# Solar UV in our World

## Secondary Education Information and Investigations

Education

Physics

MATH

Astronomy

Meteorology

PHYSICS

Ecology

CHEMISTRY

Physiology

BIOLOGY

PHYSICAL EDUCATION/HEALTH

MATH

ECOLOGY

ASTRONOMY

Environment Canada / Environnement Canada

Health Canada / Santé Canada

ACER Association for Canadian Educational Resources / ACRE Association canadienne des ressources éducatives

Canada

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**Also available under the title "UV Index, Weather and You":**

- UV Index posters
- UV Index brochures, pamphlets
- UV Index Web site: (www.msc-smc.ec.gc.ca/uvindex)

Additional copies may also be obtained, free of charge, from:

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ACER Association for Canadian Educational Resources / ACRE Association canadienne des ressources éducatives

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**Note: calc. = calculations**

# Introduction

Ahhh… nothing feels quite like the warmth of the sun on your skin, especially after a long, cold winter. But did you know that sunlight could have serious negative effects on your health and the environment?

For example:

- Ultraviolet (UV) radiation can cause skin cancer, weaken your immune system, damage your eyes and lead to wrinkles and premature aging.
- The effects of UV exposure are cumulative, increasing over time.
- 80 per cent of the damage from UV exposure may be done before you reach 18.
- The average thickness of the ozone layer changes seasonally over Canada.
- Ozone can have positive or negative effects on your health – depending on where it is in the atmosphere.

But the news is not all gloomy. We can each take precautions to protect ourselves from harmful UV radiation. Simple activities, such as standing in the shade, wearing protective clothing, applying sunscreen and visiting a doctor if you suspect skin cancer, are positive steps. In addition, opting for activities that decrease the amount of fossil fuel you consume will help reduce the number of UV rays that reach our planet.

The Government of Canada, recognizing the need for action, has launched this UV-awareness program and other initiatives that include monitoring the rate and effects of change on our climate and in our forest ecosystems. Governments are also supporting research and pilot projects in transportation, sustainable agriculture and energy production that will reduce greenhouse gas emissions.

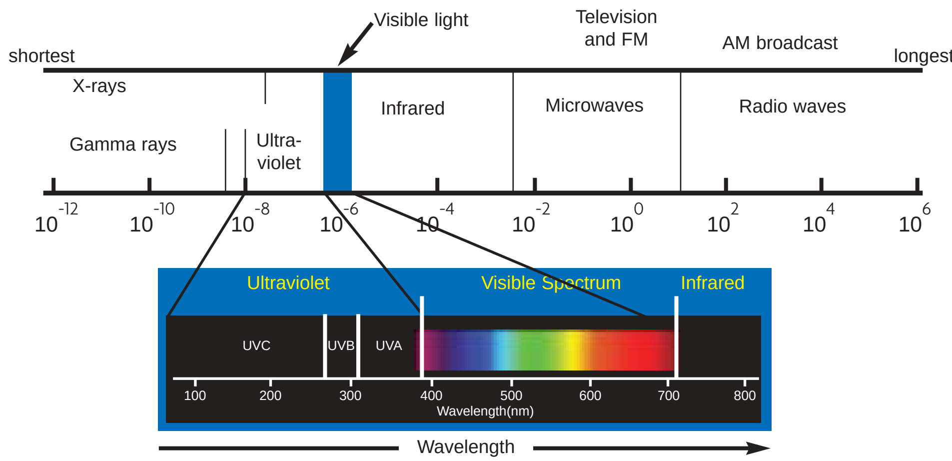
Students can lead the way by taking positive steps. And they can also protect themselves and others against UV exposure. They can reduce their use of fossil fuels directly (in vehicles) and indirectly (through energy conservation). Students can help others understand the serious, long-term effects of the damage we are imposing on our planet.

We need to work together today to prevent tomorrow's problems!

# What is UV?

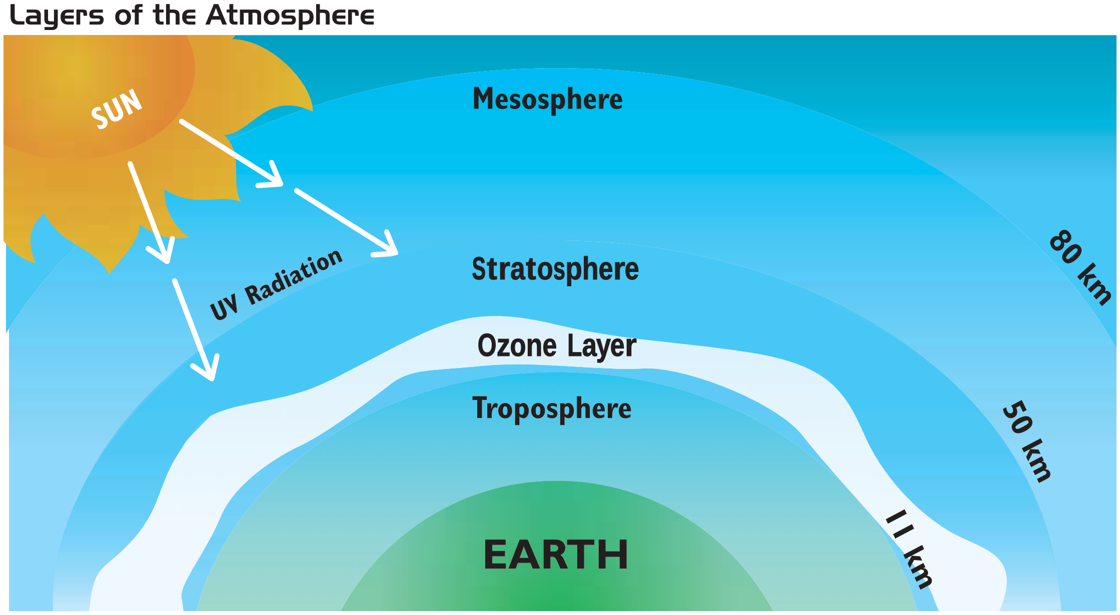
UV (ultraviolet radiation 100-400nm) is part of the electromagnetic radiation spectrum (sunlight) travelling from the sun to the earth. The radiation or energy is of the nature of waves extending from gamma rays (shortest) to radio waves (longest). Visible light is shown in blue in the diagram below. UVA, UVB and UVC radiation wavelengths are shorter than visible light(vl). Note: 1 nm = nanometer = $1 \times 10^{-9}$ m or 0.000000001 metres

## Electromagnetic Radiation Spectrum




UV radiation is affected by time of day and year; altitude and latitude; thickness of atmospheric ozone layer; cloud cover; and the levels of reflection from elements such as snow, water, concrete and sand. It is not affected by surface temperature.

## Layers of the Atmosphere

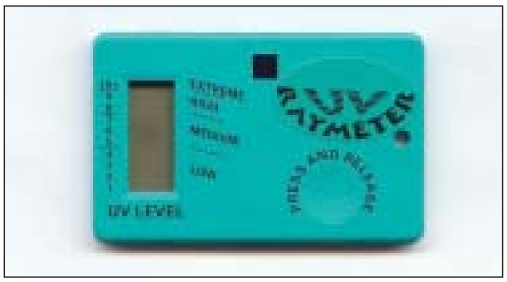


# Using a UV Meter

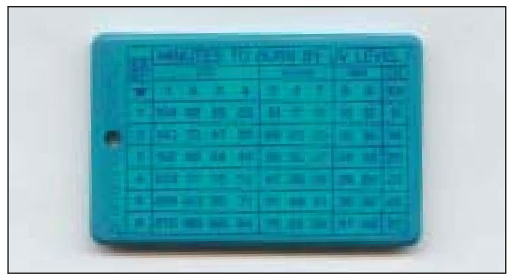
The UV Index (UVI) is a measure of the intensity of UVB radiation reaching Earth's surface. To find the level of UV radiation:

- Hold the UV meter horizontally. Press the switch until the LED screen activates.
- Release the switch and note the UV level shown.
- Record your reading.

UV Meter Photo Front




Back

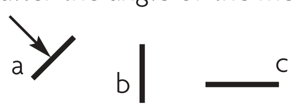


Use the chart on the back side of the UV meter only to determine the maximum minutes for your skin type to burn at different UV levels (Precautionary principle!)

***NOTE:*** The heat you feel on your skin is from the longer wavelengths of infrared radiation.

**Questions:**

1. How do the readings change when you alter the angle of the meter?
   a) Perpendicular to sun's rays?
   b) Perpendicular to ground?
   c) Parallel to ground?




2. Determine your skin type using the 1 – 6 scale (lightest to darkest) and UV level.
3. Is there a relationship between the degrees of slope and the UV Index?

**Optional:**

4. How many minutes (maximum) will it take your skin to burn at this level?
5. Is there a linear relationship between skin type and minutes to burn?

# Daily UV Index Forecast

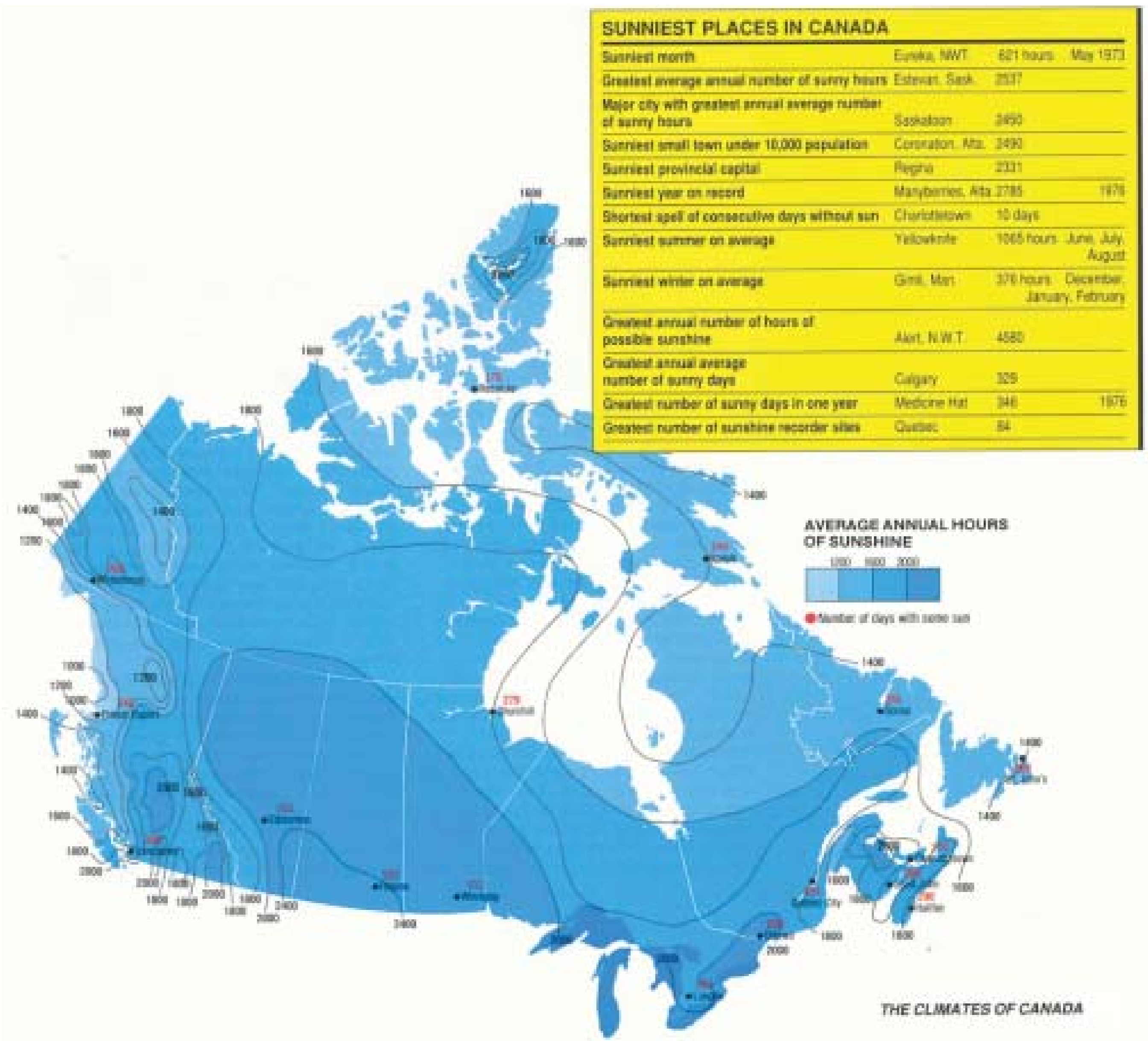
The local UV Index forecasts found on the radio, television, in the newspapers or on the web are available from April through October. The UV Index forecast is a prediction of the maximum UV Index value for that day (morning forecast) or the next day (evening forecast). It is a combination of computer predictions of ozone-layer thickness and observations at the 12 Canadian ozone-monitoring (Brewer) stations. The latitude and time of year are factored into the local clear-sky UV Index, which is adjusted based on forecasts for local cloud cover and precipitation.

**Questions:**

1. What was the UV Index (UVI) in your area at solar noon today?
2. How does the UVI forecast in the media compare with your UV reading?

# UV Radiation and Sunlight in Canada

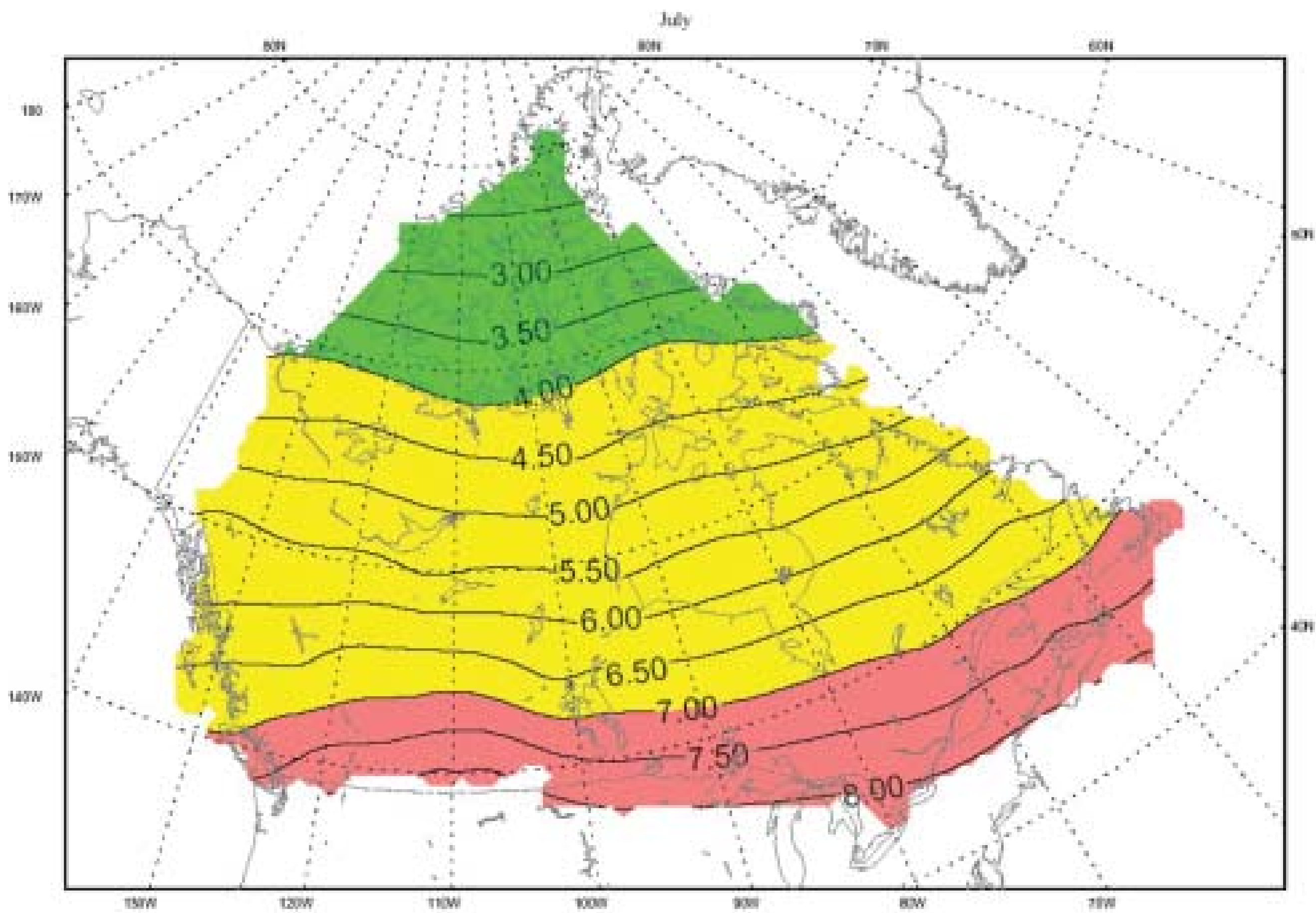
## Average Annual Hours of Bright Sunshine in Canada



**SUNNIEST PLACES IN CANADA**

| | | | |
|---|---|---|---|
| Sunniest month | Eureka, NWT | 621 hours | May 1973 |
| Greatest average annual number of sunny hours | Estevan, Sask. | 2537 | |
| Major city with greatest annual average number of sunny hours | Saskatoon | 2450 | |
| Sunniest small town under 10,000 population | Coronation, Alta. | 2490 | |
| Sunniest provincial capital | Regina | 2331 | |
| Sunniest year on record | Manyberries, Alta | 2785 | 1976 |
| Shortest spell of consecutive days without sun | Charlottetown | 10 days | |
| Sunniest summer on average | Yellowknife | 1065 hours | June, July, August |
| Sunniest winter on average | Gimli, Man. | 376 hours | December, January, February |
| Greatest annual number of hours of possible sunshine | Alert, N.W.T. | 4580 | |
| Greatest annual average number of sunny days | Calgary | 329 | |
| Greatest number of sunny days in one year | Medicine Hat | 346 | 1976 |
| Greatest number of sunshine recorder sites | Quebec | 84 | |

**Average July UV Index levels calculated over the 1979-1987 period.**




## Questions:

***Note:*** These maps plot the annual averages.

1. Which area receives the most sunlight annually? What is the annual UV reading there?
2. Which area receives the least sunlight annually? What is the annual UV reading there?
3. How much sunlight and UV radiation does your area receive annually?
4. What is your risk to UV exposure compared to other Canadians?

## Optional Investigations:

5. What is the relationship between average annual reports for UV rays and sunlight hours?
6. What geographical factors are included in sunlight calculations for your area?
7. Study the climograph for your area. Is there a correlation between UV radiation and temperature?
8. Check the relief map of Canada. How are UV rays and altitude related?

# How Cool is Cool?

Use the steps of the scientific method to design an experiment measuring UV filtration through different materials with the UV Index Meter. Read the experiment below, then design your own questions and choose your own materials.

Keys to Success: 1. Determine your experimental variables and constants/controls.
2. Make sure your results are quantifiable.

## PURPOSE OF THIS EXPERIMENT:

To determine which materials are better UV filters (e.g., sunglasses).

## BACKGROUND:

Different materials filter out different amounts of UV radiation. This means that, the better a material's UV filtration is, the less UV radiation it allows through.

## CONTEXT:

The UV Index, its influencing factors and the protective measures you may take to protect yourself from UV radiation, may lead to changes in behaviour.

## HYPOTHESIS/PREDICTION:

Glass is a better UV filter than plastic.

## METHOD:

Control conditions: angle to the sun, length of time, tint, location on lens.

Standardize the control conditions and method to ensure that only one variable is responsible for your results.

## OBSERVATION/DISCUSSION QUESTIONS:

Use the UV meter to make the following observations on non-rated (NR) UV glasses.

| **Material** | **UV Level Reading** | **UV Filtration Rating... or "Being Cool"** |
|---|---|---|
| Under plastic sunglasses NR | | |
| Under glass sunglasses NR | | |

## CONCLUSION:

Answer the purpose in one sentence.

## Optional Investigations:

1. Check out different lens colours, prices, materials, ratings and manufacturers.
2. How cool is cool? Why could wearing sunglasses with a poor UV rating do more eye damage than wearing none? (See Eye Damage on page 20)

# UV Radiation and Clouds

Scattered clouds reflect UV, increasing the UV rays reaching the earth's surface.

Mainly cloudy conditions partly reduce UV transmission.

Heavy overcast conditions greatly reduce UV transmission.

## UV Index Adjustment for Cloud and Precipitation

| Type | Factor | % UV Absorbed |
|---|---|---|
| Scattered clouds | 1.1 | +10% |
| Hazy | 0.9 | |
| Mainly cloudy with/without precipitation | 0.7 | 30% |
| Cloudy | 0.6 | 40% |
| Cloudy with/without precipitation | 04 | |
| Overcast | 0.3 | |
| Heavily overcast with/without rain/drizzle | 0.2 | 80% |

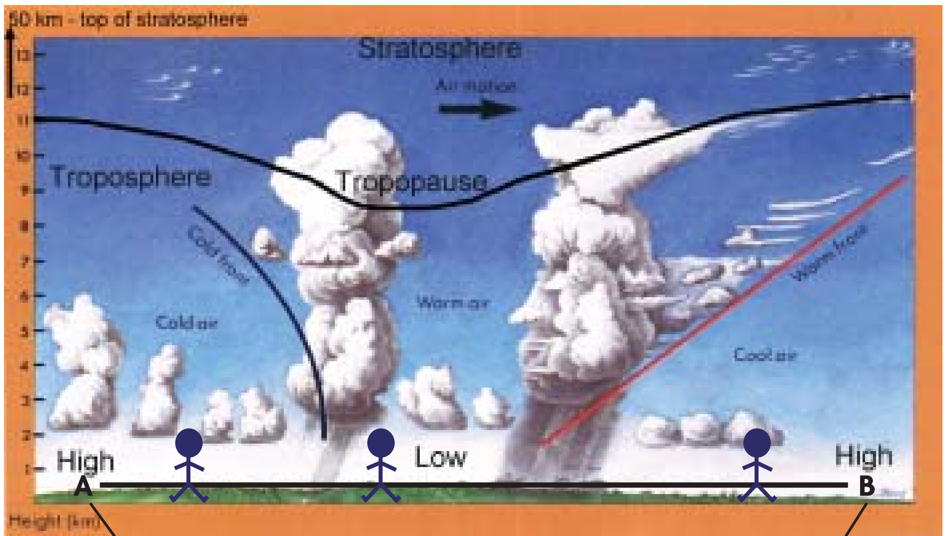
***Note:*** The factor shown is determined by statistical analysis of weather effects.

**Questions:**

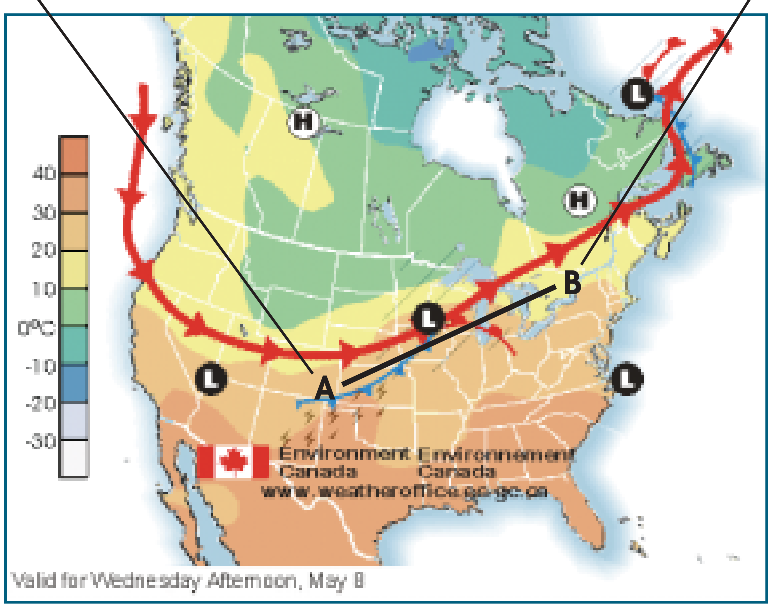
1. Complete the chart.
2. What relationship do you see between cloud type and UV filtration?
3. From your knowledge of science, in what ways could water vapour or droplets affect the amount of UV radiation reaching the earth's surface?

# UV Radiation and Air Pressure

**Cross-section of the weather map below from A to B.**




**Weather map of Canada showing pressure systems.**




**Questions:**

1. Compare the two perspectives of this weather system. Where is the ozone level the thickest along the line *AB*?
2. What is the weather like on most high-pressure days?
3. Who needs the most sunscreen in the lower diagram — the figure at the left, in the centre or on the right?

**Optional Investigation:**

4. Explain your answer by describing the relationship of air pressure, the thickness of the ozone layer and UV radiation. Assume the top of the ozone layer is relatively flat.

# What is Ozone?

Ozone ($O_3$) is a toxic gas molecule composed of three oxygen atoms. It forms as a natural layer in the stratosphere. Ozone is formed over the tropics under intense UVC radiation from the sun and flows toward the poles. The density and thickness of the ozone layer is constantly changing as meteorological conditions change. The average thickness of the ozone layer over Canada ranges from 300 to 500 Dobson Units (DU) where 1 DU = .01mm of pure ozone at standard temperature and pressure at sea level.

The ozone layer is our natural sunscreen since it absorbs UV radiation in the cycle of making ozone and breaking down ozone. All UVC radiation from the sun is absorbed in breaking the oxygen molecules apart to form ozone. Ozone is constantly broken down in the stratosphere by UVB/UVA radiation. During this process, only part of the UVB is absorbed. Almost all UVA reaches the Earth's surface.

The ozone layer is maintained by a natural balance between the UV-driven reactions that form ozone from molecular oxygen ($O_2$), and oxygen from ozone. Atomic oxygen (O) is extremely active and immediately reacts to form new molecules of oxygen or ozone.

$O_2 + UVC \rightarrow O^- + O^-$

$O + O_2 + M \rightarrow O_3 + M$ (M can be any given molecule, e.g., $N_2$ or $O_2$, to act as a collision partner needed to conserve energy and momentum.)

Ozone is photodissociated by UVB/UVA and visible light.

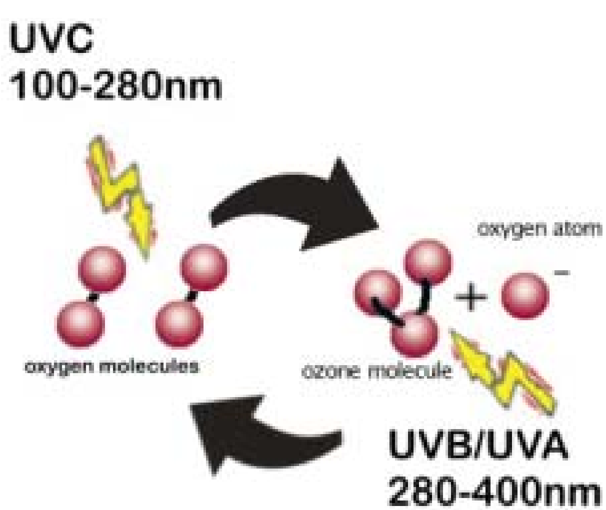
$O_3 + UVB/UVA \rightarrow O_2 + O^-$

Which in turn allows the oxygen atom to break down ozone.

$O_3 + O^- \rightarrow O_2 + O_2$

Ozone is also broken down by additional catalytic reactions involving a hydrogen radical (H), a hydroxyl radical (OH), a nitrous radical (NO), a chlorine radical (Cl) or a bromine radical (Br). The catalyst is reformed after the reaction with ozone and is able to perform the ozone cycle once again.

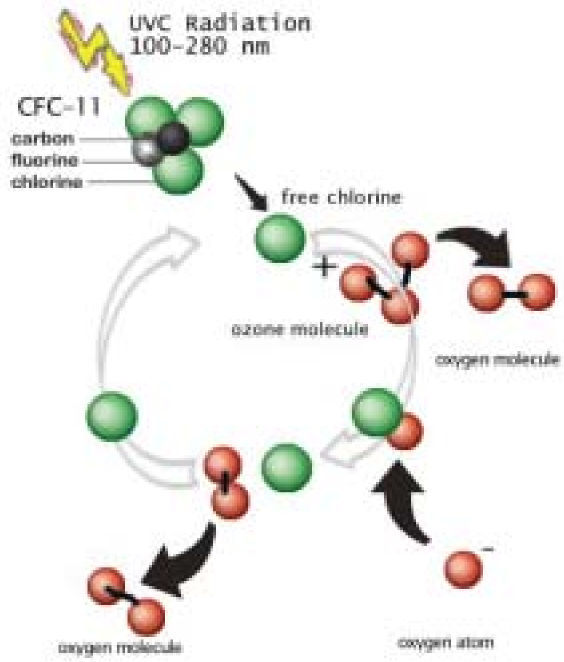
In summary, the oxygen-ozone balance in the stratosphere can be shown as:



### Action of Pollutants on the Natural System

In the stratosphere, reactions normally maintain equilibrium keeping the ozone layer at approximately the same thickness. Pollutant molecules, like the chlorine from CFCs, unbalance these natural reactions by destroying ozone molecules at a faster rate. CFCs have, in the past, been used as refrigerants and aerosol propellants. This has led to severe ozone depletion that is predicted to take from 50-500 years to recover.

(CFC-11 = chlorofluorocarbon – $CFCl_3$)

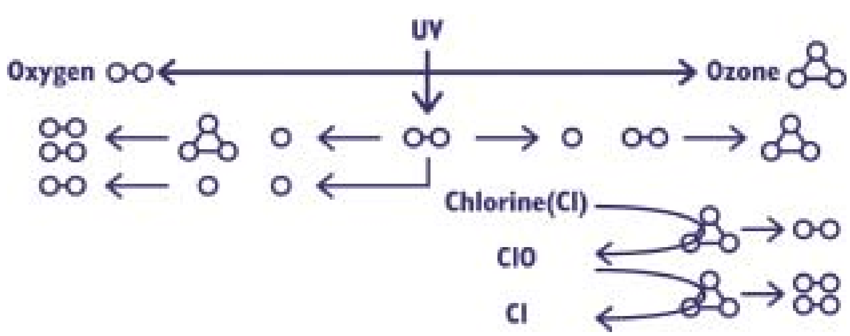



$CFCl_3 + UV + O_3 \rightarrow ClO + O_2$ THEN $O^- + ClO \rightarrow O_2 + Cl^-$

This frees the chlorine atom to act as a catalyst and repeat the process for many decades, destroying more stratospheric ozone. Thus, the loss of global ozone becomes greater than its formation.

### Exercise

1. The chlorine in the CFCs depletes ozone by catalyzing its breakdown to oxygen($O_2$). Using your chemistry kit, build a model to demonstrate this.
2. Bromine found in halons and methyl bromine destroys ozone. How effective is it in destroying ozone compared to chlorine?



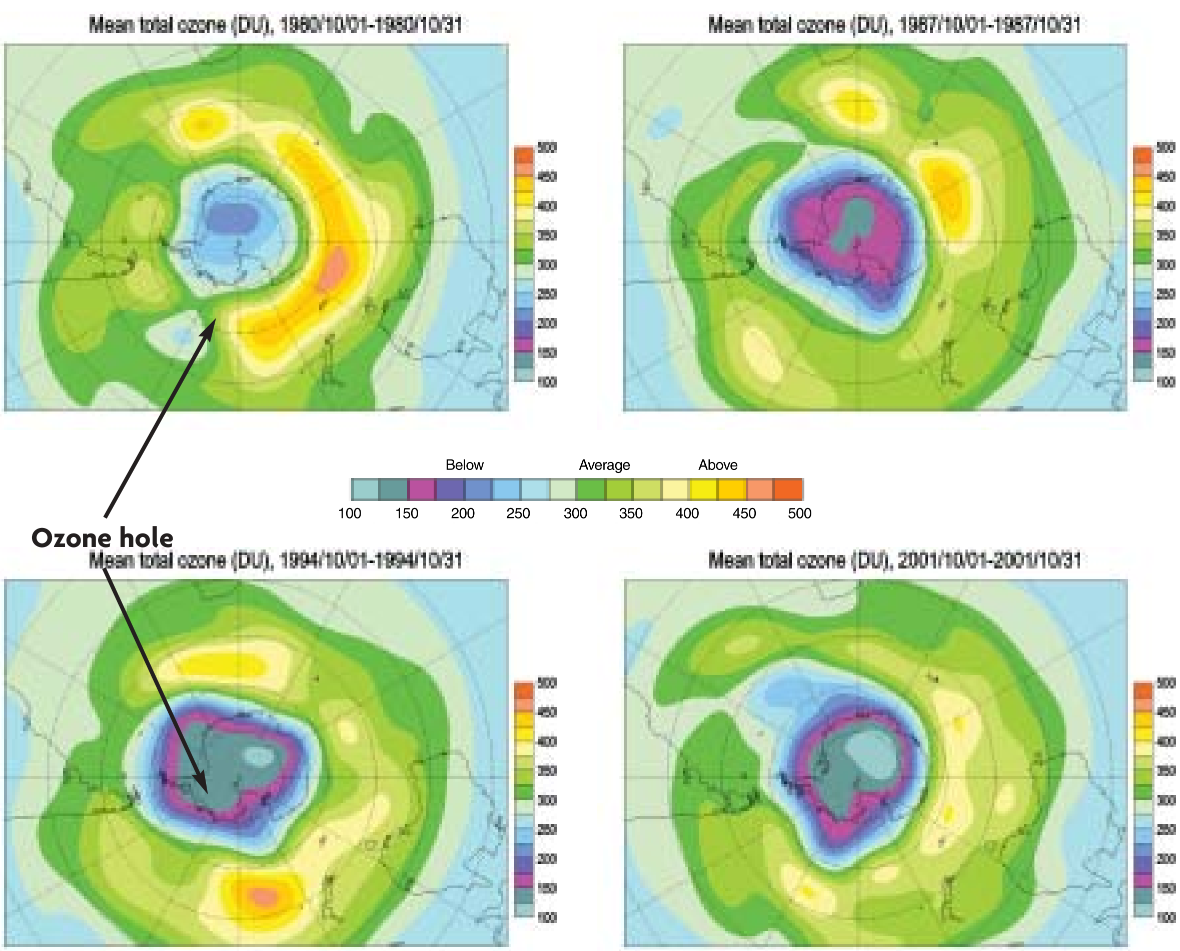
# What are Ozone Holes?

Satellite observations in 1985 confirmed scientists' hypotheses linking CFCs and ozone loss over the Antarctic. The extreme ozone losses over the Antarctic are caused by a combination of high concentrations of ozone-depleting substances and unique meteorological conditions in winter and early spring.  Severe ozone losses can also occur in the Arctic polar region during extremely cold winters. Polar ozone losses are part of the global ozone loss.

As the cold winter air arrives at the poles, a vortex of winds develops and isolates the stratosphere. The air gets very cold since sunlight disappears and milder air from the lower latitudes stops flowing.  Below -80 °C, polar stratospheric clouds (PSCs) of ice, nitric and sulphuric acids form. When the sunlight returns in spring, PSCs act as a catalyst in changing reservoir compounds into unstable compounds releasing chlorine or bromine atoms that destroy ozone. Arctic stratospheric temperatures are generally warmer than those in the Antarctic, so that in some years severe Arctic depletion does not occur.

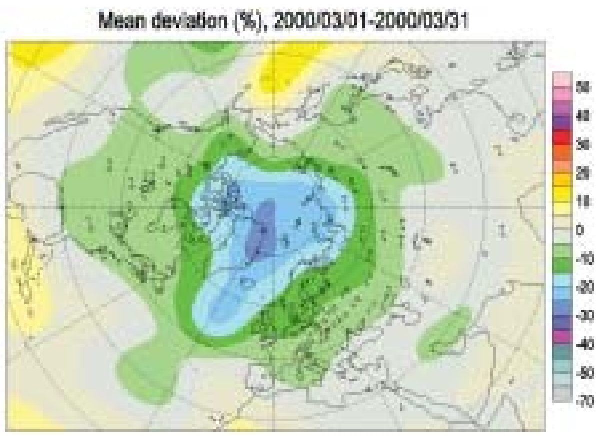
**Antarctica ozone hole development from 1980-2001.**

***NOTE:*** Ozone hole is defined by contours less than 220 Du.



# Polar Projections

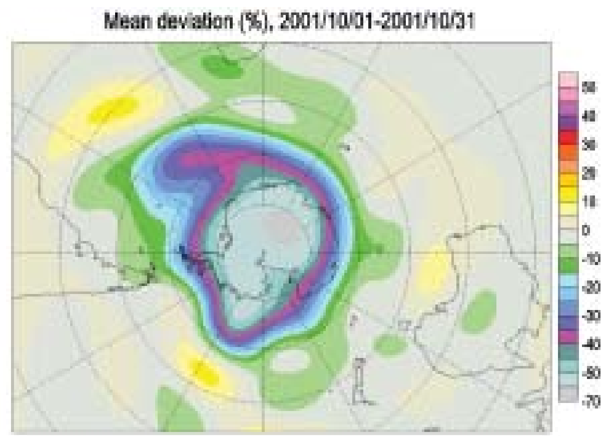
**Severe *Arctic* Ozone Depletion (2000)**




Find the North Pole.

**_Antarctic_ Ozone Hole (2001)**

28 million square kilometers




% Increase

Zero

% Decrease

Find the South Pole.

Mean deviation is the percentage loss of ozone layer thickness as compared to pre-1980 values. i.e., changes in Dobson Units as percent.

**Questions:**

1. Which longitude has the greatest % change in UV protection?
2. Which area has the greatest UV protection?
3. What is the % change in the ozone layer in your area?

**Optional Investigations:**

4. Why is the Arctic ozone layer thicker than the Antarctic ozone layer? Why are both regions vulnerable to UV damage?
5. What chemicals in our atmosphere are most responsible for ozone loss?
6. Why was the record for the month of March chosen for this projection?

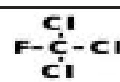
# What Are Greenhouse Gases?

Greenhouse gases (GHGs) trap thermal energy (heat) from the sun's infrared radiation within our troposphere and slows its rate of escape into the thermosphere and outer space. GHGs are created by fossil-fuel combustion and natural processes such as photosynthesis, digestion and respiration. Examples of greenhouse gases causing heating of our atmosphere are: carbon dioxide, nitrogen oxides, methane and halocarbon gases (e.g., $CO_2$, $N_2O$, $CH_4$, $CFCl_3$ or $CFCl_2$). Since the 1750s, the atmospheric concentration of $CO_2$ has increased by about 31%, $N_2O$ by 17% and $CH_4$ by 151%. Many of the halocarbons are both ozone-depleting and greenhouse gases, and have a high global warming potential compared to carbon dioxide.

Global warming and ozone depletion are linked at the physical, chemical and ecosystem levels, and by human-related stresses on natural systems. The health of the ozone layer depends on our ability to control greenhouse gases and to rid the atmosphere of ozone-depleting substances. As Pogo says "We have seen the enemy, and them is us!"

**Exercise:**

Complete the chart below showing the chemical and structural formulae for the GHGs named and their source.

| Name | Chemical formulae | Structural formulae | Role(s) |
|---|---|---|---|
| Carbon Dioxide | $CO_2$ | | Photosynthesis |
| | $N_2O$ | | |
| | $CH_4$ | | |
| | $CFCl_3$ |  | |
| CFC – 12 | $CFCl_2$ | | Pollutant |

**Optional:**

Research other GHG's and add to the chart.

# TRIPLE WHAMMY

## UV, Climate Change, Global Warming and Us

Climate change and global warming are caused by the changes in concentration and in the composition of greenhouse gases. Some greenhouse gases are produced naturally, and, in normal concentrations, have historically kept the temperature of the earth 33C° warmer than it would otherwise be and the planet is able to support life.

***Note:*** Remember that our ozone layer normally keeps the stratosphere warm by UV-driven reactions of ozone. This also reduces the amount of UV reaching earth.

## Enhancing our heat trap

Greenhouse gas concentration in our troposphere has increased due to increased emissions from land use, landfills, and fossil fuel combustion from transportation, energy production, air conditioning, etc. These emissions trap long-wave radiation (heat) in the troposphere, causing its temperature to rise. However, with less heat reaching the stratosphere, it is becoming cooler. **A single whammy**

## Making a better heat trap

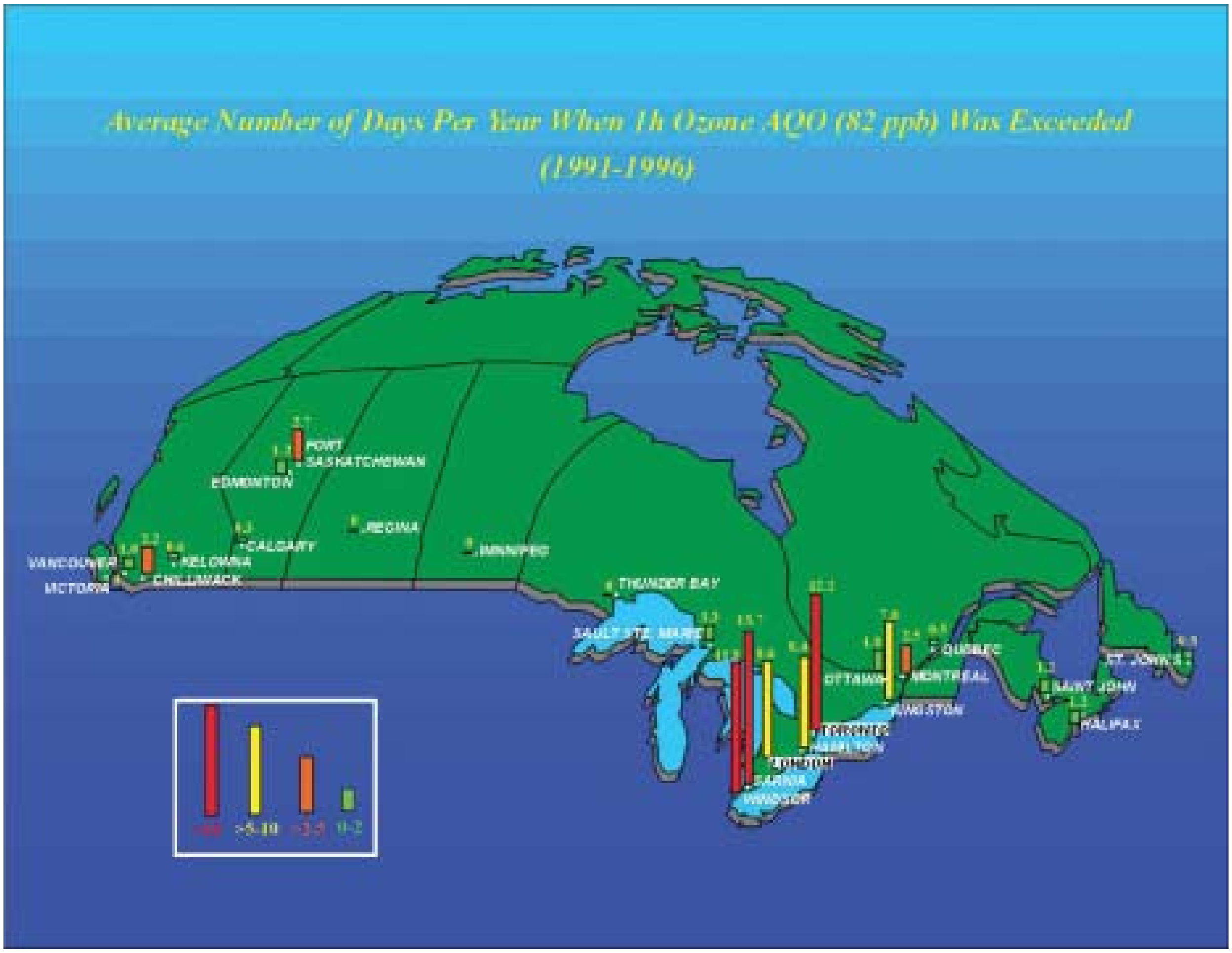
Carbon dioxide makes up a large percentage of fossil fuel emissions into the atmosphere. In the troposphere, the more carbon dioxide released, the more heat is retained and the warmer the troposphere becomes. In the stratosphere, however, increases in carbon dioxide cause more heat to be reflected back into the troposphere than into space resulting in a cooler stratosphere. **Double whammy**

## The better the heat trap, the better the cooling effect

At the poles, a cooling of the stratosphere causes the polar vortex to become more stable with an increased frequency of polar stratospheric clouds (PSC). These clouds, made up of ice crystals and nitric and sulphuric acids, act as a catalyst in the destruction of ozone. Thus, a cooler and more stable polar vortex during winter will result in a higher frequency of PSCs and higher rates of spring ozone loss. Loss of ozone thus results in a cooler stratosphere, and a negative feedback loop that causes more ozone loss each year. **Triple Whammy**

To sum up: The more greenhouse gas emissions produced, the more heat is trapped in the troposphere, the greater the stratospheric cooling effect especially at the poles, the greater the ozone loss becomes, and the more UV radiation can reach us! **Bingo**

# Smog Levels in Canada




**AQO = Air Quality Objectives**

**Questions:**

1. What is smog?
2. Which area has the most days exceeding the smog standard?
3. Which area has the fewest smog days? What is the smog situation where you live?

**Optional Investigations:**

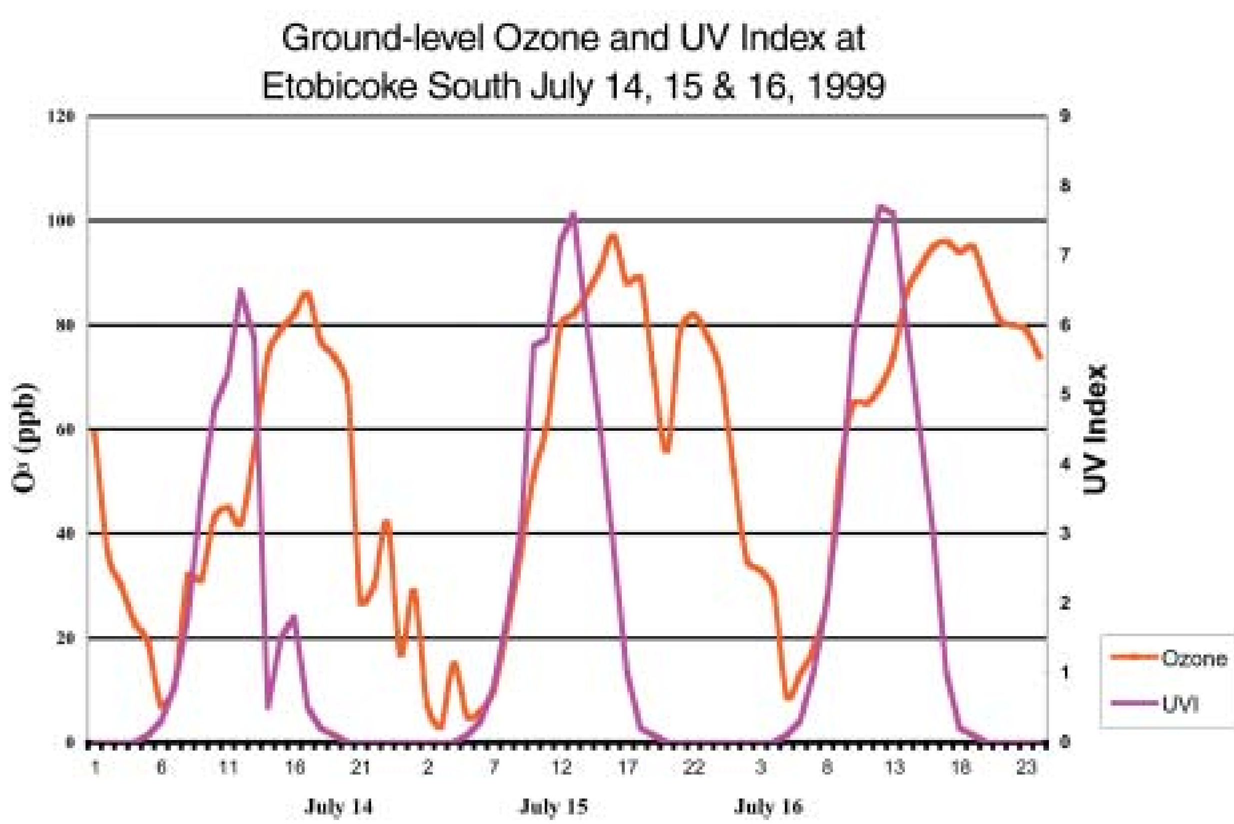
4. What is the effect of temperature inversion on the behaviour of smog?
5. Check for correlation(s) between city size and smog production or between city hospital respiratory admissions and smog or sunlight hours /UV hours /smog.

# Making Smog

The combustion of fossil fuels release primary pollutants (e.g., nitrogen oxides, sulphur dioxide, volatile hydrocarbons (VOCs) and carbon monoxide) in great quantities. The UV radiation in sunlight causes these compounds to form smog, which is full of highly reactive secondary pollutants or photochemical oxidants, such as ozone, that damage plants and animals. Smog production peaks after the release primary pollutants. See the graph below.

***Example:*** $NO_2 + H_xC_x$ - UV → ozone + aldehydes + ketones + PANs + others

primary pollutants secondary pollutants




**Question:**

1. At what time does the maximum concentrations of ozone occur each day?
2. At what time do the highest UV values occur each day?
3. What is the average time lag between the peak in UV radiation and the peak in ground level ozone?

**Optional:**

4. What emissions do vehicles using water as fuel release?

# How Do We Know?

**Identify the equipment below used to study the ozone layer.**






1. Stevenson Screen
2. Tethered Sonde
3. Brewer Spectrophotometer
4. SCISAT-1: Canadian Scientific Satellite
5. Polyethylene Ballon carrying ozone instruments

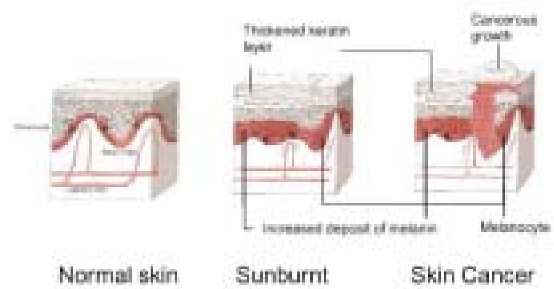
# UV and U: 20 Questions

1. What does *SPF* mean?
2. Does UV radiation have long or short waves?
3. What does *GHG* mean?
4. Define *melanoma*.
5. How high do ozone sondes fly?
6. Define the *UV Index*.
7. What does *CFC* mean?
8. How many oxygen atoms are there in ozone?
9. Is ozone toxic?
10. How many Canadian Brewer stations are there in 2002?
11. Where is the ozone hole in our atmosphere in winter?
12. Name one volatile hydrocarbon.
13. What ratio of Canadians will likely develop melanoma?
14. Name one secondary pollutant from automobiles.
15. How high does the UV Index unit go?
16. How does high UV exposure damage a food chain?
17. When was the Montreal Protocol signed?
18. What is the percentage of Canadian green house gas emissions that are attributed to individual/personal actions?
19. How many tonnes of GHG do Canadians produce in a year? How does this compare to the global average?
20. Is damage from exposure to UV radiation cumulative?

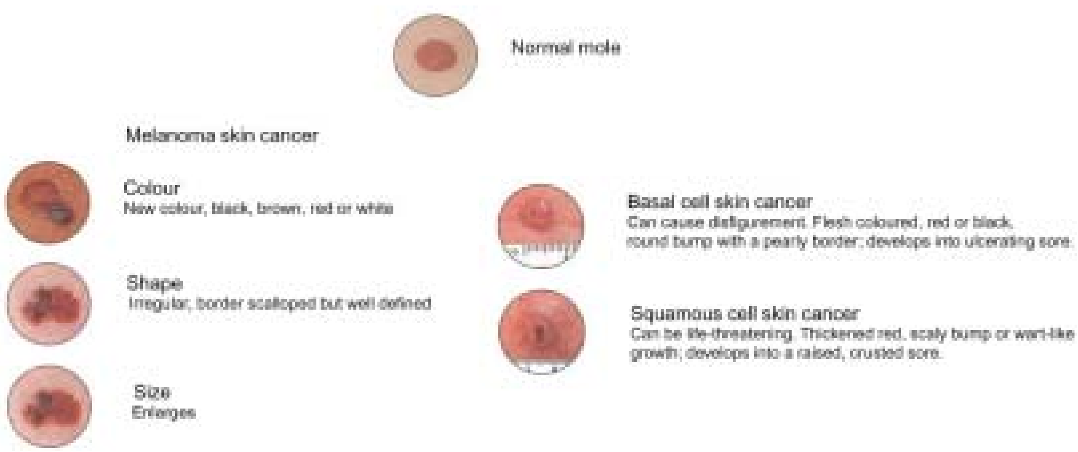
# UV and Your Health

## Skin Damage

Have you ever been complimented on your "sunny glow", or your great tan? While that may be a flattering statement, research shows there is no such thing as a healthy tan. Skin produces a dark pigment called melanin (a tan) as a shield against UV damage. Any change from our natural skin colour is a sign of damage to the skin cells and susceptibility to further negative effects. Skin burns because high doses of UV radiation have killed most cells in the upper skin layer and damaged the rest.




In 2001, 3900 cases of malignant melanoma were diagnosed in Canadians. From these, 840 people died. An additional 70,000 new cases of non-melanoma skin cancer were reported in the same year. Research has tied UV exposure directly to the development of non-melanoma skin cancer and there is also an indication that it might be linked to melanoma but more research is needed to be certain. One in five Canadians can expect to develop some form of skin cancer in their lifetime.




Does darker skin have more natural UV protection? Yes, about 8 SPF. But on darker skin, it is also harder to detect the signs of skin cancer–moles and dark skin patches. If you detect any signs of skin cancer on your body, see your doctor immediately. The sooner a cancer is detected, the greater your chances for its complete removal.

## Question:

Look around your classroom – how many people may experience a UV-related skin disease?

## Immune Deficiency and Infectious Diseases

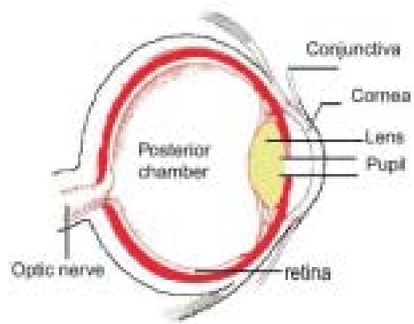
Hanging out in the sun can also have negative impacts on the immune system — the body's natural defense against disease. One experiment showed that about 100 minutes of midday sun exposure can suppress resistance to Listeria monocytogenese, a bacterial agent that can cause meningitis. Long-term research in Australia (where half the population may get skin cancer) has demonstrated that the rate of skin cancers increases in medically immune-suppressed patients. For example, of people who had kidney transplants, 7 per cent developed skin cancer after one year, 45 per cent after 11 years and 70 per cent after 20 years.

UV radiation can also take its toll on infectious diseases. Smallpox lesions grow in sunlight, and Herpes simplex Virus I and II (manifested in cold sores) are reactivated. In fact, ground-level UV radiation may act synergistically with climate changes to increase the frequency and severity of infectious diseases.

## Eye Damage

Is it possible to sunburn your eyes? Yes. Extreme UV radiation from strong reflection from water, sand or snow can inflame the cornea and conjunctiva within minutes. This is like burning the sensitive, skin-like tissues of the eyeballs and eyelids. "Snow blindness" is a term used by skiers and snowboarders when they experience this after a day on the slopes. Remember to wear those shades — with 100 per cent UV filtration, of course. Exposure to sunlight (UV) acute or long-term, direct or reflected, can prematurely age the lens, causing opaqueness (cataracts).

The figure below shows the eye section highlighting the cornea and lens. Cataracts form in the lens of the eye.




## Prevention

While these facts and figures can scare you into never leaving the dark, you can venture outside safely. Protecting yourself against UV exposure is easy, and allows you to participate in many outdoor activities. Check the UV Index before you decide on your activities for the day.

Here are the steps to proper skin protection:

1. Stay inside during hours of high UV intensity, or stay in the shade outside.
2. Wear appropriate clothing, including a wide-brimmed hat.
3. Save your eyes with sunglasses that offer the best UV filtration.
4. Apply sun block hourly.

If dark moles appear on your skin, become itchy or change shape, see your doctor soon. The health effects of UV exposure are cumulative, but avoidable.

# More Damage...

Humans are not the only beings affected by UV radiation. It also affects plants, animals, food webs and entire ecosystems.

## Plants

Sunlight is the source of life for "primary production", or plant growth, which forms the foundation of the food chains and webs that support all life. Any changes to UV levels on the earth's surface directly affect the productivity of plants. UV radiation damages membranes around plant cells as well as the DNA within cell nuclei. It also targets membrane-bound chloroplasts, decreasing a plant's ability to produce energy by altering leaf area, plant height, fruit size and taste. Exposed pollen and eggs can also be damaged, decreasing fertility and seed production.

The effects of UV exposure can be devastating for Canada's agricultural sector. In studies on more than 100 varieties of 12 important crop species, scientists found negative effects on biomass production on over 60 per cent of plant varieties exposed to UV levels equivalent to a 20-per-cent reduction in the ozone layer. This effect on production means that farm income in Canada would likely decrease by $387 million per year (based on 1995 yield estimates).

## Forest Ecosystems

Although forests comprise 80 per cent of total terrestrial biomass, not much is known about the effects of increased UV on forests, except that they are cumulative (trees live for a lot longer than agricultural crops, which are generally grown for one season). Also, photosynthesis system (PS) II, used by trees, is more affected by UV radiation than PS I.

Knowing that plants use $CO_2$ in photosynthesis, some people think that global warming (caused largely by increased $CO_2$ in the atmosphere) can be positive for plant growth. Studies have shown, however, that while biomass production has increased with higher $CO_2$ levels, productivity has decreased with corresponding higher UV exposure, due to a thinner ozone layer.

## Fresh-water Ecosystems

Our lakes and river systems are also fragile. An increase in UV radiation can decrease primary productivity, disrupt nutrient cycles, alter community structures and modify toxic chemical patterns in the food chain. Research has shown that, while primary production of phytoplankton may decrease with higher UV, the population of the creatures that feed on phytoplankton (chromonid family) decreases even more. In the study, phytoplankton biomass increased because the feeder population was so diminished that it disrupted a vital food chain link.

UV penetration in fresh water has been directly correlated to the amount of dissolved organic carbon (DOC). Less DOC means more UV penetration and more intense effects. In Ontario, 46 lakes studied for 20 years have shown a 15 to 20 per-cent decrease in DOC levels with a corresponding 22 to 60 per-cent rise in UV penetration. Originally thought to be effects of climatic change and acid rain, these changes are now recognized as being related to UV radiation. Shade trees along the banks provide some UV protection for streams, creeks and small ponds.

### Marine Ecosystems

Canada has the longest ocean coastline in the world. Marine ecosystems are important to our coastal communities. Oceans cover 71 per cent of the earth's surface and account for 40 per cent of the world's primary biological productivity. Besides being the basis of marine food chains, phytoplankton also plays a crucial role in climate change by maintaining a large and variable sink for atmospheric $CO_2$. As in freshwater ecosystems, increased UV exposure can kill algae causing a decrease in phytoplankton production and thus limit the dependent food webs.

### Animals

Documented evidence exists that Chilean sheep and Australian kangaroos have gone blind from UV damage to their eyes. More research is needed to document such damage to Canadian animals.

### Paint

UV causes "chalking" or formation of a powdery coating. "Fading" occurs as inorganic pigments are degraded, especially in lighter reds, oranges and yellows.

### Clothing

Fabric tests for UV penetration show that heavier fabrics, tighter weaves and darker colours, offer better protection. Polyester or polyester blends are recommended.

***Note:*** UV shields are often used on lights in clothing stores to prevent colour shift in fabrics due to long-term UV exposure.

## Beneficial Aspects

While we have focused on the negative effects of UV radiation, we must keep in mind that it does kill bacteria, build bones and provide "black light" effects.

- Water Purification Systems — Use UVC + UVB. (***Note:*** Check system needs for energy, cleaning, quality of intake water and its ability to kill parasitic cysts.)
- Sterilization — UVC radiation is a bactericide in different locations and processes.
- Vitamin D, formed by summer sun UV: 10 to 15 minutes 3 times a week on face, forearms and hands, will maintain bone calcium, immune functions and blood-cell formation.

# What Can I Do?

## Protect Yourself

These protective measures are listed from most to least important.

1. Use shade when available — if no UV protection, stay indoors for peak UV hours.
2. Choose appropriate protective clothing.
3. Wear a hat.
4. Purchase and wear approved UV-filtering sunglasses.
5. Wear appropriate sunscreen and reapply it often since it is absorbed very quickly and becomes ineffective, usually after one hour.

ALSO REMEMBER TO:

- Educate yourself about the dangers of immediate and long-term effects.
- Check yourself for possible skin cancer signs: irregular spots, moles, or patches.
- Add your ideas to sun protection — beginning with you and your friends.

## Help Others

- Share information with others about UV protection and damage.
- Establish a "Sun Smart" school program.
- Check out UV precautions taken by your friends to prevent sunburns.
- Start reducing the size of your ecological footprint by launching an energy conservation program. Remember that most of the electricity produced for your home is from the burning of fossil fuels, not to mention the fossil fuel consumption in our vehicles.
- Start a "walking school bus" program, a waste audit and/or a recycling program as energy conservation measures to reduce the school's ecological footprint.
- Investigate developing a program of political action to increase awareness and political will to work toward solutions to this problem.
- Your ideas — beginning with you and your friends.

PS. Make sure you understand the connection between increased greenhouse gas emissions and increased UV radiation on our planet.

## Answers to 20 questions:

**1.** Sun Protection factor
**2.** Short waves
**3.** Greenhouse gas
**4.** Dangerous type of skin cancer
**5.** 20 km
**6.** Measure of UVB intensity
**7.** Chlorofluorocarbons
**8.** 3
**9.** Yes
**10.** 12
**11.** Over the North Pole
**12.** Ethanol, Propane, Propylene, Acetylene
**13.** 1 in 5
**14.** NO, CO
**15.** 16+
**16.** Changes the productivity of plants
**17.** 1987
**18.** 28%
**19.** 23 tonnes per year, 6 to one
**20.** Yes

# Political Action

## Montreal Protocol

In 1974, scientists Rowland Sherwood and Mario Molina suggested that chlorine from CFCs could deplete stratospheric ozone. In 1987, the Montreal Protocol — an international agreement on ozone-depleting substances found in refrigerants, solvents and propellants — was signed by 81 countries acting on the precautionary principle.

Canada was one of the first nations to ban the use of CFCs as an aerosol propellant. Because of its northern location, Canada is one of the countries most at risk from ozone depletion. The Arctic ecosystems, already suffering from the impacts of climate change, are especially vulnerable.

If this agreement had not been signed, one-third of the world's population would have become new ozone-destroyers. The follow-up meetings in London (1990), Copenhagen (1992), Vienna (1995) and Beijing (1999) led to the Montreal Protocol's ratification by 175 nations. The benefits of this action are expected to outweigh costs by ten to one. Atmospheric concentrations of CFC-11 and CFC-12 are now decreasing or slowing.

### Questions:

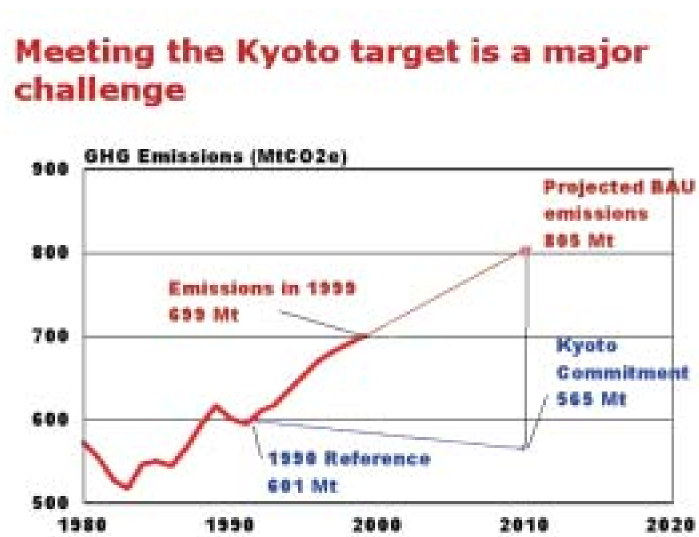
1. What factors would be included in calculations of this cost/benefit ratio?
2. What pro and anti forces were involved in the signing of the Montreal Protocol?
3. Are these forces still at work in the agreement process for the Kyoto Accord?

## Kyoto Accord

In 1997, Canada agreed to reduce its greenhouse gas (GHG) emissions to six per cent below 1990 levels by 2008.

Actions taken since then focus on education, research and voluntary programs. Our GHG emissions rose 15 per cent between 1990 and 2000.

***Note:*** B.A.U. = Business As Usual
Mt = megatonnes
e = equivalent



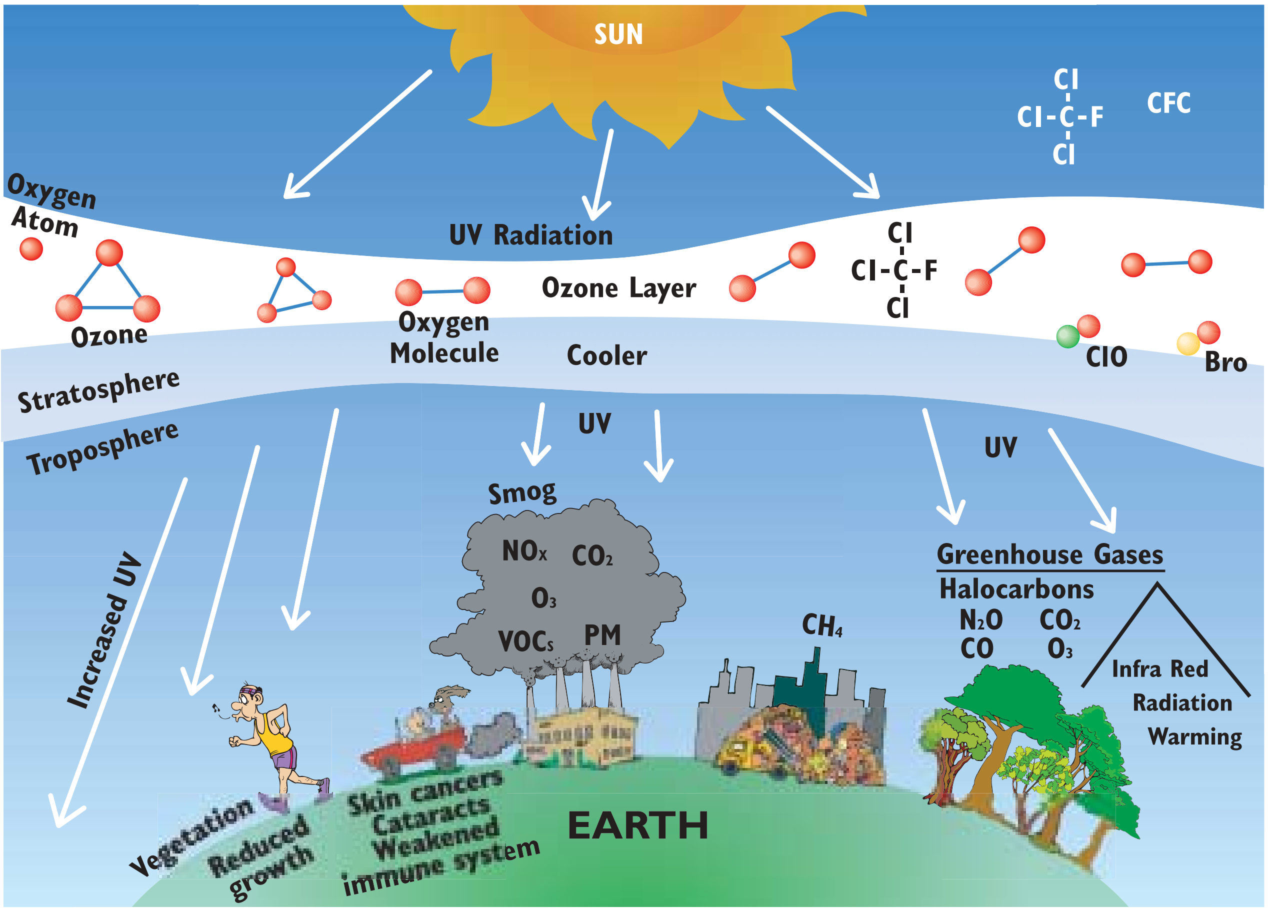

### Questions:

4. What is the progress toward agreement on this accord?

   Canadians produce 22.5 tonnes of greenhouse gases per person annually. The global average is 3.8 tonnes of GHGs per person annually. What factors account for this?

5. How does use of carbon credits make this a world issue?

# Tying It All Together




Find the DIFFERENCES in our atmosphere shown in this diagram that are due to the impact of human activities on our ozone layer. Check the box to show the change.

| CONDITION | CHANGE ( + or - ) + more | - less |
|---|---|---|
| 1. Concentration of ozone molecules | ❒ | ❒ |
| 2. Temperature of our stratosphere | ❒ | ❒ |
| 3. Amount of UV reaching us on earth | ❒ | ❒ |
| 4. Greenhouse gas concentrations | ❒ | ❒ |
| 5. Smog concentration | ❒ | ❒ |
| 6. Vegetation health | ❒ | ❒ |
| 7. Temperature of our troposphere | ❒ | ❒ |
| 8. Ground level ozone concentration | ❒ | ❒ |
| Other differences you can find on this diagram? | ❒ | ❒ |

You may be able to list related changes not shown on this diagram from your work in this booklet and other research, e.g.,extreme weather events, increased incidence of skin cancer-melanoma.

# UV Glossary

**Basal cell carcinoma (BCC)**

Most common type of skin cancer, originating from basal cells. Usually appears as a scaly, red lump and rarely metastasizes (spreads to other organs).

**Black Light**

UV radiation ranging from 350 to 390 nanometers; used for special theatre effects.

**Carcinogen**

An agent or substance that induces cancer.

**Cataract**

A disease that partially or completely clouds the eye lens, impairing vision or causing blindness. Vision can be restored by surgically removing the lens and replacing it with an artificial one.

**Chlorofluorocarbon (CFC)**

Compound containing carbon, chlorine, fluorine and sometimes hydrogen. Used as a refrigerant, solvent, aerosol propellant or element in plastic foam.

**Conjunctiva**

Mucous membrane that lines the inner surface of the eyelids and covers the front part of the eyeball.

**Cornea**

Transparent part of the eyeball that covers the iris and pupil. Admits light to the interior of the eye.

**Dobson Units (DU)**

The standard unit for total ozone (100 DU = 1mm at standard temperature and pressure). It is an indication of thickness.

**Electromagnetic Radiation (EMR)**

Waves of energy primarily from the sun. Also generated by high-voltage transmission lines, cell phones, microwave ovens, computers and televisions.

**Electromagnetic Spectrum**

Range of wavelengths of radiant energy measured from the shortest (gamma rays) in nanometres (nm) to the longest (radiowaves) in metres (m). Includes the visible light spectrum from approximately 380 nm – 720 nm.

**Erythema**

Redness of the skin. Mildest form of sunburn.

**GHGs**

Greenhouse gases that trap heat energy in our atmosphere and include carbon dioxide, methane, dinitrogen oxide and chlorofluorocarbons (CFCs).

**Ionosphere**

A layer of charged particles in the upper mesosphere and thermosphere created when atoms and molecules absorb UV energy from the sun. The ionosphere allows microwaves through but reflects radio waves back to earth.

**Immune system**

System involving some special cells that protects the body from foreign substances. Produces antibodies to fight intruders.

**Malignant melanoma (Melanoma)**

Malignant cancer of melanocytes. Usually has an irregular outline and patchy colouring. Rarest but most dangerous type of skin cancer that often spreads to other organs and could be fatal (metastasizes).

**Melanin**

Black, dark brown or reddish pigments produced by specialized skin cells called melanocytes.

**Melanocyte**

Cell in the upper skin layer that produces the pigment melanin.

**Metastasis**

Process where cells break away from a tumour to spread to other parts of the body and start to grow as a new tumour.

**Nitrogen Oxides ($NO_x$)**

Molecules containing combinations of nitrogen and oxygen ($NO$, $N_2O$, $NO_2$, $N_2O_5$).

**Ozone ($O_3$)**

Form of oxygen with three atoms in each molecule. Formed and destroyed in UV-driven reactions.

**Ozone layer**

Layer of high ozone concentration in the stratosphere that absorbs most solar ultraviolet (UV) radiation, preventing UV from entering the lower atmosphere.

**PANs**

Peroxyacetyl nitrates, which are highly reactive compounds. Secondary pollutant products of reactions forming smog.

**Photochemical activity**

Chemical changes produced by light, e.g., UV radiation in the production of smog.

### Photosensitivity

Skin condition that makes a person particularly sensitive to ultraviolet radiation. Exposure leads to allergic reactions such as rashes or severe sunburn. Often a side effect of medication.

### Phototherapy

Therapeutic use of light and/or ultraviolet radiation to diseases such as rickets, psoriasis, eczema and jaundice.

### Planetary wind pattern

Global movement of air determined by the convection created by the sun's uneven heating of the earth and the daily earth' s rotation. These are called prevailing westerlies, global winds, worldwide winds or trade winds.

### Polar projection

A map showing the perspective from the earth's North or South Pole.

### Precautionary Principle

The guiding rule used to put into place the most conservative measures possible until the science or a process is better understood.

### Quasi-biennial oscillation

Reversal of direction of stratospheric winds that circle the globe in an easterly and westerly direction. Occurs every 20-30 months. Not fully understood, but we know there are a number of causal factors, including atmospheric ozone.

### Skin cancer

A tumour on the skin. Classified as melanoma and non-melanoma skin cancers (basal and squamous cell carcinoma).

### Snow blindness

Inflammation of the cornea leading to temporary blindness. Caused by exposure of the eyes to ultraviolet B radiation reflections from snow or ice.

### Solar noon

The time of day when the sun is directly overhead or as high as possible for your latitude.

### Squamous cell carcinoma (SCC)

Scaly or plate-like malignant tumour of the skin that sometimes spreads (metastasizes) to other organs. Second most common form of skin cancer.

### Stratosphere

The atmospheric layer between the tropopause and the stratopause (10-50 km).

**Stratopause**

The layer separating the upper stratosphere from the mesosphere, at an altitude of about 50 km.

**STP**

Standard pressure and temperature conditions measured at sea level.

**Sun protection factor (SPF)**

A measure of the amount of UVR protection provided by a sunscreen product. Measures the ability of a sunscreen product to prevent sunburn on the skin.

**Troposphere**

The lowest layer of the atmosphere, between the earth's surface and the tropopause (0-10 km).

**Tropopause**

The atmospheric layer separating the troposphere and stratosphere.

**Ultraviolet (UV) radiation**

Part of the solar emissions that include light, heat and UV radiation. UV region covers the wavelength range of 100-400 nm and is divided into three bands: UVA, UVB, and UVC. All three bands are classified as probable human carcinogens.

**UVA radiation**

Long wavelength UVA covers a range of 315-400 nm, and makes up approximately 90 per cent of UV radiation reaching the earth's surface. Not significantly filtered by the atmosphere.

**UVB radiation**

Medium wavelength UVB covers a range of 280-315 nm. Approximately 90 per cent of solar UVB radiation is absorbed by the ozone layer.

**UVC radiation**

Short wavelength UVC covers a range of 100-280 nm. All solar UVC radiation is absorbed by the ozone layer.

**UV Index (UVI)**

Describes the level of solar UV radiation at the earth's surface and provides a useful way to alert people about the need to adopt protective measures.

**Vitamin D**

Vitamin that is essential for normal bone and tooth structure. Found in cod-liver oil, egg yolk and milk. Bodily synthesis is activated by ultraviolet B radiation on the skin.

**VOCs**

Volatile organic carbons – compounds that are reactants in the making of smog. May be hydrocarbons, like methane.

# UV and Further Research

Some ideas for further research:

- establish a protocol for rating the severity of sunburn
- determine the UV sensitivity of specific plants and animals
- quantify the relationship between UV penetration and freshwater algae
- quantify this effect on the rest of the freshwater ecosystem
- apply this research to stream bank or riparian restoration programs
- quantify the relationship between UV penetration of canopies of shade trees
- develop "breathing" clothing materials with better UV filtration
- take hourly readings of nitrogen oxides/hydrocarbons/ozone at ground level in high-traffic areas to quantify the direct relationship and timing of the formation of ground-level ozone
- and......?

# You and the Brewer

The Meteorological Service of Canada (MSC) forecasts the UV Index (UVI) levels for each day of the year for 48 locations across the country. These are posted at **www.cmc.ec.gc.ca/cmc/data/fpcn48.html** by the Canadian Meteorological Centre in Montreal.

From April to October each year, the regional offices of MSC issue precise UV Index forecasts that take into account regional characteristics. These forecasts are reported in the media (radio, television and newspaper) and on the Meteorological Service of Canada website at **www.weatheroffice.com**

***Note:*** Brewer spectrophotometer is the name of the UV measuring instrument. (12 Brewers in Canada)

## Purpose

To compare UV values from different locations.

## Method/Observations

Use the chart below to record two weeks of UV Index listings from: the MSC Web site, your own reading, and your local media. From the website, you will obtain the max UVI value for the closest Brewer station to you. The local media will give you the UV Index forecast for today. Use the meter at solar noon to obtain your maximum UV Index value.

| DAY | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UV Web | | | | | | | | | | | | | | |
| UV meter | | | | | | | | | | | | | | |
| UV media | | | | | | | | | | | | | | |

## Discussion

Using your data, plot a graph of the daily UV radiation levels.

## Optional

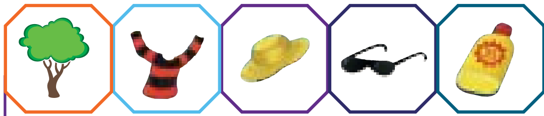
Continue to record and post a two-week period so that the class can produce cumulative graphs of UV readings over several months.

a) Which month(s) of the school year have the highest UV readings?

b) How does this relate to the reported seasonal ozone layer thickness?

## Conclusion

What have you learned from your comparison?





# What's in our Atmospheric Soup?

1. Write the chemical and structural diagrams for these natural components of our atmosphere: molecular oxygen, nitrogen gas and carbon dioxide.

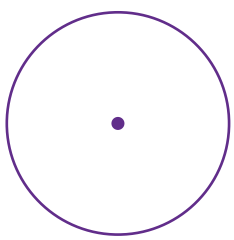
   A. $O_2$ | O = O  B. ______________  C. ______________

2. Write the chemical formulae for these 4 major human-made additives: methane, ozone, nitrous oxide, chlorofluorocarbons. Does UV react with these additives?

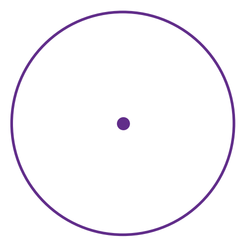
   A. ______________  B. ______________  C. ______________  D. CFC $l_3$

***BONUS:*** Show the structural formulae for these 4 molecules.

3. Draw two pie charts: One to illustrate the quantities of natural components of the atmosphere and another to show the quantities of human-made additives. Work clockwise and start with the largest per cent at 12 o'clock.



% of natural components



% of human-made additives

| Additive % | Source | Effect |
|---|---|---|
| **1.** | | |
| **2.** | | |
| **3.** | | |
| **4.** | | |

4. What are the health effects of the four leading human-made additives?

5. What actions are being taken to reduce these levels:

   a) Locally? b) Provincially? c) Nationally? d) Internationally?

6. What actions can you personally take to reduce these levels?

I'M SUN SAVVY

# Going South for a Tan?

The intensity of solar radiation depends partly on the latitude of a given place and time of year.

We know the sun is directly overhead at the:

- Equator (0°) on/about March 21 and September 21 (spring and autumn equinoxes);
- Tropic of Cancer (23.5° N) on/about June 21 (summer solstice);
- Tropic of Capricorn (23.5° S) on/about December 21 (winter solstice).

The sun therefore moves through a latitude range of 47° every six months (182.5 days) or about one degree of latitude every four days. Knowing this, we can calculate when the sun will be directly overhead in different latitudes.

For example, the sun will be directly overhead at 10° S latitude on:

23.5° S - 10° S = 13.5° S

13.5° S x 4 days/degree = 54 days after December 21 (when the sun was overhead at 23.5° S)

Adding 54 days to December 21, the date is February 13.

Use the steps above to calculate when the sun's rays will be directly overhead for the following popular vacation spots:

| Vacation Site | Latitude (°) | Date of Overhead Sun |
|---|---|---|
| Montego Bay, Jamaica | | |
| Cancun, Mexico | | |
| Acapulco, Mexico | | |
| Rio de Janeiro, Brazil | | |
| Havana, Cuba | | |
| San Jose, Costa Rica | | |
| Ambergris Caye, Belize | | |

**Questions:**

1. What is the relationship between UV radiation and the angle of the sun's rays?
2. At what time of year are you most susceptible to UV radiation in these places?
3. What is the second time in the year when the sun's angles will be directly overhead?
4. Trick question: When are the sun's rays directly overhead in your home latitude?

# Protection makes a Difference

UVB damage is cumulative. However, diligent use of sunscreens during the first 18 years of life could reduce the lifetime incidence of non-melanoma skin cancer by 78%. Studies also show that long-term unprotected exposure to UVB increases the rate of aging of the skin, similar to the effects of heavy smoking, i.e., increased keratinization (the leathery look), and increased wrinkles.

Your outside activities, the amount of clothing and sunscreen you have on, all determine the amount of UVB you are exposed to in your area. Knowing this you can take measures to protect yourself.

1. List four of your school 's outdoor programs / events in the chart below.

| School Program/Event | Month(s) Usually Held |
|---|---|
| **1.** | |
| **2.** | |
| **3.** | |
| **4.** | |

2. Calculate the monthly averages from the UV values obtained in the " You and the Brewer" investigation.
3. Plot these UV averages on the climograph for your city (closest) and compare the trend to those for temperature and precipitation.
4. Describe and explain any relationship found among these three averages. See the solar radiation and UV radiation maps for Canada on pages 4 and 5
5. Use this information for planning to host a school outdoor sporting event. What would be the cost of providing sunscreen for your team? For all teams invited? See the protection priority list.

***Note:*** To use sunscreen as a factor you must standardize. e.g., applications, number of games.

## Optional Investigations:

6. SPF 15 is about 96% effective. How much more does a sunscreen with a SPF of 30 protect you? Is it cost effective?
7. Melanoma is a skin cancer that may be caused by cumulative UVB exposure. It is projected that 1 in 5 Canadians will develop melanoma.
   a) List the factors that might be taken into account to determine the risk of a baseball player developing melanoma. (Minimum of eight factors)
   b) Calculate the difference in exposure to sunlight for a person who plays one season of soccer: i) with no sunscreen ii) with SPF 15 iii) with SPF 45.

# WEB SITES

Listed below are a few Web sites that contain information about the UV Index, the ozone layer, ozone depletion and protection from the sun. These sites also have hot links that students can explore. Many more sites can be found through search engines.

## WEATHER

| | |
|---|---|
| Canadian Weather | **www.weatheroffice.ec.gc.ca** |
| Sky Watchers | **www.weatheroffice.ec.gc.ca/skywatchers/index_e.html** |

## THE UV INDEX

| | |
|---|---|
| Meteorological Service of Canada | **www.msc-smc.ec.gc.ca/uvindex** |
| United States Climate Prediction Center | **www.cpc.ncep.noaa.gov/products/stratosphere/uv_index** |
| World Health Organization | **www.who.int/peh-uv** |
| U.S. Environment Protection Agency | **www.epa.gov/sunwise** |

## THE OZONE LAYER

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|---|---|
| Experimental Studies Division of Environment Canada | **http://exp-studies.tor.ec.gc.ca** |
| Climate Prediction Center, Ozone Tour, USA | **www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/ozone_hole.html** |
| The Ozone Hole Tour | **www.atm.ch.cam.ac.uk/tour/index.html** |
| British Antarctic Survey | **www.antarctica.ac.uk/met/jds/ozone** |

## HEALTH SITES

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|---|---|
| Canadian Dermatology Association | **www.dermatologie.ca/english/index.html** |
| Canadian Dermatology Association Spot Check | **www.dermatologie.ca/english/public-patients/spotcheck_e.html** |
| Health Canada | **www.hc-sc.gc.ca/english/feature/summer/air_sun/links.html** |
| The Anti-Cancer Council of Victoria (Australia) | **www.sunsmart.com.au** |

## EDUCATION SITES

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|---|---|
| ACER – Association for Canadian Educational Resources | **www.acer-acre.org** |

## RESOURCES FROM ENVIRONMENT CANADA produced in collaboration with Health Canada

To obtain the information below, please send an email to Angus.Fergusson@ec.gc.ca

- UV Index Posters 1998, 1999, 2000, 2001 and 2002
- *UV and You* brochure: Living with Ultraviolet
- *UV Index, Weather, and You:* Activity and Information Guide
- *Arctic Ozone: The sensitivity of the Ozone layer to Chemical Depletion and Climate Change*
- *Ozone Depletion and Climate Change: Understanding the Linkages*

## UV and U: 20 Questions

1. What does *SPF* mean?
2. Does UV radiation have long or short waves?
3. What does *GHG* mean?
4. Define *melanoma*.
5. How high do ozone sondes fly?
6. Define the *UV Index*.
7. What does *CFC* mean?
8. How many oxygen atoms are there in ozone?
9. Is ozone toxic?
10. How many Canadian Brewer stations are there in 2002?
11. Where is the ozone hole in our atmosphere in winter?
12. Name one volatile hydrocarbon.
13. What ratio of Canadians will likely develop melanoma?
14. Name one secondary pollutant from automobiles.
15. How high does the UV Index unit go?
16. How does high UV exposure damage a food chain?
17. When was the Montreal Protocol signed?
18. What is the percentage of Canadian green house gas emissions that are attributed to Individual/personal actions?
19. How many tonnes of GHG do Canadians produce in a year? How does this compare to the global average?
20. Is damage from exposure to UV radiation cumulative?