Dynamical Downscaling of Global Reanalysis

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INTRODUCTION

Climate research, particularly application studies for water, agriculture, forestry, fishery and energy management require fine scale multi-decadal information of meteorological, oceanographic and land states. Unfortunately, spatially and temporally homogeneous multi-decadal observations of these variables in high horizontal resolution are non-existent. Some long term surface records of temperature and precipitation exist, but the number of observations is very limited and the measurements are often contaminated by changes in instrumentation over time. Some climatologically important variables, such as soil moisture, surface evaporation, and radiation are not even measured on regular basis.

Reanalysis is one approach to obtaining long term homogeneous analysis of needed variables. Unfortunately, the horizontal resolution of global reanalysis is of the order of 100 to 200 km, too coarse for many application studies. Recently, regional reanalysis over North America was conducted (North American Regional Reanalysis, (NARR) Mesinger et al, 2006). The horizontal resolution of 32 km and the duration of

25 years used in that study are still not completely satisfactory for application requirements, but the product is definitely valuable.

In this paper, we present another attempt to produce even higher resolution regional “reanalysis” over a longer period for the state of California using a dynamical downscaling technique (California Reanalysis Downscaling at 10 km; CaRD10 hereafter) with Scale Selective Bias Correction (SSBC, Kanamaru and Kanamitsu, 2006). This method is based on the concept that small scale detail can be attained by laterally forcing the high resolution regional model with large scale analysis. The essential difference between the dynamical downscaling method and data assimilation, which is used in NARR and in all the global reanalyses, is that the former does not utilize station observations to correct model forecast error. In this context, the dynamical downscaling can be referred to as “regional data assimilation without observation” (von Storch et al, 2000). Using the results from extensive validation of the downscaled analysis with dense surface observations, we demonstrate that the downscaling with higher resolution regional model outperforms lower resolution regional data assimilation analysis. This is due to the fundamental difficulties in using dense surface observation in the current state-of-the-art data assimilation system.

This work has been published as a two parts paper in Journal Climatology (Kanamitsu and Kanamaru, 2007; Kanamaru and Kanamitsu, 2007), and the readers are encouraged to read these original manuscripts for full detail.

CaRD10

For the purpose of producing datasets for regional scale climate change research and application, the NCEP/NCAR Reanalysis for the period 1948-2005 was dynamically downscaled to hourly, 10 km resolution over California using the Regional Spectral Model.

Extensive validation showed that, in general, the CaRD10 near-surface wind and temperature fit better to regional scale station observations than the NCEP/NCAR reanalysis used to force the regional model, supporting the premise that the regional downscaling is a viable method to attain regional detail from large scale analysis. This advantage of CaRD10 was found on all time scales, ranging from hourly to decadal scales, i.e. from diurnal variation to multi-decadal trend. In table 1, detailed comparison of 10-meter wind analysis with airport station observations in California between Reanalysis and CaRD10 is presented. It shows that the CaRD10 fits with near surface observation much closer with the coarse resolution global analysis.

Table 1. Vector RMSE of winds of two analyses and twelve land station observations during 2000. Smaller RMSE is indicated in bold.

	January		August	
	CaRD10	NNR	CaRD10	NNR
BFL	**2.33**	2.85	**1.59**	2.03
BIH	**3.45**	4.12	**4.00**	4.41
CQT	**2.29**	3.25	**0.96**	1.45
FAT	**2.94**	3.63	**1.72**	1.96
LAX	**2.81**	3.58	**1.62**	2.28
LGB	**2.63**	4.07	**2.35**	2.81
RDD	**4.18**	5.35	**1.52**	1.87
SAC	**3.52**	4.41	**2.34**	2.55
SAN	2.94	**2.87**	**2.68**	2.93
SCK	**3.73**	4.44	**2.39**	3.23
SFO	**4.12**	4.25	**4.53**	4.62
SMX	**4.01**	4.02	1.74	**1.28**
All	**3.24**	3.90	**2.29**	2.62

CaRD10 was also compared with the NARR which is a data assimilation regional analysis at 32 km resolution and 3-hourly output using the Eta model for the period 1979-present using the NCEP/DOE Reanalysis as lateral boundary conditions. The large-scale component of atmospheric analysis is similar in CaRD10 and NARR due to the use of SSBC. The CaRD10 daily winds fit better to station observations than NARR over land everywhere and ocean where daily variability is large. The daily near-surface temperature comparison shows a similar temporal correlation with observations in CaRD10 and NARR. Several synoptic examples such as the Catalina Eddy, Coastally Trapped Wind Reversal, and Santa Ana winds are better produced in CaRD10 than NARR. One example of Catalina Eddy is shown in Figure 1. Note that the actual lateral boundary is located further (more than 500km) away from the domain shown. It is remarkable to see that the small scale eddy over coastal ocean is realistically generated by downscaling. The NARR analysis has the eddy, but this is due to the use of available coastal ocean buoy data. The difference in the shape of the eddy between CaRD10 and NARR is due to difference in model and resolution, since buoy observation is limited to the north of the center of the eddy. The satellite picture

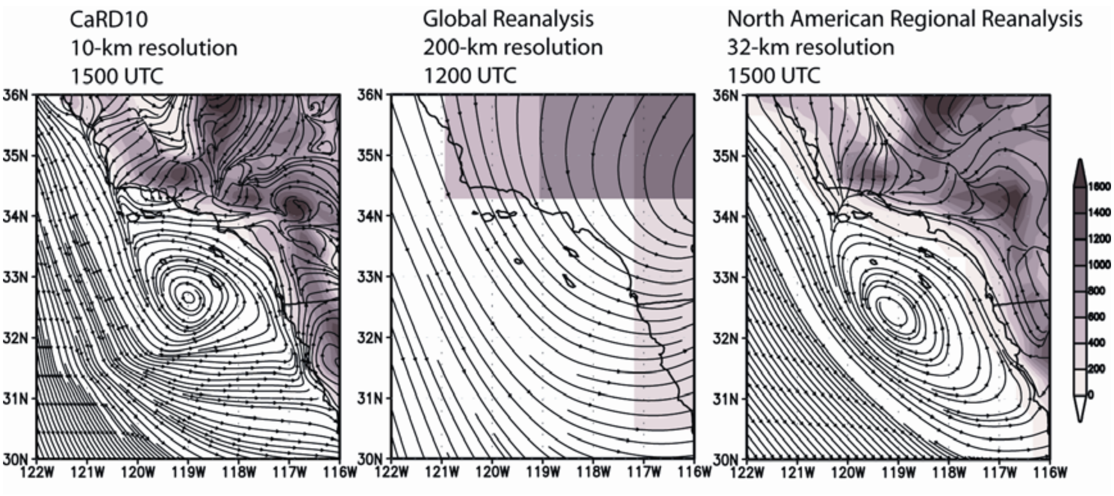

Fig. 1. Comparison of the near surface streamline from CaRD10 (left), global reanalysis (center) and NARR (right).

taken at the same time (Figure 2) show clear eddy formation and some suggestion of the superior per reproduction of CaRD10. Also note more detail flow features in CaRD10 than in NARR. In Figure 3, the fit of the 6-hour forecast guess with station observations of 10-meter wind over continental U.S. is plotted for Global model and NARR. The straight horizontal line is the estimated fit of CaRD10 based on Table 1. It is clearly shown that the model resolution is much more important than the data assimilation for obtaining more accurate near surface wind analysis. These comparisons suggest that the horizontal resolution of the model has a large influence on the regional analysis, and the near-surface observation is not properly assimilated in the current state-of-the-art regional data assimilation system.

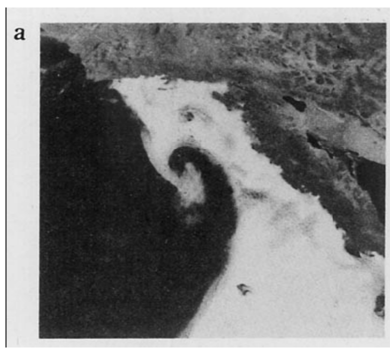

Fig 2. Satellite picture of the Catalina Eddy.

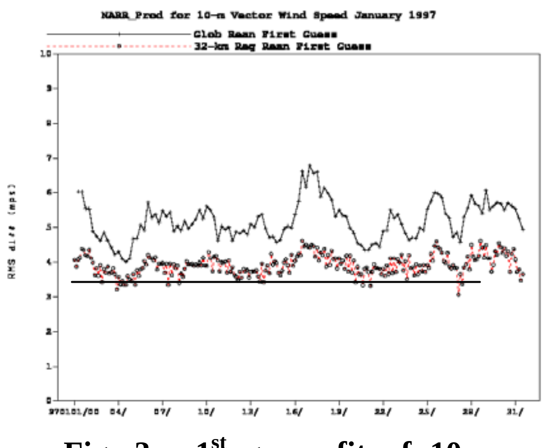

Fig. 3. 1st guess fit of 10m wind over U.S.

The CaRD10 near-surface temperature and winds on monthly and hourly scales are similar to NARR with more regional details available in CaRD10. The spatial pattern of the two precipitation analyses is similar but CaRD10 shows smaller scale features despite a positive bias. The trends of 500-hPa height and precipitation are similar in the two analyses but the near-surface temperature trend spatial patterns do not agree, suggesting the importance of regional topography, model physics, and land surface schemes. A comparison of a major storm event shows that both analyses suffer from budget residual. CaRD10's large precipitation is related to wind direction, spatial distribution of precipitable water, and a large moisture convergence.

CONCLUSIONS

Dynamical downscaling forced by a global analysis is a computationally economical approach to regional scale long-term climate analysis and can provide a high quality climate analysis comparable to current state-of-the-art data assimilated regional reanalysis. However, uncertainties in regional analyses can be large and caution should be exercised when using them for climate applications. Dynamically downscaled analysis provides ways to study dynamics and thermodynamics of various regional climate phenomena of different time scales because all produced variables are dynamically, physically and hydrologically consistent, which is not possible with the statistical downscaling.

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