SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

April 2014
Board of Consultants Meeting (#4)

Probable Maximum Precipitation Review and Update

ALASKA ENERGY AUTHORITY

Site-Specific PMP Susitna-Watana Basin

Applied Weather Associates, LLC
Monument, CO

Bill Kappel
President/Chief Meteorologist

Doug Hultstrand
Senior Hydrometeorologist

PMP Overview Presentation Outline

- Work Completed to Date
  - Review Completed Tasks
  - Review Ongoing Tasks
  - Review PMP Development
    - Seasonality
    - Met time series
  - Draft Final Report

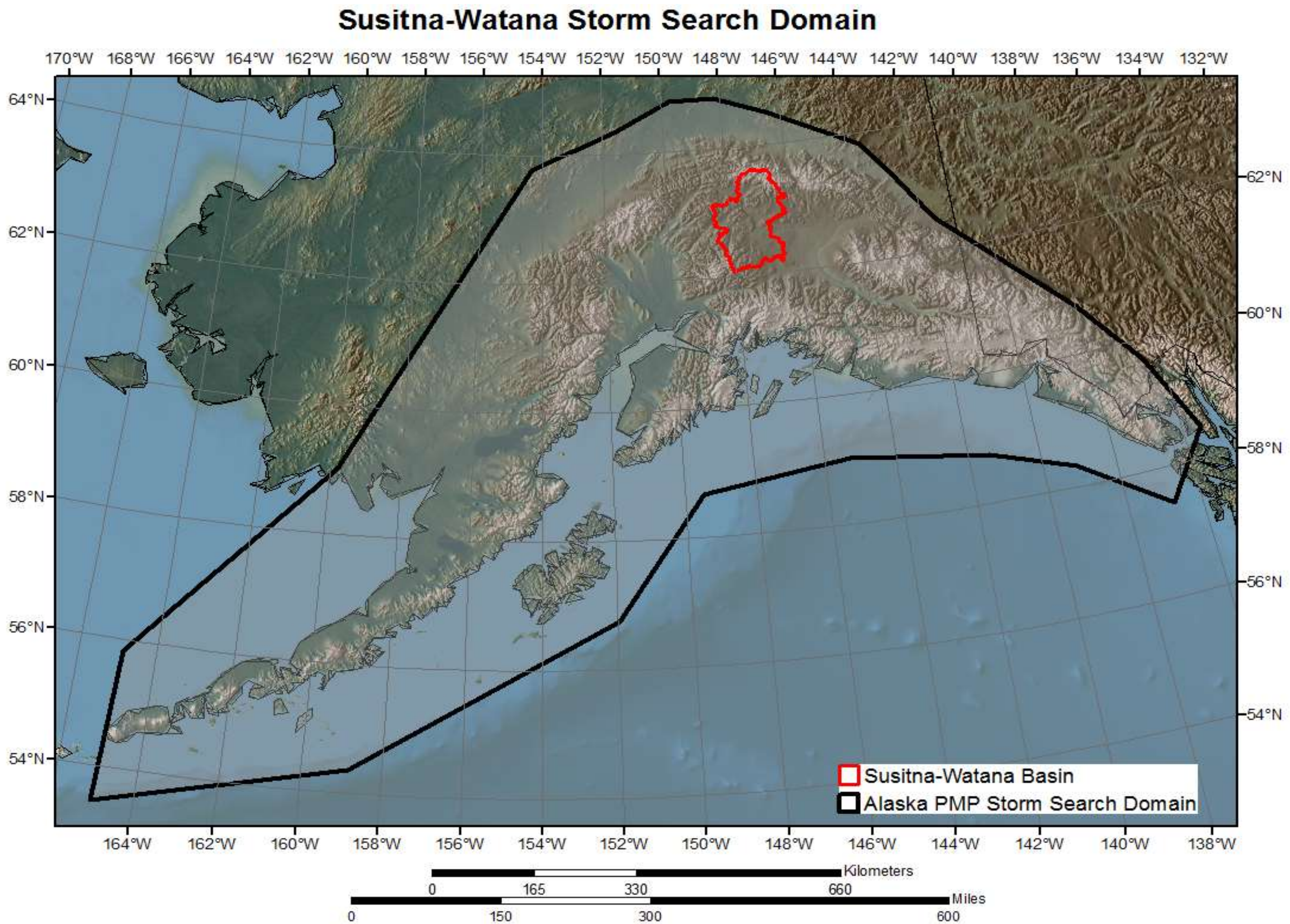
PMP Overview

- Task 1-Review Previous Work – Completed
  - All previous PMP/Rainfall analysis work
    - HMR 42
    - USACE 1975
    - Acres 1982
    - Harza-Ebasco 1984
    - NWS storm studies
    - Other articles/reports

PMP Overview

- Task 2-Storm Search/Short Storm List – Completed
  - Initial storm search
    - Long list of storm derived
      - All storm analyzed to determine if further analysis required
    - Short storm list
      - All storms fully analyzed using SPAS
        - Used to derive PMP
        - To be used for model calibration and snowmelt calcs
        - Used for spatial/temporal distributions

PMP Overview



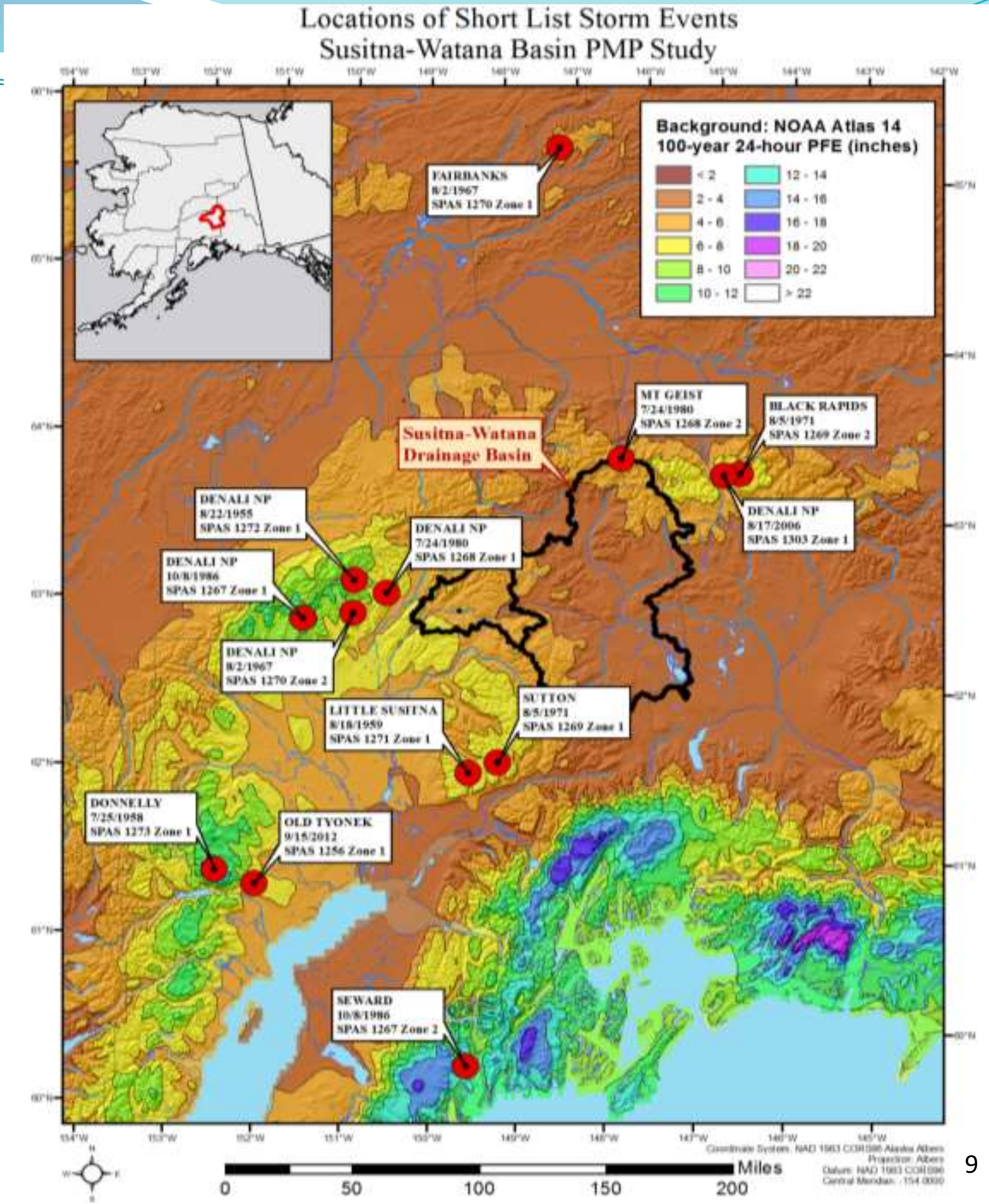
Long Storm List

Name	ST	Lat	Lon	Year	Mon	Day	Total Rainfall	AWA Storm Analysis	Transpositionable to Basin	Snow in the basin	Larger Storm in Similar Location	No Rain in basin or region	Data to Complete Analysis	More than 35% of Max Storm amount (>12.00")
COAL HARBOR	AK	55.400	-160.817	1900	4	23	10.00							No
COAL HARBOR	AK	55.400	-160.817	1909	4	3	8.00							No
CORDOVA WB A	AK	60.500	-145.500	1912	9	26	19.75						No	
CORDOVA WB A	AK	60.500	-145.500	1917	9	9	9.40							No
CORDOVA WB A	AK	60.500	-145.500	1925	9	20	15.69				Yes			
CORDOVA WB A	AK	60.500	-145.500	1925	10	6	24.12						No	
CHIGNIK	AK	56.300	-158.400	1927	8	15	14.99		No			Yes	No	
CHIGNIK	AK	56.300	-158.400	1927	9	19	15.43		No			Yes		
CHIGNIK	AK	56.300	-158.400	1929	9	8	16.38		No				No	
CHIGNIK	AK	56.300	-158.400	1930	5	9	18.93		No				No	
CHIGNIK	AK	56.300	-158.400	1930	5	25	15.78		No			Yes		
DENALI NP	AK	63.038	-150.471	1955	8	22	13.75	Yes						
CORDOVA	AK	60.646	-145.554	1955	8	22	21.67	Yes						
CAPE SPENCER	AK	58.200	-136.633	1956	11	24	20.93		No					
MT SPURR	AK	61.346	-152.329	1958	7	25	6.62	Yes						
LITTLE SUSITNA	AK	61.854	-149.229	1959	8	18	13.05	Yes						
CAPE HINCHINBROOK	AK	60.233	-146.650	1962	4	13	20.50		No	Yes				
CAPE HINCHINBROOK	AK	60.233	-146.650	1962	5	9	29.95		No					
CAPE HINCHINBROOK	AK	60.233	-146.650	1962	5	25	13.75				Yes			
CAPE SPENCER	AK	58.200	-136.633	1966	11	23	15.80		No					
DENALI NP	AK	62.846	-150.513	1967	8	2	12.45	Yes						
FAIRBANKS	AK	65.521	-147.329	1967	8	2	12.45	Yes						
HOMER	AK	59.871	-150.563	1967	8	2	12.45	Yes						
CHIGNIK	AK	56.300	-158.400	1969	6	4	14.81		No			Yes		
CAPE HINCHINBROOK	AK	60.233	-146.650	1969	7	24	22.90		No					
CHIGNIK	AK	56.300	-158.400	1969	10	12	14.68			Yes		Yes		
BLACK RAPIDS	AK	63.471	-145.479	1971	8	5	12.17	Yes						
SUTTON	AK	61.904	-148.863	1971	8	5	11.39	Yes						
PORTAGE	AK	61.004	-148.663	1971	8	5	12.17	Yes						
DENALI NP	AK	62.954	-150.079	1980	7	24	7.33	Yes						
ANGOON PWR	AK	57.499	-134.586	1982	10	12	15.20		No					
DENALI NP	AK	62.829	-151.138	1986	10	8	11.01	Yes						
SEWARD	AK	60.113	-149.513	1986	10	8	20.80	Yes						
OUZINKIE	AK	57.933	-152.500	1991	11	1	10.76			Yes				
WHITTIER	AK	60.713	-148.779	1995	9	19	26.03		No					
SEWARD	AK	60.117	-149.450	1995	9	20	9.81							No
BIG RIVER LA	AK	60.817	-152.300	1996	3	22	7.50							No
ELFIN COVE	AK	58.200	-136.667	1996	9	25	8.61							No
CANNERY CREEK	AK	60.696	-145.688	2003	9	29	23.69		No					
PELICAN	AK	57.950	-136.233	2005	11	17	26.87		No					
BLACK RAPIDS	AK	63.465	-145.685	2006	8	17	16.12	Yes						
CANNERY CREEK	AK	60.696	-145.688	2006	10	7	23.63		No			Yes		
OLD TYONEK	AK	61.260	-151.860	2012	9	15	15.91	Yes						
KENAI FJORDS NP	AK	59.610	-150.220	2012	9	15	33.96	Yes						

Short Storm List

Name	ST	Lat	Lon	Year	Mon	Day	Total Rainfall	Precipitation Source
DENALI NP	AK	63.038	-150.471	1955	8	22	13.75	SPAS 1272 Zone 1
MT SPURR	AK	61.346	-152.329	1958	7	25	6.62	SPAS 1273 Zone 1
LITTLE SUSITNA	AK	61.854	-149.229	1959	8	18	13.05	SPAS 1271 Zone 1
DENALI NP	AK	62.846	-150.513	1967	8	2	12.45	SPAS 1270 Zone 2
FAIRBANKS	AK	65.521	-147.329	1967	8	2	12.45	SPAS 1270 Zone 1
BLACK RAPIDS	AK	63.471	-145.479	1971	8	5	12.17	SPAS 1269 Zone 2
SUTTON	AK	61.904	-148.863	1971	8	5	11.39	SPAS 1269 Zone 1
MT GEIST	AK	63.638	-146.971	1980	7	24	5.26	SPAS 1268 Zone 2
DENALI NP	AK	62.954	-150.079	1980	7	24	7.33	SPAS 1268 Zone 1
DENALI NP	AK	62.829	-151.138	1986	10	8	11.01	SPAS 1267 Zone 1
SEWARD	AK	60.113	-149.513	1986	10	8	20.80	SPAS 1267 Zone 2
BLACK RAPIDS	AK	63.465	-145.685	2006	8	17	16.12	SPAS 1303 Zone 1
OLD TYONEK	AK	61.260	-151.860	2012	9	15	15.91	SPAS 1256 Zone 1

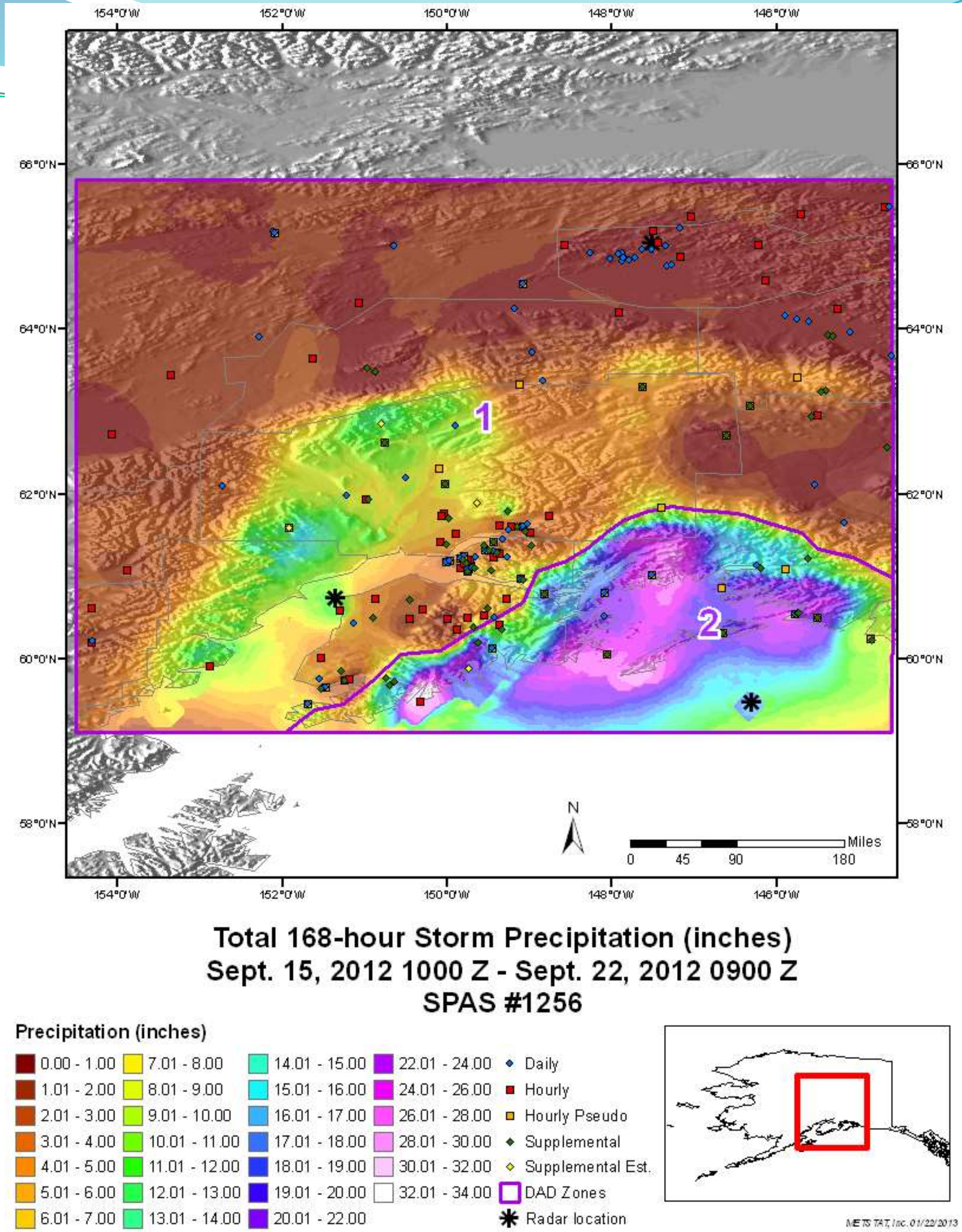
Short Storm List Locations in Relation to Susitna-Watana Basin



PMP Overview

- Task 3-SPAS Storm Analyses – Completed
  - Nine completed (budgeted for 10)
    - Sept 2012 (SPAS 1256)
    - August 2006 (SPAS 1303)
    - Oct 1986 (SPAS 1267)
    - July 1980 (SPAS 1268)
    - Aug 1971 (SPAS 1269)
    - Aug 1967 (SPAS 1270)
    - Aug 1959 (SPAS 1271)
    - Aug 1958 (SPAS 1272)
    - Aug 1955 (SPAS 1272)

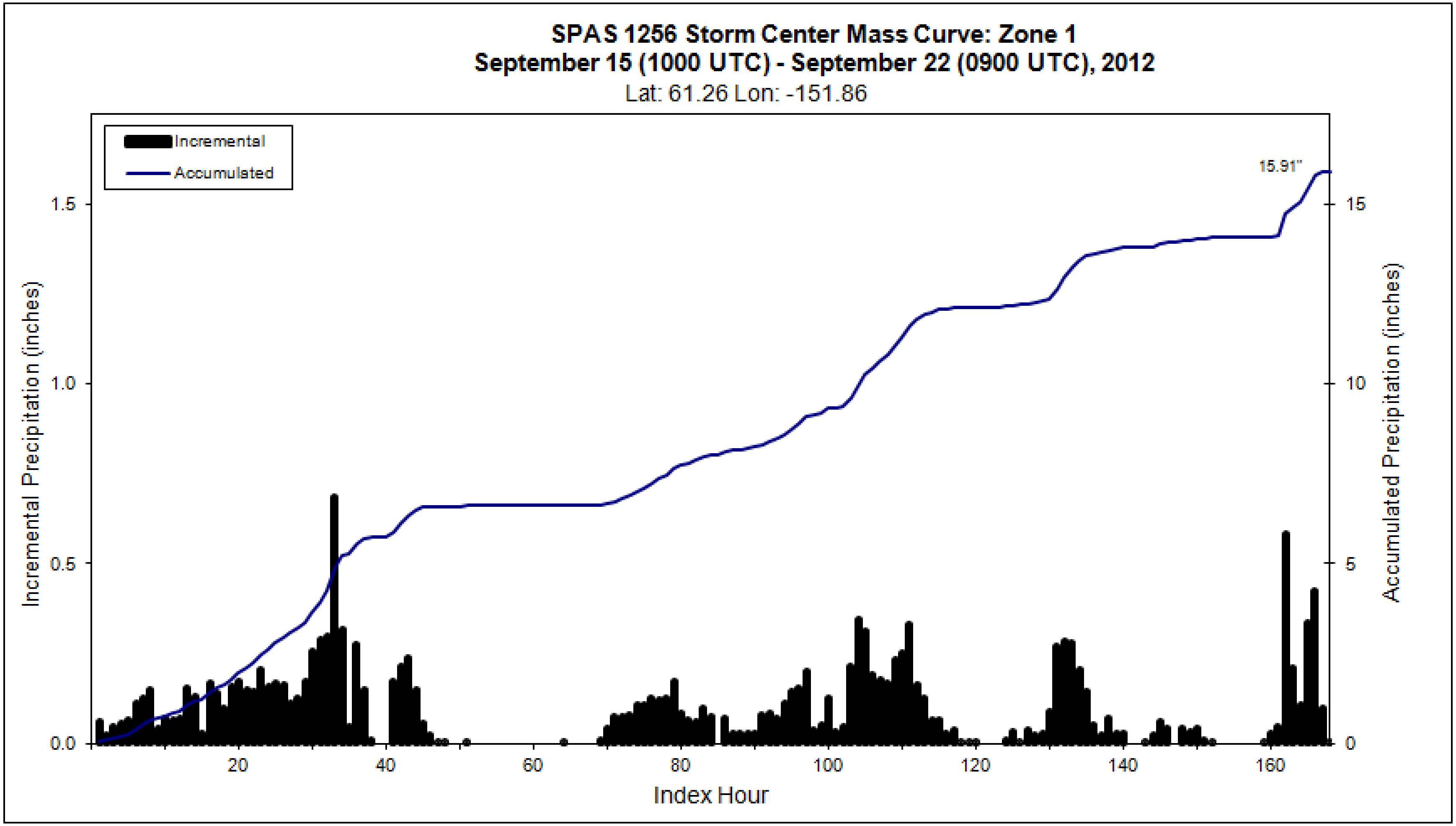
September 2012 Total Storm Rainfall Image



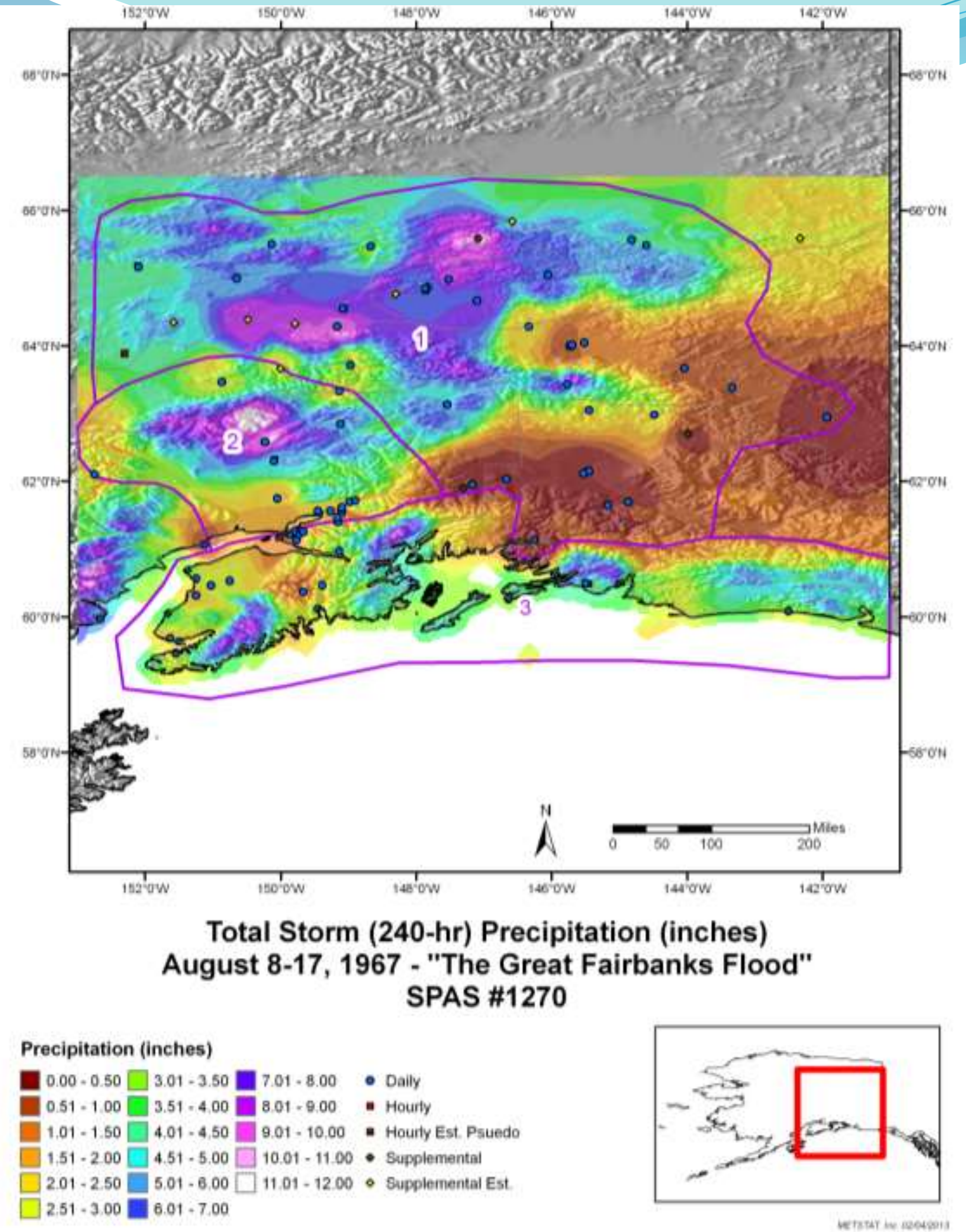
September 2012
Depth-Area-Duration Rainfall

Storm 1256 - Sep. 15 (1000 UTC) - Sep. 22 (0900 UTC), 2013												
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)												
	Duration (hours)											
Area (mi^2)	1	6	12	24	36	48	72	96	120	144	168	Total
0.2	0.88	3.26	3.98	6.23	8.76	8.86	9.3	10.52	12.34	13.83	15.91	15.91
1	0.86	3.16	3.9	6.06	8.53	8.63	9.06	10.03	11.87	13.27	15.32	15.32
10	0.86	3.16	3.87	6.06	8.31	8.59	9.03	10.03	11.87	13.27	15.32	15.32
25	0.86	3.04	3.72	5.88	8.25	8.36	8.79	10.01	11.86	13.27	15.32	15.32
50	0.86	2.88	3.64	5.63	7.94	8.01	8.42	9.73	11.55	13.27	15.32	15.32
100	0.85	2.58	3.61	5.09	7.34	7.41	7.86	9.66	11.52	13.16	15.25	15.25
150	0.84	2.45	3.57	4.79	6.74	6.78	7.63	9.66	11.49	13.04	15.13	15.13
200	0.83	2.42	3.53	4.49	6.41	6.58	7.5	9.66	11.29	12.92	15	15.00
300	0.81	2.37	3.46	4	5.83	6.44	7.43	9.58	11.13	12.57	14.76	14.76
400	0.77	2.32	3.4	3.98	5.23	6.31	7.36	9.5	10.99	12.33	14.52	14.52
500	0.77	2.29	3.35	3.96	5.21	5.95	7.27	9.43	10.83	12.33	14.34	14.34
1,000	0.75	2.12	3.14	3.8	4.76	5.85	7.05	9.08	10.43	11.77	13.61	13.61
2,000	0.71	1.83	2.73	3.64	4.55	5.5	6.78	8.61	9.95	11.22	12.86	12.86
5,000	0.59	1.57	2.52	3.28	4.03	4.98	6.34	7.66	9.07	10.66	11.83	11.83
10,000	0.46	1.38	2.28	3.03	3.66	4.52	5.91	6.82	8.16	9.77	10.72	10.72
20,000	0.32	1.12	1.91	2.58	3.18	3.9	5.14	5.82	7.07	8.38	9.24	9.24
50,000	0.13	0.72	1.18	1.73	2.27	2.6	3.49	4.02	4.49	5.42	6.24	6.24
100,000	0.08	0.43	0.77	1.08	1.42	1.86	2.17	2.58	2.74	3.47	3.92	3.92
116,206	0	0	0.67	0.94	1.29	1.63	1.94	2.24	2.55	3.04	3.29	3.29

September 2012 Storm Center Mass Curve



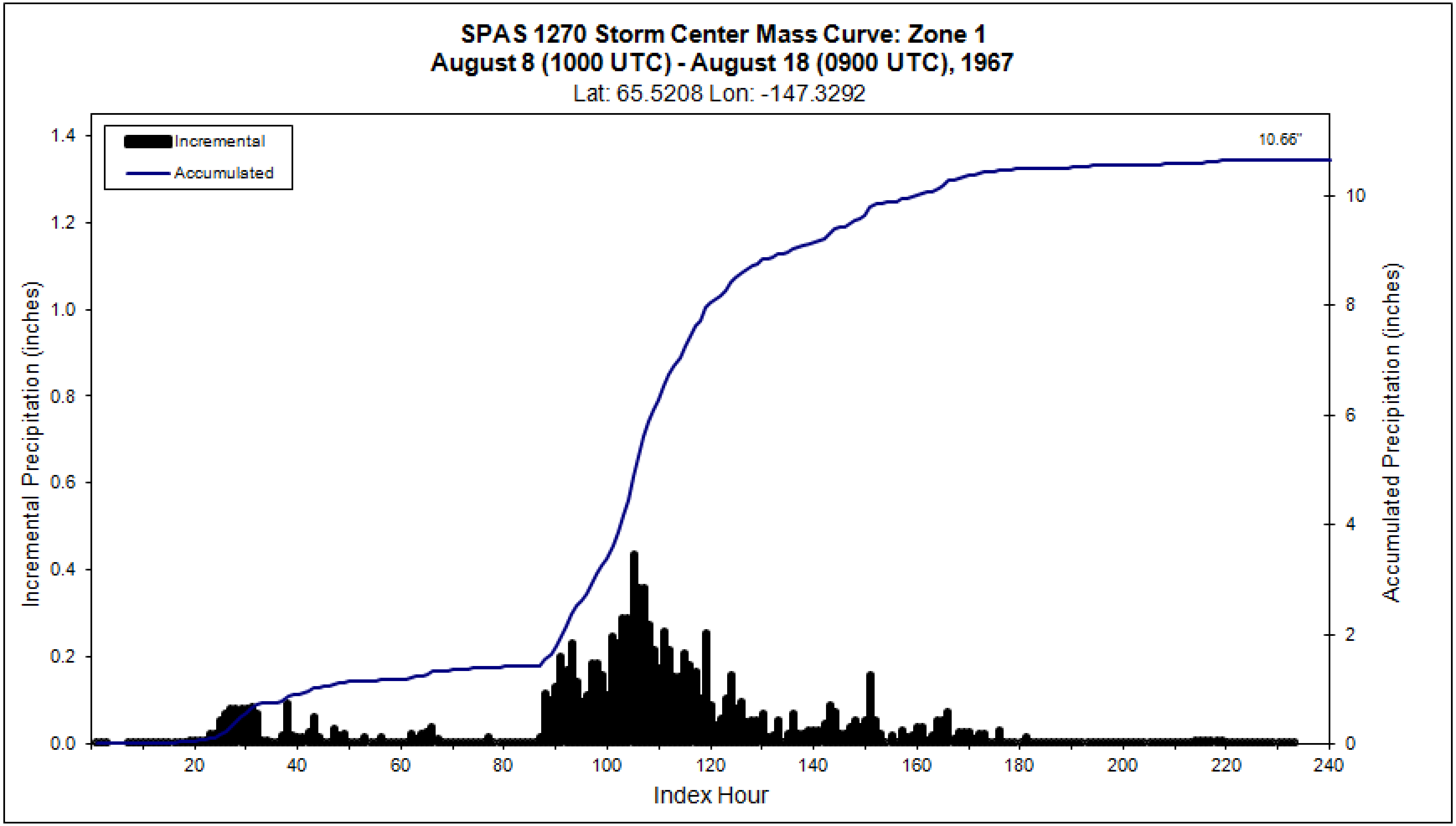
August 1967 “Great Fairbanks Flood” Total Storm Rainfall Image



August 1967 Depth-Area-Duration Rainfall

Storm 1270 - Aug. 8 (1000 UTC) - Aug. 18 (0900 UTC), 1967 MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)														
	Duration (hours)													
Area (mi^2)	1	6	12	24	48	72	96	120	144	168	192	216	240	Total
0.3	0.58	2.04	3.37	5.36	7.54	8.55	9.1	9.71	10.21	10.5	10.56	10.65	10.66	10.66
1	0.55	1.96	3.26	5.18	7.32	8.3	8.83	9.35	9.89	10.19	10.22	10.33	10.33	10.33
10	0.55	1.96	3.26	5.18	7.32	8.3	8.83	9.35	9.89	10.19	10.22	10.33	10.33	10.33
25	0.55	1.96	3.26	5.18	7.32	8.3	8.83	9.35	9.89	10.19	10.22	10.33	10.33	10.33
50	0.55	1.96	3.26	5.18	7.32	8.3	8.83	9.35	9.89	10.19	10.22	10.33	10.33	10.33
100	0.53	1.94	3.16	5.07	7.18	8.16	8.59	9.35	9.75	9.94	9.96	10.2	10.26	10.26
150	0.51	1.91	3.16	5.04	7.1	8.07	8.54	9.16	9.63	9.8	9.88	10.12	10.18	10.18
200	0.5	1.88	3.06	4.91	6.98	7.98	8.49	9.12	9.59	9.79	9.86	10.05	10.11	10.11
300	0.48	1.84	3.04	4.83	6.85	7.67	8.39	9.1	9.51	9.79	9.83	9.9	9.95	9.95
400	0.47	1.79	2.93	4.71	6.69	7.64	8.26	8.9	9.41	9.62	9.65	9.79	9.85	9.85
500	0.46	1.75	2.91	4.66	6.54	7.64	8.21	8.84	9.33	9.5	9.51	9.72	9.78	9.78
1,000	0.44	1.69	2.77	4.51	6.37	7.44	7.81	8.4	8.98	9.13	9.17	9.42	9.5	9.50
2,000	0.41	1.62	2.59	4.27	6.11	7.1	7.51	7.92	8.56	8.71	8.97	9.07	9.18	9.18
5,000	0.37	1.5	2.42	3.91	5.67	6.32	7.1	7.36	7.92	8.21	8.28	8.53	8.59	8.59
10,000	0.33	1.32	2.17	3.55	5.04	5.99	6.45	6.83	7.37	7.56	7.83	7.95	7.97	7.97
20,000	0.28	1.14	1.9	3.03	4.29	5.05	5.63	6.07	6.49	6.89	6.95	7.12	7.17	7.17
50,000	0.16	0.73	1.32	2.23	3.11	3.89	4.3	4.51	4.86	5.24	5.38	5.46	5.5	5.50

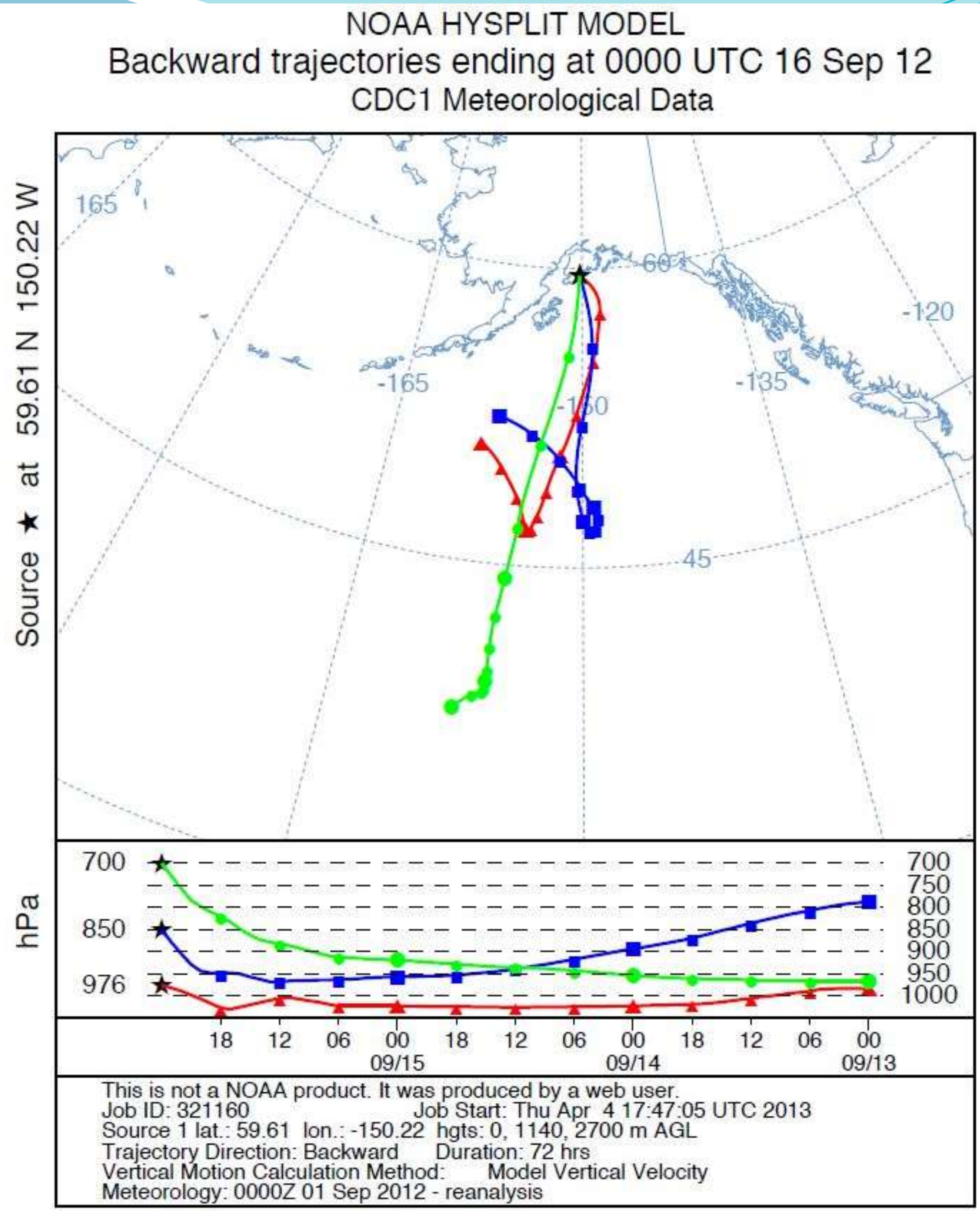
August 1967 Storm Center Mass Curve



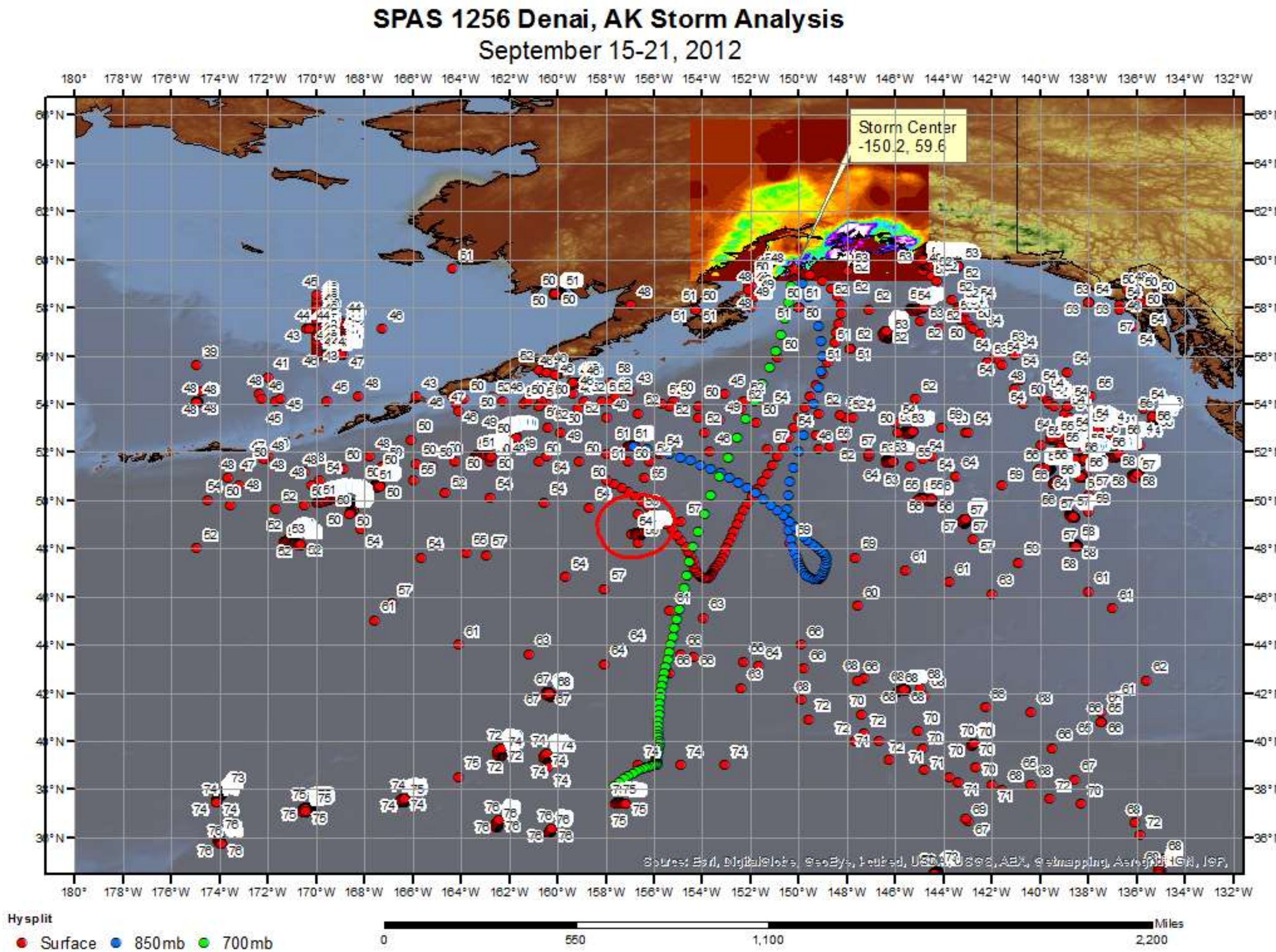
PMP Overview

- Task 4-Storm Maximization, Transposition, Orographic Analysis – Completed
  - Follows standard HMR-AWA process
    - How much bigger could a storm have been had met parameters been perfect versus what actually occurred
  - In-place maximization factors calculated all storms
    - Use Sea Surface Temperature (SST) observations and 2-sigma SST climatology
    - Storm rep SST subjectively analyzed by AWA
      - HYSPLIT used as guidance in all evaluations
      - Sensitivity ~%5 per 1°F
  - Transposition of storm centers over the south side of coastal range NOT transpositionable to basin
    - Different meteorology/topography
      - Evidenced by rainfall amounts, rainfall patterns, climatological rainfall patterns, etc
  - OTF process employed
    - Explicitly quantifies effects of orographics
    - Calculated all values

HYSPLIT Backward Trajectory from Storm Center



Storm Representative SST Analysis



Storm Spreadsheet with all Calculation Inputs

Storm Name:	SPAS 1256 Old Tyonek, AK DAI	**Storm Adjustment for Susitna-Watana**
Storm Date:	9/15-22/2012	
AWA Analysis Date:	1/22/2013	

Temporal Transposition Date 15-Sep

	Lat	Long
Storm center location	61.26 N	151.86 W
Storm Rep SST location	49.00 N	157.00 W
Transposition SST location	NA	NA
Basin location	42.76 N	74.12 W

Moisture Inflow Direction:	SSW @ 870	miles
Basin Elevation	NA	feet
Storm Elevation	2,730	feet
Storm Duration	24	hours
Effective Barrier Height	NA	feet

The storm representative SST is	54.0 F	with total precipitable water above sea level of			1.02	inches
The in-place maximum SST is	57.0 F	with total precipitable water above sea level of			1.19	inches
The transpositioned maximum SST is	NA	with total precipitable water above sea level of			4.44	inches
The in-place storm elevation is	2,730	which subtracts	0.18	inches of precipitable water at	54.0 F	
The in-place storm elevation is	2,730	which subtracts	0.20	inches of precipitable water at	57.0 F	
The transposition storm elevation at	NA	which subtracts	xx	inches of precipitable water at	NA	
The moisture inflow barrier height is	NA	which subtracts	xx	inches of precipitable water at	NA	

The in-place maximization factor is	1.18
The transposition/elevation factor is	#VALUE!
The barrier adjustment factor is	#VALUE!
The total adjustment factor is	#VALUE!

Notes: Storm representative SST value was based on SST values for September 13-14, 2012 along the surface HYSPLIT trajectory data. The HYSPLIT trajectory also represents the second period of precipitation well. Values were selected in region where temperature did not vary more than a 1-degree over a large area and had temperature recordings throughout the period.

Observed Storm Depth-Area-Duration

	1 Hour	6 Hours	12 Hours	24 Hours	36 Hours	48 Hours	72 Hours	96 Hours	120 Hours	168 Hours
10 sq miles	0.9	3.2	3.9	6.1	8.3	8.6	9.0	10.0	11.9	15.3
100 sq miles	0.9	2.6	3.6	5.1	7.3	7.4	7.9	9.7	11.5	15.3
200 sq miles	0.8	2.4	3.5	4.5	6.4	6.6	7.5	9.7	11.3	15.0
500 sq miles	0.8	2.3	3.4	4.0	5.2	6.0	7.3	9.4	10.8	14.3
1000 sq miles	0.8	2.1	3.1	3.8	4.8	5.9	7.1	9.1	10.4	13.6
2000 sq miles	0.7	1.8	2.7	3.6	4.6	5.5	6.8	8.6	10.0	12.9
5000 sq miles	0.6	1.6	2.5	3.3	4.0	5.0	6.3	7.7	9.1	11.8
10000 sq miles	0.5	1.4	2.3	3.0	3.7	4.5	5.9	6.8	8.2	10.7
20000 sq miles	0.3	1.1	1.9	2.6	3.2	3.9	5.1	5.8	7.1	9.2

Adjusted Storm Depth-Area-Duration

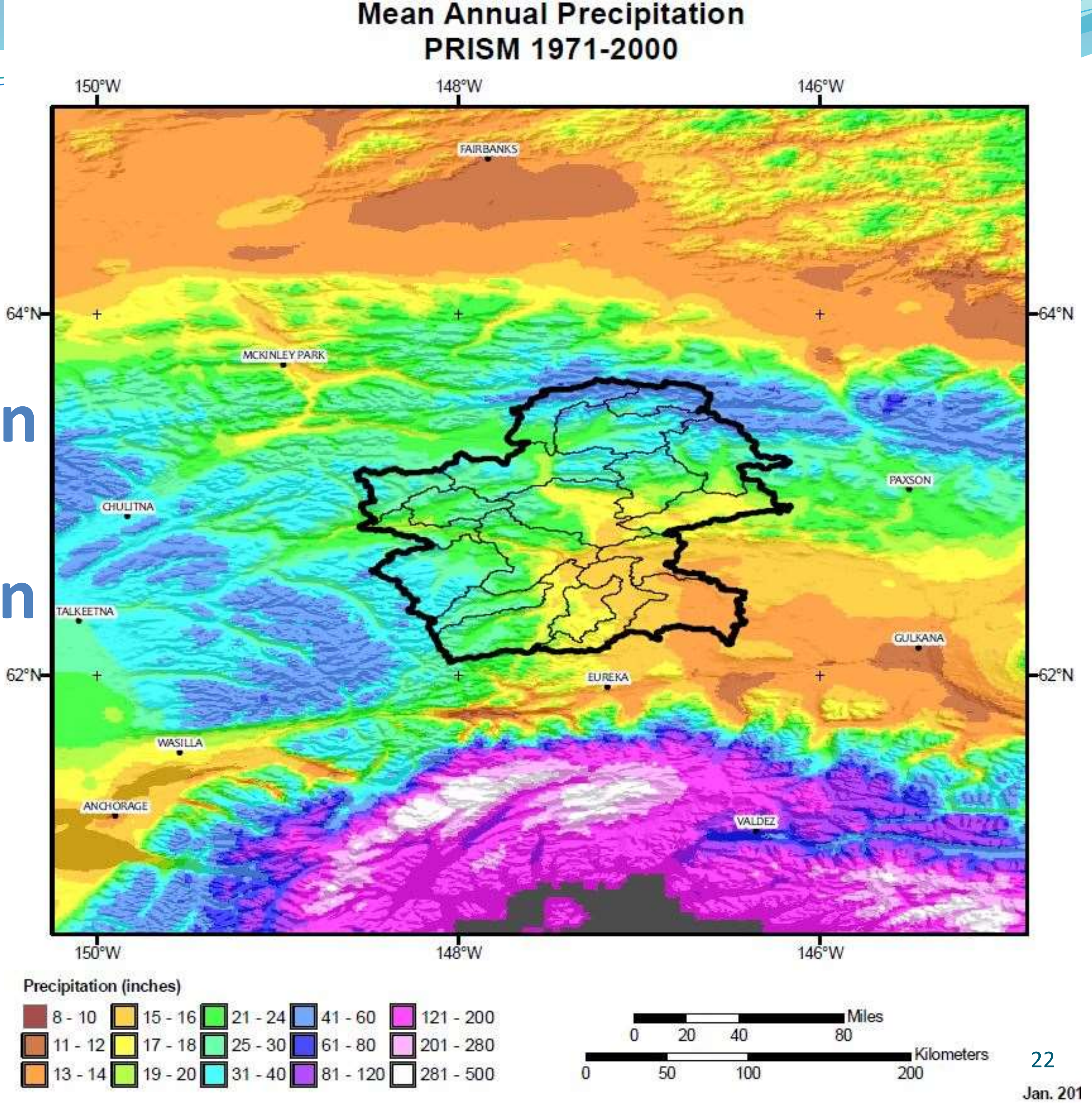
	1 Hour	6 Hours	12 Hours	24 Hours	36 Hours	48 Hours	72 Hours	96 Hours	120 Hours	168 Hours
10 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
100 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
200 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
500 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
1000 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
2000 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
5000 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
10000 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
20000 sq miles	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

Storm or Storm Center Name	**SPAS 1256 Old Tyonek, AK DAD Zone 1**			
Storm Date(s)	9/15-22/2012			
Storm Type	Atmospheric River			
Storm Location	61.26 N	151.86 W		
Storm Center Elevation	2,730			
Precipitation Total & Duration	15.91 inches in 168 hours			
Storm Representative SST	54.0 F		15-Aug	15-Sep
Storm Representative SST Location	49.00 N	157.00 W	56.5	57.0
In-place Maximum SST	57.0 F			
Moisture Inflow Vector	SSW @ 870			
In-place Maximization Factor	1.18			
Temporal Transposition (Date)	15-Sep			
Transposition SST Location	NA	NA		
Transposition Maximum SST	NA			
Transposition Adjustment Factor	#VALUE!			
Average Basin Elevation	NA			
Highest Elevation in Basin	NA			
Inflow Barrier Height	NA			
Elevation Adjustment Factor	#VALUE!			
Total Adjustment Factor	#VALUE!			

PMP Overview

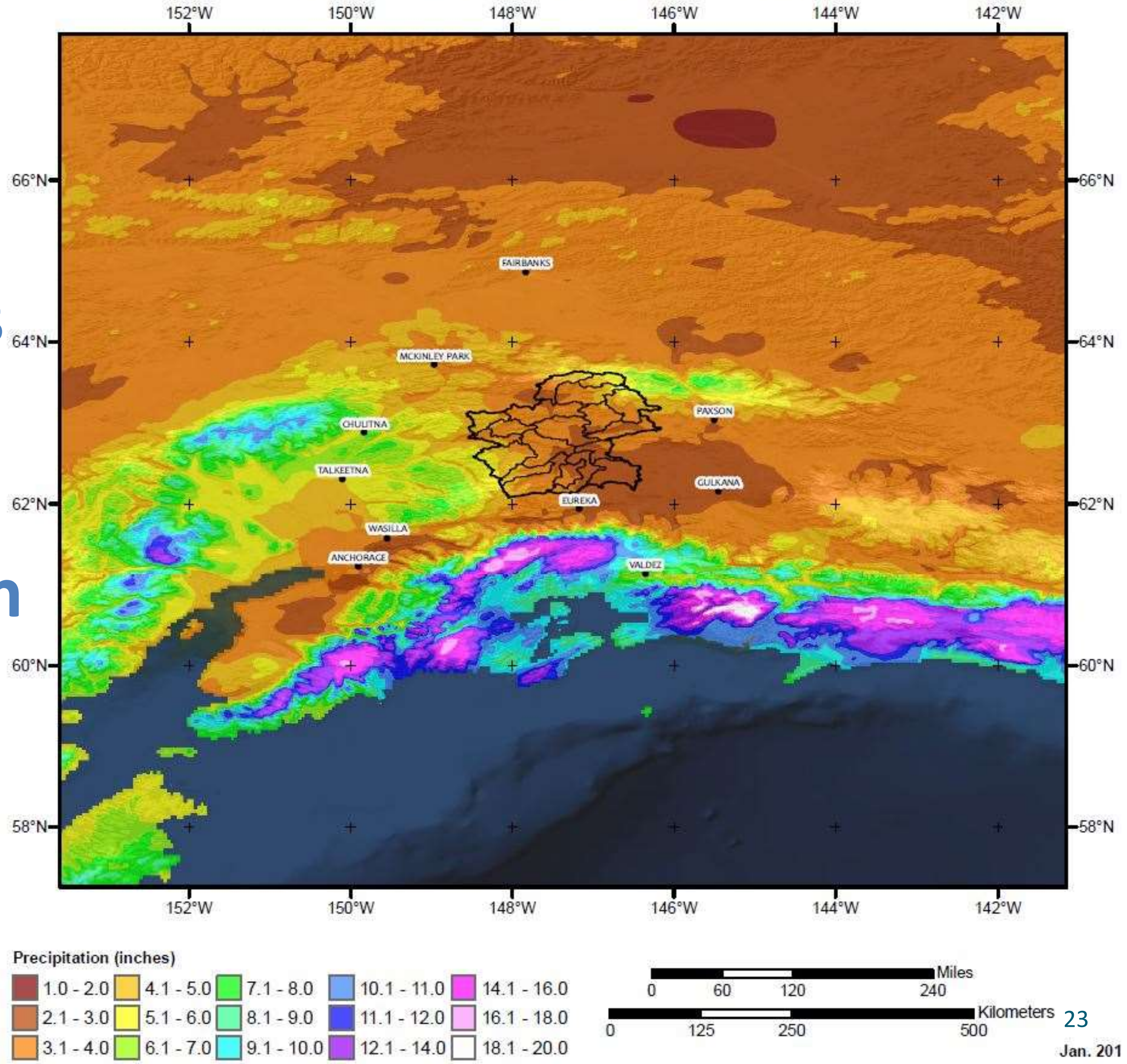
- Task 4-Storm Maximization, Transposition, Orographic Analysis – Completed
  - Transpositionable-must have similar meteorology and topography
  - Transposition of storm centers over the south side of coastal range NOT transpositionable to basin
    - Different meteorology/topography
      - Evidenced by rainfall amounts, rainfall patterns, climatological rainfall patterns, etc.

PRISM Mean Annual Precipitation



NOAA Atlas 14 24-hour 100-year Precipitation Frequency

100-yr 24-hr Precipitation
NOAA Atlas 14, Volume 7, Version 2



Moisture Sources and Climate Regions

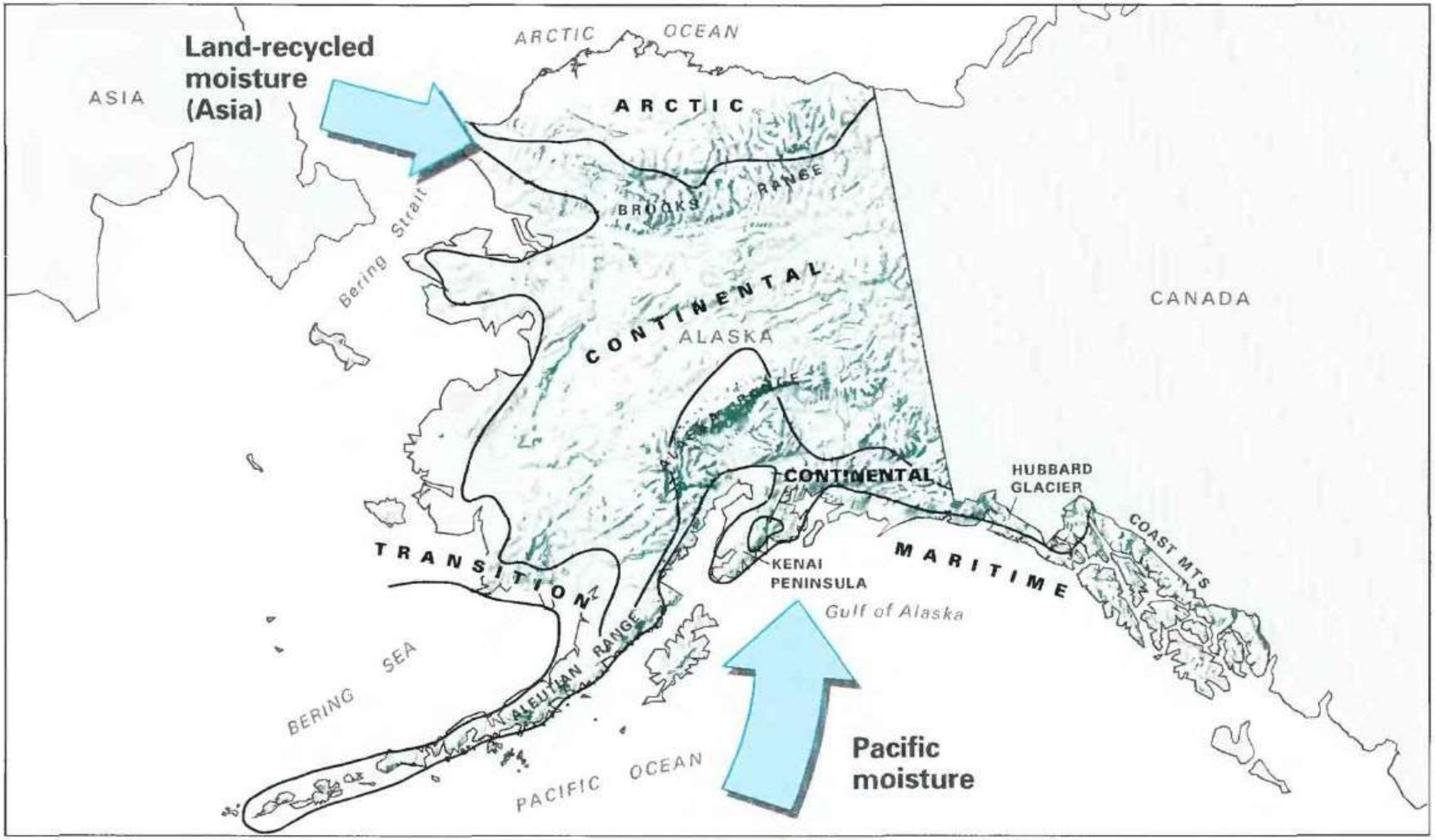


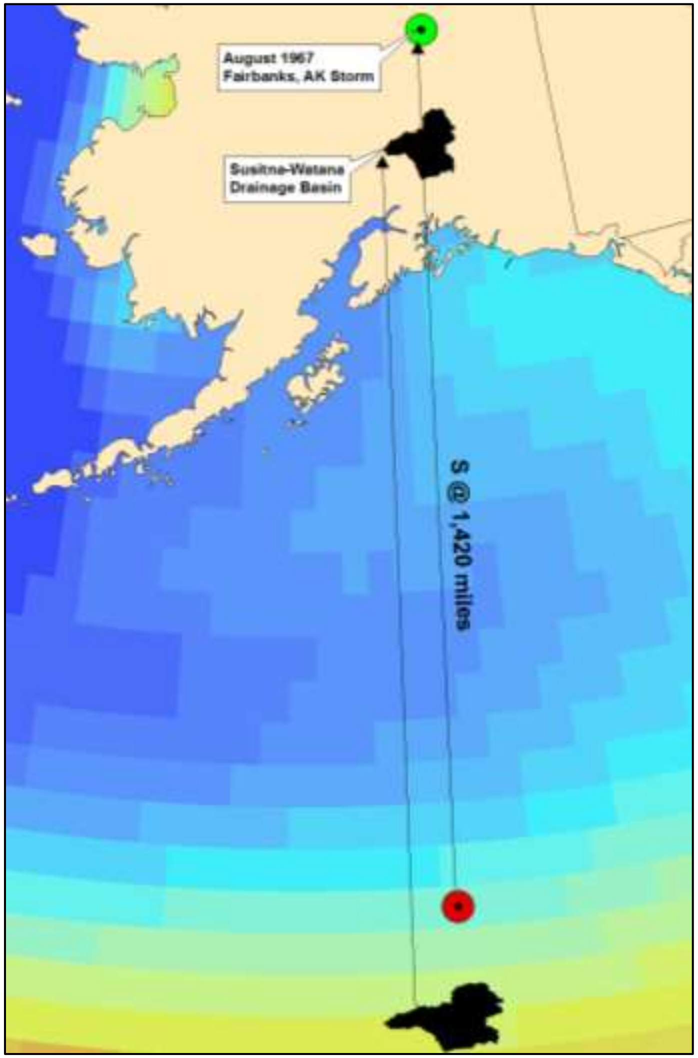
Figure 1. Principal sources and patterns of delivery of moisture into Alaska. Size of arrows implies relative contribution of moisture from source shown. (Sources: Data from Selkregg, 1974, and Douglas R. Clark and Andrea Lage, Wisconsin Geological and Natural History Survey; climatic zones from Selkregg, 1974.)

PMP Overview

- Task 4-Storm Maximization, Transposition, Orographic Analysis – Completed
  - Short-list Storms Maximized
  - MTF process employed
    - Explicitly quantifies variation in precipitable water
    - Calculated for each storm at each grid point
  - OTF process employed
    - Explicitly quantifies effects of orographics
    - Dimensionless ratio representing differences between in-place and basin effects of terrain on precip
      - < 1 = In-place location has more effective terrain
      - > 1 = Basin has more effective terrain

Moisture Transposition

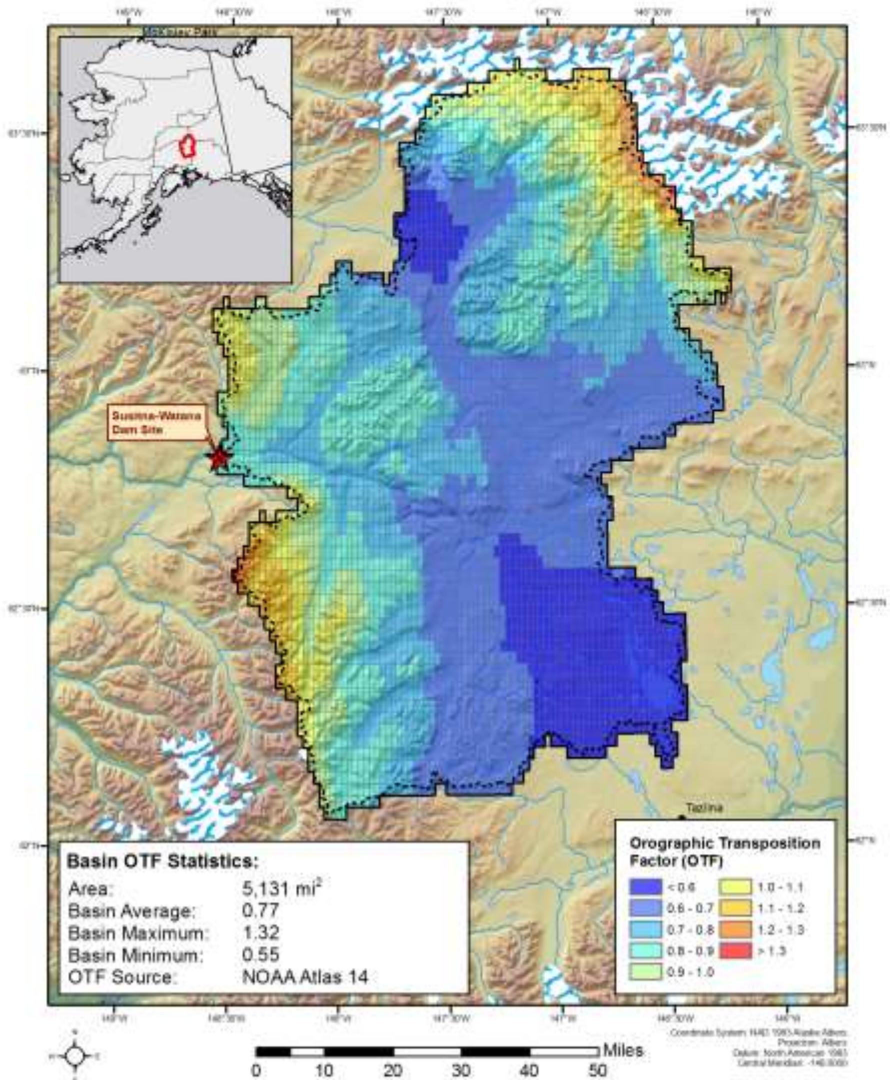
- Moisture Transposition Factor
  - Calculated for each grid point
  - Ratio of precipitable water at storm location to each basin grid point
  - Precipitable water calculated from maximum +2σ SST climatology



Orographic Transposition

- Assumption
  - Orographic effects on rainfall are explicitly captured in climatological analyses
  - The climatology is based on storms of the same type
    - Extreme rainfall storms over the basin are similar synoptic storms
  - Climatological analyses of these storms should adequately reflect the differences in topographic influences at different locations, i.e. in-place and transpositioned to the basin

Gridded Orographic Transpositon Factors over the Susitna-Watana Basin (inches)
Upper Susitna River, Alaska



Orographic Proportionality

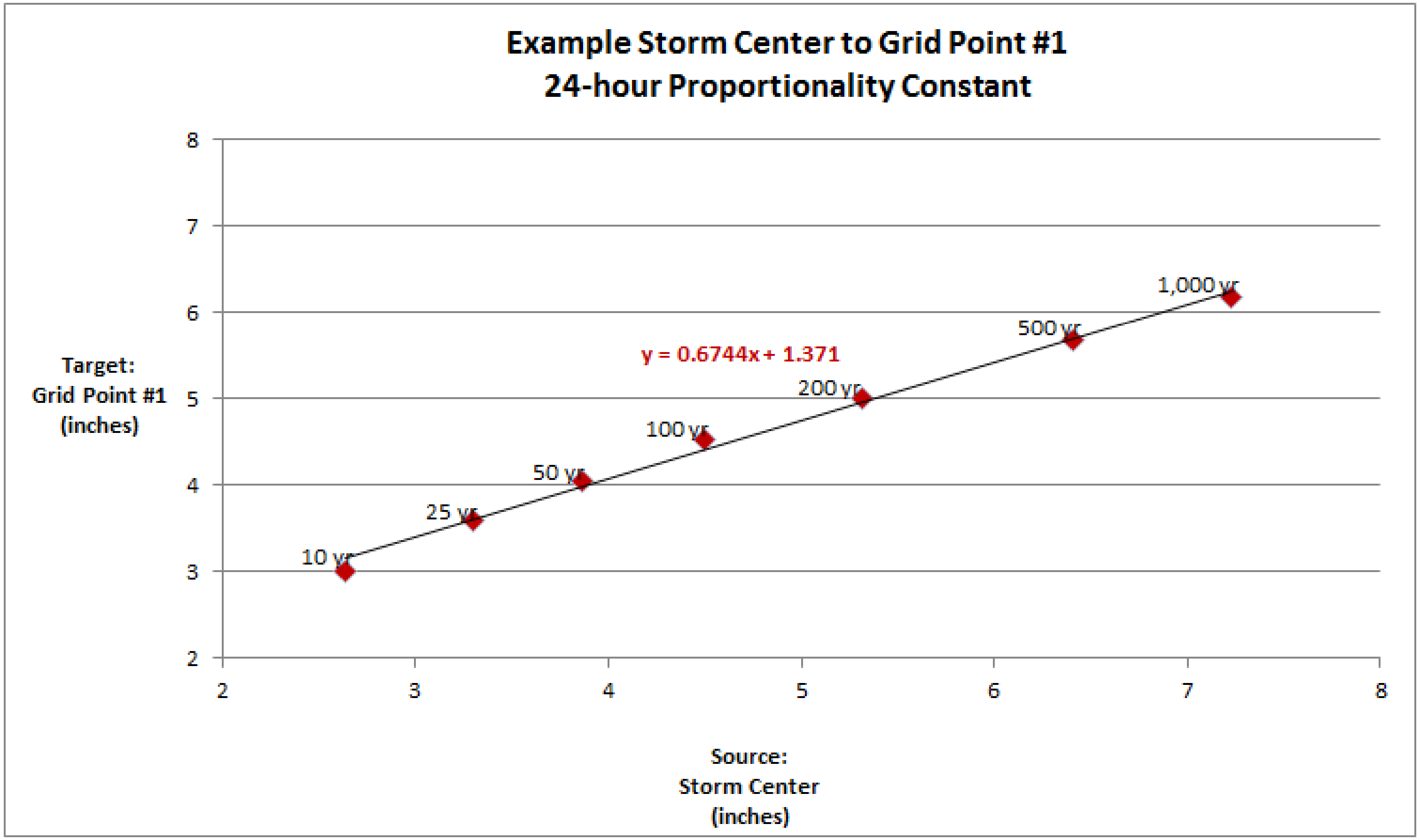
- By evaluating the rainfall values for a range of return frequencies at both locations, a relationship between the two locations is established
- Calculated by comparing precipitation from NOAA Atlas 14 at the 10 through 1,000-year return frequencies
  - Rainfall over the Susitna-Watana basin is plotted on the y-axis
  - Rainfall over the in-place area is plotted on the x-axis
  - A best fit linear regression is used to estimate the orographically adjusted rainfall

$$P_o = mP_i + b$$

  - The slope (*m*) of the linear regression provides the relationship between the two basins, i.e. the proportionality constant

Orographic Proportionality

	Proportionality Constant - 24-hour							Y =	0.6744	x	+1.3710
	10 year	25 year	50 year	100 year	200 year	500 year	1000 year				
SOURCE (X-axis)	2.64	3.30	3.87	4.50	5.32	6.41	7.23				
TARGET (Y-axis)	3.01	3.60	4.05	4.51	5.01	5.67	6.17				



Meteorological Time Series for Snowmelt

- Task 5-Meteorological Time Series for Snow Melt Calculations – Completed
  - Limited Data Available
    - Data sets have been evaluated and archived
    - Used to derive expected temp, dew point, wind speeds during PMP storm
  - Used data from the 6 model calibration events
  - Temp and dew point values maximized
  - Worked extensively with MWH to provide guidance on snowpack/antecedent conditions
- Model Calibration for six storms – Completed

Model Calibration

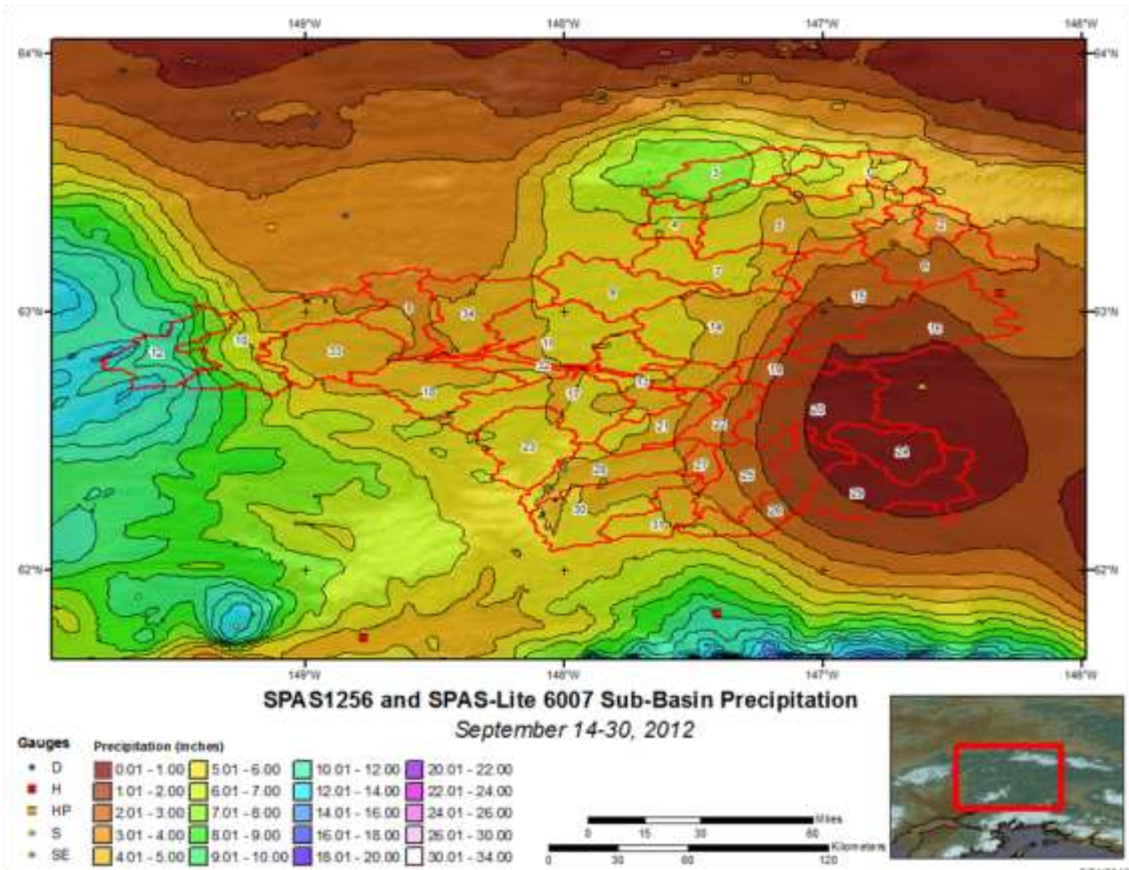
- Model calibration input
- Required by MWH for proper hydrologic modeling
  - Storms used
    - 3 June storms
    - 3 SPAS storms (2 August, 1 Sept)
  - Sub-basin average rainfall
  - Sub-basin average Meteorological time series

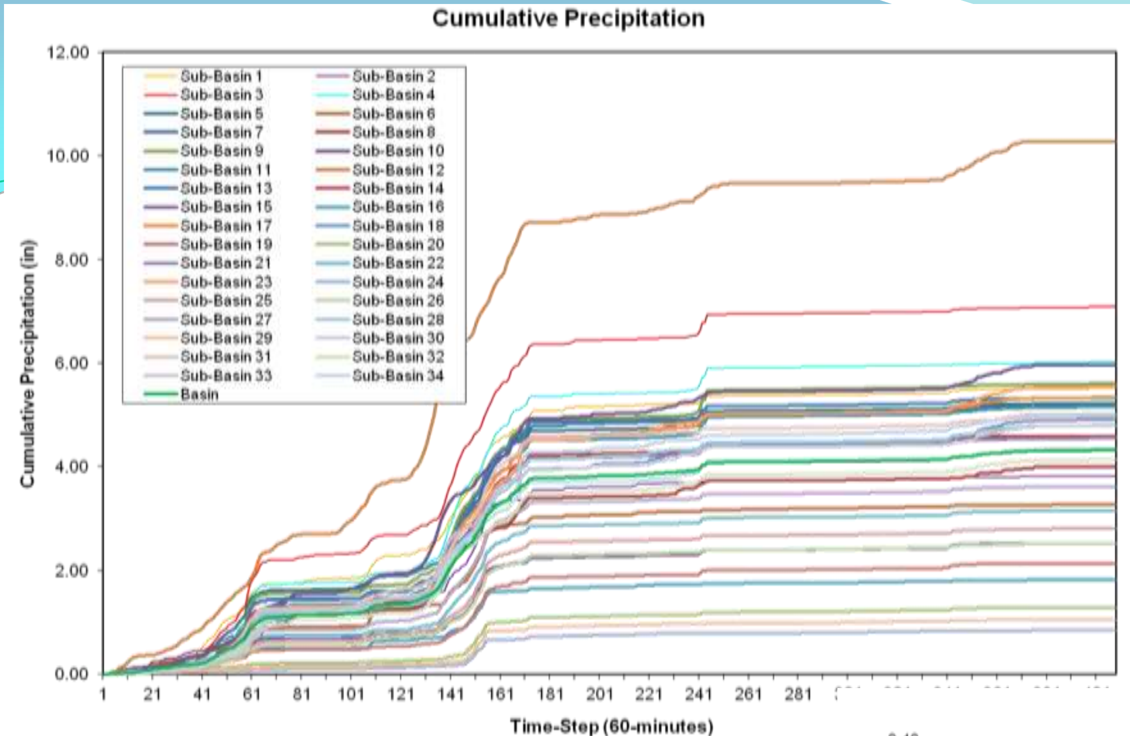
Hydrologic Calibration Events Selected

SPAS #	Date	Radar
1256	Sep-12	Yes
1269	Aug-71	No
1270	Aug-67	No
6008	Jun-64	No
6009	Jun-71	No
6010	Jun-72	No

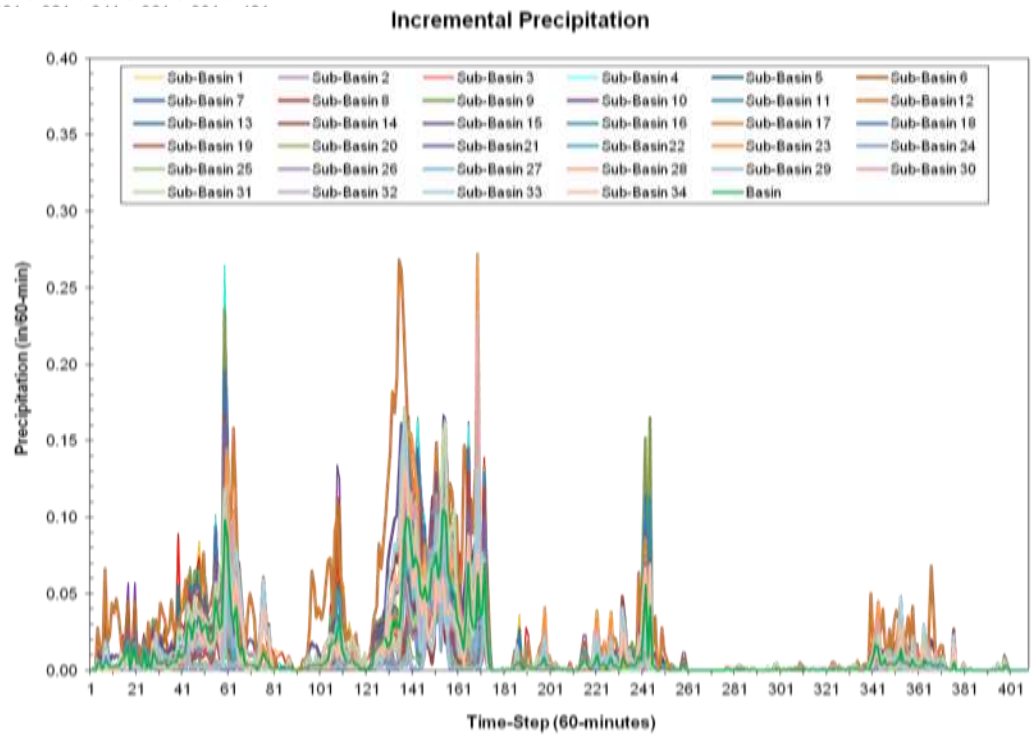
Model Calibration: Precipitation

- Utilized SPAS to analyze rainfall over the Susitna-Watana basin
  - Extracted 60-min sub-basin average precipitation





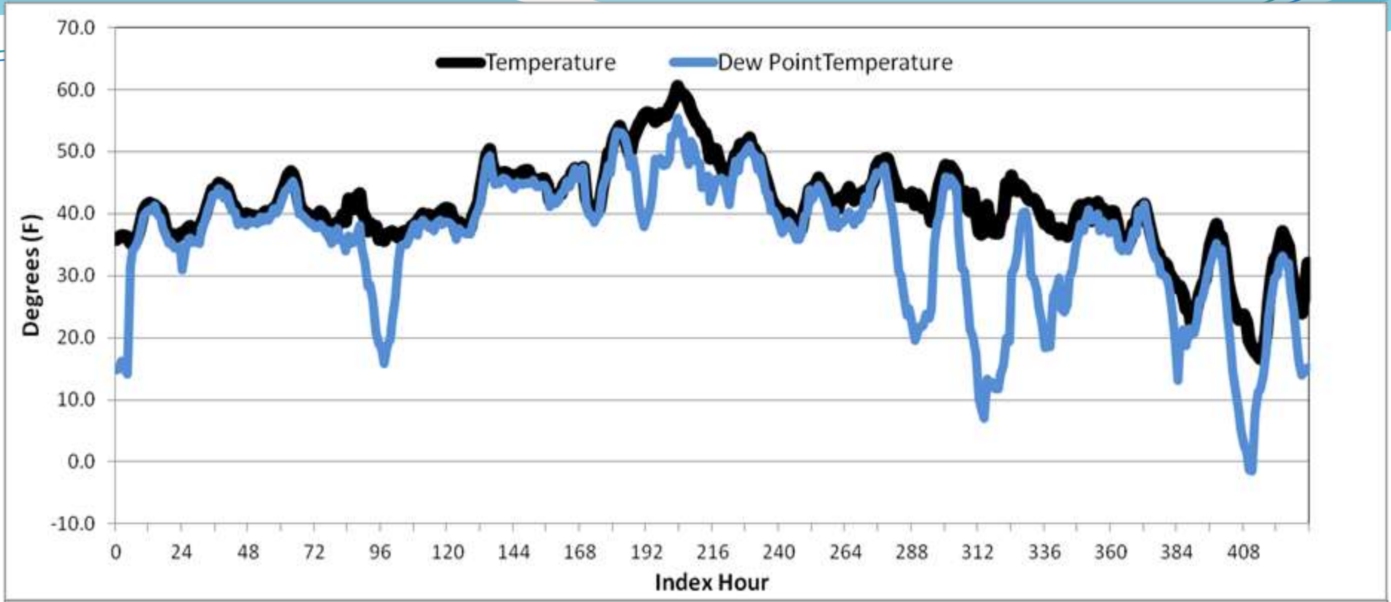
Model Calibration: Precipitation

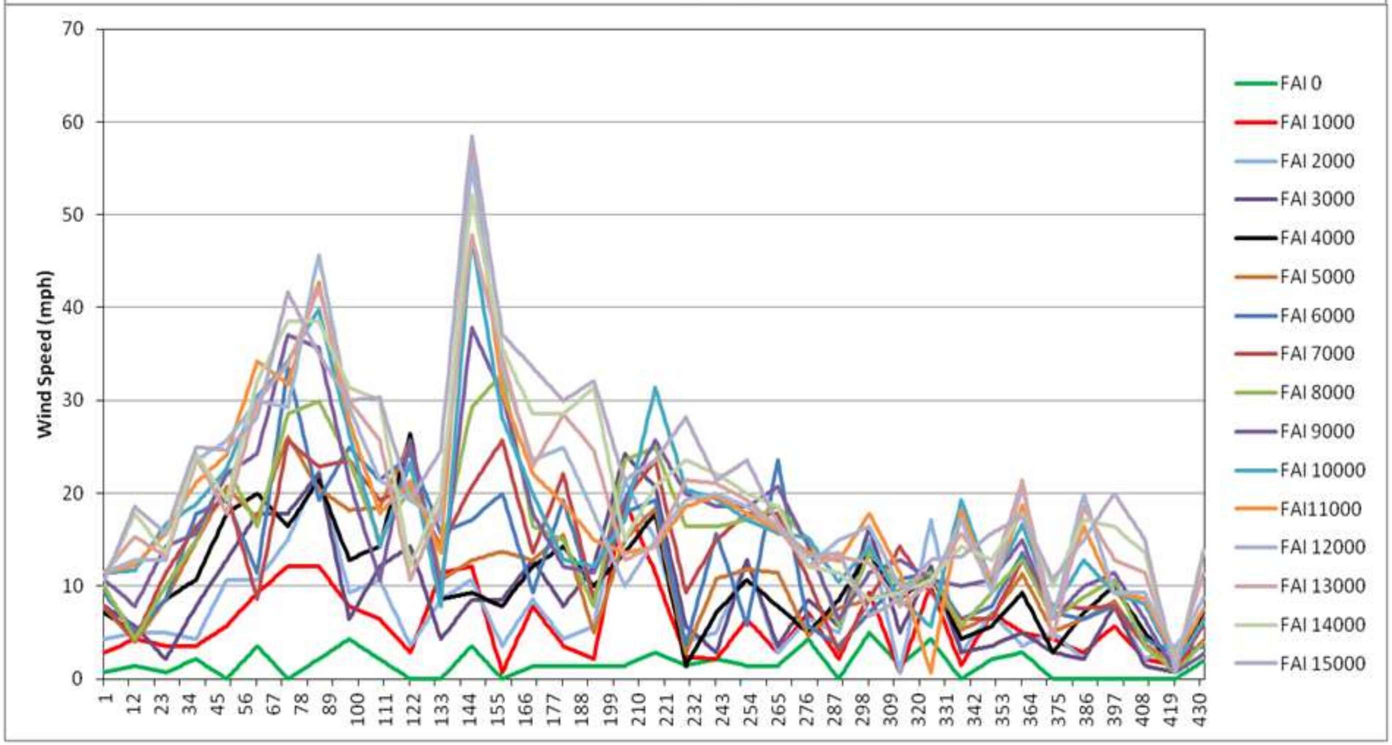


Model Calibration: Ta, Td, and Ws

- Hourly meteorologic time series were developed for the six calibration events
  - Ta and Td based on surface stations
    - Calculated base elevation Ta and Td
    - Calculated lapse rate for entire calibration
  - Ws derived at 1000-ft increments
    - RAOB data from Fairbanks
      - Adjusted free-air wind to surface

Model Calibration: Ta, Td, and Ws

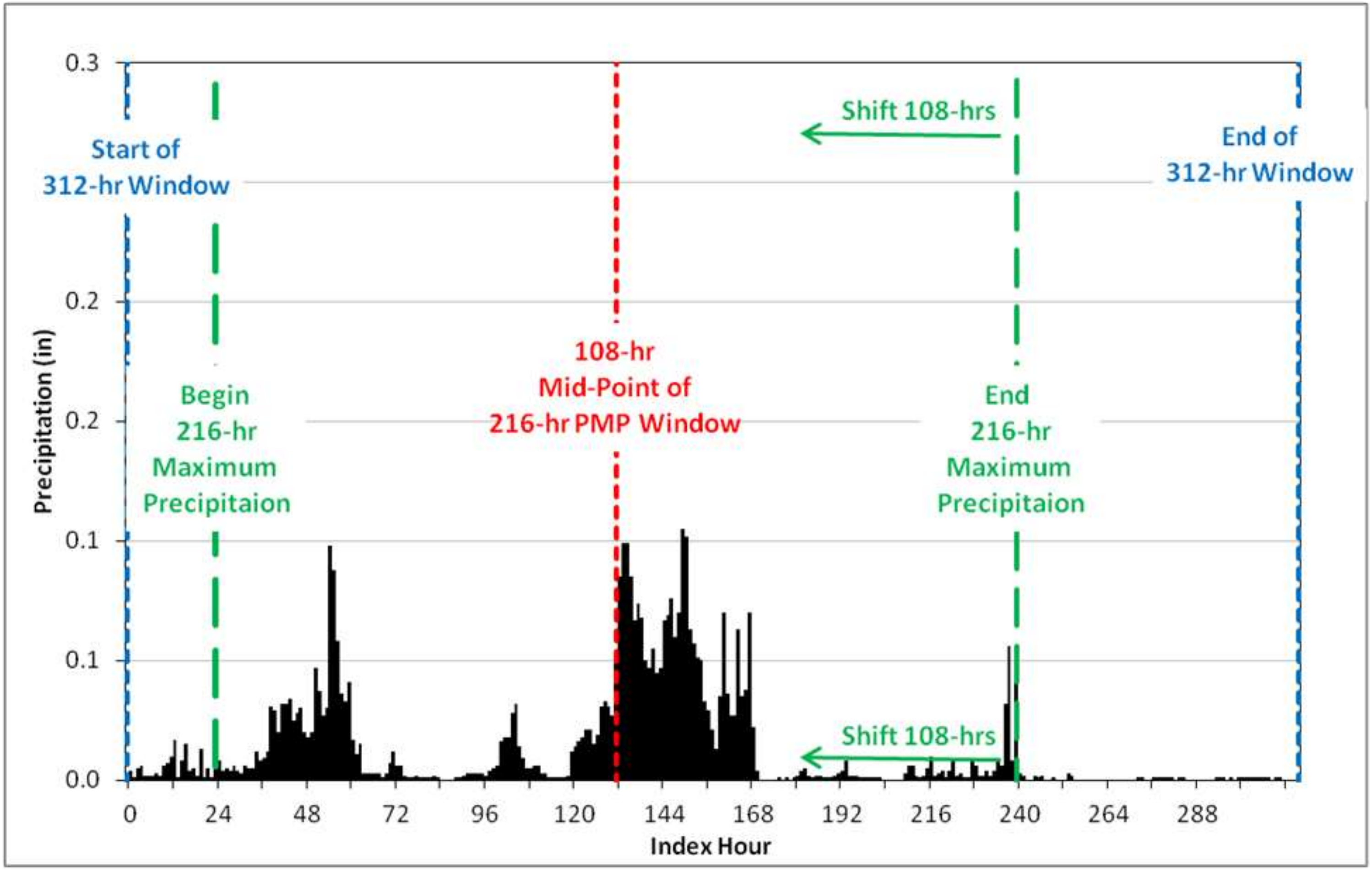




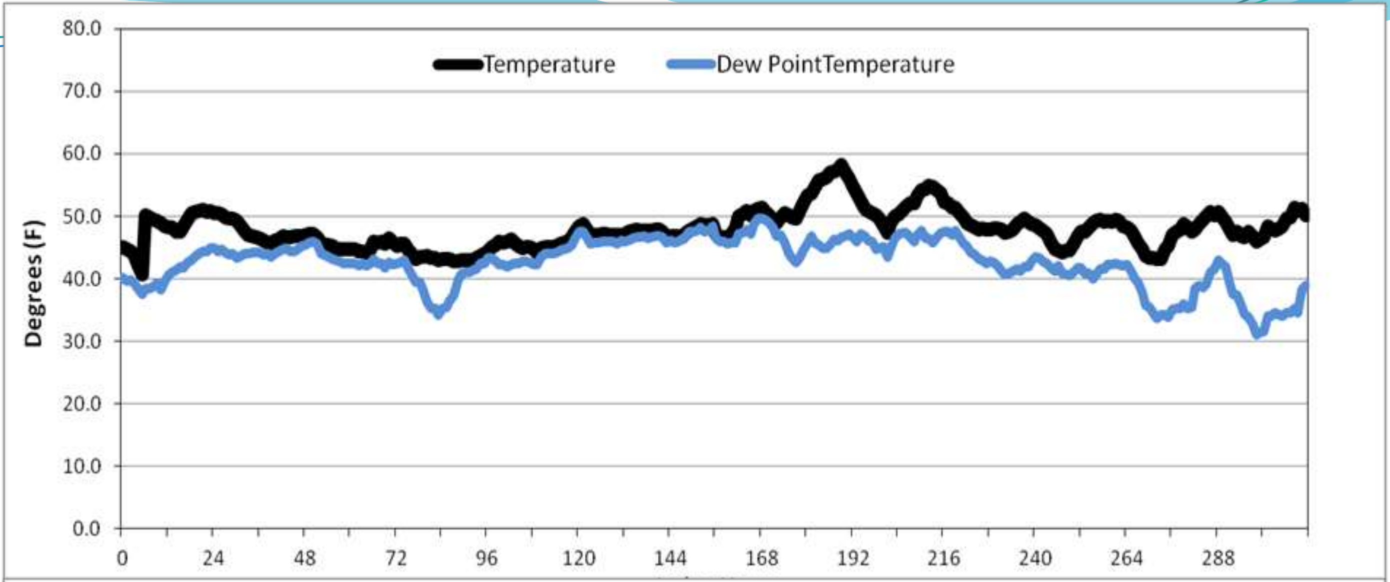
PMP Meteorological Time Series for Snowmelt

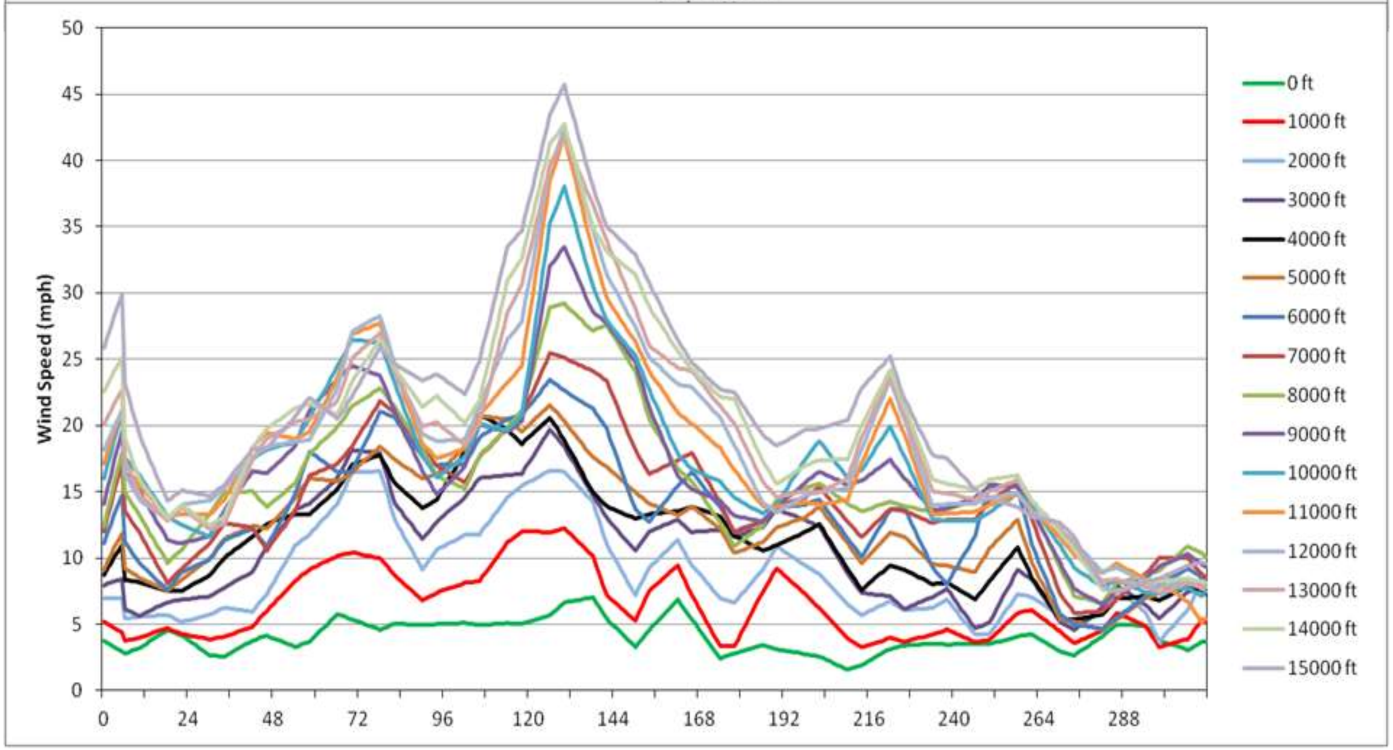
- Task 5-Meteorological Time Series for Snow Melt Calculations – Completed
  - Limited Data Available
    - Data sets have been evaluated and archived
    - Used to derive expected temp, dew point, wind speeds during PMP storm
  - Used data from the 6 model calibration events
  - Temp and dew point values maximized
  - Worked extensively with MWH to provide guidance on snowpack/antecedent conditions
  - Derived seasonality adjustments for metrological time series

PMP Meteorological Time Series for Snowmelt



Indexed Met. Time Series

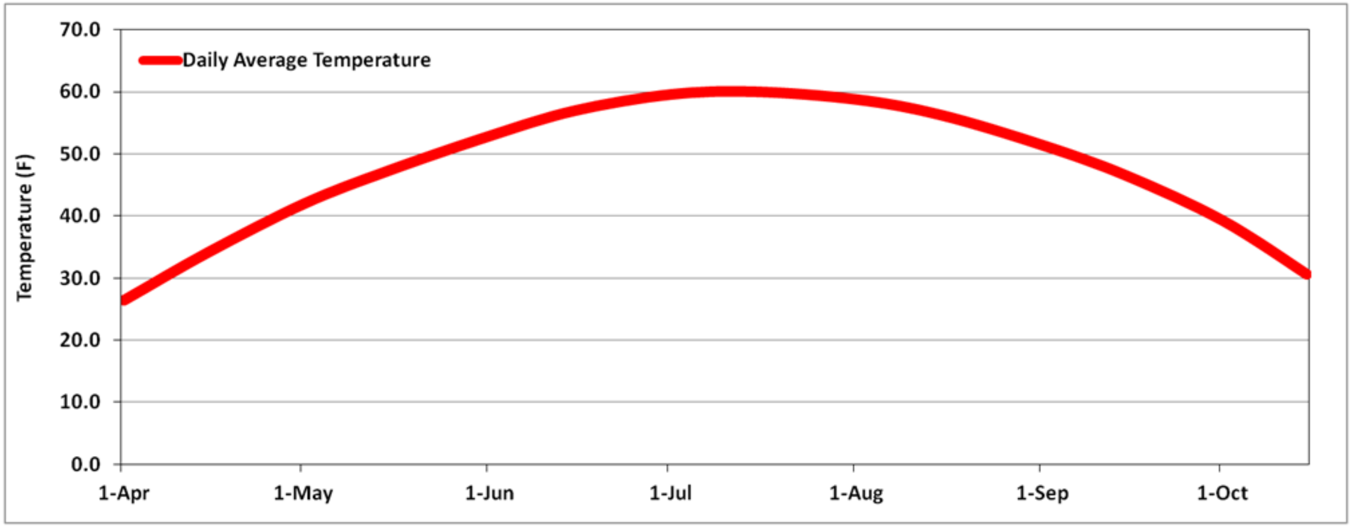




PMP Temperature Seasonality

- Daily climate normal (1981-2010)
  - Limited Data Available
    - Data sets have been evaluated and archived
    - Used to derive expected daily temperature
  - Scaled daily average temperature (0 to 1) based on maximum daily

Station	Elevation (ft)
Anchorage	130
Fairbanks	433
Talkeetna	350
Gulkana	1560
Chulitna River	1355
Paxson	2700
Lake Susitna	2375
Cantwell 2E	2130
Tahneta Pass	2620
Sutton 1W	550



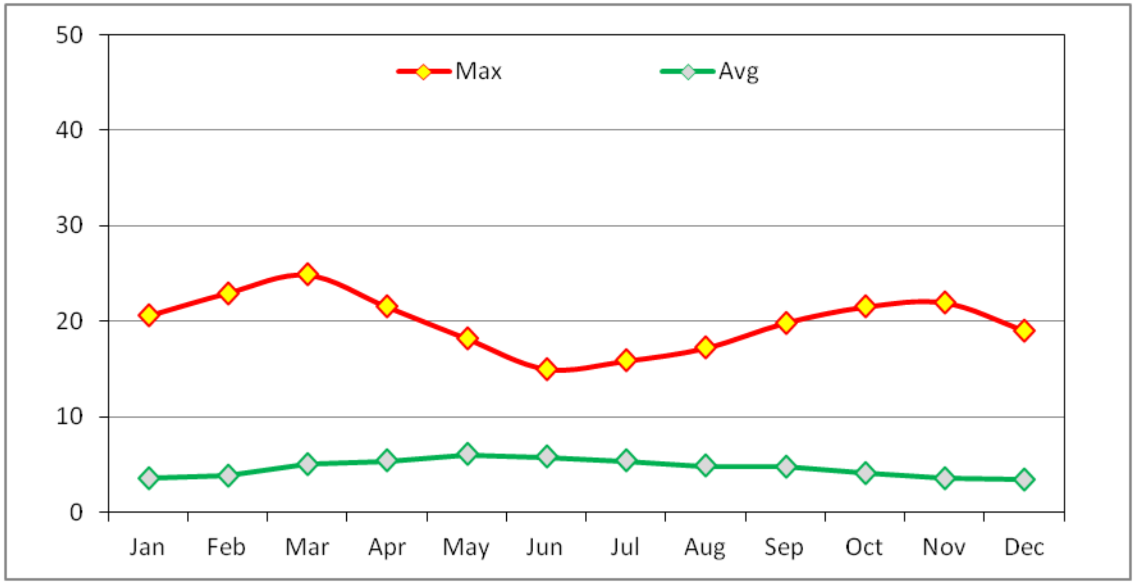
PMP Temperature Seasonality

Ta Td Time Series Seasonality	
Date	Ratio
1-Apr	0.39
15-Apr	0.55
1-May	0.69
15-May	0.80
1-Jun	0.90
15-Jun	0.95
1-Jul	1.00
15-Jul	1.00
1-Aug	1.00
15-Aug	1.00
1-Sep	0.94
15-Sep	0.86
1-Oct	0.77
15-Oct	0.64
1-Nov	0.51

PMP Wind Speed Seasonality

- Daily average wind speed from Global Historical Climatology Network (GHCN)
  - 4 stations
    - Calculated monthly average maximum wind speed
    - Calculated monthly average wind speed
  - Scaled monthly average temperature (0 to 1) based on maximum August wind speed

Station	Elevation (ft)
Gulkana	1560
Talkeetna	350
Anchorage	433
Fairbanks	500



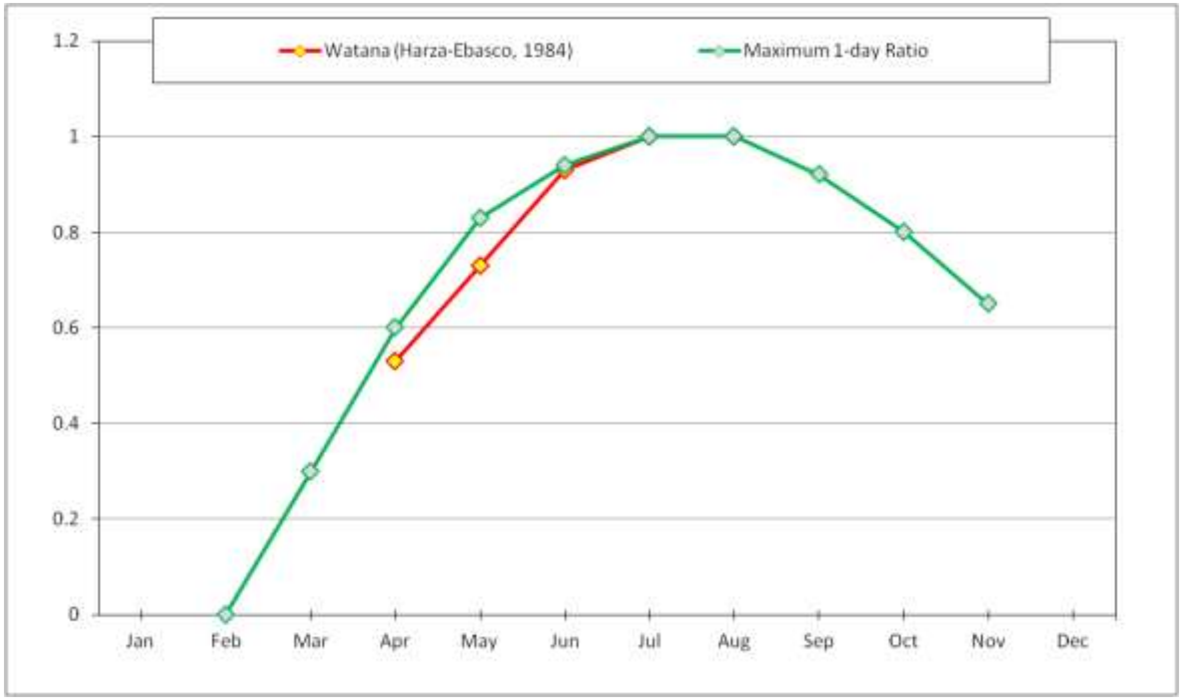
PMP Wind Speed Seasonality

Ws PMP Seasonality	
Month	**Ratio**
15-Jan	-
15-Feb	-
15-Mar	1.45
15-Apr	1.25
15-May	1.06
15-Jun	0.87
15-Jul	0.92
15-Aug	1.00
15-Sep	1.15
15-Oct	1.25
15-Nov	1.28
15-Dec	-

PMP Seasonality

- Maximum 1-day precipitation acquired from Alaska Climate Research Center
  - 4 stations
    - Calculated monthly maximum 1-day precipitation
  - Scaled 1-day maximum precipitation (0 to 1)

Station	Elevation (ft)
Gulkana	1560
Talkeetna	350
Anchorage	433
Fairbanks	500

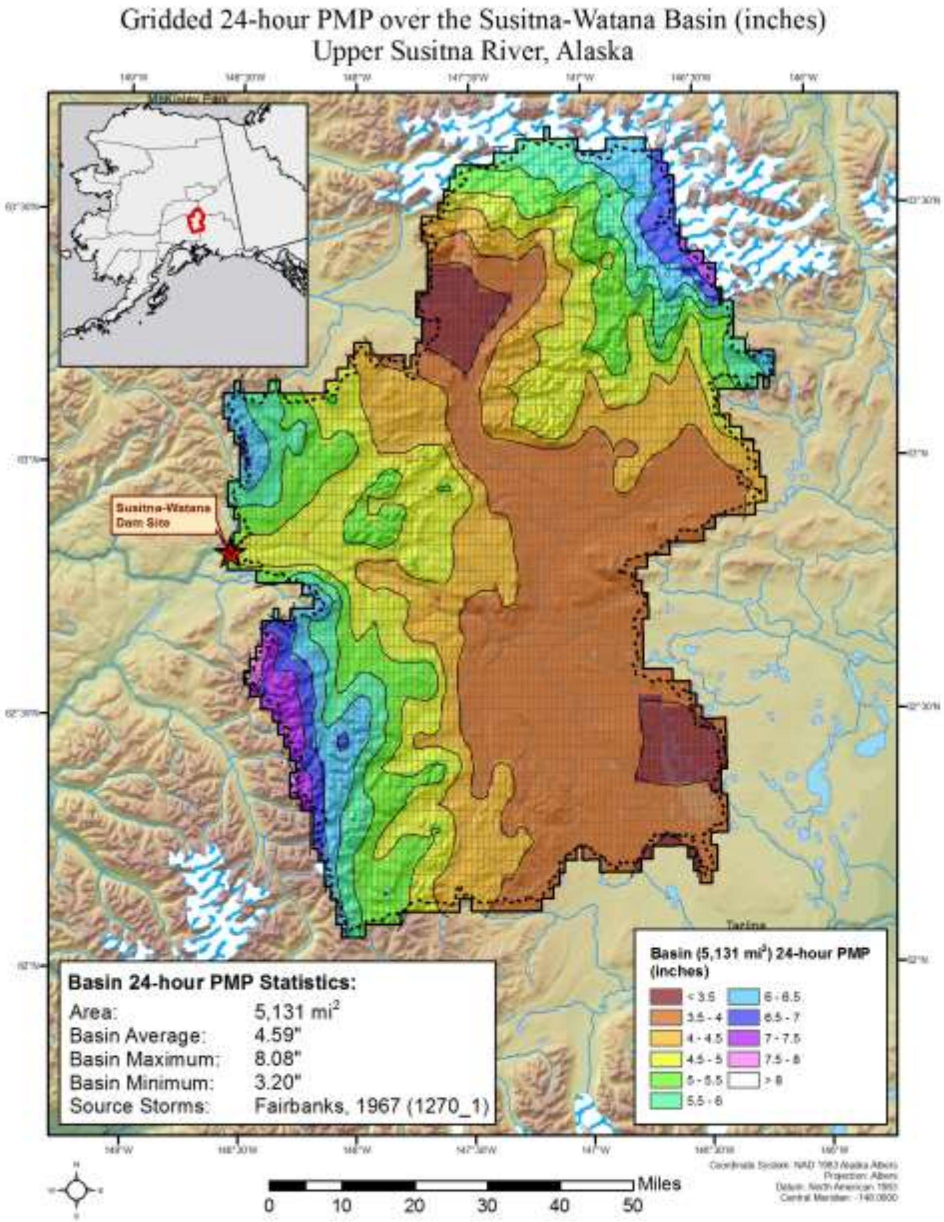


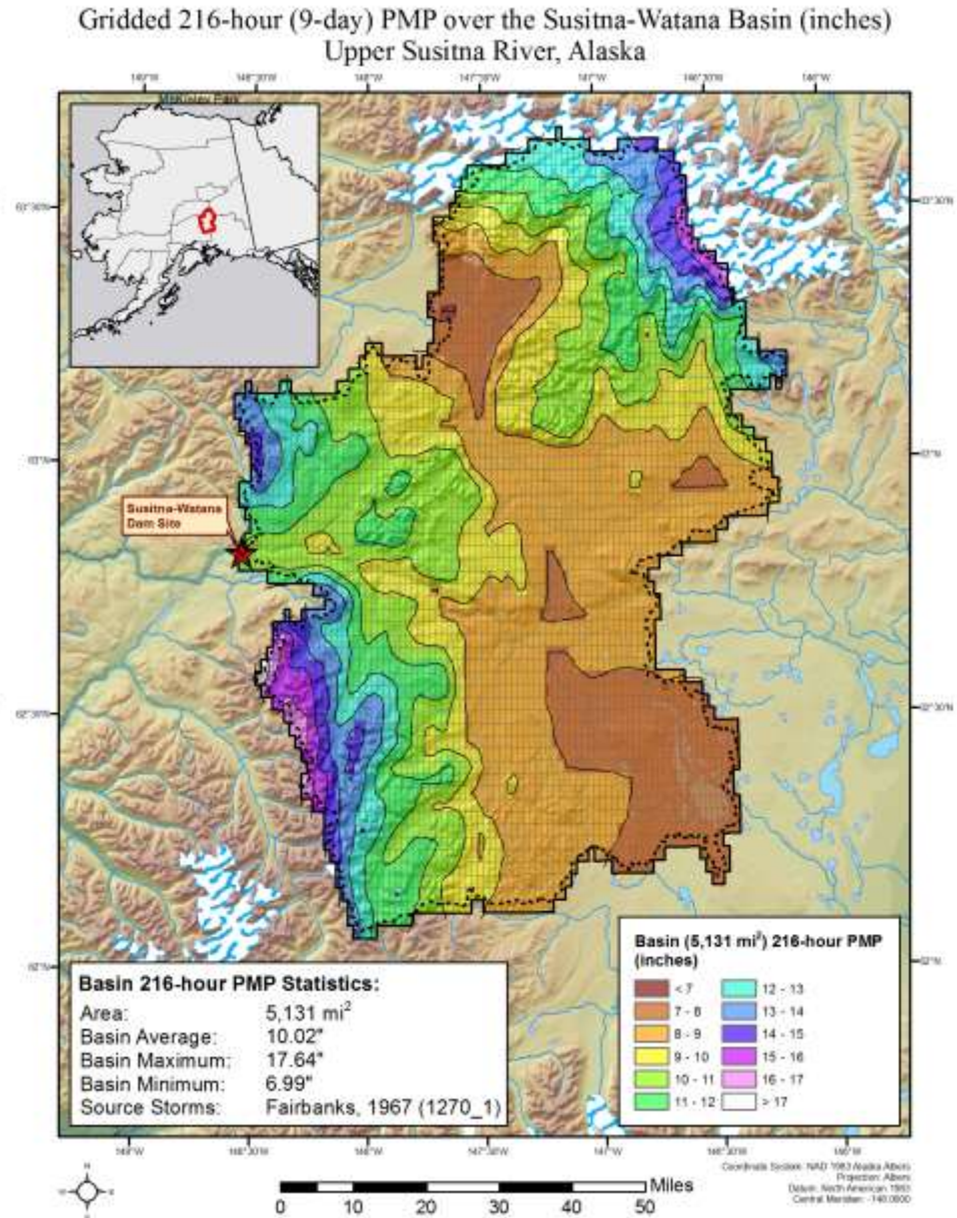
PMP Seasonality

PMP Seasonality	
Month	Ratio
15-Jan	-
15-Feb	-
15-Mar	0.30
15-Apr	0.60
15-May	0.83
15-Jun	0.94
15-Jul	1.00
15-Aug	1.00
15-Sep	0.92
15-Oct	0.80
15-Nov	0.65
15-Dec	-

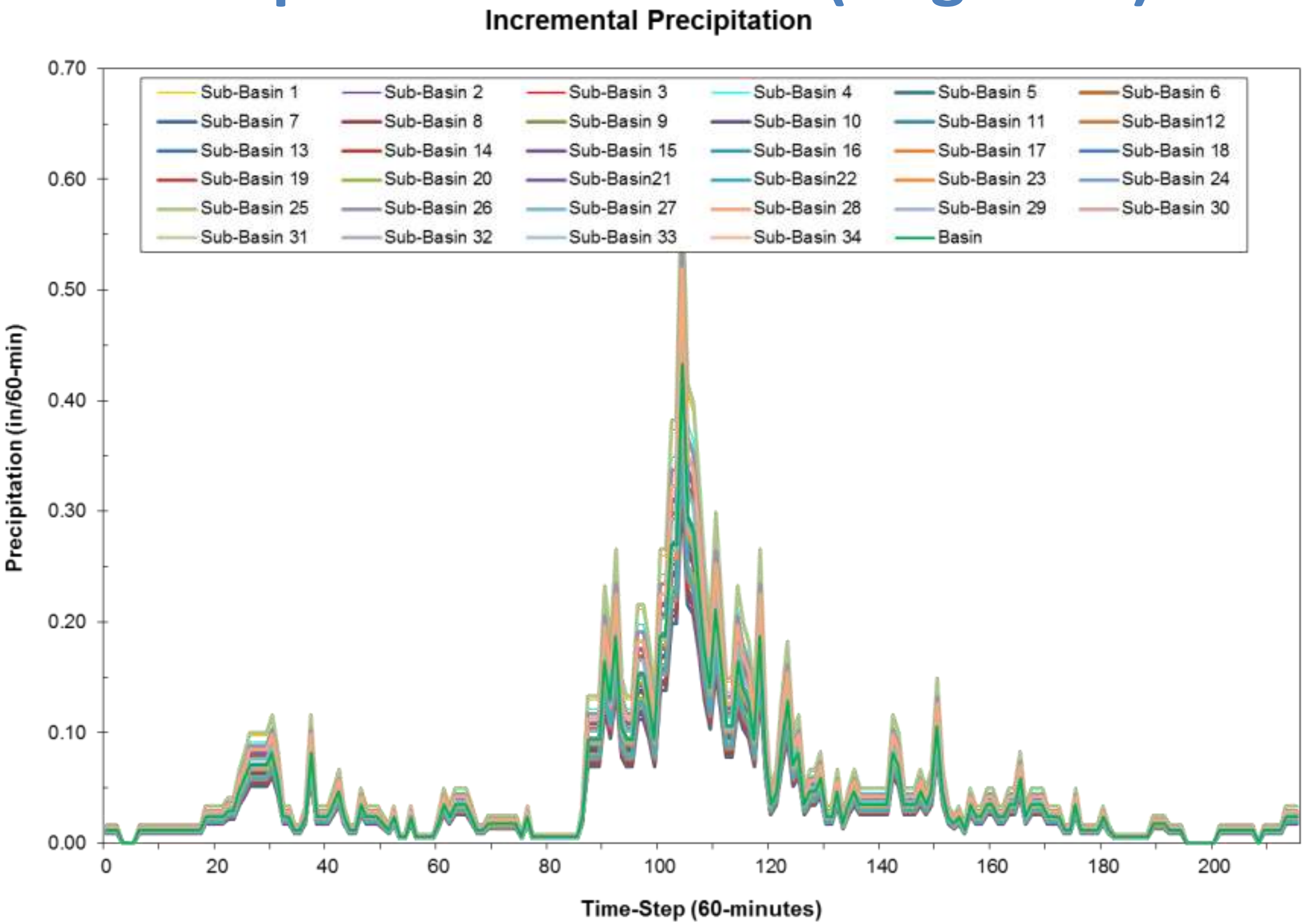
PMP Overview

- Develop PMP values – Draft Completed
  - PMP values calculated over the basin at each grid point
    - 4,013 grid points at durations 1-216 hours
    - For each duration/grid point…
      - Total adjusted rainfall calculated
      - Each of the 13 short-list storms compared
      - Python-scripted GIS tool used to handle comparisons
      - Largest rainfall becomes PMP for that duration
      - Python-scripted GIS tool used to handle comparisons
      - Fairbanks, 1967 drives PMP
  - Applied temporal distribution patterns to PMP using existing storm timing
    - Denali NP – Aug, 1955
    - Fairbanks – Aug, 1967
    - Old Tyonek – Sep, 2012
  - Averaged gridded PMP for each sub-basin


Gridded 24-hour PMP over the Susitna-Watana Basin (inches)
Upper Susitna River, Alaska
Susitna-Watana Dam Site
Basin 24-hour PMP Statistics:
Area: 5,131 mi²
Basin Average: 4.59"
Basin Maximum: 8.08"
Basin Minimum: 3.20"
Source Storms: Fairbanks, 1967 (1270_1)
Basin (5,131 mi²) 24-hour PMP (inches)
< 3.5
3.5 - 4
4 - 4.5
4.5 - 5
5 - 5.5
5.5 - 6
6 - 6.5
6.5 - 7
7 - 7.5
7.5 - 8
> 8
Miles
0
10
20
30
40
50


Gridded 216-hour (9-day) PMP over the Susitna-Watana Basin (inches)
Upper Susitna River, Alaska
Susitna-Watana Dam Site
Basin 216-hour PMP Statistics:
Area: 5,131 mi²
Basin Average: 10.02"
Basin Maximum: 17.64"
Basin Minimum: 6.99"
Source Storms: Fairbanks, 1967 (1270_1)
Basin (5,131 mi²) 216-hour PMP (inches)
< 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
16 - 17
> 17
Miles
0
10
20
30
40
50

Temporal Distribution (Aug 1967)



PMP Overview – Major Tasks

- Task 7-Quality Control and Sensitivity – Completed
  - QC and Sensitivity
    - Ongoing during the study
    - Comparisons with NOAA Atlas 14
    - Previous studies
    - Sensitivity of subjective variables
      - In-place maximization factors
      - Elevation affects

PMP Compared to NOAA Atlas 14 24-hr 100-Year

	10-year	25-year	50-year	**100-year**	200-year	500-year	1,000-year
24-hr Precip. Frequency (NOAA Atlas 14)	2.37	2.85	3.24	**3.65**	4.11	4.73	5.19
Gridded Basin Average 24-hour PMP (0.2sqmi)				6.34			

Average Basin Ratio (24hr PMP:NOAA Atlas 14 100-yr)	**1.74**
Max. Basin Ratio (24hr PMP:NOAA Atlas 14 100-yr)	1.86
Min. Basin Ratio (24hr PMP:NOAA Atlas 14 100-yr)	1.58

The ratio of the PMP to the 24-hour 100-year return period rainfall amounts is generally expected to range between two and four, with values as low as 1.7 and as high as 5.5 found in HMRs 57 and 59 (Hansen et al. 1994, Corrigan et al. 1999). In HMR 59 it is stated "*…the comparison indicates that larger ratios are in lower elevations where short-duration, convective precipitation dominates, and smaller ratios in higher elevations where general storm, long duration precipitation is prevalent*". Therefore, it would be reasonable to expect the ratios for the Susitna-Watana basin to be in the low end of the range.

PMP Compared to Previous Studies

Harza-Ebasco 1984 Susitna 72-hour Basin PMP and spring season adjustments

Season	72-hour PMP: Harza-Ebasco	
	Factor	PMP
All-season	1.00	6.85
15-Jun	0.93	6.37
15-May	0.73	5.00

Season	72-hour PMP: AWA	
	Factor	PMP
All-season	1.00	7.43
15-Jun	0.94	6.98
15-May	0.83	6.17

Acres 1982 Susitna 72- and 216-hour Basin PMP and spring season adjustments

Season	72-hour PMP: Acres	
	Factor	PMP
All-season	1.00	5.90
15-Jun	0.70	4.13
15-May	N/A	N/A

Season	72-hour PMP: AWA	
	Factor	PMP
All-season	1.00	7.43
15-Jun	0.94	6.98
15-May	0.83	6.17

Season	216-hour PMP: Acres	
	Factor	PMP
All-season	1.00	12.54
15-Jun	N/A	8.90
15-May	N/A	N/A

Season	216-hour PMP: AWA	
	Factor	PMP
All-season	1.00	10.02
15-Jun	0.94	9.42
15-May	0.83	8.32

PMP Overview – Major Tasks

- Task 9 – Final Report – In Progress
  - Draft report submitted
    - All background data/calculations included
    - Review comments will be addressed