Evaluation of Satellite Estimation Techniques for Improving Rainfall Monitoring in Arid Areas

Dr. Emad Habib, Ph.D., P.E.
Department of Civil Engineering
University of Louisiana, USA
Rainfall Hazards and Benefits

- Heavy and localized rainfall events
- Flash floods
- A potential source for fresh water
How do we monitor rain?

- **Rain Gauges**
  - Most direct measurements
  - They suffer from being “near-point” observations
  - They require frequent maintenance and downloads and are subject to breakdowns

- **Weather radars**
  - Continuous spatial and temporal coverage
  - A network of radars over large arid area is costly

- **Satellites**
  - Global coverage
  - Most viable in remote regions and areas with limited resources.
Motivation & Objectives

- Take advantage of recent advances in satellite-rainfall estimation algorithms and their potential for water resources management applications
- Satellites don’t measure rainfall directly
  - Estimation algorithm
  - Uncertainty
- This study will perform an assessment of satellite algorithms for quantifying surface rainfall amounts as a potential water resource in arid areas
Satellite Rainfall Estimation Methods

- Two main approaches
  - Visible (VIS)/Infrared (IR) Algorithms
  - Microwave Algorithms
# IR vs. Microwave Comparison

<table>
<thead>
<tr>
<th></th>
<th>IR</th>
<th>Microwave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physics</strong></td>
<td>Based on cloud-top properties; weakly related to actual rainfall rates</td>
<td>Based on bulk vertical cloud ice content; sensitive to moisture throughout the cloud</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>4-km, 15-min (CONUS) from GEO</td>
<td>15-km, 2x/day from LEO</td>
</tr>
</tbody>
</table>

**Goal:** combine IR and MW to optimize accuracy and resolution
Study Sites
Satellite Data:
TRMM Multi-sensor Estimates (TMPA)

- produced by merging MW from Tropical Rainfall Measuring Mission (TRMM) with high quality infrared (IR) precipitation
  - 0.25° × 0.25°
  - 3-hourly resolution
  - extending from 50° S - 50° N latitude
Validation Datasets: rain gauges

- Saudi Arabia and Yemen:
  - Daily & Monthly rain gauges
  - Acquired from NCDC archives
- Sinai
  - Storm-total rainfall from WRRI
Evaluation Methods

- Examination of spatial rainfall distribution
- Analysis of monthly rainfall time series
- Analysis of rainfall seasonal cycle of monthly-mean distribution
- Comparison of storm rainfall total depths
- Statistical assessment using standard measures
Accumulated Rainfall [mm]

Generated by NASA's Giovanni (giovanni.gsfc.nasa.gov)
Comparison of rainfall seasonal cycle based on TRMM-TMPA dataset (upper two panels) and gauge observations (two lower panels) over two stations in Saudi Arabia.
Comparison of rainfall seasonal cycle based on TRMM-TMPA dataset (upper two panels) and gauge observations (two lower panels) over two stations in Yemen.
- Monthly rainfall from TRMM-TMPA satellite estimates versus the corresponding monthly rain gauge observations over four stations in Saudi Arabia and Yemen.
Scatter plot comparisons of monthly rainfall from TRMM-TMPA satellite estimates versus the corresponding monthly rain gauge observations over four stations in Saudi Arabia and Yemen.
## Statistical Assessment

<table>
<thead>
<tr>
<th></th>
<th>TAIZ</th>
<th>SANAA</th>
<th>ABHA</th>
<th>AL-BAHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation Coefficient</td>
<td>0.56</td>
<td>0.71</td>
<td>0.52</td>
<td>0.67</td>
</tr>
<tr>
<td>Mean Absolute Error (mm)</td>
<td>52.81</td>
<td>8.31</td>
<td>8.93</td>
<td>8.05</td>
</tr>
<tr>
<td>Bias (ratio)</td>
<td>3.46</td>
<td>1.59</td>
<td>1.86</td>
<td>2.21</td>
</tr>
</tbody>
</table>
St. Catherine catchment; Sinai
Gauges Issues

St. Katherine Catchment

correlation coefficient between gauges

distance (km)
Summary & Conclusions

- Satellite estimates are showing much wetter Sinai than expected
  - more evident over land more than over water
  - “desert artifacts” with unrealistically high rainfall
  - occurring more during cold-temperature hours/days

- Seasonal patterns were mostly similar to those from gauges.

- Statistical analysis shows reasonable agreement in timing and detection

- However, considerable differences were reported in bias and mean absolute errors.

- Such differences could be attributed to algorithmic problems; but also to the low quality of rain gauges.
Concluding remarks

- Satellites provide viable rainfall information in un-gauged regions
  - global coverage
  - Relatively high temporal resolution

- High potential for hydrologic applications

- Satellites don’t measure rainfall directly:
  - Estimation
  - Validation (Uncertainty Analysis)

- We need surface observations (‘ground truth’)
  - Limited number and records of rain gauges in arid regions
  - Establish experimental rain gauge sites.
Thank You!

- Acknowledgment:
  - USA National Science Foundation
  - Graduate Students:
    - Nasrin Nasrollahi
    - Amy Henschke
    - Boone Larson

- For more information:
  - habib@louisiana.edu
  - www.ull.edu/~exh5102