PROBABLE MAXIMUM PRECIPITATION, OREGON STORMS

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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

- Types of PMP studies:
  - Generalized (Hydrometeorological Reports)
    - Provides PMP values for a region
    - HMR 57 – Columbia River, Snake River, and Coastal drainages
  - 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

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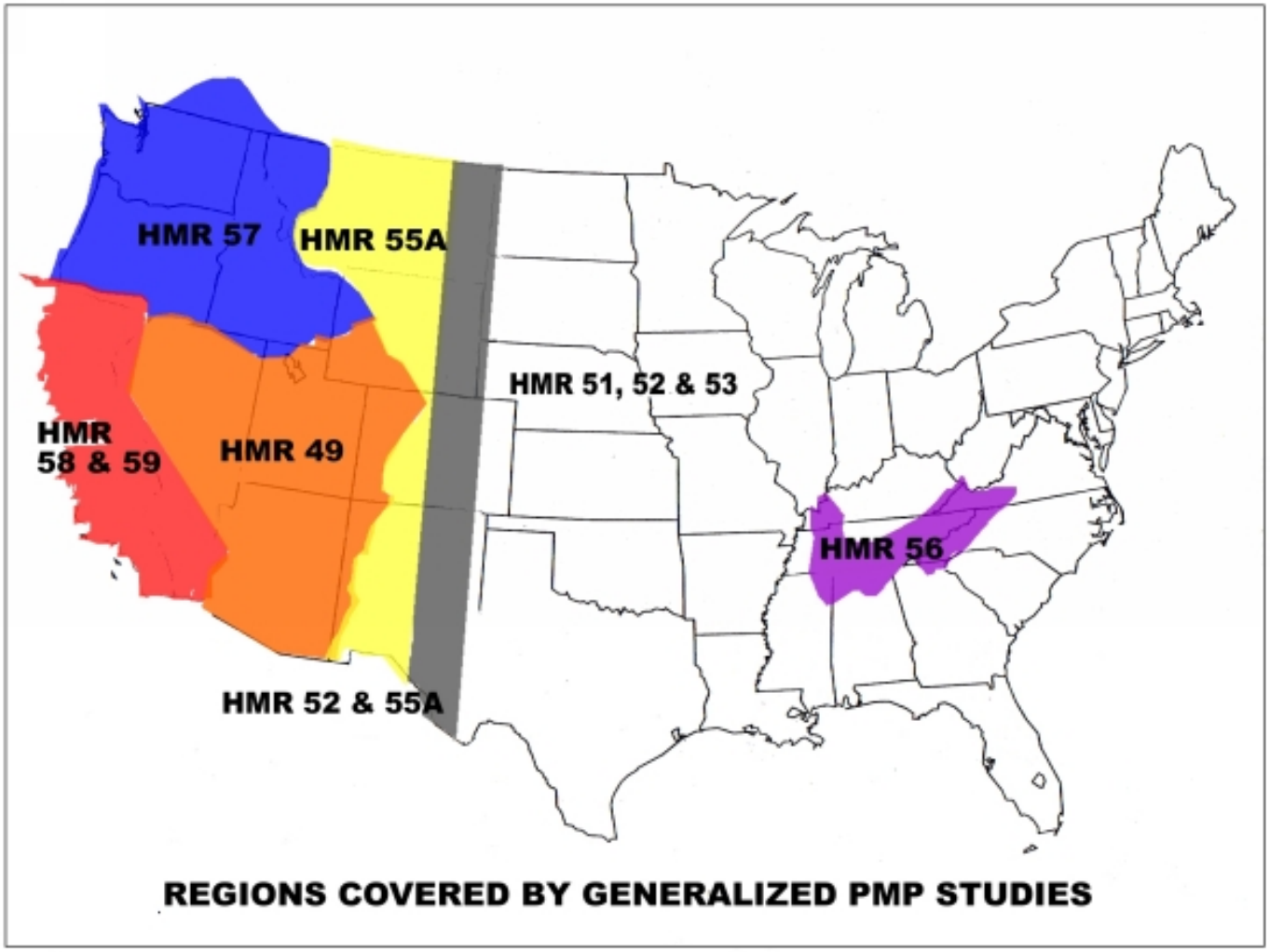
Coverage of HMRs



AWA PMP Studies

- Site-specific/statewide PMP values used instead of HMR values to compute the PMF
- PMP studies have produced significant reductions
  - Individual basins
  - Statewide regions
  - Large regions
- AWA site-specific and statewide PMP studies have been accepted by appropriate regulators
  - State Dam Safety, Federal Energy Regulator Commission (FERC), Natural Resources Conservation Service (NRCS), etc

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Do PMP Studies Provide Improved PMP Values?

- More storms considered
- New technologies used
- Problems/Unknowns in the HMRs corrected
- Topographic features addressed
- Updated climatologies used
- Conservatisms relaxed where data supports

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Background-HMR 57

- HMR 57-Published in 1994
  - Storm database old
  - Based on outdated methods and techniques
    - Subsequently been improved
      - Better understanding of meteorology
      - Updated datasets
      - Improved spatial analysis
- Major issues with HMR 57
  - Improper handling of orographic effects
  - Inconsistent use of storm data used to develop the PMP values
  - Covers a widely varying region
    - Climatologically/Topographically
  - Several calculation errors corrected

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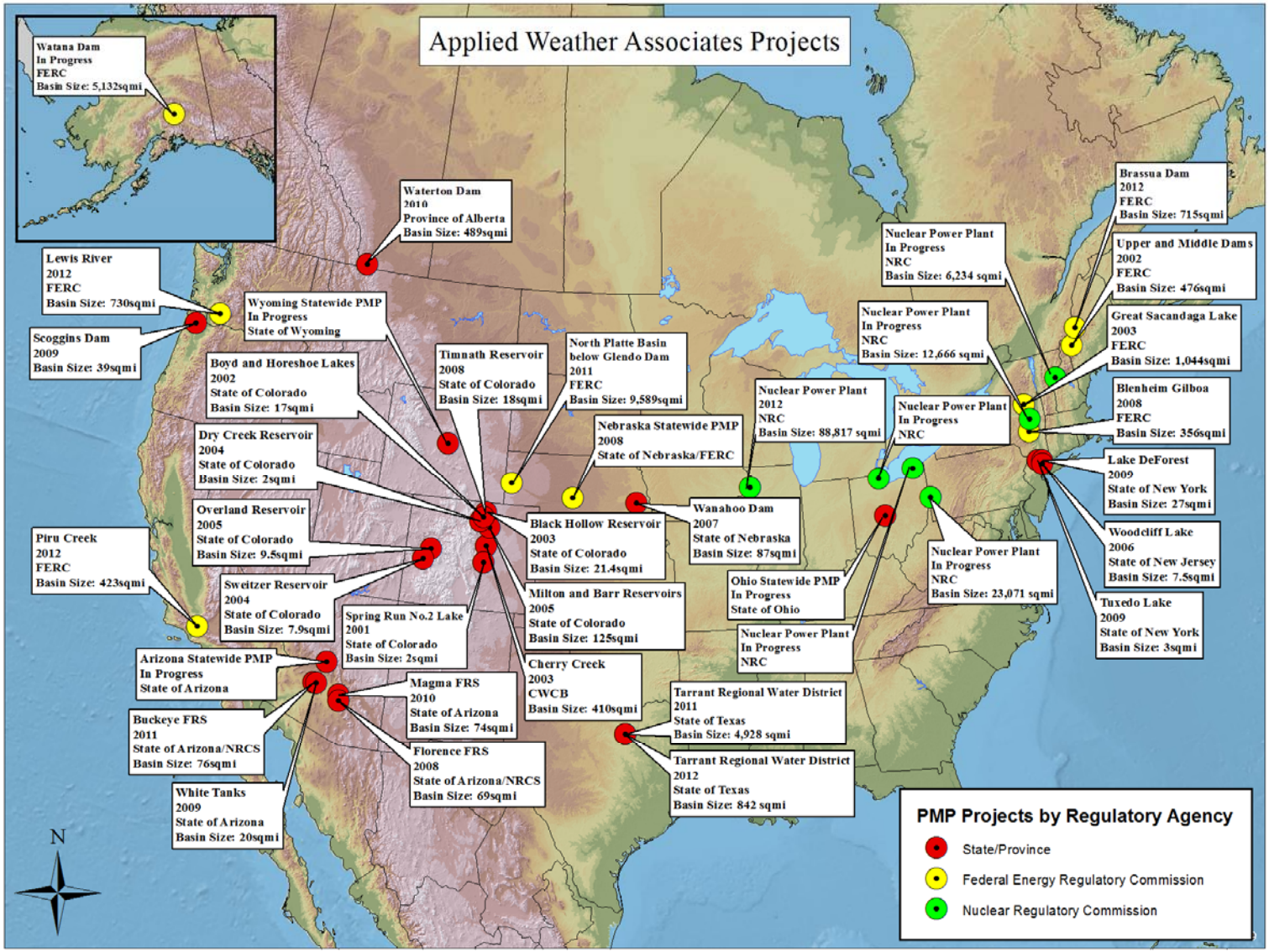
How Does AWA Compute PMP?

- 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

Not Our First PMP Study



Method for Computing PMP Values

- Identify unique topography
  - Precipitation enhancement/decrease
    - Orographics
  - Effects on rainfall center location
    - Physically possible storm centering/orientation
- Review HMR procedures used
  - Identify inconsistent assumptions
  - Apply new technologies and data
  - Apply new/updated methods

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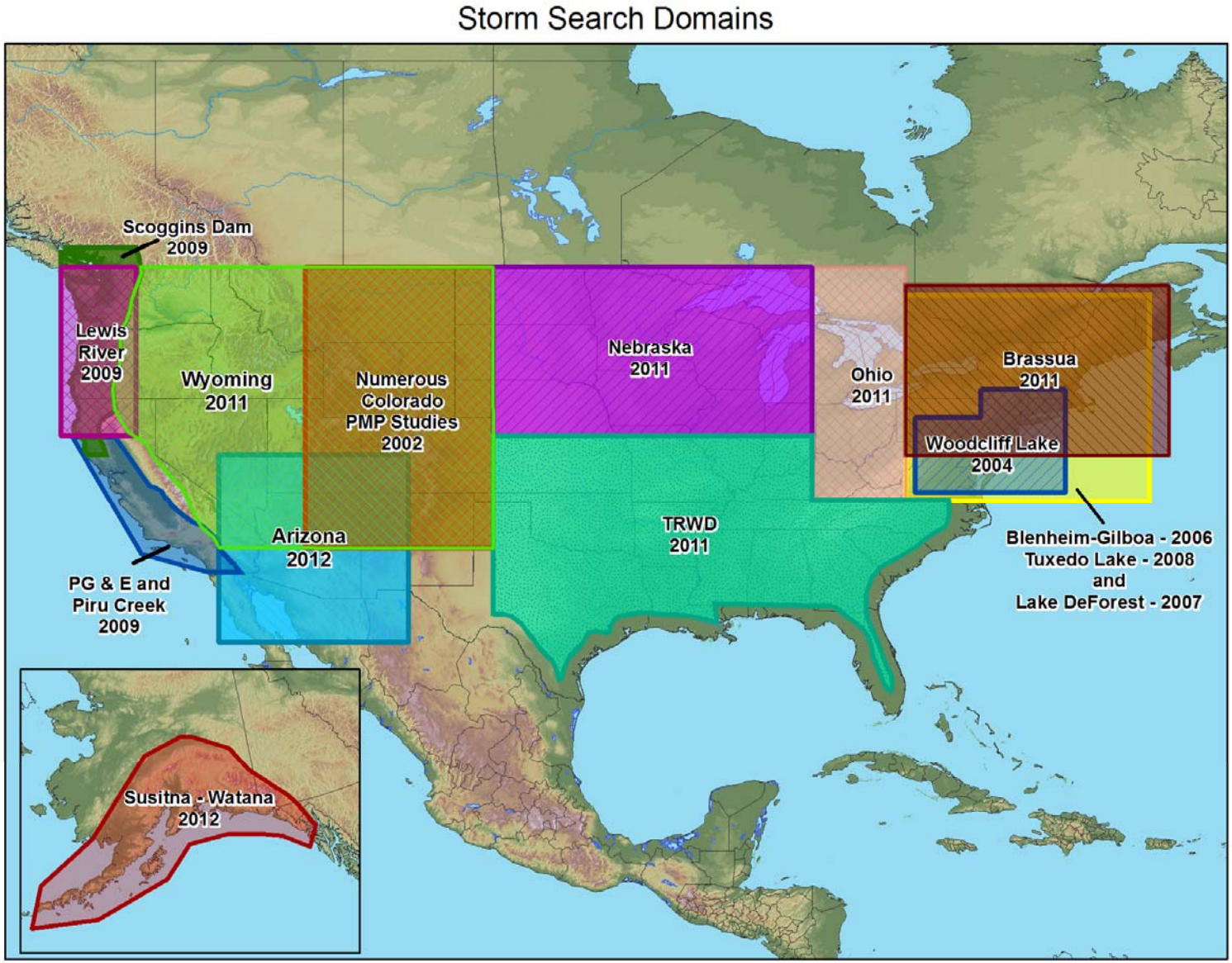
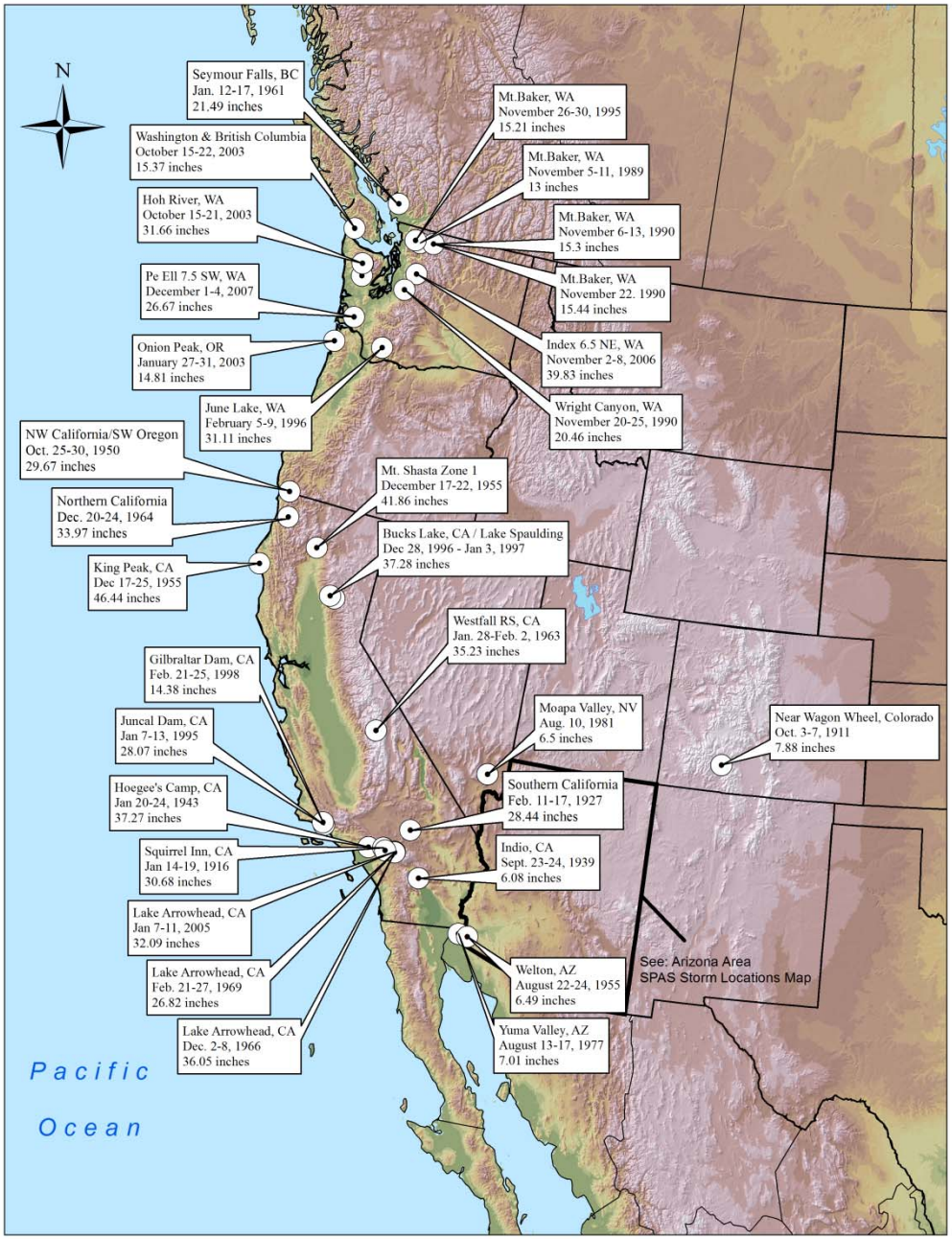
AWA Storm Search Domains



Storm Locations Analyzed by AWA

West of the Continental Divide

SPAS Storm Locations - West of Continental Divide



Updating PMP-Storm Analysis

- Storm Precipitation Analysis System (SPAS)
  - Depth-Area-Duration
  - Mass Curves
  - Storm Isohyetal
  - Hourly (5-minute rainfall) at 1/3rd square mile
  - Dynamically adjusted radar and/or basemap for spatial interpolation

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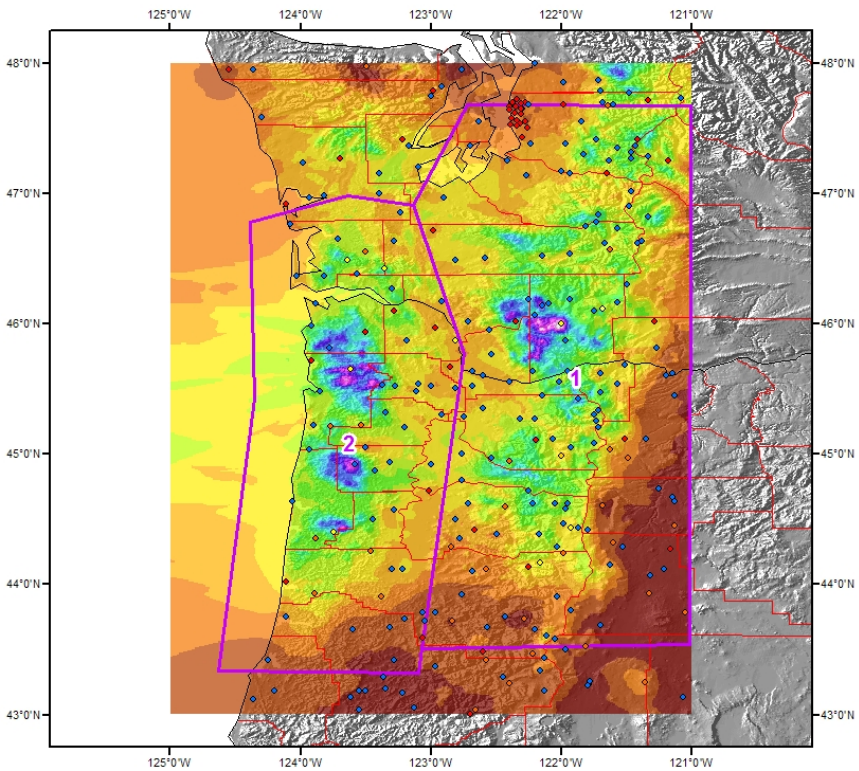
SPAS Storm Analysis Results



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

Gauging Stations

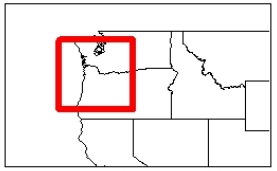
D HE S
H HP SE

Miles 0 20 40 80
Kilometers 0 30 60 120 180

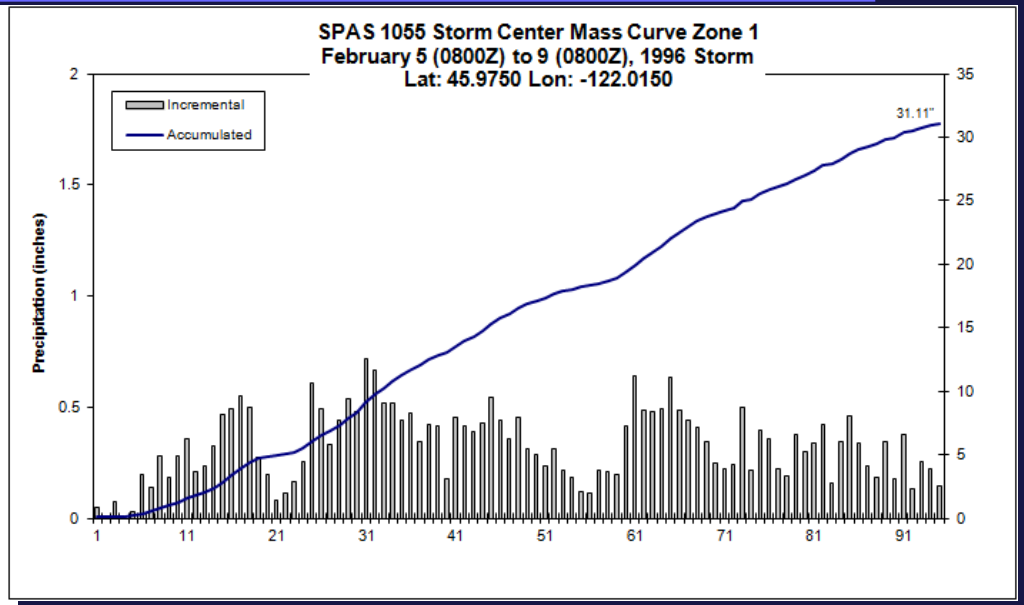
N

Precipitation (inches)

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



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



Storm 1055 - Lewis River February 5 (0800 Z) - 9 (0800 Z), 1996

MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)											
Area (mi^2)	1	2	3	4	5	6	12	24	36	48	72	Total
0.33	1.36	2.55	3.21	3.81	4.22	4.74	7.21	11.34	14.76	18.98	26.66	31.11
1	1.30	2.41	3.13	3.73	4.09	4.58	7.02	11.07	14.38	18.54	25.92	30.21
10	1.19	2.21	2.83	3.48	3.91	4.36	6.52	10.69	14.01	17.97	25.20	30.09
25	1.09	2.03	2.63	3.24	3.68	3.98	5.78	10.11	13.30	17.26	24.22	29.11
50	0.98	1.88	2.42	2.96	3.43	3.71	5.59	9.66	12.51	16.62	23.28	28.09
100	0.87	1.67	2.17	2.64	2.94	3.36	5.27	9.25	11.85	15.94	22.44	26.77
150	0.78	1.50	2.01	2.39	2.76	3.13	5.00	8.96	11.76	15.35	21.98	25.89
200	0.77	1.33	1.85	2.28	2.70	3.04	4.89	8.79	11.37	14.73	21.35	25.17
300	0.67	1.11	1.70	2.15	2.41	2.82	4.69	8.51	10.91	14.21	20.13	24.02
400	0.66	1.10	1.60	2.02	2.32	2.66	4.32	8.23	10.57	13.48	19.27	23.11
500	0.62	1.08	1.49	1.88	2.21	2.58	4.31	8.01	10.44	13.19	18.83	22.32
1,000	0.52	0.87	1.18	1.60	1.99	2.32	3.99	7.11	9.23	11.75	16.69	20.32
2,000	0.42	0.77	1.09	1.49	1.80	2.02	3.62	6.15	8.52	10.72	14.90	18.15
5,000	0.34	0.59	0.85	1.21	1.48	1.70	3.10	5.27	7.28	9.28	12.61	15.10
10,000	0.26	0.51	0.71	0.91	1.16	1.34	2.52	4.47	6.09	7.76	10.93	12.92
20,000	0.17	0.32	0.44	0.58	0.73	0.88	1.71	3.29	4.48	5.90	8.55	10.14
26,853	0.13	0.25	0.37	0.49	0.61	0.73	1.37	2.50	3.68	4.62	6.91	8.22

How Does AWA Compute PMP?

- Each storm maximized
  - Make it as big as physically possible
  - Storm rainfall = dynamics + moisture
    - Can’t quantify dynamics, can quantify moisture
    - Assume most efficient storm dynamics
    - Only moisture varies
  - Use surface dew points or SST for maximization
- Determine moisture which fed the storm = fuel
- Ratio: climatological maximum moisture to actual storm moisture = in-place maximization factor

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How Did We Compute PMP?

- Move maximized storms to each grid/basin centroid
- Account for differences in moisture and elevation
- Calculate the Orographic Transposition Factor
  - Uses Precip Frequency-WSDOT or NOAA Atlas 14
  - Difference between source and target location
- OTF-Quantifiable/Reproducible
  - Replaces HMR SSM, K-Factor
    - Highly subjective
    - Not reproducible
- Results in total adjustment factor
- Apply to the DAD values

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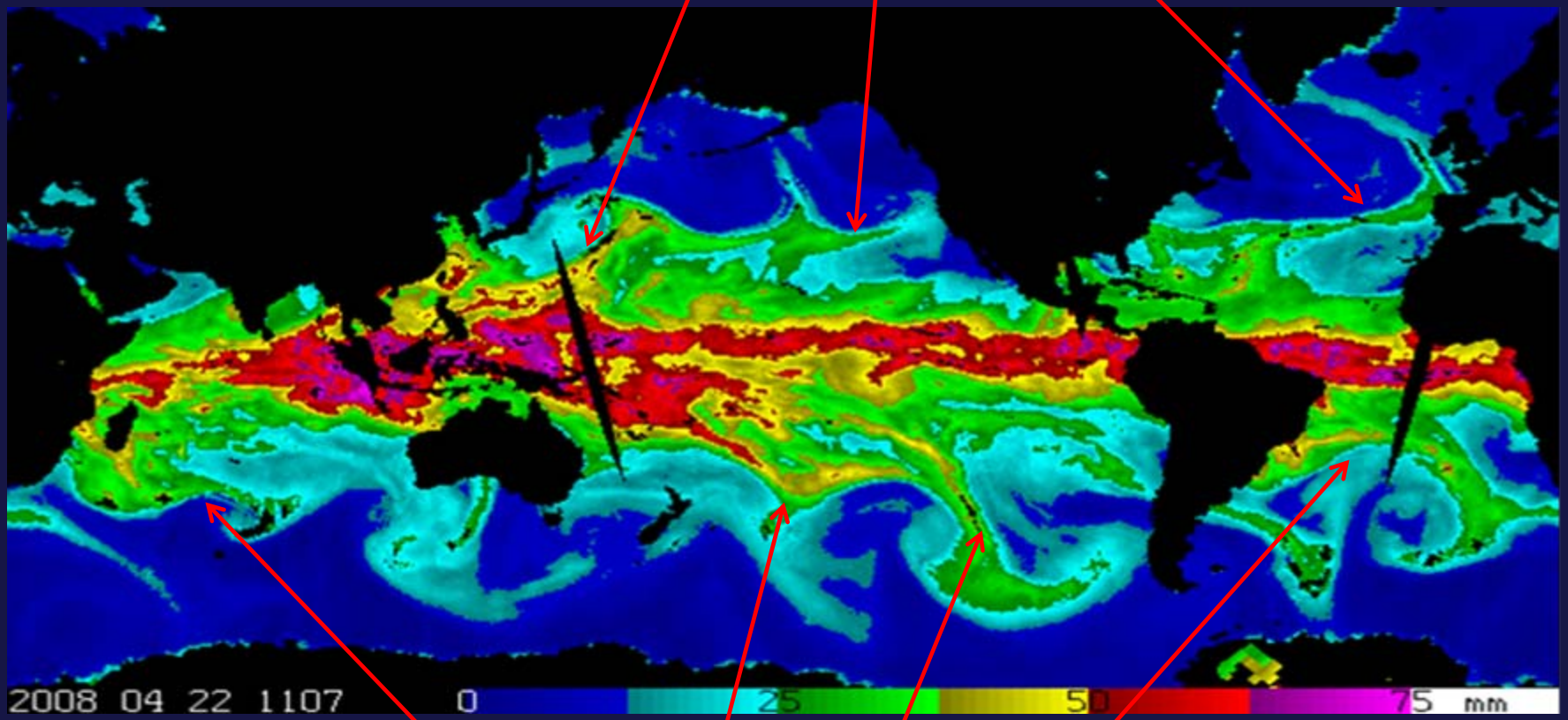
General Storms

Atmospheric Rivers
aka Pineapple Express

Atmospheric Rivers



Atmospheric Rivers

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

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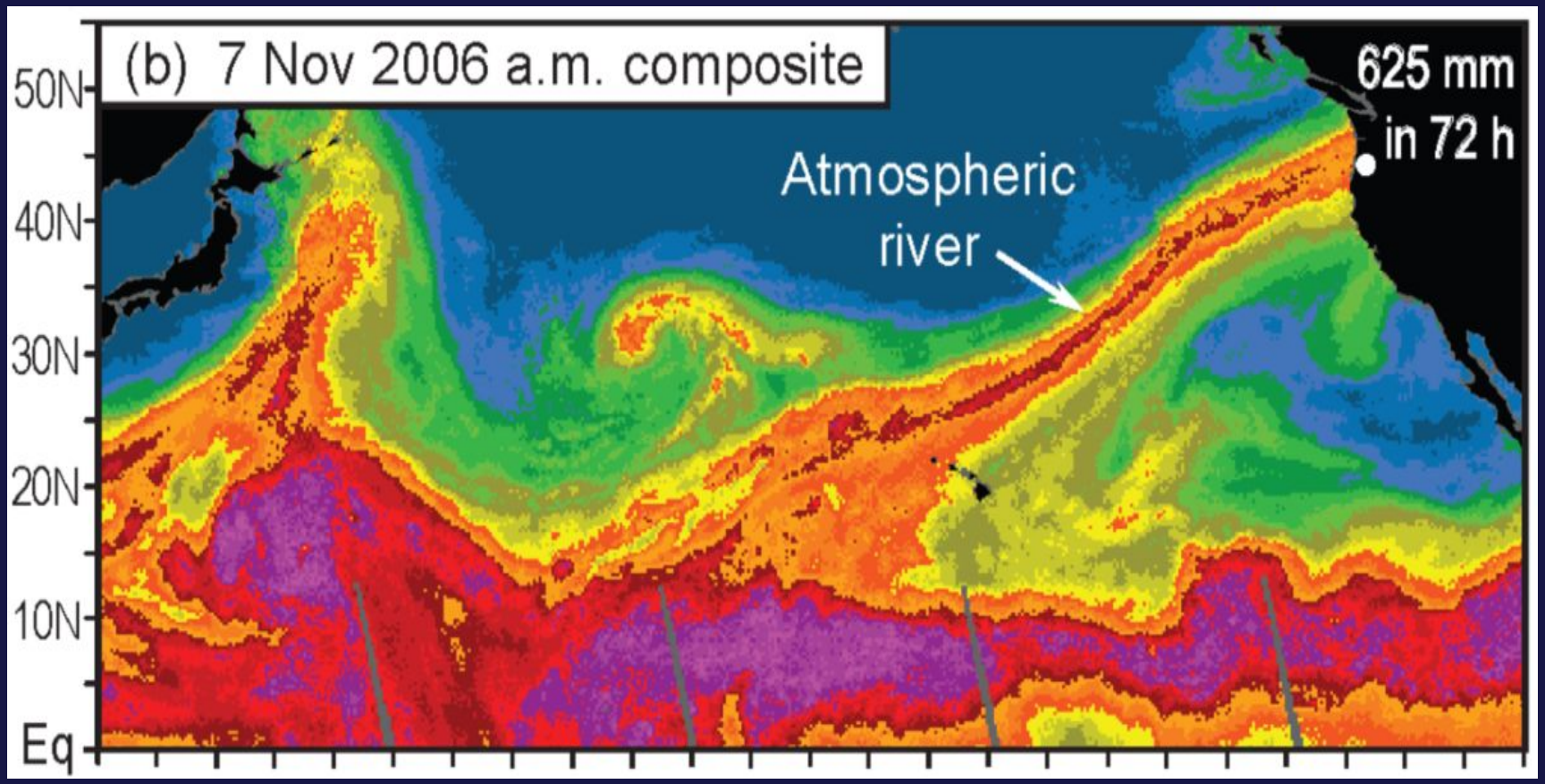
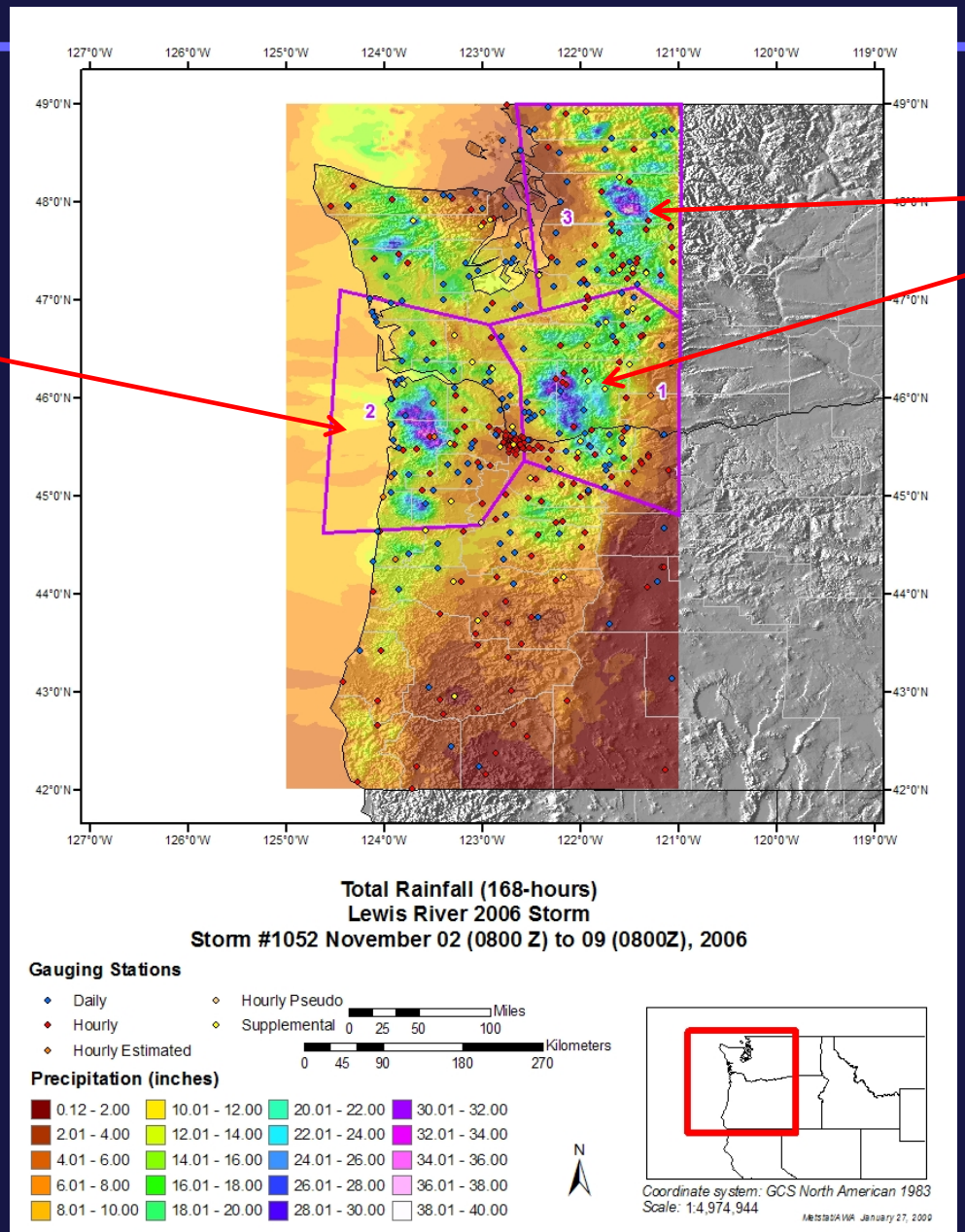


From http://www.esrl.noaa.gov/psd/atmrivers/

Pacific Northwest, November 2006

Rainfall Center

More than 35 Inches!



Rainfall Centers

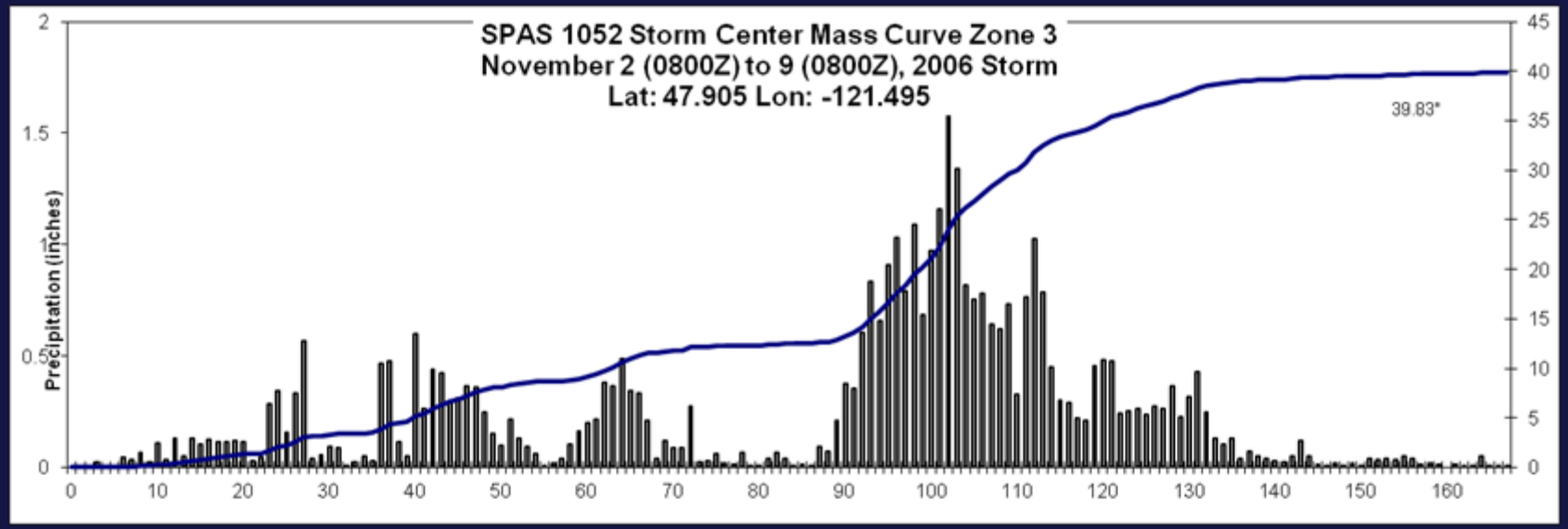
More than 35 Inches!

Pacific Northwest, November 2006

Storm 1052 - Lewis River November 2 (0800 Z) - 9 (0800 Z), 2006

MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)															
Area (mi^2)	1	2	3	4	5	6	12	18	24	36	48	72	96	120	144	Total
0.33	1.69	3.07	4.27	5.32	6.28	7.06	12.20	16.45	20.36	24.19	26.82	29.61	34.84	38.18	39.42	39.83
1	1.60	2.97	4.18	5.20	6.19	6.92	12.15	16.26	20.16	23.95	26.59	29.40	34.58	37.93	39.17	39.59
10	1.48	2.74	3.82	4.68	5.60	6.34	11.30	15.17	18.88	22.38	25.12	28.03	33.21	36.57	37.80	38.25
25	1.30	2.42	3.38	4.21	4.96	5.74	10.30	14.11	17.33	20.90	23.29	26.33	31.05	34.51	35.81	36.29
50	1.23	2.21	2.90	3.53	4.32	5.05	9.37	12.71	15.69	19.01	21.39	24.46	29.06	32.47	33.66	34.26
100	1.10	1.98	2.59	3.22	3.84	4.41	8.20	11.33	14.22	17.36	19.71	22.42	26.58	30.15	31.67	32.18
121	0.98	1.90	2.52	3.12	3.69	4.25	7.88	10.84	13.81	16.87	19.01	21.81	26.04	29.74	31.13	31.59
135	0.98	1.86	2.45	3.08	3.55	4.22	7.62	10.74	13.50	16.69	18.88	21.31	25.64	29.40	30.84	31.24
150	0.97	1.81	2.40	3.03	3.54	4.16	7.56	10.66	13.22	16.36	18.62	21.24	25.46	29.03	30.51	30.91
200	0.97	1.63	2.24	2.88	3.41	3.97	7.18	10.01	12.74	15.66	17.78	20.25	24.51	27.98	29.46	29.92
300	0.82	1.54	2.11	2.64	3.12	3.75	6.75	9.35	12.01	14.72	17.08	19.55	23.15	26.58	27.81	28.42
475	0.72	1.39	2.05	2.57	3.06	3.50	6.35	8.93	11.17	13.99	15.91	18.43	21.77	24.94	25.98	26.59
500	0.71	1.36	2.03	2.56	3.03	3.48	6.29	8.87	11.03	13.87	15.91	18.18	21.56	24.45	25.92	26.38
1,000	0.66	1.23	1.82	2.24	2.70	3.20	5.66	8.00	10.15	12.61	14.52	16.62	19.54	22.21	23.27	23.62
2,000	0.56	1.06	1.60	2.06	2.44	2.88	4.97	7.19	9.00	11.25	12.95	14.93	17.44	19.48	20.36	20.91
5,000	0.44	0.82	1.23	1.61	1.91	2.30	3.98	5.77	7.12	8.86	10.31	12.03	14.12	15.87	16.59	17.00
9,838	0.32	0.59	0.85	1.11	1.36	1.62	2.79	3.98	4.87	6.05	7.09	8.41	9.90	11.27	11.90	12.10



Local Storms

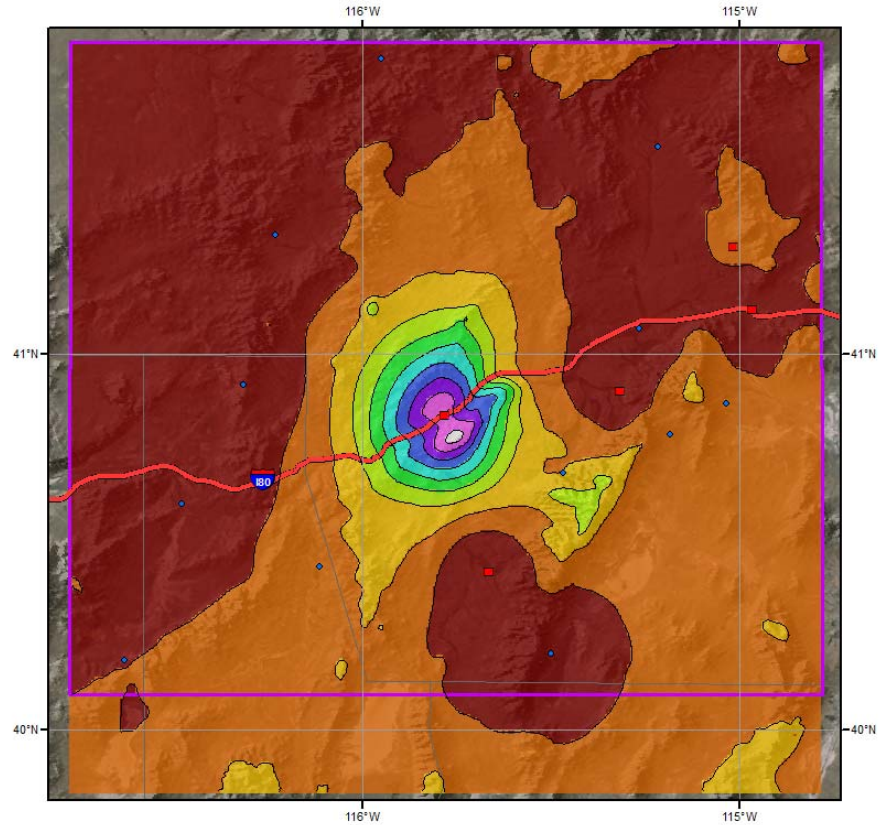
Thunderstorms-Flash Floods

HMR 57 Local Storms

Table 11.1.--Major Local Storms - Pacific Northwest

Location	Lat °	N '	Lon °	W '	Elev. (feet)	Date	Dur. Min.	Amount (in.)	Reference
Birch Creek, OR	45	20	118	55	3000	6/22/38	20	2.50	Riedel, et al., 1966
Skykomish 1ENE, WA	47	42	121	22	1030	5/25/45	30	1.78	Schaefer, 1989
Girds Creek, OR	44	40	120	10	4000	7/13/56	30	4.00	Riedel, et al., 1966
Simon Ranch, ID	43	15	114	45	5000	7/21/56	20	2.50	Riedel, et al., 1966
Knapp Coulee, WA	47	49	120	08	1500	8/15/56	5-10	1.50	Hendricks, 1964
Winthrop, WA	48	20	120	11	1755	7/29/58	60	3.00	Private communication
Castle Rock, WA	46	16	122	55	43	8/23/63	12	0.90	NCDC, 1963
Meridian, ID	43	37	115	25	2600	6/21/67	12	2.75	Rostvedt, 1972
John Day, OR	44	25	118	53	3200	6/9/69	180	7.00	Reid, 1975
Heppner, OR	45	20	114	33	2500	5/25/71	20	3.00	Bauman, 1980
Reynolds Creek, ID	43	15	116	45	3700	7/21/75	5	0.80	USDA, 1975
Aberdeen 20 NNE, WA	47	16	123	42	440	5/28/82	45	2.30	NCDC, 1982
BORDERING AREA									
Morgan, UT	41	03	111	38	5150	8/16/58	60	6.75	Riedel, et al., 1966
Elko, NV	40	50	115	47	5080	8/27/70	60	3.47	NCDC, 1970
Opal, WY	41	45	110	15	6900	8/16/90	120	7.00	Private communication

SPAS Storm Analysis Results
Elko, NV August, 1970



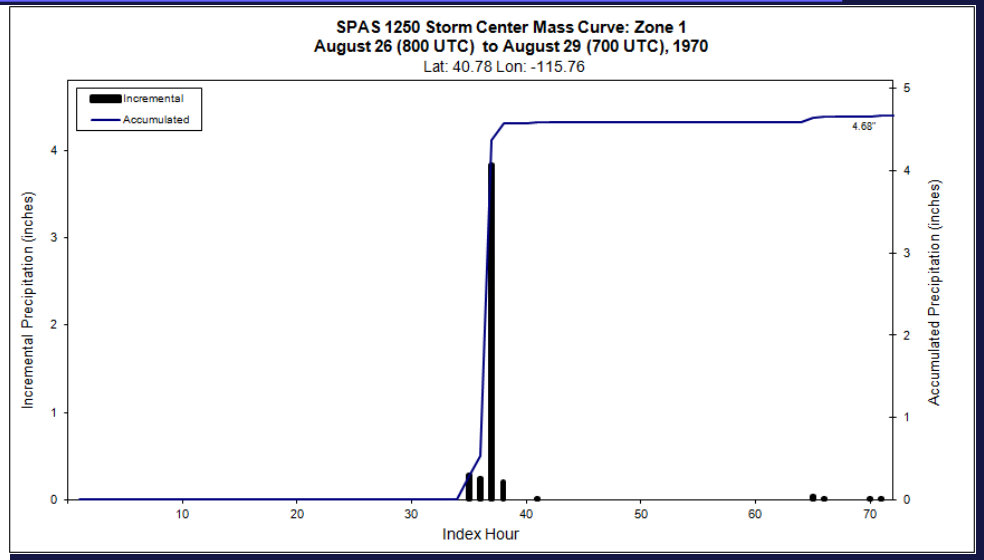
Total Precipitation (72-hours)
SPAS 1250 - Elko, NV
8/26/1970 0800 GMT - 8/29/1970 0700 GMT

Gauges
- Daily
- Hourly

Miles: 0 10 20 40
Kilometers: 0 20 40 80

Precipitation (inches)
- 0.00 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 4.50
- 4.51 - 5.00

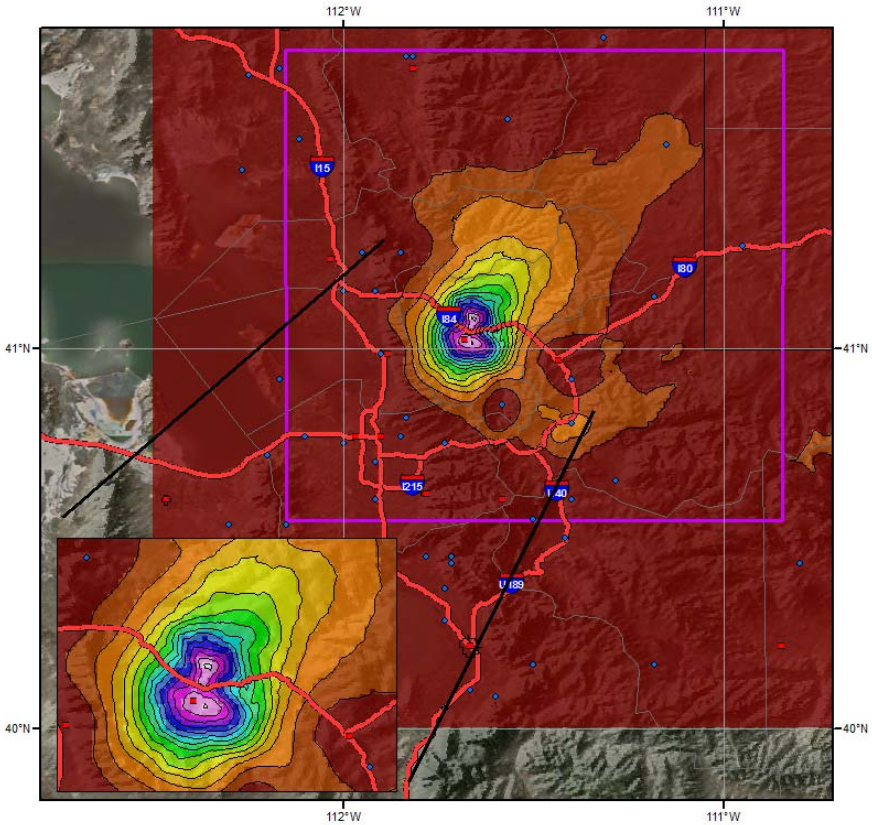
9/10/2012



Storm 1250 - August 26 (800 UTC) - August 29 (700 UTC), 1970
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)												
Area (mi^2)	1	2	3	4	5	6	12	18	24	36	48	72	Total
0.3	3.84	4.09	4.38	4.58	4.58	4.58	4.59	4.59	4.59	4.66	4.68	4.68	4.68
1	3.78	4.00	4.25	4.46	4.46	4.46	4.46	4.46	4.46	4.55	4.55	4.55	4.55
10	3.70	3.90	4.22	4.41	4.41	4.41	4.42	4.42	4.42	4.44	4.44	4.50	4.50
25	3.57	3.75	4.05	4.25	4.25	4.25	4.26	4.26	4.26	4.26	4.26	4.34	4.34
50	3.45	3.65	3.93	4.11	4.11	4.11	4.12	4.12	4.12	4.14	4.15	4.19	4.19
100	3.26	3.46	3.71	3.88	3.88	3.88	3.88	3.88	3.88	3.95	3.95	3.96	3.96
150	3.09	3.26	3.49	3.53	3.53	3.53	3.70	3.70	3.70	3.70	3.70	3.77	3.77
200	2.93	3.11	3.31	3.46	3.46	3.46	3.52	3.52	3.52	3.56	3.56	3.59	3.59
300	2.68	2.85	2.98	3.21	3.21	3.21	3.23	3.23	3.23	3.23	3.25	3.30	3.30
400	2.47	2.62	2.69	2.96	2.96	2.96	2.98	2.98	2.98	2.98	3.00	3.05	3.05
500	2.30	2.43	2.61	2.75	2.75	2.75	2.77	2.77	2.77	2.82	2.83	2.83	2.83
1,000	1.70	1.82	1.90	2.11	2.11	2.11	2.12	2.12	2.12	2.12	2.19	2.22	2.22
2,000	1.26	1.36	1.42	1.57	1.57	1.57	1.59	1.59	1.59	1.59	1.63	1.64	1.64
5,000	0.85	0.85	0.85	0.90	0.90	1.00	1.02	1.02	1.02	1.06	1.08	1.16	1.16
10,000	0.48	0.57	0.59	0.63	0.64	0.65	0.70	0.70	0.70	0.71	0.74	0.74	0.74
12,573	0.37	0.45	0.47	0.50	0.51	0.53	0.56	0.56	0.56	0.60	0.60	0.60	0.60

SPAS Storm Analysis Results
Morgan, UT, August 1958



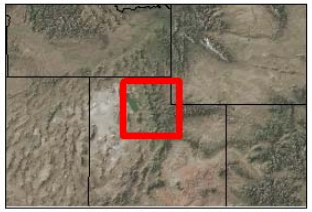
Total Precipitation (72-hours)
SPAS 1248 - Morgan, UT
8/15/1958 0800 GMT - 8/18/1958 0700 GMT

Gauges
- Daily
- Hourly

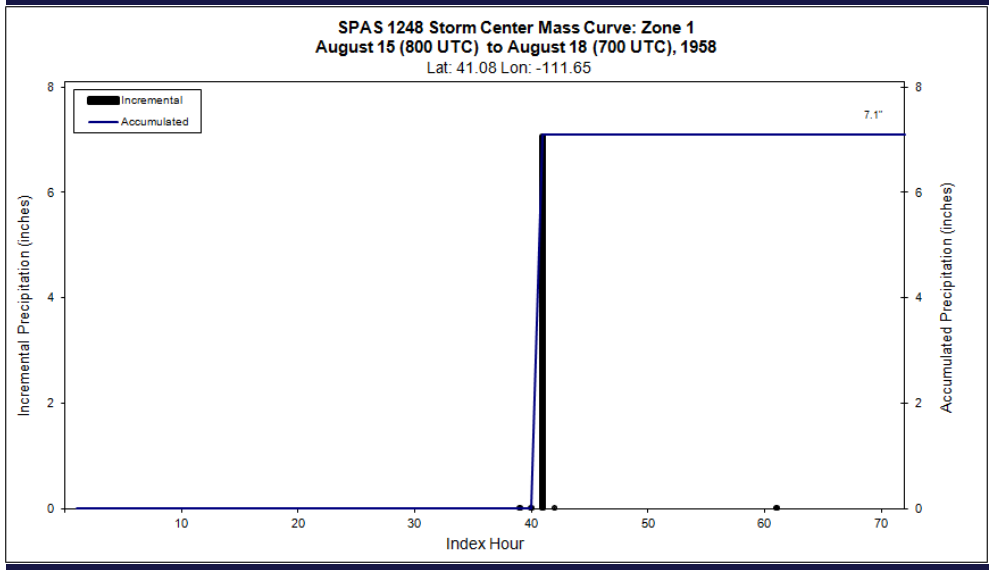
Miles: 0 5 10 20
Kilometers: 0 15 30 60

Precipitation (inches)

0.00 - 0.50	1.51 - 2.00	3.01 - 3.50	4.51 - 5.00	6.01 - 6.50
0.51 - 1.00	2.01 - 2.50	3.51 - 4.00	5.01 - 5.50	6.51 - 7.00
1.01 - 1.50	2.51 - 3.00	4.01 - 4.50	5.51 - 6.00	7.01 - 7.50



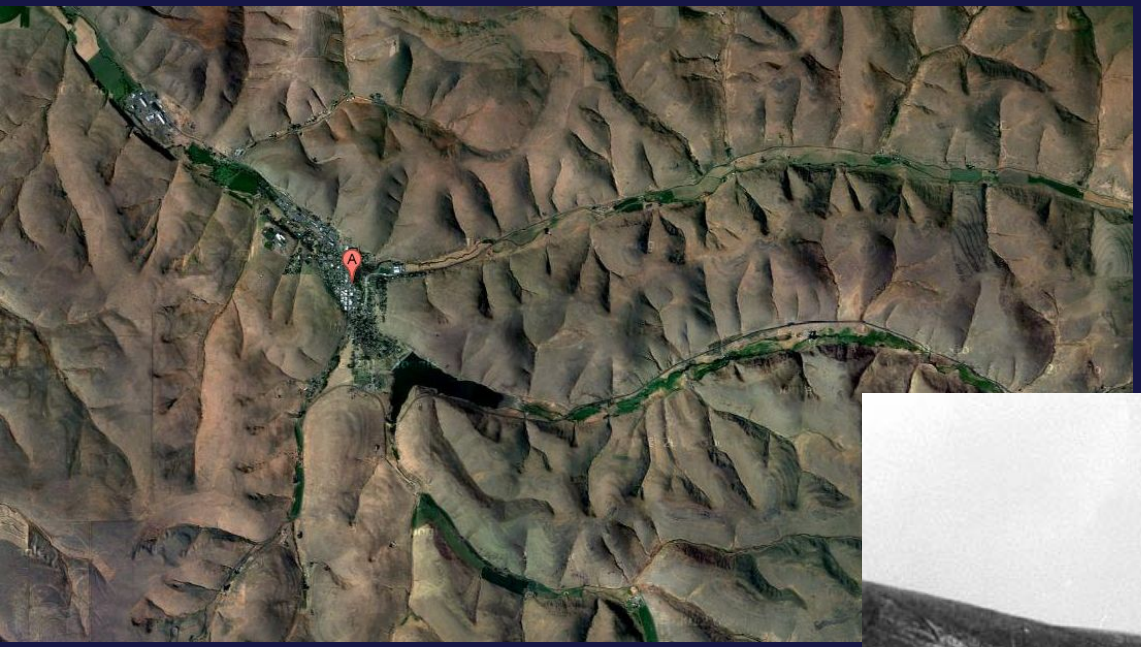
8/24/2012



Storm 1258 - August 15 (800 UTC) - August 18 (700 UTC), 1958
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)							
Area (mi^2)	1	2	3	4	5	6	72	Total
0.3	7.08	7.09	7.09	7.10	7.10	7.10	7.10	7.10
1	6.91	6.91	6.91	6.92	6.92	6.92	6.92	6.92
10	6.73	6.74	6.74	6.74	6.74	6.74	6.74	6.74
25	6.39	6.39	6.39	6.39	6.39	6.39	6.40	6.40
50	5.87	5.87	5.88	5.88	5.88	5.88	5.88	5.88
100	5.01	5.02	5.02	5.02	5.02	5.02	5.04	5.04
150	4.39	4.40	4.41	4.42	4.42	4.42	4.42	4.42
200	3.92	3.93	3.93	3.93	3.93	3.93	3.97	3.97
300	3.27	3.28	3.29	3.29	3.29	3.29	3.33	3.33
400	2.87	2.88	2.88	2.89	2.89	2.89	2.91	2.91
500	2.59	2.60	2.60	2.60	2.61	2.61	2.70	2.70
1,000	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
2,000	1.37	1.39	1.39	1.39	1.39	1.39	1.45	1.45
5,000	0.42	0.45	0.48	0.49	0.49	0.49	0.60	0.60
5,804	0.35	0.37	0.40	0.41	0.41	0.41	0.47	0.47

Heppner, OR 1903



What About Oregon?

- Build of PMP work at Lewis River, Scoggins Dam, Baker River, Chelan
  - Leverage off storm lists/analyses
  - Significant cost/time savings
- Same structure/products as Arizona and Wyoming
  - PMP for any point in state
  - Updateable, flexible, user friendly
  - Regulator confidence and understanding
  - Involvement of stakeholders from beginning

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What About Oregon?

- Return On Investment (ROI) very high
  - Often pays for itself right away
    - Lower Rehab cost
    - Lower Construction costs
  - Reclaimed Opportunity Costs
    - Flood protection
    - Storage capacities
    - Operational availability

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Summary

- Storm based and reproducible
  - Ability to consider site-specific characteristics
- Higher confidence in results/data
- Significant cost savings
  - Properly sized spillways
  - Infrastructure not overbuilt
- PMP study produces updated/reliable values
  - PMP values for any point
  - Developed using the most current methods and data available

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QUESTIONS

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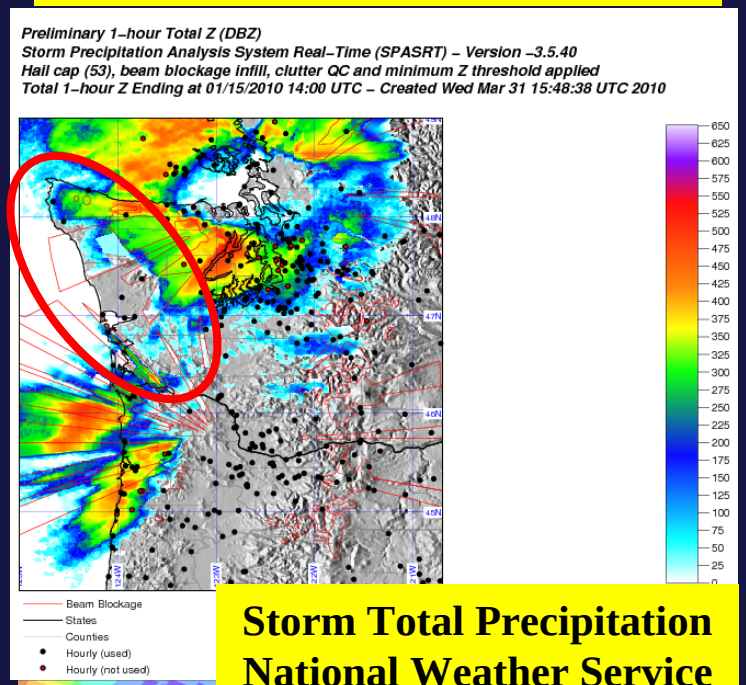
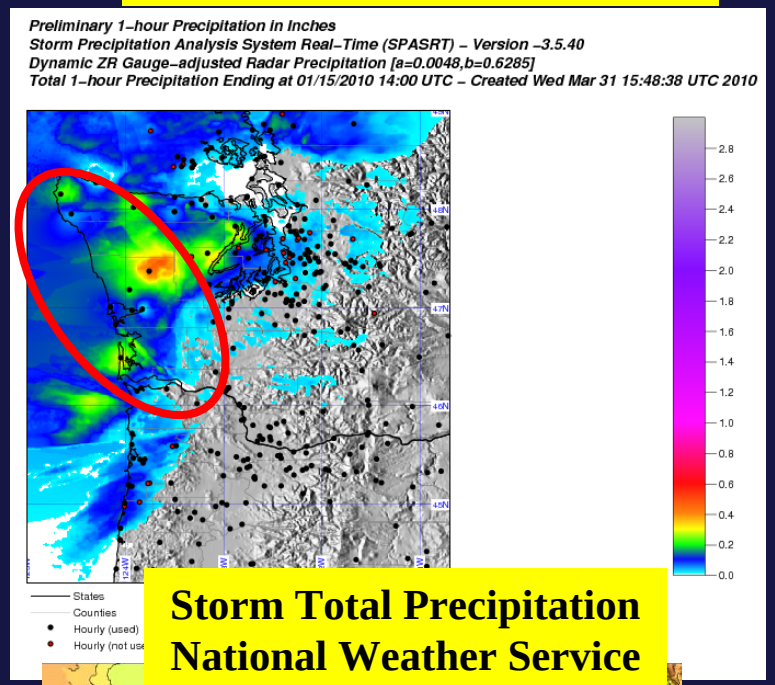
EXTRA SLIDES

SPAS–Radar Blockage- Basemap Concept

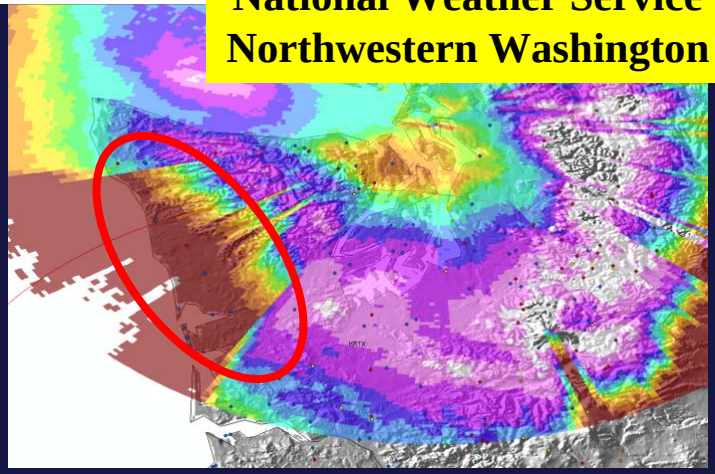
Unadjusted Radar Reflectivity



SPAS Precipitation



Storm Total Precipitation
National Weather Service
Northwestern Washington



Storm Total Precipitation
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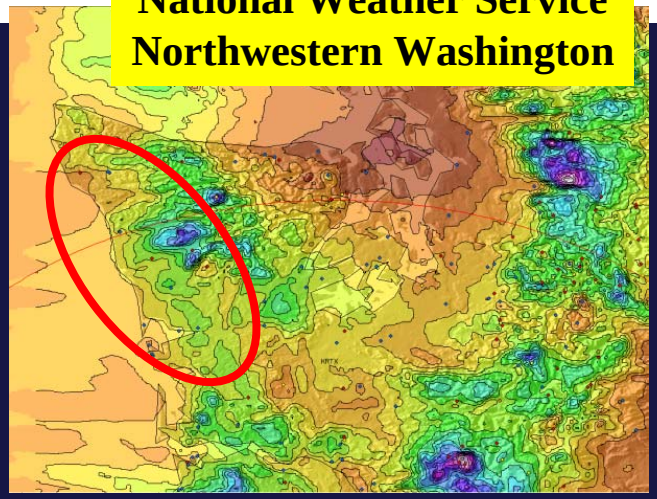
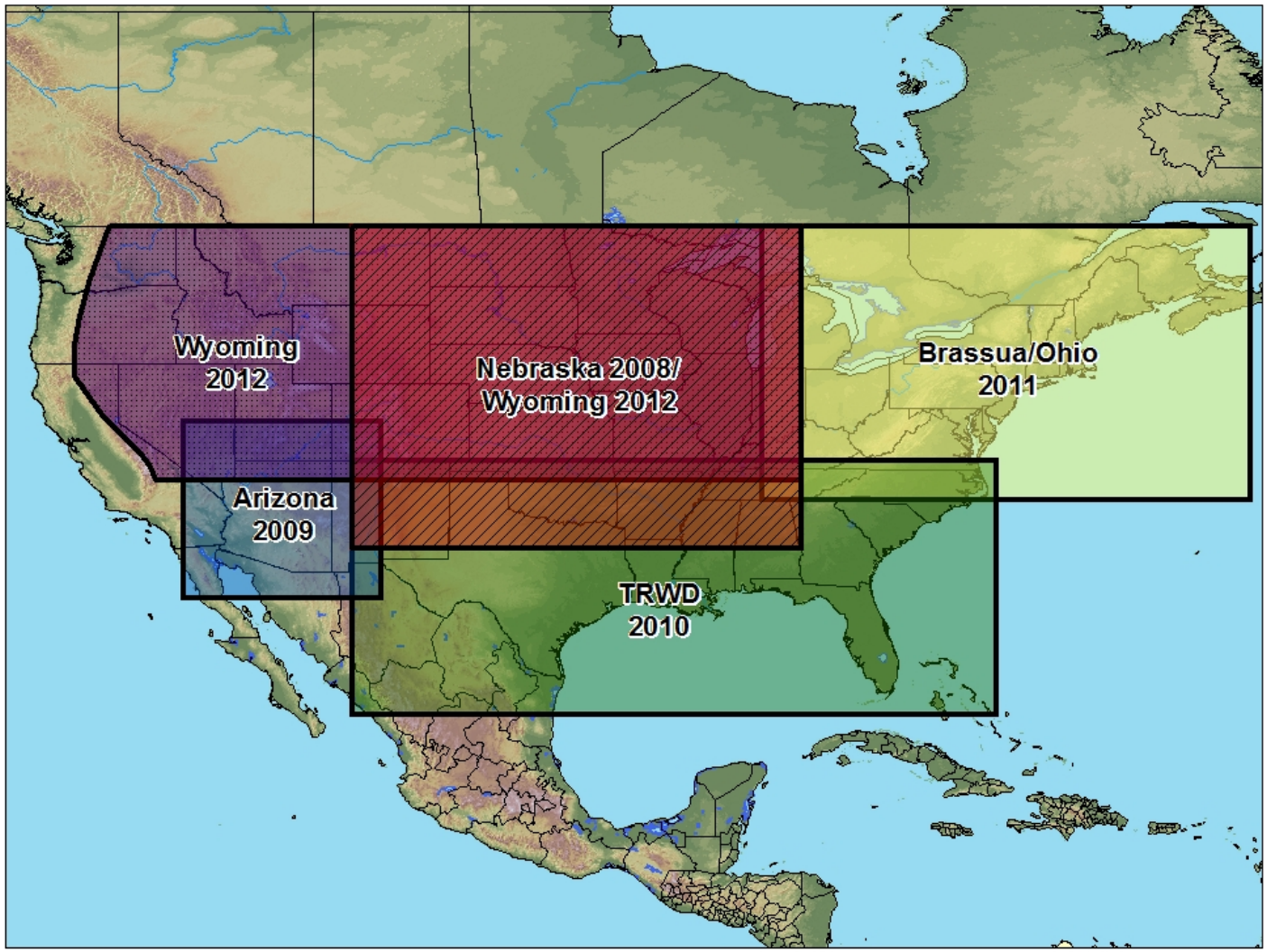
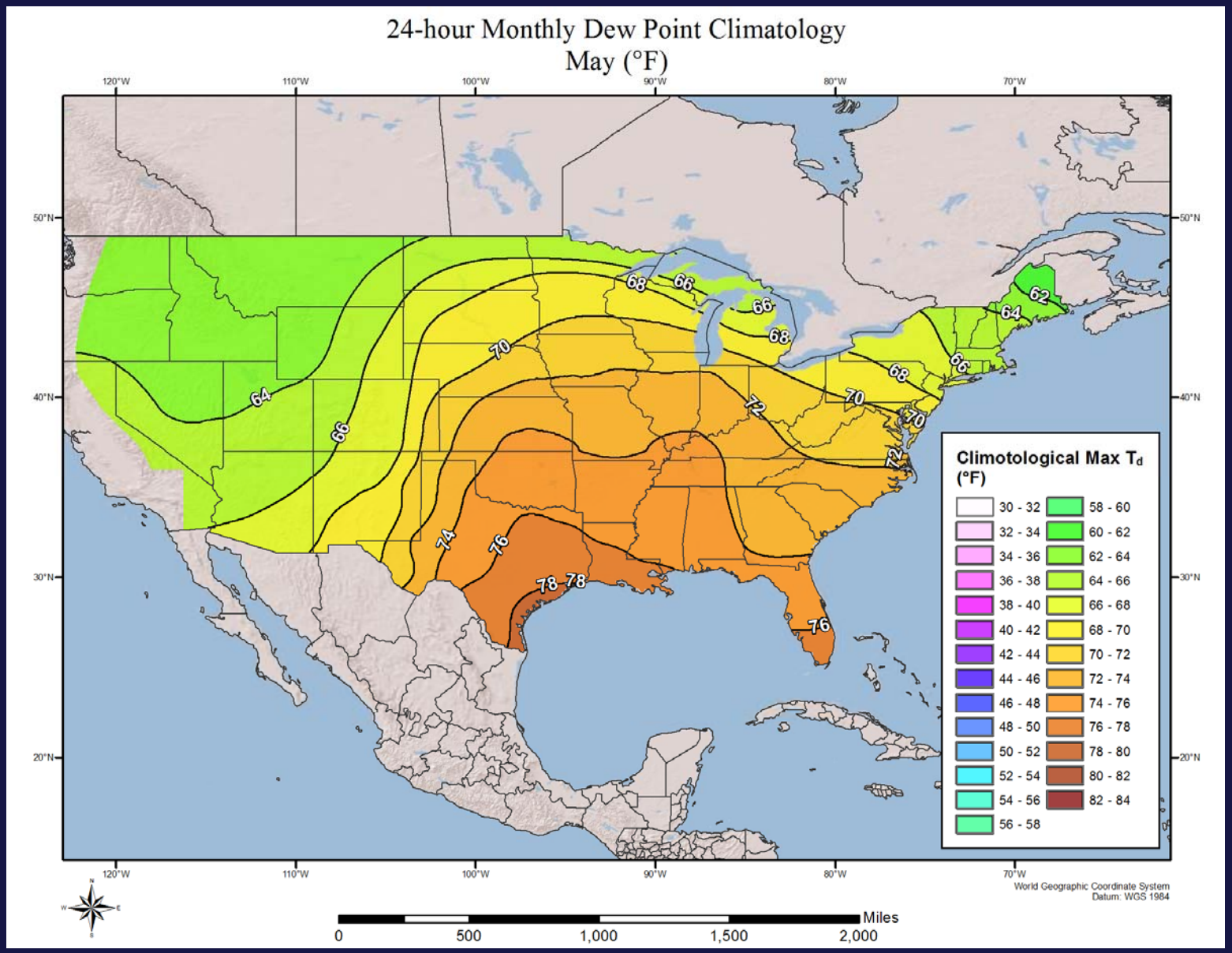


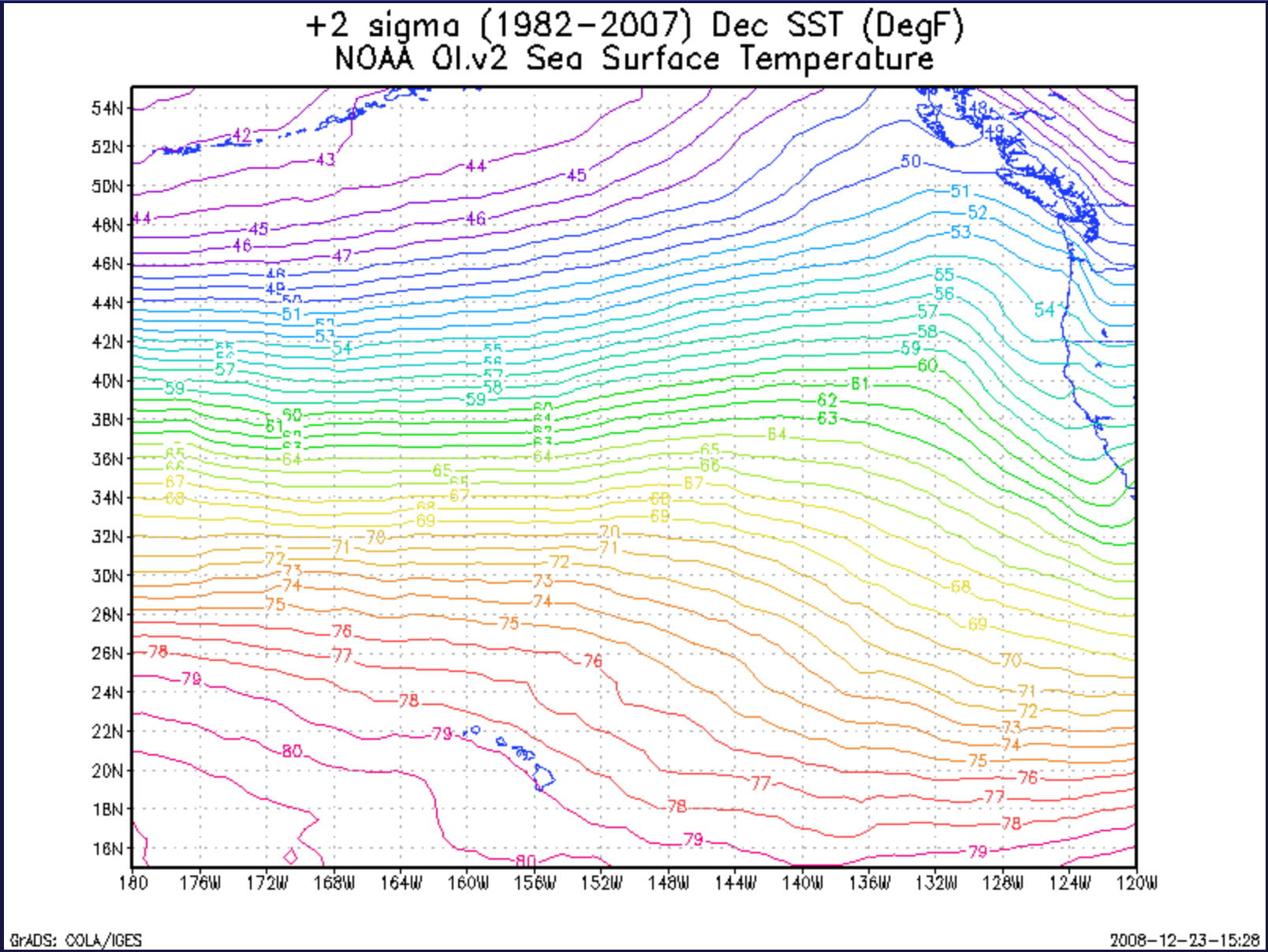
Maximum Dew Point Climatologies

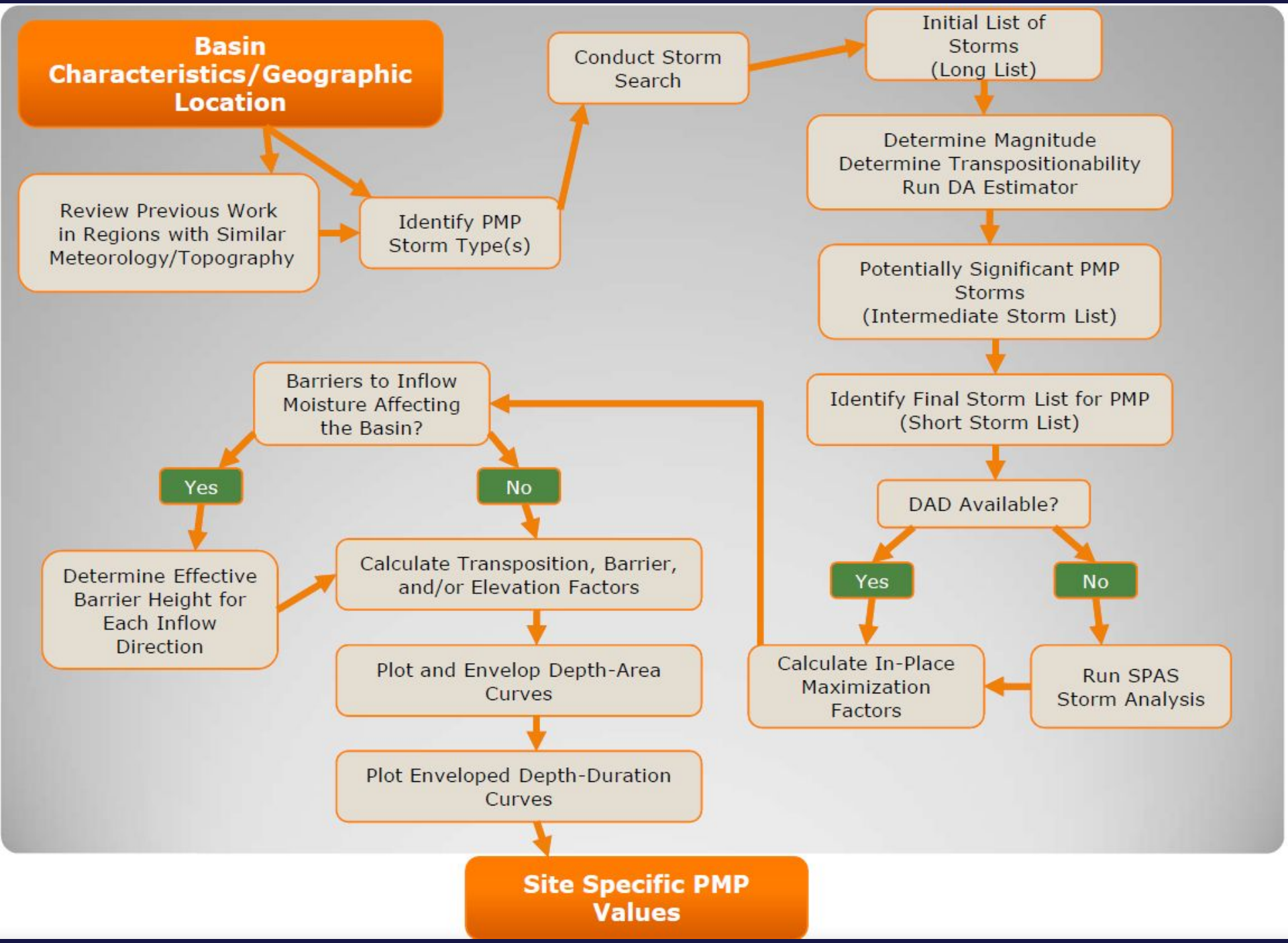


Dew Point Map, May 24-hr 100-yr



Sea Surface Temp, Dec +2-sigma




Basin Characteristics/Geographic Location
Review Previous Work in Regions with Similar Meteorology/Topography
Identify PMP Storm Type(s)
Conduct Storm Search
Initial List of Storms (Long List)
Determine Magnitude
Determine Transpositionability
Run DA Estimator
Potentially Significant PMP Storms (Intermediate Storm List)
Identify Final Storm List for PMP (Short Storm List)
DAD Available?
Yes
No
Run SPAS Storm Analysis
Calculate In-Place Maximization Factors
Barriers to Inflow Moisture Affecting the Basin?
Yes
No
Determine Effective Barrier Height for Each Inflow Direction
Calculate Transposition, Barrier, and/or Elevation Factors
Plot and Envelop Depth-Area Curves
Plot Enveloped Depth-Duration Curves
Site Specific PMP Values

How Did We Compute PMP?

- PMP on a ~2.5mi^2 grid
  - 64,103 grid cells-that's a lot of data!
- Move maximized storms to each grid
- Account for differences in moisture and elevation
- Calculate the Orographic Transposition Factor (OTF)
  - Uses Precip Frequency-NOAA Atlas 14
  - Difference between source and target location
- OTF-Quantifiable/Reproducible
  - Replaces HMR SSM, K-Factor
    - Highly subjective
    - Not reproducible
- Results in total adjustment factor
- Apply to the DAD values

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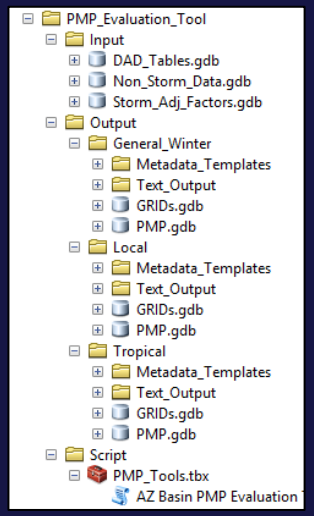
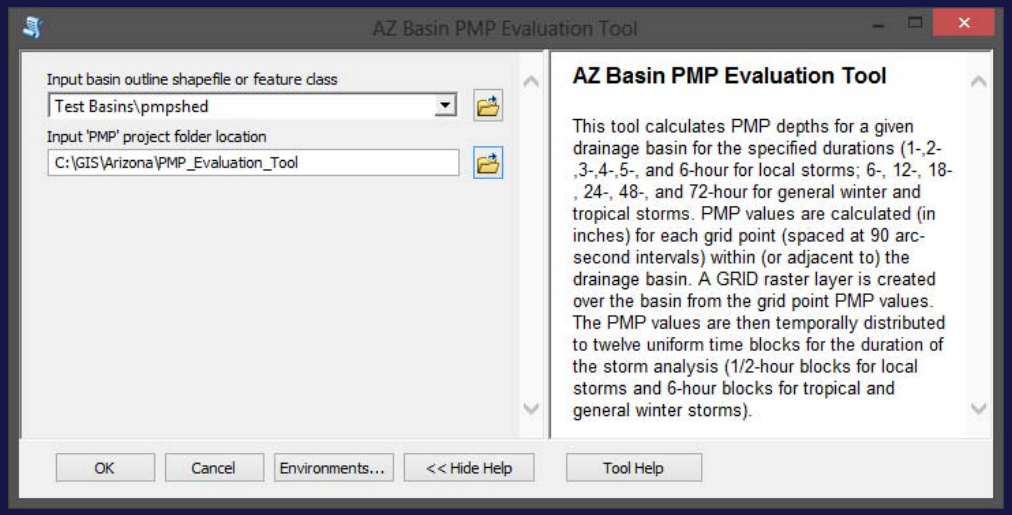
PMP Evaluation Tool (PET)

- Calculates gridded PMP for a user-defined drainage basin
- Custom Python-based scripted tool
  - Designed to be used within the ArcGIS environment
  - Flexible for future updates/enhancements
- Iterates through a storm database
  - Currently 93 maximized historical DAD tables
  - Adjusted to each grid cell
- Produces temporally distributed PMP output in both vector and raster GIS file formats for the basin spatial extent





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Example PMP Results

Tool Running on 8 Basins

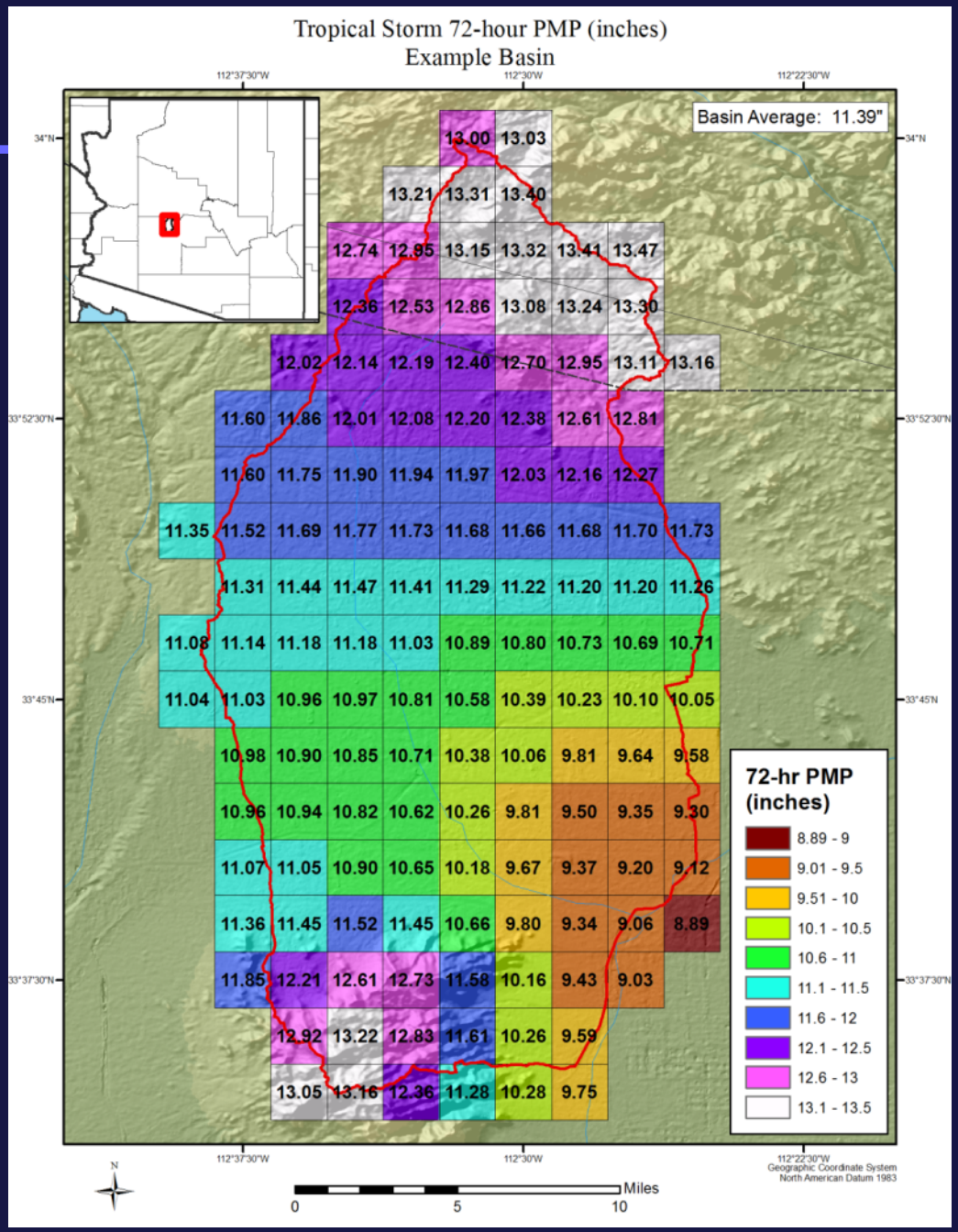
Different Regions, Different Area Sizes

Example PMP Results

72-hour tropical storm PMP values

Provide basin, sub basin, or grid values/average

Associated with storm type temporal timing

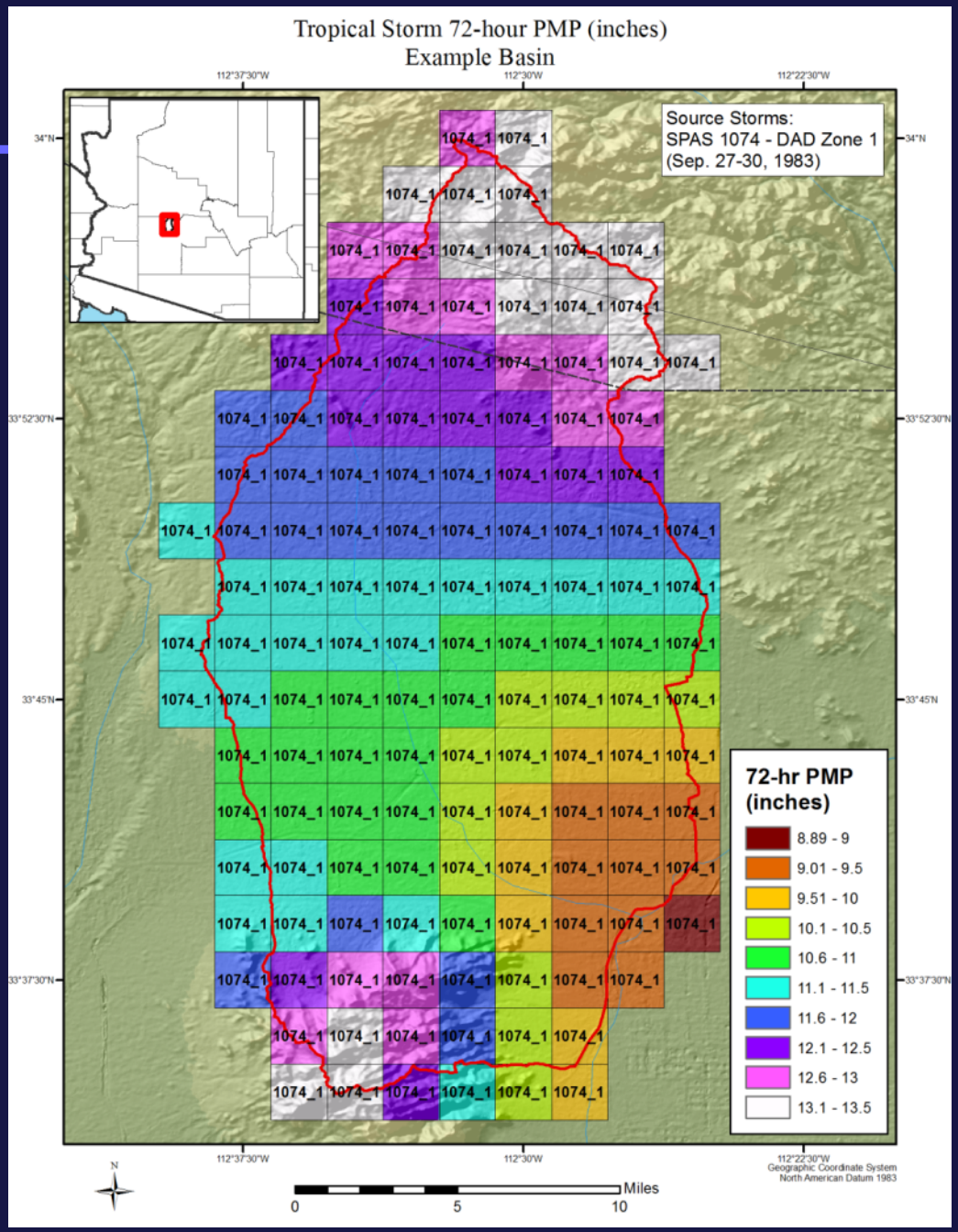


Example PMP Results

72-hour tropical storm PMP

Source storm ID by SPAS storm number

Allows for back calculation and verification



Presentation Outline

- Reason for the study
- Regulator Perspective
- PMP Development Process
- Storm based approach
  - 49 new storms analyzed!
  - Updated dew point/SST climatologies
  - Explicitly Address orographics
- Results/findings
  - Quantifiable/Reproducible
  - No black box

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Deliverables for Arizona

- Updated storm database
  - 51 new storm analyses using SPAS
  - 3 PMP storm types
- Enormous amount of data
- PMF hydrologic implementation parameters
  - Temporal distributions
  - Basin specific distributions
- One PMP process using state-of-the-science understanding and techniques

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Updating PMP-What Did We Do

- Storm Search
  - Update the storm database
  - Identify the most extreme rainfall events
    - Throughout the state
    - Surrounding regions
  - Identify Storm Types
    - Local Convective
    - Remnant Tropical
    - General Frontal

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Updating PMP-Storm Search

- 1000's of storms initially captured
- Grouped by storm type
  - Local Convective, tropical, Frontal
  - Location
  - Duration
- Storms used in HMRs included
- Ensure no potential PMP storms missed
- Storms must be transpositionable
  - Meteorological and topographical similar characteristics

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