On the Importance of Radio Occultation data for Ionosphere Modeling

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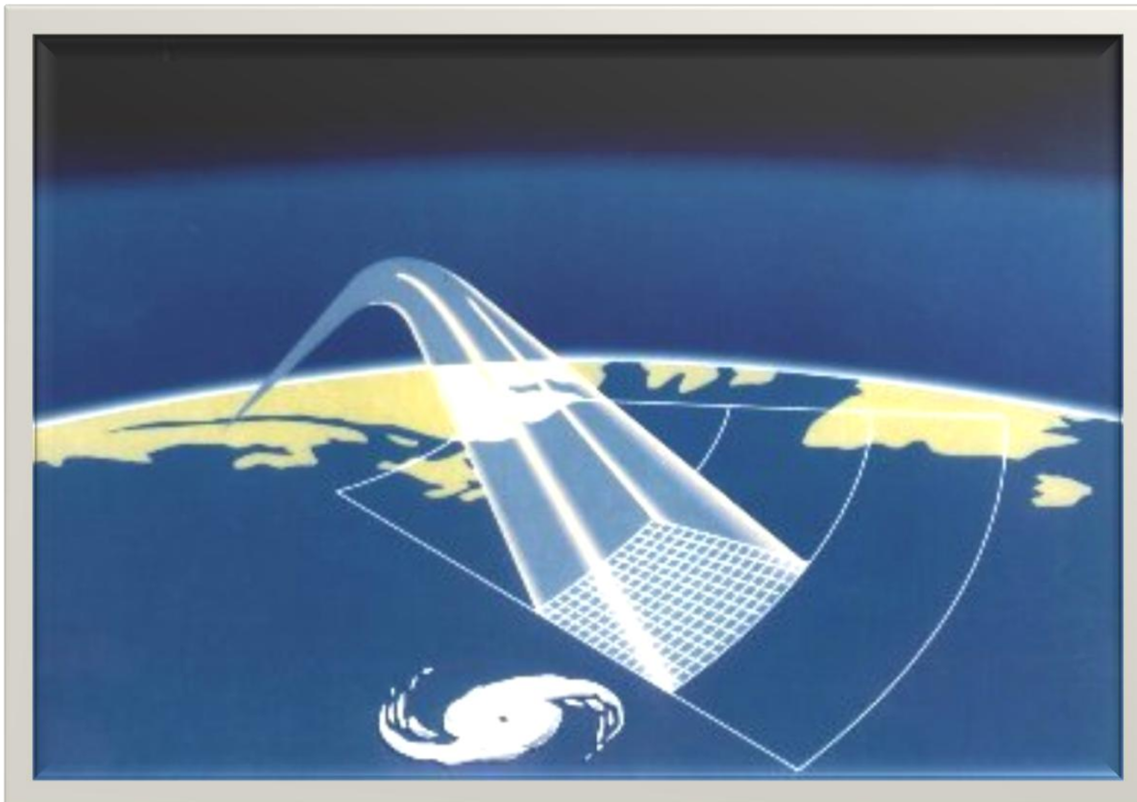
ABSTRACT

The availability of unprecedented amounts of Global Navigation Satellite Systems (GNSS) ground receiver data over the last decade has been driving a new wave of ionosphere research. Data of unprecedented time and spatial resolution have contributed to a renaissance of ionosphere science and have open new ways of specifying and forecasting the state of the ionosphere. Global ionosphere monitoring and forecasting schemes are already emerging on operational stages. However, ground GNSS data alone do not contain enough information about the vertical distribution of electron density and must be supplemented by other measurements. Ionosonds provide vertical electron density profiles but only below the F2 peak and at much lower spatial resolution. The best complement to global ground GNSS measurements is provided by GNSS Radio Occultations from a Low Earth Orbit (LEO). Ground based together with Occultation GNSS measurements and the present ionosonde network can form a necessary and sufficient set of observations to constrain physics based models used in data assimilation schemes. LEO measurements of GNSS signals can also offer a way toward specification and possibly short term prediction of ionosphere irregularities and scintillation. In this paper measurement requirements in terms of cadence, spatial resolution, and latency for Radio Occultation will be discussed. Possible tradeoffs between quality and quantity of data and the background models used in data assimilation schemes and scintillation products will be mentioned.

OUTLINE

- Motivation
- The System
- The Problem
- The Solution
- Data Needs
- Conclusions

Why the ionosphere?



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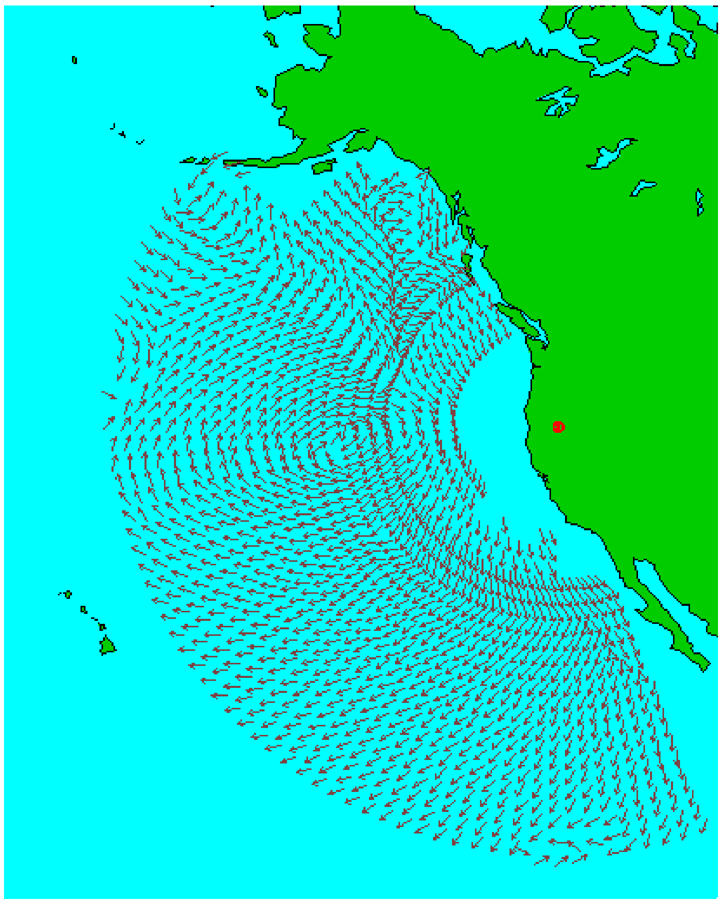
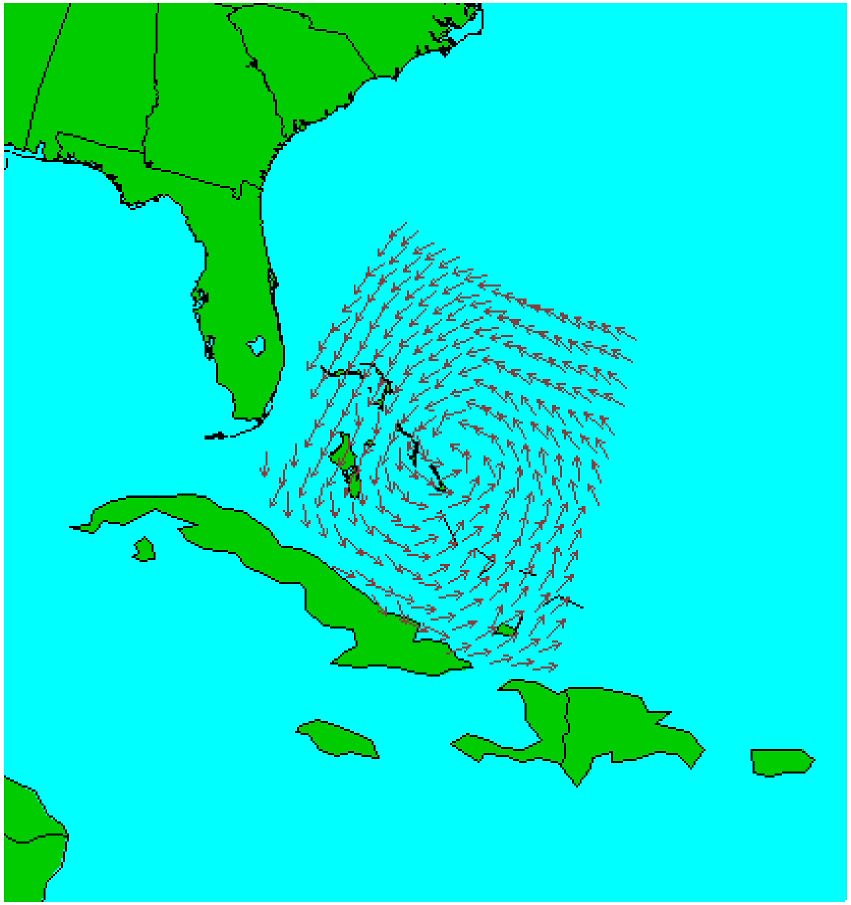
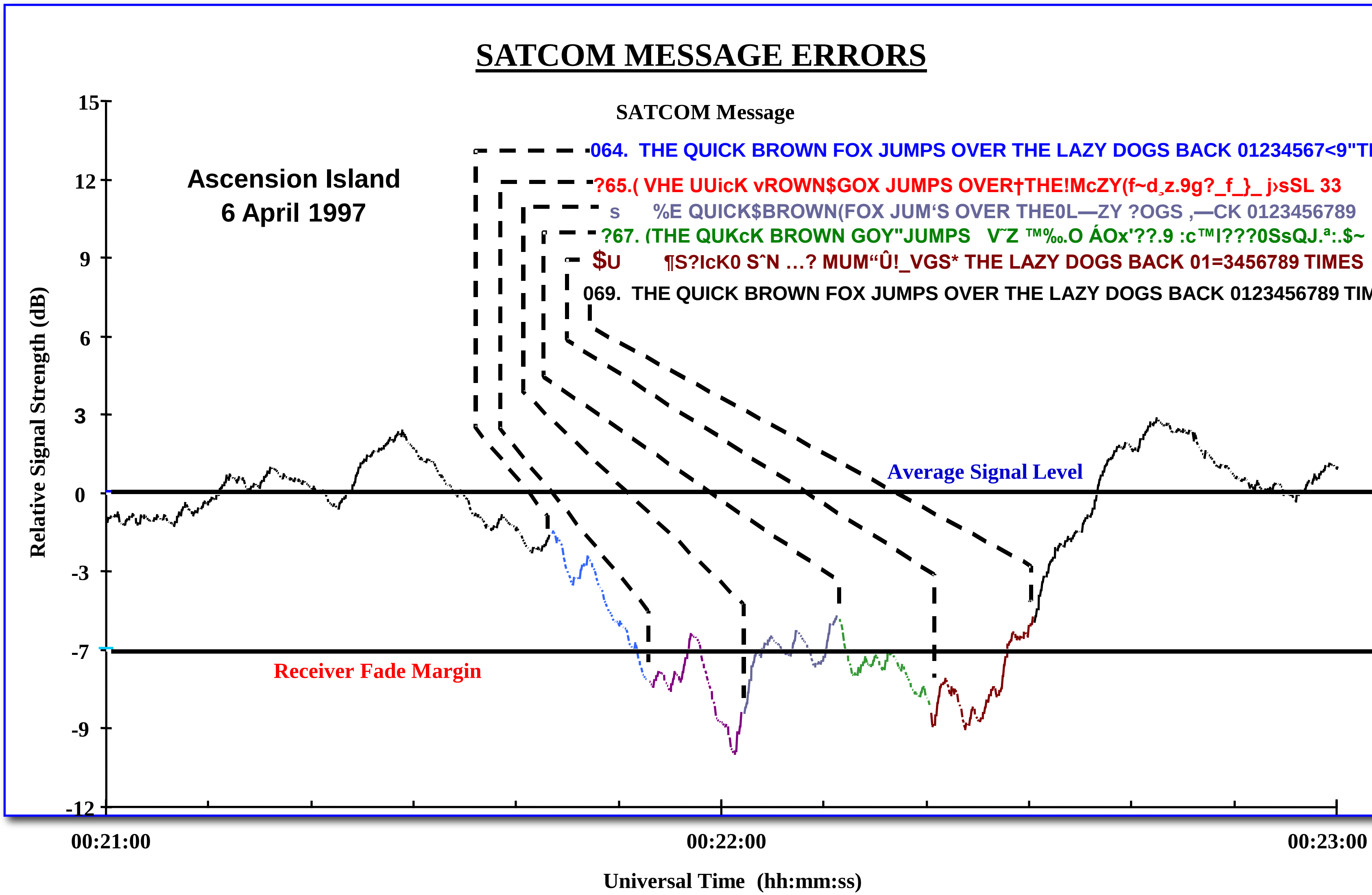
Would it be nice?



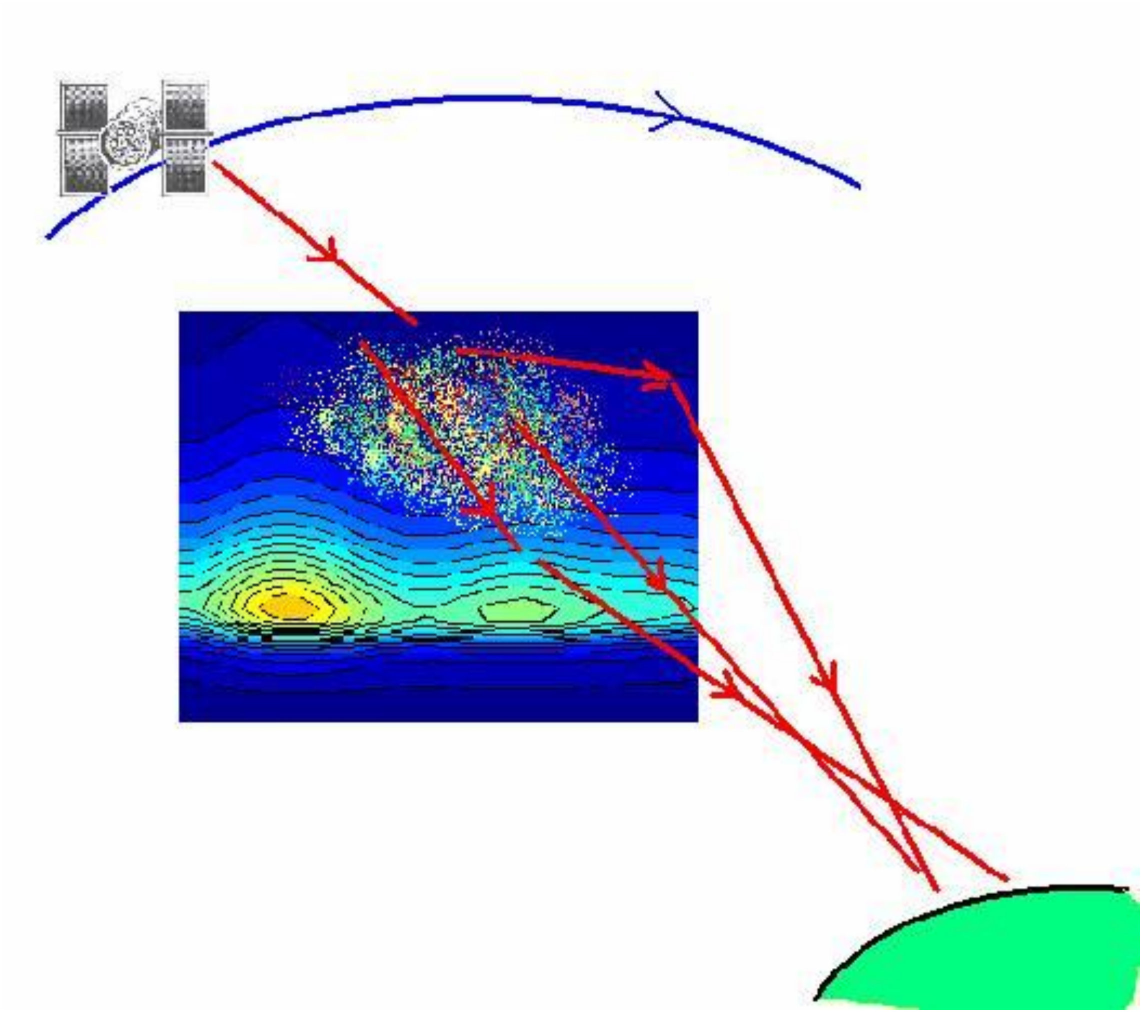


ACTUAL SATCOM MESSAGES



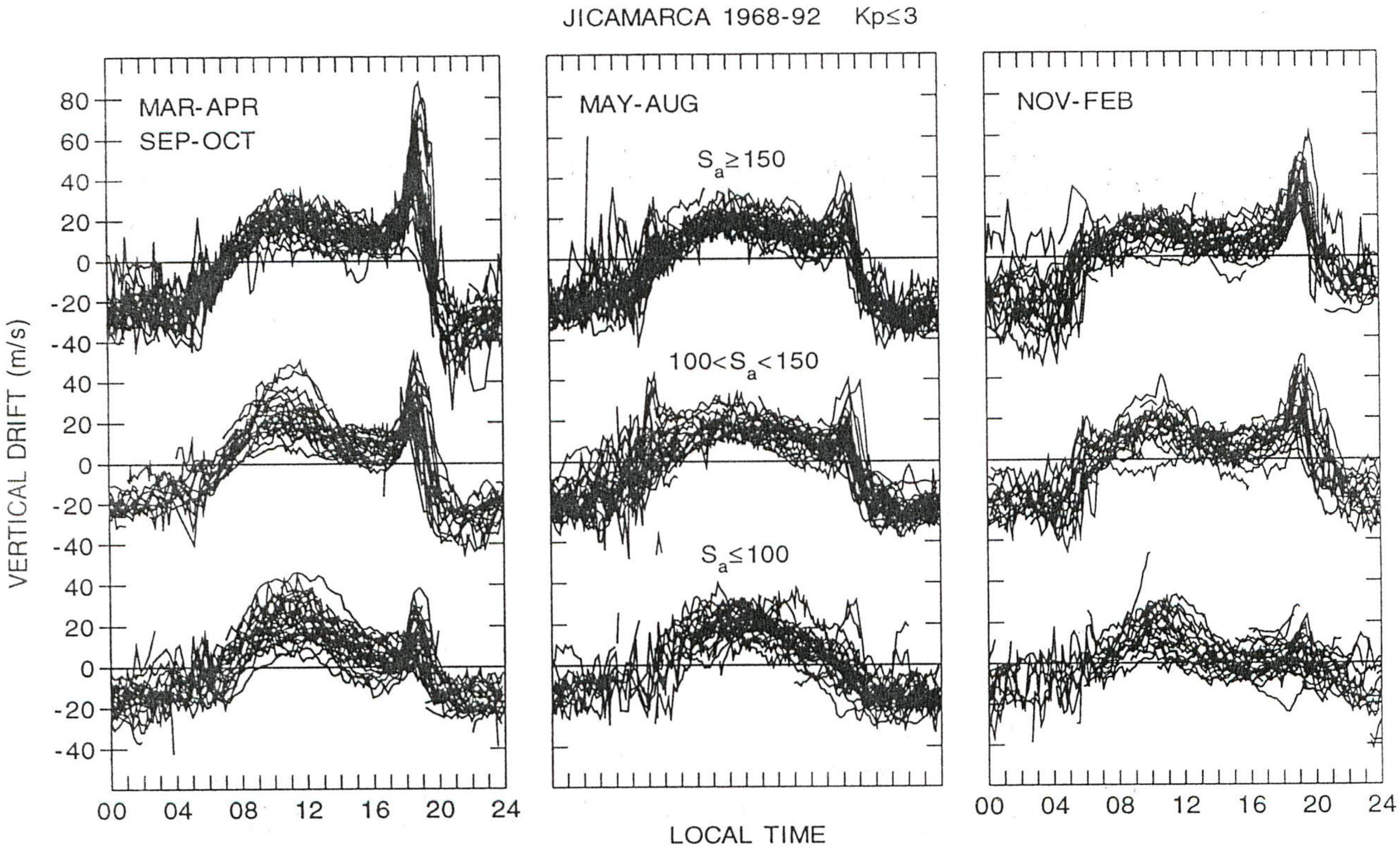
S. Basu, private communication

Scintillation



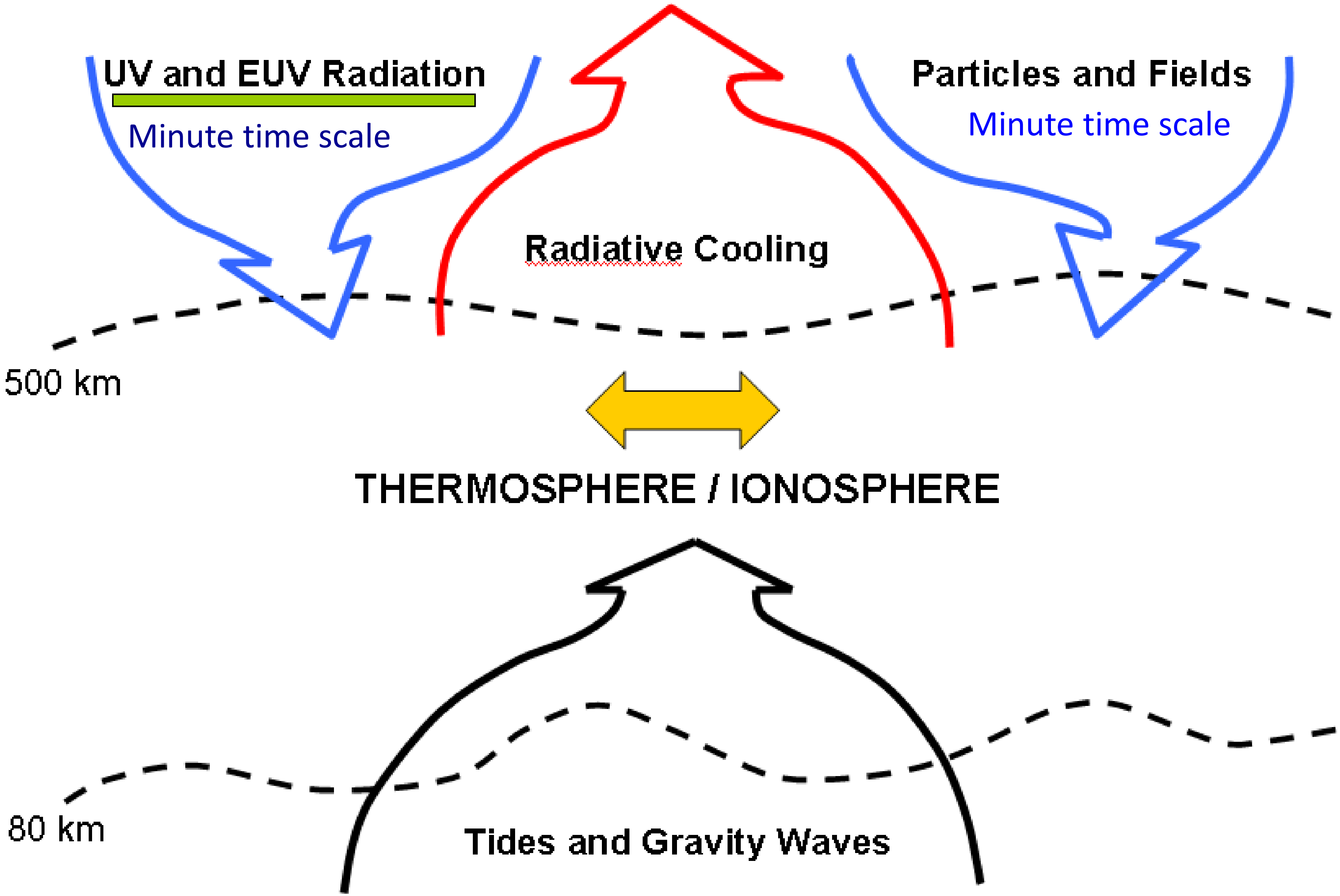
http://roma2.rm.ingv.it/en/themes/11/ionospheric_scintillation

Large Variability



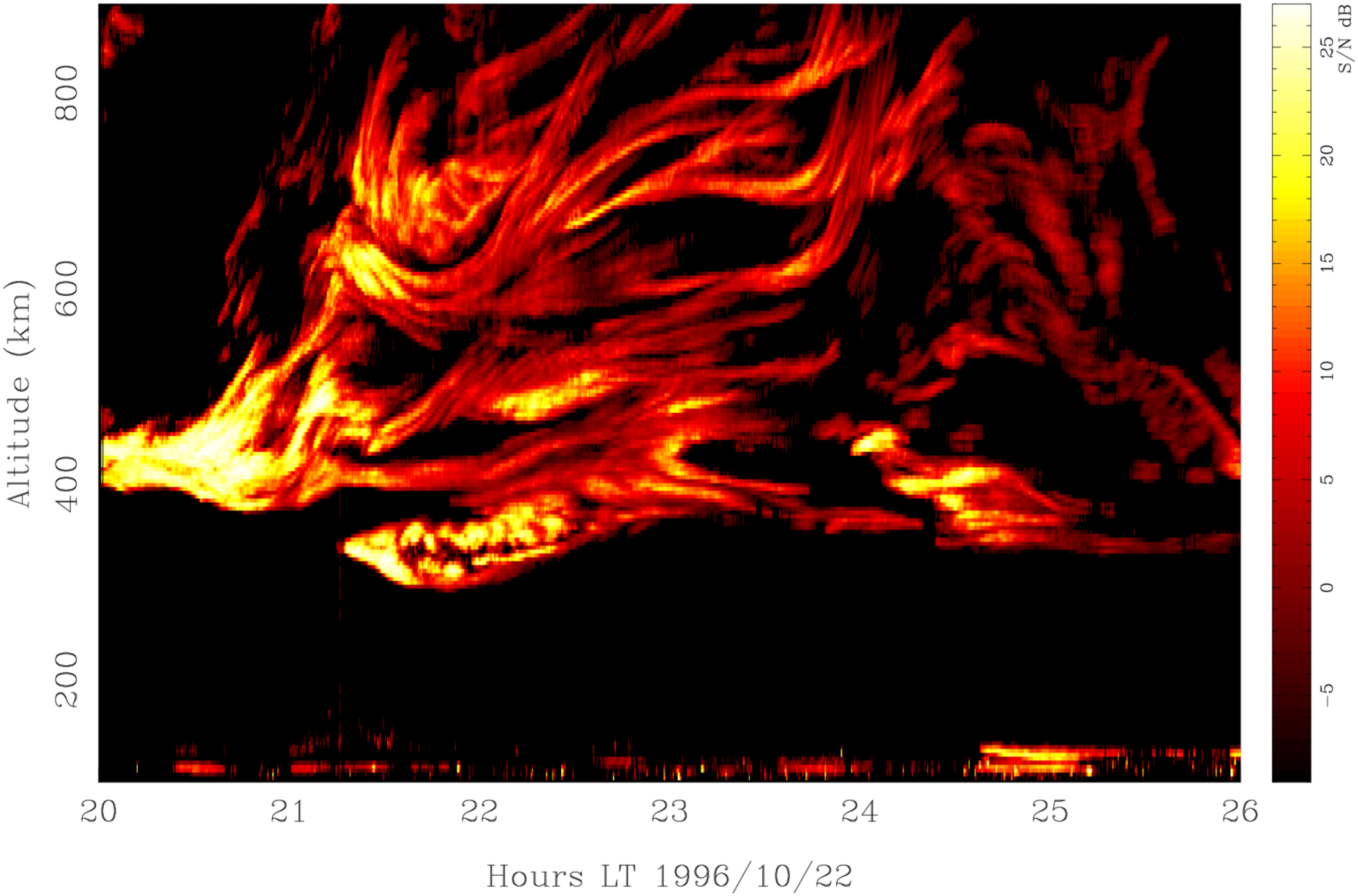
Fejer and Scherliess, 2001

THE SYSTEM



UV and EUV Radiation
Minute time scale
Particles and Fields
Minute time scale
Radiative Cooling
500 km
THERMOSPHERE / IONOSPHERE
80 km
Tides and Gravity Waves

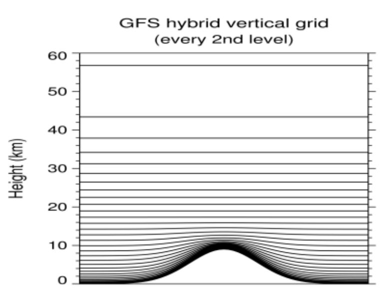
Many low and mid latitude ionospheric structures are driven from below



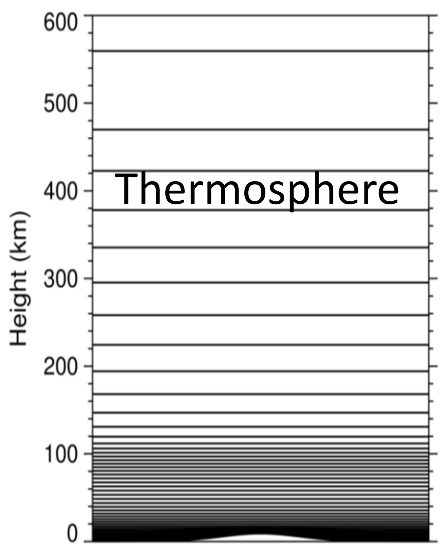
JULIA radar observations (Hysell & Burcham, 1998)

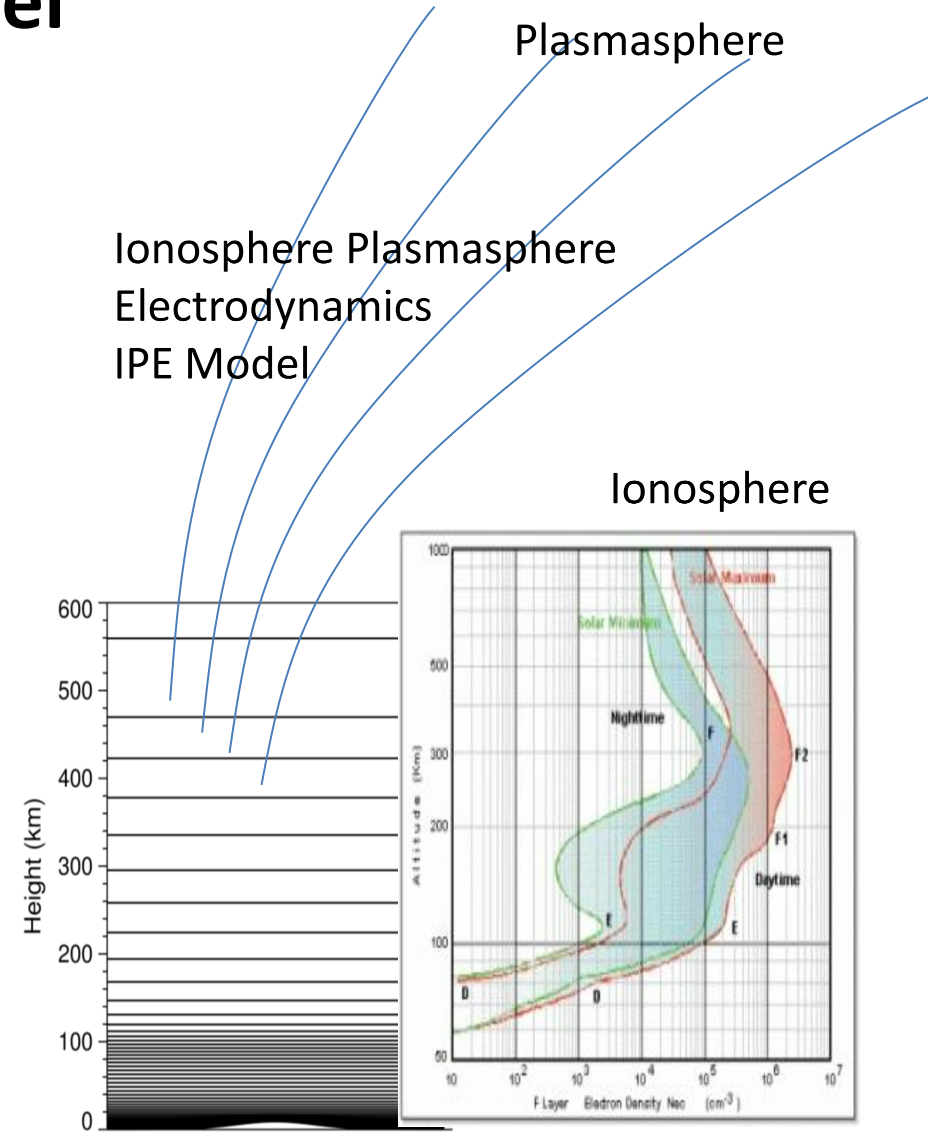
Need to Couple "Whole Atmosphere Model" to "Ionosphere Plasmasphere Electrodynamics" Model

GFS
(Global Forecast Systems)
Weather forecast model
0 – 60 km



Whole Atmosphere Model
WAM = Extended GFS
0 – 600 km





The IonoThermo Problem

- Uncertainties in energy inputs and sinks result in uncertainties in global temperature, circulation, and neutral composition.
- Neutral changes affect production, loss and transport of ionization and have dramatic effects on global electron density and TEC structure.
- Variability makes it difficult to reduce the uncertainties

=> We can model generic storms but not specific ones

Several solutions

The Solution

Combine model and data: Data Assimilation

Challenges

Choose the appropriate assimilation scheme for a strongly forced system

Find the best model representation for state evolution in time

Secure the necessary measurements

- latency
- spatial coverage
- known statistical characteristics

Spatial Coverage

Ground-based GPS data provide accurate information about the horizontal electron density distribution, but limited information about its vertical structure.

On the other hand, radio occultation data obtained from the low-Earth orbit (LEO) satellites equipped with GPS receivers contain high-resolution information about the vertical structure and entangled information about the horizontal distribution of the electron density.

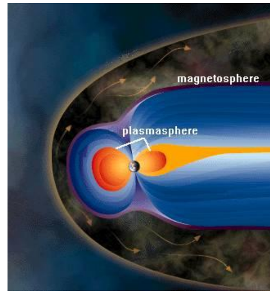
Combining the two data sources provides the best combination of data for improving the ionosphere specification and opens the way for global ionosphere forecasting, including scintillation prediction.

Fully Coupled System

(Five Years Away)

Data

Solar Wind Conditions →



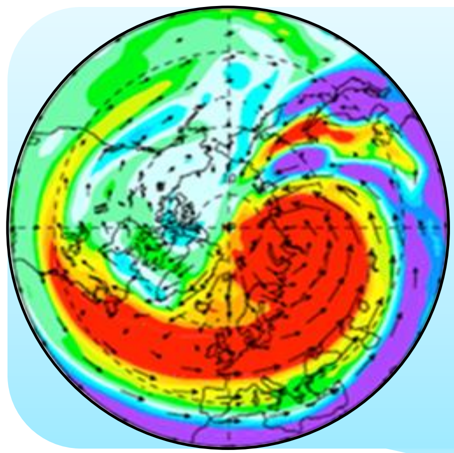
Magnetosphere Models

- **Convection electric fields**
- **Auroral precipitation**

Solar EUV →

Assimilated Data

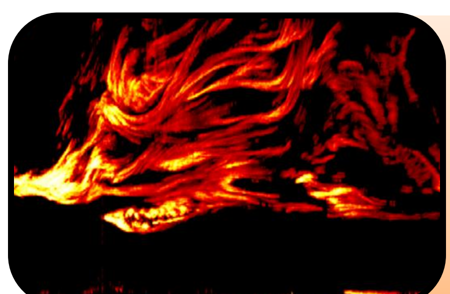
- Ground GPS →
- Space-based GPS →
- Magnetometers →
- Ionosondes →
- Satellite Drag →



IDEA

WAM+IPE

- **Large-scale dynamics**
- **Wave seeding**
- **Plasma densities**
- **Electric fields**
- **Plasma drifts**



Ionosphere Irregularity Models

CONCLUSIONS

- **We are building a fully coupled troposphere to thermosphere system that includes the ionosphere, electrodynamics, and data assimilation**

- **The new system has potential to improve specification and forecasting even in the troposphere**

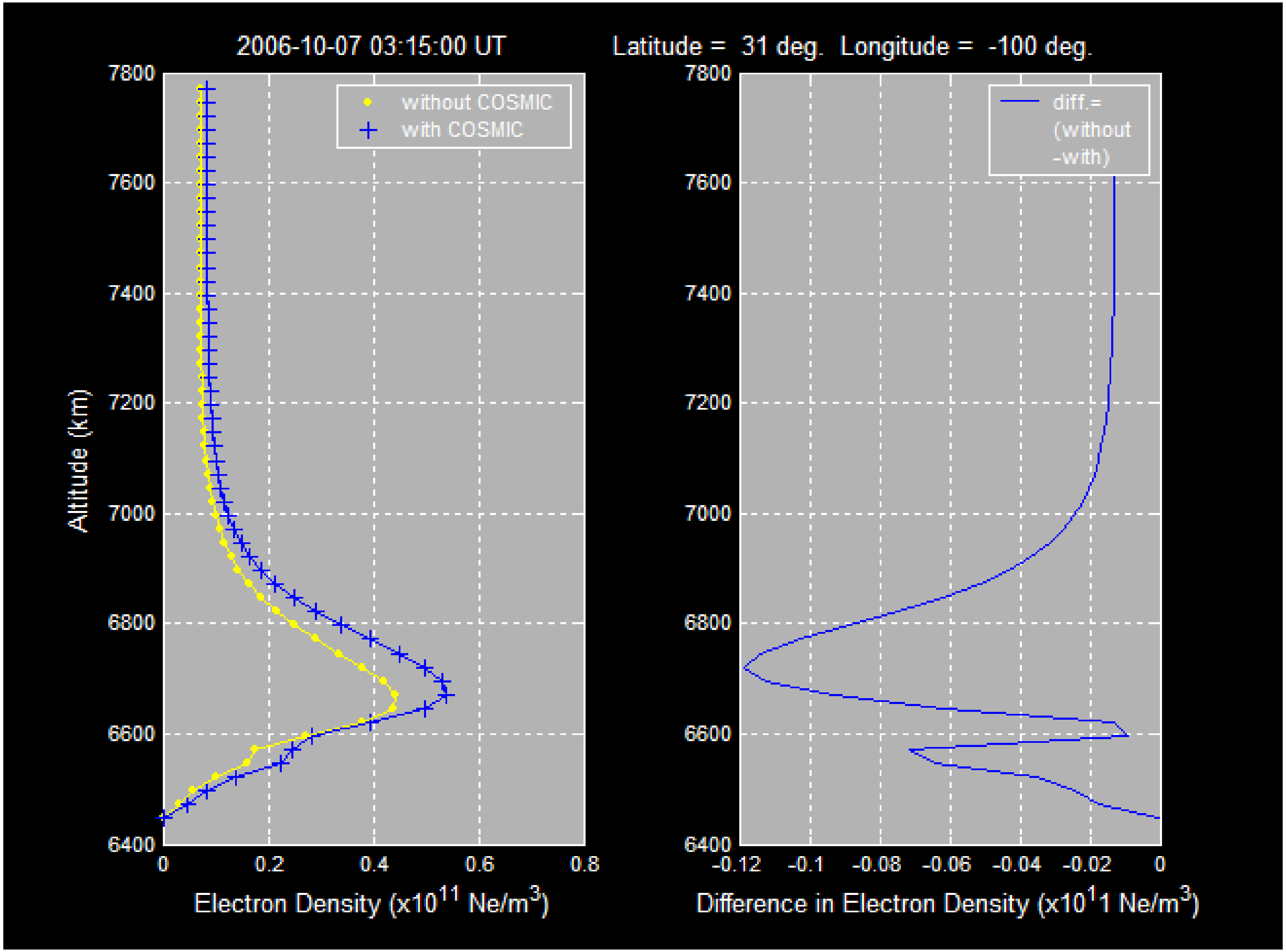
- **The electron density height profile cannot be accurately specified from ground-based GPS data alone**

- **COSMIC GPS occultation data can provide the height distribution information needed to specify the global 3-D Ne structure**

- **The correlation between Ne values measured at the same location decreases dramatically beyond 45 minutes**

- **Scintillation specification requires even shorter latency for the S_4 and Sigma Phi measurements**

Electron Density Height Profile



Electron Density Height Profile