Geostationary Precipitation Estimates (GPE): An IR Based Technique

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Outline

- Background
- Objective
- GPE Development
- Global Examinations
- Validation with CWB Radar Data
- Summary and Future Work

Background [1]

- Estimating precipitation from satellites is indispensable
  - *To fill in observation gaps over ocean and sparsely populated land areas*
  - *To enhance observations by gauges and weather radars*

- Precipitation estimates derived from satellite IR measurements play important role together with those from passive microwave (PMW) data
  - *Indirect relationship to precipitation*
  - *Frequent sampling with fine spatial resolution*

Background [2]

- Primary assumptions for IR based precipitation estimates
    - *Precipitation comes from tall clouds with cold cloud top temperature (TBB)*
    - *The taller the cloud, the colder the cloud top temperature, and the heavier the precipitation*

- Primary estimation strategy
    - *Empirical relationship between precipitation and cloud top temperature*
    - *Calibration against ground truth (gauge/radar/satellite PMW retrievals)*

Background [3]

- Primary approaches
  - *Index methods*
    - *Empirical relationship between precipitation and indices computed from TBB*
    - *GOES Precipitation Index (GPI): deriving precipitation from fraction of cloud top temperatures colder than 235K*
  - *PDF matching*
    - *Matching the probability density function (PDF) of TBB against co-located ground truth (radar / PMW retrievals)*
    - *Naval Research Lab (NRL, Turk et al. 2004)*
    - *NASA TRMM Multi-sensor Precipitation Analysis (TMPA)*
    - *IRFREQ (input to CMORPH1)*
  - *AI (neural network)*
    - *Calibrating the TBB array against ground truth (PMW)*

Objective

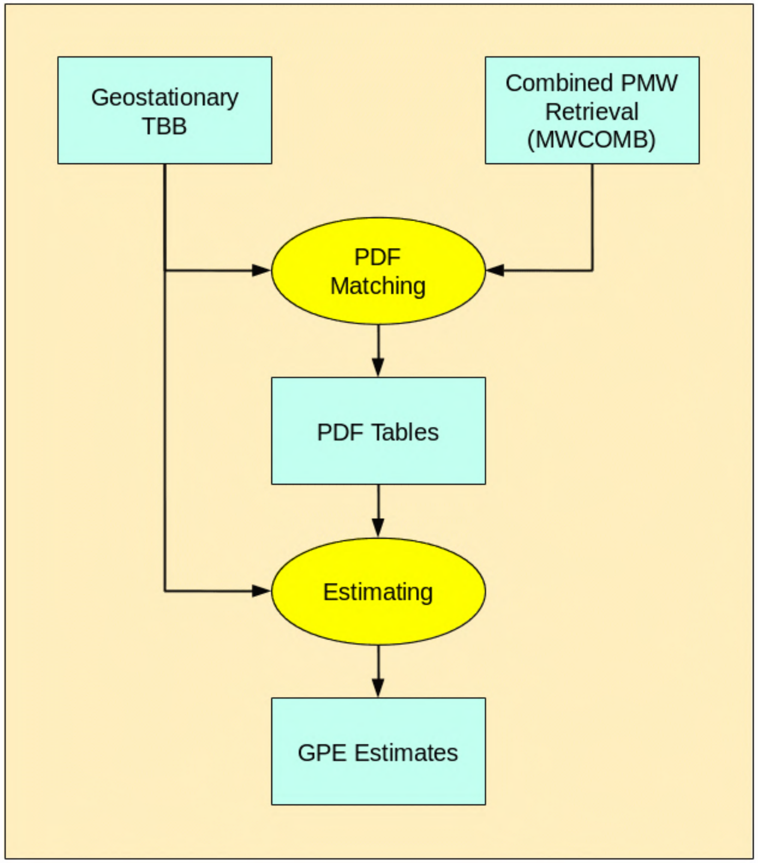
- To develop a technique that derives high-resolution global precipitation estimates from geostationary satellite observed TBB data
  - *To be used as one of the inputs to the second generation CMORPH integrated satellite precipitation products;*
  - *Might be also used independently;*
  - *Long-term record of temporal homogeneity;*
  - *Real-time production at very short latencies;*

GPE Development

1) Approach and Flow Chart

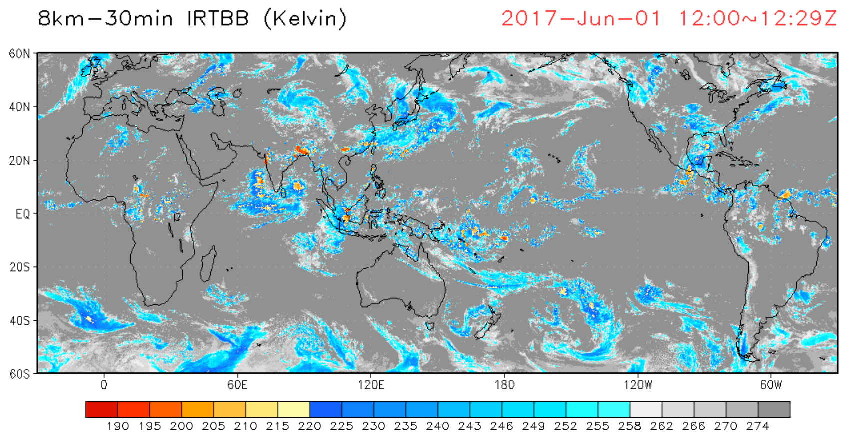
- Assumptions
  - *Passive microwave (PMW) retrievals presents reasonable quality everywhere over the globe but with limited temporal / spatial sampling*
  - *GEO IR provides quasi complete spatial coverage, fine spatial resolution and frequent temporal sampling*
  - *Precipitation – TBB relationship is monotonic, non-linear, and regionally, seasonally, diurnally dependent*
- Strategy
  - *Take the MWCOMB as the ground truth to calibrate the GEO TBB*
  - *Precipitation – TBB relationship is established locally and evolves with time through matching the PDF of TBB against that of the MWCOMB*

GPE Algorithm



GPE Development

2) Input TBB and MWCOMB



Global TBB array:

- *Defined through inter-calibrating and combining parallax corrected TBB from 5 GEOs*
- *0.04ºlat/lon converted to 0.05ºlat/lon over the globe (60ºS-60ºN)*
- *30-min interval*

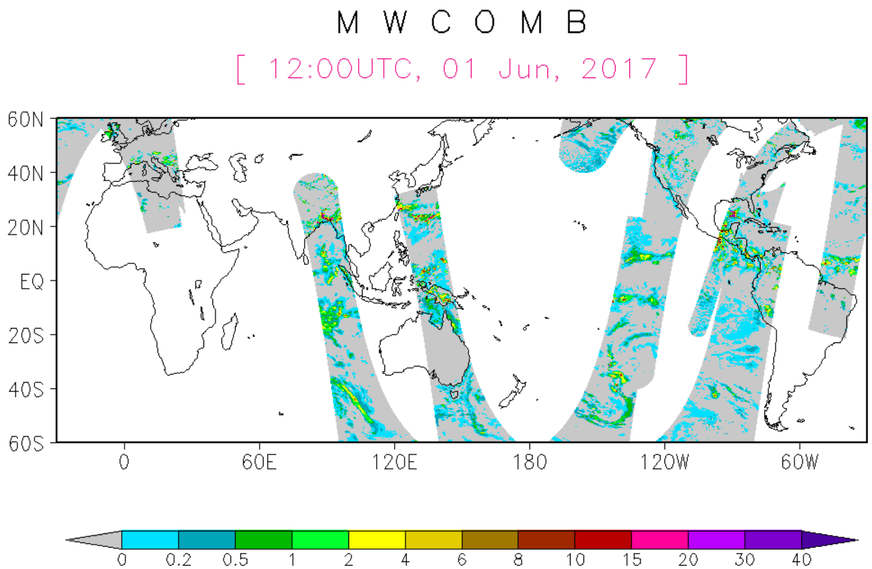
MWCOMB:

•Defined through inter-calibrating and combining PMW retrievals from ~10 LEO satellites

•0.05ºlat/lon over the globe (90ºS-90ºN)

•30-min interval

•Large portions of missing gaps due to LEO sampling patterns

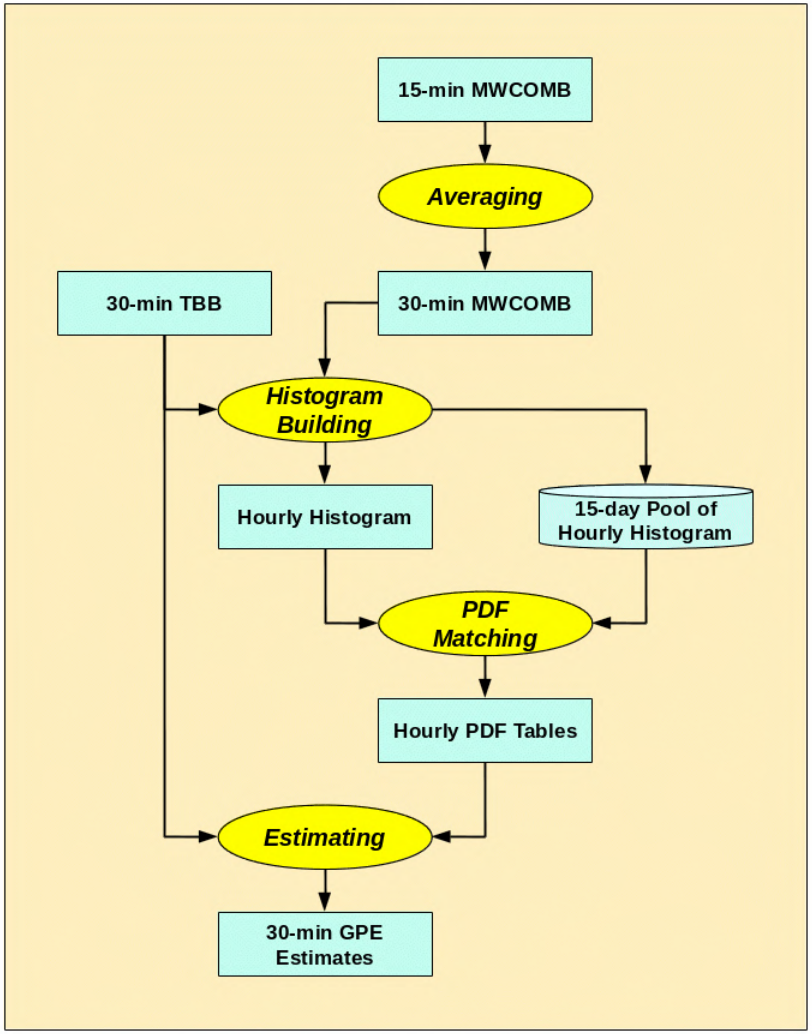


GPE Development

3) Algorithm Implementation

- *Co-locatedTBB / MWCOMB data pairs collected;*
- *Histograms for TBB and MWCOMB assembled for each **0.5ºlat/lon** and for each hour;*
- *PDF tables (cumulated histogram) constructed for each hour and for each 0.5ºlat/lon using histograms for a **7-hour** duration centering at the target hour, for a **31-day** period centering at the target date and over a spatial domain of **1.5ºlat/lon** centering at the target grid box;*
- *The data (histogram) collecting domain is expanded until at least **2000 pairs** of raining cases are included;*
- *The established PDF tables are then converted to a precipitation – TBB relationship assuming TBB at a certain percentile is associated with precipitation at the same percentile*

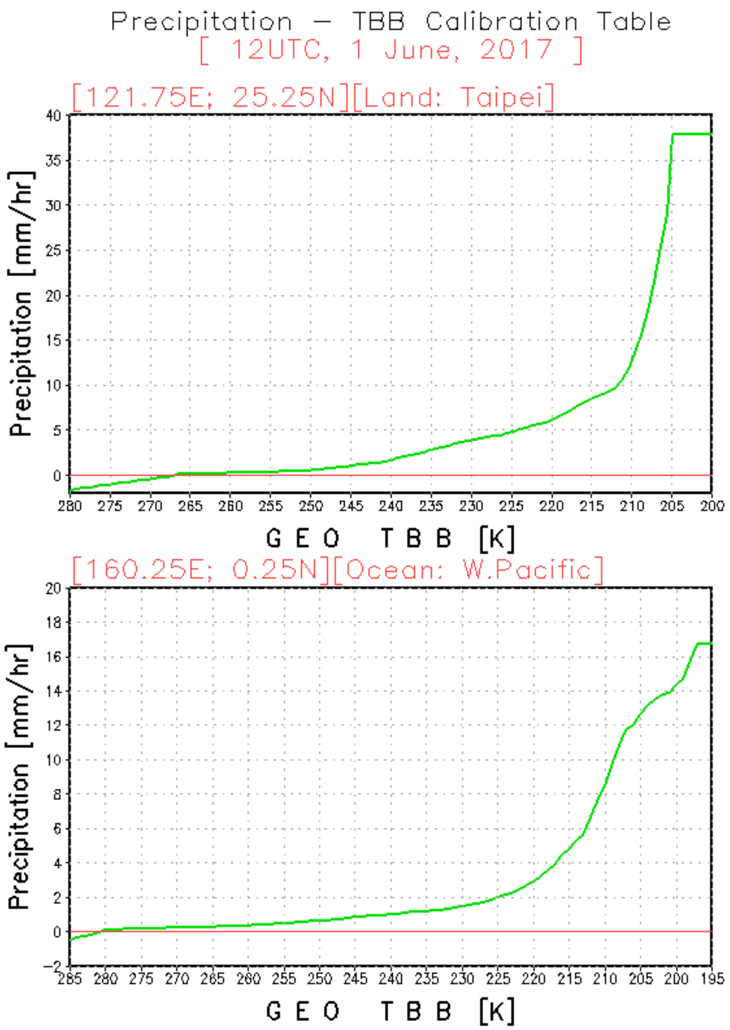
GPE Algorithm



GPE Development

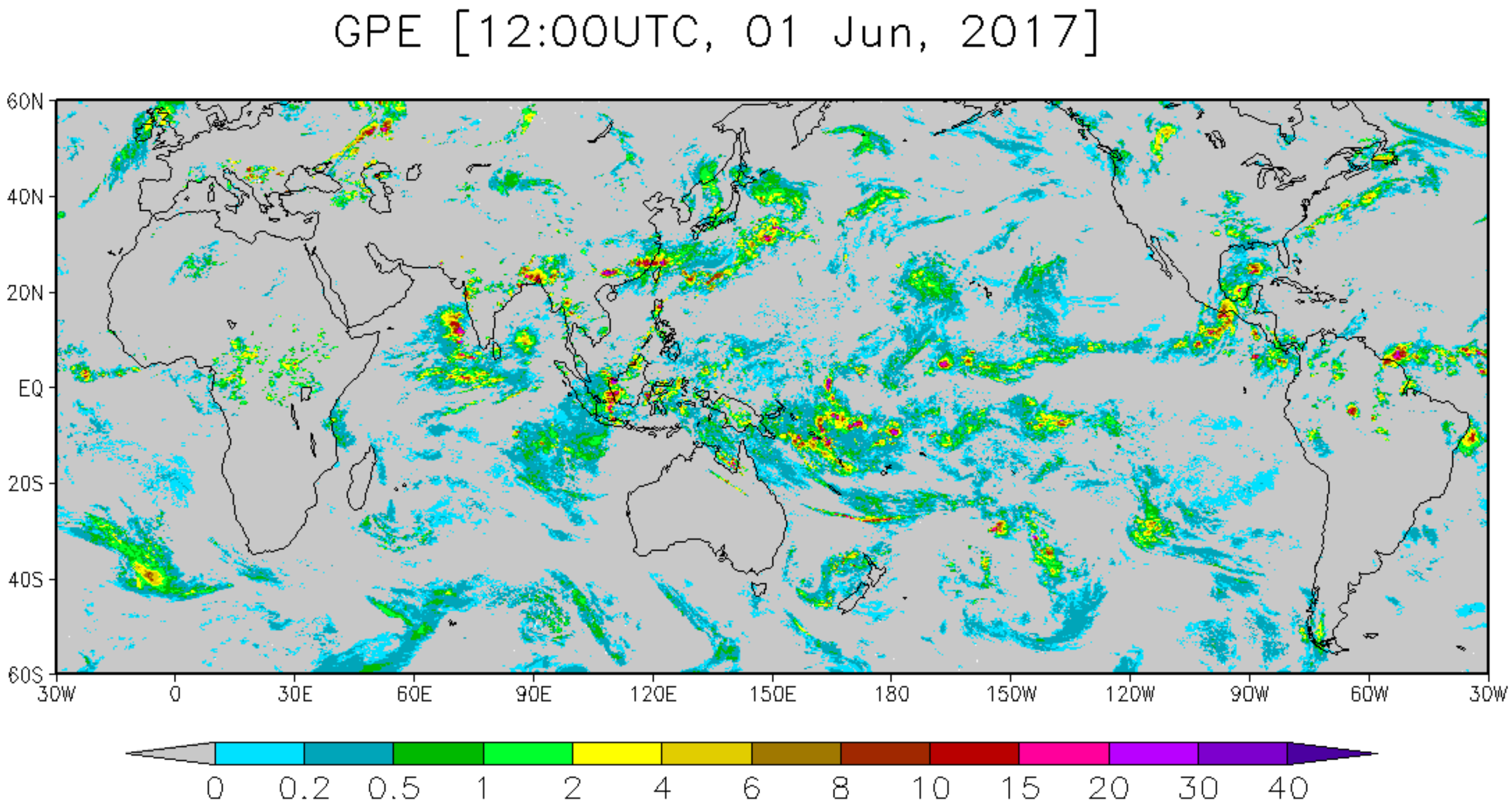
4) Sample Precipitation – TBB Calibration Curves

- *Top:*
  - *example of land case (Taipei)*
- *Bottom:*
  - *Example of oceanic case (W. Pacific)*
- *Negative precipitation:*
  - *Curves extend into negative precipitation for warmer TBB, reserved for future use in inter-calibration against other references*



GPE Development

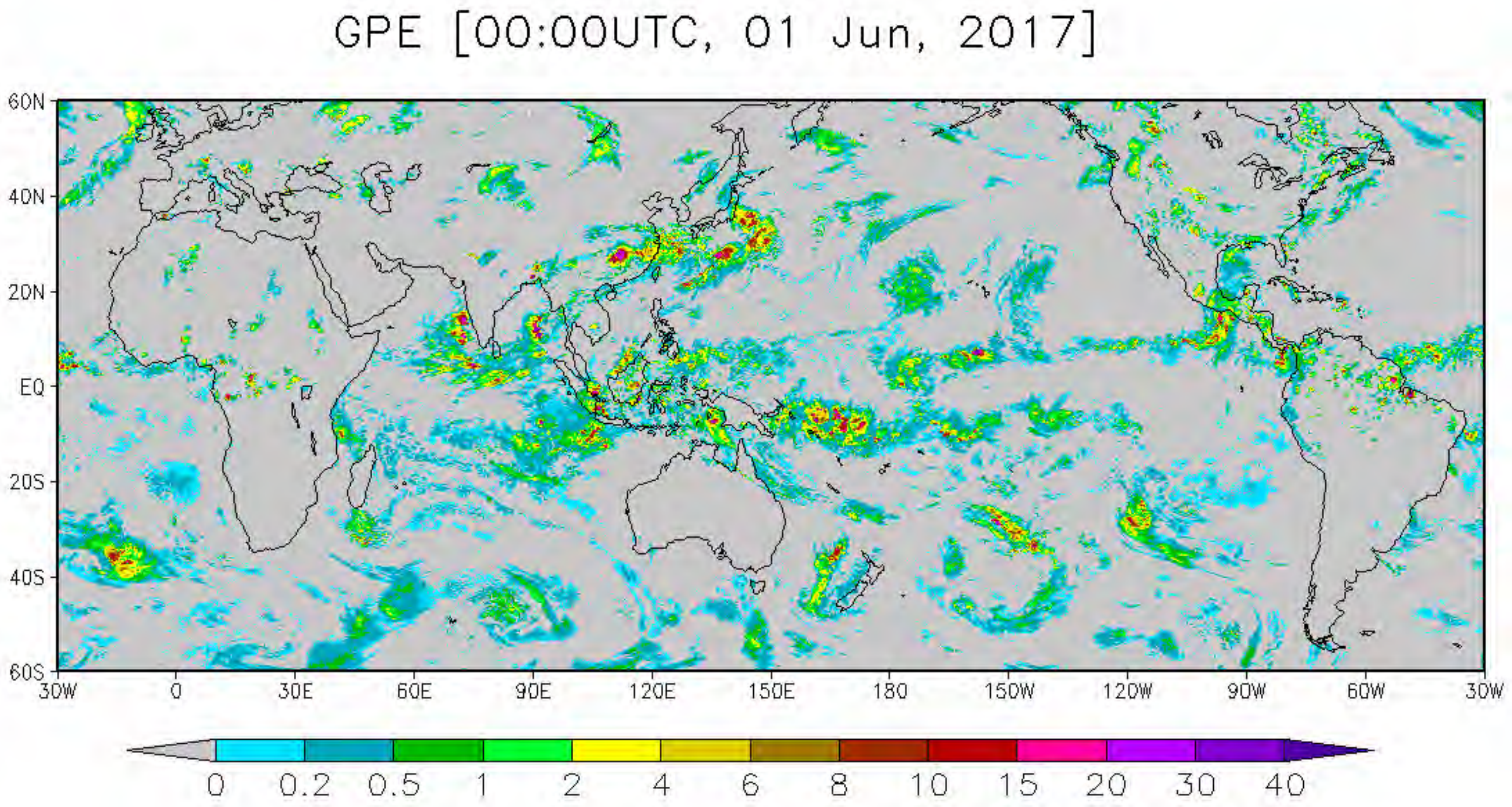
5) Sample Global Precipitation Estimates [GPE]



For convenience purpose, we name this new product as
*‘**Global Precipitation Estimates [GPE]**’.*

GPE Development

6) Sample GPE Animation



GPE Development

7) Current Status

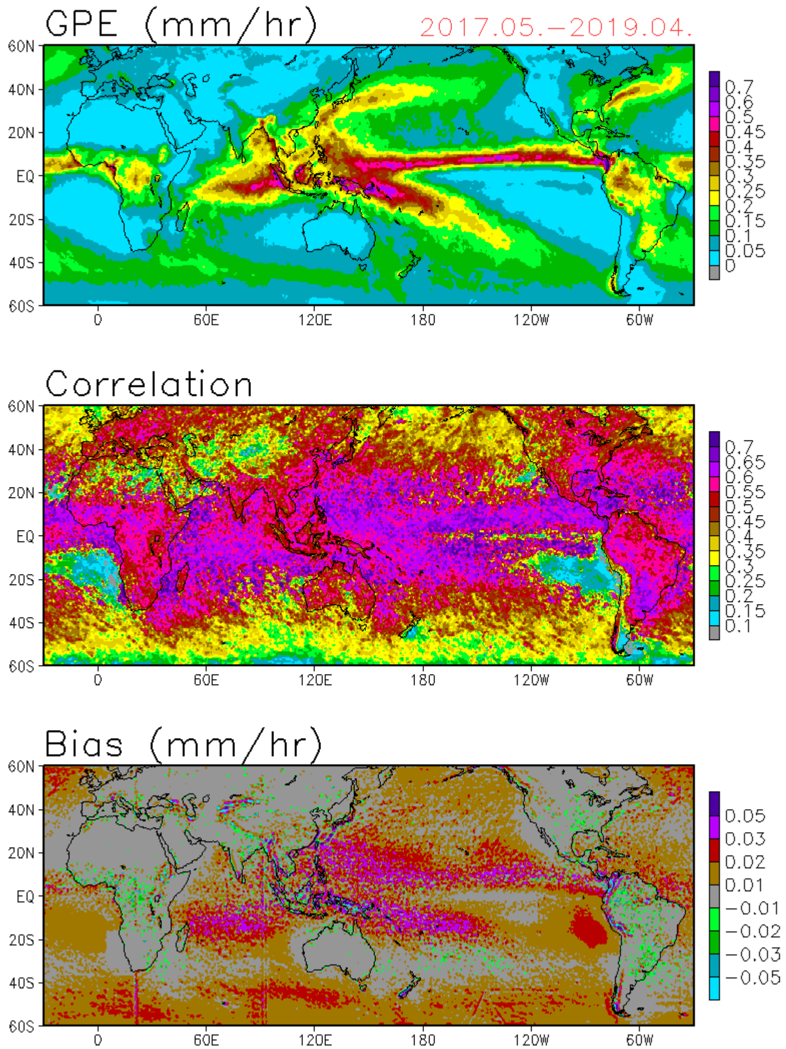
- Retrospective Processing
  - *Completed for May 2017 to April 2019;*
  - *Pending retrospective processing of MWCOMB;*

- Real-time Production
  - *A processing system is being migrated to a supercomputer for real-time production;*
  - *Algorithm developed for retrospective processing is modified to facilitate the real-time production at short latencies*
    - *Co-located data pairs collected over the past 15 days; throughout the 24 hours diurnal cycle for the most recent 3 days, and for a 7-hour duration only centering at the target hour for the rest 12 days;*
    - *The production starts at a latency of 1 hour and repeated once an hour with the updated MWCOMB until 12 hours after the target time*

Global Examinations

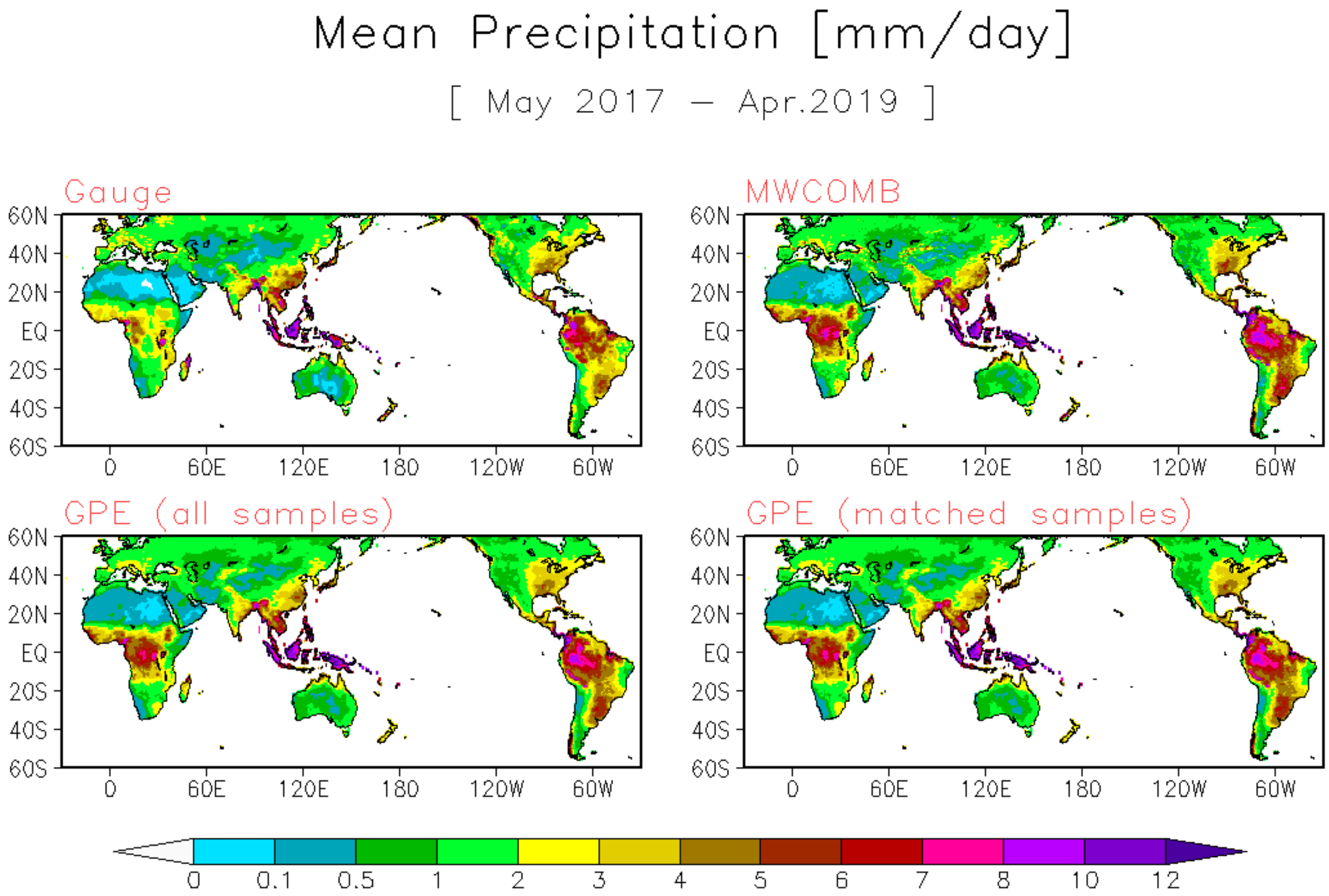
1) Dependent Examinations against MWCOMB

- ***(Objective)*** *To make sure the algorithm is capable of re-producing the MWCOMB at a reasonable accuracy*
- ***(right)*** *comparison of GPE at 0.05ºlat/lon / 30-min against MWCOMB*
- *Quite good performance in reproducing MWCOMB with high correlation and small biases*



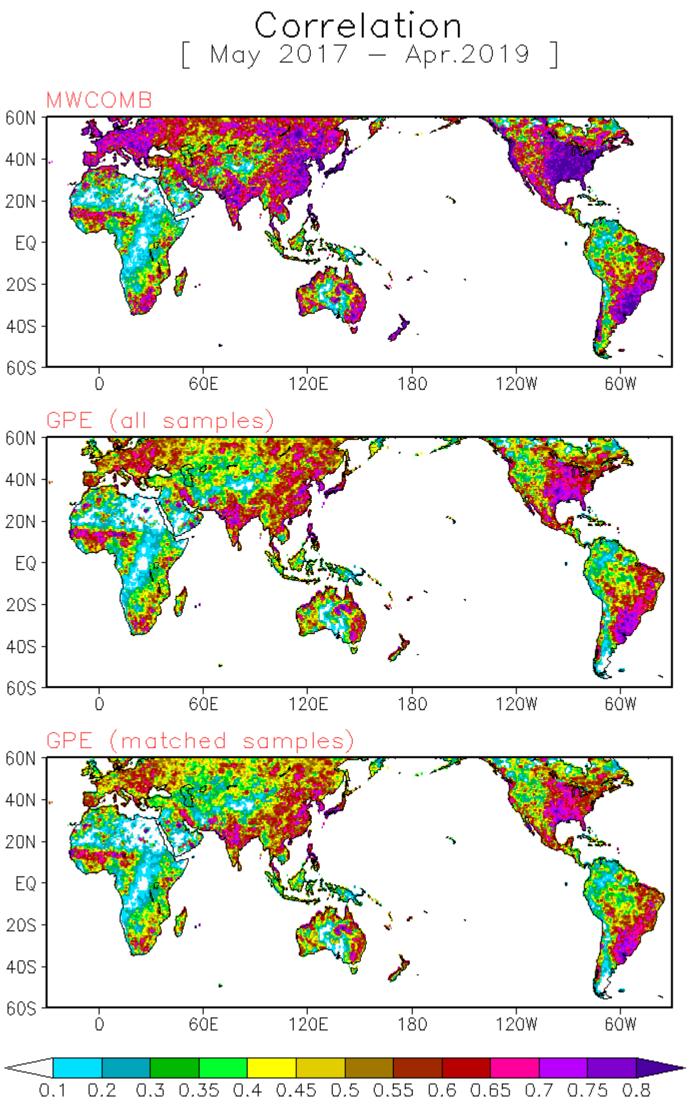
Global Examinations

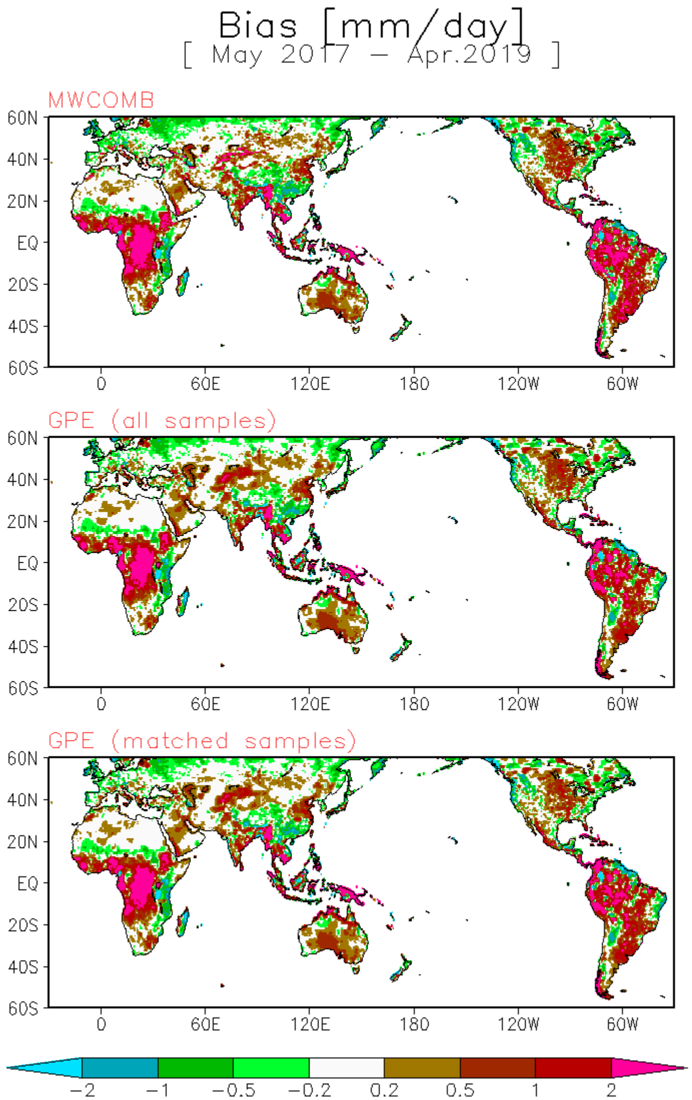
2) Comparison against CPC Daily Gauge Analysis [1/3]



Global Examinations

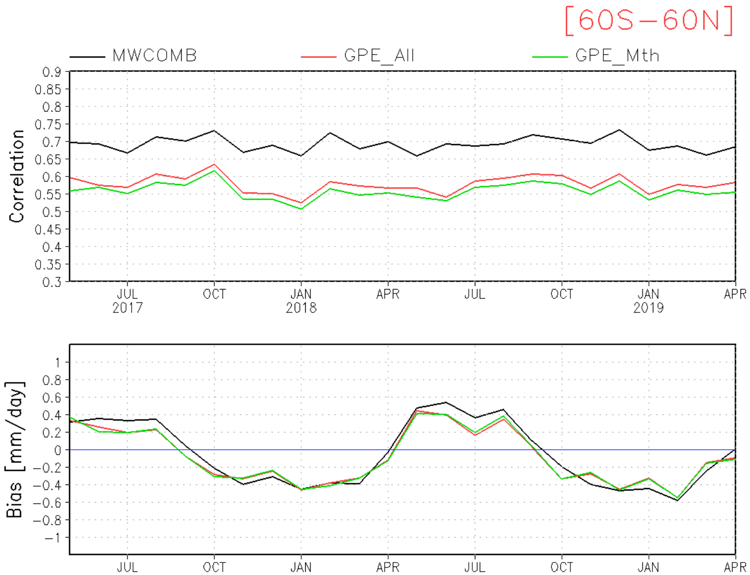
2) Comparison against CPC Daily Gauge Analysis [2/3]

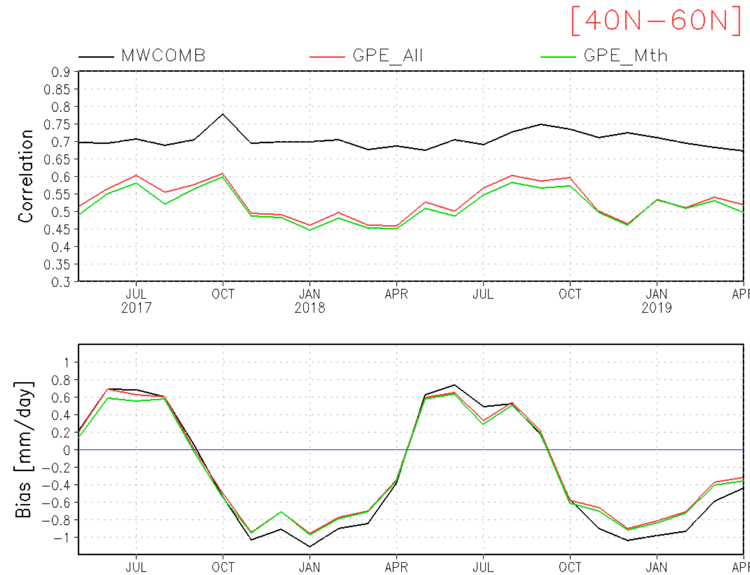


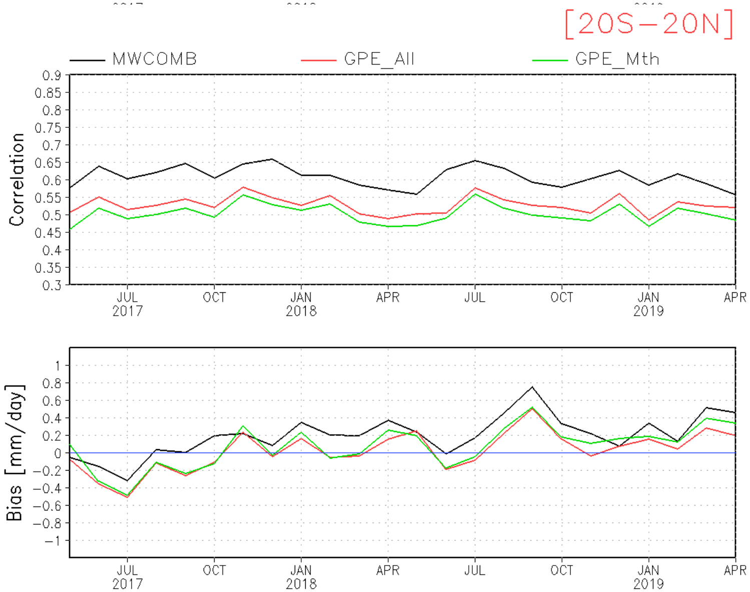


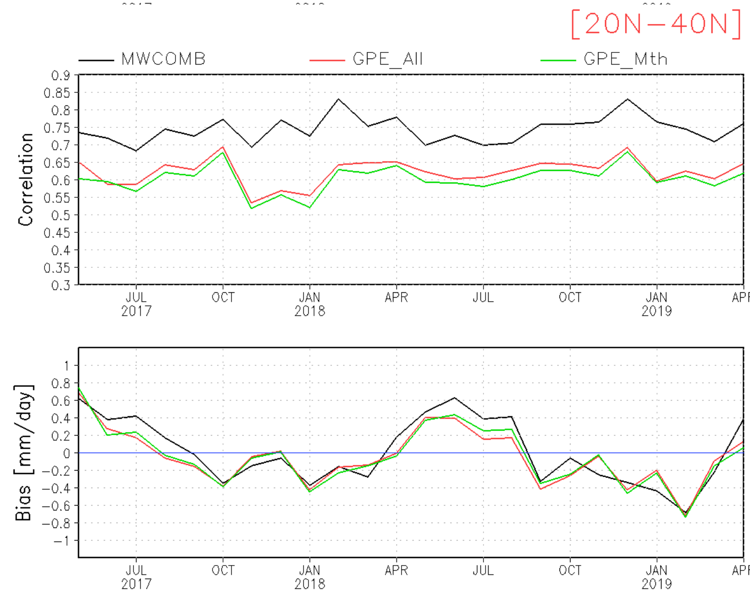
Global Examinations

2) Comparison against CPC Daily Gauge Analysis [3/3]









Validation with CWB Radar Data

1) Objective

- To get a first insight into the performance of the high-resolution precipitation estimates derived from the geostationary TBB (GPE);

- In particular, we would like to know:

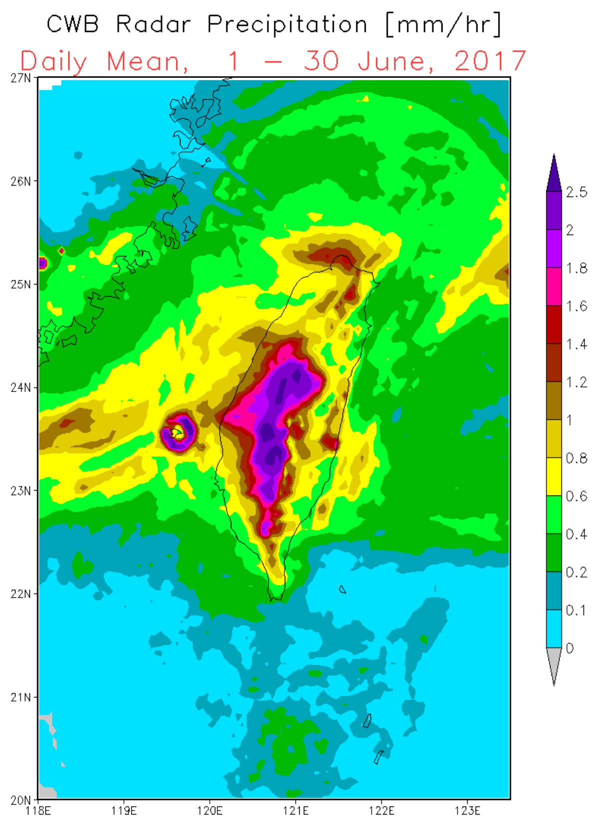
  - *How well the GPE reproduces the precipitation information depicted in its calibrator, the CPC combined passive microwave retrievals (MWCOMB); and*

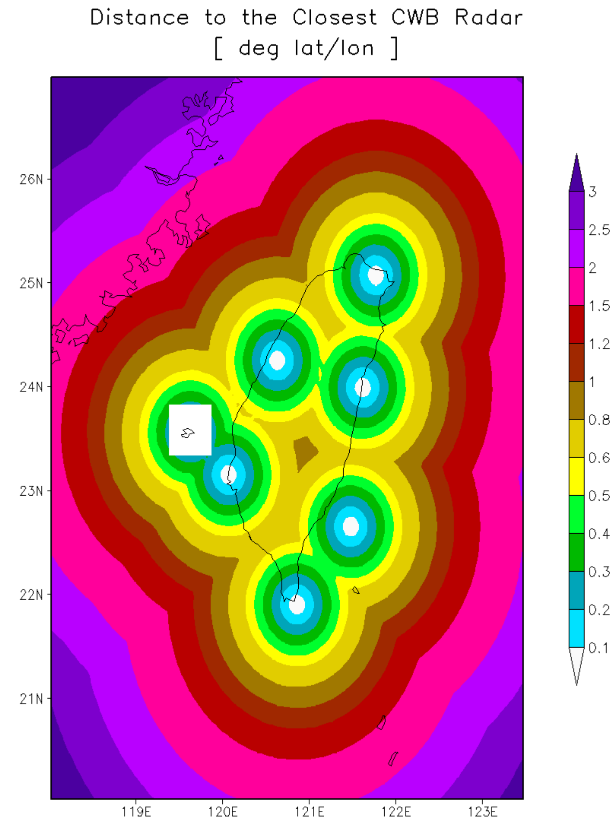
  - *How well the GPE and the MWCOMB2 perform compared against the ground 'truth' of precipitation as depicted by radar observations*

Validation with CWB Radar Data

2) CWB Radar Data

- Provided by Taiwan Central Weather Bureau (CWB);
- Native data arrays of 10-min precipitation on 0.0125ºlat/lon grid;
- Up-scaled to 30-minute precipitation on 0.05ºlat/lon grid;
- Overall very good quality over land (gauge corrected) and over oceanic regions not far away from radar sites;
- An area around the Penghu Island is masked out to avoid contamination of fault heavy rainfall (a ring) caused by hardware malfunction;





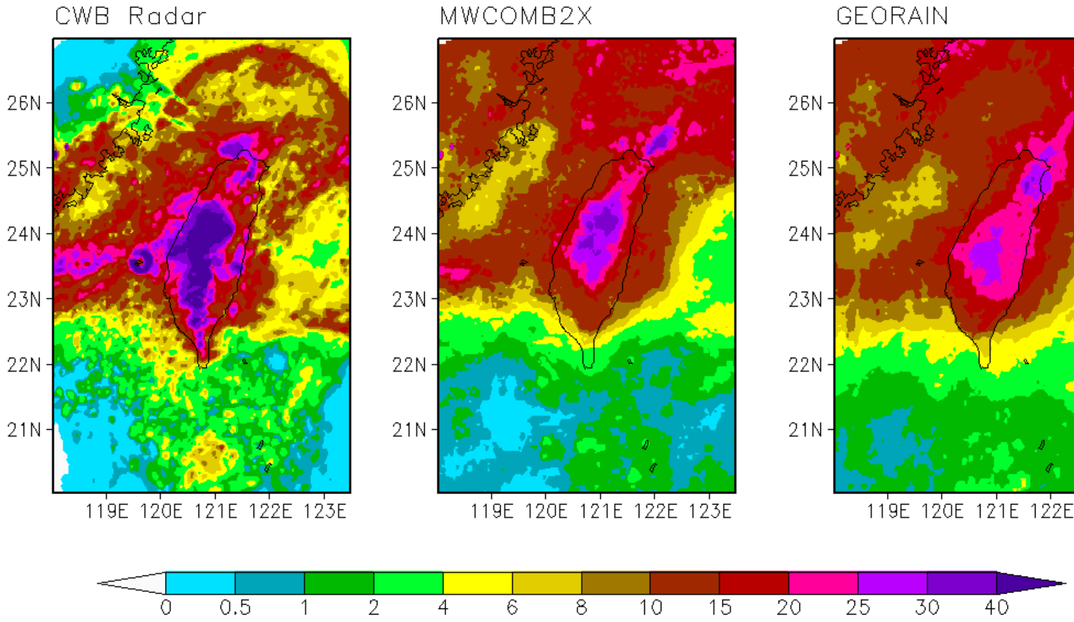
Validation with CWB Radar Data

3) Comparison Strategy

- A three-way comparison is made among the CWB radar, the MWCOMB2X, and the GPE, to quantify the performance of the two satellite products;
- Comparisons are made for precipitation on a total of 3x3=9 combinations of time (30-min,hourly,daily)s/ space resolutions (0.05^{o}, 0.10^{o}, 0.25^{o}) to understand the performance as a function of accumulating scales;
- Over ocean, only data within 80-km to the closest radar sites are included in the comparison to ensure reasonable quality of the radar precipitation estimates as the ground 'truth';
- Data over a square area over and near the Penghu Island is excluded from the comparison for the combined time / space domain;

Validation with CWB Radar Data

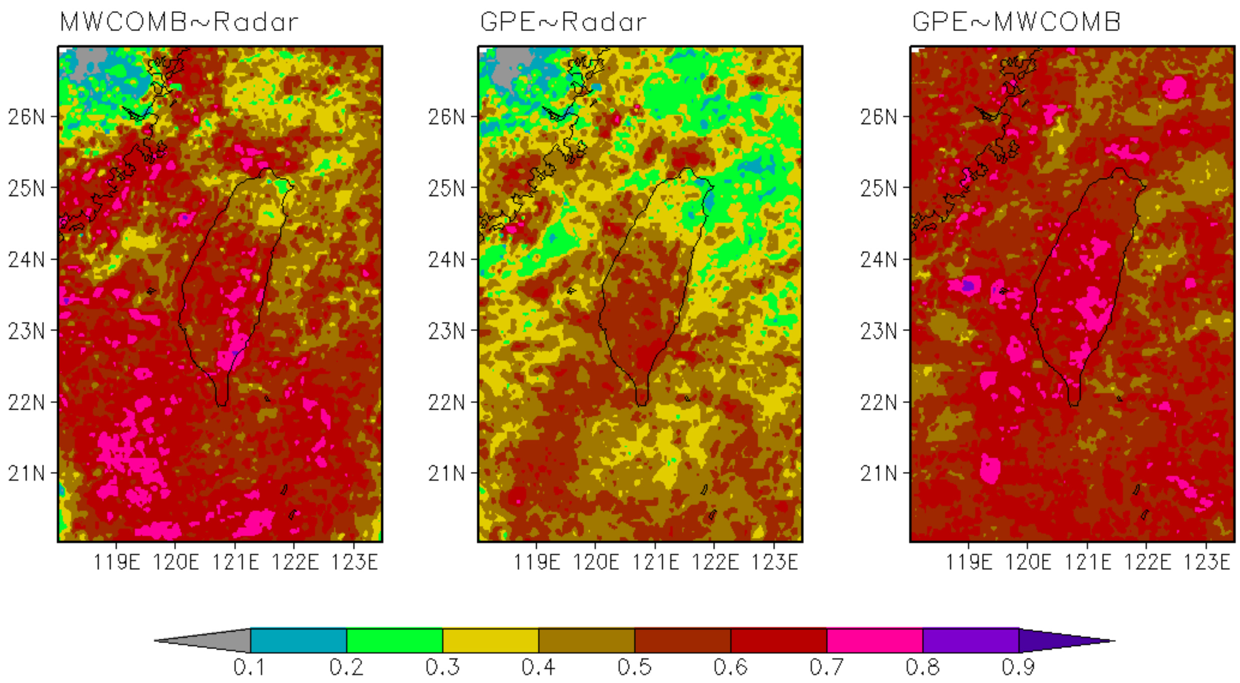
4) Mean Precipitation [June 2017]



- Only data when / where all three are available are utilized in the calculation;
- The MWCOMB captures the overall spatial distribution patterns of the precipitation depicted in the CWB radars. In particular, the band of heavy rainfall along the west side of the mountain ridge is reproduced very well. Precipitation over the southern and northern tips of the island, however, is under-estimated;
- The GPE also captures the overall spatial patterns of the precipitation quite well, although not as good as its calibrator, the MWCOMB. The band of heavy rainfall in the GPE, however, is expanded westward, an artifact probably caused by imperfect reflection of the rapid spatial variations of TBB – precipitation relation over this region of complex topography;

Validation with CWB Radar Data

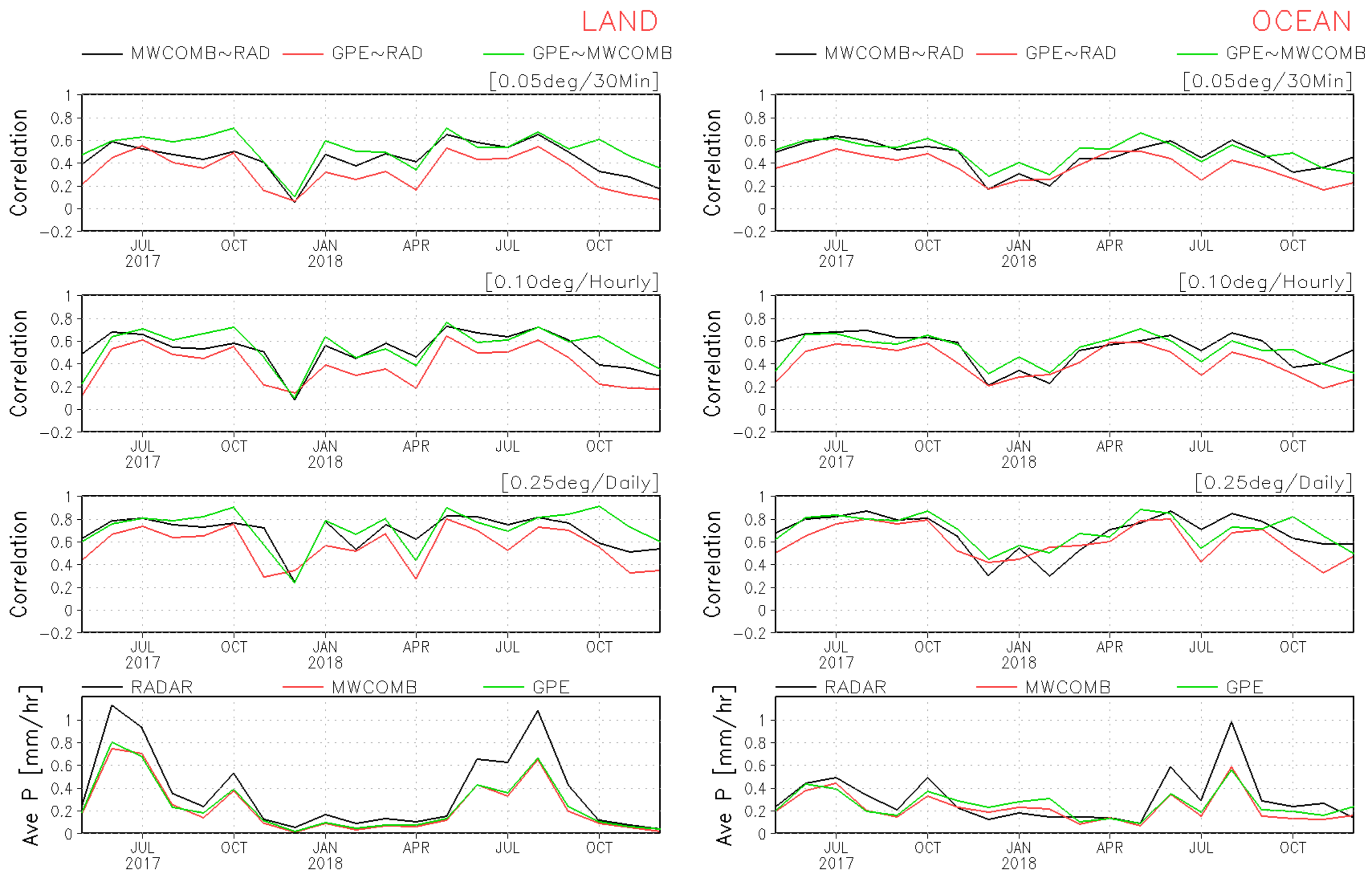
5) Correlation for Precipitation at 0.05°lat/lon / 30-min



- Calculated using data from May 2017 to Dec 2018
- Quite high correlation between GPE and MWCOMB, indicating GPE reproduced MWCOMB very well;
- Both MWCOMB and GPE present good correlation with radar over most of the Taiwanese land and adjacent oceans, but correlation degrades over NW corner of Taiwan;

Validation with CWB Radar Data

6) Performance Metrics as a function of Time



Validation with CWB Radar Data

7) Correlation for precipitation of various scales

MWCOMB~Radar	Ocean			Land		
Scale	*0.05º*	*0.10º*	*0.25º*	*0.05º*	*0.10º*	*0.25º*
30-min	0.528	0.580	0.689	0.552	0.613	0.720
Hourly	0.558	0.603	0.698	0.592	0.652	0.750
Daily	0.726	0.744	0.794	0.774	0.801	0.845

GPE ~ Radar	Ocean			Land		
Scale	*0.05º*	*0.10º*	*0.25º*	*0.05º*	*0.10º*	*0.25º*
30-min	0.413	0.446	0.541	0.476	0.511	0.610
Hourly	0.442	0.470	0.546	0.496	0.529	0.609
Daily	0.653	0.664	0.707	0.736	0.755	0.795

GPE~MWCOMB	Ocean			Land		
Scale	*0.05º*	*0.10º*	*0.25º*	*0.05º*	*0.10º*	*0.25º*
30-min	0.558	0.584	0.638	0.623	0.649	0.709
Hourly	0.564	0.589	0.635	0.627	0.656	0.709
Daily	0.776	0.786	0.806	0.831	0.840	0.863

Summary and Future Work

1) General

- A technique (GPE) developed to derive precipitation estimates from the geostationary TBB through calibration against PMW retrievals (MWCOMB);

- GPE is capable of producing precipitation estimates of very high resolution (30-min, 5km) with quite good performance over most of the globe, especially over tropics and sub-tropics;

- Further improvements are needed to deal with the **cold season precipitation** and **orographic rainfall**. The calibrator (MWCOMB) used in the current version does not capture the precipitation very well under the two situations, while the data collection domain probably is too large to reflect the rapid changes of precipitation – cloud relationship over regions with significant orographic effects;

- Work is underway:
  - Complete the migration of the real-time processing system to a super computer system;
  - Continue the retrospective processing with the current version algorithm

Summary and Future Work

2) Suggestions to CWB Colleagues

- Satellite precipitation estimation should be a useful addition to the weather / climate monitoring tools for precipitation
  - Extending the coverage to oceans
  - Enhancing radar coverage over regions of beam blockage et al
  - Removing range-dependent bias in the radar precipitation estimates

- H8 IR based precipitation estimates could be a starting point
  - Fine time /space resolution
  - Stable real-time availability of TBB data

- Orographic effects need to be better represented
  - Fundamental importance for precipitation estimation for Taiwan and adjacent oceans
  - Estimates in global products (GPE, CMORPH, IMERG, GSMaP) not optimized for performance over a region of specific meteorological conditions