



**TTÜ KÜBERNEETIKA INSTITUUT**  
Institute of Cybernetics at TUT



The  
University  
Of  
Sheffield.

# Seasonal and long-term variations of wave conditions in Estonian coastal waters

International Conference on  
**Complexity of Nonlinear Waves**

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**Tarmo Soomere**

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# Aim of the study

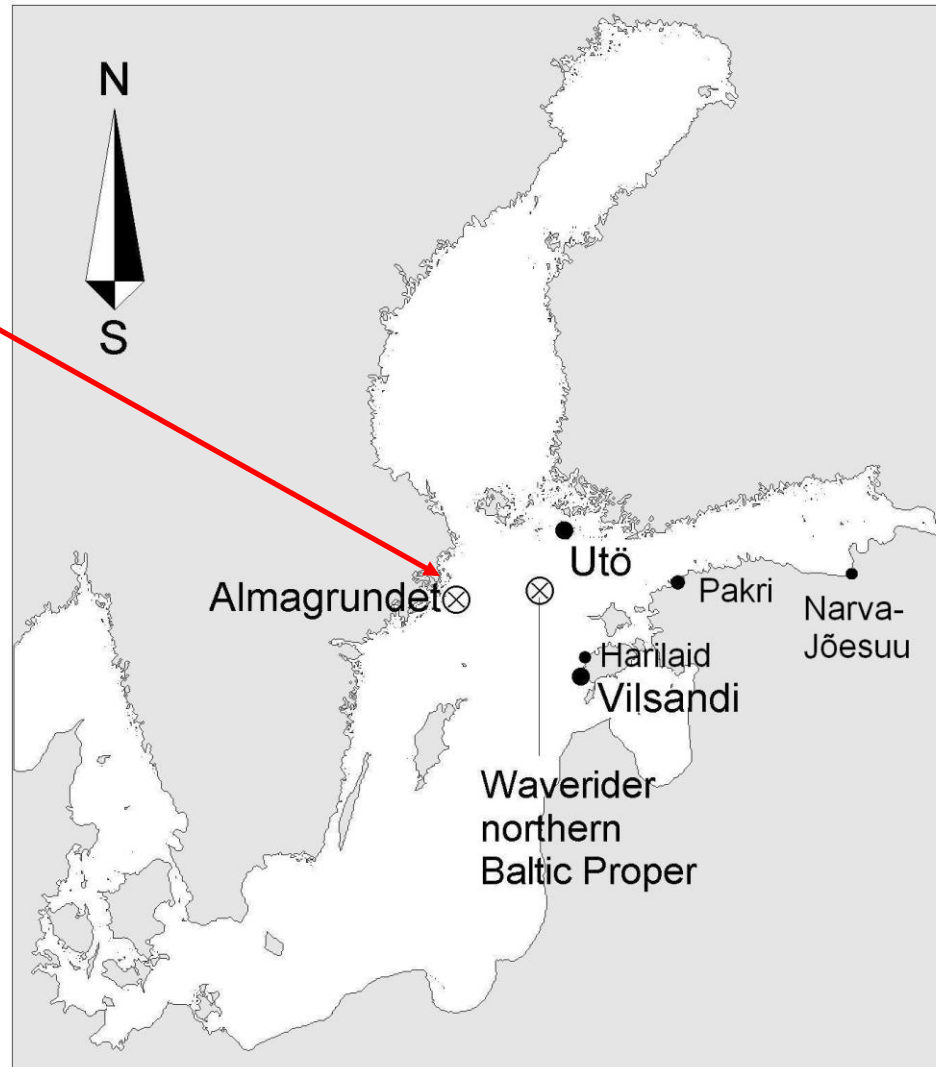
- Understanding of the status and changes of the wave climate
- Merge historical visual observations, instrumental measurements and modeled data
- to reveal the
  - seasonal,
  - interannual, and
  - long-term changesin the basic wave properties in the Northern Baltic Proper

# Wave measurements in the Baltic Sea

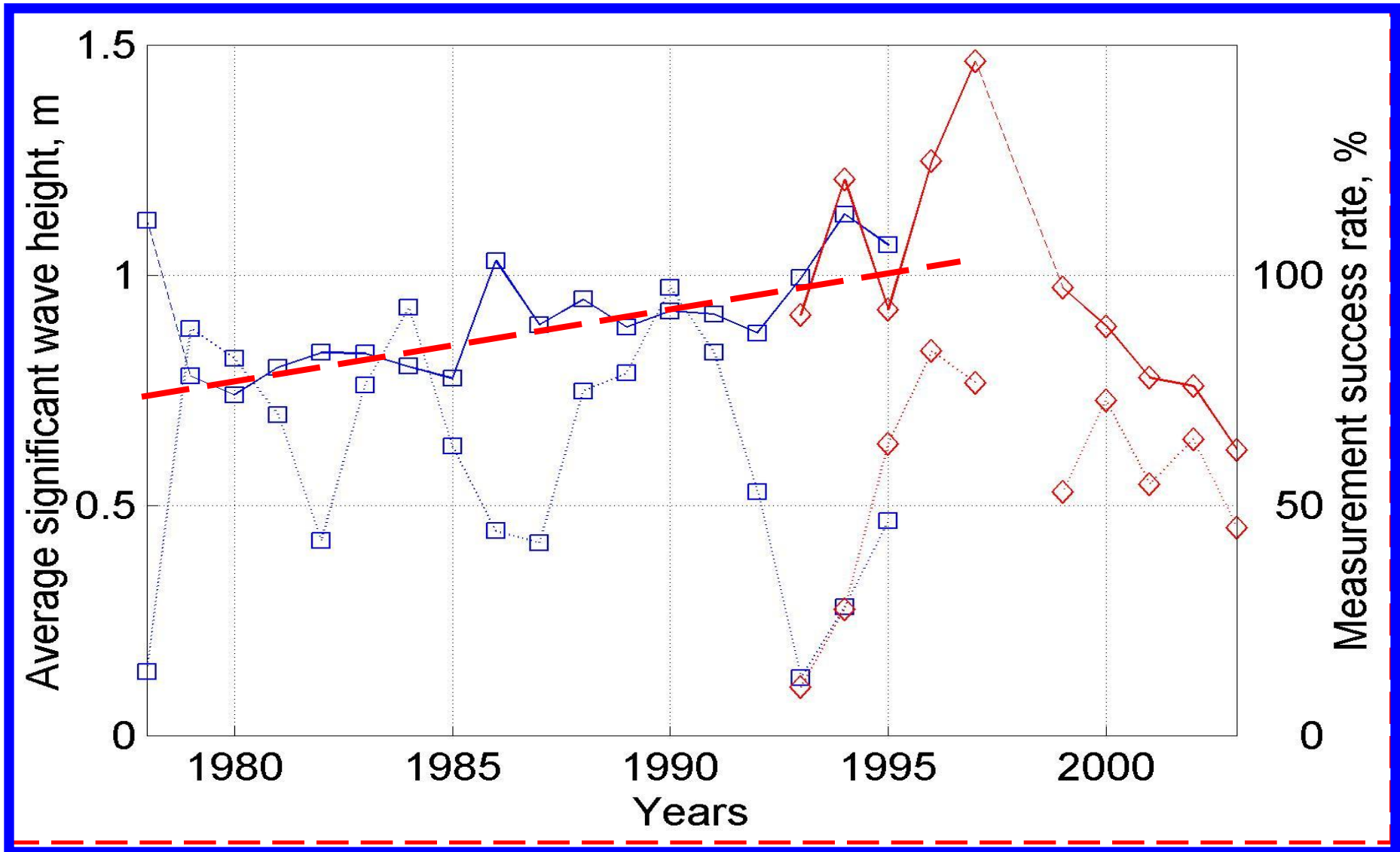
**Instrumental  
data set**

**1978–2003**

(Broman *et al.*, 2006)

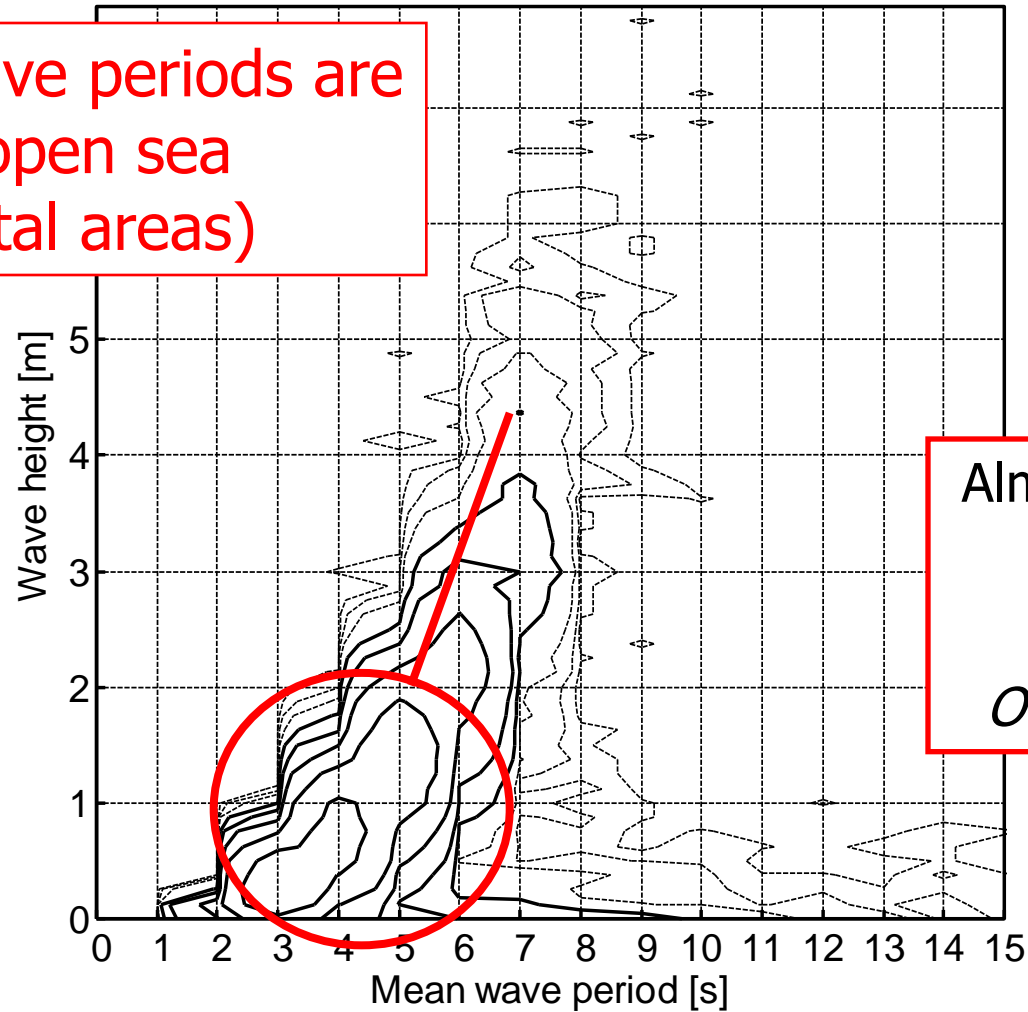


# Example of decadal variations



# Wave heights and periods

The typical wave periods are 3–6 s for the open sea (2–4 s in coastal areas)



Almagrundet: open sea

Broman et al.,  
*Oceanologia* 2006

# Wave measurement sites

Wind data set

1978–2001

Visual observations

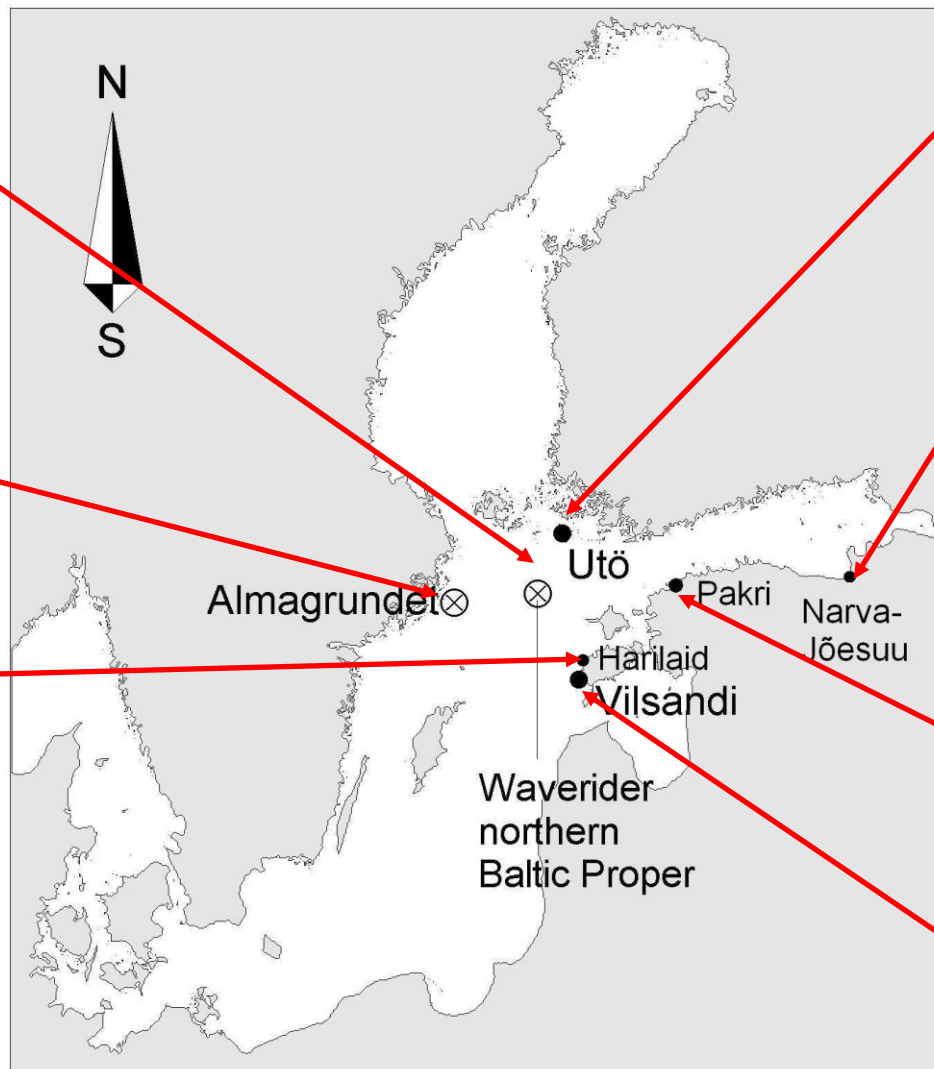
1954–2008

Visual observations

1954–1985

Visual observations

1954–2008



Data set  
1996–2002

(Kahma *et al.*, 2003)

Data set  
1978–2003

(Broman *et al.*, 2006)

SMB-model  
1966–2006

(Suursaar *et al.*,  
2008)

Ice Cover at  
Kihnu and  
Narva-Jõesuu

1950–2005

# Diary example

Day Time

Direction Max / mean wave Height

Станция *Глобул* № станции *594240* (3, 4, 5, 6, 7, 8) год *62* (9, 10) Месяц *04* (11, 12)

Число	Срок	Декада	Удельный вес р/л/о (‰)	Температура воды (°C)	Удельный вес р/л/о	Солёность ‰	Влажность в сторону морозов	Скорение	Количество льда	Волнение			Ветер					
										Форма	Направление	Сила	Средняя высота волн (м)	Длина волн (м)	Скорость (м/сек.)	Период (сек.)	Направление	Сила
1	03.00	1	—	—	—	VVVVV	7	V	36	V	—	—	—	—	—	—	—	—
	09.00	1	486	0.3	—	—	8	V	V	V	V	V	V	V	V	30	16	1.2
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	30.3	2.0	6
	21.00	1	480	0.5	—	—	—	V	V	V	V	V	V	V	V	30.3	2.0	7
2	03.00	1	—	—	—	—	8	V	V	V	V	V	V	V	V	30.3	1.8	4
	09.00	1	486	1.0	—	—	8	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	490	0.6	—	—	—	V	V	V	V	V	V	V	V	—	—	—
3	03.00	1	—	—	—	—	8	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	480	0.5	—	—	8	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	498	0.5	—	—	—	V	V	V	V	V	V	V	V	—	—	—
4	03.00	1	—	—	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	485	0.9	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	488	0.8	—	—	—	V	V	V	V	V	V	V	V	—	—	—
5	03.00	1	—	—	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	486	0.5	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	486	0.9	—	—	—	V	V	V	V	V	V	V	V	—	—	—
6	03.00	1	—	—	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	486	0.8	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	498	1.0	—	—	—	V	V	V	V	V	V	V	V	—	—	—
7	03.00	1	—	—	—	—	2.5	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	486	1.0	—	—	2.5	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	486	0.5	—	—	—	V	V	V	V	V	V	V	V	—	—	—
8	03.00	1	—	—	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	492	0.5	—	—	8	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	488	1.5	—	—	—	V	V	V	V	V	V	V	V	—	—	—
9	03.00	1	—	—	—	—	6	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	498	1.0	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	512	1.5	—	—	—	V	V	V	V	V	V	V	V	—	—	—
10	03.00	1	—	—	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	09.00	1	488	0.5	—	—	7	V	V	V	V	V	V	V	V	—	—	—
	15.00	1	—	—	—	—	—	V	V	V	V	V	V	V	V	—	—	—
	21.00	1	486	0.9	—	—	—	V	V	V	V	V	V	V	V	—	—	—
Среднее за декаду	03.00	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	09.00	1	487	0.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	15.00	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	21.00	1	491	0.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—



- \* Типы волнения:
- 1. Ветровое
  - 2. Зыбь
  - 3. Мертвая зыбь
  - 4. вв
  - 5. зыбь
  - 6. зыбь
  - 7. вв

# Time of observations

- 3 times a day (1-2 times in autumn & winter)
- 0700, 1300, 1900 Local Time ( UTC +2 hours)
- From the 1960s  
0900, 1500, 2100 Moscow Time ( UTC +3 hours)

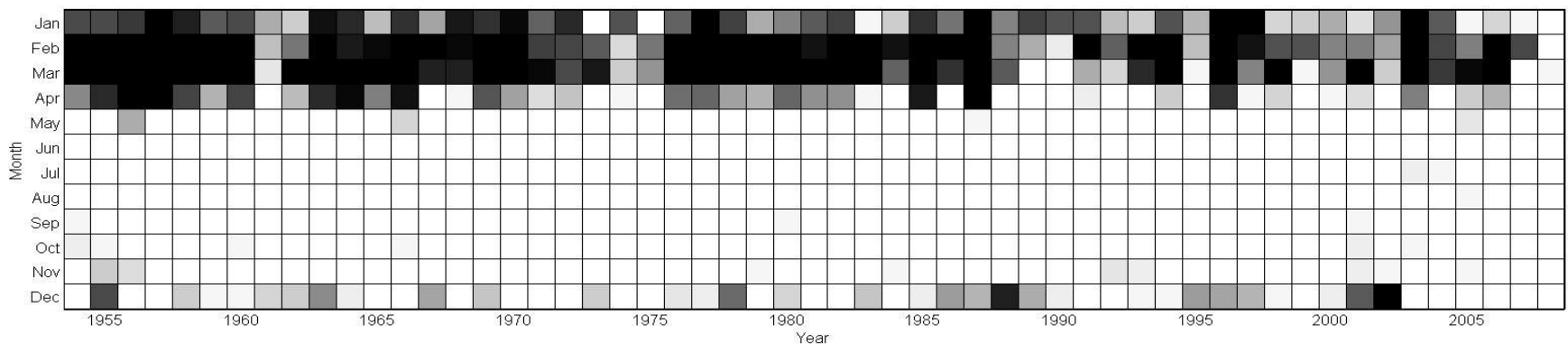
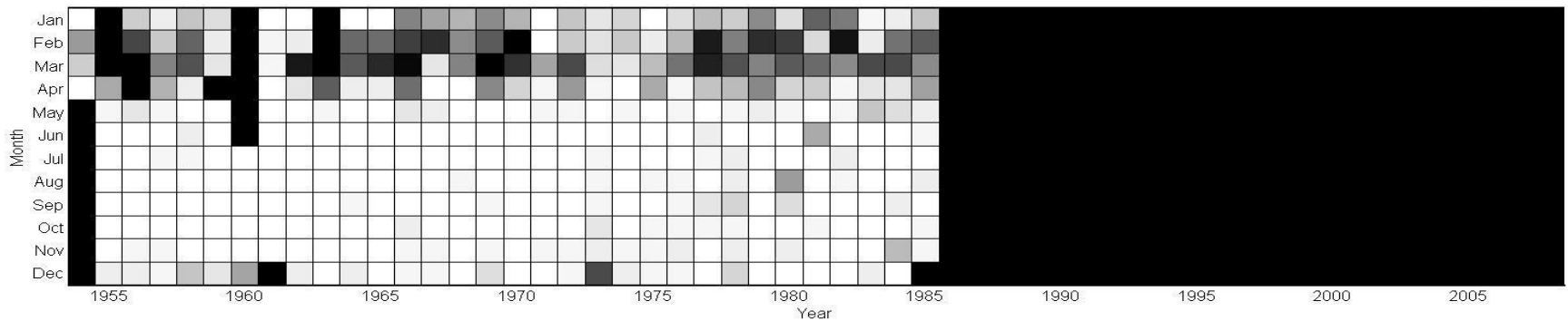
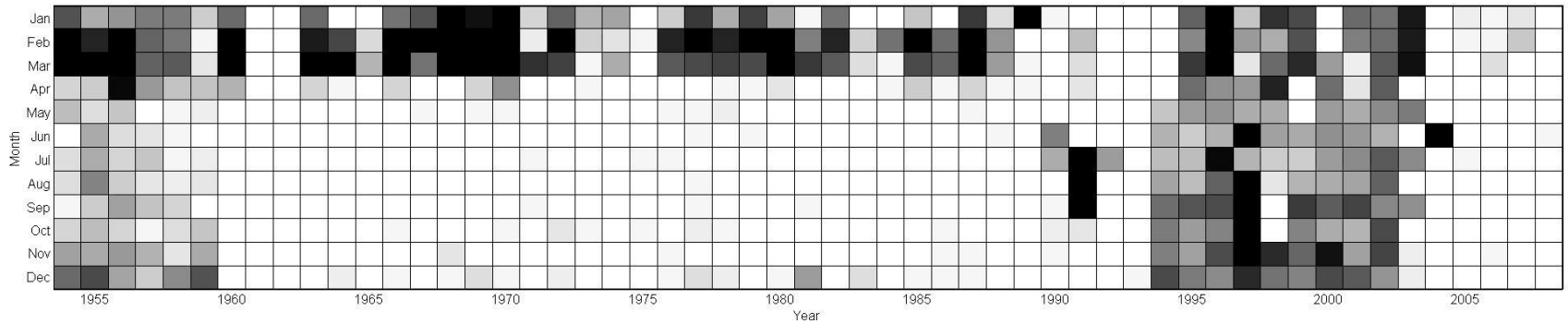
No problems with homogeneity



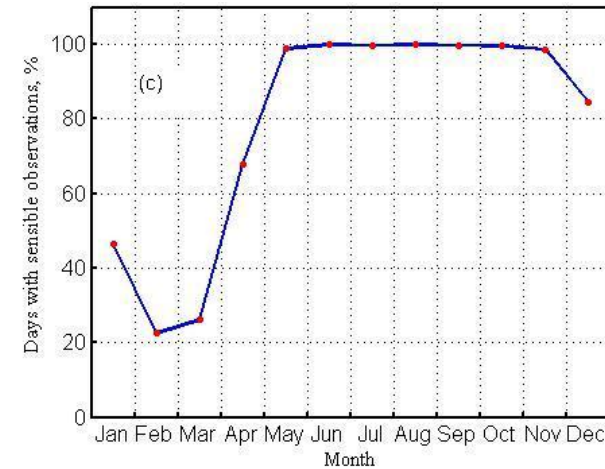
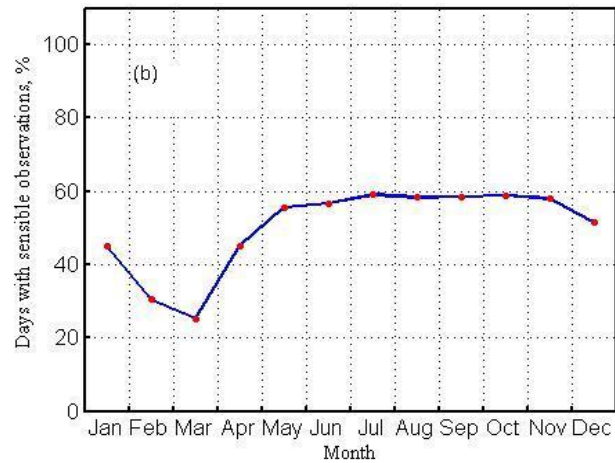
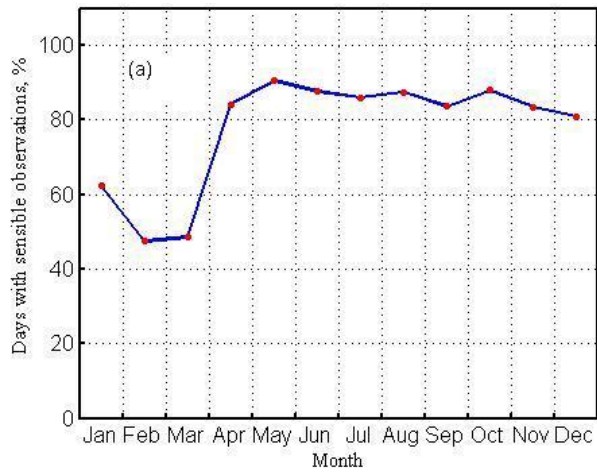
# Measured parameters

- the type of the sea state,
- the general appearance of the wave field,
- the wave direction
- the intensity of waves,
- the maximum wave height
- the mean wave height,
- wave steepness,
- length and
- mean period

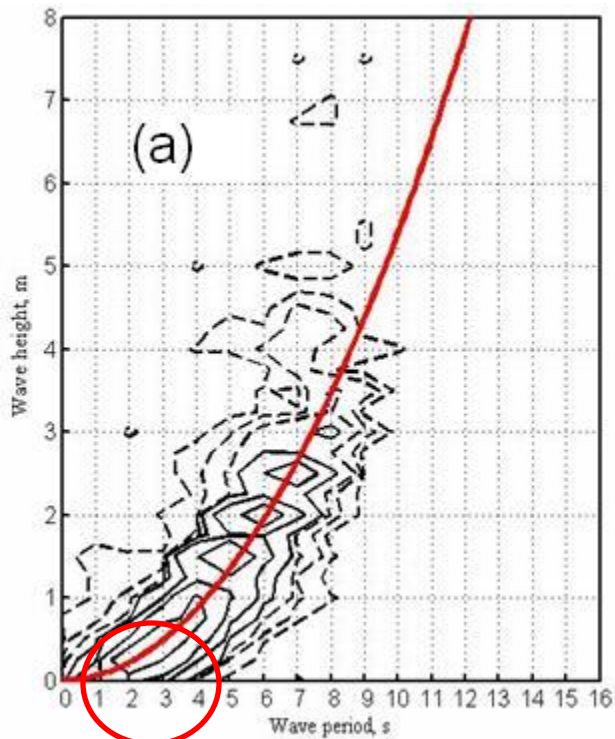
# Temporal distribution of days containing at least one sensible wave observation for Vilsandi, Pakri and Narva-Jõesuu .



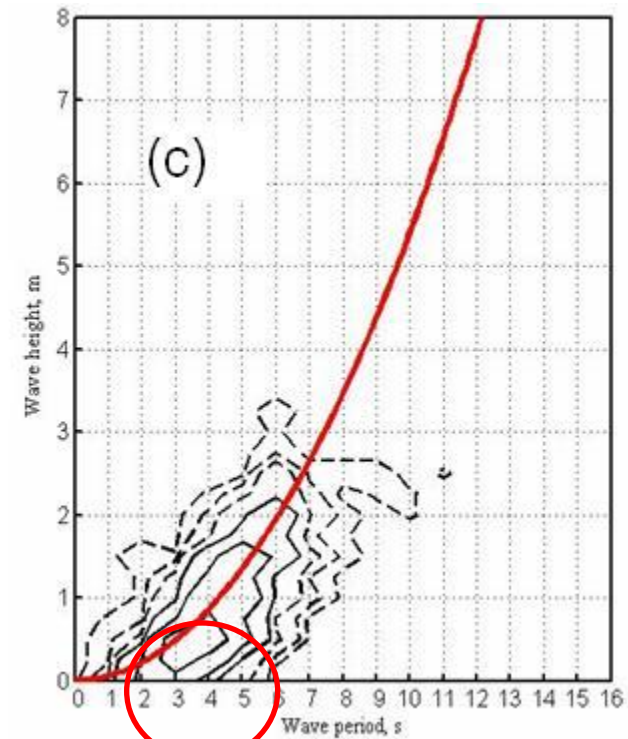
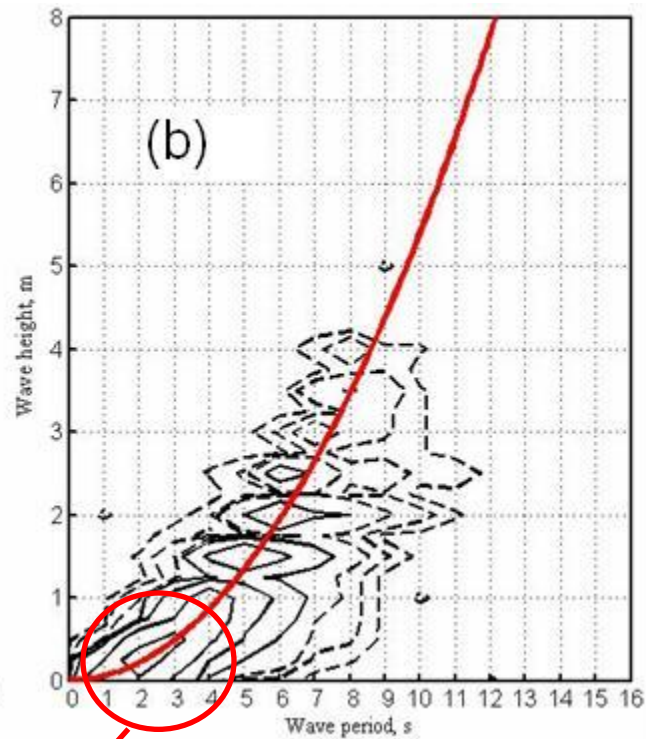
# Percentage of days with at least one sensible wave observation in different months for Vilsandi (a), Pakri (b) and Narva-Jõesuu (c)



**Joint distribution of observed wave heights  $H$  and periods  $T$  at Vilsandi (a), Pakri (b) and Narva-Jõesuu (c).**

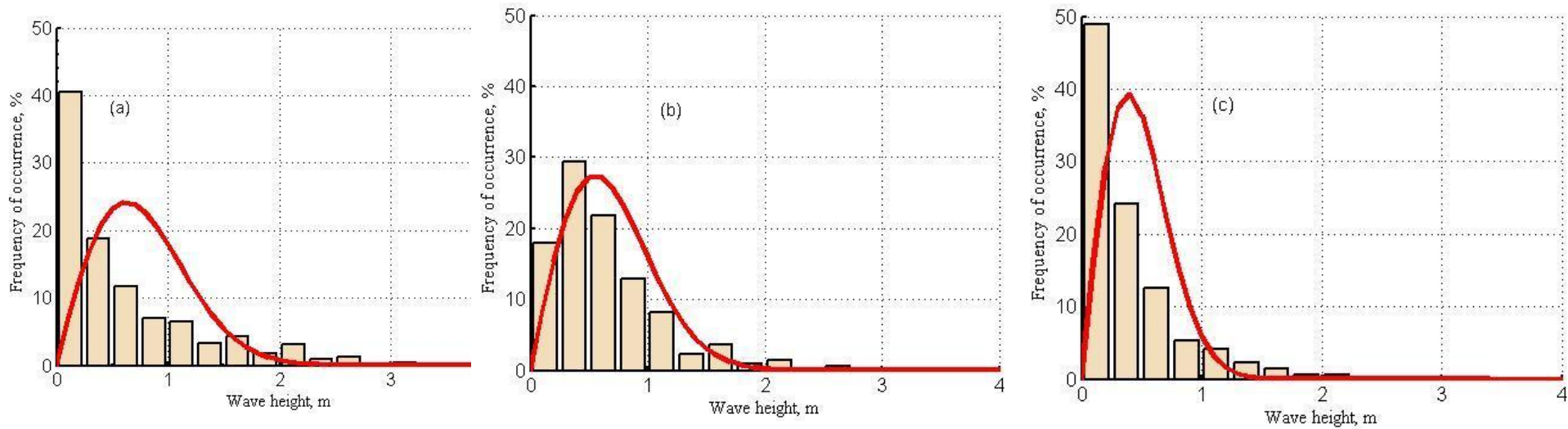


**2-4 s period**

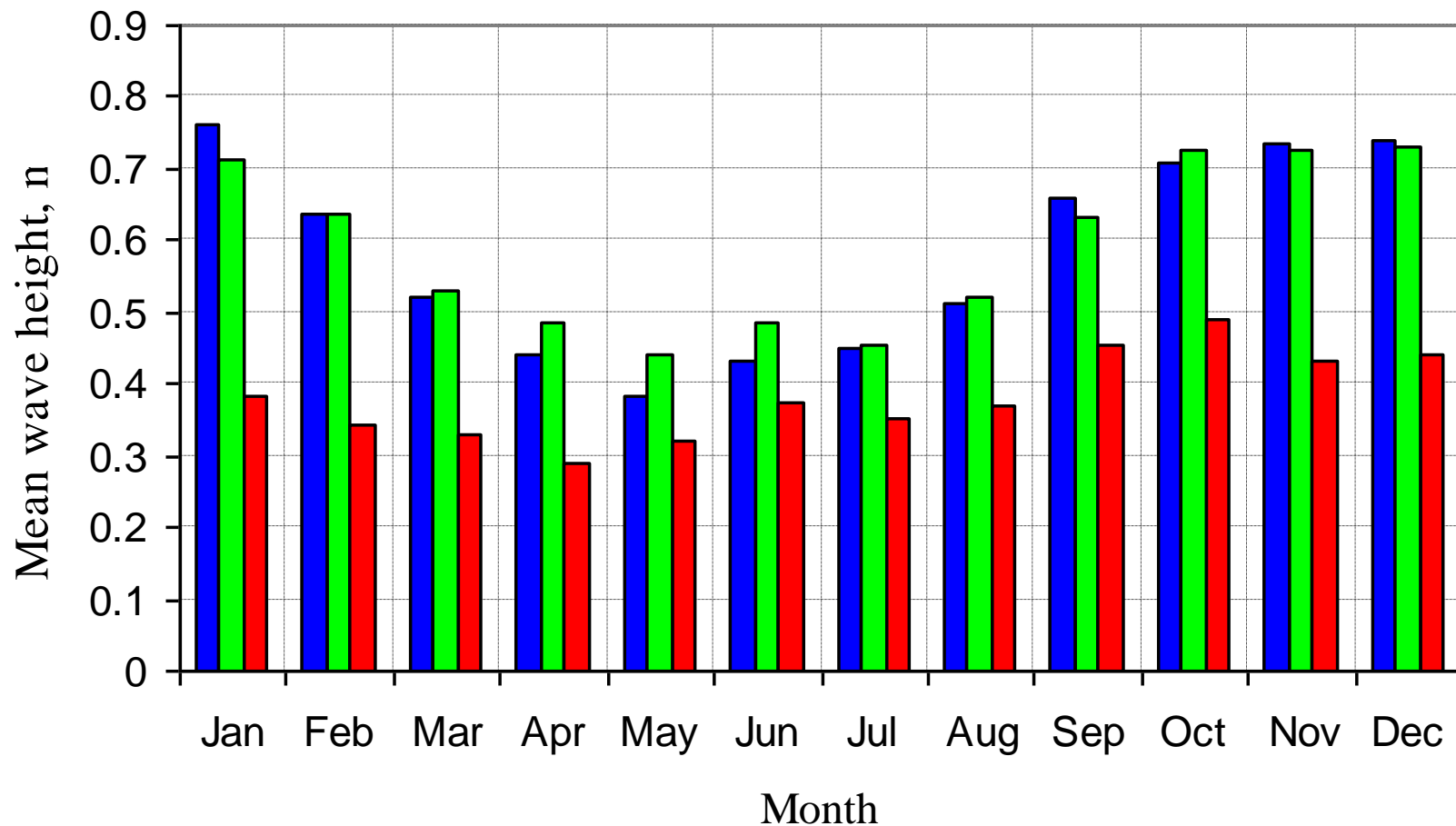


**3-5 s period**

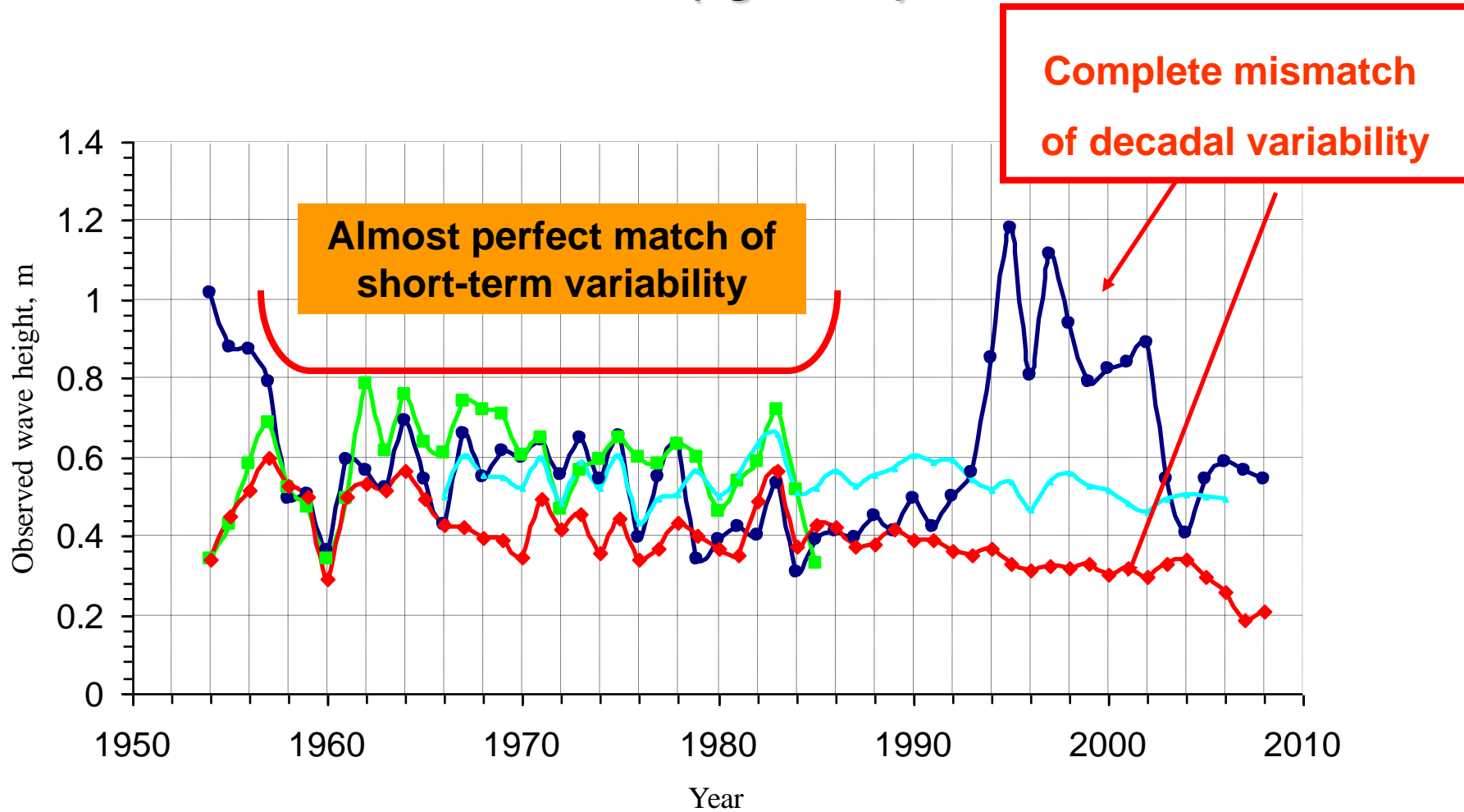
# Distributions of the occurrence of daily mean wave heights at Vilsandi (a), Pakri (b) and Narva-Jõesuu (c)



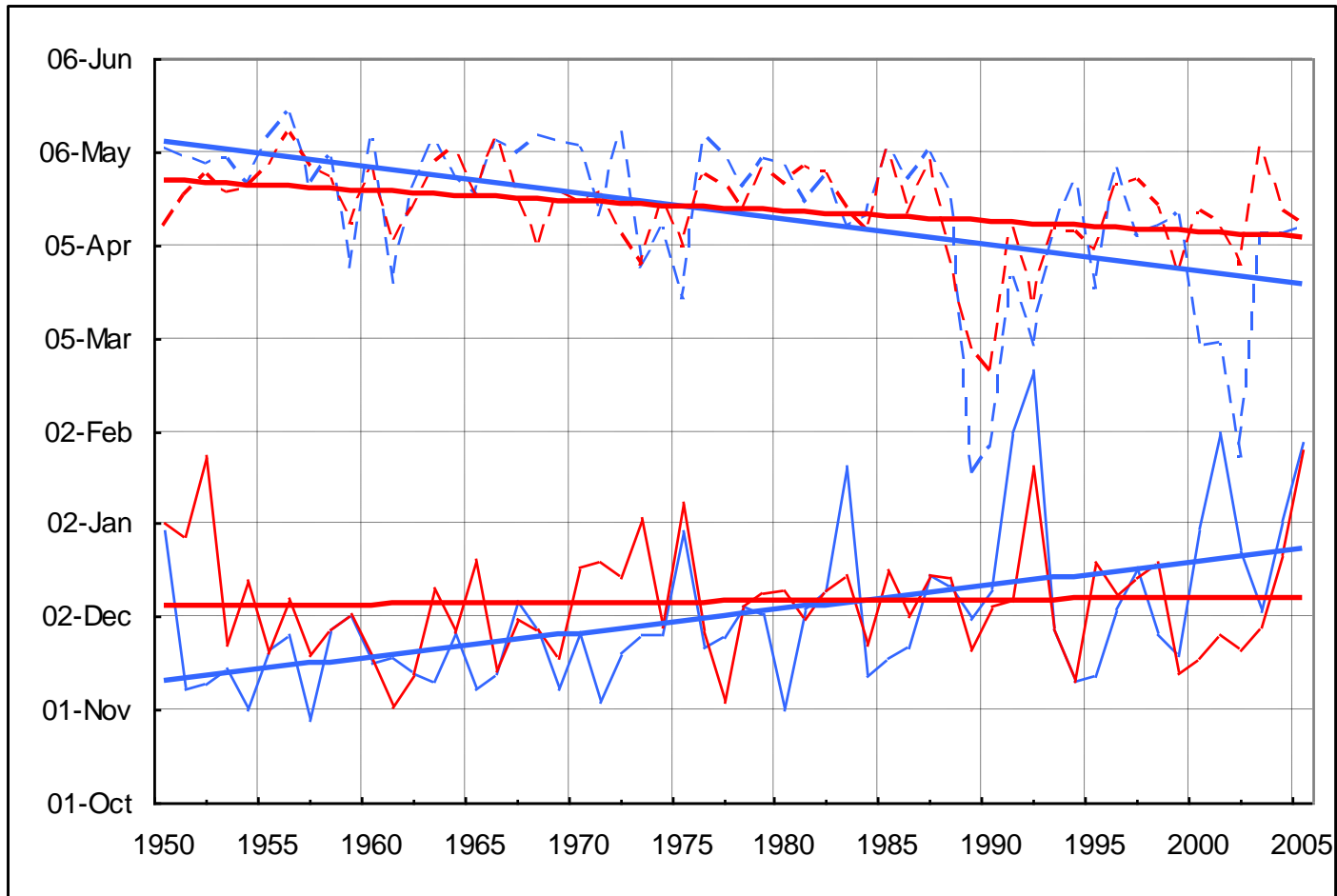
The monthly mean wave height at Vilsandi (blue) , at Pakri (green) and at Narva-Jõesuu (red)



**The annual mean wave height at Vilsandi (dark blue),  
at Pakri (green), at Narva-Jõesuu (red)  
and at Harilaid (light blue)**

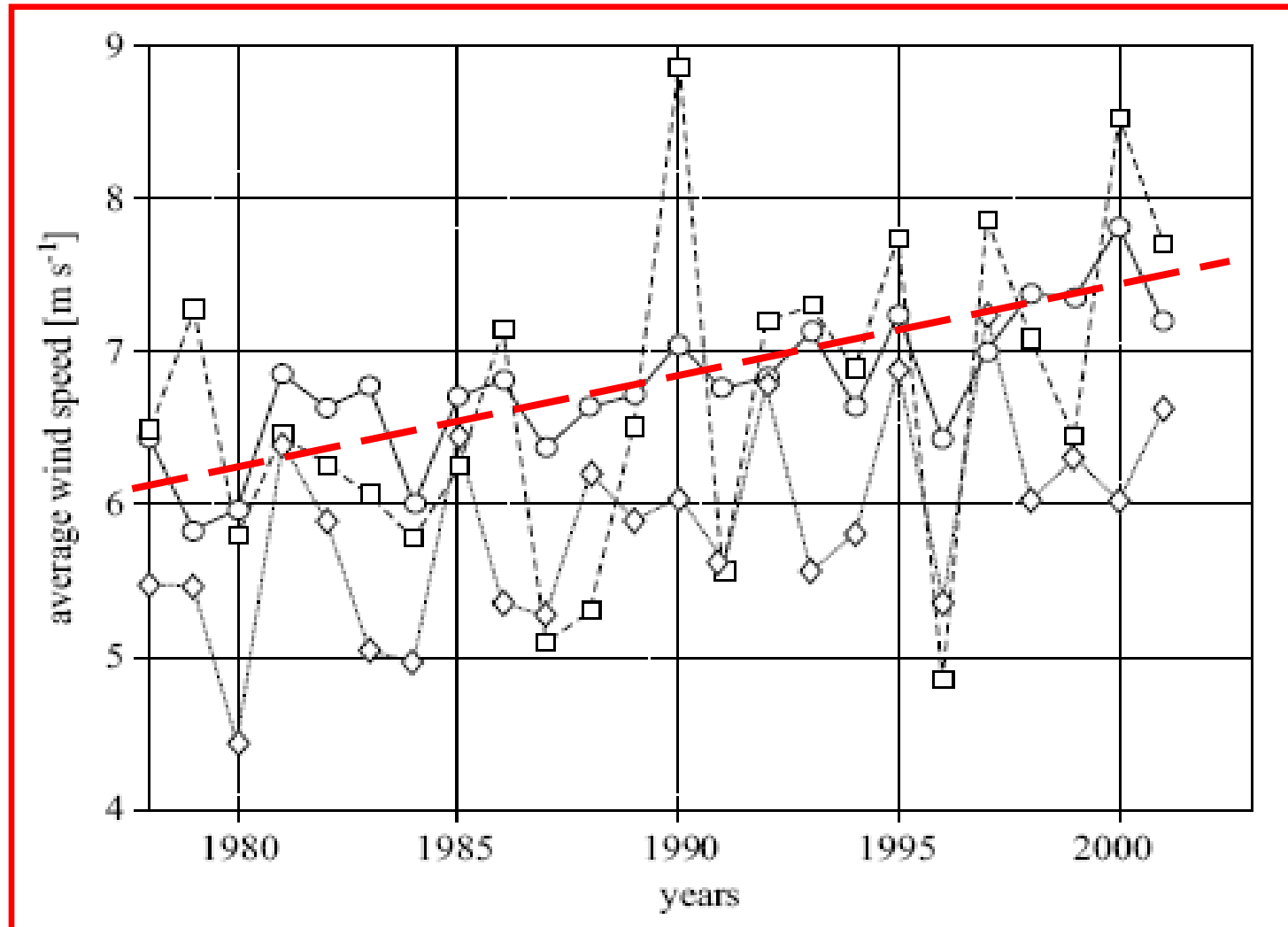


# Ice coverage at Kihnu (blue) and Narva-Jõesuu (red)





At the same time:  
The annual average wind speed (circles on solid line) gradually increases in 1978–2001



# Main conclusions:

- The typical wave periods are 3–6 s (2–4 s in coastal areas)
- The monthly mean wave height follows the seasonal variation in wind speed
- Synchronous, substantial decadal-scale variations in the entire region until 1985
- Drastic variations in wave intensity in 1985-2008
- The mean wind speed continues to increase over the area.