Rainfall estimation from satellite data is of great importance, especially in areas where gauge stations are absent or sparse. However, most of the satellite-based precipitation estimation products rely on the relationship between cloud-top brightness temperature and actual rainfall, assuming that precipitation originates from convective clouds with cold tops. This assumption fails to work for precipitation that originates from warm clouds. It also overestimates rainfall over areas with cold cloud tops, which includes mistaking non-precipitating cirrus as rainy. Another issue of these products is that their rainfall estimates are areal averages that suffer from biases due to complex terrain leading to the underestimation of extreme rainfall events. This work does a fit-for-purpose validation of five satellite-based rainfall estimation products in Zambia for use in the Participatory Integrated Climate Services for Agriculture (PICSA).

### Study Area and Station Data

![Zambia stations](image)

### Satellite-Based Rainfall Estimation Products

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CHIRPS</td>
<td>Satellite + gauge merge</td>
<td>Global 1983 - present</td>
<td>0.05°</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td>CHIRP</td>
<td>Satellite</td>
<td>Global 1983 - present</td>
<td>0.05°</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td>TAMSAT</td>
<td>Satellite + gauge calibration</td>
<td>Africa 1983 - Present</td>
<td>0.0375°</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td>ERAS</td>
<td>Reanalysis</td>
<td>Global 1983 - present</td>
<td>0.25</td>
<td>Hourly</td>
<td></td>
</tr>
<tr>
<td>AGERAS</td>
<td>ERAS</td>
<td>Global 1983 - present</td>
<td>0.1</td>
<td>Daily</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Details of 5 satellite-based rainfall estimation products used

### Seasonality

We fitted a zero-order Markov Chain model with three harmonics to study the seasonality of rainfall day frequency. It is written mathematically as:

\[
g(t) = \beta_0 + \sum_{k=1}^{K} \beta_k \cos \left( \frac{2\pi t}{p} + B_k \right) + \epsilon,
\]

where \(K\) is the number of harmonics, \(p\) is the period, \(t\) is the time (day of year), \(\beta_0, A_k, B_k\) are parameters to be estimated, and \(\epsilon\) is the error term.

![Gauge and ERAS estimated rain day frequency (rain days/year) at various thresholds](image)

### Bias Correction

We corrected the biases in the satellite estimates using the local intensity scaling (LOCI) by [1] as defined below:

\[
\beta = \frac{\text{mean}(y_i | x_i \geq T_{xm}) - \text{mean}(y_i)}{\text{mean}(x_i | y_i \geq T_{ym}) - \text{mean}(x_i)}
\]

where \(y_i\) are the daily station values, \(x_i\) are the daily satellite values for month \(m\), \(T_{xm}\) is the rain day threshold of the satellite data in month \(m\) calculated such that the long-term proportion of rain days for the satellite is the same as the station with rain day threshold \(T_{ym} = 0.85\) in accordance with [2]. Finally, the bias-corrected satellite values \(y_i^{\prime}\) are obtained by:

\[
y_i^{\prime} = y_i + \beta (x_i - \text{mean}(x_i)) \quad \text{if} \quad x_i \geq T_{xm}
\]

otherwise

### Results on PICSA Indicators: Start of the season

![Gauge vs product estimates vs bias-corrected estimates - rain day frequency (rain days/year)](image)

### Conclusion and Recommendation

**Conclusion**

The results show that the products in their current form are likely unsuitable as a replacement for station rain-gauge-recorded data on PICSA indicators such as the start of the season. However, if they are adjusted with a bias-correction method such as the Local Intensity Scaling (LOCI) method, they may be suitable for calculating overall risks on these indicators.

**Recommendation**

Further work is needed to make them suitable for detecting the PICSA indicators, such as the start of the season dates, on individual years.

### Acknowledgements

This research was made possible by a grant from Carnegie Corporation of New York (provided through the African Institute for Mathematical Sciences). The statements made and views expressed are solely the responsibility of the author(s).

### References
