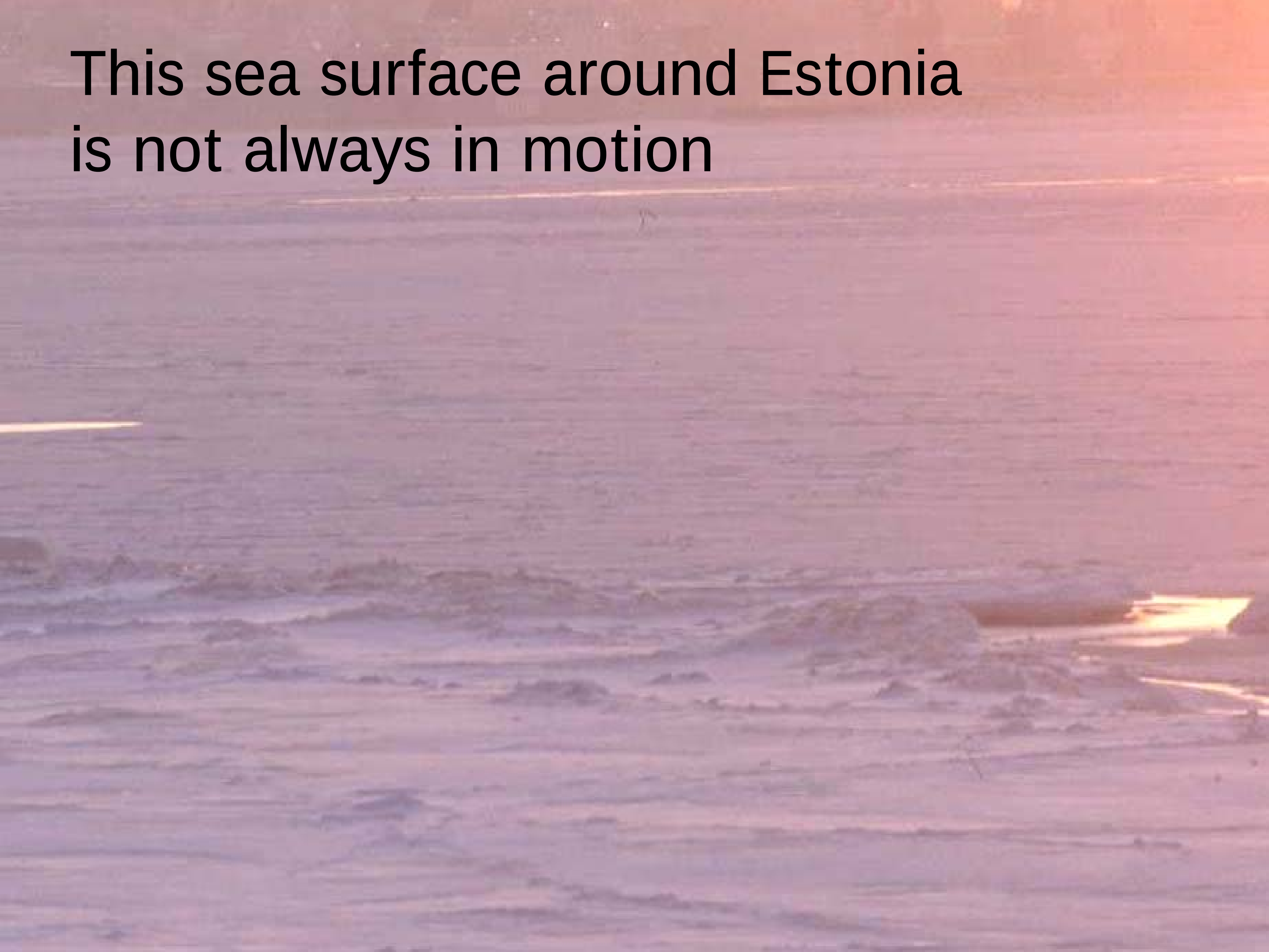
Measured 7.2 m; model 8.5 m

Model >11m;

Factual Hs ~9.5m



This sea surface around Estonia is not always in motion

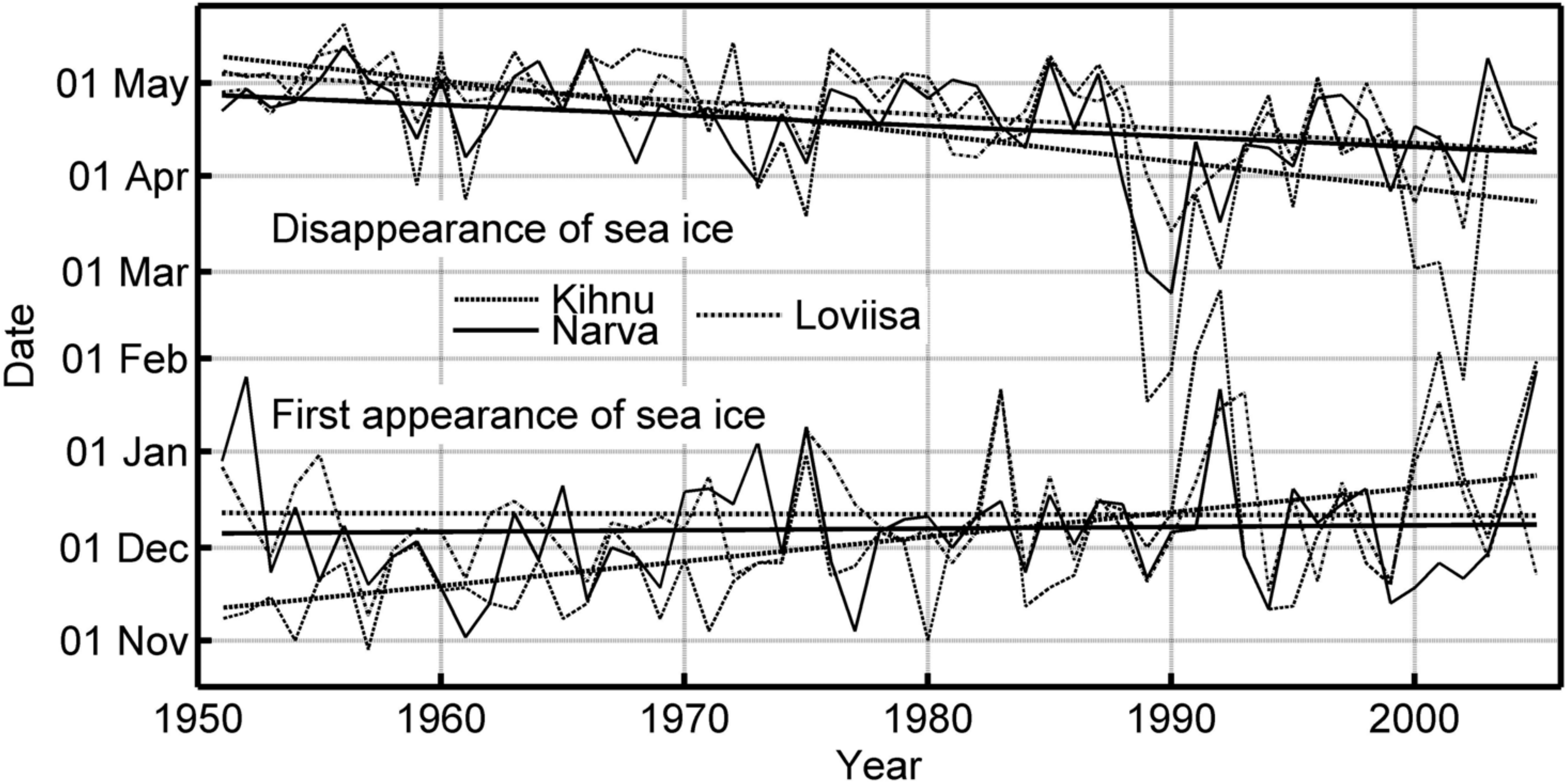


Ice climatology (Svetlana Jevrejeva, Matti Leppäranta)

- large east – west variability: one month in both freezing date and break-up date in the Gulf of Finland alone
- ice break-up has become earlier by 10 days/100 years (Utö)
- probability of freezing decreasing 20% units per 100 years

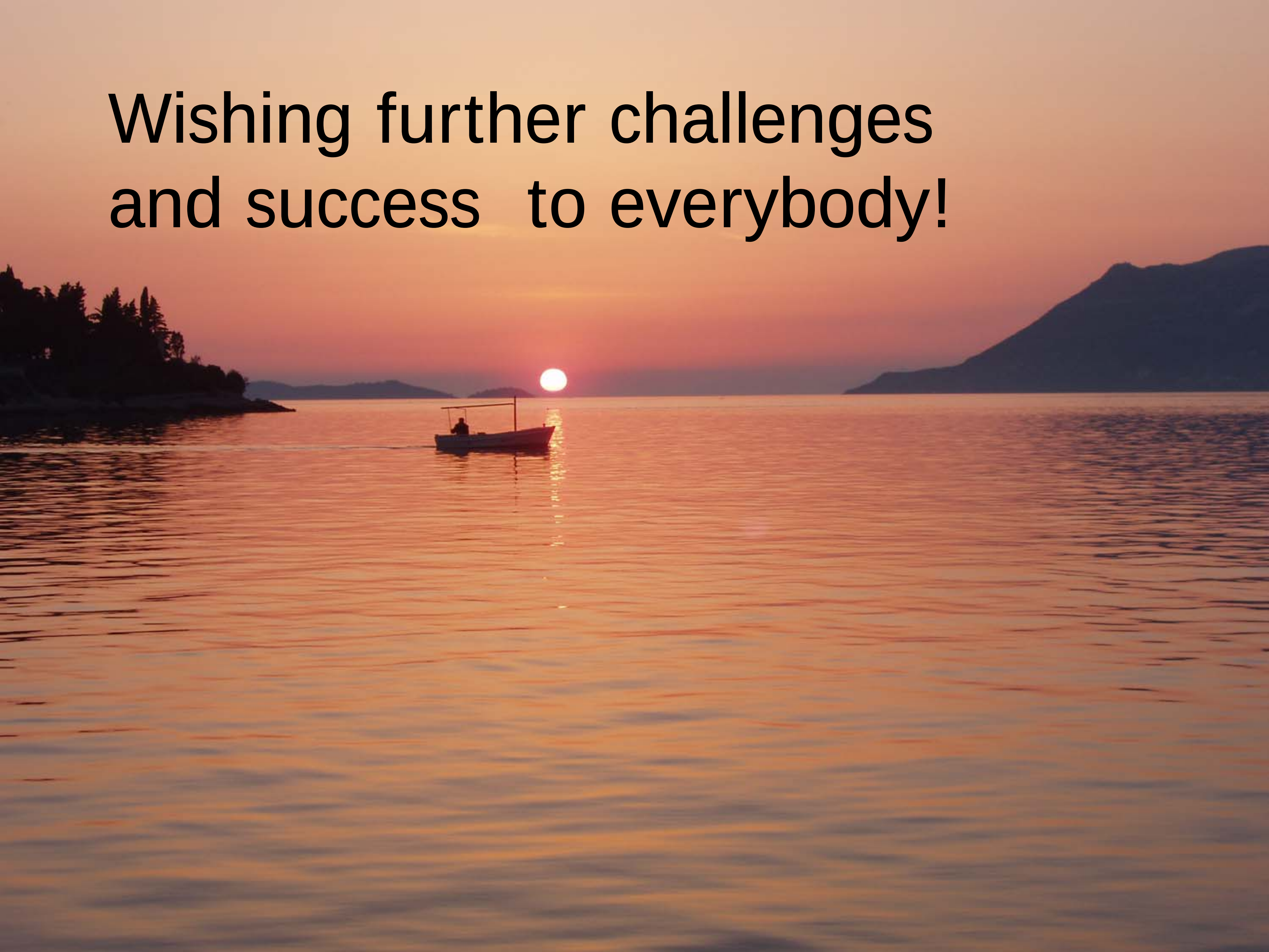
Change in ice conditions: drastic

Sooäär and Jaagus 2007



(some) lessons to learn

- extremes becoming more extreme
- the factual (extent of) response poorly understood
- trends of the average and of extreme values of certain properties are different!
- and even trends of the forcing factor and the response are different (wind // waves)


Wishing further challenges
and success to everybody!