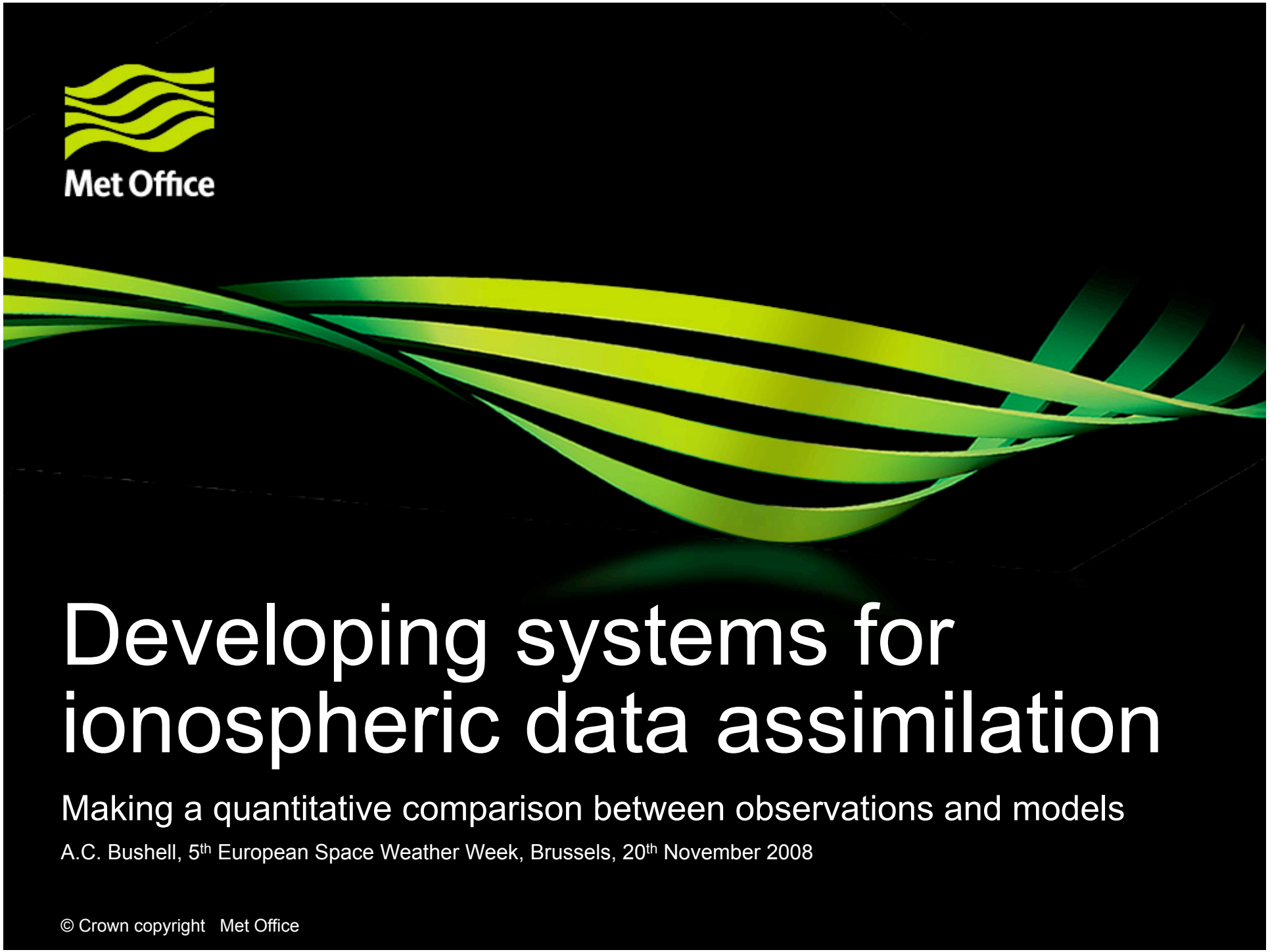


Developing systems for ionospheric data assimilation

Making a quantitative comparison between observations and models

A.C. Bushell, 5th European Space Weather Week, Brussels, 20th November 2008

Collaborators & Contributors

- **Met Office (Data Assimilation Applications)**
  - David Jackson, Camilla Mathison
- **University College London (Atmospheric Physics Laboratory)**
  - Alan Aylward, Tabitha Arnesen
- **Institute of Atmospheric Physics, ASCR, Prague**
  - Jan Lastovicka, Petra Sauli, Josef Boska
- **GEO6 project**
  - FP6 (via **GNSS Supervisory Authority**)
  - Miquel Garcia (**Starlab**) - tomography
  - B.Nava (**Abdul Salam ICTP, Trieste**) - artificial Galileo data.

Contents

This presentation covers the following areas

- Introduction
- GEO6 Project: Ionosphere – Gravity wave detection
- GEO6 Project: Ionosphere – Investigating GNSS ionospheric data assimilation
- Conclusions

Developing operational systems

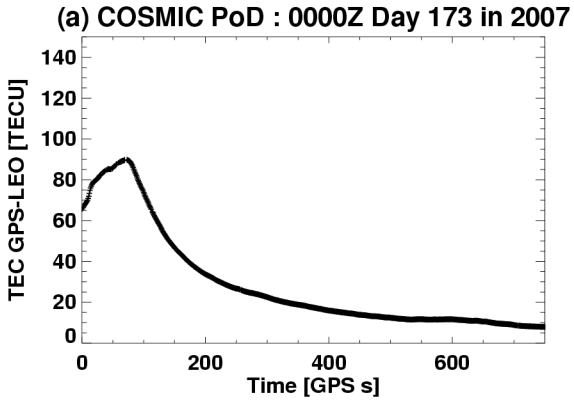
- **Monitoring & forecasting** the **state of the ionosphere** is a significant component for **Space Weather service** provision, a primary activity strand of **Space Situational Awareness**
- **Meteorological services** (e.g. Met Office) could potentially plug a gap in provision of **routine analyses** of the **ionosphere & thermosphere**
- **Operational centres** would require **infrastructure** for:
  - Acquiring observations in reliable and timely manner
  - Processing observations in a data analysis system to produce an analysis state
  - Running forecasts with a physical upper atmosphere model
  - Making output available for downstream products and end-user applications

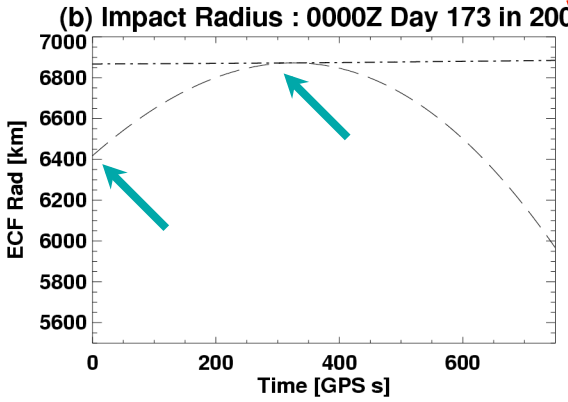
FP6 Project GEO6 (Galileo)

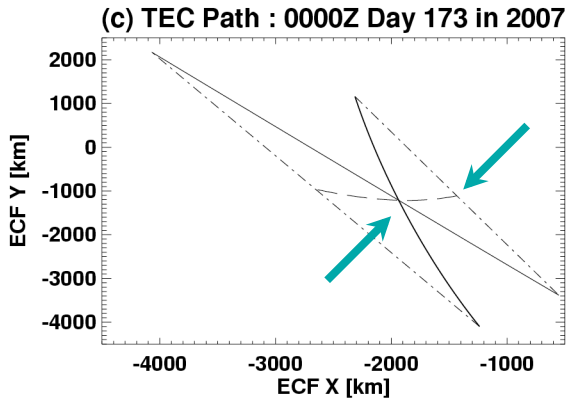
- Sponsored by GNSS Supervisory Authority
- Explore new applications of the Galileo Global Navigation Satellite System for the Scientific User Community
- Priority Application 2 – Ionosphere
  - Exploitation of GNSS Radio Occultation data
  - Gravity Wave Detection
  - Investigating GNSS Ionospheric Data Assimilation
- Expect publication in near future.

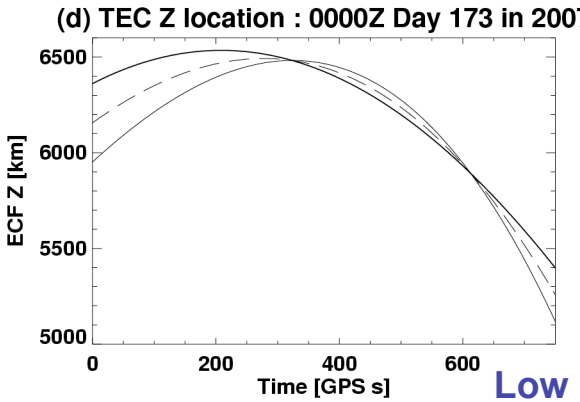
GEO6 Observations: GPS Radio Occultation

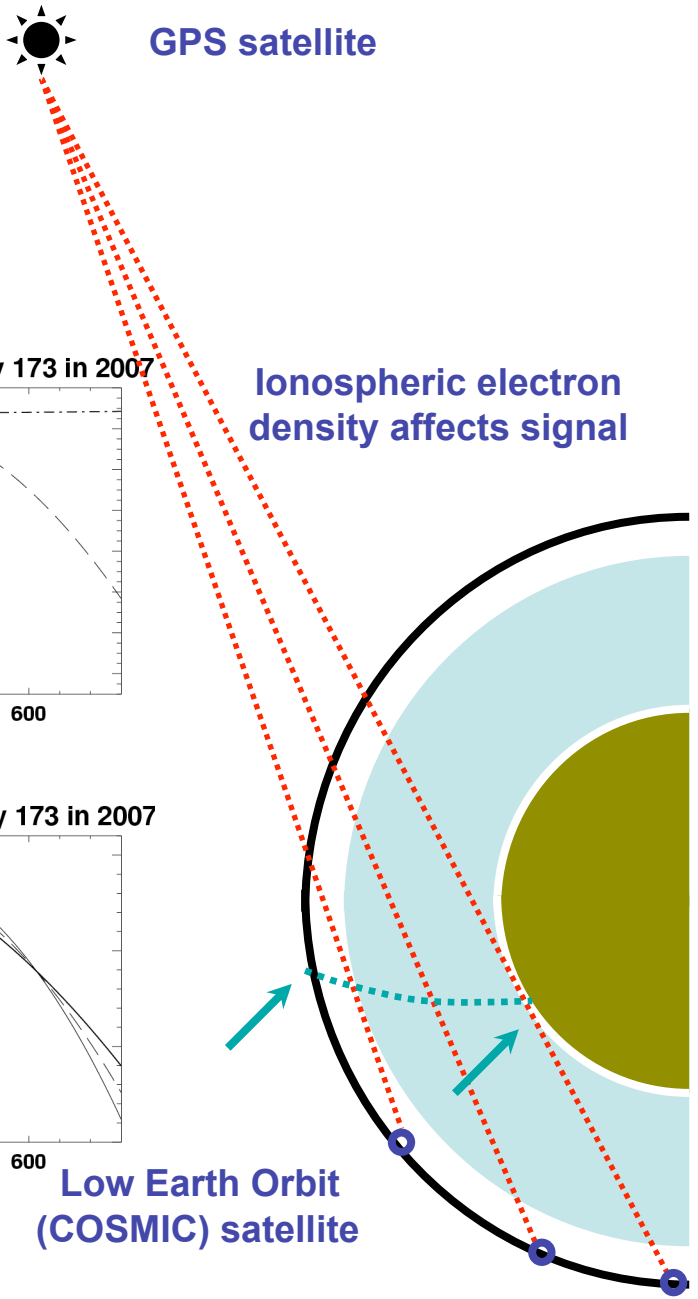
Constellation Observing System for Meteorology, Ionosphere, Climate



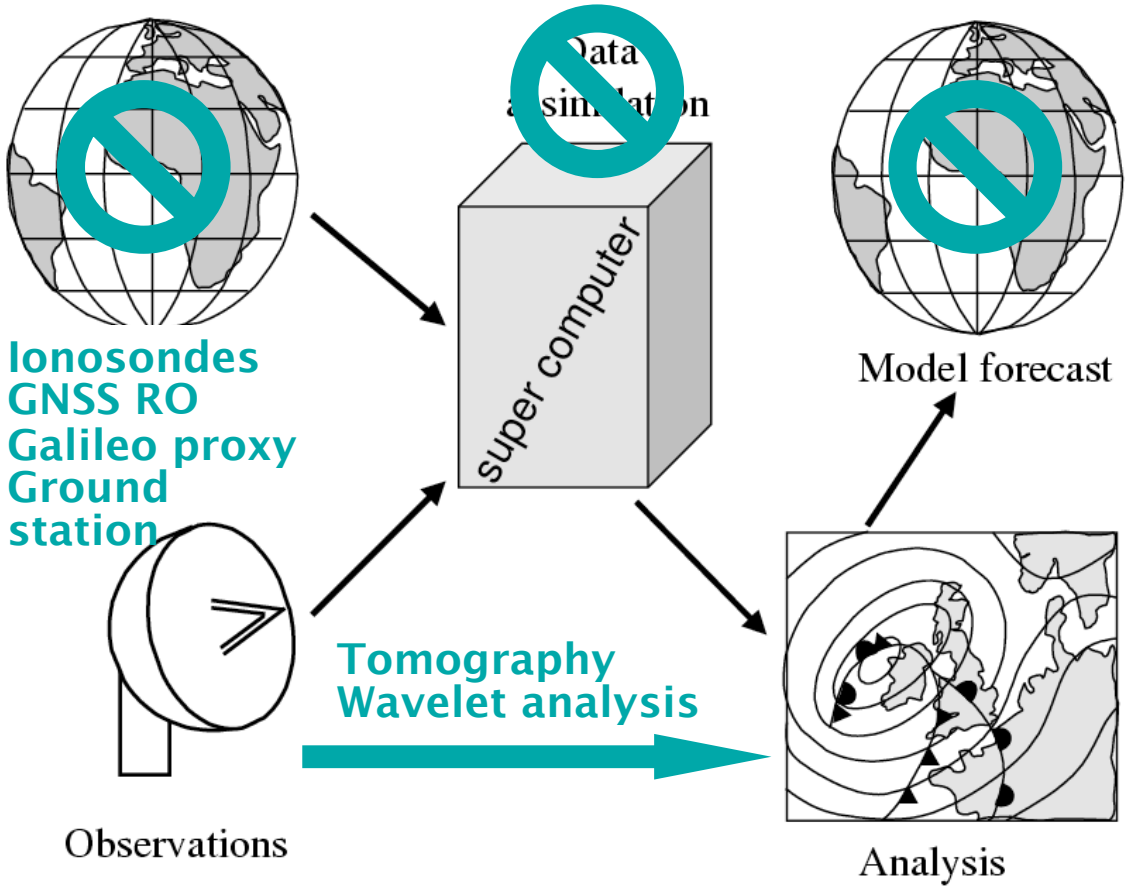








Components of a data assimilation & forecast system (GEO6 Gravity wave detection)



Gravity Wave Detection

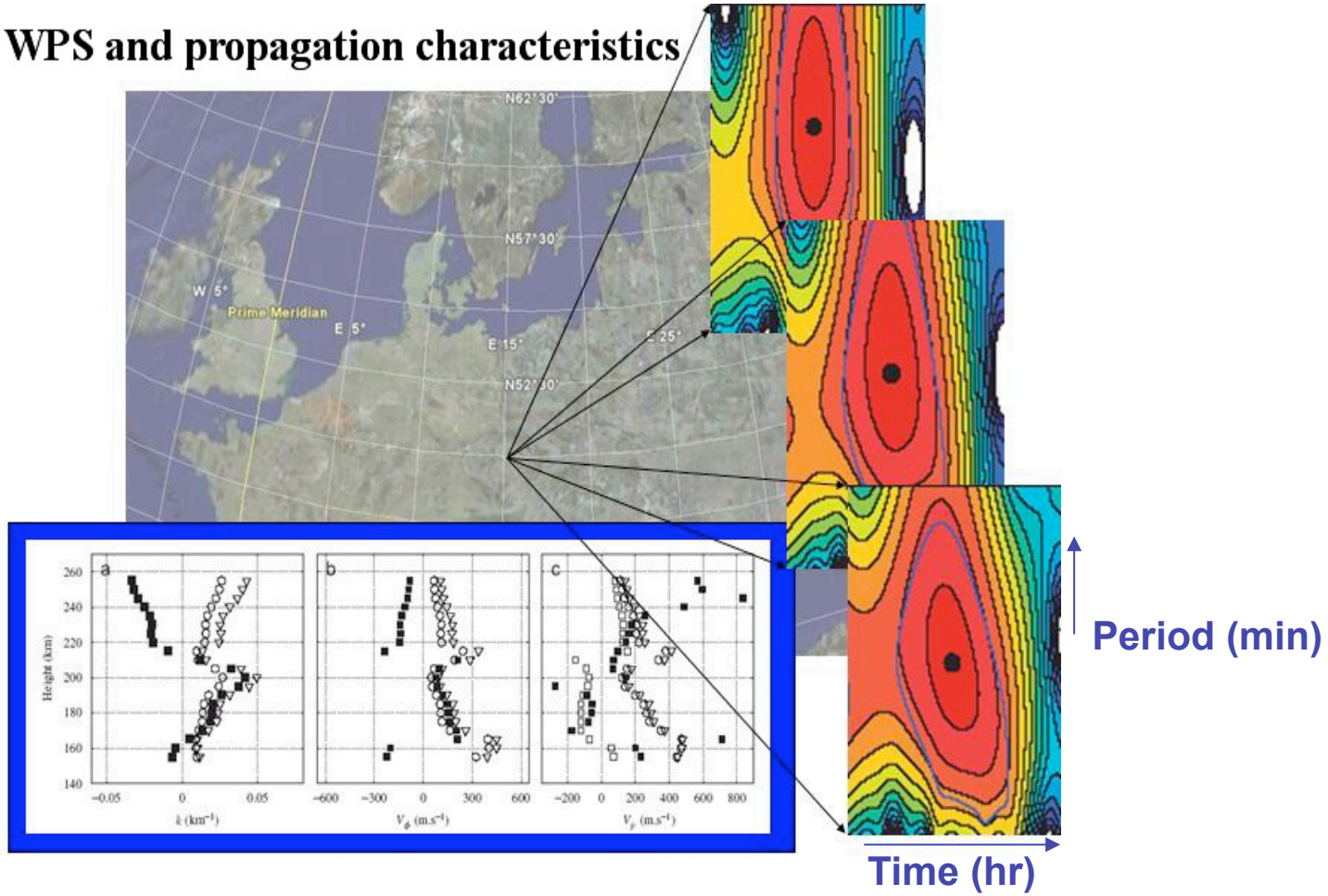


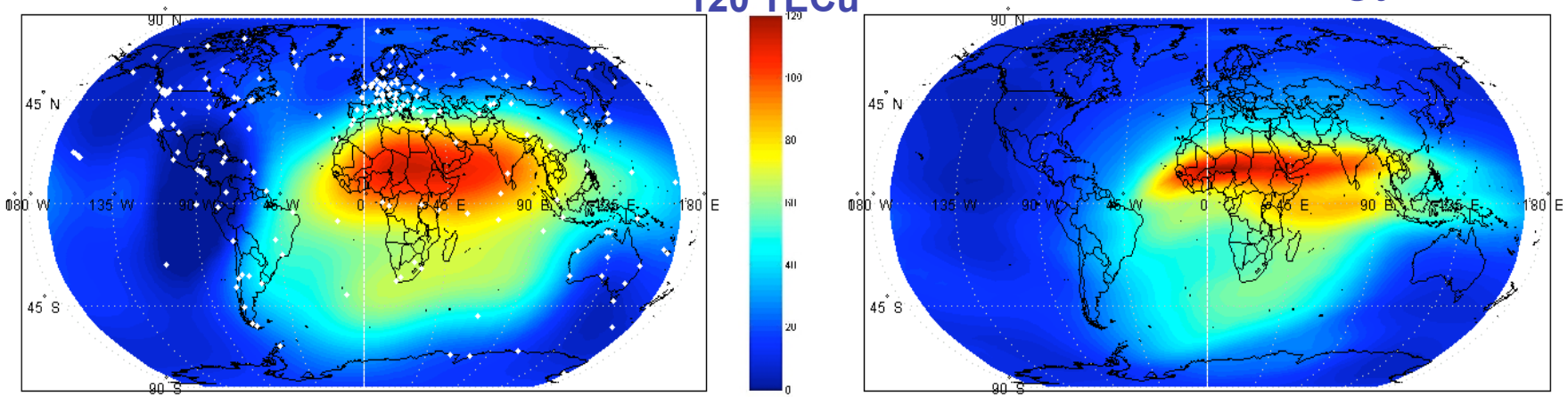
Fig. 1. Example output of the 3-D computer code/toolbox calculations. Coloured figures – results of wavelet analysis for different heights of one event Black-and-white panels – vertical profile of wave number, phase speed, packet (group) speed of three different gravity waves.

Tomography – new approach H-representation

Recovered TEC

120 TECu

PIM climatology



n=8 ca 22° horizontal, 100km vertical

Fig. 2. (Left) Recovered TEC with n=8 (204 coefficients, a=20), using ground data (IGS stations appear as white dots) and all LEO data (over 10,000 measurements). (Right) Ionosphere modelled with PIM.

Polar orbital ring – penalizing high-n spherical harmonics

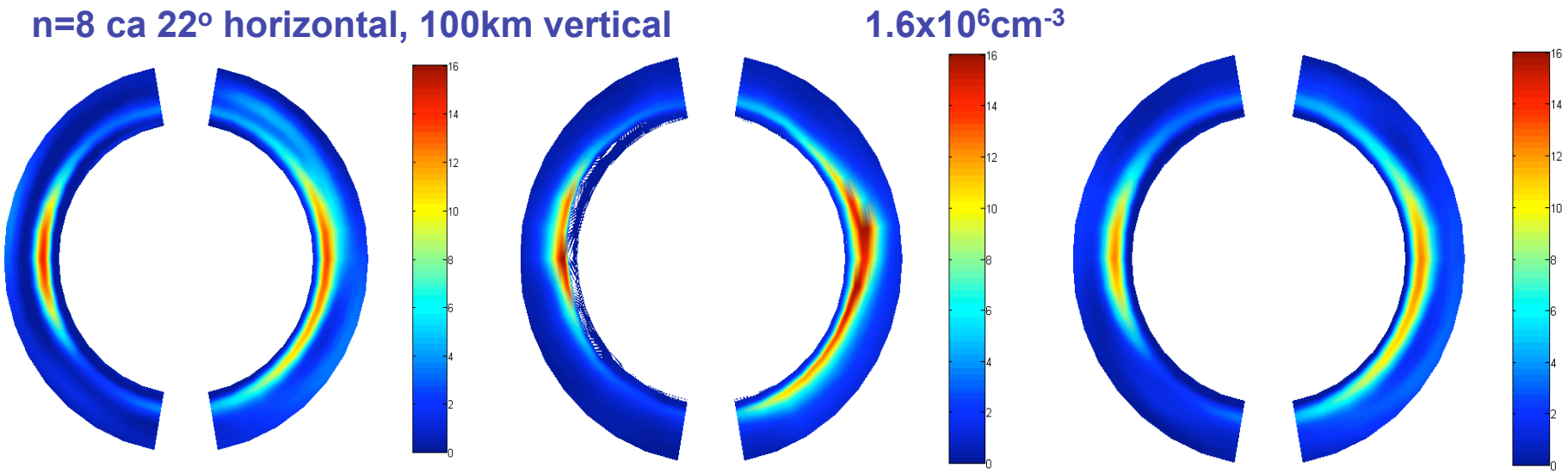
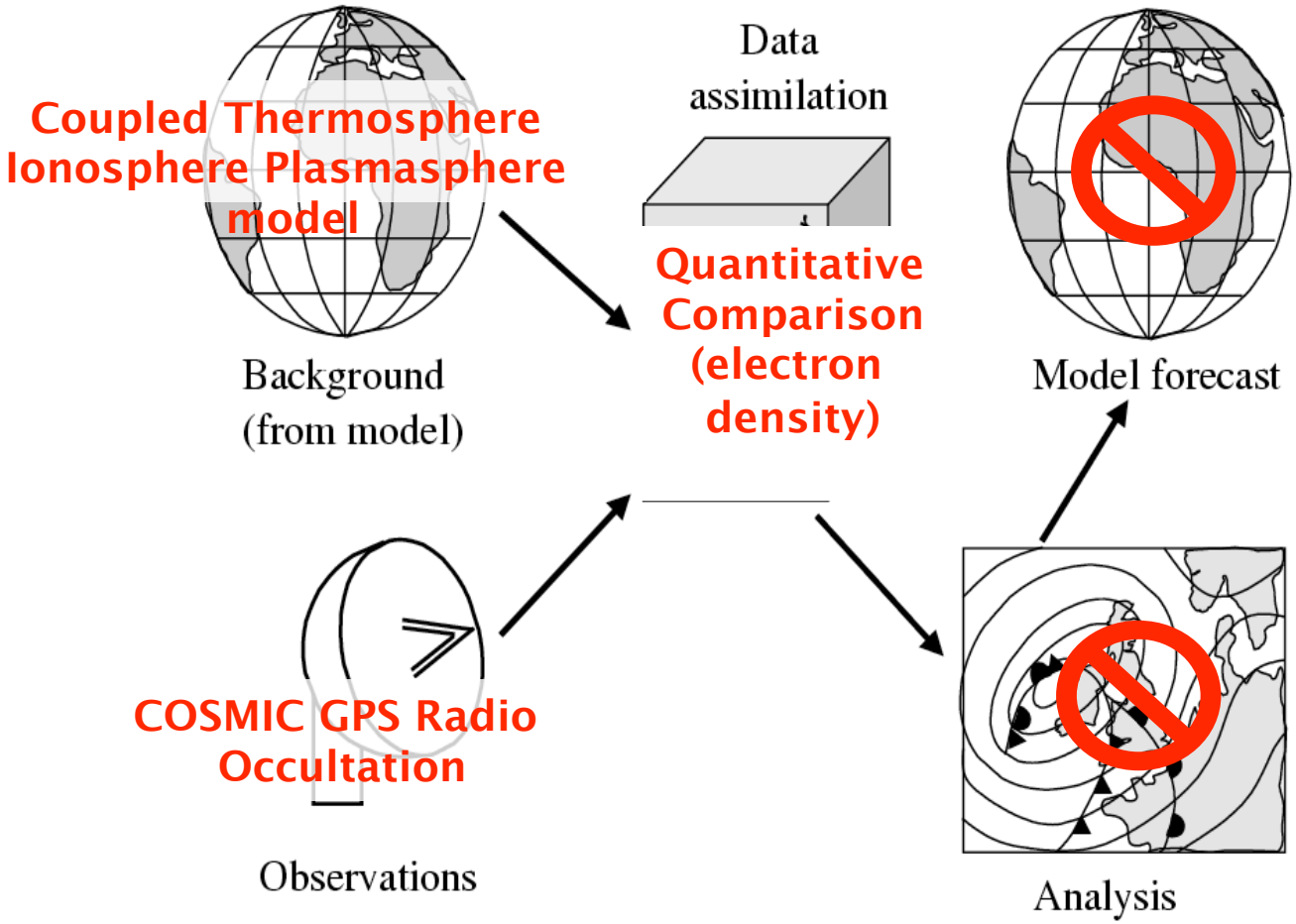


Fig. 3. Solution with an H-representation of order n=8 (204 unknowns, a=10 km) with GNSS-R data (left), reference truth (middle) and with a *n*-constraint (of $\lambda[n^2]$ type) (right). No ground data has been used. Altitude spans from 0 to 1,000 km of altitude. Units are 10^{11} electrons/m^3.

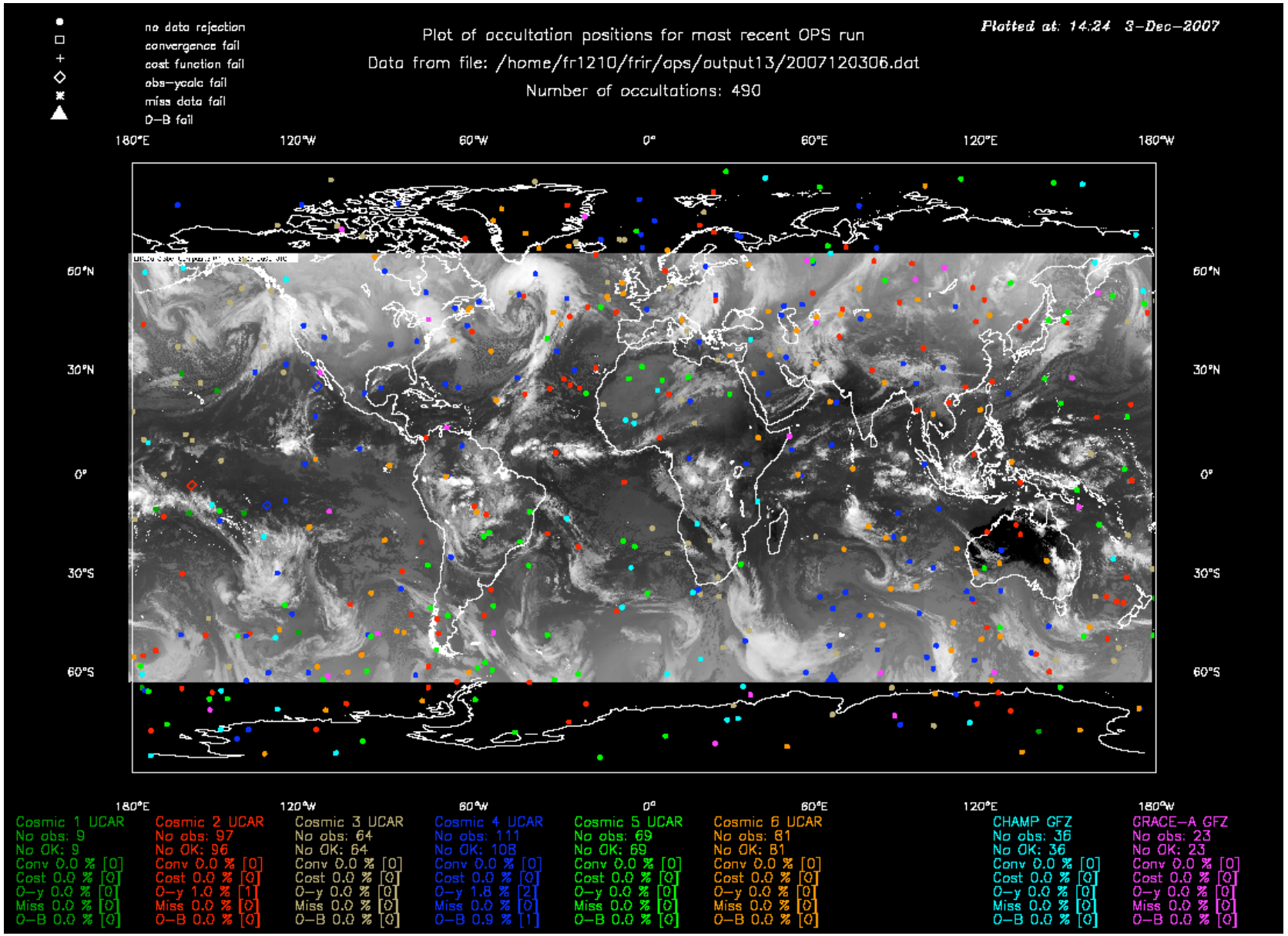
GWD Conclusions

- Simulated Galileo electron density profiles & ionosonde data for pronounced GW events produced
- 2-D AGW toolbox publicised at http://www.ufa.cas.cz/html/climaero/sauli.html
- H-representation tomography would allow detection of medium-scale Travelling Ionospheric Disturbances
- Need higher spatio-temporal coverage to obtain smaller scale GWs or acoustic waves with periods O(minutes) using 3-D toolbox. Galileo data should make procedure viable.

Components of a data assimilation & forecast system (Investigating GNSS Ionospheric DA)

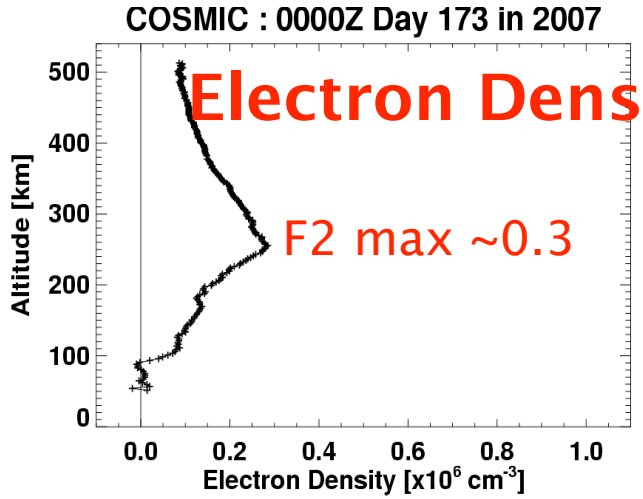


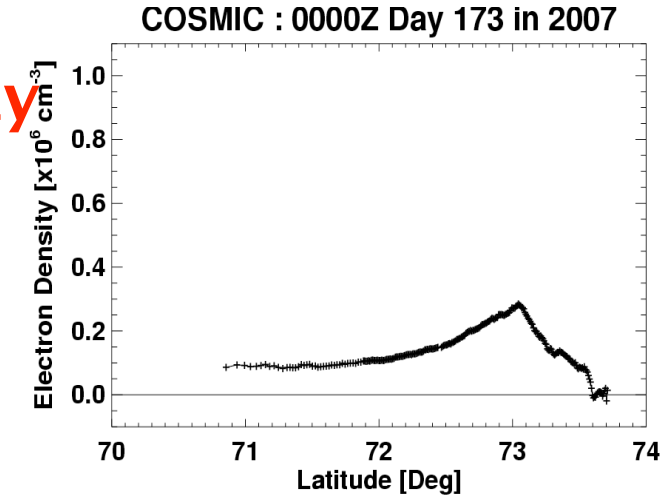
6-hr Operational GPS-RO (M.Rennie)

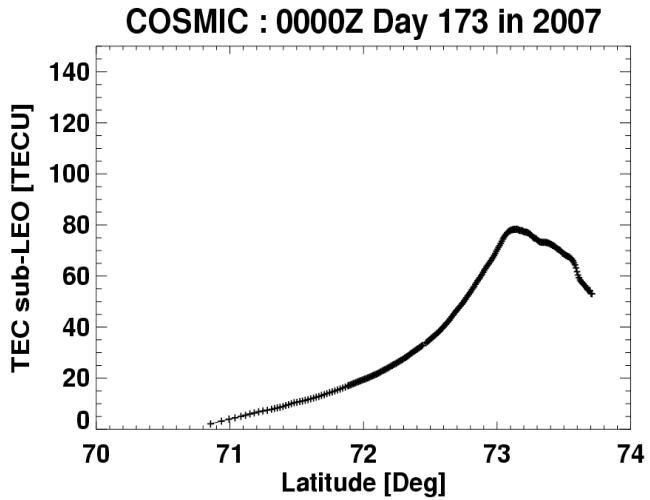


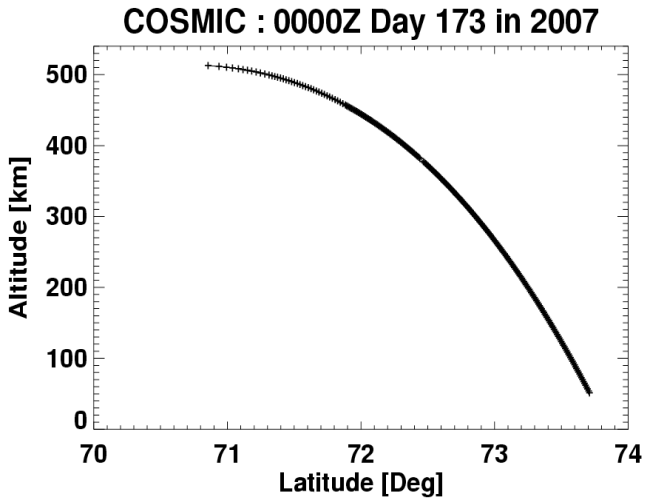
GEO6 Observations: Results

Source: COSMIC Data Analysis & Archival Center (CDAAC)





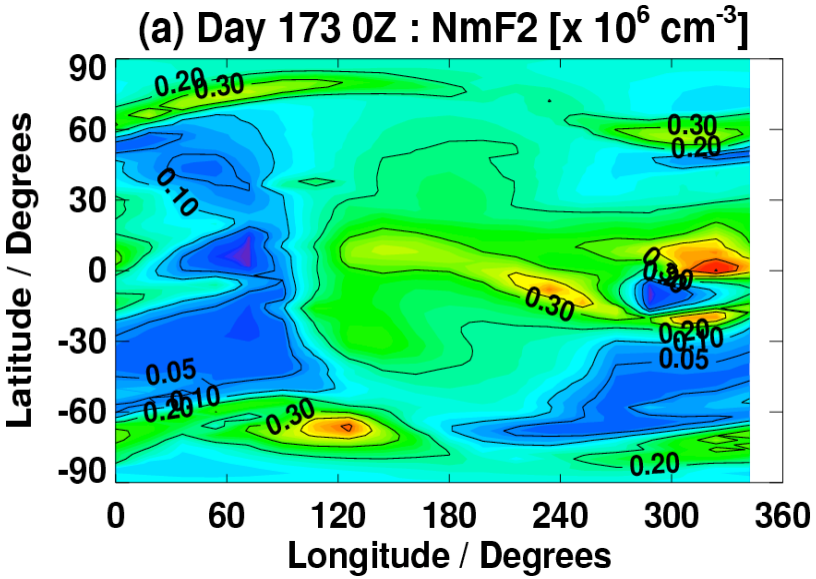




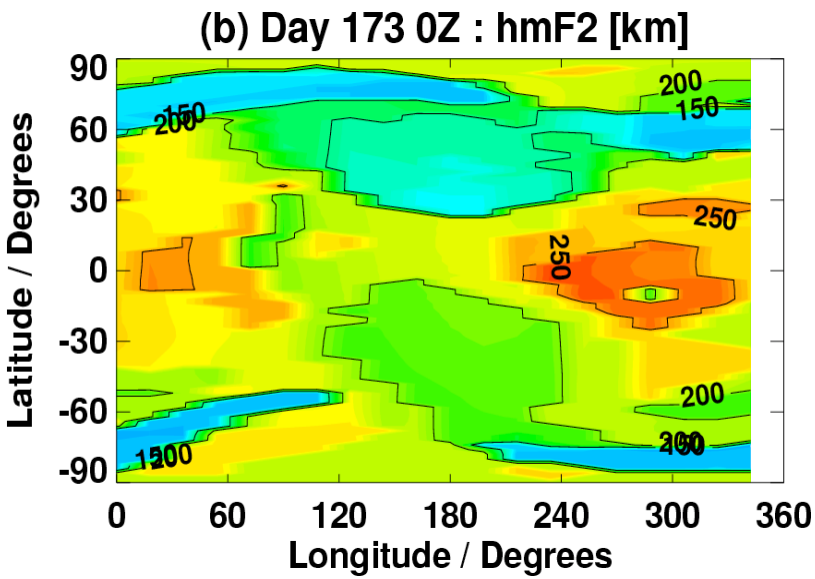
GEO6 Models: Solar Min Experiment

Met Office

Value of maximum electron density



Height of maximum electron density

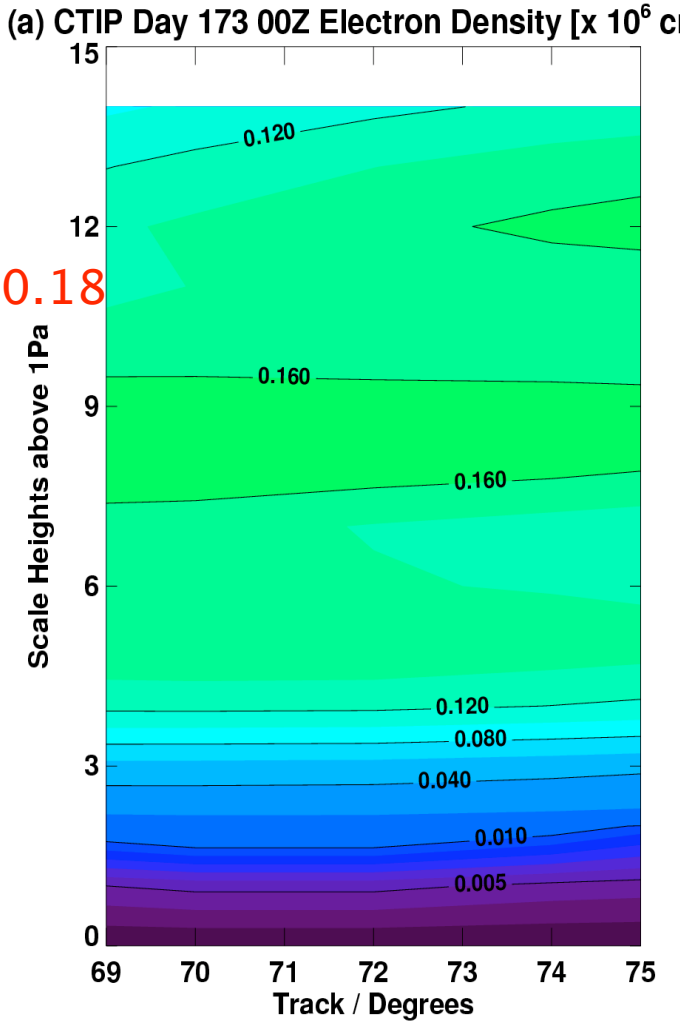


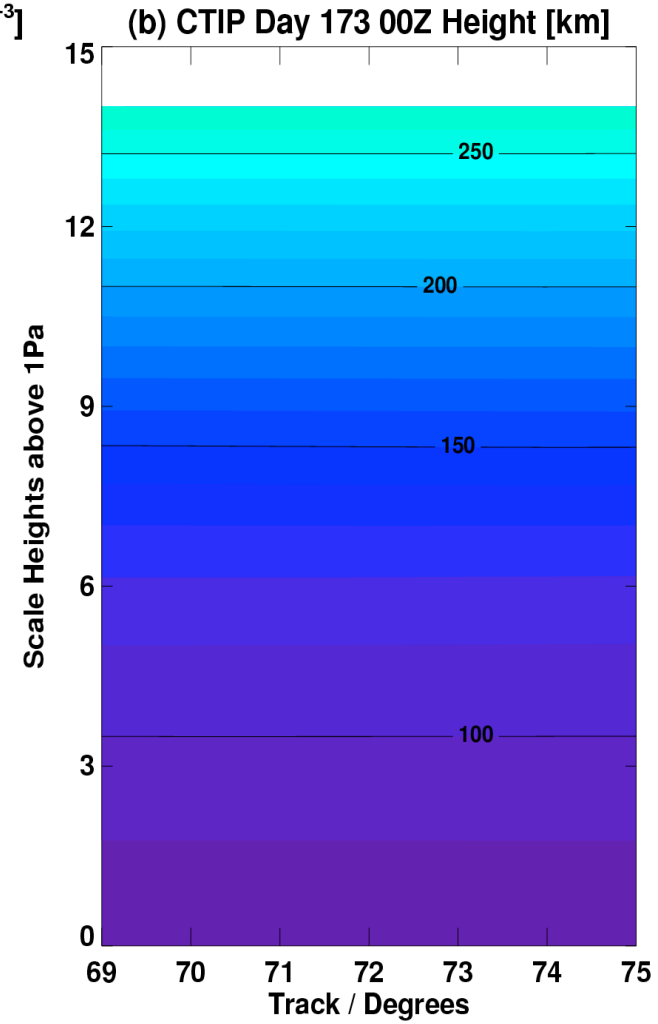
CTIP model

- Global Thermosphere (geographic)
- 18º x 2.5º
- Flux tubes (geomagnetic grid)
- 1min timestep
- June 2007 Solstice case

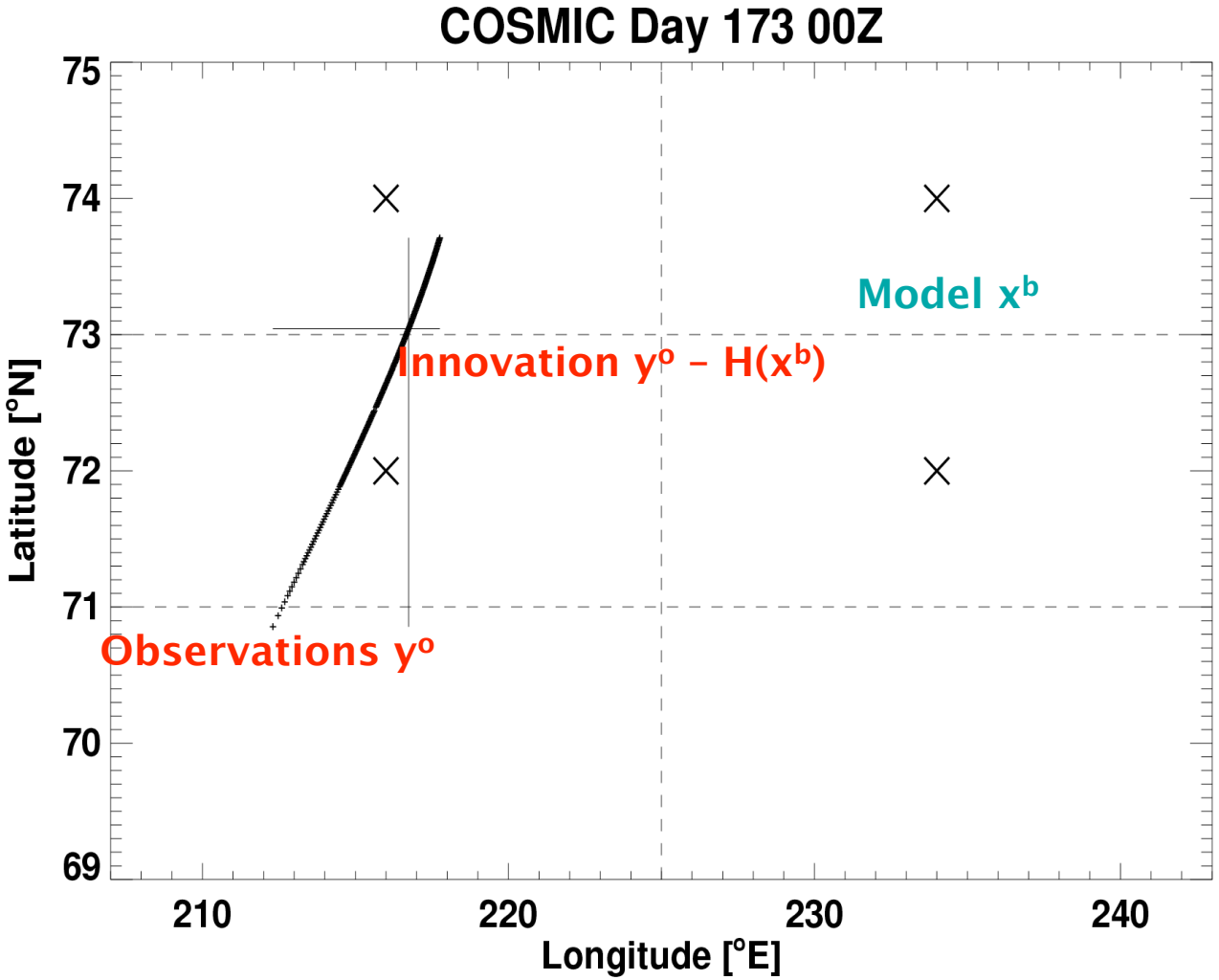
GEO6 Models: Results

F2 max ~0.18

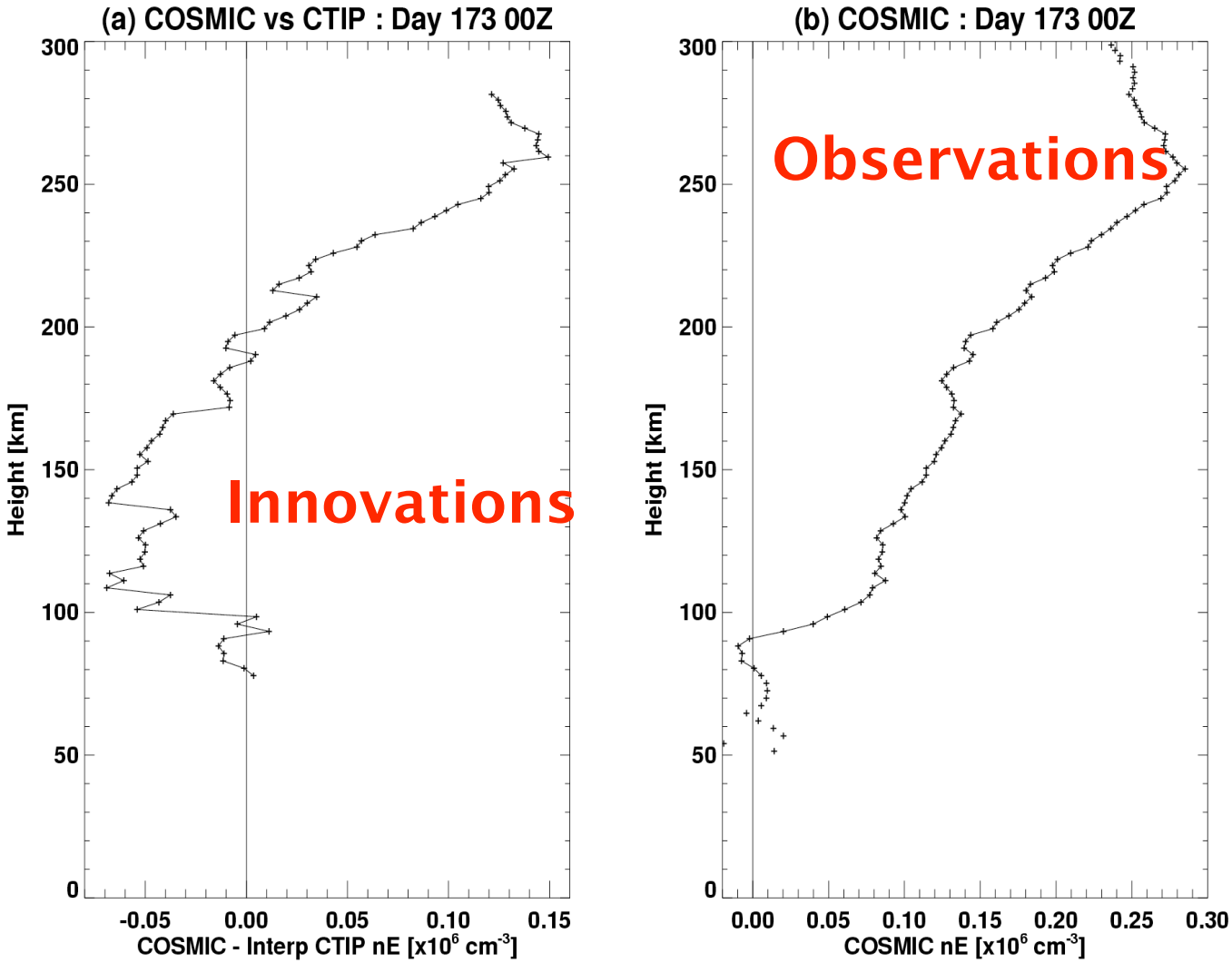




GEO6 Comparison: Matching



GEO6 Comparison: Results



Categorized options for future activities

- Obtaining observations
- Upper atmosphere model experimentation
- External drivers and coupling
- Quantitative comparison
- Developing an observation operator
- Data assimilation

GEO6 Recommendations

- “GSA consider the advantages of funding activity to catalyse development of operational ionospheric data assimilation systems … and, if appropriate, take steps to enable FP7 support for such activity.”
- In the absence of a “system in place to exploit Galileo-derived RO data on the ionosphere” , recommend that GSA address this “by undertaking or sponsoring some exploration of the possible systems via which ionospheric RO data might be provided to the scientific UC.”

Questions and answers