An introduction to

The validation of satellite precipitation products

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Validation: Overview

There are many ways to validate precipitation, but consider:

• What is the purpose/goal of validating precipitation products?

• Does it address your needs, the needs of the algorithm/product providers and/or those of the user community?

• What sources of data are available – both satellite and surface data?

• What are the characteristics and quality of the data sets?

• What are the local/regional meteorological/climatological conditions?

• How will the products be compared, both visually and statistically?

• How do you make the best use of your own limited resources?
## Validation data sources

<table>
<thead>
<tr>
<th>Data source</th>
<th>Advantages</th>
<th>Disadvantages (examples)</th>
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</thead>
<tbody>
<tr>
<td><strong>Direct</strong></td>
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<tr>
<td>Gauge networks</td>
<td>Physically most direct</td>
<td>Under-catch, representativeness</td>
</tr>
<tr>
<td>Radar networks</td>
<td>Direct &amp; spatial</td>
<td>Variable backscatter-precipitation</td>
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<tr>
<td>Distrometers/aircraft</td>
<td>Direct - particles</td>
<td>Very specific, limited coverage/data</td>
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<tr>
<td><strong>Indirect</strong></td>
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<tr>
<td>Stream flow</td>
<td>Hydrology related: effective</td>
<td>Regulated rivers affect flow</td>
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<tr>
<td>Soil moisture</td>
<td>precipitation</td>
<td>Coarse resolution &amp; soil depth (?)</td>
</tr>
<tr>
<td>Vegetation</td>
<td></td>
<td>Indirect relationship</td>
</tr>
</tbody>
</table>

Selection of validation sources is often determined by availability, but they should be appropriate to study proposed;

The errors within the validation data must be significantly less than those in the data that is being validated.
Validation considerations

• **Gauge data** are not independent – they are spatially and temporally correlated: small scale-lengths for instantaneous, longer for monthly; time \( \equiv \) space. Crucially all gauge data is auto-correlated with the GPCC gauge data set.

• Most data sets use gauge data: models through reanalysis, satellite products through bias-correction, radars through calibration/adjustment.

• Avoid interpolation of gauge data – and do not extrapolate gauge data beyond the extent of gauge coverage.

• **Weather radars** measure backscatter from precipitation, buildings, birds, even the ground – however, the backscatter \( \rightarrow \) precipitation conversion not constant (rain/snow) & height of radar beam increases with distance from radar site.

• **Timing of data**: e.g. start/end times of observations, period of accumulation, non-UTC (Z) times/time zones, daylight savings time, etc.
# Precipitation Observing Systems

<table>
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<tr>
<th>Instrument</th>
<th>Temporal</th>
<th>Spatial</th>
<th>Notes</th>
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<tr>
<td><strong>Surface</strong></td>
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<tr>
<td>Gauges: accumulation</td>
<td>Variable</td>
<td>Point</td>
<td>Temporal scale dependent upon observation frequency</td>
</tr>
<tr>
<td>Gauges: Tipping Bucket</td>
<td>Quantised</td>
<td>Point</td>
<td>Quantisation of bucket (0.1 or 0.2 mm or 1/100&quot;) and data logger</td>
</tr>
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<td>Distrometers</td>
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<td>Micro rain radar</td>
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<td>Vertical profiles of precipitation</td>
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<tr>
<td>Weather radar</td>
<td>Instantaneous</td>
<td>Radial</td>
<td>Radial measurements of dBZ converted to a Cartesian grid (some with vertical profiles).</td>
</tr>
<tr>
<td><strong>Satellite</strong></td>
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<tr>
<td>Visible imagery</td>
<td>Instantaneous</td>
<td>1-4 km</td>
<td>Intermittent (LEO) / 15 min sampling (GEO)</td>
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<tr>
<td>Infrared imagery</td>
<td>Instantaneous</td>
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<tr>
<td>Passive Microwave Imagers</td>
<td>Column</td>
<td>5-25 km</td>
<td>Intermittent sampling (LEO) Resolution = frequency dependent</td>
</tr>
<tr>
<td>Passive Microwave Sounders</td>
<td>Column</td>
<td>16-48 km</td>
<td>Intermittent sampling (LEO) Resolution = frequency/scan position depen.</td>
</tr>
<tr>
<td>Active Microwave (radar)</td>
<td>Instantaneous</td>
<td>5 km</td>
<td>80 vertical levels; Intermittent sampling (LEO)</td>
</tr>
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</table>
Validation Domains

**Physical** (centimetres/instantaneous):
- Fine scale comparisons aimed at understanding precipitation microphysical processes, relating particle characteristics to precipitation systems.
- Distrometers, gauges, radar vs aircraft/satellite observations.

**Instantaneous** (ca.10-15 km/instantaneous):
- Algorithm performance, usually at the (full) resolution of the retrieval scheme.
- National/regional gauge/radar data, vs satellite products.

**Regional/global** (ca.0.25 degrees/daily-monthly):
- Performance of precipitation products over different regions and climates, over days to months.
- Regional/global gauge data sets vs satellite products.
Physical validation: Field Campaigns

Concerted validation efforts through organised field campaigns, as exemplified by the GPM-GV multi-tier approach.

Surface data sets:
- Gauge network (usually TBRs, & 2 per location)
- Distrometers – measuring particle size
- Radar(s) – polarmetric, Doppler.

Aircraft:
- Microphysics sensors (particles, met. measurements)
- Earth observation instruments – radiometers and radars

Satellites:
- Observations coordinated with satellite overpasses
Instantaneous cases and summaries

**Individual overpasses**

- **RADAR**
- **GMI**

**4+ years of instantaneous cases**

- **Europe**
  - DPR-Ku
  - GMI
  - AMSR2
  - SSMIS
  - MHS
  - ATMS

- **SE USA**
  - DPR-Ku
  - GMI
  - AMSR2
  - SSMIS
  - MHS
  - ATMS

**Statistics**

- **Europe**
  - DPR-Ku: Bias 0.15, NRMSE 1.55, CC 0.61, obs 1882339
  - GMI: Bias 0.15, NRMSE 1.55, CC 0.54, obs 2557415
  - AMSR2: Bias 0.06, NRMSE 1.54, CC 0.49, obs 545113
  - SSMIS: Bias 0.19, NRMSE 1.62, CC 0.44, obs 6392559
  - MHS: Bias 0.19, NRMSE 1.66, CC 0.45, obs 3210533
  - ATMS: Bias 0.58, NRMSE 1.63, CC 0.37, obs 360292

**SE USA**

- DPR-Ku: Bias 0.04, NRMSE 1.66, CC 0.61, obs 1882339
- GMI: Bias 0.15, NRMSE 1.55, CC 0.54, obs 2557415
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**Instantaneous cases**

- 20160914_1920

**Pressures by summenos**

- **Obs**
- **Est**

**Error of total rain (instantaneous summenos) by summenos**

- **Obs**
- **Est**

**Europe**

- DPR-Ku, GMI, AMSR2, SSMIS, MHS, ATMS

**SE USA**

- DPR-Ku, GMI, AMSR2, SSMIS, MHS, ATMS

**Number of points**

- Observed: 24661
- Estimated: 24663

**Rainfall points**

- DPR-Ku: 4258
- GMI: 2601

**Mean rain total**

- DPR-Ku: 11.05
- GMI: 9.88

**Conditional rain total**

- DPR-Ku: 2.87
- GMI: 2.19
Regional/global – daily 0.25x0.25 degree
GPCC number of gauges & analysis regions

Gauge coverage not even across regions

N.America
C.America
S.America
Europe
Africa
India
Asia
Australia

gauges/1x1deg
Common statistical metrics used in validation studies

**Understandable, relevant and correct**

**Bias:** Estimated–Observed

**Ratio:** Estimated/observed
- Rainrate dependent
- should have zero bias w.r.t. calibration data
- Superfluous in bias-correction techniques

**RMSE:** $\sqrt{\text{estimates-observed}}^2$
- Rainrate dependent
- superfluous in bias-correction techniques

**Correlation:** *e.g.* Pearsons
- Affected by spatial patterns and dynamic range of rainrates

**Probability of Detection (POD)**
**False Alarm Ratio (Rate) (FAR)**
- POD/FAR affected by rain occurrence, form (area) of precipitation, geolocation issues

**Skill Score (SS)**
- variable thresholds can be used to determine intensity skill scores; but same issues as POD/FAR

**Heidke Skill Score (HSS)**
- Similar to SS – but splits intensity into categories – either fixed groups, or dynamic by numbers in each group.
Validation data

Precipitation product

Occurrence comparison

Accumulation comparison

Contingency tables

PoD/FAR/HSS

Descriptive Statistics

Cumulative distribution

**IPWG inter-comparisons/validation**

IPWG Webinar: The Validation of Global Satellite Precipitation. 4 November 2020
Conclusions

Remember:

• **Precipitation is real** – not just numbers – get to know its subtleties;
• Data, satellite and surface, should be of the **highest quality**;
• Statistics should be used with caution – **visualise the data**!

Crucially,

• **There are good reasons why satellite and surface precipitation products should not agree**: there are fundamental differences in their observation and/or measurement which need to be understood.

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