SOLAR MAGNETIC FIELD AND GEOMAGNETIC ACTIVITY

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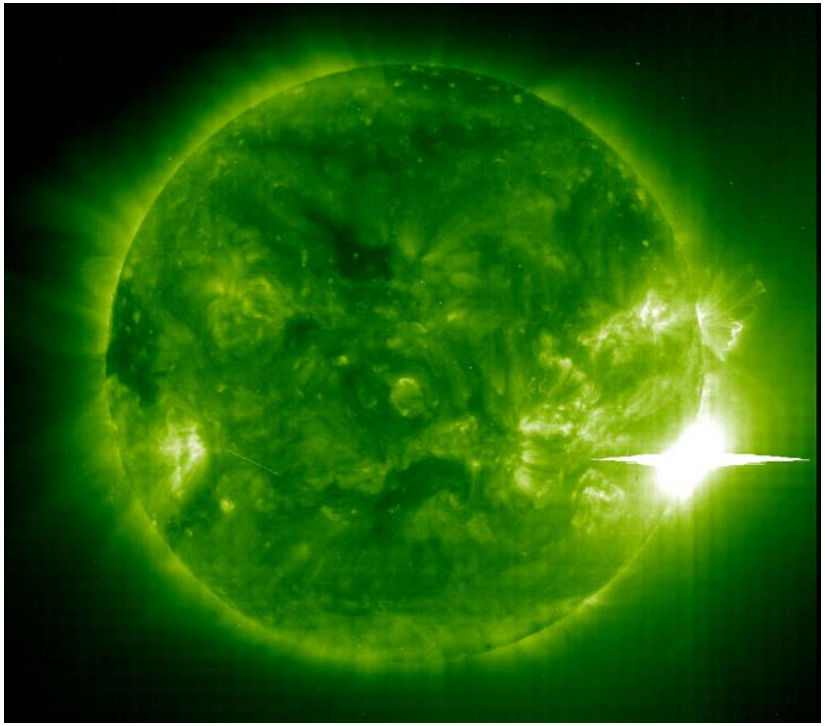
When we say "solar activity", usually we measure it by the sunspot number

- Good reason: the longest data record (400 years)
- But solar activity is not only "sunspot-related"
- Other manifestations of solar activity are not measured by the sunspot number but are reflected in geomagnetic activity
- What are the solar sources of geomagnetic activity?

Sunspots alone do not affect the Earth, they are just a measure of the Sun's activity

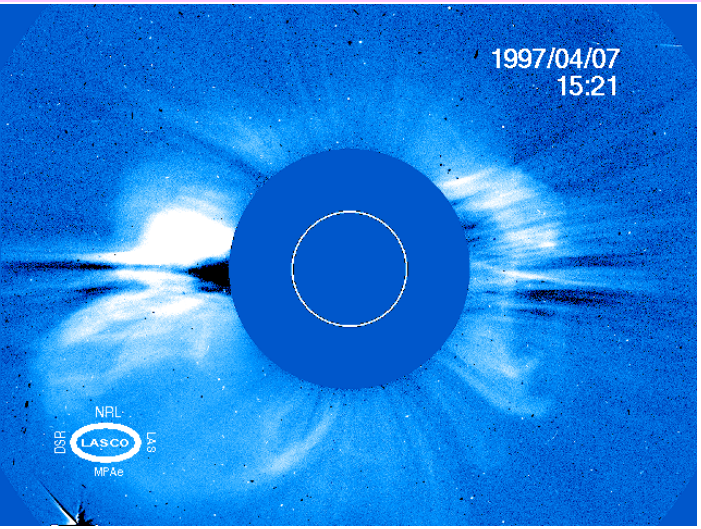
During periods with more sunspots there are more solar flares and coronal mass ejections

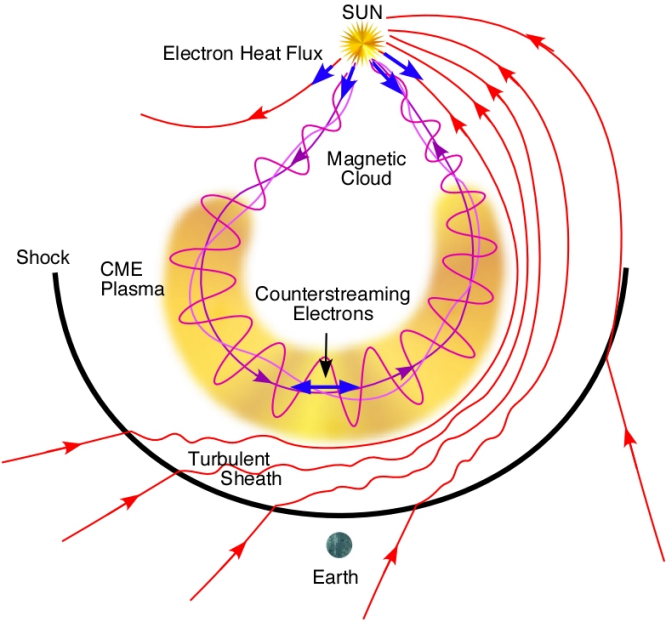


Solar flare – a sudden, rapid and intense variation in brightness

Solar flares emit huge bursts of electromagnetic radiation including X-rays, UV, visible light and radiowaves.

Solar sources of geomagnetic activity: (1) coronal mass ejections





huge eruptions from the corona of plasma and embedded magnetic fields

Sources of the strongest but sporadic geomagnetic storms

Sunspot-related:

Maximum in number and intensity in sunspot max, minimum in sunspot min

- Coronal mass ejections interact with the Earth's magnetic field
- Lead to the strongest geomagnetic storms

Solar sources of geomagnetic activity: (2) Quasi-stationary fast solar wind from coronal holes

Origin:

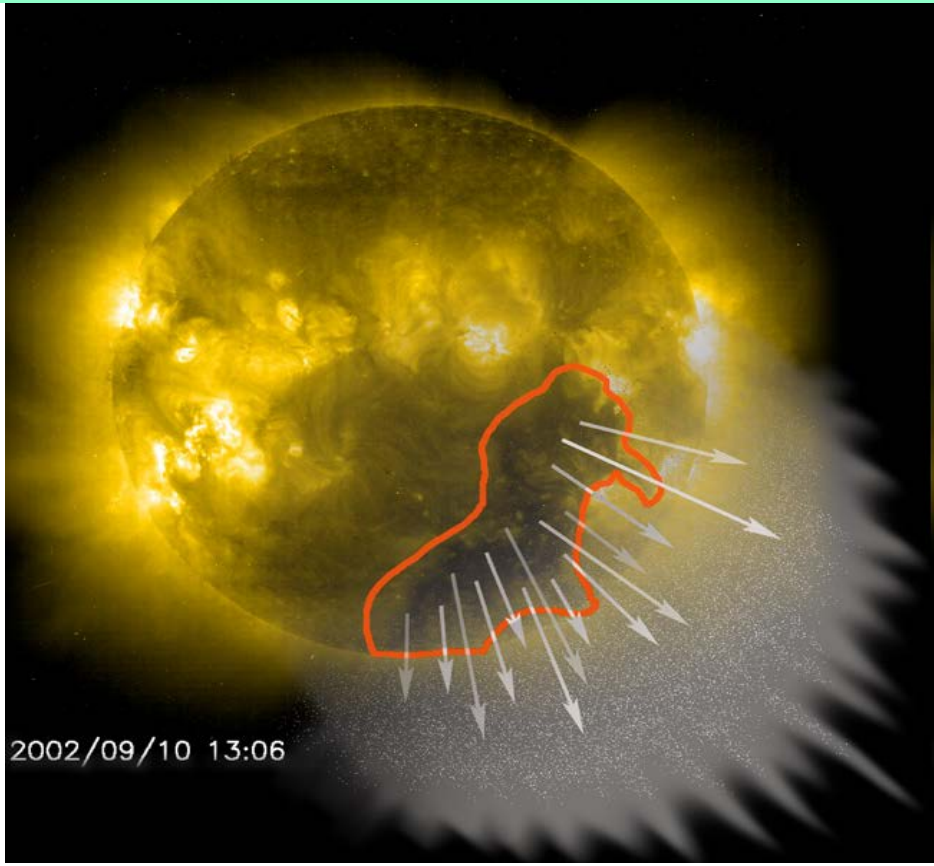
Unipolar open magnetic field regions

Long lived

⇒Sources of **recurrent geomagnetic storms**

Non-sunspot-related

Maximum during sunspot declining and minimum phase, minimum in sunspot maximum



Manifestations of the solar poloidal field

Different effects on geomagnetic activity

Coronal mass ejections

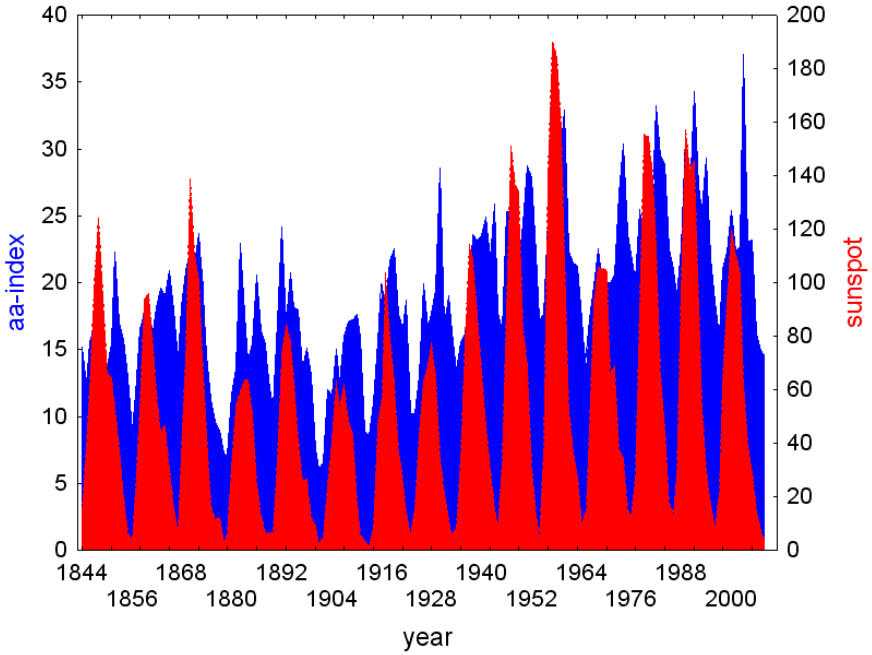
- Most often and strongest around sunspot maximum
- Related to the solar toroidal field
- Sporadic magnetic storms
- Strong, but short-lasting
- **Sudden commencement storms**

High speed solar wind

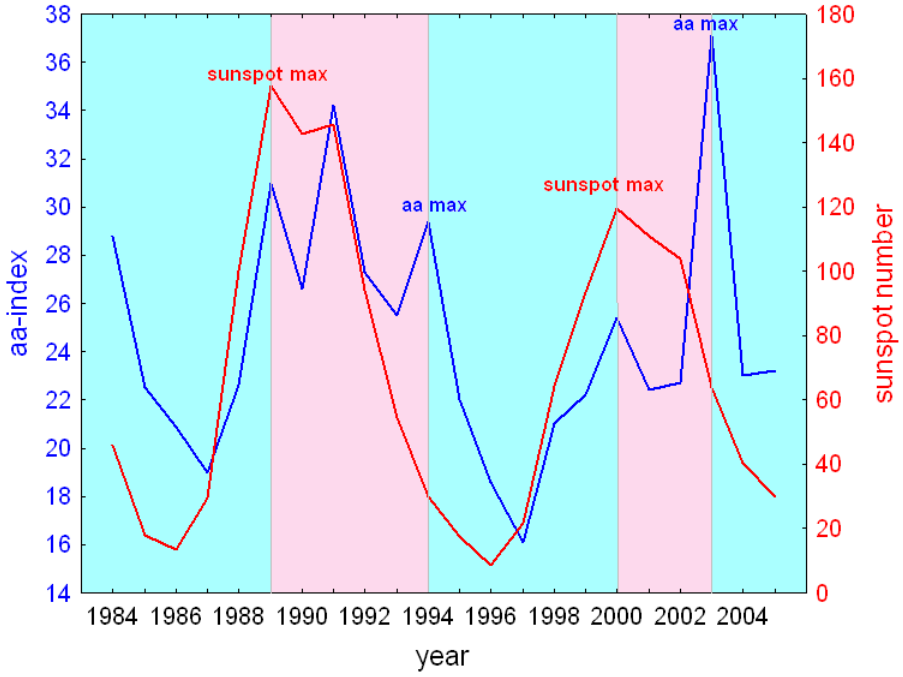
- Most often and strongest on sunspot decline phase
- Related to the solar poloidal field
- Recurrent magnetic storms
- Moderate, but long-lasting
- **Gradual commencement storms**

How can we evaluate
the relative influence
of these two types of solar activity
on the Earth?

Sunspot Number and aa index



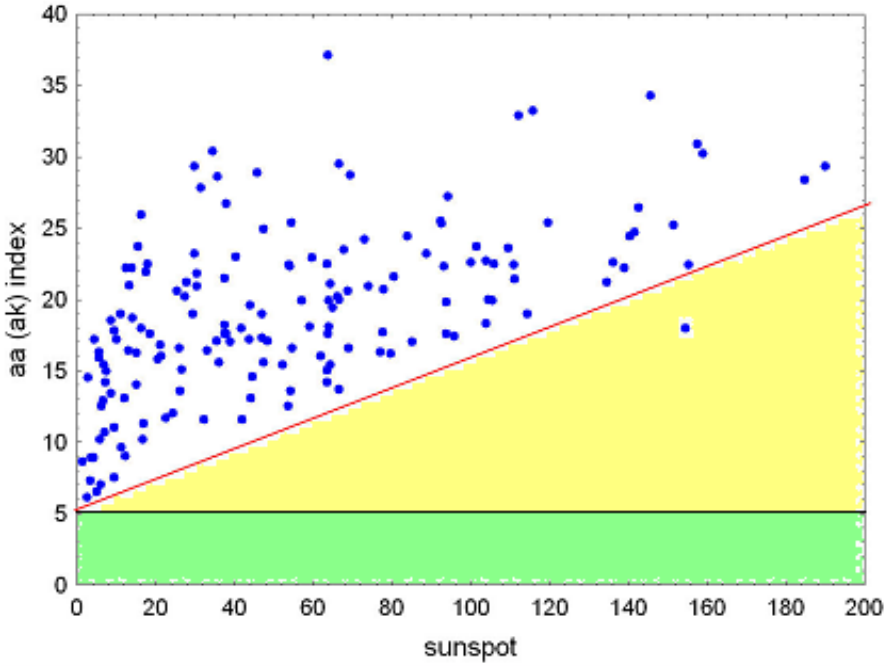
Two geomagnetic activity peaks in the 11-year sunspot cycle



Sunspot max peak – max in sporadic solar activity (CMEs)

Sunspot decline phase peak – max in recurrent solar activity (high speed solar wind from coronal holes)

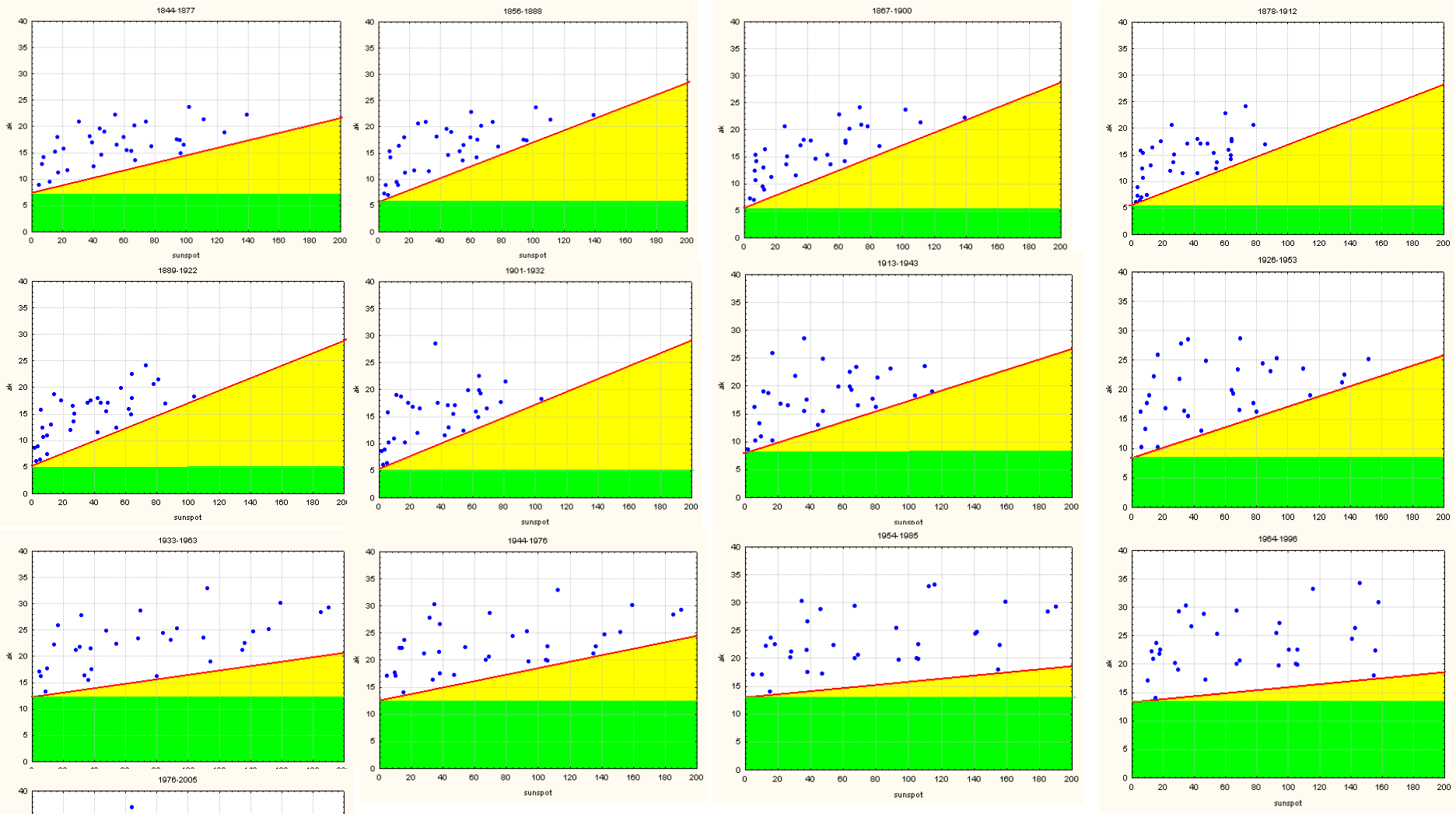
Two parts of geomagnetic activity (Feynman, 1982)



$aa_R = a + b*R$

$aa_P = aa - aa_R$

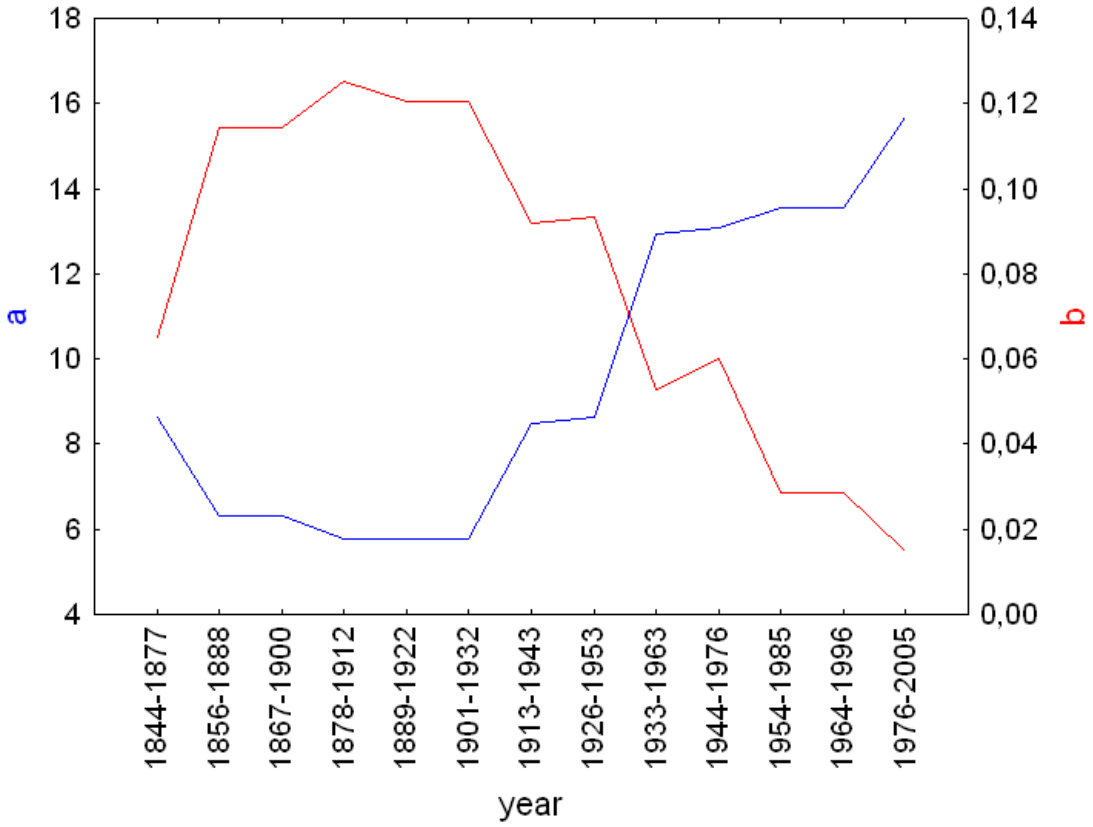
- $aa_R = 5.38 + 0.12*R$
  (Feynman, 1982)
- $aa_R = 5.17 + 0.07*R$
  (Ruzmaikin and Feynman, 2001)
- $aa_R = 10.9 + 0.097*R$
  (Hathaway and Wilson, 2006)
- $aa_R = 7.1 + 0.106*R$
- (Georgieva and Kirov, 2007)



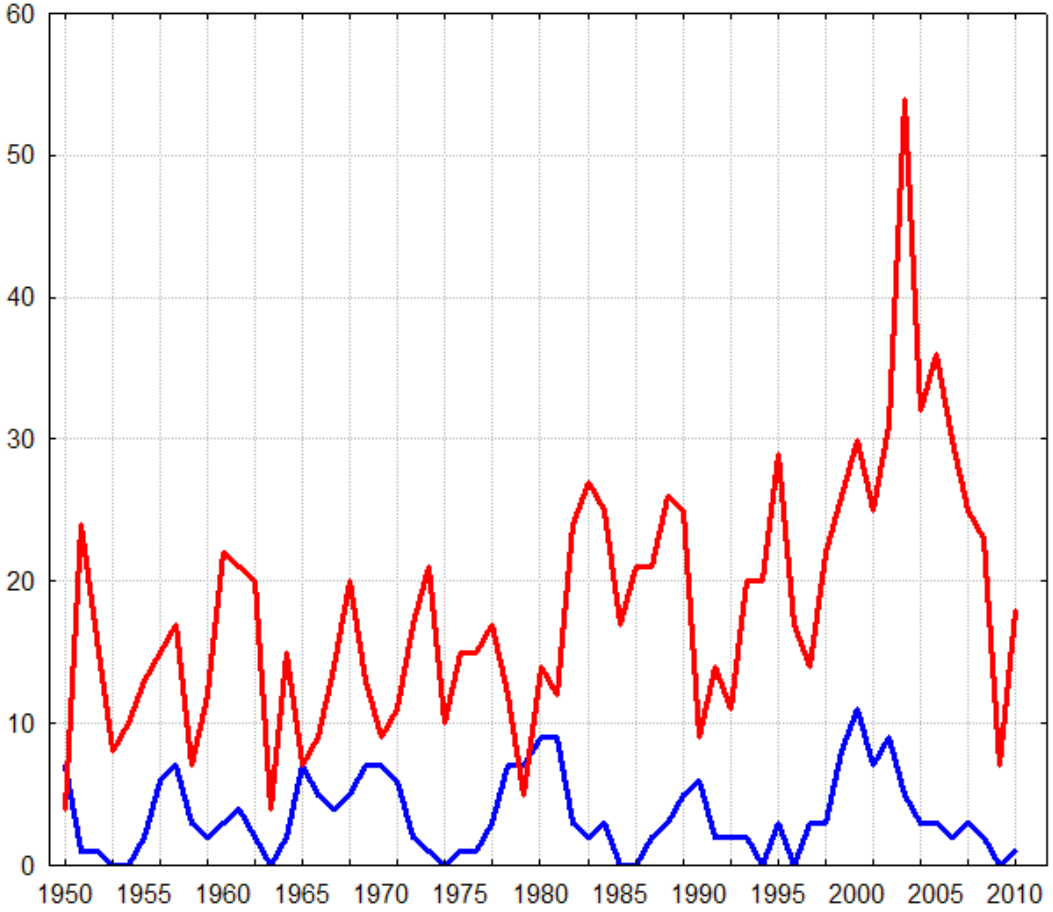
Different a and **b** values calculated for different intervals

The two components of aa_R **are** variable

Cyclic variations of the coefficients a and b

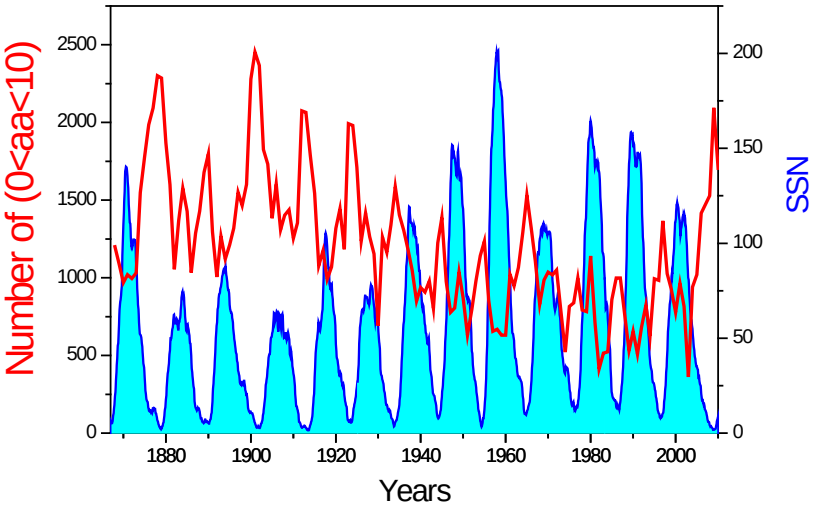


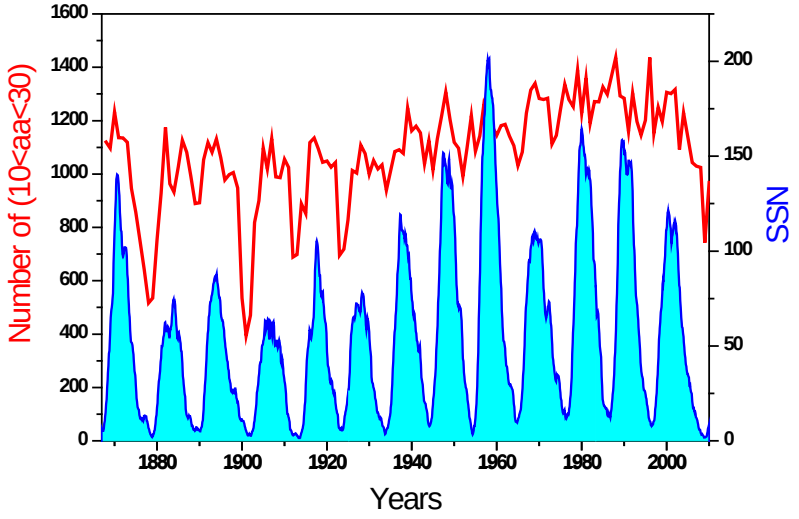
What the floor in geomagnetic activity depends on?

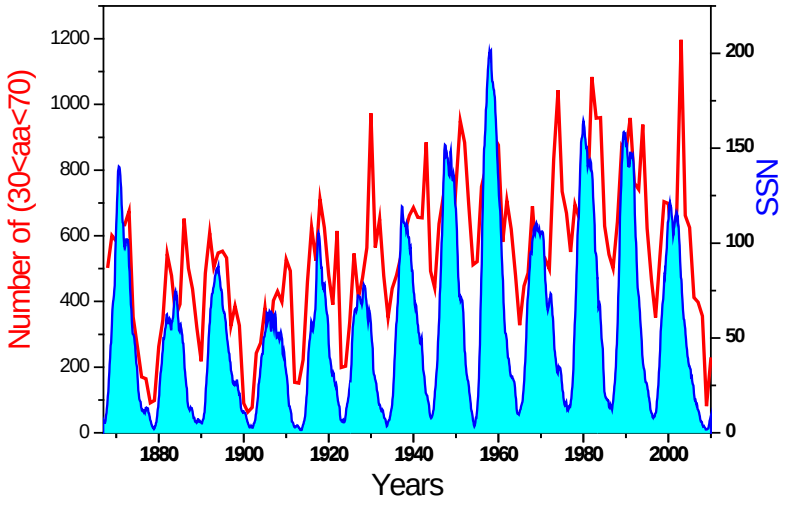


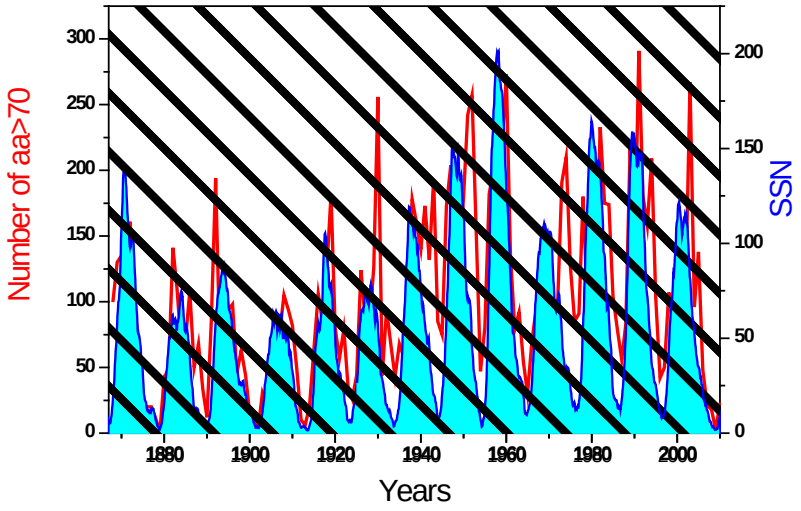
Annual number of weak sudden commencement and gradual commencement storms

Time variation of geomagnetic disturbances of different intensity and the number of sunspots



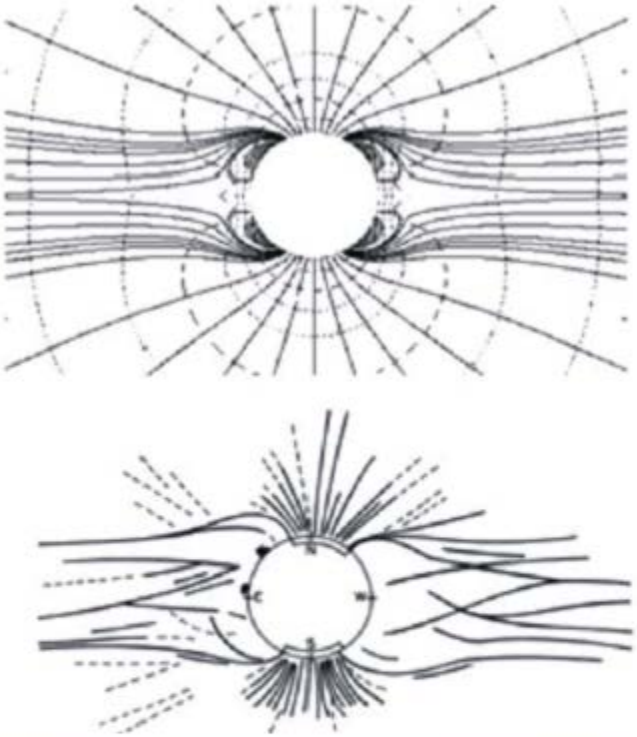


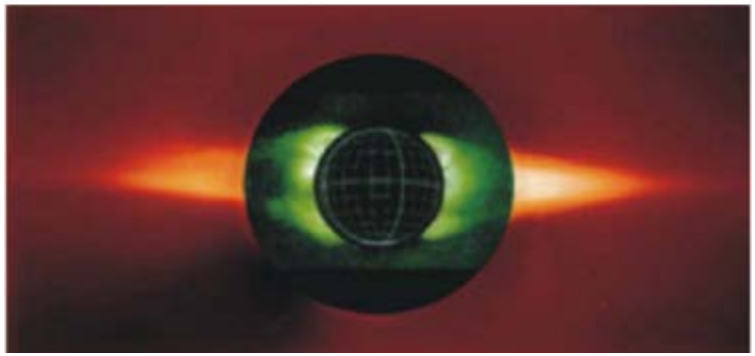




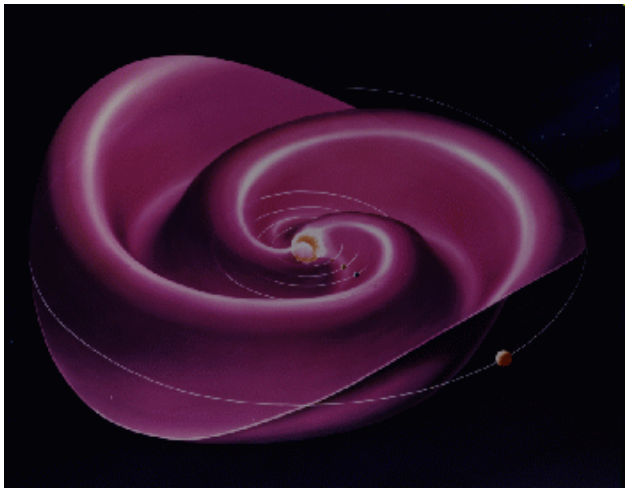
A gradual increase in geomagnetic activity is registered: decreasing number of geomagnetically quiet days (with aa<10) and increasing number of the disturbances in all other ranges (10-30, 30-70, >70). This is best seen for moderate disturbances caused by fast solar wind from coronal holes. Some authors have noted this, but no difference in this increase have been reported for the different levels of disturbances.

Solar sources of geomagnetic activity: (3) Slow solar wind from the equatorial streamer belt





Propagates along the Parker spyral

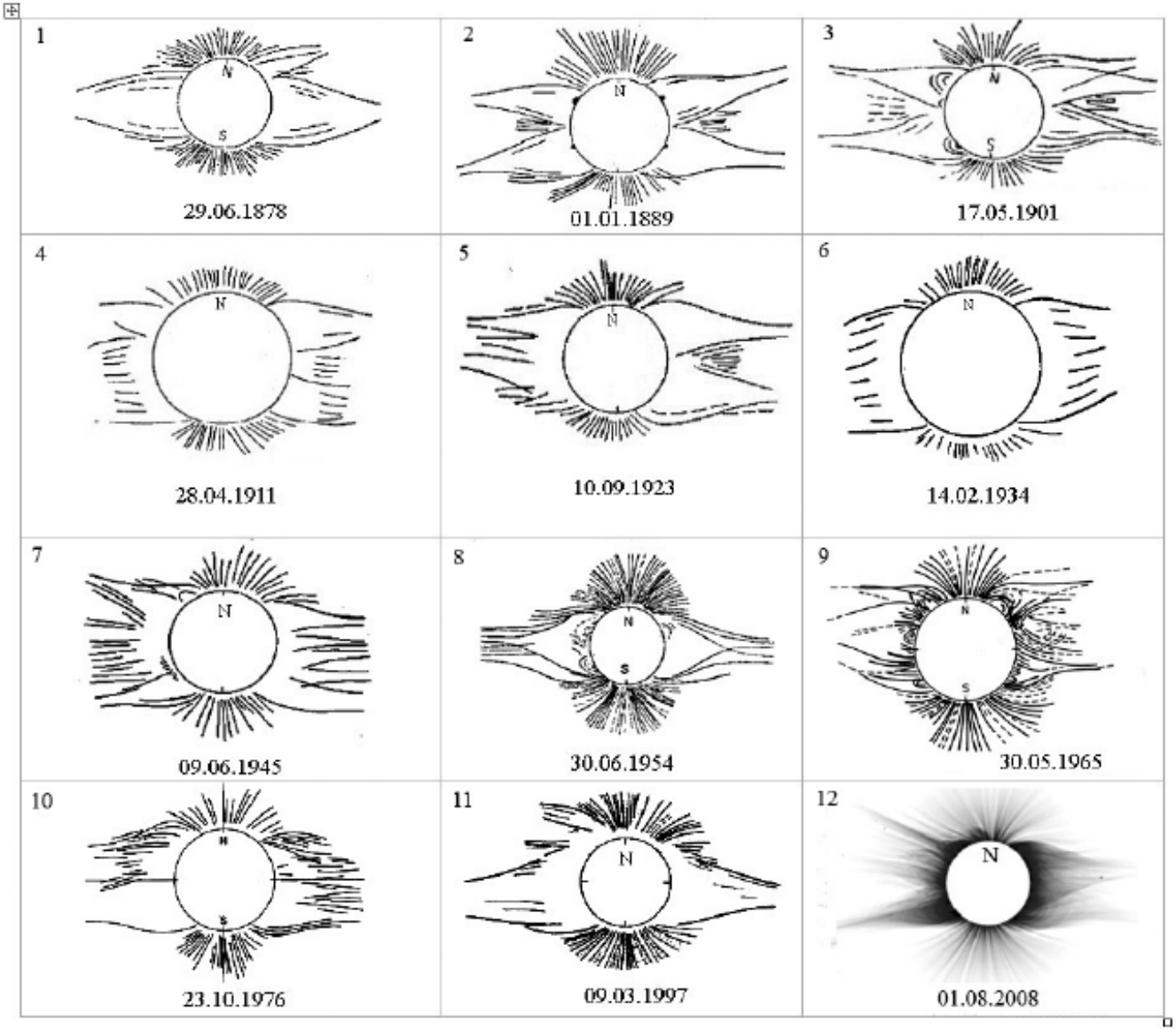


Source of weak geomagnetic disturbances

Non-sunspot-related

Manifestation of the solar poloidal field

Confirmation: The solar corona during minima



(Tlatov, 2010)

The variations in aa_{min} and aa_p are both due to the variations in the solar polar field

The annual number of geomagnetically "quiet" and "very quiet" days is determined by the time the Earth spends in slow solar wind from the equatorial streamer belt

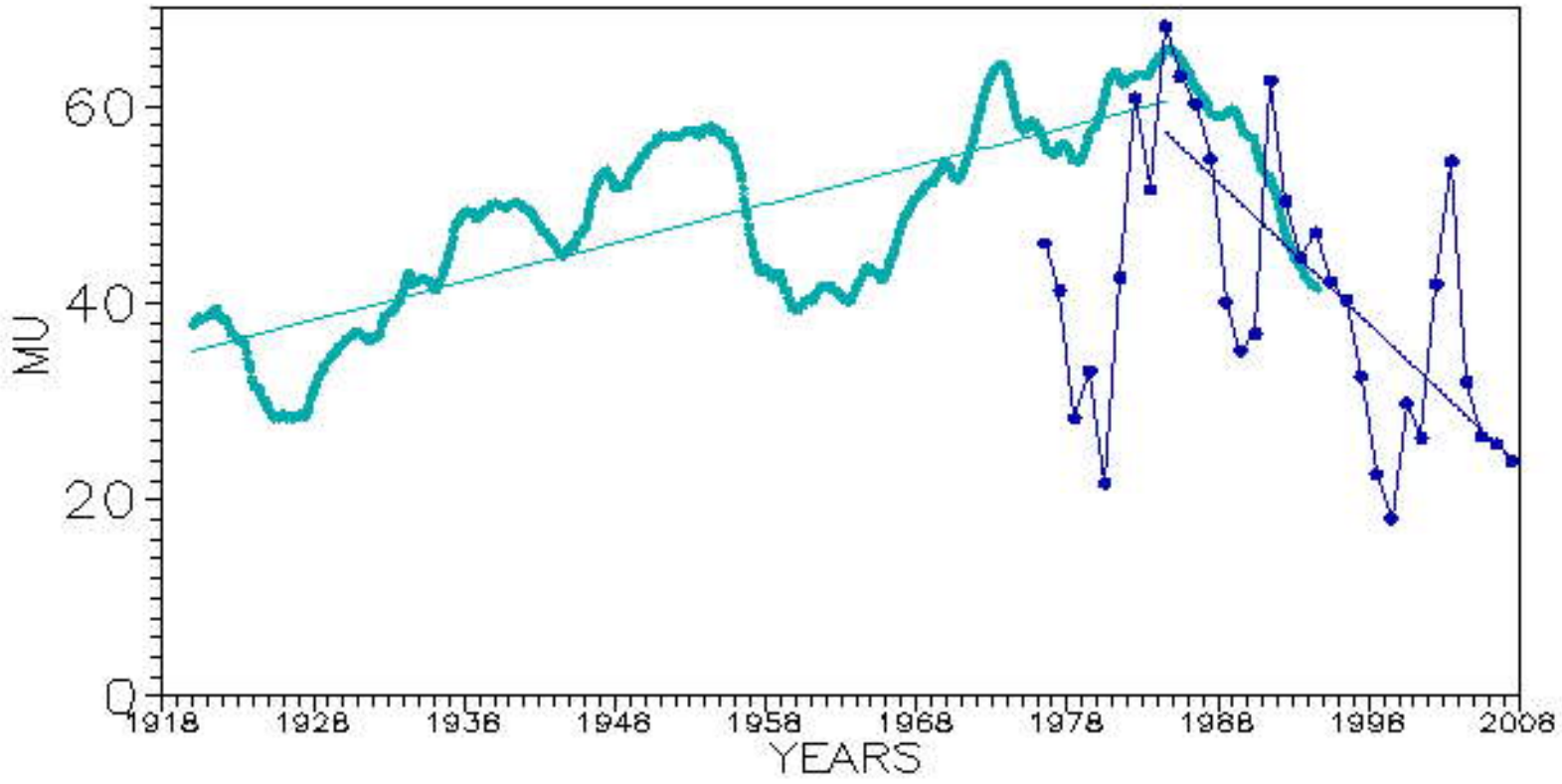
- The geomagnetic activity floor depends on the thickness of the heliosheet

- The thickness of the heliosheet is determined by the strength of the superradially expanding polar fields

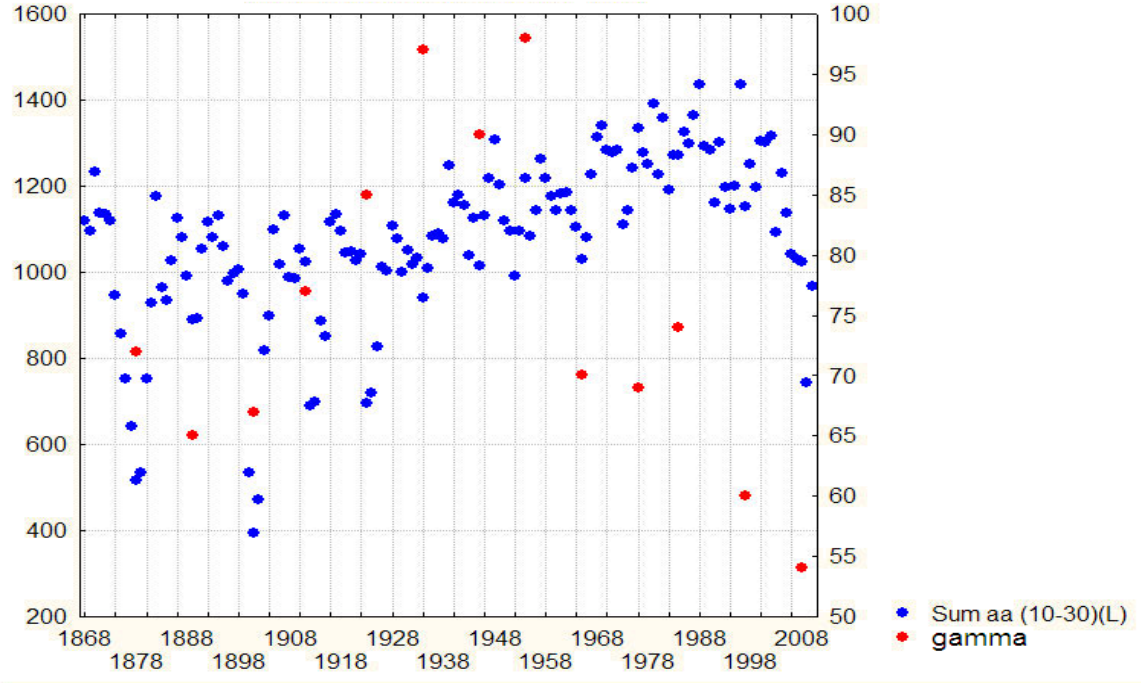
- Stronger polar fields (higher aa_p) = thinner heliosheet (higher aa_{min})

(Simon and Legrand, 1987)

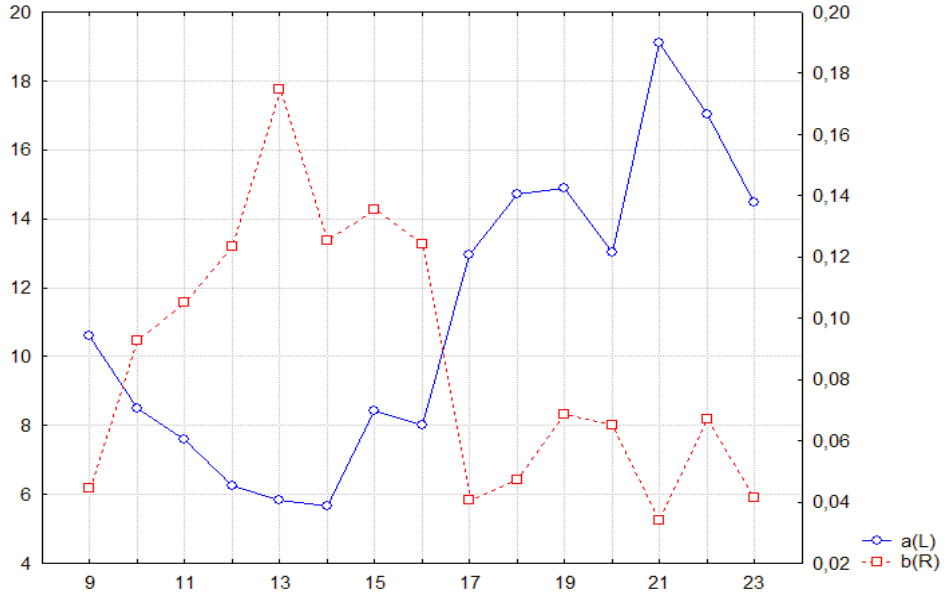
In 1985 the increase in the global solar magnetic moment changed to decrease



- In 1985 the increase in intervals with moderate geomagnetic disturbances changed to decrease



- Also in 1985 the increase in the geomagnetic activity floor changed to decrease



Conclusions

- The sunspot number is not the only indicator of solar activity and should be regarded as such when studying the solar influences on the Earth

- The relative importance of sunspot-related and non-sunspot-related solar activity varies on centennial time-scales

- In 1985 the long-term increase of the global solar magnetic moment changed to decrease. In the same time, the continuous increase in the geomagnetic activity floor changed to decrease.