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IUGONET

超高層大気長期変動の全球地上ネットワーク観測・研究

Inter-university Upper atmosphere Global Observation NETwork

Metadata DB for Upper Atmosphere

Long-term analysis of geomagnetic solar quiet daily (Sq) variation and neutral winds in the mesosphere and lower thermosphere (MLT) region using the IUGONET observation data

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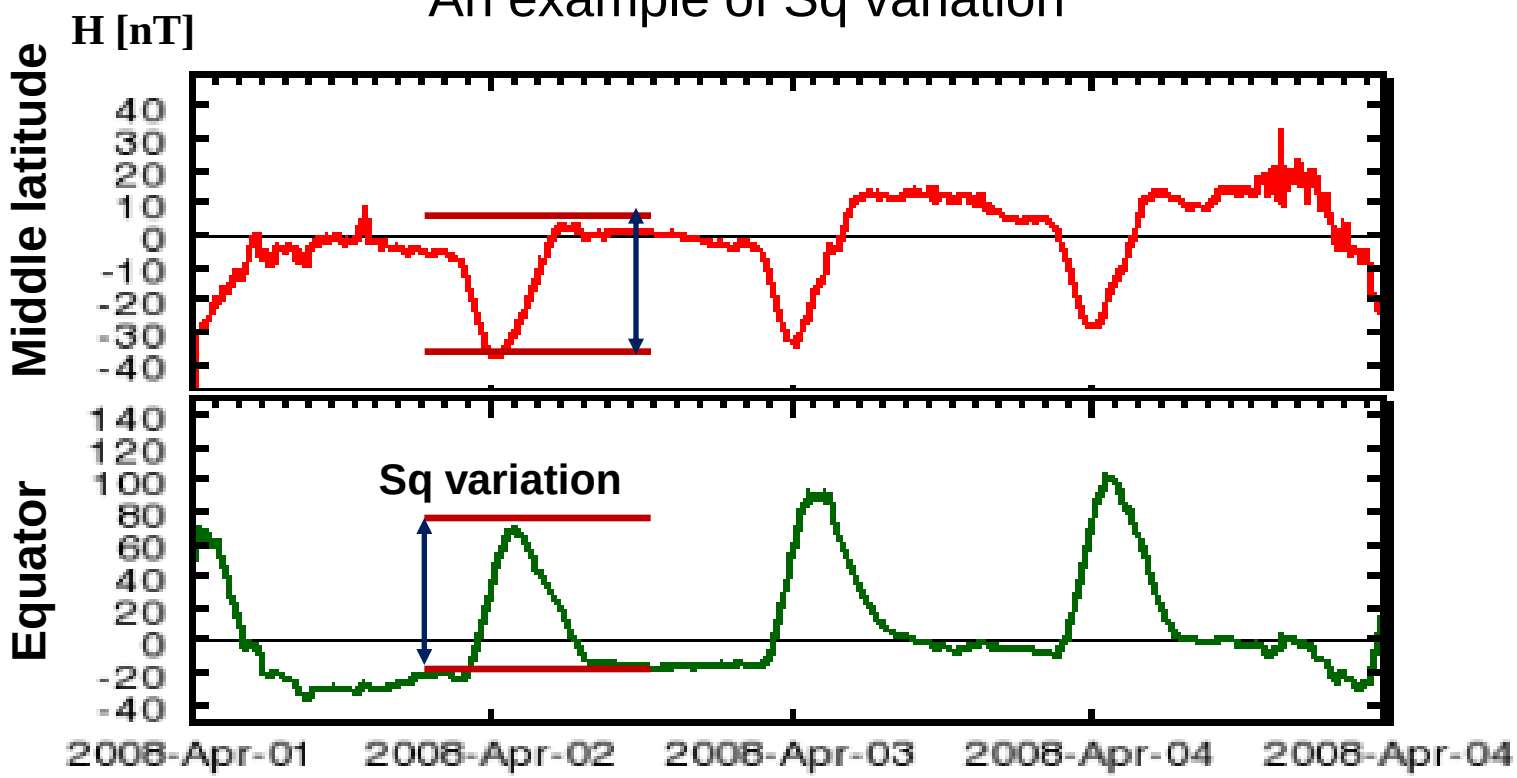
1. Introduction

1.1 Geomagnetic solar daily quiet variation

The daily variation of geomagnetic field during a solar quiet day has been called Sq (geomagnetic Solar daily Quiet variation), and is mainly produced by ionospheric currents, which are driven by ionospheric dynamo of the E-region.

An example of Sq variation



1. Introduction

1.2 Knowledge of the amplitude of Sq field

○Amplitude of Sq field is

proportional to the magnitude of ionospheric current

The ionospheric currents depends strongly on ionospheric conductivity, geomagnetic field and neutral wind.

Ohm's law: $$\mathbf{J} = \Sigma \cdot (\mathbf{E} + \mathbf{U} \times \mathbf{B})$$

○Ionospheric conductivity (Σ) depends on

Solar activity＝11-year periodicity of the UV/EUV solar radiation

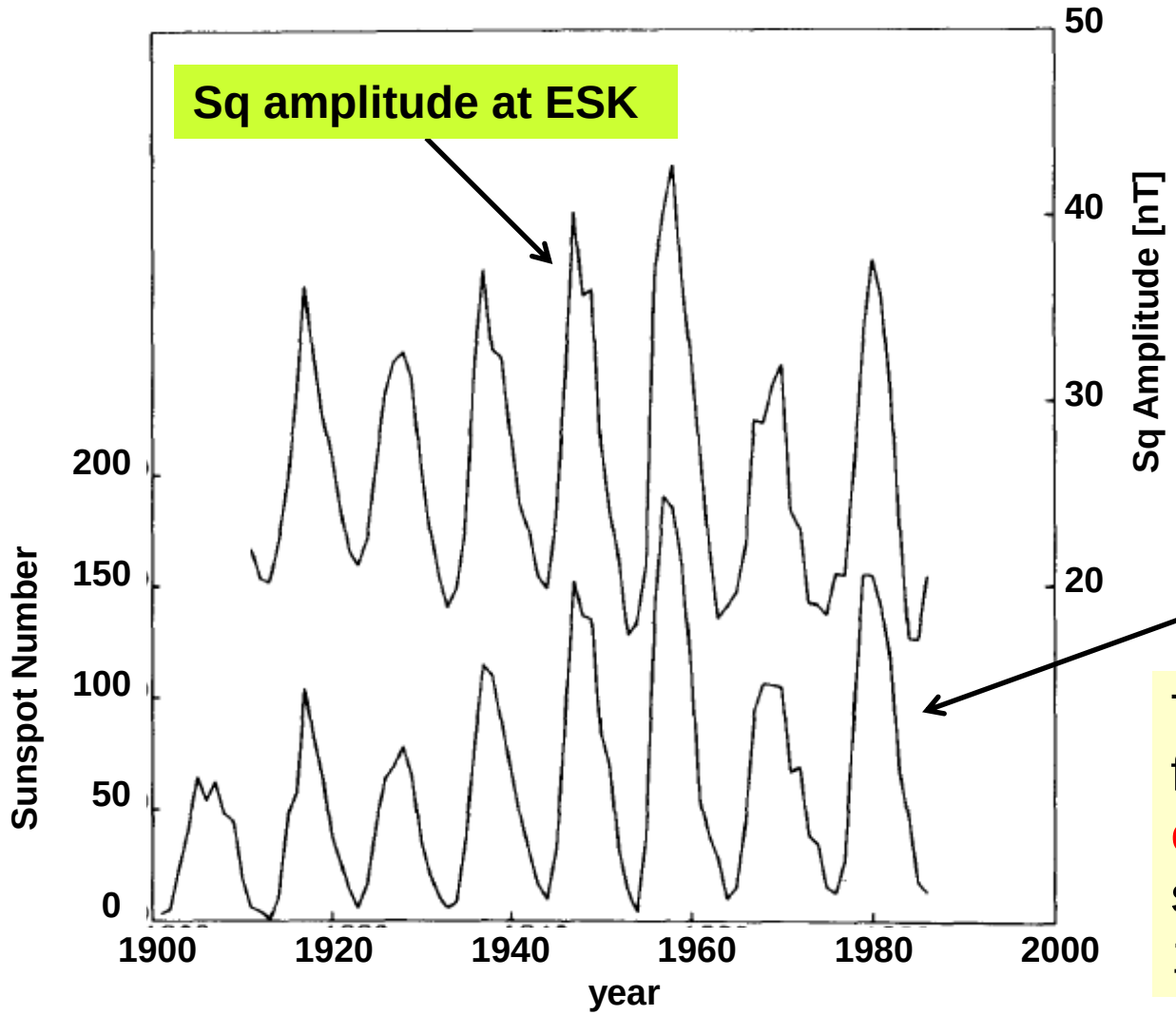
Season ＝tile angle of the Earth's rotation axis

Annual variation of geomagnetic field＝enhancement of ionospheric conductivity due to decrease of magnetic field intensity

Greenhouse effect＝enhancement of electron density due to cooling effect of the upper atmosphere. [e.g., Elias et al., JGR, 2010]

1. Introduction

1.3 Dependence of Sq amplitude on solar activity

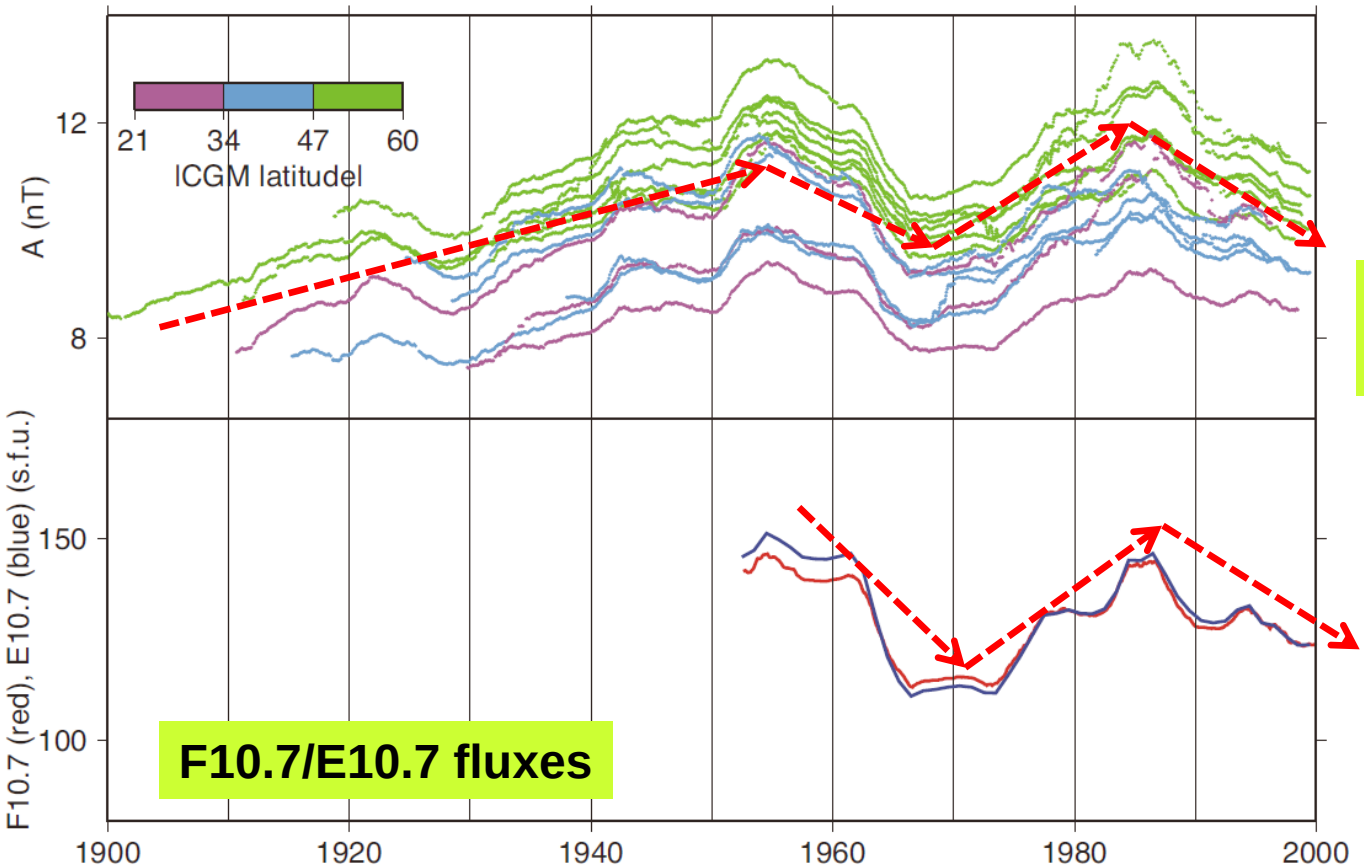


Schlapp et al. [1990]

The amplitude of Sq field is closely correlated with the sunspot number with 11-year solar activity.

1. Introduction

1.4 Long-term variation of the amplitude of the Sq field



Macmillan and Droujinina [2007]

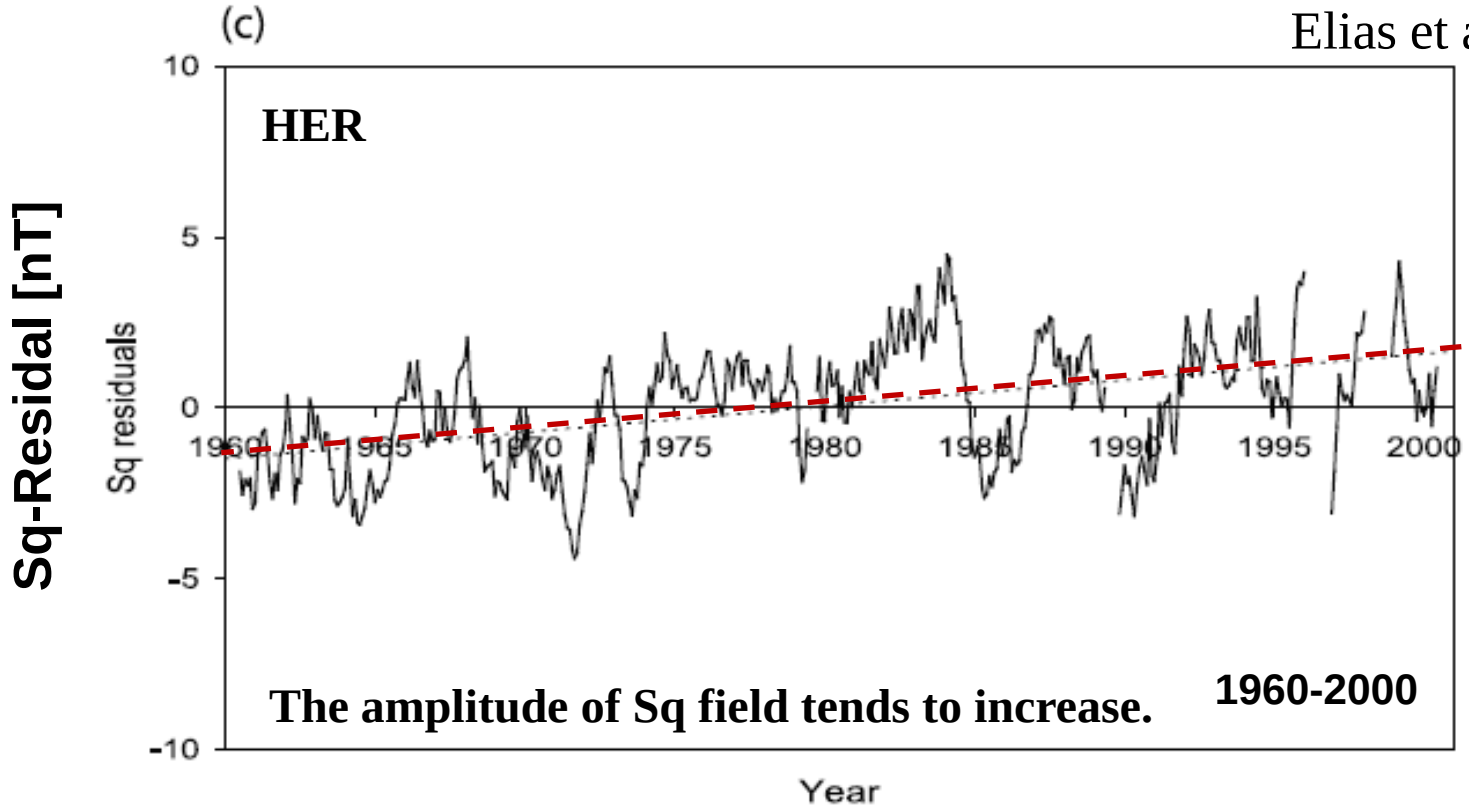
Sq amplitude at 14 stations

The 11-year smoothed amplitude of Sq field shows a very good correlation with that of F10.7/E10.7 fluxes without dependence on geomagnetic latitude.

1. Introduction

1.5 Previous investigations of the long-term variation of Sq field

Elias et al., 2010



Elias et al. [2010] proposed that the long-term trend of the residual Sq field is caused by the enhancements of ionospheric conductivity due to decrease of geomagnetic field and cooling effect of the upper atmosphere associated with greenhouse effect.

1. Introduction

1.6 Problem of previous researches of the long-term Sq field

- Shortage of observation locations

Although it has been well-known that the amplitude of Sq field shows 11-year solar cycle dependence and annual variation, a global feature of the long-term variation of the Sq field remains unknown.

- Shortage of integrated analysis of observation data between different field

Elias et al. [2010] suggested that the long-term trend of Sq field contributes to ionospheric variation due to the greenhouse effect; however, they did not discuss the variation of electron density and neutral wind in the MLT region, based on the observation data analysis result.

- Problem of analysis method

Because they used the sunspot number in order to exclude solar activity dependence from the Sq field variation, we cannot evaluate the residual Sq field during the solar minimum (no sunspot period).

2. Purpose of this study

The purpose of the present study is to clarify a cause of the long-term variation of the Sq field using the geomagnetic field and neutral wind in the MLT region provided from the IUGONET project. In this study, we added the following modification of data analysis in order to overcome the problems of previous investigations.

(1) Long-term data analysis of geomagnetic field observed at many sites and neutral wind in the mesosphere and lower thermosphere.

We used the metadata search system and the integrated data analysis software which have been developed in the IUGONET project.

(2) Improvement of data analysis method

We defined geomagnetic quiet days as the period when the Kp index gives less than 4.

We adapted the second-order fitting method in order to derive solar activity dependence from the variation of Sq field.

3. Analysis Method

2.1 Observation data used in the present analysis

Geomagnetic field (1 hour since 1900) : WDC, Kyoto Univ.

Geomagnetic index (Kp, 1932-2010) : WDC, Kyoto Univ

F10.7 flux (1947-2010) : NGDC/NOAA

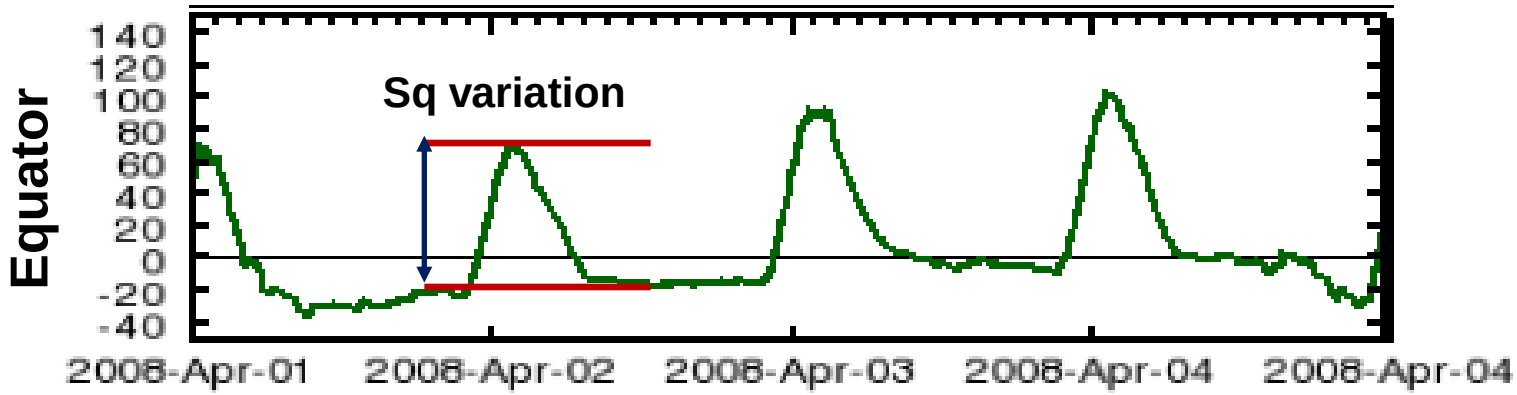
Neutral wind in the MLT region (1-day average) : RISH, Kyoto Univ.

2.2 Identification of quiet day and Sq amplitude

Quiet day: the maximum of Kp index is less than 4 every day.

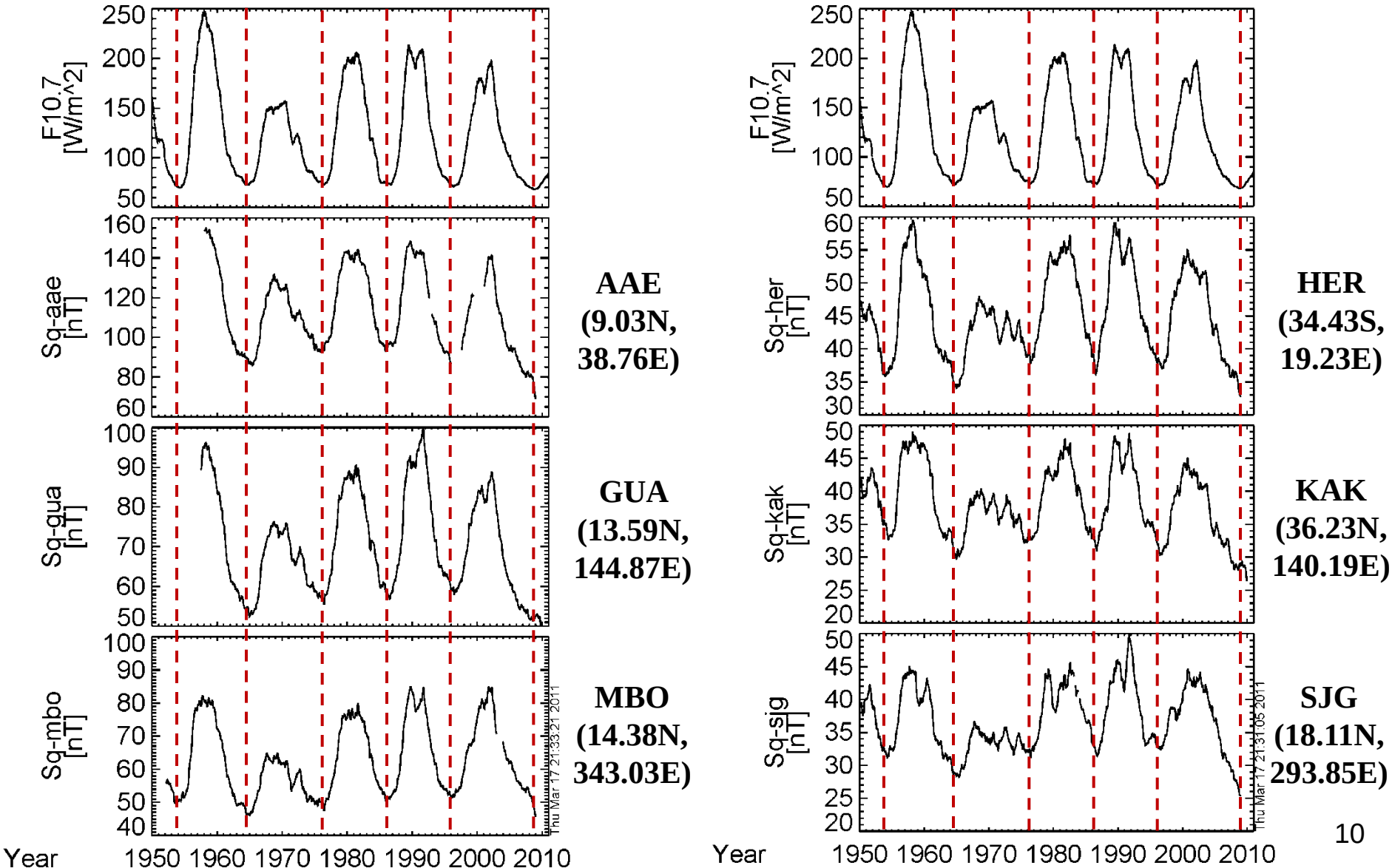
Sq amplitude : difference between the maximum and minimum values of the daily variation of the H-component of geomagnetic field

Residual solar activity : deviation of second-order fitting curve



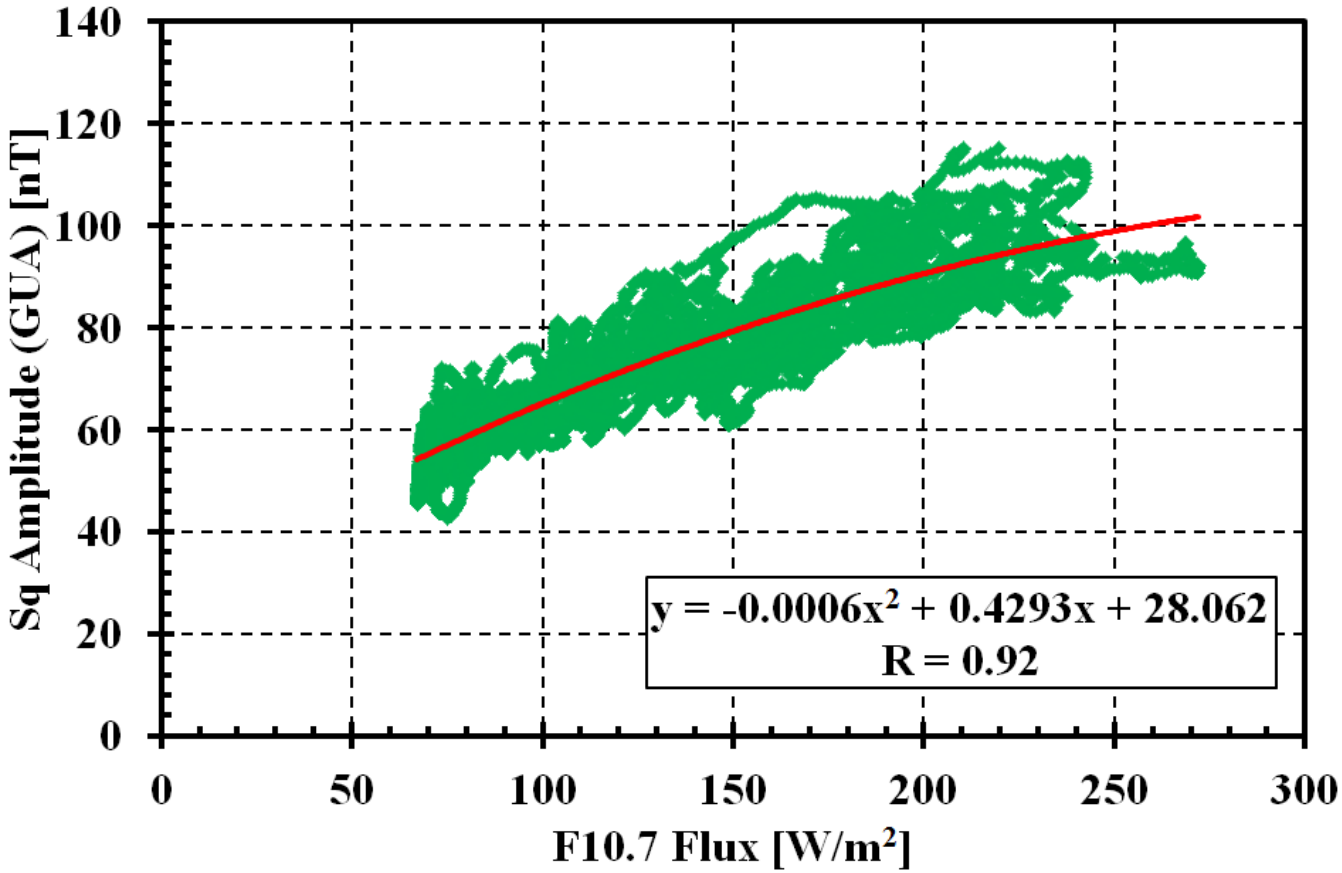
4. Result

4.1 Long-term variation of Sq amplitude



4. Result

4.2 Relationship between the Sq amplitude and solar F10.7 flux



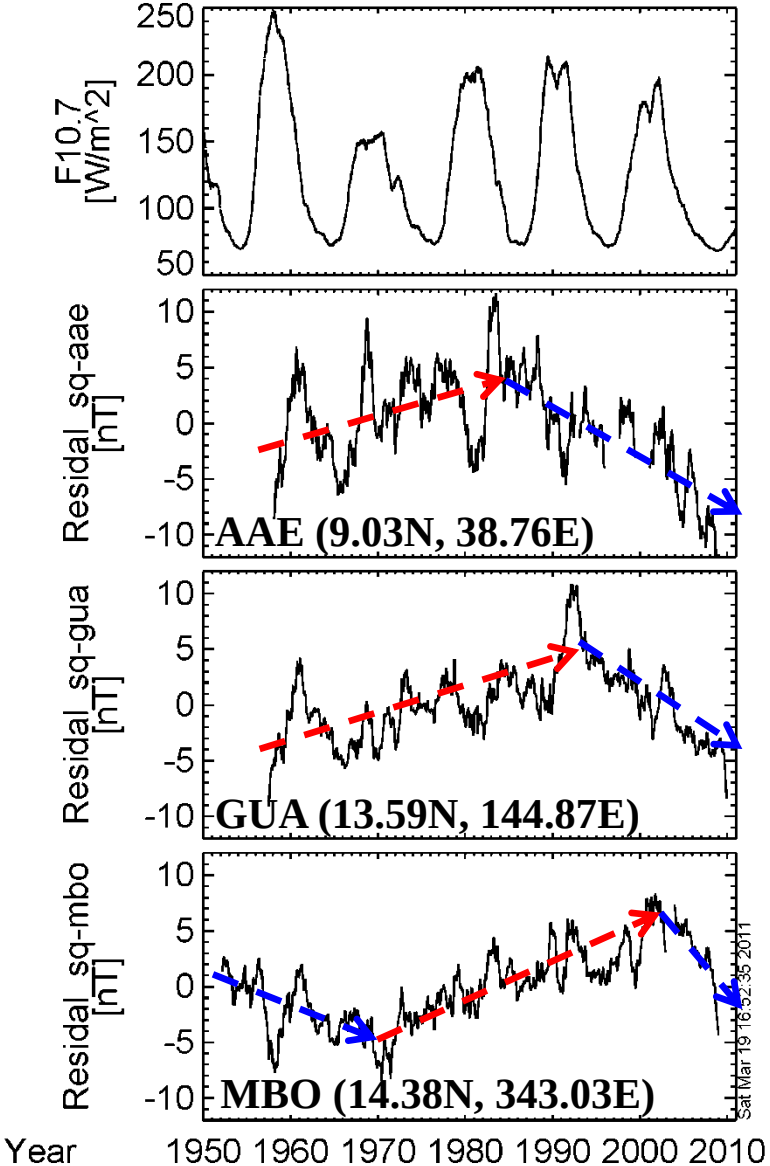
We exclude the component of solar activity from the Sq amplitude

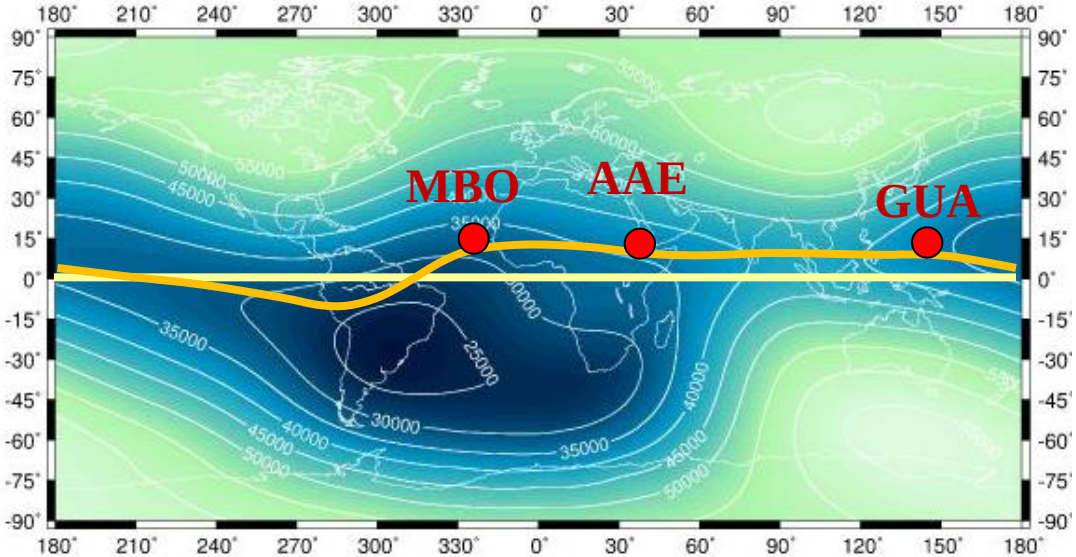
Sq amplitude ＝ solar activity dependence (F10.7)

＋geomagnetic annual variation＋upper atmosphere variation

4. Result

4.3 Long-term trends of residual Sq amplitude (Equator)





Station map

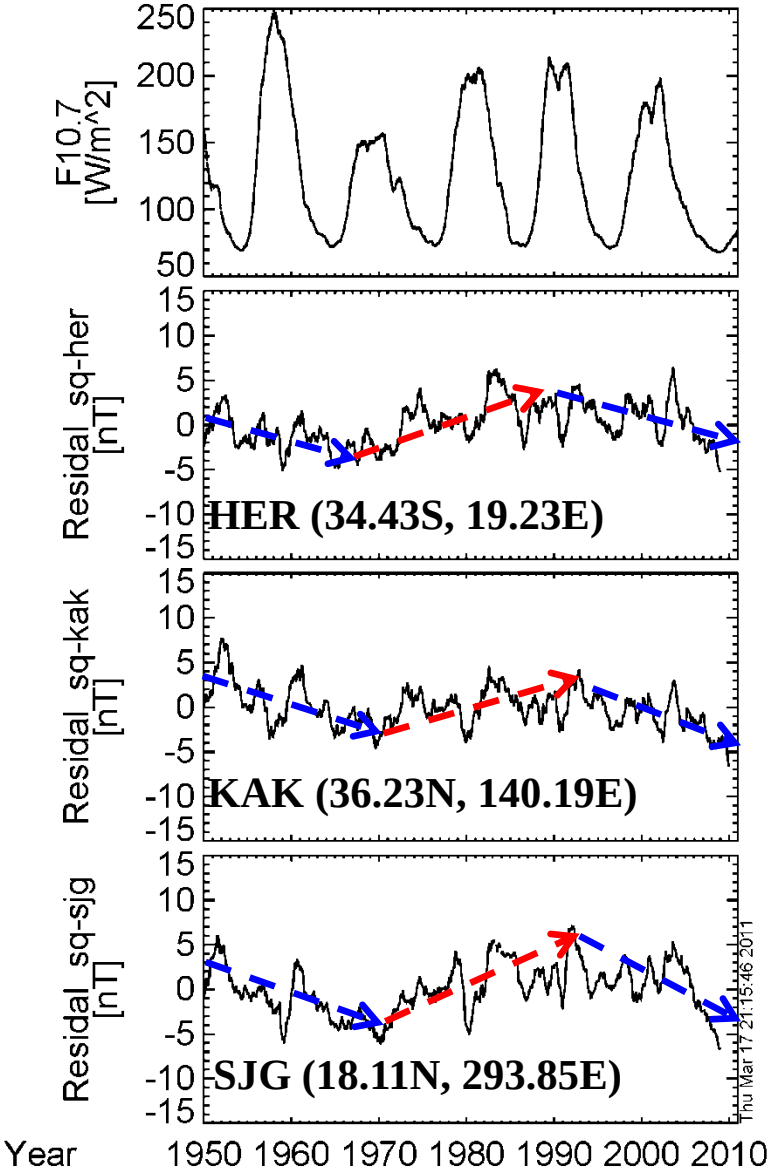
Increase

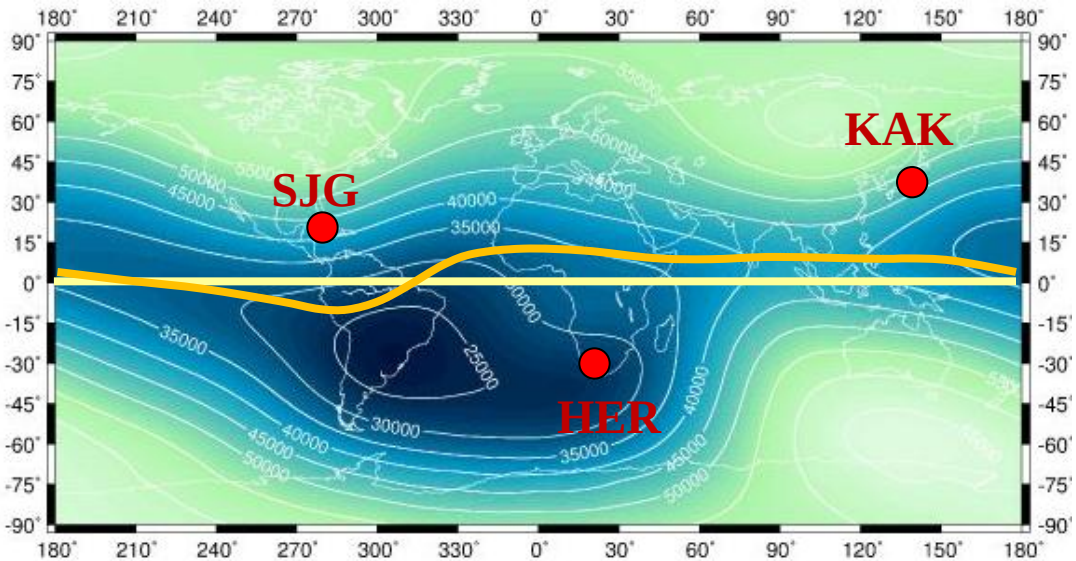
Decrease

The long-term trend of the residual Sq field near the equatorial region depends on geographic longitude. The trend shows both positive and negative variations.

4. Result

4.3 Long-term trends of residual Sq amplitude (Low lat.)





Station map

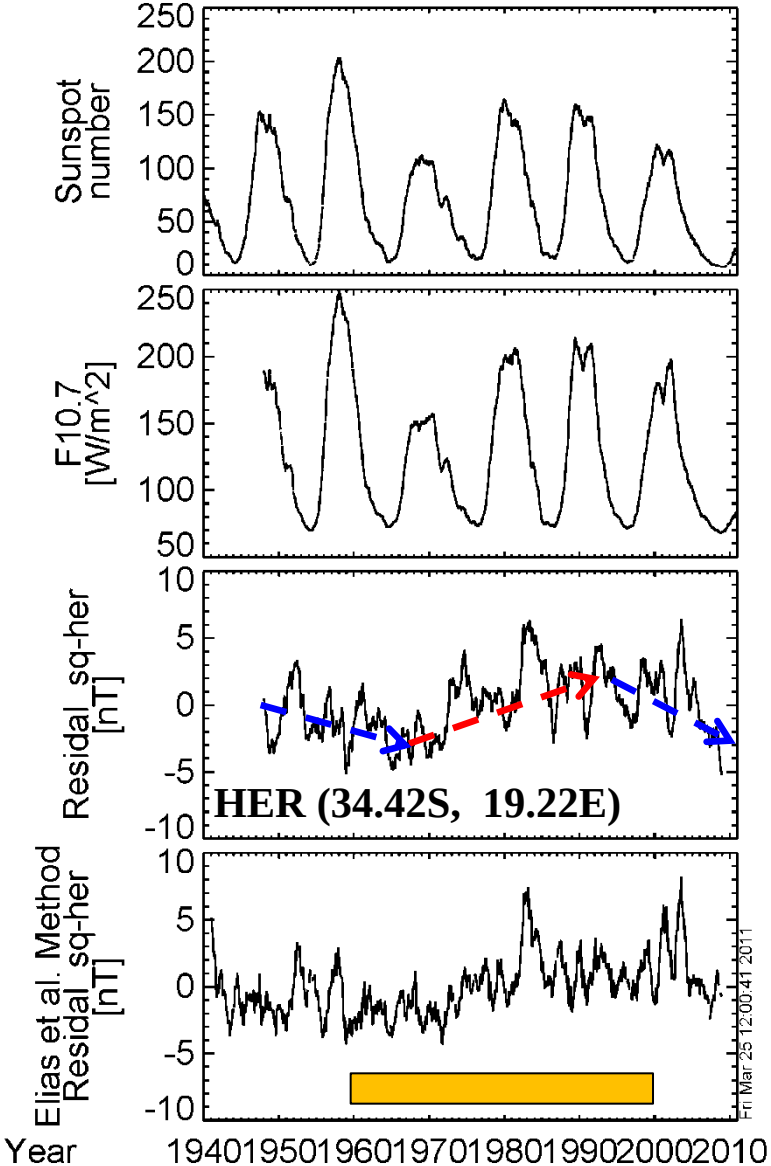
Increase

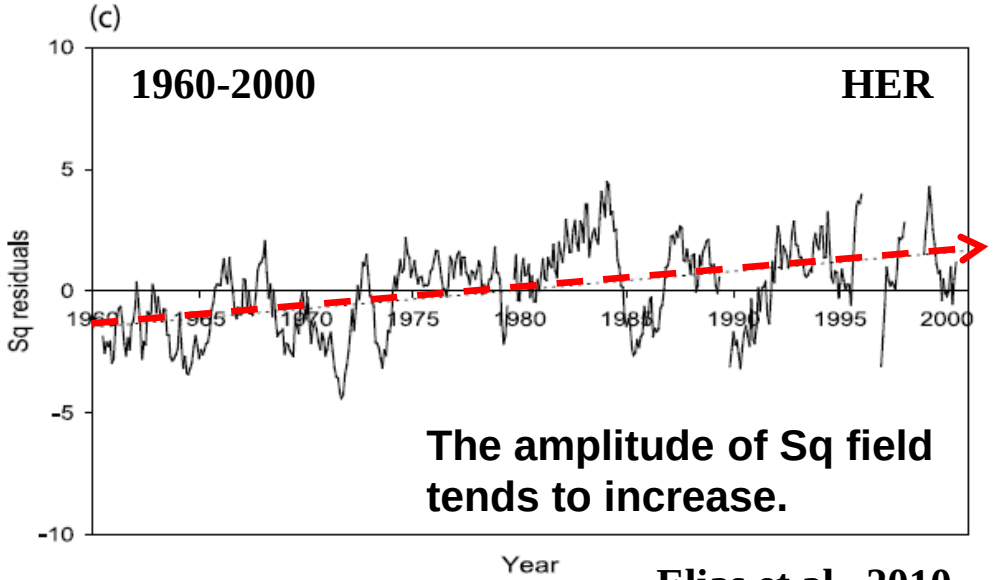
Decrease

The long-term trend of the residual Sq field in low latitudes shows positive and negative changes. The positive variation appears during 1970-1990.

5. Discussion

5.1 Comparison of the previous investigations



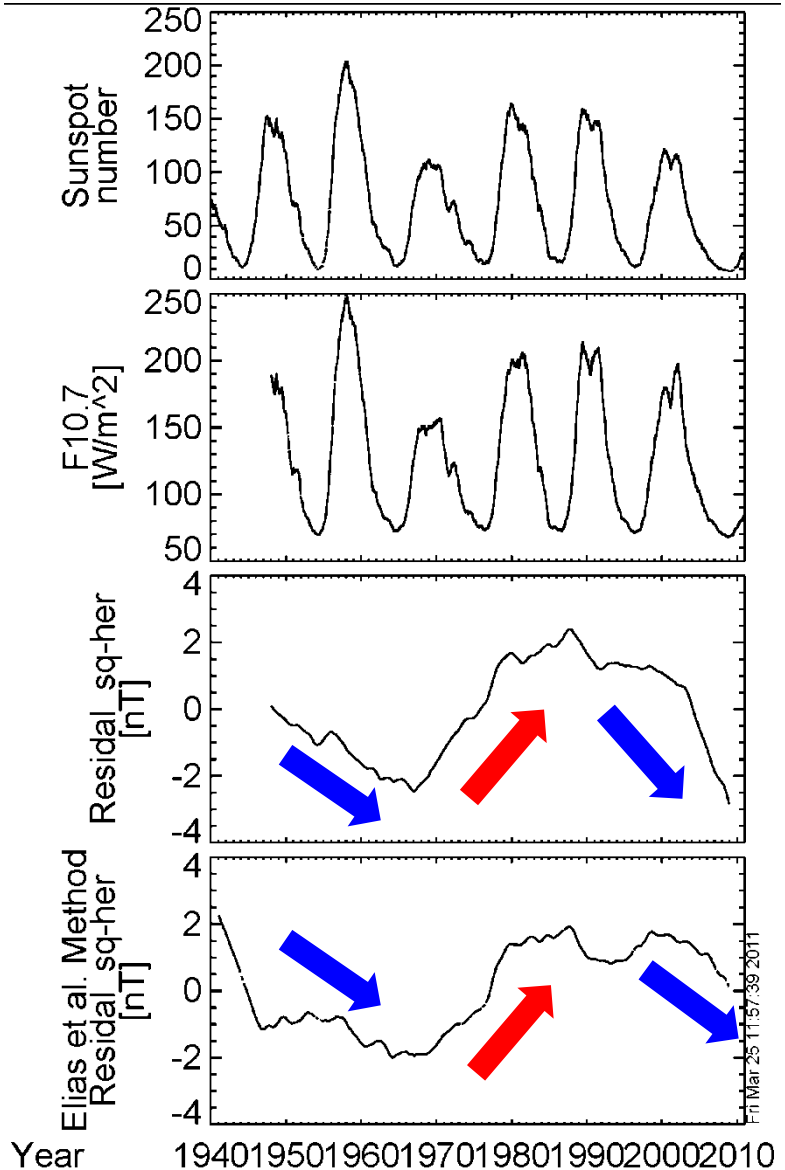


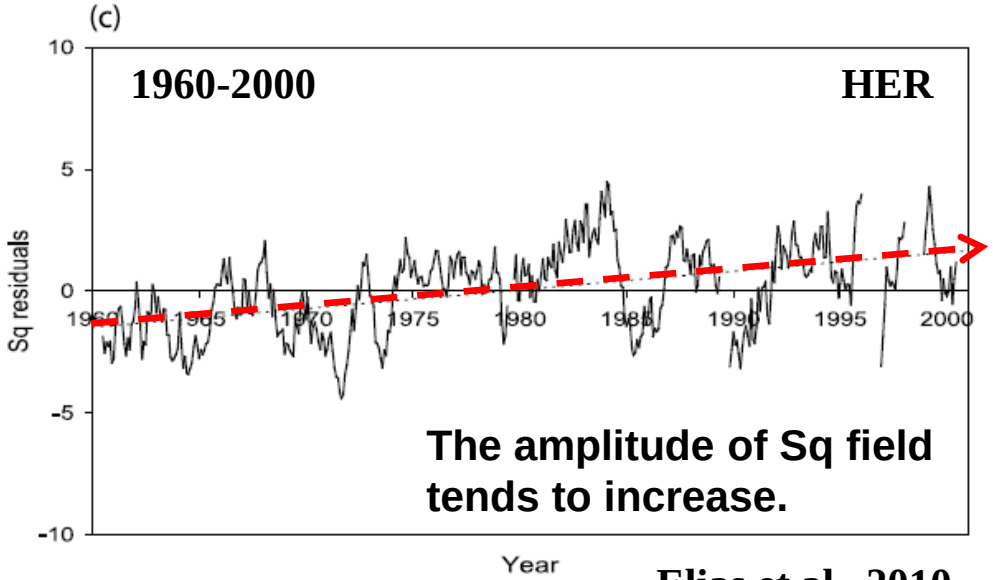
Elias et al., 2010

The residual Sq field during the period (1960-2000) by Elias et al. [2010] tends to gradually increase; however, this tendency does not always show a positive change during other periods.

5. Discussion

5.2 Comparison of the previous investigations





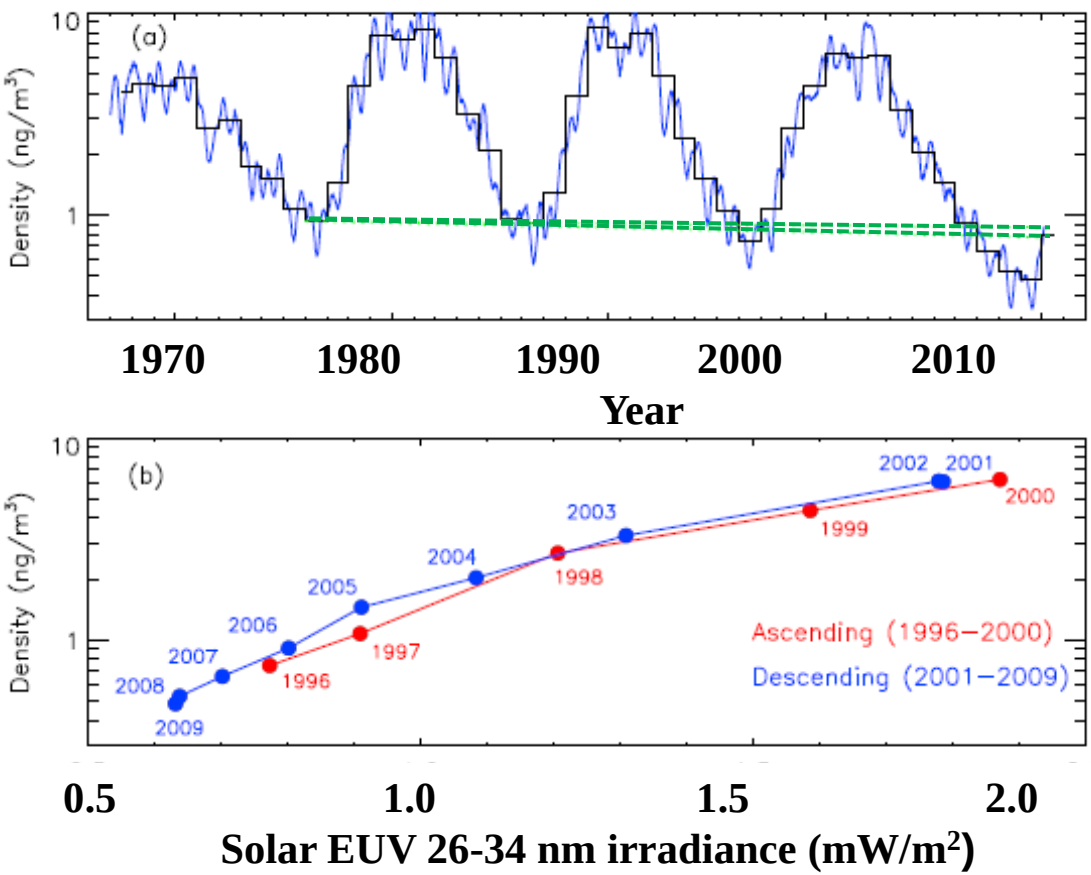
Elias et al., 2010

The long-term trend of 11-year running average residual Sq field shows negative and positive changes without solar activity dependence.

This residual Sq variation is caused by a gradual change in the Earth's upper atmosphere environment??

5. Discussion

5.3 Causes of the Sq field depression during 23 solar minimum



[Stanley et al., GRL, 2010]

(a) Yearly variation of the neutral density at 400 km in the thermosphere during 1960-2010.

The green line shows the neutral density variation due to the green house effect based on the model calculation

(b) Dependence of the neutral density in the thermosphere on solar EUV intensity.

The neutral density in the thermosphere during 23 solar minimum is the smallest during 40 years. The significant depression of the neutral density may contribute to decrease of ionospheric conductivity.

6. Conclusion

- We performed the integrated analysis of the long-term trend of Sq field, using the ground observation data of geomagnetic field, solar F10.7 flux and sunspot number during 1932- 2010.

1. The amplitude of Sq field observed in a wide region from middle latitude to the equator depends strongly on solar activity, and the Sq amplitude is proportional to the solar F10.7 flux.

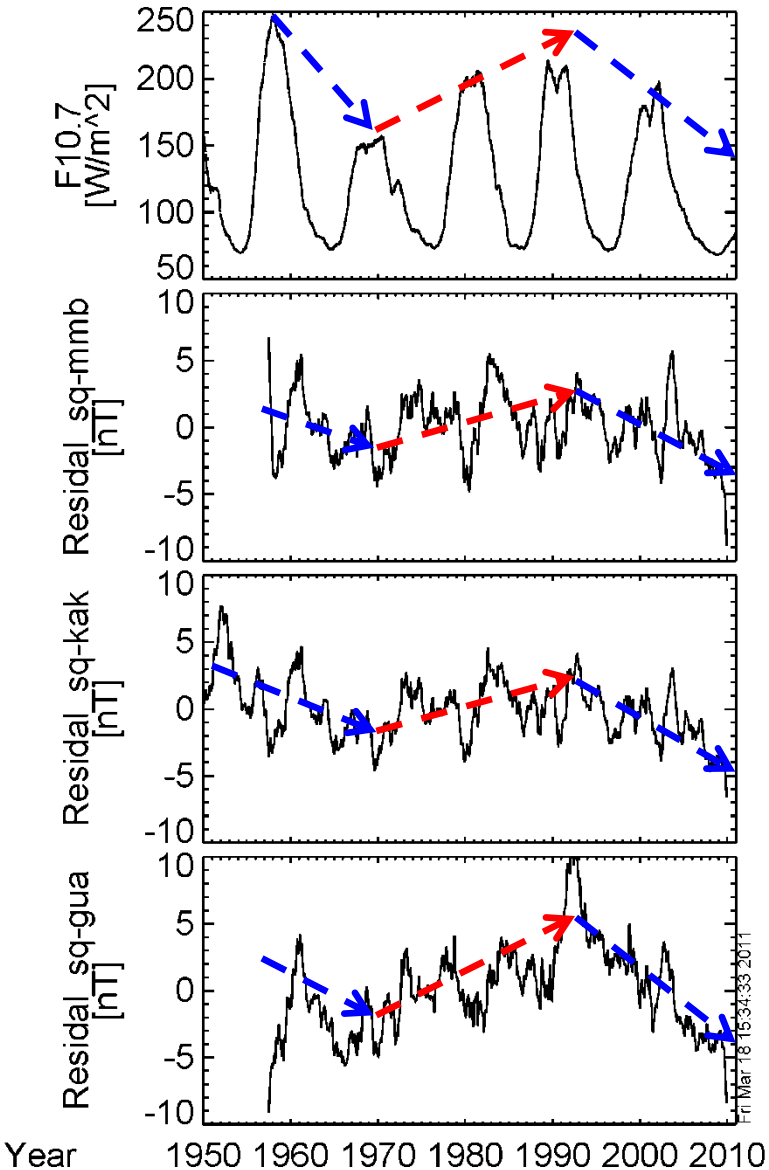
2. The long-term trend of the residual Sq field showed a positive change during 1970-1990, which is consistent with that of Elisa et al. [2010]. However, it decreases significantly during two periods (1940-1970 and 1990-2010).

   - This tendency is different from that of Elias et al. [2010], who proposed that the long-term increase of Sq field contributes to both the decrease of the ambient magnetic field intensity and cooling effect of the upper atmosphere due to greenhouse effect.

   - The interval of decrease and increase of the residual Sq field is 30-40 year periods, which suggests the long period variation of the Earth's upper atmosphere environment?

4. Result

4.3 Long-term trends of residual Sq amplitude-2



The long-term trends of residual Sq field from the middle to low latitudes on almost the same meridian.

The Sq amplitude shows the minimum and maximum around 1970 and 1990, respectively, without dependence on latitude.

MMB (43.91N, 144.18E)

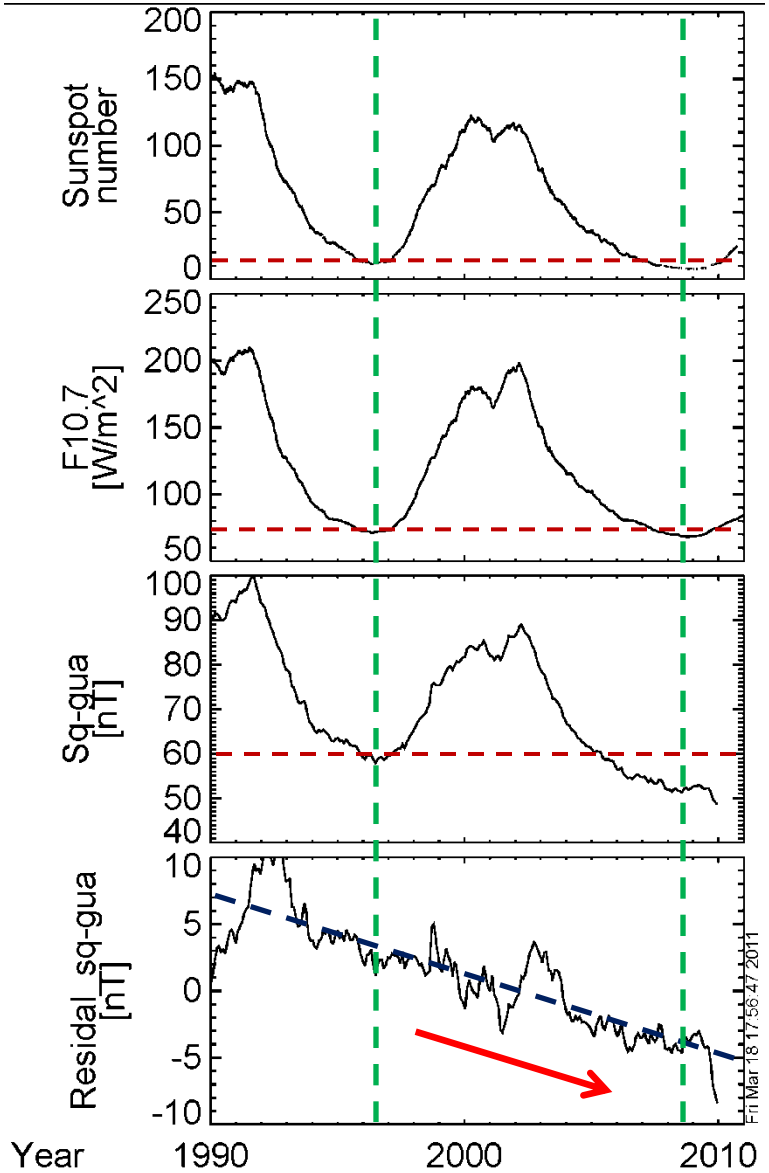
KAK (36.23N, 140.18E)

The trends of Sq amplitude resembles the upper envelope of solar F10.7 flux.

GUA (13.59N, 144.87E)

5. Discussion

5.3 Difference of Sq field between the 22 and 23 solar minima



22 cycle minimum : 1996-1997

23 cycle minimum : 2008-2009

Observation site : GUA (13.59N, 144.87E)

Normalized F10.7 and Sq field during the 22 and 23 solar minima

	22 cycle (1996/7/18)	23 cycle (2008/8/15)	Variation
F10.7	0.346	0.327	-0.019 (2 %↓)
Sq field	0.573	0.502	-0.071 (7 %↓)

※ The change in the Sq field during the two solar minima is about 3.7 times larger than that in the F10.7 flux.