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

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Our Goal: Improve methods for projecting climate change impacts to watershed scale

Our Focus: Downscaling climate model output to capture changes in hydrology

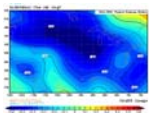
Our Methods:

1 – Downscale precipitation and temperature over the Western U.S. using two different techniques

2 – Drive a hydrology model with each, and compare their performance

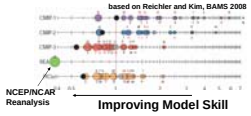
3 – Develop an improved method

What we downscale: NCEP/NCAR Reanalysis



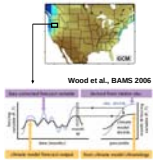
- Reanalysis represents the best possible GCM since obs are assimilated
  - Should show max differentiation in methods
  - T62 (~1.9°) resolution, comparable to GCMs
- Full period daily and monthly data available

- **1950-1976** used to "train" downscaling
- **1977-1999** used to assess, used as a "changed climate" for projections
- Shift in PDO in 1976-77, late 20th century warming
- Change in data sources to Reanalysis in 1979
- Warmer, wetter in later period over Western U.S.



Downscaling Methods

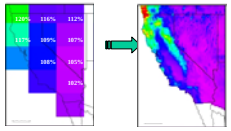
Bias Correction/Spatial Downscaling (BCSD)



Step 1: Bias-Correction

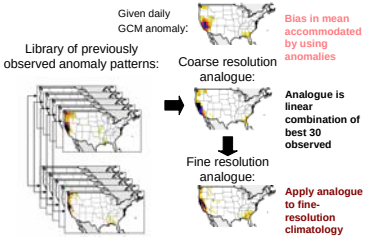
At each grid cell, use quantile mapping to match monthly statistics (at GCM scale)

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)



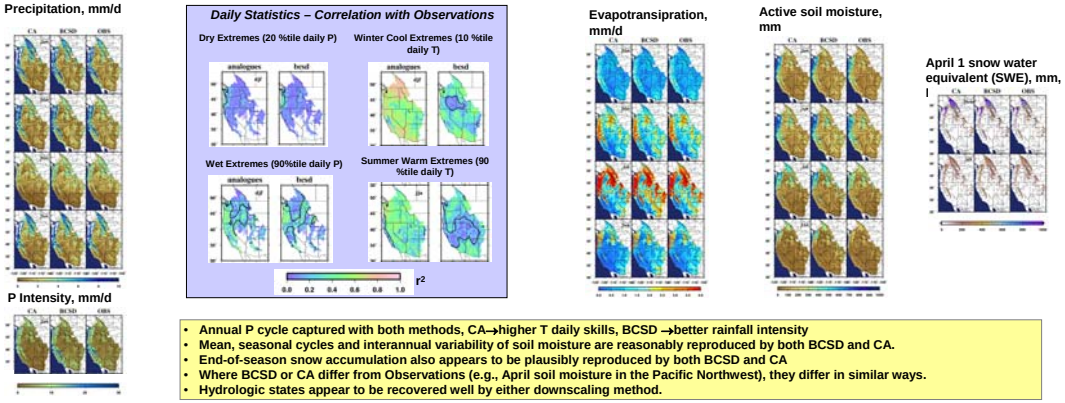
Common Characteristics of BCSD and CA

- 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

Important Differences Between BCSD and CA

- CA uses **daily** GCM data; BCSD uses **monthly** w/random resampling to produce daily values
- BCSD explicitly corrects for systematic GCM biases based on historic GCM performance
- CA corrects mean bias (using anomalies) but not
  - spatial GCM biases
  - variability biases

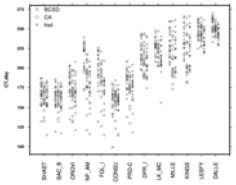
Downscaled Meteorology and Derived Hydrology



- Annual P cycle captured with both methods, CA→higher T daily skills, BCSD →better rainfall intensity
- Mean, seasonal cycles and interannual variability of soil moisture are reasonably reproduced by both BCSD and CA.
- End-of-season snow accumulation also appears to be plausibly reproduced by both BCSD and CA
- Where 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.

Streamflow Simulations: 22 Years

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

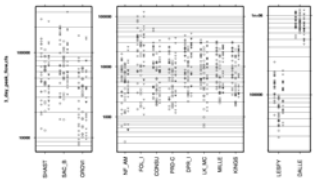


Center Timing of Annual Hydrograph, day in water year

- Center timing (driven by temperature) 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.

3-Day Peak Flow, cfs

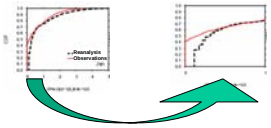
- For precipitation-driven daily statistics of low and high flows, BCSD shows correspondence with observations at more locations that CA.



Combining Downscaling Methods

Problematic Biases at large scale

Daily precipitation probabilities at reanalysis grid point at 37.1422, -110.625:



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

Solution: Bias Correct before CA method (BCCA)

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

- Bias correction at large scale solves problems with peak flows and annual volumes
- Problems remain at low flows
- BCCA outperforms both CA and BCSD for most measures

Gauge in bold face and highlighted indicates downscaled distribution of 22 values differs from the observed distribution, compared with a Kolmogorov-Smirnov 2-sample test (at p=0.05).

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

- Daily large-scale skill can be successfully downscaled to local scales
- Anomalizing is not adequate for coping with large-scale biases
- Explicit bias correction solves many problems, but post-processing needed

Maurer, E.P. and H.G. Hidalgo, 2008, Utility of daily vs. monthly large-scale climate data: an intercomparison of two statistical downscaling methods, Hydrology and Earth System Sciences Vol. 12, 551-563.
Reichler, T., and J. Kim, 2008: How Well Do Coupled Models Simulate Today's Climate? Bull. Amer. Meteor. Soc., 89, 303–311.
Wood, A.W., and D.P. Lettenmaier, 2006: A Test Bed for New Seasonal Hydrologic Forecasting Approaches in the Western United States. Bull. Amer. Meteor. Soc., 87, 1699–1712.

Acknowledgement

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