Acoustic sensing of ocean temperature in Fram Strait

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Acoustic Thermometry Experiment in Fram Strait

Motivation

- Fram Strait is the only deep connection between Arctic and world oceans. It is of great importance for Arctic Climate
- High spatial and temporal variability makes Fram Strait a very challenging area to measure representatively
- There is a need for large scale average measure, measured with high time resolution

Experiment

- 3 combined acoustic source and receiver moorings (2 recovered) and 1 acoustic receiver mooring (ACOBAR project)
- 2 year time series from 3 acoustic sections with a total length of 620 km, measurement every 3 hours
- Time for measuring temperature along a 300 km section: 205 seconds

Method

- Measurement of acoustic travel time from source to receiver
- Data processing to resolve arrivals and obtain a stable arrival pattern
- Forward modeling of arrival pattern to determine acoustic ray paths
- Acoustic inversion to obtain depth-range average sound speeds, which are converted to temperature

Results

- Unique synoptic depth-range averaged temperature measurements with an accuracy of 70m^{0}C
- Temperatures are 0.25-1^{0}C warmer compared with a regional Fram Strait circulation model based on the TOPAZ model system
- Acoustically measured temperature shows large temporal variability for all sections, section-average temperature changes of more than 0.5^{0}C within 10 days

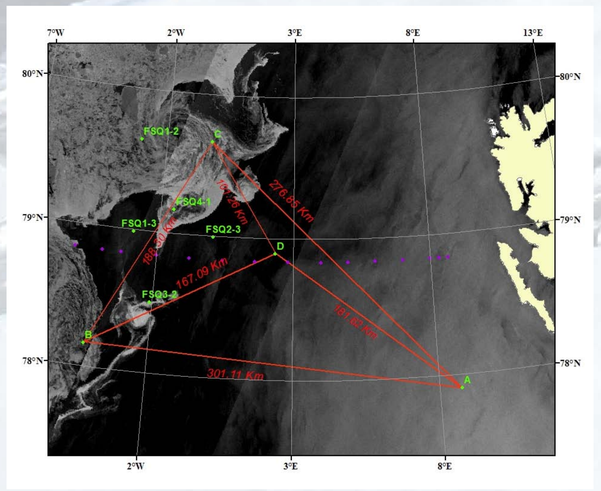

***Fig. 1**. Map of Fram Strait Experiment, sections (red lines) between tomographic moorings A – D (green dots) overlaid on ENVISAT wide swath images dated 23 and 24 Sept. 2011.Additional green dots denote RAFOS sources supporting the acoustic network used for navigation of gliders.*

Conclusions

- Acoustic thermometry provides very accurate large-scale ocean temperature in a challenging area
- 3 sections with a total length of 620 km were sampled several times a day for 2 years
- Observations can be used for model validation and in the future for constraining ocean models
- Short term variability of section averaged temperature in Fram Strait was on the same scale as seasonal temperature variations
- Acoustic data can also be used to analyze noise in the marginal ice zone both from natural and anthropogenic sources

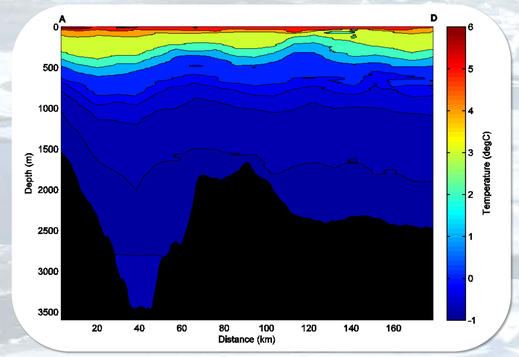

***Fig. 2.** Temperature along section DA in September 2012 from CTD measurements*

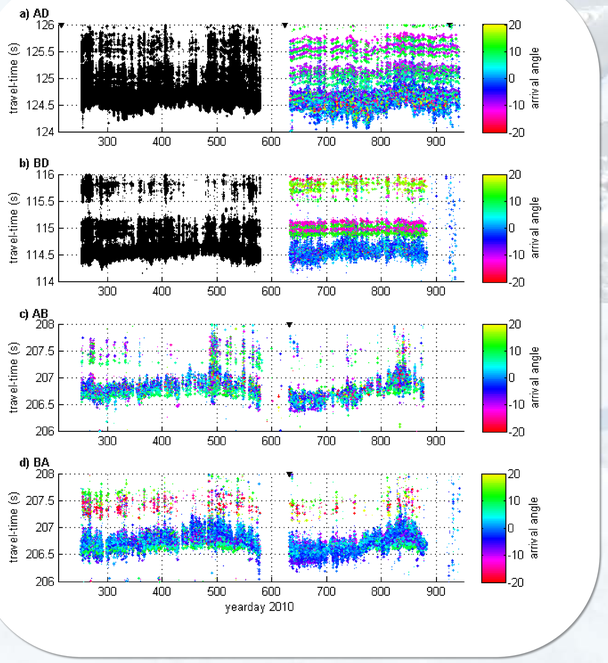

***Fig. 3.** Processed acoustic travel times for 3 acoustic sections, observations in both directions exist for section AB, respectively BA*

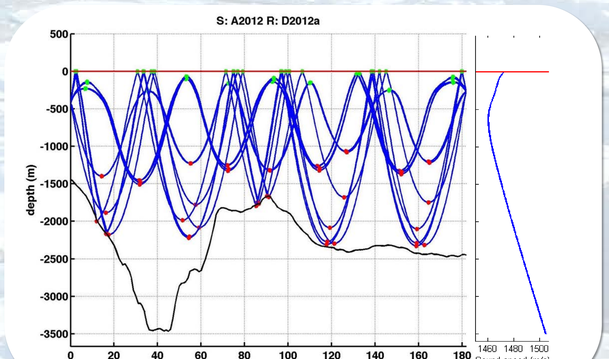

***Fig. 4.** Modeled ray paths between sound source and receiver for section AD and section-average sound speed profile*

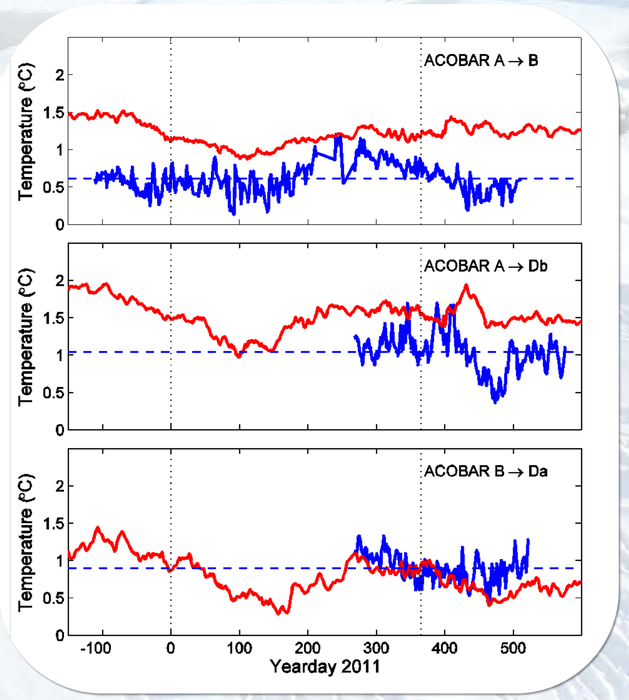

***Fig. 5.** Result of inversion: section average temperature between sea surface and 1000 m depth (blue) compared to the regional Fram Strait circulation model (red)*

Passive Acoustics / Ambient Noise

Motivation

- Increasing shipping and exploration activity in the Arctic
- Need for baseline observations of ambient noise for the evaluation of possible future environmental changes

Experiment

- Long-term measurements using hydrophones from thermometry moorings (ACOBAR)
- Short term measurements from drifting ice stations and sonobuoy drops from aircrafts (WIFAR)

Results

- Soundscape of the MIZ is shaped by sea state/wave /ice edge conditions and marine mammals.
- Passive acoustics can provide information about changes in the presence of marine mammals in the MIZ and changes in sea ice dynamics.
- At low frequencies the sound is often dominated by human activities even in Fram Strait.
- Distant seismic surveys (1400 km away) dominate the ambient noise below 200 Hz.

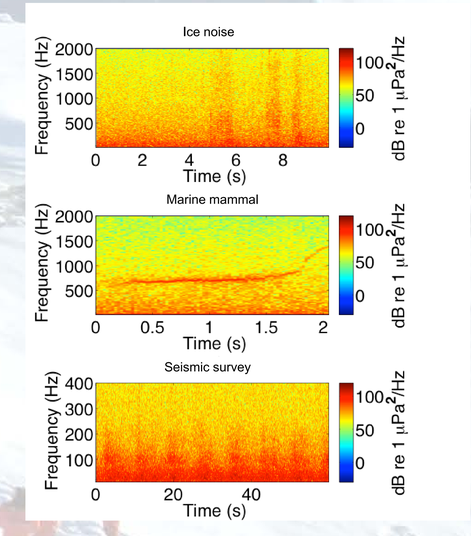

***Fig. 6.** Acoustic noise from different sound sources. From top to bottom: ice noise, marine mammal, distant seismic survey*

Future activity

- The expanded interdisciplinary project UNDER-ICE: Arctic Ocean under melting ice has started up in 2013
- See poster EGU2014-10849 Observing the Arctic Ocean under melting ice - the UNDER-ICE project by Hanne Sagen et al.

Acknowledgements
WIFAR: Waves-in-Ice Forecasting for Arctic Operators, proj. nr. 200642/560 is supported by the Research Council of Norway under the Petromaks programme.
ACOBAR: Acoustic technology for observing the interior of the Arctic Ocean, grant agreement nr. 212887 was supported by the commision of the European Communities under FP7