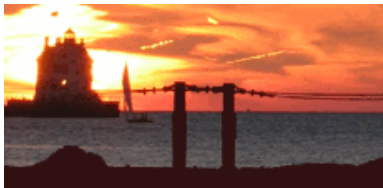


Thunderstorms: A Primer For Sailors

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Marine Weather Education and Forecasting Resources



Mark Thornton

LakeErieWX: *Marine Weather Education and Forecasting Resources*

Thunderstorm Hazards

It Only Takes One To Ruin Your Outing

- Lightning
- Damaging Wind
- Higher Waves
- Hail
- Heavy Precipitation / Reduced Visibility
- Tornadoes / Waterspouts



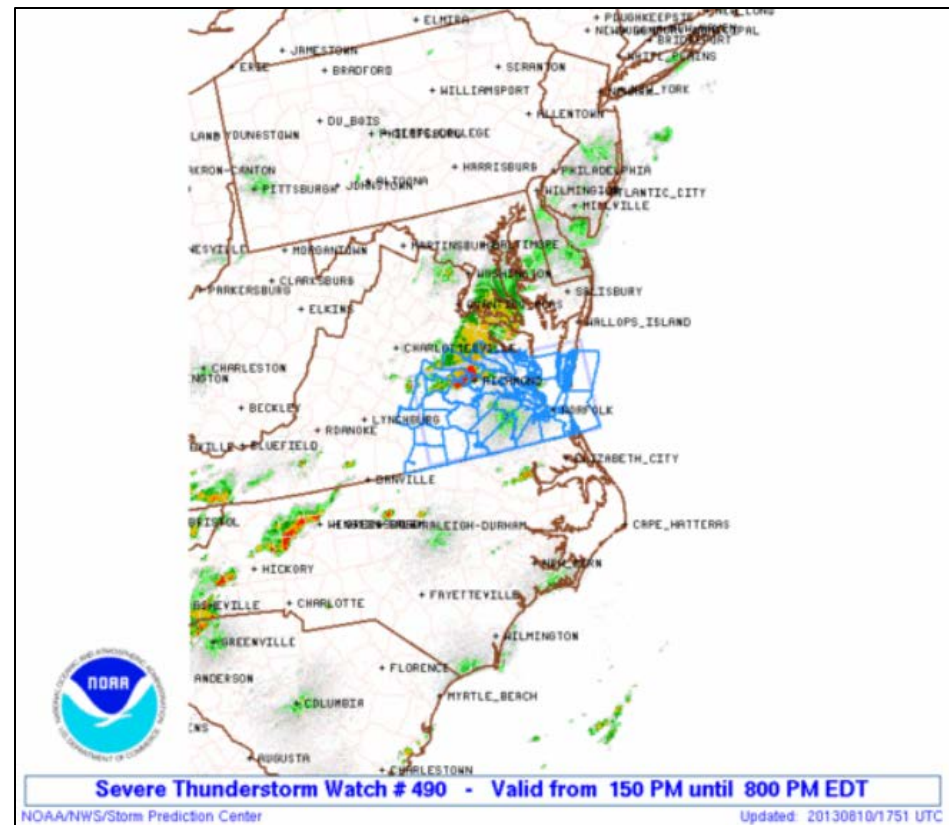
A Short Quiz

- Thunderstorms are 100% unpredictable? **TRUE or FALSE**
- Thunderstorms are always associated with a low pressure system? **TRUE or FALSE**
- Most thunderstorms have a lifespan of 45-60 minutes? **TRUE or FALSE**
- A squall line is a cluster of individual thunderstorms? **TRUE or FALSE**
- It is possible to accurately predict the speed of a downdraft? **TRUE or FALSE**
- The speed and direction of the surface wind is a good proxy for determining thunderstorm motion? **TRUE or FALSE**
- Lightning may occur up to 10 miles ahead of an approaching thunderstorm? **TRUE or FALSE**
- Thunderstorms often form along sea (lake) and land breezes boundaries? **TRUE or FALSE**
- The threshold for a severe thunderstorm is 34 knots? **TRUE or FALSE**
- A Watch is more serious than a Warning? **TRUE or FALSE**

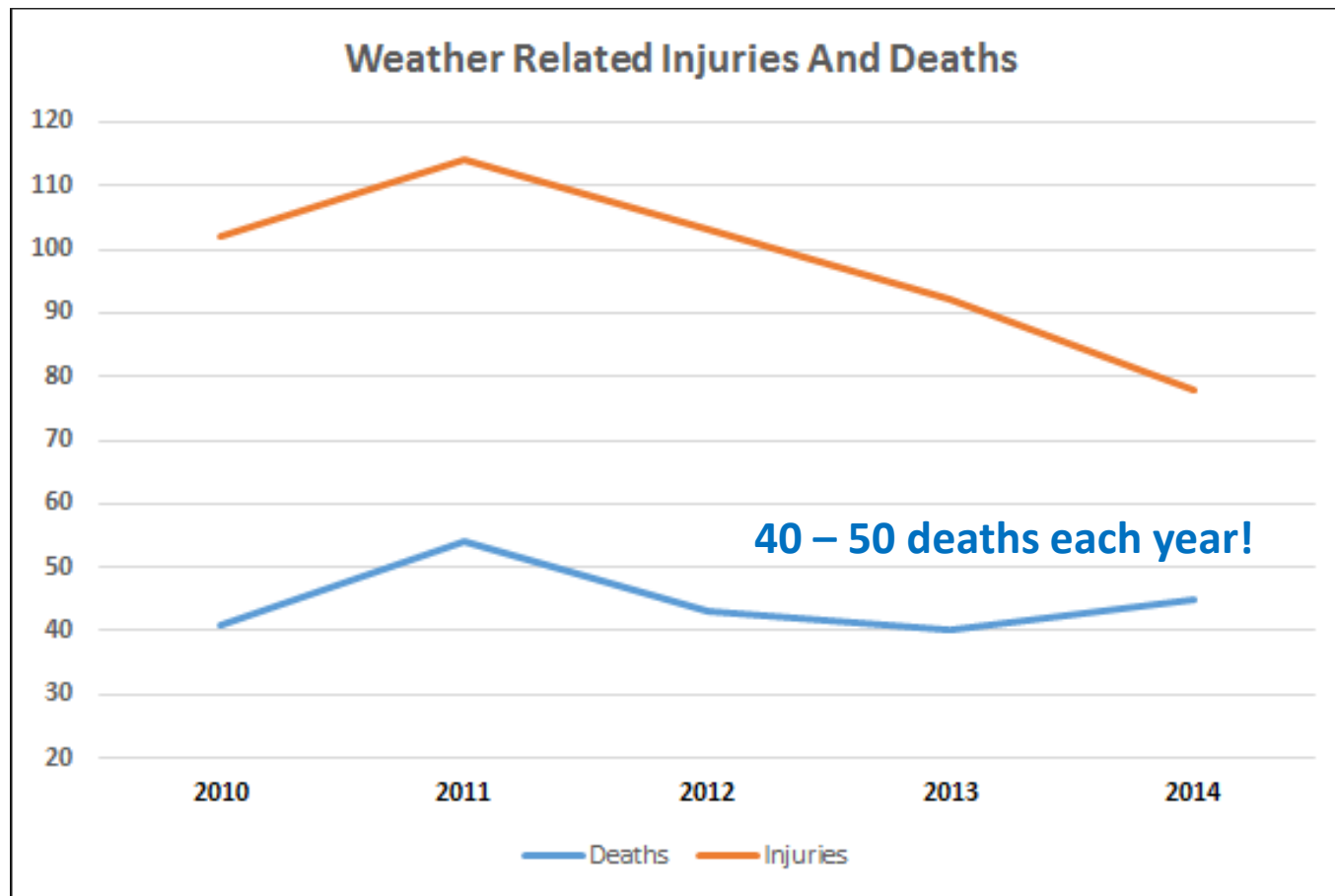


“Severe” Thunderstorms

- All types of thunderstorms may be classified as severe.
- NWS Severe thunderstorm thresholds:
 - Hail ≥ 1 ”
 - Surface wind gust ≥ 50 knots
 - The storm produces at least one tornado
- The potential for severe status increases as the duration of the storm increases.



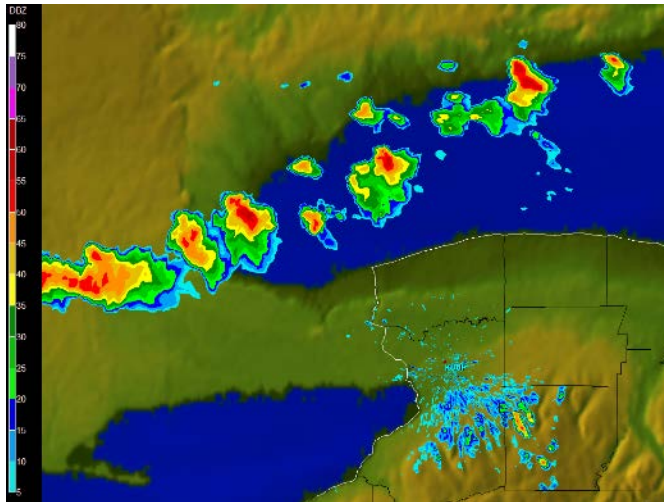
Weather And Sailing: The Need To Be Weather-Wise



Source: Recreational Boating Statistics 2010-2014 USCG

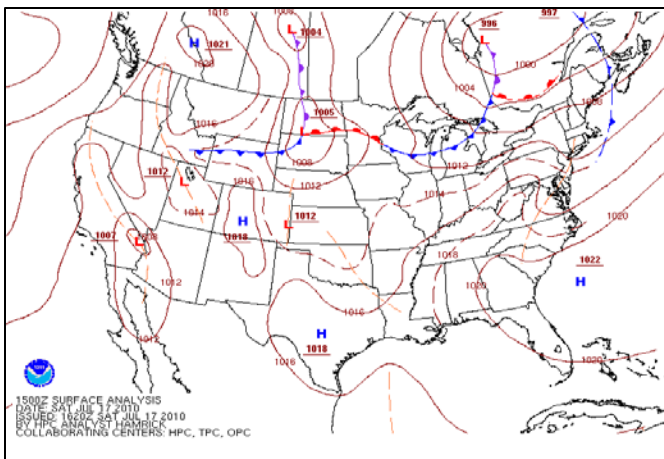
Thunderstorm Wind -- The Most Significant Risk To Sailors

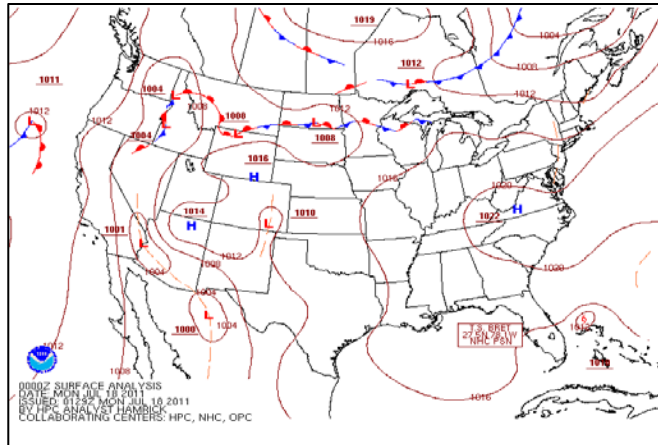
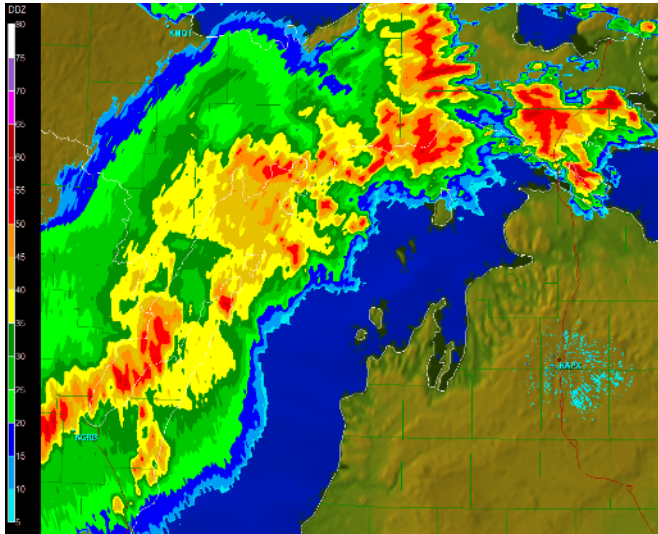
A Few Notable Examples



Lake Ontario 300 – July 17, 2010

- Downburst winds to 70 knots.
- Two boats dismantled.
- 31' trimaran capsized.
- 61 boats (34%) withdrew from the race because of injuries or damage.





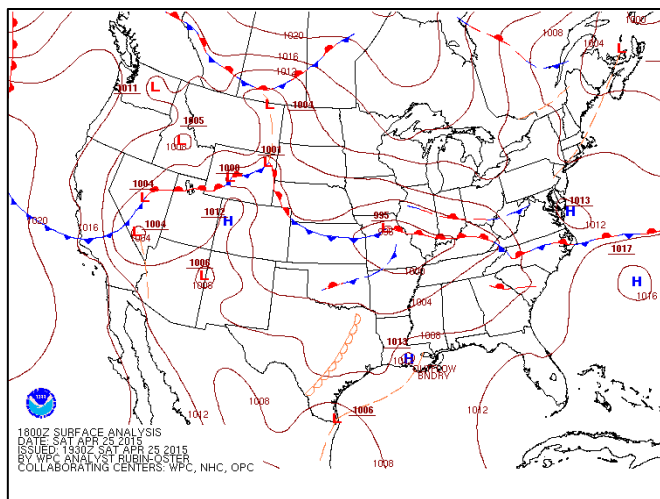
Chicago Mac – July 17, 2011

- Downburst winds 70 to 80 knots.
- Capsize of a Kiwi 35 resulted in the death of two participants.
- 37 boats reported being knocked down, many repeatedly for several minutes at a time.
- 12 boats reported coming very close to a collision.
- 47 boats withdrew due to the storms.



Dauphin Island Regatta – April 25, 2015

- Downburst winds to 70 knots.
- Six fatalities.
- Eights boats sank.
- Forty people required rescue from the water.

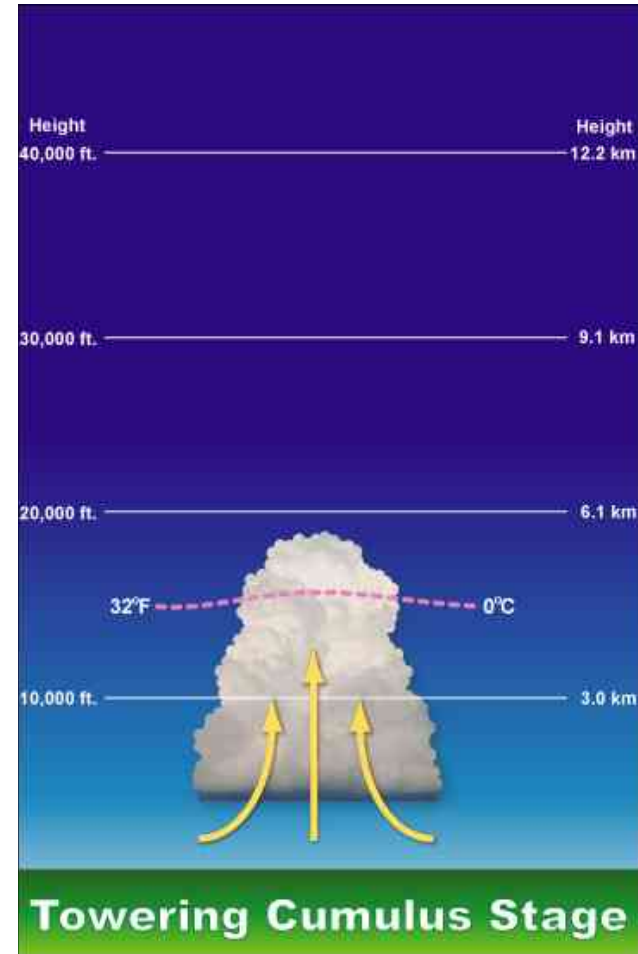


Understanding Thunderstorms

Stages of Development

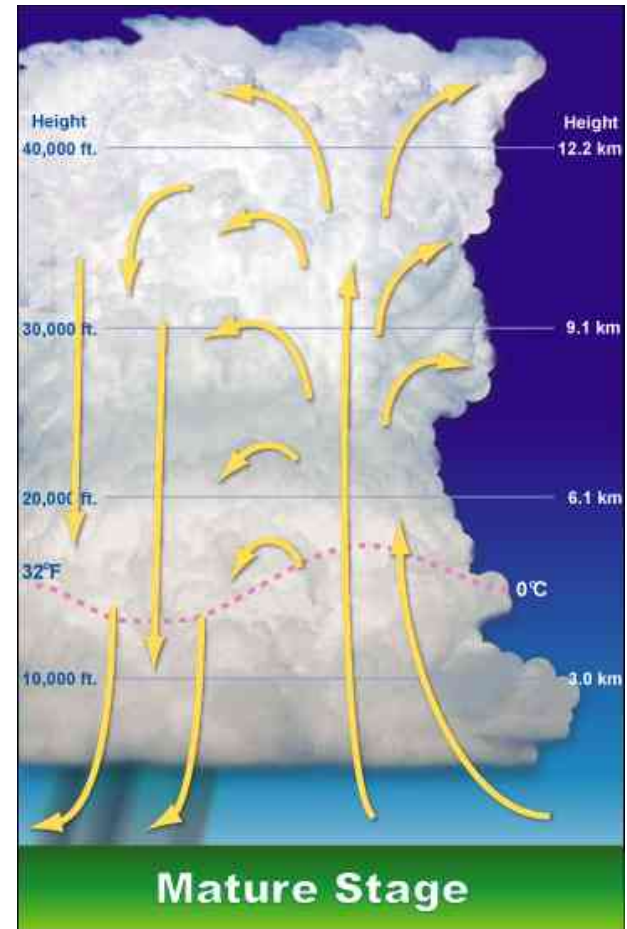
Thunderstorms: Stages of Development

- **Towering Cumulus Stage** – development begins with warm, moist air parcels being lifted.
- During ascent, the parcels cool to the point that the water vapor contained within the parcels condenses to form a cloud.
- Latent heat of condensation warms the air column.
- The warming of the air column results in subsequent parcels condensing at a higher level and the cloud grows in height.
- Updrafts may reach speeds of 20 knots.
- The storm has no observable downdraft, precipitation or lightning at this stage.
- The storm first appears on radar late in the cumulus stage.



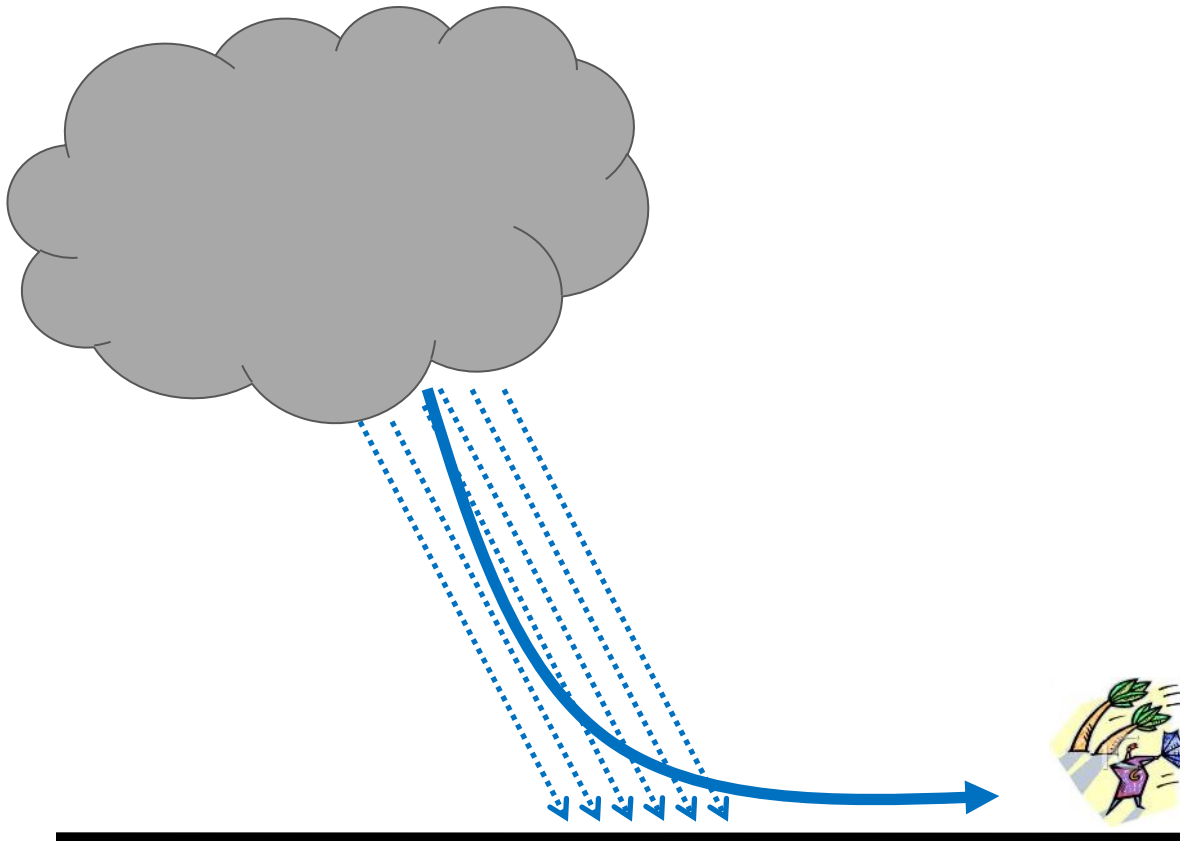
Thunderstorms: Stages of Development

- **Mature Phase** – this phase is characterized by both an updraft and a downdraft (the prerequisite for a thunderstorm cell).
- The storm reaches its greatest height and strength during this most dangerous phase.
- If the updraft is sufficiently strong, the storm may develop an anvil as upward growth reaches the top of the troposphere.
- Rain, lightning and thunder are present.
- The downdraft, characterized by air cooled by the evaporation of precipitation, can be felt in the form of the gust front/outflow boundary (may easily reach 60-70 knots).

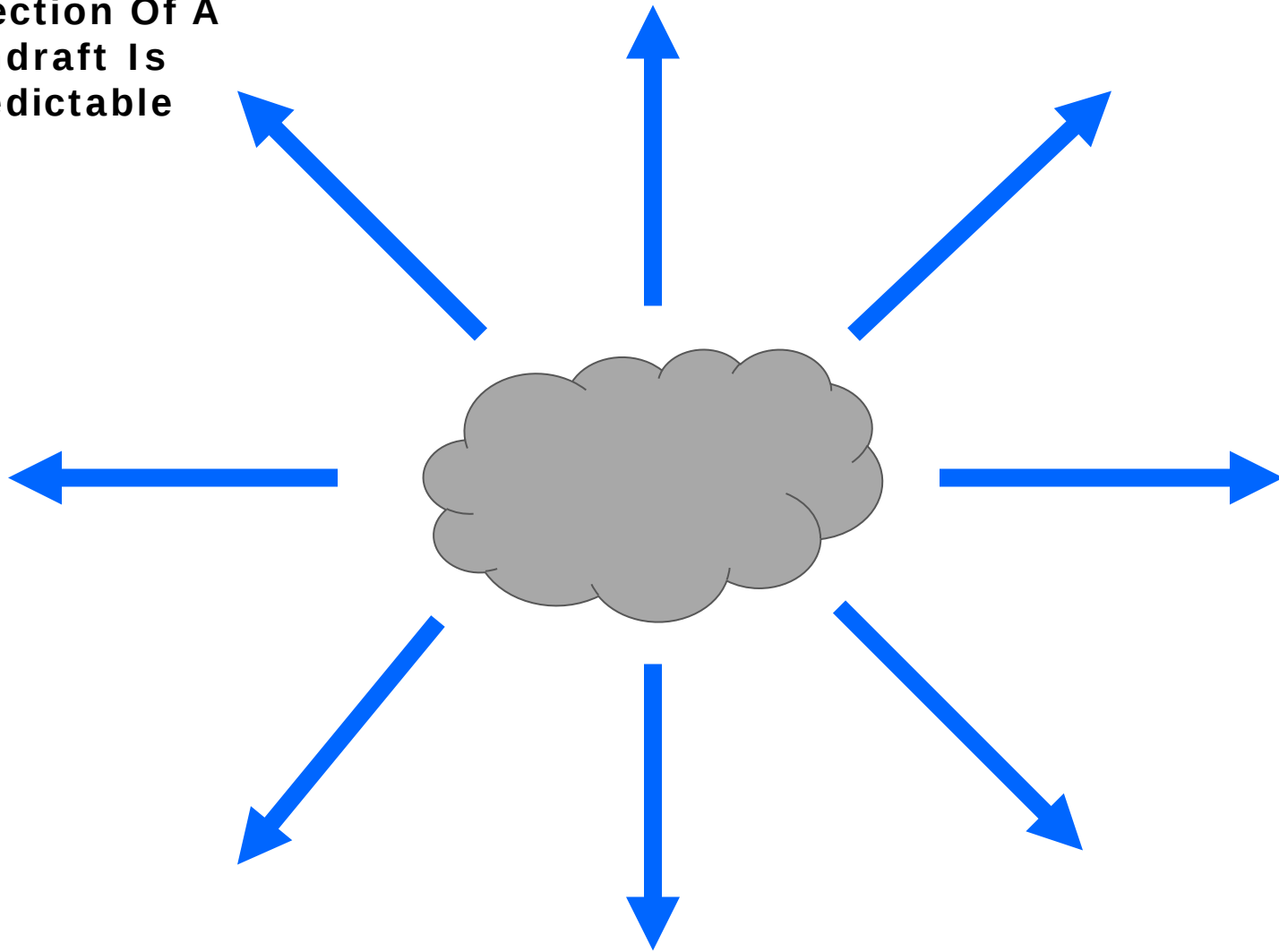


Downbursts – A Closer Look

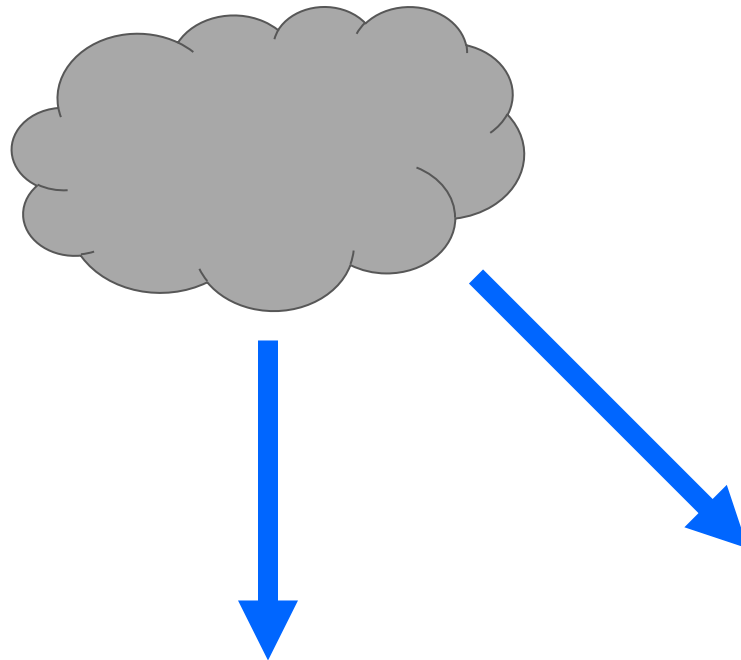
- Wind from a thunderstorm downdraft (outflow) can be quite strong – 100 kts (microburst & macrobursts).
- May come from a direction that is very different from the large-scale wind.



**The Direction Of A
Downdraft Is
Unpredictable**

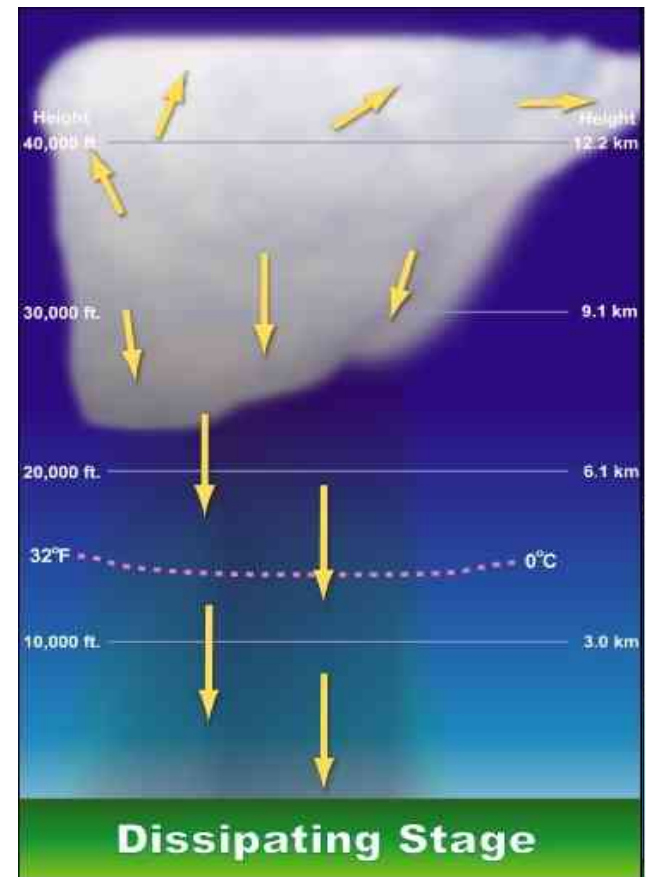


The Direction Of A Downdraft Is Unpredictable

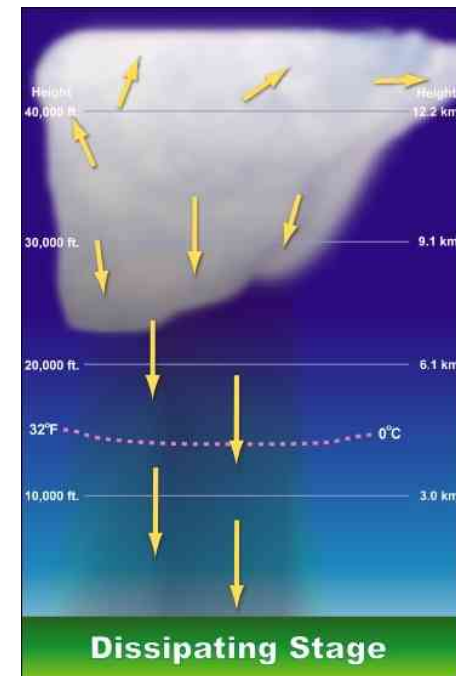
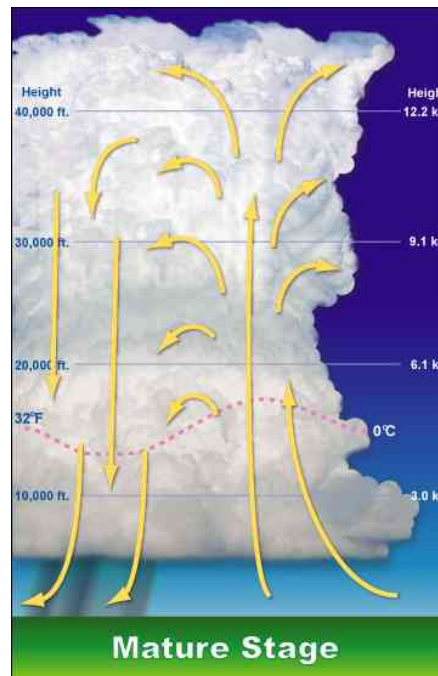
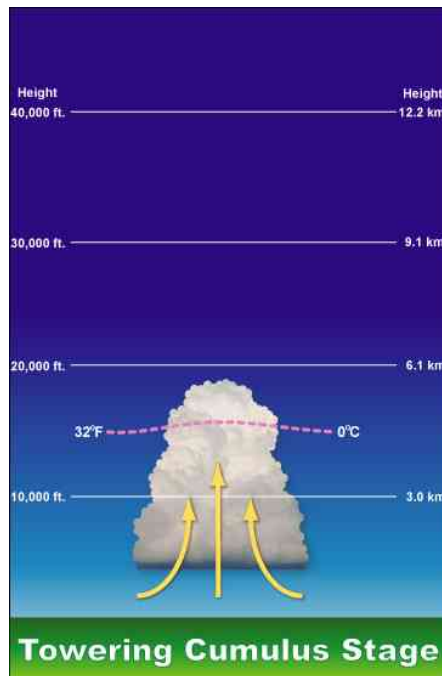


Thunderstorms: Stages of Development

- **Dissipating Stage** – the storm dissipates as the downdraft (gust front) and precipitation cuts off the updraft's access to warm, moist air.
- Precipitation may continue during this phase, but it is noticeably less intense than during the mature phase.



Stages of Development -- Summary

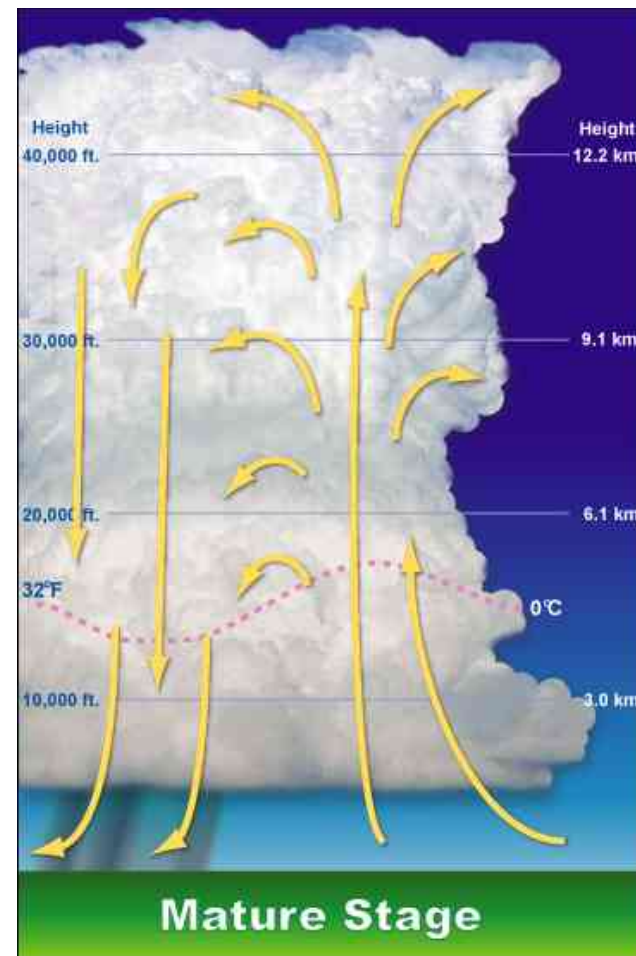
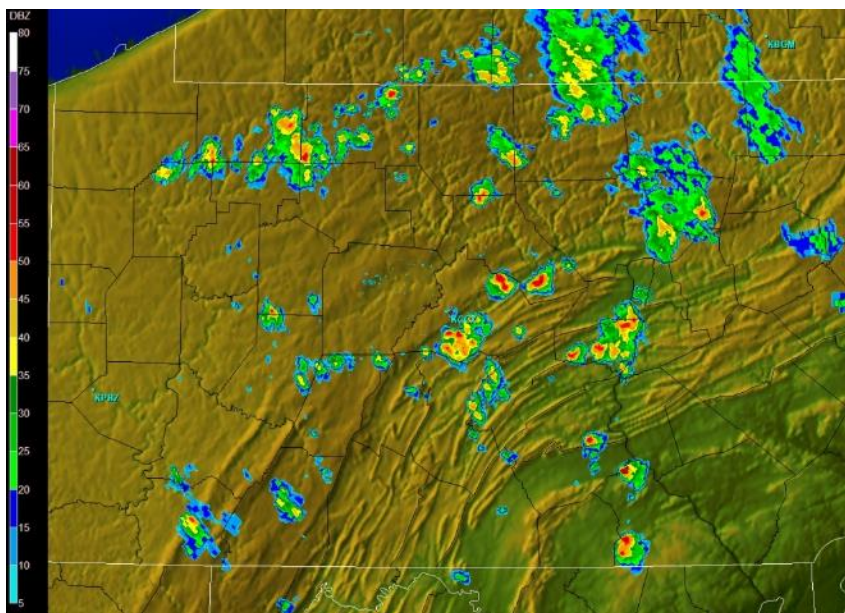


- A single cell may pass from the cumulus to the dissipating stage in 45 to 60 minutes.
- Not all cumulus columns reach the mature stage due to a lack of instability or moisture.
- Warning -- lightning may occur several miles ahead of the approaching storm.

Thunderstorm Types

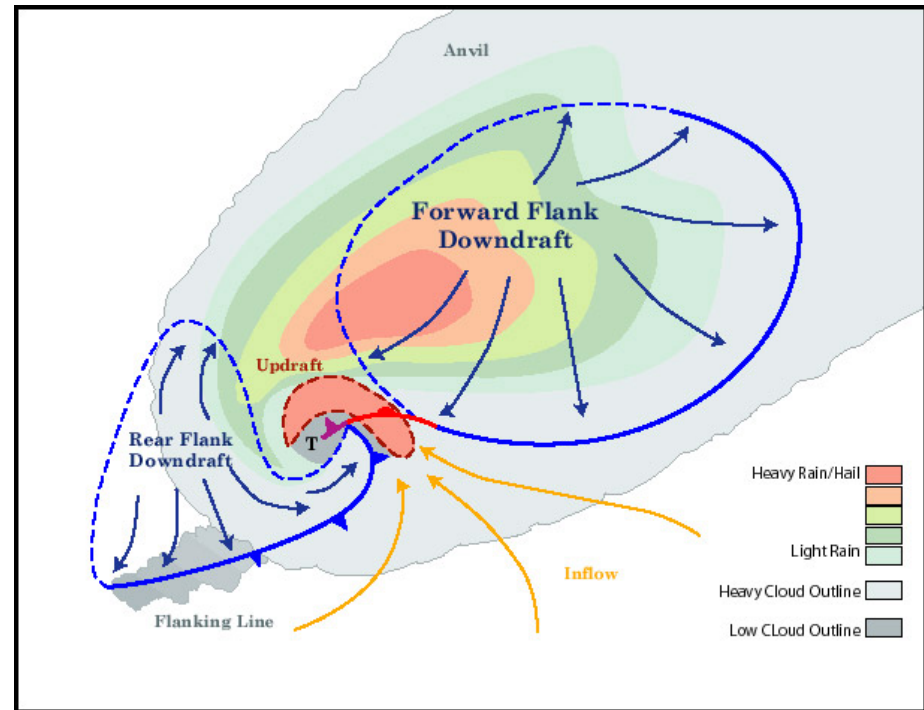
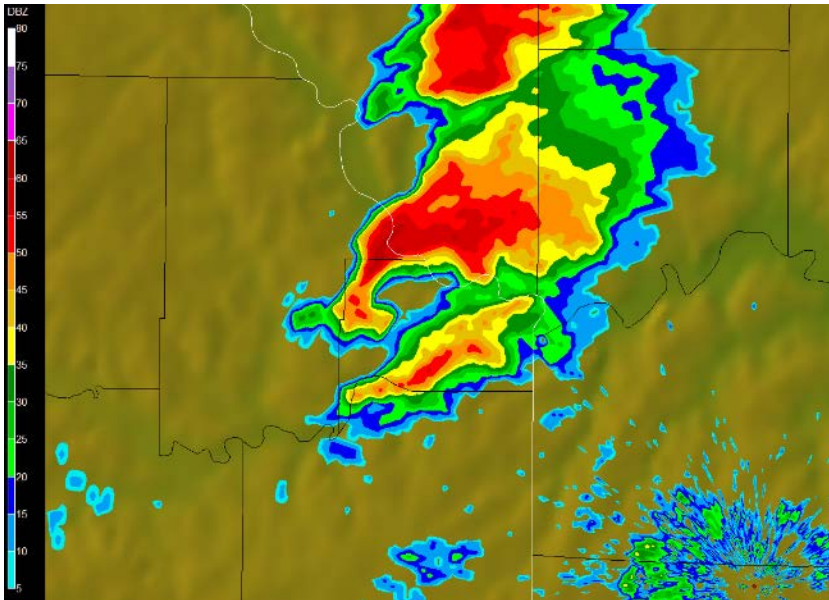
Single Cell Storms

- Single cell storms are characterized by a single, non-recurring updraft and downdraft.
- The “garden variety” summer thunderstorms that tend to build and dissipate quickly (typically 1 hour or less).
- Also called pulse, pop-up, or “air-mass” storms.
- Generally form in response to localized instability in the absence of frontal boundaries and weak wind shear.
- Capable of producing severe weather.



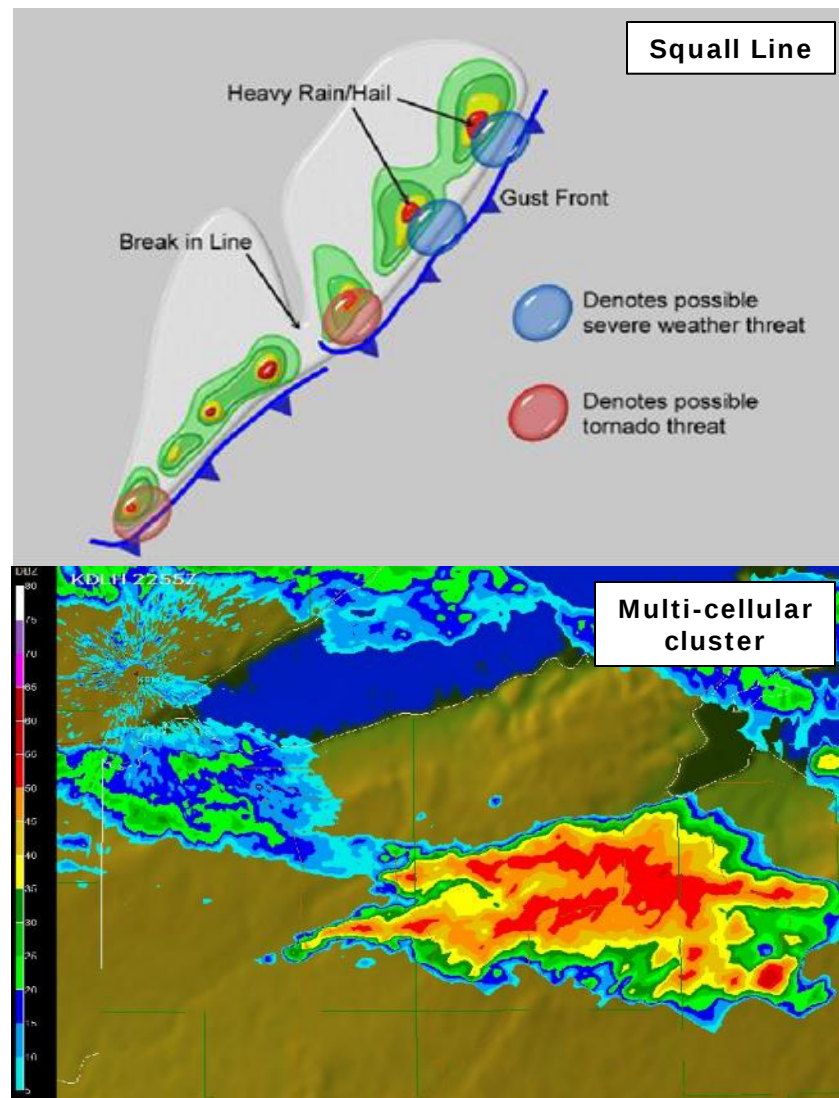
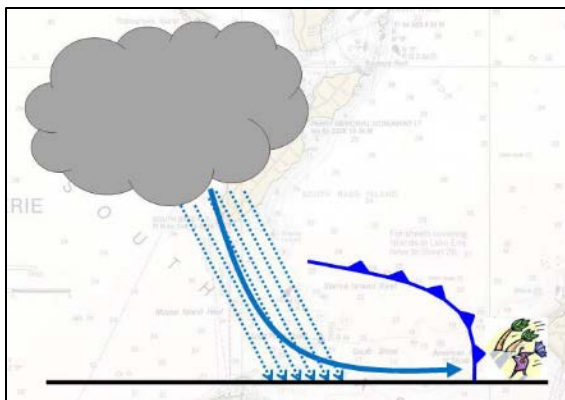
Single Cell Storms

- **Supercells** – a special type of single cell thunderstorm, known for their large hail, lightning and tornadoes.
- Less than 5% of all severe storms.
- Supercells have very strong rotating updrafts where wind speeds can reach 150-175 mph.
- Long-lived and destructive storms.

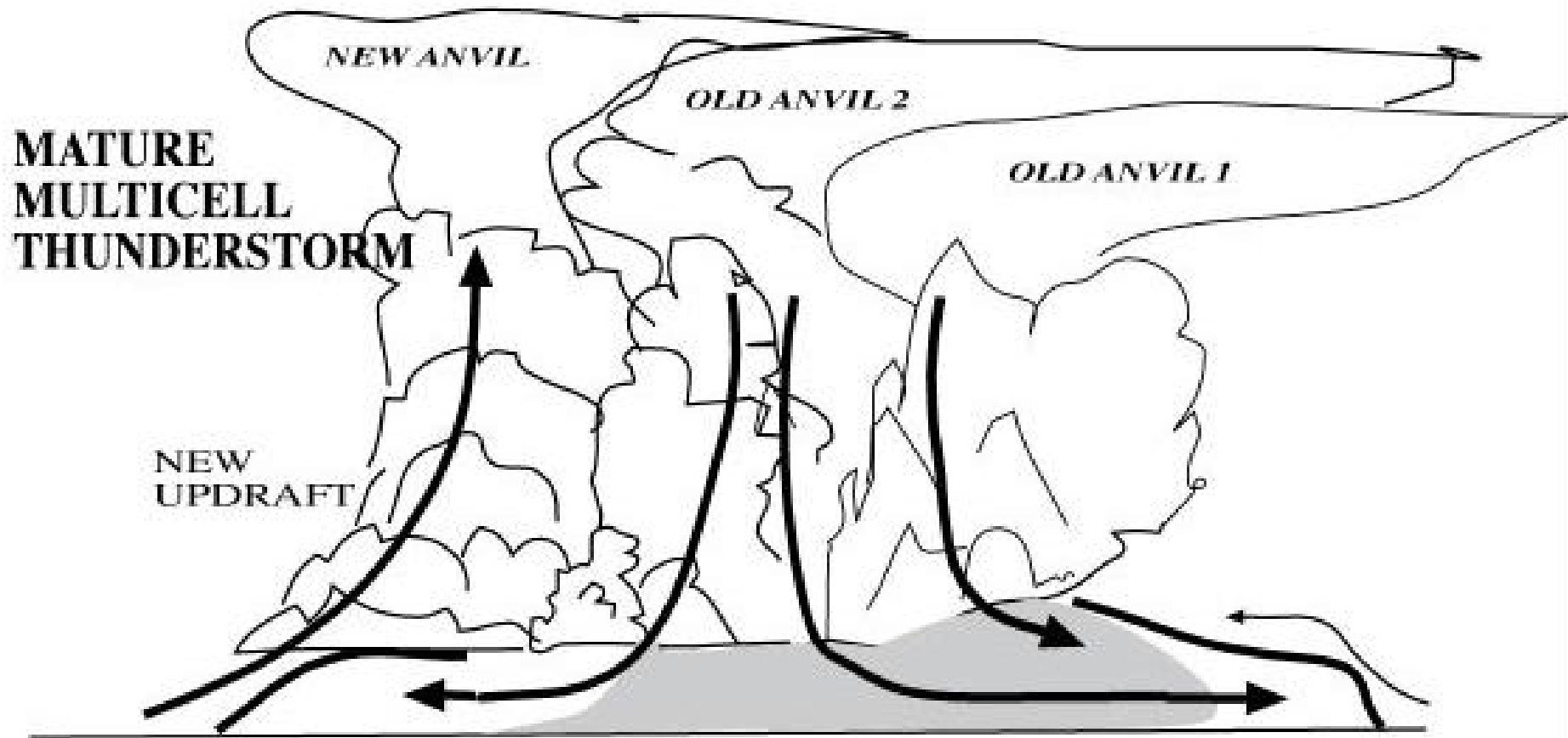


Multi-Cellular Storms

- Multi-cellular thunderstorms are those storms where cells in various stages of development co-exist in a cluster.
- The outflow boundaries from mature cells contribute to the cumulus stage of development by acting as mini cold fronts.
- This is the most common form of thunderstorm development and is responsible for most severe weather reports.
- A multi-cellular thunderstorm cluster may persist for several hours and contain severe thunderstorms – squall lines are an excellent example.



Multi-Cellular Storms

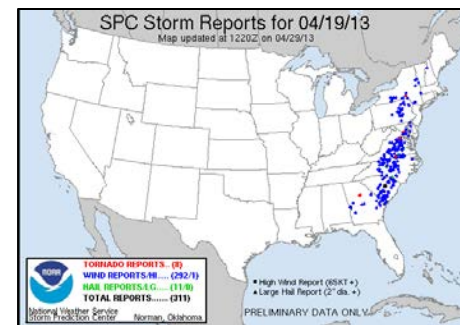
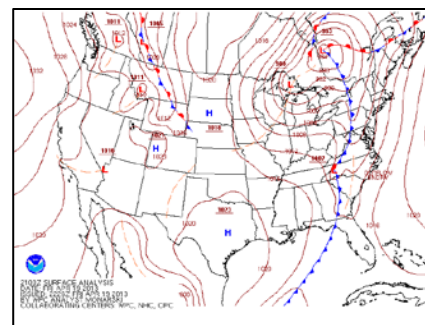
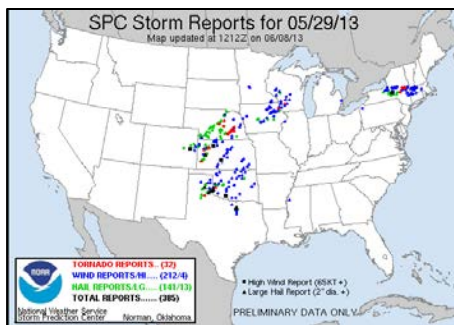
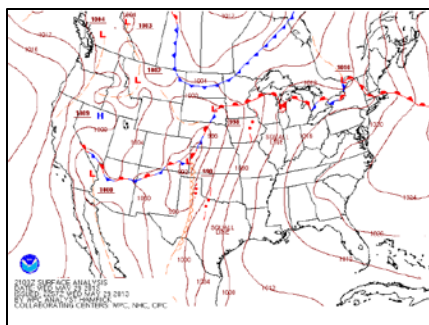


Multi-Cellular Storms

May 29, 2013

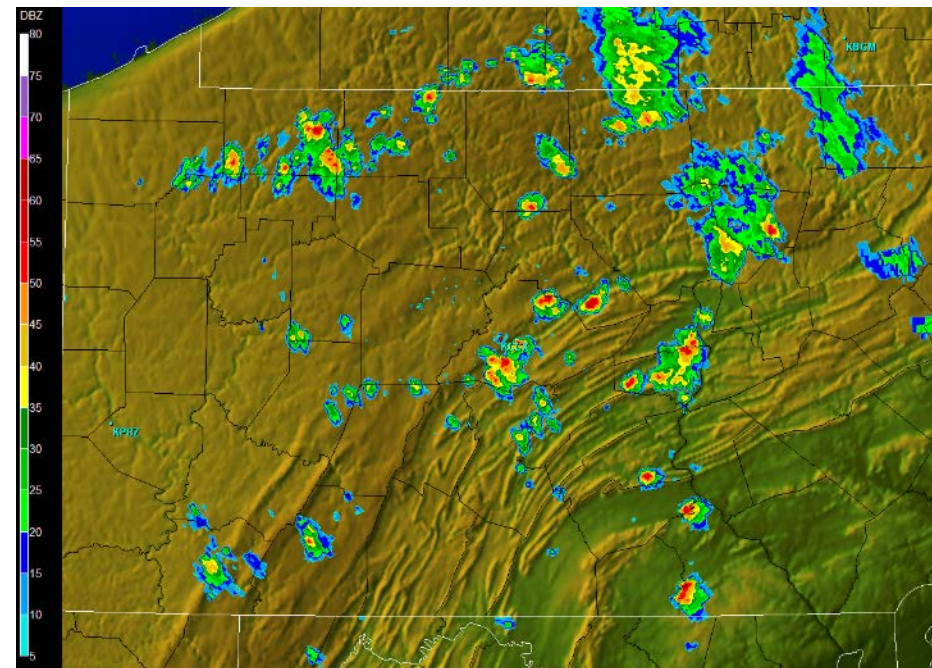


April 19, 2013

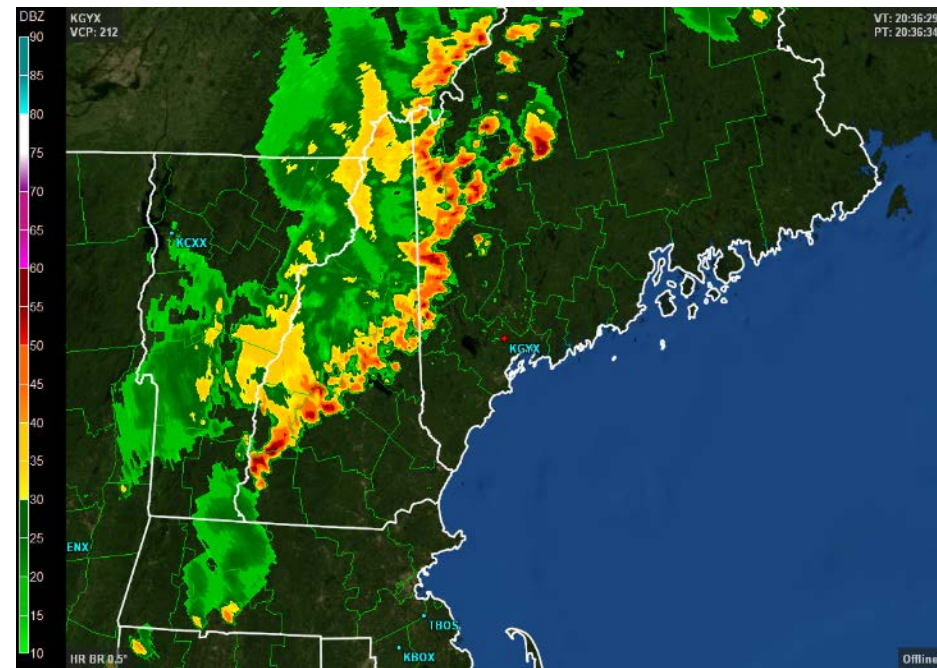


Pulse vs. Multicellular Thunderstorms

Disorganized vs. Organized



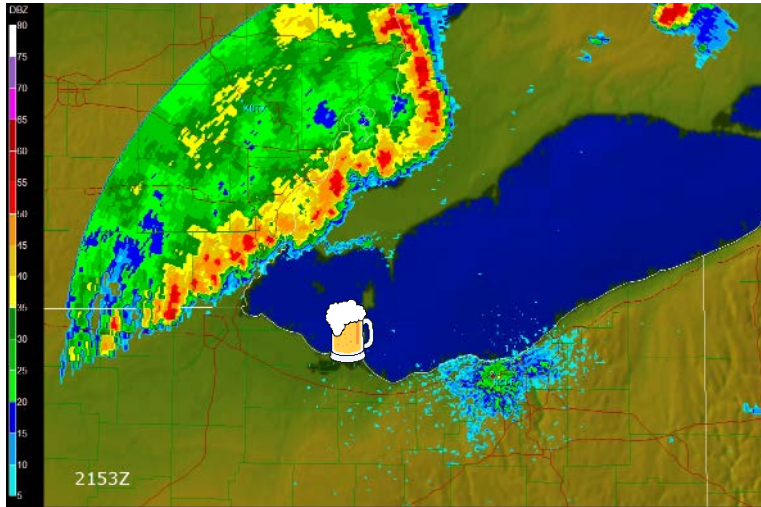
Pennsylvania: June 9, 2006 @ 1545Z



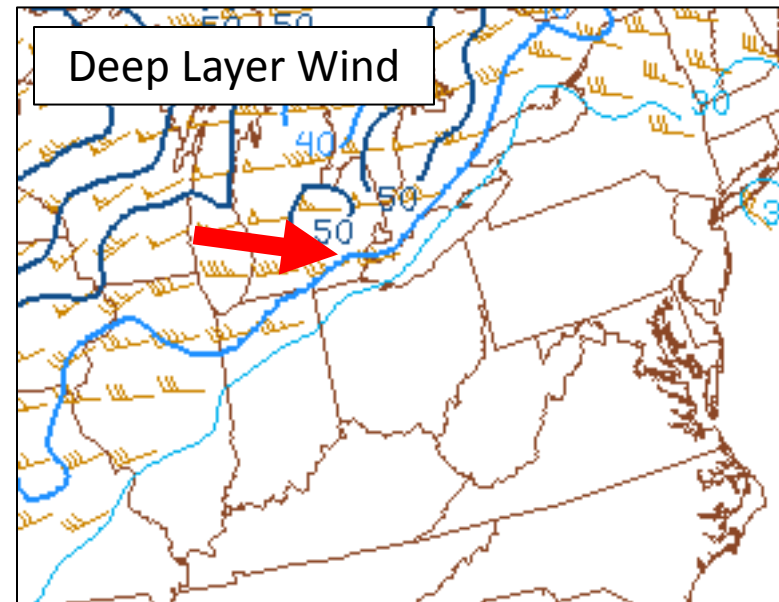
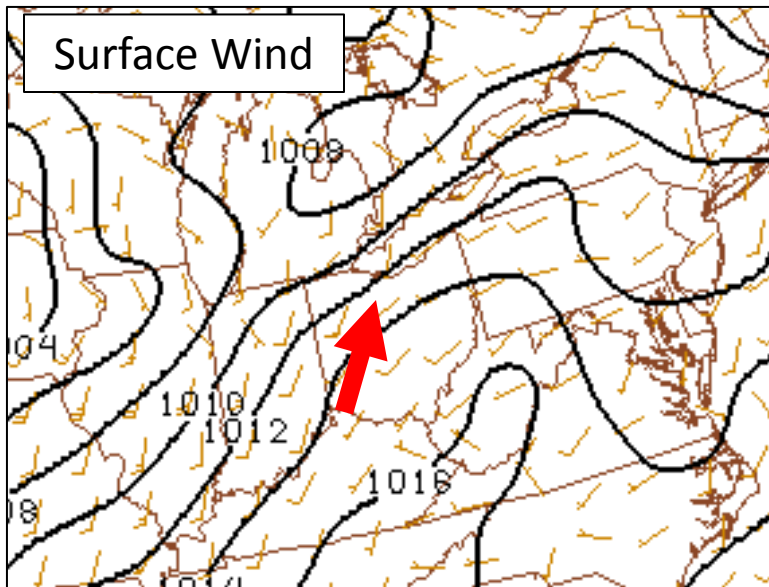
Coastal Maine: June 2, 2013 @ 2036Z

Storm Motion

Determining Storm Motion



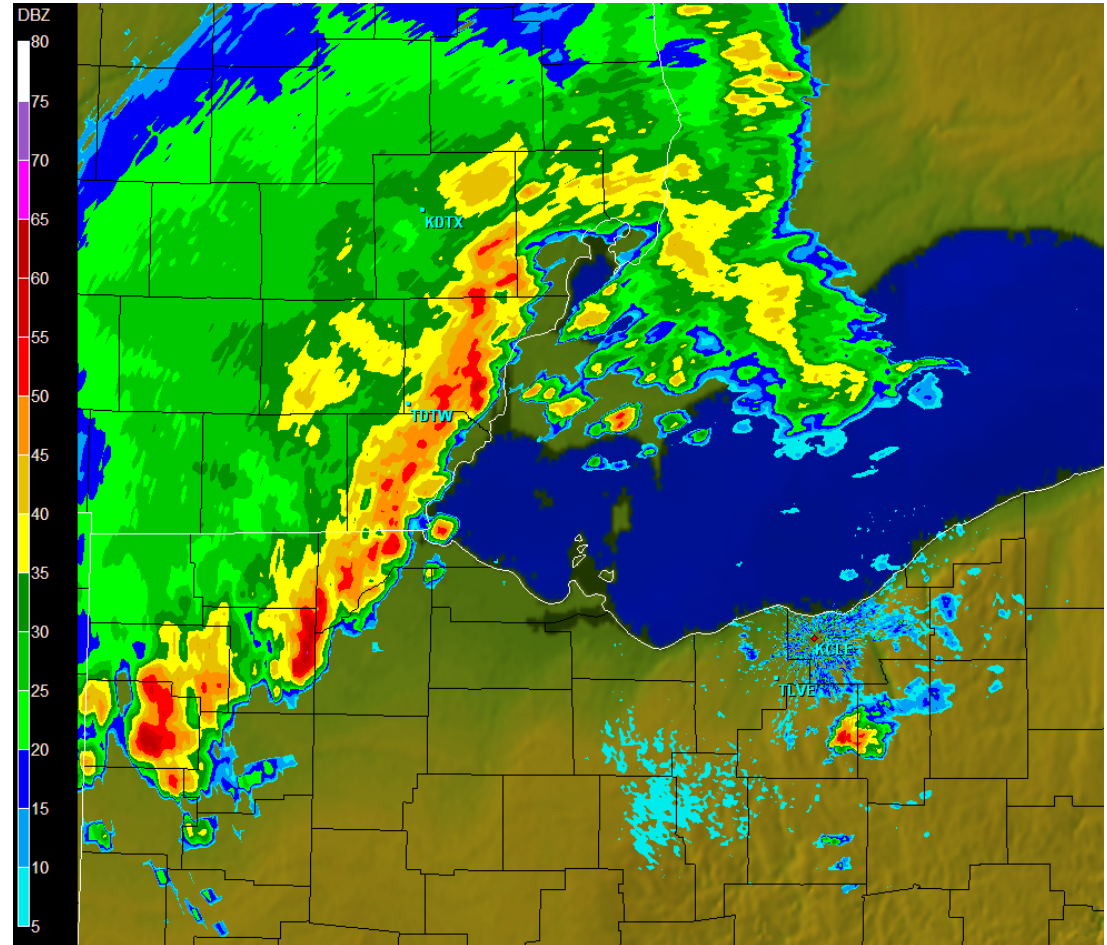
- Don't trust the speed and direction of the surface wind to judge motion of storm systems.
- Storm motion is influenced by the combination of winds in a deep layer of the atmosphere and storm propagation.
- As the squall line passed buoy 44063, the wind veered from 180° at 15 knots to 225° at 39 knots.
- Doppler radar is an effective method of monitoring storm motion.



A Recipe For Thunderstorms

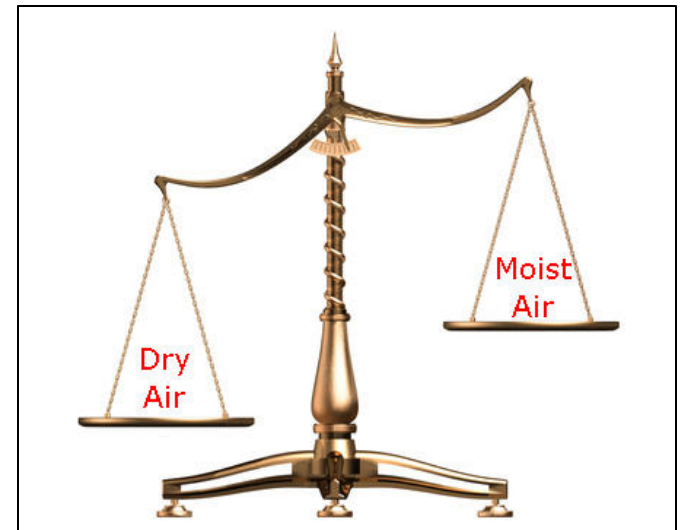
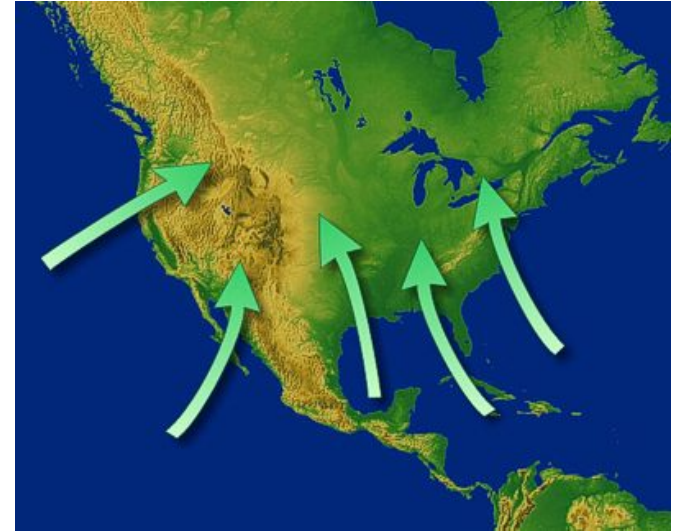
List of Ingredients

- Moisture
- Atmospheric Instability
- Source of Lift
- Wind Shear
- Mid- & Upper-Level Support



Moisture

- The Atlantic Ocean and the Gulf of Mexico provide ample moisture for coastal and offshore storms.
- An air molecule that contains water vapor is lighter than a dry air molecule.
 - This increases the potential for upward motion and the development of severe weather.





Atmospheric Instability

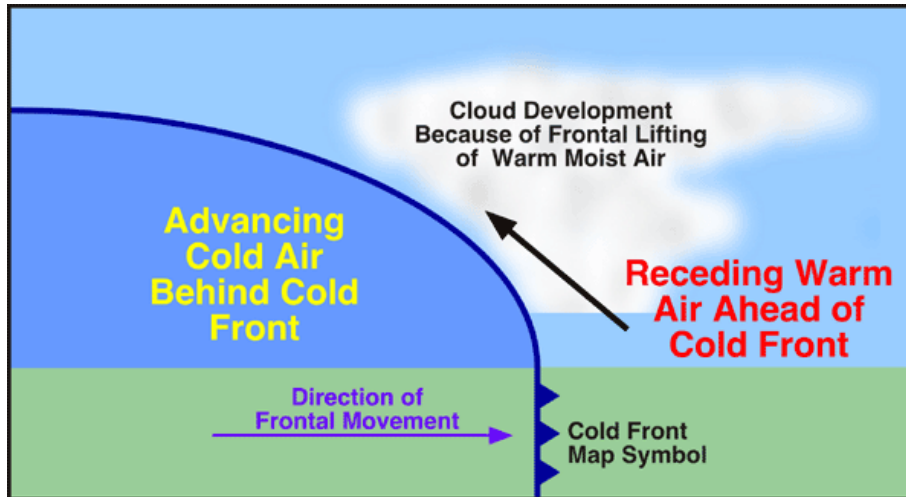


Characteristics of an Unstable Environment

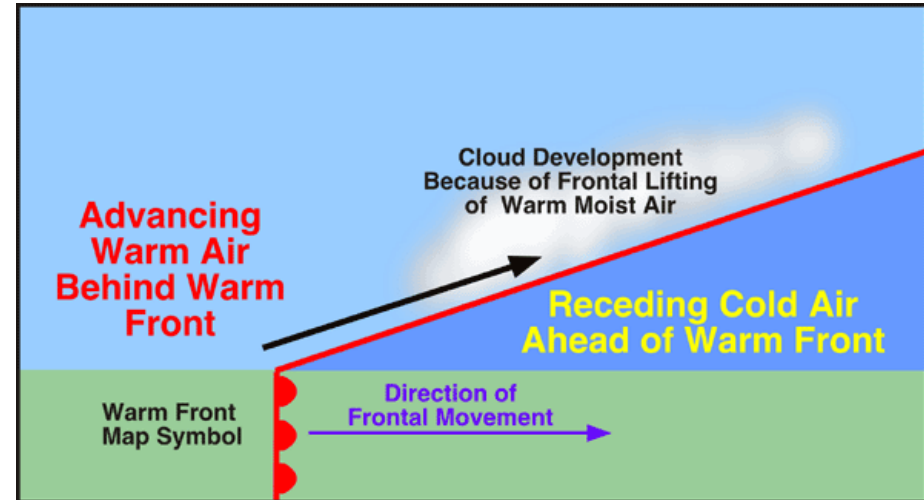
- An environment where upward motion of air parcels is supported.
- An air column where a rising (and cooling) air parcel remains warmer (less dense) than the surrounding environment.
- A deep layer of cold air aloft over a layer of warm and moist air at or near the surface.
- This upward motion promotes condensation, cloud development and precipitation.
- Unstable environments support the development of thunderstorms and severe weather.

Source of Lift

Frontal Boundaries

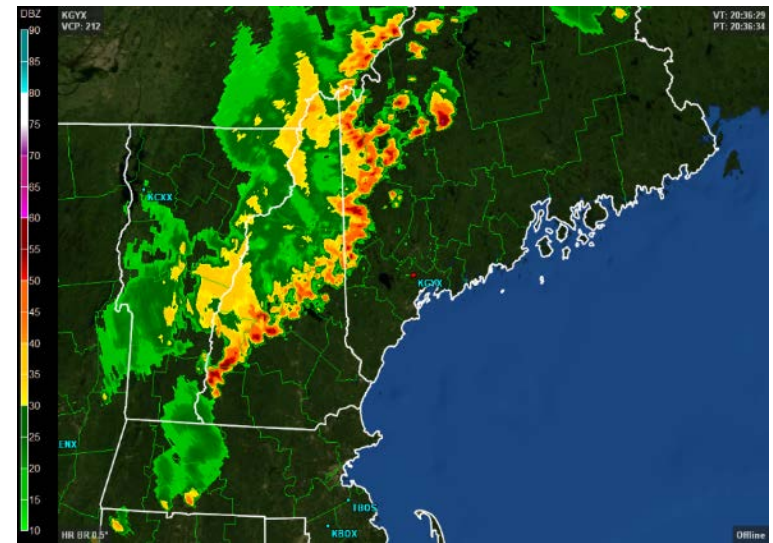
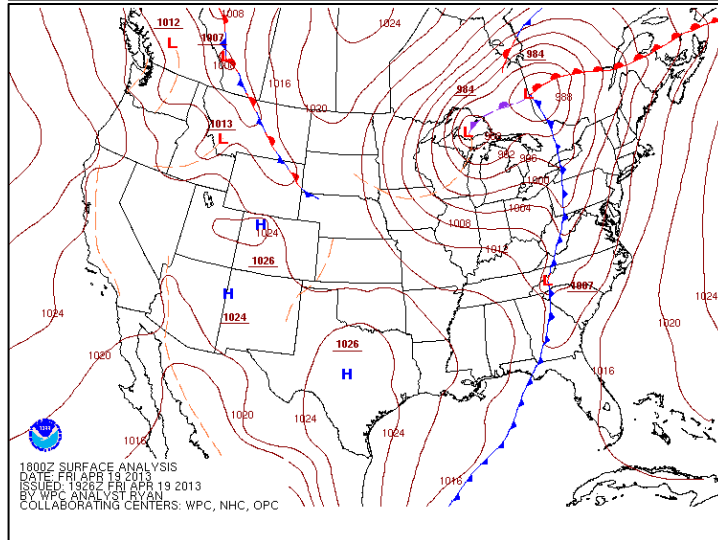
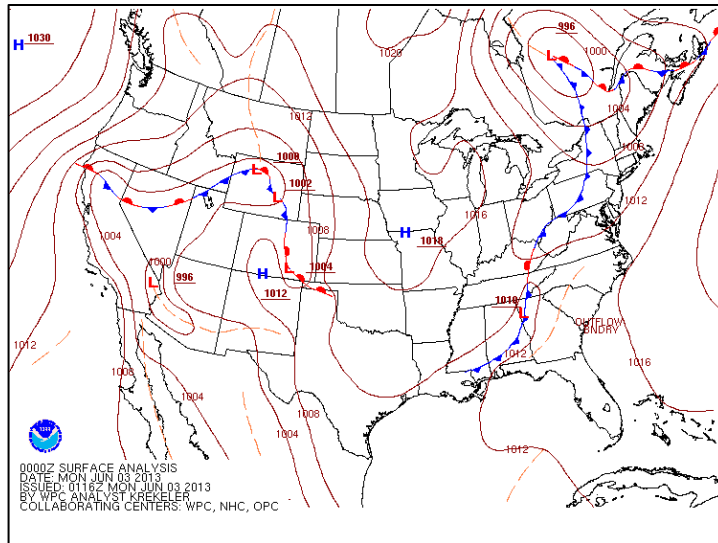


Cold Front



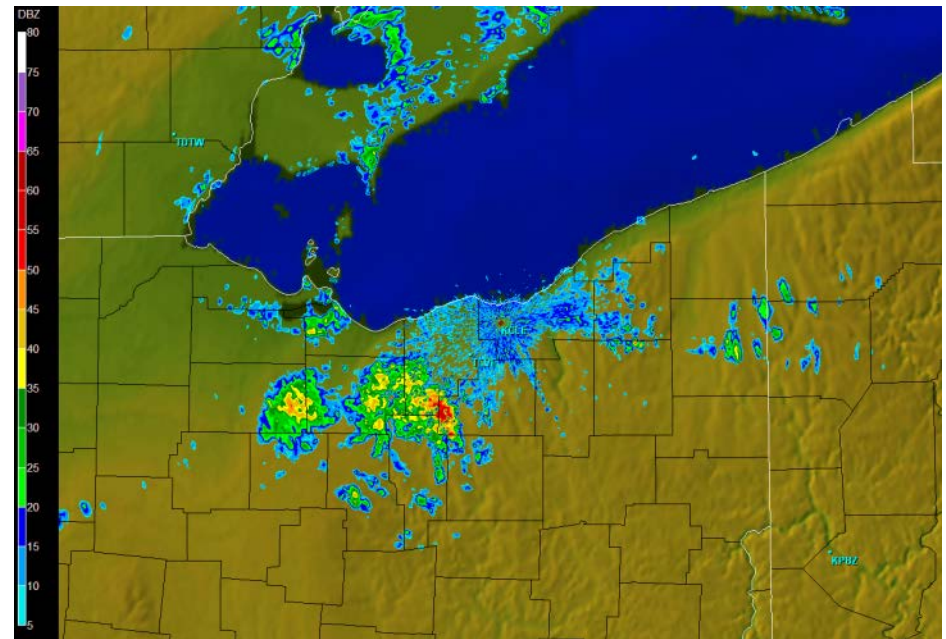
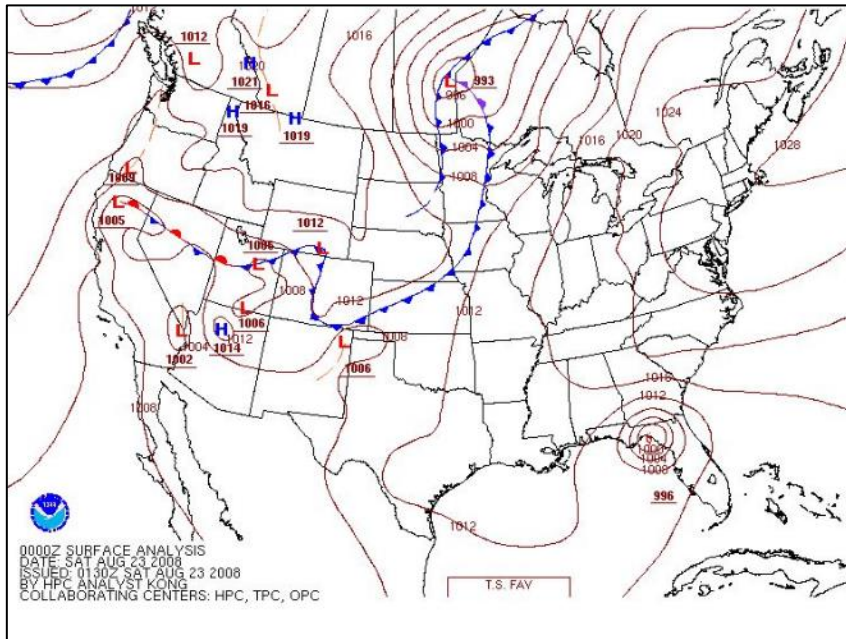
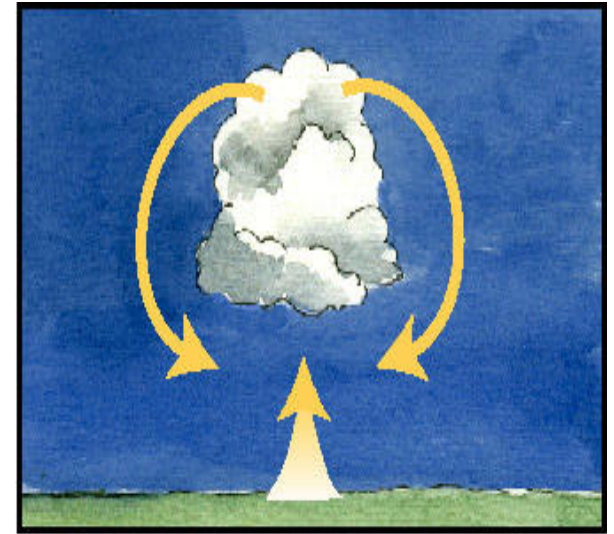
Warm Front

Frontal Boundaries and Thunderstorms



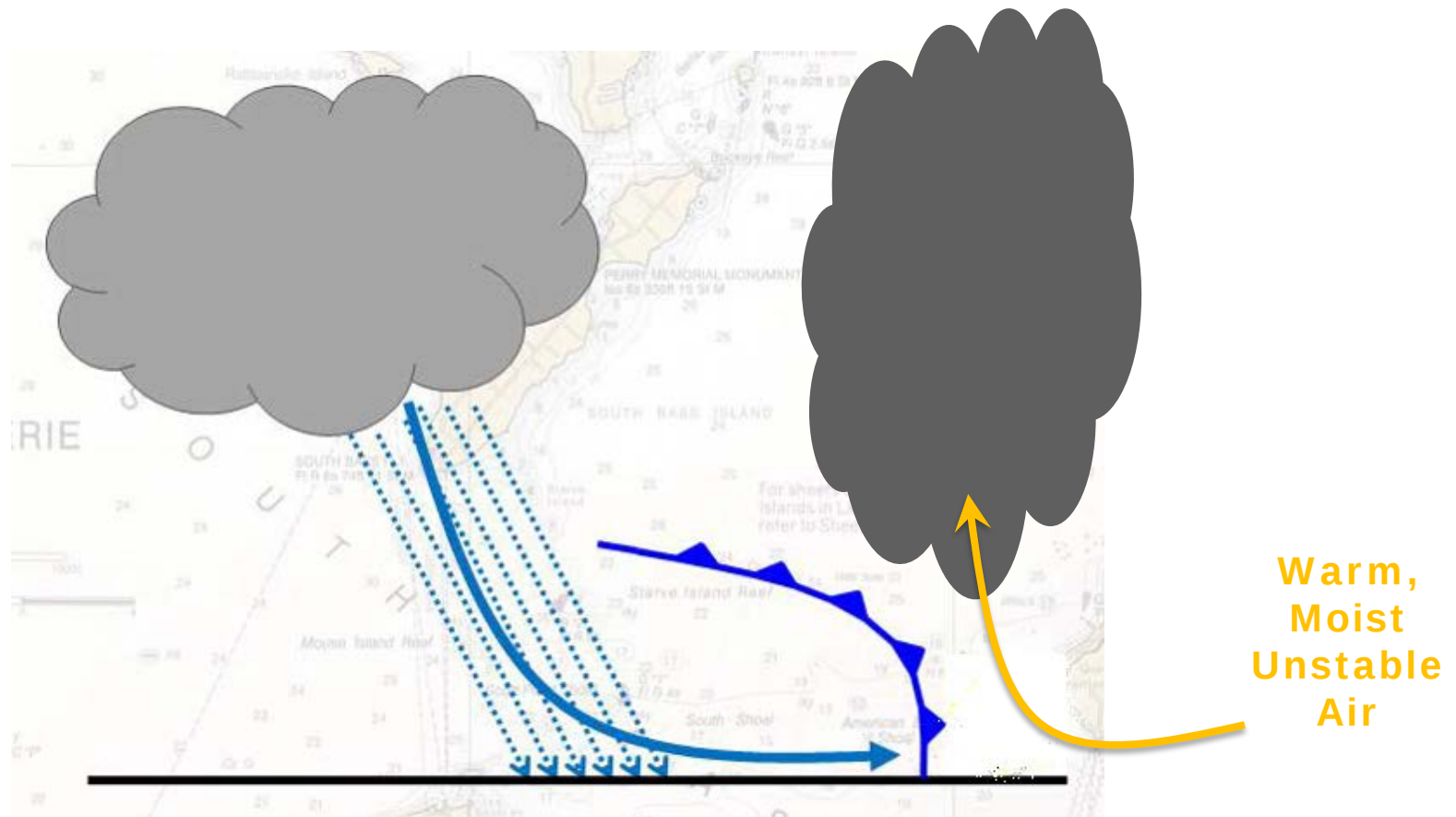
Differential Heating

- **Differential Heating (Convection)** – the difference in the rate of heating of different types of surfaces promotes upward motion referred to as thermals.
- Can promote air-mass or “pop-up” thunderstorms in the absence of frontal or other boundaries.
- Activity generally peaks in late afternoon or early evening as solar heating reaches a maximum.
- Example – Northern Ohio August 23, 2008.



Outflow Boundaries

- **Outflow Boundary** – outflow from thunderstorms may promote the development of new storms along this “mini cold front”.
- New thunderstorms may develop rapidly in an area away from the previous convection.
- An important factor in multi-cellular storms such as squall lines and Mesoscale Convective Systems.

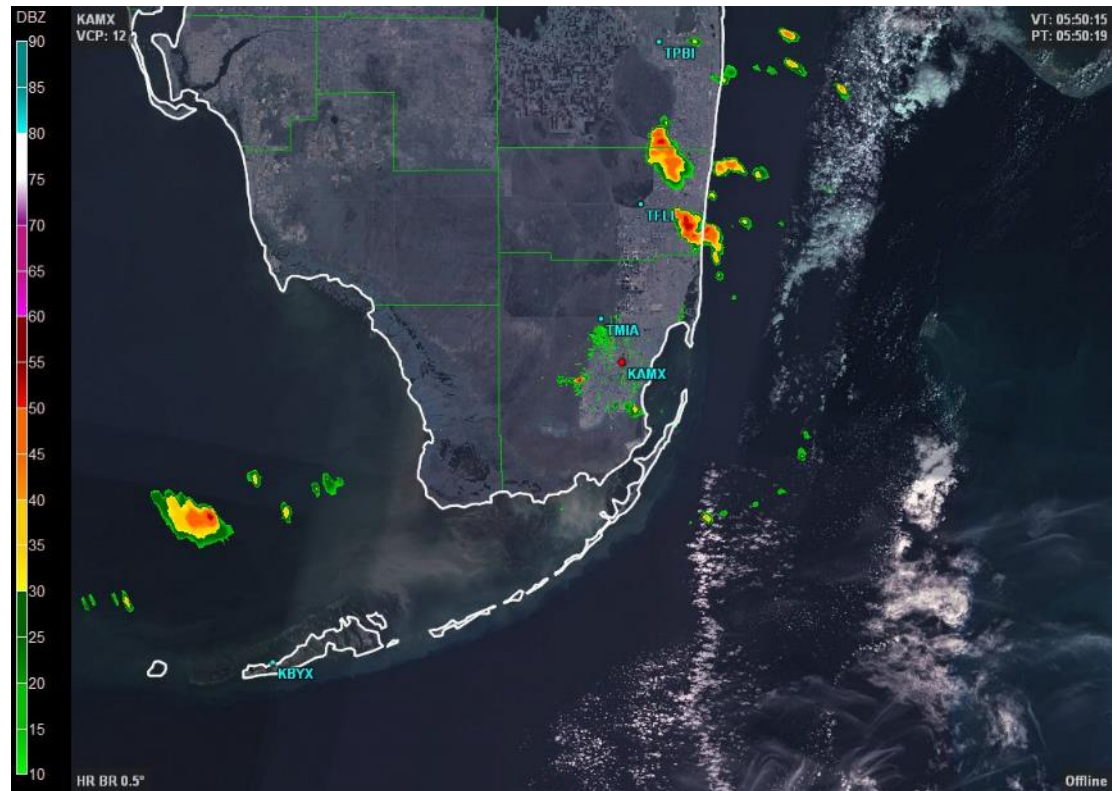
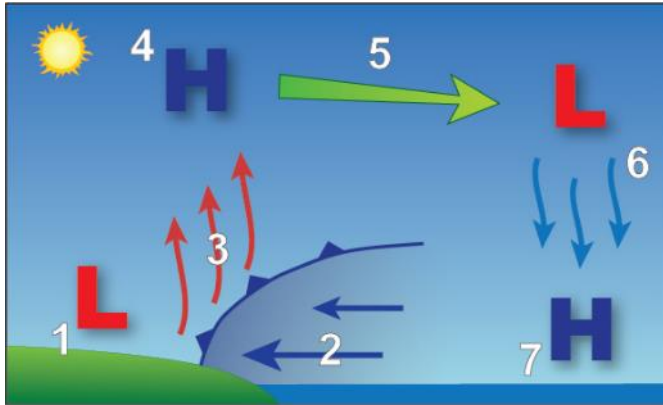


Sea and Land Breeze Boundaries

Sea – Land Breezes Boundaries

- Sea & land breeze boundaries can promote the development of showers and severe thunderstorms – particularly where two sea breeze fronts collide or interact with a thunderstorm outflow boundary.
- Sea & land breeze fronts can enhance thunderstorms as they approach the shore.
- Sea breeze fronts are a focal point for the development of waterspouts.

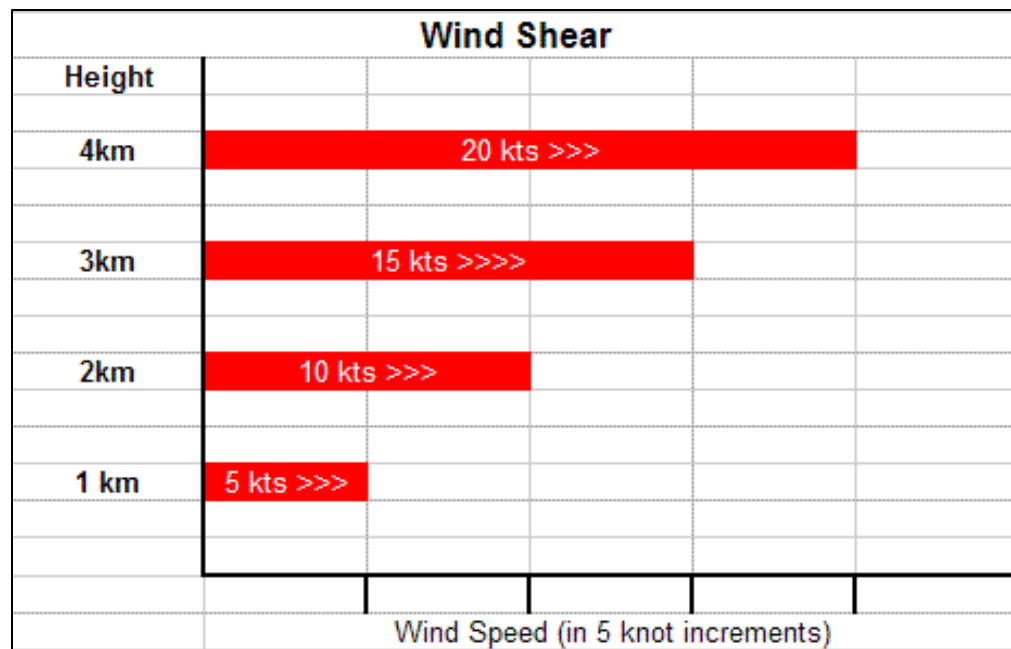
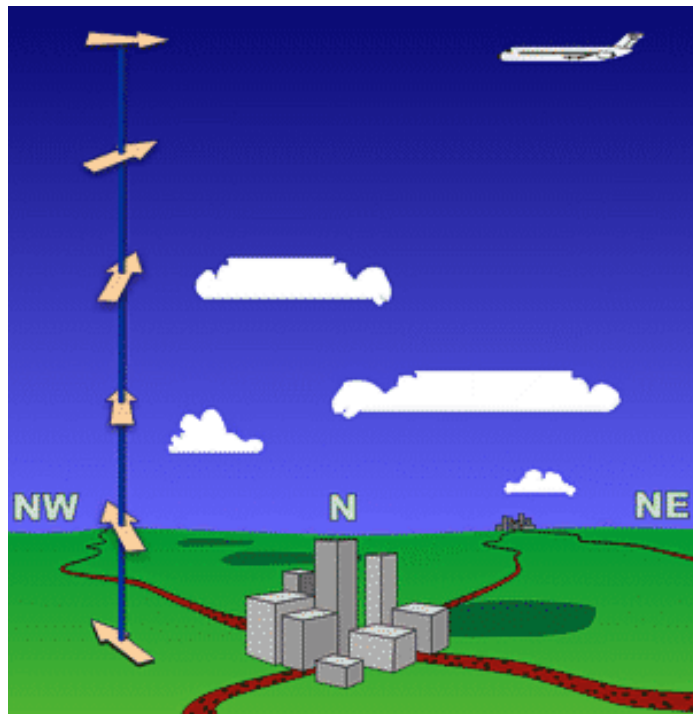
**Miami, FL
June 20, 2013 –
0550Z to 0651Z**



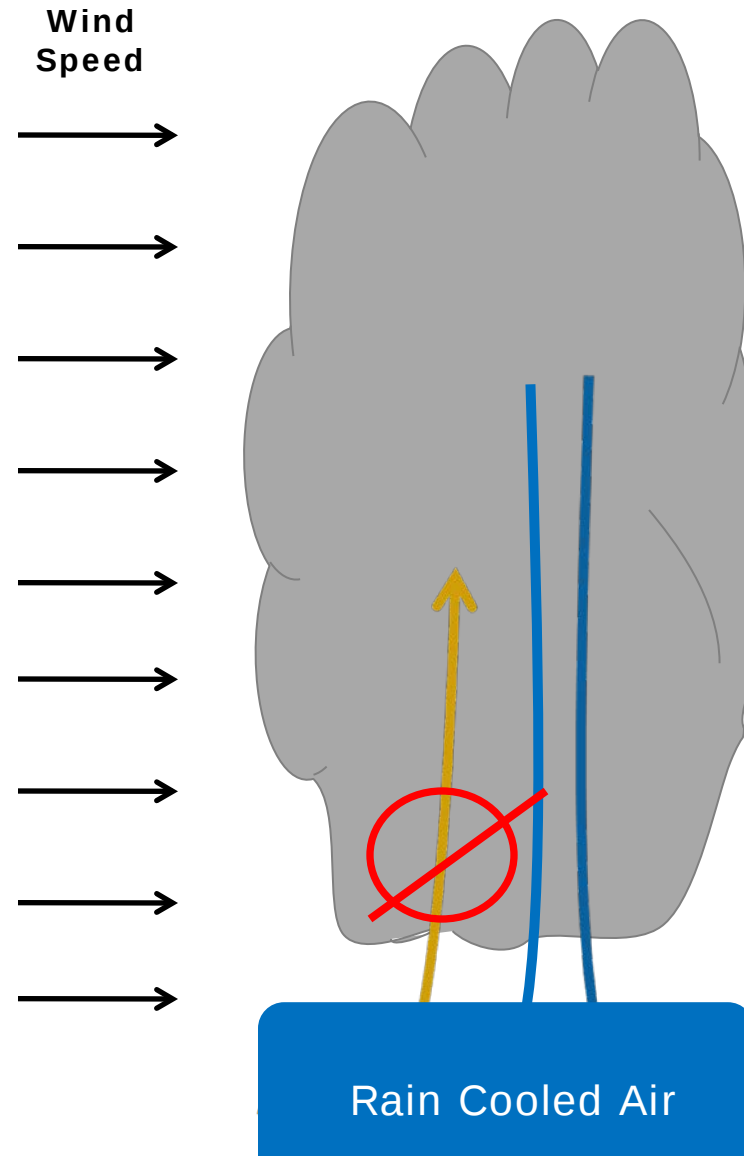
Wind Shear

Wind Shear

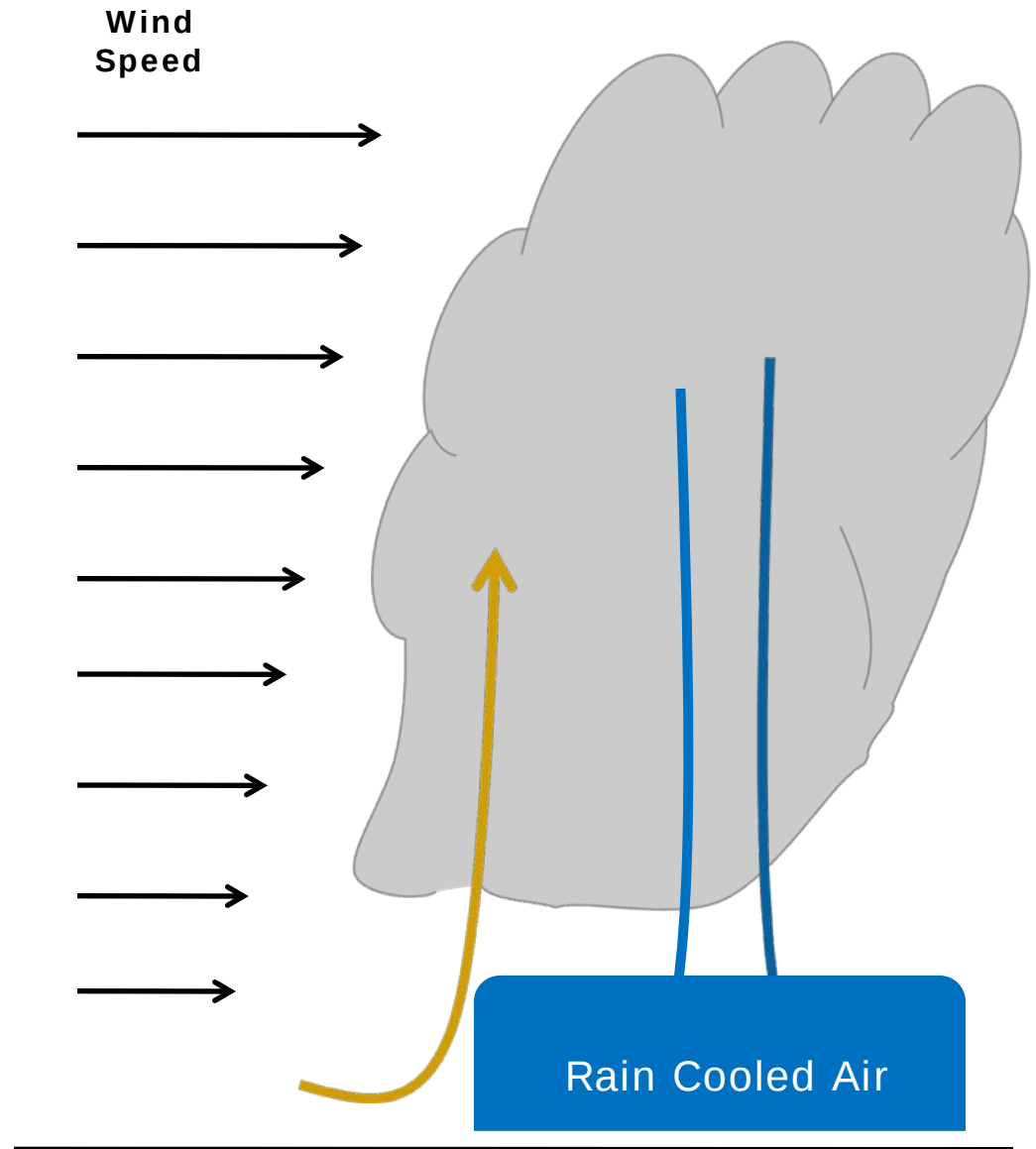
- A change in the direction and speed of the wind with increasing altitude.



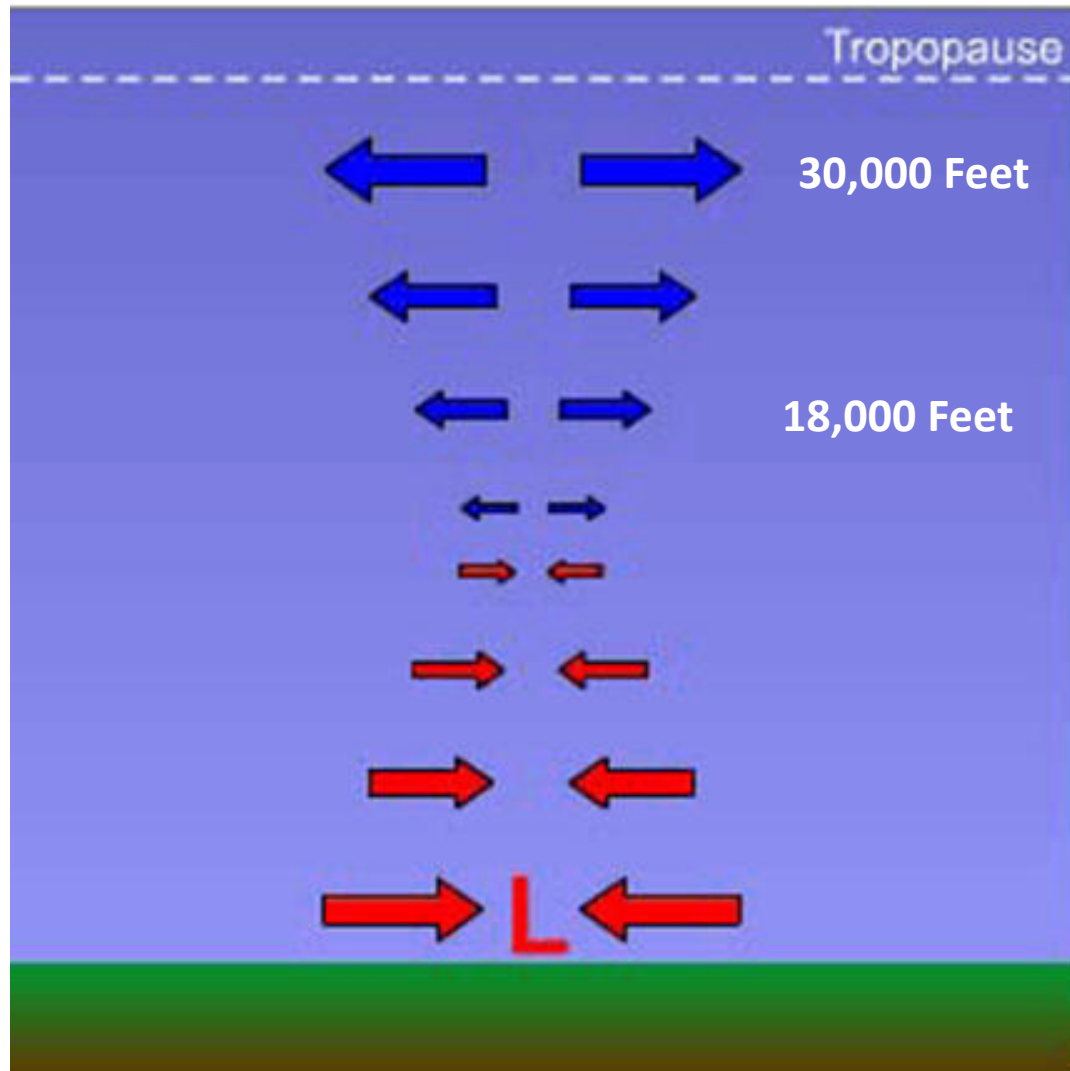
- **Wind Shear** – the change in wind speed or direction with increasing altitude.
- Weak wind shear allows cold pool and downdraft to disrupt the storm's updraft.
- Important factor in storm mode (single v. multi-cell storms) based upon relationship between deep-layer shear and initiating boundary.



- **Wind Shear** – the change in wind speed or direction with increasing altitude.
- Wind shear contributes to storm organization and longevity by separating the downdraft and cold pool from the updraft.
- Can impart rotation in storm updrafts (supercell thunderstorms).



Mid- And Upper-Level Support



The Key To Forecasting Thunderstorms

Knowing When And To What Degree All Of The Ingredients Will Be In Place. Once again they are ...

Moisture

Atmospheric Instability

Source of Lift

Wind Shear

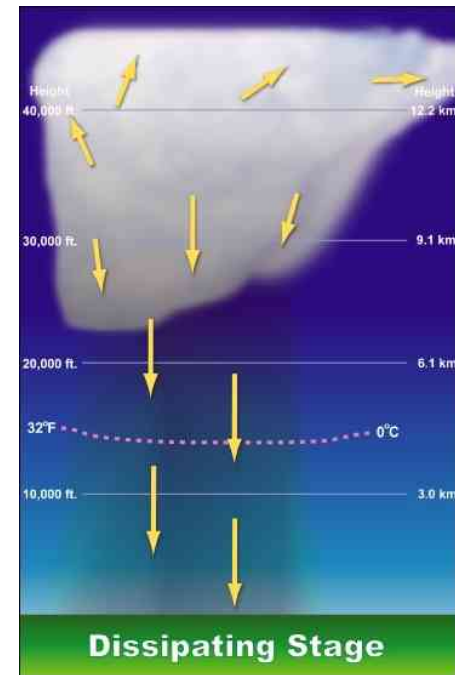
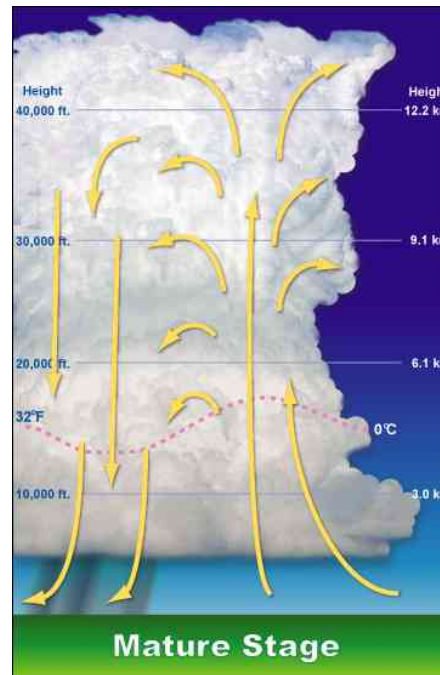
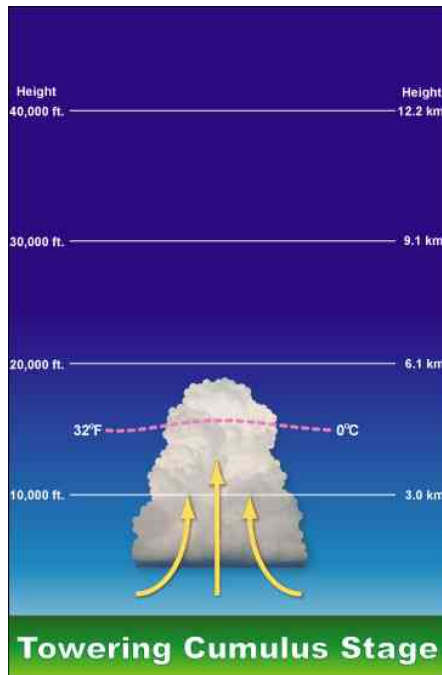
Mid- and Upper-Level Support

Disclaimer – Good Dynamics Don't Always Produce Thunderstorms.

Four Steps To Improving Your Management Of A Severe Weather Event

Step 1

Understand Thunderstorm Dynamics

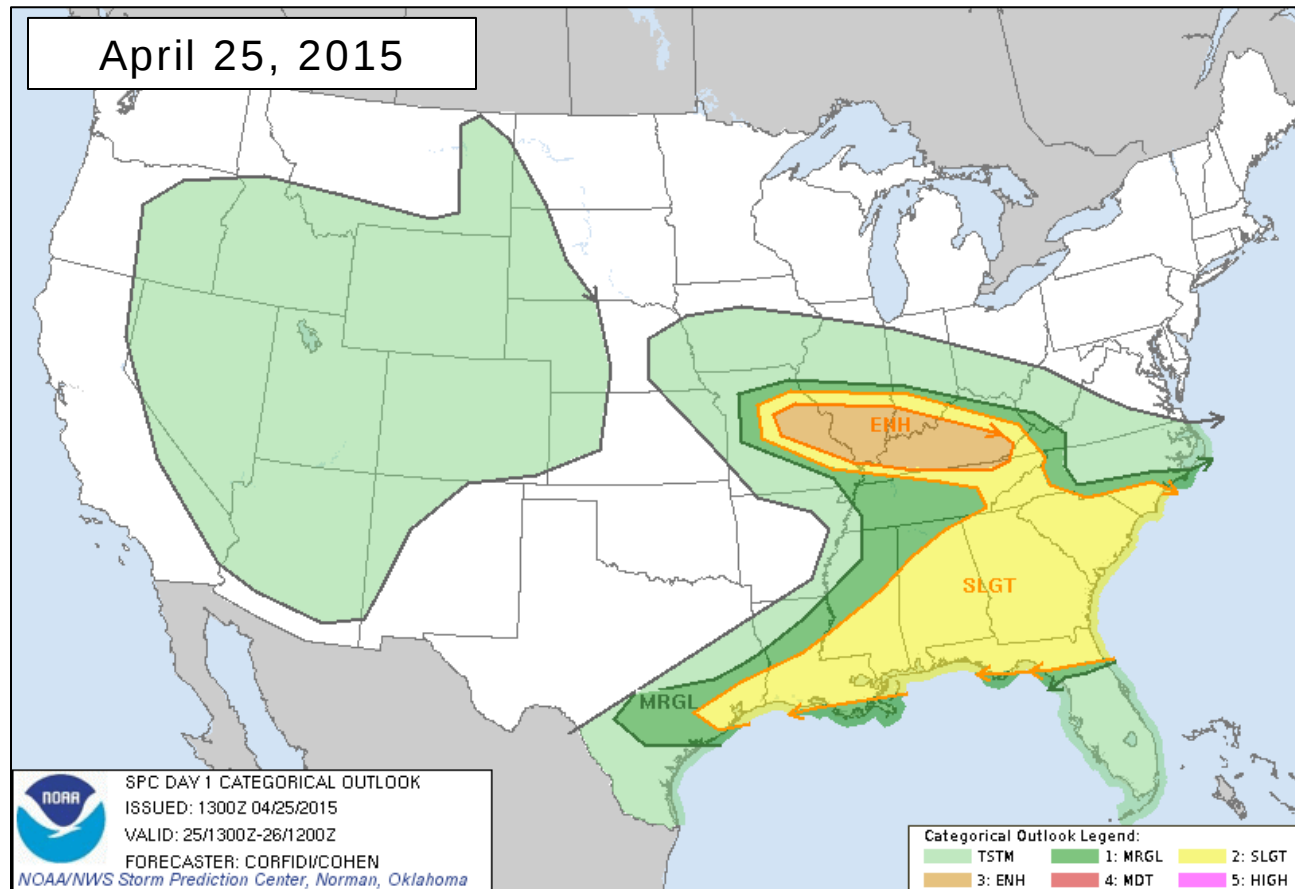


Step 2

**Understand The NWS Severe Weather Forecast Process
(Using The Dauphin Island Race)**

Storm Prediction Center

- Convective Outlooks (graphic and text products for the probability of severe weather).
- Mesoscale Discussions, Watches and Warnings.
- A suite of forecast graphics.

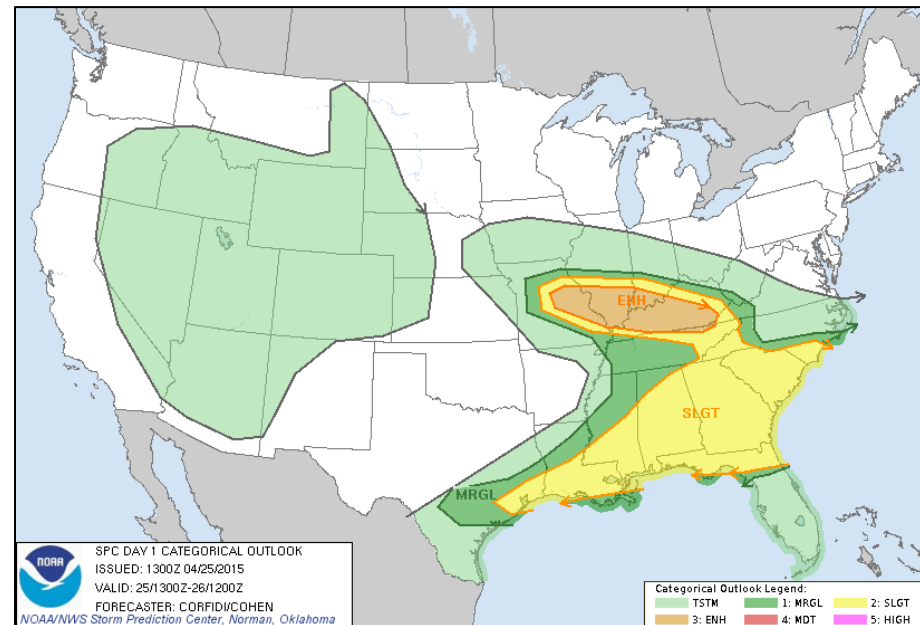


Storm Prediction Center

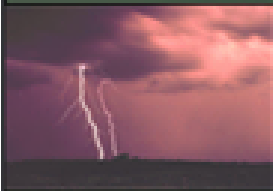
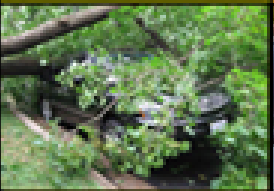
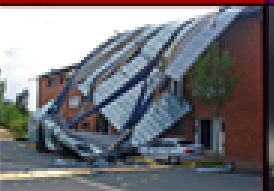
Expressing Probability and Risk

Six Risk Categories

- **See Text/No Label**: no severe t-storms are expected.
- **Marginal**: isolated severe t-storms possible but limited duration / coverage /intensity.
- **Slight**: scattered, short-lived severe storms possible. Approximately 5-25 reports of large hail, 5-25 damaging wind reports and/or 1 to 5 tornadoes.
- **Enhanced**: numerous, persistent and widespread severe storms possible.
- **Moderate**: widespread long-lived severe storms likely.
- **High**: a major severe weather outbreak is expected with the potential for very damaging wind gusts and/or 20 or more tornadoes.



Understanding Severe Thunderstorm Risk Categories

THUNDERSTORMS (no label)	1 - MARGINAL (MRGL)	2 - SLIGHT (SLGT)	3 - ENHANCED (ENH)	4 - MODERATE (MDT)	5 - HIGH (HIGH)
No severe* thunderstorms expected	Isolated severe thunderstorms possible	Scattered severe storms possible	Numerous severe storms possible	Widespread severe storms likely	Widespread severe storms expected
Lightning/flooding threats exist with <u>all</u> thunderstorms	Limited in duration and/or coverage and/or intensity	Short-lived and/or not widespread, isolated intense storms possible	More persistent and/or widespread, a few intense	Long-lived, widespread and intense	Long-lived, very widespread and particularly intense
					
• Winds to 40 mph • Small hail	• Winds 40-60 mph • Hail up to 1" • Low tornado risk	• One or two tornadoes • Reports of strong winds/wind damage • Hail ~1", isolated 2"	• A few tornadoes • Several reports of wind damage • Damaging hail, 1 - 2"	• Strong tornadoes • Widespread wind damage • Destructive hail, 2" +	• Tornado outbreak • Derecho

* NWS defines a severe thunderstorm as measured wind gusts to at least 58 mph, and/or hail to at least one inch in diameter, and/or a tornado. All thunderstorm categories imply lightning and the potential for flooding. Categories are also tied to the probability of a severe weather event within 25 miles of your location.



National Weather Service

www.spc.noaa.gov



Storm Prediction Center

Convective Outlook: April 25, 2015

DAY 1 CONVECTIVE OUTLOOK

NWS STORM PREDICTION CENTER NORMAN OK
1255 AM CDT SAT APR 25 2015

VALID 251200Z - 261200Z

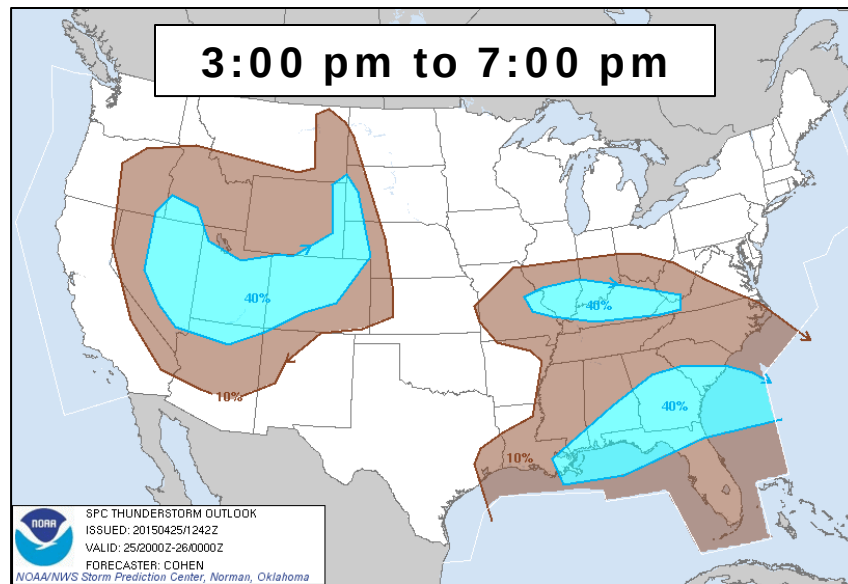
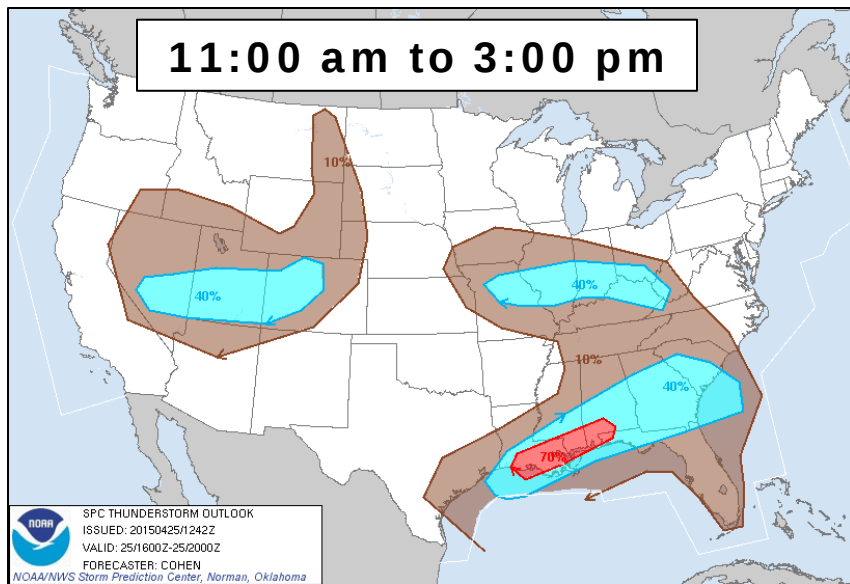
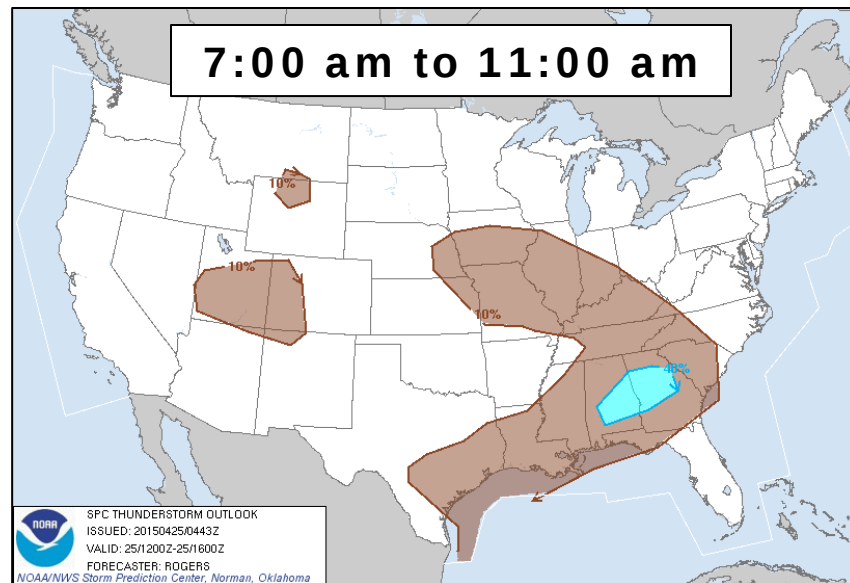
...THERE IS AN ENH RISK OF SVR TSTMS THIS AFTERNOON AND EVENING ACROSS PARTS OF THE LOWER OHIO AND TENNESSEE VALLEYS...THERE IS A SLGT RISK OF SVR TSTMS ACROSS SURROUNDING PORTIONS OF THE MIDDLE MISSISSIPPI AND OHIO VALLEYS...AS WELL AS THE EASTERN GULF STATES INTO SOUTH ATLANTIC COAST STATES....THERE IS A MRGL RISK OF SVR TSTMS IMMEDIATELY SURROUNDING THE SLGT RISK AREA...THERE IS A MRGL RISK OF SVR TSTMS LATE THIS AFTERNOON AND EVENING ACROSS PARTS OF THE NORTH CENTRAL HIGH PLAINS...

...SUMMARY...

SEVERE THUNDERSTORMS ARE EXPECTED TODAY ACROSS PARTS OF THE LOWER OHIO AND TENNESSEE VALLEYS PARTICULARLY ACROSS PORTIONS OF SOUTHERN KENTUCKY INTO NORTHERN TENNESSEE WHERE STRONGEST ACTIVITY COULD BE ACCOMPANIED BY VERY LARGE HAIL, STRONG WIND GUSTS, AND PERHAPS A COUPLE OF TORNADOES BY EARLY EVENING. **OTHER STRONG TO SEVERE STORMS ARE POSSIBLE ACROSS THE EASTERN GULF STATES INTO SOUTHERN ATLANTIC COAST STATES.**

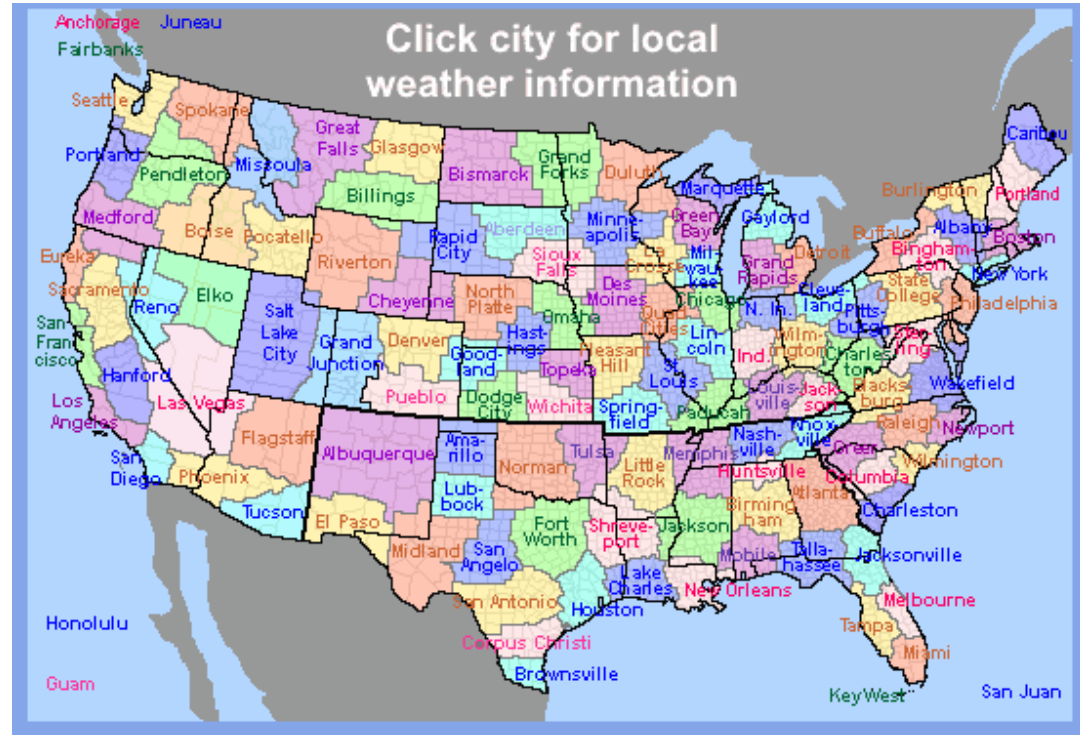
Storm Prediction Center

Thunderstorm Outlooks: April 25, 2015



➤ NWS – Weather Forecast Offices

- Point Forecasts – point and click forecast from the office's home page.
- Area Forecast Discussions and text Marine Forecasts.
- **Hazardous Weather Outlooks (HWO)**
- Doppler Radar imagery.
- Severe weather watches and warnings.



NWS Mobile Hazardous Weather Outlook

April 25, 2015

THIS HAZARDOUS WEATHER OUTLOOK IS FOR PORTIONS OF SOUTH CENTRAL ALABAMA...SOUTHWEST ALABAMA...NORTHWEST FLORIDA AND SOUTHEAST MISSISSIPPI..DAY ONE...

TODAY AND TONIGHT

SHOWERS AND THUNDERSTORMS WILL MOVE INTO THE AREA FROM THE WEST THIS AFTERNOON. SOME OF THE THUNDERSTORMS MAY BECOME STRONG OR SEVERE WITH DAMAGING WINDS AND LARGE HAIL THE PRIMARY THREATS.

GMZ630>635-650-655-670-675-261200-

NORTHERN MOBILE BAY-SOUTHERN MOBILE BAY-MISSISSIPPI SOUND-PERDIDO BAY-PENSACOLA BAY SYSTEM-CHOCTAWHATCHEE BAY-COASTAL WATERS FROM PENSACOLA FL TO PASCAGOULA MS OUT 20 NM-COASTAL WATERS FROM DESTIN TO PENSACOLA FL OUT 20 NM-WATERS FROM PENSACOLA FL TO PASCAGOULA MS FROM 20 TO 60 NM-WATERS FROM DESTIN TO PENSACOLA FL FROM 20 TO 60 NM-

1045 AM CDT SAT APR 25 2015

THIS HAZARDOUS WEATHER OUTLOOK IS FOR PORTIONS OF THE COASTAL WATERS OF ALABAMA AND NORTHWEST FLORIDA.

.DAY ONE...TODAY AND TONIGHT

THUNDERSTORMS WILL MOVE IN FROM THE WEST THIS AFTERNOON AND ACROSS THE MARINE AREA. SOME OF THE THUNDERSTORMS MAY BE STRONG OR SEVERE WITH GUSTY WINDS AND LARGE HAIL THE PRIMARY THREAT.

Step 3

**Understand The NWS Severe Weather Warning Process
(Using The Dauphin Island Race)**

Storm Prediction Center

Mesoscale Discussions

MESOSCALE DISCUSSION 0452
NWS SPC NORMAN OK
0935 AM CDT SAT APR 25 2015

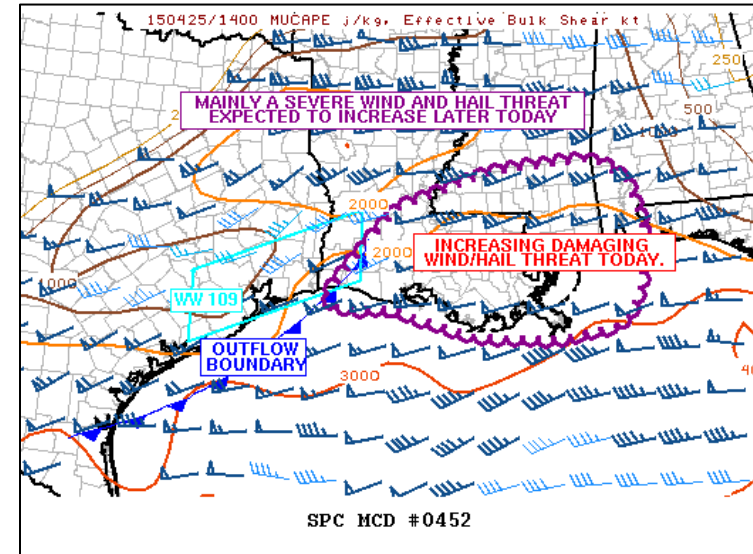
AREAS AFFECTED SERN TX INTO LA AND SRN MS

CONCERNING SEVERE THUNDERSTORM WATCH 109

VALID 251435Z - 251630Z
THE SEVERE WEATHER THREAT FOR SEVERE THUNDERSTORM
WATCH 109 CONTINUES.

SUMMARY THE SEVERE THREAT IS MOVING MOSTLY OFFSHORE THE
UPPER TX COAST THIS MORNING WITH A DEVELOPING THREAT
ACROSS MUCH OF SRN LA INTO SRN MS LATER TODAY. THE
PRIMARY SEVERE THREATS ARE DAMAGING WIND AND LARGE HAIL
AND ANOTHER WATCH IS LIKELY DOWNSTREAM ACROSS LA AND
MS.

**THE MAIN SEVERE THREAT IS EXPECTED TO DEVELOP AHEAD
OF THE OUTFLOW BOUNDARY FROM SRN LA INTO SRN MS/AL**
WHERE HEATING WILL LEAD TO ADDITIONAL DESTABILIZATION
WITH AMPLE MOISTURE AND DEEP-LAYER SHEAR/FLOW IN PLACE.
THE STRONG MEAN-LAYER FLOW AND RELATIVELY STEEP LAPSE
RATES ALOFT GIVEN THE MOIST AIR MASS WILL FAVOR BOTH
DAMAGING WINDS AND LARGE/DAMAGING HAIL. THIS ACTIVITY
WILL LIKELY EVOLVE OUT OF THE ACTIVITY OVER SWRN LA AND
JUST OFFSHORE.



Storm Prediction Center

Severe Weather Watches

URGENT - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WATCH NUMBER 113
NWS SPC NORMAN OK
135 PM CDT SAT APR 25 2015

THE NWS SPC HAS ISSUED A SEVERE THUNDERSTORM WATCH FOR PORTIONS OF SOUTHWEST ALABAMA WESTERN FLORIDA PANHANDLE COASTAL WATERS

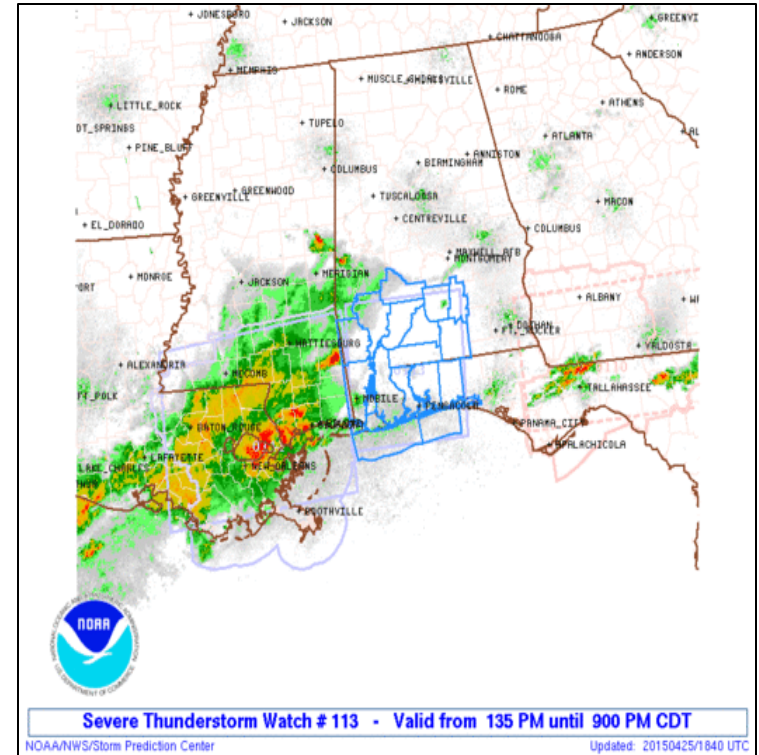
EFFECTIVE THIS SATURDAY AFTERNOON AND EVENING FROM 135 PM UNTIL 900 PM CDT.

PRIMARY THREATS INCLUDE ISOLATED VERY LARGE HAIL EVENTS TO 2 INCHES IN DIAMETER POSSIBLE ISOLATED DAMAGING WIND GUSTS TO 70 MPH POSSIBLE

SUMMARY

SEVERE STORMS ONGOING OVER SOUTHEAST MISSISSIPPI ARE EXPECTED TO SPREAD EAST ACROSS THE WATCH AREA THIS AFTERNOON INTO EVENING. LARGE HAIL AND DAMAGING WINDS WILL BE THE PRIMARY HAZARDS WITH THESE STORMS.

THE SEVERE THUNDERSTORM WATCH AREA IS APPROXIMATELY ALONG AND 60 STATUTE MILES EAST AND WEST OF A LINE FROM 35 MILES SOUTH SOUTHWEST OF PENSACOLA FLORIDA TO 35 MILES NORTH NORTHWEST OF EVERGREEN ALABAMA.



National Weather Service

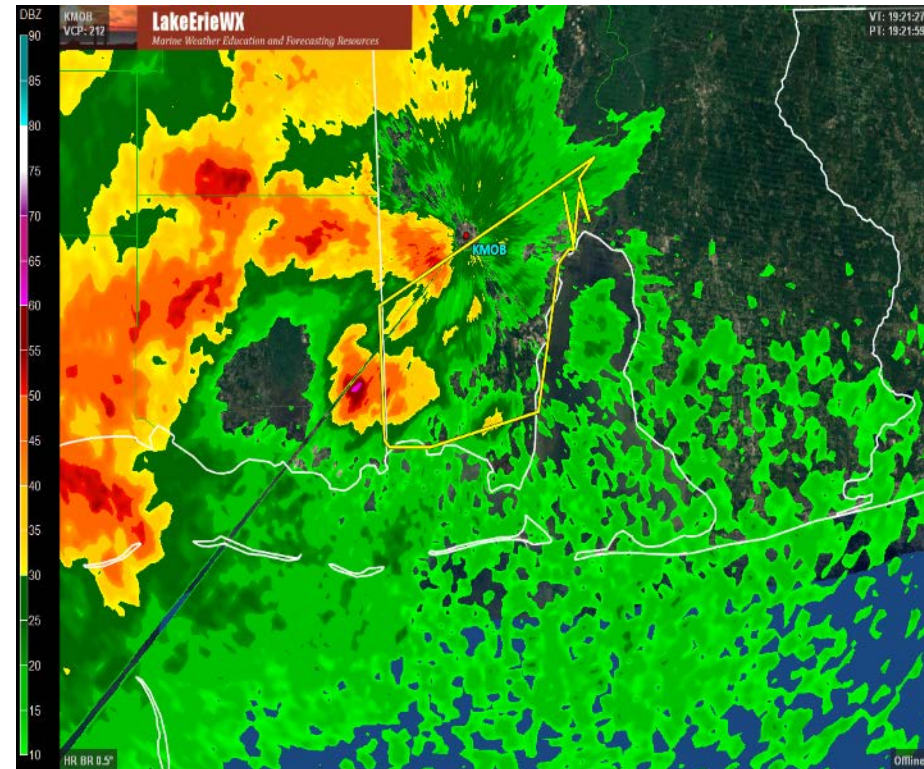
Severe Thunderstorm Warnings

**BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE MOBILE AL
221 PM CDT SAT APR 25 2015**

THE NATIONAL WEATHER SERVICE IN MOBILE HAS ISSUED A SEVERE THUNDERSTORM WARNING FOR SOUTHWESTERN MOBILE COUNTY IN SOUTHWESTERN ALABAMA UNTIL 245 PM CDT

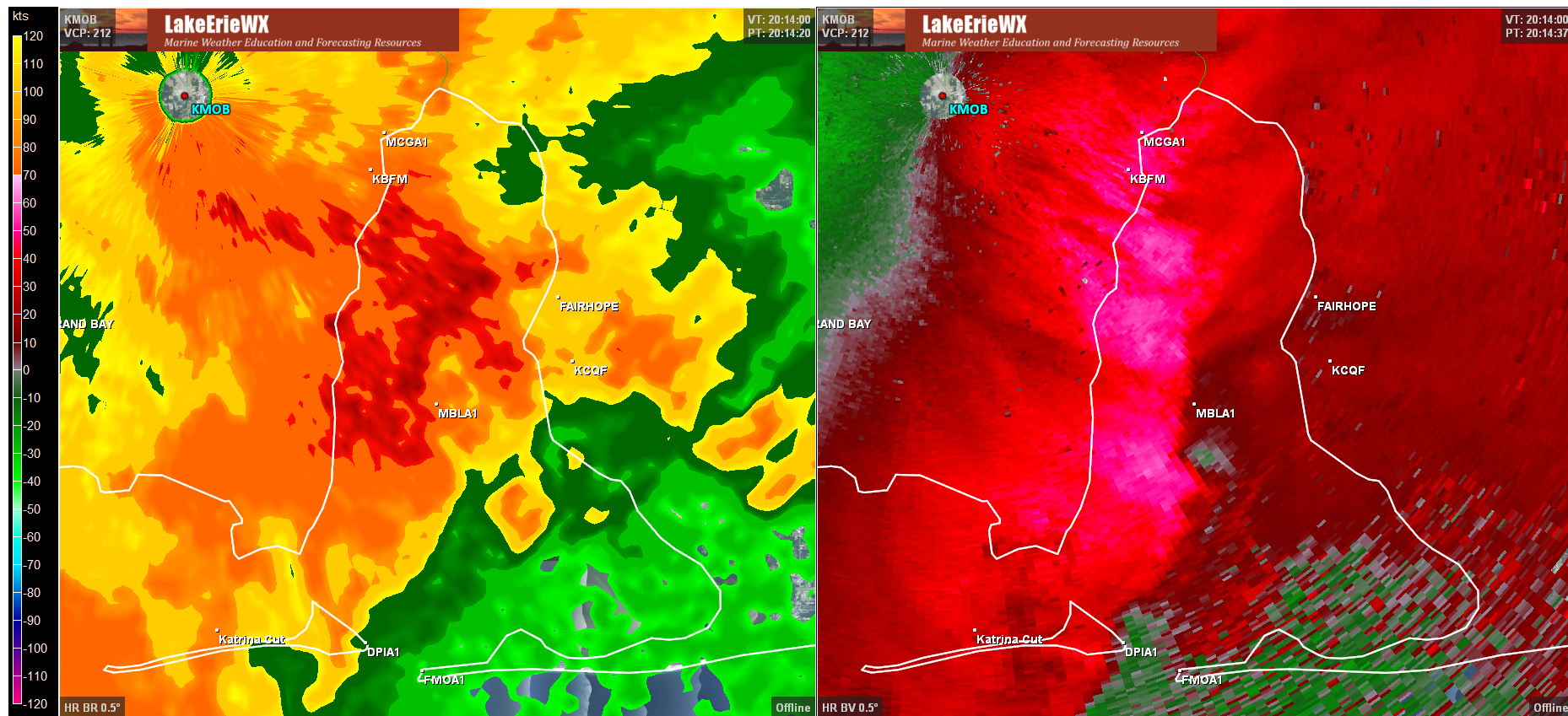
**AT 221 PM CDT A SEVERE THUNDERSTORM
CAPABLE OF PRODUCING QUARTER SIZE HAIL
AND DAMAGING WINDS OVER 60 MPH WAS
LOCATED NEAR GRAND BAY AND MOVING EAST AT
70 MPH.**

LOCATIONS IMPACTED INCLUDE MOBILE PRICHARD
BAYOU LA BATRE DOWNTOWN MOBILE GRAND BAY
MIDTOWN MOBILE TILLMANS CORNER THEODORE
I10 AND I65 BELLE FONTAINE BROOKWOOD
COCHRANE BRIDGE



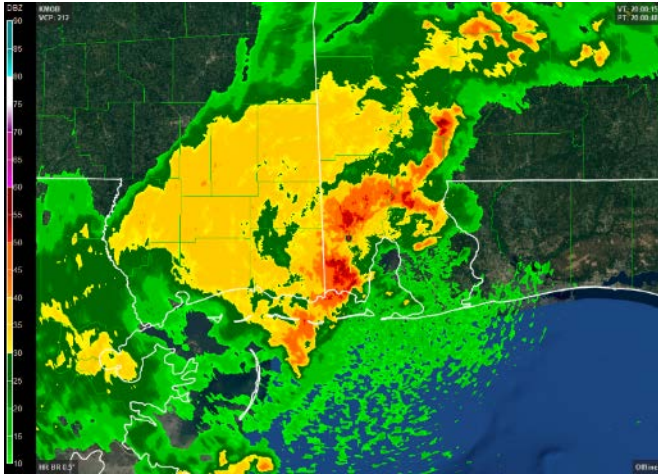
Step 4

Learn How To Use Doppler Weather Radar



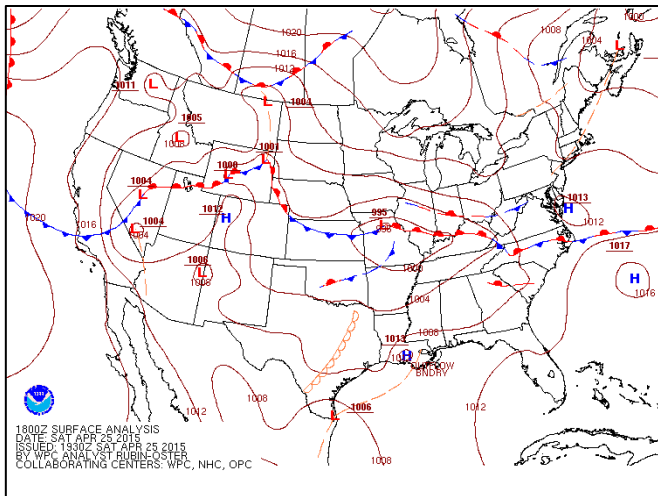
Summary

Dauphin Island Regatta – April 25, 2015



➤ MD / Watch / Warning Summary

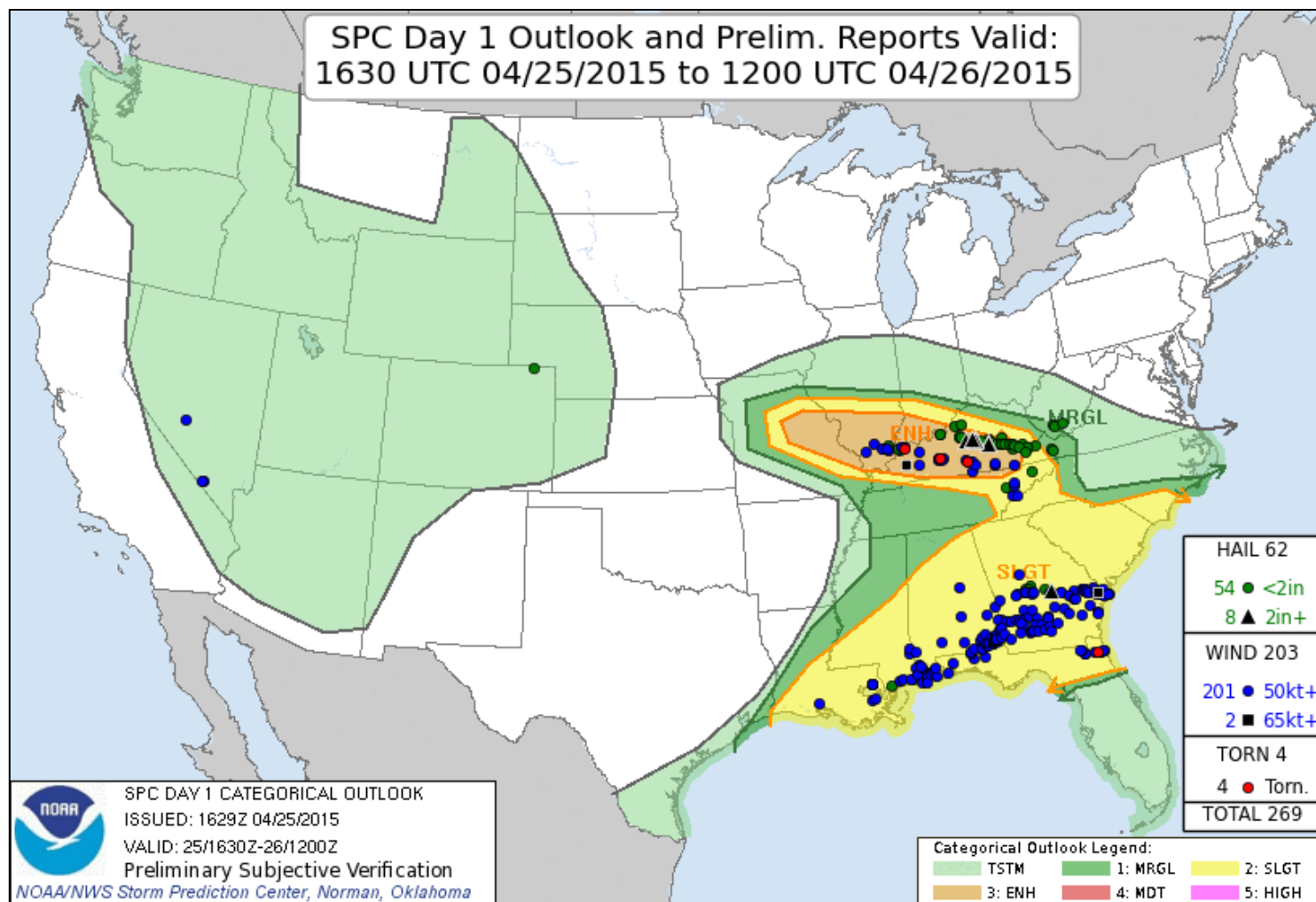
- Convective Outlooks
- Mesoscale Discussions – 3 Issued
- Severe Thunderstorm Watches – 2 Issued
- Severe Thunderstorm Warnings – 21 Issued



➤ Incident Summary

- Downburst winds to 70 knots.
- Six fatalities.
- Eights boats sank.
- Forty people required rescue from the water.

Storm Prediction Center Verification



A Short Quiz-Take Two

- Thunderstorms development is 100% unpredictable? **TRUE** or **FALSE**
- Thunderstorms are always associated with a low pressure system? **TRUE** or **FALSE**
- Most thunderstorms have a lifespan of 45-60 minutes? **TRUE** or **FALSE**
- A squall line is a cluster of individual thunderstorms? **TRUE** or **FALSE**
- It is possible to accurately predict the speed of a downdraft? **TRUE** or **FALSE**
- The speed and direction of the surface wind is a good proxy for determining thunderstorm motion? **TRUE** or **FALSE**
- Lightning may occur up to 10 miles ahead of an approaching thunderstorm? **TRUE** or **FALSE**
- Thunderstorms often form along sea (lake) and land breezes boundaries? **TRUE** or **FALSE**
- The threshold for a severe thunderstorm is 34 knots? **TRUE** or **FALSE**
- A Watch is more serious than a Warning? **TRUE** or **FALSE**

Enjoy Your Weather-Wise Sailing



Mark@LakeErieWX.com

Your Opinion Matters

Please open the **Sailing Leadership Forum app** and complete the **session survey** found in the **menu bar**.

Thank you for attending this session