CI-WATER
A Utah-Wyoming Cyberinfrastructure Water Modeling Collaboration

Climate Modeling & HPC Access for Urban Water Research

UU Team 2
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2013 CI-WATER Symposium
Natural History Museum of Utah, University of Utah
May 24, 2013

Climate Modeling and Data Access

Hydrologic Model (CBRFC, RHESSys)

Hydrologic Model (GSSHA, ADHydro)

Stormwater Model (SWMM)

http://www.hiddenwaters.org/

climate impacted flows

climate impacted flows

SLC Water Supply System Model (Goldsim)

Water System Model (TOPNET/ WEAP)

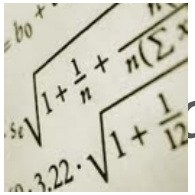
Water Quality Model

Demand Scenarios

Climate Modeling Flowchart

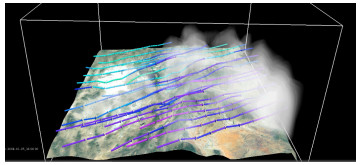
Coarse-resolution climate simulations (200-km)

CMIP *Coupled Model Intercomparison Project*



statistical downscaling

dynamical downscaling



Hydrology projections (BCSD; 12-km)

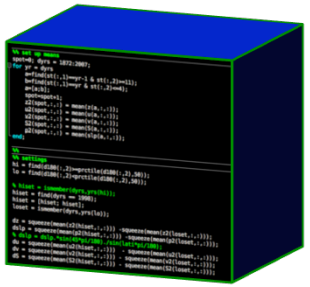
RECLAMATION USGS CLIMATE CENTRAL Santa Clara University SCRIPPS INSTITUTION OF OCEANOGRAPHY

WRF

Regional Climate model (WRF; 4-km)

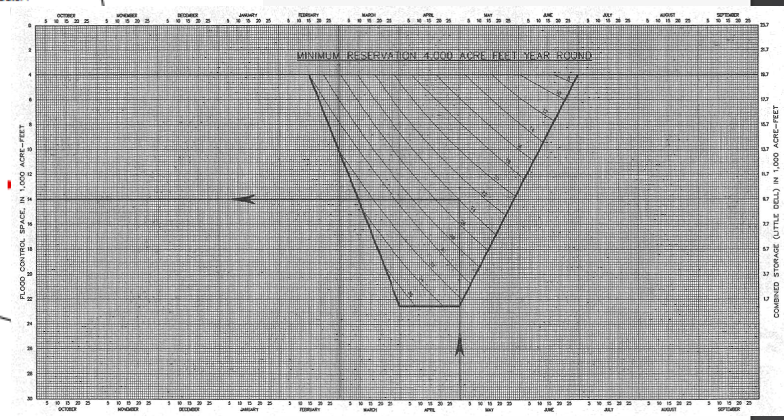
Web portal

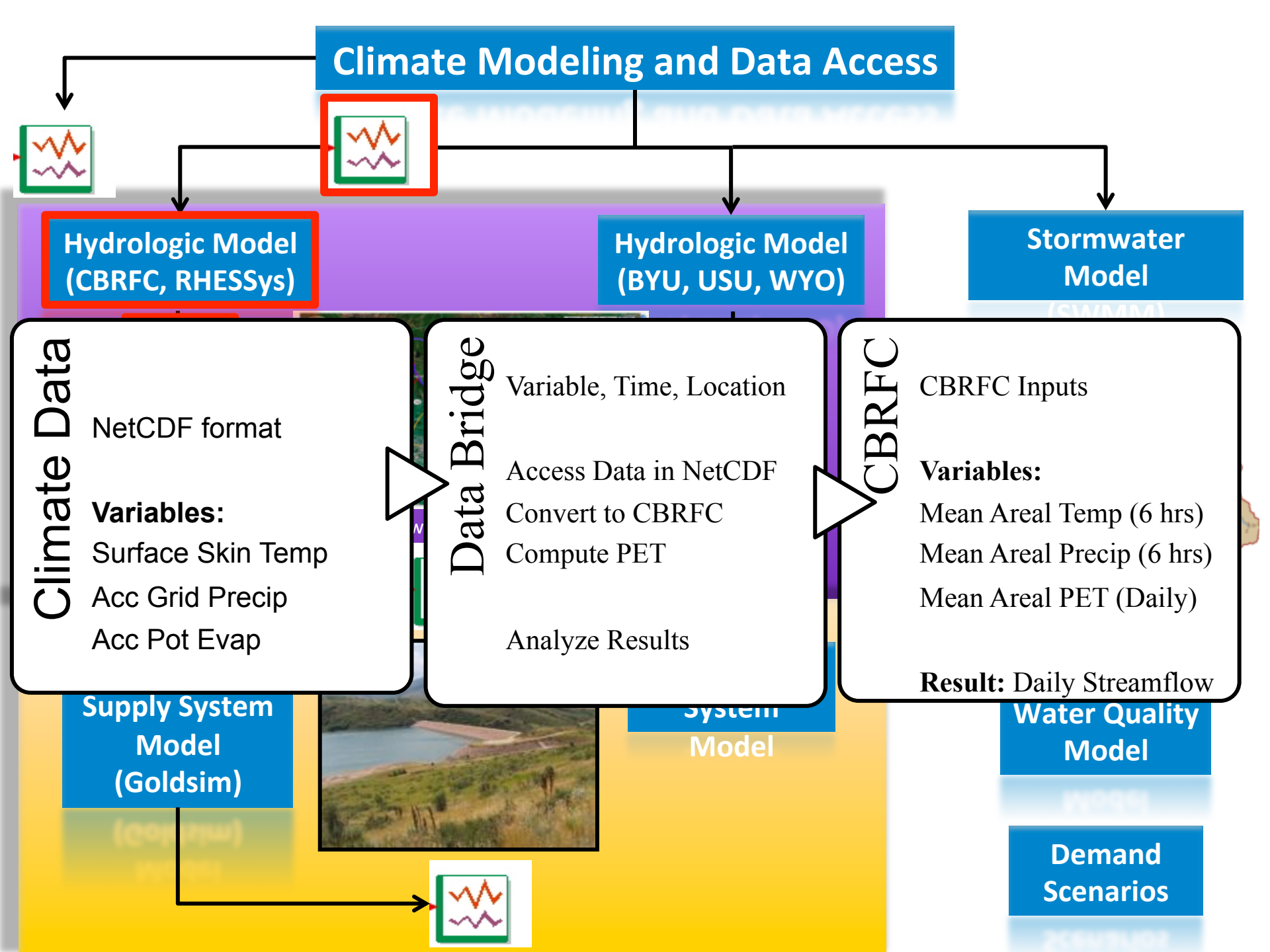
Climate Scenario module (CSmod)



Completed: Parlays Pilot Project

Completed: 2-Reservoir Model




Climate Modeling and Data Access
Hydrologic Model (CBRFC, RHESSys)
Hydrologic Model (BYU, USU, WYO)
Stormwater Model
Climate Data
NetCDF format
Variables:
Surface Skin Temp
Acc Grid Precip
Acc Pot Evap
Data Bridge
Variable, Time, Location
Access Data in NetCDF
Convert to CBRFC
Compute PET
Analyze Results
CBRFC
CBRFC Inputs
Variables:
Mean Areal Temp (6 hrs)
Mean Areal Precip (6 hrs)
Mean Areal PET (Daily)
Result: Daily Streamflow
Supply System Model (Goldsim)
Water Quality Model
Demand Scenarios

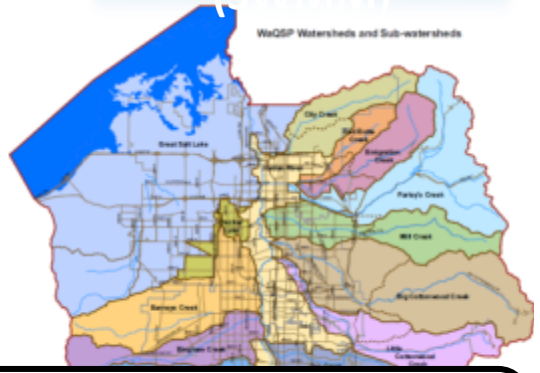
Climate Modeling and Data Access

Hydrologic Model (CBRFC, RHESSys)

Hydrologic Model (BYU, USU, WYO)

Stormwater Model (SWMM)

http://www.hiddenwaters.org/



climate impacted flows

climate impacted flows

CBRFC

CBRFC Inputs

Variables:

Mean Areal Temp

Mean Areal Precip

Mean Areal PET

Data Bridge

Daily Streamflow

Location

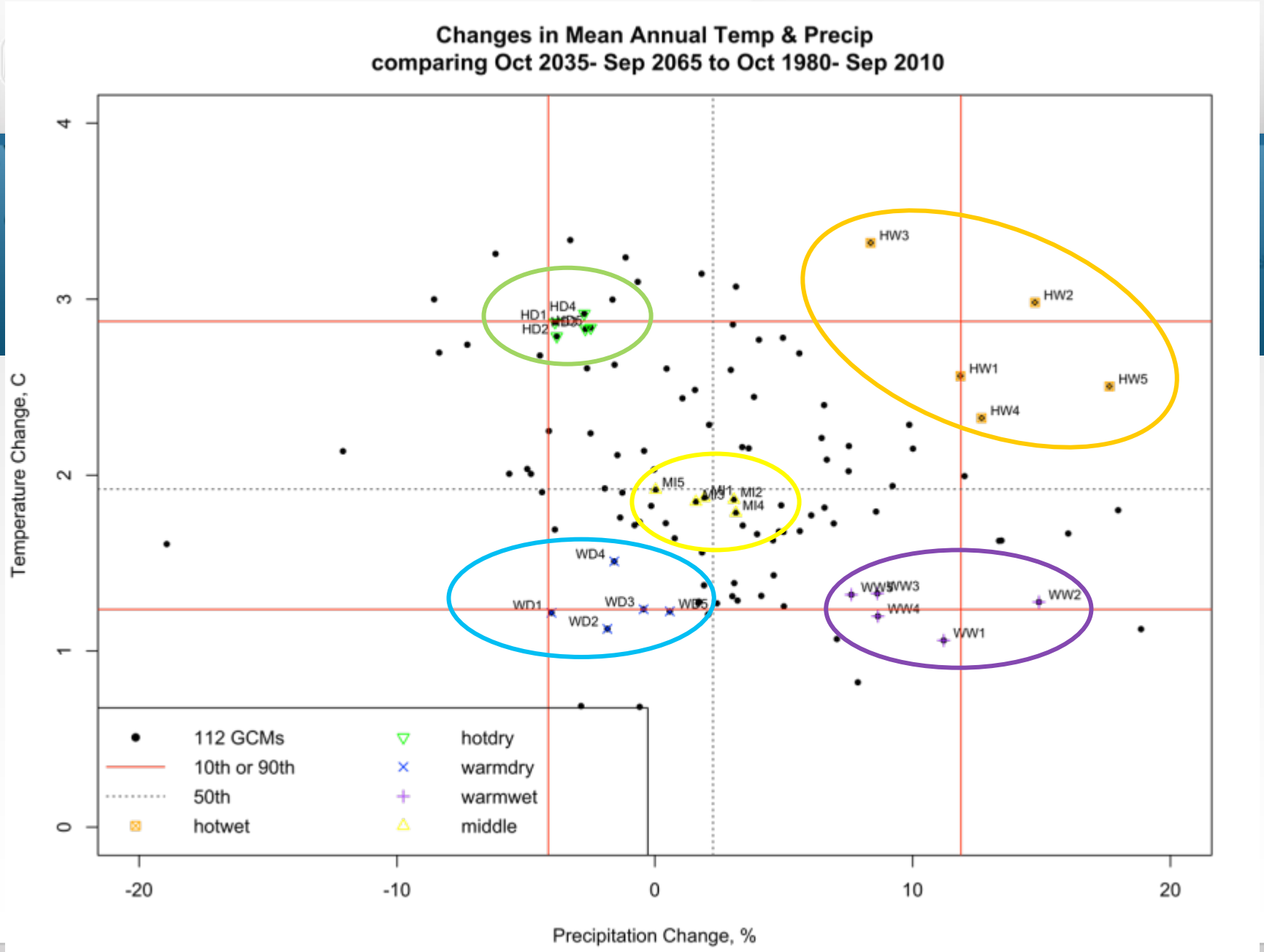
Daily Time Step

Analyze Results

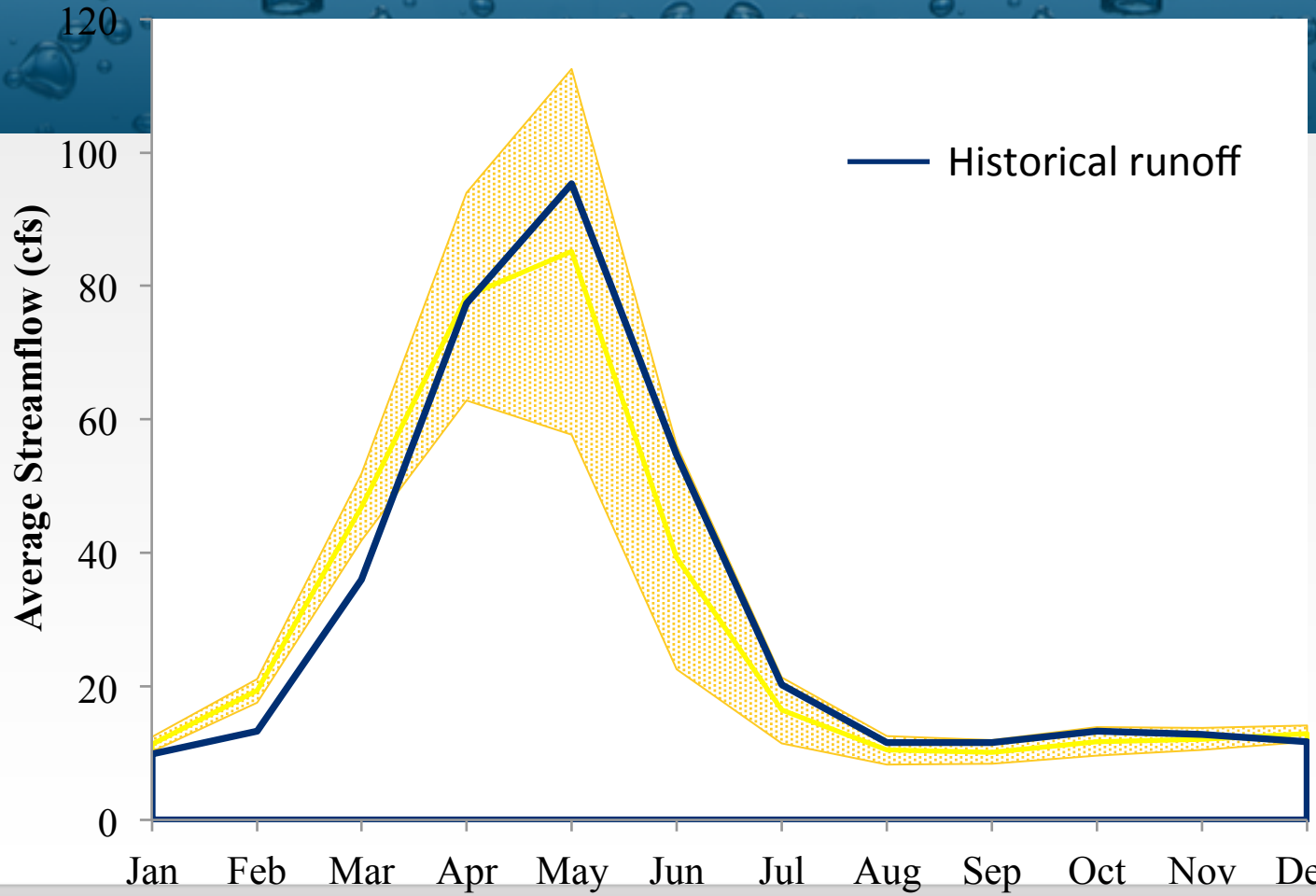
Goldsim

Pre-processed CBRFC Output

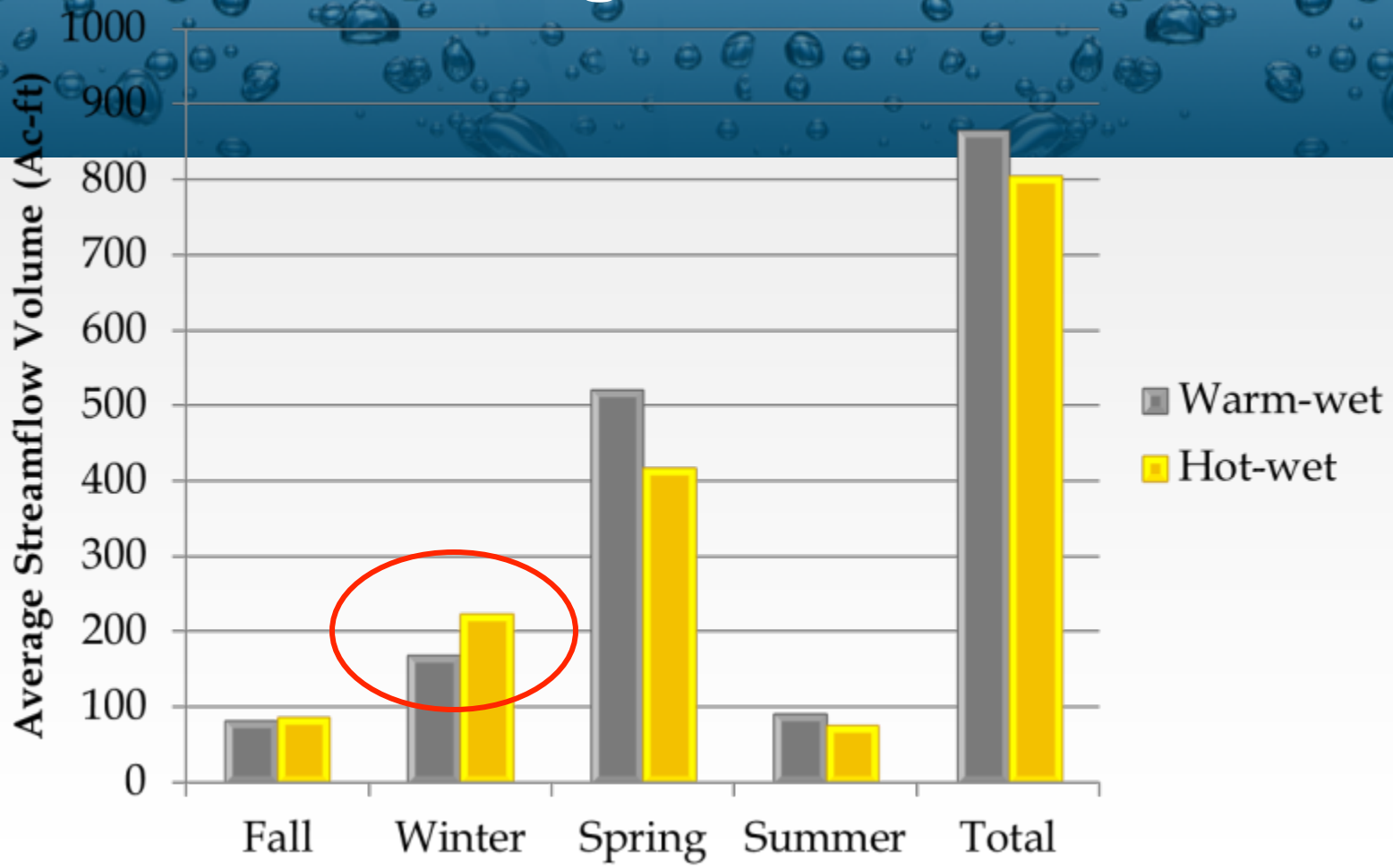
Result: Daily Streamflow


Changes in Mean Annual Temp & Precip
comparing Oct 2035- Sep 2065 to Oct 1980- Sep 2010
Temperature Change, C
Precipitation Change, %
0
1
2
3
4
-20
-10
0
10
20
HW3
HW2
HW1
HW5
HW4
HD1
HD4
HD2
HD5
MI5
MI1
MI2
MI3
MI4
WD4
WD1
WD3
WD5
WD2
WW5
WW3
WW2
WW4
WW1
112 GCMs
10th or 90th
50th
hotwet
hotdry
warmdry
warmwet
middle

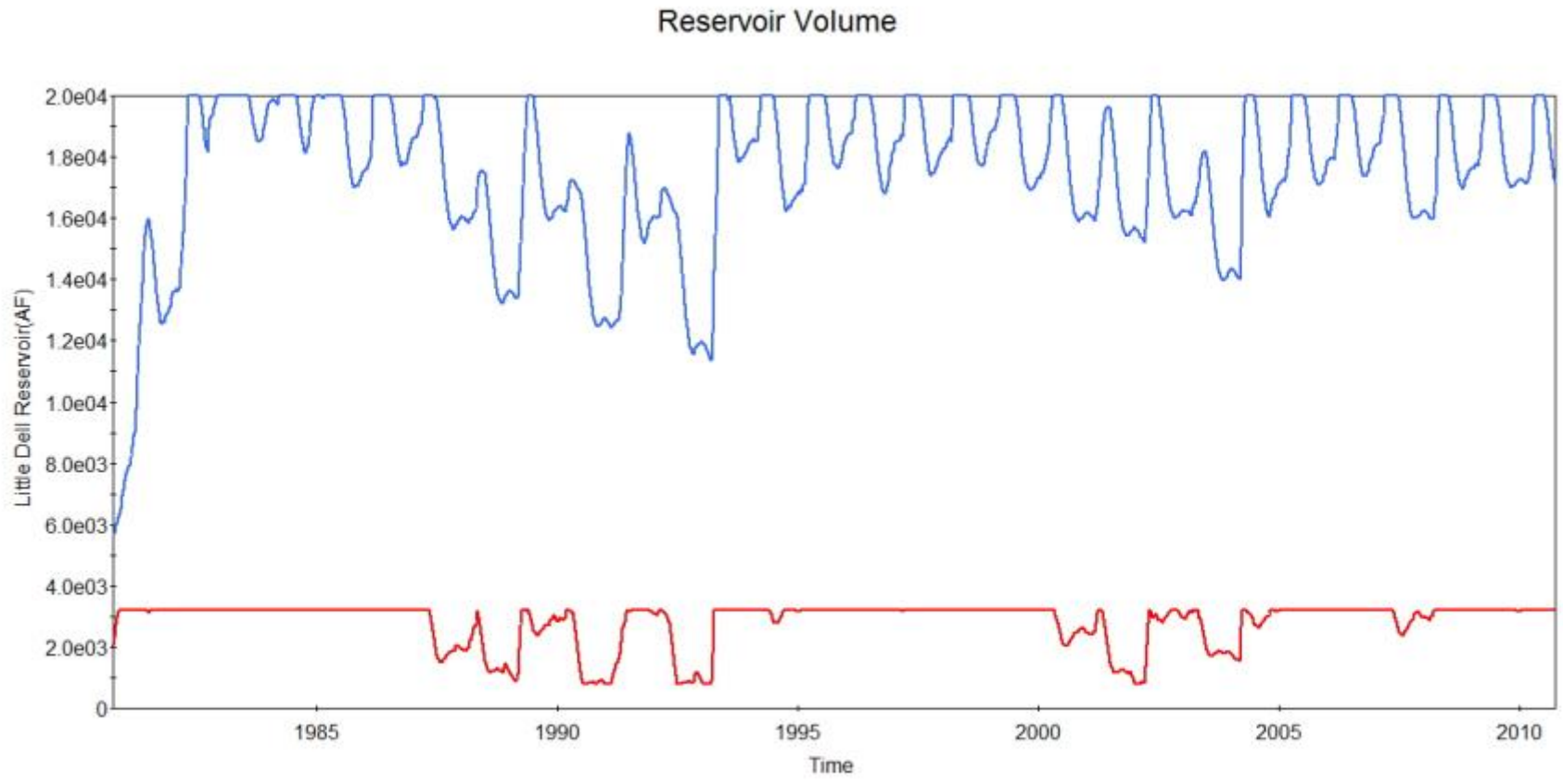
Future Streamflow Uncertainty



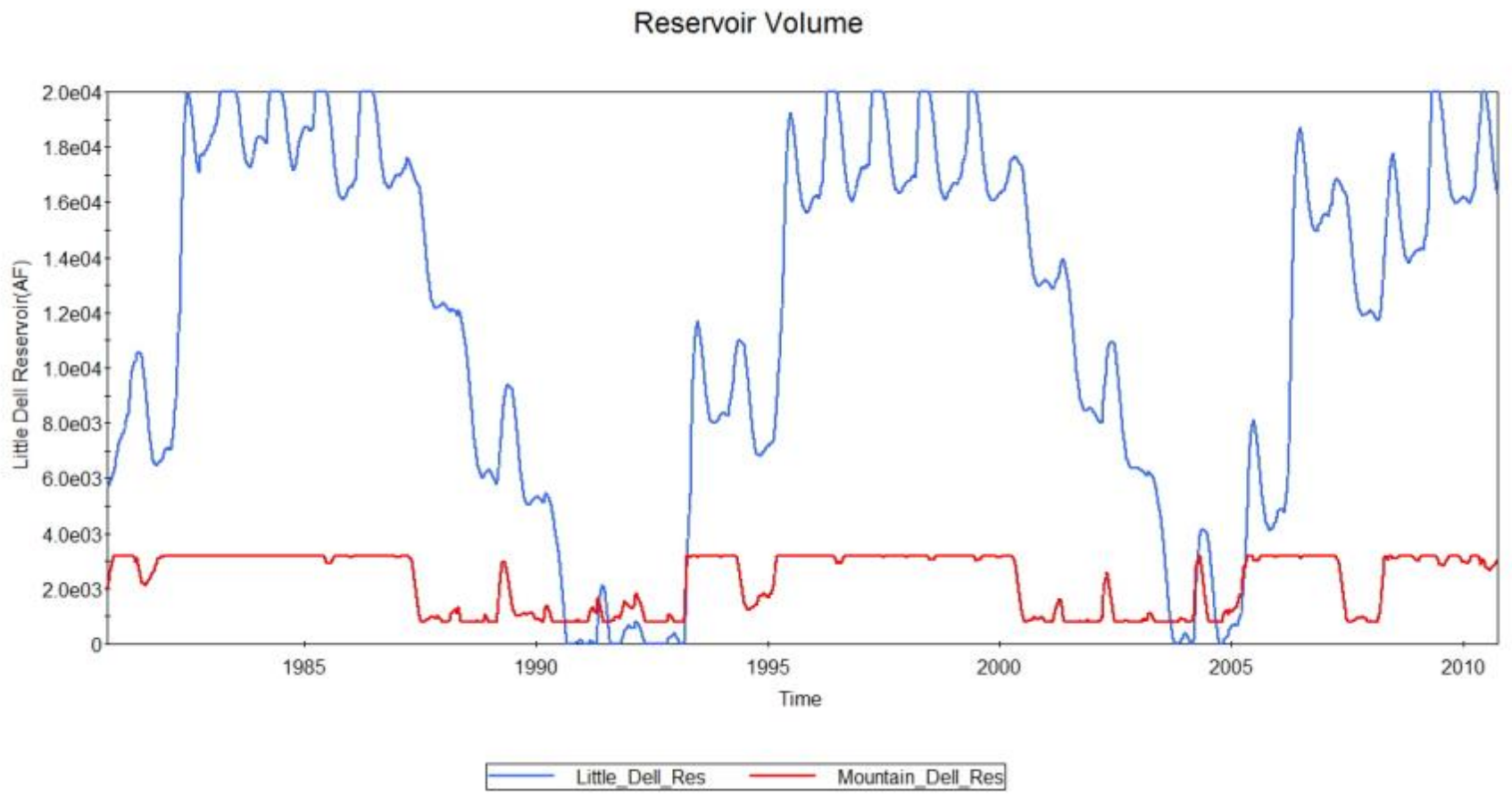
Results: Average Streamflow Volume

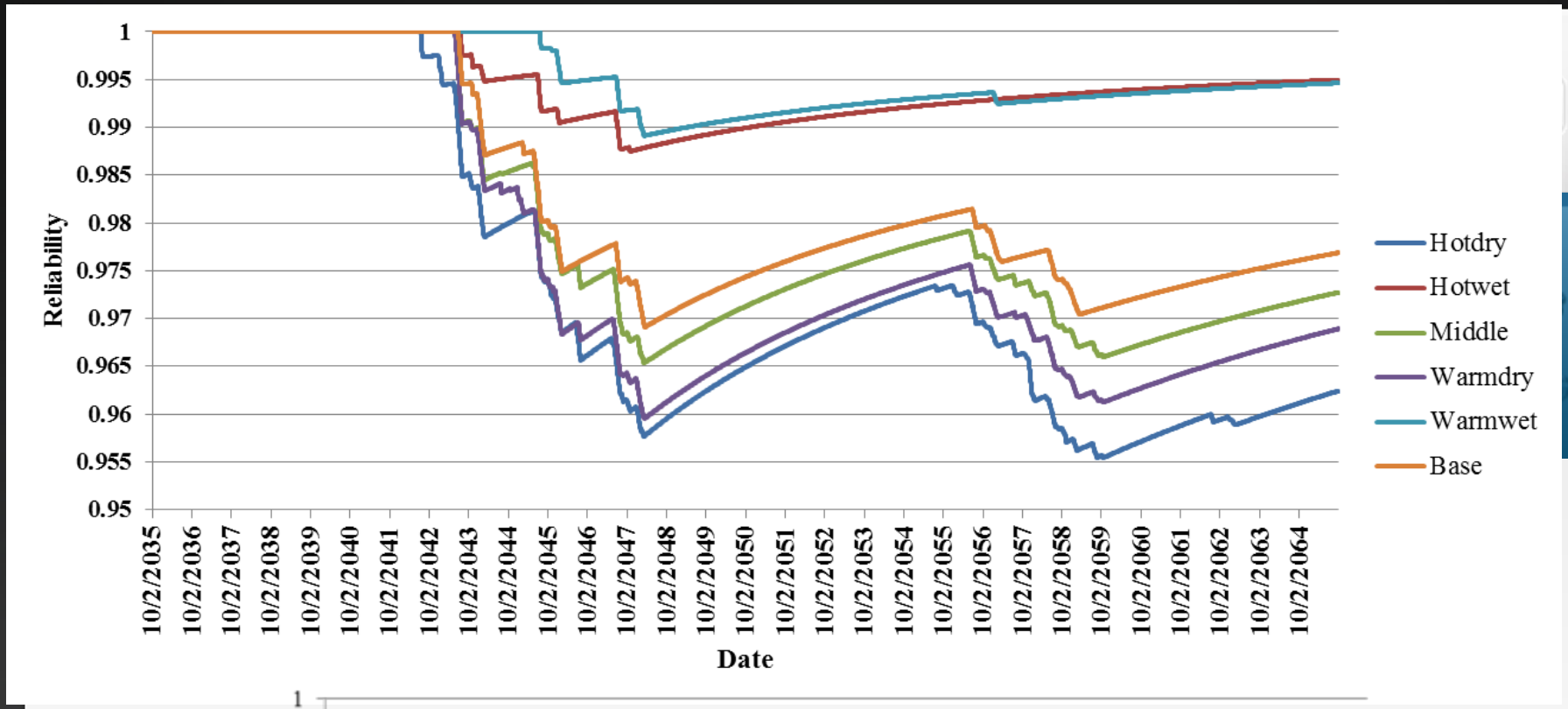


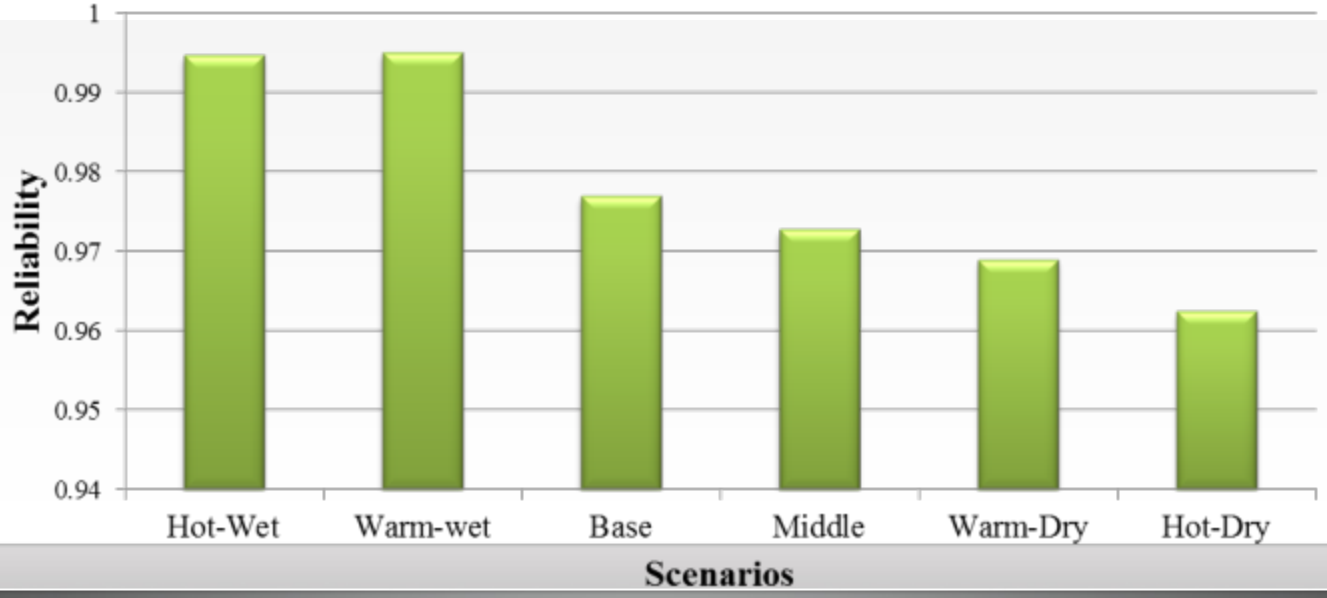
Results: Reservoir Storage (Warm-Wet)



Results: Reservoir Storage (Hot-Dry)



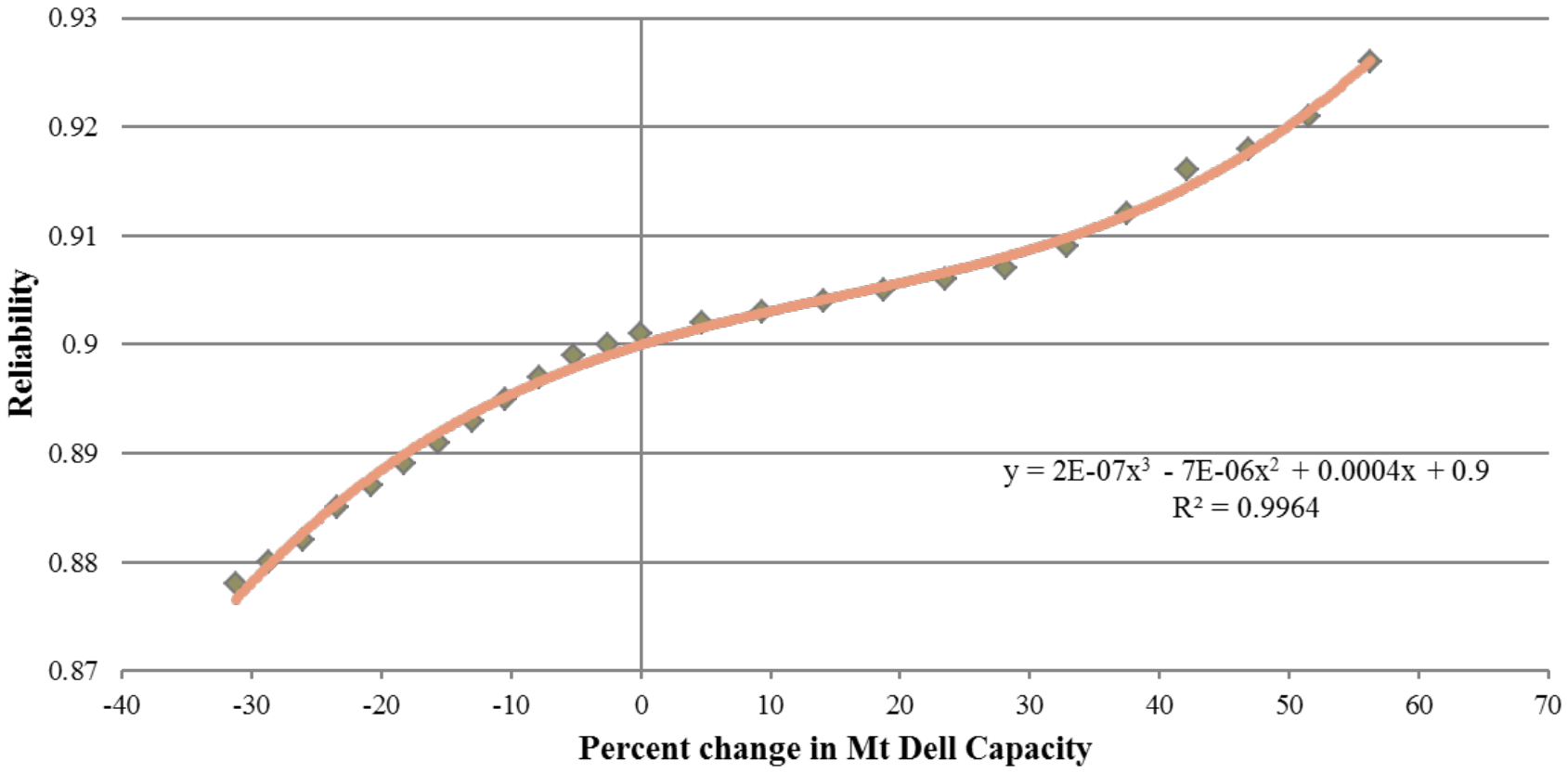

Reliability
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95
10/2/2035
10/2/2036
10/2/2037
10/2/2038
10/2/2039
10/2/2040
10/2/2041
10/2/2042
10/2/2043
10/2/2044
10/2/2045
10/2/2046
10/2/2047
10/2/2048
10/2/2049
10/2/2050
10/2/2051
10/2/2052
10/2/2053
10/2/2054
10/2/2055
10/2/2056
10/2/2057
10/2/2058
10/2/2059
10/2/2060
10/2/2061
10/2/2062
10/2/2063
10/2/2064
Date
Hotdry
Hotwet
Middle
Warmdry
Warmwet
Base


Reliability
1
0.99
0.98
0.97
0.96
0.95
0.94
Hot-Wet
Warm-wet
Base
Middle
Warm-Dry
Hot-Dry
Scenarios

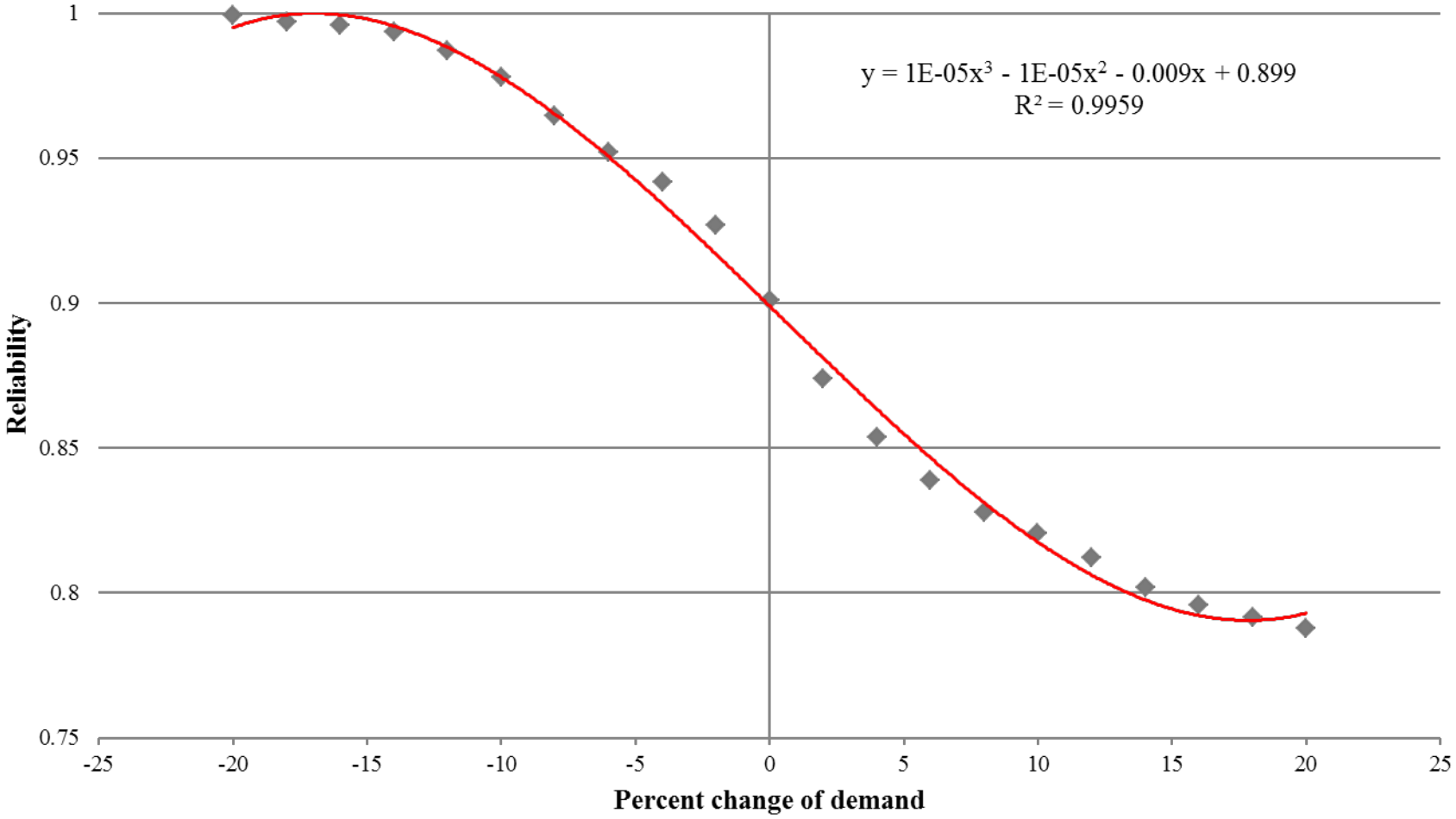
Climate Adaptation Strategies

- Invest in natural resource stewardship
- Water conservation ✓
- Land use planning
- Aquifer storage and recovery
- Increased reservoir storage ✓
- Additional water sources
- Water reuse

Results: Increased Storage



Results: Water Conservation

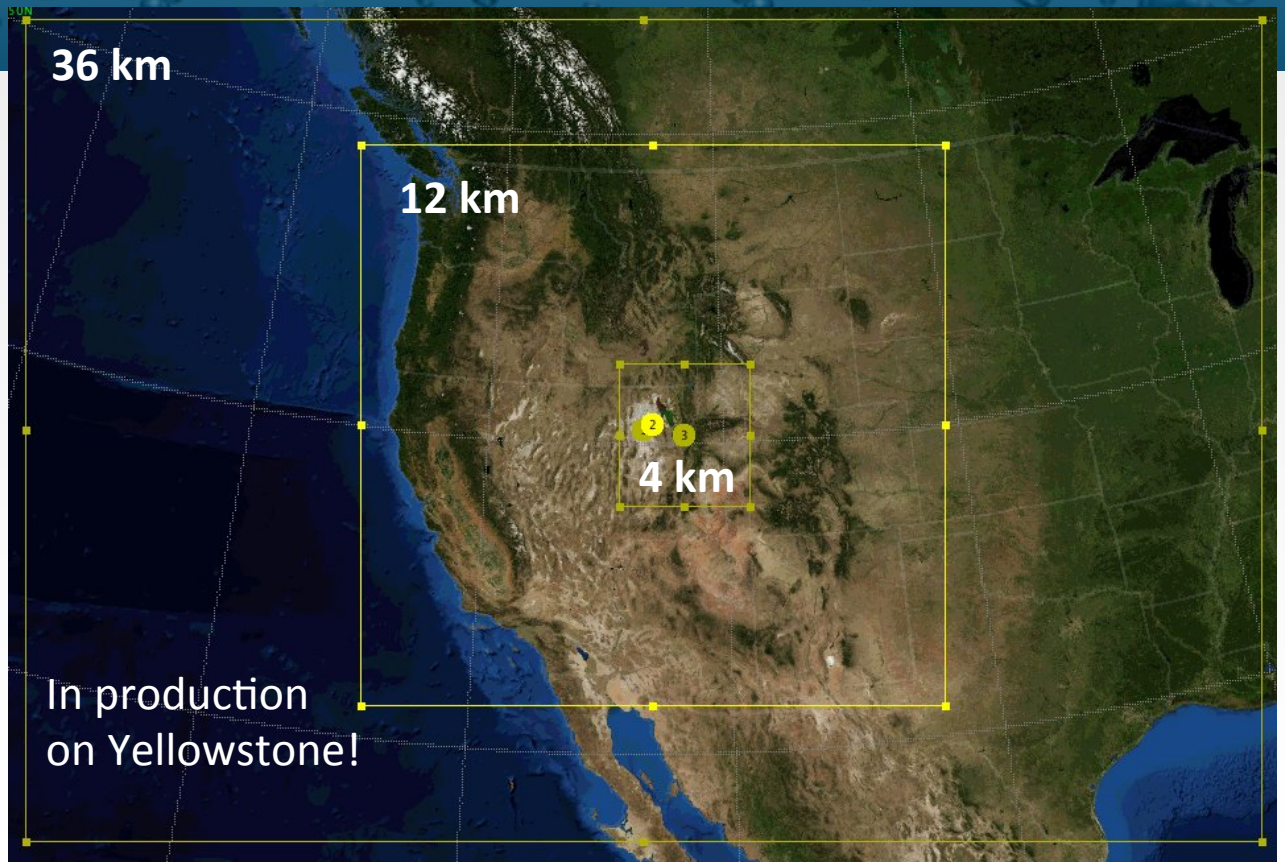


In Progress: Dynamical Downscaling

- **WRF customized with Great Salt Lake model and urban irrigation scheme**

Boundary conditions:
6-houlry NCEP Climate Forecast System Reanalysis (CFSR)
~38 km resolution
1985-2004,
2007-2009

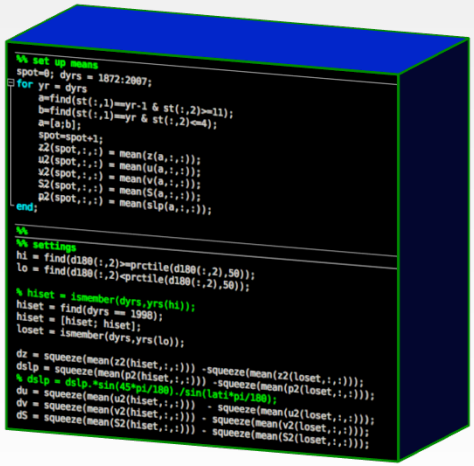
CMIP5 (~1°)
2025-2035
2055-2065
2085-2095



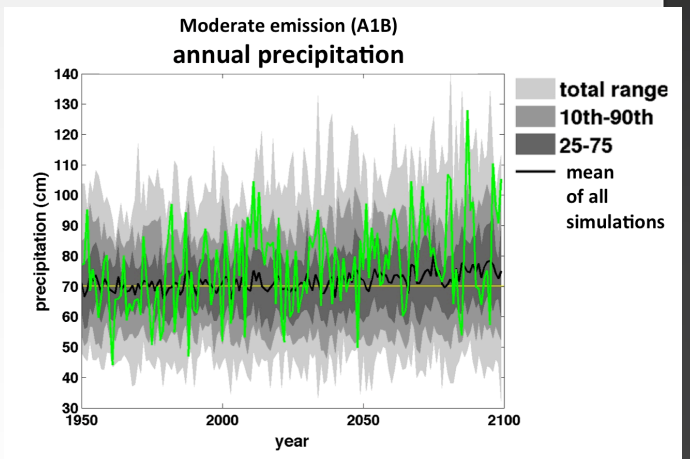
In Progress: CSmod

- Developing a "Climate Scenario module" (CSmod) to generate on-demand, stochastic realizations of climate

Spatial domain
Temporal domain
Variables
Scenario

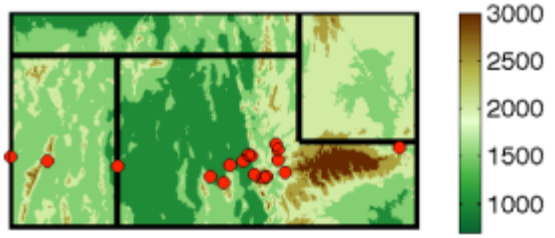


MATLAB, Python, Excel, …



Statistical downscaling

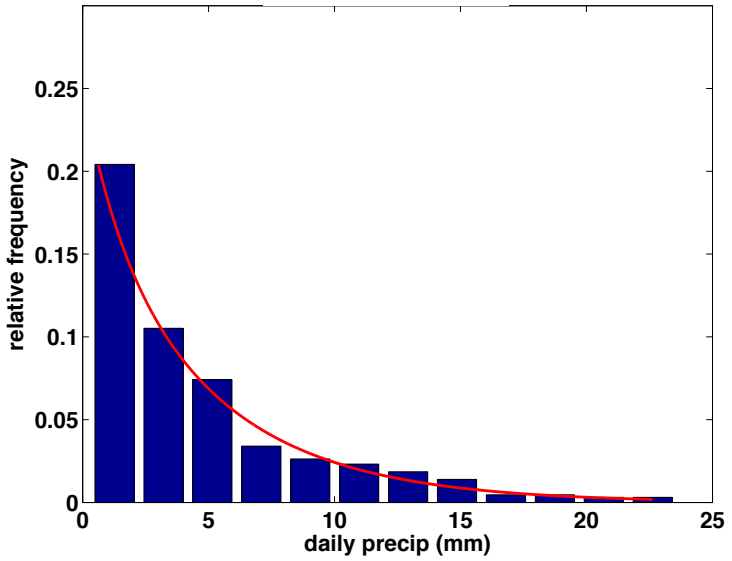
CSmod engine:



Occurrence: two-state, 2nd-order Markov chain process

$$p_{000}(k);\ p_{100}(k);$$
$$p_{010}(k);\ p_{110}(k);$$
$$k = 1, \ldots, K$$

KSLC March



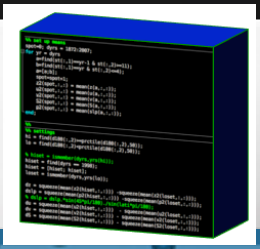
Amount: fit mixed exponential

$$f\left[r(k)\right] = \frac{\alpha(k)}{\beta_1(k)} \exp\left[\frac{-1r(k)}{\beta_1(k)}\right] + \frac{1-\alpha(k)}{\beta_2(k)} \exp\left[\frac{-1r(k)}{\beta_2(k)}\right]$$

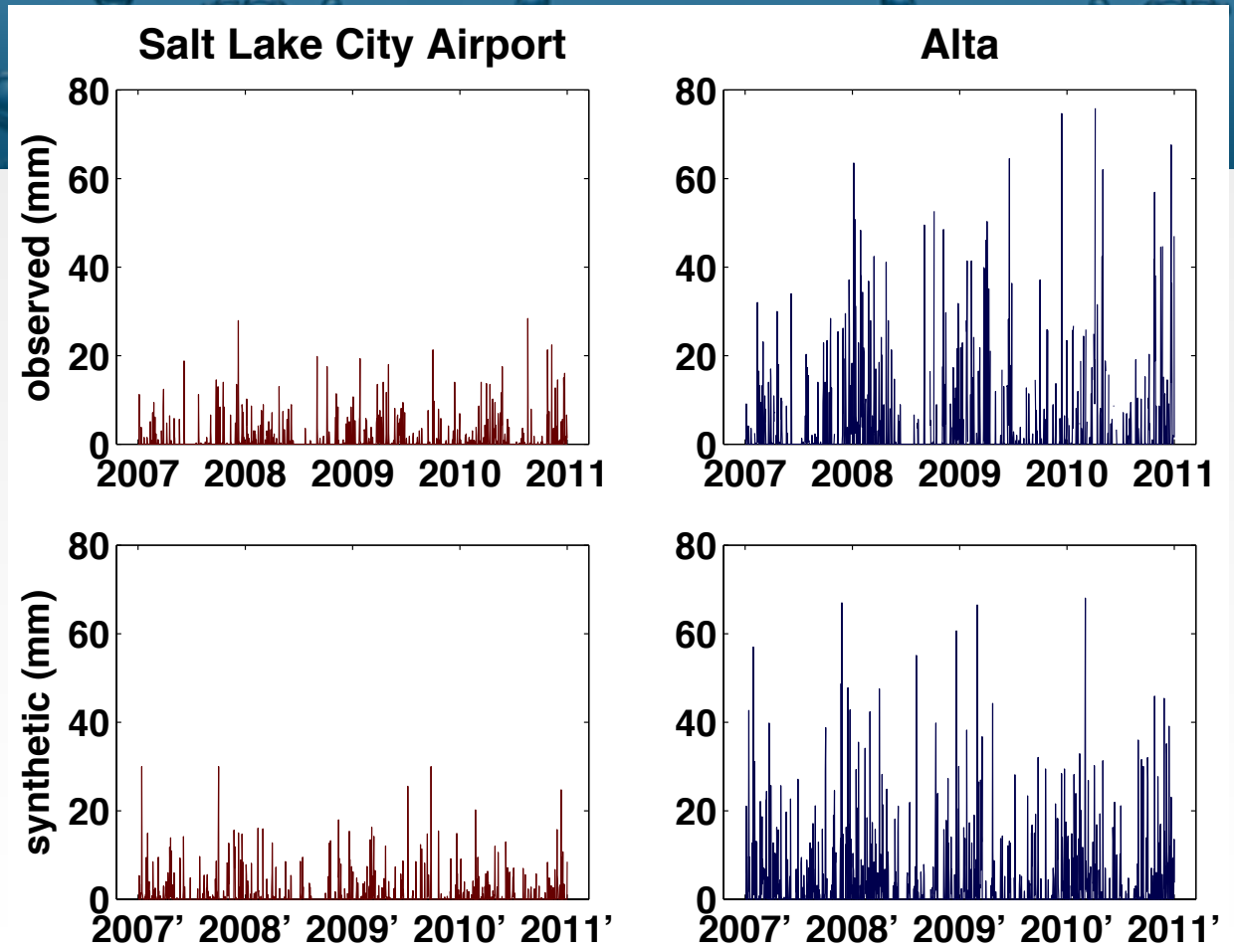
Stochastic driver: spatially-correlated multivariate Gaussian

$$g(\mathbf{x}) = \frac{1}{(2\pi)^{K/2}\sqrt{\det \mathbf{\Sigma}}} \exp\left[-\frac{1}{2}(\mathbf{x}-\mu)^T \mathbf{\Sigma}^{-1}(\mathbf{x}-\mu)\right]$$

Wilks (1999,2009)



CSmod test: generate synthetic historical precipitation data



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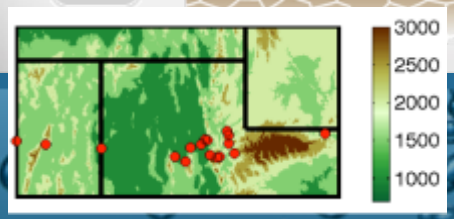
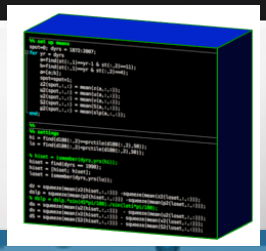
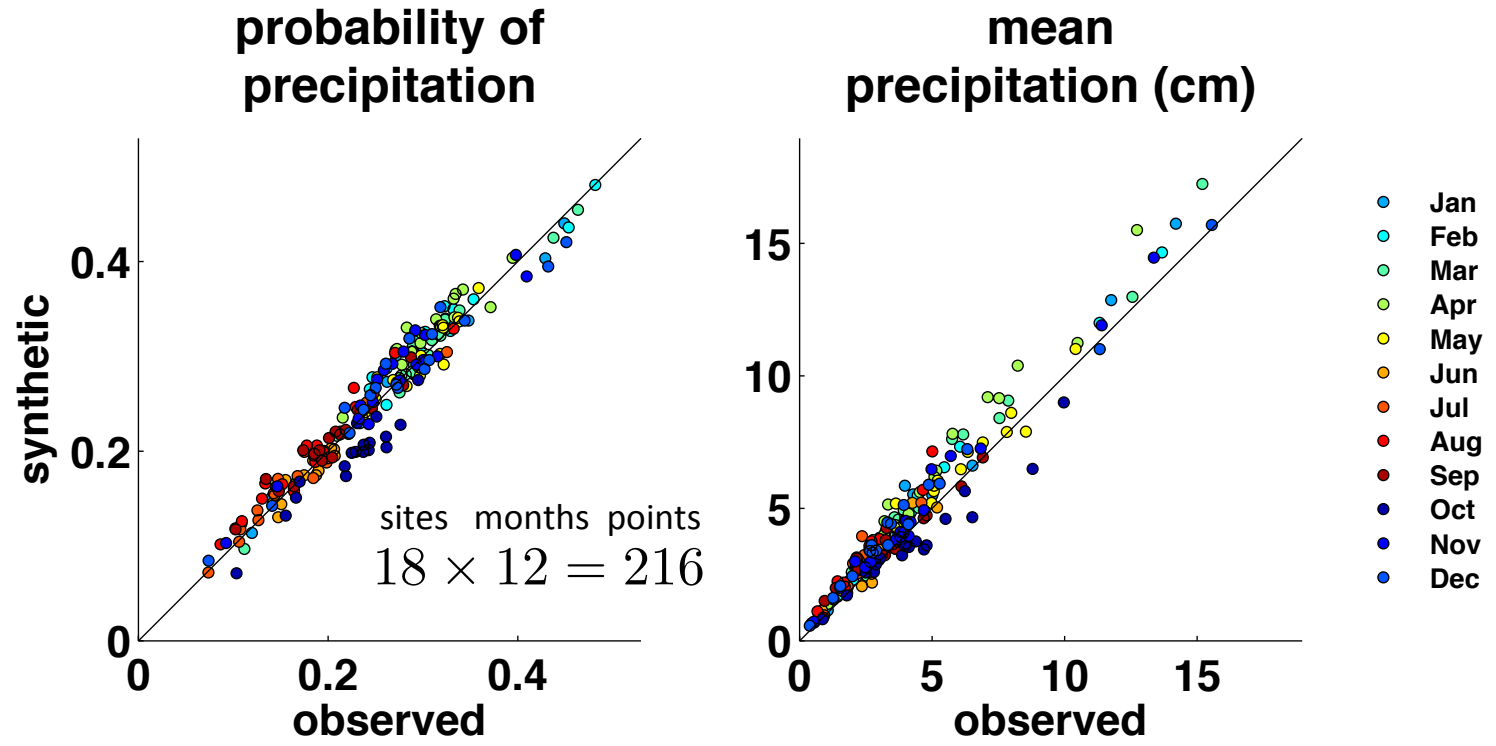




CSmod test: generate synthetic historical record (1958-2012)



CSmod future climate: amount and occurrence functions are re-fit allowing nonstationarity if justified by change in log-likelihood

Climate Modeling and Data Access

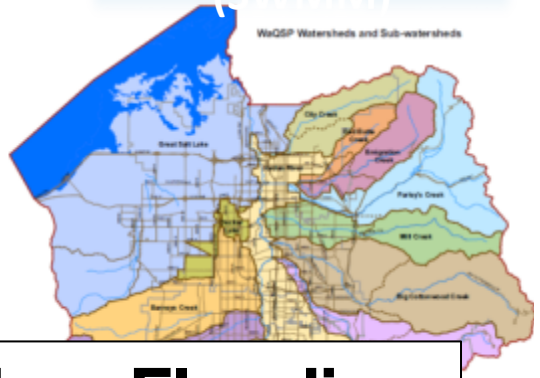
In Progress

Hydrologic Model (CBRFC, RHESSys)

Hydrologic Model (GSSHA, ADHydro)

Stormwater Model

http://www.hiddenwaters.org/

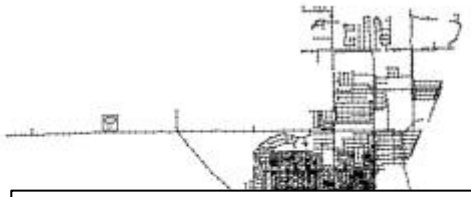


Papers: Parlays Pilot Project, NYC Urban Flooding

Future Integration: UU-BYU-USU upgrade climate data access, UU-BYU connect GSSHA (Climate, Goldsim) (date for UU visit to BYU pending, in June, USU pending)

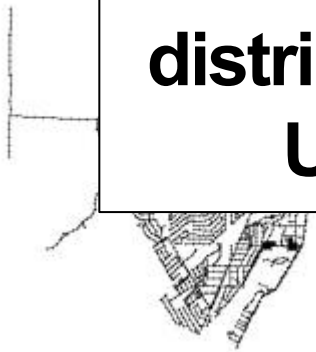
Demand Scenarios

Next Step: SWMM Climate Access & Distributed Computing



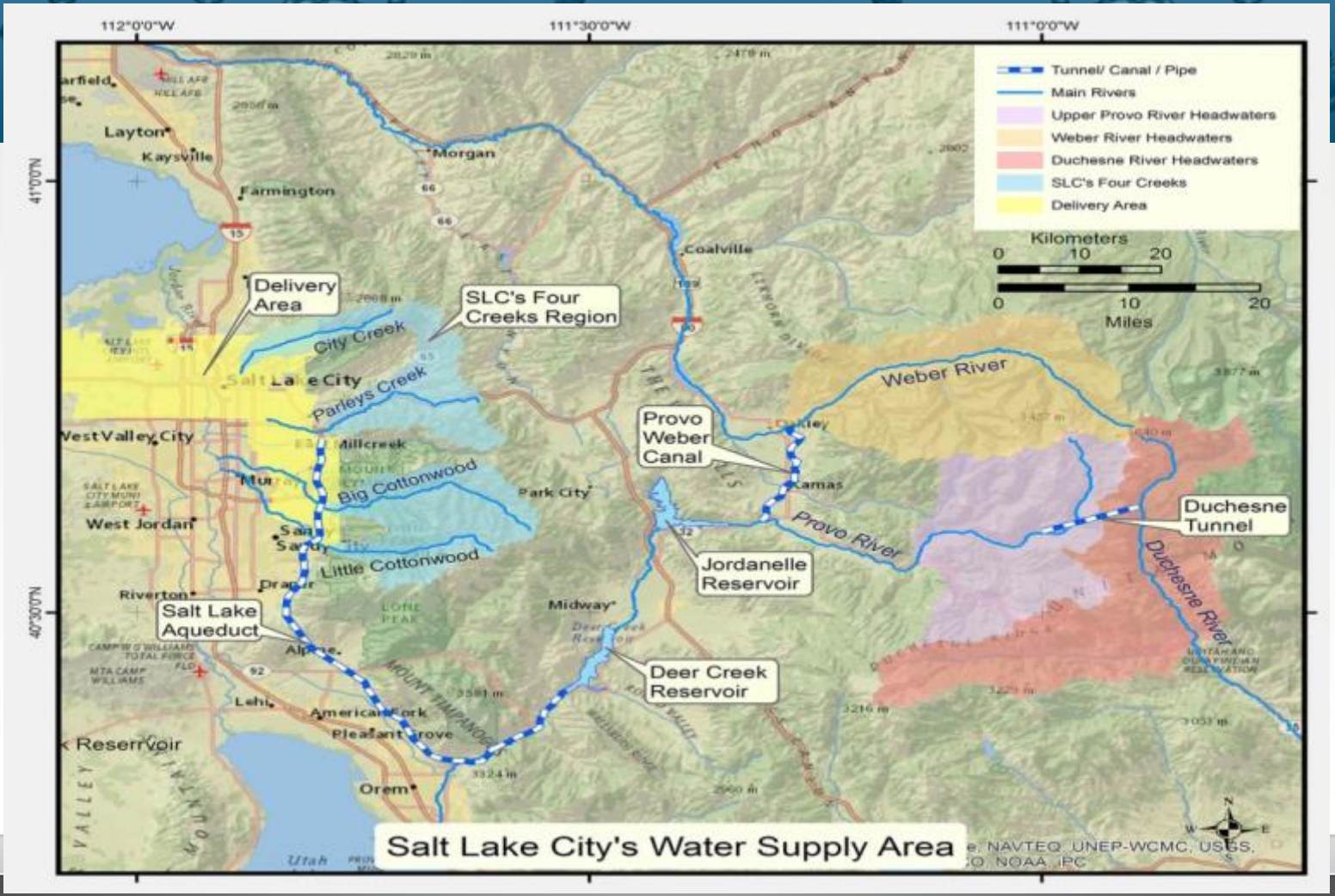
HTCondor
High Throughput Computing

Papers: CSO Control Optimization in Toledo
Integration: UU-BYU-USU to provide SWMM integration, BYU-UU to provide HT Condor distributed computing power for SWMM (pending UU visit to BYU, June, USU visit pending)



LAN Desktop Computing Resources

Next Step: Whole System Model



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Next Analy Tool

Climate

- Extreme Precipitation Analysis
- Temperature Analysis

Hydrologic

- Flood Frequency
- Flow Duration Curves
- Baseflow

System model

- Reliability
- Resilience
- Vulnerability

Integration: BYU-USU-UU develop web based tools (UU – Python, HPC in summer, interface with USU/BYU)

Temporal Disaggregation

Sustainability Index + Water Conservation Scenarios + If … Then scenarios + Operation Policy Design and Optimization

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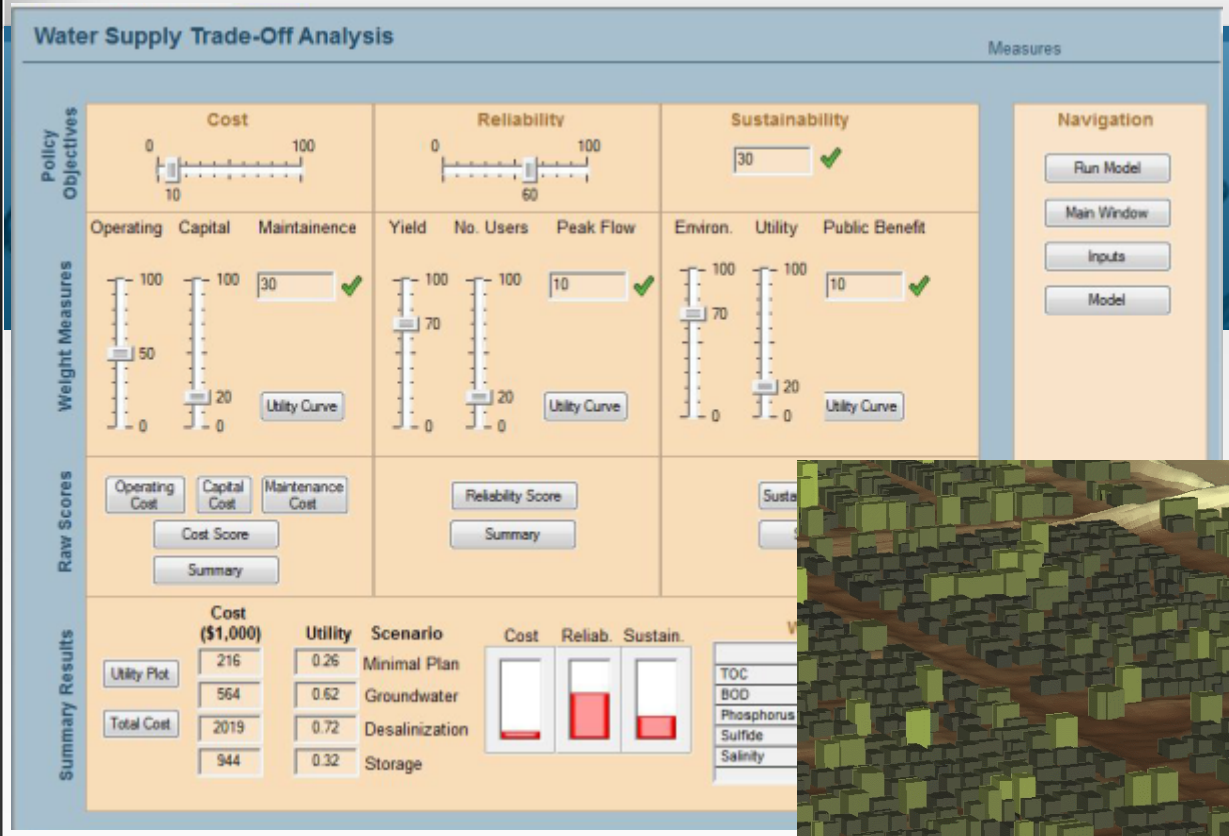
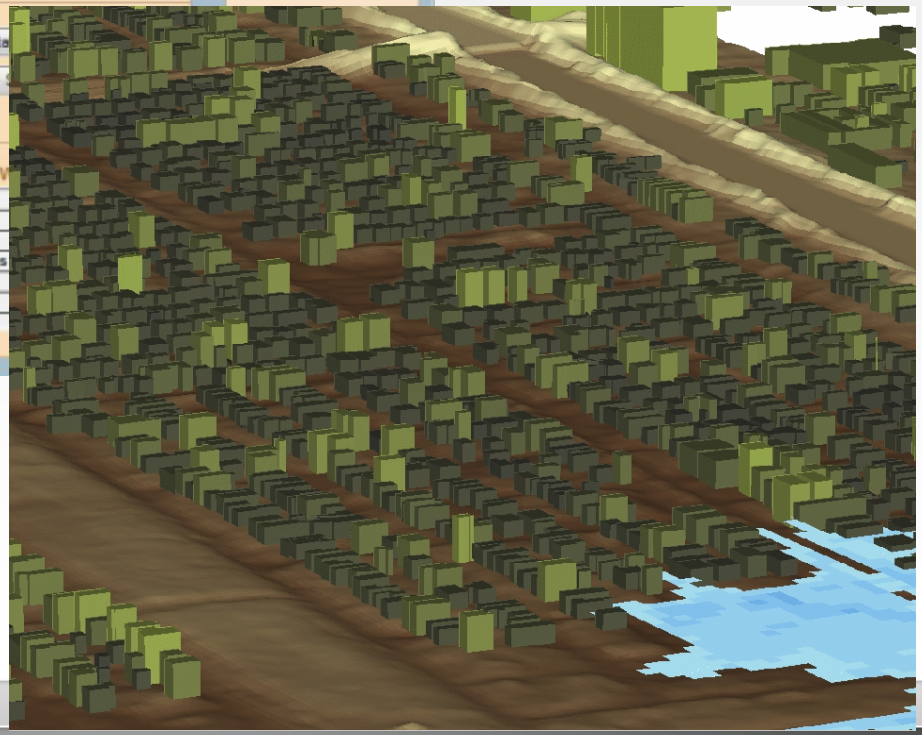
Water Modeling Collaboration

Next Step: User Interface & Viz





Questions?

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  - steve.burian@utah.edu
  - 801-585-5721