Project Atmosphere Canada

MODULE 3

Weather Radar: Detecting Motion

Teacher's guide

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

Environment Canada
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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.

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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.

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

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INTRODUCTION

When weather threatens, meteorologists can track storms by radar. Weather radar provides information on storm size, shape, structure, intensity, and direction of movement. With the advent of Doppler radar, motions inside a storm can also be determined. For instance, air motions that would indicate possible tornado development can be detected. The capability of sensing motion is made possible by the Doppler effect. The Doppler effect is the change in the frequency of sound or radiant energy waves reaching a receiver when the receiver and source are in motion relative to each other.

Examples of the Doppler effect include the easily heard drop in pitch as a train blowing its whistle or a car with its horn blowing passes by the listener. The change in pitch occurs since a sound source that is moving towards a listener causes a higher frequency sound to be heard than if the source were stationary. A sound source moving away from the listener lowers the frequency. The same effect occurs with light, causing what is known in astronomy as the "red shift". The Doppler effect is used in many modern technologies. Radar guns, for example use the Doppler effect to measure the speed of vehicles or other objects such as baseballs.

Similarly, the same effect on frequency takes place when a radar signal is reflected from a target, such as a cluster of raindrops. If the raindrops have motion towards the radar, the reflected signal returned to the radar has a higher frequency than if the target were motionless. If the raindrops have motion away from the radar, the returned signal's frequency is lowered. How much the frequency is raised or lowered leads to a determination of how fast the reflecting targets are moving directly towards or away from the radar. Weather radars, which can detect such motion, are called Doppler radars.

In the atmosphere, the motion of precipitation is partly due to the winds within the clouds. Therefore, some of the air motions within the storm can be inferred. For hazardous weather situations such as hurricanes, tornadoes, and thunderstorms, the developing patterns of motion may make it possible to issue warnings that can save lives.

BASIC UNDERSTANDINGS

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

2. Weather radars are designed to emit microwave signals at a particular frequency - the number of waves passing a point per unit time.

3. 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 sky within a given distance around the radar has been scanned.

4. 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, birds, and insects) within its path.

5. 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 echoes.

6. 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. The elevation angle of the antenna plus the distance to the target determines the target height.

7. Modern weather radars can also evaluate the returned signal to detect target motion toward or away from the radar using the Doppler effect.

8. Higher frequency signals are received when the target has motion towards the radar. Lower frequencies are received when the target has motion away from the radar.

9. The difference in the frequencies of transmitted and returned signals is directly proportional to the speed of the target directly towards or away from the radar.

10. Stationary targets, e.g. buildings, trees or mountains or targets moving perpendicular to the radar beam, e.g. precipitation moving from the south would not be detected when the radar beam is aimed east or west, return at the same frequency as the transmitted signal.

11. The variation of speeds toward and away from the radar detected in a target volume give a measure of the turbulence in the atmosphere around the target.

12. 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 220 kilometres around the site.

13. 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 through the atmosphere in a particular direction.

14. The reflectivity data generally indicate only those cloud particles large enough to fall as precipitation.

15. 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.

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

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

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

19. These intensities can be related to precipitation amounts over a period of time.

20. Radar velocities are colour coded to commonly display incoming speeds (targets moving directly towards the radar) as shades of blues and greens and outgoing speeds (targets moving directly away from the radar) as shades of reds and oranges.

21. The computer connected to the new weather radars can alert operators to patterns that may indicate hail, the potential for flash flooding and tornadoes.

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

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

24. 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.

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

26. As noted above, not all echoes are caused by meteorological phenomena, even buildings, hills and trees near the radar transmitter may return a signal. As a result, a reflectivity pattern of strong, non-moving echoes is displayed near the radar site. This is called ground clutter.

27. The shape, size, structure and strength of a radar echo can lead to the detection of severe weather situations.

28. Individual thunderstorm cells may exist along fronts or squall lines. The cells may join to form clusters of severe thunderstorms. These patterns tend to show strong reflectivity indicating possible heavy rain or hail.

29. Doppler weather radars can detect the temperature and humidity change along the leading edge of thunderstorm outflow winds. Colliding outflows from several thunderstorms often lead to new thunderstorm development.

30. Aviation hazards, such as low-level wind shear (abrupt changes of wind speeds or directions at low levels) may also be detected in velocity displays near the radar site.

31. Tornadoes may show hook-shaped echoes in reflectivity displays, while velocity images show strong, circular, localized areas of high wind speed towards (green) and away (red) from the radar.

32. The vertical slices of the atmosphere are very useful because the greater the height of thunderstorms, the more intense the weather associated with them is likely to be.

33. The spiraling bands of heavy thunderstorms within hurricanes show up clearly in reflectivity patterns.

34. 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.

35. 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.

36. Unusual temperature and humidity patterns may distort echoes and give false impressions.

37. The radar beam spreads out as distance from the radar increases. This can cause distortion in the shapes and sizes of echoes.

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

Recent weather maps, forecasts, satellite images and radar images from across Canada are available on the internet and can be viewed through Environment Canada's web site at:

http://weatheroffice.ec.gc.ca