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Supplementary Materials for:

Evaluation of Sixteen Gridded Precipitation Datasets Over the Caribbean Region Using Gauge Observations

1. Introduction

This document describes the gridded precipitation products (GPP), including the number of gauges used by each of them over the Caribbean. We have grouped the GPP based on the sources of data used to construct them: (1) gauge-based GPP, (2) Gauge and satellite-based GPP, (3) Reanalysis-based GPP, and (4) Gauge and reanalysis-based GPP.

2. Description of the Gridded Precipitation Products (GPP)

2.1. Gauge-Based GPP

2.1.1. CRU-TS4.01

The Climatic Research Unit (CRU) Time-series (TS) version 4.01 dataset is a monthly climate product that spans from 1901 to 2016, at 0.5° horizontal resolution. This dataset includes precipitation, temperature (daily mean temperature, monthly average daily maximum and minimum temperature), cloud cover, diurnal temperature range, frost day frequency, potential evapotranspiration (PET), and vapor pressure [1]. The number of gauges used by CRU-TS4.01 varies on the climate variable. For example, precipitation is based on more than 4,000 stations worldwide, with about 20 stations for the Caribbean [1]. This product is based on monthly observational data calculated from daily or sub-daily data by National Meteorological Services and other external agents [1].

2.1.2. CPC-Global

A gauge-based analysis of daily precipitation has been constructed over the global land areas. Gauge reports from over 30,000 stations are collected from multiple sources including the Global Telecommunication System (GTS), Cooperative Observer Network (COOP), and other national and international agencies. Quality control is performed through comparisons with historical records and independent information from measurements at nearby stations, concurrent radar/satellite observations, as well as numerical model forecasts. Quality controlled station reports are then interpolated to create analyzed fields of daily precipitation with consideration of orographic effects [2,3]. The daily analysis is constructed on a 0.125° lat/lon grid over the entire global land areas, and released on a 0.5° lat/lon grid over the global domain for a period from 1979 to the present [3]. This dataset has two components: (a) the "retrospective version" which uses 30K stations and spans 1979−2005 and (b) the "real-time version" which uses 17,000 stations and spans 2006-present. The real-time data will be reprocessed in the future to be consistent with the retrospective analysis.

2.1.3. PRECL

The Precipitation Reconstruction Land (PRECL) dataset is a gridded monthly averaged precipitation totals product based on high quality station gauge measurements over land [4]. PRECL uses 17,000 gauges worldwide from the Global Historical Climatology Network version 2 (GHCN-v2), with approximately 20 stations over the Caribbean [4]. PREC/L spans from 1948 to near present, and has horizontal resolutions varying from 0.5° to 1.0°, and 2.5° interpolated via optimal interpolation. In this work, we use PRECL at 0.5° over the target 1983–2010, obtained from https://psl.noaa.gov/data/gridded/data.precl.html.

2.1.4. GPCC-v2018

The Global Precipitation Climatology Centre (GPCC) version 2018 (v2018), land surface dataset [5] is based on more than 85,000 quality-controlled rain gauges worldwide, including approximately 400 in the Caribbean and Central America. We used the GPCC v2018 (https://psl.noaa.gov/data/gridded/data.gpcc.html), which has a native horizontal resolution of 0.25°, 0.5°, 1.0° and 2.5° on regular grids [5]. This version incorporates the full dataset from 1891 to 2016 with a monitoring product spanning from 2016 to the near present [5]. In this work we used this product at 0.25° and 0.5° horizontal resolutions. As compared to the previous version (GPCCv7), GPCCv2018 has an improved interpolation method, which now uses a "climatological infilling" in areas of ~5° lat/lon where there is not station data available. This method is aimed to avoid interpolation artifacts [5].

2.1.5. HERRERAULT

HERRERAULT dataset is a high-resolution (4 km or ~0.04°) monthly climate dataset for the Caribbean islands and Central America, spanning from 1949 to near-present [6]. The product uses statistical methods to downscale GPCCv7 data for precipitation and the Berkeley Earth Surface Temperature (BEST) data for temperature (minimum, mean, and maximum temperature). Due to the scarcity of long-term gauges over the Caribbean and Central America, this product further uses the Climate Hazards group Infrared Precipitation with Stations (CHIRPS; [7]) to correct biases from the downscaled GPCCv7 product using a quantile mapping approach as in [8]. Ref. [6] provides the details about this product, and it can be downloaded at: https://ecommons.cornell.edu/handle/18-13/58763.

2.2. Gauge and Satellite-Based GPP

2.2.1. CHIRPS

CHIRPS (Climate Hazards group Infrared Precipitation with Stations) is quasi-global rainfall dataset spanning 50°S-50°N (and all longitudes) and ranging from 1981 to near-present. This GPP builds on a global 0.05° monthly precipitation climatology CHPclim [7] and uses the Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis version 7 (TMPA 3B42 v7)7 to calibrate the estimates from the global Cold Cloud Duration (CCD). The high resolution CCD derived rainfall estimates are combined with station data, producing a final dataset which falls somewhere between a curated interpolated gauge datasets and sparse gauge plus satellite products [7]

2.2.2. PERSIANNCDR

The Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Climate Data Record (PERSIANNCDR) provides daily rainfall estimates at a spatial resolution of 0.25° in the latitude band 60°S-60°N from 1983 to the near-present. The precipitation estimate is produced using the PERSIANN algorithm on GridSat-B1 infrared satellite data, and the training of the artificial neural network is done using the National Centers for Environmental Prediction (NCEP) stage IV hourly precipitation data. To reduce the biases in the estimated precipitation, while preserving the temporal and spatial patterns in high resolution, the resulting estimates are then adjusted using the GPCP monthly 2.5° precipitation products [9]. PERSIANN CDR is a Climate Data Record, which the National Research Council (NRC) defines as a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. It is aimed at hydrological and climate studies that require long-term consistent data, for instance for trend and risk analysis [9].

2.3. Reanalysis-Based (Modeled) GPP

2.3.1. CFSR

The Climate Forecast System Reanalysis (CFSR) is a third generation reanalysis at high horizontal resolution, spanning 1979–2011. CFSR global has an atmospheric horizontal resolution of approximately 38 km (~0.3°) and 64 levels [10,11]. Over the ocean, however, its horizontal resolution is 0.25° at the equator and 0.5° beyond the tropics, and 40 vertical levels. The CFSR atmospheric model further assimilates variations in carbon dioxide (CO2) aerosols and other trace gases, and solar variations.

2.3.2. ERAi

The European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalysis (ERAi) spans from January 1979 to August 2019, with temporal resolutions ranging from 3-hourly to monthly time-steps. ERAi has an original, model-horizontal resolution of 0.70° Gaussian grid, and a vertical resolution of 60 levels, with the top level at 0.1 mb [12]. ERA-Interim uses a 4-dimensional variational assimilation scheme with an improved low-frequency variability, stratospheric circulation, and hydrological cycle [12].

2.3.3 ERA5

ERA5 is the latest climate reanalysis produced by ECMWF, replacing the ERA-Interim reanalysis. This reanalysis provides hourly data on many atmospheric, land-surface and sea-state parameters together. The data cover the Earth on a 30 km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80 km. ERA5 includes information about uncertainties for all variables at reduced spatial and temporal resolutions [13,14]. The monthly precipitation data for ERA5 were downloaded from https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-land-monthly-means

2.3.4. JRA-55

Spanning 1958-present, the Japanese 55-year Reanalysis (JRA-55) is one of the longest third-generation reanalysis that uses the full observing system (in contrast, products like ERA-20C and NOAA 20CR assimilate a very limited set of observations while NCEP R1 uses an antiquated model and assimilation scheme) [15]. Compared to the previous generation Japanese Meteorological Agency (JMA) reanalysis, JRA-25, JRA-55 uses a more advanced data assimilation scheme (4Dvar vs 3Dvar), increased model resolution (T319L60 with a reduced Gaussian grid system vs T106L40 in JRA25), a new variational bias correction for satellite data, and several additional observational data sources. Among the improvements in the product are reduced biases in stratospheric temperature and Amazonian rainfall, and greater temporal consistency of the temperature analysis. Some notable biases persist, including a dry bias in the upper and middle troposphere, and a warm bias in the upper troposphere. The impacts of changes in the observing system on the forecast error are generally more evident in the Southern Hemisphere than the Northern Hemisphere. Two companion datasets are available that allow users to address the impact of data assimilation: JRA-55C using conventional observations only and JRA55-AMIP using no data assimilation.

2.4. Gauge and Reanalysis-Based GPP

2.4.1. TerraClimate

TerraClimate is a global gridded dataset of meteorological and water balance variables for 1958-present, available on a monthly time-step. Its relatively fine spatial resolution, global extent, and long length are a very useful combination for several climate analysis and applications. This dataset provides a long record of monthly climate data for global terrestrial surfaces on a spatial resolution of ~4-km (1/24th degree) grid. This product was developed by blending spatial attributes from WorldClimV2 with temporal attributes from CRU Ts4.0 and reanalyses products through climatically aided interpolation [16].

2.4.2. CHELSA

CHELSA (The Climatologies at high resolution for the earth's land surface areas) is a high resolution (~1 km over the equator) climatologies global dataset of temperature and precipitation for various time periods [17]. CHELSA is based on a quasi-mechanistical statistical downscaling of ERA-interim reanalysis data. This gridded product also has statistically-downscaled CRU TS4.01 data using the delta method by B-spline interpolation of anomalies of the CRU TS 4.01 dataset [18]. Ref. [17] provides the details on how CHELSA was built.

2.5. Multiple Data Sourced GPP

2.5.1. MSWEP Version 1 (MSWEP)

Is a global gridded 3-hourly precipitation dataset at a spatial resolution 0.25°, for the period 1979-2015. This GPP was specifically designed for hydrological modeling by optimally merge the highest quality rainfall data from different sources (gauge observations, satellite remote sensing and atmospheric model reanalysis) as a function of timescale and location. MSWEP development process includes corrections for gauge under-catch and orographic effects and a weight average of the anomalies from several datasets such as CPCGLOBAL, GPCC (gauge), CMORPH, GSMaP-MVK, and TMPA 3B42RT (satellite), and ERA-Interim and JRA-55 (reanalysis) [19].

2.5.1. MSWEP 2.1 (MSWEP2)

Is an improvement of MSWEP, taking the advantage of the complementary strengths of gauge, satellite, and reanalysis data to provide reliable precipitation estimates. As it is reported by [20], some of the improvements of MSWEP2 includes (a) a higher spatial resolution (0.1°); (b) the introduction of cumulative distribution function (CDF) and precipitation frequency corrections, to account for spurious drizzle, attenuated peaks, and temporal discontinuities; (c) the use of a large database of daily gauge observations compiled from several sources to replace the 0.5° Climate Prediction Center (CPC) unified dataset; (d) extension of the data record to 2017; and (e) the use of a daily gauge correction scheme that accounts for regional differences in reporting times, to minimize timing mismatches when applying the daily gauge corrections;

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