NEXRAD for Small Ungaged Watersheds

Wes Cattoor
IDNR – OWR
IAFSM Workshop
August 23, 2010

Example from Union, IL
in McHenry County

Overview

- Gage Calibration Overview
- Nexrad Overview
- Obtaining Nexrad Data
- Adjusting Nexrad Data
- Comparing Gage to Nexrad

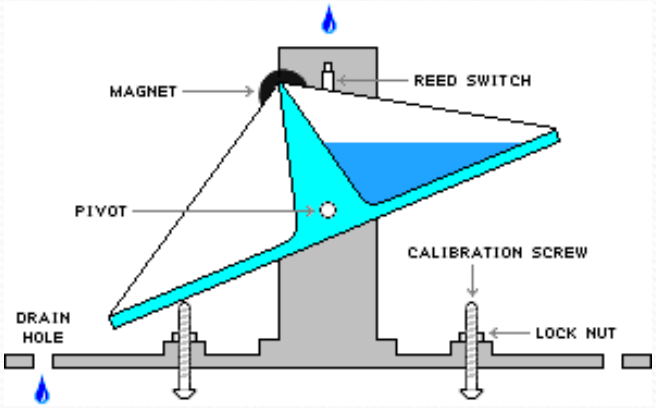
Example from Union, IL in McHenry County

Background of Union

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

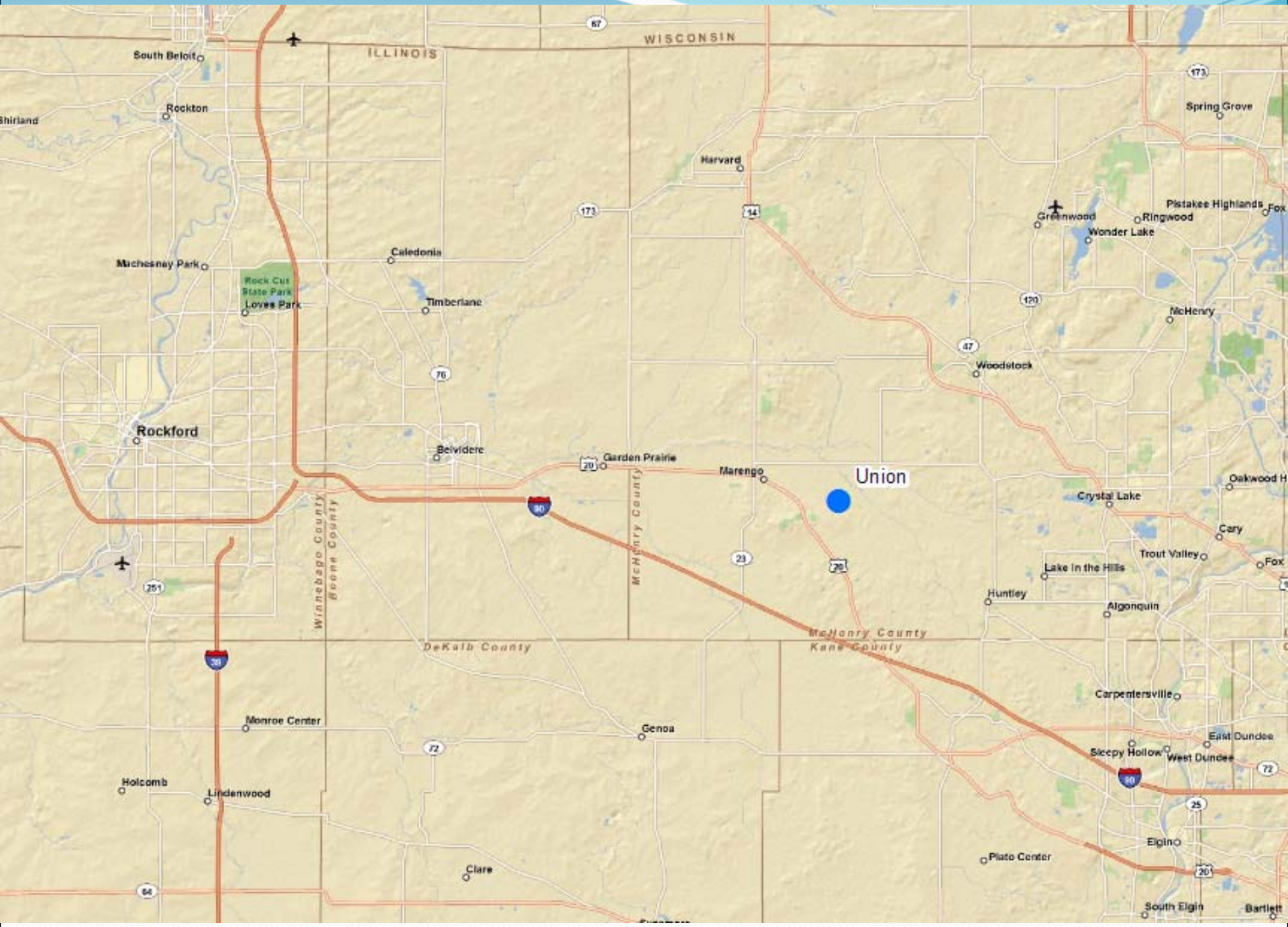
Gage Only Calibration

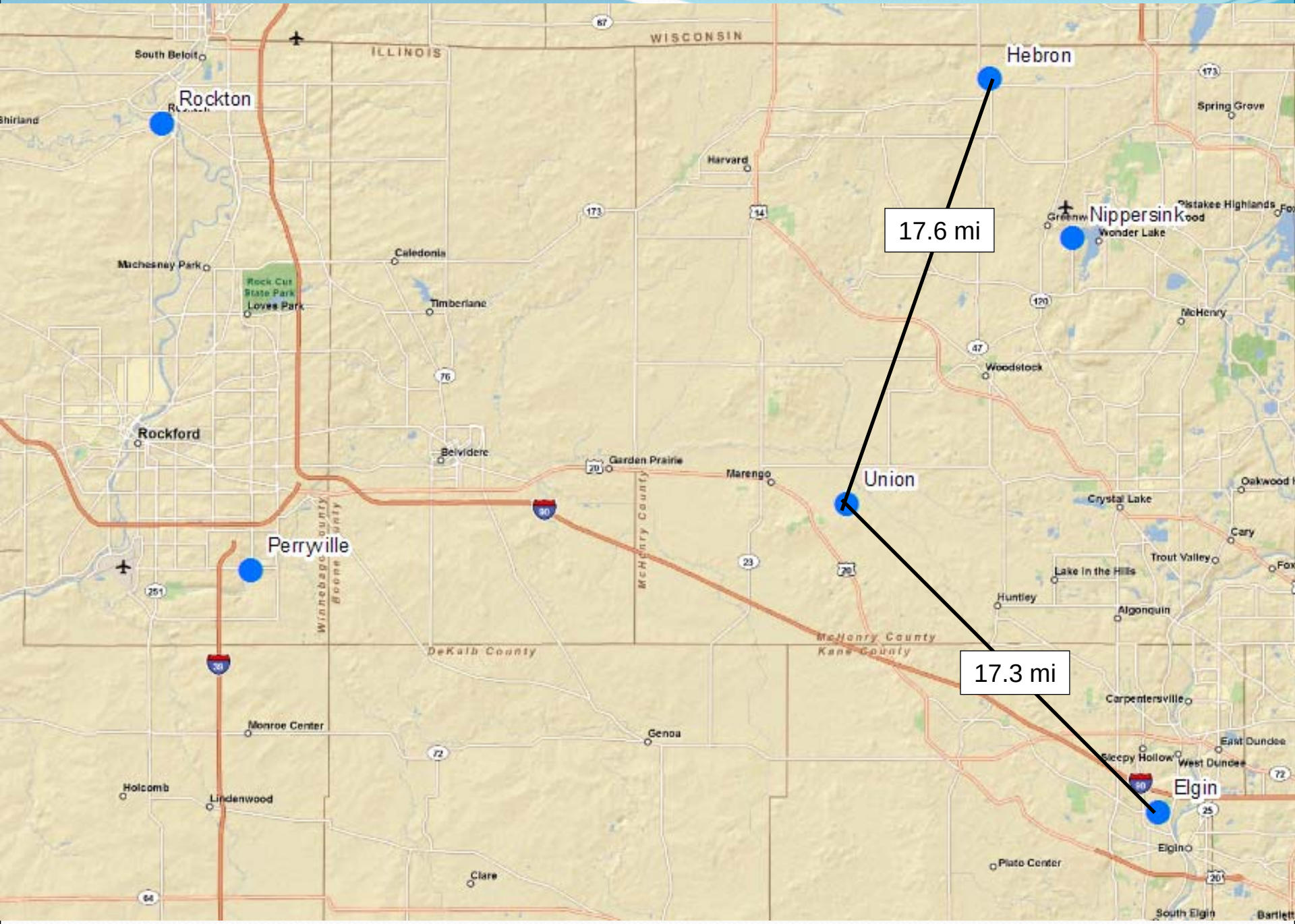
- Benefits
  - Continuous sampling
  - Measures at Ground elevation



- Limitations
  - Only samples a small area (<1ft^2)
  - 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)

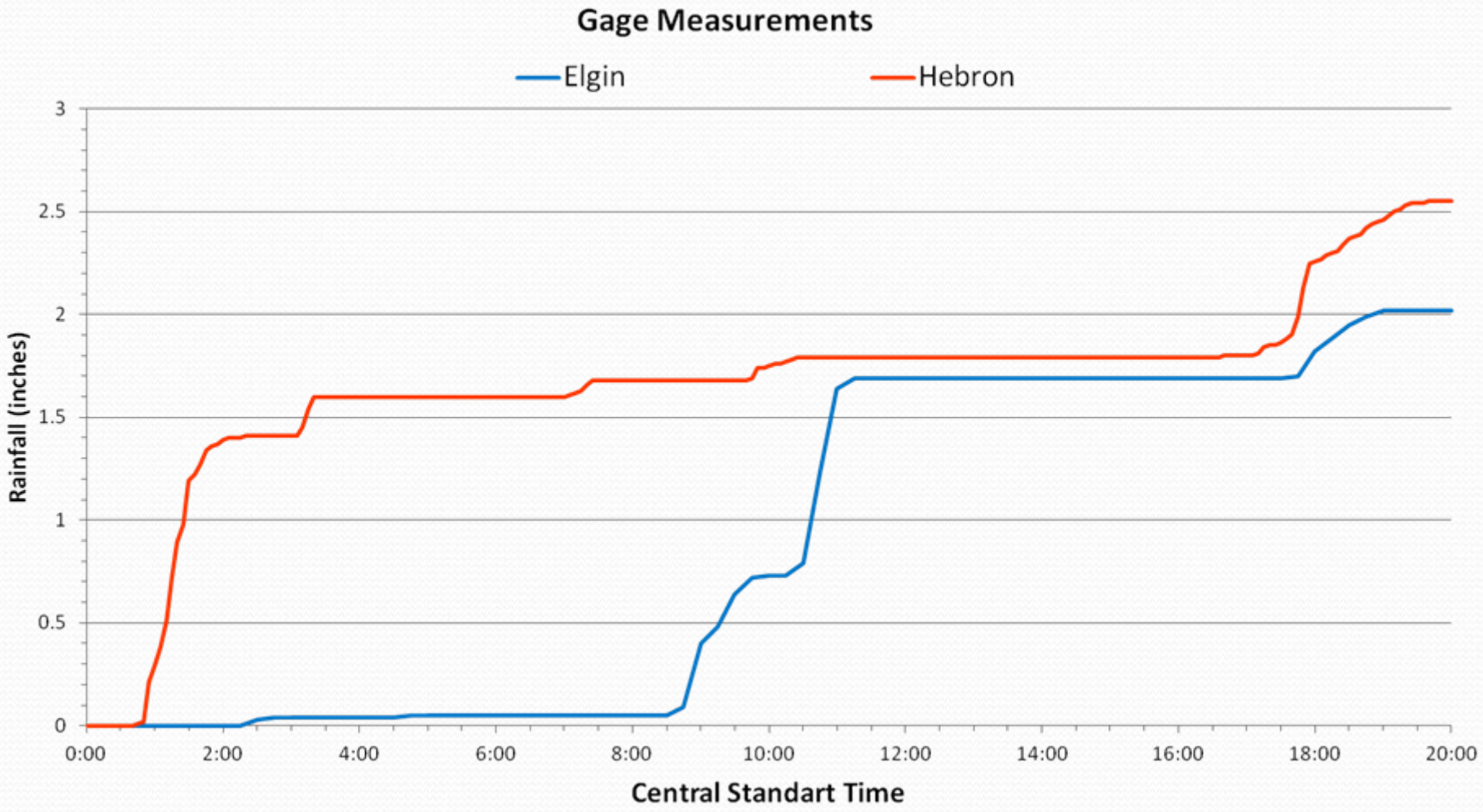
*Source: Larson, Lee and Eugene L. Peck; Accuracy of Precipitation Measurements for Hydrologic Modeling, Water Resources Research, Vol. 10, No. 4, 1974, pp.857-863


WISCONSIN
ILLINOIS
South Beloit
Rockton
Shirland
Harvard
Spring Grove
Pistakee Highlands
Greenwood
Ringwood
Wonder Lake
Caledonia
Machesney Park
Rock Cut State Park
Loves Park
Timberlane
McHenry
Woodstock
Rockford
Belvidere
Garden Prairie
Marengo
Union
Crystal Lake
Oakwood H
Cary
Trout Valley
Fox
Lake in the Hills
Huntley
Algonquin
Winnebago County
Boone County
McHenry County
DeKalb County
McHenry County
Kane County
Carpentersville
East Dundee
Sleepy Hollow
West Dundee
Monroe Center
Genoa
Holcomb
Lindenwood
Elgin
Plato Center
Clare
South Elgin
Bartlett

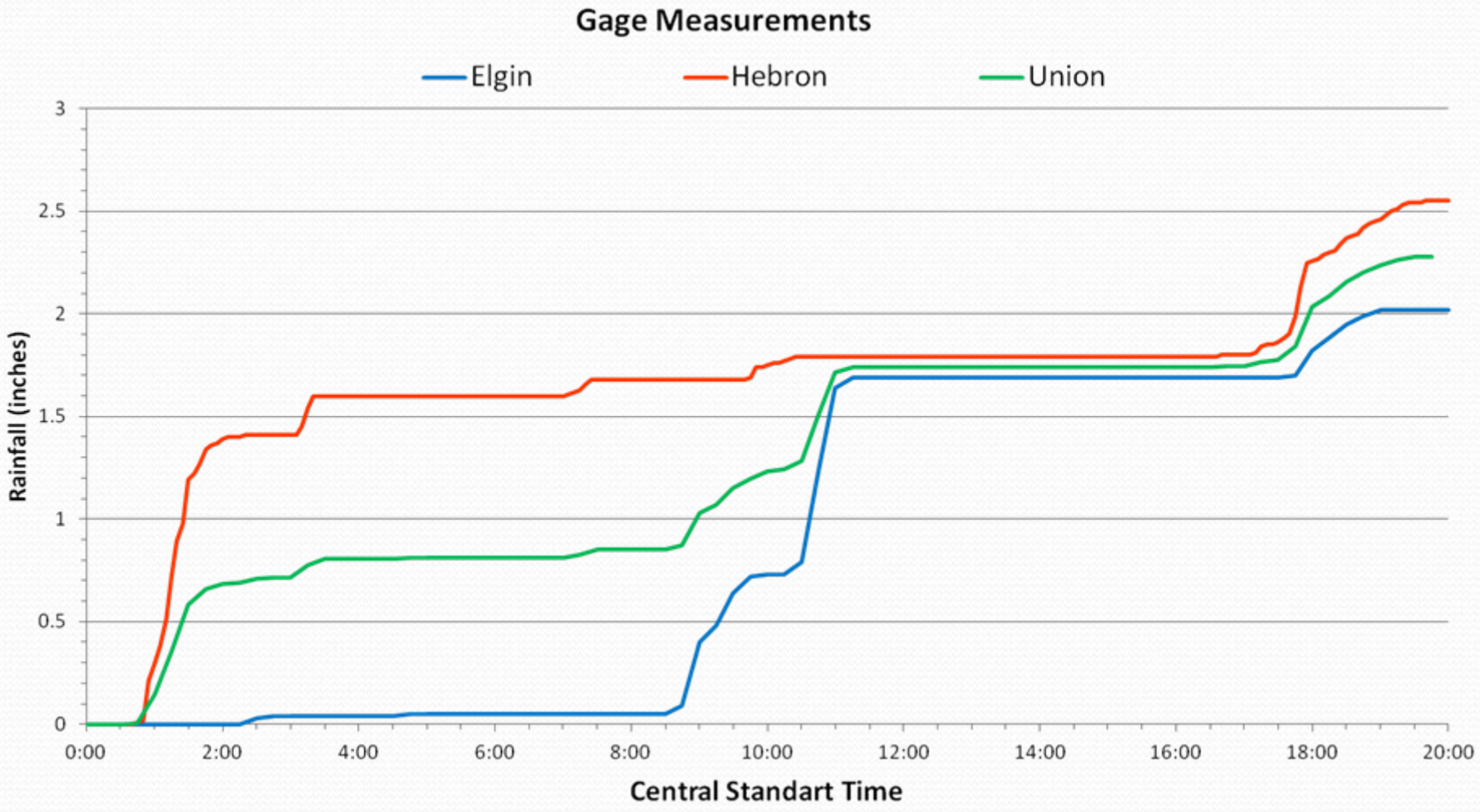


Hebron
Rockton
Nippersink
Union
Perryville
Elgin
17.6 mi
17.3 mi
WISCONSIN
ILLINOIS
South Beloit
Shirland
Harvard
Spring Grove
Pistakee Highlands
Wonder Lake
Machesney Park
Caledonia
Rock Cut State Park
Loves Park
Timberlane
McHenry
Woodstock
Rockford
Belvidere
Garden Prairie
Marengo
Crystal Lake
Oakwood
Cary
Trout Valley
Lake in the Hills
Huntley
Algonquin
Winnebago County
Boone County
McHenry County
DeKalb County
McHenry County
Kane County
Carpentersville
East Dundee
Sleepy Hollow
West Dundee
Monroe Center
Genoa
Holcomb
Lindenwood
Elgin
Plato Center
Clare
South Elgin
Bartlett

Gages – 6/19/2009

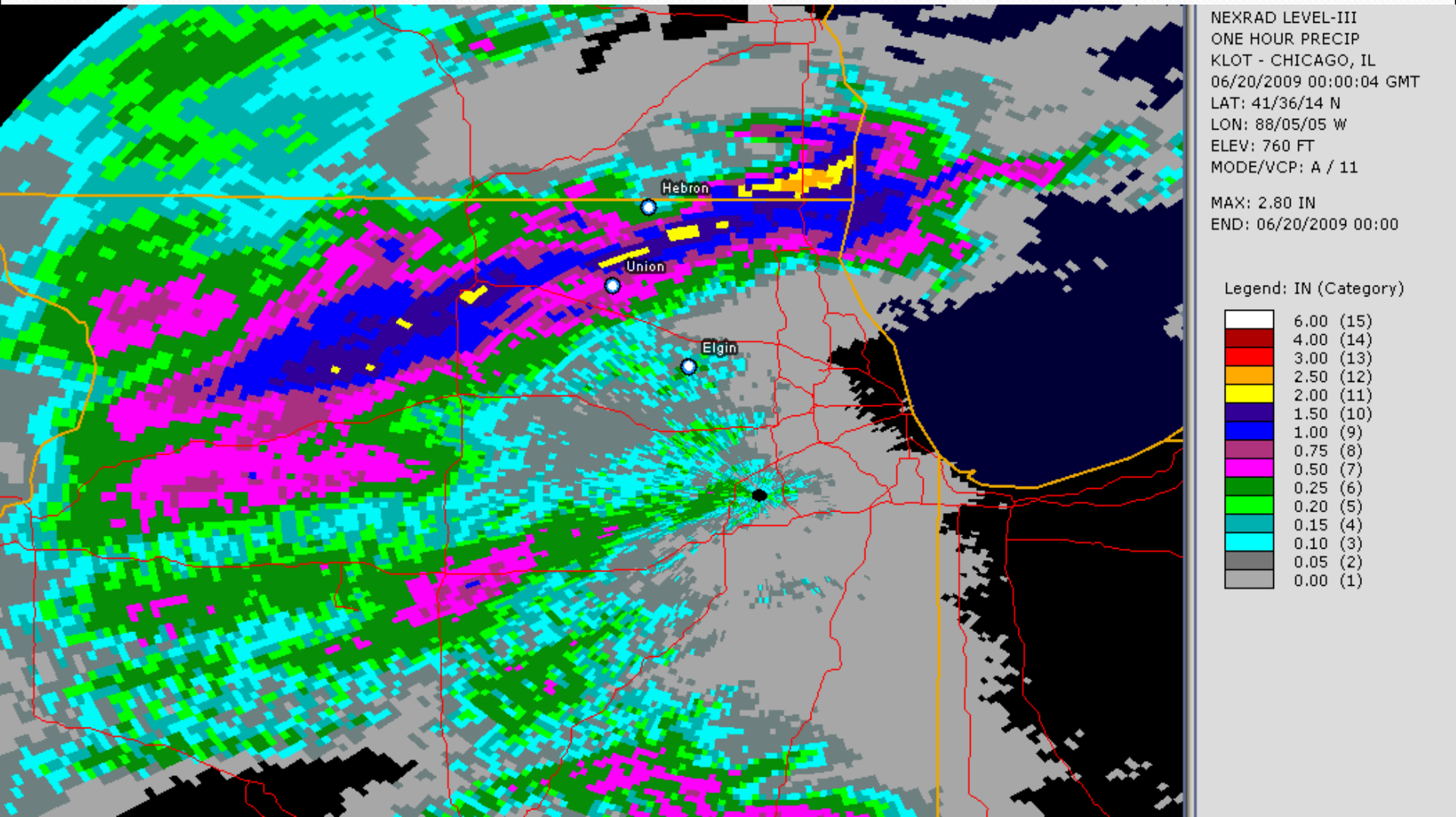


IDSM at Site – 6/19/2009



Next Generation Radar - NEXRAD

Its better than your 3G smart phone!

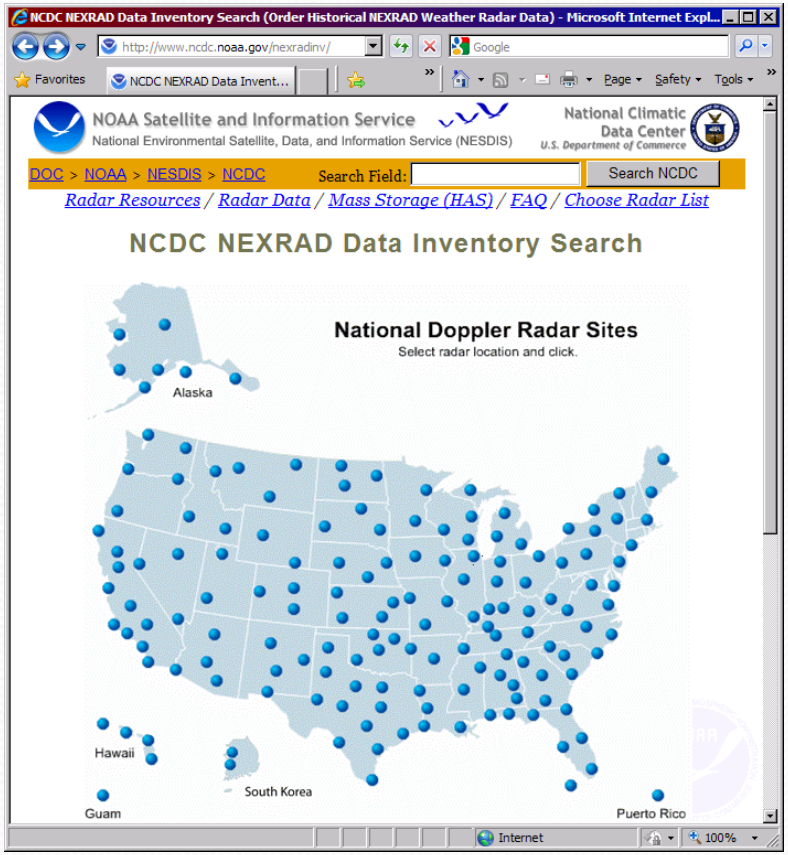


Radar Overview

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

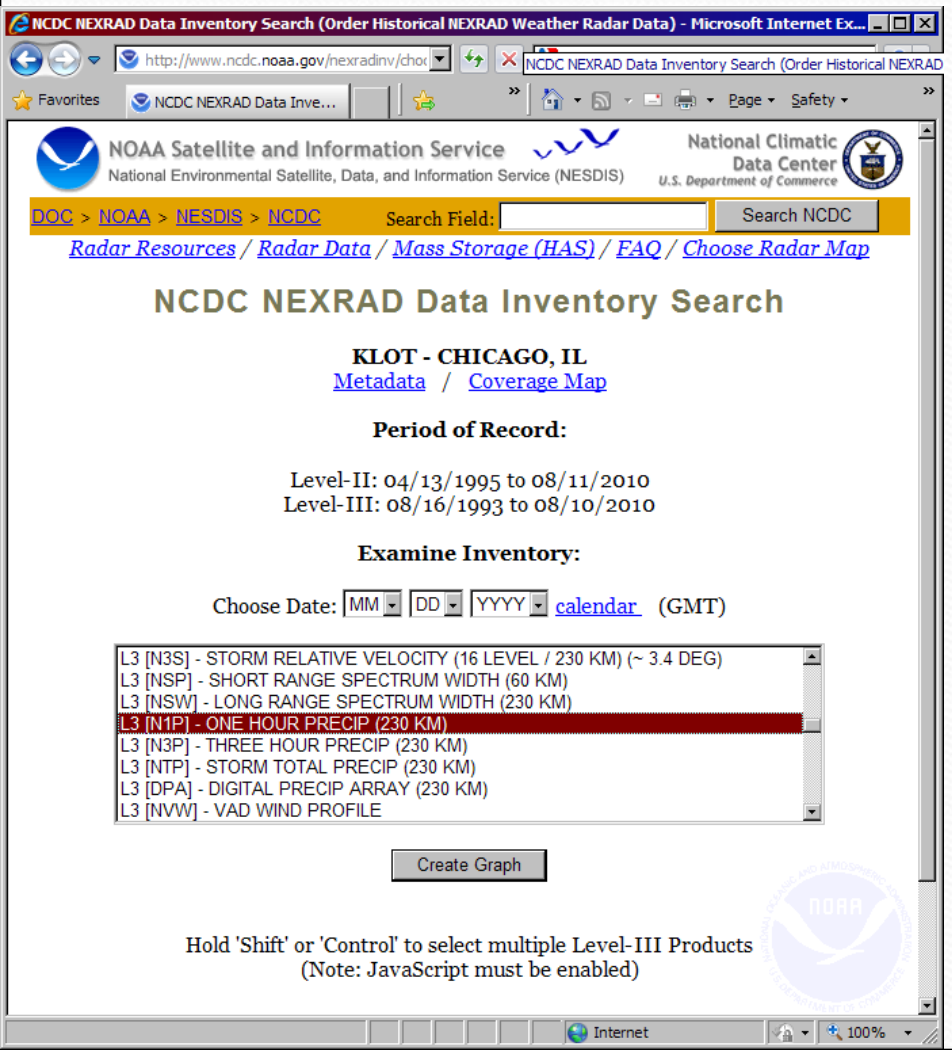
- Benefits
  - Spatial distribution of rainfall over watershed
- Limitations
  - Assumes a standard condition (drop size)
  - Elevated beam not sampled at ground elevation
  - Doesn’t directly measure rain
    - can detect hail, dust, birds, wind farms, buildings, etc
  - Not a continuous measurement (snapshot every 4-6 minutes)

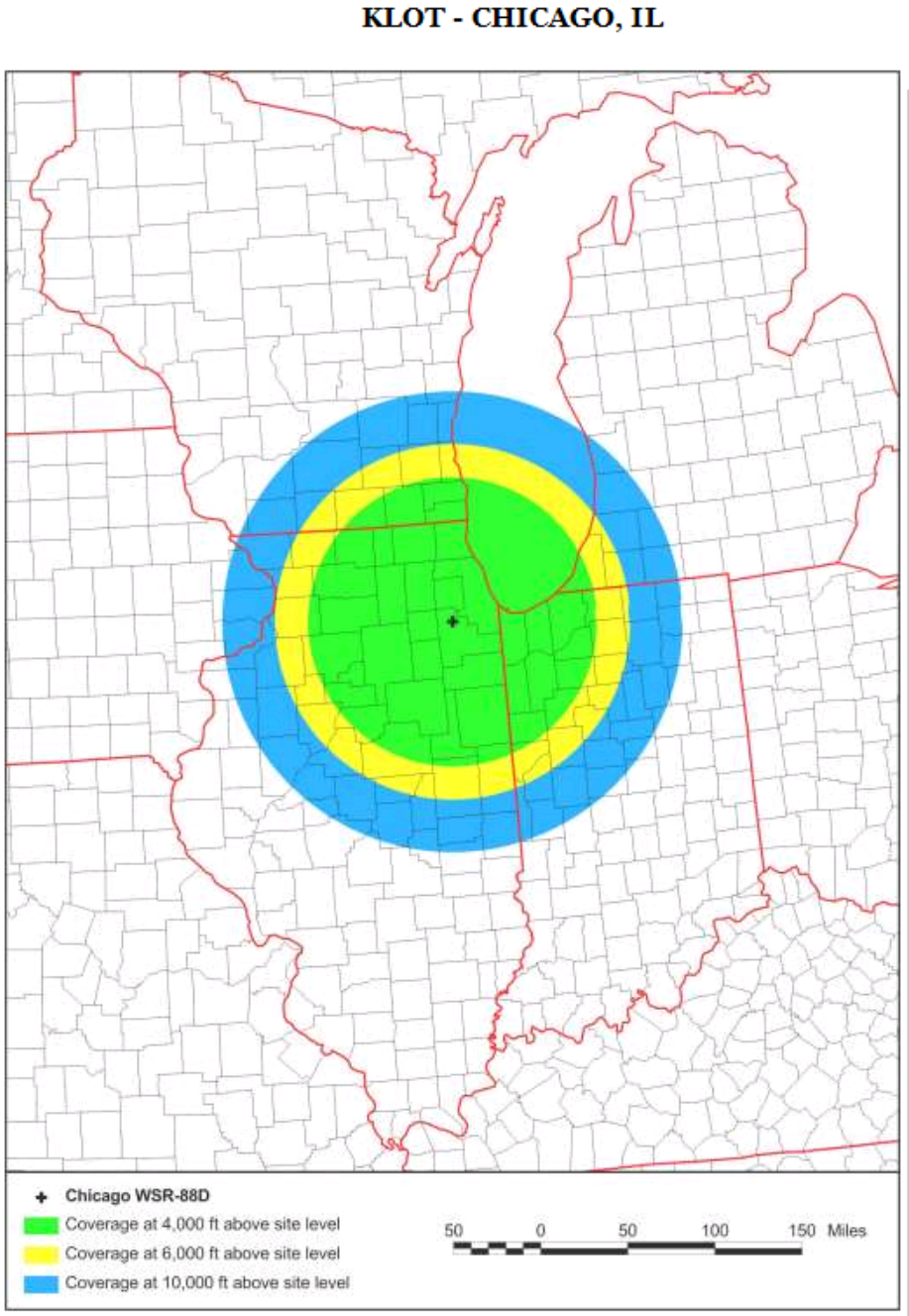
Getting Nexrad Data



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

NEXRAD Data

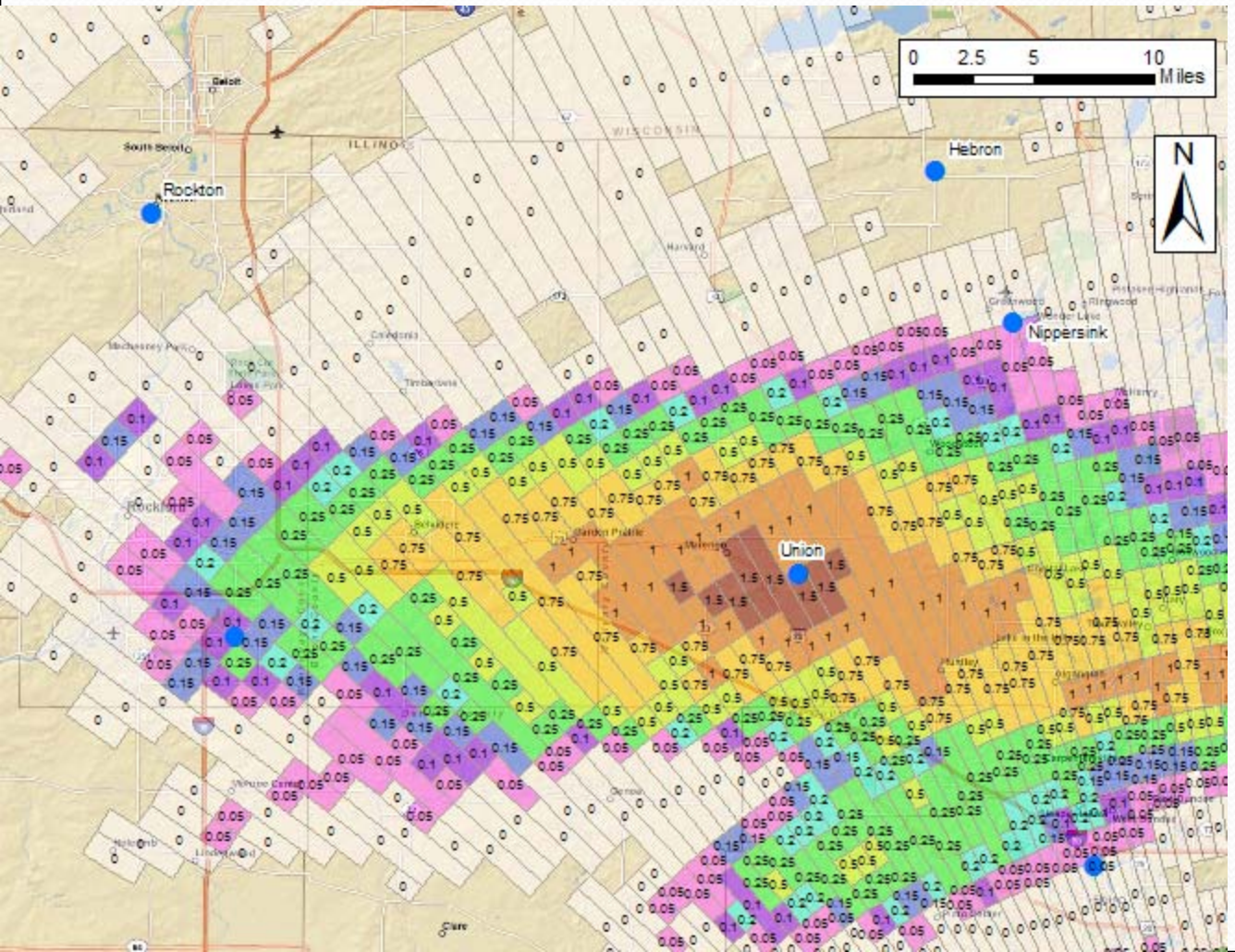

NCDC NEXRAD Data Inventory Search (Order Historical NEXRAD Weather Radar Data) - Microsoft Internet Ex...
http://www.ncdc.noaa.gov/nexradinv/choo
NCDC NEXRAD Data Inventory Search (Order Historical NEXRAD
Favorites
NCDC NEXRAD Data Inve...
Page
Safety
NOAA Satellite and Information Service
National Environmental 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)
Internet
100%


KLOT - CHICAGO, IL
Chicago WSR-88D
Coverage at 4,000 ft above site level
Coverage at 6,000 ft above site level
Coverage at 10,000 ft above site level
50 0 50 100 150 Miles

NEXRAD Data

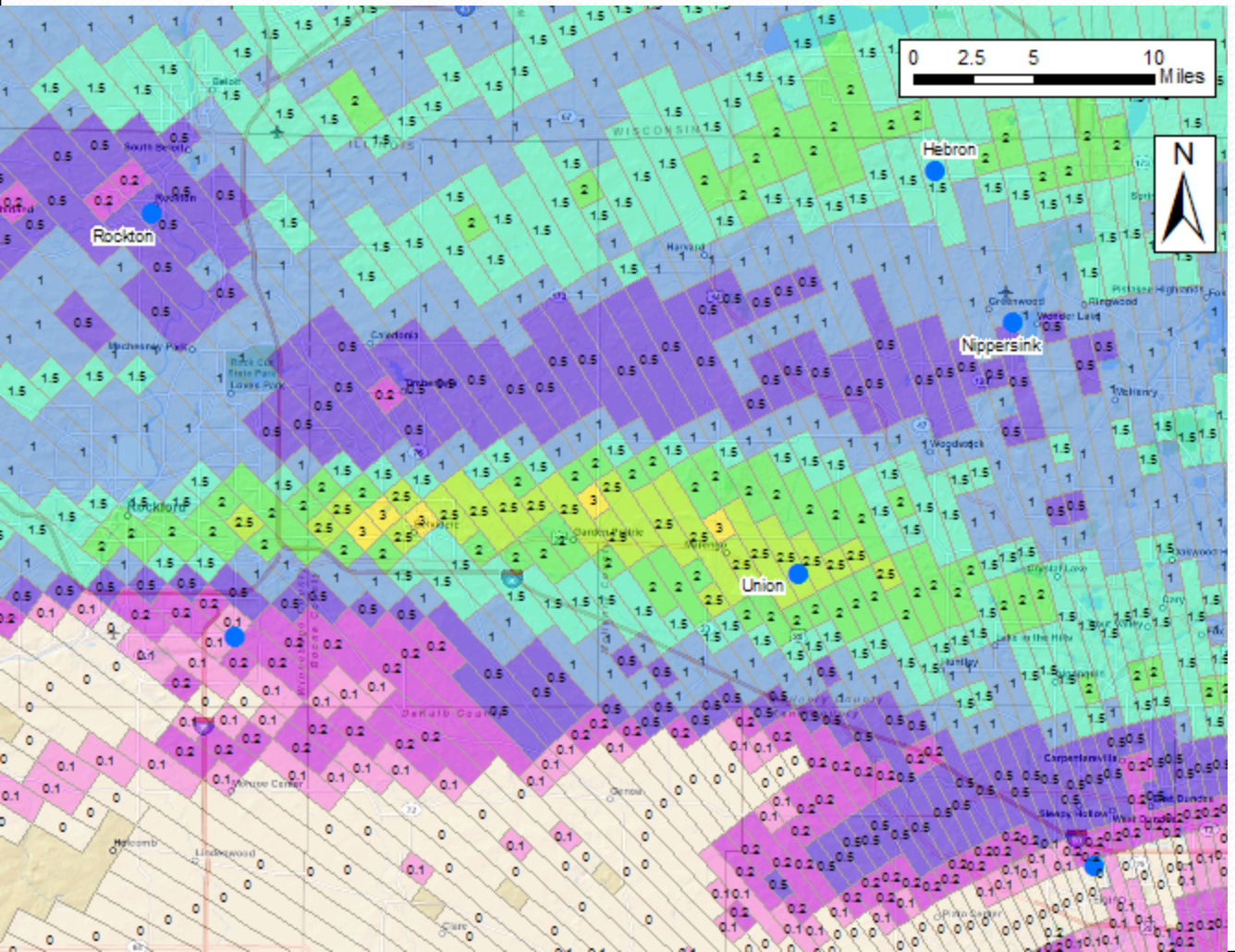
- Reflectivity Data
  - Short Range (230km) or Long Range (460km)
  - Base (0.5, 0.9 1.5, 1.8, 2.4, 3.4 Deg) or Composite
  - 16 or 256 Level
- Wind Data
  - Base Velocity (0.5, 0.9 1.5, 2.4, 3.4 Deg) (16 or 256 Level)
- Rainfall Data
  - 1 hour Intensity – Short Range, 16 Level
  - 3 hour Intensity – 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



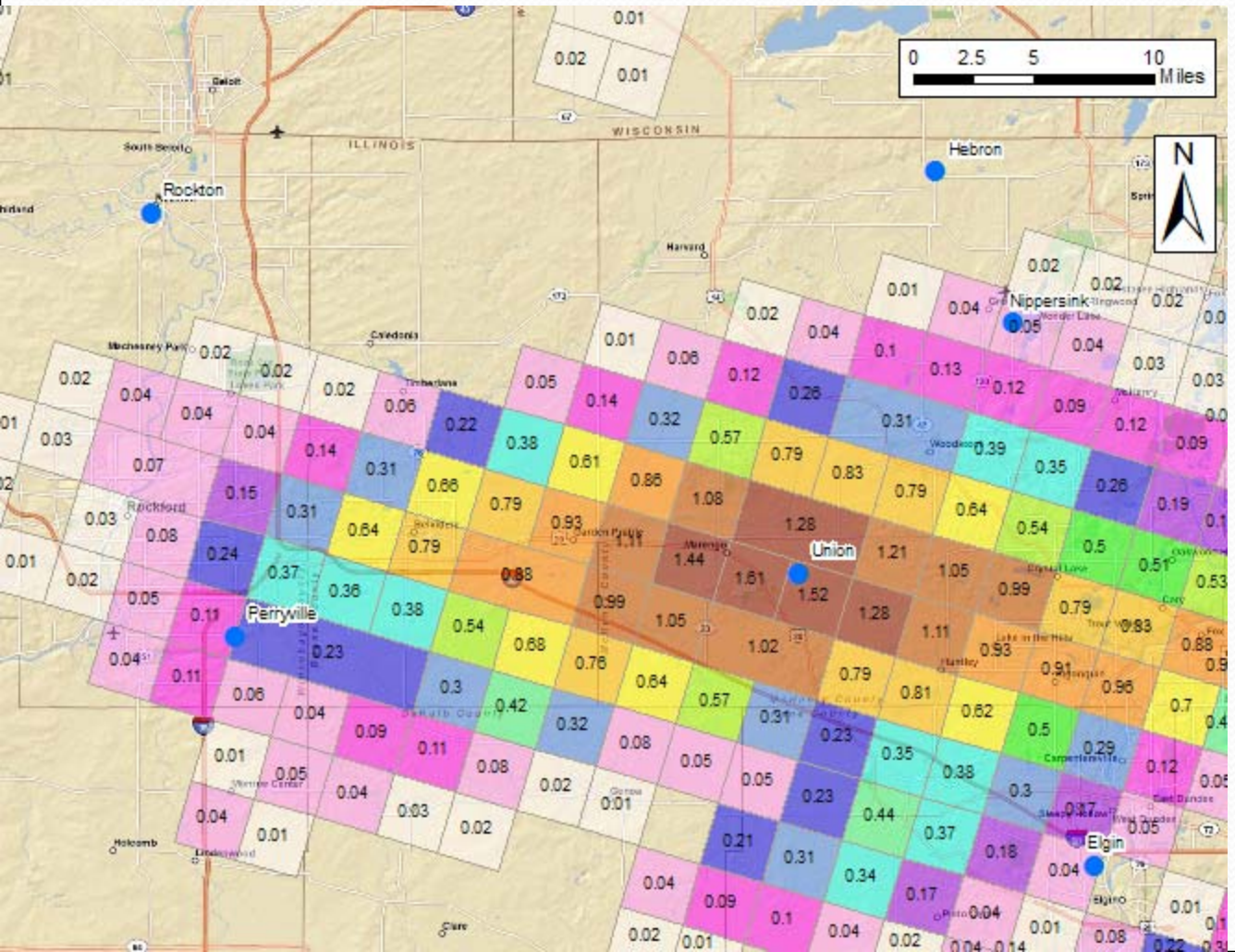
- 16 values
- 1.1nm x 1°
- Must calculate hyetograph

NPT – Storm Totals



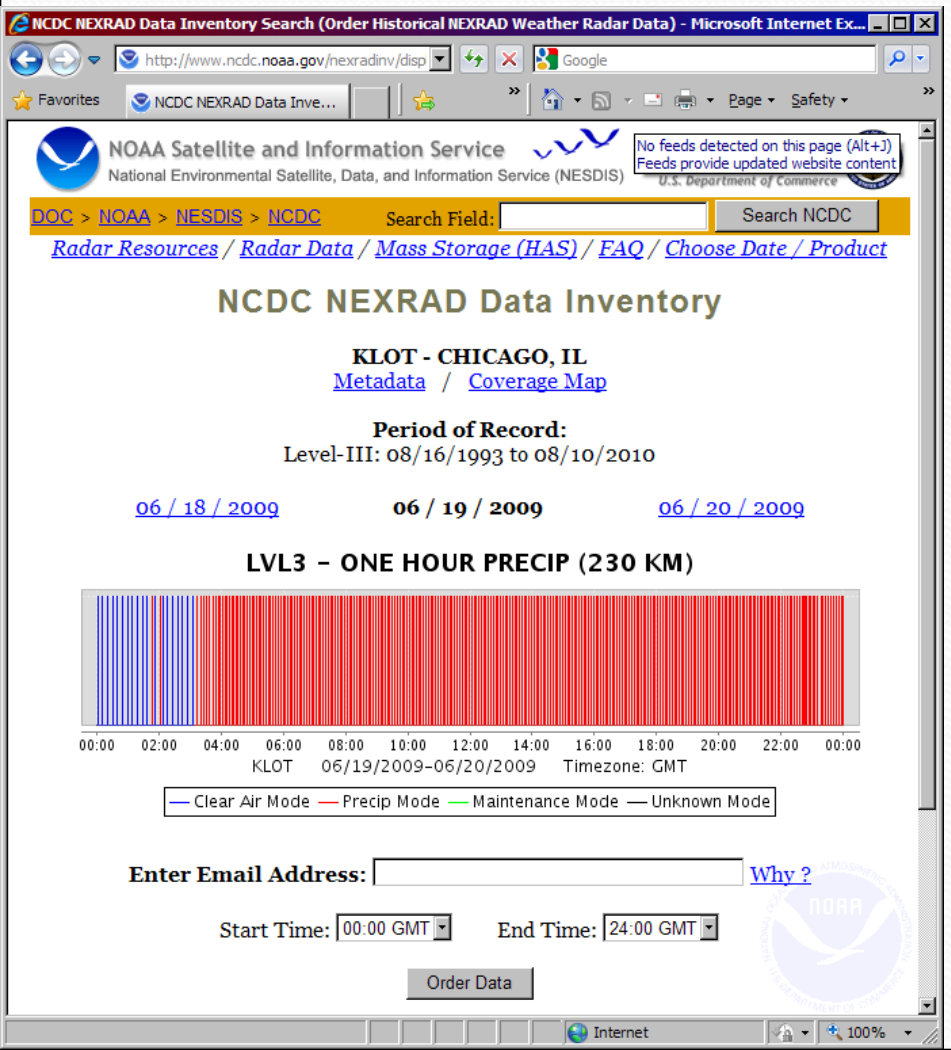
- 16 values
- 1.1nm x 1°
- Stair step hyetograph
- Resets after 1 hour of no rainfall

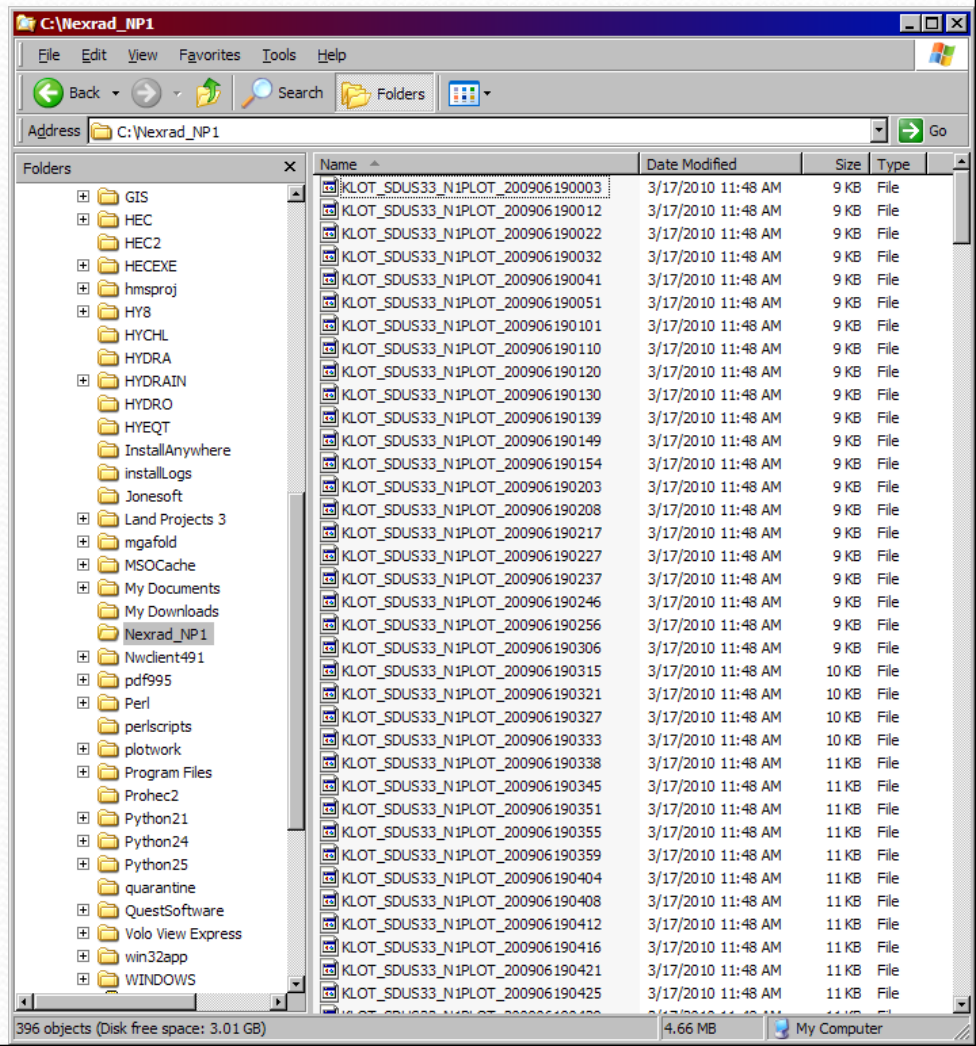
DPA – 1 hour intensities



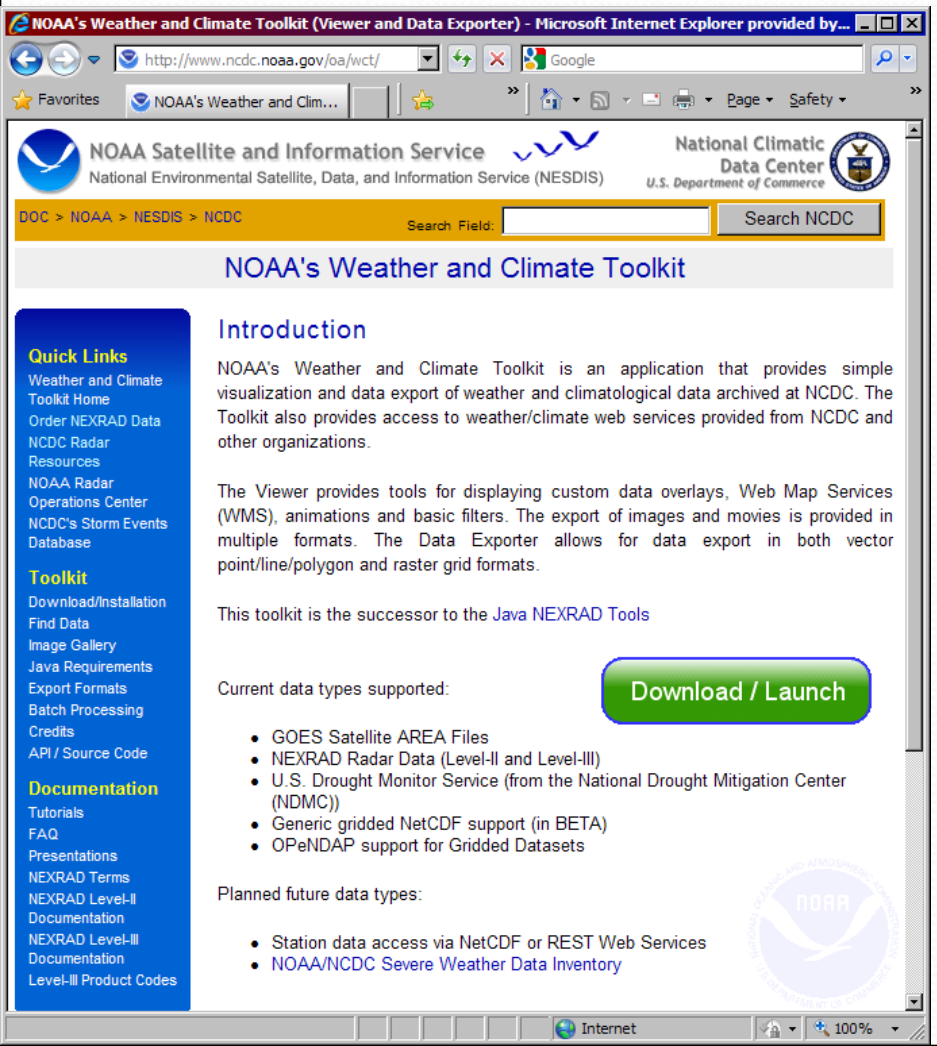
- 256 Values
- 2.6m x 2.6m
- Must calculate hyetograph
- Developed for use with Hydrologic Modeling

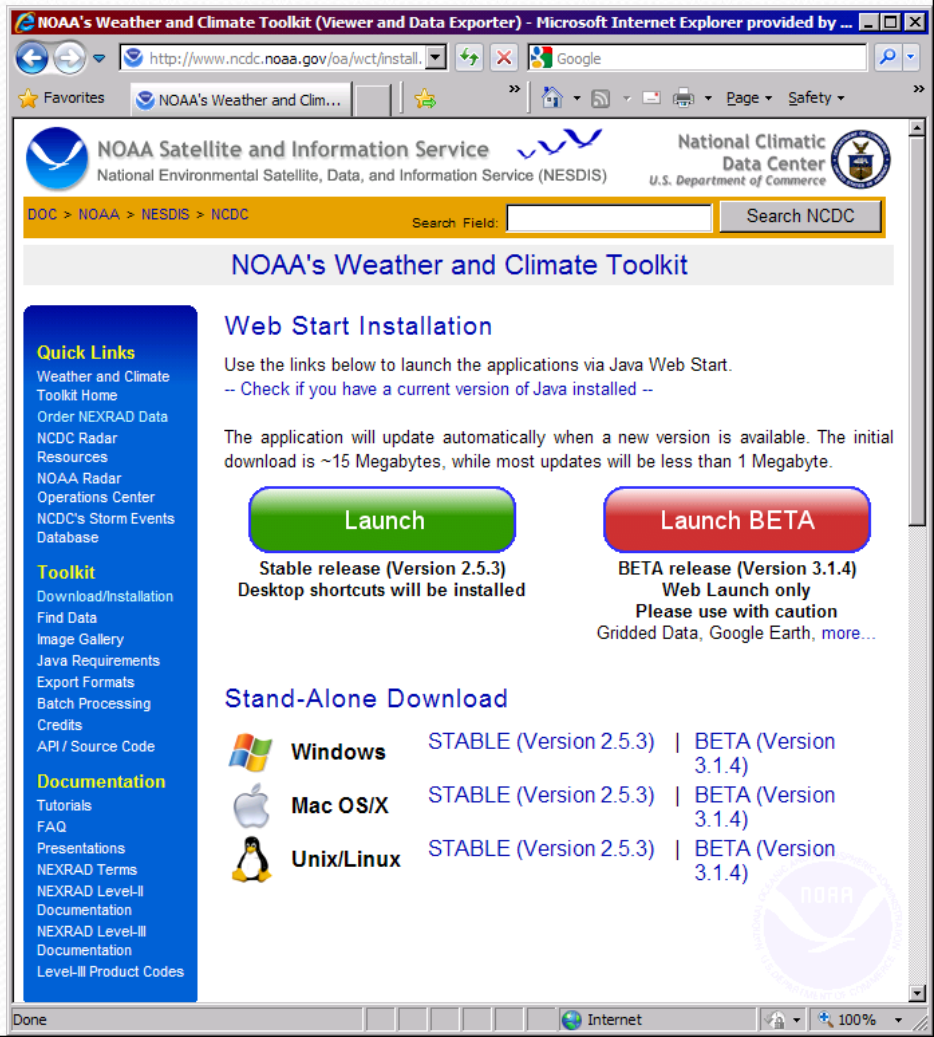
Getting the Data



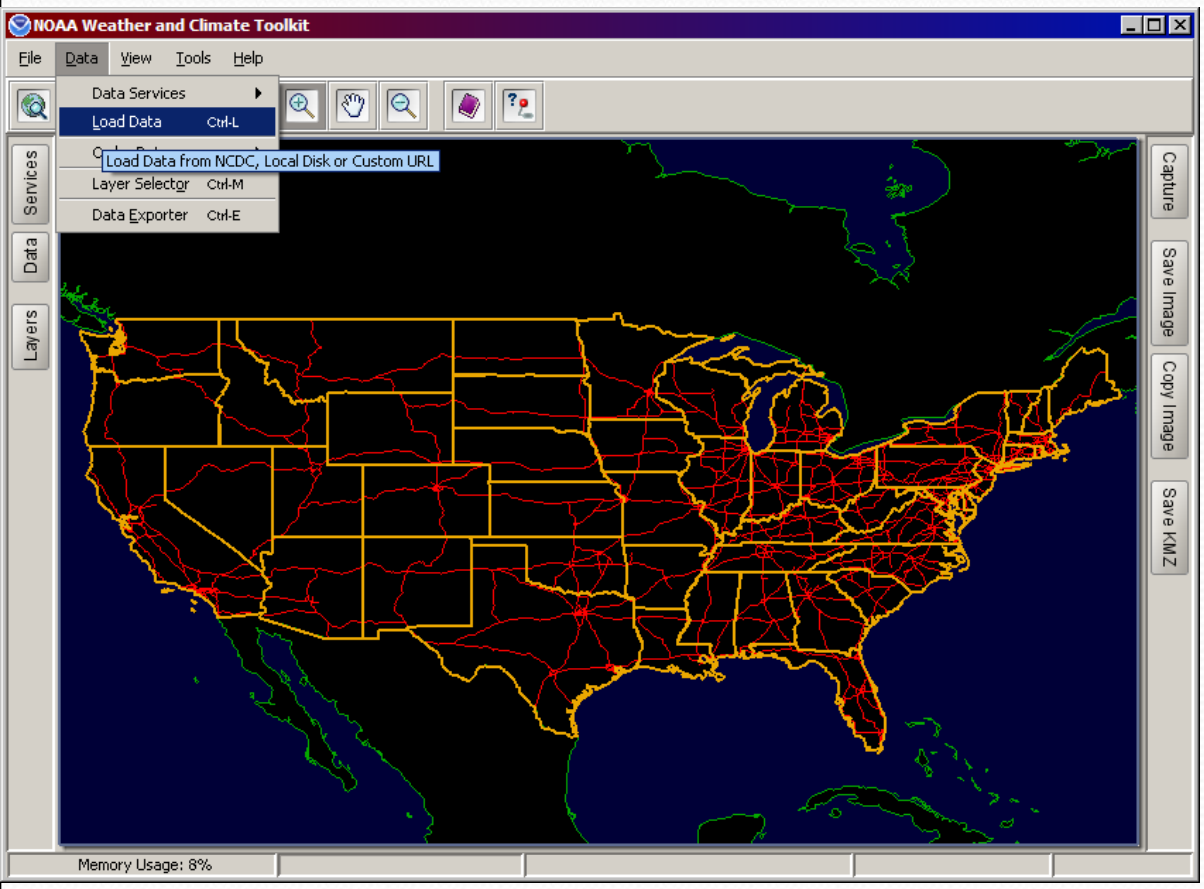


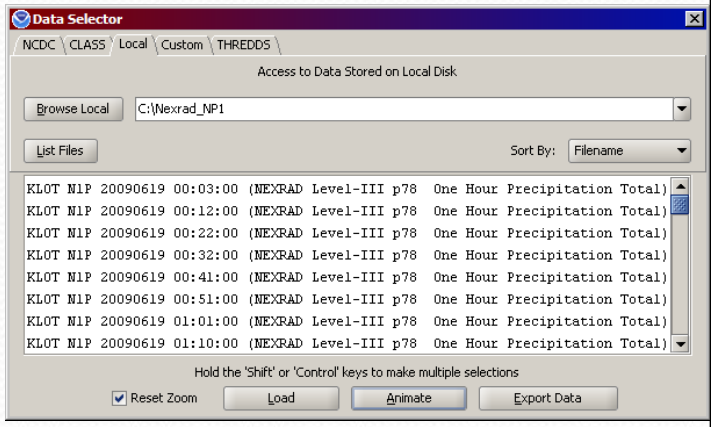
http://www.ncdc.noaa.gov/oa/wct/



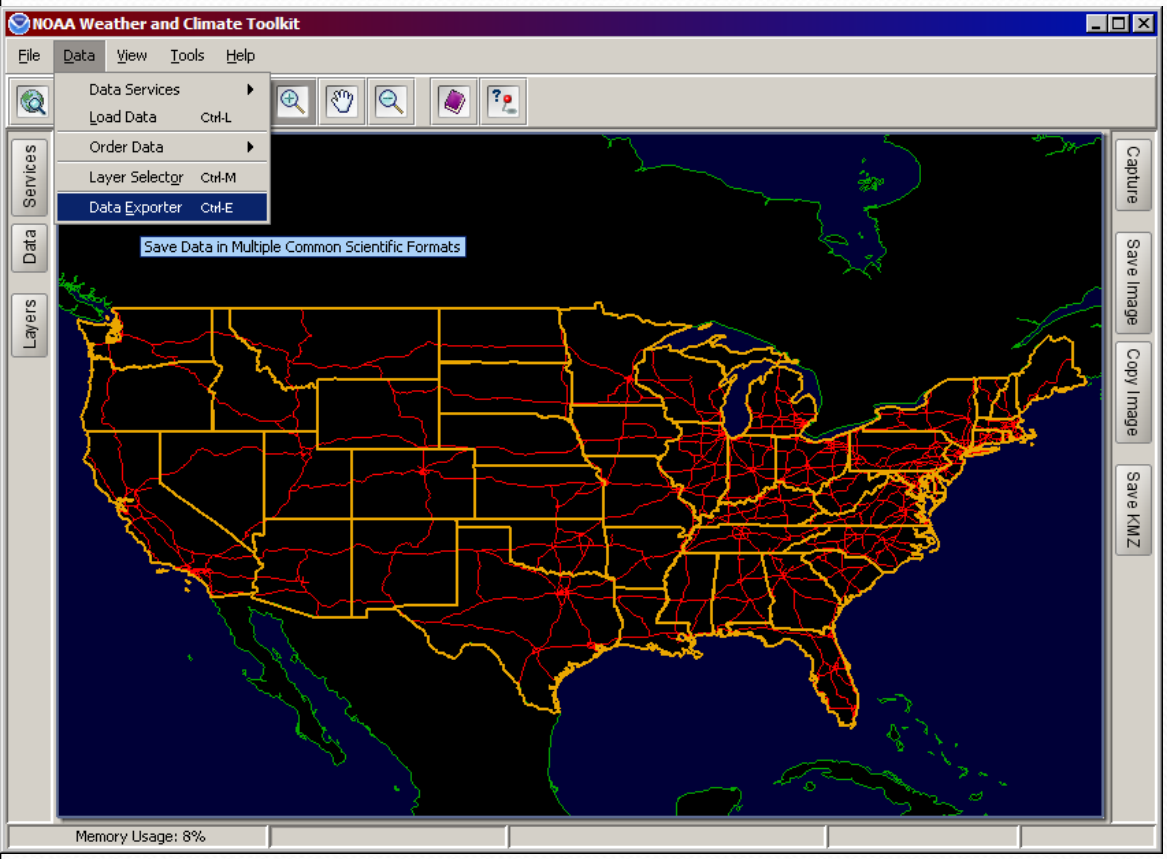


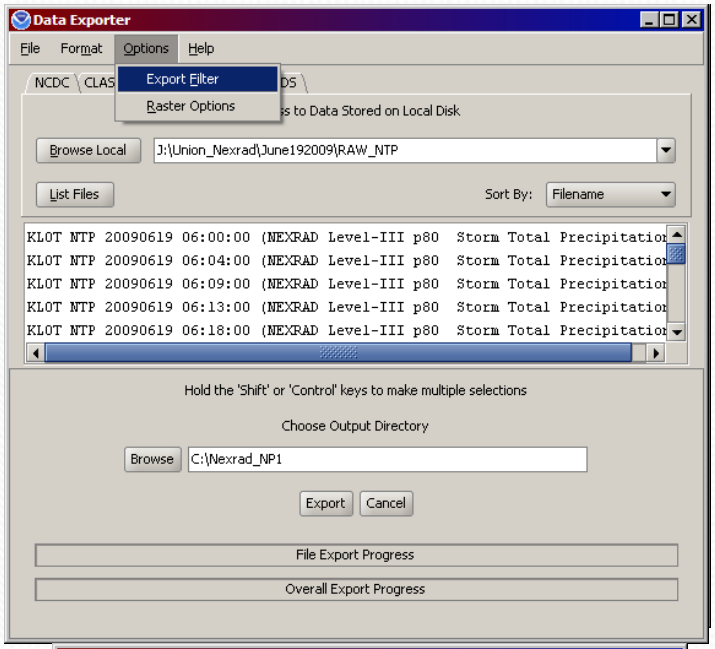
Weather & Climate Toolkit - (WCT)

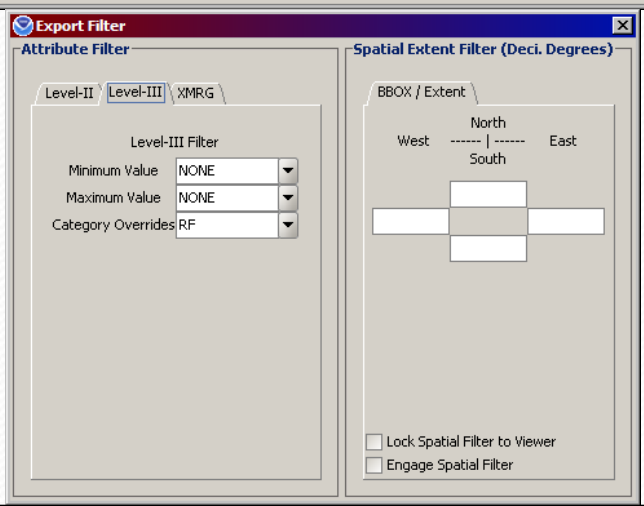




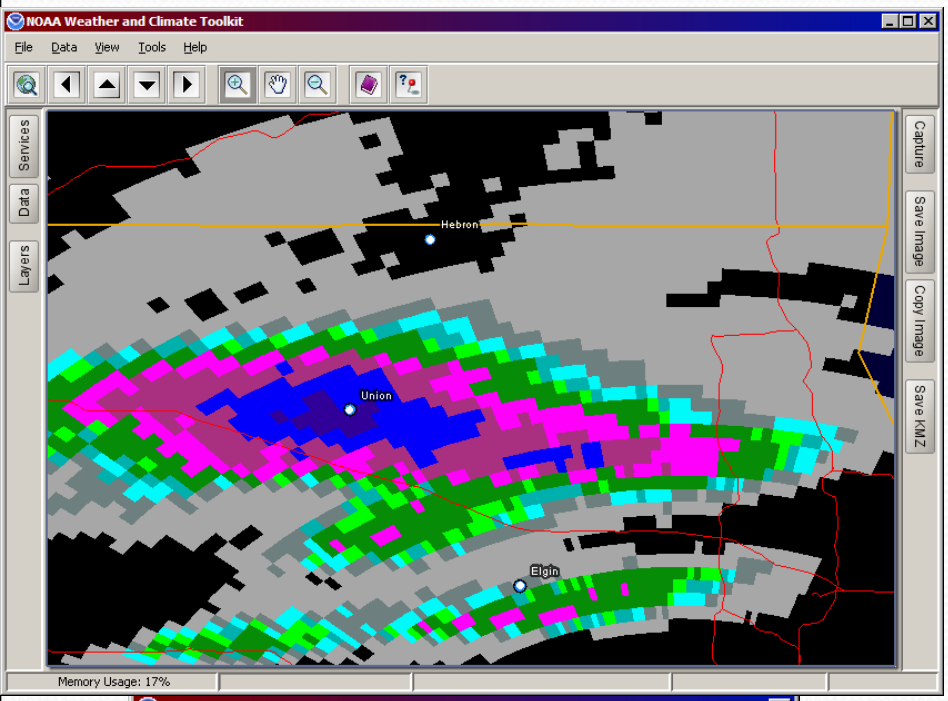
WCT - Exporting Data

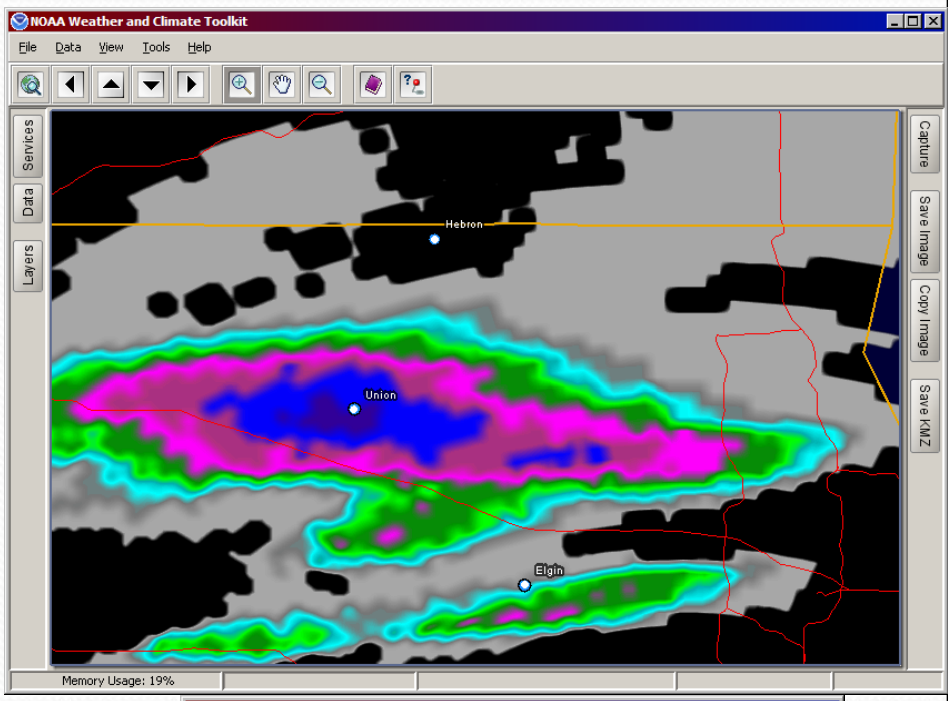




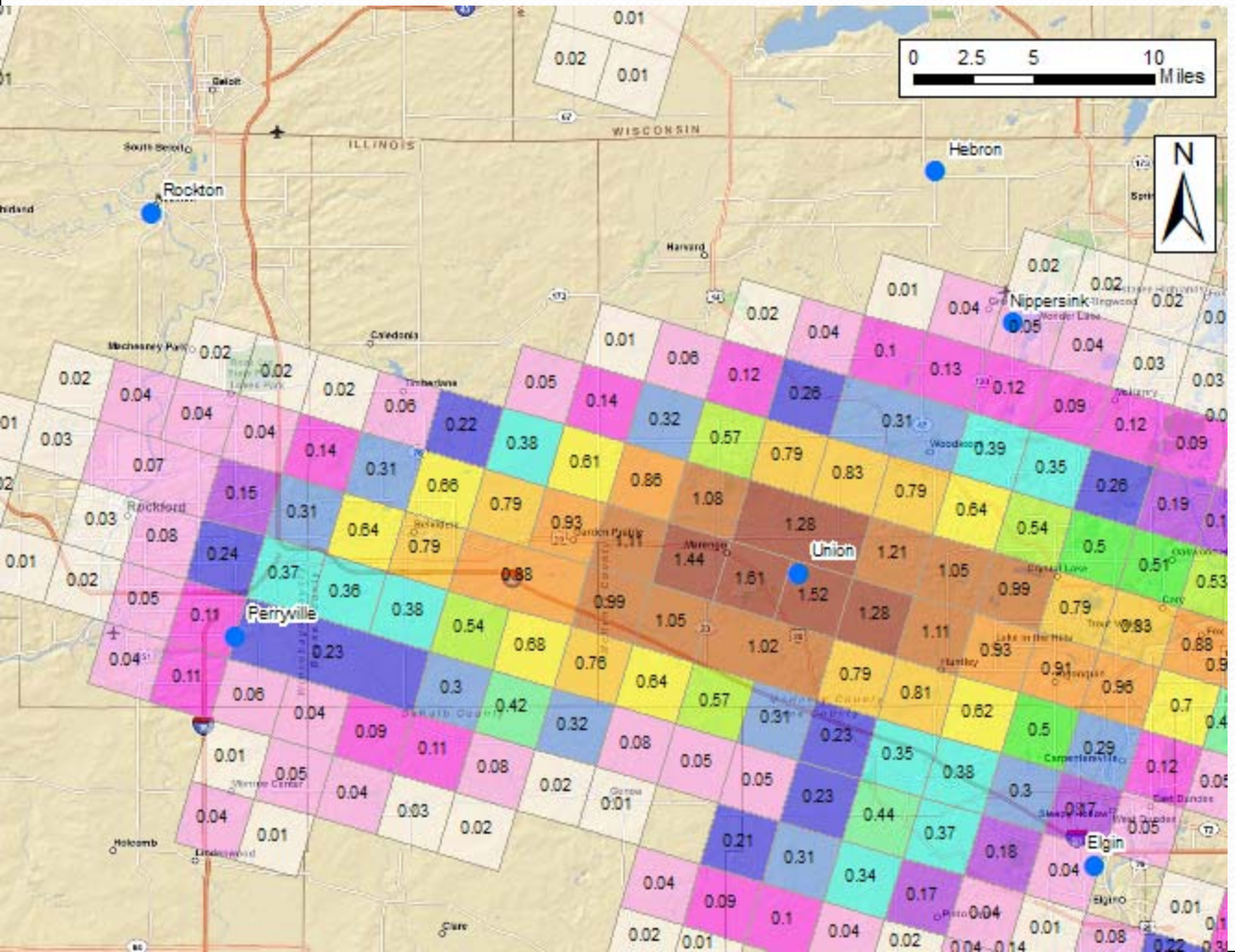


WCT - Smoothing



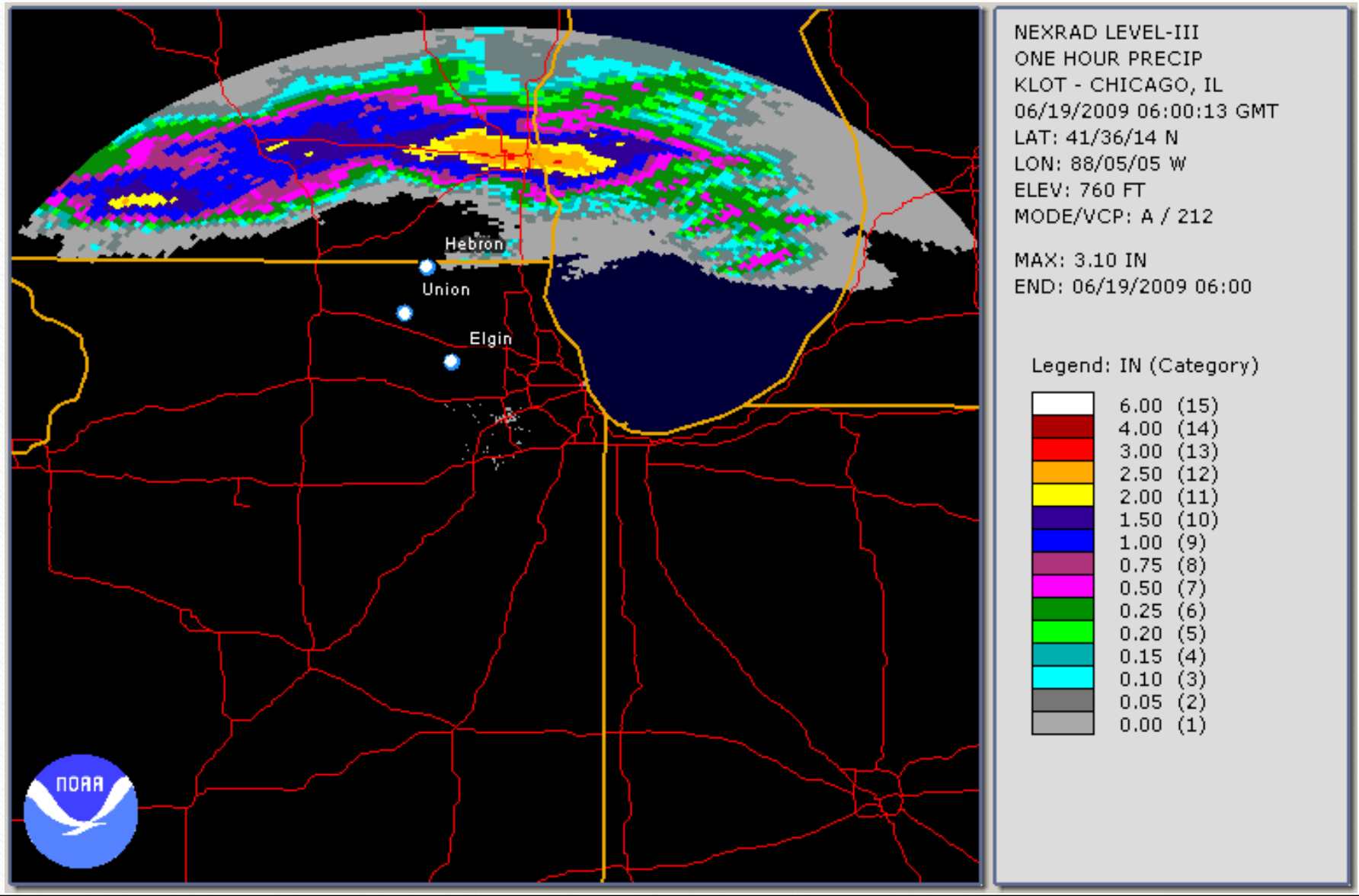


From Radar into Hyetograph

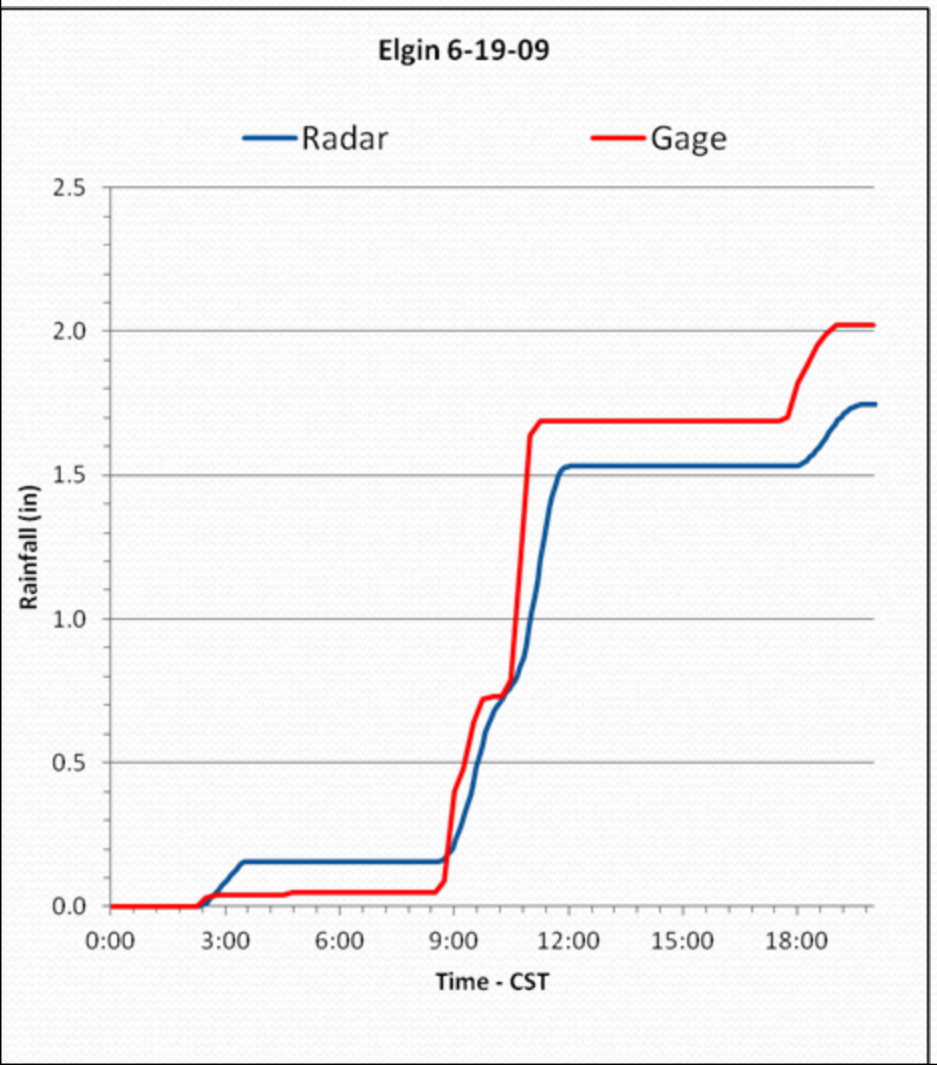


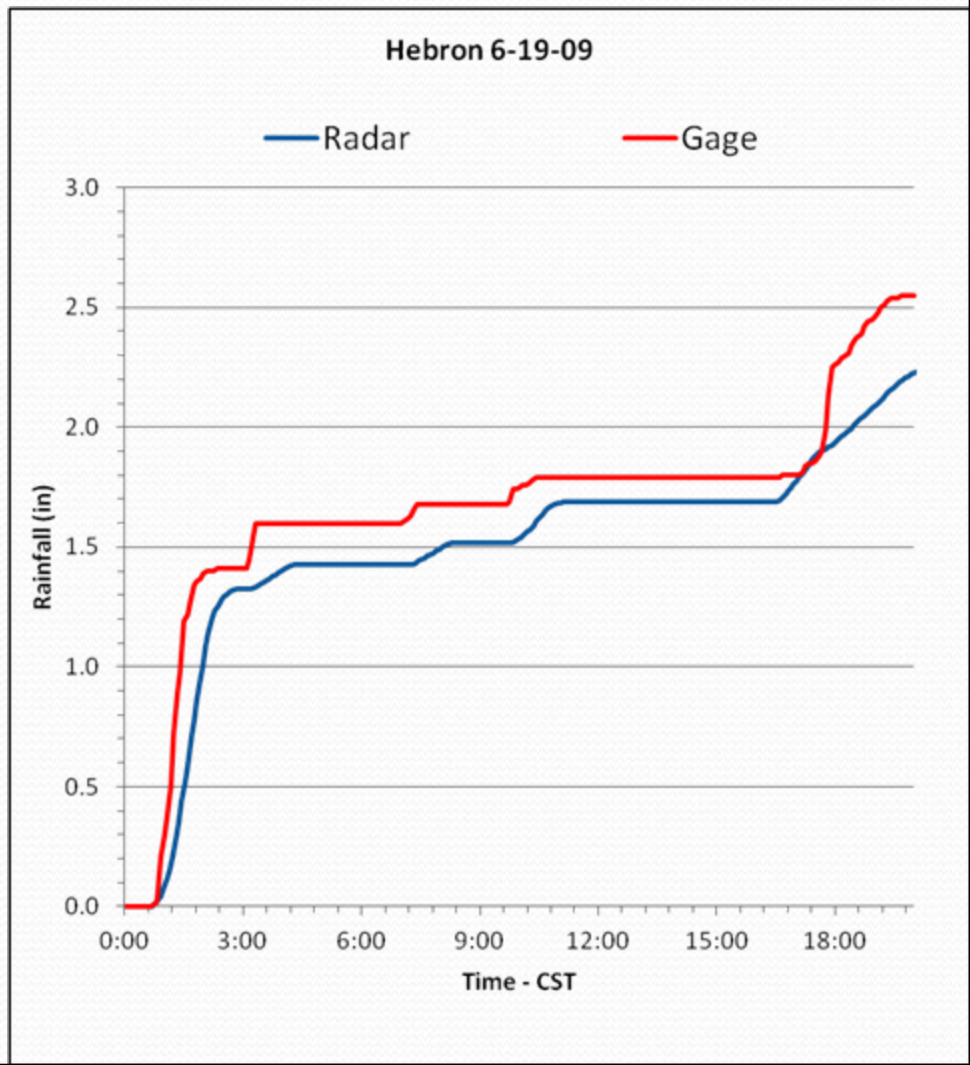
- Extract data from each time step
- Convert intensity into rainfall depth
- Construct hyetograph
- Adjust Time Zones

Case Study Storm Event



Rain Gage vs. Radar





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

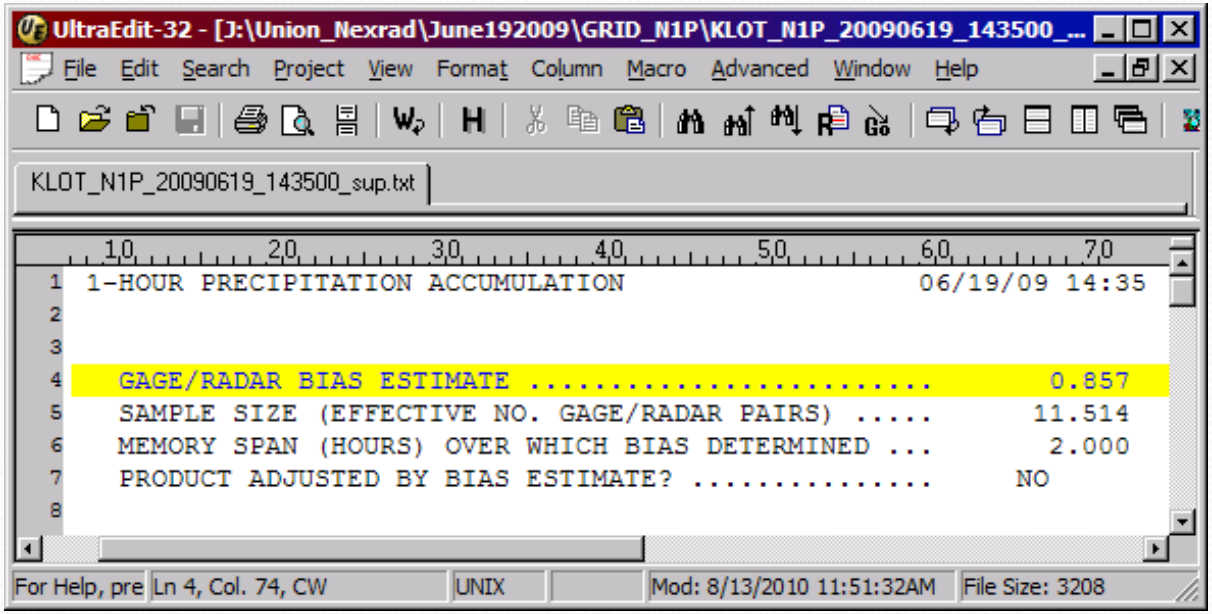
- Adjusts per storm event
  - Gage total / Radar total
- Adjusts for each time step
  - Gage (time = t) / Radar (time = t)
    - Gage or Radar may have no value when other does
- Adjusts over given duration
  - $$\frac{\text{Gage Total (time} = t + x) - \text{Gage Total (time} = t - x)}{\text{Radar Total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



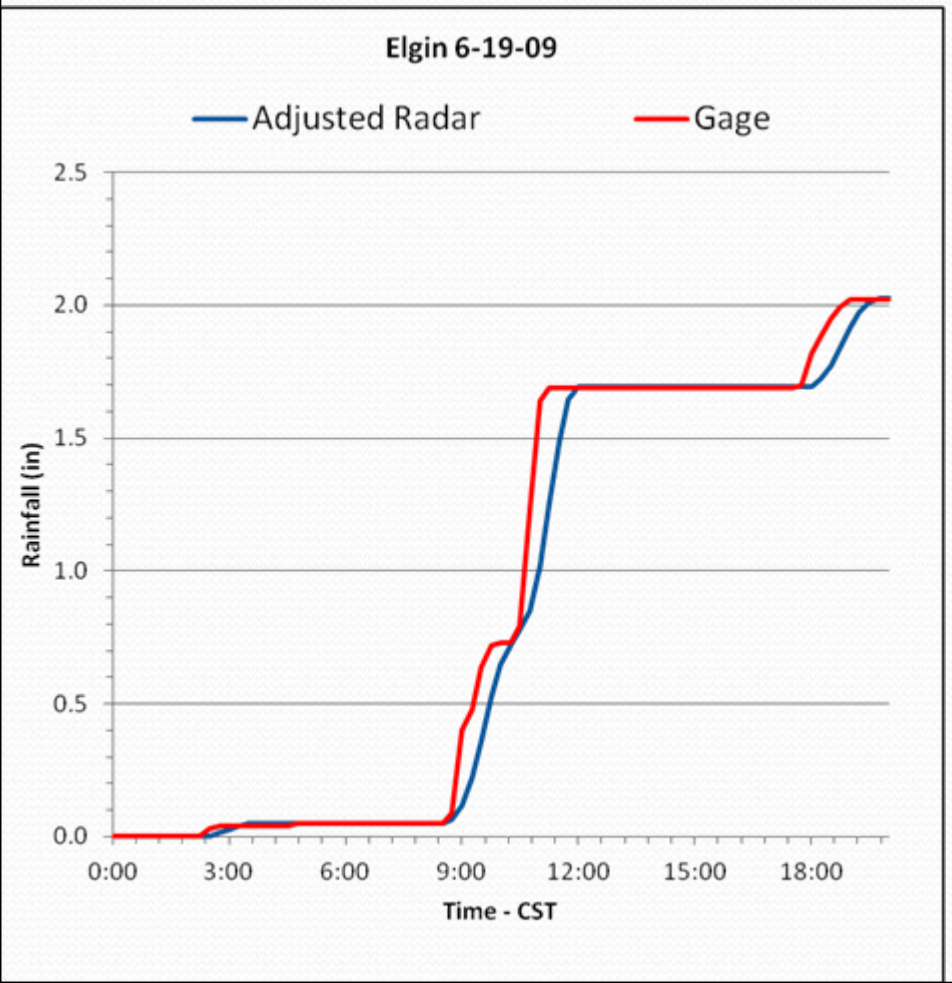
Adjusting Radar - Brandes (1975)

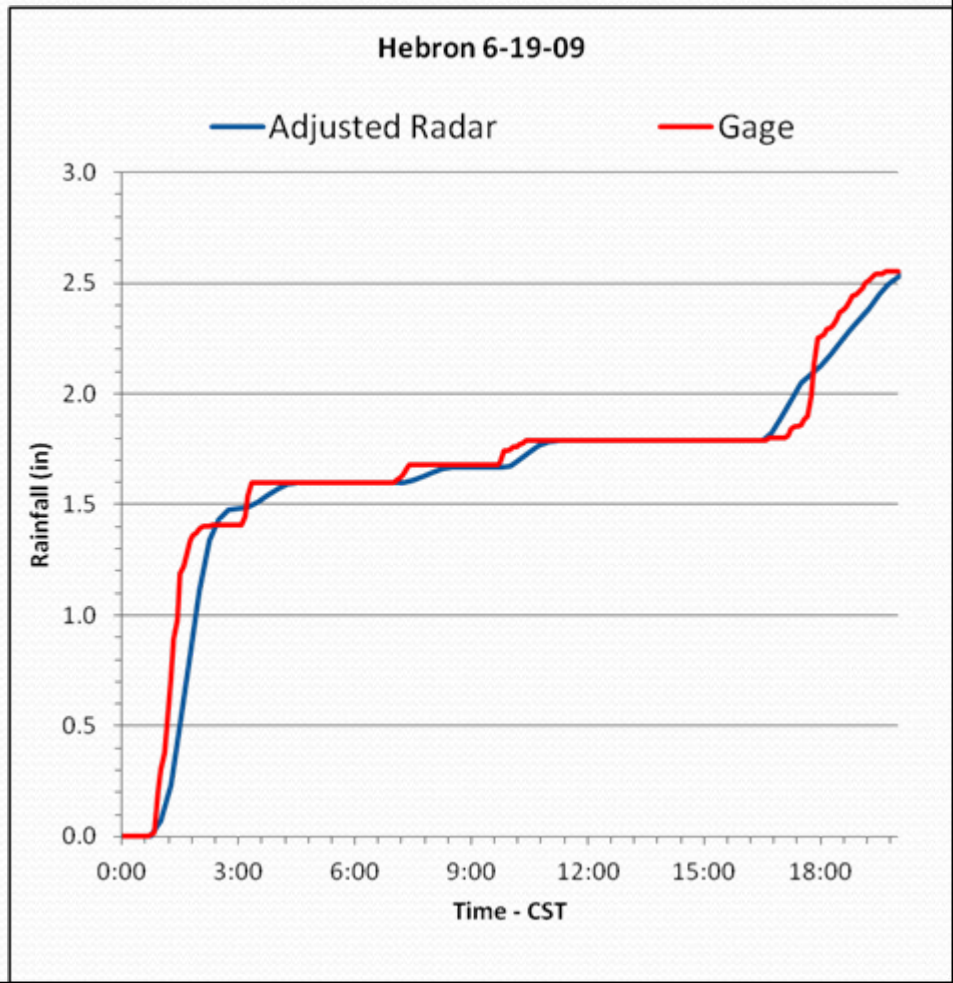
- Each cell value adjusted based on surrounding cell values
- Each cell calibrated based on distance to gages in network
- Calibration multiplier determined for each time step
- Cell value at gage location may not match gage data

Adjusting Radar for Union

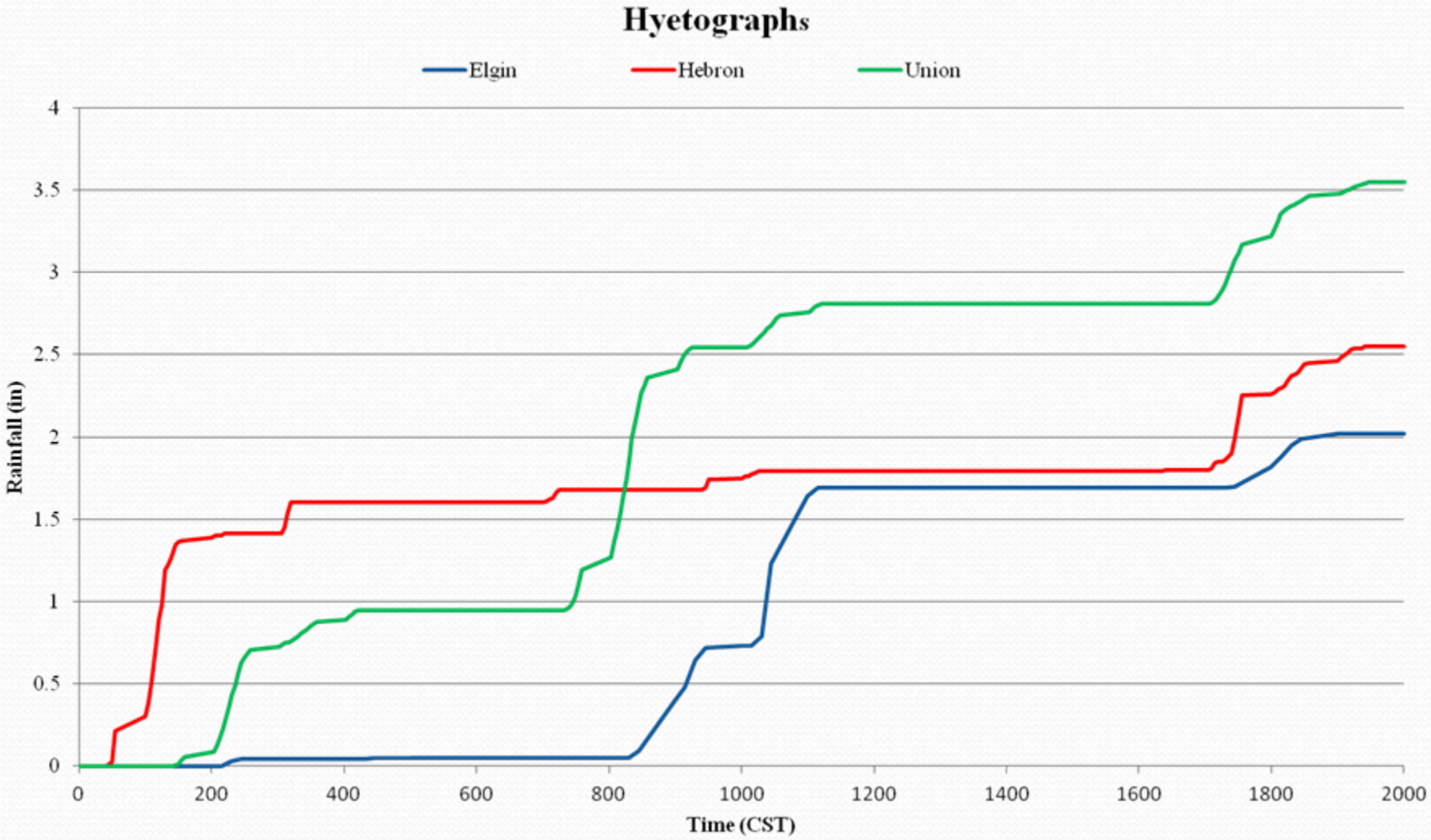
- Time Adjustment
  - Radar adjusted per storm cell
- Magnitude Adjustment
  - Union Rainfall adjusted for weighted distance to gages
- No Spatial Adjustment

Adjusted Radar Rainfall

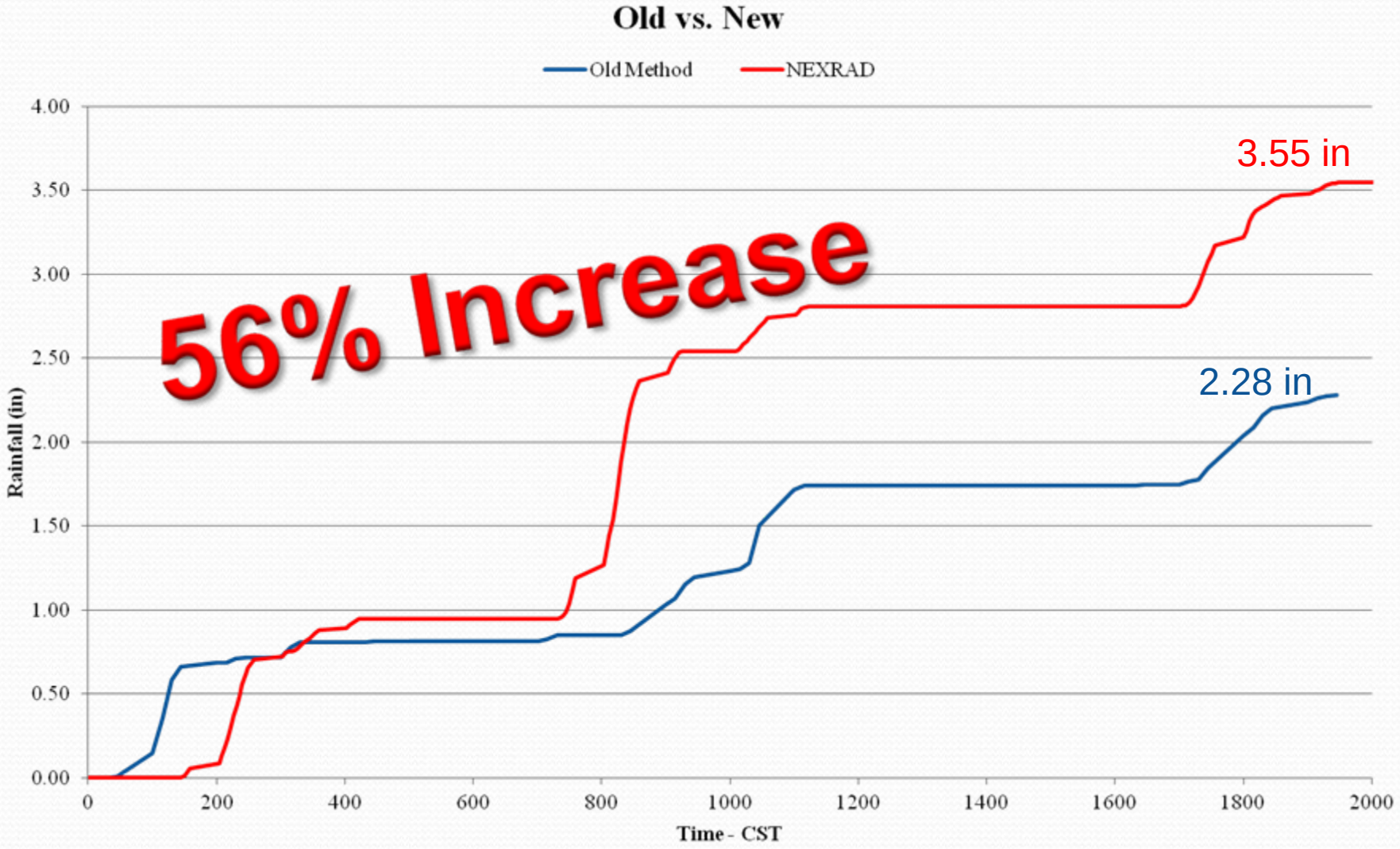




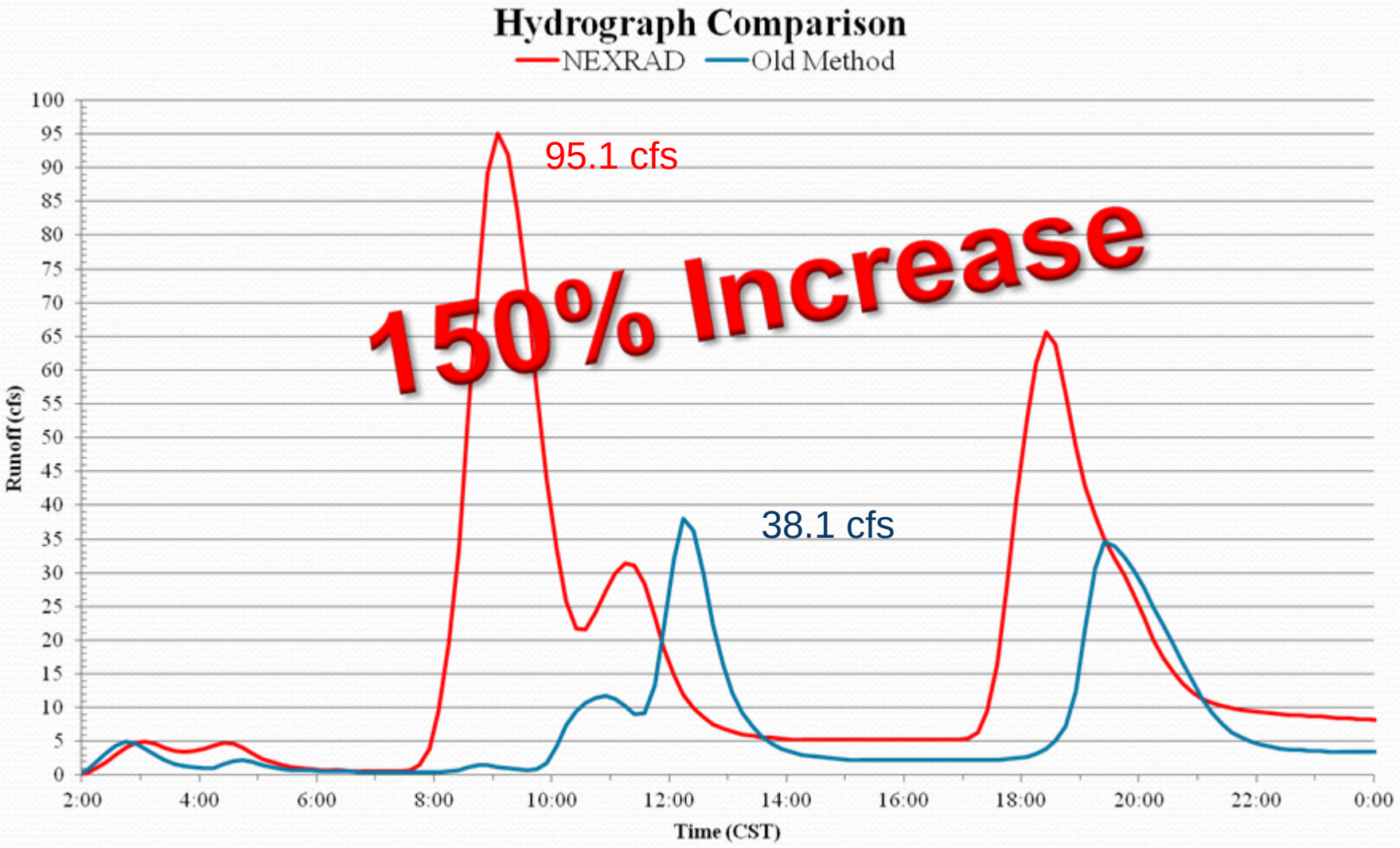
Adjusted Site Radar Rainfall



Hyetograph Differences



Hydrograph Differences



Runoff Impacts

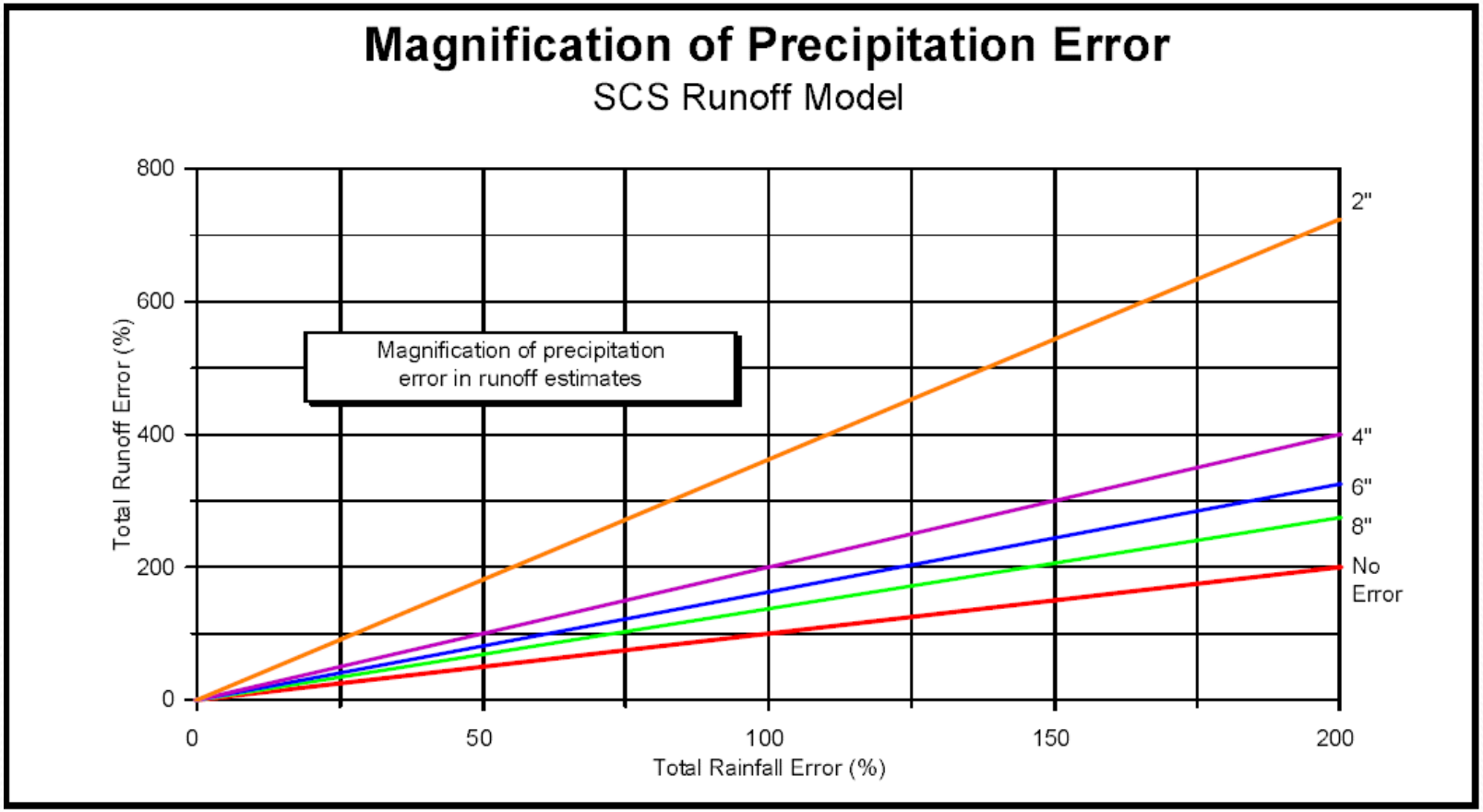


Figure 7: Errors in rainfall estimates produce relatively greater errors in runoff estimates.

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

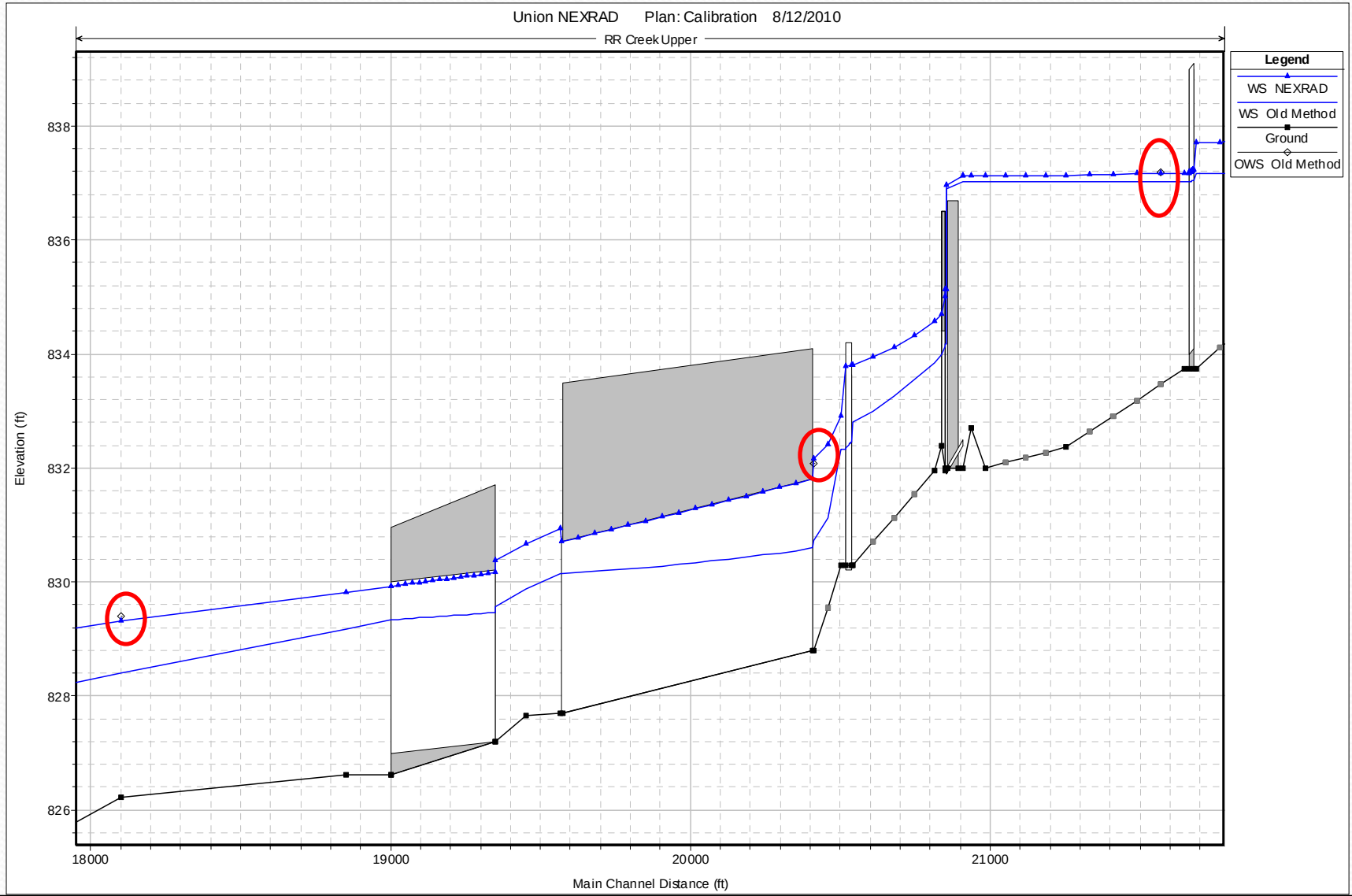
- Model at least two storms that vary in event size
  - 2 - 5 year event
  - 25 - 100+ year event
  - Normal flow
  - Low flow

- 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

ILLINOIS
DEPARTMENT OF
NATURAL
RESOURCES