Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 1465-1468.

INTERANNUAL VARIABILITY IN PRECIPITATION OVER THE SOUTHERN HEMISPHERE: WHAT HAVE WE LEARNED SINCE 1985?

P. A. Arkin, M. R. P. Sapiano* and P. P. Xie

ESSIC, University of Maryland, College Park, MD

1. Introduction

Precipitation is a critical element of the climate of the Southern Hemisphere (SH), and observations of its mean annual cycle and interannual variability are crucial to understanding SH climate variability. Twenty-two years ago, at the time of the first Conference on Southern Hemisphere Meteorology in Sao Jose dos Campos, Brazil, our knowledge of SH precipitation over land was based on rain gauge observations (Jaeger, 1983; Legates and Wilmott, 1990), yielding climatologies with excellent detail but with no information on year-to-year variability. Over the Southern Ocean (SO) the situation was even less satisfactory, as our knowledge was limited to climatologies based on a variety of limited information, including ship observations of present weather and island rain gauges; no time series of precipitation analyses existed. Linking land and oceanic precipitation variability was essentially impossible aside from some limited information that was available from convective indices based on infrared satellite observations for the tropics and subtropics (Arkin and Meisner, 1987).

The situation has improved greatly over the years, with the first big step being the introduction of the merged gauge/infrared/ passive microwave estimates of the Climate Prediction Center Merged Analysis of Precipitation (CMAP; Xie and Arkin, 1997b) and the Global Precipitation Climatology Project (GPCP; Huffman *et al.*, 1997; Adler *et al.*, 2003). These estimates were both originally available at 2.5˚, monthly mean and pentad (five-day mean) resolution (Xie and Arkin, 1997b; Xie *et al.*, 2003). More recently, a 1˚ daily version of GPCP has been produced (Huffman *et al.*, 2001).

The current version of the GPCP 2.5˚ monthly mean dataset is the version two dataset (Adler *et al.*, 2003) which improved on the first version with a longer record and the addition of TOVS data for improved estimates at mid and higher latitudes. Both CMAP and GPCP have problems with high-latitude precipitation due to the lack of reliable data: there are few gauges in these sparsely populated regions and available satellite-derived precipitation estimates are of limited use over ice or snow-covered surfaces. Therefore, in the high-latitudes, there remains uncertainty in the superiority of the merged estimates over reanalysis data. Thus a version of CMAP includes reanalysis precipitation forecasts from the NCAR NCEP reanalysis (Kalnay *et al.*, 1997) over the high latitudes, and it is this version that is used in this paper (note: the data set is also available without the reanalysis data).

2. Global Precipitation Climatology

Figure 1 shows the global seasonal precipitation from GPCP version 2 and CMAP for December, January, February (DJF) and June, July, August (JJA) from 1979 to 2005. Unsurprisingly, there is good qualitative agreement between the two datasets since they are constructed from similar inputs. In the Northern hemisphere, major features such as the Atlantic and Pacific climatological storm tracks and the dry high pressure zones of the major continents are clearly visible in DJF (NH winter). In JJA (NH summer) these features are weakened due to the weaker westerly flow in mid-latitudes, and convective processes are more dominant as can be seen over the major land masses.

In the tropics precipitation is dominated by convective processes and the Intertropical Convergence Zone (ITCZ) is clearly visible, as is the south-north shift in the ITCZ which takes place between DJF and JJA. The datasets differ quantitatively over the tropical oceans, where CMAP estimates greater precipitation than GPCP primarily due to the atoll raingauge-based bias adjustment applied to CMAP. However, the details of

* *Corresponding author address:* Mathew R. P. Sapiano, Earth Systems Science Center, Computer and Space Sciences Building, The University of Maryland, College Park, MD, 20742; email: msapiano@essic.umd.edu

spatial variability and seasonal evolution in GPCP and CMAP are quite similar.

In the Southern Hemisphere, the South Pacific Convergence Zone can be clearly seen in DJF (SH summer) as can the subtropical subsidence regions under the semi-permanent high pressure zones. Mid-latitude oceanic precipitation maxima are found in JJA, apparently associated with wintertime synoptic storminess.

3. High Resolution Precipitation Estimates

The CMAP and GPCP products have greatly enhanced our understanding of global precipitation and the one-degree daily GPCP product has been a useful addition due to its increased spatial and temporal resolution. However, a new generation of precipitation datasets with spatial resolutions of at least 0.25˚ and temporal resolution of at least three hours is now becoming available. These products are based on a variety of innovative methods for combining estimates derived from passive microwave (PMW) polar-orbiting satellite observations with geostationary satellite infrared (IR) imagery. The Pilot Evaluation of High Resolution Precipitation Products (PEHRPP, http://www.umd.edu/~msapiano/PEHRPP) aims to intercompare and validate these new datasets. PEHRPP currently includes a number of datasets: the TRMM Multi-satellite Precipitation Analysis (TMPA; Huffman *et al.*, 2003), the CPC Morphing technique (CMORPH; Joyce *et al.*, 2004), the Hydro-Estimator (Scofield and Kuligowski, 2003), the NRL-Blended technique (NRL-Blended; Turk and Miller, 2005) and the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN; Hsu *et al.*, 1997; Sorooshian *et al.*, 2000) project. It is also hoped that the project will ultimately include the Global Satellite Mapping of Precipitation (GSMaP) project and the Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR; Kuligowski, 2002) algorithm.

Generally speaking, these techniques use the high spatial and temporal resolution of IR data to make up for the deficiencies in the resolution of the high quality PMW but each algorithm differs slightly. CMORPH uses the IR data to evolve the sparse PMW estimates, thus creating a continuous rainfall field. The main TMPA product (3B42) uses the high quality PMW data where available and calibrated IR data where the PMW data is unavailable. This product is then calibrated to be consistent with the monthly satellite gauge product. The Hydro-Estimator uses additional model estimates to adjust the rain-rates derived from the IR estimates. The NRL Blended technique uses histogram matching to calibrate IR estimates with PMW data. Finally, PERSIANN uses an adaptive neural-network to calibrate IR estimates with PMW estimates.

4. Summary

In the past 22 years, our knowledge of global precipitation has increased greatly. Climatologies based on ship's records and land gauges have been enhanced and replaced by climatologies and global time-series based on satellite estimates. The merged gauge/satellite GPCP and CMAP datasets have been instrumental in a great number of studies of precipitation, and are still widely used today for climatological studies and model validation. However, these products do not provide a perfect record and validation is currently impossible over much of the globe. Furthermore, our best estimates of global precipitation are usually ones where some gauge calibration has taken place.

The next major step in global precipitation estimates has come in the form of higher resolution merged IR/PMW estimates. There are currently several different algorithms available, all exploiting similar raw datasets in different ways, with efforts to validate and intercompare these datasets under way. The major drawback with these datasets is that the longer series extend back only as far as 1997 (several of the series are considerably shorter than that) and none of the techniques can be applied poleward of 60˚ latitude. Despite these drawbacks, these new datasets have on occasion exhibited accuracies approaching those of radar precipitation measurement. If this standard can be achieved, then these high resolution precipitation products could provide vital new information to aid in the understanding of oceanic precipitation in both the Northern and Southern Hemispheres. PEHRPP is expected to advance this effort.

References

Adler, R. F., Huffman, G. J., Chang, A., Ferraro, R., Xie, P., Janowiak, J., Rudolf, B., Schneider, U., Curtis, S., Bolvin, D., Gruber, A., Susskind, J., Arkin, P., and Nelkin, E., 2003: The version-2 Global Precipitation Climatology Project (GPCP) monthly precipitation analysis (1979-present). *J. Hydromet.*, **4**(6), 1147–1167.

Arkin, P. A. and Meisner, B. N., 1987: The relationship between large-scale convective rainfall and cold cloud over the western hemisphere during 1982-84. *Mon. Wea. Rev.*, **115**, 51–74.

Hsu, K., X. Gao, S. Sorooshian, and H. V. Gupta, 1997: Precipitation estimation from remotely sensed information using artificial neural networks. *J. App. Meteor*, **36**, 1176-1190.

Huffman, G. J., Adler, R. F., Arkin, P. A., Chang, A., Ferraro, R., Gruber, A., Janowiak, J., McNab, A., Rudolf, B., and Schneider, U., 1997: The Global Precipitation Climatology Project (GPCP) combined precipitation dataset. *Bull. Amer. Meteor. Soc.*, **78**(1), 5–20.

Huffman, G. J., Adler, R. F., Morrissey, M. M., Bolvin, D. T., Curtis, S., Joyce, R., McGavock, B., and Susskind, J., 2001: Global precipitation at one-degree daily resolution from multisatellite observations. *J. Hydrology*, **2**(1), 36–50.

Huffman, G. J., R. F. Adler, E. F. Stocker, D. T. Bolvin, and E. J. Nelkin, 2003: Analysis of TRMM 3-hourly multi-satellite precipitation estimates computed in both real and post-real time. *Combined Preprints CD-ROM, 83rd AMS Annual Meeting*, Poster P4.11 in: 12th Conf. on Sat. Meteor. and Oceanog., 9-13 February 2003, Long Beach, CA, 6 pp.

Jaeger, L., 1983: Monthly and areal patterns of mean global precipitation. *Variations in the Global Water Budget,* A. Street-Perrott, M. Beran, and R. Ratcliffe, Eds., D. Reidel Publ. Co., Dordrecht, 129-140.

Joyce, R. J., J. E. Janowiak, P. A. Arkin and P. Xie, 2004: CMORPH: a method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution. *J. Hydromet.*, **5**(3), 487–503.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White, G., Woollen, J., Zhu, Y., Chelliah, M., Ebisuzaki, W., Higgins, W., Janowiak, J., Mo, K. C., Ropelewski, C., Wang, J., Leetmaa, A., Reynolds, R., Jenne, R., and Joseph, D., 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**(3), 437–471.

Kuligowski, R. J., 2002: A self-calibrating GOES rainfall algorithm for short-term rainfall estimates. *J. Hydromet.*, **3**, 112-130.

Legates, D. R. and Willmott, C. J., 1990: Mean seasonal and spatial variability in gauge-corrected, global precipitation. *Int. J. Clim.*, **10**(2), 111–127.

Scofield, R. A. and R. J. Kuligowski, 2003: Status and outlook of operational satellite precipitation algorithms for extreme-precipitation events. *Weather and Forecasting*, **18**, 1037-1051.

Sorooshian, S., K. Hsu, X. Gao, H. V. Gupta, B. Imam, and D. Braithwaite, 2000: Evaluation of PERSIANN system satellite-based estimates of tropical rainfall. *Bull. Amer. Meteor. Soc.*, **81**, 2035-2046.

Turk, F. J. and S. D. Miller, 2005: Toward improved characterization of remotely sensed precipitation regimes with MODIS/AMSR-E blended data techniques. *IEEE Trans. Geoscience and Remote Sensing*, **43**(5), 1059-1069.

Xie, P. and Arkin, P. A., 1997a: Global pentad precipitation analysis based on gauge observations, satellite estimates and model outputs. In *Extended Abstracts, American Geophysical Union 1997 Fall Meeting, San Francisco, CA*. AGU.

Xie, P. and Arkin, P. A., 1997b: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, **78**(11), 2539–2558.

Xie, P., Janowiak, J. E., Arkin, P. A., Adler, R., Gruber, A., Ferraro, R., Huffman, G. J., and Curtis, S., 2003: GPCP Pentad precipitation analyses: An experimental dataset based on gauge observations and satellite estimates. *Journal of Climate*, **16**(13), 2197–2214.

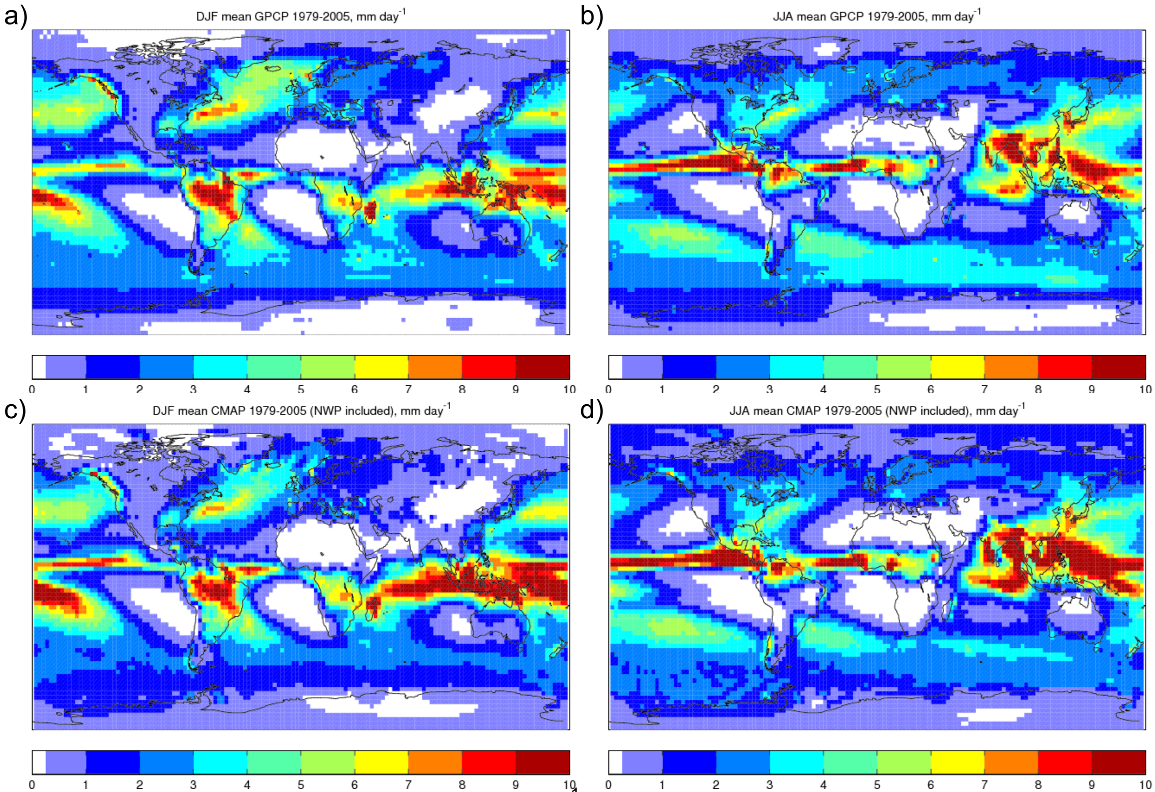

Figure 1: Seasonal mean precipitation (mm day^{-1}) for (a and c) DJF and (b and d) JJA for (a and b) GPCP and (c and d) CMAP.