Estimates of Global Precipitation Frequency and Intensity and their Dependence on Data Resolution

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Introduction and Motivation

Precipitation frequency (F) and intensity (I) are important characteristics that affect surface hydrology. These two characteristics are likely to behave differently under greenhouse gas-induced global warming (Trenberth et al. 2003).

Estimates of F and I are complicated by 1) a lack of sub-daily data, and 2) the calculated F and I values are sensitive to the resolution of input data. As the temporal aggregation increases, estimated F increases while I decreases (Biasutti and Yuter 2013). Yet, the quantitative relationship with data resolution remains unclear.

This study quantifies and explains the dependence of the calculated F and I on the resolution of input data. The results should improve our understanding of the resolution-dependence of estimated precipitation F and I and facilitate proper comparisons of them between models and observations.

Data and Method

We used the blended precipitation data from TRMM 3B42 and CMORPH_V1_ADJ, both are 3-hour averaged precipitation on a 0.25° grid. Comparison with GPCP and CPC US hourly rain gauge data suggest that TRMM 3B42 performs better than CMORPH_V1_ADJ, which has issues with cold season precipitation.

For calculating precipitation F and I, here a precipitation event is defined as a time period (e.g., a 3-hour period for 3-hourly data) with a precipitation rate equal or larger than a criterion (e.g., P>0.1mm/hr). The F is the number of the precipitation events expressed as a percentage of the number of observations, and the I is the mean precipitation rate averaged over all precipitation events, following Dai et al. (2007).

To help understand and explain the dependence of the estimated precipitation F and I on data resolution, we developed a simple statistical model based on basic probability concepts.

References

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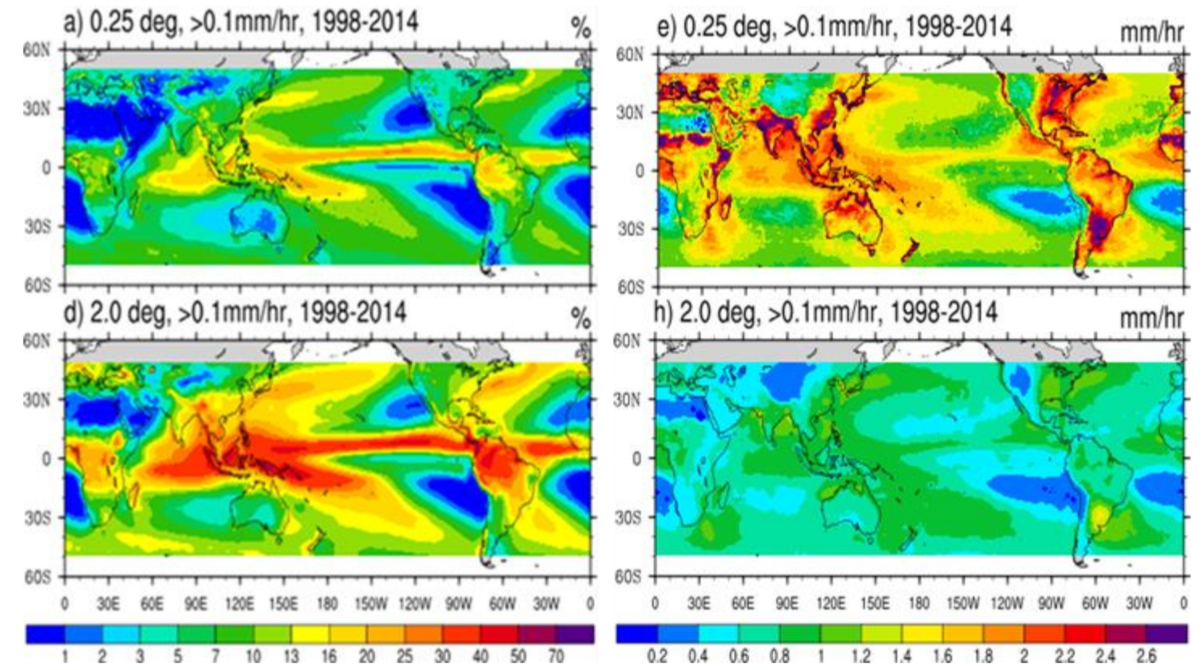
Dai A, Lin X, Hsu K (2007) The frequency, intensity, and diurnal cycle of precipitation in surface and satellite observations over low- and mid-latitudes. *Clim Dyn* 29: 727–744.

Trenberth KE, Dai A, Rasmussen RM, Parsons DB (2003) The changing character of precipitation. *Bull Am Meteorol Soc* 84: 1205–1217.

Biasutti M, Yuter SE (2013) Observed frequency and intensity of tropical precipitation from instantaneous estimates. *J Geophys Res* 118: 9534-9551.

Results

1. Dependence on Spatial Resolution



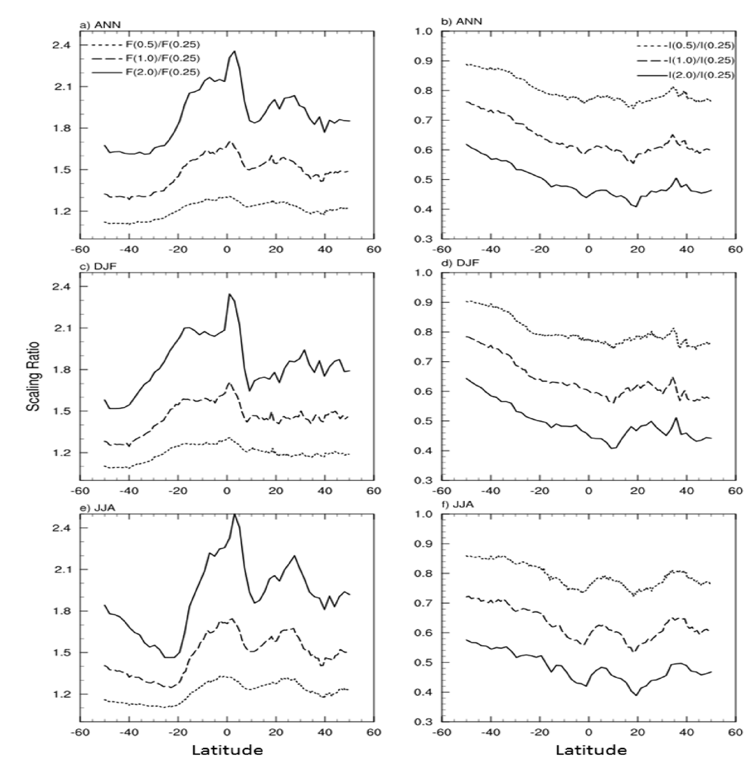
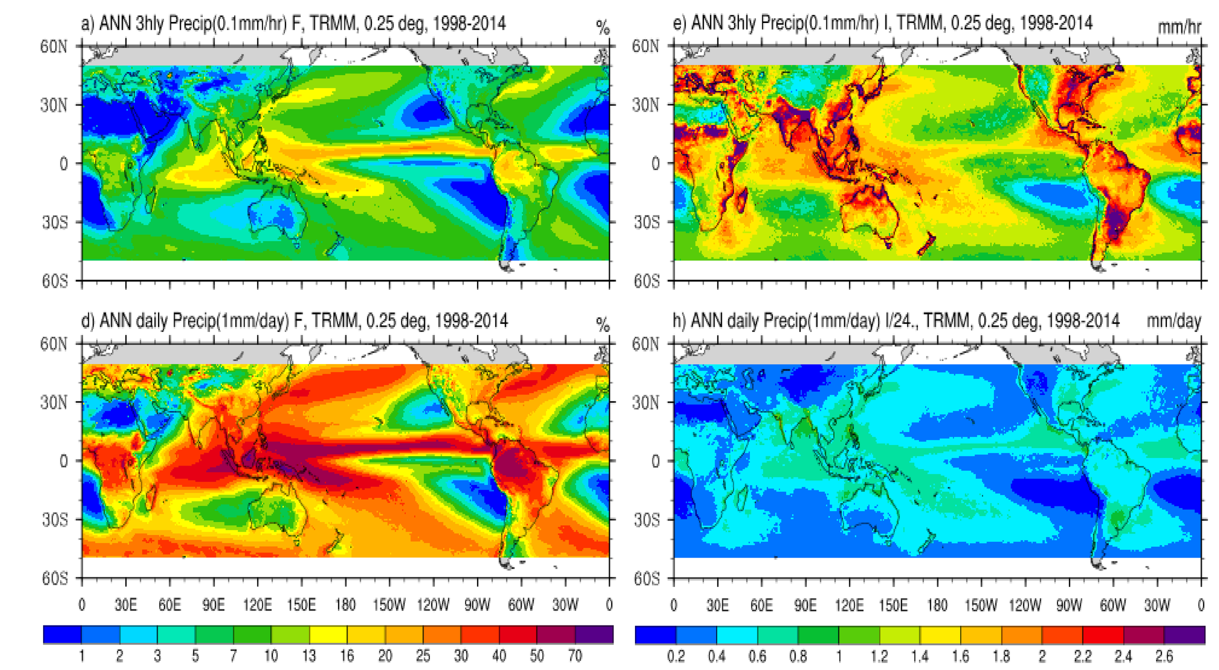


Fig. 1 (above). 1998-2014 mean annual precipitation (>0.1mm/hr) frequency (left column) and intensity (right column) estimated using TRMM 3B42 3-hourly data on two different grids. F (I) increases (decreases) substantially as the data are averaged over increasingly larger areas.

Fig. 2 (left). The ratio of zonal-mean frequency (a, c, e) and intensity (b, d, f) estimated using TRM3B42 1998-2014 data on coarser grids to those estimated using the data on 0.25° grid. The ratios may be used as an approximate scaling factor to convert the F and I onto common grids to facilitate the comparison.

2. Dependence on Temporal Resolution



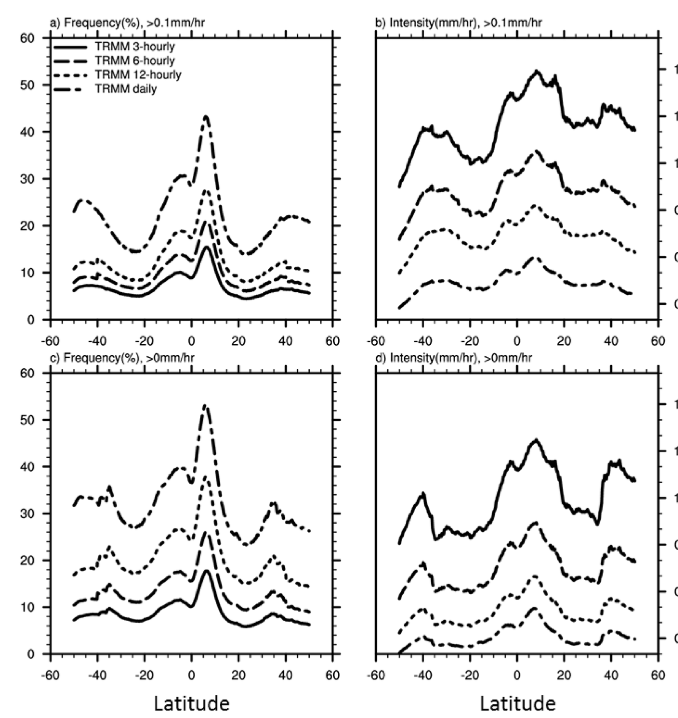


Fig. 3 (above). 1998-2014 mean annual precipitation frequency (%, left) and intensity (mm/hr, right) calculated using TRMM 3B42 data averaged onto (a, e) 3-hourly and (d, h) daily resolutions on the same 0.25° grid. Overall, the daily F is about 2-3 times higher than the 3-hourly F.

Fig. 4 (right). Zonal-mean annual precipitation (a) frequency and (b) intensity estimated using TRMM 3B42 data on the 0.25° grid on four different temporal resolutions using the P>0.1mm/hr and P>0 threshold for all cases.

4. Other results

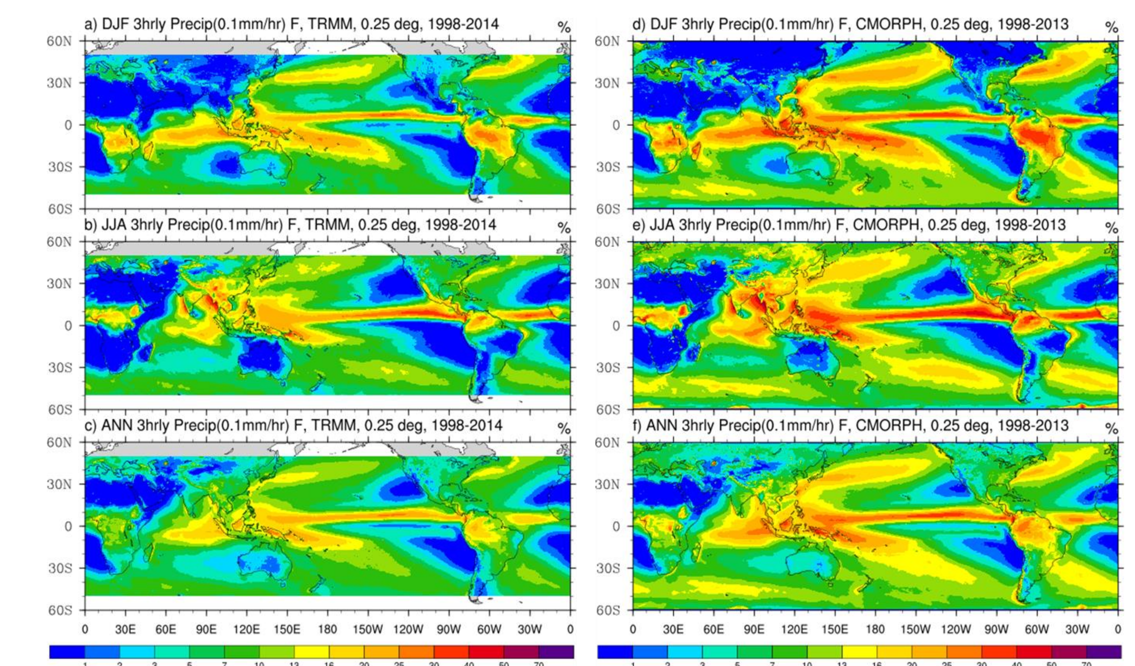


Fig. 8 (above). 1998-2014 mean (top) DJF, (middle) JJA, and (bottom) annual precipitation frequency (%) from (a-c) TRMM 3B42 and (d-f) CMORPH_V1_ADJ. Extremely low F (<1%) are seen over the subtropics while the highest F (20-40%) are located mostly over the tropics.

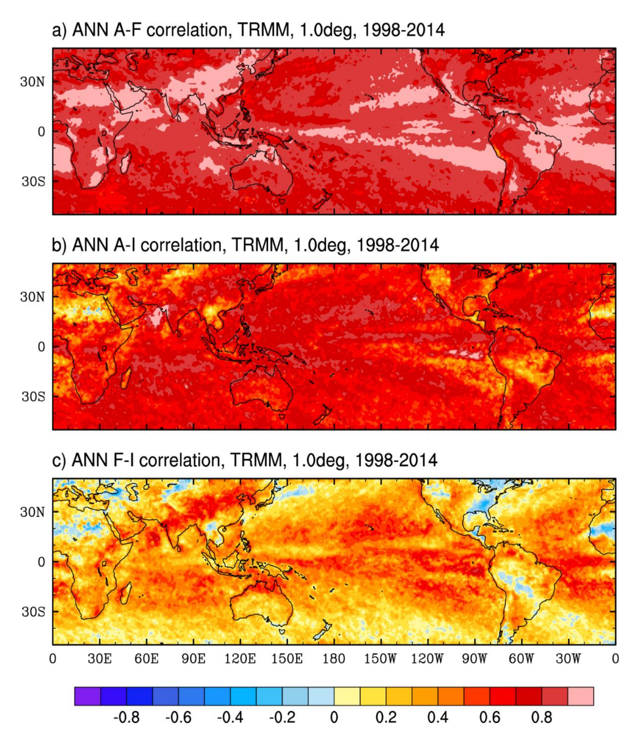
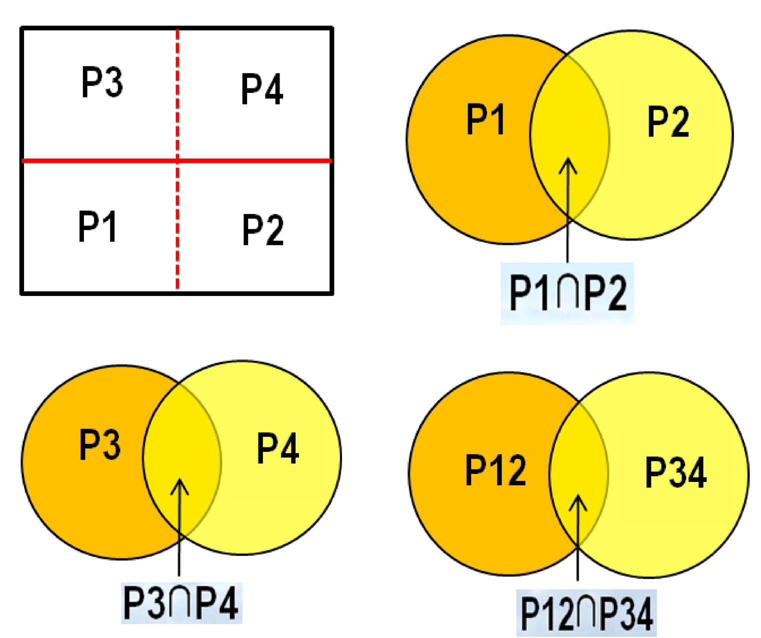


Fig. 9 (left). Local correlation between monthly anomalies of precipitation (a) amount and frequency, (b) amount and intensity, and (c) frequency and intensity based on TRMM 3B42 3-hourly precipitation from 1998 to 2014. Strong correlations between the amount and frequency confirm that F plays a bigger role than I in determining precipitation variations.

3. Probability-based Explanation

Figs. 6-7 show that increases of precipitation frequency with data averaging area and time period can be quantitatively explained purely based on probability considerations. This probability-based model (Fig. 5) can be further applied to other spatial and temporal resolutions, not limited by the example shown here.



$$P_{12} = P_1 + P_2 - P_1 \cap P_2$$

$$P_{1234} = P_{12} + P_{34} - P_{12} \cap P_{34}$$

Fig. 5. A schematic diagram illustrating the overlapping (i.e., concurring) part of the precipitation events over two small grid boxes (denoted as P1-P4) shown in the top-left panel. P12 and P34 represent the occurrence frequency for the lower and upper part of the larger box. P1234 is the frequency over whole large box and it is linked to the frequency over the smaller boxes through the equations. The circles represent the occurrence frequency of precipitation events for each of the indicated boxes, and the overlapped area of the circles represent the concurring part of the frequency (i.e., the fractional times when precipitation happens over both boxes).

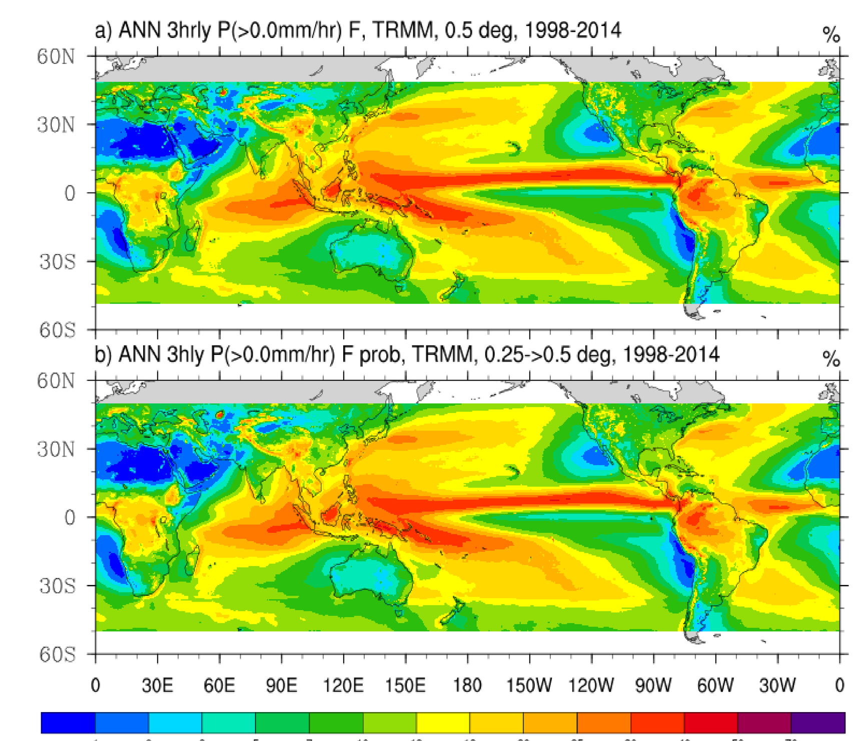


Fig. 6. 1998-2014 mean annual precipitation frequency estimated (a) directly from TRMM 3B42 3-hourly data averaged onto the 0.5° grid, and (b) using the TRMM data on the 0.25° grid and applying the simple model. The threshold of P>0 was applied for both cases, yo avoid the issue of the equivalent threshold that may change with data resolution .

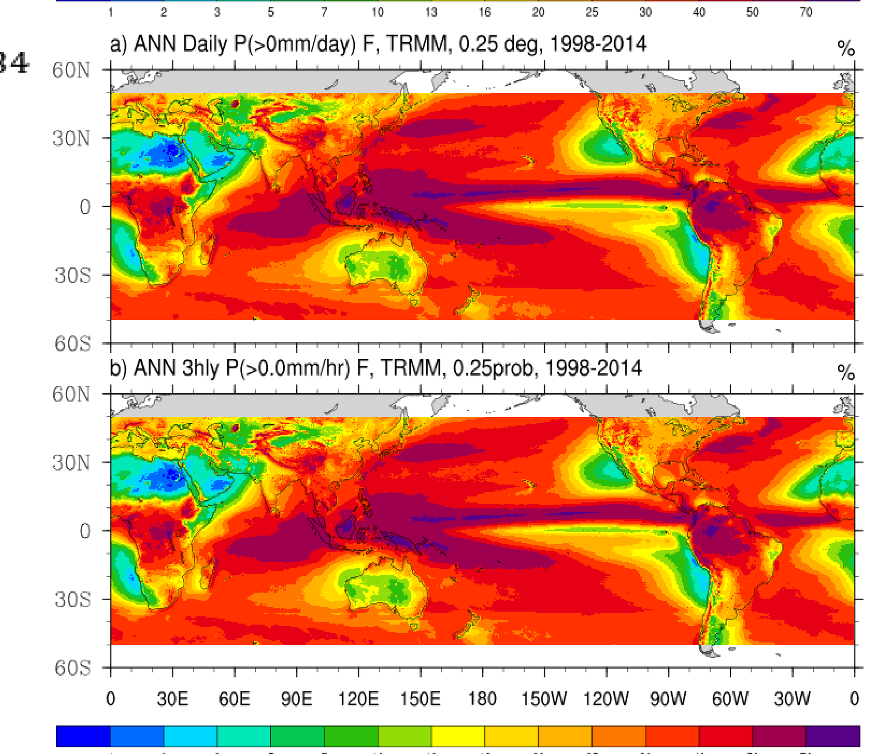


Fig. 7. 1998-2014 mean annual precipitation frequency estimated from (a) daily mean precipitation rates derived from TRMM 3B42, and (b) 3-hourly TRMM 3B42 data on the 0.25° grid and applying the simple model (Chen and Dai 2016).

Summary

- Precipitation F (I) increases (decreases) with the size of the area or time interval over which the data are averaged, but the magnitude of this change varies with location, and is strongest in the tropics and weakest in the subtropics.
- Our simple model can quantitatively explain this dependence of the estimated F and I on the spatial or temporal resolution of the input data.
- The results highlight the need to have similar resolution in comparing two datasets or between observations and models.

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