Diurnal variations of electron density at mid- to high- latitudes

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Introduction

- Diurnal variation of the ionospheric electron density is well established at least at low and mid-latitudes, which is mostly determined by solar EUV production, chemical recombination, and transport processes by neutral winds and electric fields.

- At high latitude, however, there are additional processes to complicate the diurnal variations, for example, energetic particle precipitation and magnetospheric electric field.

- In this study, we investigate the climatological characteristics of diurnal variations of the electron density in the high latitude ionosphere using ISR electron density measurements.

Data analysis

- In this study, we use only ISR data the following conditions:
  - ➢ Data under quite and moderate geophysical conditions (Kp ≤ 4)

- Numbers of day for ISR observations

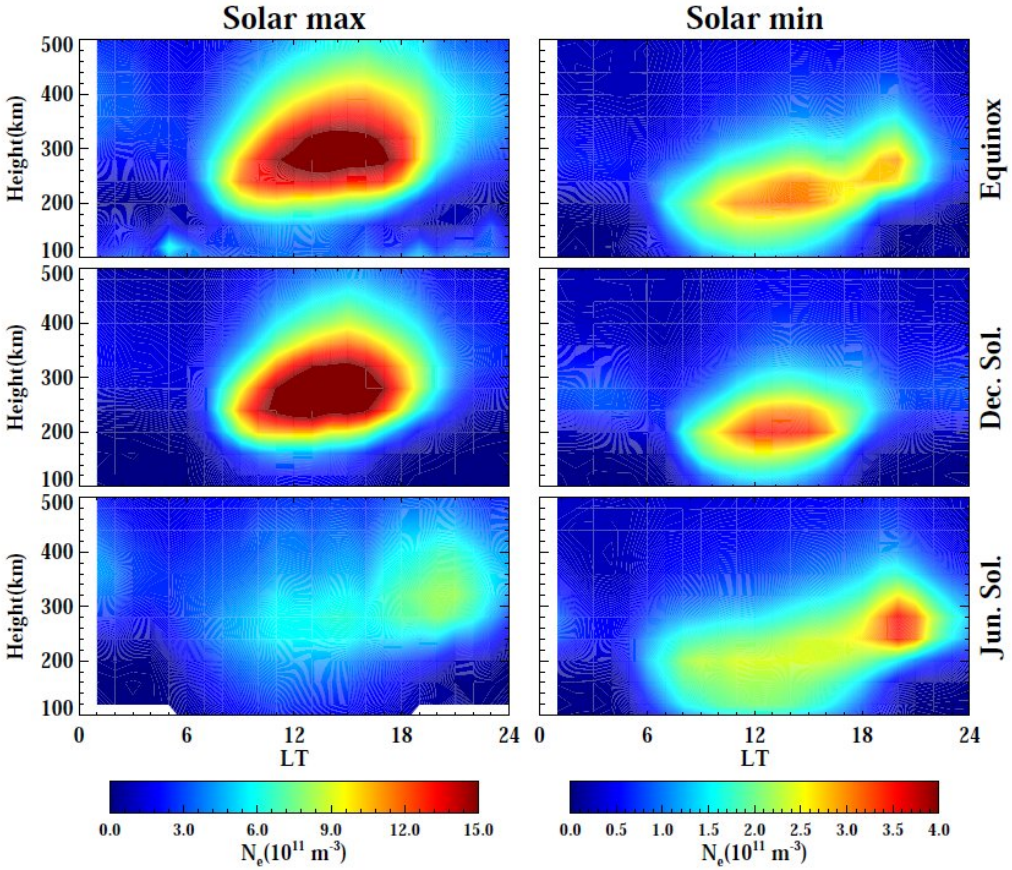
✓ Solar maximum period : **2000 – 2002**, solar minimum period : **2008 – 2009**

	Millstone Hill		**EISCAT**		**ESR**	
	Max	Min	Max	Min	Max	Min
Equinox	48	32	55	44	87	43
Dec. Sol.	35	55	64	79	96	61
Jun. Sol.	34	31	33	56	40	11
Total	**117**	**118**	**152**	**179**	**223**	**115**

- Data binning

➢ Binning resolution for height and LT : 40 km X 1 hour

Comparison of diurnal variation at Millstone Hill



- **<u>Mid-latitude</u>**

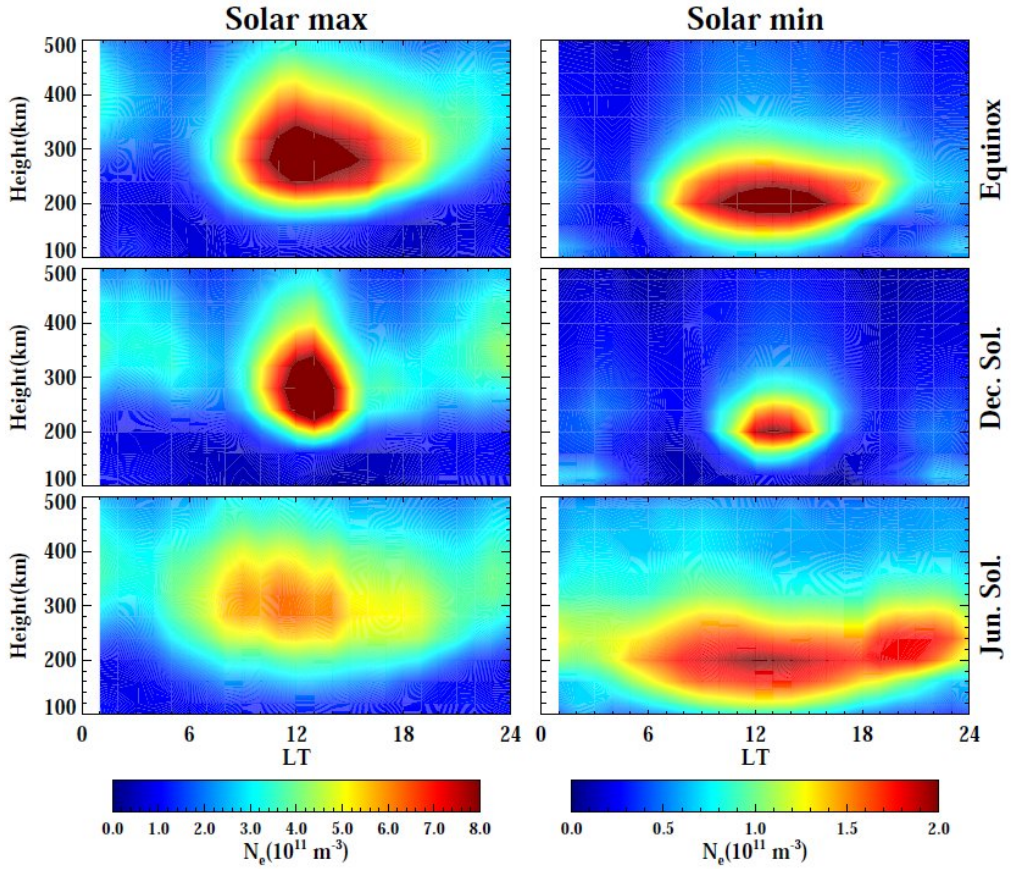
✓ At Jun. Sol., the electron density at evening sector is larger than that at dayside.

- ➢ Mid-latitude summer evening anomaly (MSEA)

✓ Daytime electron density at Dec. Sol. is higher than that at Jun. Sol.

- ➢ Annual anomaly
- ➢ Appear as a winter anomaly in the northern hemisphere
- ➢ Much stronger during solar max.

Comparison of diurnal variation at EISCAT (Tromsø)



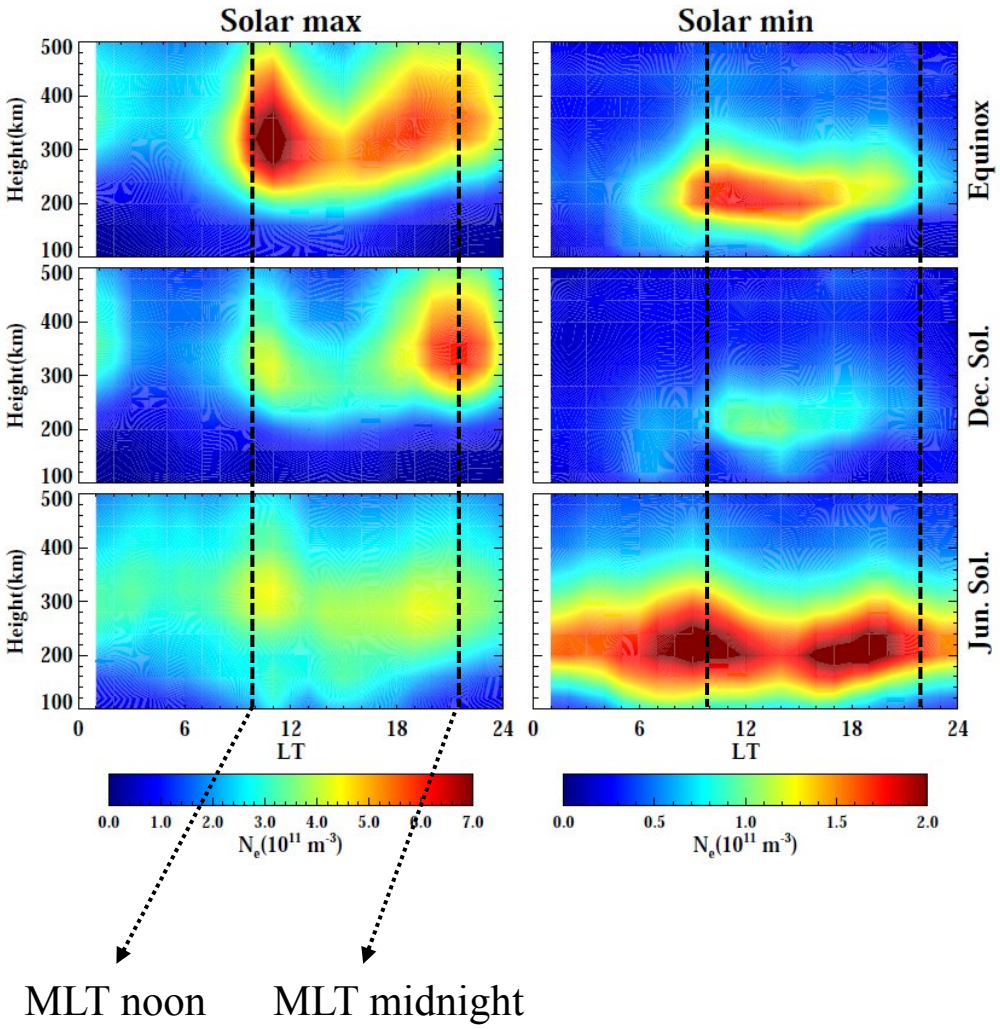
- **<u>Auroral oval region</u>**

✓ Strong annual anomaly also occurs during solar max.

✓ During Dec. Sol., the daytime density enhancement is narrowly confined within around the noon.

✓ Two density peaks appear for Jun. Sol. during solar min.

Comparison of diurnal variation at ESR (Svalbard)



- **Polar cap region**

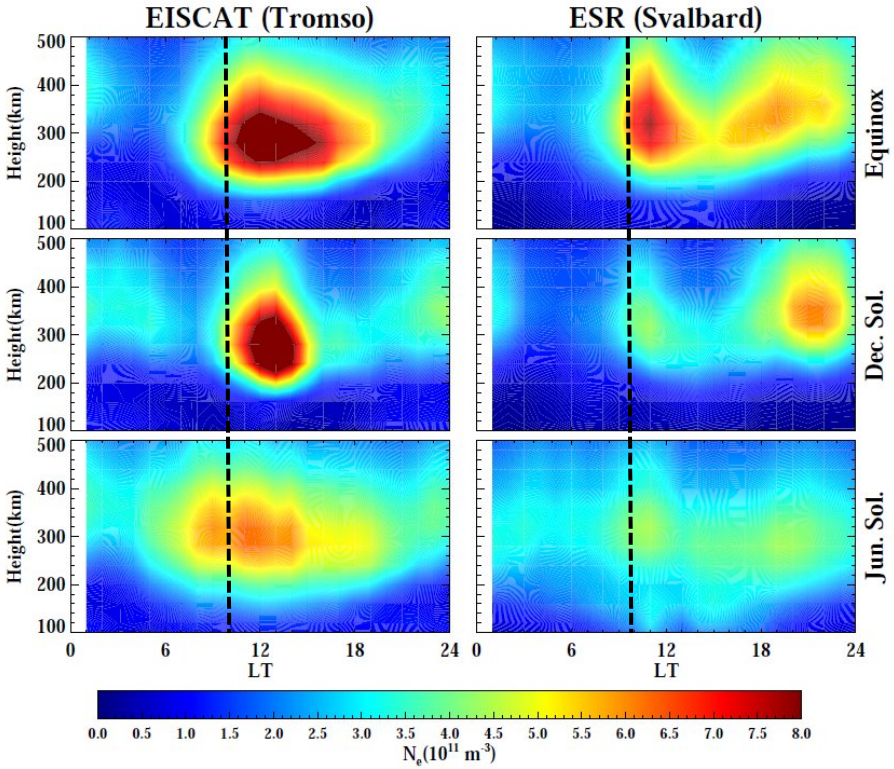
✓ During solar max. nighttime peak appears in addition to the daytime peak
  - ➢ Daytime : MLT noon
  - ➢ Nighttime : MLT midnight

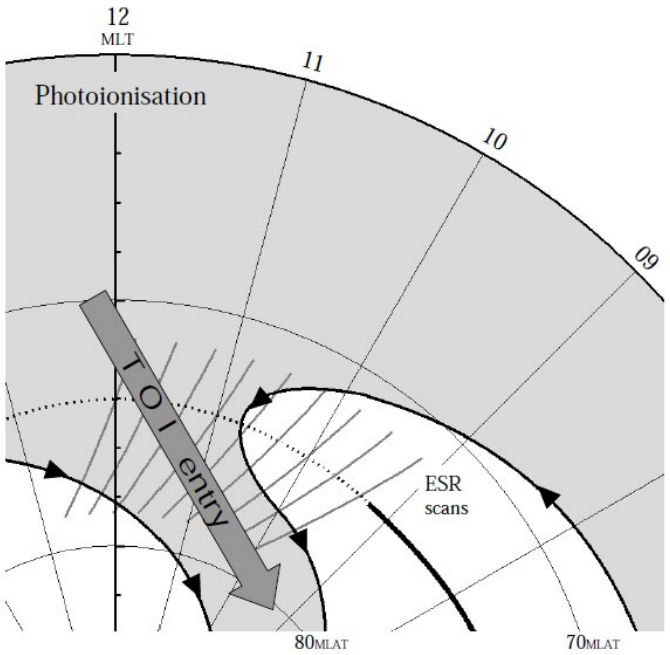
✓ The nighttime peak is even larger than the daytime peak for Dec. Sol.

✓ Two-peak structure also appears for Jun. Sol. during solar min.

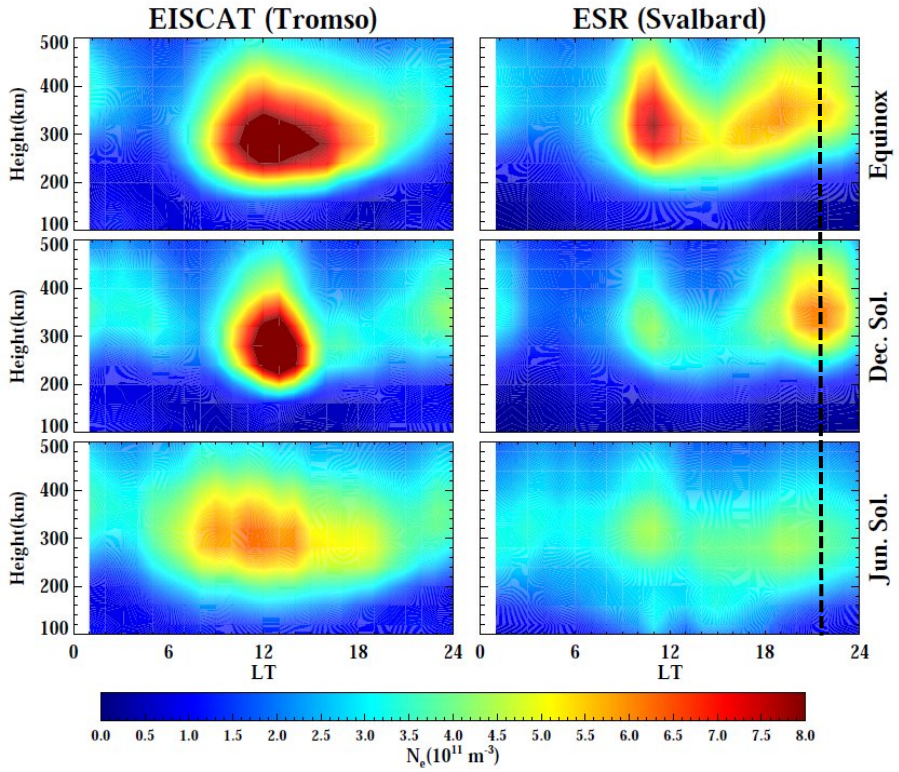
✓ During solar max. the electron density is largest for equinox but it is largest for Jun. Sol. during solar min.

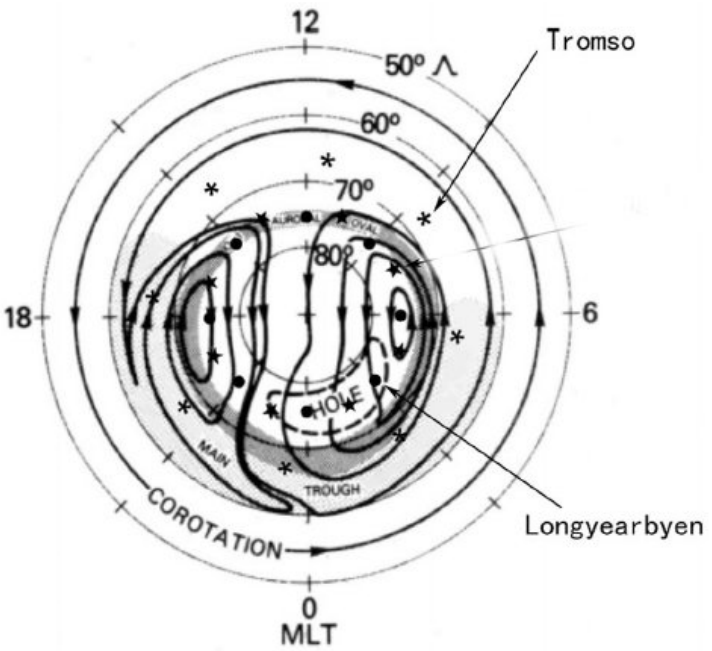
1) Why there is the peak difference between Tromsø and Svalbard during solar max.





- **Tromsø (EISCAT)**
  - Daytime peak : at LT noon
    - Photoionization caused by solar EUV radiation tends to be the dominant source of F layer ionization.
- **Svalbard (ESR)**
  - Daytime peak : at MLT noon
    - It is related to solar EUV ionized plasma in the cusp inflow region by plasma convection and/or soft particle precipitation in the cusp region. [Moen et al. 2008; *Xu et al.*, 2014].





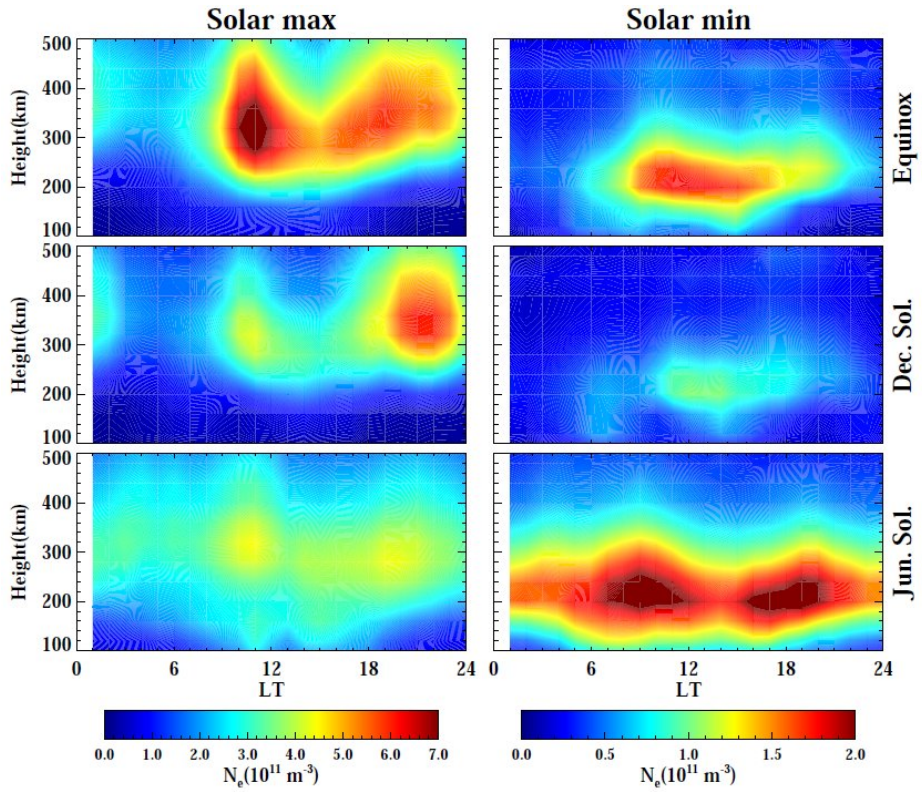
- **Svalbard (ESR)**

➢ Nighttime peak : MLT midnight

➢ Cross-polar transport process – Transport of solar EUV ionized plasma across the polar cap to form a TOI from day to night [Foster, 1993; Pryse et al., 2004; Cai et al., 2007; Moen et al., 2008; Xu et al., 2014]

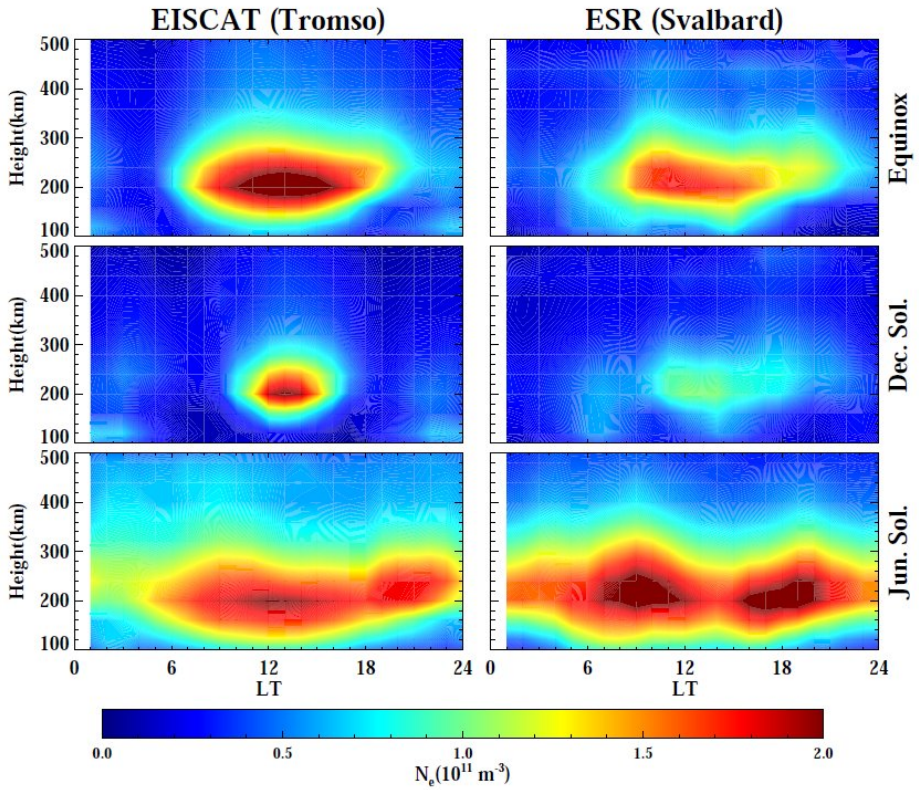
✓ At Tromsø, the effect of plasma convection is not noticeable. Therefore, there are not the electron enhancement caused by the cross-polar plasma convection during nighttime.

2) Why there is the difference of electron density with solar activity in Svalbard



- **Solar maximum – Plasma convection**
- **Solar minimum – Solar EUV radiation**
  - At solar minimum, the plasma convection is largely weaker than that at solar maximum [*He et al.*, 2012; *Xu et al.*, 2014]. Therefore, the photoionization caused by the solar radiation is dominant source of F layer ionization during solar minimum.

3. Why the two peaks only appear at Jun. Sol. during solar min.



- **Solar EUV radiation :** Solar radiation produced significant ionization at location with solar zenith angle (SZA) smaller than 70°, such as in the regions > 72° MLAT in the northern summer during nighttime [*Luan et al.*, 2014]

✓ For Dec Sol., the solar illumination/sunlit conditions are absent during nighttime.

Summary

- Using the ISR data at Millstone Hill, Tromsø, and Svalbard from 2000 to 2009, we studied the climatology of the diurnal variations of electron density in the middle and high latitude ionospheres.

✓ In the middle latitude ionosphere at Millstone Hill,
  - Mid-latitude summer evening anomaly(MSEA) appears for both solar activities
  - Annual anomaly (i.e., seasonal anomaly) is much stronger during solar maximum

✓ In the auroral region at Tromsø,
  - Two density peaks appear for June solstice
  - Strong annual anomaly also occurs during solar maximum

✓ In the polar cap region at Svalbard,
  - Nighttime peak appears in addition to the daytime peak only during solar maximum
  - Electron density for Jun. sol is greater than the other seasons during solar minimum

✓ Electron densities in the auroral and polar cap regions:
  - Daytime peak in the auroral region occurs at local noon, but in the polar cap region, it occurs at magnetic local noon time
  - During solar max, the nighttime peaks at magnetic local midnight are much stronger in the polar cap region