An Open Framework for Global Tracking and Analysis of Satellite-Derived Precipitating Systems

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Introduction

Grid-based precipitation statistics describe where and how much rain occurs, but they do not fully capture how precipitating systems form, move, merge, split, grow, and decay. These object-level life-cycle properties are essential for understanding organized rainfall, diagnosing regional precipitation regimes, and improving short-term prediction. Object-based tracking provides a complementary view by following coherent precipitation features through time rather than analyzing each grid cell independently. Here, we present pyForTraCC, an open-source Python framework derived from the ForTraCC methodology and extended for reproducible global tracking of satellite-derived precipitating systems. The objective is to evaluate its capability to produce a 2015–2024 global climatology of PS occurrence, size, lifetime, propagation, and regional variability using GSMaP–MVK v8 and IMERG Final V07.

Method

We applied pyForTraCC to two global satellite precipitation products: GSMaP–MVK v8 from JAXA and GPM IMERG Final V07 from NASA. The analysis covers 2015–2024 and is presented over the common latitude band 60°S–60°N. Both products have native 0.1° × 0.1° spatial resolution; GSMaP–MVK v8 is hourly and IMERG Final V07 is half-hourly. The workflow uses user-defined configuration files and reading functions to preprocess precipitation fields, apply threshold-based segmentation, identify clusters, associate objects between consecutive time steps, assign persistent identifiers, and generate system life-cycle attributes. pyForTraCC explicitly classifies complex temporal interactions, including merging and splitting, and provides alternative displacement-vector correction methods, including merge, split, inner-core, ellipse, and optical-flow approaches. Outputs are consolidated into tracking tables stored in Apache Parquet format and queried for global climatological diagnostics of PS occurrence, size, lifetime, seasonality, initiation/dissipation regions, propagation, and preliminary trends.

Key Results

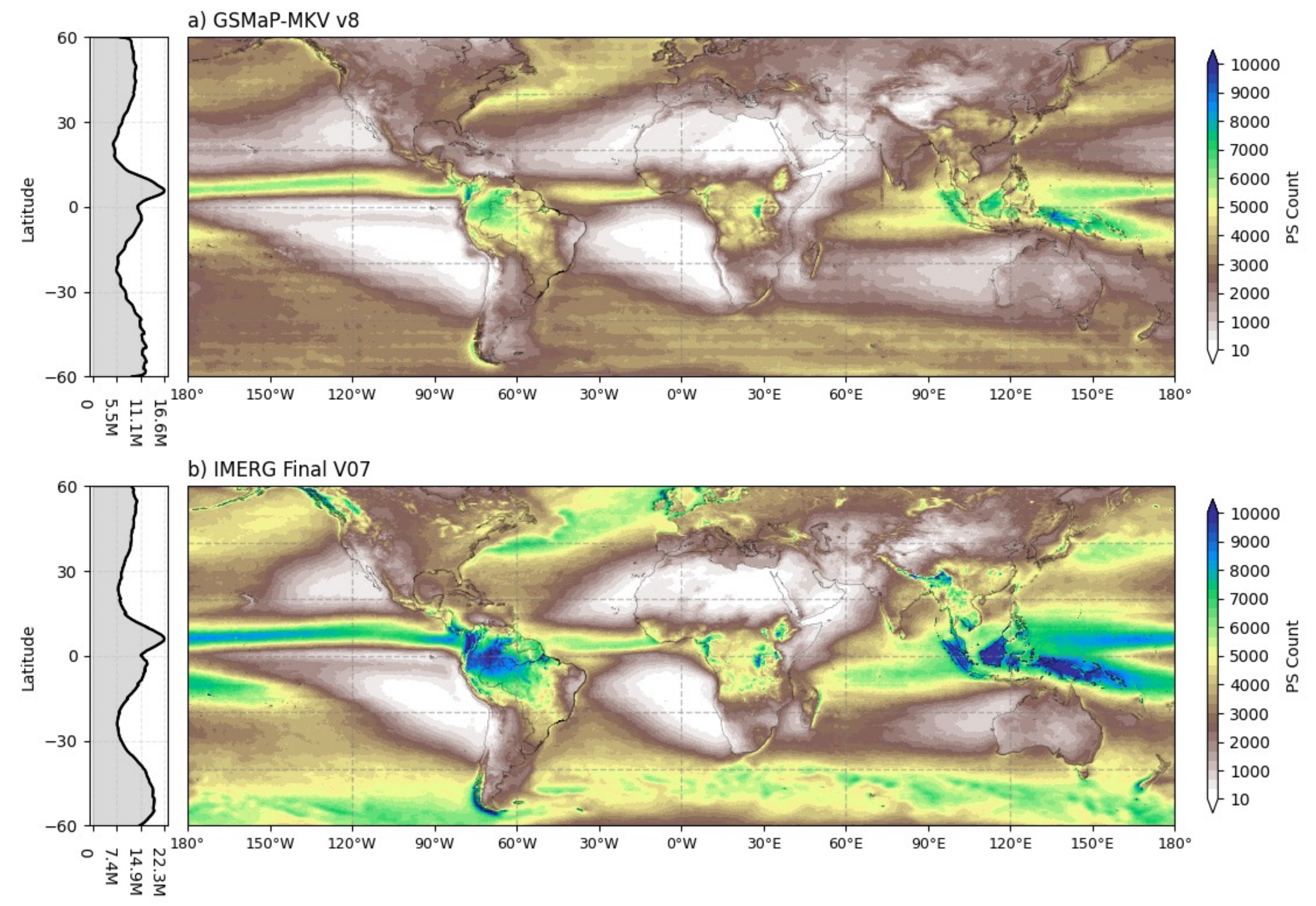
- pyForTraCC processed decade-long global GSMaP and IMERG datasets into structured tracking tables suitable for large-scale climatological analysis.
- The global PS census reproduces known spatial organization, with high occurrence in tropical convergence and monsoon regions.
- Object properties show physically coherent behavior: longer-lived systems tend to be larger, and large/long-lived systems are especially evident over tropical oceans.
- IMERG detects more short-lived features than GSMaP, consistent with its finer temporal sampling, while both products capture similar large-scale spatial patterns.
- Displacement-vector diagnostics indicate that optical-flow and inner-core corrections are central tools for reducing uncertainty in non-rigid PS motion.
- Preliminary trend finding: 2015–2024 trends suggest regional changes in PS activity, including precipitation decreases over parts of the equatorial Pacific and southern Africa and area increases across South Asian / Maritime Continent monsoon regions, with some product-dependent differences.

Open Science / Reproducibility

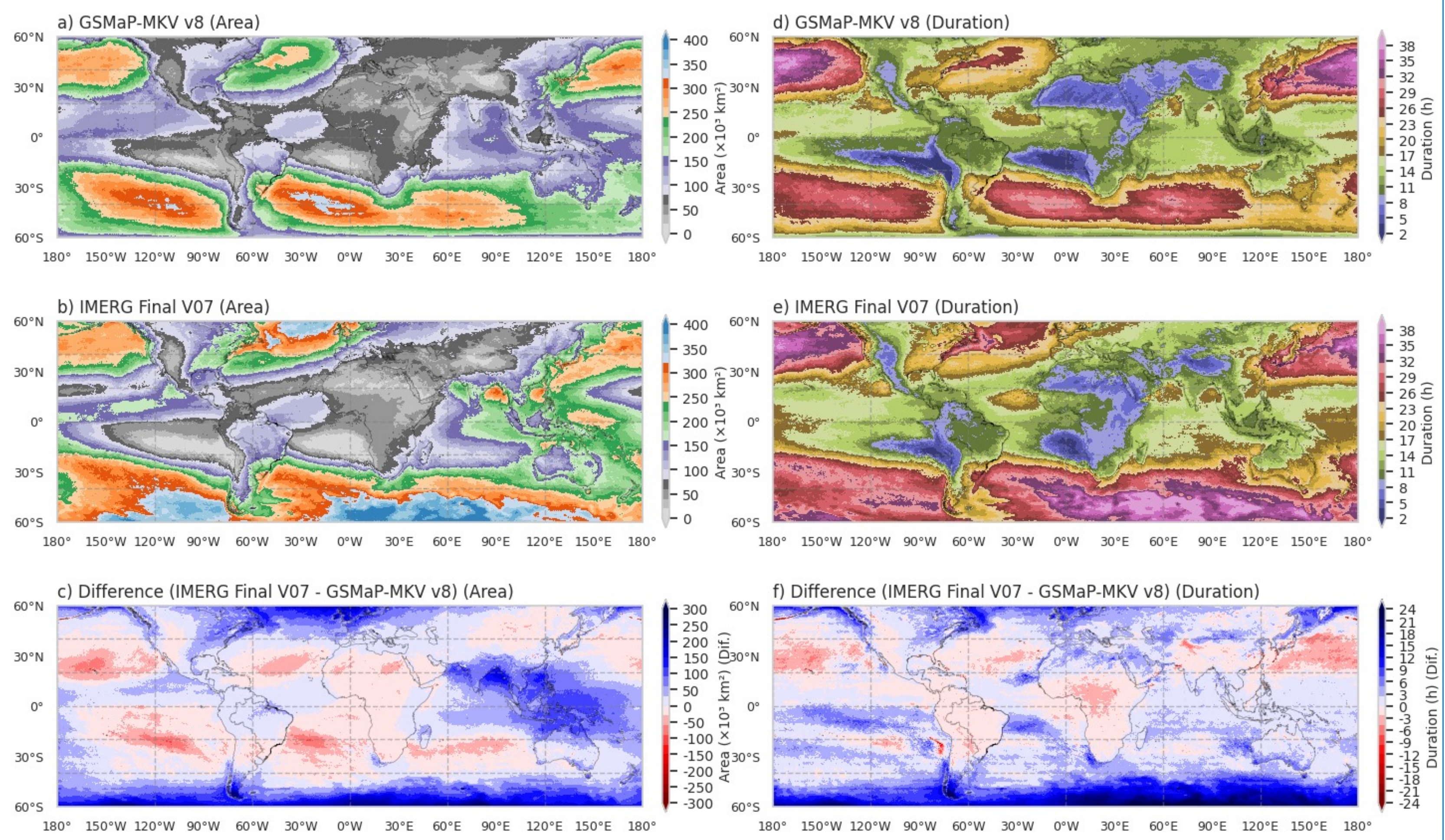
pyForTraCC is an open-source Python framework distributed through GitHub and PyPI, with a modular design that separates configuration, data reading, tracking, and post-processing. The tracking outputs are stored as Parquet tables, enabling reproducible SQL-based analyses.
See details:

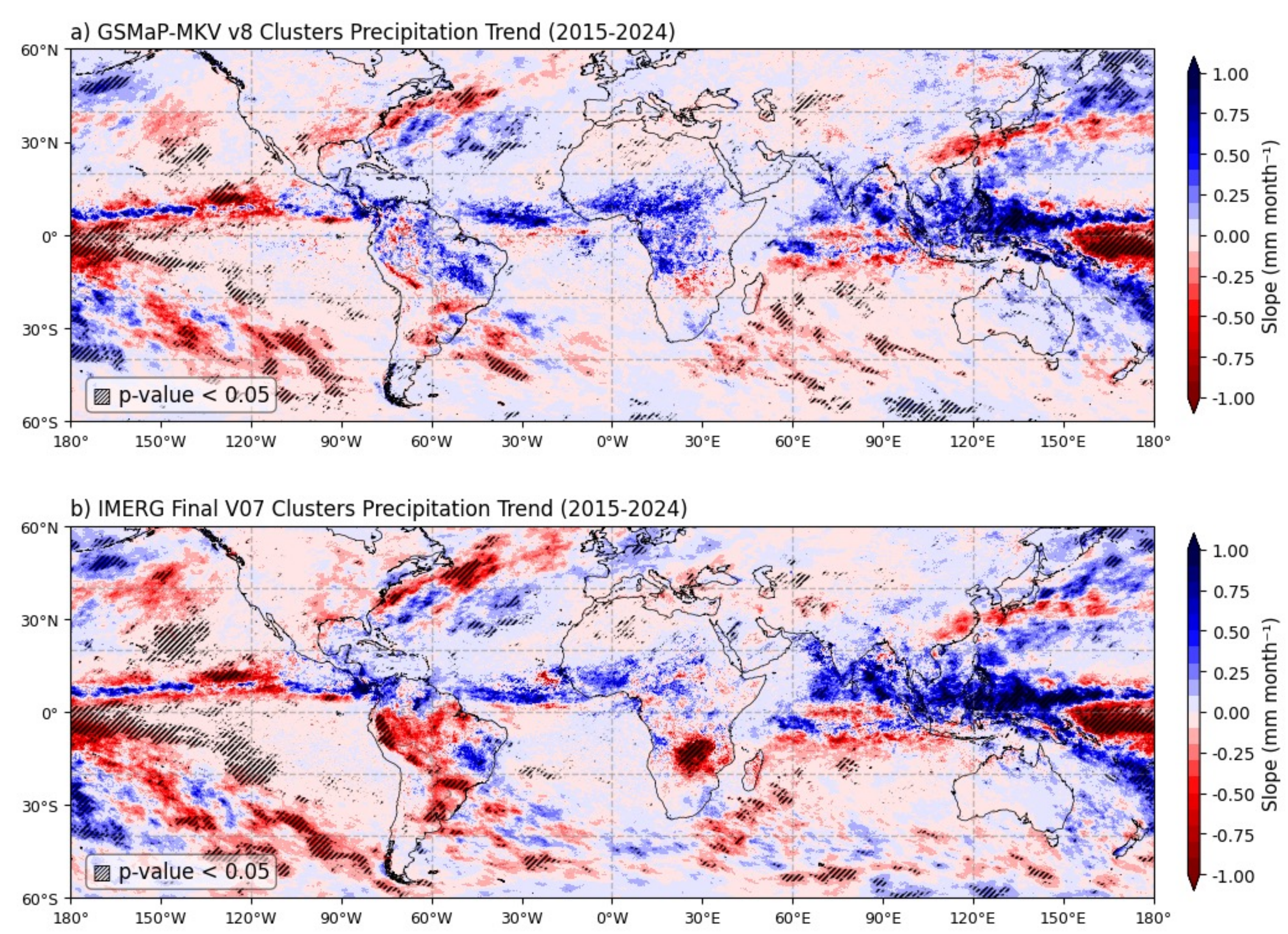
- https://pyfortracc.readthedocs.io

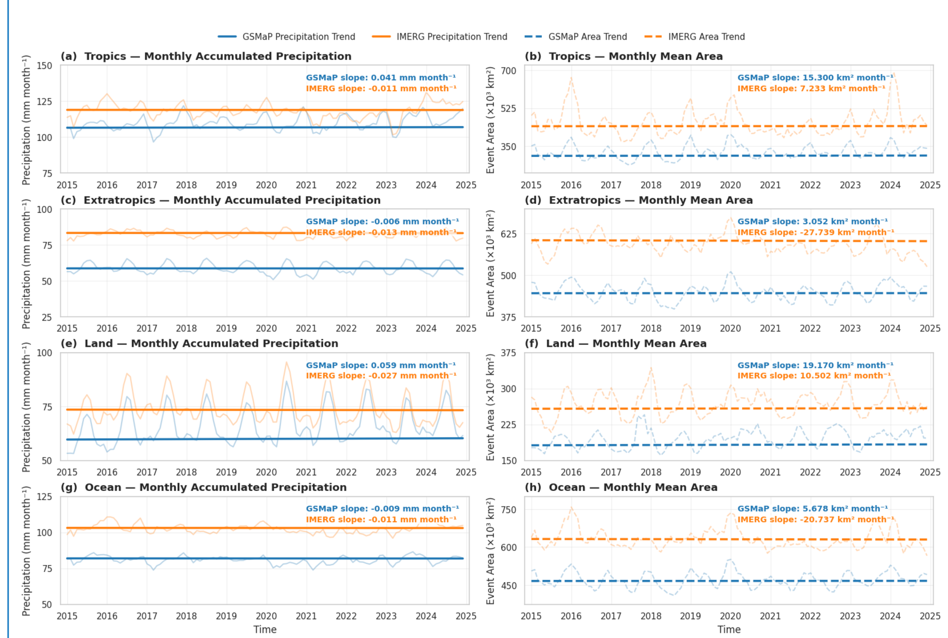
Global density of tracked precipitating systems from GSMaP–MVK v8 and IMERG Final V07 during 2015–2024.



Mean PS area and duration reveal organized, long-lived systems over tropical oceanic regions.







Preliminary trends show regional changes, including precipitation declines over the equatorial Pacific/southern Africa and area expansion over South Asian and Maritime Continent monsoon regions

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