Global Precipitation—GPCP, TRMM and GPM

Means and Variations

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and others
Global Precipitation Climatology Project (GPCP)

Climatology (1979-2015)

GPCP is an often-used analysis based on satellite and gauge data (1979-near present).

*No TRMM, GPM or Cloudsat data are in the current GPCP.*

- Adler et al., 2003 J. Hydromet
- Huffman et al., 2009 GRL
Web Address for Current GPCP products: GPCP.umd.edu

**Global Precipitation Climatology Project (GPCP)**

University of Maryland College Park
Earth System Science Interdisciplinary Center (ESSIC) and Cooperative Institute for Climate and Satellites (CICS)

**GPCP Monthly Analysis (GPCP-Interim) -- Latest Month**

Interim GPCP estimates are provisional estimates of GPCP available ~10 days after the end of the month. They can be used for the most recent months for which GPCP is unavailable.

- New GPCP Monthly (V2.3) being produced at UMD for NOAA’s Climate Data Record (CDR) program
- Final analysis available a few months after time; Interim CDR (ICDR) available ~10 days after end of month for real-time climate analysis
- V2.3 Daily and Pentad products under development
Differences due to cross-calibration errors (SSMI to SSMIS and TOVS to AIRS) over ocean and use of new GPCC “Full” gauge analysis

- Biggest difference after 2009 (~1.8% over ocean)
- Regionally biggest difference 40-60N over ocean
**Absolute Magnitude of **Global Precipitation**

<table>
<thead>
<tr>
<th>Precipitation</th>
<th>Ocean</th>
<th>Land</th>
<th>Ocean + Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>2.90 mm/d</td>
<td>2.24 mm/d</td>
<td>2.69 mm/d</td>
</tr>
</tbody>
</table>

Current GPCP global long-term number is **2.69 mm/d +/- ~7%**

With the error based on variations among different estimates (including TRMM)

(Adler et al. 2012 JAMC)

*These global numbers and continental-scale values fit well with large-scale water and energy budget studies (e.g., Rodell et al. 2015 J. Clim.)*

*But, how well do these very large-scale precipitation numbers compare with TRMM, GPM and CloudSat?*

* New values based on GPCP V2.3*
### How do TRMM-based estimates fit with GPCP?

**Tropical Mean (Ocean) Rainfall Estimates**

<table>
<thead>
<tr>
<th>mm/d</th>
<th>TRMM Radar (2A25 NS--adjusted)</th>
<th>TRMM Composite Climatology (TCC)*</th>
<th>GPCP</th>
<th>TRMM PR + CloudSat**</th>
</tr>
</thead>
<tbody>
<tr>
<td>35N-35S (ocean)</td>
<td>2.9</td>
<td>2.9</td>
<td>2.9</td>
<td>3.0 (3 years)</td>
</tr>
</tbody>
</table>

*TRMM-based mean tropical ocean values agree well with GPCP and with TRMM PR/CloudSat value.*

*Adler et al. 2009 JMSJ*

**Behrangi et al., 2014 JClim**
Global Mean (Ocean) Rainfall Estimates

<table>
<thead>
<tr>
<th></th>
<th>GPCP</th>
<th>PR + CloudSat; AMSR + CloudSat</th>
</tr>
</thead>
<tbody>
<tr>
<td>60N-60S (ocean)</td>
<td>3.04 mm/d</td>
<td>3.13 [GPCP + ~ 3%]</td>
</tr>
</tbody>
</table>

**GPCP global ocean number still seems reasonable.**

If there are faults in the GPCP global precipitation magnitude (e.g., underestimation) it probably doesn’t have to do with light rain or snow, but perhaps with intense convective rainfall in the tropics.
GPM Two-Year Precipitation from Passive Microwave (GMI) and Radar (DPR)

- GPM somewhat higher than GPCP in tropics
- GPM lower in extra-tropics

<table>
<thead>
<tr>
<th>Region</th>
<th>PMW</th>
<th>Radar</th>
<th>Comb</th>
<th>GPCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>25N-25S</td>
<td>3.50</td>
<td>3.63</td>
<td>3.37</td>
<td>3.33</td>
</tr>
<tr>
<td>65N-65S</td>
<td>2.70</td>
<td>2.83</td>
<td>2.63</td>
<td>3.07</td>
</tr>
</tbody>
</table>

Ocean Zonal Mean (March 2014-Feb. 2016)
CloudSat High Latitude Study
Behrangi et al, (2016) JGR
Mean values of precipitation (rain plus snow) over five years, 55-80° latitude:

CloudSat-based estimates agree closely with GPCP means (over ocean and land); both higher than GPM

GPM and CloudSat should be the Standards to which GPCP is tuned!
Variations in Global Surface Temperature and Precipitation

Trends, Inter-decadal Shifts and ENSO and Volcano Effects

**Surface Temperature:**
- Trend: \(0.15\) C/decade
- ENSO: \(0.2\)C amplitude
- Volcano: \(0.4\)C amplitude

**Precipitation:**
- Trend: \(\sim\) zero
- ENSO: \(0.05\) mm/d (2%) amplitude
- Volcano: \(0.09\) mm/d (3%) amplitude
- Volcano: \(9\%/K\)
- Volcano: \(8\%/K\)
Comparison of Water Vapor and Precipitation Changes in Relation to Temperature Changes for Inter-annual and Trend Time Scales

<table>
<thead>
<tr>
<th></th>
<th>Water Vapor</th>
<th>Precipitation (GPCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trends</strong></td>
<td>10 %/C (ocean)</td>
<td>~ 1 %/C (global)</td>
</tr>
<tr>
<td><strong>Inter-annual ENSO</strong></td>
<td>15 %/C (ocean)</td>
<td>9 %/C (global)</td>
</tr>
<tr>
<td><strong>Inter-annual Volcano</strong></td>
<td>9 %/C (ocean)</td>
<td>8 %/C (global)</td>
</tr>
</tbody>
</table>

Precipitation variations vary differently from water vapor on trend scale, but are much more similar for inter-annual scale—for both ENSO and volcanoes.
TRMM-based Sfc. Temp.-Rainfall Relations (Active vs. Passive Microwave)  
1998-1999 El Nino to La Nina Transition

Precipitation Anomaly vs. Temperature Anomaly (Ocean, 25° S-25° N) 
1998.01 - 1999.12

Rainfall Anomaly (%)  
Surface Temperature Anomaly (°)

TRMM Passive Microwave  
GPCP Passive Microwave  
TRMM Radar 6 km  
TRMM Combined  
TRMM Radar NS, 2 km, 4 km  
TRMM Radar does not confirm PMW T-R relations—Attenuation issues?
GPM-based Sfc. Temp.-Rainfall Relations (Active vs. Passive Microwave)

2014-2016 Neutral to El Nino Transition

GPM vs. Ocean

Rainfall Anomaly (%)

Precipitation Anomaly vs. Temperature Anomaly (Ocean, 25° S-25° N)

2014.04 - 2016.04

GPM Radar 6 km
GPM Passive Microwave
GPCP Passive Microwave
GPM Radar NS, 2 km, 4 km
GPM Combined

GPM Radar ~13%/C
TRMM Radar ~0%/C

GPM Radar better confirms PMW T-R relations—not clear why different from TRMM?
1. Satellite era has resulted in a mature view of the magnitude and distribution of precipitation across our planet, although there is still much to be done in terms of accuracy, length of record and space and time resolutions.

2. Recent missions (TRMM, Cloudsat, GPM) confirm earlier GPCP planetary climatological mean of ~2.7 mm/d within error bounds of +/-7%. GPM mean values slightly higher (5-8%) in the tropics than GPCP and TRMM numbers, but lower in higher latitudes (over ocean). CloudSat confirms GPCP mean estimates in high latitudes.

3. Based on PMW retrievals, planetary-scale variations of precipitation related to ENSO and volcanoes are evident in the record, although no significant trend in global mean precipitation has been found for the satellite era (1979-present).

1. GPM radar results for 2014-2016 (including El Nino) better agree with surface temperature – rainfall relations for PMW results (including GPCP) than did TRMM radar results. Reasons for this are under investigation.

Summary
Extra Slides
GPM-GPCP Precipitation Mean & SST/Nino3.4 Anomalies
(Ocean, 25S-25N)
Trends in Global Precipitation During Satellite Era (1979-2013)

Although the trend in global total precipitation is near zero (in GPCP analysis), the pattern of observed regional trends (left panel) is related to Global Warming (GW) plus inter-decadal signals such as PDO and AMO (ENSO impact is small). Bottom left panel shows trend pattern after PDO effect is removed, a better estimate of GW impact on precipitation regional trends and also a pattern closer to that predicted by CMIP climate models (bottom right), but with smaller magnitudes—by factor of 2-3.

Gu, Adler and Huffman (2016) Climate Dynamics
Estimated Trend Distribution for Satellite Era due to Global Warming

Wet getting wetter and dry getting drier in most areas with a few exceptions
Trends in Precipitation (1900-2010) due to Global Warming
[with aerosol effect taken out]

Gauges over land; “reconstruction” over water

Climate model forced by observed SST, etc.

Composite, i.e., mean of the three other fields

“RECONS” is a reconstruction of global precipitation by Smith et al. (2012) J. Atmos.Oceanic Tech.