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Estimating storm surges and waves from synthetic low-pressure systems

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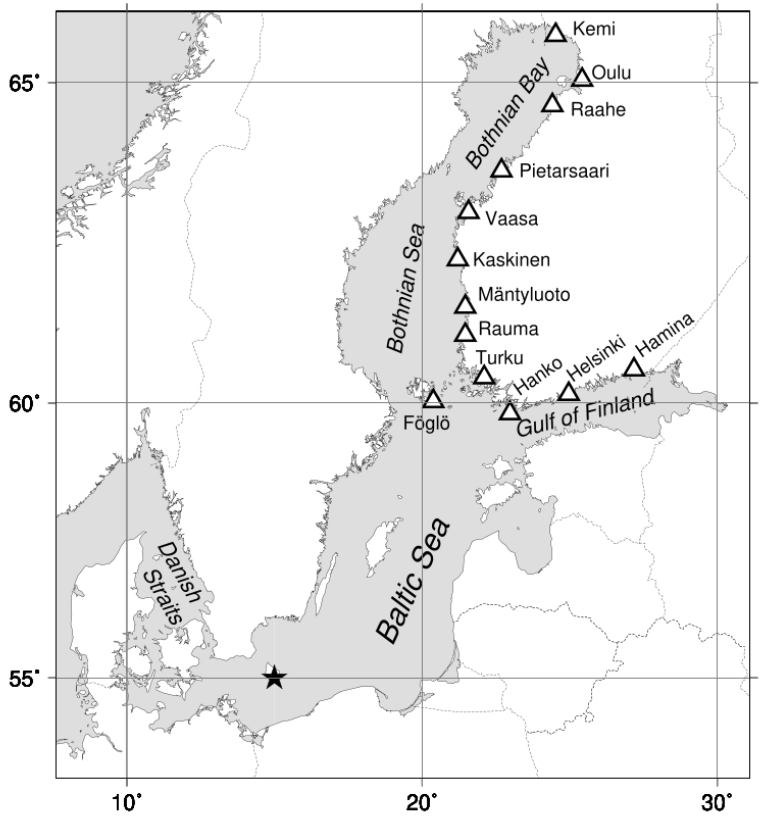
5.10.2025 **Jani Särkkä**

Baltic Sea level maxima



- Sea level affected by wind, air pressure, seiches, water flow from the North Sea
- Highest maxima in the ends of bays
- Tide gauge data covers mainly less than 200 years

Historical floods in the Baltic Sea


Die Sturmfluth an der Ostsee: Ansicht aus Eckernförde I. (S. 279.)

- Baltic Sea flood in 1872, 3.3 m sea level at Travemünde
- In St. Petersburg 4.2 m sea level in 1824, 3.8 m in 1924

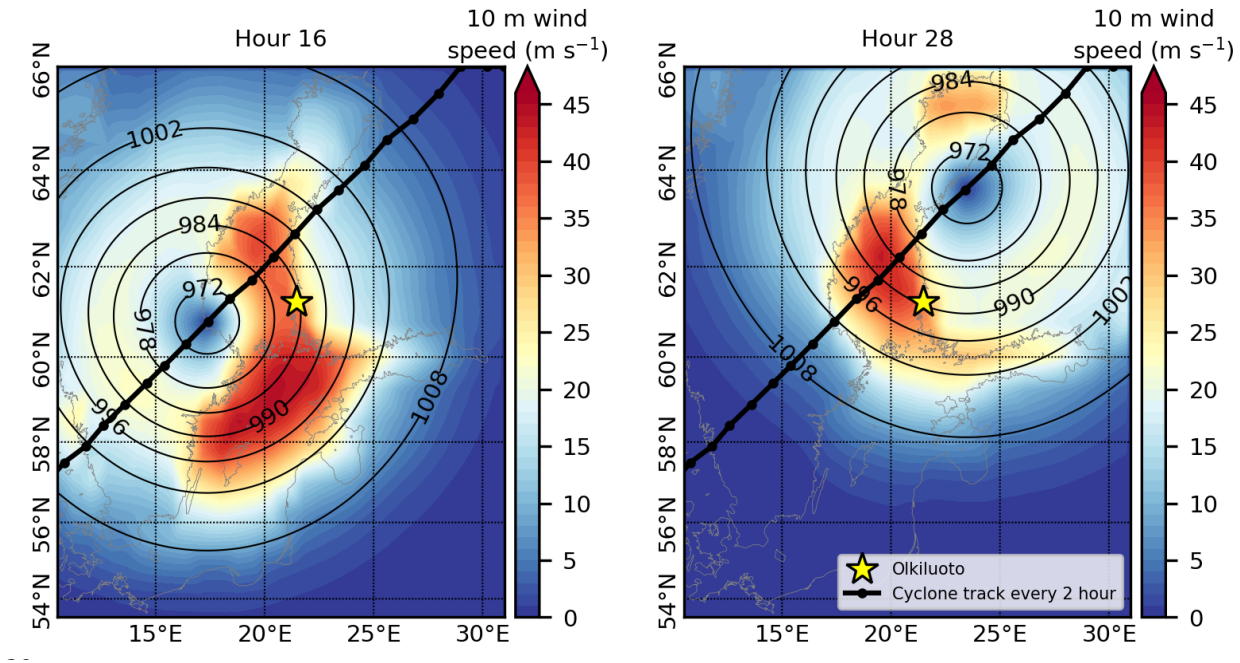
Method to simulate sea level and wave extremes

- Aim is to study coastal sea level maxima due to windstorms
- Looking for the storm tracks that cause the highest storm surges
- Generate an ensemble of synthetic cyclones (moving pressure fields)
- Calculate the surface winds from the pressure field
- Sea levels are simulated with a barotropic numerical model, having surface wind and pressure as forcing
- Waves are simulated with WaweWatchIII using surface winds as forcing, accounting for sea level dynamics

Cyclone parameters

- Cyclone pressure anomaly and radius were fixed to realistic maximum values
- For large pressure anomalies, surface wind speeds could exceed 40 m/s
- Cyclone point of origin, velocity and propagation direction were varied

Sea level at Olkiluoto from synthetic cyclone



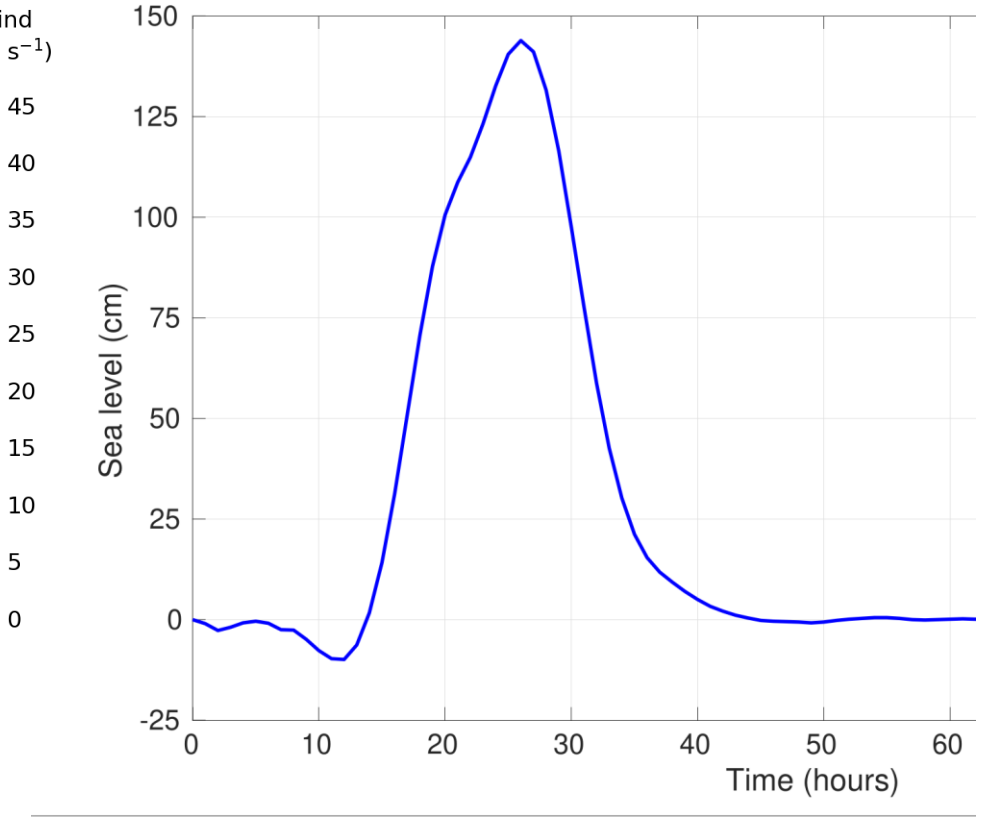
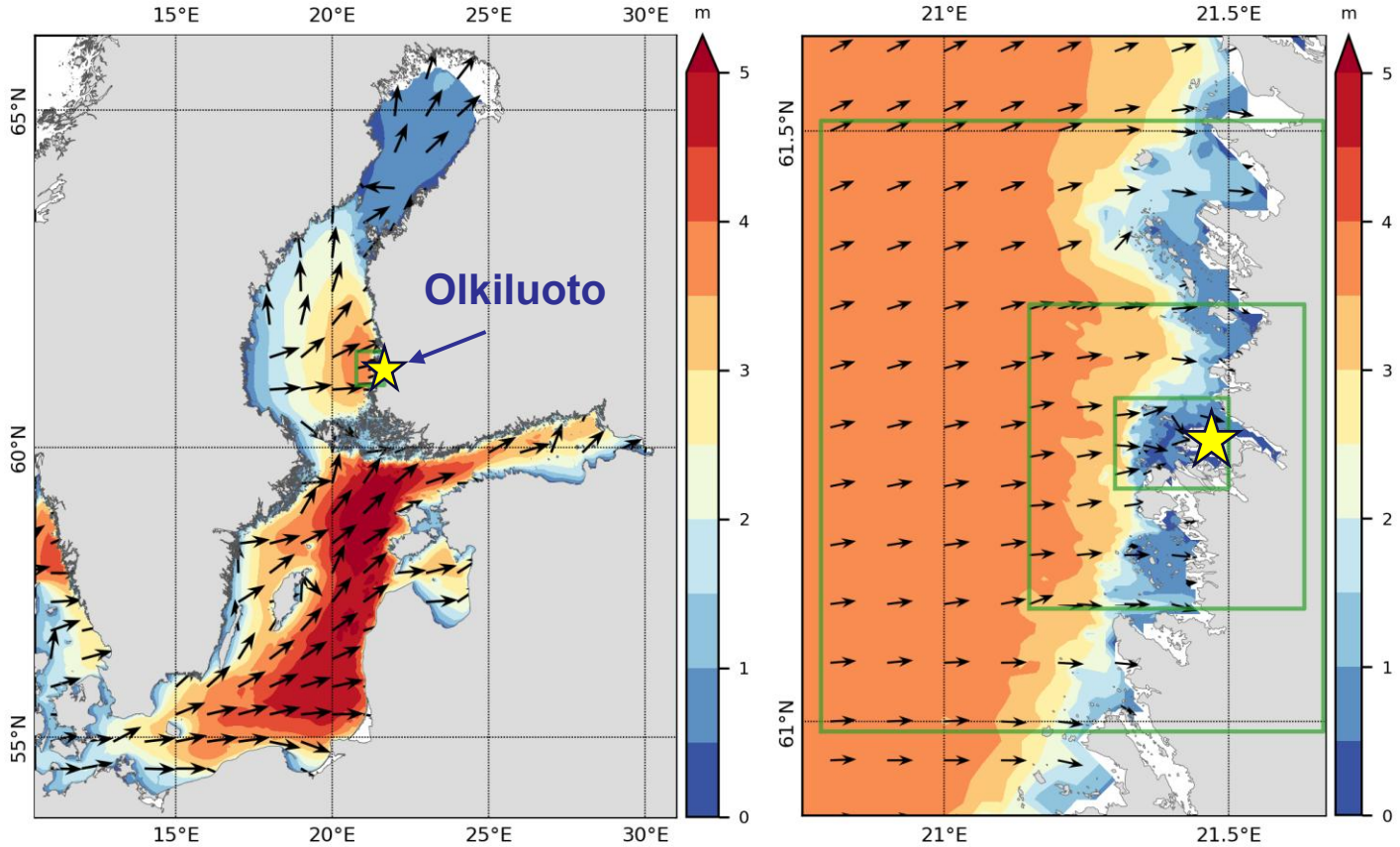


*Figure shows **synthetic cyclone track** over the Baltic Sea with **corresponding wind speeds** (colourmap) and **atmospheric pressure isobars** in hPa*

Wave simulations at Olkiluoto

- Wave simulations with WaveWatchIII with wind speeds over 40 m/s generated by the synthetic cyclones lead to unreliably high SWH values in the Baltic Sea.
- Experiments ongoing with past events with high sea level and high waves to better understand the effects of sea level variation on the coastal wave fields.

Case study at Olkiluoto, Finland: 22.02.2020 storm



Nested grids for wave simulations, resolutions 0.1, 0.25, 0.5 nmi

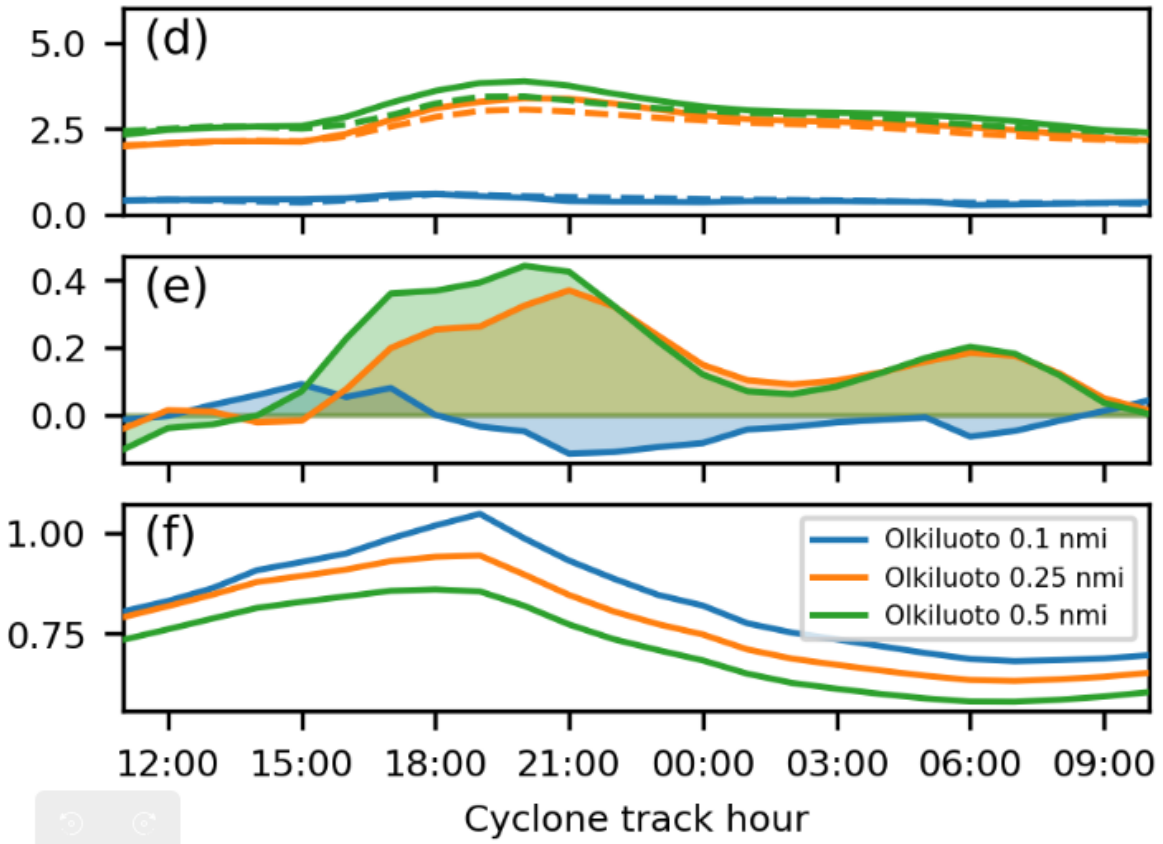
*Figure shows **SWH and spectral peak direction** on 22 Feb 2020 at 20 UTC*

Case study at Olkiluoto, Finland 22.02.2020

SWH(m)

SWH_SSH(t)-
SWH_SSH_0 (m)

SSH(m)



Olkiluoto maximum sea level estimate

- Highest observed flood at Rauma (nearest tide gauge) 22.02.2020 **135 cm**
- Highest simulated flood at Olkiluoto 144 cm + adding 50–100 cm of preceding long-term mean sea level in the Baltic Sea
- A flood height of **250 cm** at Olkiluoto is possible

Summary

- Highest simulated sea level extreme at Olkiluoto 144 cm
- Mean water level of the Baltic Sea (up to 100 cm) should be added to the storm surge
- 250 cm sea level at Olkiluoto is possible, exceeding observed maximum by 100 cm
- Wave studies continue with real storm events to have realistic SWHs in the Baltic Sea
- Details about the methods and results for other sites: https://nhess.copernicus.org/articles/24/1835/2024/

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Thank you for your attention!

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