

# NEXRAD for Small Ungaged Watersheds

Example from Union, IL  
in McHenry County

Wes Cattoor  
IDNR – OWR  
IAFSM Workshop  
August 23, 2010



# Overview

Gage Calibration Overview

Nexrad Overview

Obtaining Nexrad Data

Adjusting Nexrad Data

Comparing Gage to Nexrad

Example from Union, IL in McHenry County

# Background of Union

- Hydrology Developed in HEC-1
- Drainage Area < 1 mi<sup>2</sup>
- Study for Flood Reduction Alternatives
- Previously not Calibrated

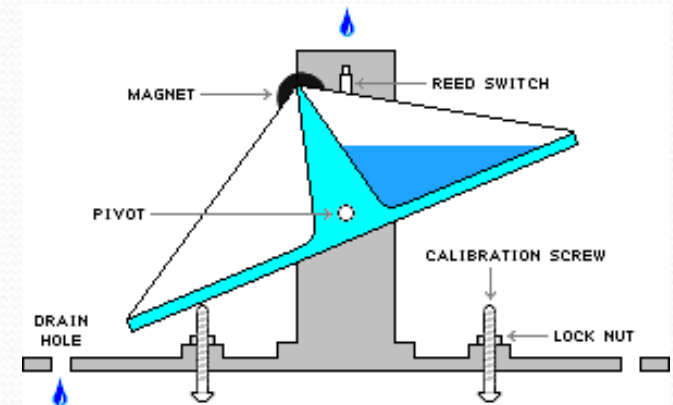
# Gage Only Calibration

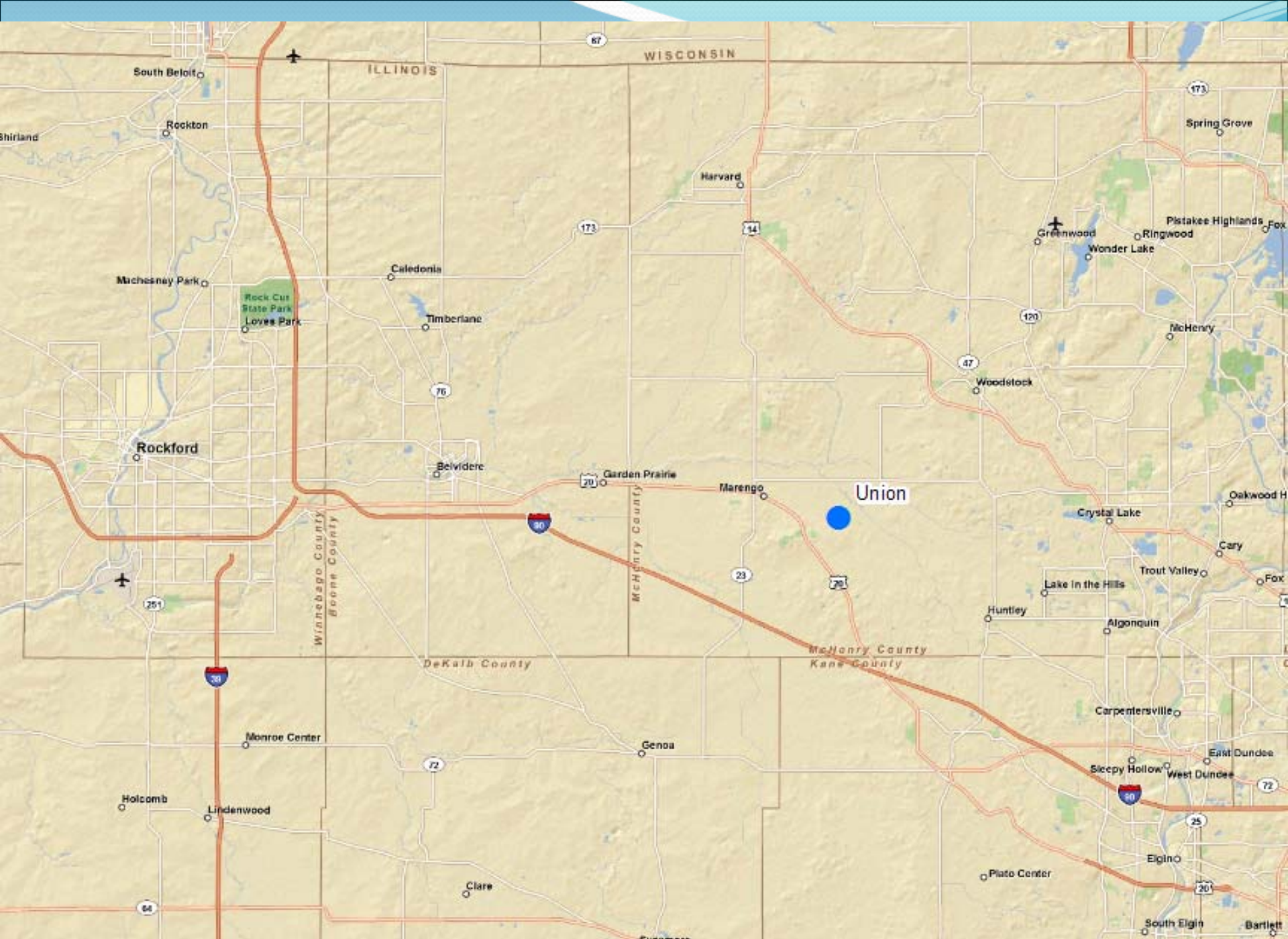
- Benefits

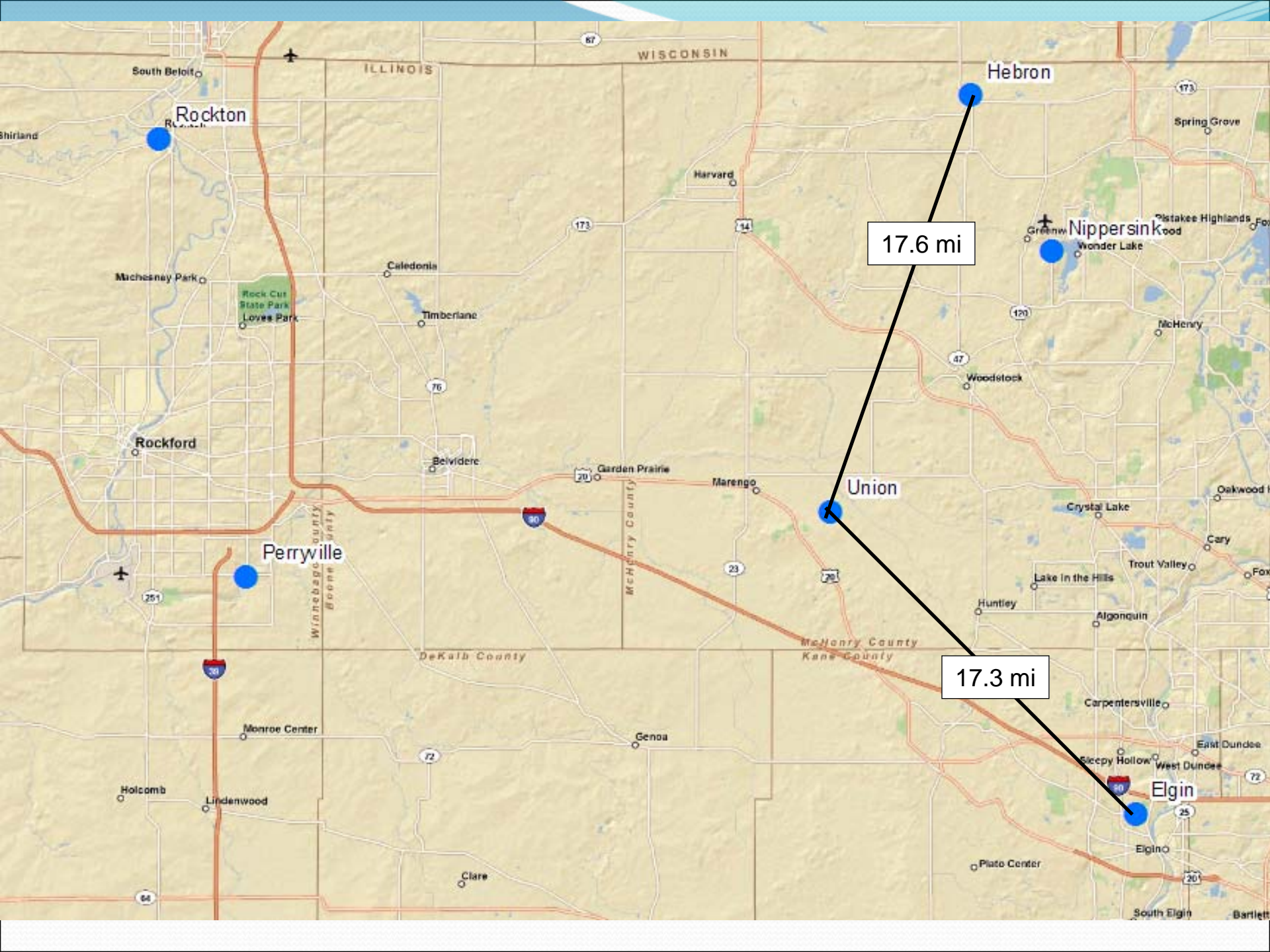
- Continuous sampling
- Measures at Ground elevation

- Limitations

- Only samples a small area (<1ft<sup>2</sup>)
- Wind field deformation at gage
  - 1% underestimate per mph of wind for unshielded gages\*
- Other errors (tipping time, rim wetting, splash out/in, etc)
- Assumes uniformity between gages (IDSM) or
- Assumes uniformity in surrounding area (Thiessen)



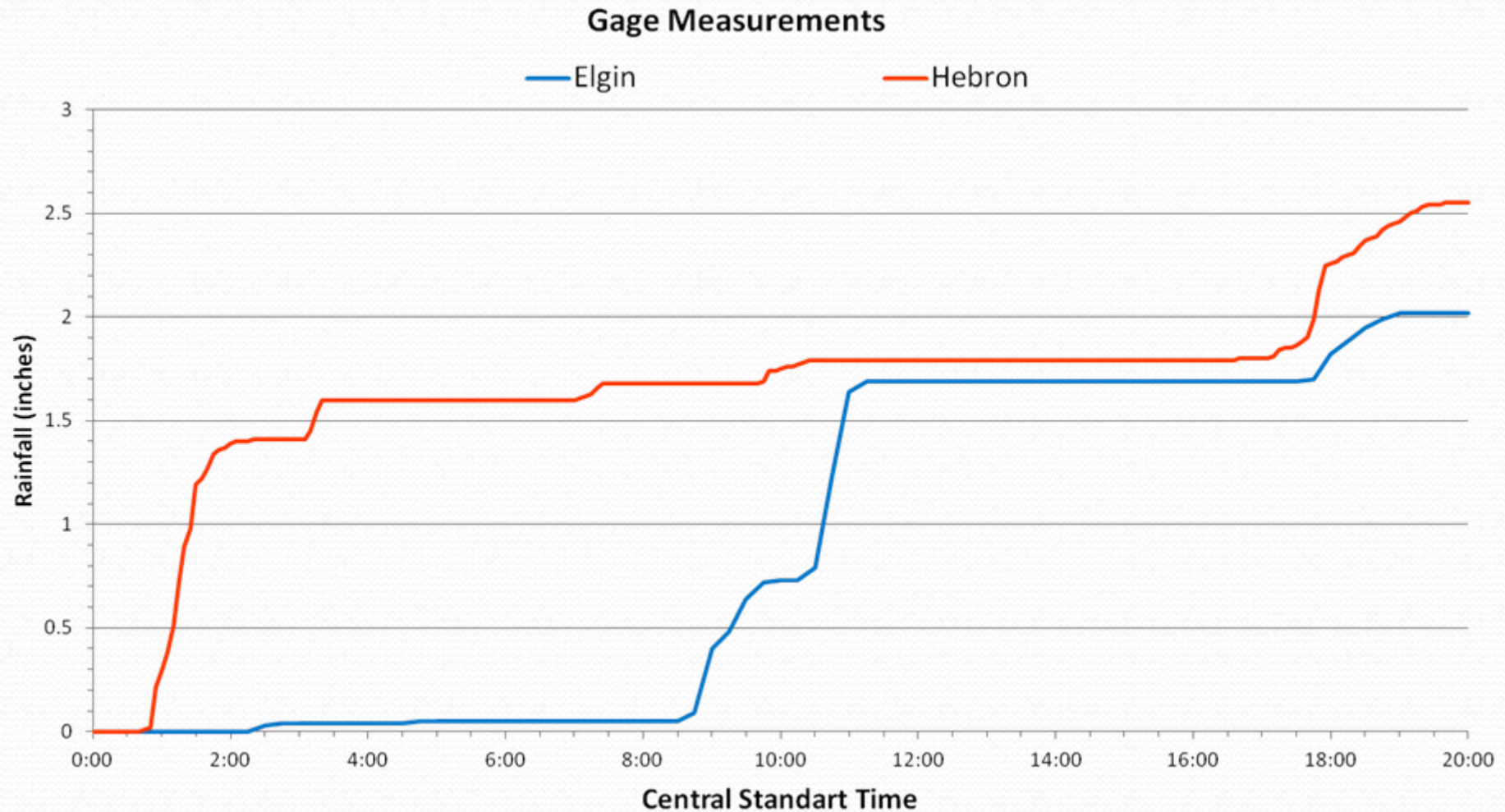




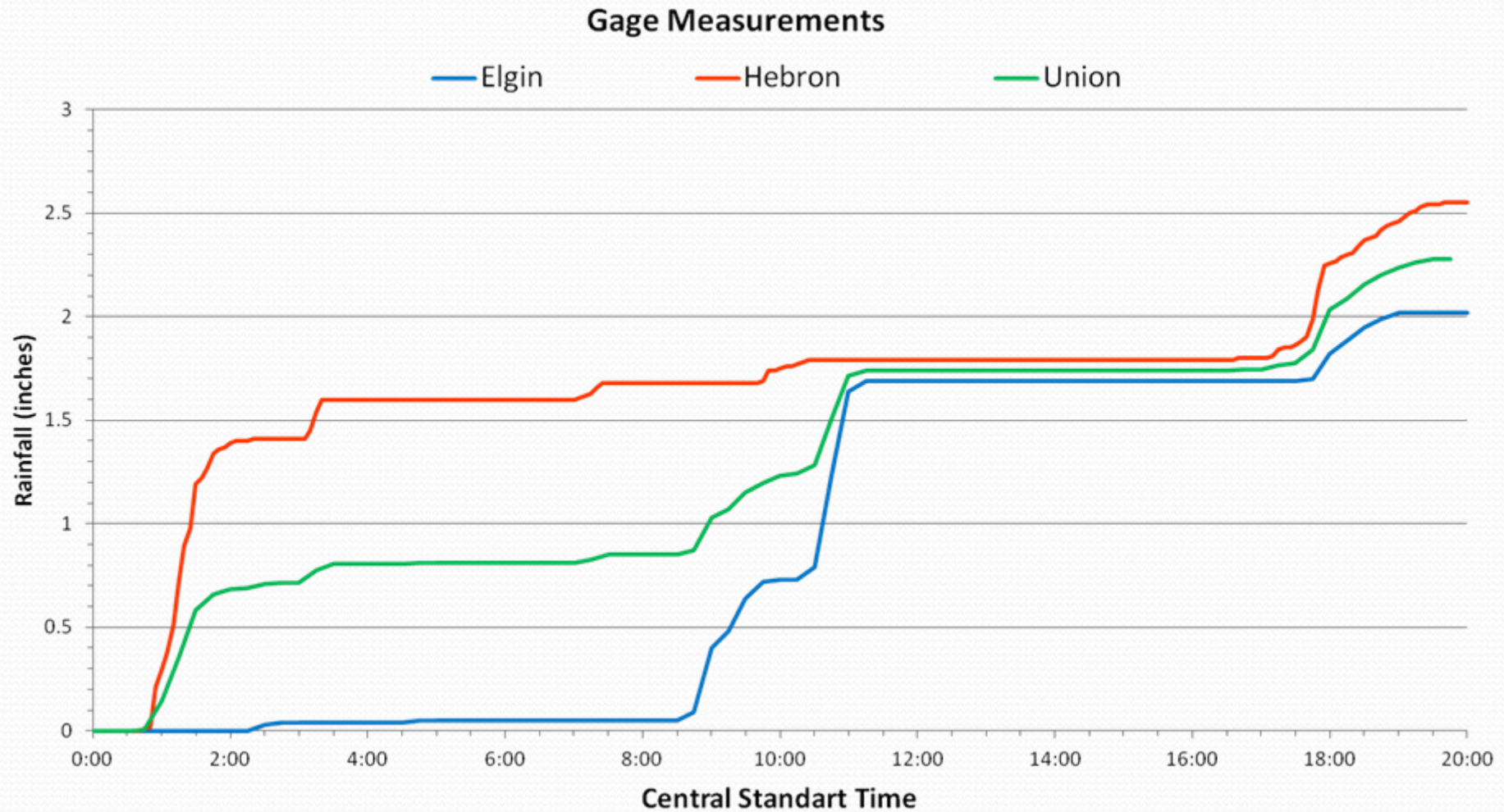
17.6 mi

17.3 mi

# Gages – 6/19/2009



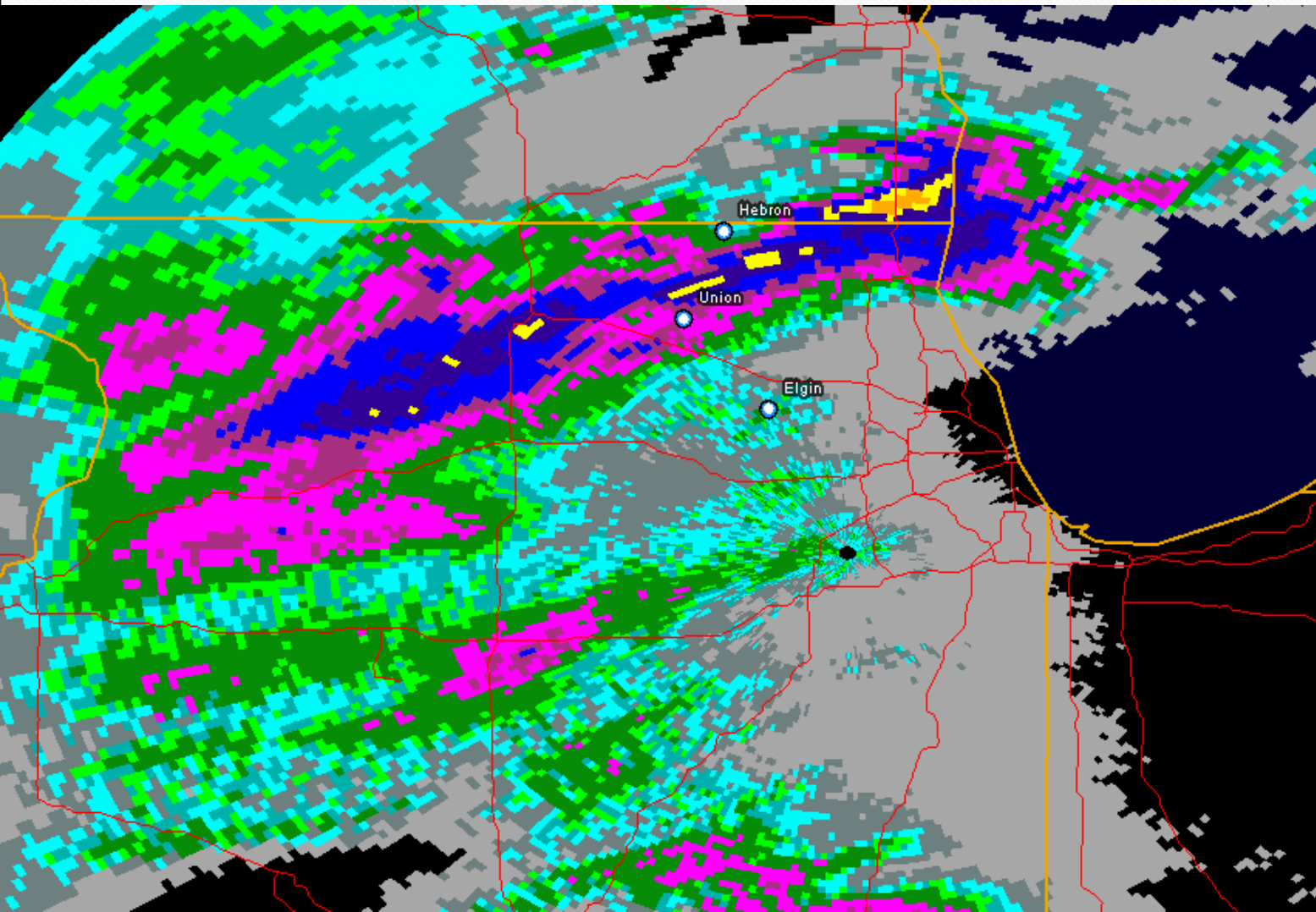
# IDSMS at Site – 6/19/2009





# Next Generation Radar - NEXRAD

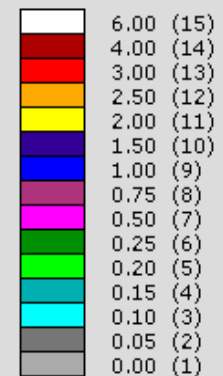
*Its better than your 3G smart phone!*



NEXRAD LEVEL-III  
ONE HOUR PRECIP  
KLOT - CHICAGO, IL  
06/20/2009 00:00:04 GMT  
LAT: 41/36/14 N  
LON: 88/05/05 W  
ELEV: 760 FT  
MODE/VCP: A / 11

MAX: 2.80 IN  
END: 06/20/2009 00:00

Legend: IN (Category)



# Radar Overview

$$\text{Rainfall rate(mm/hr)} = [10^{(\text{dBz}/10)}/200]^{0.625}$$

- Benefits

- Spatial distribution of rainfall over watershed

- Limitations

- Assumes a standard condition (drop size)
- Elevated beam not sampled at ground elevation
- Doesn't directly measure rain
  - can detect hail, dust, birds, wind farms, buildings, etc
- Not a continuous measurement (snapshot every 4-6 minutes)

# Getting Nexrad Data

The screenshot shows a web browser window displaying the NCDC NEXRAD Data Inventory Search page. The browser's address bar shows the URL <http://www.ncdc.noaa.gov/nexradinv/>. The page header includes the NOAA logo and the text "NOAA Satellite and Information Service" and "National Climatic Data Center". Below the header, there is a navigation menu with links for "DOC > NOAA > NESDIS > NCDC" and a search field. The main content area is titled "NCDC NEXRAD Data Inventory Search" and features a map of the United States with numerous blue dots representing "National Doppler Radar Sites". The map includes labels for Alaska, Hawaii, South Korea, and Puerto Rico. The browser's status bar at the bottom shows "Internet" and a zoom level of "100%".

<http://www.ncdc.noaa.gov/nexradinv>

# NEXRAD Data

KLOT - CHICAGO, IL

Microsoft Internet Explorer window showing the NEXRAD Data Inventory Search page for KLOT - CHICAGO, IL.

NOAA Satellite and Information Service  
National Environmental Satellite, Data, and Information Service (NESDIS)

National Climatic Data Center  
U.S. Department of Commerce

DOC > NOAA > NESDIS > NCDC

Search Field:  Search NCDC

[Radar Resources](#) / [Radar Data](#) / [Mass Storage \(HAS\)](#) / [FAQ](#) / [Choose Radar Map](#)

## NCDC NEXRAD Data Inventory Search

**KLOT - CHICAGO, IL**  
[Metadata](#) / [Coverage Map](#)

**Period of Record:**

Level-II: 04/13/1995 to 08/11/2010  
Level-III: 08/16/1993 to 08/10/2010

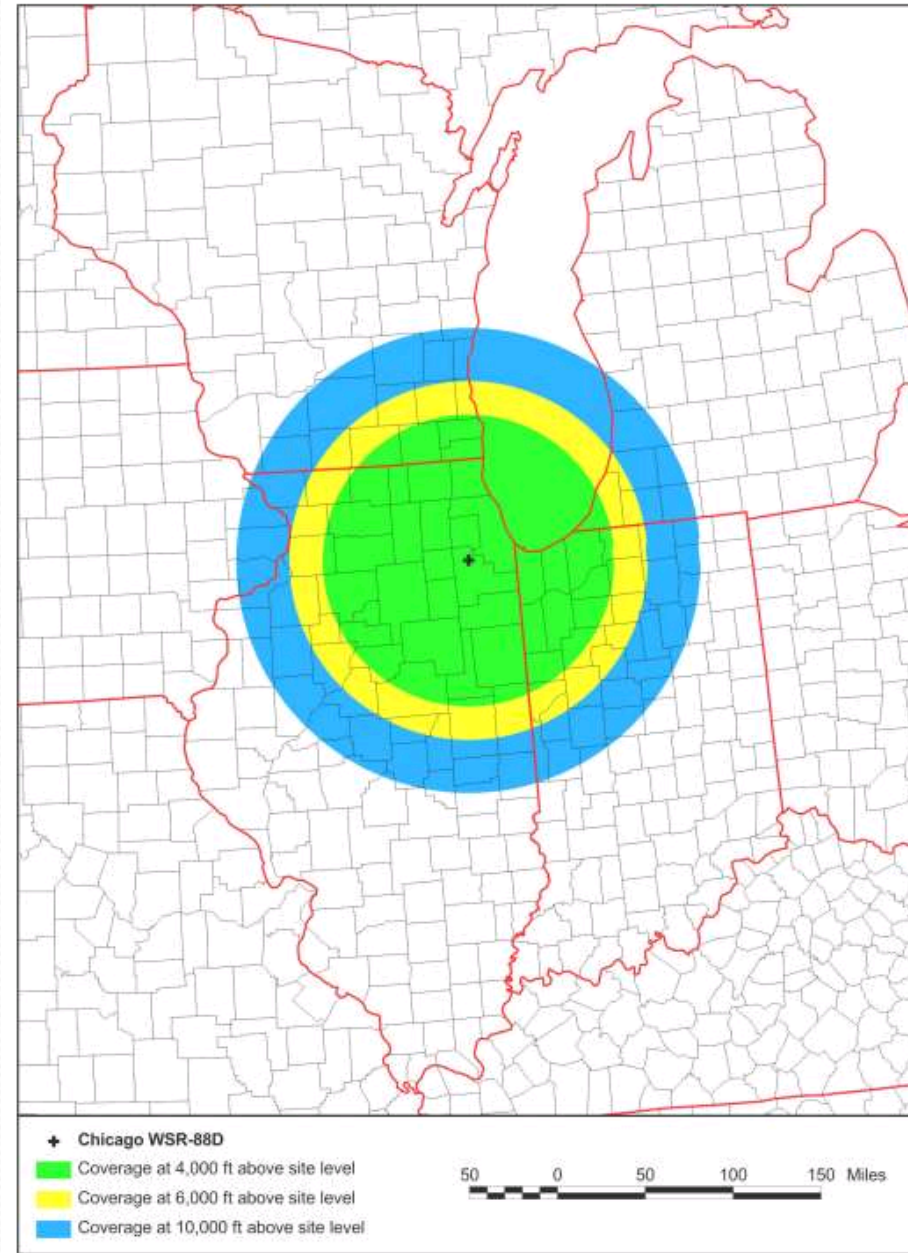

**Examine Inventory:**

Choose Date:  MM  DD  YYYY [calendar](#) (GMT)

- L3 [N3S] - STORM RELATIVE VELOCITY (16 LEVEL / 230 KM) (~ 3.4 DEG)
- L3 [NSP] - SHORT RANGE SPECTRUM WIDTH (60 KM)
- L3 [NSW] - LONG RANGE SPECTRUM WIDTH (230 KM)
- L3 [N1P] - ONE HOUR PRECIP (230 KM)**
- L3 [N3P] - THREE HOUR PRECIP (230 KM)
- L3 [NTP] - STORM TOTAL PRECIP (230 KM)
- L3 [DPA] - DIGITAL PRECIP ARRAY (230 KM)
- L3 [NVW] - VAD WIND PROFILE

Create Graph

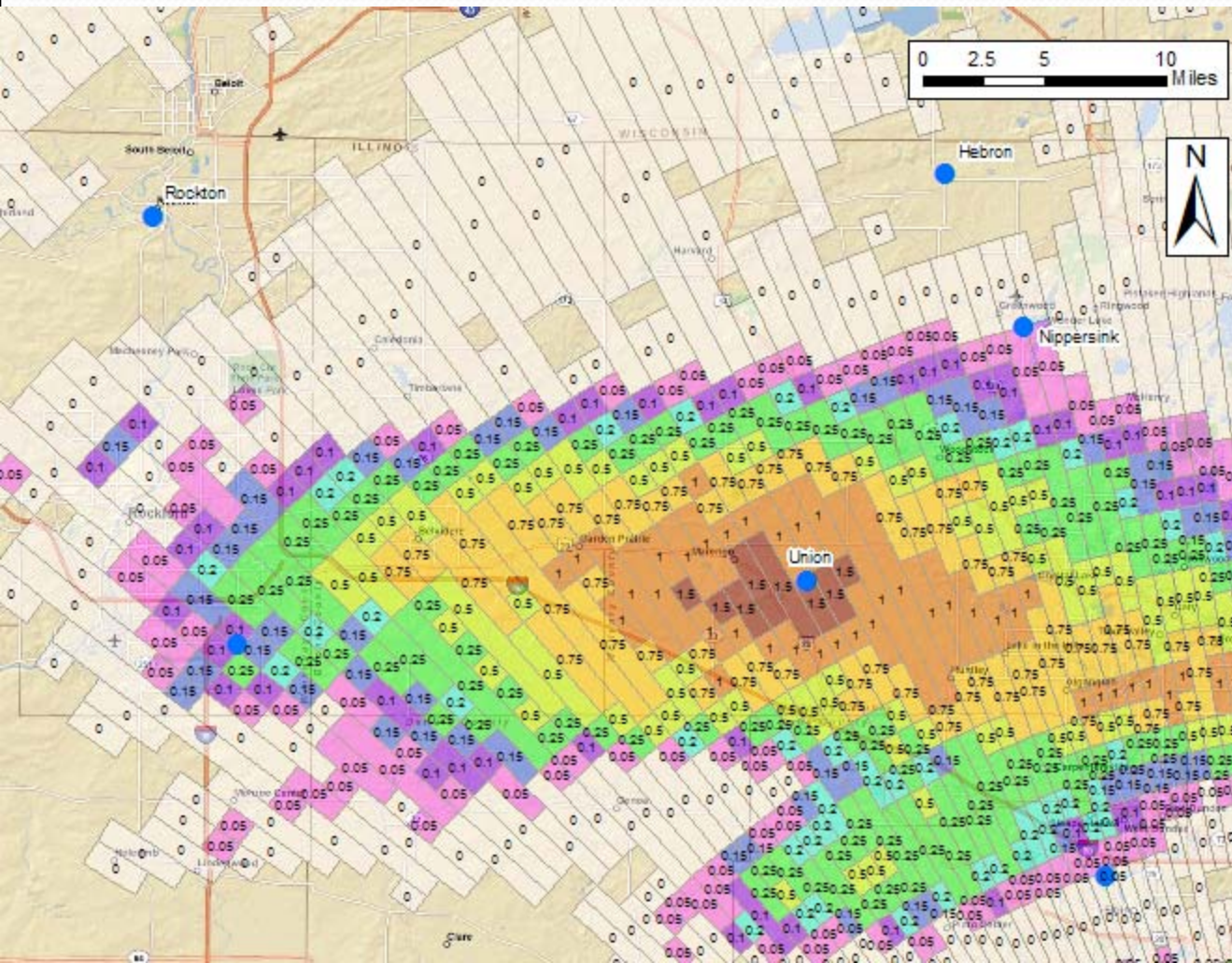
Hold 'Shift' or 'Control' to select multiple Level-III Products  
(Note: JavaScript must be enabled)



# NEXRAD Data

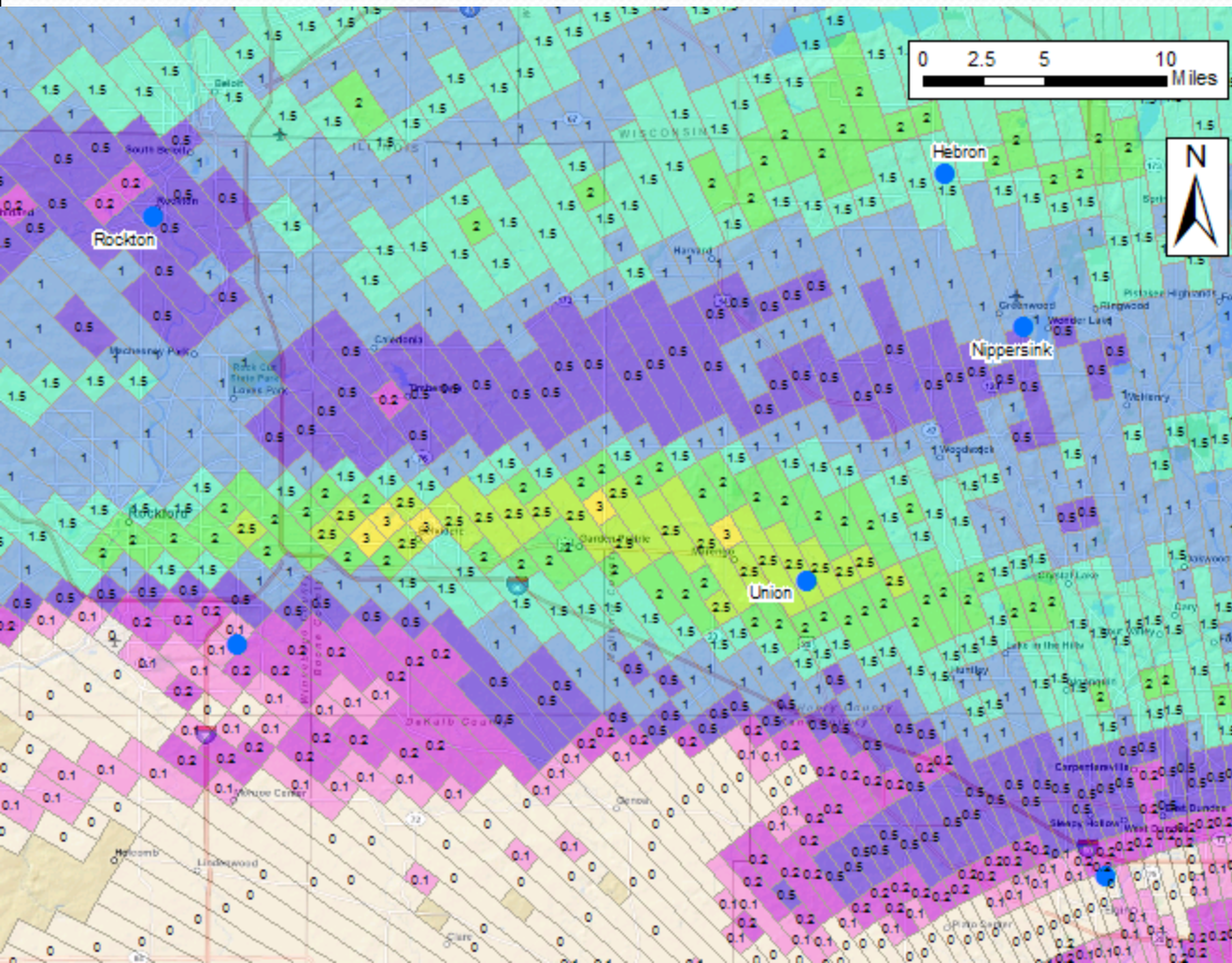
- Reflectivity Data
  - Short Range (230km) or Long Range (460km)
  - Base (0.5, 0.9 1.5, 1.8, 2.4, 3.4 Deg) or Composite
  - 16 or 256 Level
- Wind Data
  - Base Velocity (0.5, 0.9 1.5, 2.4, 3.4 Deg) (16 or 256 Level)
- Rainfall Data
  - 1 hour Intensity – Short Range, 16 Level
  - 3 hour Intensity – Short Range, 16 Level
  - Storm Total – Short Range, 16 Level
  - Digital Precipitation Array (1hr Intensities) - Short Range, 256 Level
- Other (Hail, Storm Path, Storm Velocity etc.)

# N1P – 1 hour intensities



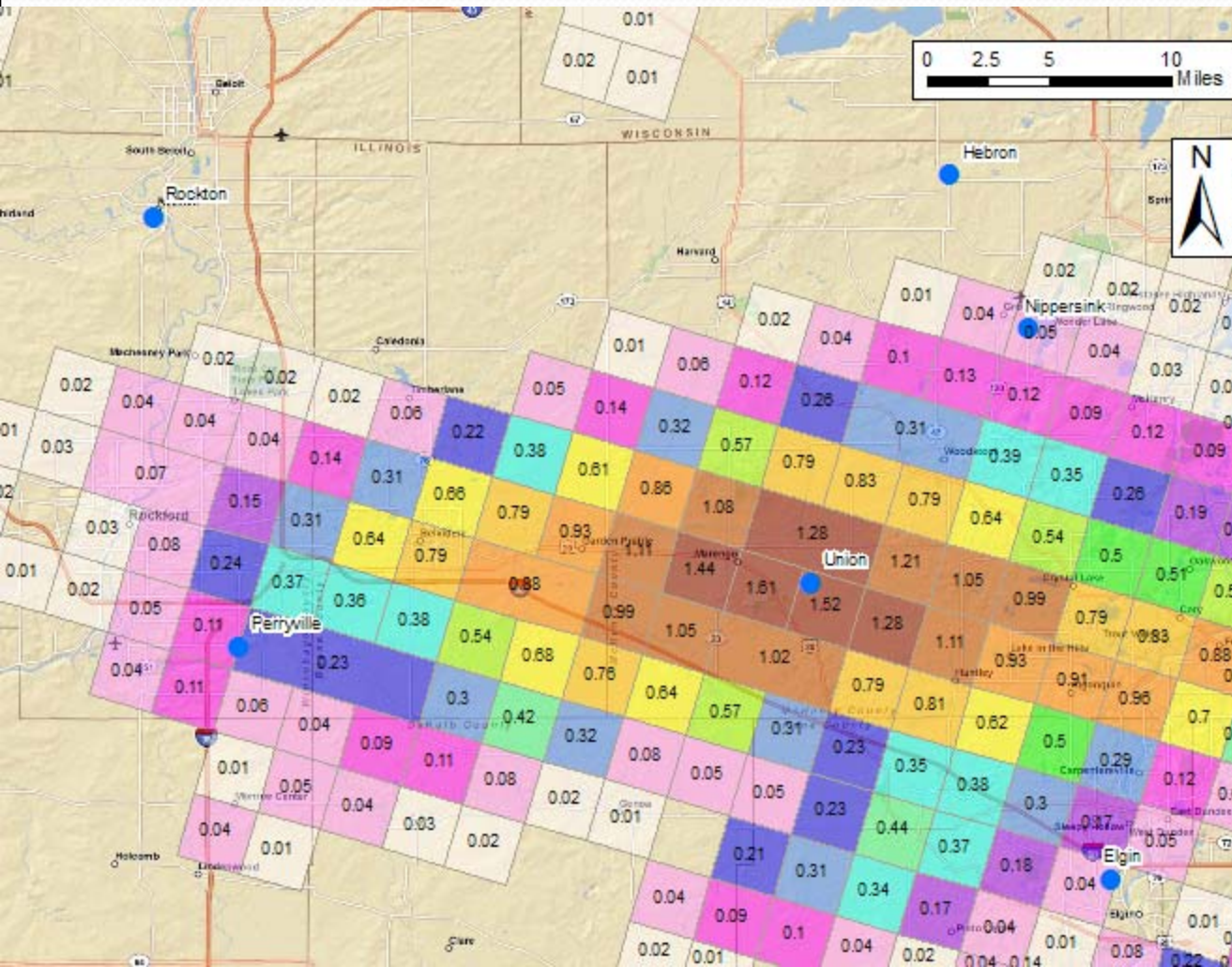
- 16 values
- $1.1\text{nm} \times 1^\circ$
- Must calculate hyetograph

# NPT – Storm Totals



- 16 values
- $1.1\text{nm} \times 1^\circ$
- Stair step hyetograph
- Resets after 1 hour of no rainfall

# DPA – 1 hour intensities



- 256 Values
- 2.6m x 2.6m
- Must calculate hyetograph
- Developed for use with Hydrologic Modeling



# Getting the Data

NOAA NEXRAD Data Inventory Search (Order Historical NEXRAD Weather Radar Data) - Microsoft Internet Explorer

http://www.ncdc.noaa.gov/nexradinv/disp

NOAA Satellite and Information Service  
National Environmental Satellite, Data, and Information Service (NESDIS)  
U.S. Department of Commerce

DOC > NOAA > NESDIS > NCDC

Search Field: Search NCDC

[Radar Resources](#) / [Radar Data](#) / [Mass Storage \(HAS\)](#) / [FAQ](#) / [Choose Date](#) / [Product](#)

## NCDC NEXRAD Data Inventory

**KLOT - CHICAGO, IL**  
[Metadata](#) / [Coverage Map](#)

**Period of Record:**  
Level-III: 08/16/1993 to 08/10/2010

[06 / 18 / 2009](#)      [06 / 19 / 2009](#)      [06 / 20 / 2009](#)

### LVL3 - ONE HOUR PRECIP (230 KM)

— Clear Air Mode — Precip Mode — Maintenance Mode — Unknown Mode

Enter Email Address:  [Why?](#)

Start Time:  End Time:

C:\Nexrad\_NP1

File Edit View Favorites Tools Help

Back Forward Stop Search Folders

Address  Go

Folders	Name	Date Modified	Size	Type
GIS	KLOT_SDUS33_N1PLOT_200906190003	3/17/2010 11:48 AM	9 KB	File
HEC	KLOT_SDUS33_N1PLOT_200906190012	3/17/2010 11:48 AM	9 KB	File
HEC2	KLOT_SDUS33_N1PLOT_200906190022	3/17/2010 11:48 AM	9 KB	File
HECEXE	KLOT_SDUS33_N1PLOT_200906190032	3/17/2010 11:48 AM	9 KB	File
hmsproj	KLOT_SDUS33_N1PLOT_200906190041	3/17/2010 11:48 AM	9 KB	File
HY8	KLOT_SDUS33_N1PLOT_200906190051	3/17/2010 11:48 AM	9 KB	File
HYCHL	KLOT_SDUS33_N1PLOT_200906190101	3/17/2010 11:48 AM	9 KB	File
HYDRA	KLOT_SDUS33_N1PLOT_200906190110	3/17/2010 11:48 AM	9 KB	File
HYDRAIN	KLOT_SDUS33_N1PLOT_200906190120	3/17/2010 11:48 AM	9 KB	File
HYDRO	KLOT_SDUS33_N1PLOT_200906190130	3/17/2010 11:48 AM	9 KB	File
HYEQT	KLOT_SDUS33_N1PLOT_200906190139	3/17/2010 11:48 AM	9 KB	File
InstallAnywhere	KLOT_SDUS33_N1PLOT_200906190149	3/17/2010 11:48 AM	9 KB	File
installLogs	KLOT_SDUS33_N1PLOT_200906190154	3/17/2010 11:48 AM	9 KB	File
Jonesoft	KLOT_SDUS33_N1PLOT_200906190203	3/17/2010 11:48 AM	9 KB	File
Land Projects 3	KLOT_SDUS33_N1PLOT_200906190208	3/17/2010 11:48 AM	9 KB	File
mgafold	KLOT_SDUS33_N1PLOT_200906190217	3/17/2010 11:48 AM	9 KB	File
MSCache	KLOT_SDUS33_N1PLOT_200906190227	3/17/2010 11:48 AM	9 KB	File
My Documents	KLOT_SDUS33_N1PLOT_200906190237	3/17/2010 11:48 AM	9 KB	File
My Downloads	KLOT_SDUS33_N1PLOT_200906190246	3/17/2010 11:48 AM	9 KB	File
Nexrad_NP1	KLOT_SDUS33_N1PLOT_200906190256	3/17/2010 11:48 AM	9 KB	File
Nwclient491	KLOT_SDUS33_N1PLOT_200906190306	3/17/2010 11:48 AM	9 KB	File
pdf995	KLOT_SDUS33_N1PLOT_200906190315	3/17/2010 11:48 AM	10 KB	File
Perl	KLOT_SDUS33_N1PLOT_200906190321	3/17/2010 11:48 AM	10 KB	File
perlscrips	KLOT_SDUS33_N1PLOT_200906190327	3/17/2010 11:48 AM	10 KB	File
plotwork	KLOT_SDUS33_N1PLOT_200906190333	3/17/2010 11:48 AM	10 KB	File
Program Files	KLOT_SDUS33_N1PLOT_200906190338	3/17/2010 11:48 AM	11 KB	File
Prohec2	KLOT_SDUS33_N1PLOT_200906190345	3/17/2010 11:48 AM	11 KB	File
Python21	KLOT_SDUS33_N1PLOT_200906190351	3/17/2010 11:48 AM	11 KB	File
Python24	KLOT_SDUS33_N1PLOT_200906190355	3/17/2010 11:48 AM	11 KB	File
Python25	KLOT_SDUS33_N1PLOT_200906190359	3/17/2010 11:48 AM	11 KB	File
quarantine	KLOT_SDUS33_N1PLOT_200906190404	3/17/2010 11:48 AM	11 KB	File
QuestSoftware	KLOT_SDUS33_N1PLOT_200906190408	3/17/2010 11:48 AM	11 KB	File
Volo View Express	KLOT_SDUS33_N1PLOT_200906190412	3/17/2010 11:48 AM	11 KB	File
win32app	KLOT_SDUS33_N1PLOT_200906190416	3/17/2010 11:48 AM	11 KB	File
WINDOWS	KLOT_SDUS33_N1PLOT_200906190421	3/17/2010 11:48 AM	11 KB	File
	KLOT_SDUS33_N1PLOT_200906190425	3/17/2010 11:48 AM	11 KB	File

396 objects (Disk free space: 3.01 GB) 4.66 MB My Computer

# http://www.ncdc.noaa.gov/oa/wct/

NOAA's Weather and Climate Toolkit (Viewer and Data Exporter) - Microsoft Internet Explorer provided by...

http://www.ncdc.noaa.gov/oa/wct/

NOAA Satellite and Information Service  
National Environmental Satellite, Data, and Information Service (NESDIS)

National Climatic Data Center  
U.S. Department of Commerce

DOC > NOAA > NESDIS > NCDC

Search Field:  Search NCDC

## NOAA's Weather and Climate Toolkit

### Introduction

NOAA's Weather and Climate Toolkit is an application that provides simple visualization and data export of weather and climatological data archived at NCDC. The Toolkit also provides access to weather/climate web services provided from NCDC and other organizations.

The Viewer provides tools for displaying custom data overlays, Web Map Services (WMS), animations and basic filters. The export of images and movies is provided in multiple formats. The Data Exporter allows for data export in both vector point/line/polygon and raster grid formats.

This toolkit is the successor to the [Java NEXRAD Tools](#)

Current data types supported:

- GOES Satellite AREA Files
- NEXRAD Radar Data (Level-II and Level-III)
- U.S. Drought Monitor Service (from the National Drought Mitigation Center (NDMC))
- Generic gridded NetCDF support (in BETA)
- OPeNDAP support for Gridded Datasets

Planned future data types:

- Station data access via NetCDF or REST Web Services
- NOAA/NCDC Severe Weather Data Inventory

[Download / Launch](#)

Quick Links  
Weather and Climate Toolkit Home  
Order NEXRAD Data  
NCDC Radar Resources  
NOAA Radar Operations Center  
NCDC's Storm Events Database

Toolkit  
Download/Installation  
Find Data  
Image Gallery  
Java Requirements  
Export Formats  
Batch Processing  
Credits  
API / Source Code

Documentation  
Tutorials  
FAQ  
Presentations  
NEXRAD Terms  
NEXRAD Level-II  
Documentation  
NEXRAD Level-III  
Documentation  
Level-III Product Codes

NOAA's Weather and Climate Toolkit (Viewer and Data Exporter) - Microsoft Internet Explorer provided by ...

http://www.ncdc.noaa.gov/oa/wct/install.

NOAA Satellite and Information Service  
National Environmental Satellite, Data, and Information Service (NESDIS)

National Climatic Data Center  
U.S. Department of Commerce

DOC > NOAA > NESDIS > NCDC

Search Field:  Search NCDC

## NOAA's Weather and Climate Toolkit

### Web Start Installation

Use the links below to launch the applications via Java Web Start.  
-- Check if you have a current version of Java installed --

The application will update automatically when a new version is available. The initial download is ~15 Megabytes, while most updates will be less than 1 Megabyte.

[Launch](#)      [Launch BETA](#)

Stable release (Version 2.5.3)  
Desktop shortcuts will be installed

BETA release (Version 3.1.4)  
Web Launch only  
Please use with caution  
Gridded Data, Google Earth, more...

### Stand-Alone Download

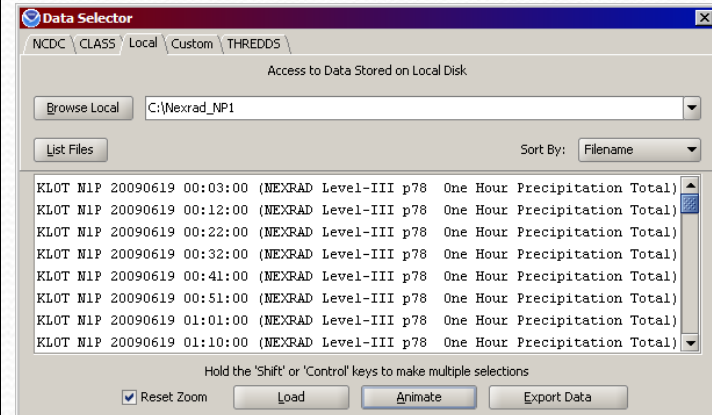
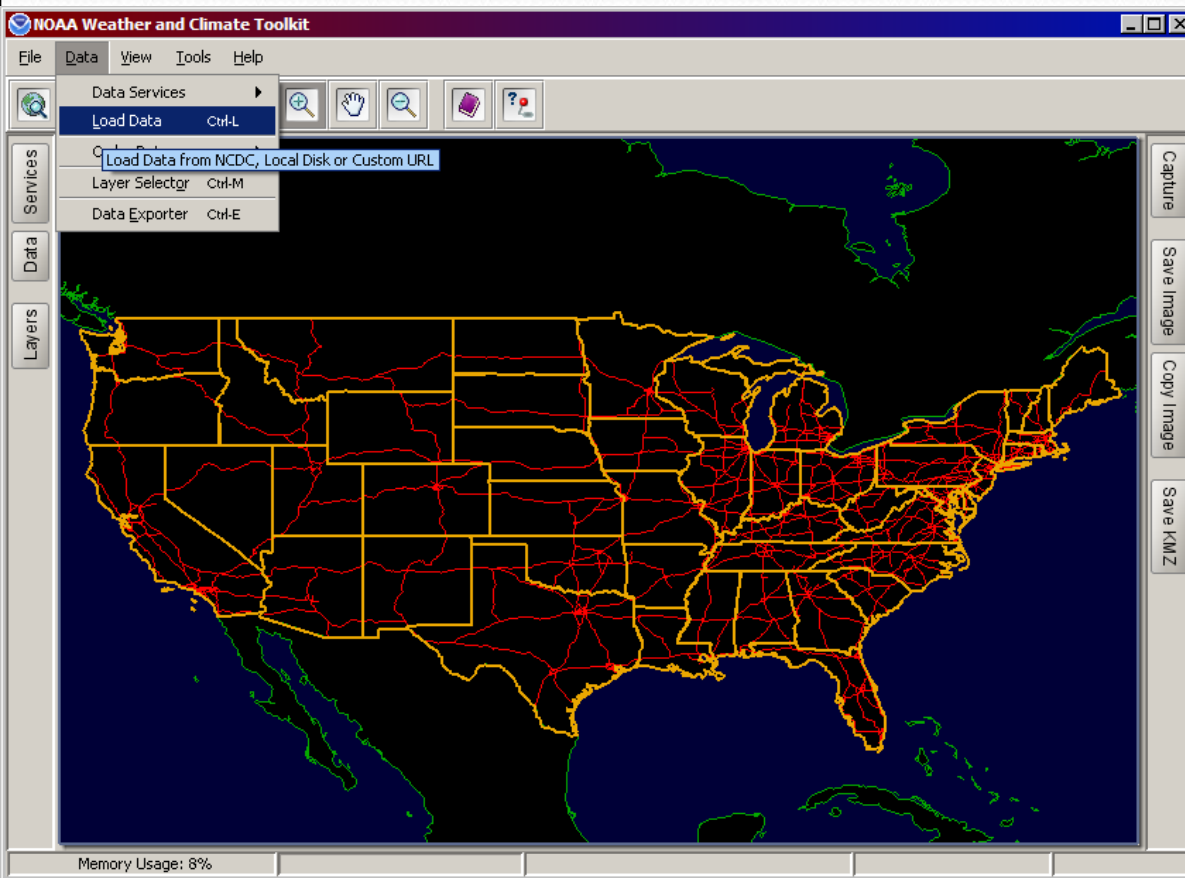
	<b>Windows</b>	STABLE (Version 2.5.3)   BETA (Version 3.1.4)
	<b>Mac OS/X</b>	STABLE (Version 2.5.3)   BETA (Version 3.1.4)
	<b>Unix/Linux</b>	STABLE (Version 2.5.3)   BETA (Version 3.1.4)

Quick Links  
Weather and Climate Toolkit Home  
Order NEXRAD Data  
NCDC Radar Resources  
NOAA Radar Operations Center  
NCDC's Storm Events Database

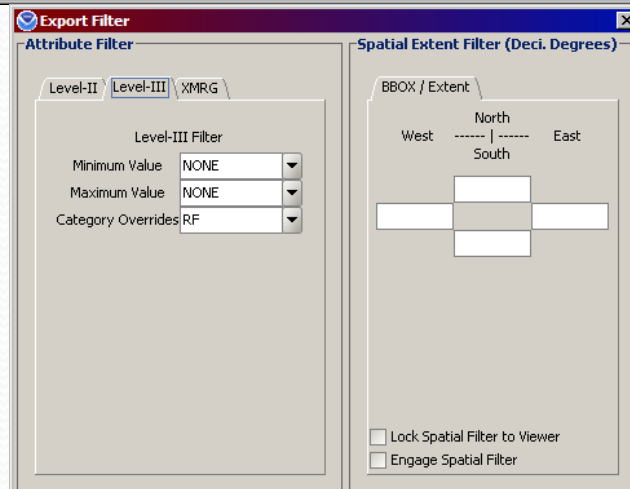
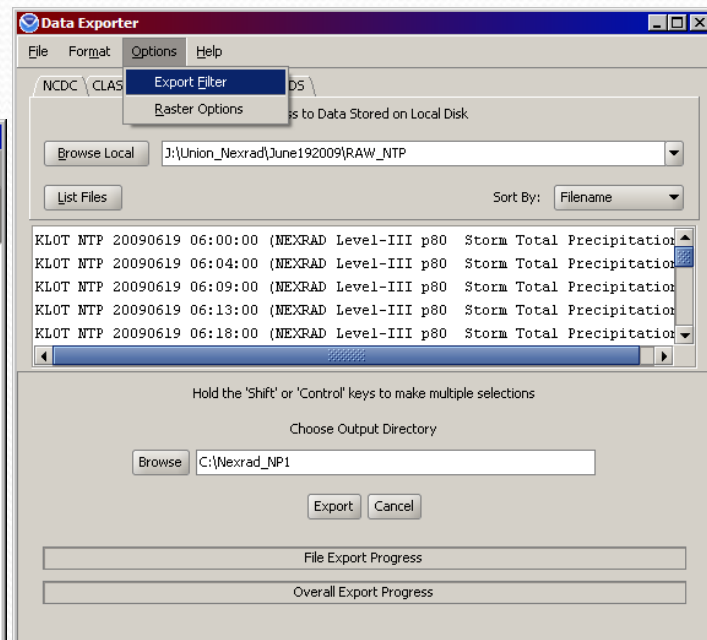
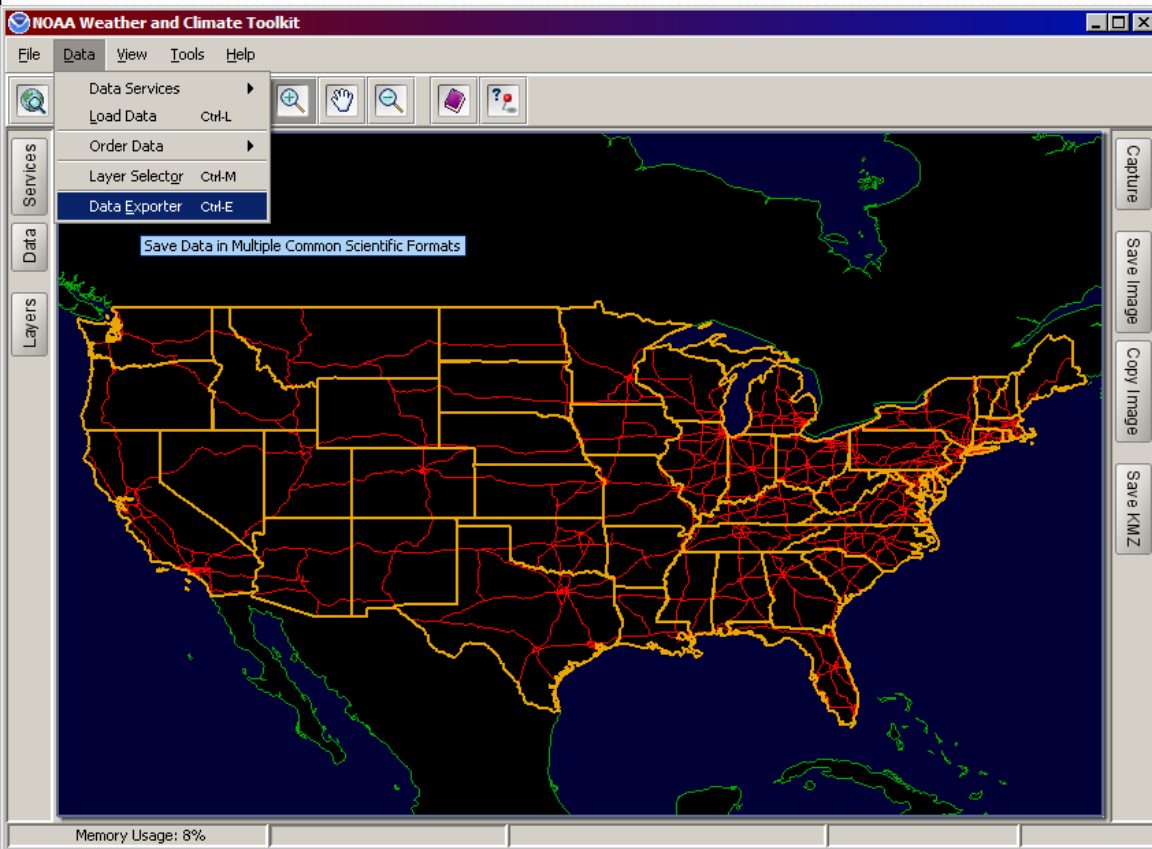
Toolkit  
Download/Installation  
Find Data  
Image Gallery  
Java Requirements  
Export Formats  
Batch Processing  
Credits  
API / Source Code

Documentation  
Tutorials  
FAQ  
Presentations  
NEXRAD Terms  
NEXRAD Level-II  
Documentation  
NEXRAD Level-III  
Documentation  
Level-III Product Codes

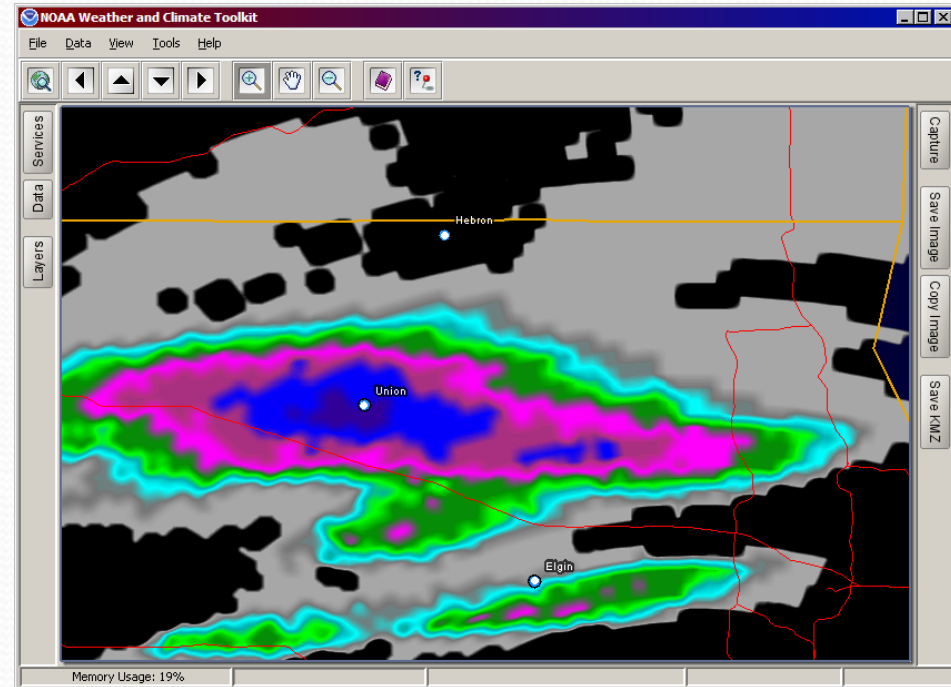
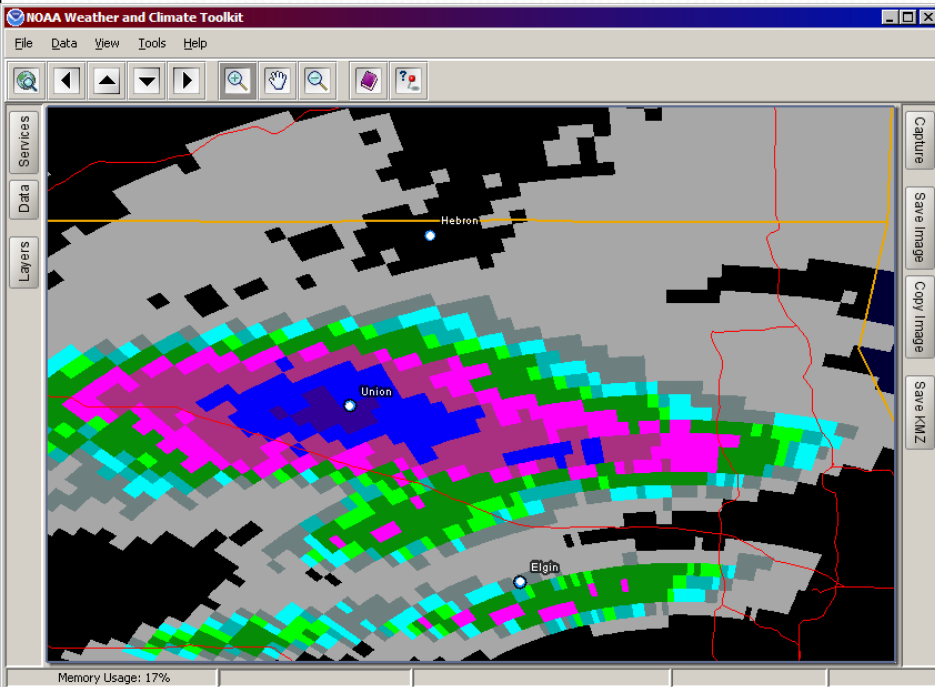
# Weather & Climate Toolkit - (WCT)



# WCT - Exporting Data



# WCT - Smoothing



**Layer Selector**

Data Layers | Overlay Selector | Background Maps (WMS)

Radar

<input checked="" type="checkbox"/> Visible	Transparency: 0 %	Smoothing: 0	Legend: Large
---	-------------------	--------------	---------------

Satellite

<input type="checkbox"/> Visible	Transparency: Default	Smoothing: 0	Legend: Medium
----------------------------------	-----------------------	--------------	----------------

Color Table: Default

Clear All Data

**Layer Selector**

Data Layers | Overlay Selector | Background Maps (WMS)

Radar

<input checked="" type="checkbox"/> Visible	Transparency: 0 %	Smoothing: 12	Legend: None
---	-------------------	---------------	--------------

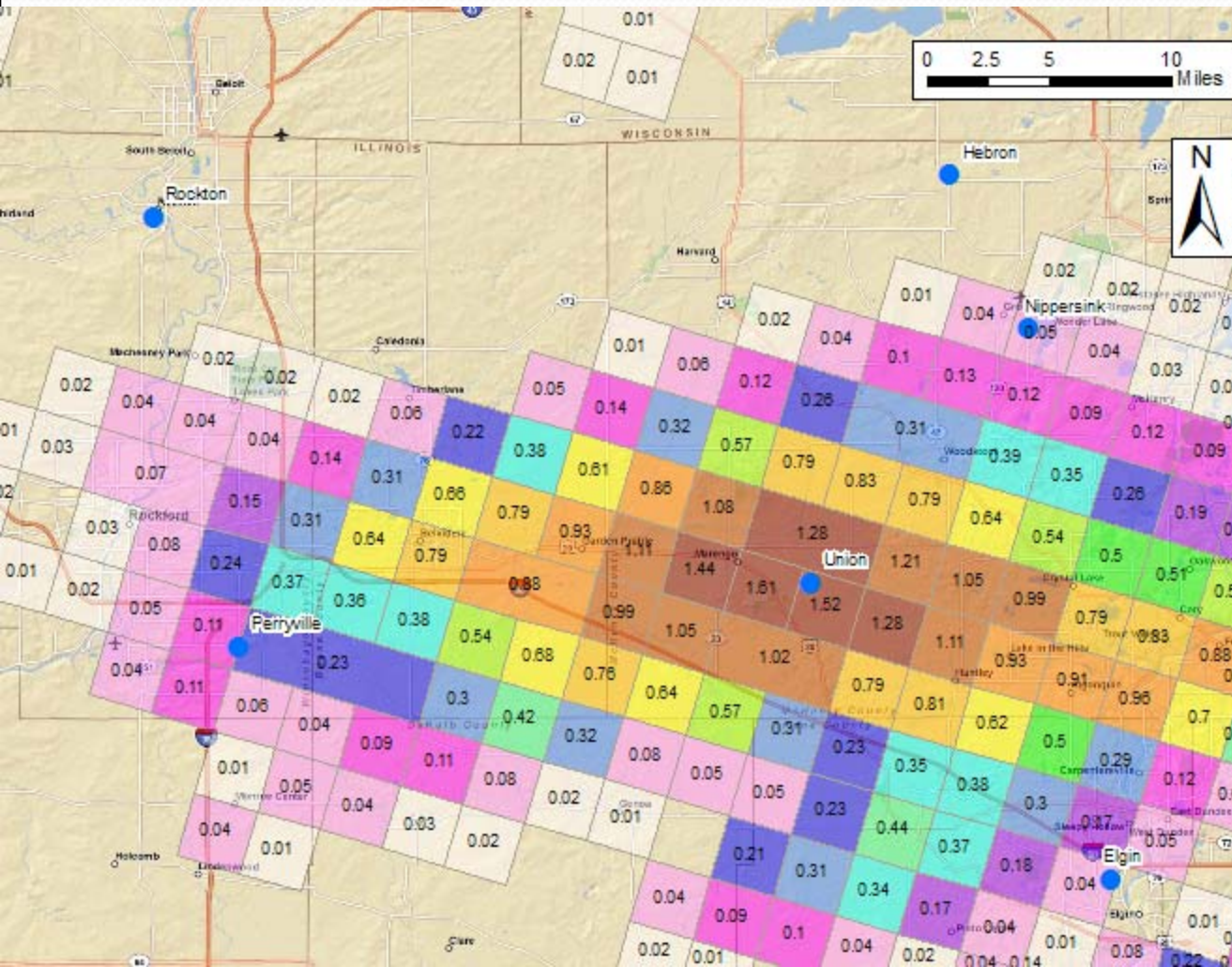
Satellite

<input type="checkbox"/> Visible	Transparency: Default	Smoothing: 0	Legend: Medium
----------------------------------	-----------------------	--------------	----------------

Color Table: Default

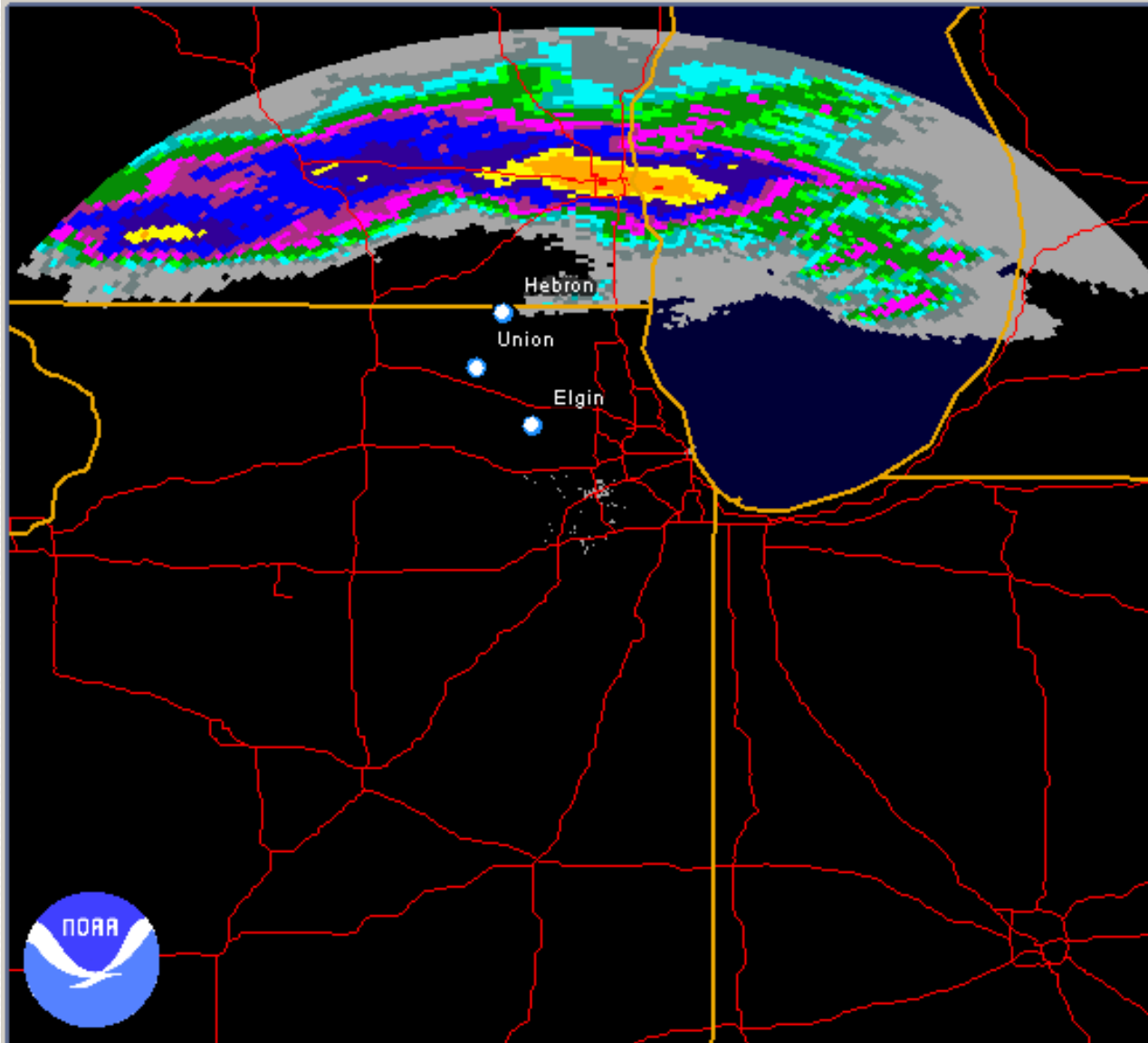
Clear All Data

# From Radar into Hyetograph



- Extract data from each time step
- Convert intensity into rainfall depth
- Construct hyetograph
- Adjust Time Zones

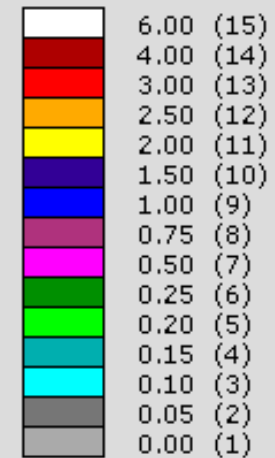
# Case Study Storm Event



NEXRAD LEVEL-III  
ONE HOUR PRECIP  
KLOT - CHICAGO, IL  
06/19/2009 06:00:13 GMT  
LAT: 41/36/14 N  
LON: 88/05/05 W  
ELEV: 760 FT  
MODE/VCP: A / 212

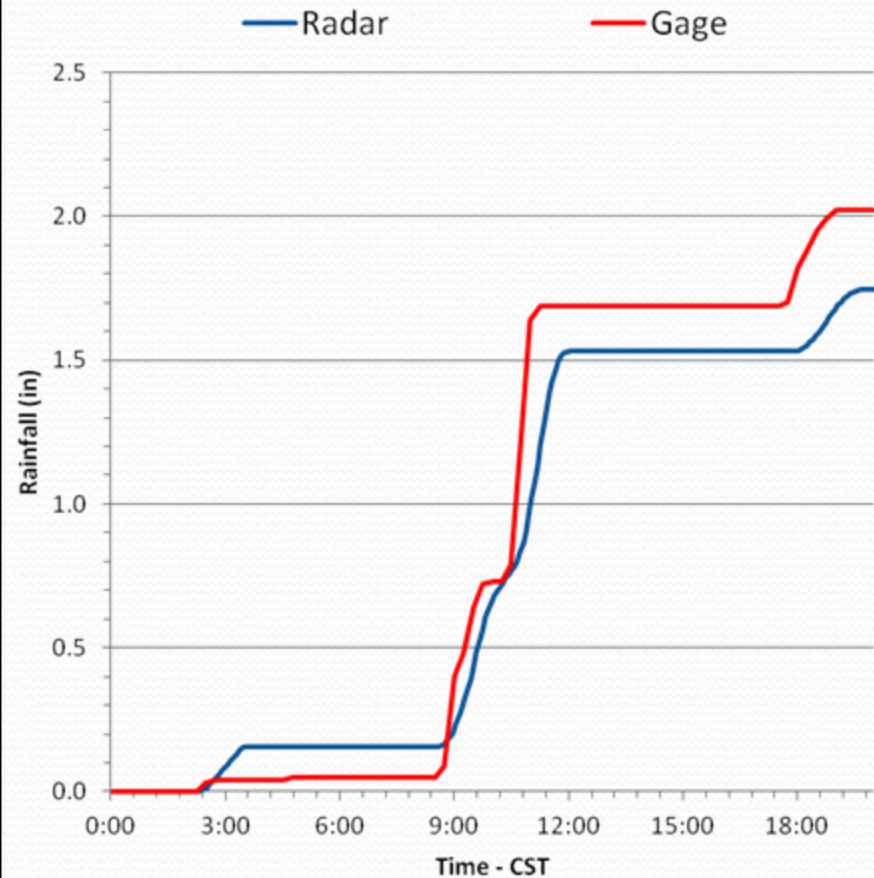
MAX: 3.10 IN  
END: 06/19/2009 06:00

Legend: IN (Category)

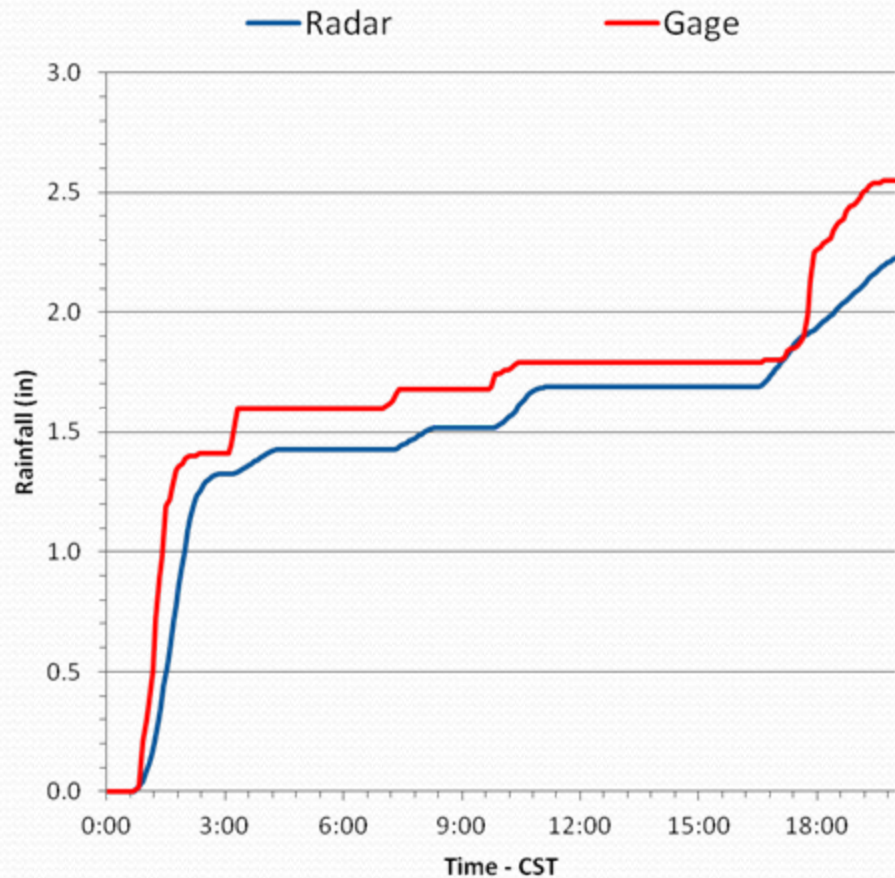


# Rain Gage vs. Radar

Elgin 6-19-09



Hebron 6-19-09





# Adjusting Radar

- Keeps depth accuracy at gage while allowing variation throughout watershed
- Adjust for differences in:
  - Magnitude
  - Timing
  - Location
- Variations for calibration
  - Many methods & combination of methods
  - No set standards

# Adjusting Radar for Magnitude

- 1 uniform multiplier for all cells
  - Averaged from multiple rain gages
- Each cell or basin has individual adjustment factor based on weighted distance to surrounding gages
  - Inverse Distance Squared Method

# Adjusting Radar for Timing

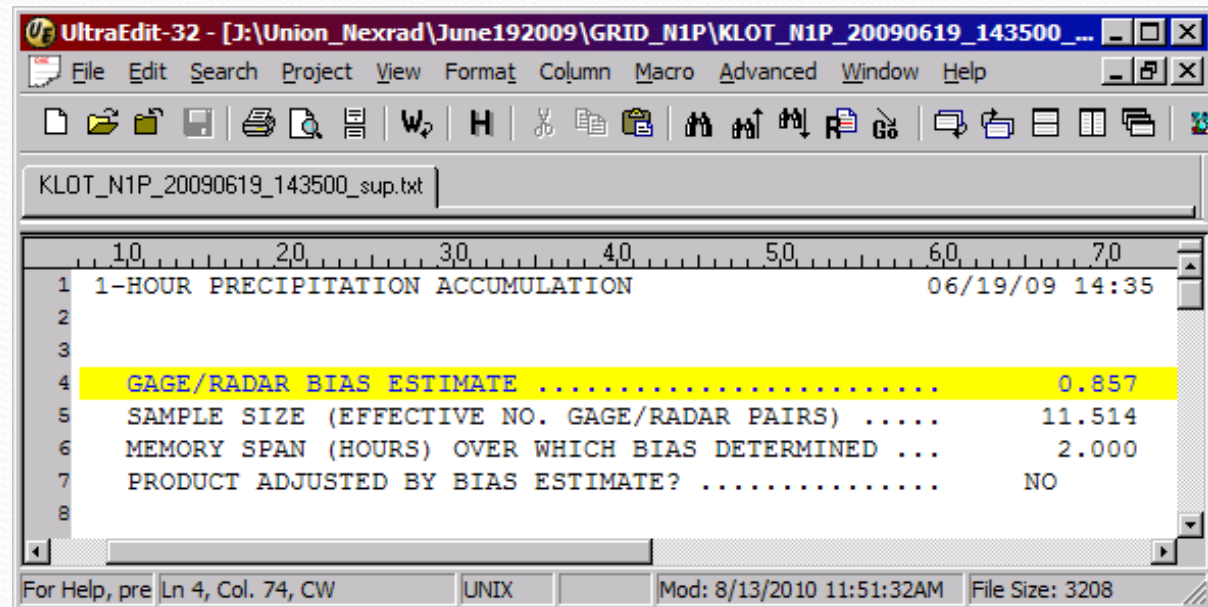
- Adjusts per storm event
  - Gage total / Radar total
- Adjusts for each time step
  - Gage (time = t) / Radar (time = t)
    - Gage or Radar may have no value when other does
- Adjusts over given duration
  - $$\frac{\text{Gage Total (time = t + x)} - \text{Gage Total (time = t - x)}}{\text{Radar Total (time = t + x)} - \text{Radar Total (time = t - x)}}$$
    - Factor changes per interval

# Adjusting Radar for Location

- Corrects for non-vertical rainfall
  - Cell values within given range from gage used to determine adjustment factor
  - Each cell value adjusted based on surrounding cell values

# Adjusting Radar - Bias

- 1 uniform multiplier for all pixels
- Averaged from multiple rain gages



The screenshot shows the UltraEdit-32 interface with a text file named 'KLOT\_N1P\_20090619\_143500\_sup.txt'. The file content displays the following data:

```
1 1-HOUR PRECIPITATION ACCUMULATION 06/19/09 14:35
2
3
4 GAGE/RADAR BIAS ESTIMATE ..... 0.857
5 SAMPLE SIZE (EFFECTIVE NO. GAGE/RADAR PAIRS) ..... 11.514
6 MEMORY SPAN (HOURS) OVER WHICH BIAS DETERMINED ... 2.000
7 PRODUCT ADJUSTED BY BIAS ESTIMATE? ..... NO
8
```

The status bar at the bottom indicates: For Help, pre Ln 4, Col. 74, CW | UNIX | Mod: 8/13/2010 11:51:32AM | File Size: 3208

# Adjusting Radar - Brandes (1975)

- Each cell value adjusted based on surrounding cell values
- Each cell calibrated based on distance to gages in network
- Calibration multiplier determined for each time step
- Cell value at gage location may not match gage data

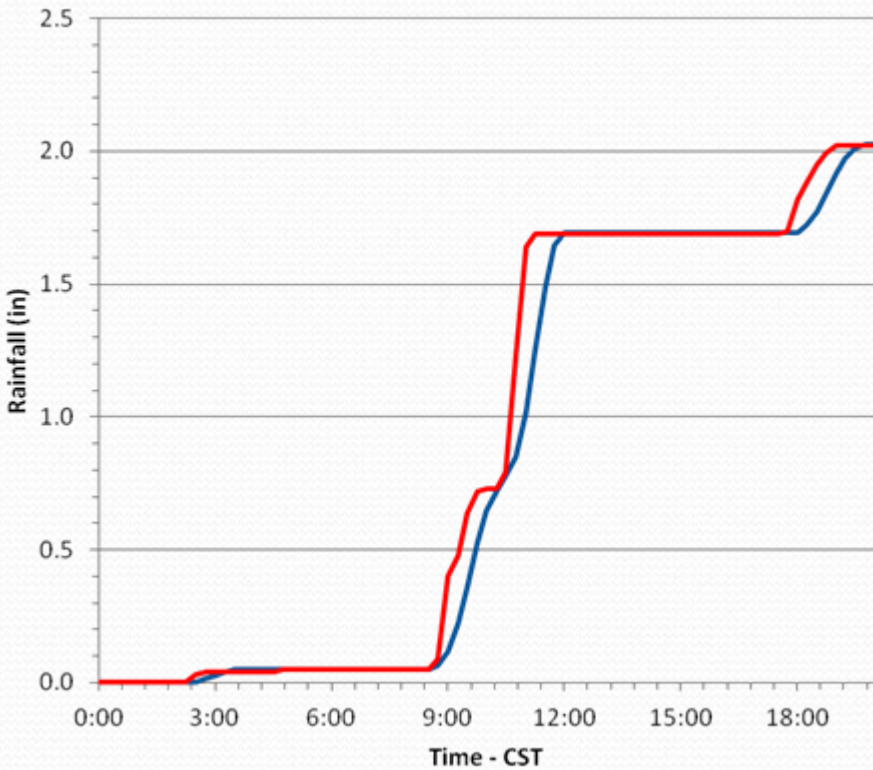
# Adjusting Radar for Union

- Time Adjustment
  - Radar adjusted per storm cell
- Magnitude Adjustment
  - Union Rainfall adjusted for weighted distance to gages
- No Spatial Adjustment

# Adjusted Radar Rainfall

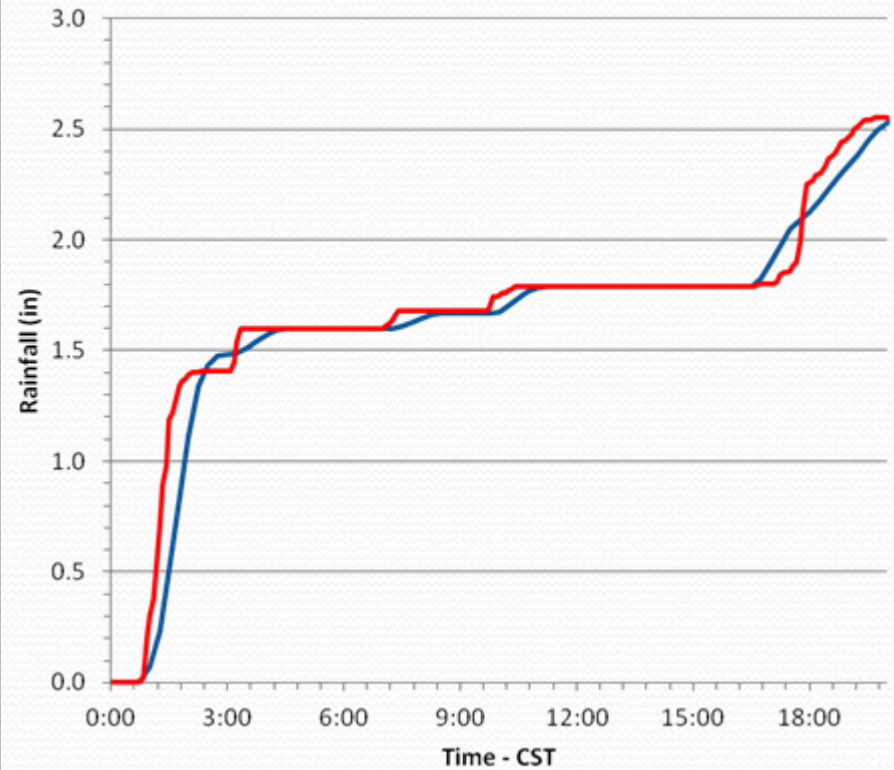
Elgin 6-19-09

Adjusted Radar Gage



Hebron 6-19-09

Adjusted Radar Gage

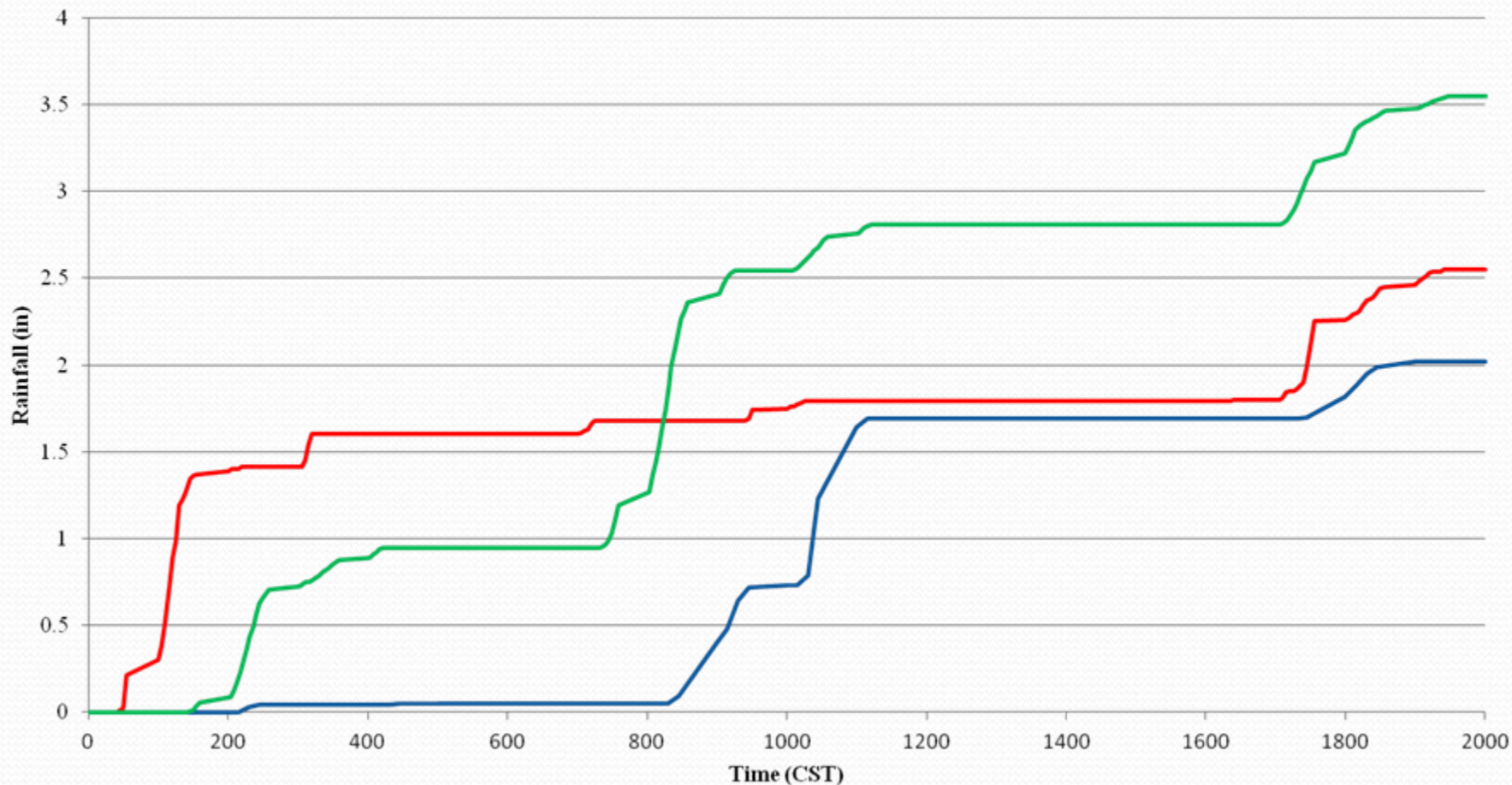




# Adjusted Site Radar Rainfall

## Hyetographs

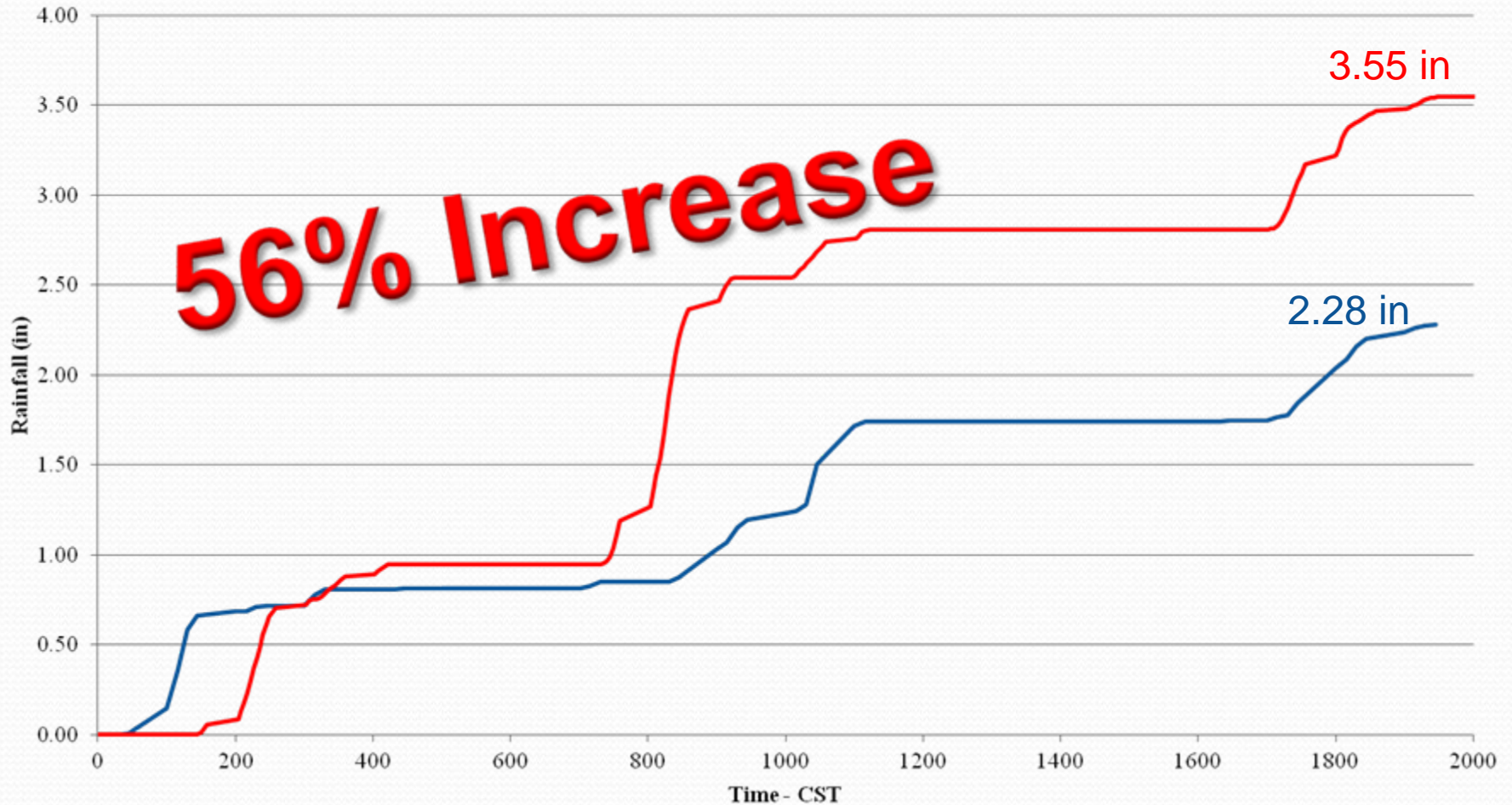
— Elgin      — Hebron      — Union



# Hyetograph Differences

Old vs. New

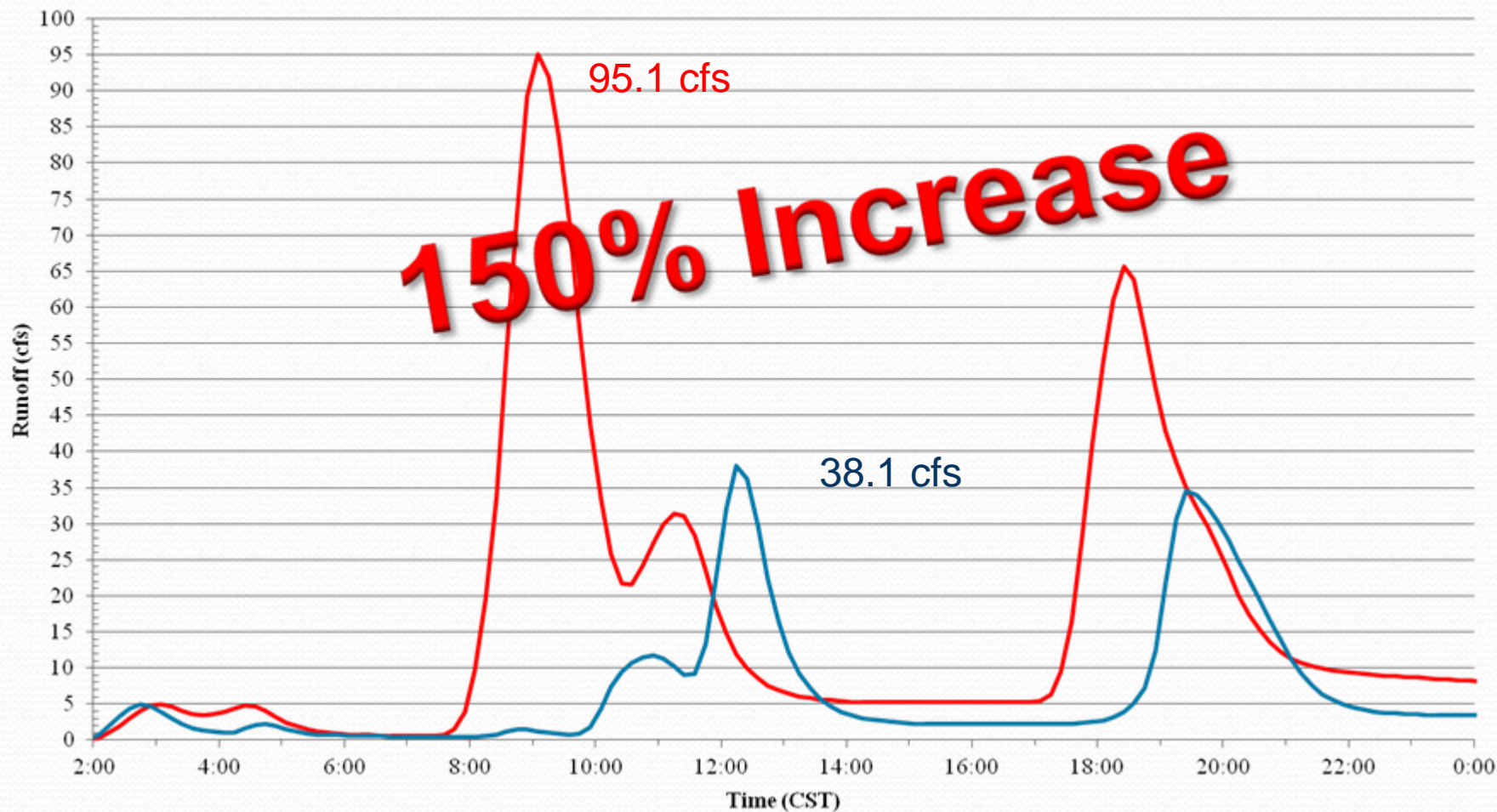
— Old Method — NEXRAD



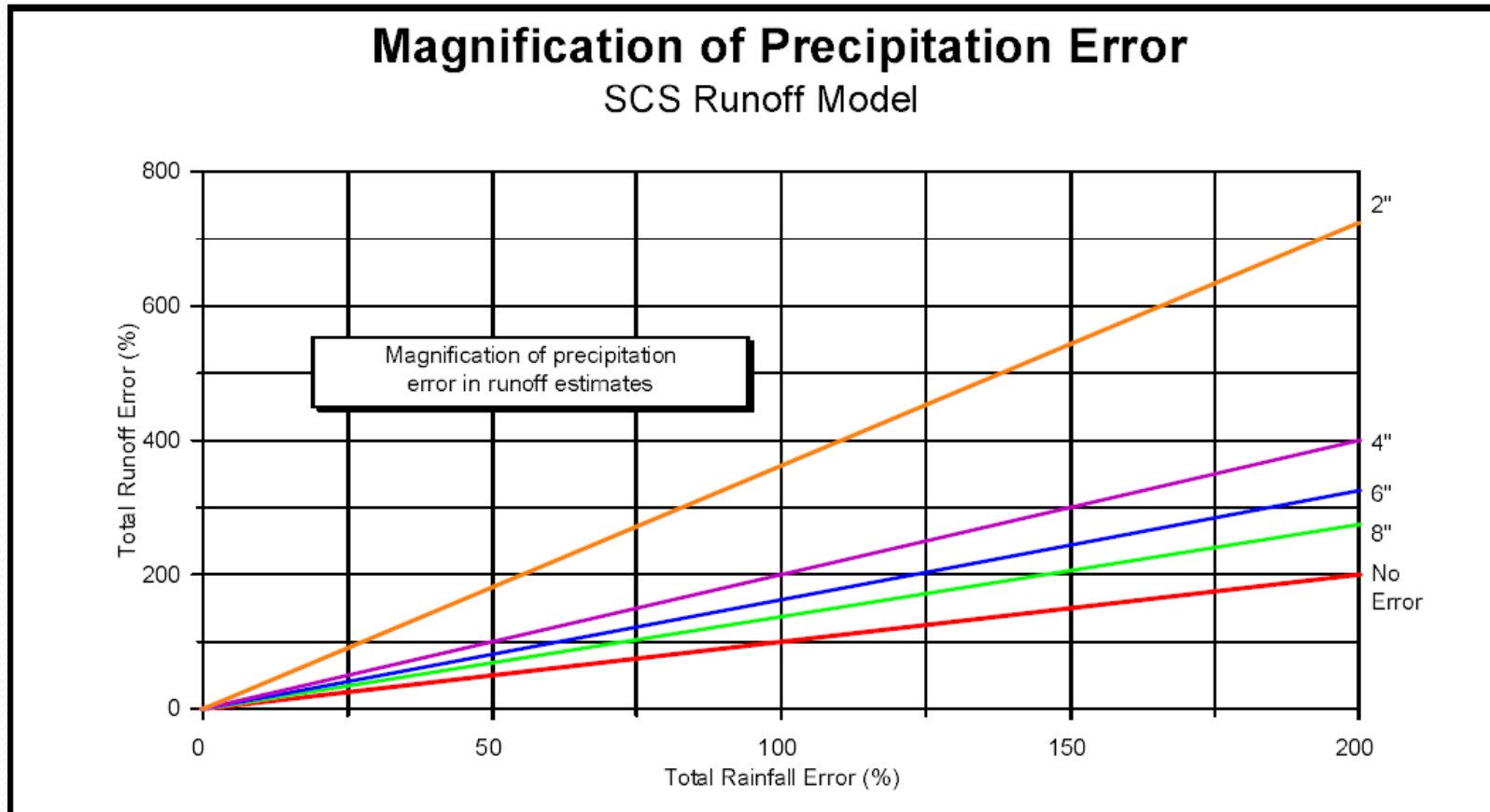
# Hydrograph Differences

## Hydrograph Comparison

— NEXRAD — Old Method



# Runoff Impacts



*Figure 7: Errors in rainfall estimates produce relatively greater errors in runoff estimates.*

Source: Curtis, D.C. and R. Burnash, 1996; Inadvertent Rain Gage Inconsistencies and Their Effect on Hydrologic Analysis. California-Nevada ALERT Users Group Conf., Ventura, CA, 4.

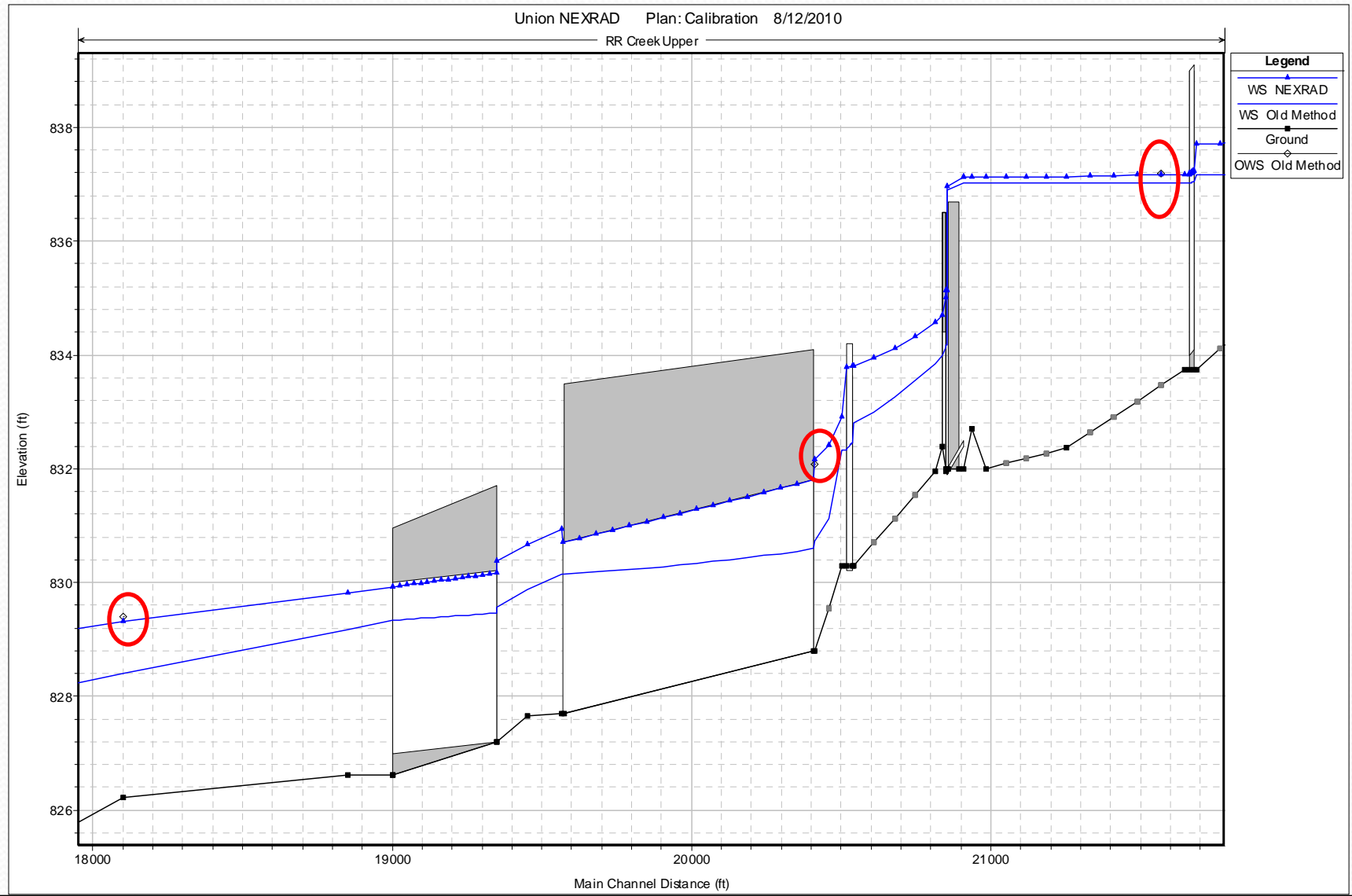
# Model Calibration

- Model at least two storms that vary in event size
  - 2 - 5 year event
  - 25 - 100+ year event
  - Normal flow
  - Low flow
  
- Calibration storm should reflect the purpose of project
  - Flood Control
  - Environmental Impacts
  - Dam Removal

# Ungaged Model Calibration

- Compare with high water elevations
  - Crest stage gages
  - Debris lines
  - Observations

# Profile Comparison 2



# Questions?

Wes Cattoor, P.E., CFM  
wes.cattoor@illinois.gov  
(217) 782-4847

