

Meeting report on Stratosphere-troposphere coupling in the Earth System: where next?

April 28, 2015

Over the past few decades, the importance of the stratosphere for weather and climate has become a strong focus of research. The research has shown that the stratosphere has a key role in affecting surface variability and predictability. For example, the recent WMO/UNEP Ozone Assessment Report (2014) described how stratospheric ozone depletion is likely to have been the main driver of changes in the Southern Hemispheric surface climate in recent decades. Most weather and climate models now aim to represent the stratosphere better.

Many outstanding issues remain around the ways in which the stratosphere can affect the troposphere. The above-titled meeting, held at the University of Reading on the afternoon of 21 January 2015, aimed to discuss these issues. Five main talks by experts were followed by a discussion session led by meeting chair Peter Haynes, and preceded by an introduction from meeting organizer Amanda Maycock (both from the University of Cambridge).

The meeting was popular and fully subscribed for people attending in person and remotely via a new webcast system. This is the second time the Royal Meteorological Society has trialled a web conferencing service for those unable to travel to the meeting. The online chat feature and Twitter (RMetSMeet) allowed remote participants to ask questions.

Amanda's introduction reminded us that a cold cyclonic polar vortex forms in the stratosphere every winter and that it is disturbed by breaking planetary-scale Rossby waves propagating up from the troposphere. In about two-thirds of Northern Hemispheric winters, the waves disturb the polar vortex so violently that the zonal-mean winds reverse and polar temperatures rise, by several tens of degrees. Such events are called stratospheric sudden warmings (SSWs) and account for the dominant mode of variability of the zonal mean circulation, as measured for instance by the Northern Annular Mode (NAM) index. Figure 1 is the well known Baldwin-Dunkerton "dripping paint plot", a time-height cross-section of the NAM index composited with respect to the onset of many SSWs. The plot suggests, but does not prove, downward influence from stratosphere to troposphere, affecting the weather over the next few months. More recently, however, numerical experiments with stratospheric nudging have confirmed such influence.

Adam Scaife (Met Office) spoke on climate and seasonal forecasting. Research has shown that the responses to different drivers of Atlantic winter climate often exhibit the same large-scale surface pressure pattern, that of the North Atlantic Oscillation (NAO). Several participants likened the NAO to a nonlinear 'bell' waiting to be rung by the stratosphere, or by another driver. Adam showed that with the Met Office's new Global Seasonal Forecasting System (GloSea5) significant progress has been made in improving forecasting skill over months for the winter NAO, beyond the traditional forecasting timescale, but only in models with well-resolved stratospheres.

Ted Shepherd (University of Reading) presented results on the impact of long and short lived SSWs on the troposphere in observations and climate models. Even though the existence of downward influence is clear from model experiments, the complex mechanisms mediating it are not clearly understood. Ted suggested regarding the troposphere as a whole, including internal feedbacks between jet-shifts and eddy fluxes – the nonlinear NAO 'bell' idea again – rather than looking for a single mechanism for downward influence as such. Model biases in representing the internal tropospheric feedbacks need scrutiny.

Mark Baldwin (University of Exeter) offered a different view of downward influence from the polar vortex. He demonstrated that changes in the vortex, as measured by an index for anomalies at roughly 25 km altitude, are well correlated to vertical displacements of the tropopause. He hypothesised that the associated mass displacement extends down into the troposphere, picturing the situation as a 'stratospheric

plunger'. Such a picture is consistent with the observed upper-tropospheric, but not lower-tropospheric, vertical profile of pressure anomalies that correlate with SSWs. The lower-tropospheric part of the profile is amplified, most intensely at sea level, but the feedback process is not clear.

Alexey Karpechko (Finnish Meteorological Institute) discussed results from the Fifth Coupled Model Intercomparison Project (CMIP5) ensemble, aiming to diagnose the contribution of stratospheric processes to surface climate change. The inter-model spread in future stratospheric wind changes cannot be attributed solely to internal variability, and indeed was much greater than intra-model spread (e.g. from year to year). Under current climate conditions, stronger subtropical winds seem somewhat correlated to a strengthening of the polar vortex, in the responses to increased greenhouse gases, though the correlation appeared weak, as well as variable across the ensemble of models. Nevertheless, it might hint at a way of reducing uncertainty in predictions of future stratospheric changes.

Peter Hitchcock (University of Cambridge) spoke on the interplay between SSWs and the troposphere on seasonal timescales. Whilst the tropospheric jet shift following major SSWs is clear in the observational record, that record is not long enough to get good statistics on the finer tropospheric details. A better way forward is to use carefully designed model experiments. Peter used stratospheric nudging experiments to produce clear evidence of downward influence from stratosphere to troposphere. Strong SSWs of a particular kind, in which the polar vortex is largely destroyed, suppress upward wave propagation and produce a radiation-dominated lower stratosphere that leads to better predictability over radiative timescales of a month or two. The troposphere inherits some of that predictability. A simple 'toy model' was used to gain mechanistic insight into how that occurs.

The meeting concluded with lively discussion where many interesting points were raised by audience members and the speakers. The general consensus was that there is a need to improve understanding of mechanisms for responses to external forcing. There was a spirited defence of intelligent model experimentation, as a method of testing and clarifying proposed mechanisms, by Jo Haigh (Imperial College London). We should aim for improved understanding of the vertical propagation of waves in the atmosphere, the role of the oceans in stratosphere-troposphere coupling, and interactions between the tropics and extratropics.