Tomographic imaging and modelling of a LSTID during geomagnetic storm conditions

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Introduction

• The extensive coverage of GNSS receiver networks provide an ideal tool to image LSTIDs over large areas.

• The aim of this presentation is to demonstrate large area imaging of a TID using GNSS Tomography
Background

- **Tomography:**
  - Produces 2D-4D images of ionospheric electron density
  - Tomography from LEO to ground UHF-VHF signals successfully image TIDs in 2D
  - Some previous studies using various GNSS tomography methods to image TIDs in 3D-4D*
  - MIDAS has not previously been used to investigate TIDs.

- **Large scale TIDs:**
  - LSTIDs common during geomagnetic storm conditions
  - One of the largest storms in recent history occurred on **29-31 Oct 2003**. We are focussing on the third day of the storm

GPS receivers from IGS & UNAVCO
Waves in TEC on 31 Oct 2003 from an individual receiver.
By visual inspection: Azimuth ≈ 15° (S-W), $\lambda_h \approx 700$ km, $T \approx 30$ min, $\Rightarrow V_{ph} \approx 390$ m/s, $V_g \approx 320$ m/s
Verification

- LSTID has been identified from TEC measurements
- However, previous studies [Wan & al 1997, Penney & Jackson-Booth (2015)] warn of distortion in the apparent TID due to satellite movement
- Can the full process be replicated by end-to-end modelling and simulation?
  - In order to do this, we need to simulate a realistic TID


Modelled TID

- W. H. Hooke’s [1968] physical model representing TID
- IRI 2016 representing “background” electron density


D. Bilitza et al. (2017), International Reference Ionosphere 2016: From ionospheric climate to real-time weather predictions, Space Weather, 15, 418–429
Verification by simulation

Actual $N_e$

Actual sTEC

MIDAS

Reconstructed $N_e$

Model $N_e$

Line integration

Emulated sTEC

MIDAS

Reconstructed $N_e$

Hooke + IRI

compare
Comparing simulation result with model

(2 h running average subtracted to isolate the foreground)

We can reproduce the TID, but there are effects from sparse receiver coverage
Verification by simulation

- Actual $N_e$
- Actual TEC
- MIDAS
- Reconstructed $N_e$

- Emulated TEC
- MIDAS
- Reconstructed $N_e$

- Model $N_e$
- Line integration
- Hooke + IRI

compare
Comparing simulation result with real result

(2 h running average subtracted to isolate the foreground)
Comparing simulation result with real result

(2 h running average subtracted to isolate the foreground)

If a real TID with these parameters (Azimuth ≈ 15°, λh ≈ 700 km, T ≈ 30 min, Vph ≈ 390 m/s, Vg ≈ 320 m/s) were in an otherwise undisturbed ionosphere, it would have resulted in the left movie. The movie from the real data is showed on the right.
Summary

• Tomographic reconstruction of LSTID from actual GPS TEC

• This was a previously unreported LSTID from the 2003 Halloween storm

• An end-to-end simulation demonstrated that the tomographic imaging process was able to reproduce the actual TID without distorting the parameters
Future work

• A more realistic “background” electron density model can improve validation

• Further analyse the TID in context of the storm

• Use multi-GNSS and denser networks to improve image resolution in order to image smaller TIDs