NEWS
Project Report
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Global Precipitation Variations and Extremes

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1. Project Description. This project focuses on the science question: How are the characteristics of global precipitation changing in terms of means, variations and extremes, and what is the confidence in our conclusions? Important characteristics of global precipitation (including global and regional means, extremes, variations and trends, and the confidence limits thereof) will be determined by extending, improving and analyzing the 29+ year standard merged precipitation analyses of the Global Precipitation Climatology Project (GPCP) of the WCRP/GEWEX and other shorter, high quality data sets such as from TRMM.

Specifically, this project will: 1) establish the climatology of global precipitation, the mean spatial and seasonal variations, and inter-annual variations, and the uncertainty of these estimates; 2) examine inter-decadal changes and recent (30-year) trends in precipitation (global and regional) and relate these to large-scale forcing (*e.g.*, ENSO, NAO and volcano/aerosol impacts) and variations and trends in surface temperature; 3) develop a climatology of precipitation extremes (and time history of such); and 4) continue to produce, monitor, validate and improve the monthly global, merged GPCP analyses.

This project will also actively contribute to the integrated NEWS effort to analyze the full global water cycle as a whole, examining all the relevant observational global data sets (*e.g.*, ocean evaporation, clouds, water vapor, *etc.*), in conjunction with other investigators, to identify inconsistencies, artifacts and limitations in the data sets and better understand both the means and variations in all the water cycle components. As part of this effort we will derive best estimates of precipitation and confidence limits so that overall water (and energy) balances can be derived.

2. Accomplishments of past year.

2.1 Release of new GPCP Version 2.1 global precipitation analysis.

Our group has developed Version 2.1 of its long-term (1979-present) global Satellite-Gauge (SG) data sets to take advantage of the improved GPCC gauge analysis, which is one key input. As part of this work the OPI estimates that are used in the pre-SSM/I era have been rescaled to 20 years of the SSM/I-era SG. All of the monthly, pentad, and daily GPCP products have been reprocessed for their entire periods of record, continuing to enforce consistency of the submonthly estimates to the monthly. Version 2.1 estimates are generally close to Version 2, with the global ocean, land, and total values about 0%, 6%, and 2% higher, respectively, for ocean defined as 100% coverage

by water, and land encompassing all other areas. The revised long-term global precipitation rate is 2.68 mm/d. In the tropics (25°N-S) the corresponding increases are 0%, 7%, and 3%. Generally, the long-term linear changes in the data record tend to be smaller in Version 2.1, but the statistics are sensitive to the threshold for land/ocean separation and use of the pre-SSM/I part of the record.

2.2 Estimation of Bias Errors in Regional and Global Precipitation

We have been examining the state of knowledge of the climatology of global and regional surface precipitation is summarized by examining a number of satellite and satellite-gauge analyses. The goal is to produce best estimates of global precipitation values, monthly climatological maps and estimates of bias errors. The approach uses the Global Precipitation Climatology Project (GPCP) monthly data set and is also part of a larger effort with other investigators to estimate balanced global and regional water cycle means and variations with the help of estimated errors of the various fluxes.

With the GPCP data as the base, a zonal-averaged analysis (land and ocean separately) is carried out using a number of included data sets, which were selected by being within +/- 50% of GPCP zonal means. For the global total precipitation during this period the GPCP number is 2.64 mm/d, with an estimated error of +/- 9%. This is probably an upper bound of the error estimate, due to inclusion of some questionable estimates. Regionally, the error maps indicate relatively large errors as expected in higher latitudes (up to ~ 50%), indicating serious questions at these latitudes even as to the total precipitation. Mountainous areas are also regions with larger uncertainty, as well as areas with poor gauge coverage.

2.3 Precipitation/surface temperature relations

Inter-annual and long-term changes in both surface temperature and precipitation are being examined to understand the processes on both these time scales and use this information to develop a better understanding of the potential impact of global warming and shorter scale changes. Results indicate some interesting similarities between the inter-annual relations and the long-term linear changes and some expected differences. Large long-term increases in surface temperature are located mainly in the N.H. middle to high latitudes, while increases in precipitation are centered in the Tropics. On an inter-annual basis correlations between temperature and rain are positive over tropical oceans, negative over tropical land and seasonally varying in higher latitudes with mostly negative correlations over land.

Zonally-averaged linear changes during the 1979-2006 period in the ratio of precipitation change to temperature change are 2%/C (global), 6%/C (global ocean) and for the tropics (25N-25S) are 11%/C (land+ocean), 17%/C (ocean). These are important numbers in the evaluation of global processes and how climate models handle those processes. The values peak strongly in the deep tropics (double peak at about 10° N and S, relative minimum at the Equator), are slightly negative in the N.H. mid-latitudes. Examination of

the $\Delta P/\Delta T$ ratios for both the long-term change and the inter-annual variations show similarity over oceans as a function of latitude in both sign and magnitude of the ratio. Over land a distinct difference exists over the Tropics related to ENSO (inter-annual) being a very different process than that associated with the long-term warming. These relations will shortly be re-examined with the GPCP V2.1 product and with the additional years of data.

2.4 Preliminary results comparing MERRA with the GPCP analysis

Preliminary results indicate that MERRA in general provides a reasonable description of global and regional precipitation and variability. Zonal-mean profiles of MERRA precipitation are within the bound of bias errors estimated based on the GPCP and several other satellite-derived products such as CMAP, RSS, HOAPS, and TRMM. Seasonal variations in MERRA precipitation agree well with described by GPCP with exceptions of amplitudes and some regional features, for instance, in the tropical Atlantic-West Africa. MERRA also provides a good account of interannual variability, including the transition from El Niño to La Niña during 1998 and the weak El Niño event in 2002.

Nevertheless, large discrepancies are evident between MERRA and GPCP precipitation. MERRA generally overestimates (underestimates) tropical oceanic (land) precipitation. Oceanic evaporation in MERRA is weaker than the passive-microwave-based HOAPS product. Surface winds and moisture divergence fields in MERRA are also weaker than derived from the QuikSCAT product. This work will continue in collaboration with NEWS PI Bosilovich.

2.5 Routine GPCP production.

The successful production of the 30th year (1979-2008) of monthly GPCP analysis (now Version 2.1) was accomplished (with much help from GPCP team members outside this proposal at NASA, NOAA, universities, German Weather Service). As of August 2009, monthly and daily GPCP products have been produced through June 2009. Planning for Version 3 of GPCP is advancing via GEWEX and other meetings and planning sessions. This is being coordinated with other GEWEX data projects under the GEWEX Radiation Panel, some associated with NEWS. The GPCP products have been used and referenced in over 1000 journal articles.

3. Work plan for next year (and beyond)

a) Examination of relationships between surface temperature and precipitation on global and regional scales with the GPCP 30+ year record and MERRA and other models.

b) Careful analysis of monthly extremes with GPCP monthly, pentad and daily data, along with the 3-hr TMPA data in relation to ENSO and possible trends.

c) Thorough inter-comparison of MERRA with various precipitation data sets focusing on extremes over land.

d) Continue to contribute to NEWS analysis of integrated water cycle data sets looking at variations in clouds, water vapor, precipitation and other fields.

e) GPCP data set will be extended through 2009 and into 2010.

h) Finalize form of Version 3 of GPCP via GEWEX-related activities and possible start of testing and processing.

Recent NEWS-funded journal articles:

Gu, G., R. Adler, G. Huffman, and S. Curtis , 2007: Tropical Rainfall Variability on Interannual-to-Interdecadal/Longer-Time Scales Derived from the GPCP Monthly Product, *J. Climate*, 20, 4033-4046

Curtis, S., A. Salahuddin, R. F. Adler, G. J. Huffman, G. Gu, and Y. Hong, 2007: Precipitation extremes estimated by GPCP and TRMM: ENSO relationships. *J. Hydrometeor*. (GEWEX Special Issue), 8, 678-689.

Bosilovich, M. G., J. Chen, F. R. Robertson and R. F. Adler, 2008: Evaluation of Global Precipitation in Reanalyses. J. Appl. Meteor. and Climat., 47, 2279–2299.

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Huffman, G. J., R. F. Adler, D. T. Bolvin, and G. Gu (2009), Improving the global precipitation record: GPCP Version 2.1, Geophys. Res. Lett., 36, L17808, doi:10.1029/2009GL040000

Gu, G. and R. F. Adler, 2009: Interannual variability of boreal summer rainfall in the equatorial Atlantic. *Int. J. of Climat,.,* 29, 175-184.