# A Report of the Gordon Research Conference on "Solar Radiation and Climate"

## New London (NH), USA, July 13-18, 2003

Venkatachalam Ramaswamy, NOAA/GFDL, Princeton, USA (V.Ramaswamy@noaa.gov)

The Gordon Research Conference (GRC) on "Solar Radiation and Climate" was held in Colby-Sawyer College, New London (NH), USA, July 13-18, 2003. This was the 3rd in the series, following the first one in 1997 and the second in 2000. The Chair of the Conference was **V. Ramaswamy**, with **J. Kiehl** being the co-Chair. The Gordon Conferences provide an ideal forum for the presentation, communication and discussion of frontier research topics, with this particular one focusing on radiation-climate links and interactions. The Gordon meetings are designed to stimulate ideas at the frontiers of the science and foster creative ideas for its advancement. The format of the present Conference consisted of morning (with 3 talks) and evening (with 2 talks) sessions, with the afternoons kept aside for recreation and freewheeling informal interactions amongst the participants, these being integral components of a Gordon Conference. All the talks were invited presentations only and poster exhibition sessions were scheduled during late afternoon on two of the days. In addition, at the conclusion of the talks every evening, the "social" provided the opportunity to continue the poster discussions, exchange ideas and engage in in-depth conversations on a host of scientific issues raised during the course of the meeting. The younger scientists benefited in particular from a format that promoted lengthy, unhurried interactions with speakers, discussion leaders, and other researchers.

The thematic focus of the 3rd and change: interpretations from observations and model simulations". The questions sought to be addressed were twofold: (a) How do the various processes (physical, chemical, etc.) interact with and/or determine the observed radiative properties and energy budget of the planet, and how do they affect the general circulation of the atmosphere and explain the observed climate? (b) How does the perturbation of the radiative energy budget, owing to natural and anthropogenic factors, affect or is associated with climate variations and changes, ranging in timescales from seasonal to annual to decadal to centennial (including paleoclimate and future climate changes)?

There were 50 poster presentations whose contents spanned the breadth indicated by the Conference theme, and whose substance amplified the issues raised in the talks. The posters ranged from discussions of fundamental radiation and climate modelling problems to satellite and other observations to diagnostic interpretations of model simulations and measurements. A distinctive feature of this Conference was the award by the Gordon Research Board of the prestigious Alexander M. Cruickshank Lecture. This year, this Conference was the only one chosen to receive the distinction in the physical sciences, with **V. Ramanathan** selected as the Lecturer.

The sessions were arranged as follows:

| Session Number | Session Title | Speaker and Discussion Leader (DL) |
|---|---|---|
| Session 1 (Keynote) | Radiation and climate change | V. Ramanathan, S. Solomon; J. Kiehl (DL) |
| Session 2 | Radiative interactions in the climate system | Q. Fu, R. Pincus, S. Klein; J. Coakley (DL) |
| Session 3 | Cloud processes in the climate system | C. Bretherton, L. Donner; S. Krueger (DL) |
| Session 4 | Radiative forcing of climate change (tropospheric aerosols) | O. Boucher, U. Lohmann, W. Collins; J. Haywood (DL) |
| Session 5 | Radiative forcing of climate change (stratospheric species, solar irradiance) | J. Haigh, A. Robock; K. Shine (DL) |
| Session 6 | Paleoclimate changes | B. Otto-Bliesner, A. Clement,T. Crowley; C. Covey (DL) |
| Session 7 | Recent climate variations and change | D. Seidel, B. Soden; J. Hack (DL) |
| Session 8 | Climate feedbacks and sensitivity | A. Hall, S. Bony, D. Hartmann; B. Wielicki (DL) |
| Session 9 | Detection and attribution | B. Santer, P. Stott; D. Karoly (DL) |

The mix of speakers, discussion leaders, poster presenters and participants came from universities and national laboratories, and from a number of countries. Particular attention was paid to facilitate qualified young scientists to attend the Conference. The number of persons attending the Conference was 148 (107 US and 41 non-US), a higher-than-usual number, with about one-third being graduate students and post-doctoral researchers. The Conference benefited considerably from funding received from a variety of agencies. Matching funds from GRC for Eastern Europe and minority scientists complemented funds from NASA, NOAA, DOE, NSF, IGAC and WCRP/SPARC. The WCRP/SPARC funds were utilised to provide for the participation of students, post-doctoral researchers and lecturers from developing countries.

In the keynote session, the emerging climatic significance of soot particles, as exemplified by the anthropogenic carbonaceous aerosol emissions from the Indian subcontinent, was discussed. These give rise to a substantial atmosphere and surface radiative forcing, with consequences for changes in the regional climate (including surface temperature and hydrological cycle), effects that merit considerations alongside the global climate change due to greenhouse gas increases. A look ahead to planning for the next Intergovernmental Panel on Climate Change (IPCC) assessments followed, focusing on the climate responses to anthropogenic radiative forcing. In addition to the aerosol effects, other emerging questions were raised, such as changes in circulation, unforced climate variability, stratosphere-troposphere connections, carbon cycle and climate response time scales; these are issues that are likely to be explored in the next IPCC assessment (due in 2007).

Session 2 highlighted unresolved problems in fundamental radiative transfer, including the infrared water vapour continuum, light scattering by ice crystals and 3D radiation effects. The representation of cloud processes and their radiative description in general circulation models continues to pose serious uncertainties, with the need to represent the fields more realistically on the sub-grid scale and consider new approaches in models. The evolution of cloud parameterizations in models was discussed, with a microphysics and radiation fields, and treat radiation-turbulence interactions in an appropriate manner.

Session 3 highlighted the processes that control the global distribution and radiative effects of boundary-layer clouds by synthesizing global observations, field experiment data and numerical model simulations. Feedbacks between the clouds, turbulence and underlying surface properties were emphasised. The role of deep convection in determining the microphysical and radiative properties of high clouds and its evolution was illustrated using cumulus parameterization as a conceptual framework. Cloud-resolving models, together with the use of observations, are enabling the identification of key physical processes associated with deep convection.

Session 4 discussed the basic definitions in aerosol forcing, including the various facets of the indirect effect. A review of satellite observations and model simulations of the direct aerosol effect was presented taking into consideration the question of atmospheric aerosol absorption. Processes that control the aerosol indirect effect were highlighted, and the complexity of the interplay between aerosol forcing, clouds, radiation and hydrologic cycle was elaborated using observations and model results. The radiative role of natural and anthropogenic aerosols was distinguished. Absorbing aerosols can influence the hydrologic cycle considerably in heavily polluted regions, and a way to reduce uncertainties in global aerosol properties description was demonstrated utilising observations and models.

Session 5 presented the radiative forcing due to solar irradiance variations considering the measurements available over the past two decades, the reconstructions going back to late 19th century, and the influence due to changes in stratospheric ozone chemistry. The radiative role of stratospheric water vapour and ozone changes, and the response of the troposphere to a stratospheric radiative perturbation, were also discussed. Both observational and modelling knowledge have advanced concerning the climatic effects of stratospheric aerosols from explosive volcanic eruptions, following studies of the 1991 Pinatubo eruption and its aftermath. These include: the radiatively induced cooling of the feedback effects in the column water vapour due to the tropical cooling; and the high-latitude warming during the winter following the eruption possibly arising as a result of stratospheric-tropospheric dynamical coupling.

In Session 6, the simulated global climate change during past warm periods in the Earth's history owing to the Milankovitch orbital variations of insolation and the manner in which this modulates the modes of climate variability were discussed, along with the issue of feedbacks in the Arctic and implications for global warming in the future. Paleoclimate records reveal that there are fluctuations in the global ice volume on the same timescale as the orbital insolation forcing, but the linkages are not fully understood. In addition, abrupt shifts in climate occur on millennial timescales that may be due to internal instabilities in the climate system. Correlations of solar irradiance variations and climate on the decadal-millenial timescales suggests a relatively minor role for solar variability on hemispheric scale climate change; however, lower frequency millennial-scale oscillations of solar variability have a greater correlation with some millennial-scale climate oscillations, suggesting a frequency-dependent role to the Sun-climate link.

Session 7 discussed upper-air temperature changes in satellite and radiosonde datasets. Care is required in the analyses of these data since the platforms were not originally intended for climate monitoring; however, several problems involving time-varying biases, inhomogeneity of station records, and satellite data problems have been addressed, the datasets have been intercompared, and reasonably reliable estimates of temperature variation (and less reliable trend estimates) have been obtained. Uncertainty of changes in the distribution of water vapour and clouds leads to a significant uncertainty in the quantification of climate feedback. Observations of the variations in water vapour, clouds, precipitation and radiative fluxes from satellite observations over the past two decades were analysed to focus on the documented discrepancies between observations and climate model results, and explore hypotheses for their explanations.

Session 8 discussed climate sensitivity and feedbacks. The relevance of variations in the shortwave optical proper-

with ice/snow albedo and vegetation albedo feedbacks as examples. Results from models and satellite observations show that water vapour and cloud responses to a radiative forcing can be forced by large-scale circulation changes, as well as by changes in the atmospheric thermodynamical structure. A framework to unravel the components in the tropics was proposed. The behaviour of tropical convection-cloud interactions, including the net radiative effect of the clouds and their implication for climate sensitivity, and the feedback uncertainties regarding planetary boundary layer in the tropics and subtropics, were also highlighted.

Session 9 presented recent developments in detection and attribution research consisting of improved characterization of satellite data uncertainties leading to improved analyses of model simulations with observations, and introduction of new fingerprints in identifying anthropogenic effects on climate e.g., ocean heat content and tropopause height changes. Climate model simulations are enabling the estimation of contributions by the different natural and anthropogenic radiative forcing agents to the observed climate changes in the 20$^{th}$ century. Trends in global-mean and continental-scale surface temperature are becoming detectable above the noise of the unforced internal variability in the climate system, while evidence is also beginning to emerge of trends in other climatic indicators.

Each of the talks dwelt on state-of-the-art research, starting with a brief review of current knowledge and relevance of the topic, followed by a balanced presentation of the latest research results, and concluding with views on the future course of research including the outstanding issues and challenges. The discussion leaders, chosen for their expertise and experience, helped in emphasizing the key points, steered the discussions by providing additional thoughts and introduced related ideas. A particularly gratifying feature was that the younger scientists (especially students) energetically participated in the discussions period. Substantive points were raised on all three fronts - observations, modelling and diagnostic interpretations concerning present-day climate and climate change – during the course of the discussions.

As is customary at every Gordon Conference, all participants were invited to respond to a questionnaire distributed by GRC. About 85% responded, an unusually high return that is indicative of the high degree of interest stirred up by the meeting. The evaluation comprised 5 categories: science/ideas, discussion, management/organization, atmosphere and overall Conference suitability. The results of the evaluation were highly complimentary in all categories, with significant improvements compared to the prior two Conferences. The participants' ranking places this Conference in the upper echelons of the meetings held by GRC in the physical, chemical and biological sciences and technology. At the conclusion of the meeting, the Conference participants voted to elect **W. Collins** as Chair of the Conference in 2007, with **P. Russell** as the co-Chair. The Chair and co-Chair of the next Conference in 2005, who were elected during the 2000 meeting, are **H. Barker** and **R. Ellingson**, respectively.