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Managing Water in the West

Diagnosing the moisture sources for extreme precipitation events in the intermountain west: Part 2

NOAA/CIRES Future & Reclamation Complementary Efforts

Jason Caldwell, John England, Victoria Sankovich, David Keeney, Katie Holman
Michael Alexander, Mimi Hughes, Joe Barsugli, Kelly Mahoney, Jamie Scott, Dustin Swales, etc.

Reclamation Climate and Hydrology Research - 2nd Annual Progress Meeting
Wednesday, January 29, 2014

U.S. Department of the Interior
Bureau of Reclamation

CIRES
Cooperative Institute for Research in Environmental Sciences

NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Outline

- ***Overview:*** Building from the FY12/13 AR Project
- ***Perspective:*** Meteorological Inputs to Dam Safety Studies
- ***Motivation:*** Modern Methods Needed/Required
- ***Collaborations:*** NOAA/CIRES FY14/15 Projects
  FHCG FY14/15 Projects
- ***Summary:*** Anticipated Accomplishments

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Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard studies

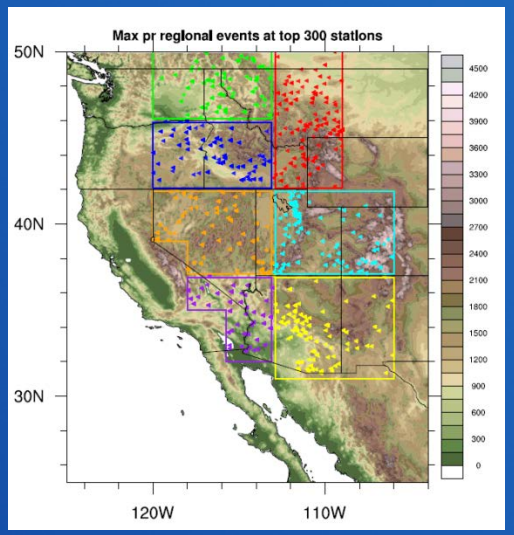
Gap(s) Addressed

LT3.01 Understanding of observed climate variability from daily to multidecadal timescales, which underpins interpretation of future variability in climate projections and its relation to planning assumptions (High Priority)

LT 3.06 Method and basis for estimating extreme meteorological event possibilities, deterministically or probabilistically, in a changing climate (High Priority)

Graphic

Primary domains used for selection of maximum precipitation events from historical record for backtrajectory analysis



Research Question(s)

1. How results best used in Dam Safety? Which data/technology?
2. What are the preferred pathways for moisture?
3. How do the moisture sources and synoptic processes, especially ARs, influence extreme precipitation events over key dam locations and the surrounding watersheds?
4. Is there utility in using ensemble of model simulations to explore the range of plausible storm outcomes?
5. How are the pathways/extreme events influenced by climate factors including global warming?

Collaborators/Schedule/Source of Support

- RDO/S&T
- CIRES-Reclamation Coop Agreement and NOAA-ESRL
- Incorporates both FY12/13 research and extension of that through FY14/15
- Flood Hydrology & Consequences Group
  - X6917 → A390F
  - DSO Tech Development (TREX)

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TSC FHCG Collaboration with NOAA CIRES

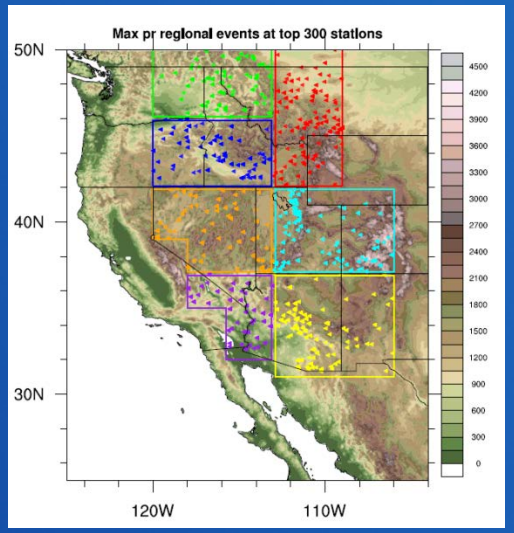
Gap(s) Addressed

LT3.06 Method and basis for estimating extreme meteorological event possibilities, deterministically or probabilistically, in a changing climate (High Priority)

Research-to-Operations Focus (R2O):
Software development, integration of research and technology into FHCG applications

Graphic

Grand Coulee
Boise River
Island Park
Truckee
Hyrum/Echo
Hoover
El Vado



Research Question(s)

1. How can the FHCG best capitalize on former and future work of the NOAA/CIRES cooperative agreements to include products and knowledge in dam safety, hydrologic hazard analyses?
2. What documents are required to provide guidance to NOAA/CIRES and FHCG staff on the implementation of grid-based datasets in hydrologic hazards studies?
3. Can Reclamation perform WRF-based computer simulations to meet hydrologic study requirements?

Collaborators/Schedule/Source of Support

- RDO/S&T, DSO/Tech Development, CIRES-Reclamation Cooperative Agreement, NOAA-ESRL, NCAR/UCAR
- Focus in FY14, anticipated continued support in FY15
- As previously mentioned, two primary projects within the FHCG:
  - A390F (X6917 and X1385)
  - TREX Development

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Meteorological Inputs to Dam Safety Studies

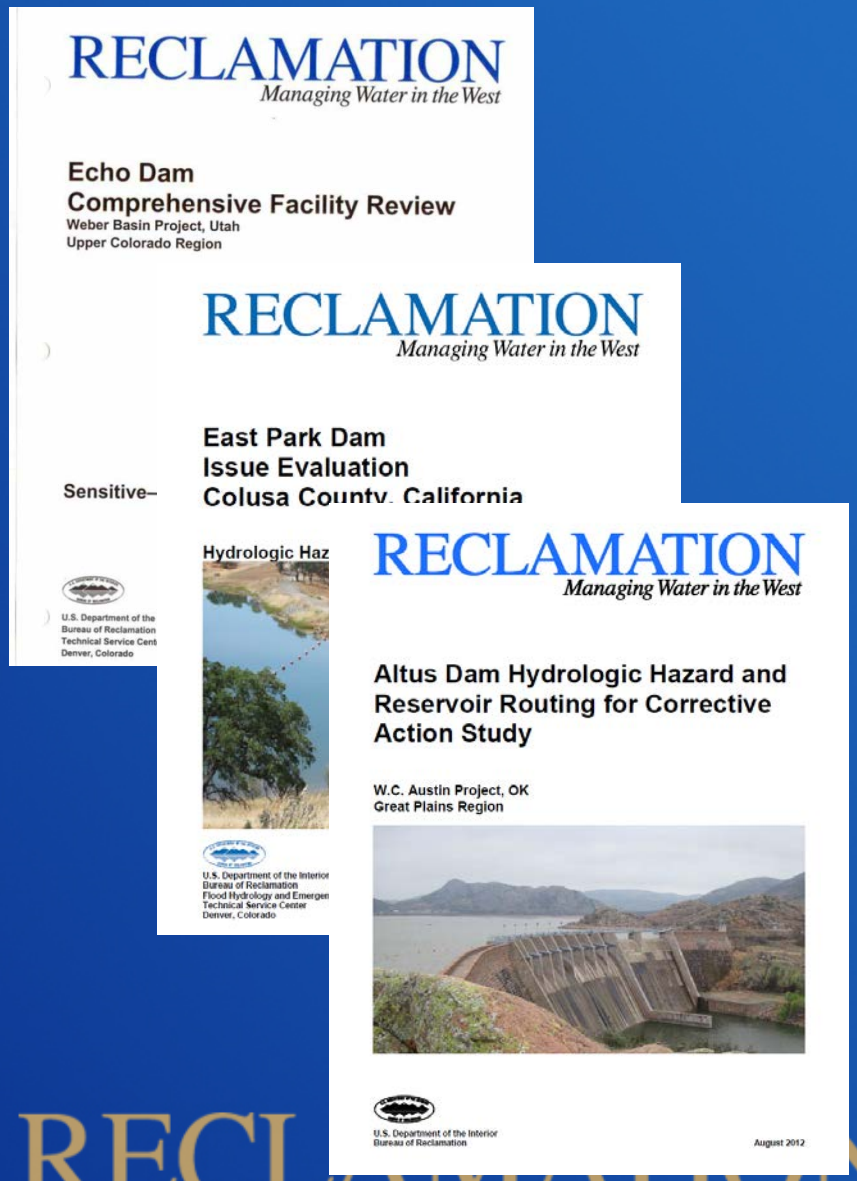
Hierarchy of Dam Safety Studies

- Comprehensive Review
- Issue Evaluation
- Corrective Action

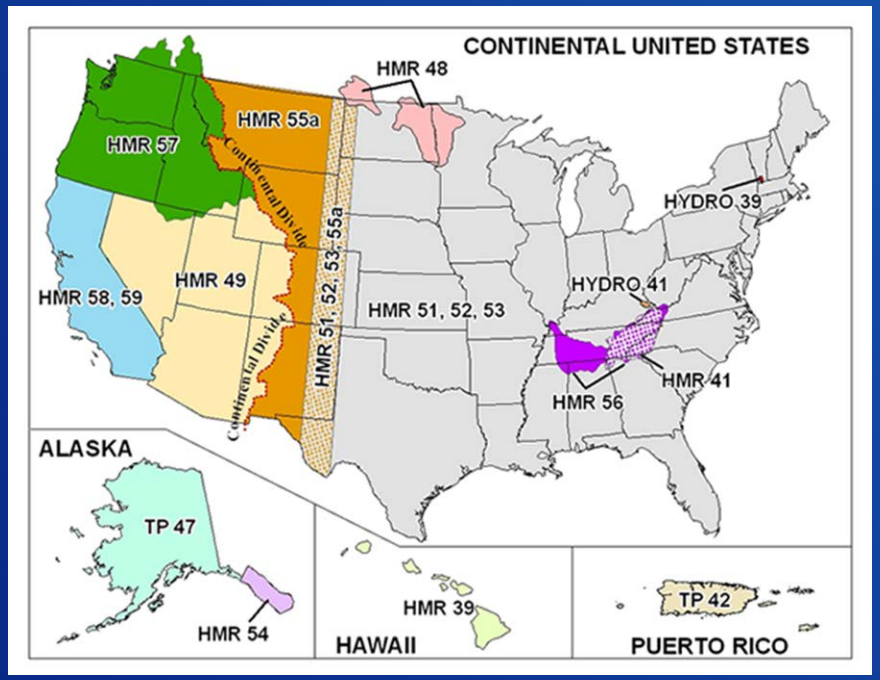
Study Level → Level of Complexity

Primary Meteorology Inputs

- Probable Maximum Precipitation
- Historical Storm Patterns
- Climatology
  - Antecedent Conditions
  - Seasonality
  - Duration
- Precipitation Frequency
- Uncertainty Analyses



Meteorological Inputs to Dam Safety Studies



Probable Maximum Precipitation

- Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year (HMR 52).
- PMP is used (in many cases) for the upper limit design precipitation estimate for the design and assessment of critical infrastructure.

Conceptual Components:

- D-A-D analysis of events
- Storm maximization
- Transposition
- Envelopment

Please note that these concepts have not changed in several decades

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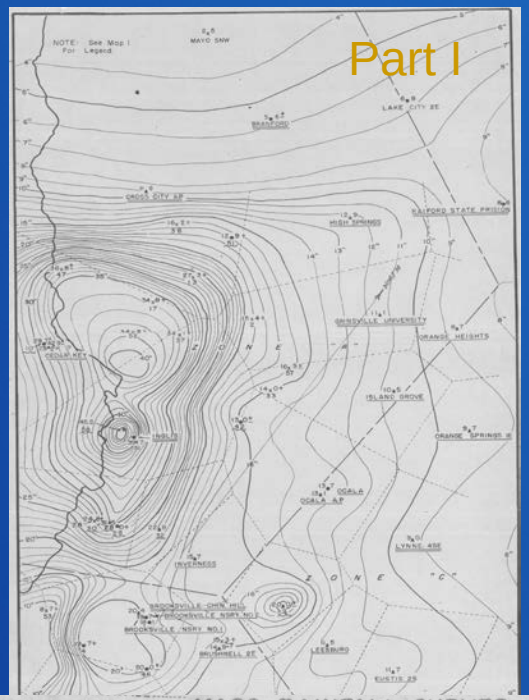
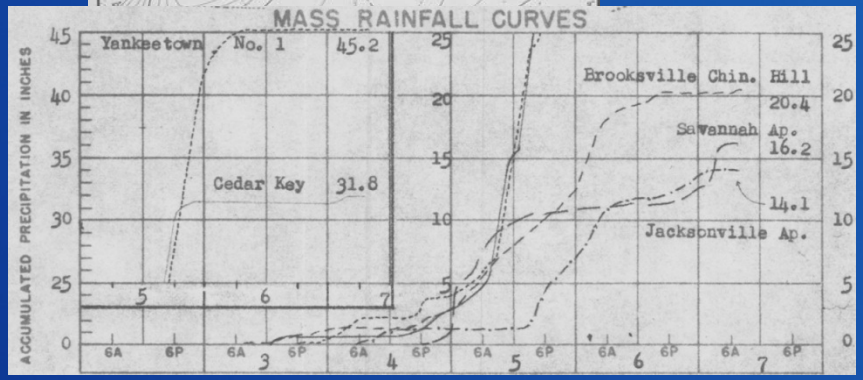
Meteorological Inputs to Dam Safety Studies

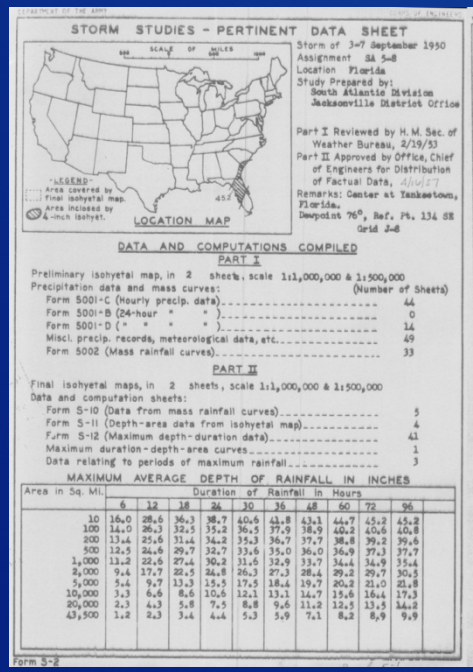
Depth-Area-Duration

- Catalog of existing storms serves as basis for PMP estimates
- Part I: Basic data collection/mass curves
- Part II: Storm Analysis and D-A-D
- Historically, hand drawn isohyets used to compute basin average values through Thiessen polygons or similar





3-7 Sept. 1950
Hurricane Easy



STORM STUDIES - PERTINENT DATA SHEET

Storm of 3-7 September 1950
Assignment SA 5-8
Location Florida
Study Prepared by: South Atlantic Division, Jacksonville District Office

Part I Reviewed by H. M. Sec. of Weather Bureau, 2/19/53
Part II Approved by Office, Chief of Engineers for Distribution of Factual Data, 4/6/57
Remarks: Center at Yanketown, Florida. Dewpoint 76°, Ref. Pt. 134 SE Grid J-8

LOCATION MAP

DATA AND COMPUTATIONS COMPILED

PART I

Preliminary isohyetal map, in 2 sheets, scale 1:1,000,000 & 1:500,000

Precipitation data and mass curves:	(Number of Sheets)
Form 5001-C (Hourly precip. data)	44
Form 5001-B (24-hour " ")	0
Form 5001-D (" " " ")	14
Miscl. precip. records, meteorological data, etc.	49
Form 5002 (Mass rainfall curves)	33

PART II

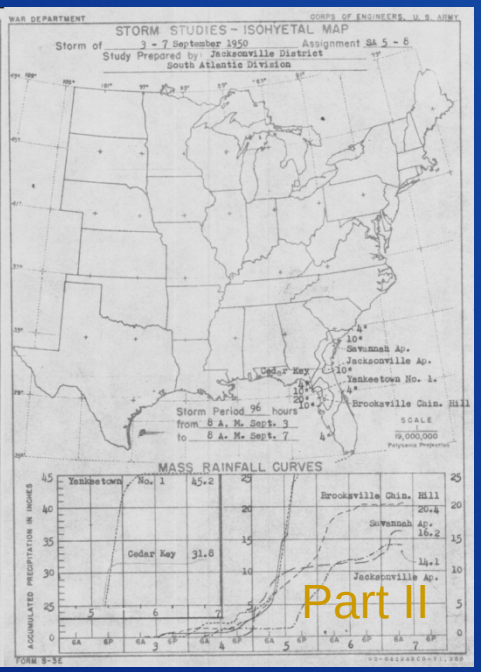
Final isohyetal maps, in 2 sheets, scale 1:1,000,000 & 1:500,000

Data and computation sheets:	
Form S-10 (Data from mass rainfall curves)	5
Form S-11 (Depth-area data from isohyetal map)	4
Form S-12 (Maximum depth-duration data)	41
Maximum duration-depth-area curves	1
Data relating to periods of maximum rainfall	3

MAXIMUM AVERAGE DEPTH OF RAINFALL IN INCHES

Area in Sq. Mi.	Duration of Rainfall in Hours									
	6	12	18	24	30	36	48	60	72	96
10	16.0	28.6	36.3	38.7	40.6	41.8	43.1	44.7	45.2	45.2
100	14.0	26.3	32.5	35.2	36.5	37.9	38.9	40.2	40.6	40.8
200	13.4	25.6	31.4	34.2	35.3	36.7	37.7	38.8	39.2	39.6
500	12.5	24.6	29.7	32.7	33.6	35.0	36.0	36.9	37.3	37.7
1,000	11.2	22.6	27.4	30.2	31.6	32.9	33.7	34.4	34.9	35.4
2,000	9.4	17.7	22.5	24.8	26.3	27.3	28.4	29.2	29.7	30.5
5,000	5.4	9.7	13.3	15.5	17.5	18.4	19.7	20.2	21.0	21.8
10,000	3.3	6.6	8.6	10.6	12.1	13.1	14.7	15.6	16.4	17.3
20,000	2.3	4.3	5.8	7.5	8.8	9.6	11.2	12.5	13.5	14.2
43,500	1.2	2.3	3.4	4.4	5.3	5.9	7.1	8.2	8.9	9.9

Form S-2



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Meteorological Inputs to Dam Safety Studies

Storm Maximization

– Process by which existing storm patterns are maximized through moisture adjustments

$$P_a = P_o \frac{W_{p,a}}{W_{p,o}}$$

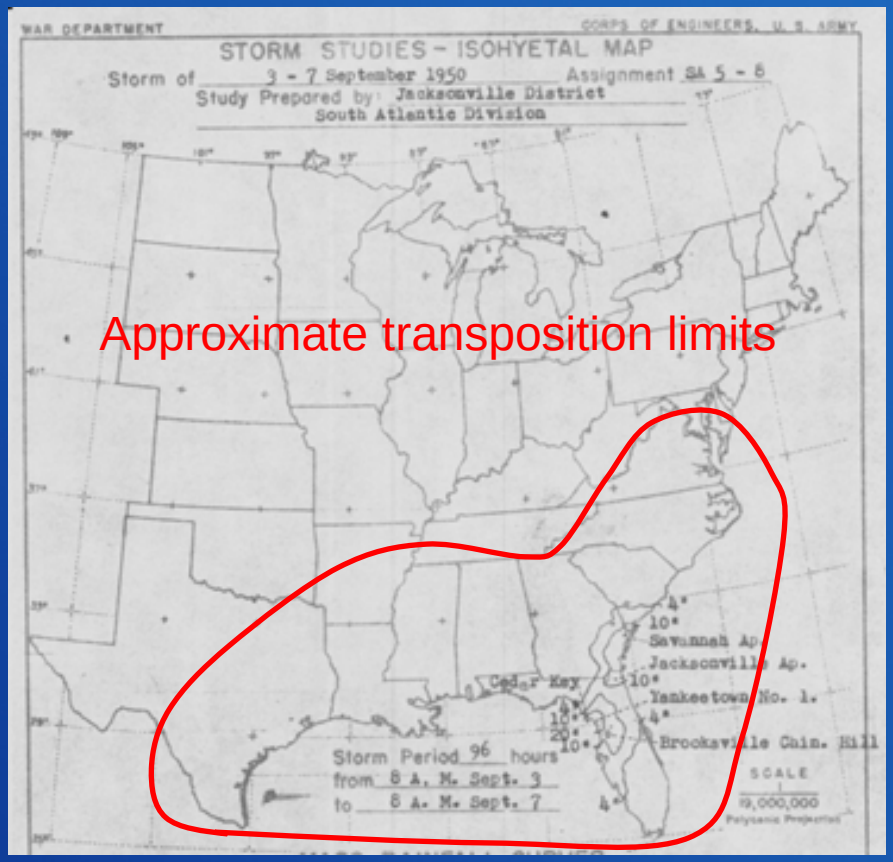
where P_a is the precipitation with maximized moisture, P_o is the observed precipitation, $W_{p,a}$ is the maximum precipitable water for the storm reference location (in place), and $W_{p,o}$ is the observed precipitable water

Storm Transposition

– Process by which existing storm patterns are relocated to other regions through moisture and orographic adjustment

$$P_{a,t} = P_o \left(\frac{W_{p,t}}{W_{p,o}} \right)$$

where $P_{a,t}$ is the adjusted, moisture-maximized precipitation amount in the transposed location, P_o is the observed precipitation, $W_{p,t}$ is the value of maximum precipitable water in the transposed location (region), and $W_{p,o}$ is the maximum precipitable water in the region where the storm was observed. This is the equation for moisture adjustment multiplied by the ratio of maximum precipitable water in the region of transposition to the maximum value for precipitable water in the observed storm region



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Meteorological Inputs to Dam Safety Studies

Climatological information serves as the basis for establishing antecedent conditions, seasonality, and duration

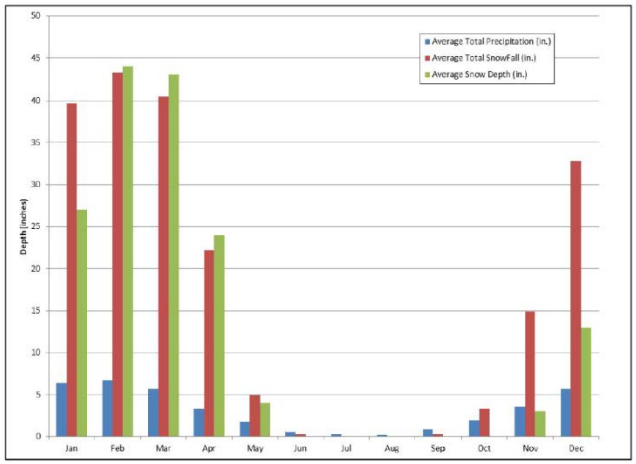


Figure 1.3 – Monthly precipitation and snowfall averages for Friant watershed. Information taken from Huntington Lake COOP station (WRCC, 2013)

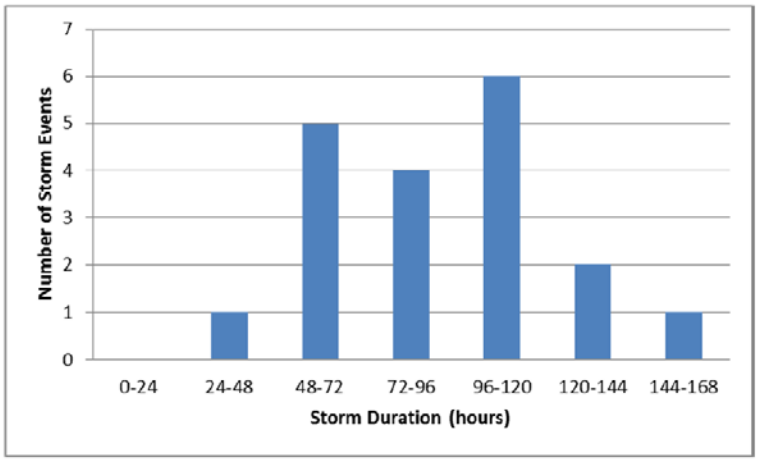


Figure 5.2 – The number of storm events per 24-hour increment from the historical events analyzed for this study.

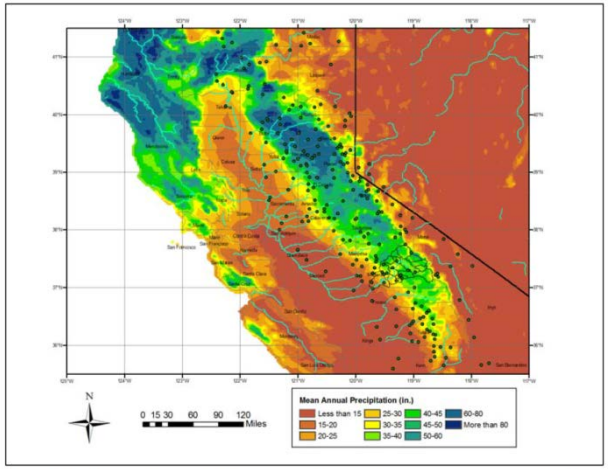


Figure 5.1 – Map of study area, black dots are the locations of precipitation gauges used in the regional precipitation-frequency analysis.

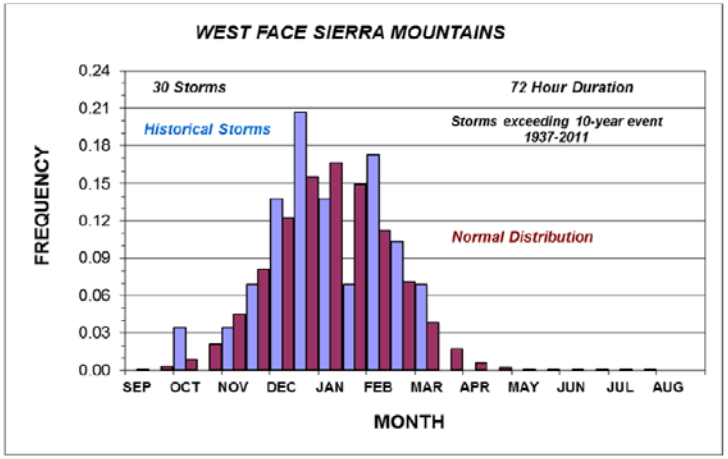
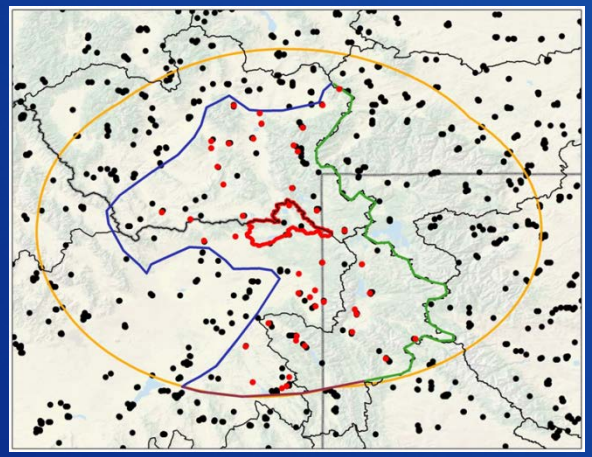
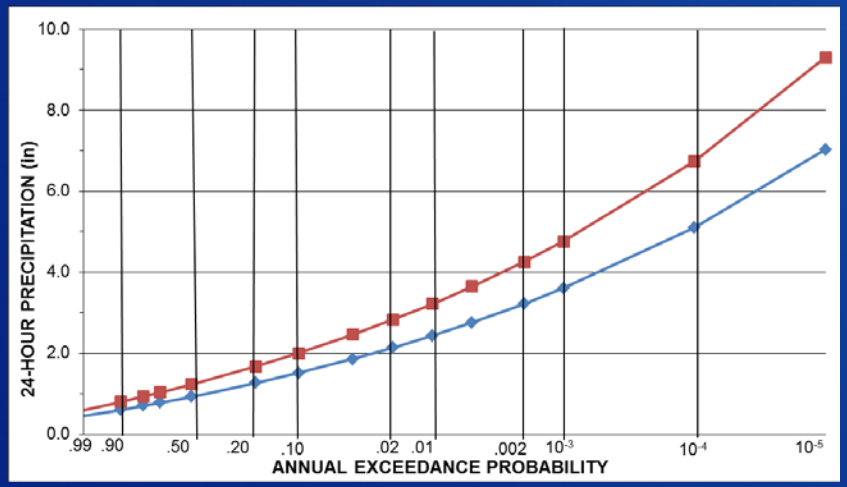


Figure 5.5 – Frequency of 10-year events by month, observed historical events (blue) and the polynomial smoother (purple). (Schaefer and Barker, 2009b)

Meteorological Inputs to Dam Safety Studies





- *Define a "region of interest", aka homogeneous region*
- *Various inputs, highly subjective to individual meteorologist*
- *Utilizes seasonality and duration information*
- *Selection of annual/seasonal maxima*
- *Space-for-time substitution → ability to get beyond 1000-yr*
- *Allows the regional frequency relationship to be scaled by local means (see NOAA14)*

Regional Precipitation Frequency Analysis

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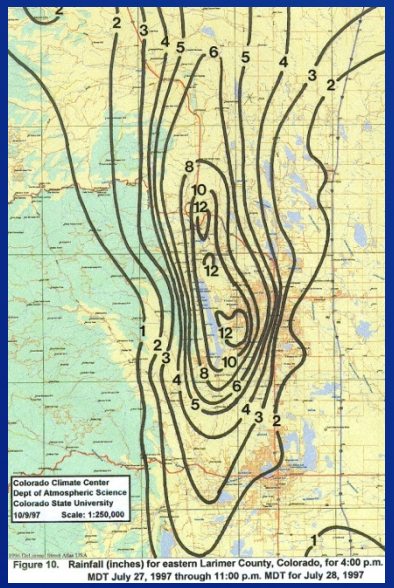
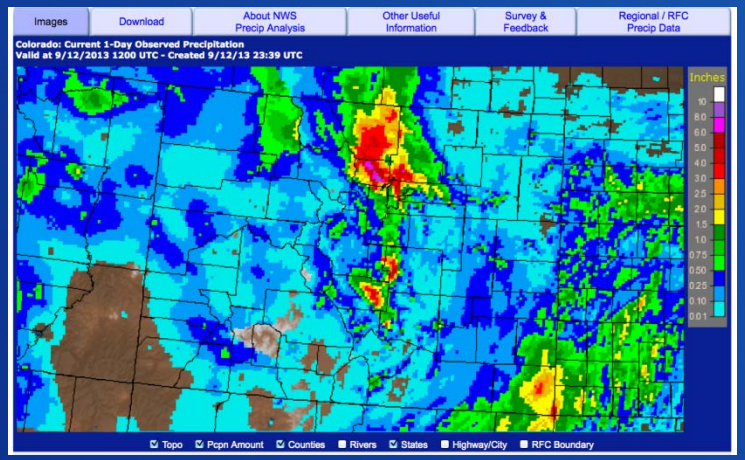
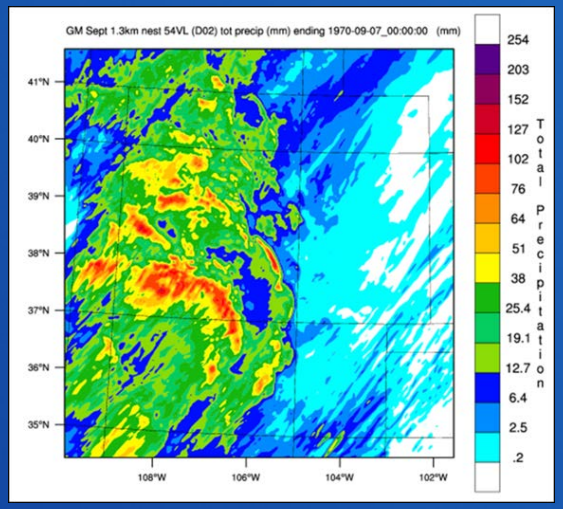
Modern Methods Needed/Required

- The storm database is up to 40 years old (last 1970s to 1986)
- The database is not being updated
- The concepts to formulate PMP were created before the age of computers
- PMP has the potential to be exceeded



Only available back to late 1990s





Can numerical models be used to calculate needed DAD through storm-based analysis?

July 31, 1976	Big Thompson, CO (HMR 55A)
July 27, 1997	Fort Collins, CO (post-HMR)
Sept 2013	Front Range Floods (post-HMR)

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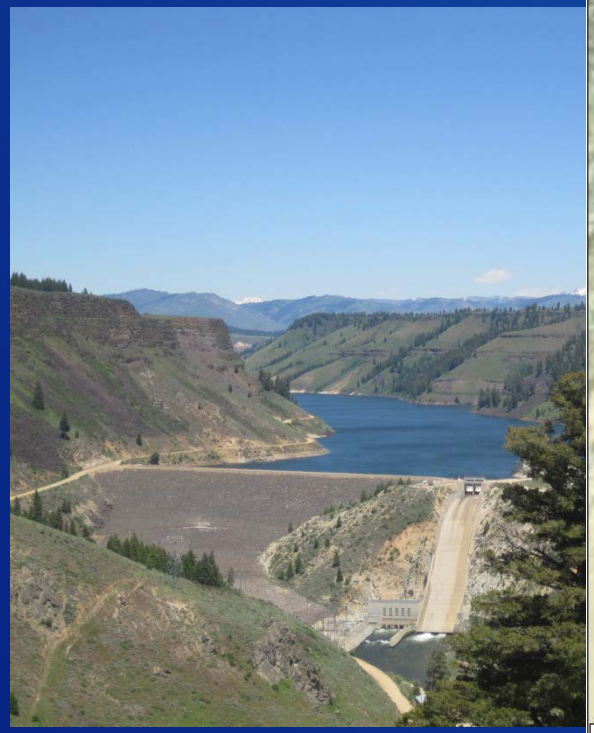
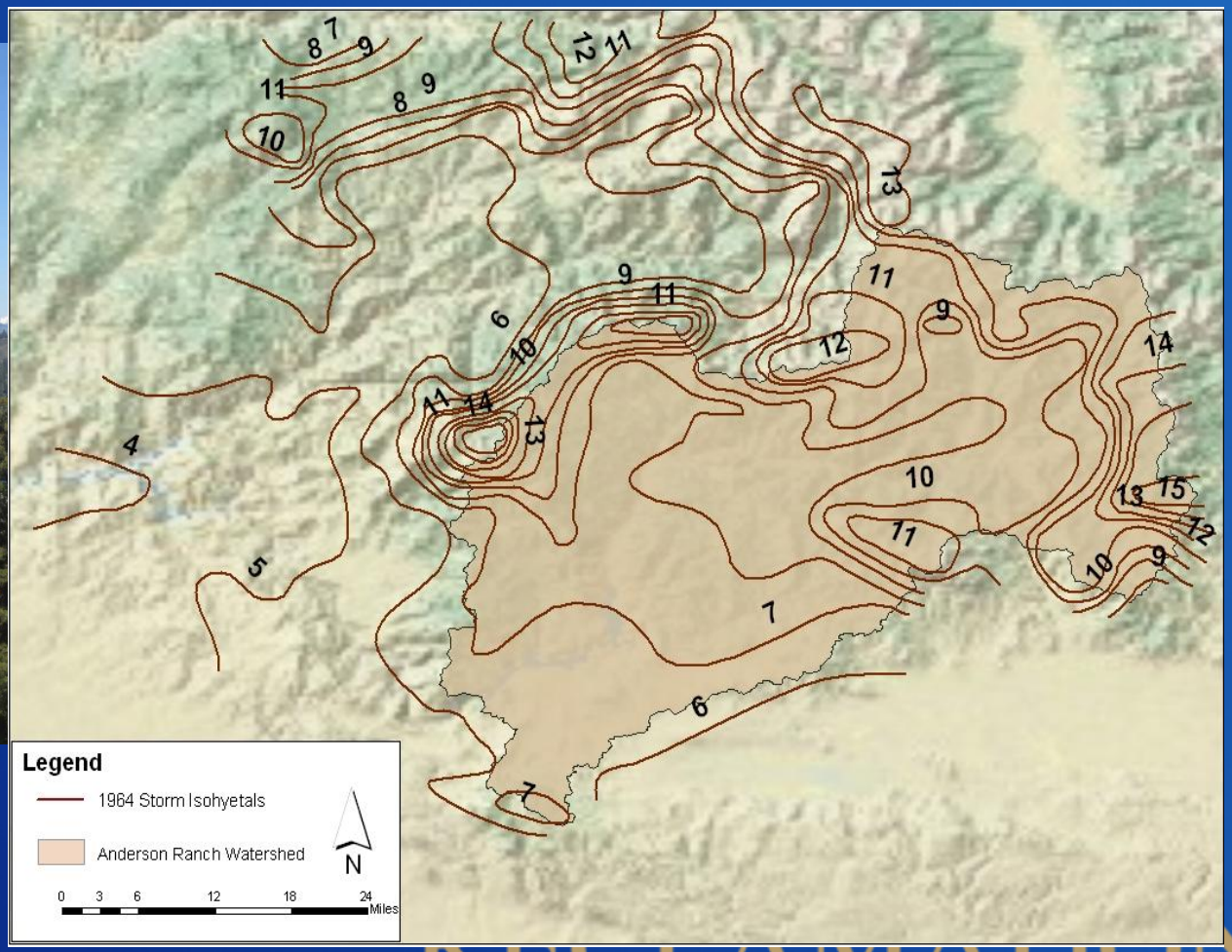
Modern Methods Needed/Required

December 1964 near Boise, ID: would pattern be different in future? Magnitudes increase? A maximized storm look like? Where/how could this storm be moved in a physical and realistic manner?

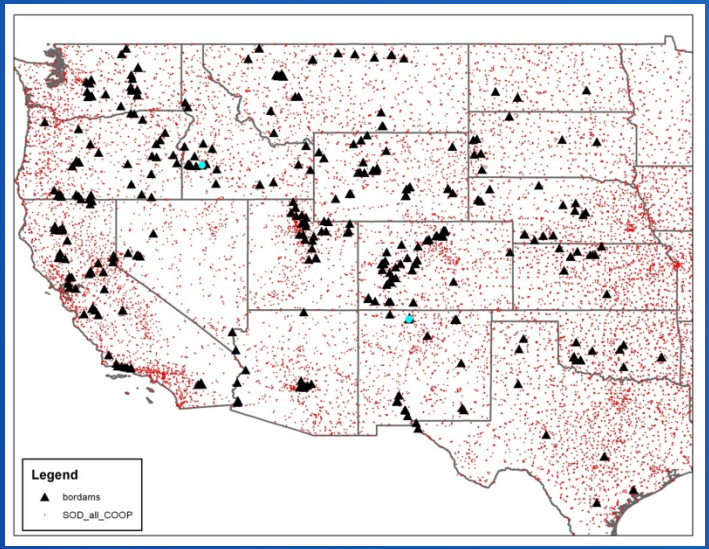


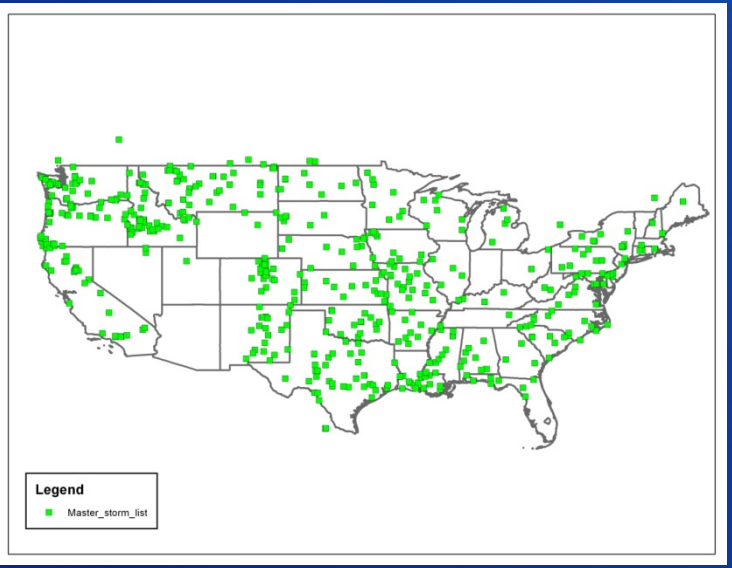


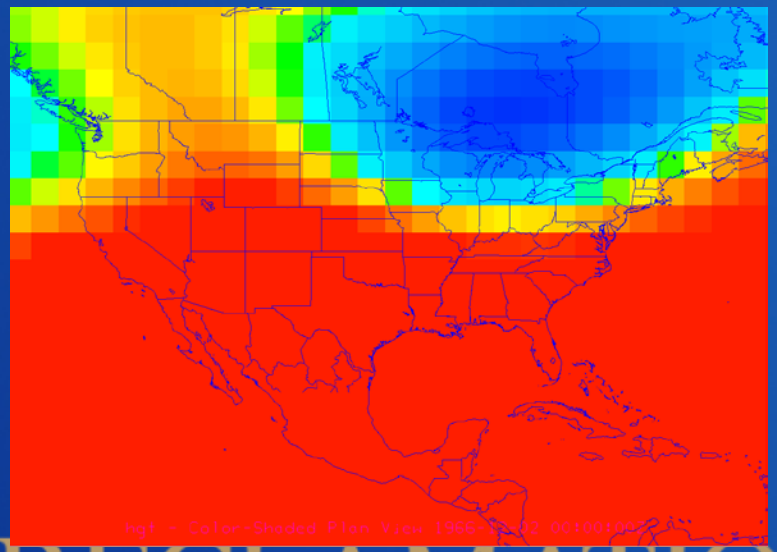
Modern Methods Needed/Required

Limited spatial and temporal resolution of existing meteorological datasets, particularly in orographic terrain:

- Point/gauge-based precipitation
- Reanalysis products (e.g., CFS-R, NCEP/NCAR , NARR)
- Multisensor Precipitation Estimates (MPE)







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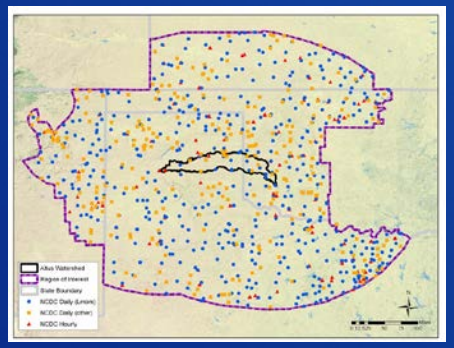
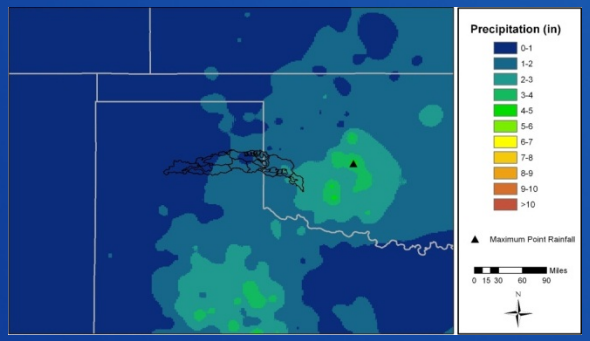
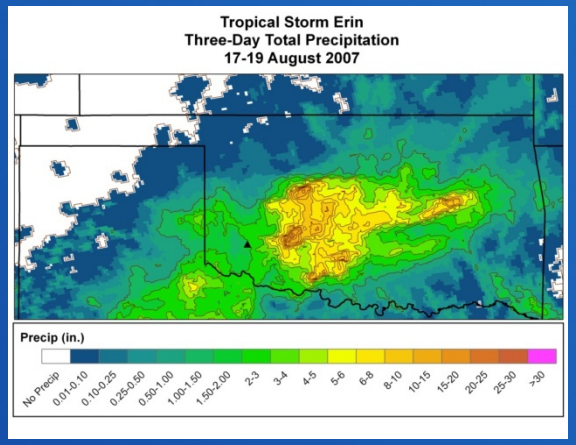
Modern Methods Needed/Required







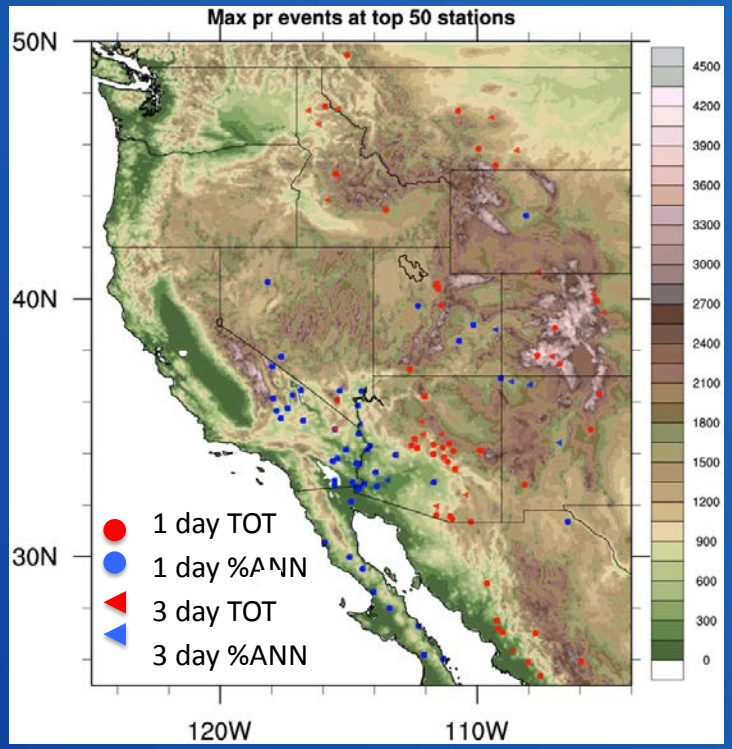
- Methodology for grid-based data processing
  - Precipitation gage only cases
  - Gridded data processing
  - Temperature patterns
- Software development
  - GDAL/Python
  - IDL
  - Other netCDF processing (CDO)
  - Shell scripting

Subbasin #	11	21	31	41	42	71	72	61	62	51	52	81	82	91	92
Area (Mi^2)	293.84	276.83	215.28	242.41	53.25	70.68	68.09	81.91	25.37	135.70	13.31	490.66	110.92	144.90	23.46
24-Hr Precip	1.27	1.10	1.54	1.00	0.97	1.62	1.47	1.93	2.12	1.84	2.00	2.31	2.37	1.71	1.76
Hour	Dimensionless Mass Curves														
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.0094	0.0107	0.0076	0.0128	0.0142	0.0090	0.0103	0.0070	0.0063	0.0062	0.0068	0.0081	0.0078	0.0148	0.0215
25	0.0102	0.0114	0.0086	0.0145	0.0157	0.0096	0.0108	0.0075	0.0067	0.0071	0.0073	0.0083	0.0081	0.0151	0.0217
26	0.0116	0.0127	0.0104	0.0176	0.0185	0.0105	0.0118	0.0086	0.0074	0.0088	0.0082	0.0087	0.0085	0.0154	0.0221
27	0.0162	0.0168	0.0161	0.0271	0.0270	0.0135	0.0148	0.0118	0.0096	0.0138	0.0111	0.0099	0.0099	0.0169	0.0235
28	0.0195	0.0197	0.0200	0.0339	0.0331	0.0156	0.0169	0.0140	0.0111	0.0173	0.0131	0.0108	0.0109	0.0180	0.0246
29	0.0195	0.0197	0.0200	0.0339	0.0331	0.0156	0.0169	0.0140	0.0111	0.0173	0.0131	0.0108	0.0109	0.0180	0.0246
30	0.0262	0.0258	0.0284	0.0480	0.0457	0.0201	0.0214	0.0188	0.0144	0.0248	0.0174	0.0127	0.0130	0.0200	0.0265
31	0.0304	0.0295	0.0334	0.0565	0.0534	0.0228	0.0241	0.0216	0.0163	0.0292	0.0199	0.0138	0.0143	0.0214	0.0278
32	0.0305	0.0296	0.0336	0.0568	0.0536	0.0228	0.0241	0.0217	0.0164	0.0294	0.0200	0.0138	0.0143	0.0214	0.0278
33	0.0441	0.0420	0.0504	0.0851	0.0790	0.0317	0.0331	0.0312	0.0228	0.0443	0.0285	0.0176	0.0185	0.0255	0.0317
34	0.0442	0.0420	0.0505	0.0854	0.0792	0.0318	0.0331	0.0313	0.0229	0.0444	0.0285	0.0176	0.0186	0.0255	0.0317
35	0.0469	0.0445	0.0540	0.0913	0.0845	0.0337	0.0350	0.0333	0.0242	0.0475	0.0303	0.0184	0.0194	0.0264	0.0327
36	0.0549	0.0516	0.0637	0.1079	0.0994	0.0389	0.0402	0.0388	0.0280	0.0562	0.0353	0.0205	0.0219	0.0287	0.0349
37	0.0572	0.0537	0.0666	0.1128	0.1038	0.0404	0.0418	0.0405	0.0291	0.0588	0.0367	0.0211	0.0225	0.0293	0.0354
38	0.0681	0.0636	0.0799	0.1351	0.1238	0.0475	0.0488	0.0480	0.0343	0.0706	0.0435	0.0241	0.0260	0.0327	0.0387
39	0.0756	0.0703	0.0891	0.1507	0.1377	0.0523	0.0537	0.0532	0.0378	0.0788	0.0481	0.0261	0.0282	0.0349	0.0408
40	0.1039	0.0959	0.1237	0.2090	0.1901	0.0707	0.0722	0.0728	0.0512	0.1095	0.0657	0.0338	0.0369	0.0435	0.0491
41	0.1125	0.1036	0.1343	0.2270	0.2062	0.0764	0.0778	0.0789	0.0553	0.1190	0.0711	0.0362	0.0396	0.0462	0.0518
42	0.1143	0.1052	0.1365	0.2309	0.2097	0.0776	0.0791	0.0801	0.0562	0.1210	0.0722	0.0367	0.0402	0.0467	0.0522
43	0.1165	0.1072	0.1392	0.2355	0.2138	0.0791	0.0805	0.0817	0.0572	0.1234	0.0736	0.0373	0.0408	0.0473	0.0528
44	0.1178	0.1084	0.1409	0.2383	0.2163	0.0799	0.0814	0.0826	0.0578	0.1249	0.0744	0.0376	0.0412	0.0476	0.0531

FY12/13 NOAA/CIRES Cooperative Agreement

Diagnosing the moisture sources for extreme precipitation events in the intermountain west

- ✓ ***Cold season focus, atmospheric rivers***
- ✓ ***Primary deliverables:***
  - ✓ *Point-specific storm identification and magnitudes (1- and 3-day)*
  - ✓ *Back-trajectories to identify moisture source regions, climatological pathway preference*
  - ✓ *High-resolution modeling efforts to identify sensitivity to topography and model resolution; also, simplified linear model approach*
  - ✓ *Principal component analysis to identify key atmospheric set-up for extreme precipitation events*
  - ✓ *Project Completion Report and associated journal articles*



Max Precipitation events at each station are sorted 4 ways: 1-day and 3-day events, total precipitation and fraction of annual precipitation. Red events are total precipitation and blue events are based on % annual precipitation. Triangles are 1-day events and circles are 3-day. Top 50 events shown for each method. West Coast stations have been excluded to focus on intermountain region.

RECLAMATION

FHCG FY14/15 Collaborative Projects

TSC FHCG Collaboration with NOAA/CIRES

- ✓ ***Focus on R2O: how to integrate in Dam Safety Studies***
  - ✓ ***FY14: Applying FY12/13 NOAA/CIRES Deliverables, Techniques, & Software***
  - ✓ ***Production of guidance documentation for FHCG and NOAA/CIRES benefit***
  - ✓ ***FY15: Extension would address FY14/15 NOAA/CIRES outcomes***
- ✓ ***Current FHCG Projects with immediate application potential:***
  - ✓ ***Boise River Diversion Dam***
  - ✓ ***Island Park Dam***
  - ✓ ***El Vado Dam (post-mortem proposed)***
  - ✓ ***Friant Climate Change***
  - ✓ ***Taylor Park Dam***
  - ✓ ***Grand Coulee Dam***

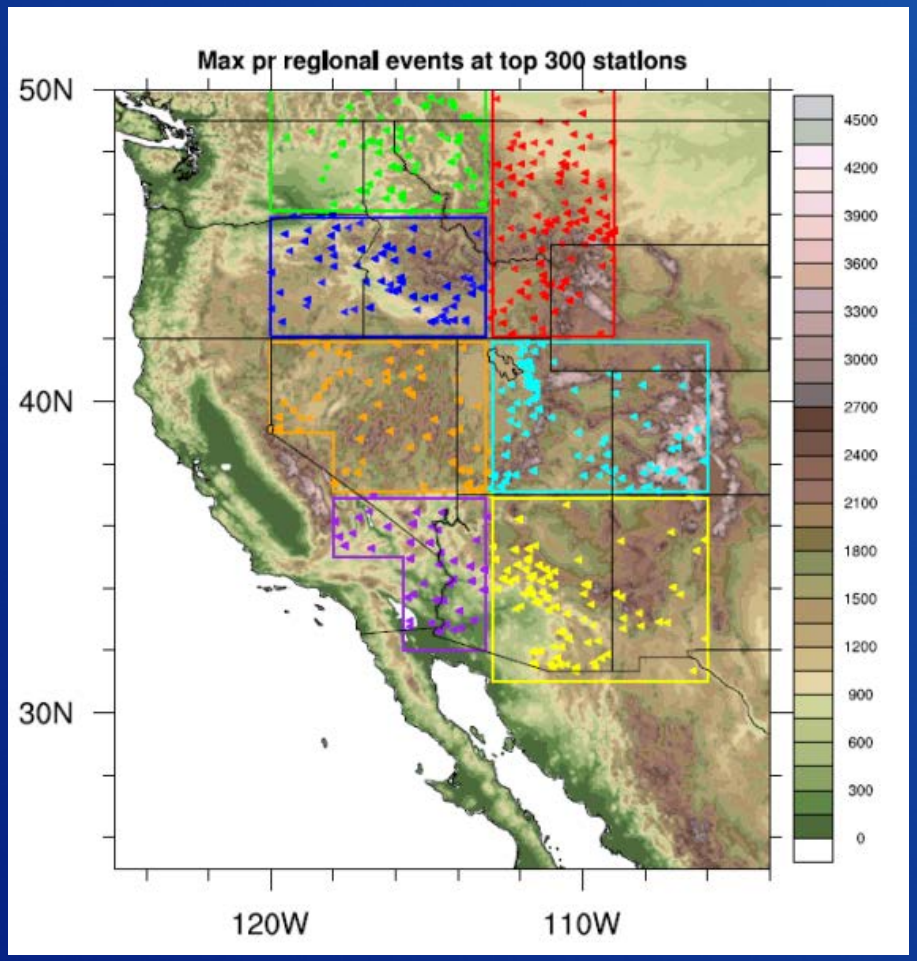
1st Step to Guidance Document → What can we use and how?

FHCG FY14/15 Collaborative Projects

Potential Cross-Overs:

- *Study Area*
- *Storm Duration/Seasonality*
- *Storm Selection*
- *Transposition Region*
- *Storm Classification*
- *Spatial/Temporal Patterns*
- *Precipitation Frequency*
- *Uncertainty Analysis*
- *Storm Maximization*
- *Orographic Adjustment*

Research-to-Operations Guidance



1- to 3-day Precipitation Data

Maximum precipitation events from COOP stations
* >30 years and 80% reports
* netCDF (seasonal, monthly)

APPLICATIONS:

- Seasonality
- Storm Duration
- Storm Event Selection
- Key Events for Precipitation Frequency

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Research-to-Operations Guidance

Back Trajectory Analyses

Single event based backtrajectories back in time from different atmospheric levels

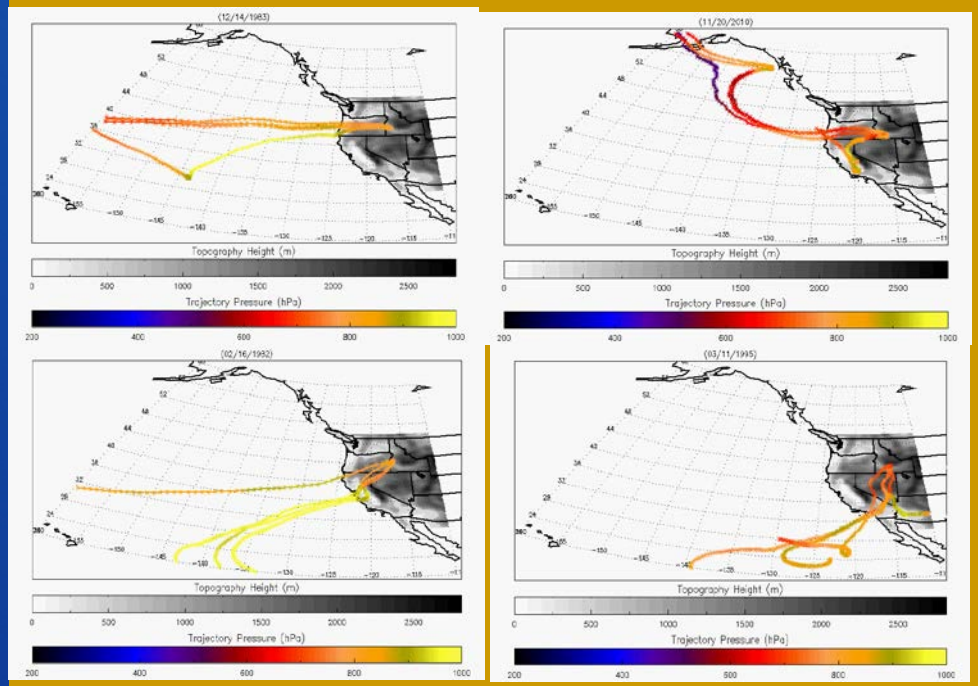

Fig. 3 Examples of backward trajectories that originated (meaning when the backwards in time trajectories were initiated) in southwestern Idaho during one of 150 top precipitation events in that target region. Grey scale represents terrain height (m) color denotes pressure at that point in the trajectory.

APPLICATIONS:

- Transposition limits
- Moisture maximization and ensemble approaches/uncertainty
- Preferred pathways for specific regions/dams

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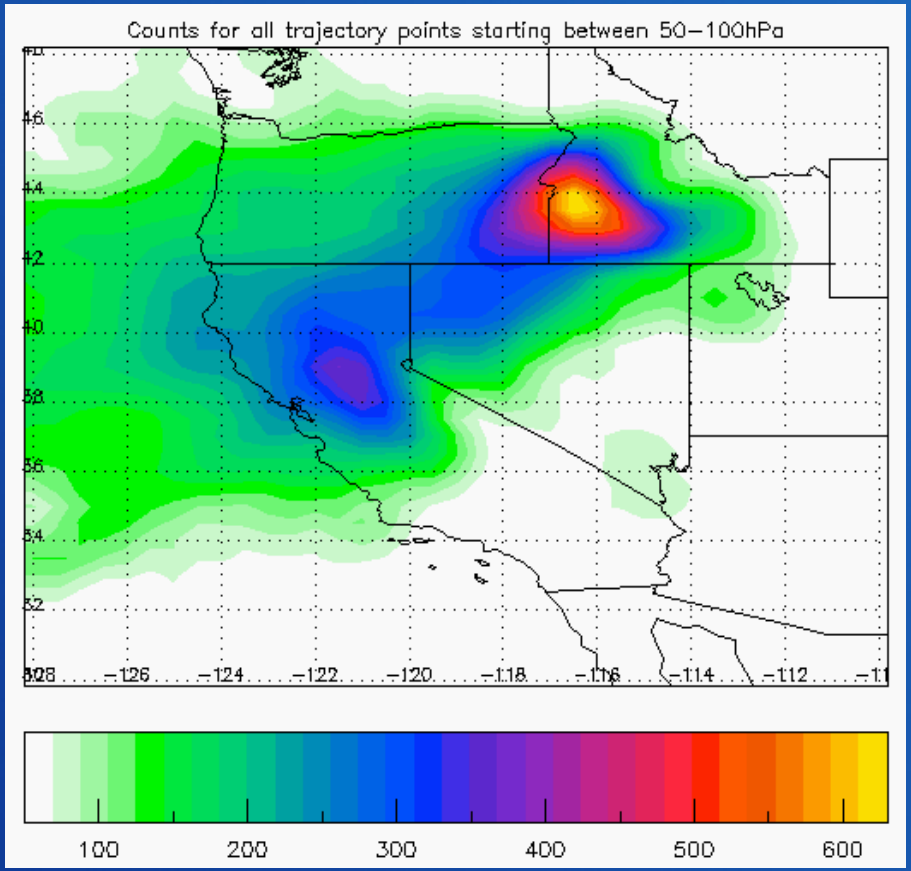
Research-to-Operations Guidance

Back Trajectory Analyses

Composite counts for surface-based trajectories with regional/dam-specific origin



APPLICATIONS:

- Transposition limits
- Moisture adjustment for storms along trajectories
- Identification of key synoptic set-up for heavy precipitation events (i.e., inflow direction); may inform orographic spatial distribution

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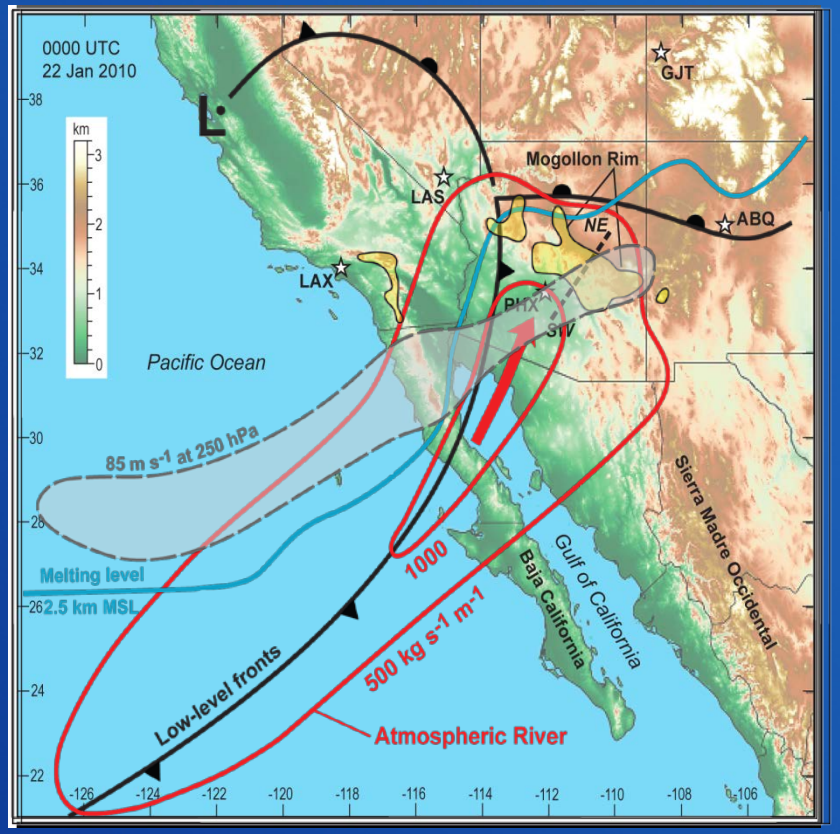
Research-to-Operations Guidance

Back Trajectory Analyses

Schematics of key attributes of extreme storms

APPLICATIONS:

- Synoptic set-up of heavy precipitation events
- Historical storm analyses for application in storm databases



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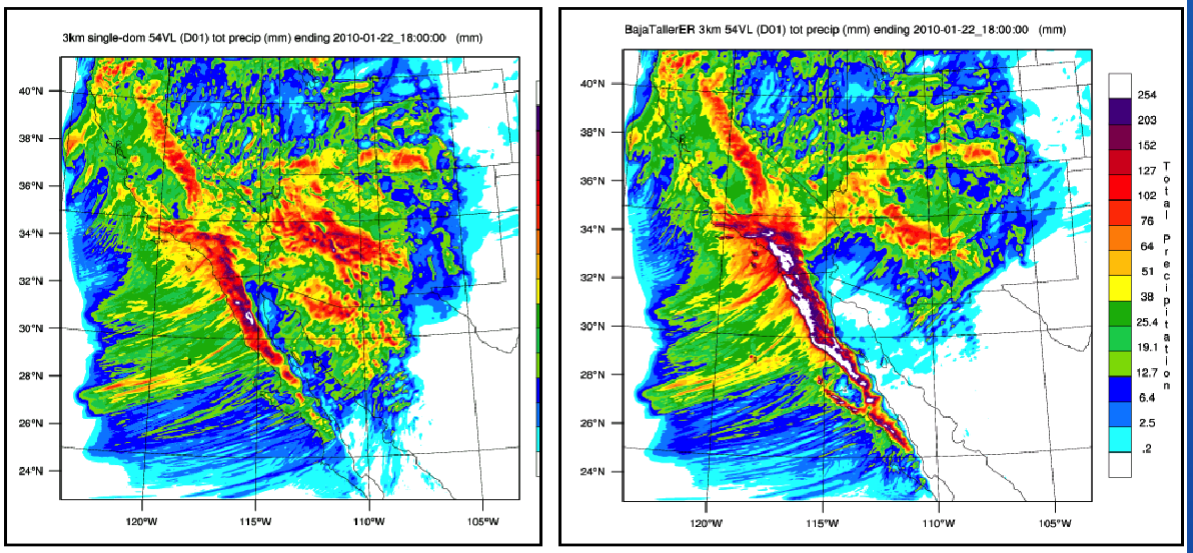
Research-to-Operations Guidance

High-Resolution Modeling

WRF model simulations at different resolutions w/ different underlying topography

APPLICATIONS: Spatial/temporal patterns, DAD tables, ARFs, moisture adjustment factors, orographics, historical storm reanalysis



3 km CTRL precipitation

Tall Baja precipitation

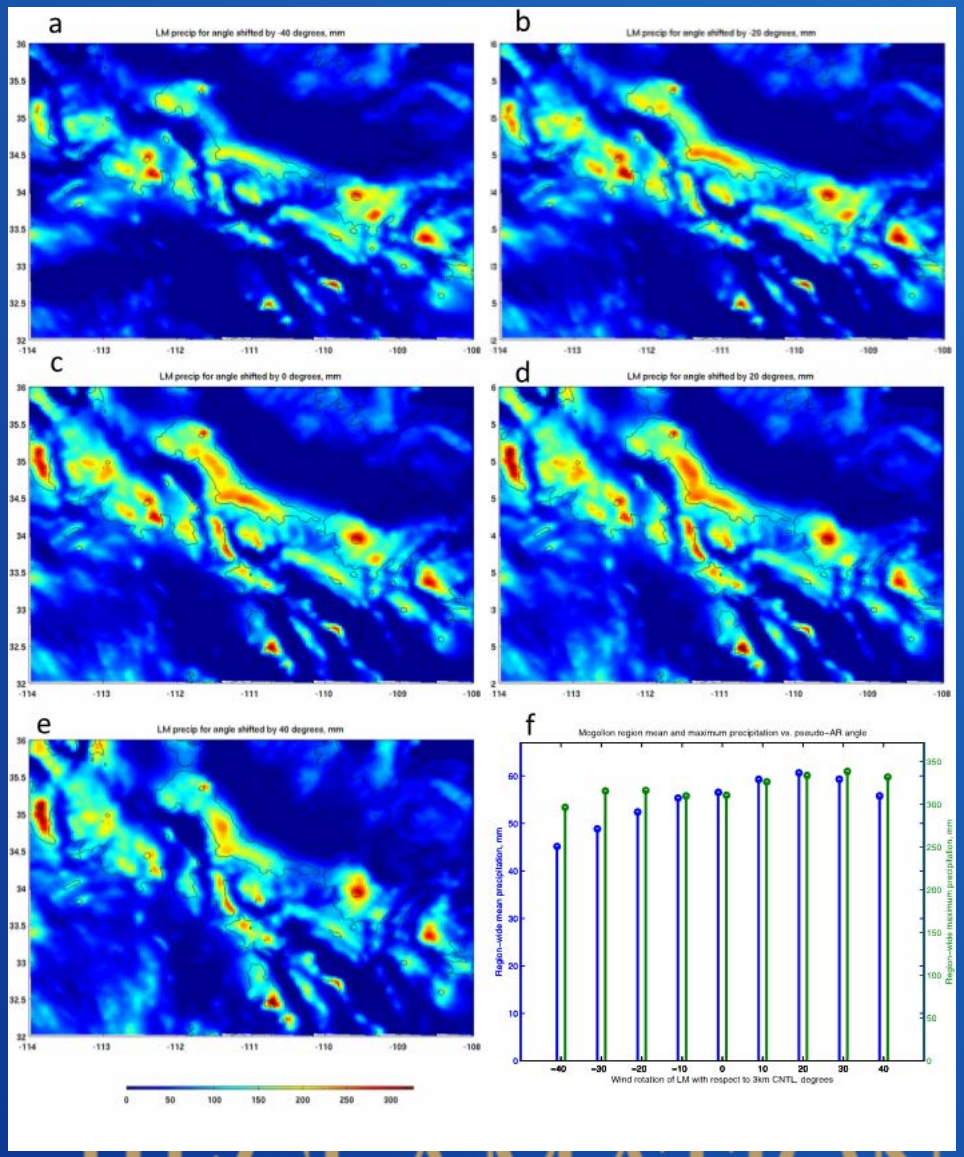
Research-to-Operations Guidance

Statistical Approaches: LM of Orographic Precip

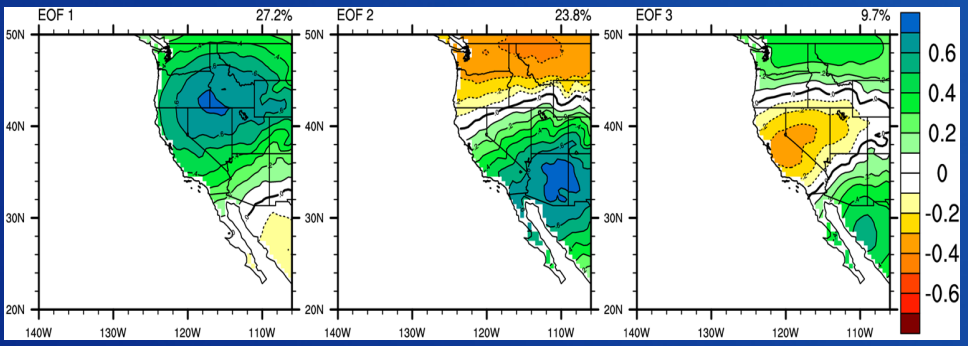
Simplified method to predict spatial distribution of precipitation downstream

APPLICATIONS:

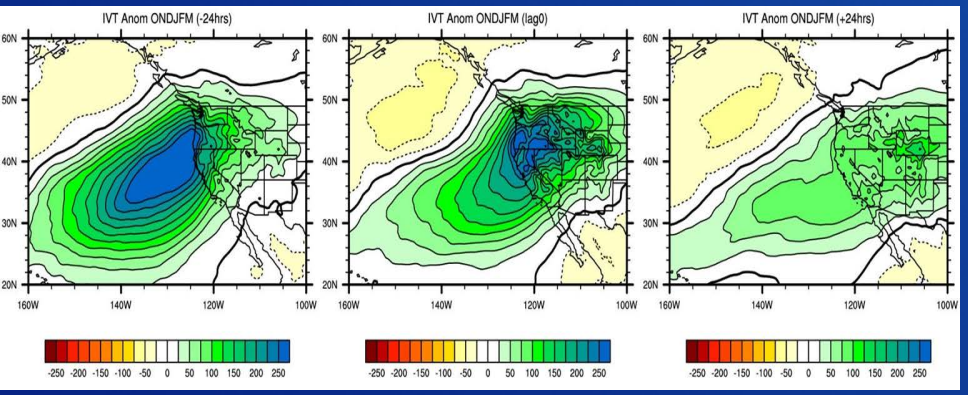
- Spatial patterns of precipitation given initial moisture, topography, and inflow vector
- Ensemble of patterns with flow variability



Research-to-Operations Guidance



The three leading EOFs of the normalized 6-hourly IVT anomalies during October-March computed over the western United States.



Composites maps of IVT (Kg s^{-1} m^{-1}) based on extremes of the time series (prinicpal component, PC) associated with EOF 1

Statistical Approaches: EOFs and PCA

Leading EOFs explain majority of variance in heavy precipitation over western US; composite maps of IVT based on PC time series from EOFs

APPLICATIONS:

- Synoptic classification
- Spatial/temporal patterns from PC time series
- Stochastic modeling

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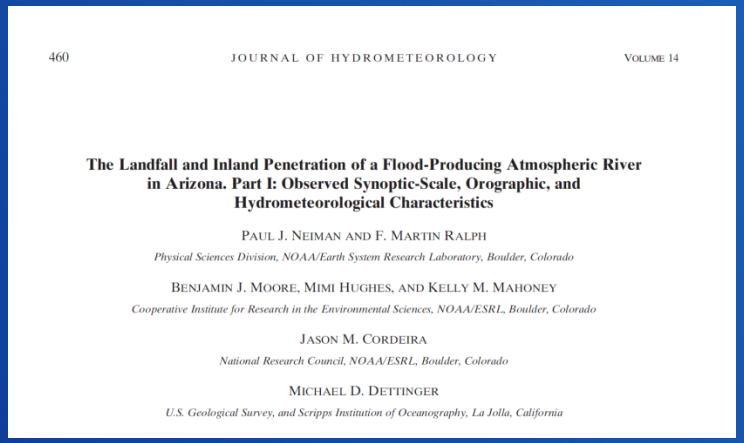
Research-to-Operations Guidance

Research Papers

Provide the technical background, methods, data, and results


460 JOURNAL OF HYDROMETEOROLOGY VOLUME 14

The Landfall and Inland Penetration of a Flood-Producing Atmospheric River in Arizona. Part I: Observed Synoptic-Scale, Orographic, and Hydrometeorological Characteristics

PAUL J. NEIMAN AND F. MARTIN RALPH

Physical Sciences Division, NOAA/Earth System Research Laboratory, Boulder, Colorado

BENJAMIN J. MOORE, MIMI HUGHES, AND KELLY M. MAHONEY

Cooperative Institute for Research in the Environmental Sciences, NOAA/ESRL, Boulder, Colorado

JASON M. CORDEIRA

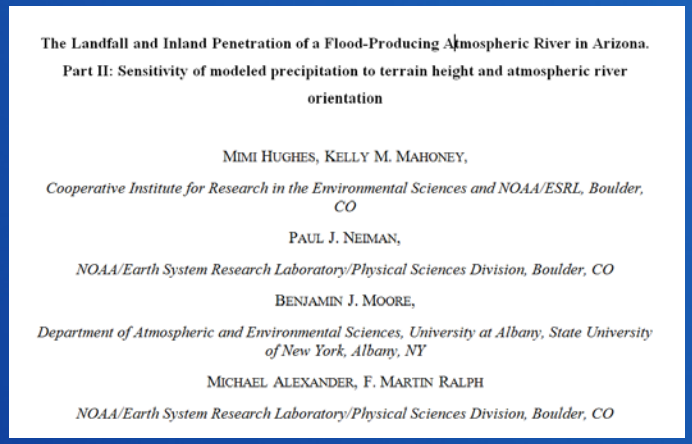
National Research Council, NOAA/ESRL, Boulder, Colorado

MICHAEL D. DETTINGER

U.S. Geological Survey, and Scripps Institution of Oceanography, La Jolla, California

APPLICATION:

- Basis for guidance to FHCG on pertinent applications and summary for the end goal


The Landfall and Inland Penetration of a Flood-Producing Atmospheric River in Arizona. Part II: Sensitivity of modeled precipitation to terrain height and atmospheric river orientation

MIMI HUGHES, KELLY M. MAHONEY,

Cooperative Institute for Research in the Environmental Sciences and NOAA/ESRL, Boulder, CO

PAUL J. NEIMAN,

NOAA/Earth System Research Laboratory/Physical Sciences Division, Boulder, CO

BENJAMIN J. MOORE,

Department of Atmospheric and Environmental Sciences, University at Albany, State University of New York, Albany, NY

MICHAEL ALEXANDER, F. MARTIN RALPH

NOAA/Earth System Research Laboratory/Physical Sciences Division, Boulder, CO

Goal (Summer 2014) →

Potential Applications of Modern Meteorological Datasets in Engineering Hydrology

ASCE J. Hydrol. Engineering, J. Hydromet, JAMC, BAMS, Eos

Caldwell, Sankovich, England, Keeney, Alexander, Mahoney, Hughes, Nieman, etc.

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard analyses

✓ ***TASK 1:*** ***Transfer to Reclamation the data, information, methods, and documentation developed by CIRES and NOAA under the FY12/13 CIRES agreement to study extreme events***

Transfer of the following:

Task 1.1: Identify heavy precip events in watersheds of interest (Idaho)

Task 1.2: Develop an archive of back-trajectories (Idaho)

Task 1.3: IVT Anomaly maps and associated files

Task 1.4: Trajectory-EOF analysis methods

Task 1.5: Evaluation of Inland penetration of ARs

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard analyses

✓ ***TASK 2:*** ***Develop additional methods for diagnosing and grouping storms***

Cluster Analysis

Task 2.1: ***Develop a Trajectory Similarity Score, based on cluster analysis, and assess its potential use in dam safety studies. Investigate the use of these scores to support choice of storms for dam safety***

Self-Organizing Maps

Task 2.2: ***Develop SOMs and assess its potential use in dam safety studies, IVT-based with maps of other pertinent variables mapped to SOM nodes with potential applications to transposition regions.***

Research-to-Operations

Task 2.3: ***Collaborate on research-to-operations initiative.***

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

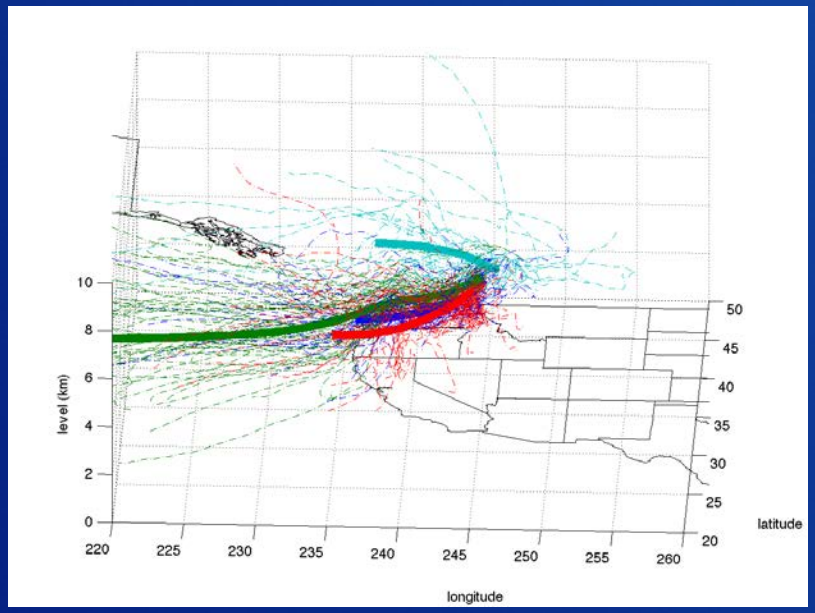
Trajectory Clustering & Scoring for Storm Transposition

Problem: Current storm selection practice sometimes selects storms that are meteorologically very different than the storms that create a flooding risk in a target area.

Goal: To inform storm selection for dam safety analysis using quantitative analysis based on air parcel trajectories.

Conceptual Outline

Clustering We have computed air parcel trajectories for events that produced heavy precipitation over target area of interest. We can perform cluster analysis on these trajectories to identify preferred air parcel trajectories.



Clustering using “standardized Euclidean distance” for N. Idaho heavy precipitation targets

Note that trajectories are clustered in 3 dimensions, and in overall speed at which they travel (green cluster travels farther then red cluster).

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

Trajectory Clustering & Scoring for Storm Transposition

The basic insight is that clustering of trajectories involves computing a "distance" between each pair of trajectories. This "distance" can be used to create a similarity score for candidate storms as if they had been transposed.

Similarity Candidate storms from a much larger library can then be transposed to the "target" point and their air parcel trajectory compared to the target clusters by calculating the normalized Euclidean distance, and a similarity score developed.

Other similarity scores are possible, depending on the target and what is judged to be meteorologically relevant: Angle of incidence to terrain, passage through topographic gaps, origin of air parcel…

The result is a list of scores for candidate storms for transposition that can be ranked according to similarity and can inform ***storm selection***.

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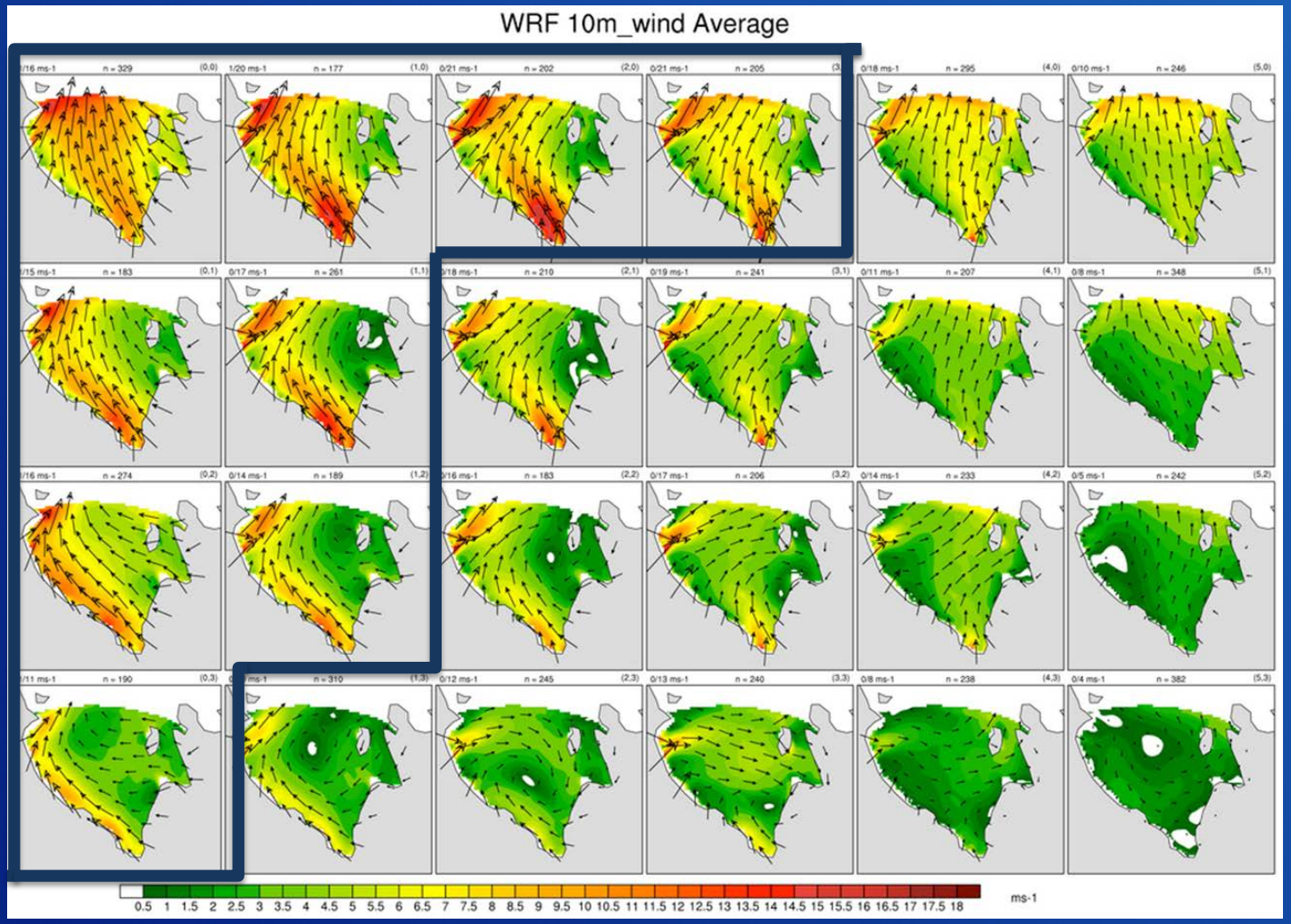
FY14/15 NOAA/CIRES Cooperative Agreement

SOM "Real" Example: Ross Ice Shelf Wind Climatology



Statistics-based learning algorithm to identify historical events that represent different patterns (e.g., Ross air stream)

AR Potential: Patterns associated with AR events and large precipitation events → composites of moisture pathways

Identification of historical events

Courtesy: Melissa Nigro/Dr. John Cassano

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard analyses

✓ ***TASK 3:*** ***Generate and analyze an ensemble of high-resolution simulations***

Task 3.1: ***Conduct an ensemble of simulations using the Weather Research and Forecast (WRF) simulations of heavy winter precipitation event over a critical watershed and infrastructure for Reclamation.***

Task 3.2 ***FHCG will use gridded precipitation data to explore potential for extracting precipitation frequency information from gridded datasets.***

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard analyses

✓ ***TASK 4: Climate Change/Variability***

Task 4.1: *Examine ARs and how they change due to greenhouse gas forcing in the CMIP5 model archive. Explore methods to gain sub-monthly information from the CMIP5 projections.*

Task 4.2: *Experiments of future AR-related storms can be conducted using the "pseudo global warming" (or "delta") method.*

Task 4.3: *We will also explore the role of climate variability, as it can obscure the climate change signal and influence the moisture pathways into the western US and the related precip extremes.*

Task 4.4 *While exploratory, the results from these analyses may provide guidance to the FHCG for estimating extreme meteorological event possibilities, deterministically or probabilistically, in a changing climate*

RECLAMATION

FY14/15 NOAA/CIRES Cooperative Agreement

Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard analyses

✓ ***TASK 5: Final Assessment, Publications, and Next Steps***

Task 5.1: ***Assess progress on the project including transferring knowledge, data, and documentation to Reclamation.***

Task 5.2: ***Publish findings from Tasks 2 through 4.***

Task 5.3: ***Outline steps for future work.***

Task 5.4: ***Collaborate with the FHCG in the development of a Reclamation-specific document for application of available tools, datasets, and methods.***

Diagnosing the moisture sources for extreme precipitation events in the western US: Application to hydrologic hazard studies

Summary

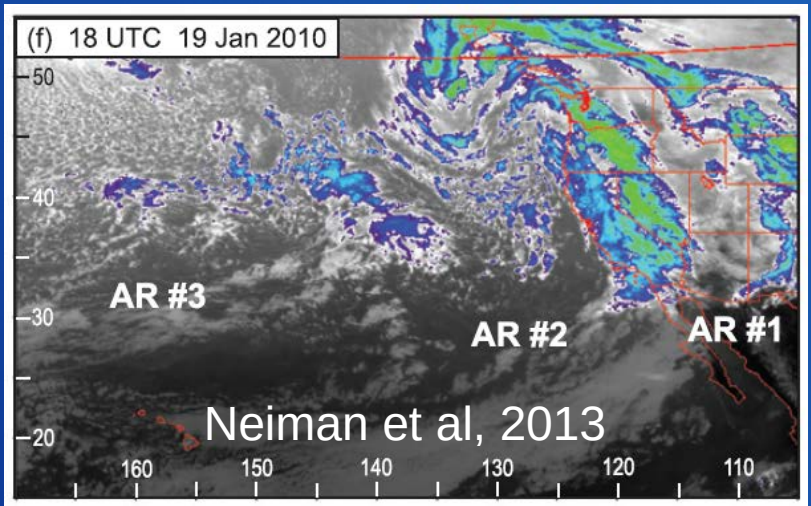
- Focus on R2O with heavy collaboration with Reclamation TSC FHCG
- Expansion of statistical analyses to cluster analysis, trajectory similarity scores, and self organizing maps
- Research-informed, ensemble-based numerical modeling of key storm event(s)
- AR pathways under CMIP5 projections

Key Lessons Learned

- FY12/13 → Key understanding of atmospheric rivers and orographic impacts
- FY12/13 → Identified need for enhanced collaboration and on-the-ground application of results

Next Steps/Future Work

- Continued collaboration with FHCG to enhance hydrologic hazard studies
- Investigate new, more robust statistical methods for identifying key AR features
- Post-mortem and real-time flood hazard applications (El Vado and Grand Coulee?)
- Publications – both NOAA/CIRES and collaborative with FHCG



Neiman et al, 2013

RECLAMATION

TSC FHCG Collaboration with NOAA CIRES

Summary

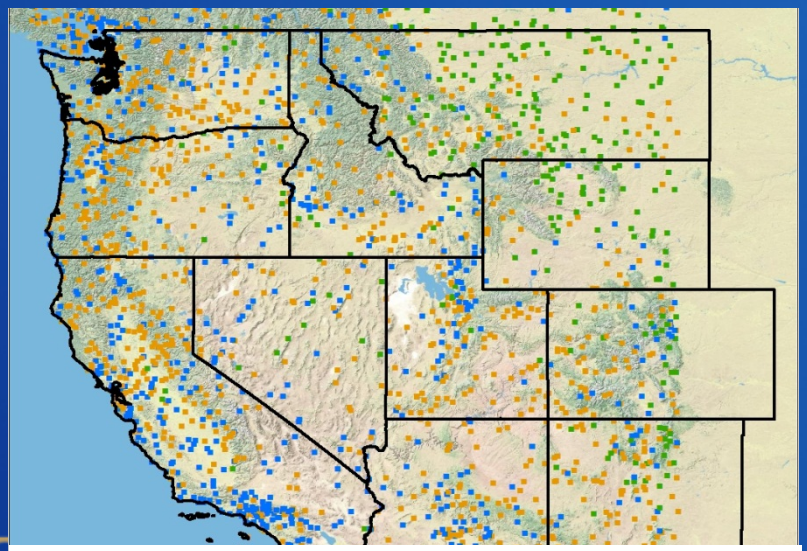
- Need for updates to historical storm patterns for multiple applications from PMP to full-blown stochastic modeling
- Past projects (X6917, X1385) initiated development of methods to generate grid-based inputs to flood hydrology models
- Funds refocused for FY14 → R2O
- Guidance document and software development planned in FY14

Key Lessons Learned

- Research activities at NOAA/CIRES fill essential gaps in both the LT documents and everyday operations
- Additional resources must be allocated within FHCG to enable full integration
- Support from DSO Tech Development and FHCG management to incorporate into ongoing and future HHAs
- Continued/close interaction with NOAA/CIRES is critical to success in R2O

Next Steps/Future Work

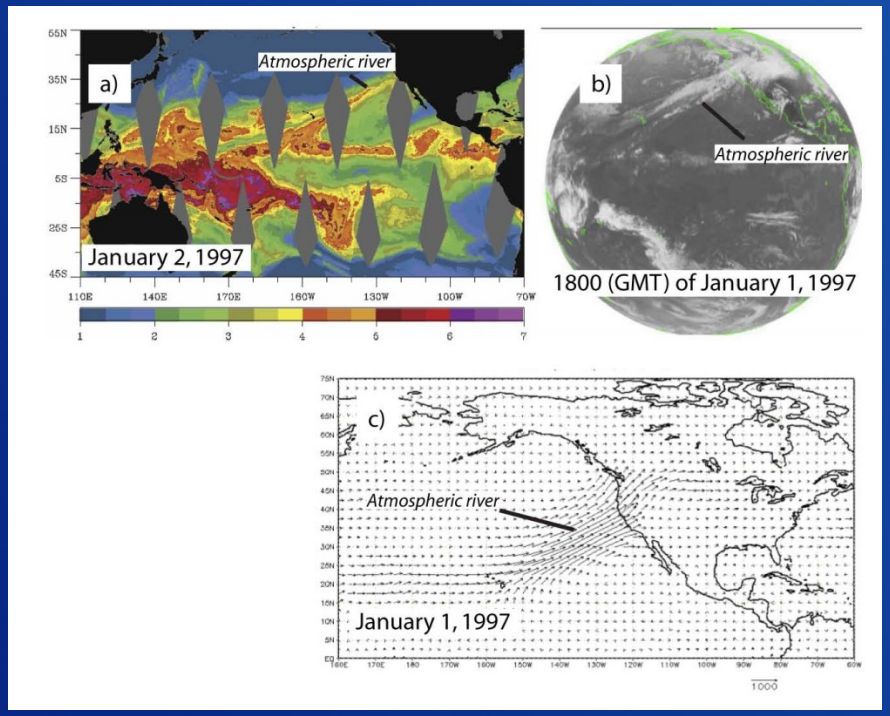
- Collaborate with NOAA/CIRES to bring tools, data, and documentation in-house (most completed in CY13)
- R2O Presentation at Annual AMS Meeting in Atlanta – February 2014
- Complete guidance document in Summer 2014
- Propose future work for FY15 to incorporate newest findings during current 2-yr project



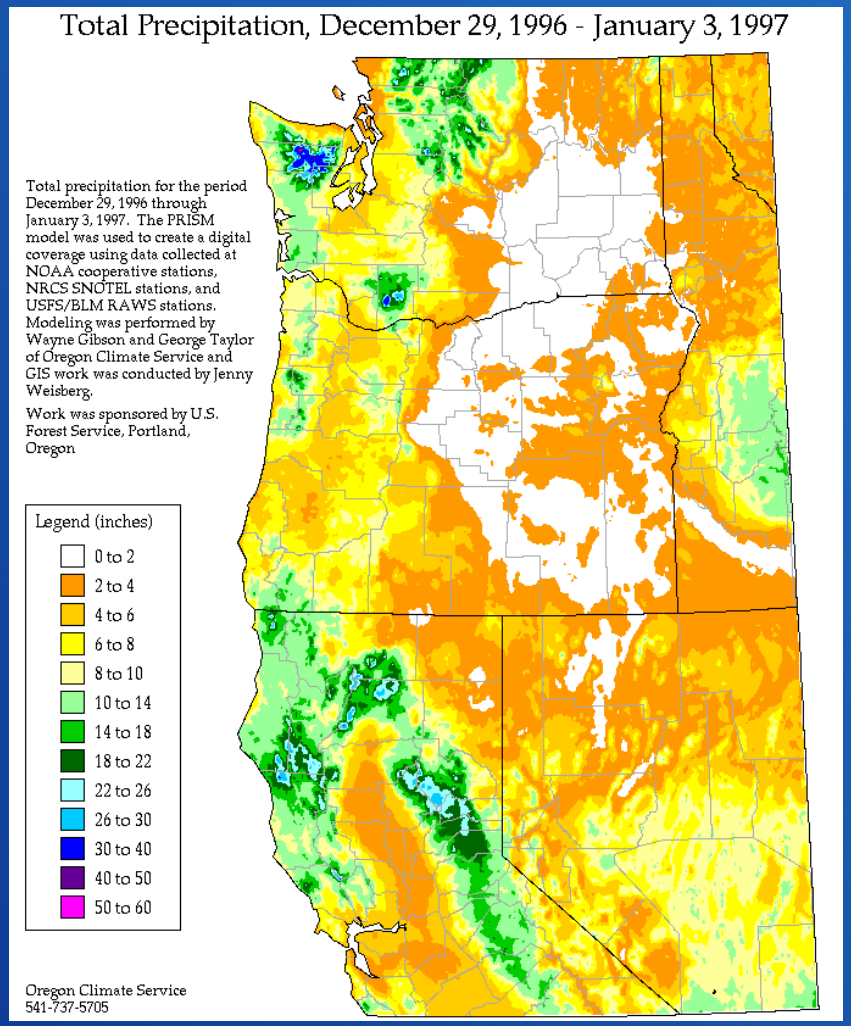
Month of maximum 3d precipitation

Questions/Comments?

Contact:
Jason Caldwell
rcaldwell@usbr.gov
303-445-2524



courtesy M. Dettinger (USGS) et al., Water Intl 2011



Downloaded from CNRFC website, courtesy of Oregon Climate Service

RECLAMATION