Deep ionospheric hole caused by sudden stratospheric warming at night

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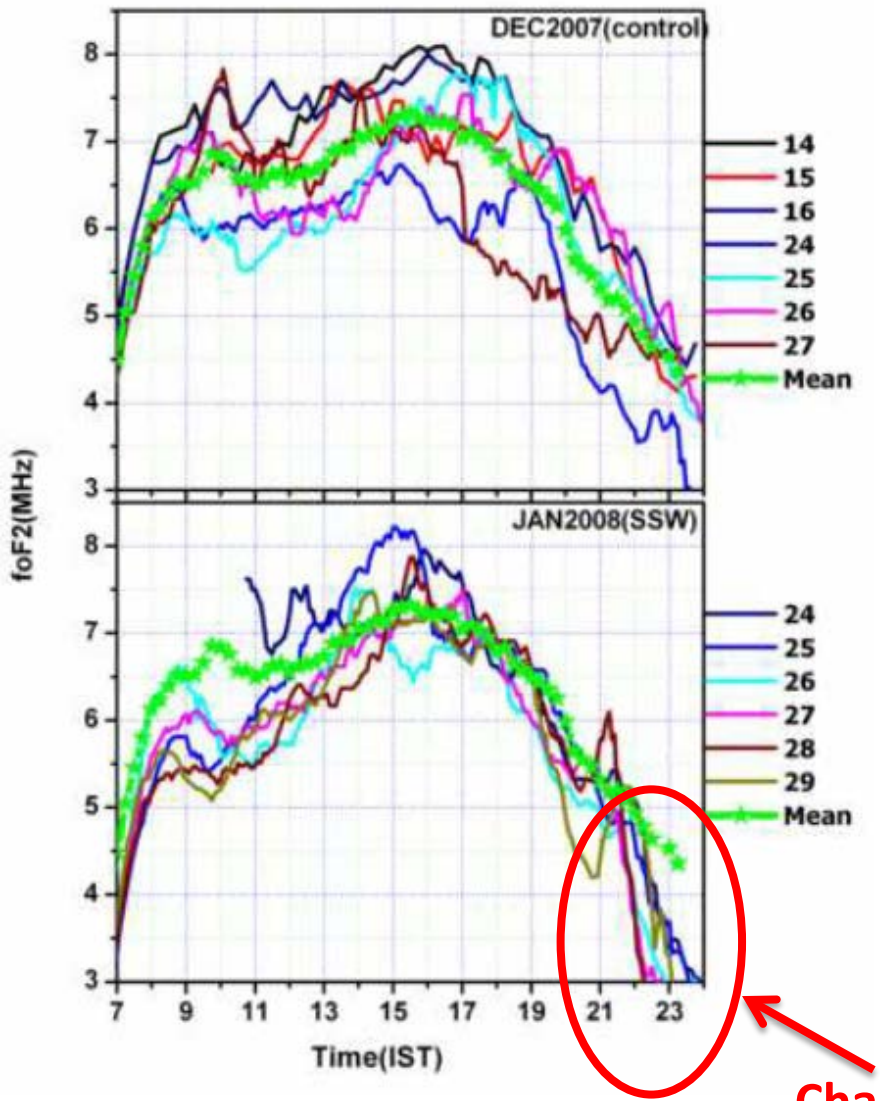
Background and motivation

- Current studies of ionospheric effects during SSW focused on daytime variations only
- Nighttime anomalies are not discussed
- Are there any significant changes after the sunset?

Evidence of ionospheric disturbances during SSW in post-sunset hours



Sumod et al., 2012

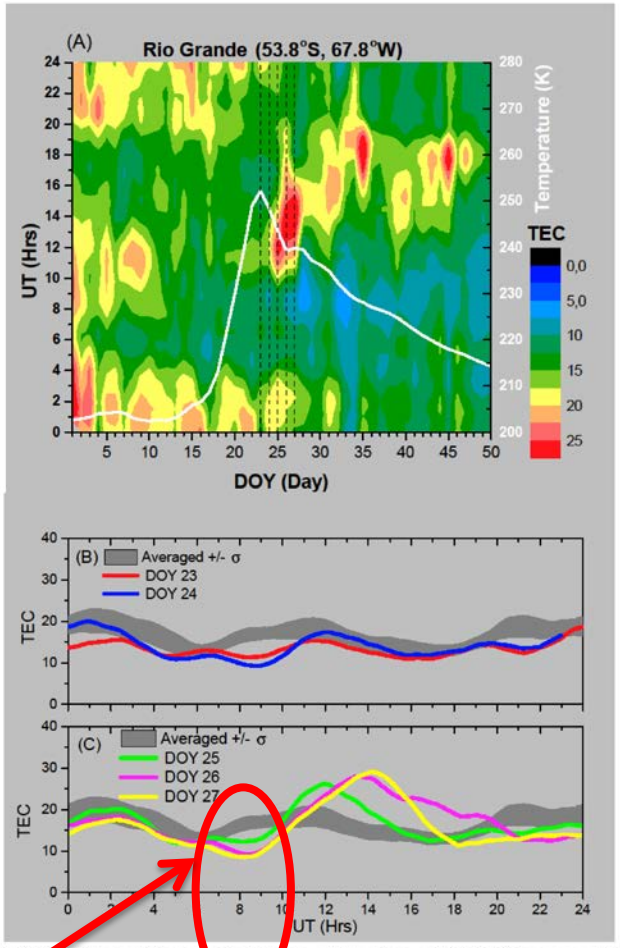


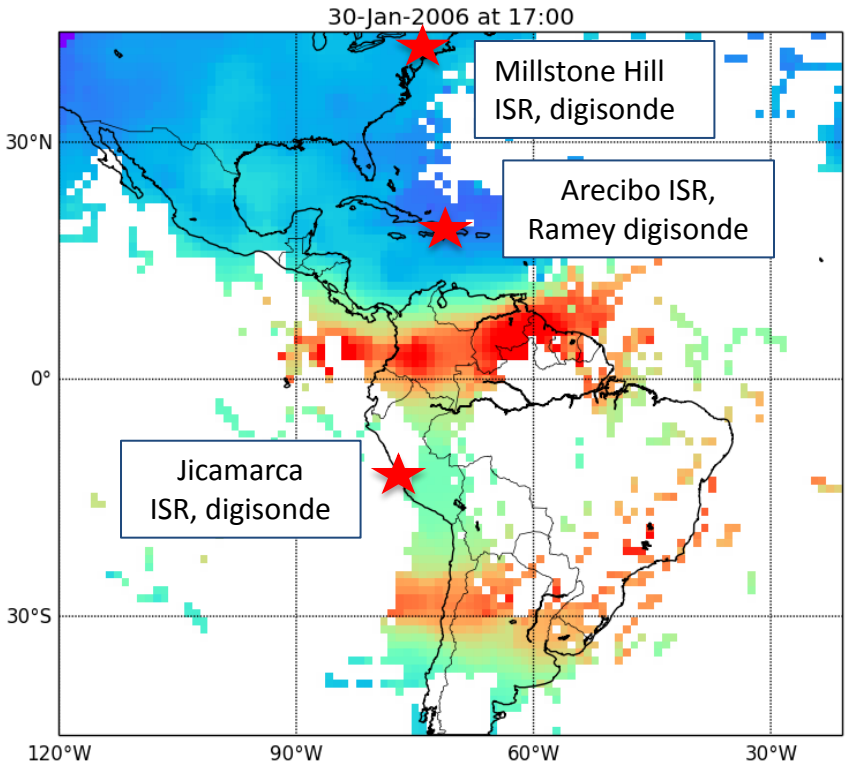
Figure 8. (A) TEC variations with UT as a function of DOY (January-February,

Fagundes et al., 2015, subm.

Changes at night

Data used

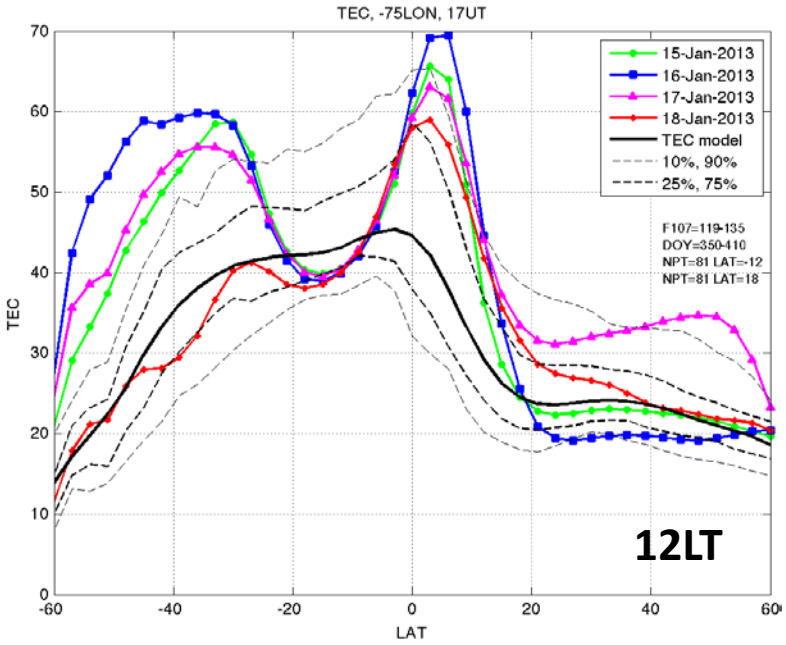
- GPS TEC – 2000-2014, American sector, 75°W
- Digisondes:
  - Jicamarca, 1993-2014
  - Ramey, 1999-2014 (without 2008-2010)
  - Millstone Hill, 1997-2014
- Incoherent scatter radars:
  - Aresibo ISR, Jan 2013
  - Millstone Hill ISR, Jan 2013
- Nov 1 – Mar 31 data (150 days)

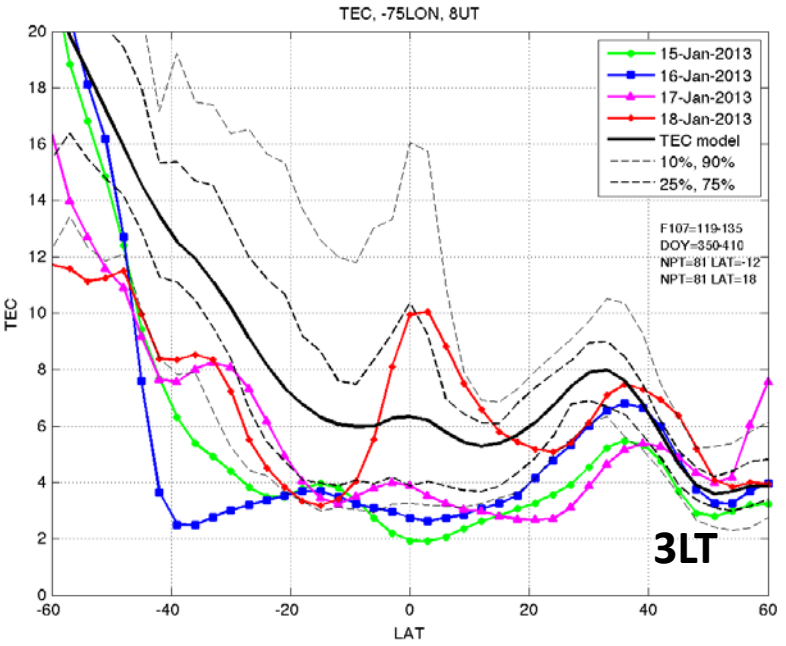


Leveraging multiple observational techniques:

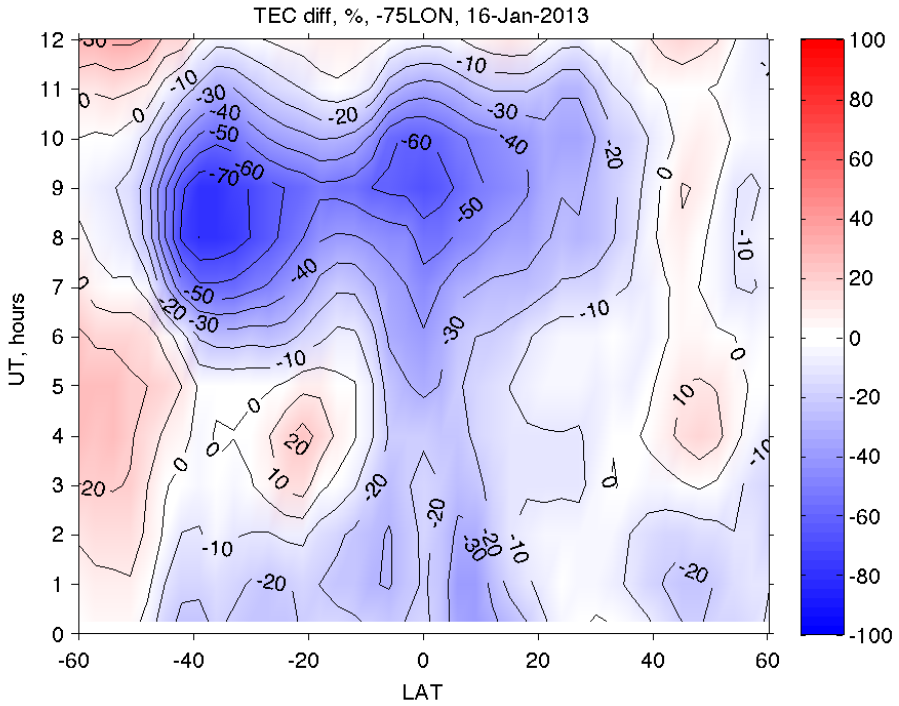
- GPS TEC – continuous coverage in latitude
- Ionosondes/digisondes – long historic records
- IS radars – multiple ionospheric parameters in a large altitude range

TEC at 75°W

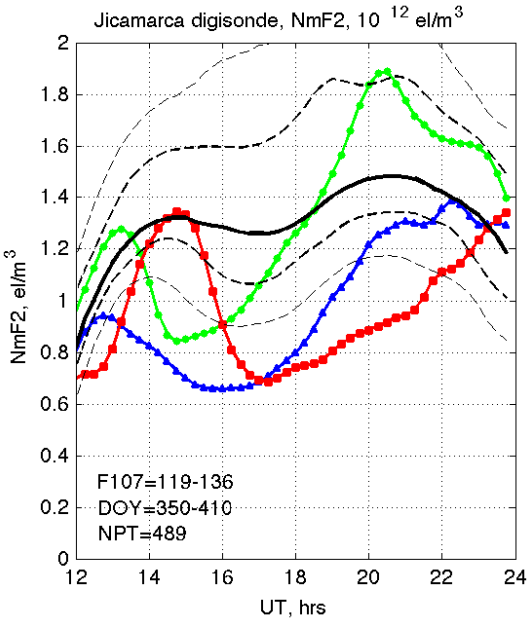


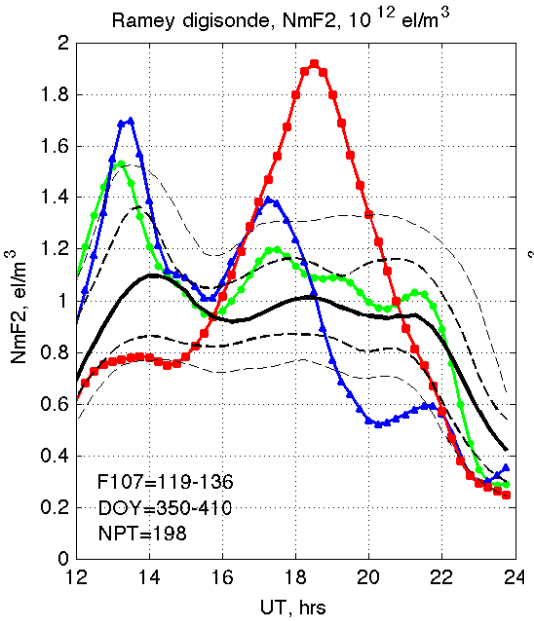


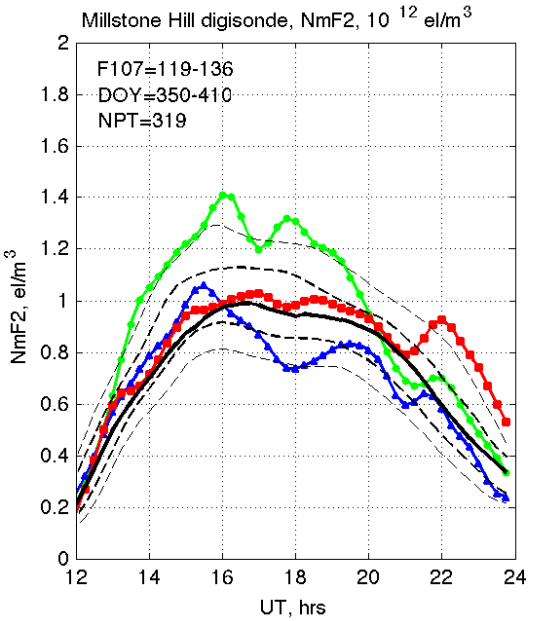
- During time periods of large variations in daytime TEC, nighttime TEC is strongly decreased
- Strongest decrease ~70%
- Extended from ~50°S to 40°N



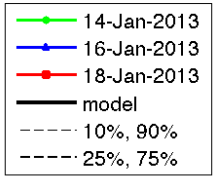
Digisonde data



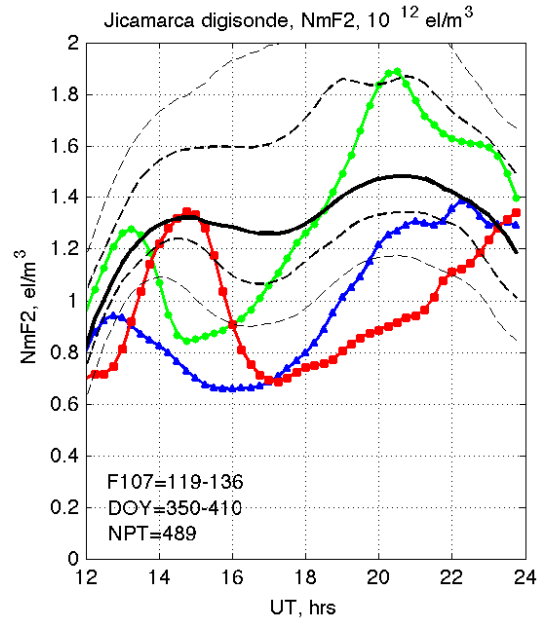


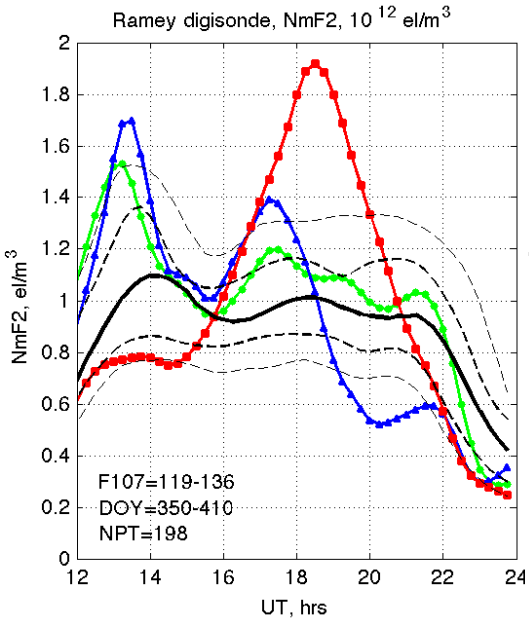


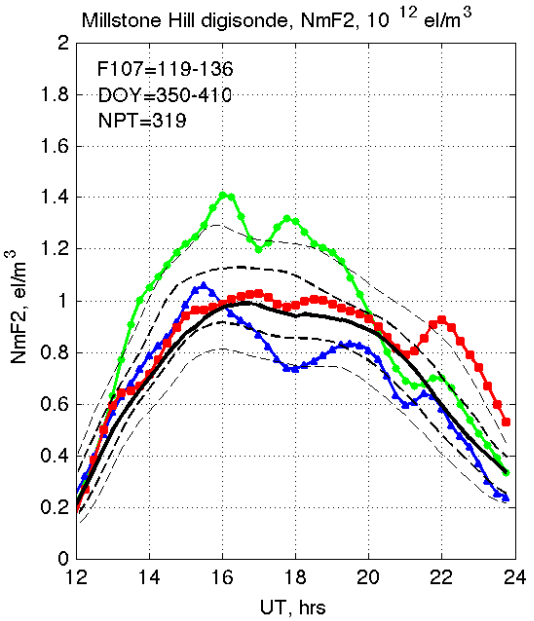
Daytime



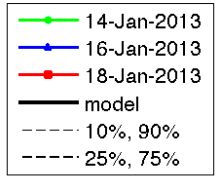
Digisonde data

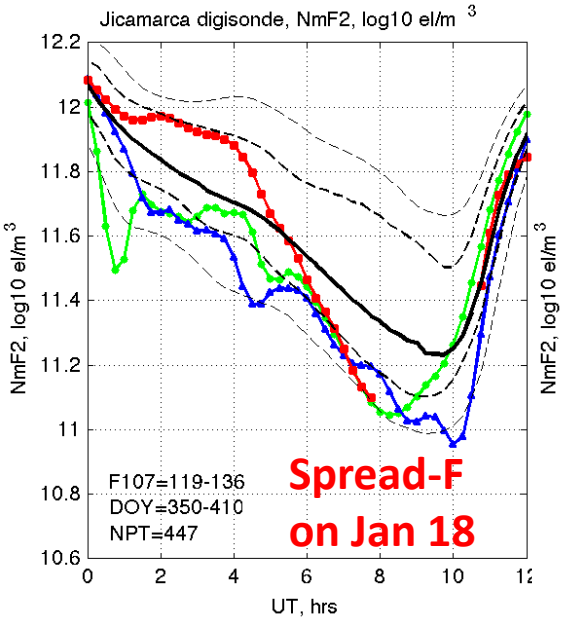


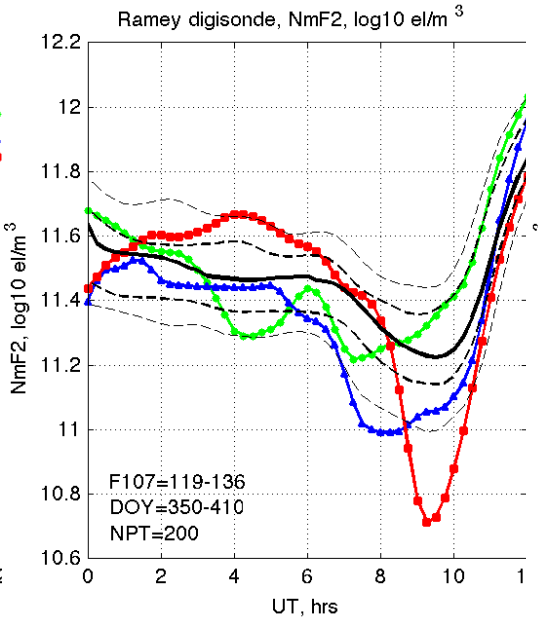


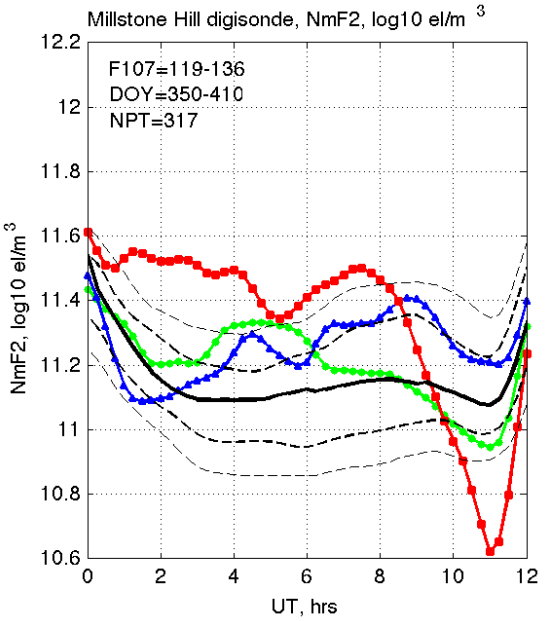


Daytime

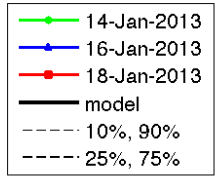




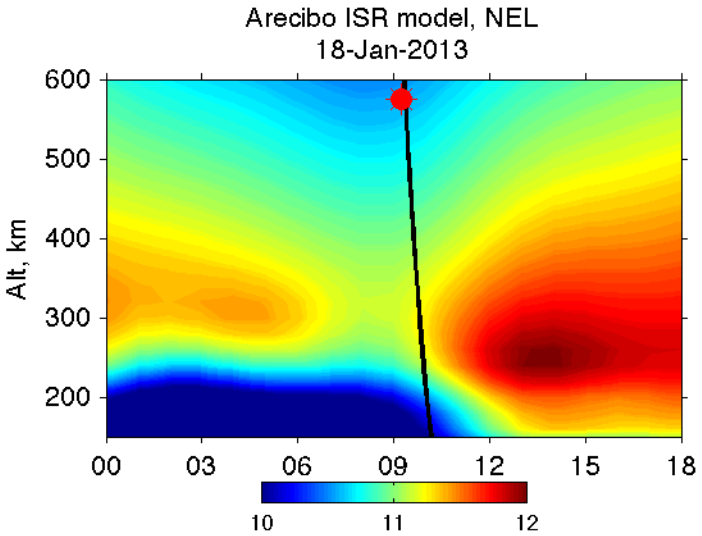


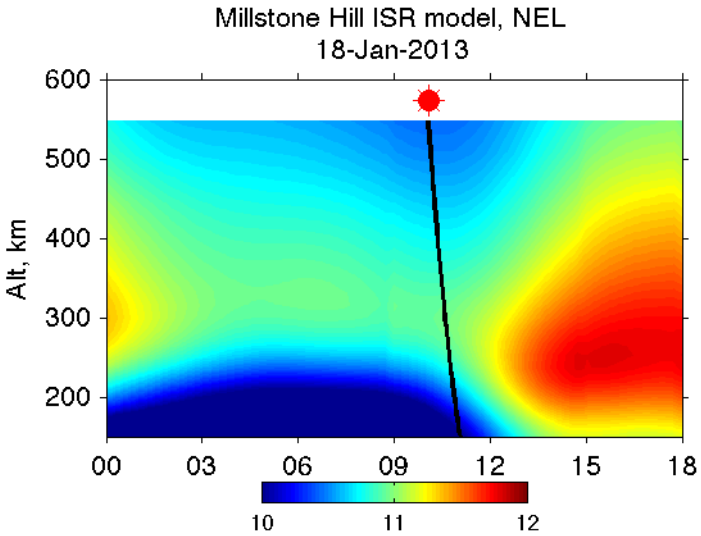


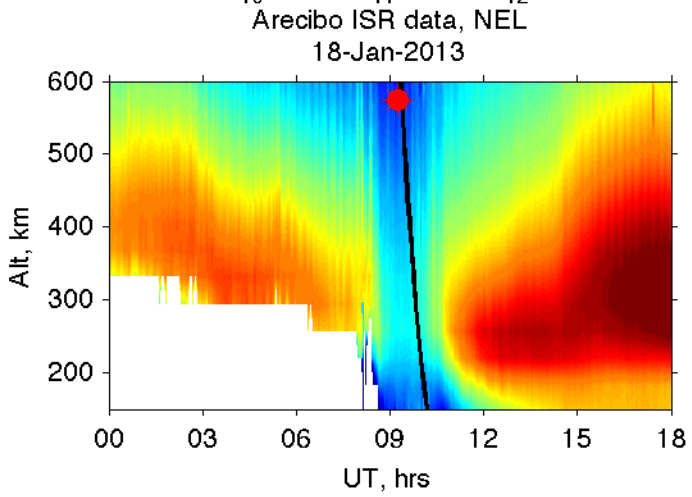
Nighttime

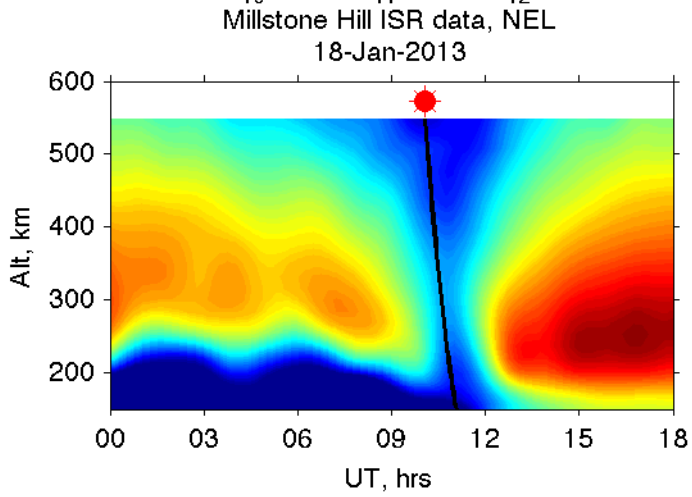


Incoherent scatter radars



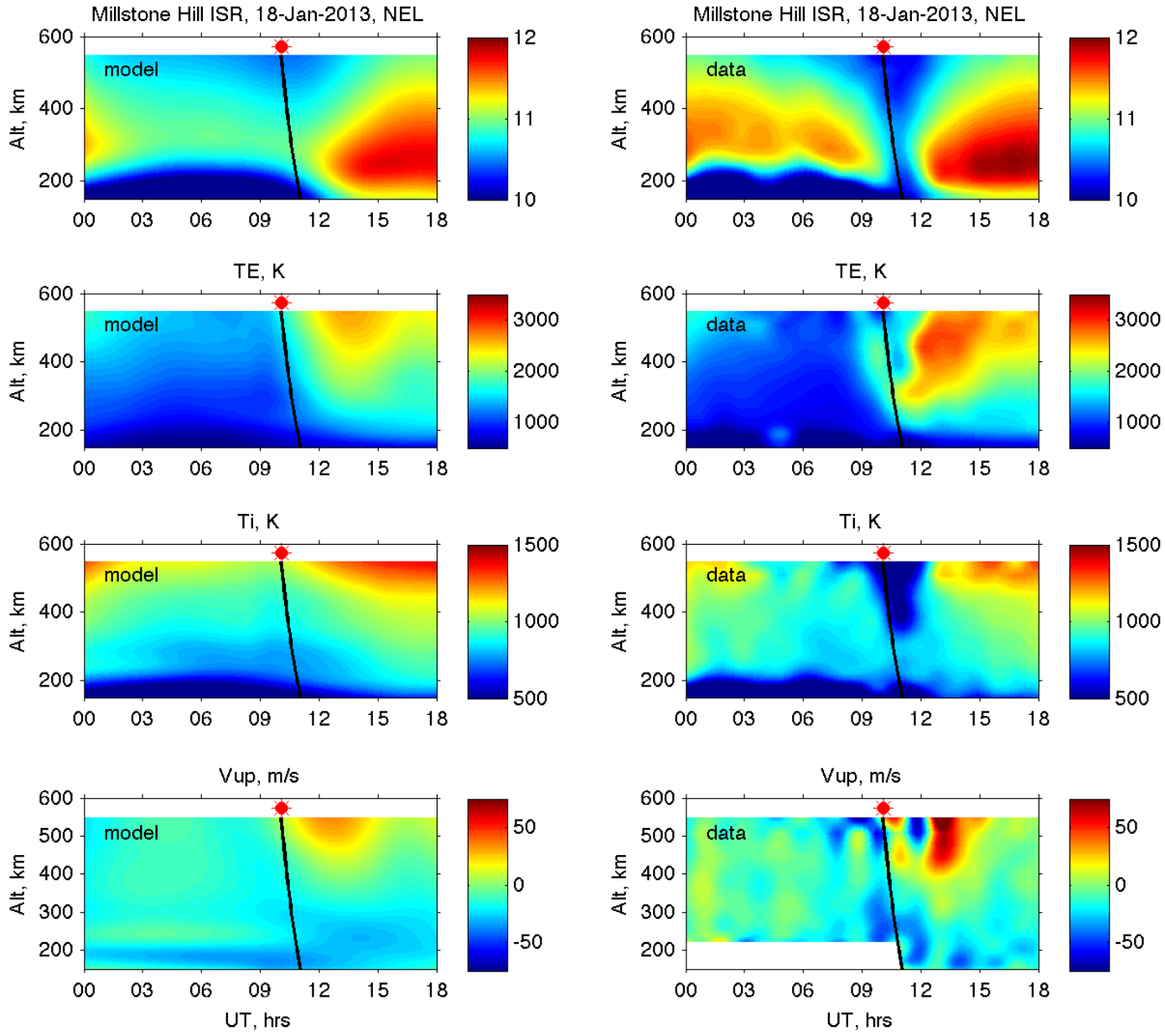




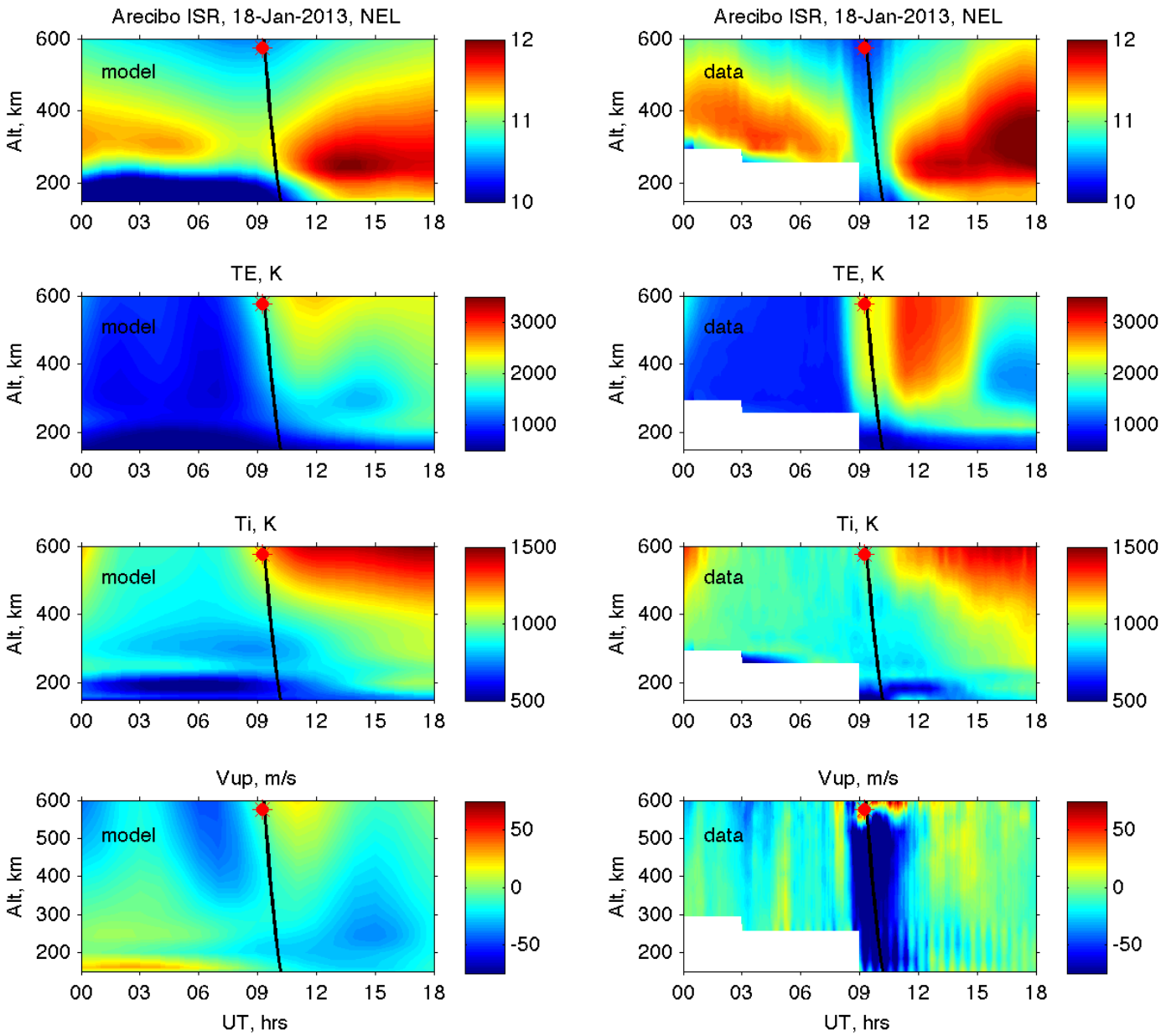


- Sharp, deep decrease in Ne before the sunrise
- ~1.5 hours later at 42°N than at 18°N

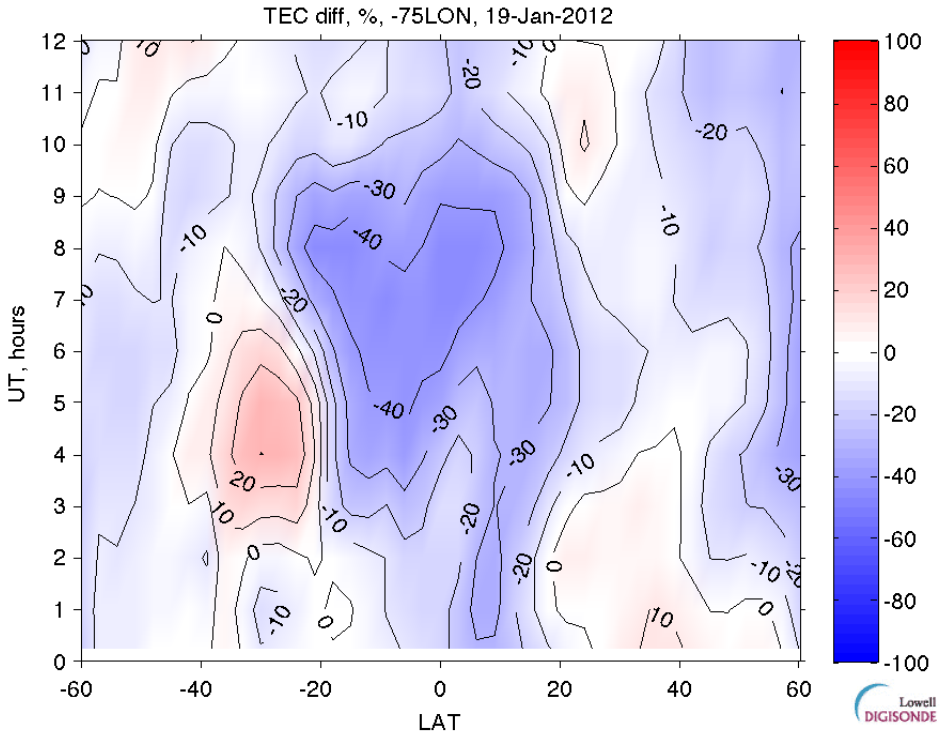
Millstone Hill ISR, 42°N

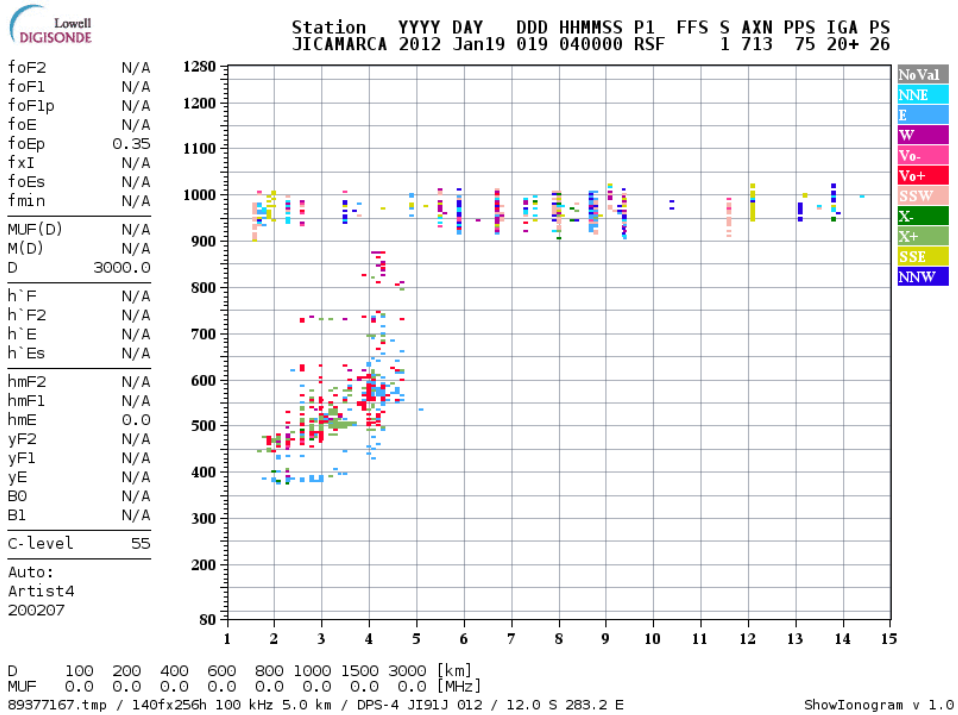


Arecibo ISR, 18ºN



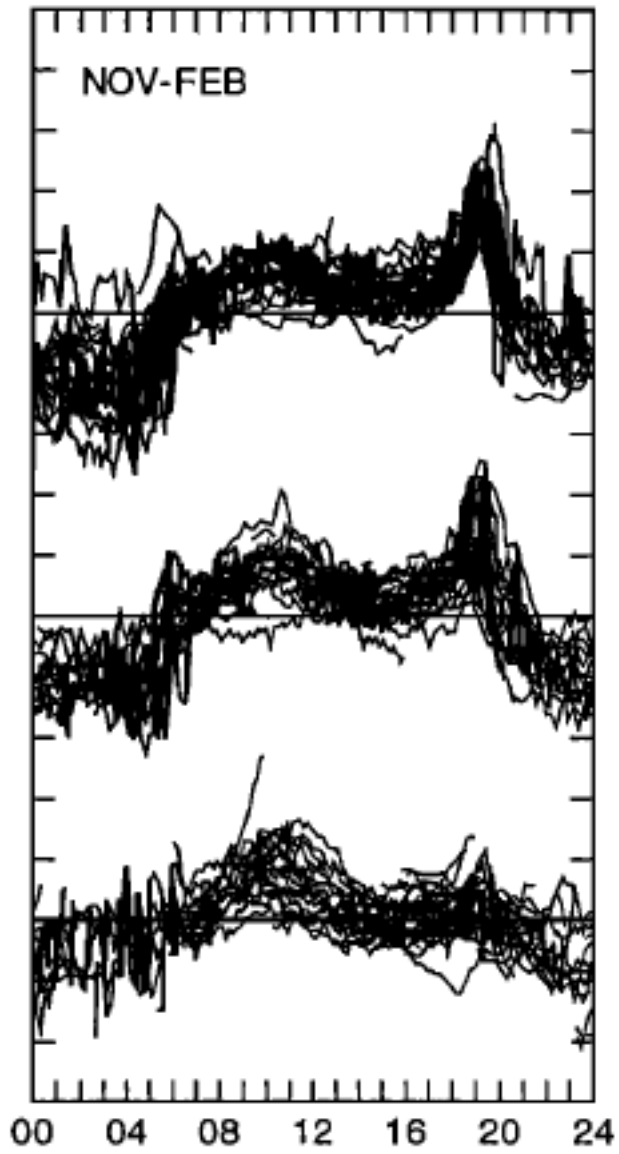
Jan 19, 2012, minor SSW





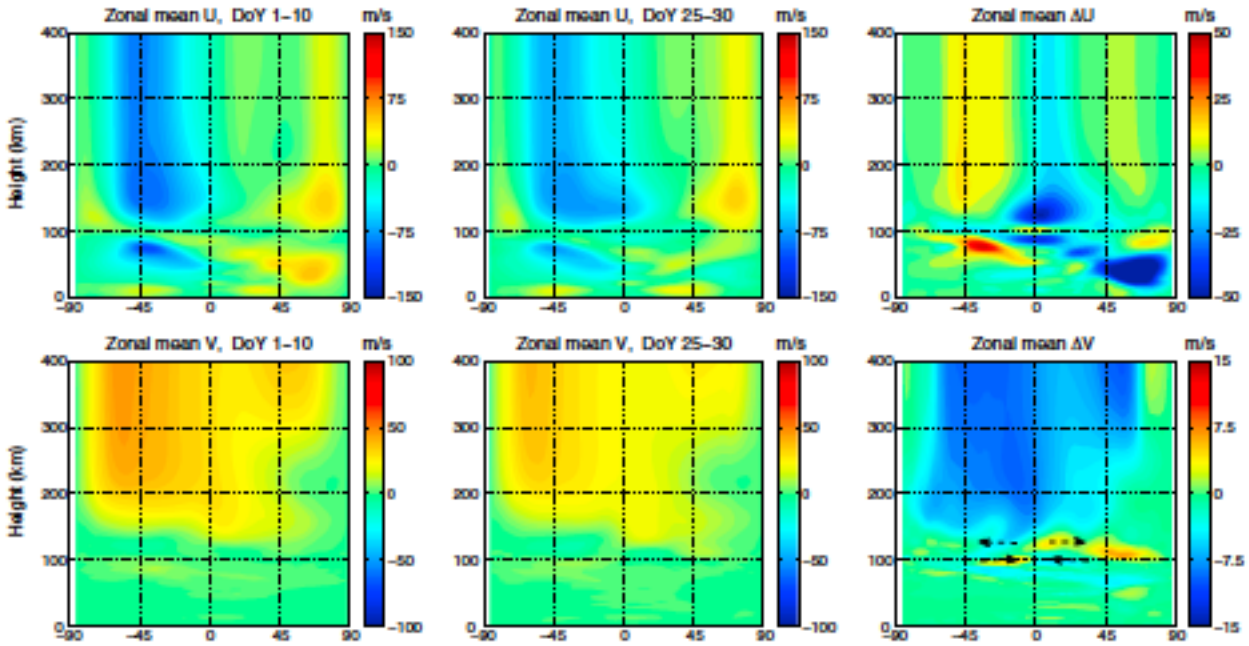
Spread-F at Jicamarca, 4UT

Plausible mechanism



Scherliess and Fejer, 1999

Pre-sunrise downward drift – the opposite of pre-reversal enhancement
Both can be driven by thermospheric zonal wind
Pre-sunrise downward drift strongly enhanced during SSW
Result of strong disturbances in the upper thermospheric zonal wind system?



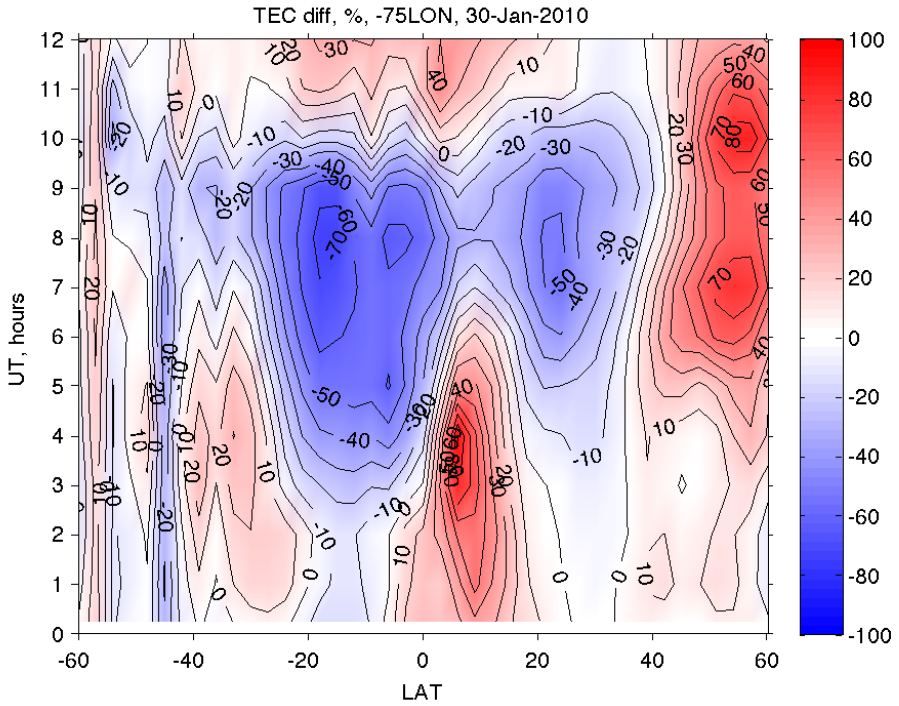
Liu et al., 2014, GAIA model

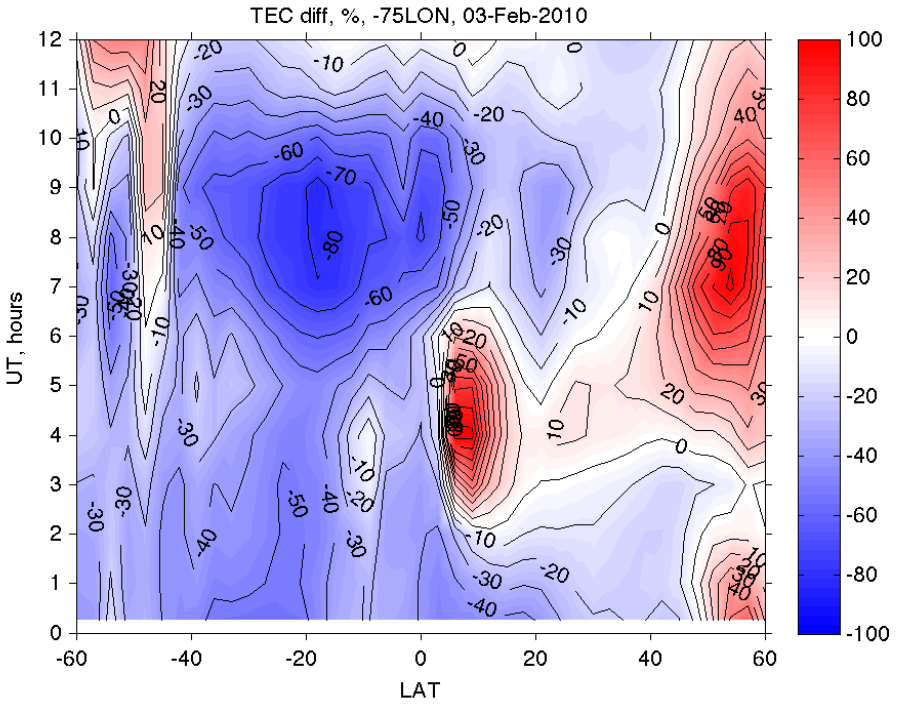
Summary

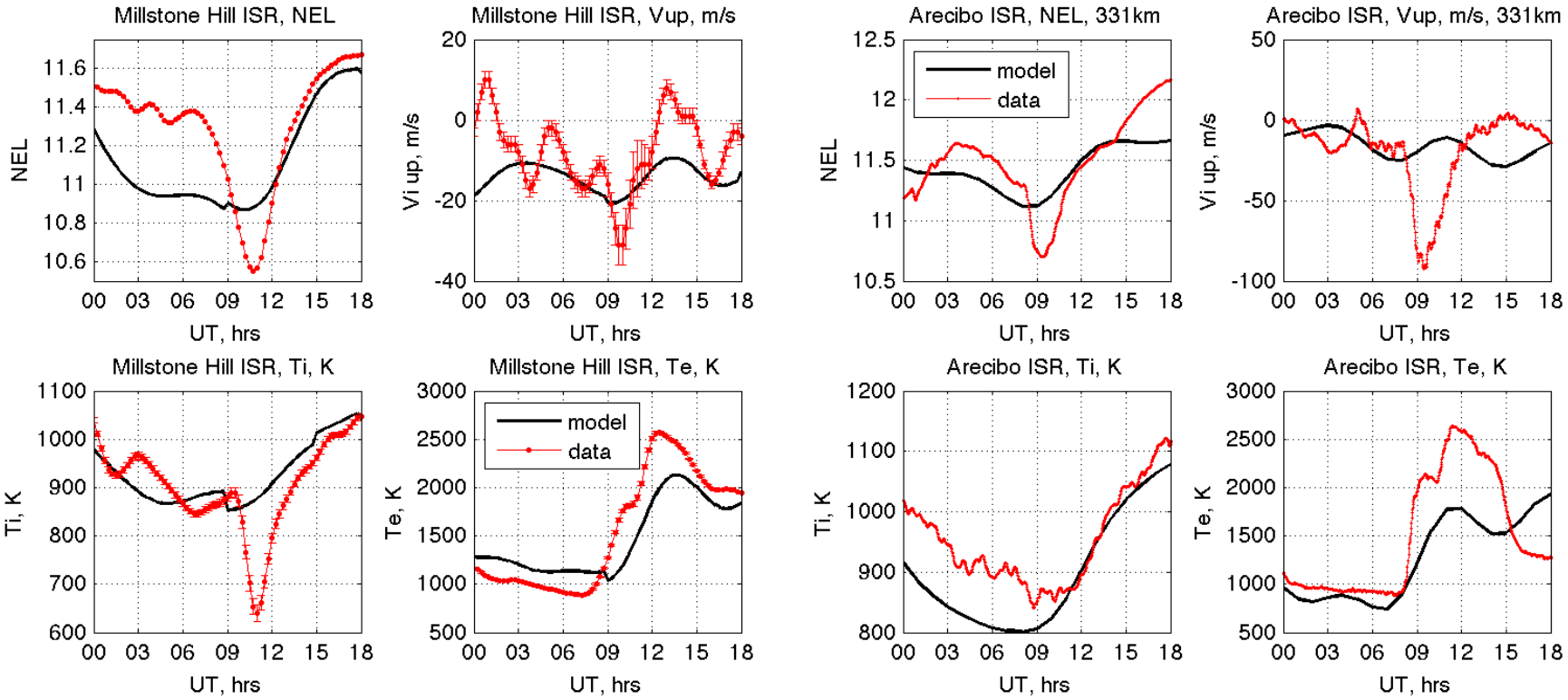
- We report strong decrease in electron density during SSW events in the nighttime ionosphere
- It covers latitude range from ~50^{o}S to ~40^{o}N and reaches 70-80% from the background
- This decrease is observed for many SSW events
- Spread-F often develops at low latitudes on these nights
- Particularly dramatic changes observed around local sunrise at higher latitudes include sharp decrease in Ne, strong downward drift (> 80m/s), and 100-300K ion temperature cooling
- These features indicate that nighttime ionosphere is strongly modified during SSW events
- **Some of these features are consistent with enhancement in the thermospheric zonal wind, which presents additional anomaly not considered prior to this study**

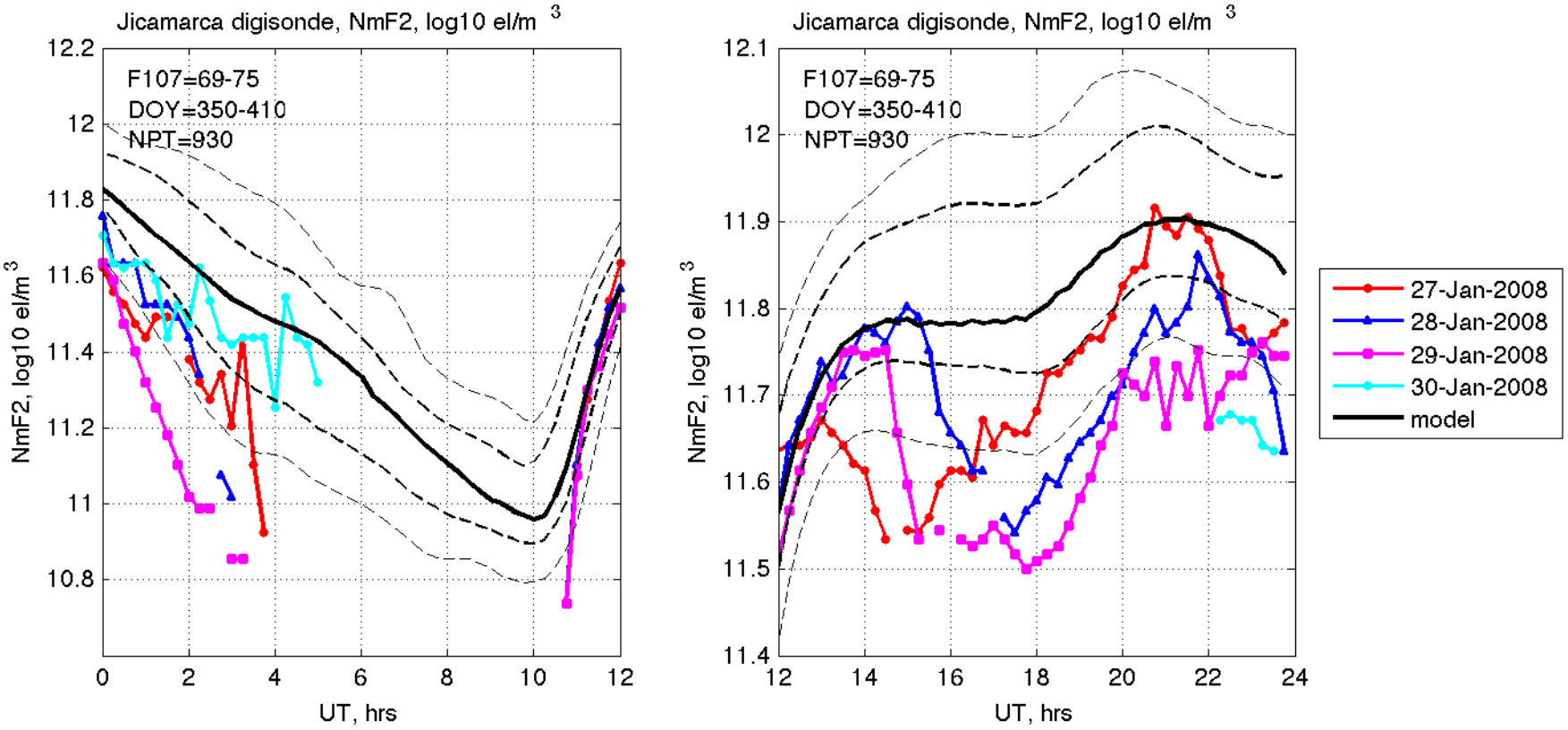
Extra slides

Other SSW events

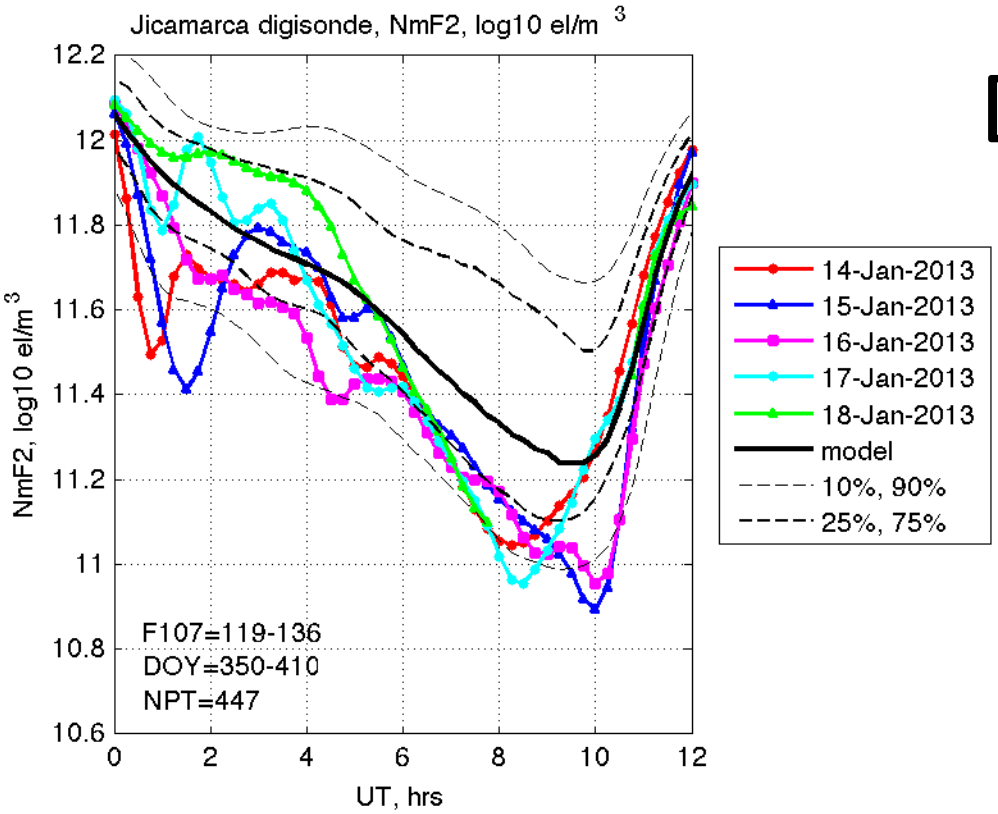


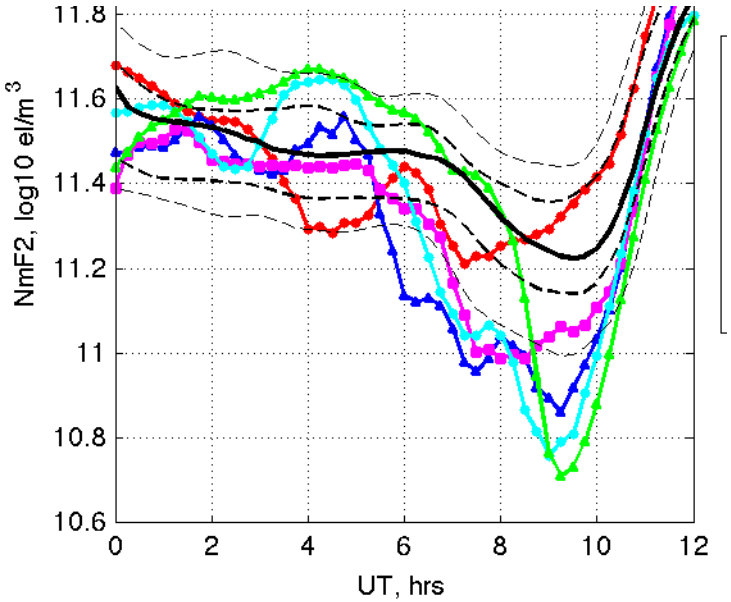


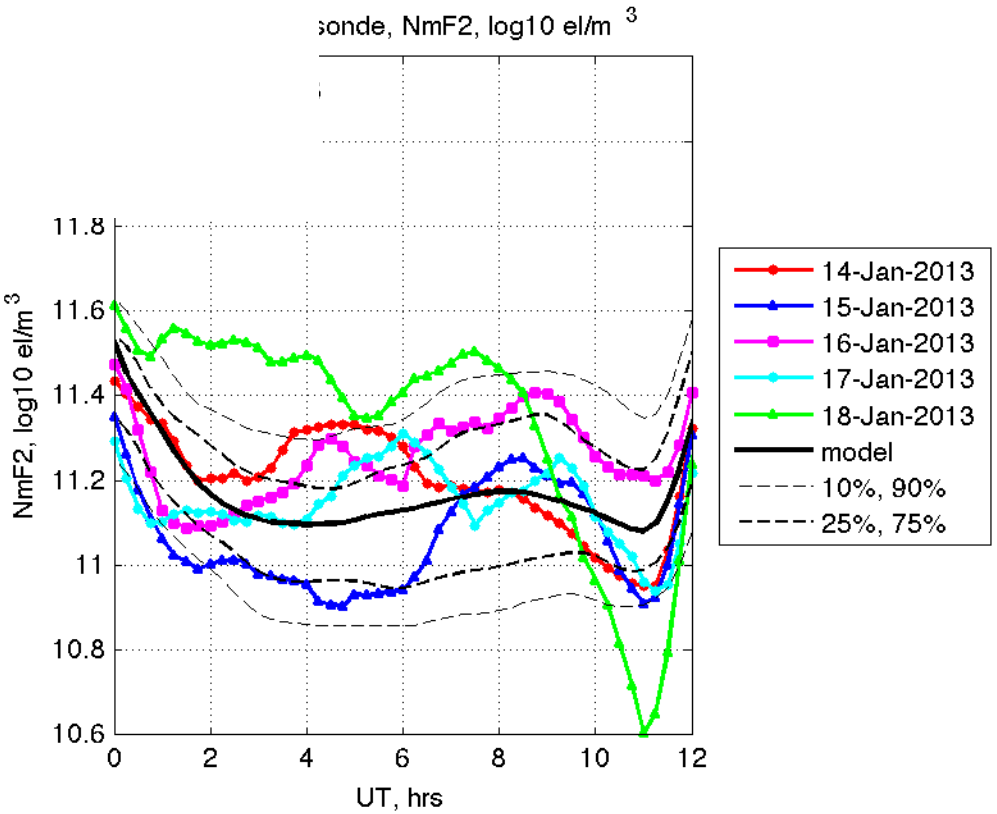

Millstone Hill ISR, NEL
NEL
UT, hrs
Millstone Hill ISR, Vup, m/s
Vi up, m/s
UT, hrs
Arecibo ISR, NEL, 331km
model
data
NEL
UT, hrs
Arecibo ISR, Vup, m/s, 331km
Vi up, m/s
UT, hrs
Millstone Hill ISR, Ti, K
Ti, K
UT, hrs
Millstone Hill ISR, Te, K
model
data
Te, K
UT, hrs
Arecibo ISR, Ti, K
Ti, K
UT, hrs
Arecibo ISR, Te, K
Te, K
UT, hrs

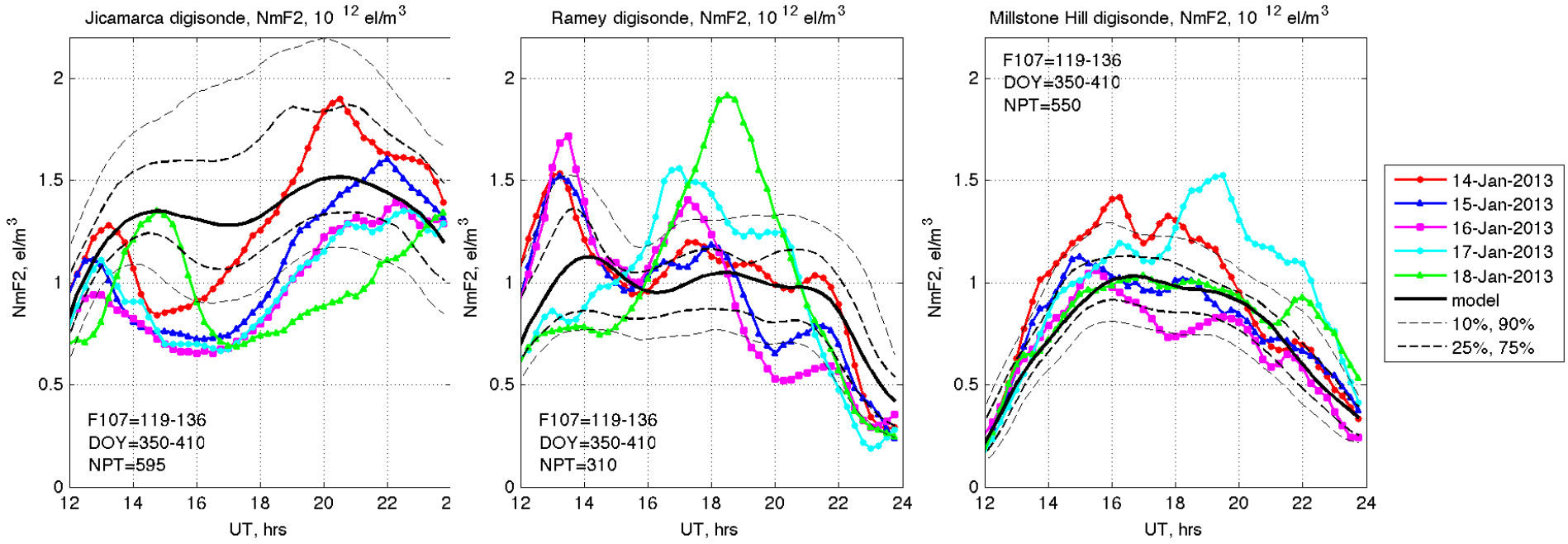

Jicamarca digisonde, NmF2, log10 el/m 3
F107=69-75
DOY=350-410
NPT=930
NmF2, log10 el/m3
UT, hrs
12.2
12
11.8
11.6
11.4
11.2
11
10.8
0
2
4
6
8
10
12
Jicamarca digisonde, NmF2, log10 el/m 3
F107=69-75
DOY=350-410
NPT=930
NmF2, log10 el/m3
UT, hrs
12.1
12
11.9
11.8
11.7
11.6
11.5
11.4
12
14
16
18
20
22
24
27-Jan-2008
28-Jan-2008
29-Jan-2008
30-Jan-2008
model

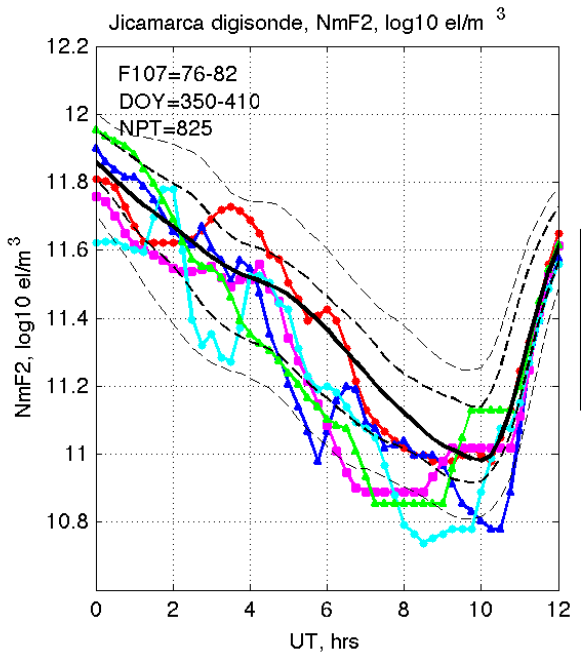
Digisonde data

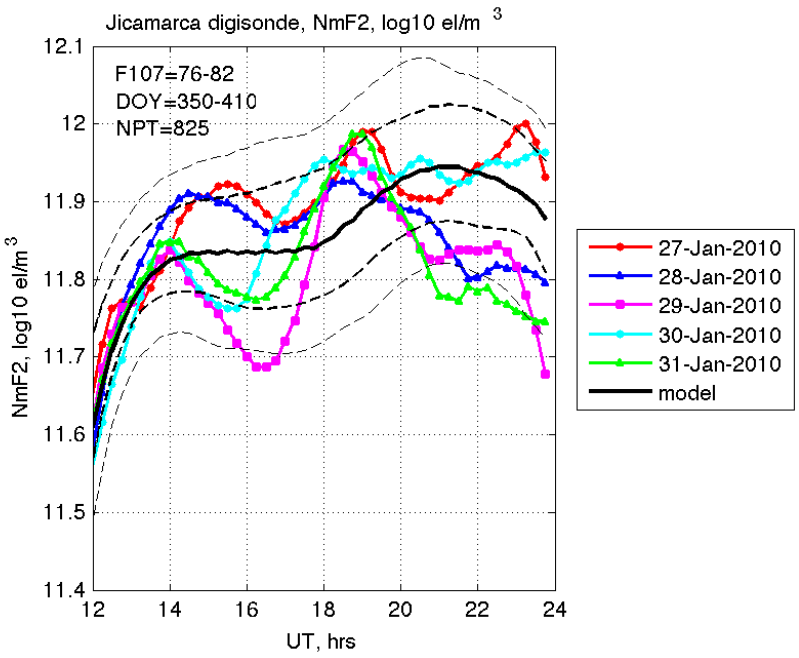


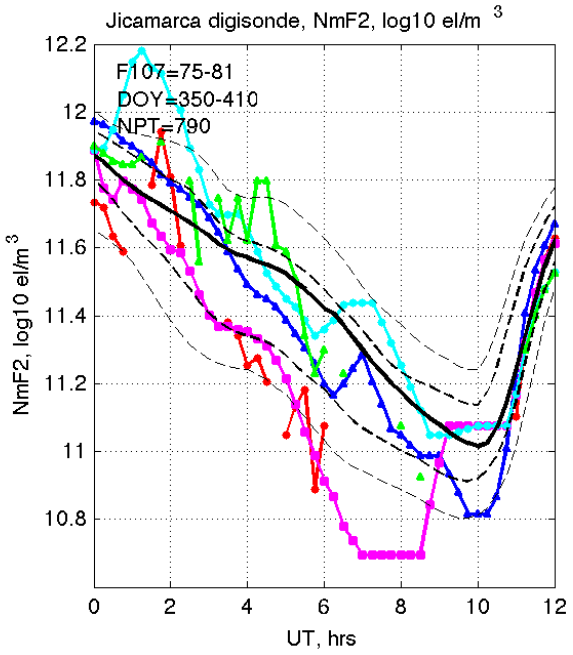





Jicamarca digisonde, NmF2, 10 12 el/m3
NmF2, el/m3
UT, hrs
F107=119-136
DOY=350-410
NPT=595
Ramey digisonde, NmF2, 10 12 el/m3
NmF2, el/m3
UT, hrs
F107=119-136
DOY=350-410
NPT=310
Millstone Hill digisonde, NmF2, 10 12 el/m3
NmF2, el/m3
UT, hrs
F107=119-136
DOY=350-410
NPT=550
14-Jan-2013
15-Jan-2013
16-Jan-2013
17-Jan-2013
18-Jan-2013
model
10%, 90%
25%, 75%


Jicamarca digisonde, NmF2, log10 el/m 3
F107=76-82
DOY=350-410
NPT=825
NmF2, log10 el/m3
UT, hrs


Jicamarca digisonde, NmF2, log10 el/m 3
F107=76-82
DOY=350-410
NPT=825
NmF2, log10 el/m3
UT, hrs
27-Jan-2010
28-Jan-2010
29-Jan-2010
30-Jan-2010
31-Jan-2010
model


Jicamarca digisonde, NmF2, log10 el/m 3
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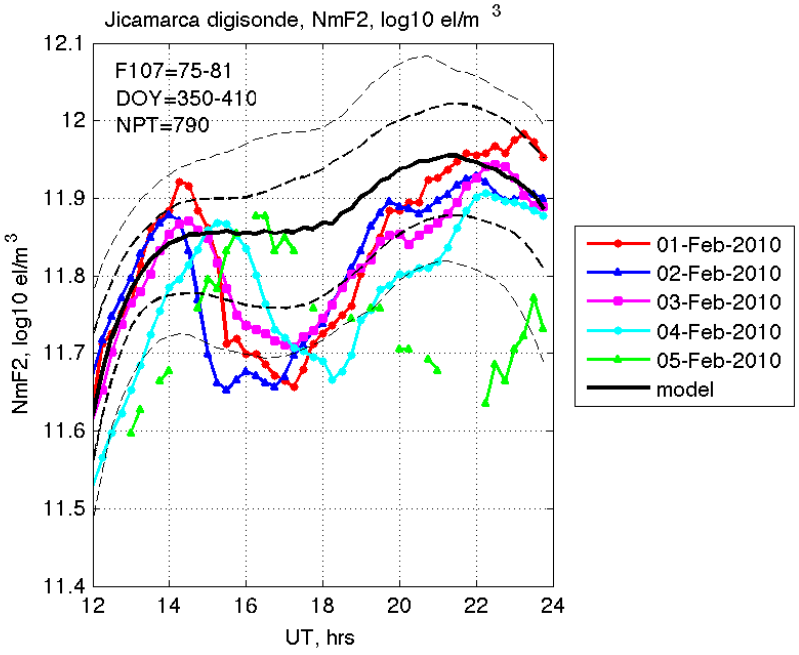
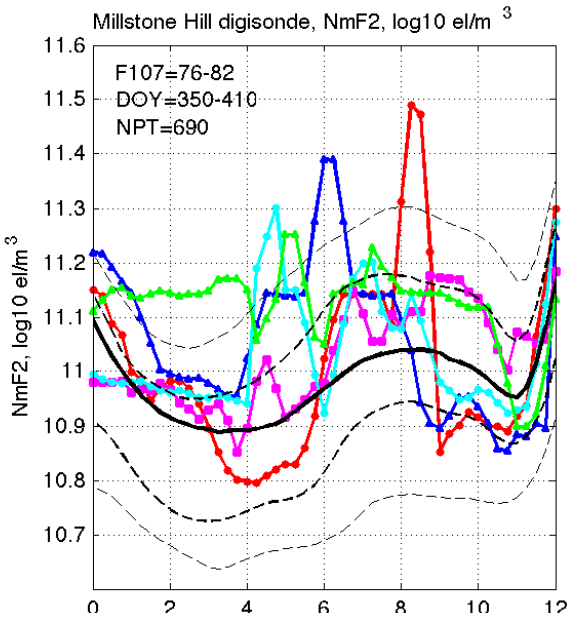
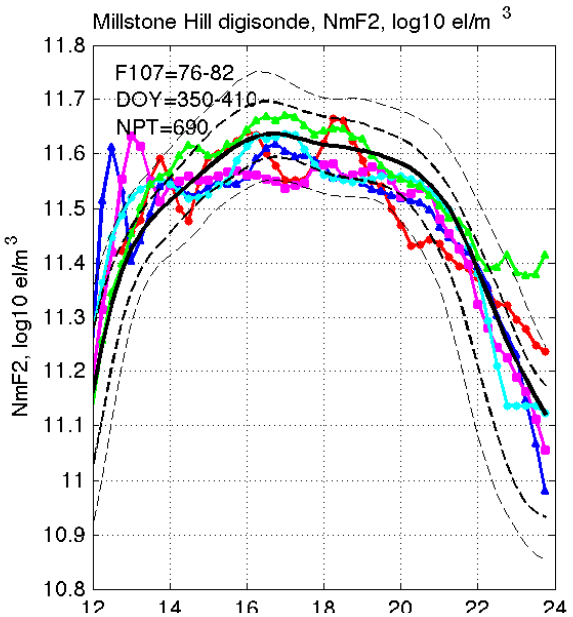
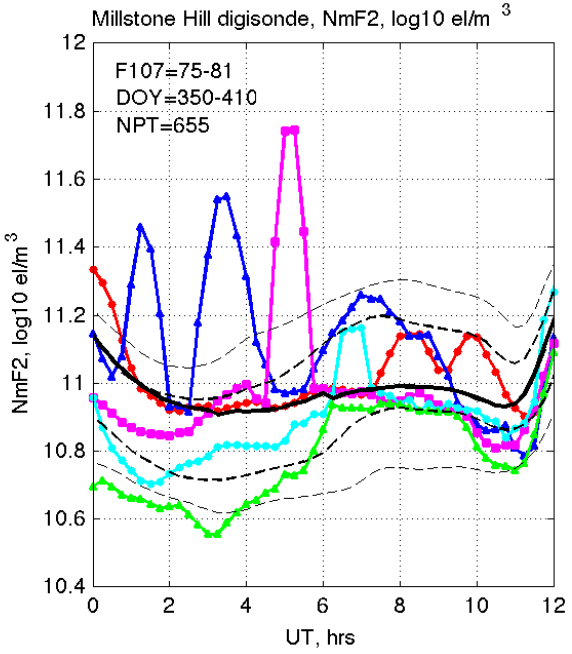
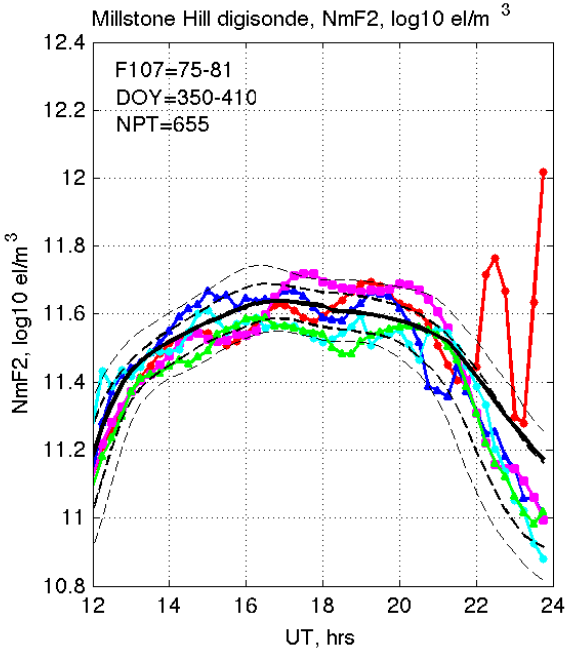
DOY=350-410
NPT=790
NmF2, log10 el/m3
UT, hrs


Jicamarca digisonde, NmF2, log10 el/m 3
F107=75-81
DOY=350-410
NPT=790
NmF2, log10 el/m3
UT, hrs
01-Feb-2010
02-Feb-2010
03-Feb-2010
04-Feb-2010
05-Feb-2010
model


Millstone Hill digisonde, NmF2, log10 el/m 3
F107=76-82
DOY=350-410
NPT=690
NmF2, log10 el/m 3


Millstone Hill digisonde, NmF2, log10 el/m 3
F107=76-82
DOY=350-410
NPT=690
NmF2, log10 el/m 3
27-Jan-2010
28-Jan-2010
29-Jan-2010
30-Jan-2010
31-Jan-2010
model


Millstone Hill digisonde, NmF2, log10 el/m 3
F107=75-81
DOY=350-410
NPT=655
NmF2, log10 el/m 3
UT, hrs


Millstone Hill digisonde, NmF2, log10 el/m 3
F107=75-81
DOY=350-410
NPT=655
NmF2, log10 el/m 3
UT, hrs
01-Feb-2010
02-Feb-2010
03-Feb-2010
04-Feb-2010
05-Feb-2010
model