# The ionospheric quiet-time variation as a challenge for model validation tests: preliminary considerations

I. Tsagouri[1], J. S. Shim[2], M. M. Kuznetsova[3]
*[1]National Observatory of Athens, Greece*
*[2]CUA/ NASA GSFC, Greenbelt, MD, USA*
*[3] NASA GSFC, Greenbelt, MD, USA*

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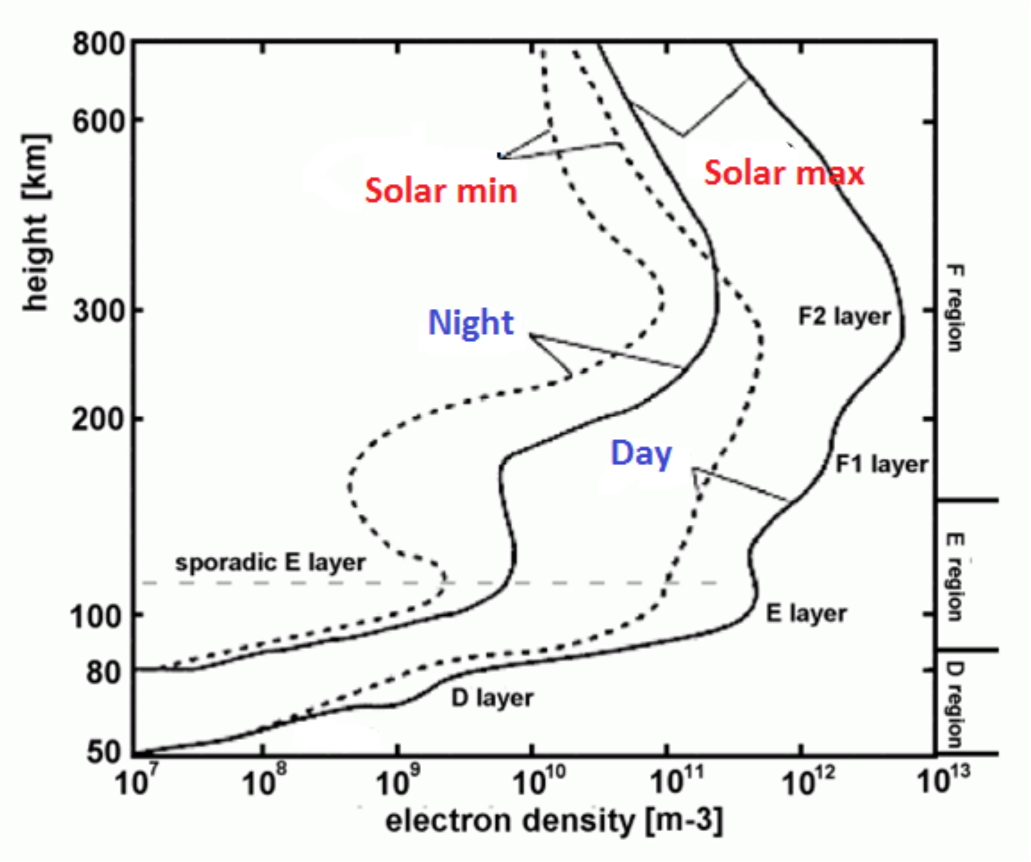
# Ionospheric variability



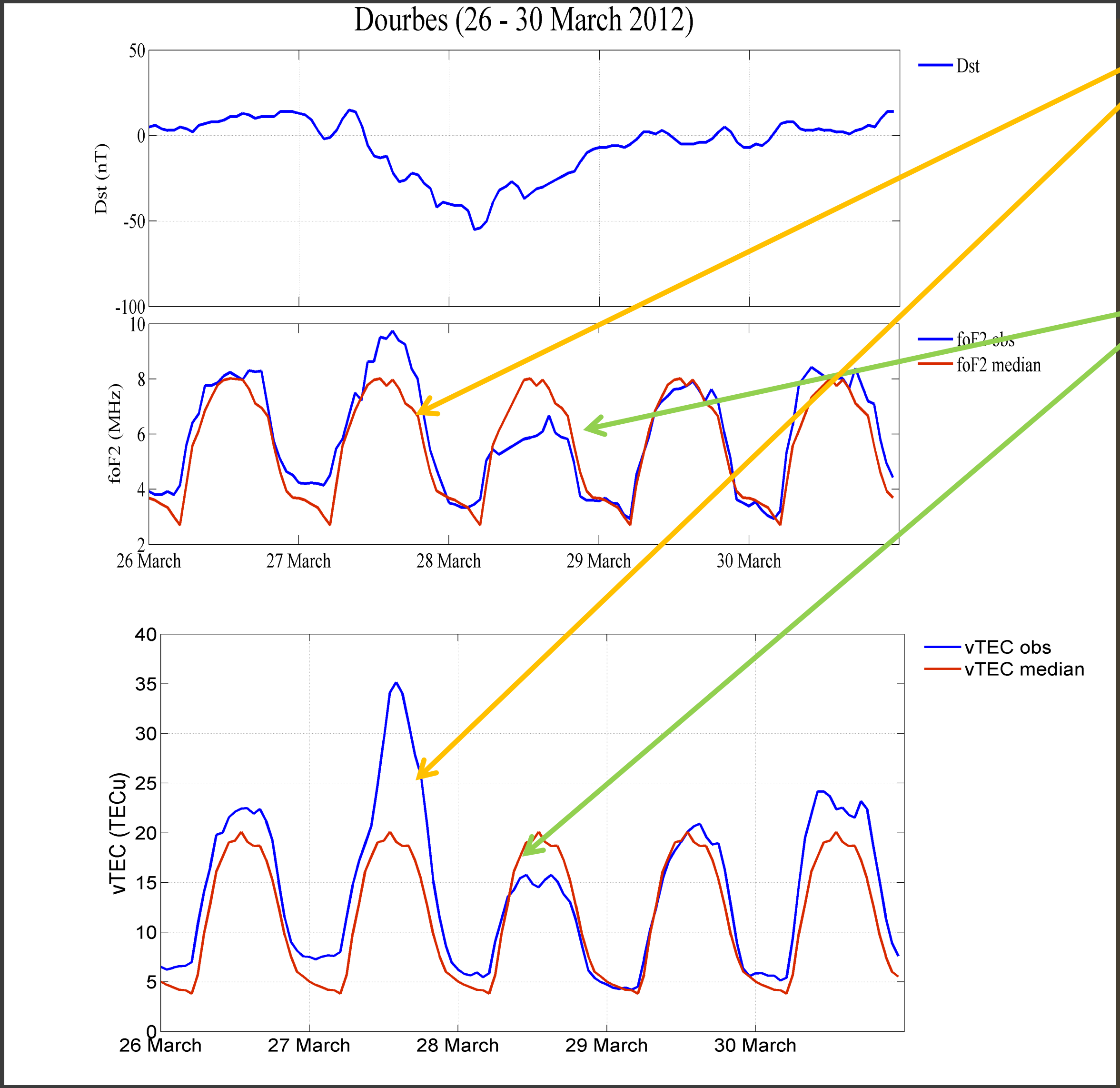
The ionosphere is not the same every day since it is a highly coupled system: ionization production, loss and transport

$$\partial N_e / \partial t = q - l\,(N_e) - \mathrm{div}\,(N_e V)$$

Electron density: changes over multiple timescales ranging from approximately minutes (e.g., solar flare effects) to solar cycle durations (~11 years).

**Normal** (diurnal, monthly, seasonal, solar cycle, latitudinal, longitudinal depedence)
**Transient** (e.g. space weather effects) defined with respect to normal changes

# Large scale ionospheric storm-time disturbances in plasma density



Dourbes (26 - 30 March 2012)

**Positive storm effects:** increase in ionospheric ionization wrt background conditions

**Negative storm effects:** decrease in the ionospheric ionization below background conditions

# Motivation

## Quantification of the quiet time ionospheric variation

- Assessment of climatological models (long-term predictions)
- Quantification of the storm impact – assessment of modeling capabilities for ionospheric short-term forecasting applications

Physical quantities:

NmF2/foF2; hmF2; vTEC

## Options

- ❑ Average over 5-quietest days within a month
- ❑ Average over 5-quietest days within 30-days prior to an event

Standard "prediction" approaches

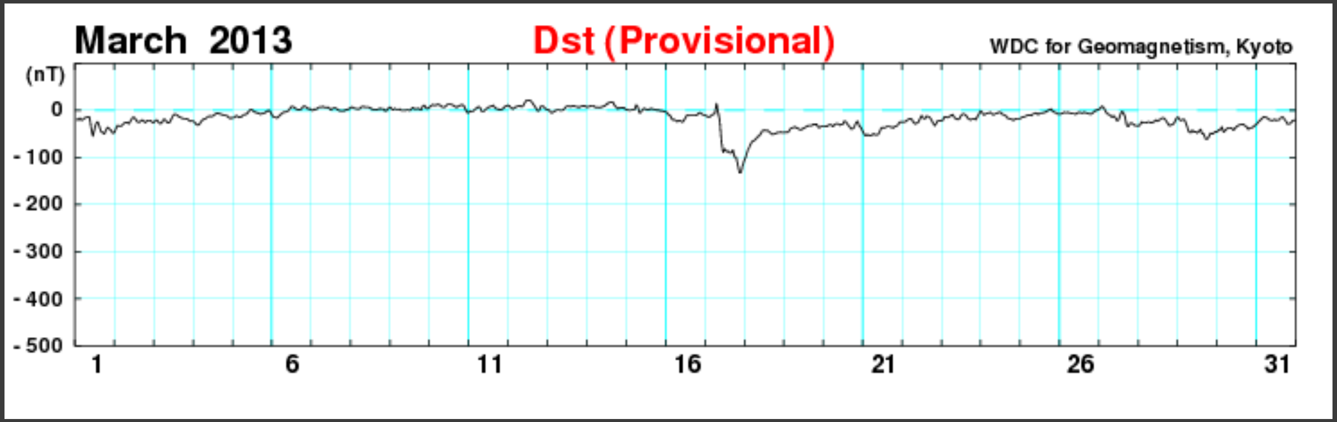
- ❑ Monthly medians
- ❑ Running medians (30-days prior to an event) – Suitable for "real time" applications

# Selection of the quiet days

For the selection of the five days we use the following criteria:

- Min Dst index ≥ -30 nT for the day and the previous one
- Max AE index ≤ 250 nT for the day and the previous one

| **Storm time interval** | **5 Quietest days within the month** | **5 Quietest days prior to the event** |
|---|---|---|
| 16-20 March 2013 | 6/3, 7/3, 8/3, 25/3, 26/3 | 25/2, 27/2, 6/3, 7/3, 8/3 |



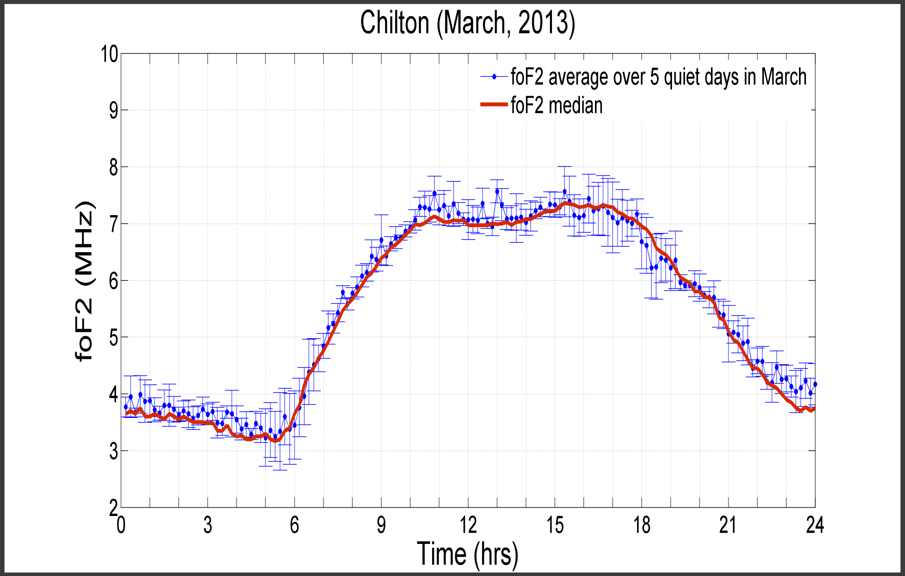
# Data presentation

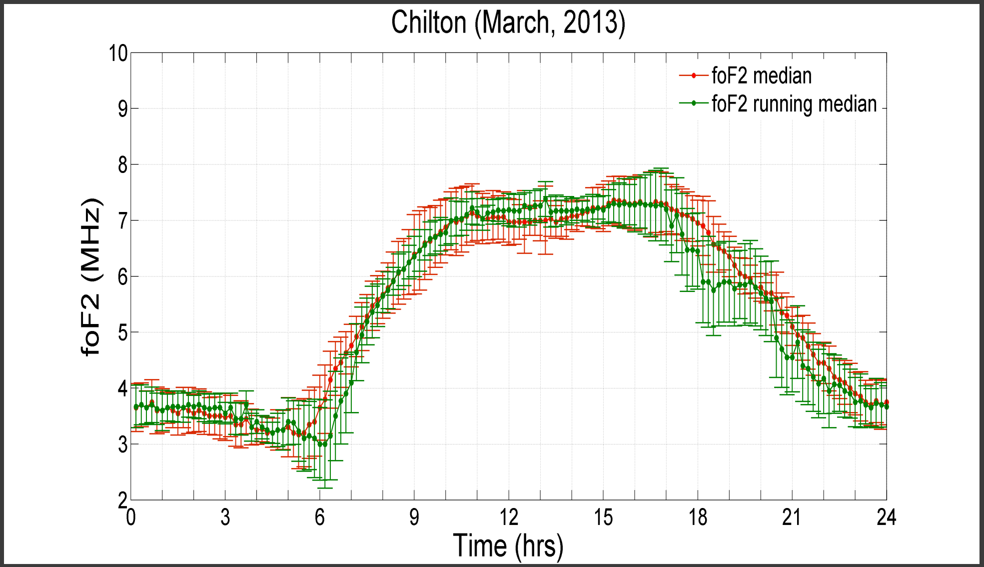
Autoscaled values of foF2 and hmF2 from Chilton ionosonde: Autoscaling error less than 0.7 MHz (Bamford et al., Radio Science, 2008)

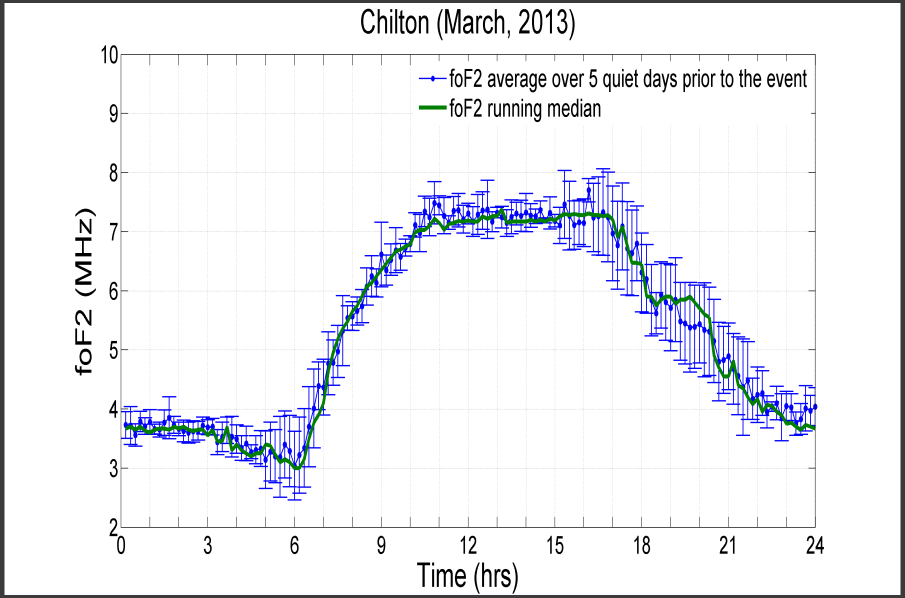
| **Ionospheric Station** | **Geographic longitude (°E)** | **Geographic latitude (°N)** | **GPS Station** | **Geographic longitude (°E)** | **Geographic latitude (°N)** |
|---|---|---|---|---|---|
| Chilton | 359.4 | 51.5 | HERT | 0.334 | 50.867 |

vTEC estimates used here are based on data from HERT GPS receiver. They are calculated from Receiver Independent Exchange Format (RINEX) files with 30 s sampling, using the single station solution proposed by Ciraolo (2005) and Ciraolo et al. (2007) that assumes that the ionosphere is a thin layer at 300 km altitude.

# Chilton (foF2) – March 2013







**Error bars: STDs** (Uncertainties mainly due to ionogram autoscaling errors and quiet time variability)

Mean STD monthly medians: **0.4 MHz**
Mean STD 5 quiet days in the month: **0.3 MHz**

Mean STD running medians: **0.4 MHz**
Mean STD 5 quiet days before the event: **0.4 MHz**

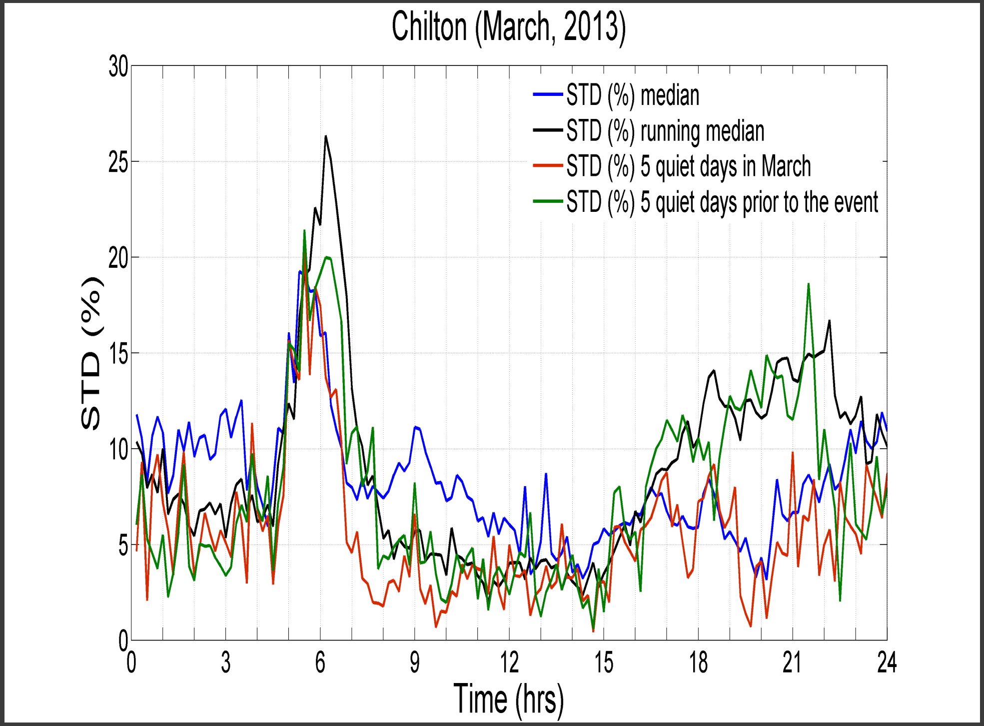
# Chilton (foF2) – March 2013

STD (%) = (STD_foF2x / foF2x)*100

x: median, running median, average over 5 quiet days

STD (%) is estimated over each time of the day

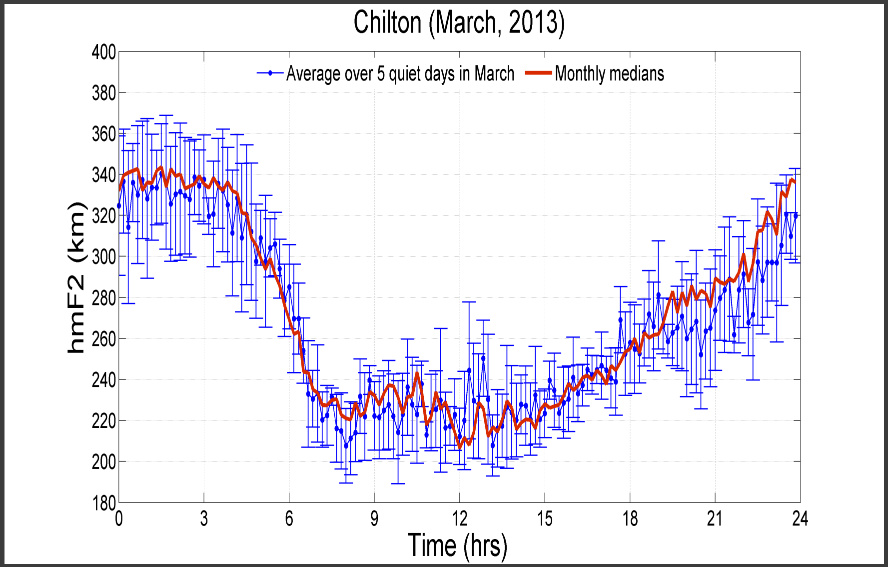
Mean STD (%)monthly medians: **8 %**
Mean STD (%) 5 quiet days in the month: **6 %**
Mean STD (%) running medians: **9%**
Mean STD (%) 5 quiet days before the event: **8%**

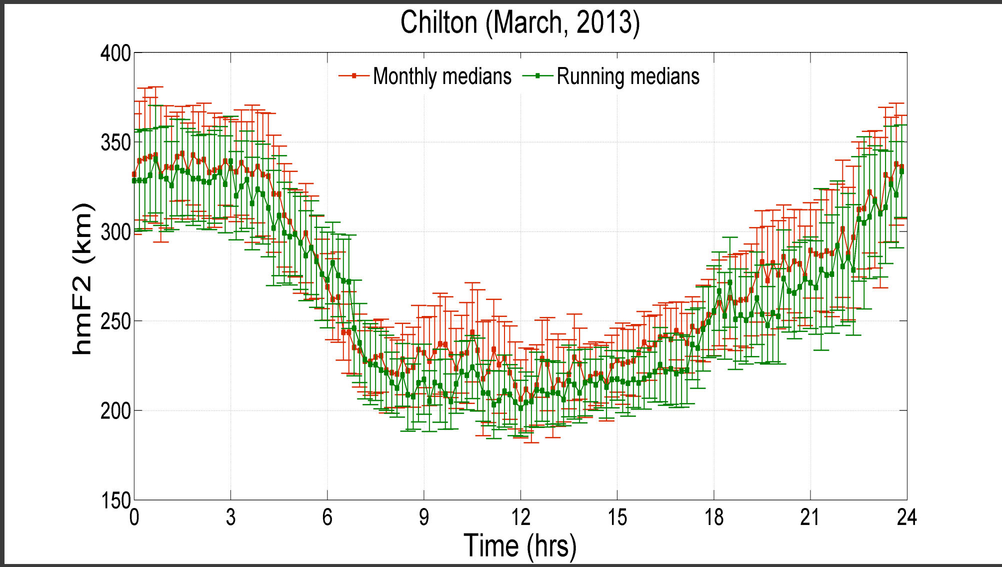


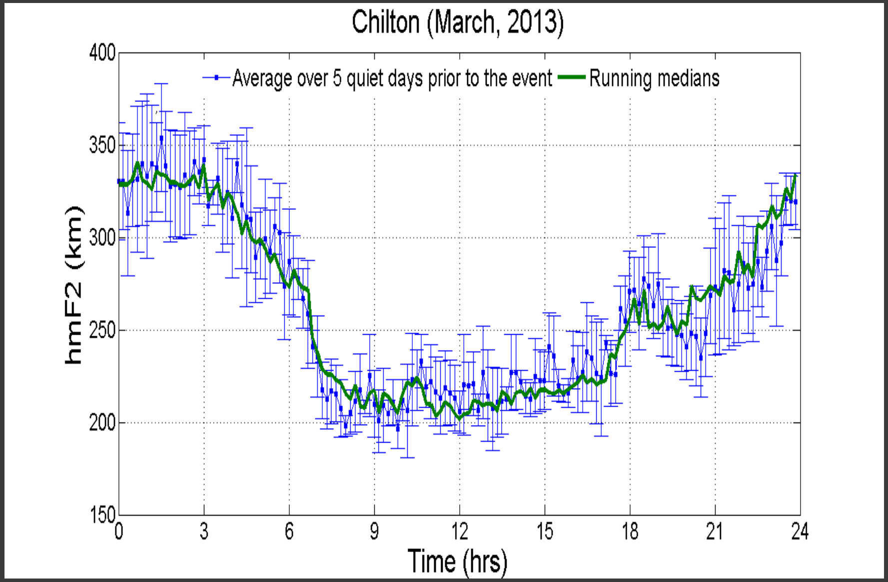
## Information that may be extracted

- Local time dependence of the uncertainties: e.g., for the case under study here the uncertainties are significantly larger in dawn sector in all terms (for Chilton UT=LT)
- Monthly medians are comparable to the average of 5 quiet days within the month, while running medians are comparable to the average of 5 quiet days prior to the storm event. On average, all approaches may be considered comparable
- On average, ionospheric variations of about 10% wrt quiet conditions may be ignored.

# Chilton (hmF2) – March 2013







**Error bars: STDs** (Uncertainties mainly due to ionogram autoscaling errors and quiet time variability)

Mean STD monthly medians: **26 km**
Mean STD 5 quiet days in the month: **21 km**

Mean STD running medians: **23 km**
Mean STD 5 quiet days before the event: **23 km**

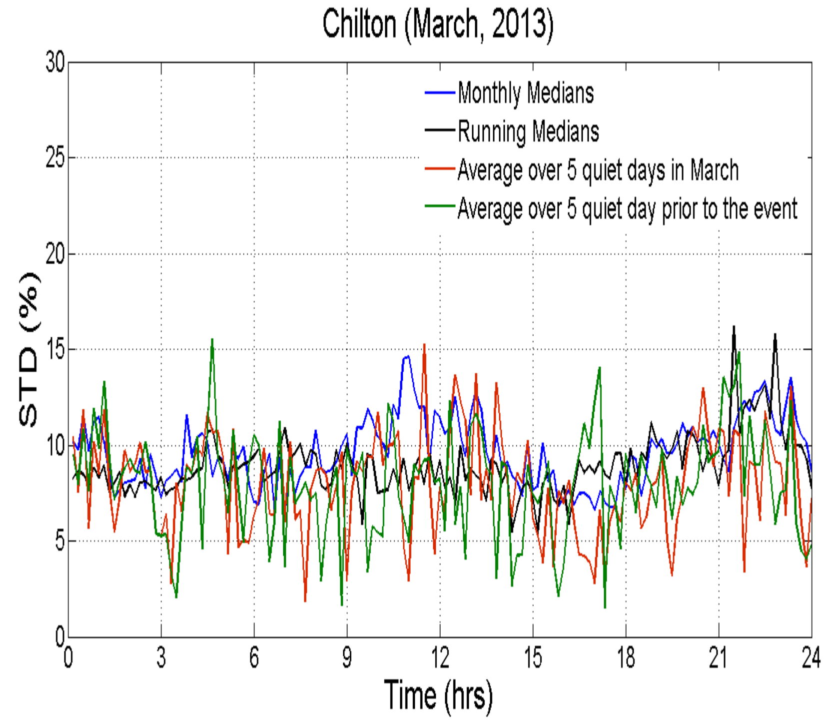
# Chilton (hmF2) – March 2013

STD (%) = (STD_hmF2x / hmF2x)*100

x: median, running median, average over 5 quiet days

STD (%) is estimated over each time of the day

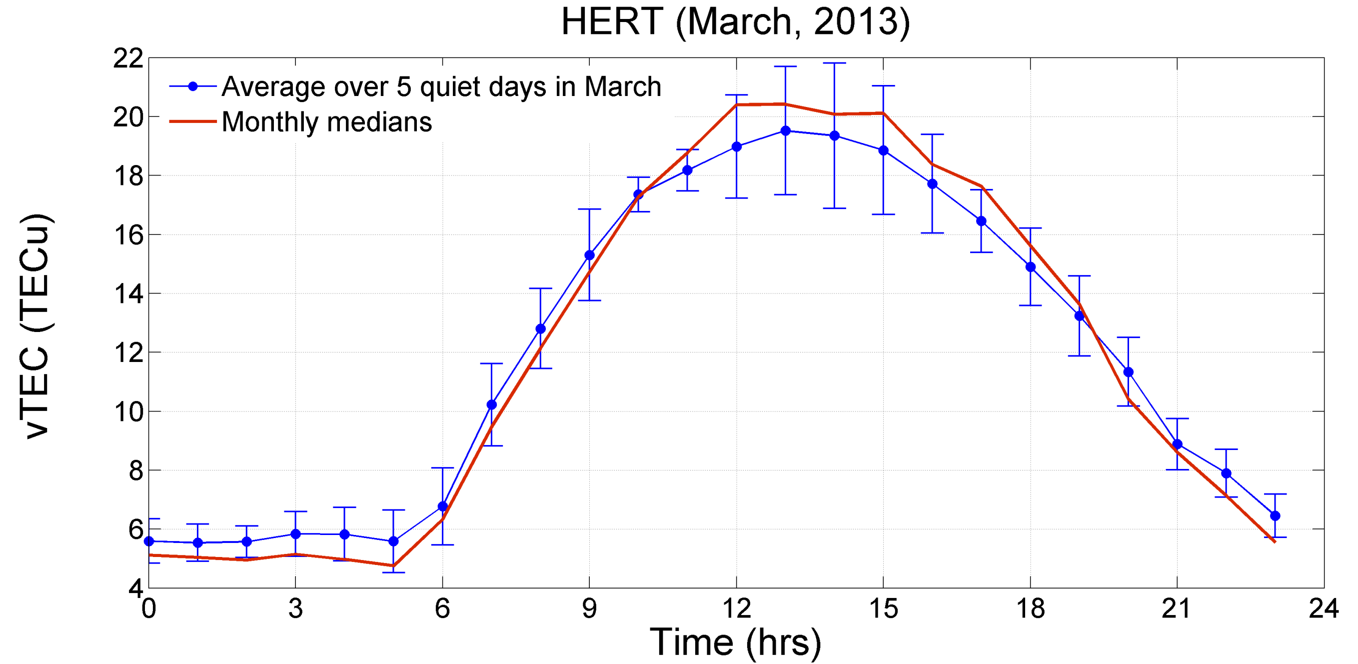
Mean STD (%)monthly medians: **10 %**
Mean STD (%) 5 quiet days in the month: **8 %**
Mean STD (%) running medians: **9%**
Mean STD (%) 5 quiet days before the event: **8%**



**Extracted information**

- Some local time dependence of the uncertainties in monthly medians in the prenoon sector (for Chilton UT=LT)
- On average, all approaches may be considered comparable
- On average, ionospheric variations of about 10% wrt quiet conditions may be neglected.

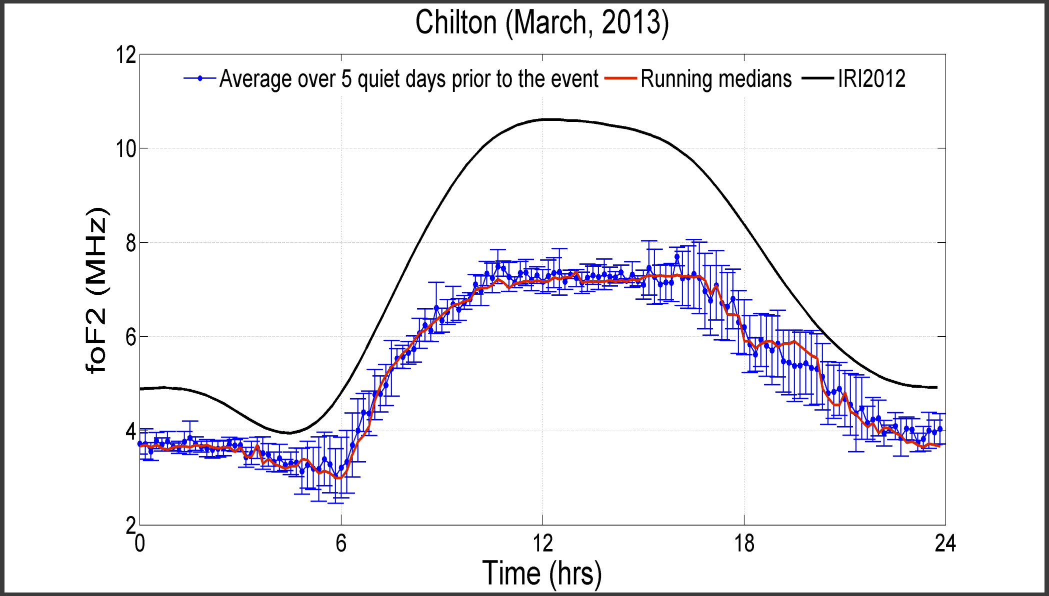
# HERT (vTEC) – March 2013

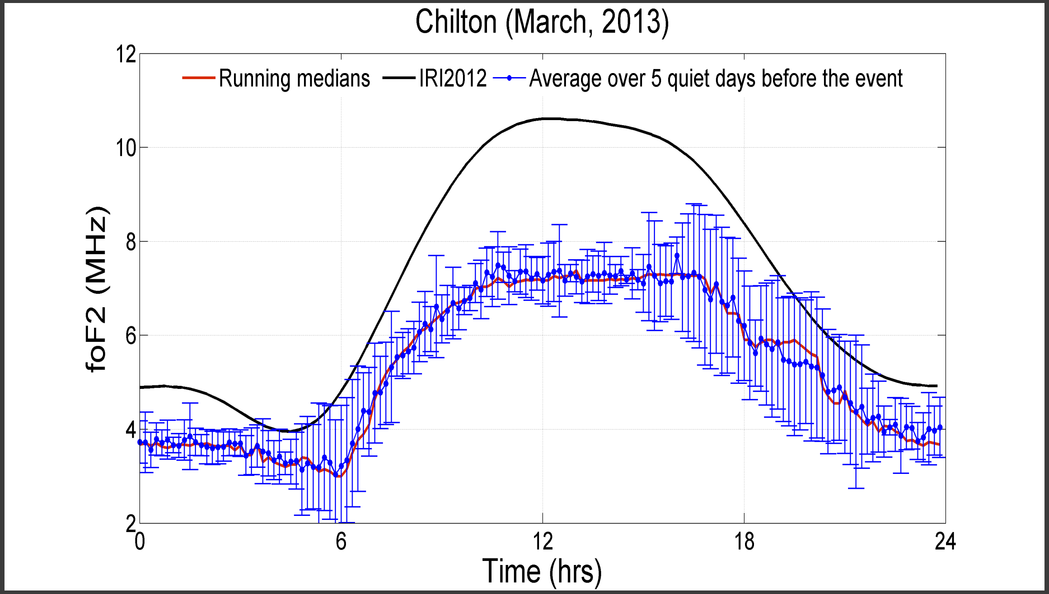


Mean STD monthly medians:
Mean STD 5 quiet days in the month: **1.2 TECu**

Mean STD (%)monthly medians:
Mean STD (%) 5 quiet days in the month: **11 %**

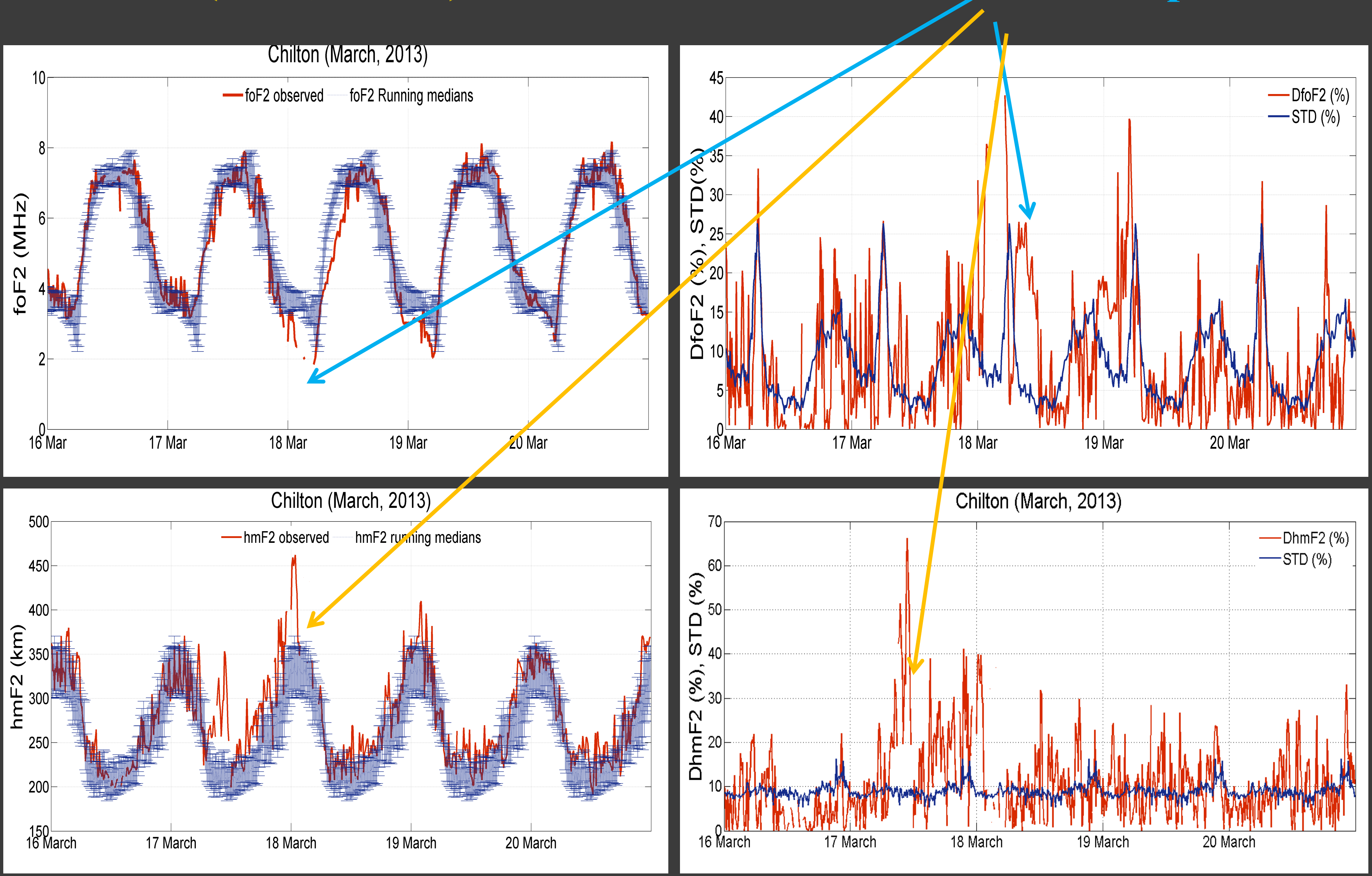
# Chilton (foF2) – March 2013





# Chilton (foF2, hmF2) – March 2013

**Storm Impact**



- DfoF2(%) = [(foF2obs - foF2runningmedian)/foF2running median]*100