CLOUDS IN WEATHER AND CLIMATE

The International Satellite Cloud Climatology Project at 30: What Do We Know and What Do We Still Need to Know?

BY WILLIAM ROSSOW

Several dates from August 2012 through July 2013, from the first formal international meeting to the beginning of data collection, mark the 30th anniversary of the events that began the International Satellite Cloud Climatology Project (ISCCP), the first project of the World Climate Research Programme. A three-and-a-half-day conference titled "ISCCP at 30" was held to mark this occasion, to review and assess what we have learned about the role of cloud processes in weather and climate, and to discuss where cloud research should go next. The conference, featuring both invited and contributed presentations, was sponsored by the World Climate Research Programme's Global Energy and Water Cycle Experiment (GEWEX) project and by participating satellite agencies: the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the Japan Meteorological Agency (JMA), and the Instituto Nacional de Pesquisas Espaciais (INPE; the National Institute for Space Research).

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ISCCP AT 30

WHAT: A celebration sponsored by GEWEX, along with numerous satellite agencies, of the 30th anniversary of the ISCCP examining the state of knowledge of clouds and their role in weather and climate.
WHEN: 22–25 April 2013
WHERE: Grove School of Engineering, City College of the City University of New York, New York, New York

SESSION 1: WELCOME AND OVERVIEW (INVITED PRESENTATIONS BY ROBERT A. SCHIFFER AND WILLIAM B. ROSSOW). The key theme of the first session was to note that, once upon a time, a multinational, multiagency cooperation was developed to operate a multisatellite global observing system as a single system and to perform a multidata analysis to produce systematic and comprehensive cloud products. Such a cooperative activity has not been repeated in 30 years. Also noted was the fact that the project went beyond production of just the cloud statistics to characterizing the associated properties of the atmosphere and surface that affect cloud processes and, together with cloud properties, also affect Earth's radiation budget. A brief summary of all the research achievements employing ISCCP and other satellite data products highlighted 1) the capability to determine the surface and in-atmosphere radiation budgets as well as the cloud effects on radiative fluxes at the surface, in the atmosphere, and at the top of atmosphere; 2) the beginning of the quantification of the relationships of cloud properties and precipitation; 3) the beginning of the characterization of different weather states from cloud property patterns and their associated radiative and latent heating amounts, atmospheric properties, and dynamics; and 4) setting upper limits on the magnitude of the interannual variability of clouds.

SESSION 2: CLOUDS AND RADIATION (INVITED PRESENTATIONS BY CLAUDIA STUBENRAUCH AND LAZAROS OREOPOULOS). This session reported on the conclusions of a major international cloud product assessment effort that emphasized the generally excellent quantitative agreement among a dozen products concerning the basic cloud properties—amount, cloud top temperature/pressure, optical thickness, and particle size—and their latitudinal and seasonal variations. Most of the larger differences in cloud properties among these products could usually be ascribed to differing instrument sensitivities to the optically thinnest clouds (usually upper-level ice clouds), which also affected the proportions of high, middle, and low clouds reported. Also demonstrated were new measurements of cloud properties, such as cloud phase and vertical structure, which add to understanding their nature and behavior. A key consequence of this progress in measuring cloud properties is the accuracy of radiative flux determinations, now providing quantitative information on the cloud effects on the top of the atmosphere, in atmosphere and surface radiative fluxes, where remaining differences come mostly from disagreements about surface properties and aerosols. These radiative flux products were also recently assessed in an international effort and are now being used to investigate the detailed cloud effects on radiative heating of the atmosphere under different meteorological conditions. The consensus in this session was that we have achieved one of the major goals of ISCCP (with help from other data products): to quantify the effects of clouds on Earth's radiation budget. Work has begun to connect the cloud–radiative flux results to the atmospheric circulation to complete the feedback loop.

SESSION 3: CLOUDS AND PRECIPITATION (INVITED PRESENTATIONS BY CHRIS KUMMEROW AND ROBERT HOUZE). Clouds are the intermediate stage between water vapor and precipitation produced by atmospheric motions. There has been a lot of activity to improve determinations of precipitation from satellites in order to obtain coverage of the (dynamical) scales of variation from mesoscale to global, but the comprehensive study of the relationship of water vapor, clouds, and atmospheric motions with precipitation has only just begun, even with the appearance of several new detailed data products. Early studies reported at the conference focused on the association of precipitation and atmospheric dynamics, especially for shallow and deep tropical convection. Work has now begun to relate precipitation, clouds, and water vapor in the context of differing meteorological conditions in a general way.

SESSION 4: CLOUD MICROPHYSICS AND AEROSOLS (INVITED PRESENTATIONS BY TERIYUKI NAKAJIMA AND BJORN STEPHENS). Remote sensing of the microphysical properties of clouds and aerosols continues to advance by exploiting new kinds of measurements with more spectral and polarimetric information to refine and increase the number of known parameters. Analysis of these new data products, which provide global coverage with high spatial resolution, suggests a broader range of cloud properties and more complicated relationships with aerosols. Cloud phase and the properties of ice clouds continue to be a challenge both to remote sensing and to diagnosing cloud processes. The focus of current work is still on improving the determination of microphysical properties of clouds, especially ice clouds, from satellite observations, but work is only just beginning on placing these cloud and aerosol observations into more detailed meteorological contexts.

SESSION 5: CLOUD DYNAMICS (INVITED PRESENTATIONS BY ANTHONY DEL GENIO AND CHRISTIAN JAKOB). This session highlighted a number of new satellite observations and analysis tools being used to study the association of clouds and atmospheric dynamics. It is now possible to study the temporal behavior of cloud systems (cloud meteorology) in the context of the global atmospheric circulation while resolving the finer-scale dynamics. Notably, these analyses now combine multi-instrument observations of several cloud parameters simultaneously to investigate the joint relationships of the atmospheric circulation, water vapor, clouds, and precipitation. Work has also begun to apply the same analysis tools to atmospheric circulation models, thereby making comparisons with observations more informative about cloud dynamical processes. Although "cloud dynamics" has been studied for a very long time, these earlier studies were limited to field campaign datasets (surface- and aircraft-based measurements) that strongly constrained the space–time scales that could be studied and provided only a small number of samples. The new studies are now exploiting the "satellite view" to generalize the results to cover the full range of variations.

SESSION 6: CLOUD FEEDBACKS (INVITED PRESENTATIONS BY GRAEME STEPHENS AND GEORGE TSELIOUDIS). Inferring the complete feedbacks of cloud processes on weather and climate remains a major research challenge. Recent work has begun extending the problem beyond cloud–radiative feedbacks to include (simultaneous) water cycle feedbacks. Several presentations emphasized that different cloud feedbacks operate on different parts of the climate system under different conditions. Work continues to investigate parts of the problem, either the behavior of particular types of clouds or simple relations between clouds and one or two attributes of the atmosphere. This session also highlighted the use of new analysis tools applied to the rich combinations of satellite observations and general circulation models to study this problem. Some qualitative results now seem firm—namely, that cloud radiative feedback on the mean (thermal) circulation of the atmosphere is positive and that this feedback reinforces the atmospheric heating by storm (or precipitating) systems in both the tropics and extratropics. Much work remains to usefully quantify these effects and extend the analysis to the full set of energy and water cycle connections involving cloud processes.

SESSION 7: FUTURE ACTIVITIES (INVITED PRESENTATION BY JOHN BATES). The final session included reports on the next spacecraft missions planned by the operational and research satellite agencies. The new operational missions will provide continuity of established measurements and enhancements in terms of number of spectral channels, signal-to-noise ratio, and spatial and temporal resolution. Some of these changes are driven by requirements to better observe cloud processes so as to advance cloud–radiation and cloud–climate feedback issues. However, it was also emphasized that it is already possible to make more use of the existing geostationary satellites to continuously observe changes of clouds to infer cloud dynamical processes over a large range of space–time scales. Some research missions planned in the near term focus on clouds but there is a need for the research community to identify new cloud measurements that can advance understanding, particularly concerning ice and mixed-phase clouds. There followed a discussion of the practical arrangements, like those put in place for ISCCP, that would constitute a truly global satellite observing system that systematically produces comprehensive climate-quality data products. The final discussion focused on identifying the next cloud research topics: the most crucial ones mentioned were tropical and extratropical deep convection, coupling of cloud-scale processes to the larger-scale atmospheric circulation, and comprehensive diagnosis of cloud processes in the full global energy and water cycle.

SUMMARY. There were two views of what future research on clouds should entail. One was traditional in that it constituted a continuation of atmospheric research that emphasizes studies of cloud processes and convection (shallow and deep) to be based mainly on field campaigns and modeling. The leading priorities were deep convection in the tropics (but oddly not in the midlatitudes), precipitation processes (including low-level cloud drizzle but oddly not snow), and aerosol interactions with clouds. The other view was more climate oriented in that it emphasized studies of cloud process effects on the atmospheric general circulation and cloud coupling of the climate components to be based mainly on analysis of multivariate global satellite observations covering weather-to-climate scales of variability. The leading priorities were convective dynamics (tropical and midlatitude), precipitation including snow, diagnosing the role of storms in the general circulation, and diagnosing cloud feedbacks on atmosphere–surface coupling. The latter group of researchers, much more than the former group, urged the development of a global climate observing system that systematically produces high-quality, comprehensive data products that are both climate quality and record length but resolve the process-scale variations.