Cool-Season PMP/PMF Meteorological Time Series for Snow Melt Calculations

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PMP Definition

The ***theoretically*** greatest depth of precipitation for a given duration that is ***physically possible*** over a given storm area at a particular ***geographic location*** at a certain time of year (HMR 59, 1999)

PMP Background

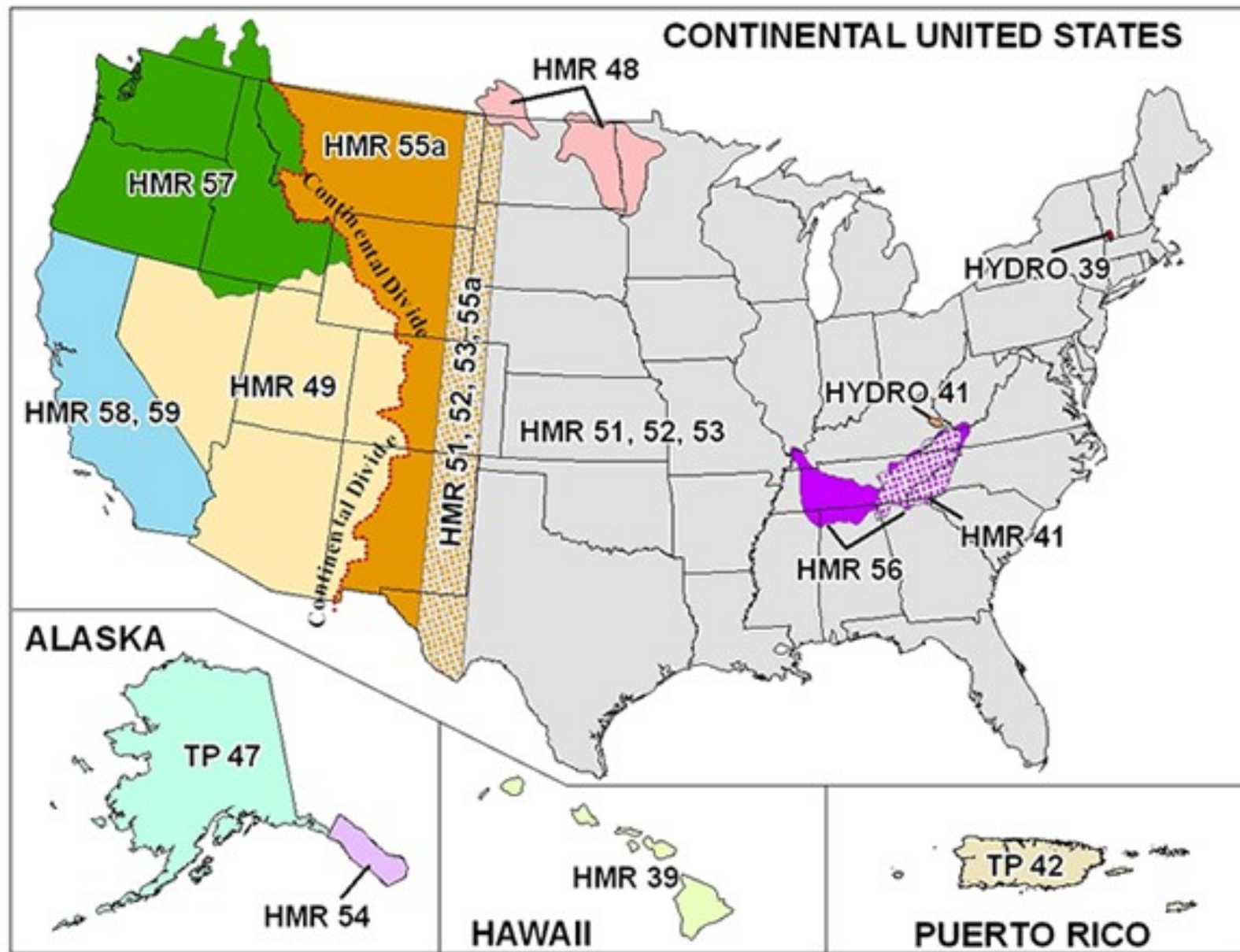- **T**ypes of PMP studies:
  - **G**eneralized (Hydrometeorological Reports)
    - Provides PMP values for a region
  - Regional/Statewide
    - Provide PMP values over regions with varying topography
    - Individual basins are included in the results
  - Site-Specific
    - Provides PMP values for individual drainage basins
    - Considers unique meteorology and topography

Coverage of HMRs

HMRs and Cool Season PMP

- Very little work done to define Cool-Season PMP
  - How much rain can fall on antecedent snowpack
- Lack of guidance on snowpack
  - Antecedent conditions
  - SWE amount
  - Ripeness
  - How much will melt, When, Where
- What AWA Does
- Follow same methods at all-season to derive cool-season specific PMP
  - Storm based approach
  - Based on data

Cool-Season PMP and Snowmelt

- Develop hourly meteorological time series
  - Input into snow budget/snow melt equations
  - Based on actual storm environments that occurred durin heavy cool-season rain events
- Provide Temperature, Dew Point, Wind Speed
  By Sub basin or elevation band
- Data availability limiting factor
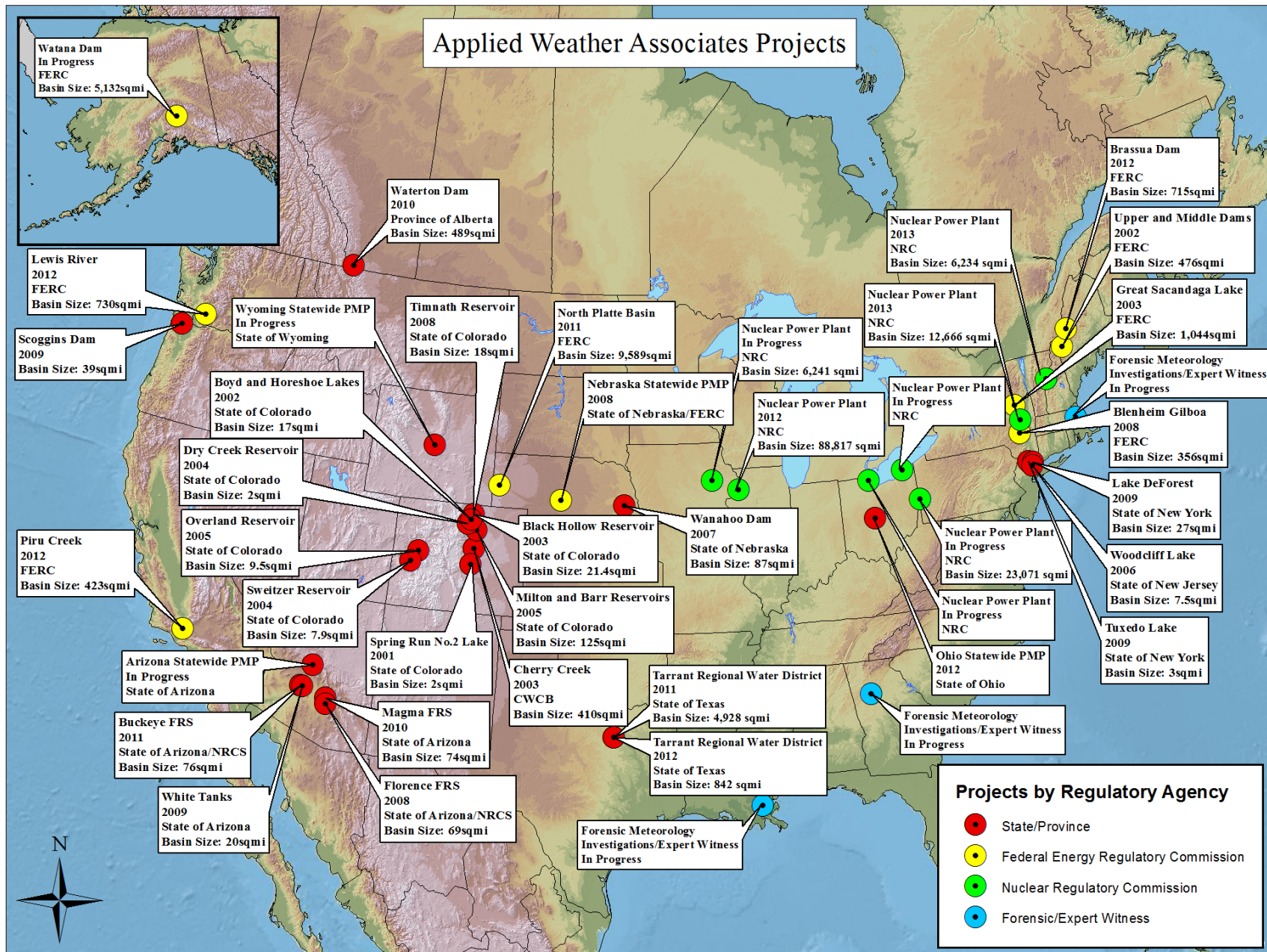 - Use all data sources
    - NWS, SNOTEL, RAWS, Yours…..

How Does AWA Compute PMP?

- Storm Based Approach
  - Similar to HMR/WMO procedures
  - Deterministic-but there is uncertainty
- Maintain consistency with AWA PMP studies
  - Improvements in understanding
  - Expanded database
  - Use of computer technologies
  - Use of NEXRAD weather radar
  - Better understanding of meteorology

Applied Weather Associates Projects

Watana Dam
In Progress
FERC
Basin Size: 5,132sqmi

Lewis River
2012
FERC
Basin Size: 730sqmi

Scoggins Dam
2009
Basin Size: 39sqmi

Waterton Dam
2010
Province of Alberta
Basin Size: 489sqmi

Wyoming Statewide PMP
In Progress
State of Wyoming

Timnath Reservoir
2008
State of Colorado
Basin Size: 18sqmi

North Platte Basin
2011
FERC
Basin Size: 9,589sqmi

Nebraska Statewide PMP
2008
State of Nebraska/FERC

Boyd and Horeshoe Lakes
2002
State of Colorado
Basin Size: 17sqmi

Dry Creek Reservoir
2004
State of Colorado
Basin Size: 2sqmi

Overland Reservoir
2005
State of Colorado
Basin Size: 9.5sqmi

Piru Creek
2012
FERC
Basin Size: 423sqmi

Sweitzer Reservoir
2004
State of Colorado
Basin Size: 7.9sqmi

Black Hollow Reservoir
2003
State of Colorado
Basin Size: 21.4sqmi

Wanahoo Dam
2007
State of Nebraska
Basin Size: 87sqmi

Arizona Statewide PMP
In Progress
State of Arizona

Spring Run No.2 Lake
2001
State of Colorado
Basin Size: 2sqmi

Milton and Barr Reservoirs
2005
State of Colorado
Basin Size: 125sqmi

Cherry Creek
2003
CWCB
Basin Size: 410sqmi

Buckeye FRS
2011
State of Arizona/NRCS
Basin Size: 76sqmi

Magma FRS
2010
State of Arizona
Basin Size: 74sqmi

White Tanks
2009
State of Arizona
Basin Size: 20sqmi

Florence FRS
2008
State of Arizona/NRCS
Basin Size: 69sqmi

Tarrant Regional Water District
2011
State of Texas
Basin Size: 4,928 sqmi

Tarrant Regional Water District
2012
State of Texas
Basin Size: 842 sqmi

**Forensic Meteorology
Investigations/Expert Witness**
In Progress

Brassua Dam
2012
FERC
Basin Size: 715sqmi

Upper and Middle Dams
2002
FERC
Basin Size: 476sqmi

Great Sacandaga Lake
2003
FERC
Basin Size: 1,044sqmi

Nuclear Power Plant
2013
NRC
Basin Size: 6,234 sqmi

Nuclear Power Plant
2013
NRC
Basin Size: 12,666 sqmi

Nuclear Power Plant
In Progress
NRC
Basin Size: 6,241 sqmi

Nuclear Power Plant
In Progress
NRC

Nuclear Power Plant
2012
NRC
Basin Size: 88,817 sqmi

**Forensic Meteorology
Investigations/Expert Witness**
In Progress

Blenheim Gilboa
2008
FERC
Basin Size: 356sqmi

Lake DeForest
2009
State of New York
Basin Size: 27sqmi

Woodcliff Lake
2006
State of New Jersey
Basin Size: 7.5sqmi

Nuclear Power Plant
In Progress
NRC
Basin Size: 23,071 sqmi

Nuclear Power Plant
In Progress
NRC

Ohio Statewide PMP
2012
State of Ohio

Tuxedo Lake
2009
State of New York
Basin Size: 3sqmi

**Forensic Meteorology
Investigations/Expert Witness**
In Progress

Projects by Regulatory Agency

- State/Province
- Federal Energy Regulatory Commission
- Nuclear Regulatory Commission
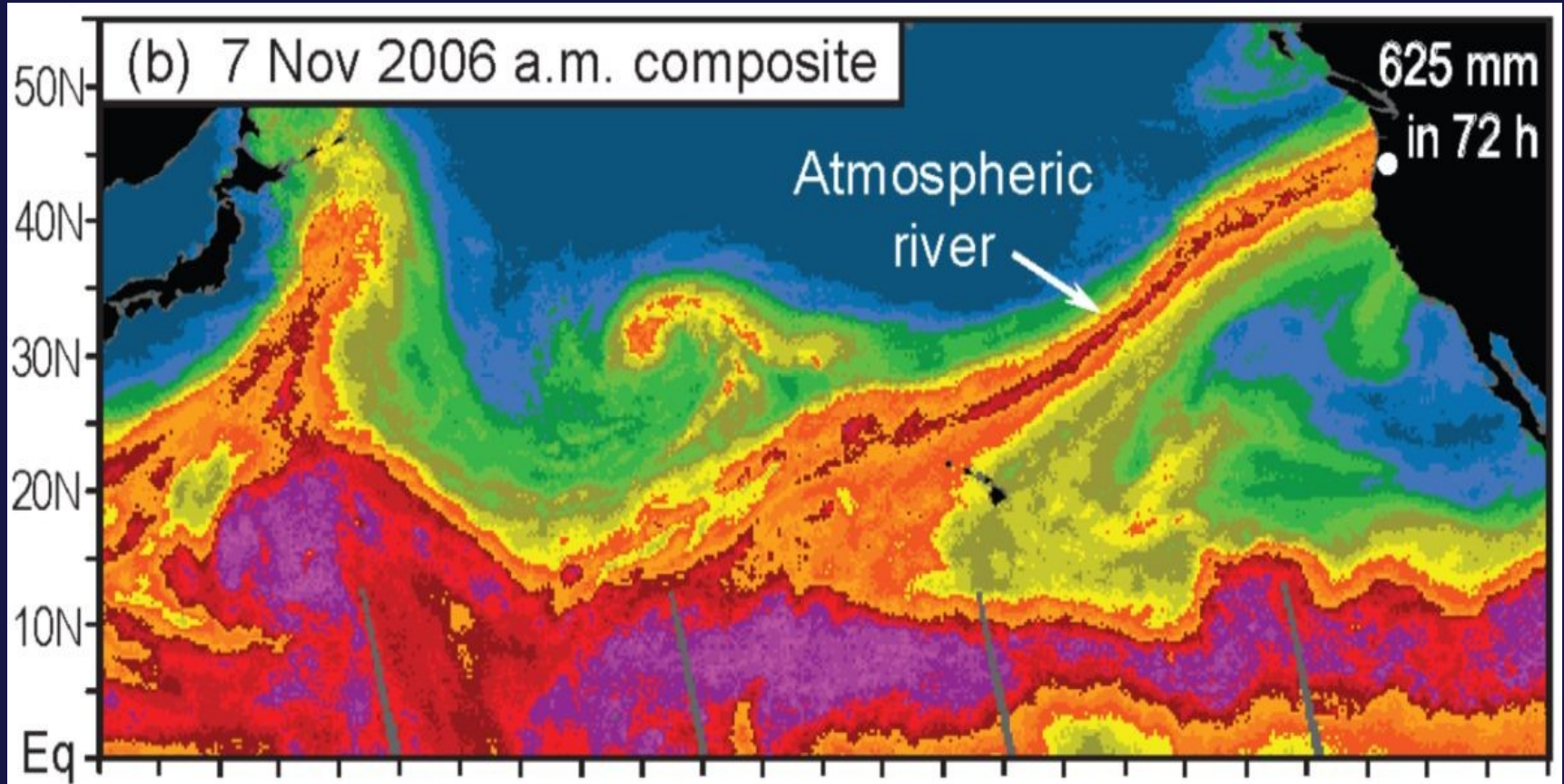- Forensic/Expert Witness

Example Analyses

- Lewis River, Washington Cascades
- Atmospheric River
  - Warm moisture feed from sub-tropics
  - Rain on antecedent snow over several days
  - All major floods in PacNW result from these
- Most common Nov-Feb
  - Earlier in season north, later south
- Infamous Storms
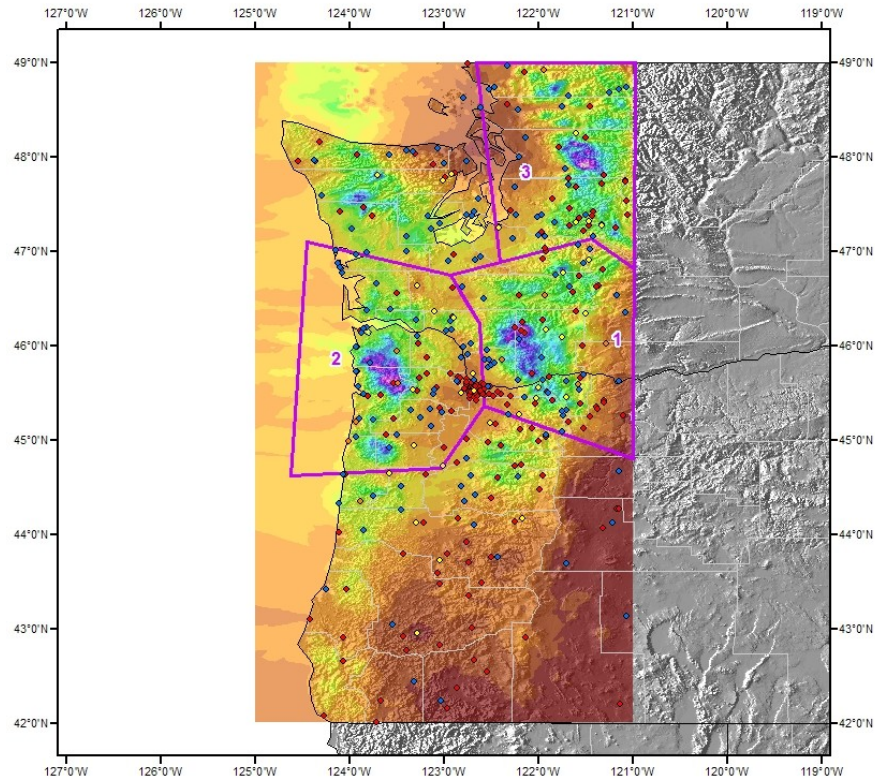 - December 1964
  - February 1996
  - November 2006

SPAS Storm Analysis

(b) 7 Nov 2006 a.m. composite

625 mm in 72 h

Atmospheric river

From http://www.esrl.noaa.gov/psd/atmrivers/

SPAS Storm Analysis
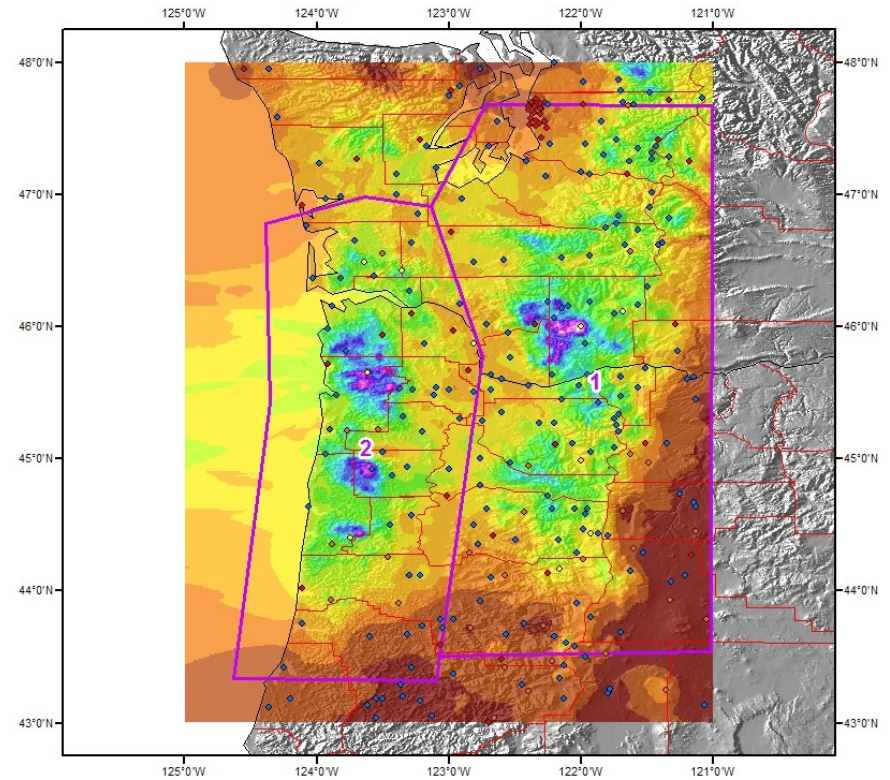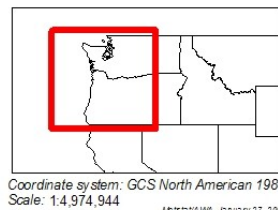

Total Rainfall (168-hours)
Lewis River 2006 Storm
Storm #1052 November 02 (0800 Z) to 09 (0800Z), 2006

Gauging Stations
- Daily
- Hourly
- Hourly Estimated
- Hourly Pseudo
- Supplemental

Miles
0 25 50 100
Kilometers
0 45 90 180 270

Precipitation (inches)
- 0.12 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 - 12.00
- 12.01 - 14.00
- 14.01 - 16.00
- 16.01 - 18.00
- 18.01 - 20.00
- 20.01 - 22.00
- 22.01 - 24.00
- 24.01 - 26.00
- 26.01 - 28.00
- 28.01 - 30.00
- 30.01 - 32.00
- 32.01 - 34.00
- 34.01 - 36.00
- 36.01 - 38.00
- 38.01 - 40.00

Coordinate system: GCS North American 1983
Scale: 1:4,974,944
Metstat/AWA January 27, 2009

Total Rainfall (96hours)
Lewis River, WA 1996 Storm
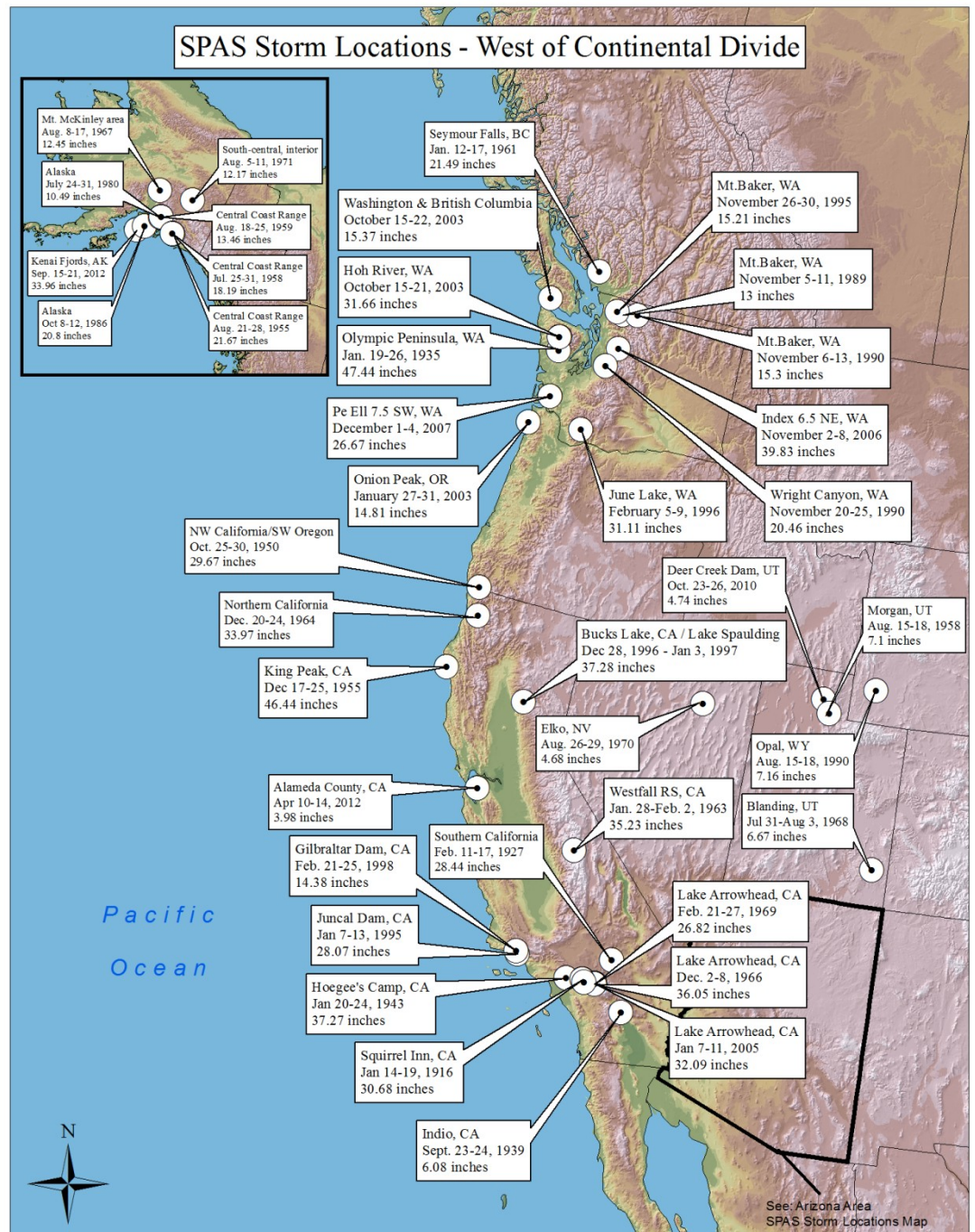Storm #1055 February 5 (0800 Z) to 9 (0800 Z), 1996

Gauging Stations
- D
- H
- HE
- HP
- S
- SE

Miles
0 20 40 80
Kilometers
0 30 60 120 180

Precipitation (inches)
- 0.08 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 - 12.00
- 12.01 - 14.00
- 14.01 - 16.00
- 16.01 - 18.00
- 18.01 - 20.00
- 20.01 - 22.00
- 22.01 - 24.00
- 24.01 - 26.00
- 26.01 - 28.00
- 28.01 - 30.00
- 30.01 - 32.00

Coordinate system: GCS North American 1983
Scale: 1:3,553,531
Metstat/AWA February 9, 2009

SPAS Storm Analysis Locations

SPAS Storm Locations - West of Continental Divide

Methods

- Lewis River, Washington Cascades
  - Temperature and Dew Point time series
  - Hourly data 144-hr
- Hourly and Daily stations used
  - Daily stations timed based on max, min, and observation time with closest hourly station
  - Linear lapse rate calculated from 0 to 5000ft
- KSLE radiosonde data
  - Lapse rate calculated from 0 to 12,000ft
- Blend station data and sounding data at 5000ft
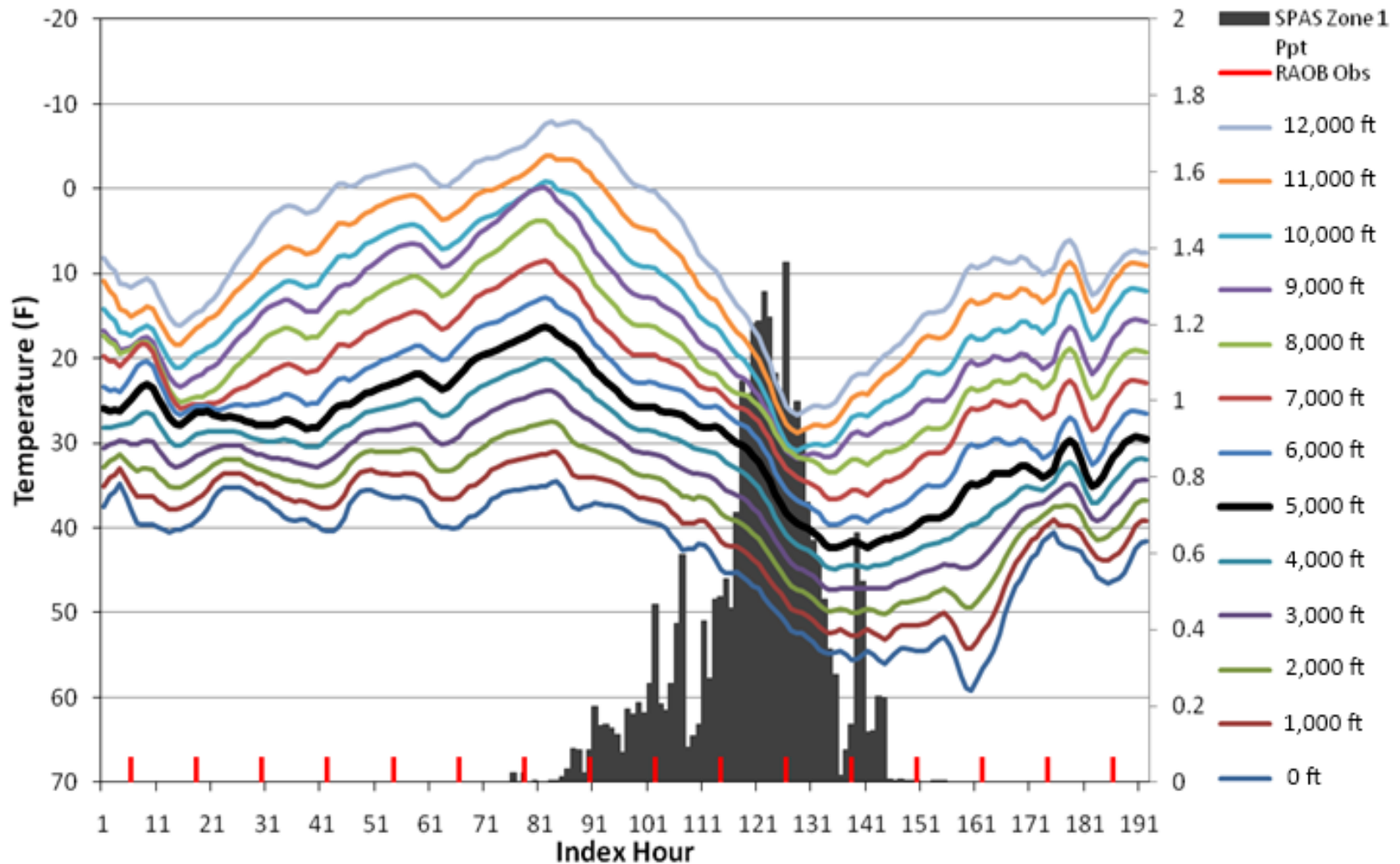
Stations Used-Basin Area
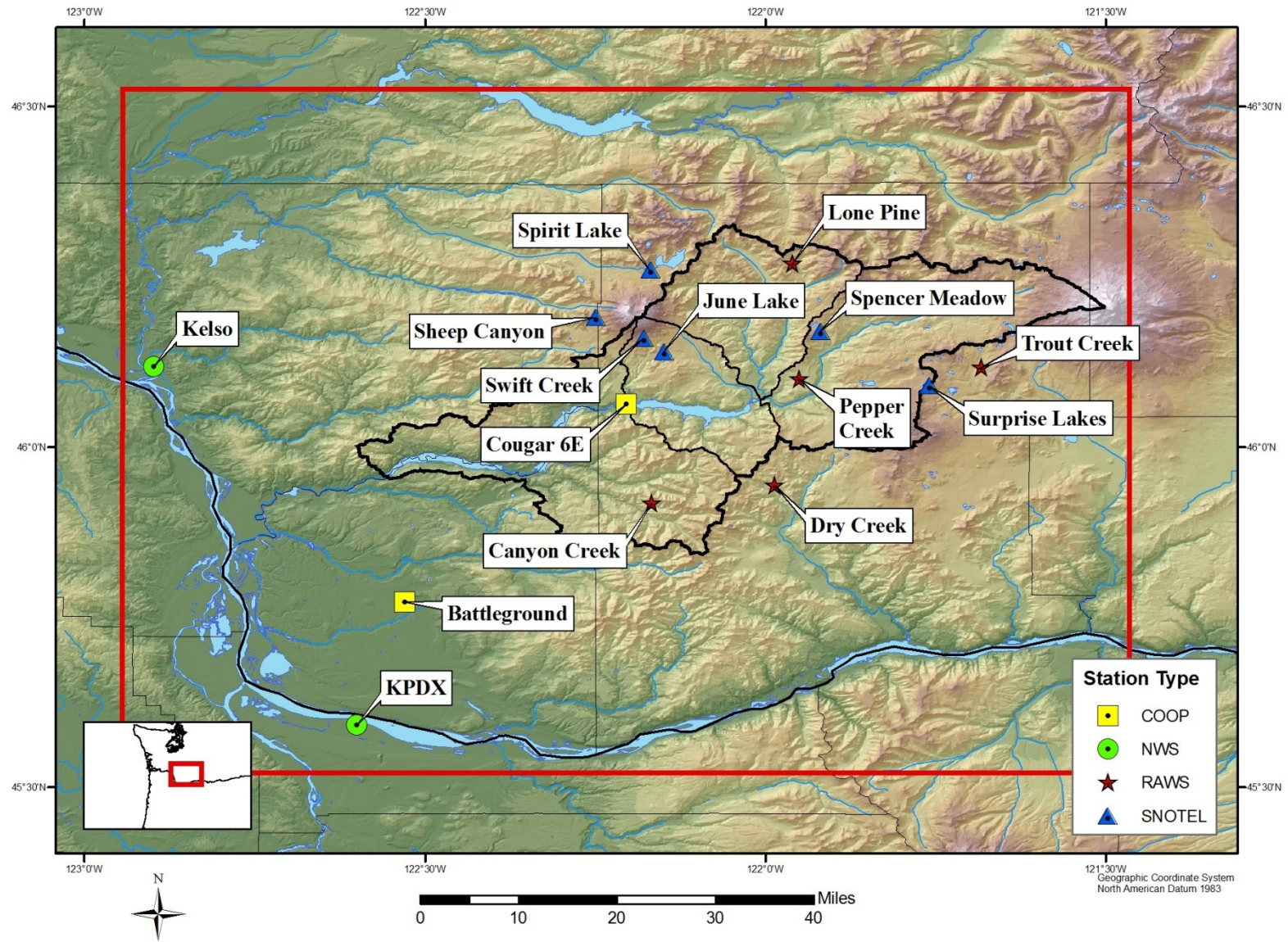
Meteorological Time Series

Example Analyses
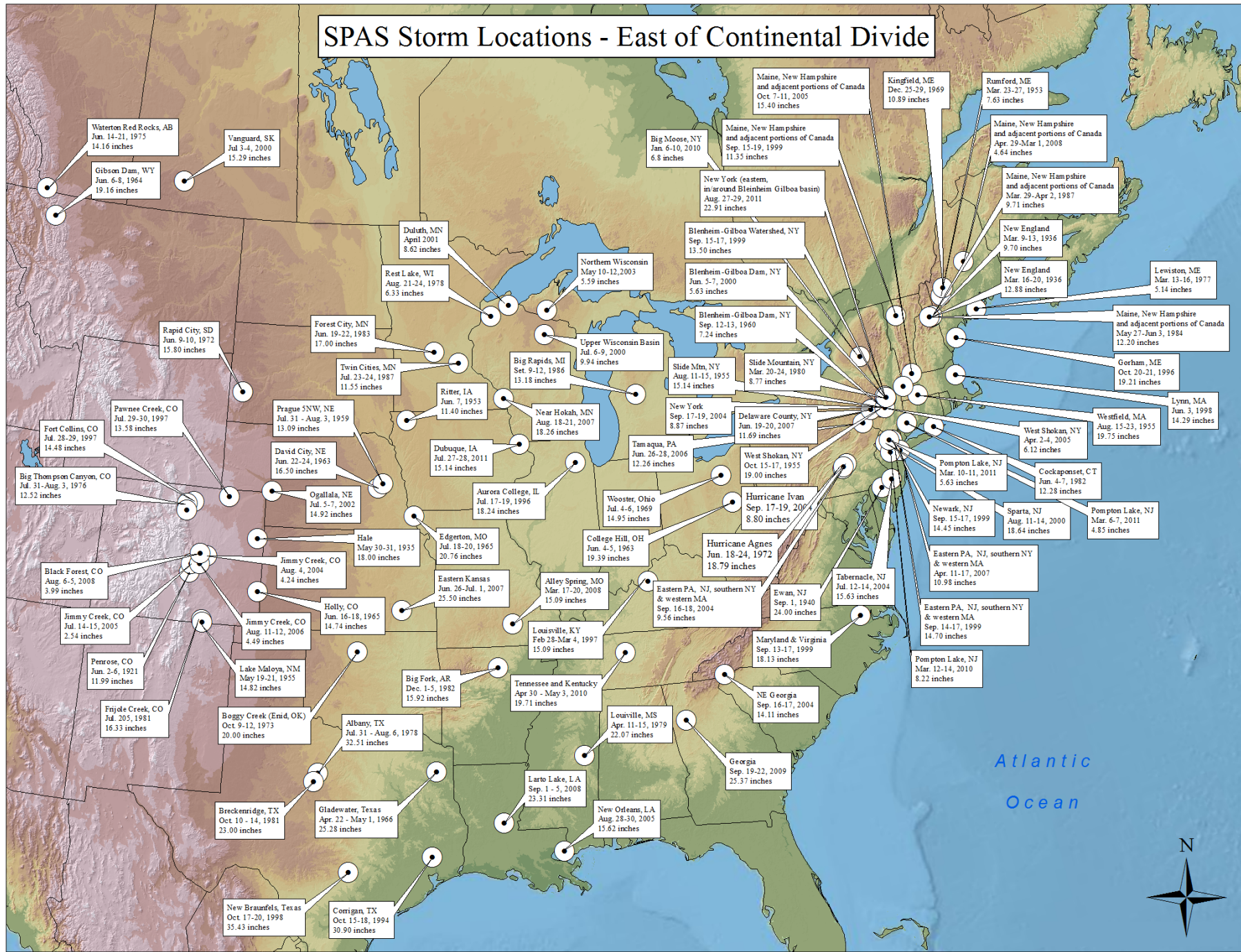
- Upper Mississippi River Basin
- Very Large basin ($90,000mi^2$)
  - Volume driven
  - Long time for flood wave to pass
- Synoptic storm pattern
  - Slow moving front-heavy rain on Spring snowpack
  - Deep flow of southerly moisture from the Gulf
- Infamous Storms
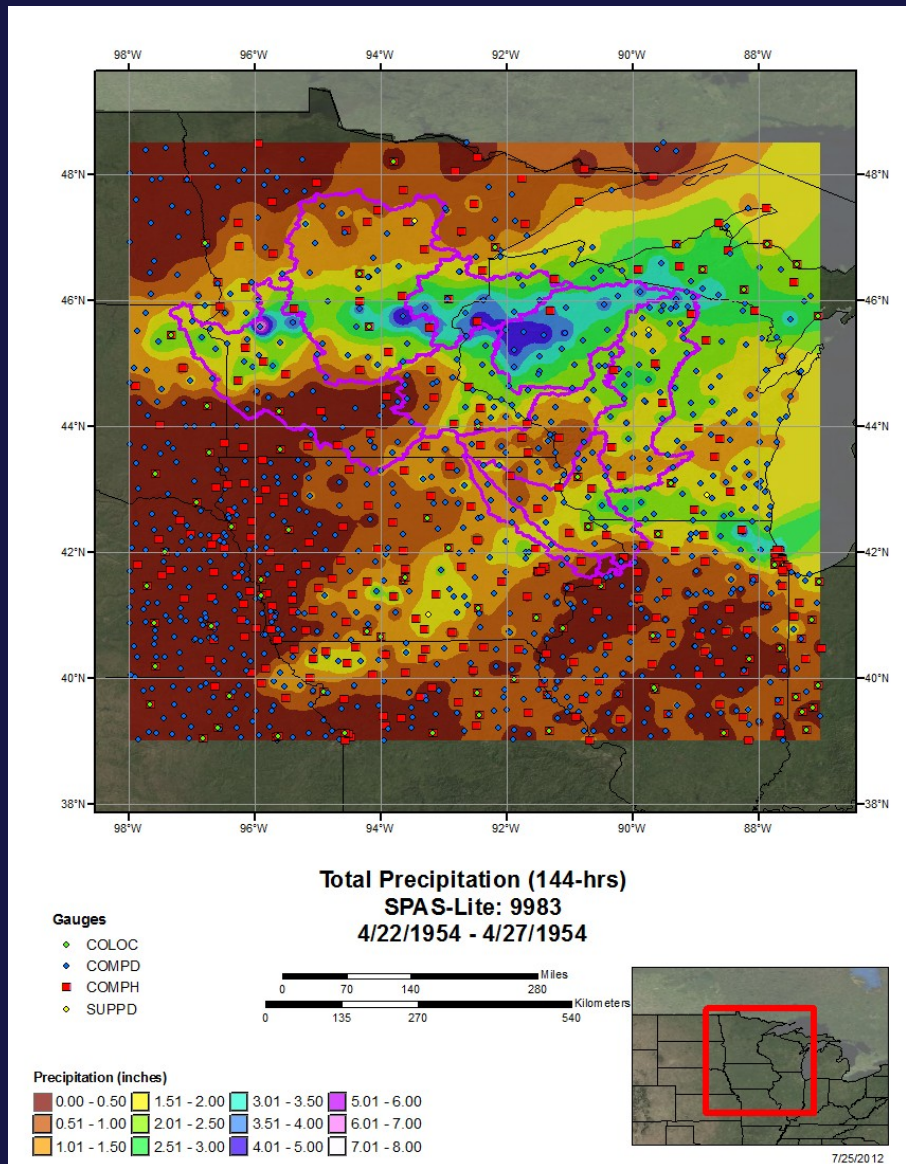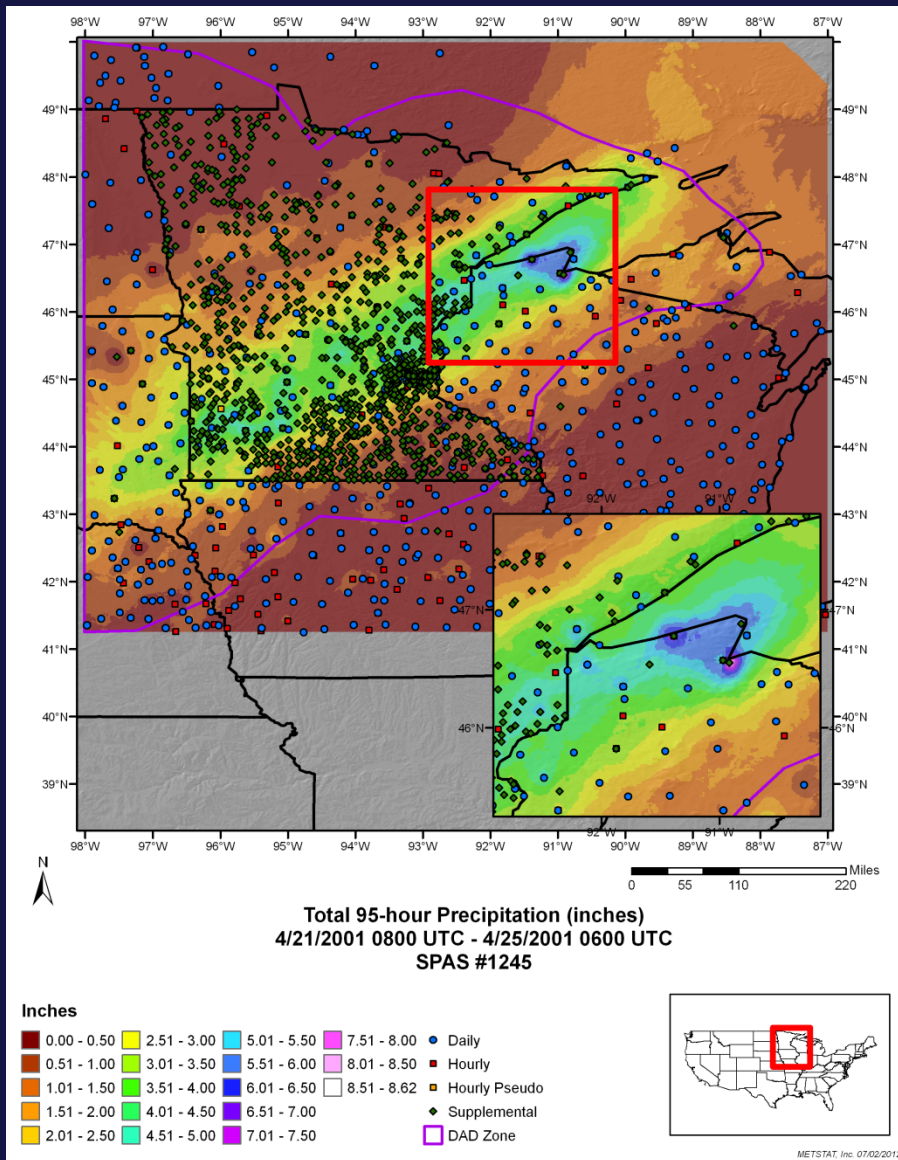 - April 1954
  - April 2001
  - May 2011

SPAS Storm Locations - East of Continental Divide

Waterton Red Rocks, AB
Jun. 14-21, 1975
14.16 inches

Vanguard, SK
Jul 3-4, 2000
15.29 inches

Gibson Dam, WY
Jun. 6-8, 1964
19.16 inches

Maine, New Hampshire
and adjacent portions of Canada
Oct. 7-11, 2005
15.40 inches

Kingfield, ME
Dec. 25-29, 1969
10.89 inches

Rumford, ME
Mar. 23-27, 1953
7.63 inches

Big Moose, NY
Jan. 6-10, 2010
6.8 inches

Maine, New Hampshire
and adjacent portions of Canada
Sep. 15-19, 1999
11.35 inches

Maine, New Hampshire
and adjacent portions of Canada
Apr. 29-Mar 1, 2008
4.64 inches

New York (eastern,
in/around Bleinheim Gilboa basin)
Aug. 27-29, 2011
22.91 inches

Maine, New Hampshire
and adjacent portions of Canada
Mar. 29-Apr 2, 1987
9.71 inches

Duluth, MN
April 2001
8.62 inches

Blenheim-Gilboa Watershed, NY
Sep. 15-17, 1999
13.50 inches

New England
Mar. 9-13, 1936
9.70 inches

Rest Lake, WI
Aug. 21-24, 1978
6.33 inches

Northern Wisconsin
May 10-12,2003
5.59 inches

Blenheim-Gilboa Dam, NY
Jun. 5-7, 2000
5.63 inches

New England
Mar. 16-20, 1936
12.88 inches

Lewiston, ME
Mar. 13-16, 1977
5.14 inches

Rapid City, SD
Jun. 9-10, 1972
15.80 inches

Forest City, MN
Jun. 19-22, 1983
17.00 inches

Upper Wisconsin Basin
Jul. 6-9, 2000
9.94 inches

Blenheim-Gilboa Dam, NY
Sep. 12-13, 1960
7.24 inches

Maine, New Hampshire
and adjacent portions of Canada
May 27-Jun 3, 1984
12.20 inches

Big Rapids, MI
Set. 9-12, 1986
13.18 inches

Slide Mtn, NY
Aug. 11-15, 1955
15.14 inches

Slide Mountain, NY
Mar. 20-24, 1980
8.77 inches

Gorham, ME
Oct. 20-21, 1996
19.21 inches

Twin Cities, MN
Jul. 23-24, 1987
11.55 inches

Pawnee Creek, CO
Jul. 29-30, 1997
13.58 inches

Prague 5NW, NE
Jul. 31 - Aug. 3, 1959
13.09 inches

Ritter, IA
Jun. 7, 1953
11.40 inches

Near Hokah, MN
Aug. 18-21, 2007
18.26 inches

New York
Sep. 17-19, 2004
8.87 inches

Delaware County, NY
Jun. 19-20, 2007
11.69 inches

West Shokan, NY
Apr. 2-4, 2005
6.12 inches

Westfield, MA
Aug. 15-23, 1955
19.75 inches

Lynn, MA
Jun. 3, 1998
14.29 inches

Fort Collins, CO
Jul. 28-29, 1997
14.48 inches

David City, NE
Jun. 22-24, 1963
16.50 inches

Dubuque, IA
Jul. 27-28, 2011
15.14 inches

Tamaqua, PA
Jun. 26-28, 2006
12.26 inches

West Shokan, NY
Oct. 15-17, 1955
19.00 inches

Pompton Lake, NJ
Mar. 10-11, 2011
5.63 inches

Cockaponset, CT
Jun. 4-7, 1982
12.28 inches

Big Thompson Canyon, CO
Jul. 31-Aug. 3, 1976
12.52 inches

Ogallala, NE
Jul. 5-7, 2002
14.92 inches

Aurora College, IL
Jul. 17-19, 1996
18.24 inches

Wooster, Ohio
Jul. 4-6, 1969
14.95 inches

Hurricane Ivan
Sep. 17-19, 2004
8.80 inches

Newark, NJ
Sep. 15-17, 1999
14.45 inches

Sparta, NJ
Aug. 11-14, 2000
18.64 inches

Pompton Lake, NJ
Mar. 6-7, 2011
4.85 inches

Black Forest, CO
Aug. 6-5, 2008
3.99 inches

Jimmy Creek, CO
Aug. 4, 2004
4.24 inches

Edgerton, MO
Jul. 18-20, 1965
20.76 inches

College Hill, OH
Jun. 4-5, 1963
19.39 inches

Hurricane Agnes
Jun. 18-24, 1972
18.79 inches

Eastern PA, NJ, southern NY
& western MA
Apr. 11-17, 2007
10.98 inches

Jimmy Creek, CO
Jul. 14-15, 2005
2.54 inches

Hale
May 30-31, 1935
18.00 inches

Eastern Kansas
Jun. 26-Jul. 1, 2007
25.50 inches

Alley Spring, MO
Mar. 17-20, 2008
15.09 inches

Eastern PA, NJ, southern NY
& western MA
Sep. 16-18, 2004
9.56 inches

Ewan, NJ
Sep. 1, 1940
24.00 inches

Tabernacle, NJ
Jul. 12-14, 2004
15.63 inches

Eastern PA, NJ, southern NY
& western MA
Sep. 14-17, 1999
14.70 inches

Penrose, CO
Jun. 2-6, 1921
11.99 inches

Jimmy Creek, CO
Aug. 11-12, 2006
4.49 inches

Holly, CO
Jun. 16-18, 1965
14.74 inches

Louisville, KY
Feb 28-Mar 4, 1997
15.09 inches

Maryland & Virginia
Sep. 13-17, 1999
18.13 inches

Pompton Lake, NJ
Mar. 12-14, 2010
8.22 inches

Frijole Creek, CO
Jul. 205, 1981
16.33 inches

Lake Maloya, NM
May 19-21, 1955
14.82 inches

Big Fork, AR
Dec. 1-5, 1982
15.92 inches

Tennessee and Kentucky
Apr 30 - May 3, 2010
19.71 inches

NE Georgia
Sep. 16-17, 2004
14.11 inches

Boggy Creek (Enid, OK)
Oct. 9-12, 1973
20.00 inches

Albany, TX
Jul. 31 - Aug. 6, 1978
32.51 inches

Louisville, MS
Apr. 11-15, 1979
22.07 inches

Georgia
Sep. 19-22, 2009
25.37 inches

Breckenridge, TX
Oct. 10 - 14, 1981
23.00 inches

Gladewater, Texas
Apr. 22 - May 1, 1966
25.28 inches

Larto Lake, LA
Sep. 1 - 5, 2008
23.31 inches

New Orleans, LA
Aug. 28-30, 2005
15.62 inches

New Braunfels, Texas
Oct. 17-20, 1998
35.43 inches

Corrigan, TX
Oct. 15-18, 1994
30.90 inches

Atlantic

Ocean

N

SPAS Storm Analysis

Total 95-hour Precipitation (inches)
4/21/2001 0800 UTC - 4/25/2001 0600 UTC
SPAS #1245

Inches

0.00 - 0.50	2.51 - 3.00	5.01 - 5.50	7.51 - 8.00	● Daily
0.51 - 1.00	3.01 - 3.50	5.51 - 6.00	8.01 - 8.50	■ Hourly
1.01 - 1.50	3.51 - 4.00	6.01 - 6.50	8.51 - 8.62	■ Hourly Pseudo
1.51 - 2.00	4.01 - 4.50	6.51 - 7.00		◆ Supplemental
2.01 - 2.50	4.51 - 5.00	7.01 - 7.50		▭ DAD Zone

METSTAT, Inc. 07/02/2012

Total Precipitation (144-hrs)
SPAS-Lite: 9983
4/22/1954 - 4/27/1954

Gauges
◆ COLOC
● COMPD
■ COMPH
◆ SUPPD

Precipitation (inches)

0.00 - 0.50	1.51 - 2.00	3.01 - 3.50	5.01 - 6.00
0.51 - 1.00	2.01 - 2.50	3.51 - 4.00	6.01 - 7.00
1.01 - 1.50	2.51 - 3.00	4.01 - 5.00	7.01 - 8.00

7/25/2012

Methods

- Upper Mississippi River Basin
  - Temperature, dew point, and wind speed
  - Hourly data 120-hr and 30 day daily data
  - Based on sub-basins

- Hourly and Daily stations used
  - Daily stations timed based on max, min, and observation time with closest hourly station
  - No lapse rate calculated (elevation not important)

Stations Used-Basin Area
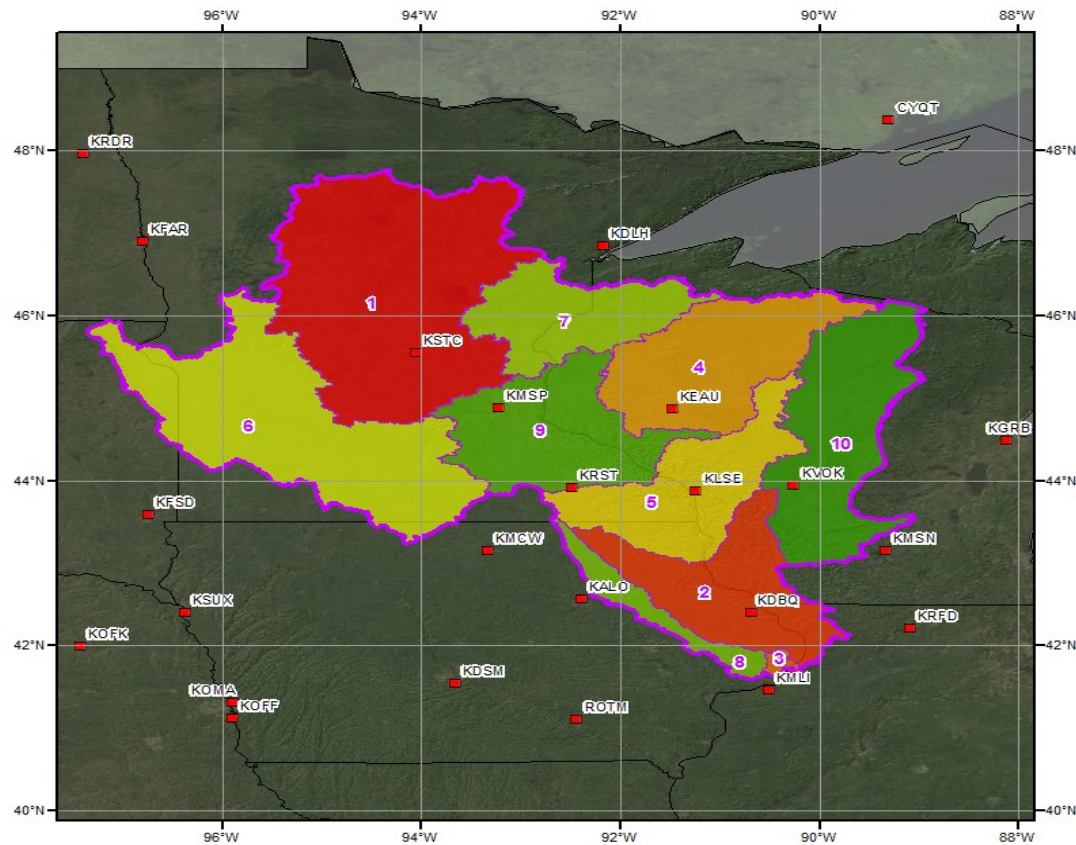
Quad Cities Nuclear Generating Station
April 1-30, 1965 Stations

Gauges
- April 1965 Timeseries Stns

Quad City Sub-Basins
1 3 5 7 9
2 4 6 8 10
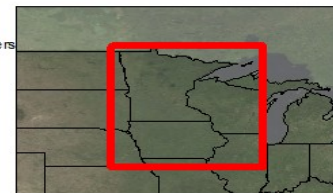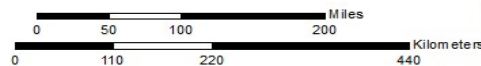
Meteorological Time Series

Example Analyses

- Brassua Dam, Maine

- Snow pack ripe for runoff by Spring

- Synoptic storm pattern
  - Slow moving front-heavy rain on Spring snowpack
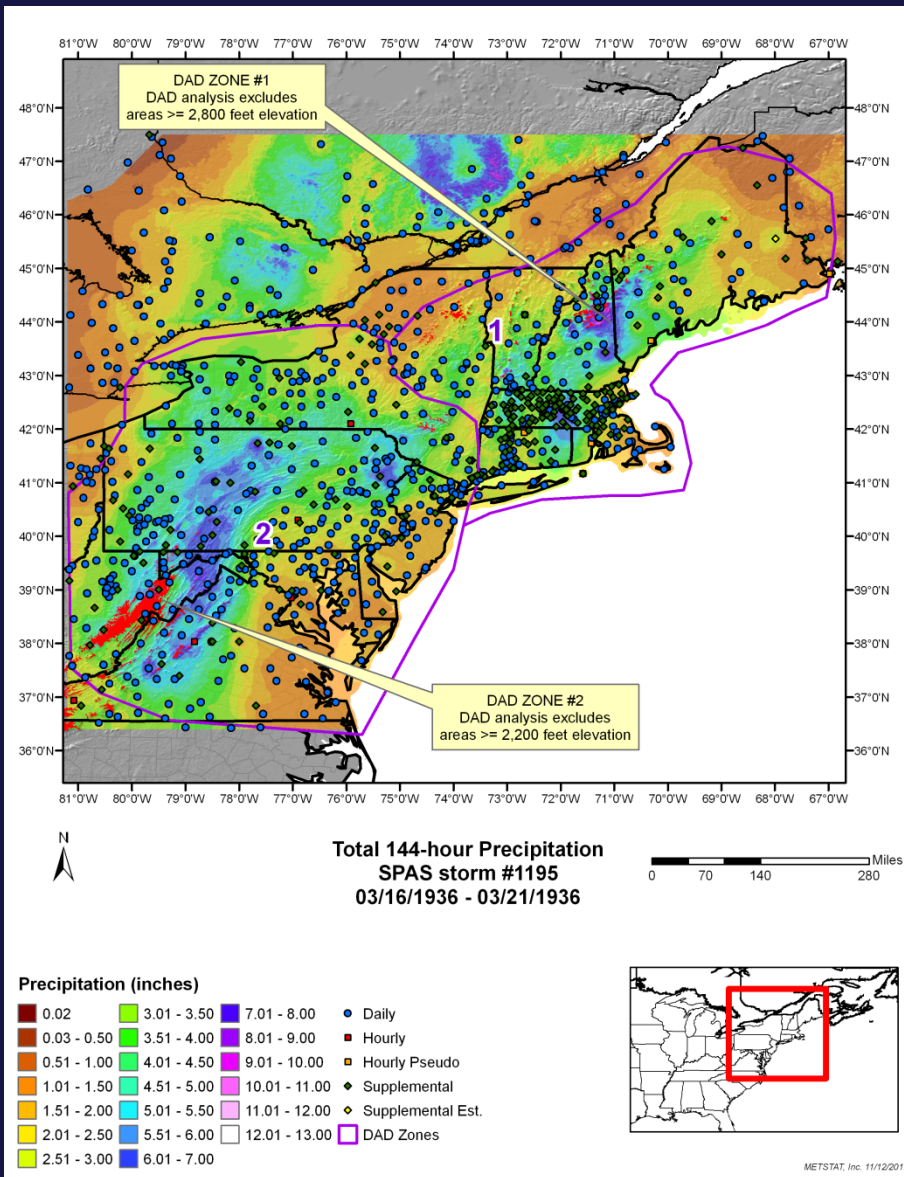 - Deep flow of moisture from the Gulf/Atlantic

- Infamous Storms
  - March 1936
  - April 1987
  - April 2008
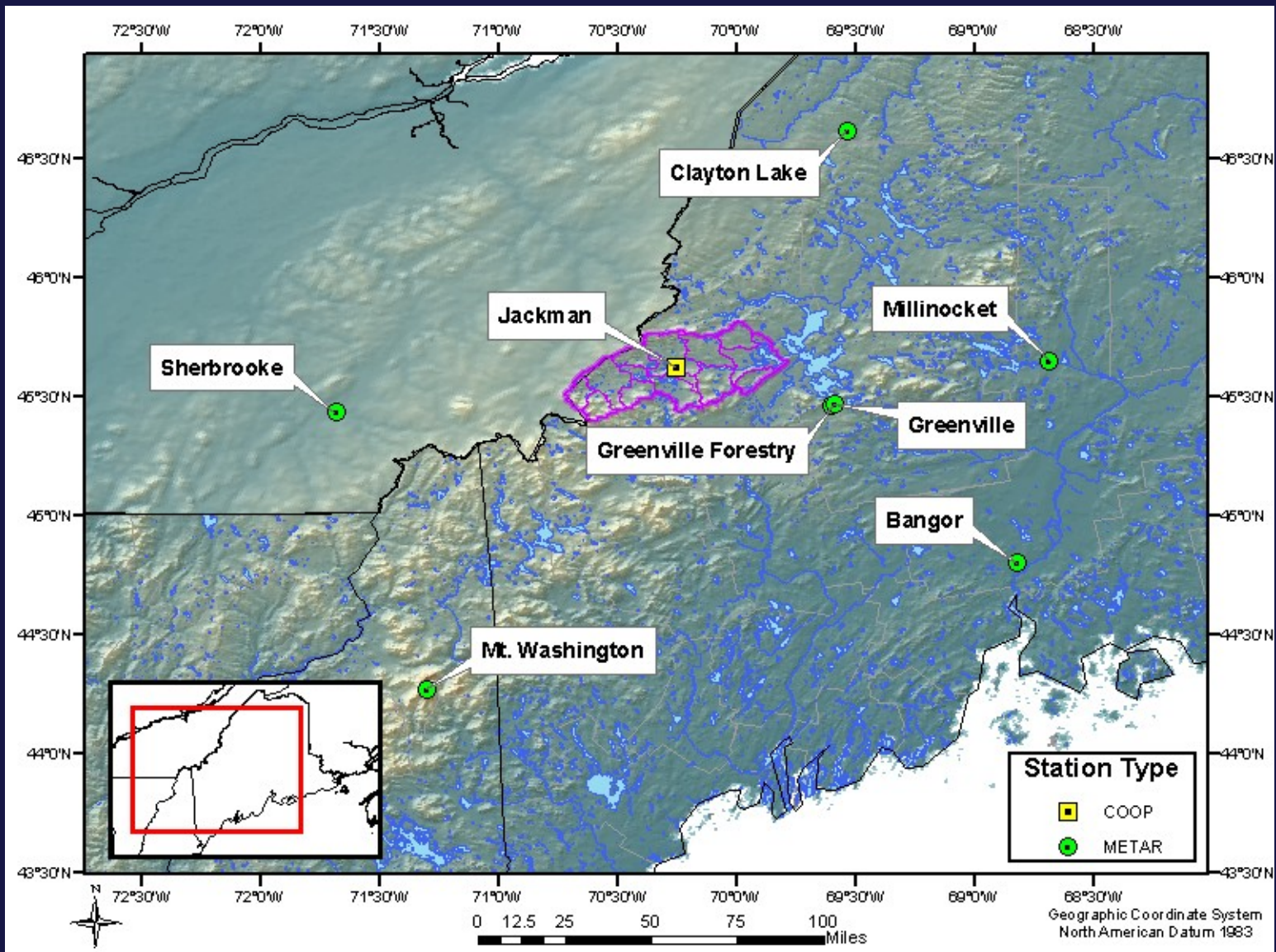
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Waterton Red Rocks, AB
Jun. 14-21, 1975
14.16 inches

Vanguard, SK
Jul 3-4, 2000
15.29 inches

Gibson Dam, WY
Jun. 6-8, 1964
19.16 inches

Maine, New Hampshire
and adjacent portions of Canada
Oct. 7-11, 2005
15.40 inches

Kingfield, ME
Dec. 25-29, 1969
10.89 inches

Rumford, ME
Mar. 23-27, 1953
7.63 inches

Maine, New Hampshire
and adjacent portions of Canada
Apr. 29-Mar 1, 2008
4.64 inches

Big Moose, NY
Jan. 6-10, 2010
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Maine, New Hampshire
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Maine, New Hampshire
and adjacent portions of Canada
May 27-Jun 3, 1984
12.20 inches

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Jul. 6-9, 2000
9.94 inches

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Set. 9-12, 1986
13.18 inches

Slide Mtn, NY
Aug. 11-15, 1955
15.14 inches

Slide Mountain, NY
Mar. 20-24, 1980
8.77 inches

Gorham, ME
Oct. 20-21, 1996
19.21 inches

Twin Cities, MN
Jul. 23-24, 1987
11.55 inches

Pawnee Creek, CO
Jul. 29-30, 1997
13.58 inches

Ritter, IA
Jun. 7, 1953
11.40 inches

New York
Sep. 17-19, 2004
8.87 inches

West Shokan, NY
Apr. 2-4, 2005
6.12 inches

Westfield, MA
Aug. 15-23, 1955
19.75 inches

Prague 5NW, NE
Jul. 31 - Aug. 3, 1959
13.09 inches

Near Hokah, MN
Aug. 18-21, 2007
18.26 inches

Delaware County, NY
Jun. 19-20, 2007
11.69 inches

Lynn, MA
Jun. 3, 1998
14.29 inches

Fort Collins, CO
Jul. 28-29, 1997
14.48 inches

David City, NE
Jun. 22-24, 1963
16.50 inches

Dubuque, IA
Jul. 27-28, 2011
15.14 inches

Tamaqua, PA
Jun. 26-28, 2006
12.26 inches

West Shokan, NY
Oct. 15-17, 1955
19.00 inches

Pompton Lake, NJ
Mar. 10-11, 2011
5.63 inches

Cockaponset, CT
Jun. 4-7, 1982
12.28 inches

Big Thompson Canyon, CO
Jul. 31-Aug. 3, 1976
12.52 inches

Ogallala, NE
Jul. 5-7, 2002
14.92 inches

Aurora College, IL
Jul. 17-19, 1996
18.24 inches

Wooster, Ohio
Jul. 4-6, 1969
14.95 inches

Hurricane Ivan
Sep. 17-19, 2004
8.80 inches

Newark, NJ
Sep. 15-17, 1999
14.45 inches

Pompton Lake, NJ
Mar. 6-7, 2011
4.85 inches

Black Forest, CO
Aug. 6-5, 2008
3.99 inches

Hale
May 30-31, 1935
18.00 inches

Edgerton, MO
Jul. 18-20, 1965
20.76 inches

College Hill, OH
Jun. 4-5, 1963
19.39 inches

Hurricane Agnes
Jun. 18-24, 1972
18.79 inches

Sparta, NJ
Aug. 11-14, 2000
18.64 inches

Jimmy Creek, CO
Aug. 4, 2004
4.24 inches

Eastern Kansas
Jun. 26-Jul. 1, 2007
25.50 inches

Alley Spring, MO
Mar. 17-20, 2008
15.09 inches

Eastern PA, NJ, southern NY
& western MA
Sep. 16-18, 2004
9.56 inches

Ewan, NJ
Sep. 1, 1940
24.00 inches

Eastern PA, NJ, southern NY
& western MA
Apr. 11-17, 2007
10.98 inches

Jimmy Creek, CO
Jul. 14-15, 2005
2.54 inches

Holly, CO
Jun. 16-18, 1965
14.74 inches

Louisville, KY
Feb 28-Mar 4, 1997
15.09 inches

Maryland & Virginia
Sep. 13-17, 1999
18.13 inches

Tabernacle, NJ
Jul. 12-14, 2004
15.63 inches

Eastern PA, NJ, southern NY
& western MA
Sep. 14-17, 1999
14.70 inches

Jimmy Creek, CO
Aug. 11-12, 2006
4.49 inches

Penrose, CO
Jun. 2-6, 1921
11.99 inches

Lake Maloya, NM
May 19-21, 1955
14.82 inches

Big Fork, AR
Dec. 1-5, 1982
15.92 inches

Tennessee and Kentucky
Apr 30 - May 3, 2010
19.71 inches

NE Georgia
Sep. 16-17, 2004
14.11 inches

Pompton Lake, NJ
Mar. 12-14, 2010
8.22 inches

Frijole Creek, CO
Jul. 205, 1981
16.33 inches

Boggy Creek (Enid, OK)
Oct. 9-12, 1973
20.00 inches

Albany, TX
Jul. 31 - Aug. 6, 1978
32.51 inches

Louiville, MS
Apr. 11-15, 1979
22.07 inches

Georgia
Sep. 19-22, 2009
25.37 inches

Larto Lake, LA
Sep. 1 - 5, 2008
23.31 inches

Breckenridge, TX
Oct. 10 - 14, 1981
23.00 inches

Gladewater, Texas
Apr. 22 - May 1, 1966
25.28 inches

New Orleans, LA
Aug. 28-30, 2005
15.62 inches

New Braunfels, Texas
Oct. 17-20, 1998
35.43 inches

Corrigan, TX
Oct. 15-18, 1994
30.90 inches

Atlantic

Ocean

N

SPAS Storm Analysis

Total 144-hour Precipitation
SPAS storm #1195
03/16/1936 - 03/21/1936

Total Precipitation
SPAS storm number: 1202
04/28/2008 0900 UTC - 04/30/2008 0800 UTC

Stations Used-Basin Area
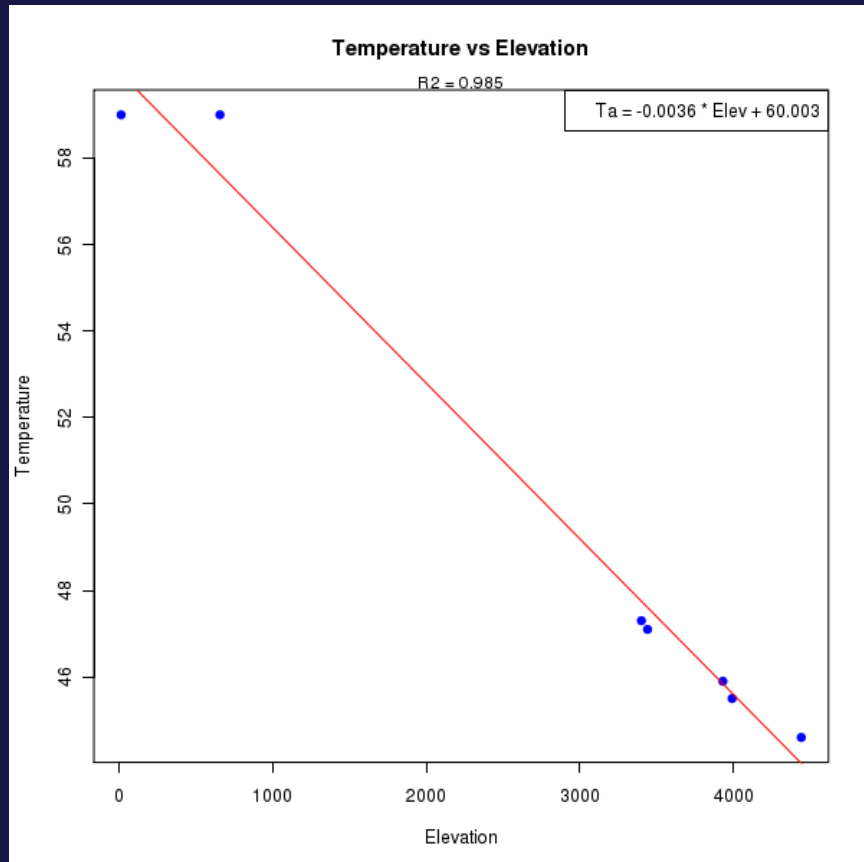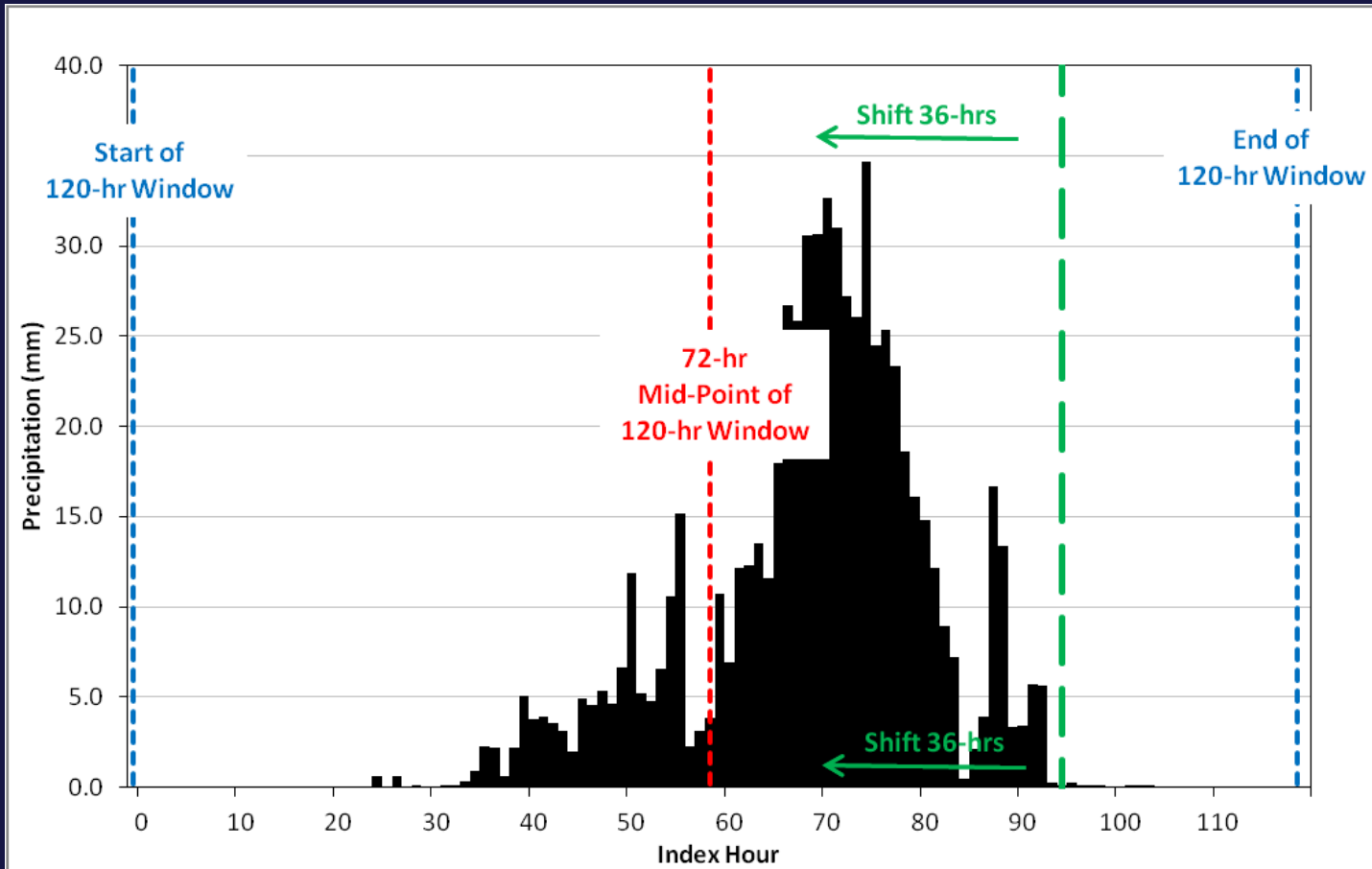
Methods

- Brassua Dam, Maine
    - Temperature and dew point
    - Hourly data 120-hr
- Hourly and Daily stations used
    - Daily stations timed based on max, min, and observation time with closest hourly station
    - Lapse rate calculated based on station data
- No radiosonde data-Mt Washington data

Methods
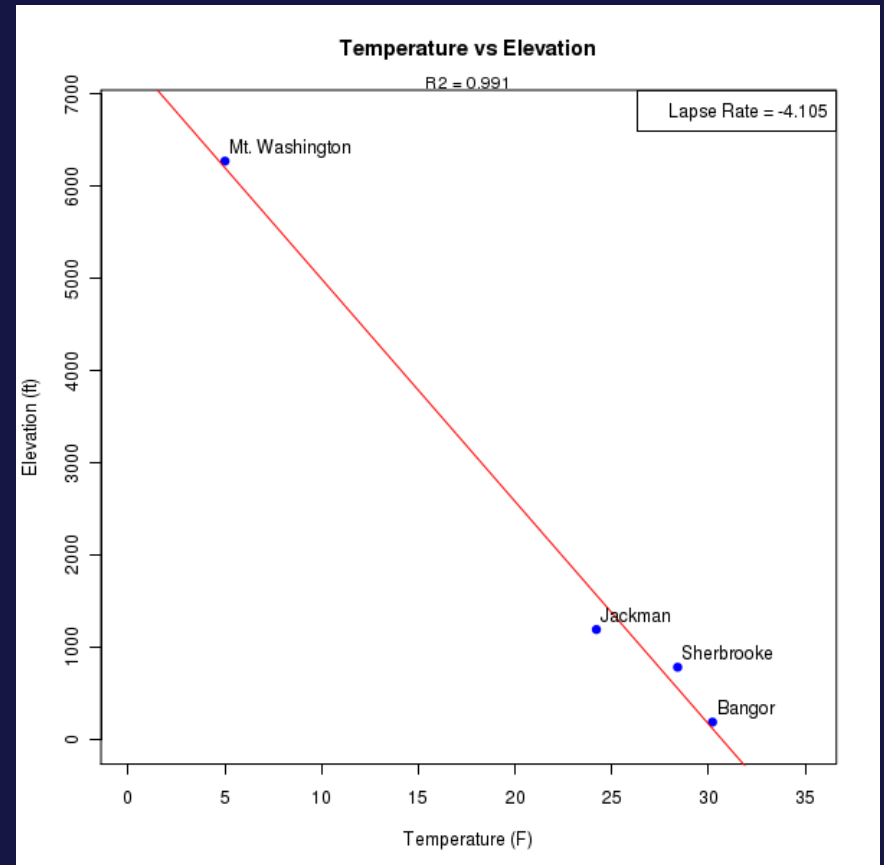
Methods

Meteorological Time Series

Storm: SPAS 1199
3/24/1987 (1200) - 4/3/1987 (1100)
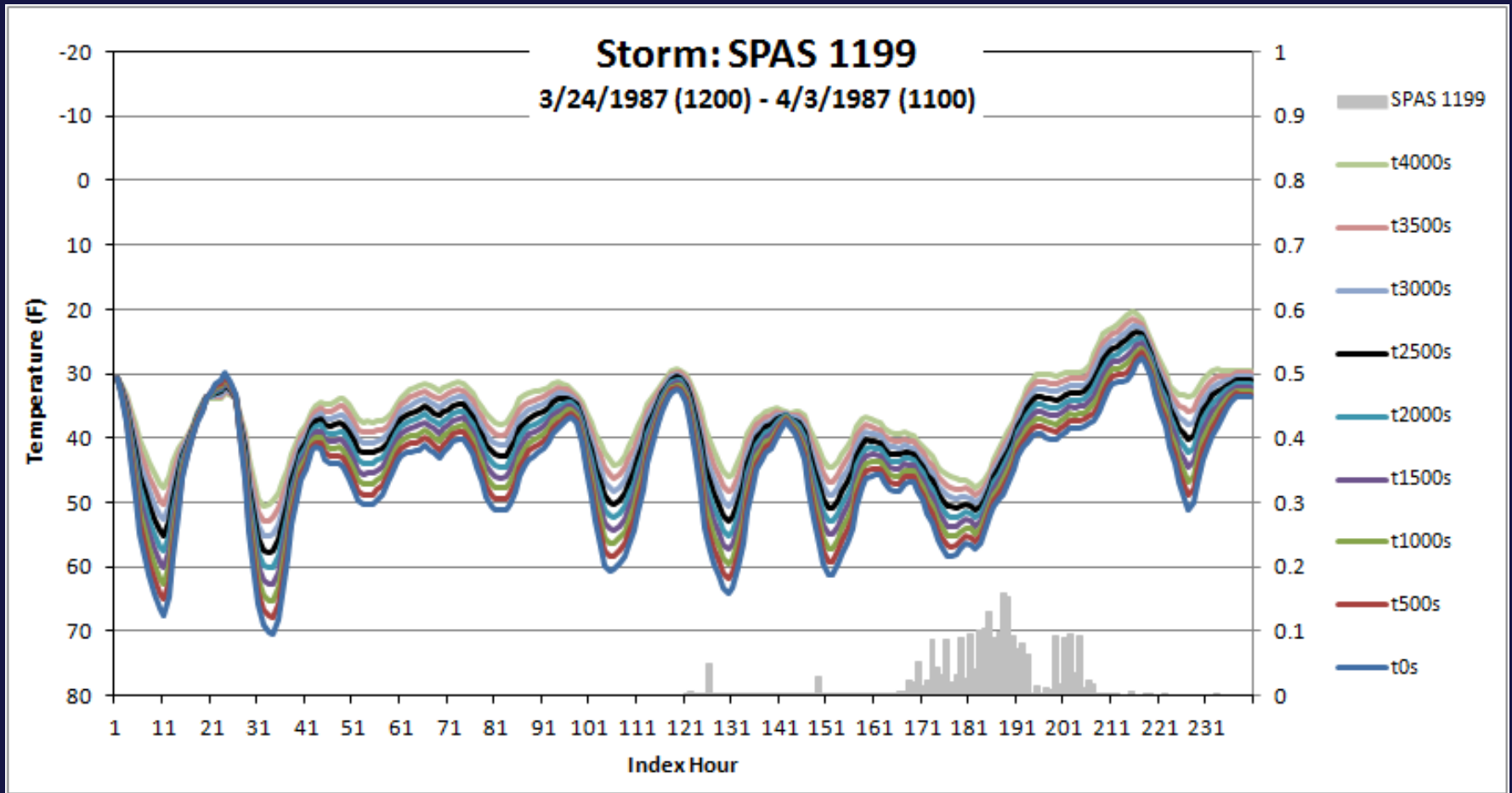
Example Analyses

- Susitna-Watana Dam, Alaska
- Snow pack ripe for runoff by Spring
- Atmospheric River type events
- Late spring to early summer
  - Heavy rain on deep snowpack
  - Deep flow of moisture from the Gulf of Alaska
- Infamous Storms

SPAS Storm Analysis Locations

SPAS Storm Locations - West of Continental Divide
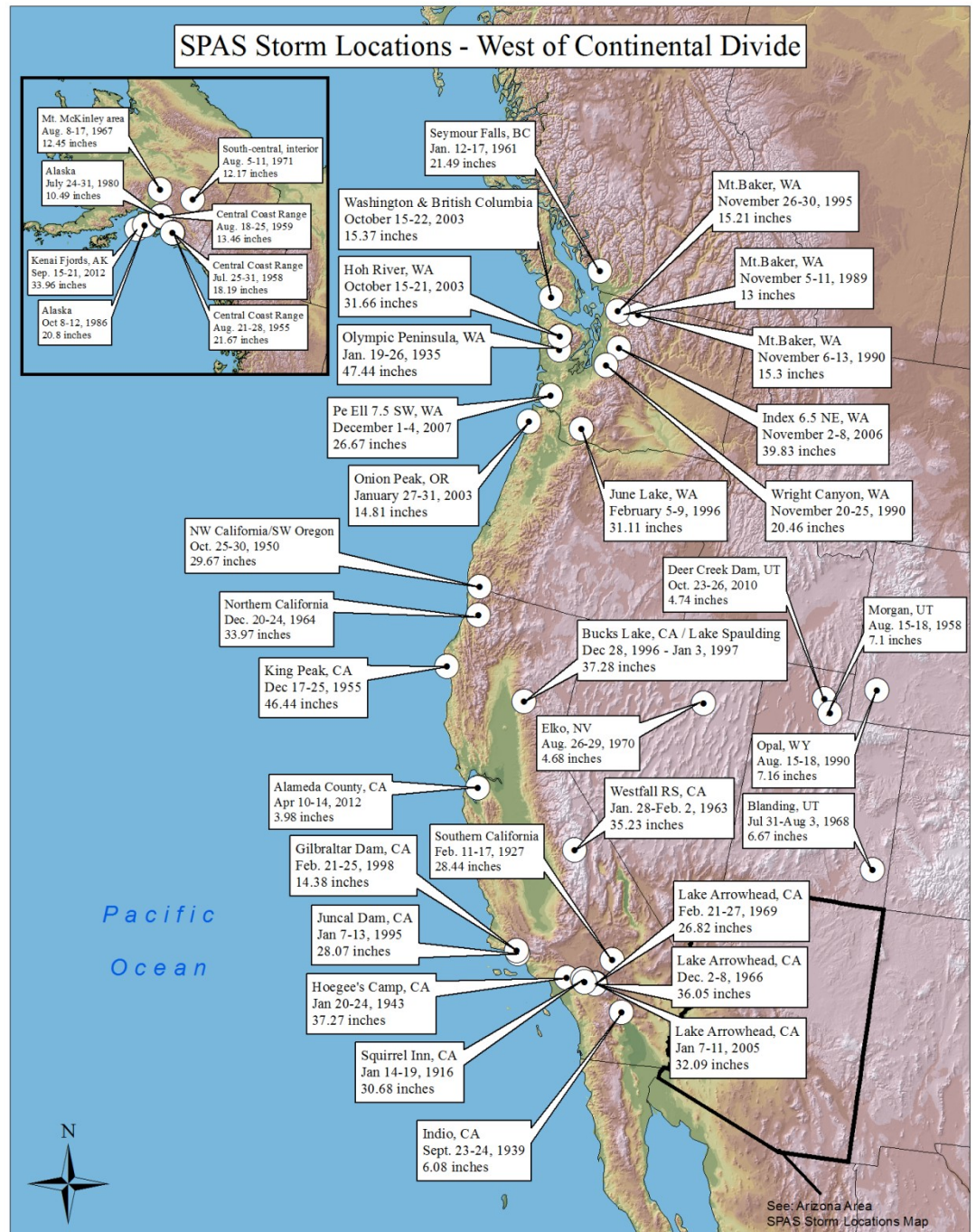
SPAS Storm Analysis
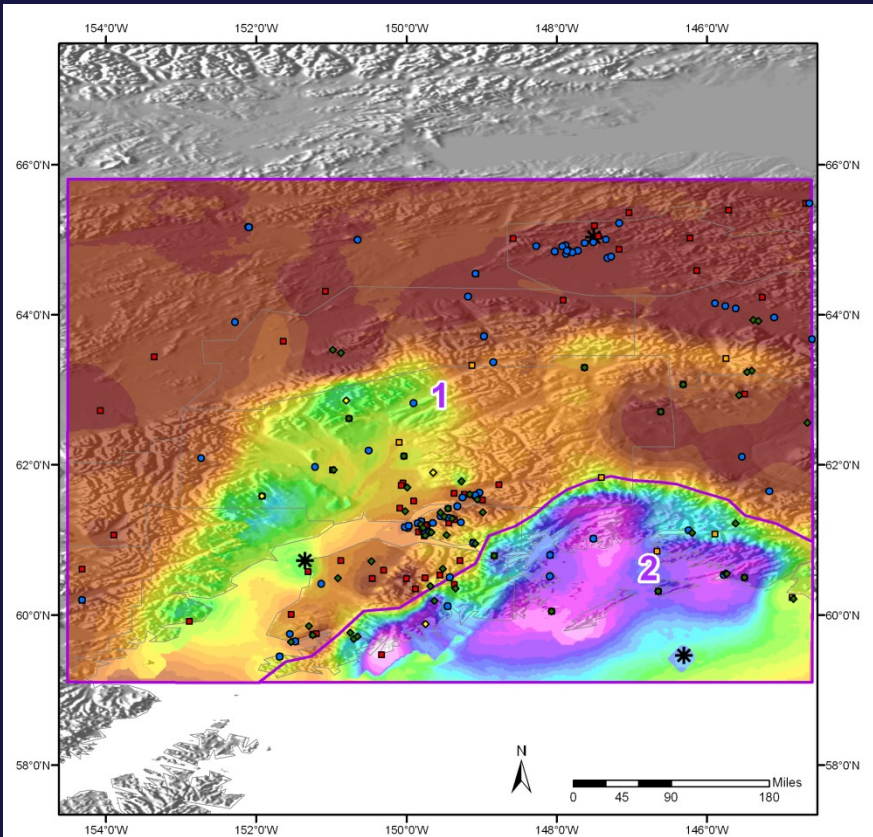
Total 168-hour Storm Precipitation (inches)
Sept. 15, 2013 1000 Z - Sept. 22, 2013 0900 Z
SPAS #1256
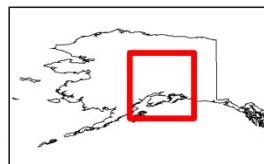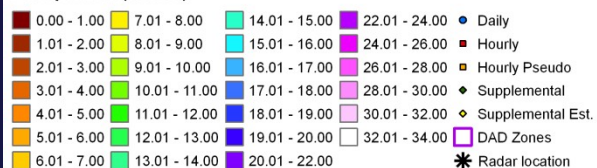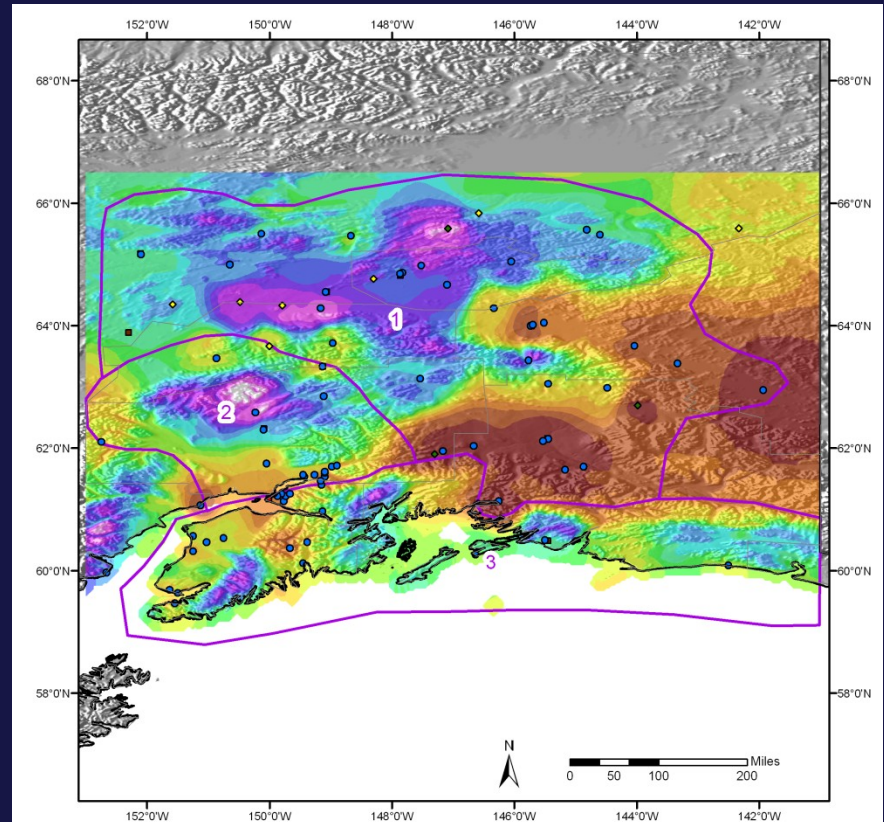
Total Storm (240-hr) Precipitation (inches)
August 8-17, 1967 - "The Great Fairbanks Flood"
SPAS #1270
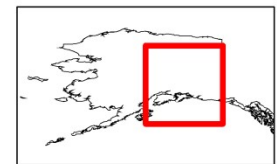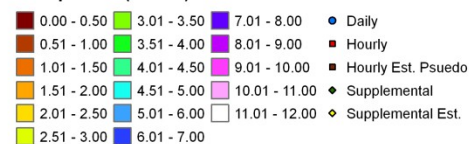
Stations Used-Basin Area
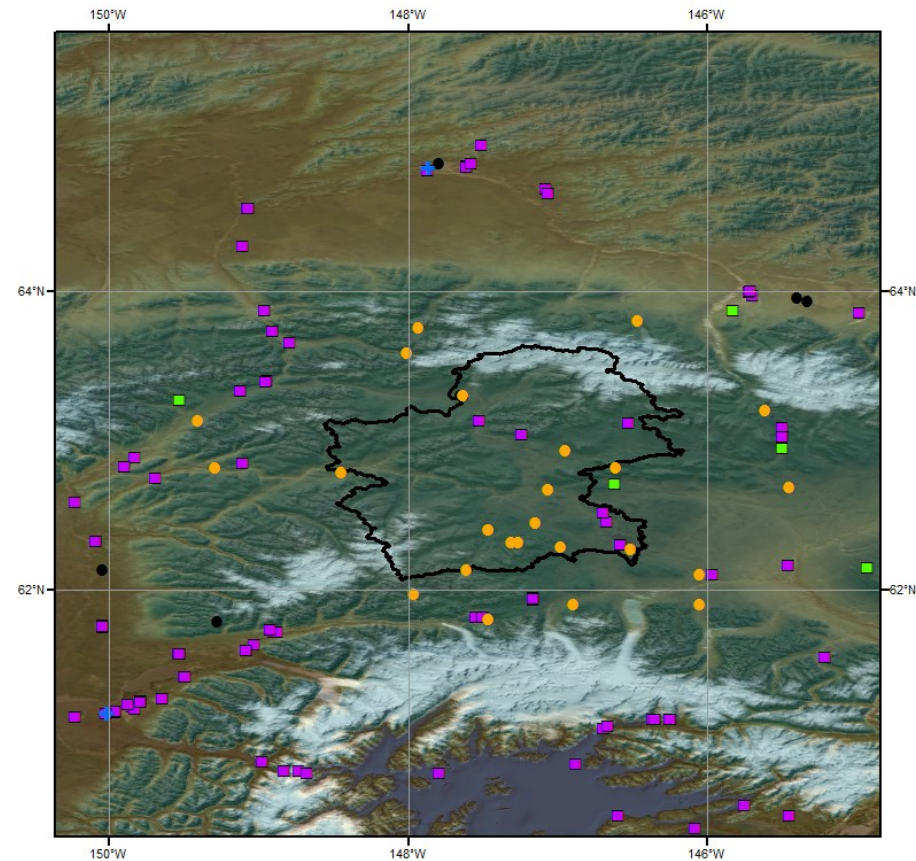
Stations Surrounding Basin
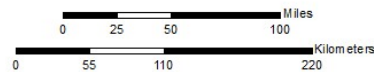
Summary

- Cool-Season PMP controls PMF in many locations
  - Ability to consider site-specific characteristics\
  - Properly quantify rain, snow, SWE, Meteorology
- Higher confidence in results/data
- Data incredible valuable
  - More is needed

Applied Weather Associates

QUESTIONS

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