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Diurnal, seasonal and solar activity pattern of ionosphere disturbances from Irkutsk Digisonde data (2003-2012)

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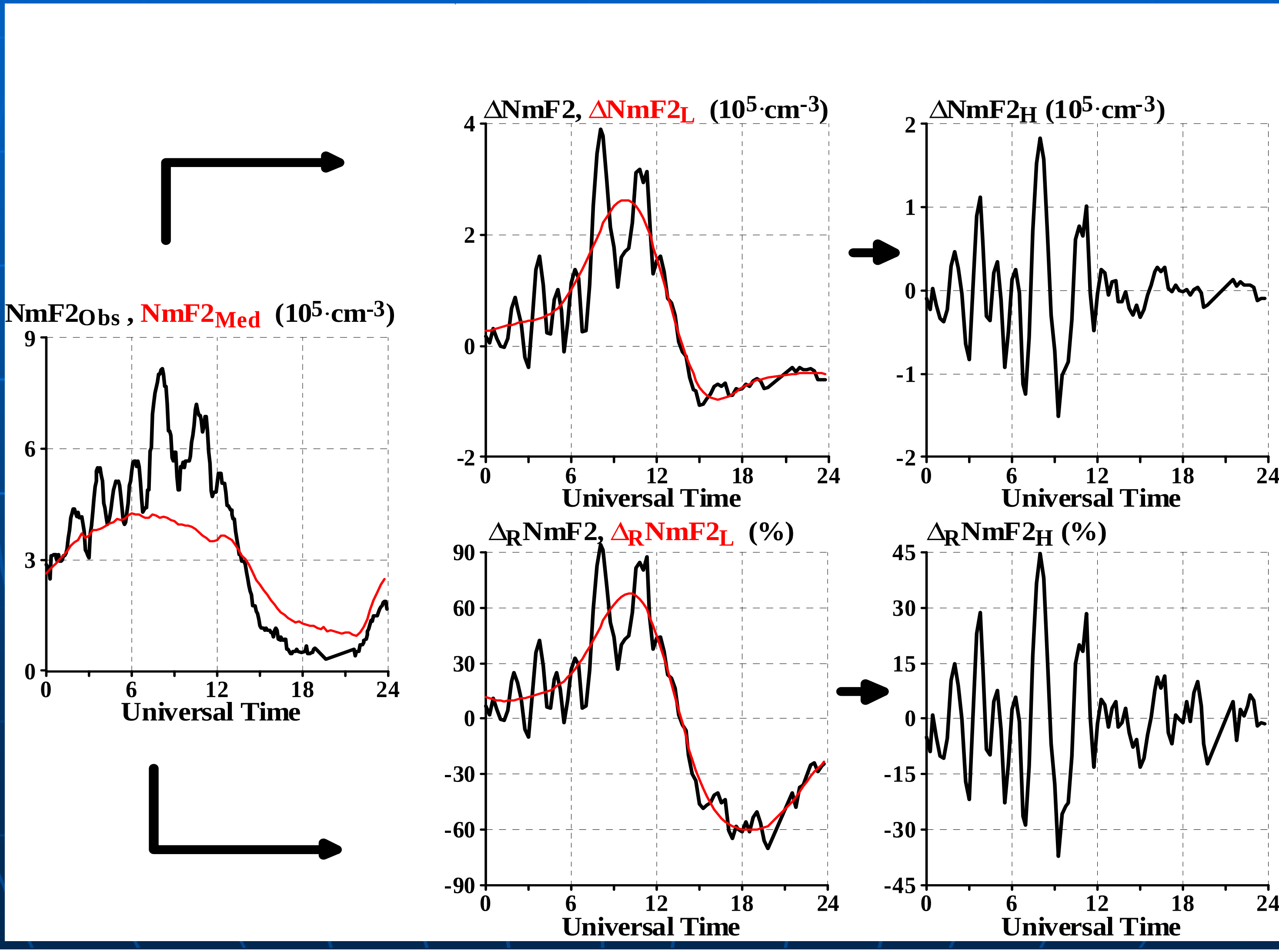
Disturbance is the difference between observed and 27-day median value.

$\Delta NmF2 = NmF2_{OBS} - NmF2_{MED}$ $\Delta_R NmF2(\%) = \Delta NmF2/NmF2_{MED} \cdot 100\%$

Low frequency part $\Delta NmF2_L$, $\Delta_R NmF2_L$ (6 hrs to 27 days) is related to day-to-day variability

High frequency part $\Delta NmF2_H$, $\Delta_R NmF2_H$ (less than 6 hrs) is related to traveling ionospheric disturbances caused by internal gravity waves.



Ionospheric variability

- Definition

Variability is the root mean square of NmF2 disturbances:

$$\sigma NmF2 = \langle \Delta NmF2^2 \rangle^{1/2}, \ \sigma_R NmF2 = \langle \Delta_R NmF2^2 \rangle^{1/2},$$

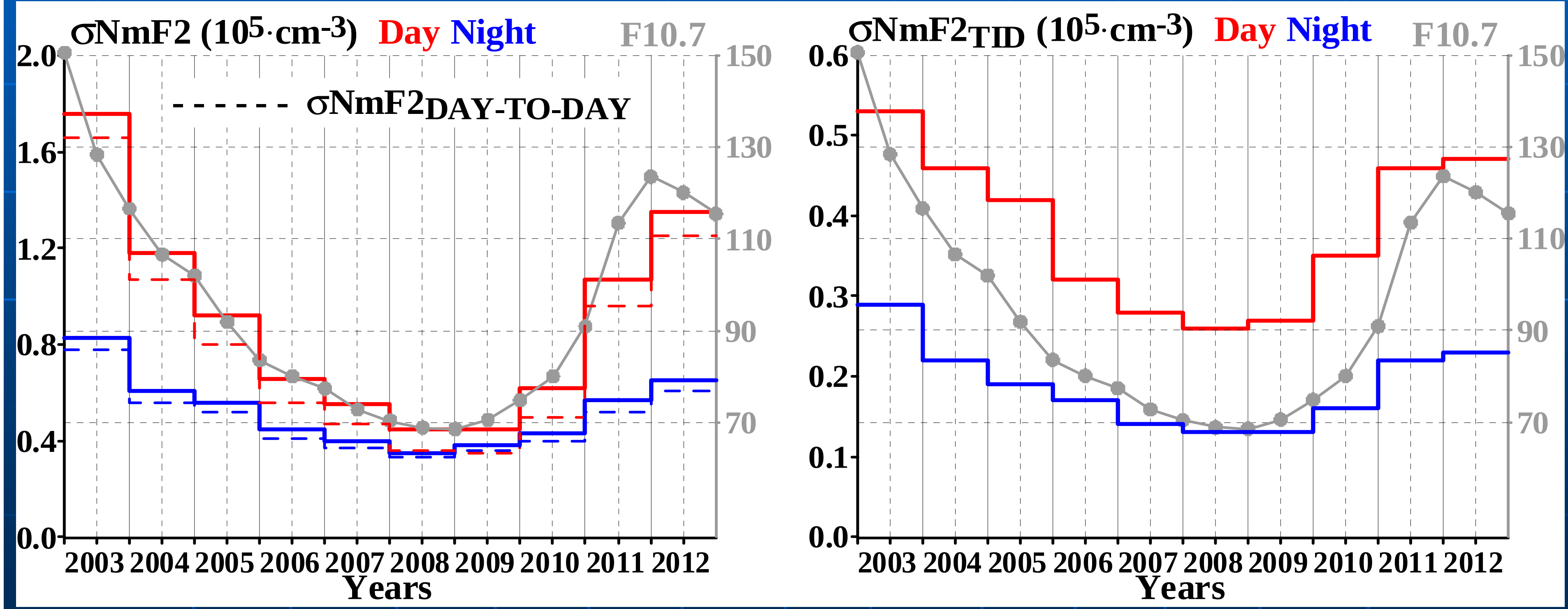
where brackets denote some averaging.

- Different types of averaging :
- Day- and nighttime averaging → difference between day- and nighttime variability (boundary ground terminator)
- Annual averaging → year-to-year changes in variability (solar cycle variations)
- Averaging over years for each local time and day of year → Diurnal-seasonal behavior of variability

Absolute Variability. Solar cycle variations.

1. Total variability is mainly due to day-to-day variability.
2. Absolute Variability depends strongly on background NmF2.

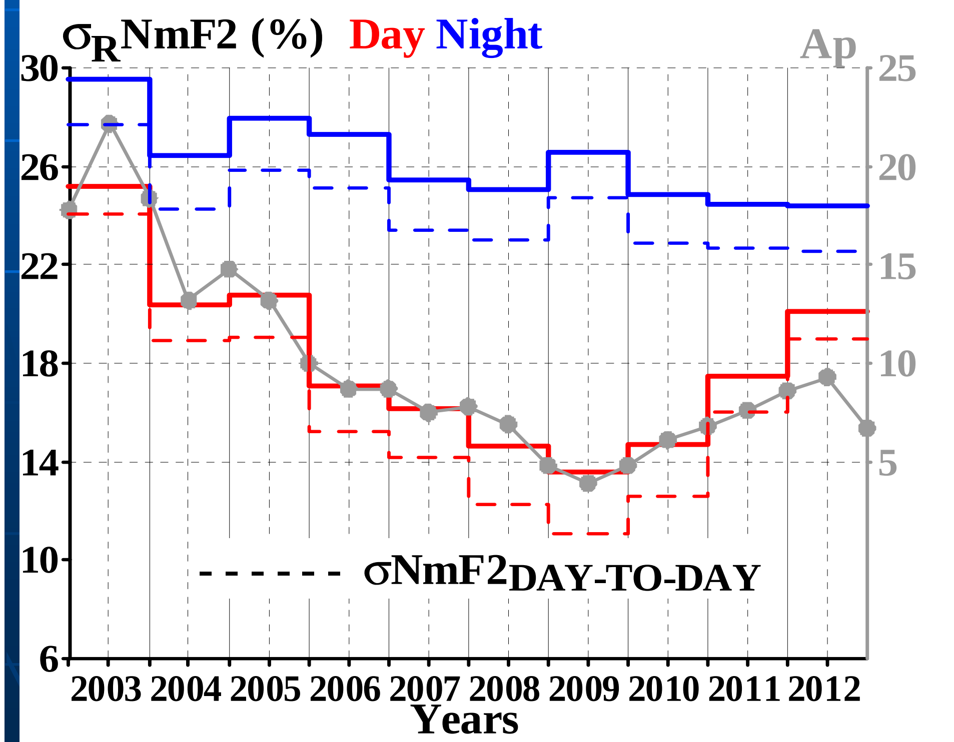
Further we consider only Relative Variability in assumption that it characterizes activity of ionospheric disturbance sources, i.e. geomagnetic, meteorological, short-term solar activity and gravity waves activity.

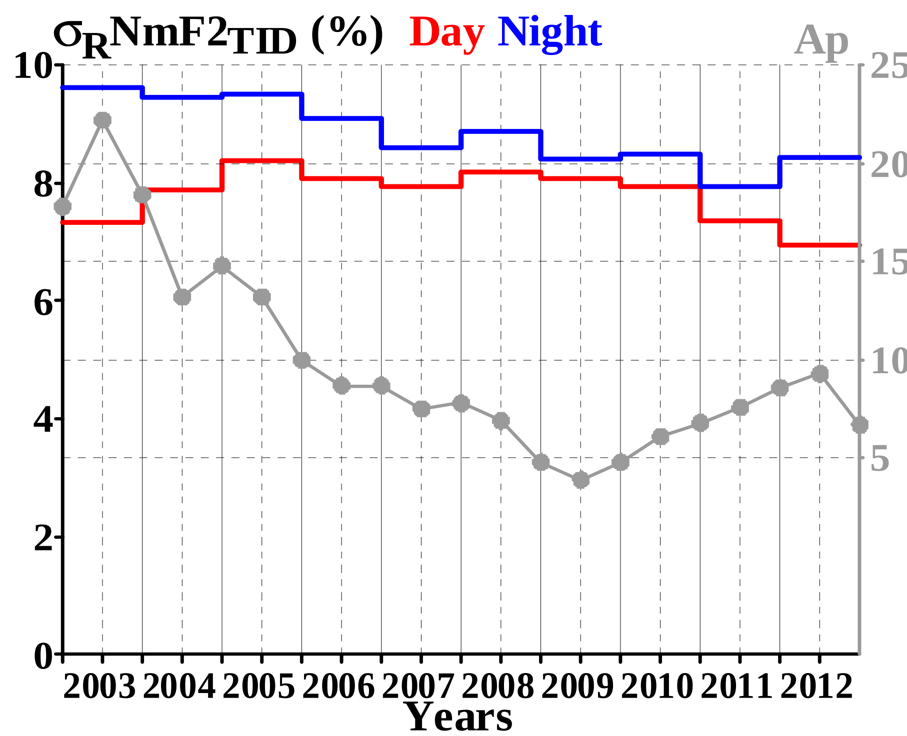


Relative Variability. Solar cycle variations.

Low solar activity years (2006-2011) show the meteorological contribution.
Solar cycle variations show the contribution of geomagnetic/solar activity.
Geomagnetic/solar contribution is clearly seen **only** for total daytime variability.
No or weak geomagnetic influence on total nighttime variability and TID activity.

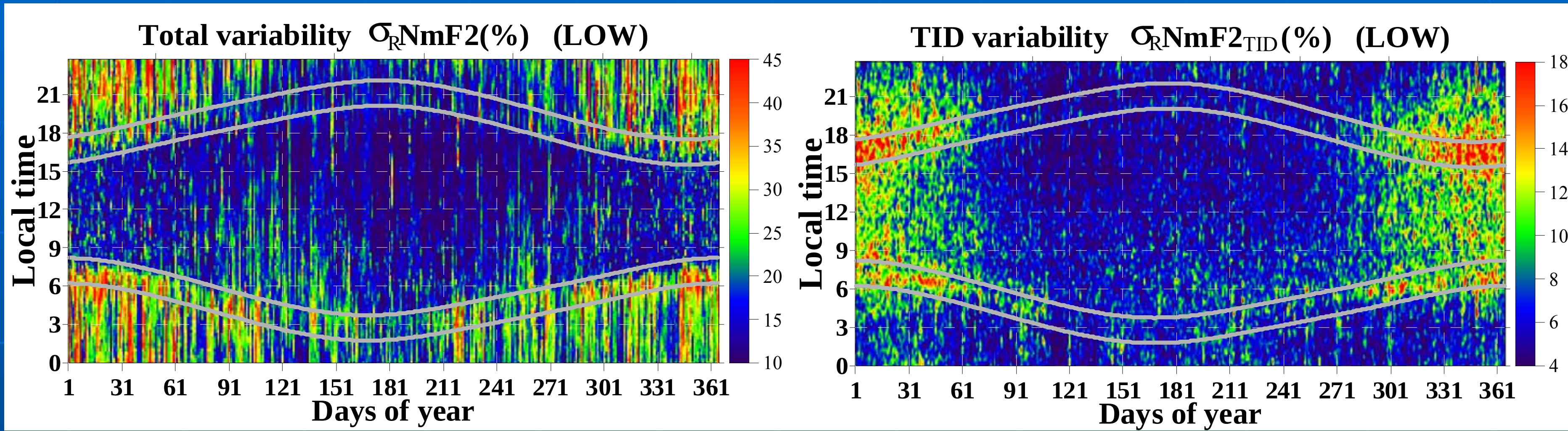
Night-Day difference
Nighttime total variability is larger than daytime one.
Day and nighttime TID variabilities are close together.



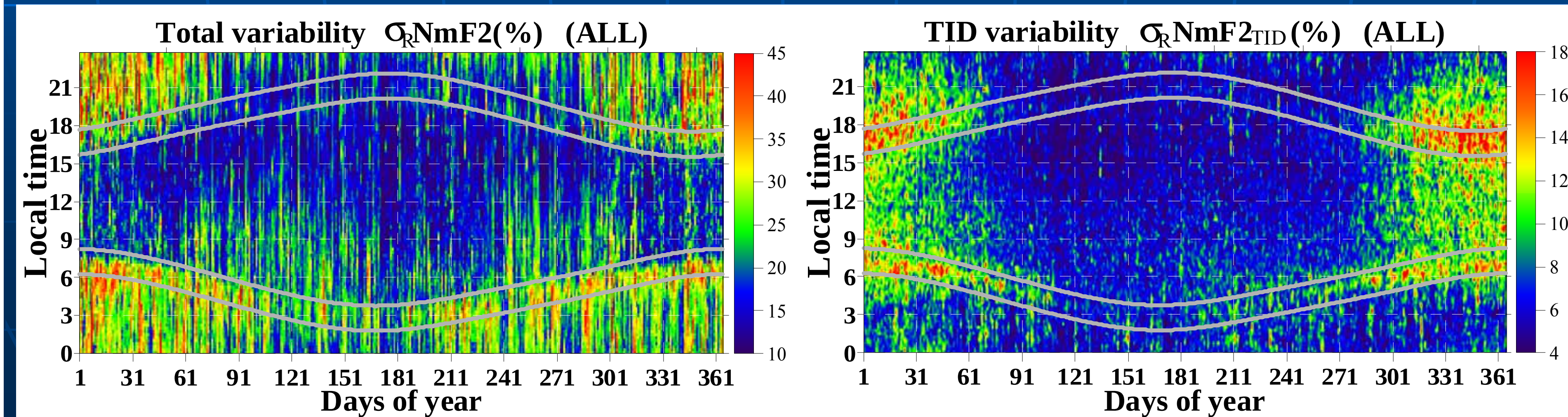


Diurnal-seasonal behavior (averaging over low solar activity years or all years)

Low solar activity years (2006-2011).
Total variability. Clear day-nighttime difference. Clear nighttime seasonal behavior.
TID variability. Highest activity is seen near the terminator. Clear seasonal behavior.

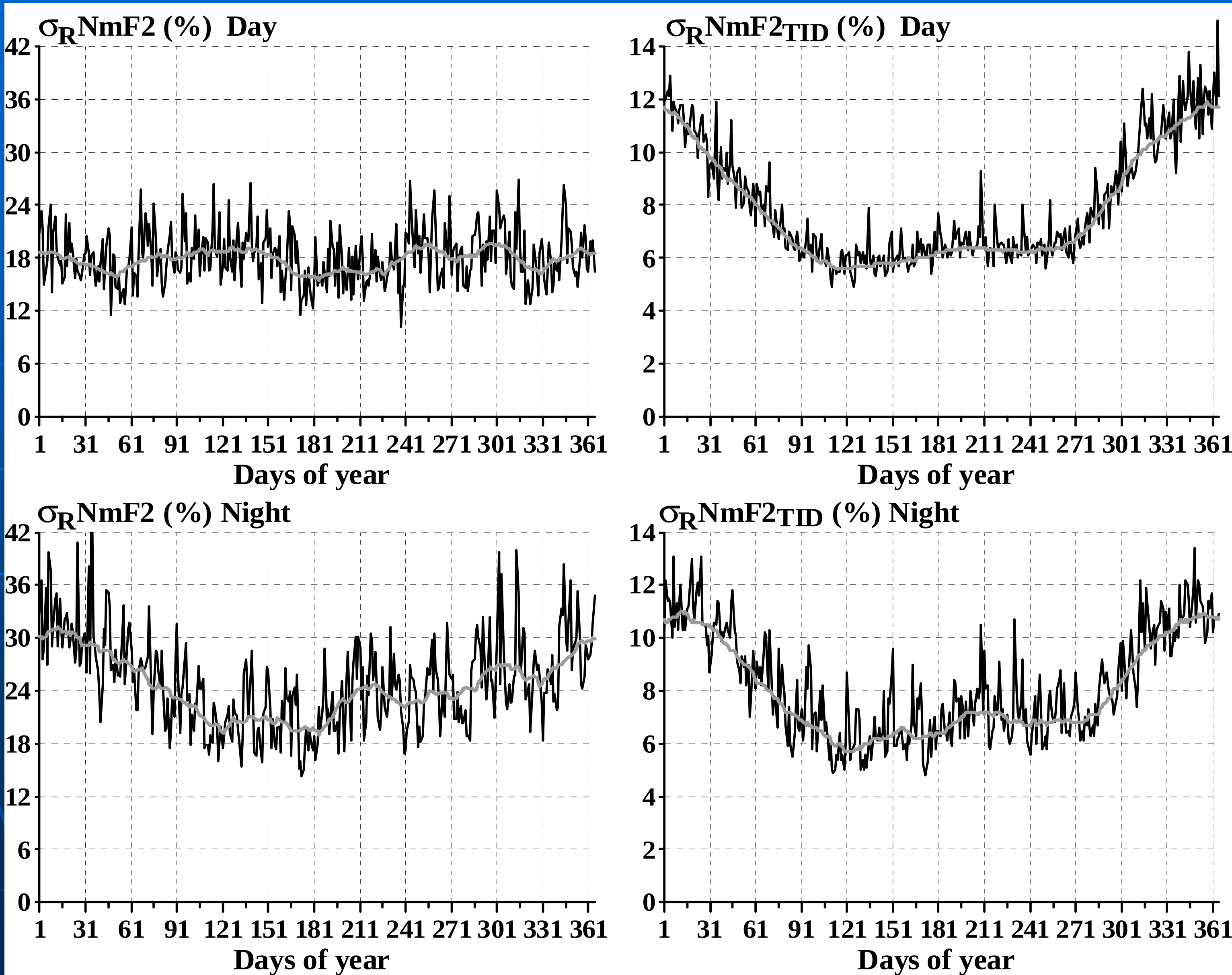


ALL years Total variability. Emergence of Spring and Autumn daytime activity.
TID variability. No difference between Low solar activity and All the years.



Seasonal behavior and 27-day smoothed seasonal behavior (All years)

Seasonal pattern is seen without smoothing, but smoothing is suitable for comparison.



Comparison of 27-day smoothed seasonal behaviors

Total variability.

The most active period is Winter Nighttime under any solar activity conditions (σ_RNmF2 ~30%).

The least active period is Summer Daytime (σΔRNmF2 ~12%) under low solar activity.

Clear nighttime seasonal behavior with Max in Winter (~30%) and Min in Summer (17-19%)

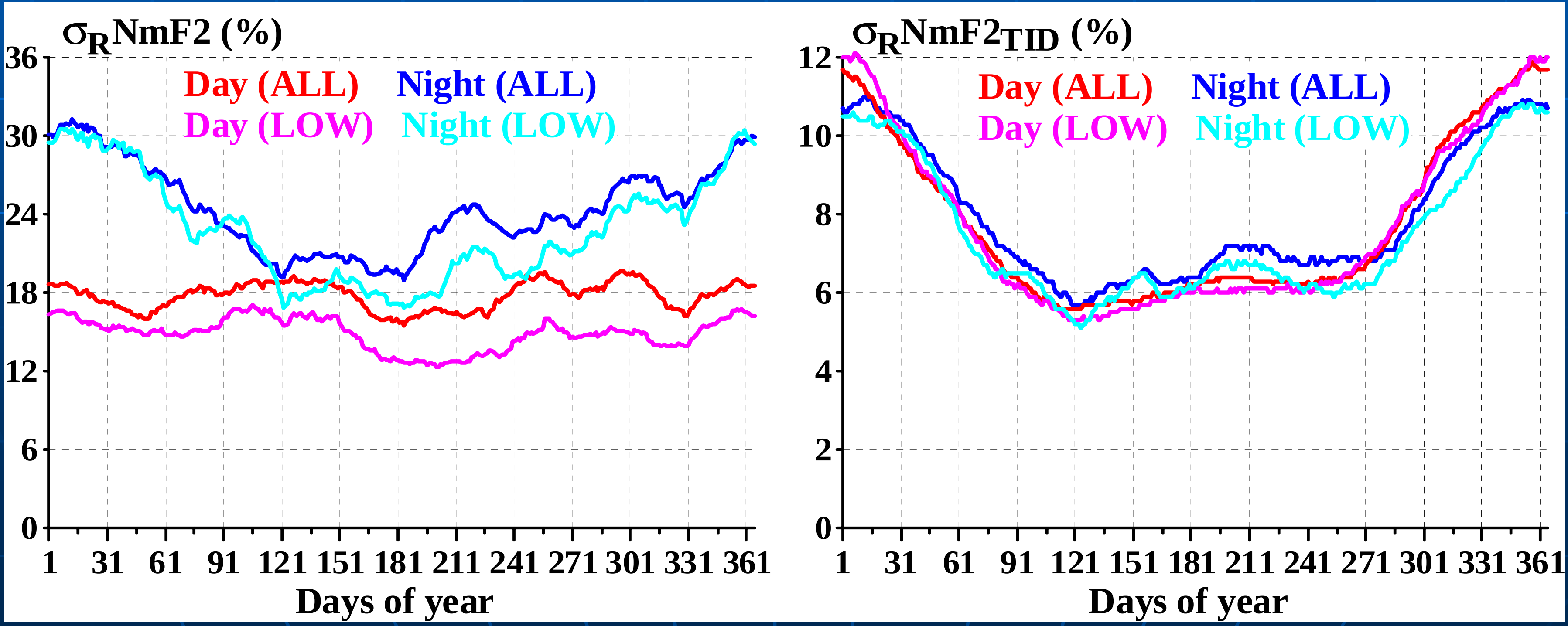
Night-Day difference is largest in January (~13-14%) and smallest in May (~ 1%).

ALL years nighttime variability is 2.5% higher than low solar activity one from May to October.

Daytime seasonal behavior needs more detailed consideration.

TID variability.

All the presented seasonal behaviors are close to each other with Max in Winter (11-12%) and Min in Summer (5-6%). Diurnal behavior needs more detailed consideration.



Comparison of 27-day smoothed seasonal behaviors (Details)

Total variability.

Multi-peak behavior with Max in Dec-Jan, Apr-May and Sep-Oct and Min in Jul, Feb and Nov.

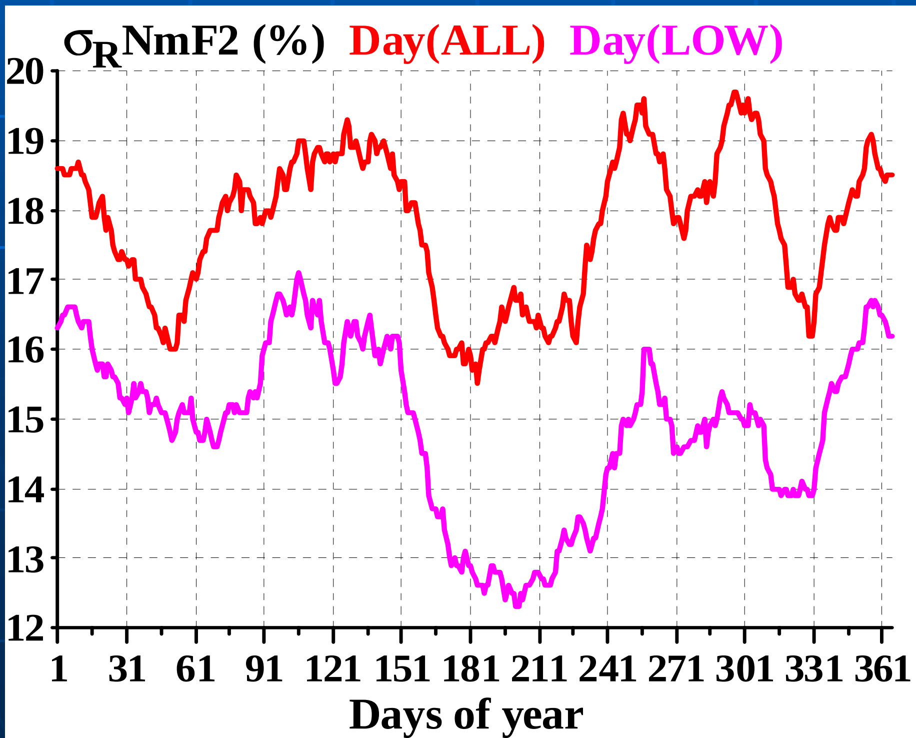
The pattern looks like superposition of annual (Max in Winter) and semiannual (Max near Equinoxes) behaviors.

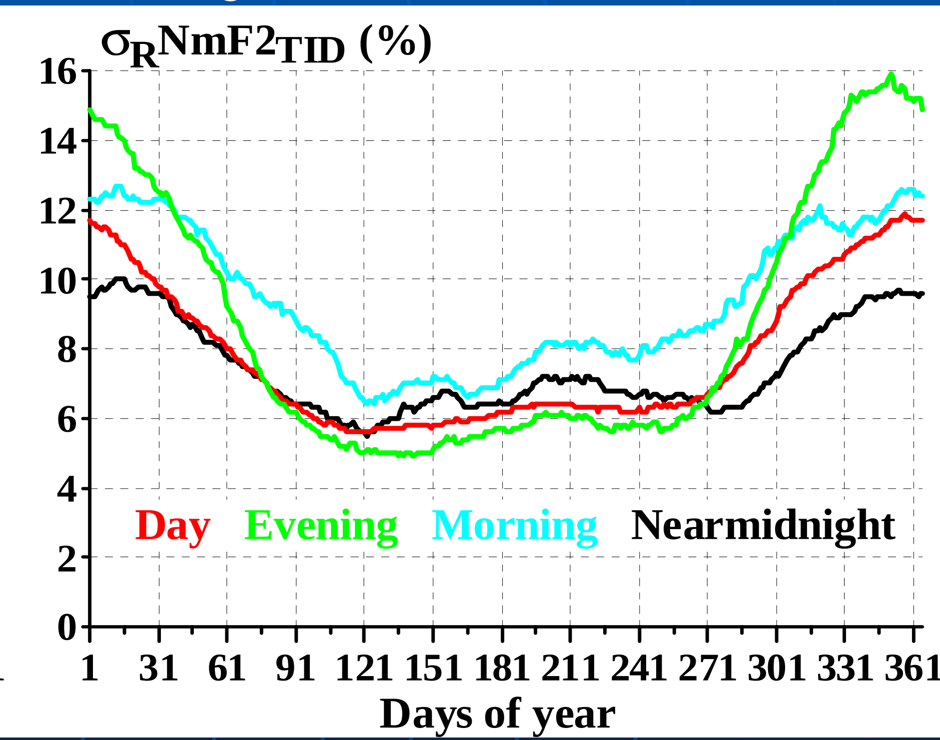
ALL years variability is ~3% higher than low solar activity one.

TID variability

The night was divided into Evening (sunset + 2 hrs), Morning (sunrise - 2 hrs) and Nearmidnight (between sunset + 2 hrs and sunrise - 2 hrs).

Evening TID variability is highest in Winter, Morning TID variability is highest from March to October and on average.





Total ionospheric variability. Discussion and Conclusions.

- **1. Night-Day difference**

  Nighttime variability is larger than the daytime one especially in Winter.

1a Nighttime meteorological activity is higher than the daytime one (no known evidence).

1b Nighttime ionosphere is more sensitive to meteorological activity compared to the daytime one because Solar control is replaced by Plasma flux control. Night-Day difference should be largest in Winter, which agrees with empirical statistics.

- **2. Seasonal behavior**

Clear annual pattern with Max in Winter for nighttime and Multi-peak daytime behavior.

2a) Different seasonal behavior of Meteorological activity for daytime and nighttime

2b) Meteorological activity has Multi-peak Seasonal behavior. Annual nighttime pattern is explained by **highest sensitivity** in Winter (**agrees with 1b**).

- **3. Solar cycle variations**

  Geomagnetic/solar contribution is clearly seen for daytime variability.
  No or weak geomagnetic influence on nighttime variability.

3a) Nighttime annual mean variability is mainly determined by Winter contribution. For this period, geomagnetic influence may compete with meteorological impact. Geomagnetic activity causes negative disturbances but reduces number of large positive disturbances.

TID variability. Discussion and Conclusions

- **1. Night-Day difference**

  Variability is highest in evening or morning hours.

  Emergence of terminator induced waves or/and zero wind conditions favorable for internal gravity waves propagation.

- **2. Seasonal behavior**

  Variability in Winter is ~ 2 times higher than in Summer.

  Seasonal dependence of internal gravity wave activity of meteorological origin.

- **3. Solar cycle variations**

  No or weak geomagnetic/solar influence on TID variability

  Geomagnetic contribution to internal gravity wave activity is small compared to meteorological one ????