The Relative Importance of Variations in CCN Spectra and Updraft Strength

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The Twomey equation is an analytic expression relating CCN spectral parameters (C and k) and updraft speed (U) to the number of activated nuclei (N) in the base of a growing cloud (Twomey, 1959). Braham (1976) illustrated the usefulness of the Twomey equation in analyses of CCN data. Another important use of this equation is the evaluation of the effect of natural variations or measurement uncertainties in C, k and U.

Using the Twomey equation, the fractional change in the number of activated nuclei resulting from variations in C and U can easily be obtained:

$$\frac{1}{N}\left(\frac{\partial N}{\partial C}\right)dC=\frac{2}{2+k}\left(\frac{dC}{C}\right),$$

$$\frac{1}{N}\left(\frac{\partial N}{\partial U}\right)dU=\frac{3k}{4+2k}\left(\frac{dU}{U}\right).$$

In both cases the contribution to the fractional change in the number of activated nuclei is directly related to the fractional change in C or U. In the case of C, the relative importance of variations in C decreases with increasing k. On the other hand, the importance of variations in U increases with k. For $k>1.33$ a given fractional change in U will be more important than a corresponding fractional change in C. For example, if $k=1.5$ a 10% increase in C will result in a 5.7% increase in N, while a 10% increase in U will result in a 6.4% increase in N.

TABLE 1. Percent change in N resulting from a 10% increase in k for an updraft of 2 m s^{-1}.

	C			
k	1000	2000	3000	4000
1.6	−3.8	−5.5	−6.5	−7.2
1.4	−3.9	−5.6	−6.6	−7.3
1.2	−4.0	−5.6	−6.6	−7.2
1.0	−4.0	−5.5	−6.4	−7.1
0.8	−3.9	−5.3	−6.1	−6.7
0.6	−3.5	−4.8	−5.5	−6.0
0.4	−2.9	−3.9	−4.4	−4.8

The effect of variations in k is more difficult to analyze, and was evaluated numerically for various combinations of C, k and U. In general, N decreases with increasing k although the rate of decrease is dependent on C, k and U. Expressed as the fractional change in N resulting from a fractional change in k, the magnitude of the change is relatively constant, increasing slightly with increasing C or k and decreasing slightly with increasing U. Table 1 illustrates the percentage change in N resulting from a 10% increase in k for an updraft of 2 m s^{-1}.

One of the major difficulties in studies of inadvertent weather modification is the evaluation of simultaneous changes in cloud dynamics and microphysics. The Twomey equation can be a useful tool in such studies since it analytically describes the combined influences of CCN spectra and updraft strength on cloud base microstructure.

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