Analysis of CMIP5 historical runs for south west US precipitation

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We examined historical runs from the CMIP5 archive to evaluate model performance against present climate. We focus on mechanisms linked to decadal variations in south west US precipitation, and the occurrence of drought. Drought is characterized by a prolonged lack of moisture, due to anomalous subsidence, diverted storm tracks, or low soil moisture. Our analysis indicates that variability in precipitation in the south west US in summer and winter, which may result in periods of drought, is associated with specific atmospheric circulation patterns arising from sea surface temperature anomalies in the Pacific Ocean. The Great Basin region (32-42^{o}N, 242-254^{o}E; Meehl and Hu 2006) is used to characterize the hydrological climate of the south west US, and 130 years of NOAA-CIRES 20th century reanalysis data is compared to the CMIP5 model historical runs.

The winter (DJF) precipitation in the south west US is dominated by storms arriving across the coast of California. In the observations, this precipitation extends east to the Rocky Mountains at around 108^{o}W. Precipitation on the east side of the mountains is predominately due to the summertime (JJA) North American monsoon (Douglas et al. 1993). In the models, the cutoff between the summer and winter precipitation regimes is shifted west to around 110^{o}W, due in part to errors in representing the effects of topology and varying model resolutions. Figures 1 and 2 show the standardized anomalies of area averaged precipitation regressed onto geopotential height or SST anomalies for five-year averages of a single season. In winter, higher than average precipitation in the south east US is associated with coastal low pressure and high height anomalies over northern North America (Fig 1a, 2a). Warm equatorial Pacific Ocean and local SST anomalies are related to the magnitude of the winter precipitation anomaly (Fig 1d, 2d). The average of the CMIP5 model results is consistent with the observations, due to their ability to accurately represent coastal storms. Cool northern Pacific SST anomalies are correlated with precipitation in the north-west of the continent near Vancouver. This influence can extend as far south as the Great Basin region, however it is not the main source of variability in the south west US in this season.

In summer, higher than average precipitation in the Great Basin region is associated with anomalously high heights over North America, and lower than average heights over the north east Pacific Ocean (Fig 1b, 2b). This relationship, which is highly correlated with monsoon precipitation in Mexico, Arizona and New Mexico, is weaker for the average of the models than for the observations. Precipitation from the north east of the Great Basin region, separate to the monsoon signal, is associated with high height anomalies over Canada, and low height anomalies over the US (Fig 1c, 2c). While the observations show that this precipitation anomaly is associated with positive SST anomalies in the northern Pacific Ocean (Fig 1f), the models show the opposite response (Fig 2f), suggesting that even the sign of the atmospheric bridge is not robust in the models. Likewise, warmer than usual ocean surface temperatures near the Gulf of California (Fig 1e) are correlated with higher than usual monsoon precipitation in the observations only. This may be due to variation in the spatial extent of monsoon precipitation in the models, associated with errors in the location of the monsoon ridge, and the failure to accurately capture the reversal of winds due to surface heating. Therefore, the atmospheric bridge between SST anomalies and south west US precipitation anomalies on decadal timescales is not well represented by the CMIP5 historical runs in summer.

There is evidence of an atmospheric bridge between typical SST anomalies in the north Pacific Ocean and near the Gulf of California to south west US precipitation in reanalysis data in summer and winter. This may be useful in predicting decadal drought in the Great Basin region if the SST anomalies are predictable on long time scales. However, the CMIP5 model historical runs are unable to robustly match the observational results for summer, despite some indication of similar circulation patterns.

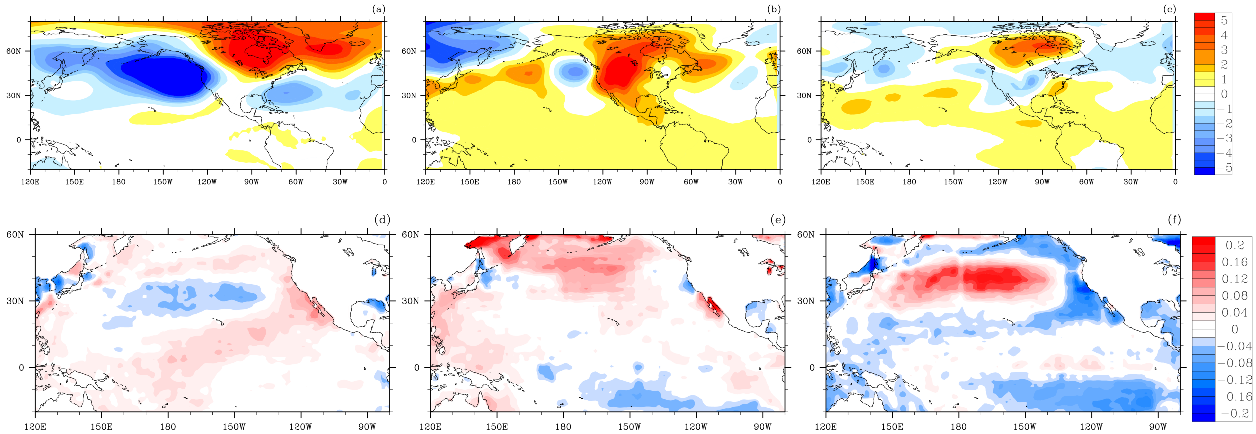

Fig 1. Results for observational data. (a)-(c) Precipitation standardized anomalies regressed onto 500hPa geopotential height anomalies (a) for west SW US precipitation in DJF, (b) for SW US precipitation in JJA, (c) for east SW US precipitation in JJA. Units are the geopotential height anomaly in meters associated with one standard deviation increase in precipitation. (d)-(f) Precipitation standardized anomalies regressed onto SST anomalies (a) for west SW US precipitation in DJF, (b) for SW US precipitation in JJA, (c) for east SW US precipitation in JJA. Units are the SST anomaly in Kelvin associated with one standard deviation increase in precipitation.

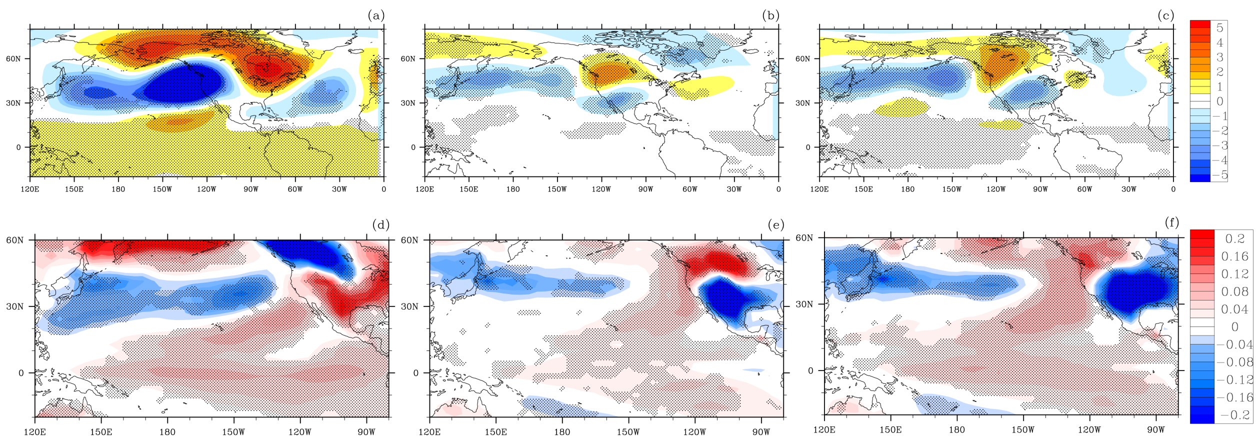

Fig 2. As above, for average of CMIP5 models re-gridded to a common resolution. (d)-(f) Precipitation index is regressed onto skin temperature, which is the SST over oceanic regions. Hatching indicates that two-thirds of the models agree on the sign of the result.

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