Impact Assessment of Climate Change on Spatial Patterns of Precipitation in the Western United States

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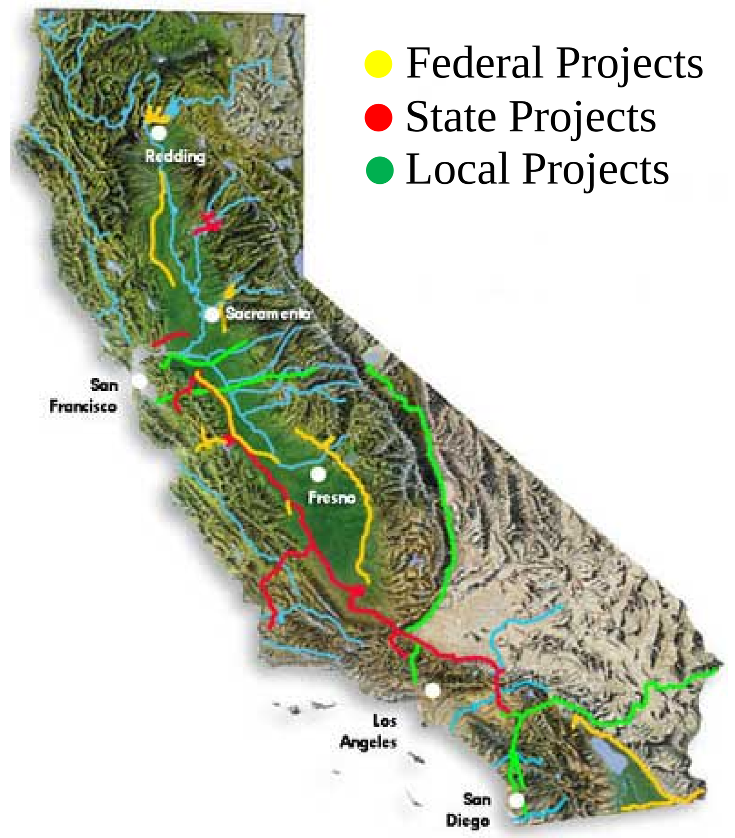
Background

Spatial patterns in precipitation matter in the western United States

The spatial distribution of precipitation is very important for water planning over the western United States, where vast manmade infrastructures, such as the Central Valley Project and California Water Project, were built to resolve the mismatch between where precipitation falls and where water is consumed.



☐In a typical year, southeastern California receives 2 inches of precipitation and places in northern California receive more than 100 inches.

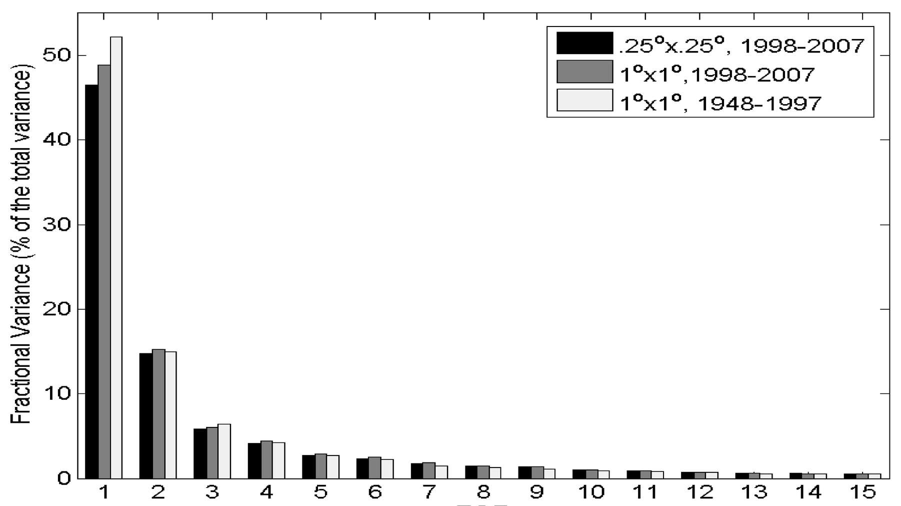
☐70% of annual runoff originates north of Sacramento; 75% of state's urban and agricultural demand for water occurs south of Sacramento.

☐ 75% of California's precipitation falls between Nov. and March, when the fate of precipitation (turning into infiltration, runoff, or snow pack) depends on its geographical location.

Fig. 1. Massive water projects in California. (Map courtesy of California Department of Water Resources.)

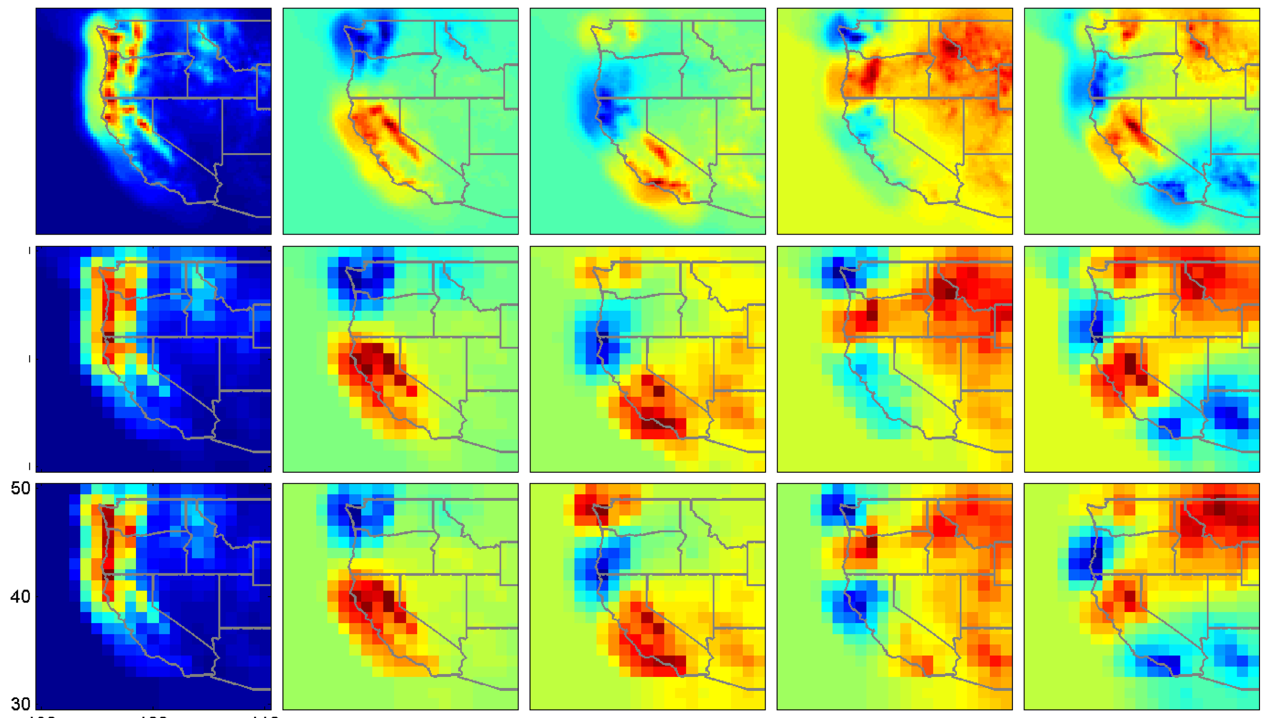
Strong spatial patterns in the precipitation field

Recently, EOF analysis on the U.S. daily precipitation product of Climate Prediction Center (CPC) revealed that there exists dominant spatial patterns in the precipitation field over the western United States (***Chu*** et al., 2011). The spatial patterns are consistent at different spatial resolutions and persistent over decades.



Daily Precipitation fields of different time periods and at different spatial resolutions yield very similar variance spectra from EOF analysis (Fig. 2). The spatial patterns represented by the leading EOFs also highly resemble each other (Fig. 3).

Fig. 2. Fractional variance explained by the first 15 EOFs of precipitation fields .



1998 - 2007
0.25° × 0.25°

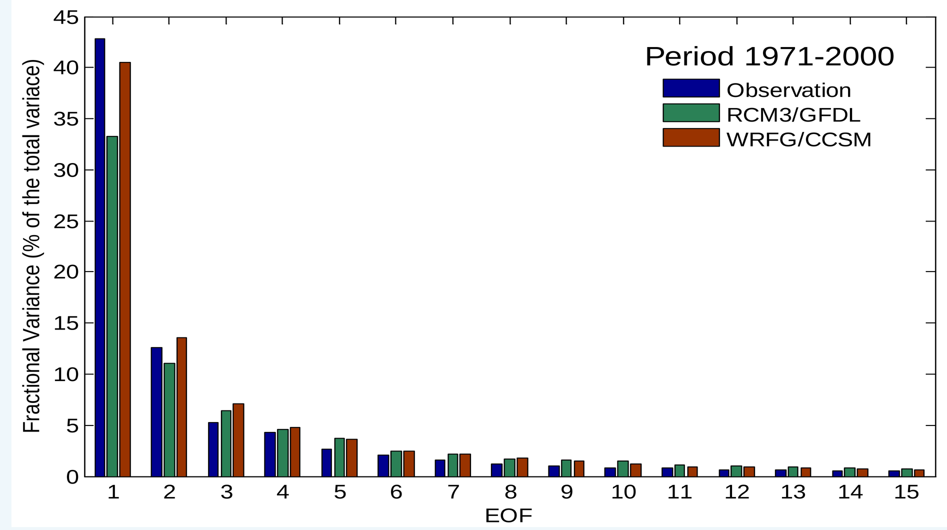
1998 - 2007
1° × 1°

1948 - 1997
1° × 1°

Fig. 3. Comparison of first five EOFS of different precipitation fields.

Evaluation of Dynamical Downscaling Results

To evaluate climate models' skill of simulating the observed spatial patterns, we applied the EOF analysis to the NARCCAP results (Mearns et al., 2011). Due to time constraint, only the precipitation from two GCM/RCM combinations are analyzed. The two combinations are Regional Climate Model version 3 driven by Geophysical Fluid Dynamics Laboratory GCM (**RCM3/GFDL**) and Weather Research & Forecasting Model driven by Community Climate System Model (**WRFG/CCSM**).

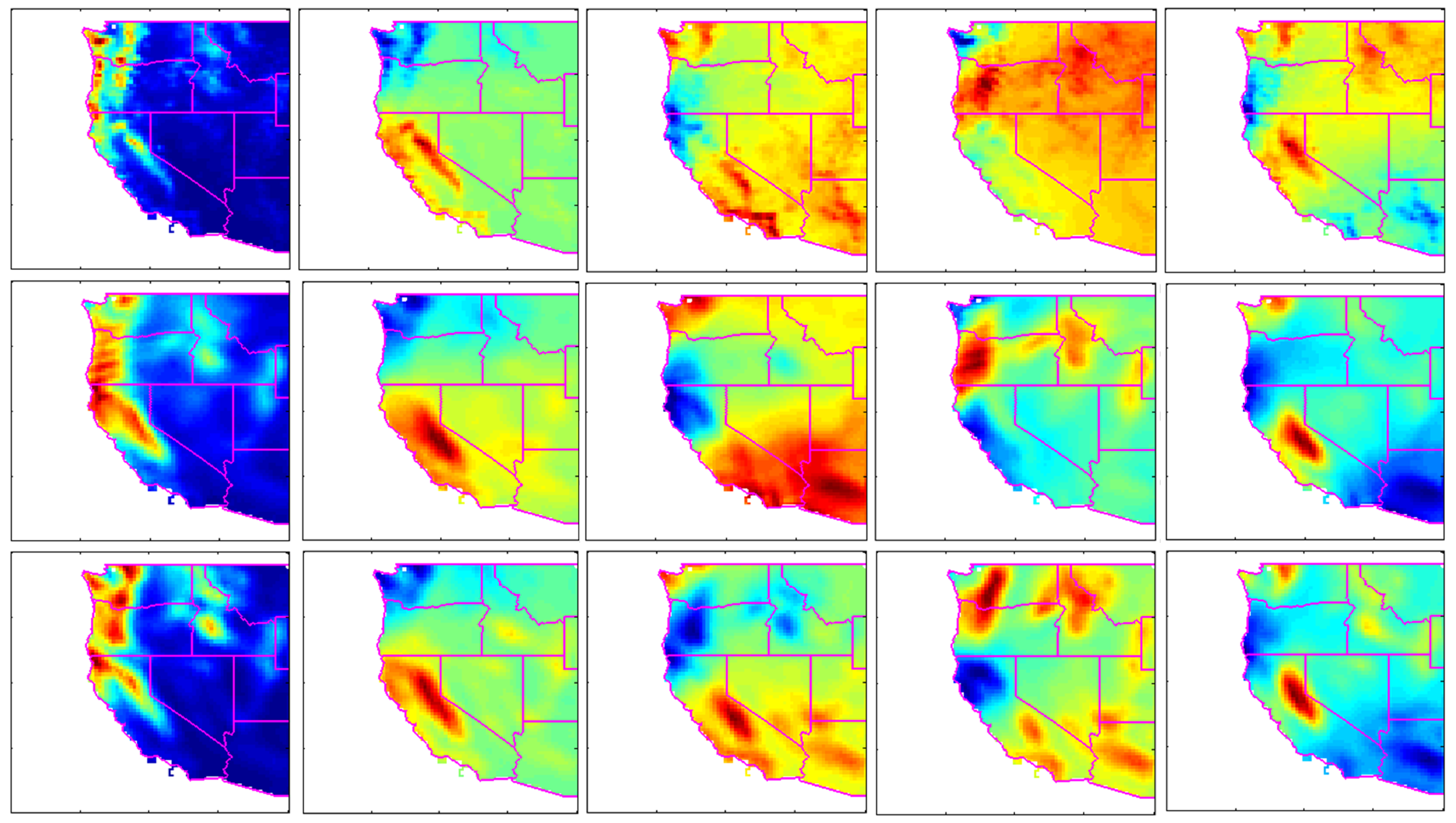


Period: 1971-2000

Observation:
U.S. daily precipitation product
0.25° × 0.25° and overland only

RCM3/GFDL, WRFG/CCSM:
Integrated daily volume from precipitation flux,
50 km × 50 km, over land and ocean

Fig. 4. Fractional variance explained by the first 15 EOFs of precipitation fields.



Obser-vation

GFDL ⬇ RCM3

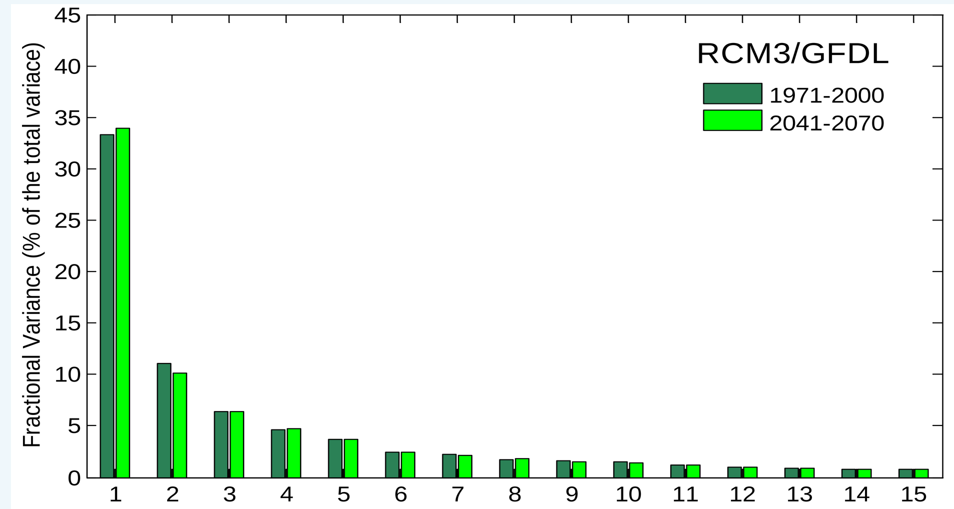
CCSM ⬇ WRFG

Fig. 5. Comparison of first five EOFS of precipitation fields of observation and model simulations. The model simulation EOFs are interpolated to the grid (0.25° × 0.25°) of observation.

Simulations of both combinations yield EOF patterns and spectra similar to those of the observation. Due to the lower resolution, EOF patterns can not resolve the fine features presented in the observation EOFs.

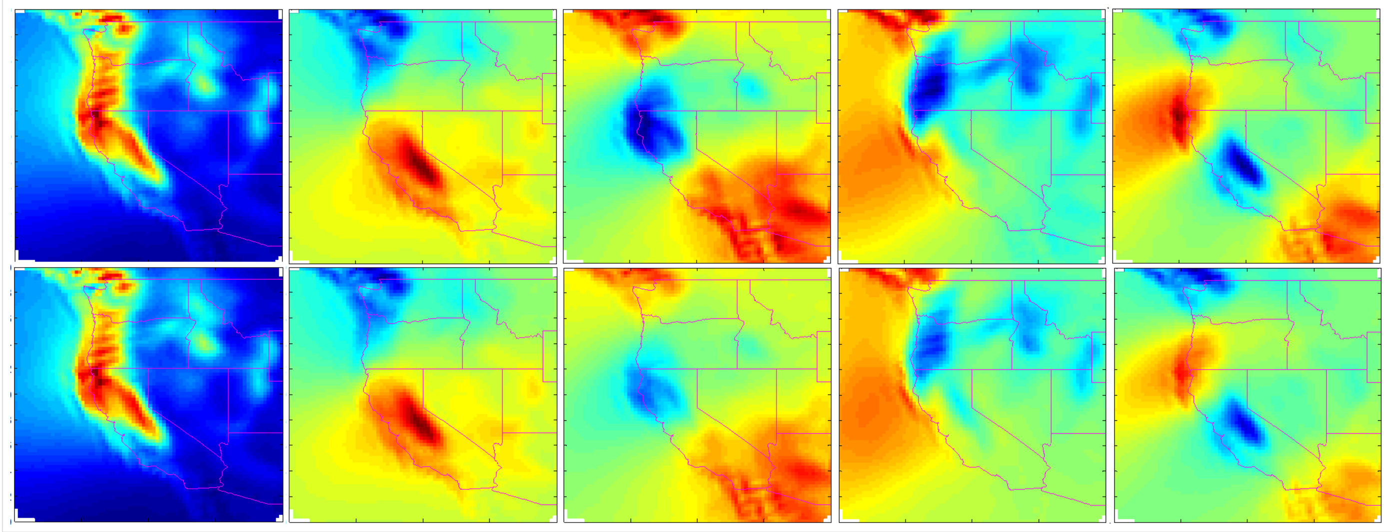
Impact of Climate Change

For each of the RCM/GCM combinations, the simulation of future period 2041-2071 with IPCC SRES A2 emissions scenario is provided. By comparing the spatial patterns of historical (1971-2000) period and future period, we can assess the impact of the projected climate change on the spatial distribution of precipitation.



As shown in Figs. 6 and 7, only very slight difference is shown in the variance spectra and EOF patterns of the simulation by RCM3/GFLD, indicating that the spatial patterns are persistent over time and are not affected by the projected climate change caused by increased CO_2 emission.

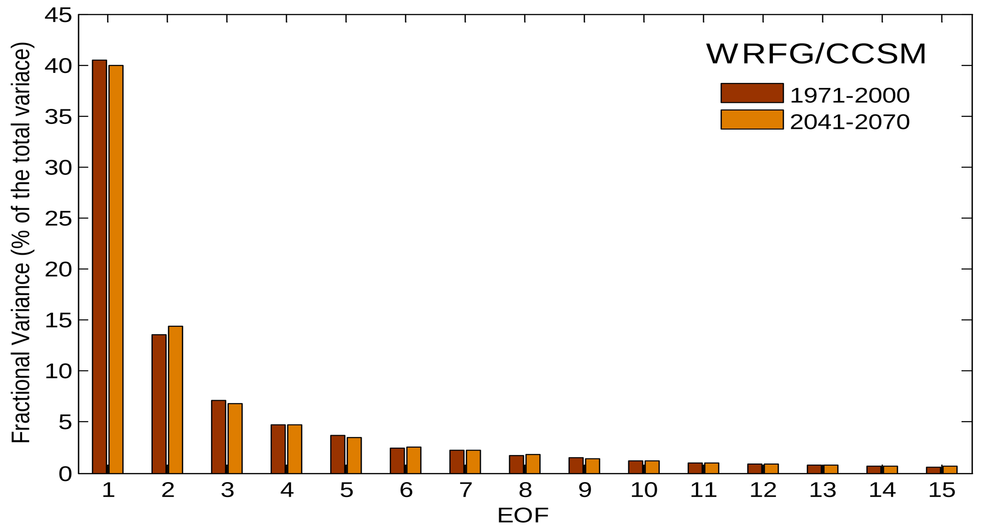
Fig. 6. Fractional variance explained by the first 15 EOFs of RCM3/GFDL precipitation in historical and future periods.



1971-2000

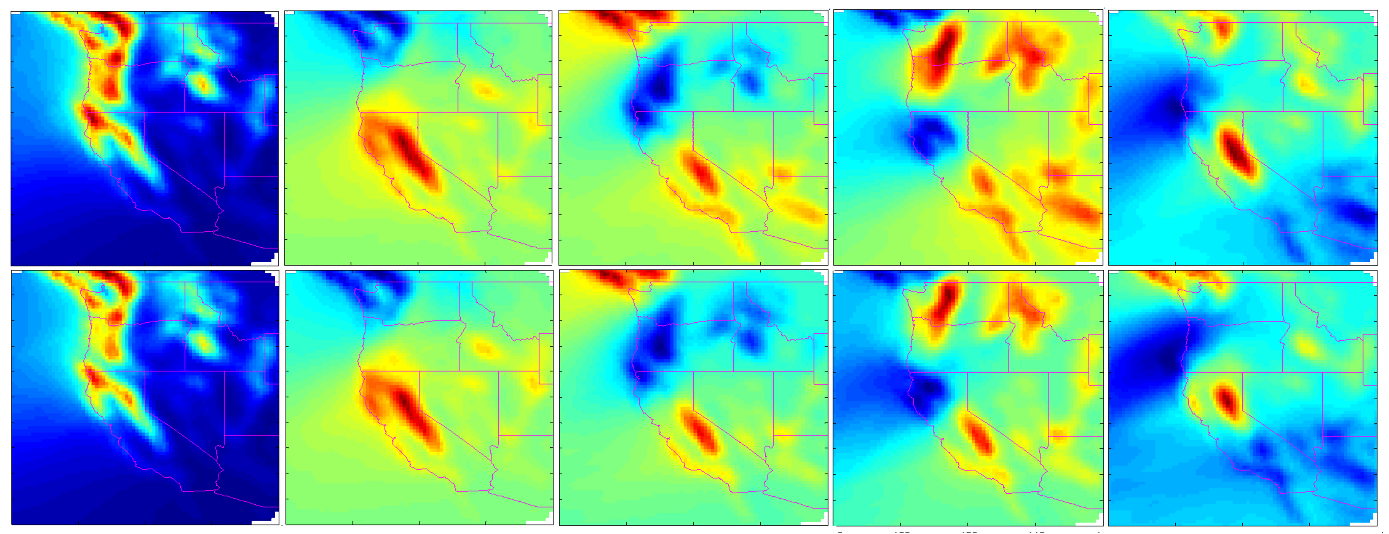
2041-2070

Fig. 7. The first five EOFS of precipitation fields of RCM3/GFDL precipitation in historical and future periods.



Similar to the result of RCM3/GFDL, the analysis on WRFG/CCSM supports the persistence of the spatial patterns in the precipitation field. The consistency across models indicates that there are physical processes underlying the spatial patterns.

Fig. 8. Fractional variance explained by the first 15 EOFs of WRFG/CCSM precipitation in historical and future periods.



1971-2000

2041-2070

Fig. 9. The first five EOFS of precipitation fields of WRFG/CCSM precipitation in historical and future periods.

Conclusions and Future Work

Our study leads to the following conclusions:

•Dynamic downscaling can capture the spatial patterns of precipitation in the western U.S..

•Model simulation indicates that the spatial patterns are not affected by climate change.

Currently, we are working on:

•Developing analytical approaches to quantify models' skill of simulating the observed patterns.

•Based on the skill, generating a ensemble of precipitation projection from NARCCAP output for water planning in the western U.S..

•Further downscaling the precipitation to finer spatial resolutions, and study the patterns resolved at finer resolutions

References

[1] Chu, W., X. Gao, Thomas J. Phillips and S. Sorooshian, Consistency of spatial patterns of the daily precipitation field in the western United States and its application to precipitation disaggregation, *Geophysical Research Letters*, 38, L04403, doi:10.1029/2010GL046473.

[2] Mearns, L.O., et al., 2007, updated 2011. The North American Regional Climate Change Assessment Program dataset, National Center for Atmospheric Research Earth System Grid data portal, Boulder, CO.