Warning and Mitigation technologies for Travelling Ionospheric Disturbances Effects

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CIR/HSSS-related TID activity and their interhemispheric circulation

Dalia Buresova[1], John Bosco Habarulema[2], Jurgen Watermann[3], I. Edemskyi[1], J. Urbar[1], David Altadill[4], Estefania Blanch[4], Antoni Segarra[4], Z. Katamzi[2] and TechTIDE team

[1] Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague, Czech Republic,
[2] SANSA Space Science, Hermanus, South Africa
[3] JFWCONSULT, Tourrettes, France,
[4] Observatori de l'Ebre, OE (CSIC - Universitat of Ramon Llull), Roquetes, Spain,

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TID detection method	Brief description of the method
HF-TID	A new technique, based on the exploitation of DPS4D ionosondes, is implemented to directly identify TID in real-time. For the real-time detection and evaluation of TIDs remote-sensing data from synchronized, network coordinated HF sounding between pairs of DPS4D ionosondes are exploited. (*Reinisch et al., 2017; Huang et al., 2016)*
HF Interferometry method	The method identifies coherent TID activity at different sites and sets bounds to time intervals for which such activity occurs into a given region. *(Altadill et al., 2017)*
TID activity monitoring using GNSS data	TEC observations used for the analysis are calculated utilizing L1 and L2 Global Positioning Systems (GPS) frequency measurements (i.e. 1575.42 and 1227.60 MHz, respectively) in an algorithm developed at Boston College.

TechTIDE project HF-TID network (including possible extension)

1D Altitude profile of TID

- Detailed view of propagation along z-axis
- Pin-point to particular altitude region

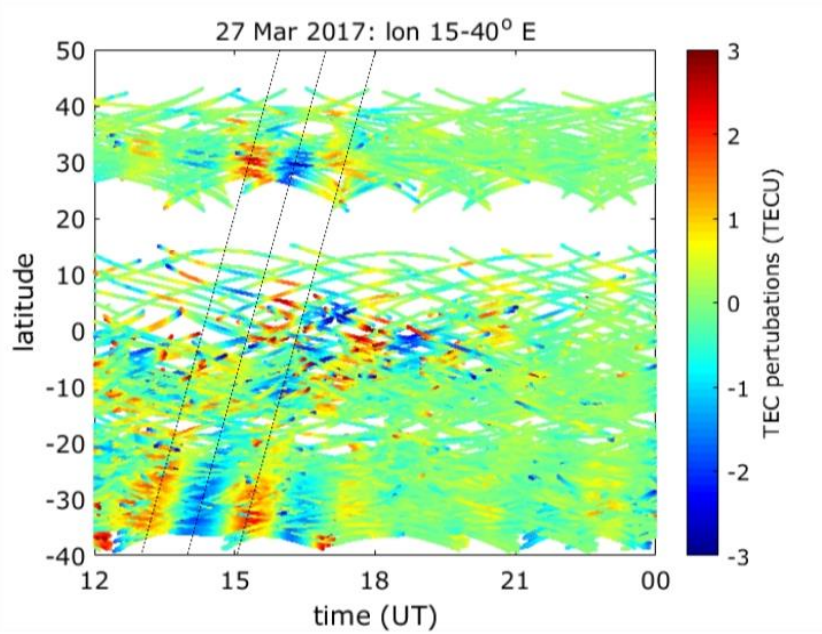
Sensitivity (amplitude)

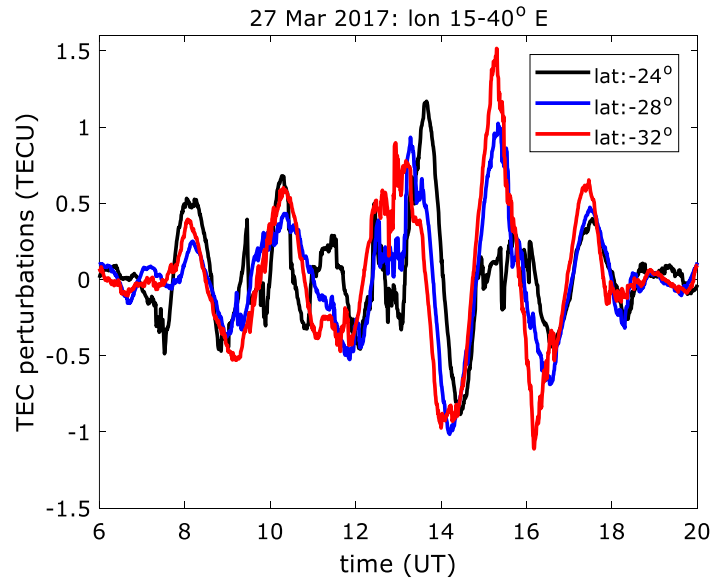
- Detection of a 5% TID vs underlying density
- "TID are always present" < 2%

Direction, Velocity, Wavelength

- Direct measurement
- Static platform
- No geometric transformation needed
- 24/7 operations with automatic intelligent system analysis

LSTIDs observed over both hemispheres based on GNSS data for 27 March 2017





The slant TEC is mapped to vertical TEC by using a thin shell model at ionospheric altitude of 350 km. In order to reduce the impact of multi-path, only data from satellites with elevation angle 30˚ are used.

Map of TEC perturbations over African southern middle latitudes shows TID activity between 8:00 and 20:00 UT that is intensified between 12:00 and 16:00 UT.
TID propagating equatorward.

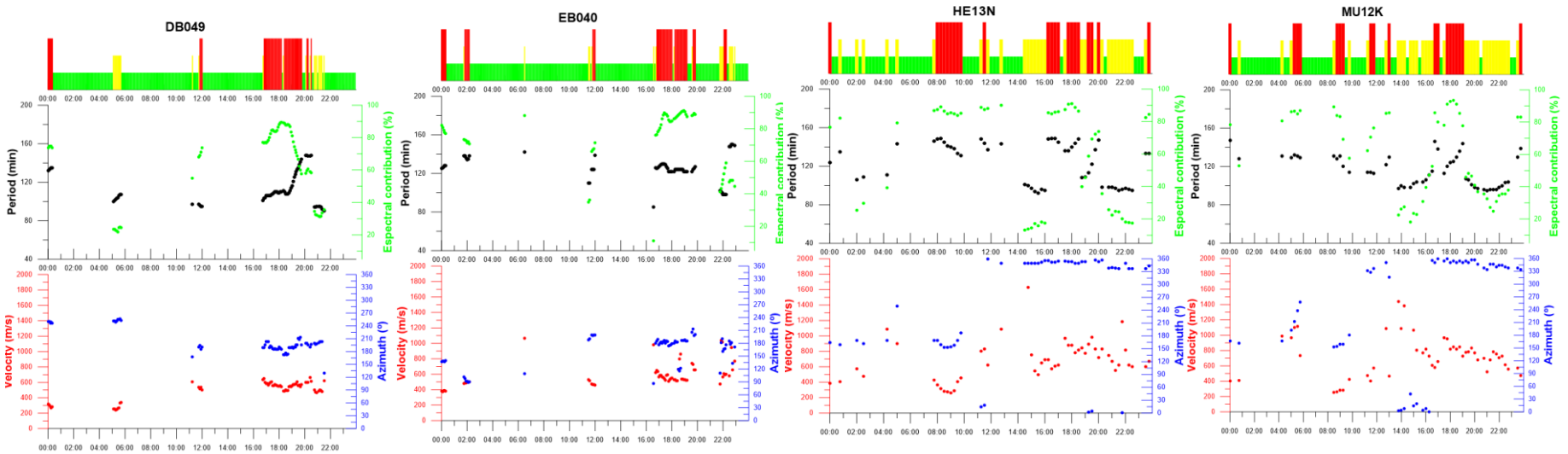
LSTID amplifies during course of main phase of the storm:

Mean velocity = 772 m/s
Period of wave roughly 2 hours

Results of the HF Interferometry and HF-TID techniques

27 March 2017

Path	Time, UT	Frequency, kHz	WA, %	WAz, deg	WL, km	WP, min
JR-PQ	00:30-03:00	2450	34,2	199	2289	160
JR-PQ	03:20-05:40	2450	90,3	141	1755	130
JR-PQ	17:40-20:20	2450	66,3	175	769	160
JR-PQ	20:20-23:00	2450	77,4	54	1253	75
JR-PQ	21:15-23:00	2450	32,8	191	1420	110

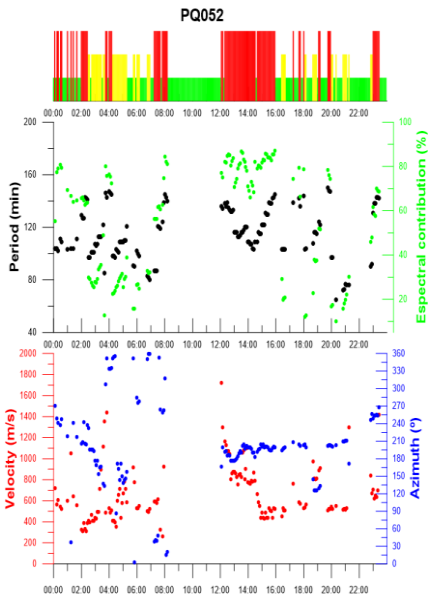


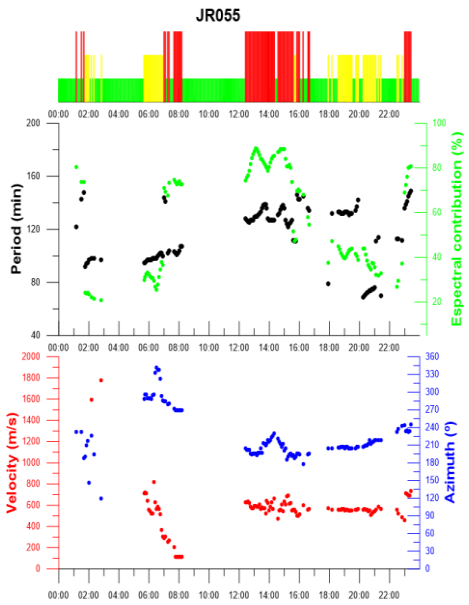
"Traffic lights" on the basis of correlation and coherency of periods between stations. **Green** means correlations lower than 0.6 or incoherent periods. **Yellow** means 3 or more stations have coherent periods, correlation larger than 0.6, and the spectral contribution is less than 50%. **Red** means 3 or more stations have coherent periods, correlation larger than 0.6, and the spectral contribution is more than 50%.

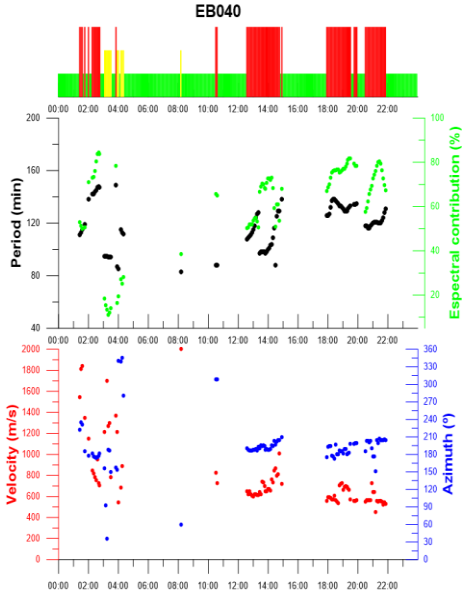
The results of the HF Interferometry and HF-TID techniques

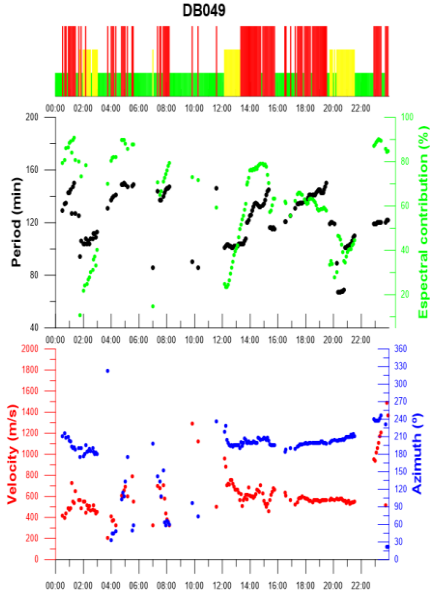
27 September 2017

Path	Time, UT	Frequency, kHz	WA, %	WAz, deg	WL, km	WP, min
EB-AT	04:00-05:50	4725	44,2	299	681	105
EB-DB	02:30-05:30	4725	35,3	265	982	165
JR-PQ	00:00-03:00	2450	77,2	123	4678	170
EB-AT	21:00-23:00	4725	31,1	136	2272	105
EB-DB	16:15-19:15	9125	50,9	127	7360	180
	21:00-23:00	4725	39,2	157	1101	85
JR-PQ	21:15-23:00	2450	32,8	191	1420	110









Appearance of LSTIDs in both hemispheres and interhemispheric circulation

38 TID events from the TechTIDE project event catalogue were analysed

26 events indicated LSTID occurrence

The 26 events in detail (each of the three groups below sums up to 26)

16 events: LSTID in both hemispheres, no interhemispheric propagation
4 events: interhemispheric propagation of LSTID
6 events: LSTID occurrence in one hemisphere (insufficient data coverage of the other hemisphere)
NOTE: no case of LSTID observed in one hemisphere and definitely excluded in the other one

14 events: LSTID originating at high latitudes and propagating equatorward
3 events: LSTID originating near the geomagnetic equator and propagating poleward
9 events: LSTID origination at high latitudes and near the geomagnetic equator

13 events: LSTID during stronger storms (*SYM-H* exceeding -90 nT) during or immediately after the main phase
8 events: LSTID during weak storms (*SYM-H* not exceeding -90 nT)
5 events: LSTID during absence of storm conditions or late in the recovery phase of a storm

The reaming **12** events
4 events: no LSTID during weak storm periods (*SYM-H* not exceeding -90 nT)
8 events: no LSTID during storm-free periods or late in the storm recovery phase

Summary of what we observed:

TID driver	Number of analysed events	Magnitude of EGNOS availability degradation	Range of EGNOS availability degradation
CME	5	2 - high degradation 2 – moderate degradation 1 – low degradation	22.7% - 33.9% 8.7% - 12.0% 1.8%
CIR/CH HSS	25	23 – moderate degradation 2 – low degradation	5.4% - 15.7% 4.1% - 4.3%
SSBS	1	moderate degradation	6.8%

- Both CME- and CIR/HSSS-related events are significant sources of the LSTIDs.
- The CIR/HSSS-related LSTID activity has longer duration.