REMOTE SENSING OF ATMOSPHERIC TEMPERATURE PROFILE USING THREE COSMIC-RAY MUON COMPONENTS (EXTENDED ABSTRACT)

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A cosmic ray muon (μ-meson) produced at an altitude of H decays naturally into an electron after traveling the mean free path L in air. Then, the muon intensity, I, observed on the ground varies with altitude variations of the muon production layer. The variance of I at time t, ΔI, is expressed by the equation

$$\frac{\Delta I(t)}{I} = -\frac{\Delta H(t)}{L}, \tag{1}$$

where the altitude variance of ΔH depends on the vertical distribution of air density, that is, the atmospheric temperature profile below the production height of muons. This is called the negative temperature effect on cosmic ray muons. Meanwhile, the decay probability of cosmic ray pions (π-mesons), from which muons are produced, is similarly subject to the atmospheric temperatures above the production height of muons. This is called the positive temperature effect on cosmic ray muons. In practice, the production height of muons is not fixed at the altitude L, but extends statistically over the whole column of the atmosphere. Accordingly, the following equation is evaluated in place of eq.(1):

$$\frac{\Delta I(t)}{I} = \int_0^x W(x) \cdot \Delta T(x, t) \cdot \mathrm{d}x, \tag{2}$$

where x is the height represented by the atmospheric pressure, and ΔT is the temperature variance at x. The partial temperature coefficient W is given theoretically as a function of both the atmospheric depth and the energy of muons at the observing site (DORMAN, 1954; MAEDA and WADA, 1954). If this temperature effect is applied in the opposite sense, it is possible to estimate the time variations of vertical temperature profiles from the muon intensity variations observed on the ground.

In this work, the following three cosmic ray muon components were used to estimate the temperature profile on a daily basis. They are 1) muons which reached the underground depth equivalent to 54 meters of water (underground component, U); 2) muons stopped inside a plastic scintillator slab of a muon detector having a thickness of 10 cm (slow component, S); and 3) muons capable of penetrating 10 cm thickness of lead (hard component, H) (KOHNO *et al.*, 1981). We note that the former two were newly added in order to give improvement over the conventional method using the hard component alone. The component U was observed at Takeyama Underground Observatory, which lies about 60 km south of Tokyo, and the components S and H were observed at the Institute of Physical and Chemical Research in Tokyo.

The temperatures at the i-th isobar level, $T_i(t)$, are reproduced from the intensities of the three muon components, $U(t)$, $H(t)$ and $S(t)$, by the following equation:

$$T_i(t) = A_{iu}U(t) + A_{ih}H(t) + A_{is}S(t) . \tag{3}$$

The coefficients A_{ij} are determined statistically by a multiple regression analysis using the observed temperature data for a selected period. On this way, it is convenient to use deviations from the respective averages for the four parameters, T, U, H and S.

After deducing the coefficients A_{ij} from the multiple regression analysis for the whole period from November 1980 to March 1981, the estimations of temperatures were performed for 17 different isobar levels covering the 50 to 1000 mb range on a daily basis. The temperature profiles thereby obtained were compared with those actually observed by radiosonde at Tateno Aerological Observatory located about 60 km northeast of Tokyo. Figure 1 shows an example of day-to-day variations of the vertical temperature profiles, where solid and dotted lines represent the observed and the estimated values, respectively. It is obvious from the figure that both the curves fit well with each other throughout the whole range

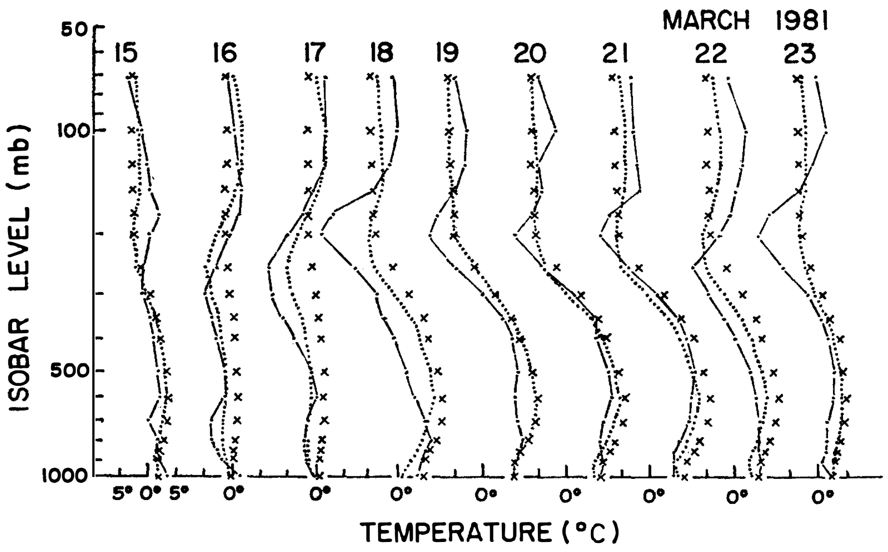

Fig. 1. A successive day-to-day pattern of vertical profiles of temperature. Solid and dotted lines show the observed and the estimated profiles, respectively, where cross marks are for the hard muon analysis. All values of temperature are deviations from the common profile averaged over the period from November 1980 to March 1981.

of atmospheric depth. In particular, it is of interest to note that the introduction of the two muon components, S and U, considerably improves the estimates in comparison with the method using the hard component alone, as indicated by cross symbols in Fig. 1.

According to the statistical analysis of the selected 14-day sample, the rms deviations of the estimated values from the observed ones are 2.2 and 3.8°C for the three components and the hard component analyses, respectively. One of the greatest advantages inherent to this cosmic ray technique is continous remote sensing of vertical temperature profiles with better time resolution. It will easily give diurnal variations of temperature at any isobar level height or three-dimensional motions of meteorological cold (or warm) front surfaces. Details of them will be given elsewhere in the near future.

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