CFMIP-GCSS plans for advancing assessments of cloud-climate feedbacks

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The 4th assessment report of the IPCC reaffirms the spread in equilibrium climate sensitivity and in transient climate response among current climate models. Inter-model differences in cloud feedbacks remain the primary source of this spread (Randall et al. 2007, Dufresne and Bony 2008). It should be emphasized, however, that uncertainties in cloud processes and feedbacks go far beyond the sole problem of climate sensitivity estimates. Clouds play a critical role in anthropogenic aerosol-induced climate forcing. In addition to modulating the Earth's radiation balance, clouds also play a key role in the hydrological cycle and in the large-scale atmospheric circulation, both at planetary and regional scales. By affecting precipitation and atmospheric dynamics, uncertainties in cloud and moist processes are a concern for virtually all aspects of climate modeling and climate change research. In a context where the climate modeling community is increasingly focusing its efforts on the assessment of regional climate change impacts and biochemical (e.g. carbon and aerosols) climate feedbacks, improving our understanding of cloud-climate interactions and the representation of cloud and moist processes in climate models thus remains imperative. It has actually become an urgent need if we are to gain confidence in simulations of future climate changes, both at the global and regional scales.

The difficulty of general circulation models to predict clouds, which was first emphasized thirty years ago by A. Arakawa and J. Charney, has been an unresolved problem for the modeling community. Yet, great resources are now available to observe clouds, such as the A-Train constellation of satellites, long time series of ground-based observations from instrumented sites and many observational campaigns. On the modeling side, cloud-resolving models (CRMs) and large-eddy simulation models (LES) are now run on increasingly large space and time scales, and a new generation of climate models is emerging, that uses CRM physics in place of conventional parameterizations, and starts to perform global simulations of the Earth's atmosphere. In such a context, two questions arise: why has progress been so slow in the representation and the understanding of cloud-climate interactions, and how can we ensure that these new resources will actually lead to progress in this area ? Part of the response is that bridges have been missing between the different research communities involved in cloud studies.

To remedy this situation, the second phase of the Cloud Feedback Model Inter comparison Project (CFMIP-2), in close collaboration with the GEWEX Cloud System Study (GCSS), is currently engaged in the construction of three such bridges.

One of them has been the CFMIP Observation Simulator Package (COSP). This community software tool developed among several research centers (Hadley Centre, LMD/IPSL, CSU and LLNL) allows us to diagnose from climate model outputs some quantities (e.g. brightness temperatures at specific wavelengths, radar reflectivities or lidar scattering ratios) that can be directly and consistently compared to satellite retrievals, while taking into account issues related to the viewing geometry, the cloud vertical overlap, the sensitivity of instruments and the attenuation of the remote signals (Klein and Jacob 1999, Webb et al. 2001, Chepfer et al. 2008, Bodas-Salcedo et al. 2008). COSP, which currently includes modules capable of simulating ISCCP, CloudSat and Calipso satellite observations, is to be widely distributed to the modeling groups (http://www.cfmip.net).

The second bridge under development through the CFMIP-GCSS collaboration is process-oriented diagnostics. The evaluation of general circulation model simulations not only at the large-scale and on long timescales but also at the process level will help to better understand the physical processes involved in the large-scale behavior of predicted clouds and their dependence on model parameterizations, and to better assess their credibility by comparison with LES/CRM models and in-situ observations from instrumented sites or field campaigns.

The third bridge is idealized simulations. One condition to narrow the widening gap between simulation and understanding in climate modeling (Held 2005), is to better understand the reasons why complex climate models behave the way they do and why they differ from each other. Examining moist processes and cloud-climate feedbacks in a suite of simplified or idealized contexts, such as in aqua-planet experiments (e.g. Medeiros et al. 2008) or through uni-dimensional cloud feedback experiments aiming to mimic the behavior of specific cloud types predicted by GCMs under climate change (e.g. Zhang and Bretherton 2008), will help to determine and to prioritize the most critical processes. Such guidance is critical if we are to design observational and modeling strategies to improve our confidence in climate models' predictions. Such experiments will also help to build a bridge between global climate modeling, very fine-scale modeling, and conceptual or theoretical representations of the climate system. By so doing, the benefits associated with each approach may complement each other in a constructive way.

To foster these different activities, the CFMIP and GCSS communities, supported by WGNE and the GEWEX SSG, have prepared a set of recommendations for advancing the assessment of cloud-climate feedbacks. Those recommendations were discussed at the last meeting of the WCRP Working Group on Coupled Modeling (WGCM) held in Paris on 22-24 September 2008, and led WGCM to recommend that (i) COSP be used in a subset of the main numerical experiments that will be coordinated by CMIP in support of the next IPCC assessment report, (ii) that a few idealized experiments be included into the set of CMIP5 experiments, and (iii) that additional cloud diagnostics proposed by CFMIP-GCSS be extracted from the models participating in CMIP5. A broad scientific community interested in cloud studies, both on the modeling and observation sides, is keen to participate in this effort and to contribute to advances in cloud-climate feedback assessments by the time of the 5^{th} assessment report of the IPCC. By that time and beyond, these initiatives will also benefit from and support GEWEX-WGNE joined efforts on the improvement of physical parameterizations in climate models.

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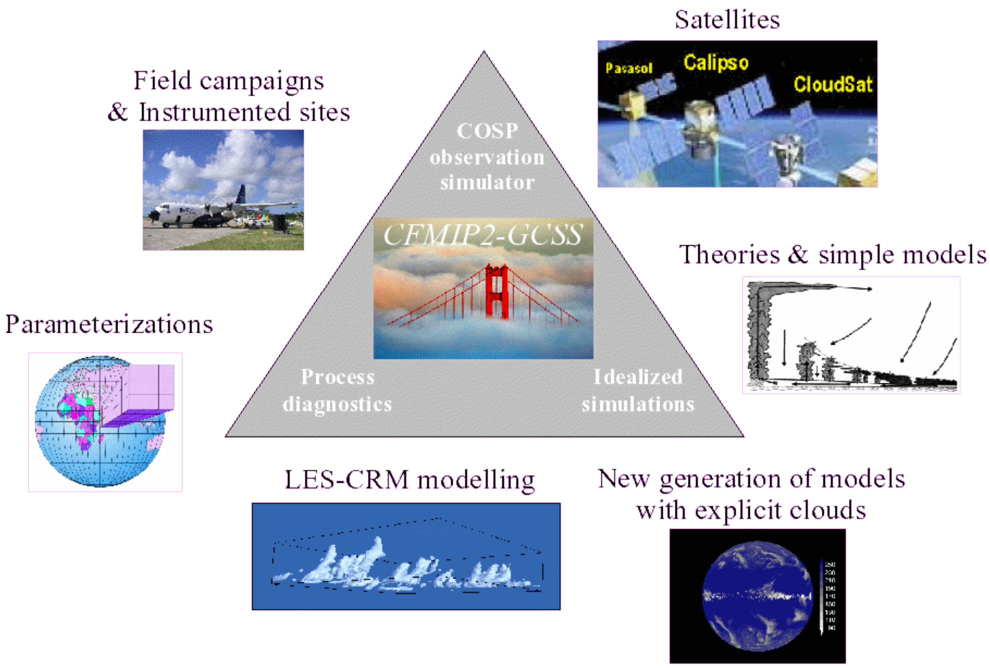

Figure 1: To better evaluate and improve the representation of cloud and moist processes by climate models and to better understand cloud-climate feedbacks, CFMIP2, in close collaboration with GCSS, has been engaged in three main activities : the development of an observation simulator package to better evaluate models' clouds using satellite observations, process diagnostics to better evaluate and understand the processes responsible for the large-scale behavior of clouds in general circulation models, and idealized simulations to better understand the cloud-climate feedbacks produced by climate models. These activities aim to build a bridge between the climate modeling community and communities involved in the observation of clouds from satellite or ground-based measurements, in very fine-scale modeling and in theoretical or conceptual studies of the climate system.