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TITLE: Cloud Radiative Forcing Effects on Observed and Simulated Global Energetics

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RESEARCH OBJECTIVES:

1. To examine how cloud-radiation processes generate/destroy available potential energy by altering both meridional and zonal temperature gradient.
2. To investigate how the atmospheric dynamic fields respond to the cloud-altered mass distributions through the energy conversion circuit.
3. To examine how the improved version of CCM1 simulates observationally obtained cloud-radiative forcing and its associated energetics and circulations.

SIGNIFICANT ACCOMPLISHMENTS IN THE PAST YEAR:

This is the first year of an effort to understand cloud radiative effects on atmospheric energetics. As an initial part of this study, an intercomparison of cloud forcing determined by the ERBE clear sky scene identification method and two regression methods has been made for the time period of February and March, 1985. This period was selected because of coexisting satellite radiation budget and cloudiness data sets from ERBE, Nimbus 7 and ISCCP. The intercomparison is motivated by substantial differences in magnitudes of the annual global mean of cloud forcing; recent estimates of net cloud forcing range from -2 Wm^{-2} to -27 Wm^{-2} depending on methods, data sources, and analysis period. Different cloud forcing estimates will bring about different results in diabatic heating estimation. Because we intend to use the satellite-estimated cloud forcing as a constrained top boundary condition of the radiative transfer model in order to obtain cloud-induced atmospheric heating, it is essential to clarify why there are differences in order to obtain reliable heating distributions. Here we intercompare three recent cloud forcing estimation methods using the same data sources and analysis period.

The three methods each support the conclusion that in the global mean the increased reflection of SW radiation induced by clouds is greater than the reduced outgoing longwave energy loss by clouds. The estimates of net effects obtained from the three methods are in near agreement on a global average basis. On the basis of error analysis of LW and SW cloud forcing, it appears that all estimates differ by less than their uncertainties. Based on the close agreement of the global average of net cloud forcing between five estimates, we conclude that large differences between published cloud forcing estimates are mainly due to substantially different data sources as well as analysis period rather than to deficiencies in methods.

Since global means of net forcing from two regression methods are close to the ERBE value we further conclude that a best estimate of global annual mean of net cloud forcing would be close to that of the ERBE estimate, i.e., -17.3 Wm^{-2}. However, the systematic bias of the ERBE estimate toward larger magnitudes in both LW and SW would bring in uncertainties examining the role of clouds in regional and planetary atmospheric energetic processes or the general circulation. Errors in either LW or SW cloud forcing induce errors in vertical diabatic heating profiles as well as surface radiation fluxes. Since

LW-induced heating errors cannot counterbalance those induced by SW, the close agreement between net cloud forcing estimates does not necessarily imply the same quality of agreement in net heating profiles or net surface radiation flux. Because diabatic heating is one of most important factors of clouds in modulating global climate, additional work is necessary to improve our ability to precisely measure the effects of clouds and their role in regulating regional and global climate.

FOCUS OF CURRENT RESEARCH AND PLANS FOR NEXT YEAR:

In order to examine radiative impact of clouds upon atmosphere as well as surface, we are retrieving atmospheric diabatic heating profiles and surface radiation budget components. The direct simulation of the radiative transfer processes relevant to the atmosphere and surface radiation budget is used for the retrieval. Input data to drive the model include satellite-estimated clear and cloudy sky TOA fluxes of both solar and infrared radiation. Retrieval strategies consist of 4 steps and are following:

1. LW clear sky run: In determining atmospheric contribution to the TOA LW flux, we insert ECMWF temperature and moisture data at 1000, 850, 700, 500, 300, 200, 100 mb into LW radiative transfer model. Since the calculated TOA flux is usually different from satellite-measured clear sky LW flux, we minimize the difference between these two fluxes by perturbing temperature and moisture profiles. The resultant T and q profiles now will yield the satellite-estimated TOA LW flux.

2. SW clear sky run: Atmospheric temperature and moisture data yielding LW clear sky flux will then be used for SW clear sky calculation. By perturbing surface albedo in the radiative transfer calculation and minimizing the flux difference at the TOA we will obtain surface albedo which produces satellite-measured clear-sky SW flux.

3. SW cloudy sky run: The areal coverage of low, middle, high cloudiness from ISCCP cloud climatology will be inserted into the SW radiative transfer model. Considering the influences of cloud liquid water content and effective radius of cloud droplets on SW radiation, the SW cloud forcing will be redistributed vertically.

4. LW cloudy sky run: Same as in step 3, LW cloud forcing will be redistributed by specifying low, middle, and high cloudiness.

The obtained cloud-induced heating profiles through steps 1 - 4 will then be used for diagnosing the global and regional APE and KE balance with a particular focus on the generation of APE by cloud-induced radiative heating. The calculation will be performed for a Dec. - Jan. period and a Jun. - Aug. period.

PUBLIATIONS:

Sohn, B.J., and F.R. Robertson, 1992: Intercomparison of observed cloud radiative cloud forcing. To be submitted to *Bull. Amer. Meteor. Soc.* for publication.