Extreme Ultraviolet Radiation Flux Changes and Electron Density Enhancement During Solar Flares

MIT Haystack REU 2011
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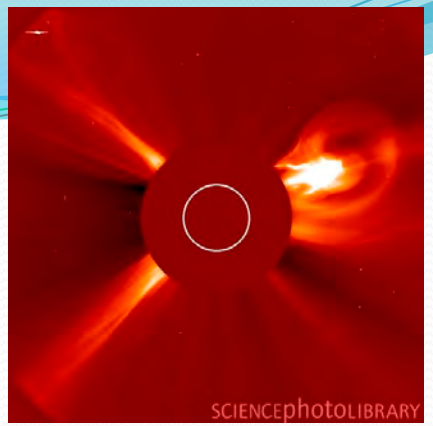
Effects of Solar Flares on Electron Density



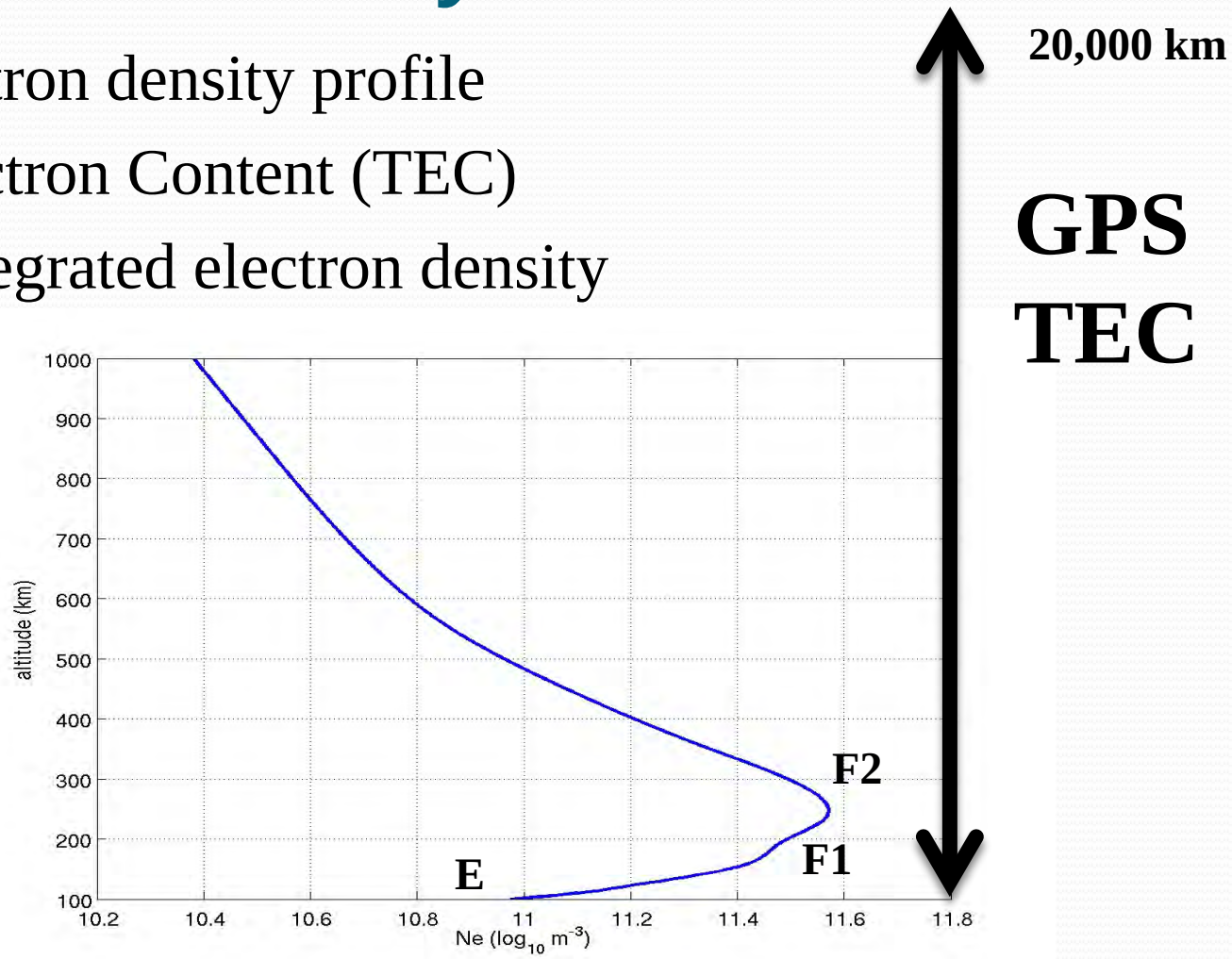
- Solar flares are characterized by sudden enhancements in solar X-ray irradiance and solar EUV flux.
- It is well known that solar flares have a clear effect on the total electron content of the ionosphere
- The portion of the electromagnetic spectrum that is responsible for this is not clear.
- We think the TEC enhancement is due to enhanced EUV which provides the primary source of ionization in the E, F1layers (100-150km)

Analysis

- Study takes place in September 2005 and October 2002, which have 114 and 329 flares respectively
- The Millstone Hill ISR was running 30 day experiments during these months with 8-16 minute time resolution.
- Looks at variations in the daytime global average TEC derived from GPS on the time scale of the solar flare (30 min - 3 hours). GPS has a time resolution of 5 minutes.
- Altitude stratification of electron density analyzed through ISR data.

Electron Density Data Sources

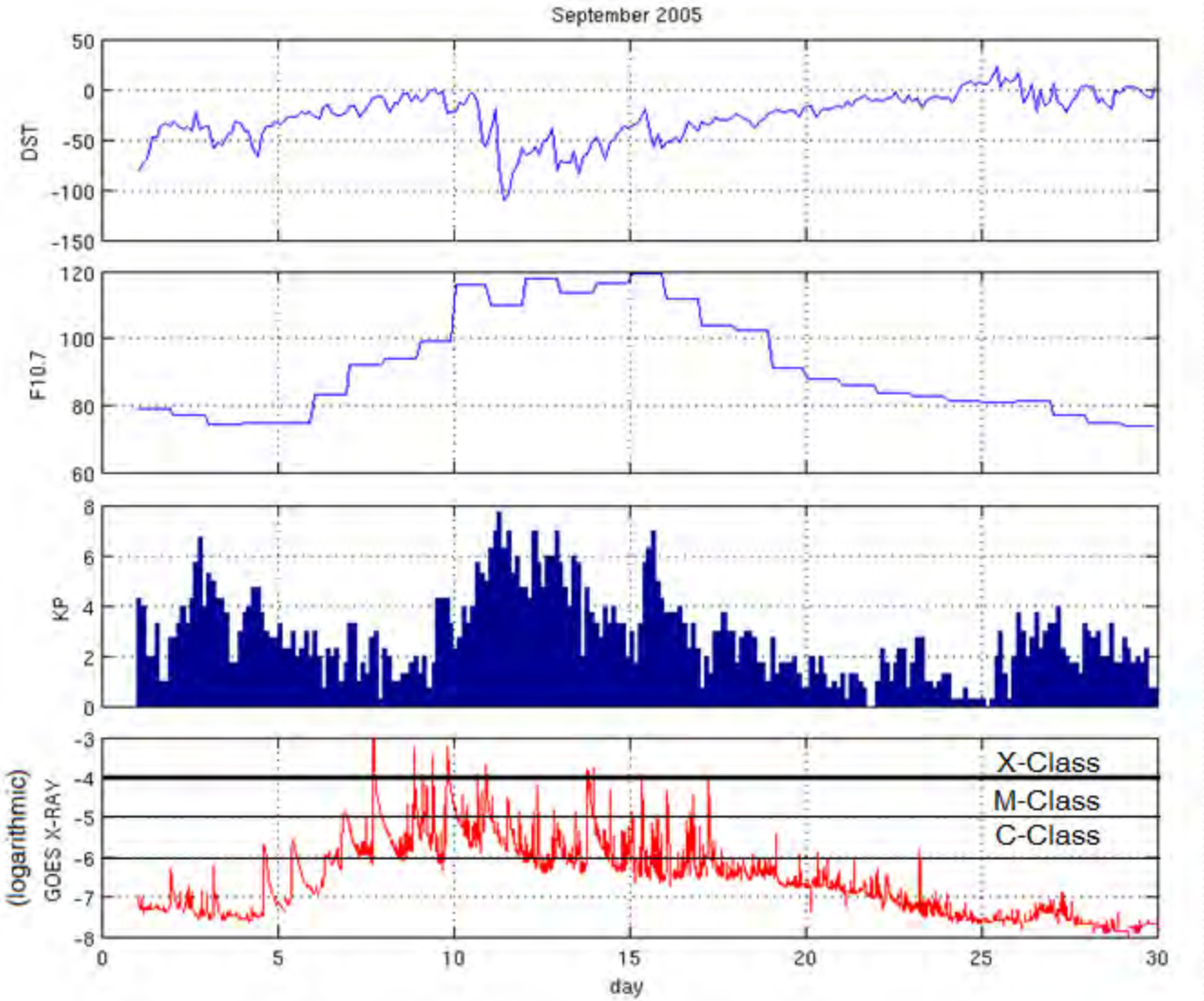
- ISR- electron density profile
- Total Electron Content (TEC)
  - integrated electron density



EUV and X-ray Data Sources

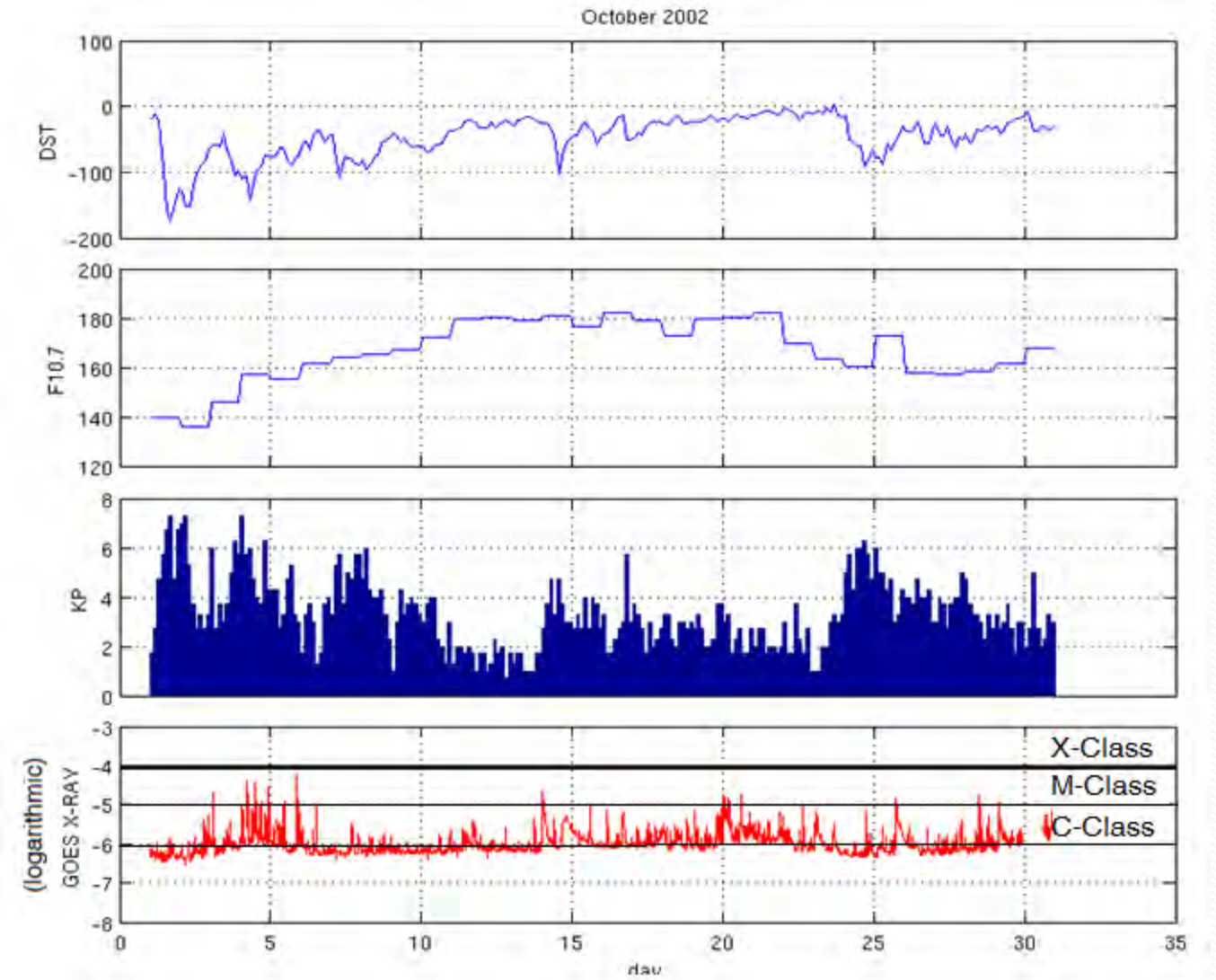
Instrument	Data Set	Wavelength/ Frequency	Units	Time Resolution	Orbit
SEM on the SOHO	EUV flux	26-34 nm .1-50 nm	Photons /cm^2/s	10 minute	First Lagrangian Point (1.5 x 10^6 km)
EGS on the TIMED SEE	EUV spectral irradiance	27-34 nm	W/m^2/nm	30 minute	Low Earth Orbit (625 km)
GOES X-ray detector	X-ray irradiance	.1-.8nm	W/m^2	1 minute	Geostationary (35,790 km)

Geophysical Indices for September 2005



114 Flares

Geophysical Indices for October 2002

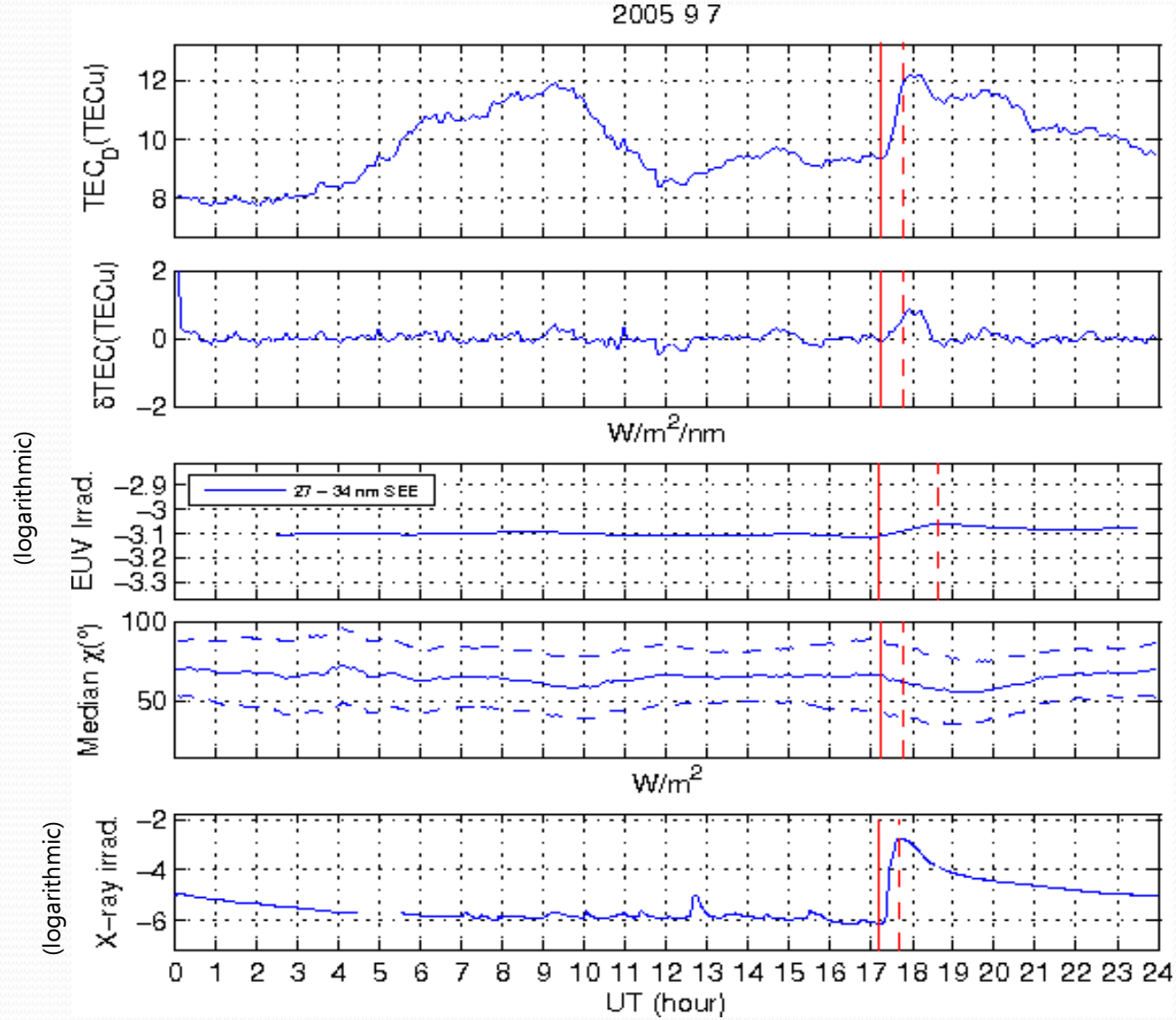


329 flares
Only 1 even close to X-class

Method

- Difference taken between TEC at the time of solar flare and the quiet time value.
- Look for sudden changes in TEC (1-2 TECu) at almost the exact time of the X-ray spike (as close as time resolution allows)
- Careful to not select a fraction of a larger scale variation

Demonstration of Method



Diff: 2.67 TECu

Key Cases

- September 13th 2005

  Solar flare has a long decay time. SOHO EUV flux coverage

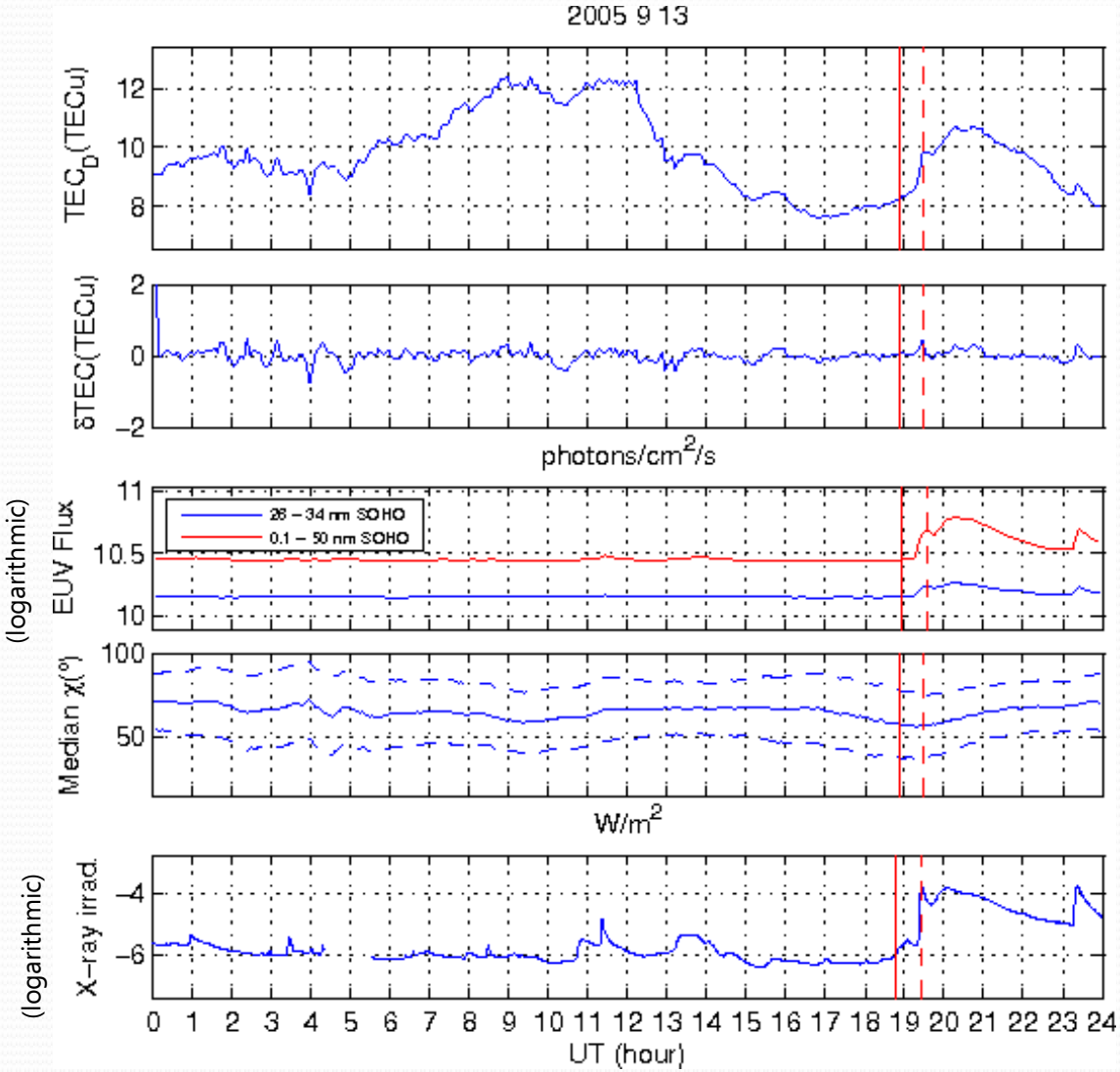
- September 9th 2005

  Solar flare has a shorter decay time. No SOHO EUV flux coverage, TIMED SEE used instead.

- Both cases have a solar flare occurring where the Millstone Hill ISR can see it.

TEC effects of flare with long decay time

September 13th



Diff: 1.67 TECu

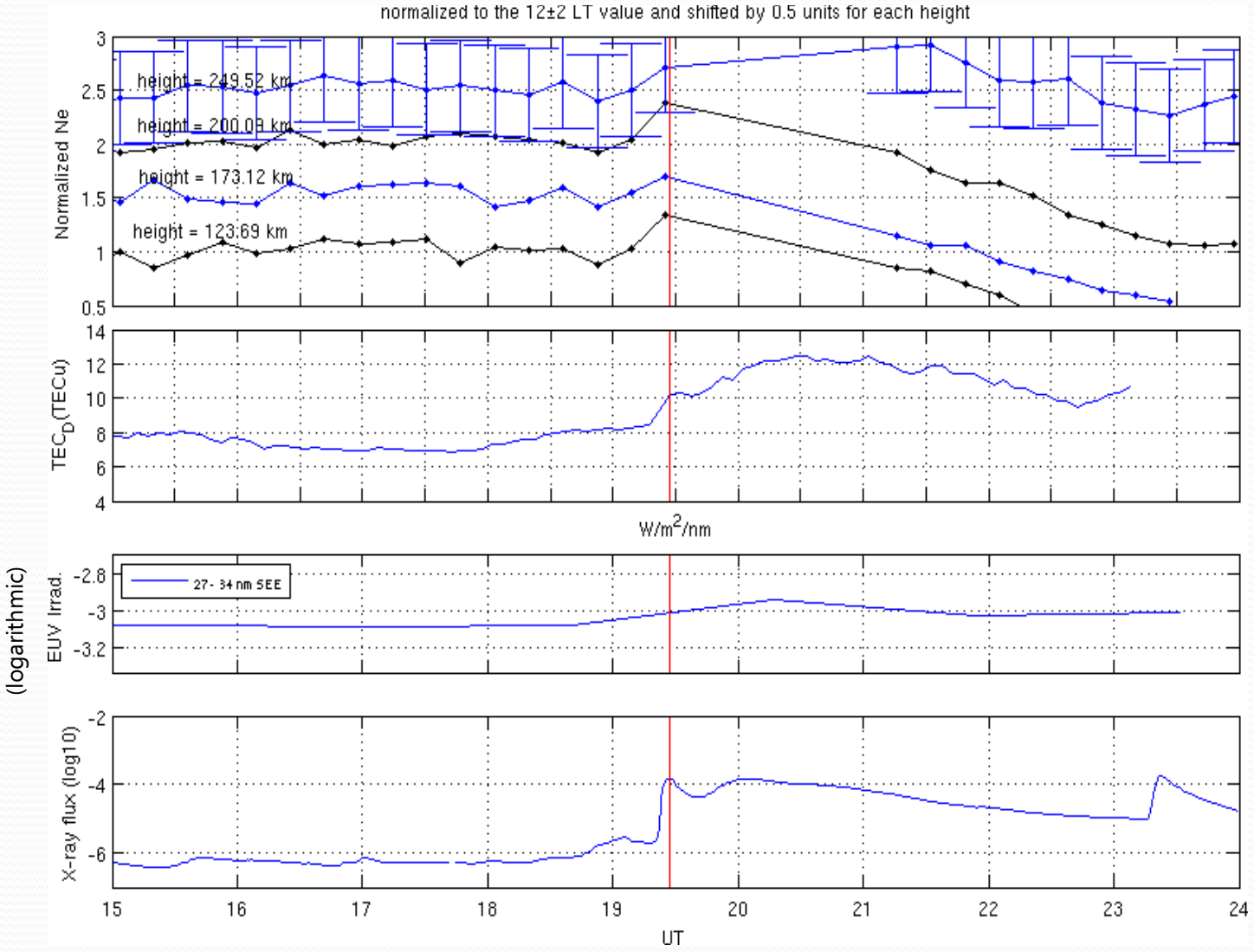
Daytime Global Average TEC

SOHO EUV Coverage

Electron Density Response as a Function of Height

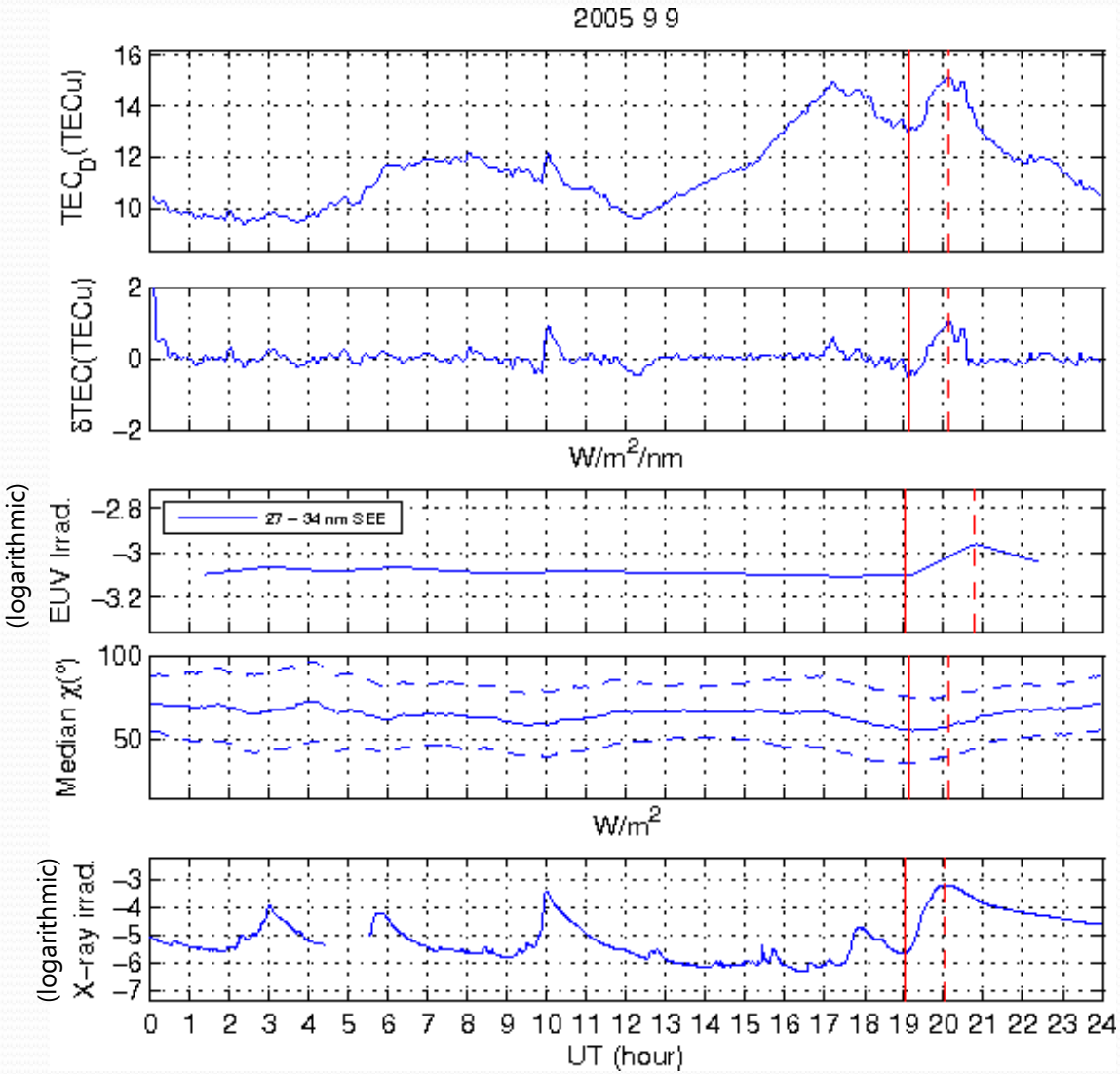
September 13th

TEC only over Millstone Hill



TEC effects of flare with shorter decay time

September 9th



Diff: 2.067 TECu

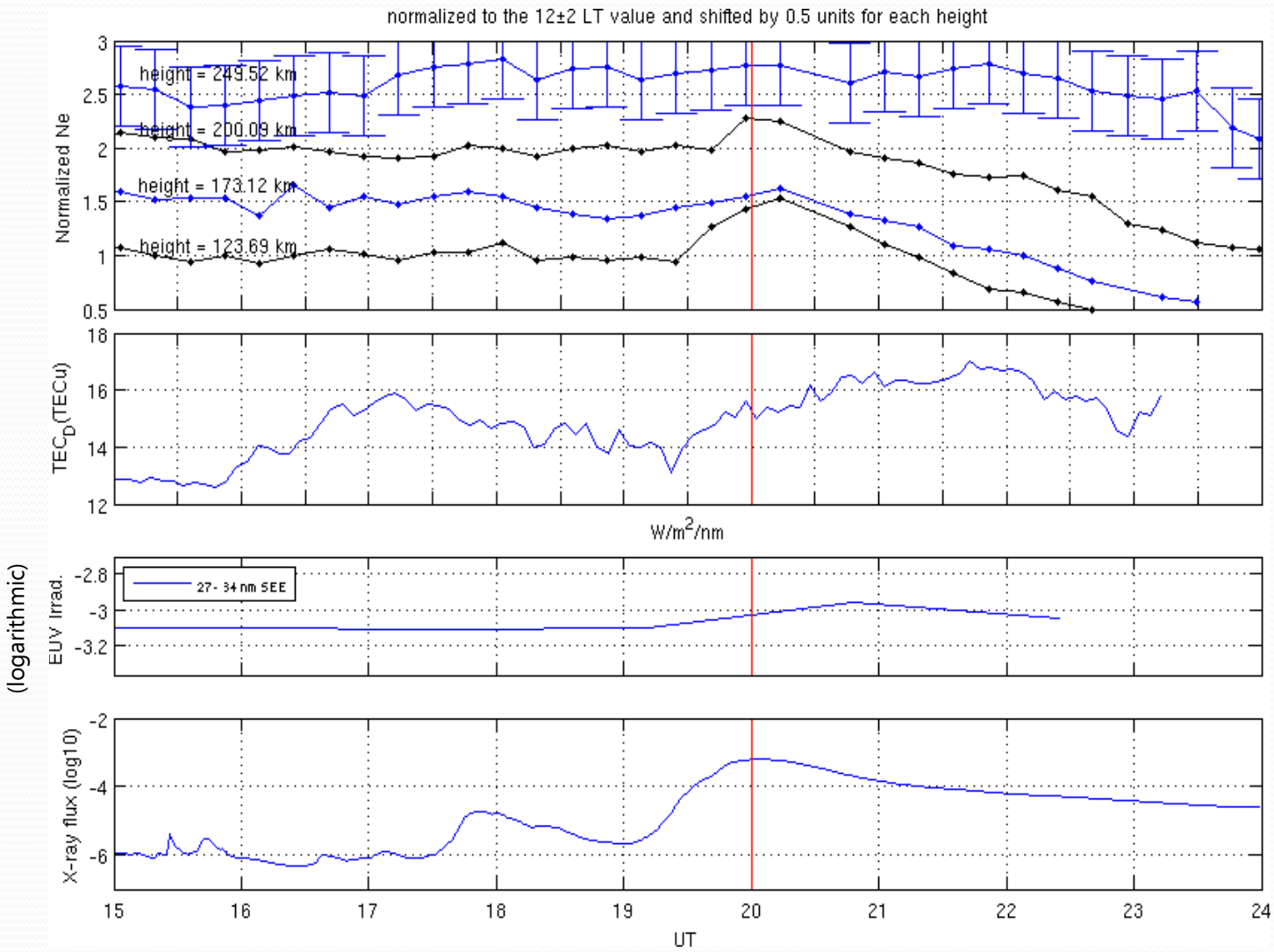
Daytime Global Average TEC

TIMED SEE Coverage Used

Electron Density Response as a Function of Height

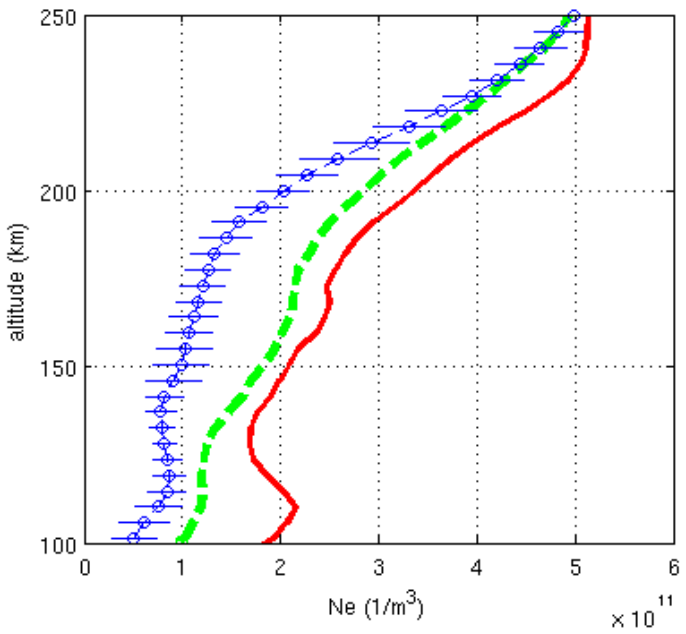
September 9th

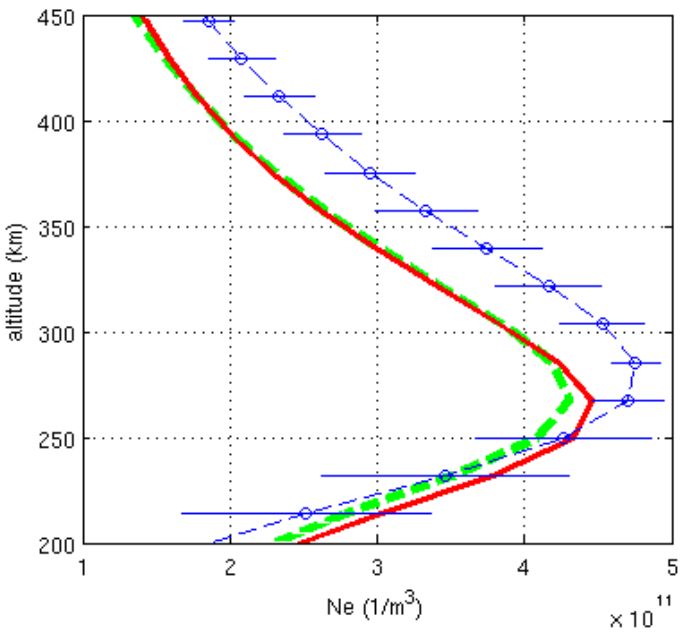
TEC only over Millstone Hill

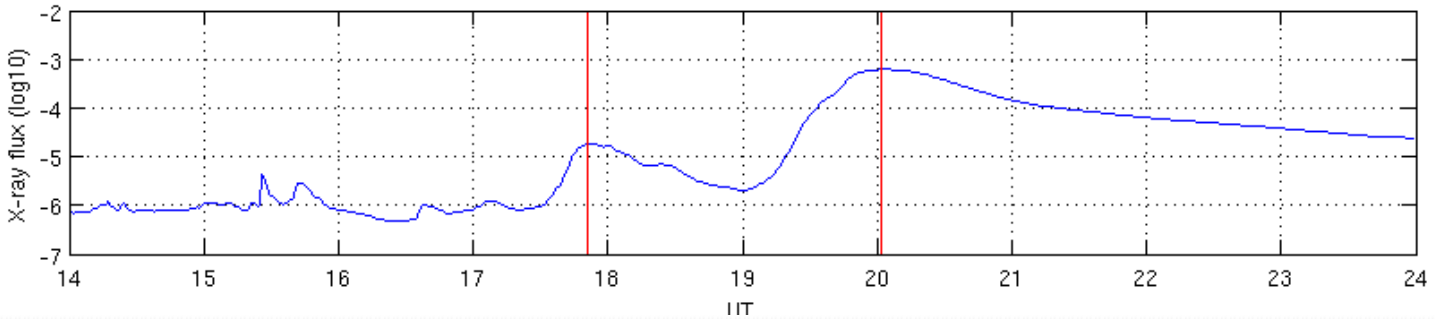


ISR profiles for September 9th 2005

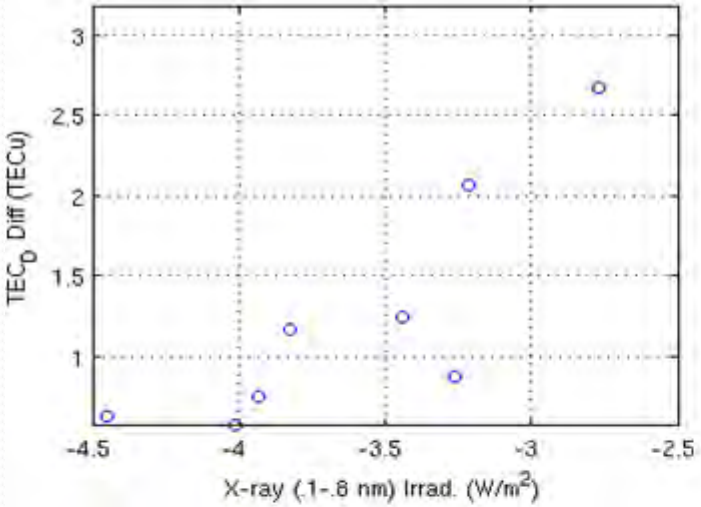
Green – 19 UT
Red – 20 UT
Blue- 22 UT

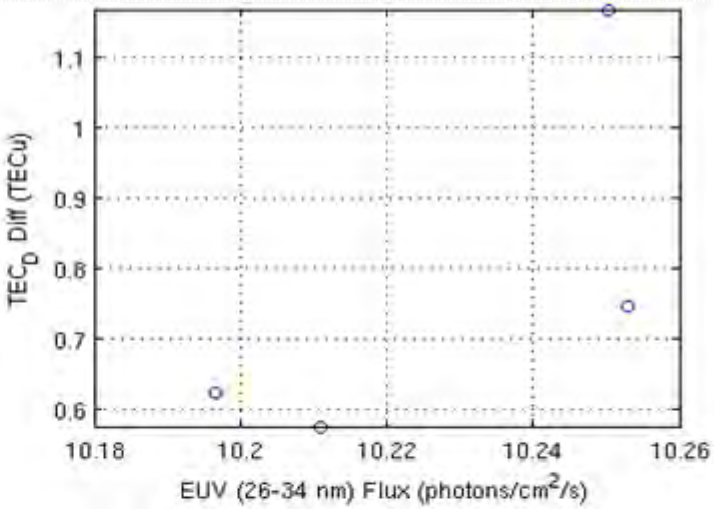


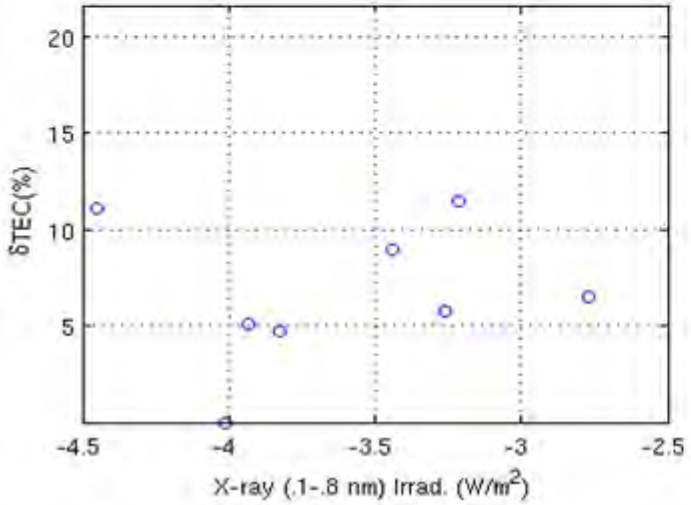


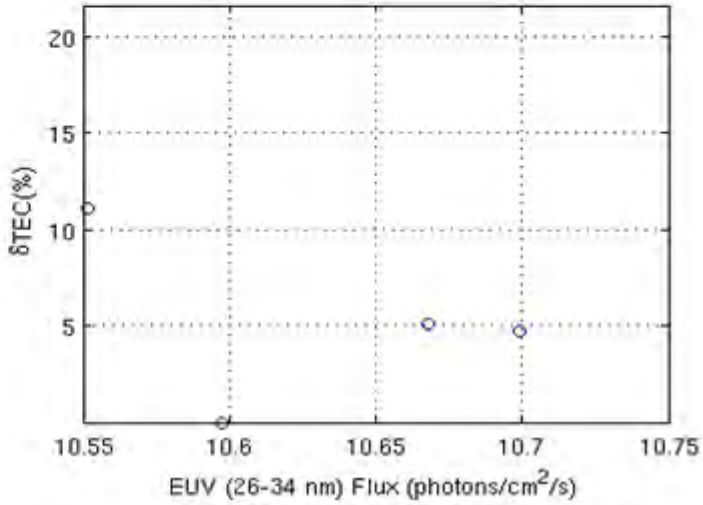


Statistics for September 2005





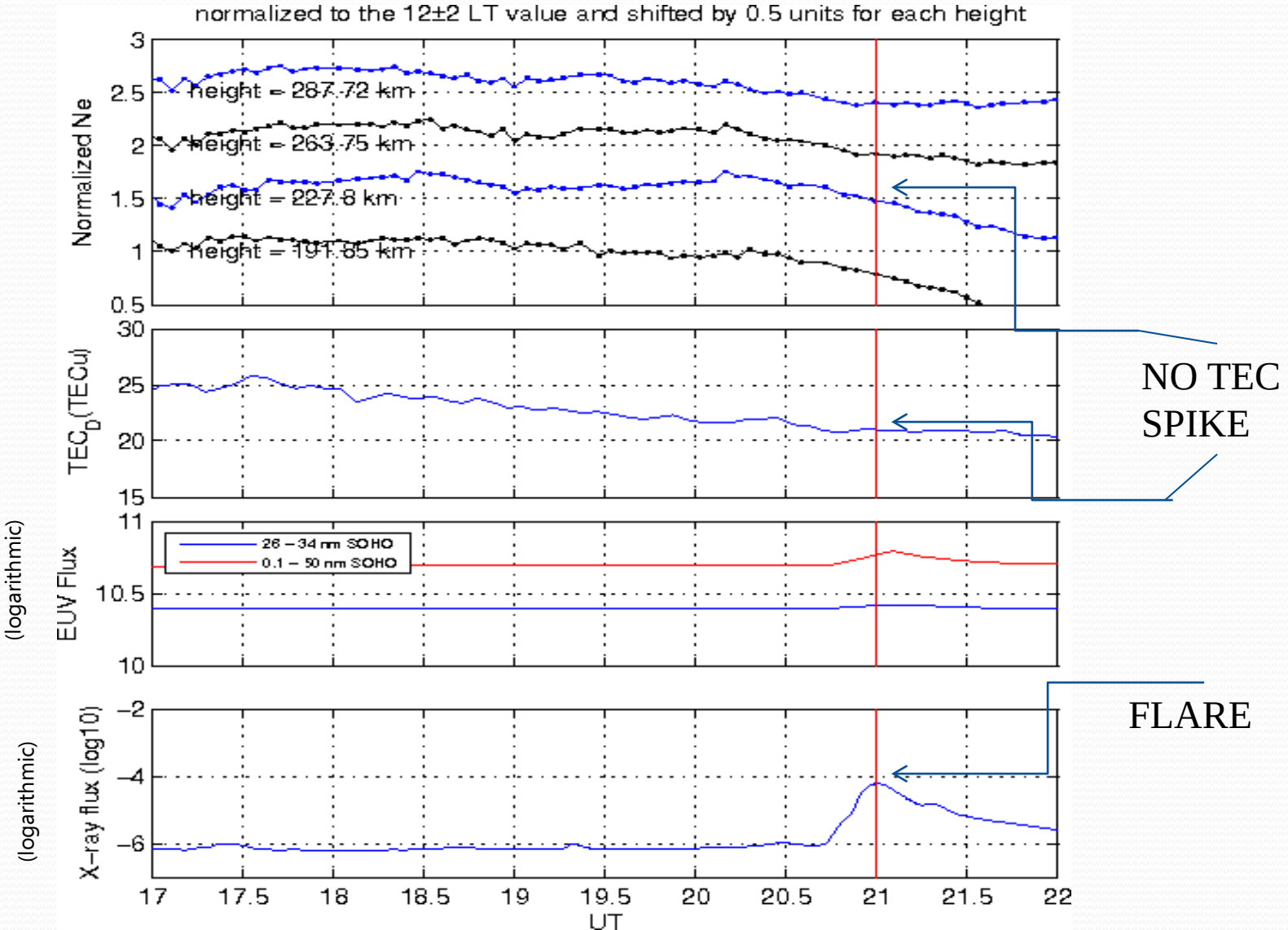




Comparison to October 2002

- October 2002 had a higher F10.7 and background TEC of around 20-30 TECu for most cases
- Even the strongest flare in October 2002, an M class on the 5th, produced little TEC enhancement.

October 5th 2002



Conclusions and Future Work

- In the cases studied, a promising positive correlation was seen between EUV, X-ray, and TEC enhancement
- Most of the TEC enhancement is seen at lower altitudes, where EUV is the primary contributor of photoionization
- Flare induced TEC enhancement seems to be dependent on background TEC and solar activity
- Many more cases are needed to establish whether these correlations are real
- It’s hard to get the right data coverage at the right time.

Acknowledgements

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