Modulation of Annual and Semiannual Areal Variations of Global Lightning on the 11-Year Solar Cycle

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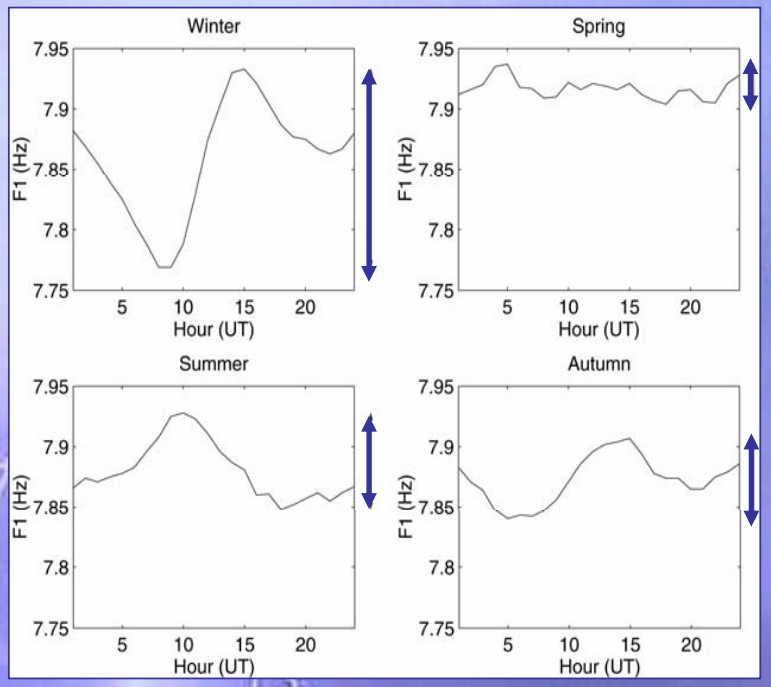
Long-term time series of Schumann resonance (SR) parameters, like as amplitude, intensity, frequency and quality factor can give robust estimations on variations of global lightning and are also dependent on the characteristics of the Earth-ionosphere cavity.

SR frequency can be characteristic either for the cavity properties or the source-observer distance. The diurnal frequency range (f_{max}- f_{min}) , DFR is informative for the mean area of lightning regions.

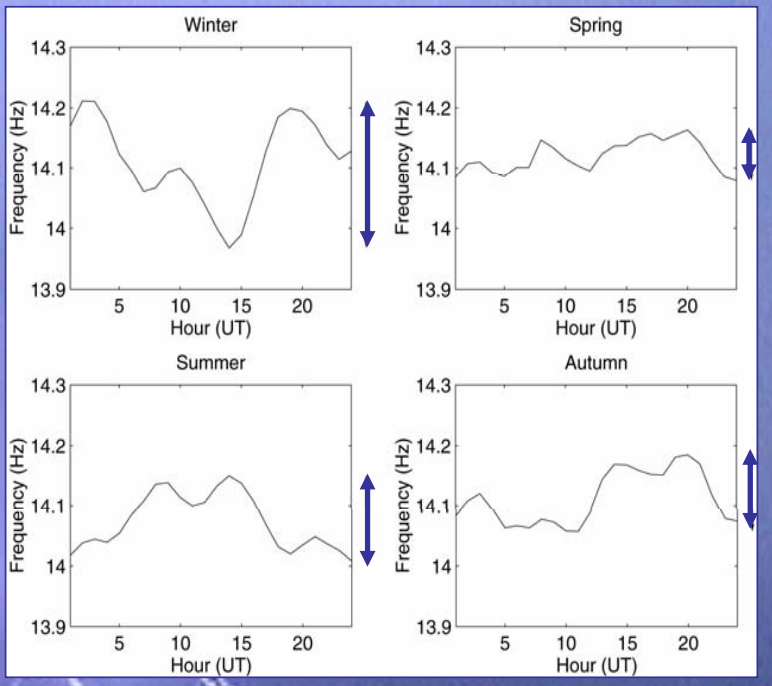
DFR time series was built up based on long-term (14 years) Schumann resonance records at Nagycenk (NCK), Hungary to study areal variations of global lightning.

Ball antenna at NCK for SR measurements

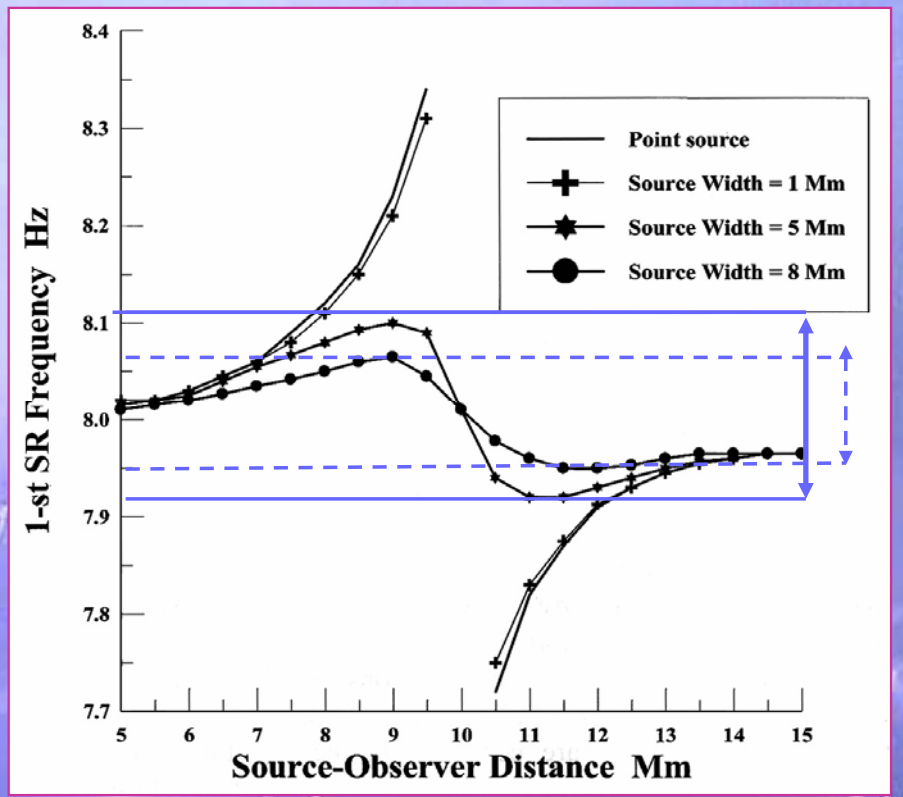
1st SR mode at NCK, Hungary



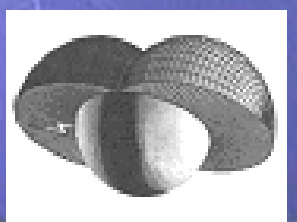
2nd SR mode at NCK, Hungary



The daily frequency range (DFR) of Schumann resonances (SR) is the band in which the resonance frequency shifts up and down during a day as indicated by arrows. The DFR is related to the size of the region where the random lightning discharges are distributed. The wider, the region is, the smaller the DFR becomes, and vice versa [Nickolaenko et al., 1995].

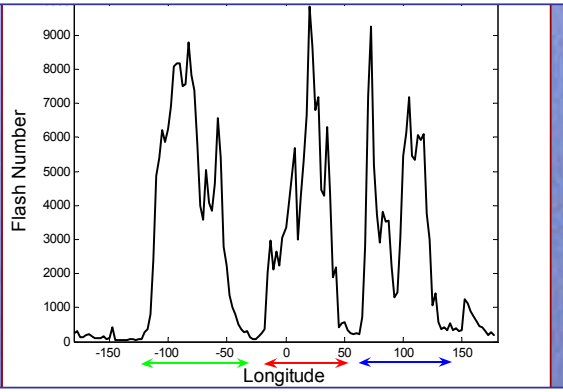


Nickolaenko and Hayakawa, 2002

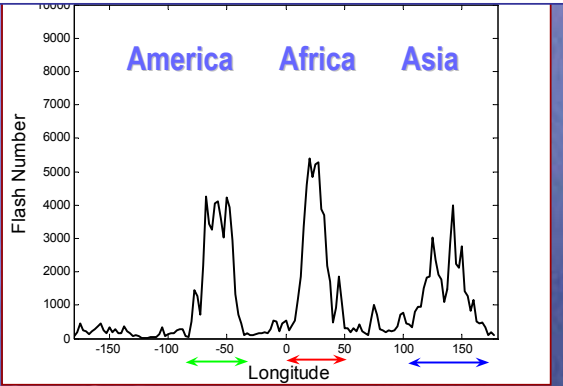


Sentman, 1995

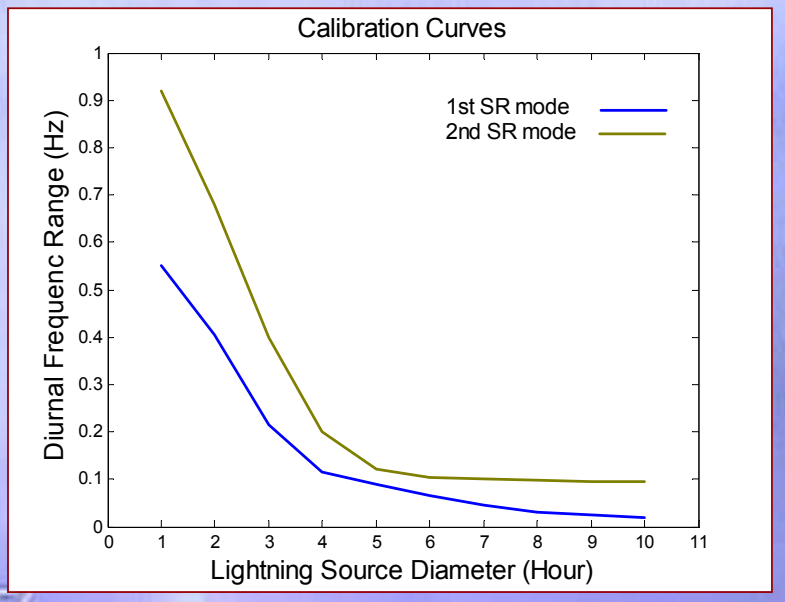
Longitudinal Lightning Distribution (NH Summer)

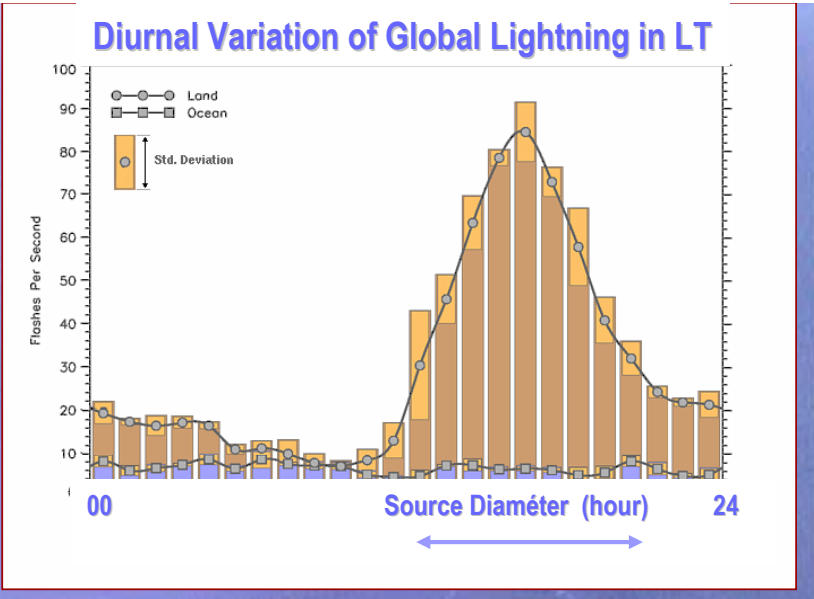


Longitudinal Lightning Distribution (SH Summer)

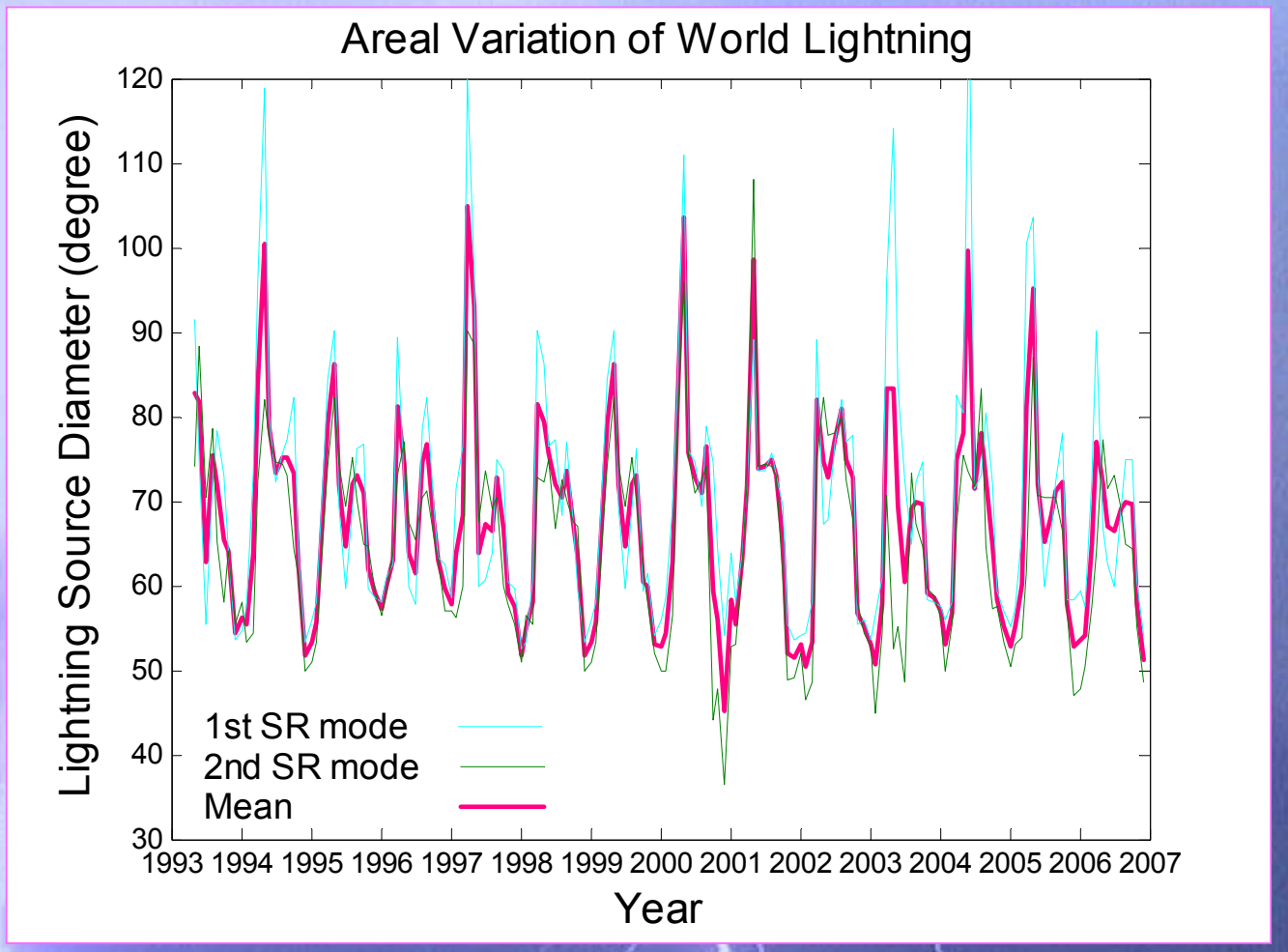


The „longitudinal diameters" of the three main lightning regions (Americas, Africa/Europe, Asia/Maritime Continent) are larger in the Northern hemisphere (NH) summer than in the Southern hemisphere (SH) summer (LIS satellite observations) in accordance with DFR of Schumann resonances at NCK.

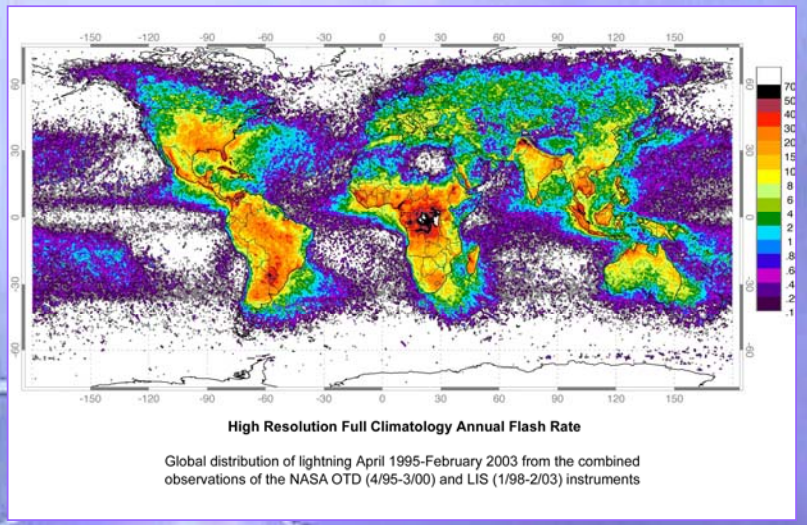




The calibration curve shows the relationship between the DFR and the source diameter given in hours. One hour corresponds to 15º angular distance. It is assumed that the lightning discharges are uniformly distributed in a single circular area with diameter measured in hours or angular distances. The centre of the area moves uniformly along the equator, and the diurnal frequency variations can be observed at NCK.



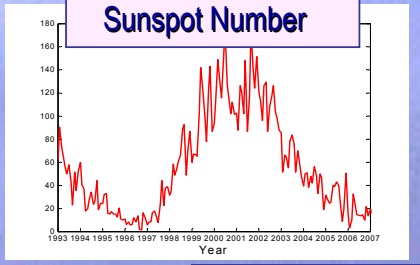
Long-term areal variation of world lightning has been deduced from DFR at NCK. Pronounced annual variations with Northern hemisphere summer maxima and semiannual changes with maxima in April and October months can be identified.



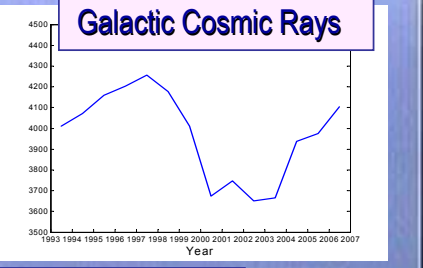
High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

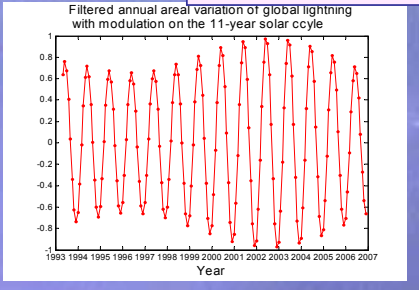
Sunspot Number

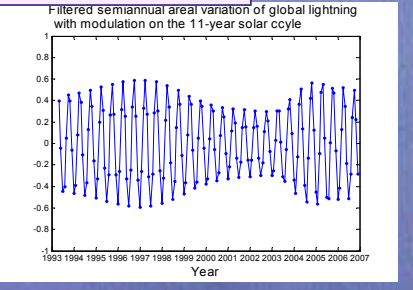


Galactic Cosmic Rays



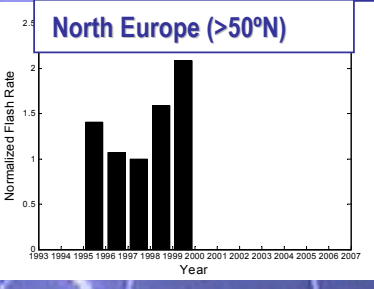
Schumann resonance observations



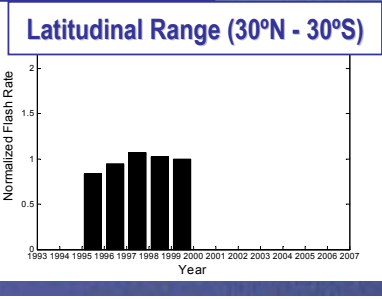


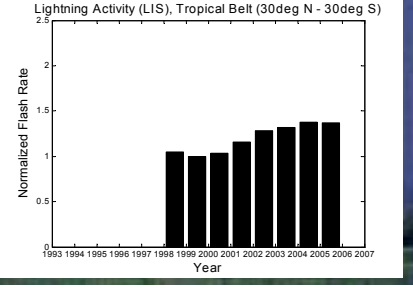
OTD/LIS satellite observations

North Europe (>50ºN)

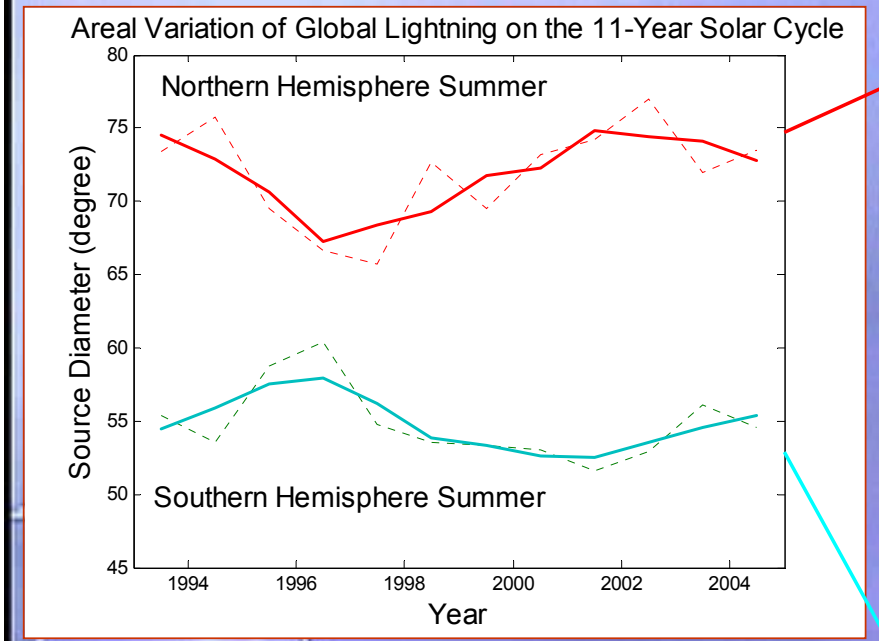


Latitudinal Range (30ºN - 30ºS)



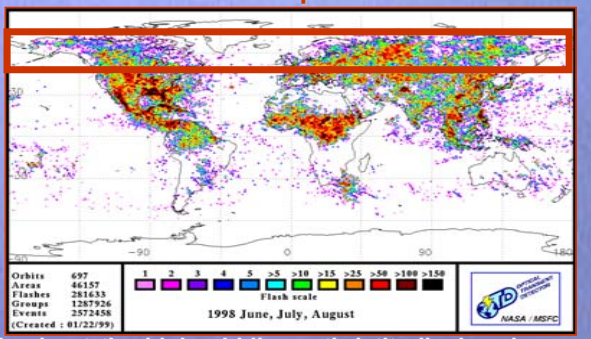


Satellite lightning measurements indicate similar latitude dependent responses on the 11-year solar cycle like as the areal variations deduced from Schumann resonance frequency range variations. Lightning activity seems to follow the solar activity variation at higher (northern) latitudes (lightning areas extend to northward) while lightning activity tends to change parallel with the galactic cosmic rays in The tropical-subtropical belts (contracted lightning areas).



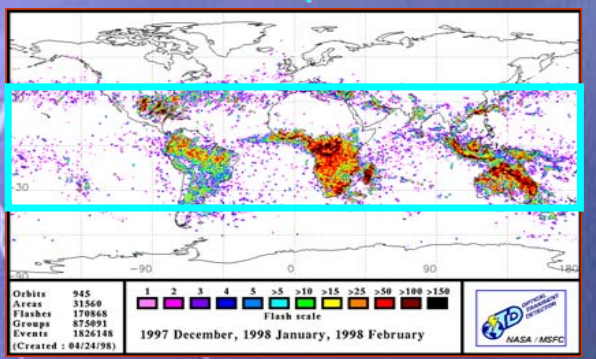
Contradictory or mixed lightning results based on observations by surface lightning detection systems in country-size regions in different latitudes of the world might be resolved by the latitude dependent response of lightning activity on the 11-year solar cycle.

OTD satellite lightning observations in a Northern hemisphere summer



'Red box' cut the high-middle north latitudinal region candidate for lightnings influenced by increased solar activity (*Stringfellow*, 1974). There is no corresponding lightning belt in the Southern hemisphere due to the missing land covered areas there.

OTD satellite lightning observations in a Southern hemisphere summer



'Cyan box' cut the tropical and extratropical latitudinal region candidate for lightnings influenced by galactic cosmic rays. One of the mechanisms suggested is as follows: Galactic cosmic ray particles can contribute to the cloud nucleation processes (*Svensmark and Friis-Christensen*, 1997).

Conclusions

- The annual and semiannual areal variations of global lightning exhibit pronounced 11-year solar cycle modulation.
- The magnitude of the modulation of the annual areal variation increases with increasing solar activity.
- The modulation of the semiannual areal variation follows rather the variation of galactic cosmic rays on the 11-year solar cycle.
- The latitude dependent areal response of global lightning on the 11-year solar cycle indicates different physical mechanisms influencing lightning generations.
- Both lightning triggering by high energy particles and nucleation as well as charging processes of clouds by galactic cosmic rays can be candidates as physical mechanisms for the areal modulation of global lightning on the 11-year solar cycles.

Some relevant references

Schlegel, K., D.Diendorfer, S. Thern and S. Schmidt, Thunderstorm, lghtning and solar activity- Middle Europe, J. Atmos. Sol.-Terr. Phys., 63, 1715-1728, 2001.

Stringfellow, M.F., 1974. Lightning incidence in Britain and the solar cycle. Nature 249, 332–333.

Svensmark, H., Friis-Christensen, E., 1997. Variation of cosmic ray flux and global cloud coverage—a missing link in solar climate relationship. Journal of Atmospheric and Terrestrial Physics 59, 1225–1232.

Udelhofen, P.M. and R.D. Cess, Cloud Cover Variations Over the United States: An Influence of Cosmic Rays or Solar Variability, Geophysical Research Letters, 28(13), 2617-2620, 2001.