Evaluation of GPM IMERG rainfall estimates with WegenerNet gauge data in Austria

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The Wegener Center of the University of Graz in Austria is operating a high-resolution climate station network, **WegenerNet Feldbach (WEGN)**, at 1-km-scale resolution that serves as a long-term monitoring and validation facility for research and applications.

**Alpine Forelands**
- Feldbach region network in the Alpine foreland of southeastern Austria
- Cold winters, hot summers, occasionally strong winter storms, summer precipitation dominated by heavy rain from thunderstorms

**Mountainous Terrain**
- Johnsbachtal network in the alpine upper Styrian region of National Park Gesäuse
- A ‘sister network’ of WegenerNet Feldbach region for supporting studies in mountainous terrain
Station Locations and Measurements

- **153 stations** in ≈ 23 km x 18 km region (a station per ≈ 2 km²)
- altitudes from 250 to 520 m.s.l.
- automatic near-real-time observation and quality control of parameters such as temperature, humidity, precipitation, wind, pressure, radiation, complemented by soil measurements
- data available since Jan. 1, 2007; can be downloaded from the WegenerNet data portal, [www.wegenernet.org](http://www.wegenernet.org)

153 stations in the Feldbach network, two blue stars indicate Austrian national weather stations.
### Station Types and Measured Parameters

<table>
<thead>
<tr>
<th>Base stations</th>
<th>Special base stations</th>
<th>Primary stations</th>
<th>Reference station</th>
</tr>
</thead>
<tbody>
<tr>
<td>127 stations</td>
<td>11 stations</td>
<td>11 stations</td>
<td>1 station</td>
</tr>
<tr>
<td>- Air temp., precipitation (tipping bucket, unheated), Air rel. humidity</td>
<td>- Air temp., precipitation (tipping bucket, unheated), Air rel. humidity</td>
<td>- Air temp., precipitation (tipping bucket, <em>heated</em>), Air rel. humidity</td>
<td>- Air temp., precipitation (heated), Air rel. humidity</td>
</tr>
<tr>
<td>- Soil parameters</td>
<td>5 stations</td>
<td>- Wind parameters (incl. wind gusts)</td>
<td>- Soil parameters</td>
</tr>
<tr>
<td>5 stations</td>
<td>Air temp. and humidity/precipitation</td>
<td></td>
<td>- Wind parameters</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Net radiation, Air pressure</td>
</tr>
</tbody>
</table>

**Temporal resolution**  
(all parameters, except soil)  
5 minutes
WegenerNet Data Products

- The incoming raw data are tested for their technical and physical plausibility by a quality control system.

- Weather and climate data products are derived on the basis of best quality station data for single stations and also for regular grids on various temporal scales ranging from 5 min to annual data.

- A major sensor replacement cycle, after about 10 years of WegenerNet operations, was recently completed by August 2016. As a result, all stations are equipped with Meteoservis high-quality sensors now.

Evolution of temperature (left) and precipitation (right) for a convective event on July 4, 2009.
Station Locations and Measurements

- 11 meteorological stations, and one hydrographic station in ≈ 25 km x 18 km mountainous terrain
  (inter-station distance is around 3 to 5 km)
- altitudes from below 700 to over 2100 m.s.l.
- data available since 2010

Johnsbachtal, Austria (top), and the 11 stations in the network (bottom), stations with blue circles measure precipitation
Station Types and Measured Parameters

- **Precipitation**: 7 stations
  
  (4 weighing gauges, 3 tipping bucket gauges)

- **Snow depth**: 4 stations

- Temperature and rel. humidity: 9 stations

- Wind parameters: 9 stations

- Radiation parameters: 7 stations

- Air pressure: 1 station

- Water discharge, outflow: 1 station

- Temporal resolution: **10 minutes**
Q1. How well can GPM IMERG estimate precipitation at a pixel-level? IMERG final run can show better performance than the NRT runs?

=> Evaluation of GPM IMERG Early, Late, and Final rainfall estimates with WEGN gauge data in southeast Austria

Average-to-grid to grid comparison

- Eight IMERG grids (46.8°N-47.0°N, 15.7°E-16.1°E) are overlapped with the WEGN domain
- Two 0.1° x 0.1° IMERG grids, covered by 40 and 39 WEGN stations, respectively, are selected
- Apr to Oct for 2014 and 2015
DATA

GPM IMERG

- GPM Level 3 product ‘Final’ run; gridded data from PMW, IR estimations and rain gauges analysis at 0.1 degree with 30-min resolution, from Apr 2014
- ‘Late’ and ‘Early’ run datasets, both data are available from Apr 2015
  - Early: forward-only morphing, 4 hr latency, for whom needing a quick answer
  - Late: forward/backward morphing, 12 hr latency, for next-day users

WegenerNet

- WegenerNet Level 2 gridded products; gridded data from 150 tipping bucket gauges at 200 m x 200 m with 5-min resolution, from Jan 2007
Probability density functions by occurrence and cumulative rain volume

- **PDFs** (dashed lines): percentage of rain-rate occurrence at each predefined bin
- **CDFs** (solid lines): relative contribution of rain-rate volume at each bin to the total rain volume

Computed with a bin width of 0.5 mm/30-min
Scatter plots with Q25, Q50, and Q75 values at each bins

- Q75, median, and Q25 at each bins (grey and black lines), on the scatter plots (light pink dots), 30-min data used.
- Scatter plots show WEGN (x-axis) versus IMERG (y-axis) in millimeter per 30-minutes
- Warm (Apr, May, and Oct) and Hot (Jun to Sep) seasons are considered.
Part III WEGN-IMERG Comparison

Time series of IMERG data for rain events

- (left) rainfall event captured by the WEGN. Red boxes indicate two used grids in the study.

- (right) time series of IMERG and WEGN rainfall data for each grid; corresponding time in shaded area
Part III WEGN-IMERG Comparison

Time series of IMERG data for rain events

PMW based data

• (left) rainfall event captured by the WEGN. Red boxes indicate two used grids in the study.

• (right) time series of IMERG and WEGN rainfall data for each grid; corresponding time in shaded area

• It shows clearly the value of more (accurate) PMW estimates in the morphing process, as well as the gauge adjustment to remove systematic biases.
Part III WEGN-IMERG Comparison

RMSE in terms of gauge accumulation time and offset

Final (2014-15)

• Plots of RMSE in millimeter between IMERG and WEGN

• Minimum RMSE at a combination of accumulation: 25 mins and Offset: +40 min

Final (2015)

=> IMERG-F estimates during 09:00-09:30 UTC can be considered as gauge measurements during 09:40-10:05 UTC.
Part III WEGN-IMERG Comparison

RMSE in terms of gauge accumulation time and offset

Final (2014-15)

- Entire
- Spring/Autumn
- Summer

- Plots of RMSE in millimeter between IMERG and WEGN
- Minimum RMSE at a combination of accumulation: 25 mins and Offset: +40 min

=> IMERG-F estimates during 09:00-09:30 UTC can be considered as gauge measurements during 09:40-10:05 UTC.
Q2. GPM IMERG estimates over complex terrain?

Comparing GPM IMERG with Multi-Radar Multi-Sensors in mountain areas

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Data

IMERG

- GPM Level 3 product ‘Final’ run; gridded data from PMW, IR estimations (satellite-only data) and rain gauges analysis (gauge corrected data) at 0.1° with 30-min resolution

MRMS

- Multi-Radar Multi-Sensor system; 0.01°, 2-min resolution precipitation data from ~180 polarimetric radars, ~9,000 gauges every hour, Model hourly 3D analyses, over the CONUS
- aggregated into 0.1°, 30-min resolution for the study

Only best quality MRMS data (RQI=100) are selected.
Part IV IMERG Estimates over Mountains

IMERG-MRMS comparison in Western US

Mountains (UNEP WCMC) Vulnerable Areas (PRISM Normals)

Mountains information based on elevation and slope
- red: mountains
- green: plains

Climatological data cover the period 1981-2010
- blue: Q80 (wet areas) in June
Part IV IMERG Estimates over Mountains

Daily data comparison over mountains and plains

Mountains

Plains

Q-Q plot
Linear Regression Line
Data number (density)
Sub-regions in Western US

- **Mountains**
  - PNW: Pacific Northwest
  - SC: South California
  - IM: Intermountain (Rocky)
  - NAM: NA monsoon region

- **Plain**
  - GP: Great Plains

Plain and Mountain
  - PNW: Pacific Northwest
  - SC: South California
  - NAM: NA monsoon region

ref. Carrera et al., 2004; Q Li 2005; Lee et al., 2007
Part IV IMERG Estimates over Mountains

Diurnal cycle comparison in the sub-regions

- **average**: averaged rainfall (including zero)
- **frequency**: non-zero data num./each hour’s total data num.
- **gauge corrected and satellite-only IMERG** are used.

X-axis is Local Time
Diurnal cycle comparison in the sub-regions

- MRMS
- IMERG gauge corrected
- IMERG satellite-only

Corresponding areas to IM (left) and GP (right)
Part IV IMERG Estimates over Mountains

Diurnal cycle comparison in the sub-regions

- **MRMS**
- **IMERG gauge corrected**
- **IMERG satellite-only**

Corresponding areas to IM (left) and GP (right)

- Satellite data well describe diurnal cycle patterns, although they tend to overestimate rainfall especially in plains.
- The amplitude of diurnal cycle is affected by the gauge correction.
Looking Forward

**Future Plans**

- Apply the research methodology for comparing IMERG-WEGN to the next version of the IMERG data,
- Analyze IMERG-MRMS diurnal cycles more completely, focusing on heavy precipitation areas,
- Extend the research framework to the WegenerNet Johnsbachtal which is also located in mountains.
Further Information

www.wegcenter.at/wegenernet
WegenerNet homepage and Literature

www.wegenernet.org
WegenerNet Feldbach data portal

www.bogner-lehner.net/xeis_datenportal.php
WegenerNet Johnsbachtal data portal

http://nmq.ou.edu/
MRMS radar data portal

References


O. et al. (2016): Validation and correction of rainfall data from the WegenerNet high density network in southeast Austria. (*under review*)

O. et al. (2016): Evaluation of GPM IMERG Early, Late, and Final rainfall estimates with WegenerNet gauge data in southeast Austria. (*in preparation*)