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Time-series Analysis of Environmental Radiation Data

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1. Introduction

To find the relationship between environmental radiation and weather data, a time-series analysis is conducted for ambient gamma-dose rates of Seoul, from 1998 to 2004. The results show that ambient gamma-dose rate has a strong auto-correlation and a long memory process. Ambient gamma-dose rate and precipitation are the most highly correlated (0.44) among weather data and rainfall stress is directly transmitted to ambient gamma-dose rate without delay.

2. Methods and Results

Auto-correlation analysis can compare linearity and memory effect of time-series data. As time-series data have strong linearity and memory effect, auto-correlation function has a positive value during a longer delay time. Cross-correlation analysis is used to find a linkage between input and output time-series data and provides information of causal relationship between them. Auto-correlation and cross-correlation function are calculated as follows.

$$r(k) = \frac{C(k)}{C(0)} \quad (1)$$

$$C(k) = \frac{1}{n}\sum_{i=1}^{n-k}\left(x_t - \bar{X}\right)\left(x_{t+k} - \bar{X}\right) \quad (2)$$

$$r_{xy}(k) = \frac{C_{xy}(k)}{\sigma_x \sigma_y} \quad (3)$$

$$C_{xy}(k) = \frac{1}{n}\sum_{i=1}^{n-k}\left(x_t - \bar{X}\right)\left(y_{t+k} - \bar{Y}\right) \quad (4)$$

where k is time lag, n length of time-series, $\bar{X}$ and $\bar{Y}$ average of x_t and y_t, σ_x and σ_y standard deviation of x_t and y_t, respectively. Using the cross-correlation, we can get the delay time defined by time lag between zero lag and any lag of maximum cross-correlation value. As the delay time is shorter, the response of output time-series to input time-series and the propagation of environmental stress are faster.

Figure 1 shows the time-series of daily variations of ambient gamma-dose rate, air pressure, precipitation, and temperature in Seoul, from 1998 to 2004. Pressure and temperature show a strong yearly periodicity which is reflected in the periodicity of the auto-correlation function in Figure 2. The yearly pattern of pressure and temperature changes very little from one year to another over at least 7 years (from 1998 to 2004). Characteristics of temperature time-series are similar to those of pressure data for auto-correlation and cross-correlation function as shown in Figure 2 and Figure 3. On the other hand, precipitation shows a nearly random time-series where auto-correlation drops suddenly from 1 at zero lag to near zero at lags equal to ten or larger. For ambient gamma-dose rates, it can be seen that there is positive correlation for lags up to 367 days, but no strong evidence for a periodicity. Strong auto-correlation of ambient gamma-dose rate means a large memory effect and a sustaining stability for a long time. Cross-correlation function between ambient gamma-dose rate and precipitation do not show any delay time, and the response time is very short as shown in Figure 3. When rainfall or snow occurs, the time lag between the rise and fall rates of ambient gamma-dose rate and them is nearly zero. Cross-correlation function is positive immediately after rainfall or snow, but negative after the elapse of one day because the increase of soil moisture decreases the terrestrial gamma-dose rate.

3. Conclusion

The response of environmental radiation to weather stress is analyzed using time-series technique of auto-correlation and cross-correlation function. Ambient gamma-dose rate is strongly auto-correlated and it is proven to be more sensitive to rainfall phenomenon due to washout effect than other weather variables. This study demonstrates a usefulness of time-series analysis for the interpretation of environmental radiation relationship with various weather variabilities.

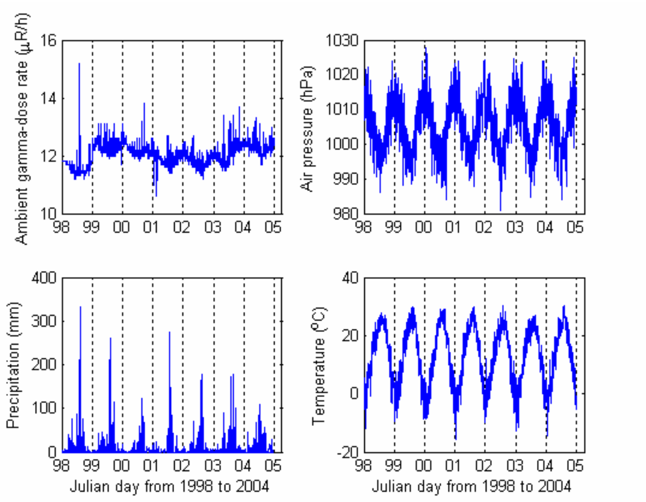

Figure 1. Time-series of ambient gamma-dose rate, pressure, precipitation, and temperature in Seoul, from 1998 to 2004.

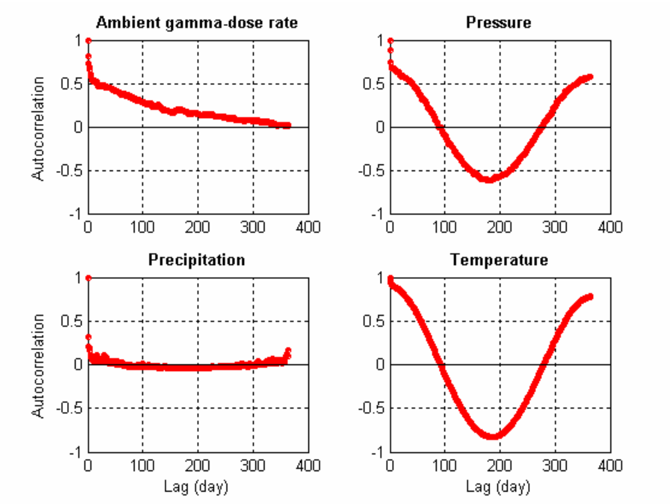

Figure 2. Auto-correlation functions of ambient gamma-dose rate, pressure, precipitation, and temperature.

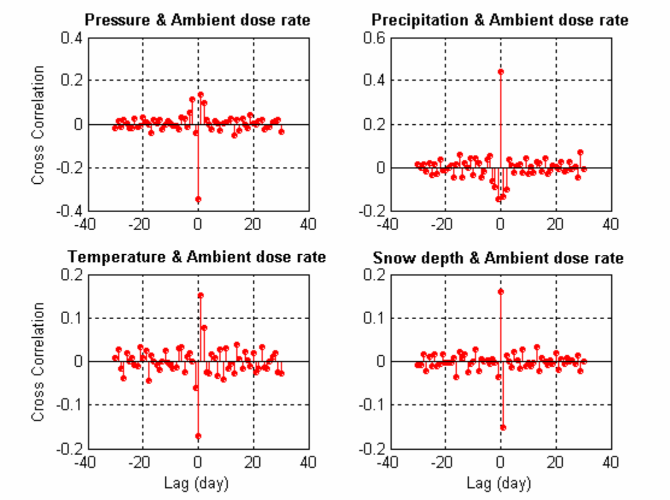

Figure 3. Cross-correlation functions between ambient gamma-dose rate and four weather data (pressure, precipitation, temperature, and snow depth).

REFERENCES

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