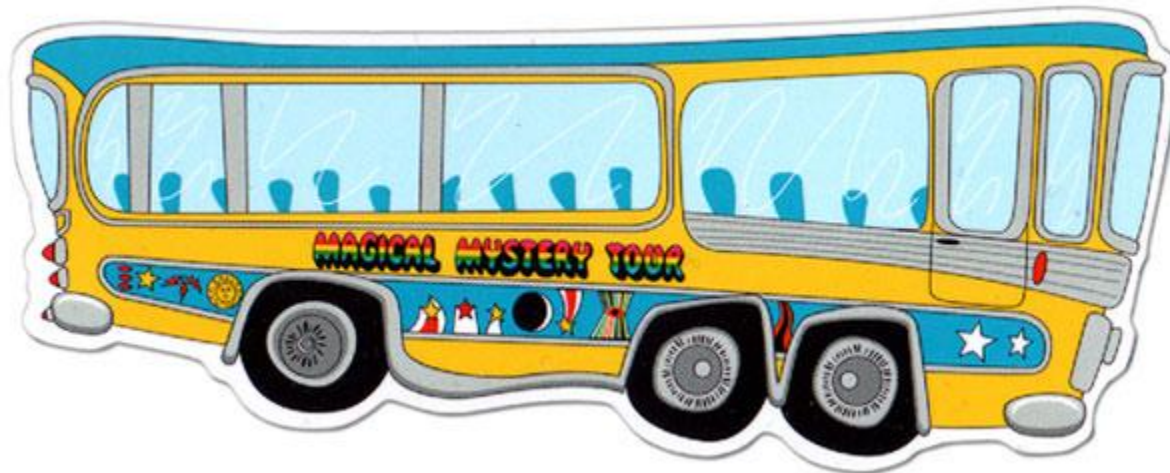


Chapter 1

Introduction to Mesoscale Meteorology



1.1 What is the “mesoscale”?

- Classification of the mesoscale

Nomenclature	Spatial Scale	Temporal Scale	Typical Weather Feature
Synoptic	> 2000 km	3 days – weeks	Extratropical cyclone (fronts, lows, highs)
Mesoscale alpha (α)	200-2000 km	6 hrs – 2 days	Jet streak, small hurricanes, weak anticyclones
Mesoscale beta (β)	20 – 200 km	30 min – 6 hrs	Mountain/valley winds, land/sea breeze, mesoscale convective complex (mcc), large thunderstorms
Mesoscale gamma (γ)	2 – 20 km	3 – 30 min	Most thunderstorms, large cumulus, extremely large tornadoes

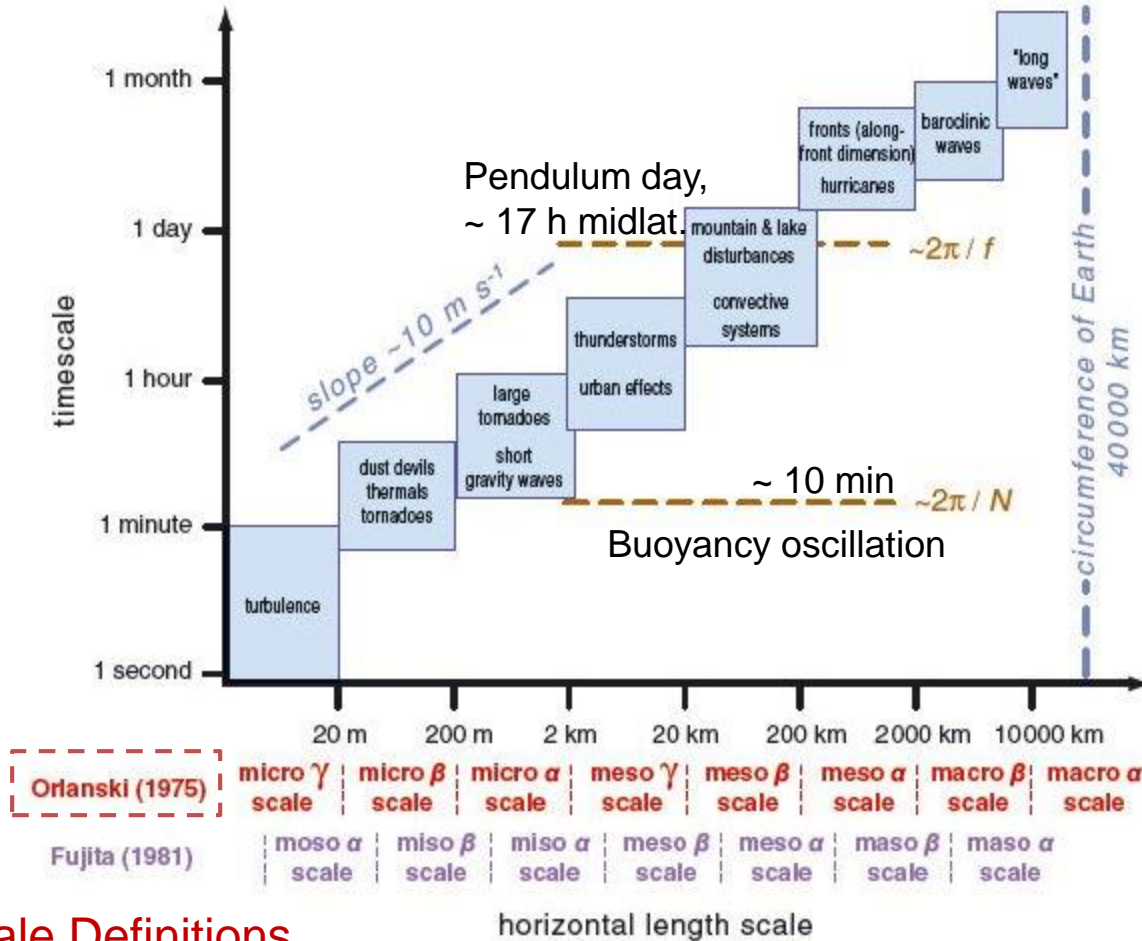
- Other definitions:
 - Mesoscale is an intermediate range of scales where very few simplifications can be made to the governing equations
 - Examples
 - On the synoptic scale, vertical accelerations are considered small enough to neglect (i.e., the synoptic scale is in hydrostatic balance – more on this in a moment)
 - On the microscale, the Coriolis force is often neglected
 - The full, unsimplified governing equations must be considered when dealing with mesoscale phenomenon
 - Mesoscale is the scale on which motions are driven by a variety of mechanisms rather than a single dominant instability (such as the synoptic scale in the midlatitudes)
 - Must consider instabilities such as thermal, symmetric, barotropic, and Kelvin-Helmholtz on the mesoscale
 - What instability is midlatitude synoptic systems largely driven by?
 - baroclinic instability
 - Topography also plays an important role in the mesoscale

Characteristic time and length scales of various atmospheric phenomena.

Mesoscale phenomena range from the period of a pure buoyancy oscillation to that of a pendulum day

$$f = 2\Omega \sin \phi$$

f: Coriolis parameter
 Ω : Earth angular velocity
 ϕ : latitude



$$N = \left[\frac{g}{T_0} (\Gamma_d - \gamma) \right]^{1/2}$$

N: Brunt-Vaisala frequency
g: gravity
 T_0 : temperature
 Γ_d : dry adiabatic lapse rate
 γ : environmental lapse rate

Scale Definitions

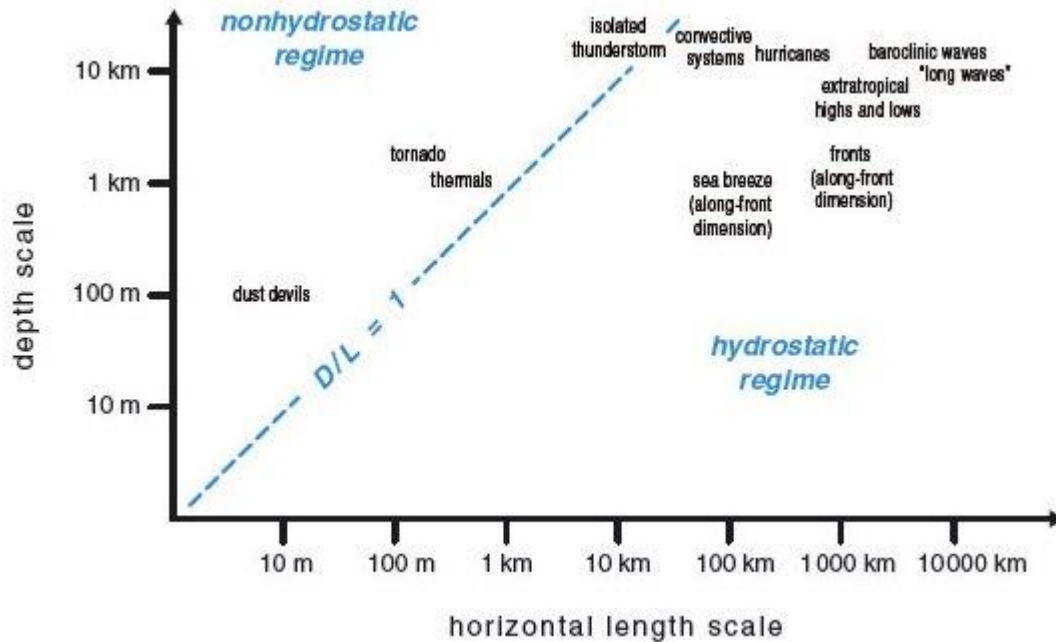
Fig. 1.1 Markowski and Richardson (2010)

1.1.1 Dynamic Distinction of Mesoscale

- Hydrostatic Balance
 - Physical implication of temporal and spatial scales
 - Non-hydrostatic vs hydrostatic balance
 - Non-geostrophic vs geostrophic balance
 - Scale analysis

Scale Analysis of Hydrostatic and Non-hydrostatic Regimes

D



L

Non-Hydrostatic

$$L \sim D$$

$$D/L \sim 1$$

Hydrostatic

$$L \gg D$$

$$D/L \ll 1$$

Fig. 1.4. Markowski and Richardson (2010)

1.2 What is Convection (meso- γ)?

- In physics, convection refers to the transport of some property (e.g., heat) by fluid motion
 - Convection vs. conduction / radiation
 - Conduction – energy transferred by direct contact
 - Radiation – energy transferred by electromagnetic waves
- In meteorology, convection refers to heat (or energy) transport by the vertical component of the flow associated with **buoyancy**
 - Buoyancy is a force or acceleration (more next unit)

Life-cycle of an ordinary convective cell

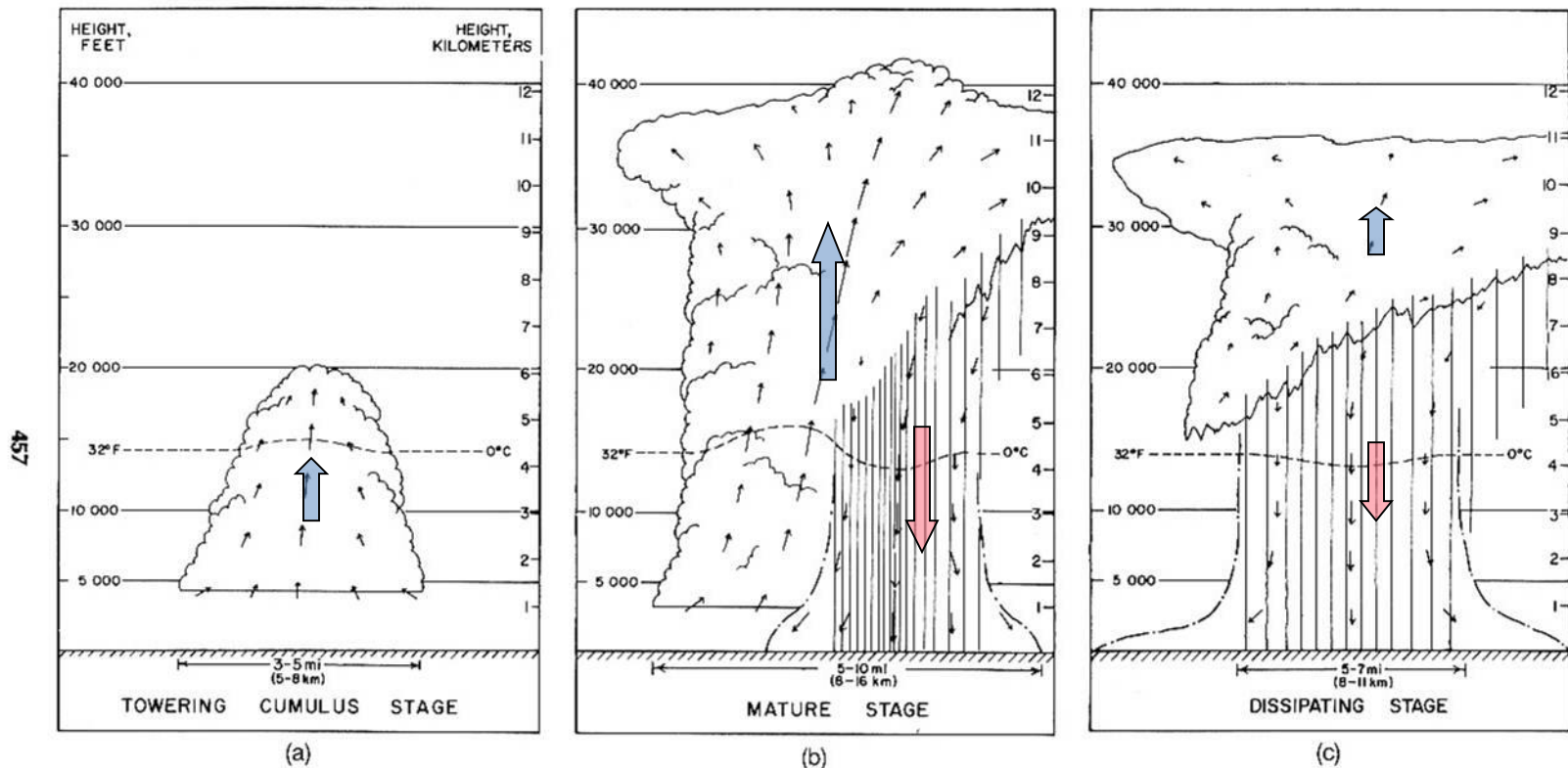


Figure 3.15 The Byers–Braham model of the three stages in the life of a thunderstorm: (a) towering cumulus stage, (b) mature stage, and (c) dissipating stage. Arrows indicate the sense of air motion (from Doswell, 1985).

↑ updraft

↓ downdraft

1.3 What is “severe (convective) weather”?

- Official NWS definition:
 - Tornado
 - Large hail with diameter ≥ 1.0 ” (2.54 cm) (“quarter size”)
 - Straight-line wind ≥ 50 kts (25 m/s) (58 mph)
 - “Significant” severe weather
 - EF2-EF5 tornadoes
 - Hail ≥ 2.0 ” diameter (“hen egg size”)
 - Straight-line wind ≥ 75 MPH (hurricane force)
- Things not in this list but clearly affects life and property?
 - Lightning, flash flooding, winter weather, etc.
 - We will discuss processes for all of these

1.4 The Storm Prediction Center (SPC)

- Responsible for short-medium range severe, winter, and fire weather forecasts for the lower 48 states
- Products issued by SPC
 - Convective outlooks (Day 1, Day 2, Day 3, Day 4-8)
 - Fire weather outlooks (Day 1, Day 2, Day 3-8)
 - Mesoscale Discussions for severe weather and winter weather threats, usually in a 1-3 hour lead-time
 - Tornado and severe thunderstorm watches
- See reading assignment for complete overview of products

SPC Outlooks – Probabilities to Categories

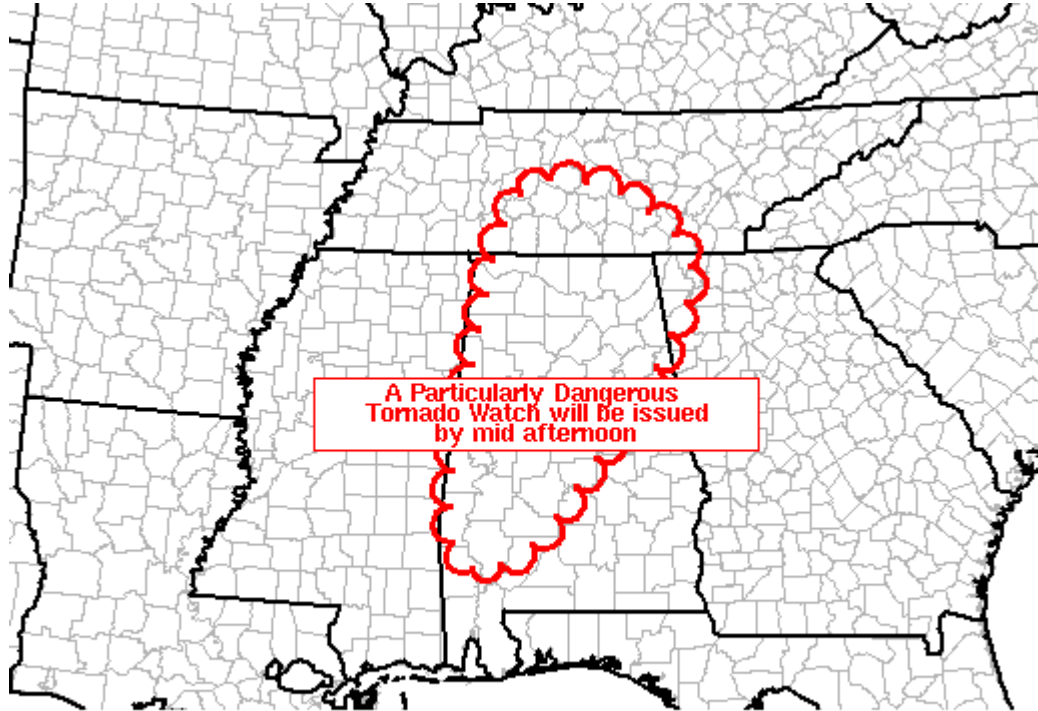
Day 1 Outlook Probability	TORN	WIND	HAIL
2%	MRGL	Not Used	Not Used
5%	SLGT	MRGL	MRGL
10%	ENH	Not Used	Not Used
10% with Significant Severe	ENH	Not Used	Not Used
15%	ENH	SLGT	SLGT
15% with Significant Severe	MDT	SLGT	SLGT
30%	MDT	ENH	ENH
30% with Significant Severe	HIGH	ENH	ENH
45%	HIGH	ENH	ENH
45% with Significant Severe	HIGH	MDT	MDT
60%	HIGH	MDT	MDT
60% with Significant Severe	HIGH	HIGH	MDT

Day 2 Outlook Probability	Combined TOR, WIND, HAIL
5%	MRGL
15%	SLGT
15% with Significant Severe	SLGT
30%	ENH
30% with Significant Severe	ENH
45%	ENH
45% with Significant Severe	MDT
60%	MDT
60% with Significant Severe	HIGH

Day 3 Outlook Probability	Combined TOR, WIND, HAIL
5%	MRGL
15%	SLGT
15% with Significant Severe	SLGT
30%	ENH
30% with Significant Severe	ENH
45%	ENH
45% with Significant Severe	MDT

SPC Mesoscale Discussions

- Goal: issuance 1-3 hours before a convective watch
- Outlines areas where watches may be necessary based on evolving environment
- Also issued for winter weather hazards (heavy snow, ice, sleet, mixed precipitation, blizzard conditions)



SPC MCD #0626

MESOSCALE DISCUSSION 0626
 NWS STORM PREDICTION CENTER NORMAN OK
 0105 PM CDT WED APR 27 2011

AREAS AFFECTED...MUCH OF AL INTO MIDDLE TN/NORTHWEST GA

CONCERNING...SEVERE POTENTIAL...**TORNADO WATCH LIKELY**

VALID 271805Z - 271930Z

A LONG DURATION PARTICULARLY DANGEROUS /PDS/ TORNADO WATCH WILL BE ISSUED BY MID AFTERNOON FOR MUCH OF AL INTO MIDDLE TN/NORTHWEST GA...WITH AN ISSUANCE PROBABLE BY AROUND 19Z.

AMID CLOUD BREAKS...THE AIRMASS CONTINUES TO QUICKLY DESTABILIZE IN THE WAKE OF A DECAYING MORNING WEST-EAST BOUNDARY ACROSS AL...AND TO THE SOUTH OF A MORE RECENT MCS-INDUCED BOUNDARY/COLD POOL ACROSS FAR NORTHERN AL. WITH A CLASSIC/SYNOPTICALLY EVIDENT OUTBREAK SETUP VIA A SHORTWAVE TROUGH/STRONG JET STREAK CURRENTLY NEARING THE LOWER-MIDDLE MS RIVER VALLEY PER SATELLITE IMAGERY...AN INCREASINGLY VOLATILE SETUP IS LIKELY THROUGH THE AFTERNOON. SUPERCELLS CAPABLE OF STRONG/VIOLENT TORNADOES ARE EXPECTED TO BECOME PREVALENT ACROSS AN INCREASINGLY UNSTABLE/WEAKLY CAPPED WARM SECTOR...WITH WSR-88D VWP OBSERVED AND RUC FORECASTS REFLECTING INCREASINGLY LONG/LOOPING LOW LEVEL HODOGRAPHS. IN THE WAKE OF A MORNING SEVERE MCS...THE AIRMASS IS EXPECTED TO RAPIDLY RECOVER ACROSS FAR NORTHERN AL INTO MIDDLE TN BY LATE AFTERNOON/EARLY EVENING.

..GUYER.. 04/27/2011

ATTN...WFO...MRX...FFC...OHX...BMX...HUN...MOB...

LAT...LON 31738724 31628828 33268819 35858732 34808504 31738724

AREAS AFFECTED...MUCH OF MS/AL TO NORTHWEST GA

CONCERNING...TORNADO WATCH 232...235...

VALID 272201Z - 272330Z

THE SEVERE WEATHER THREAT FOR TORNADO WATCH 232...235...CONTINUES.

PARTICULARLY DANGEROUS SITUATION /PDS/ TORNADO WATCHES 232/235
CONTINUE UNTIL 00Z/03Z RESPECTIVELY.

A TORNADO OUTBREAK WILL CONTINUE INTO THIS EVENING ACROSS MUCH OF
MS/AL INTO NORTHWEST GA. THIS IS AN EXTREMELY
DANGEROUS/LIFE-THREATENING SITUATION! CITIES AND AREAS AT GREATEST
RISK INCLUDE BIRMINGHAM...HUNTSVILLE...THE I-59 CORRIDOR OF NORTHERN
AL...AND I-65 NEAR/NORTH OF BIRMINGHAM.

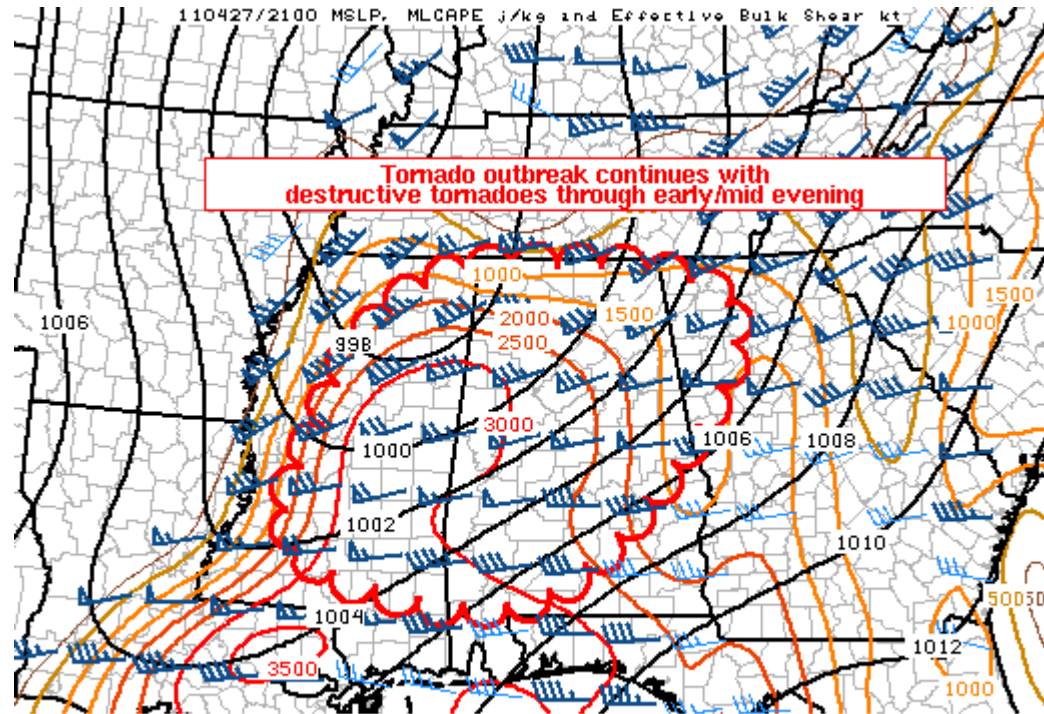
A NUMBER OF SEMI-DISCRETE/LONG-LIVED TORNADIC SUPERCELLS CONTINUE TO
FORM WITHIN A PRE-DRYLINE/PRE-COLD FRONTAL WARM SECTOR FROM
SOUTH-CENTRAL MS NORTHEASTWARD INTO MUCH OF NORTHERN AL. OTHER
TORNADIC STORMS CONTINUE TO INTERACT WITH A MODIFYING EFFECTIVE WARM
FRONTAL-TYPE BOUNDARY ACROSS FAR NORTHERN AL IN THE GENERAL
VICINITIES OF DECATUR/HUNTSVILLE.

THE SPATIALLY WIDE WARM SECTOR IS VERY UNSTABLE AMID MIDDLE-UPPER
60S F SURFACE DEWPOINTS...WITH LOWER 70S F SURFACE DEWPOINTS ACROSS
PORTIONS OF SOUTHERN/MS. MLCAPE VALUES ARE AS HIGH AS 2000-4000 J/KG
WITHIN THE WEAKLY CAPPED WARM SECTOR.

RECENT REGIONAL WSR-88D VWP DATA IS INDICATIVE OF AN INCREASE IN LOW
LEVEL WIND SPEEDS/HODOGRAPH CURVATURE OVER THE PAST FEW HOURS...WITH
0-1 KM SRH VALUES NOW ESTIMATED TO BE IN EXCESS OF 300-400 M2/S2 AND
0-3 KM SRH IN EXCESS OF 600 M2/S2 PER BIRMINGHAM/HUNTSVILLE WSR-88D
VWPS. THIS WILL REMAIN HIGHLY FAVORABLE FOR LONG-LIVED
STRONG/POTENTIALLY VIOLENT TORNADOES WITH ANY SUSTAINED SUPERCELLS
WITHIN THE BROAD/VOLATILE WARM SECTOR INTO THIS EVENING.

WHILE STRONG TORNADOES WILL BE POSSIBLE WITH ANY SUSTAINED
SUPERCELLS WITHIN PDS TORNADO WATCH 232/235...THE RELATIVELY HIGHEST
CONCERN OVER THE NEXT FEW HOURS WOULD APPEAR TO BE ACROSS
WEST-CENTRAL AL AND NORTHERN HALF OF AL INTO FAR NORTHWEST GA.
HERE...IN ADDITION TO THE AFOREMENTIONED RESIDUAL SURFACE
BOUNDARY...RELATIVELY STRONG/BACKED LOW LEVEL FLOW IS EVIDENT IN 21Z
SUBJECTIVE ANALYSIS AMID A RELATIVE MAXIMA OF 2-HR PRESSURE
FALLS...ESPECIALLY ALONG/NORTH OF I-20 IN NORTHERN AL.

..GUYER.. 04/27/2011



SPC MCD #0634

SPC Convective Watches

- Four types
 - Severe thunderstorm
 - Tornado
 - Particularly Dangerous Situation (PDS) Severe Thunderstorm
 - PDS Tornado
- PDS severe thunderstorm watches most uncommon
- Watches now dictated by probabilities (see next slide)
- Goal: 1-3 hour lead time before severe weather in the watch area



Tornado Watch # 235 - Valid from 145 PM until 1000 PM CDT

IOAA/NWS/Storm Prediction Center Updated: 20110427/0846 UTC

Hazard	Tornadoes	EF2+ Tornadoes	Severe Wind	65 kt+ Wind	Severe Hail	2"+ Hail
Likelihood	High	High	High	High	High	High

Tornadoes

Probability of 2 or more tornadoes	High (>95%)
Probability of 1 or more strong (F2-F5) tornadoes	High (>95%)

Wind

Probability of 10 or more severe wind events	High (>95%)
Probability of 1 or more wind events > 65 knots	High (>95%)

Hail

Probability of 10 or more severe hail events	High (>95%)
Probability of 1 or more hailstones > 2 inches	High (>95%)

Combined Severe Hail/Wind

Probability of 6 or more combined severe hail/wind events	High (>95%)
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For each watch, probabilities for particular events inside the watch (listed above in each table) are determined by the issuing forecaster. The "Low" category contains probability values ranging from less than 2% to 20% (F2-F5 tornadoes), less than 5% to 20% (all other probabilities), "Moderate" from 30% to 60%, and "High" from 70% to greater than 95%. High values are bolded and lighter in color to provide awareness of an increased threat for a particular event.

SEL5

URGENT - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 235
NWS STORM PREDICTION CENTER NORMAN OK
145 PM CDT WED APR 27 2011

THE NWS STORM PREDICTION CENTER HAS ISSUED A TORNADO WATCH FOR PORTIONS OF

- MUCH OF ALABAMA
- NORTHWEST GEORGIA
- SOUTHEAST MISSISSIPPI
- SOUTHERN MIDDLE TENNESSEE

EFFECTIVE THIS WEDNESDAY AFTERNOON AND EVENING FROM 145 PM UNTIL 1000 PM CDT.

...THIS IS A PARTICULARLY DANGEROUS SITUATION...

DESTRUCTIVE TORNADOES...LARGE HAIL TO 4 INCHES IN DIAMETER... THUNDERSTORM WIND GUSTS TO 80 MPH...AND DANGEROUS LIGHTNING ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS APPROXIMATELY ALONG AND 80 STATUTE MILES EAST AND WEST OF A LINE FROM 45 MILES NORTHEAST OF HUNTSVILLE ALABAMA TO 60 MILES WEST SOUTHWEST OF EVERGREEN ALABAMA. FOR A COMPLETE DEPICTION OF THE WATCH SEE THE ASSOCIATED WATCH OUTLINE UPDATE (WOUS64 KWNS WOU5).

REMEMBER...A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR TORNADOES AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS AND POSSIBLE WARNINGS.

OTHER WATCH INFORMATION...CONTINUE...WW 230...WW 231...WW 232...WW 233...WW 234...

DISCUSSION...A CLASSIC TORNADO OUTBREAK SITUATION IS DEVELOPING ACROSS MUCH OF AL AS DISCRETE TORNADIC SUPERCELLS FORM OVER MS AND TRACK ACROSS THE WATCH AREA. STRONG LOW LEVEL AND DEEP LAYER VERTICAL SHEAR...COMBINED WITH A MOIST AND MODERATELY UNSTABLE AIR MASS...WILL POSE A DANGEROUS RISK OF STRONG/VIOLENT AND POTENTIALLY LONG-TRACK TORNADOES.

AVIATION...**TORNADOES AND A FEW SEVERE THUNDERSTORMS WITH HAIL SURFACE AND ALOFT TO 4 INCHES. EXTREME TURBULENCE AND SURFACE WIND GUSTS TO 70 KNOTS. A FEW CUMULONIMBI WITH MAXIMUM TOPS TO 500. MEAN STORM MOTION VECTOR 25040.**

1.5 The Weather Prediction Center (WPC)

- The center formerly known as the Hydrometeorological Prediction Center (HPC)
- Responsible for synoptic analyses of lower-48 weather and short-medium range precipitation forecasts
- Some products issued by WPC (**not inclusive**):
 - Quantitative precipitation forecasts (QPFs)
 - Excessive Rainfall Outlooks
 - Mesoscale Precipitation Discussions (similar to SPC mesoscale discussions; formerly written by SPC)
 - Short-term forecasts
 - Medium range/extended forecasts (3-7 day range)
 - Probabilistic Heavy Snow/Icing Forecasts
- Further information (optional reading):

<http://www.wpc.ncep.noaa.gov/html/fam2.shtml>

Reading Assignment #1

MR10

Ch 1, pp 3-10, What is Mesoscale

UCAR COMET MetEd Modules

“Definition of the Mesoscale” on the Internet at

<http://www.meted.ucar.edu/mesoprim/mesodefn/>

“SPC and its products”

<http://www.spc.noaa.gov/misc/about.html>