2020 EGU - D2638 | EGU2020-7390

Spire's EI/GNSS Team

Monitoring Perturbations in the Lower-Ionosphere Using GNSS Radio Occultation Observed from Spire's Cubesat Constellation

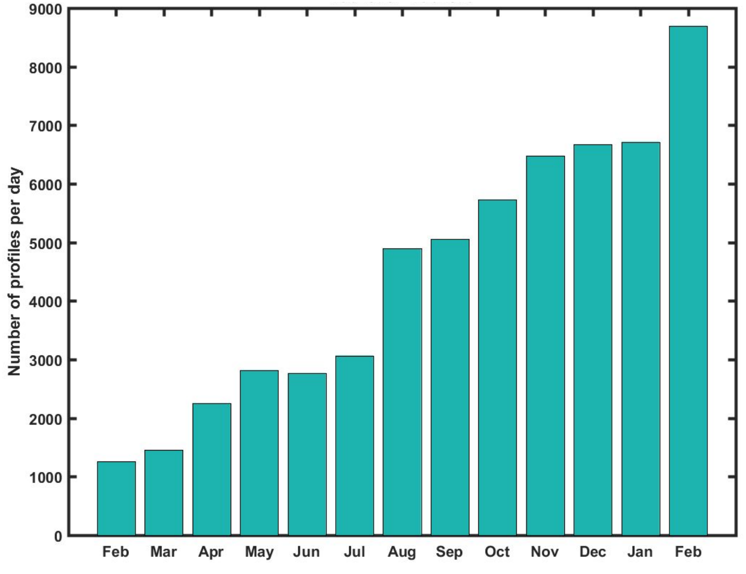
Giorgio Savastano[1], Karl Nordstrom[2], Matthew Angling[2], Vu Nguyen[3], Timothy Duly[3], Takayuki Yuasa[4], and Dallas Masters[3]

[1] **Spire Global Luxembourg S.a.r.l.**
[2] **Spire Global UK Ltd., UK**
[3] **Spire Global, Inc., USA**
[4] **Spire Global, Singapore Pte Limited, Singapore**

Outline

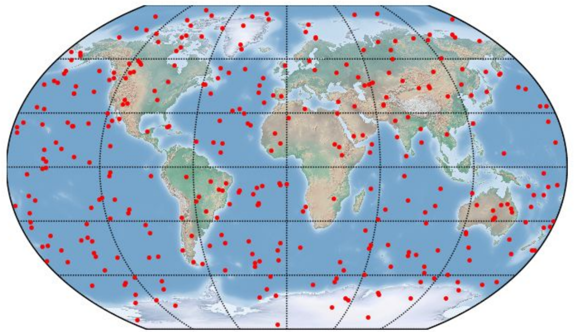
1. Growing Data Volume & Coverage
2. ML-Based Classification Pipeline
3. Key Takeaways

GROWING DATA VOLUME & COVERAGE

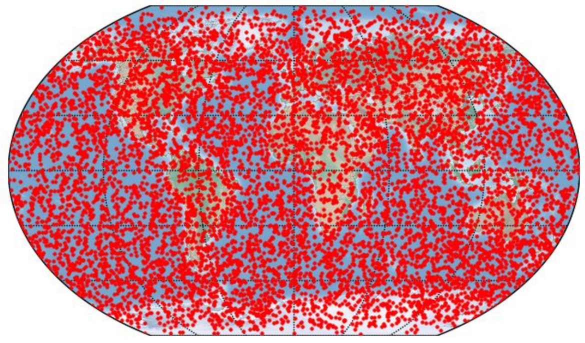


- Spire LEO data provides **unprecedented coverage over the oceans**

- **Continual data latency reduction**



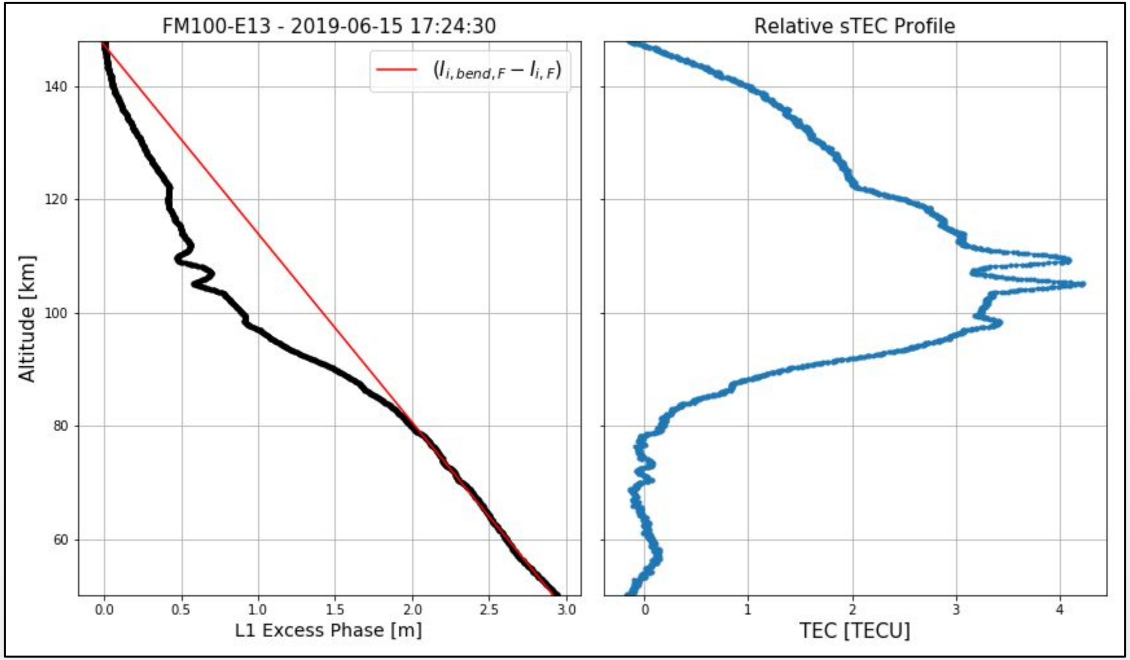
June 1, 2019:
100s of profiles per day



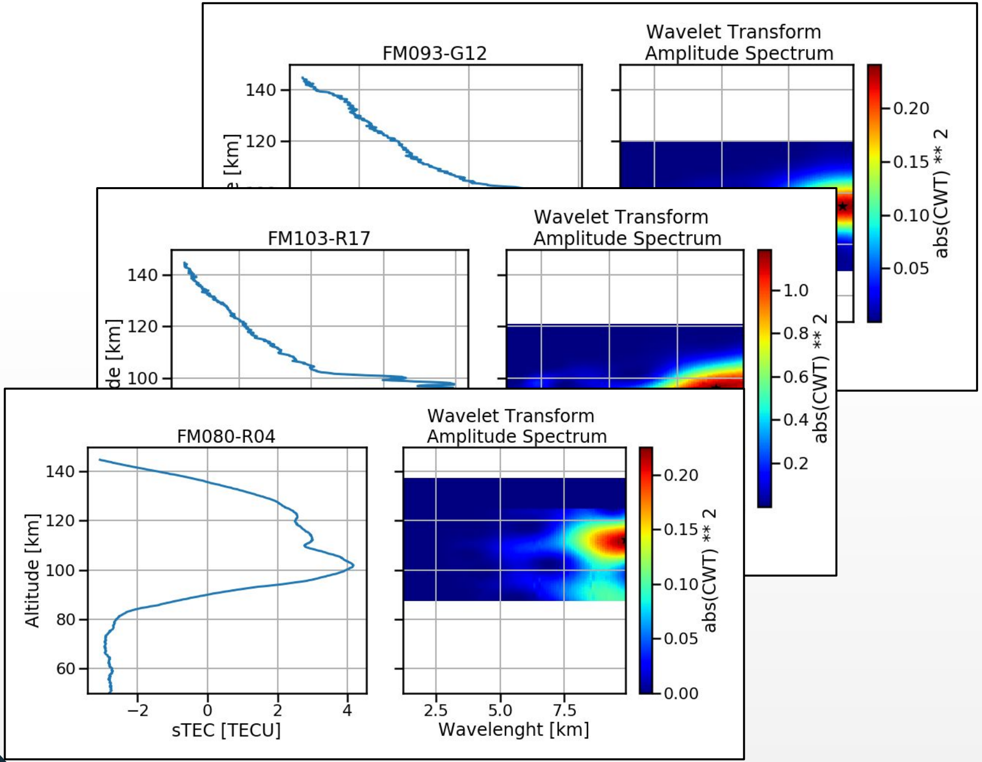
**Feb 15, 2020:
~10K profiles per day
(100x increase)**

LOWER-IONOSPHERIC PERTURBATIONS

- **Relative sTEC profiles** obtained from **single frequency** 50 Hz excess phase data:
  - F region contribution **removed** by fitting a linear trend below 80km
  - **vertical resolution < 100 m**
  - detection of **perturbations in the lower-ionosphere (< 150 km)**



ML-BASED CLASSIFICATION PIPELINE



1. Select **dataset of perturbed profiles**
2. Compute **wavelet power spectra** (WPS)
3. Compute **Earth's mover distance** as a measure of similarity
4. Find **clusters** with a ML-based algorithm (**Spectral Clustering**)
5. Build a **reference database** of **ionospheric perturbations**

DATASET OF PERTURBED PROFILES

- 100 profiles per day for the year 2019
- *min*(SNR) > 15 dB
- *std*(sTEC below 70 km) < 1 TECU

↓

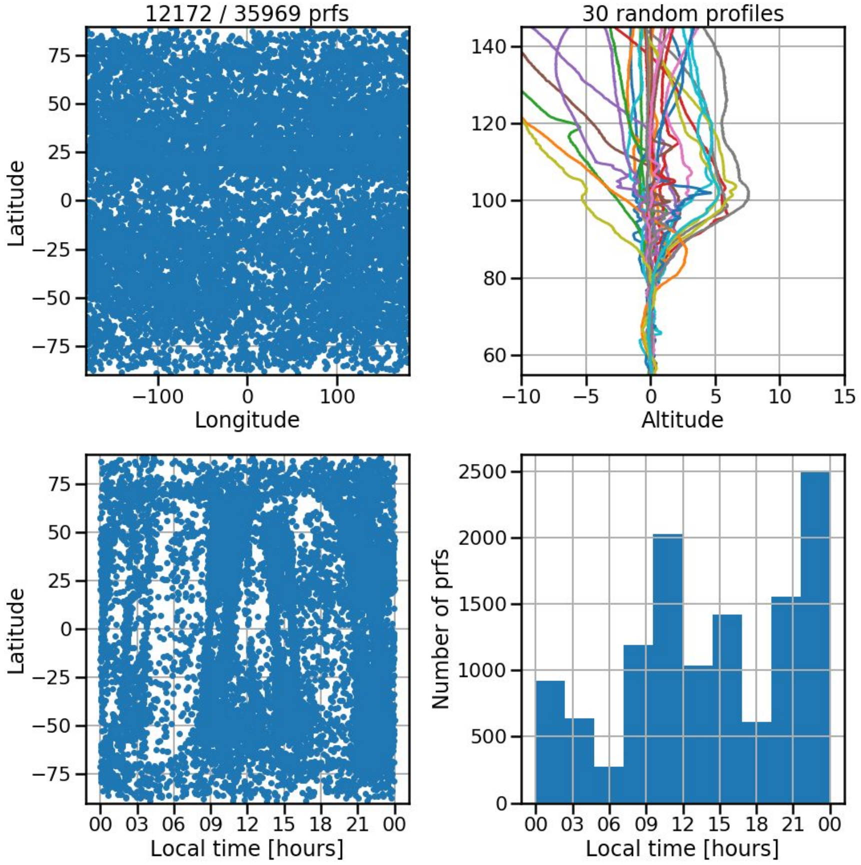
~36000 profiles

↓

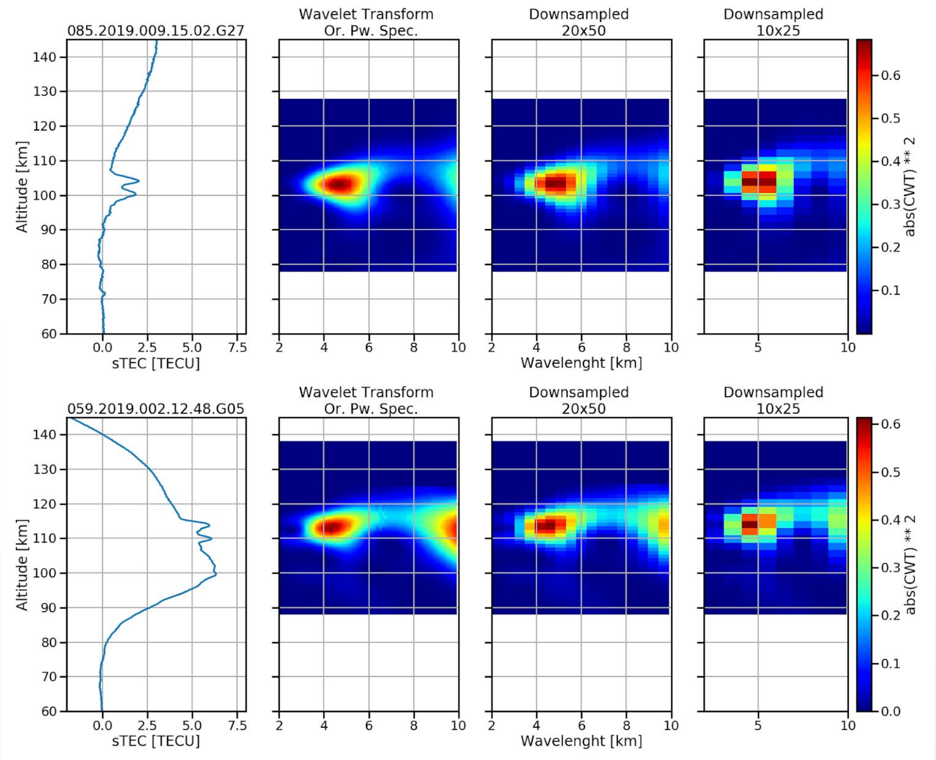
- *max*(WPS) > 0.20 $TECU^2$
- *sum*(WPS) > 15 $TECU^2$

↓

~12000 perturbed profiles



WAVELET POWER SPECTRA (WPS)



1. Compute **wavelet power spectra**
2. **Center** the spectra in altitude around peak of power
3. **Downsample** the spectra to *20x50*
4. Store spectra into a *(nx20x50)* **matrix of spectra** (where *n* is ~12000 profiles)

EARTH MOVER'S DISTANCE (EMD)

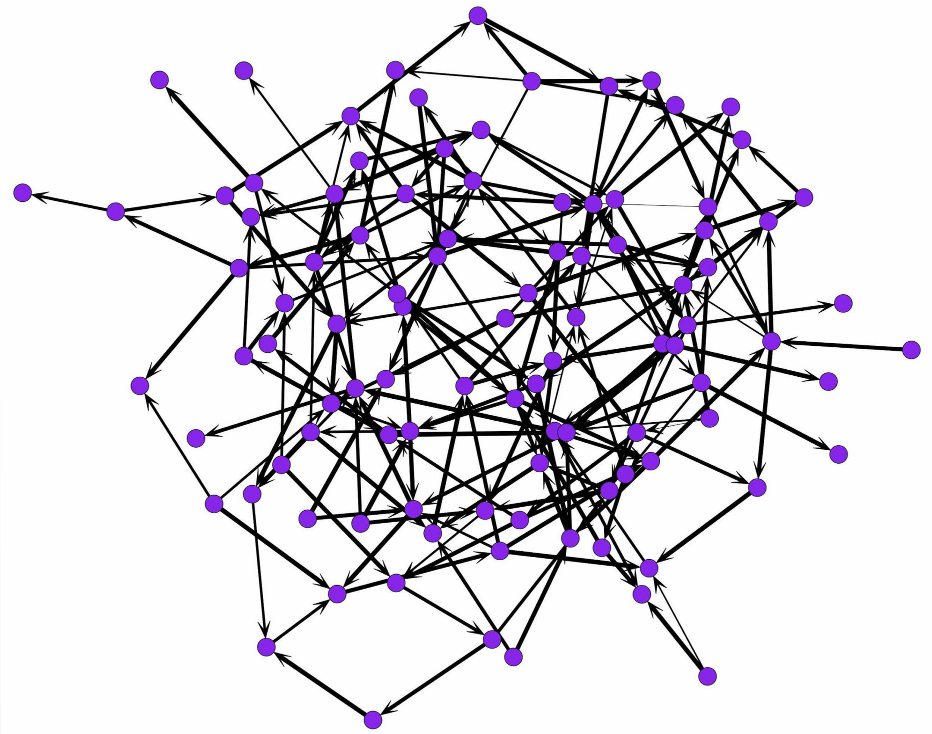
Intuitively, given two distributions, one can be seen as a mass of earth properly spread in space, the other as a collection of holes in the same space. Then, the EMD measures the least amount of work needed to fill the holes with earth. Here, a unit of work corresponds to transporting a unit of earth by a unit of ground distance.

1. Compute **pairwise EMD** between all the *n* elements in the matrix of spectra

2. Store EMD distances into a *(nxn)* matrix known as **distance matrix**

EMD-based similarity analysis (EMDSA)

SPECTRAL CLUSTERING



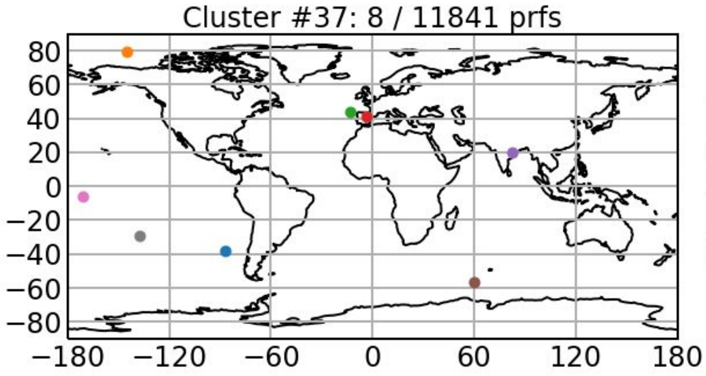
Finding clusters in a graph:

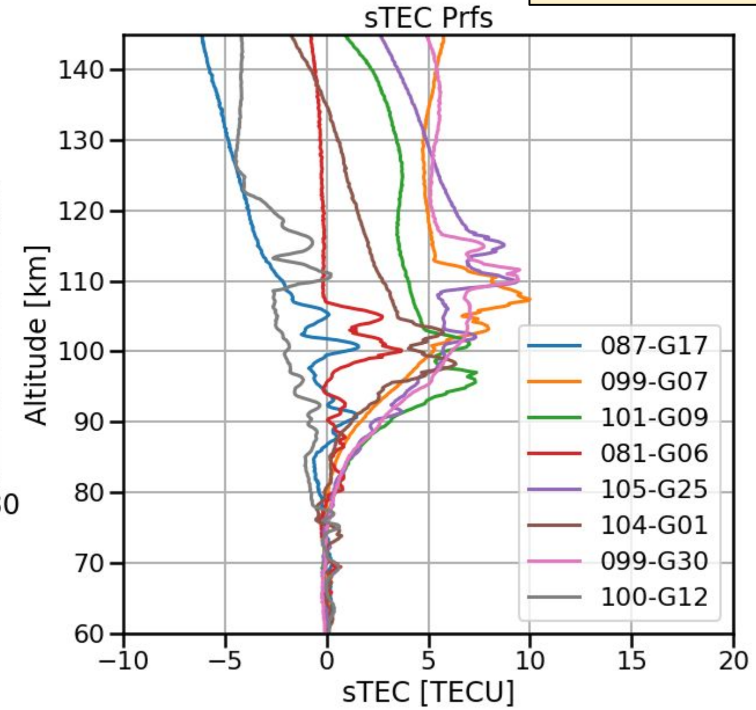
- **Graph** as an abstraction of our dataset (nodes as profiles, edges as connections)
- Distance matrix can be converted to **adjacency matrix** (entries as weights of the edges)
- **Spectral analysis** of the adjacency matrix (eigenvalues and eigenvectors)
- Find ***k*** **clusters**

CLASSIFICATION RESULTS

- ML-based **perturbations clustering and classification**:
  - **Atmospheric Gravity Waves (AGW)**
  - Sporadic E layer (Es)

Independent observations:
- **Different GNSS Tx**
- **Different Spire's Rx**

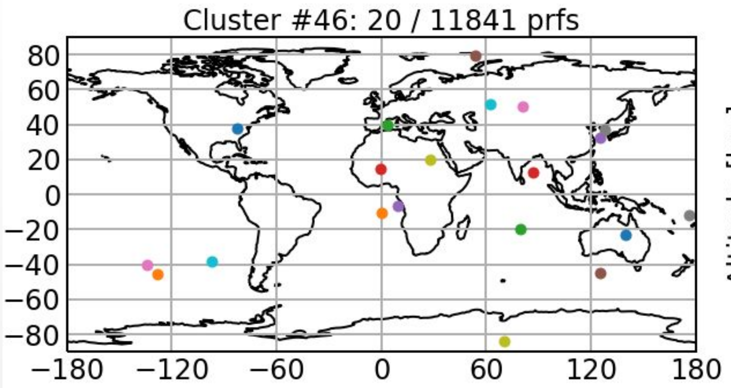


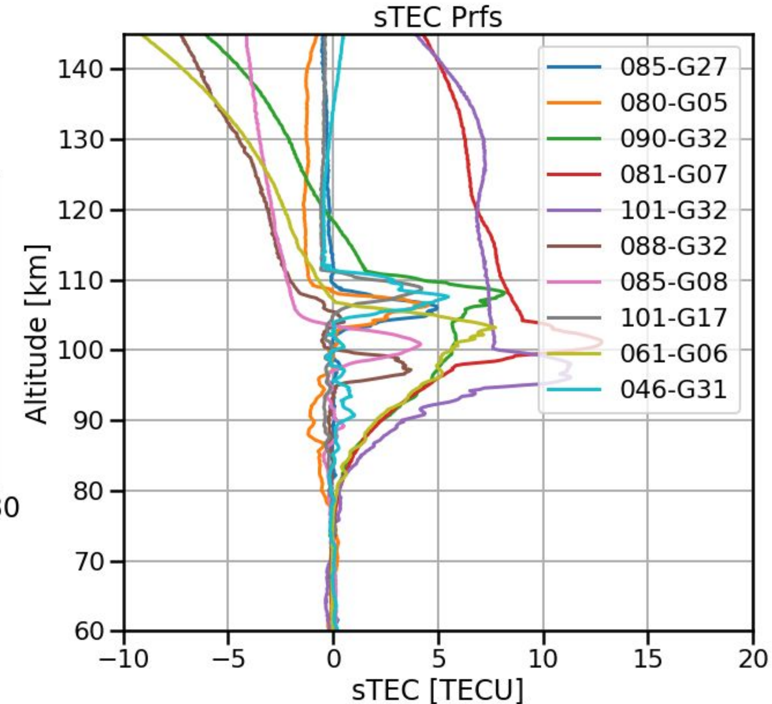


CLASSIFICATION RESULTS (Cont.)

- ML-based **perturbations clustering and classification**:
  - Atmospheric Gravity Waves (AGW)
  - **Sporadic E layer (Es)**

Independent observations:
- **Different GNSS Tx**
- **Different Spire's Rx**





KEY TAKEAWAYS

- Spire's constellation is the largest producer of RO and SpWx measurements ever launched
    - Currently producing **~ 8K RO profiles and 7M+ TEC** measurements per day **and increasing**
    - **Unprecedented coverage over the oceans**

- We are building a **system** to automatically detect and **classify perturbations in the lower-ionosphere**

- **Spire will provide consistent, long-term GNSS-based Earth observations**

For more questions or information please contact giorgio.savastano@spire.com