# SPACE WEATHER IMPACTS on GNSS

SWIC

Collaboration of

Solar-Terrestrial Centre of Excellence

UNIVERSITY OF TWENTE. | RADIO SYSTEMS

Koninklijk Nederlands Meteorologisch Instituut
*Ministerie van Infrastructuur en Milieu*

# Monitoring the ionosphere

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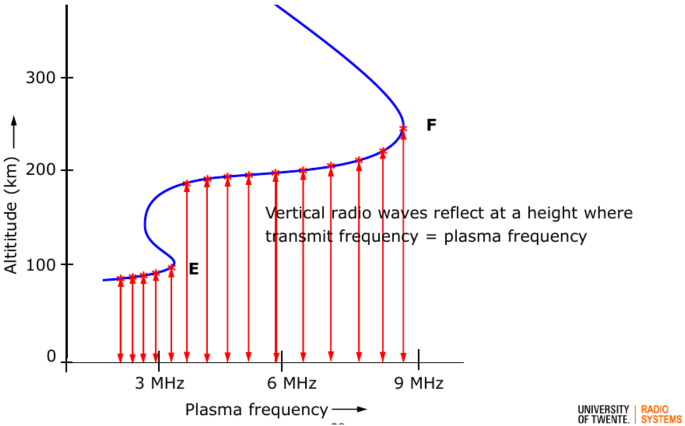
# Outline

# Introduction

How to observe the ionosphere?

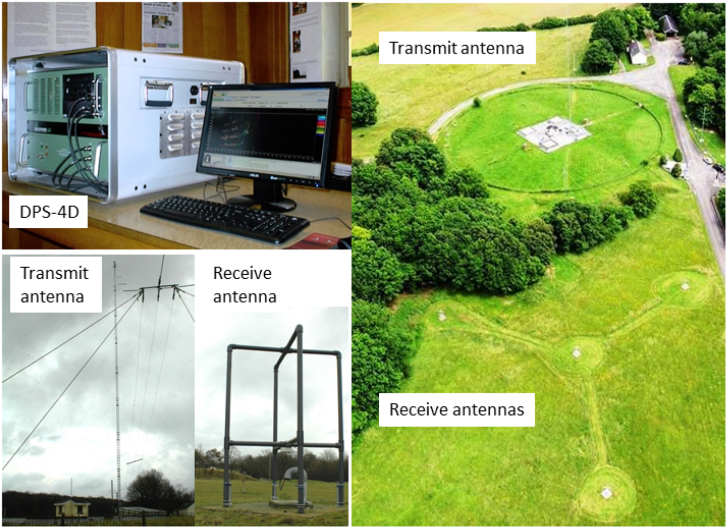
1. *in situ* (sounding rockets, satellites): very good, but limited in coverage and expensive
2. Using radio waves:
   1. Trans-ionospheric signals (GNSS, radio telescopes,...)
   2. Reflection from the ionosphere (ionosonde, Doppler sounder,...)
   3. Incoherent scatter radar

# The principle of the ionosonde

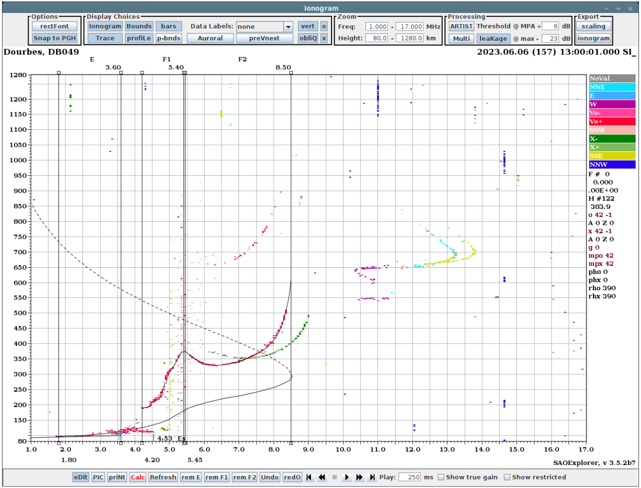



1. Transmit various frequencies, one after the other.
2. For each frequency, register the time of arrival for the echoes (if any).
3. From the arrival times, reconstruct electron density profile up to $hmF_2$.

# The Dourbes Ionosonde



# A quiet, day-time example

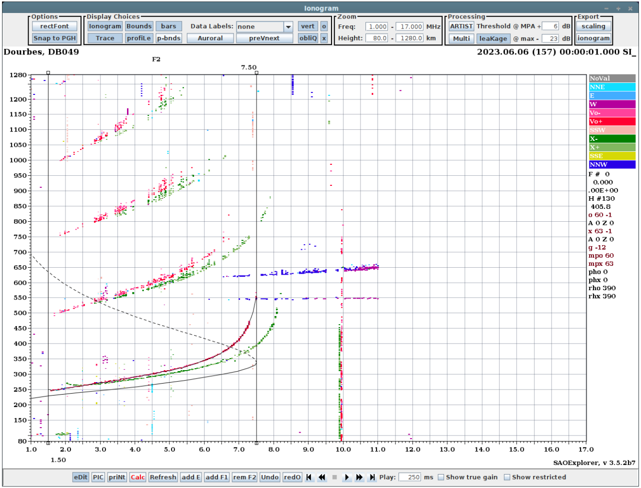



All the main layers visible.

Minor sporadic-*E*, up to 4.5 MHz.

Oblique trace from Spanish ionosonde.

# A quiet, night-time example

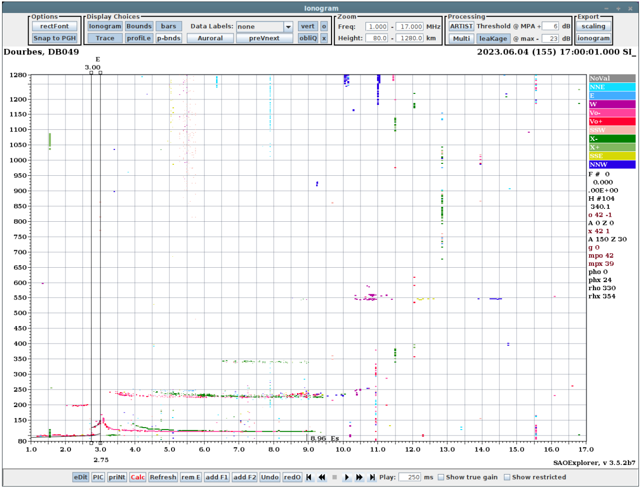



Only a single *F*-layer exists.

$foF_2$ is (somewhat) lower.

In this case, $hmF_2$ close to day-time value.

# Sporadic-*E*

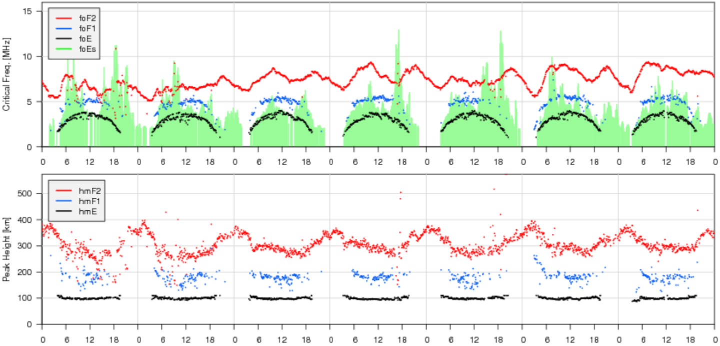



Sporadic *E*-layers: very thin but very high electron density layers below the *F* layer.

Little effect on the *TEC*, but makes Ionosonde soundings impossible.

Also lower ionosphere absorption can prevent ionogram soundings.

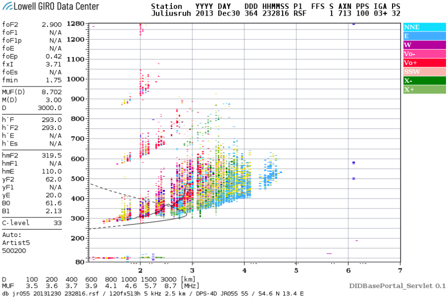
# Ionogram derived characteristics

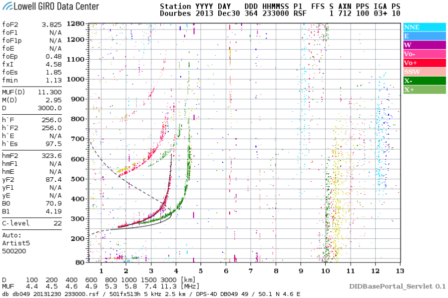



From the ionosonde, we can obtain (automatically, in real-time) most ionospheric weather parameters. The main exception is *TEC*.

# Scintillation ↔ spread-*F*

Example of expanding auroral oval during geomagnetic disturbances.

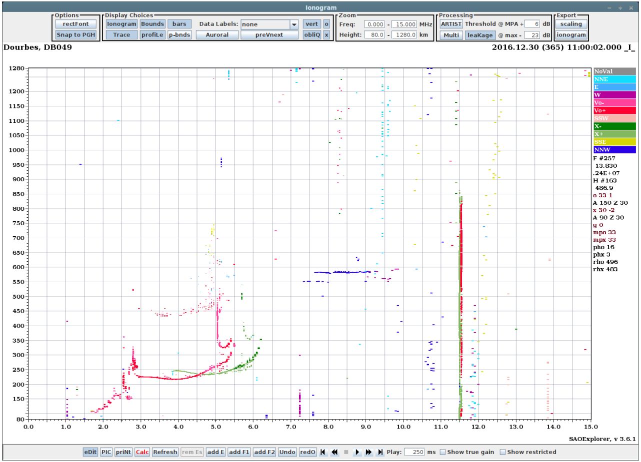



The auroral oval extends here to between Juliusruh (55°N, left) and Dourbes (50°N, right). Spread-*F* in ionograms is associated with scintillation in GNSS signals.

# Small scale disturbances

Electron density gradients and small scale travelling disturbances can be seen as distortions to the “normal” ionogram traces.



# Strengths & limitations of ionosondes

Strengths:

- Detailed observations of the bottomside ionosphere.
- Fairly good time resolutions (five minutes).
- For high-end instruments: oblique measurements, Doppler data,...

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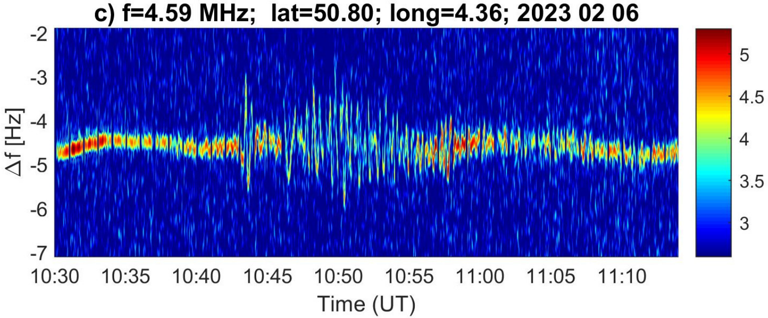
Limitations:

- No information above $hmF_2$ (so no *TEC*).
- Measurements affected by absorption & sporadic-*E*.
- No information at very short scales (both in time and space).
- Big and expensive equipments, so a sparse network of observatories.

# Continuous wave Doppler sounding

The time resolution of the ionosonde is limited by the duration of a single ionogram sounding.

Continuous-wave sounding allows detection of smaller disturbances.




However: only a single frequency is sounded, so no complete electron density profile can be obtained.

# Absorption measurements

Various techniques can be used to measure absorption in the lower ionosphere:

- **Method A1: pulse reflection.** A fixed pulse at a single frequency (usually around 2 MHz) is transmitted, and the amplitude of the echo is measured. This can be done either vertically or oblique.
- **Method A2: cosmic radio noise detection.** A riometer (Relative Ionospheric Opacity Meter for Extra-Terrestrial Emissions of Radio noise) is used to monitor the amount of cosmic radio noise that passes through the ionosphere.
- **Method A3: oblique signal strength.** The SNR of oblique ionogram traces can be used to estimate absorption at various frequencies.

The end!

Questions?

References:


- R.D. Hunsucker: *Radio Techniques for Probing the Terrestrial Ionosphere*, Springer-Verlag, 1991.
- R. Schunk & A. Nagy: *Ionospheres: physics, plasma physics, and chemistry*, Cambridge University Press, 2000.
- K. Davies: *Ionospheric Radio Propagation*, The Institution of Engineering and Technology, 1990.