Weather Radar and A3
Introduction

The term **RADAR** is an acronym formed from the term **Ra**dio **D**etection **a**nd **R**anging. Nikola Tesla (of electric car fame) suggested in 1900 that moving targets should be observable through radio-frequency shifts (predicted by C.J. Doppler in 1842 for waves in general). The first patent for elementary radar technology was issued in Germany in 1904. The threat of World War II accelerated development. Five radar stations in Britain were operational in 1938 and this network is credited with making decisive difference in the Battle of Britain.

The mid-20th Century featured military refinements of radar (Example; Ballistic Missile Early Warning System – BMEWS) and parallel civil applications – air traffic control, ship navigation weather and storm-centre tracking and police use for measuring speed of vehicles. Other uses include atmospheric sounding and radar astronomy. Canadians have made major contributions to development of radar, including RADARSAT-1 and RADARSAT-2 (launched in 2007) with "powerful technical advancements that enhance marine surveillance, ice monitoring, disaster management, environmental monitoring, resource management and mapping in Canada and around the world" (http://www.asc-csa.gc.ca/eng/satellites/radarsat2/) The first meteorological satellite TIROS-1 was launched by the United States in April 1960.

Weather radar was developed from the 1950s through the 1970s. Networks in North America, Europe, Japan and other developed countries were in place from 1980 and 2000 and provided position and intensity of precipitation. Conventional radars were replaced by Doppler radars, which also track the relative velocity of the particles in the air.

Weather surveillance radar systems generally use a parabolic antenna to focus a pulsed radio-frequency beam into the atmosphere, something like a searchlight. This narrow beam sweeps the sky for 360 degrees around the radar site, pointing at different elevation angles each time it sweeps around.

Energy emitted by the radar antenna strikes particles of precipitation, such as drops of water, snowflakes, ice pellets, or hail, and part of this energy is reflected back to the radar receiver. The intensity of this energy is related to the number, size and type of the precipitation particles. Radar echoes are represented by a series of coloured pixels, as illustrated on the scale to the right of the radar image (see Figure 2 and various Environment Canada regional sites). The intensity scale on the right represents what is called "reflectivity in dBZ" (unit of reflectivity), and the scale on the left is the corresponding rate of fall which is an interpretation of how light or heavy the precipitation is. In the winter season, this reflectivity is linked to the snowfall rate in centimetres per hour (cm/hr), and in the warmer months, the reflectivity is linked to the rainfall rate in millimetres per hour (mm/hr).

Radar-derived potential rainfall accumulations are used by meteorologists in weather forecasting, and by hydrologists for flood modelling and flash flood warning. Emergency services often use radar to ascertain if flood mitigation action may be required. Another important use of radar data is for assessment of precipitation that has fallen over large basins for hydrological calculations; such data is useful in flood control infrastructure planning construction. The computed data from radar weather may be used in conjunction with data from ground stations.

Reflectivity not only depends on the precipitation intensity, but also the type of precipitation. Rain is more easily detected by radar than snow because it generally reflects more radar energy. Consequently, moderate to heavy snow can appear light in intensity. Meanwhile, ice pellets and hail are highly reflective thus light ice pellets or hail can appear as heavy precipitation. In order to better represent precipitation during times with colder temperatures, a certain relationship is used to relate the reflectivity to a rainfall rate.

Generally, the higher the reflectivity value on a radar image, the heavier the precipitation rate that is being detected. For example, the dark purple colour represents the heaviest precipitation of snow (meaning it has a snow rate of fall of 20 cm/hr), while the aqua colour is the lightest precipitation (meaning it has a snow rate of fall of 0.1cm/hr).

In some cases, the radar does not distinguish between real echoes (precipitation) and false echoes (trees, hills, tall buildings). It is also important to understand some common interpretation errors, if you are hoping to accurately interpret radar images.

Environment Canada's network of “31 sites is concentrated in the most populated parts of Canada, providing radar coverage to more than 95 per cent of Canadians. The network’s primary purpose is the early detection of developing thunderstorms and high impact weather, as well the tracking of precipitation. Environment Canada’s weather radars have a range of 250 km around each site.
See http://weather.gc.ca/radar/index_e.html?id=ONT

for Ontario sites.

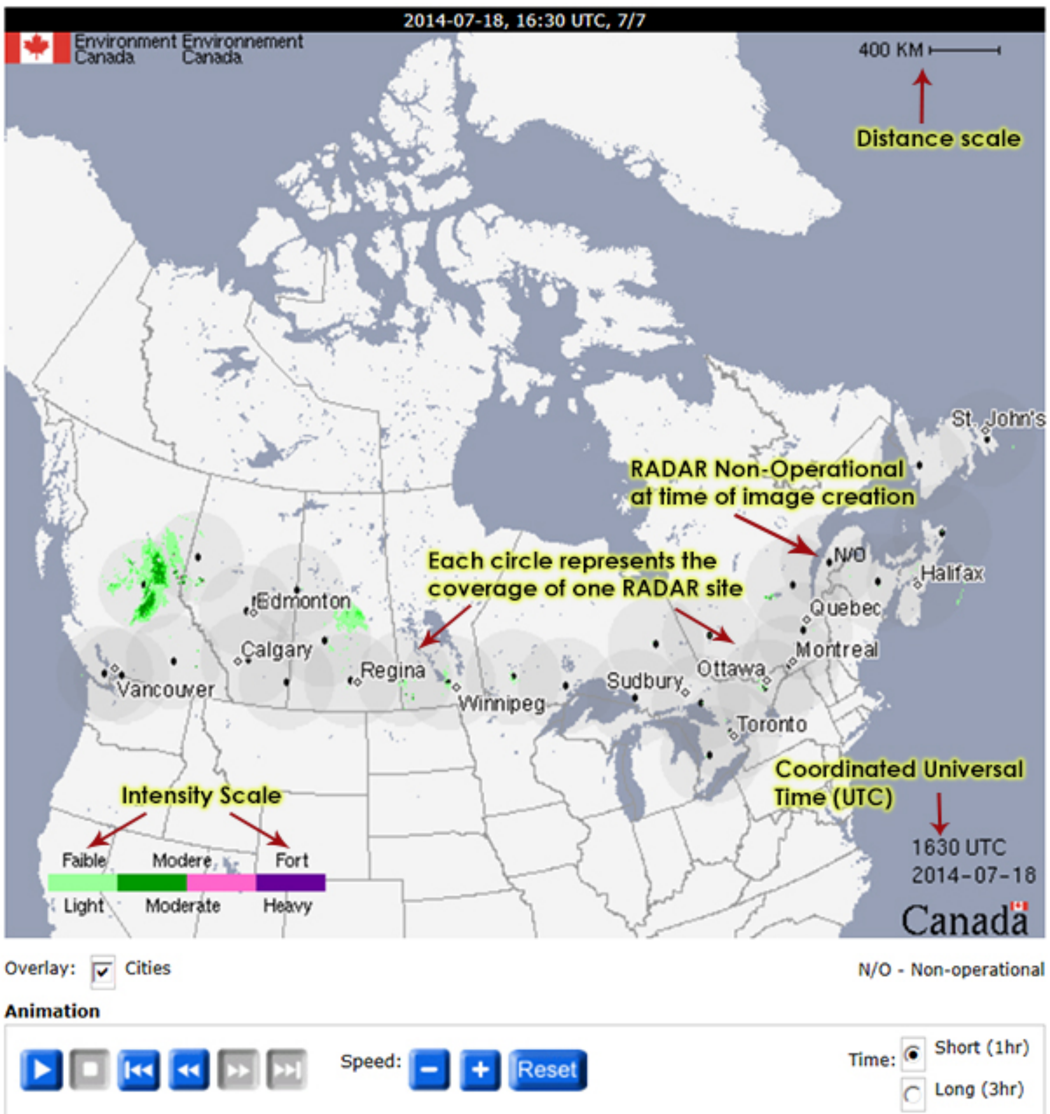

Figure 1 National Radar Network
Source: Environment Canada

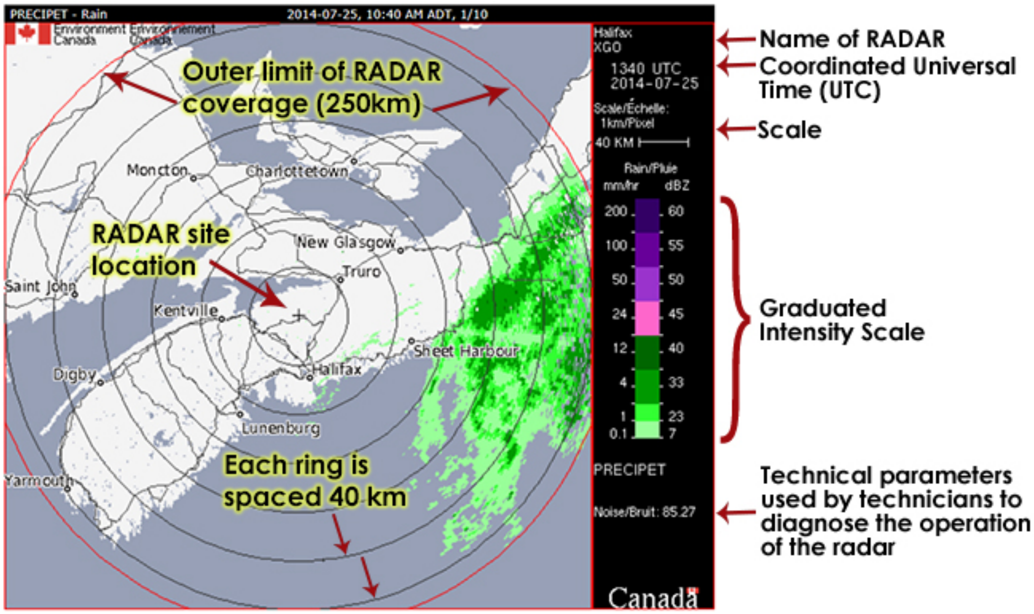

Figure 2 An example of a Regional Radar site
Source: Environment Canada

Doppler Radar

Precipitation is found in and below clouds. Precipitation is subject to the air currents, and scanning radar can pick up the horizontal component of this motion. Precipitation targets move slightly between each pulse; the returned wave has a noticeable phase difference or shift from pulse to pulse. Doppler weather radars use this phase difference (pulse pair difference) to calculate the motion of precipitation. Analysis of motion can contribute to detection of tornadoes and other severe wind events

Interpreting Radar Images

Due to the curvature of the Earth, the height of a radar beam, in relation to the ground, increases as it travels further from the radar. When the radar is pointed down near the ground (a low elevation angle), the beam starts off near the ground but then its height above the ground slowly increases. By the time that same beam is 200 km from the radar, it is at a height of about 4 km above the ground. In order to get a better sense of what is happening at one approximate height above the ground (i.e. 1.5 km), a whole series of radar beams with different elevation angles (low, medium, high) are used to create one radar product.

Note that radar does not "see" clouds, as cloud droplets are too small, but does “see” the rainfall produced by clouds in the form of radar echoes. The radar may sometimes detect echoes from aircraft, topography, flocks of birds, swarms of insects, areas of smoke/ash from large fires, or even the ground or water surface, when unusual atmospheric conditions bend the radar beam back down to the surface. As a result, there may be patterns on the radar images that do not represent falling rain or gaps in displays of actual precipitation. Hills and mountains can block a radar beam and leave noticeable gaps in the pattern. This situation is common in areas with mountainous and hilly terrain.

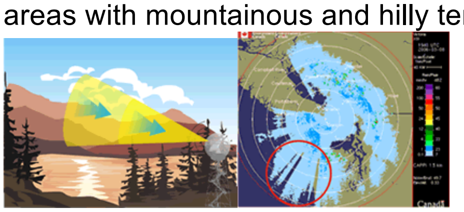

Figure 3 Illustration of Influence of Terrain on Radar Reception

Beam Attenuation

- Storms closest to a radar site reflect or absorb most of the available radar energy. Only a reduced amount of this energy is available to detect more distant storms.
- Storms in the attached example's circled area were quite intense, but were not being detected appropriately by the radar. Strong storms occurring closer to the radar kept a significant portion of the radar energy from penetrating beyond these storms.

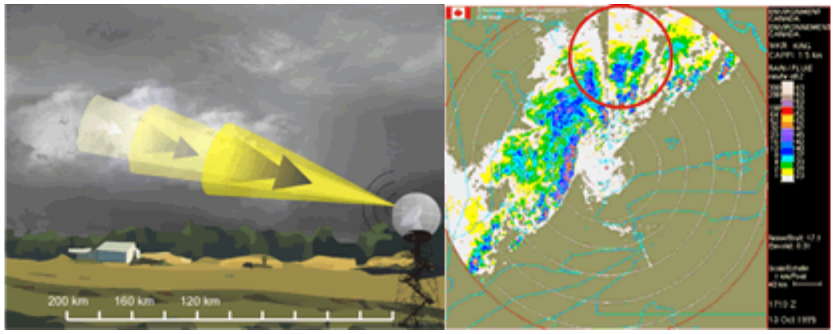

Figure 4 Example of Beam Attenuation

Overshooting Beam

- Intense precipitation such as lake effect snow squalls can be associated with clouds close to the ground. In such cases, the radar beam may overshoot most of the area of precipitation and therefore indicate only weak echoes, when in fact significant precipitation is occurring.
- The example image shows lines of precipitation on the Prairies. Although it was raining inside the radar coverage area, the radar overshoots at long range and the bands are not seen.

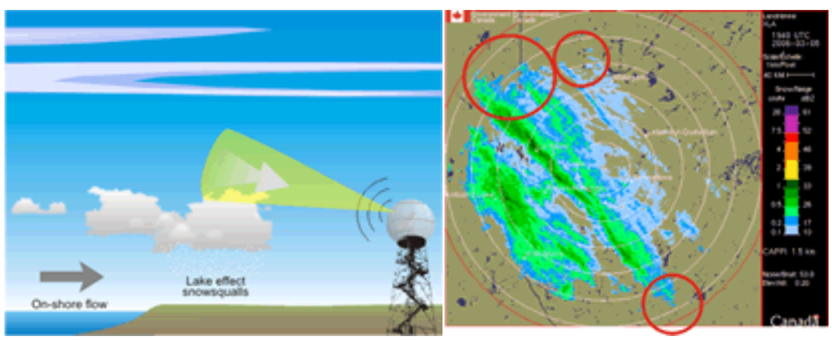

Figure 5 Example of Overshooting Beam

Virga

- Precipitation that is occurring in the air but not reaching the ground is called virga. It occurs with very dry conditions at low levels; the dry air absorbs all the moisture before it reaches the ground.
- No precipitation was hitting the ground in the example displayed.

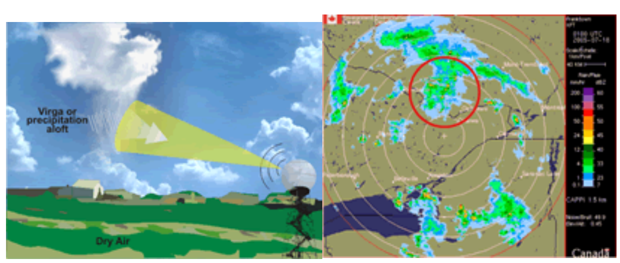

Figure 6 Example of Virga

Anomalous Propagation

In the low levels of the atmosphere when a layer of warm air is over a layer of much cooler air (a temperature inversion), the radar beam can't pass between the layers, and gets bent to the ground. A false strong signal is reflected back to the radar site.

- This phenomenon is most common during the early morning hours when it is clear. The false echoes generally dissipate by midday.
- In the example image, there was no precipitation occurring.

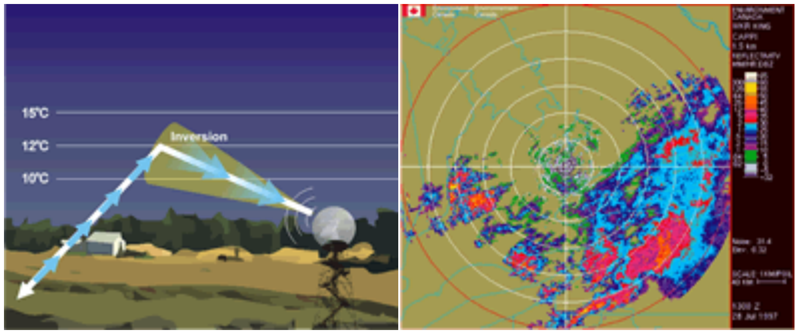

Figure 7 Example of Anomalous Propagation

Ground Clutter

- These echoes are called "ground clutter" and they occur when a portion of the radar beam comes into contact with tall buildings, trees or hills.
- It is good to learn the common ground clutter "signature" in your area, so you can distinguish it from real precipitation.
- Radars near large bodies of water may also receive echoes from moving waves. Since waves depend on wind speed and direction, "sea clutter" is more variable than standard ground clutter and is therefore more difficult for existing processing to filter out.

Electromagnetic Interference

- Environment Canada operates its radars in the “C-band” frequency range of 5600 - 5650 MHz. As the demand for wireless devices increases, the frequency spectrum becomes more crowded and it becomes harder to isolate the weather radar signals from interference. Tracking down the source of the interference can be a difficult task.
- Typical interference from a wireless device appears as a persistent spike on the radar going out from the radar in one direction (i.e. along a **radial**). A typical spike is shown in the image below.
- Sometimes a “sun spike” can be briefly seen at sunrise or sunset when the radar has a clear view of the sun low on the horizon. This is caused by the solar radiation being picked up by the sensitive radar receiver.

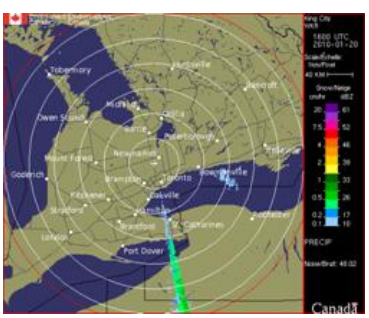

Figure 8 Example of Electromagnetic Interference

Using this background, storm scenarios will be examined in class.

WRM Assignment #3 Name(s)

You are the General Manager of "Utilities and Operations" in a medium-sized municipality in Canada. Your duties include responsibility for the operation and maintenance of the transportation and works infrastructure, parks and planning. This includes roads and bridges (including snow removal), street lighting, traffic control, water supply and distribution, waste reduction and recycling, garbage collection and disposal, sewage and sewage treatment, drainage, park operation and maintenance, and administrative functions.

Your background in water resource management has been valuable over the years. You have noted an increase in severe weather in recent times, especially related to heavy precipitation. A recent flood event was a disaster for the municipality, affecting some flood-prone areas severely and some areas for the first time. You have become the "go to person" in a weather-related emergency and have alarms for various parameters in your office, vehicle and home. You routinely check current weather, forecasts and current radar images.

You review weather maps and radar images of the recent storm – see PPt slides and make some notes:

Scenario A
An examination of radar on slide 16 triggers some concerns. Some flood reports are coming in from a city about 300 km south of your location.
What is your main concern(s)?

Who do you inform and in what order?

What information do you obtain?

Scenario B
You have been watching a relatively slow moving system for about 30 hours. The direction has been approximately west to east. There have been moderate rainfalls southwest of your location and the recently installed weather station network is reporting rainfall of 10 mm/hr and 15 mm/hr from two southern locations.

What is likely routine during the next hours?

Is the "B" scenario similar to the previous situations?

Differences?

As mentioned above "you have noted an increase in severe weather in recent times". Discuss in the context of the above events your brief list of recommendations to the municipality for planning and improvements in infrastructure for the next few years: