

### Probabilistic Reservoir Inflow Forecasting

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## Introduction

Need for hydrologic prediction that incorporates risk

Use a probabilistic prediction model

Test this model on a real site

Calculate risk based on current conditions

Evaluate the effectiveness of the current operating scheme

Similar to the AHPS – Advanced Hydrologic Prediction Service created by the National Weather Service (<u>https://water.weather.gov/ahps</u>)



## Model Process Overview

Predict risk of flood due to uncontrolled flows over spillway

14-day weather forecast

Stochastic weather generator (for > 14 days)

Transition from weather forecast to long-term stochastic weather generator

Include snowmelt and hydrologic runoff modeling

Input current conditions and planned operating scheme

Predict risk based on operating scheme

Use GoldSim as the modeling platform



# Model Platform - GoldSim

What is GoldSim?

- Highly graphical, object-oriented
- Generic and flexible (like a spreadsheet or programming language)
- Dynamic and probabilistic simulation

GoldSim born in early 1990s

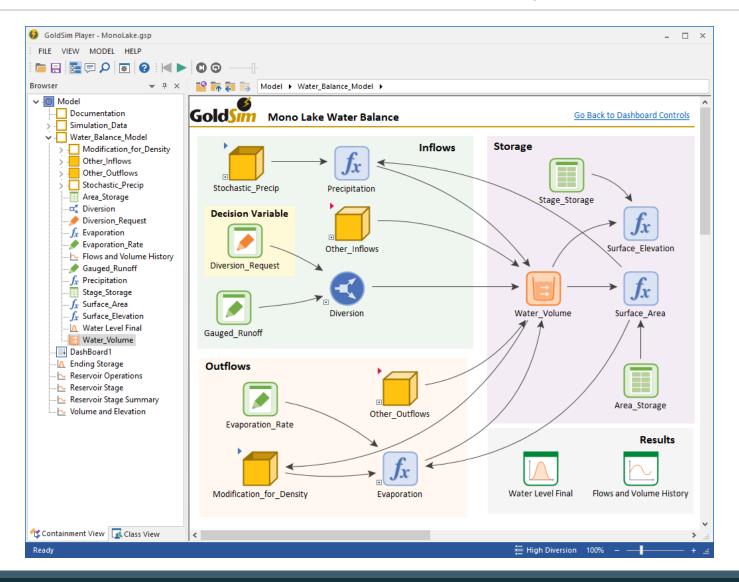
- Golder Associates
- GUI built in 1998
- Became GoldSim in 2004

Large and diverse user base

- Over 600 organizations in 54 countries worldwide
- Over 2000 current users
- Applications in water, mining, radwaste, energy, economics, and risk



## GoldSim Interface Example



### GoldSim

# Application – Little Dell Reservoir

Located in the Wasatch mountains east of Salt Lake City, Utah

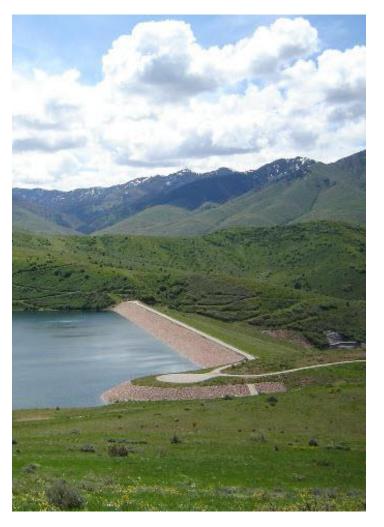
Dam is operated by SLCPU

Provides flood control and drinking water supply

Constructed finished in 1993

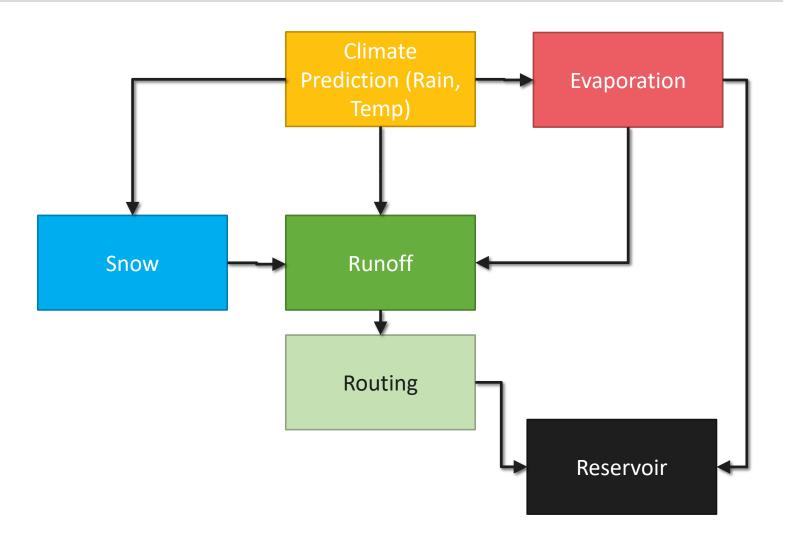
Capacity = 20,500 AF

Earthfill dam with height = 224 ft





## Model Components





# Model Components

### Precipitation & Temperature

- 14-day forecast with correlation to watershed
- Markov based simulator (WGEN)

### Evaporation

• FAO Penman-Monteith

### Snowmelt

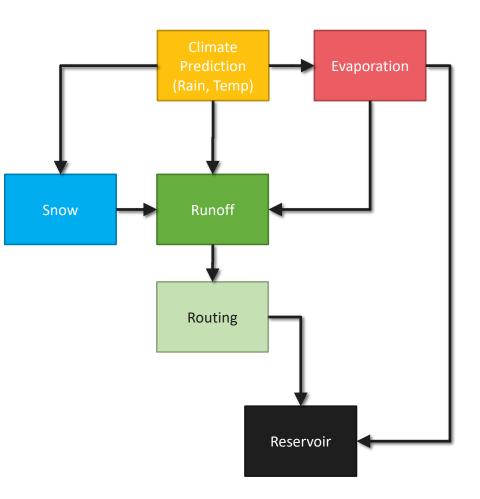
Snow accumulation and ablation model (Snow17)

**Runoff and Routing** 

• Australian Water Balance (AWBM)

### Reservoir

- Dynamic, level pool simulator
- Orifice controlled discharge
- Weir flow for spillway





## Input Data

Historic Precipitation, Temperature, Snow pack (SWE)

- Parley's Summit and Lookout Peak Snotel Gages
  - $\circ$   $\,$  Located within watershed and very near
- Operated by NRCS
- 1981 Current data

Historic streamflow

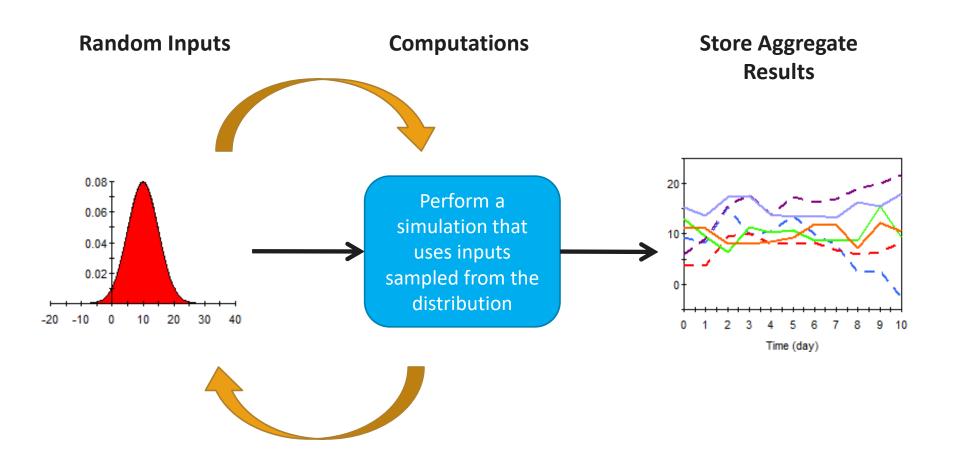
• Salt Lake City Public Utilities (1980 – 2014)

### Forecast

- <u>www.weather.com</u> (14-day)
- Chance of rain
- Min/max temperature
- Correlation between SLC Snotel sites used
- Calibrated WGEN model



## Monte Carlo Simulation

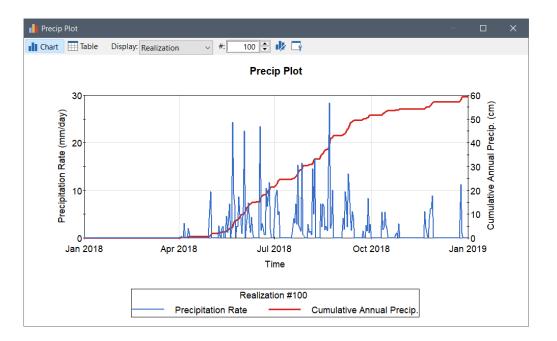




## Markov Process Rain Simulator

Inputs:

- Probability of being wet (can change through the year)
- Average length of wet periods
- Average monthly rain depth

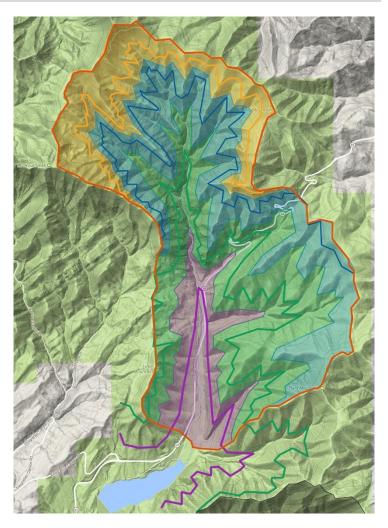




## Delineate Watershed

**Elevation zones** 

More is not always better





## Manual Results Analysis

### GoldGm - Comment to Reservoir Application v1 511 new Þ FILE FOIT VIEW GRAPHICS MODEL RUN HELP + 0 × 😰 🏹 🟹 🐚 Model + System\_Model + Watershed\_Runoff + Calibra Forecast\_Runo Model\_Inputs SWE Calibratio 115 📶 Chart 🔟 Table Display: Realization 🗸 4: 1 🔅 🥼 📑 🚹 Chart Table Display: Realization 🗸 #: 1 🗄 🗗 Snow Water Equivalent (SWE) Calibration Surface Stores **Cumulative Exces** 180 Elev\_Ref 160 Excess Wate Excess\_Wate 140 History 10 History 3 History 6 120 Period Sur **f** Precipitation 100 Snow Calibration Snow17 Snow17 Depth 80 SWE\_TS fr Tavg Watershed\_Runoff 60 C01 C02 Calibr Cumulative\_Runof Cumulative Runoff 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2004 2005 2006 2007 2008 2009 2010 2012 2013 2014 Dell\_Creek\_TS 2014 2011 Flow Component Time Time History 2 Lambs\_TS Parleys\_TS E R03 Realization #1 Realization #1 Zone[2] ---- Measured Surface Store Zone Runoff Zone[1] - 1 Weather Generator di Calibration Plot Flow eservoir Plot di Chart Table Display Realization - # 1 C db Cy 📶 Chart Table Display: Realization 🗸 🐮 1 🕄 🥼 🖓 Snowpack and Ten Calibration Plot Flow Components 200 16 12 £ 120 (a) Ð ete 100 40 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 Time Time Realization #1 Realization #1 Measured ----- Simulated Cumulative Meas. Cumulative Sim Surface01 ---- Baseflow01 ---- Surface02 ---- Baseflow02 Containment Vi 💽 Class View



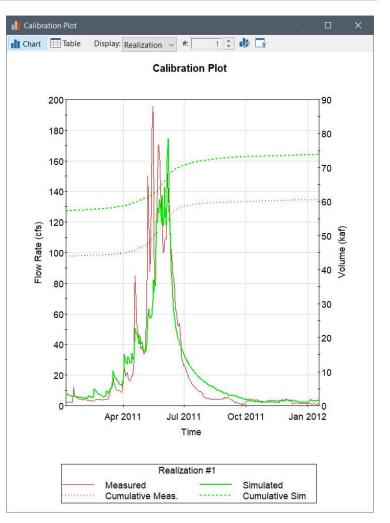
## Automate Calibration

Compare simulated results to measured data

### RMSE

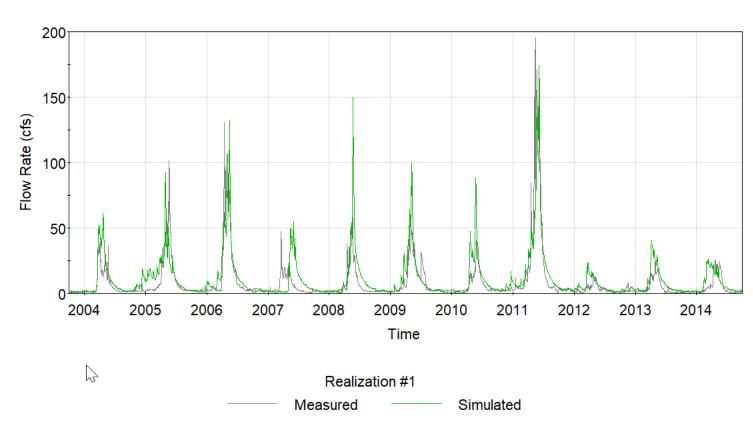
 demonstration using Basic Runoff mass balance model

R^2





## Final Calibration







# Forecast Model (parts added)

### Model components:

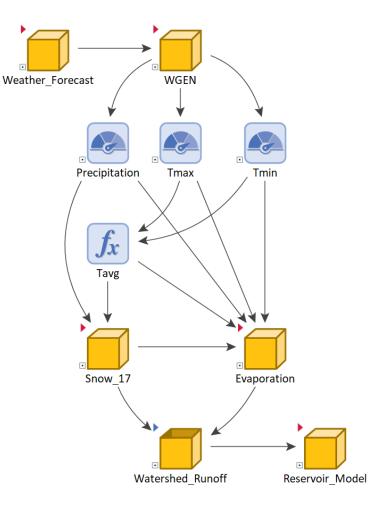
- Weather Forecast
- WGEN

### Uncertainty:

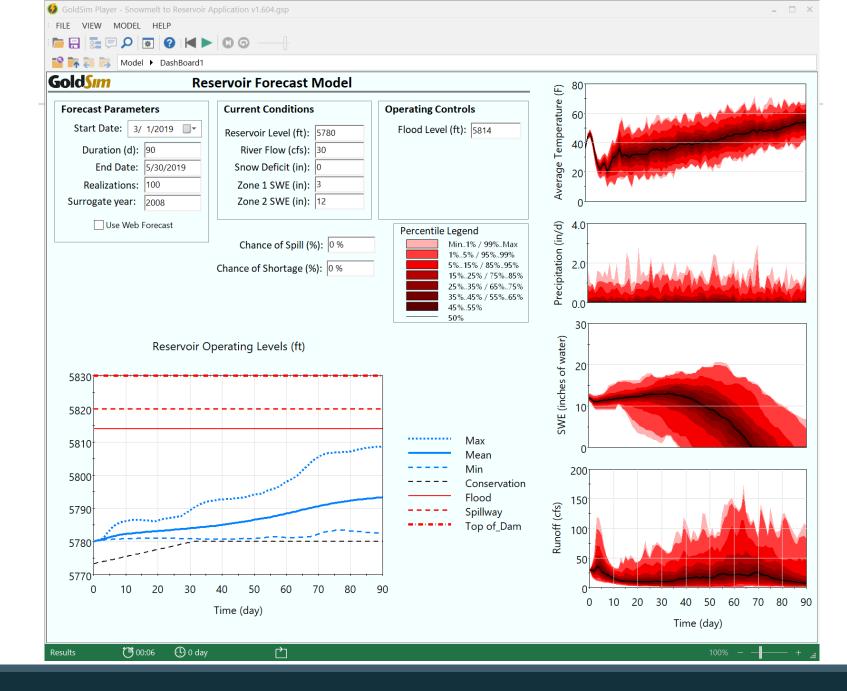
- Static inputs (albedo, recessions, loss factors, etc.)
- Dynamic inputs "Stochastic" (baseflow, chance of rain, temperature)

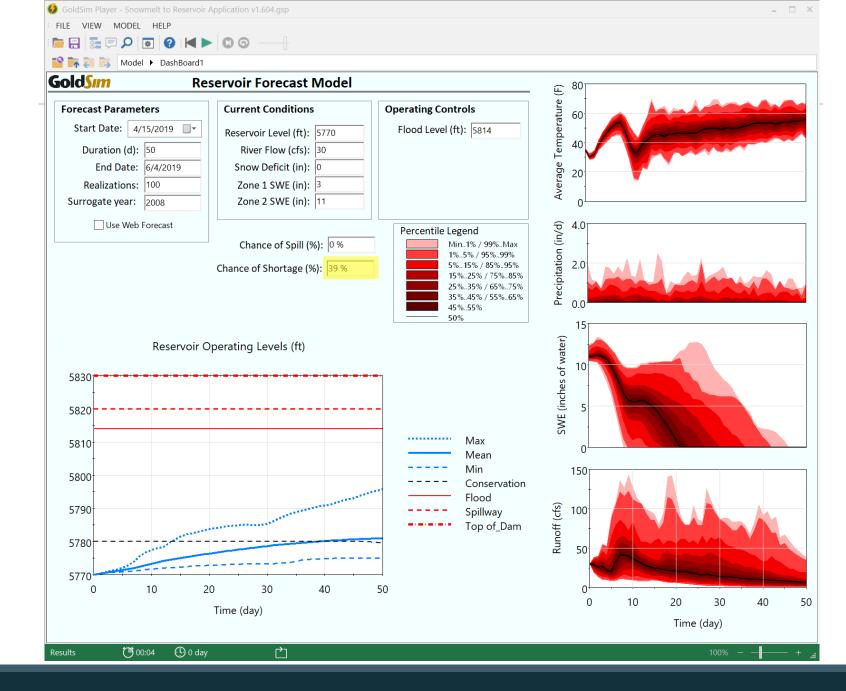
Monte Carlo simulation

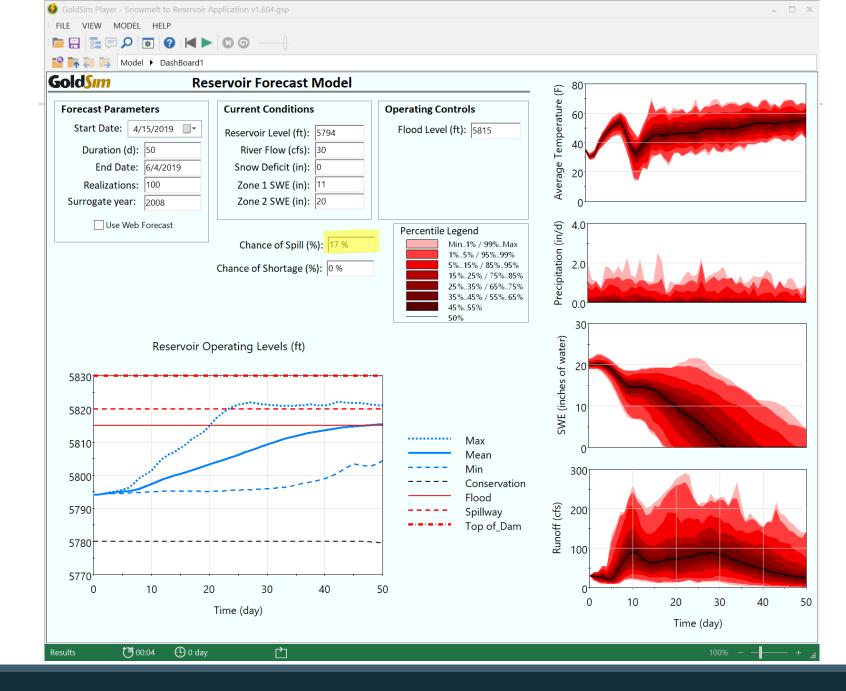
Calculate risk of spillway flow and supply shortage













## Conclusion

Calibration

Robust logic

Provides value in guiding operating decisions

Risk allows for more informed decision-making





## Questions?