NOTES AND CORRESPONDENCE

On the Elimination of Aliasing in Finite-Difference Schemes by Filtering High-Wavenumber Components

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It is generally thought that, to eliminate aliasing errors in finite-difference approximations to equations with quadratic nonlinearity (e.g., the Navier-Stokes equations for incompressible flow), it is necessary to filter the top half of (each of the components of) the wavenumbers present, as first done by Phillips (1959). This is not correct. It is only necessary to filter the top one-third. If the cutoff wavenumber is K (equal to half the number of grid points in one space dimension) and if only modes k with $|k|<\frac{2}{3}K$ are allowed to be excited, then there can be no aliasing. With quadratic interaction, mode p and mode q interact to give $k=p+q$ and its aliases $k_A=p+q\pm 2K$, $p+q\pm 4K$, etc. However, for $|p|<\frac{2}{3}K$, $|q|<\frac{2}{3}K$, all the aliases satisfy $|k_A|>\frac{2}{3}K$ so that they are all filtered out. An alternative statement of the result is that it is not necessary to filter all waves with wavelengths between $2\Delta x$ and $4\Delta x$ (where Δx is the grid spacing) to eliminate aliasing. It is sufficient to filter waves with wavelengths between $2\Delta x$ and $3\Delta x$.

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REFERENCE

Phillips, N. A., 1959: An example of nonlinear computational instability. *The Atmosphere and the Sea in Motion*, New York, Rockefeller Institute Press, p. 501.

Comments Regarding Operation of the NCAR Ice Nucleus Counter

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The recent comments by Bigg (1970) and Hobbs and Locatelli (1970) and questions raised informally by others regarding the validity of ice nuclei counts obtained with the NCAR Ice Nucleus Counter deserve an answer. A detailed evaluation of the NCAR counter will be completed by the fall of 1971, but results now available should be helpful to users of the counter in the interim.

Bigg's criticism of the NCAR counter covers the points listed, in his order below, and we will answer each of them.

1) Ice crystals may not reach the critical size required for detection by the acoustic sensor.

2) Ice crystals are lost by settling to the exit cone of the continuous mixing chamber.

3) Water drops may grow large enough to trigger the sensor if they remain long enough in the chamber.

4) Large particles, over 20 μm, suspended in the incoming sample could trigger the counter.

5) On the basis of Bigg's measurements, the NCAR counter seems to detect only 2% of the ice nuclei present in the atmosphere.

6) The humidifier and salt generator may not operate reproducibly. [This relates to item 3).]

7) Low counts are associated with low dew points.

8) Some or all of the above problems should account for the shape of the curve observed by Hobbs (1970) and Hobbs and Locatelli (1970) showing the number of ice nuclei vs temperature.

First of all, the points listed above are applicable, at least to some extent, to the commercial versions of the NCAR counter (Langer, 1970a). Also, the manual for the commercial counter does not provide the information necessary for proper operation at various temperatures. Therefore, I agree with Bigg that much of the data obtained with the commercial counters is ques-

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