



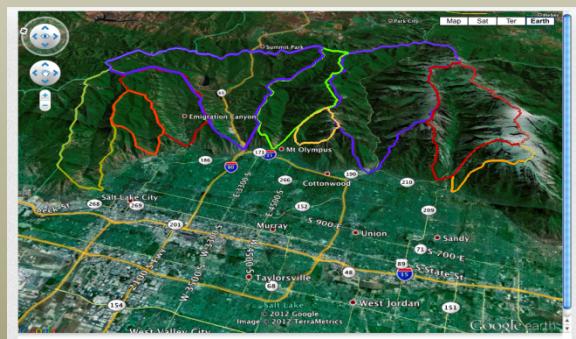
UU Team 2 Integrated Modeling Updates

Climate Modeling
Web Interface
Wasatch Integrated Water Model
Climate Data Access Tool

Steven Burian, Court Strong, Erfan Goharian, Adam Kochanski, and Debadrita Das

Use future climate modeling and downscaling to inform probabilistic scenario development (Strong/Kochanski, UU)

Natural system hydrologic and hydraulic modeling (Burian, UU)



<http://www.hiddenwaters.org/>

Operations model
(Potential iUTAH)

Water System Models

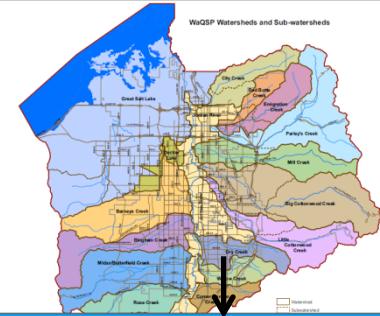
Demand scenarios (Tim Bardsley, WWA; SLC PU)

Planning model
(Burian, UU; SLC PU)



Urban watershed and green infrastructure modeling
(SWMM-ET, Pomeroy/Burian, UU)

Hydrologic Models



Water Quality Modeling (SL County, Potential iUTAH)

Outcomes

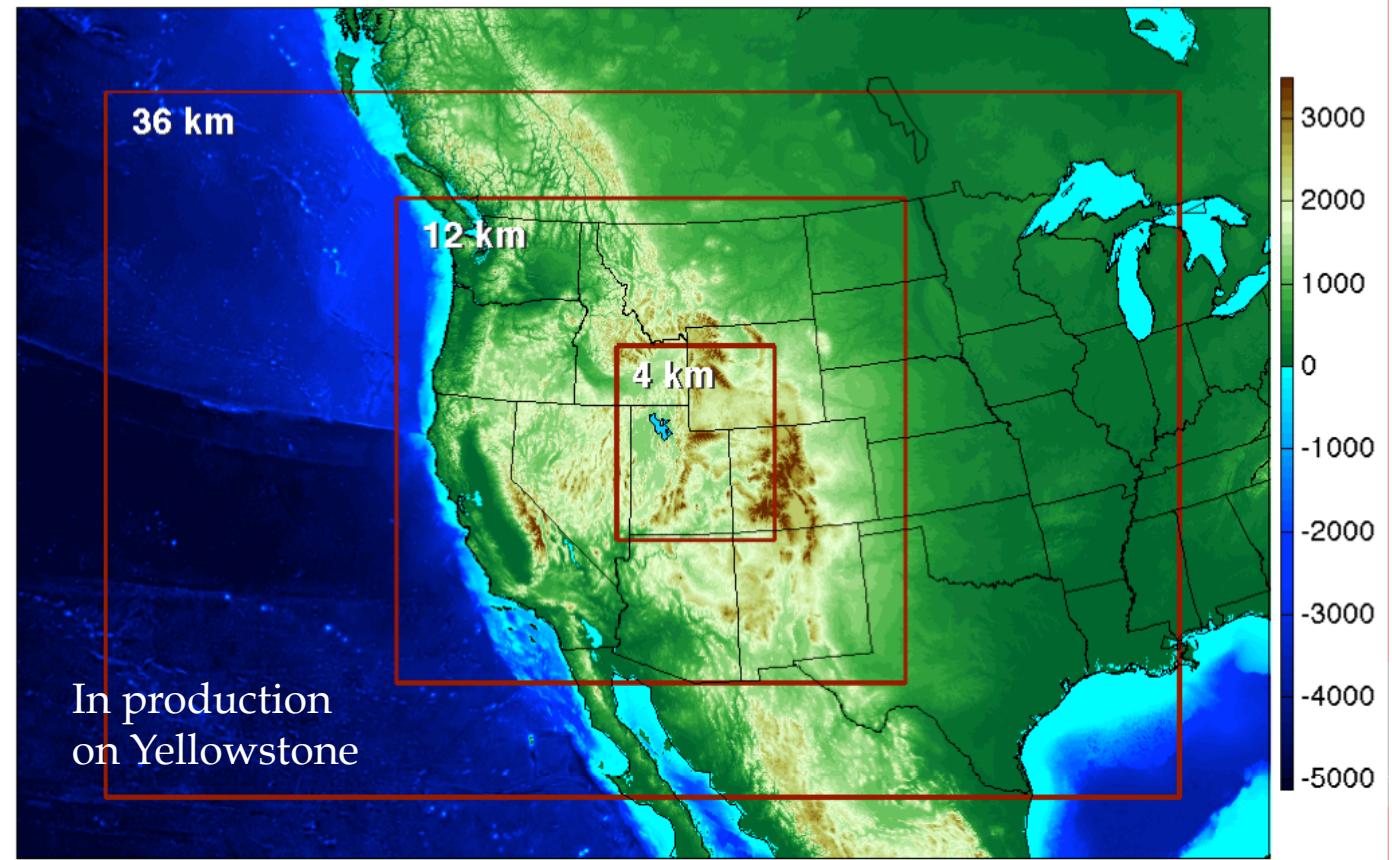
- expanded information for:
- climate-water science
- water operations
- long-term planning
- infrastructure upgrades

Dynamical downscaling

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

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

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



Dynamical downscaling

- WRF Great Salt Lake “slab” model

Differential equation at each grid point

$$\frac{dT_L}{dt} = -\frac{1}{\rho_w c_w h} F$$

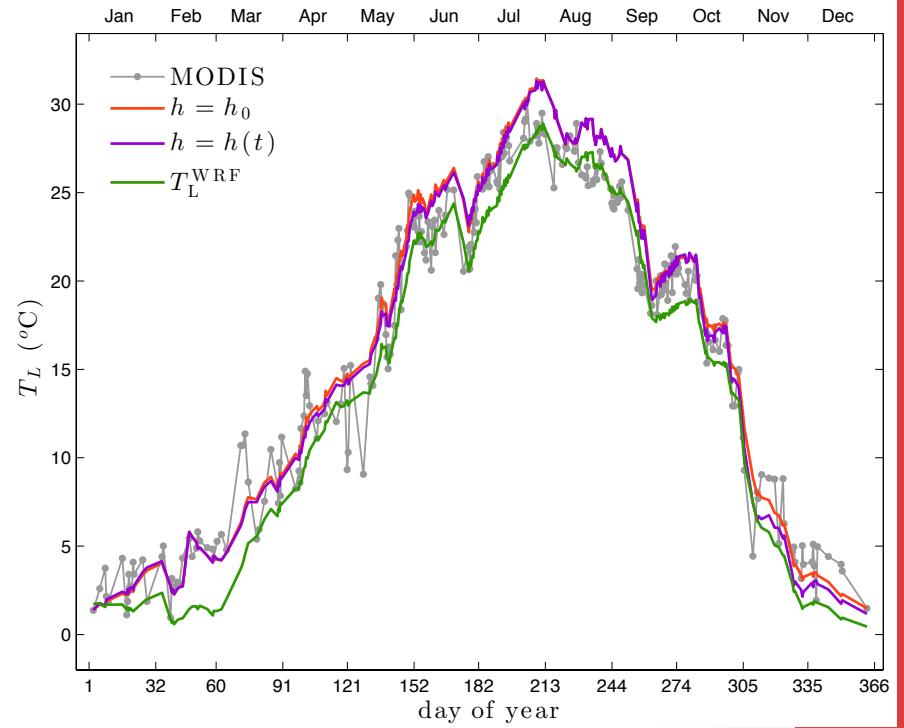
Cost function

$$J(h) = \left\{ \frac{1}{n_\Gamma} \sum_{t \in \Gamma} [T_L^o(t) - T_L^b(t, h)]^2 \right\}^{1/2}$$

Numerical optimization

$$\arg \min_h J(h); \text{ subject to : } h \in [0, \infty]$$

$$h = 5.1 \text{ m}$$



Strong et al. (2013), *JAMES*, in prep.

CSmod

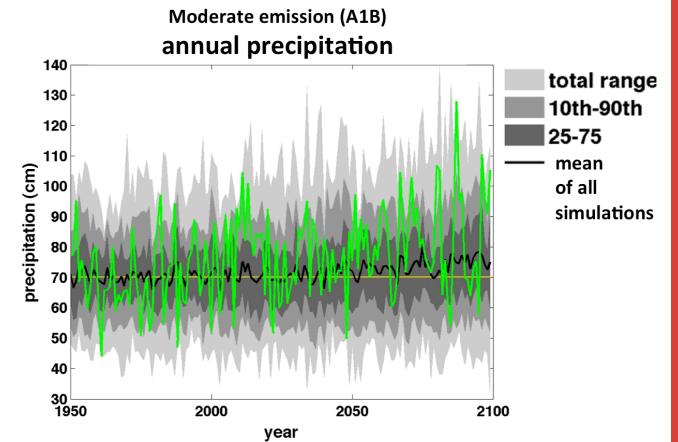
- Developing a “Climate Scenario module” (CSmod) to generate on-demand, stochastic realizations of climate

Spatial domain
Temporal domain
Variables
Scenario

```
% set up means
spot=dyrs = 1872:2007;
for yr = yr
    ifndyrs(:,1)==yr-1 & st(:,2)>11;
    bfind(st(:,1)==yr & st(:,2)<=4);
    a=[a;b];
    spot=spot+1;
    z2(spot,:,:) = mean(z(a,:,:));
    u2(spot,:,:) = mean(u(a,:,:));
    v2(spot,:,:) = mean(v(a,:,:));
    S2(spot,:,:) = mean(S(a,:,:));
    p2(spot,:,:) = mean(p(a,:,:));
end;

% settings
hi = find(dyrs(:,2)>prctile(dyrs(:,2),50));
lo = find(dyrs(:,2)<prctile(dyrs(:,2),50));
% hiset = ismember(dyrs, yrs(hi));
% hiset = find(dyrs>1980);
% hiset = [hiset; hiset];
% loset = ismember(dyrs,yrs(lo));
%
dz = squeeze(mean(z2(hiset,:,:))-squeeze(mean(z2(loset,:,:)));
dsdp = squeeze(mean(p2(hiset,:,:))-squeeze(mean(p2(loset,:,:)));
% ddp = sin(45*pi/180).*sin(lat*pi/180);
du = squeeze(u2(hiset,:,:))-squeeze(mean(u2(loset,:,:)));
dv = squeeze(v2(hiset,:,:))-squeeze(mean(v2(loset,:,:)));
ds = squeeze(mean(S2(hiset,:,:))-squeeze(mean(S2(loset,:,:))));
```

MATLAB, Python, Excel, ...



Statistical downscaling

CSmod engine:

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

$$p_{000}(k); p_{100}(k);$$

$$p_{010}(k); p_{110}(k);$$

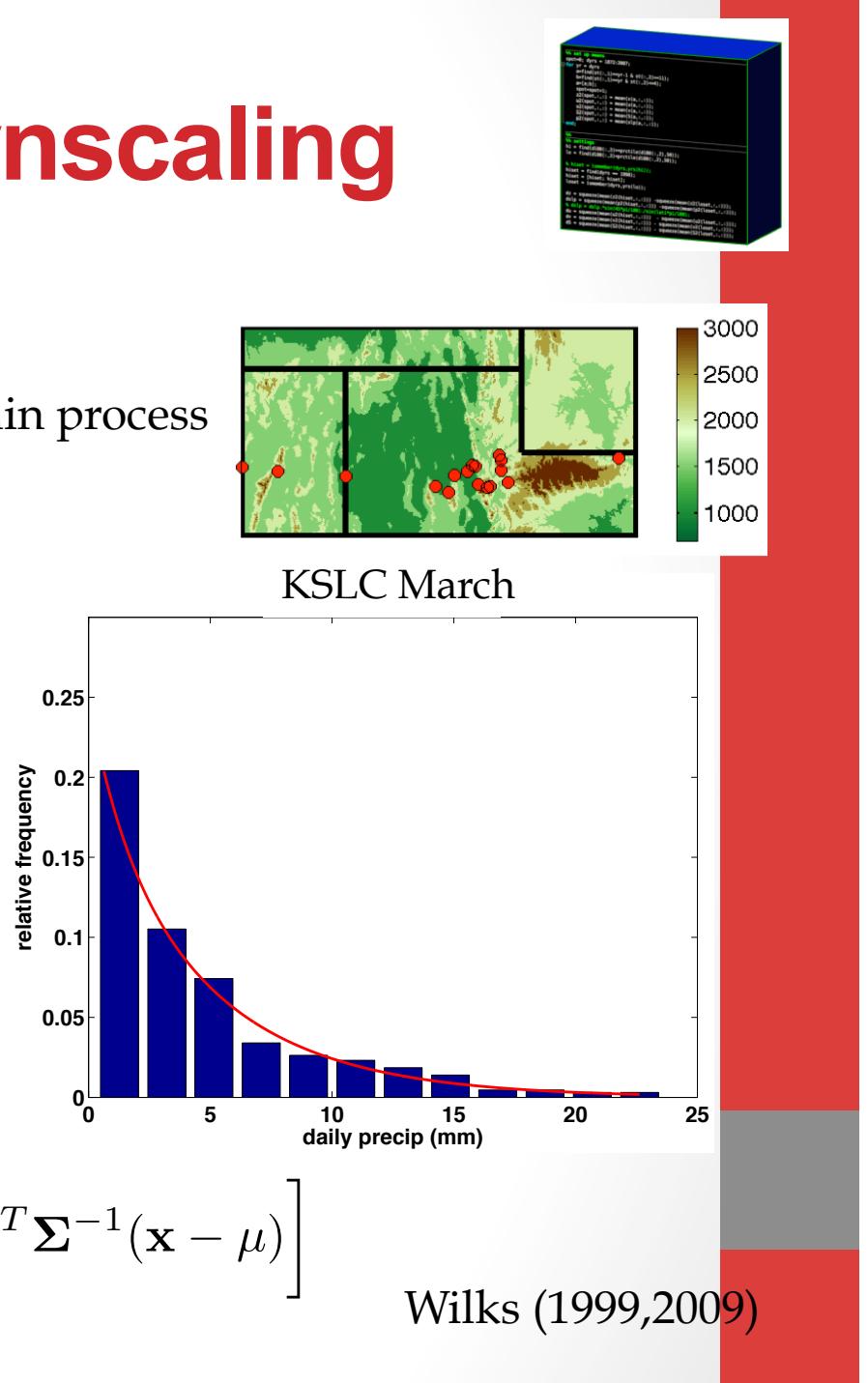
$$k = 1, \dots, K$$

Amount: fit mixed exponential

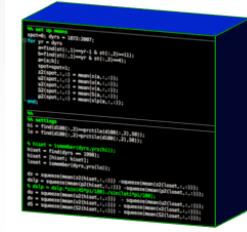
$$f[r(k)] = \frac{\alpha(k)}{\beta_1(k)} \exp\left[\frac{-1r(k)}{\beta_1(k)}\right] + \\ \frac{1 - \alpha(k)}{\beta_2(k)} \exp\left[\frac{-1r(k)}{\beta_2(k)}\right]$$

Stochastic driver: spatially-correlated multivariate Gaussian

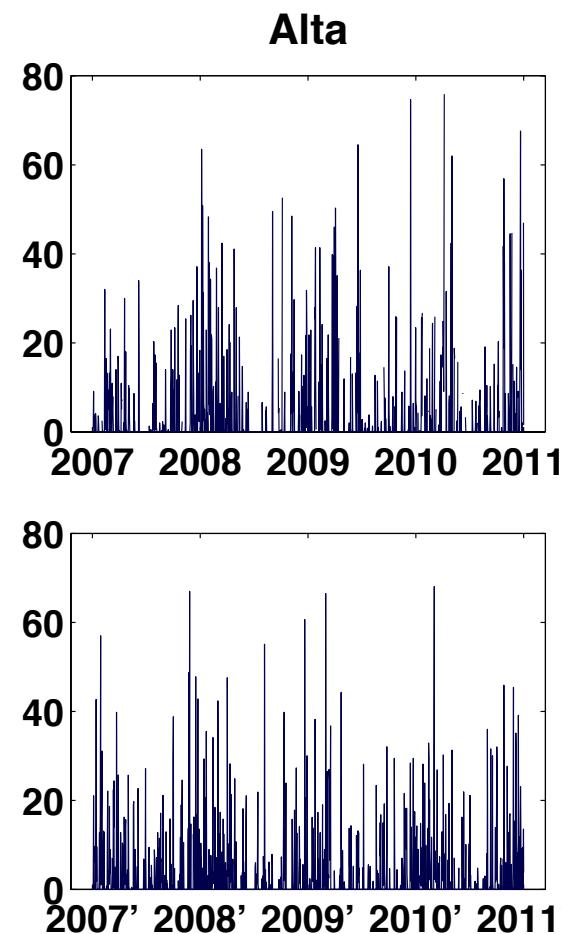
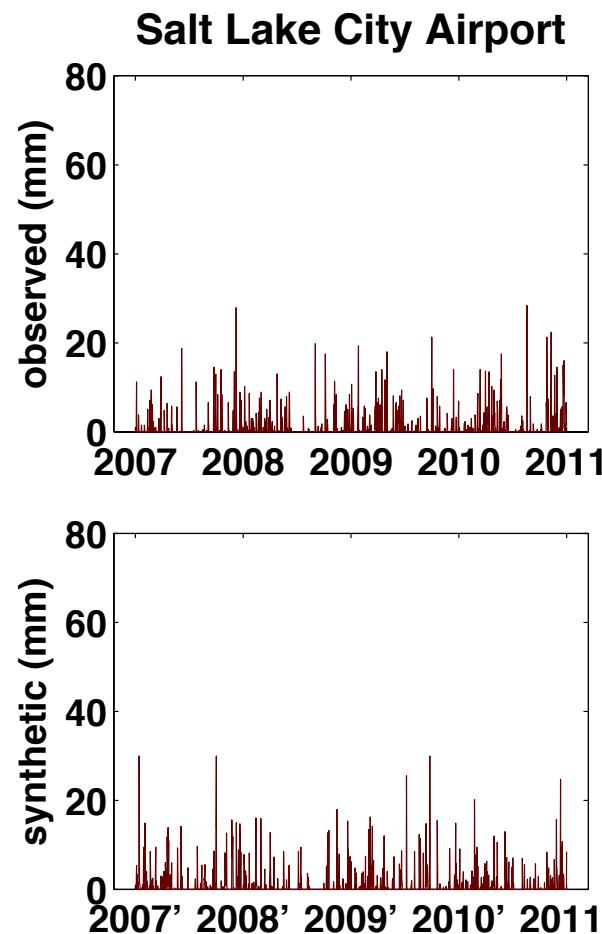
$$g(\mathbf{x}) = \frac{1}{(2\pi)^{K/2} \sqrt{\det \Sigma}} \exp\left[-\frac{1}{2}(\mathbf{x} - \mu)^T \Sigma^{-1} (\mathbf{x} - \mu)\right]$$



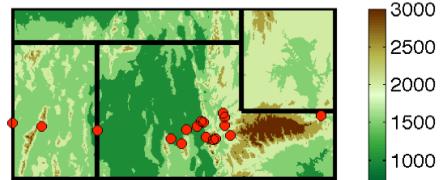
Climate Scenario module



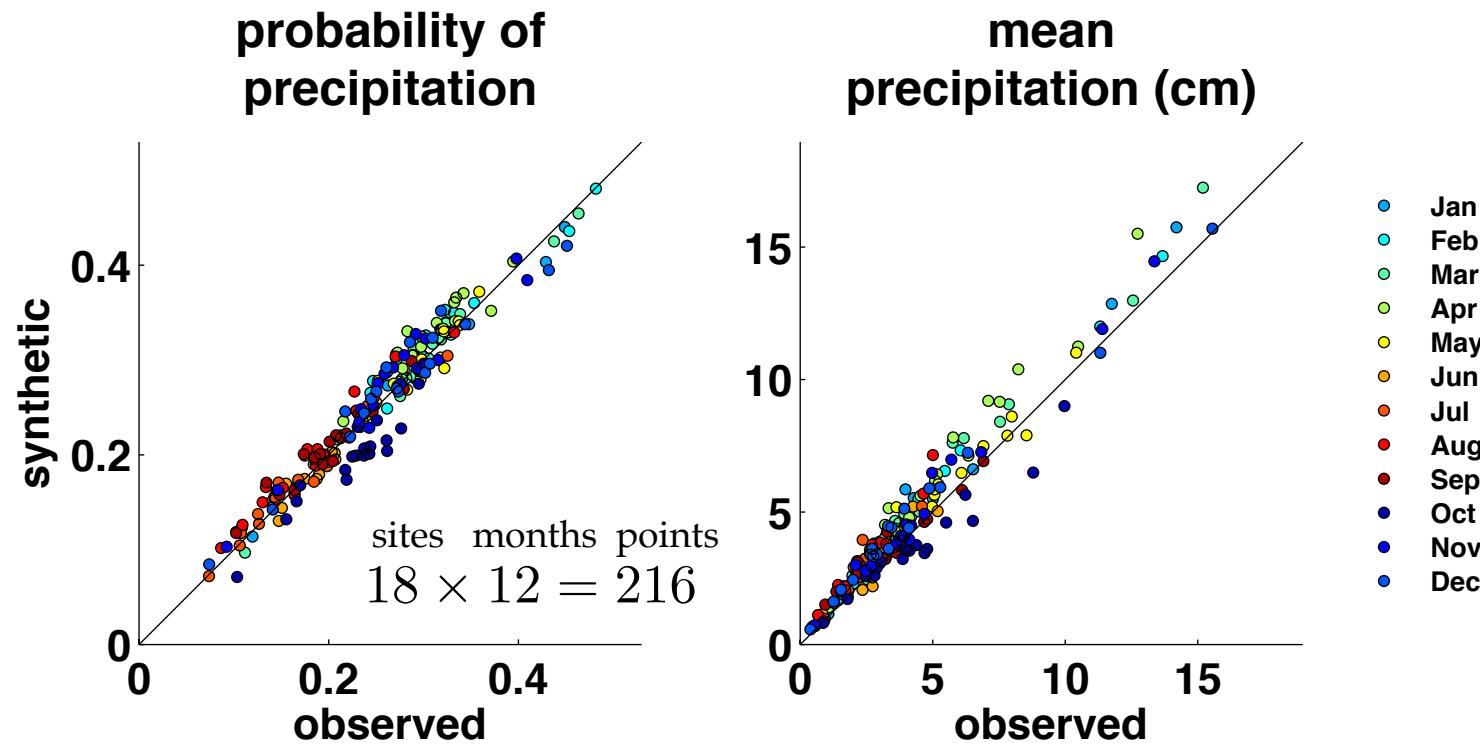
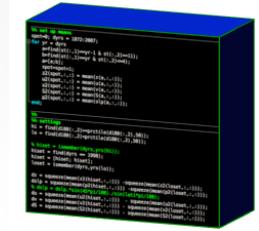
CSmod test: generate synthetic historical precipitation data



Climate Scenario module

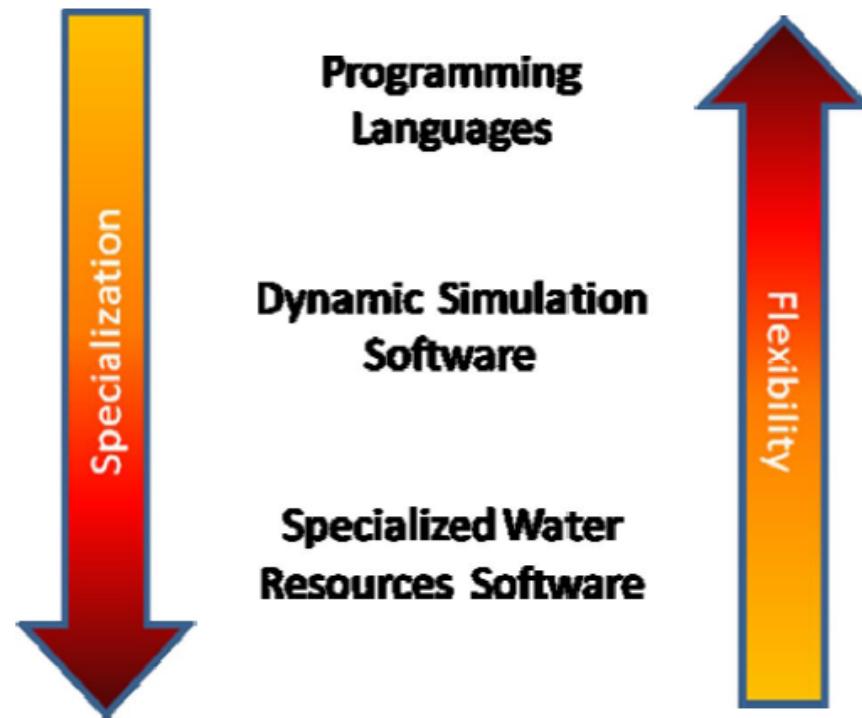
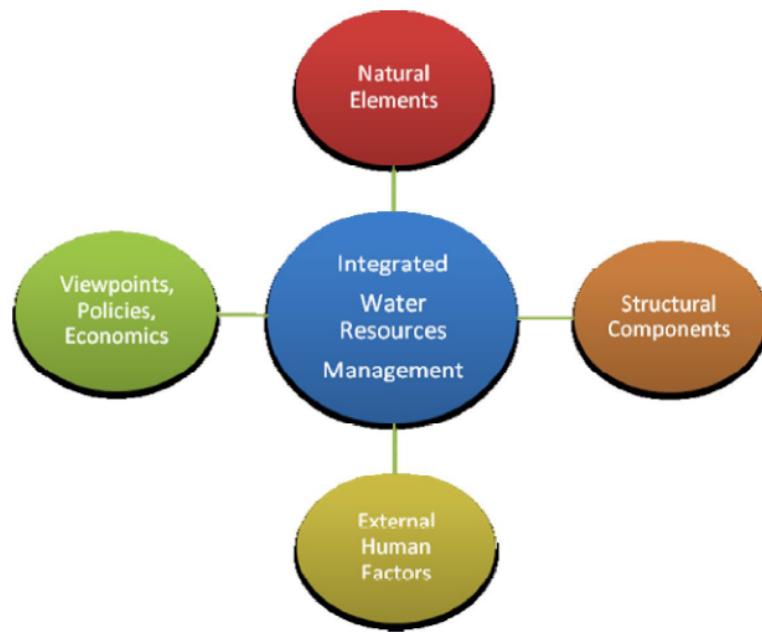


CSmod test: generate synthetic historical record (1958-2012)

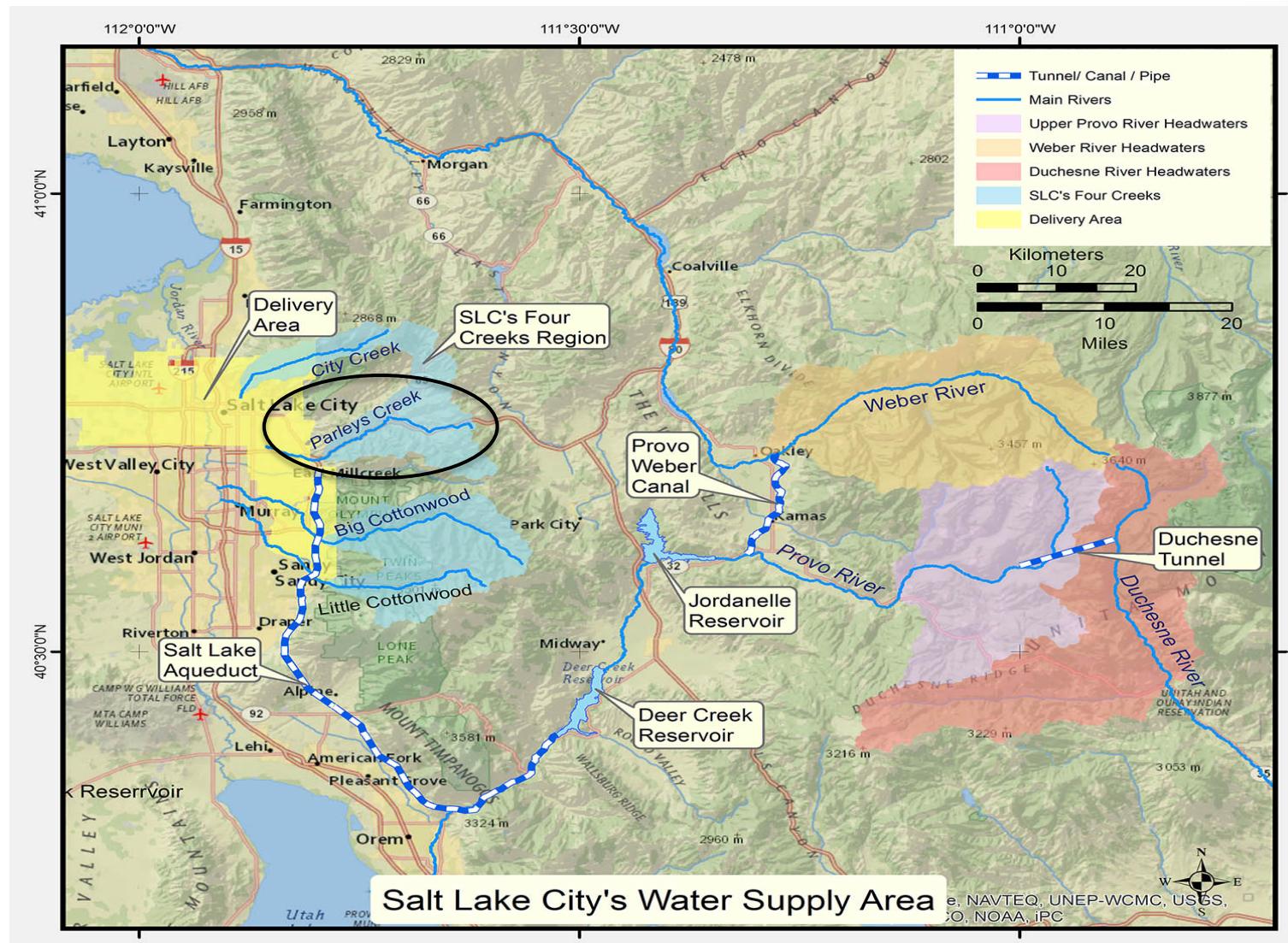


CSmod future climate: amount and occurrence functions are re-fit allowing nonstationarity if justified by change in log-likelihood

Integrated Water Resources Management (IWRM)



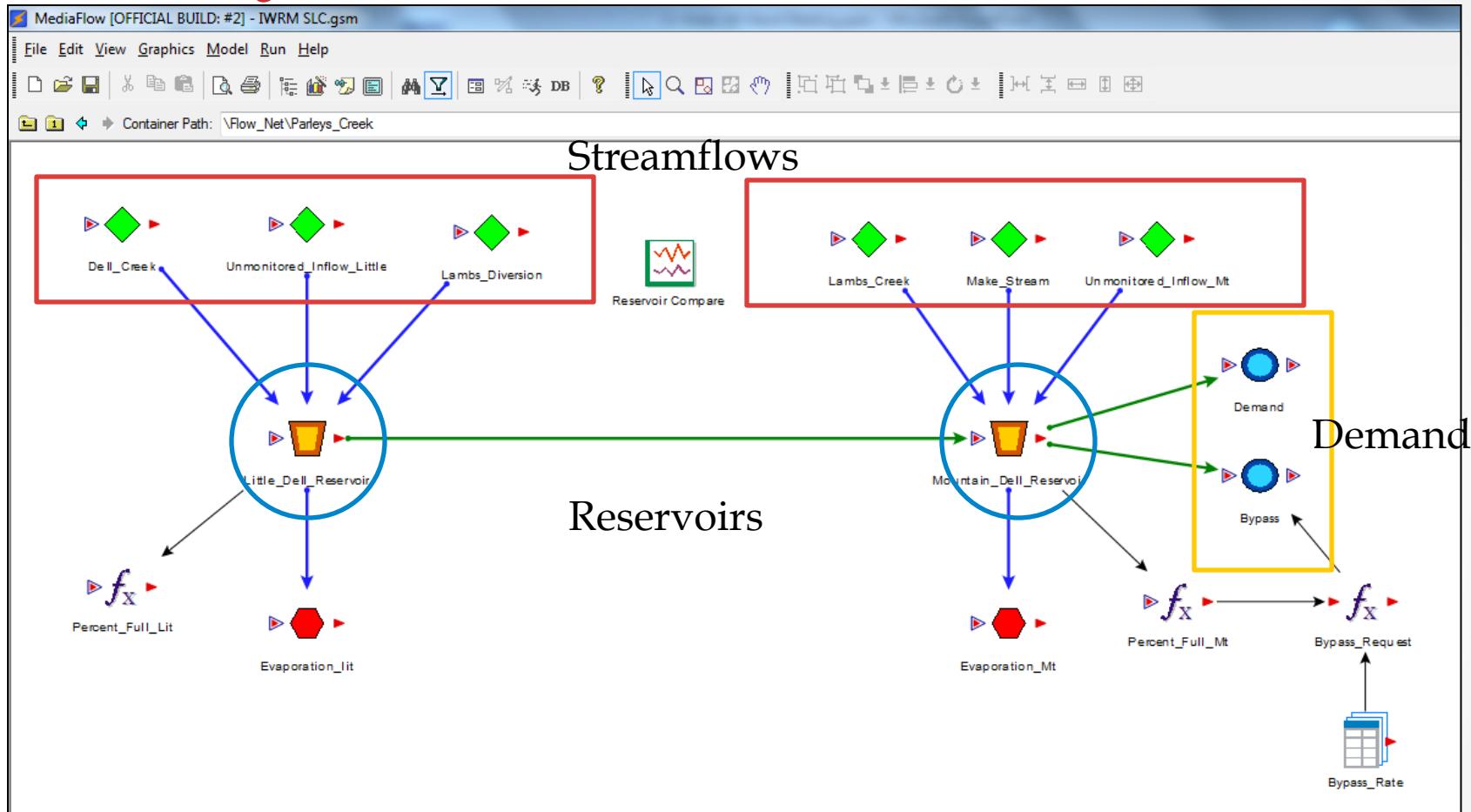
Case Study



Parley's Water System



Parleys GoldSim model



GoldSim Player allows you to view, navigate, and run an existing GoldSim model without having to purchase GoldSim Pro.



Player File Dashboard

Parleys Creek Management Tool



Demand Rate

General Mountain Dell Reservoirs Characteristics

Capacity [af]	3200
Dead Pool [af]	800
Initial Volume [af]	2000

General Little Dell Reservoirs Characteristics

Capacity [af]	20000
Dead Pool [af]	0
Initial Volume [af]	5700

Reliability Results

Choose a scenario

Warm Dry

Historical Run

 Run the Model

 Simulation Settings

Mountain Dell Reservoir

Scenario Results

Little Dell Reservoir

Scenario Results

Reliability

Scenario Results



GoldSim 

Dell Creek Inflow Rate

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	1	1	1	1	1	1	1	1	1	1

Lambs Creek Inflow Rate

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	1	1	1	1	1	1	1	1	1	1

Reliability Results

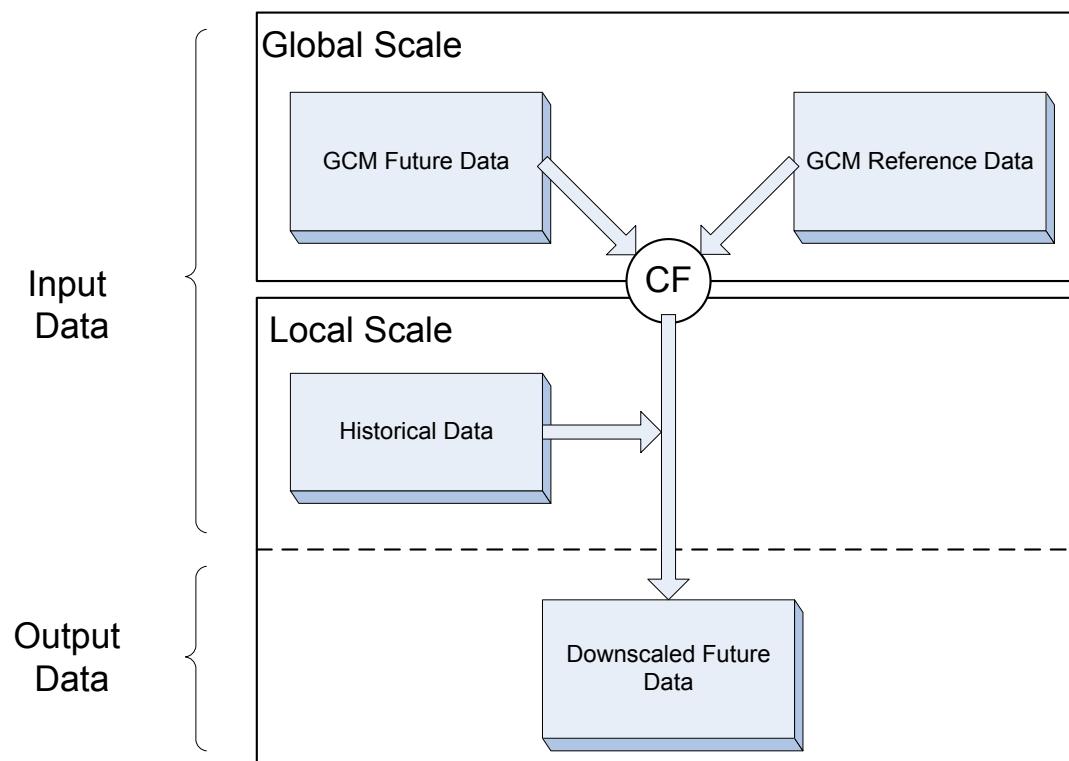
Historical	Hot Dry	Hot Wet	Wam Dry	Wam Wet
1 0	1 0	1 0	1 0	1 0

Reliability

Historical Result	Historical Result	Historical Result
-------------------	-------------------	-------------------

Adjustment

□ Change factor approach (CFA):

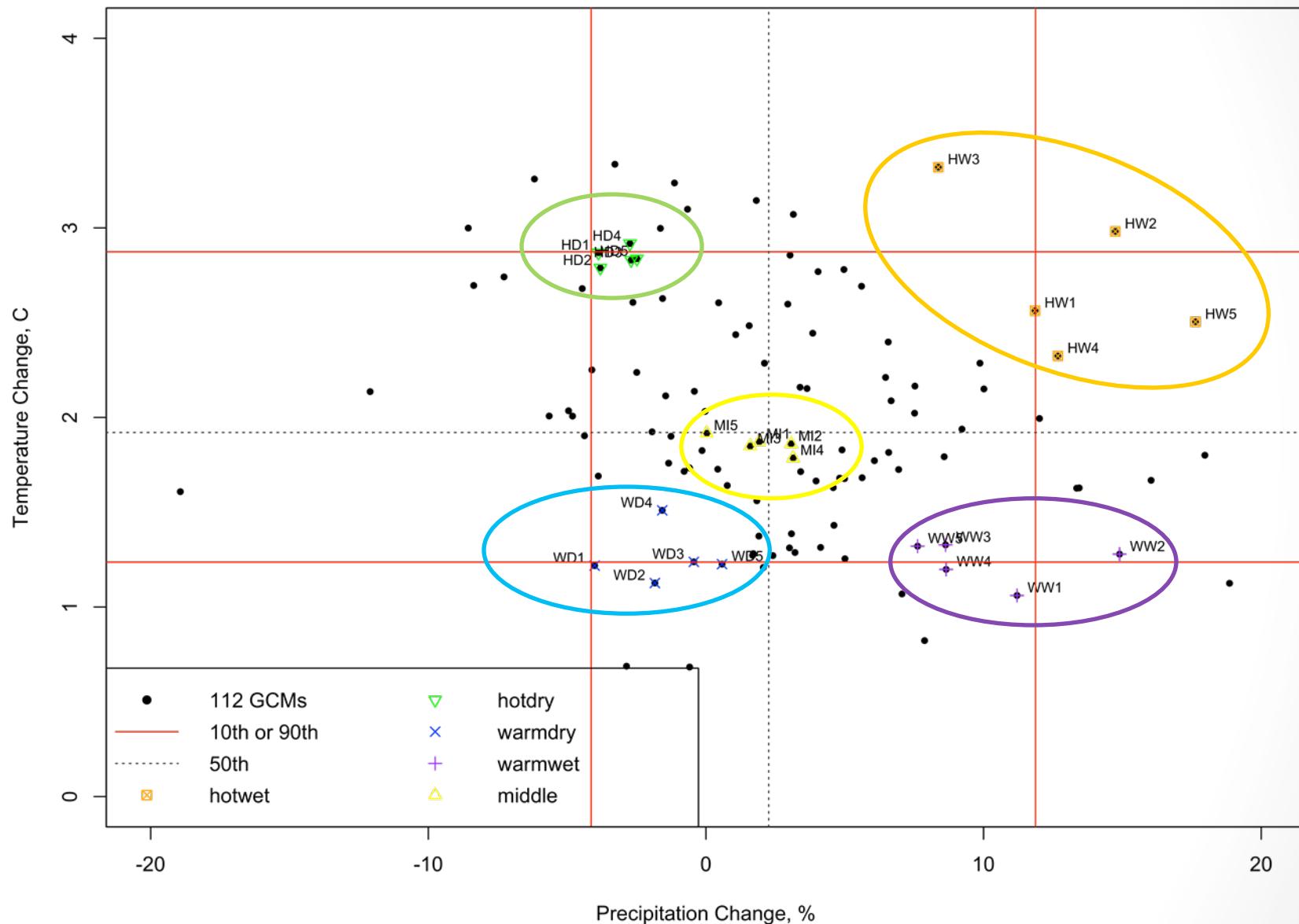


$$\begin{cases} P_{sim} = P_{obs} \cdot \Delta P \\ \Delta P = \left(\frac{P_{GCM,fut}}{P_{GCM,base}} \right) \end{cases}$$

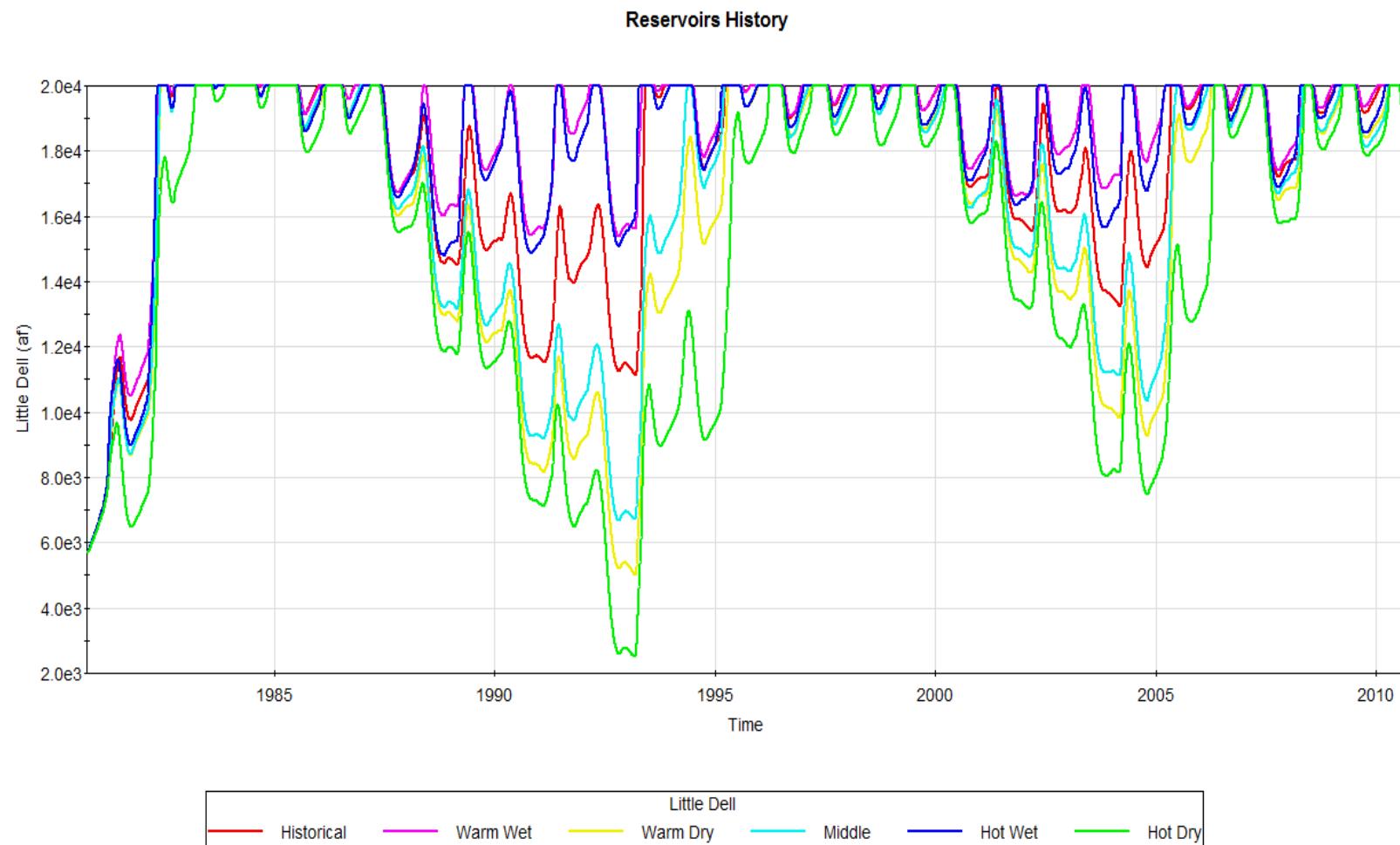
$$\begin{cases} T_{sim} = T_{obs} + \Delta T \\ \Delta T = (T_{GCM,fut} - T_{GCM,base}) \end{cases}$$

- ΔT and ΔP are monthly change factors (CFs) of temperature and precipitation

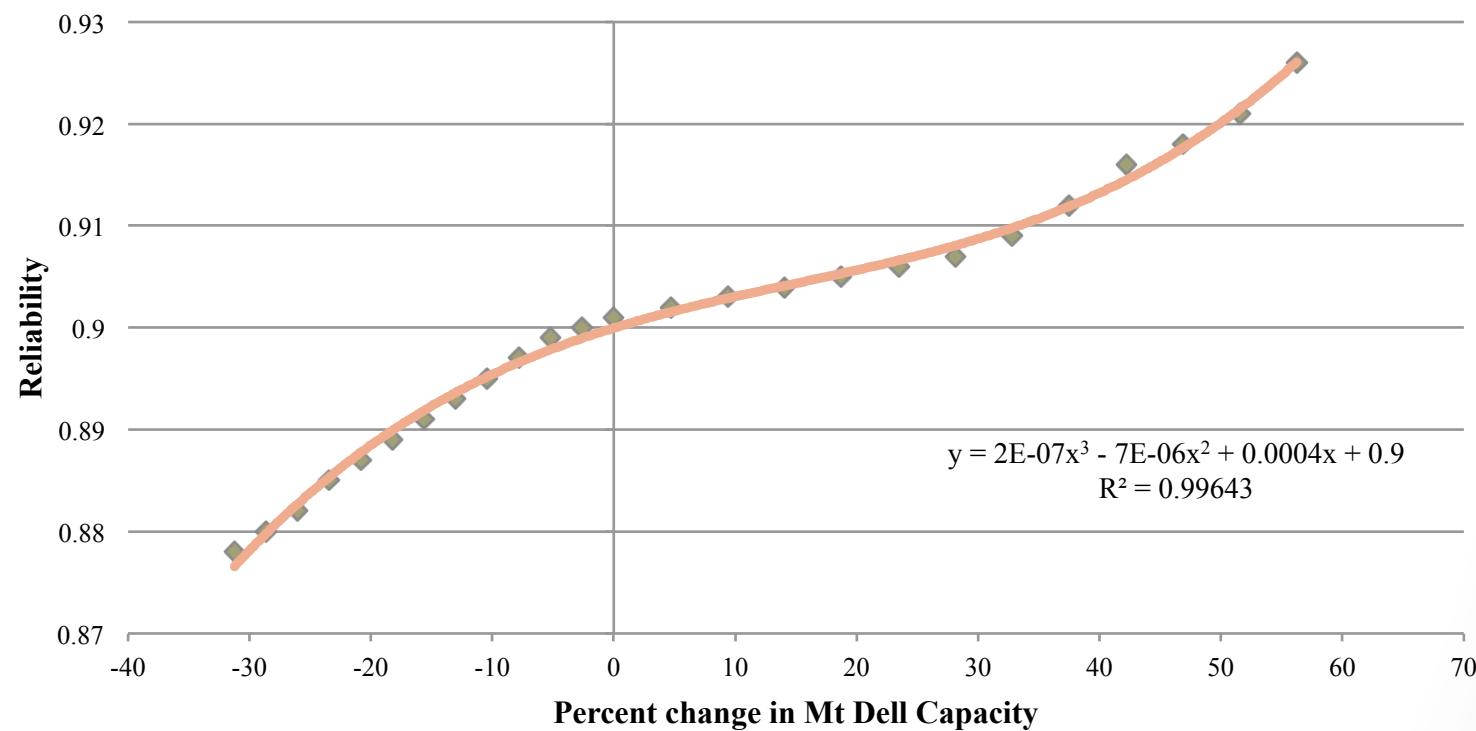
Changes in Mean Annual Temp & Precip
comparing Oct 2035- Sep 2065 to Oct 1980- Sep 2010



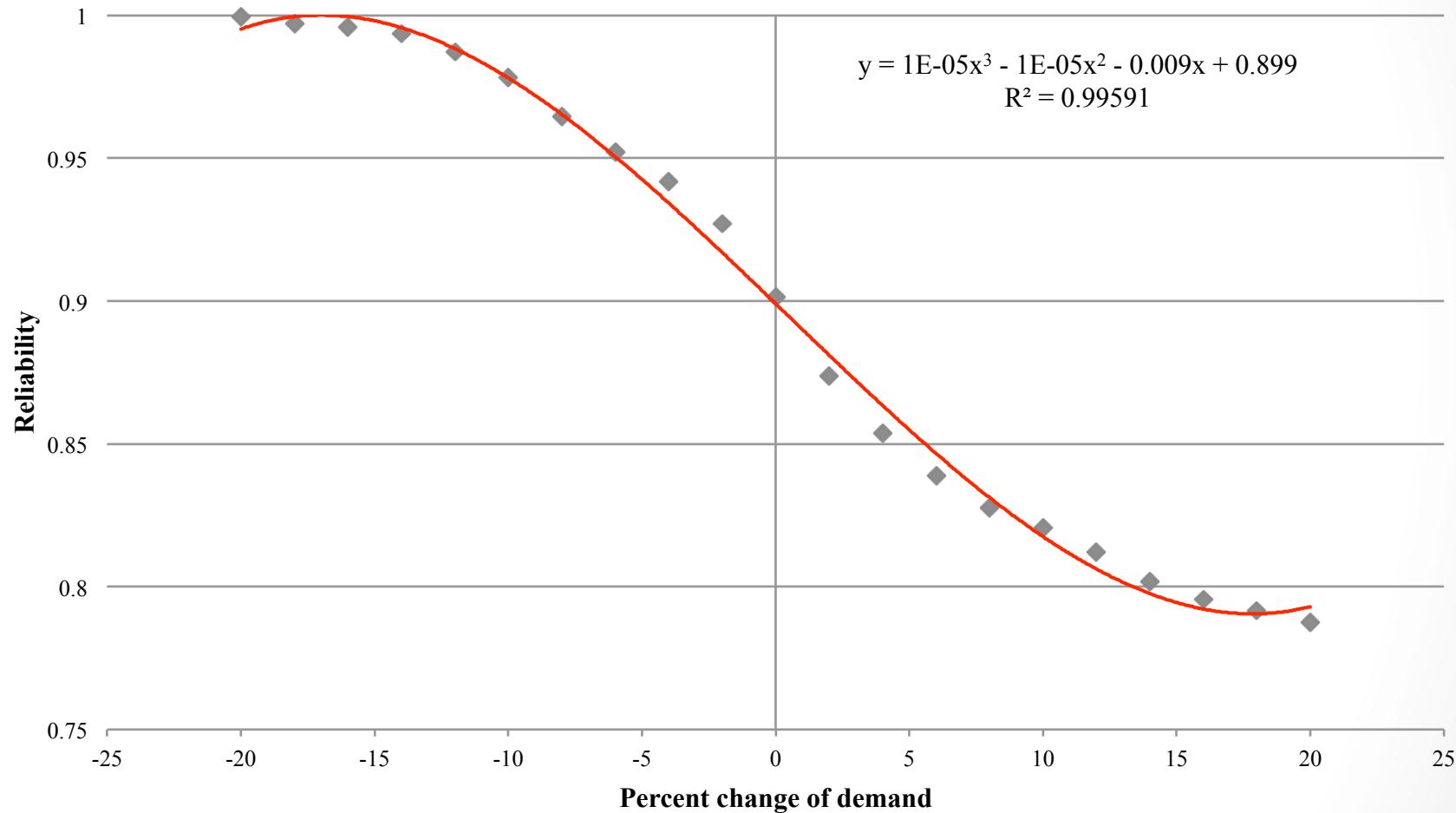
Climate Scenario results

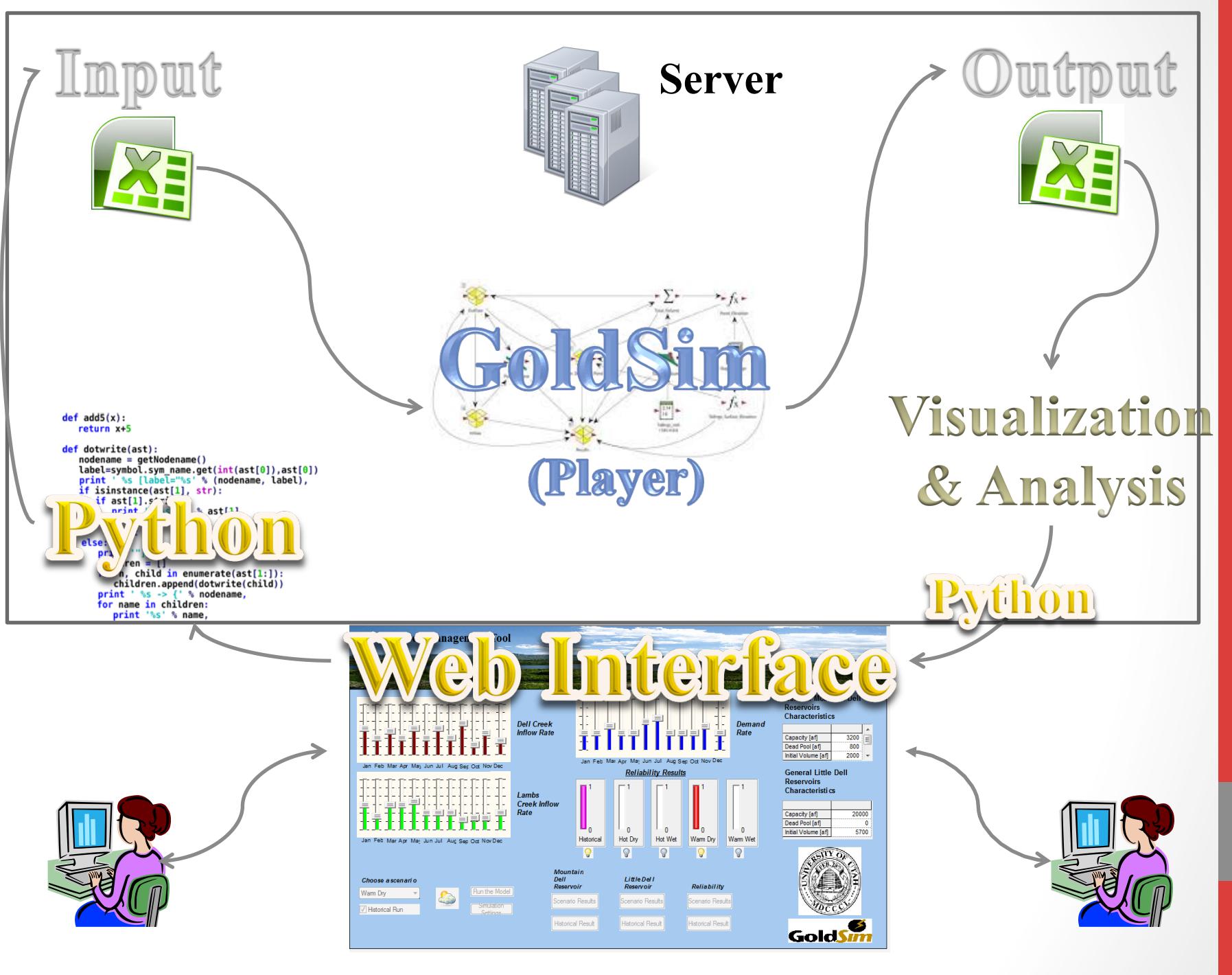


Development Plans



Water Conservation or Population Growth?





Web Interface (Collaboration with BYU)

The image displays two screenshots of the TETHYS web application interface. The left screenshot shows the 'Apps' section of the TETHYS homepage. It features a sidebar with a 'What are Apps?' section explaining that apps are custom tailored for certain datasets or models, providing workflows for analyzing, executing, and visualizing models. Below this is a section titled 'Apps' with three items: 'Example' (a blue button), 'Parleys Creek Management Tool' (circled in blue with a pointer arrow from the right screenshot), and 'GSSHA-Explorer' (a blue button with a water drop icon). The right screenshot shows a detailed view of the 'Parleys Creek Management Tool'. It includes a 'Get Started' button, a descriptive paragraph about the tool, and a large image of a lake and surrounding hills. Both screenshots have a red footer bar containing links for 'About Tethys', 'Powered by ckan', and a language selection dropdown set to 'English'.

TETHYS

Apps Datasets Organizations Groups About Search

What are Apps?

Apps

App Example

App Parleys Creek Management Tool

GSSHA-Explorer

About Tethys

Powered by ckan

Language: English

TETHYS

Apps Datasets Organizations Groups About Search

Ready? Let's get Started.

Click on the "Get Started" button to begin.

Get Started

Parleys Creek Management Tool

Parleys Creek Management Tool

Nonumy melius atomorum ut qui, et odio suscipit pericula mea. Non mei soluta persius, ad iracundia persecuti his. Eos legendos disputando at, mel postulant voluptatibus ne, ipsum mediocrem repudiare ea quo. Ut est ponderum electram, nam omittam suscipit verterem ea. At quo epicurei honestatis definitionem, his detracto salutatus in.

About Tethys

Powered by ckan

Language: English

Management Tool for Users

The image displays three screenshots of the TETHYS Management Tool interface, illustrating its user-friendly design and functionality.

Screenshot 1: General Characteristics

This screenshot shows the "General Characteristics" step of the tool. It includes sections for "Mountain Dell Reservoir Characteristics" and "Little Dell Reservoir Characteristics", each with input fields for Capacity, Initial Volume, and Dead Pool, all measured in ac-ft. A "Need Help?" section allows users to write explanations or links to help pages. Navigation buttons at the bottom include "Cancel", "Next: Set Inflow Rates", and "Back: Set General Characteristics".

Screenshot 2: Inflow Rates

This screenshot shows the "Inflow Rates" step. It displays monthly inflow rates for "Mountain Dell" from January to December. The rates are as follows:

Month	Inflow Rate
January	1.1
February	1.3
March	2.1
April	2.6
May	1
June	1
July	1.5
August	1.5
September	1.8
October	1.6
November	0.4
December	2.1

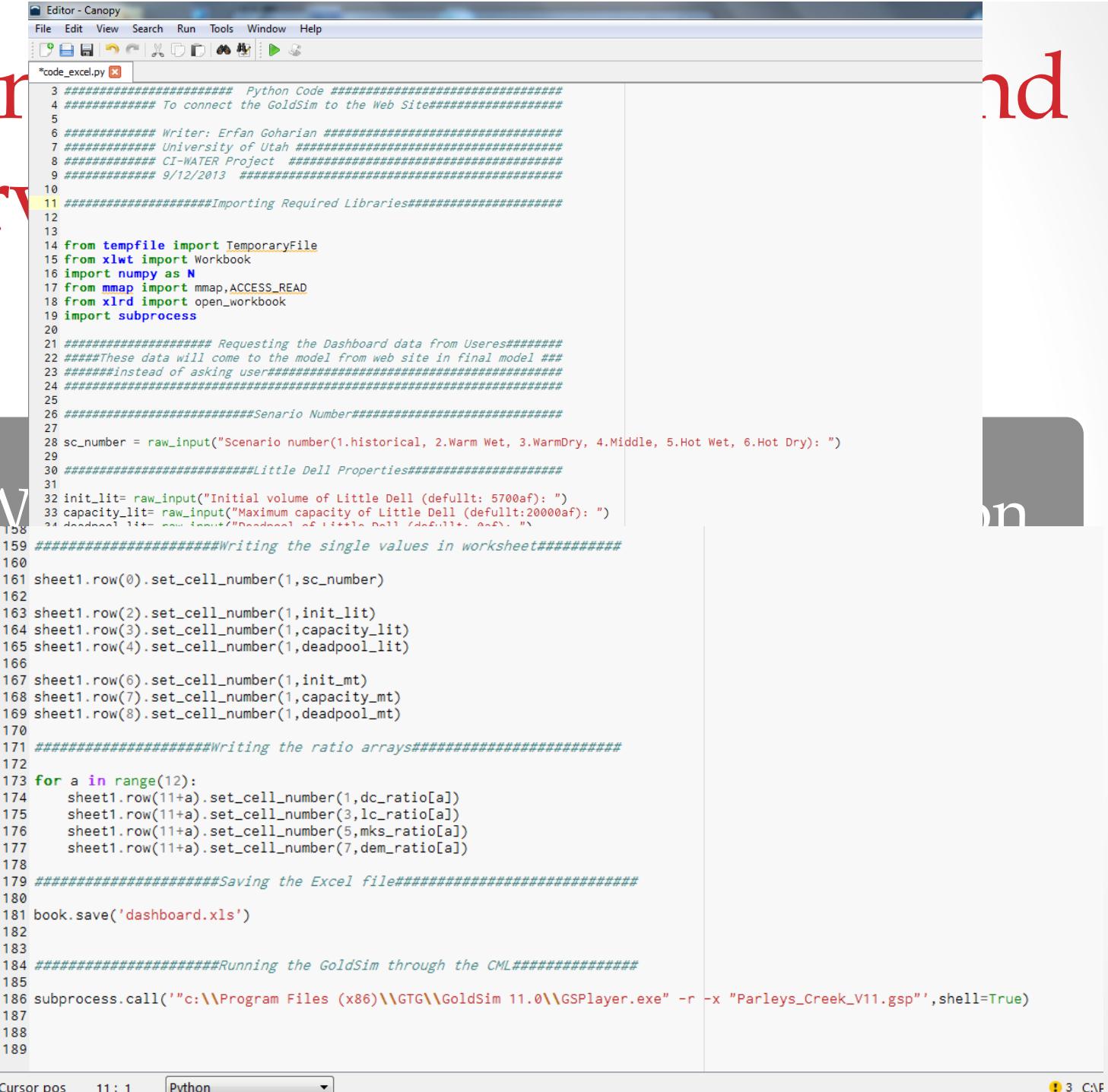
A "Need Help?" section is present, and navigation buttons include "Cancel", "Next: Set Demand Rates", and "Back: Set Inflow Rates".

Screenshot 3: Climate Scenario

This screenshot shows the "Climate Scenario" step. It features a dropdown menu for "Climate Scenario" set to "Hot Dry" and a checkbox for "Historical Run". Navigation buttons include "Cancel", "Back: Set Demand Rates", and "Finish".

Cloud Server

With
In
Mind

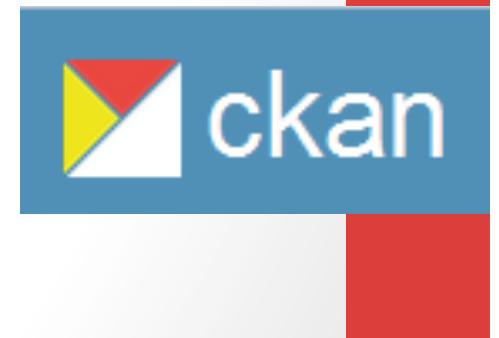


The screenshot shows the Canopy Python IDE interface with a script named "code_excel.py" open. The code is a Python script designed to interact with a GoldSim model via a web site. It uses various Python libraries like tempfile, xlwt, numpy, mmap, and xlrd to handle file operations and data conversion. The script prompts the user for a scenario number, reads initial values for Little Dell properties, and then writes these values along with ratio arrays into an Excel file named "dashboard.xls". Finally, it runs the GoldSim model through a CML command.

```
Editor - Canopy
File Edit View Search Run Tools Window Help
code_excel.py x
3 ##### Python Code #####
4 ##### To connect the GoldSim to the Web Site#####
5
6 ##### Writer: Erfan Goharian #####
7 ##### University of Utah #####
8 ##### CI-WATER Project #####
9 ##### 9/12/2013 #####
10
11 #####Importing Required Libraries#####
12
13
14 from tempfile import TemporaryFile
15 from xlwt import Workbook
16 import numpy as N
17 from mmap import mmap,ACCESS_READ
18 from xlrd import open_workbook
19 import subprocess
20
21 ##### Requesting the Dashboard data from Useres#####
22 #####These data will come to the model from web site in final model #####
23 #####instead of asking user#####
24 #####
25
26 #####Scenario Number#####
27
28 sc_number = raw_input("Scenario number(1.historical, 2.Warm Wet, 3.WarmDry, 4.Middle, 5.Hot Wet, 6.Hot Dry): ")
29
30 #####Little Dell Properties#####
31
32 init_lit= raw_input("Initial volume of Little Dell (defullt: 5700af): ")
33 capacity_lit= raw_input("Maximum capacity of Little Dell (defullt:20000af): ")
34 deadpool_lit= raw_input("Deadpool of Little Dell (defullt: 0af): ")
35
36 #####Writing the single values in worksheet#####
37
38 sheet1.row(0).set_cell_number(1,sc_number)
39
40 sheet1.row(2).set_cell_number(1,init_lit)
41 sheet1.row(3).set_cell_number(1,capacity_lit)
42 sheet1.row(4).set_cell_number(1,deadpool_lit)
43
44 sheet1.row(6).set_cell_number(1,init_mt)
45 sheet1.row(7).set_cell_number(1,capacity_mt)
46 sheet1.row(8).set_cell_number(1,deadpool_mt)
47
48 #####Writing the ratio arrays#####
49
50 for a in range(12):
51     sheet1.row(11+a).set_cell_number(1,dc_ratio[a])
52     sheet1.row(11+a).set_cell_number(3,lc_ratio[a])
53     sheet1.row(11+a).set_cell_number(5,mks_ratio[a])
54     sheet1.row(11+a).set_cell_number(7,dem_ratio[a])
55
56 #####Saving the Excel file#####
57
58 book.save('dashboard.xls')
59
60
61 #####Running the GoldSim through the CML#####
62
63
64 subprocess.call('c:\\Program Files (x86)\\GTG\\GoldSim 11.0\\GSPlayer.exe' -r -x "Parleys_Creek_V11.gsp",shell=True)
65
66
67
68
69
```

Comprehensive Knowledge Archive Network (CKAN)

- Web-based open source data management system for the storage and distribution of data
- CKAN provides a rich API for querying and accessing dataset information.
- Publish and Manage Data
- Search and Discovery
- Geospatial
- Community
- Visualize
- Themable
- Store
- History
- API



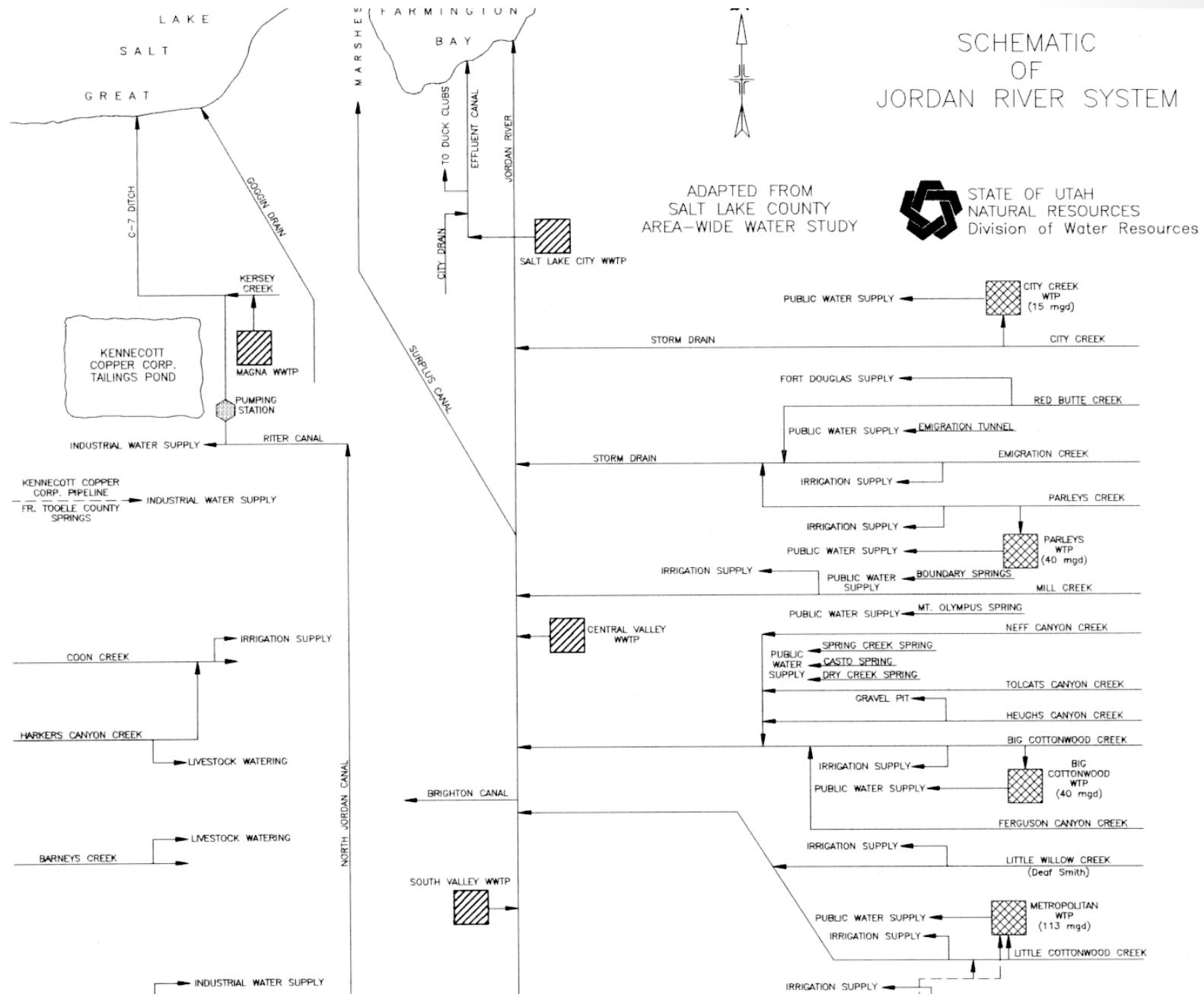
Visualize

Supports:

- line,
- spline,
- area,
- column,
- bar,
- pie,
- Scatter
- Etc...



SCHEMATIC OF JORDAN RIVER SYSTEM



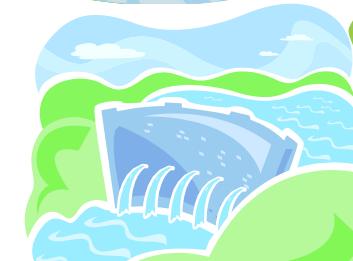
Farmington Bay



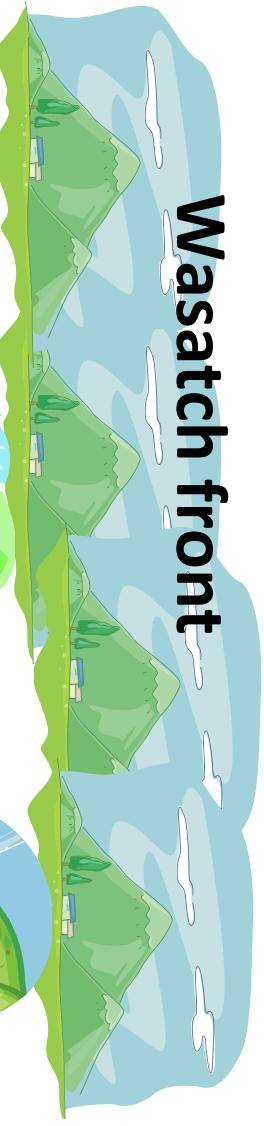
Jordan River



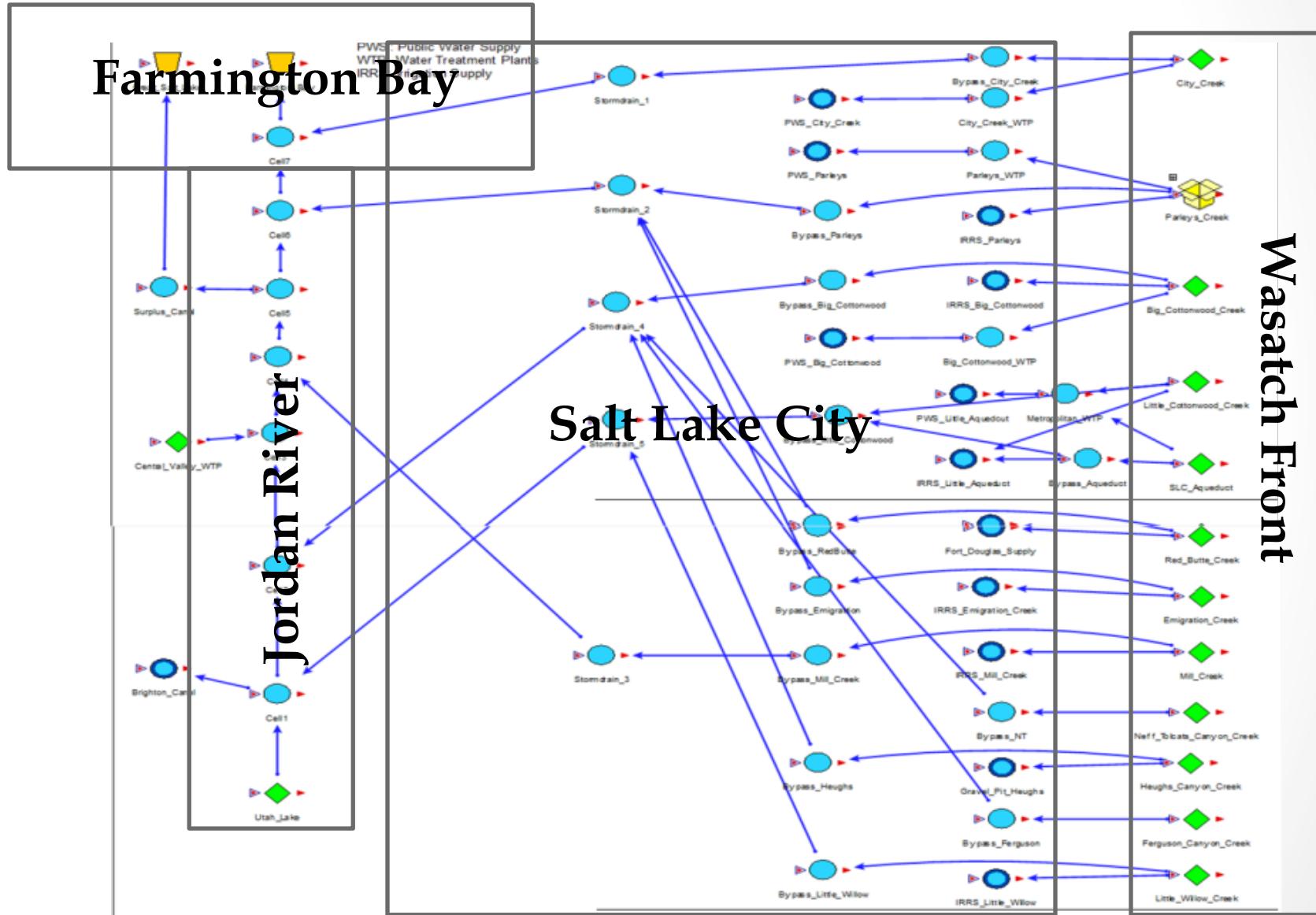
Salt Lake City

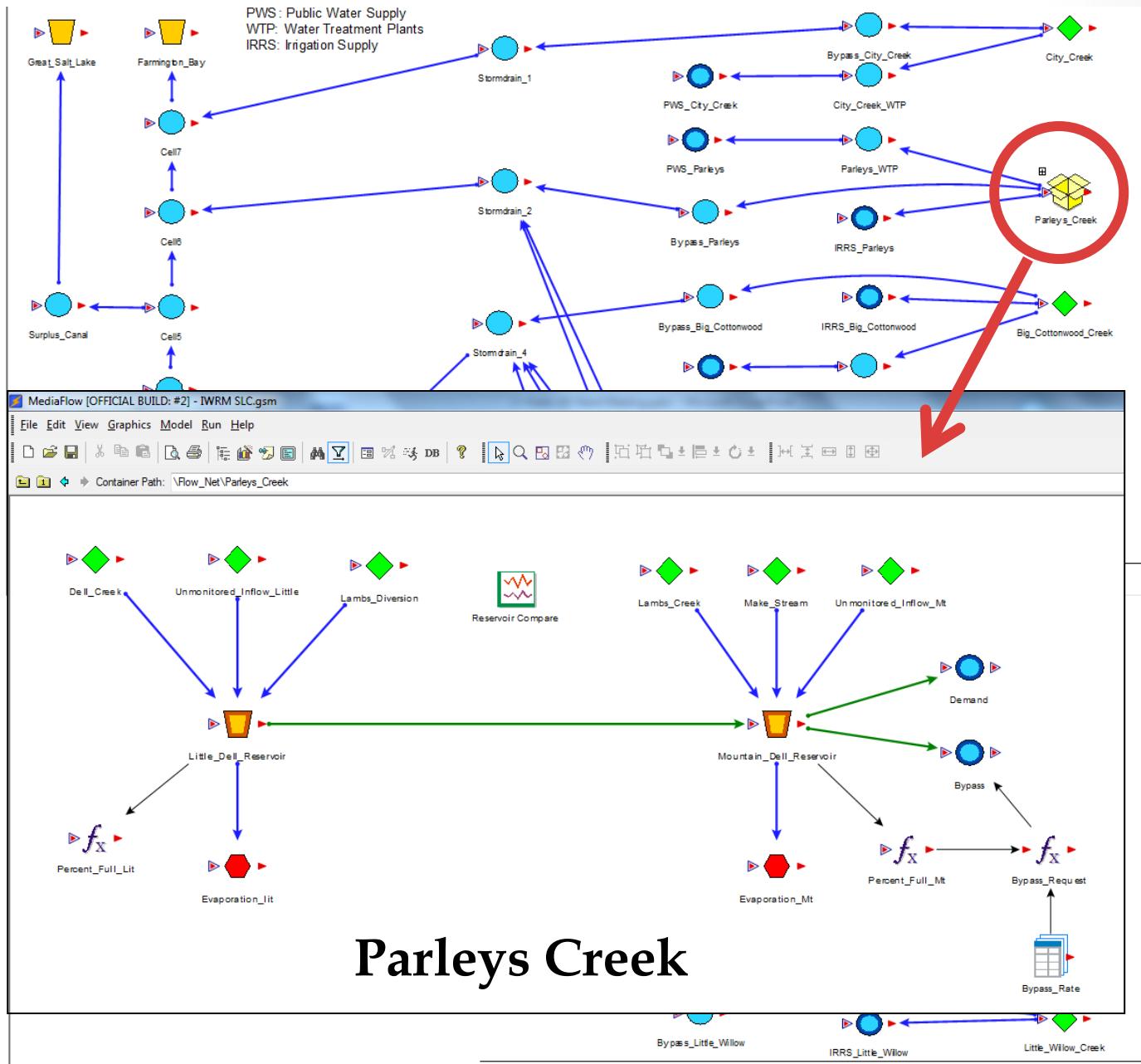


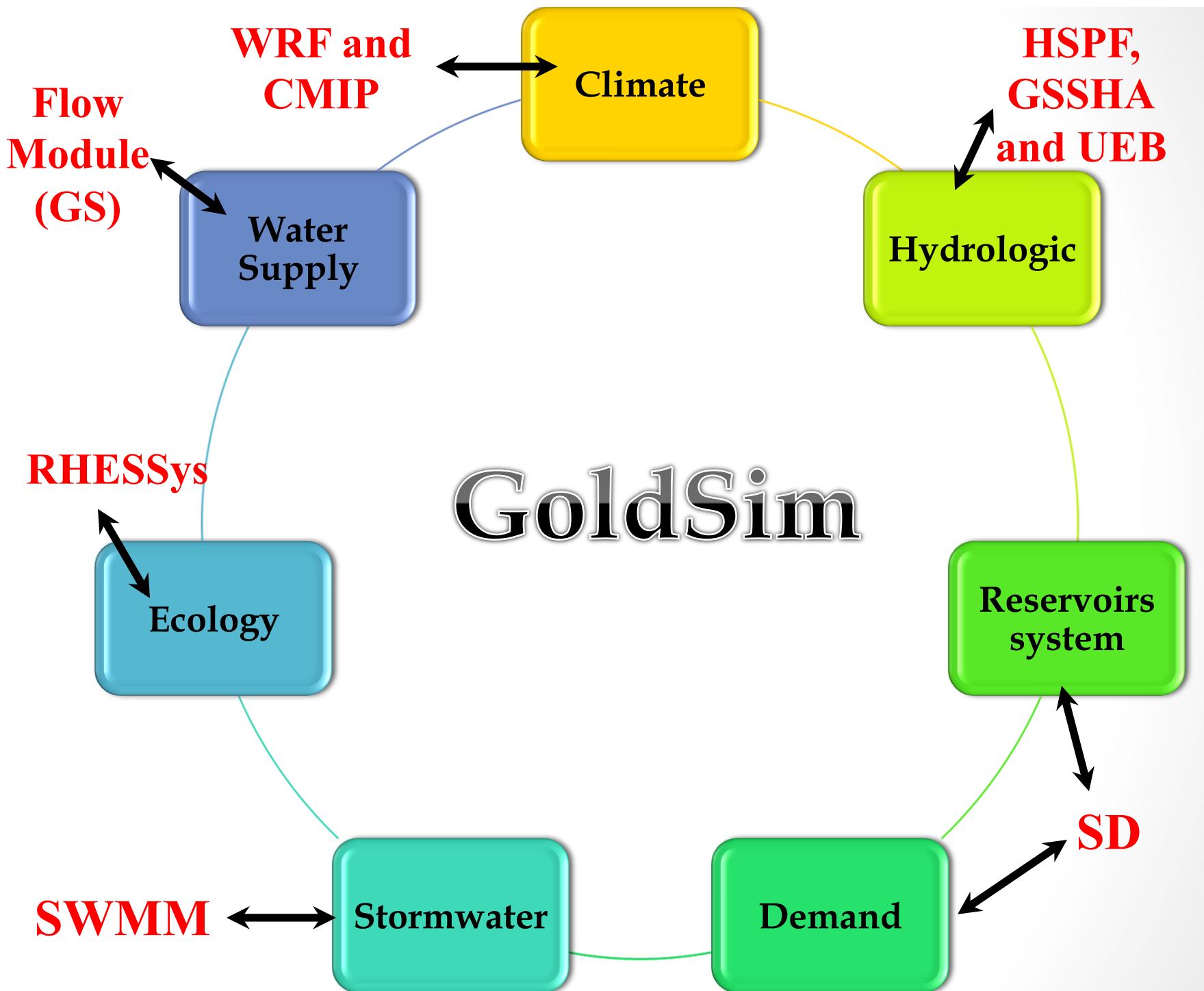
Wasatch front



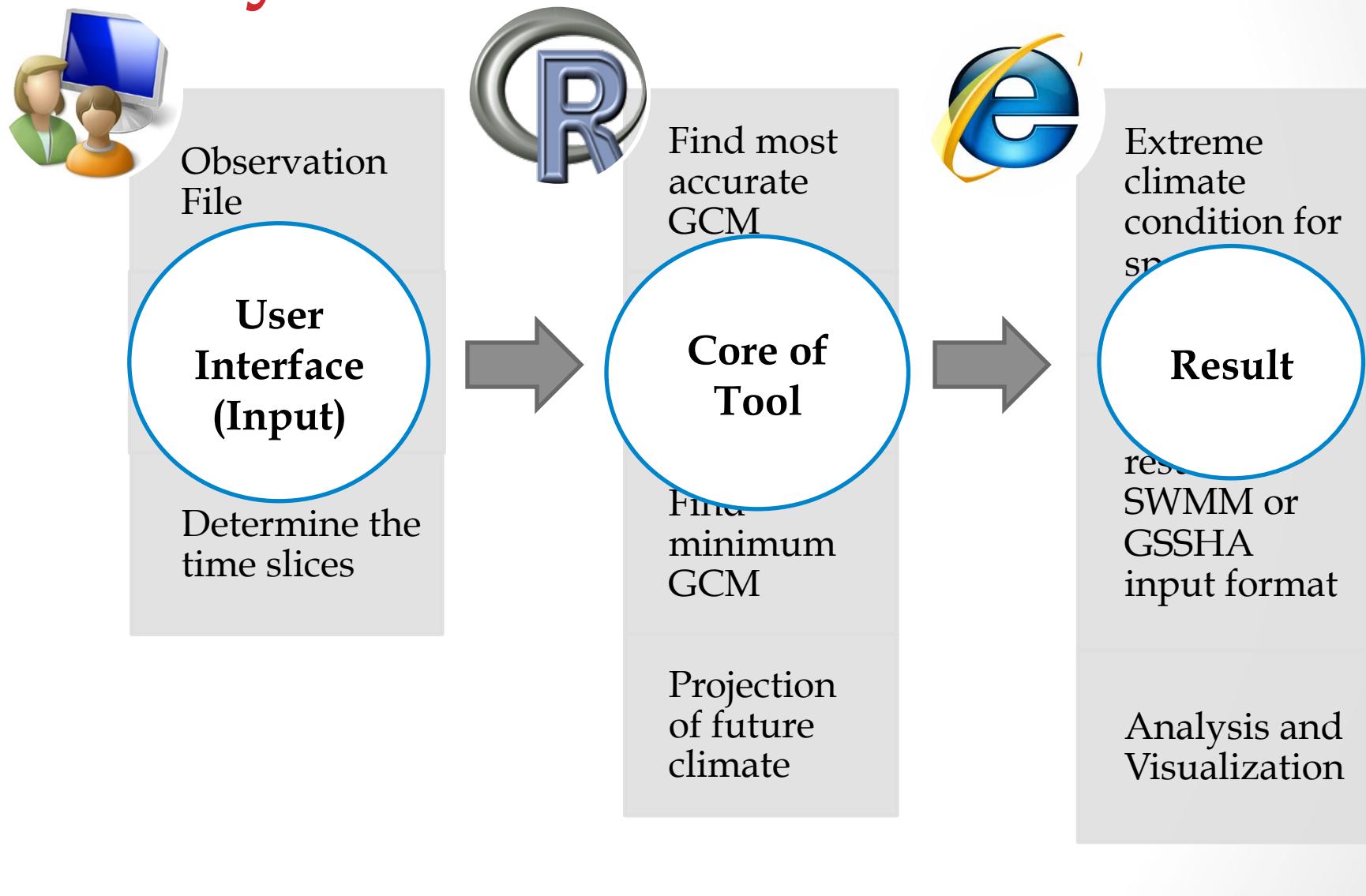
Wasatch Integrated Water Model







Climate Data Access Tool for Analysis of Water Resources



Method

- Download climate data for the required grids(daily and monthly) for all models in NetCDF
(NOT AUTOMATED)
- Write R code to calculate which model predictions are closest to the observations
- Determine monthly change factors for every model
- Use these change factors to determine which models project extreme conditions

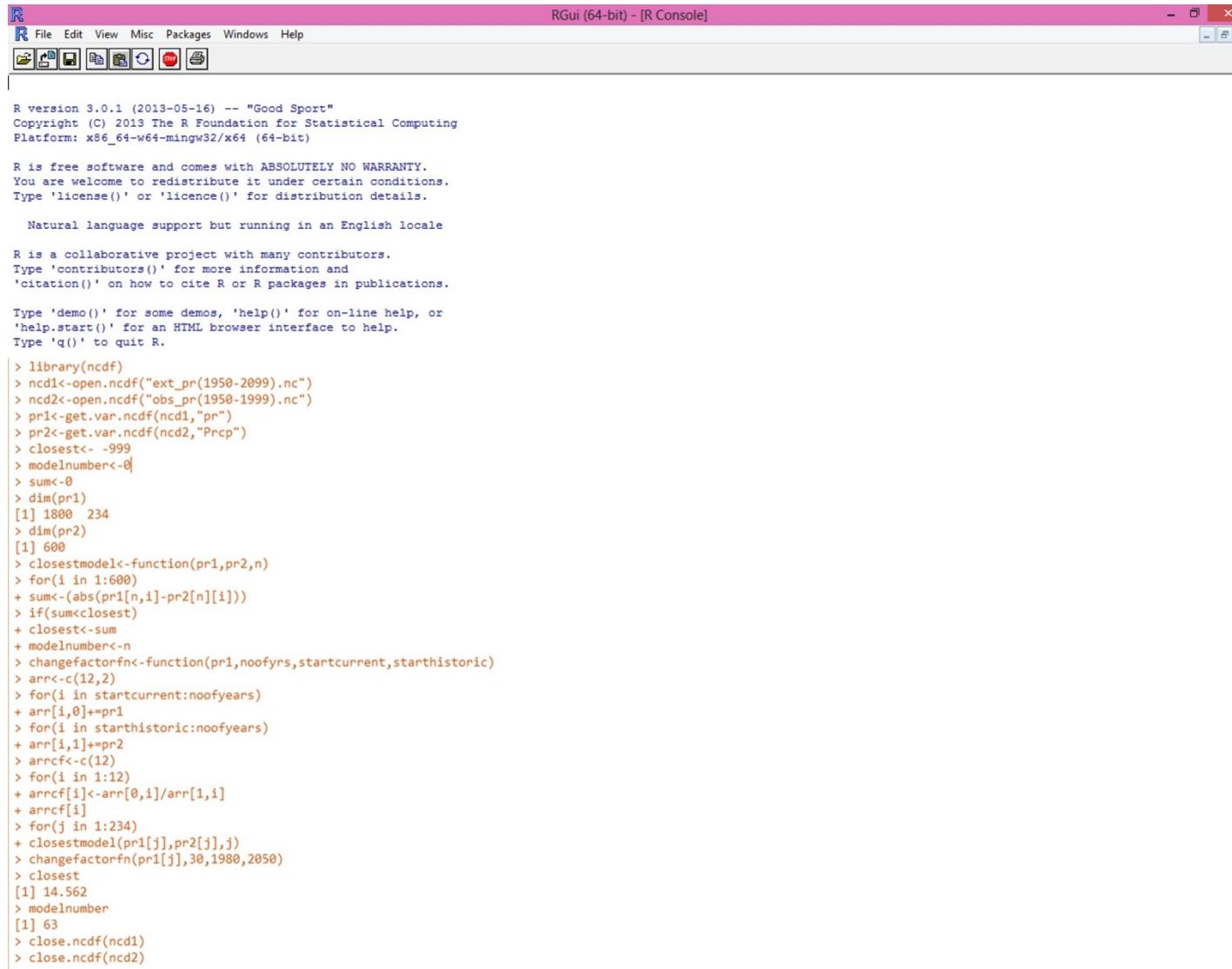
Potential Climate Analysis Tools

- Intensity : Mean, Maximum, Moving Average, ...
- Events and Duration: Average Duration, Interevent, mean event Depth, ...
 - Time series
 - Hourly
 - Weekday
 - Monthly
 - Annual
- Frequency Analysis: Probability distribution, return period, Exceedence probability, ...
- Drought: Dry proceeding days, longest drought, ...
- Spatial Analysis
- Indices: Standard Precipitation Index, Palmer Drought Index, Extreme Precipitation Index
- etc

Main Idea

- This package can determine which model (GCM) is most appropriate (based on historical projection and observation) for each part of the USA and prepare an assembled model for future use
- This package can present a good estimation of future extreme climate condition for each part of the USA and prepare an assembled model for future use. (now we are working on three different parts: Salt Lake City, NYC and Toledo)
- The result can be used for different water models like SWMM, GSSHA and HSPF

R-Code



The screenshot shows the RGui (64-bit) - [R Console] window. The menu bar includes File, Edit, View, Misc, Packages, Windows, and Help. The toolbar contains icons for file operations like Open, Save, Print, and Help. The console area displays the R startup message, followed by a series of R commands and their outputs. The code involves reading two netCDF files ('ext_pr(1950-2099).nc' and 'obs_pr(1950-1999).nc'), extracting precipitation variables (pr1 and pr2), calculating closest model numbers, and performing a change factor calculation between 1950 and 2050.

```
R version 3.0.1 (2013-05-16) -- "Good Sport"
Copyright (C) 2013 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

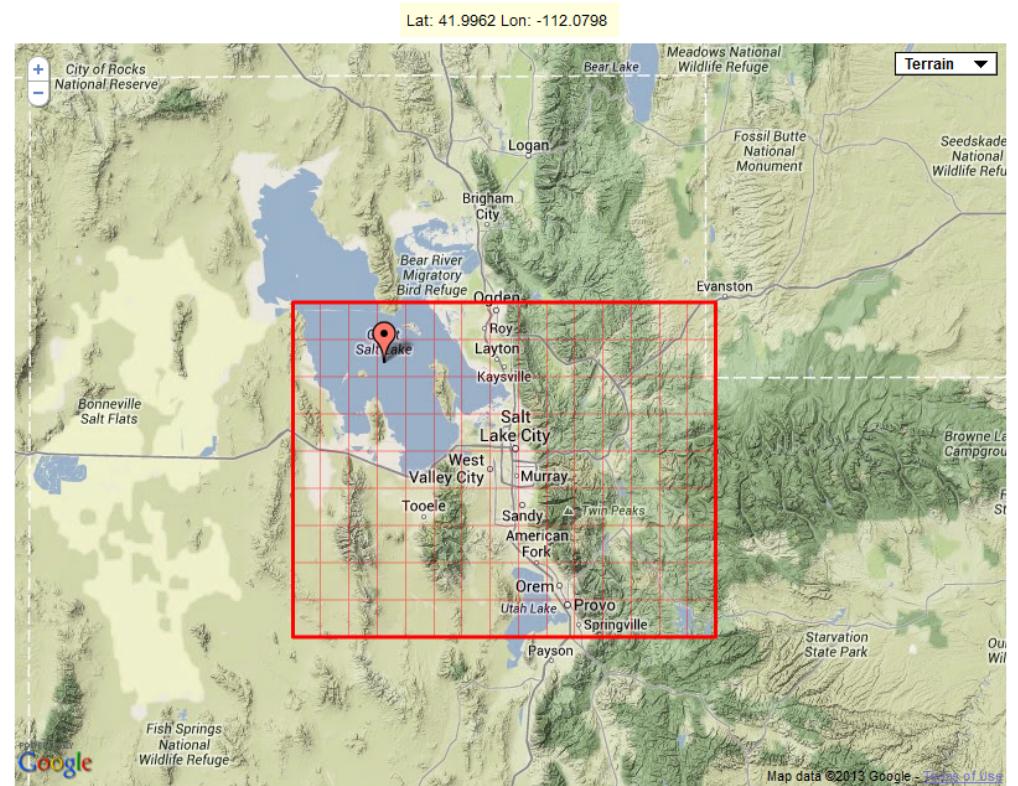
> library(ncdf)
> ncd1<-open.ncdf("ext_pr(1950-2099).nc")
> ncd2<-open.ncdf("obs_pr(1950-1999).nc")
> pr1<-get.var.ncdf(ncd1,"pr")
> pr2<-get.var.ncdf(ncd2,"Prcp")
> closest<- -999
> modelnumber<-0
> sum<-0
> dim(pr1)
[1] 1800 234
> dim(pr2)
[1] 600
> closestmodel<-function(pr1,pr2,n)
> for(i in 1:600)
+ sum<-abs(pr1[n,i]-pr2[n][i])
> if(sum<closest)
+ closest<-sum
+ modelnumber<-n
> changefactorfn<-function(pr1,noofyrs,startcurrent,starthistoric)
> arr<-c(12,2)
> for(i in startcurrent:noofyears)
+ arr[i,0]+=pr1
> for(i in starthistoric:noofyears)
+ arr[i,1]+=pr2
> arrcf<-c(12)
> for(i in 1:12)
+ arrcf[i]<-arr[0,i]/arr[1,i]
+ arrcf[i]
> for(j in 1:234)
+ closestmodel(pr1[j],pr2[j],j)
> changefactorfn(pr1[j],30,1980,2050)
> closest
[1] 14.562
> modelnumber
[1] 63
> close.ncdf(ncd1)
> close.ncdf(ncd2)
```

Results



Climate Tool

- Developing the Climate tool for the first case study, Salt Lake City for precipitation (1950-2100) in monthly and daily mode.
- Using disaggregation methods to produce result in hourly scale.



Accomplishments

Conferences:

- Evaluating the reliability of a water supply system based on system dynamics modeling: A Case Study of Salt Lake City, Utah. **EWRI Congress 2013 – Cincinnati, OH.**
- Assessing climate change risks to a municipal water supply: A pilot project incorporating downscaled climate projections, operational hydrologic modeling, and a systems planning model. **2013 Spring Runoff Conference.**
- Assessing climate change risks to a municipal water supply: A pilot project incorporating downscaled climate projections, operational hydrologic modeling, and a systems planning model. **2013 CPASW Climate Prediction Applications Sciences Workshop.**
- Strong C. Future precipitation and snowpack along the Wasatch Range, **American Water Resources Association Utah Section Annual Conference, Salt Lake City, Utah, 14 May 2013.**

Journal paper:

- Bardsley, T., Wood, A., Hobbins, M., Kirkham, T., Briefer, L., Niermeyer, J., and Burian, S. “Planning for an uncertain future: Climate change sensitivity assessment towards adaptation planning for public water supply.” *Earth Interactions* (in press).

Future

Conferences:

- Web-Based Reservoirs System Management Tool based on Dynamic Simulation for Water Utilities in Salt Lake City, Utah - **EWRI Congress 2014 - Portland, Oregon. (Submitted)**
- Using Dynamic Simulation to Support Integrated Water Resources Management in Cities - **EWRI Congress 2014 - Portland, Oregon. (Submitted)**
- Integrated Water Resource Management Tool based on Extreme Climate Change Impact. **HIC 2014 - New York, USA. (Not submitted)**

Proposal:

- NSF Hydrologic Sciences, Fall 2013, Climate-Vegetation Impacts on Hydrologic Response

Journal paper:

- Strong C, Kochanski A, Crosman E. A slab model of the Great Salt Lake for regional climate simulation. *Journal of Advances in Modeling Earth Systems*, in prep.
- Impact of climate change on water resources (Salt Lake City, Utah). (in prep)

Any Question?

Thank you