AN INTERNATIONAL CONFERENCE THAT PRESENTS CURRENT ADVANCES IN SIMULATING AND OBSERVING ATMOSPHERIC PROCESSES

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Clouds, through their impact on radiative transfer, play a decisive role in determining Earth's energy budget and its susceptibility to perturbations. Their associated precipitation processes are important in their own right, but also influence the dynamics of large circulation systems, especially those in the tropics. Likewise, cloud radiative effects are increasingly being appreciated as not only influencing global mean temperatures, but as also being important for circulation systems of various scales. For these reasons, cloud research is multifaceted, in terms of the scales addressed by specific questions and the methodologies employed. With a great number of exciting past and planned field studies, new approaches to laboratory science, breakthroughs in the ability to computationally link cloud processes to large-scale circulations, and new data-driven approaches to cloud research, the field is evolving rapidly. To help anticipate the impact of explicitly resolving clouds and the ability to simulate the atmospheric circulation, the German national project HD(CP)^2 (High Definition Clouds and Precipitation for Advancing Climate Prediction) was initiated. HD(CP)^2 set out to circumvent what many perceive to be a deadlock in efforts to parameterize clouds and deep convection by enabling high-resolution (grid spacings down to the ~100-m scale) simulations over very large and realistically forced domains. By combining these simulations with new syntheses of

UCP2019—UNDERSTANDING CLOUDS AND PRECIPITATION

What: The UCP2019 conference was aimed at bringing together leading scientists from the observational and modeling communities to present their latest findings and coordinate future activities to advance the understanding of the role of clouds and precipitation in the climate system.
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Where: Berlin, Germany

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observational data,[1] the project aimed at exploring global storm-resolving or large-eddy-resolving models and how they can provide more informative descriptions of the climate system. In so doing, the project demonstrated how simulating clouds and precipitation on scales similar to observational scales helps bridge the gap between the modeling and observational communities.

With this in mind, UCP2019 organized itself broadly around five topics:

1) looking toward global storm-resolving climate simulations;
2) insights from clouds and precipitation from recent and planned field studies;
3) technical advances for simulating, computing, and observing clouds and precipitation;
4) coupling of aerosols, clouds, and precipitation to circulation systems or the environment; and
5) progress in understanding and representing unresolved processes in storm-resolving simulations.

The conference also explored many ways to facilitate communication, not just between those who observe and simulate clouds, but among people at different career stages, with often very different perspectives on cloud research.

WORKSHOP HIGHLIGHTS. The format of, and venue for, the conference was chosen to provide ample time for interaction. The conference centered around a variety of topics, ranging from technical advances in climate simulations to planned observational activities and novel approaches such as machine learning. There were no parallel sessions and the poster sessions were configured to maximize discussion. There were 128 posters on display, each for two full days, instead of the usual 1-day display time. By filling poster sessions randomly (rather than by topic) people working on similar topics could interact, and it ensured poster presentations on each topic every day. The conference benefited from a healthy gender balance, with two of five presenters being female for oral presentations, which was slightly better than for posters, where presentations by men outnumbered those by women by two to one. UCP2019 provided financial assistance for travel and on-site child care assistance to allow for the widest possible participation, and it experimented with new formats of interactions. For example, the Harnack House provided meals for all participants, thereby intensifying interactions, also in informal settings. Additional topics were identified for an evening of researcher round-table discussions. The setup for these was such that ~10 participants could share a post-dinner conversation for about 30–60 min, on a specific, not necessarily academic,[2] topic. One or two (usually more senior) individuals were asked to initiate and lead the discussion at each table, not lecture, but rather introduce and facilitate a discussion. The format was well received as it enabled dialogue on issues of mutual interest and gave voice to those who might otherwise find it difficult to share their ideas. Surprisingly, the topics "publishing" and "the future of HPC for the weather and climate community" sparked the most interest, while fewer participants seemed interested in topics such as "criteria for identifying faculty candidates."

Through the week there were 72 oral presentations, with each day adopting one of the five thematic foci. Topics were introduced by invited keynote presentations given by Masaki Satoh (University of Tokyo) and Christoph Schär (ETHZ) on topic 1, Christopher Bretherton (University of Washington) and Susanne Crewell (University of Cologne) on topic 2, Peter Düben (ECMWF) and Mike Pritchard (University of California, Irvine) on topic 3, Cathy Hohenegger (MPI for Meteorology) and Aiko Voigt (KIT) on topic 4, and Irina Sandu (ECMWF) on topic 5. A conference keynote was presented by Sandrine Bony (CNRS) and focused on the achievements and next steps of the World Climate Research Programme Grand Challenge on Clouds, Circulation, and Climate Sensitivity. Dr. Bony highlighted the important role that convective organization—also of shallow convection—plays in explaining variations in the radiation budget, illuminating a common link among some of the questions raised by the Grand Challenge. Several subsequent initiatives that will make progress answering the many questions of the Grand Challenge were highlighted in numerous presentations and across sessions. These include the Radiative–Convective Equilibrium Model Intercomparison Project (RCEMIP), which incorporates both cloud-resolving and general circulation models in an idealized setting, and the planned EUREC^{4}A (Elucidating the Role of Clouds-Circulation Coupling in Climate) field campaign.

An exciting aspect of the meeting was the progress and promise of global storm-resolving simulations. These simulations (grid spacing on a scale of a few

[1] Project-own database SAMD: https://icdc.cen.uni-hamburg.de/projekte/samd.html.

[2] List of topics: https://indico.mpimet.mpg.de/event/1/page/19-round-table-discussion.

kilometers) that resolve most circulations in storms received considerable attention and were featured in many presentations. For example, results from a first storm-resolving model intercomparison project, DYAMOND (DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains), were presented. This was a comparison between nine different models for a simulation period of 40 days. The comparison was done with the goal of reducing the uncertainties of Earth's climate caused by convective clouds. In addition, many presentations used results from the HD(CP)^2 project, and some also showed the diversity of the ICON (Icosahedral Nonhydrostatic) model, ranging from flexible small-scale nesting approaches to larger (Germany-wide) full-day simulations with ~150-m horizontal resolution and a highly resolving topography.

As model simulations are performed on finer scales with a larger coverage of area and more detail of the actual physical processes, this opens up new possibilities of using observational data. A new concept to disclose the spatial heterogeneity of the atmosphere was presented in the form of the Ruisdael Observatory (http://ruisdael-observatory.nl/), which essentially proposes to turn the Netherlands into a cloud and precipitation supersite. The planned observatory combines a variety of data that are available through remote sensing and in situ measurements over the Netherlands, covering different land surfaces such as water area, forests, and cities, with associated simulation capabilities of the type highlighted by the HD(CP)^2 project. The planned observatory is a combination of four core facilities with top-notch instrumentation (Rotterdam, Cabauw, Loobos, Lutjewad), an existing network of meteorological and air quality measurements, and various mobile laboratories (e.g., atmospheric profiler, mobile radar). The observations are accompanied with real-time simulations from DALES (Dutch Atmospheric Large-Eddy Simulation), providing a 4D representation of the atmosphere. The aforementioned EUREC^{4}A field campaign, scheduled to take place in January–February 2020, also combines a multitude of instruments (the Barbados Cloud Observatory, several research aircraft and vessels, and atmospheric and ocean measurements). It aims at quantifying the response of cloud amount in shallow cumulus layers, investigating the structure of organized shallow convection, and studying ocean mixing processes and their connection to shallow convective organization in the atmosphere. EUREC^{4}A is an opportunity to test new atmospheric retrieval algorithms using satellite, airborne, and ground-based remote sensing observations, that is, by applying multifrequency radar and lidar approaches. Similar approaches are being used for the Atmosphere Radiation Measurement (ARM) Program field sites through the LASSO (Large-Eddy Simulation ARM Symbiotic Simulation and Observation) projects, where a variety of observational data are used in synergy with modeling efforts.

Another hot topic was machine learning, as it came up in several presentations at UCP2019. These showed the potential to learn parameterizations by training deep neural networks and the use of artificial intelligence to probe inputs and outputs of existing parameterizations. They also highlighted how computationally expensive parts of a model can be replaced by faster algorithms. Another example of how machine learning approaches can be leveraged was presented with the classification of organizational structures of shallow convection to train learning algorithms. These presentations were nuanced, as some of the pitfalls with machine learning, often taking the form of lack of generalizability, were a point of discussion.

In addition to global storm-resolving models, exciting new field studies, and machine learning, a subject that appeared many times was convective organization, ranging from self-aggregation to cold pools. This topic has long been neglected by the climate community, but aside from being linked to large variations in Earth's energy budget, extremes, and circulation changes, it also constitutes a major issue in understanding radiative–convective equilibrium (RCE) simulations. Although this approach, using the balance between net radiative cooling and convective heating, is very simple, RCE can, for example, be used for understanding tropical dynamics and to describe the response of clouds to warming. RCE simulations were combined in the aforementioned community RCEMIP[3] project, where models were configured in the idealized radiative–convective equilibrium case. Various models (large-eddy resolving, storm-resolving, or general circulation models) were used in this study to try to determine the role of convective self-aggregation in climate and assess mechanisms for changes in convective clouds with warming.

OUTCOMES. UCP2019 brought together German and international researchers from the field of atmospheric science and allowed for exchange on various topics.[4] It also presented the HD(CP)^2 project to a

[3] Details on the MIP: http://myweb.fsu.edu/awing/rcemip.html.

[4] A complete schedule and the conference contributions of UCP2019 can be found at the conference web page: https://indico.mpimet.mpg.de/e/UCP2019.

greater audience and sparked interest in the use of the modeling approaches and output generated in this project. The meeting showed a rich diversity of scientific approaches to improve the understanding of clouds and precipitation and explored new formats of interaction. The growth of interest in the meeting, the quality of the presentations and subsequent discussions, and the buzz surrounding many of the new approaches made it an exciting meeting, and many of us are looking forward to see how the new research lines will pan out. Hopefully, in three years UCP will reincarnate itself as UCP2022 to allow us to find out—by then some important intercomparison projects like DYAMOND and RCEMIP will have run their course, exciting new field campaigns will be well into their analysis phase, and the cloud and precipitation deadlock may be tackled by exascale computing.

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