Atmospheric Effects of the September 2005 Solar Flares and Solar Proton Events

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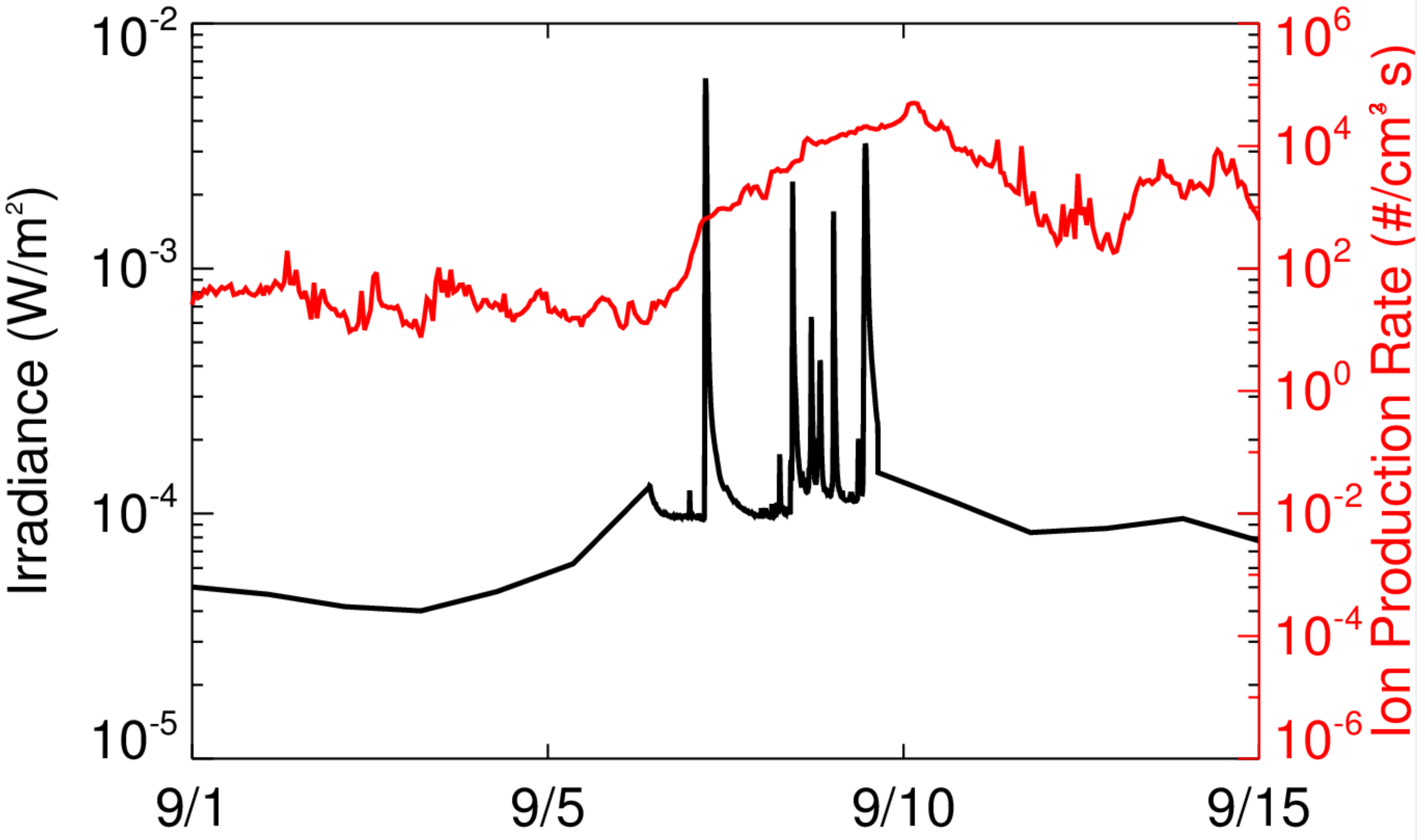
2/28/16

Solar storms in September 2005

- Solar flares: September 7th and September 9th
- Solar proton events (SPEs): September 10th and September 15th
- Previous studies on flare effects in ionosphere and thermosphere: *(e.g. Qian et al. 2010; Enell et al. 2008; Afraimovich et al. 2001a,b; Liu et al. 2006)*
- WACCM: ground to the 140 km, 5-min temporal resolution

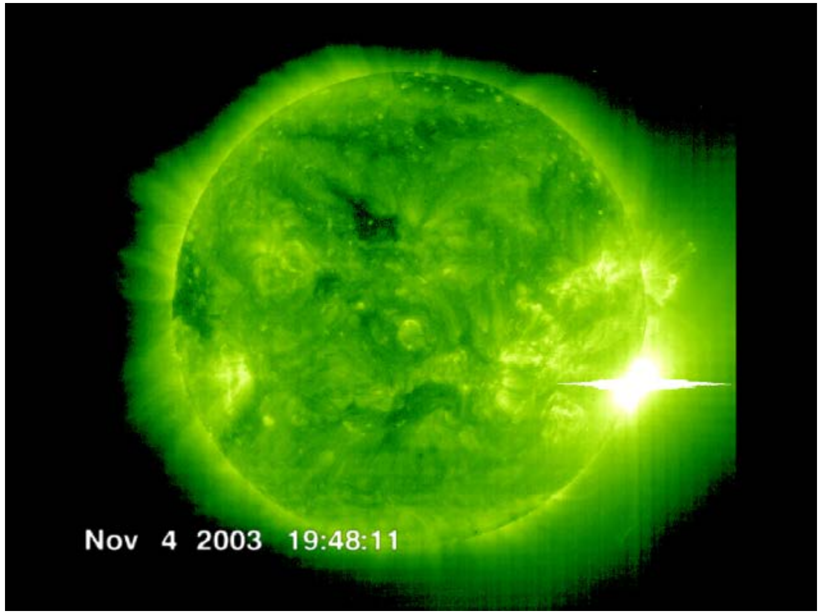


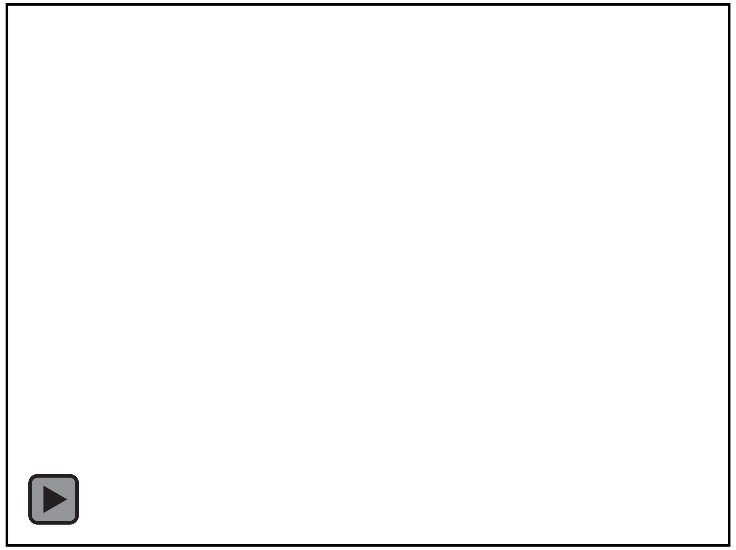
Motivation

1. How much influence do solar flares have on the atmosphere?

2. Can these effects be seen in WACCM?

3. How do these changes compare with solar proton effects?





Whole Atmosphere Community Climate Model (WACCM)

- 3D fully coupled numerical model using NCAR's CESM as numerical framework
- 88 pressure levels from the surface to ~140 km
- Horizontal resolution of 1.9° x 2.5° and vertical resolution 1.1 km in troposphere to 3.5 km above stratosphere (> 65 km)
- Applied 'specified dynamics'

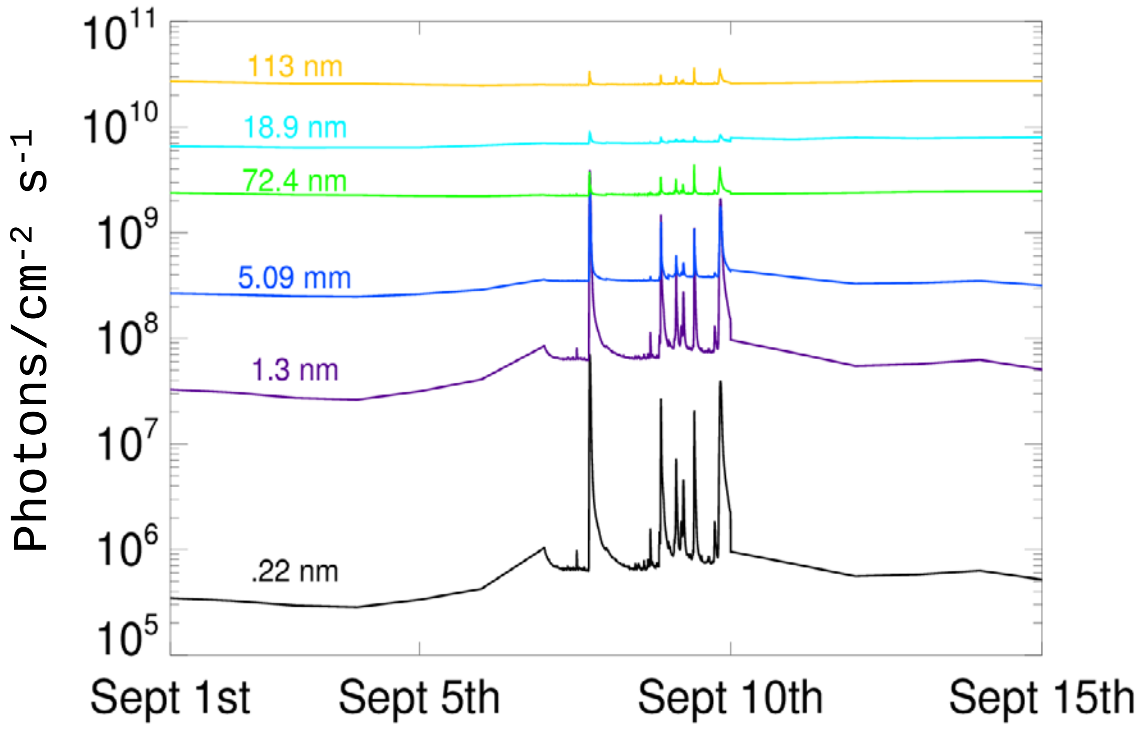
- *SPE Input:* Uses GOES satellite from proton fluxes and follows Porter et al. (1976) and Jackman et al. (1980) for ionization rates
- *Flare Input:* Uses Flare Irradiance Spectral Model (FISM) to compute irradiances at various short wavelengths

WACCM Simulations

	Baseline	SPEs + Flares	SPEs	Solar Flares
SPEs	None	Hourly	Hourly	None
Solar Flares	None	5-minute	None	5-minute

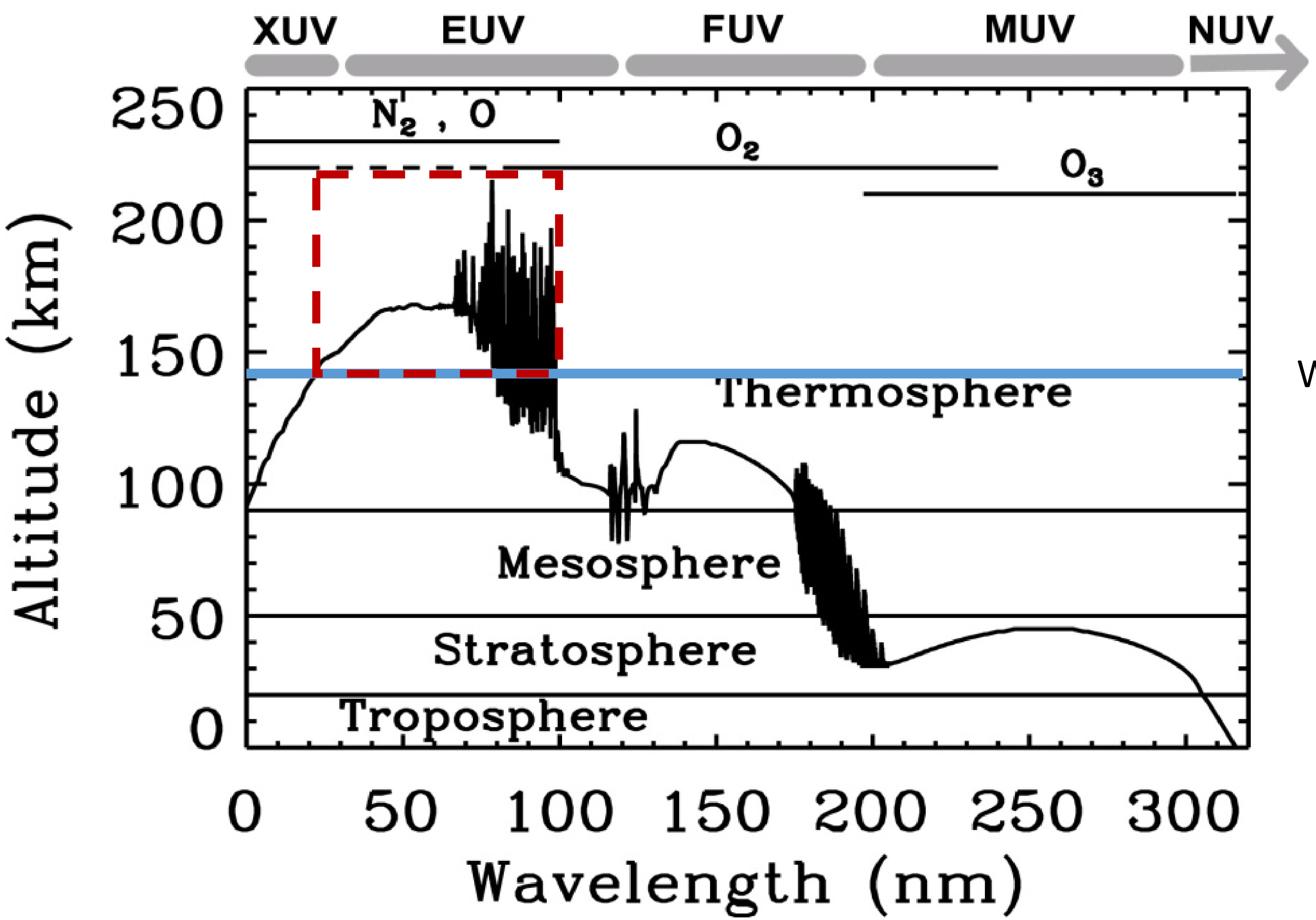
Flare Irradiance Spectral Model (FISM)

- FISM is a solar spectral irradiance empirical model
- Uses data from the TIMED-SEE and the SORCE-SOLSTICE
- Includes wavelengths from .1 to 190 nm at 1 nm spectral resolution with a 1-minute time cadence
- FISM data was processed into 5-minute averages across 23 wavelengths



Chamberlin et al., 2008

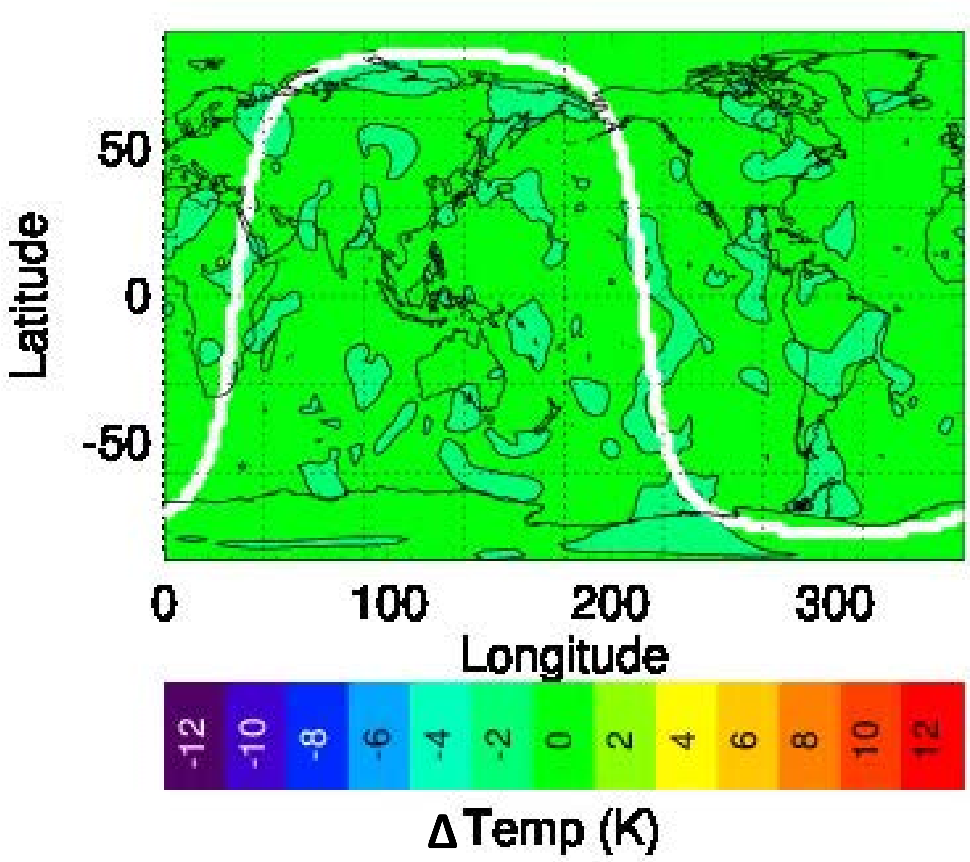
Altitudes where photons from solar flares can influence the atmosphere

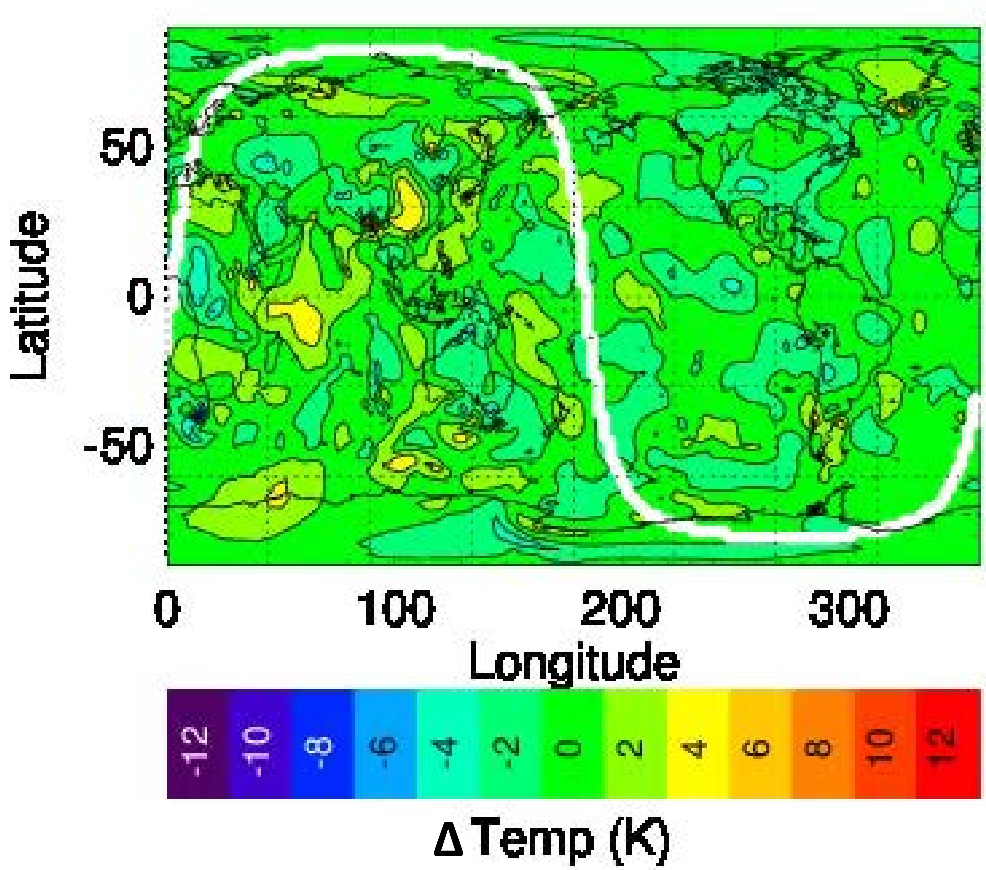


WACCM Domain

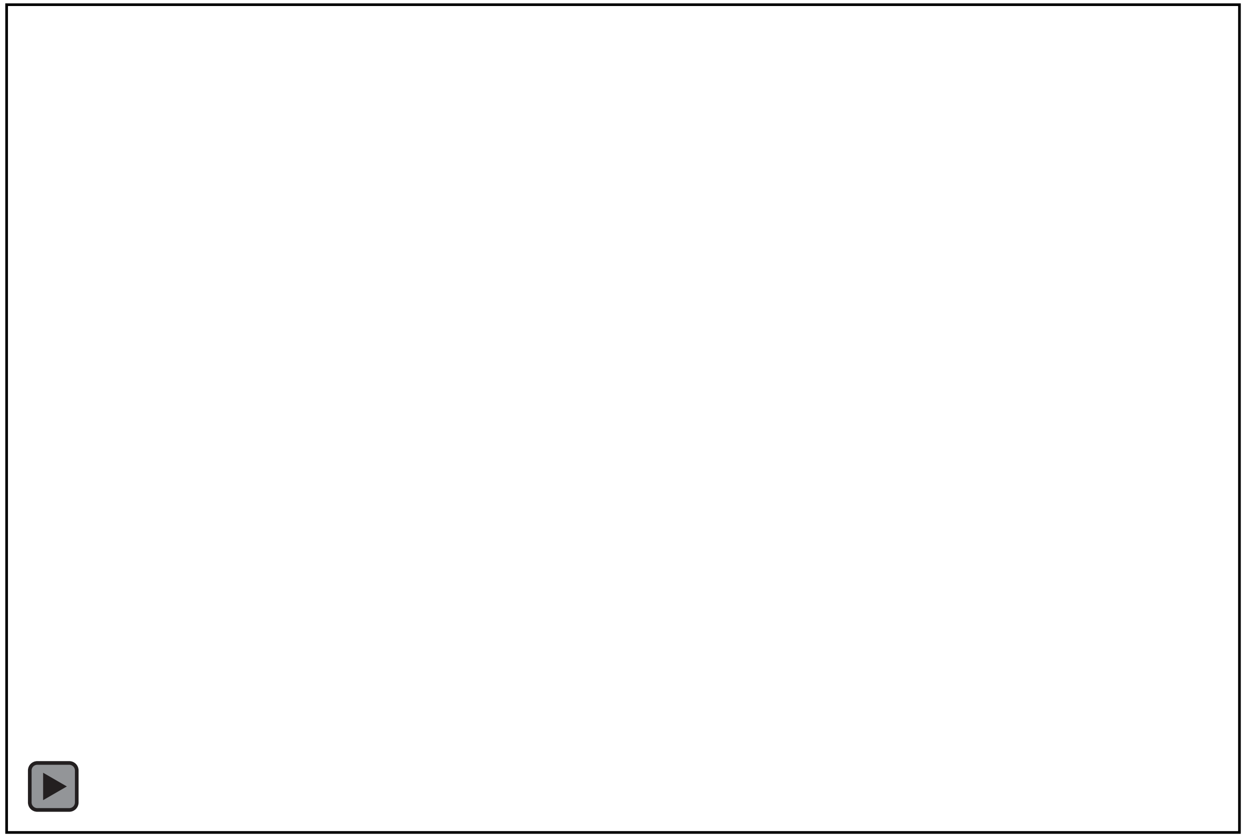
Courtesy of Peter Pilewskie

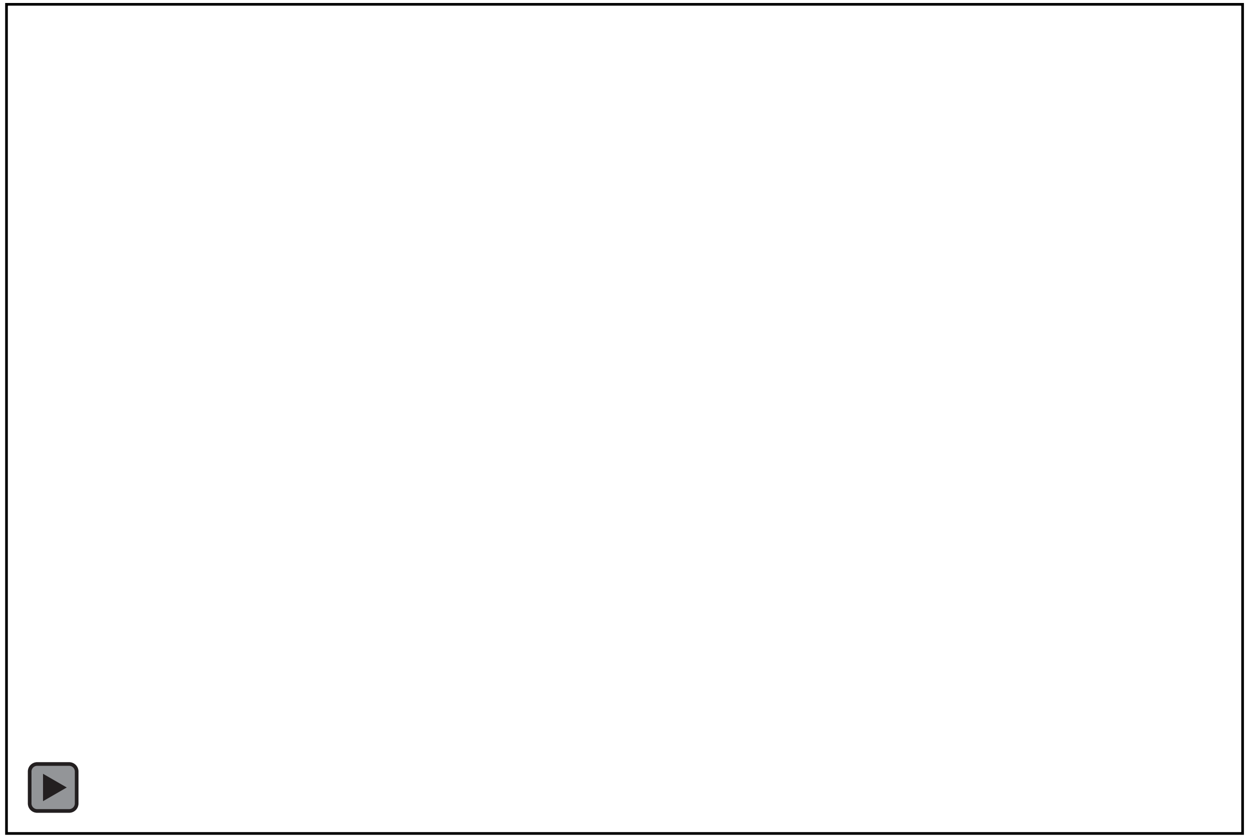
Flares cause temperature increases lower thermosphere (~ 120 km)





TEC for X-17 flare and X-6.2 flare in WACCM

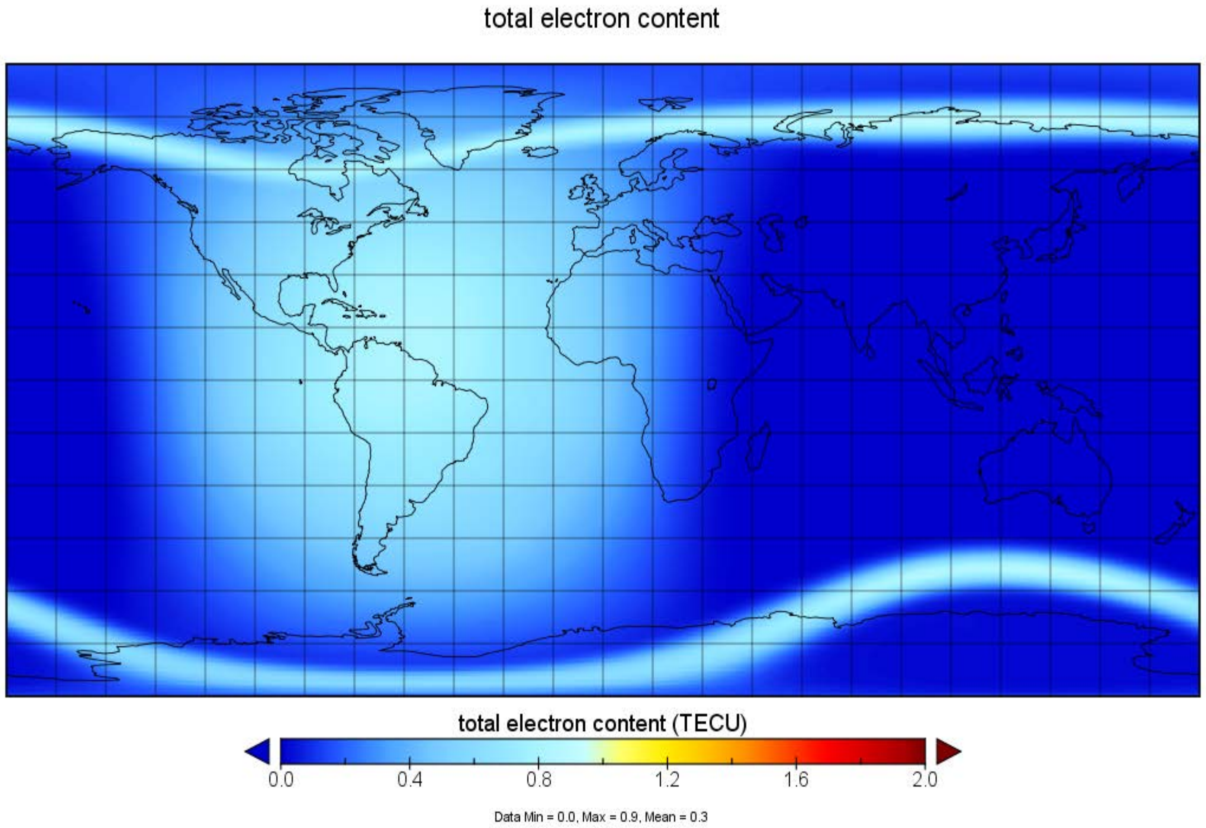




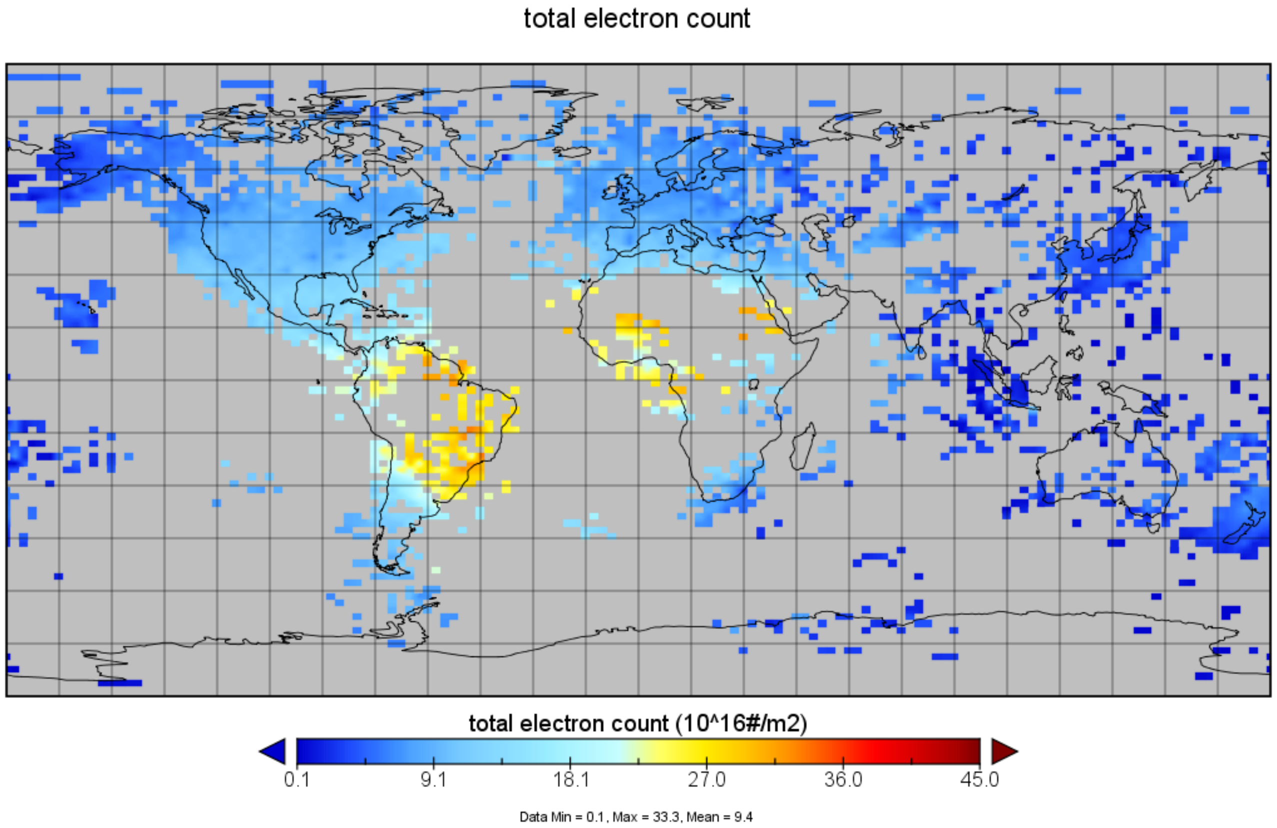
- Larger immediate TEC increase but brief
- Smaller immediate TEC increase but longer

9-7 Flare (X-17)
16:00 UTC

WACCM

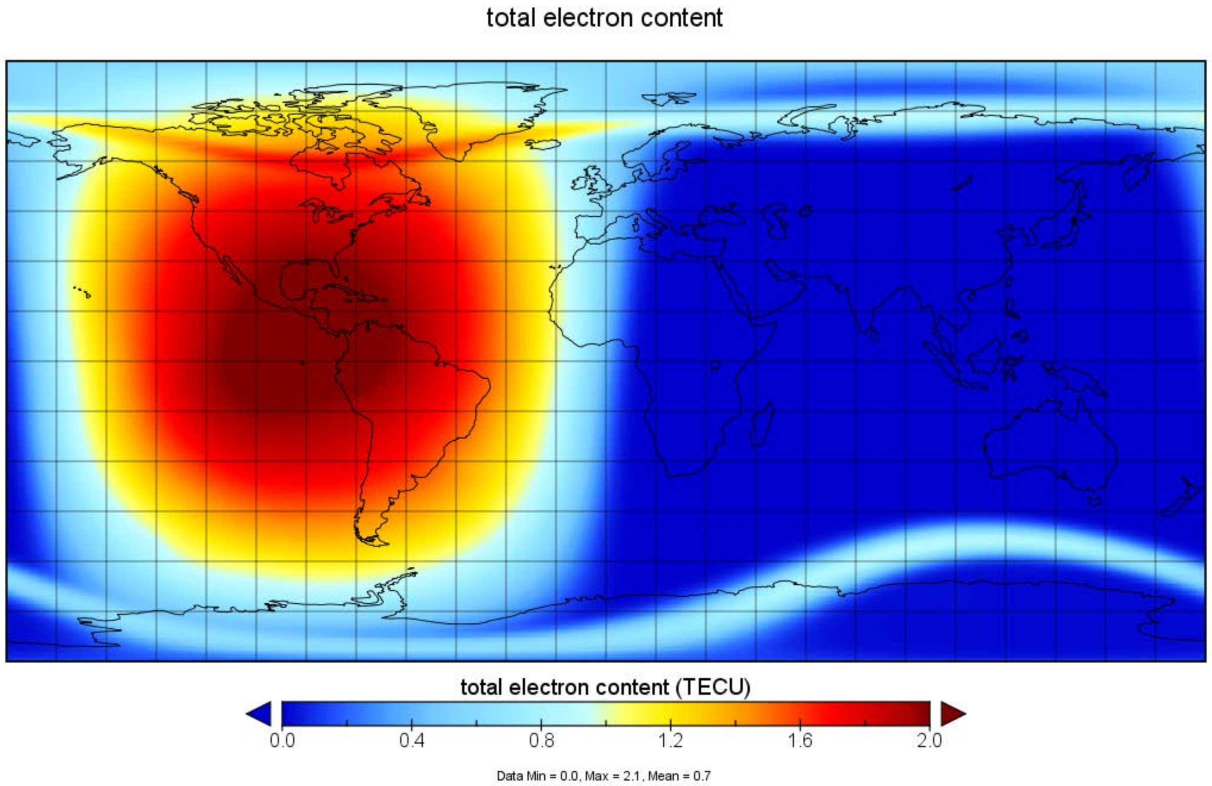


GPS



9-7 Flare (X-17)
18:00 UTC

WACCM



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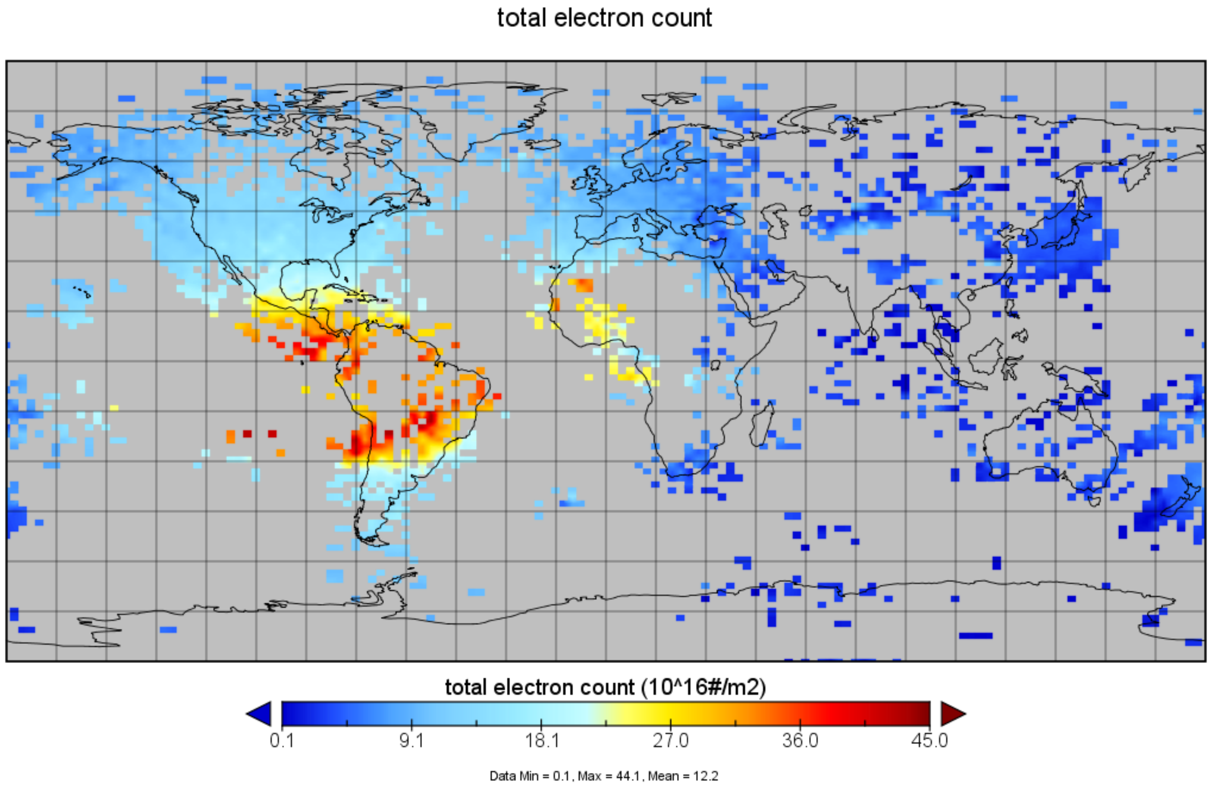
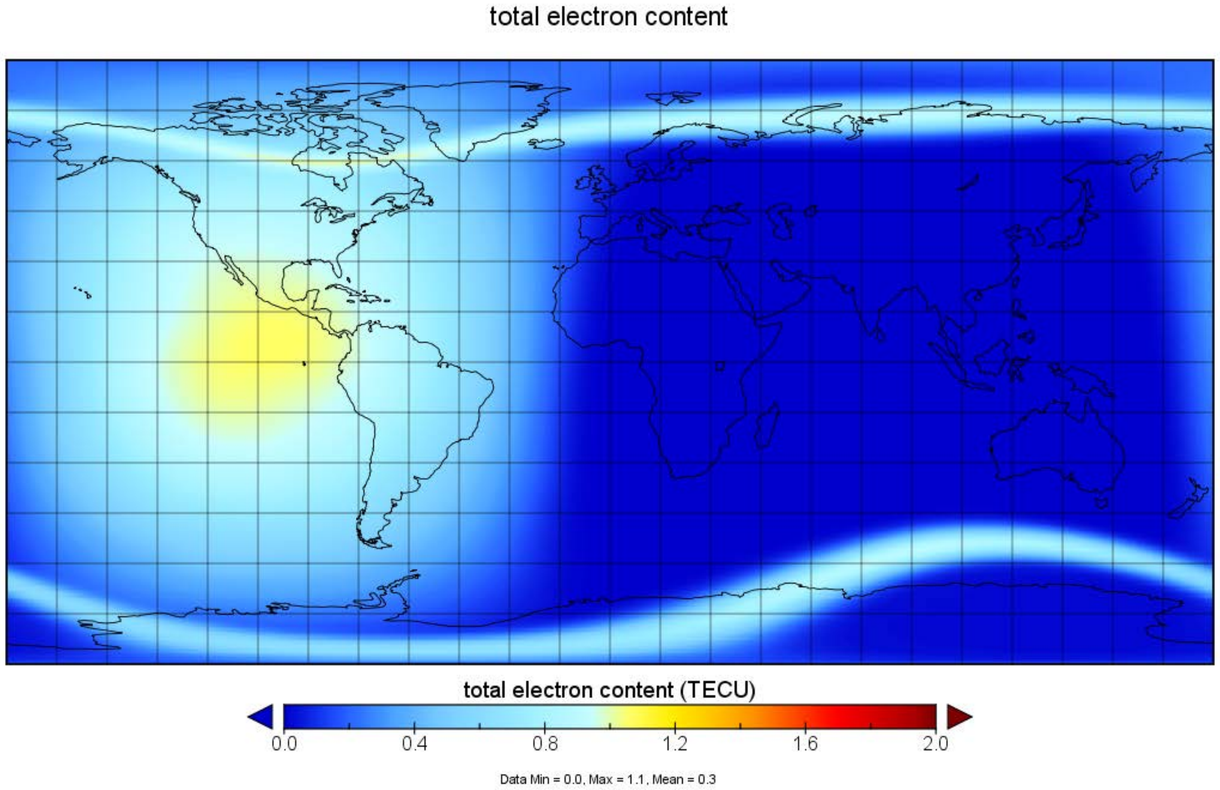
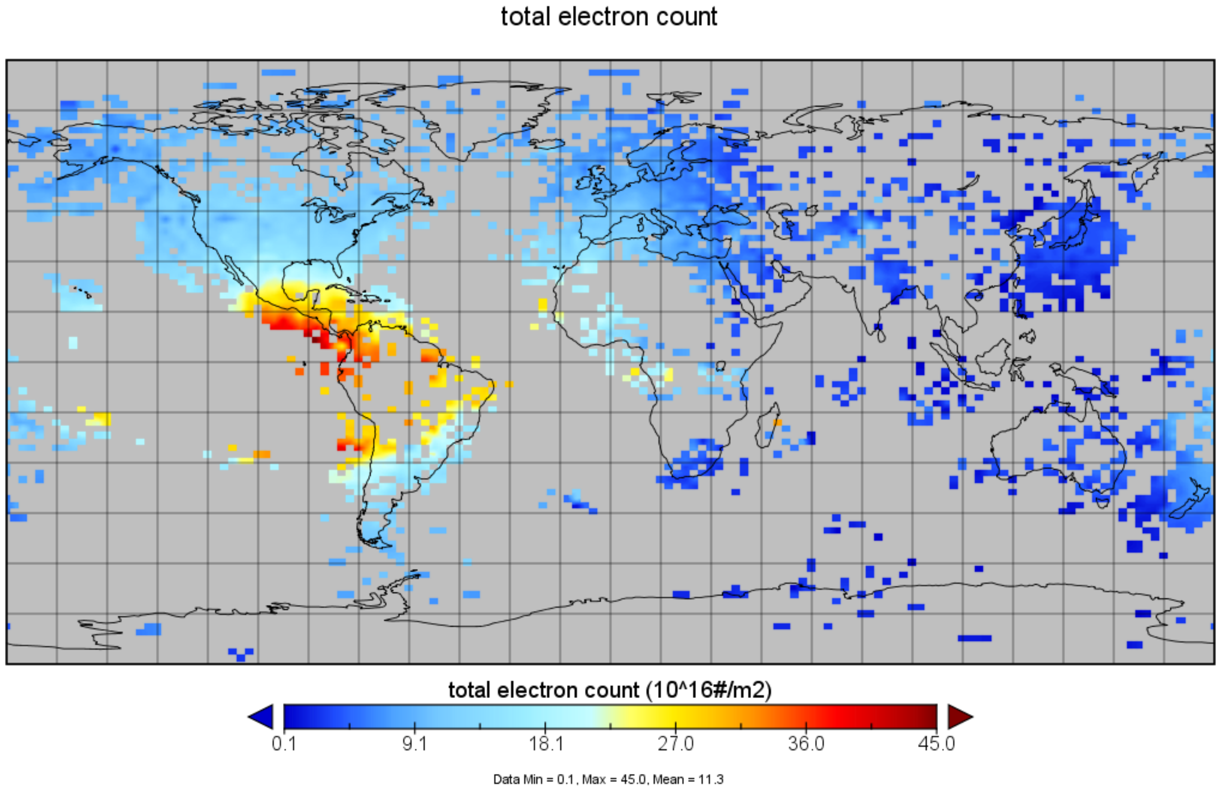


9-7 Flare (X-17)
19:00 UTC

WACCM

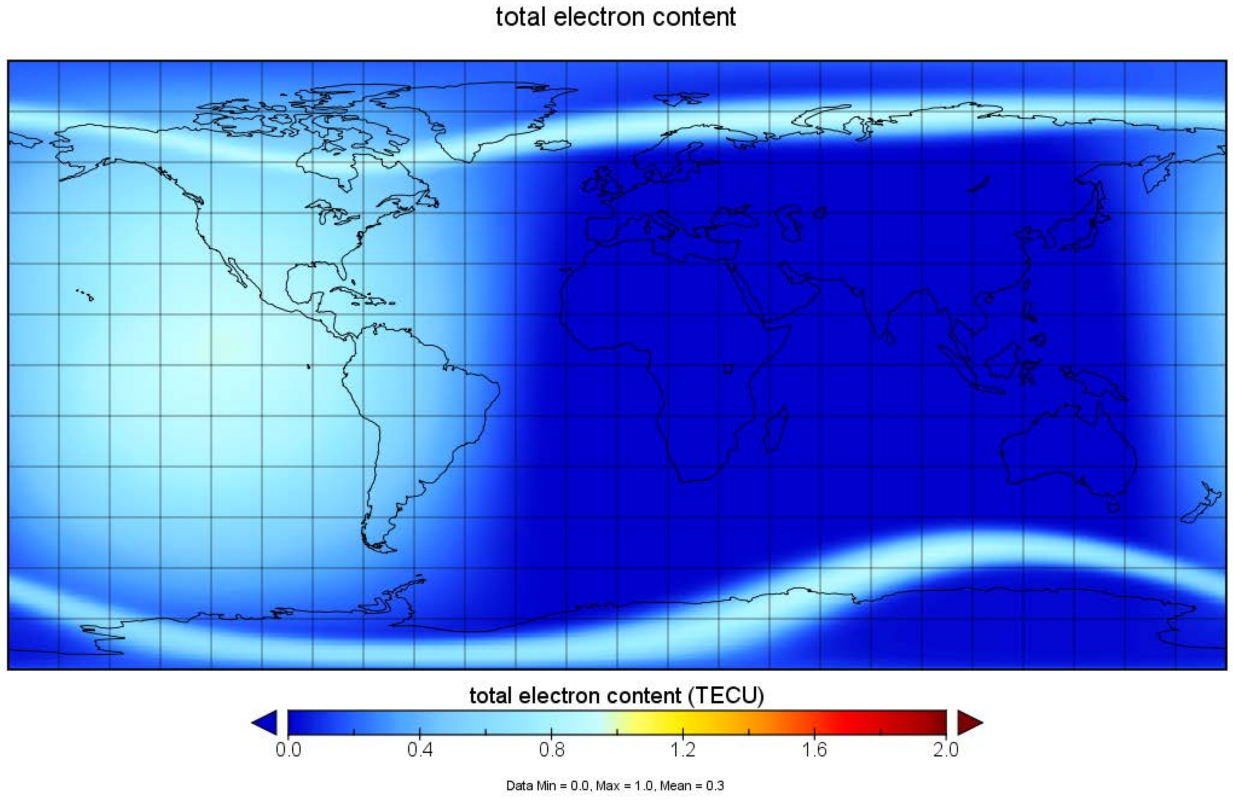


GPS

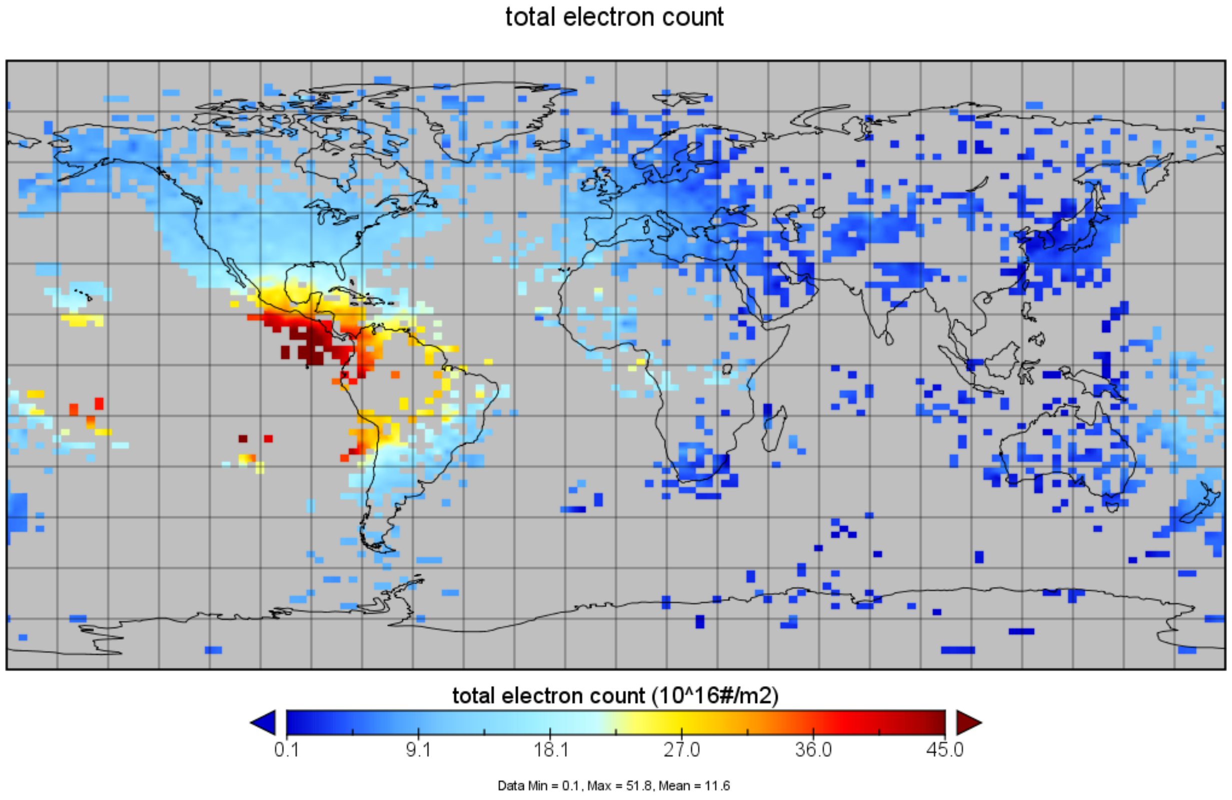


9-7 Flare (X-17)
20:00 UTC

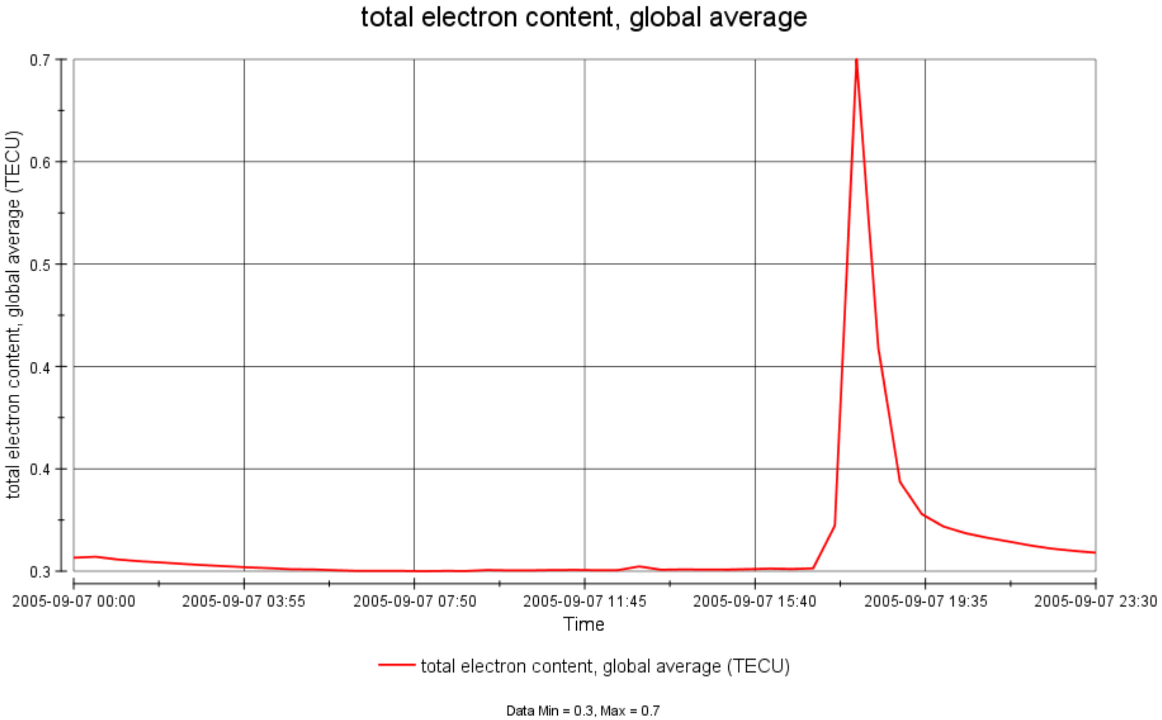
WACCM

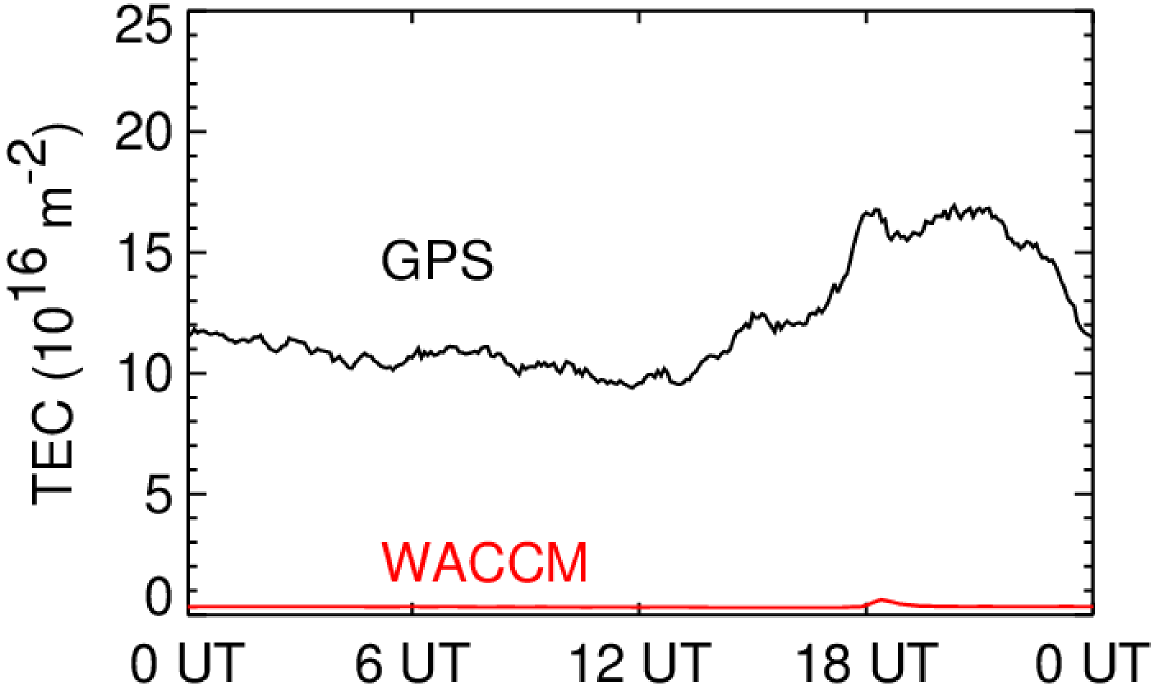


GPS



TEC from WACCM is only a fraction of GPS TEC



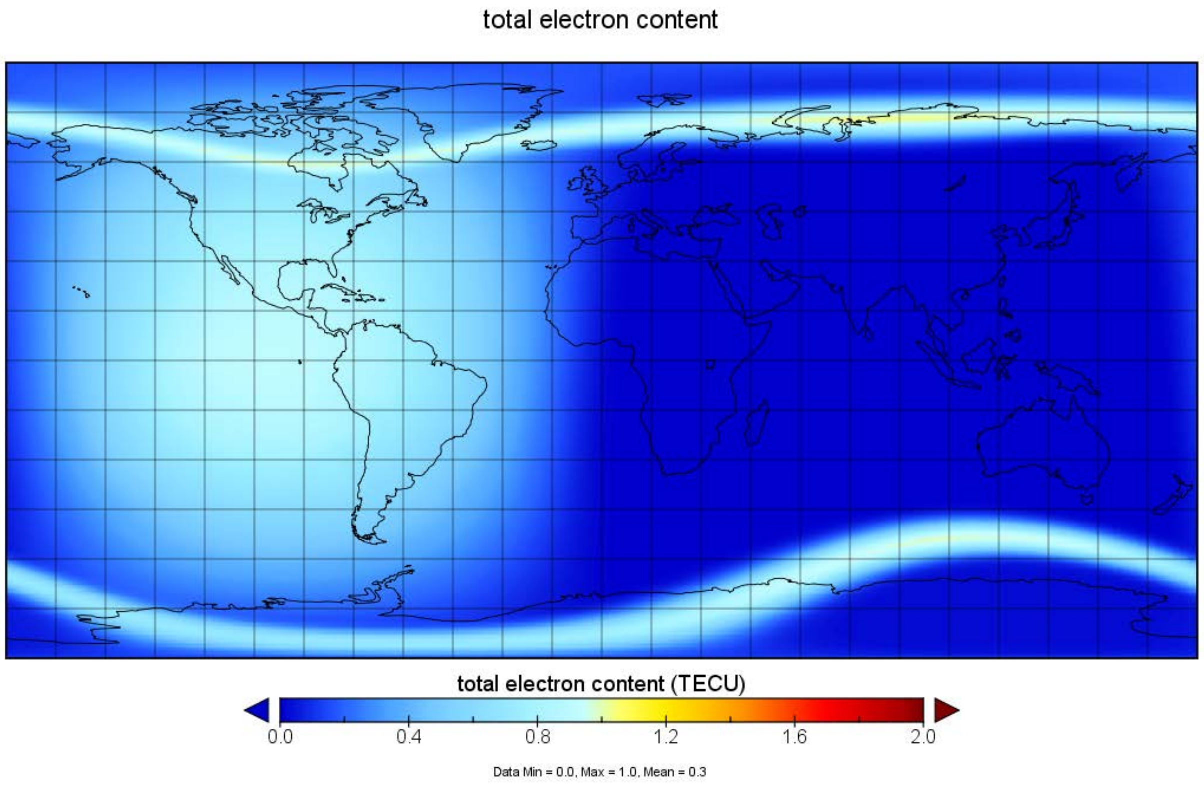


Δ .5 TECU

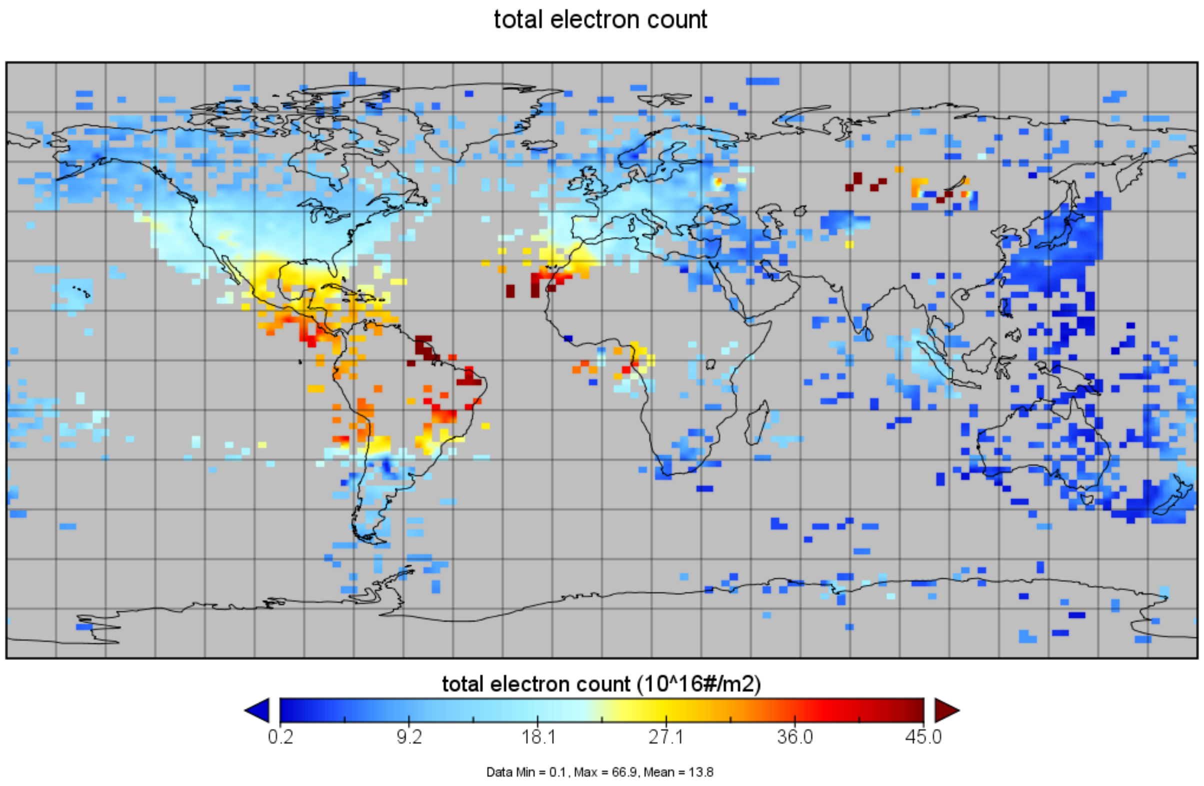
Δ 5 TECU

9-9 Flare (X-6.2)
18:30 UTC

WACCM

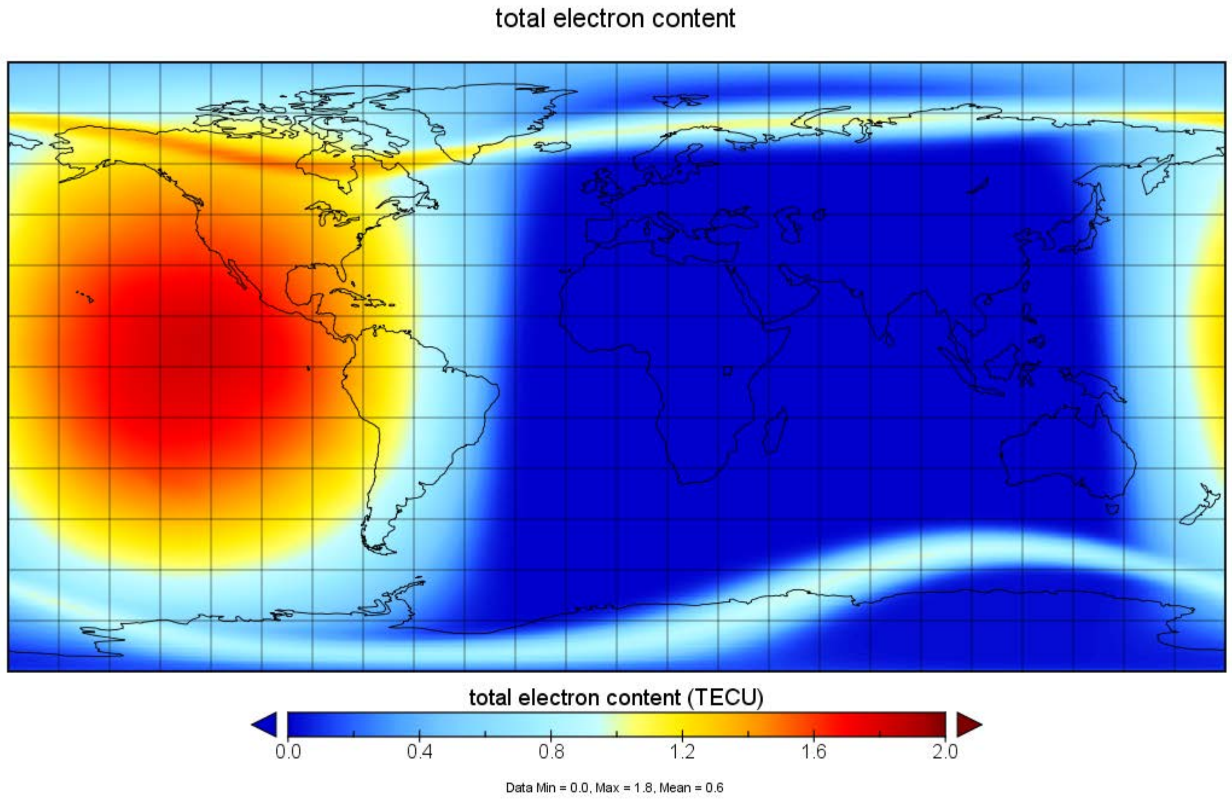


GPS

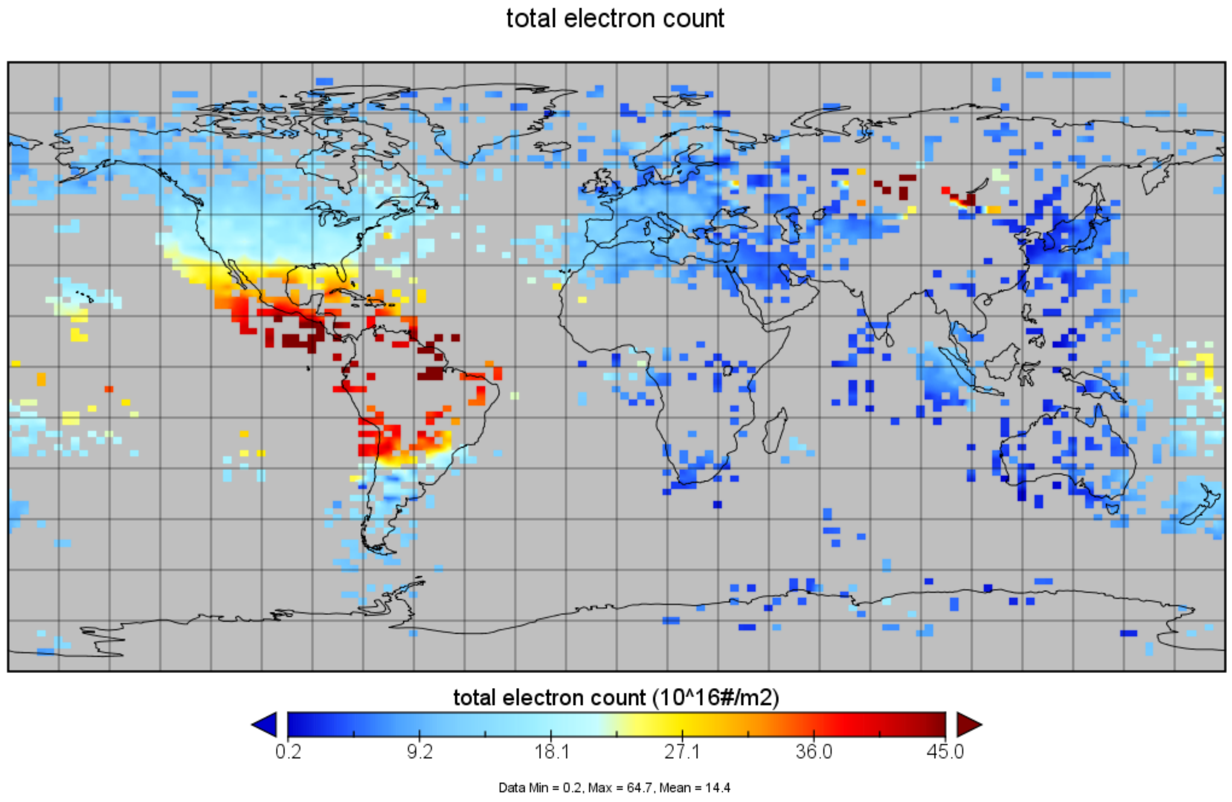


9-9 Flare (X-6.2)
20:30 UTC

WACCM

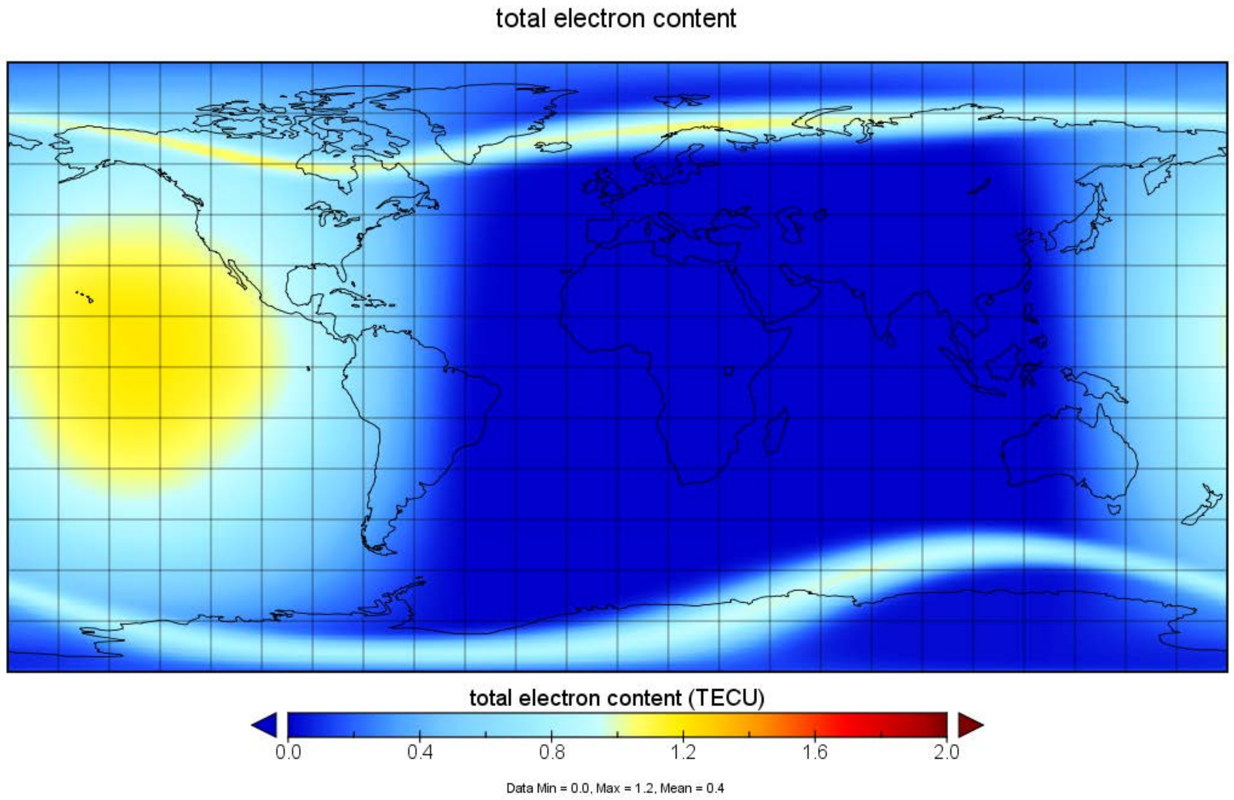


GPS

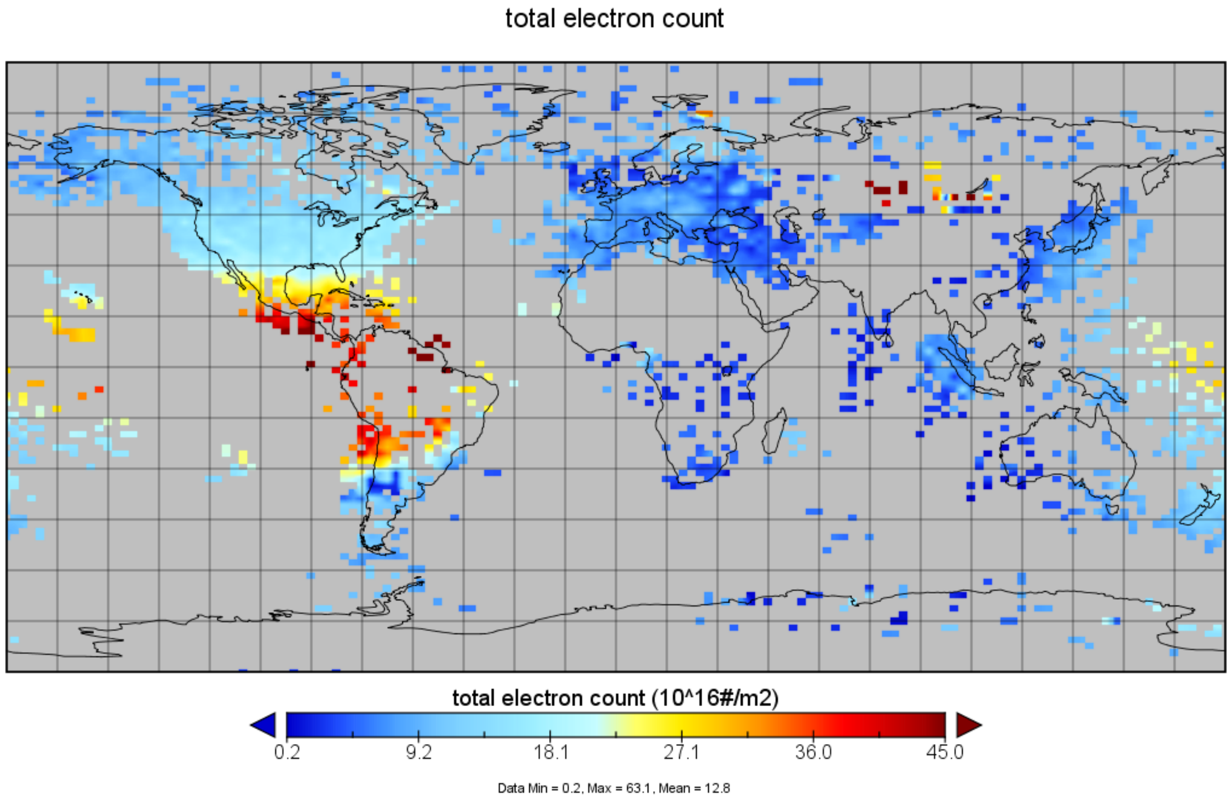


9-9 Flare (X-6.2)
21:30 UTC

WACCM

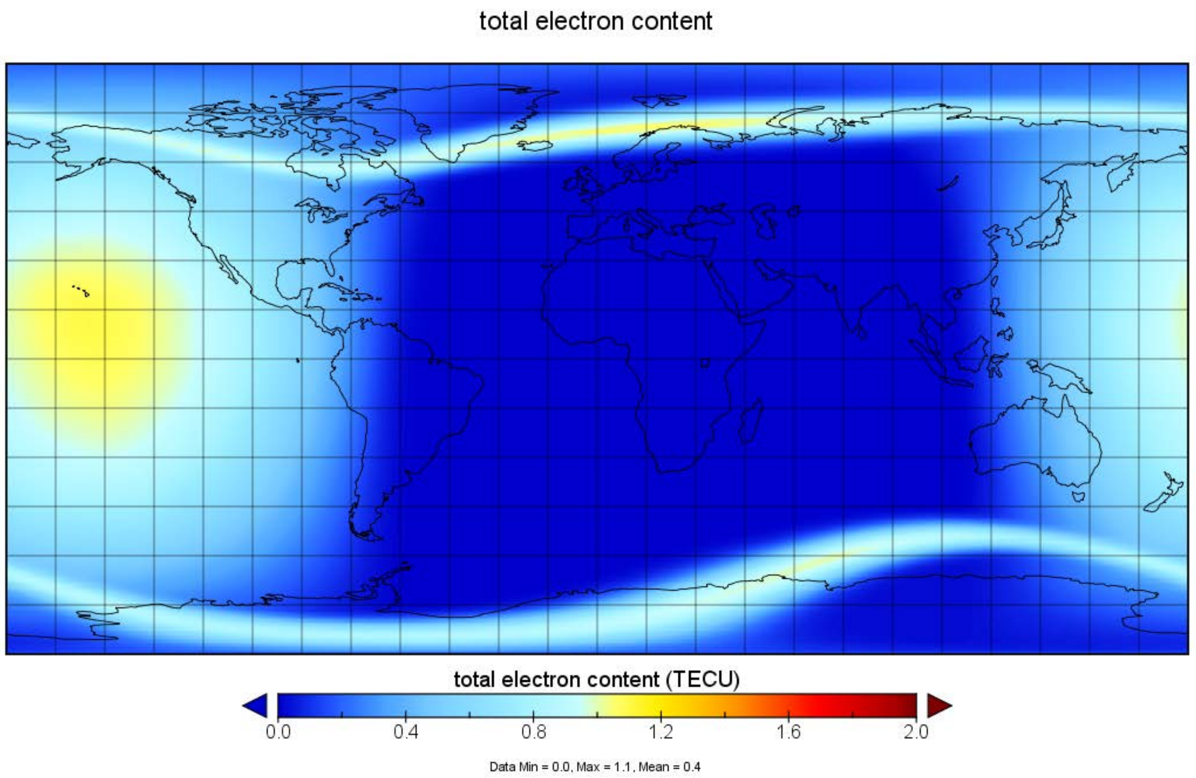


GPS

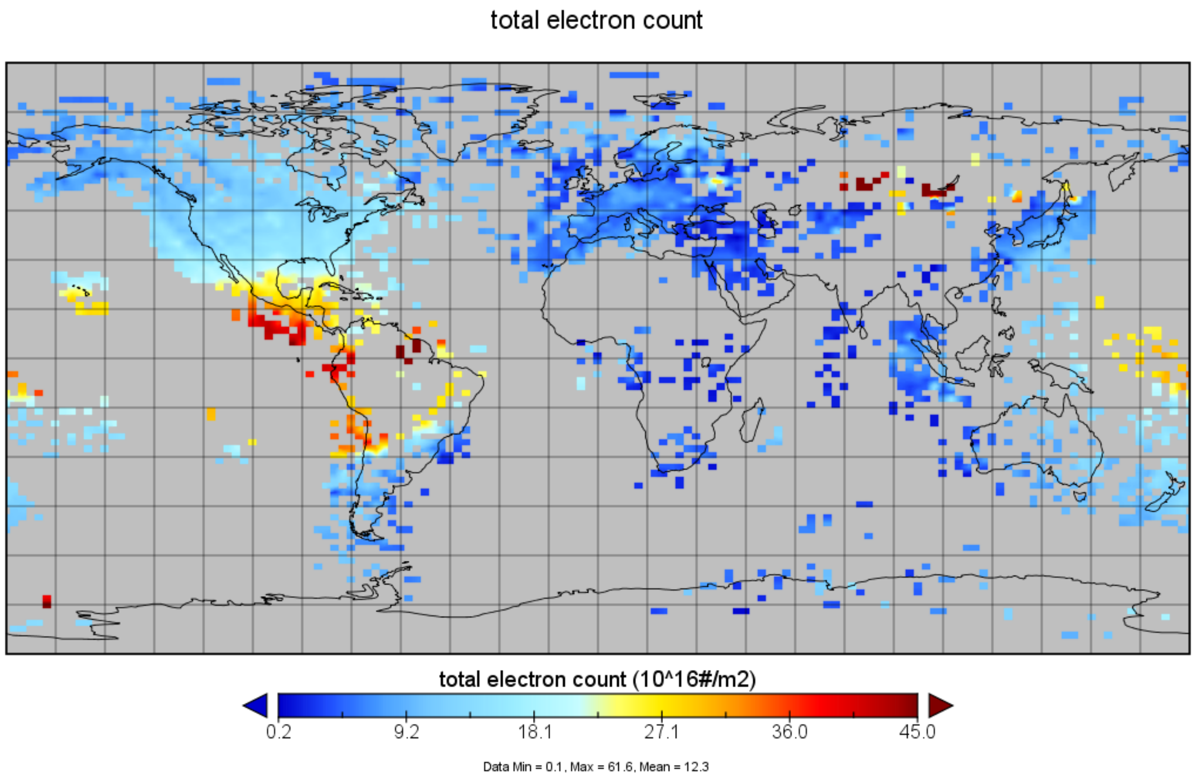


9-9 Flare (X-6.2)
22:30 UTC

WACCM



GPS



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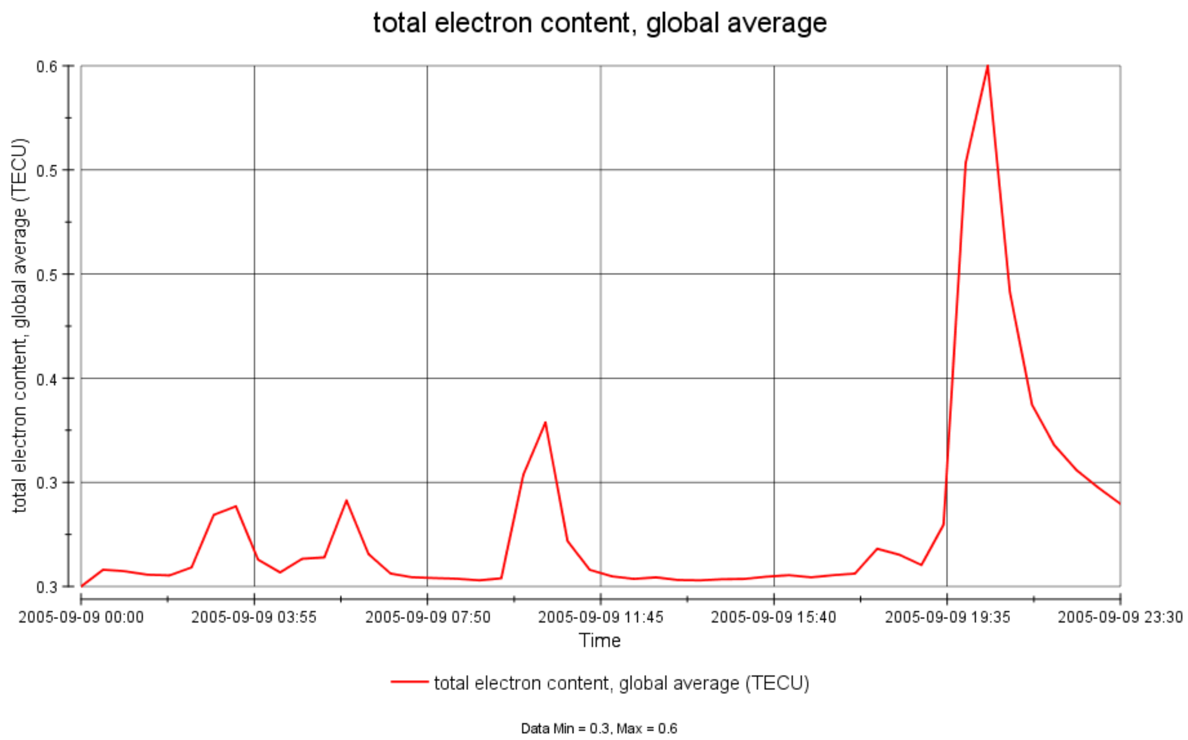
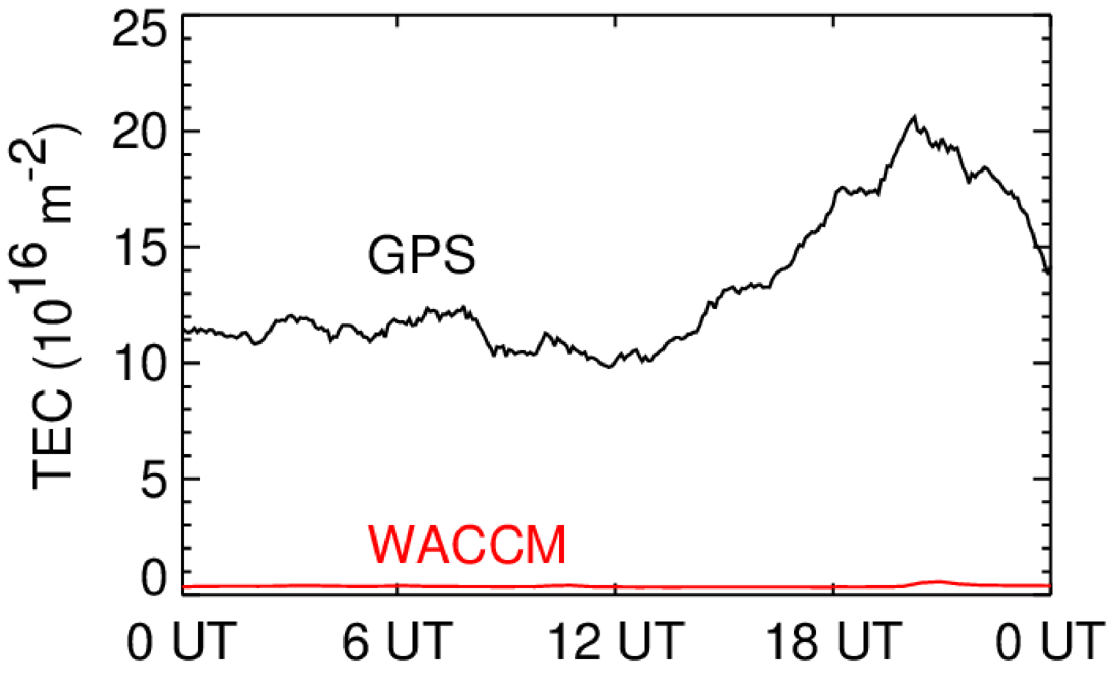
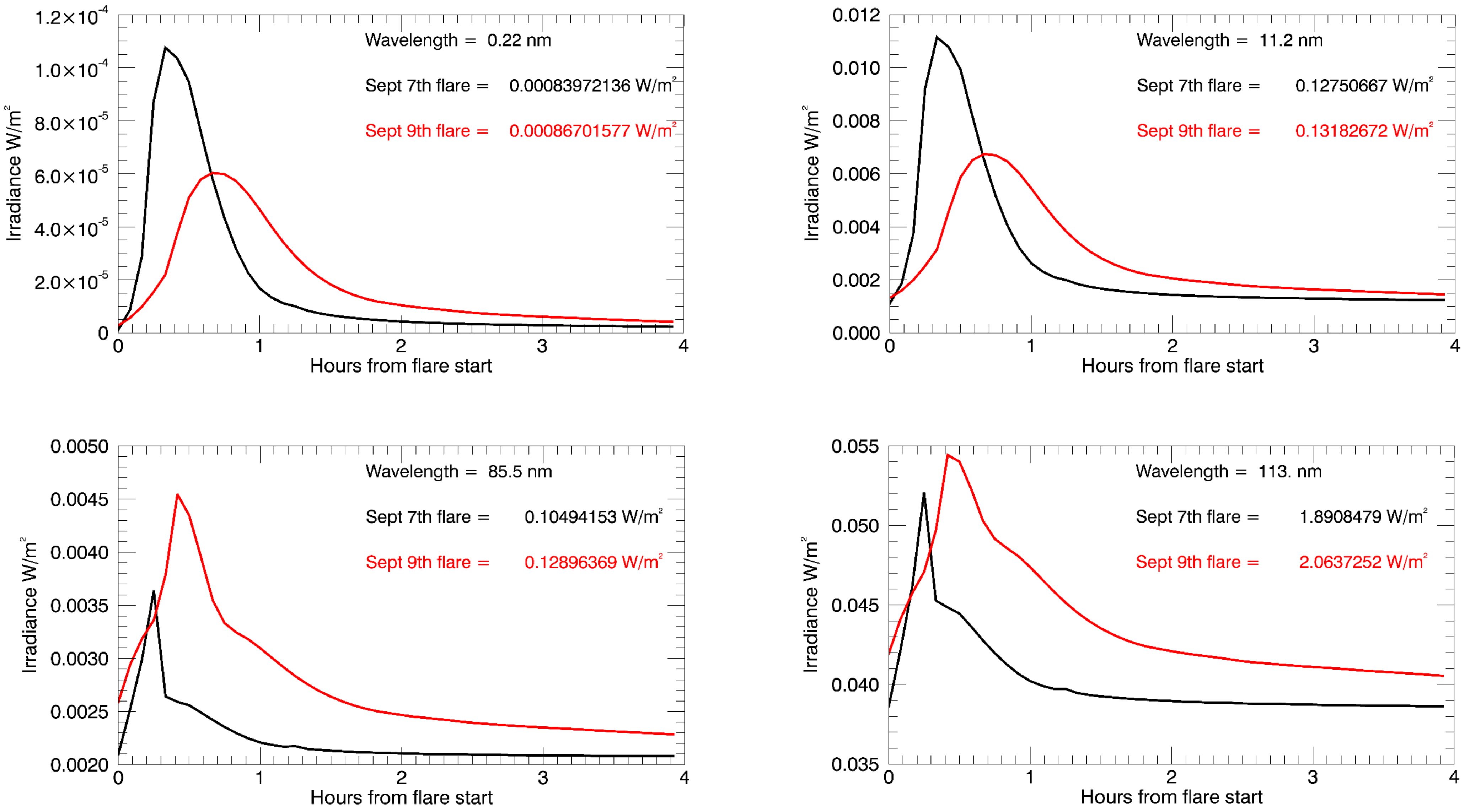




Δ .4 TECU

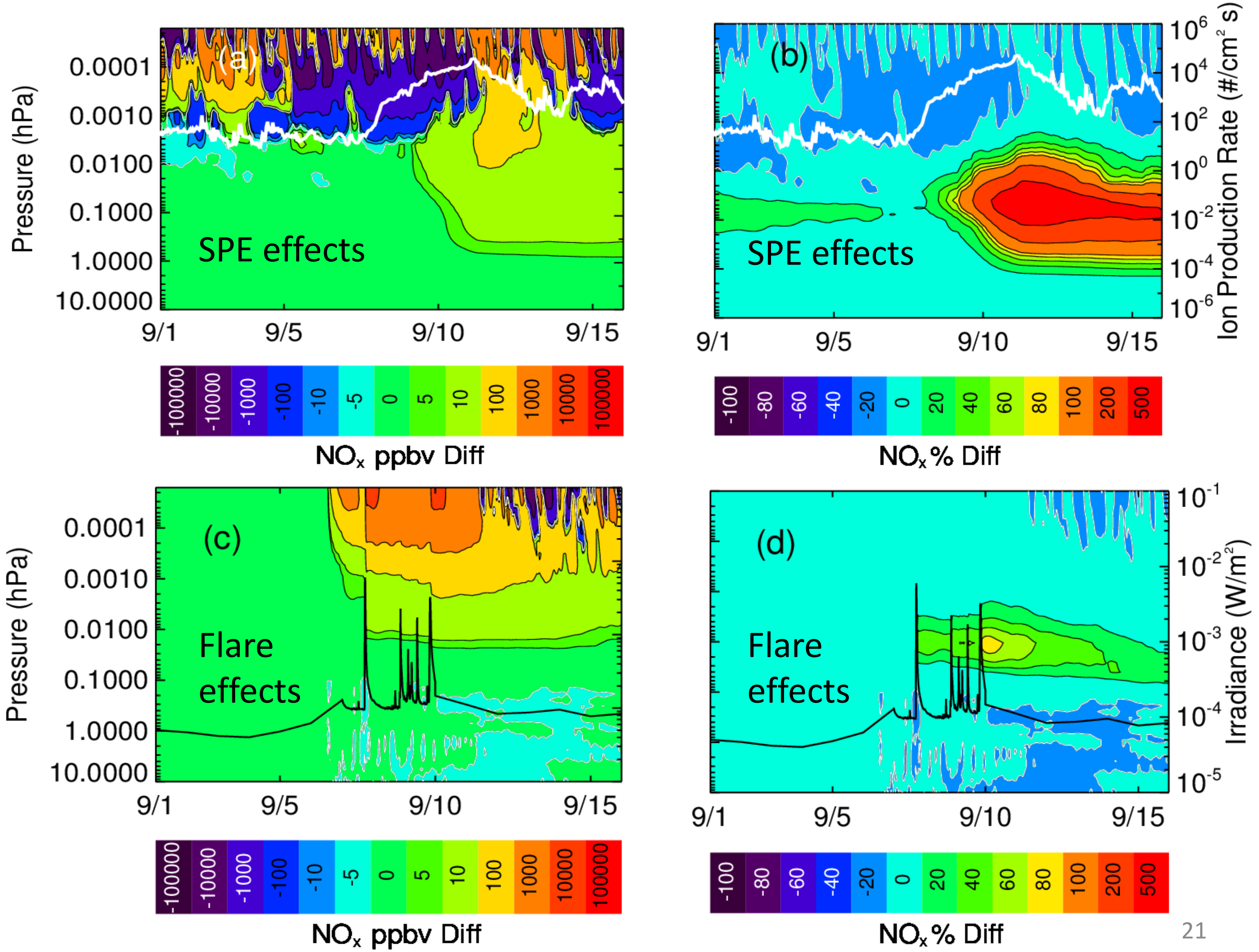
Δ 6-7 TECU

Spectral variability has a large impact on WACCM results



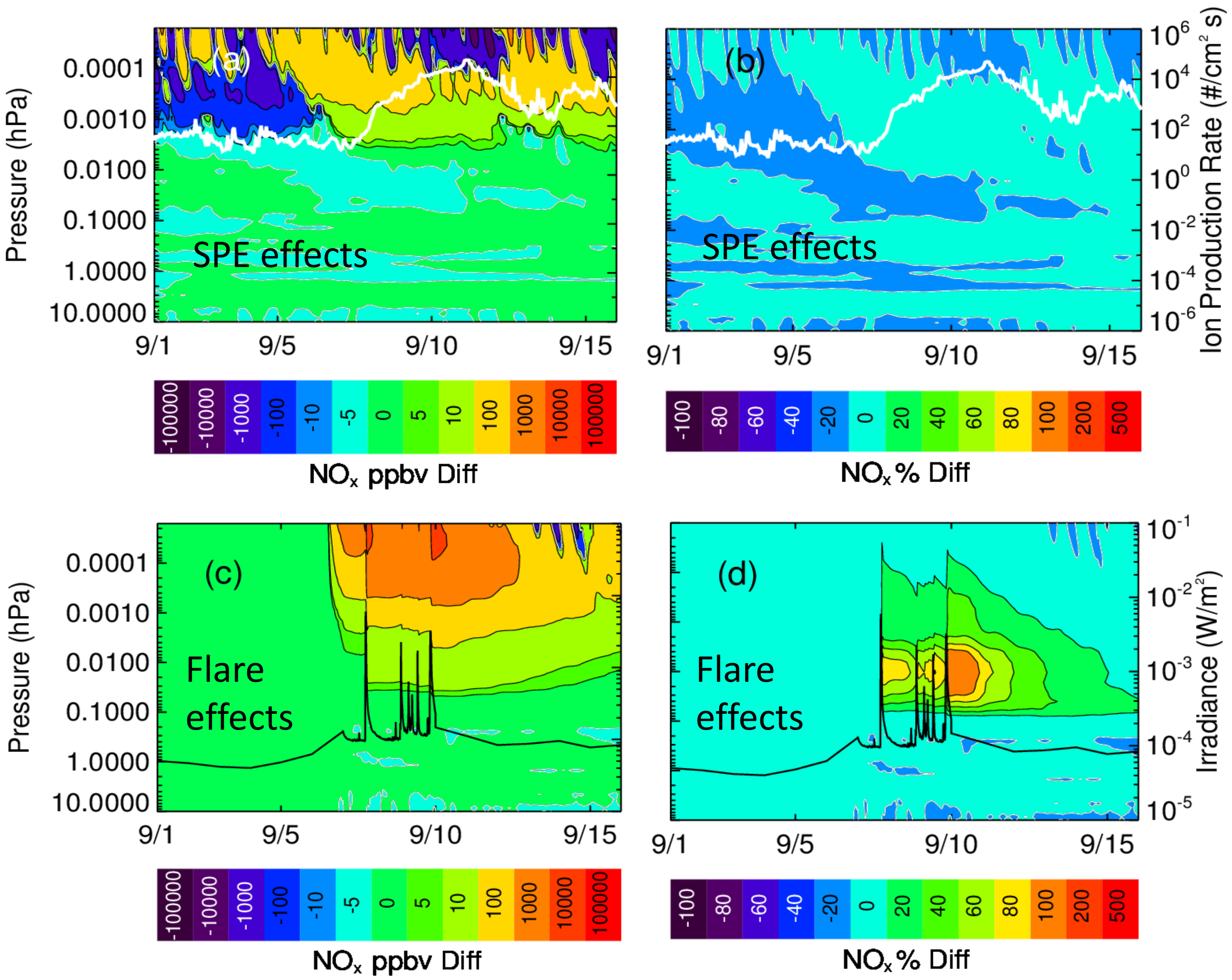
Odd nitrogen production from SPEs and solar flares in Arctic

- 60N – 90N average
- Flare produces NO_x at higher altitudes
- More SPE NO_x in middle atmosphere
  - ❑ SPE: 500%
  - ❑ Flare: 80%

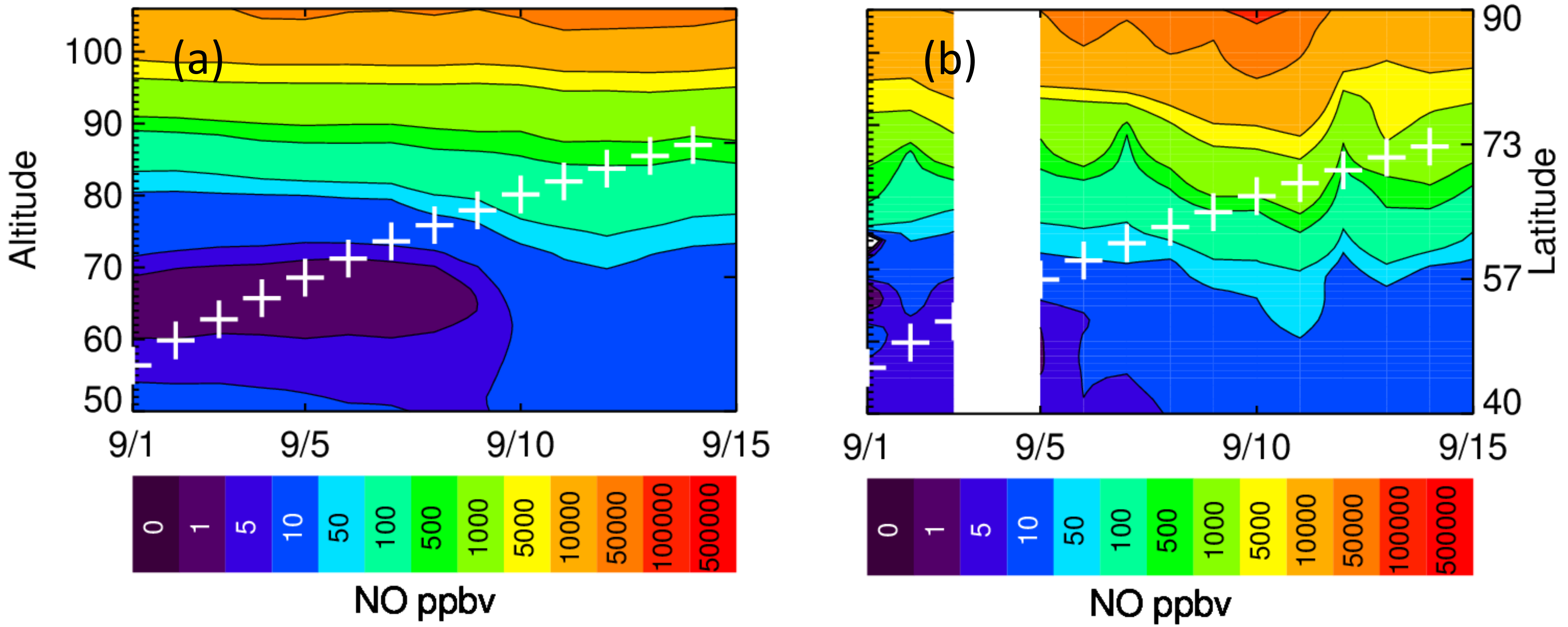


Odd nitrogen production from SPEs and solar flares at equator

- 30S – 30N average
- No response from SPEs
- Flare response of 100% larger than Arctic



WACCM NO compares reasonably well with ACE-FTS



Summary and conclusions

- WACCM shows temperature variation of as much as 12 K immediately after the flare

- Spectral variability of flare plays a large role on atmospheric effects in WACCM

    - September 7th flare greater impact in WACCM TEC yet smaller impact in the GPS data
    - September 9th flare lesser impact in WACCM yet TEC greater impact in GPS data
    - Odd nitrogen shows the opposite

- Odd nitrogen production is dominated at polar regions by SPEs and by flares at equatorial, sunlit areas

- To get full flare effects from the EUV spectrum, WACCM-X will be needed