Correspondence

COMMENTS ON "ANALYSIS OF SATELLITE INFRARED RADIATION MEASUREMENTS ON A SYNOPTIC SCALE" AND "SYNOPTIC USE OF RADIATION MEASUREMENTS FROM SATELLITE TIROS II"

PHILIP F. CLAPP

Extended Forecast Branch, U.S. Weather Bureau, Washington, D.C.

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Two recent papers [1], [2] reveal quite clearly a close relationship between cloud cover and outgoing long-wave radiation to space from the earth-atmosphere system, in the sense that the outgoing radiation as measured by satellites is largest in areas of clear skies or low overcast, and smallest in regions of high cloudiness. Among other things, these satellite radiation observations will be invaluable in supplementing the cloud photographs over darkened areas of the earth and will be useful in determining the height and type of clouds.

I was especially interested in a remark by Fritz and Winston [2] that the lowest radiation measurements for the case studied by them were located in a region of substantial precipitation. This suggests that it is in such regions that dense overcast conditions are likely to extend to the greatest elevations, so that at least the portion of outgoing long-wave radiation in the water-vapor "window" is at a minimum. Weinstein and Suomi [1] strongly imply that such a relationship holds just as well for the total infrared radiation, summed over all wavelengths, since they show that the lowest values of radiation occur near intense LOWS and fronts.

It these findings are generally valid, then a significant positive correlation can be expected between outgoing radiation (considered as a heat loss, and therefore given a negative sign) and the total heating and cooling of the atmosphere, because as Albrecht [3] has pointed out, there is a close positive relationship between total heating and rainfall.

Some light is thrown on this question by a recently completed (and as yet unpublished) study by the writer and his colleagues, in which estimates were made of the vertical distribution of the most important components of atmospheric heating at Washington, D.C., for the tropospheric layer 1000 to 200 mb., and for each successive 12-hour period from June 1 to July 31, 1961. The estimated heating components include cooling of the troposphere by long-wave nocturnal and heating by short-wave solar radiation, net heating by condensation (measured by the rain falling in the Washington area), and heating by direct turbulent contact with the ground. The estimates were subject to many uncertainties, the most serious one being the rather crude determinations of cloud amount, type, base, and thickness. However, it is felt that the computations of each heating component give reasonably meaningful results when averaged for the entire troposphere.

A few preliminary results of this study are summarized here in table 1, where the various symbols are explained in the legend.

The first row of this table reveals a high positive correlation between outgoing radiation at 200 mb. and cloudiness (i.e., smaller negative values of radiation tend to be associated with large cloud cover). Because of low moisture values in the stratosphere, the 200-mb. radiation is probably only a little smaller than the total outgoing radiation as measured by a satellite. Therefore, these results confirm the close relation between these parameters as revealed in the two papers under discussion. The correlation coefficient would have been larger if all cases of low cloudiness had been removed, because, as pointed out by Fritz and Winston, in these cases the outgoing radiation may be almost as large as that for clear skies.

TABLE 1.—*Linear correlation and regression coefficients relating selected heating parameters at Washington, D.C. First column contains symbols for parameters:* R_2, ΔR, *and* H *are respectively long-wave radiation at 200 mb.; difference in net outgoing radiation 200 mb. minus 1000 mb.; and total individual heating from all sources in layer 1000 to 200 mb., all expressed in ly./day. (The first two parameters always have a negative sign.)* C *is total sky cover in tenths. The last three columns contain respectively the correlation coefficient (times 100), intercept, and slope of a linear regression equation, where the dependent and independent variables are respectively the first and second parameter in column 1.*

Parameters	$r\times100$	a	b
R_2, C	73	−515	11.5
ΔR, R_2	54	−201	.3
H, R_2	43	1376	2.9

The second row shows that there is a fairly large positive correlation between outgoing radiation and the net cooling of the atmosphere by long-wave radiation alone; i.e., the satellite radiation measurements probably give a fair indication of that fraction of the total heat source or sink due to long-wave radiation. This has been pointed out by Professor Suomi in several recent talks.

The third row shows that, as suggested intuitively, there is a tendency for a positive correlation between outgoing radiation and total heating. Since the latter enters directly into the thermodynamic energy equation as used in numerical models for predicting the general circulation, these results may be of some assistance in establishing a relation between total heating and other parameters of the circulation. However, it should not be concluded from this result that, on the average, warm air is cooled and cold air warmed, a condition which would lead to a systematic destruction of the potential energy available for maintaining the circulation (E. Lorenz [4]). This would only be true if the atmosphere were always cloudless. Actually, the Washington study indicates that there is a small but significant positive correlation between total heating and temperature in the troposphere.

It should be pointed out that the correlation between outgoing radiation and total heating would probably have been higher were it not for certain computational difficulties. Thus, the statistically-averaged cloud thicknesses were probably too small on the days of heaviest precipitation, resulting in too large values of outgoing radiation. Also, on some days with high thin cirrus overcast and lower stratiform clouds with little rainfall, the computed outgoing radiation was probably too small, because the high clouds were always assumed to radiate as black bodies. As pointed out by Fritz and Winston, high thin clouds are not opaque, so that the effective radiation comes from a level lower than the cirrus tops. Finally, in the summer the average cloudiness may be small but the rainfall large for a given 12-hour period. This difficulty would not arise if it had been possible to make the computations on a synoptic basis.

On the other hand, there are several reasons for expecting that the real correlation is far from perfect: On clear days in summer the contribution to total heating from turbulent interchange with the ground tends to be larger than on cloudy days; and thick high clouds occur on some days with little or no rainfall. In winter, strong heating from below often occurs in cold dry air flowing over warmer land and ocean surfaces, while at the same time the outgoing radiation to space probably is large. This tends to give a negative correlation between radiation and net heating. From this and other considerations, one may conclude that the relation between total heating and outgoing long-wave radiation depends heavily on geographical location and season.

REFERENCES

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