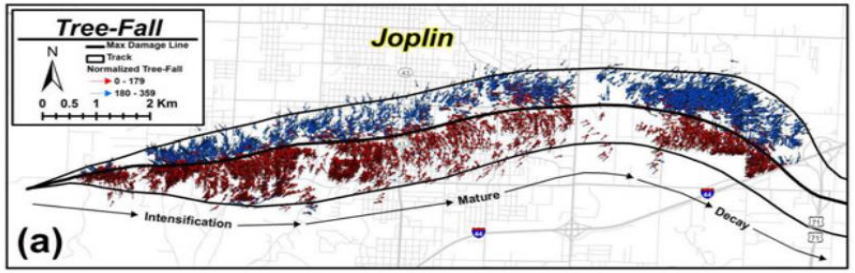
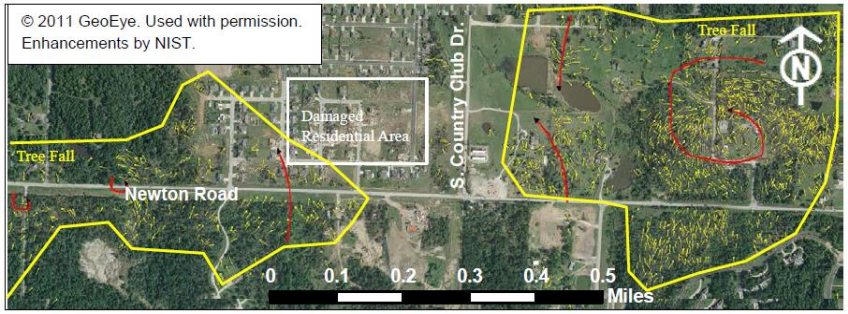
Tree Fall Patterns



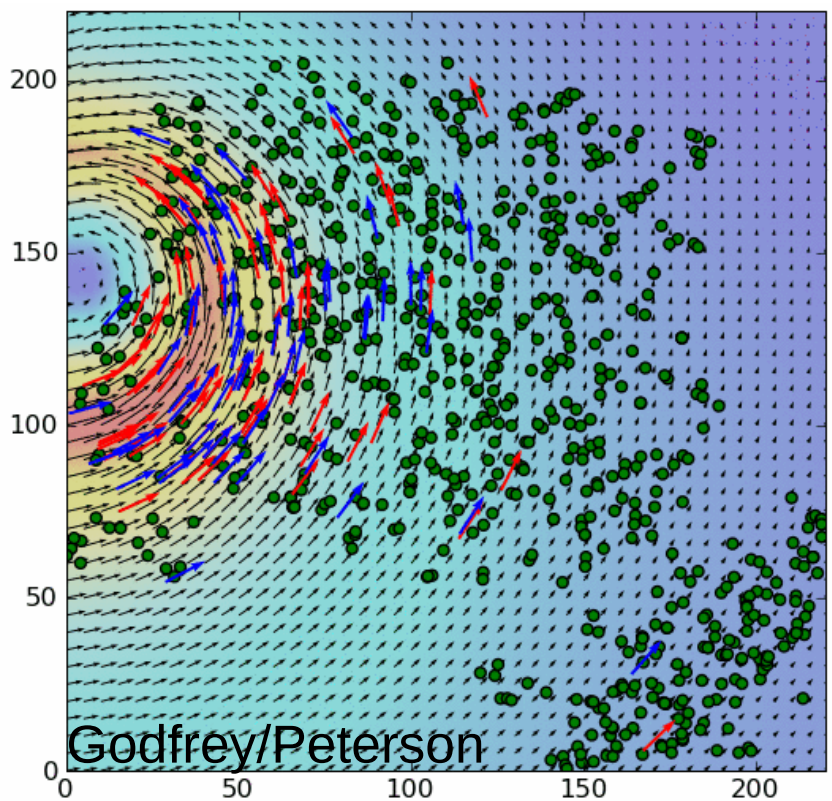


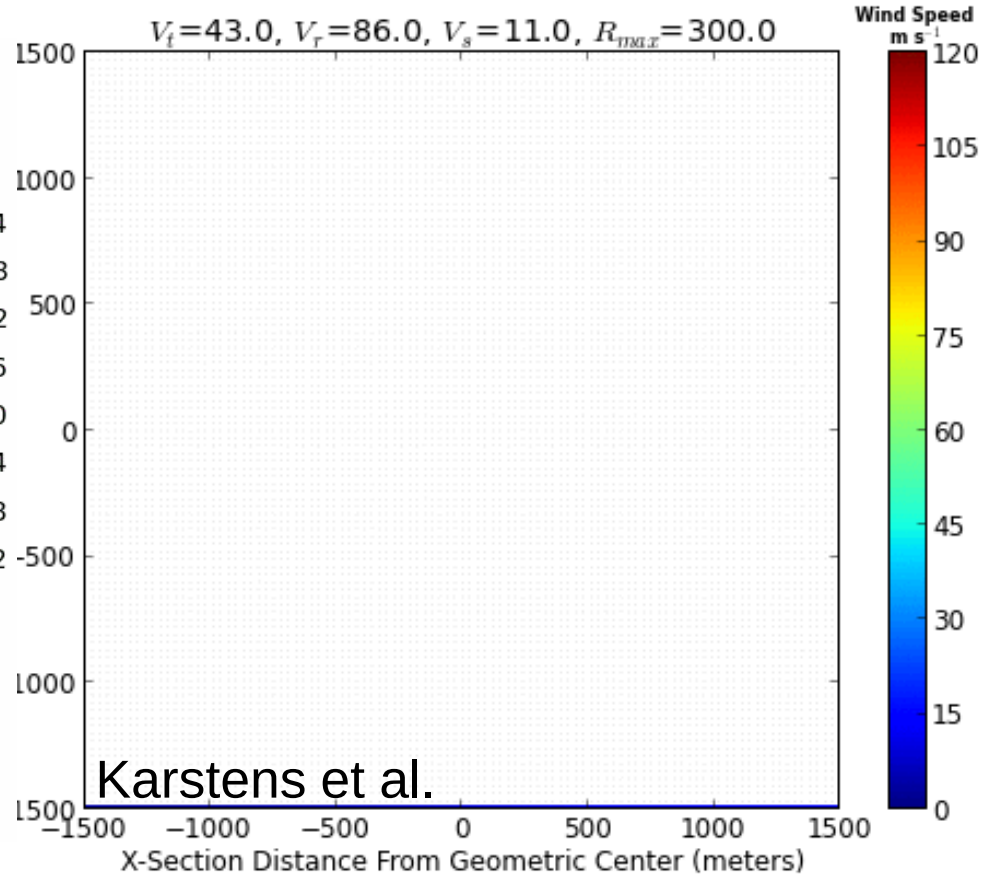
C. Godfrey, C. Karstens, F. Lombardo, C. Peterson
Adapted from EF-Scale Group Presentation
February 3, 2014

Background

- Wegener (1917), Letzmann (1923) – schematic illustrations of wind-field/tree fall patterns based on Rankine model
- Hall and Brewer (1959), Budney (1965), Fujita (1989) – case studies of tree fall in tornadoes
- Peltola (1997, 1999) – mechanistic tree fall models
- Spurred significant research in last 10 years or so
  - Peterson (2003, 2007)
  - Holland et al. (2006)
  - Bech et al. (2009)
  - Beck and Dotzek (2010)
  - Godfrey and Peterson (2012)
  - Karstens et al. (2013)
  - Blanchard (2013)
  - NIST (2013)
  - Others

Tree-fall Patterns





- Couple analytical vortex model with tree-fall model (left) or idealized distribution of critical tree-falling wind speeds (right)
- Produce tree-fall patterns sensitive to the simulated vortex configuration.
- **<u>Goal</u>: "Match" simulated pattern with observed pattern -> *estimate near-surface wind field*.**

Analytical Vortex Model

Holland et al. (2006)

$$V_{tan} = V_{max} r R_{max}{}^{n} \quad r \leq R_{max}$$

$$V_{tan} = V_{max} r^{n} R_{max} \quad r > R_{max}$$

$$V_{r} = V_{r-max} r R_{max}{}^{n} \quad r \leq R_{max}$$

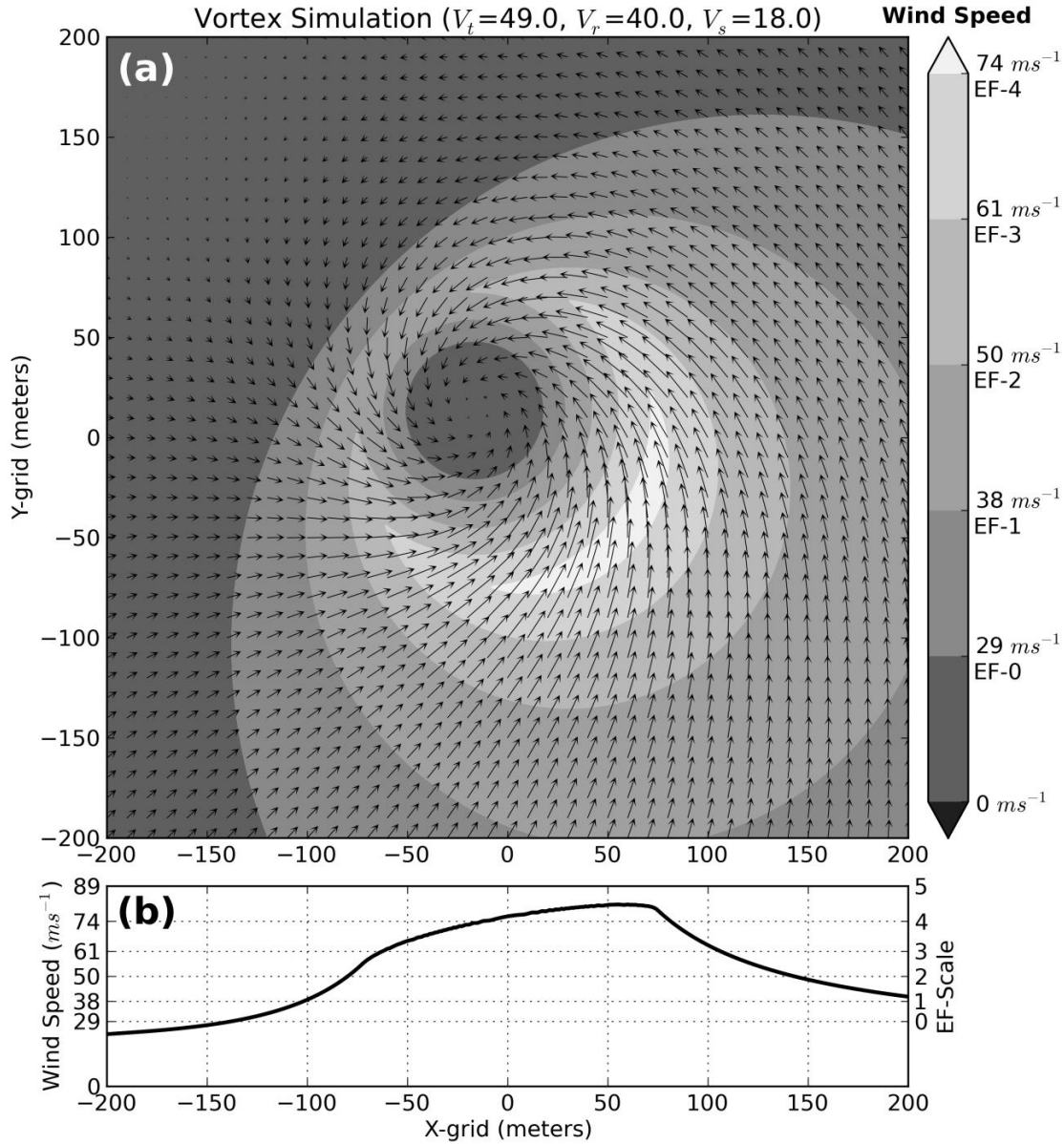
$$V_{r} = V_{r-max} r^{n} R_{max} \quad r > R_{max}$$

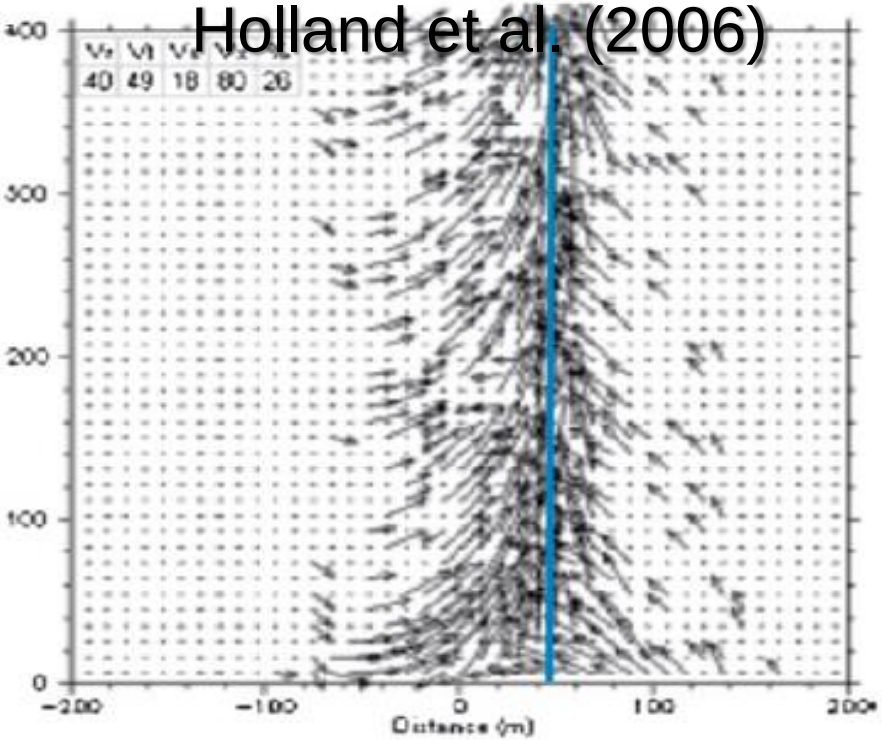
Beck and Dotzek (2010)

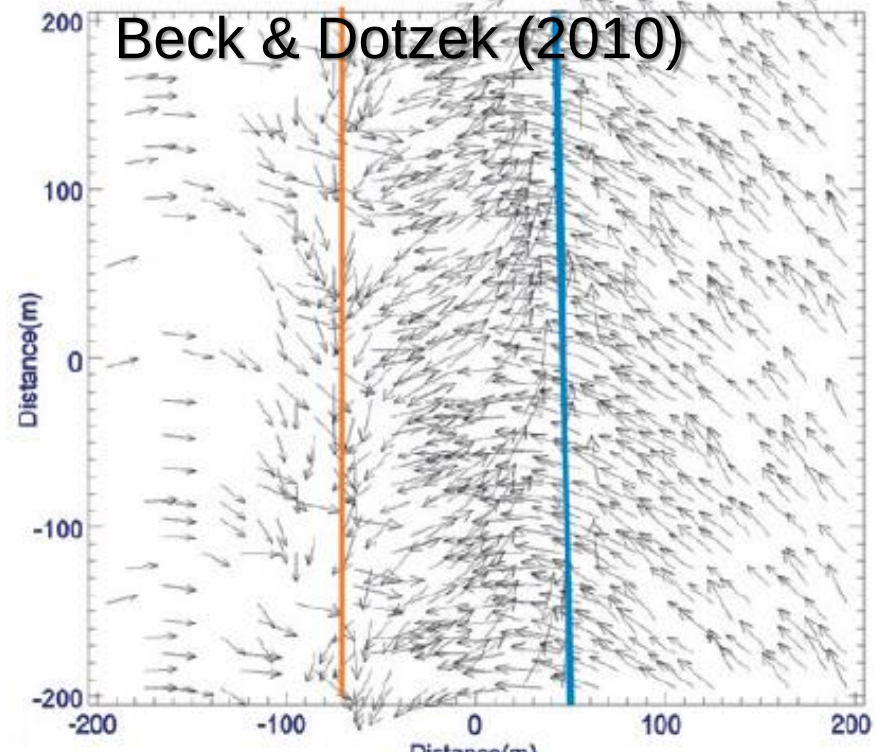
$$\Delta t \leq \frac{\Delta y}{V_s}$$

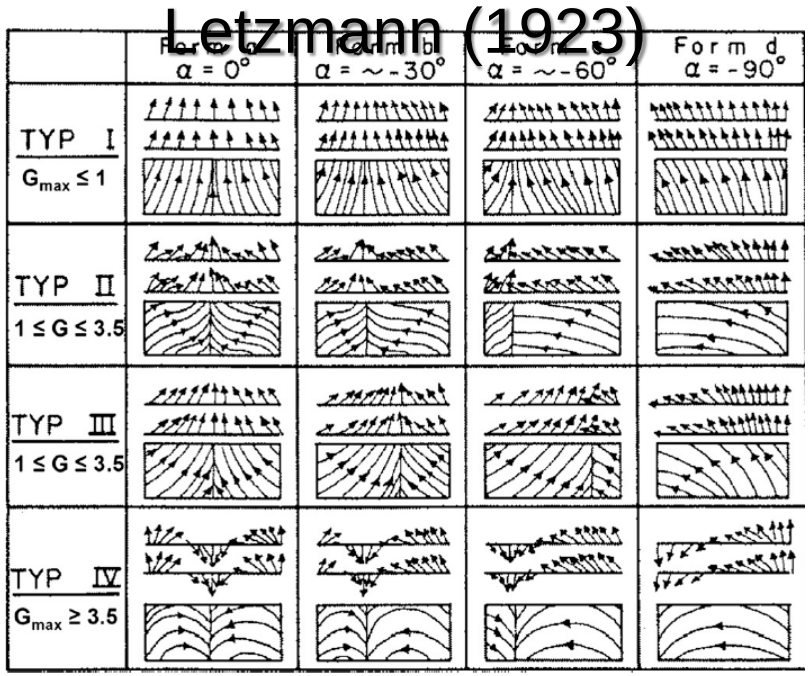
Main Inputs:

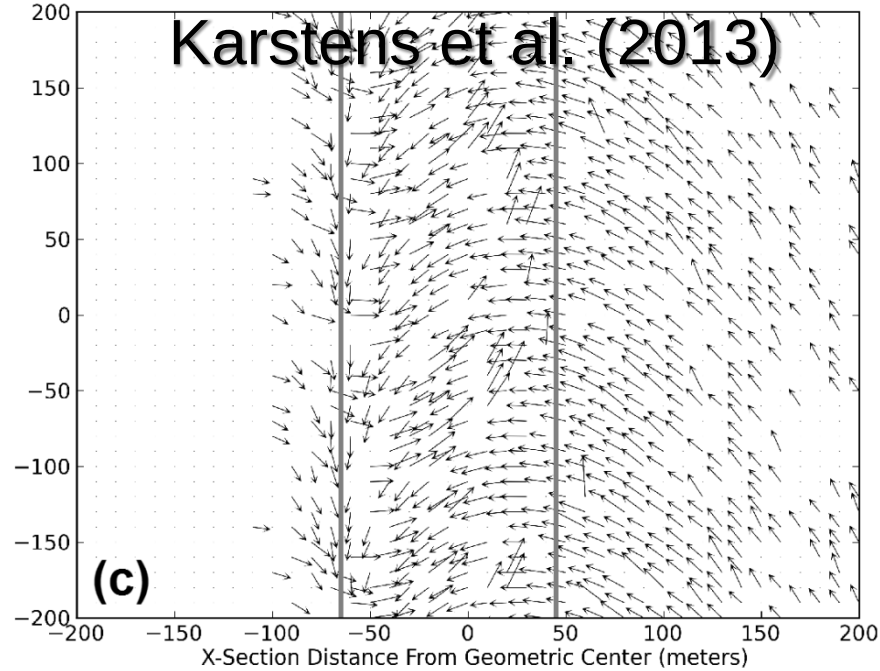
V_s: Translation speed
R_{max}: Radius of max winds
V_{tan}: Tangential Vel. @ R_{max}
V_{rad}: Radial Vel. @ R_{max}



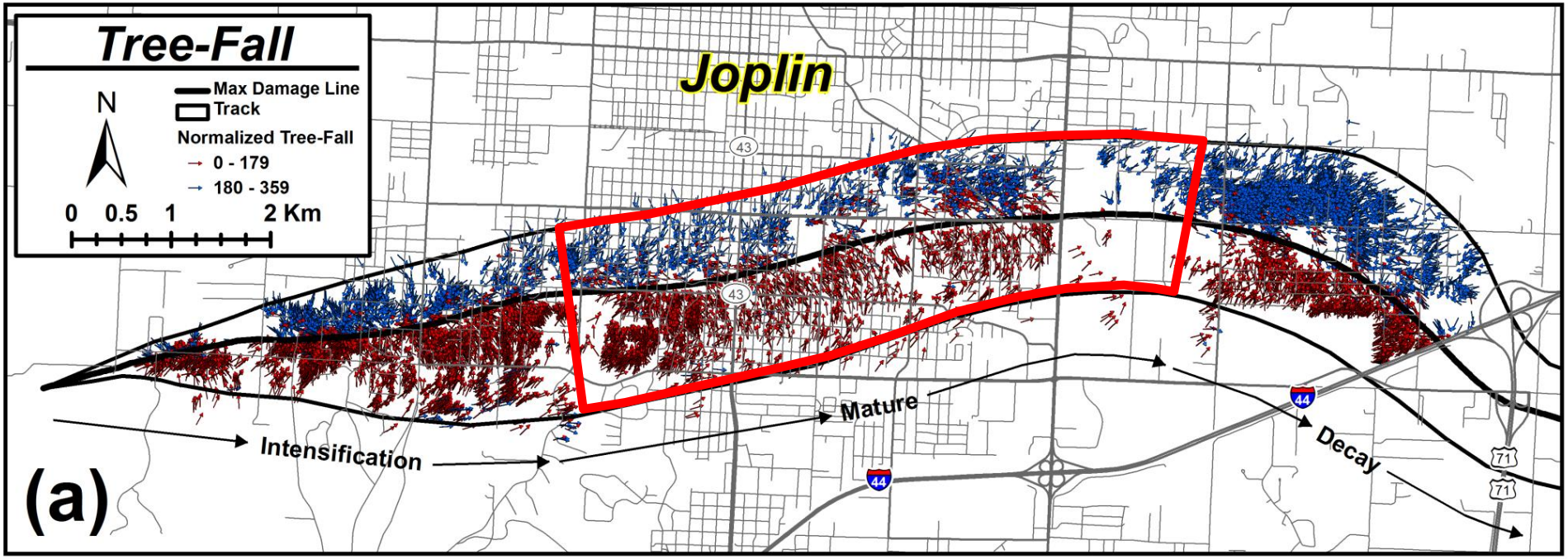

Holland et al. (2006)
40 49 18 80 26
400
300
200
100
0
−200
−100
0
100
200
Distance (m)


Beck & Dotzek (2010)
200
100
0
-100
-200
Distance(m)
-200
-100
0
100
200


Letzmann (1923)
α = 0°
α = ~-30°
α = ~-60°
Form d
α = -90°
TYP I
G_max ≤ 1
TYP II
1 ≤ G ≤ 3.5
TYP III
1 ≤ G ≤ 3.5
TYP IV
G_max ≥ 3.5

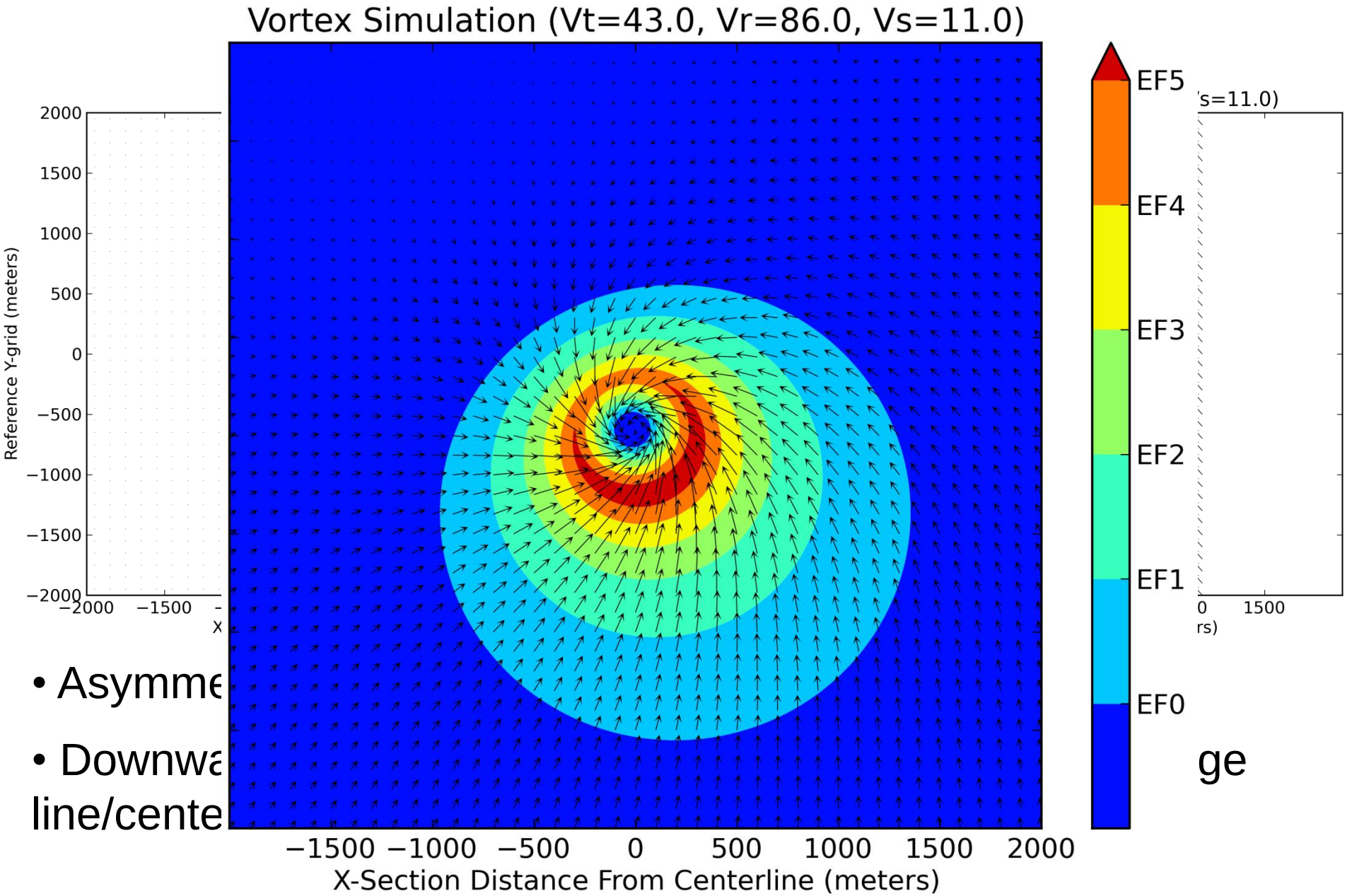

Karstens et al. (2013)
(c)
200
150
100
50
0
−50
−100
−150
−200
−200
−150
−100
−50
0
50
100
150
200
X-Section Distance From Geometric Center (meters)

Karstens et al. Method



1. Digitize tree-fall, max damage line.
2. Define a region of track.
3. Normalize tree distance to line of max damage.
4. Compute normalized mean cross section of tree-fall.
5. Compare to results from analytical vortex simulations.
6. Approximate mean near-surface wind field.

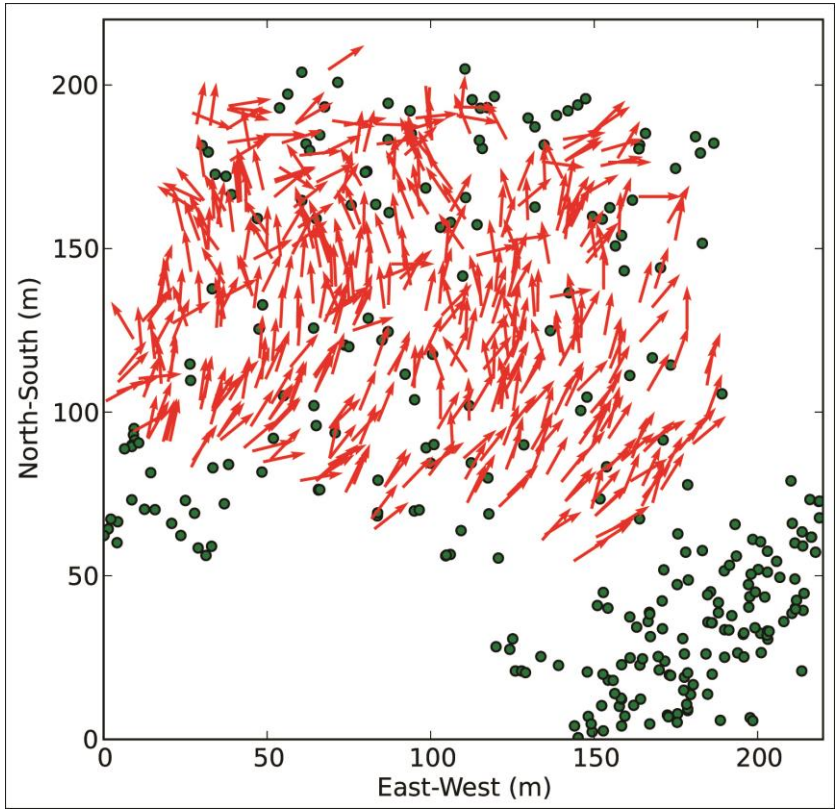
Karstens et al. Method



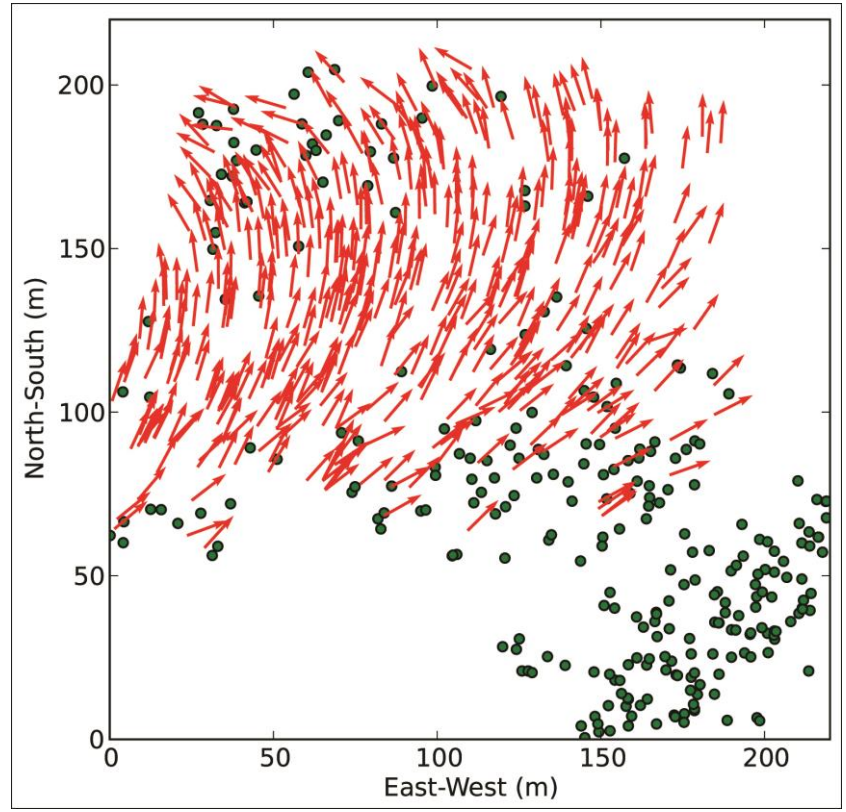
- Asymme
- Downwa ge

line/cente

Find the best match to the observed damage by adjusting the vortex parameters



Observed Tree Damage



Simulated Tree Damage

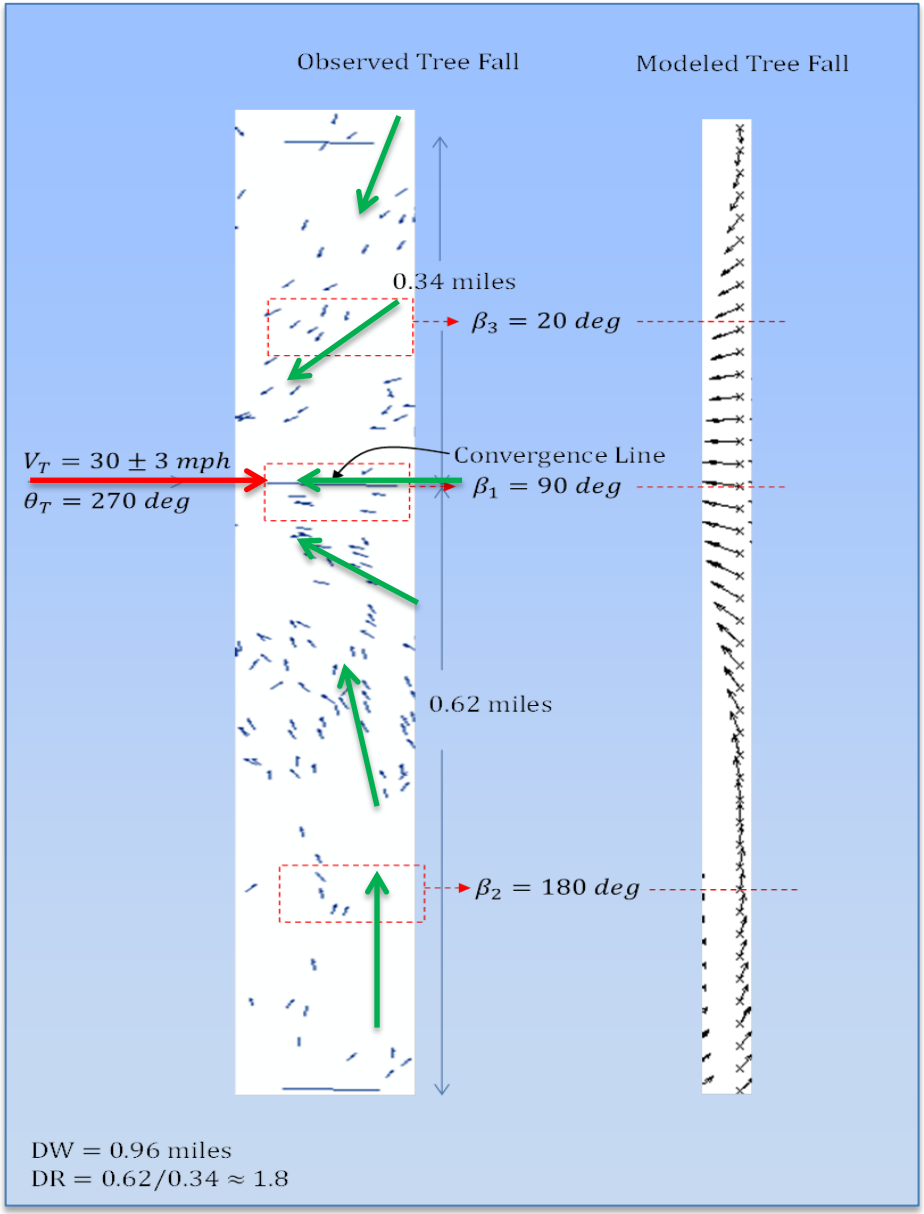
Godfrey and Peterson

Joplin, MO Tornado – NIST

Damage Width (DW): Width of tree fall

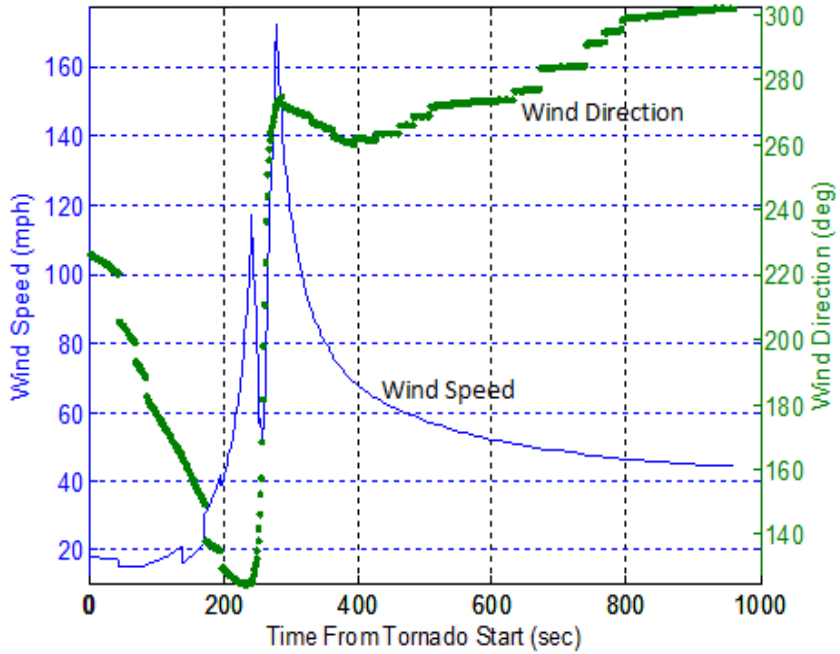
Damage Ratio (DR): Ratio of tree fall width on either side of "convergence line" (180 deg to V_T)

Tree Fall Direction (β): Distance from convergence line where tree fall directions were 90 and 180 degrees



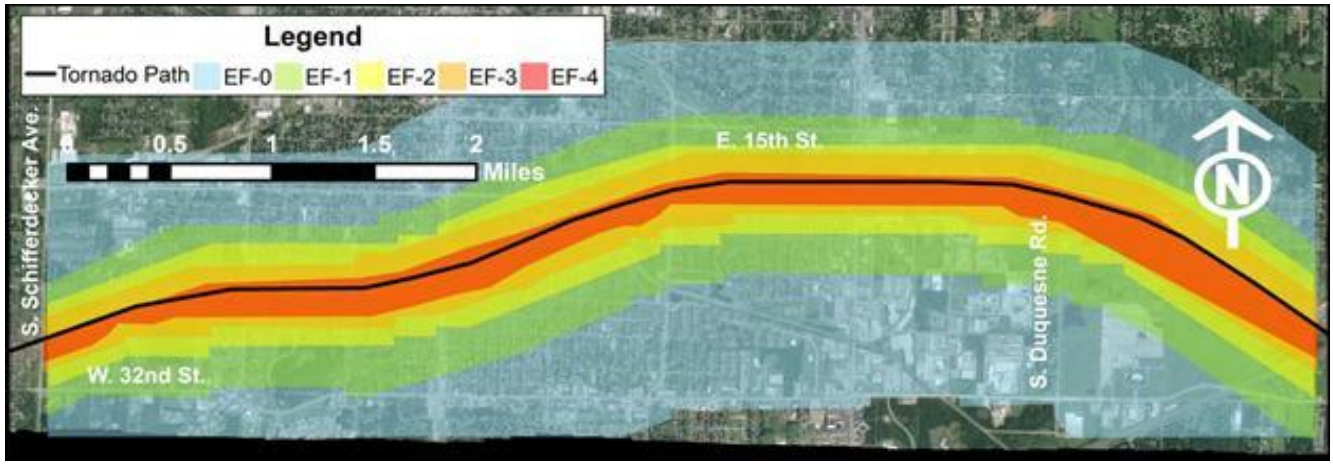
Lombardo/NIST

Joplin, MO Tornado – NIST



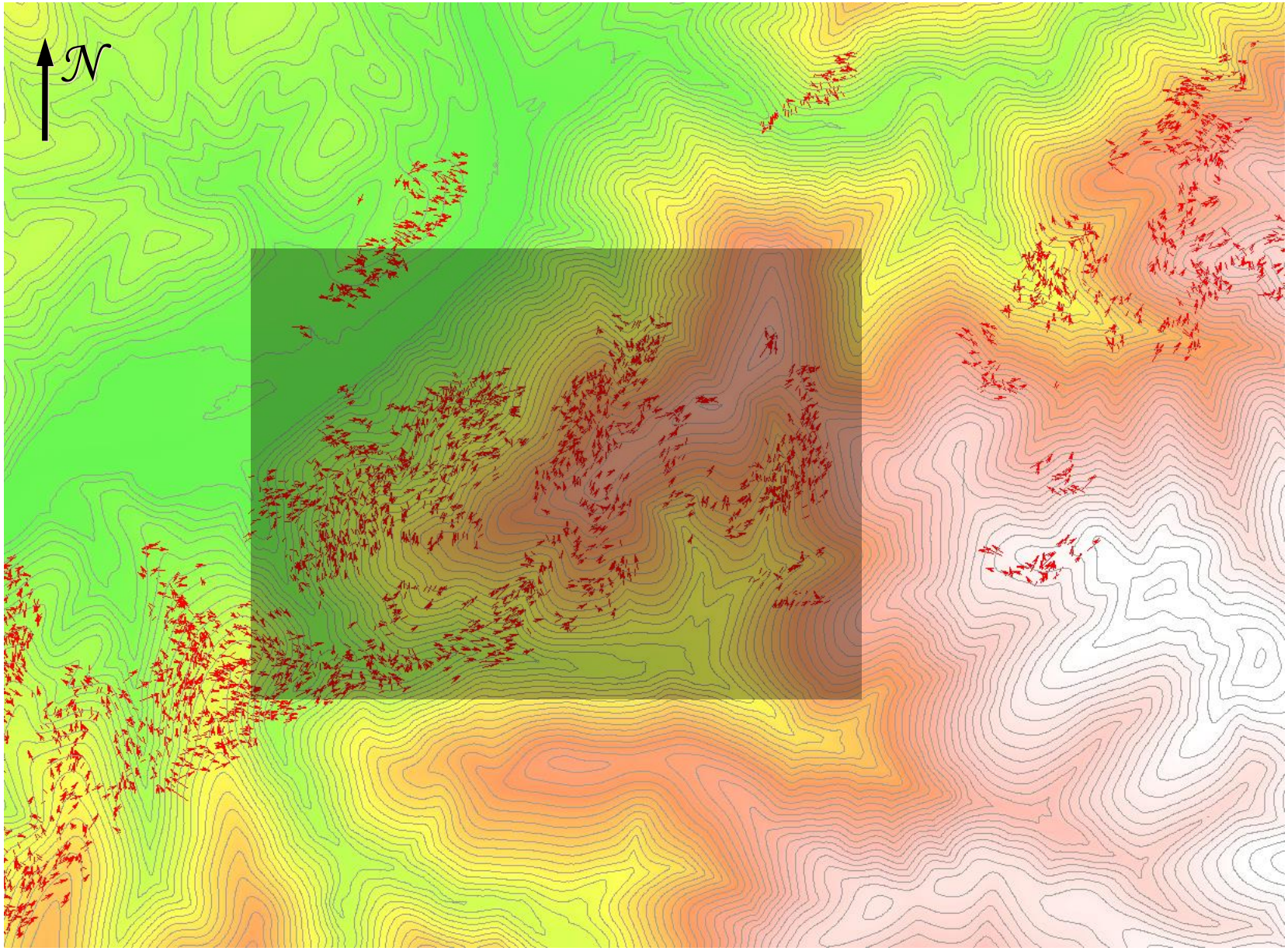
Left: Estimated wind speed and direction time history for a specific grid-point

Below: Estimated maximum wind speed associated with EF-number in Joplin



Lombardo/NIST

Terrain influences the tornadic flow field



Godfrey and Peterson

Terrain influences the tornadic flow field

Godfrey and Peterson

Operational Implementation - Challenges

1. Arduous process to digitize tree-fall.
   - Acquiring aerial photographs (spatially referenced?)
   - Digitization (typically via GIS software).
   - Can take several hours of time.
   - *Advantageous to develop image processing algorithm to automate process.*
2. Familiarity with vortex model & output
   - Many “knobs” to configure vortex.
   - Takes time to run model.
   - Best “match” is subjective
   - *Advantageous to develop objective matching procedure (e.g., self-organizing maps, least-squares) to automate selection of best “matches”.*
3. Complex Topography
   - Notable disruption of near-surface tornado flow.
   - Correlation between terrain roughness and variability in tree-fall directions

Greg Stumpf