DISPEC

Scientific exploitation of space Data for improved Ionospheric SPECification

SDA - 1

Outliers detection by Fourier Transform

NOA, UWM and DISPEC Team

DISPEC Third Networking Meeting, Tolulouse, 10 Nov 2025

Funded by the European Union

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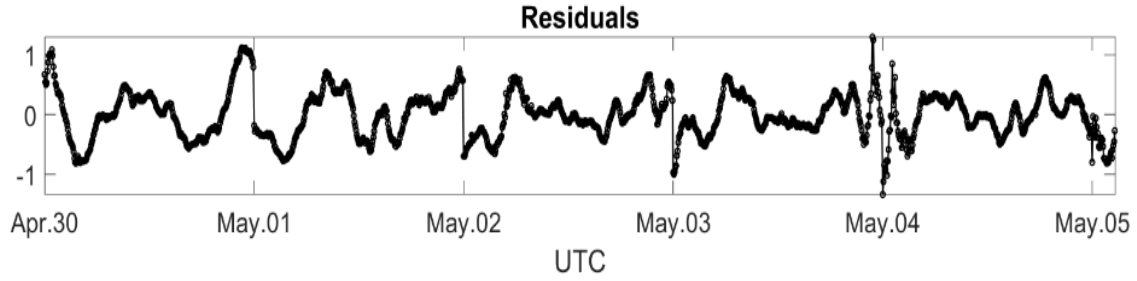
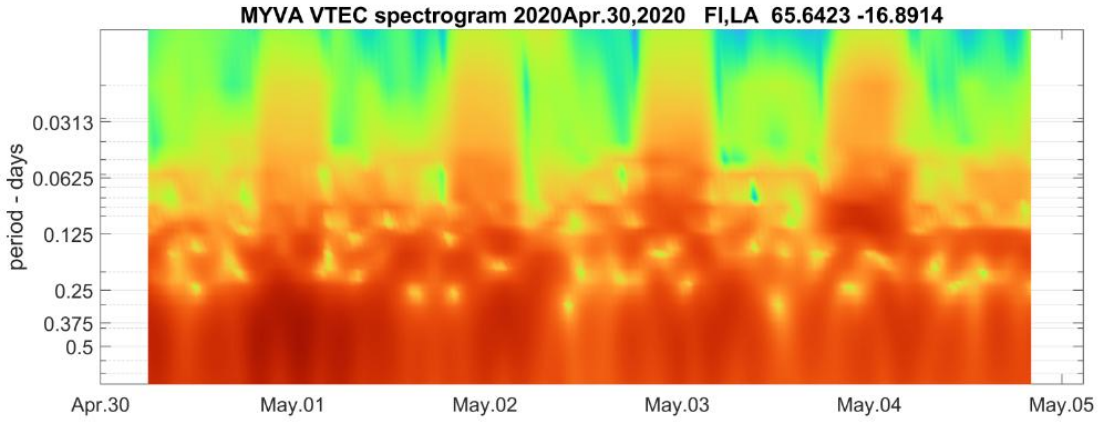
Outlier detection by Fast Fourier transform – FFT and short-term Fourier transform - STFT

It is easy to track outliers in time-frequency domain (e.g. using short-term Fourier transform - STFT) under some assumptions:

- The outliers are individual mistakes/deviations/abruptions…. uncorrelated with surrounding signal or other outlying values
- The outliers are surrounded by at least short time spans of correct correlated signal including lower frequencies

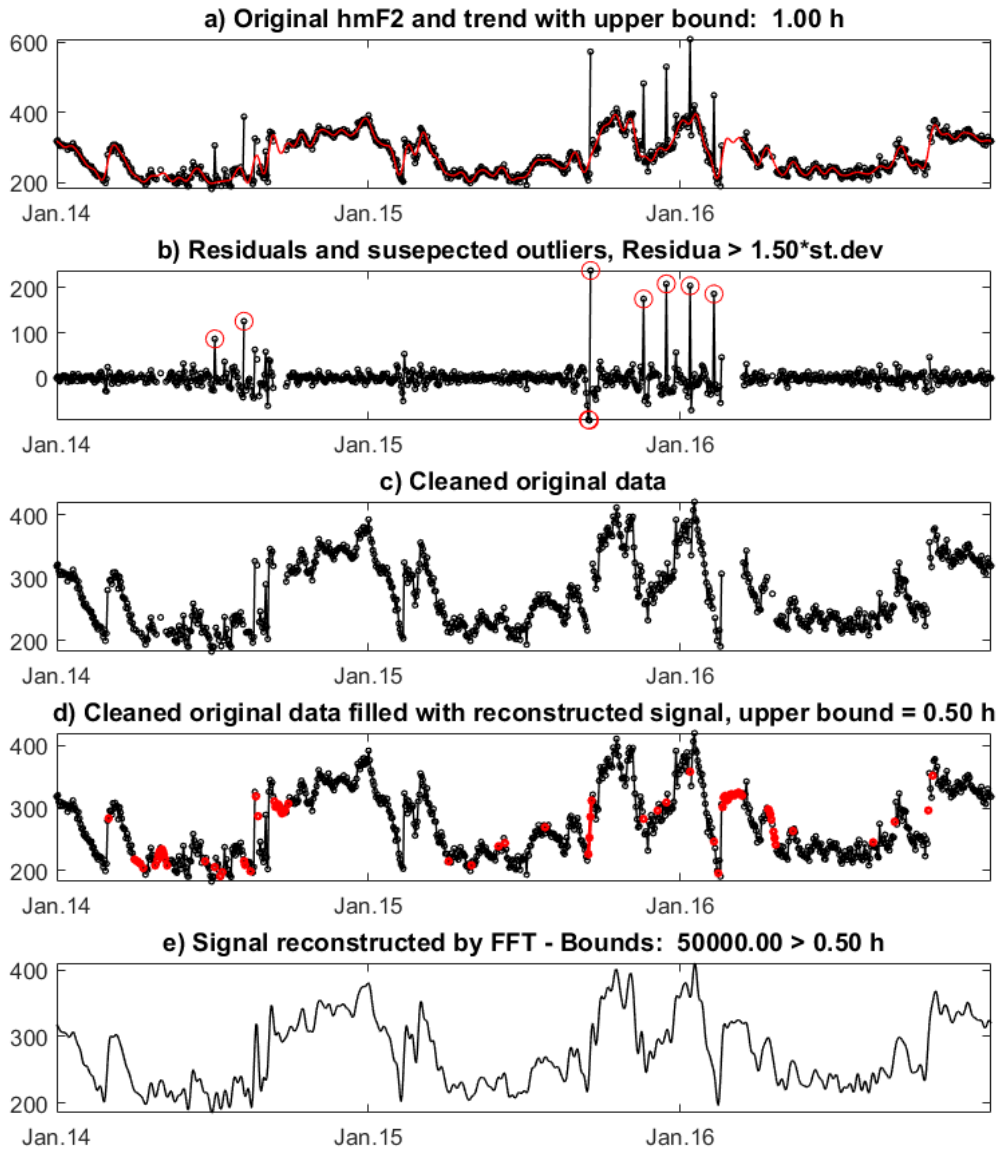
In the presented log-scale spectrogram, ground-based GNSS VTEC includes the outlier (here systematic error) at the start of every analyzed day, and it is detectable at the highest frequencies of the spectrogram.





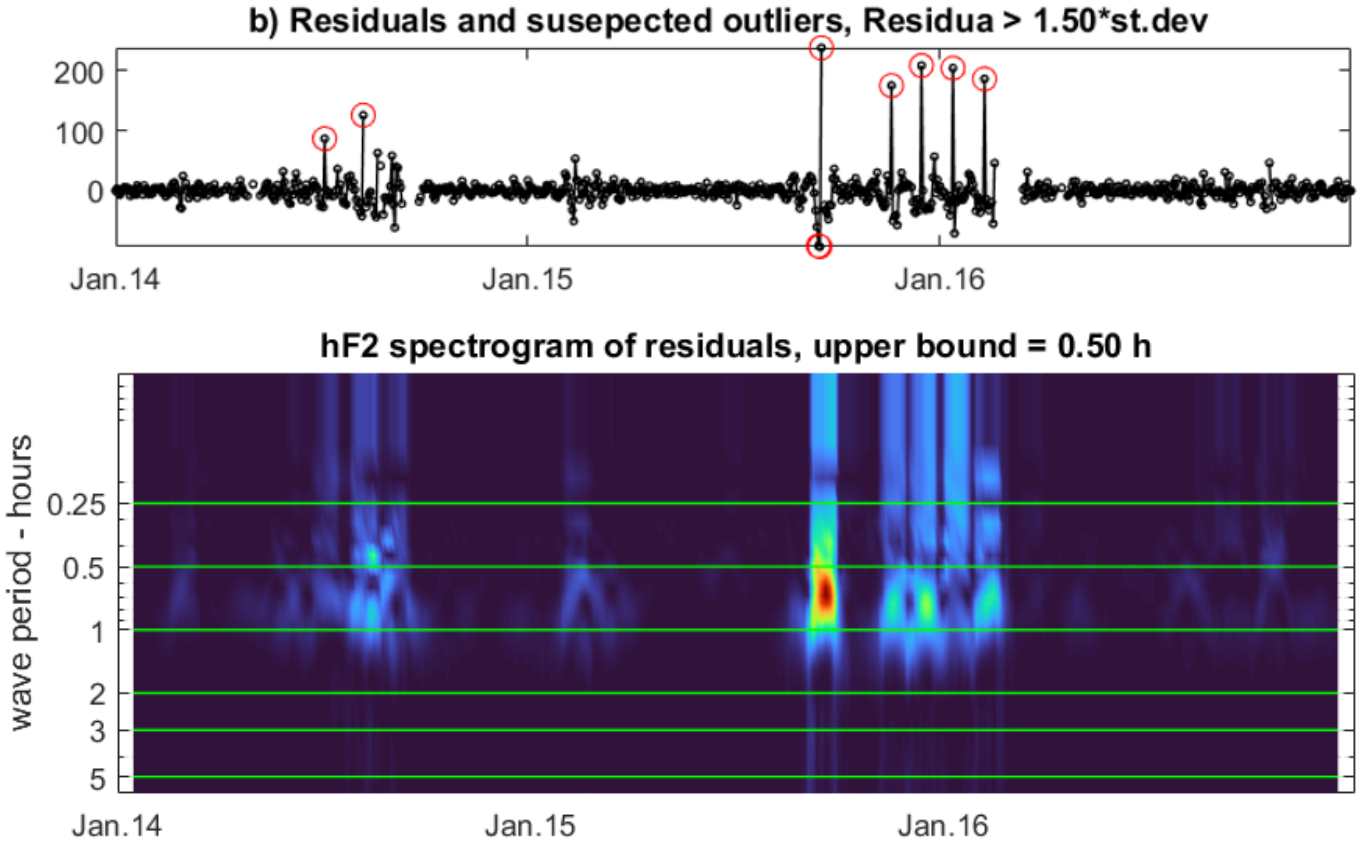
Low-pass filter with high upper filtering bound

1. FFT as low-pass filter for the decomposition and reconstruction of time series up to quite high frequencies, the bound of which is set to 1 h
2. Subtraction/removal of these reconstructed time series from the original signal
3. Selection of the outlier removal threshold, which can be calculated relatively to time series standard deviation, and it is here set to 1.5·std
4. Data gaps can be replaced with the signal reconstructed from the FFT, but the FFT must be repeated without outliers. The upper bound of low-pass filter can also be changed depending on the user requirements
5. additional possibility coming from the FFT-based filter is the reconstruction of the signal over entire time span. The reconstructed time series doesn't include any signal above the threshold wave period (here 0.5 h), but it does contain all errors remaining in the observations



Outliers in the evolutionary power spectrum calculated by STFT

- The verification of the outliers can be done after filtering or in the iterative process.
- The STFT is applied to residual hmF2 time series at short wave periods from 0.0625 h to 6 h.
- The spectrograms of hmF2 residuals allow the verification of outlier occurrence
- Outliers can be identified at wave periods shorter than 1 h, at the highest power spectral density (PSD) values



MAIN CONCLUSIONS

- **The condition is to find significant amount of correct data enabling estimation of true signal around standalone outliers.**
- **The groups of outlying values without true signal between them are harder to detect automatically**

- **The outliers deteriorate the Fourier coefficients, so filling the gaps must be done after their removal**
- **The frequency of reconstructed data in the gaps theoretically shouldn’t be higher than that corresponding to the gap size – otherwise we create false signal …**

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Thank you for your attention!

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