Statistical Work and Predictability of Tornados

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- Tornado (violently rotating column of air ?)
- Statistics
- Predictability
- Work

Seymour, Texas, tornado of April 10, 1979

MSNBC, 09/16, 2006 :

Rogers, MN - A tornado swept through this Minnesota town, killing a 10-year-old girl, damaging hundreds of homes and scattering debris across the city, officials said. 200 to 300 homes were significantly damaged in Rogers, a town 26 miles northwest of Minneapolis. It just came out of nowhere and really did a lot of damage." Six other people were injured, and two remained hospitalized (Sunday) morning. The National Weather Service determined that the storm was an F2 tornado, with winds of 113 to 157 mph. **No tornado warning was issued for Rogers, but a severe thunderstorm warning had been issued.** They did not hear any warning sirens. Tim Turnbull, director of emergency preparedness for Hennepin County, said that sirens were activated in Rogers before the storm hit, but that people indoors may not have heard them because of the wind.

Rogers, MN

Minnesota is at the northern edge of the Tornado Valley

Texas, Nebraska, Oklahoma, and Kansas.

Kansas: The Wonderful Wizard of Oz by L. Frank Baum in 1900.

USSR:

Alexander M. Volkov translates the book into Russian - 1939

Urfin Jus and his Wooden Soldiers (1963)

The Seven Underground Kings (1964)

The Fiery God of the Marrans (1968)

The Yellow Fog (1970)

The Secret of the Abandoned Castle (1975, published in 1982)

Top 10

Rank	State(s)	Date	Time	Dead	Injured	F-Scale	Town(s)
1	MO-IL-IN	March 18, 1925	1:01PM	695	2027	F5	Murphysboro,Gorham, DeSoto
2	LA-MS	May 7, 1840	1:45 PM	317	109	F?	Nachez
3	MO-IL	May 27, 1896	6:30PM	255	1000	F4	St. Louis, East St. Louis
4	MS	April 5, 1936	8:55 PM	216	700	F5	Tupelo
5	GA	April 6, 1936	8:27 AM	203	1600	F4	Gainesville
6	TX-OK-KS	April 9, 1947	6:05 PM	181	970	F5	Glazier, Higgins, Woodward
7	LA-MS	April 24, 1908	11:45AM	143	770	F4	Amite, Pine, Purvis
8	WI	June 12, 1899	5:40PM	117	200	F5	New Richmond
9	MI	June 8, 1953	8:30 PM	115	844	F5	Flint
10	TX	May 11, 1953	4:10PM	114	597	F5	Waco

#1 #2 #3 #4 #5 #6 #7 #8 #9 #10

Minnesota: 30-40 days of thunderstorm activity per year.

Peak of tornado activity is in June and July with May and August being somewhat active as well. On average, 24 tornados per year

http://climate.umn.edu/doc/historical/tornadic.htm
http://www.crh.noaa.gov/mpx/TornadoStats/TornadoStats.php
http://www.crh.noaa.gov/mpx/svrData.php
http://www.crh.noaa.gov/mpx/svrData.php#TornadoStats
http://climate.umn.edu/
http://climate.umn.edu/doc/twin_cities/twin_cities.htm

Soil, Water and Climate

Mark Seeley http://www.soils.umn.edu/

In a state that often sits at the crossroads of weather systems, interest in the topic runs high. It's a phenomenon Seeley dubs "meteorological affected disorder, or MAD."

NOAA, NSSL, SPC, NCEP

Computer Models

Global: GFS, NOGAPS, GEM, ECMWF

Regional: WRF, NAM, NMM-WRF, AR-WRF,
MM5, HIRLAM, ARPS, RUC, RSM,
NGM, SREF

Watches: SPC

Warnings: Regional NWS offices

Data collection, accumulation and assimilation

Research: CAPS, CIMMS, NCAR

FROM SPC

Damage Survey

National Weather Service Employees have determined that the damage in Rogers on September 16, 2006 resulted from a tornado. Radar data indicate that the tornado touched down shortly before 10:00 PM. The survey results show that the path length was 8 miles, from 3.5 miles west of downtown Rogers to the city of Dayton, then continued east across the Mississippi River to the city of Ramsey. The tornado was rated an F2 on the Fujita Scale, and had a maximum width of 100 yards.

Event Synopsis

During the late afternoon and evening hours of Saturday, September 16th, storms developed rapidly over western Minnesota around 5:30 PM, before moving into central Minnesota and west central Wisconsin between 7:00 PM and Midnight. The most intense damage occurred across the northern suburbs of the Twin Cities between 10:00 PM and Midnight, when a series of very intense storms resulted in widespread damage and sadly, one fatality, near Otsego and Rogers. Other storms produced hail in excess of an inch in diameter near Benson, 59 mph winds in Redwood Falls, and downed trees in Albert Lea, across Anoka County, and near Amery, Wisconsin.

Ensembles

Edward Lorenz (1963) - impossible to definitively predict the state of the atmosphere (chaotic nature of rotating fluid bodies).

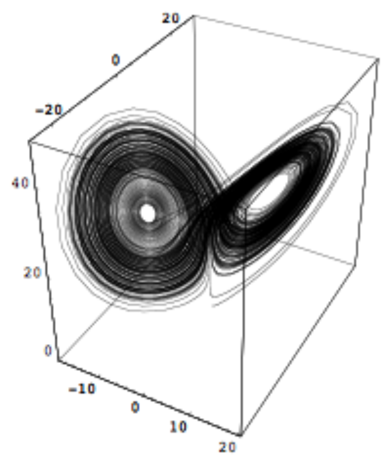
To combat this uncertainty, stochastic or "ensemble" forecasting is used, involving numerous forecasts created with different model systems, different physical parameterizations, or varying initial conditions.

The ensemble forecast is usually evaluated in terms of the ensemble mean of a forecast variable, and the ensemble spread, which represents the degree of agreement between various forecasts in the ensemble system, known as ensemble members. When the ensemble members are in relatively high agreement, the ensemble spread is low and the forecast confidence high.

Lorentz Attractor

$$\frac{dx}{dt} = 10\,(y - x)$$
$$\frac{dy}{dt} = 28\,x - y - xz$$
$$\frac{dz}{dt} = -\frac{8}{3}\,z + xy$$

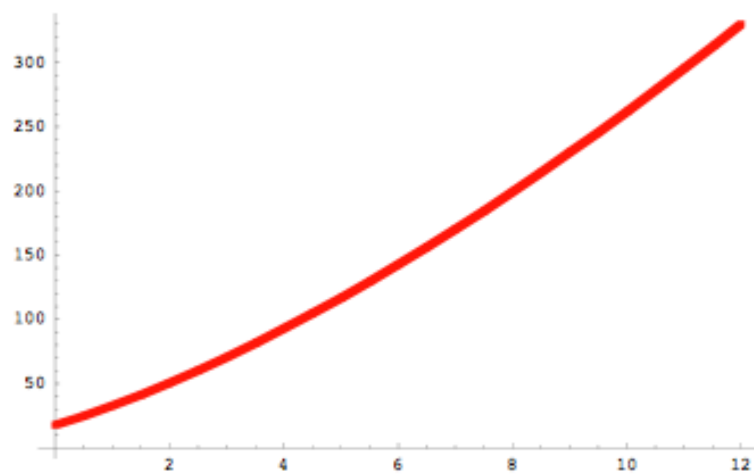
```
In[35]:= Clear[x, y, z, t, L];
         L = 200;
         NDSolve[{x'[t] == 10 * (y[t] - x[t]), y'[t] == 28 * x[t] - y[t] - x[t] * z[t],
           z'[t] == x[t] * y[t] - (8 / 3) * z[t], x[0] == z[0] == 0, y[0] == 1},
          {x, y, z}, {t, 0, L}, MaxSteps → Infinity]
         ParametricPlot3D[Evaluate[{x[t], y[t], z[t]} /. %], {t, 0, L}, PlotPoints → 10000]

Out[37]= {{x → InterpolatingFunction[{{0., 200.}}, <>],
           y → InterpolatingFunction[{{0., 200.}}, <>],
           z → InterpolatingFunction[{{0., 200.}}, <>]}}
```




```
Out[38]= - Graphics3D -
```

Fujita scale : $V = 6.3\ (F+2)^{1.5}$

```
Clear[V, F, i]; V[x_] := 6.3 * (x + 2) ^ 1.5;
Plot[V[x], {x, 0, 12},
 PlotStyle → {{Thickness[0.01], RGBColor[1, 0, 0]}}]
MatrixForm[Table[
  {"F", F, V[F], 2.236936292 * V[F]}, {F, 0, 12}]]
```



		m/s	mi/h
F	0	17.8191	39.8602
F	1	32.7358	73.2278
F	2	50.4	112.742
F	3	70.4361	157.561
F	4	92.5907	207.12
F	5	116.678	261.
F	6	142.553	318.881
F	7	170.1	380.503
F	8	199.223	445.65
F	9	229.842	514.142
F	10	261.886	585.822
F	11	295.295	660.555
F	12	330.014	738.221

http://www.spc.noaa.gov/faq/tornado/f-scale.html

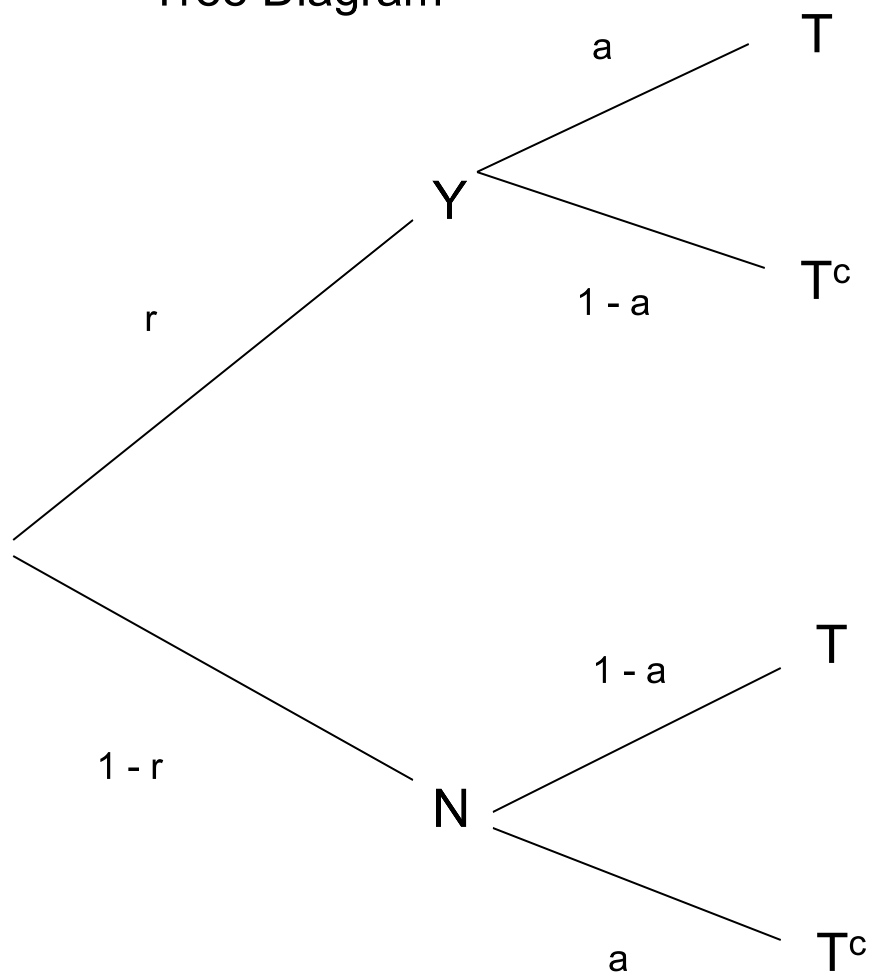
Severe Thunderstorms Statistics

1. Reports for each day are put onto a grid 80 km x 80 km.
2. If one or more reports occur in a grid box, that box is assigned the value "1" for the day. If no reports occur, it's a zero.
3. The raw frequency for each day at each grid location is found for the period (number of "1" values divided by number of years) to get a raw annual cycle.
4. The raw annual cycle at each point is smoothed in time, using a Gaussian filter with a standard deviation of 15 days.
5. The smoothed time series are then smoothed in space with a 2-D Gaussian filter (SD = 120 km in each direction).

http://www.nssl.noaa.gov/hazard/index.html

http://www.crh.noaa.gov/mpx/TornadoStats/TornadoStats.php

Tree Diagram



Rare Events

a – accuracy

r – probability of rare event

$$\frac{ra}{ra + (1 - r)\ (1 - a)} > \frac{1}{2}$$

$$a > 1 - r$$

Barry Cipra (1998)

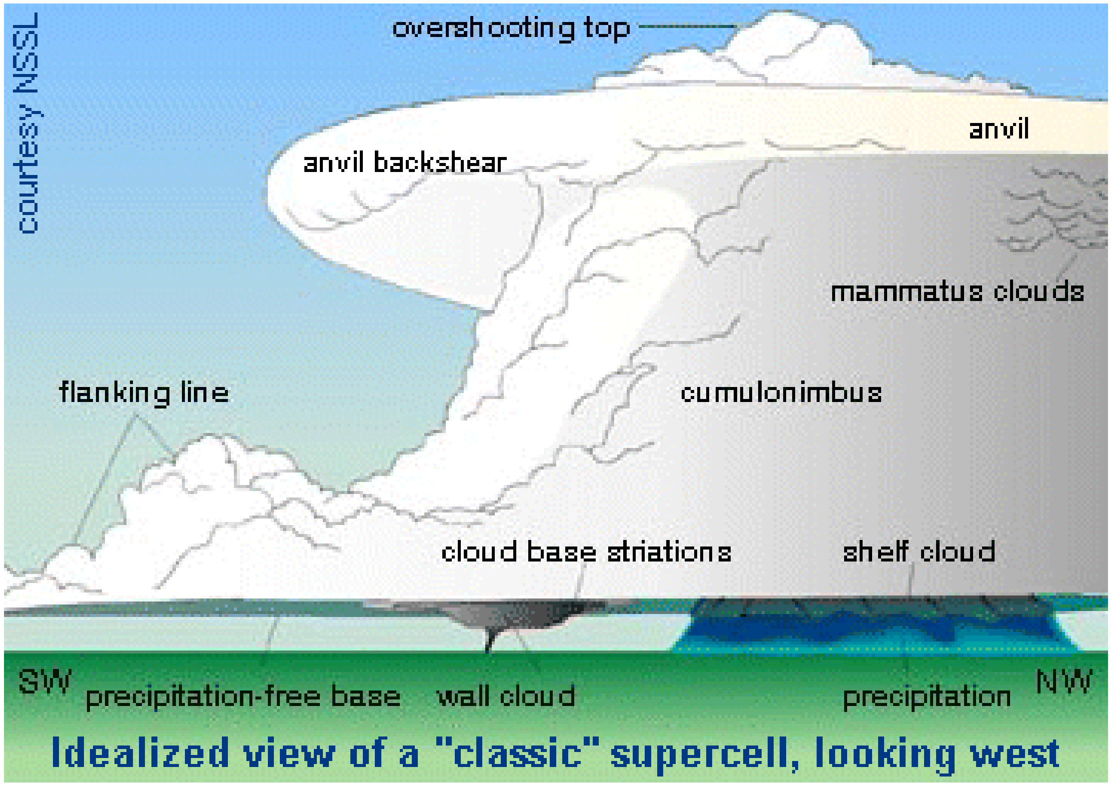
In 1978, Joseph Klemp of the National Center for Atmospheric Research and Robert Wilhelmson of the University of Illinois developed a three-dimensional model that enabled them to perform realistic computer simulations of storms. The Klemp-Wilhelmson model is still the basis for much of the work being done in tornado dynamics.

Mathematically speaking, a tornado is **vector calculus with a vengeance**. Severe storms bubble up in a witch's brew of two scalar fields - pressure and humidity - and a vector field known as wind. These elements conspire to produce a moist mass of rotating air, which meteorologists have taken to calling a "supercell." The term was coined in the 1960s by British meteorologist Keith Browning, who proposed a theory describing how updrafts become tilted and start to rotate in what's called the mesocyclone. Roughly speaking, wind near the ground tends to come from the southeast; moving upward, the wind shifts, coming from the south at a half mile and from the east at a mile. It's the rotational shear that creates the possibility of tornadoes, which concentrate energy much as an ice skater turns a slow spin into a blur by pulling in her arms

Supercell

http://www.spc.noaa.gov/exper/mesoanalysis/
http://www.srh.noaa.gov/shv/SPOTTER2004Netscape.htm

From Edwards (SPC)



$$\nabla (\mathbf{F} \cdot \mathbf{G}) = (\mathbf{F} \cdot \nabla) \mathbf{G} + (\mathbf{G} \cdot \nabla) \mathbf{F} + \mathbf{F} \times (\nabla \times \mathbf{G}) + \mathbf{G} \times (\nabla \times \mathbf{F})$$

$$\nabla \cdot (\mathbf{F} \times \mathbf{G}) = \mathbf{G} \cdot (\nabla \times \mathbf{F}) - \mathbf{F} \cdot (\nabla \times \mathbf{G})$$

$$\nabla \times (\mathbf{F} \times \mathbf{G}) = \mathbf{F}\, \nabla \cdot \mathbf{G} - \mathbf{G}\, \nabla \cdot \mathbf{F} + (\mathbf{G} \cdot \nabla) \mathbf{F} - (\mathbf{F} \cdot \nabla) \mathbf{G}$$

$$\nabla \times (\nabla \times \mathbf{F}) = \nabla (\nabla \cdot \mathbf{F}) - \nabla^2 \mathbf{F}$$

$$\mathbf{H} \cdot ((\mathbf{F} \times \nabla) \times \mathbf{G}) = ((\mathbf{H} \cdot \nabla) \mathbf{G}) \cdot \mathbf{F} - (\mathbf{H} \cdot \mathbf{F}) (\nabla \cdot \mathbf{G})$$

$$\mathbf{F} \times (\mathbf{G} \times \mathbf{H}) = (\mathbf{F} \cdot \mathbf{H}) \mathbf{G} - \mathbf{H} (\mathbf{F} \cdot \mathbf{G})$$

$$\rho \frac{D\mathbf{u}}{Dt} = -\nabla p \qquad \mathbf{u}_t + (\mathbf{u} \cdot \nabla)\,\mathbf{u} = -\nabla w$$

$$\nabla \frac{1}{2} (\mathbf{u} \cdot \mathbf{u}) = (\mathbf{u} \cdot \nabla)\,\mathbf{u} + \mathbf{u} \times (\nabla \times \mathbf{u})$$

$$\mathbf{u}_t = -\nabla w - \nabla \frac{1}{2} (\mathbf{u} \cdot \mathbf{u}) + \mathbf{u} \times \boldsymbol{\xi}$$

$$\boldsymbol{\xi}_t = \nabla \times (\mathbf{u} \times \boldsymbol{\xi})$$

$$\boldsymbol{\xi}_t = \mathbf{u}\, \nabla \cdot \boldsymbol{\xi} - \boldsymbol{\xi}\, \nabla \cdot \mathbf{u} + (\boldsymbol{\xi} \cdot \nabla)\,\mathbf{u} - (\mathbf{u} \cdot \nabla)\,\boldsymbol{\xi}$$

$$\xi_t = \boldsymbol{\xi}_H \cdot \nabla_H w + \xi w_z - \mathbf{u}_H \cdot \nabla_H \xi - w\, \xi_z$$

$$\frac{dH}{dt} = \frac{d}{dt}\int_E \mathbf{u} \cdot \xi = \int_E (\mathbf{u}_t \cdot \xi + \mathbf{u} \cdot \xi_t)$$

$$\mathbf{u}_t = -\nabla\left(\frac{1}{2}\mathbf{u}\cdot\mathbf{u} + w\right) + \mathbf{u} \times \xi$$

$$\xi_t = \nabla \times (\mathbf{u} \times \xi)$$

$$\mathbf{u}_t \cdot \xi + \mathbf{u} \cdot \xi_t$$

$$= \nabla \cdot \left[-\left(\frac{1}{2}\mathbf{u}\cdot\mathbf{u} + w\right)\xi + (\mathbf{u} \times \xi) \times \mathbf{u}\right]$$

$$\int_0^{2\pi} \cos nx \, dx = 0$$

$$\int_0^{2\pi} \cos^2 nx \, dx = \pi$$