Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure
and Water Management*

P1.1-547: Microbarometer arrays for the monitoring of extreme weather in a changing climate

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Microbarometer arrays are used for the verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) with infrasound. Such arrays can be used to characterize (the propagation of) atmospheric gravity waves as well. We demonstrate this by analysing gravity waves from a meteo-tsunami event. Our results suggest that microbarometers could aid in the forecasting of extreme weather events that are predicted to occur more frequently in a changing climate.

Background

In the early morning of 29 May 2017, unusually large waves of over 2 m height hit the west coast of the Netherlands, leading to property damage. The waves were due to a meteo-tsunami, which is a tsunami of meteorological origin, unlike seismogenic tsunamis. This particular event was caused by a rapidly moving cold front which featured a sharp squall-line that moved towards the coast (Figure 1).

While the meteorological conditions leading up to such an event are relatively common, the more extreme events appear to happen under specific conditions only. Obtaining an understanding of such storms is of interest for safety and damage control, also in the context of a changing climate.

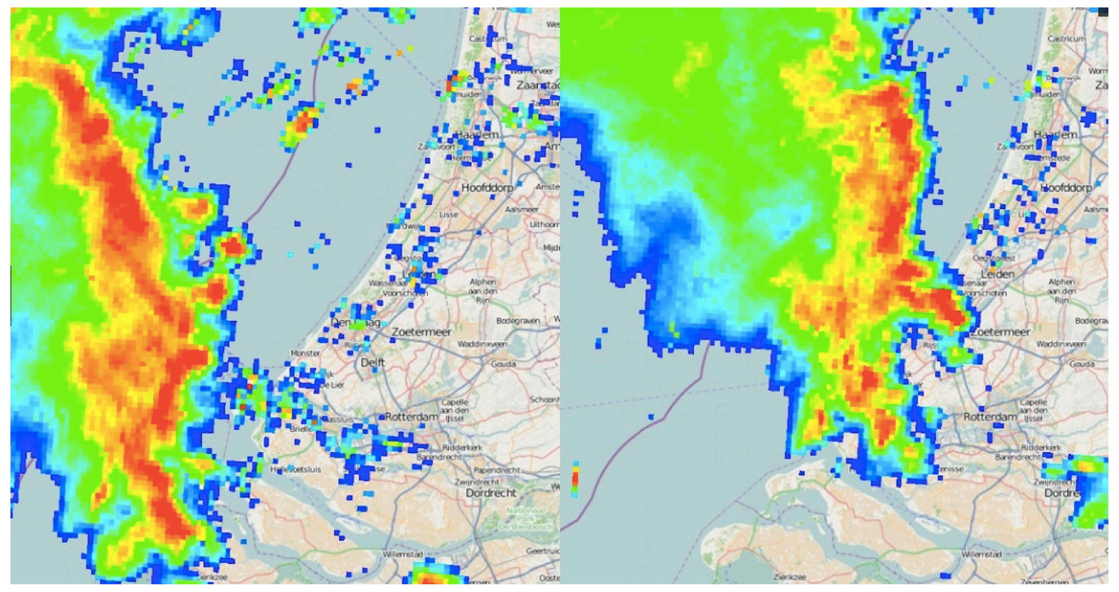

Figure 1: *Precipitation image obtained from weather radar at 03:30 and 04:00 UTC, showing the squall-line mesosystem. The storm moves at 75 km/h along the coast.*

Mechanism

The sea is pushed down by the storm with 1 cm/hPa which leads to a small water wave (the inverse barometer effect). This wave is amplified through interaction with the moving weather front (Proudman effect), shelf amplification and harbour resonance (Figure 2). Associated with these systems is the generation of atmospheric gravity waves that may propagate through the atmosphere over long distances.

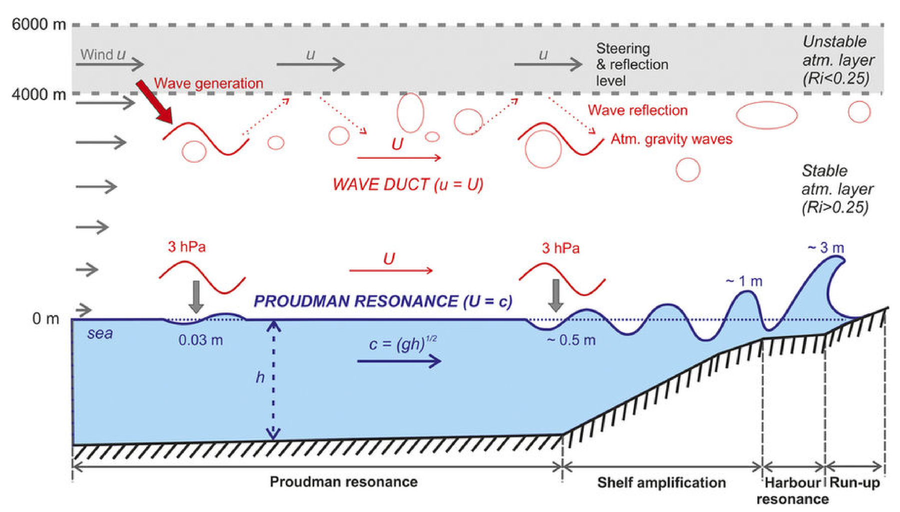

Figure 2: *A summary of the meteo-tsunami generation process (Figure by Šepić et al., 2015; Nature Sci. Rep., doi: 10.1038/srep11682)*

Observations

Barometric observations

KNMI operates an automatic weather station (AWS) network throughout the Netherlands. The barometers sample every 12 seconds. The dispersion of the gravity waves over the Netherlands can be tracked over the network, well into Germany.

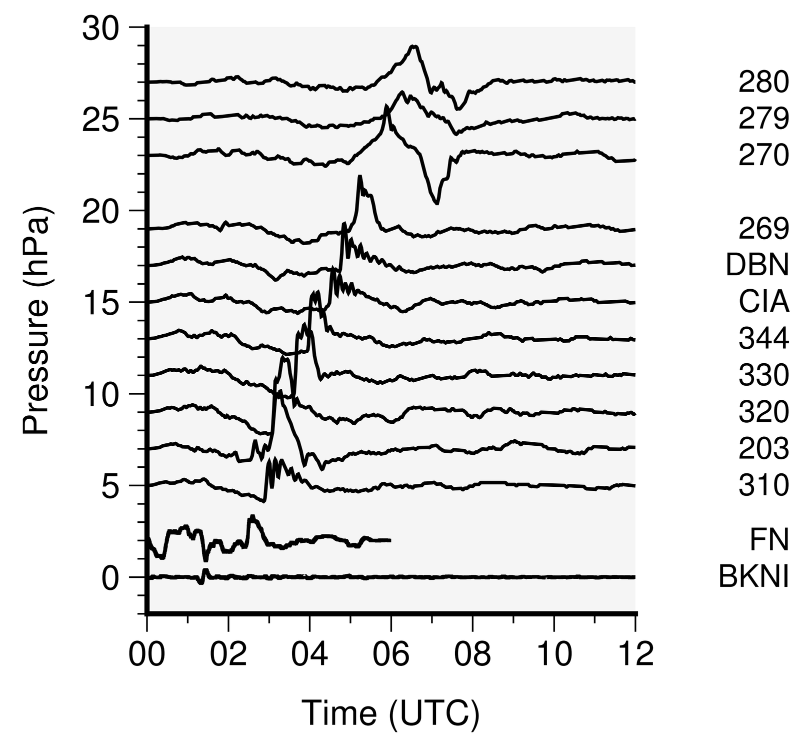

Figure 3: *Recordings of gravity waves in the 0.05 - 10 mHz band on British and Dutch barometers. The onset of the storm is visible as a positive pressure disturbance. Such a 'pressure nose' is typical of a squall-line mesosystem.*

The Department of Seismology and Acoustics operates a microbarometer array network. The sensors respond to pressure fluctuations in the 0.1 mHz - 20 Hz band and are sampled at 100 Hz. Array techniques are used to estimate propagation speed and direction of the gravity waves (Figure 4).

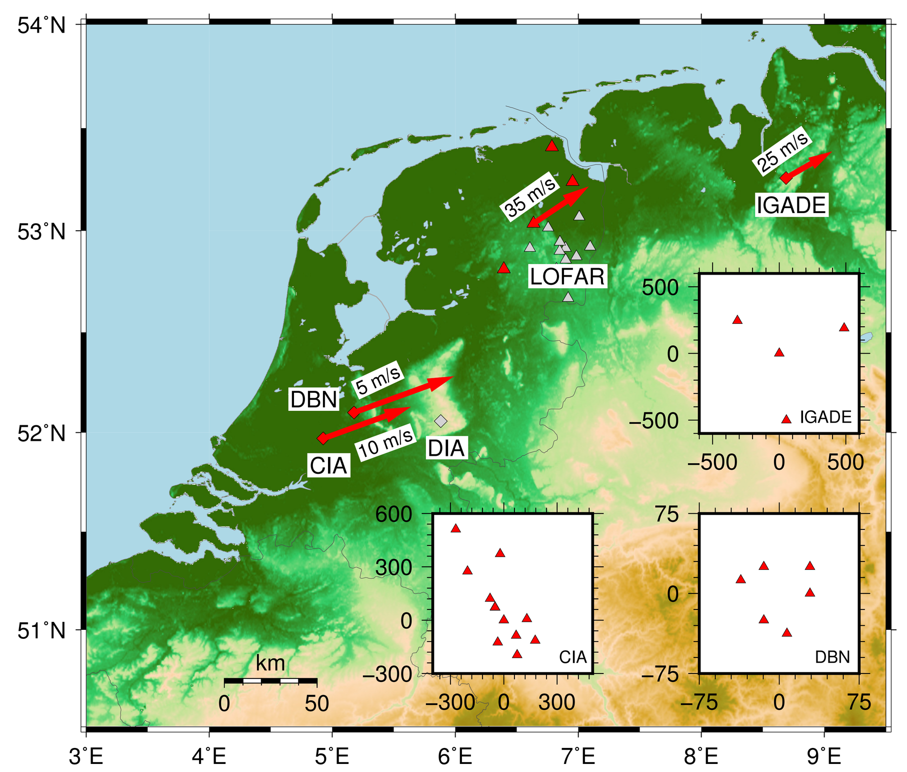

Figure 4: *Recordings of the gravity waves on the microbarometer array network in the Netherlands and NW Germany. Array processing allows for the estimation of propagation speed and direction of the gravity waves*

By combining the barometric recordings over the Netherlands, the individual wave crests of the gravity waves can be visualized. The sense of propagation is compatible with the array processing results (Figure 4).

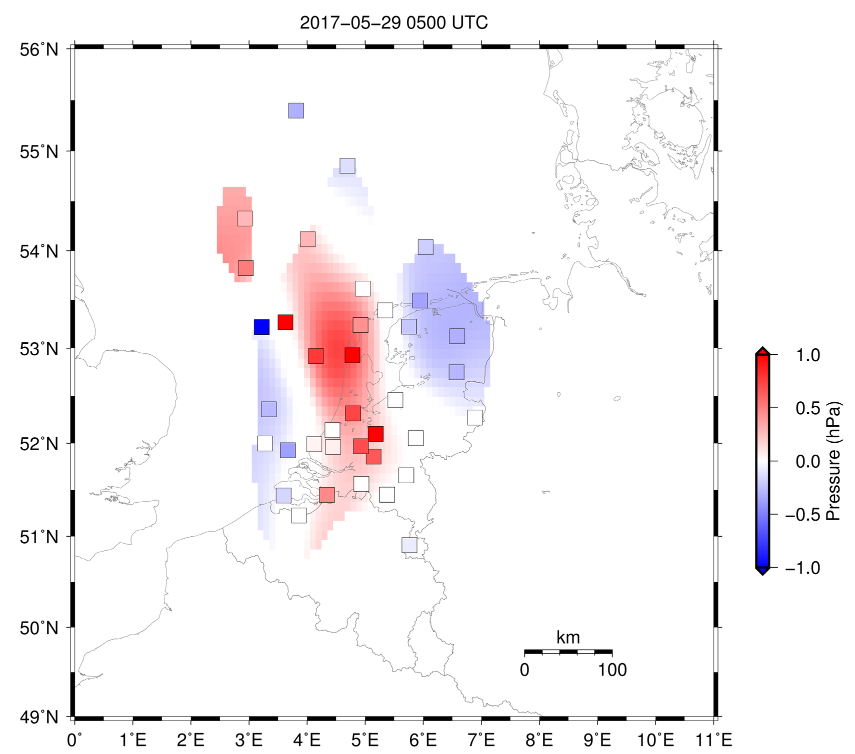

Figure 5: *Snapshot of pressure waves over The Netherlands around 0500 UTC. The individual wave crests of the gravity waves are visible as NW-SE trending lines.*

Ceilometer observations

KNMI operates a network of ceilometers (LIDAR technology). The observed undulations of the clouds in the observed backscatter correspond to the passage of the gravity waves and match the barometers.

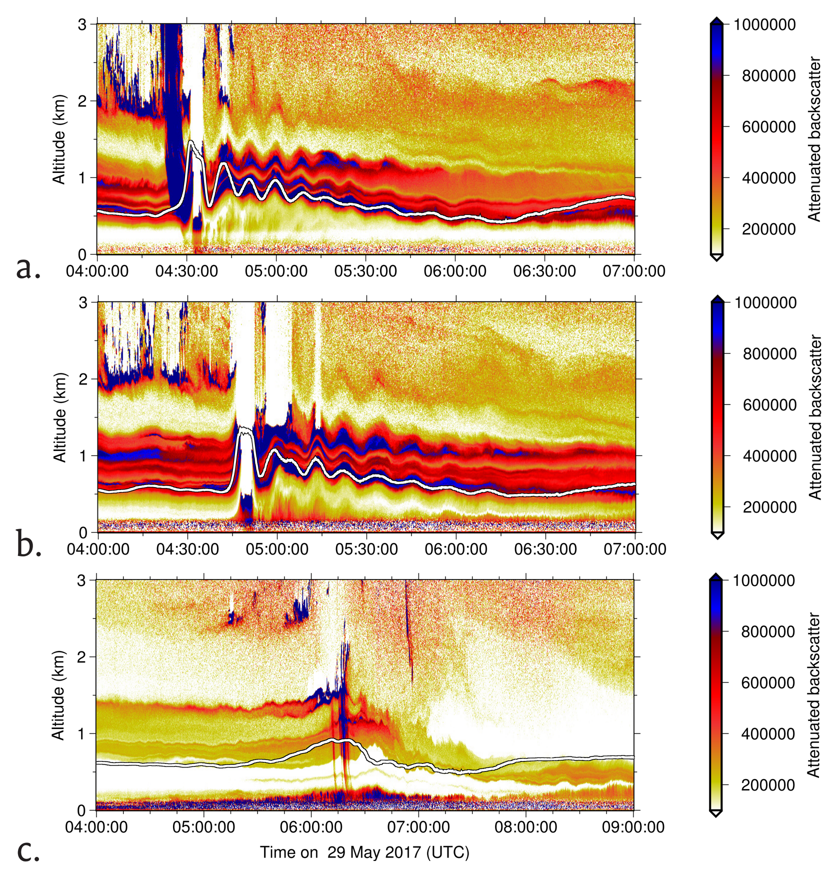

Figure 6: *Co-located barometer and ceilometer recordings at (a) Cabauw (CIA), (b) De Bilt (DBN) and (c) Hoogeveen. The ceilometer shows backscatter from clouds and captures the gravity waves throughout the lower troposphere.*

Forecasting the storm

The observed gravity waves are partly resolved by the non-hydrostatic mesoscale HARMONIE weather model (Figure 7). HARMONIE resolves the weather with 2.5 x 2.5 km grid spacing with 1 minute time-steps. The hourly forecast steps show the NE trending gravity waves over the Netherlands.

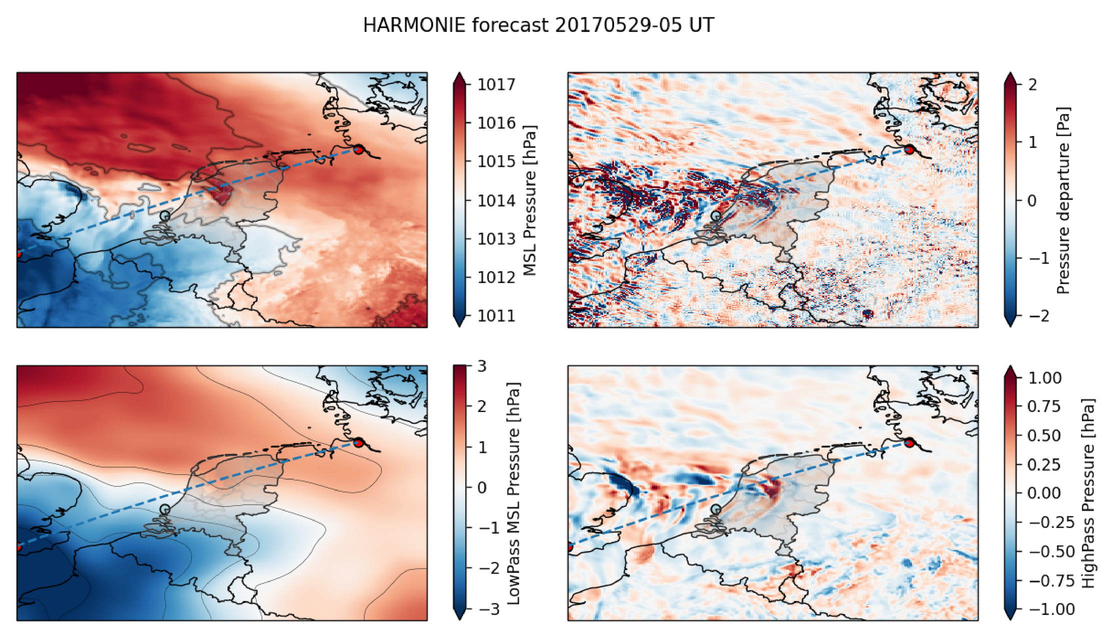

Figure 7: *Forecast of gravity waves over the Netherlands at 0500 UTC.*

Figure 8 shows the forecast along the dotted path shown in Figure 7. The forecast is initiated at 00 UTC. The match between the observed gravity waves and the forecast suggest forecast skill.

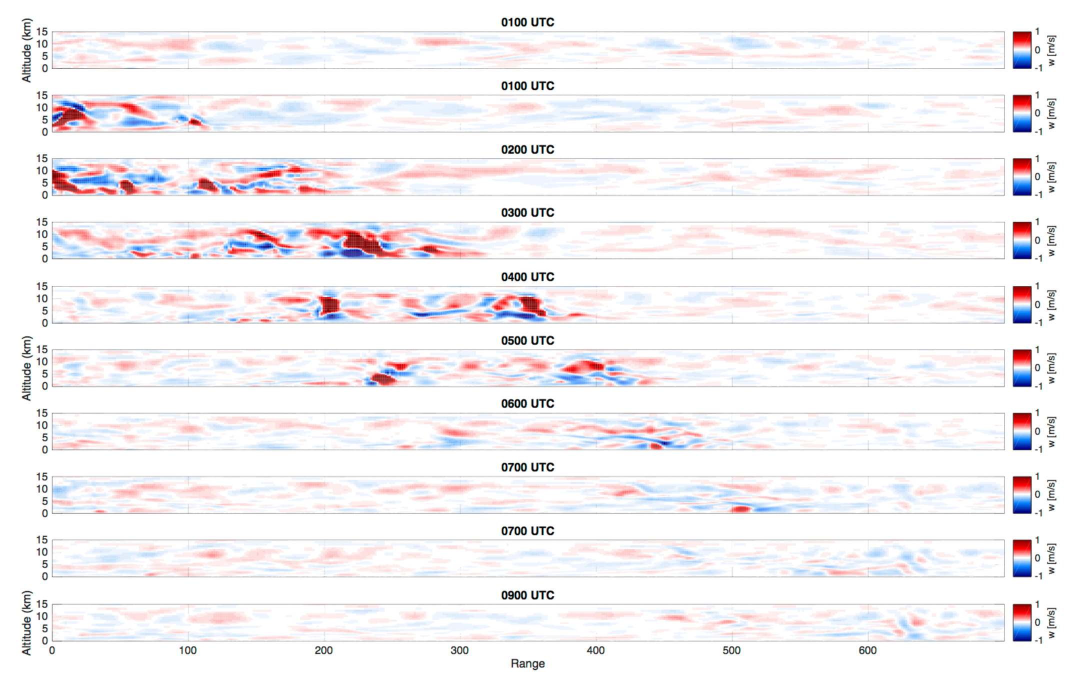

Figure 8: *HARMONIE hourly forecasts along the red profile shown in Figure 7.*

Discussion and conclusion

Dispersive gravity waves are observed over The Netherlands due to a convective storm over the North Sea that lead to a Meteo-Tsunami and significant damage. The observed gravity waves are partly resolved by a non-hydrostatic model which suggest forecast skill for such convective storms. The occurrence of such storms in a changing climate is a topic of research.

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