Simulating Climate Variability and Change for Central Asia Using a Nonhomogeneous Hidden Markov Model

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Introduction

We demonstrate one potential method of using a 8-State, Nonhomogeneous Hidden Markov Model (NHMM) to stochastically generate two future 50 year precipitation series for 110 subcatchments in the Tien Shan region in Central Asia (60-80E, 40-50N). The first is a baseline scenario derived from TRMM Observations (2000-2009) and the second is an IPCC AR4 SRES A2 (2070-2099) experiment trend adjusted scenario.

Methodology

NHMM - Description

The NHMM fits a single model to the 110 subcatchment observed rainfall records. The NHMM introduces a small number discrete rainfall states. Each state has a precipitation distribution for location. Using a mixture model approach for each of the 110 subcatchments, a Delta function represents wet/dry days and a mixture of one or two NHMMs introduces a small number discrete rainfall states. Each state has a precipitation distribution for location. We demonstrate one potential method of using a 8-State, Nonhomogeneous Hidden Markov Model (NHMM) to stochastically generate two future 50 year precipitation series for 110 subcatchments in the Tien Shan region in Central Asia (60-80E, 40-50N). The first is a baseline scenario derived from TRMM Observations (2000-2009) and the second is an IPCC AR4 SRES A2 (2070-2099) experiment trend adjusted scenario.

Step 1 - Baseline Scenario - Derived from TRMM:

Input (Baseline Predictor): 1) TRMM Daily Averaged Observations (2000-2009) for the Tien Shan region, 2) Apply Low Pass Filter (60 Days), 3) Interpolated daily values, 4) Repeat to 10 years, 5) Standardize

Step 2a - GCM Trend Expansion:

WCRP-CMIP3 IPCC AR4 GCM Monthly data (60-80E, 40-50N):
- 20th Century Experiment (20C3M: 1950-1999), 18 Models (56 runs)
- SRES A2 Experiments (SRESA2: 2070-2099), 18 Models (37 runs)

First we define the mean monthly cycle (average values for each month of the year) for the TRMM observations and the GCM 20C3M runs.

Step 2b - GCM Delta Adjusted Scenario:

Input (Delta Adjusted Predictor): 1) TRMM Daily Averaged Observations, 2) Low Pass Filter (60 Days), 3) Delta Adjusted (Monthly, SRES A2, 2070-2099), 4) Interpolated daily values, 5) Repeat to 10 years, 6) Standardize

We discard GCMs that do not reproduce the mean seasonal cycle in the observations. 11 Models highlighted in yellow (Table 1) were used in the final analysis. Defining 20C3M model ensembles for the retained model set, we divide each SRES A2 run by its respective 20C3M to obtain delta change in mean monthly values (Eq. 1).

(1) \[ \delta = \frac{\text{SRESA2} - \text{20C3M \text{ (ensemble)}}}{\text{20C3M \text{ (ensemble)}}} \]

Delta Adjusted = \delta \times \text{Baseline}  

We then average delta values for all SRES A2 model runs. Next we interpolate to daily values and multiply the daily delta values by the baseline predictor deriving the "delta adjusted" predictor (Eq. 2).

\[ \text{NHMM DA Predictor} = \text{NHMM BL Predictor} \times \delta \]

Results

NHMM results were satisfactory and seasonal shifts in precipitation were captured as well as the GCM shifts in future mean monthly cycle.

Conclusion

We demonstrate the ability of NHMM to represent precipitation at the regional level. We also developed one potential method of incorporating regional GCM information into this model framework. NHMM can be seen as useful tool for simulating stochastic precipitation for hydrological model and reservoir operating rules testing. The stochastic nature of precipitation is represented in this methodology, but some problems did arise. Extreme precipitation events seem to not be well represented and further research is needed.

References

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