The Newly Released GPCP V3.3 Daily and Monthly Products and Efforts Towards GPCP V4.0

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Introduction

- The Global Precipitation Climatology Project (GPCP) is well maintained, widely used as an observational reference (e.g., IPCC report, annual climate reports, etc.).

Started with V3.2 (released in Feb 2022) we:

- Used recent satellite products (TRMM, GPM, CloudSat, GRACE) directly or indirectly in the products.
- Moved from 2.5°x2.5° Monthly and 1.0°x1.0° Daily to 0.5°x0.5° spatial resolution for both monthly and Daily GPCP products.
- Added new fields to the output file
- Included IMERG for downscaling from Monthly to Daily scale, thus we used various PMW imagers and sounders calibrated by GPM's combined radar and PMW precipitation estimates.
- New gauge analysis from GPCC was used.

Few of the main changes from monthly GPCP V2.3 to V3.2 & V3.3

- **Upgraded PMW** precipitation retrieval **(GPROF 2010 -> GPROF V07)**

  - V3.3 uses GPROF V07 and the updated combined Radar-PMW precipitation products

- **Upgraded GEO-IR brightness temperature datasets and retrieval (V3.2),**

  - V3.3 uses PERSIANN-RAW instead of PERSIANN calibrated by GPCP V2.3

- **Included new satellite data from TRMM, GPM, and CloudSat** via:

  MCTG: Merged CloudSat/TRMM/GPM climatology – Behrangi et al. (Univ. of Arizona) **(Both V3.2 & V3.3)**

  TCC: TRMM Composite Climatology – Adler et al. (U. of Maryland) **(V3.2), TCC was replaced by MCTG in V3.3**

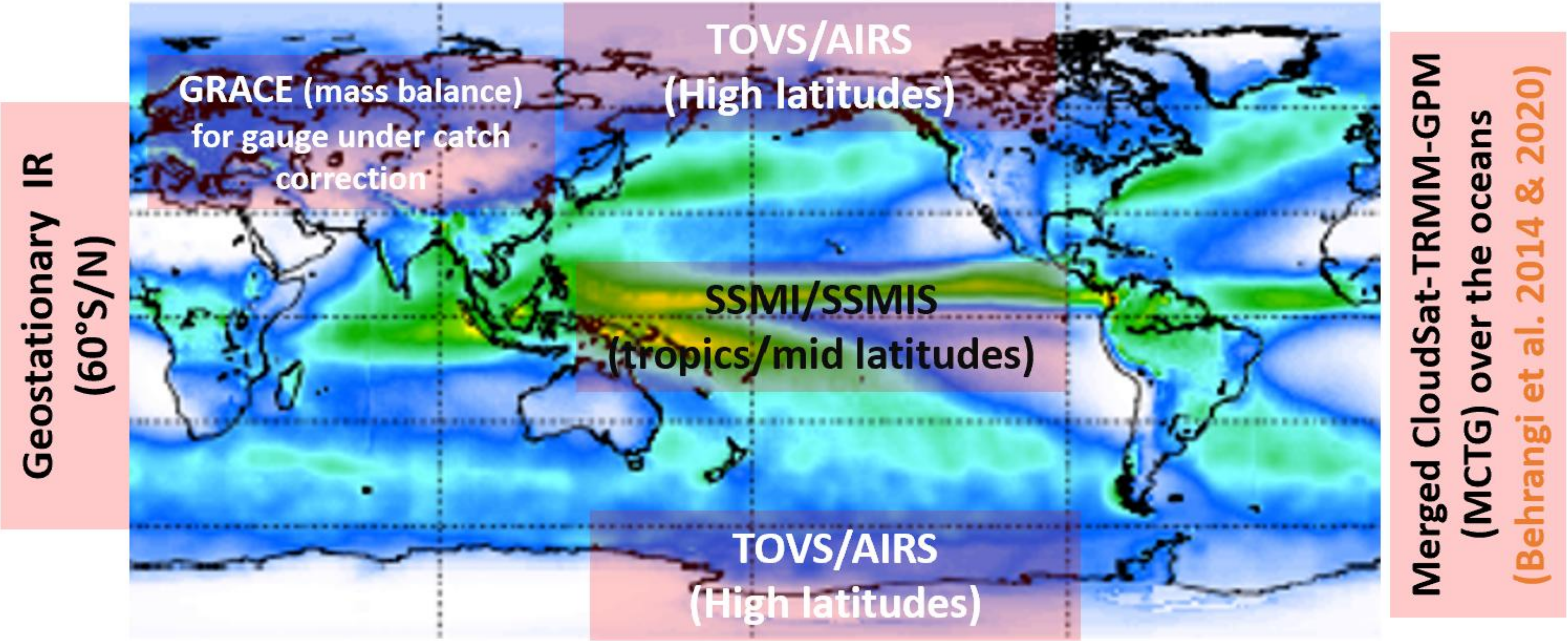
- **Added three new fields to the output file:**
  V3.2 : *1. probability of liquid-phase precipitation, 2. Gauge Relative Weighting*, and *3. Quality Index(QI).*
  V3.3: *Absolute Bias error*

- ***Latest GPCC product***

  - V3.3 uses GPCC V2022 Final and Monitoring analyses, while V3.2 uses the older GPCC.

- ***Gauge undercatch correction:*** Replaced Legates with Fuchs method over northern Asia and Eurasia (poleward of 45°N) based on a few published analyses with insights from **GRACE, CloudSat, streamflow observations** (Behrangi et al. 2018; 2019) , and water vapor convergence analysis. **(Since V3.2)**

Main satellites used in GPCP Monthly (V3.2 & V3.3)



GPCP V3.2 monthly product data fields

1983-01 to 2024-03

Data Field Name	Description	Units
lat	latitude of the center of the grid element	degrees_north
lon	longitude of the center of the grid element	degrees_east
time	begin date and time of the data	minutes since 1979-01-01 00:00:00
sat_gauge_precip	combined satellite-gauge precipitation estimate	mm/day
sat_gauge_error	combined satellite-gauge precipitation random error estimate	mm/day
sat_gauge_random_error	combined satellite-gauge precipitation random error estimate	mm/day
sat_gauge_absolute_bias_error	combined satellite-gauge precipitation absolute bias error estimate	mm/day
satellite_precip	satellite-only precipitation estimate	mm/day
satellite source	source of the contributing satellite estimate *	index values
gauge_precip	wind-loss adjusted gauge precipitation	mm/day
probability_liquid_phase	probability of liquid phase precipitation	percent
gauge_relative_weight	relative weighting of gauges in sat_gauge_precip	percent
quality index	equivalent number of gauges	unitless

* The satellite source field has the index values 0 = PMW-adj. IR, 2 = blend of PMW-adj. IR and TOVS/AIRS, 4 = TOVS/AIRS.

The latitude/longitude use the WGS84 reference datum.

New Fields:

V3.3

V3.2

RESULTS

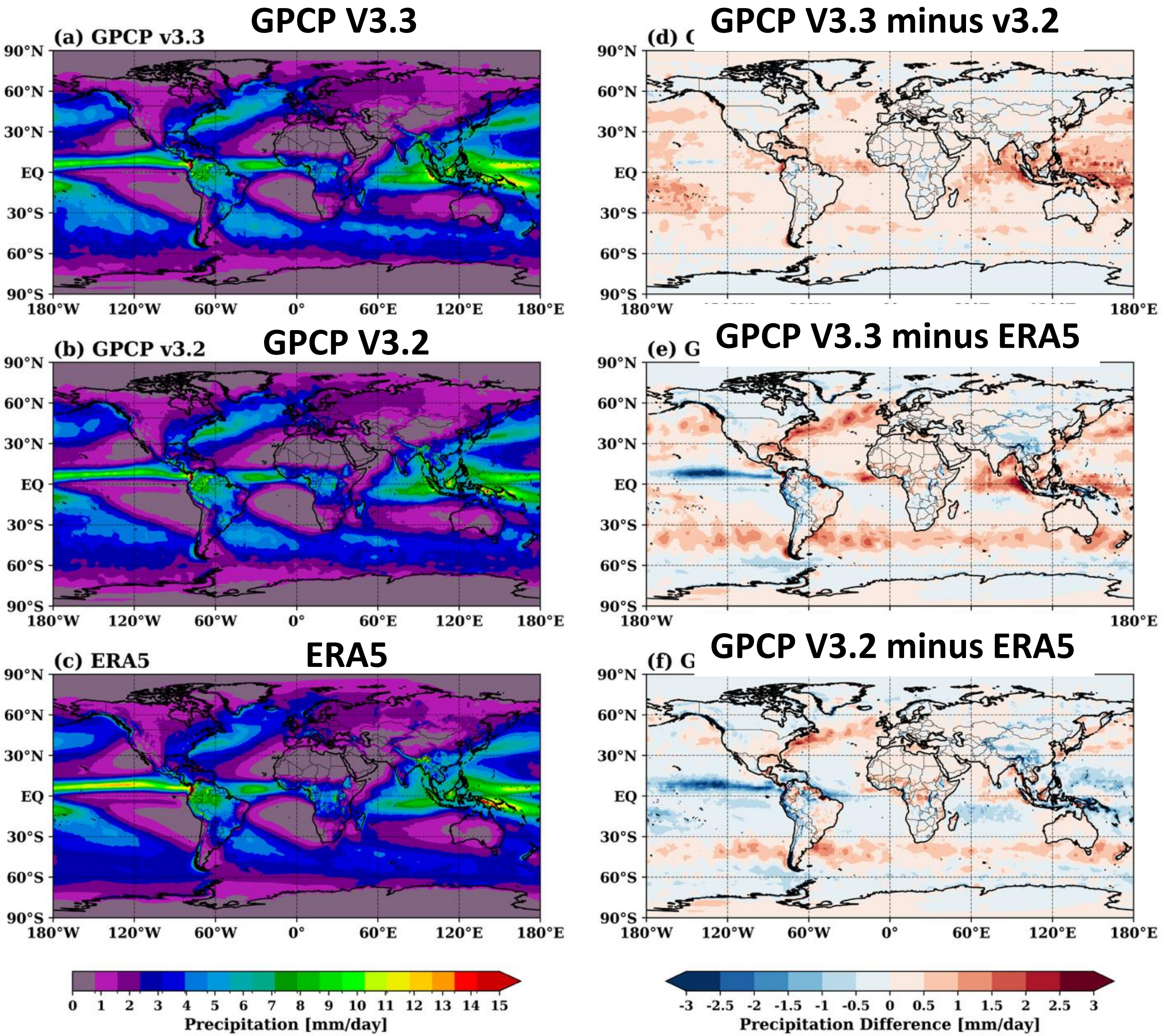
- ❑ **We will compare GPCP V3.3 with GPCP V3.2, and ERA5**
- ❑ **Analysis includes mean precipitation, trends, extremes, precipitation fraction, and interannual variations**

Note:

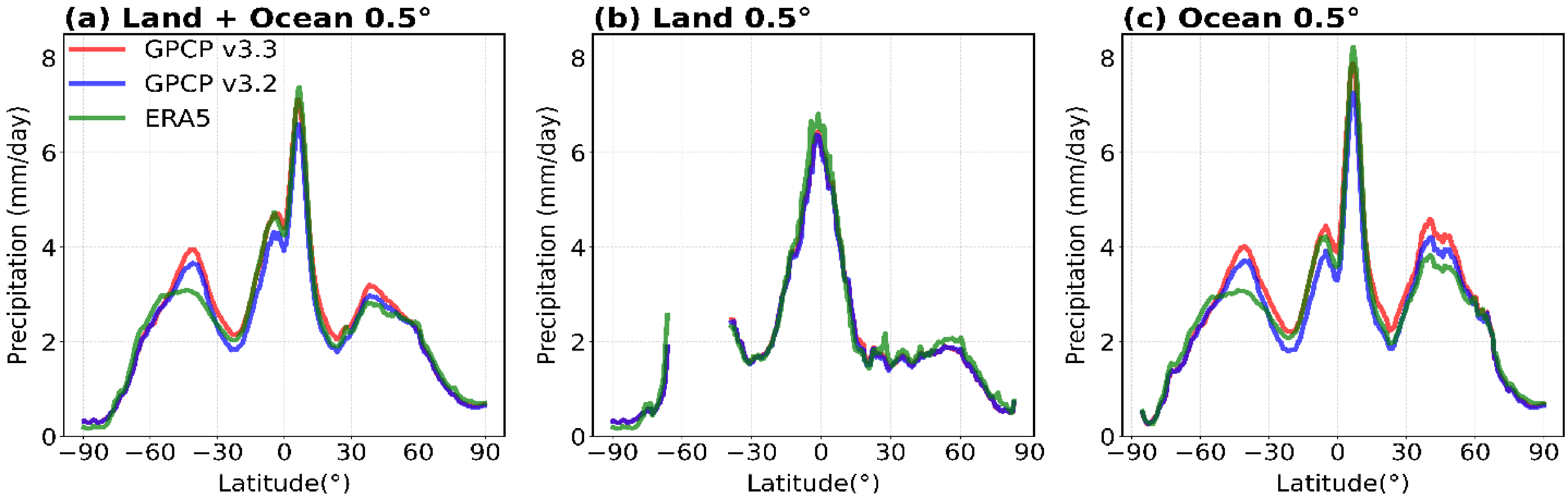
- ❖ Early years (1983–1991) are excluded in analysis due to missing SSM/I high-frequency channels, which could introduce sampling biases in trend estimates over the oceans (but not important over land).
- ❖ To ensure consistent coverage across different versions, we used 1992–2023 for monthly and 2000–2021 for daily products.

Comparison of mean precipitation maps

- ❑ GPCP V3.3 preserves the large-scale global precipitation patterns seen in GPCP V3.2 and ERA5.
- ❑ Compared to V3.2, GPCP V3.3 shows generally higher precipitation over oceans, with minimal changes over land due to gauge adjustment.
- ❑ Relative to ERA5, GPCP V3.3 indicates higher precipitation along NH storm tracks, tropical regions, and southern mid-latitude oceans.
- ❑ Differences between GPCP V3.3 and ERA5 highlight regions that require further investigation, particularly across the tropical Pacific.



Zonal distribution



- GPCP V3.3 and V3.2 show similar zonal precipitation patterns, with V3.3 slightly wetter over most oceans within 65°S–65°N.
- Over land, differences between GPCP V3.3 and V3.2 are minimal due to only minor updates in gauge-based adjustments.
- ERA5 reproduces the overall zonal structure but differs notably from GPCP near precipitation maxima around 45°S and 45°N (more noticeable over the oceans)

Quantitative comparison of total precipitation amount
(important for water and energy budget studies)

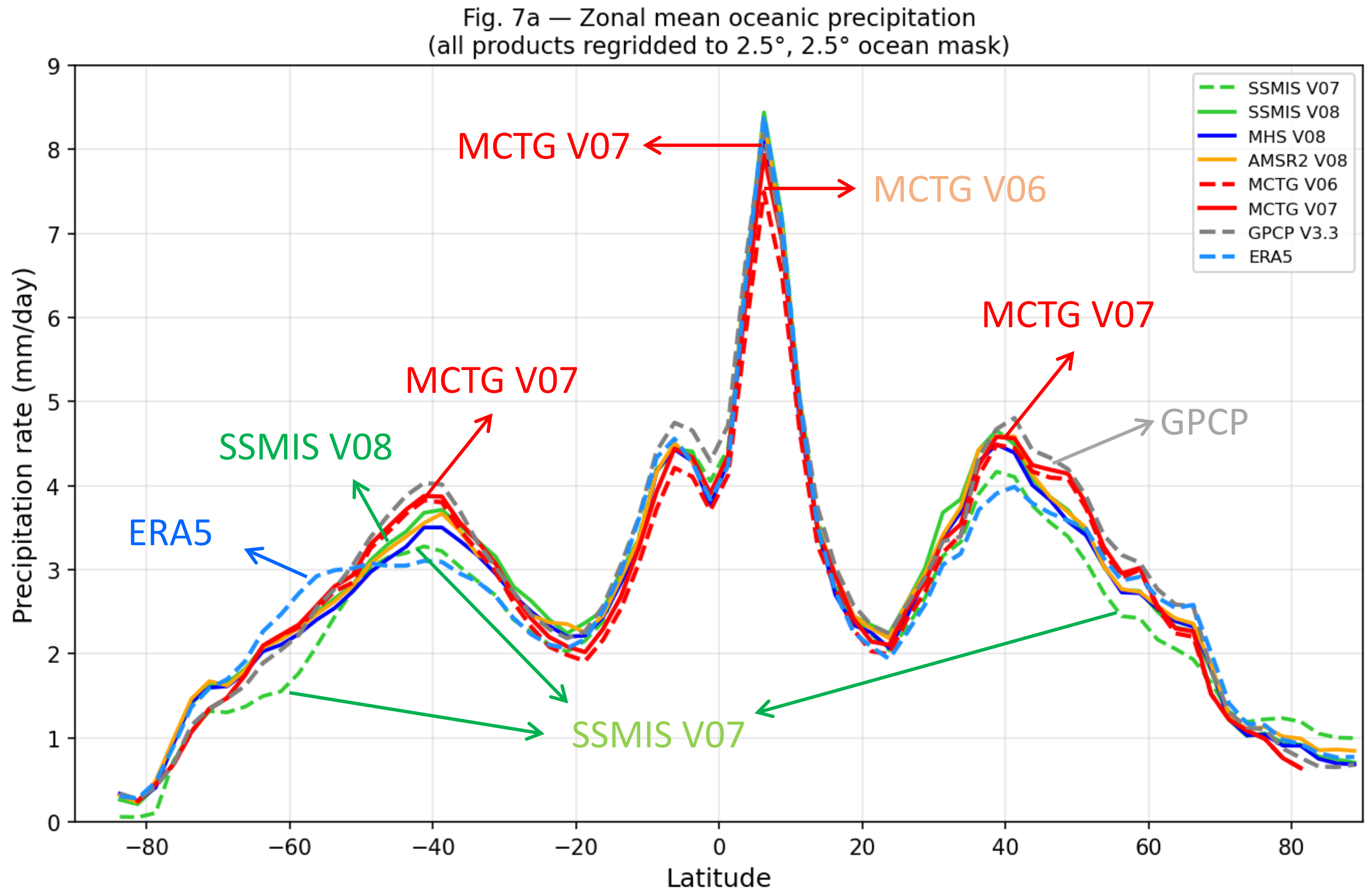
Region	Ocean					Land					Ocean plus Land				
	v3.3	v3.2	ERA5	$\Delta\%_{(v3.2)}$	$\Delta\%_{(ERA5)}$	v3.3	v3.2	ERA5	$\Delta\%_{(v3.2)}$	$\Delta\%_{(ERA5)}$	v3.3	v3.2	ERA5	$\Delta\%_{(v3.2)}$	$\Delta\%_{(ERA5)}$
25N-25S	3.89	3.38	3.77	15.09	3.18	3.47	3.41	3.54	1.76	-1.98	3.79	3.39	3.71	11.80	2.16
60N-60S	3.64	3.26	3.36	11.66	8.33	2.53	2.49	2.62	1.61	-3.44	3.34	3.05	3.16	9.51	5.70
90N-90S	3.43	3.08	3.19	11.36	7.52	2.21	2.18	2.30	1.38	-3.91	3.06	2.82	2.93	8.51	4.44

$\Delta\%_{(base)} = 100 \times (v3.3 - base) / base$, where base denotes the comparison baseline (either GPCP V3.2 or ERA5).

Precipitation rate unit: mm/day

Some insights from previous studies in support of the new findings:

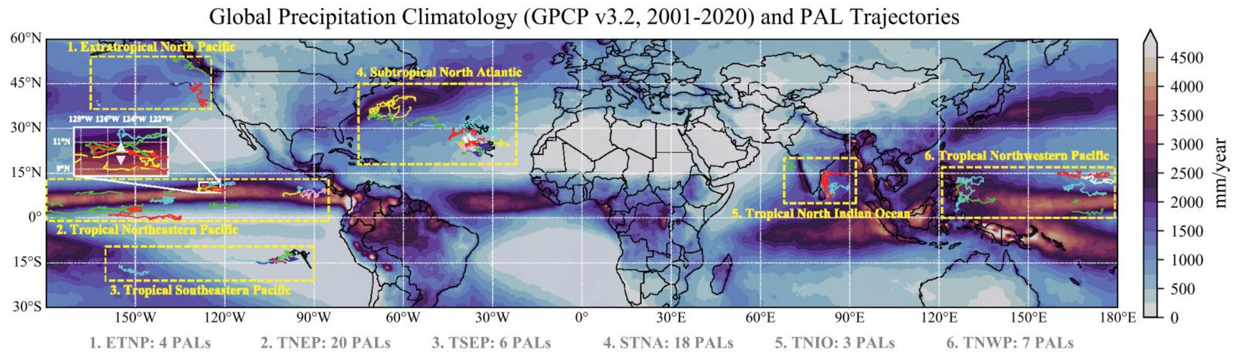
- ❑ Water- and energy-budget studies suggest earlier GPCP versions likely underestimated global precipitation, especially over the oceans (e.g., Stephens et al. 2012). The new estimate fits well.
- ❑ GPCP V3.3 global mean oceanic precipitation (~3.43 mm day^{-1}) aligns more closely with recent budget-based estimates(e.g., Mayer et al. 2024), although Mayer study also suggested V3.3 is still low over land ?!

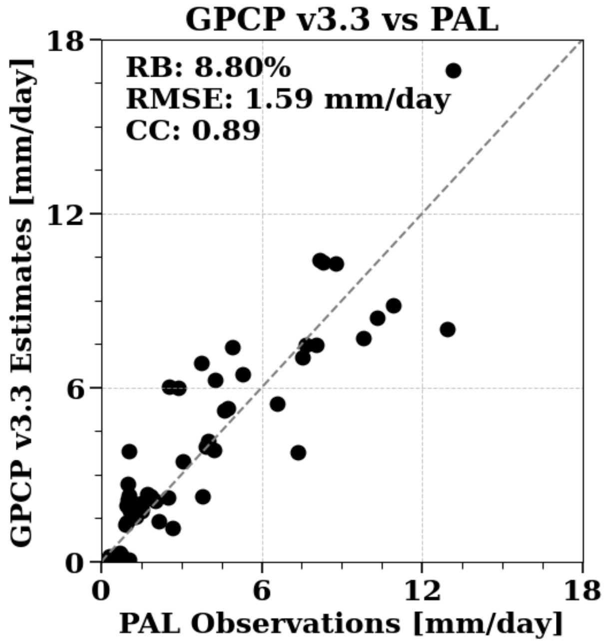


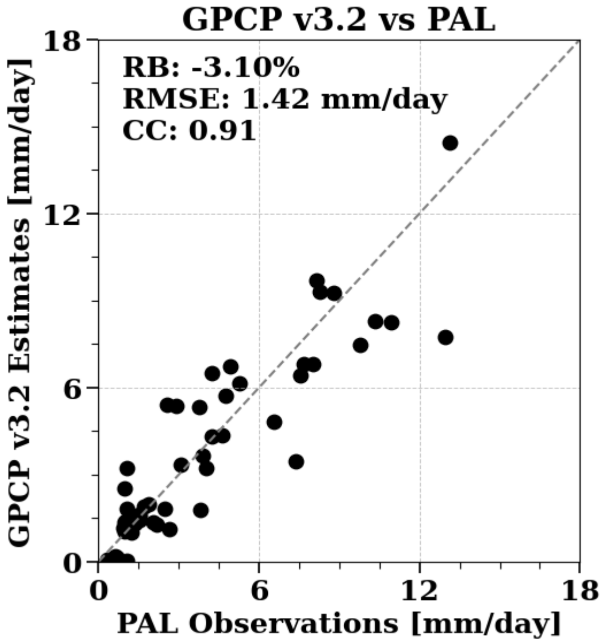
- **Global oceanic precipitation from PMW V08 is now almost matching MCTG V07 and GPCP V3.3, *which were constructed from PMW V07!***
- **PMW V08 is about 6% -12% higher than PMW V07**

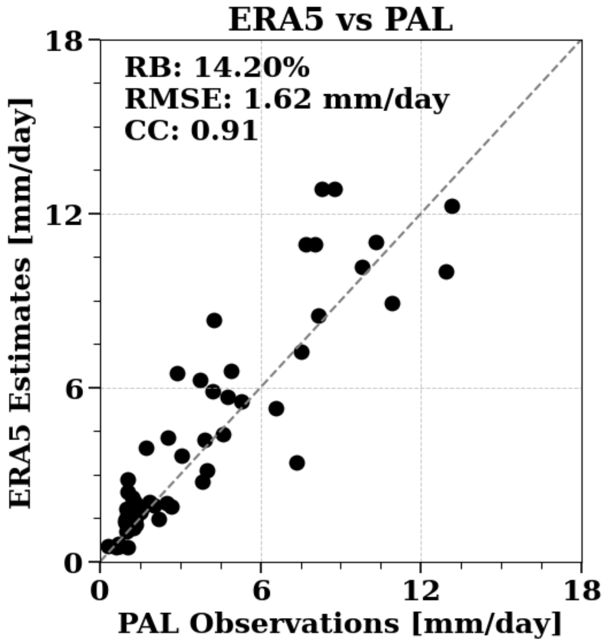
In situ observations over the oceans

(using Passive Aquatic Listeners, PALs, 2010-2021)









- ❑ Validation against 58 oceanic PAL observations shows GPCP V3.2 slightly underestimates precipitation, while GPCP V3.3 and ERA5 exhibit positive biases.
- ❑ All products show similar correlations with PAL data, although GPCP V3.2 has slightly lower RMSE than GPCP V3.3 and ERA5.
- ❑ Further evaluations using PALs, atolls, buoys, and OceanRAIN are ongoing.

Antarctic basin seasonal precipitation estimates using multiple observations

Method is closing water budget in 19 Antarctic basins and back calculating seasonal precipitation

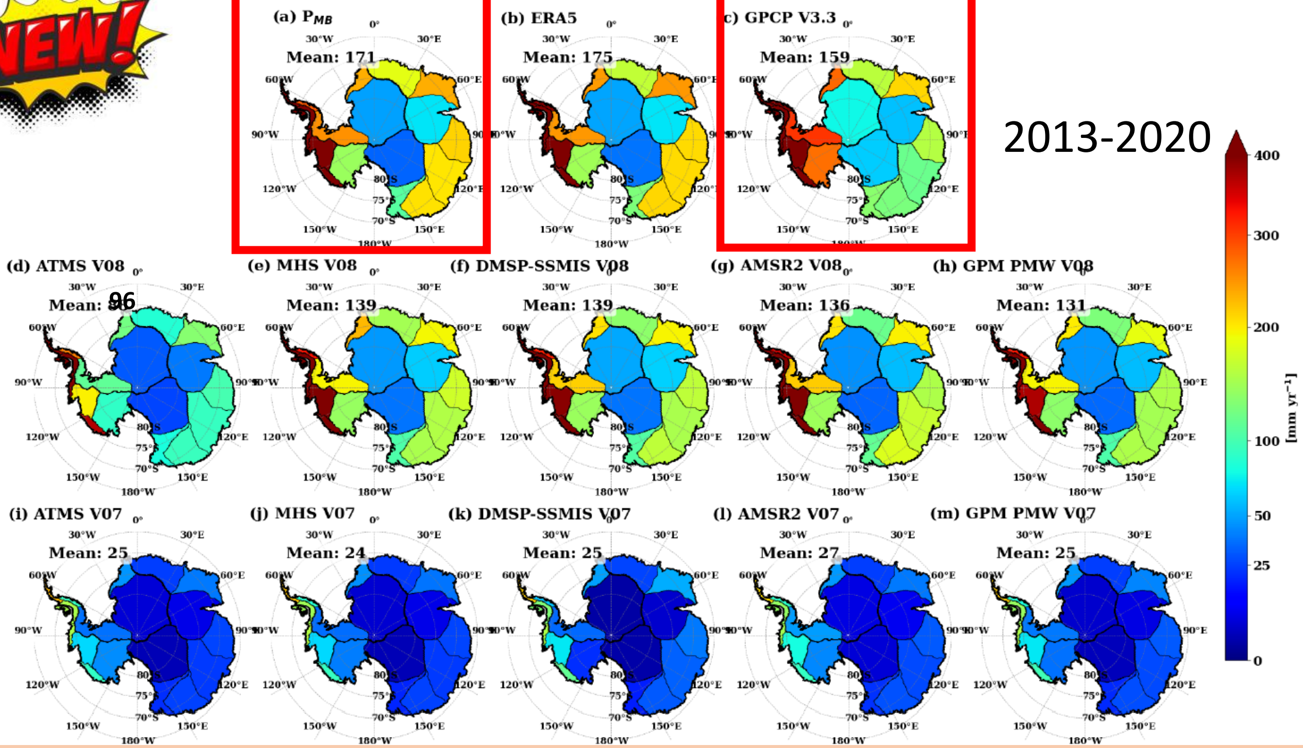
- ❑ (GRACE/GRACE-FO + ICESat-2 high res.) → Basin scale snow mass change
- ❑ High res. Radar/Landsat imagery derived ice discharge for each basin

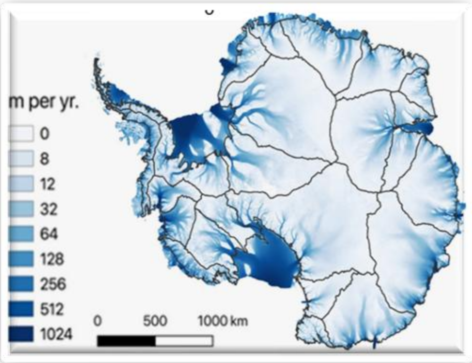
P_{MB}

GPCP V3.3

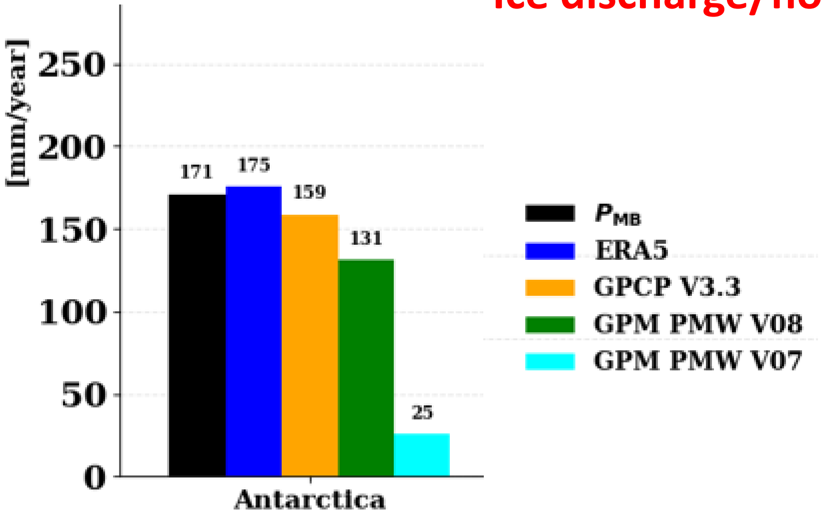
GPROF V08

GPROF V07





Ice discharge/flow



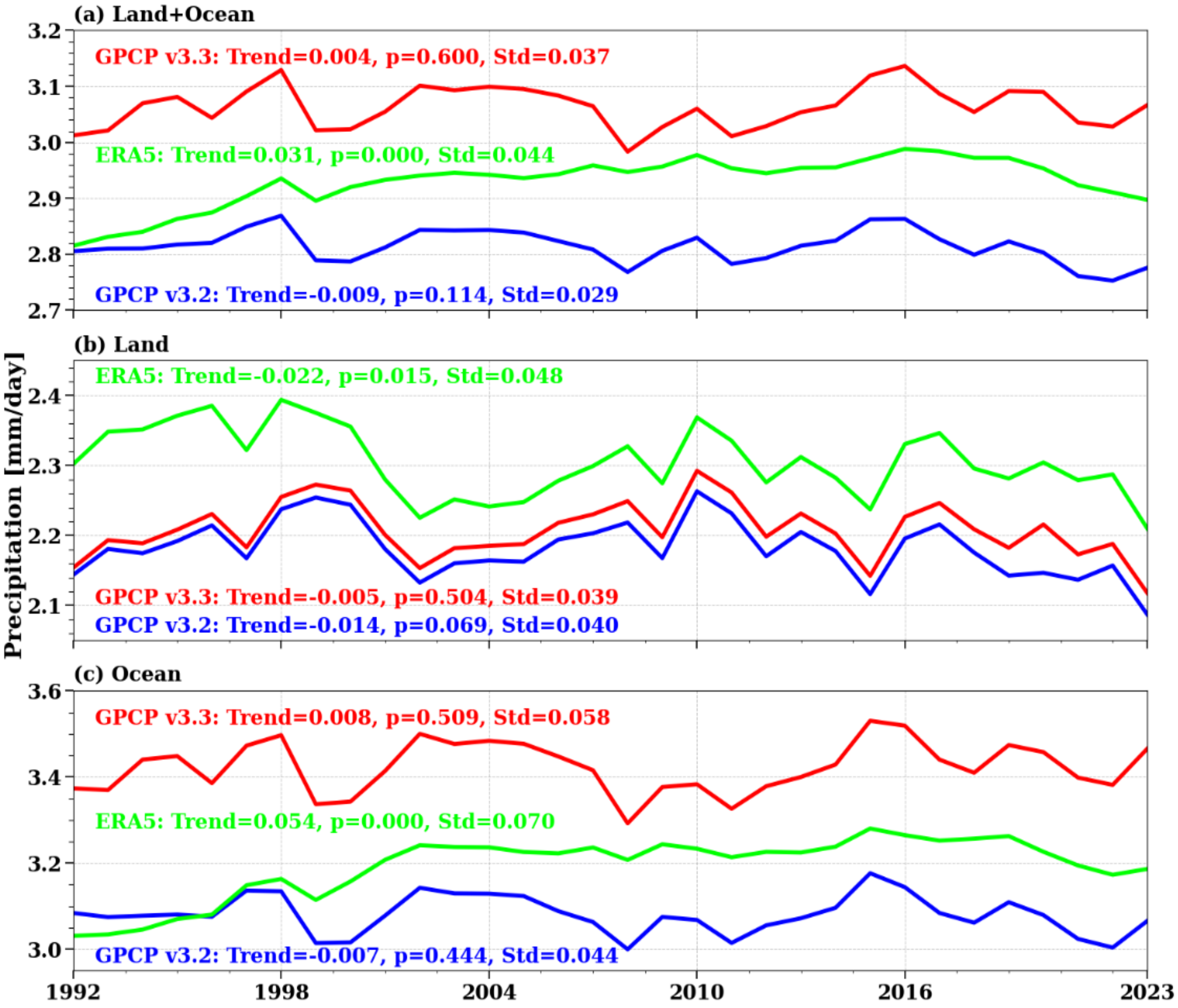
- **GPCP V3.3 shows about 7% lower than our mass budget estimate**
- **PMW V08 shows major improvement, only 23% underestimation compared with PMW V07 that had about 84% underestimation based on Pmb and ERA5.**

Related REFERENCE:

Behrangi, A., A. S. Gardner, and D. N. Wiese, 2020: ***Comparative analysis of snowfall accumulation over Antarctica in light of Ice discharge and gravity observations from space***. *Environmental Research Letters, 15, 104010.*

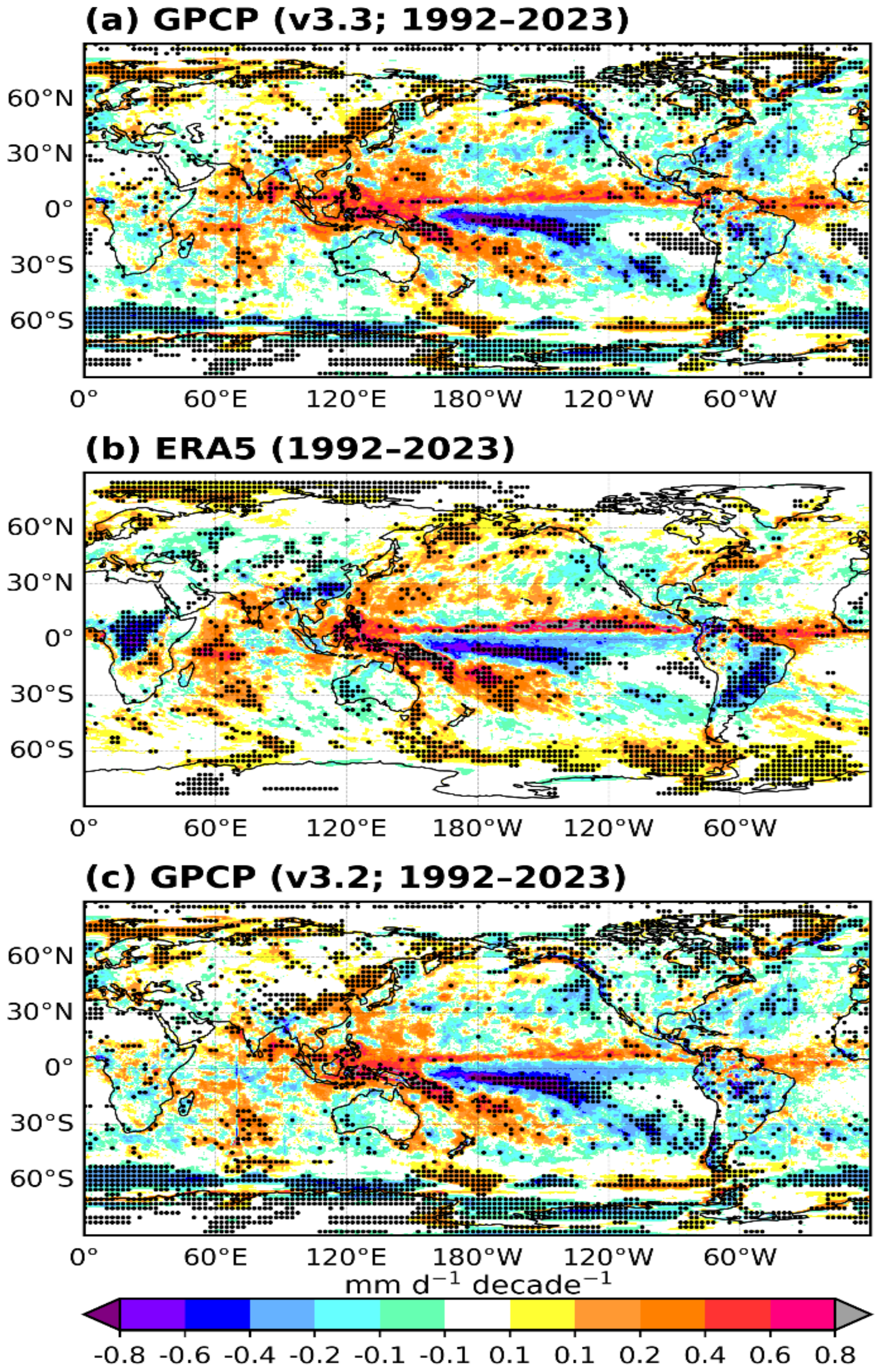
Trend Analysis *(annual)*

- GPCP V3.3 produces higher precipitation than V3.2 over both land and ocean, reducing differences with ERA5 over oceans.
- Unlike ERA5, which shows significant positive precipitation trends, GPCP V3.3 exhibits weak and statistically insignificant long-term "global" trends.
- GPCP V3.3 captures ENSO-related variability consistently while maintaining a temporally stable climate record for long-term precipitation analysis.
- GPCP V3.3 shows slightly higher variability than V3.2 over the oceans



Trend Analysis
(regional)

- Despite near-zero global mean trends, strong regional precipitation trends are evident across all products.
- The spatial trend patterns in GPCP V3.3 closely resemble earlier GPCP versions, demonstrating long-term consistency.
- Regional trends likely reflect both natural climate variability (e.g., PDO) and externally forced climate change signals.



Extreme Precipitation Analysis

(using daily products and ETCCDI metrics)

ETCCDI: Expert Team on Climate Change Detection and Indices

•**R95p measures extreme precipitation contribution**, defined as annual rainfall from wet days (≥1 mm/day) exceeding the 95th percentile threshold.

•**GPCP V3.3 and V3.2 show consistent spatial patterns**, with maxima in ITCZ, warm pools, monsoon regions, tropical South America, and storm tracks.

•**V3.3 vs V3.2 differences are modest but coherent**, with increases over tropical oceans and decreases in parts of the eastern Pacific and Southern Ocean.

•**ERA5 differs substantially**, generally underestimating extreme rainfall in major convective regions while overemphasizing moderate/light precipitation events.

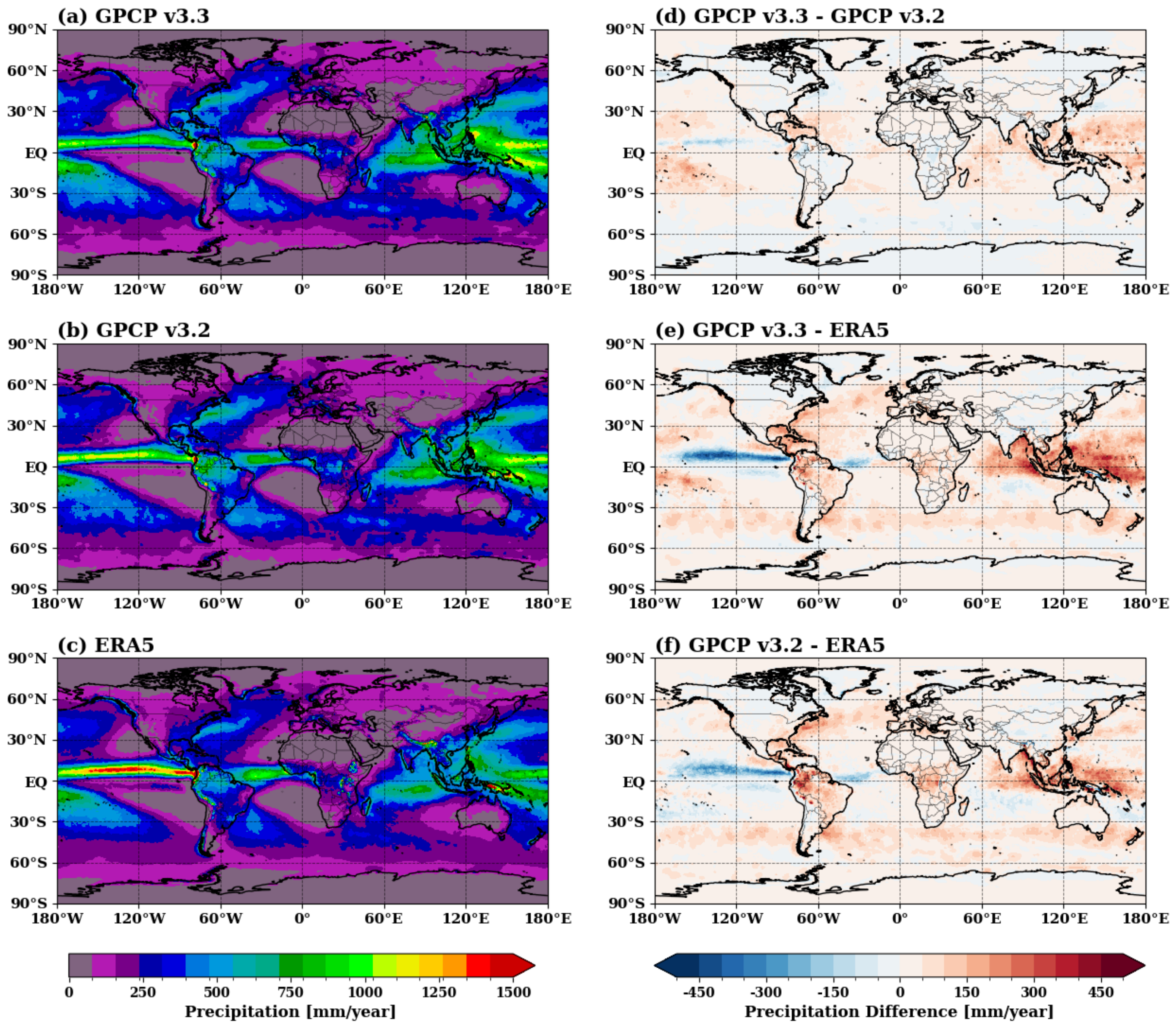


Figure: Total annual precipitation from heavy precipitation days (R95p, mm), calculated as the sum of daily precipitation exceeding the 95th percentile.

Wet-day precipitation fraction and total
(using daily products and ETCCDI)

- **PRCPTOT represents annual total precipitation from wet days (≥1 mm/day)**, summarized over 2000–2020 alongside wet-day frequency.
- **GPCP V3.3 and V3.2 are highly consistent**, with V3.3 showing slightly more wet days and marginally higher total precipitation.
- **ERA5 shows more frequent wet days but lower total precipitation**, indicating a bias toward light, persistent rainfall rather than intense events.

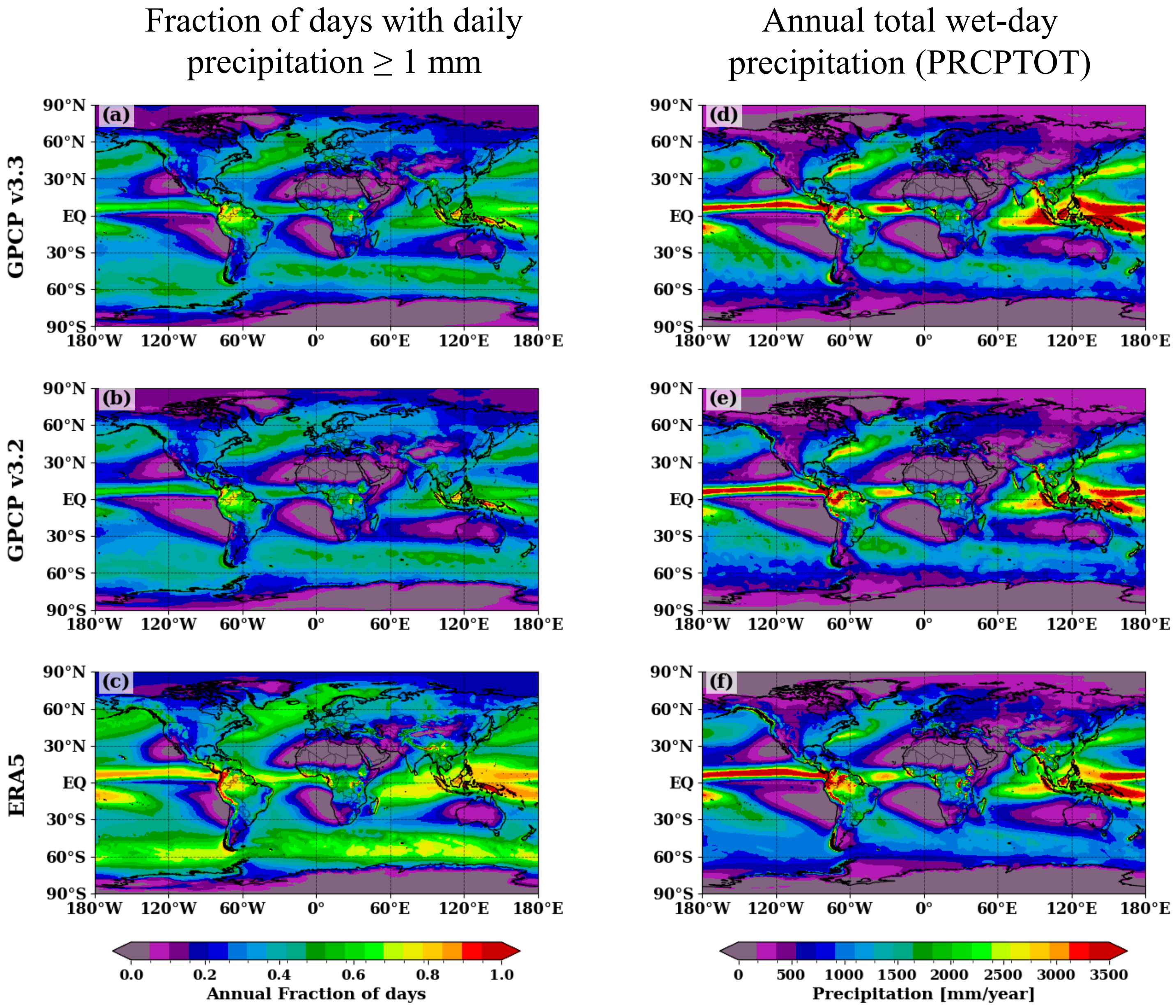
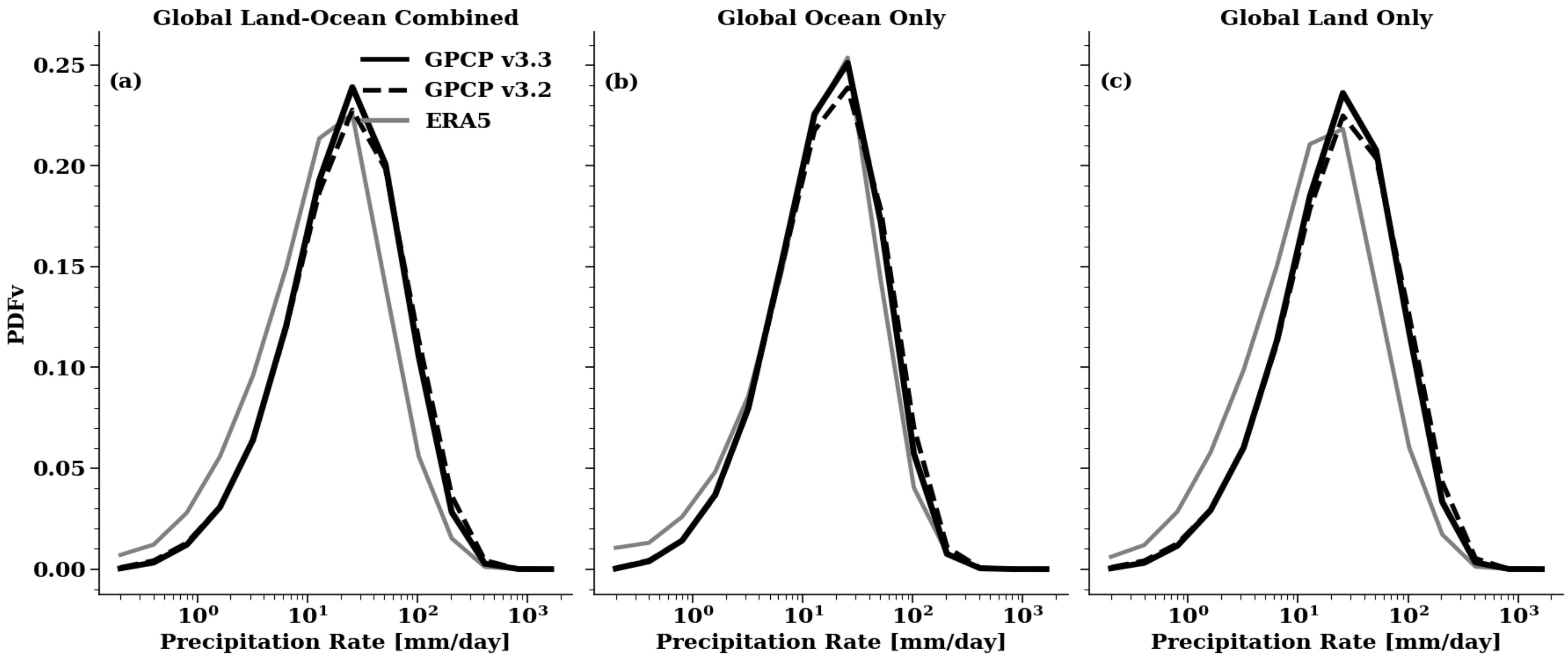


Figure: Fraction of days with daily precipitation ≥ 1 mm (left column) and annual total wet-day precipitation (PRCPTOT; right column) averaged over the 2000–2020 period. Rows correspond to (top) GPCP V3.3, (middle) GPCP V3.2, and (bottom) ERA5.

PDFs of global daily precipitation rates (mm day^{-1})



- ❑ **GPCP V3.3 and V3.2 show very similar precipitation distributions**, with V3.3 slightly reducing the most extreme rainfall while increasing moderate-to-heavy rain intensities.
- ❑ **ERA5 is strongly shifted toward light precipitation**, with higher frequency of weak rain and reduced moderate-to-heavy and extreme events across land and global domains.

GPCP V4 planning/effort has started (targeting mid 2027)

PI: Ali Behrangi (U of Arizona), Co-Is: George Huffman (NASA GSFC), Bob Adler (UMD), Chris Funk (UCSB)

Over the next 3 years we will work on GPCP V4 (under NASA MEaSUREs program)

GPCP V4 will significantly improve the GPCP V3 in four major areas:

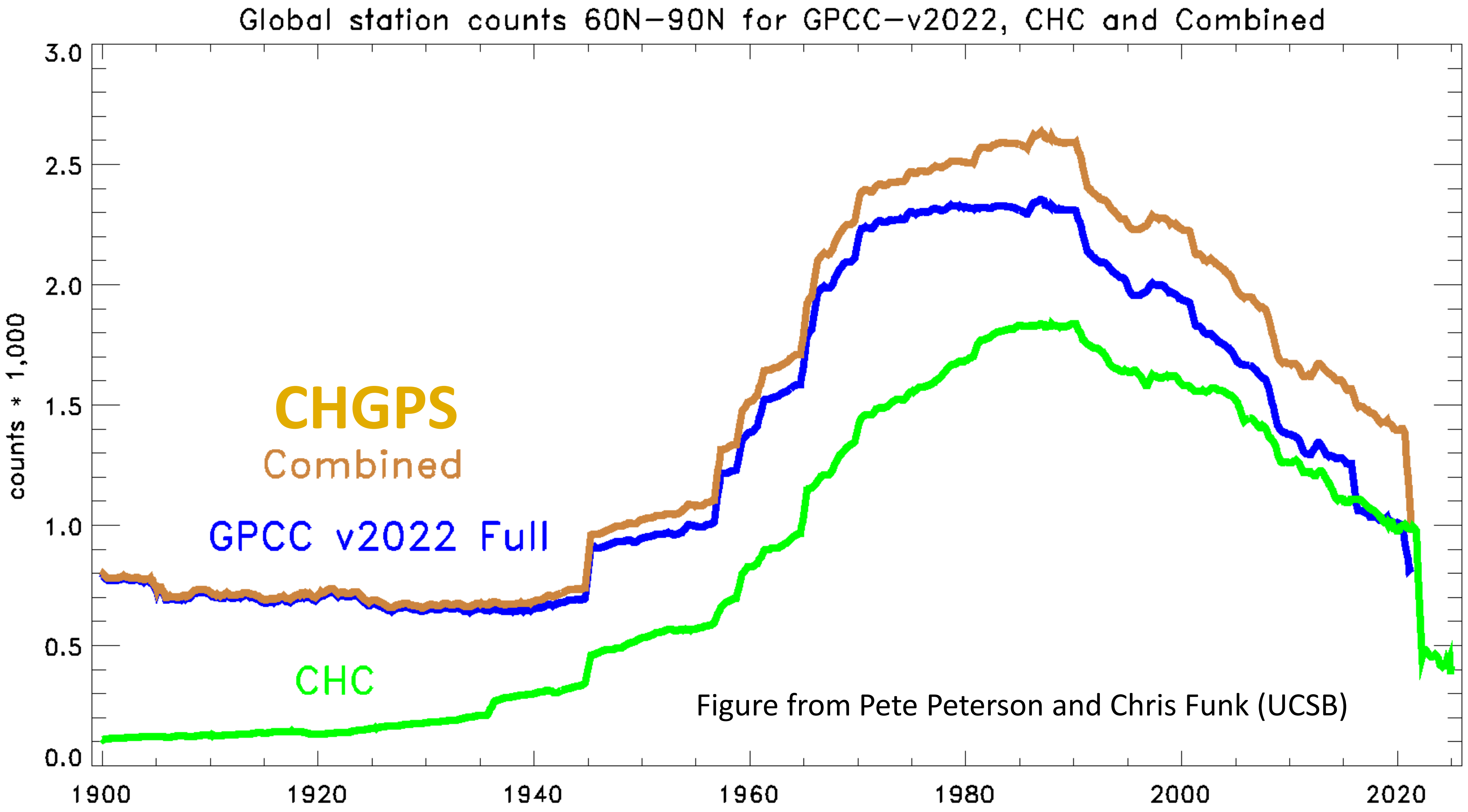
(1) Consistency and accuracy , by improving satellite and gauge analyses

(2) Duration, daily going back to 1983 (GridSat + CPC+AVHRR)

(3) Resolution, GPCP V4 will be computed at 0.1° resolution (instead of 0.5° in GPCP V3.2)

(4) Latency, quality gauge adjustment with about 2 weeks latency

Developing a comprehensive gauge analysis product as part of GPCP V4



Thanks for your attention

For questions contact:

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Acknowledgments:

NASA MEaSUREs program

MEaSUREs: Making Earth Science Data Records for Use in Research Environments program

Monthly GPCP V3.3 product: DOI:10.5067/MEASURES/GPCP/DATA307 (01/1983-12/2025)

Daily GPCP V3.3 product: DOI:10.5067/MEASURES/GPCP/DATA307 (01/1998-12/2025)

BACK-UP SLIDES

GPCP V3.3 – Daily Product Approach (released in Feb 2025)

June 1998-March 2024 (global 0.5º x 0.5º lat./lon. Grid)

The inputs are:

- Integrated Multi-satellitE Retrievals for GPM (IMERG V07)
- TOVS, AIRS-IR daily: Susskind cloud volume (for high latitudes)
- GPCP V3.3 Monthly
- Improvements in GPCP V3.3 Daily over V3.2 are due to changes in the GPCP V3.3 Monthly and the IMERG V07B Final Run products. The use of GridSat in IMERG V07 allows IMERG, and therefore GPCP V3.3 Daily to cover Jan1998-May 2000 for the first time.

Approach:

- average IMERG (originally 0.1º, ½ hr) to 0.5º daily
- histogram-calibrate TOVS/AIRS-IR to IMERG (we are currently working on switching to AVHRR precipitation record due to its better resolution and consistent record)
- use IMERG in the band 55º N-S and IMERG-calibrated TOVS/AIRS at higher latitudes
- “feather” the IMERG-AIRS difference just outside 55º to reduce seams
- scale the Daily to (approximately) sum to the Monthly product

Data Fields: (1) satellite precipitation estimate (mm/d), **(2)** probability of liquid-phase precip (%)