Indiana Rainfall Patterns, Flooding and a Network for Future Measurements

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The National Weather Service is a component of the National Oceanic and Atmospheric Administration (NOAA). NOAA is an Operating Unit of the U.S. Department of Commerce.

Our Mission - Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.

Our Vision - A Weather-Ready Nation: Society is Prepared for and Responds to Weather-Dependent Events

http://www.weather.gov/
Three Main Patterns for Heavy Rainfall

As Defined by Maddox et al. 1979

• Synoptic – Associated with intense, slow moving synoptic scale cyclone or frontal boundary

• Meso-high – Associated with nearly stationary thunderstorm outflow boundary

• Frontal – Associated with slow moving or nearly stationary front oriented in an east-west direction
This pattern is associated with an intense synoptic scale cyclone or frontal system. There is a significant, slow moving trough at 500mb and a strong, moist low level flow at 850mb. The average wind difference between 850-300mb is 25 knots with 40 degrees of veering. The surface front is slow moving or quasi-stationary and the northward extent of the heavy rain is limited by the warm front. The location of heavy rainfall is generally on the warm side of the boundary. Convective storms repeatedly develop and move over the same areas. These events may last several days and impact several states. The Synoptic pattern usually occurs in the Fall or Spring months when strong dynamics are present (Maddox et al. 1979).
Synoptic Set-Up for Heavy Rainfall in Indiana
This pattern is associated with a nearly stationary thunderstorm outflow boundary. The heaviest rainfall occurs near the large scale ridge position but there is usually a detectable short wave trough at 500mb. There is a moderate moist low level southerly flow at 850mb. Wind speed increases little from 850-300mb but there is significant veering with height. The location of heavy rainfall is generally on the cool side of the outflow boundary as warm, unstable air moves over it. (Maddox et al. 1979).
This pattern is associated with a stationary or very slow moving synoptic east-west oriented frontal boundary. The heaviest rainfall occurs near the 500mb large scale ridge axis. There is a moderate moist low level southerly flow at 850mb. Wind speed increases little from 850-300mb but there is significant veering with height. The location of heavy rainfall is generally on the cool side of the front as warm, unstable air moves over the front. Winds aloft are parallel to the surface front. Convective storms can repeatedly develop and move over the same areas. (Maddox et al. 1979).
Frontal Set-Up for Heavy Rainfall in Indiana

June 26-27th, 2013
Floods of January 2008
Floods of January 2008

[Map showing precipitation totals with color coding for different ranges]

Precipitation Totals
- 0-0.50" *
- 0.50-1.00"
Floods of January 2008

January 7th - 9th Rainfall

Legend
- 0.00-1.2
- 1.25-1.7
- 1.75-2.2
- 2.25-2.7
- 2.75-3.2
- 3.25-3.7
- 3.75-4.2
- 4.25-4.7
- 4.75-5.2
- 5.25-5.7
- 5.75-6.2

Floods of February 2008
Floods of January and February 2008

Historical Crests for Tippecanoe River below Oakdale Dam

(1) 21.75 ft on 01/08/2008
(2) 19.00 ft on 02/06/2008
(3) 18.72 ft on 03/11/2009
(4) 16.01 ft on 04/28/2011
(5) 15.32 ft on 04/19/2013
(6) 13.24 ft on 12/27/2008
(7) 12.99 ft on 12/28/2008
(8) 12.51 ft on 02/11/2009
(9) 11.20 ft on 01/30/2013
(10) 11.10 ft on 03/06/2011
(11) 10.48 ft on 06/22/2010
Floods of January and February 2008
Flooding is Costly and Deadly

- Floods are the #1 natural disaster in the United States
- From 2003 to 2012, total flood insurance claims averaged nearly $4 billion per year

http://www.floodsafety.noaa.gov/
Factors Affecting Flooding Potential

- Soil type
- Vegetation
- Land use
- Slope of terrain (FF) / channel depth and width (River)
- Meteorological/hydrological and antecedent conditions
  - Heavy and/or prolonged rainfall
  - Deep and/or melting snowpack
  - Frozen ground
  - River and stream levels
  - Saturated ground
  - Drought conditions/dry and hard ground
Flash Flood Potential Index

The Flash Flood Potential Index (FFPI) was developed to study the effect of Indiana’s diverse geography on flash flood likelihood. Factors that affect flash flood potential include:

1. Slope of terrain – how quickly runoff occurs
2. Soil type – Less penetrable soil types will increase flash flood potential
3. Land use – Impervious surfaces (streets, urban areas) will increase flash flood probability
4. Tree cover (forest canopy) – more dense forests will slow rainfall runoff

In December 2010, the NWS Ohio River Forecast Center unveiled a flash flood Monitoring Program (FFMP) which incorporated many of these FFPI concepts to previously used flash flood guidance.

From Evan’s Poster P:\Evan\FFPI
Most Common Forms of Flooding in Indiana

- Flash Floods – A flood caused by heavy rain/snow melt, ice jam or dam failure in a short period of time, usually 6 hours or less.

- River/Stream Flooding – Inundation of normally dry areas caused by rising water in an existing waterway. Flooding is longer duration, usually days or weeks.

  - Many record river flood events occur in winter and early Spring and are often due to snow melt and heavy rainfall
## Top 5 Flooding Events by River

### Through Fall 2013

<table>
<thead>
<tr>
<th>River</th>
<th>Event Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio</td>
<td>1/26/1937, 3/8/1945, 4/1/1913, 3/13/1964, 2/16/1884</td>
</tr>
</tbody>
</table>

13 Records in Winter Months (Dec-Feb)
14 Records in Spring Months (Mar-May)
3 Records in Summer Months (Jun-Aug)
1 Record in Fall Months (Sep-Nov)

18 Records up to 1950
13 Records after 1950
Different Types of Meteorological Events Can Lead to Flooding in Indiana

1. Slow moving thunderstorms with heavy rainfall
2. “Training” Thunderstorms
3. Snow Melt with or without heavy rain
4. Tropical Systems
Importance of Tropical Storms to Indiana Precipitation 1980-2012

The following storms contributed to greater than 50% of the total observed precipitation in the listed climate division during the month of storm passage.

- Erin 1995: Climate Divisions 6, 8, and 9
- Isidore 2002: Climate Divisions 6, 8, and 9
- Ivan 2004: Climate Division 6
- Arlene 2005: Climate Divisions 4, 5, 7, 8, 9
- Katrina 2005: Climate Divisions 5, 6, 7, 8, 9
- Gustav and Ike 2008 (combined storm totals greater than 50% of Sept. 2008 precip. (Over 10 inches in 2 days at SBN): CD 1, 2, 3, 4
- Isaac 2012: Climate Division 1.
Importance of Tropical Storms to Indiana Precipitation 1980-2012

The following storms prevented drought conditions (analyzed at climate division level with drought based on 15% below normal... PDSI conditions) for the month of their passage through the state.

- Elena 1985
- Gilbert 1988
- Erin and Opal 1995 (Southern 2/3 climate divisions)
- Lili and Isador 2002 (northern 2/3 climate divisions)
- Ivan 2004
- Arlene 2005
- Katrina 2005 (central and eastern climate divisions)
- Gustave and Fay 2008
- Hermine 2012

Courtesy of Chris Helvren
Ph.D. Student, Purdue University
Department of Earth, Atmospheric, and Planetary Sciences
Climate Specialist and Forecaster, Indiana State Climate Office
chhelvren@purdue.edu
Widespread flood event in progress this morning as July like STG LL MSTR feedconts to impinge into composite stationary FNTL BNRV/Convective outflw ovrl TN/IN/IL. Situation bad already but looks to get worse and of secondary FCT FNTL wave lifting out of W/n MD and even stronger LL MSTR transport Dvlpng through this morning. 88-D Precip estimates look pretty good lined up w/Ground truth. Reports so far and really highlight Wvry cwa at most risk. Current FAA headline delineation spot on and will be left alone. Will though... given shft term mesoscale analysis and Run 13 output... Augment dyqsp much higher, deepening SFC low missing NW of CWA and ramping LL Fw may overwhelm current convective bubble high and result in Nvd push of most active convection TWD daybreak back ACRS areas hardest hit overnight as seen in latest radar trends and born out per Wocott profiler although everyone will see heavy rain through the morning within extensive stratiform/Embedded convection north of training NR SFC based convective line. PEnAing how convection further evolves through this morning... MAJOR FLOODING PSBL in the KANKAKEE BASIN ESP WITHIN THE UPSTREAM PORTION OF THE YELLOW RIVER AND ALONG THE KANKAKEE RIVER GIVEN Widespread 2-3 inches which had fallen overnight and consensus QPF solutions showing 2-3 inches more through this AFTN. Remington Indiana already nearing 5 inches.
Indiana Precipitation Project

- Joint Project between Indiana State Climate Office and NWS Northern Indiana
  - Sam Lashley – NWS Senior Meteorologist
  - Steven Chun – Purdue Student Researcher
  - Dev Niyogi – Indiana State Climatologist

- Studying hourly precipitation observations between May and October
  - 62 years of data from 1950 to 2012
  - Data being broken down into 4 daily periods

- 4 Indiana cities selected
  - South Bend
  - Fort Wayne
  - Indianapolis
  - Evansville

- Work in progress, some interesting preliminary findings
South Bend, IN
Hourly Observations
May - October

- 0.01≤x≤0.25
- 0.25≤x≤0.50
- 0.50≤x≤0.75
- 0.75≤x≤1.00
## South Bend, IN

- **Greatest 1 hour Rainfall Since 1950**

<table>
<thead>
<tr>
<th>Time</th>
<th>Temperature</th>
<th>Humidity</th>
<th>Rainfall</th>
<th>Wind</th>
<th>Wind Gust</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:56 AM</td>
<td>75.2°F</td>
<td>78%</td>
<td>0.10 in</td>
<td>North</td>
<td>36.7 mph</td>
<td>0.00 in, Rain, Thunderstorm</td>
</tr>
<tr>
<td>1:58 AM</td>
<td>75.6°F</td>
<td>83%</td>
<td>0.10 in</td>
<td>North</td>
<td>33.0 mph</td>
<td>0.02 in, Rain, Thunderstorm</td>
</tr>
<tr>
<td>2:01 AM</td>
<td>68.0°F</td>
<td>94%</td>
<td>0.11 in</td>
<td>NNE</td>
<td>28.8 mph</td>
<td>0.26 in, Rain, Thunderstorm</td>
</tr>
<tr>
<td>2:14 AM</td>
<td>66.2°F</td>
<td>100%</td>
<td>0.03 in</td>
<td>ENE</td>
<td>17.1 mph</td>
<td>1.49 in, Fog, Rain, Hail, Thunderstorm</td>
</tr>
<tr>
<td>2:18 AM</td>
<td>66.2°F</td>
<td>100%</td>
<td>0.01 in</td>
<td>ENE</td>
<td>23.0 mph</td>
<td>1.63 in, Rain, Hail, Thunderstorm</td>
</tr>
<tr>
<td>2:26 AM</td>
<td>66.2°F</td>
<td>94%</td>
<td>0.04 in</td>
<td>East</td>
<td>13.8 mph</td>
<td>1.98 in, Rain, Hail, Thunderstorm</td>
</tr>
<tr>
<td>2:28 AM</td>
<td>66.2°F</td>
<td>94%</td>
<td>0.05 in</td>
<td>East</td>
<td>15.0 mph</td>
<td>2.02 in, Rain, Hail, Thunderstorm</td>
</tr>
<tr>
<td>2:31 AM</td>
<td>68.0°F</td>
<td>100%</td>
<td>0.08 in</td>
<td>ENE</td>
<td>10.4 mph</td>
<td>2.12 in, Rain, Hail, Thunderstorm</td>
</tr>
<tr>
<td>2:43 AM</td>
<td>68.0°F</td>
<td>100%</td>
<td>0.06 in</td>
<td>ENE</td>
<td>13.8 mph</td>
<td>2.23 in, Rain, Hail, Thunderstorm</td>
</tr>
<tr>
<td>3:54 AM</td>
<td>68.0°F</td>
<td>100%</td>
<td>0.05 in</td>
<td>ESE</td>
<td>13.8 mph</td>
<td>2.42 in, Rain, Thunderstorm</td>
</tr>
</tbody>
</table>

http://www.wunderground.com/
Using a Volunteer Network of Observers to Measure and Monitor Precipitation Trends

CoCoRaHS
Volunteer Precipitation Observations:
Providing Valuable Information in Extreme Rainfall Events
CoCoRaHS was born in response to the 1997 Fort Collins, Colorado Flood
The Community Collaborative Rain, Hail and Snow Network

CoCoRaHS is a grassroots, high-density, precipitation network.

It is made up of over 15,000 volunteers of all ages and backgrounds who take daily precipitation measurements in their own backyards each morning.

CoCoRaHS has quickly become the largest source of daily precipitation measurements in the United States.
The four-inch diameter high capacity plastic rain gauge

Cost less than $30

Gauge measures to the hundredth of an inch. Holds eleven inches.
CoCoRaHS’ s goal is to provide:

*High Quality Precipitation Measurements*
*and*
*Educational Resources and Outreach*
CoCoRaHS Volunteers measure both snowfall depth (new and accumulated), as well as the water content of the snow (SWE)
Volunteer’s observations are immediately available for the public to view.
CoCoRaHS data is used regularly

- NOAA’s National Weather Service
- NOAA’s River Forecast Centers
- NOAA’s National Hurricane Center
- NOHRSC – National Operational Hydrologic Remote Sensing Center
- Indiana State Climatologist
- Denver’s Urban Drainage and Flood Control District

<table>
<thead>
<tr>
<th>engineers</th>
<th>city/county planners</th>
<th>universities</th>
<th>local municipalities</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>flood control districts</td>
<td>urban drainage organizations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>broadcast meteorologists</td>
<td>conservation districts</td>
<td>floodplain managers</td>
</tr>
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</table>
How can your organization benefit from this complementary citizen science network?

- Real-Time extreme precipitation data – can be integrated into your system
- Archived data free and exportable

For those who do not have a network in their area, feel free to use CoCoRaHS

- Infrastructure for reporting, mapping, data extraction already there
- Free QC’ed high quality daily data
- Tutorials and educational components provided for your observers
- Only cost to the observer is the price of a 4” diameter rain gauge
For further information:

www.cocorahs.org

Sam Lashley - NWS Northern Indiana - Sam.Lashley@noaa.gov