University of Western Hungary

PhD Thesis

On Extraterrestrial Effects in the Troposhpere and the Stratosphere

Sándor Cseh

Sopron

2004

Objective

The interest in the effects of extraterrestrial factors on weather has considerably increased since the 1940's and 1950's. Results since the 1970's have suggested that solar activity has an impact on the weather of the troposhpere and stratosphere. These results are available on a global scale. Nowadays, when changes of greenhouse gases and aerosol concentration enhance global warming, it should be examined if impacts of extraterrestrial factors do modify or can modify that process. Studies require regional climatic scenarios with sufficient temporal and spatial resolution. In the Thesis, besides the effects of solar activity as one of the major extraterrestrial factors, we look for an answer to the question what relationship between local changes and global-scale impacts is. We have extended the study of the number of meteorological elements in an effort to support the development of climatic scenarios, which require the knowledge of temporal changes of meteorological elements. Therefore, scalar wind velocity and potentially precipitable water have also been studied in addition to the generally examined temperature and height of the isobaric levels.

Methods and data used

Methods used

1. Single- and multi-variable correlation analysis
2. Time series analysis
3. Regression analysis
4. Spectral analysis (Fast Fourier Transformation)

In the course of our work, we have classified the data series of extraterrestrial factors and meteorological elements on the basis of the two phases of quasi bi-annual oscillation. We have studied the distribution and changes of meteorological elements in two classes as a function of the $F_{10,7}$ index ($F_{10,7}$ index<100, and $F_{10,7}$ index ≥100) expressing the solar activity.

Data series used

1. Climatic data series for Budapest with monthly breakdown

- temperature, height of the isobaric level, scalar wind velocity for 1962-1994; at 10 levels (ground, 850hPa, 500 hPa, 250 hPa, maximum wind velocity, tropopause, 150 hPa, 30 hPa, 20 hPa, 10 hPa),
- relative humidity for 1962-1994; 7 levels (ground, 850 hPa, 700 hPa, 600 hPa, 500 hPa, 300 hPa, 200 hPa)

2. Data series of extraterrestrial factors

- $F_{10,7}$ index for 1962-1994 expressing solar activity;
- galactic-cosmic ray counts for 1962-1994;
- geomagnetic activity index Ap for 1962-1994.

3. Data series with a global aspect

- values of the quasi bi-annual oscillation (QBO) (1962-1994)

4. Macro-synoptic data series

- series of Hess-Brezowsky type (1962-1990)

Results

I. Results of the study of the relationship between height of the isobaric level and solar activity, geomagnetic activity, galactic-cosmic rays

The trend of solar activity and geomagnetic activity is incremental in the period studied (1962-1994), while galactic-cosmic rays showed a decreasing trend.

The trend of the height of isobaric levels studied (500 hPa, 150 hPa, 30 hPa, 20 hPa, 10 hPa) is increasing up to 150 hPa, while decreasing thereafter. The warming of the troposhpere and/or the cooling of the stratosphere may be assumed on the basis of those figures.

The linear correlation coefficients expressing the relationship between solar activity and the height of the isobaric level are negative in the months of spring and early summer, while they are positive in winter months. The effect of the quasi bi-annual oscillation can definitely be

demonstrated. Considering the effect of QBO, the significant negative correlation coefficients of the months of spring and early summer are apparent in the western phase, while significant correlation coefficients of winter months are apparent in the eastern phase. The maximum values of correlation data expressing the importance of the relationship is apparent near the 150 hPa level in winter and 30 hPa level in summer.

The impact of geomagnetic activity on the height of the isobaric level is similar to that of the solar activity. Correlation coefficients considerably exceed absolute values expressing the impact of solar activity, especially in the stratosphere.

The sign of correlation coefficients indicating the relationship between the galactic-cosmic rays and height of the isobaric levels is smaller and generally opposite to the sign of correlation between the solar activity or geomagnetic activity and height of the isobaric levels, with their absolute values being smaller than those of the latter.

The shift of winter and summer values of linear correlation coefficients representing the relationship between extraterrestrial factors and height of the isobaric levels reflects the impact of stratospheric warming, which is known as Berlin effect, and transitions in the stratospheric flow system.

The results of spectral analysis definitely show the periods between 4 and 5 years and around 2 years attributed to geomagnetic activity at the height of the isobaric levels of the troposhpere, the effect of the 11-year period of solar activity, and 4 to 5-year periods of geomagnetic activity at the height of the isobaric levels of the stratosphere.

II. Results of the study of relationship between the temperature at the height of the isobaric level and the solar activity, geomagnetic activity, galactic-cosmic rays

This relationship is based on energetic considerations. It is demonstrated by Tinsley et al. (1989) that formation processes of clouds and precipitation in the air column are closely related to the solar activity (sector boundary transition) and/or the galactic-cosmic rays. As the solar activity modulates the galactic-cosmic rays, the assumption is reasonable.

That means, the flux of galactic-cosmic rays is reduced in case of enhanced solar activity, therefore the intensity of cloud and precipitation formation processes is also reduced. That leads to a reduced quantity of latent heat released in the air column, followed by smaller increase of the temperature in the air column.

The temperature measured at the isobaric levels show an increasing trend up to the 500 hPa level. That increase can be explained with the impact of the change of increase of the

greenhouse gases. The temperature trend is decreasing above the 500 hPa level, including the tropopause level, however, the 10 hPa level shows an increasing trend again.

The relationship between the temperature found at height of the isobaric level and the extraterrestrial factors in the troposhpere is similar to that of the height of the isobaric level and the extraterrestrial factors. The correlation coefficients characterising the relationship between the three extraterrestrial factors and the temperature observed at the isobaric level in the troposhpere are generally greater than the correlation coefficients between the same factors in the stratosphere.

The value of correlation coefficient between temperature and solar activity is negative and approximating zero in the lower stratosphere, especially in the summer period. However, the same correlation is already positive at the 20 hPa and 10 hPa levels. The values of correlation coefficients are higher if the impact of QBO is taken into account but no significant difference can be shown between the two phases. The different tendency in the middle stratosphere, when the correlation changes from negative to positive during summer, is due to the temperature increasing effect of ozone. The growth of ozone is supported by two factors. The decrease of galactic-cosmic rays with increasing solar activity, decreased galactic-cosmic ray flux causes lower ionisation and thus the decrease of charged condensation nuclei, which are more effective increasing condensation than uncharged aerosol particles, accompanied by the reduction of NO concentration affecting the decomposition of ozone, and dynamic process creates the flow of "surplus" ozone generated within the sub-tropical belt towards the North Pole. We can assume that such processing causes the increasing the temperature trend at the 10 hPa level.

The correlation coefficients expressing the relationship between the geomagnetic activity and the temperature of height of the isobaric levels are slightly higher but actually follow the behaviour of the correlation between the solar activity and the temperature of height at the isobaric levels.

The sign of correlation coefficients expressing the relationship between the galactic-cosmic rays and the temperature at isobaric levels is opposite to the correlation coefficient between the solar activity or the geomagnetic activity and the temperature at isobaric levels.

The spring-time stratospheric warming as well as the transitions in stratospheric flow systems also have an impact on coefficients of correlation between extraterrestrial factors and temperatures of the height of the isobaric levels, though to a lesser extent than the impact found at the height of the isobaric level.

On the figures showing spectral density, the amplitude around the 5 year periods attributed to geomagnetic activity is considerably higher than that at the periodicity related to the solar period.

III. Results of the study of relationship between the scalar wind velocity at the isobaric levels and the solar activity, geomagnetic activity, galactic-cosmic rays

Wind conditions of the troposhpere on the ground are relatively well known. The scalar wind velocity used to characterise wind conditions shows an increasing trend in the lower troposhpere in the period studied.

However, the trend of scalar wind velocity is decreasing from the wind maximum to the 10 hPa level in the lower and middle stratosphere, while it is increasing at the 10 hPa level.

The change of trend of the wind velocity is similar to that of the temperatures of the isobaric levels.

A significant negative correlation between scalar wind velocity and solar activity has been found at the isobaric levels studied, especially in summer months. A similar relationship has been obtained between geomagnetic activity and the scalar wind velocity related to the different isobaric levels. The correlation between the scalar wind velocity measured at the isobaric levels and the galactic-cosmic rays is positive. A significant value is only obtained if the correlation between solar activity and scalar wind velocity is negative.

On the basis of those results, we may assume, in accordance with energetic considerations, that galactic-cosmic rays may also influence wind intensity.

Considering the effects of QBO, winter months in the eastern phase show a more significant correlation between solar activity and scalar wind velocity, with a positive sign, in the troposhpere.

Negative correlation between the wind velocity related to the isobaric levels and the solar activity is dominant at 150 hPa in the stratosphere, especially in the months of the summer to autumn transition. In the western phase, correlation is positive in the summer months but it is not significant.

In the middle stratosphere, correlation between wind velocity related to the isobaric levels and solar activity is already negative in the summer months. Correlation coefficients in the eastern phase are also negative in the summer months but they are inferior to the corresponding values in the western phase. Corresponding correlation coefficients of the autumn and winter of the eastern phase are negative and approximating zero.

The correlation between the wind velocity measured at the isobaric levels and the galactic-cosmic rays is positive in both phases, and values in the western phase are especially high in summer.

The sign of correlation coefficients between geomagnetic activity and wind intensity referring to the isobaric levels is identical to that of the correlation coefficients between wind intensity measured at the isobaric levels and solar activity. The correlation considering the two phases of the QBO is not significantly different but the negative values of the western phase indicate a more definite relationship. It is to be noted that the correlation coefficients between the extraterrestrial factors and scalar wind intensity measured at the isobaric levels is always pronounced upwards in the middle stratosphere as opposed to those obtained in case of the geopotential height or those referring to the temperature of the isobaric levels.

The spectrum analysis displays the 11-year periodicity with the highest amplitude at the 150 hPa level in the time series of scalar wind velocity values. The nearly two-year period attributed to the impact of QBO is apparent with the highest amplitude at the 500 hPa level.

IV. Results of the study of the relationship between the potentially precipitable water and the solar activity, geomagnetic activity, galactic-cosmic rays

The potentially precipitable water as an indirect humidity parameter shows a decreasing tendency in the period studied. The time series of precipitable water shows that the quantity of precipitable water has a local minimum at the time of solar activity maximums and a local maximum near solar activity minimums.

A negative correlation has been obtained between potentially precipitable water and solar activity on the basis of annual averages. The time series of correlation coefficients is approximately identical if the quantity of water refers to the air column between the ground level and the 200 hPa and/or the air column between 850 hPa and 200 hPa.

The correlation between the galactic-cosmic rays and the potentially precipitable water is positive in summer months. The sign is opposite to that of the correlation between solar activity and precipitable water. The geomagnetic activity has approximately the same impact on the potentially precipitable water as the solar activity does. The impact on the potentially precipitable water is slightly stronger in response to the effect of galactic-cosmic rays than the impact of solar activity and geomagnetic activity.

Investigation of the potentially precipitable water as a function of the QBO function shows that the relationship between precipitable water and the solar activity is negative in the western phase with the exception of February and March. Medium-size correlation coefficients in the summer months are significant at a 95 % level. Correlation coefficients in the winter months are low. Correlation between the potentially precipitable water and the solar activity shows a high degree of variability in the eastern phase, correlation has a changing sign and it is insignificant. Thus the potentially precipitable water shows a definite relationship with the solar activity in western phase of the QBO, which is not true for the eastern phase. At the same time, the actual values of precipitable water do not show significant differences in the western and eastern phases. It was found, at the study of the impact of QBO, that the impact of galactic-cosmic rays on precipitable water was more significant in the western phase than that of geomagnetic activity or solar activity.

Study of the relationship between the potentially precipitable water and the extraterrestrial factors reveals that the correlation increases as we approach the region where the column of air includes both the height region of cloud formation and the height region where the cosmic ray flux approximates the maximum value of secondary galactic rays. The latter region is formed at a height of 15 km. Thus, the relation between precipitable water and galactic cosmic rays is indicated not only by the significant correlation between the two quantities, but it is also supported by the increasing correlation as the height range is limited to the cloud formation region.

The consequence of the increase of solar activity is a reduced galactic-cosmic ray flux, which leads to a reduced ionisation in the troposhpere and stratosphere. As a result, the quantity of precipitable water should increase due to the reduction of the concentration of electrically charged aerosol particles that are more efficient as regards condensation, as shown by Tinsely's results (1989). According to simplified theoretical models, the solar activity and precipitable water should change in the same way, while the galactic-cosmic rays and precipitable water should change in an inverse manner. The result of studies show an opposite effect on the basis of both trends and correlation coefficients, i. e., the results have established an inverse relationship between the solar activity and precipitable water, and a direct relationship between the galactic-cosmic rays and precipitable water. The ensemble of complex mechanisms of impacts and feed-back processes could offer an explanation.

We can assume, on the basis of research by Svensmark and Friis-Christensen (1997), that as the flux of galactic-cosmic rays decreases due to the increase of the solar activity, cloudiness increases at the isobaric level above 3 km. Assuming the inverse relationship

between cloudiness and evaporation, the quantity of precipitable water decreases due to the limited evaporation.

That process can be an explanation for the significant positive correlation between precipitable water and galactic-cosmic ray flux. That circumstance can be an explanation why the inverse relationship between precipitable water and solar activity as well as the change of geomagnetic activity will result in the drying-out of the troposhpere in the case of increased solar activity or geomagnetic activity. That is supported by the decreasing trend of potentially precipitable water during the last three solar periods, when solar activity shows an increasing trend.

Spectral analysis proves the relationship between the quantity of precipitable water and extraterrestrial impacts. A definite peak is apparent at the 11-year period of the solar activity. The spectral density is considerably lower than values obtained in case of the geopotential heights, the temperatures and the wind velocity in the course of similar studies. Comparing the spectra of precipitable water shows that 11-year amplitude is larger in the first case than in the latter case in the air column between ground level and the 200 hPa level with that in the air column between 850 hPa level and the 200 hPa level.

V. Regional results are different from global-scale findings

The relationship between the four weather elements involved in the study and extraterrestrial factors can be assumed on the basis of results obtained. The results can also be explained from the energetic side, by supposing the joint impact mechanism of the three extraterrestrial factors.

Changes of the four meteorological parameters as a function of extraterrestrial impacts result in coherent conclusions.

The interaction between weather elements and extraterrestrial factors is distorted by, among others, the stratospheric ozone and the oscillation effect. The oscillation effect shows fluctuation generated dynamically in the eastern phase, while the same is not apparent in the western phase. That means, the QBO and the solar activity amplifies each other in the winter of eastern-phase years. The same does not apply to western-phase years, the reason of which is that the air-eddy at the North Pole did not work in the study period of the western years of the QBO.

Shea et al (1992) showed that the correlation between the stratospheric height of the isobaric levels, temperature at these levels and solar activity in the winter at the North Circles

and correlation between corresponding isobaric levels, temperature at these levels and solar activity at lower parallels are inversely proportional.

Results also show that solar period has the strongest effect on the northern hemisphere in the late phase of winter (March-May).

K. Labitzke and H. van Loon (1998) obtained more significant correlation coefficients for the region including Hungary, especially for summer months, on the basis of global data as opposed to climate data series of Budapest and correlation factors derived from values expressing the solar activity. The values of correlation coefficients do not only differ from global values but they also have a different sign. Considerable differences are found in the relationship between the height as well as temperature of height of the isobaric levels and solar activity. No global-scale studies related to scalar wind velocity and potentially precipitable water have been carried out so far. The deviations evidence and support the necessity of the knowledge of regional studies and impact mechanisms.

Applications

Impact studies of extraterrestrial factors influencing the weather and climate by way of exploring the cause-and-effect relationship of global warming and climate changes has been in the focus of attention. Some trends of research reject, some others emphasise the climate affecting role of extraterrestrial factors. The complex and joint impact study of extraterrestrial factors like solar activity, galactic-cosmic rays and geomagnetic activity would certainly produce better founded results as opposed to the study of individual factors. Conclusions drawn from the relationship between 33 years of climatic data for Budapest processed so far and extraterrestrial factors provide results applicable to this region. As a result of the Thesis, the impact of extraterrestrial factors on both the direct meteorological parameters such as temperature, scalar wind velocity and indirect meteorological parameters such as height of the isobaric levels, precipitable water has become known.

The results obtained can be compared, on the basis of the length of time series processed, to the corresponding global scale data of temperature and their geopotential height conditions at the poles. One of the possible applications is the regional climatic scenarios. The results obtained can serve as the basis for the study of cyclone activity, cyclone migration and weather conditions.

Literature

Labitzke, K., van Loon, H. (1998): The signal of the 11-year solar period in the global stratosphere. Journal of Atmospheric and Solar-Terrestrial Physics 61, 53-61.

Shea, D. J., van Loon, H., Labitzke, K. (1992): Point correlations of geopotential height and temperature at 30 mb and between 500 mb and 30 mb. NCAR, Boulder, Colorado, NCAR/TN-368+STR, 6pp. and 285 map pages.

Svensmark, H., Friis-Christensen, E. (1997): Variations of cosmic ray flux and global cloud coverage - a missing link in solar-climate relationships. Journal of Atmospheric and Solar-Terrestrial Physics 59, 1225-1232.

Tinsley, B. A., Brown, G. M., Scherrer, P. H. (1989): Solar variability influences on weather and climate: possible connections through cosmic ray fluxes and storm intensification. J. Geophys. Res., 94, 14783-14792.

The Author's publications related to the topic of the Thesis

Cseh, S. (1981): The potentially precipitable water above Budapest. Időjárás 85, 95-102.

Cseh, S. (1985): Climatic characteristics at the isobaric level of uplift condensation above Budapest. Időjárás 89, 219-227.

Cseh, S. (2001): A fenntartható fejlődés néhány kérdése a Kárpát-medencében. NYME ATFK Volume of Studies, 35-52.

Cseh, S. (2002): A globális felmelegedés kezdetén… NYME ATFK Volume of Studies, 95-108.

Cseh, S., Bencze, P., (2003): Solar activity and precipitable water. Publication underway.

Cseh, S., Bencze, P. (2004): Long-term variations of temperature, wind and precipitable water in the troposphere and lower stratosphere. Publication underway.