J6.1 VERIFYING THE REANALYSIS AND CLIMATE MODELS OUTPUTS USING A 56-YEAR DATA SET OF RECONSTRUCTED GLOBAL PRECIPITATION

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1. INTRODUCTION

In recent years, several merged analyses of global monthly precipitation have been produced and applied successfully in climate analysis and numerical model verifications (e.g. Huffman et al., 1997; Xie and Arkin, 1997). These analyses, however, cover only the most recent two decades due to their dependence on estimates from satellite observations. A precipitation analysis with extended temporal coverage is desired for many applications.

To this end, a new data set of global monthly precipitation has been constructed at the NOAA Climate Prediction Center (CPC). Called PREC (Precipitation REConstruction), this monthly analysis covers the globe from 60°S to 75°N on both land and ocean and extends over a 56-year period from 1948 to the present.

The purpose of this paper is to provide a brief description of the new data set and to present an illustration of its potential applications in verifying numerical models.

2. THE PREC DATA SET

The current version of the PREC analysis is constructed on a 2.5° lat/lon grid over the globe from 60°S – 75°N. It is composed of two portions: the land (PREC/L) and the oceanic components (PREC/O). Over the global land areas, the analysis (PREC/L) is defined by optimal interpolation of gauge observations of monthly precipitation at over 17,000 stations. These gauge data are collected from two individual data sets, i.e., the Version 2 data set of the Global Historical Climatology Network (GHCN) of NOAA National Climatic Data Center (NCDC) and the precipitation data set of the Climate Anomaly Monitoring System (CAMS) of NOAA Climate Prediction Center (CPC). Various tests have been conducted for the gauge-based analysis and the results showed that it is capable of reproducing the spatial distribution and temporal variation patterns of precipitation with a high accuracy over most of the global land areas (Chen et al. 2002).

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Over the global oceanic areas, the analysis (PREC/O) is defined by EOF reconstruction using the technique of Smith et al. (1996). With this method, oceanic precipitation anomalies are calculated by projecting the historical gauge observations over islands and land areas onto EOF patterns derived from satellite-based estimates for later years (Xie et al. 2002).

First, an EOF analysis is performed for the satellite estimates of OPI (Xie and Arkin, 1998) over the global domain (60°S-75°N) for a 20-year period from 1979 to 1998. Gauge observations of monthly precipitation over islands and land areas are then projected to the spatial loading functions of the first 8 EOF modes to determine the time series of the principal components. The oceanic precipitation anomaly fields are constructed by multiplying the spatial loading functions with the corresponding principal components for these modes.

Since the global EOF is strongly dominated by precipitation variability over the tropical Pacific Ocean, regional EOF reconstruction is implemented over regional domains on the residuals of the global EOF so as to improve the quality of the reconstructed precipitation fields. In this version of the PREC/O data set, this regional reconstruction is performed only for the Atlantic Ocean and its vicinity.

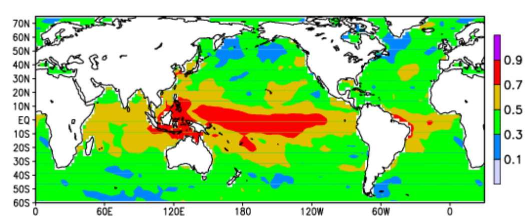

Fig. 1: Correlation between the monthly precipitation anomaly in the PREC/O and that in the OPI satellite estimates for a 20-year period from 1979 to 1998.

Cross-validation tests and comparison with independent satellite observations showed that the reconstructed oceanic precipitation (PREC/O) is able to retrieve the precipitation anomaly associated with ENSO and other large-scale circulation patterns reasonably well over most of the tropical and sub-tropical oceanic areas (Chen et al. 2003). Fig.1 shows the correlation between the monthly precipitation anomaly in the PREC/O and that in the OPI satellite estimates calculated for a 20-year period from 1979 – 1998. The correlation is higher than 0.5 over most of the tropical oceanic areas and exceeds 0.7 over tropical western and central Pacific. The quality of the reconstructed oceanic precipitation over extra-tropical oceans, however, is degraded, with anomaly correlation less than 0.5.

Fig.2 presents an example of the precipitation anomaly fields for January 1998 as obtained from the OPI satellite estimates and the PREC analysis. It is clear that large-scale precipitation anomaly patterns associated with the warm ENSO episode observed in the OPI satellite estimates are very well reproduced in our new data set.

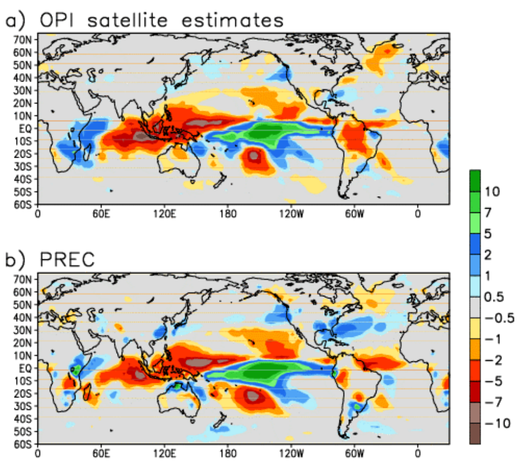

Fig. 2: Precipitation anomaly (mm/day) for January 1998 derived from the OPI satellite estimates (top) and the PREC gauge-based and reconstructed data set (bottom).

In short, the PREC data set has very reliable quantitative accuracy over global land areas, while over ocean, it is useful for applications involving precipitation anomaly associated with ENSO and other large-scale circulation patterns over tropics.

3. APPLICATIONS

As an illustration of the potential applications of our 56-year global monthly precipitation data set, seasonal and interannual variations of global large-scale precipitation are examined and compared to those generated by numerical models. In this preliminary research, precipitation fields produced by the NCEP/NCAR reanalysis and the climate models (AMIP runs) of NCEP/GFS, ECHAM and NASA/NSIPP are included in the comparison.

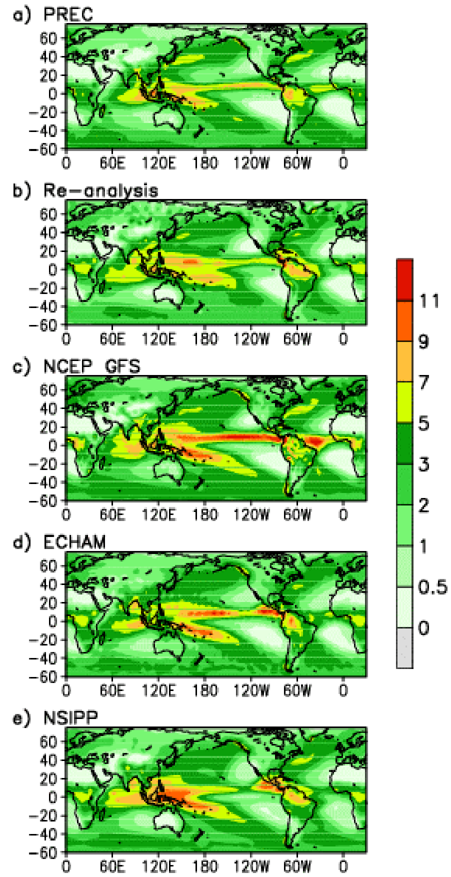

Fig. 3: Annual mean precipitation (mm/day) for a 52-year period from 1950 – 2001, as obtained from the PREC data set, the NCEP/NCAR reanalysis and the AMIP runs of the three climate models.

Shown in fig.3 is the annual mean precipitation averaged over a 52-year period from 1950 to 2001 as defined by the PREC, the reanalysis and the three selected climate models. Characterized by rainbands associated with the ITCZ, SPCZ, and convection centers over tropics and by storm tracks over extra-tropics, the large-scale structure of global precipitation observed in the PREC data set is well captured by the reanalysis and all of the three models examined here. Differences, however, are observed in the smaller scale structures and in the magnitude. In general, the reanalysis exhibits wider and smoother distribution of precipitation compared to that in the PREC. All of the 3 climate models examined here produced heavier precipitation than that in our PREC data set. A minimum of ITCZ precipitation is observed over central Pacific in the PREC data set, while it appears over the eastern Pacific in the ECHAM and NSIPP models and over central western Pacific in the NCEP/GFS.

Shown in fig. 4 are latitudinal profiles of the annual cycle of mean precipitation averaged over the entire globe. The evolution of mean precipitation is dominated by the migration of the ITCZ, SPCZ and convection centers over tropical Africa and South America. The center of heavy rain is located south of the equator during boreal winter, moves northward during spring and reached ~10^{o}N in boreal summer. The maximum precipitation is observed over tropics during the June-July-August period. This annual cycle of tropical precipitation as observed in the PREC is reproduced well by the reanalysis and the climate models. In addition to the smoother distribution in the reanalysis and the larger precipitation in the 3 climate models as discussed earlier, slight differences are observed in the phase of the maximum precipitation during boreal summer in the precipitation fields produced by the NASA/NSIPP.

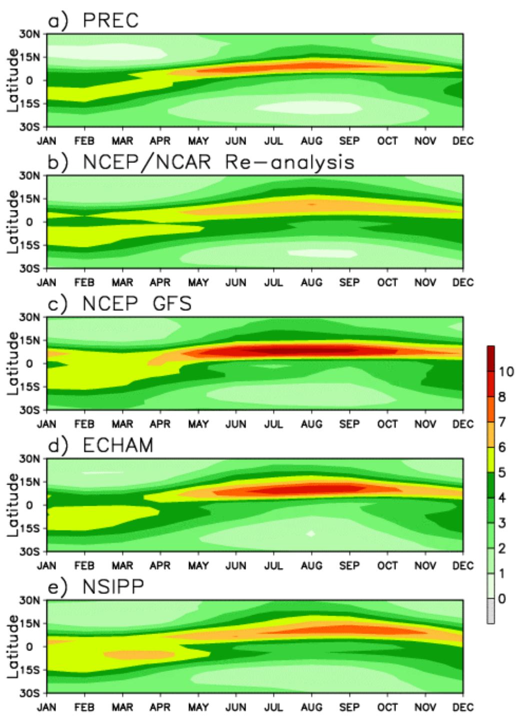

Fig. 4: Latitudinal profiles of the mean annual cycle of precipitation (mm/day) for a 52-year period from 1950 – 2001 averaged over the entire globe as defined by a) the PREC data set; b) the NCEP/NCAR reanalysis; and the AMIP runs of the climate models of c) NCEP/GFS; d) ECHAM; and e) NASA/NSIPP.

With the 56-year PREC data set, it becomes possible to examine the interannual variability of large-scale precipitation for an extended period, especially before 1979 when no satellite observations are available. Presented in fig.5 are the Hovermoller diagrams of SST (left) and precipitation averaged over the equatorial tropical Pacific as obtained from the PREC (fig.5b), OPI satellite estimates (fig.5c), Reanalysis (fig.5d), and the climate models of NCEP/GFS (fig.5e), ECHAM (fig.5f) and the NASA/NSIPP (fig.5g). The anomaly patterns associated with the evolution of ENSO were well captured by the reconstruction as evidenced by its good agreement with the OPI estimates for the period from 1974. The anomaly patterns produced by the reanalysis and the 3 climate models are in general agreements with those in our PREC data set. Close examinations of the figure show that the anomaly patterns in the reanalysis precipitation present an eastward displacement compared to that in the OPI estimates and the PREC, while the NCEP/GFS exhibits smaller scale anomaly patterns that are not observed in the PREC.

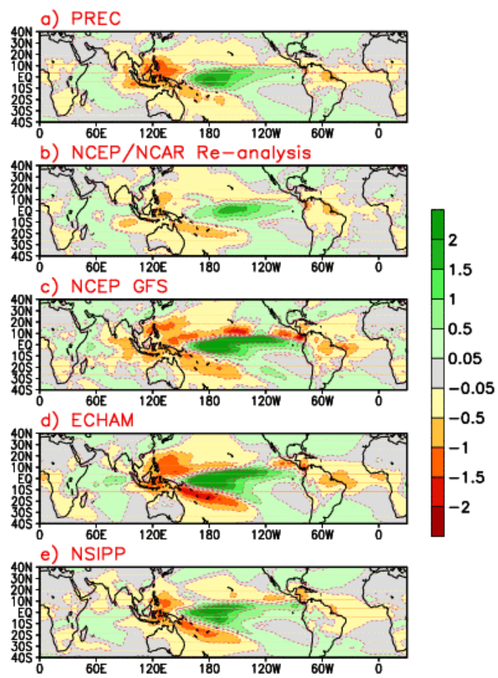

Fig. 6: Linear regression coefficients between precipitation anomaly and the NINO3.4 index for the 52-year period from 1950 – 2001.

To further examine precipitation anomaly patterns associated with ENSO, regression analysis is performed between the precipitation anomaly and the NINO3.4 index for the PREC, reanalysis and the 3 climate models. Warm ENSO events are characterized by positive precipitation anomaly over central and eastern Pacific, western Indian Ocean, and the northwest Atlantic Ocean, and by negative anomalies over western Pacific and the northern portion of South America (fig.6a). Compared to those for the PREC, the regression coefficients for the reanalysis are weaker and the action centers are shifted eastward. The three climate models, meanwhile, reproduced the overall patterns of the ENSO reaction very well but presented stronger responses in precipitation anomaly.

4. SUMMARY

An analysis of global monthly precipitation (PREC) has been constructed on a 2.5^o lat/lon grid over the globe for a 56-year period from 1948 to the present;

Over land, the analysis is defined by interpolating gauge observations. The accuracy of this land analysis (PREC/L) satisfies requirements for most applications in climate analysis, model verification, and hydrological studies. Over ocean, the analysis (PREC/O) is defined by EOF reconstruction of historical gauge observations over islands and land areas. The reconstructed precipitation data set is able to retrieve precipitation variability associated with ENSO and major large-scale circulation patterns with reasonable accuracy over tropical and sub-tropical regions;

This new analysis (PREC) is applied to verify the precipitation fields produced by the NCEP/NCAR reanalysis and the AMIP runs of the NCEP/GFS, ECHAM and NASA/NISPP for a 52-year period from 1950 to 2001. The results demonstrated that the PREC data set is useful in similar applications in verifying the overall performance of models in reproducing seasonal and interannual variations of large-scale precipitation;

The 56-year global monthly precipitation data set is available through ftp at: ftpprd.ncep.noaa.gov/pub/precip.

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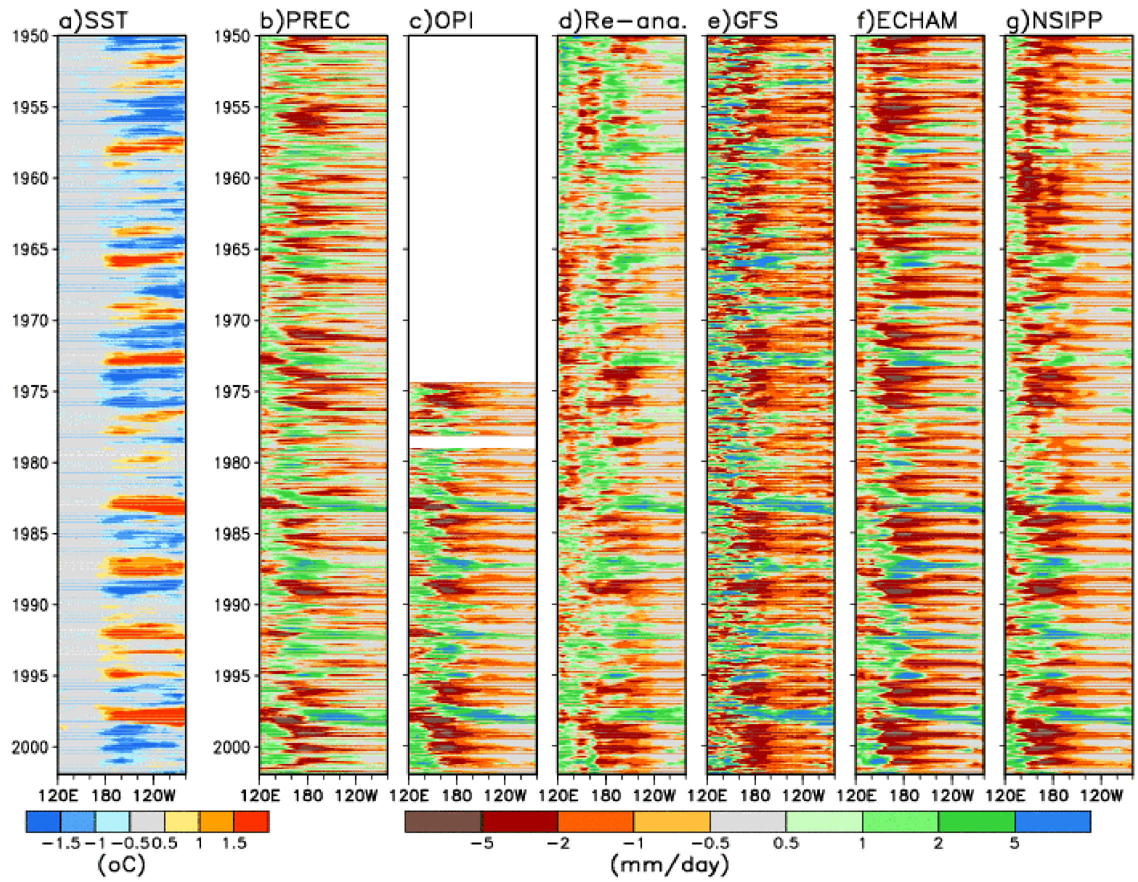

Fig. 5 : Longitude-Time section of SST (^{o}C) and precipitation anomaly (mm/day) over the equatorial tropical Pacific Ocean.