SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Studying infrasound propagation in the middle atmosphere with the upper-atmosphere model UA-ICON: parameterisation and characterisation of gravity waves

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INTRODUCTION AND MAIN RESULTS

To properly understand infrasound propagation, one must have a solid understanding of atmospheric conditions up to the thermosphere, including the effects of small scale perturbations e.g. gravity waves (GW). The UA-ICON model provides such information.

We demonstrated that GW affect infrasound propagation (waveform and trajectory), and that their inclusion helps to improve such estimates.

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Introduction

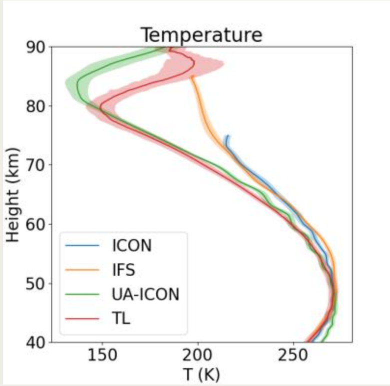
Infrasound propagation depends heavily on the atmosphere, notably the temperature, pressure, and wind up to the lower thermosphere. Many operational atmospheric models do not include the mesosphere and lower thermosphere (MLT). Additionally, they use simplified (1D static) gravity wave (GW) parameterisations.

We have used the upper atmosphere Icosahedral Non-hydrostatic (UA-ICON) model with the Multi-Scale Gravity Wave Model (MS-GWaM) to perform simulations with a 3D transient GW parameterisation. We will demonstrate the improvements to atmospheric temperature profiles using MS-GWaM, and the effects of GWs on infrasound propagation (waveforms and source localisation).

Results – temperature profile

Lidar profiles were used to verify temperature and wind profiles.

Summer MLT temperatures are overestimated by operational models. **UA-ICON, with MS-GWaM correctly predicts cold mesosphere.**



MS-GWaM

1D (commonly used parameterizations) – GW energy and momentum is instantly transported for each.

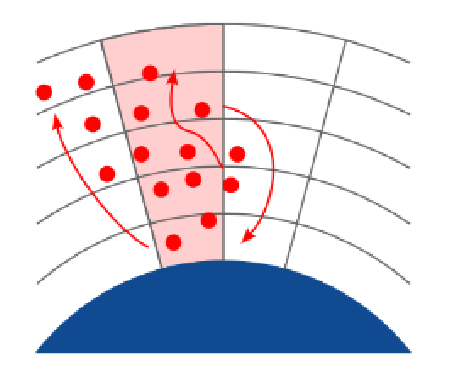
1D transient – there is a finite time for energy to be transported throughout the entire column.

3D transient (MSGWAM-3D) – GW energy is transported 3-dimensionally through the atmosphere.

This 3D GW transport allows for more realistically parameterized GWs.

Infrasound context:

- 3D parameterization provides more realistic background atmospheric fields (e.g. wind, temperature etc.)
- Global GW spectral parameters allow for estimation of the GW amplitudes.



GW Spectra – Desaubies

We start with the assumption that the spectrum follows a modified Desaubies spectrum:

$$F_u = \frac{2\pi < u'^2 >}{\eta m^*} \frac{\left(\frac{m}{m^*}\right)^2}{1 + \left(\frac{m}{m^*}\right)^5}$$

Where

$$2\pi < u'^2 > = \frac{KE}{\rho};\ \eta = \frac{\pi}{5} \frac{1}{\sin\left(\frac{3}{5}\pi\right)}$$

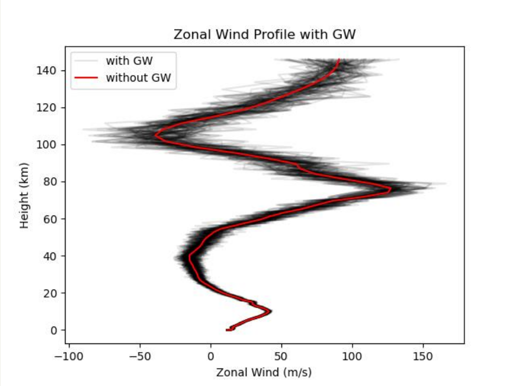
$$< m^2 > = \frac{A_{m^2}}{A}$$

Where A is the wave action and

$$A_{m^2} = \int d^3k\, m^2\, N$$

Where N is the phase-space wave-action density
Finally, m* is approximated within MS-GWaM by

$$m^* = \sqrt{< m^2 >}$$



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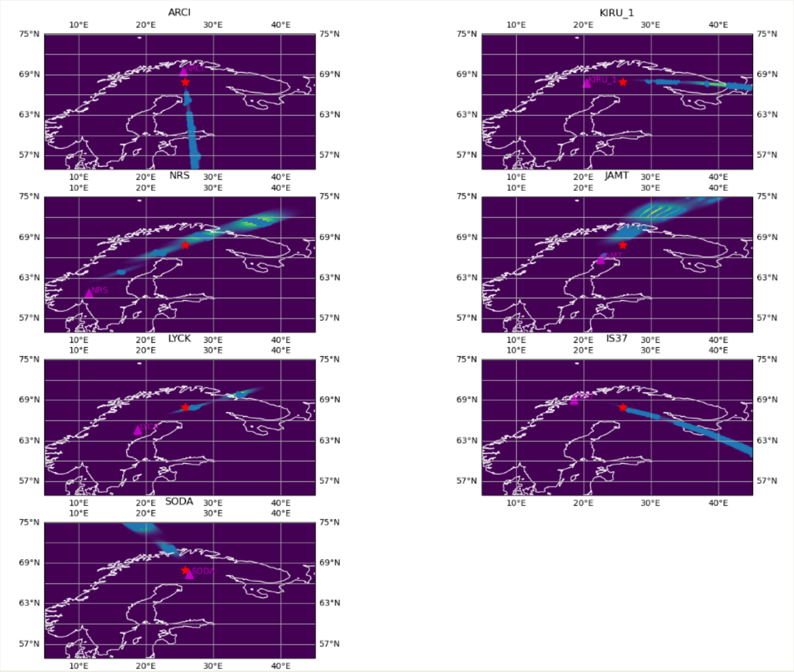
Source localisation

3D ray tracing can be used to predict the infrasound trajectory in time and space including the effects of cross-winds and horizontal refraction. Bayesian inference is used to determine the probability of a source location.

$$P(S|Obs) = (P(Obs|S)P(S))/(\int P(Obs|S)P(S)dS)$$

Gaussian kernel density estimators are then used to determine the likelihood of the source location for each observation.



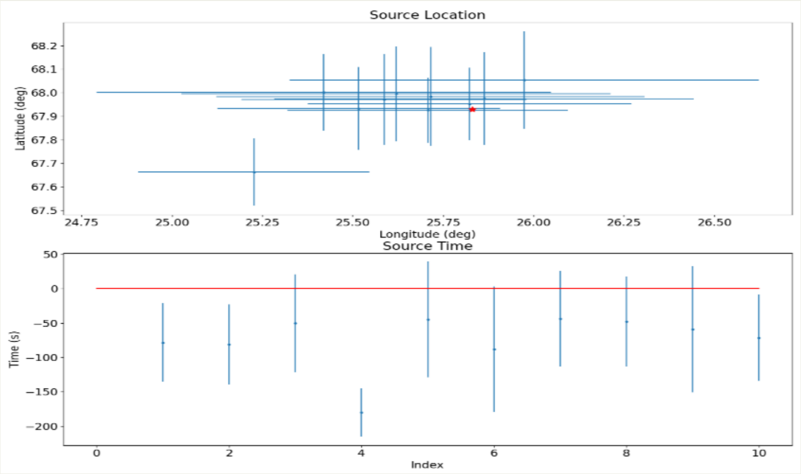
Results: Source localisation

10 different GW fields were estimated from the MSGWaM spectral outputs.

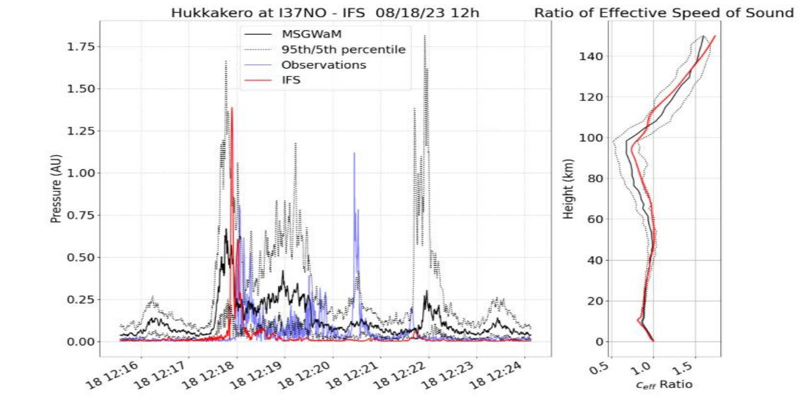
Each provides a source location and time estimate. Source locations and times (with errorbars representing 95% confidence intervals) with MSGWaM are generally in agreement with the ground truth.

The gravity wave fields can have a substantial impact on the source location estimates (this is also observed with the waveforms).

This demonstrates the importance of including a statistically robust estimate of the GW fields for infrasound propagation.



Results: Waveform estimation



Similar initial stratospheric returns are observed with both IFS and UA-ICON, however GW perturbations result in the elongated stratospheric returns.

UA-ICON provides more realistic energy estimates of thermospheric return due to slightly lower thermospheric guide compared to IFS.

Additional variability in the mesosphere (in particular winds) that are not re-created with the climatology, results in (partial) refractions in the mesosphere due to both GW perturbations and the increased variability of the background profiles influenced by GW breaking.

Inclusion of gravity wave perturbations is essential for proper waveform reproduction.