Project Atmosphere Canada

TEACHER'S GUIDE

Project Atmosphere Canada

MODULE 1

Hazardous Weather

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

MODULE 1 Hazardous Weather

OVERVIEW

Weather is variable, from the gentle breezes of a balmy evening to the heavy wind and rain of a late afternoon thunderstorm. Hazardous weather, such as thunderstorms, hurricanes, and winter storms — the subjects of this guide — can cause property damage, bodily injury or even death. With the necessary information, proper preparation, and sensible reactions, most people can protect themselves and to some extent their property from the ravages of most kinds of hazardous weather.

Hazardous weather may affect anyone, anywhere in the world at any time. The table below shows the annual approximate numbers of various types of severe weather for several countries world-wide. Canada is certainly no slouch when it comes to dramatic weather.

Hazardous weather in Canada results in dozens of lives lost each year with total property losses typically reaching into the hundreds of millions of dollars. These are ample reasons why everyone should keep track of the weather and understand what to do if severe weather occurs.

Environment Canada has the responsibility of warning people in this country of the possibility of a severe weather-related event. Warning programs have been developed to inform the public of the weather hazard and to help initiate appropriate adaptive measures. Prompt response to such information can save lives, reduce injuries, and lessen property damage.

Relative Comparison of Weather Risks **

Country	Severe Thunderstorms	Tornadoes	Severe Winter Storms	Hurricanes Tropical Cyclones Typhoons	Flash Floods
(per year)					
U.S.A.	10,000	1000	10	10	1000
Australia	500	<100	0	10	100
Canada *	1000	80	20	2	40
France	100	<10	10	0	10
Germany	100	<10	10	0	10
Japan	500	<10	10	10	50
United Kingdom	100	10	10	0	10
China	10,000	<10	5	20	500

** Data courtesy of NOAA, NWS

* Data courtesy of EC-MSC

Cautionary Note: *Due to the potential for significant variations in the criteria and definitions of each weather risk used by the various countries a linear comparison of the data in the table above cannot be made.*

Note that the U.S.A., Canada and Australia get many more tornadoes than other parts of the world. Warm humid air at low levels and much drier air aloft that cools off rapidly with height are key ingredients. Countries with very dry interiors and that have frequent flows off very warm oceans / seas meet these criteria. The Gulf of Mexico and the dry western plains are the factors that give Canada / U.S. more tornadoes.

BASIC UNDERSTANDINGS Thunderstorms

Thunderstorm Development

1. A thunderstorm is a localized storm cloud producing thunder, lightning and often gusty winds, heavy rain and hail.
2. Thunderstorms occur when warm, humid air is lifted by surface heating, upslope flow, or a front.
3. Most thunderstorms are composed of individual cells which exhibit three stages. These cells start with what is called the cumulus stage. It is characterized by upward motion. Unstable moist air rises and cools and water vapour condenses to form cumulus clouds.
4. In the mature stage of thunderstorm cell development, the cloud reaches its maximum vertical development and falling precipitation creates a downdraft. This stage is associated with thunder and lightning as well as the possibility of severe weather.
5. A mature thunderstorm cell is characterised by both updraft and downdraft. As the upward motion builds the cloud, it may produce an overshooting top, which penetrates into the stratosphere, and forms an anvil cloud blowing downwind due to the strong winds in the upper atmosphere.
6. The downward-moving air caused by falling precipitation results in the outflow spreading away from the cloud base at the Earth's surface. This sometimes results in a squall line forming as much as three hundred kilometres ahead of the front.
7. The dissipating stage of a thunderstorm cell occurs when the precipitation-induced downdraft cuts off the supply of warm humid air and the cloud eventually sinks and evaporates away.
8. The typical thunderstorm cell exists for about thirty minutes, although some may last longer.
9. The gust front is the boundary separating the cool air outflow from the warm, moist air feeding the updraft of the thunderstorm cell. As the gust front forms it may result in severe localized downdrafts called downbursts or microbursts. The rapid changes in wind speed and direction of these downdrafts can be deadly threats to aircraft.

Thunderstorm Forecasting

10. Severe thunderstorms commonly threaten life and property with lightning, strong gusty winds, heavy rain or hail.
11. If thunderstorms occur in areas with restricted drainage, flash floods may result.
12. Thunderstorms may also generate funnel-shaped tornadoes, with their violent rotating winds and hazardous pressure drops.
13. Weather satellites and radars have greatly improved the observation of thunderstorms. Such improvements are used to analyze storm structure and provide advanced warning to minimize the danger associated with such storms.
14. Weather satellites enable forecasters to observe from above the initial development, movement, and severity of thunderstorms.
15. Infrared satellite imagery enables meteorologists to identify the most intense part

of the storm by observing the coldest cloud top temperatures, which coincide with the region of strongest updraft in the cloud cluster.

16. With radar, the meteorologist can determine where the storm is moving, hence where the weather is most likely to cause damage.

17. Doppler radar systems enable the estimation of actual air motion within the storm by measuring the phase shift of the radar return from the wind-driven precipitation.

18. Environment Canada issues a severe thunderstorm watch when there is a threat of a severe thunderstorm developing for a specified area and time.

19. A severe thunderstorm warning is issued when a severe thunderstorm is imminently expected to occur or has actually been observed in that area.

20. The hazardous weather associated with thunderstorms can develop very rapidly and with little advance warning. Consequently, a vigilant watch and awareness of local and broad-scale weather conditions is essential to ensure adequate preparedness and response.

NARRATIVE Thunderstorms

What is a thunderstorm?

The thunderstorm is usually a storm composed of one or more cells. Each cell is a few kilometres in diameter and develops from clouds that grow rapidly upward and produce thunder and lightning. A thunderstorm often brings heavy precipitation, such as rain or hail, as well as strong gusty winds. Sometimes thunderstorms can become quite violent and may generate flash floods or tornadoes.

What causes thunderstorms?

Thunderstorms can occur when warm, humid air is lifted upward. The air rises either by mechanical lifting, such as when a cold, dense air mass undercuts warm, moist air, or by thermal lifting due to solar heating of the Earth's surface. The rising air expands and cools, and water vapour contained in the air condenses to form cloud water droplets. As the air continues upward, individual cloud towers can become a towering thunderstorm cloud. Once an individual thunderstorm cell reaches maturity, downdrafts, caused by falling precipitation, eventually destroy the cloud.

Normally a thunderstorm is composed of more than one cell, and as one cell dies, usually within twenty to thirty minutes, another may develop nearby.

Stages of a Thunderstorm

Thunderstorms have three stages of development:

Cumulus Stage — initial stage of cloud development, as warm, humid air rises and water vapour condenses to form the cloud; characterized by upward motion throughout the cloud

Mature Stage — cloud reaches maximum vertical development, precipitation starts to fall, creating a downdraft; this is the stage with the most violent weather and the occurrence of thunder and lightning

Dissipating Stage — precipitation-induced downdraft is observed throughout the cloud; the cloud sinks and evaporates away.

The typical thunderstorm cell exists for about thirty minutes, although some may last longer.

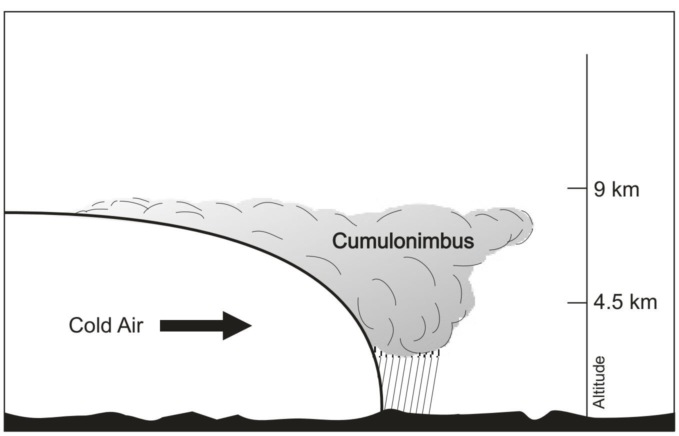


Illustration of warm, moist air being mechanically lifted over a cold front, resulting in the formation of cumulonimbus clouds (thunderstorms)

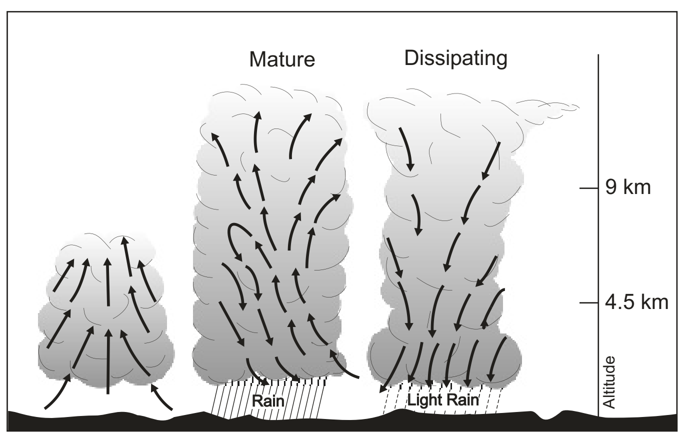


Illustration of the three stages of development of a thunderstorm: cumulus, mature and dissipating stages. Arrows denote motions within the thunderstorm.

Structure of a Thunderstorm

The figure below displays a mature thunderstorm, which is composed of:

Updraft — the region of upward motion responsible for building the cloud

Overshooting Top — the uppermost part of the cloud above the updraft core which may penetrate into the stable stratosphere above

Anvil — the top of the cloud blowing downwind due to strong winds at higher altitudes

Downdraft — downward-moving air associated with falling precipitation

Outflow — downdraft air spreading away from the cloud base as it reaches the Earth's surface below

Gust Front — the boundary separating the cool air outflow and the warm, moist air feeding the updraft

Weather Accompanying Thunderstorms

Ordinarily, the most severe thunderstorms form along narrow bands called squall lines, in the warm, moist air ahead of an approaching cold front.

Examples of weather accompanying thunderstorms include

Lightning — the visible electrical discharge which occurs in mature thunderstorms due to large voltage differences within the cloud, between clouds, or between the cloud and the ground below. The heat produced by the stroke causes the air to expand explosively, creating a shock wave which is heard as thunder. Lightning kills an average of 7 people every year in Canada.

Damaging winds and wind shear — the cool air outflow from a thunderstorm, which may achieve wind speeds great enough to damage objects in its path. Wind shear is an abrupt change in the wind (speed or direction) with distance. Strong wind shears exist between the updraft and downdraft areas.

Hail — particles of ice, ranging in size from a pea to a softball or larger, that form in the updraft of thunderstorms as liquid water drops are forced upward to regions of freezing temperatures. Hail storms cause hundreds of millions of dollars in damage to crops and property annually in Canada.

Flash Floods — floods that arise rapidly with little or no advance warning. Such flooding often is associated with slow-moving thunderstorm systems bringing heavy rains to a limited area, especially in regions that are unable to handle the volumes of water because of terrain features (such as canyon walls and hills), soil composition or improper drainage. Lives are occasionally lost to flash floods in Canada.

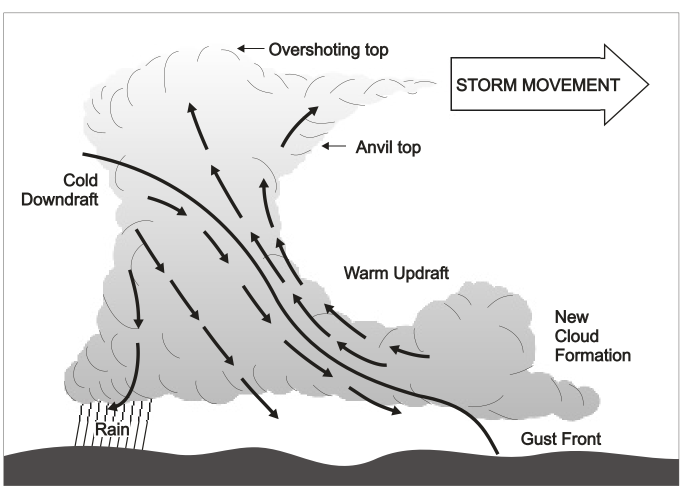
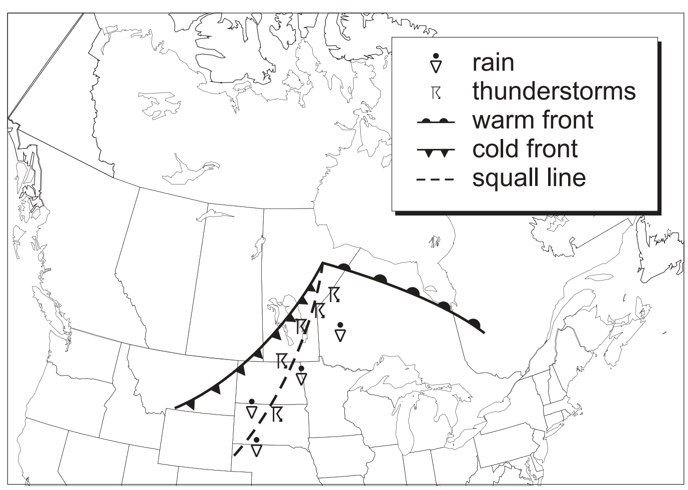


Illustration of a mature thunderstorm. Arrows denote direction of air flow in and around the thunderstorm.



Squall Line of Thunderstorms With Associated Warm & Cold Fronts.

Tornadoes — violent, rapidly rotating columns of wind that descend from the bases of thunderstorms and come in contact with the Earth's surface. These strong, rotating winds can cause considerable damage and loss of life.

Severe Thunderstorm Detection and Forecasting

Technology has greatly improved the ability to observe and predict the occurrence and movement of thunderstorms. Such advances as weather satellites and Doppler radars provide valuable information about where thunderstorms might develop and move, which greatly assists in providing adequate warning to minimize the damage and risk to people associated with such storms.

Tools for Observing Thunderstorms

Weather satellites enable forecasters to observe the initial development of cumulonimbus clouds, providing a "birds-eye' view of the location of such storms as they build upward though the atmosphere. Infrared satellite imagery enables meteorologists to identify the most intense part of the storm. For example, the coldest cloud top temperatures usually coincide with the region of strongest updraft in the thunderstorm.

Weather radar is perhaps the best tool for tracking a severe thunderstorm. The radar emits microwave energy, which produces an image of the interior of the storm. The radar beam strikes precipitation particles, which reflect energy (return signal) back to the radar antenna with an intensity proportional to the strength of the storm. In the figure on the right, the contoured area corresponds to the return signal from an approaching storm. By evaluating and tracking the return signal, the meteorologist is able to determine where the storm is moving, hence where the weather is most likely to cause damage.

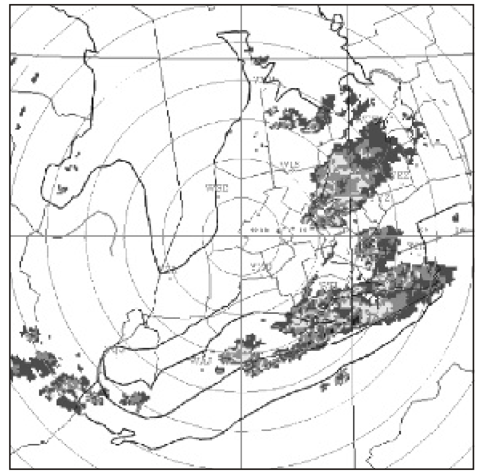


Illustration of Southwestern Ontario Radar showing an area of showers and thunderstorms

Watches and Warnings

Thunderstorms can produce a variety of severe weather events that can damage property or cause bodily injury. Environment Canada issues severe weather watches and warnings to advise the public of the approach of a severe thunderstorm and to minimize damage to property and loss of life.

A severe thunderstorm watch is issued when there is a threat of a severe thunderstorm developing in a specified area over a certain period of time.

A severe thunderstorm warning is issued when a severe thunderstorm is imminently expected to occur or has been observed (visually or by radar) in a given location. One should take immediate steps to avoid imminent danger.

Hazardous weather associated with thunderstorms can develop very rapidly. Events such as flash floods or tornadoes may occur with little advance warning. Thus, a vigilant watch and awareness of local and broad-scale weather conditions is essential to ensure adequate preparedness and response to such weather hazards.

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

ACTIVITY Thunderstorms

Suggested Activities

1. Which country listed on page 2 has the greatest variety of hazardous weather and need for timely weather forecasts, watches and warnings?
2. Of the threats listed, which is of greatest concern in your local area? What should you, your family, and your community do to try to adequately prepare and respond to the threat or threats?
3. What was the most recent hazardous weather you and/or your community faced? What was done or could have been done to lessen its effects?
4. Does your family, school, and community have a plan for all types of hazardous weather that might occur? What has been done or should be done? Who should do it?
5. What are the basic safety rules individuals should follow in facing the different kinds of hazardous weather? (Contact Environment Canada or Emergency Preparedness Canada for specific information on safety rules and hazardous weather preparedness and response.)

ACTIVITY Tracking the Grand Valley Tornado

After completing this exercise, you should be able to:

- describe the motion of a severe tornado, including the width of its path, average speed and direction
- list appropriate actions to take to save lives when tornadoes threaten, including those that address the special threats of mobile-home living

Introduction

During the late afternoon and evening of May 31 1985 a powerful cold front moved across Southern Ontario and the Ohio Valley. A total of 88 people were killed by some 40 odd tornadoes. The figure on page 10 shows the track of all these storms.

In Canada there were 9 separate tornado tracks. The map on page 11 details the 3 largest storms. The northern track through Barrie killed 8 people and caused very extensive damage.

The middle track known as the Grand Valley-Tottenham storm killed 4 people and is the longest tornado track on record in Canada.

The Grand Valley and Barrie tornadoes both reached F4 on the Fujita scale. Damage brought by tornadoes is ranked by the Fujita scale which runs from F0 with winds up to 120 km/h with light damage possible, to F5 with winds in the neighbourhood of 500 km/h and damage described as "incredible" with almost total above-ground destruction. F4 storms have wind speeds up to 400 km/h and can nearly flatten even the most well built home.

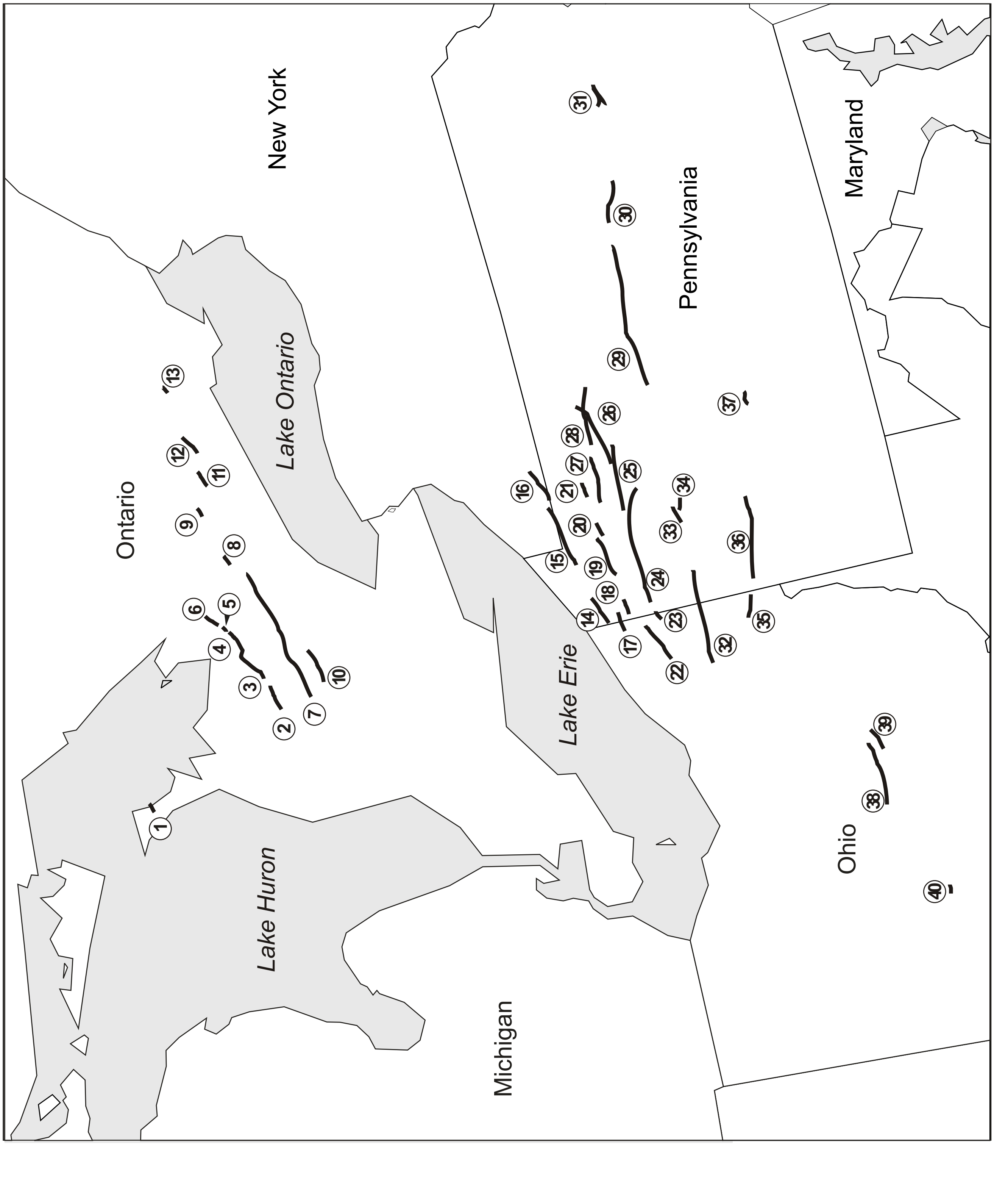
Tornadoes are dangerous storms. This activity will demonstrate some of the characteristics of severe tornadoes and appropriate preparedness and response actions you should make when the threat of tornadoes occurs.

Activity

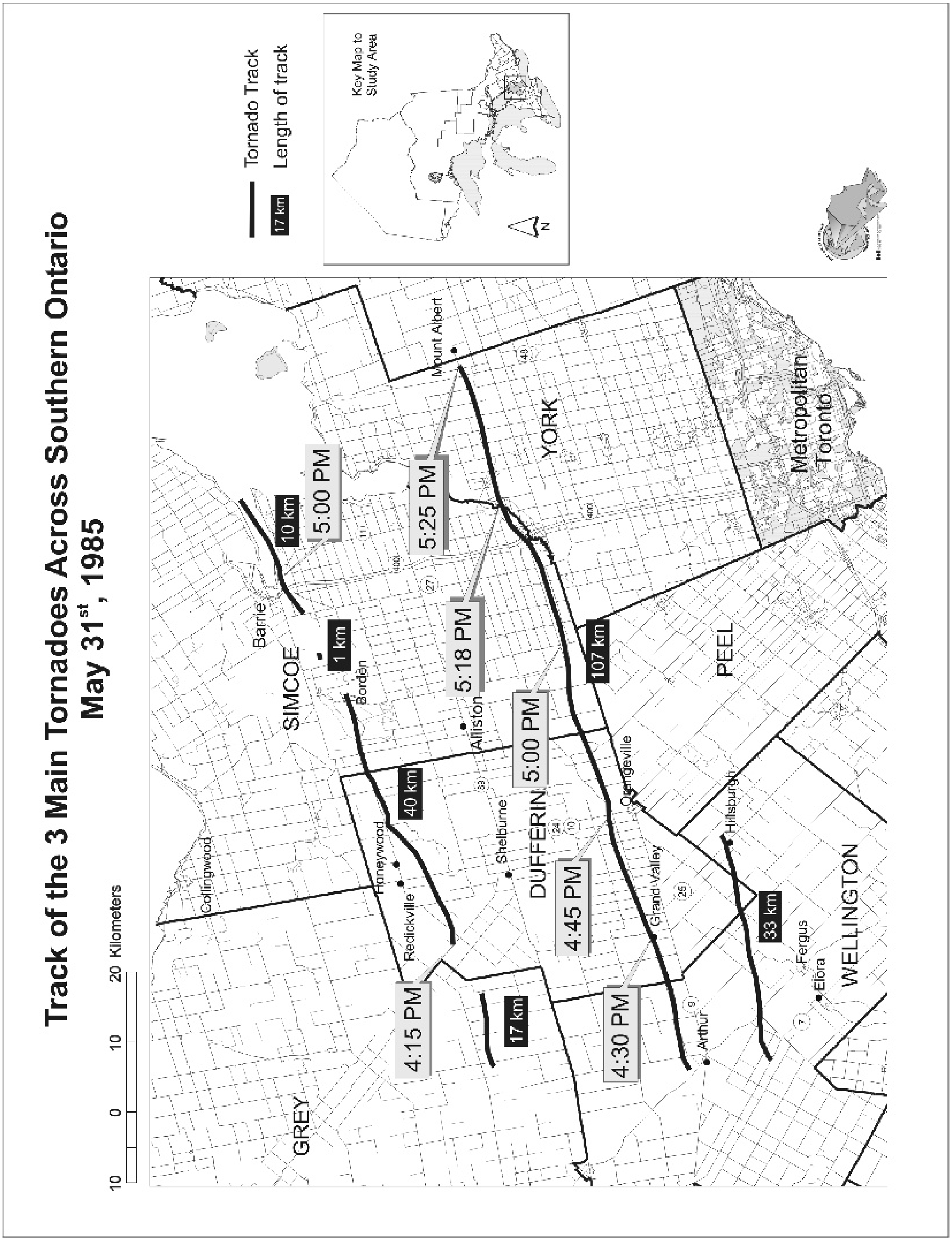
Attached is a map of the 3 longest tornado tracks from May 31 1985. Concentrate on the longest track… the Grand Valley tornado

Answer the following questions based on the map information.

1. For how long a time period was the tornado on the ground?
2. Towards what general direction (E.g. Southeast, Southwest, Northwest, Northeast) did the tornado move?
3. What was the length of the tornado path?
4. What was the average ground speed of the tornado?
5. The width of the Grand Valley tornado was consistently around 200 metres. What was the total area damaged by this tornado.
6. Looking at these 3 tornadoes what was the total area damaged. Significant tornado damage was observed in 5 counties. As a rough guess what was the percentage of the total area of these counties damaged by tornadoes.
7. Use safety rules and information provided by the Environment Canada or Emergency Preparedness Canada to determine where you should take shelter when a tornado threatens. What special precautions should mobile home parks and residents take to reduce severe weather threats?



Track of all tornadoes associated with the May 31, 1985 outbreak



Track of the 3 main tornadoes across Southern Ontario on May 31 1985. The middle track is the Grand Valley tornado

ACTIVITY Answer Key

Activity - Tracking the Grand Valley Tornado

1. About 1 hour.
2. East-northeast.
3. 105 km
4. Close to 100 km/h
5. 100 km/h long x 200 m wide = 20 square km
6. About 50 or 60 square km