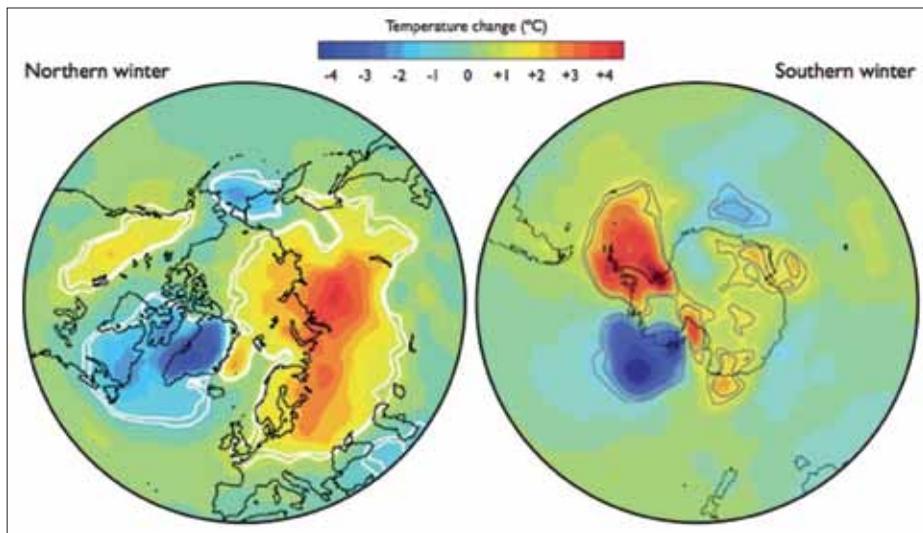


From atmosphere to space: a new scientific frontier

Progress in the science of weather – on Earth and in space – depends on understanding the whole of the atmosphere, from the surface of the Earth into space. Tracy Moffat-Griffin reports on an RAS specialist discussion meeting that crossed traditional disciplinary boundaries.



1: Northern and southern hemisphere wintertime differences in surface air temperature arising from energetic particle precipitation (high EPP – low EPP) from ERA-40 meteorological re-analysis data. Dynamical coupling between atmospheric layers may link space weather to surface climate. For the northern hemisphere, years with a major sudden stratospheric warming event during the winter are excluded. The contours represent the 90% and 95% confidence levels. (From Seppälä *et al.* 2009)

On 11 January 2013 the RAS in London hosted a meeting entitled “Integrated atmospheric and space science” organized by Prof. Mark Lester (University of Leicester), Dr Mervyn Freeman and Dr Tracy Moffat-Griffin (both British Antarctic Survey). The rationale for this meeting was the awareness that continued progress in both conventional meteorology and space weather will require an integrated approach: an understanding of the whole atmosphere (charged and neutral) from the ground to space. This meeting aimed to bring together the UK space, atmosphere and meteorological communities to explore this new scientific frontier.

The meeting was divided into three sessions in which all speakers were invited: “Top-down effects” covering solar and space effects on the atmosphere; “Bottom-up effects” covering instrument and modelling studies of waves in the atmosphere and ionosphere; and “Looking

forward – extending the models”, which covered the planned extension, upwards in altitude, to the Met Office Unified Model. There was also a poster session over the lunch break.

Top-down effects

The morning session was opened by Lesley Gray (University of Oxford) with a talk on the solar effects on climate. The talk provided a good overview of the evidence for the effects of the solar cycle on the Earth’s climate system and discussed the mechanisms that responded to the variations in solar cycle. The current understanding of the processes involved in these various mechanisms and how well we are able to represent them in climate models were also discussed.

The second talk of the session was by Annika Seppälä (Finnish Meteorological Institute) on energetic particles, focusing on global analysis and models. She provided an overview of the

effects of energetic particle precipitation (EPP), from both solar storms and the magnetosphere, on the atmosphere. She showed the impact that this ionization has on chemistry (the production of NO_x and HO_x) and the related ozone depletion during the winter months in polar regions. She also presented re-analysis data and modelling results that showed a link between surface temperatures and EPP chemistry changes higher up in the atmosphere, as shown in figure 1. It was proposed that dynamical coupling between the atmospheric layers were the mechanism for linking space weather effects to the polar climate.

The third talk of the session was by David Newnham (British Antarctic Survey) on “Energetic particles – vertical transport and mechanisms”. He presented results from the ground-based microwave radiometer located in Antarctica, which is able to measure the concentrations of various chemical species in the mesosphere that are related to EPP events. Results from the period of solar minimum (2008–2009) showed that even during periods of low geomagnetic activity there is significant production of NO_x , which then impacts on stratospheric ozone.

The fourth talk of the session was by Giles Harrison (Reading University) on coupling of space weather into the lower atmosphere by the global electric circuit. The speaker provided a clear explanation of the circuit and how it can propagate space weather effects (such as cosmic-ray changes) down to the troposphere. He focused on the influence of cloud layers on the global circuit, arising from the reduction of the conductivity of the air in clouds, and possible links to lower atmospheric temperature changes.

The final talk of the morning session was by Mai Mai Lam (British Antarctic Survey) on the influence of interplanetary magnetic fields on the surface climate. She reported a new result that a variation in the mid-latitude surface atmospheric pressure corresponded to variations in the IMF (which influences the atmosphere via the global electric circuit). Previous work had assumed that this effect was only present at high latitudes. Their interpretation was that the polar effect is able to modify Rossby waves, and thereby alter weather patterns, at mid-latitudes.

The poster session was held between the morning and afternoon sessions in the RAS library. Eleven posters covered topics including access to atmospheric and space weather datasets, studies using their data, new atmospheric modelling work and data re-analysis studies. Despite the restrictions on space, the poster session was busy and provided the opportunity for many enthusiastic discussions.

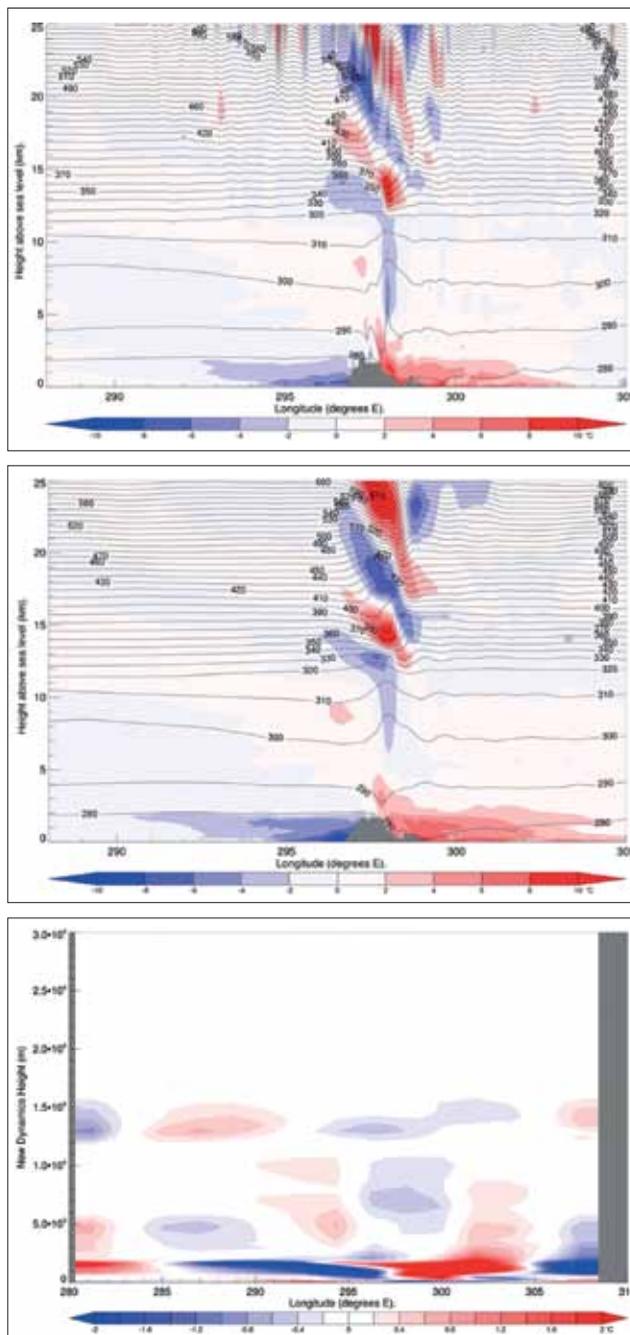
Bottom-up effects

The first afternoon session on bottom-up effects was opened by Jack McConnell (York Univer-

sity, Canada) who gave a talk on the Canadian Ionosphere–Atmosphere Modelling System (CMAM-UAM). He outlined their approach, of looking to develop a whole-atmosphere model, so that they could study the effects of lower atmosphere dynamics on the upper atmosphere and also the effect of space weather features such as energetic particles on the lower atmosphere. The first step to achieving the whole-atmosphere model has been to couple the Canadian Middle Atmosphere Model (CMAM) and the ionospheric Upper Atmosphere Model (UAM). A case study of model results was shown where the effect of upward propagating waves (from the lower atmosphere) on ionospheric structure was examined. Comparisons were done with data from the IMAGE-FUV imager, looking at the longitudinal structure of the features. Analysis of the model results implied that the zonal difference in wave penetration to ionospheric altitudes modified the ionospheric electric current, which in turn modified the emission seen in the imager data.

The second talk was by Andrew Orr (British Antarctic Survey) on modelling stratospheric temperature fluctuations induced by gravity waves over the Antarctic Peninsula. Stratospheric temperature perturbations in satellite data have been linked to the formation of polar stratospheric clouds (PSCs). These perturbations are thought to be caused largely by gravity-wave activity. PSCs are important because they are linked to the loss of ozone. This talk concerned a case study of modelling over the Antarctic Peninsula. The Unified Model (UM) was used to try to reproduce temperature perturbations seen in satellite data. The Antarctic Peninsula is a mountainous region and generates lots of gravity waves (mountain waves). The results from the case study showed that the high-resolution UM was able to reproduce realistically the magnitude, timing and location of the temperature fluctuations, but that the low-resolution version was unable to represent the structure and magnitude of the disturbances (see figure 2). This highlights the need for a better representation of gravity waves in low-resolution climate models in order to capture important effects such as fine-scale temperature perturbations and PSCs.

The final talk of the session was by Steve Milan on medium-scale travelling ionospheric disturbances (MSTIDs) observed over the Ant-



2: Vertical cross-sections of potential temperature (contours) and gravity-wave-induced temperature disturbance (shading) above the Antarctic Peninsula at a latitude of 65°S for 03.00 UTC 7 August 2011 (during which a strong westerly flow crossed the Peninsula). The plots come from forecasts of the UK Met Office Unified Model run as a limited-area mesoscale model (top two plots, 1.5 and 4 km horizontal resolution respectively) and as a climate model (bottom, N96, [~135 km] horizontal resolution, ensemble mean of 13 runs). Note that the low-resolution model (bottom) is not realistic.

arctic Peninsula by HF radar. The HF radar was located in the Falkland Islands between May 2010 and April 2011 and its field of view covered the Drake Passage and Antarctic Peninsula, known regions of high gravity-wave activity. Using the observations of ground backscatter from the radar, they were able to identify MSTIDs which had scales consistent with medium-scale gravity waves. The MSTIDs were found to have a primary population of northward-propagating waves, which

are associated with coupling between the solar wind, magnetosphere and ionosphere, and a smaller westward-propagating population, thought to be associated with gravity waves from the mountains of South America/Antarctic Peninsula or those formed at the edge of the polar vortex.

Looking forward

The final session of the meeting was a detailed talk by David Jackson (Met Office) on the thermosphere extension in the Met Office Unified Model (UM). The UM is widely used for weather forecasting and climate studies and has an upper boundary at 85 km. The motivation for expanding upwards is to improve capability for space-weather forecasting and accurately represent space-weather effects on the whole atmosphere. The need to understand the dynamical links between the lower atmosphere and thermosphere/ionosphere is also very important. He outlined plans for the expansion of the UM up to 600 km in order to produce a model that represents the coupling between the layers in a self-consistent manner. The challenges in such an expansion were discussed, highlighting the need to incorporate features such as non-LTE heating schemes and gravity-wave drag; the issue of how to expand the chemistry side of the model was also discussed. He showed that work towards the goal of a whole-atmosphere model was progressing well, but that it was going to take a lot of research and development to get it right and an important element of the process is for the community to work together.

Summary

The meeting was attended by more than 50 people from all areas of the space weather, atmospheric and meteorology communities. There were many discussions during the meeting breaks and lots of comments

were made about how interesting the talks were and how much attendees had learnt. Overall the meeting was hugely successful and we hope it has forged many new links between the different communities and highlighted the importance of an integrated approach to our research areas. ●

Dr Tracy Moffat-Griffin (British Antarctic Survey), Prof. Mark Lester (University of Leicester) and Dr Mervyn Freeman (British Antarctic Survey).