Development of a Dynamic Reservoir Flow Model: Sensitivity of Policy Impacts to Changing Hydrologic Conditions

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Motivation

POLICY FORUM

CLIMATE CHANGE:
Stationarity Is Dead: Whither Water Management?
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Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.
What is stationarity?

“A stationary process has the property that the mean, variance and autocorrelation structure do not change over time.”

http://www.itl.nist.gov/div898/handbook/pmc/section4/pmc442.htm
Many water policy, management and infrastructure design decisions rest on the **stationarity assumption**

There is considerable **uncertainty** surrounding the effects of climate change on precipitation and streamflow in the northeast region

Preparation for and **adaptation to potential change** must include exploring the sensitivity of desired outcomes to non-stationarity in hydrologic parameters
Objective

Design a modeling tool that will allow users to investigate how the outcomes of reservoir release policies may be affected by non-stationarity in input streamflow statistics.
Today’s Talk

I. Main components of the basic reservoir flow model
II. Design goals for hydrograph alteration component
III. Implementation
IV. Testing, refinement
V. Example application: Pseudo-Climate Change
VI. Future Work
I. The CTIWR Reservoir Model
GUI: Basic Runtime Options

CTWR RESERVOIR MODEL: USER INTERFACE
Version 8B, March 26, 2008

IMPORTANT! Make sure the number of timesteps in the "Run Specs" matches the number in your dataset.

Step 1. Choose model RUNTIME OPTIONS

Step 3. OVERRIDE imported parameters if necessary

Step 4. Set SENS! SPECS if desired

Step 5. RESTORE Graphs & Tables

Step 6. RUN the model

Step 7. VIEW/EXPORT OUTPUT

MAIN MENU

SET MODEL RUNTIME OPTIONS

PRECIPITATION

Reservoir Type: Gen
Reservoir Type: Custom
Leakage: No Leakage
Leakage: Use Leakage

Evaporation

Evaporation Type: No Evap
Evaporation Type: DPH

Demand

Average Demand
Average Daily Demand

Reservoir Release Rules

Release Rule[NoResRelease]
Release Rule[FreeCoreNoFloor]
Release Rule[FreeCoreFloor]
Release Rule[FreeCoreRandomFloor]
Release Rule[FixedCoreNoFloor]
Release Rule[FixedCoreFloor]
Release Rule[FixedCoreRandomFloor]
Release Rule[FixedCoreNoAug]
Release Rule[FixedCoreFloor]
Release Rule[FixedCoreRandomFloor]
Release Rule[FixedCoreNoAug]
Release Rule[FreeFloor]
Release Rule[FixedFloor]
Release Rule[Adaptive]
Release Rule[Random]

RULE NOTE: "PreDefFloor" Monthly fractions are currently set to .75. These should be reconfigured before this rule is used.
GUI: Input Parameters
II. Design goals for hydrologic alteration component

EX: “More total annual flow, higher winter flows, lower summer flows, more variability”

- Must be able to change both the overall series statistics, individual monthly statistics, or both simultaneously
- Must be able to manipulate separate statistical parameters independently or simultaneously
- Must be able to apply constant changes, trends or both
III. Implementation

Initial Signal Decomposition: Mean, Standard Deviation, Random Process

\[ Q_i = \bar{Q} + q_i \]

\[ Q_i = \bar{Q} + S X(t) \]

\[ \frac{Q_i - \bar{Q}}{S} = X(t) \]

\[ Q_i = \bar{Q}_{M_i} + S_{M_i} X_{M_i}(t) \]

\[ Q_i = \alpha_{M_i} \bar{Q} + \beta_{M_i} S X_{M_i}(t) \]

\[ Q_i = \bar{Q}_{J_i} + \beta_{J_i} S X_{J_i}(t) \]
Four pre-calculated altered, statistical parameters:

- Monthly means
- Monthly standard deviation
- Series means
- Series standard deviations

\[
\begin{align*}
\alpha'_{M_t}(t) &= (a_0 + a_1 t) \alpha_{M_t} \\
\beta'_{M_t}(t) &= (b_0 + b_1 t) \beta_{M_t} \\
\bar{Q}'(t) &= (c_0 + c_1 t) \bar{Q} \\
S'(t) &= (d_0 + d_1 t) S
\end{align*}
\]
Internal Processing Steps

- **Step 1.** Extract the random process using the pre-calculated statistical parameters
- **Step 2.** Alter the statistical parameters
- **Step 3.** Reconstruct a hydrograph using ORIGINAL random process and ALTERED statistical parameters
GUI: Hydrograph Alteration

GENERATING ALTERED INPUT HYDROGRAPHS:

ALTED_PARAM = (Intercept + FirstOrder * t)' ORIG_PARAM

Click on "Altered" to use altered input stream.

NOTE: To run the input stream "as is", without altering it, use "EQUATION ON". This will keep the intercepts at 1 and the first order terms at 0.

The monthly controls have 2 lists per parameter. Click on the triangle to see the other list.
IV. Testing the Alteration Process

Test Questions

- Is the intended parameter scaled appropriately?
- Are there any significant, unintended side effects?
- Will this work on actual streamflow data?
Alteration Test Scenarios

- Intercept terms only, not trend terms
- Data: Normal(1,1), Hubbard Brook 40 yr
- Scaled Series Mean
- Scaled Series Standard Deviation
- Scaled “March” Mean
- Scaled “September” Standard Deviation
- “Climate Change:”
  - Overall mean: 1.05
  - Monthly means: Oct-Mar, 1.1, Apr-Sep, 0.9
  - Overall standard deviation: 1.2
V. Effects of Alteration on Flow: Pseudo-Climate-Change Scenario

HUBBARD BROOK: Release Rule: Fixed Constant Augmented, .2cfs/m
ALTERATION: Series Mean: 1.05, Series SD: 1.3
“Wet” Mo Means: 1.1 “Dry” Mo Means: 0.8

NO CHANGE IN SAFE YIELD FOR STORAGE RATIO .6
VII. Future work

- **Current Approach: Mean, SD:**
  - Finish testing, trend term
  - Decide how to handle negative flows (most likely by doing log transformation)

- **Refined Approach: Stochastic parameterization**
  (ie, autoregressive or similar)

- **Evaluate robustness of release policies in the under different hydrologic alteration scenarios**
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