



wege entstehen, indem wir sie gehen
paths emerge in that we walk them

Wegener Center
www.wegenercenter.at



Atmospheric Remote Sensing and Climate System Research Group

ARSCISys

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

Sungmin O, G. Kirchengast, J. Fuchsberger, and U. Foelsche

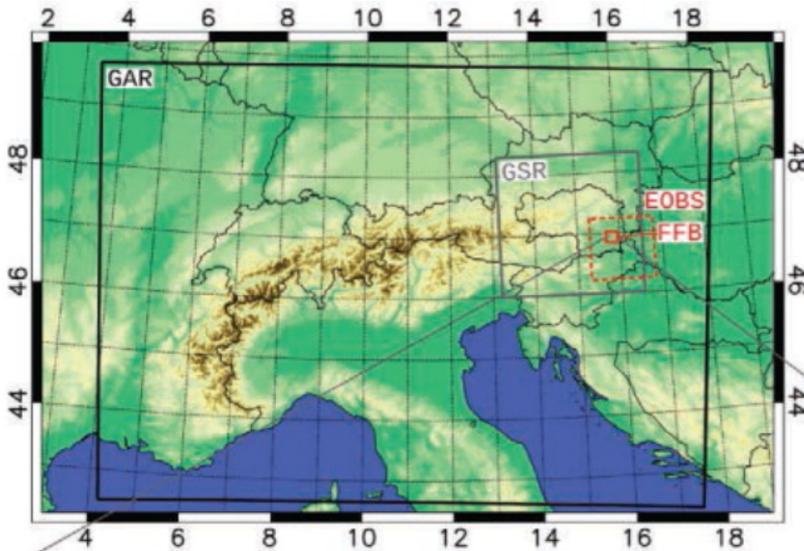
Wegener Center for Climate and Global Change

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(1) Universities Space Research Association, and NASA Goddard Space Flight Center, and

(2) NASA Marshall Space Flight Center, Huntsville, Alabama, USA



- 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.

Feldbach

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

Johnsbachtal

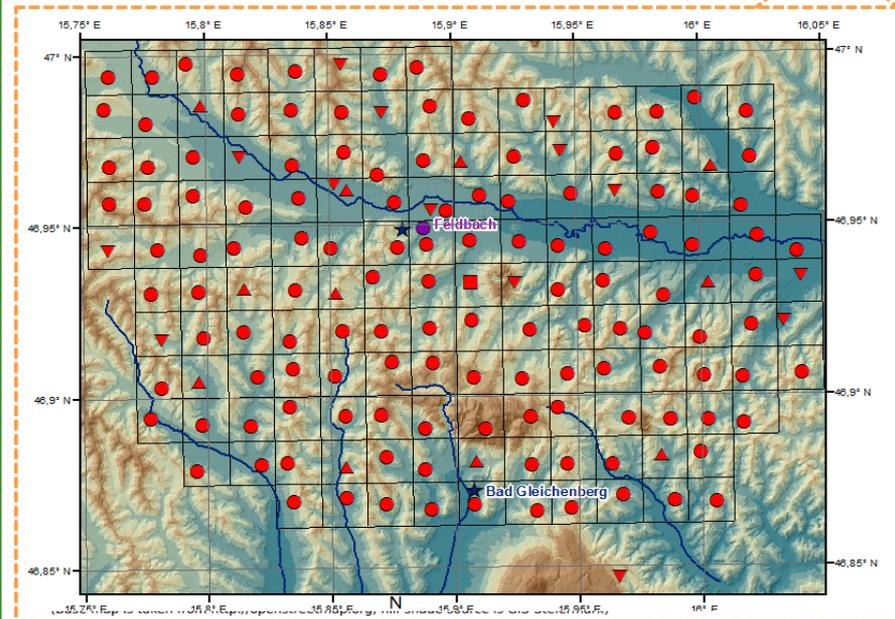
Mountainous Terrain

- 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 $\approx 23 \text{ km} \times 18 \text{ km}$ region
(a station per $\approx 2 \text{ km}^2$)
- 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

Feldbach Network (orange)
Johnsbachtal Network (yellow)
Weather Radar Zirbitzkogel
(blue)



Station Types and Measured Parameters

Base stations	Special base stations	Primary stations	Reference station
<u>127 stations</u> <ul style="list-style-type: none">Air temp., precipitation (tipping bucket, unheated), Air rel. humidity	<u>11 stations</u> <ul style="list-style-type: none">Air temp., precipitation (tipping bucket, unheated), Air rel. humiditySoil parameters <u>5 stations</u> <p>Air temp. and humidity/ precipitation</p>	<u>11 stations</u> <ul style="list-style-type: none">Air temp., precipitation (tipping bucket, heated), Air rel. humidityWind parameters (incl. wind gusts)	<u>1 station</u> <ul style="list-style-type: none">Air temp., precipitation (heated), Air rel. humiditySoil parametersWind parametersNet radiation, Air pressure

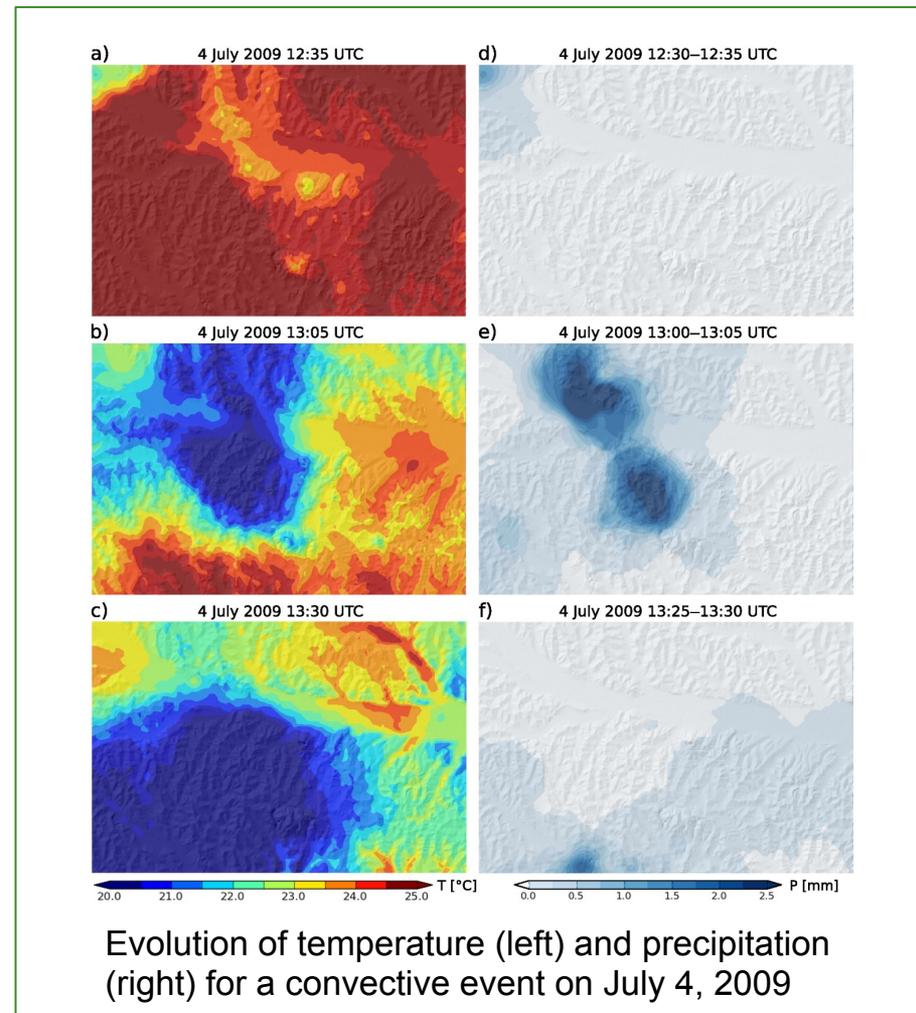


Temporal resolution
(all parameters, except soil)
5 minutes



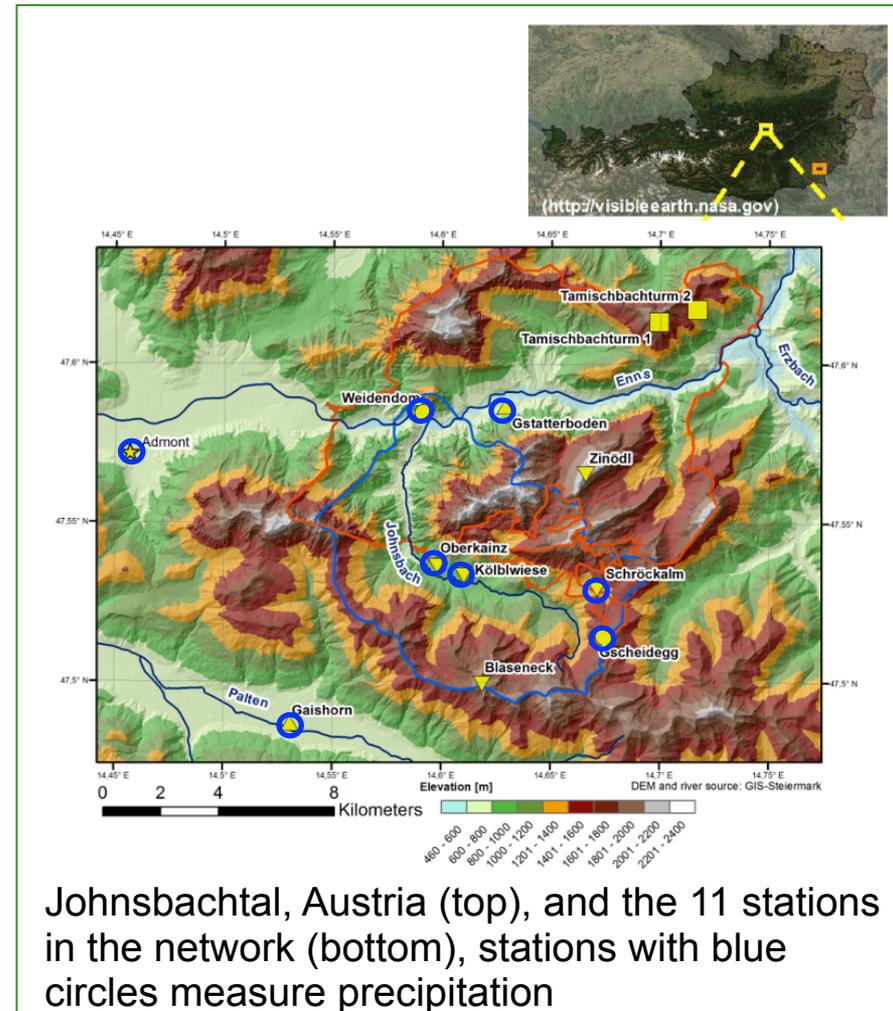
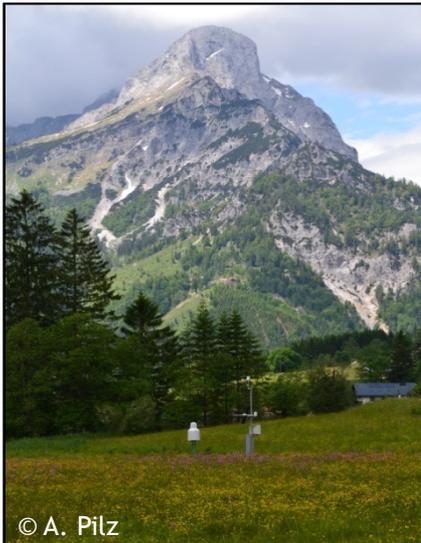
WegenerNet Data Products

- 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.



Station Locations and Measurements

- 11 meteorological stations, and one hydrographic station in $\approx 25 \text{ km} \times 18 \text{ km}$ 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



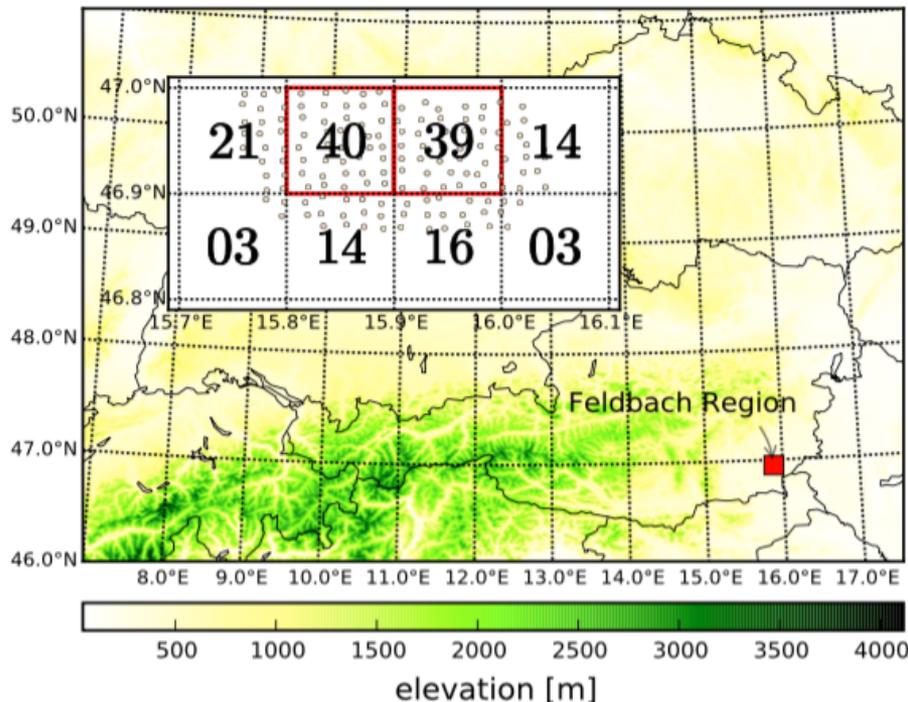
Station Types and Measured Parameters

- **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

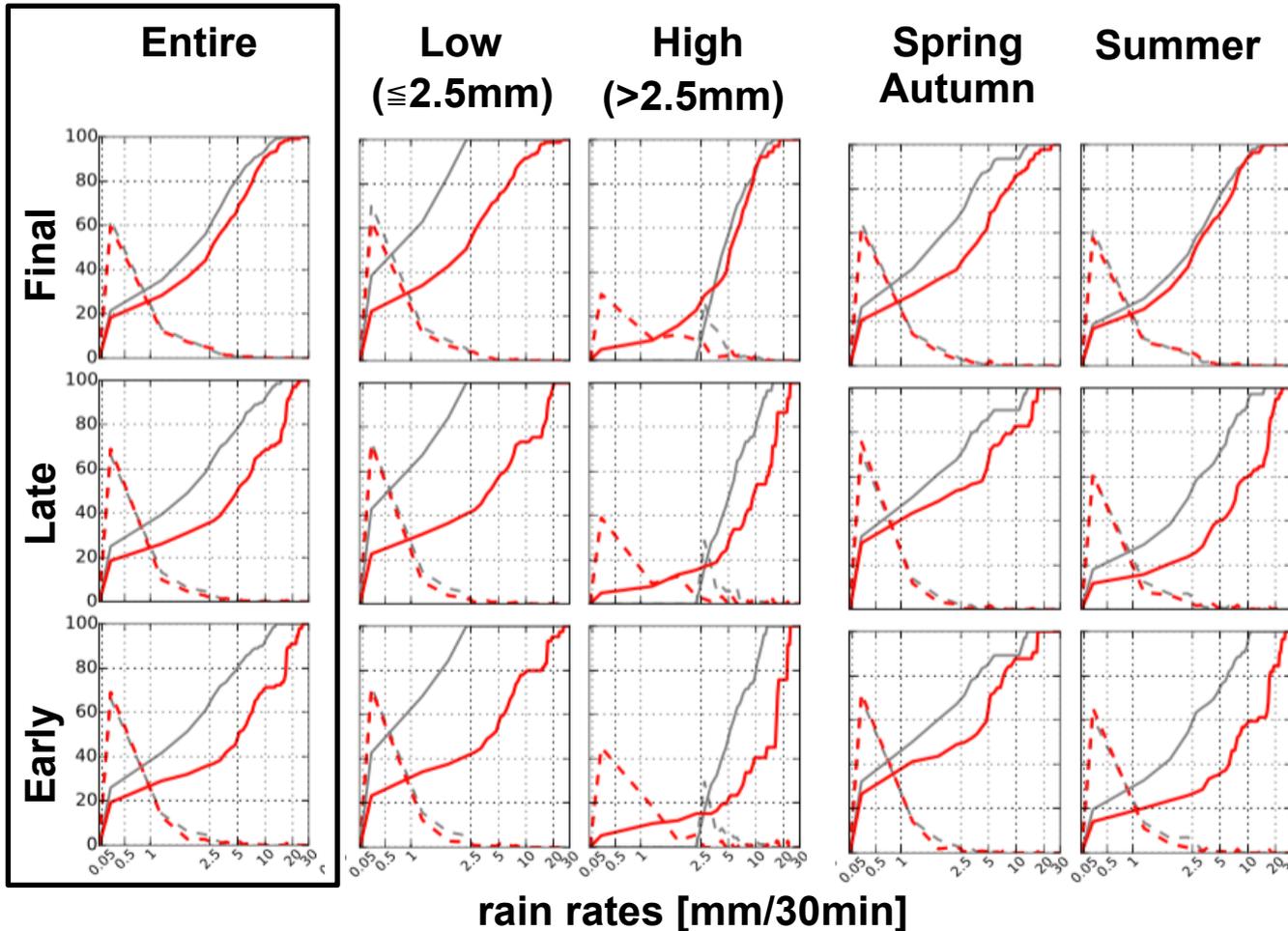
GPM IMERG

- [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

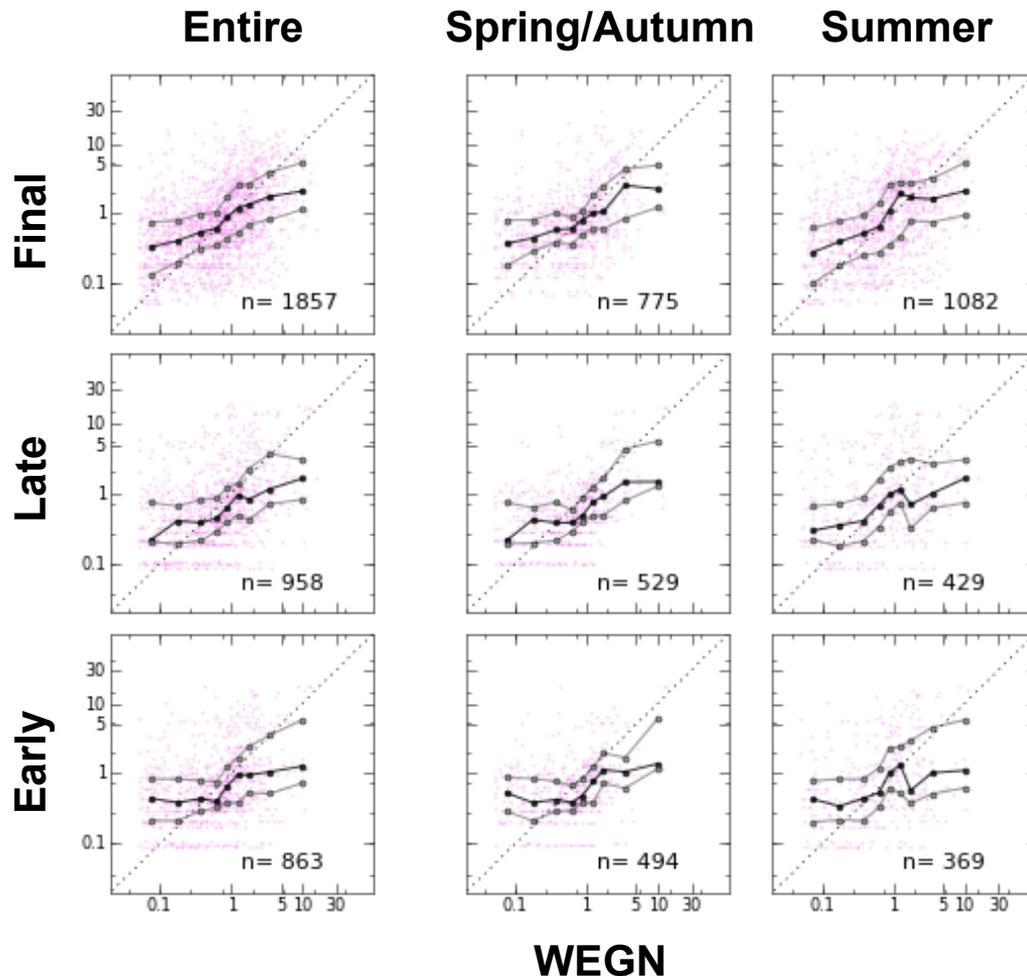
Probability density functions by occurrence and cumulative rain volume



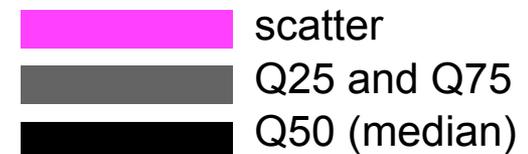
- **PDFs** (dashed lines); percentage of rain-rate occurrence at each pre-defined bin
- **CDFs** (solid lines); relative contribution of rain-rate volume at each bin to the total rain volume
- Computed with a bin width of 0.5 mm/30-min

IMERG
 WEGN

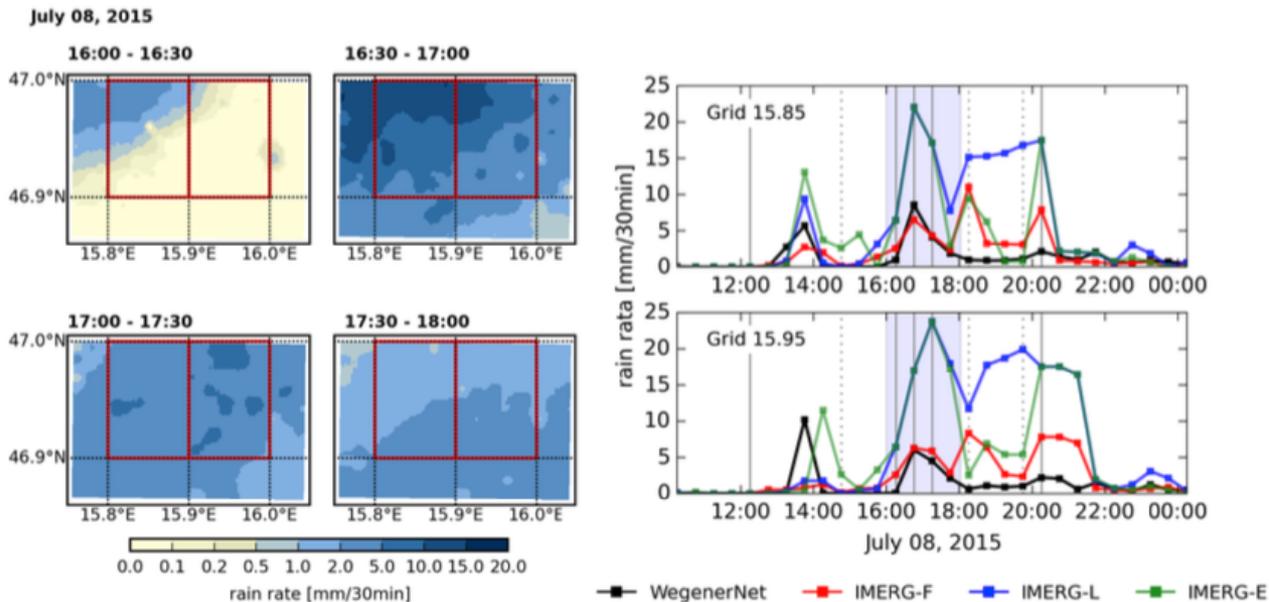
Scatter plots with Q25, Q50, and Q75 values at each bins



- 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.



Time series of IMERG data for rain events



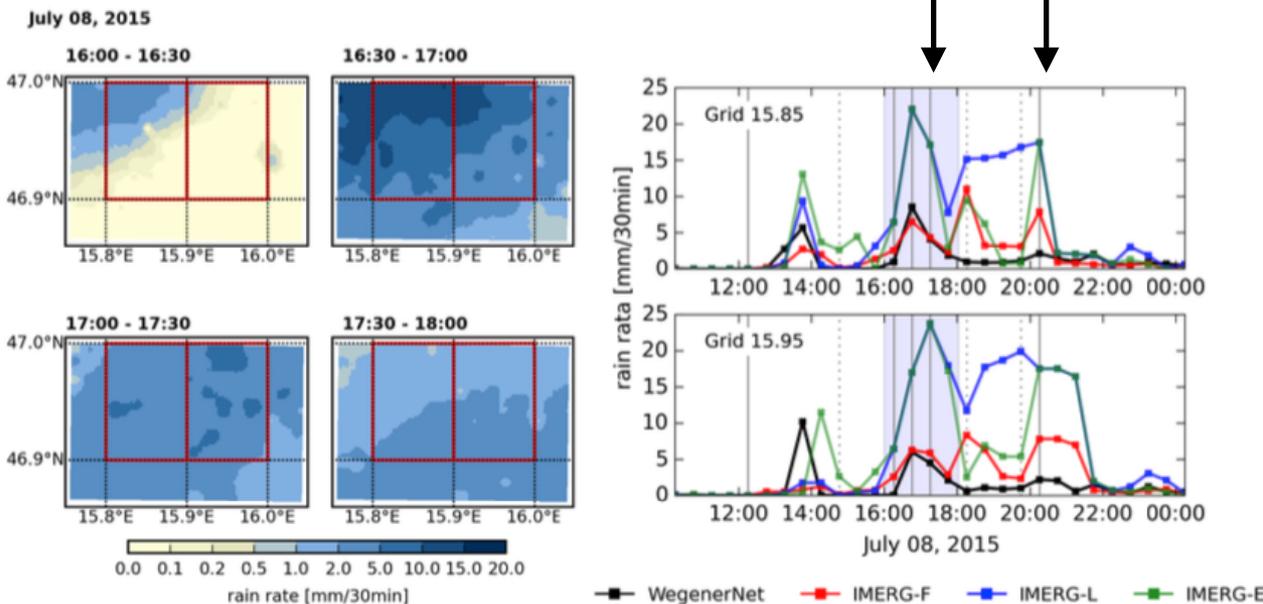
- (left) rainfall event captured by the WEGN. Red boxes indicate two used grids in the study.

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



Time series of IMERG data for rain events

PMW based data



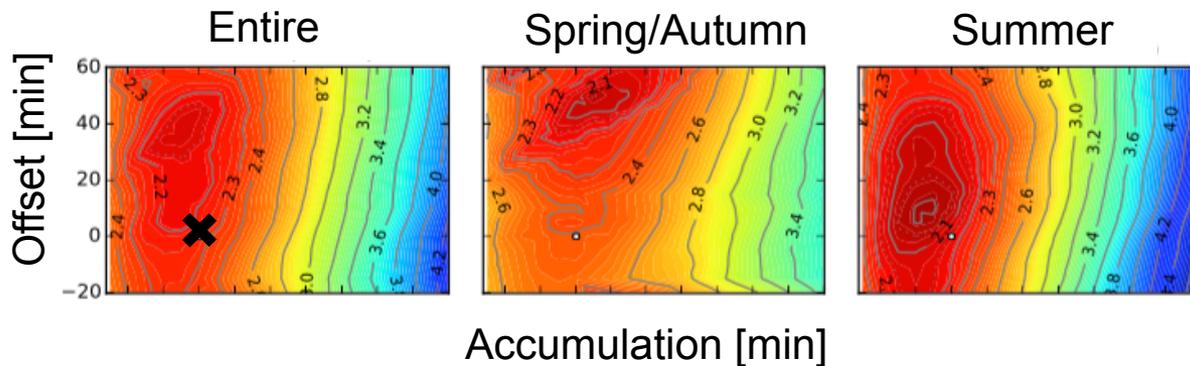
- (left) rainfall event captured by the WEGN. Red boxes indicate two used grids in the study.
- (right) **time series** of IMERG and WEGN rainfall data for each grid; corresponding time in shaded area

- It shows clearly the **value of more (accurate) PMW estimates** in the morphing process, as well as the gauge adjustment to remove systematic biases.



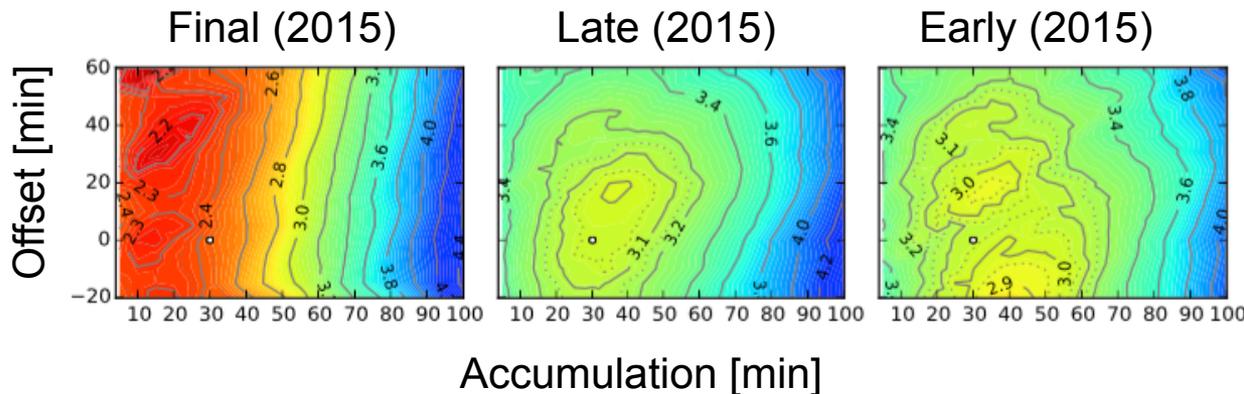
RMSE in terms of gauge accumulation time and offset

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

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



Low RMSE
 High RMSE

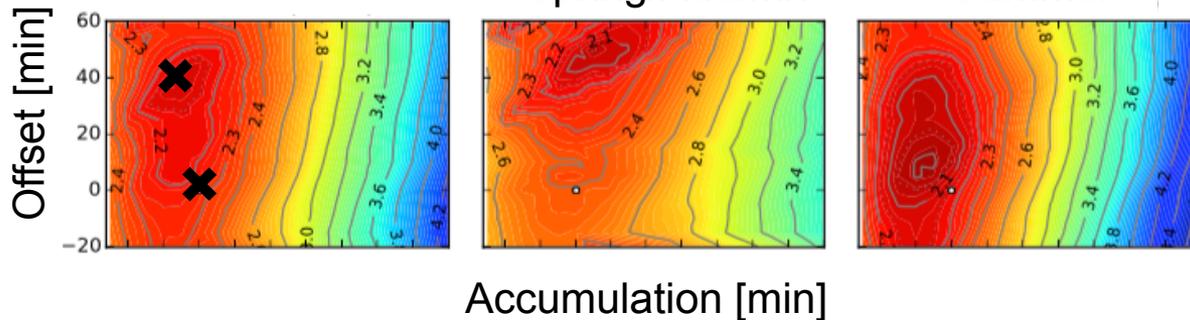
RMSE in terms of gauge accumulation time and offset

Final (2014-15)

Entire

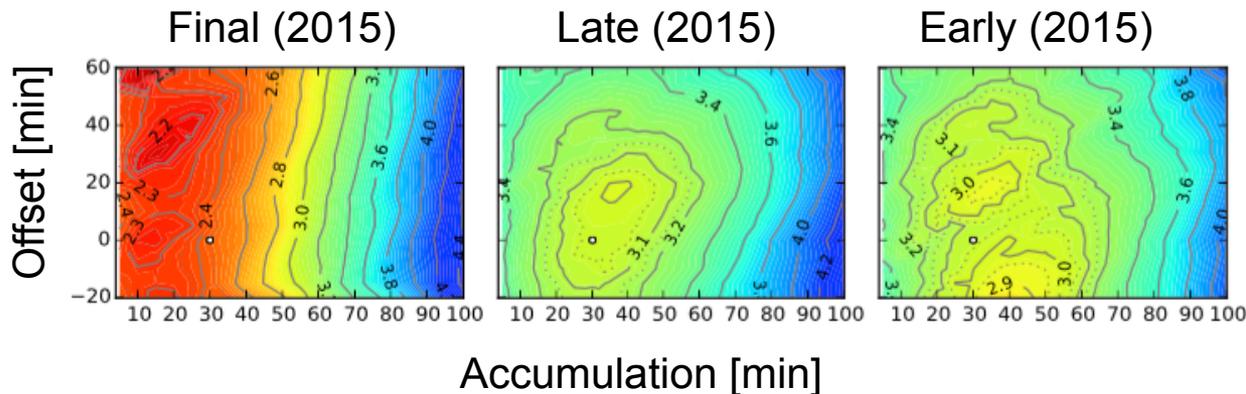
Spring/Autumn

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.



 Low RMSE
 High RMSE

Q2. GPM IMERG estimates over complex terrain?

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

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(2) Inst. for Geophysics, Astrophysics, and Meteorology / Inst. of Physics, University of Graz, Austria

(3) Advanced Radar Research Center, University of Oklahoma, Norman, Oklahoma, USA

(4) NOAA/National Severe Storms Laboratory, Norman, Oklahoma, USA

(5) School of Civil Engineering and Environmental Sciences, University of Oklahoma, Norman, Oklahoma, USA

Data

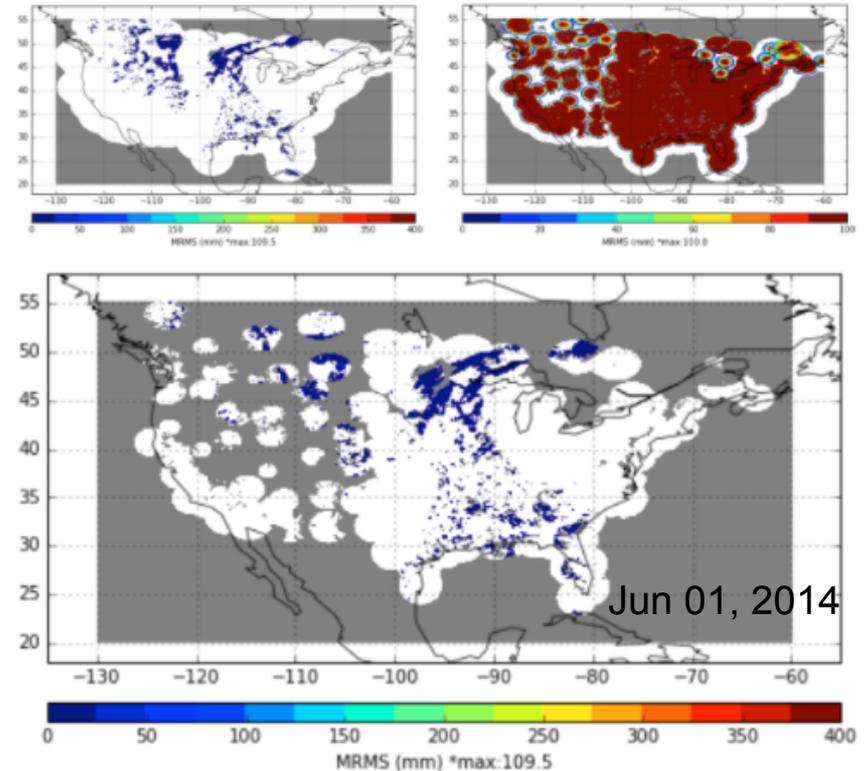
IMERG

- 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

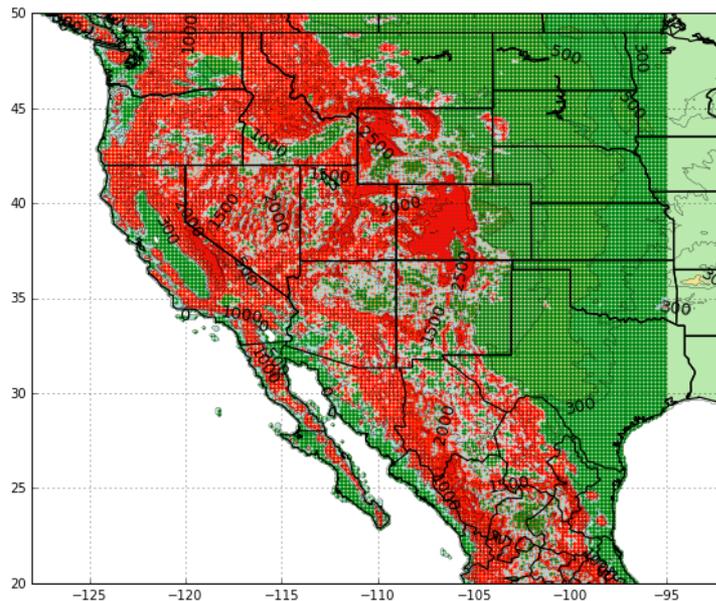
MRMS data (left) RQI (right)
MRMS data where RQI is 100 (bottom)



Only best quality MRMS data (RQI=100) are selected.

IMERG-MRMS comparison in Western US

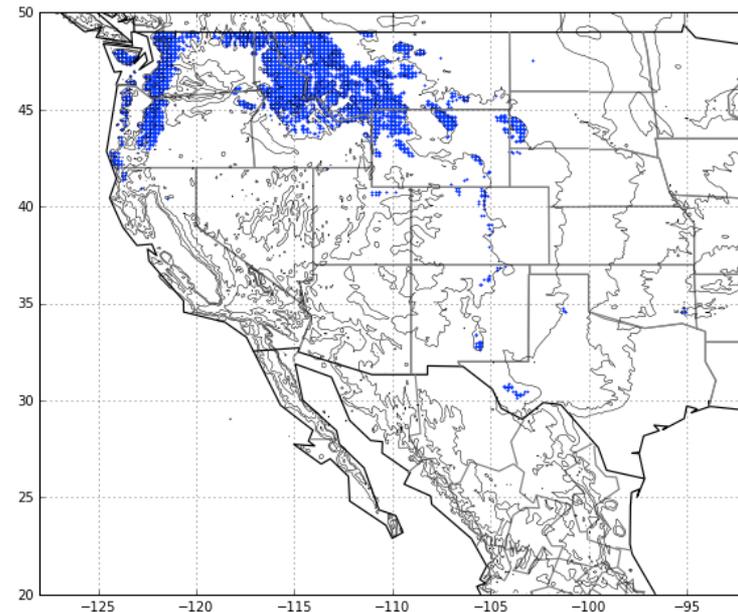
Mountains
(UNEP WCMC)



Mountains information based on
elevation and slope



Vulnerable Areas
(PRISM Normals)

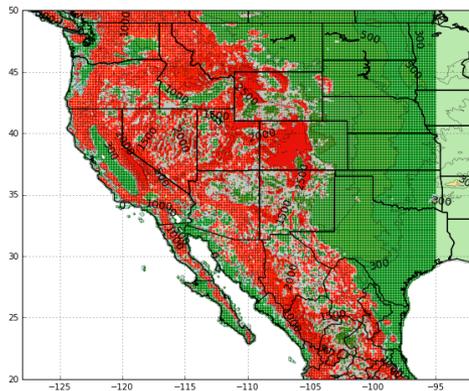


Climatological data cover the period
1981-2010



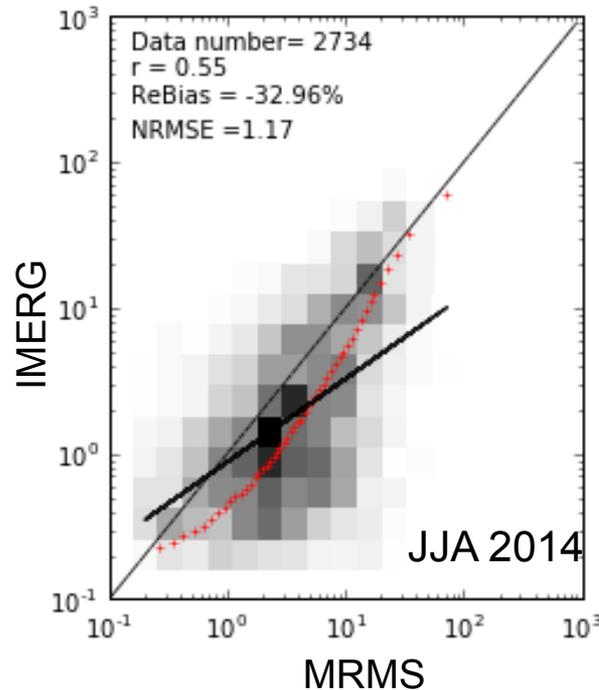
Daily data comparison over mountains and plains

Mountains

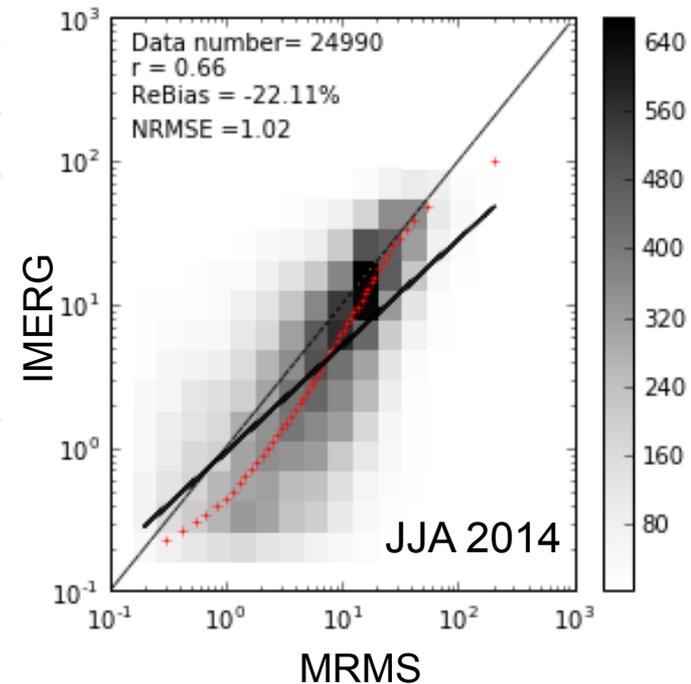


mountains
 plains

Mountains



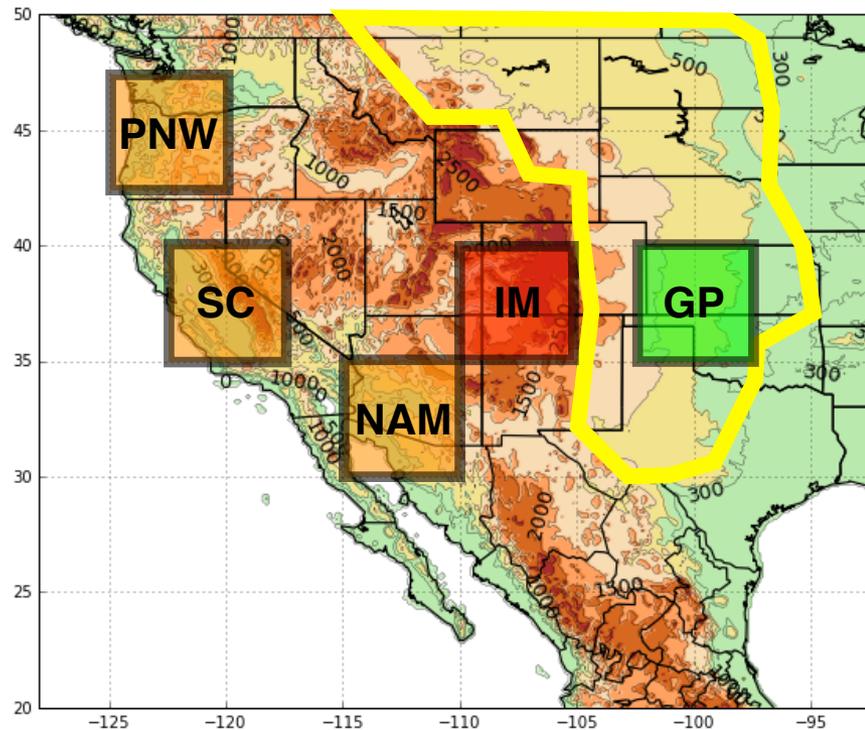
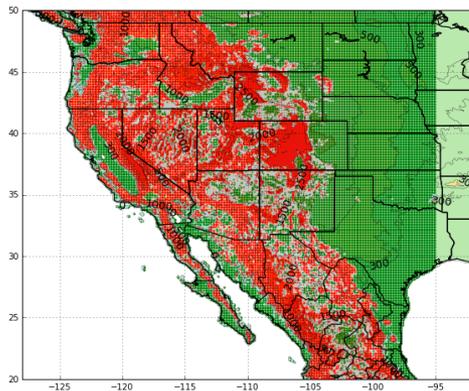
Plains



Q-Q plot
 Linear Regression Line
 Data number (density)

Sub-regions in Western US

Mountains



Great Plains

Plain

- GP: Great Plains

Mountain

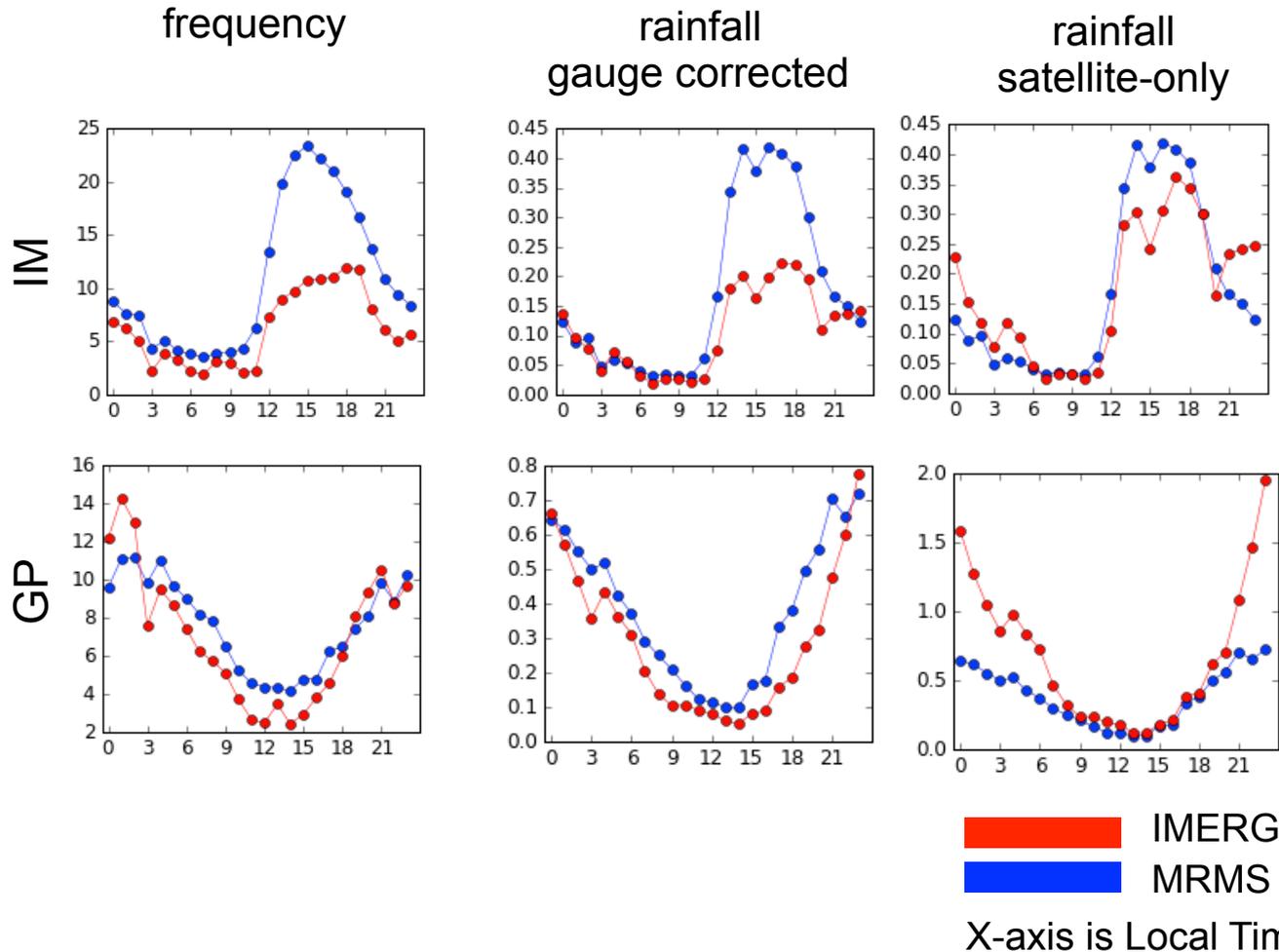
- IM: Intermountain (Rocky)

Plain and Mountain

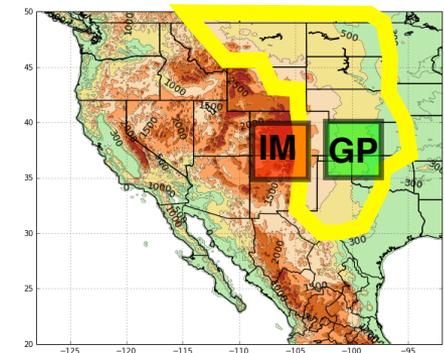
- PNW: Pacific Northwest
- SC: South California
- NAM: NA monsoon region

ref. Carrera et al., 2004; Q Li 2005; Lee et al., 2007

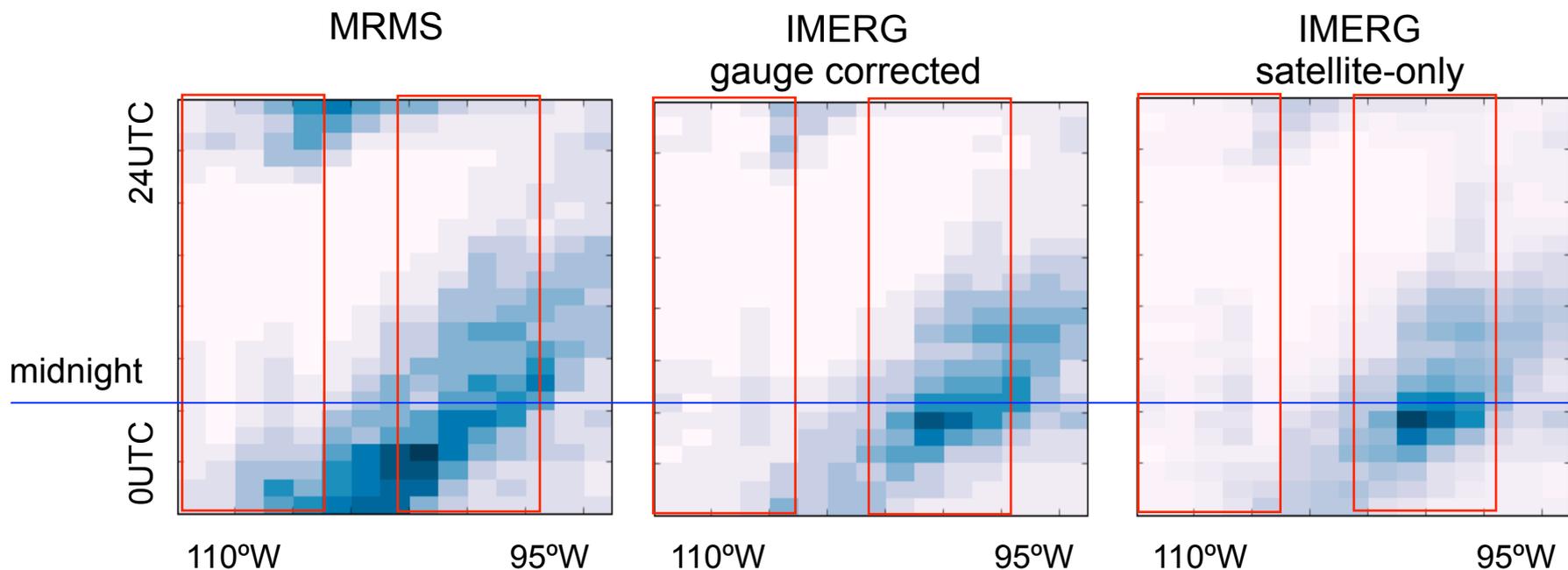
Diurnal cycle comparison in the sub-regions



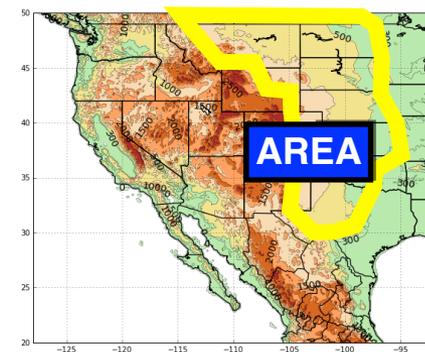
- **average**: averaged rainfall (including zero)
- **frequency**: non-zero data num./each hour's total data num.
- **gauge corrected and satellite-only IMERG** are used.



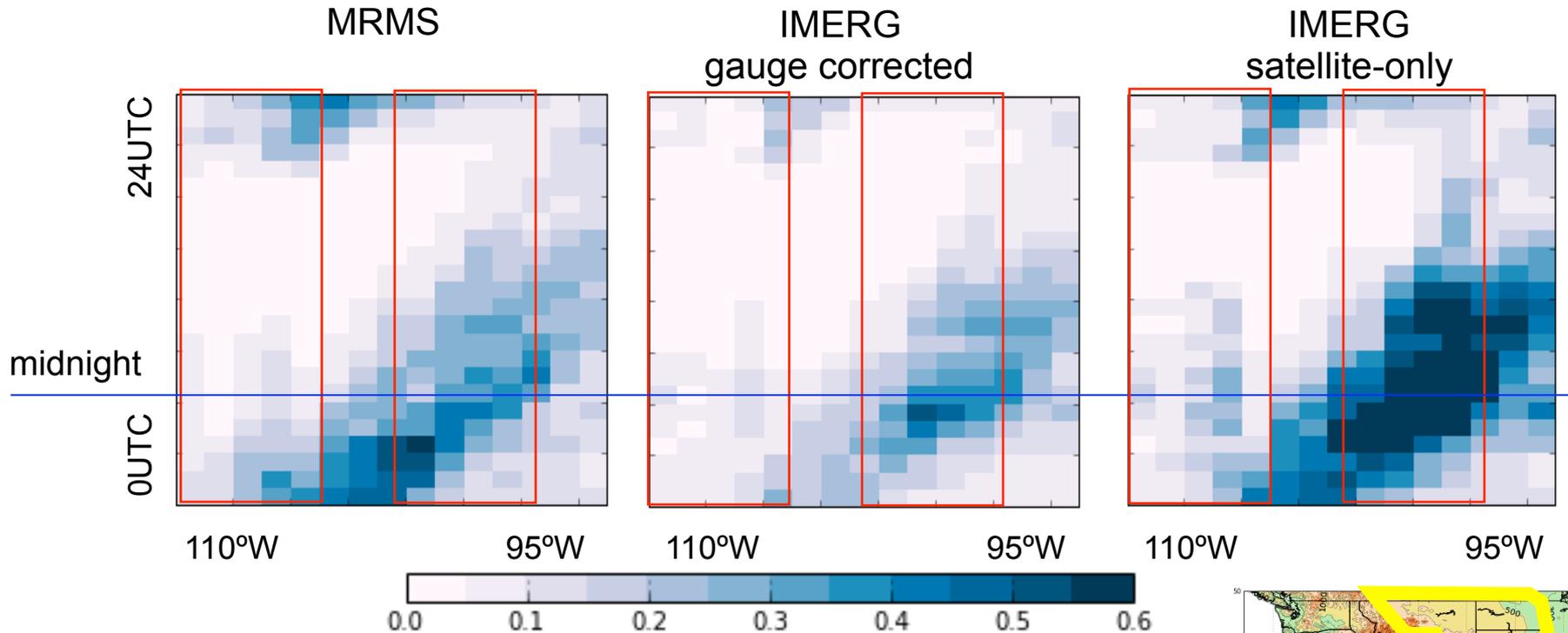
Diurnal cycle comparison in the sub-regions



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

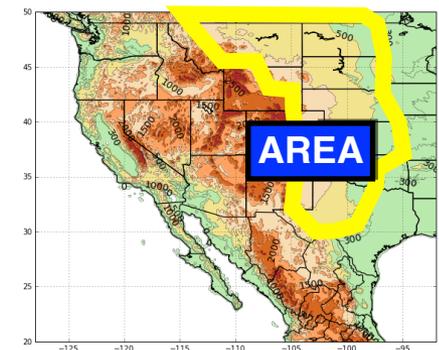


Diurnal cycle comparison in the sub-regions



  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



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_datportal.php

WegenerNet Johnsachtal data portal

<http://nmq.ou.edu/>

MRMS radar data portal

References

Kirchengast, G., et al. (2014): WegenerNet: A pioneering high-resolution network for monitoring weather and climate. *Bull. Amer. Meteor. Soc.*, 95, 227–242

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*)

