

# Supporting Information for “High-resolution regional climate model evaluation using variable-resolution CESM over California”

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## Additional Supporting Information (Files uploaded separately)

1. VR-CESM  $0.25^\circ$  grid mesh file
2. VR-CESM  $0.125^\circ$  grid mesh file

## Introduction

This supporting information includes:

- 1) The original grid-refined mesh files for implementing the variable-resolution cubed-sphere grids, which can be used by other scientists working in the field;
- 2) The interannual variability plots of mean  $T_{max}$ ,  $T_{min}$ ,  $T_{avg}$  and  $Pr$  in simulations and PRISM over 5, 10, 20 and 25 seasons or years respectively, which show that our simulation period from year 1980-2005 is appropriate for the regional climatology studies in this paper;
- 3) The time trend result figures of  $T_{max}$ ,  $T_{min}$ ,  $T_{avg}$  and  $Pr$  in models and PRISM over year 1980-2005, including probability for a statistically significant trend under the

two-tailed t-statistic with a significance level of 0.05 and the magnitude of the linear trend fit coefficients;

4) Plots of other seasons for  $T_{max}$ ,  $T_{min}$ , and  $T_{avg}$  not addressed in this paper and statistics metric tables of other seasons over our simulation period;

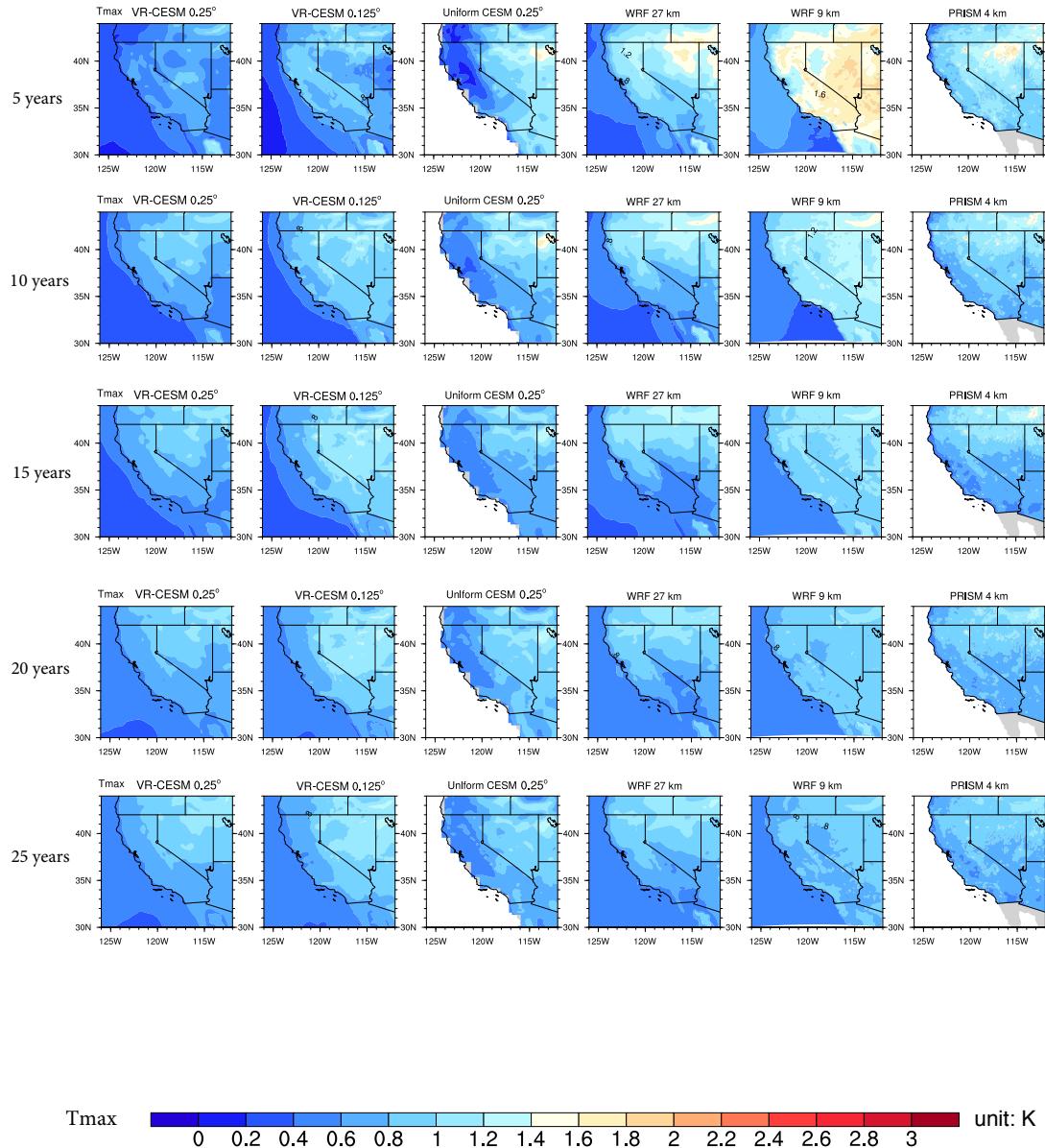
5) Result figures together with the output from a globally uniform CESM run at  $0.25^\circ$  spatial resolution with the finite volume (FV) dynamical core [Wehner *et al.*, 2014].

## References

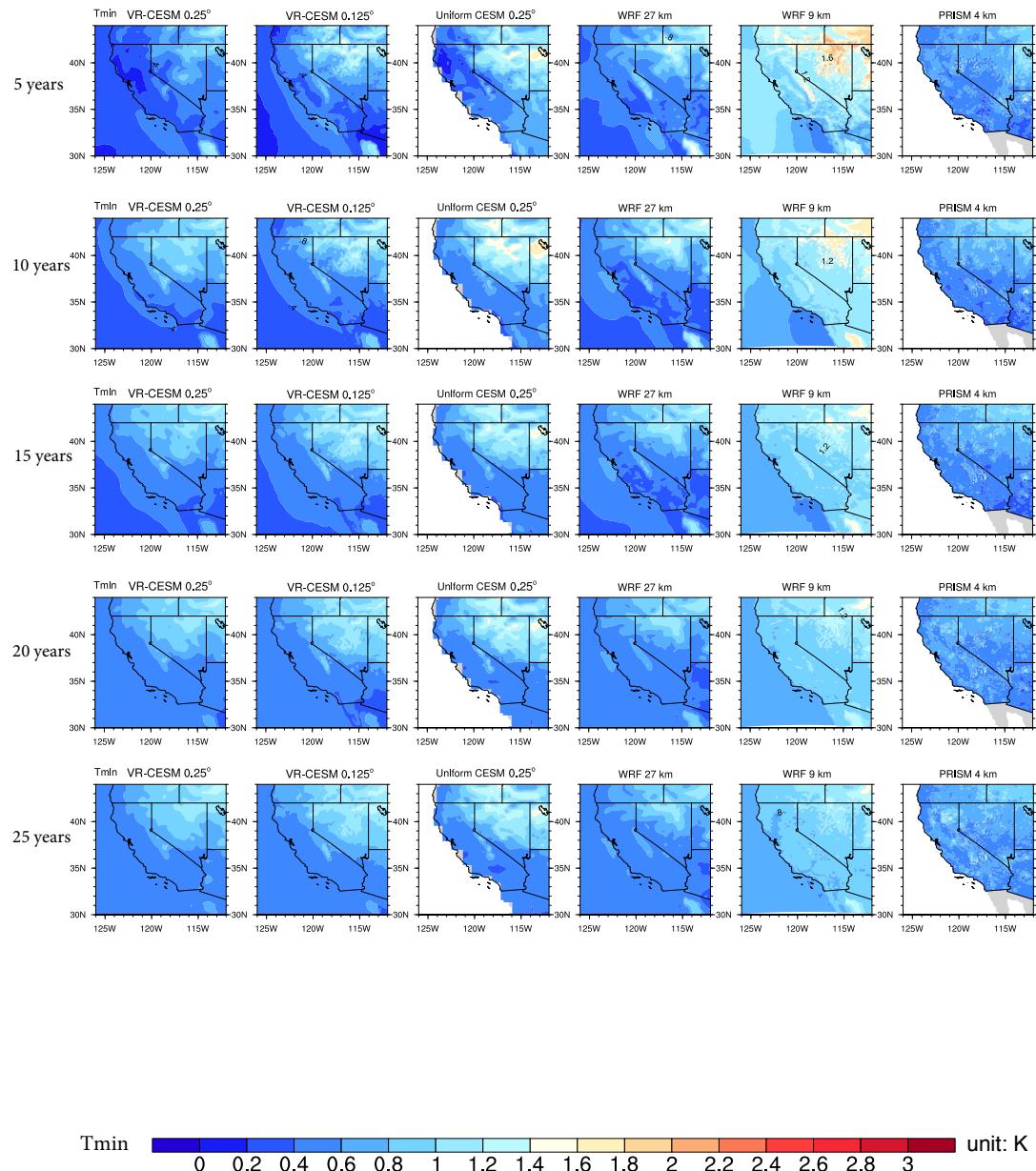
- Wehner, M. F., K. Reed, F. Li, Prabhat, J. Bacmeister, C.-T. Chen, C. Paciorek, P. Gleckler, K. Sperber, W. D. Collins, A. Gettelman, and C. Jablonowski (2014), The effect of horizontal resolution on simulation quality in the Community Atmospheric Model, CAM5.1, *J. Model. Earth. Sys.*, doi: 10.1002/2013MS000276.

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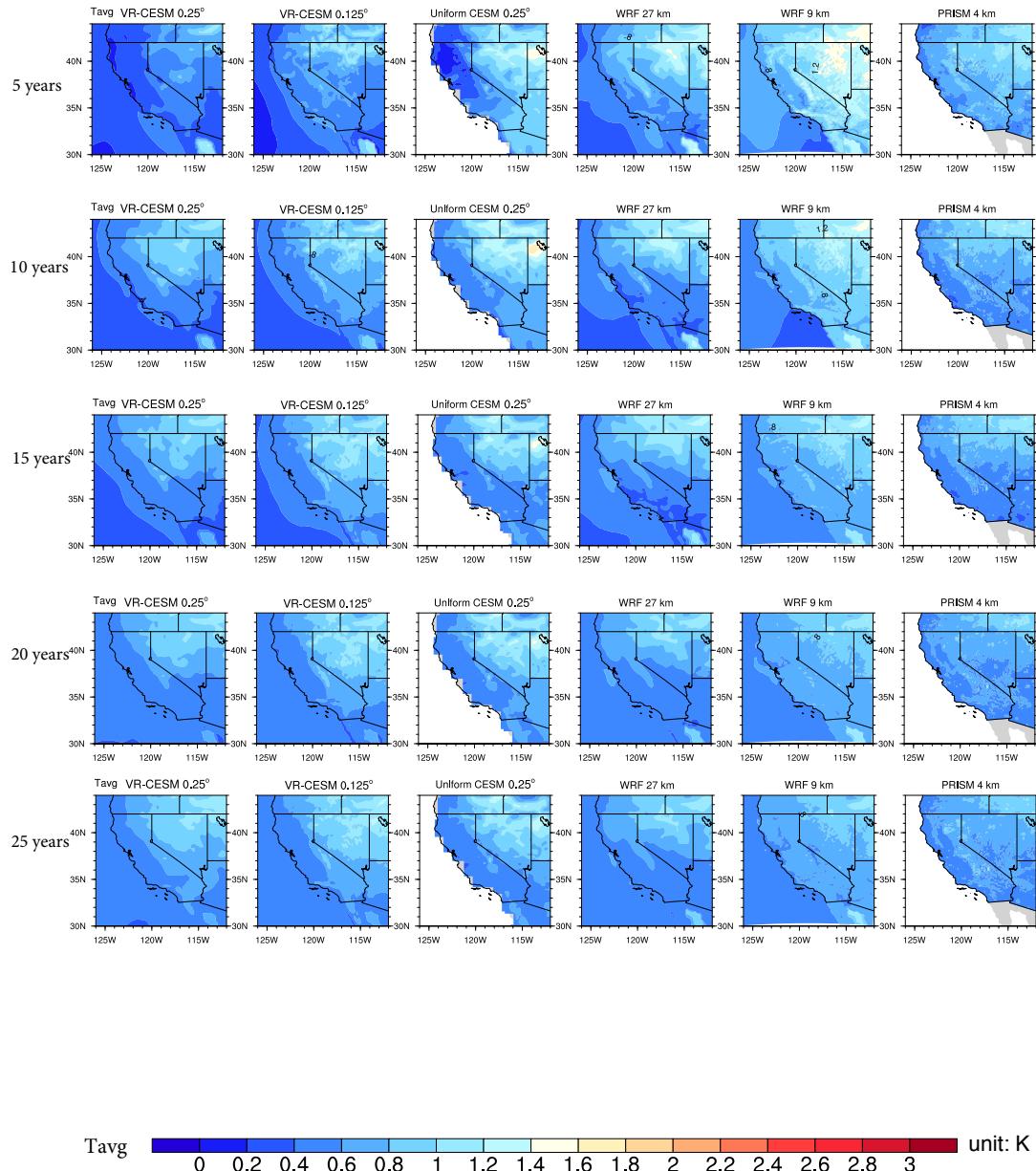
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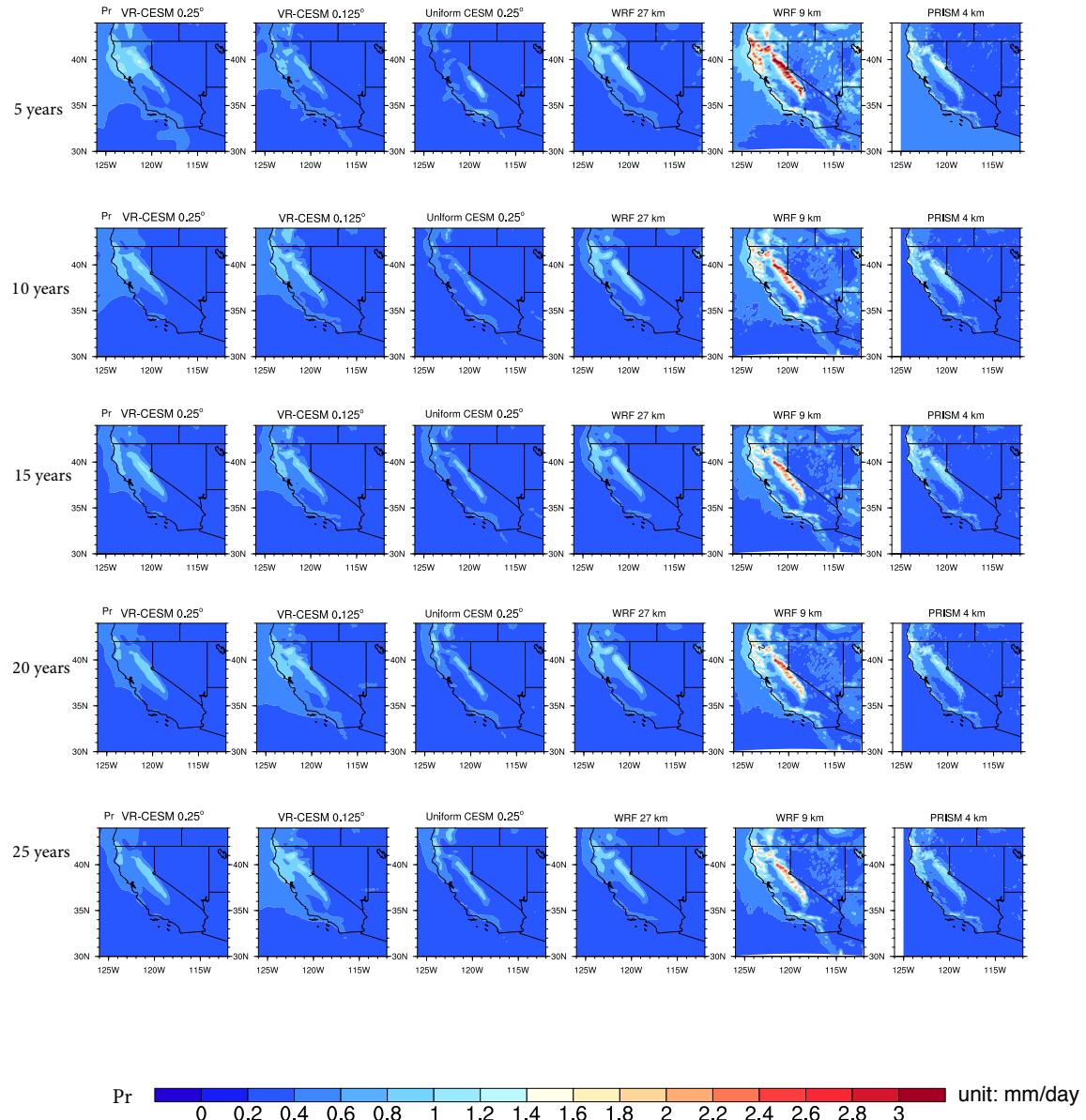
**Figure S1.** Sample standard deviation of annual  $T_{max}$  from models and PRISM with 5 year step from year 1980.



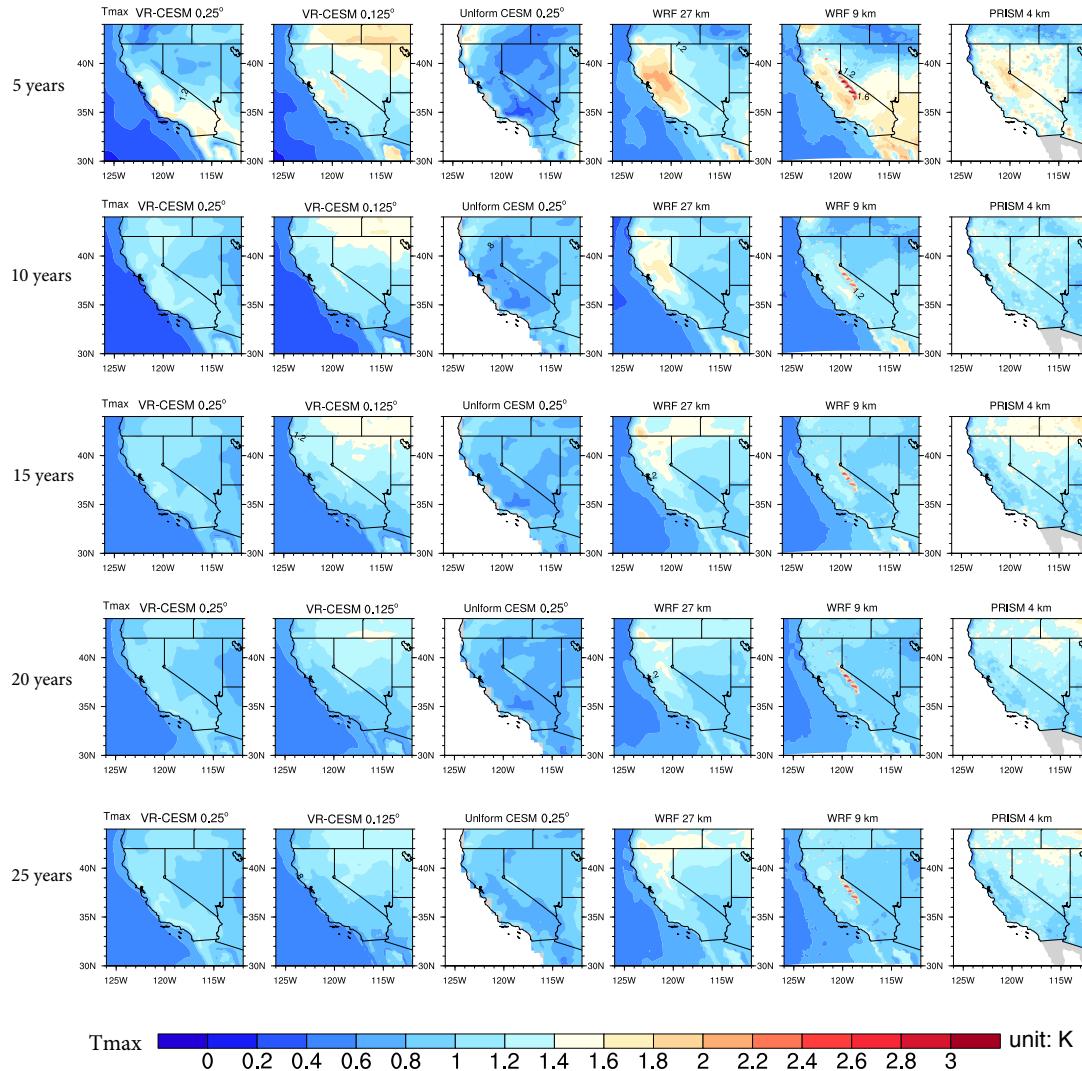
**Figure S2.** Sample standard deviation of annual  $T_{min}$  from models and PRISM with 5 year step from year 1980.



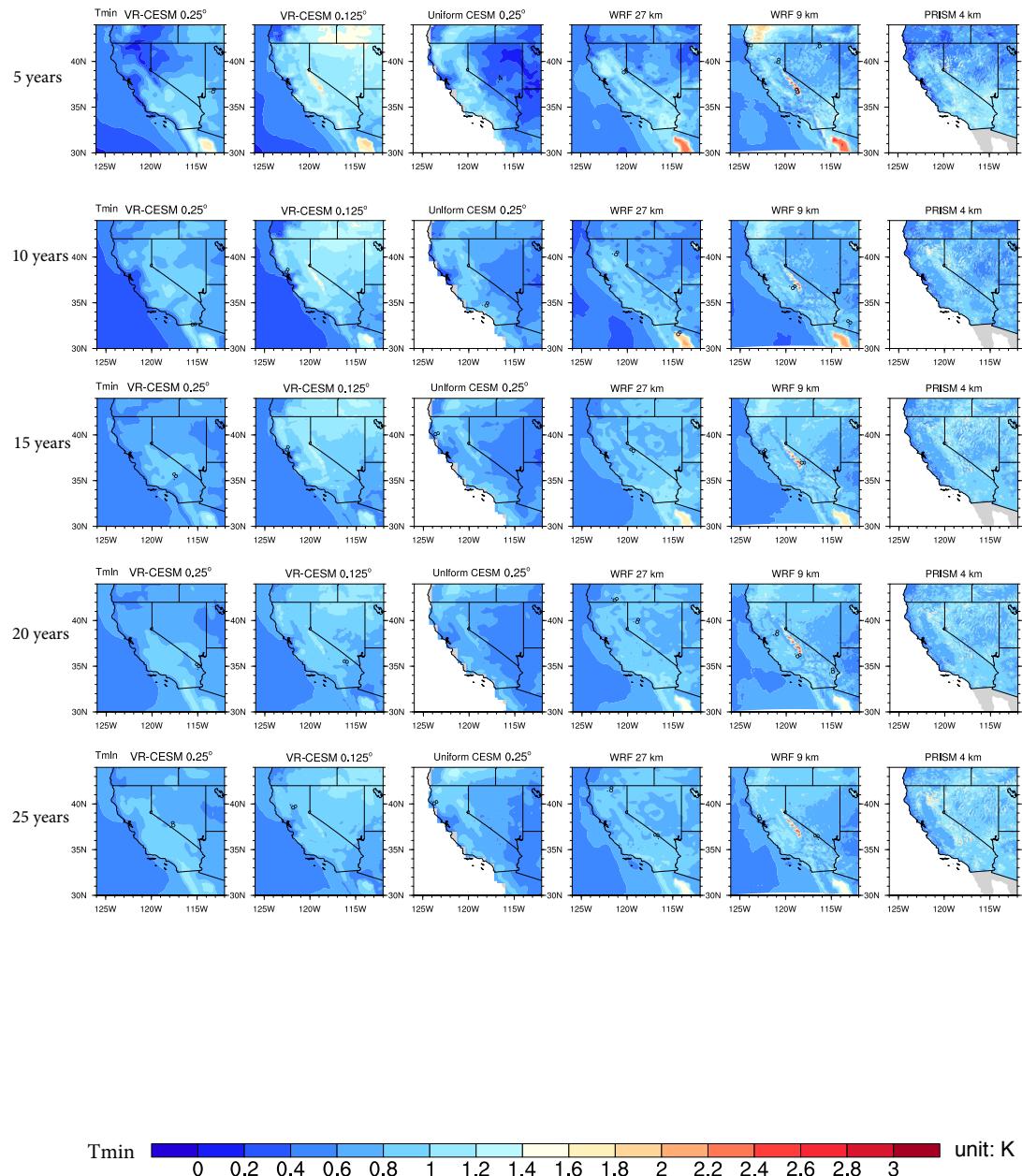
**Figure S3.** Sample standard deviation of annual  $T_{avg}$  from models and PRISM with 5 year step from year 1980.



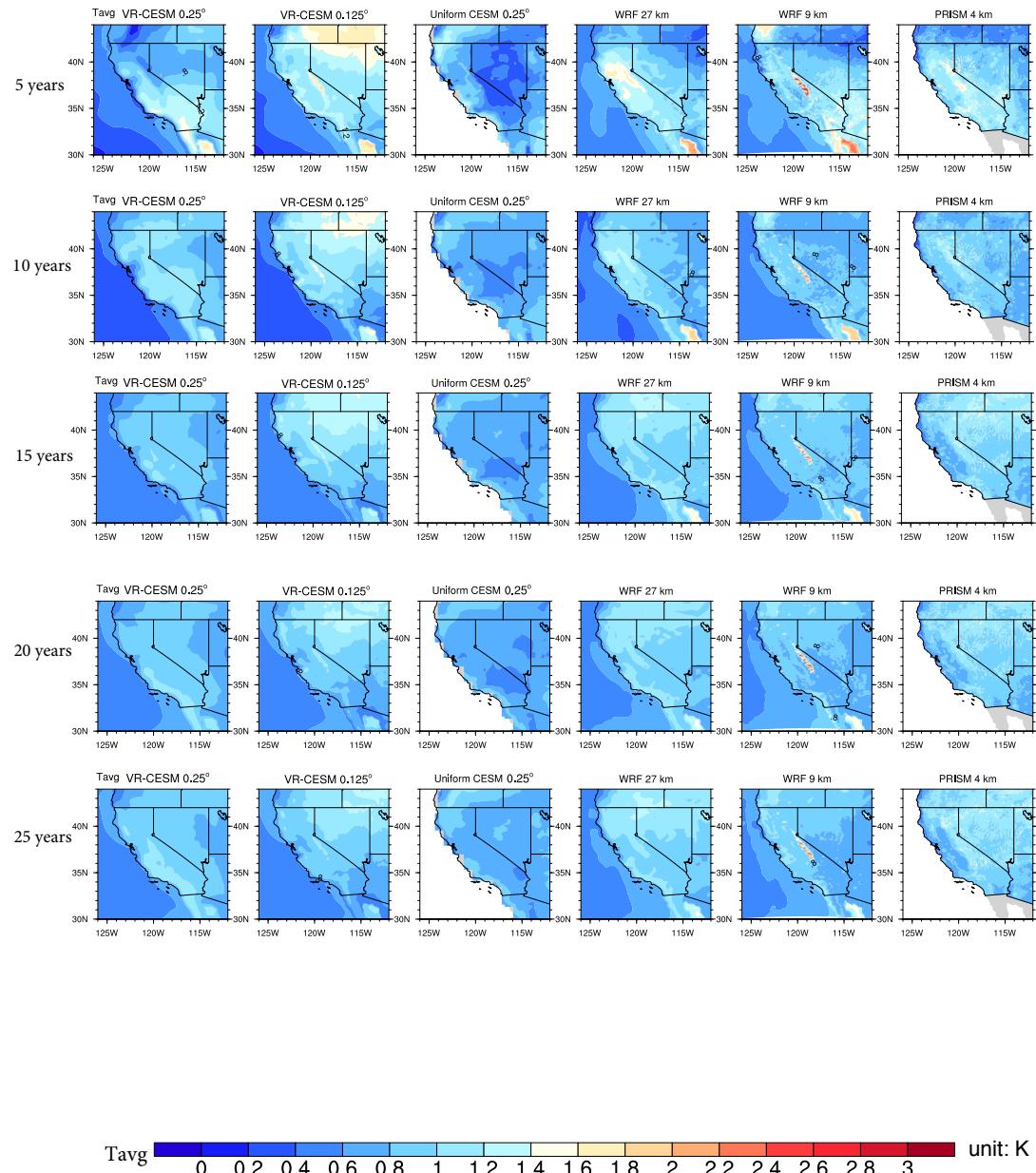
**Figure S4.** Sample standard deviation of annual Pr from models and PRISM with 5 year step from year 1980.



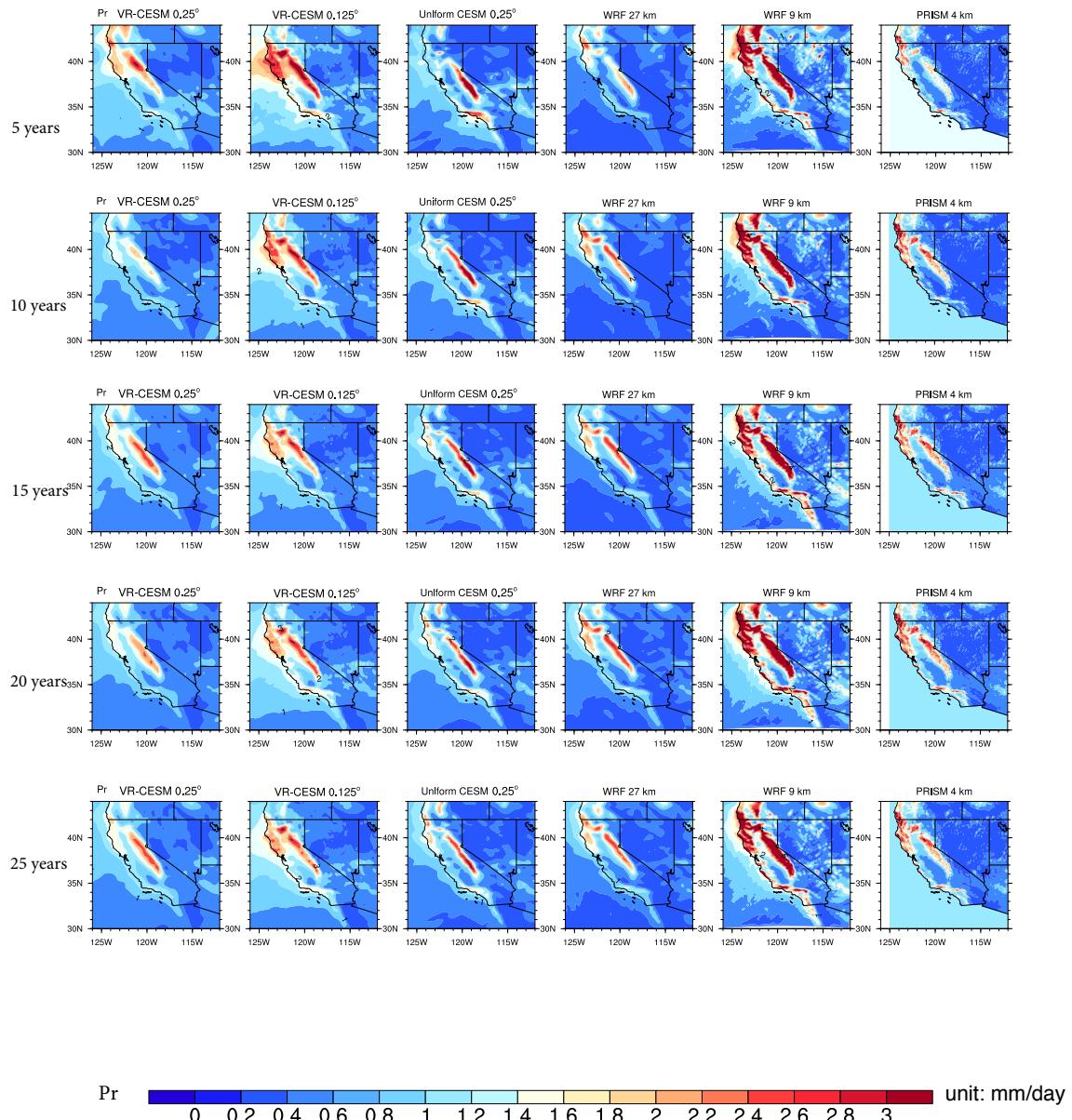
**Figure S5.** Sample standard deviation of JJA  $T_{max}$  from models and PRISM with 5 year step from year 1980.



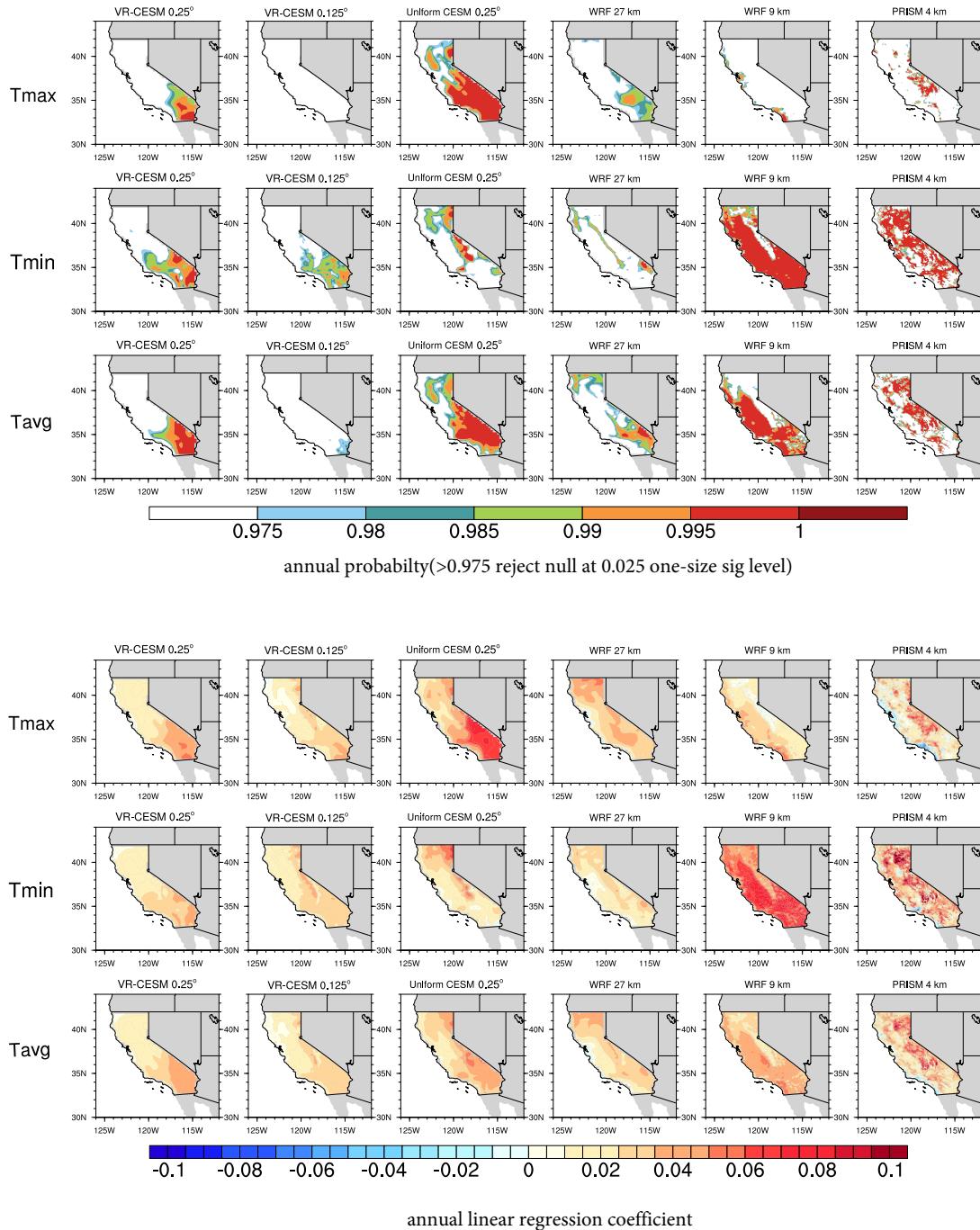
**Figure S6.** Sample standard deviation of JJA  $T_{min}$  from models and PRISM with 5 year step from year 1980.



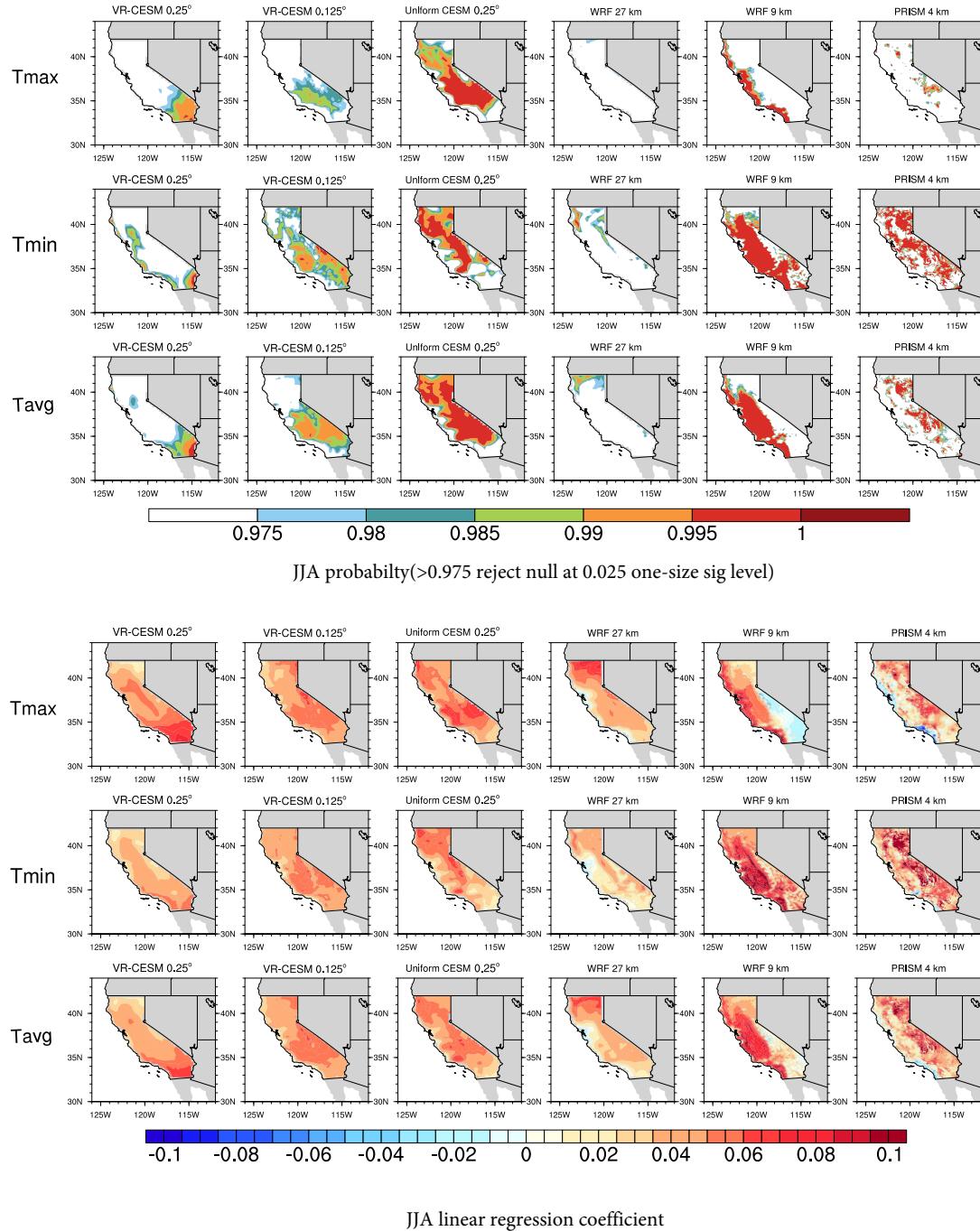
**Figure S7.** Sample standard deviation of JJA  $T_{avg}$  from models and PRISM with 5 year step from year 1980.



**Figure S8.** Sample standard deviation of DJF Pr from models and PRISM with 5 year step from year 1980.

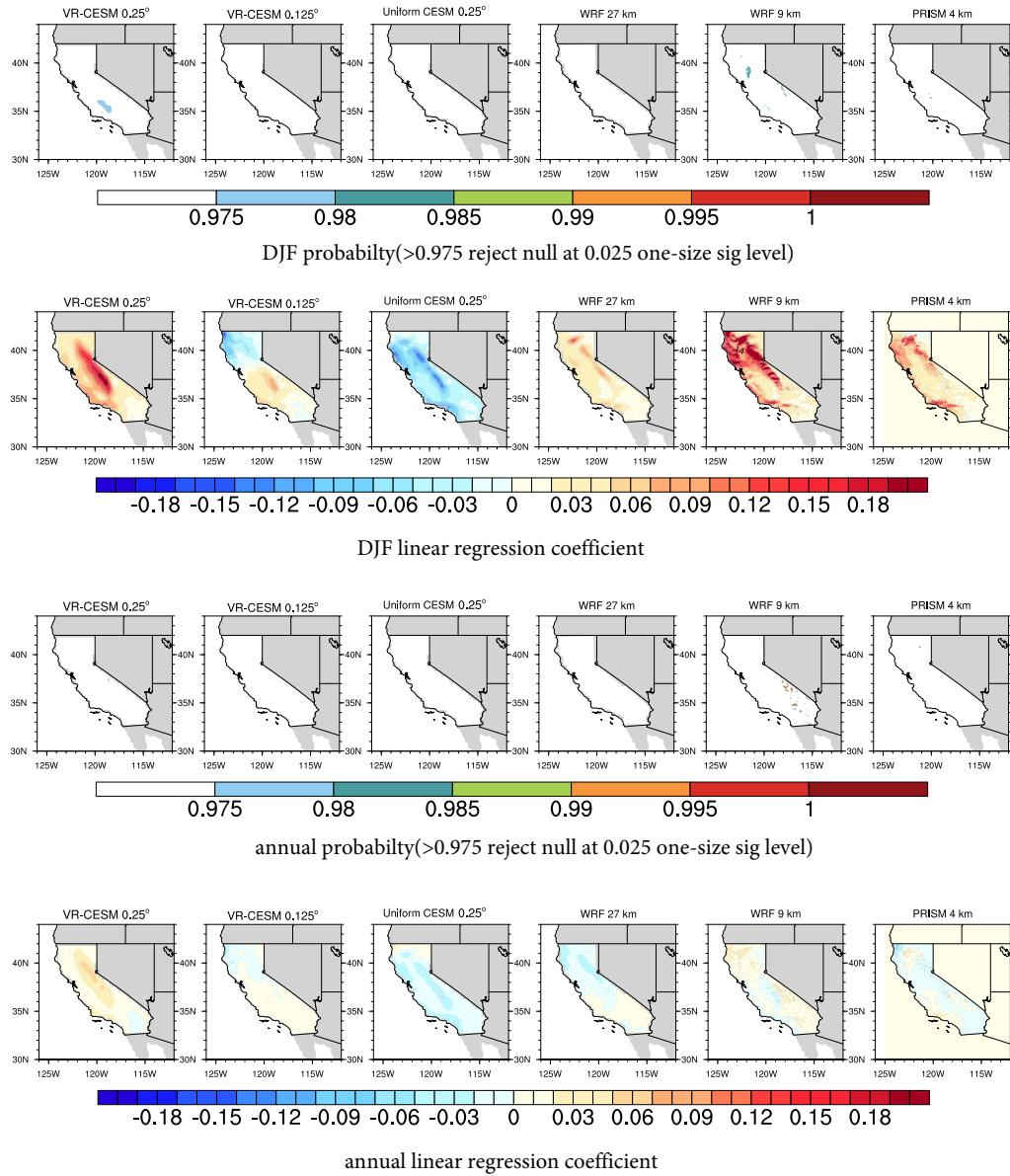


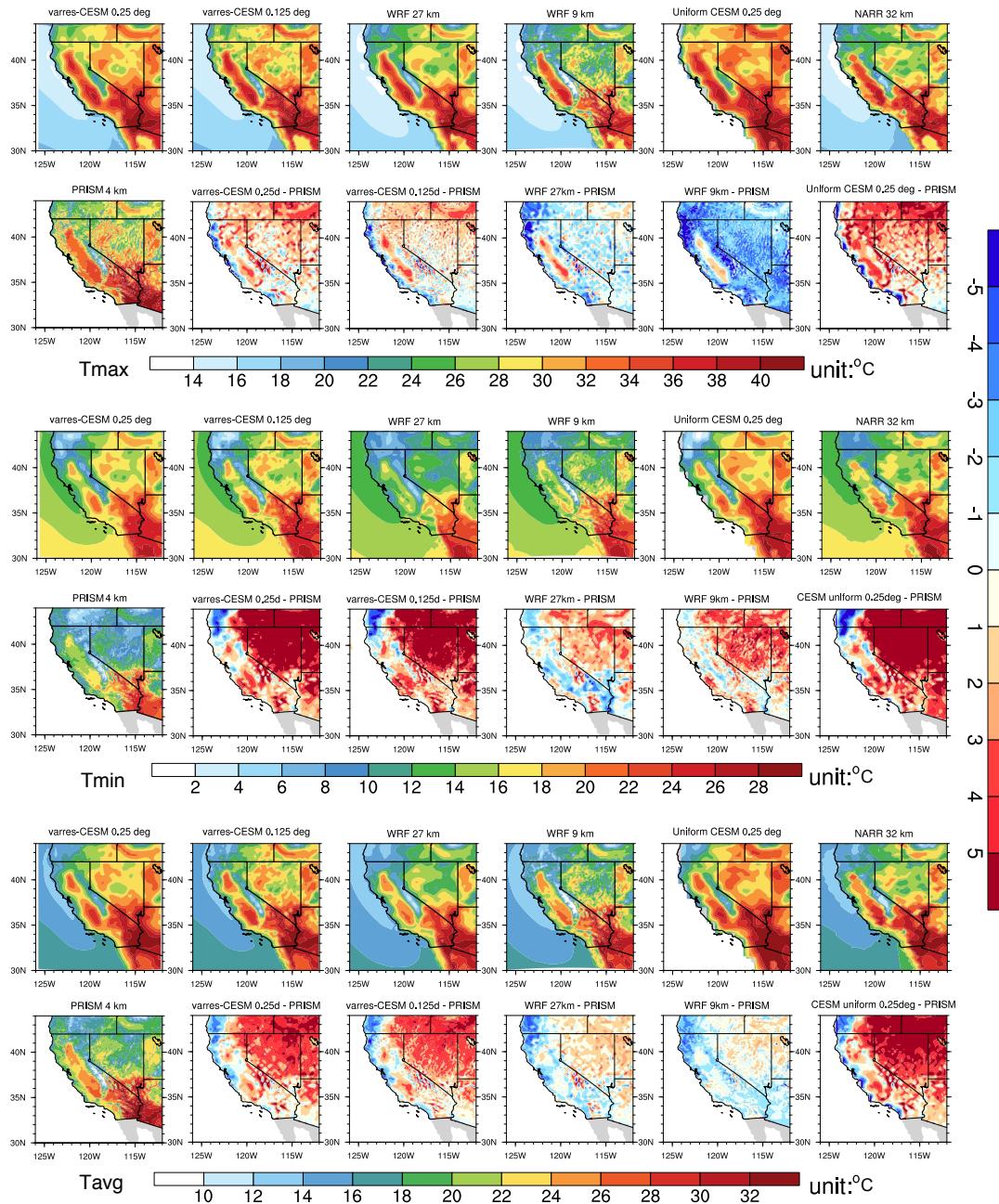
**Figure S9.** T-test for a statistically significant linear time trend of annual  $T_{max}$ ,  $T_{min}$  and  $T_{avg}$  over 1980-2005 of models and PRISM.



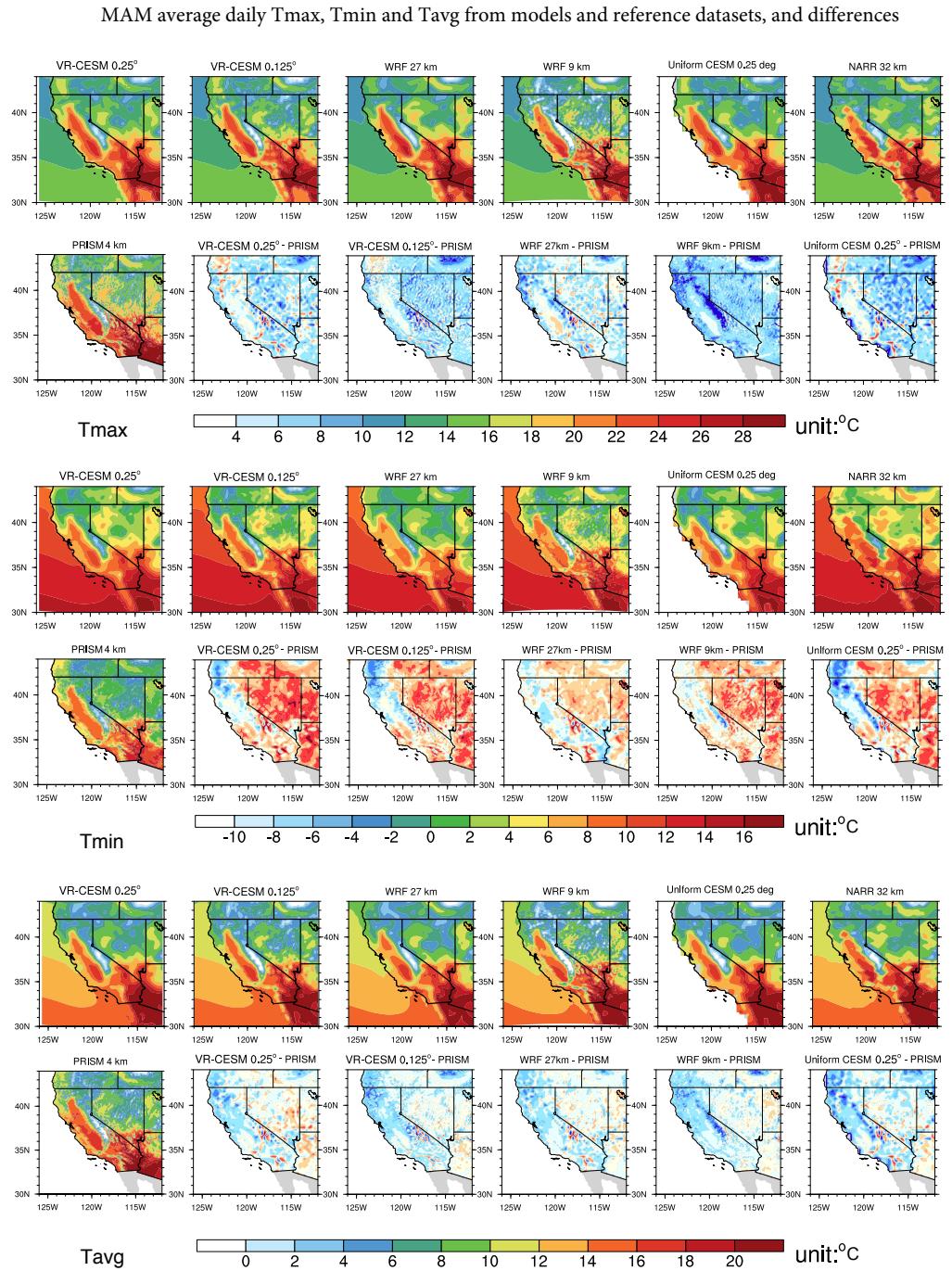
**Figure S10.** T-test for a statistically significant linear time trend of JJA  $T_{max}$ ,  $T_{min}$  and  $T_{avg}$  over 1980–2005 of models and PRISM.

T-test for a statistically significant linear time trend of annual and DJF precipitation over 1980-2005

**Figure S11.** T-test for a statistically significant linear time trend of annual and DJF precipitation over 1980-2005 of models and PRISM.

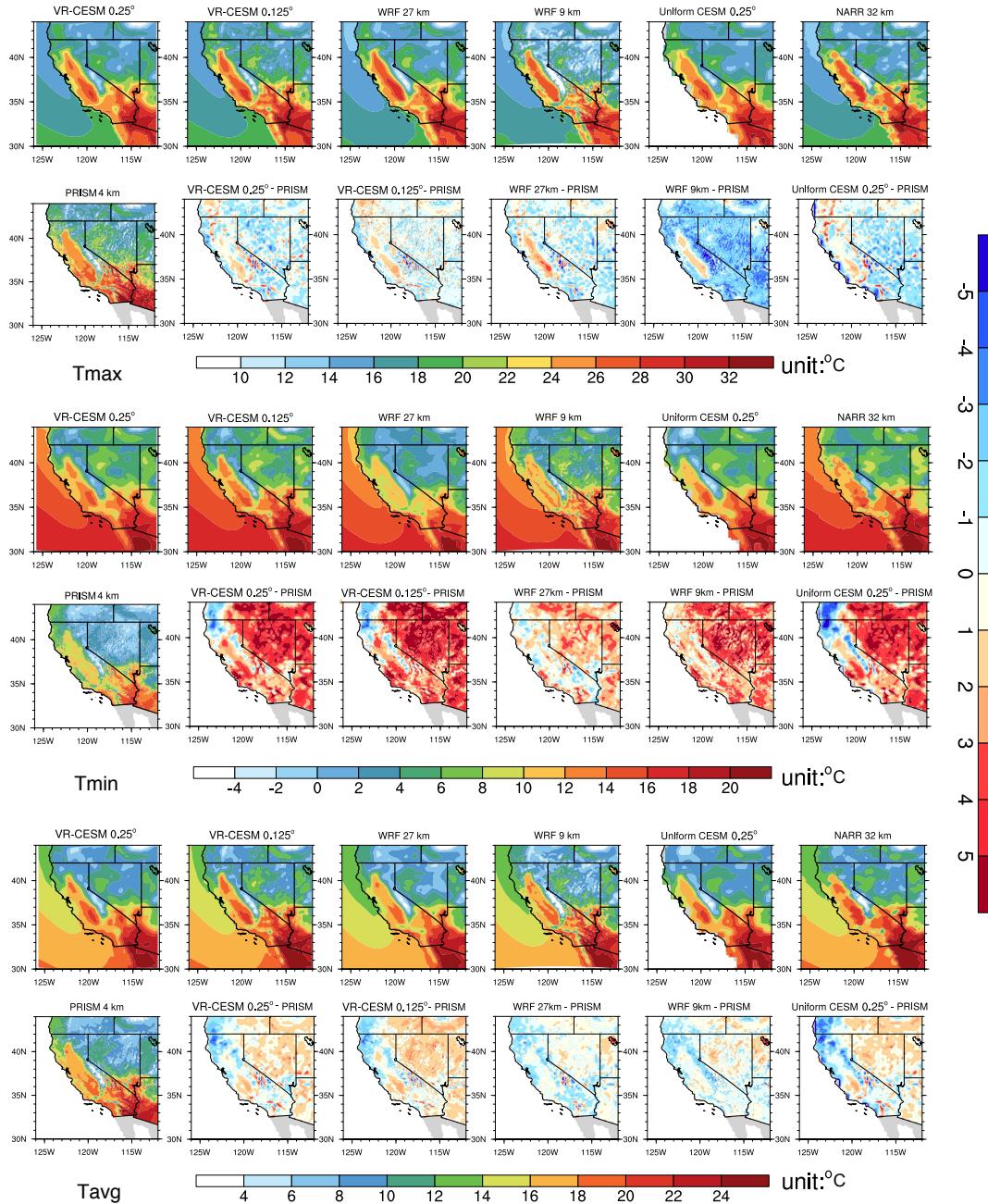


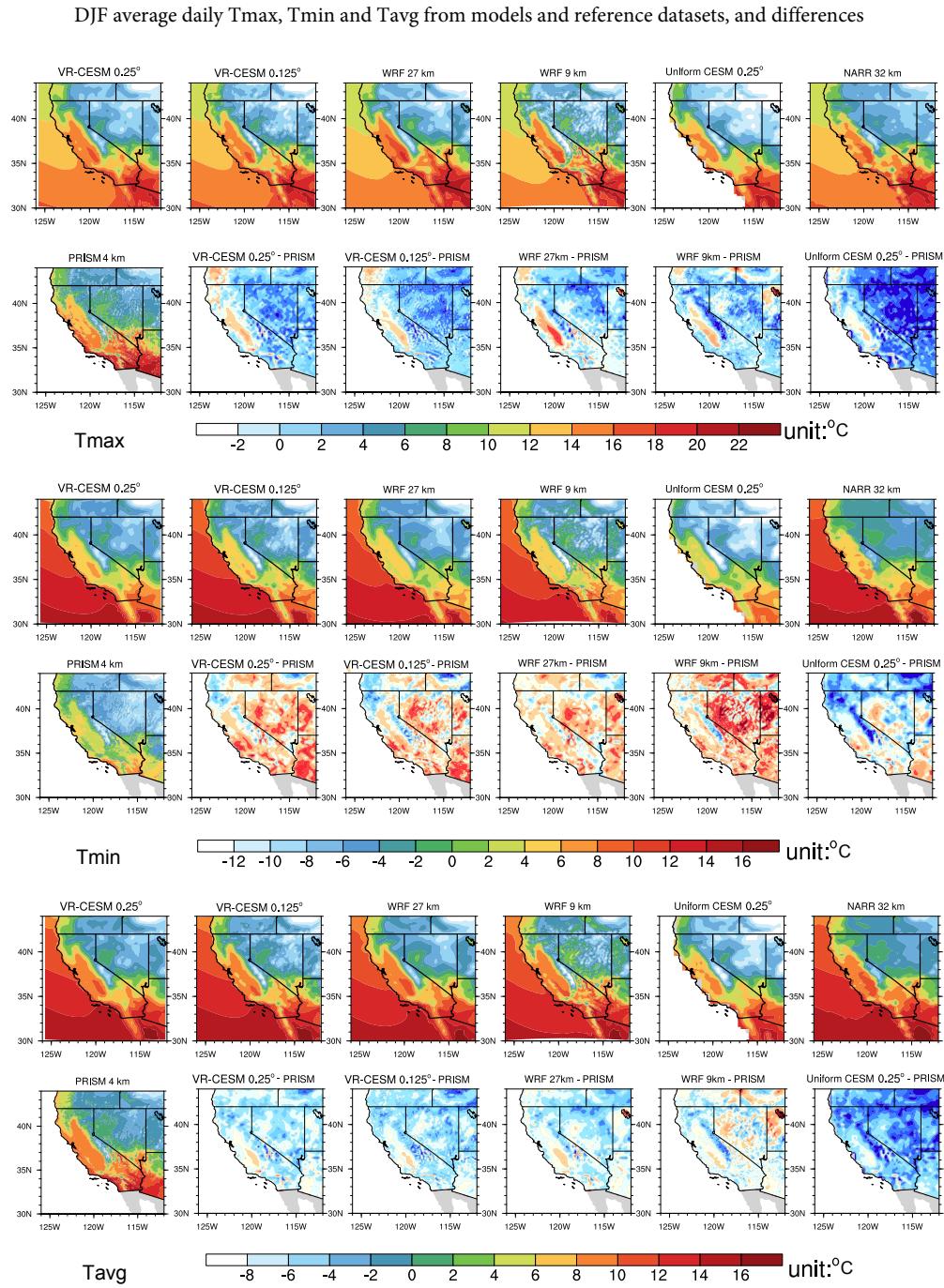
**Figure S12.** Same as Figure 4 in the paper but adding uniform CESM 0.25°.



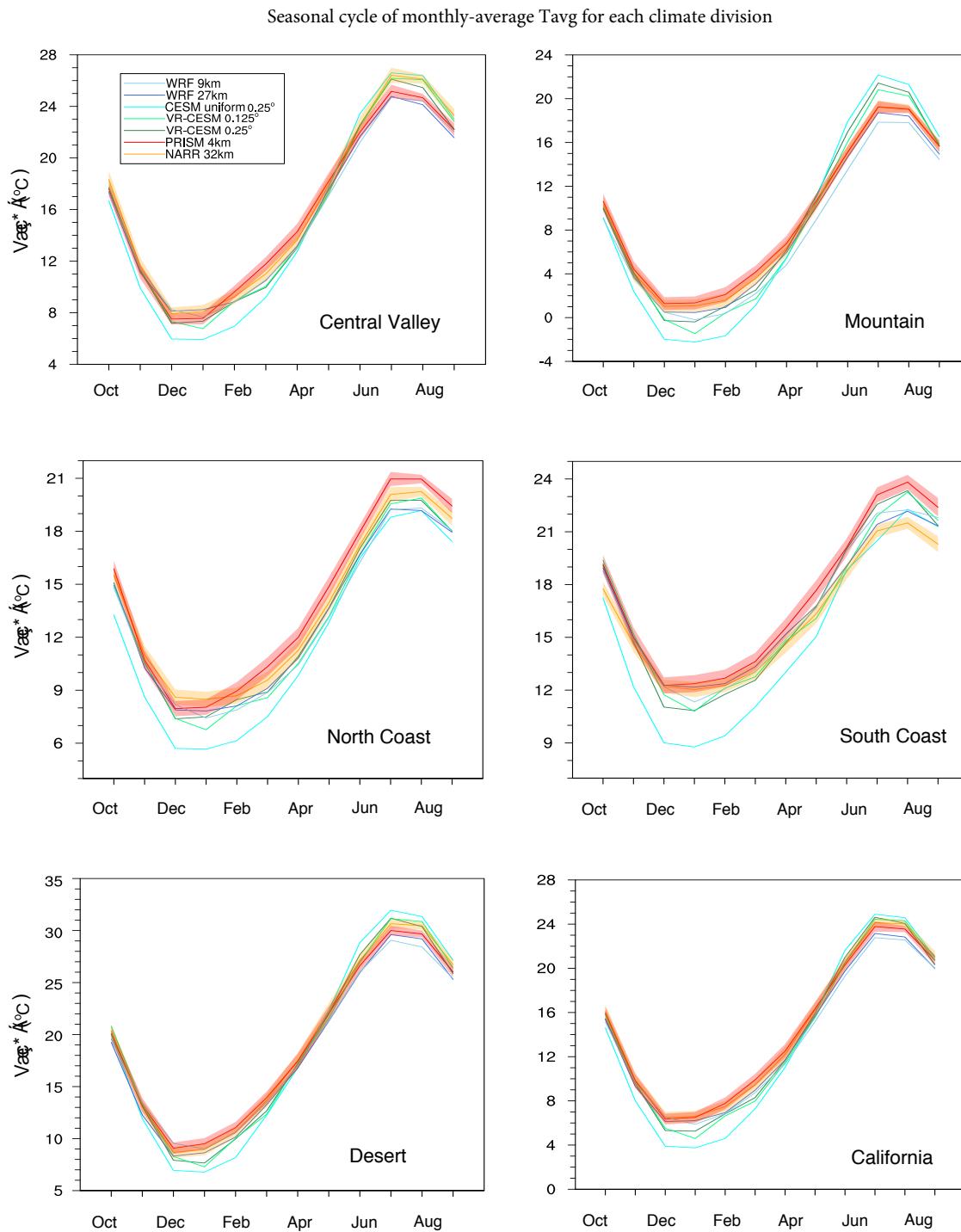
**Figure S13.** Similar to Figure 4 in the paper but for season MAM.

SON average daily Tmax, Tmin and Tavg from models and reference datasets, and differences

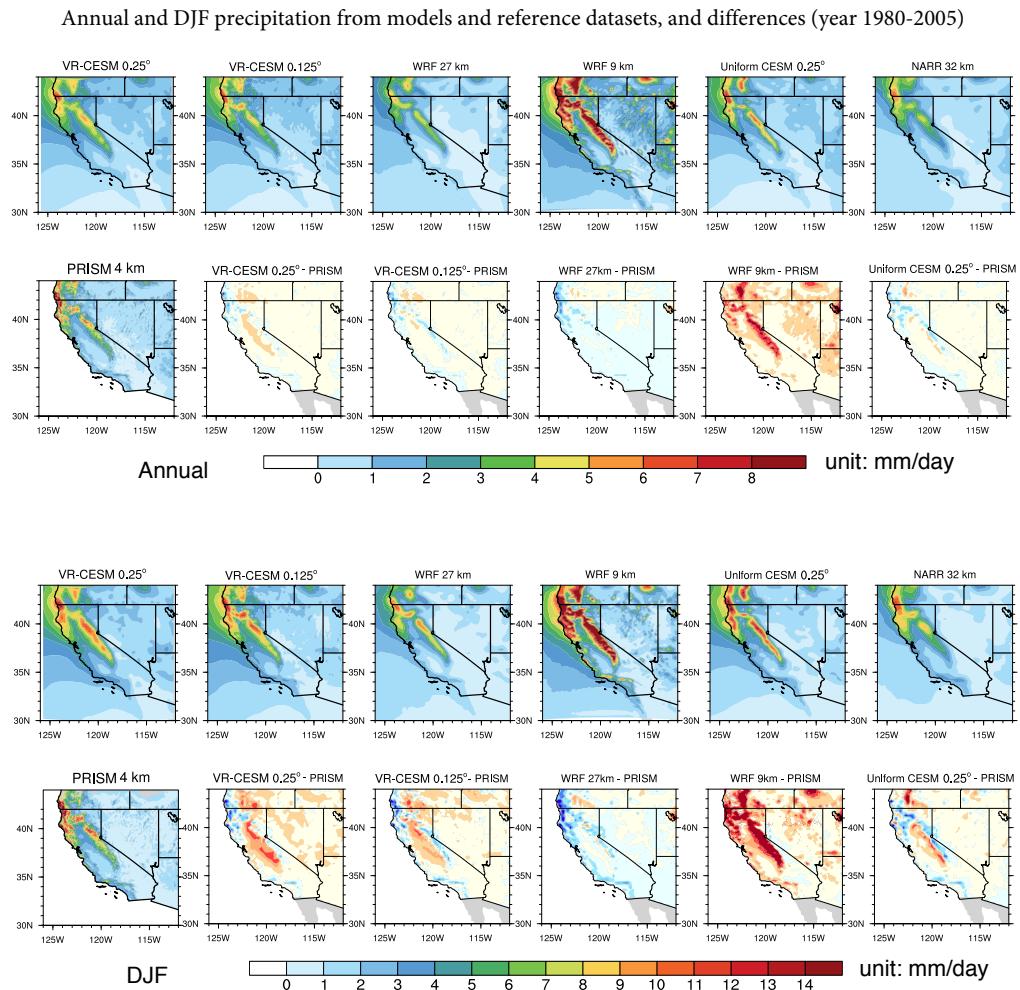
**Figure S14.** Similar to Figure 4 in the paper but for season SON.



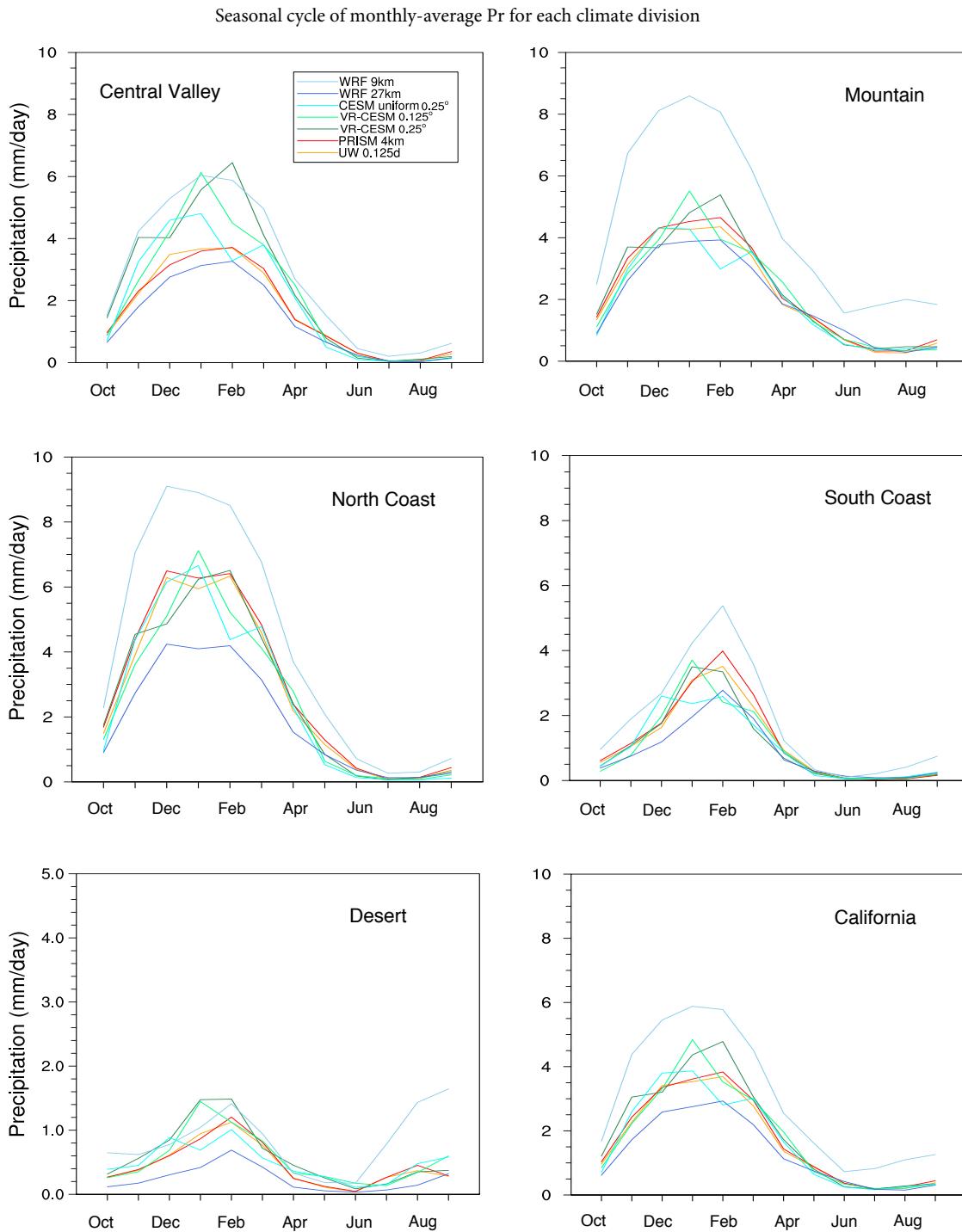
**Figure S15.** Similar to Figure 4 in the paper but for season DJF.



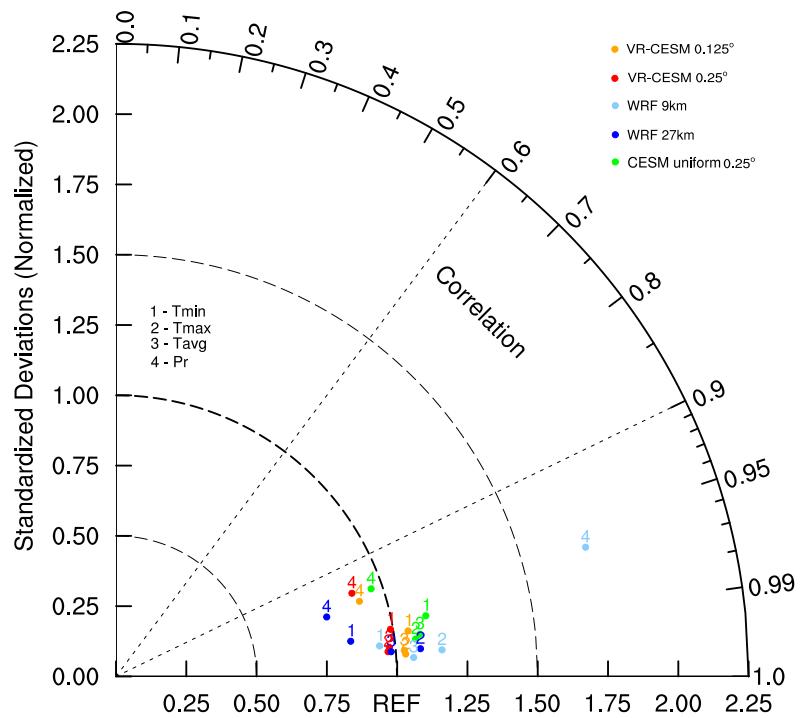
**Figure S16.** Similar to Figure 6 in the paper but adding uniform CESM  $0.25^{\circ}$ .



**Figure S17.** Similar to Figure 9 in the paper but adding uniform CESM 0.25°.



**Figure S18.** Similar to Figure 11 in the paper but adding uniform CESM  $0.25^\circ$ .



**Figure S19.** Similar to Figure 14 in the paper but adding uniform CESM 0.25°.

**Table S1.** RMSD ( $^{\circ}C$ ), MSD ( $^{\circ}C$ ) and Spatial Correlation (Corr) for seasonally-averaged MAM (March-April-May) temperature over California

<b>RMSD</b>	<b>UW</b>		<b>PRISM</b>		<b>Daymet</b>		
	T <sub>max</sub>	T <sub>min</sub>	T <sub>max</sub>	T <sub>min</sub>	T <sub>avg</sub>	T <sub>max</sub>	T <sub>min</sub>
<b>VR-CESM 0.25°</b>	1.776	2.212	2.297	2.164	2.033	2.344	2.686
<b>VR-CESM 0.125°</b>	1.727	1.841	2.145	1.883	1.908	2.214	2.287
<b>WRF 27km</b>	1.945	2.062	2.433	1.863	1.991	2.366	2.541
<b>WRF 9km</b>	3.114	2.065	3.060	1.568	1.801	2.969	2.293
<b>Uniform CESM 0.25°</b>	2.680	2.112	3.059	2.404	2.674	3.099	2.631

<b>MSD</b>	<b>UW</b>		<b>PRISM</b>		<b>Daymet</b>		
	T <sub>max</sub>	T <sub>min</sub>	T <sub>max</sub>	T <sub>min</sub>	T <sub>avg</sub>	T <sub>max</sub>	T <sub>min</sub>
<b>VR-CESM 0.25°</b>	-0.859	1.308	-0.813	0.681	-0.819	-0.608	1.350
<b>VR-CESM 0.125°</b>	-1.261	0.983	-1.274	0.328	-1.202	-1.052	0.952
<b>WRF 27km</b>	-1.066	0.745	-1.020	0.117	-0.942	-0.818	0.788
<b>WRF 9km</b>	-2.516	1.259	-2.530	0.604	-1.312	-2.305	1.227
<b>Uniform CESM 0.25°</b>	-1.191	0.417	-1.139	-0.212	-1.398	-0.938	0.458

<b>Corr</b>	<b>UW</b>		<b>PRISM</b>		<b>Daymet</b>		
	T <sub>max</sub>	T <sub>min</sub>	T <sub>max</sub>	T <sub>min</sub>	T <sub>avg</sub>	T <sub>max</sub>	T <sub>min</sub>
<b>VR-CESM 0.25°</b>	0.997	0.963	0.995	0.963	0.990	0.994	0.942
<b>VR-CESM 0.125°</b>	0.998	0.975	0.996	0.972	0.993	0.995	0.959
<b>WRF 27km</b>	0.996	0.959	0.994	0.968	0.991	0.994	0.937
<b>WRF 9km</b>	0.993	0.971	0.994	0.983	0.994	0.993	0.962
<b>Uniform CESM 0.25°</b>	0.993	0.960	0.990	0.949	0.984	0.989	0.938

**Table S2.** RMSD ( $^{\circ}C$ ), MSD ( $^{\circ}C$ ) and Spatial Correlation (Corr) for seasonally-averaged SON (Sept.-Oct.-Nov.) temperature over California.

<b>RMSD</b>	<b>UW</b>		<b>PRISM</b>		<b>Daymet</b>		
	T <sub>max</sub>	T <sub>min</sub>	T <sub>max</sub>	T <sub>min</sub>	T <sub>avg</sub>	T <sub>max</sub>	T <sub>min</sub>
<b>VR-CESM 0.25°</b>	1.591	3.866	2.065	2.788	1.777	2.088	3.837
<b>VR-CESM 0.125°</b>	1.212	3.906	1.652	2.851	1.524	1.900	3.797
<b>WRF 27km</b>	1.665	3.022	2.111	1.784	1.663	2.059	3.060
<b>WRF 9km</b>	2.262	3.788	2.574	2.322	1.285	2.402	3.615
<b>uniform CESM 0.25°</b>	2.605	3.344	2.970	2.789	2.464	2.999	3.444

<b>MSD</b>	<b>UW</b>		<b>PRISM</b>		<b>Daymet</b>		
	T <sub>max</sub>	T <sub>min</sub>	T <sub>max</sub>	T <sub>min</sub>	T <sub>avg</sub>	T <sub>max</sub>	T <sub>min</sub>
<b>VR-CESM 0.25°</b>	0.122	3.303	-0.353	1.766	-0.240	0.102	3.063
<b>VR-CESM 0.125°</b>	0.394	3.439	-0.126	1.908	-0.048	0.353	3.134
<b>WRF 27km</b>	0.181	2.044	-0.295	0.507	-0.739	0.158	1.807
<b>WRF 9km</b>	-1.412	3.310	-1.931	1.779	-0.673	-1.451	3.004
<b>uniform CESM 0.25°</b>	-0.187	2.415	-0.655	0.877	-0.826	-0.205	2.175

<b>Corr</b>	<b>UW</b>		<b>PRISM</b>		<b>Daymet</b>		
	T <sub>max</sub>	T <sub>min</sub>	T <sub>max</sub>	T <sub>min</sub>	T <sub>avg</sub>	T <sub>max</sub>	T <sub>min</sub>
<b>VR-CESM 0.25°</b>	0.998	0.950	0.996	0.975	0.994	0.996	0.951
<b>VR-CESM 0.125°</b>	0.999	0.957	0.998	0.978	0.996	0.997	0.961
<b>WRF 27km</b>	0.997	0.949	0.996	0.982	0.995	0.996	0.948
<b>WRF 9km</b>	0.996	0.953	0.996	0.986	0.997	0.996	0.959
<b>uniform CESM 0.25°</b>	0.993	0.956	0.992	0.965	0.989	0.991	0.952

**Table S3.** RMSD ( $^{\circ}\text{C}$ ), MSD ( $^{\circ}\text{C}$ ) and Spatial Correlation (Corr) for seasonally-averaged DJF temperature over California.

RMSD	UW		PRISM			Daymet	
	$T_{max}$	$T_{min}$	$T_{max}$	$T_{min}$	$T_{avg}$	$T_{max}$	$T_{min}$
<b>VR-CESM 0.25°</b>	1.959	2.751	2.196	2.015	1.742	2.253	2.700
<b>VR-CESM 0.125°</b>	1.633	2.302	2.035	1.840	1.747	2.089	2.318
<b>WRF 27km</b>	1.699	2.756	2.106	1.734	1.537	2.033	2.665
<b>WRF 9km</b>	1.876	2.753	2.324	1.865	1.324	2.169	2.625
<b>uniform CESM 0.25°</b>	2.979	2.072	3.339	2.500	3.211	3.310	2.408

MSD	UW		PRISM			Daymet	
	$T_{max}$	$T_{min}$	$T_{max}$	$T_{min}$	$T_{avg}$	$T_{max}$	$T_{min}$
<b>VR-CESM 0.25°</b>	-0.549	2.108	-0.984	0.977	-0.920	-0.774	1.836
<b>VR-CESM 0.125°</b>	-0.723	1.678	-1.178	0.541	-1.202	-0.978	1.345
<b>WRF 27km</b>	-0.075	2.027	-0.510	0.895	-0.620	-0.302	1.759
<b>WRF 9km</b>	-1.049	2.214	-1.504	1.077	-0.594	-1.301	1.880
<b>uniform CESM 0.25°</b>	-1.862	-0.010	-2.293	-1.142	-2.616	-2.085	-0.280

Corr	UW		PRISM			Daymet	
	$T_{max}$	$T_{min}$	$T_{max}$	$T_{min}$	$T_{avg}$	$T_{max}$	$T_{min}$
<b>VR-CESM 0.25°</b>	0.989	0.856	0.988	0.925	0.978	0.987	0.856
<b>VR-CESM 0.125°</b>	0.993	0.900	0.991	0.941	0.979	0.989	0.898
<b>WRF 27km</b>	0.992	0.842	0.987	0.931	0.982	0.988	0.838
<b>WRF 9km</b>	0.990	0.859	0.987	0.942	0.987	0.988	0.870
<b>uniform CESM 0.25°</b>	0.980	0.922	0.977	0.885	0.926	0.976	0.893

**Table S4.** RMSD (mm/day), MSD (mm/d), MRD, Spatial Correlation (Corr) for averaged precipitation over California

MAM	CPC				UW			
	RMSD	MSD	MRD	Corr	RMSD	MSD	MRD	Corr
<b>VR-CESM 0.25°</b>	0.542	0.279	0.264	0.981	0.589	0.193	0.265	0.968
<b>VR-CESM 0.125°</b>	0.554	0.291	0.267	0.979	0.579	0.217	0.263	0.970
<b>WRF 27km</b>	0.448	-0.183	0.209	0.975	0.587	-0.269	0.234	0.970
<b>WRF 9km</b>	2.143	1.370	0.881	0.966	1.991	1.295	0.783	0.971
<b>uniform CESM 0.25°</b>	0.601	0.182	0.254	0.971	0.611	0.096	0.259	0.964
MAM	PRISM				DAYMET			
	RMSD	MSD	MRD	Corr	RMSD	MSD	MRD	Corr
<b>VR-CESM 0.25°</b>	0.542	0.279	0.264	0.981	0.589	0.193	0.265	0.968
<b>VR-CESM 0.125°</b>	0.554	0.291	0.267	0.979	0.579	0.217	0.263	0.970
<b>WRF 27km</b>	0.448	-0.183	0.209	0.975	0.587	-0.269	0.234	0.970
<b>WRF 9km</b>	2.143	1.370	0.881	0.966	1.991	1.295	0.783	0.971
<b>uniform CESM 0.25°</b>	0.601	0.182	0.254	0.971	0.611	0.096	0.259	0.964
JJA	CPC				UW			
	RMSD	MSD	MRD	Corr	RMSD	MSD	MRD	Corr
<b>VR-CESM 0.25°</b>	0.138	-0.017	0.361	0.903	0.138	-0.008	0.359	0.905
<b>VR-CESM 0.125°</b>	0.153	-0.006	0.388	0.889	0.148	0.005	0.375	0.897
<b>WRF 27km</b>	0.213	0.010	0.587	0.850	0.186	0.019	0.515	0.892
<b>WRF 9km</b>	1.013	0.644	2.518	0.853	1.000	0.654	2.654	0.881
<b>uniform CESM 0.25°</b>	0.177	-0.034	0.471	0.835	0.179	-0.025	0.467	0.837
JJA	PRISM				DAYMET			
	RMSD	MSD	MRD	Corr	RMSD	MSD	MRD	Corr
<b>VR-CESM 0.25°</b>	0.138	-0.017	0.361	0.903	0.138	-0.008	0.359	0.905
<b>VR-CESM 0.125°</b>	0.153	-0.006	0.388	0.889	0.148	0.005	0.375	0.897
<b>WRF 27km</b>	0.213	0.010	0.587	0.850	0.186	0.019	0.515	0.892
<b>WRF 9km</b>	1.013	0.644	2.518	0.853	1.000	0.654	2.654	0.881
<b>uniform CESM 0.25°</b>	0.177	-0.034	0.471	0.835	0.179	-0.025	0.467	0.837
SON	CPC				UW			
	RMSD	MSD	MRD	Corr	RMSD	MSD	MRD	Corr
<b>VR-CESM 0.25°</b>	0.536	0.346	0.338	0.984	0.579	0.323	0.351	0.966
<b>VR-CESM 0.125°</b>	0.381	-0.054	0.223	0.969	0.471	-0.067	0.260	0.956
<b>WRF 27km</b>	0.382	-0.271	0.247	0.982	0.506	-0.294	0.278	0.971
<b>WRF 9km</b>	1.851	1.297	1.091	0.960	1.779	1.283	1.065	0.964
<b>uniform CESM 0.25°</b>	0.365	0.022	0.214	0.972	0.479	-0.001	0.271	0.955
SON	PRISM				DAYMET			
	RMSD	MSD	MRD	Corr	RMSD	MSD	MRD	Corr
<b>VR-CESM 0.25°</b>	0.536	0.346	0.338	0.984	0.579	0.323	0.351	0.966
<b>VR-CESM 0.125°</b>	0.381	-0.054	0.223	0.969	0.471	-0.067	0.260	0.956
<b>WRF 27km</b>	0.382	-0.271	0.247	0.982	0.506	-0.294	0.278	0.971
<b>WRF 9km</b>	1.851	1.297	1.091	0.960	1.779	1.283	1.065	0.964
<b>uniform CESM 0.25°</b>	0.365	0.022	0.214	0.972	0.479	-0.001	0.271	0.955