Accuracy of Numerical Evaluations of the Pseudoadiabatic Cooling Rate

J. E. McDONALD

Institute of Atmospheric Physics, University of Arizona

19 November 1962 and 21 January 1963

The numerical data defining the pseudoadiabats that appear in the *Smithsonian Meteorological Tables* (List, 1951) and that underlie all current U. S. Weather Bureau pseudoadiabatic diagrams were calculated (L. P. Harrison, private communication, 1962) by a number of U. S. Weather Bureau personnel as parts of several distinct computing projects beginning about 1935. In view of the fact that these values were all computed prior to formulation of the Goff-Gratch revisions of the thermal and psychrometric properties of water substance, the present writer began, over a year ago, with the helpful advice of the U. S. Weather Bureau and World Meteorological Office personnel, to undertake an automatic computer re-evaluation of all of the pseudoadiabats, incorporating the new data. Although such an effort still appears desirable from a formal viewpoint, the present writer has put aside plans to carry out such computations because of results of three different studies that subsequently came to his attention. The specific numerical implications of those studies, which led to this decision, should be of some interest to other workers; and the most detailed treatment of the aforementioned three (Reardon's unpublished thesis) is unlikely to come to the attention of meteorologists; so a brief summary of salient numerical implications will be given here.

It is clear from general considerations that the pseudoadiabats will tend to be most sensitive to psychrometric data-revisions at higher rather than lower temperatures, so it is fortunate that intercomparisons can be made for a pseudoadiabat of potential wet-bulb temperature as high as 30C. If any data revisions are to make meteorologically significant changes in the slopes of a pseudoadiabat, they must show up as a significant alteration of the intersection-pressure of that adiabat for some low temperature. Here the 0C isotherm intersection will be used, which gives an intersection pressure P_0 in the vicinity of 400 mb. In Table 1 are listed values of P_0 for four different calculations of the specified pseudoadiabat. The first is the value appearing in the 1951 *Smithsonian Tables*. Next is the value Godson (1953) obtained

TABLE 1. Comparison of OC intersection pressures P_0 for pseudo-adiabat of potential pseudo-wet-bulb temperature 30C.

Source	P_0 (mb)
Smithsonian	412.4
Godson	411.2
Reardon	410.1
Wurtele and Finke	410.1

in calculations for a revision of the Canadian Tephigram using the Goff-Gratch formulations. Next is given the value obtained by Reardon (1956), using the latest Goff-Gratch data and also making allowance for the 1954 international revisions in the Kelvin temperature scale, a minor refinement not found in the other calculations. Finally, there appears the result obtained by Wurtele and Finke (1961), the precise numerical value of which was kindly communicated to the writer by Dr. Wurtele.

Intercomparison of the four values of P_0 in Table 1 sufficed to make the writer lose his original interest in undertaking a detailed revision of the *Smithsonian* values, since it is apparent that the largest change in P_0 amounts to a trifling 2.3 mb in P_0 over this roughly 400-mb interval considered. One can barely read large pseudoadiabatic diagrams to within 2 mb, and few cloud physics computations demand anything like this precision at the present time or in the foreseeable future. It should be noted that the close agreement of the results of Reardon and of Wurtele and Finke is particularly encouraging, since very different computational techniques were employed in their respective studies, Reardon using a desk calculator in a repeated-smoothing technique, Wurtele and Finke employing an IBM 709 automatic computer in a forward-integration method. Godson used a method which could give results as accurate as the other two; but where Wurtele and Finke used 0.25C iteration intervals, Godson employed steps of 2C, so his results are not likely to be quite as accurate.

Reardon (1956) numerically integrated the pseudoadiabats for three potential wet-bulb temperatures, 20C, 30C, and 40C, carrying the integrations to -50C. The absolute maximum discrepancy between his intersection pressures and the *Smithsonian* values is found to be 2.7 mb for the case of the 30C adiabat's intersection with the -10C isotherm. The absolute maximum discrepancy between his and Godson's intersection pressures is found to be 2.1 mb for the 40C adiabat's intersection with the 10C isotherm. Reardon's intersection pressures were, without exception, *lower* than the corresponding values in both the *Smithsonian* and the Godson tables. It is also of interest to note that Reardon's mixing ratio values agree with the *Smithsonian* values to four digits, quite adequate agreement for almost all meteorological purposes.

In summary of these remarks on numerical evaluation of the pseudoadiabatic relation, it can be said that the results of Reardon, corroborated by those of Wurtele and Finke and rather well confirmed by Godson's figures, show so slight an improvement on the present *Smithsonian* values for a good sampling of check points ranging over the most frequently used portions of the standard pseudoadiabatic diagram that there appears to be little need for an extensive recalculation of the *Smithsonian* values despite the changes contained in the latest Goff-Gratch psychrometric reformulations.

REFERENCES

Godson, W. L., 1953: *New Canadian tephigram.* Meteor. Div., Circular 2237, TEC-140, Toronto, Canadian Dept. of Transport.

List, R. J., 1951: *Smithsonian meteorological tables*, 6th rev. ed. Washington, Smithsonian Inst., 527 pp.

Reardon, F. H., 1956: *The reversible pseudoadiabats of moist air.* Unpublished Master's thesis, School of Mech. Eng., Univ. Pennsylvania, Philadelphia, 39 pp. [Obtainable on interlibrary loan from Univ. Pennsylvania.]

Wurtele, M. G., and B. Finke, 1961: A note on the computation of the saturation- and pseudo-adiabatic processes. *J. Meteor.*, **18**, 809–812.