DISPEC

Scientific exploitation of space Data for improved Ionospheric SPECification

Time-frequency domain of ionospheric parameters from GNSS stations and Digisondes

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The DISPEC project is funded by the European Union (GA 101135002). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HaDEA). Neither the European Union nor the granting authority can be held responsible for them.

Outline

- **Objectives**
  - Spectral analysis and filtering of ground-based and satellite ionospheric data
  - Correlation analysis between filtered ionospheric data and solar/magnetic parameters
- **Task description and participating teams**
  - Task 3.1 Assessment of data requirements (T01 – T06) (UWM,UPC,NOA)
  - Task 3.2 Spectral analysis and correlation analysis (T07 – T24) (UWM, NOA,UPC)
  - Task 3.3 Band-pass filtering (T10 – T24) (UWM, UPC)
  - Task 3.4 Verification and Final release of band-pass filtered and multiband data (T24 – T32) (UWM, UPC,NOA)

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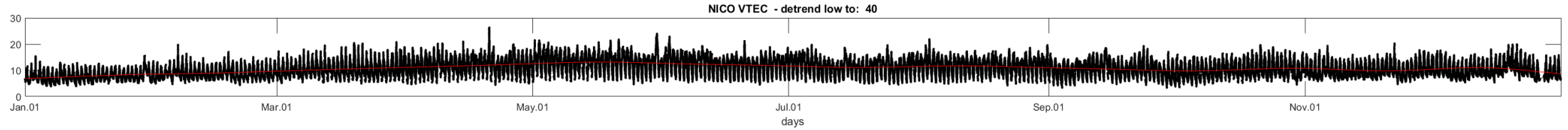
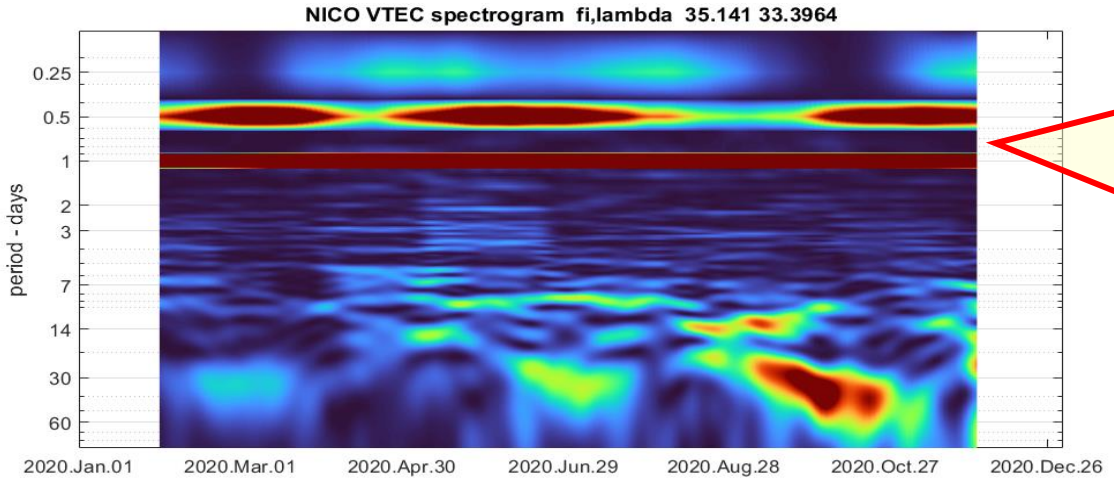
Time-frequency analysis of terrestrial GNSS data

- **NICO IGS station, VTEC calculated for tracked satellites and averaged using inverse disatance weighting.**
- **The signal is continuous for this station, but several IGS stations provide data including discontinuities**
- **We remove 40-day trend to work with signals from around 27-day wave period to just over diurnal wave period**





Diurnal and semi-diurnal components are the strongest, and therefore the option is to work with shorter (inter-diurnal) or longer (over-diurnal) wave periods.

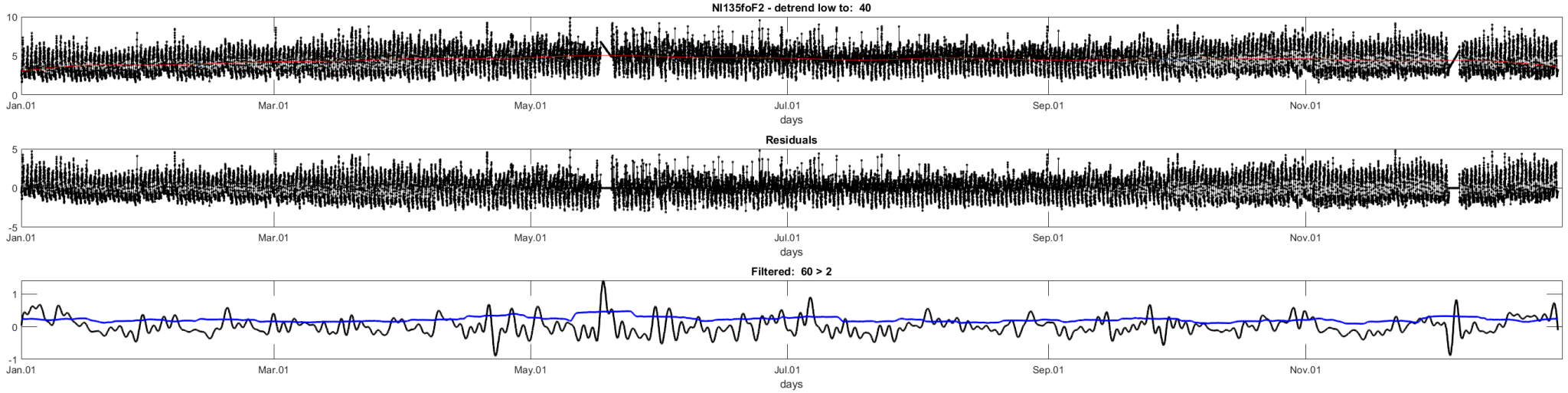
The work with inter-diournal periods needs extremely complete data. The GIMs do not assure such resolutions.

A several-day increases of Ne are observed by Swarm, and therefore the choice of over-diurnal periods is chosen.

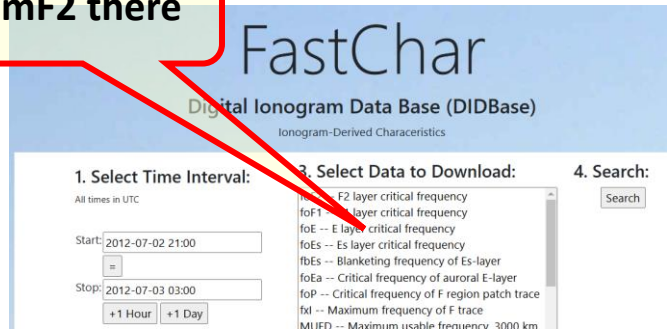
Jarmołowski,W., Wielgosz, P.; Hernández-Pajares,M.; et al... 2023, The Correlation between Ionospheric Electron Density Variations Derived from Swarm Satellite Observations and Seismic Activity at the Australian–Pacific Tectonic Plate Boundary. Remote Sens. 15, 5557. https://doi.org/10.3390/rs15235557

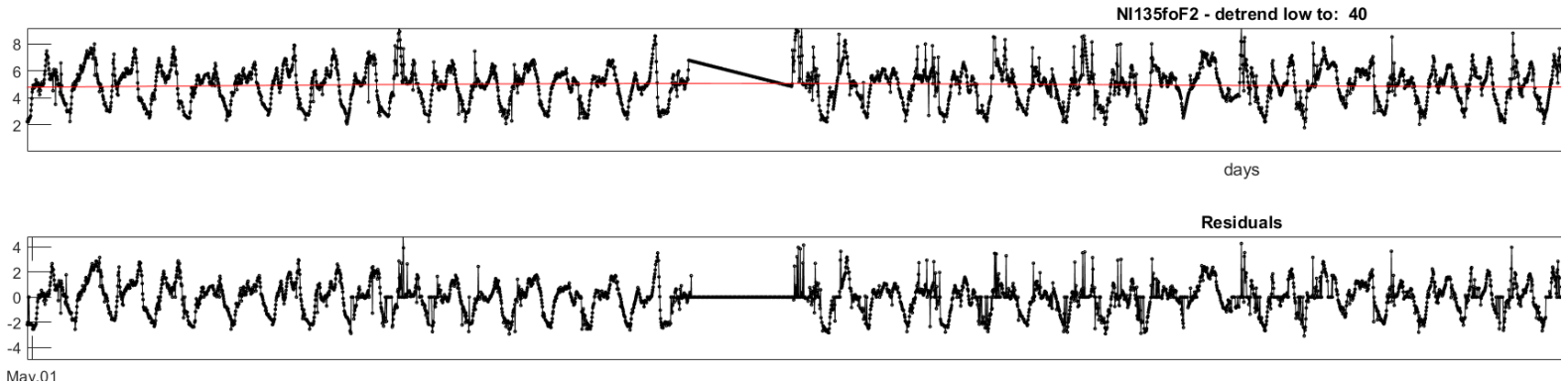
Time-frequency analysis of terrestrial Digisonde data

- NI135 Digisonde station, foF2 downloaded from FastChar service and allocated to 15’ regular time axis (no interp).
- The signal includes moderate discontinuities, but also many outliers (inter-diurnal periods impossible),
- Over-diurnal have some chance, but cleaning is really advised (potential influence on over-diurnal signals)



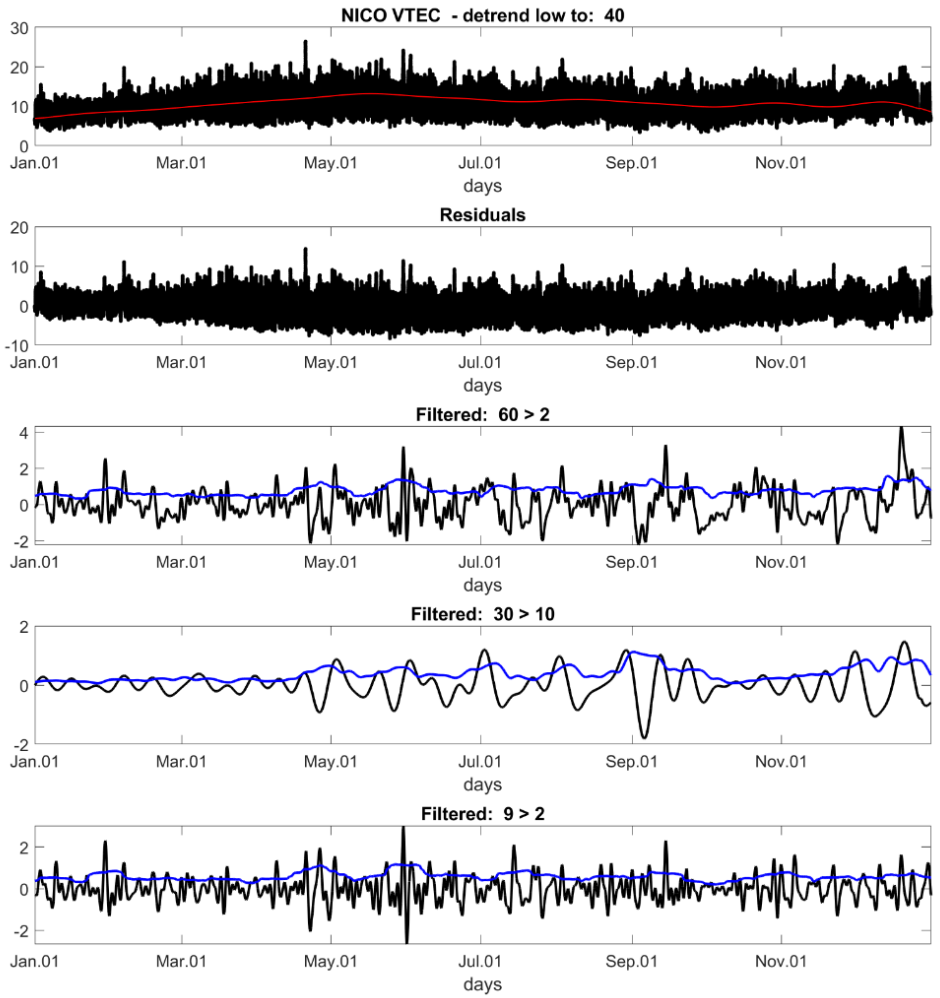
No NmF2 there

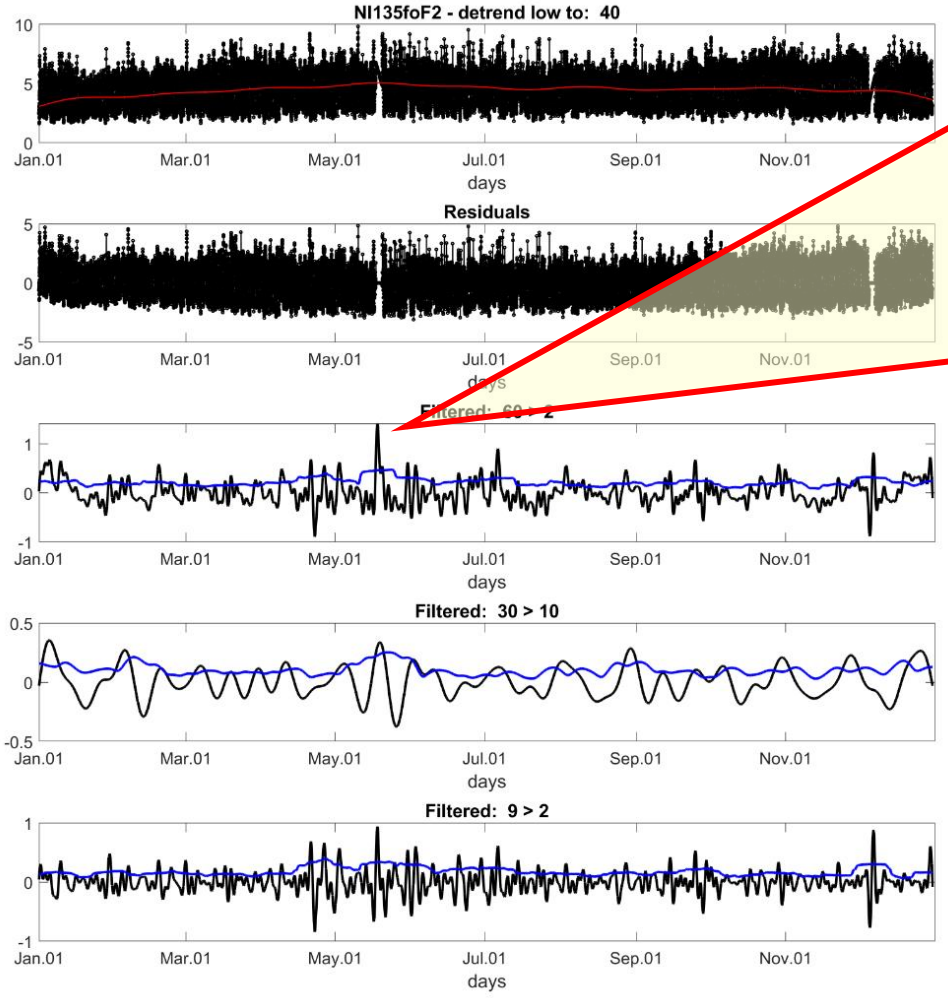




Filtering of terrestrial data

- The 40-day high-pass filtering (a-b) and band-pass filtering (c-e) (the same for GNSS and Digisonde)
- Region surrounding Nicosia to -15°<λ<15° -10°<ϕ<10°





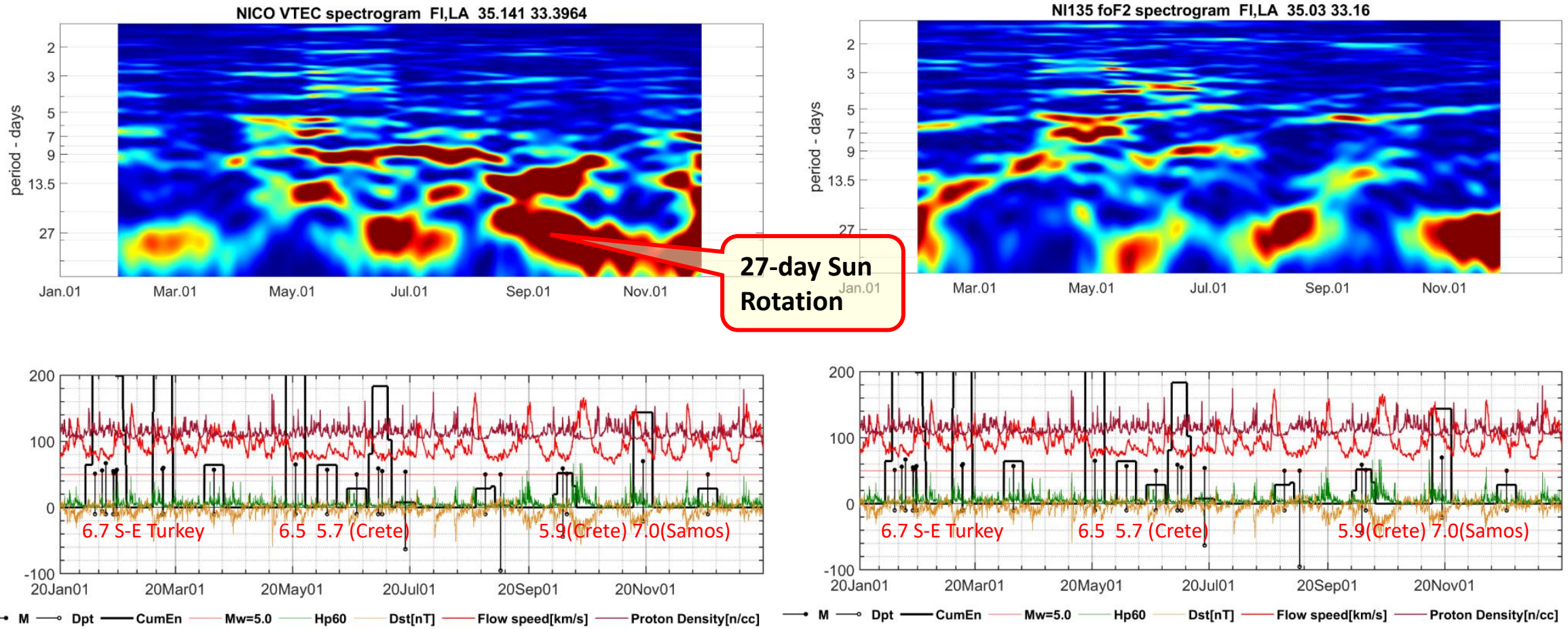
Blue lines are standard deviation of residuals.

The Gibbs' phenomena occurs at data gaps.

But this is in filtering from data filled by linear interpolation. For spectrograms we use original-trend-filled with zeros

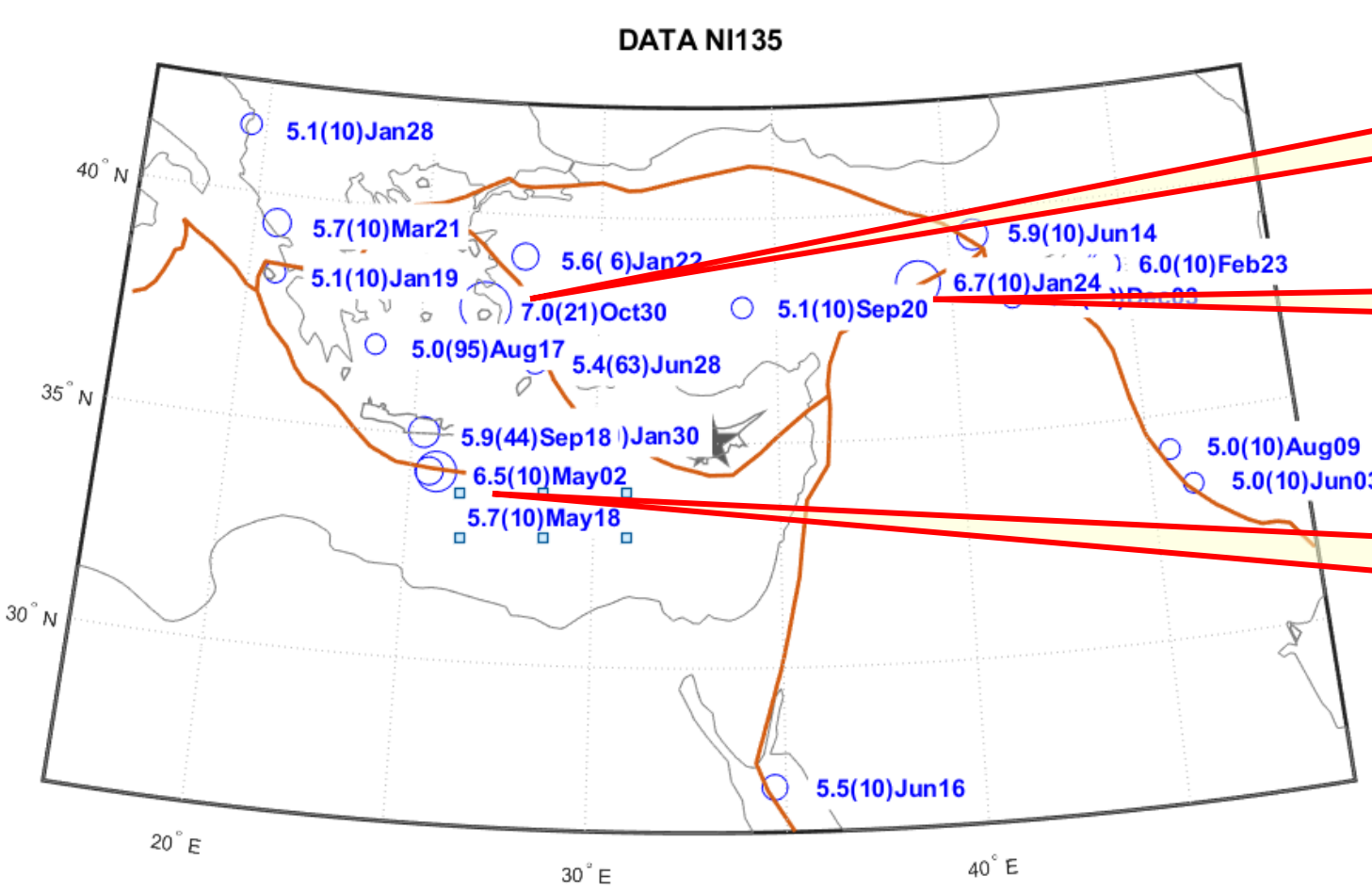
Time-frequency analysis of GNSS/Digisonde

- The 50-1.4-day spectrograms (the same for GNSS and Digisonde)
- Ancillary data: Solar wind Flow speed, Proton Density, Hp60, Dst, Earthquakes and 10-d Cum. Seismic Energy



The earthquakes M>=5.0

- The earthquakes in 2020 with M>=5.0 surrounding the station (the same for GNSS and Digisonde)
- Region surrounding Nicosia to -15°<λ<15° -10°<ϕ<10°



Samos, M=7.0, end of October 2020

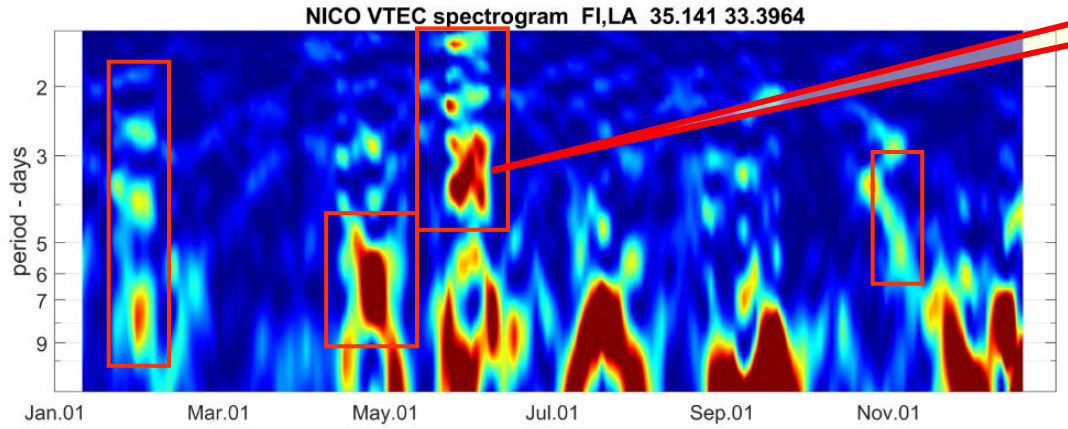
S-E Turkey, M=6.7, January 24, 2020

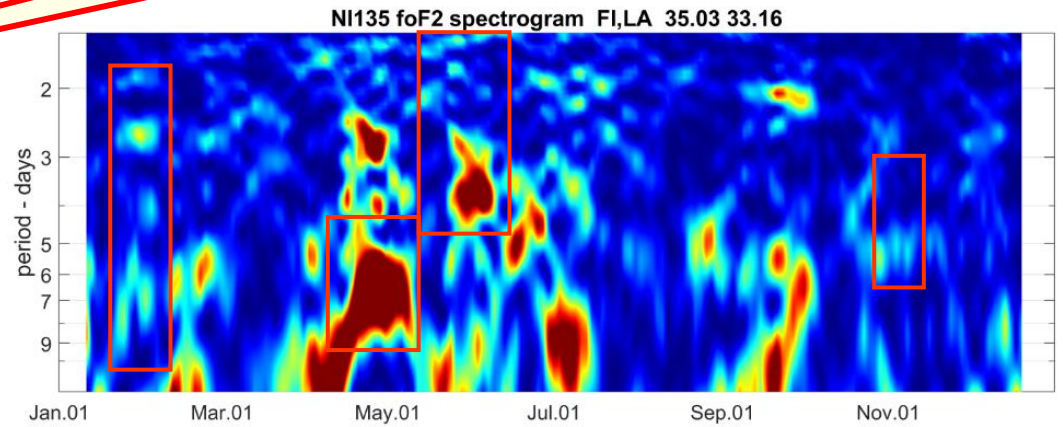
Two earthquakes in May 2020, close to Crete, the stronger M=6.5 first

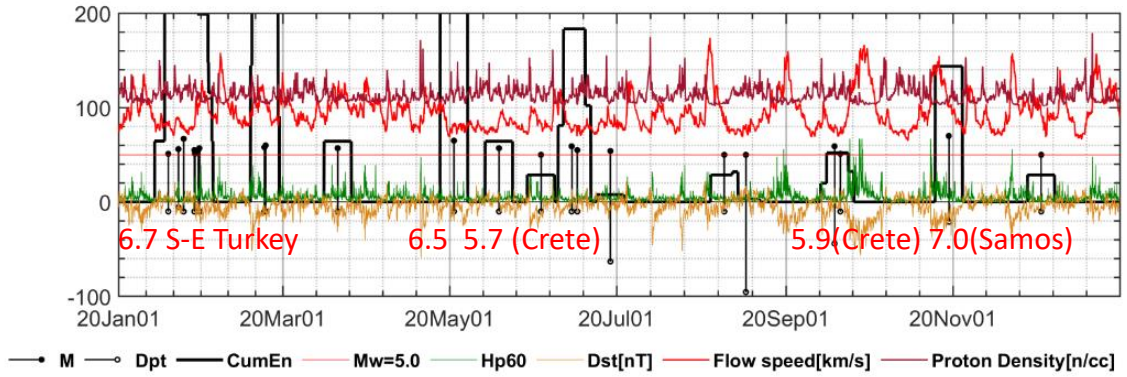
Time-frequency analysis of GNSS/Digisonde

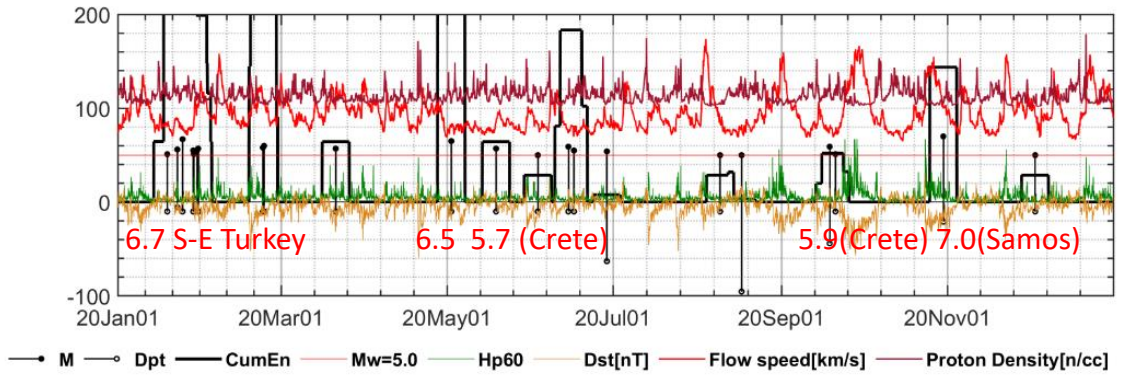
- The 12-1.4-day spectrograms (the same for GNSS and Digisonde)
- The signals must differ as the soundings are from 20000 km and 600? km

This is not Edge effect from gap, because we have it in GNSS

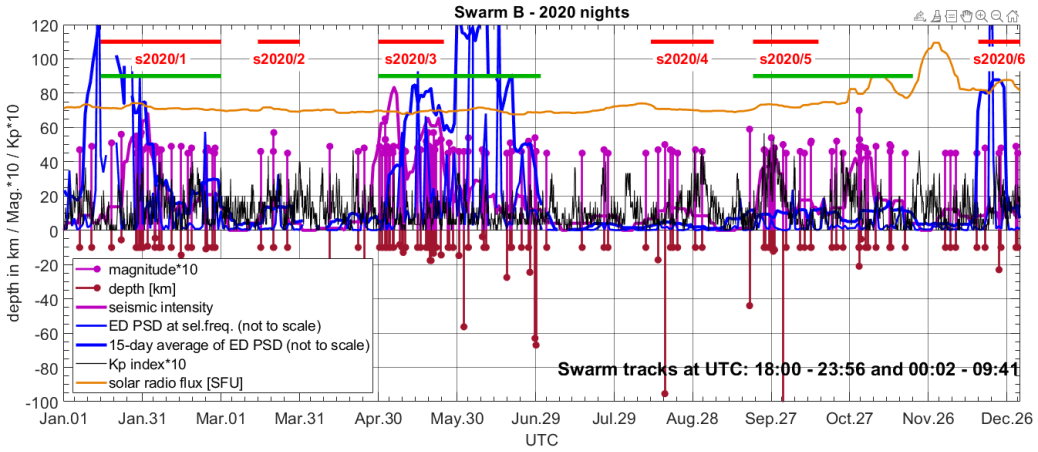




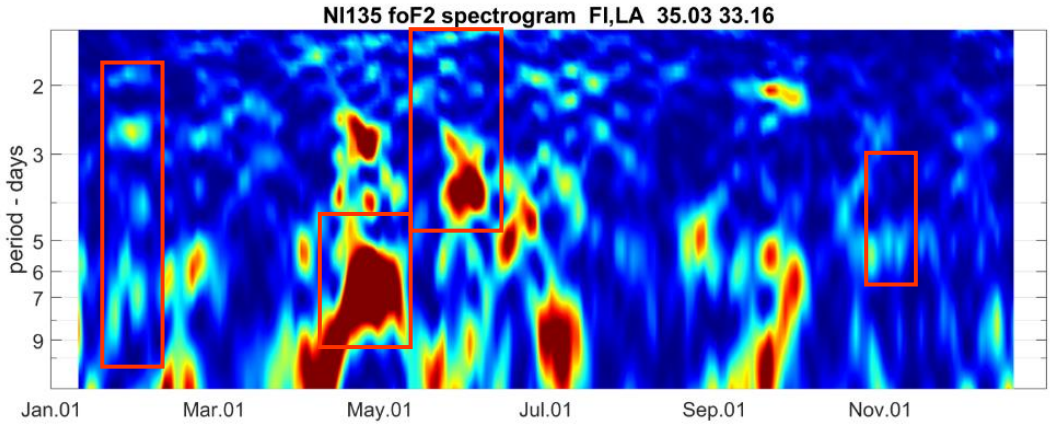


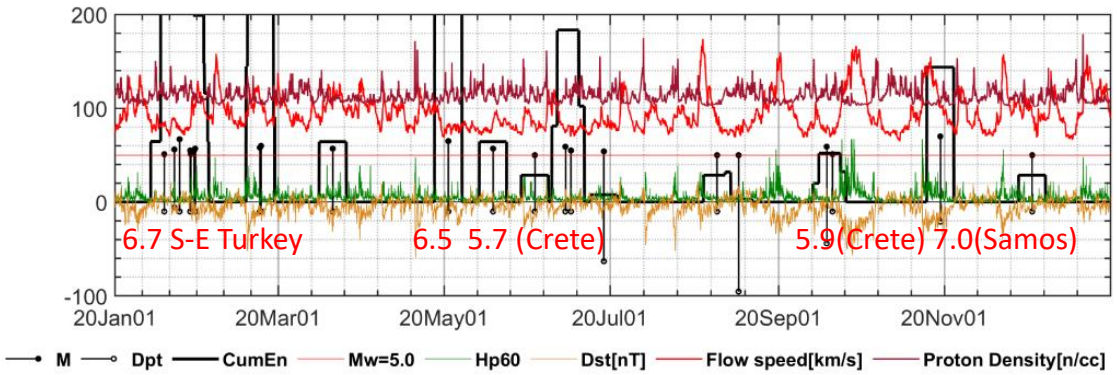


Swarm-digisonde correlation



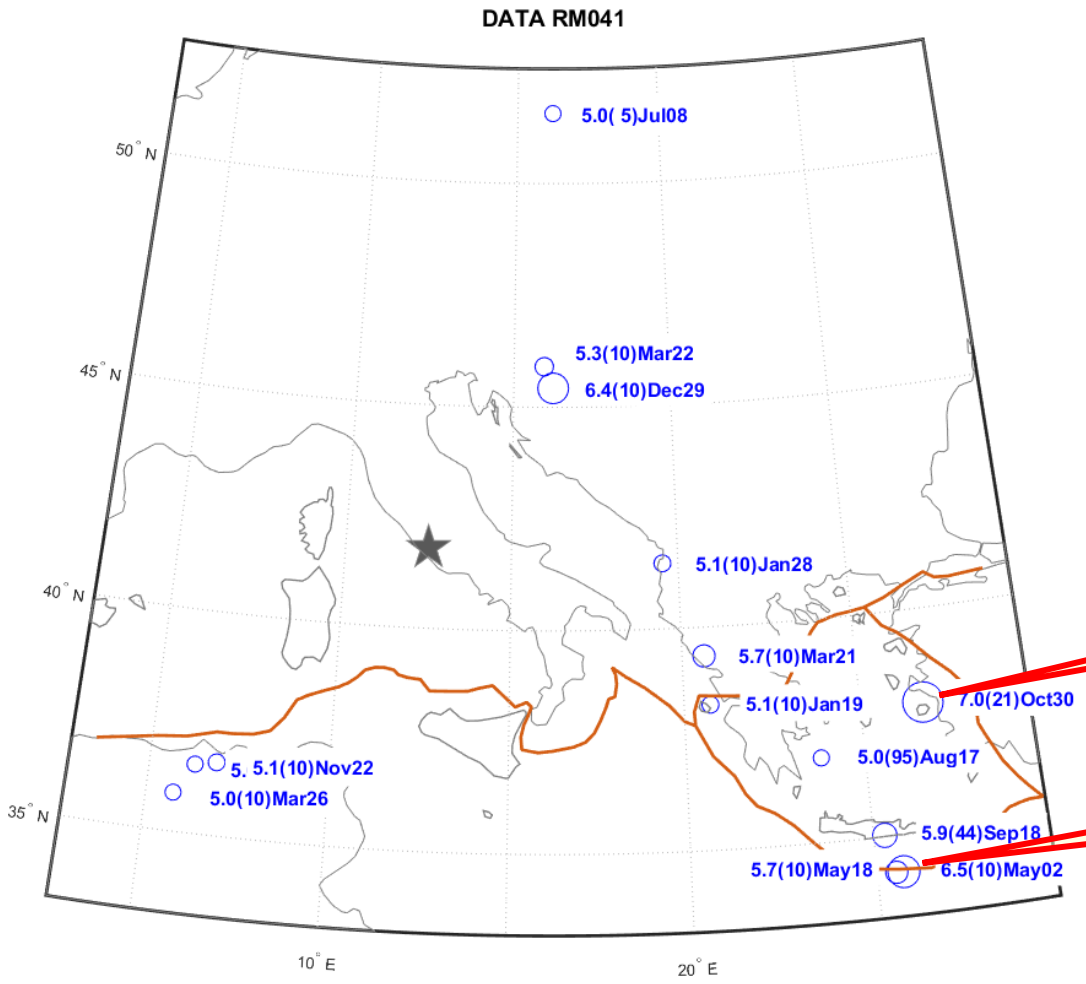
6.7 S-E Turkey 6.5 5.7 (Crete) 5.9(Crete) 7.0(Samos)





The earthquakes M>=5.0 around Rome

- The earthquakes in 2020 with M>=5.0 surrounding two Digisonde stations from Rome
- Region surrounding Rome to -15°<λ<15° -10°<ϕ<10°

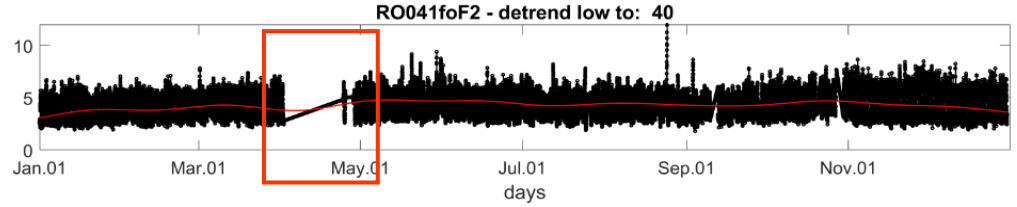


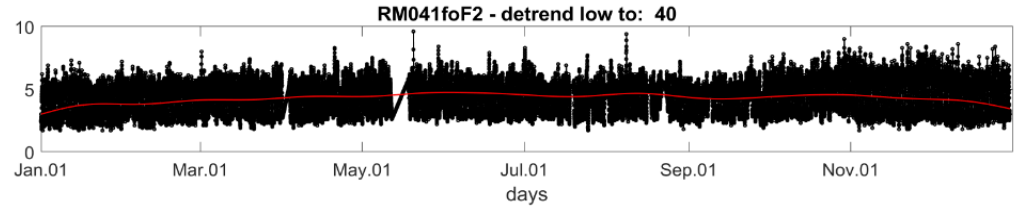
Samos, M=7.0, end of October 2020

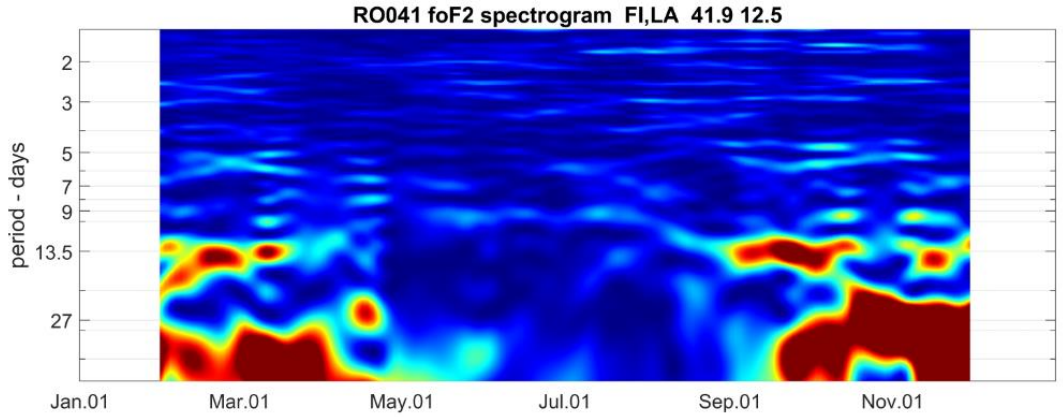
Two earthquakes in May 2020, close to Crete, the stronger M=6.5 first

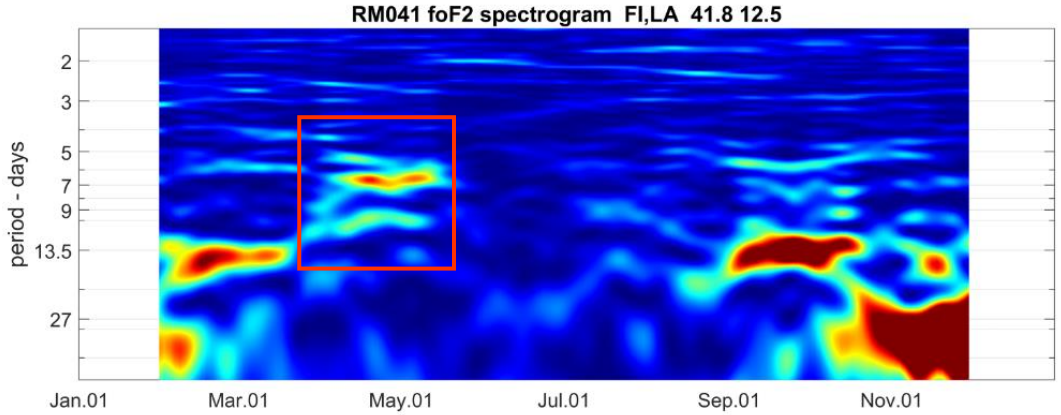
Time-frequency analysis of foF2 from Rome Digisonde

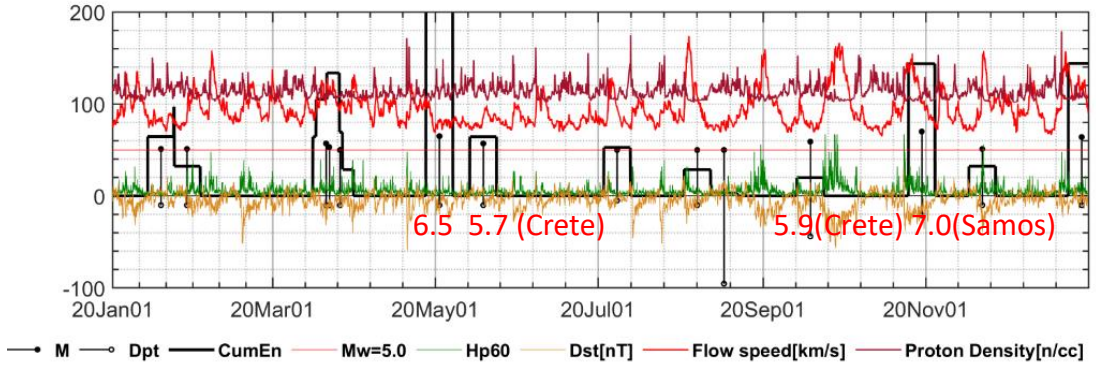
- **The 50-1.4-day spectrograms, the datasets have different gaps, and the one from the left is during the earthquake**

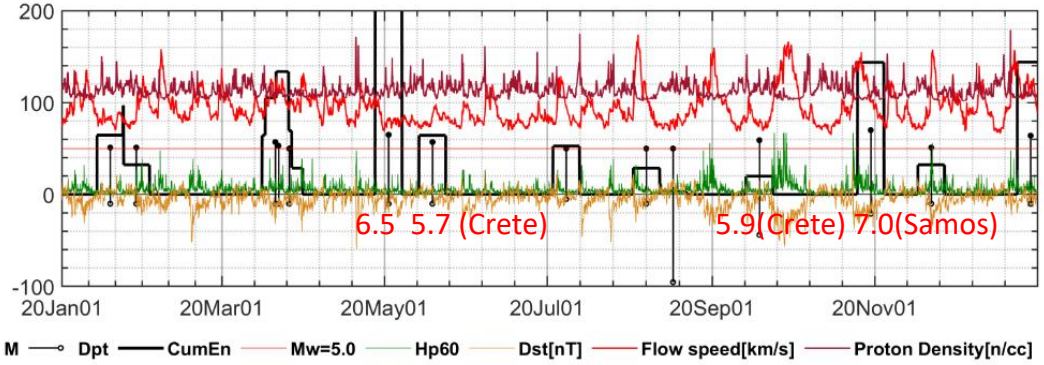








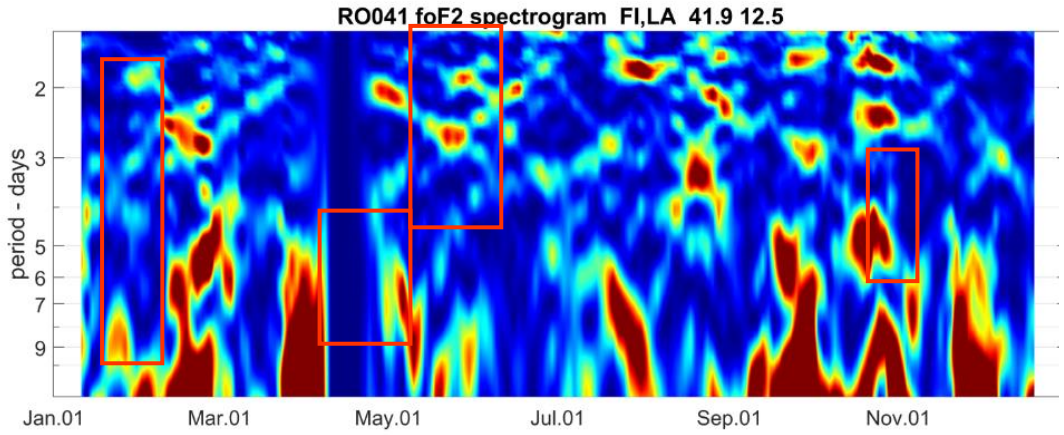


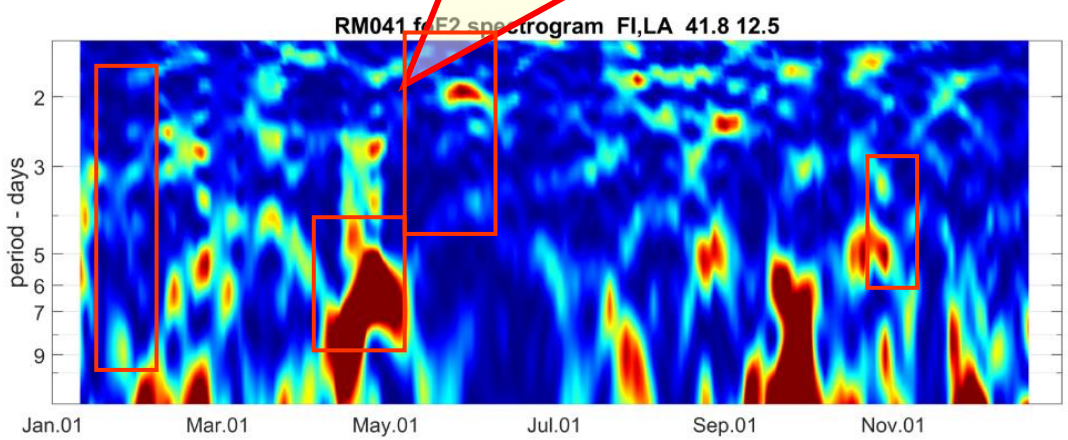


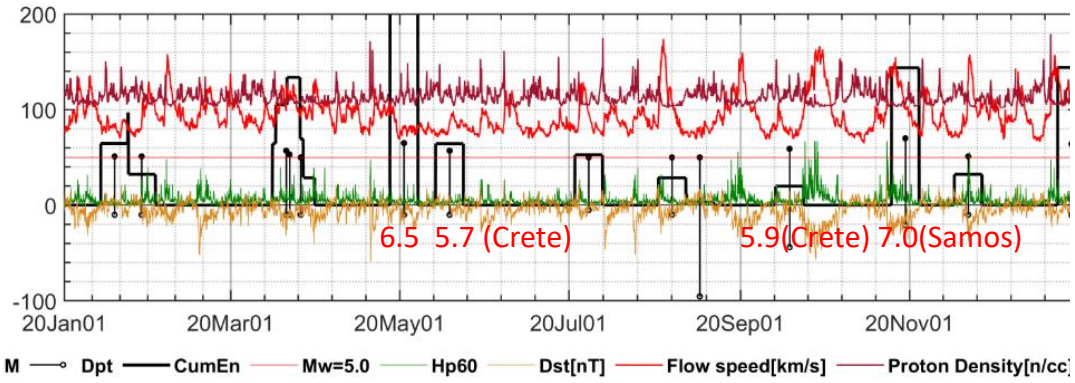
Time-frequency analysis of foF2 from Rome Digisonde

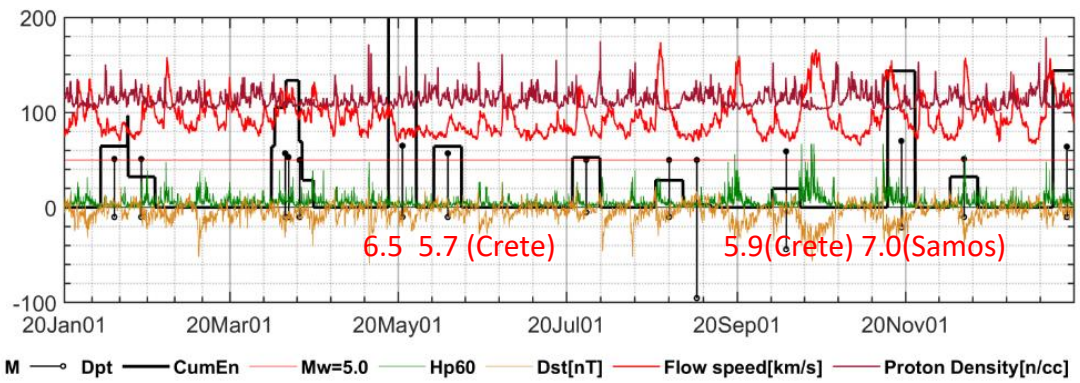
- The 12-1.4-day spectrograms
- Rome is much more distant from Crete in comparison to Nicosia

Due to relative scale, different gaps, different maxima, these irregularities can be, in fact similar



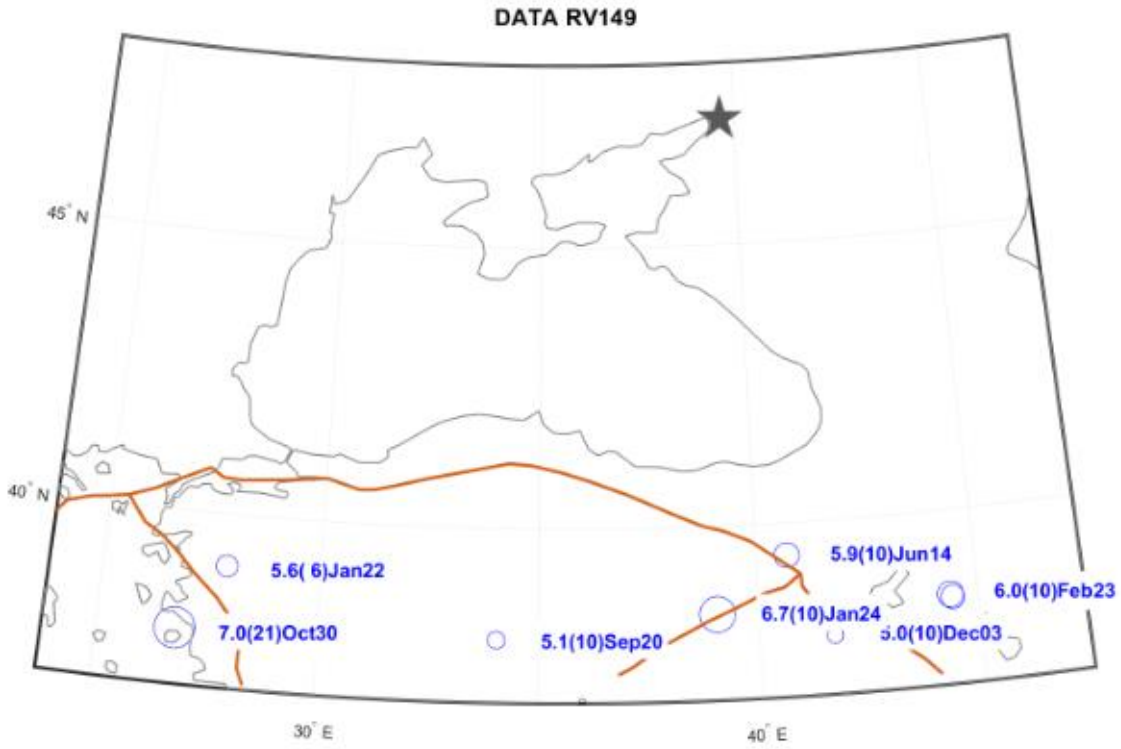


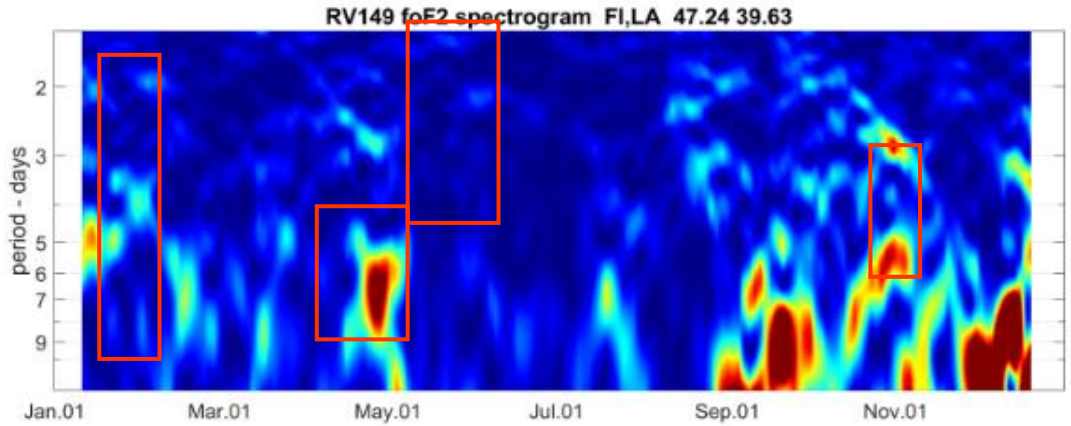


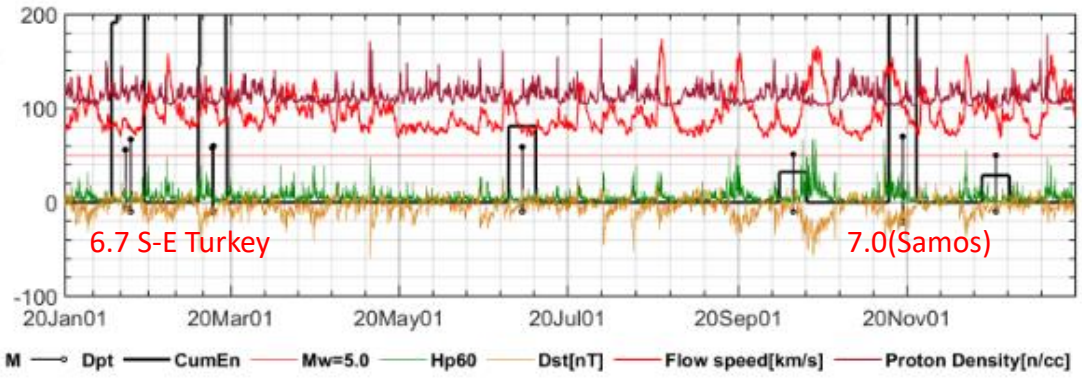


Time-frequency analysis of foF2 from Rostov Digisonde

- **The 12-1.4-day spectrograms**
- **Rostov is far from Crete**







REMARKS, CONCLUSIONS

- Spectrograms show how complex are the signals and how many signal components are hidden without spectrogram (scalogram)
- The most evident variations of foF2 are similar over time to GNSS (but not all)
- Time of the most pronounced variations from GNSS/Digisonde coincide with that from Swarm Ne
- Large number of outliers can potentially affect over-diurnal wavelengths, especially if they exhibit high amplitudes of peaks, and for sure will affect inter-diurnal wavelengths (to be done)
- There are many interesting Digisondes, but have no data in this service.
- In the gaps we cannot do anything, as we do not have data. The option is setting to zero. Incontinuity leads to edge effects (Gibbs) but this is easy to distinguish
- Spectral analysis of solar parameters, assesment of their periodic or quasi-periodic impact on the ionosphere is needed (to be done)

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