Projecting climate change impacts on hydrology: the potential role of daily GCM output

E.P. Maurer, H.G. Hidalgo, T. Das, M.D. Dettinger, D. R. Cayan
[1] Santa Clara University, Civil Engineering Department, emaurer@engr.scu.edu, [ii] Scripps Institution of Oceanography, [iii] Scripps Institution of Oceanography and US Geological Survey

Our Goal: Improve methods for projecting climate change impacts to watersheds. Our Focus: Downscaling climate model outputs to capture changes in hydrology.

What we downscale: NCEP/NCAR Reanalysis

- Reanalysis represents the best possible GCM since obs are assimilated
  - Should show same differentiation in methods
  - TSD pre-1990 resolution, comparable to GCMs
  - Full period daily and monthly data available
- 1950–1976 used to “train” downscaling
- 1977–1996 used to assess, used as a “changed climate” for projections
- Shift in PDO in 1976–77, late 20th century warming
- Warmer, wetter in later period over Western U.S.

Downscaling Methods

1. Bias Correction/Spatial Downscaling (BCSD)
   - Discrete daily anomalies, no spatial interpolation
   - Scale not achieved: bias correction
2. Constructed Analogues (CA)
   - Coarse resolution, 22+ GCMs
   - Library of previously observed anomaly patterns
   - Analyze in mean to model combination of best 3 GCMs
   - Interpolate anomalies to 1/8° grid
   - Apply to 1/8° climate

Common Characteristics of BCSD and CA

- Both provide spatially continuous (grided) downscaled fields
- Observed spatial and temporal climate structure maintained
- Capable of downscaling long transient GCM runs

Important Differences Between BCSD and CA

- CA uses daily GCM data; BCSD uses monthly to annual resampling to produce daily values
- BCSD explicitly corrects for systematic GCM biases based on historic GCM performance
- CA corrects mean bias due to using anomalies but not spatial GCM biases

Streamflow Simulations: 22 Years

- Get precipitation-driven daily statistics of low and high flows, BCSD shows correspondence with observations at more locations than for CA

Combining Downscaling Methods

- Step 1 from BCSD applied to daily reanalysis precip
- CA applied (without anomalizing)
- New streamflows generated

Solution: Bias Correct before CA method (BCCA)

- New streamflows generated
- Bias correction at large scale solves problems with peak flows and annual volume
- Problems remain at low flows for BCSD (PCCA outperforms both CA and BCSD for most measures)

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Downscaled Meteorology and Derived Hydrology

- Precipitation, mm/d
- Active soil moisture, mm
- Evapotranspiration, mm/d

April 1 snow water equivalent (SWE), mm.

Bias in mean

- SHAST Sacramento R. at Shasta Dam
- SAC_B Sacramento R. at Bend Bridge
- OROVI Feather R. at Oroville
- NF_AM North Fork American R. at N.F. Dam
- FOL_I American R. at Folsom Dam
- PRD_C Mokelumne R. at Pardee
- LK_MC Merced R. at Lake McClure
- MILLE San Joaquin R. at Millerton Lake
- KINGS Kings R. at Pine Flat Dam
- LESFY Colorado R. at Lees Ferry
- DALLE Columbia R. at The Dalles

Bias Correction/Spatial Downscaling (BCSD)

Bias Correct before CA method (BCCA)

Downscaling Methods

Step 1: Bias-Correction
   - At each grid cell, use quantile mapping to match monthly statistics at GCM scale

Step 2: Spatial Downscaling
   - Calculate anomalies relative to coarse-scale climatology
   - Interpolate anomalies to 1/8° grid
   - Apply to 1/8° climatology

constructed analogues (CA)

- Library of previously observed anomaly patterns
- Coarse resolution analogue
- Fine resolution analogue
- Apply analogue to fine resolution climatology

Daily Statistics – Correlation with Observations

- Annual P cycle captured with both methods
- BCSD shows higher 1 daily skills
- Wet and dry seasonaly and interannual variability of soil moisture is rarely reproduced by both BCSD and CA
- End-of-season snow accumulation also appears to be plausibly reproduced by both BCSD and CA
- When BCSD or CA differ from Observations (e.g., April soil moisture in the Pacific Northwest), they differ in similar ways.
- Hydrologic states appear to be recovered well by either downscaling method.

Precipitation, mm/d

- Dry Extremes (20%tile daily P)
- Winter Cool Extremes (10%tile)
- Summer Warm Extremes (90%tile)
- Wet Extremes (90%tile daily P)

Center Timing of Annual Hydrograph, day in water year

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Drizzle bias (January shown here)
Obs shows 40% of days with zero precip
Reanalysis never has zero precip