Project Atmosphere Canada

MODULE 2

Weather Radar: Detecting Precipitation

Teacher's guide

Canadian Meteorological and Oceanographic Society
La Société Canadienne de Météorologie et d'Océanographie

Environment Canada
Environnement Canada

Canada

Project Atmosphere Canada

Project Atmosphere Canada (PAC) is a collaborative initiative of Environment Canada and the Canadian Meteorological and Oceanographic Society (CMOS) directed towards teachers in the primary and secondary schools across Canada. It is designed to promote an interest in meteorology amongst young people, and to encourage and foster the teaching of the atmospheric sciences and related topics in Canada in grades K-12.

Material in the Project Atmosphere Canada Teacher's Guide has been duplicated or adapted with the permission of the American Meteorological Society (AMS) from its Project ATMOSPHERE teacher guides.

Acknowledgements

The Meteorological Service of Canada and the Canadian Meteorological and Oceanographic Society gratefully acknowledge the support and assistance of the American Meteorological Society in the preparation of this material.

Projects like PAC don't just happen. The task of transferring the hard copy AMS material into electronic format, editing, re-writing, reviewing, translating, creating new graphics and finally formatting the final documents required days, weeks, and for some months of dedicated effort. I would like to acknowledge the significant contributions made by Environment Canada staff and CMOS members across the country and those from across the global science community who granted permission for their material to be included in the PAC Teacher's Guide.

Eldon J. Oja
Project Leader Project Atmosphere Canada
On behalf of
Environment Canada and the Canadian Meteorological and Oceanographic Society

Published by Environment Canada
Cat. no. En56-172/2001E-IN
ISBN 0-662-31474-3

Project Atmosphere Canada

Contents

Introduction	2
Basic Understandings	3
Activity	7

MODULE 2

Weather Radar: Detecting Precipitation

Introduction	Basic Understandings	Activity
Page 2	Page 3	Page 7

INTRODUCTION

In many ways, modern meteorology originated during World War II. The extensive expansion of aviation at that time led to the formation of networks of balloon-borne instruments to take upper air measurements, the training of vast numbers of meteorologists, the expansion of weather observing locations around the world, the utilization of electronic computers, and the early development of rockets for launching satellites. It also was the impetus for developing radar, an acronym for Radio Detection and Ranging.

Radar began as a tool to detect aircraft. Radio waves in the microwave band beamed outward at the speed of light are reflected back from objects which they strike. One-half of the total time needed to travel to and return from the target multiplied by the speed of light determines the target's distance. Watching the target's movement for a few minutes then gives the target speed and direction in comparison to the radar station. This use of radar is basic to modern aircraft safety.

Early radar observations revealed echoes from "shower-clouds". The first significant use of radar to track weather occurred in 1942 in England when a thunderstorm with hail was followed for eleven kilometres. Today this is one of the major uses for modern radars, with sophisticated analysis of the return signal being performed to study and predict the development of hail and other forms of severe weather.

Precipitation is not the only target that reflects the radar beam. Almost all radars detect strong echoes that are created by stray signal reflections off trees, hills, buildings and even lakes in the vicinity of the radar site. These are known as "ground clutter" or anomalous propagation and can fool the meteorologist who is watching the radar if he or she is not careful. Ground clutter is usually caused by reflection from close-by targets, but is occasionally found at much longer distances if atmospheric conditions are right.

The post-war period saw the development of techniques to estimate precipitation rates from the strength of the echoes detected by the radar. The relationship between the types of echoes and the associated weather also became better known. The Meteorological Service of Canada developed a national network of radars to provide warning capability for severe thunderstorms, tornadoes, and hurricanes.

More recent development produced Doppler radar. Doppler radar is a system that sends out a series of rapid microwave pulses and measures the movement of precipitation droplets in the interval between the pulses. This enables the computer to reconstruct the internal air motion within and around the area of precipitation, and often provides vital clues about the nature and strength of the weather system. Meteorologists use Doppler radar to detect circulations inside thunderstorms that indicate the development of tornadoes, wind flow in a large winter storm, or damaging winds from a decaying thunderstorm. For hazardous weather situations such as hurricanes, tornadoes and thunderstorms, recognition of the developing wind pattern may allow warnings that can save lives.

Radar is one of science's major tools for observing weather and precipitation on a scale and time frame that makes it possible for the Meteorological Service of Canada to provide detailed information to the public when it is most needed.

BASIC UNDERSTANDINGS

1. Radar, short for Radio Detection and Ranging, transmits microwaves as a focussed signal designed to detect precipitation particles in the atmosphere (rain, snow, and hail).

2. Radar energy travels through the atmosphere at the speed of light in a narrow beam. The radar's antenna directs the beam around the horizon and up and down at various angles until most of the atmosphere within a given distance around the radar has been scanned.

3. After a radar sends out a signal, it "listens" for returning signals. A returning signal, called an echo, occurs when the transmitted signal strikes and reflects off objects (raindrops, ice, snow, trees, buildings, mountains, birds, or even insects) within its path.

4. Part of the reflected signal is received back at the radar. The display of the strength of the signals returned from echoes is called *reflectivity*. Reflectivity can be correlated to the intensity of the echo and in turn, the amount and type of precipitation that is falling.

5. The time from transmission of a signal to the receipt of an echo determines the distance to a target. The direction the antenna is aimed determines the direction to the target.

6. Modern weather radars can also evaluate the returned signal to detect target motion toward or away from the radar.

7. A computer attached to the radar stores the values of reflectivity from each distance and direction as the radar beam spirals around the horizon and up through several elevation angles until a volume of the sky is covered for about 350 kilometres around the site.

8. Selections of the stored reflectivity values can be displayed on a monitor to show a horizontal view of the atmosphere at any level or a vertical slice up thorough the atmosphere in a particular direction.

9. The reflectivity data generally indicate only those cloud particles large enough to fall as precipitation. Not all of this precipitation will reach the ground, as it is common for falling rain to evaporate after it leaves the cloud.

10. Each horizontal image can show reflectivity for i) any elevation angle, ii) at a constant height, or iii) the greatest value at that location from any elevation. Each vertical image can show the height of echoes along any direction.

11. Since the radar beam is normally bent downward by the atmosphere as it travels, radar views generally extend far beyond the visual horizon.

12. The range of horizontal coverage depends on atmospheric effects, the curvature of the earth, and the radar beam characteristics.

13 Radar reflectivity values are displayed on screen by assigning colours to indicate precipitation *intensity* ranges.

14. These intensities can be related to precipitation *amounts* over a period of time by collecting and adding individual radar images.

15. The computer connected to the new weather radars can alert operators for patterns that may indicate hail, flash flooding and tornadoes, or the operators may detect these patterns themselves.

16. Successive radar images can be animated to illustrate storm development, structure, and movement.

17. Precipitation echoes generally occur in cells, lines, or areas. Regions of most intense precipitation are usually in the centre of the echoes.

18. Snow returns a weak echo, rain a stronger echo and wet hail a very strong signal. Water droplets comprising clouds are usually too small to be detected by normal radar operations.

19. Now radars are so sensitive that even dust, birds, insects and sudden changes in atmospheric temperature and humidity can be seen.

20. As noted above, not all echoes are caused by meteorological phenomena. Buildings, hills and trees near the radar transmitter may return a signal. As a result, a reflectivity pattern of strong, <u>non-moving</u> echoes is often displayed near the radar site. These are called *ground clutter* or *anomalous propagation.*

21. The shape, size, and strength of a radar echo can lead to the detection of hazardous weather situations, especially those involving thunderstorms.

22. Individual thunderstorm cells may exist along cold fronts or squall lines. The cells may join to form clusters of severe thunderstorms. Patterns such as these tend to show strong reflectivities indicating possible heavy rains or hail.

23. Tornadoes may show hook-shaped echoes or pendants in reflectivity displays.

24. Vertical slices of the atmosphere constructed from the radar scans are very useful because they show the pattern of reflectivity through the depth of the atmosphere. One of the elements revealed by such a display is the vertical extent of thunderstorms; the highest (or biggest) thunderstorms are most likely to have severe weather such as hail or tornadoes associated with them.

25. The spiralling bands of heavy thunderstorms within hurricanes show up clearly in reflectivity patterns because of the huge amount of precipitation they contain.

26. Occasionally a band of very high reflectivities will appear on the radar. This is called "bright banding" and is related to an area in the clouds where snow is melting into rain. The melting/wet snow has a much higher reflectivity than snow and a higher reflectivity than rain. The "bright band" occurs at the altitude where the temperature is around 0 degrees Celsius, i.e. temperature in the upper reaches of the cloud is below freezing and temperature of the cloud closer to ground is above freezing. The

weather forecaster must be aware of this process so as not to confuse the bright band with an intense area of precipitation.

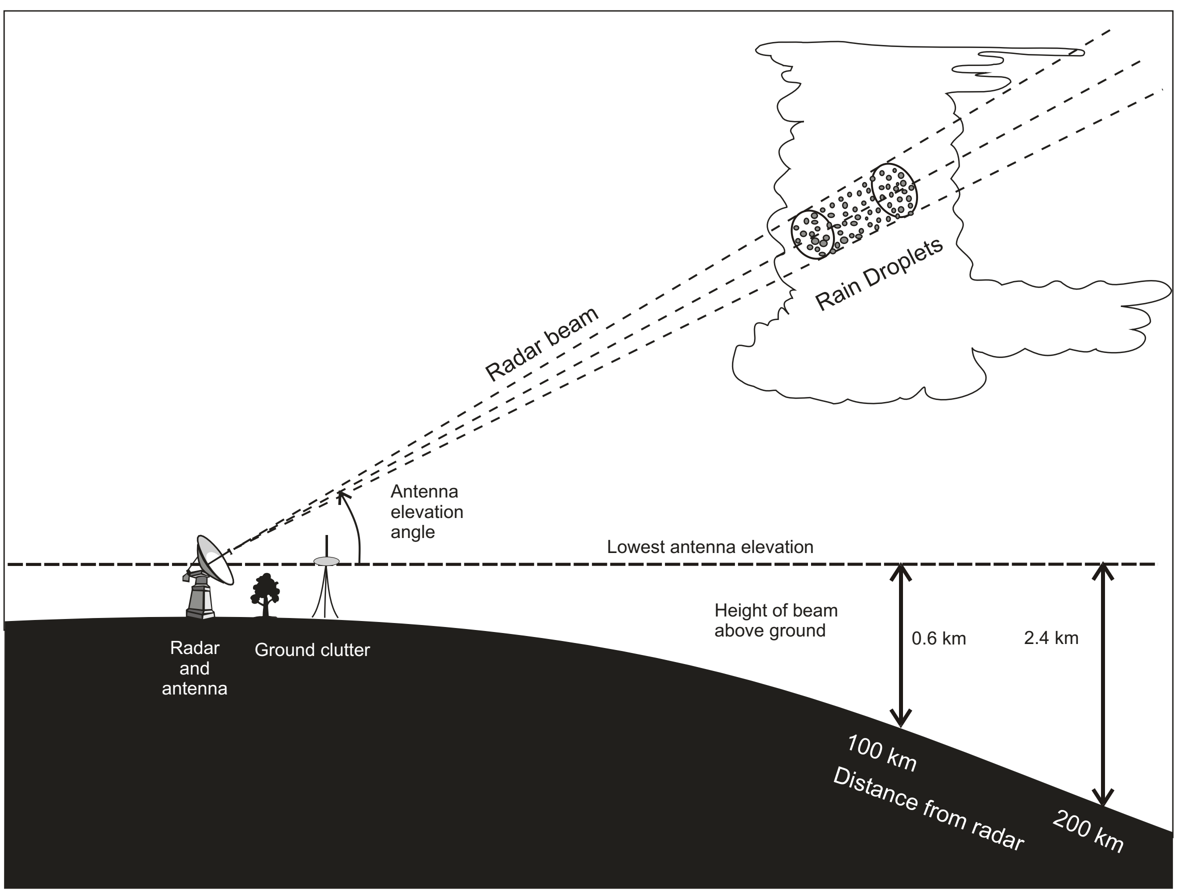
27. Radar displays require careful interpretation. For example, the radar beam, usually less curved than the Earth's surface, may pass over the tops of more distant targets. Low level precipitation (especially snow) is often unseen beyond a certain distance (100 km or so) because it is below the radar beam.

28. Heavy precipitation between the radar site and distant targets can weaken the radar signal so echoes of rain areas further away can be distorted or undetected. This is caused by the absorption and scattering of the radar beam by the intervening precipitation.

29. Unusual temperature and humidity patterns may distort echoes and give false impressions of their size and shape.

30. The radar beam spreads out as distance from the radar increases. This can cause distortion in the shapes and sizes of echoes, making distant objects appear weaker and larger than in reality.

31. As the distance between the radar site and the precipitation increases, the ability of the radar to accurately detect the occurring precipitation decreases.



Radar scans this entire volume by raising and lowering the beam as the antenna rotates.