

Arctic Sunrise Over PEARL

It's about as far North in Canada as you can go (80 degrees North, in fact), and it's dark all day and all night as we get off the charter plane at Eureka, Nunavut to start another year of measurements at Arctic sunrise. It's cold, below minus forty centigrade, and the weather can get pretty wild, keeping us in the buildings for days at a time. Still we come here year after year to measure the atmosphere as it moves from the cold, dark winter to sunlight – Polar Sunrise.



Figure 1: Sunrise seen at PEARL's Ridge Lab. (Photo by R. Lindenmaier.)

The instruments we use are varied – ozone sondes and spectrometers and lidars. Ozone sondes – data recorders attached to balloons launched into the atmosphere – measure ozone at various heights until the balloons burst. We have a friendly betting pool going as to how high they will go. Will it be 30 km (a good day) or only 15 km (bad) or will it fail entirely because of the wind or the cold. When we first arrive, there is no sun and so we use our own lights, beaming lasers into the atmosphere to measure energy scattered back to our instruments, looking at clouds, mostly of ice, but strangely

sometimes with water in them even at these temperatures. These powerful lasers, called lidars, can reach 10-20 km into the sky. As the sunlight returns, we can use spectrometers to measure the absorption of sunbeams to work out the concentrations of many of the chemicals in the atmosphere and how they are changing with time.

Why bother to do this, year after year? The first answer is that we are monitoring the recovery of the ozone layer from the damage done by the chlorofluorocarbons (CFCs). We want to see if it is recovering as we expect or if something else is causing changes. For that reason we measure not only ozone, the big name in this type of chemistry, but also the lesser-known players in this game: hydrogen chloride, chlorine nitrate, nitric acid, and other chemicals present in minute concentrations, yet having significant effects, both in the Arctic and globally. The second answer is that we learn new things every year from these unique atmospheric conditions just after the polar dawn when the sunlight returns to the Arctic.

The winter Arctic atmosphere is strange. Deprived of sunlight, the atmosphere cools by losing energy to the darkness of space and temperatures start to fall. At the same time the winds around the pole become stronger

and a huge “Arctic vortex”, or whirlpool, is formed in the darkness, isolating a region of cold air in a “chemical cauldron” around the pole. The vortex is not stationary, it moves around and changes shape over the course of the winter. These changes are driven by the large-scale weather patterns around the Arctic as the winter progresses; during this time the air in the vortex remains relatively isolated from the rest of the atmosphere.



Figure 2: Preparing to launch an ozondesonde. (Photo by G. Nott.)

Sometimes the vortex is very disturbed and it splits into several pieces. When this happens, there is often a large, rapid increase in temperature called a “sudden stratospheric warming”. In 2009, temperatures in the stratosphere reached -15C. That's 60 degrees hotter than usual. In January 2010 we had another warming while several of our instruments were running in ‘campaign mode’ meaning that there is a wealth of measurements taken of this phenomenon at this time. We noted temperatures in the upper atmosphere that were 40 degrees above normal, as warm as -20 C at 30 km above the surface – in the Arctic in winter!

Sometimes the vortex is very strong and temperatures fall to very low levels and below -78°C new clouds made of nitric acid and water start to form at the altitude of the ozone layer. At this point, the chemistry of the region starts to change its composition and then when the sunlight returns, the ozone in the vortex is suddenly destroyed through photochemistry. That happened in 2011 with the biggest depletion of ozone

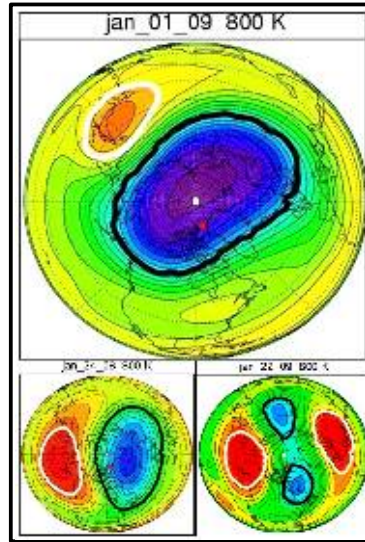


Figure 4: Arctic vortex over the pole (top), offset from the pole (bottom left) and split (bottom right). White dot is the pole; red dot is Eureka. Blue indicates cold air rotating clockwise (cyclonic rotation); red shows warm air with an anti-clockwise (anti-cyclonic) rotation. (Figure courtesy V. Lynn Harvey.)

ever recorded in the Arctic – almost 40% of the ozone disappeared – and the vortex was right over Eureka where we were making measurements.

Will the next year be a warm year or a cold year? Will there be significant ozone depletion or none? That's impossible to predict at the start of the winter when we start making our plans to return at Polar Sunrise. That's why we have to be there – to find out if the changes are “normal” or if there are huge disturbances.

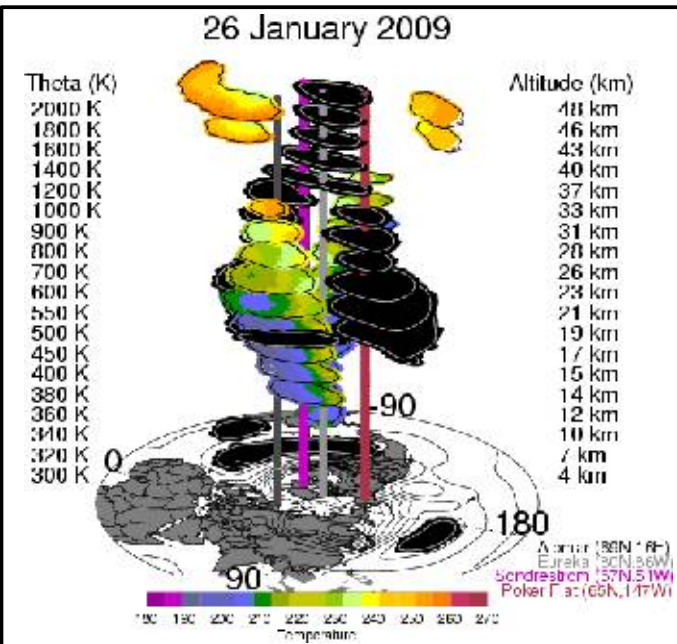


Figure 3: GEOS-5 model analyses of Arctic vortex over a Northern Hemisphere polar map. Eureka is shown as a grey vertical line. The vortex is coloured by temperature (in degrees K) and black indicates anti-cyclones. See figure 4. (Figure from <http://research.iarc.uaf.edu/IPY-CTSM>.)

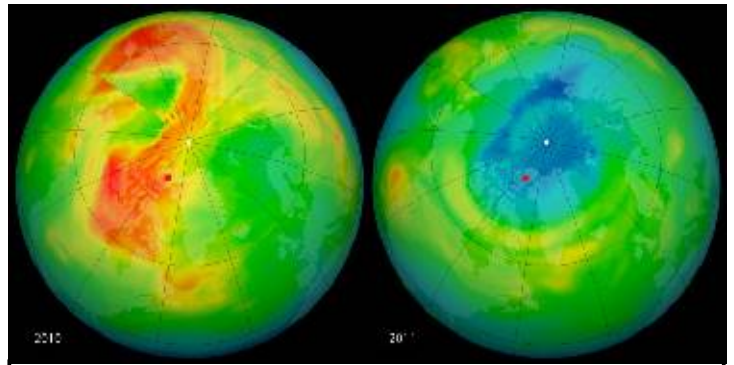


Figure 5: Arctic ozone in March 2010 (left) and March 2011 (right). The amounts in 2010 were nearly 2.5 times as great as in 2011. Eureka is indicated with a red dot. (Figure from <http://earthobservatory.nasa.gov>.)

Will we ever know enough to stop doing these measurements? Probably not, because the Earth is changing in new ways: Temperatures in the Arctic are rising rapidly, greenhouse gases are increasing, new chemicals are being released into the atmosphere. All these can produce surprises, just as the discovery of the Antarctic ozone hole surprised us in the 1980s. If we are to stay ahead of the game, we need to stay alert and know what is going on as it happens.

We return from Eureka in the daylight, which is rapidly moving towards 24 hours a day, with another season of data and with another set of experiences to add to our growing collection. This part of our planet is foreign to most of us, but our fascination with it will last a lifetime.

Article contributed by the CANDAC Team.



CANDAC
Department of Physics
University of Toronto
60 St. George Street
Toronto, ON M5S 1A7
info@candac.ca