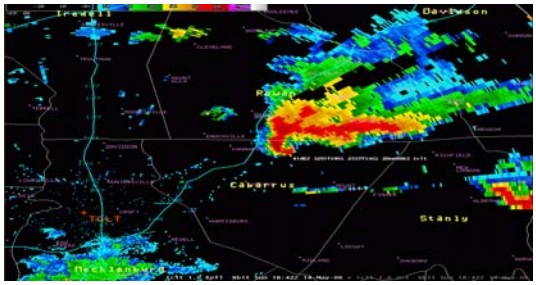

A2 Geography

Tornadoes – How do they form and in what ways do they represent a hazard to people?

Learning Objectives:
To be able to describe the conditions leading to tornadoes and the ways they represent a hazard to people.

Curriculum Links:
OCR Advanced GCE in Geography H483: The study of the development of tornadoes to illustrate:

- The atmospheric and surface conditions that give rise to their development
- An understanding, with examples, of how such systems develop
- Through examples, the hazards they present to particular areas and the impacts that these hazards can have.

Edexcel Advanced Subsidiary GCE in Geography Unit 2 6GE02: Students need to learn "There are a wide variety of extreme (severe or unexpected) weather phenomena". Define and examine the nature and distribution of different types of extreme weather such as ....tornadoes.

Materials: Graph paper, A4 plain paper. If making a water tornado – Jam jar with lid, water, vinegar, clear liquid dish soap, glitter

Suggested activities: **Following the PowerPoint**
Starter – Q - What do the photos show? A - Tornadoes

Definition of a tornado

Tornadoes do not just form in the USA. Show animation of confirmed UK tornadoes and explain that the UK gets on average 50 tornadoes a year but most are weak and insignificant. Next slide shows a world map of where tornadoes are more likely to occur.

Show graphic of US and outlined area showing tornado alley where tornadoes most frequently occur. Also map showing confirmed tornado tracks in US from 1950 to 2004.

At this point **students could plot a graph of tornado occurrence per month** (data in figure 4) and **tornado occurrence per hour in the day** (figure 5). This will identify that tornadoes are most frequent in spring months and in the afternoon. They may then deduce that daytime heating and moisture is required.

Next you can use the slides to explain the process of supercell thunderstorm formation and tornado formation. The animation which is a hyperlink on slide16 is good. Figure 6 below is a **cut and paste activity** students can use to make notes. **The stretching of a vortex increasing rotation can easily be demonstrated in a sink with a plug**.

A diagram of a supercell is given (figure7). **This can be handed out or a drawing game played**. Divide the class into groups of 3 or 4. Have the diagram printed at the front of the room but hidden from sight. Allow each team to send one person to the front to study the diagram for 30 seconds. They must then go back to the group and either draw the diagram or describe to the others what to draw. This process is then repeated with different group members until one group claims they have finished. Teacher then judges the most accurate diagram.

Introduce the Enhanced Fujita Scale. **There is a link to an online game**. Pictures of tornado damage are given and using the descriptions students have to decide on the tornado rating.

May3rd 1999 Oklahoma City Case Study

-Watch YouTube video showing the EF5 tornado on 03-05-1999 in Oklahoma City.
-Next two slides give stats and a satellite image of the event.
Students can **mind map social/economic and environmental issues associated with the tornado outbreak**. A few are summarised on the following slide.

A brief overview of the US Watch/Warning system is given for information on how people are adapting to living in a region which encounters frequent severe weather.

Plenary – Refer back to lesson objectives – Can students now answer the questions? Hot seat game – Students each write down a question about today's lesson. A volunteer comes to the front and answer the questions. When they give an incorrect answer they swap seats with the questioner. A prize could be awarded to the student answering the most correct questions.

Suggested homework – Research the Birmingham, UK tornado 28th July 2005 or Greensburg, Kansas May 4th 2007 for another classic US tornado.
Extension – Research in detail why the USA gets more tornadoes and why they are generally more violent than anywhere else on Earth. OR discuss the pro's and con's in living in a region which experiences extreme weather – should we continue building there?

Extra activity - Making a tornado

What you will need:

- Jam jar with lid
- Water
- Vinegar
- Clear liquid dish soap
- Glitter

Make it happen!

1. Fill the jar 3/4 full of water.
2. Put in one teaspoon of vinegar and one teaspoon of dish soap.
3. Sprinkle in a small amount of glitter.
4. Close the lid and twist the jar to swirl the water, and then stop, and see a vortex like a tornado form in the centre of the jar.

Resources:

Figure 4 – US tornadoes by month – NOAA

Month	Average number of tornadoes 2003-2005
Jan	20
Feb	22
Mar	54
Apr	109
May	180
Jun	171
Jul	96
Aug	60
Sep	41
Oct	29
Nov	30
Dec	17

Figure 5 - No. of tornadoes in St Louis warning area - NOAA

Time of day	No. of tornadoes in St Louis warning area
00:00:00	7
01:00:00	4
02:00:00	9
03:00:00	0
04:00:00	1
05:00:00	1
06:00:00	1
07:00:00	1
08:00:00	0
09:00:00	1
10:00:00	3
11:00:00	10
12:00:00	2
13:00:00	6
14:00:00	7
15:00:00	13
16:00:00	15
17:00:00	23
18:00:00	18
19:00:00	16
20:00:00	9
21:00:00	9
22:00:00	10
23:00:00	2

Figure 6a - Answers

A surface low pressure system develops to the East of the Rocky Mountains
This causes warm, moist air to be dragged up from the Gulf of Mexico, warm/hot dry air from the desert states and cold, dry air down from the Rocky Mountains
These three air masses converge over the Southern States (e.g. Texas and Oklahoma) and cause instability in the atmosphere to develop.
Convection occurs during the peak heating time of the day (mid-afternoon). This results in cumulonimbus clouds developing.
If the wind varies in direction and strength with increasing height (this is called wind shear), then the updraft (rising air) and downdraft (sinking air containing rain and hail) will separate. The updraft may also rotate. We now have a supercell thunderstorm.
This rotating updraft is called a mesocyclone and can be seen using Doppler Radar. If this is seen then a Tornado Warning is issued for the county under the supercell thunderstorm.
If warm moist air continues to flow into the mesocyclone (rotating updraft) then it can become stretched, becoming thinner and rotating more quickly (just like water down a bath plug hole).
The stretched mesocyclone can begin to descend to the ground. The air pressure inside it starts to fall rapidly and so water vapour cools, condenses and therefore becomes visible. A funnel cloud has formed.
If this continues to descend and touches the ground then we have a tornado. Wind speeds can vary from a few mph to over 300mph. Wind speeds are estimated from Doppler Radar and damage surveys by referring to the Enhanced Fujita Scale (EF Scale)

Figure 6b - Student Copy

The stretched mesocyclone can begin to descend to the ground. The air pressure inside it starts to fall rapidly and so water vapour cools, condenses and therefore becomes visible. A funnel cloud has formed.
Convection occurs during the peak heating time of the day (mid-afternoon). This results in cumulonimbus clouds developing..
If warm moist air continues to flow into the mesocyclone (rotating updraft) then it can become stretched, becoming thinner and rotating more quickly (just like water down a bath plug hole).
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If the wind varies in direction and strength with increasing height (this is called wind shear), then the updraft (rising air) and downdraft (sinking air containing rain and hail) will separate. The updraft may also rotate. We now have a supercell thunderstorm.
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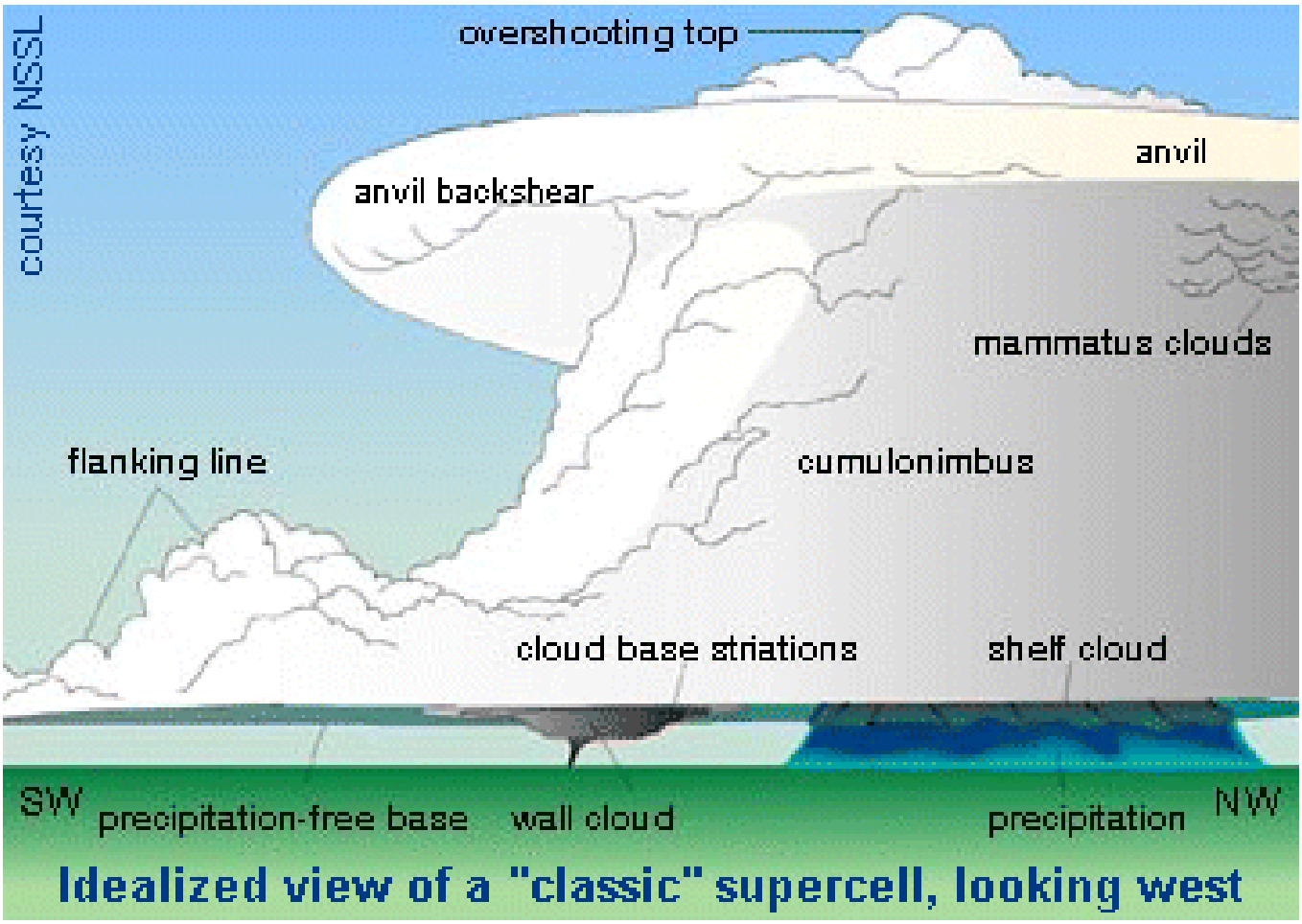
This causes warm, moist air to be dragged up from the Gulf of Mexico, warm/hot dry air from the desert states and cold, dry air down from the Rocky Mountains
A surface low pressure system develops to the East of the Rocky Mountains
This rotating updraft is called a mesocyclone and can be seen using Doppler Radar. If this is seen then a Tornado Warning is issued for the county under the supercell thunderstorm.

Figure 7 – Diagram of a supercell – National Severe Storms Laboratory (NSSL)



Background Information:

A tornado is defined as 'A rotating column of air ranging in width from a few yards to more than a mile and whirling at destructively high speeds, usually accompanied by a funnel-shaped downward extension of a cumulonimbus cloud'[1]. Tornadoes have likely occurred in all countries of the world but are most common in North America and especially the central area of the US know as Tornado Alley where the geography of the land is just right for formation. However, it is a lesser known fact that the UK experiences more tornadoes per land area than any other country in the world[2] with around 50 per year. Tornadoes here though are usually weak and only cause slight damage to roofs and trees.

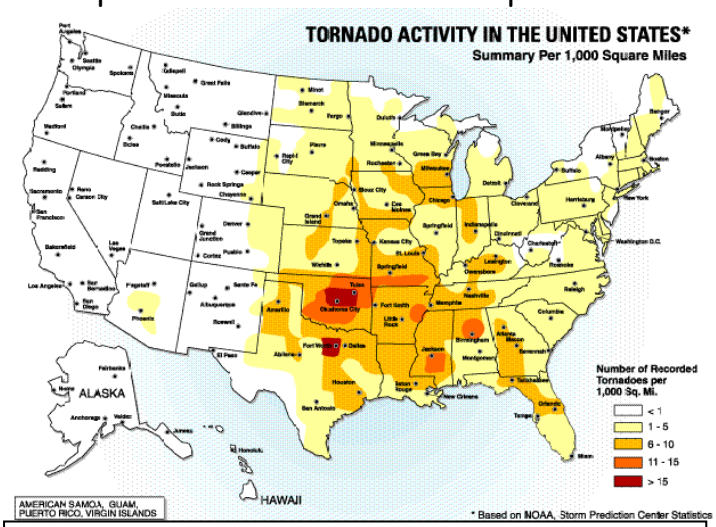


Figure 1 - Map of tornado activity in the US – Courtesy of FEMA

Tornado Alley is an area of the US stretching from Nebraska in the North to Texas in the South and across to Tennessee in the East (see figure 1). However, as shown from Figure 2 tornadoes can and do occur outside of this area. So why is this area hit so hard?

Tornadoes form from the bases of the most violent thunderstorms on Earth known officially as supercells. For these to form there needs to be instability caused by warm moist air being overridden by cool, dry air. The Gulf of Mexico gives an unlimited supply of warm, moist air and the desert states (e.g. Arizona and New Mexico) supply warm dry air (this limits

convection so that only one or two storms form rather than widespread thunderstorms) and overriding both of these is cool dry air from the Rocky Mountains.

The shape of the Rocky Mountains often allows low pressure systems to form to their East in the spring and these move eastward driven by the polar front jet stream (a strong ribbon of wind going from west to east around the Earth at a height of approximately 10km). These low pressure systems bring all of the above air masses together and provide the ingredients for thunderstorms. For a supercell to form, the thunderstorm must have a rotating updraft and this is caused by the changing direction of winds with height up to the jet stream.

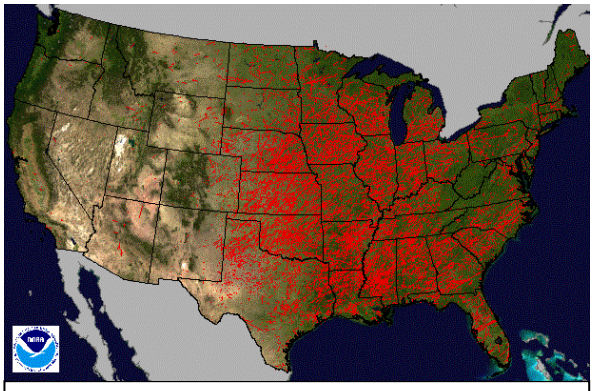


Figure 2 – Tornado tracks from 1950- 2004 Courtesy of NOAA

Once a supercell forms with its rotating updraft (mesocyclone) there is a one in three chance it will form a tornado. It is not understood well why some supercells spawn tornadoes and others do not. If the air is rising quickly into the storm then the mesocyclone will become stretched vertically and spin more quickly (just as when a plug is removed from a bath and the small rotation is stretched down the drain and causes the spin in the water to rotate every rapidly). This spinning column of air begins to descend to the ground and the low pressure inside it causes water to condense so that it becomes a visible funnel. As soon as this funnel touches the ground we say that a tornado has formed.

Tornadoes wind speeds can range from a few mph to in excess of 300mph (tornadoes themselves move at speeds ranging from 0mph to 70mph[14]). This is far too high to be measured directly and so wind speed estimates are made by radar scans and an assessment of the damage caused. This estimate is performed using the Enhanced Fujita Scale (figure 3).

Figure 3 – The Fujita Scale - Courtesy of the Storm Prediction Center

SCALE	WIND ESTIMATE *** (MPH)	TYPICAL DAMAGE	DAMAGE PHOTOS
F0	< 73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.	
F1	73-112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.	
F2	113-157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.	
F3	158-206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.	
F4	207-260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.	
F5	261-318	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur.	

References:

1 – Tornado Definition – http://www.thefreedictionary.com/tornado
2 – BBC tornado information - http://www.bbc.co.uk/weather/features/az/alphabet60.shtml
3 – US Storm Prediction Centre - http://www.spc.noaa.gov
4 – Storm Chasers homepage - http://www.tornadovideos.net
5 – TORRO Homepage - http://www.torro.org.uk/site/index.php
6 – US Meteorologist explaining the conditions required for tornado formation - http://www.youtube.com/watch?v=7E2hNNrU-sU&feature=related
7 – Website animation of thunderstorm formation - http://www.wiley.com/college/strahler/0471480533/animations/ch06_animations/index.html
8 – Website animation of tornado formation - http://esminfo.prenhall.com/science/geoanimations/animations/Tornadoes.html
9 – Website game assessing tornado damage - http://www.pbs.org/wgbh/nova/tornado/dama-flash.html
10 – News footage of the 3rd May Oklahoma City EF5 tornado - http://www.youtube.com/watch?v=Ark6R3sN-q4
11 – Video of a tornado siren test - http://www.youtube.com/watch?v=nuu2iNisoQc&feature=player_embedded
12 – Trailer for the Storm Chasers series - http://www.youtube.com/watch?v=CmTSfqyOzuU&feature=player_embedded
13 – Massive hail video - http://www.youtube.com/watch?v=0UNi4jo3cyg&feature=related
14 – Texas Weather Network - http://www.tsgc.utexas.edu/stars/tornado.html
15 - Making a tornado activity - http://eo.ucar.edu/kids/dangerwx/tornado4.htm

Images

Top image – NOAA - http://www.erh.noaa.gov/gsp/tdwr/info/TCLT1842Refl.gif
Figure 1 – FEMA - http://www.fema.gov/plan/prevent/saferoom/tsfs02_torn_activity.shtm
Figure 2 – NOAA – http://www.spc.noaa.gov/gis/svrgis/
Figure 3 – SPC - http://www.spc.noaa.gov/faq/tornado/f-scale.html
Images – F0 – NWS Birmingham
- F1 – Roger Edwards SPC
- F2 – NWS Memphis
- F3 – Mike Branick NWS
- F4 - Mike Branick NWS
- F5 – Chuck Doswell FEMA

Figure 4 – NOAA – http://www.ncdc.noaa.gov/oa/climate/severeweather/tornadoes.html
Figure 5 – NOAA - http://www.ncdc.noaa.gov/oa/climate/severeweather/tornadoes.html
Figure 6 – Author
Figure 7 – NSSL - http://www.spc.noaa.gov/faq/tornado/suprcell.htm

Books:

- Tornado – Natures Ultimate Windstorm – Thomas P.Grazulis
- Meteorology Today – C Donald Ahrens