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Report on the Latsis Symposium 'Atmosphere and Climate Dynamics' 18-21 June 2014, Zurich, Switzerland

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Fundamental advances in climate modelling need to come from an improved understanding of the dynamical processes shaping climate, and their interactions across an enormous range of scales: from the micrometre scales of cloud droplet formation to the global scales of atmospheric circulations. Neither can be completely understood in isolation from the other, yet they are traditionally addressed in separate sub-communities that rarely interact with each other. The Latsis Symposium 2014, 'Atmosphere and Climate Dynamics: From Clouds to Global Circulations', was envisioned as a conference to bring together leading researchers from these diverse sub-communities in the climate sciences, in order to map out promising new avenues for research to answer the most pressing questions in climate dynamics. The meeting was primarily supported by the Geneva-based Latsis Foundation, which sponsors two annual conferences on topics from across the sciences. SPARC and other WCRP projects provided support for early-career scientists to attend the meeting.

About 200 scientists from 6 continents gathered in June for the four-day Latsis Symposium in Zurich, Switzerland. Each day consisted of one-hour invited overview lectures interspersed with shorter contributed talks and poster sessions. The topics of the overview lectures ranged from 'The Global Warming Hiatus in the Context of the Past Millennium' (**Mark Cane**), to 'Climate Change Uncertainty: The Role of Internal Atmospheric Variability' (**Clara Deser**) and 'Aerosol Forcing - Last Century's Problem' (**Bjorn Stevens**). The overview lectures formed the backbone of the symposium and structured the themes of the contributed talks in between.

One afternoon was devoted to interactive breakout sessions, which were anchored by invited talks in Pecha Kucha format: 5-minute talks consisting of 15 slides that each advanced automatically after 20 seconds (the format is used successfully, for example, at the World Economic Forum). In these very dynamic and engaging presentations, the speakers each introduced an important open question in climate dynamics and sketched ways of resolving it. The questions were then discussed in breakout groups, followed by a summary plenary. The Pecha Kucha talks and breakout groups addressed 'Transient Monsoon Dynamics: Understanding Synoptic and Subseasonal Variations'

(**William Boos**), 'Polar Climate Dynamics: What Drives Arctic Amplification?' (**Rodrigo Caballero**), 'Tropical Precipitation Extremes: Can we Predict Their Response to Warming?' (**Caroline Muller**), 'Why Do GCMs Have Trouble With the MJO?' (**David Randall**), and 'General Circulation Dynamics: What Determines the Regional Response to Global Warming?' (**Tiffany Shaw**).

Recurring Themes

A few recurring themes emerged from the broad range of talks and poster presentations: (1) There is a resurgence of interest in the dynamics of extra-tropical storm tracks. For example, presentations addressed how storm tracks equilibrate and vary on sub-seasonal timescales (**Maarten Ambaum**), and the great variety of processes that can influence their position: from orography (**Rachel White**), stratospheric processes (**Ted Shepherd, Gang Chen, David Ferreira**), baroclinic mechanisms (**Orli Lachmy, Cheikh Mbengue, Yu Nie, Yang Zhang)**, to cloud-radiative processes (**Dennis Hartmann**). Detailed dynamical descriptions of how extra-tropical storms lead to extreme events are emerging (**Brian Hoskins, Nili Harnik, Heini Wernli, Volkmar Wirth**). What is missing is a closed theory that relates the position and energy of extra-tropical storm tracks to mean climate variables such as the thermal structure of the atmosphere. (2) Atmosphere-ocean interactions are important contributors to decadal climate variations and modulators of long-term climate changes, but they remain insufficiently understood. For example, El Niño and the Southern Oscillation (ENSO) appear to be linked to climate variations in higher latitudes, with implications for the recent global warming hiatus (**Mark Cane**). Yet the nature of such links, and their implications for climate changes on geological time scales, remain to be clarified (**Riccardo Farneti, Alexey Fedorov, Malte Stuecker, Jin-Yi Yu**). Similarly, spatially varying ocean uptake of energy and carbon strongly and non-linearly modulates the long-term response to climate change; however, the dynamics controlling the spatial pattern of that uptake are not fully understood, leading to uncertainties in climate projections (**Kyle Armour, David Brayshaw, Nicole Feldl, Thomas Frölicher, Brian Rose**). Clearly, we need an improved understanding of how processes in the upper ocean couple both to the atmosphere above and to the deep ocean below. (3) The hydrologic cycle and how it responds to climate changes remain areas of intense research. Recent work addresses how stationary circulations, both thermally and orographically driven, shape patterns of net precipitation (precipitation minus evaporation) and their changes with climate (**Xavier Levine, Isla Simpson, Robert Wills**). Observations and theories of how precipitation and net precipitation more broadly have changed over the past decade and are expected to change in the future are being refined (**Michael Byrne, Peter Greve, Angeline Pendergrass**), as is our understanding of what controls atmospheric humidity and its variability (**William Collins**). (4) Substantial progress is being made in observing, modelling, and understanding the processes controlling clouds and convection, but these processes remain at the heart of our uncertainties about how the climate system responds to perturbations. The multitude of processes that influence clouds and convection - from large-scale overturning circulations to the microphysics of droplet formation - continue to make it challenging to arrive at a comprehensive theory or at least a clear understanding of the relative importance of the various processes. Yet progress is being made in designing frameworks for simulating these processes (**Adam Sobel, Isaac Held**) and in using observations and high-resolution simulations to elucidate, for example, how important different processes are for convective self-aggregation (**Allison Wing, Adrian Tompkins**) and how complex the representation of clouds and convection in climate models needs to be (**David Randall**). The Madden-Julian Oscillation is a good test bed of our understanding of how convection, surface exchange processes, and tropical waves interact, and it came up in several presentations (**Larissa Back, Henrik Carlson, Penelope Maher, Brian Mapes**). There continues to be debate about the importance of changes in aerosol loading on clouds (**Bjorn Stevens, Ulrike Lohmann**); however, progress is being made observing aerosol effects and modelling them through high-resolution simulations (**Chris Bretherton, Doris Folini, Franziska Glassmeier**). Conversely, the radiative effects of clouds on large-scale circulation features such as the ITCZ (**Romain Roehrig, Aiko Voigt**), ENSO (**Gaby Raedel**), and storm tracks (**Dennis Hartmann**) are increasingly studied and evidently play a role in modulating the circulation response to global warming. (5) It made for a particularly stimulating, albeit intense, meeting that this breadth of themes was presented in close succession in just four days, in one auditorium where all attendees remained together. The meeting made it clear that the observational

data and computational tools we now have at our disposal present rich new opportunities for studying and resolving questions in atmosphere and climate dynamics that are at the centre of how the climate system responds to perturbations on timescales from years to geological epochs.

Early-Career Scientists

WCRP, through its core projects SPARC, GEWEX, and CLIVAR, provided travel support for early-career scientists. With additional support by the ETH Centre for Climate Systems Modelling, in total 33 early-career scientists received travel support to attend the meeting, which was crucial in ensuring that a large number of younger scientists could participate and carry lessons learned from it to the future (about half of the participants were early-career scientists).

The overall impression that the meeting left is that the field of atmosphere and climate dynamics is successfully completing a generational transition. New approaches are being developed to address questions that sometimes go back decades (*e.g.*, about extra-tropical storm tracks and atmosphere-ocean interactions). Their resolution now seems within reach.

Report on the SPARC Workshop on Polar Stratospheric Clouds 27-29 August 2014, Zurich, Switzerland

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A workshop on Polar Stratospheric Clouds (PSCs) was held at ETH Zurich in Switzerland from 27-29 August 2014 and was attended by 44 scientists from 10 different countries. The workshop provided a platform to link the various individual activities underway and to assess key science developments related to PSCs. The organizers sought to encourage discussion of new observations and modelling results, identify outstanding science questions, and relate recent results to long-standing conundrums. The workshop was organized into five sessions: 'Satellite and Ground-based Lidar Observations'; 'Aircraft and Balloon-borne Observations'; 'Processes: Nucleation, Denitrification, Dynamical Forcing'; 'Chemistry and Chemistry Transport Models (CTMs)'; and 'PSC Parameterization in Chemistry Climate Models (CCMs) and Empirical Studies'. To facilitate dialogue amongst participants, dedicated discussion periods were set aside at the end of each session. A workshop steering group meeting was held on the Friday afternoon to summarize the outcomes of the workshop and discuss the content of a potential new and comprehensive paper on PSCs.

The workshop was kicked off by **Thomas Peter** who presented a historical perspective of the evolution of our understanding of PSCs. Almost three decades after the discovery of the ozone hole, he concluded that our understanding of PSC-catalysed heterogeneous chemistry is probably sufficient, whereas our knowledge about nitric acid hydrate PSC nucleation and denitrification is still incomplete. Gaps and uncertainties in our understanding make it difficult to fully parameterize PSC-related processes in global models. With Thomas' presentation, the stage was set for individual contributions from various research fields.

Satellite and Ground-based Lidar Observations

Observations from the CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarisation), MIPAS (Michelson Interferometer for Passive Atmospheric Sounding), and Aura MLS (Microwave Limb Sounder) satellite instruments were presented by **Michael Pitts**, **Michael Höpfner**, and **Alyn Lambert**, respectively. CALIOP, on-board the CALIPSO satellite, has been providing a detailed picture of PSC morphology and composition on vortex-wide scales since 2006. The CALIOP algorithm separates PSCs into different composition classes