50-year Regional Downscaling of NCEP/NCAR Reanalysis over the Contiguous United States using the Regional Spectral Model

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Regional downscaling of the 50-year 200 km resolution NCEP/NCAR Reanalysis to 10 km resolution using the Regional Spectral Model for the contiguous United States continues. The downscaling has been in a production mode since last year and so far, total of 9 years out of 57 is complete. The integration from 1948 was temporarily stopped and a new integration is started from 1988. This is to make application studies to start as quickly as possible, since many of the studies focus on the recent 10–20 years and the progress of the production run was not as fast as we expected.

In addition to the computation in progress at the Earth Simulator Center, 50-year downscaling covering only over California has now been completed using the computer resources available nationally in the United States. An intense effort to validate the product against station observations has been conducted. It was shown clearly that the downscaling is capable of generating small scale detail which agrees with station observation. Preliminary researches on various subjects, ranging from the attribution of long term trend, inter-annual variability of surface circulations as well as composite of typical California local weather system, such as Santa Ana, have been initiated. We also started a limited comparison of the California region and contiguous U.S. region downscaling analyses.

Keywords: Earth Simulator, regional climate model, Regional Spectral Model, downscaling

1. Research Objectives

Detailed research objectives have been described in the 2005 report and are excluded here. We emphasize that this project is aiming at *long term analysis* of regional scale for the global change research, thus most of the relevant research can be started only when long series of downscaled analysis becomes available. For this reason, this report concentrates on the diagnostics of long term analysis from California region performed in United States using nationally available computer resources (hereafter called CaRD10). The major objective here is to prove that the downscaling can actually produce regional detail which fits more closely to local observations. We will show, however, an example of comparisons between California and U.S. region downscaling to highlight the advantage of performing downscaling in progress at Earth Simulator Center.

2. Comparison of U. S. and California downscaling

A limited number of comparisons are made between U. S. and California downscaling to understand the effect of domain size. The Scale Selective Bias Correction (SSBC, Kanamaru and Kanamitsu, 2005)[1] applied to the downscaling is designed to minimize the effect of domain size on downscaling, but the result is still strongly affected by the domain size particularly near the lateral boundary zone where boundary relaxation is applied. Figure 1 compares 1988 July mean near surface winds between U.S run (left panel) and CaRD10 (right panel). It is clear that the downscaled analysis is distorted by the lateral boundary nudging zone particularly in the southeastern part of the CaRD10 region, as well as western and southern boundaries but the distortion is negligible in the U.S. run. The southeastern part of CaRD10 domain is crucial for the understanding of the Southwest American Monsoon, thus the advantage of the US region downscaling is obvious. The patterns of the wind speed and wind direction away from the nudging zone between the two analyses are very similar, but some differences in magnitude can be seen in regions. Comparison of

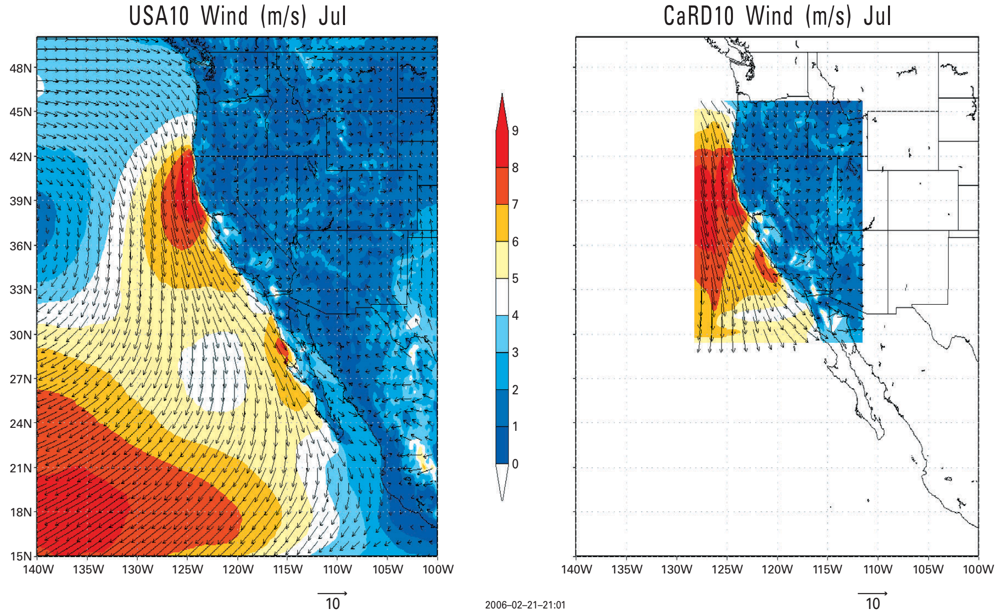

Fig. 1 Comparison of July mean surface wind vector and wind speed for U.S. region (left) and California region (right).

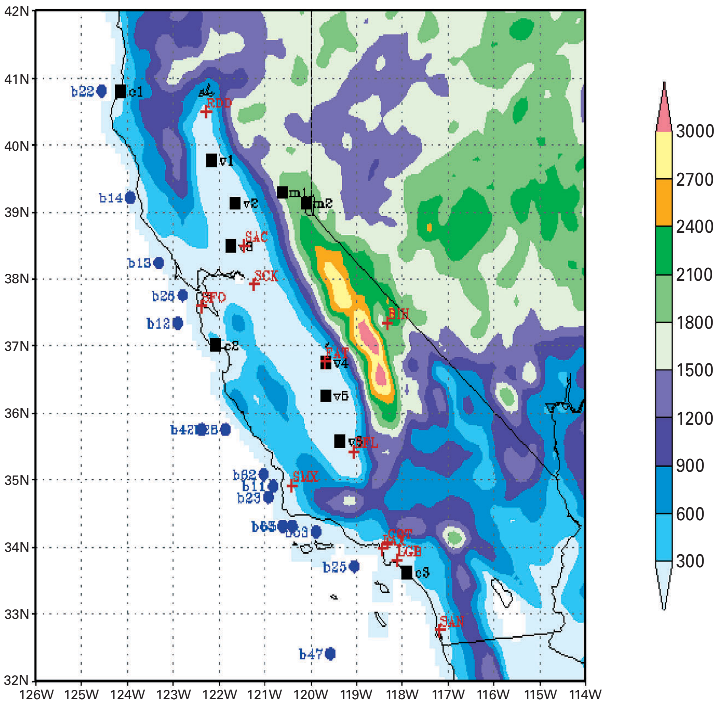

Fig. 2 Location of observation stations used in validation.

the validation of two downscaled analyses needs to be performed to further evaluate the US region analysis.

3. Validation of the downscaled analysis over California

The key to the success of the downscaling is to demonstrate that the downscaled analysis fits better with observation than the coarse resolution global analysis, particularly with near surface observation in a regional scale. Since the accuracy of the downscaled analysis is expected to vary with the time scale, we performed the validation against surface observations by separating the time scale to hourly, daily, monthly, seasonal and decadal, including long term trend. The station observation locations used in this validation are plotted in Figure 2. There are three types of station observations. Fifteen hourly buoy observations (courtesy of Steve Taylor; names start with "b"), stations from the United States Historical Climatology Network (http://cdiac.ornl.gov/epubs/ndp/ushcn/newushcn.html) for monthly and daily means (three coast locations, "c", six valley locations, "v", and two mountain locations, "m"), and 12 daily airport station observations from NCDC (three letter abbreviations).

3.1 Daily Scale

3.1.1 Wind over coastal ocean

The normalized wind vector anomaly correlation (Breaker et al, 1994)[2] and vector Root Mean Square Error (RMSE) of three daily analyses, North American Regional Reanalysis (NARR)[3], CaRD10[4] and NCEP/NCAR Reanalysis (NNR)[5] against fifteen buoy observations during January and August, 2000 are computed, and are shown in Figure 3. Note that the NARR should fit the buoy observations best, since it uses these buoy wind observations in its data assimilation. The figure clearly shows that for almost all the stations, CaRD10 has higher correlation and lower RMSE than NNR and sometimes the downscaling fits even better than the NARR. The average vector correlation and RMSE for all the buoys compared here are shown in Table 1. Compared to NNR, the improvement of the RMSE in the downscaling is impressive. Overall, CaRD10 is much closer to NARR than to NNR.

3.1.2 Wind over land

We performed similar comparisons on wind over land using 12 airport stations in Table 2. The station locations are

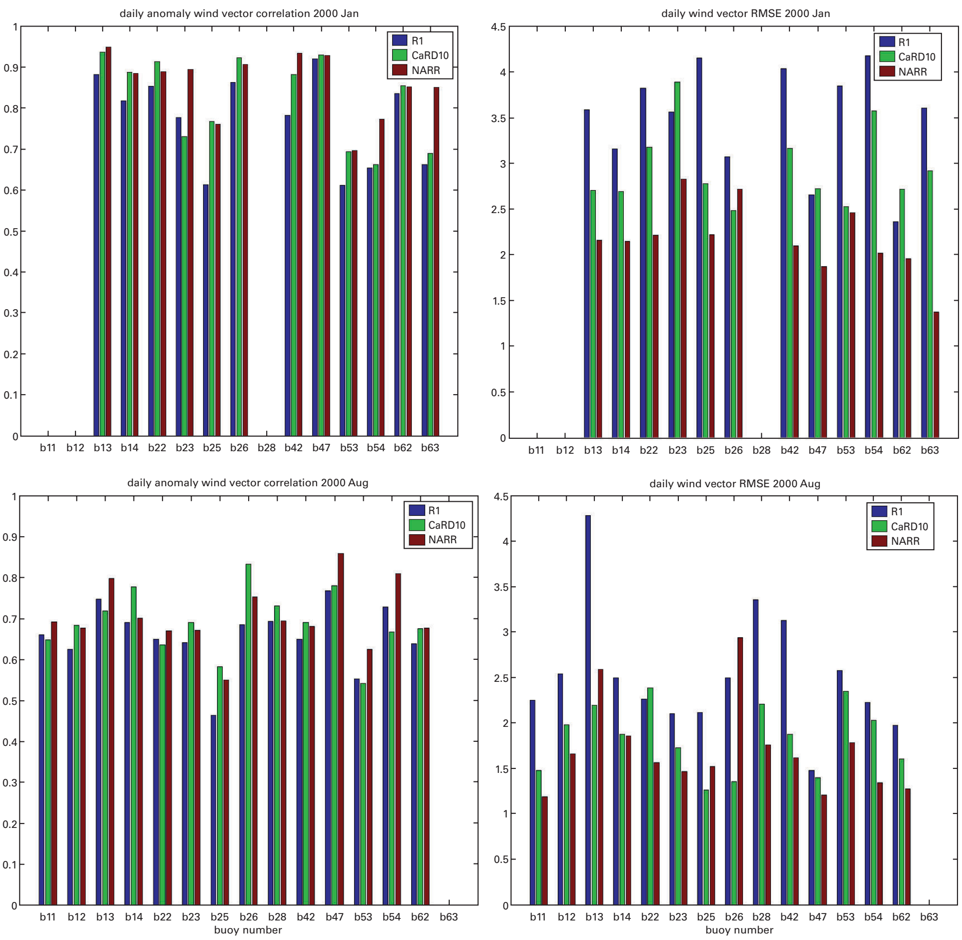

Fig. 3 Vector correlation (left) and vector RMS (right) of surface winds between California downscaling and observation. Blue bar indicates NCEP/NCAR Reanalysis, Green bar shows California downscaling and brown bar indicates North American Regional Reanalysis. The RMS is in meter/sec.

Table 1 Mean vector anomaly correlation and RMSE of winds of three analyses and fifteen buoy observations during 2000.

	Correlation			RMSE		
	NNR	CaRD10	NARR	NNR	CaRD10	NARR
January	0.77	0.82	0.86	3.50	2.94	2.17
August	0.66	0.68	0.70	2.52	1.83	1.70

Table 2 Mean vector anomaly correlation and RMSE of winds of three analyses and twelve land station observations during 2000.

	Correlation			RMSE		
	NNR	CaRD10	NARR	NNR	CaRD10	NARR
January	0.49	0.56	0.39	3.90	3.24	3.92
August	0.39	0.46	0.41	2.62	2.29	2.47

shown in red and cross hair marks on Figure 2. Overall, the fit of the three analyses to the land stations are much worse than those over ocean. This is expected since the more complex surface topography on land produces a stronger influence on winds. The differences in fit between the three analyses are more diverse, but CaRD10 seems to be consistently better than NNR and NARR, both in terms of correlation and RMSE. The CaRD10 fits best due to the detailed 10 km resolution topography in CaRD10 compared to 32 km in NARR. Although the surface wind observations are assimilated in NARR, its information content over land seems to be masked by the coarse resolution topography.

3.1.3 Daily mean and max/min temperature over land

Table 3 compares correlation and RMS averaged over all the land observation stations. The correlation of CaRD10 is almost always higher than that of NNR, except daily minimum temperature in January. The CaRD10 correlation is apparently better than that of the NARR. The RMS of CaRD10 is always less than that of NNR (except daily max temperature in August), but NARR has less RMS error for daily mean temperature both in January and August.

We also compared daily temperature ranges in summer and winter against a large number of land stations in 1996 (not shown). The geographical patterns look fairly reasonable for both January and July but CaRD10 tends to underestimate the temperature range, particularly in January.

3.1.4 Precipitation over land

The correlation of daily precipitation in August is low, but this is due to infrequent precipitation events. In January, the correlation is above 0.6 except for one station. The bias is quite large, which will be discussed in more detail later.

In general, the correlation between station observation and CaRD10 is reasonable but not necessarily excellent. Due to the non-Gaussian nature of the precipitation events, as well as to the instrumental error and the spatial representativeness of station observations, validation of daily precipitation against station observation is problematic, and further work is necessary.

3.2 Monthly averages

Validation of monthly average daily mean and maximum temperature and precipitation over land was performed using about 80 land stations during 1984–1996. The monthly average data are more easily available than the daily data and thus we have more observations available for comparison. The monthly mean 2-meter temperature in January correlates very well, above 0.7 over the entire domain. The correlation tends to be better along the southern coast of California than towards inland. The correlation in August is lower by 0.1 compared to January. In August the correlation tends to be lower along the coast and becomes better towards inland. The correlation stays above 0.6 over the entire domain. The reason for this particular distribution of the skill is not entirely clear, but some influence from ocean temperature is suspected. For the daily maximum temperature during January, correlation is mostly over 0.7. The lowest correlation occurs in the Central Valley area where the value is in the 0.6 range or lower, but other areas have very high correlations. During August, the correlation tends to be lower, particularly in the southern half of the domain.

The correlations of monthly average precipitation are also calculated and shown in Figure 4. During January, correlation is fairly high in most of California, while it is lower in Nevada where less precipitation occurs. During the summer time, correlation is much lower (less than 0.6) over most of the domain. This is partly due to the lack of precipitation during this month.

3.3 Trend

For validation of longer time scales, we examined the trends for the 1950–1996 periods at several selected stations (see Fig. 2 for the station locations. 3 coastal stations, 6 valley stations, and 2 mountain stations, denoted as c1-3, v1-6 and m1-2, respectively). Table 4 shows the comparison for the January and August trends. In January, the CaRD10 and observation trends agree fairly well, although the magnitude of the trend in the CaRD10 is consistently smaller (except Mountain station m1). All the trends in the observation are positive, while CaRD10 shows a small negative trend in the valley at some stations. In August, the CaRD10 trend does

Table 3 Mean correlation and RMSE of daily mean temperature and max/min temperature of three analyses and twelve land station observations during 2000.

		Correlation			RMSE		
		NNR	CaRD10	NARR	NNR	CaRD10	NARR
Mean T	January	0.77	0.77	0.75	1.73	1.66	1.63
	August	0.67	0.71	0.69	1.74	1.73	1.38
Tmax	January	0.45	0.47	-	2.47	2.37	-
	August	0.75	0.75	-	2.35	2.45	-
Tmin	January	0.77	0.75	-	2.53	2.47	-
	August	0.40	0.49	-	2.25	2.17	-

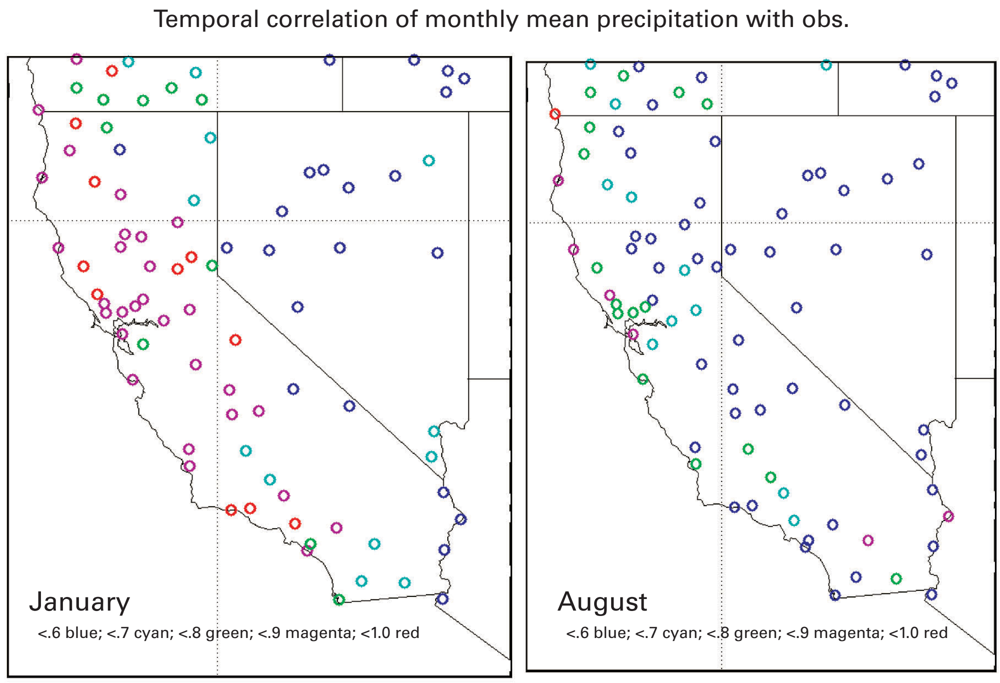

Fig. 4 Correlation of monthly mean precipitation with observation for the period 1948-1996.

Table 4 Comparison of 1950-1996 trend in monthly mean near surface temperature between observation and CaRD10.

	Station	January		August	
		Obs.	CaRD10	Obs.	CaRD10
Coast	c1	+0.04	+0.02	+0.04	-0.04
	c2	+0.05	+0.02	+0.03	-0.05
	c3	+0.04	+0.02	+0.02	-0.02
Valley	v1	+0.04	+0.01	+0.00	-0.04
	v2	+0.02	+0.00	+0.02	-0.04
	v3	+0.00	-0.00	+0.01	-0.03
	v4	+0.03	+0.01	+0.05	-0.05
	v5	+0.01	-0.00	+0.02	-0.05
	v6	+0.01	-0.00	-0.00	-0.05
Mountain	m1	+0.03	+0.05	+0.03	+0.00
	m2	+0.05	+0.00	+0.04	+0.12

not agree with observation at all. Observed trends are all positive (except at one valley station, v3), while CaRD10 trends are all negative with the exception of the mountain stations. Preliminary research suggests several causes for this discrepancy: one is that the current downscaling does not take into account changes in land use, irrigation and urbanization, or changes in green house gasses and aerosol. The second is that the land surface processes affect near surface temperature too strongly in the model. Another possible reason is the effect of poorly analyzed coastal sea surface temperature with a cooling trend affecting the long term temperature trend over land.

We also compared the trend of near surface temperature between CaRD10 and NNR for the years 1979–2002. We found that there is very little resemblance between the distributions of trends in January, but the two tend to agree better with slight cooling in the valley and warming at other places in August. The trend in downscaling at or near the surface may not be controlled by the lateral boundary forcing, but by some other mechanism, namely the regional model land surface physics and detailed topography. The seasonal variability of this response of the regional model, and accordingly the accuracy of the trend in CaRD10 still requires more detailed analysis and validation.

4. Future works

More detail report of the CaRD10 validation should be available from CEC web site (http://www.energy.ca.gov/2006publications).

We will continue production of U.S. region downscaling. We will validate the analysis and compare with the CaRD10. Attribution study of the near surface temperature trend will be performed, with a number of sensitivity experiments. Currently, effects of land use, CO2, aerosol and coastal SST are under examination. The weakness in the current downscaling will be studied in detail, also utilizing sensitivity experiments. Our preliminary test shows that the prediction of cloud water and use of Kain-Fritsch scheme significantly reduce precipitation bias. We will further examine the impact of land model, and snow model. Our goal is to perform another 10km over greater California region with improved physics coupled with regional ocean model within two years. Another developmental work involves application of Scale Selective Bias Correction method to downscale over very large area, such as hemispheric or even global. Our preliminary work on the hemispheric downscaling showed promising results.

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領域スペクトルモデルを使った北アメリカ大陸合衆国領域における50年NCEP/NCAR再解析のダウンスケール

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解像力200km、50年間のNCEP/NCAR再解析を北アメリカ大陸合衆国領域で領域スペクトルモデルを使って10kmの解像力にダウンスケールする計算が進行中である。この計算は昨年より生産過程に入り、57年のうちの9年間の計算を終えることが出来た。最近になって1948年からの計算を一時中止し、新しく1988年からの計算を始めた。これは、最近の10–20年間のデータを使った応用プロジェクトが多いことを考え、できるだけ早く我々のダウンスケールを使った応用プロジェクトが始まるようにと考慮したことによる。

地球シミュレーターセンターで行われている計算に加えて、カリフォルニア州の領域だけを目的とした1948–2005年のダウンスケールの計算をアメリカ国内の計算施設を使って行ない、57年間の計算が終了した。このデータを使って、観測地点との大掛かりな比較を行った。又、このダウンスケールを使って長期のトレンドの要因を調べたり、地上付近の風の場の年々変動及びカリフォルニア州に特有のサンタアナ等の研究が始まった。以上のほかに、カリフォルニア州の領域とアメリカ領域のダウンスケールの比較も行われている。

キーワード：地球シミュレーター，領域気候モデル，領域スペクトルモデル，ダウンスケーリング