Improving statistically downscaled daily data for hydrology: diagnosis and opportunities

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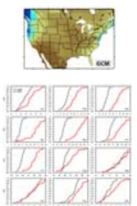
ABSTRACT

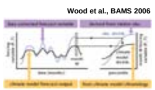
Incorporation of climate change information into long-term evaluations of water and energy resources A primary challenge facing resource managers in accommodating climate change is determining the range and uncertainty in regional and local climate projections. Since global climate models (GCMs) produce output at a spatial scale incompatible with local impact assessment, different techniques have evolved to downscale GCM output so locally important climate features are expressed in the projections. Recent research has compared skill using two statistical downscaling methods, the constructed analogues (CA) and the bias correction and spatial downscaling (BCSD). The CA method uses daily GCM output and the BCSD monthly. We evaluate the downscaled precipitation and temperature (from the NCEP/NCAR reanalysis and a GCM) for the late 20th century against observations, and compare projections with both methods. We include an assessment of the GCM biases, and present a new method for correcting for GCM biases in a hybrid method combining the most important characteristics of both methods.

Downscaling with BCSD

Step 1: Bias-Correction

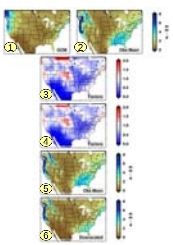


- At each grid cell for "training" period, develop monthly CDFs of P, T for
  - GCM
  - Observations (aggregated to GCM scale)
  - *Obs are from Maurer et al. [2002]*



- Use quantile mapping to ensure monthly statistics (at GCM scale) match
- Apply same quantile mapping to "projected" period

Step 2: Spatial Downscaling



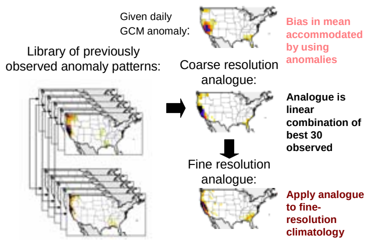
- Use bias-corrected monthly GCM output ①
- Aggregate obs to GCM scale ②
- Calculate P,T factors relative to coarse-scale climatology

  ③ = ①/② (P) ③ = ① - ② (T)
- Interpolate factors to 1/8° grid ④
- Apply to fine-scale climatology

  ⑥ = ④*⑤ (P) ⑥ = ④+⑤ (T)

Daily Values from rescaled historical values

Downscaling with Constructed Analogues



Comparing BCSD and CA

Characteristics in Common

- Both provide spatially continuous (gridded) downscaled fields
- Observed spatial and temporal climate structure maintained
- Automated and Efficient: can be used for ensembles of GCMs
- Capable of downscaling long transient GCM runs
- Capable of producing daily output

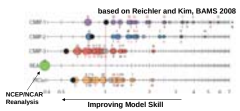
Fundamental Differences

- CA uses daily GCM data; BCSD uses monthly w/random resampling to produce daily values
- CA (like a "perfect prog" forecast system) develops relationships between coarse- and fine-scale observations, and applies them to GCM output.
- BCSD (like a "MOS" type forecast) relates GCM output directly to observations, explicitly correcting for systematic GCM biases based on historic GCM performance
- CA corrects mean bias (using anomalies) but not
  - spatial GCM biases
  - variability biases

Observational Baseline

- The "truth" against which BCSD and CA simulations are compared is hydrologic model output driven by gridded observed meteorology from 1977-1999.
- See Maurer and Hidalgo, 2008, for details on intercomparison

Surrogate GCM output: NCEP/NCAR Reanalysis

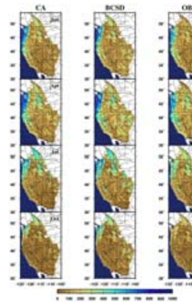


- Best possible GCM since obs are assimilated
  - Should show max differentiation in methods
  - T62 (~1.9°) resolution, comparable to GCMs
- Full period daily and monthly data available
- 1950-1976 used to "train" downscaling
  - CA: coarse obs to fine (1/8°) obs
  - BCSD: coarse reanalysis to fine (1/8°) obs
- 1977-1999 used to assess
- Shift in PDO in 1976-77, late 20th century warming
- Warmer, wetter in later period over Western U.S.

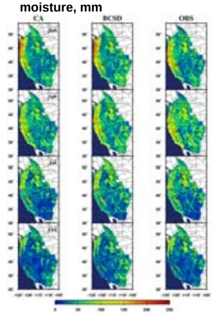
COMPARING HYDROLOGIC SIMULATIONS WITH CA AND BCSD

Hydrologic States: simulation of water storage in soil and snow pack

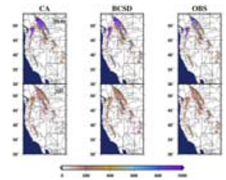
Average active soil moisture, mm



Standard deviation of active soil moisture, mm



Mean April 1 snow water equivalent (SWE), mm, top panels Standard deviation of April 1 SWE, mm, bottom panels



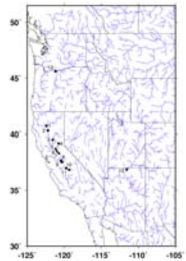
Conclusions, part 1

- **Mean, seasonal cycles and interannual variability of soil moisture is reasonably reproduced by both BCSD and CA.**
- **End-of-season snow accumulation also appears to be plausibly reproduced by both BCSD and CA**
- **Where they differ from Observations (for example, April soil moisture in the Pacific Northwest), BCSD and CA tend to differ in similar ways.**
- **Hydrologic states appear to be recovered well by either downscaling method.**

Streamflow: Statistics at Selected Sites in the Western U.S.

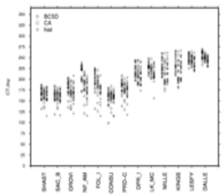
Streamflow Gauges Used in this Study

Number	Gauge	Name
1	SHAST	Sacramento River at Shasta Dam
2	SAC_B	Sacramento River at Bend Bridge
3	OROVI	Feather River at Oroville
4	NF_AM	North Fork American River at North Fork Dam
5	FOL_I	American River at Folsom Dam
6	CONSU	Cosumnes River at Michigan Bar
7	PRD_C	Mokelumne River at Pardee
8	DPR_I	Tuolumne River at New Don Pedro
9	LK_MC	Merced River at Lake McClure
10	MILLE	San Joaquin River at Millerton Lake
11	KINGS	Kings River - Pine Flat Dam
12	LESFY	Colorado River at Lees Ferry
13	DALLE	Columbia River at The Dalles

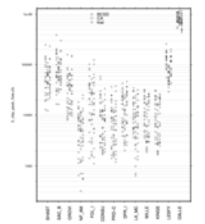


Streamflow statistics for 22 water years: 1978-1999

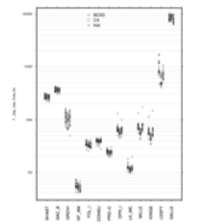
Center Timing of Annual Hydrograph, day in water year (Oct 1 = 1)



3-Day Peak Flow, cfs



7-Day Low Flow, cfs



Statistical test results for CA and BCSD. A gauge name in bold face and highlighted indicates significant difference between the test statistic for observations and downscaled. Equality of means were compared with a Mann-Whitney test (at p=0.05).

Center Timing		3-Day Peak		7-Day Low Flow		Annual Flow Vol.	
BCSD	CA	BCSD	CA	BCSD	CA	BCSD	CA
SHAST	SHAST	SHAST	SHAST	SHAST	SHAST	SHAST	SHAST
SAC_B	SAC_B	SAC_B	SAC_B	SAC_B	SAC_B	SAC_B	SAC_B
OROVI	OROVI	OROVI	OROVI	OROVI	OROVI	OROVI	OROVI
NF_AM	**NF_AM**	NF_AM	NF_AM	**NF_AM**	NF_AM	NF_AM	NF_AM
FOL_I	**FOL_I**	FOL_I	FOL_I	**FOL_I**	FOL_I	FOL_I	FOL_I
CONSU	CONSU	CONSU	CONSU	CONSU	CONSU	CONSU	**CONSU**
PRD_C	PRD_C	PRD_C	PRD_C	PRD_C	PRD_C	PRD_C	**PRD_C**
DPR_I	DPR_I	DPR_I	**DPR_I**	DPR_I	**DPR_I**	DPR_I	**DPR_I**
LK_MC	LK_MC	LK_MC	LK_MC	LK_MC	**LK_MC**	LK_MC	**LK_MC**
MILLE	MILLE	MILLE	**MILLE**	MILLE	**MILLE**	MILLE	**MILLE**
KINGS	KINGS	KINGS	**KINGS**	KINGS	**KINGS**	KINGS	**KINGS**
LESFY	**LESFY**	**LESFY**	**LESFY**	**LESFY**	**LESFY**	**LESFY**	**LESFY**
DALLE	**DALLE**	**DALLE**	**DALLE**	DALLE	**DALLE**	**DALLE**	**DALLE**

Same as table to right, but bold/highlighted indicates downscaled distribution of 22 values differs from the observed distribution, based on a Kolmogorov-Smirnov 2-sample test (at p=0.05).

Center Timing		3- Day Peak		7-Day Low Flow		Annual Flow Vol.	
BCSD	CA	BCSD	CA	BCSD	CA	BCSD	CA
SHAST	SHAST	SHAST	SHAST	SHAST	SHAST	SHAST	SHAST
SAC_B	SAC_B	SAC_B	SAC_B	SAC_B	SAC_B	SAC_B	SAC_B
OROVI	OROVI	OROVI	OROVI	OROVI	OROVI	OROVI	OROVI
NF_AM	NF_AM	NF_AM	NF_AM	**NF_AM**	**NF_AM**	NF_AM	NF_AM
FOL_I	**FOL_I**	FOL_I	FOL_I	**FOL_I**	FOL_I	FOL_I	**FOL_I**
CONSU	CONSU	CONSU	CONSU	CONSU	CONSU	CONSU	**CONSU**
PRD_C	PRD_C	PRD_C	PRD_C	PRD_C	PRD_C	PRD_C	**PRD_C**
DPR_I	DPR_I	DPR_I	**DPR_I**	DPR_I	DPR_I	DPR_I	**DPR_I**
LK_MC	LK_MC	LK_MC	LK_MC	LK_MC	LK_MC	LK_MC	LK_MC
MILLE	MILLE	MILLE	MILLE	MILLE	**MILLE**	MILLE	**MILLE**
KINGS	KINGS	KINGS	KINGS	KINGS	**KINGS**	KINGS	**KINGS**
LESFY	LESFY	LESFY	**LESFY**	**LESFY**	**LESFY**	**LESFY**	**LESFY**
DALLE	**DALLE**	**DALLE**	DALLE	DALLE	**DALLE**	**DALLE**	DALLE

Conclusions, part 2

- **Center timing, a feature driven by temperature more than precipitation, shows correspondence with observations for CA at more locations than for BCSD**
- **This reflects the successful translation of large-scale daily skill in Reanalysis temperatures by CA.**
- **For precipitation-driven daily statistics of low and high flows, BCSD shows correspondence with observations at more locations that CA.**
- **The differences in precipitation-driven differences could be explained by:**
  - **-The random resampling of daily sequences in BCSD may bear more resemblance to observations than large-scale CA's daily downscaled Reanalysis anomalies**
  - **-Observed interannual variability is preserved by bias correction in BCSD, but not in CA**

Acknowledgements

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References

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