WORKSHOP ON 3D CLOUDS AND RADIATIVE TRANSFER

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Over 40 scientists attended a 2-day workshop that was meant to foster communication between those working in the subfields of atmospheric science who are facing, in their unique combination of ways, significant issues involving the 3D geometric structure of clouds and radiative transfer. These subfields are climate and cloud modelling, remote sensing, and theoretical radiative transfer. Seventeen invited talks were given by many of the top researchers in each subfield.

The prime motivation behind the workshop was the emergence over the past 2 years of two revolutionary lines of research involving the representation of clouds and radiative transfer in global climate models (GCM). The first is the Multi-Scale Modeling Framework (MMF) method of treating clouds in GCMs. This involves imbedding a 2D (and eventually 3D) cloud-system resolving model (CSRM) in each column of a GCM. Since the MMF method has the potential to profoundly revolutionize the representation of clouds and radiation in GCMs, it was one of the foci of the workshop. Several talks were given that presented results of seminal studies with the MMF method. These included an overview as well as talks on major issues facing the MMF method and experiments that appear to demonstrate that capturing small-scale interactions between clouds and radiation is more crucial for climate modelling. This is potentially a very important point as it is difficult to envisage how regular GCMs (with grid-spacings on the order of hundreds of kilometres) will be able to capture these small-scale interactions (i.e., at scales less than ~10 km).

The second revolution involves the Monte Carlo Independent Column Approximation (McICA) method for computing radiative fluxes in conventional GCMs. By segregating description of cloud structure from the radiative transfer solver, McICA allows for unlimited statistical detail in cloud description with the assurance of unbiased radiative fluxes. The fate of McICA rests on the, as yet not fully tested, hypothesis that the random sampling noise that it produces is 'invisible', or at least not detrimental, to the host GCM. So far, this appears to be the case, but definitive tests are only in progress. In all, 7 of the 17 talks were devoted to radiation in GCMs.

The general consensus is that that *if* the statistical properties of clouds can be diagnosed well within a GCM simulation, the problem of computing accurate domain-average radiative heating profiles has been solved to ICA standards. What the MMF simulations indicate, however, is that this might not be as all important as once thought, for the systematically unresolved interactions between radiation and cloud matter much and these may be beyond the reach of regular GCMs. If this is so, one can seriously begin to question the adequacy of the McICA method for both MMF-GCMs and stand alone CSRMs. Basically, should the ICA be abandoned and replaced by 2D and 3D radiative transfer methods? This is an open question that deserves some attention. Moreover, if regular GCMs are to be parametrized so as to capture some of these unresolved interactions, it is essential that we understand better the nature of how these interactions occur and how they tie into scales resolved by the GCM.

Discussion of GCMs merged with discussions on Cloud System Resolving Models (CSRM). Attention was devoted to CSRMs because they represent one of the primary means of developing and assessing representation of cloud processes in GCMs. Focus on CSRMs in this workshop was essential since they form the basis of the MMF approach to cloud parametrization. Moreover, there are many ways that radiative transfer can be treated in CSRMs, and as yet there is little agreement on how to balance computational efficiency with necessity. This ties back to the point made at the end of the previous paragraph.

The remainder of the talks dealt with remote sensing of clouds. Since the focus of the workshop was on the representation of clouds and radiation in global models, talks dealing with remote sensing involved either satellites or long-term surface observations. Emphasis was placed on innovative methods that bank on synergy between active and passive sensors. These types of observations characterize the National Aeronautics and Space Administration's CloudSat satellite, the European Space Agency's proposed EarthCARE satellite, and surface measurements made at advanced surface sites such as those operated by the US Department of Energy Atmospheric Radiation

Measurement (ARM) Program and at Cabauw in The Netherlands. There were, however, several talks that discussed problems and limitations of traditional passive techniques. These arise via the inherent 3D structure of clouds and our inability thus far to develop unique, stable solutions for the inverse 3D radiative transfer equation.

Advances in remote sensing of clouds are beginning to investigate properties and aspects of clouds beyond those currently represented in GCM cloud parametrizations. These advances are coming from integrated multi-instrument analyses. In light of this new information, it was agreed upon generally that simple analyses in terms of geographic location have serious limitations. Alternative approaches were discussed, in particular, the sorting of cloud information in terms of cloud type (defined in several different ways), lifecycle, and the relationships of their properties/evolution with atmospheric motions (meteorological situation). New, more sophisticated (i.e., multi-variate, non-linear) methods of analysis need to be developed. These methods should also be applied to data simulated by models thereby enabling more effective comparison with observations.