# TechTIDE project
# Real-time identification of Travelling Ionospheric Disturbances and validation methodologies

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and TechTIDE Consortium (www.tech-tide.eu)

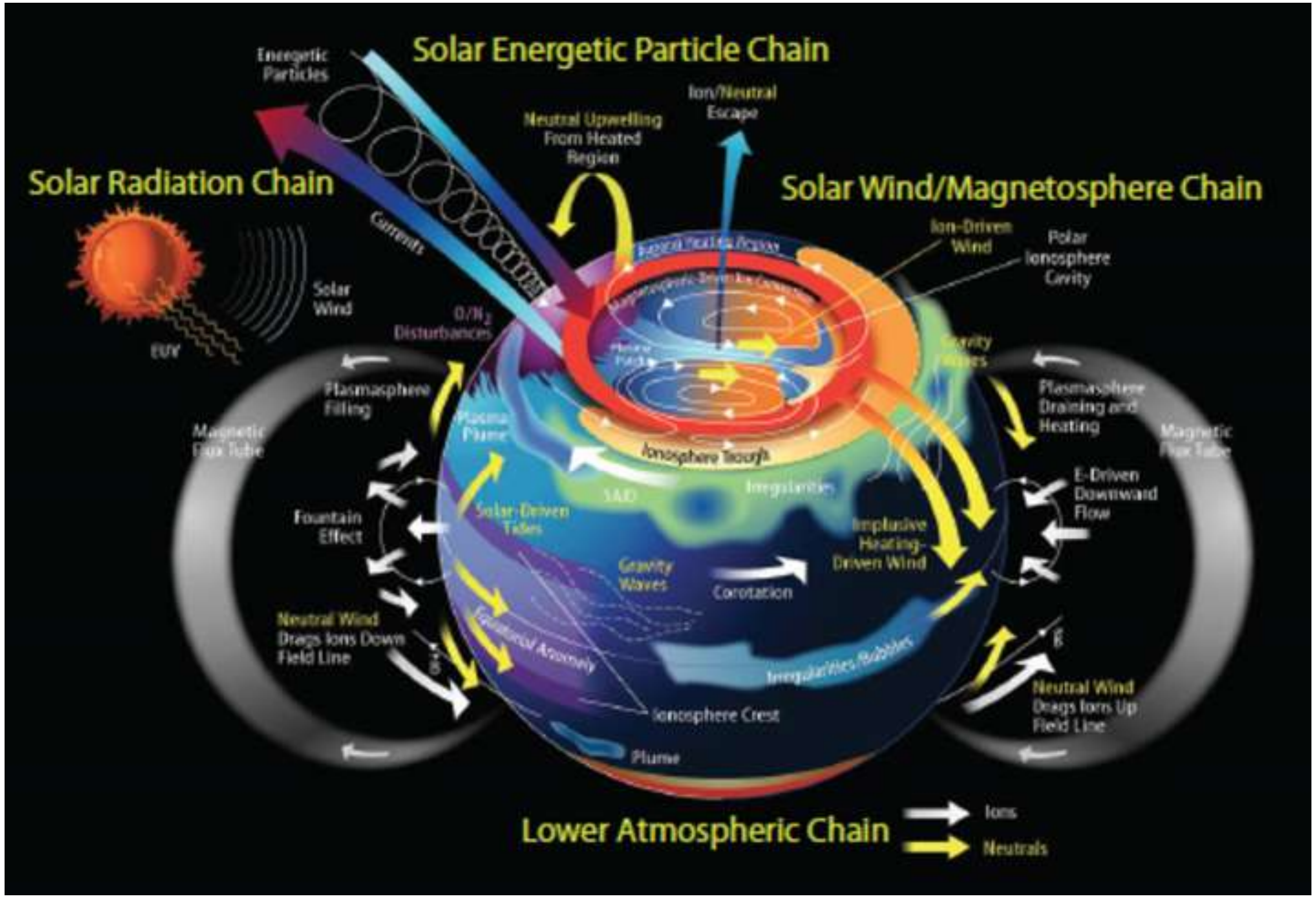
**VarSITI Closing Symposium**
***June 10÷14, 2019, Sofia, Bulgaria***

# Why do we care about TIDs

Operations at middle and low latitudes depending on predictable ionosphere characteristics are affected by TIDs:

- Systems using the ionosphere as part of their operations such as HF communication, HF geolocation operations
    - **direction finding systems**
    - **radio communication and broadcasting operations**
    - **humanitarian aid organizations and radio amateurs**
- Systems for which the ionosphere is a noise
    - **radio-astronomy experiments such as LOFAR and SKA**
    - **ground and space-based augmentation systems (EGNOS and GBAS)**
    - **enhanced precision positioning systems (such as N-RTK) which are extensively used in agriculture and drilling operations**

# What are the main physical characteristics of TIDs?




Large scale TIDs propagate with:

- wavelengths of 1000 - 3000 km
- velocity of 300 – 1000 m/s
- amplitude greater than 5-10 TECU.

LSTIDs are associated with auroral and geomagnetic activity

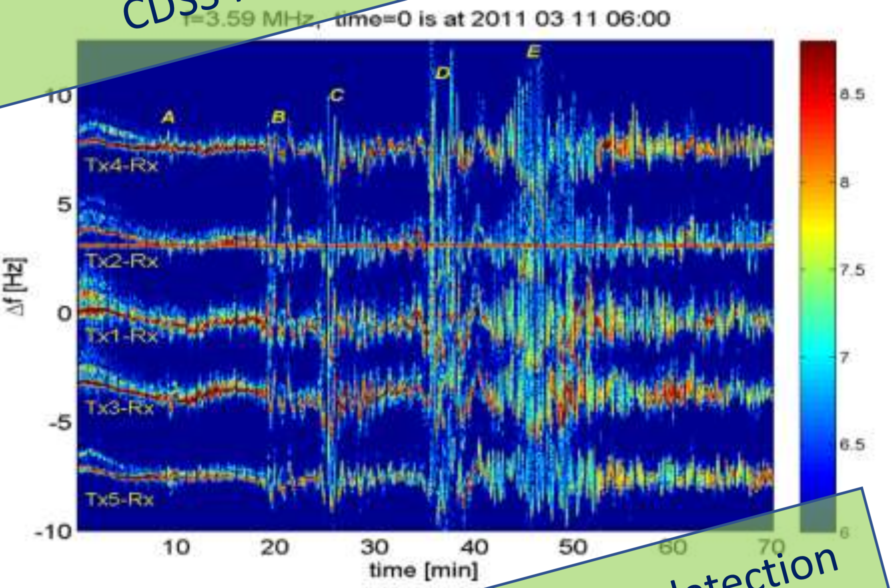
Medium scale TIDs propagate with:

- wavelength of 100-300 km
- velocity of 100m/s
- amplitude of 1 TEC, occasionally 10 TECU.

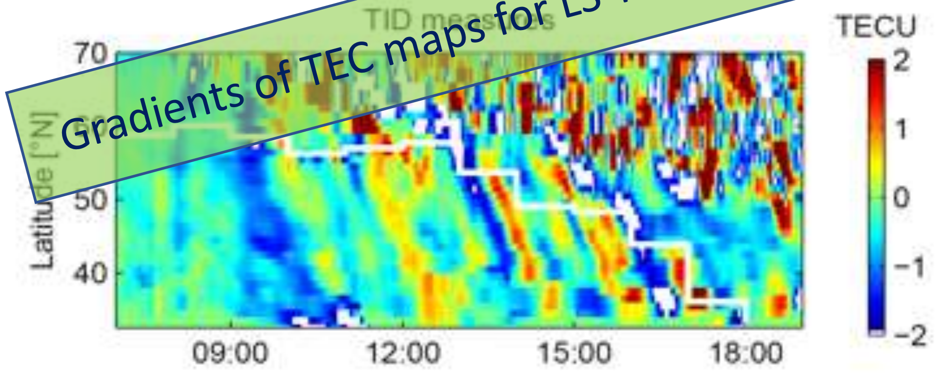
MSTIDs are mostly associated with ionospheric coupling from below, no clear correlation with geomagnetic activity.

# How to detect TIDs?

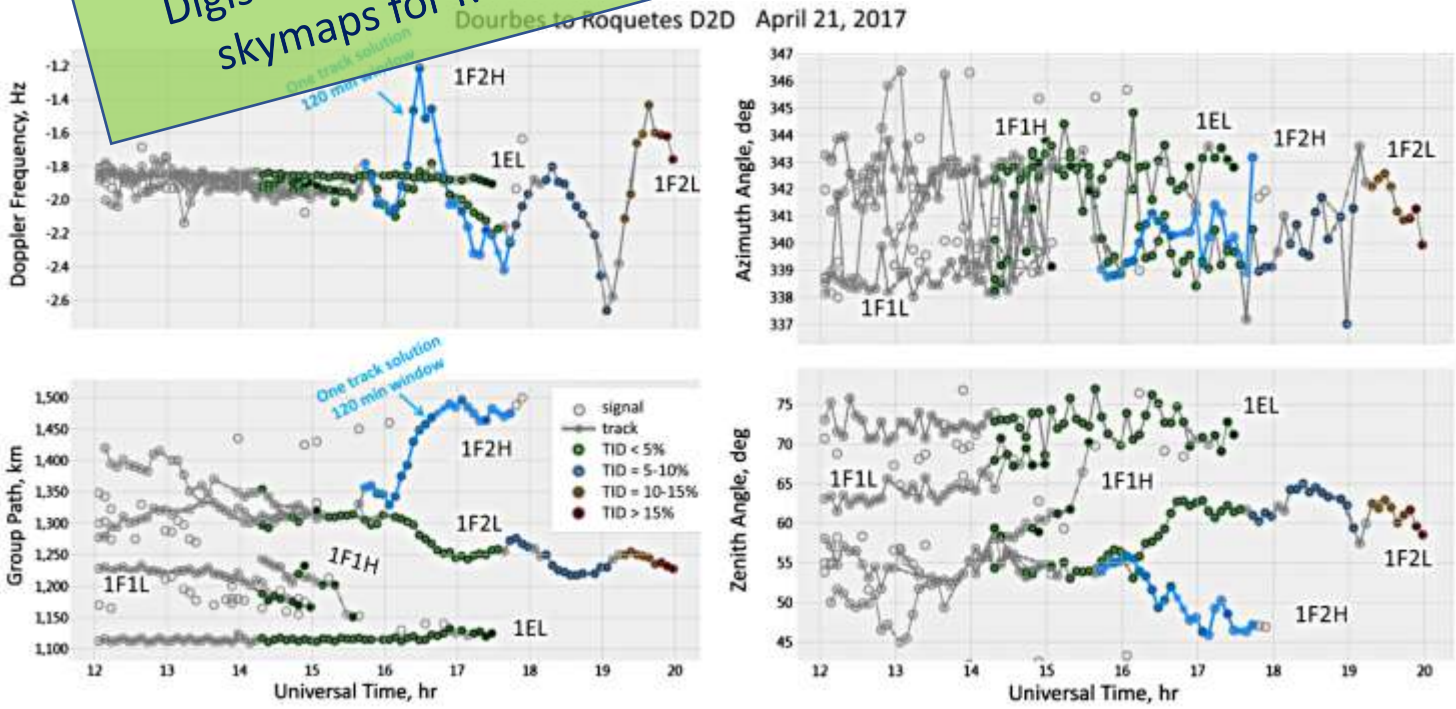
CDSS for MS TID detection




Gradients of TEC maps for LS TID detection




Digisonde – to – Digisonde (D2D) oblique skymaps for MS and LS TID detection



# Considerations

- Each method has advantages and constraints considering the users' requirements:
  - Timeliness: Real-time detection
  - Geographic coverage: local, regional
  - Prediction capability: nowcasting and forecasting
  - Amplitude of perturbation: MS and LS
  - Observed parameter that is perturbed due to TIDs: TEC, Ne(h), HF signal deviation in respect to expected conditions (angles of arrival, Doppler shift)
- There is no method to satisfy all the criteria.
- A combined analysis of results from various methodologies is used to extract a comprehensive information required by the users

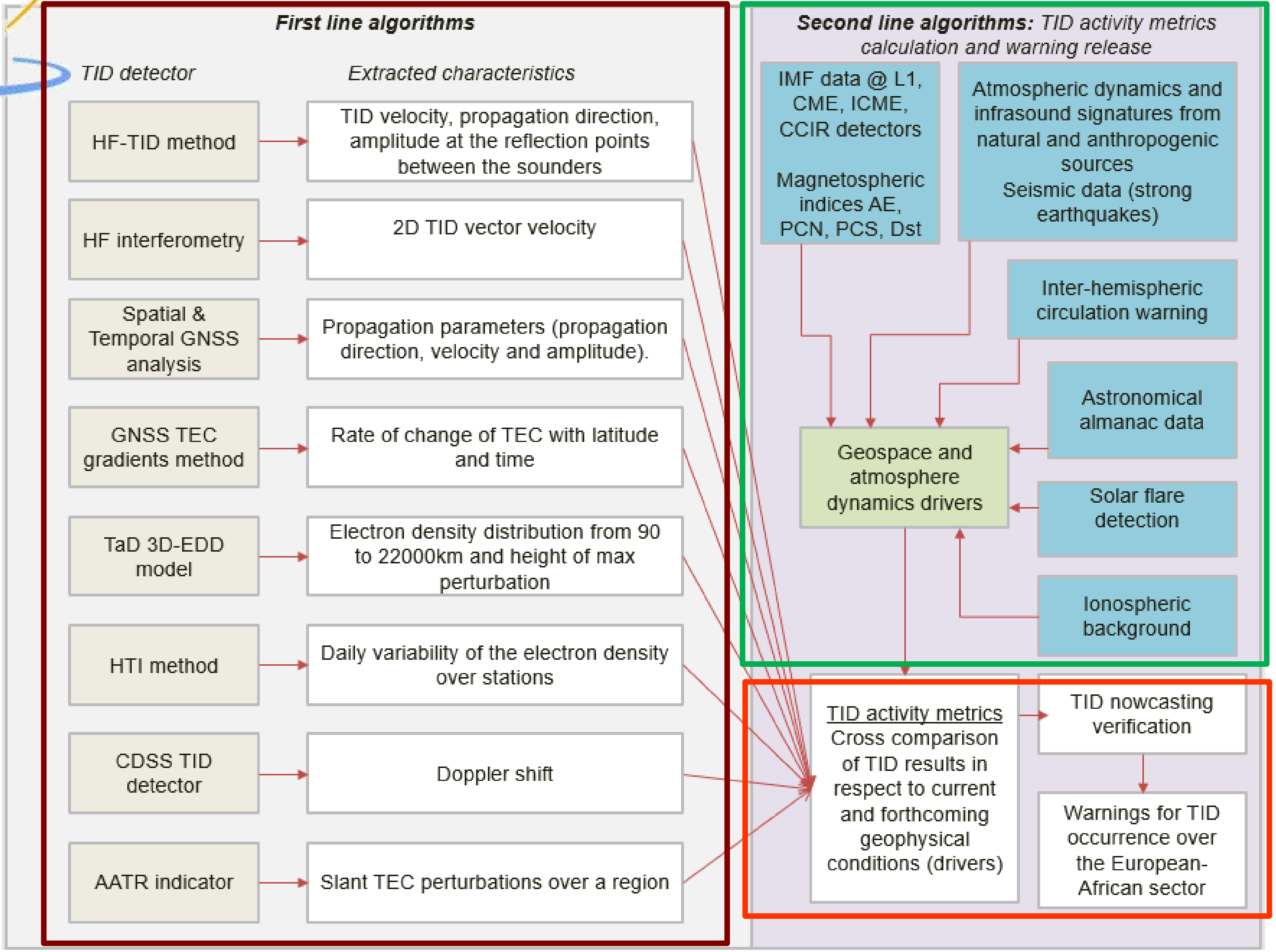
# TechTIDE consortium

Funded by
EC H2020 COMPET
Space Weather Call
2017

- National Observatory of Athens (NOA), Greece
- Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany
- Ustav Fyziky Atmosfery AV CR (IAP), Czech Republic

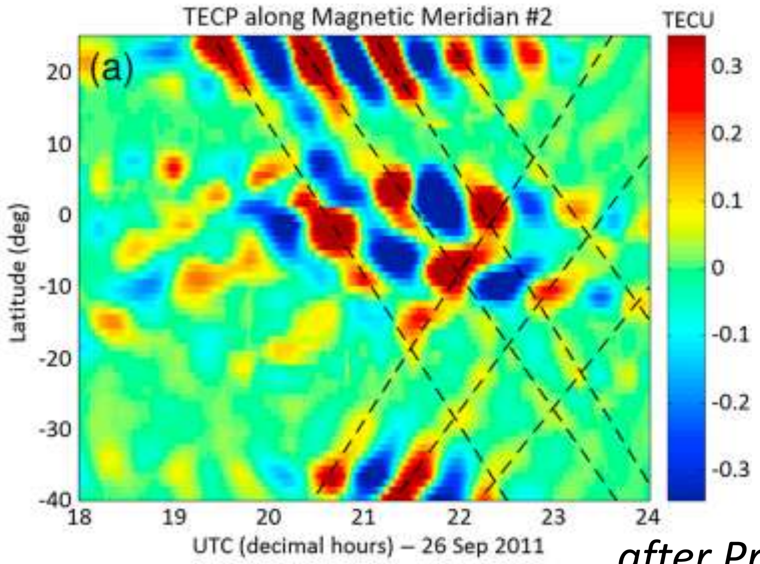
The overarching objective of TechTIDE is to design and test new viable TID impact mitigation strategies for the technologies affected by the TIDs and in close collaboration with operators of these technologies, to demonstrate the added value of the proposed mitigation techniques which are based on TechTIDE products.

- Frederick University (FU), Cyprus
- German Federal Police (GFP), Germany

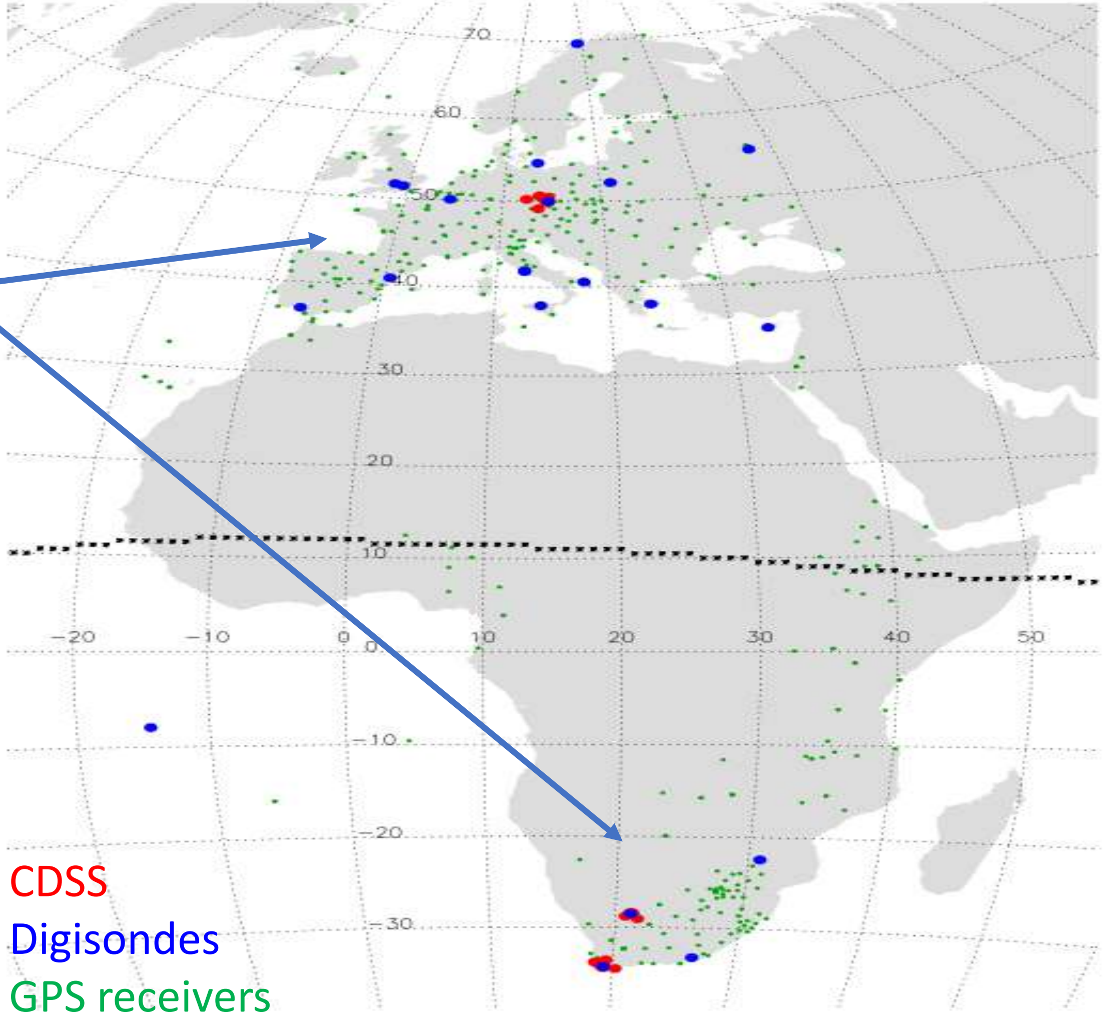

First line algorithms
TID detector
Extracted characteristics
HF-TID method
TID velocity, propagation direction, amplitude at the reflection points between the sounders
HF interferometry
2D TID vector velocity
Spatial & Temporal GNSS analysis
Propagation parameters (propagation direction, velocity and amplitude).
GNSS TEC gradients method
Rate of change of TEC with latitude and time
TaD 3D-EDD model
Electron density distribution from 90 to 22000km and height of max perturbation
HTI method
Daily variability of the electron density over stations
CDSS TID detector
Doppler shift
AATR indicator
Slant TEC perturbations over a region
Second line algorithms: TID activity metrics calculation and warning release
IMF data @ L1, CME, ICME, CCIR detectors
Magnetospheric indices AE, PCN, PCS, Dst
Atmospheric dynamics and infrasound signatures from natural and anthropogenic sources
Seismic data (strong earthquakes)
Inter-hemispheric circulation warning
Astronomical almanac data
Geospace and atmosphere dynamics drivers
Solar flare detection
Ionospheric background
TID activity metrics
Cross comparison of TID results in respect to current and forthcoming geophysical conditions (drivers)
TID nowcasting verification
Warnings for TID occurrence over the European-African sector

# The basic network of TechTIDE monitoring stations

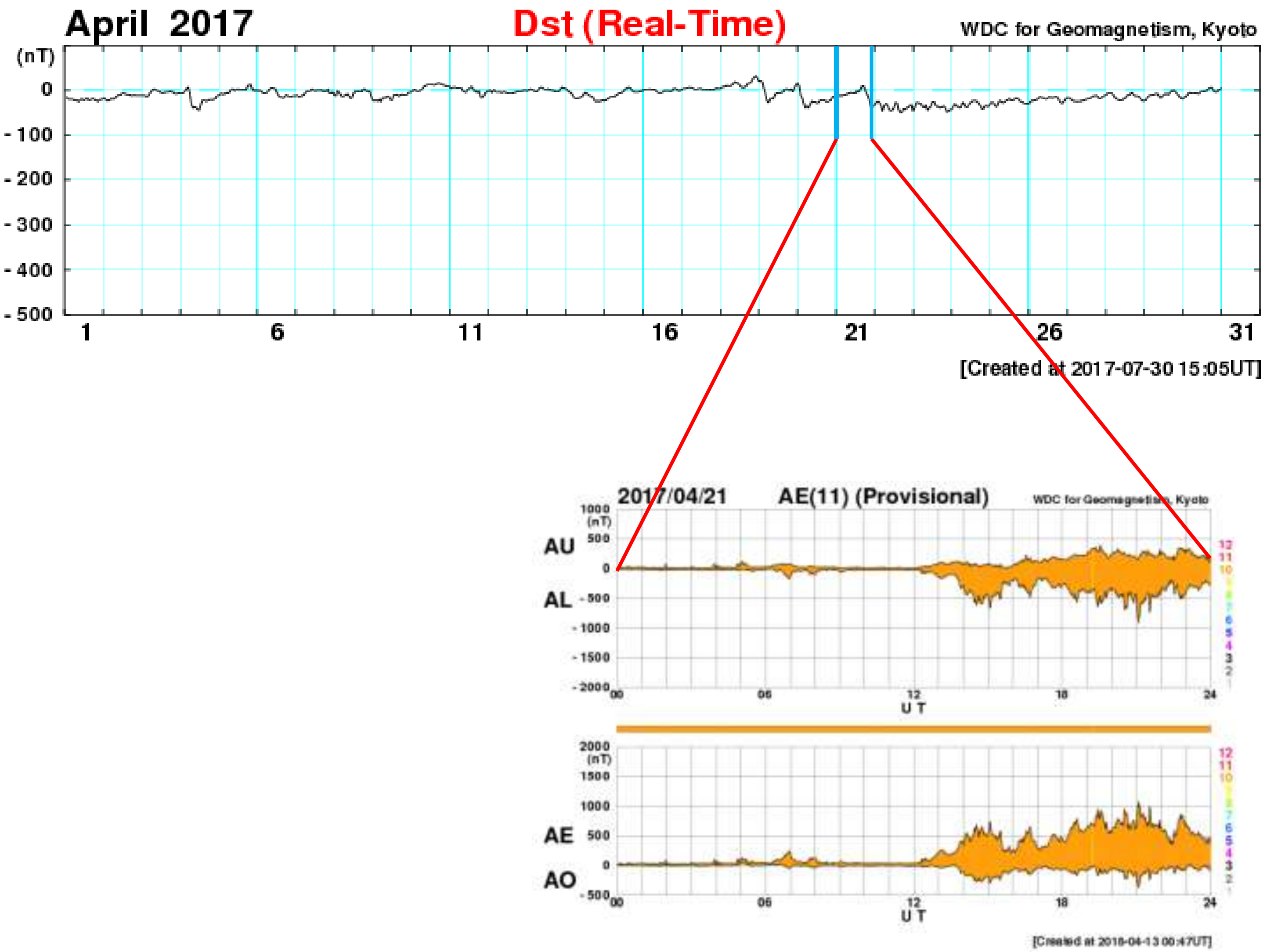
Similar monitoring facilities operate in Europe and South African regions, allowing detection of TIDs simultaneously in the two hemispheres



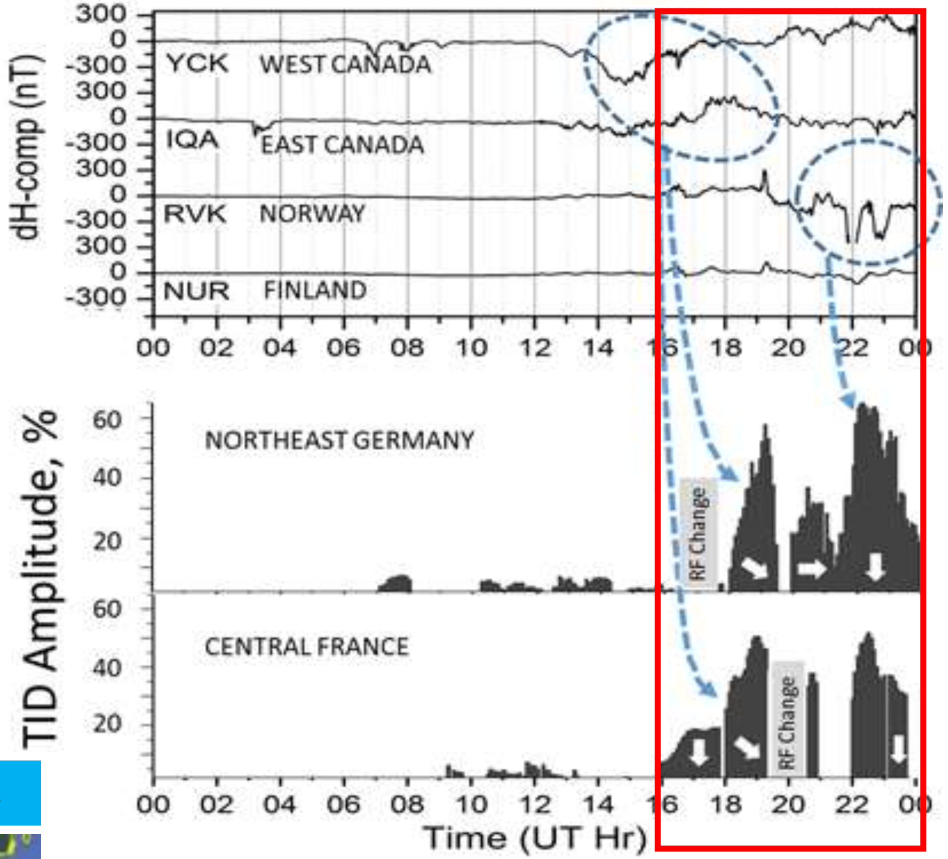

*after Pradipta et al., 2016*

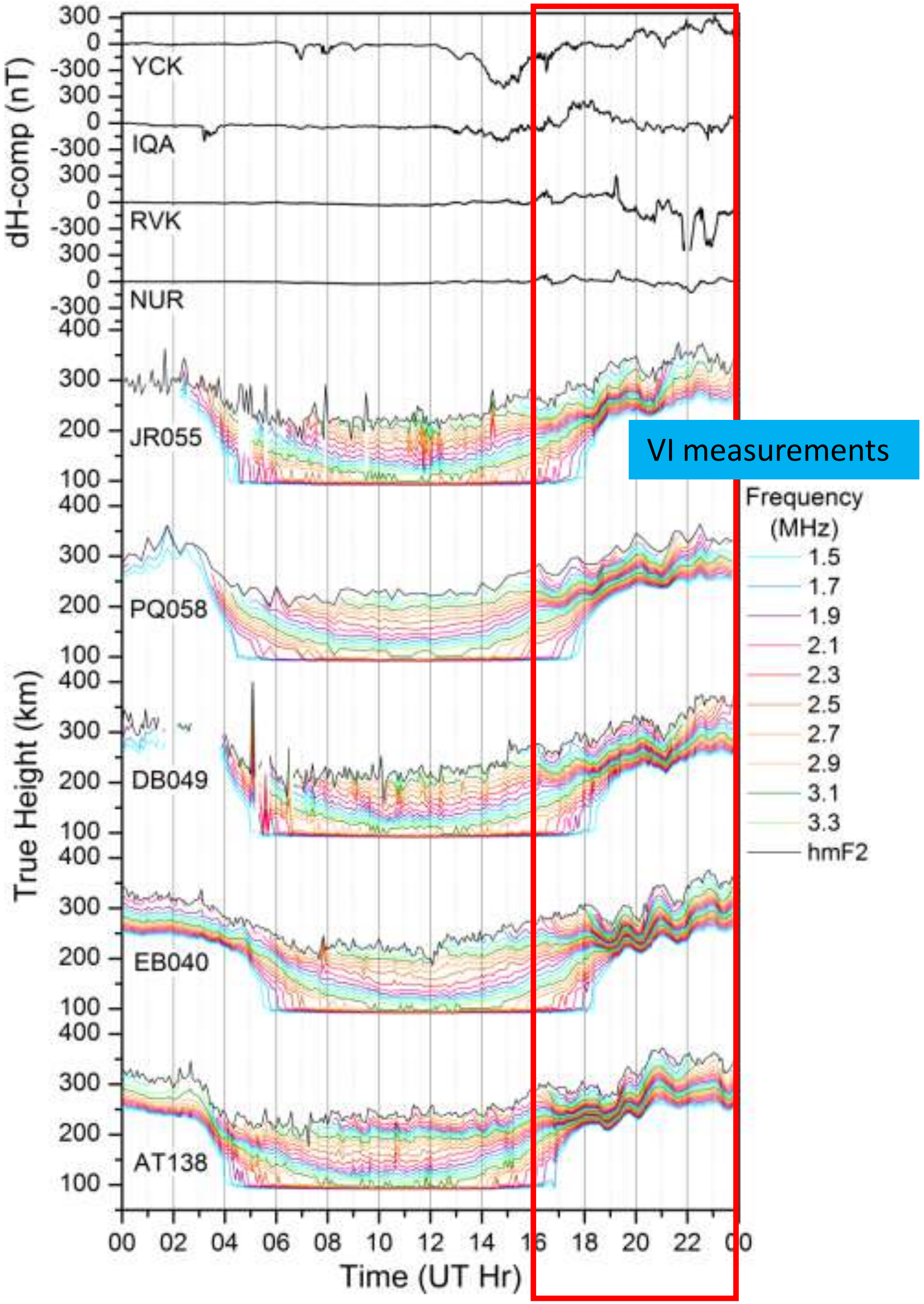


# The performance of TID detection algorithms during a moderate substorm: the case of 21 April 2017



# D2D extracted TID results for the 21 April 2017 moderate substorm




D2D measurements

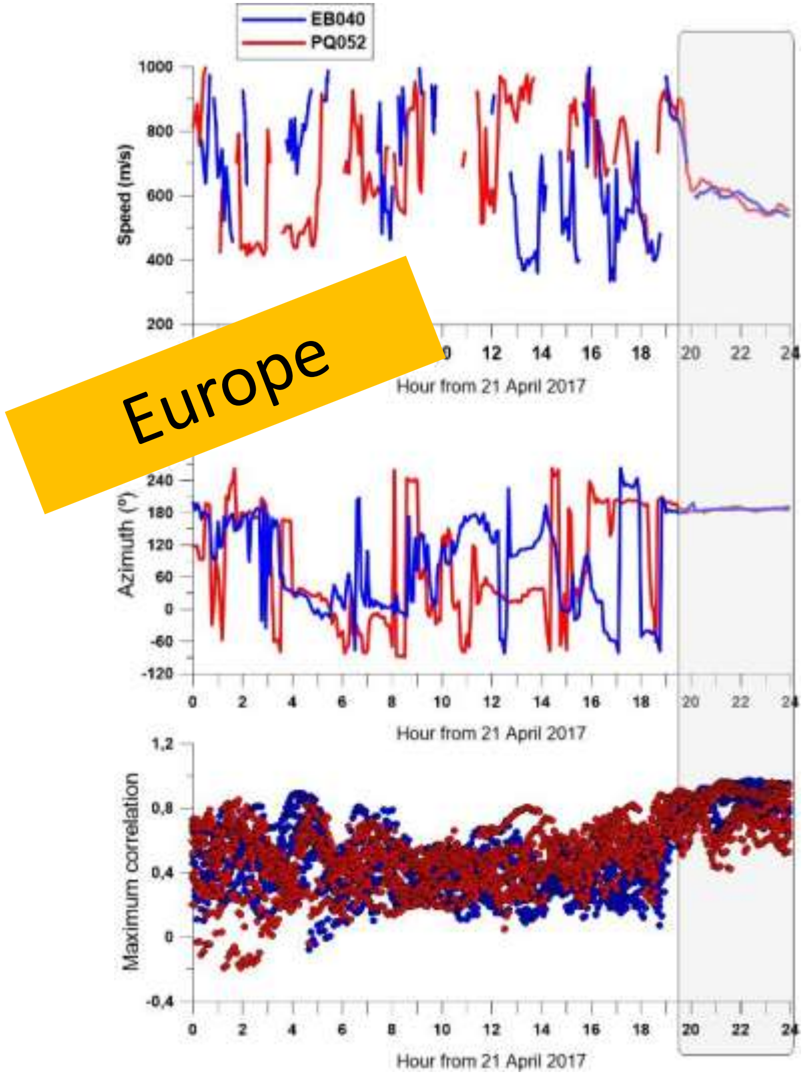
TID derived periods : from 95 to 110 minutes – 3 waves

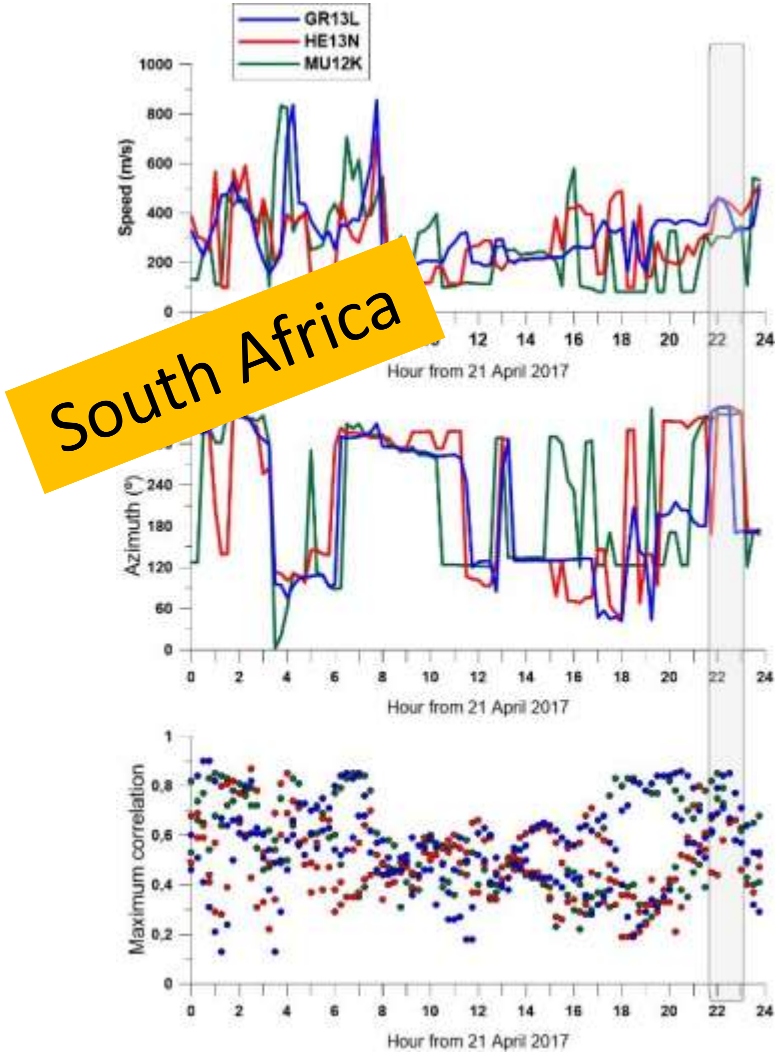
TID derived wavelengths : ~ 1370 km;

Calculated TID velocities : between 280 and 400 m/s.

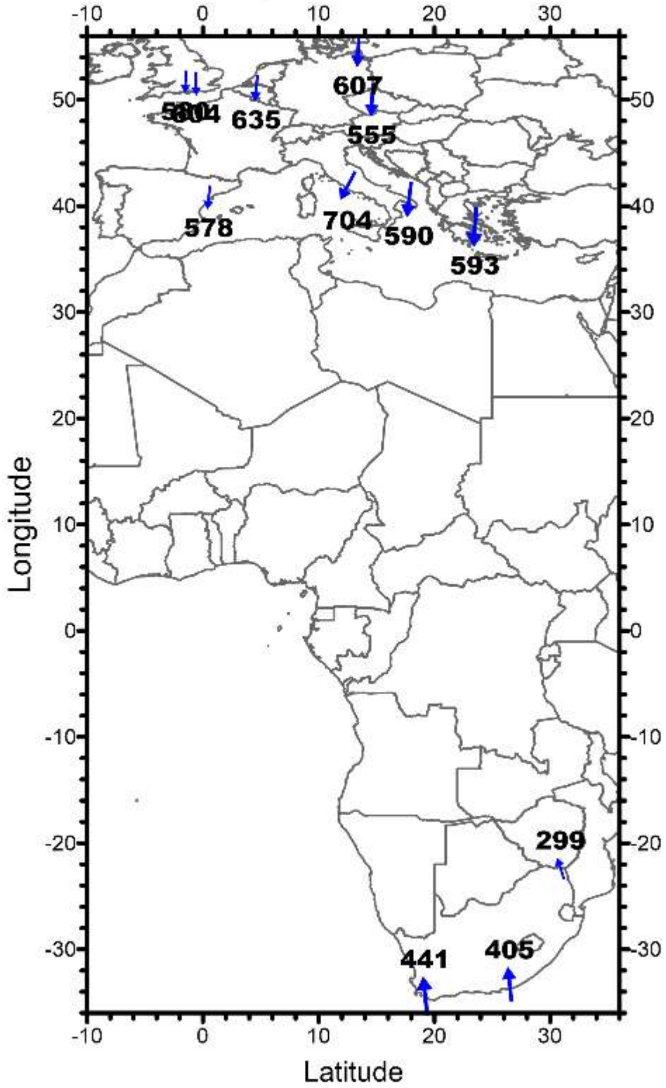
# Results from the HF interferometry method

**The HF Interferometry method analyses oscillations in MUF and HF Doppler measurements (Altadill et al., 2017)**

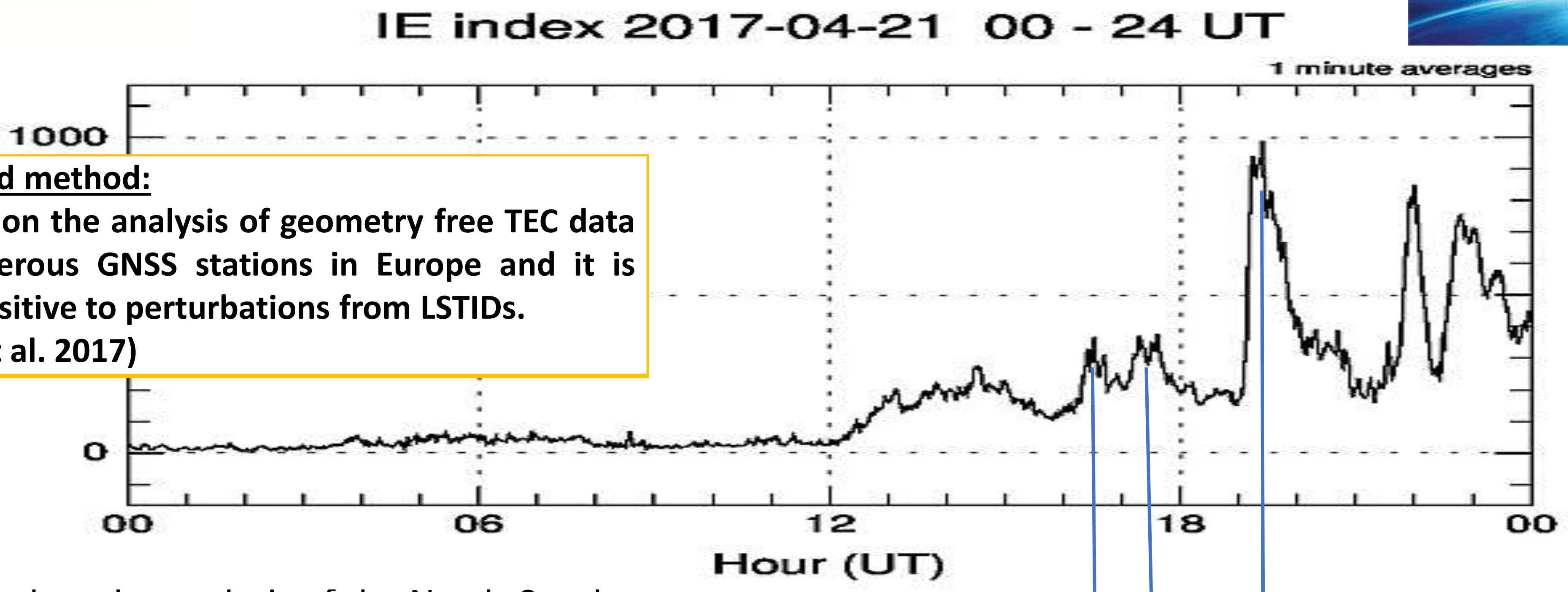



Vector velocities estimated on 21 April 2017 at 22:30 UT

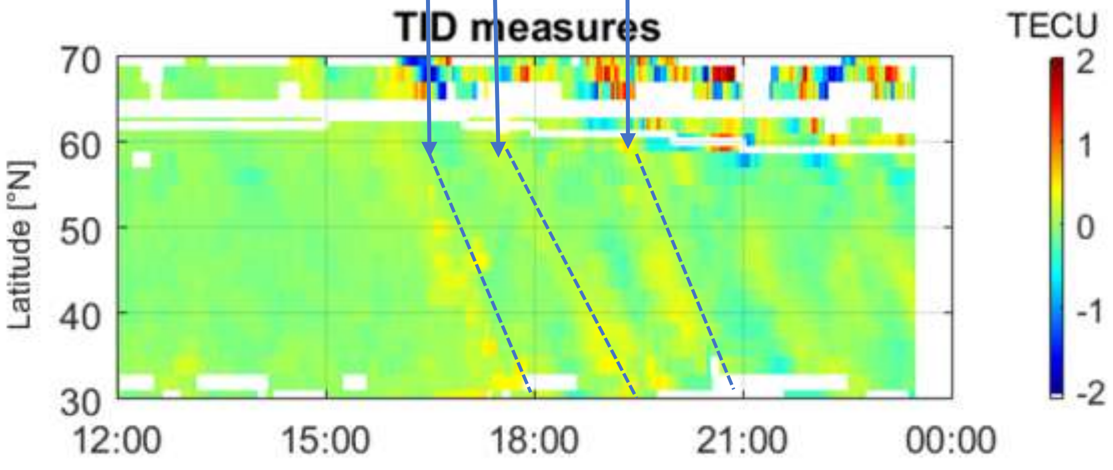


# Results from the GNSS TEC gradients method




**<u>GNSS based method:</u>**
**it is based on the analysis of geometry free TEC data from numerous GNSS stations in Europe and it is mostly sensitive to perturbations from LSTIDs.**
**(Borries et al. 2017)**

Results based on the analysis of the North-South direction.
The approx. parameters of the LSTIDs are:
- Phase speed: 460-620 m/s,
- Wavelength: 2400-3300 km,
- Period: 1-2h.

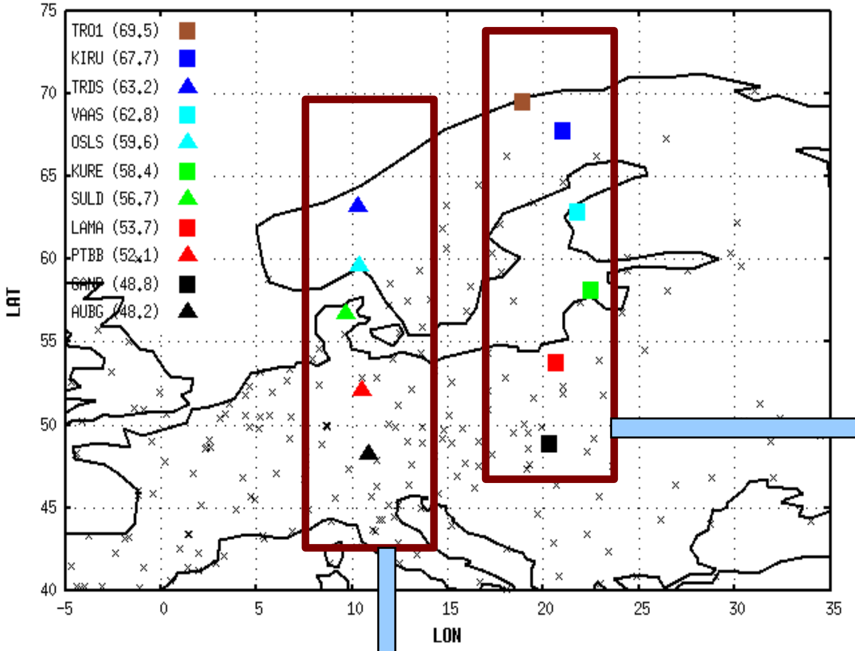


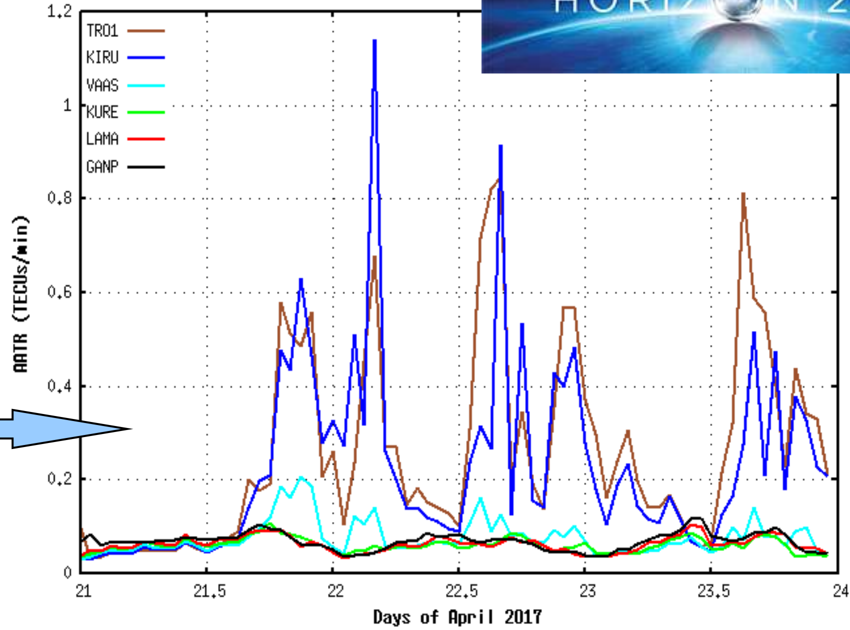

**TIDs are seen as slanted rays.**
**Between 16 and 20 UT, three LSTIDs wave signatures are observed with a strong equatorward component.**

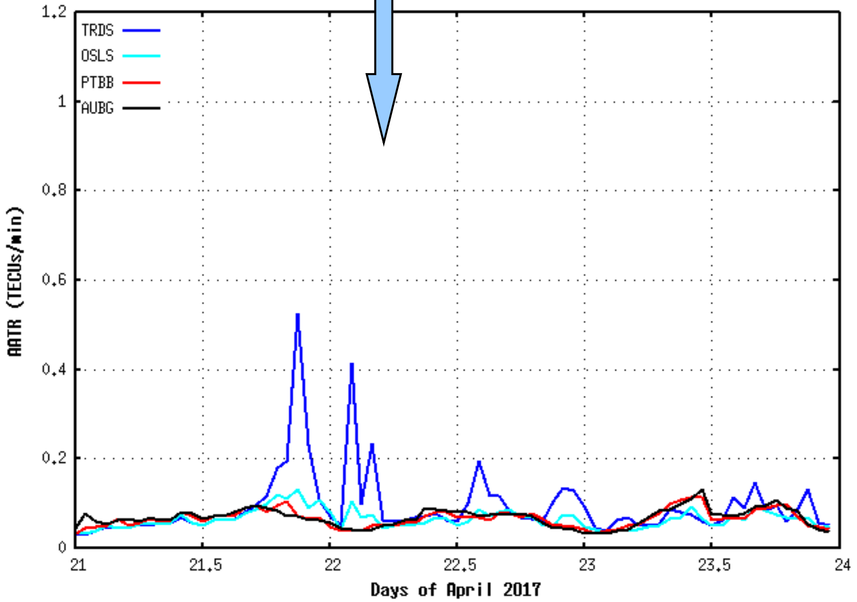
# The AATR indicator: Along the Arc TEC rate

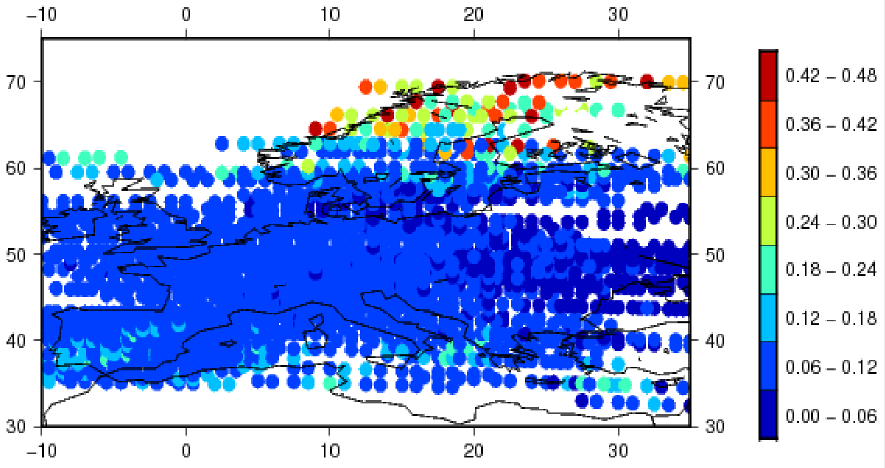
**<u>AATR indicator:</u>**
**The AATR samples ionospheric irregularities directly on the actual instantaneous GNSS signals.**
**Its computation is reset every time the arc changes (i.e., after every cycle-slip).**

**Juan et al., 2018, Journal of Space Weather and Space Climate**




Mean AATR values over Europe
21:00-22:00 2017 April 21th

# Compilation of results

| | *Direct TID detection* | *Indirect TID detection methodologies for validation* | | *TID indicator* |
|---|---|---|---|---|
| | **D2D oblique skymaps** | **HF Interferometry** | **TEC gradients** | **AATR index** |
| **Activity characteristics** | Three LSTID waves at 1800, 2000, 2130 UT<br>T: 95 – 110 min<br>L: ~1370 km | LSTID waves from 1600 to 2400 UT | 3 LSTIDs wave signatures betw. 1600 and 2000 UT.<br>T: 60-120 min<br>L: 2400-3300 km | LSTID activity detected after 1800 UT at high latitudes.<br><br>Perturbations in the 20 deg meridian are more intense than those in the 10 deg meridian. |
| **Location of observation** | Altitudinal location: Bottomside ionosphere.<br><br>Geographic location: At the reflection points between the DPS4Ds:<br>at 10 deg meridian (45 deg N)<br>At 20 deg meridian (52 deg N) | Altitudinal location: Bottomside ionosphere.<br><br>Geographic location: Europe and South Africa | Altitudinal location: not specified<br><br>Geographic location: Europe, below 60 deg. N<br>Meridian chain centered at 10 deg E | |
| **Direction of propagation** | South-East in the 10 deg meridian; south propagation in the 20 deg meridian | Equatorial propagation in the North and South hemisphere | Strong equatorward component (the east-west component is under investigation) | |
| **Velocity** | ~ 280 to 400 m/s | ~ 300 to 700 m/s | N/S component ~ 460-620 m/s. | |

# TechTIDE milestones

- January 2019: TID identification **open access codes**, in TechTIDE repository -> www.tech-tide.eu
- April 2019: Release of the first version of the TechTIDE warning system -> www.tech-tide.eu
- May 2019: Organization of the first TechTIDE users' workshop - system demonstration, users' feedback
- October 2019: Release of the second TechTIDE system + 2nd TechTIDE users' workshop
- April 2020: Release of the final TechTIDE system + 3rd TechTIDE users' workshop

# Thank you for your attention!

TechTIDE Project

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