DISPEC

Scientific exploitation of space Data for improved Ionospheric SPECification

Scientific Data Application 3

Ionospheric Effective Slab Thickness Anomaly Mapping

Ivan Galkin (BGD), Adam Fron (UWM), Andrzej Krankowski (UWM),
Manuel Hernandez Pajares (UPC)

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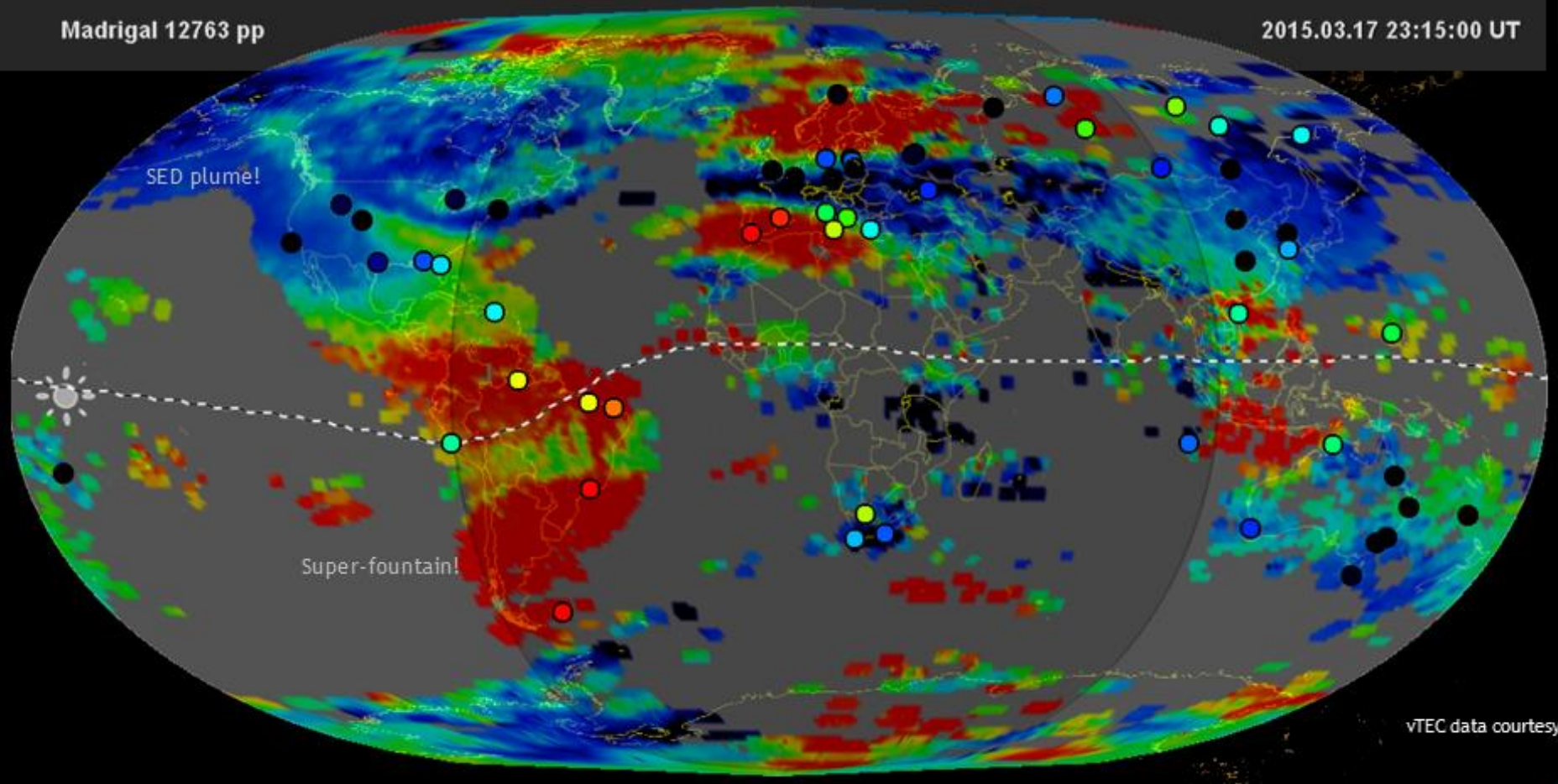
Outline

- **Background: Cooperation of GNSS and GIRO communities**
  - **DISPEC: anomaly maps of effective slab thickness τ**
- **Global mapping of τ quiet-time climatology**
  - ➢Climate NmF2: IRI
  - ➢Climate VTEC: 28-day average from UWM
- **Global mapping of τ quiet-time weather**
  - ➢Weather NmF2: IRTAM
  - ➢Weather VTEC: GIMs (several options)

Prelude

St. Patrick storm
March 17, 2015 23:15



Gambit eXplorer
giro.uml.edu/GAMBIT

vTEC data courtesy MIT Haystack Madrigal Repository

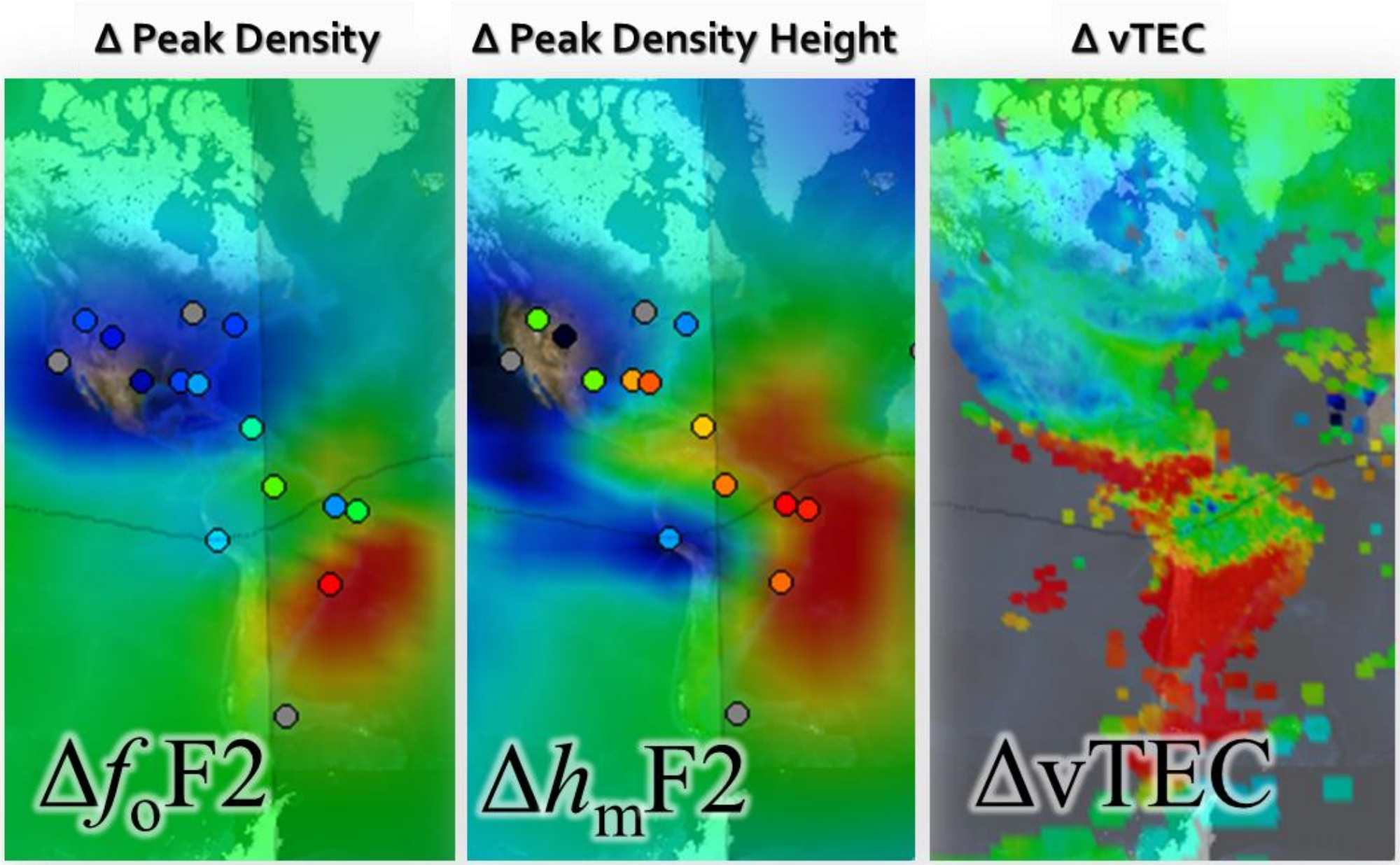
ΔNmF2 @ 60 GIRO sites

ΔvTEC @ 6342 GNSS sites

AT-AP-RASC 2022
3rd URSI Atlantic Radio Science Meeting

UMASS LOWELL

GNSS vTEC and GIRO NmF2



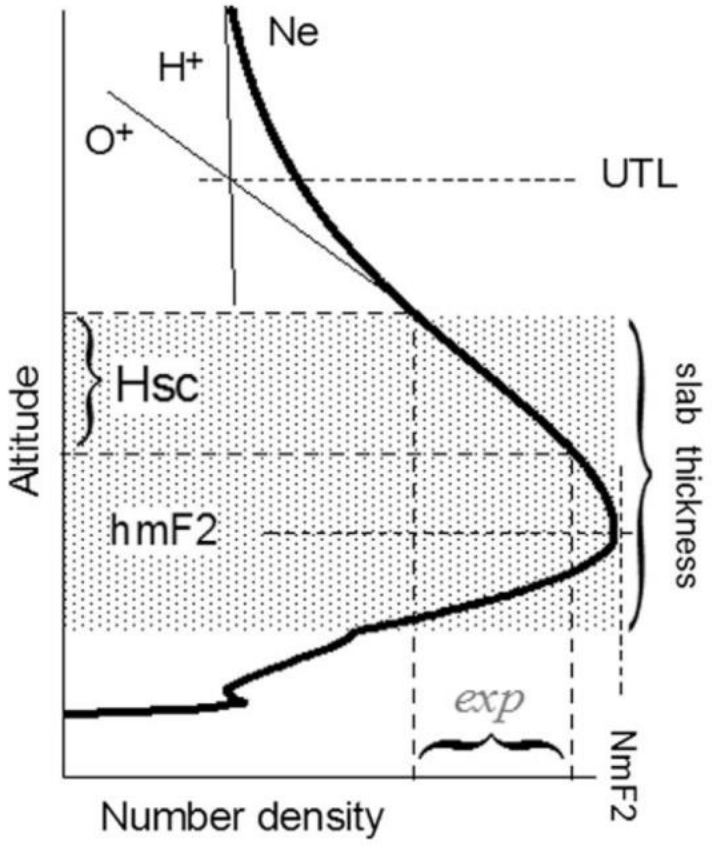
VTEC data courtesy Anthea Coster, MIT Madrigal

Cooperation of GNSS and GIRO

OTHERS:

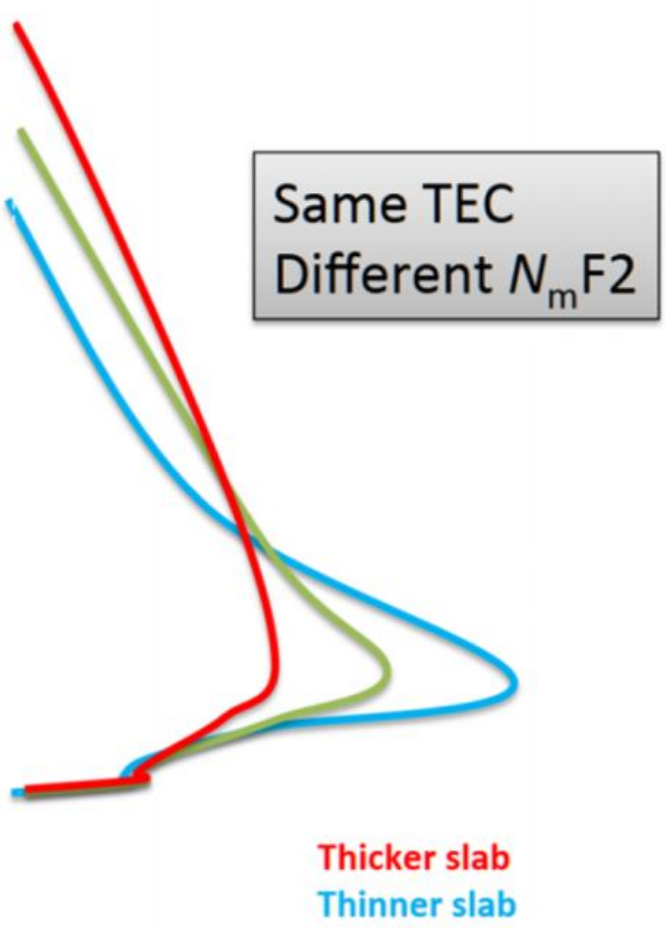
- 2D: use observed ΔvTEC to derive corrections to NmF2 over no-coverage areas
  - T. Gulyaeva et al.
  - A. Pignalberi et al.
- Assimilate GIRO and GNSS data simultaneously in a 3D model
  - 6000 vs 60 problem
    - GIRO input is insignificant
  - GPSII: weighted assimilation
    - Fridman *et al.*, NWRA/HFGeo

DISPEC:



- DATA FUSION PROJECT
  - *Combine* NmF2 and vTEC measurements to reason about slab thickness τ
  - τ = vTEC/NmF2
    - not quite a “fusion” yet
  - Also in this chart:
    - Scale height Hsc
    - Upper Transition Level UTL

Thicker/thinner slabs

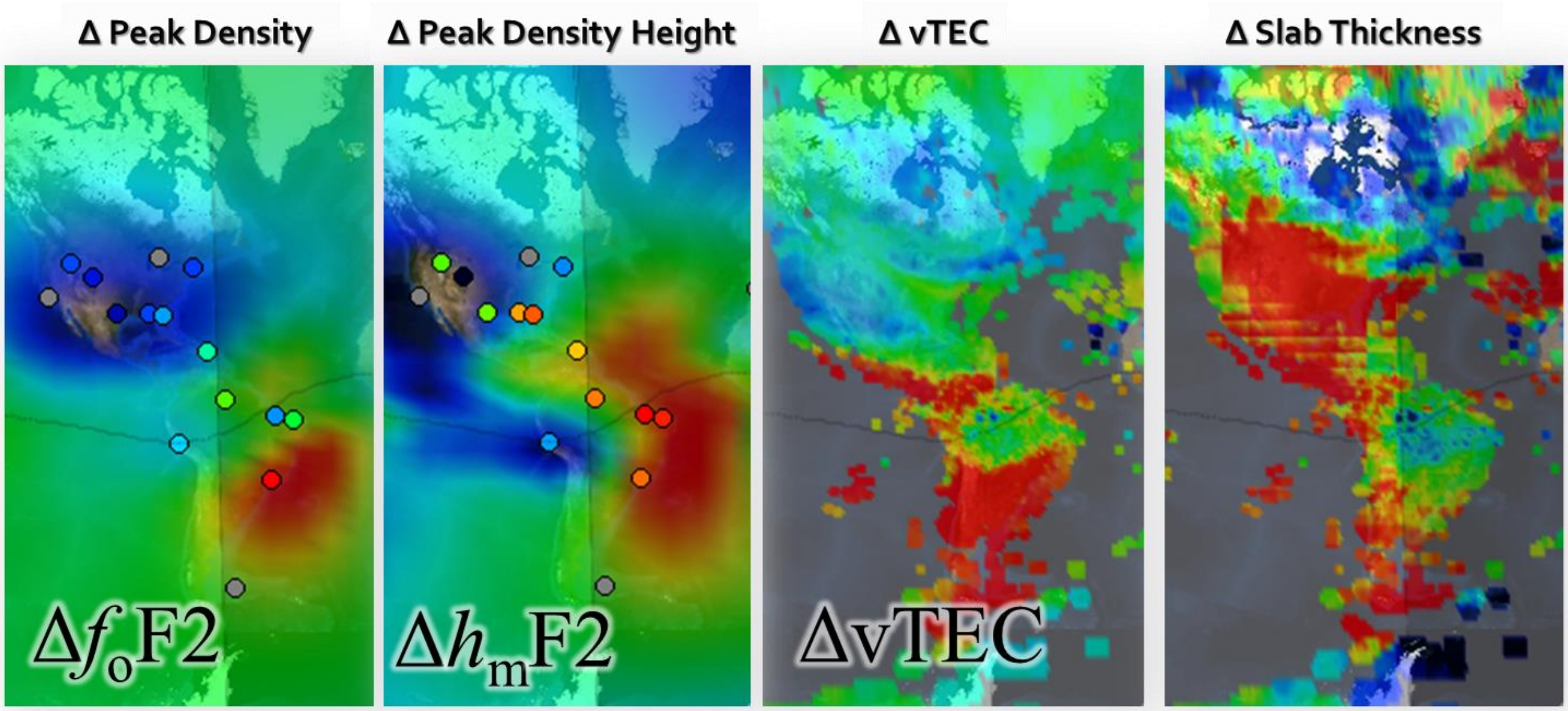


- Tempting to call thicker slabs “stretched” and thinner slabs “compressed”
  - Not quite right language
  - No plasma transport is usually involved
    - instead, this is about chemistry
    - mostly about ionization and recombination rates
      - which in turn may be related to the temperature fluctuations

Slab Thickness as a proxy

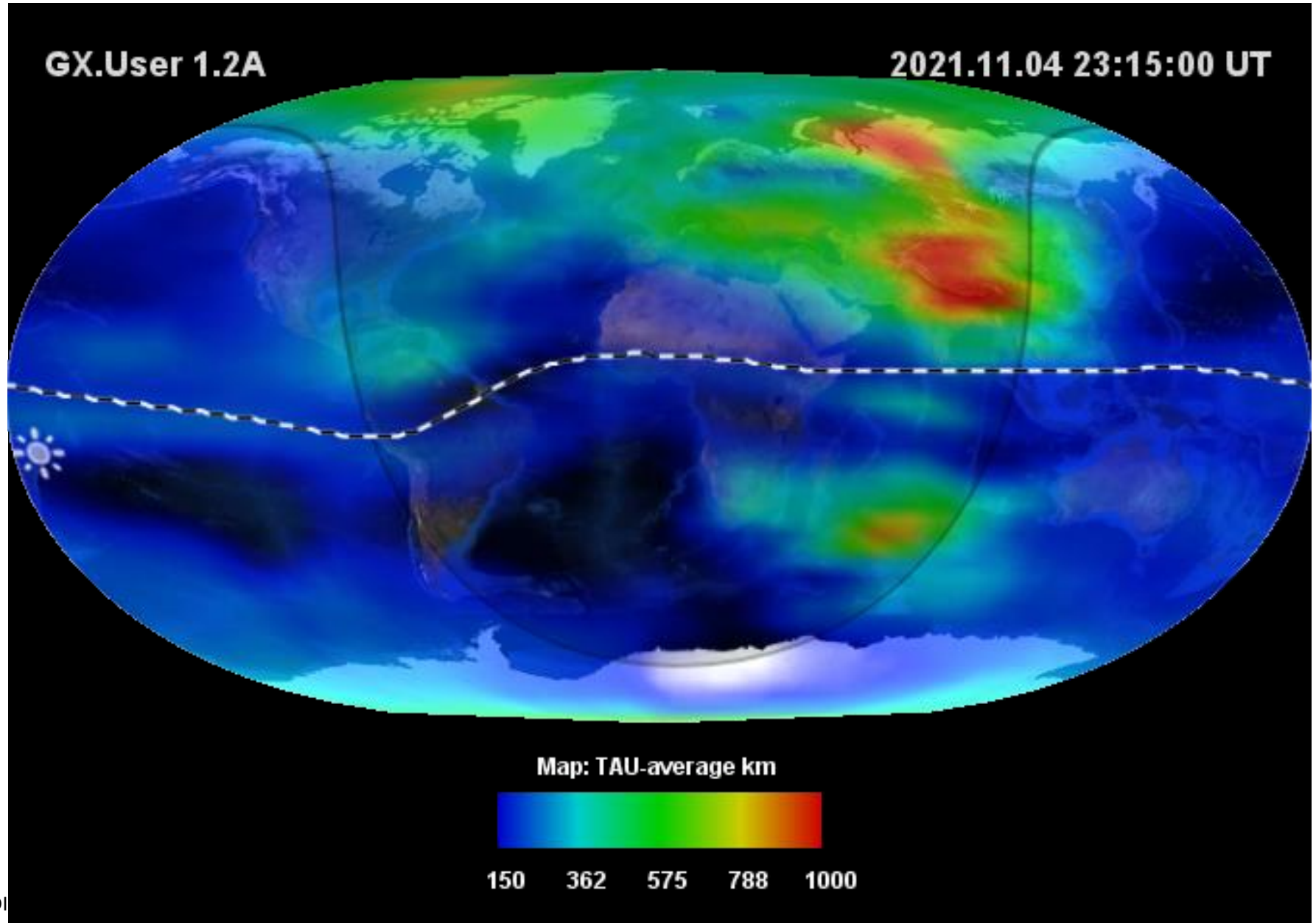
- **τ is a proxy to indicate other processes in the ionosphere and thermosphere**
  - Sensitive plasma property to detect and characterize subtle changes
    - Temperature and composition of the thermosphere and ionosphere
      - Titheridge is an active proponent of τ science
    - Vertical plasma redistribution in the ionosphere/plasmasphere/polar-cap
      - via profile shape characterization
      - relationship to the vertical scale height is noted
    - As we will see, a sensitive proxy to MUF dynamics (for HF communications)
      - anomaly maps of τ are a nice addition to the space weather toolbox
  - Climatology of τ is remarkable for diurnal/seasonal variation
  - τ shows certain dependency on solar and geomagnetic activity
    - Not quite clear, needs further analysis
      - Anomaly mapping of τ will be instrumental

Slab thickness anomaly over North America



VTEC data courtesy Anthea Coster, MIT Madrigal

Climatology of τ

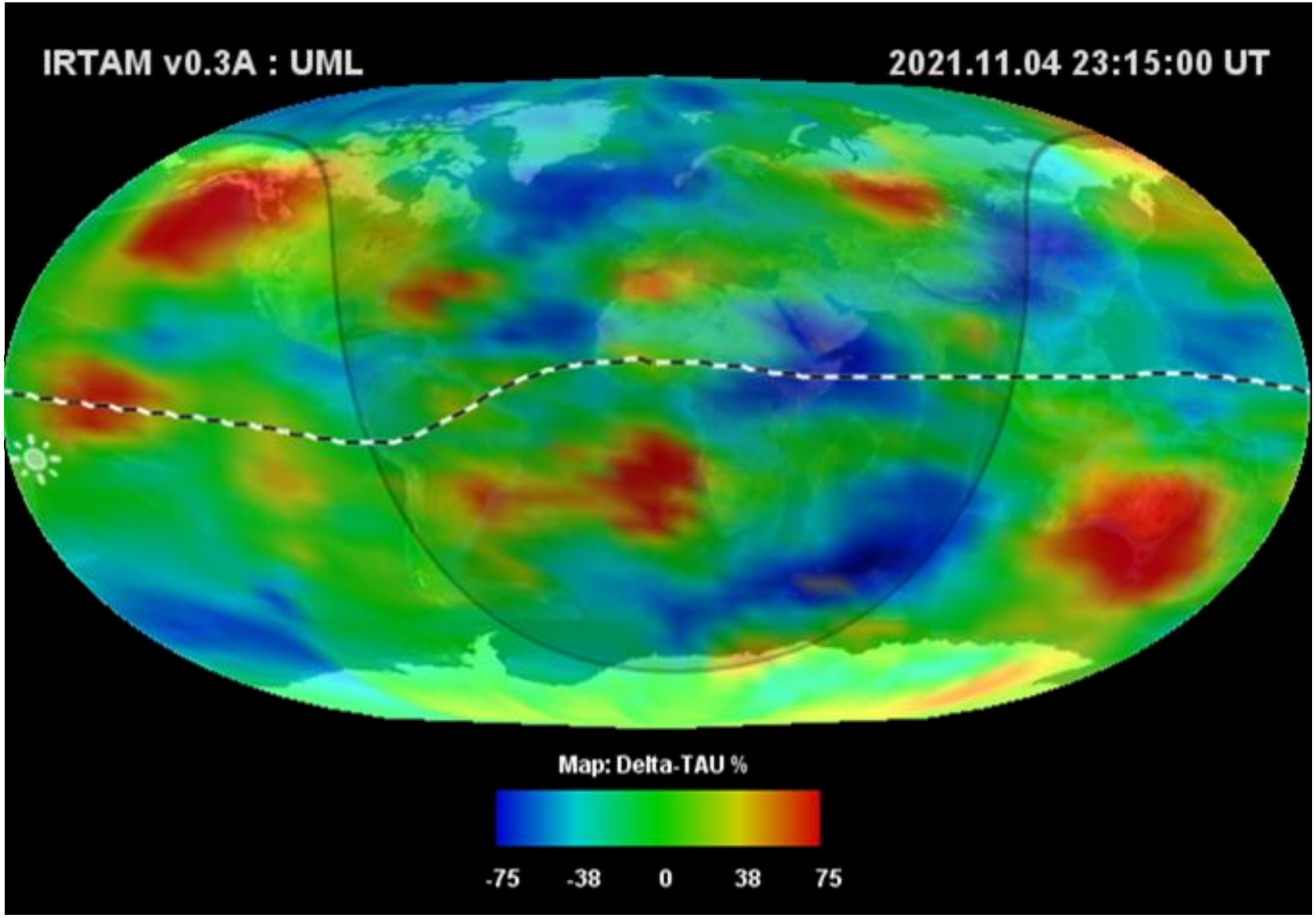


NmF2: IRI foF2 model (climate)
VTEC: IGS 28-day median vTEC

[Fron *et al.*, 2020]

Slab Thickness Anomaly Map

2021 Nov 04 storm example



NmF2: IRTAM NmF2 weather
VTEC: IGS vTEC weather GIM

Significant -75 to +75% deviations positive and negative at the same time

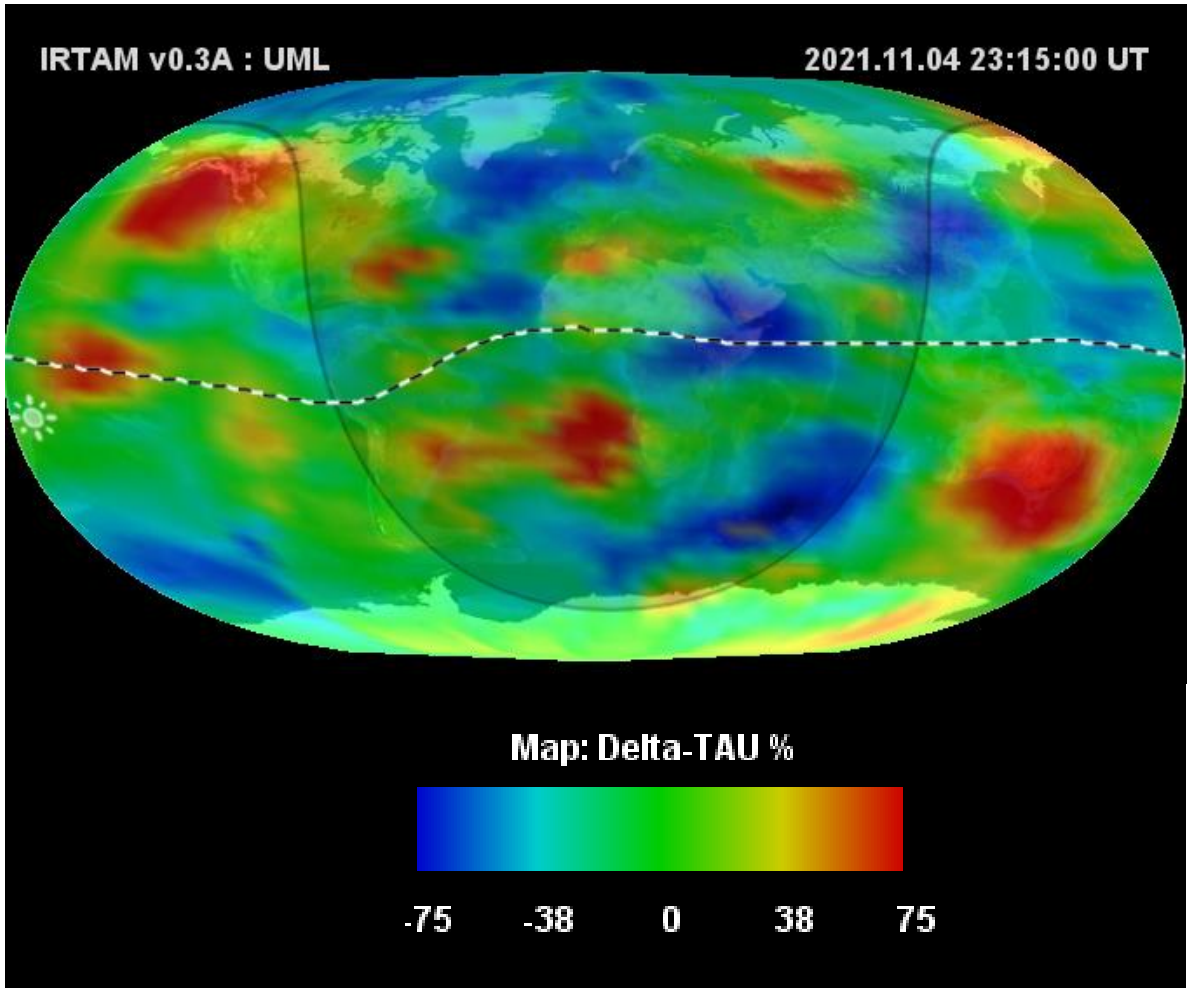
Tau-anomaly vs MUF anomaly (storm-time)

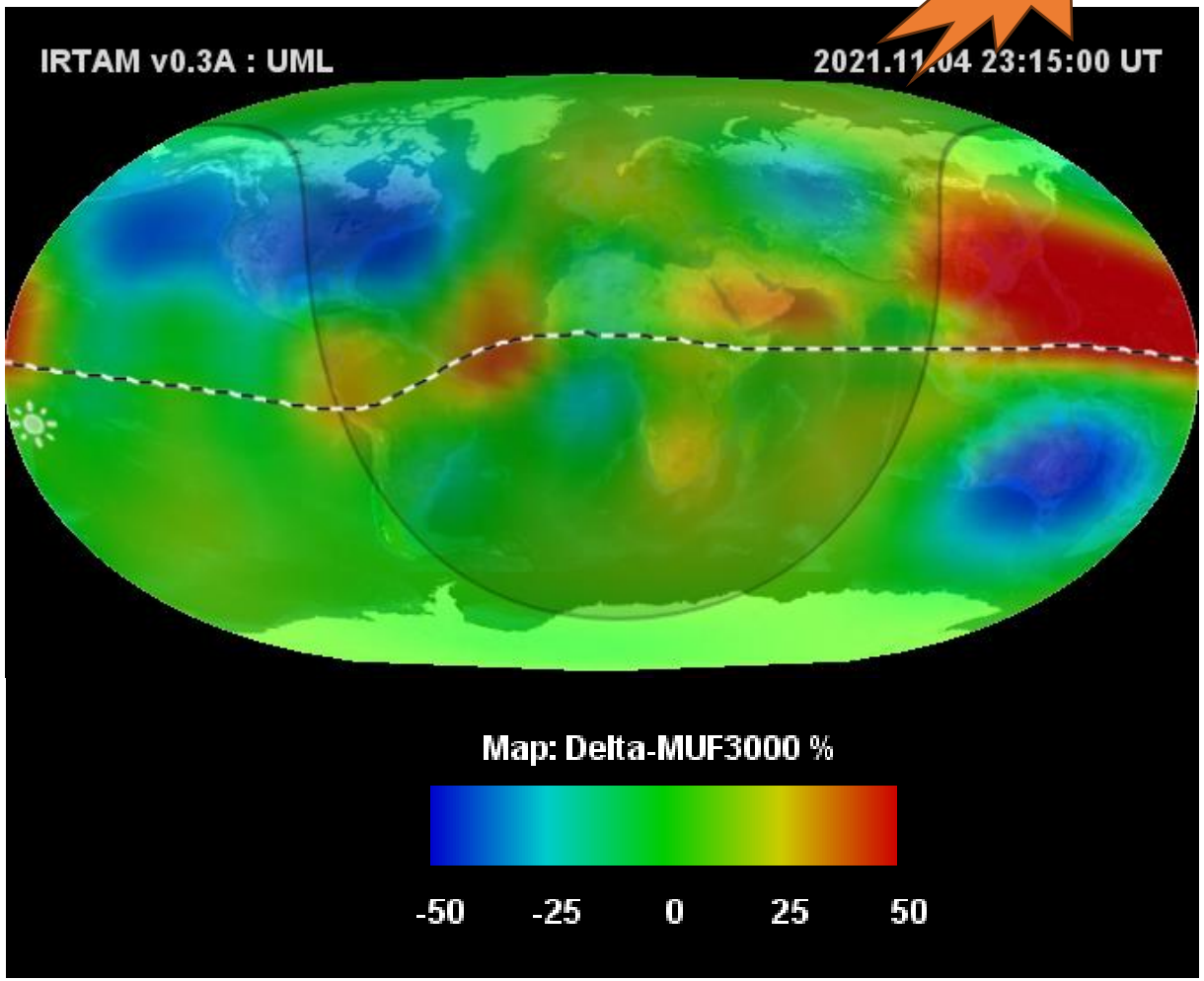
in percent

$\Delta\tau$

ΔMUF

No vTEC



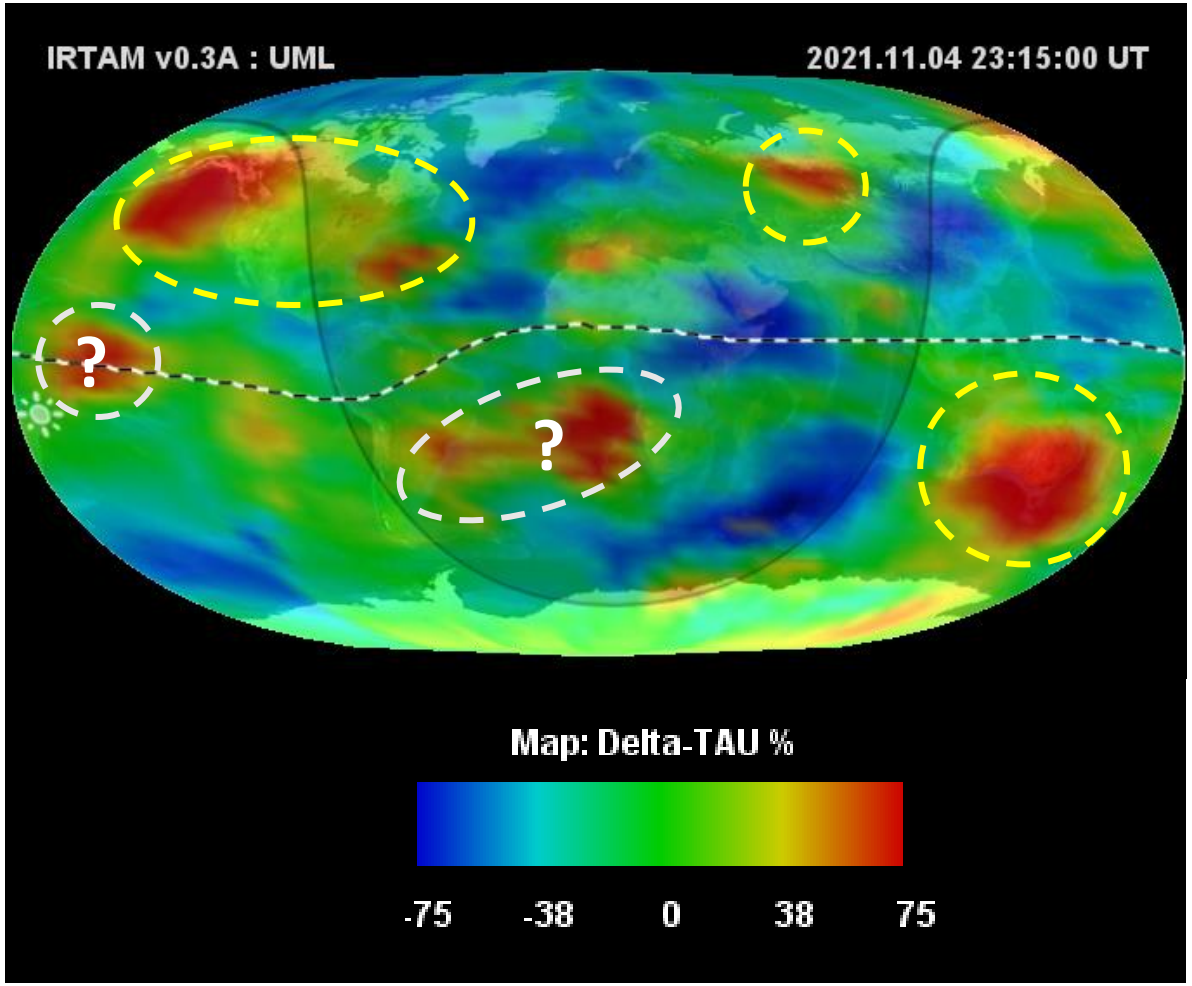


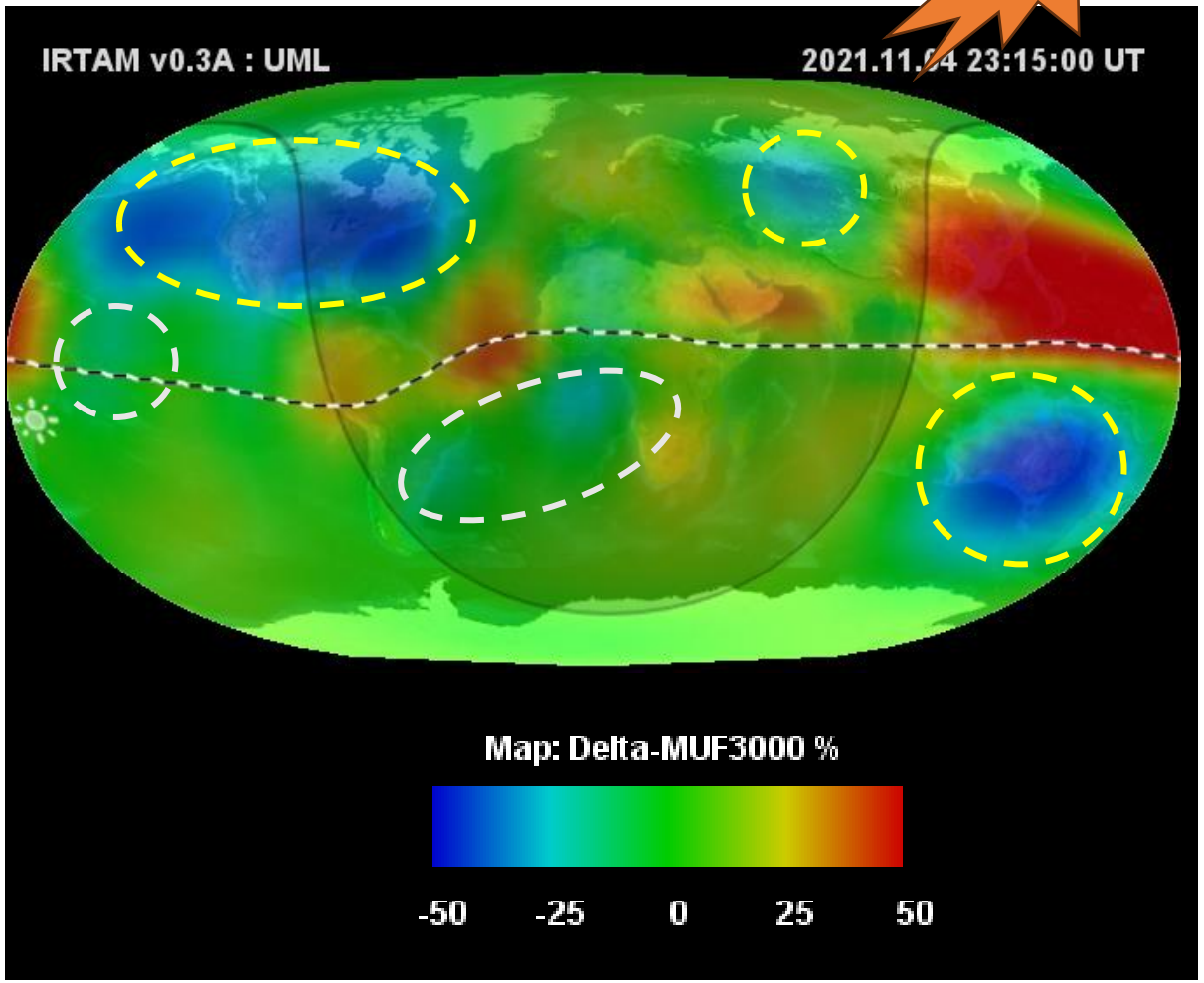
Depressed storm-time MUF

$\Delta\tau$

ΔMUF

No vTEC



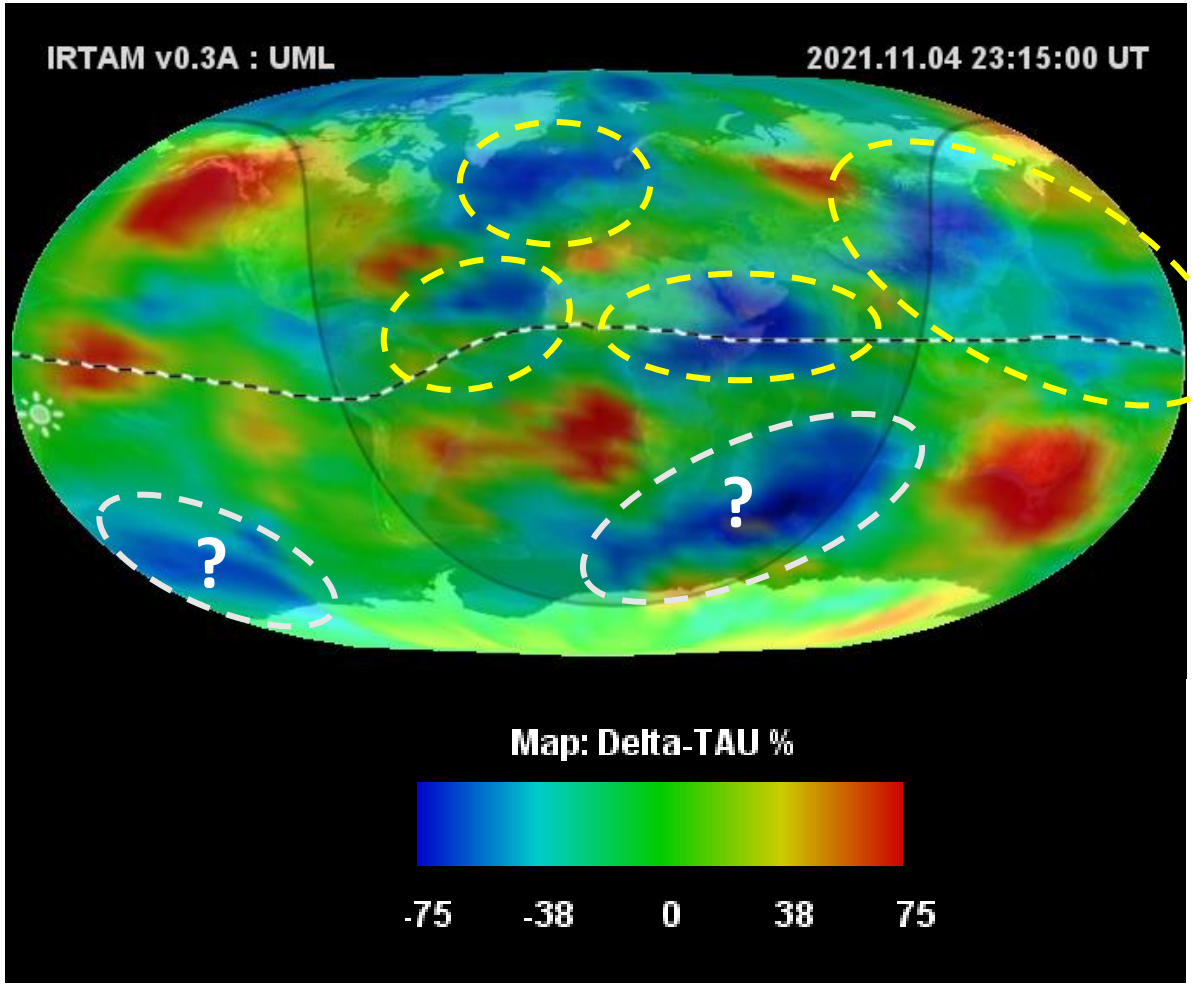


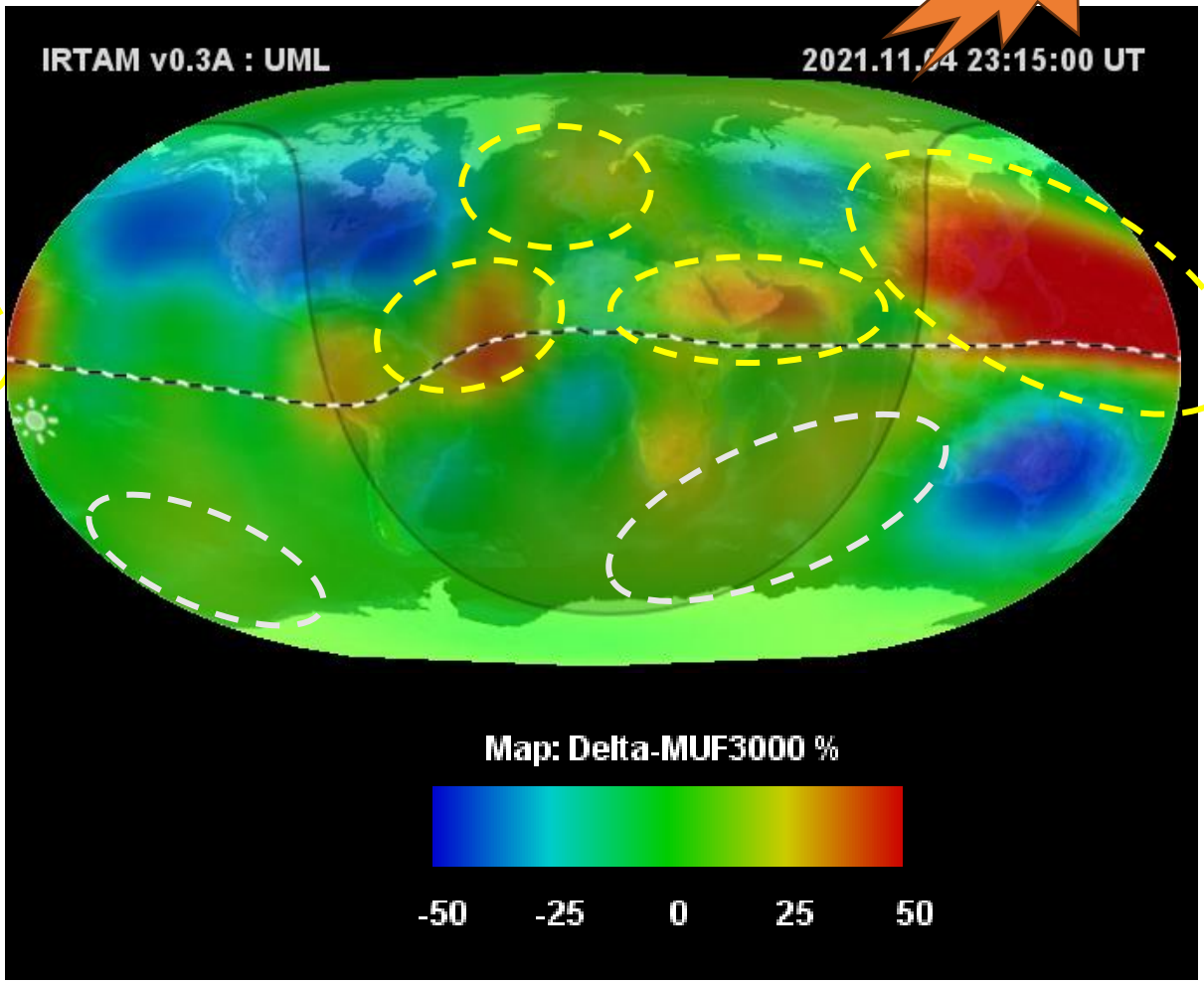
Elevated storm-time MUF

$\Delta\tau$

ΔMUF

No vTEC





Can we use Δτ to suggest MUF anomaly over no-ionosonde areas?

DISPEC Contributions

- Clarify interpretation of τ anomaly maps
  - Use a confidence metric from IRTAM
    - Grey-out data over no-ionosonde-coverage regions
    - Reduce interpolated/extrapolated data outside ionosonde sites
      - IRTAM has proven spatial prediction capability
        - So, study the covariance ellipses in IRTAM to define confidence of τ anomalies
    - MUF(3000) “Data_Confidence” 0..1 flag can be used
  - Study high-value τ cases for potential precision issues
    - small vTEC divided by small NmF2
- Study alternative GIM computation schemes
  - Climatology map
    - Is 28-day average of vTEC optimal?
    - Use 28-day average of NmF2 instead of IRI?
  - Weather and anomaly map
    - CAS, CNES, UPC-IonSAT, WHU, IRTG, JASON3 alternatives

Thank you for your attention!

WEB: https://dispec.eu

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