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FUTURE COMMUNITY EFFORTS IN UNDERSTANDING AND MODELING ATMOSPHERIC PROCESSES

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Atmospheric processes are important for weather, climate, and water prediction, as well as climate change projection, but their representation through subgrid parameterizations remains challenging. Understanding and representing these processes are therefore major goals of international research programs. The Global Atmospheric System Studies (GASS) Panel (Zeng and Klocke 2017), as part of the Global Energy and Water Exchanges Project (GEWEX), is dedicated to developing and improving the representation of the atmosphere in weather and climate models by facilitating and supporting the international community to carry out and use observations, process studies, and numerical model experiments.

UNDERSTANDING AND MODELING ATMOSPHERIC PROCESSES—THE SECOND PAN-GASS MEETING

WHAT: About 160 participants from some 20 countries, representing the weather and climate modeling community, held an international workshop to overview the progress in understanding and modeling atmospheric processes and to discuss promising ideas for future community projects.
WHEN: 26 February–2 March 2018
WHERE: Lorne, Victoria, Australia

To overview the progress in understanding and modeling atmospheric processes and to discuss promising ideas for future community projects, an international conference entitled "Understanding and Modelling Atmospheric Processes—The Second Pan-GASS Meeting" was held in the late Southern Hemisphere summer in Australia (http://singh.sci.monash.edu/Pan-GASS/index.shtml), the second such Pan-GASS meeting. About 160 participants from some 20 countries attended this conference, including individuals from government agencies, academia, private sector, and international organizations.

The 5-day conference mixed oral presentations, posters, plenary discussions, and parallel discussion

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sessions. The oral sessions covered a wide range of topics that are relevant to weather/climate models. The parallel sessions discussed seven white papers that were circulated among conference participants before the meeting. A summary report with highlights from the conference is presented below.

SCIENCE PROGRESS. Here we briefly review the contributions to the different sessions in general, instead of reporting on individual oral and poster presentations in detail. We also provide examples to illustrate the progress in various areas.

Research on how to represent convection in numerical models remains critical as horizontal resolutions approach the gray zone, where convection is partially resolved. Turbulence and microphysical processes become critical, while key ingredients of convective parameterizations are still needed, such as scale awareness, relevant triggering criteria, and convective memory. New modeling approaches, such as stochastic cloud ensembles, refined-resolution superparameterization, and multicloud methods, showed promising results but understanding how a specific development impacts the biases of a fully coupled model remains challenging. Long-term lidar and radar observations were shown to provide new insights that challenge conventional notions about shallow convective updrafts and the relationship between convective rainfall and area.

Clouds are an important driver of weather and climate through their interactions with radiation and atmospheric circulation. For instance, some talks discussed how these interactions and feedbacks influence midlatitude cyclones, radiation biases in the Southern Ocean, and tropical rainfall. Futhermore, with increasing horizontal resolutions, three-dimensional effects of clouds on radiation also become important. As radiation is one of the most computationally expensive components of atmospheric model physics, it is important to find the right balance between accuracy, speed, and flexibility in order to obtain optimal configurations for weather and climate simulations.

Observations of the atmosphere are at the heart of advancing our understanding of atmospheric processes and their represention in numerical models. Continuing measurement efforts were presented to support model development and evaluation. Examples include a recent campaign on the cloud–aerosol interaction over the Southern Ocean; an upcoming campaign on the cloud–circulation coupling in the trade cumulus regime; a long-term measurement program at fixed sites and with short-term campaigns on the cloud, radiation, and aerosol interactions over different climate regimes; and a radar network project on precipitating clouds and thunderstorms.

Surface drag and momentum feedbacks are an active area of research, motivated by the large uncertainties in the representation of surface drag in weather and climate models highlighted by recent studies. Talks covered all aspects of momentum transport, from nonorographic and orographic gravity waves to shallow and deep convection momentum transport, and observations of momentum fluxes from wind energy towers. Exciting advances were presented in terms of both process understanding and large-scale impacts of the various drag processes, and using high-resolution simulations and ensemble-based methods for constraining orographic drag processes.

Advances in atmospheric modeling were discussed, for example, in advanced numerical methods, nonhydrostatic dynamical cores, and adaptive grids. One maturing technology is to embed cloud-resolving arrays within grid cells of coarser models, to simulate subgrid processes (i.e., superparameterization). Here an emerging challenge is how to design appropriate grid resolutions for the interior scale when coupled to advective feedbacks from a host global model. While rich trade-offs in performance versus computational costs of gray-zone resolution have previously been revealed, new trade-offs are emerging in the higher degree of freedom setting of such multiscale modeling frameworks. Several unexpected behaviors of an attempt at refined-resolution superparameterization (so-called ultraparameterization) for improved low-cloud simulation especially illustrated this point.

Physics–dynamics coupling (PDC) is a ubiquitous component of any atmospheric model development process to ensure that the accuracy of individual physics and dynamics components is not compromised when they are combined with one another. Recent work was presented to improve model accuracy and our understanding of PDC's role in the construction of an atmospheric model. Examples include numerical aspects of PDC (such as the time step dependence), idealized equation sets, and common physics interfaces and choices for discretization.

There is considerable focus at the moment on polar processes in the context of the ongoing Year of Polar Prediction. Conclusions were drawn on the lessons learned from the two most recent intercomparison exercises organized in the framework of GASS, and various avenues were discussed through which the

Arctic-to-midlatitude linkages can be explored and better understood.

Substantial research in recent years has focused on the role of aerosols in weather and climate through their influence on cloud microphysics. Presentations and discussions covered a diverse range of topics, including new modeling methodologies to represent cloud microphysics, advances in cloud-aerosol observations, the parameterization of cloud–aerosol interactions, and new bulk microphysics scheme developments. A model intercomparison case study was also presented to quantify and understand simulation spread using different model representations of cloud–aerosol interactions.

Along with prediction, one of the most important uses of models is for gaining insight into the physical processes that govern weather and climate. Topics covered the use and limitation of the idealized framework of radiative–convective equilibrium, novel approaches to constructing case studies for large-eddy simulation, and new methods for estimating model uncertainty using stochastically perturbed physics. The session highlighted the benefits of both idealized and realistic studies in progressing our understanding of atmospheric processes.

The land–atmosphere interaction session covered a variety of related processes at different temporal and spatial scales. Progress was presented through several intercomparison projects. For instance, one project addressed mechanisms behind the systematic summertime land surface temperature warm biases, and another emphasized the formidable logistical challenges in confronting the discrepancies in land–atmosphere coupling strength across different models, underscoring the need for sustained effort. Also included was the investigation of convection responding to soil moisture wet/dry conditions and surface heterogeneities using a theoretical framework, such as radiative–convective equilibrium or finescale models.

FUTURE GASS PROJECTS. GASS and its predecessor panel have organized highly successful international activities (www.gewex.org/panels/global-atmospheric-system-studies-panel/gass-projects/). Looking forward, GASS is proactively pursuing new projects in four theme areas: model physics, high-resolution modeling, dynamics–physics coupling, and prediction. Specifically, seven white papers outlining six potential GASS projects were discussed in the parallel sessions. Some of these projects will be jointly sponsored by other international programs. The initial activities of these white papers are summarized below.

Surface drag and momentum feedbacks (Irina Sandu: irina.sandu@ecmwf.int). Interest in drag processes and defining pathways to constrain them build on recent efforts to highlight the importance and the potential benefits of improving the representation of these processes for both weather and climate models. Two of the science questions are below.

- Can kilometer-scale simulations and large-eddy simulations be used as a proxy for the truth for certain drag processes? Building on recent work, an intercomparison exercise based on a hierarchy of numerical simulations of various resolutions will be proposed to study the ability of current low-level blocking and gravity wave parameterizations to capture the effects of complex mountain ranges on atmospheric flow.
- How can we make better use of existing observations (e.g., towers, lidars) or upcoming satellite data (*Aeolus*) to constrain winds and to study their coupling to the large-scale circulation?

Modeling the precipitation diurnal cycle (Shaocheng Xie: xie2@llnl.gov). This project will initially focus on the use of U.S. Department of Energy Atmospheric Radiation Measurement (ARM) data (www.arm.gov/) over different regions. Two of the science questions are below.

- Which subdiurnal processes are most essential for the simulation of the diurnal cycle and subdiurnal extreme events, and how can these be improved in weather and climate models?
- What are the roles of convective memory (advection) and of the nighttime boundary layer and elevated convection initiation?

Fog modeling intercomparison (Ian Boutle: ian.boutle@metoffice.gov.uk; Adrian Hill: adrian.hill@metoffice.gov.uk). This project will initially focus on the use of the observational data collected as part of the Local and Nonlocal Fog Experiment (LANFEX), conducted in the United Kingdom from 2014 to 2016. Two of the science questions are below.

- How well can models simulate the development of radiation fog?
- What are the key processes governing the development of radiation fog (i.e., aerosol, cloud microphysics, radiation, turbulence, and dew deposition)?

Gray-zone modeling (Lorenzo Tomassini: lorenzo.tomassini@metoffice.gov.uk; Pier Siebesma: a.p.siebesma@tudelft.nl). This project identifies four headline issues

with convection parameterizations, and it will focus on both the boundary layer and the convective "gray zone" of grid sizes between 100 m and 10 km, where boundary layer and convective processes are partially resolved and partially parameterized. Its initial phase will build on a planned field campaign east of Barbados over the Atlantic Ocean [Elucidating the Role of Cloud–Circulation Coupling in Climate (EUREC4A); http://eurec4a.eu/]. Two of the science questions are below.

- What controls the convective mass flux, convective mixing, cloud depth, and cloud fraction of shallow cumulus clouds?
- What is the role of the wind and vertical momentum transport? What is the role of mesoscale organization?

Physics–dynamics coupling (Hui Wan: hui.wan@pnnl.gov; Ben Shipway: ben.shipway@metoffice.gov.uk). The first phase of this project is for participants to conduct baseline simulations, to select an initial set of evaluation metrics, and to compare results. Two of the science questions are below.

- How do different atmospheric models behave when run with different time steps?
- How does any change in behavior relate to climate sensitivities or sensitivities in model tuning?

Land temperature and snowpack impacts on subseasonal to seasonal (S2S) prediction (Yongkang Xue: yxue@geog.ucla.edu). This project will initially focus on the Third Pole Environment (TPE; www.tpe.ac.cn/) with the two questions listed below.

- What is the impact of the initialization of large-scale land surface and subsurface temperature and snowpack, including the aerosol in snow, in climate models on the S2S prediction over different regions?
- What are the relative roles and uncertainties in these land processes versus in sea surface temperature in S2S prediction? How do they synergistically enhance the S2S predictability?

At present, the authors of these white papers are developing implementation plans, and these white papers will be developed into GASS projects whenever they are ready. Please contact the lead authors if you want to participate in these activities. If you want to propose new white papers, please contact the GASS cochairs (the first two lead authors).

In the future, GASS will structure its work around four topics (representation of physical processes, high-resolution modeling, dynamics–physics coupling, predictability), and each topic will include one or more projects focusing on specific aspects. Smaller annual meetings will be organized in the next few years, focusing on specific topics/projects, and the next Pan-GASS meeting will be organized in 3 to 4 years.

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REFERENCE

Zeng, X., and D. Klocke, 2017: A new vision for GEWEX Global Atmospheric System Studies (GASS) Panel. GEWEX News, Vol. 27, No. 3, International GEWEX Project Office, Silver Spring, MD, 4–5.