



European Research Council



Citizen scientists discover a new auroral form: Dunes provide insight into the upper atmosphere

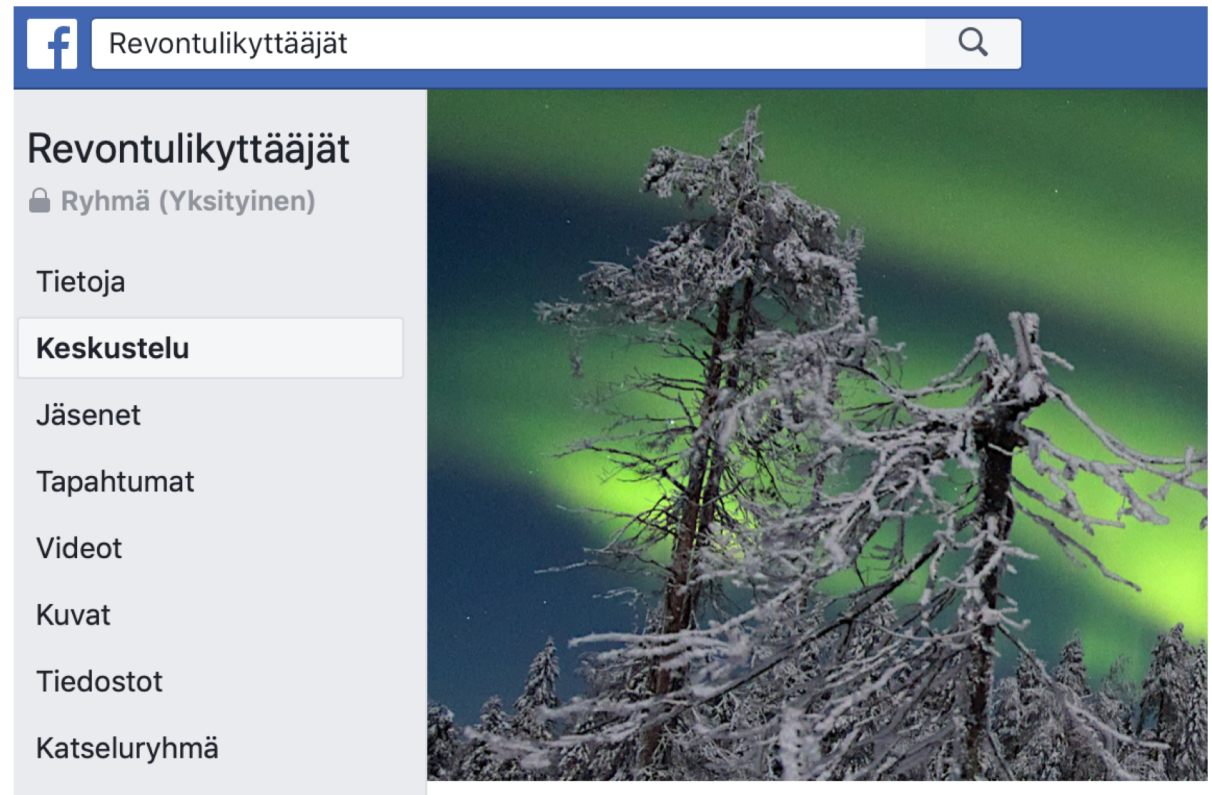
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3: Citizen Scientist, Finland; 4: Sirius Jyväskylä, Finland; 5: URSA, Finland, 6: Sodankylä Geophysical Observatory, Finland



Background

- 2015: Finnish auroral enthusiast Facebook group (*Revontulikyttäjät* – engl. Auroral Stalkers) invited me to join and explain the physics of aurora
- Over the years I became their "staff scientist" explaining many space physics phenomena





Book project

- Interactions with the FB group members initiated a guidebook project (engl. Guidebook to catch the aurora)
- The book includes auroral forms in science, their physical background, and star classification for rarity, e.g.:
 - Corona, pulsating aurora, etc.
- Figures to the book were received through a catching challenge within FB
 - Thousands of pictures
 - Choosing together with citizens to educate them in classification

Published: Oct 5, 2018





"But what are these stripes?"

- ... asked one of the citizens, Matti Helin, during the book project
- "Dunno", let's leave them out
- 2 days after publication party, right when messaging with FB members – **THE STRIPES APPEAR ON THE SKY!**



Ad-hoc measurement campaign on the evening of Oct 7, 2018 produced two exactly simultaneous pictures, one from Laitila, the other from Ruovesi.



Naming: "The Dunes"

By Pirjo Koski



Photographer: Pirjo Koski, Laitila



Triangulating the altitude and wavelength

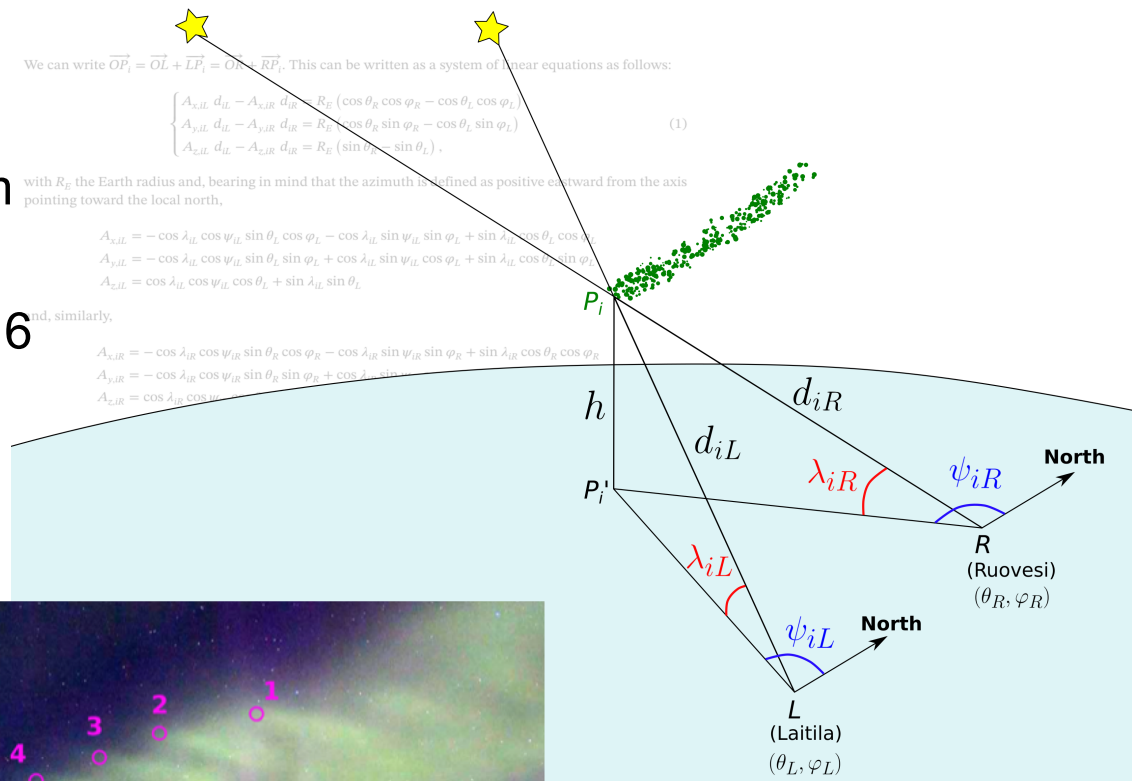
- Maxime Grandin developed a triangulation method making use of Stellarium, open-source planetarium software
- Detection of 12 known stars behind 6 dune fingers in both figures

→ Azimuth & elevation of the tips from two locations

→ Altitude: 100 km

→ Mapping to ground

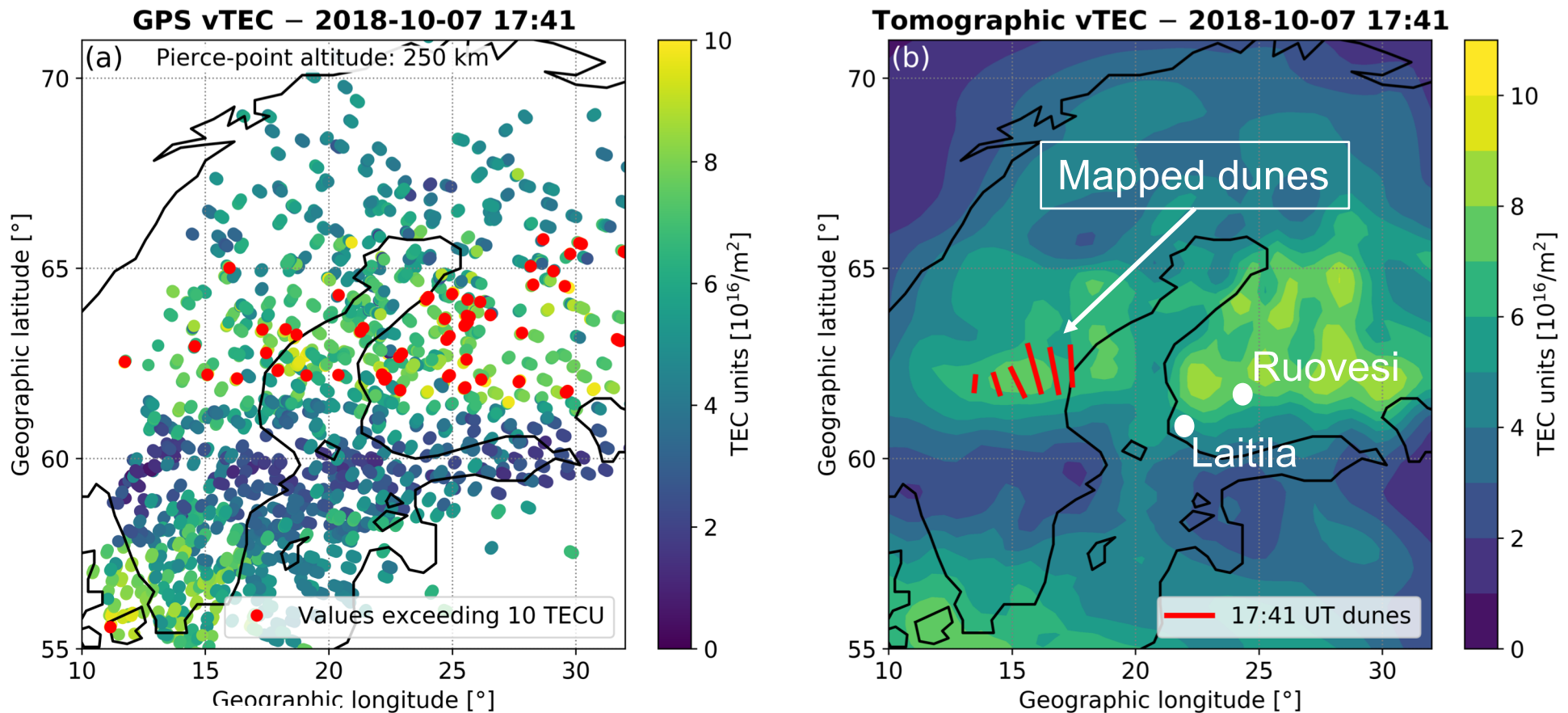
→ Wavelength: 45 km





Supporting ionospheric data

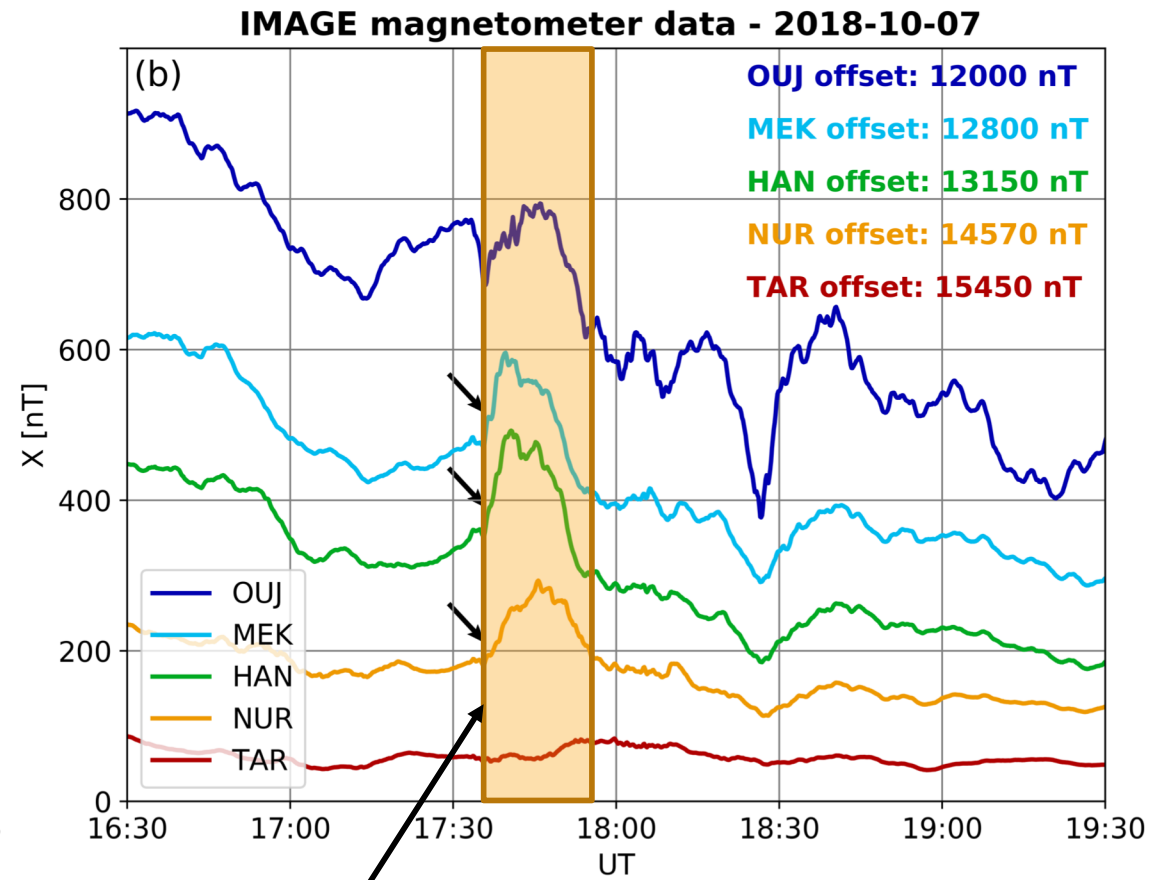
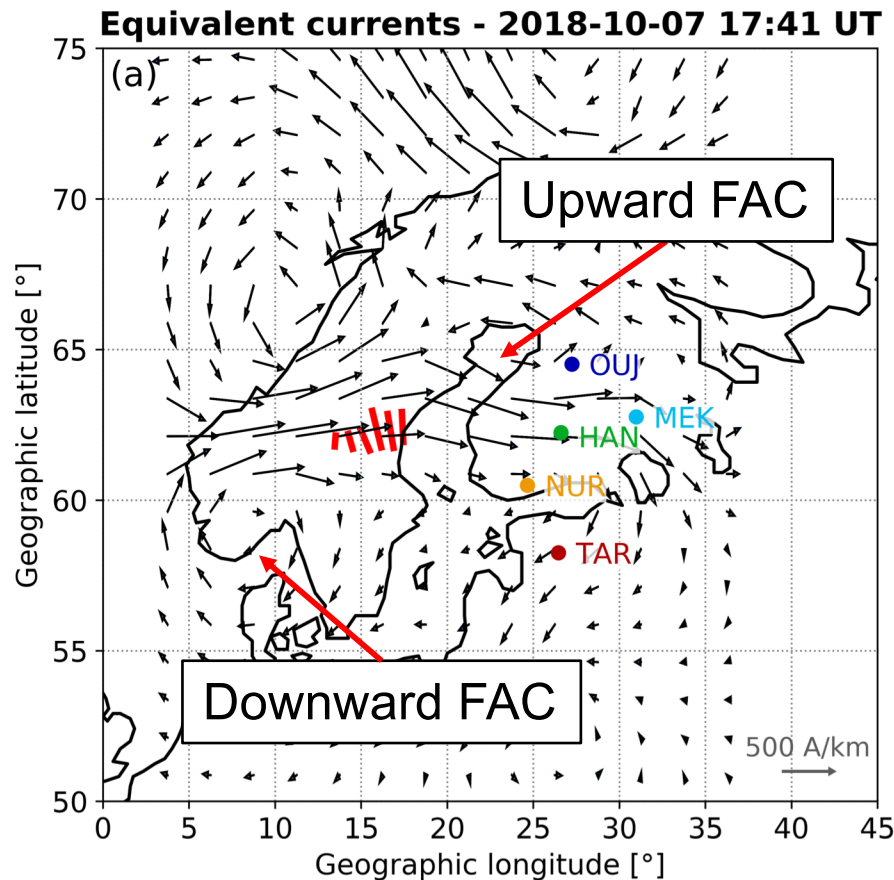
Total electron content using 3D GPS satellite tomography
electron density reconstruction (Norberg et al., 2018)





Supporting ionospheric data

Ionospheric equivalent currents from ground magnetometers



Time of dune observations



Events with similar behaviour

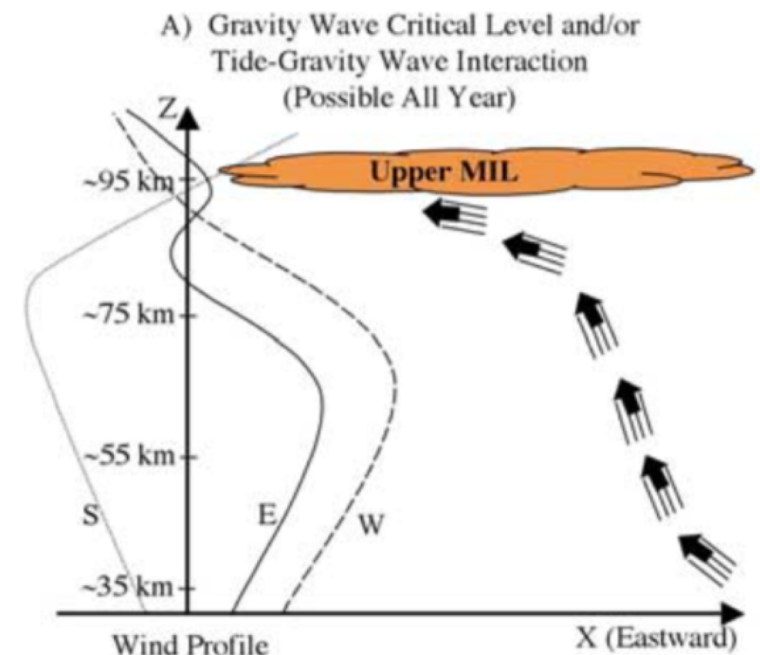
Day	Time	AE [nT]	SYM-H [nT]	Place
10 Oct 2018	17:36 - 17:45 UT	~550*	-42.5	Maaninka [63.2° N, 27.2° E]
7 Oct 2018	17:34 - 17:59 UT	~650*	-38.8	Several throughout Finland and Sweden
24 Oct 2017	~16:30 UT	756.5	-23.4	Sievi [63.9° N, 24.5° E]
13 Oct 2017	~17:00 UT	637.1	-49.5	Laitila
20 Jan 2016	17:00 - 17:30 UT	606.8	-86.1	Several places in Finland, Norway, Scotland
12 Oct 2015	~18:00 - 19:00 UT	687.2	-34.4	Several places throughout Southern Finland
07 Oct 2015	17:28 - 18:58 UT	1166.9	-86.3	Several places throughout Southern Finland

- Citizen Scientists found more events with similar stripes in the diffuse aurora
- All events
 - Have monochromatic and horizontal wave field in the diffuse green aurora
 - Occur in the evening hours
 - Are temporally and spatially associated with a pair of upward and downward FACs
 - Occur during moderate magnetic activity with AE and SYM-H indices
 - All but one event are observed in October.



Interpretation

- Mesospheric bore is a monochromatic undulation in the atmospheric density, which is horizontal and occurs in large wave fields, with wavelength of about 45 km (e.g., Miller et al., 2015)
- Born when a gravity wave is sandwiched between the mesopause and a mesospheric inversion layer (MIL)
- MIL occurrence rate is largest around equinoxes (Su et al., 2018), and during evening hours (Hozumi et al., 2019)
- We suggest the diffuse aurora illuminates a mesospheric bore



Meriwether and Gerrard (2004), Rev. Geophys.



But why are all events temporally and spatially concurrent with FAC pairs?

- Either because FAC pair indicates where the auroral zone is
- Or, this kind of electrodynamic system is associated with strong energy deposition from the magnetosphere (e.g., Palmroth et al., 2005; 2006)



Photographer: Rami Valonen, Ruovesi



Outlook

- Mesospheric bores require a ducting layer that can be formed either due to a layer of **increased temperature below** the mesopause, or by a **wind shear above the mesopause** (Dewan & Picard, 1998)
- The ionospheric energy deposition could contribute to the ducting layer by two mechanisms:
 1. Joule heating deposits energy at around 125 km altitude that enhances neutral winds (Lu et al., 2016)
 - Ducting layer between mesopause and wind shear
 2. Monoenergetic electron precipitation increases atmospheric temperature within a thin layer
 - Enhancing the mesospheric inversion layer by monoenergetic precipitation



Summary

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Paper in AGU Advances, vol 1, pages 1-12:

- Citizen scientists discover a new auroral form presenting a large-scale monochromatic wave field
- We develop a triangulation method using citizen scientist photographs as science data
- We suggest that the dunes manifest mesospheric bores, which have not been observed in the diffuse aurora before.

AGU Advances

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Palmroth, M., Grandin, M., Helin, M., Koski, P., Oksanen, A., Glad, M. A., et al. (2020). Citizen scientists discover a new auroral form: Dunes provide insight into the upper atmosphere. *AGU Advances*, 1, e2019AV000133. <https://doi.org/10.1029/2019AV000133>