Cyclone Xaver seen by SARAL/AltiKa

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Xaver — Forecast

Storm was well forecast

- Code Red along North Sea coasts of the Netherlands and Germany
- Surge of 3 meters was forecast
- References to *Watersnoodramp* of 1 Feb 1953 that killed 2400 in NL, BE, UK

Cyclone Xaver seen by SARAL/AltiKa — EUM/RSP/VWG/14/756175

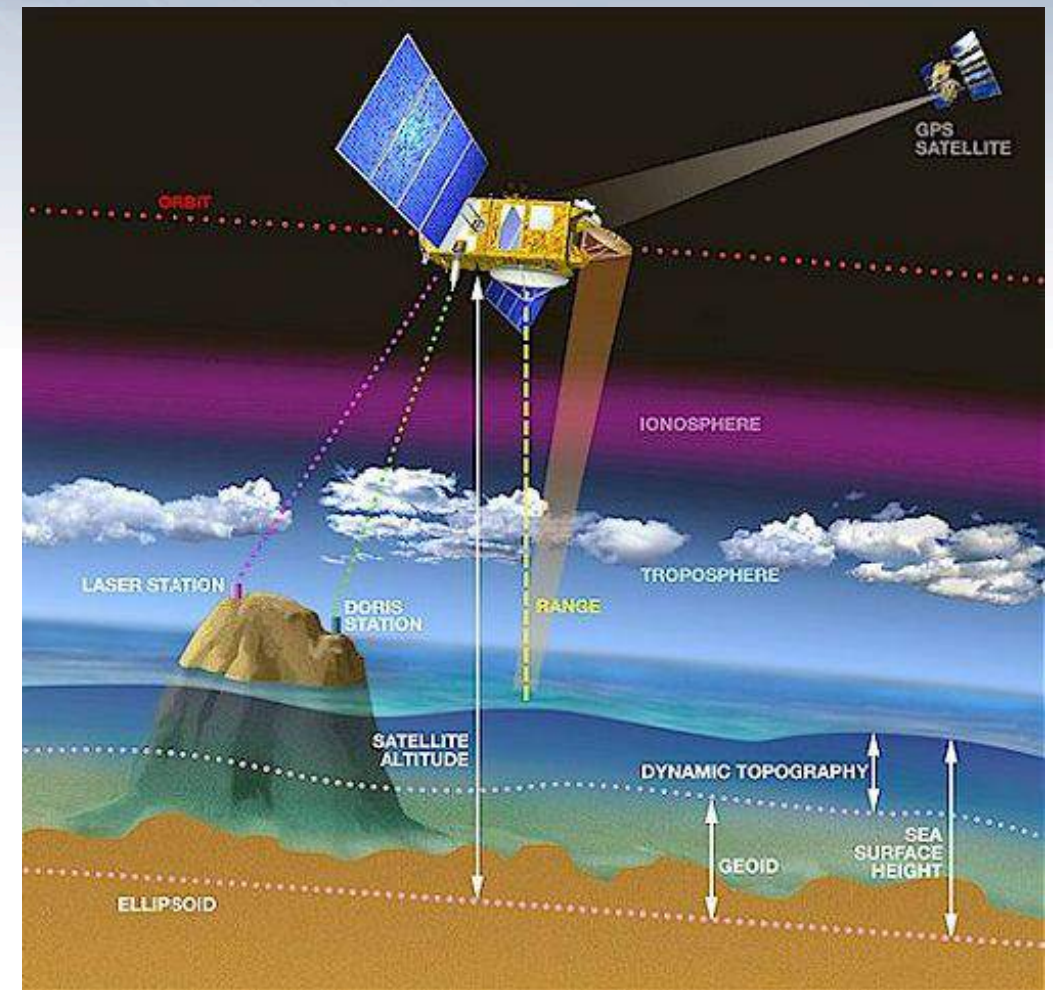
Cyclone Xaver: 5–6 December 2013

One of many severe storms

- North Sea coast repeatedly hit by storms during last winter
- Netherlands closed *Stormvloedkering* (storm barrier) for first time in 8 years
- Dubbed *Sinterklaasstorm* (St. Nicolas Storm)

Cyclone Xaver seen by SARAL/AltiKa — EUM/RSP/VWG/14/756175

The Principle of Satellite Altimetry



- Altimeter range
  - From radar round-trip time
- Satellite altitude
  - From from various tracking systems
- Sea surface height
  - Difference:
    satellite altitude – altimeter range – corrections
  - Sum of:
    geoid + dynamic topography + astronomical tides + surge

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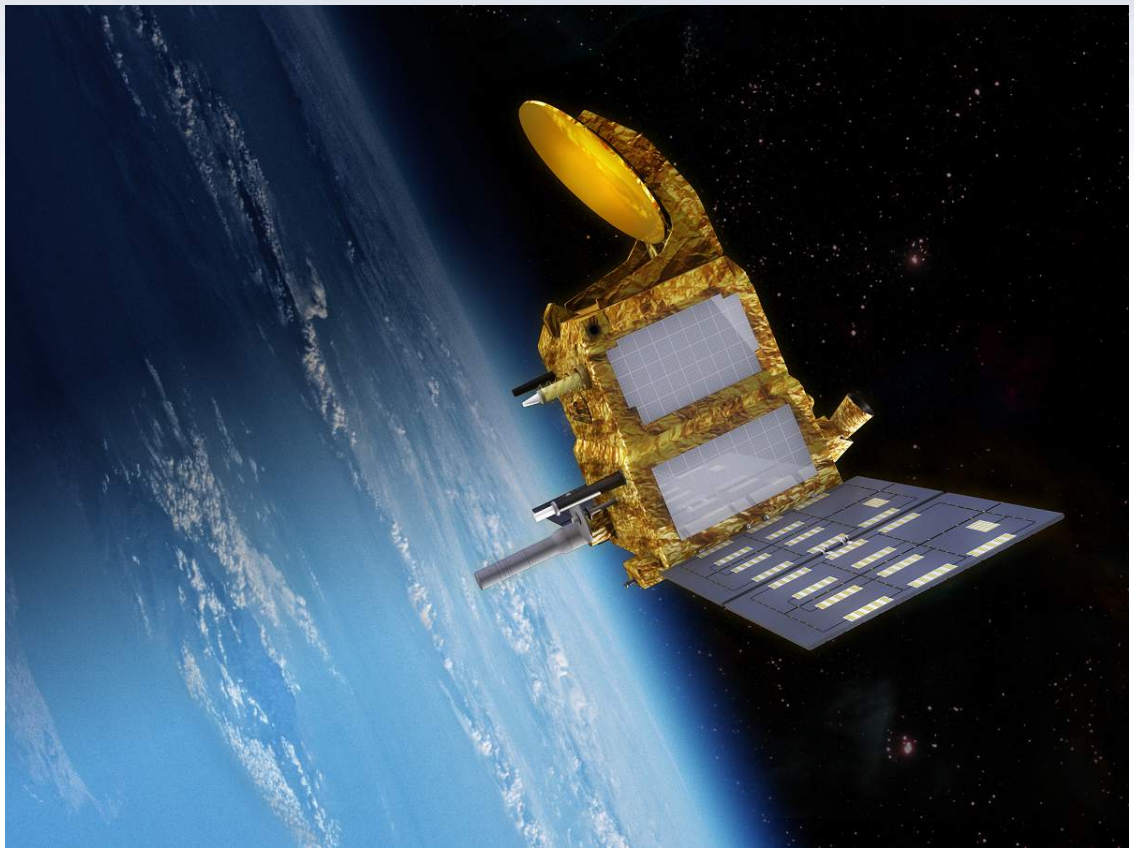
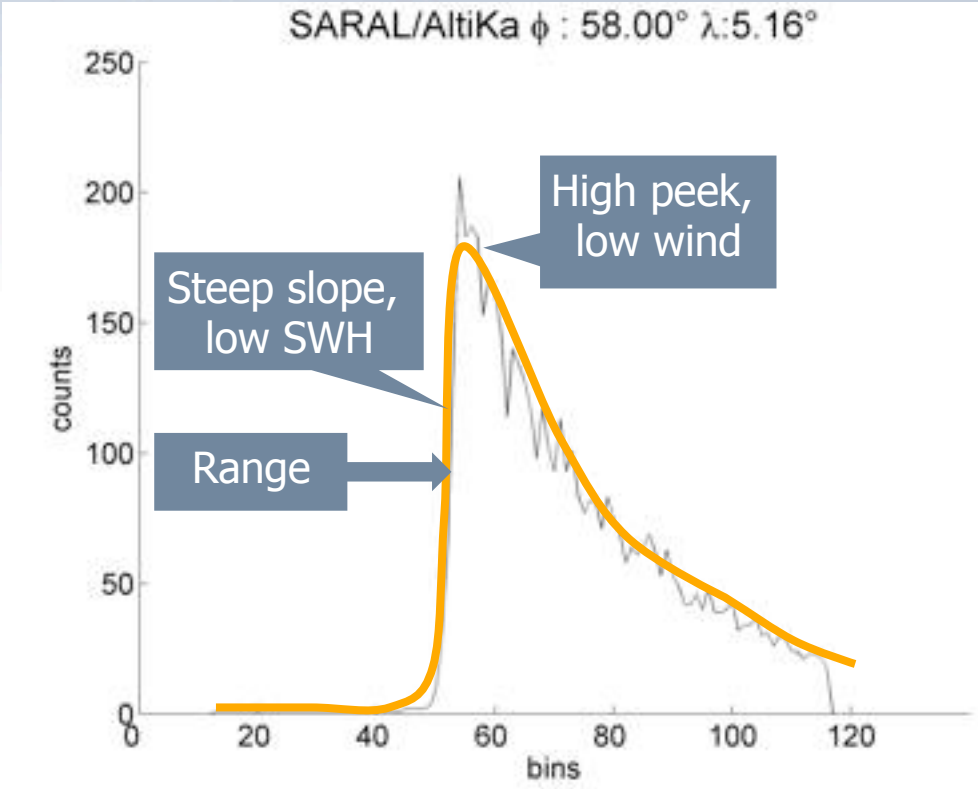
SARAL/AltiKa

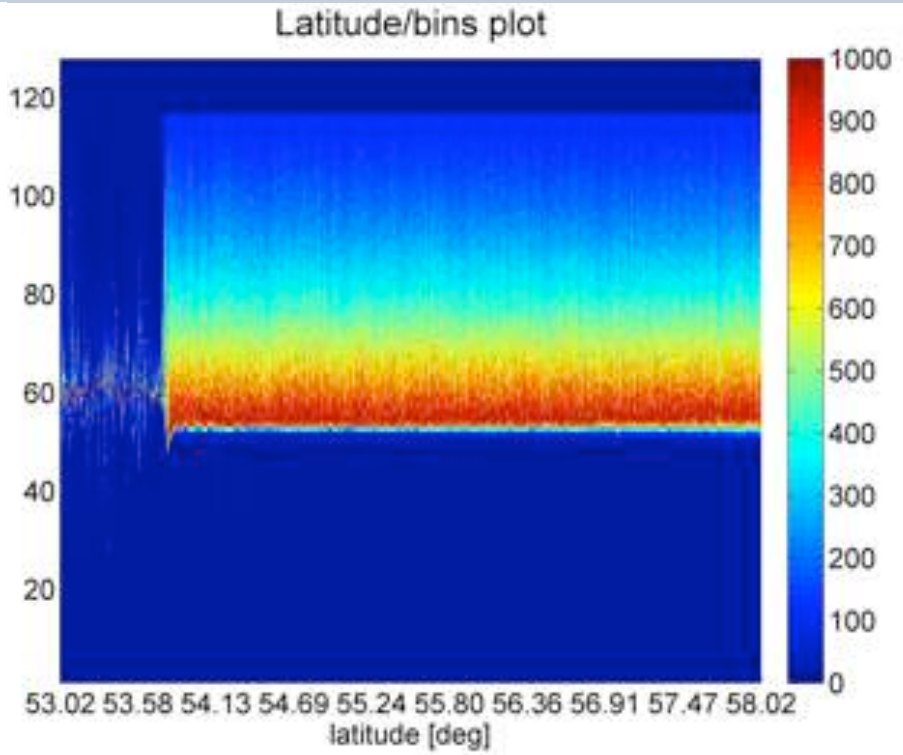
- "Satellite with ARGOS and Altimeter"
  - French/Indian satellite
  - Launched 25 Feb 2013
  - First Ka-band altimeter
  - Less affected by ionosphere
  - More power absorption by wet troposphere



Cyclone Xaver seen by SARAL/AltiKa — EUM/RSP/VWG/14/756175

Altimeter Waveforms





Cycle 5: Low wave height, low wind

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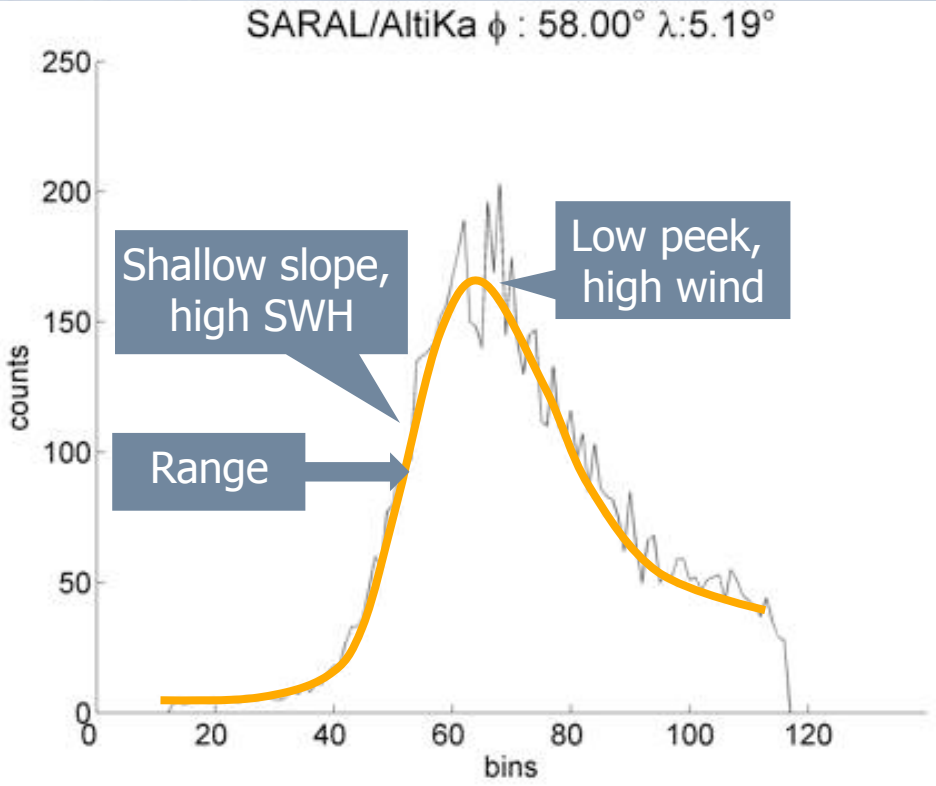
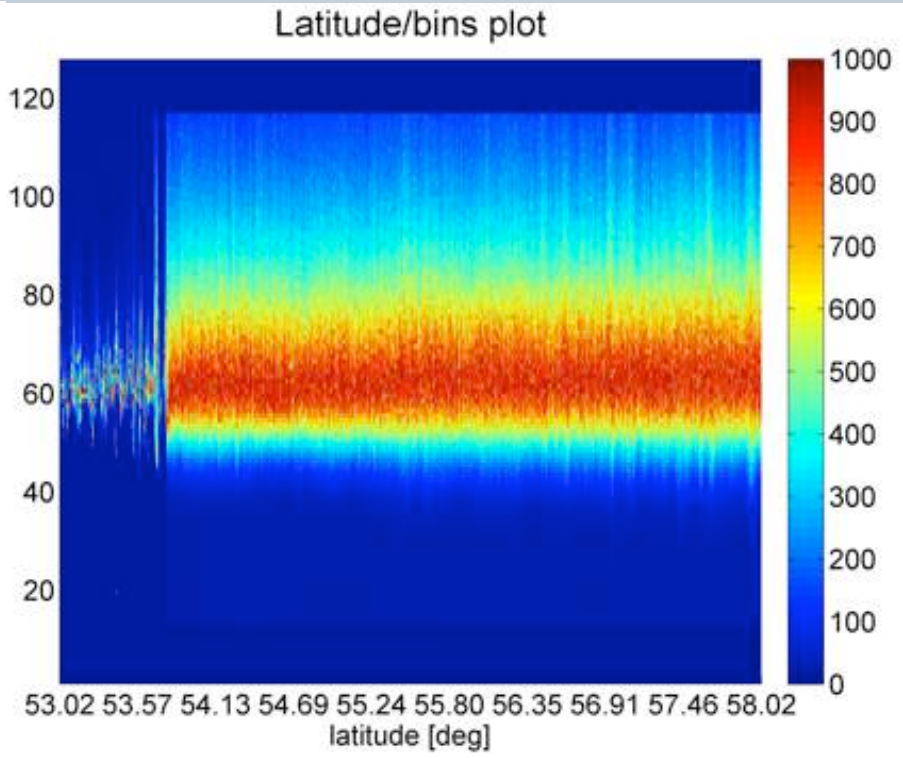
Altimeter Waveforms





Cycle 8: High wave height, high wind

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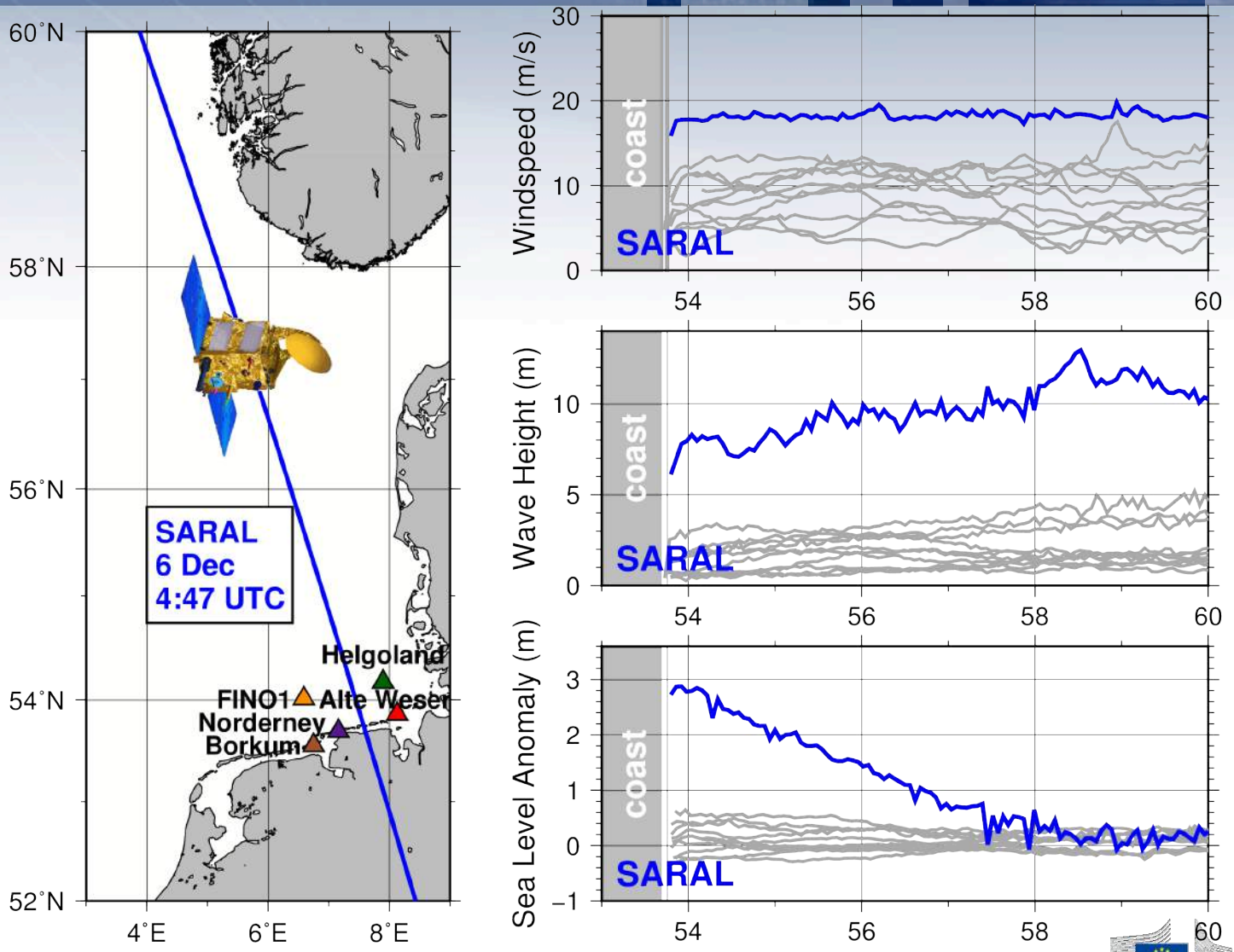
Significant Wave Height: Altimetry and Models



- Close to height of storm
- Heavily instrumented region
- Unique conditions
- Compared to 7 months before and 3 months after

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In-situ Instrumentation

German national water information system

- Data provided by Wasser- und Schifffahrtsverwaltung des Bundes (WSV)
- Tide gauges (water level)
- Anemometers (wind speed)
- Wave buoys (significant wave height, SWH)
- GNSS: making absolute sea level comparison possible
- Sampling: Every minute
- Data available in NRT at pegelonline.wsv.de

In-situ Instrumentation

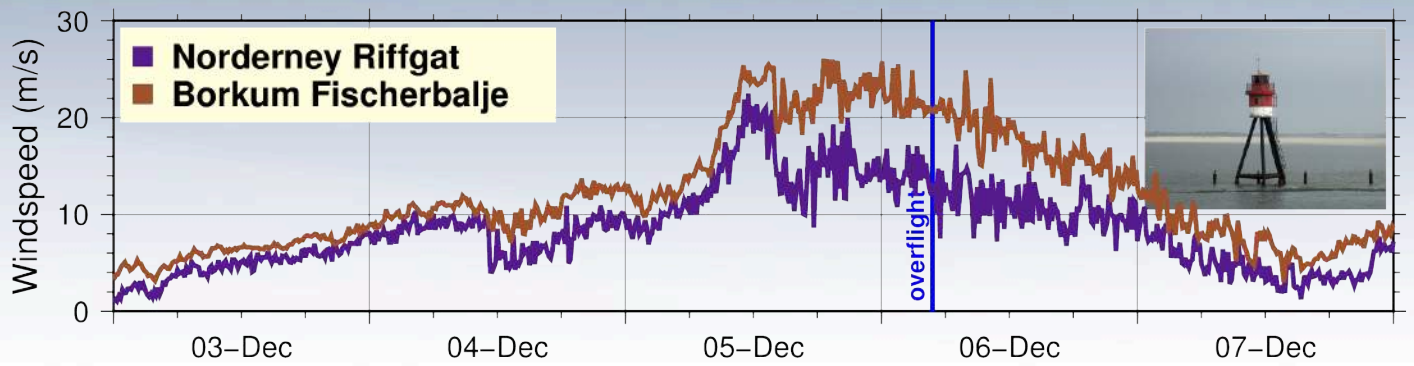
Off-shore platforms FINO1 and FINO3

- Courtesy of Bundesumweltministerium (BMU) and Projektträger Jülich (PTJ)
- Wind speed and multiple elevations
  - Will show @33 m elevation here
- Wave height
  - Acoustic Wave and Current Profiler (AWAC) every 30 minutes
  - Acoustic Doppler Current Profiler (ADCP) every 60 minutes

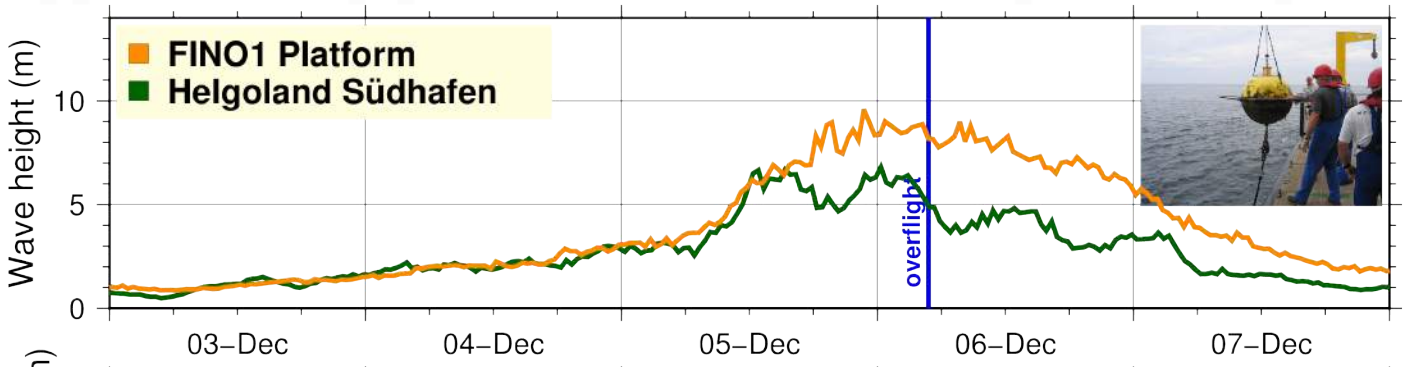
In-situ observations

Wind speed

- off-shore



Significant wave height

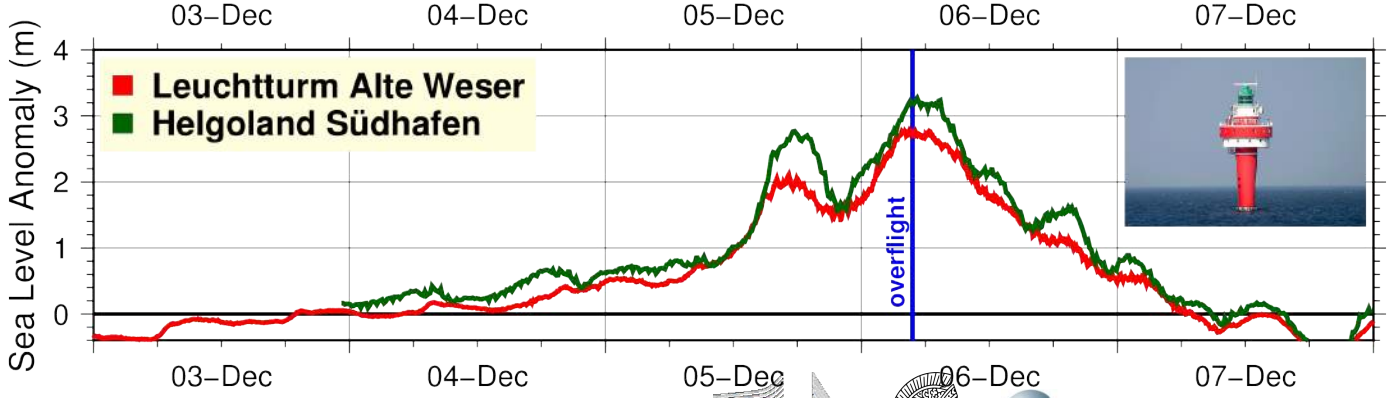


Storm surge

= water level

– astronom tide

– reference



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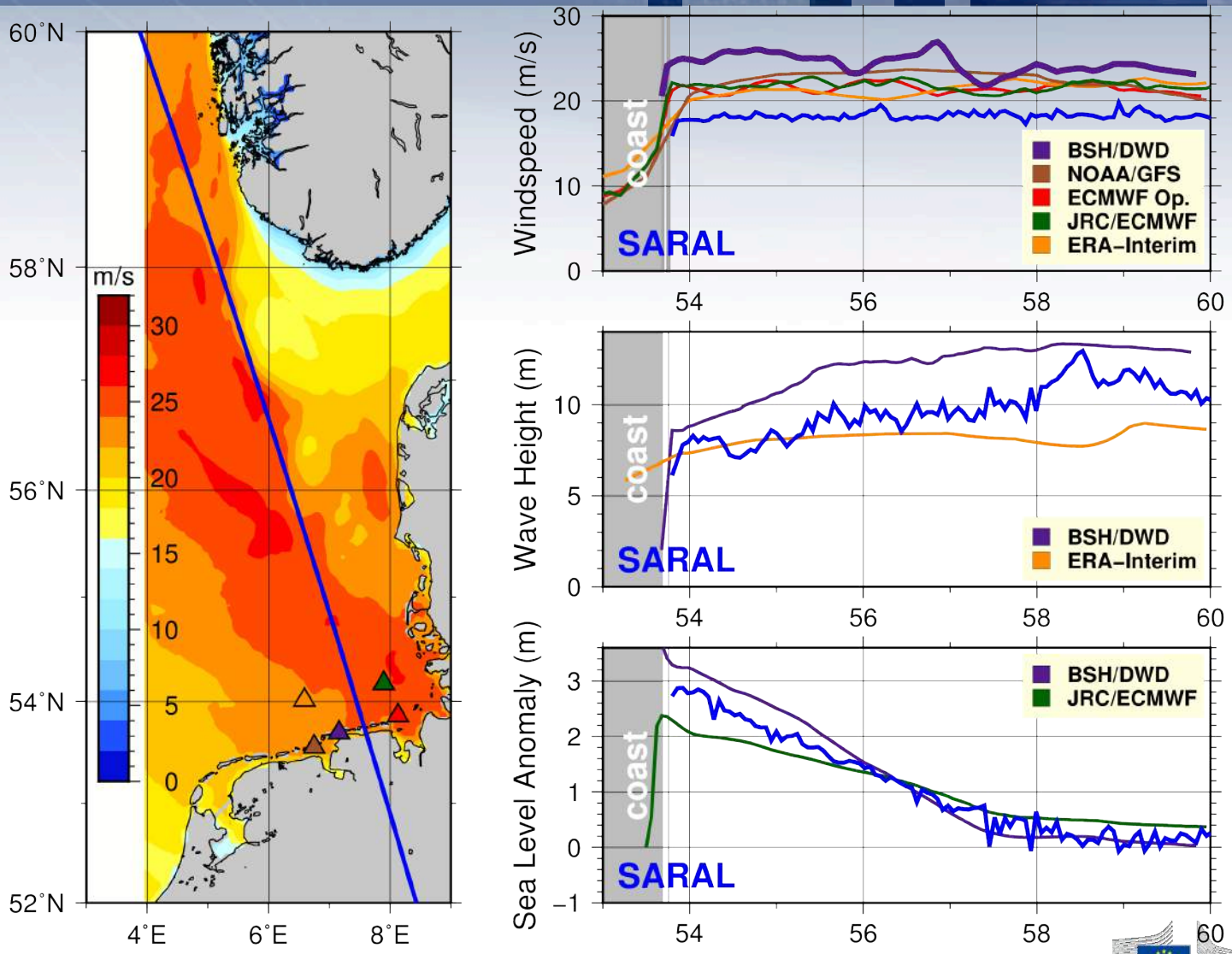
Meteorological and tide models

- ECMWF
  - Operational meteorological model (wind shown here)
- ERA-Interim
  - ECMWF Interim Reanalysis model
- NOAA/GFS
  - Global Forecasting System
- GOT4.8
  - Goddard (astronomical) Ocean Tide version 4.8
  - Used to reduce tide gauge measurements, satellite altimetry, and BSH model to surge height (sea level anomaly)

Storm surge models

- Bundesamt für Schifffahrt und Hydrologie (BSH)
  - BSHcmod is forced by Deutscher Wetterdienst (DWD) meteorological models
  - Daily 3-day forecasts of wind speed, wave height and water level (including tide)
  - Includes tides (not only surge)
  - Here GOT4.8 astronomical tide removed to obtain surge
- Joint Research Centre
  - Hyflux2 is forced by ECMWF meteorological model fields with 3-day lead time
  - Forecasts storm surge due to tropical cyclones (excluding tide)

Wind speed: Altimetry and Models



BSH/DWD Model

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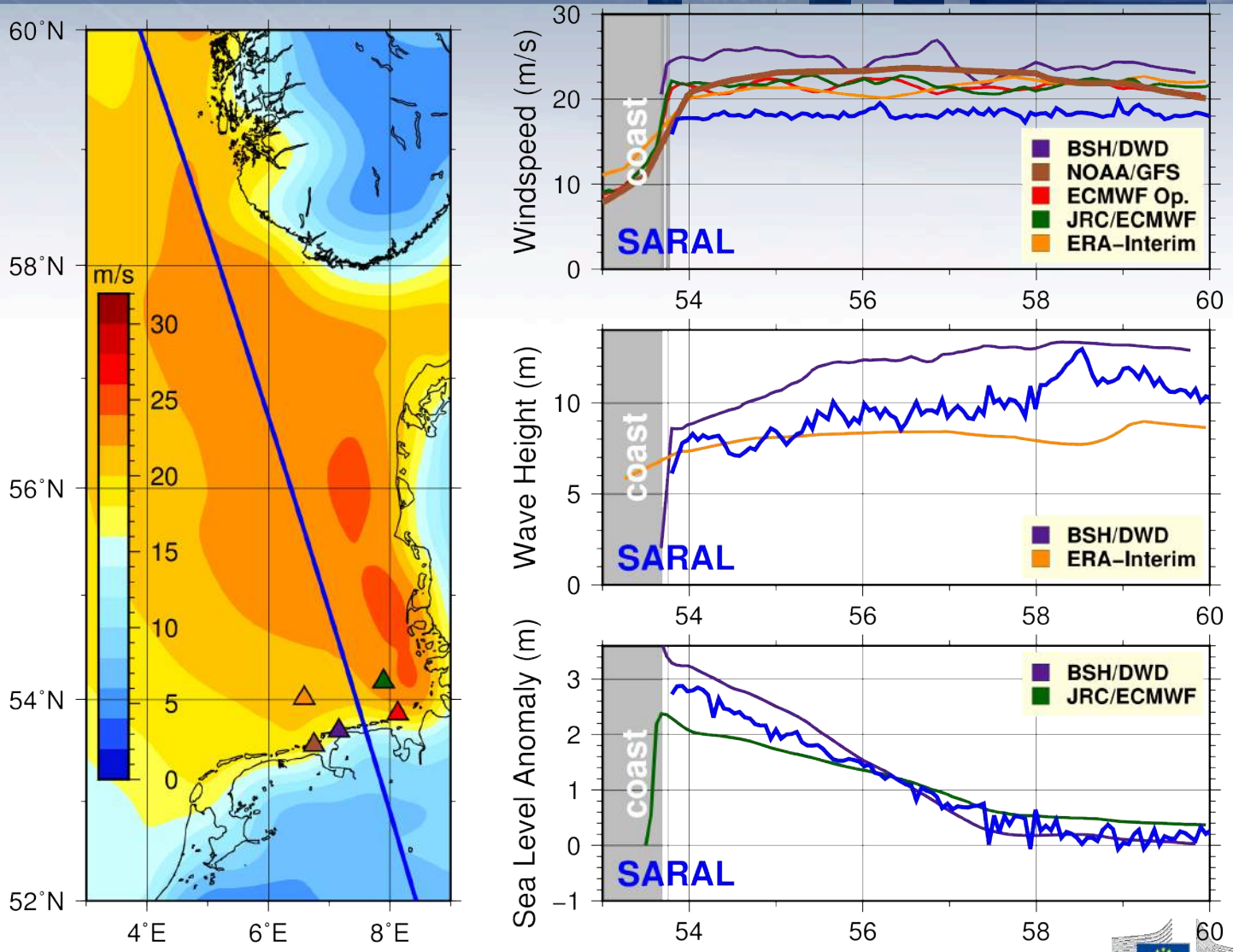
Wind speed: Altimetry and Models



NOAA/GFS Model

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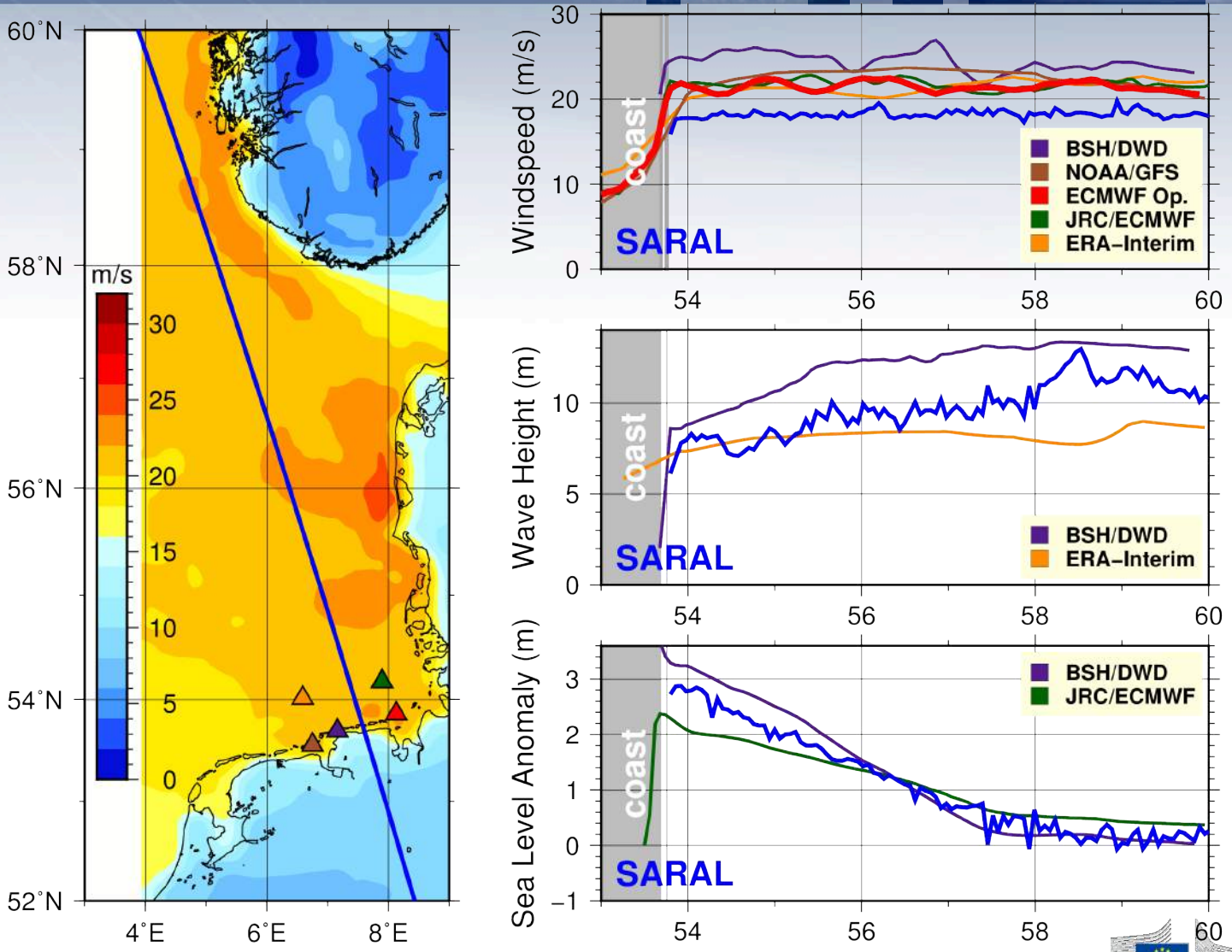
Wind speed: Altimetry and Models



ECMWF Operational Model

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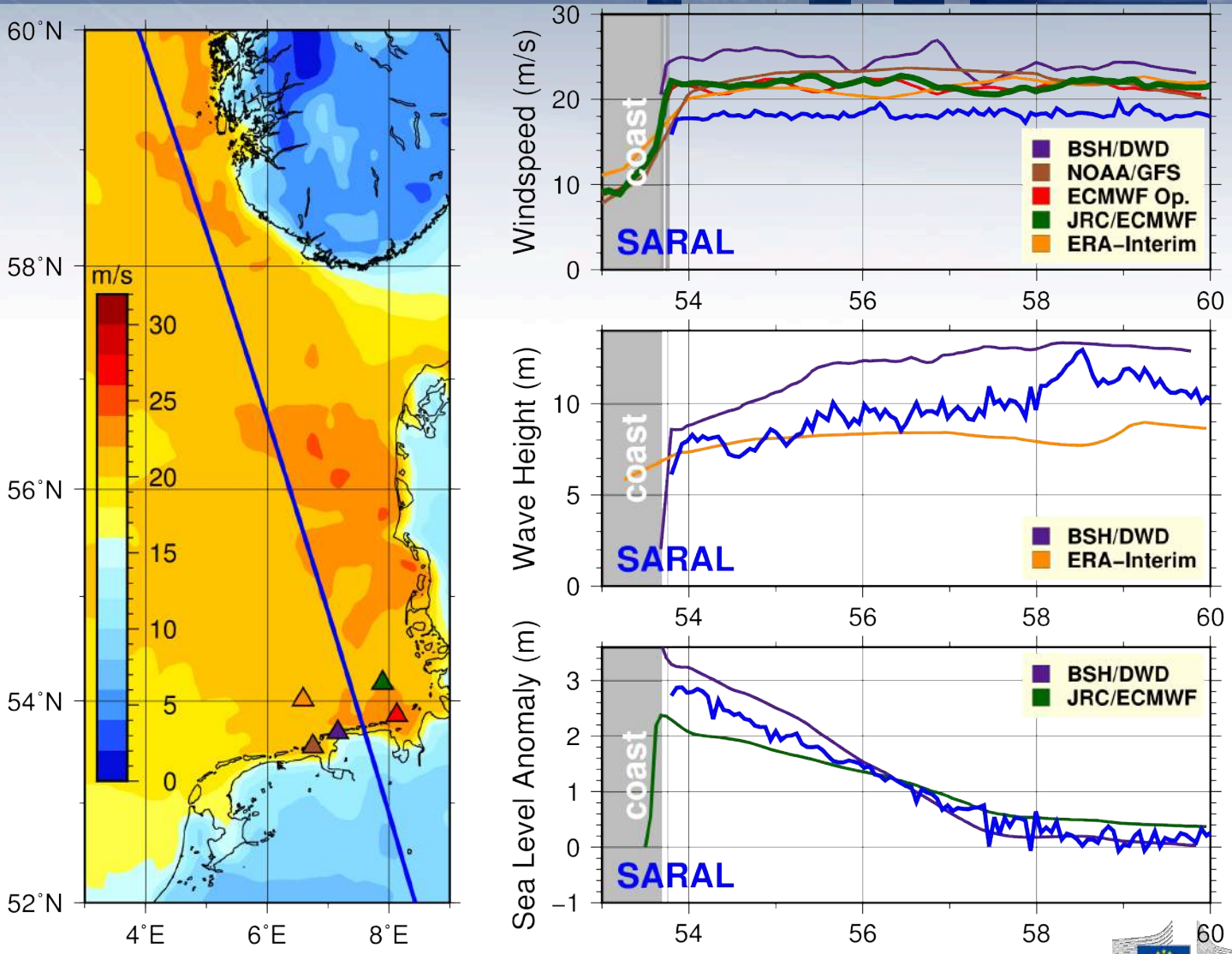
Wind speed: Altimetry and Models



JRC Hyflux2 Model

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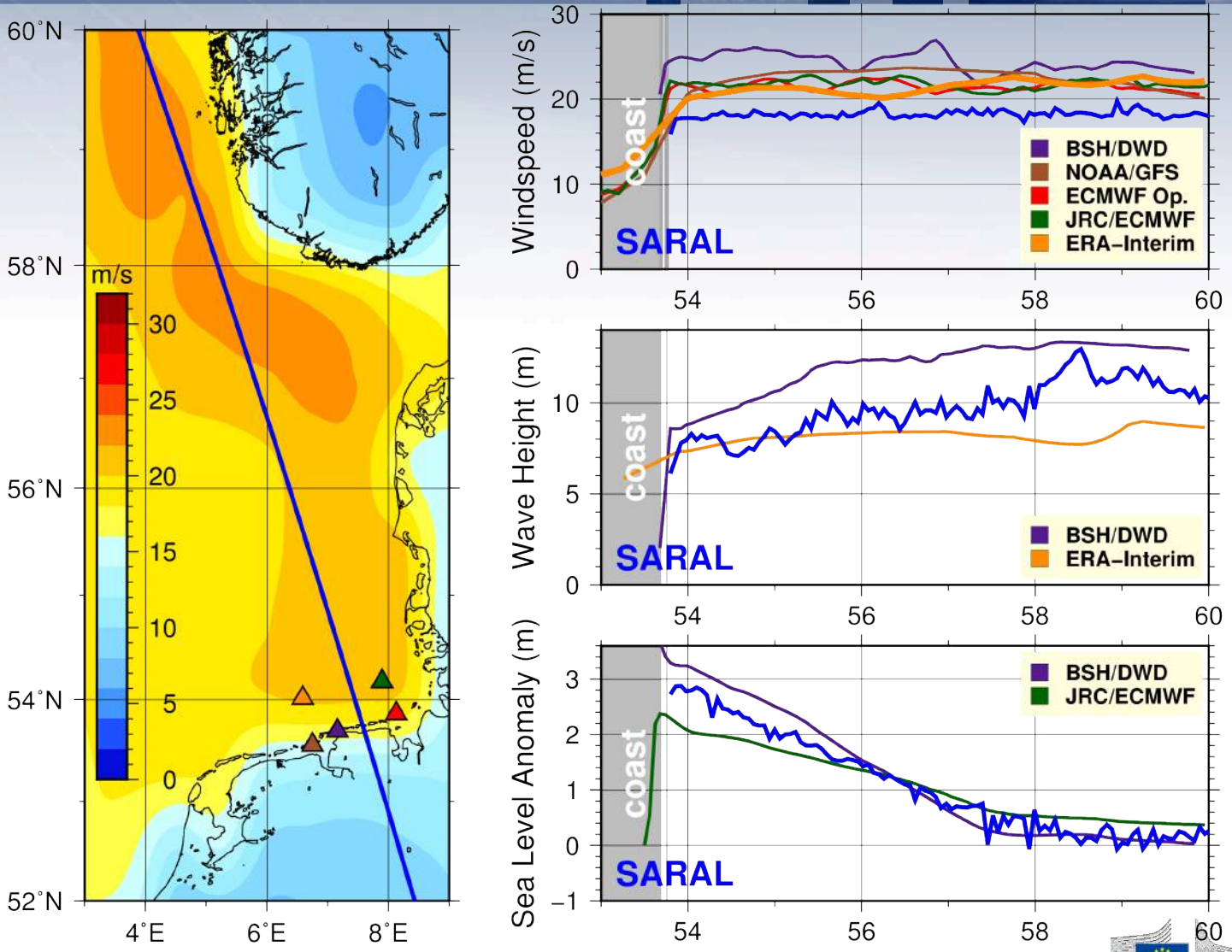
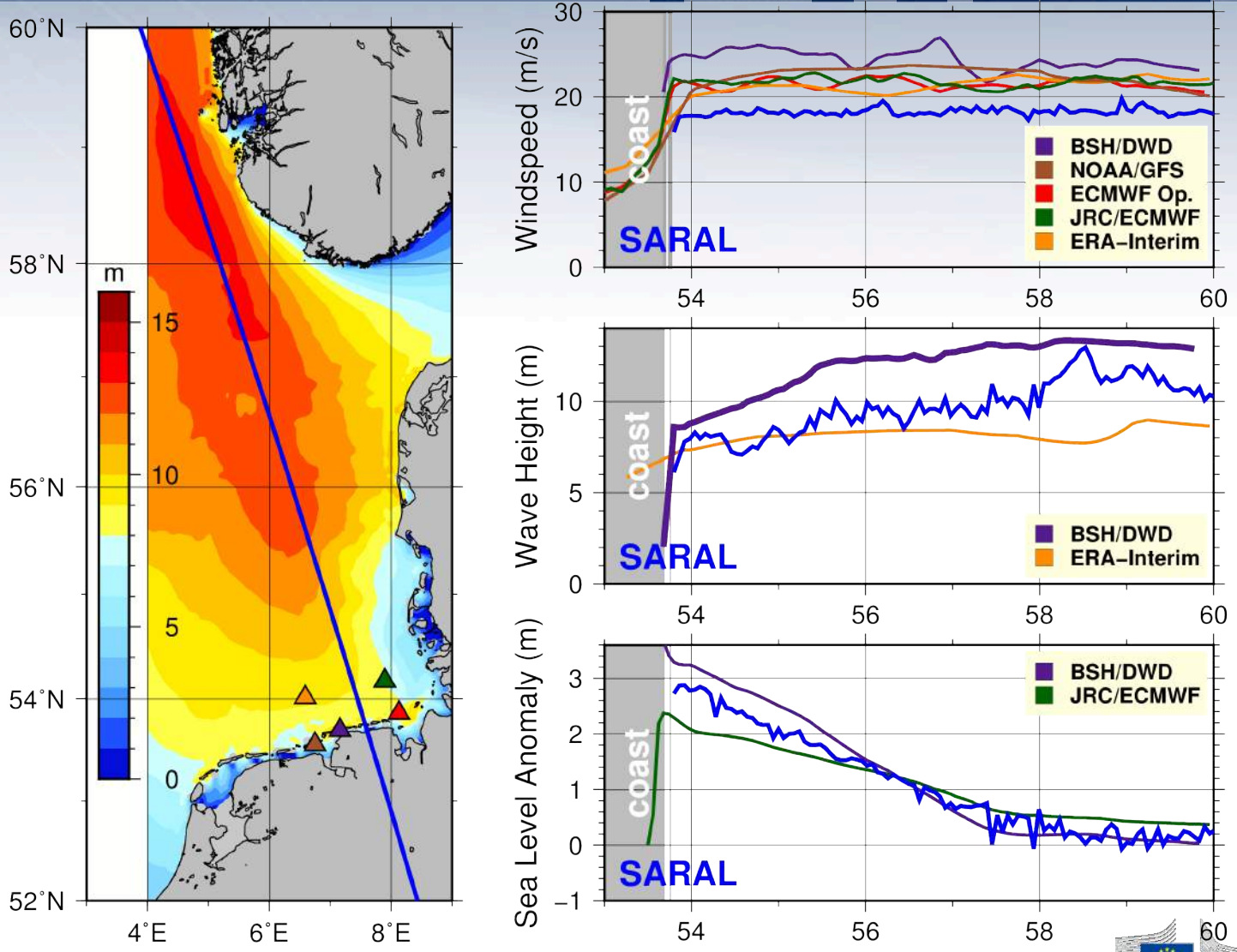
Wind speed: Altimetry and Models



ERA-Interim Model

Significant Wave Height: Altimetry and Models



BSH/DWD Model

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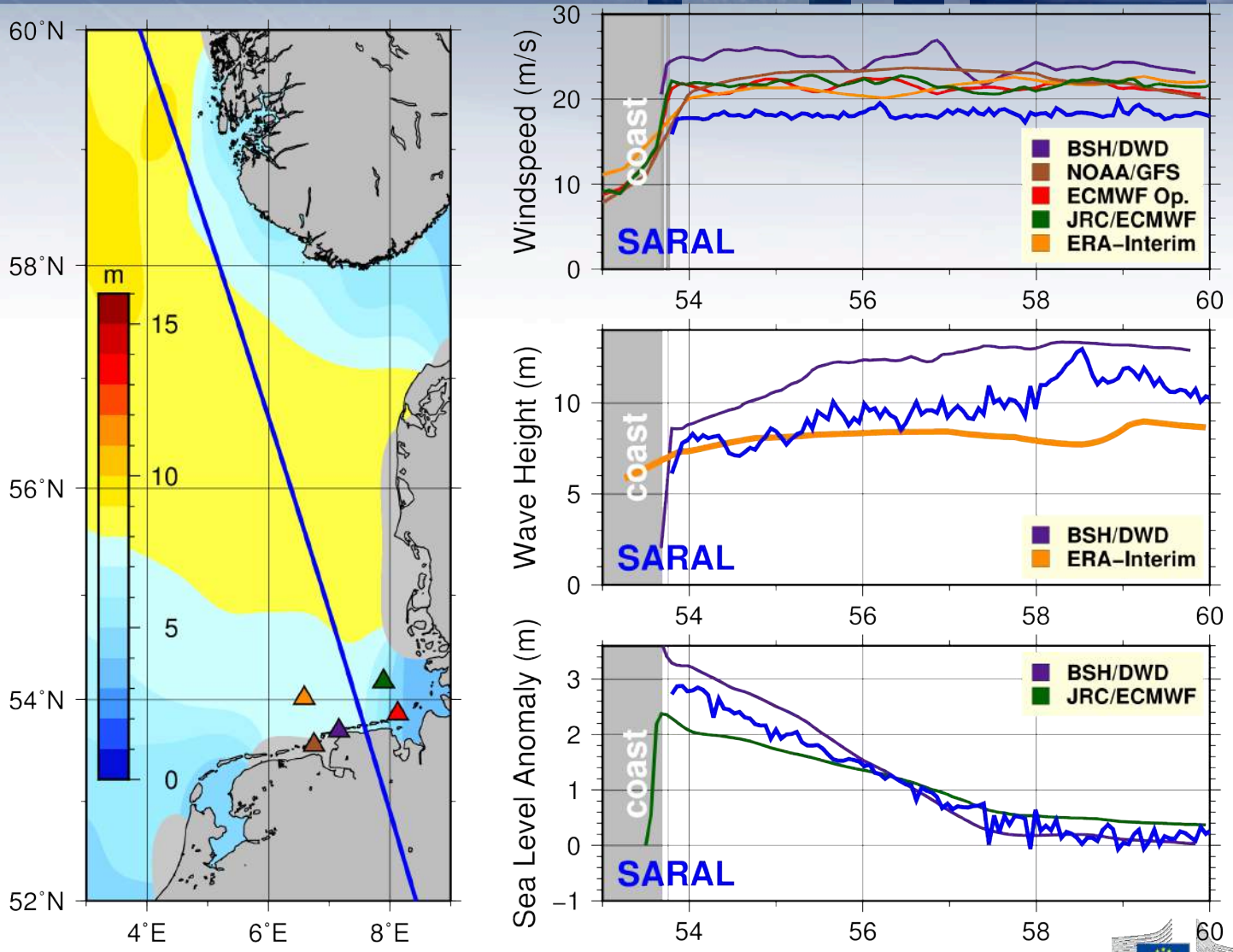
Significant Wave Height: Altimetry and Models



ERA-Interim Model

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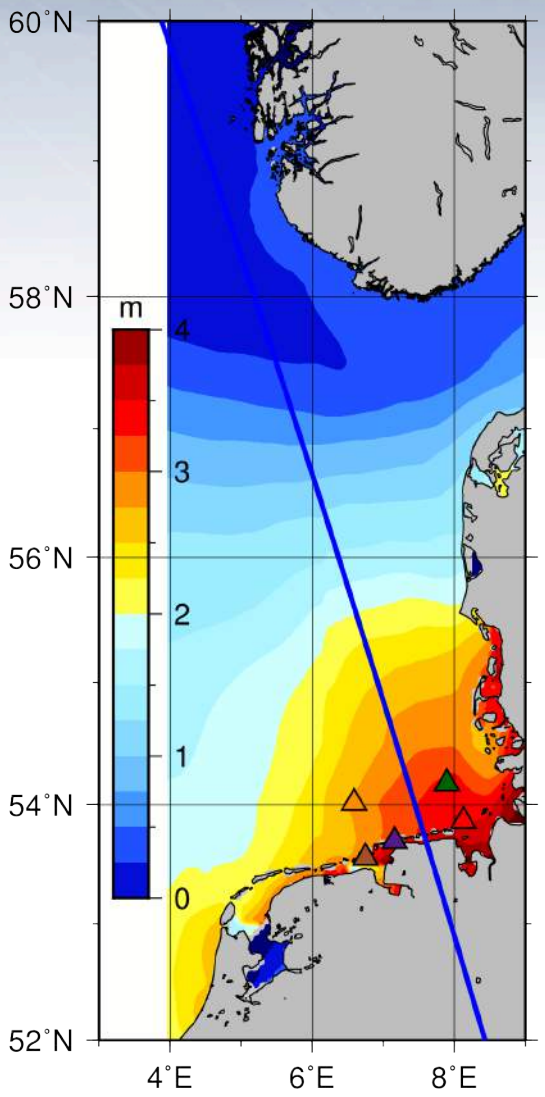
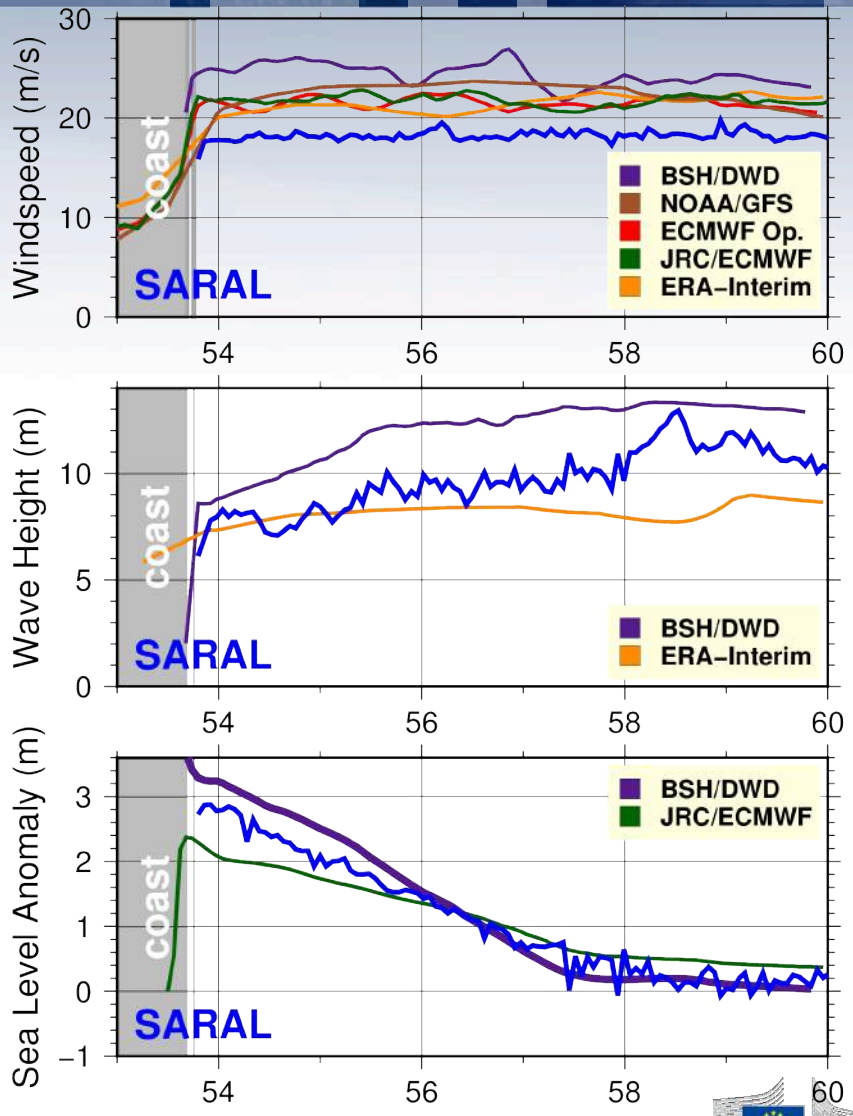
Surge Height: Altimetry and Models





BSH/DWD Model minus GOT4.8

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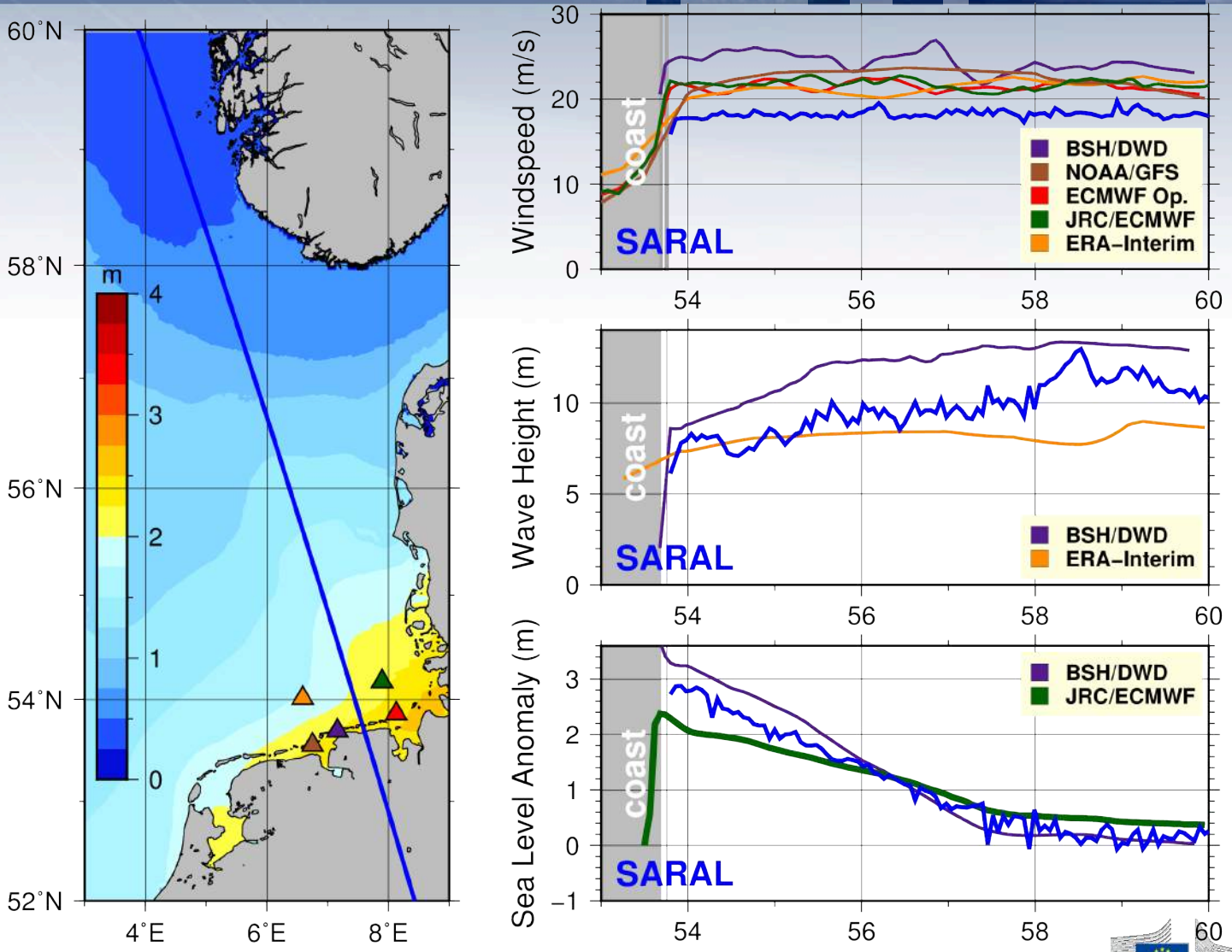
Surge Height: Altimetry and Models



JRC Hyflux2 Model

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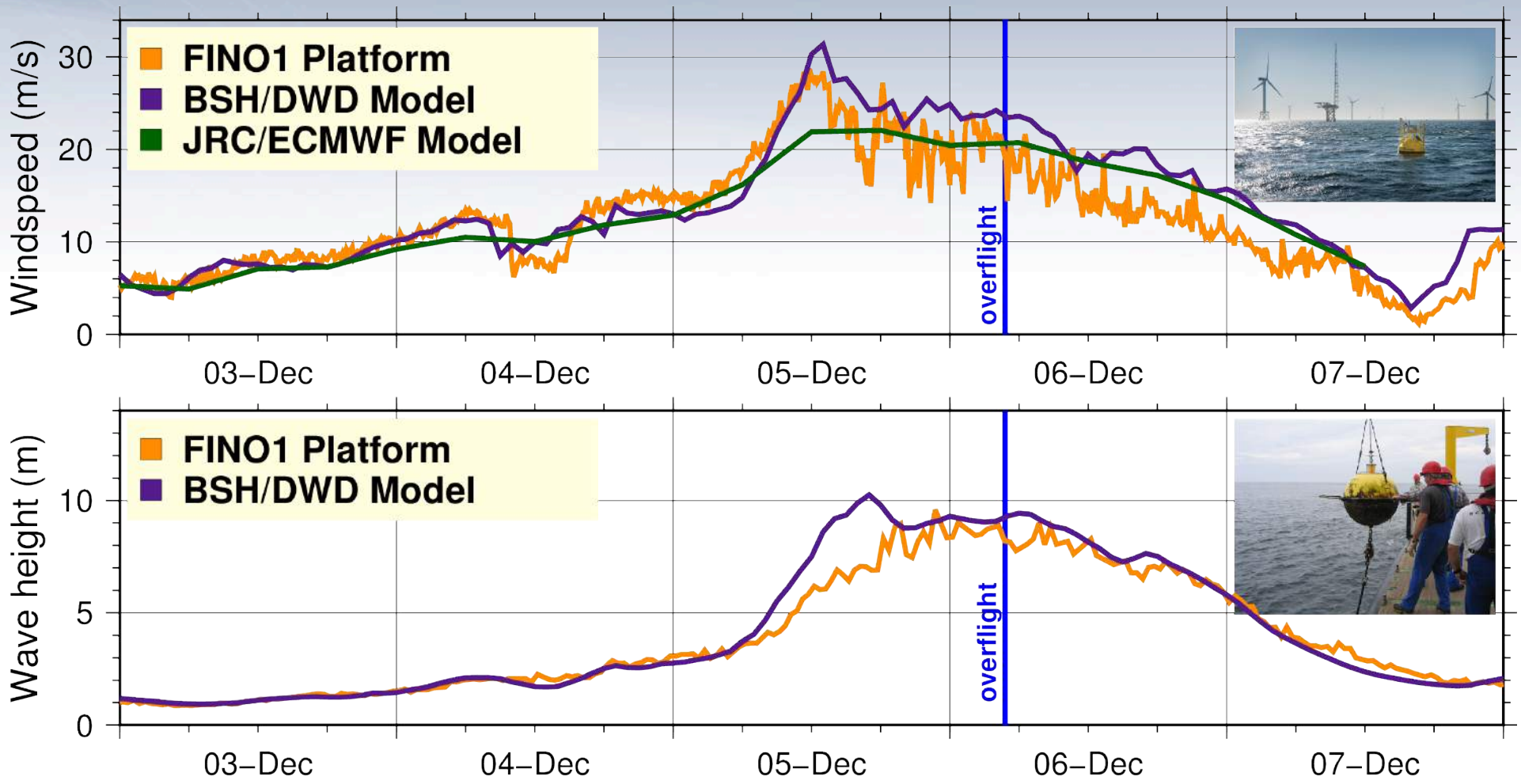
FINO1: Models and in-situ data



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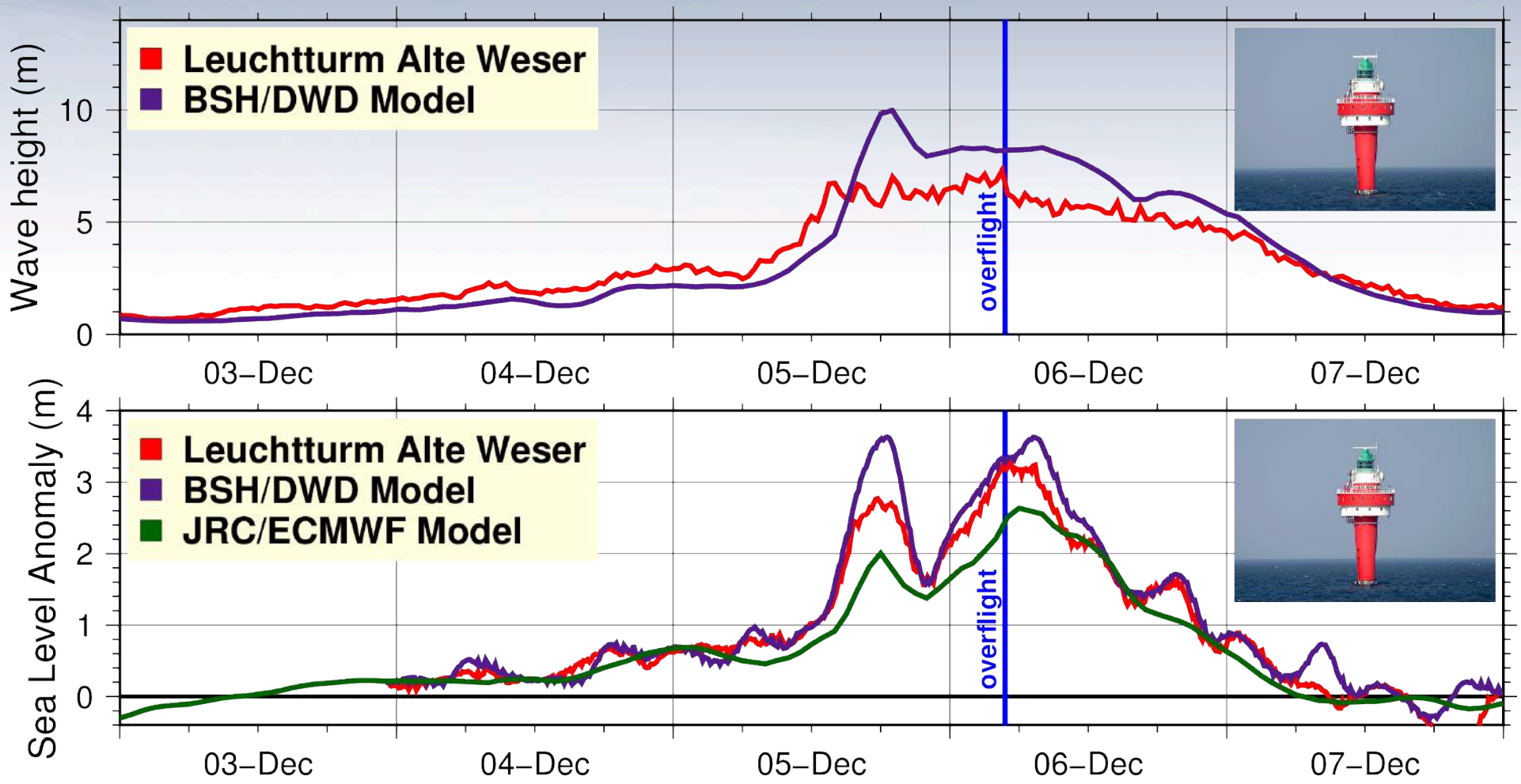
LHAW: Models and in-situ data



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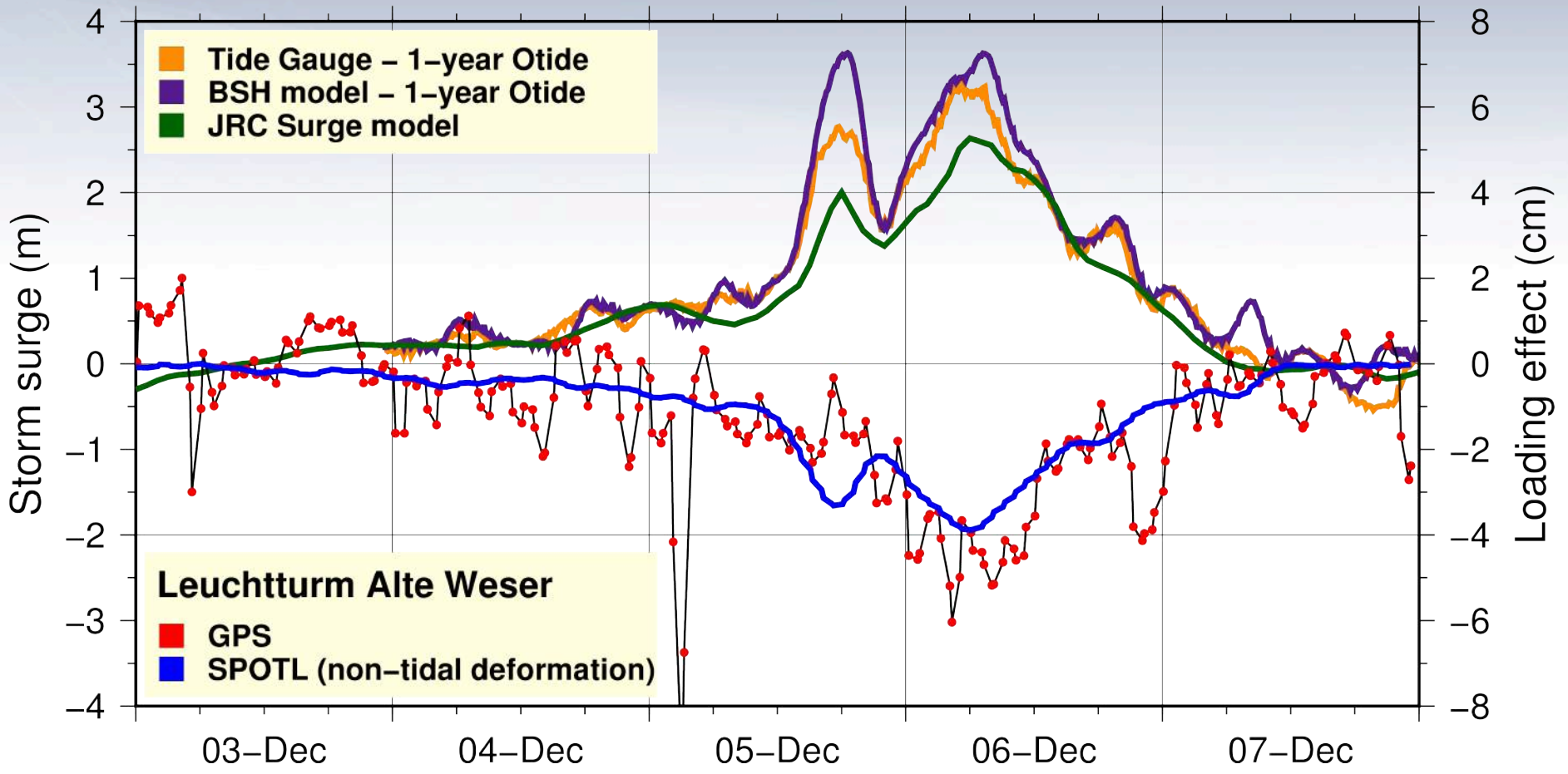
LHAW: Storm surge and induced vertical deformation



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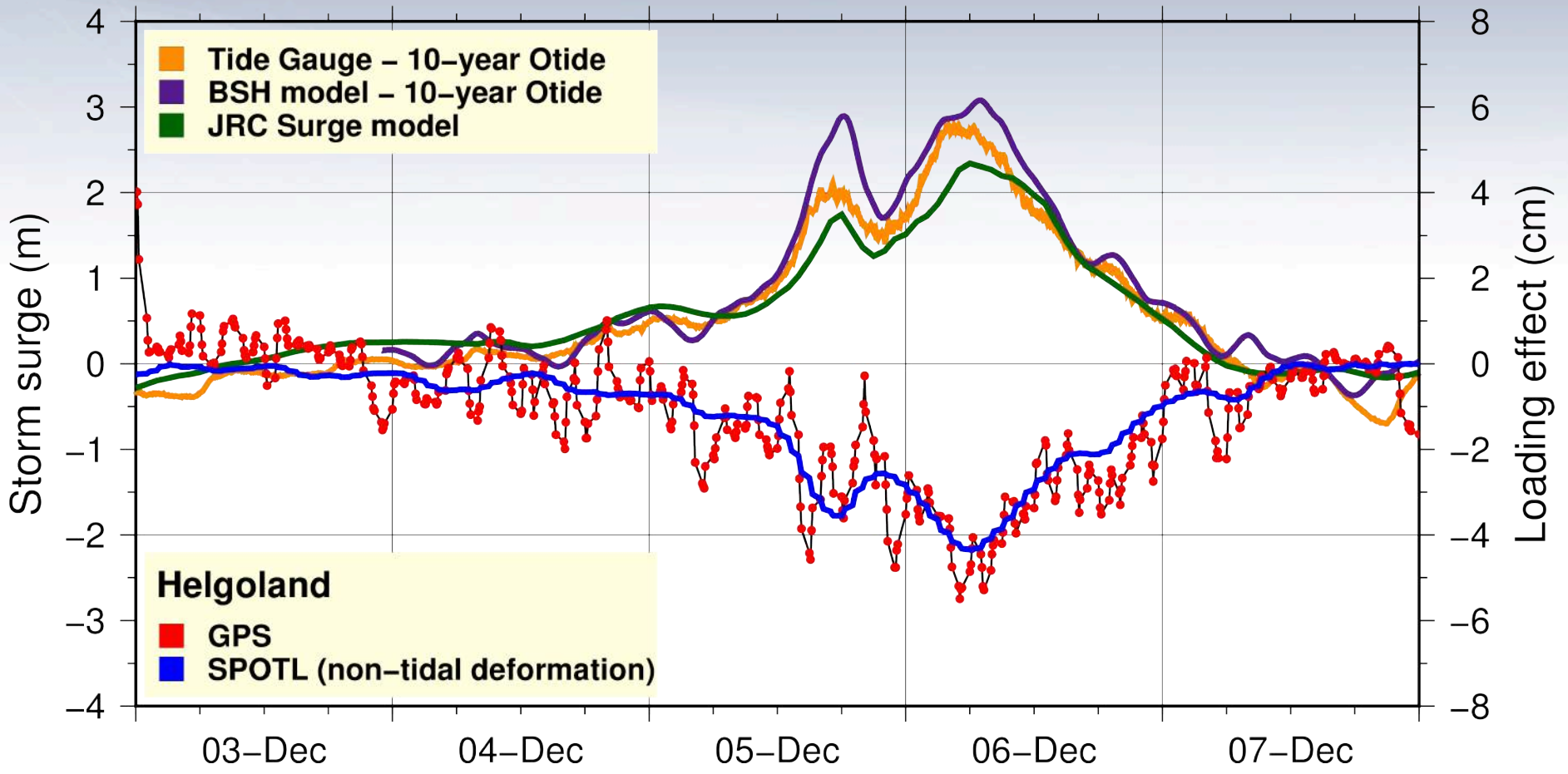
HELG: Storm surge and induced vertical deformation



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Conclusions

SARAL/AltiKa

- Unique snapshot pass of sea level, wind and wave height
- Appears to underestimate high wave height (~2 m) and high wind speed (~4 m/s)

Models

- Largely agree on wind speed (±1 m/s)
- Agree reasonably well with altimeter on surge (±50 cm)
- Differ with altimetry on wave height (±2 m)

In-situ data

- Largely agree with models, but differ on peak events
- Non-tidal VLM of 3-4 cm at maximum well detected by GPS