High-Resolution Regional Reanalysis for the Southeast United States: Seasonal, Sub-Seasonal and Diurnal Variability of Precipitation

Lydia Stefanova[1], Vasubandhu Misra[1], Steven Chan[1], Melissa Griffin[1], James J. O'Brien[1] and Thomas J. Smith III[2]

[1]Center for Ocean-Atmospheric Prediction Studies (COAPS), Florida State University; [2]USGS Southeast Ecological Science Center

Introduction

We have used the NCEP-Scripps Regional Spectral Model (RSM) (Juang and Kanamitsu, 1994) to downscale both the NCEP DOE Reanalysis II (R2) and the ECMWF ERA-40 for the period 1979-2001.

Dynamical downscaling of coarser reanalysis has been used successfully in a similar integration over California (Kanamitsu and Kanamaru 2007). This approach provides a computationally efficient regional reanalysis without the need for regional data assimilation of observations (von Storch, 2000). It has been shown by Lim et al (2010) that a downscaling of R2 with RSM at 20 km over the Southeast resulted in a reduced wet bias and a more realistic spatial pattern of summer precipitation, with improved spatial and temporal correlation of rainfall, and reduced mean square error.

Here, we present an analysis of the seasonal, sub-seasonal and diurnal variability of rainfall from the COAPS Land-Atmosphere Regional Reanalysis for the Southeast at 10 km resolution (CLARReS10).

Domain and Model Configuration

1. Domain

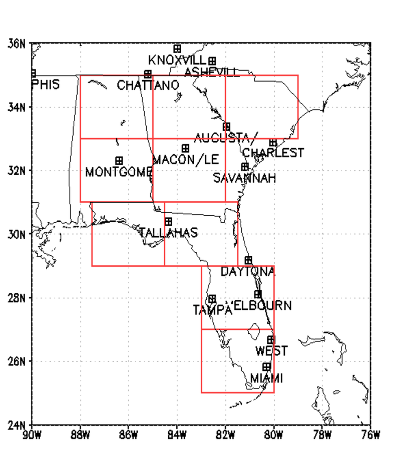

Fig. 1: Model domain

The CLARReS10 regional model domain is shown in Fig. 1. The regional model, NCEP/Scripps RSM, uses the winds, temperature, humidity and surface pressure of the global reanalyses (either R2 or ERA40, at 6-hourly intervals, as lateral boundary conditions.

2. Model Configuration

	Feature	Reference
1	Dynamics: hydrostatic primitive equations with spectrally transformed onto Fourier basis functions	Juang and Kanamitsu (1994)
2	10 km horizontal resolution; 28 vertical layers; 4-min resolution orography	Kanamaru and Kanamitsu (2007)
3	Planetary boundary layer processes	Hong and Pan (1996)
4	Shortwave and longwave radiation	Chou and Lee (1996); Chou and Suarez (1994)
3	Shallow convection	Slingo (????)
4	Deep convection: Simplified Arakawa-Schubert Scheme	Pan and Wu (1995)
5	Boundary forcing: scale selective bias correction	Kanamaru and Kanamitsu (2007)
6	Land surface: Noah; 4 soil layers	Ek et al. (2003)

Table 1: Regional model configuration and features

Validation Data

1. Hourly: precipitation from surface weather observation stations (ASOS/AWOS) from NCDC.
2. Daily precipitation:
   a) CPCDaily US Unified Precipitation, resolution 0.25° (1979-1998);
   b) Community Collaborative Rain Hail and Snow (CoCoRaHS) Network (2008-2010).
3. Monthly:
   a) PRISM Climate Group, resolution 4km , Oregon State University, http://www.prismclimate.org, created 10 Jun 2002;
   b) NCDC station climatology (1971-2000).

Results: Seasonal Cycle

1. Regional averages

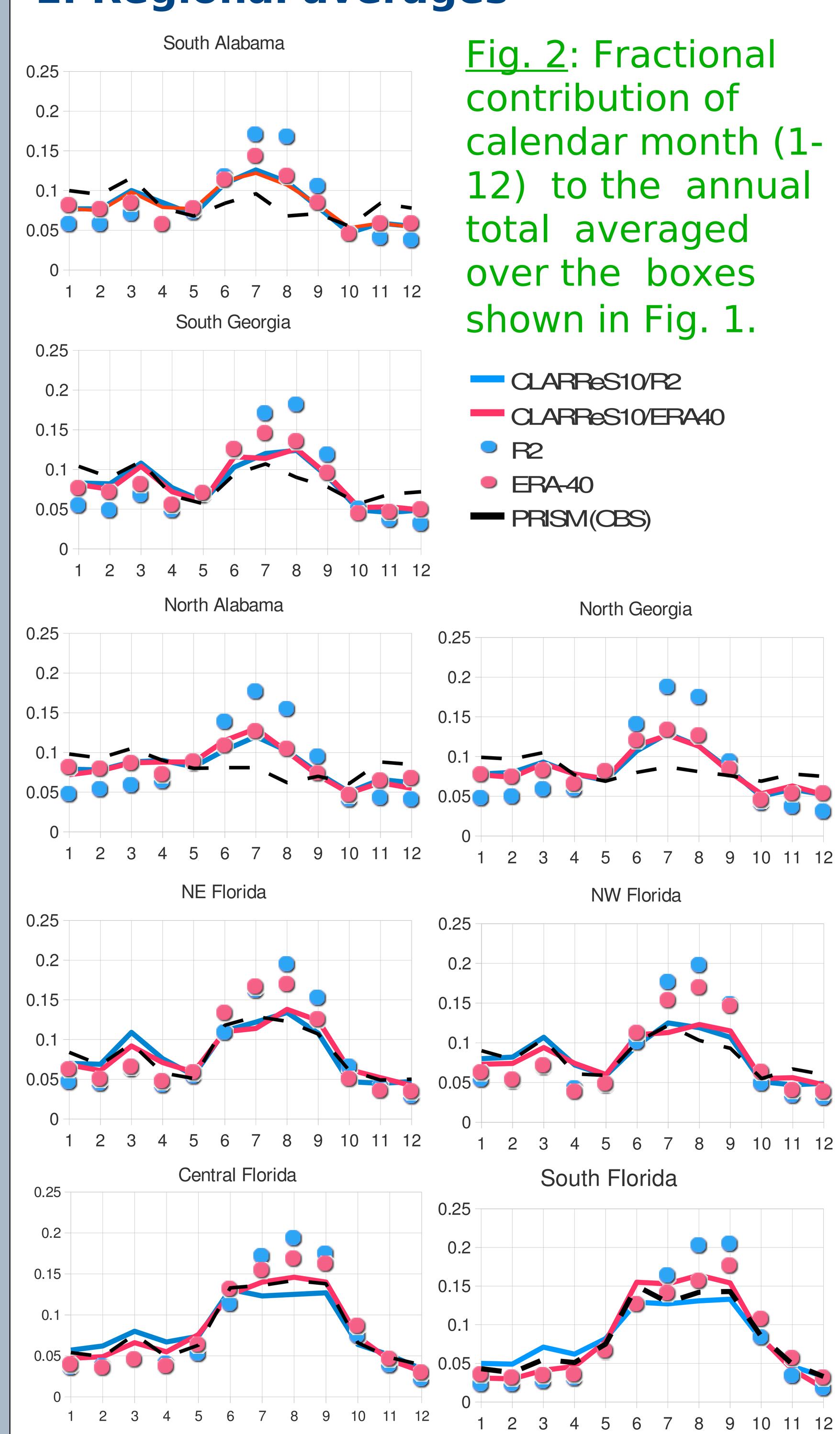

Fig. 2: Fractional contribution of calendar month (1-12) to the annual total averaged over the boxes shown in Fig. 1.

▶ The global reanalyses overestimate the contribution of summer precipitation and underestimate the contribution of spring precipitation to the annual mean in all regions of the domain.
▶ The regional reanalyses ameliorate this bias.

2. Representative Florida stations

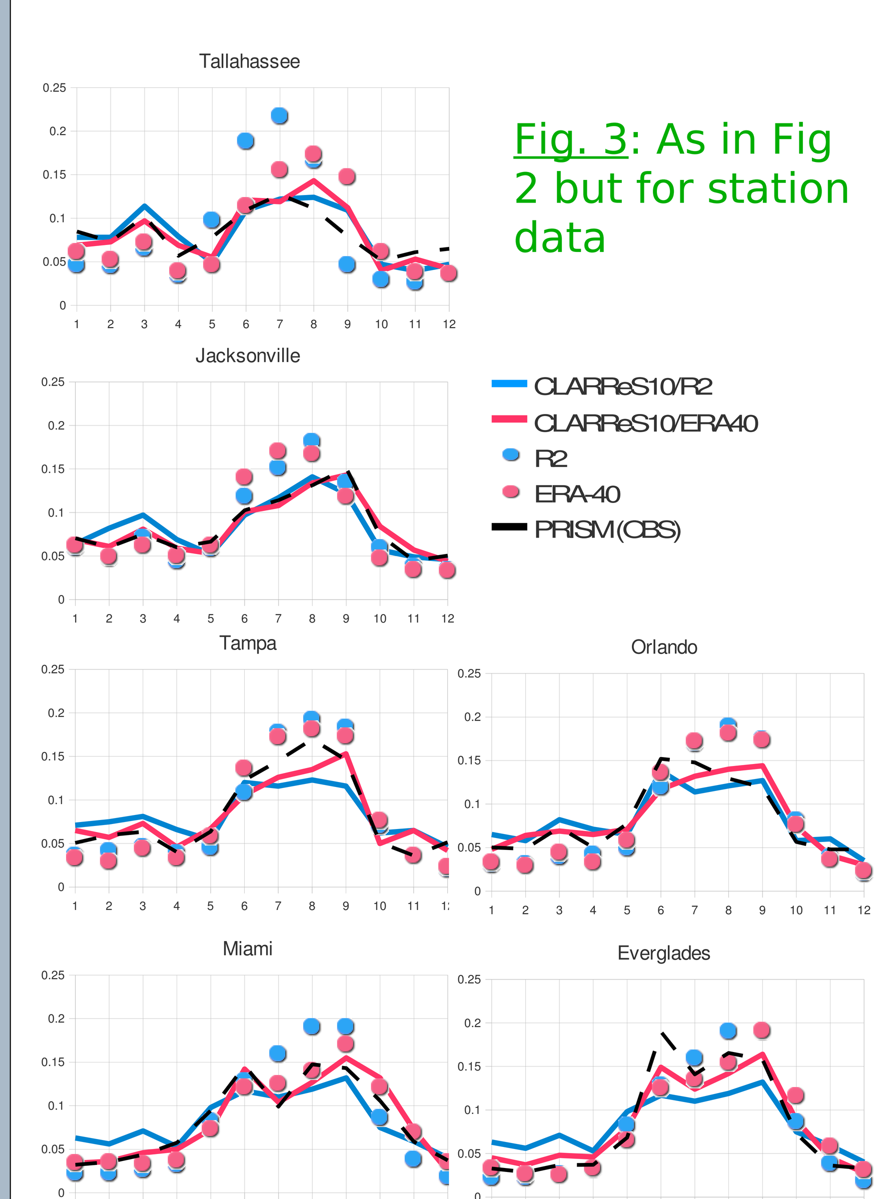

Fig. 3: As in Fig 2 but for station data

▶ Regional reanalyses improve the climatology of the seasonal cycle of precipitation in Florida, including the spring maximum seen in North Florida stations and the double summer maxumum in South Florida stations.

▶ There is some indication that CLARReS10/ERA40 outperforms CLARReS10/R2.

▶ Since the shape of the seasonal cycle is accurately represented in CLARReS10, a multiplicative rescaling of precipitation may be appropriate if needed

Results: JJA mean and variance

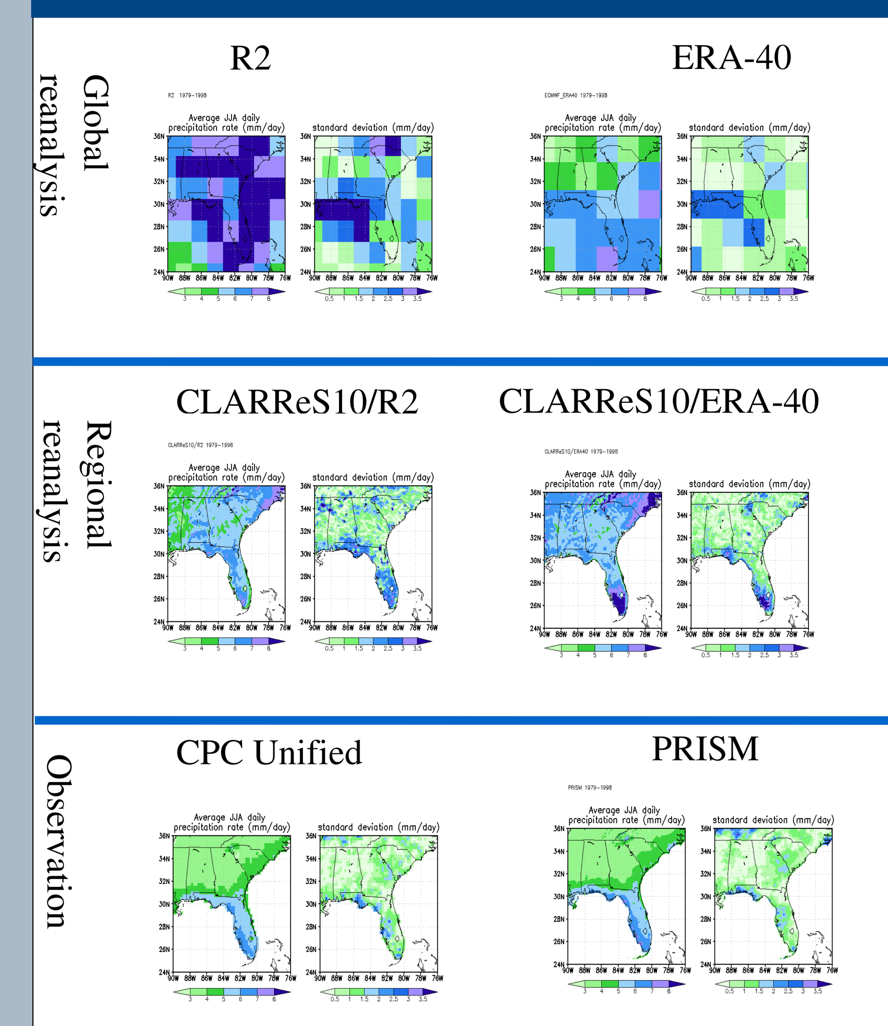

Fig. 4: Reanalysis and Obs. average summer rainfall (mm/day)

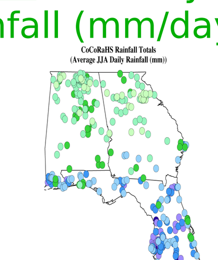

Fig. 5: CoCoRaH network observed average JJA rainfall (mm/day) for 2008-2010. Note the relatively smaller values at the coast.

▶ CLARReS10 reduces the wet bias of R2, but introduces a wet bias to ERA40. The interannual variance range, however, is simulated well.

▶ CLARReS10 accurately reproduces the relatively smaller rainfall values at the coastline.

Results: JJA Precipitation Frequency

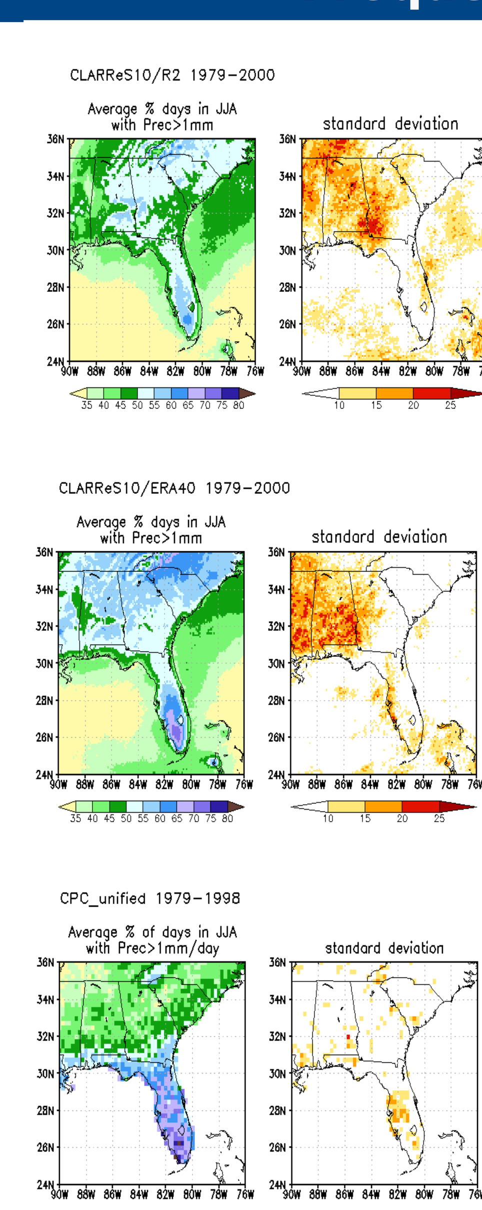

Fig. 6:

a) Average percentage of days in JJA with precipitation rate exceeding 1mm/day (right) for CLARReS10/R2, CLARReS10/ERA40 and observations (CPC Unified) b) Standard deviation (left)

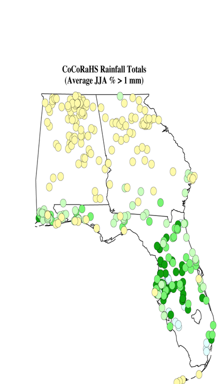

Fig. 7: CoCoRaH network average percentage of days in JJA with precipitation rate exceeding 1mm/day for 2008-2010. Note the relatively smaller values at the coast.

▶ Outside of Florida, both versions of CLARReS10 overestimate both the average summertime frequency of rainy days, and the variance of that frequency. In Florida, the frequency tends to be underestimated, particularly in CLARReS10/R2.

▶ CLARReS10 accurately reproduces the relatively smaller rainfall frequency at the coastline.

Results: Diurnal Cycle

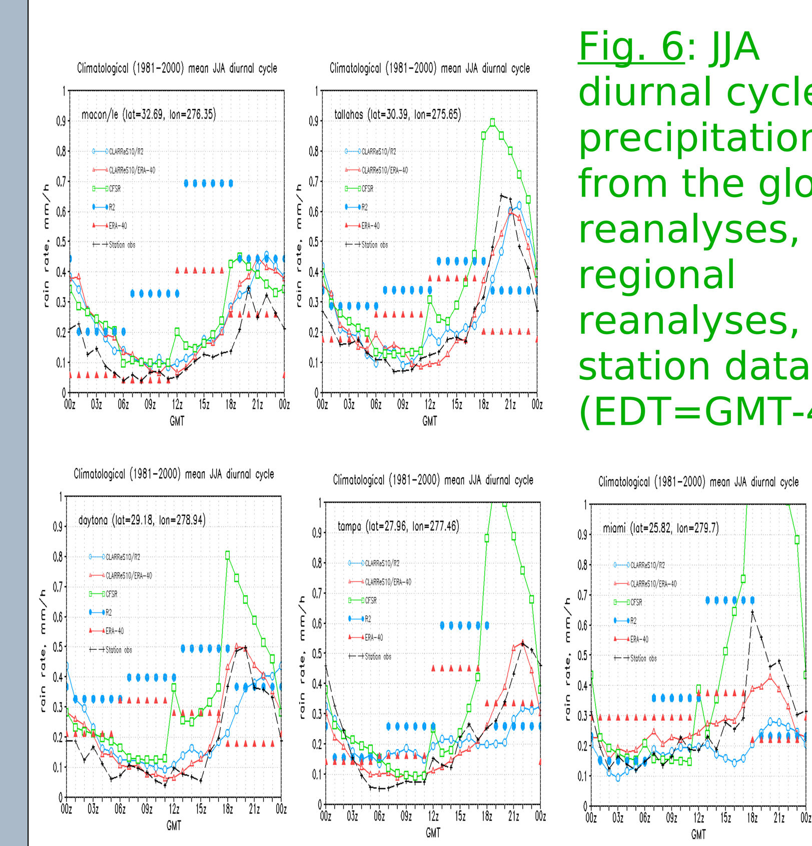

Fig. 6: JJA diurnal cycle of precipitation from the global reanalyses, the regional reanalyses, and station data (EDT=GMT-4)

Station	CLARReS10/ R2	CLARReS10/ ERA40
Augusta	0.96	0.91
Charleston	0.67	0.66
Daytona	0.80	0.97
Macon	0.93	0.92
Melbourne	0.82	0.95
Miami	0.73	0.88
Montgomery	0.93	0.92
Tampa	0.95	0.90
W. Palm Beach	0.54	0.83
Tallahassee	0.91	0.95
Savannah	0.83	0.76

Table 2: Correlation of diurnal cycle between regional reanalyses and station data

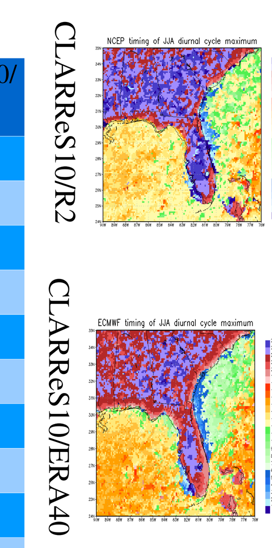

Fig. 7: Average timing of JJA diurnal maximum (GMT)

▶ The diurnal cycle in CLARReS10 is in very good agreement with station observations, particularly in Florida, and an improvement over both R2 and ERA 40.
▶ The diurnal cycle in CLARReS10 is in much better agreement with observations than CFSR (the new-generation NCEP high-resolution reanalysis)
▶ There are subtle differences between the two downscalings in the timing of the diurnal maximum.

Summary

▶ The downscaled reanalyses show good agreement with observations in terms of relative seasonal distribution and diurnal structure of precipitation.
▶ The distribution of precipitation is simulated well over Florida, but has a wet bias over Georgia, Alabama and South Carolina.
▶ There are important differences between the two simulations (CLARReS10/ERA40 tends to be wetter than CLARReS10/R2, and to have the diurnal precipitation maximum earlier in the day).
▶ A comparison of the CLARReS10 downscaling with MERRA and CFSR is currently underway.

Acknowledgements

· The University of Delaware monthly precipitation, CPC daily US Unified precipitation, and NCEP-DOE Reanalysis II data were provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/ ;
· PRISM monthly precipitation was provided by the PRISM Climate Group at Oregon State University from their website at http:www.prism.oregonstate.edu ;
ECMWF-ERA40 Reanalysis data were provided by the ECMWF, from their data server at http://data.ecmwf.int/data/ ;
· Thanks to the dedicated observers of the CoCoRaHS network;
· Thanks to Dr. Kei Yoshimura for his assistance with the RSM model;
Funding for this project is provided by USDA Grant # 05900520024744 and USGS Grant #G10AC00149.

References

Chou, M.D. and M. J. Suarez, 1994: An efficient thermal infrared radiation parameterization for use in General Circulation Models. Technical Report Series on Global Modeling and Data Assimilation, National Aeronautical and Space Administration/TM-1994-104606, 3, 85 pp.
Chou, M.D., and K.T. Lee, 1996: Parameterizations for the Absorption of Solar Radiation by Water Vapor and Ozone. *J. Atmos. Sci.*, **53**, 1203–1208.
Ek, M. B., K. E. Mitchell, Y. Lin, E. Rogers, P. Grunmann, V. Koren, G. Gayno, and J. D. Tarpley (2003), Implementation of Noah land surface model advances in the National Centers for Environmental Prediction operational mesoscale Eta model, J. Geophys. Res., 108, D228851, doi:10.1029/2002JD003296
Higgins, R. W., J. E. Janowiak, and Y.-P. Yao, 1996: A gridded hourly precipitation data base for the United States (1963-1993). NCEP/Climate Prediction Center Atlas 1, national Centers for Environmental Prediction, 46pp.
Hong, S.Y., and H.L. Pan, 1996: Nonlocal Boundary Layer Vertical Diffusion in a Medium-Range Forecast Model. *Mon. Wea. Rev.*, **124**, 2322–2339.
Juang, H. H., and M. Kanamitsu, 1994: The NMC Nested Regional Spectral Model. *Mon. Wea. Rev.* **122**, 3-26.
Kanamitsu, M. and H. Kanamaru, 2007: Fifty-seven-year reanalysis downscaling at 10km (CaRD10). Part I: System detail and validation with observations. *J. Climate*, **20**, 5553-5571.
Lim, Y.-K., L. B. Stefanova, S. C. Chan, S. D. Schubert, and J. J. O'Brien, 2010: High-resolution subtropical summer precipitation derived from dynamical downscaling of the NCEP/DOE reanalysis: How much small-scale information is added by a regional model? *Clim Dyn.*, doi: 10.1007/s00382-010-0891-2.
Pan, H.-L. and L. Mahrt, 1987: Interaction between soil hydrology and boundary layer developments. *Boundary-Layer Meteor.*, **38**, 185-202.
Pan, H.-L., and W.-S. Wu, 1994: Implementing a mass-flux convective parameterization package for the NMC Medium Range Forecast Model. Preprints, 10th Conf. on Numerical Weather Prediction, Portland, OR, Amer. Meteor. Soc., 96–98.
von Storch, Hans, Heike Langenberg, Frauke Feser, 2000: A Spectral Nudging Technique for Dynamical Downscaling Purposes. Mon. Wea. Rev., **128**, 3664–3673.
Tiedtke, M., 1983: The sensitivity of the time-mean large-scale flow to cumulus convection in the ECMWF model. Proceedings of the ECMWF Workshop on Convection in Large-Scale Models, 28 November-1 December 1983, European Centre for Medium-Range Weather Forecasts, Reading, England, 297-316.
Willmott, C. J. and K. Matsuura, 2000: Terrestrial air temperature and precipitation: Monthly and annual time series (1950-1996), V. 1.01. Online at http://climate.geog.udel.edu/ ~climate/html_pages/README.ghcn_ts.html