PRECIPITATION ANALYSES AND THEIR APPLICATIONS IN DROUGHT MONITORING At NOAA's CLIMATE PREDICTION CENTER

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1. INTRODUCTION

Substantial progress has been made in the last two decades in quantitatively documenting global precipitation. Surface gauge observations have been collected, digitized and quality controlled by data centers in several countries. Objective techniques have been developed and applied to construct analyzed fields of precipitation over global land areas from these gauge data. At the same time, space-borne measurements of precipitation became available from an assortment of platforms. Continuous development and refinements of retrieval algorithms have yielded operational precipitation products based on satellite observations of infrared (IR), passive microwave (MW) and space-borne precipitation radar (PR). Further more, combining information from multiple satellite sensors as well as gauge observations and numerical model outputs yielded analyses of precipitation with stable and improved quality.

Several sets of gauge-, satellite-based, and gauge-satellite merged analyses of global and regional precipitation have been created at NOAA's Climate Prediction Center (CPC) and applied to monitor the global climate and to assess and verify climate models. The objective of this article is to describe the CPC precipitation data sets and their applications in drought monitoring.

2. GAUGE-BASED ANALYSES

Gauge observations play a critical role in constructing precipitation analyses over land. In NOAA/CPC, several sets of gauge-based analyses have been created over the global and regional domains by interpolating station observations from the WMO Global Telecommunication System (GTS) and from national collections. Recently, a new project has been initiated at CPC to create a suite of unified precipitation products with consistent magnitude and improved quality. This is done by performing quality control for all the individual precipitation data sets available at various parts of CPC and analyzing them through an advanced objective technique.

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Table 1: Primary Features of CPC Unified Gauge-Based Analysis of Daily Precipitation

Features	**Descriptions**
Target Parameter	Precipitation
Source of Information	Gauge Observations
Spatial Res / Domain	0.5^{o}lat/lon, Global Land
Temporal Resolution	Daily
Latency	Next Day (~18 hours)
Period of Record	1979 – Present
Data Accessibility	ftp
Grid / File Format	Equal Angle / Binary
Format Compatibility	GrADS
Reliability	Highly Reliable over US
Citations	Xie et al. (2007), Chen et al. (2007)

As of December 2007, the CPC unified gauge-based analysis of daily precipitation has been constructed on a 0.5^{o}lat/lon grid over the global land for the period from 1979 to the present. This new gauge analysis is defined by interpolating gauge observations from over 30,000 stations through the optimal interpolation (OI) algorithm of Xie et al. (2007). A summary of the features of this new gauge analysis is given in Table 1, while an example of the analysis for July 11, 2003, is illustrated in Figure 1.

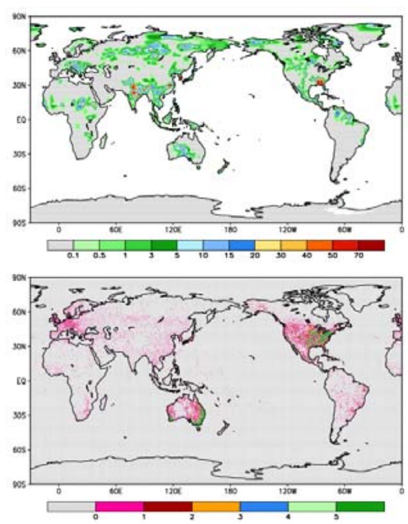

Fig.1: daily precipitation analysis (upper, mm/day) and number of gauges (bottom) in a 0.5^{o}lat/lon grid box for July 11, 2005.

3. SATELLITE-BASED HIGH-RESOLUTION PRECIPITATION ESTIMATE

In recent years, new algorithms have been developed to create high-resolution precipitation estimates over the global domain by the combined use of less physically-based but frequently available infrared (IR) observations from geostationary satellites and the physically-based but infrequently sampled passive microwave (MW) measurements aboard low orbit platforms. The CPC Morphing technique (CMORPH, Joyce et al. 2004) is one of techniques developed at NOAA/CPC and was implemented for real-time operations in December 2002. The CMORPH technique defines precipitation at a fine resolution of 8kmx8km / 30 min by interpolating MW-based precipitation estimates in the time/space domain using advection vectors of the cloud/precipitation systems derived from the geostationary IR images.

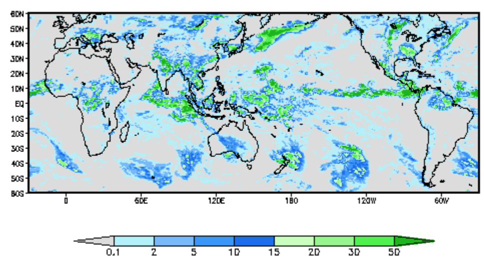

Fig.2: CMORPH precipitation (mm/day) for July 11, 2005.

Fig.2 presents an example of the CMORPH daily precipitation distribution for July 11, 2005, while primary features of the CMOPRH are given in Table 2. One of the advantages of the satellite-based estimates is its ability to provide coverage of observations over areas with sparse gauge networks. In addition, the high-resolution satellite estimates provides critical information of precipitation on a sub-daily time scale.

Table 2: Primary Features of the CMORPH High-Resolution Precipitation Estimates

Features	**Descriptions**
Target Parameter	Precipitation
Source of Information	MW & IR Sate. Obs.
Spatial Res / Domain	8km, Globe (60^oS-60^oN)
Temporal Resolution	30 min
Latency	~16 hours
Period of Record	Dec.2002 - Present
Data Accessibility	ftp
Grid / File Format	Equal Angle / Binary
Format Compatibility	GrADS
Reliability	Higher for convective rain
Citations	Joyce et al. (2004)

4. GAUGE-SATELLITE MERGE ANALYSES

Quality of the precipitation analyses can be improved by merging gauge observations with satellite estimates. One such product is the CPC Merged Analysis of Precipitation (CMAP, Xie and Arkin 1997) defined by combining gauge analysis with estimates derived from satellite observations of IR and MW. Originally developed for applications in climate monitoring and analysis, the CMAP data set is constructed on a 2.5^olat/lon grid over the globe and at monthly / pentad temporal resolution for a 29-year period from 1979 to the present. Table 3 lists the primary features of the CMAP data set generated at NOAA/CPC.

Table 3: Primary Features of the CMAP merged analyses

Features	**Descriptions**
Target Parameter	Precipitation
Source of Information	Gauge & sate. Obs.
Spatial Res / Domain	2.5^olat/lon, Globe
Temporal Resolution	Monthly / pentad
Latency	Next day (~18 hours)
Period of Record	1979 - Present
Data Accessibility	ftp
Grid / File Format	Equal Angle / Binary
Format Compatibility	GrADS
Reliability	Better over tropics / Land
Citations	Xie and Arkin (1997)

Work is under way at NOAA's Climate Prediction Center to generate analyses of precipitation at higher time/space resolution by merging daily/hourly gauge observations with the CMORPH satellite estimates. The new high-resolution merged analysis is expected to present quasi complete spatial coverage of precipitation with improved quantitative accuracy compared to the gauge-only and CMORPH estimates.

5. APPLICATIONS IN DROUGHT MONITORING

Lack of precipitation is the fundamental cause of droughts. Generally speaking, precipitation data sets are used in drought monitoring in two different ways. Monitoring of precipitation and its departure from the normal state (anomaly) provide direct observations of the input moisture to the land system. At NOAA's Climate Prediction Center, gauge-based analyses of daily precipitation are utilized in real-time monitoring of drought over the contiguous United States (CONUS, fig. 3).

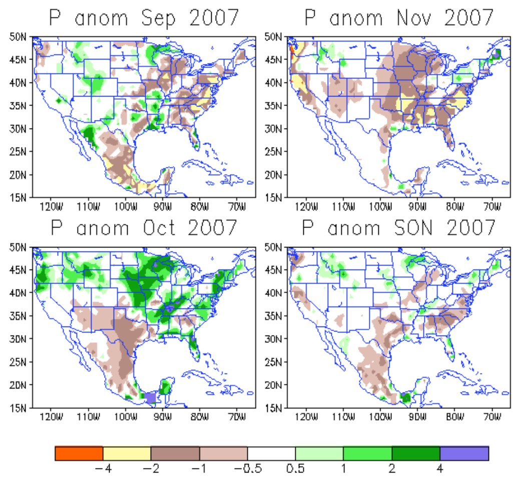

Fig. 3: Monthly and seasonal anomaly (mm/day) of precipitation over CONUS derived from the CPC gauge-based analysis of daily precipitation (courtesy of Dr. Kingtse Mo).

Gauge-based and gauge-satellite merged analyses of terrestrial precipitation are also used as one of the inputs to the land surface models. While some of the models utilize only the gauge-based analyses of daily and monthly precipitation as inputs, other systems take advantage of satellite estimates and gauge-satellite merged products as well to achieve better spatial patterns over gauge sparse regions and to dissegregate the accumulated rainfall into finer time resolution resolving diurnal cycle. At NOAA's Climate Prediction Center (CPC) and Environmental Modeling Center (EMC), gauge-satellite merged pentad CMAP analysis is used as inputs to the NCEP Reanalysis 2, while a combination of gauge-only and gauge-satellite merged data sets are employed to define soil moisture in the Land Data Assimilation System (LDAS) over CONUS and in the Global Land Data Assimilation System (GLDAS) over the global land.

6. SUMMARY

This article provides a short list of several precipitation data sets created at NOAA Climate Prediction Center for climate monitoring and analysis. While there are many other similar products of global and regional precipitation, we tried to describe here several analyses based on gauge observations, satellite estimates and their combinations. As shown in the article, these precipitation products play an important role in monitoring and diagnosing droughts over United States and other parts of the global land areas.

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