CORRELATION BETWEEN TROPICAL-LIKE CYCLONES IN THE MEDITERRANEAN SEA AND THE SPACE WEATHER

Medžida Mulić¹, Džana Halilović², and Anesa Lavić¹

¹University of Sarajevo
²Technical University of Vienna
Introduction

Medicanes or Mediterranean cyclones

- This term does not refer to a particular hurricane but to a type of cyclone that, when fully developed, has similar characteristics to a tropical cyclone – TC

- TC are fast-rotating meteorological systems characterized by:
  - a centre of low pressure,
  - closed atmospheric circulation,
  - strong winds and,
  - a spiral arrangement of thunderstorms that give a lot of rain.

Objective

- exploring the ionospheric response to Medicanes

NOAA Mediterranean Cyclone 16 Jan 1995
Methods and data

- Medicanes
  - Nov 2014
  - Oct 2016
  - Nov 2017
- GNSS TEC estimated using Vshell – ICTP Trieste
- 8 EPN GNSS
  - LAMP
  - ALME
  - MARS
  - CASB
  - NOAA1
  - ZADA
  - SRJV

Photo credit: NASA
Results

Following slides show results:

• Daily VTEC medians for the medicane and IDD* in November 2014
• Daily VTEC variations on the day of TC in November 2014
• Daily VTEC variation in October 2016
• Daily VTEC variation in November 2017
• Variation of $vTEC \times \sigma$ for all three TC

$$vTEC \times \sigma = \frac{vTEC - vTEC_{mean}}{\sigma}$$

*IDD – International Disturbed Days
Results

Medicane „Qendresa I“ November 2014

**Daily medians of VTEC**

*24/10/2014 – 30/10/2014/

*31/10/2014 - 06/11/2014*

*07/11/2014/- 13/11/2014*

*14/11/2014/- 20/11/2014*

**Day of TC „Qendresa I“**
Results

Medicane „Qendresa I“ November 2014

• Station LAMP is the closest to the eye of the storm and its max VTEC was 80.45 TECU at 12:00 UTC
• The TC reached its maximum intensity at 10:00 UTC, Nov 07, 2014
• CASB and WARN were the farthest stations from the storm and their max VTEC values were 2x smaller compared to LAMP (at the same time of the day).

Daily variation of VTEC on day of TC 07/11/2014 (DOY 311 2014)
Results

International disturbed days – IDD in the November 2014

Daily variation 04/11/2014 (DOY 308)

Daily variation VTEC 05/11/2014 (DOY 309)

Daily variations VTEC 15/11/2014 (DOY 319)

UTC time (h)

VTEC (TECU)

UTC time (h)

VTEC (TECU)
The tropical cyclone started on Oct 28, hit Malta and slowed down the next day. It re-intensified on Oct 31.

LAMP VTEC data (Italy) reflected the impact of the TC (40 TECU).

MARS (Italy-Nord) and NOA1 (Greece) showed a smaller VTEC increase (20 TECU).

SRJV (Bosnia&Herzegovina), WARN (Poland), and CASB (Ireland) showed max VTEC values of approx. 10 TECU.
Results

Medicane „Numa“, November 2017

Daily variation of VTEC (02/11/2017 – 29/11/2017)

- CIR (Co-rotating interaction regions) hit the Earth on Nov 16, 2017
- This was also the day of a hurricane close to ALME, LAMP, MARS and NOA1 on Nov 21.
- Highest VTEC values at ALME (over 90 TECU) could have been possibly caused by the hurricane, since the other stations (far from the hurricane’s eye) did not show extreme VTEC variations. On the other hand, cycle slips were found in the GNSS data of ALME, which could have also been mapped into the VTEC anomalies.
• CIR (Co-rotating interaction regions) hit the Earth on Nov 16, 2017
• The TC „Numa“ reached its highest intensity on Nov 18, becoming one of the few Mediterranean hurricanes.
• VTEC values for ALME were not reliable, due to the occurrence of cycle slips.
• LAMP, MARS and NOA1 showed increased VTEC values on Nov 21.
Time series of the $vTEC \ast \sigma$ : Station LAMP - red (Italy) is the closest to the tropical storm. Parameter $vTEC \ast \sigma$ are quite bigger within days before, during and after the day of the TC than ALME – green (Spain) or CASB - blue (Ireland) which were far away and out of the TC impact.
Results

Medicane in October 2016

Time series of the $vTEC \ast \sigma$ : Station LAMP – red (Italy) is the closest to the tropical storm. Parameter $vTEC \ast \sigma$ are bigger within three days before, during and one day after the TC than at station CASB - blue (Ireland) which was far away. Station ALME – green (Spain) did not have all available observation data for this period.
Results

Medicane November 2017

Time series of the $vTEC\ \ast \ sigma$ : Station NOA1 - red (Greece) is the closest to the hurricane. Parameter $vTEC\ \ast \ sigma$ are bigger within days after the hurricane at NOA1 than at SRJV - green (Sarajevo, B&H) or WARN - blue (Germany) which were far from the hurricane’s eye.
Conclusions

• This study was an investigation of the ionospheric response to Medicanes on Nov 2014, Oct 2016, and Nov 2017.

• GNSS TEC variations and anomalies before, during and after tropical cyclones were analyzed at EPN stations in and outside of the area impacted by Medicanes.

• The ionospheric response to tropical storms requires careful observation of geophysical conditions, since detection and identification of the ionospheric response to tropical cyclones are possible under calm geophysical conditions.

• The research showed that the main factors that suppress the effects of the troposphere on the ionosphere are geomagnetic storms.

• Results show that increased VTEC values at GNSS stations near the TC eye could be correlated with the tropical cyclones’ impact.

• There is a need for a deeper investigation of these complex systems.
This presentation is based on the research carried out within the frame of the master thesis of (Lavić, 2019).


In this research some of the used references were:

• Ciraolo, L.: Ionospheric Total Electron Content (TEC) from the Global Positioning System, Personal communication, 2012
• Lionello et al: Objective climatology of cyclones in the Mediterranean region: a consensus view among methods with different system identification and tracking criteria, Tellus A: Dynamic Meteorology and Oceanography, Italy, 2016
• Mendoza: The effects of Space weather on Hurricane activity, Recent Hurricane Research-Climate, Dynamics and Societal Impacts, Institute of Geophysics, Mexico, 2011
• Natras, R., D. Krzdalic, D. Horozovic, A. Tabakovic, M. Mulic: "GNSS ionospheric TEC and positioning accuracy during intense space and terrestrial weather events in B&H"; Geodetski Vestnik, 63 (2019), 1; 73 - 91.
Thank you!