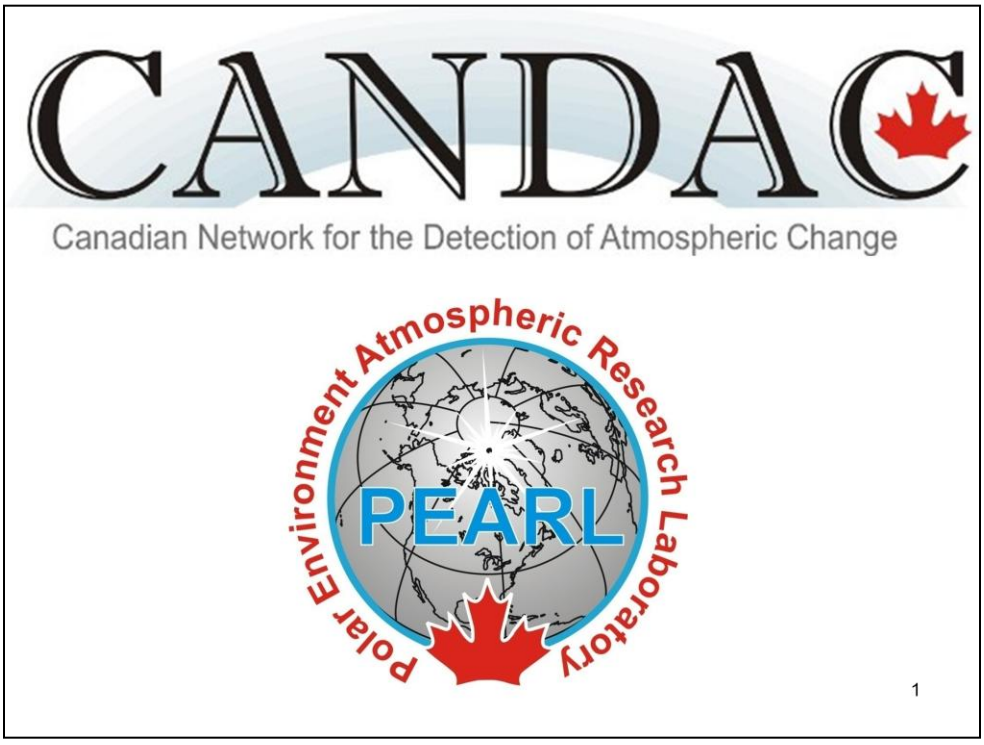


This will be a lesson for students in grades 9-12. The subject matter is atmospheric pollution – multiple types of pollution – and how it is measured in the Arctic.

This presentation was assembled as part of the outreach initiative for the Canadian Network for the Detection of Atmospheric Change.

CANDAC

Canadian Network for the Detection of Atmospheric Change

- In 2002, a group of university researchers joined together under the title of the Canadian Network for the Detection of Atmospheric Change (CANDAC) with the objective of improving the state of observational atmosphere research in Canada.
- This group recognized the need for an Arctic laboratory and identified the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nunavut as the ideal station.
- They worked enthusiastically to raise funds to run the facility and had a fully-functional Arctic lab operating in 2005.
- Since then, researchers have been taking various measurements to monitor and better understand current atmospheric conditions.

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# Funding for CANDAC has been provided by:

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Ontario Innovation Trust

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

Environment Canada

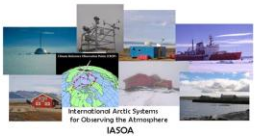
Environnement Canada

NSERC
CRSNG

Ontario MINISTRY OF RESEARCH & INNOVATION

CSA ASC

NOAA

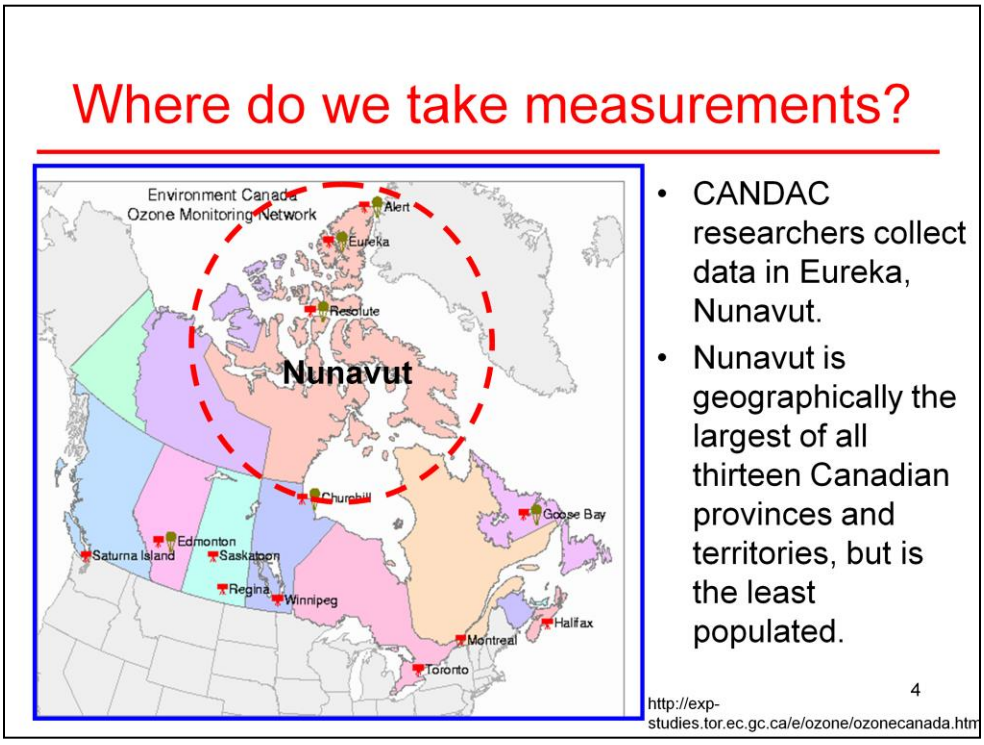



INTERNATIONAL POLAR YEAR 2007-2008

Nova Scotia Research and Innovation Trust

Polar Continental Shelf Project (PCSP)

3




Teacher: What else do you know about Nunavut?

Responses will vary depending on student knowledge and experience.

Addition al Information:

Facts about Nunavut can be found at: http://www.gov.nu.ca/en/Facts.aspx.

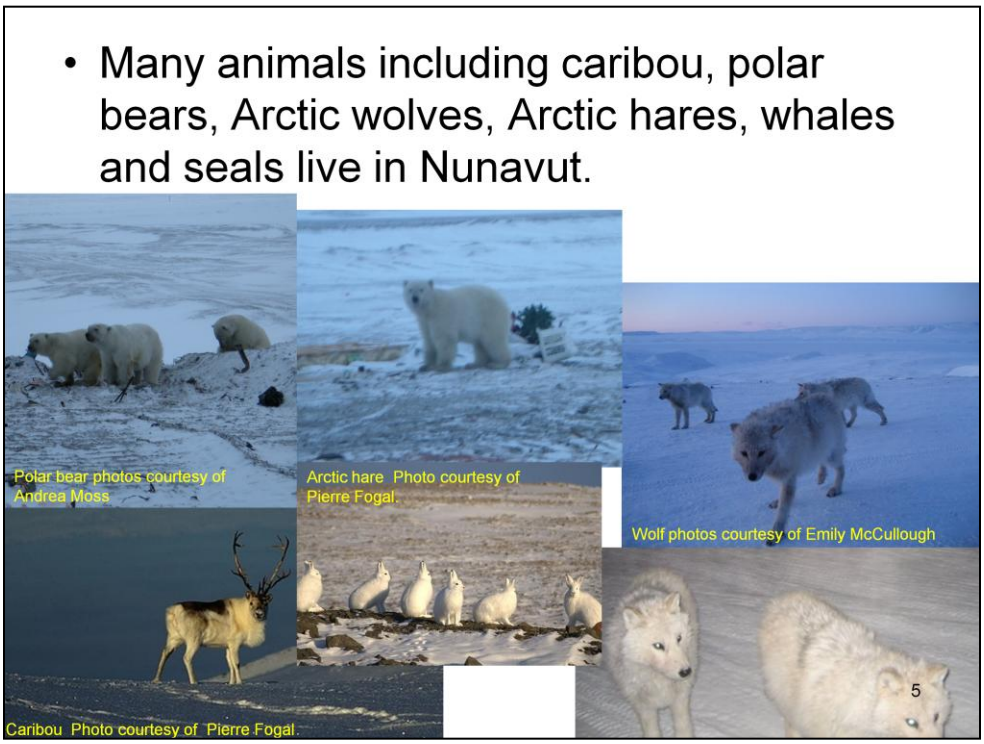
• Nunavut means “our land” in Inuktituk.

• Iqaluit is the capital city of Nunavut.

• Nunavut is the newest Canadian territory; it officially separated from Northwest Territories on April 1st, 1999.

• The total area of Nunavut is 2,093,190 $km^2$.

• The total population is 33,220.

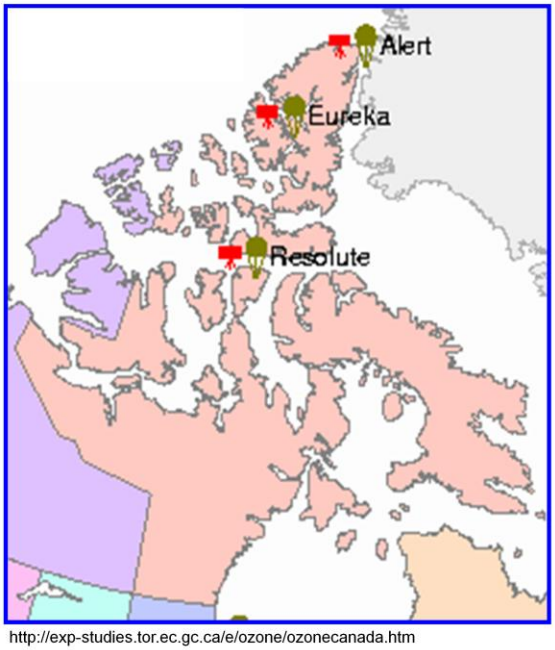



Teacher: What similarity do you notice in all of the animals shown?

Response: All of the animals have white fur.

Teacher: Correct. Why do you think many of the animals in the Arctic have white fur?

Response: They need fur to maintain a warm body temperature. Their fur is white because it provides excellent camouflage in their snow and ice-covered environment.




- Eureka is located on Ellesmere Island in the High Arctic.
- It is the second-northernmost permanent research community in the world.
- Eureka experiences complete darkness from mid-October until late February and complete Sunlight from early April to late August.

http://exp-studies.tor.ec.gc.ca/e/ozone/ozonecanada.htm 6

Teacher: Nunavut is the geographically the largest of all thirteen provinces and territories, but is the least populated.

Photo courtesy of Pierre Fogal

- Many CANDAC researchers operate their instruments from the Polar Environment Atmospheric Research Laboratory (PEARL) located in Eureka.
- Researchers typically travel to PEARL by airplane.


Photo courtesy of Pierre Fogal

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# CANDAC International Polar Year Legacy Project: Educational Resources

- As part of the International Polar Year (IPY) Legacy Project, CANDAC has created educational resources aimed at enhancing environmental science education in classes from kindergarten to grade 12.
- Educational materials can be found at: http://candac.ca/candac/Outreach/Outreach.php .
- This particular presentation is about:

**Atmospheric Pollution**

8

# Outline

- The atmosphere and types of air pollution
- Measurements of air pollution
- Air pollution in the Arctic
- Haze and cloud formation

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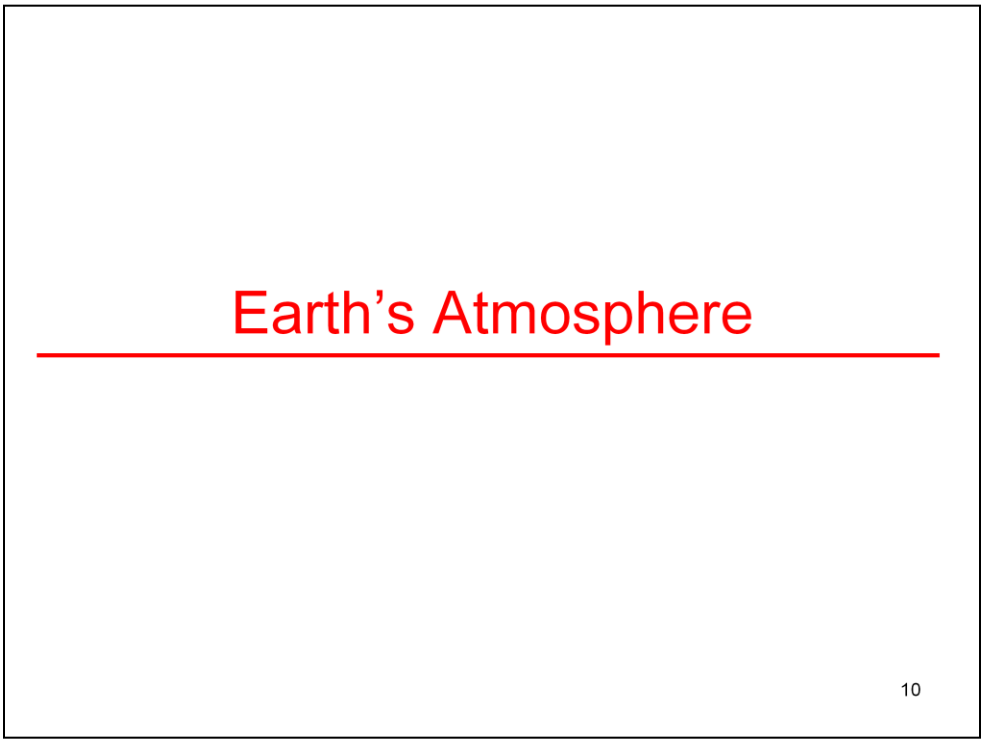
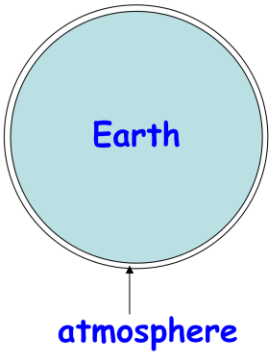



Teacher: Raise your hand if you have heard of the ozone layer. What is special about the ozone layer?

Response: It protects us from the Sun, chemicals can cause it to break apart, it allows life on Earth to exist, it keeps the Earth at temperatures warm enough for life to exist.

- The atmosphere is like a blanket of air that surrounds the Earth.
- It is about 100 km thick, but most of the air is close to the Earth's surface.
- It provides oxygen for us to breathe and contains ozone to protect us from harmful ultraviolet radiation.
- It allows life to exist on Earth.

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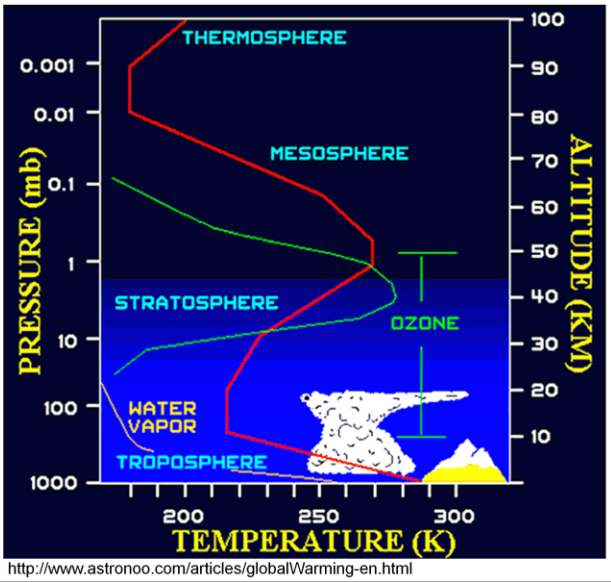
This slide is a basic review of the Earth's atmosphere. A working knowledge of the atmosphere is required to understand the basics of the greenhouse effect.

Note: Diagram is not to scale. Earth's radius is approximately 6371km and Earth's atmosphere is approximately 100km thick.

# Structure of the Atmosphere




http://www.astronoo.com/articles/globalWarming-en.html

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Important Points:

- The atmosphere is made up of layers.
- It extends to approximately 100km above the Earth's surface.
- The ozone layer is located at about 25km in altitude.
- Weather occurs in the lowest parts of the atmosphere called the troposphere.

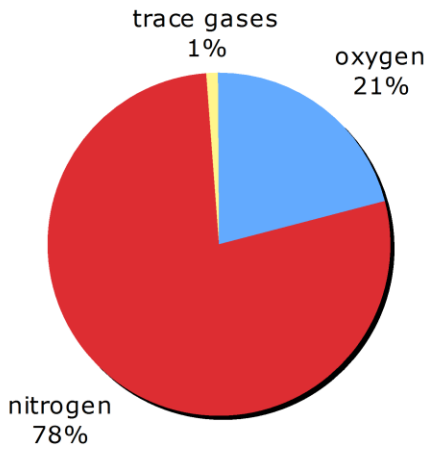
Information courtesy of: http://www.srh.noaa.gov/srh/jetstream/atmos/layers.htm

Teacher: Air becomes less dense as you move away from the Earth's surface. Why might this be the case?

Response: The force of gravity is strongest close to the surface of the Earth; this means that most of the atmosphere's air is held close to the surface (in the troposphere).

Additional Information: Pressure is displayed in mb (millbars), where 1mb = 100 kPa = 1 atm.

# What is in the air?




**Trace Gases include:**

- Argon
- Water vapour
- Carbon dioxide
- Methane
- Nitrous oxide
- Ozone
- Many many more…

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Teacher: What are the two major gases found in Earth's atmosphere?

Response: The atmosphere is primarily made up of nitrogen and oxygen. The last one percent is made up of everything else (such as trace gases). These exist at levels such as parts per million or parts per thousand.

# What else is in the air?


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Teacher: Included in trace gases are the gases that are emitted by humans (called air pollution). Several different types of gases can be considered air pollution. The picture above shows Ottawa covered by a layer of smog.

# Air Pollution

- Air pollution affects many people in the world.
  - Smog is one example of air pollution. It can cause breathing problems and irritation for asthmatics.
- Most of these gases and particles are produced by human activity.
  - Vehicles, factories, power plants and homes produce the majority of these pollutants.
- Some contributions come from natural sources.
  - Forest fires, trees and volcanoes emit pollutants; however, these are much smaller than those emitted by humans.

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Teacher: What is pollution?

Response: The introduction of contaminants into a natural environment that causes instability, disorder, harm or discomfort to the ecosystem.

Additional Information: According to Environment Canada, “Air pollution is a broad term applied to any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere. Examples include particulate matter and ground-level ozone” (http://www.ec.gc.ca/default.asp?lang=En&n=499D6B13-1). There are many different types of pollutants; individual pollutants differ from each other in terms of their chemical composition, persistence, and impacts. Air pollution is caused by both human and natural means, but each source emits pollutants differently. Human-made air pollution is consistent and persistent, while natural sources tend to be more episodic.

# Smog

- Smog is made up of:
  - Ground-level ozone (from reactions of nitrogen oxides and volatile organic compounds + sunlight)
  - Fine particulate matter ($PM_{10}$, $PM_{2.5}$)
- Most of these gases and particles are produced by human activity: Car exhaust, factories, and homes.
- But some come from natural sources: Forest fires, trees and volcanoes.

http://www.cbc.ca/canada/toronto/story/2010/08/31/toronto-smog-advisory459.html

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Additional Information: Smog is an air pollutant that compromises air quality. It is recognizable as a brownish-yellow haze or thick, dirty fog visible in the sky. Although mainly generated in big cities, smog can be transported far away from the source, thus causing rural and subrural areas to have high levels of smog. Smog contains two main pollutants: ground-level ozone ($O_3$) and particulate matter (PM). The number following PM refers to the size of the particle in micrometers. The notation $PM_{10}$ is used to describe particles of 10 micrometers or less and $PM_{2.5}$ represents particles less than 2.5 micrometers in aerodynamic diameter.

Many people, both young and old, may experience eye, nose and throat irritation when exposed to smog. People with pre-existing heart and/or lung conditions are most at risk and may experience further irritation or a worsening in their condition. Since many senior citizens are affected by heart and/or lung problems, they are especially sensitive to air pollution. Children can also be sensitive to the effects of air pollution because their respiratory systems are still developing and they tend to have an active lifestyle.

Information courtesy of: http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/smog-eng.php

# Other Pollutants

- Carbon monoxide (CO)
  - CO is made by burning fossil fuels and forest fires. It remains in the air for approximately two months.
- Nitrogen dioxide ($N0_2$)
  - $N0_2$ is made by burning fossil fuels, forest fires, and farming. It remains in the air for a couple of days.

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# How do we measure air pollution?

- From the ground
  - Ground-based instruments are stationed all over the world including PEARL.
- From balloons
  - Balloons are launched from various locations around the globe including PEARL.
- From space
  - Satellites can carry scientific instruments that measure gases related to atmospheric pollution. This allows us to see all parts of the globe and help understand how pollution is transported.

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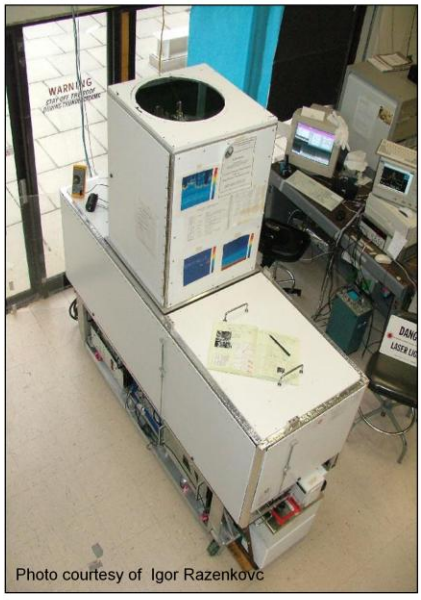
AHSR (Arctic High Spectral Resolution) LIDAR (Light Detection And Ranging)




MANTRA Balloon (Middle Atmosphere Nitrogen Trend Assessment)


Teacher: The picture on the left is of a AHSR (**A**rctic **H**igh **S**pectral **R**esolution) LIDAR (**Li**ght **D**etection **A**nd **R**anging) which is an instrument that shines laser light into the atmosphere and uses the scattered light to measure different types of air pollution http://candac.ca/candac/Instruments/Docs/HSRL_info_en.pdf). The picture on the right is the MANTRA (**M**iddle **A**tmosphere **N**itrogen **Tr**end **A**ssessment) balloon which is launched into the atmosphere to measure pollutants up to approximately 30km above the surface of the Earth (http://www.atmosp.physics.utoronto.ca/MANTRA/).

# Measuring Pollution from Space

- Satellites can carry scientific instruments that measure gases related to atmospheric pollution.
- This allows us to see a large part of the globe and help understand how pollution moves.
- For parts of the atmosphere, it is easier to study it by looking down from above than looking up from below.

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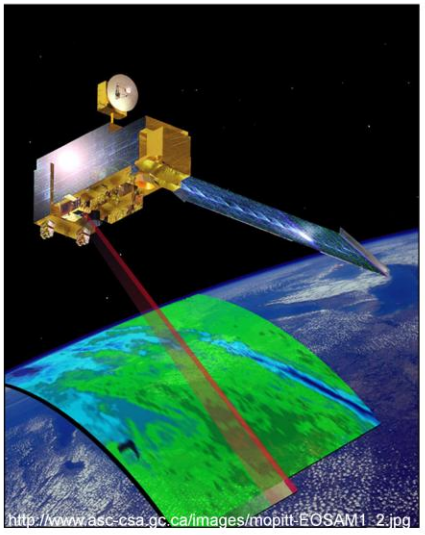
# MOPITT

## (Measurements Of Pollution In The Troposphere)

- MOPITT was successfully launched on December 18 1999, onboard the NASA Terra satellite.
- It was Canada's first major instrument to measure pollution from space (carbon monoxide).



http://www.asc-csa.gc.ca/images/mopitt-EOSAM1_2.jpg

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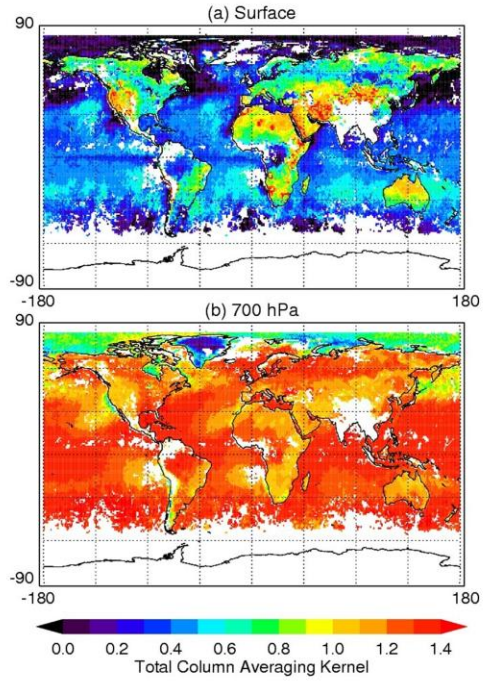
Additional Information: "The MOPITT instrument was launched on the Terra platform of NASA's Earth Observing System (EOS) on December 18, 1999. The Terra satellite is in a 705km, Sun-synchronous orbit with a 10:30am equator crossing time. MOPITT has been measuring carbon monoxide over the globe since that time. Carbon monoxide is measured because it helps demonstrate how the troposphere reacts to various stimuli. These stimuli can range from natural phenomena such as the growth of forests, through agricultural sources such as rice paddies, to catastrophic events such as biomass burning."
(http://www.atmosp.physics.utoronto.ca/MOPITT/MOPoverview.html).




- These maps were generated using measurements made by MOPITT.
- They show MOPITT's sensitivity to carbon monoxide (CO) at Earth's surface and an 700 hPa (middle troposphere).

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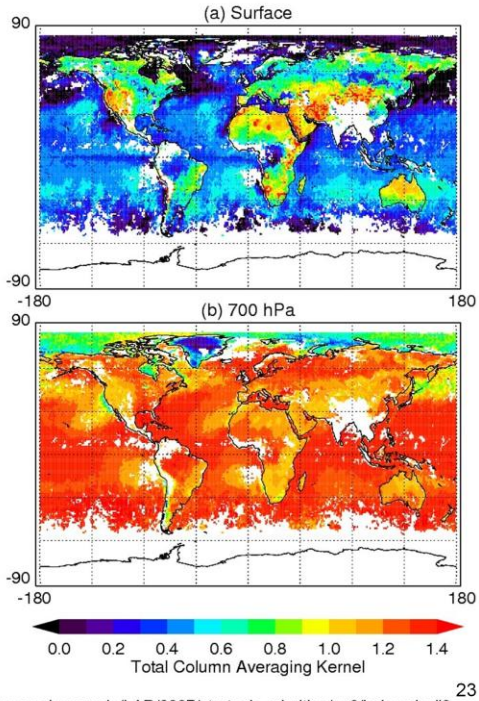
http://www.nesl.ucar.edu/LAR/2007/strategic-priorities/sp6/index.php#3

- Although MOPITT makes more accurate measurements of CO in the middle troposphere, most researchers are interested in CO levels in the lower troposphere because this is the area where humans come in contact with air pollution.

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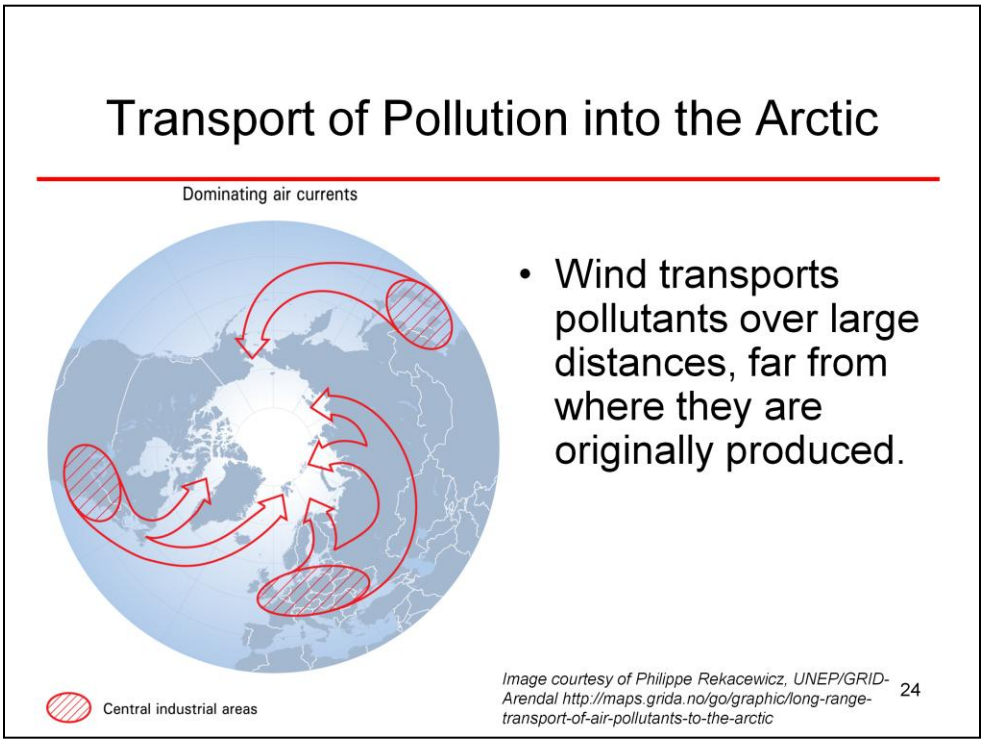
http://www.nesl.ucar.edu/LAR/2007/strategic-priorities/sp6/index.php#3

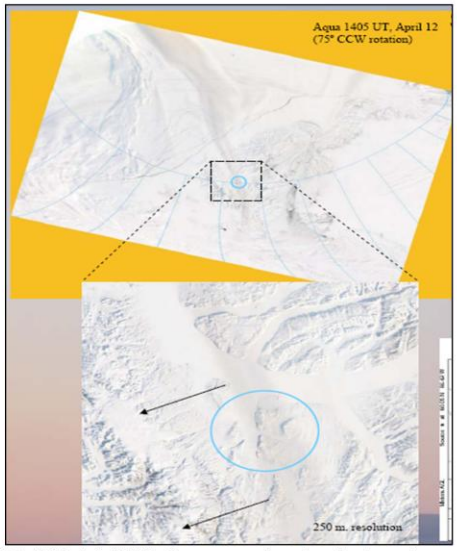
Additional Information: The maps above indicate global patterns of MOPITT sensitivity to CO (carbon monoxide) in the lower and middle troposphere. Regions shown in yellow, orange and red in the top panel indicate areas where useful sensitivity to lower-tropospheric CO can be expected (http://www.nesl.ucar.edu/LAR/2007/strategic-priorities/sp6/index.php#3). Carbon monoxide is dangerous to human health because it enters the blood through the respiratory system and reduced the ability of red blood cells to deliver oxygen to the tissues and organs. It is especially harmful to those with cardiovascular diseases.




Teacher: Prevailing winds blow towards the North. Much of the pollution produced in locations further south (Eastern North America, Europe, East Asia) is blown into the atmosphere above the Arctic.

For additional information please read the article titled *Arctic Pollution's Surprising History* found at: http://www.eurekalert.org/pub_releases/2008-03/uou-aps031808.php

# Recent Pollution Event




- Smoke was measured over Eureka in 2007.
- CANDAC scientists traced this smoke back to forest fires in Northern Canada and Russia.

O'Neill, N. T. et al. (2008). Occurrence of weak, sub-micron, tropospheric aerosol events at high Arctic latitudes. *Geophys. Res. Lett.*, 35, L14814, doi:10.1029/2008GL033733. Available from http://www.agu.org/pubs/crossref/2008/2008GL033733.shtml.

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Teacher: This picture shows a smoke event that was measured over PEARL in Eureka, Nunavut in 2007. CANDAC scientists found that the smoke originated from forest fires further south in Northern Canada and Russia.

Additional information: "Numerous fine mode (sub-micron) aerosol optical events were observed during the summer of 2007 at the PEARL, high-Arctic atmospheric observatory. Half of these events (the meteorologically simpler, single-layer events) could be traced to forest fires in southern and eastern Russia and the Northwest Territories (NWT) of Canada. The most notable findings were that (a) a combination of groundbased measurements (passive sunphotometry, high spectral resolution lidar) could be employed to determine that weak (near sub-visual) fine mode events had occurred, and (b) this data combined with remote sensing imagery products (MODIS colour and near infra-red imagery, OMIAI, FLAMBE fire sources), Fourier transform spectrometry and back trajectories could be employed to identify the smoke events" (O'Neill, 2008).

O'Neill, N. T. et al. (2008). Occurrence of weak, sub-micron, tropospheric aerosol events at high Arctic latitudes. *Geophys. Res. Lett.*, 35, L14814, doi:10.1029/2008GL033733. Available from http://pages.usherbrooke.ca/noneill/papers/ONeill_et_al_GRL_2008.pdf

# Arctic Haze

- One of the results of pollution being transported to the Arctic is Arctic haze.
- Polluted ice crystals form on condensation nuclei in the lowest part of the atmosphere.
- Happens in late winter and early spring as sun returns.
- Changes amount of sunlight getting to Earth which could change climate.

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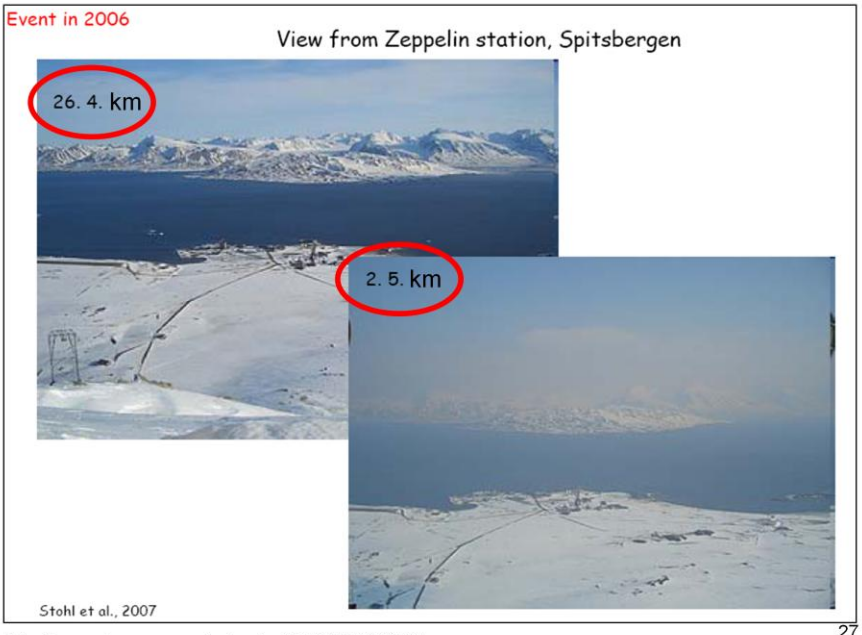
Additional Information: Condensation nuclei are tiny particles that attract water vapour, and then cause the water vapour to condense forming cloud droplets or cloud ice particles.



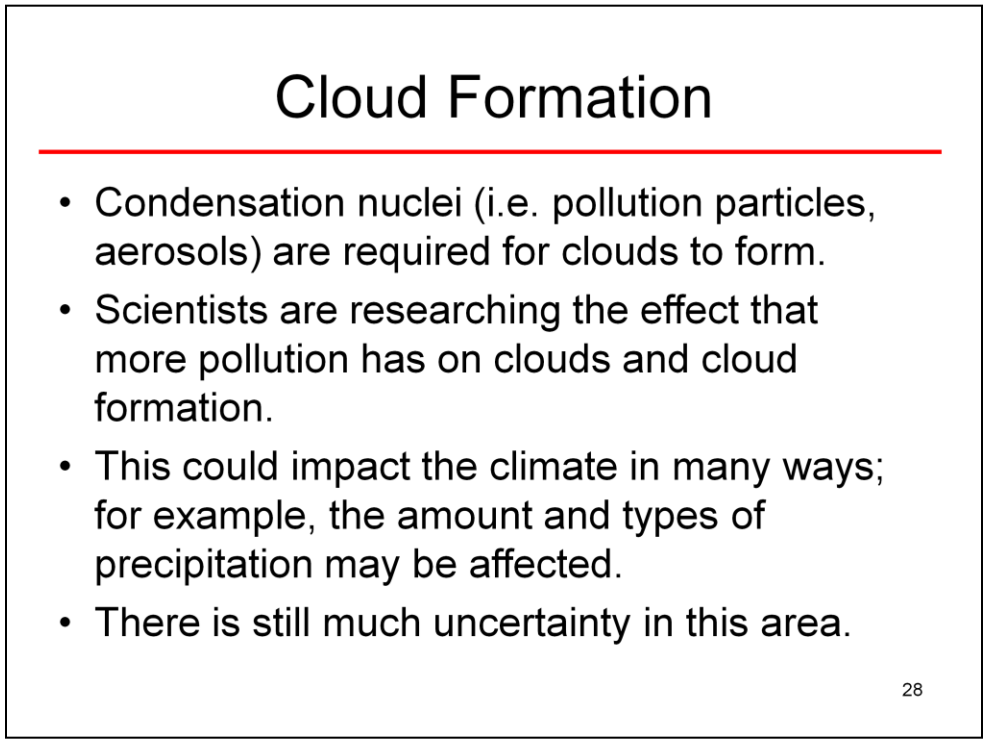

Teacher: These pictures are of the same location on a day with and without Arctic haze. What do you think the numbers in the top, left corners of the photos represents?

Response: The numbers represent the distance of visibility. So picture A has visibility of 26.4km, while picture B has visibility of 2.5km.

Teacher: Satellites measure aerosols using *aerosol optical thickness.* Particles change the way the atmosphere reflects and absorbs visible and infrared light. An optical thickness of less than 0.1 indicates a crystal clear sky with maximum visibility, whereas a value of 1 indicates very hazy conditions (http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MODAL2_M_AER_OD).

Additional information: This shows the view from the Zeppelin station near Ny Ålesund on Svalbard, Norway, under clear conditions (**A**) on 26 April 2006 and (**B**) on 2 May 2006, when smoke from agricultural fires burning in Eastern Europe was transported to the station.

Images courtesy of A.-C. Engvall, Stockholm University. Available from http://www.sciencemag.org/cgi/content/full/315/5818/1537.




Additional Information: An aerosol is a suspension of fine solid particles or liquid droplets in a gas. Some common aerosols are smoke, oceanic haze, air pollution and smog. Aerosols act as condensation nuclei, thus encouraging cloud formation. One cloud droplet forms on each aerosol particle; therefore, in areas with high aerosol concentration, the cloud droplets are smaller because the water vapour is liquid water that was available is divided among more cloud droplets. In this case, the clouds are less likely to produce precipitation, which may lead to droughts or decreases in agricultural yields (https://windows2universe.org/earth/Atmosphere/clouds/aerosols.html).

Aerosols decrease air quality and prevent solar radiation from reaching the Earth's surface. Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of -0.5 [-0.9 to -0.1] W/m2 and an indirect cloud albedo forcing of -0.7 [-1.8 to -0.3] W/m2 (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Available from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html). This radiative forcing competes with the warming caused by greenhouse gases, thus altering the amount of evaporation and precipitation occurring in the atmosphere. Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered. "At present, no transient climate simulation accounts for all aerosol-cloud interactions, so that the net aerosol effects on clouds deduced from models is not conclusive" (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Available from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html).

# Cloud in a Jar

1. Barely cover the bottom of the jar with water.
2. Hang the glove inside the jar with its fingers pointing down, and stretch the glove's open end over the mouth of the jar to seal it.
3. Insert your hand into the glove and quickly pull it outward without disturbing the jar's seal. Nothing will happen.
4. Next, remove the glove, drop a lit match into the jar, and replace the glove. The match will go out and create smoke particles in the jar which will become nucleation sites.
5. Pull outward on the glove once more. Fog forms inside the jar when you pull the glove outward and disappears when the glove snaps back. The fog will form for 5 to 10 minutes before the smoke particles settle and have to be replenished.

Source: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Weather_p007.shtml

Teacher: Have students complete chart and questions provided on the website or create your own to suit your class's needs.