Variability in NEX-GDDP CMIP6 Ensemble for Alaska, American Samoa, Guam, Northern Mariana Islands, and Hawaii

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Abstract

Here, we evaluate the NEX-GDDP statistically downscaled dataset from the CMIP6 ensemble, for four climatological variables: change in total precipitation, change in total potential evapotranspiration (PET), change in maximum temperature, and change in minimum temperature. This climate research has been conducted with a geographic focus on four Pacific domains: Alaska (AK), American Samoa (AS), Guam/Commonwealth of the Mariana Islands (GU), and Hawaii (HI). The climate projections analyzed in this study can inform climate adaptation and remediation efforts by regional planners and managers in the Pacific OCONUS (outside contiguous US), where availability and access to climate data remains a priority need.

Methods

The NASA Earth Exchange - Global Daily Downscaled Projections (NEX-GDDP)[1] a 0.25-degree dataset is an ensemble of 35 Global Climate Models (GCMs) from Coupled Model Intercomparison Project Phase 6 (CMIP6)[2], statistically downscaled using bias-corrected spatial disaggregation (BCSD) and trained with weather observations from the Global Meteorological Forcing Dataset (GMFD)[3].

CMIP6 Shared Socioeconomic Pathways (SSPs):

SSP1-2.6 ("Sustainability") assumes widespread global climate change mitigation policies, clean energy technologies, and natural environment conservancy.

SSP2-4.5 ("Middle of the Road") assumes moderate global climate mitigation and adaptation and a slow progress in climate protection measures.

SSP3-7.0 ("Regional Rivalry") assumes high challenges to mitigation and adaptation.

SSP5-8.5 ("Fossil-fueled Development") reflects high challenges to mitigation and low challenges to adaptation.

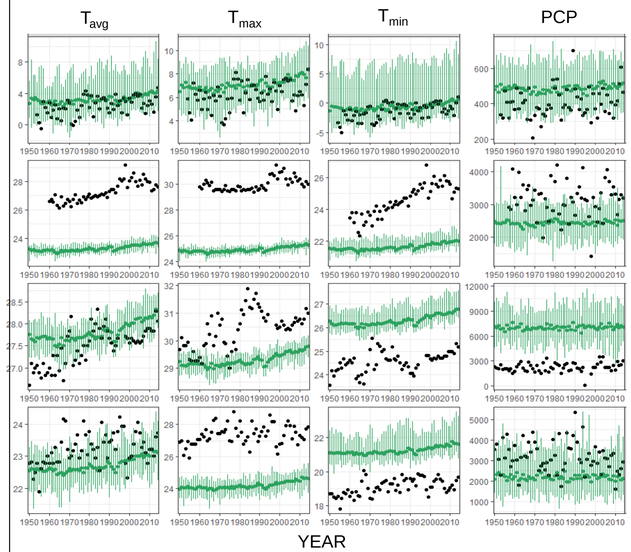
DATA PROCESSING. Downloaded global, daily data for precipitation (PCP, mm), maximum and minimum near-surface air temperature (T_{max} and T_{min}, °C) were subset to geographic domains and summarized monthly, seasonally and annually. The Potential Evapotranspiration (PET, mm) was calculated using monthly T_{max} and T_{min}, and grid-cell latitude using the Hamon method[4]. Two GCMs had corrupted files and were excluded from the ensemble. Not all the models had all scenarios or variables available, resulting in a 24-33 model ensemble per SSP.

PERIODS. Climatic variables are presented as change (Δ) between 30-year periods: the historical (1976-2005), near-term future (2025-2054), mid-term future (2045-2074), and late century future (2070-2099). Data was summarized by ensemble median, maximum, and minimum by 12-digit hydrologic unit code (HUC-12) sub-watersheds (14,034 in AK, 8 in AS, 28 in GU, and 209 in HI).

OBSERVATIONS annual averages (T_{avg}, T_{max} , T_{min}) and annual totals (PCP) [5] for one station per domain were compared with ensemble median for the grid-cell corresponding to the station location.

Results

Figure 1. *Model validation using annual station observations* using historical NEX-GDDP for 1950-2014.*

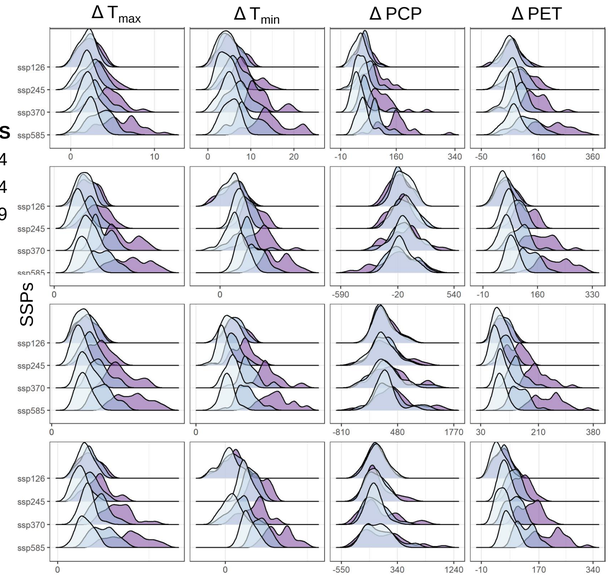


	AK		AS		GU		HI	
	obs	mod	obs	mod	obs	mod	obs	mod
T_{avg}(°C)	2.4	3.2	27.3	23.3	27.5	27.8	23.2	22.7
T_{max} (°C)	6.2	7.1	30	24.9	30.4	29.3	27.4	24.2
T_{min} (°C)	-1.4	-0.6	24.6	21.6	24.6	26.3	19.1	21.2
PCP (mm)	403	487	3143	2434	2261	7054	3201	2198

Table 1. *NEX-GDDP model (mod) validation using annual mean station observations* (obs) for 1950-2014.*

**Station observation data was downloaded from NOAA Regional Climate Center's SC ACIS data portal[4] for Anchorage Ted Stevens International Airport, AK; Weather Service Office, AS; Guam International Airport, GU; Hilo International Airport, HI.*

Figure 2. *Distribution of HUC-12 annual medians for each GCM per domain (rows) and variable (columns). Colors represent delta periods and y-axes represent SSPs.*



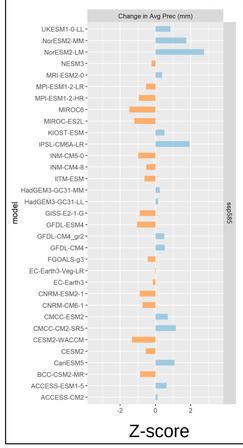


Figure 3. *Example of ensemble variability with outliers. Normalized median change in PRECIP in HI by 2070-2099.*

References and Acknowledgments

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Results and Discussion

MODEL VALIDATION *(Figure1, Table 1)*

Alaska. Modeled data show a very good fit in annual values with ~1°C overestimation in T_{avg} , T_{max}, and T_{min}, and 84mm (+21%) in PCP. **American Samoa**. Modeled data show ~5°C underestimation in T_{avg} and T_{max}, and 709mm (-23%) in PCP. The T_{min} was underestimated by ~3°C and the increasing trend is not present. **Guam & CNMI**. Modeled T_{avg} shows overall small underestimation of 0.3°C with highest differences in 1950s and 1960s. T_{max} was underestimated by ~1°C and T_{min} was overestimated by ~2°C. Precipitation was overestimated by 4,793mm (+212%). **Hawaii**. T_{avg} shows small underestimation of 0.5°C. T_{max} was underestimated by ~3°C while T_{min} was overestimated by ~2°C. Precipitation was underestimated by 1,003mm (-31%). Interannual variability in values is not well captured in all domains and variables (Figure 1, Table 1). NEX-GDDP documentation[1], states that the model may produce unrealistic values over small ocean islands, due to lack of GMFD validation, which could explain discrepancies in AS, GU, and HI results.

FUTURE CHANGES

Highest changes in the future, as expected, are projected in SSP5-8.5 by the end of the century across all domains and variables (Figure 2, Table 2). The ensemble variance increases with SSP for each variable and domain. AK shows the highest changes in future T_{min} and T_{max}, and the highest ensemble variance for temperature variables. Changes in PRECIP are highest in AK, and their ensemble variance and distribution show similar trends through time as other variables. PRECIP distribution over island domains does not show significant changes through time in the median, however it shows peak flattening through SSPs and time suggesting higher uncertainty between models in higher SSPs and through time. The results are also difficult to be interpreted between extreme dry and wet projections from different models. The highest ensemble variance is in HI. Changes in PET follow trends in temperature.

Future research on NEX-GDDP will focus on examining model outliers, especially in precipitation (Figure 3). Presented datasets are available at **USEPA EnviroAtlas (QR code in References & Acknowledgements).**

		Historical	Δ SSP1-2.6			Δ SSP2-4.5			Δ SSP3-7.0			Δ SSP5-8.5		
		med	med	min	max	med	min	max	med	min	max	med	min	max
AK	T_{max}	7.0	+2.3	+0.4	+4.4	+3.3	+0.2	+6.3	+4.5	+1.3	+8.6	+5.6	+0.9	+11.2
	T_{min}	-0.7	+4.8	+0.3	+9.9	+8.0	+3.3	+15.3	+10.6	+5.2	+19.6	+13.8	+7.0	+22.7
	PCP	489	+60	+22	+119	+91	+43	+164	+109	+50	+253	+155	+57	+323
	PET	510	+62	-22	+144	+98	-3	+194	+139	+16	+267	+196	+62	+335
AS	T_{max}	24.9	+1.3	+0.7	+1.9	+1.7	+0.8	+2.5	+2.5	+1.9	+3.7	+2.9	+1.5	+4.3
	T_{min}	24.6	+0.6	-0.5	+1.5	+1.5	+0.6	+2.3	+1.9	+0.5	+3.5	+2.6	+1.4	+4.0
	PCP	2436	-14	-194	+190	+17	-181	+255	+73	-234	+439	+3	-488	+350
	PET	1088	+60	+8	+112	+114	+61	+167	+165	+86	+278	+210	+120	+311
GU	T_{max}	29.2	+1.3	+0.8	+2.1	+1.9	+1.0	+2.7	+2.6	+2.0	+3.8	+3.2	+2.1	+4.4
	T_{min}	26.2	+1.5	+0.7	+2.2	+1.8	+0.7	+2.6	+2.7	+1.9	+4.1	+3	+1.8	+4.3
	PCP	7074	+126	-175	+724	+192	-544	+1136	+298	-436	+1204	+345	-562	+1514
	PET	1399	+97	+54	+149	+145	+73	+185	+204	+165	+315	+239	+162	+346
HI	T_{max}	24.1	+1.7	+0.9	+2.8	+2.2	+1.1	+3.7	+3.3	+2.1	+5.4	+4.0	+2.0	+5.9
	T_{min}	21.1	+0.5	-1.0	+1.6	+1.9	+0.8	+2.9	+1.9	+0.3	+3.1	+3.3	+2.0	+4.9
	PCP	2193	-7	-270	+340	-42	-250	+556	-31	-348	+748	+67	-392	+1075
	PET	1063	+59	+11	+106	+119	+62	+179	+144	+88	+211	+215	+125	+321

Table 2. *GCM median Δ by 2070-2099 and variability in HUC-12 median per domain. Variability reported as median, minimum and maximum of the ensemble across all the HUC-12s per domain.*