

AGW-TID detection with EISCAT and meteor radar and application for background neutral wind measurements

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Knowledge for Tomorrow

AGW-TIDs as information source

AGW-TID → **Atmospheric Gravity Wave - Travelling Ionospheric Disturbance**

	wavelengths	periods	forcing mechanisms
Large-Scale TIDs	$\gtrsim 1000 \text{ km}$	$\sim 30 - 180 \text{ min}$	<ul style="list-style-type: none"> ionospheric (Joule heating, Lorenz force)
Medium-Scale TIDs	several hundreds of km	$\sim 15 - 80 \text{ min}$	<ul style="list-style-type: none"> ionospheric (Joule heating, Lorenz force) atmospheric (upward-propagating AGWs)

[following Brekke, 1978; Hocke and Schlegel, 1996; van de Kamp *et al.*, 2014]

Gravity wave dispersion relation:
$$\mathbf{k}^2 = \frac{N^2 k_H^2}{\omega_I^2} \cdot \gamma - \frac{1}{4H^2}$$
 • wave parameters k_z, k_H and τ are coupled to background atmosphere
→ ionospheric waves provide information on neutral atmosphere

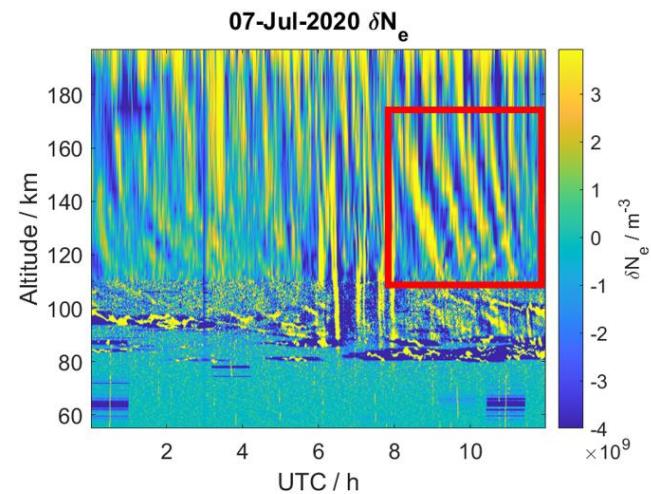
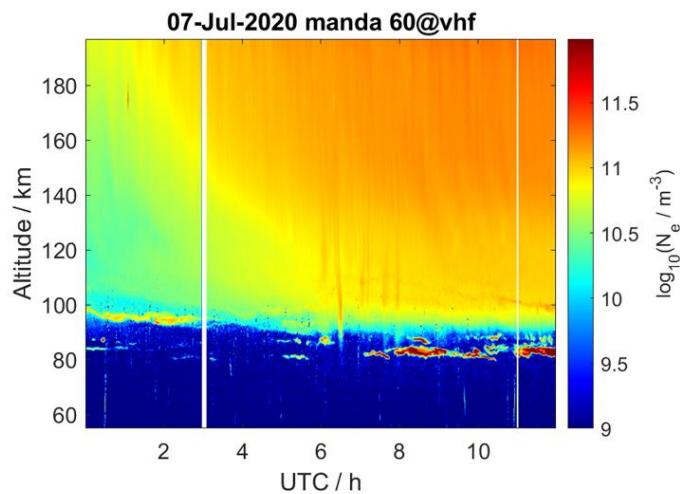
Intrinsic wave frequency:
$$\omega_I = 2\pi/\tau - k_H \cdot U$$
 • vertical and horizontal dimension difficult to measure at the same time



Combined vertical and horizontal measurements

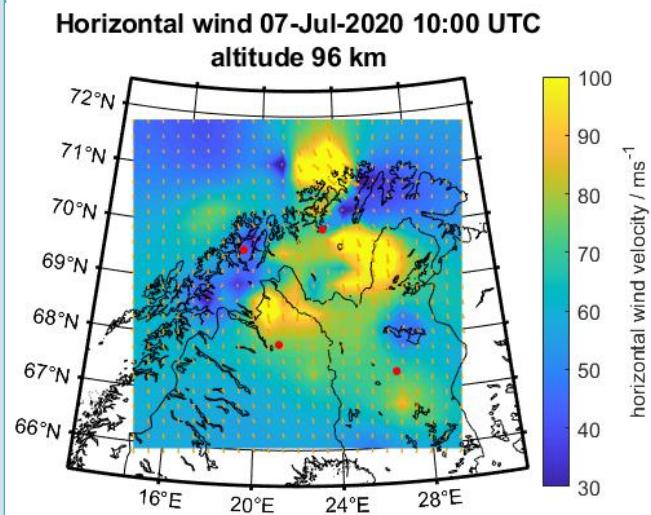
**vertically resolved
measurements:**

EISCAT



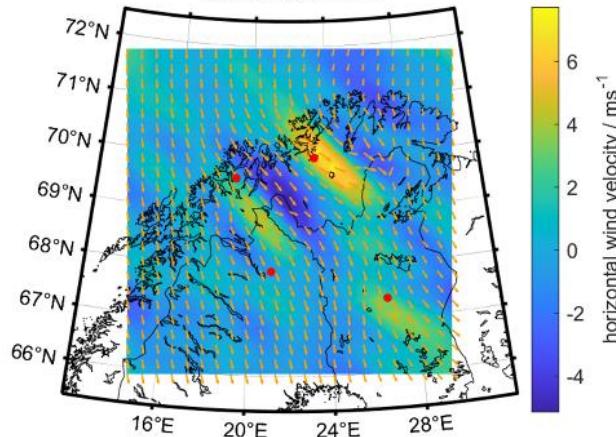
**horizontally resolved
measurements:**

**Nordic Meteor Radar
Cluster**

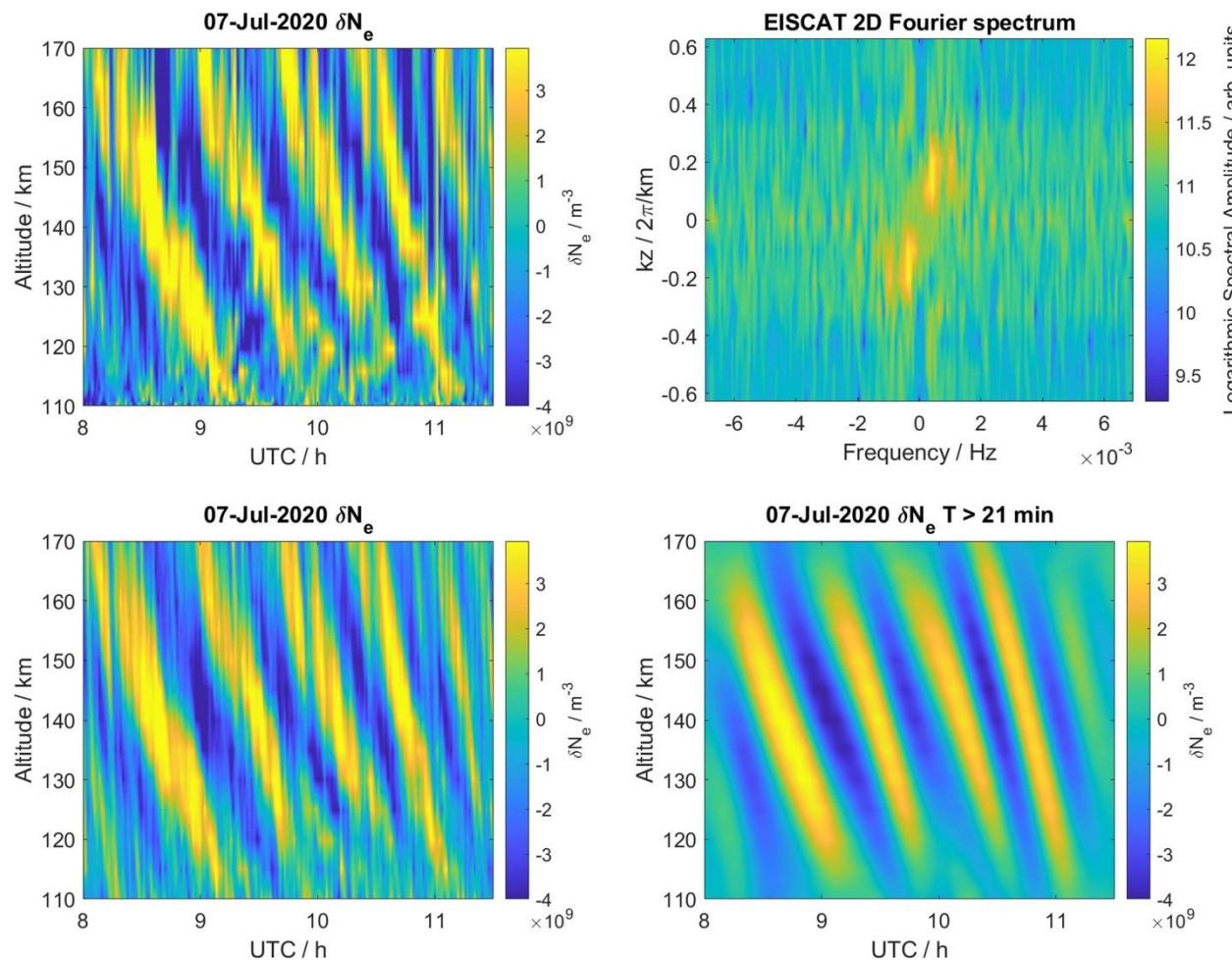


Horizontal wind 07-Jul-2020 09:10 UTC

altitude 96 km



Separation of wave modes by Fourier filtering



- checkers pattern indicates interference of multiple wave modes
- Fourier spectrum is filtered for upward propagating wave modes
- extended filtering for $\tau > 21 \text{ min}$ and $\lambda_z > 21 \text{ km}$ leaves single wave mode



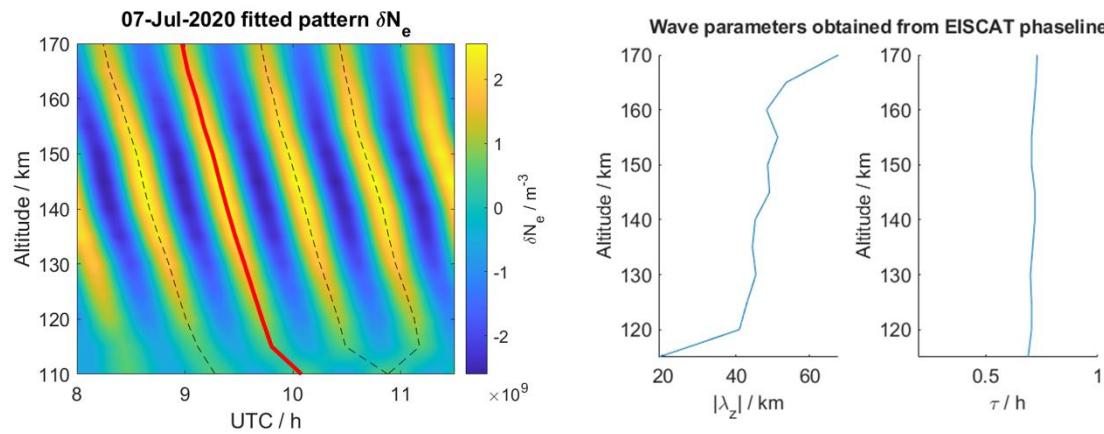
Vertical wave parameter determination

- apply 2D Fourier filter to separate different wave modes with respect to propagation direction, τ and λ_z
- fit wave separately at each altitude: $dN_e = A \cdot \cos(2\pi t/\tau + \delta)$ for A, τ, δ

$$\rightarrow \tau(z) \text{ and } \delta(z) \rightarrow t_{max}(z) = -\frac{\delta(z) \cdot \tau(z)}{2\pi} + t_0 + n \cdot \tau \rightarrow \text{phase line}$$

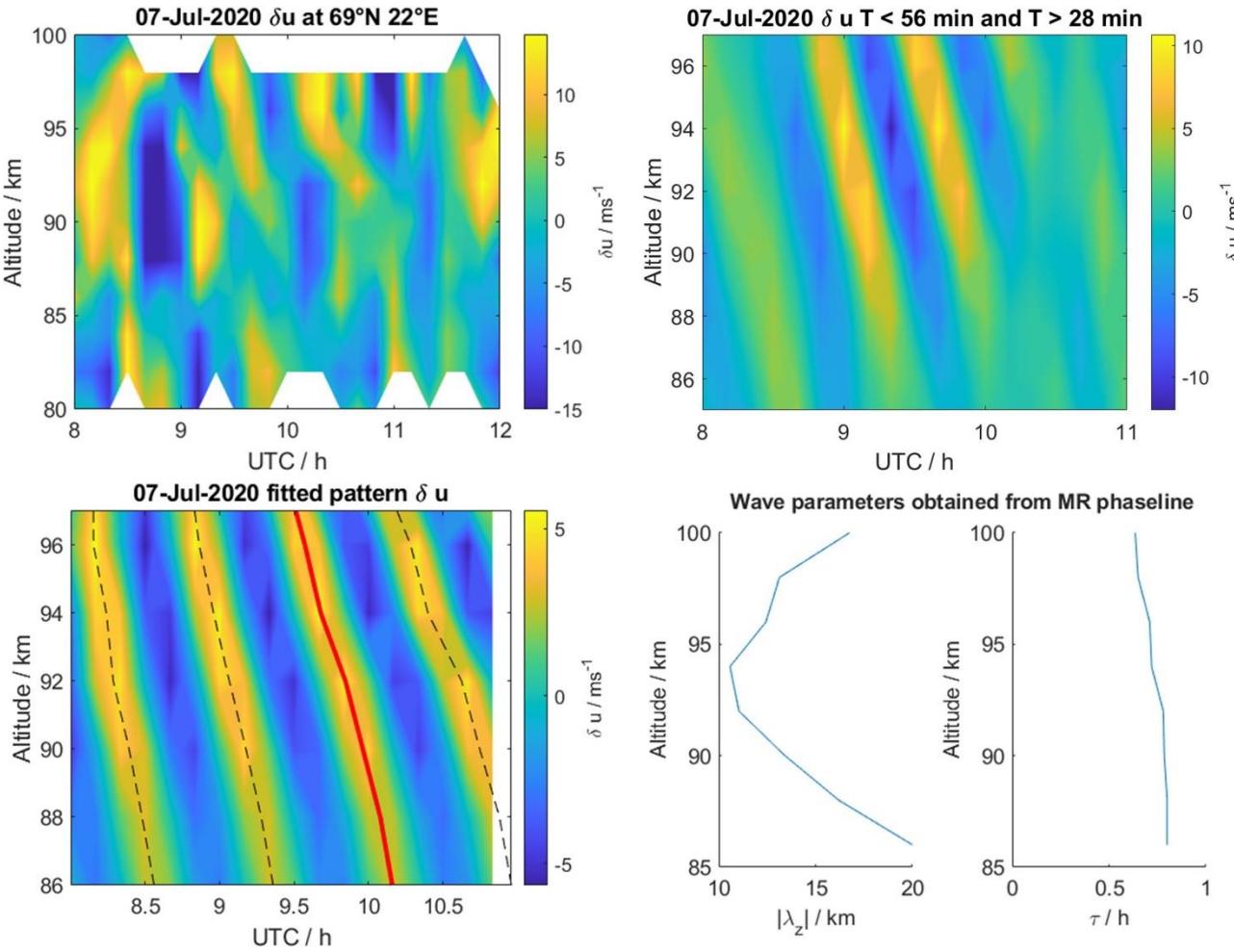
$$k_z = \frac{2\pi}{\tau} \cdot \frac{dt_{max}}{dz}$$

$$\begin{cases} k_z < 0 & \text{upward propagation} \\ k_z > 0 & \text{downward propagation} \end{cases}$$



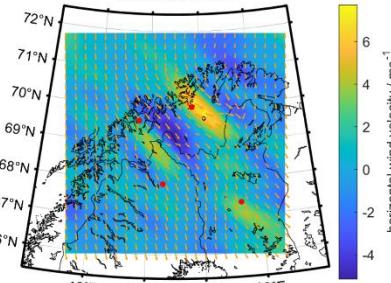
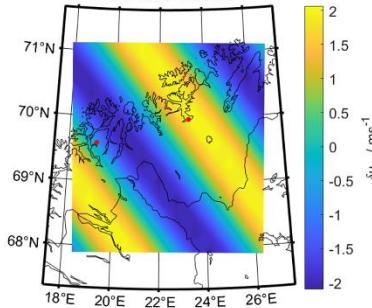
- nearly constant wave period $\tau = 43.1 \pm 1.6 \text{ min}$
- λ_z shows reasonable range of values

Pre-filter meteor radar measurements

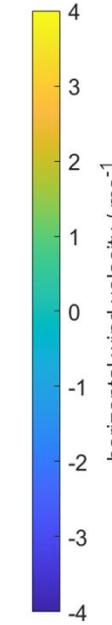
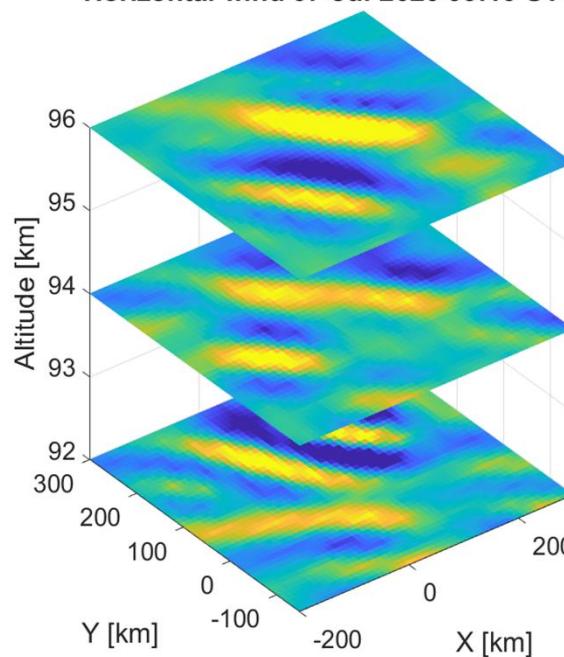


- apply gliding window filter to remove large-scale horizontal wind changes
- Fourier filter for frequency band around EISCAT TID frequency
- fit AGW pattern as done with TID before
- wave parameters agree well with EISCAT findings:
 - λ_z shows same trend and similar values to EISCAT
 - $\tau = 44.1 \pm 4.1$ min

Horizontal wavelength & propagation direction

Horizontal wind 07-Jul-2020 09:10 UTC
altitude 96 kmFitted velocity variation 07-Jul-2020 09:10 UTC
altitude 96 km

Horizontal wind 07-Jul-2020 09:10 UTC



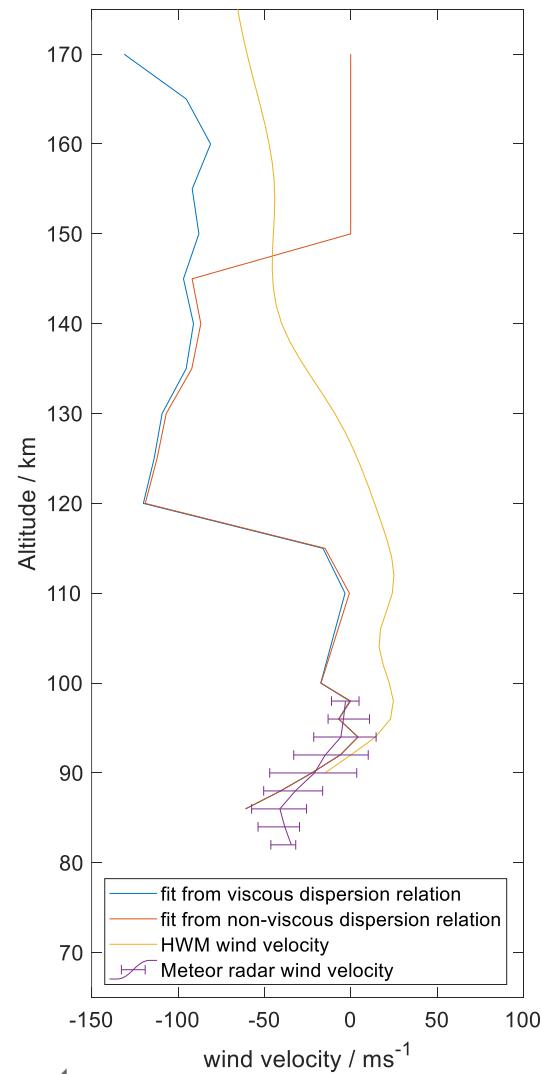
λ_z	$\sim 10 - 70 \text{ km}$
λ_H	230 km
τ	$\sim 43 \text{ min}$
α	0.644 (= 37.9°)

(α : angle of propagation direction in counter-clockwise rotation from geographic east)

- wave mode can be detected at multiple altitude levels
- horizontal wave is fitted as:

$$\delta v = A \cdot \sin \left(\cos \alpha \cdot \frac{2\pi}{\lambda_H} \cdot x + \sin \alpha \cdot \frac{2\pi}{\lambda_H} \cdot y + \delta \right)$$

Inferring wind velocities along propagation direction



- gravity wave dispersion relation includes wind velocity along the propagation direction
- apply wave parameters and NRLMSISE-00 background atmosphere
- perform non-linear least square fit of the viscous dispersion relation
 - ➔ good agreement with Meteor Radar measurements (9 – 11 UTC); error bars mark quartiles
 - ➔ non-viscous fit does not converge above 145 km



Summary

- simultaneous measurement of a single AGW-TID wave mode possible with the EISCAT radar and the Nordic Meteor Radar Cluster
- Fourier filter methods allow separating wave modes
- wave fitting functions give vertical and horizontal wave parameters
- vertical profile of thermospheric winds can be inferred from wave parameters with moderate accuracy

