Simulating Devastating Winds in 2011 American South Tornados Outbreak with the WRF-RTFDDA-LES System

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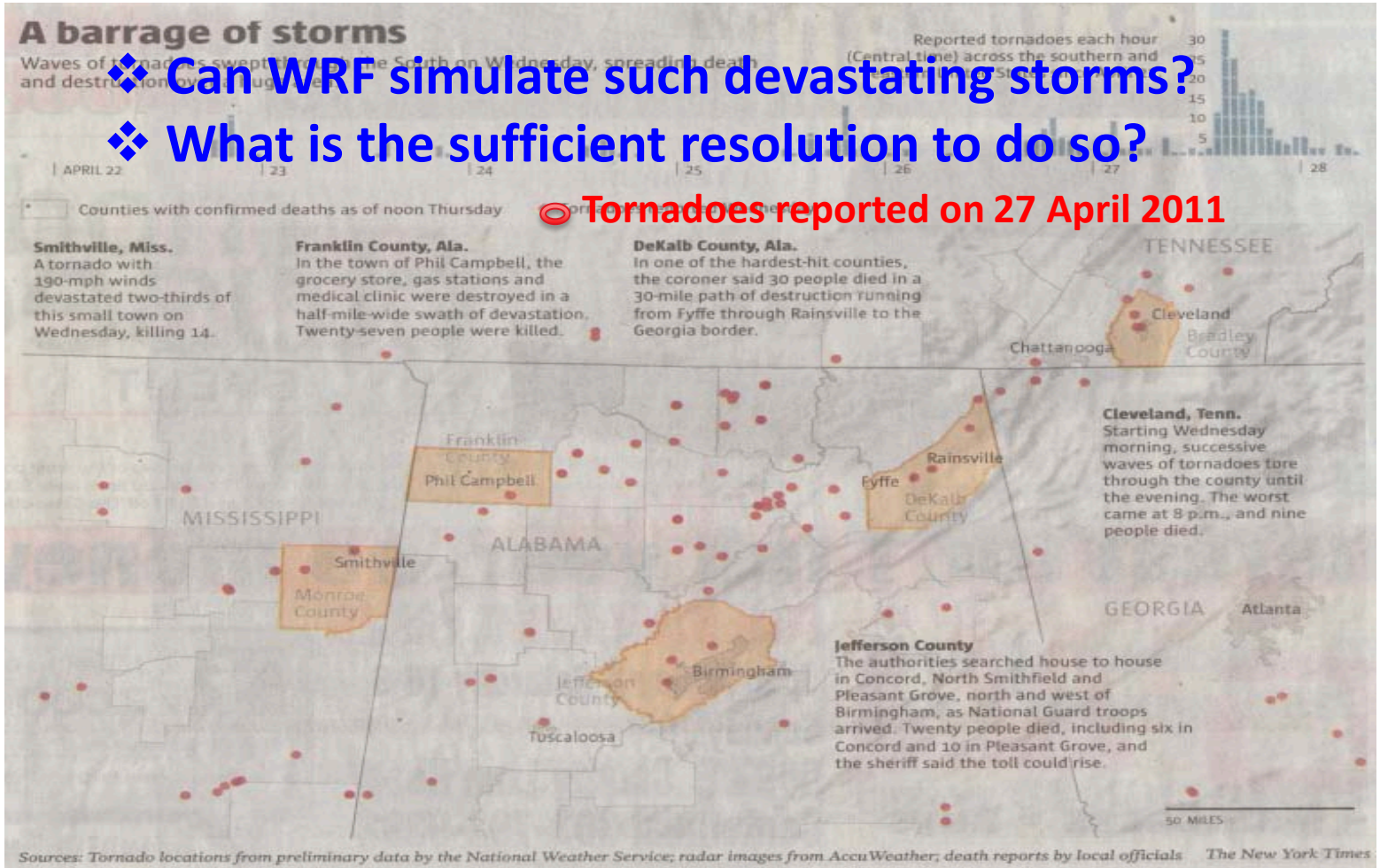
Outline

- Motivation
- Model and Experiment Design
- Results
- Summary

Motivation

- 2011: a deadliest tornado year in U.S. history: 536 fatalities.
- April 25 – 28 2011: A massive tornado outbreak in South U.S.: 300+ fatalities and $10 billion damages.

(http://www.noaanews.noaa.gov/2011_tornado_information.html)



- Can WRF simulate such devastating storms?
- What is the sufficient resolution to do so?

Model & Experiment Design

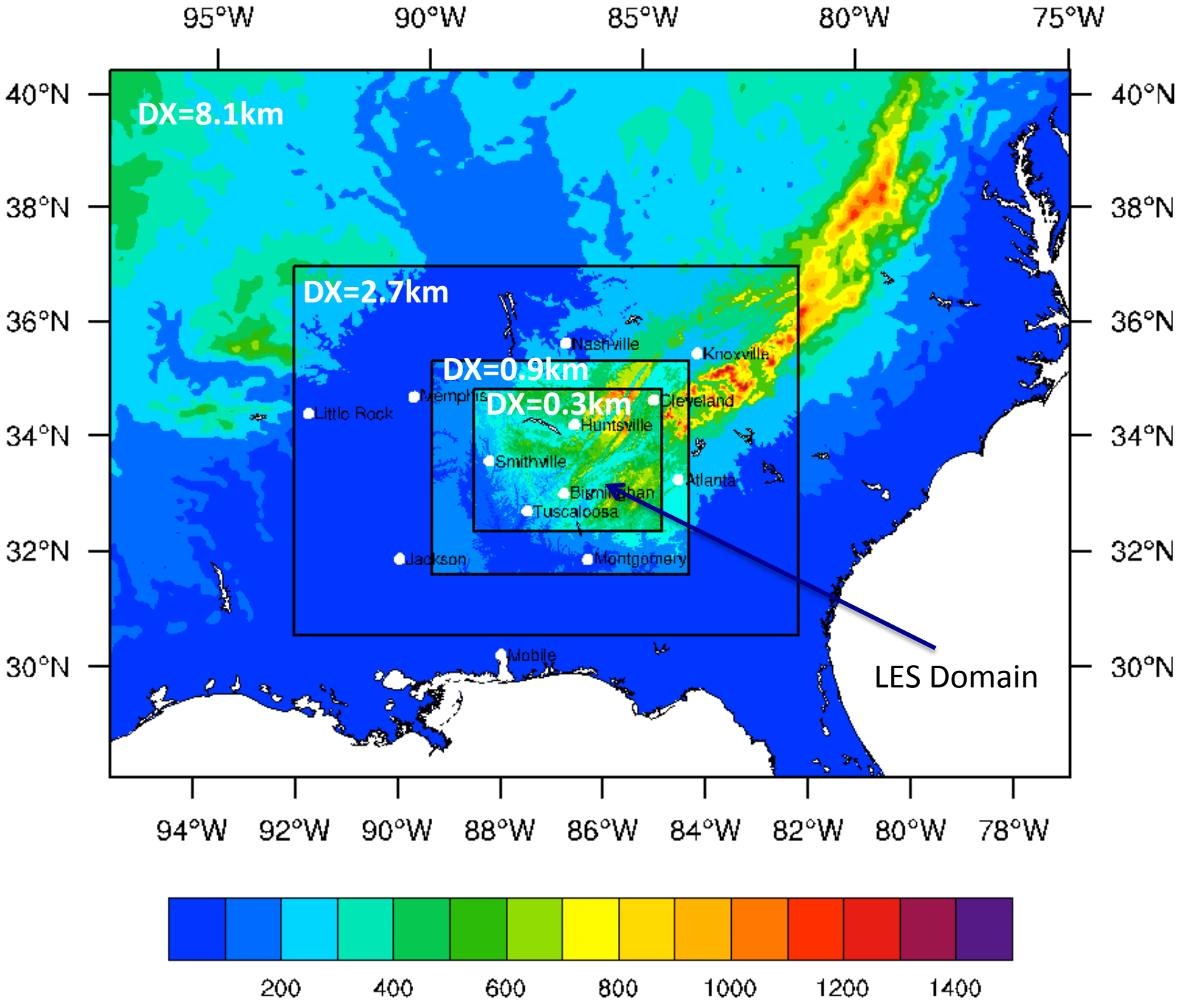
- **NCAR-RAL WRF-RTFDDA-LES system (*Liu et al. 2010, J. Wind Energy and Engineering*).**

- **Four nested domains (@ 8.1, 2.7, 0.9 and 0.3 km) with 38L.**

- **LES domain (@0.3km) with 1210X910 grids (~360x270 km^2). PBL scheme was off, but uses 3D TKE sub-grid turbulent stress.**

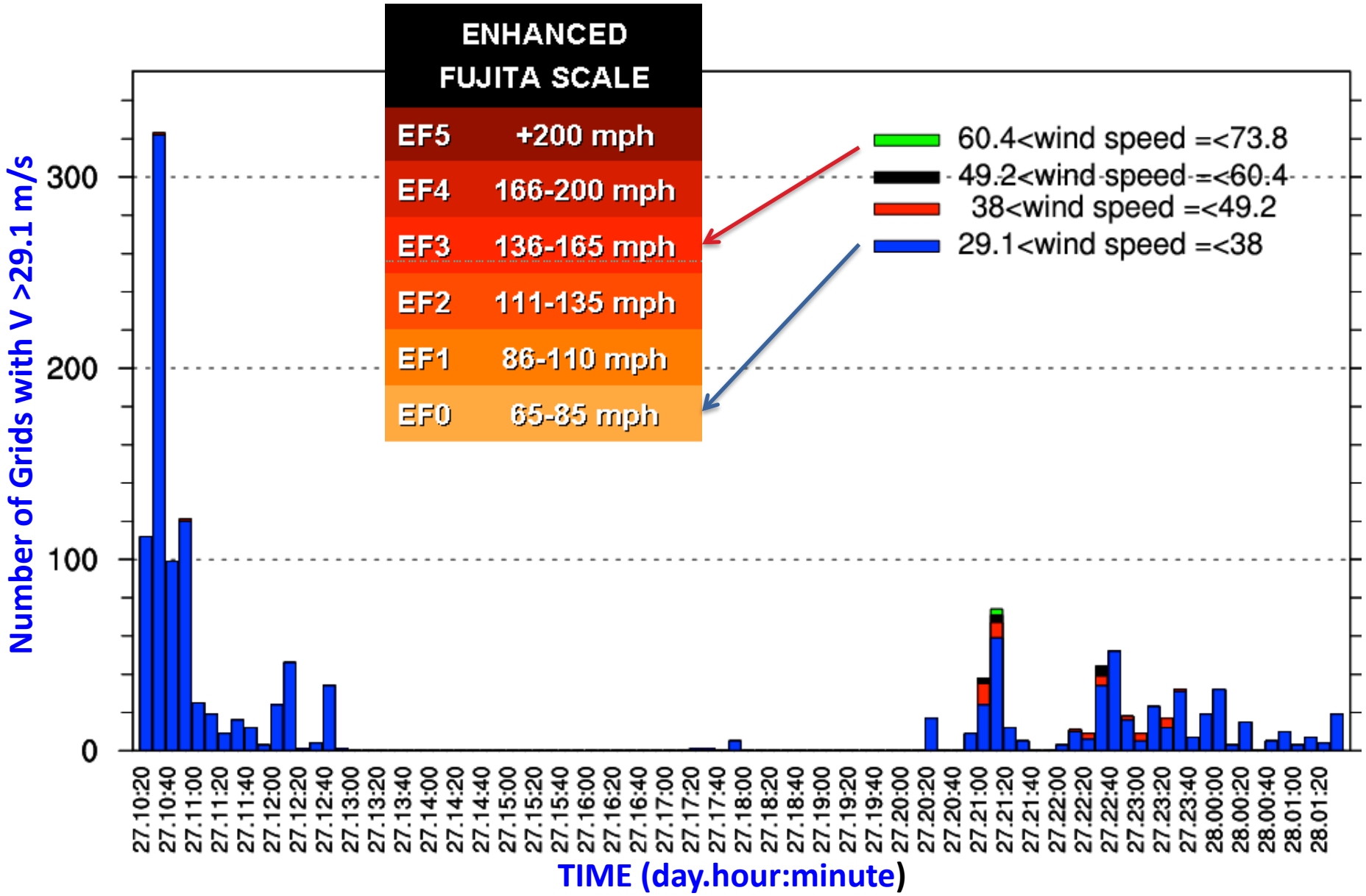
- **8.1km domain was initialized with *12km NAM* analysis at 00UTC 27 April 2011 while inner domains were delayed three hours each respectively. i.e. the LES domain was activated at 09UTC 27 April 2011. Simulation ended at 03UTC 28 April 2011.**

- **Observational Nudging was active in 8.1 and 2.7km domains**

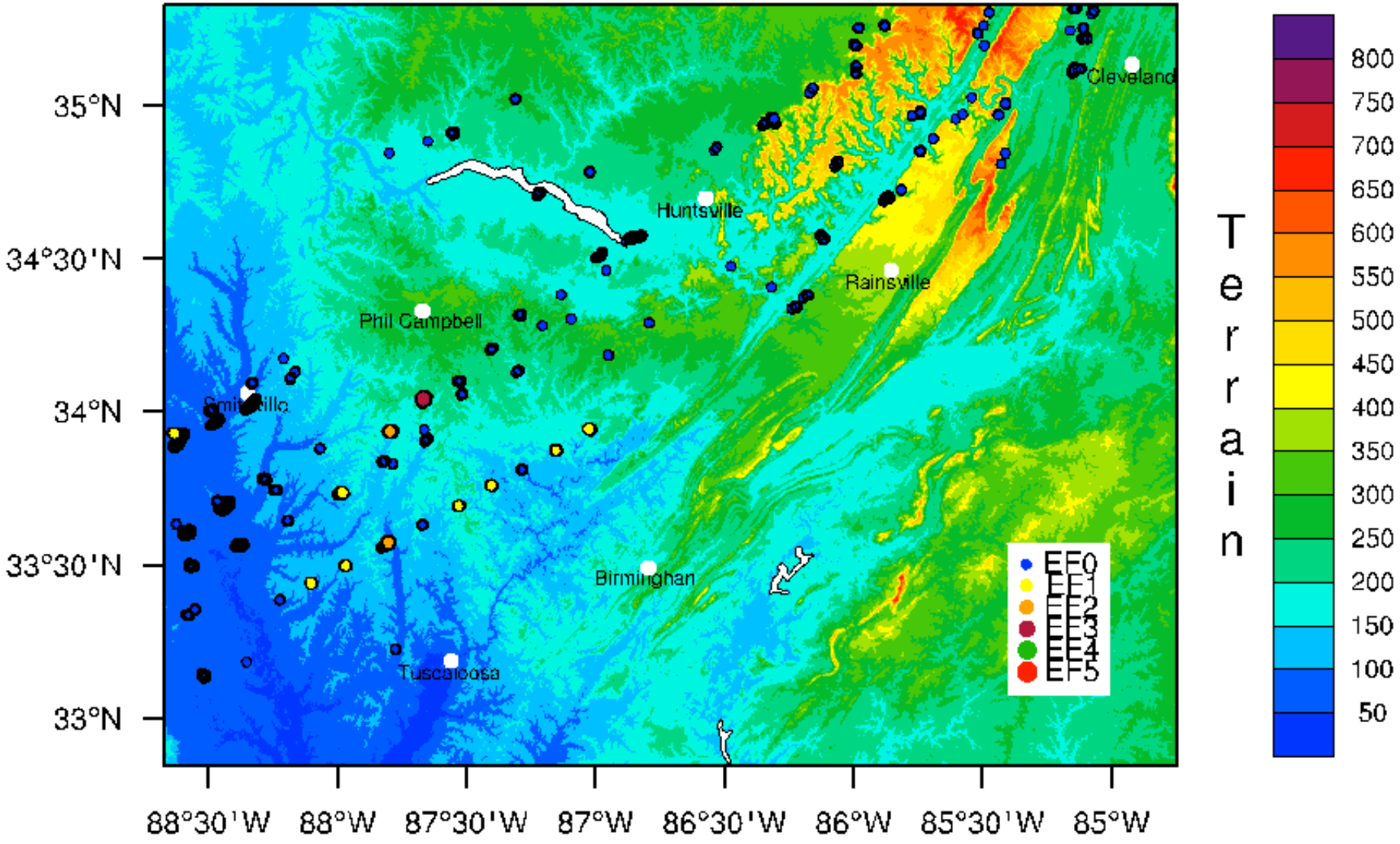

95°W
90°W
85°W
80°W
75°W
40°N
38°N
36°N
34°N
32°N
30°N
DX=8.1km
DX=2.7km
DX=0.9km
DX=0.3km
Nashville
Knoxville
Memphis
Little Rock
Cleveland
Huntsville
Smithville
Atlanta
Birmingham
Tuscaloosa
Jackson
Montgomery
Mobile
LES Domain
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
78°W
200
400
600
800
1000
1200
1400

Surface Wind Speed Reaches EF0 (29.1 m/s) or Above in LES Domain

27th April 2011 10:00UTC – 28th April 2011 01:30UTC

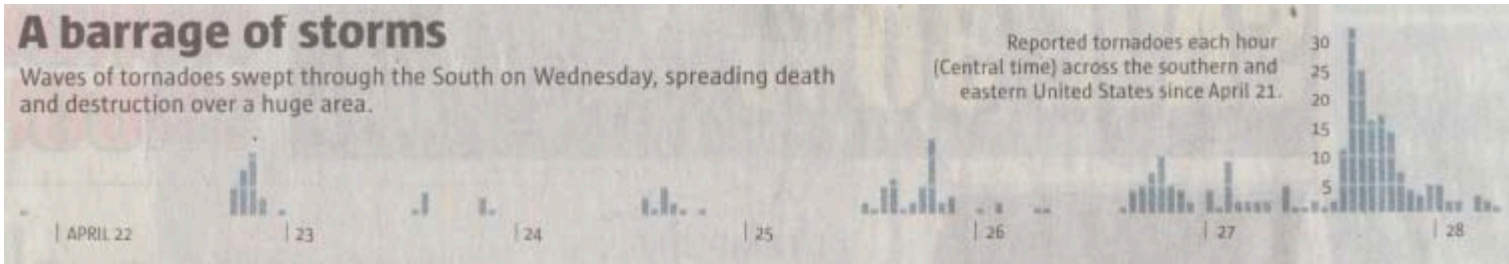


Distribution of Simulated High Surface Winds (> 29.1 m/s: EF0 or above)
10:30 UTC 27th – 01:30UTC 28th April 2011



A barrage of storms

Waves of tornadoes swept through the South on Wednesday, spreading death and destruction over a huge area.



Smithville, Miss.
A tornado with 190-mph winds devastated two-thirds of this small town on Wednesday, killing 14.

Franklin County, Ala.
In the town of Phil Campbell, the grocery store, gas stations and medical clinic were destroyed in a half-mile-wide swath of devastation. Twenty-seven people were killed.

DeKalb County, Ala.
In one of the hardest-hit counties, the coroner said 30 people died in a 30-mile path of destruction running from Fyffe through Rainsville to the Georgia border.

Cleveland, Tenn.
Starting Wednesday morning, successive waves of tornadoes tore through the county until the evening. The worst came at 8 p.m., and nine people died.

Jefferson County
The authorities searched house to house in Concord, North Smithfield and Pleasant Grove, north and west of Birmingham, as National Guard troops arrived. Twenty people died, including six in Concord and 10 in Pleasant Grove, and the sheriff said the toll could rise.

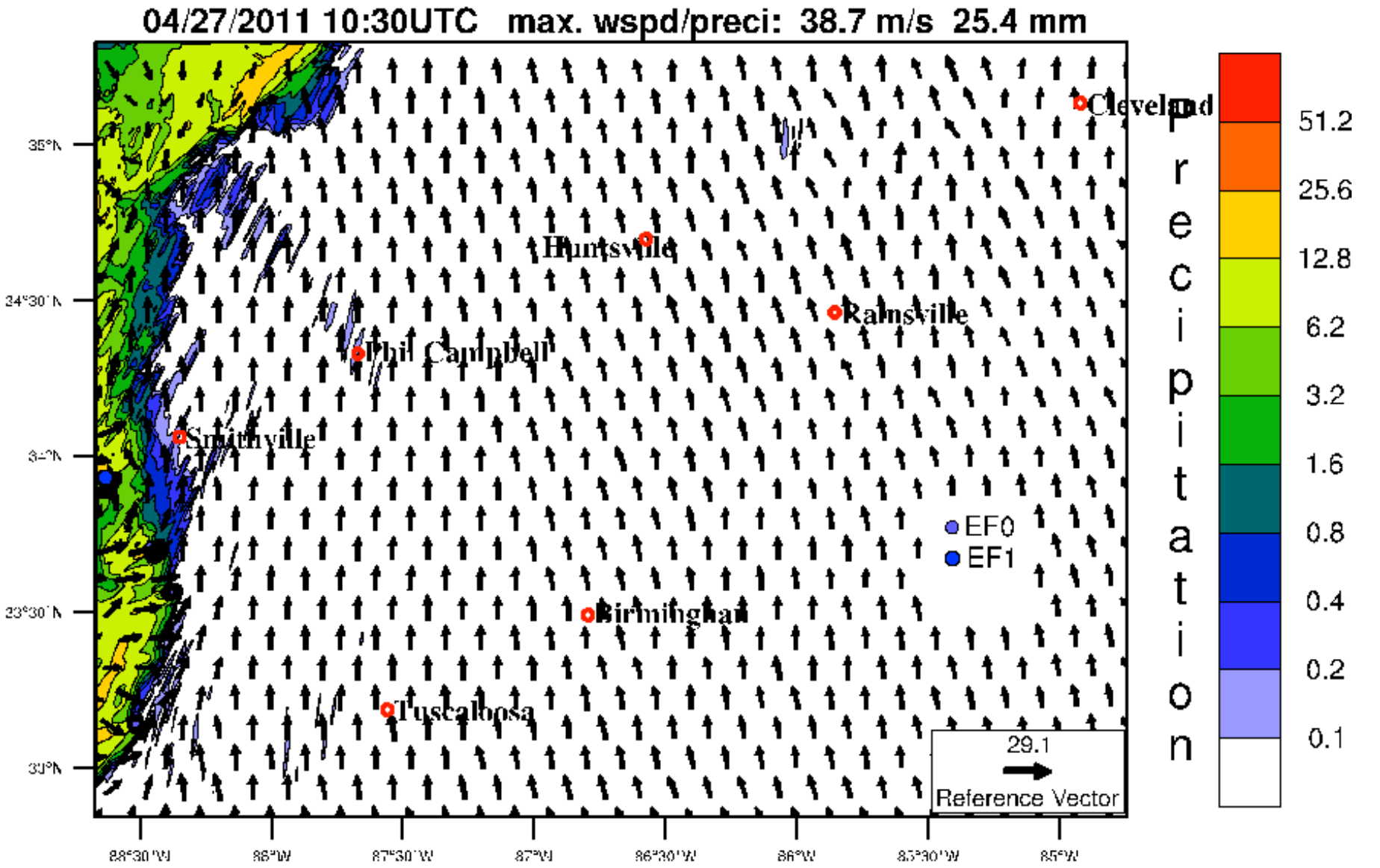
Sources: Tornado locations from preliminary data by the National Weather Service; radar images from AccuWeather; death reports by local officials The New York Times

Simulated high surface winds (> 29.1, EF0) at two individual times

- **27th April 2011 10:30UTC (5:30AM local time):**
  four clusters of high surface winds (29.1 ~ 38.7 m/s EF0-EF1)

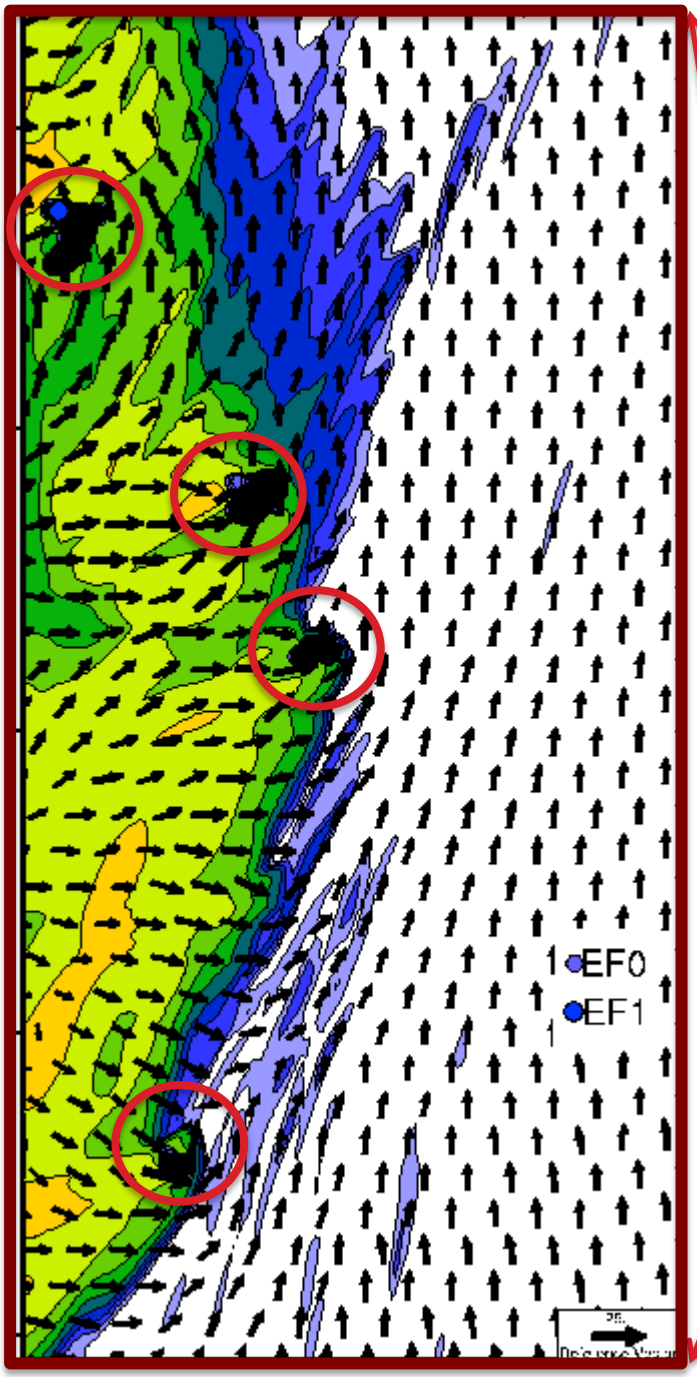
- **27th April 2011 21:10UTC (4:10PM local time):**
  surface wind ~ 63.4 m/s (EF3)
  35hPa pressure change in 10 minutes

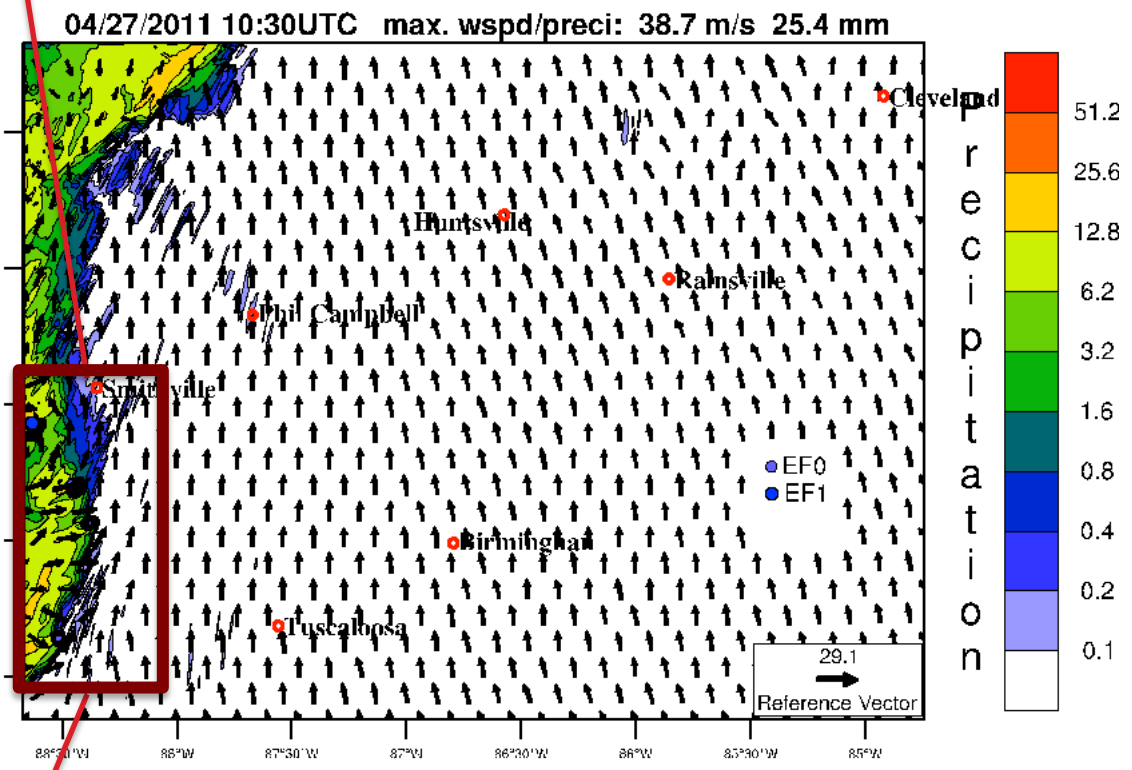
LES domain: Simulated Surface Wind and 10-minutes accumulated Precipitation
Valid at 27th April 2011 10:30UTC

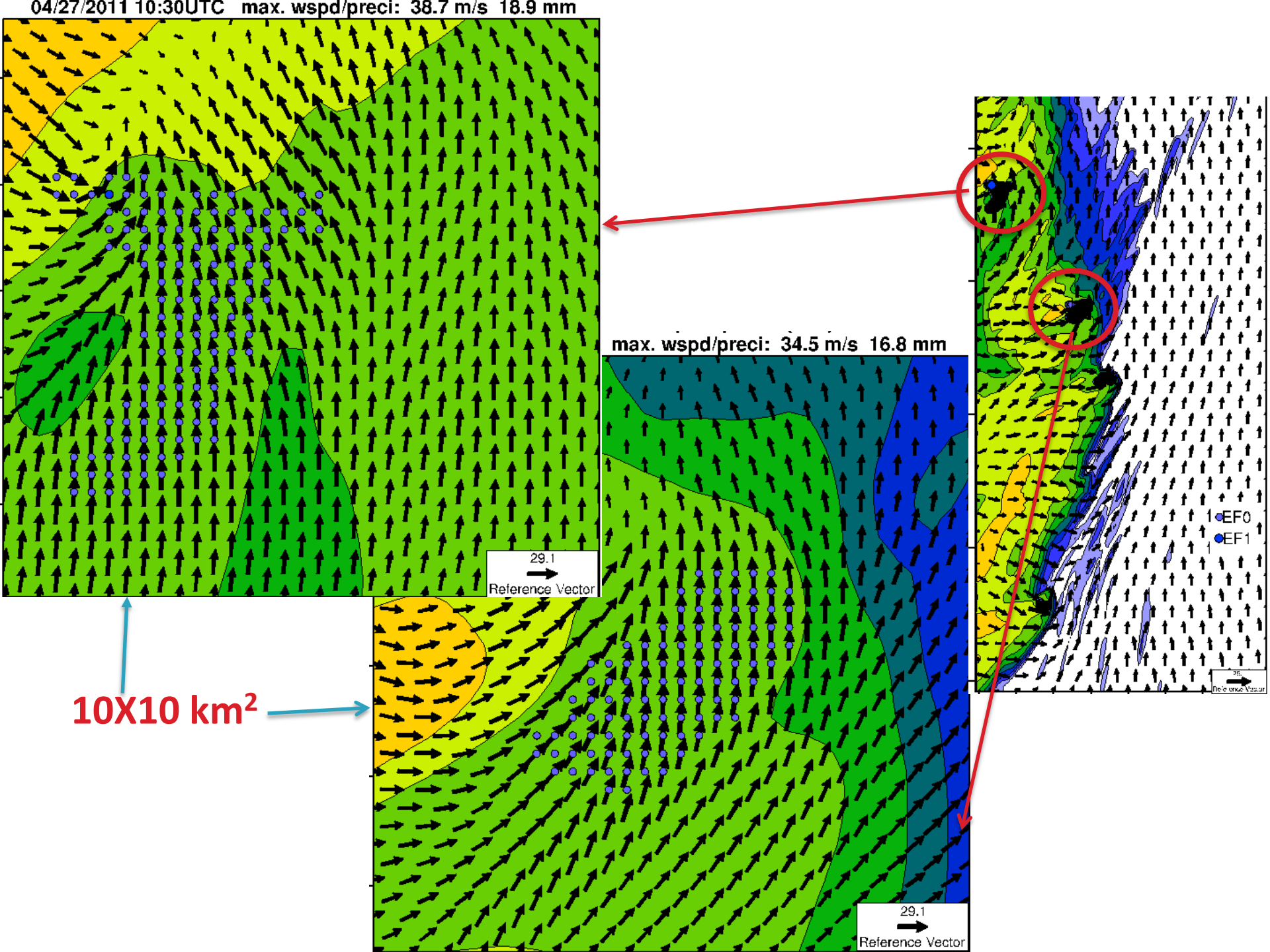


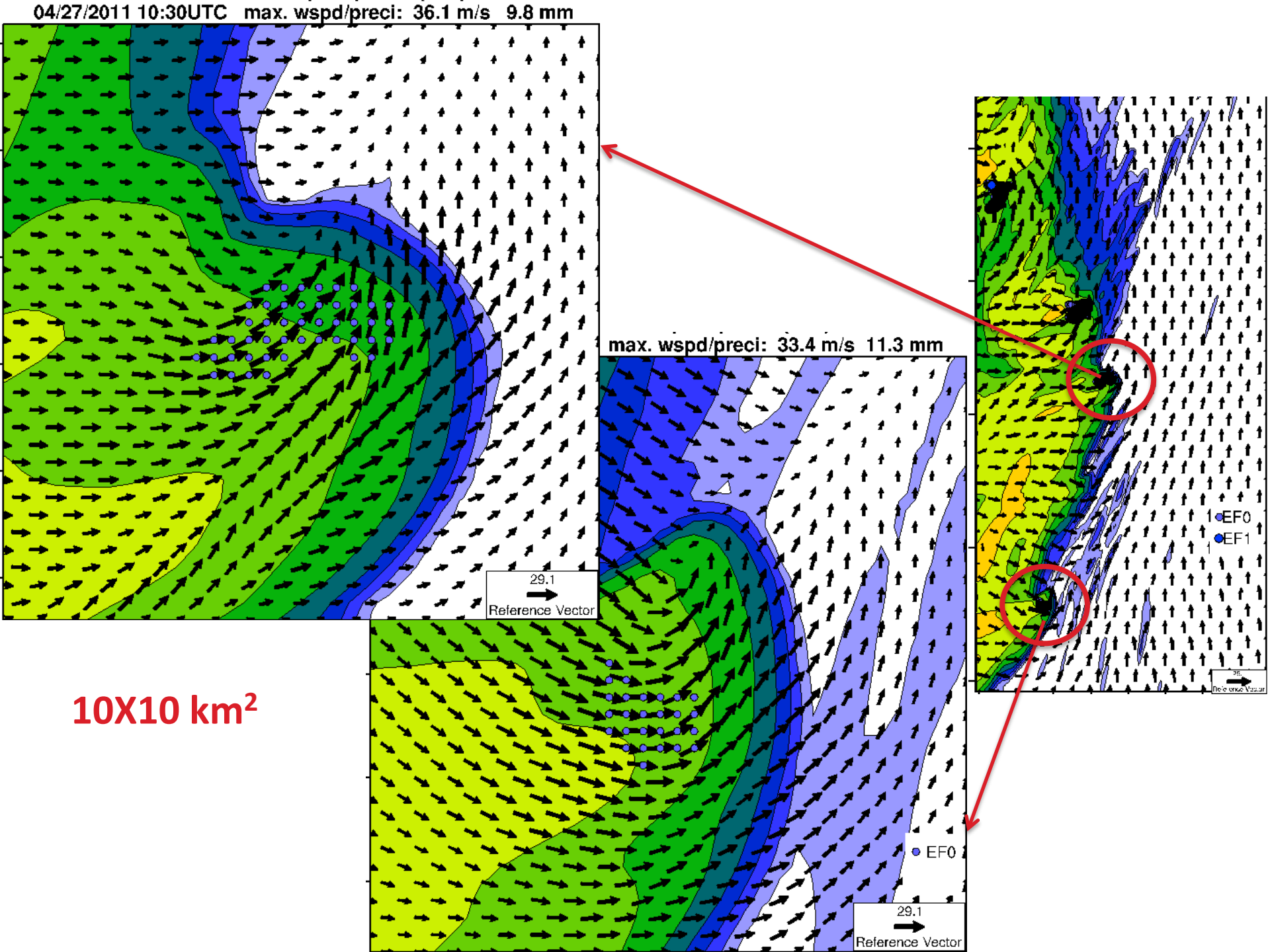
Surface wind vectors and 10 minutes rain

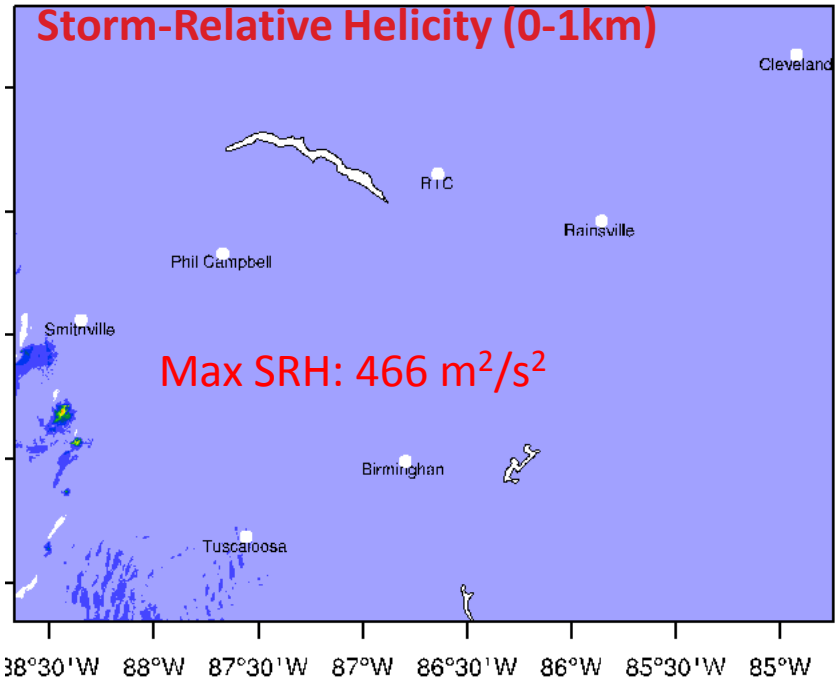
4 tornadoes

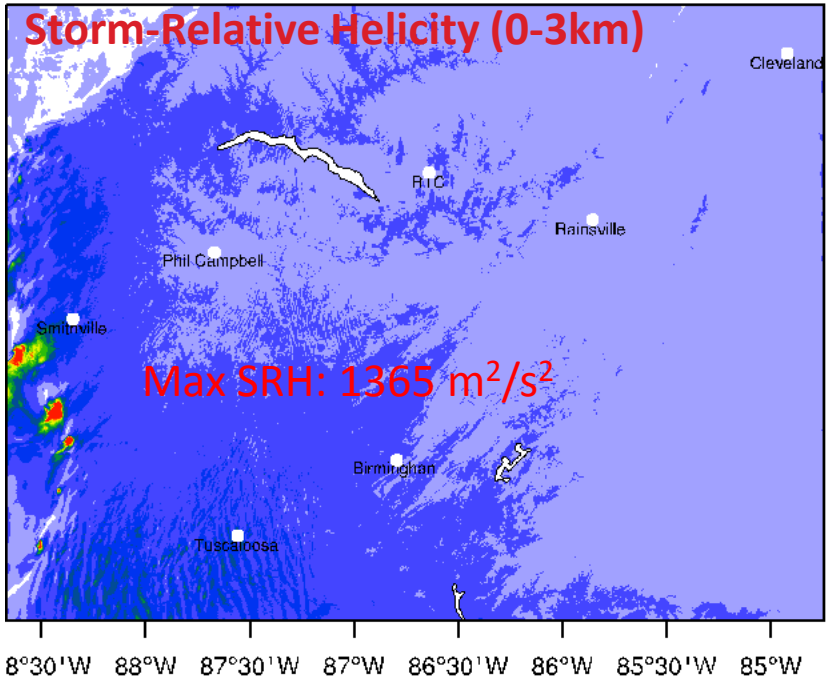


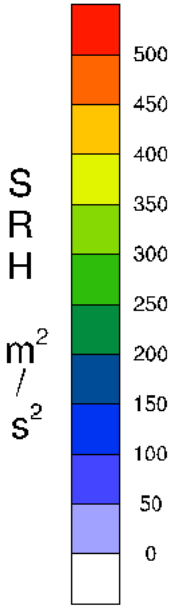



04/27/2011 10:30UTC max. wspd/preci: 38.7 m/s 18.9 mm
29.1
Reference Vector
max. wspd/preci: 34.5 m/s 16.8 mm
29.1
Reference Vector
EF0
EF1
10X10 km²


04/27/2011 10:30UTC max. wspd/preci: 36.1 m/s 9.8 mm
29.1
Reference Vector
max. wspd/preci: 33.4 m/s 11.3 mm
EF0
29.1
Reference Vector
EF0
EF1
10X10 km2

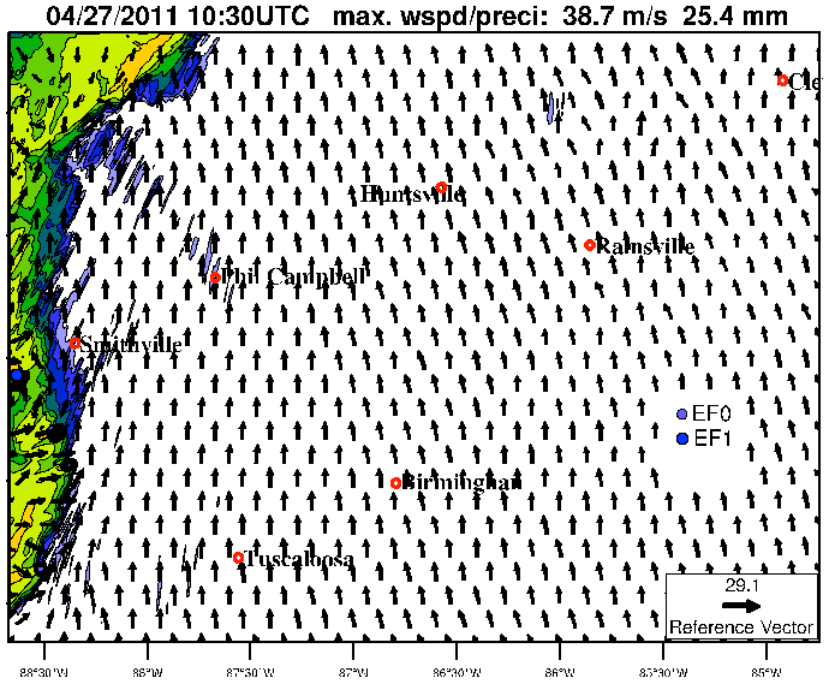




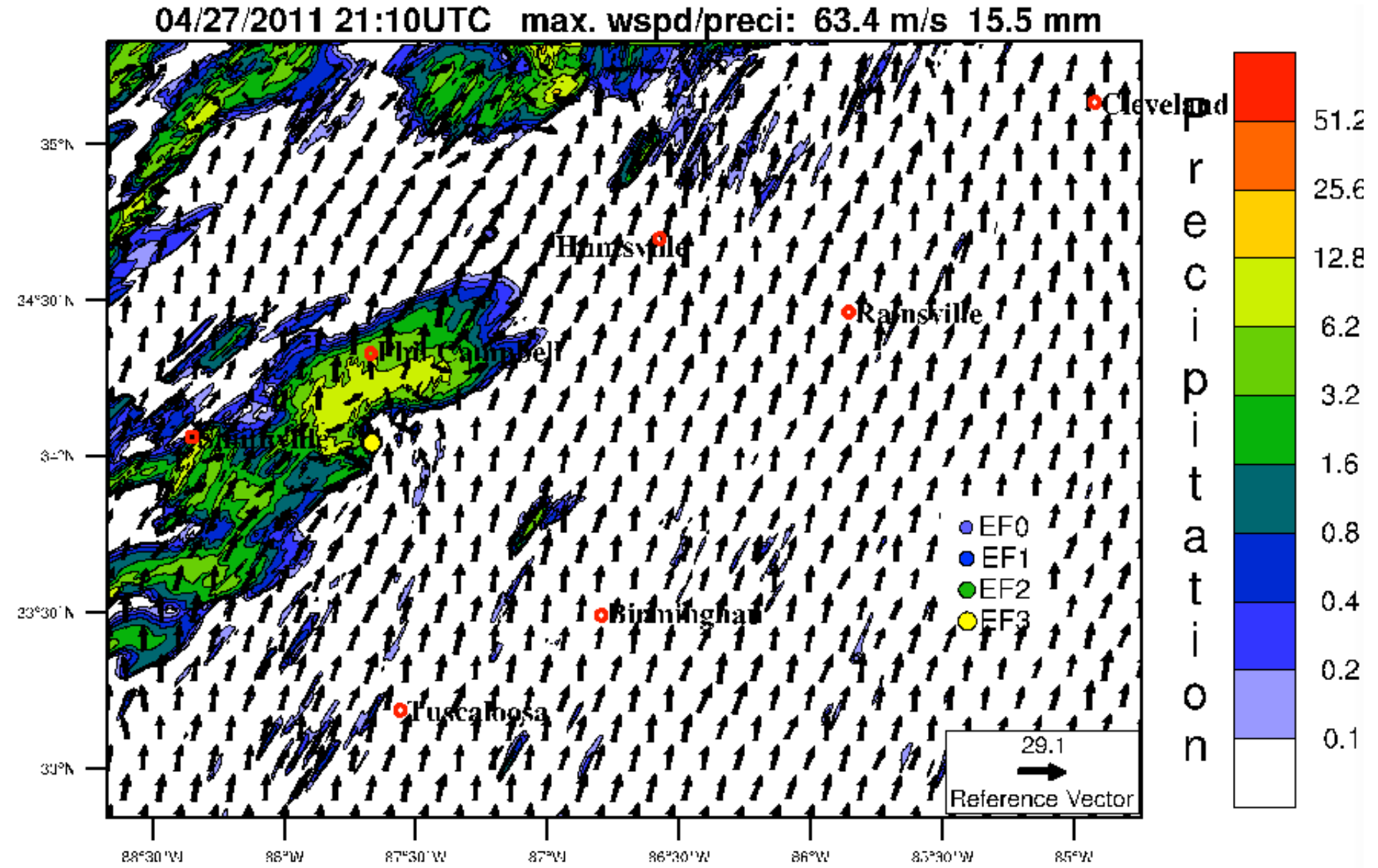


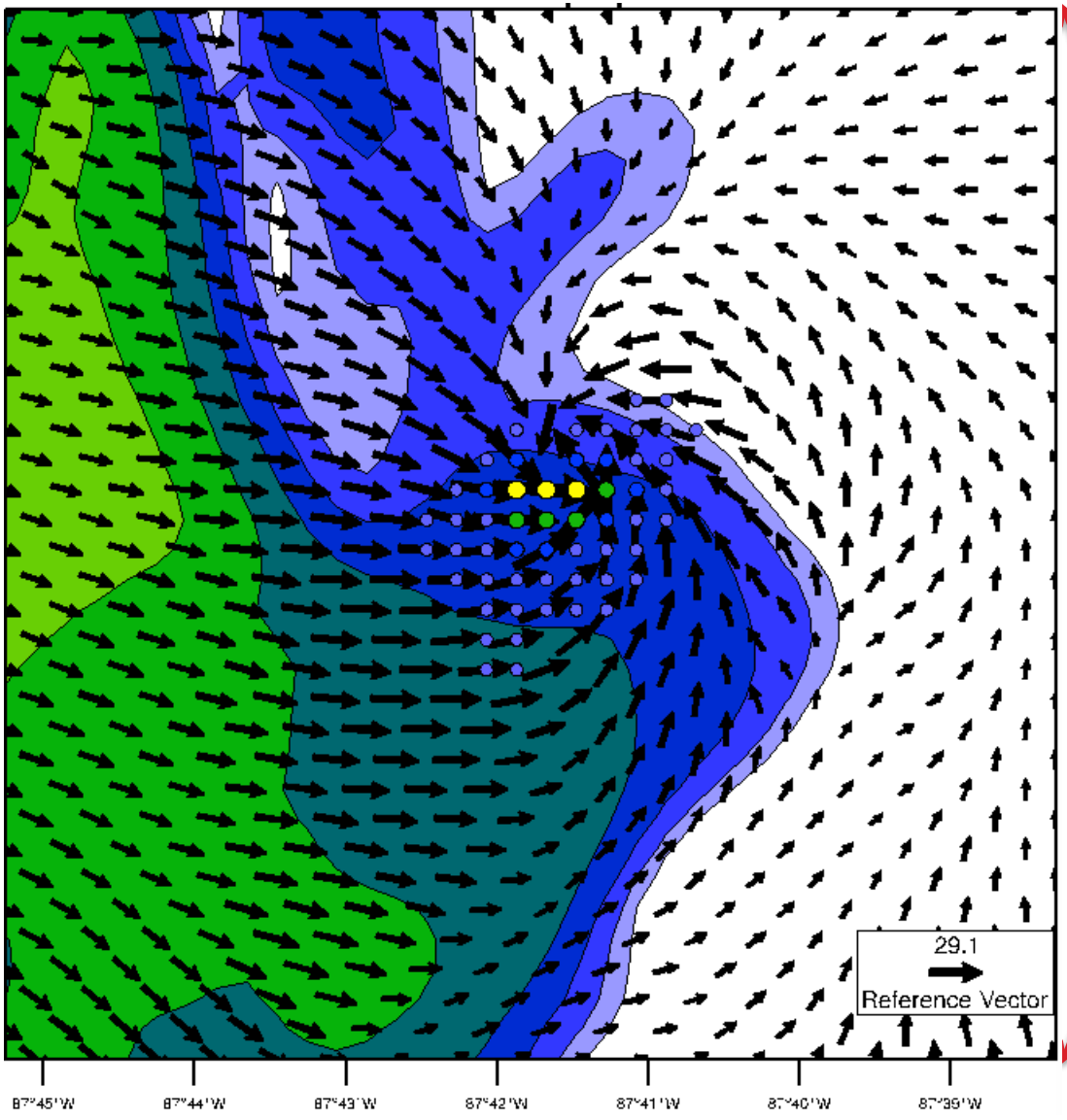
SRH (0-1km) > 100
SRH (0-3km) > 250

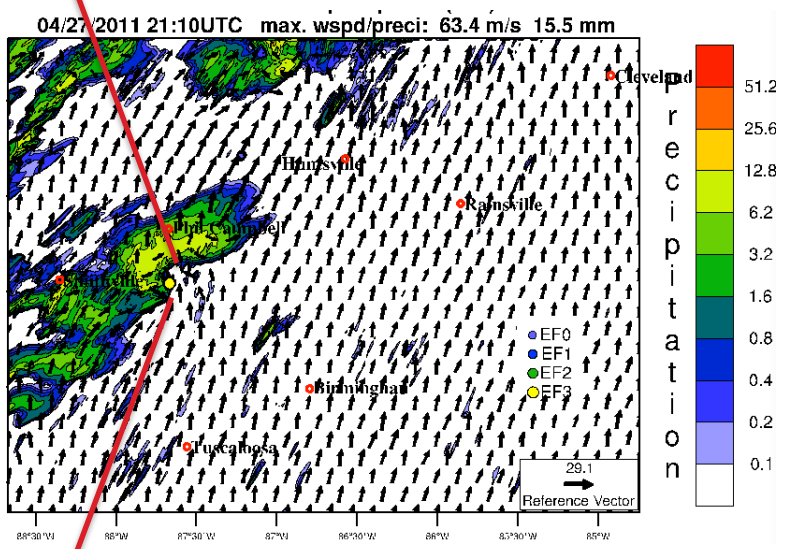
=> enhanced low-level rotation
=> increased threat of tornado



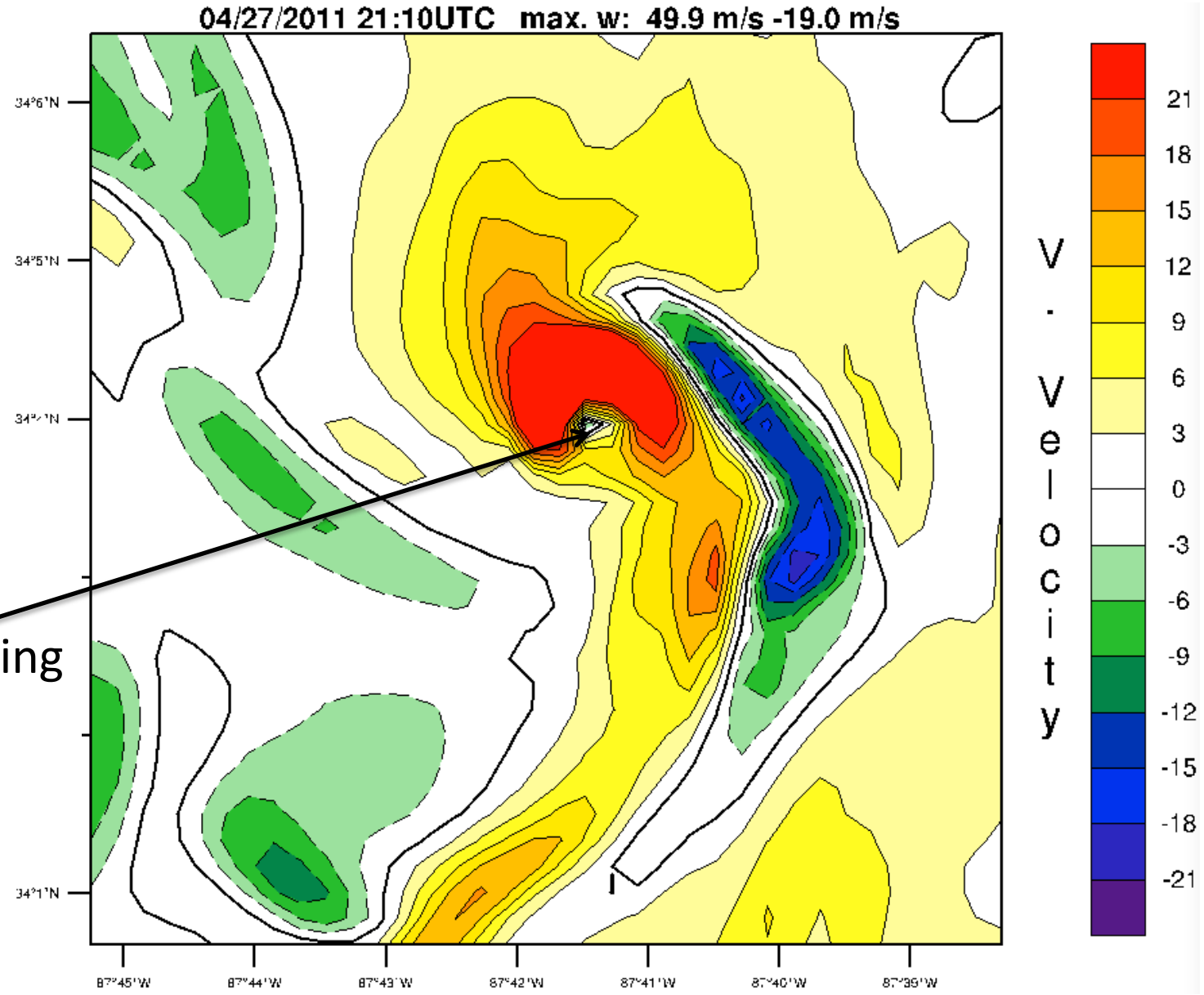
LES domain: Simulated Surface Wind and 10-minutes accumulated Precipitation
Valid at 27th April 2011 21:10UTC




10x10km²
29.1
Reference Vector
87°45'W
87°44'W
87°43'W
87°42'W
87°41'W
87°40'W
87°39'W

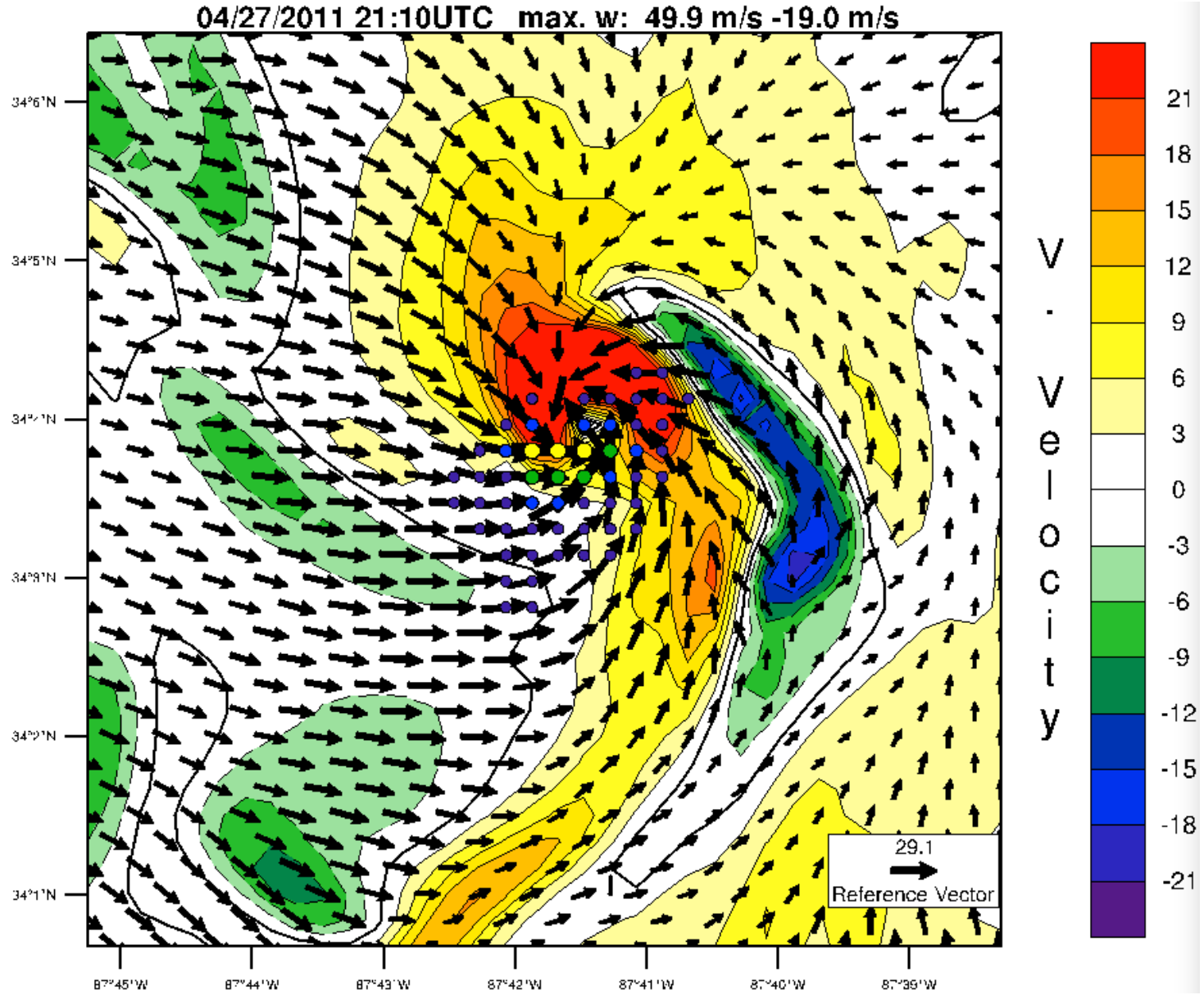

360x270km²
04/27/2011 21:10UTC max. wspd/preci: 63.4 m/s 15.5 mm
Cleveland
Hamsville
Ramsville
Birmingham
Tuscaloosa
EF0
EF1
EF2
EF3
29.1
Reference Vector
Precipitation
51.2
25.6
12.8
6.2
3.2
1.6
0.8
0.4
0.2
0.1

LES domain: Vertical velocity at 700m

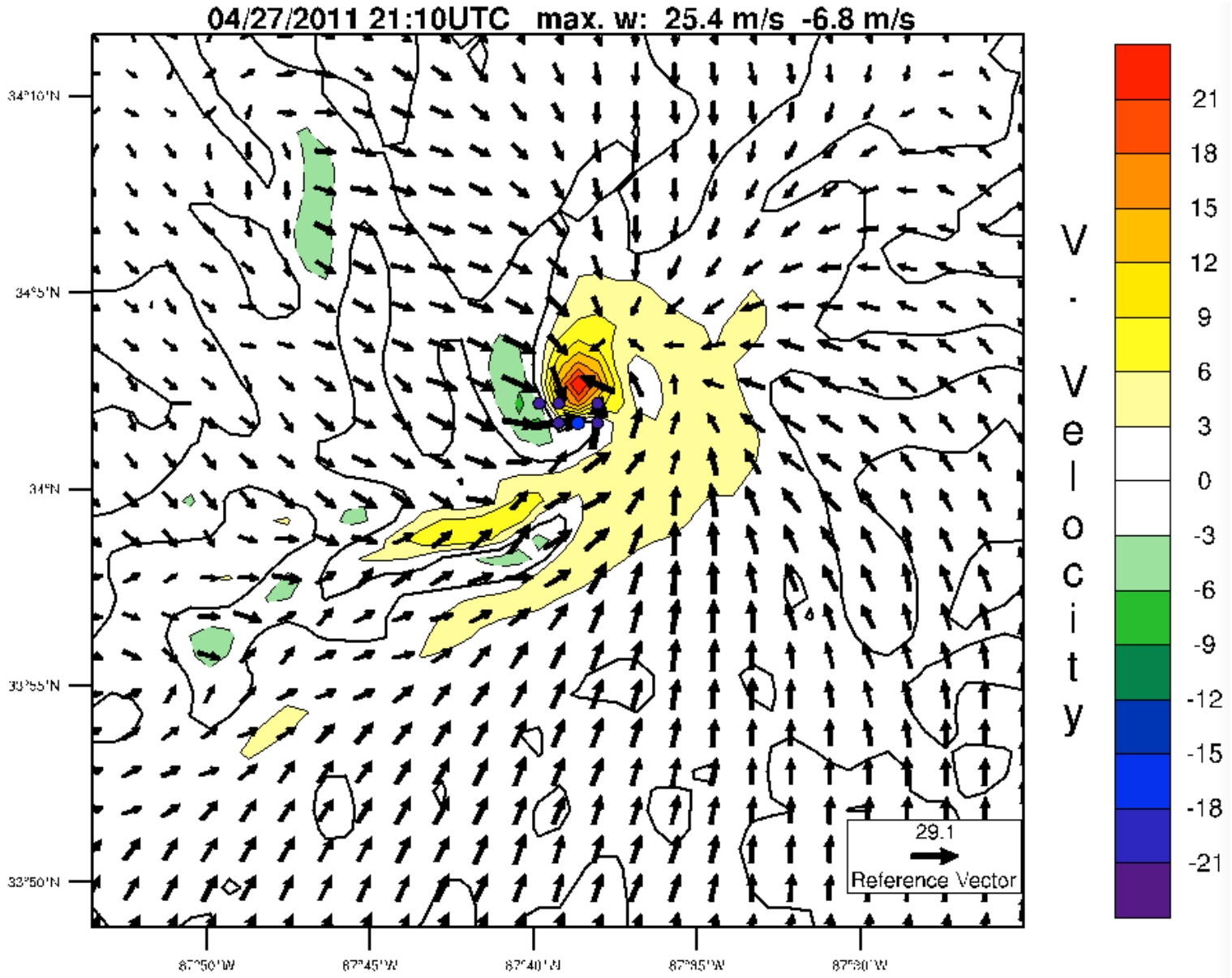


Calm/ descending eye

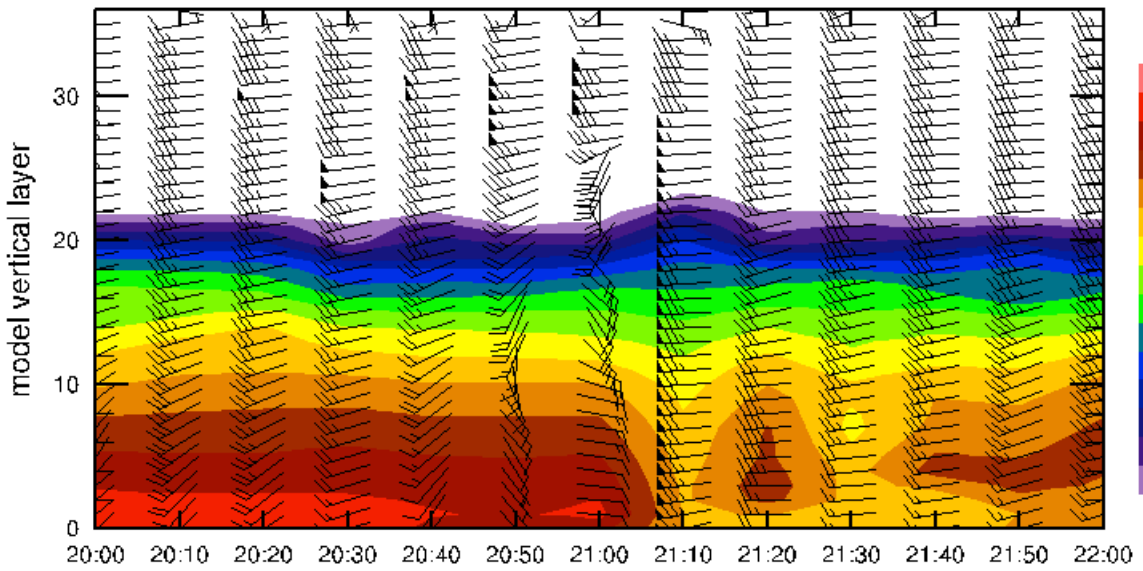
LES domain: Vertical velocity at 700m and 10m wind vectors



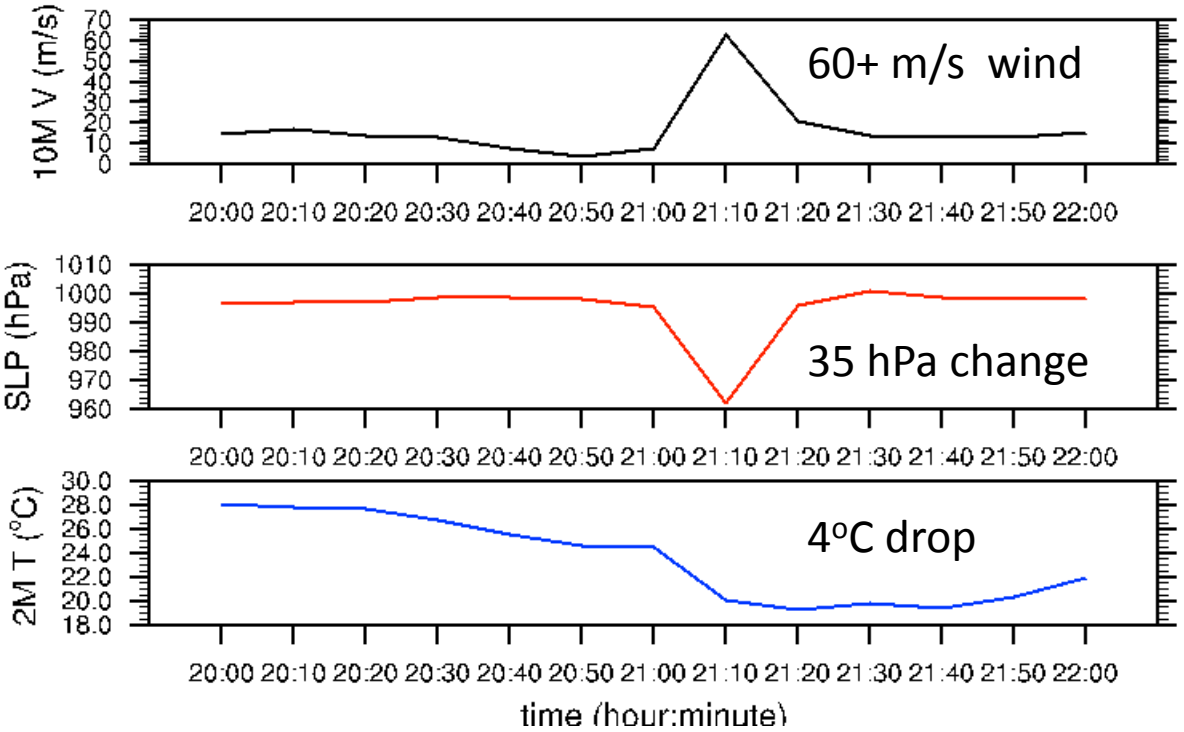
0.9km Domain: 10-m wind vector and vertical velocity at 700m



Time series 20-22UTC 27th April 2011



Vertical Profiles of Temperature & wind



At (34.064N,87.692W)

Summary

A 300m LES domain (360x270km^2) was nested into WRF-RTFDDA to simulate the American South Tornados on 27th April 2011

The nested LES domain simulated major ingredients in tornado genesis: persistent strong updrafts, enhanced low-level rotation, and rare flank downdrafts, Sub-kilometer horizontal resolution is required to do so.

The simulation demonstrates the robustness of the the WRF-RTFDDA-LES system, and it reproduced the devastating tornado outbreak with simulated winds up to 63.4 m/s (EF3), and 35 hPa pressure change in 10-minute

Such simulation is costly in computing resources (~30,000CPU/24-hour simulation on NCAR bluefire)

Thank you

The End

Severe Convective Storm **Potential** Measurements:

CAPE (Convective Available Potential Energy): Buoyancy updrafts

0 ~ 1000 marginally unstable
1000 ~ 2500 moderately unstable
2500 ~ 3500 very Unstable
3500 + extremely unstable

SRH (Storm Relative Helicity): a measure of the potential for cyclonic updraft rotation in right-moving supercells, calculated for the lowest 1 and 3km layers above ground level.

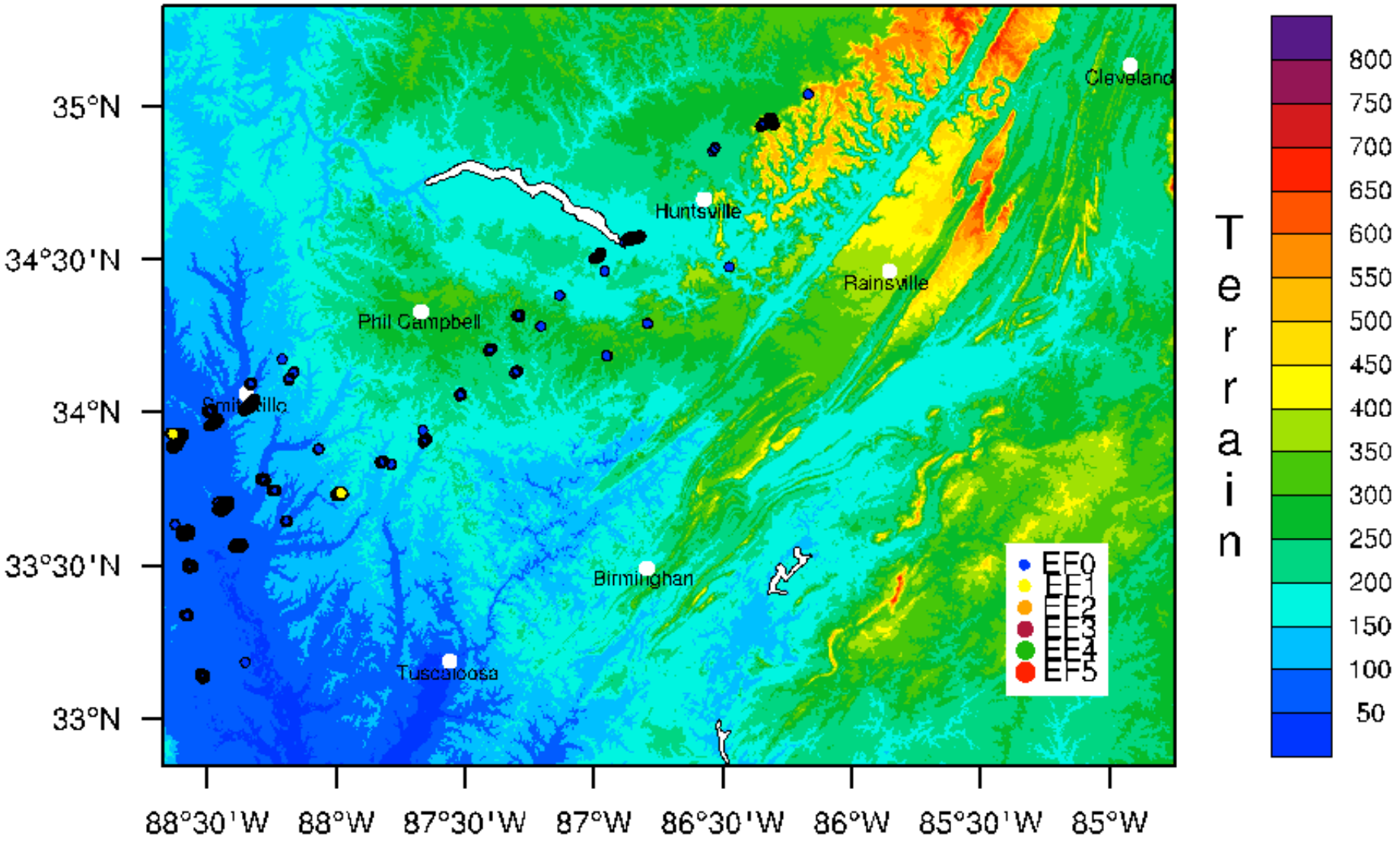
0-3km > 250 ms/s2
0-1km > 100 m2/s2

➔ Increased threat of tornadoes

EHI (Energy Helicity Index): CAPE * SRH / 160,000
Rotation should be maximized when both SRH and CAPE are large

>1 ➔ tornado potential

Distribution of Simulated High Winds (> 29.1 m/s: EF0 or above)
27th April 2011 10:00 – 13:00UTC



Distribution of Simulated High Winds (> 29.1 m/s: EF0 or above)
27th April 2011 20:30 UTC –28th April 2011 1:30UTC