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UNDERWATER SOUND MAPPING: STATISTICS AND UNCERTAINTY

JOMOPANS WP4

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TNO innovation for life

FOI

Quiet oceans

JASCO APPLIED SCIENCES

NPL National Physical Laboratory

JOMOPANS

Joint Monitoring Programme for Ambient Noise in the North Sea

- **Objective**: develop a framework for a fully operational joint monitoring programme for ambient noise in the North Sea
- **Outputs**: tools for managers, planners and other stakeholders
  - Implementation EU Marine Strategy Framework Directive

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JOMOPANS Project

- Funding: EU-Interreg North Sea Region
- Consortium: 11 partners (7 countries)
- Project Coordinator: Rijkswaterstaat (NL)
- Duration: Jan 2018 – Dec 2020

See poster **89** Kinneging et al *JOMOPANS*

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Ambient Noise Monitoring

See poster **71** Ainslie et al. *International standardization in underwater bioacoustics*

- No international standards
  - will be discussed at IQOE workshop, Saturday 13 July 2019
- Ambient noise sources:
  - Natural and Anthropogenic
- Ambient noise varies with time and (three-dimensional) location
- Measurements and modelling: SOUND MAPS

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International Quiet Ocean Experiment

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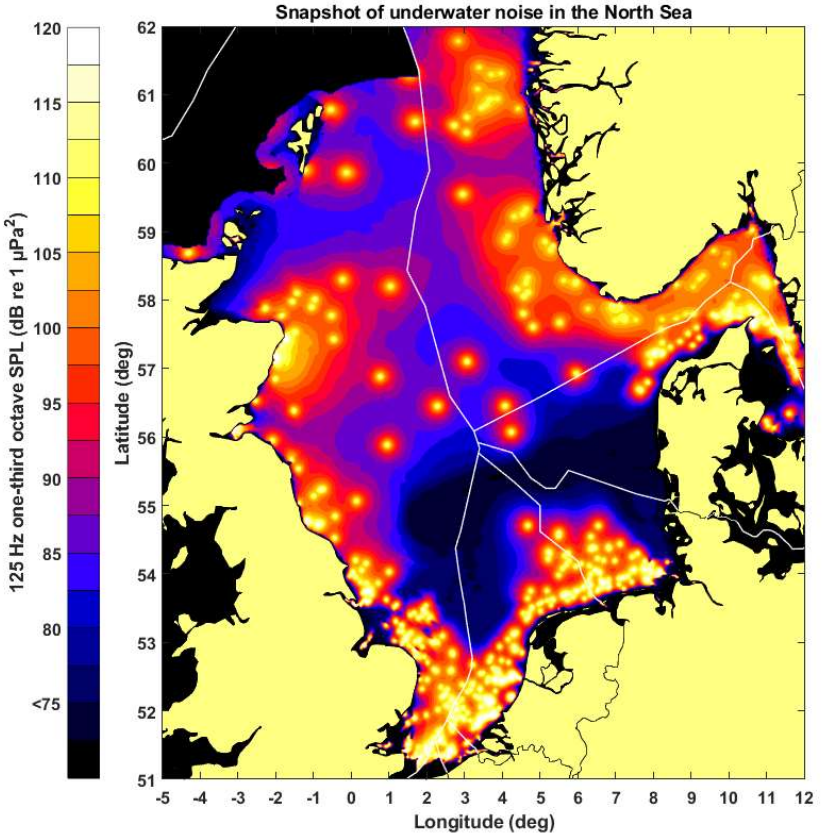
SOUND MAP - OPTIONS

- Which quantity ?
  - Sound Pressure Level $(T = 1\ \mathrm{s})$
- Which sound sources ?
  - Ships (AIS) and wind (Copernicus)
- Over which period ?
  - Single 1s snapshot on 1 Jan 2019
- Which frequency range ?
  - 125 Hz one-third octave (base-10) band
- What depth ?
  - Depth averaged
- Which models (source and propagation) ?
- Which input data ?
- At what uncertainty ?



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JOMOPANS ambient noise metric

Physical quantity	**Sound pressure level, dB re 1 µPa**
Snapshot duration	**1 second**
Analysis period	**1 month**
Time percentiles (*P*%)	**5, 10, 25, 50, 75, 90, 95**
Frequency	**One-third octave (base-10) bands**, with centre frequencies ranging from **10 Hz to 20 kHz**
Geospatial	**Depth-averaged value** either at the centroid of each grid cell, or as a spatial average of the levels within the grid cell.

Maximum depth-averaged SPL reached *P*% of the time per month

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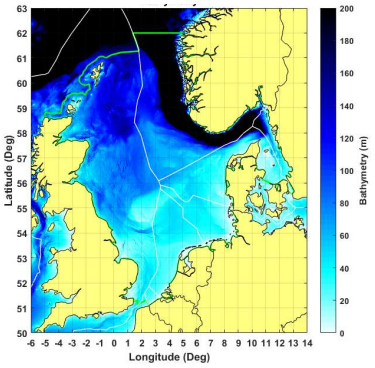
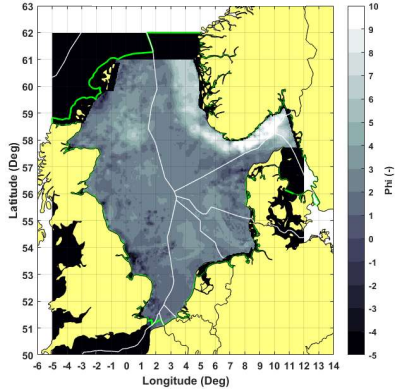
Models and data – SHIPS & WIND

- Bathymetry and geology
  - European Marine Observation and Data Network (EMODnet)
- Wind, waves and sound speed profiles
  - European Union COPERNICUS marine environment monitoring service
- Acoustic propagation models
  - Normal modes, Parabolic Equation, Rays, …
- Shipping data (from AIS)
- Empirical ship and wind source models
- Statistics & uncertainty

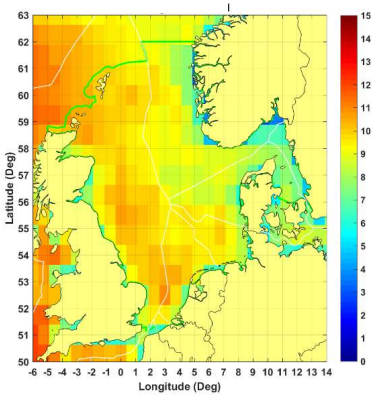
bathymetry



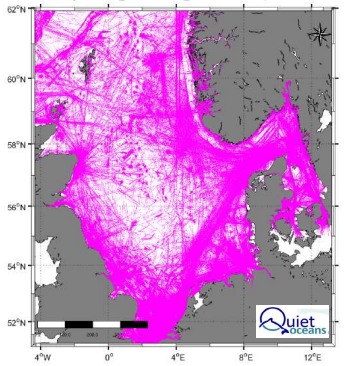
sediment



wind



ships (AIS)



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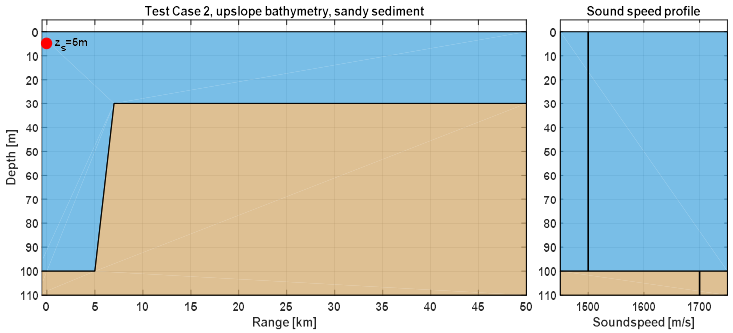
Propagation model benchmarks

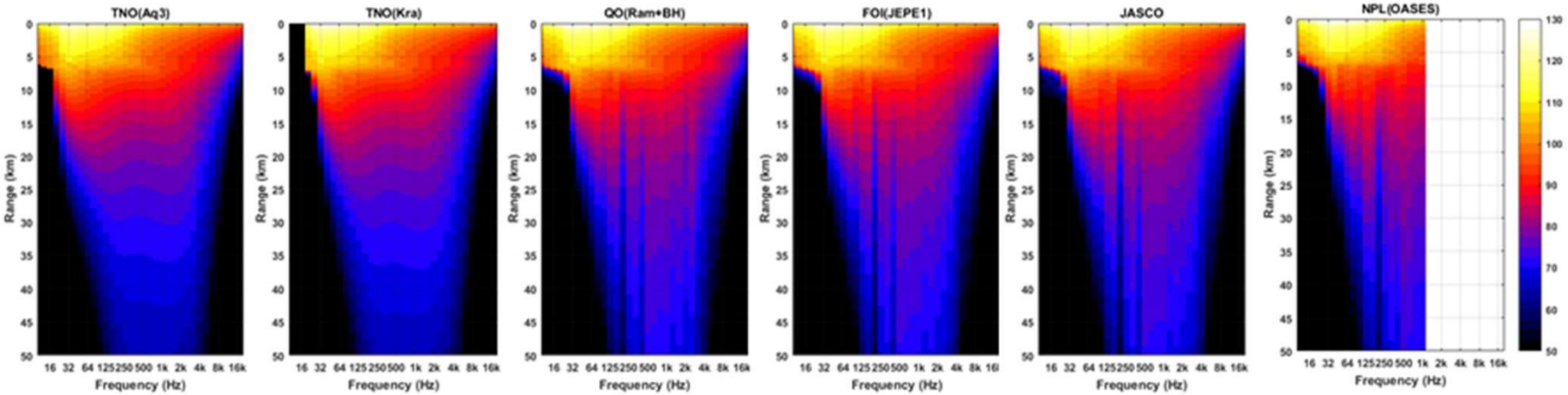
Two well-defined scenarios

- broadband SPL differences < ~2 dB (beyond 1 km)
- one-third octave band SPL differences < ~5 dB (>~32 Hz and beyond 500 m)

See UACE 2019 paper
Binnerts et al



Incoherent normal modes | Parabolic equation | Wavenumber integration



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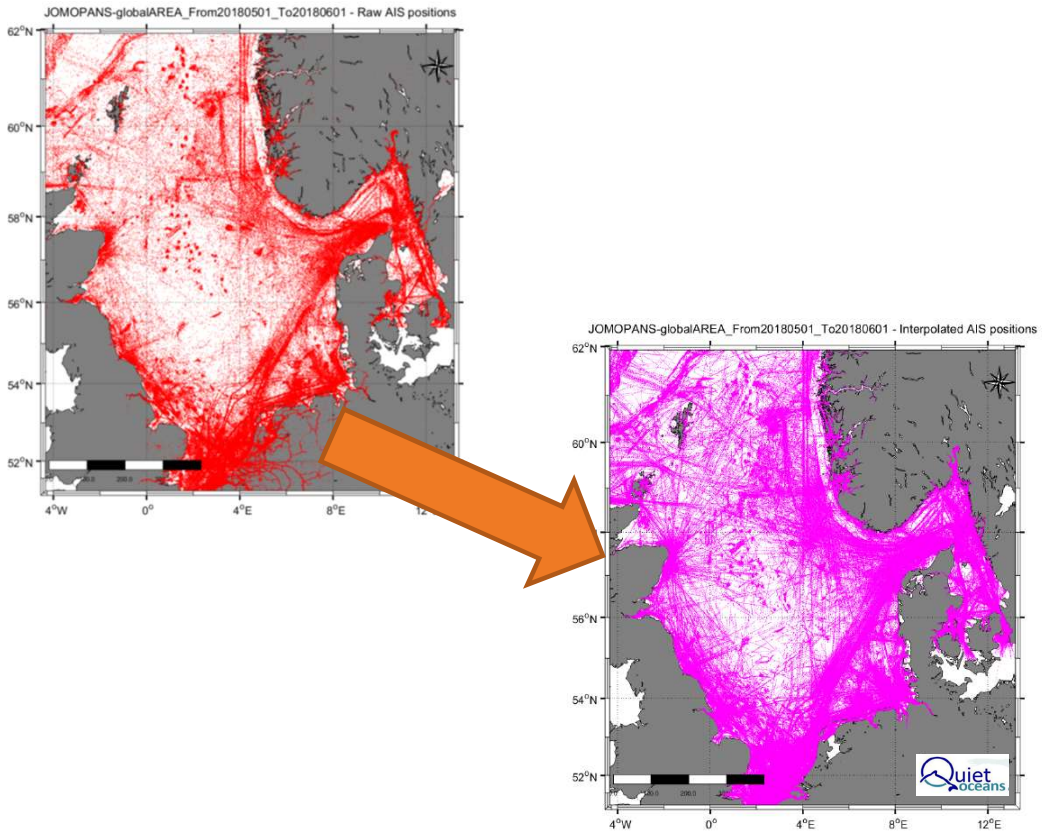
Ship noise modelling – AIS data

- Processed AIS information
  - Check & correction
  - Interpolation to a regular time grid
- Per ship, per time step
  - ship type & length
  - Location & speed



AIS Ship type

AIS 10	
AIS 30	Fishery
AIS 50	Research/Tug
AIS 60	Passenger
AIS 70	Cargo
AIS 80	Tanker
AIS 90	Bulk Carrier

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Ship Source Level: ECHO data analysis

PORT of vancouver

Enhancing Cetacean Habitat and Observation (ECHO) Program

Transport Canada / Transports Canada

JASCO APPLIED SCIENCES

- 1862 vessels measured
- SL calculated for source depth 6 m
- 'Voluntary slow down' included

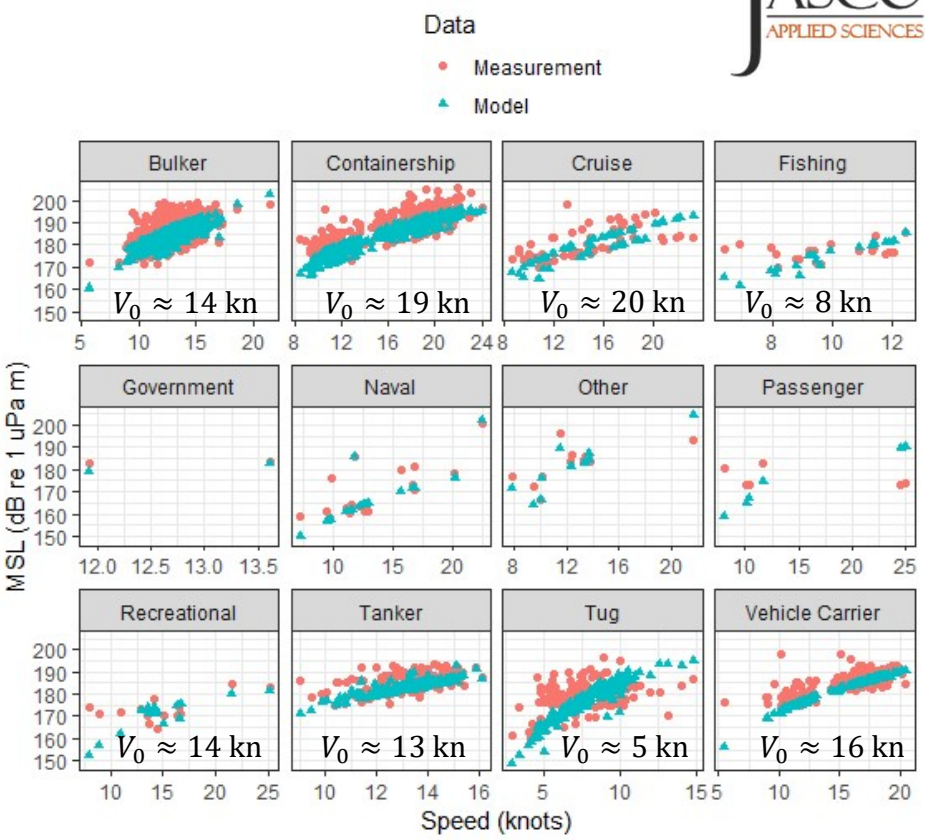
RANDI-3 model [Breeding et al 1996] :

$$L_S(f,V,L) = L_{S_0}(f) + 60\log_{10}(V/V_0)\ \text{dB} + 20\log_{10}(L/L_0)\ \text{dB}$$

speed V length L

JOMOPANS update:

- reference speed (V_0) fitted per ship type
- Standard deviation $\sigma_{L_S}(f, type)$



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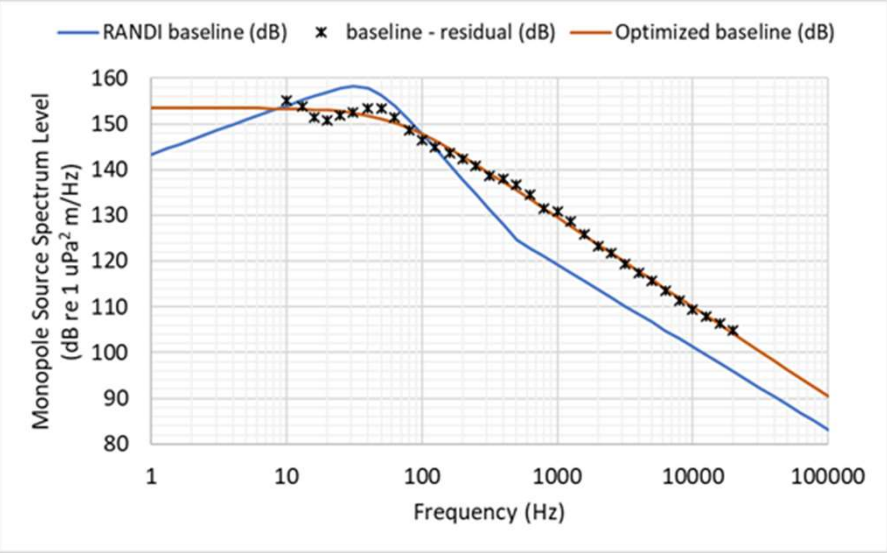
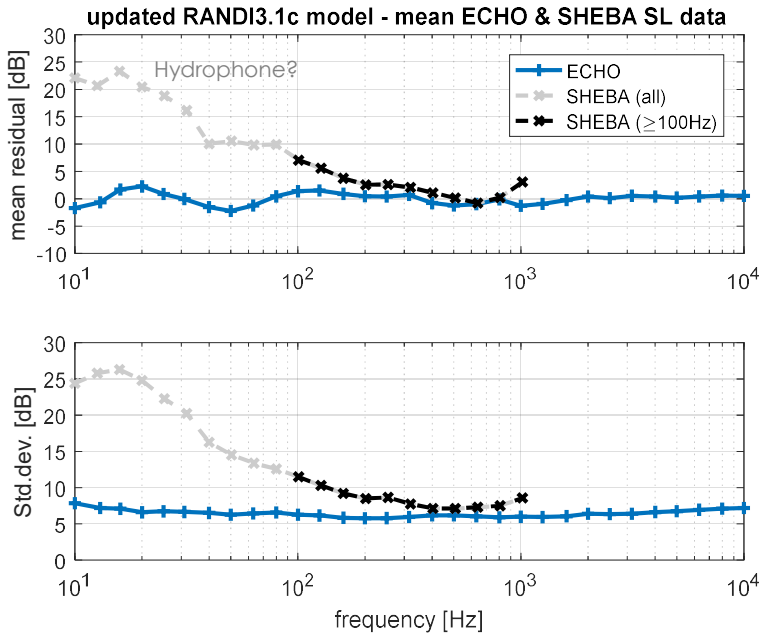
Updated ship source level model (2)

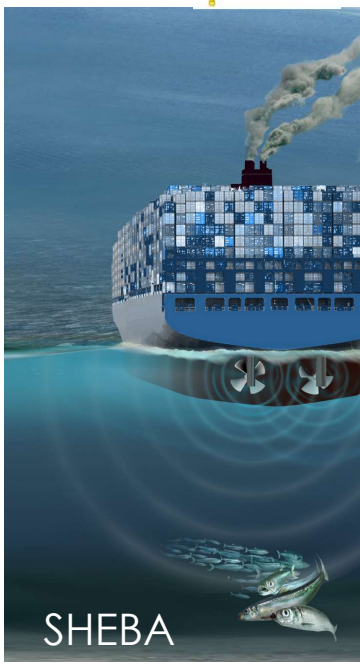
- RANDI-3 baseline spectrum $L_{S_0}(f)$ adapted to ECHO data





- Compared with SHEBA data

→ model – data residuals
and standard deviation:



Sustainable Shipping and Environment of the Baltic Sea region

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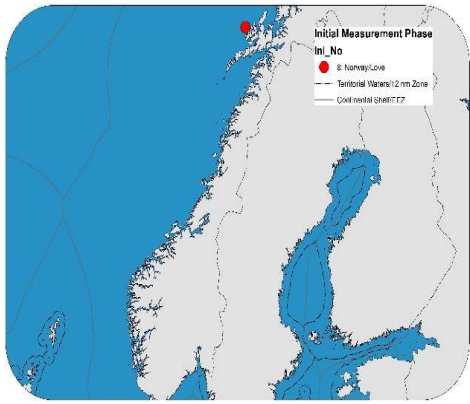
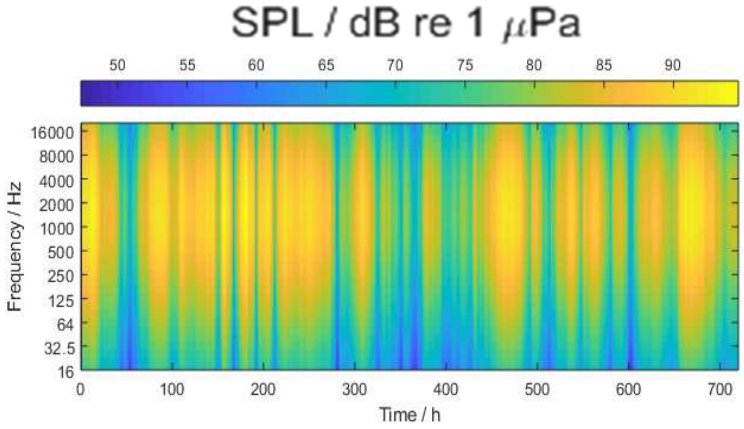
Wind noise (example)

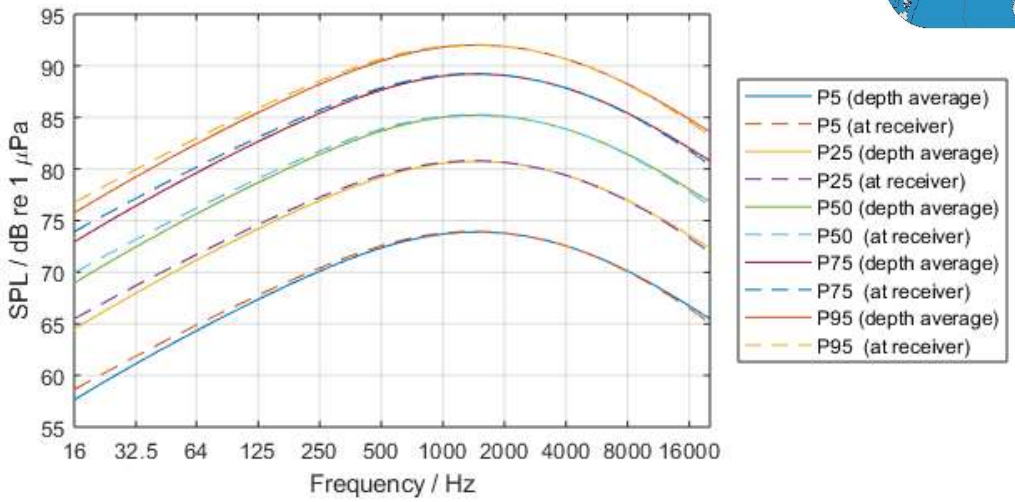
LoVe station



JASCO / TNO wind noise model



Percentiles



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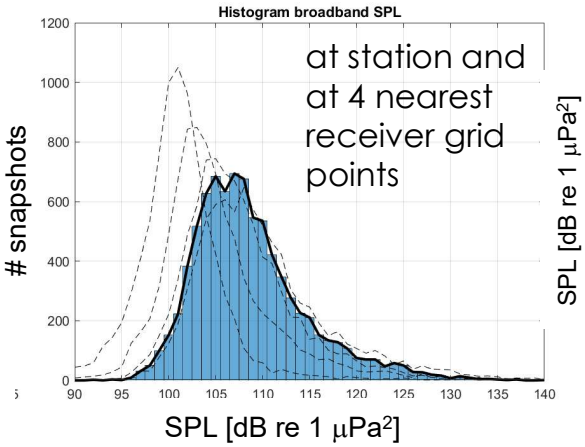
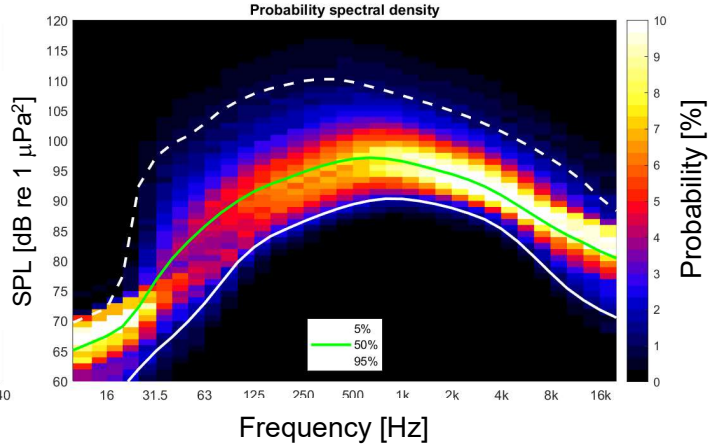
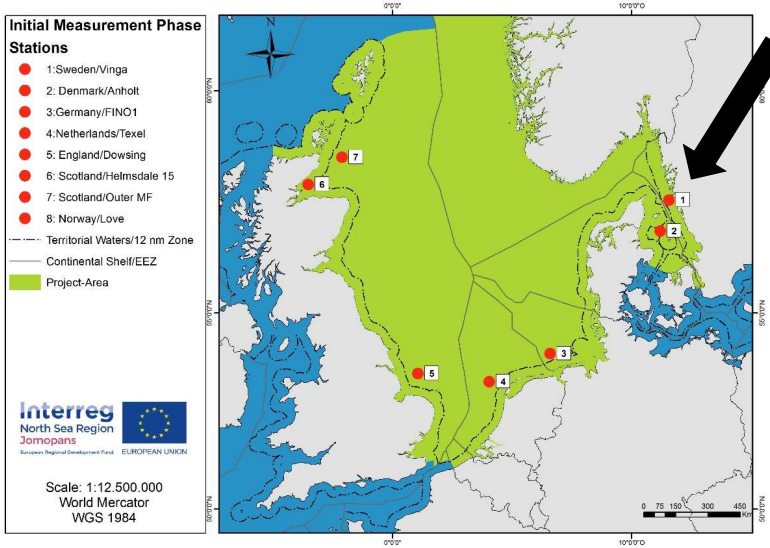
Model results for validation

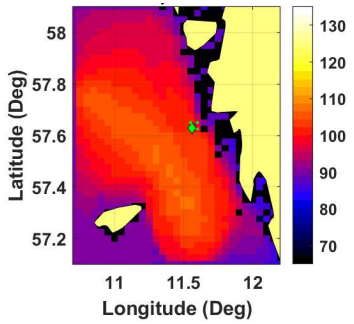
- 8 measurement sites (each one month in 2018)
- EXAMPLE: station 1 (Vinga, Sweden, April 2018)



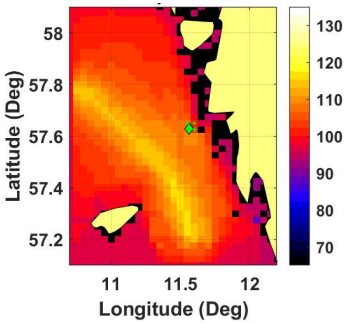




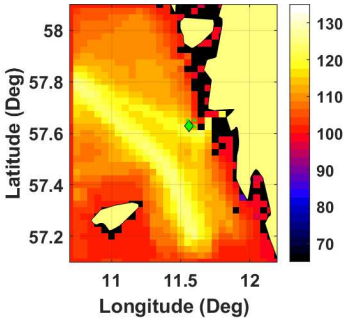
10th percentile



50th percentile



90th percentile



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Uncertainty

- Ship source level estimation (σ ~7 dB, from ECHO validation study)
- Propagation loss calculation (σ dependent on location)
- Wind noise calculation (σ to be determined)

- 'Monte-Carlo' assessment of the uncertainty in the acoustic metrics
  - SPL time percentiles + variance

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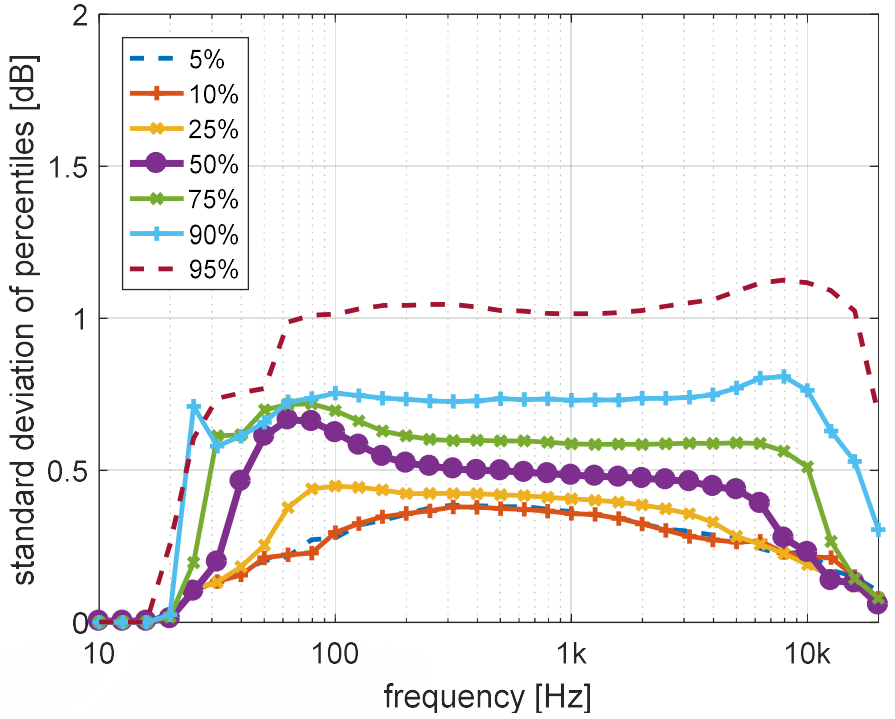
Source Level Uncertainty

- Ship source level uncertainty: σ ~7 dB (from ECHO study)
- 100 random SL realisations per ship for 2018 Vinga site modelling



Uncertainty in monthly SPL percentiles ≤ 1 dB

To be confirmed for other locations

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Conclusion

- Ambient noise monitoring = measurement + modelling
- Need for international ambient noise monitoring standards
- Proposal for model validation and uncertainty assessment

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JOMOPANS PARTNERS

- Rijkswaterstaat - NL(lead)
- Centre for Environment, Fisheries & Aquaculture Science (Cefas)– UK
- Federal Maritime and Hydrographic Agency – DE
- TNO – NL
- Aarhus University – DK
- Swedish Defence Research Agency – SE
- Royal Belgian Institute for Natural Sciences – BE
- Marine Scotland – UK
- Norwegian Defence Research Establishment - NO
- National Physical Laboratory – UK
- Institute of Marine Research - NO

JOMOPANS ambition

- Provide guidelines / standards for
  - terminology;
  - specification, calibration and deployment of measurement equipment;
  - benchmarking for analysis of the measured data;
  - benchmarking for acoustic models.

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