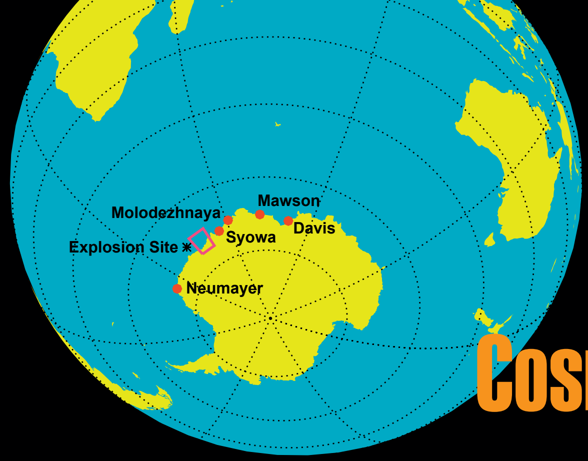


This map shows the location of the explosion site in relation to nearby wintering Antarctic stations; Syowa (Japan), Neumayer (Germany) and Molodezhnaya (Russia). The magenta rectangle shows the location of the satellite image of the dust trail. A. KLEKOCIUK, AAD

Cosmic hole-in-one: capturing dust

Picture yourself standing on an ice floe off the Antarctic coast in early spring. The Antarctic continent is about 200 km to the south and the nearest inhabited site is Japan's Syowa station over 900 km east. To catch some warmth, you stand facing the sun, which is low in the north-west. A stiff breeze blows at your back. The wind chill is -30°C.

Instinctively, you turn your head and catch sight of a dazzling second 'sun' moving eastward and trailing a thick cloud of dust. There are two flashes and the fireball quickly fades. Were there pieces of debris falling to the ice in the distance? You watch in amazement as the dust cloud starts to snake away. A minute passes and two thunderous sonic booms ring out across the ice. You have just witnessed the demise of a meteoroid*, roughly the size of a small house and weighing 1000 tonnes – one of the largest pieces of solar system debris to strike the Earth in the past decade.

Fast forward to Davis seven hours later, where the sky is dark and clear. Physicist Joseph Zagari is getting the lidar ready for another observing session. The aim tonight is to probe the stratosphere with laser light to record temperatures during the flight of an ozone-measuring balloon. Joseph has been cleaning some optics and has taken longer than expected to get the lidar fully operating. Finally it's all working. Or is it? A strange signal appears from 30 km up just as the observation starts. Joseph suspects that his cleaning is to blame. He cuts down the received light with a filter and presses on. The strange signal is still there but disappears after 30 minutes. Four hours later the balloon goes up as planned and Joseph packs up and heads to bed.

Alerted by Joseph later that day, we try to find the source of the strange signal. After ruling out instrumental effects, a vapour trail is the prime suspect. We check for stratospheric clouds, satellite re-entries, and close passes by known meteors, but don't find anything. However, the global network of infrasound stations – designed to monitor compliance with the Comprehensive Nuclear Test Ban Treaty – turns up a significant sonic event characteristic of the break-up of a large body high in the atmosphere, which is traced back to the Antarctic coast. Among other sites, the signal has been detected in Germany after propagating a distance of 14 000 km.

Running atmospheric models we start to think that Joseph has scored a cosmic hole-in-one! It looks feasible for dust to

Dust from the meteor explosion on 4 September 2004 was captured by the Davis lidar during Joseph Zagari's ozone observations in the stratosphere. The image shows laser scatter caused by the dust cloud, 28-31 km up, over about one hour. The dust was detected seven hours after the explosion, which occurred 2400 km west of Davis Station. On this scale the normal lidar signal returned from the atmosphere is one unit.

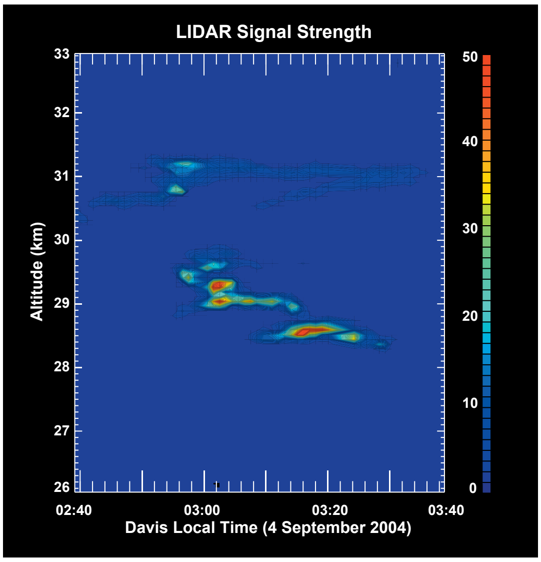
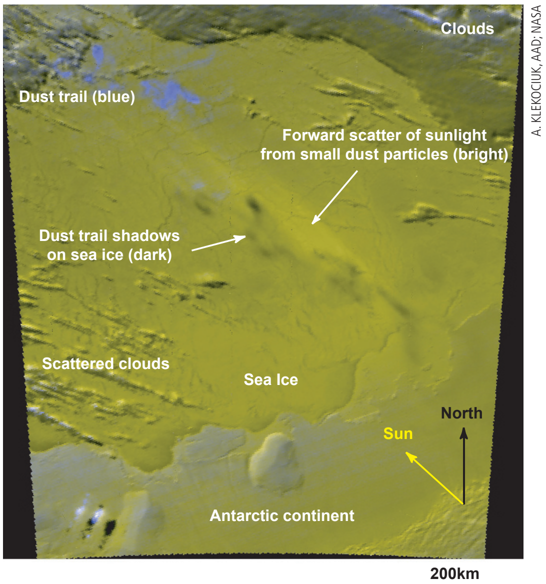


Image from NASA's Aqua satellite of the meteor's dust trail one hour after the meteoroid explosion ('bolide event'). The image has been specially processed to reveal the dust trail, as well as surface shadows and scattered sunlight from the trail. The image is entered at latitude 69°S, longitude 27°E.



from a meteoroid's fiery demise

Meteoroid's vital statistics

- 7–10 m diameter;
- Mass of 600 – 1900 tonnes (the Sydney Harbour Bridge weighs 53 000 tonnes, and the Hoover Dam weighs over 6 million tonnes);
- Energy yield of atmospheric explosion equivalent to 12 000 tonnes of TNT (similar to the yield of the Hiroshima nuclear bomb);
- 'Olivine' composition (magnesium, iron and silica);
- Impact speed of 13 km/s (equivalent to travelling from Hobart to Melbourne in 45 seconds);
- Orbital period: 293 days;
- Frequency of Earth impact by bodies of this size: once per decade.

have been carried over 2400 km from the site of the explosion by high speed winds circling the globe in the stratospheric vortex. Remarkably, these winds are predicted as blowing at speeds of up to 360 km/h – fast enough to explain the time delay between the infrasound and lidar measurements. From our modelling we infer that the cloud must have been remarkably compact by the time it reached Davis, measuring 75 km from east to west and 200 km from north to south. Miraculously, the centre of the cloud passed almost directly over our lidar. Defence satellite sensors put the icing on the cake, revealing precisely the time and point of impact and details of the explosion. This information fits with our atmospheric modelling. The dust cloud is also revealed an hour after the impact at the expected location in high resolution images from civilian satellites.

Delving into the dust

This remarkable event has enabled us to make the first measurements of the dispersal and properties of meteorite dust in the atmosphere. Our measurements tell us several things:

- The dust particles are irregular in shape, but nearly spherical.
- Most of the mass of the dust is due to particles of about one thousandth of a millimetre in diameter.
- The scattering and polarisation properties of the dust suggest it is comprised of olivine, a compound of magnesium, iron and silica that is common to a certain class of meteorites.

Why is this important? Previous research based on theoretical calculations and evaluation of meteorite dust samples collected on the surface (primarily from Antarctic ice), suggested that the fragmentation and ablation (erosion from friction) of meteoroids larger than one millimetre, produced extremely fine dust, typically less than 10 thousandths of a millimetre in diameter. We have shown that for this type of meteor the dust particles are generally much larger. This has consequences (which are yet to be fully explored) for interpreting the surface meteorite dust records, the size distribution of meteoroids encountered by Earth, and the climate effects of a large meteorite impact.

Importantly, our event occurred just inside the Antarctic stratospheric vortex – a region of air that forms over the continent each winter and which is effectively isolated from air at lower latitudes. This means that the dust was confined to the Antarctic region for several weeks, giving the particles time to fall to the surface and be incorporated in the ice record. Thanks to expeditioners at Casey, Davis and Mawson, we have surface samples in which we hope to identify dust particles. These and future samples will be important for confirming the meteor's composition and determining other properties.

The timing and location of the event also allows us to test theories relating to the impact of large meteorites on ozone and climate, as well as validating models of atmospheric circulation. The event deposited the equivalent of three weeks of the global meteorite dust influx in a confined region. While there were no obvious short-term associated changes in regional climate or ozone levels, we are still evaluating the longer term implications. Thanks to Joseph's perseverance, dedication and a sprinkling of good luck, we now have a wealth of new and exciting information to explore.

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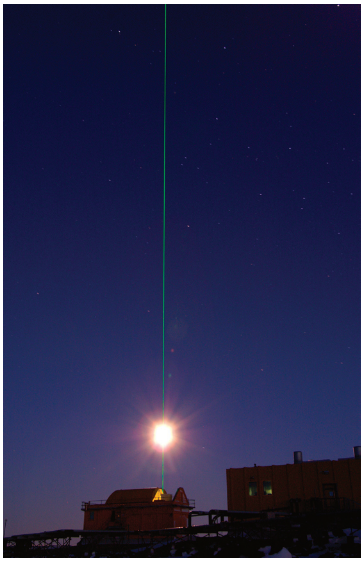

IAN PHILLIPS

The Davis lidar (pictured with its laser beam bisecting the moon) is used to study the basic properties of the atmosphere from the ground to the edge of space, including winds, temperature, clouds and dust particles. Measurements from the lidar help scientists understand climate and the structure of the atmosphere, and sometimes even the composition of meteorites.

* *meteoroid – mass of stone or metal in space*

meteor – meteoroid that enters the Earth's atmosphere

meteorite – fragments of a meteoroid that reach the Earth's surface