Variability in wake properties generated by high-speed ferries in Tallinn Bay

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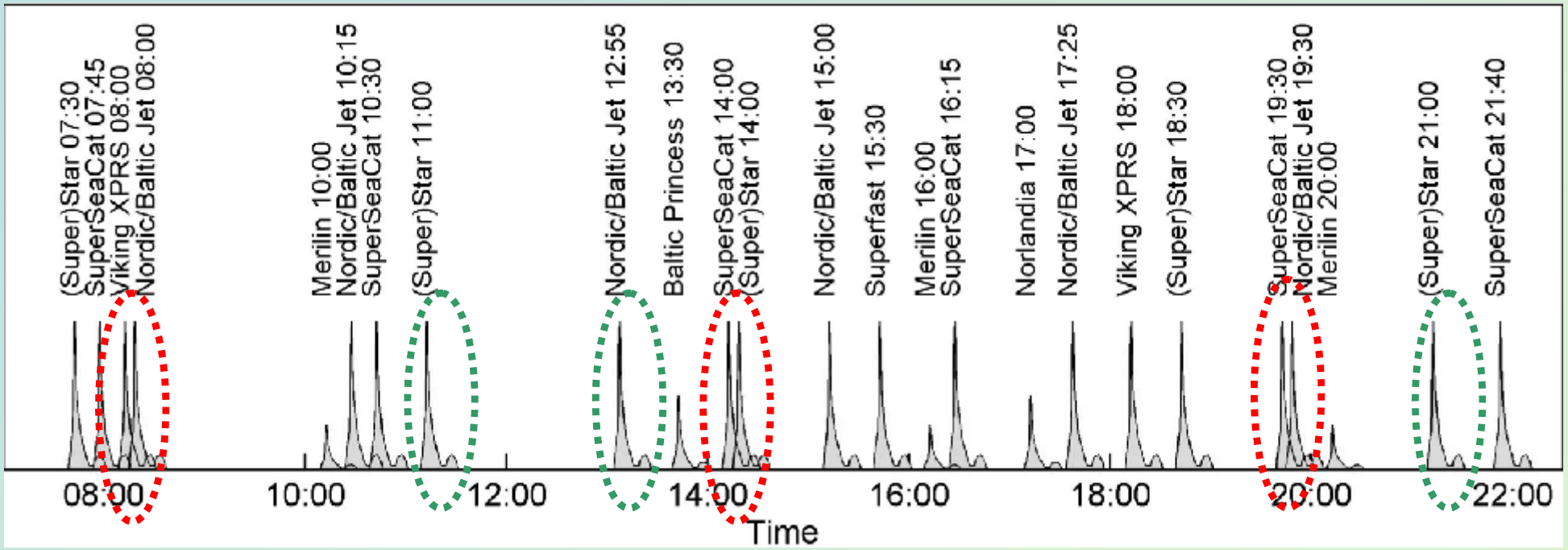
Motivation

- Vessel wakes
  - can add significant energy to coastal systems,
  - and can cause environmental problems,
  - directly affect islands and artificial islands
- A characteristic feature of all high-speed vessel wakes:
  - high variability both for the same and different vessels, at the same and different locations
- Understanding wake variability can assist coastal management
  - Average values are not enough for management
  - Extremes and outliers – the most dangerous
- Tallinn Bay
  - hosts intense fast-ferry traffic close to the shoreline
  - many large, basically conventional ships travelling at ~30 knots
  - their wake characteristics and effects are largely unknown

Daily vessel traffic in summer period



single wake

double wake

Classical High Speed Ferries (HSC, ~35-40 knots)

40
100

40
60

Conventional strong powered ferries (HSF, ~25-30 knots)

190
30

180
30

190
30

200
30

cruise speed, knots

vessel size, m

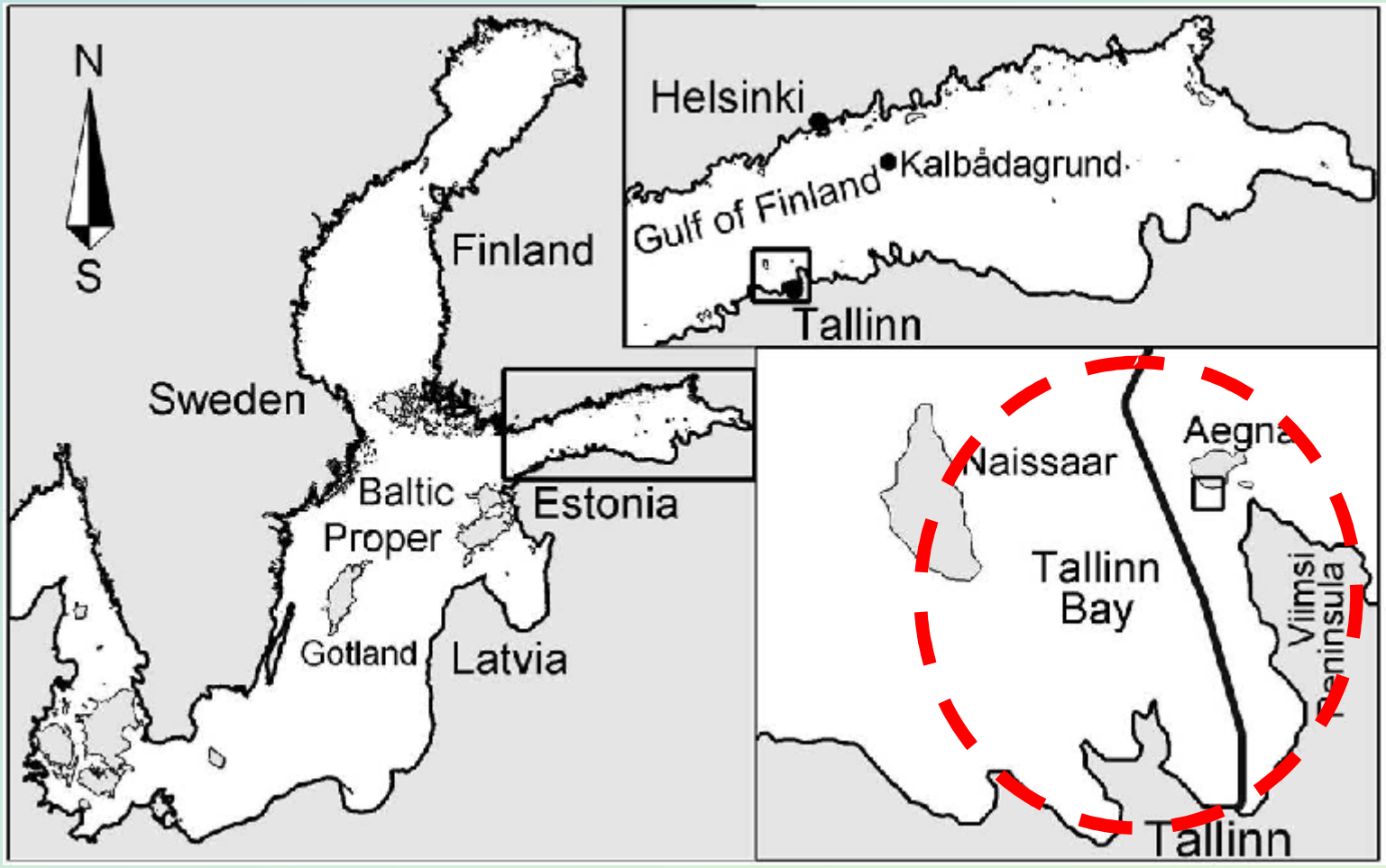
Wake Variability

This study quantifies the variability of the primary wake parameters:

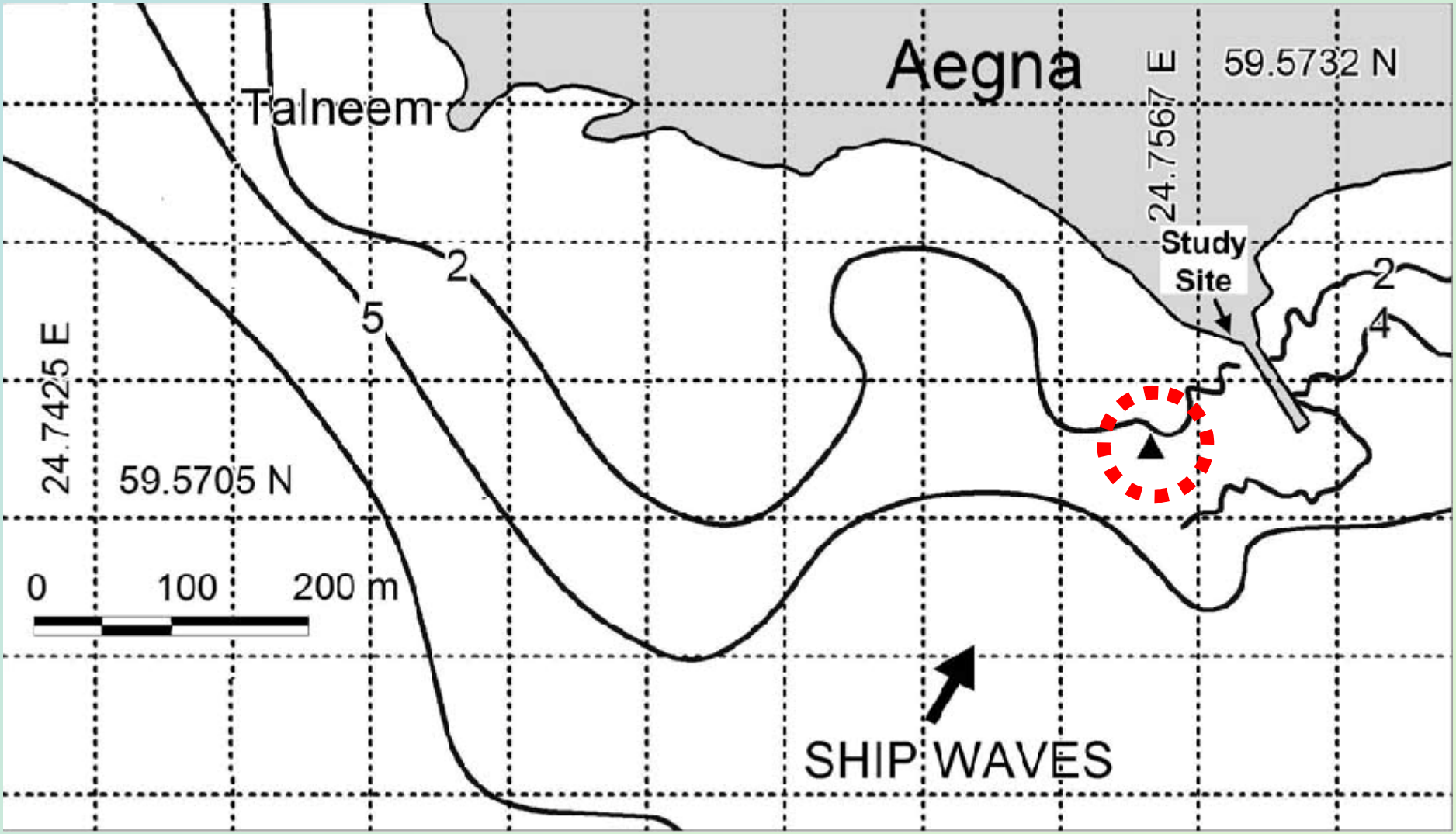
- **maximum wave height**
- **energy** and **energy flux**
- **wave shape**

for different vessel classes and for individual vessels

Study site

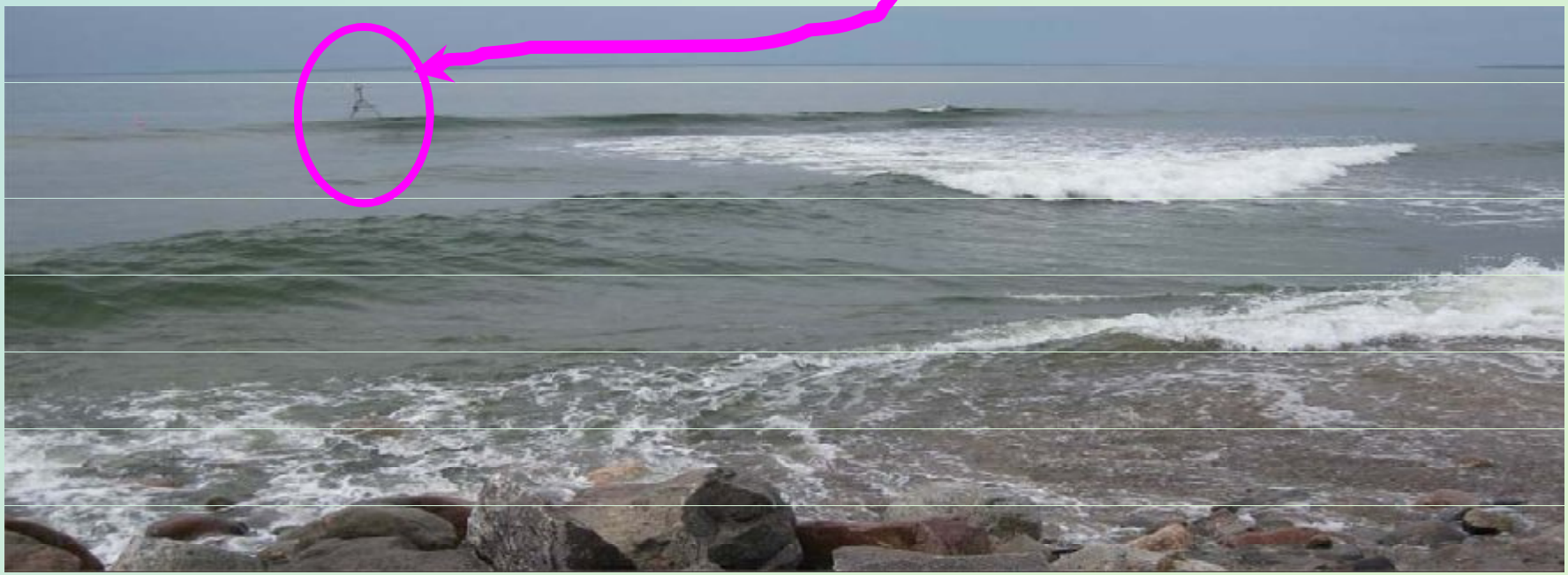

N
S
Finland
Sweden
Baltic
Proper
Gotland
Latvia
Estonia
Helsinki
Kalbådagrund
Gulf of Finland
Tallinn
Naissaar
Aegna
Tallinn
Bay
Viimsi
Peninsula
Tallinn

Measurement site



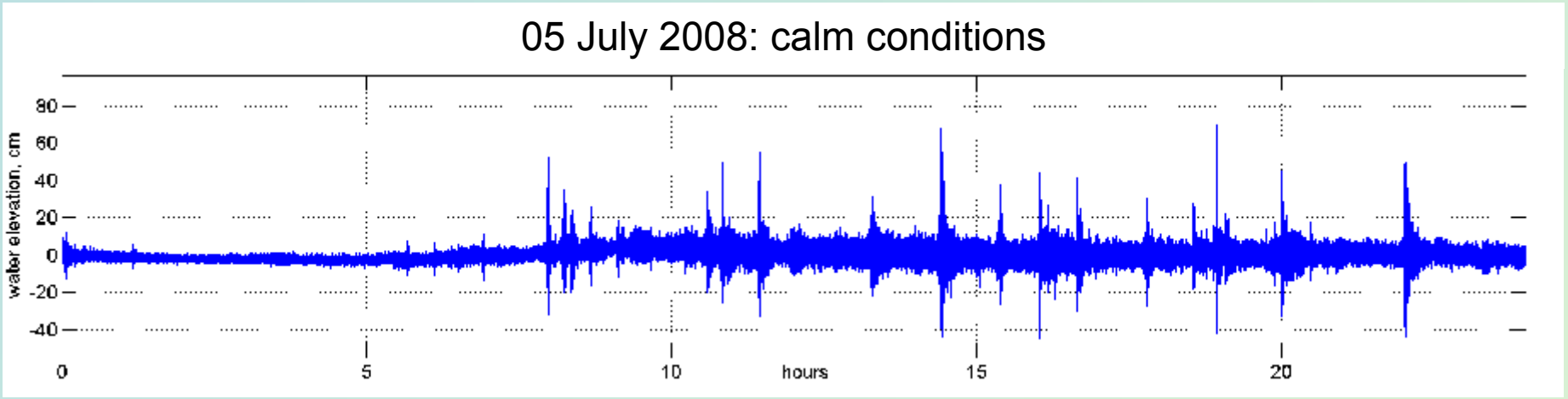
Data collection

- The water surface elevation data:
  - ultrasonic echosounder = water surface profiler
- Data from
  - ~ 650 ship wakes
  - 21 June – 20 July 2008

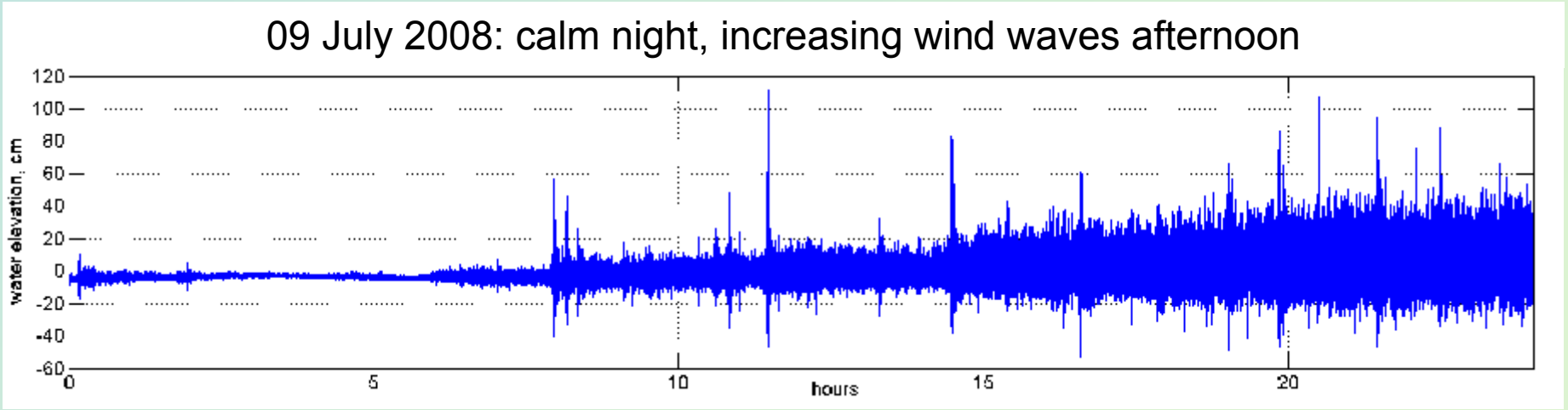


Water surface elevation

05 July 2008: calm conditions



09 July 2008: calm night, increasing wind waves afternoon

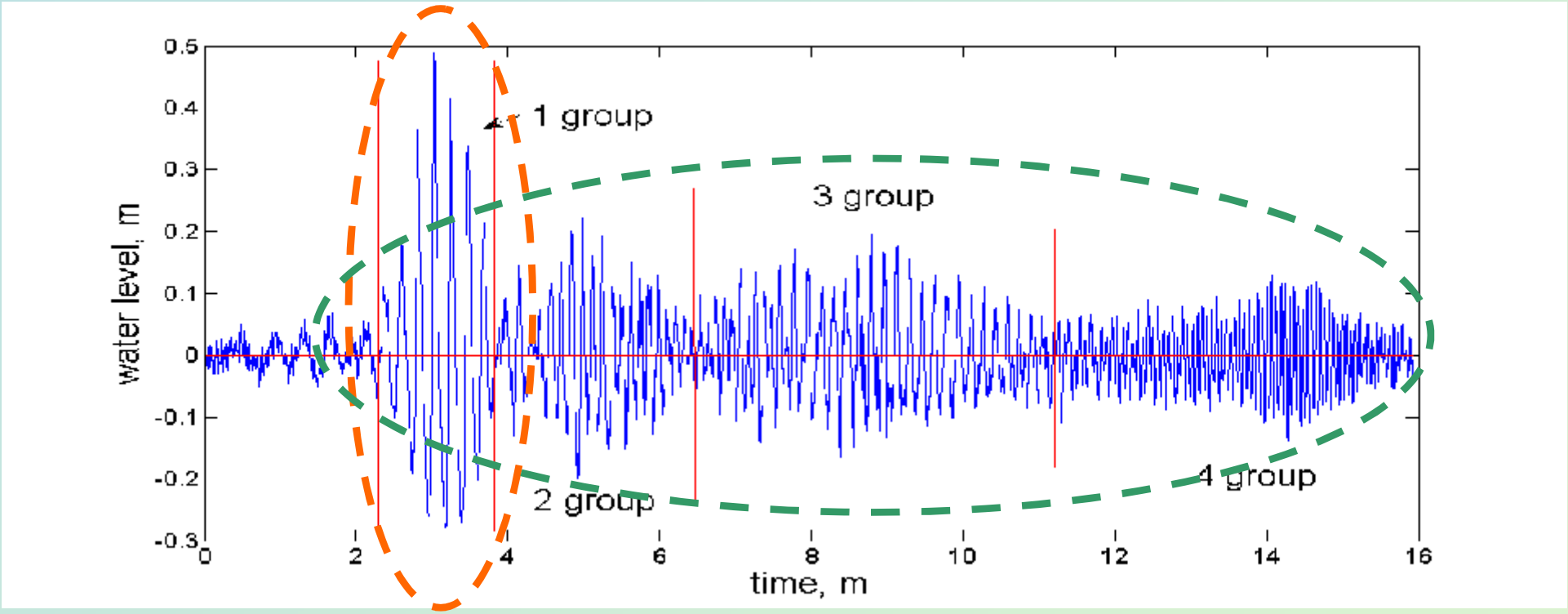


Data processing

- Ship wakes extracted using low-pass filters
  - (ship waves usually longer than wind waves)
- Ships responsible for a wake established where possible.
  - On days with substantial wind wave activity, some wake parts were masked
- 418 wakes on 15 relatively calm days used in the analysis
  - 219 single wakes
  - 42 “double” (superimposed) wakes
  - 157 wakes of small or slow ships, ships travelling to Tallinn, etc.

Typical vessel wake signal

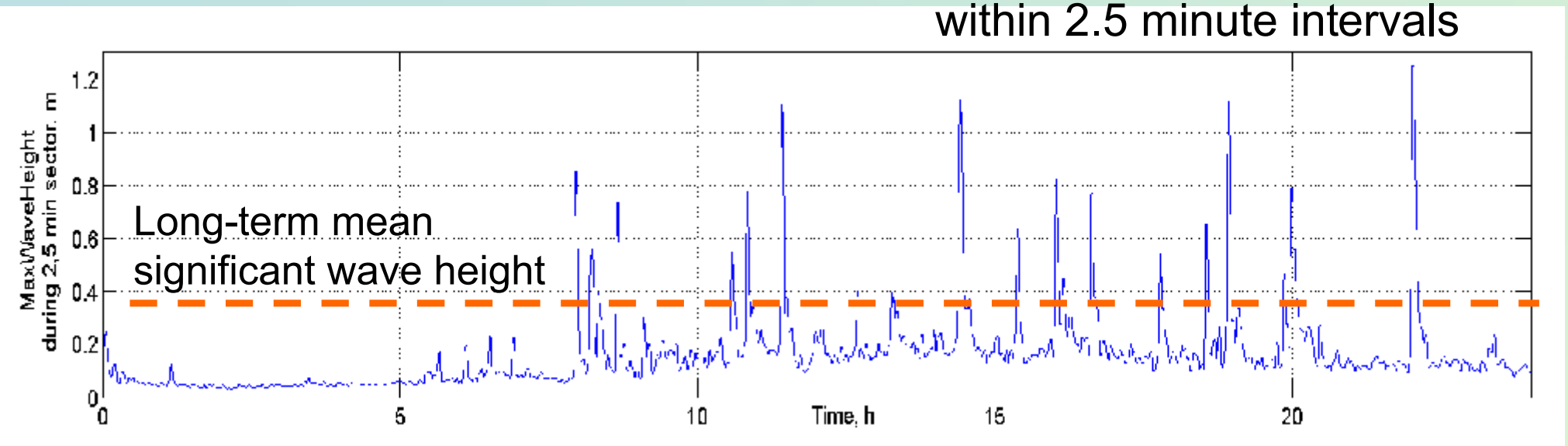
* SuperSeaCat 03 July 2008 at 21:40



HEIGHT, SHAPE

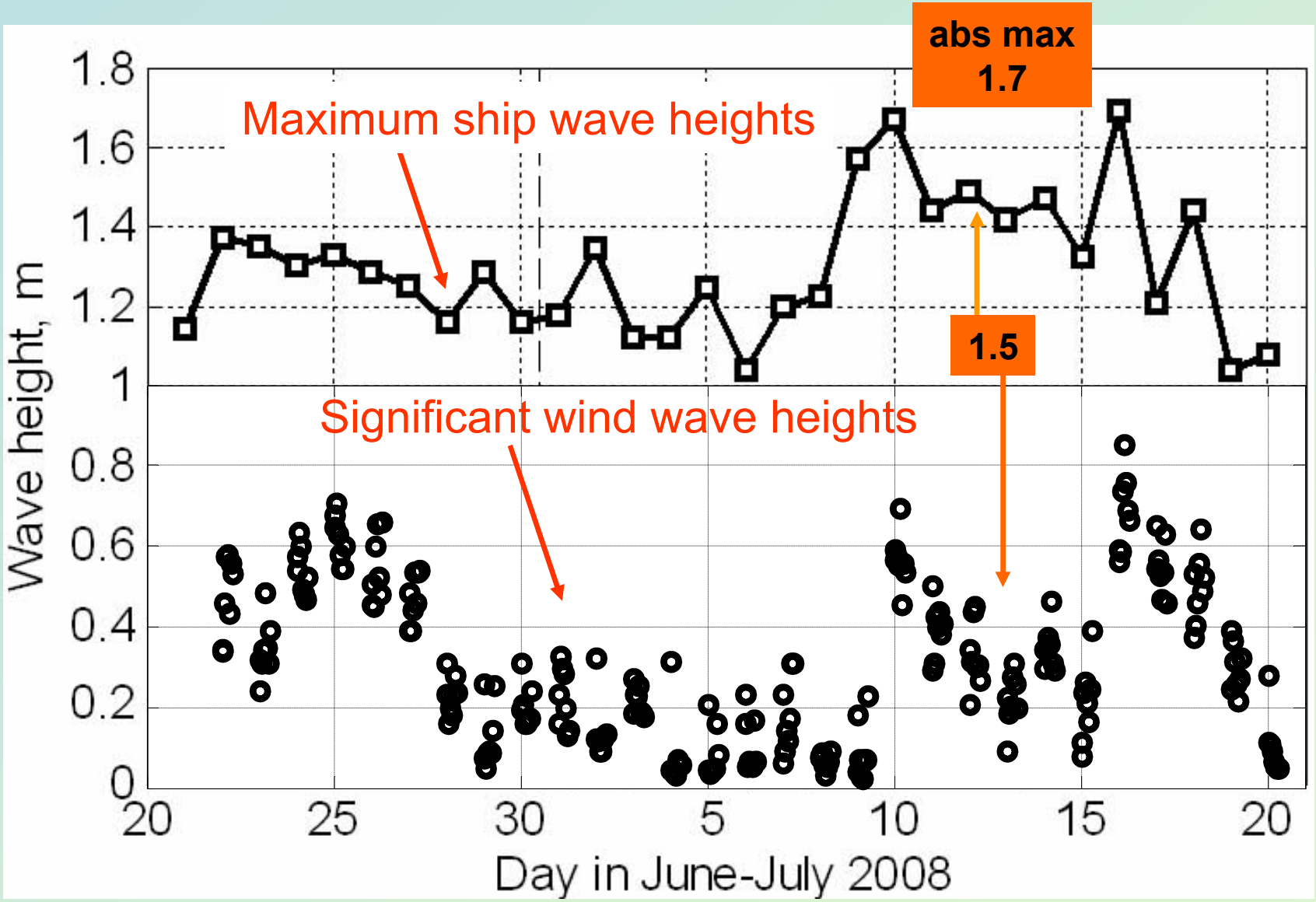
ENERGY, ENERGY FLUX

Wave height on 05 July 2008

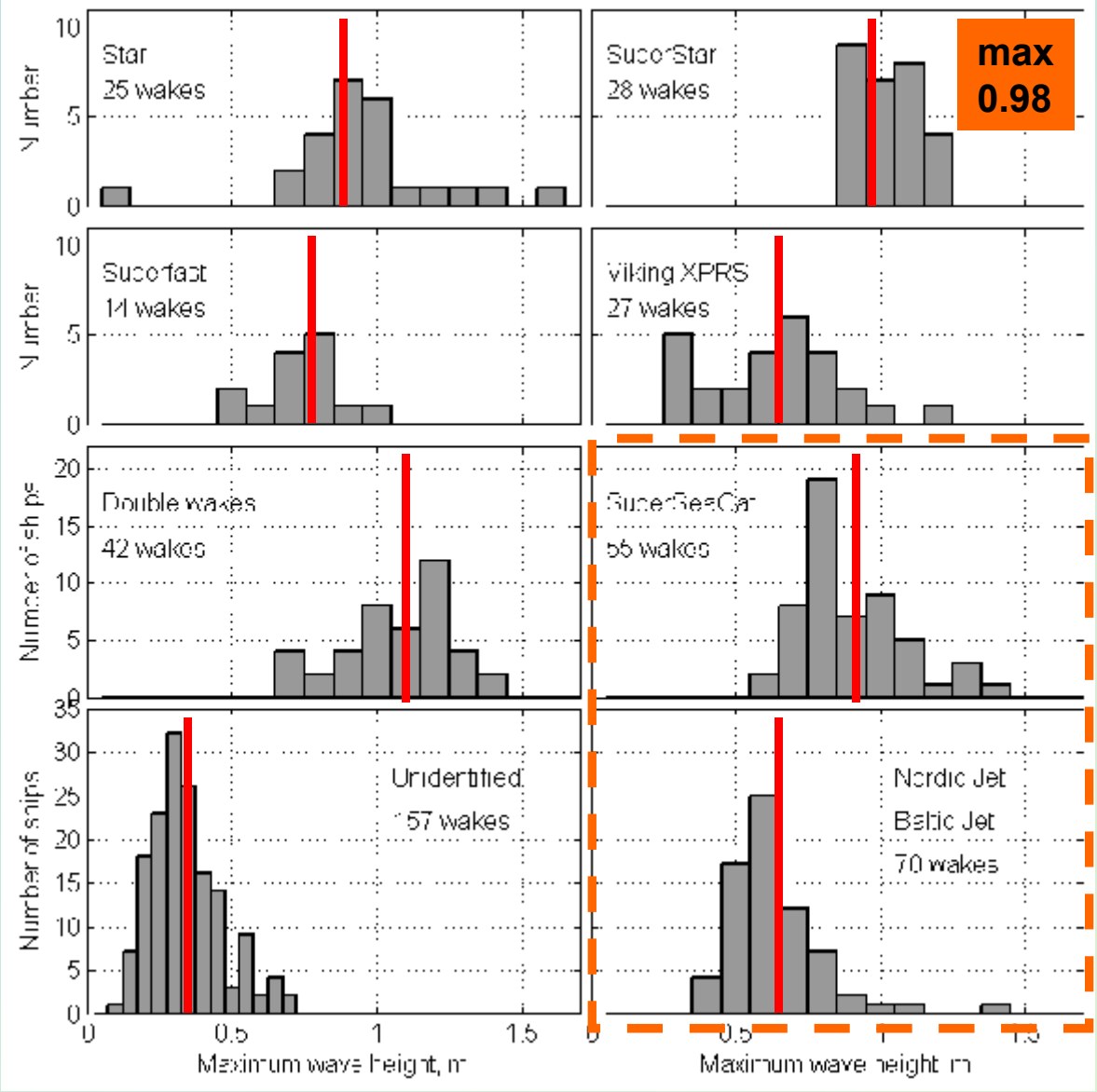


- The highest waves in the wakes – much higher than the typical wind wave background
- The maximum height of waves within a single wake – normally ~1 m

Daily maximum ship wave heights and significant wind wave heights

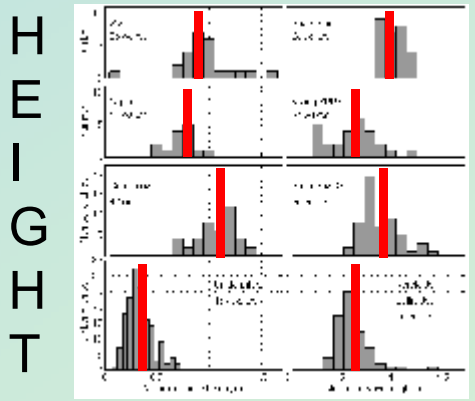


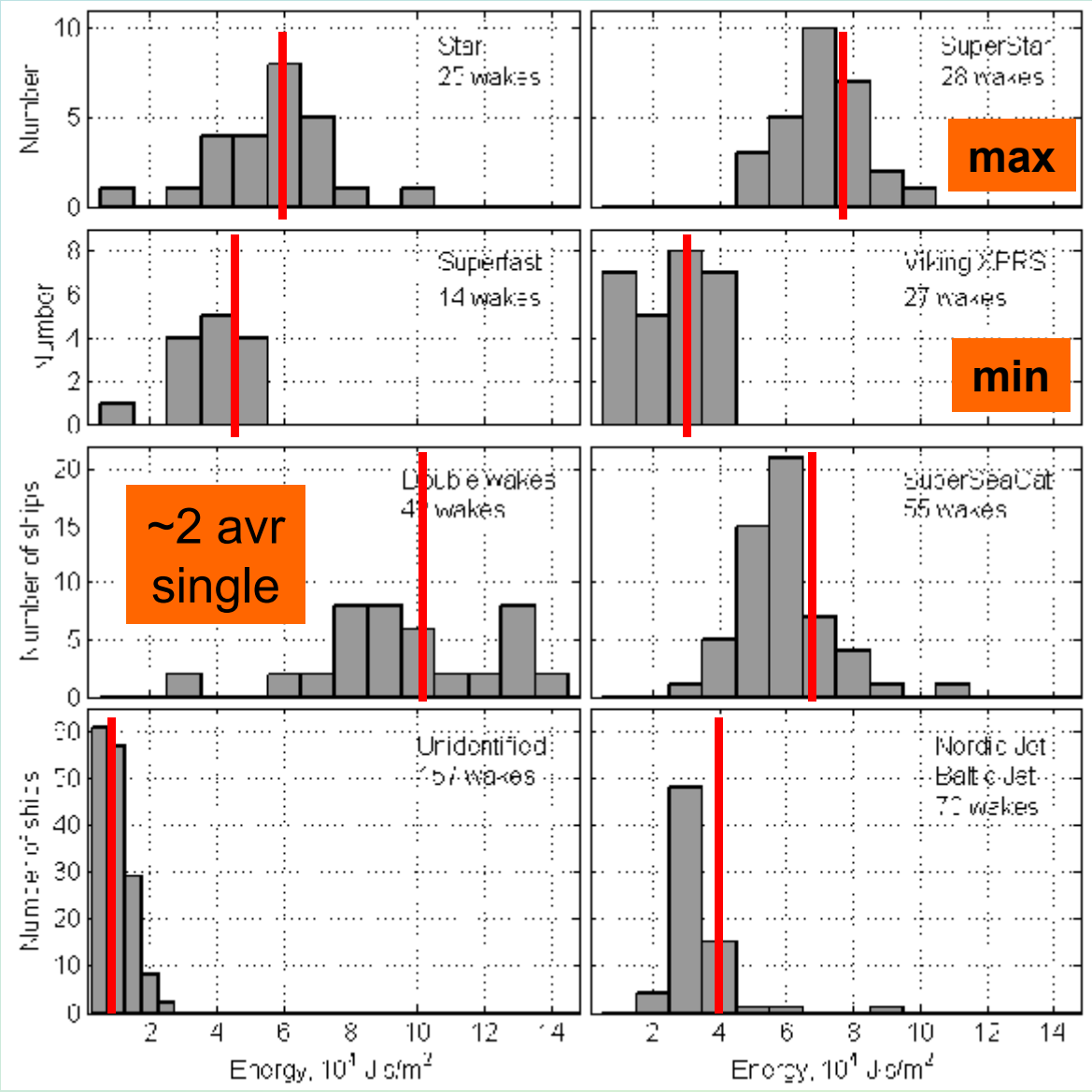
Maximum wave heights in wakes



- Different vessels have different distributions of maximum wave heights
- Highest waves: *Star*, *SuperStar* and *SuperSeaCat*
- Classical HSC have wider and skewed distributions and many outliers
- The highest average maximum wave height was 0.98 m for *SuperStar*
- Conventional ferries other vessel generated waves show a more normal distribution
- The DISTRIBUTION are ~0.60 m, but can reach > 1.50 m is an important parameter for coastal management

Energy in wakes



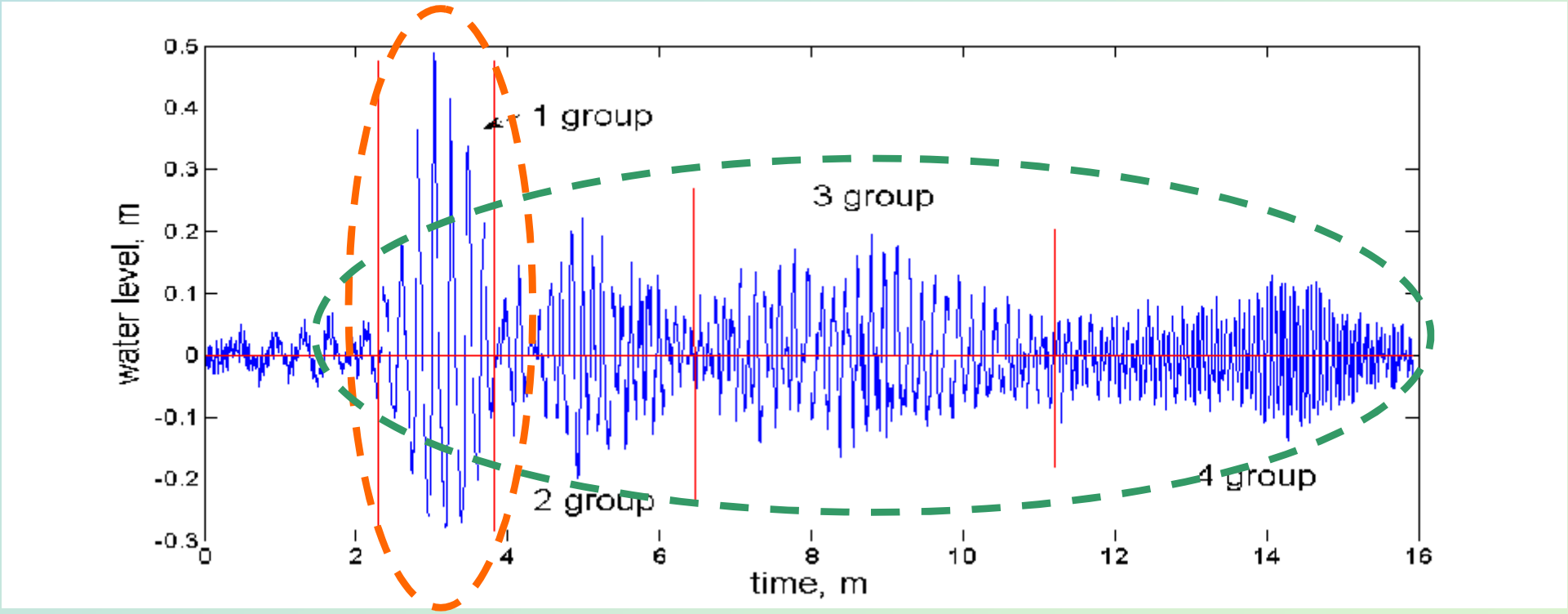


- The distributions of total **energy** and **energy flux** for SINGLE wakes
- similar to the distributions of **max wave height**

- "Double wakes" have up to 2 times the energy of single wakes
- UW energy is small (due to the nature of the vessels causing these events)
- The average wake energy and energy flux of HSC and HSF is almost similar

Typical vessel wake:

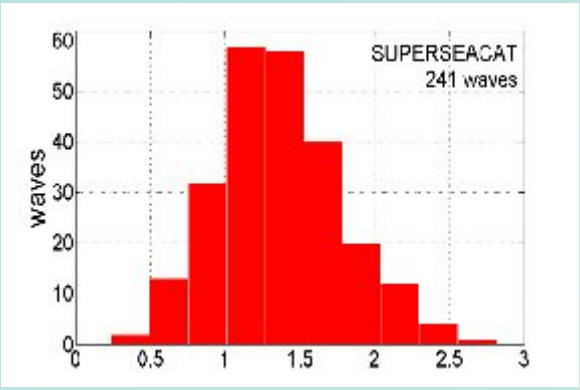
max. wave height represents also integral measures??

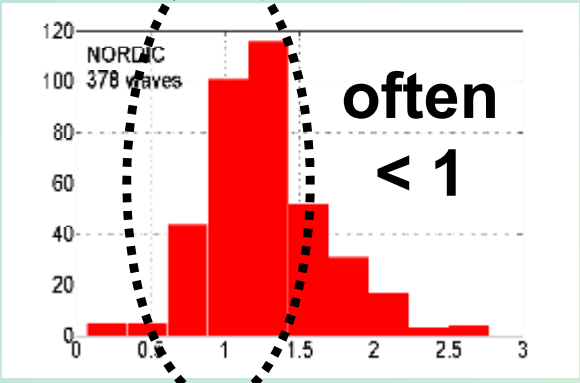


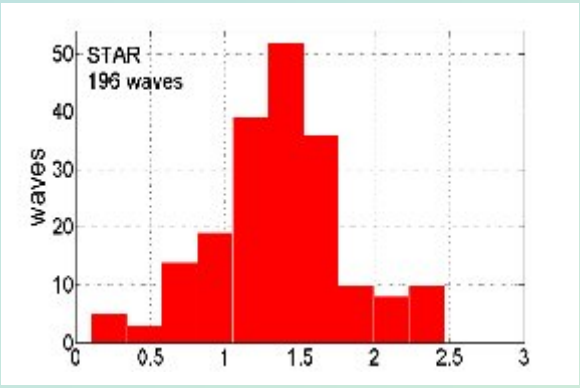
HEIGHT, SHAPE

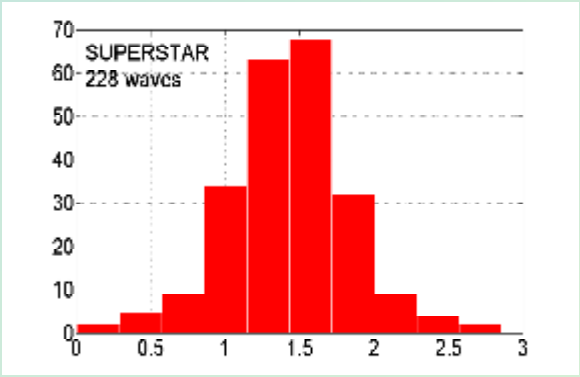
ENERGY, ENERGY FLUX

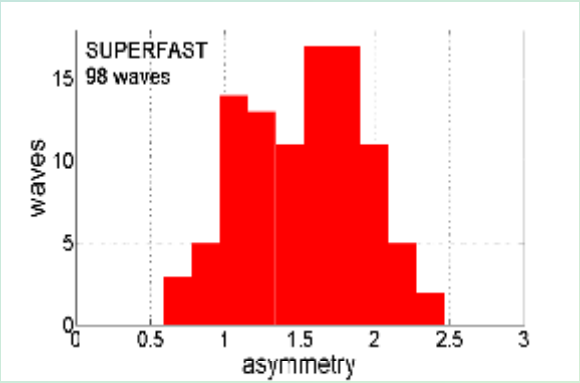
Crest-to-trough asymmetry of ship waves

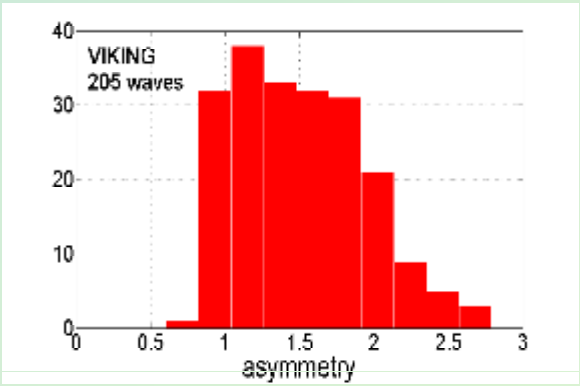












- 1346 waves from 163 single wakes
- Average asymmetry ~1.4 →significant nonlinearity
- Frequently <1 only for catamarans
- The PDF of asymmetry does not match the above distributions
- No systematic sequences of deep holes and high crests

Conclusions (1)

- A **large data set** of vessel wakes obtained and analyzed
- The largest **ship wave** heights **~1.5 m**
- The **highest waves** - by **strongly powered conventional ferries**
- The empirical probability functions of **max wave height** can assist with the management of vessel wakes
  - the empirical distribution functions of **wake energy** and **power** are very similar to the corresponding distribution of max wave height
- The **largest variability** is observed in the properties of **Classic HSC**

Conclusions (2)

WAVE SHAPE

SUMMARY

– the **largest ship waves** are **asymmetric;** wave crests exceed wave troughs by ~40%

The **variability** of properties of single wakes from particular ships is relatively **large**

– No systematic sequence of deep holes and high crests → **ship waves are not freak waves**

The **maximum wave height** is an **appropriate parameter** to characterize the ship wakes and their variability; its distribution can be used as **a tool for managing** vessel waves and their impacts

– **asymmetry is a largely independent measure** of properties of ship wakes

The **asymmetry** is another **independent parameter** to characterize vessel wakes

– the distributions of asymmetry coefficients for **catamarans and monohulls** are largely **different**

Vessel wake in Tallinn Bay