

Net-TIDE project

Pilot network for identification of Travelling Ionospheric Disturbances

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14th International Ionospheric Effects Symposium

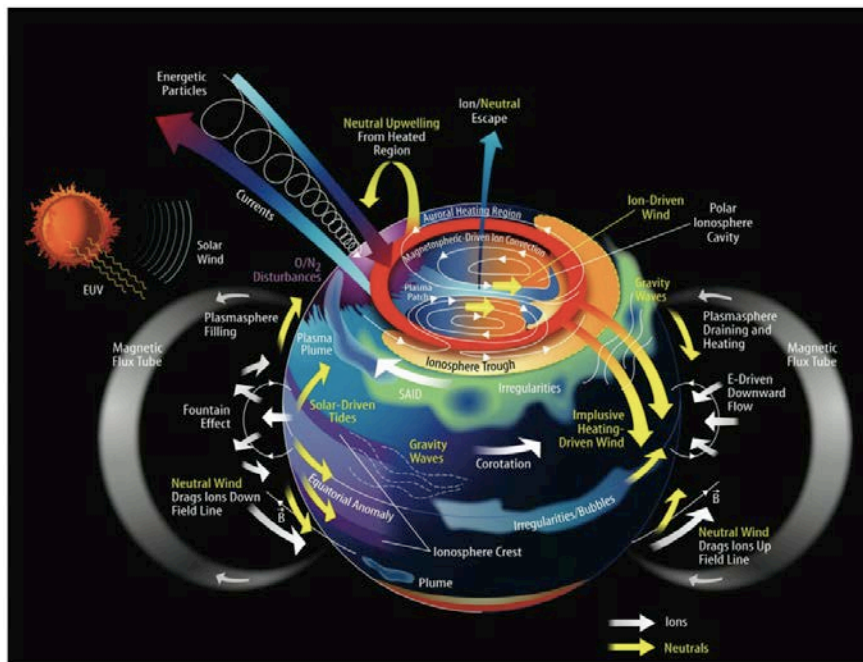
12-14 May 2015, Alexandria, VA, USA

Travelling Ionospheric Disturbances - TIDs

Travelling Ionospheric Disturbances (TIDs) are the ionospheric signatures of atmospheric gravity waves.

TIDs have various sources of excitations

- **natural** : energy input from the auroral region, earthquakes, hurricanes, solar terminator, and others
- **artificial** : ionospheric modification experiments, nuclear explosions, and other powerful blasts like industrial accidents

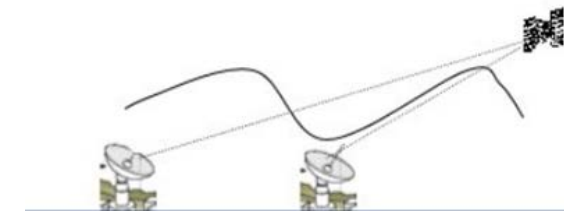


Credit: NASA / J. Grobowsky

Systems affected by TIDs

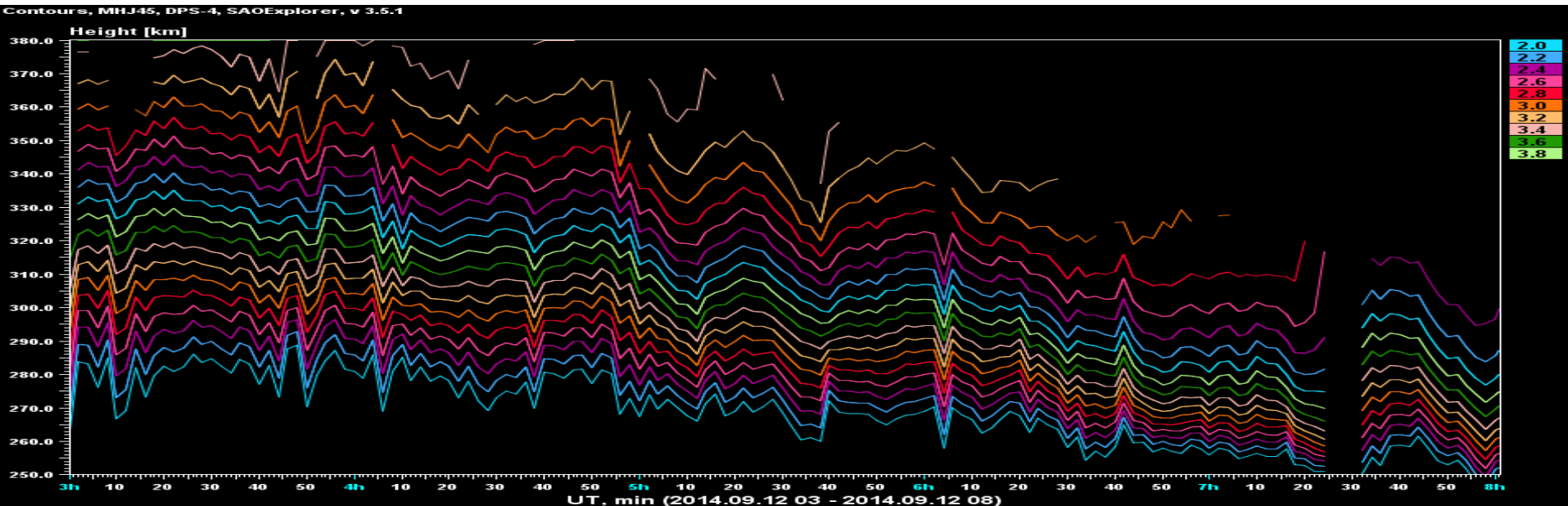
TIDs affect all services that rely on predictable ionospheric radio wave propagation. The disturbance imposed in the ionosphere is usually measured with the TEC parameter (1 TECU= 10^{16} el/m²).

- In general TIDs affect the **HF propagation**:
 - The accuracy of HF transmitter geolocation, especially at short distances (HF/DF is a radio wave direction finding technique)
 - The over-the-horizon radars
- **Large scale ionospheric biases** caused by TIDs affect:
 - High precision differential GPS applications, requiring accuracy > 2TECU
 - Single base RTK and network RTK positioning



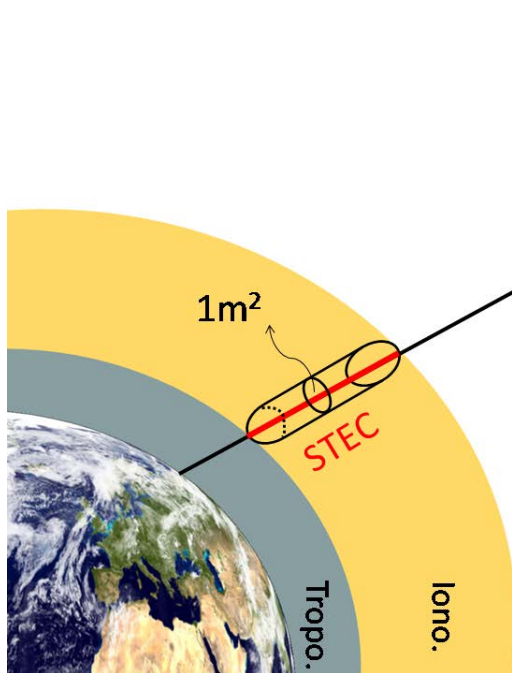
Characteristics of TIDs

- **Large scale TIDs** propagate with **wavelengths of 1000 - 3000 km**, velocity of 300 – 1000 m/s and amplitudes up to 10 TECU. LSTIDs are **associated with auroral and geomagnetic activity**
- **Medium scale TIDs** propagate with **wavelength of 100-300 km**, velocity of 100m/s and amplitude of 1 TEC, occasionally 10 TECU. MSTIDs are mostly **associated with ionospheric coupling from below**, **no clear correlation with geomagnetic activity**.

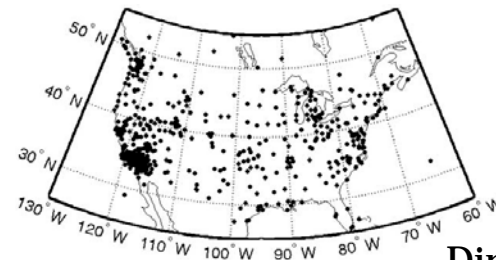


Past efforts to identify TIDs using the Total Electron Content from GPS receivers

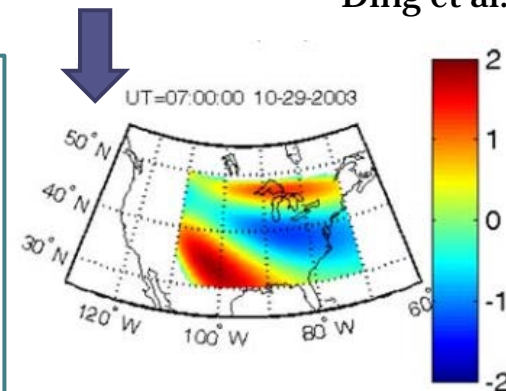
- Algorithms for calculation of TEC and its mapping contain a number of assumptions.
- Redistributions of the ionization due to TID might not be detected by TEC.
- The real-time analysis of high resolution TEC data is still a challenge.



Post-processing analysis can support the identification of TIDs **after** the event happened but **not the tracking**

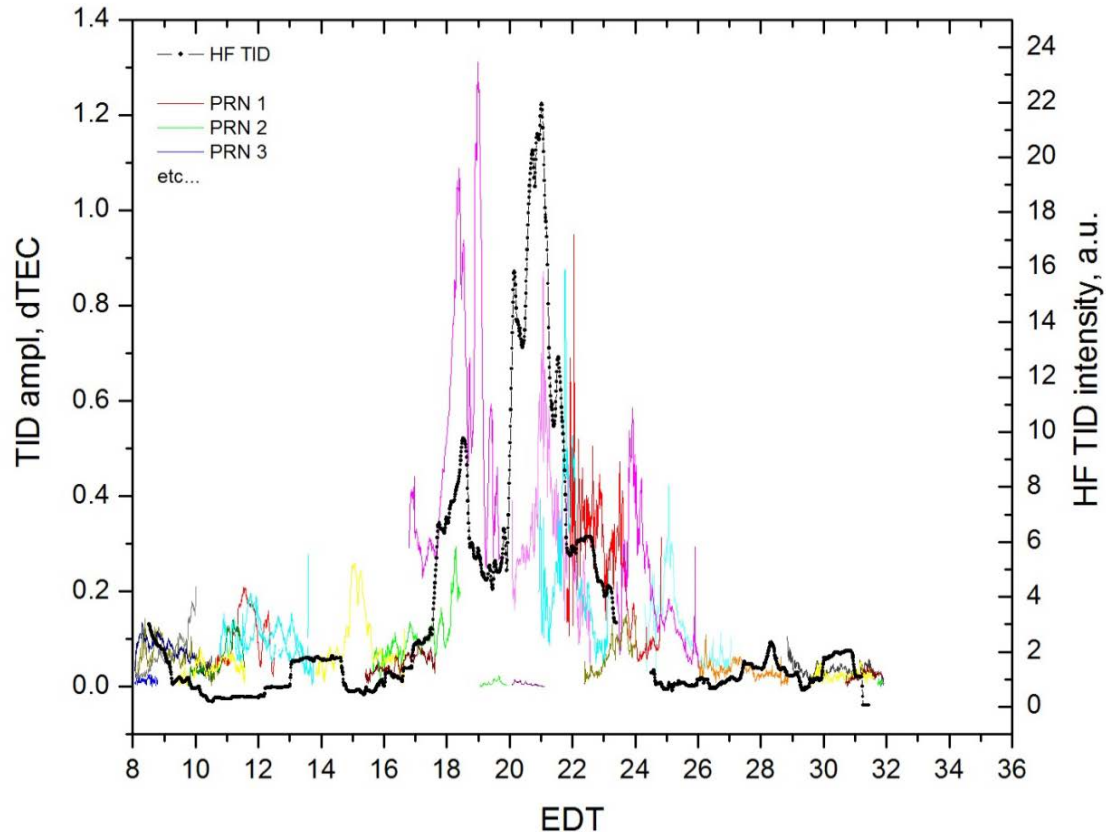


Ding et al., 2007, JGR



HF and GPS Data Comparison

Sept 12, 2014



from Paznukhov, 2015

- Ratio of responses on GPS and HF varies significantly
- Note large GPS signature at 19:00 corresponds to relatively modest signature on HF; conversely, at 21:00 HF response exceeds GPS

What needs to be done?

- The TEC TID identification approach is indirect and approximate, and a **more direct and accurate system** to identify and track TIDs in **real-time** must be developed.



Based on the exploitation of real-time observations obtained from ionospheric sounders

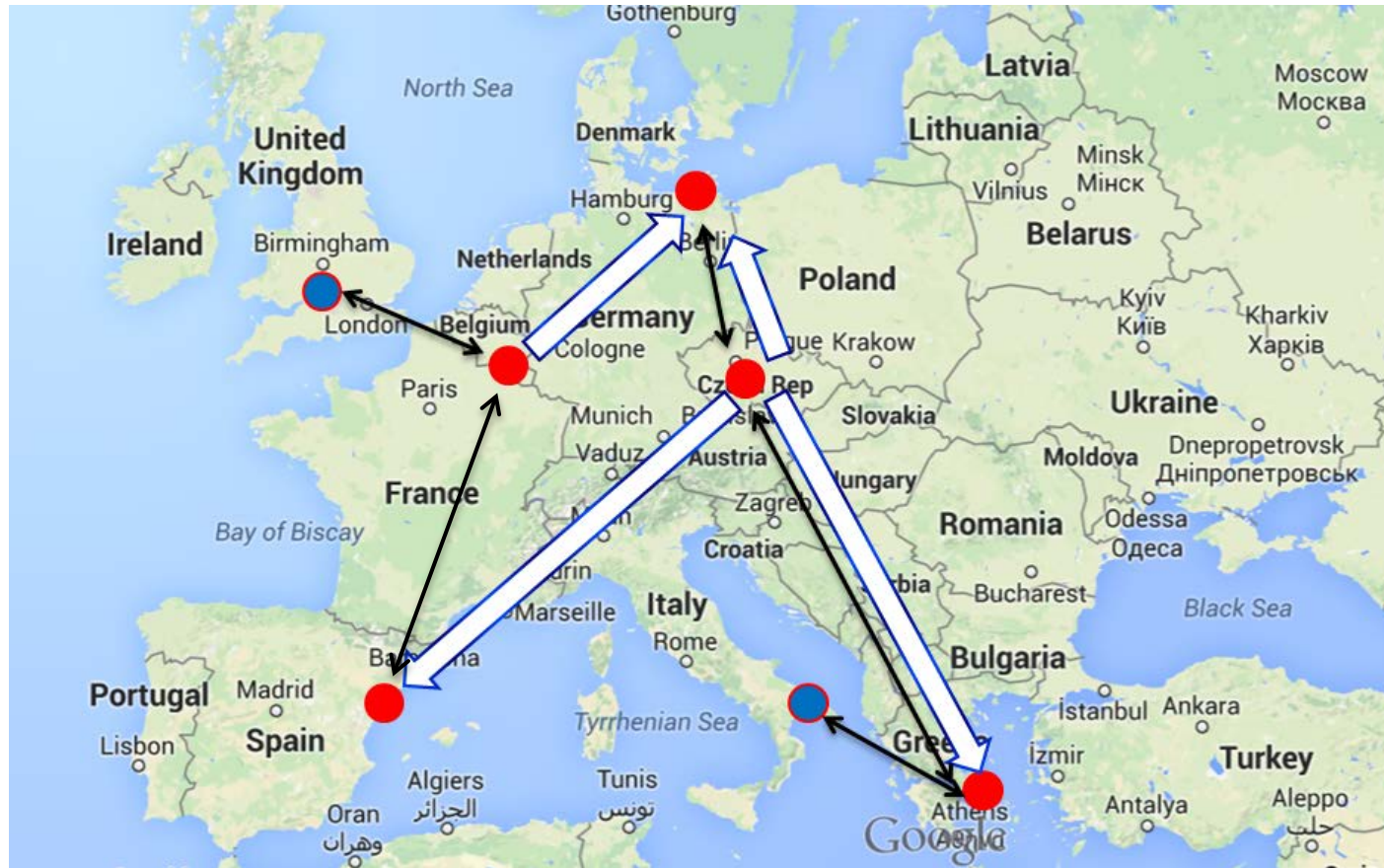
Sounding Types



D2D Skymaping Oblique drift	Synchronous Ionogramming Vertical Ionogram and Oblique Ionogram VI+OI
Dedicated Oblique Ionogram	Reception of Transmitters of Opportunity (ToO)

The DPS4D network in Europe

Preliminary settings

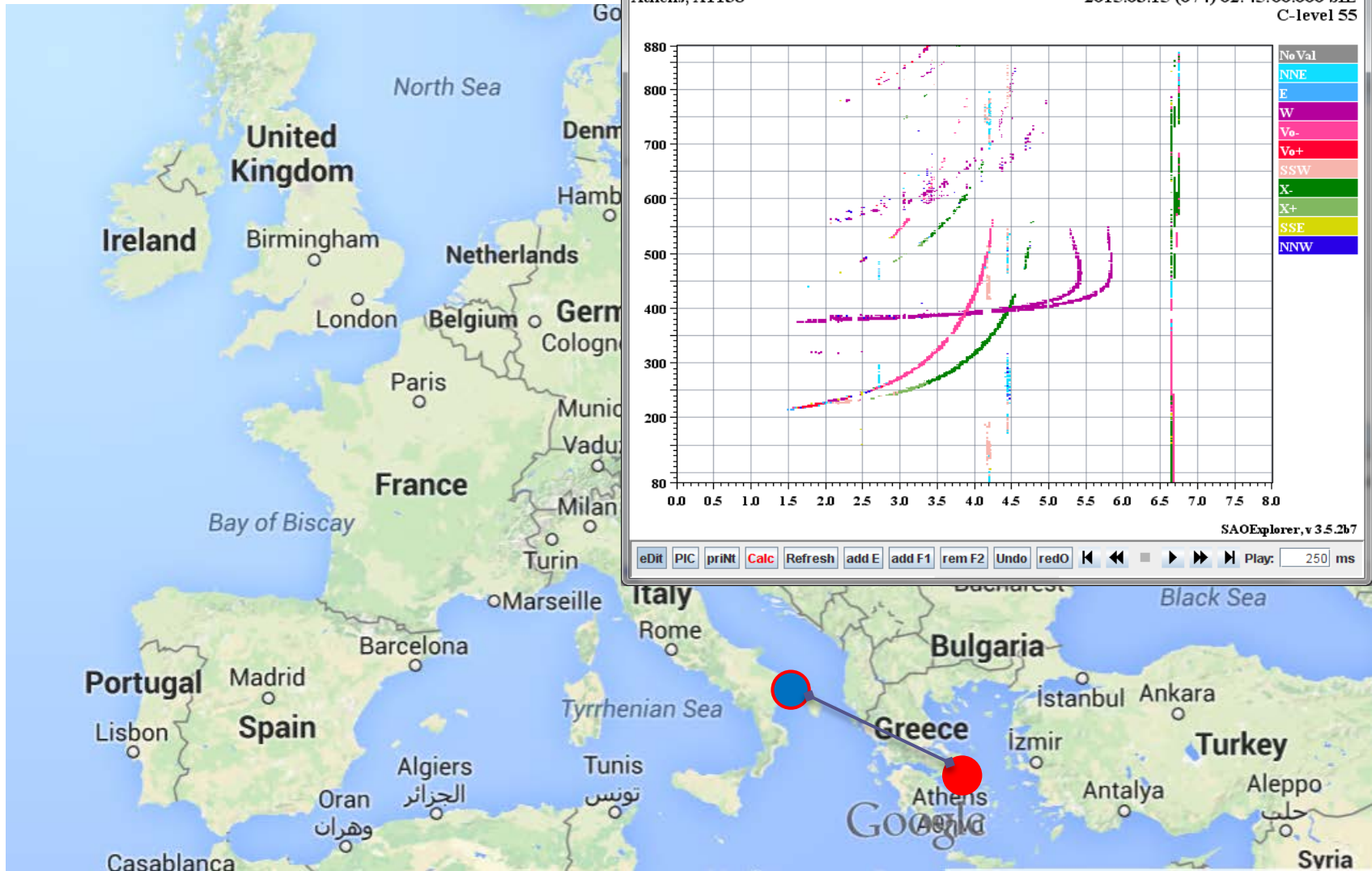


- DPS4D operated from partner institutes
- NEXION operated by AFWA

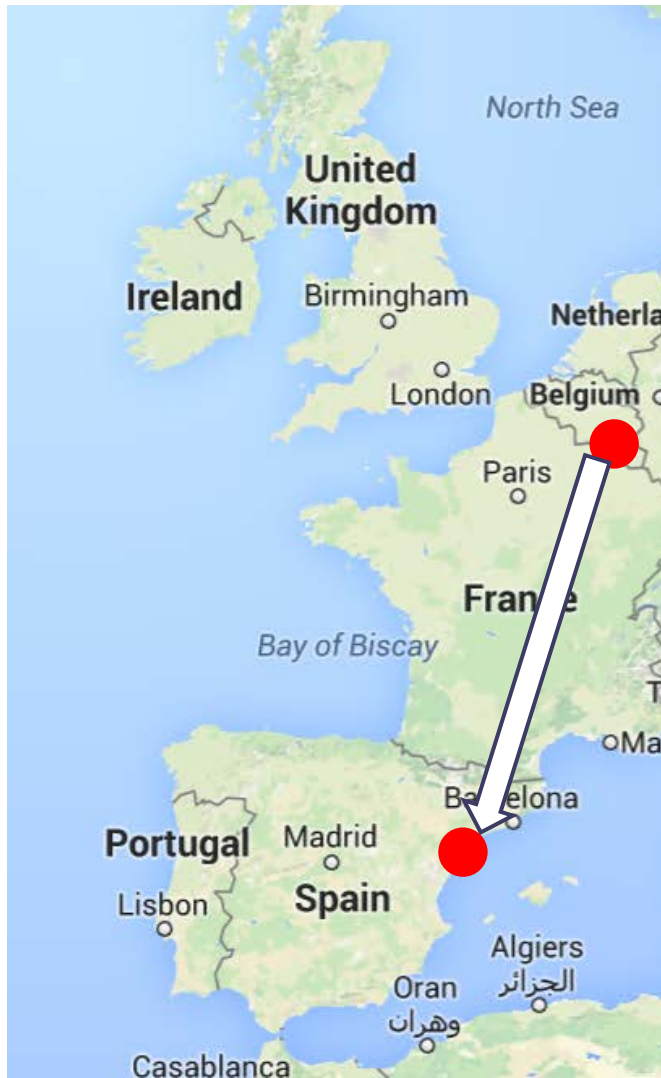


D2D skymaping
Synchronous VI+OI

Synchronized sounding VI+OI San Vito -> Athens



D2D settings for the link Ebro -> Dourbes



PROGRAM #001 Operation: Sounding Mode Measurement

FREQUENCY STEPPING

Coarse Freq Law: Fixed

Base Frequency: 8000 [kHz]

Frequency Override: from latest ionogram

Freq Set Repeats: 1

Number of Fine Steps: none

Total frequencies 1

RANGE SAMPLING

Start Range: 80 [km]

Number of Samples: 512

Inter-Pulse Period: auto 2 [5ms]

Range coverage 80 to 1357.5 / max 1500 km

PULSE INTEGRATION

Number of Integrated Repeats: 2048

Interpulse Phase Switching: disabled

Pulses/freq : CIT : total 4096 : 4096 : 4096
 CIT time 40 s 960 ms
 Exact Running Time 40 s 990 ms

SYSTEM SETTINGS

Constant Gain: FULL GAIN -9dB Tracker(9) and Antenna Switch(-9)

Auto Gain Control: use existing gain table

Rx Gain: +34dB (+12dB,+22dB)

Wave Form: 16-chip complementary

Polarizations: 0 Antennas enabled: 1 2 3 4

Radio Silent Standard Oblique Compatible

Tx station: DB049 Path= 1082 [km] auto

Tx station model: DPS-4D Delay= 0 [5ms] auto

DATA PROCESSING

RFIM in FPGA Doppler Calculation

CCEQ

D-Spike ChipComp

Data Reduction
 Select 64 best ranges
 in window 500.00 to 900.00 [km]

[View Process Chain](#)

OUTPUT FILES

Save product data Save raw data

UMS full x 4

DESC-to-DCART volume 4096 packets = 33,228 KB
 DESC-to-DCART flow 6,641 kbit/s
 Expected on-disk volume 2,049 KB

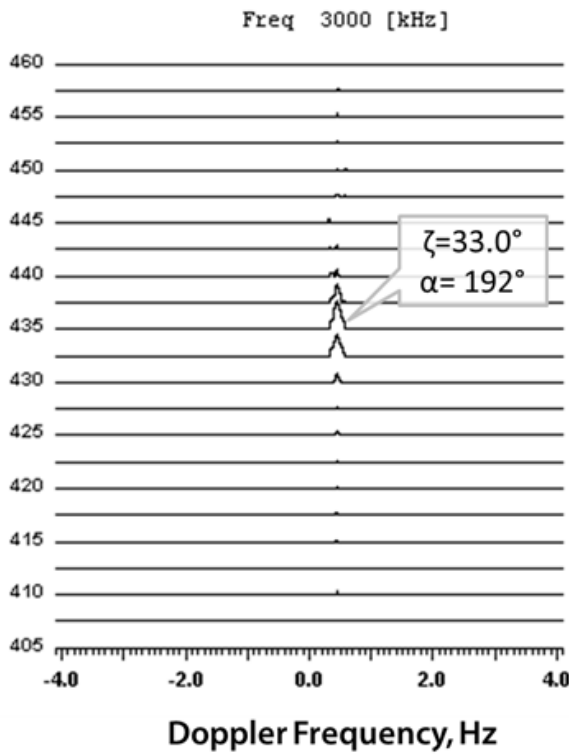
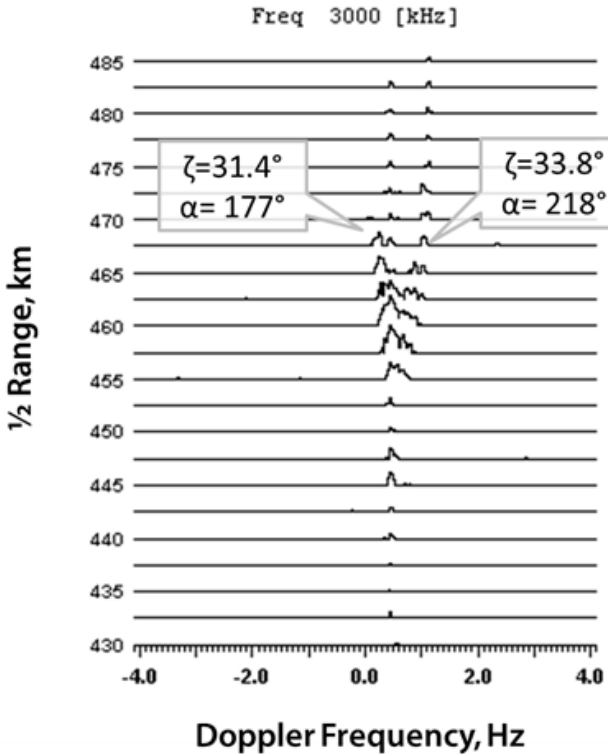
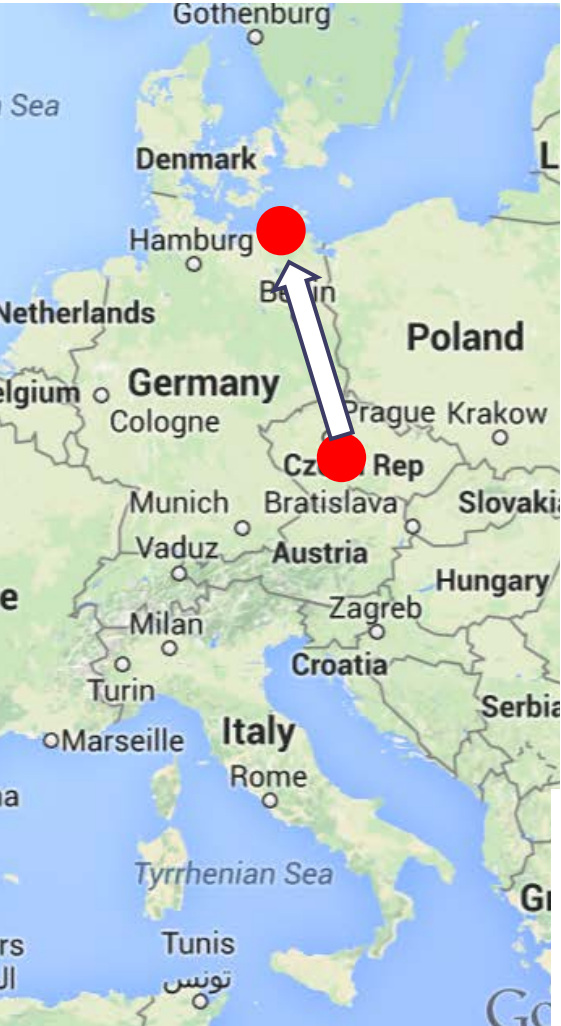
D2D waterfall displays at Juliusruh listening to the 3.0 MHz transmissions from Pruhonice

Disturbed

Quiet

STATION NAME YYYY DATE DDD HMMSS.SSS
Juliusruh 2015 Mar21 080 001918.000

YYYY DATE DDD HMMSS.SSS
 2015 Mar21 080 234418.000



During quiet conditions on the path between Pruhonice and Juliusruh (the right panel), the HF pulse arrives at an apparent range of 2x435 km, zenith of 33° and azimuth 192°.

The left panel shows substantially multimodal propagation of signal during disturbed conditions at various angles of arrival and Doppler frequencies.

Frequency Angular Sounding (FAS) Technique

- The idea: Use bistatic (or vertical) HF measurements of trajectory signal parameter variations (AoA+Doppler) to determine TID parameters

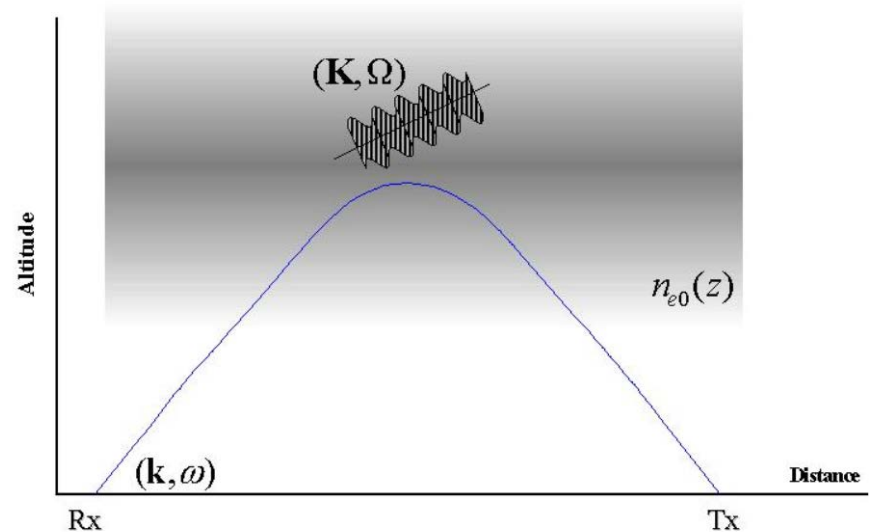
Measured signal parameters:

$e(t)$ elevation angle

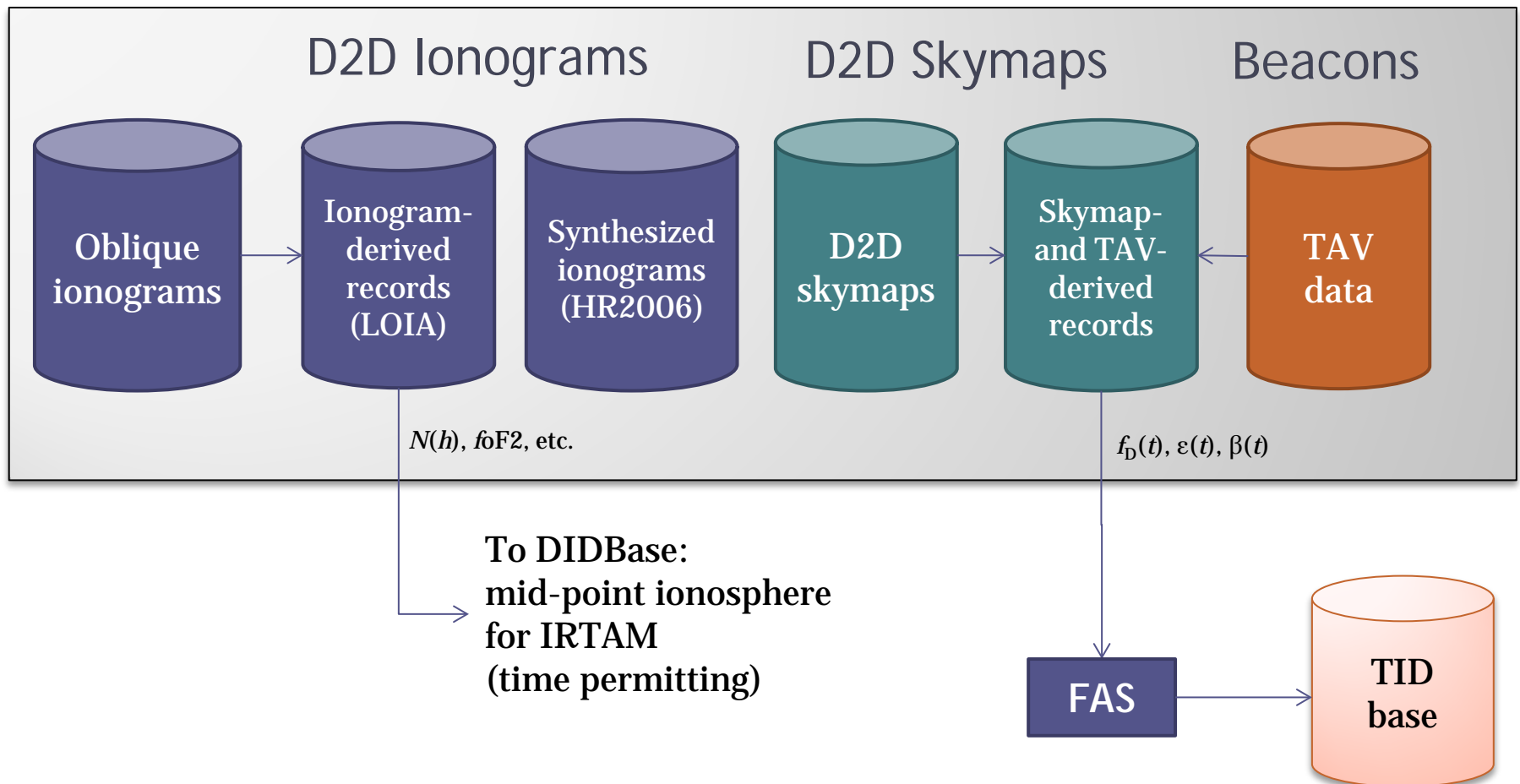
$j(t)$ azimuthal angle

$f_D(t)$ Doppler shift

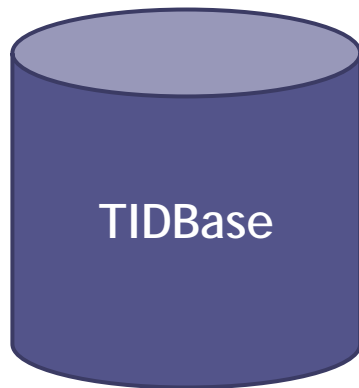
$t(t)$ Signal delay (vert. sound.)



LOUI-Base: Lowell ObliquE Incidence



TIDBase design



- Reference time UT
- Location of TID (lat, lon, altitude)
- Location of Instruments
- Input $f_D(t)$, $\varepsilon(t)$, $\beta(t)$ series and metadata
 - Frequency and virtual range
 - Uncertainty of input data
 - SNR per point
- Multiple records of derived sets of
 - Ω – TID wave period
 - N – Amplitude of TID perturbation
 - K – k-vector of TID wave propagation
 - Φ – phase of TID wave
- Uncertainty metrics
- Metadata
 - FAS and DFT2Sky versions
 - Computation timestamp

Project schedule

First Year

Kick off meeting: **21 November 2014**

First consortium meeting

Network calibration – Establishment of bi static links – First results on TID identification

Second Year

Establishment of the TID DB and real-time analysis system

Contacts with end-users – requirements collection

Second consortium and users meeting

Release of first warning system prototype

Third Year

Improving the functionality of the warning system

Meeting with users for final assessment of the warning system

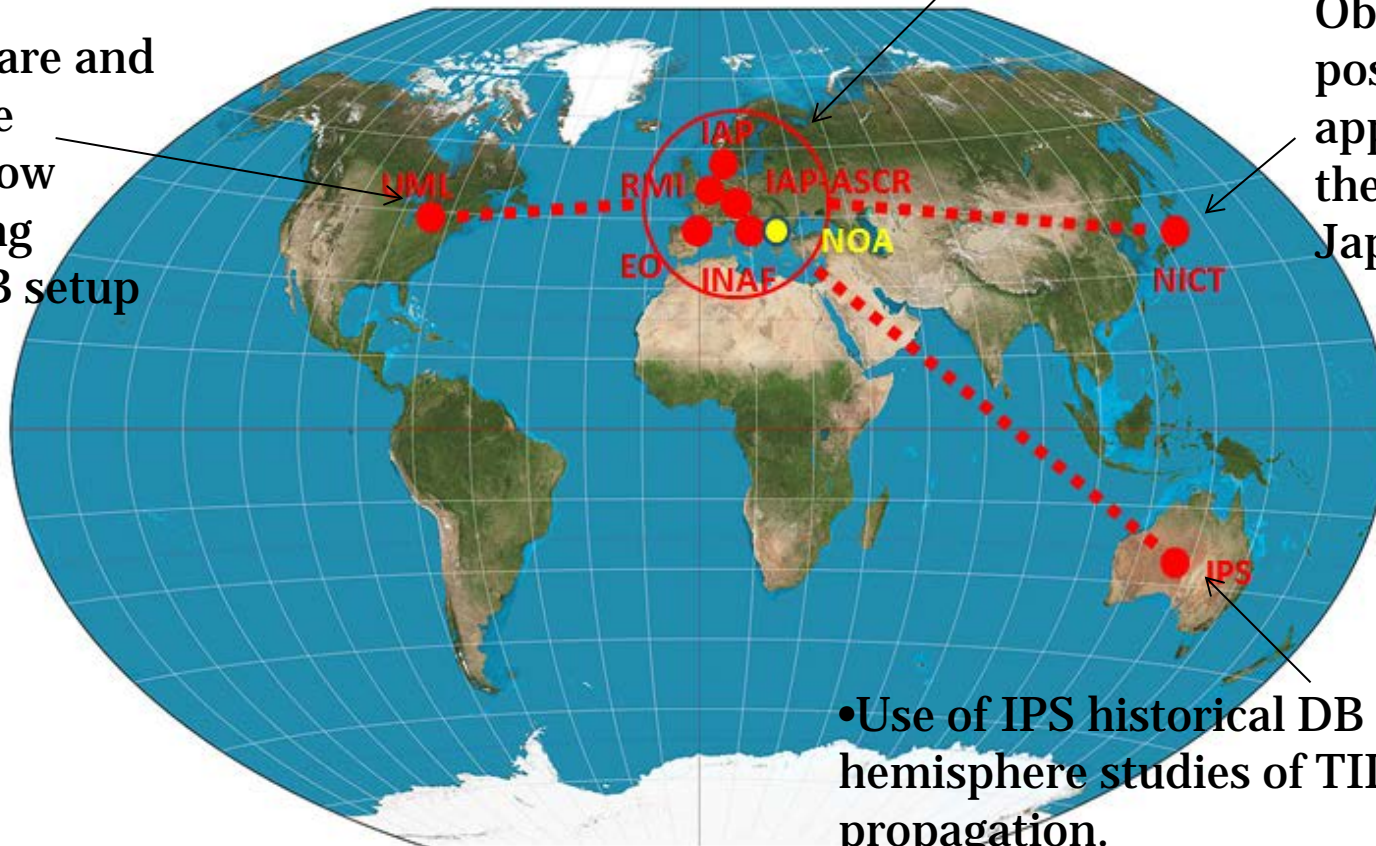
Final release of the warning system : **October 2017**

The project team

- Hardware and software know-how
- Training
- TID DB setup

- Observing platforms DPS4D
- Network operation
- NOA will set up the warning system

Observer – possible application of the method in Japan



- Use of IPS historical DB for inter-hemisphere studies of TID propagation.
- Links with IPS users for the specification of warning system specs

NIGHT

DAY

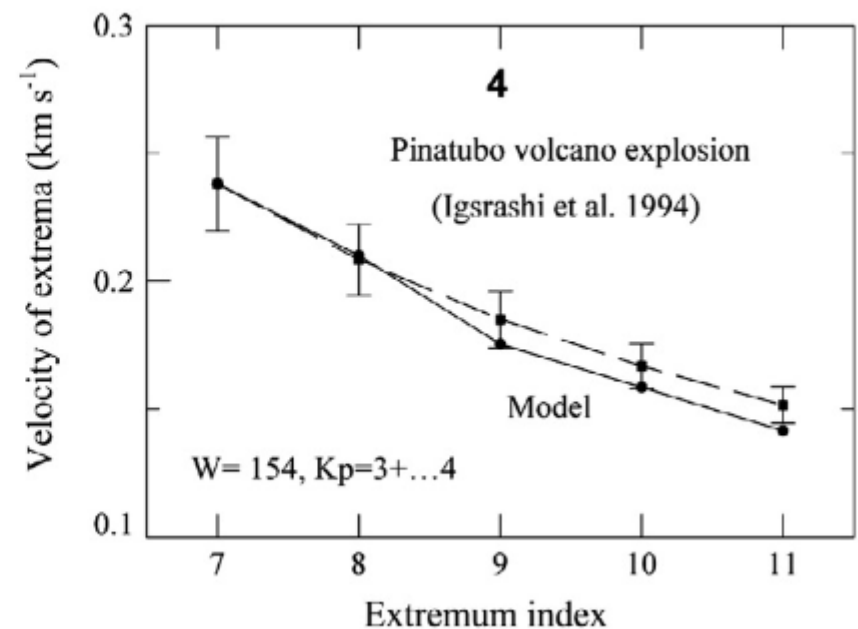
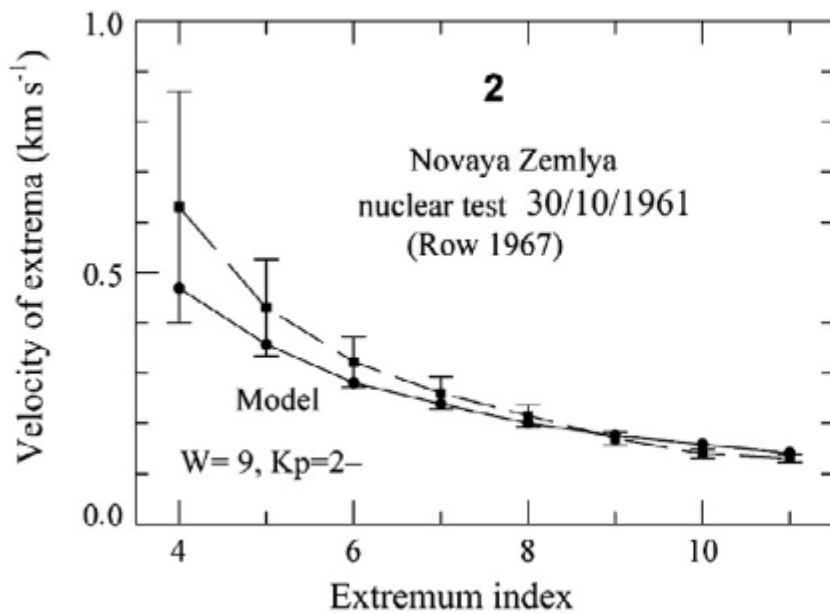
TID

Thank you for your attention!

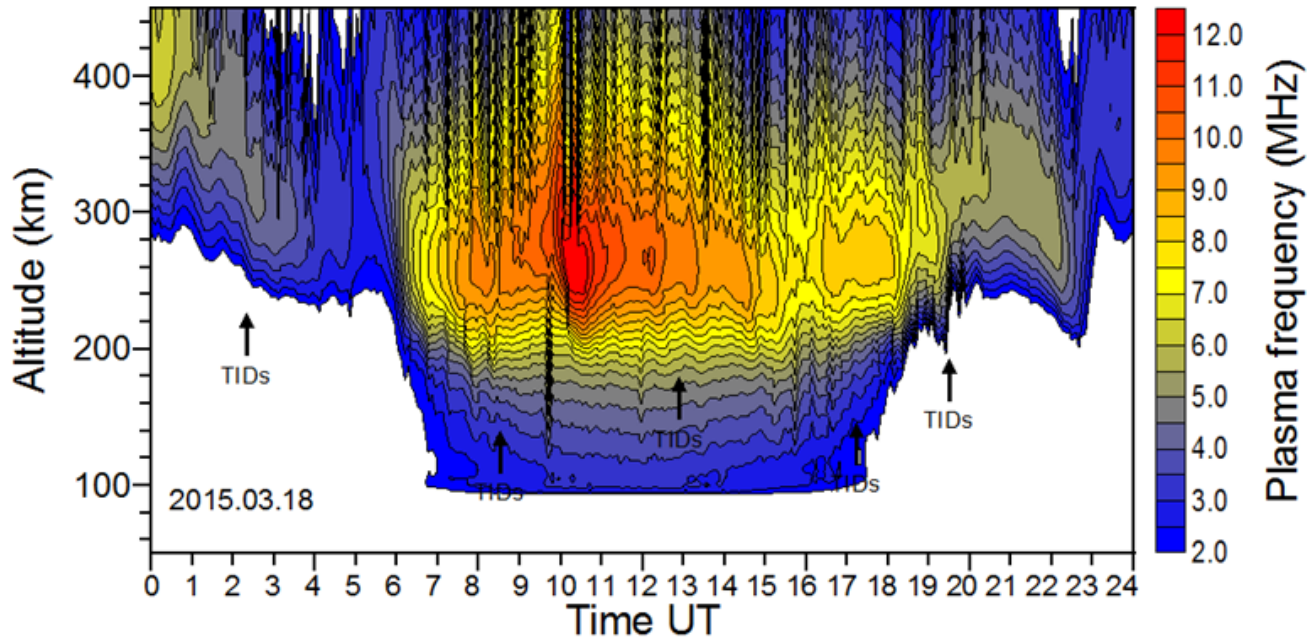


*This project
is supported by:*

The NATO Science for Peace
and Security Programme



Extrema velocities of a TID train versus its index for surface **nuclear explosions** and **volcano eruption** (Fedorenko et al., JSWSC, 2013).



Geomagnetic storm in progress

