Performance of dynamical downscaling for Colorado River basin

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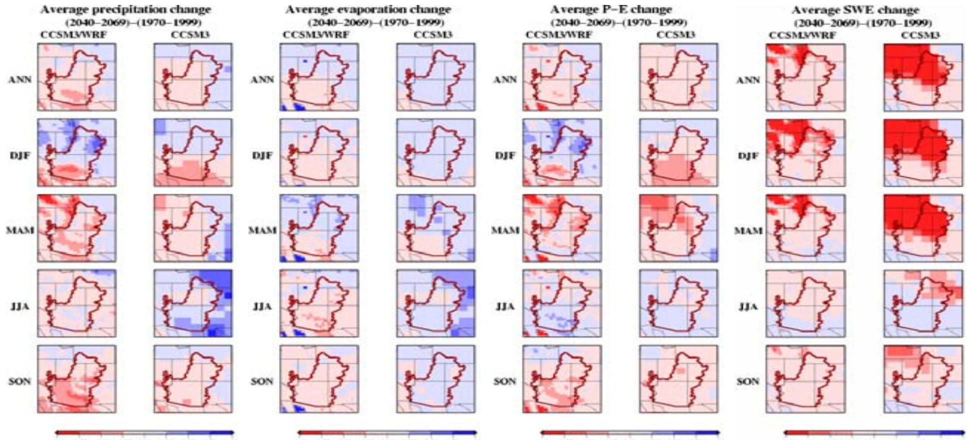
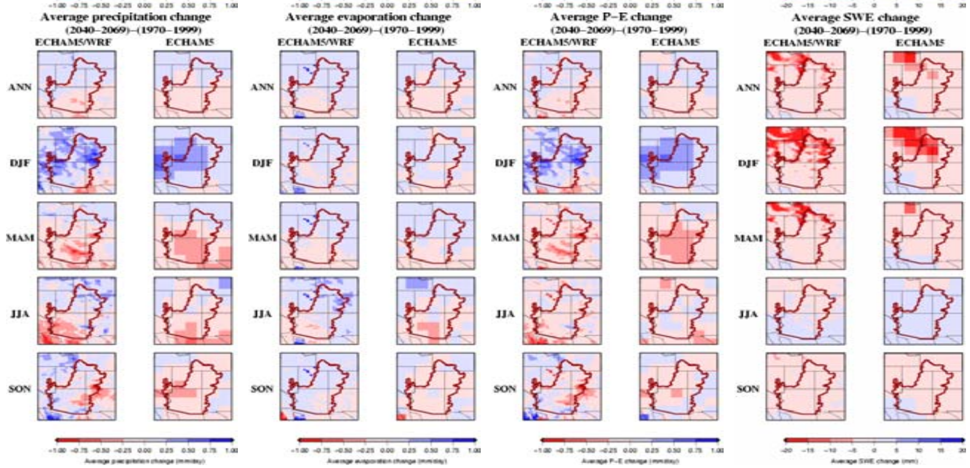
Overview

The ongoing 2000s western U.S. drought has focused attention on drought susceptibility of the Colorado River basin. There is a concern that many climate models predict permanently drier conditions for the next century over the Colorado basin, however interpretation of these projections is complicated by their coarse spatial resolution which does not resolve the role of the relatively small mountain headwaters area that is the source of much of the basin's runoff. Regional climate models (RCMs) are able to resolve these spatial scales.

Methods and results

We used two simulations with the Advanced Research Weather Research and Forecasting (WRF) mesoscale climate model. The first, CCSM3/WRF, used the CCSM3 as boundary conditions, with WRF simulations performed on a grid spacing of 50 km. The CCSM3/WRF results are part of the North American Regional Climate Change Assessment Program (NARCCAP) archive[1]. The second, ECHAM5/WRF, used ECHAM5 boundary conditions, with a WRF grid spacing of 36 km. The ECHAM5/WRF simulation came from Salathe et al. (2009). Both WRF simulations were for a 1970–1999 historical period, and a 2040–2069 future period. In the future period run, A1B emissions scenario in ECHAM5 and A2 in CCSM3 were used. The following plots summarize changes (future-historical) from the two simulations.





*1 CCSM3/WRF results are part of the NARCCAP archive for a North American domain at 50 km grid resolution. http://www.narccap.ucar.edu/

Annually trends averaged over CO River basin

Precipitation (P) 1970-1999:

mm/d	annual	winter	spring	summer	autumn
Maurer et al (2002)	1.03	0.96	1.01	1.13	1.01
ECHAM5	1.31	1.79	1.28	0.97	1.2
ECHAM5/WRF	1.81	2.24	1.74	1.59	1.68
CCSM3	1.29	1.82	1.34	0.83	1.15
CCSM3/WRF	1.02	1.5	1.17	0.51	0.93

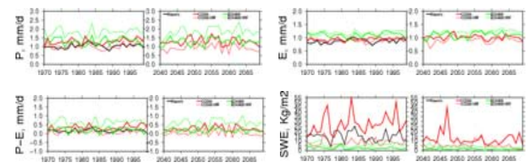
Evapotranspiration (E) 1970-1999 :

mm/d	annual	winter	spring	summer	autumn
Maurer et al (2002)	0.87	0.36	0.85	1.63	0.66
ECHAM5	1.11	0.44	1.16	1.96	0.88
ECHAM5/WRF	1.17	0.68	1.29	1.68	1.02
CCSM3	0.93	0.66	1.22	1.04	0.82
CCSM3/WRF	0.92	0.54	1.26	1.3	0.59

P-E 1970-1999:

mm/d	annual	winter	spring	summer	autumn
Maurer et al (2002)	0.16	0.6	0.16	-0.5	0.35
ECHAM5	0.2	1.35	0.12	-0.99	0.32
ECHAM5/WRF	0.64	1.56	0.45	-0.09	0.66
CCSM3	0.36	1.16	0.12	-0.21	0.33
CCSM3/WRF	0.1	0.96	-0.09	-0.79	0.34

Annually trends averaged over CO River basin:



Precipitation change (2040-2069)-(1970-1999) :

mm/d (%)	annual	winter	spring	summer	autumn
ECHAM5	-0.03 (-2.3)	0.21(11.7)	-0.13 (-10.2)	-0.1 (-10.3)	-0.08 (-6.7)
ECHAM5/WRF	0.01 (0.6)	0.17 (7.6)	-0.09 (-5.2)	-0.05 (-3.1)	0.01 (0.6)
CCSM3	0 (0)	-0.06 (-3.3)	-0.04 (-3.0)	0.21 (25.3)	-0.1 (-8.7)
CCSM3/WRF	-0.08 (-7.8)	0.04 (2.7)	-0.15 (-12.8)	-0.03 (-5.9)	-0.19 (-20.4)

Evaporation change (2040-2069)-(1970-1999):

mm/d (%)	annual	winter	Spring	summer	autumn
ECHAM5	-0.01 (-0.9)	0.01 (2.3)	0.02 (1.7)	-0.02 (-1.0)	-0.03 (-3.4)
ECHAM5/WRF	0.04 (3.4)	0.03 (4.4)	0.03 (2.3)	0.07 (4.2)	0.03 (2.9)
CCSM3	0.09 (9.7)	0.08 (12.1)	0.07 (5.7)	0.16 (15.4)	0.04 (4.9)
CCSM3/WRF	0 (0)	-0.02 (-3.7)	0.01 (0.8)	0.03 (2.3)	-0.03 (-5.1)

P-E change (2040-2069)-(1970-1999) :

mm/d (%)	annual	winter	spring	summer	autumn
ECHAM5	-0.02 (-10)	0.2 (14.8)	-0.15 (-125)	-0.08 (-8.1)	-0.05 (-15)
ECHAM5/WRF	-0.03 (-4.7)	0.14 (9.0)	-0.12 (-27)	-0.12 (-133)	-0.02 (-3.0)
CCSM3	-0.09 (-25)	-0.14 (-12)	-0.11 (-92)	0.05 (24)	-0.14 (-42)
CCSM3/WRF	-0.08 (-80)	0.06 (6.3)	-0.16 (-178)	-0.06 (-7.6)	-0.16 (-47)

SWE change (2040-2069)-(1970-1999) :

Kg/m2 (%)	annual	Winter	spring	summer	Autumn
ECHAM5	-1.4 (-55)	-4.8 (-54)	-0.44 (-62)	---	-0.34 (-69)
ECHAM5/WRF	-2.2 (-37)	-5.7 (-34)	-2.5 (-40)	---	-0.5 (-51)
CCSM3	-12 (-58)	-18.6 (-58)	-23.5 (-76)	---	-1.9 (-30)
CCSM3/WRF	-3.2 (-38)	-6.9 (-30)	-5.2 (-51)	---	-0.8 (-54)

Preliminary conclusions:

- The RCM simulations are mostly consistent with the GCMs in spatial pattern of P and E (although ECHAM5/WRF has much higher P than does ECHAM5).
- The (annual) precipitation changes in both GCMs are small (-2.3% in ECHAM5 and zero in CCSM3), however whereas ECHAM5/WRF has annual changes that are quite similar to ECHAM5, CCSM3/WRF has a substantial (-7.8%) reduction as compared to no change in CCSM3. Likewise, ECHAM5/WRF and ECHAM5 are more similar in terms of E than are CCSM3/WRF and CCSM3. As a result, changes in P-E in CCSM3 result entirely from changes in E, whereas the much larger changes in CCSM3/WRF come entirely from changes in P,
- The two global climate models CCSM3 and ECHAM5 both give smaller annual P-E in 2040-2070 than in 1970-2000 over the Colorado basin. However, the annual P-E change is smaller in ECHAM5/WRF relative to ECHAM5, but is much larger (by 2.5 times) in CCSM3/WRF relative to CCSM3.
- All the GCMs and RCMs show reduced SWE for 2040-2070 relative to 1970-2000. However, the RCMs show substantially smaller decreases than do the GCMs. This in part has to do with more accurate regional distribution of snow in the regional models, but may also have resulted from differences in model biases in the RCMs relative to the GCMs (remains to be explored).

References

Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen, 2002: A Long-Term Hydrologically-Based Data Set of Land Surface Fluxes and States for the Conterminous United States, *J. Climate* 15, 3237-3251.

Salathe, E., and L.R. Leung, Y. Qian, and Y. Zhang, 2009: Regional climate model projections for the State of Washington, in review, *Climatic Change*.