Moving Towards Gridded Precipitation Forcings in the CHPS Era

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This version includes some updates/corrections from audience input

Teleconference (866) 804-8142 passcode 2937055

Today's Topics

- Transition to gridded hydrometeorological forcings in NWS hydrologic prediction operations, associated with adoption of Community Hydrologic Prediction System (CHPS)
- Results on legacy/gridded forcings comparisons from CHPS Acceleration Team
- Need for preparation and routine updating of hydrologic calibration datasets
- Ongoing precipitation analysis activities in NWS and NOAA
- Possible approaches to preparing historical precipitation records for calibration
- Relationship to Analysis of Record

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Acknowledgements

- CHPS Acceleration Team (CAT) RFC staff:
  - Don Laurine (NWRFC)
  - Rob Hartman, Art Henkel (CNRFC)
  - Robb Shedd (NERFC)
  - Eric Jones, Briona Chester (ABRFC)
- Jamie Vavra (OST)
- Chris Dietz, Mike Smith, John Schaake (OHD)

Today's focus is precipitation, but…

- Temperature is as important a forcing as precip over areas with winter snowpack
- Many similar opportunities and challenges exist for creating long-term records of temperature and potential evapotranspiration (PET)
- Current plans in OHD place equal emphasis on temperature records

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Transition to gridded hydrometeorological forcings in NWS hydrologic prediction operations

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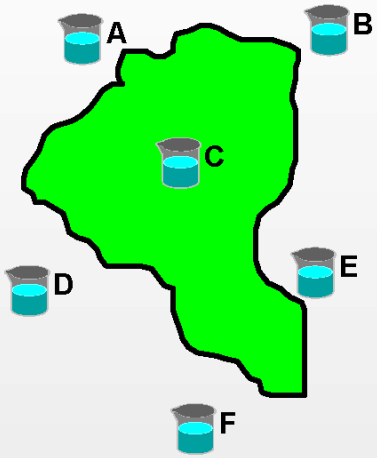
Lumped-Model Forcings

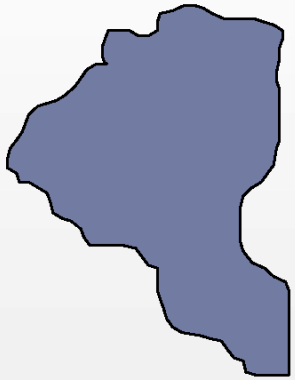
- An entire stream basin is considered as a unit
- 100's to 1000 miles^2
- Hydrologic model is forced by basin-average values
- Basin averages can be estimated from:
  - Point observations in/near basin
  - Rectangular grid of values over basin

POINTS
(stations)



Predetermined Station Weights

LUMP
(area)



$$MAP = \sum_{i=1}^{n} P_i * W_i$$

where

$\bar{A}$= area seasonal mean
N= station seasonal mean
R= relative station wt
W= scaled station wt
P= station precip catch
MAP= mean areal precip catch

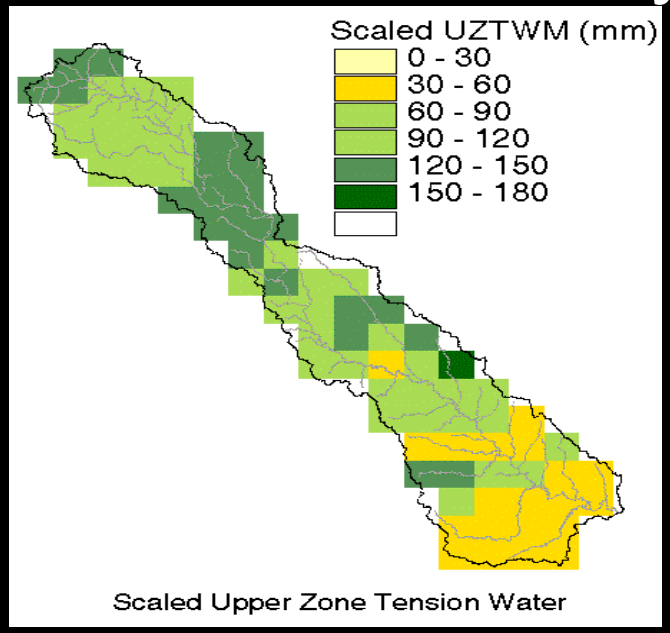
$$W_i = R_i * \frac{\bar{A}}{\sum_{j=1}^{n} \left(N_j * R_j \right)}$$

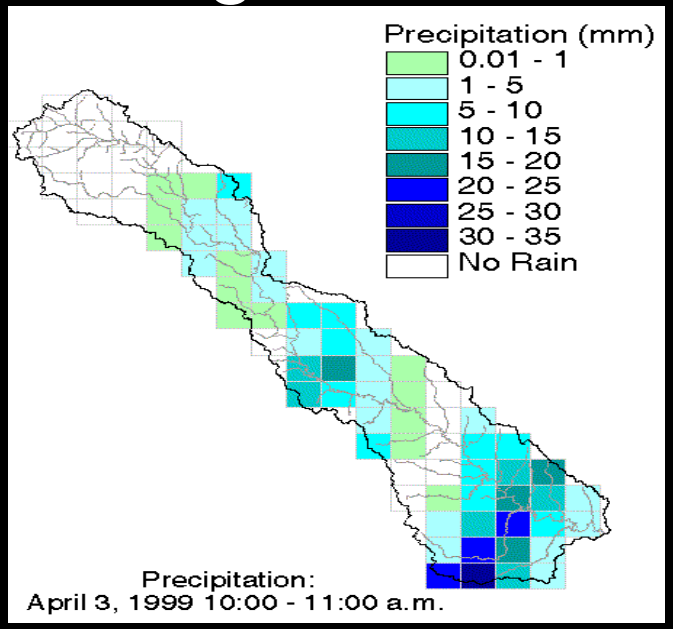
From Hartman and Henkel, CNRFC - 2010

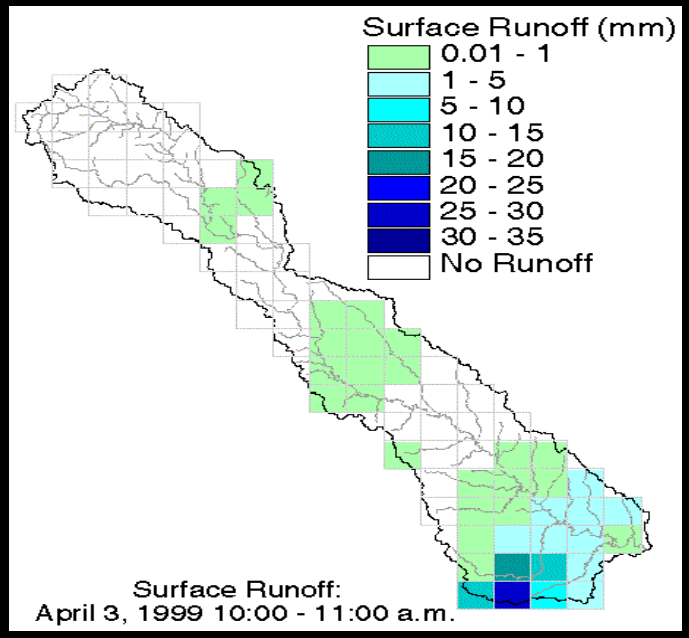
Distributed-Model Forcings

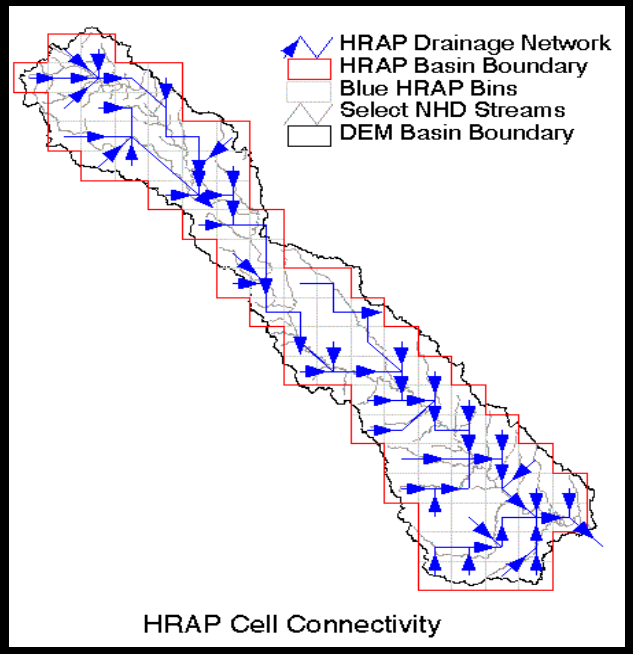
- Runoff and channel routing are distributed across numerous small basins, or a rectangular grid
- Grid or basin scale 10's km^2
- Forcings must be input on a high-resolution grid:
  - Point observations interpolated to the grid using climatology or physical model
  - Precipitation, cloud cover from radar and satellite

Distributed Hydrologic Model



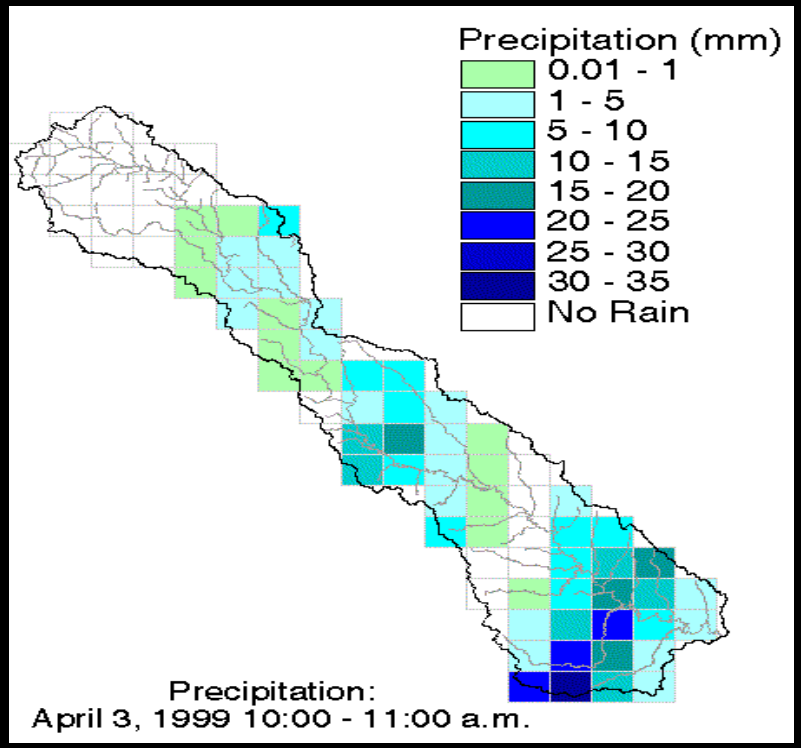




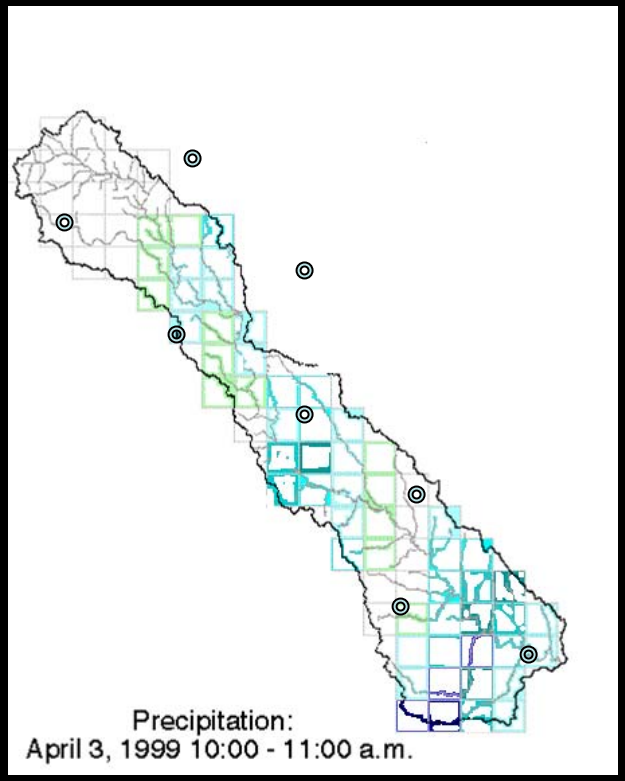


From Reed, M. Smith: HL-RMS

Distributed representation of precipitation:



Basin average (MAP) from points is a single value from weighted sum of observations



From Reed, M. Smith: HL-RMS

Potential Problems: Forcings

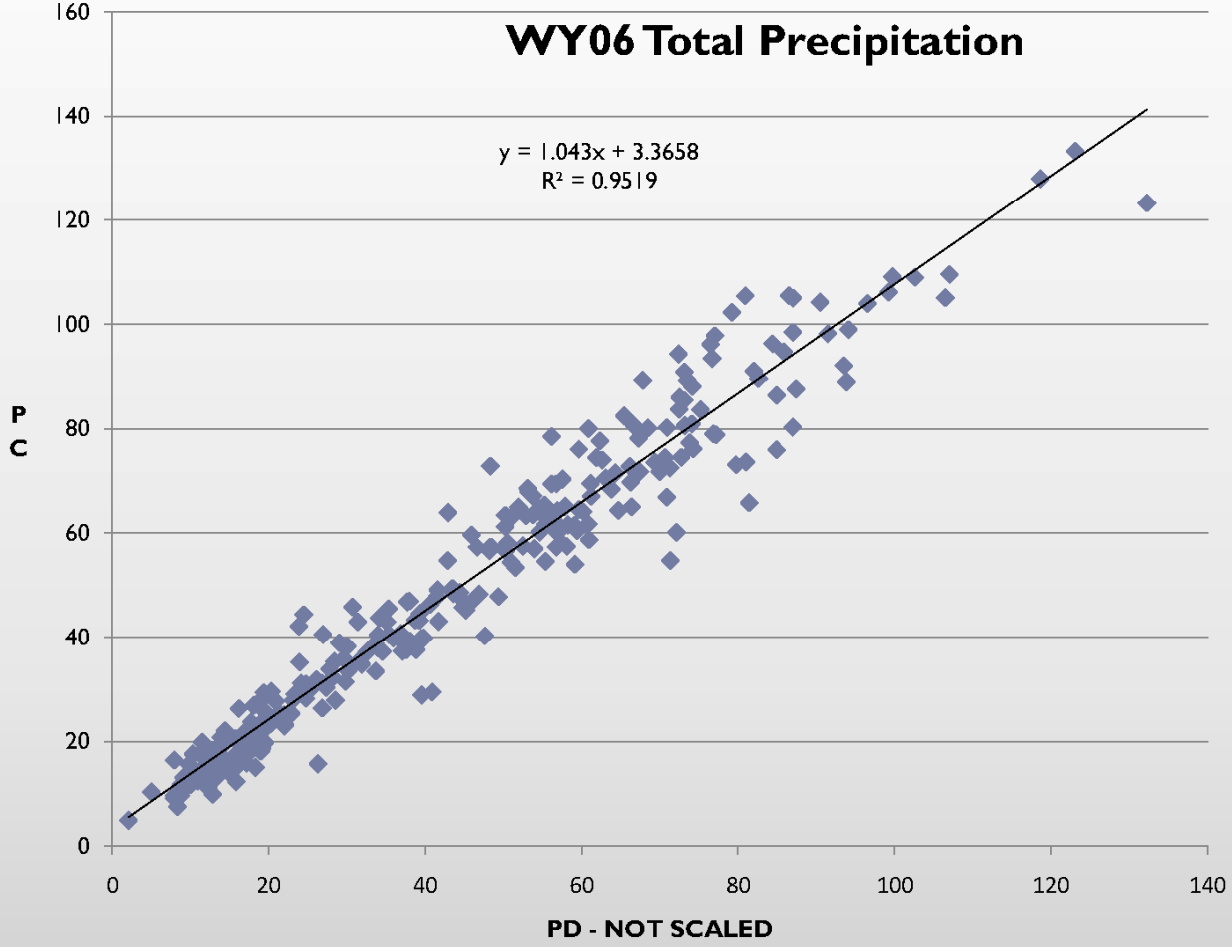
- For point observing network:
  - Stations are removed
  - Stations are moved to new locations with different temperature or precip exposure
  - Hard to use data from new stations
- For gridded observations:
  - Point input changes (see above)
  - Gridding methodology or assumptions change
- Basin averages from gridded input generally have systematic differences relative to those from points

CHPS Acceleration Team Results

- Staff at NWRFC, CNRFC, ABRFC, and NERFC have compared legacy basin average forcings computed from point observations to basin averages computed from grids
- Approaches differed as shown below
- Documentation has been gathered on differences in resulting values, and impacts on hydrologic simulations

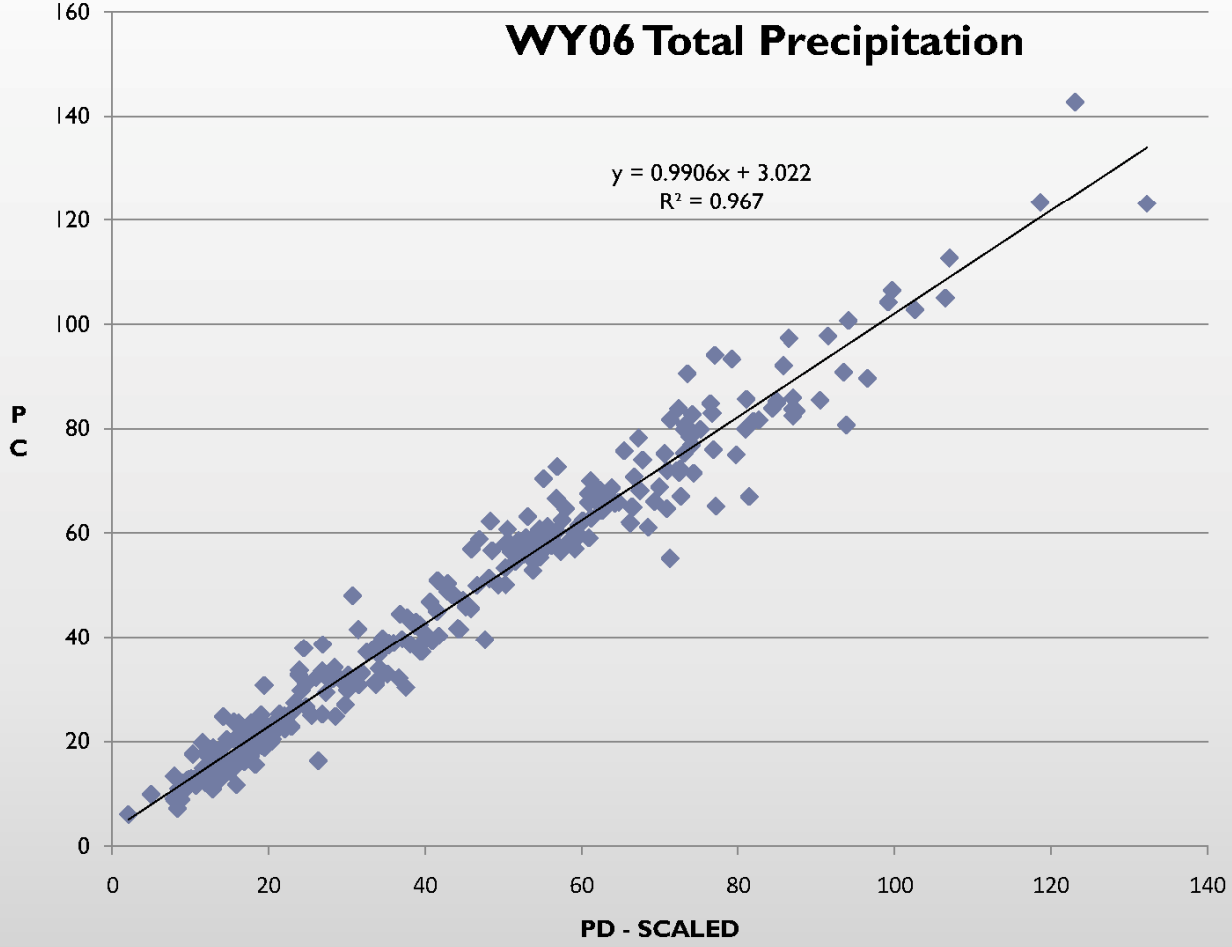
RFC	Study Approach:
NWRFC	Prepared gridded MAPX from archived point values through adaptation of existing preprocessor, and use of Mountain Mapper/DailyQC
CNRFC	Determined adjustments to constrain existing MAP and newly calculated MAPX historic time series toward PRISM climatology, subject to water balance; Applied adjustment weights prior to input of MAPX to hydrologic model; Reported streamflow simulation results
ABRFC	Gridded precipitation already in use; Studied legacy vs. new gridded MATX for most basins across their area
NERFC	Compared MAP from legacy system to gridded MAPX from gauge-radar analyses (MPE) and gauge-only Mountain Mapper/Daily QC; Reported streamflow simulation results

WY06 accumulations for all Areas **not** Scaled to Calibration Climatology



From Hartman and Henkel, CNRFC - 2010

WY06 accumulations for all Areas **Scaled** to Calibration Climatology



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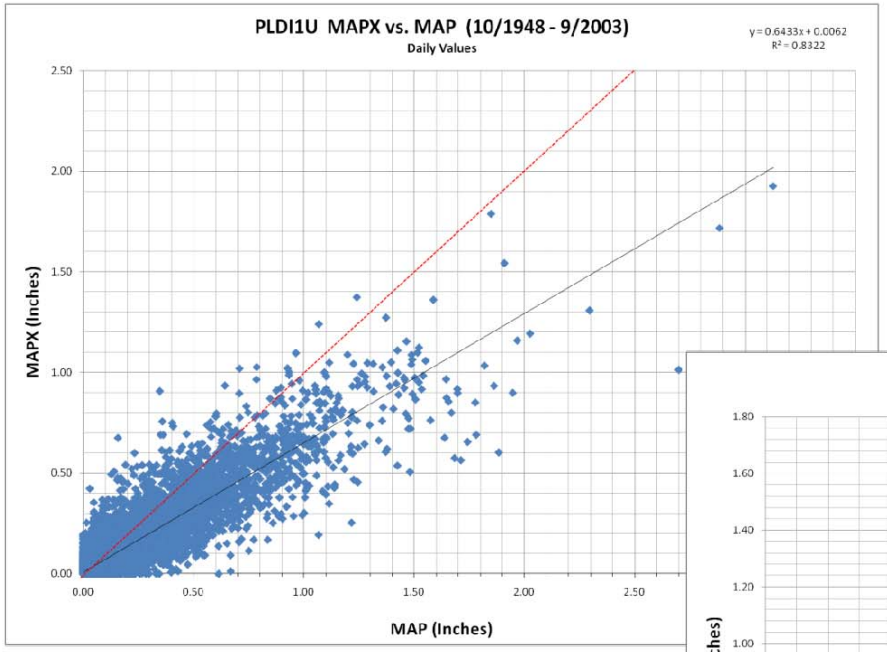
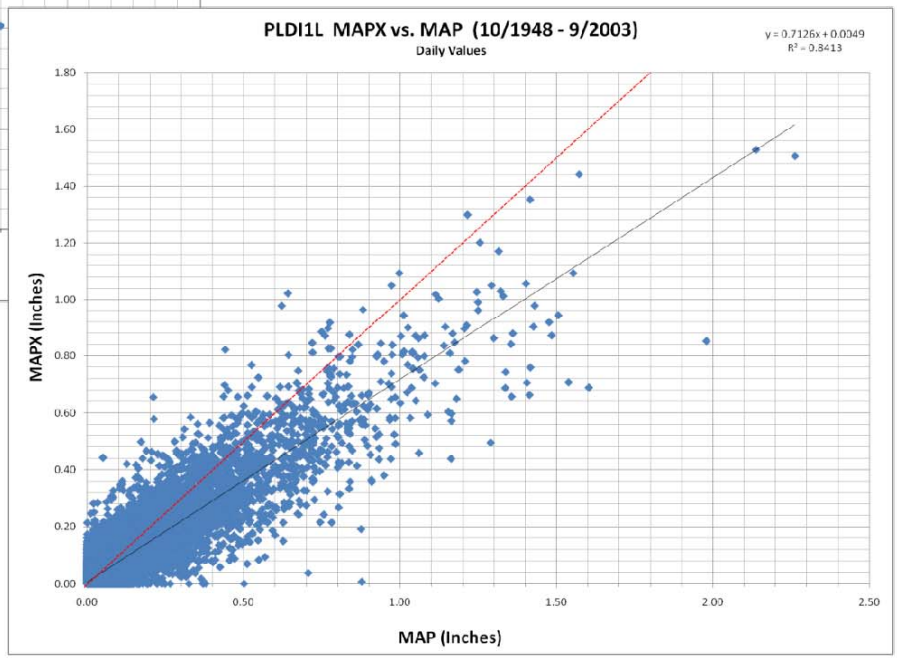
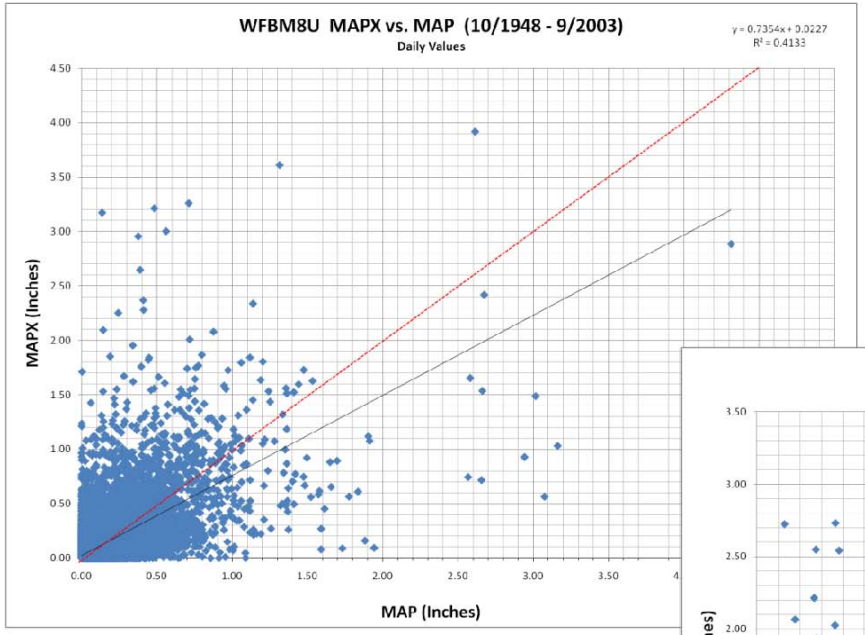


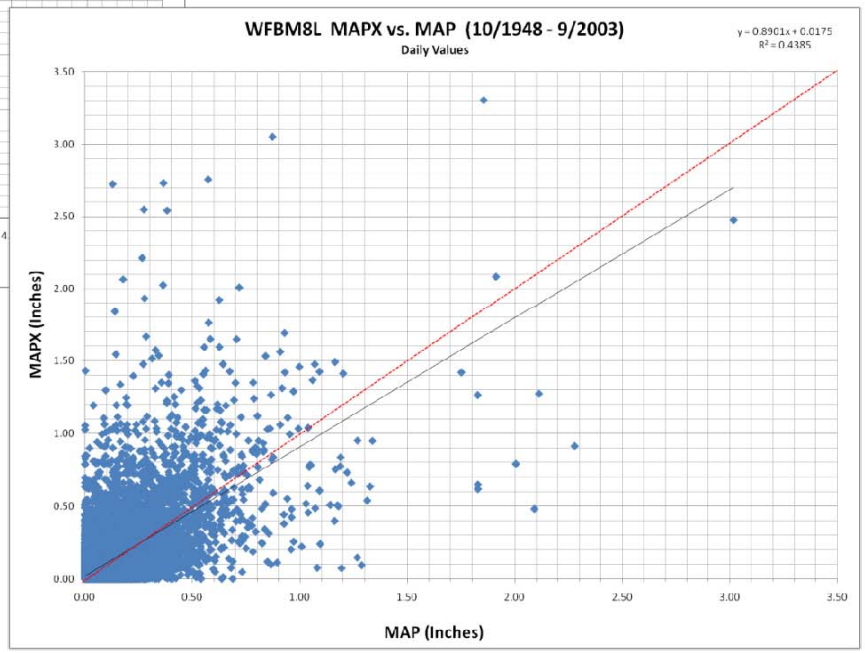
Typical Comparison



From Laurine, NWRFC - 2010



Bitterroot Basin
Has Issues



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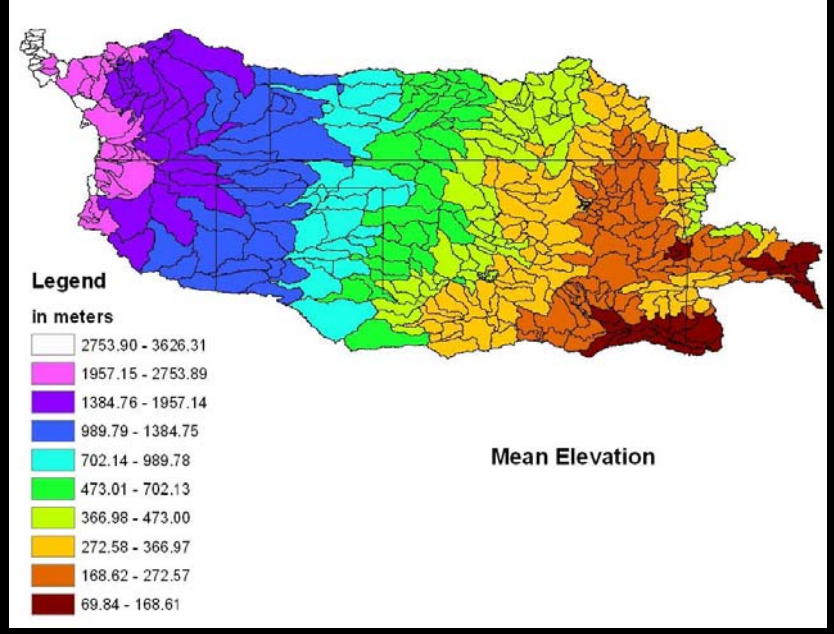
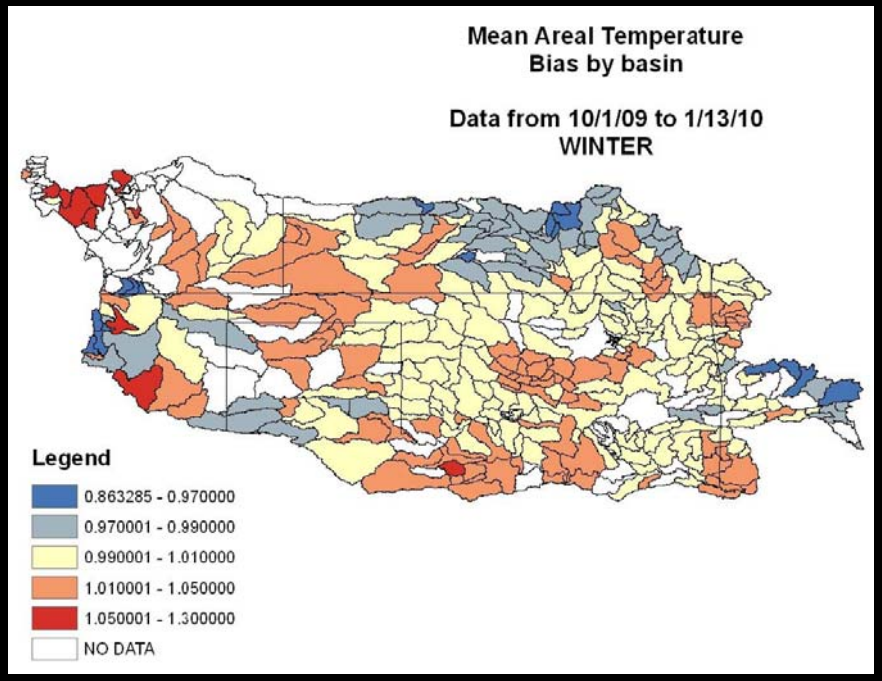
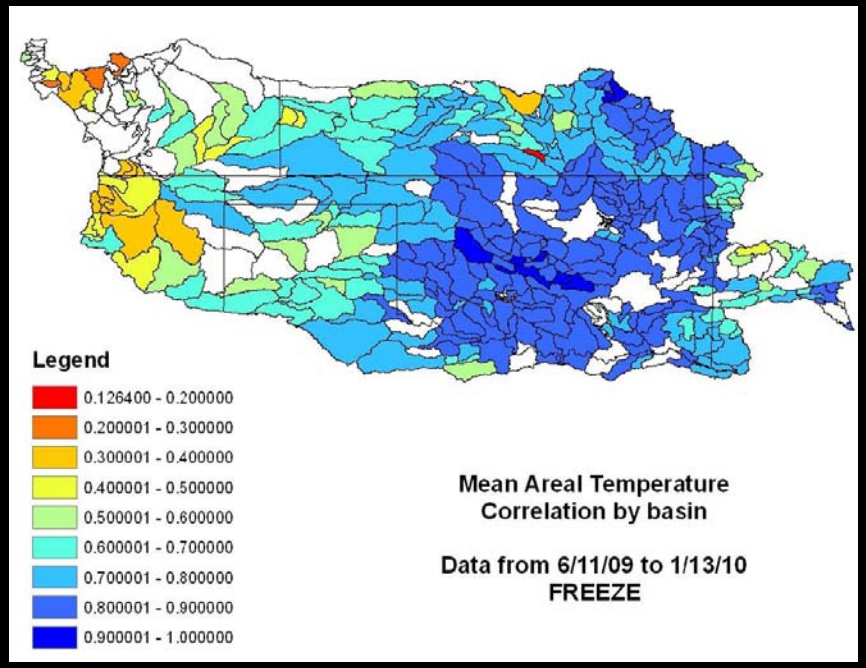


Elevation influences on point-based vs. gridded temperature differences and correlation, ABRFC area

From Jones and Chester, ABRFC - 2010





Correlation of observed vs. simulated discharge at 4 stream gauge sites, NERFC area, Jan-Apr 2010

Correlations

	Cranston	Woonsocket	Yantic	Maynard
OFS	.948	.985	.958	.966
DailyQC	.959	.990	.952	.980
MPE	.959	.987	.984	.977

Lowest Highest

From Shedd, NWRFC - 2010

Ongoing Work in OHD:

- Preparation of Distributed Model Intercomparison 2 (DMIP2) gauge-only and gauge-radar datasets
- Assisted NWRFC in using adapted legacy data preprocessor to prepare precipitation datasets
- Evaluating effects of gauge-radar analyses in Hydrometeorological Testbed – North Fork American River basin, California

Need for preparation and routine updating of hydrologic calibration datasets

Hydrologic Calibration Datasets

- Long-term meteorological records are needed to calibrate:
  - Physical parameters in hydrologic models
  - Statistical parameters for ensemble model output
- Considerable staff effort required to manually QC input to datasets used in hydrologic model calibration
- Particularly for distributed model calibration, limited suitable data exists
- Requires multiyear, gridded, hourly records with no statistical artifacts
- Precipitation, temperature, and radiation forcings (PET) must feature proper physical intercorrelations

Ongoing precipitation analysis activities in NWS, rest of NOAA, University and Private Sector

- Includes rain gauge, satellite, gauge-radar-satellite multisensor products
- Exclusive of numerical reanalysis products
- Boxes shaded in green indicate publicly-available records
- ***This list is not exhaustive – for illustrative purposes***

National Weather Service Precipitation Analyses

Organization/ office	Software and logical procedures used	Data sources	Formal designation	Update cycle or minimum time increment
Individual RFCs, WFOs	MPE, MM, P3	WSR-88D DPA, NMQ, hourly, daily gauges, PRISM climatology	"StageIII" or "MPE" or "DailyQC"	1-h, 6-h, 24-h
NWS-OCWWS-NPVU	StageIV, GFE	RFC analyses from above	"StageIV"	6-h, 24-h
NCEP - EMC	Adapted MPE	WSR-88D DPA, hourly gauges	"StageII"	1-h
NCEP – CPC	Gauge-only	Daily gauges	"CPC daily"	24-h
NCEP – CPC	CMORPH	Microwave and IR satellite	"CMORPH"	1-h
NCEP-HPC	Manual gauge analysis	Rain gauge, remote sensor		6-h
NCEP – EMC	MPE (centrally run), and disaggregation of CPC daily with StageII and/or CMORPH	NCEP StageII (adapted MPE), CPC daily, CMORPH	used in real-time land-surface modeling	1-h
NCEP-CPPA	Disaggregation of CPC daily with StageIV, by regression technique	NCEP StageIV, CPC daily		1-h (post process mode) Daily operational status pending
OST-MDL	Adjusted StageIV – remove radar artifacts	StageIV, gauge data		Hourly; updated at ~6-month intervals
Future – AOR, NCEP	*TBD*	*??*	*Analysis of record*	1-h
Future – Satellite-based global, CPC	*TBD*	*??*		*Years*

Other NOAA Analysis/Reanalysis Projects

Organization/ office	Software and logical procedures used	Data sources	Formal designation	Update cycle or minimum time increment
NSSL	WDSS, MRMS	WSR-88D base data, hourly gauges	NMQ	1-h
NCDC	MPE	WSR-88D DPA, gauges	Regional reanalysis	1-h
NCDC-NSSL	WDSS, MRMS	WSR-88D base data, hourly gauges	Regional reanalysis, NMQ	1-h

Other Precipitation Analyses

Organization/ office	Software and logical procedures used	Data sources	Formal designation	Update cycle or minimum time increment
NCASE climate group	PRISM	Daily rain gauge	"PRISM monthly"	Calendar month
U. Washington (Hamlet-Lettenmaier)	Climatic interpolation	Daily rain gauge, HCN		Daily
OneRain, Inc.	Proprietary	WSR-88D, rain gauge	"OneRain"	< 1-h

Possible approaches to preparing historical precipitation records for calibration

Possible Approaches…

- Spatial-temporal analysis “from scratch” using existing rain gauge, possibly radar input
- Spatial-temporal analysis using existing rain gauge input, with constraints to match long-term trends at a limited number of reference sites (like Historic Climate Network)

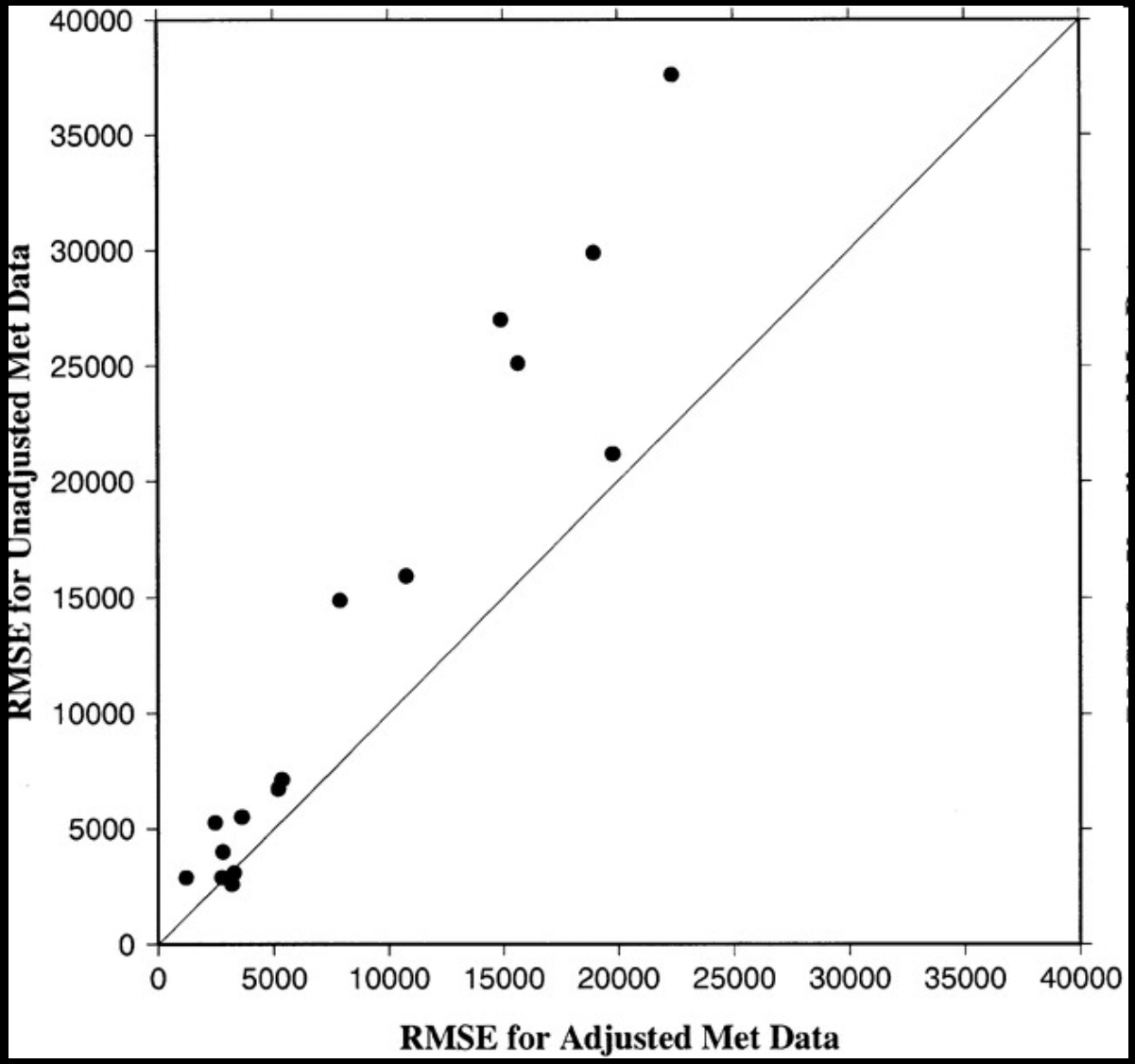
In gauge-poor areas…

- Disaggregation of monthly or daily records based primarily on daily rain gauge data, using hourly gauge and radar information
- Numerical prediction reanalysis, assimilating available surface, upper air, and satellite observations
- A blend of 2 or more of the above

Spatial-temporal analysis using existing rain gauge input, with constraints to match long-term trends at a limited number of reference sites (like Historic Climate Network)

Hamlet, Alan F., Dennis P. Lettenmaier, 2005: Production of Temporally Consistent Gridded Precipitation and Temperature Fields for the Continental United States*. *Journal of Hydrometeorology*, **6**, 330-336

Effect of Climate Reference Network Adjustment of Temperature And Precip Input on RMS Error in Discharge, 1931-1950, at 16 Gauge Points in Columbia River Basin

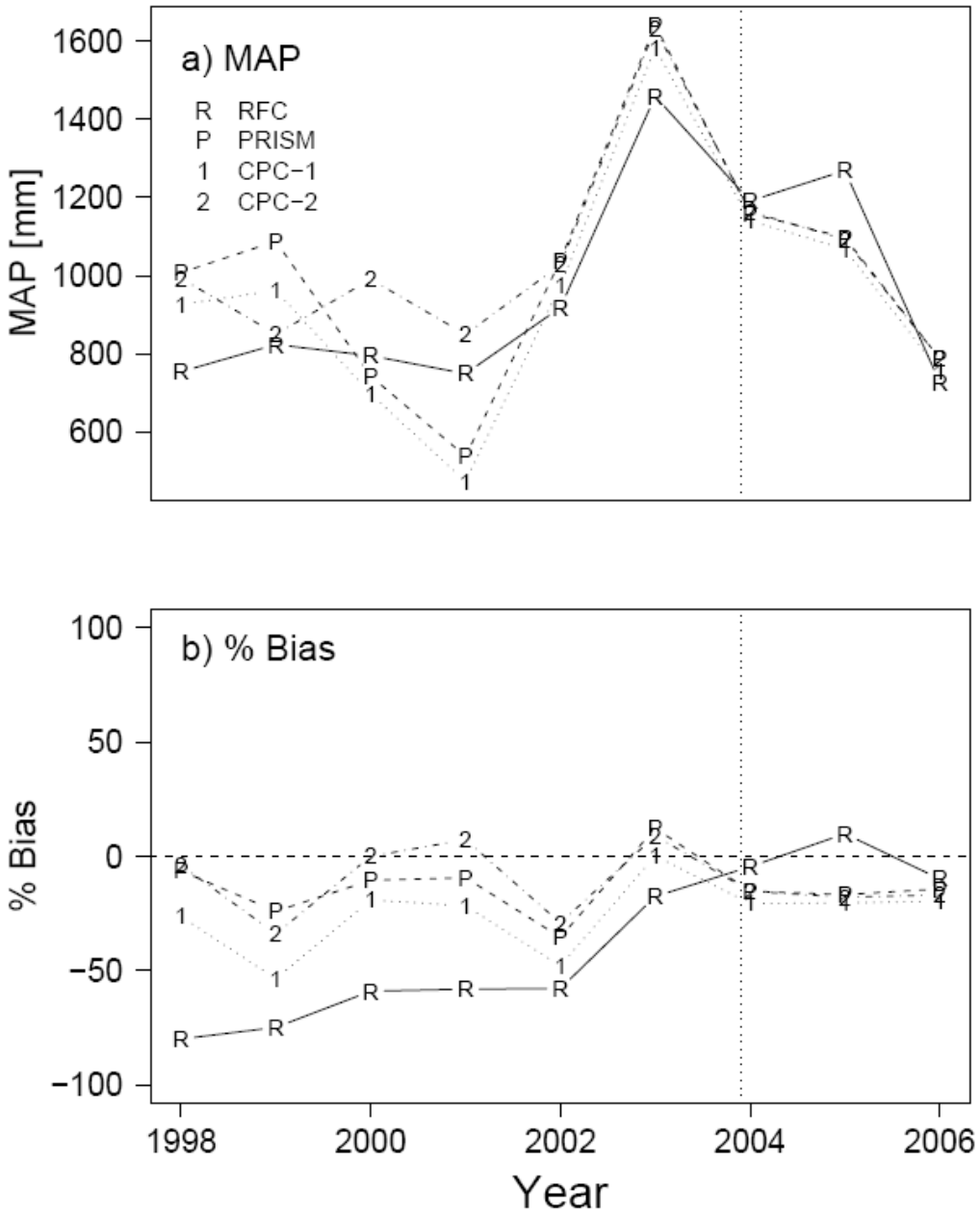


Hydrologic simulations with forcings adjusted toward HCN trends have consistently small RMS error in discharge, relative to observations

Hamlet, A. and D. Lettenmaier, 2005: Production of Temporally Consistent Gridded Precipitation and Temperature Fields for the Continental United States*.

Journal of Hydrometeorology, **6**, 330-336

Disaggregation of monthly or daily records based primarily on daily rain gauge data, using hourly gauge and radar information



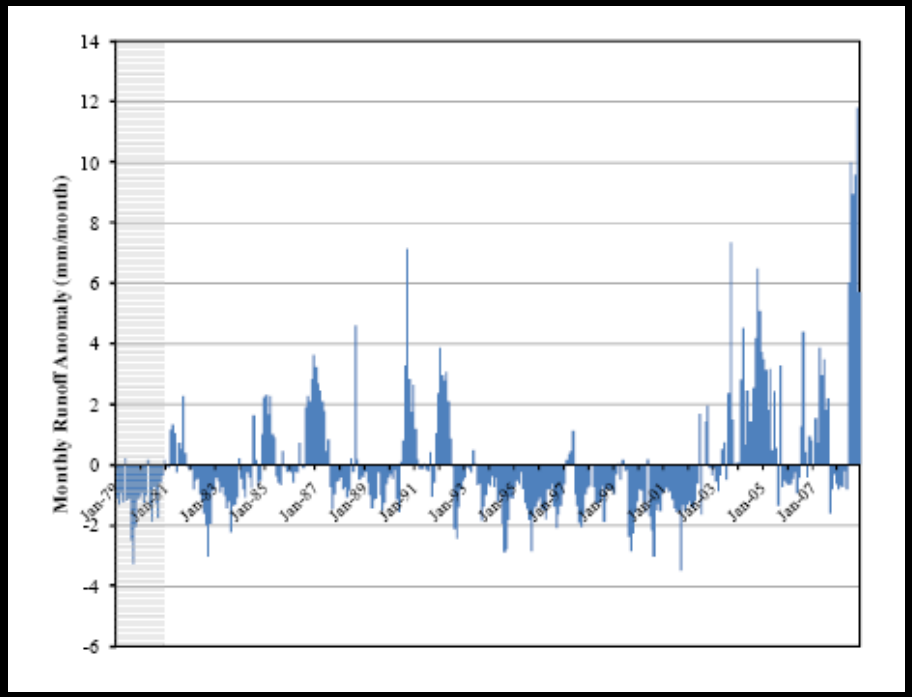
"RFC" gauge-radar estimates of precip were generally low prior to 2004, probably due to truncation in radar accumulation algorithm. Values are median among 16 basins, PA-MD

Hydrologic simulations with "RFC" precipitation were too low but improved following adjustment with PRISM or CPC reference gauge analyses

Zhang, Y., S. Reed, and D. Kitzmiller: Effects of Retrospective Gauge-Based Readjustment of Multi-Sensor Precipitation Estimates on Hydrologic Simulations. Submitted to *Journal of Hydrometeorology*

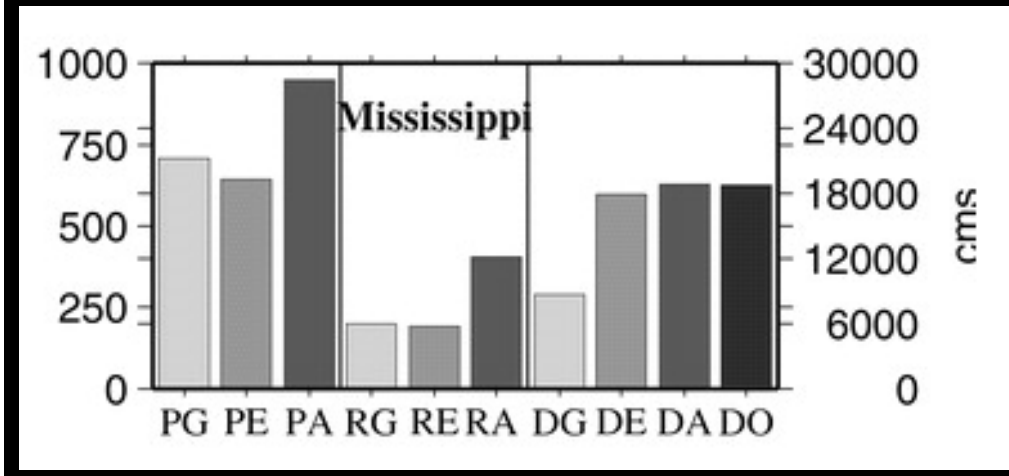
Numerical prediction reanalysis, assimilating available surface, upper air, and satellite observations

Monthly runoff anomalies in the Rio Grande Basin, 1979-2008, simulation based on NARR



From Khedun et al. 2010: Assessing the impacts of climate variability on the water resources in the Rio Grande/Rio Bravo basin. *Preprints EWRI Congress 2010*, Providence, EWRI, 69-80.

Average precipitation (Px), runoff (Rx), and discharge (Dx) from NOAH Land Surface Model forced with 3 different precipitation datasets. DO is observed discharge.



Voisin, N., A. Wood, D. Lettenmaier, 2008: Evaluation of precipitation products for global hydrological prediction. *Journal of Hydrometeorology*, **9**, 388-407

NOAA Analysis of Record

NOAA Analysis of Record

- OSIP 05-009 (IWT lead Jamie Vavra)
- Second phase of general Analysis of Record effort (1st was Real-time Mesoscale Analysis, RTMA)
- Next gate meeting (tentative) Nov 2010
- Specifications for hourly precipitation, defined on 5-km AOR grid over CONUS, latency 2-5 days
- RTMA will soon be scaled to 2.5-km grid
- Methodology for AOR to be determined
- Workshops to be held soon:
  - One led by NCEP-EMC (science issues)
  - One led by WR offices (requirements)
- 2011 AMS Annual Meeting session (to be announced)

NOAA Analysis of Record

- Town Hall Meeting – AMS Annual Meeting January 2010
- Convened by John Schaake, reporter Pingping Xie
- Presentations by:
  - John Schaake
  - Kenneth Howard (NSSL)
  - Dongsoo Kim (NCDC)
  - Pingping Xie (NCEP-CPC)
  - Yu Zhang (OHD)
  - Dennis Miller (OHD)
  - Thomas Adams (OHRFC)
- ~50 attendees, some from outside US
- My suggestion: Some interested attendees might join AOR Integrated Work Team; also join upcoming AOR workshop

NOAA Analysis of Record

- OHD effort: study for precipitation/temperature/radiation balance AORs for hydrologic calibration
- Supported by Advanced Hydrologic Prediction System (AHPS) initiative
- New contractor hire anticipated soon

NOAA Analysis of Record Avenues for Input:

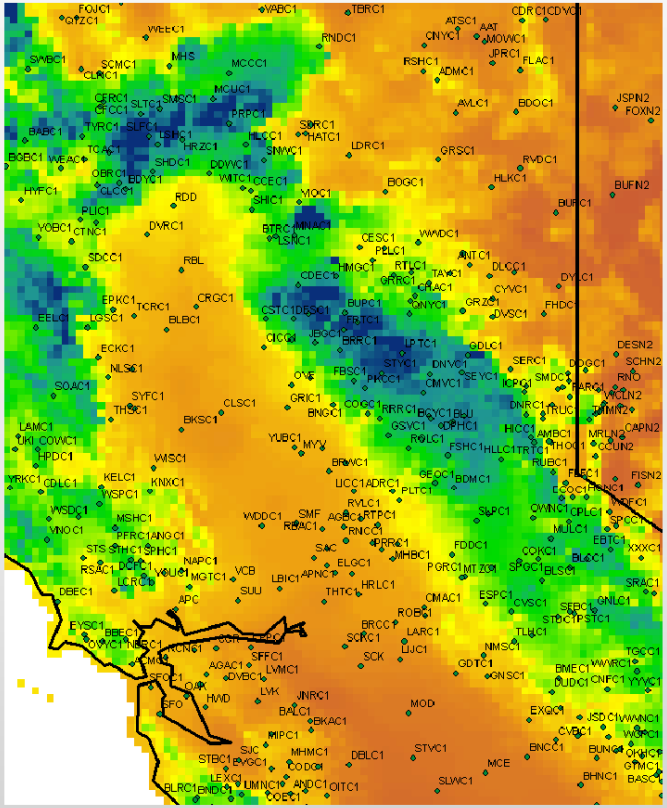
- AOR Integrated Work Team (Jamie Vavra)
- Regional OSIP representatives
- OHD; our staff will solicit input
- Upcoming AOR workshop (to be announced)
- Seminar by Mike Smith on HMT West modeling results – July 22, 11:00 EDT

Questions?
More Ideas?

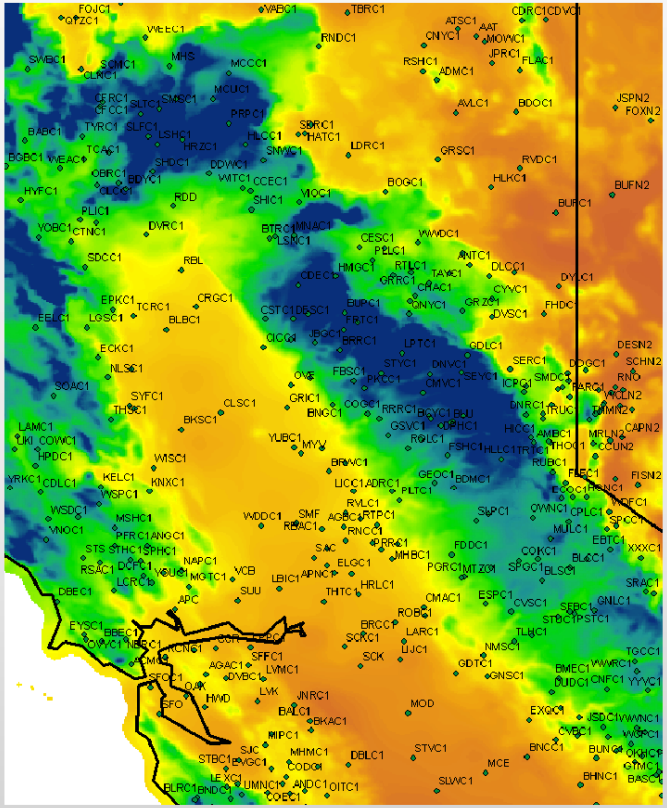
Supplemental…

Which Version of PRISM Precipitation Climatology?

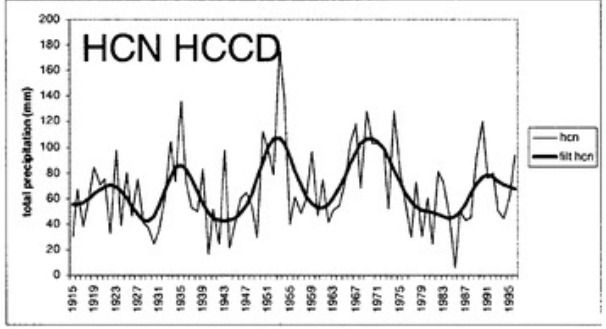
2.5 min '71-00, old vers.

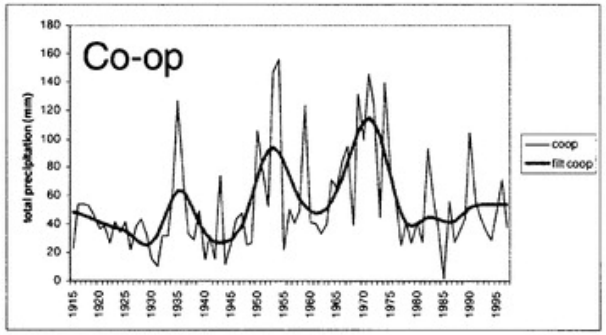


30 arc second '71-00, new



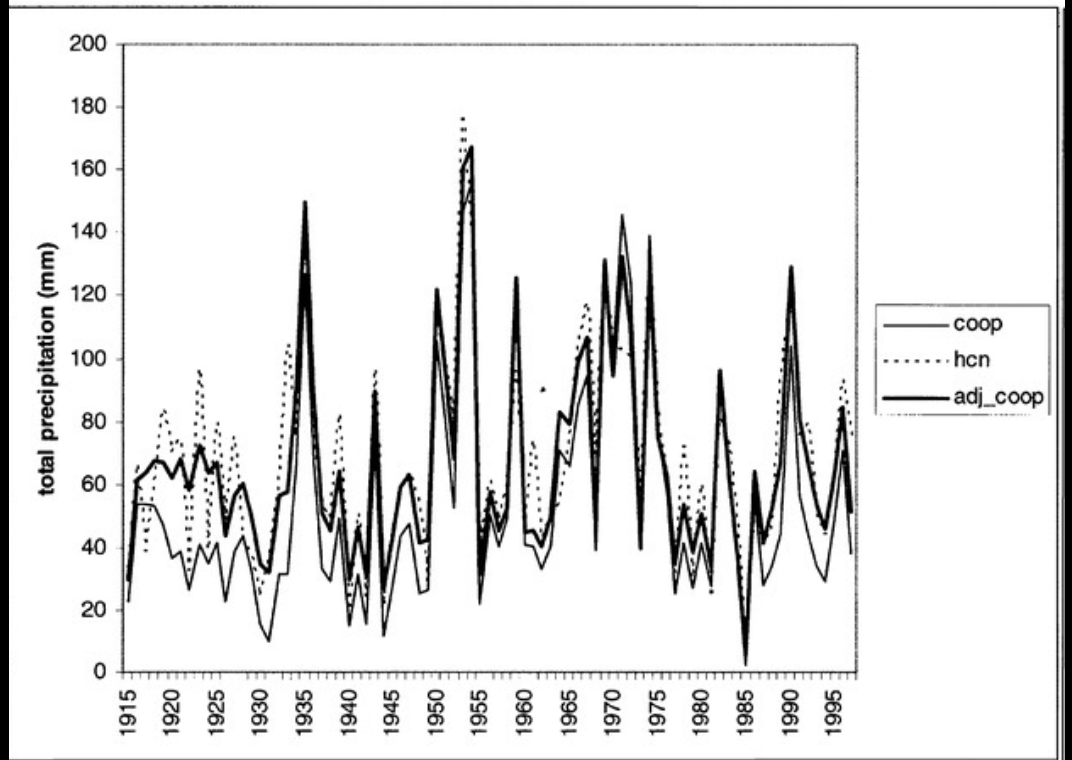
From Hartman and Henkel, CNRFC - 2010





Historic Climate Network annual precip estimates for a single location, 1915-1995

Cooperative observer network estimates for the same location have some artifacts due to station/network changes



Hamlet-Lettenmaier approach constrains trends in Coop-only time series towards those from the HCN

Hamlet, A. and D. Lettenmaier, 2005: Production of Temporally Consistent Gridded Precipitation and Temperature Fields for the Continental United States*. *Journal of Hydrometeorology*, **6**, 330-336