Home > Science > Cool science > 2011 >

# Looking for iron in the sky

## 9th June 2011

Looking for iron, not in the workshop but high up in the atmosphere at the edge of space, between 75 and 100 km above the ground, is the task of the German Fe-LIDAR, installed at Davis in November 2010. The Fe-LIDAR (Fe is the chemical symbol for iron and LIDAR is an acronym for LIght Detection and Ranging) is housed inside a single 20 ft container and comprises a sophisticated laser and a daylight-capable receiver system, including a one-metre diameter optical telescope.

The positioning of the Fe-LIDAR at Davis contributes to a scientific collaboration between Professor Franz-Josef Luebken, Director of the Leibniz Institute of Atmospheric Physics in Kuehlungsborn, Germany, and Dr Ray Morris of the Australian Antarctic Division.

#### How does the Fe-LIDAR work?

The laser is designed to operate at a wavelength in the near-infrared. Doubled in frequency

(or halved in wavelength), the light can excite iron atoms in the upper atmosphere. However, the exited state of these atoms does not last long. A tiny fraction of a millisecond later the atom emits a photon (light) and 'relaxes' to a lower energy state. This process is known as resonance scattering. The newly created photons are emitted in random directions. A few happen to follow the path of the original laser beam back to the ground, where they are collected by the receiving telescope, pass through optical filters and are subsequently counted by the detector. The optical filters reject most of the unwanted photons stemming from the sun, stars, aurora, or streetlamps on the ground and let pass the faint signal from the atmosphere. Without these filters the detector would be instantaneously blinded and the LIDAR could not be operated while the sun is up or when there is bright aurora in the sky.

## Detecting iron in the atmosphere

One important property of resonance scattering is its extreme sensitivity to changes in wavelength of the laser light. It works much the same as when you tune your radio to a station. At first you hear static, but when you hit the right frequency the music comes through. Iron atoms, or atoms in general, exhibit a similar behaviour. Only light with the right wavelength can excite atoms to a higher energy state. The laser in the LIDAR is constantly tuned from longer wavelengths to shorter wavelengths and back again, and whenever it hits the correct wavelength for resonance scattering the detector registers a blip. A large signal means much iron in the atmosphere, a small one, less.

## Where does the iron come from?

The iron stems from outer space; more precisely, from meteorites. Every day millions of tiny particles collide <sup>Photo: Bernd Kaifler</sup> with Earth's atmosphere and because of their tremendous speed most of the material is burned off between 80 and 120 km above ground. Only the few larger ones can be seen as shooting stars. Eventually the meteorite material forms a global vapour layer comprised of all the metals that were previously present in the meteorites, such as sodium, potassium and iron.

## Measuring the speed of the iron atoms...

Atoms and molecules in the atmosphere are not at rest – they are moving all the time and constantly change speed and direction in collisions with each other. However, a single 'correct' wavelength for resonance scattering is only valid for resting atoms. A moving atom 'sees' the wavelength of the laser light shifted much like the tune of the siren of an approaching police car. When the car is travelling towards you at high speed the siren appears to make a high-pitched tune and changes to a low-pitched tune once the car has passed. In reality the siren emits a constant tune all the time, and the relative movement of the car shifts the frequency (wavelength) of the sound. This so-called Doppler shift affects not only sound waves but also light. When an iron atom is moving towards the stationary laser it 'sees' the wavelength of the laser light shifted to shorter wavelengths. Therefore, the laser has to be tuned to longer wavelengths in order to compensate for the Doppler shift and match the right wavelength for resonance scattering. If the atom is moving away from the laser, the wavelength needs to be shorter.

Since the atoms in the atmosphere are all moving in random directions, there is always a fraction of the atoms approaching the laser and another fraction moving away from the laser, and those moving perpendicular to the laser beam appear to be at rest in this respect. So in reality there is not a single 'correct' wavelength for resonance scattering, but a whole range of wavelengths. This range depends on the mean speed of the atoms: the faster the atoms move, the broader the wavelength range. Thus, by measuring the wavelength interval in which resonance scattering is observed we can determine the speed.

measuring the wavelength interval in which resonance scattering is observed we can determine the speed of the iron atoms in 100 km distance at the edge to space!

#### ... and the temperature of the atmosphere

In 1860 the English James Clerk Maxwell and the Austrian Ludwig Boltzmann discovered an equation which relates the particle's speed in a gas with the temperature of this gas. By applying this equation to speed measurements of the iron atoms we can deduce the temperature in the atmosphere. Even though we are studying with the LIDAR temperature at altitudes far from the ground, we frequently observe temperature disturbances which were once created in thunderstorms close to the surface, for instance. One of



Iron Density May 25 2011. Red = High, Purple = Low (Photo: Bernd Kaifler)





The shipping container housing the iron LIDAR at Davis. Photo: Bernd Kaifler



The one-metre diameter optical telescope associated with the iron LIDAR. Photo: Bernd Kaifler

our research topics is investigating how these waves can propagate vertically more than 100 km through the atmosphere. As well as day-to-day variations the temperature exhibits large seasonal variations. The summer months are the coldest months of the year, at about -150 degrees Celcius, while in the winter the temperature rises to a 'warm' -70 degrees Celcius. During the cold summer the temperature is low enough for ice clouds to form. Occurrence rate, vertical distribution and particle density of these so called polar mesospheric clouds (noctilucent clouds) are other fascinating scientific questions which we hope to answer with the help of the LIDAR.

The LIDAR was installed, commissioned and will be operated at Davis from November 2010 until to November 2012 by IAP scientist Dr Josef Hoeffner and PhD students Timo Viehl (summer) and Bernd Kaifler (winter), supported by Dr Ray Morris, AAD (summer and winter).

#### Bernd Kaifler, Davis station

#### **Related links**

Atmospheric processes and change research stream at the Australian Antarctic Division

This page was last modified on June 10, 2011.