Tracing patterns in the

A curious instrument in Antarctica is tracking meteor trails across the sky. These are

The atmosphere is made up of many layers: closest to Earth is the troposphere; above that the stratosphere – where high-flying jet aircraft roam and the ozone layer is found – and then above the stratosphere the little-known mesosphere. The mesosphere is home to giant atmospheric waves and tides, meteors and their smoky debris, ghostly noctilucent clouds and a unique pole-to-pole atmospheric circulation. Last year we installed a sophisticated radar in Antarctica to learn more about this region and we are now beginning to reap the rewards.

The mesosphere is a deep layer of rarefied atmosphere. It lies 55 to 100 kilometres above our heads. Waves and tides launched from the lower atmosphere dominate its motion. As they ascend into the mesosphere, they break – rather like waves breaking on a beach. They transfer their momentum to the mesosphere, driving a global circulation. This circulation forces air to rise over the summer pole, it then crosses the equator and descends over the winter pole. Over the course of a winter, most of the air in the mesosphere is drawn downwards over the winter pole and is replaced by new air drawn up from below at the summer pole. The gigantic circulation reverses every six months.

This movement of air has a dramatic effect on the temperature of the mesosphere. It also affects the stratosphere directly beneath it, and ultimately has impacts in the troposphere. The air over the summer pole expands as it rises because its pressure drops and consequently it cools. This cooling reduces the temperatures to below minus 140°C, making the summertime polar upper mesosphere the coldest naturally occurring place on Earth. These extremely low temperatures condense the water vapour in the mesosphere and form thin layers of polar mesospheric clouds at heights of about 82km, the highest clouds in the atmosphere. Still illuminated by the

The arrays detect about 500 meteors a day.

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Antarctic sky

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giving **Nick Mitchell** new insights into waves and tides in the upper atmosphere.

sun long after sunset on the ground, they become visible as beautiful silvery-blue noctilucent clouds. Famously, there are no records of these clouds before 1885 and their brightness appears to have been increasing in recent decades suggesting that there has been long-term change in the mesosphere and that the clouds are 'harbingers of climate change'.

The pole-to-pole circulation gathers up particles and chemicals generated in the mesosphere by aurora and cosmic rays, or deposited as 'smoke' from meteors. These particles, which come from across the planet, are then funnelled down into the winter polar stratosphere. There they contribute significantly to aerosol layers (small particles suspended in the atmosphere), may influence ozone and ultimately descend to the troposphere and surface. The soluble iron in this meteoric dust may even fertilise the Antarctic Southern Ocean which is otherwise iron deficient.

To understand the mesosphere and how it affects the atmosphere beneath, we must understand its winds, waves, tides, clouds and meteors. However, the mesosphere is notoriously difficult to study. The air of the mesosphere is too thin to be reached by aircraft or balloon. Studies must therefore make use of the fleeting snapshots provided by rocket-borne experiments or rely on remote-sensing techniques such as radar. Even radar remote sensing is difficult because the mesosphere does not strongly reflect the radio waves of a radar system. The lack of knowledge arising from this difficulty has led to researchers referring despairingly to the mesosphere as the 'ignorosphere'.

Scientists from the University of Bath and the British Antarctic Survey (BAS) have long-standing interests in the mesosphere and its effects on the atmosphere above and below. In 2005, we installed a new meteor radar at BAS's Rothera research station in the Antarctic to study the mesosphere at its key polar latitudes. A particular interest is to understand how the waves driving the Antarctic mesosphere differ from those of the Arctic, and how these differences are reflected in its temperature and circulation.

The radar works by detecting free electrons in the charged trails left by meteors in the mesosphere. Typically, we detect about 5000 meteors per day. By measuring the drifting of the trails we can see the winds, waves and tides at these heights. The decay rate of the radio echoes lets us determine atmospheric temperature and variations in the count rate of meteors tells us something about how the quantity of meteor material being deposited in the atmosphere changes over time.

The radar itself is a collection of six stick-like antennas up to about four metres tall. These antennas have to be spread out in a precisely spaced array across a flat area about the size of a football field – and this caused our first and only headache. Rothera is on a rocky peninsula where a runway and wharf take up most of the flat ground. The only open area of any size is a narrow and sloping pebbly beach, already occupied by another type of radar, backed by a rocky ridge and capped by a Site of Special Scientific Interest where equipment cannot be sited.

Fitting the antenna array into this confined space involved a lot of head scratching and was finally solved at a visit to BAS by the simple means of drawing the array onto an overhead-projector transparency and sliding it around on top of a map of the beach until we were confident we could fit the array in the space available. In the end, we were able to fit the radar to the beach – albeit with one antenna so close to the water's edge that one could stand by the antenna and comfortably jump into the sea!

Our preliminary results are revealing details of the Antarctic part of the pole-to-pole circulation over Rothera and measuring how it changes the atmospheric temperature. We are accurately quantifying the nature of the Antarctic waves and tides and investigating the way in which different types of atmospheric wave driving the circulation interact with each other. Comparisons with Arctic observations made by the Bath group are revealing subtle but significant differences in the dynamics of the Antarctic and Arctic mesosphere. Discovering the causes of these differences and understanding how they will affect the underlying stratosphere and troposphere are questions that we can begin to address.

All eyes are now on NASA's Aeronomy of Ice in the Mesosphere satellite, due to launch in late 2006. This will be the first satellite dedicated to the study of polar mesospheric clouds and we are eagerly looking forward to combining radar and satellite observations to discover how the winds, waves and tides of the mesosphere control the behaviour of these enigmatic and spectacular clouds.

Meteoroid: a solid object in space, smaller than an asteroid, and usually less than a few millimetres in size.

Meteor: the luminous phenomena resulting from a meteoroid burning up in the atmosphere

Meteorite: the remnants of a meteoroid large enough to survive entering the atmosphere and reach the ground.

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