Can High Resolution Climate Models Reproduce Rainfall Extremes Associated with Tropical Cyclones?

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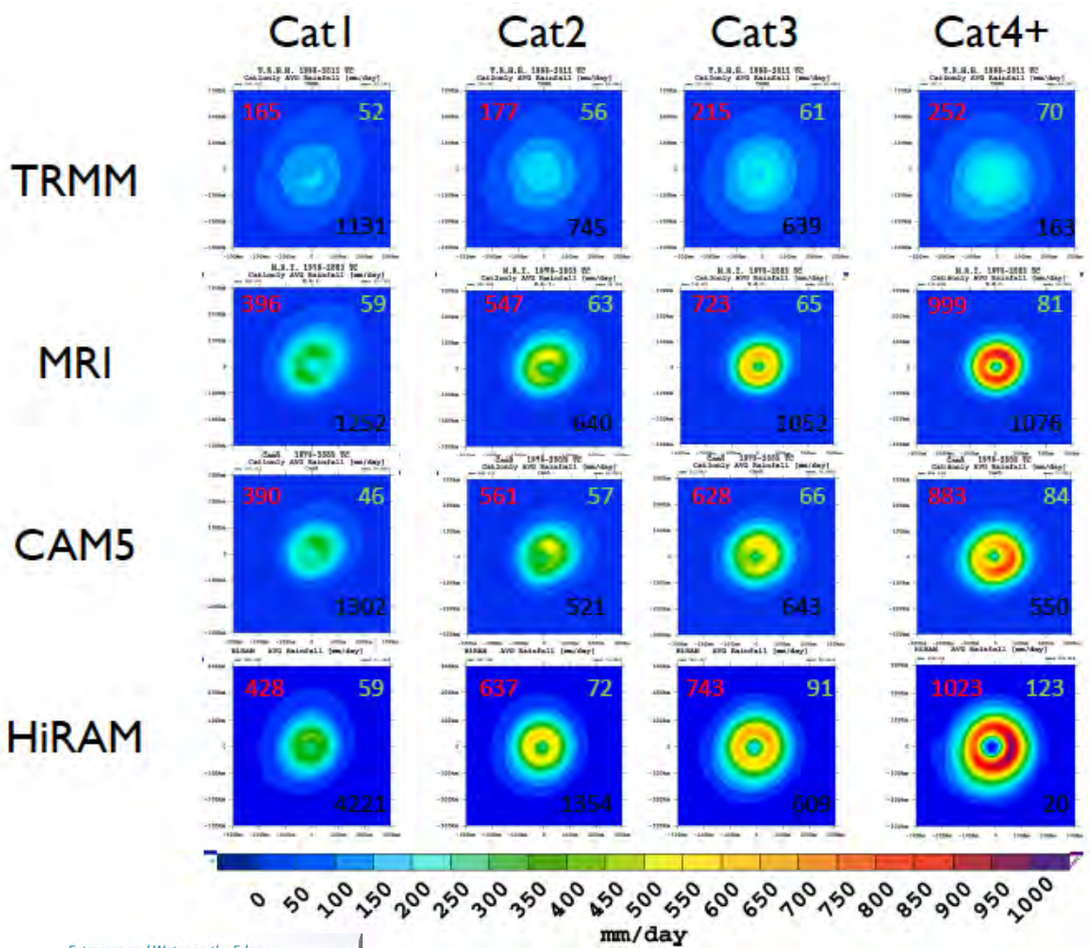
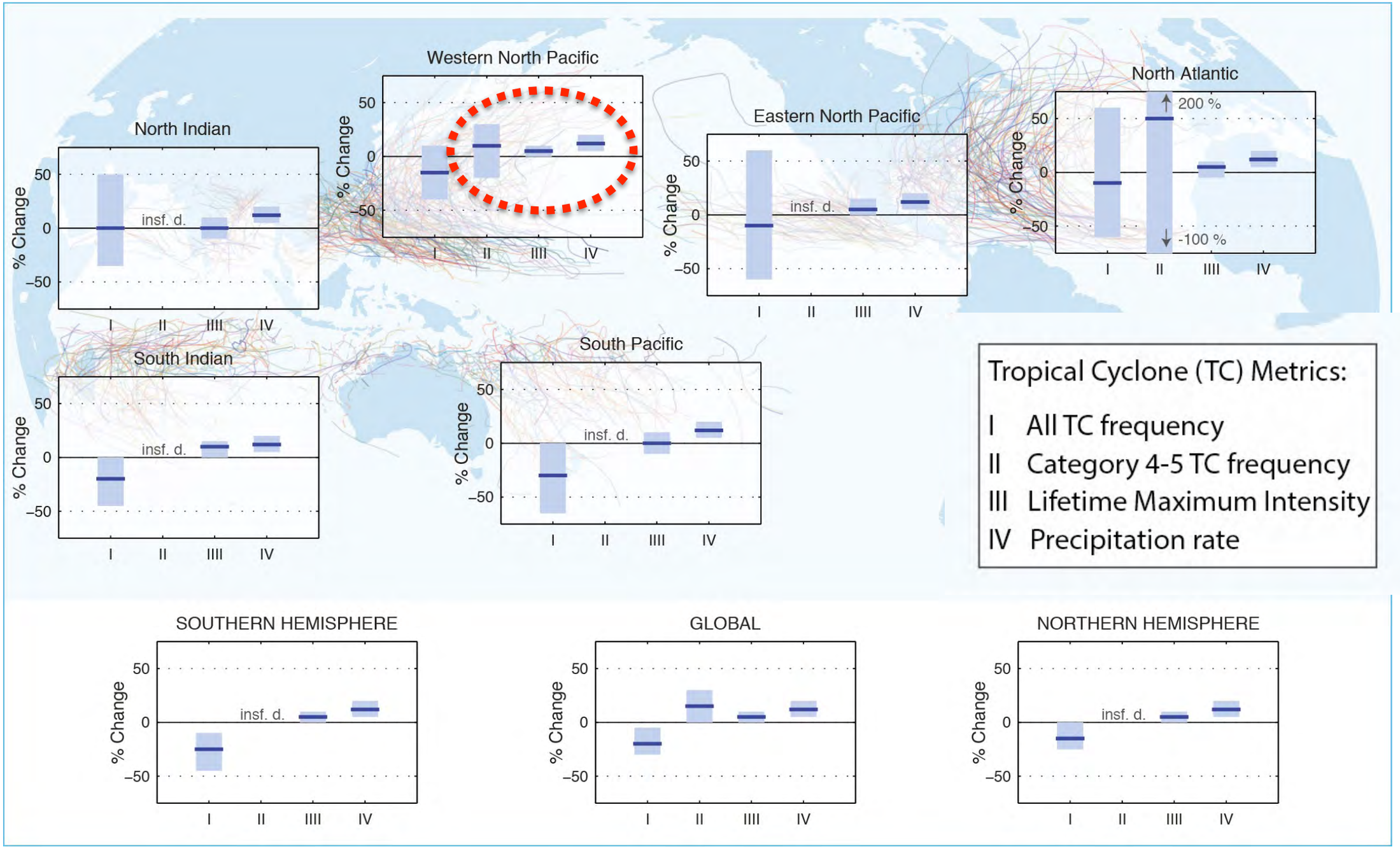


- Background and Motivation
- Model Validation and Comparison: Rainfall associated Tropical Cyclone
- Reliability of Satellite Rainfall Retrieval Against Surface Rainfall Observation associated Tropical Cyclone
- TRMM PR vs. Merged Product 3B42
- Summary

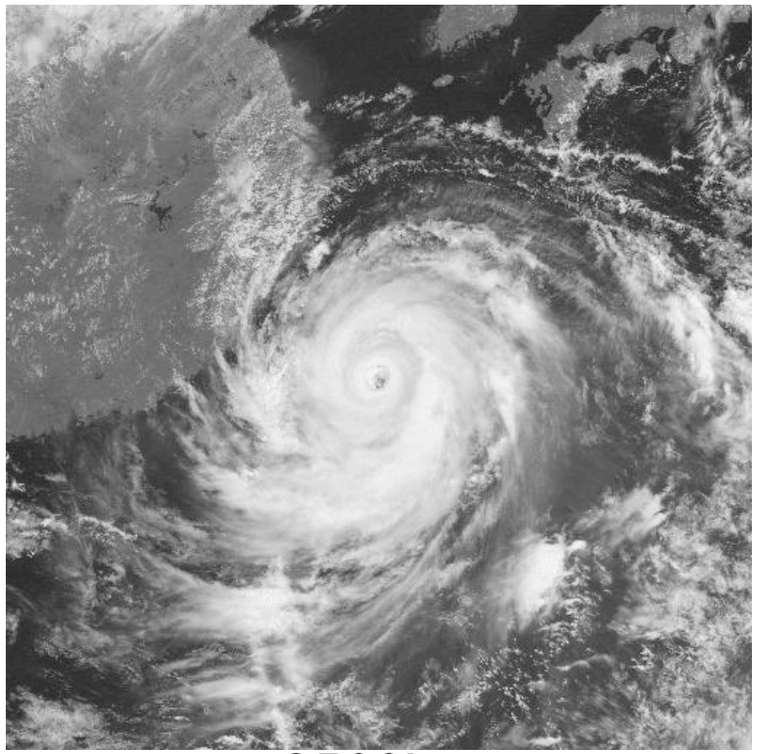
8th GEWEX Open Science Conference
Canmore, 6-11 May 2018

Climate models project increasing tropical cyclone intensities and accumulated rainfall with climate warming …

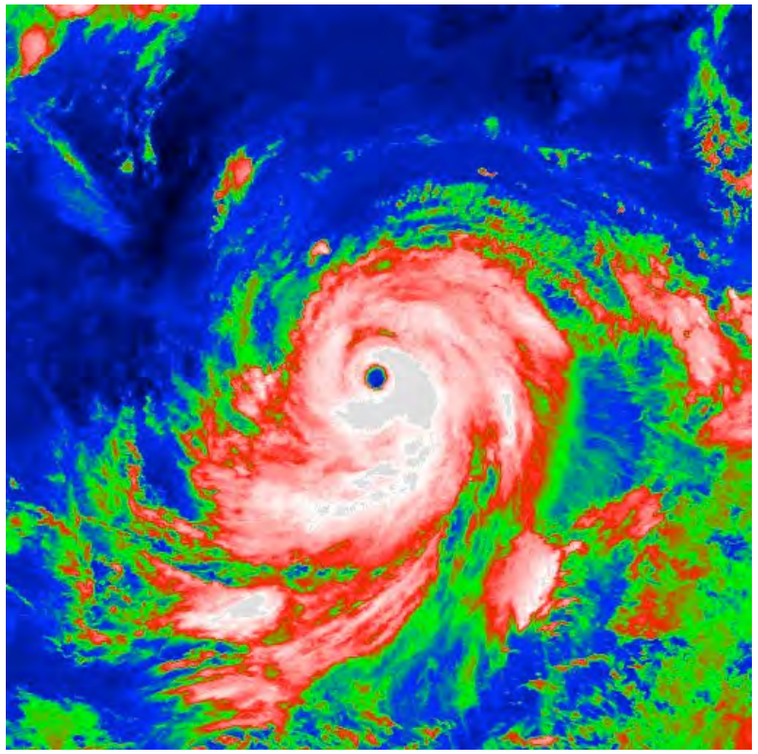


IPCC AR5 (2013)

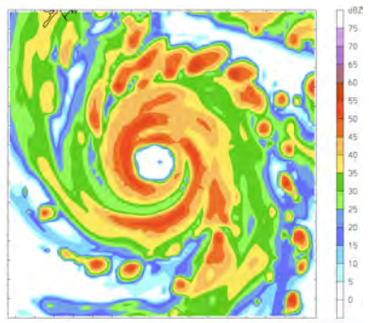
Typhoon Herb
1996



2500km



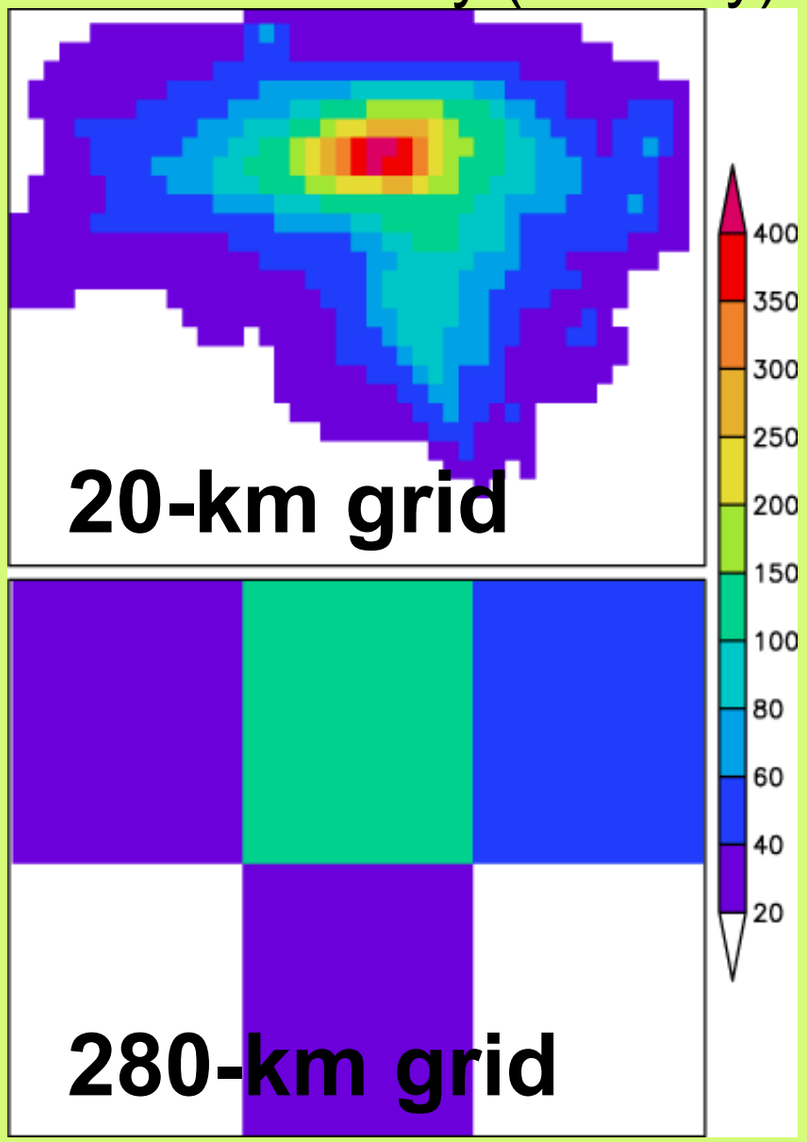
High-resolution climate model probably still can't properly resolve extreme rainfall and typhoon intensity



320km

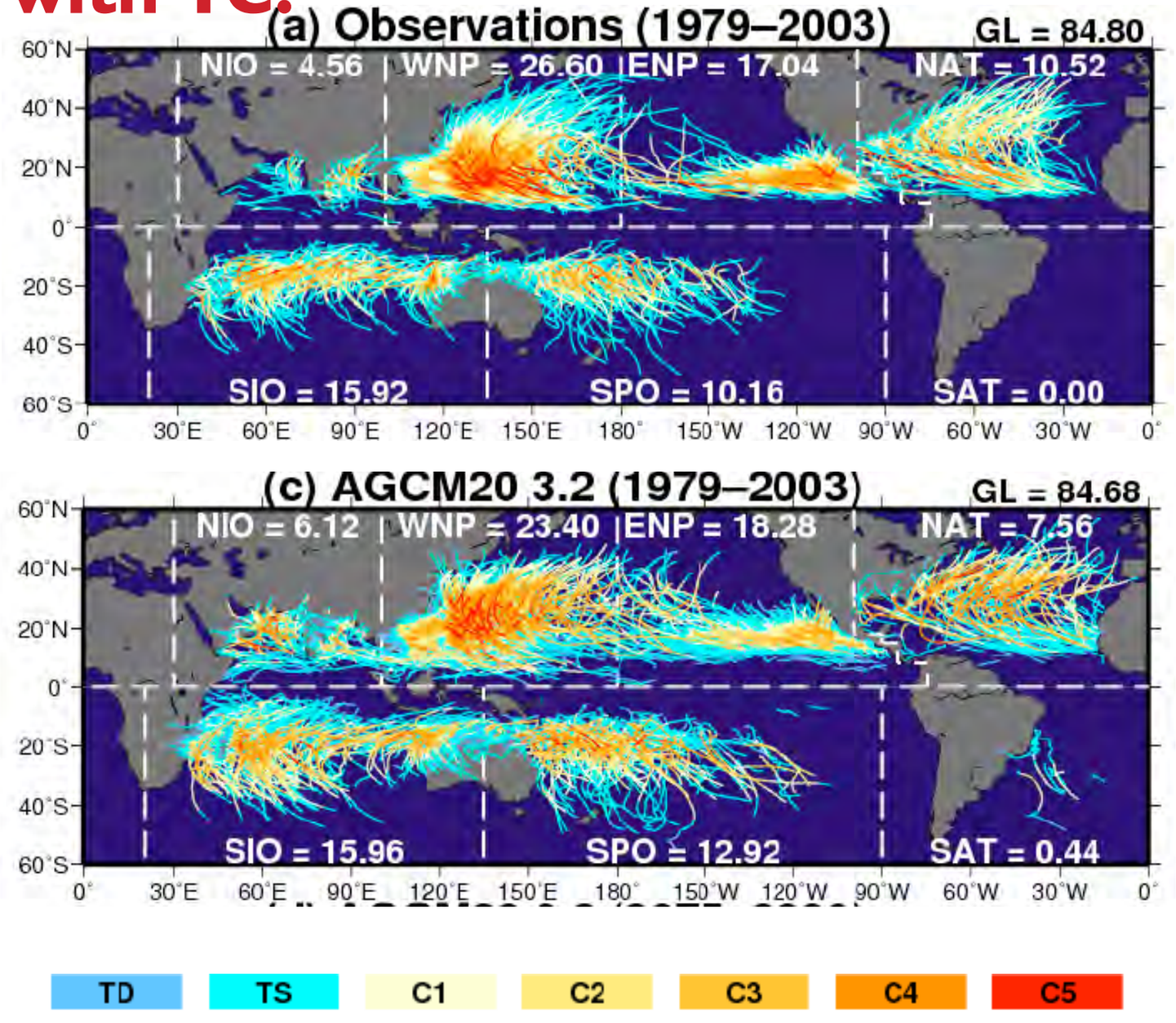
WRF simulation at
4 km resolution

Daily precipitation amount
on certain day (mm/day)

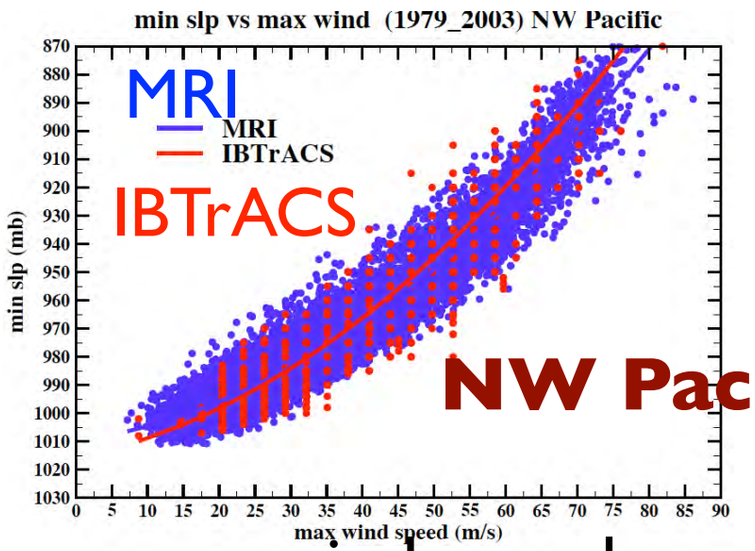


High-resolution climate model (e.g. MRI 20-km mesh model) can produce reasonable distribution of tropical cyclones (TC) frequency and intensity. (Murakami et al. 2012)

But **how reliable are model simulated rainfall associated with TC?**

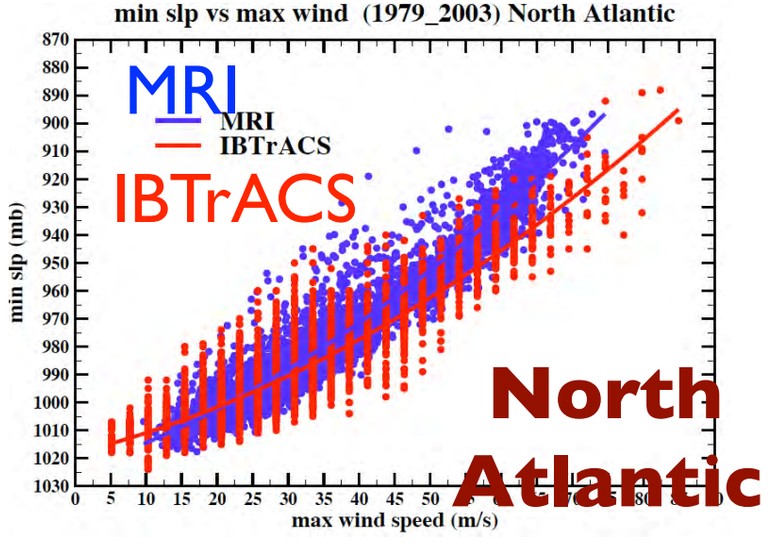


min SLP



max wind speed

min SLP



max wind speed

High-resolution AGCM Time Slice Experiments

Present-day climate experiment (1979 - early 2000s MRI, CAM, HiRAM) observed sea surface temperature (SST) and sea-ice concentration

MRI AGCM 3.2

- Based on operational JMA-GSM
- Resolution: TL959(20km) with
- 64 vertical levels (top 0.01 hPa)
- Physics
  - Cumulus convection: Yoshimura scheme (Mizuta et al 2012)
  - Cloud: Tiedtke (1993), ECMWF (2004)
  - Radiation: JMA (2007)
  - Land hydrology: MJ-SiB: SiB with 4 soil-layers and 3 snow-layers
  - PBL: Mellor & Yamada (1974,1982) level-2 closure model
  - Gravity wave drag: Iwasaki et al. (1989) + Rayleigh friction

NCAR CAM5.1

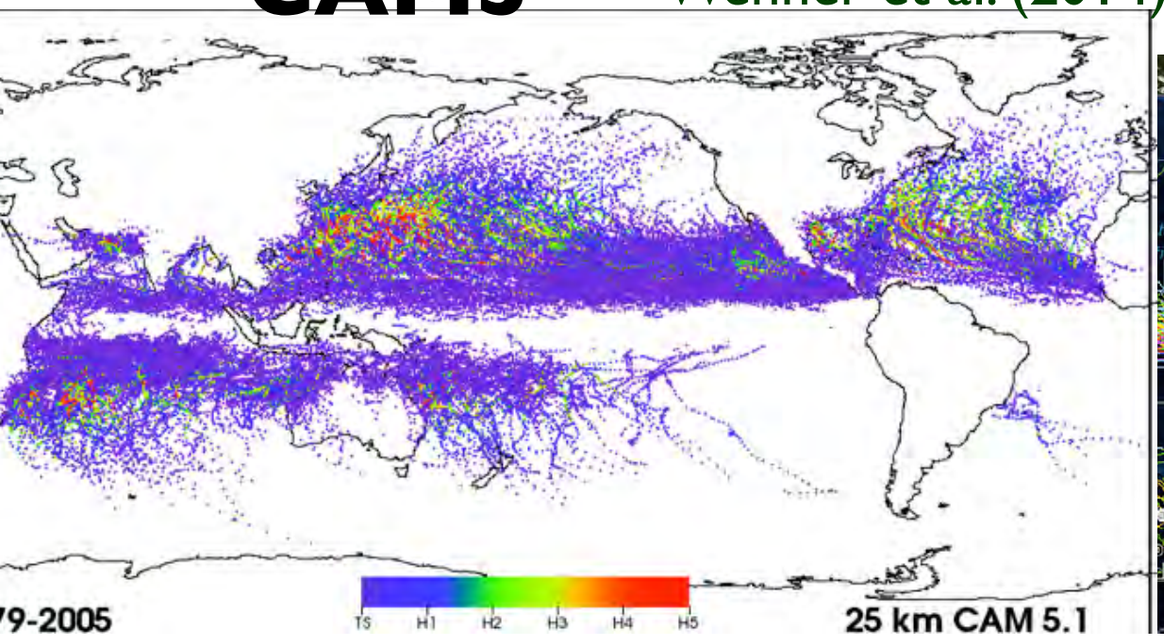
- Standard release version 5.1 with time dependent prescribed aerosol forcing. No further tuning.
- Observed ozone, CO2, solar forcing
- Resolution: 0.23 x 0.31
- 30 vertical levels (top 2 hPa)
- Physics
  - Deep convection: Zhang and McFarlane (1995)
  - Shallow convection: Park and Bretheerton (2009)
  - Radiation: RRTMG (Iacono et al. 2008)
  - Land: Community Land Model CLM2 (Bonan et al., 2002)

GFDL HiRAM

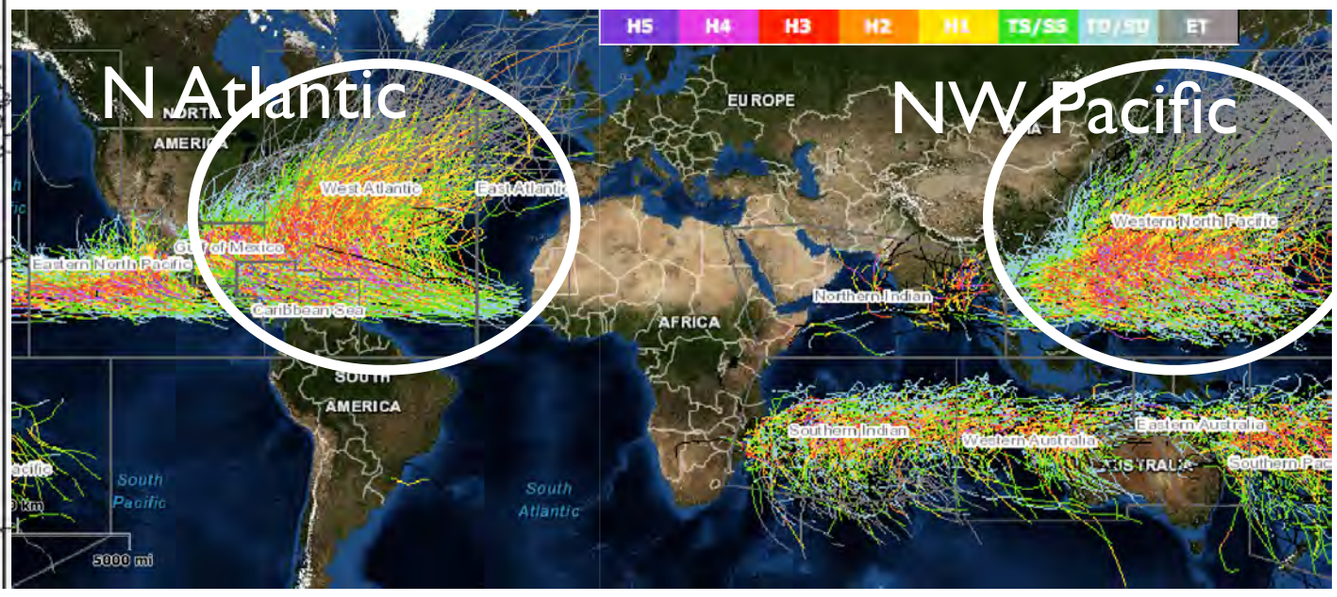
- Sharing the codes with GFDL AM2/AM3 except running with Non-hydrostatic Cubed-sphere Finite-Volume dynamical code
- Resolution: C384 (~23km)
- 32 vertical levels (top 1 hPa)
- Physics
  - Non precipitating shallow convection scheme (Bretherton et al. 2004)
  - 6-category single-moment bulk cloud microphysics with time implicit treatment of microphysics processes
  - Surface fluxes modified for high-wind situation over ocean (Moon et al. 2007)

Limited by computational resources, only a few high resolution global climate models can really reproduce intense tropical cyclone (major hurricane or super typhoon)

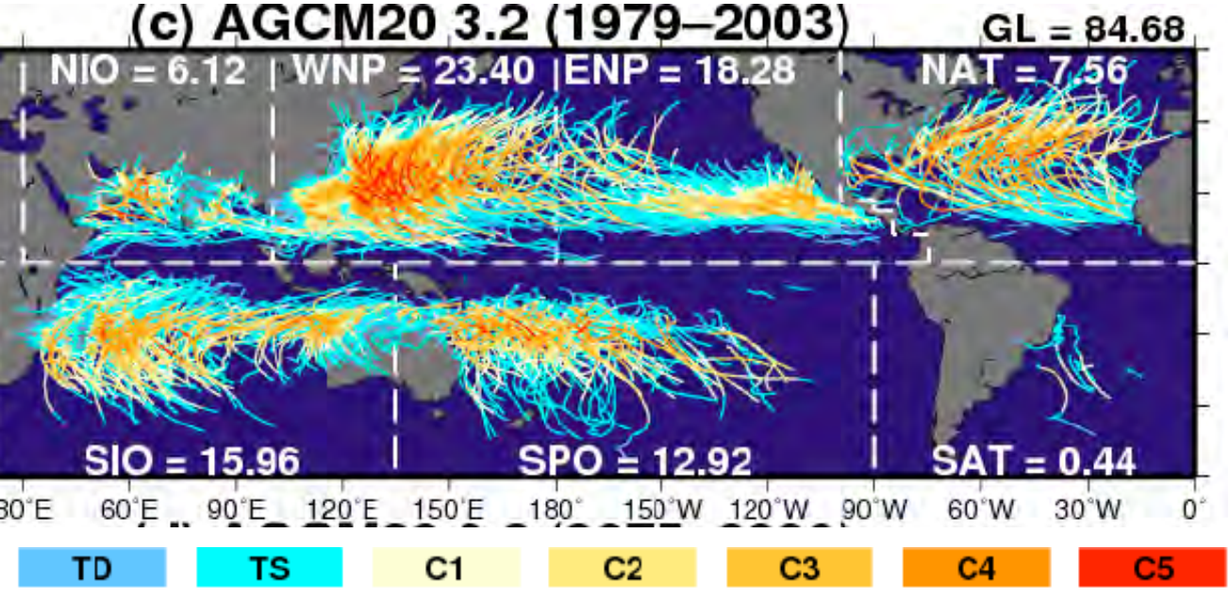
CAM5 Wehner et al. (2014)



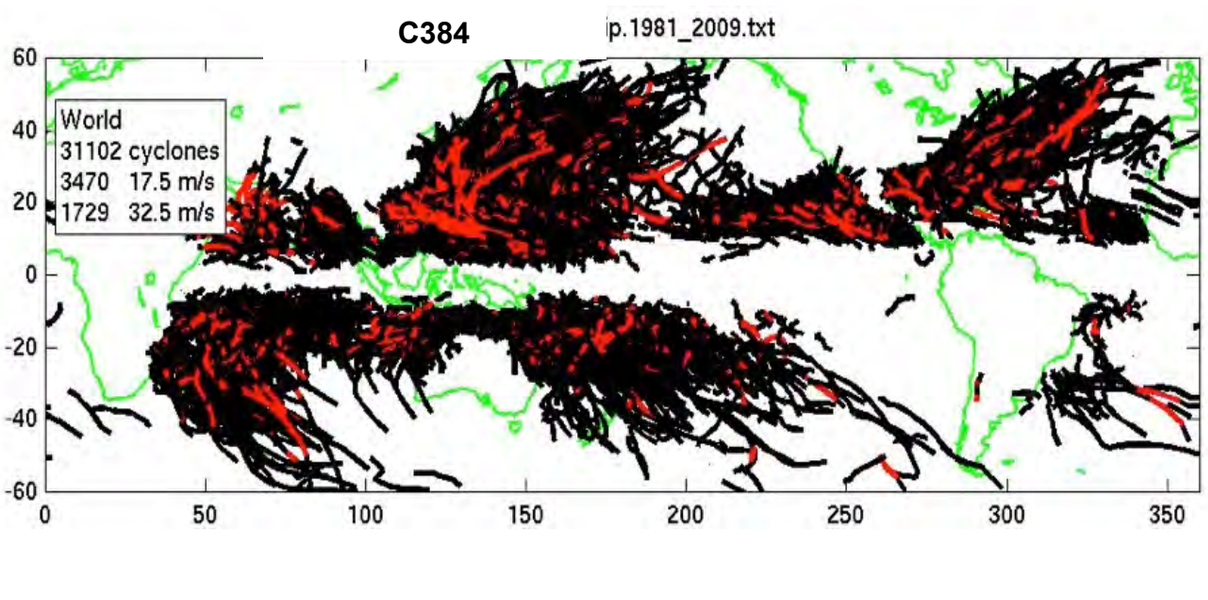
OBS IBTrACS v3r4



MRI AGCM Murakami et al. (2012)

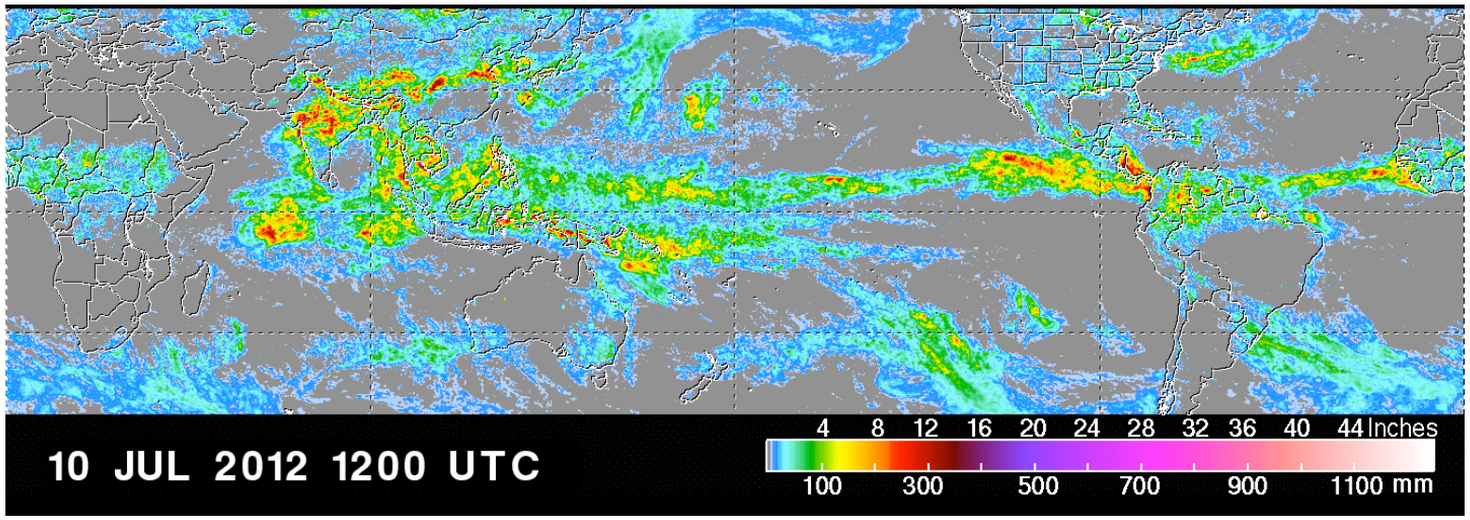


HiRAM

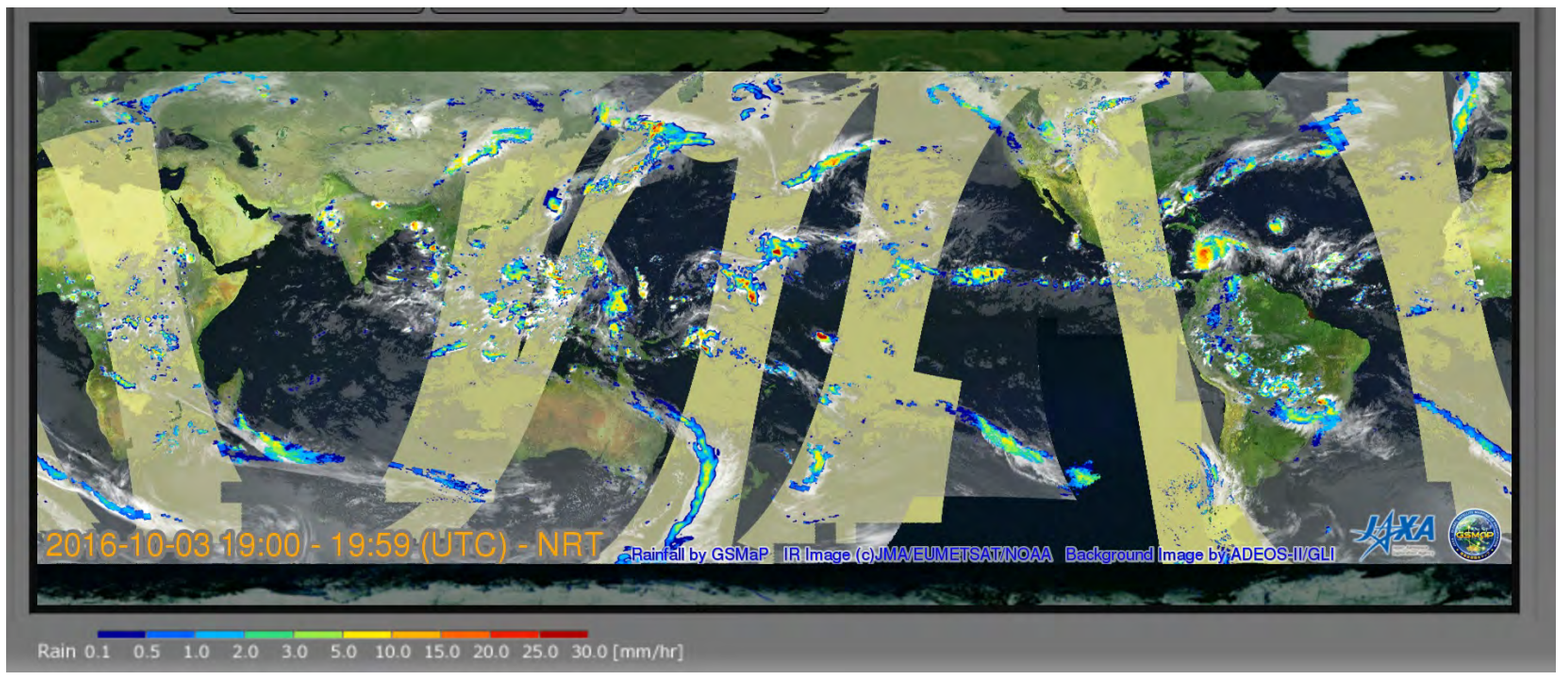


Rainfall Observation

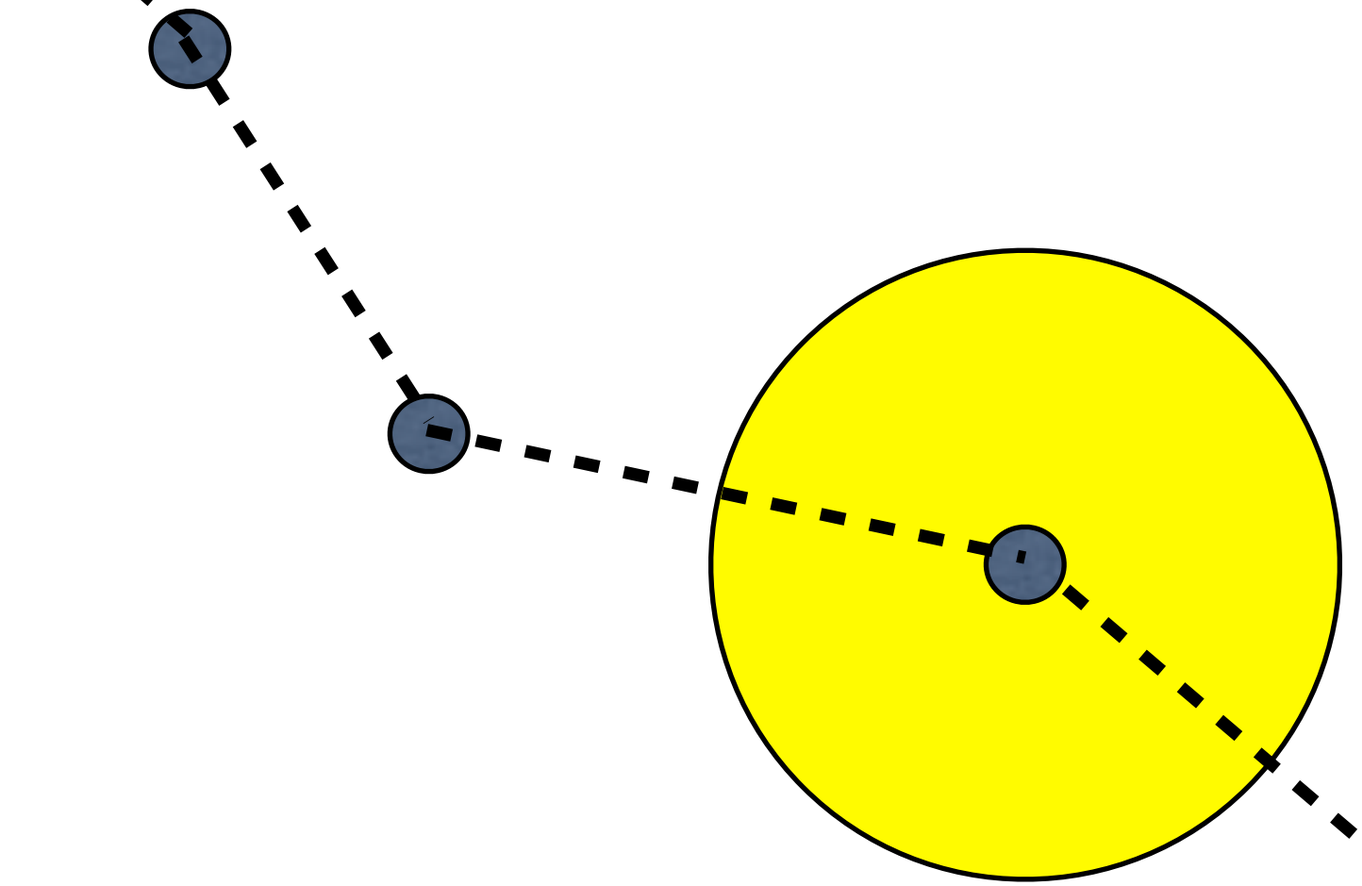
TRMM 3B42 v6 (1998-2011, 3 hourly, 0.25° resolution)



GSMaP_MVK v5 (2000-2010, hourly, 0.1° resolution)



Sample hourly rain rate from all grids within radius 300 km from TC center for all tracks found in 25 years period



Track data every 6 hours

Composite of rainfall associated with tropical cyclone during different intensity stages

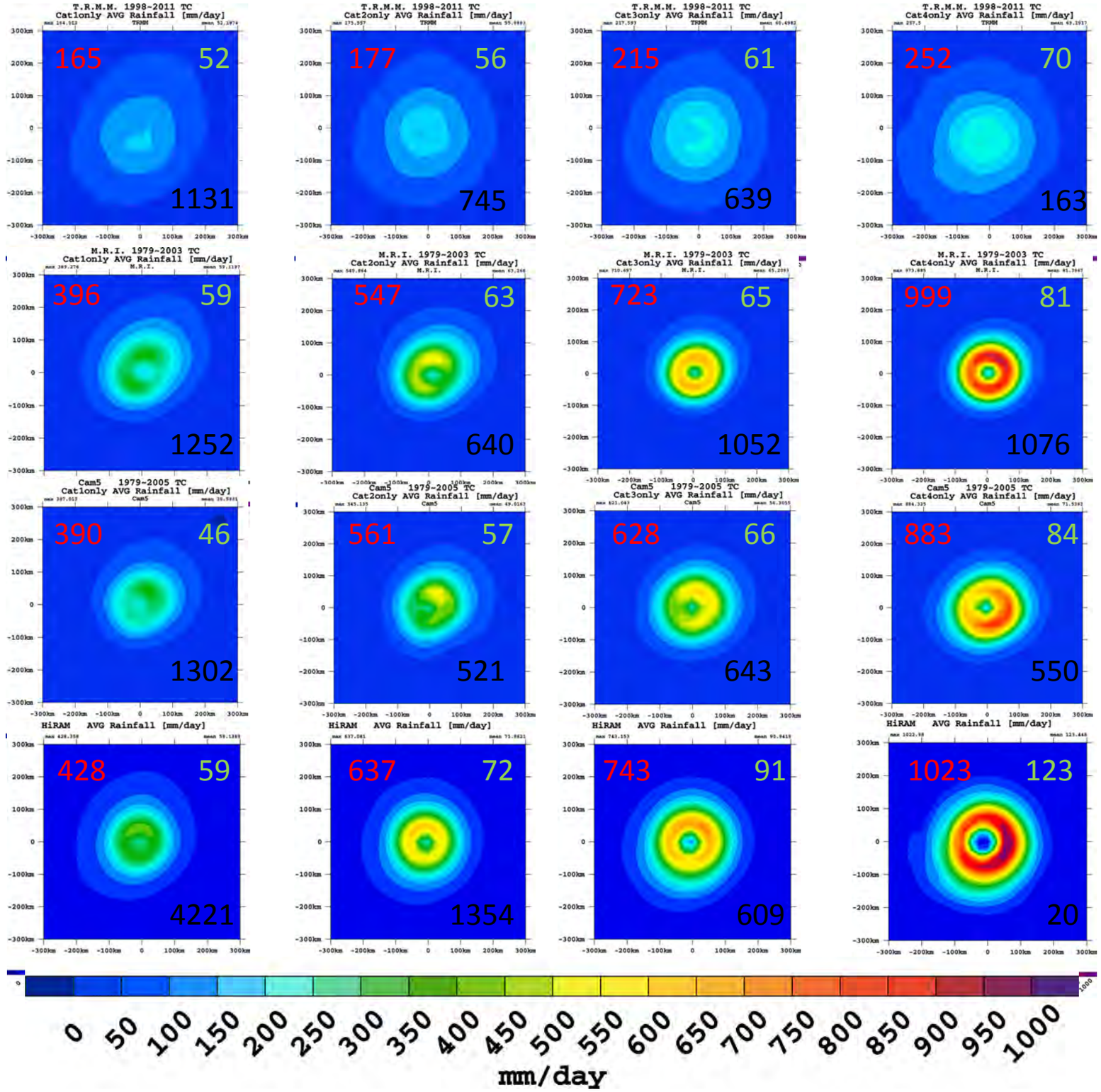
Cat1 Cat2 Cat3 Cat4+

TRMM

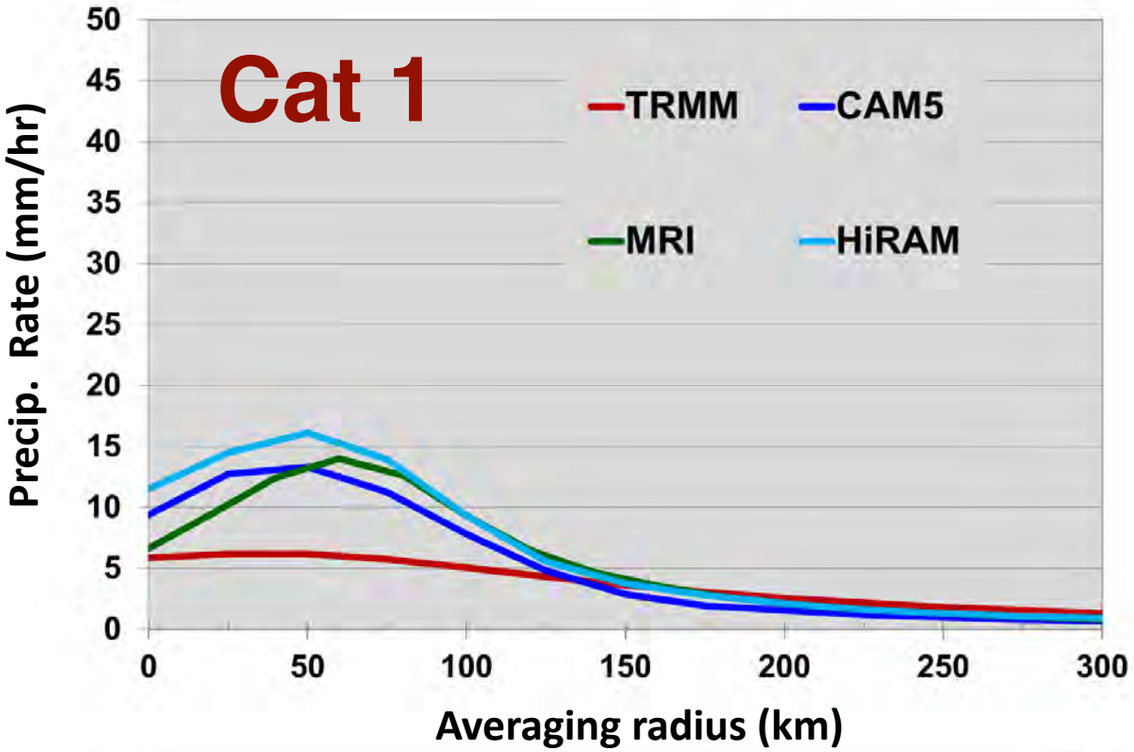
MRI

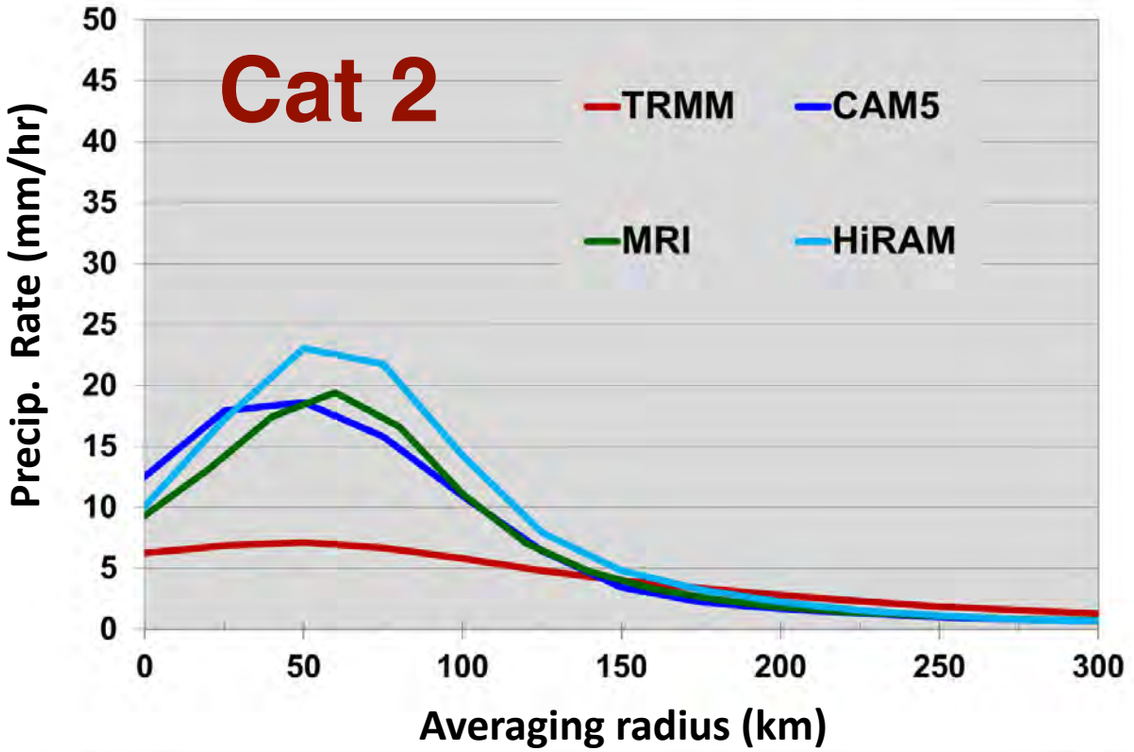
CAM5

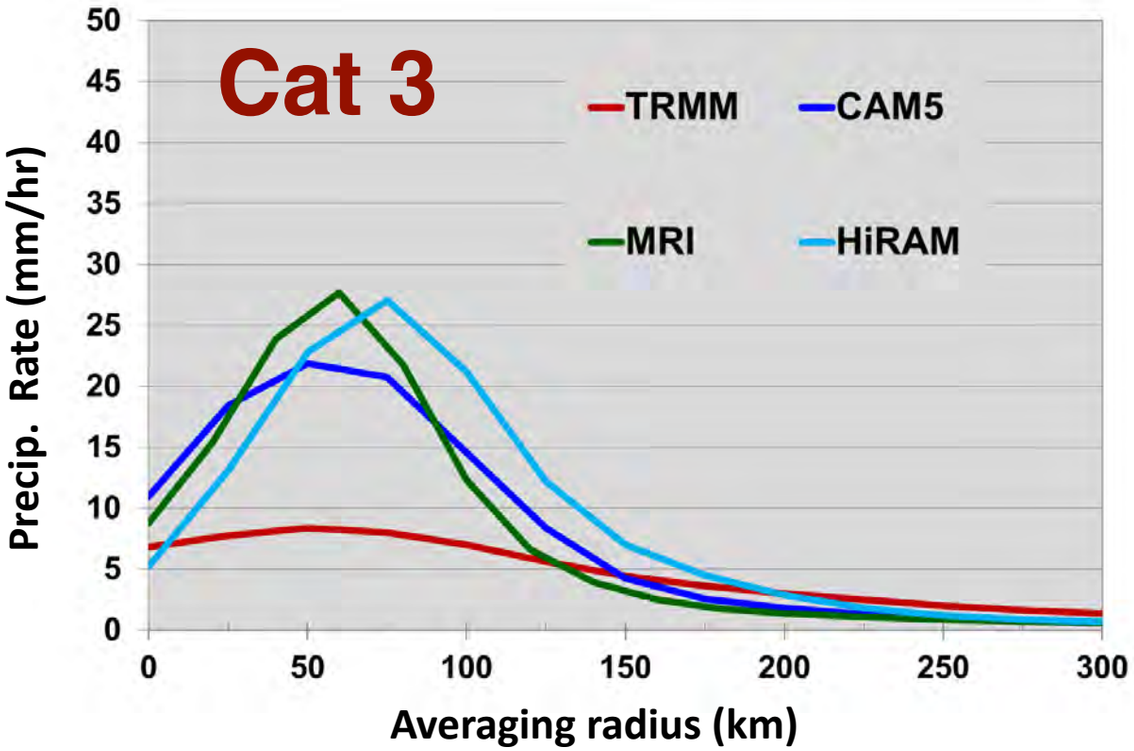
HiRAM

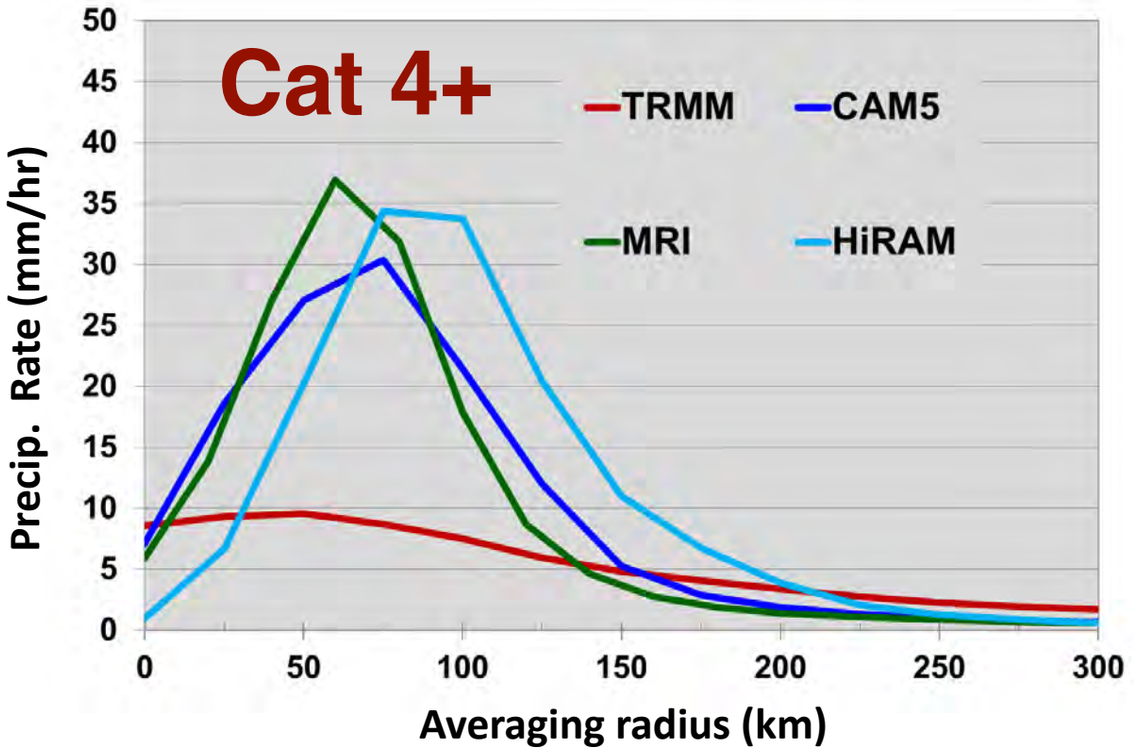


Composite of rainfall associated with tropical cyclone during different intensity stages







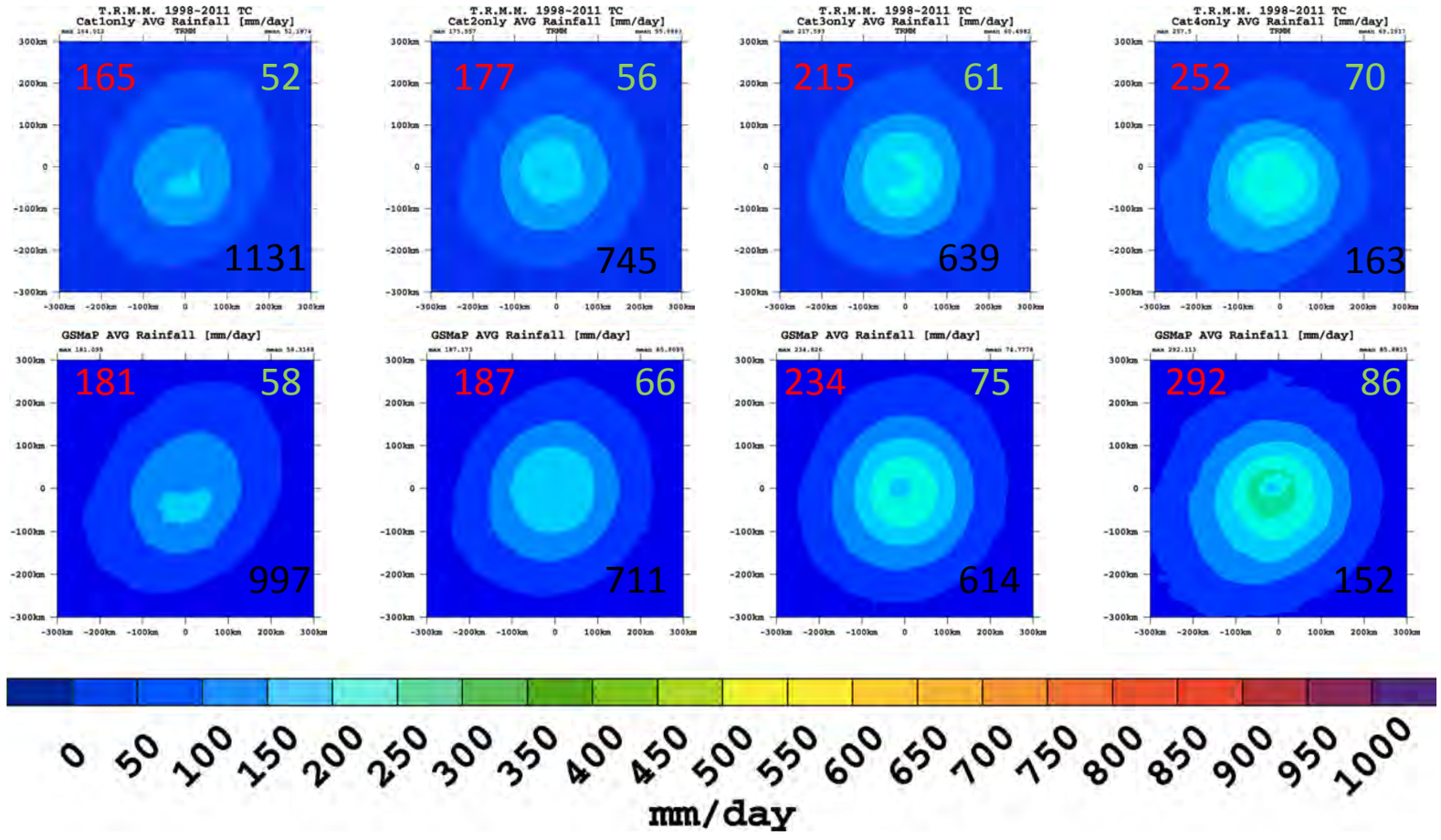


Composite of rainfall associated with tropical cyclone during different intensity stages

Cat1 Cat2 Cat3 Cat4+

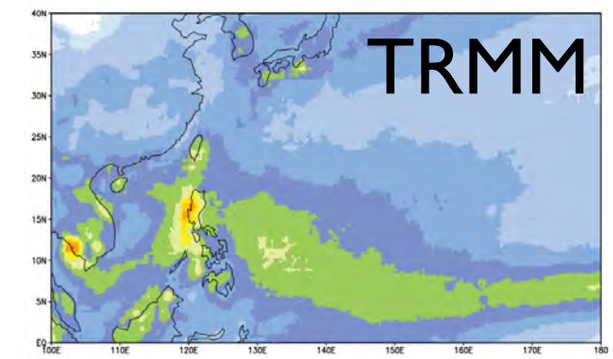
TRMM

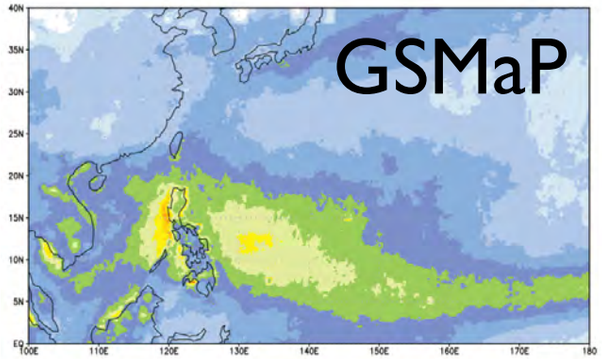
GSMaP

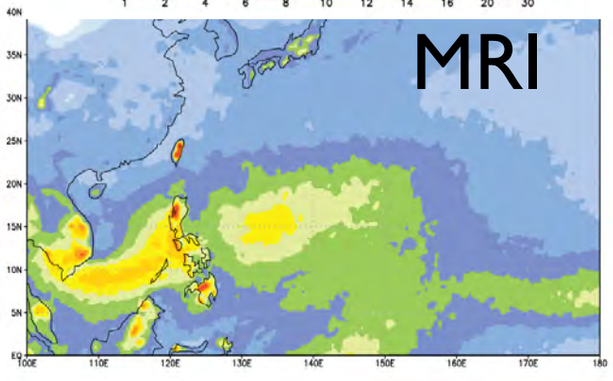


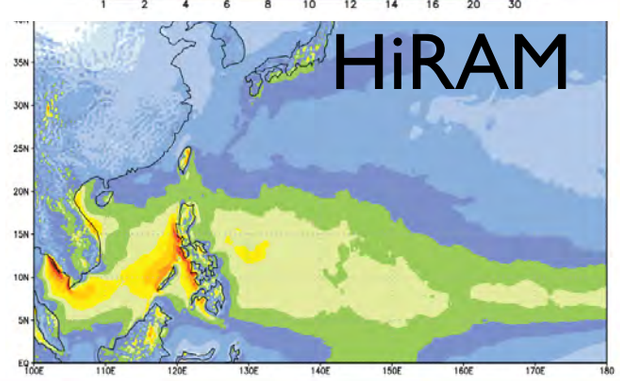
600km

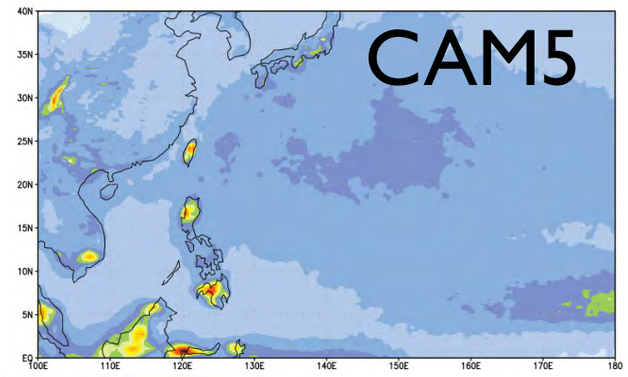
Climatological mean precipitation

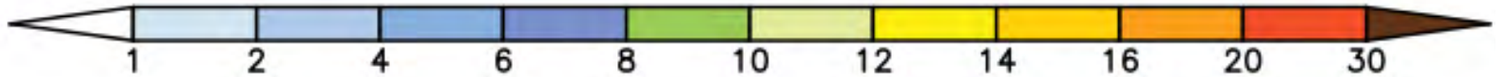






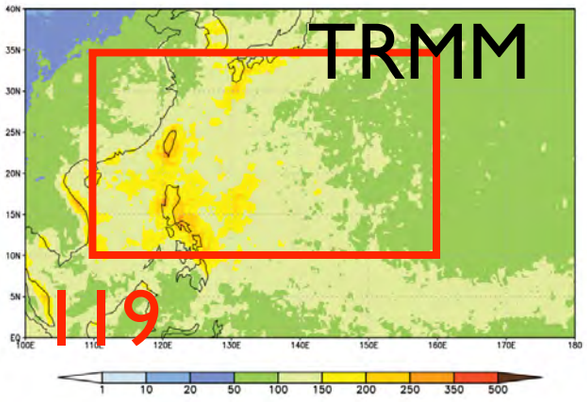


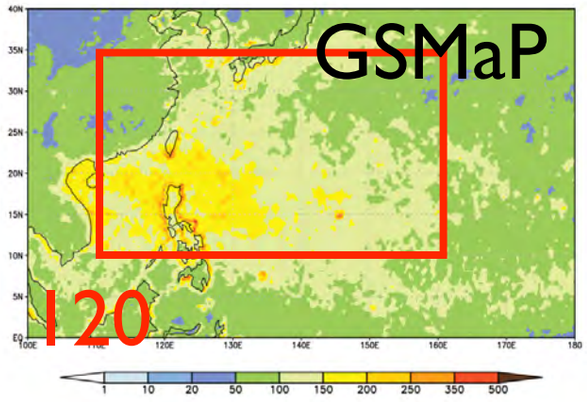


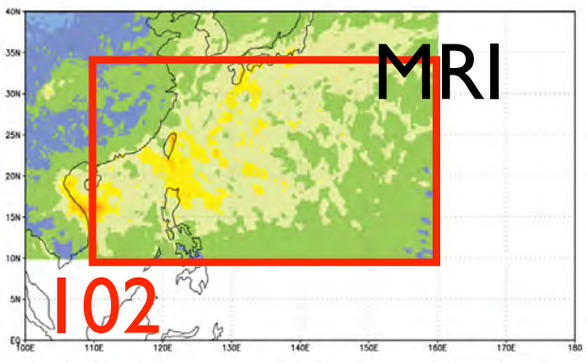


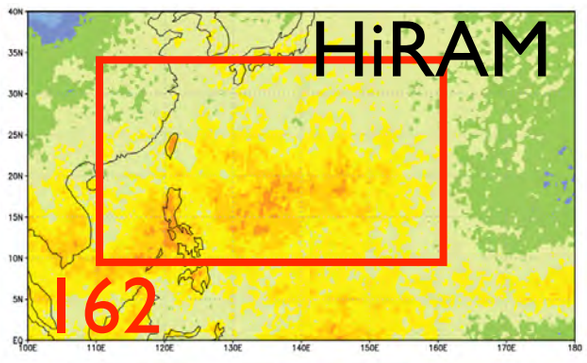
mm/day

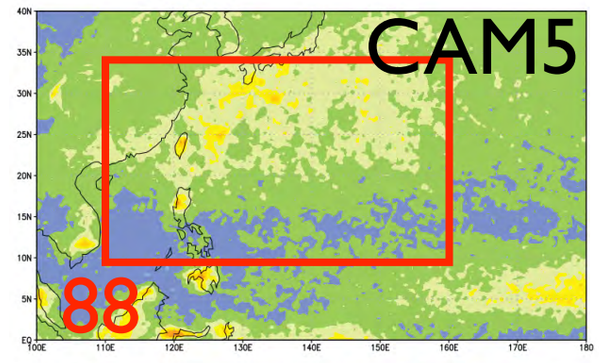
Climatological mean Rx1day

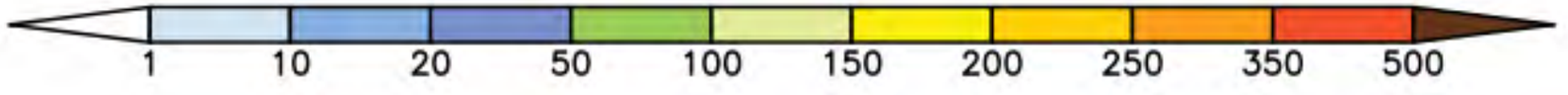






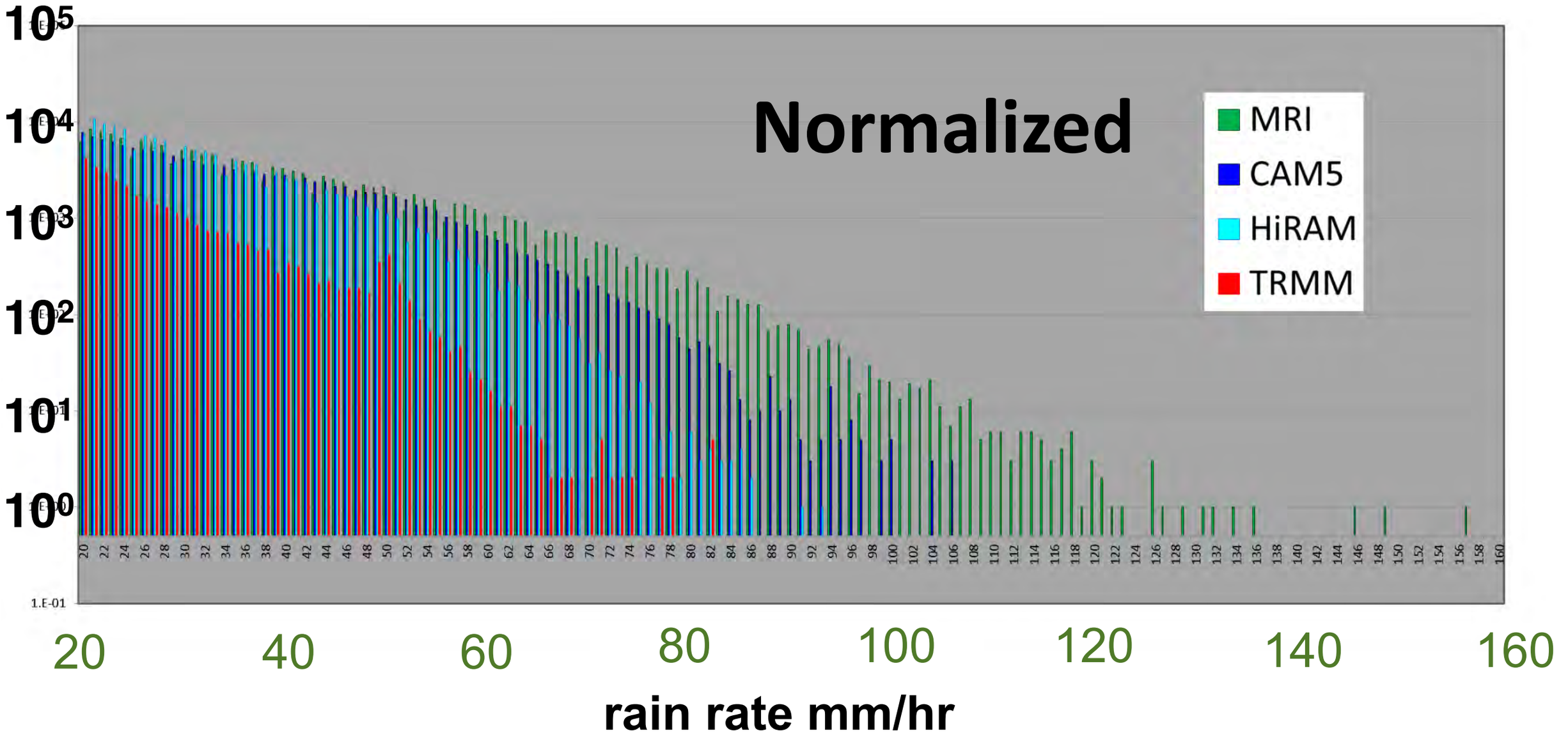






mm/day

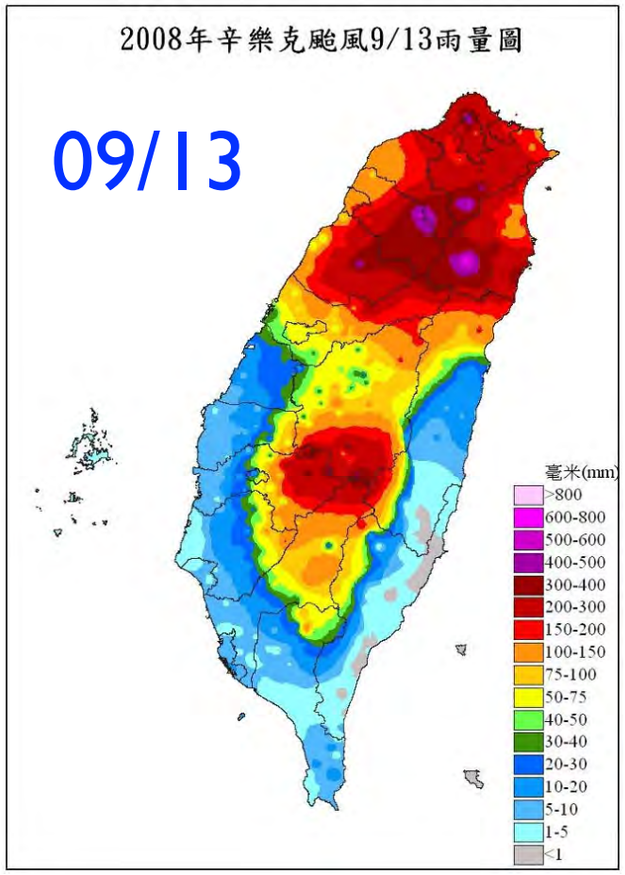
PDF of grid rainfall extremes associated with TCs

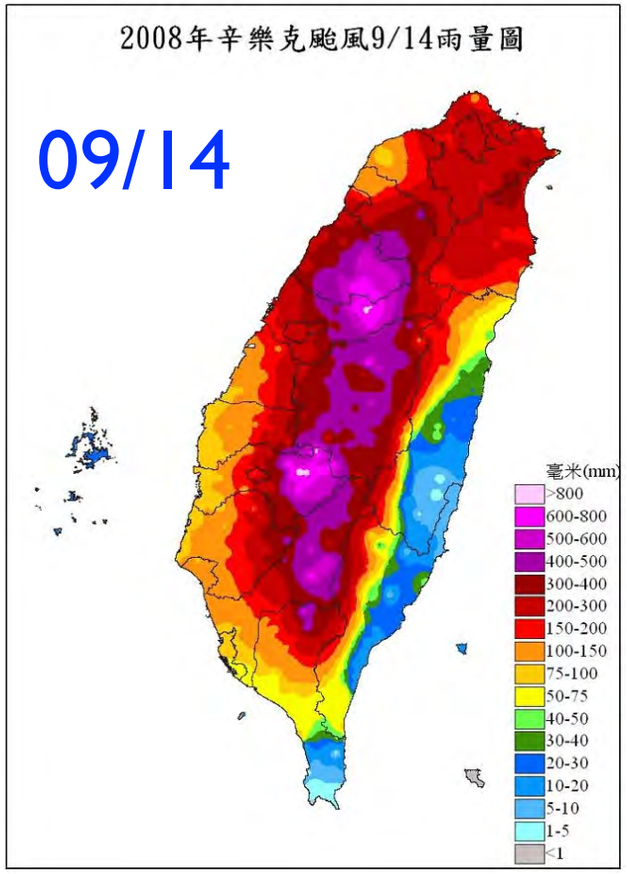


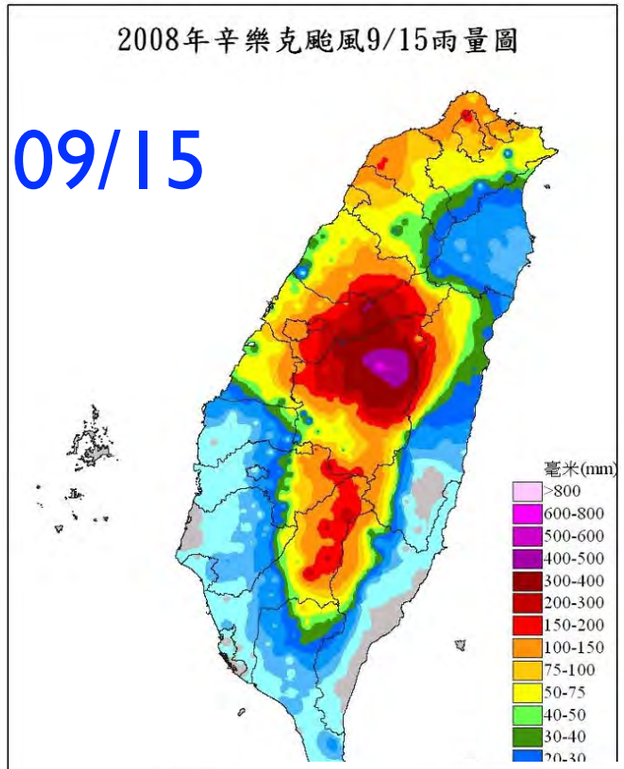
Rainfall Observation

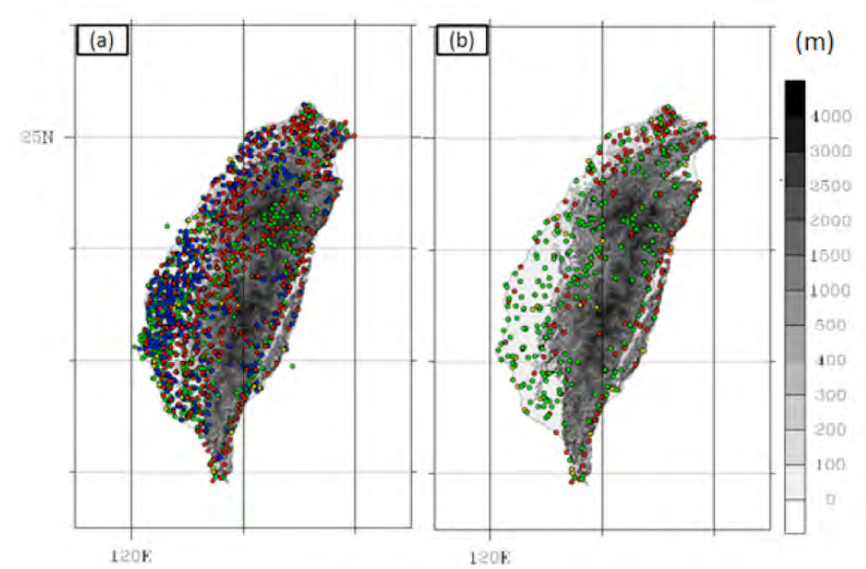
CWB hourly surface observation during typhoon

Sinlaku 2008/09/13-15

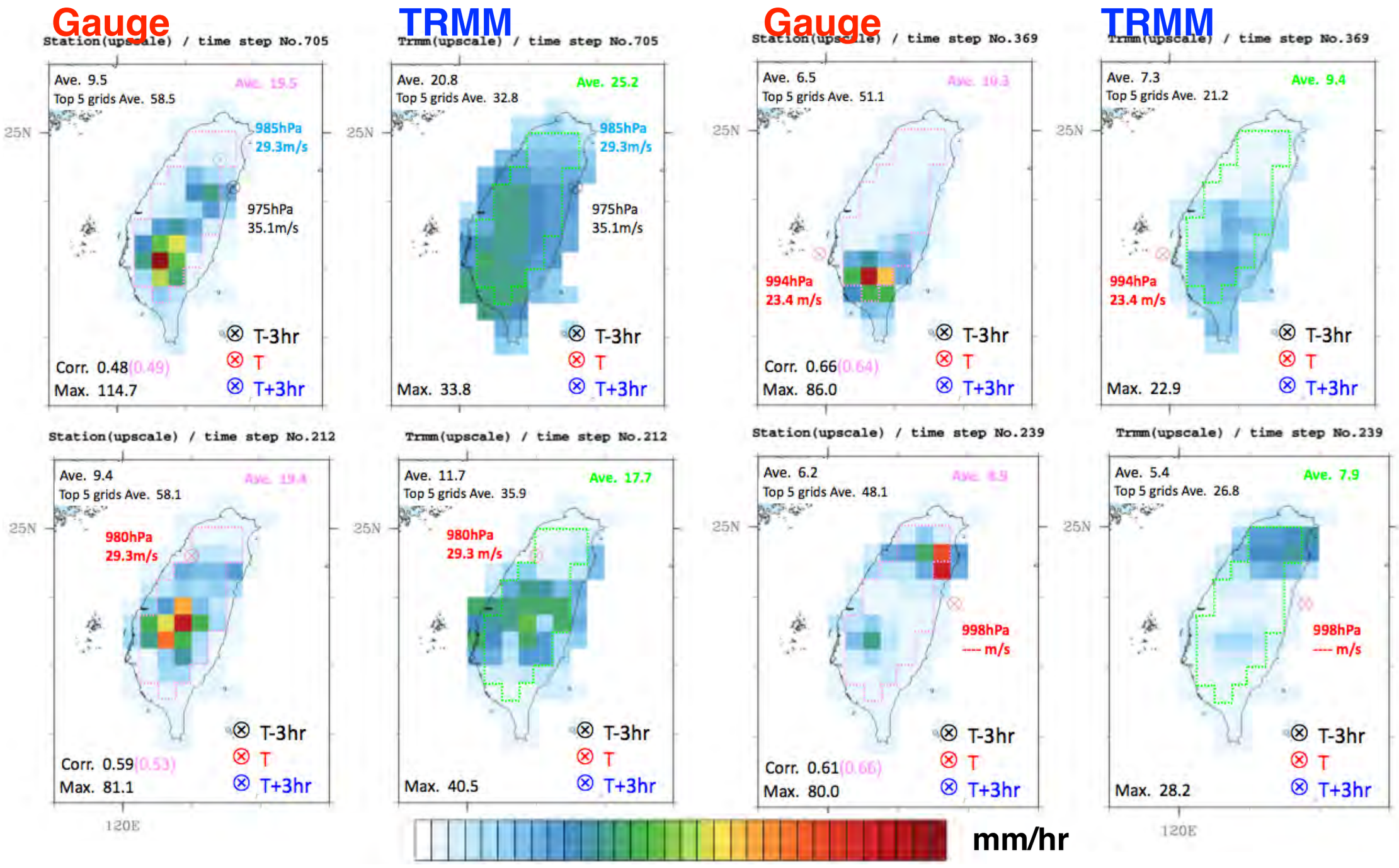




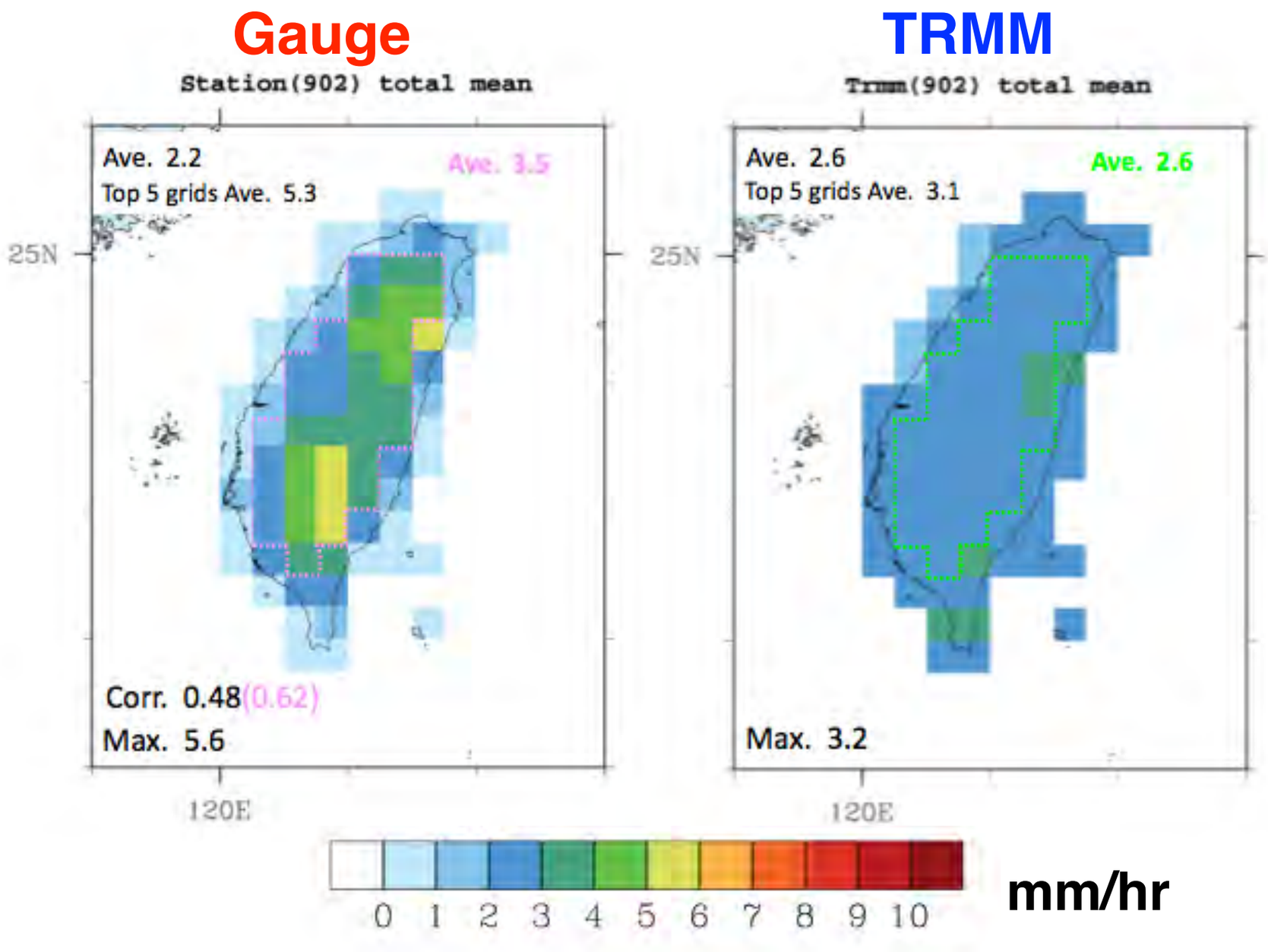




By upscaling surface rainfall observation to 0.25° TRMM data grid, the comparisons of the top surface gridded local rainfall events with concurrent TRMM data indicate the underestimation of local heavy rainfall extreme and the tendency to smooth out and enlarge the heavy rainfall area from TRMM data.



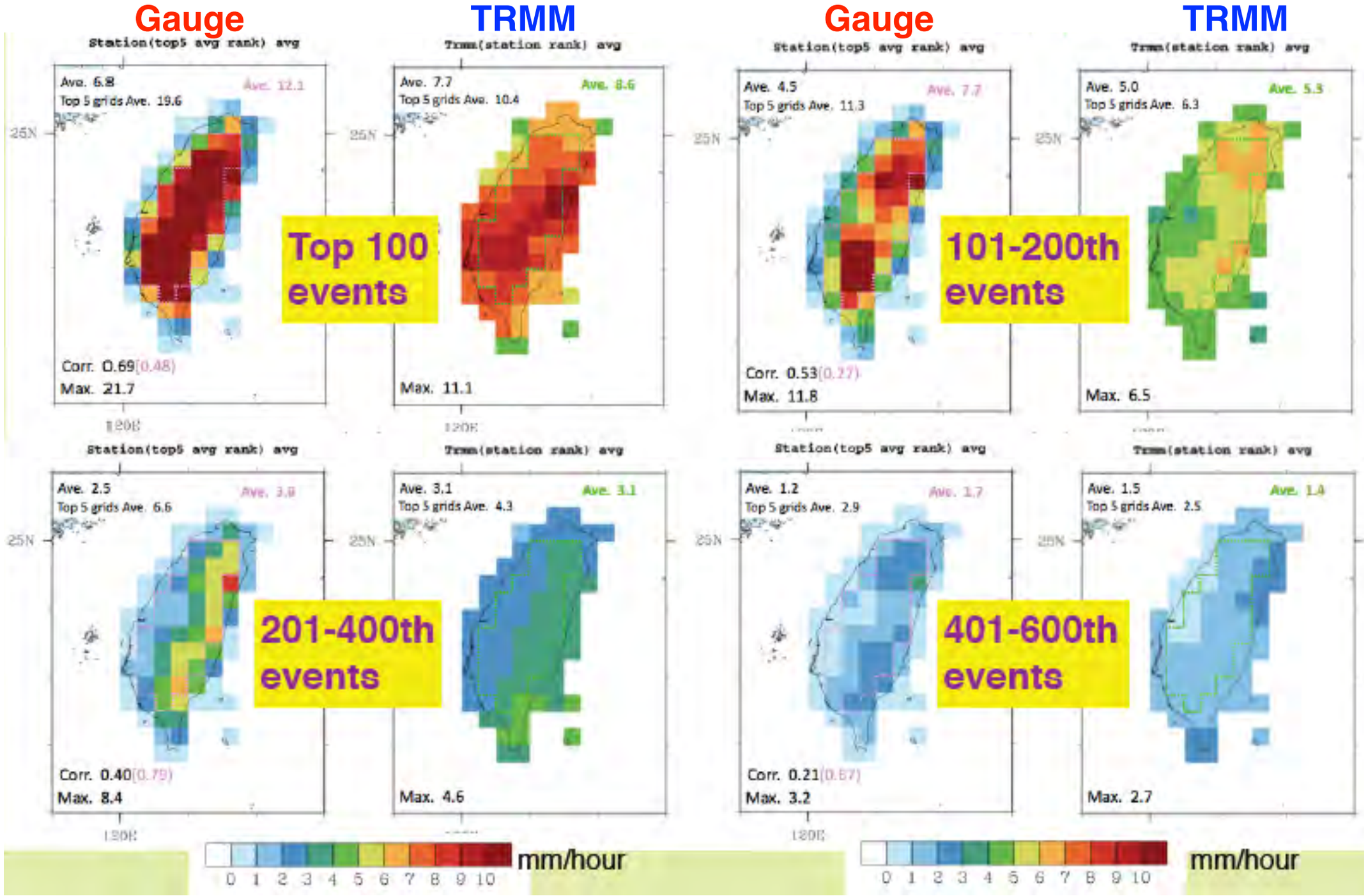
For the composite of all 902 rainfall distributions associated with TCs when their centers are within the 300 km from the coastline of Taiwan during 1998-2010 period. The rainfall from TRMM is smaller and with less spatial structure as compared to surface observation.



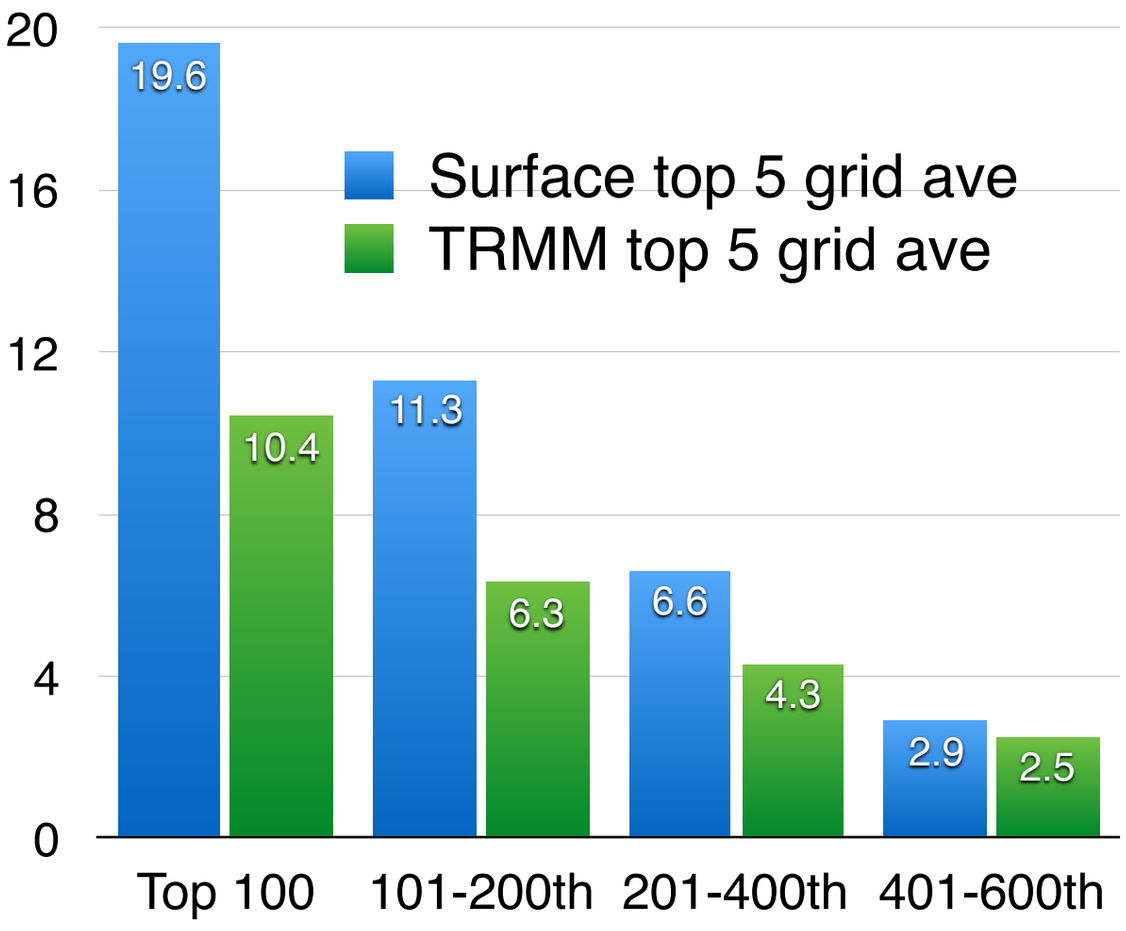
Top 5 grids:
Gauge: 5.3
TRMM: 3.1

34 overlapping grids:
Gauge: 3.5
TRMM: 2.6

Comparison of Surface and TRMM rainfall analyses for period when typhoon within 300km from Taiwan

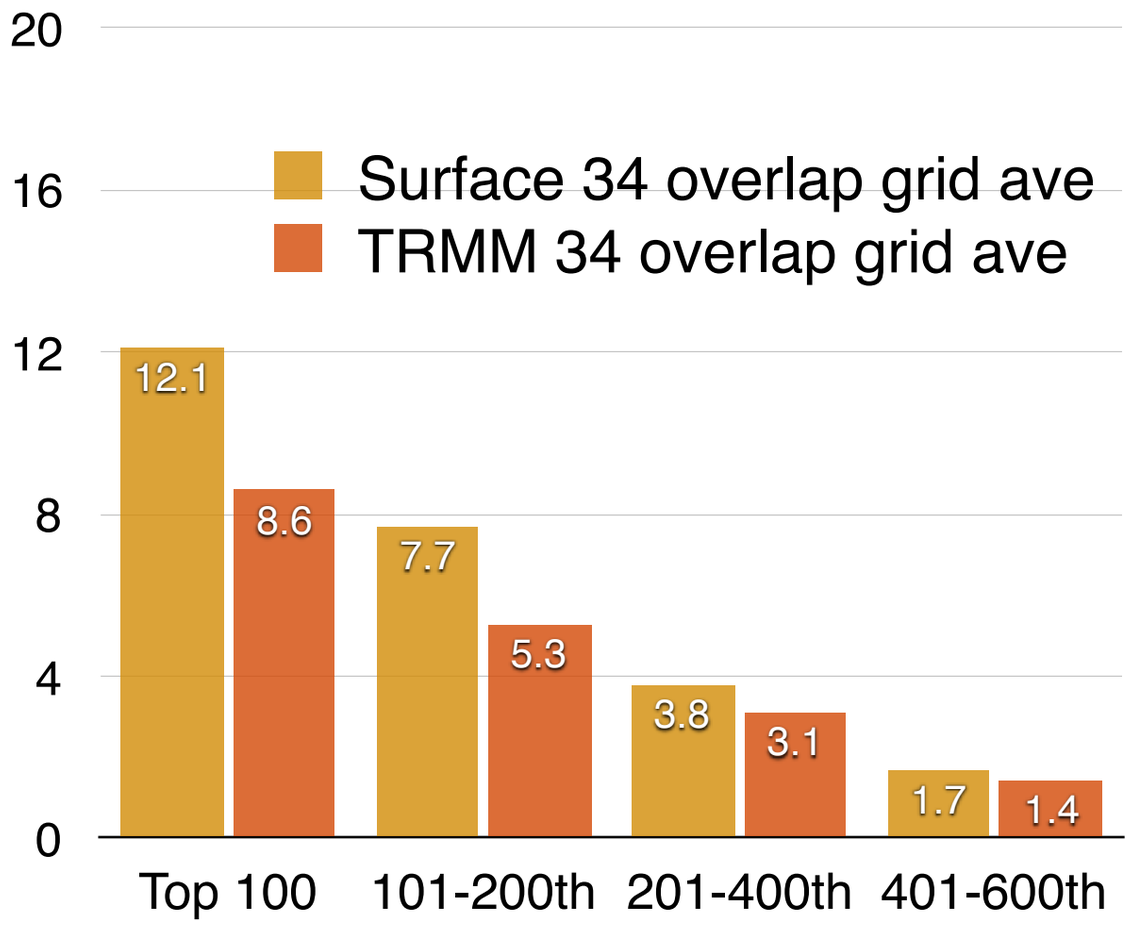


Top 5 grids



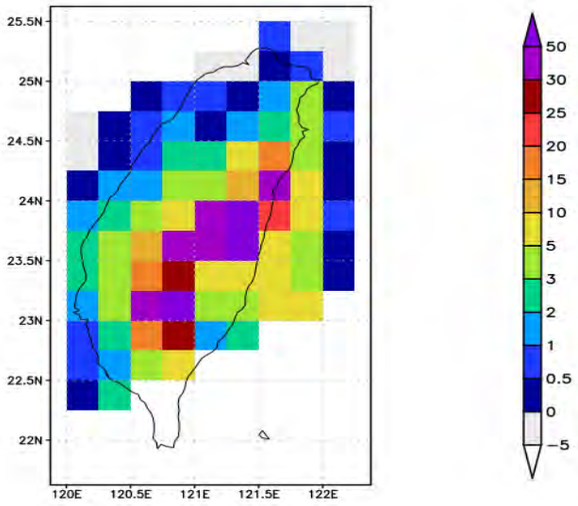
~90% ~50% ~20%

34 overlapping grids

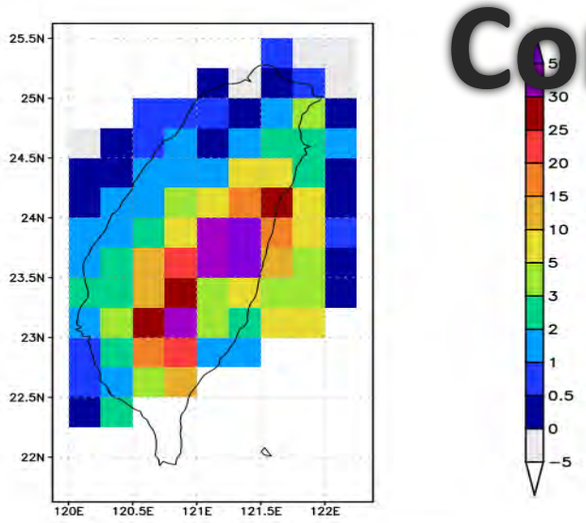


~40% ~20%

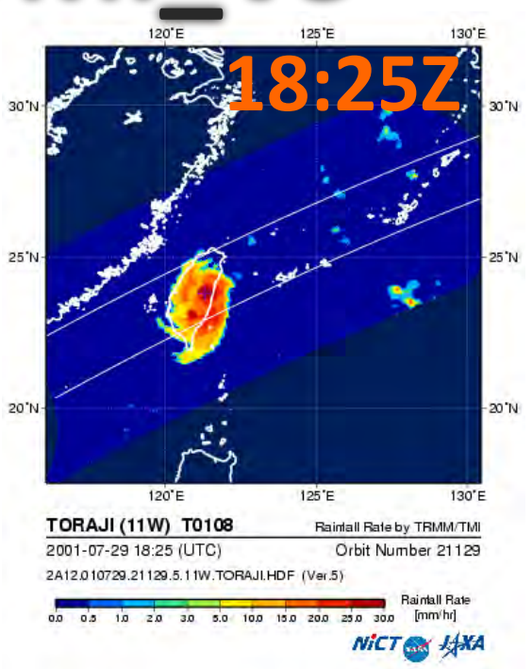
PR_V7



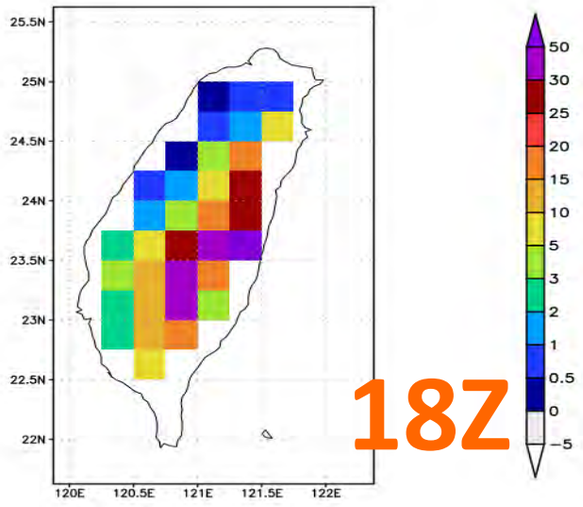
Comb_V7



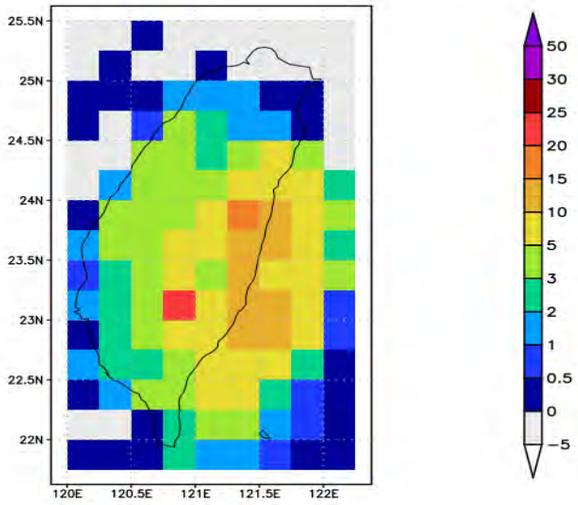
TMI_V5



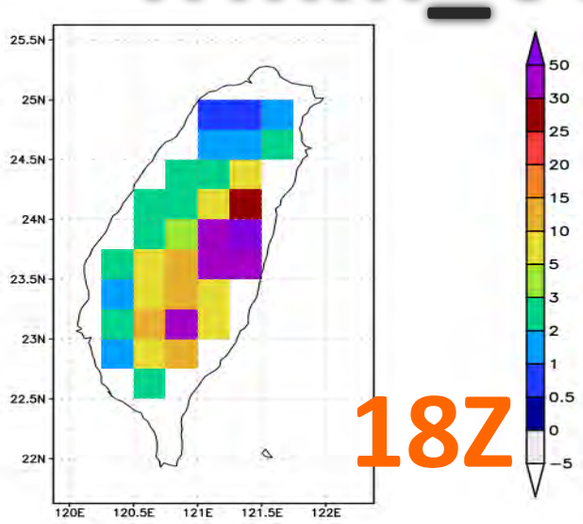
Station

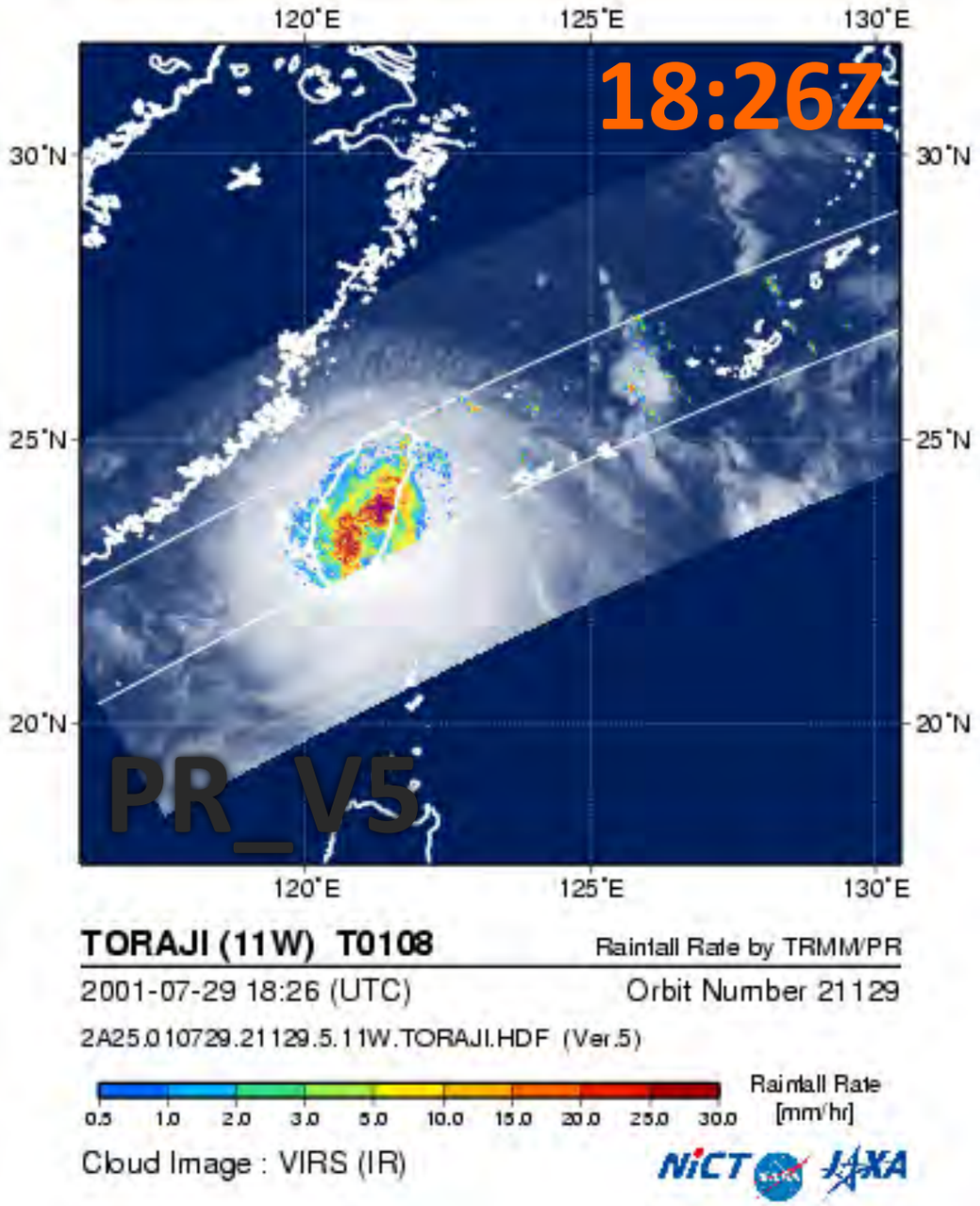


TMI_V7

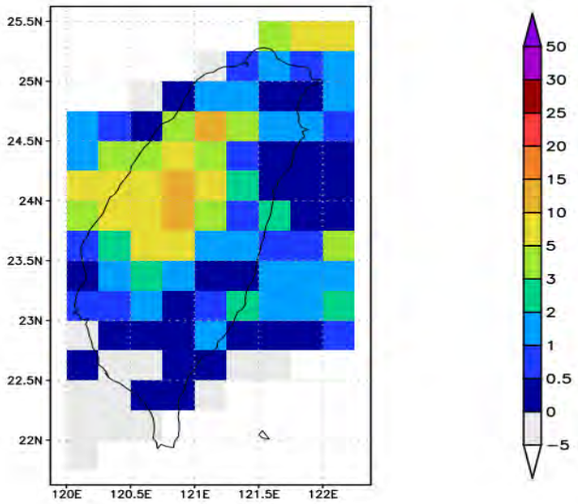


Trmm_V6





PR_V7



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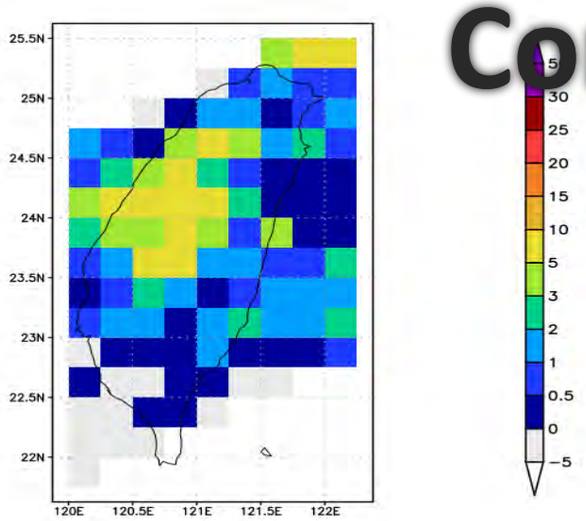

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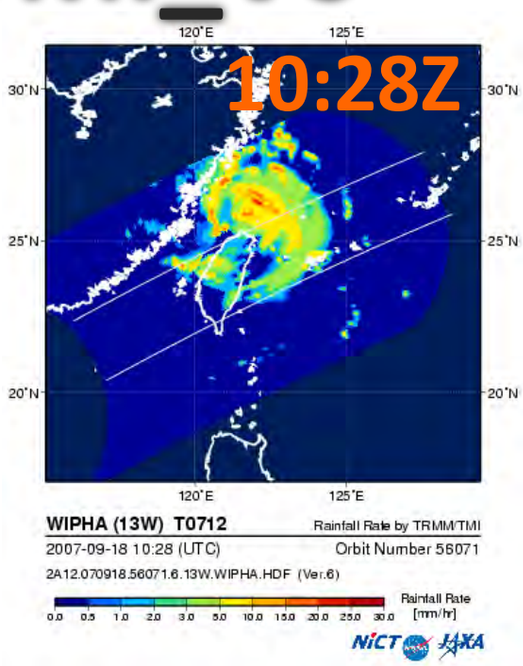

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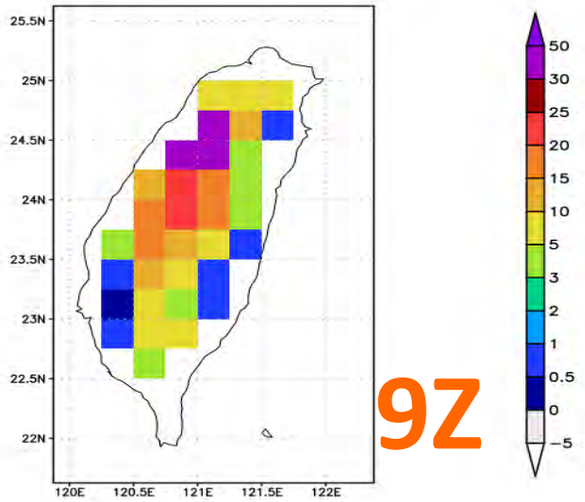

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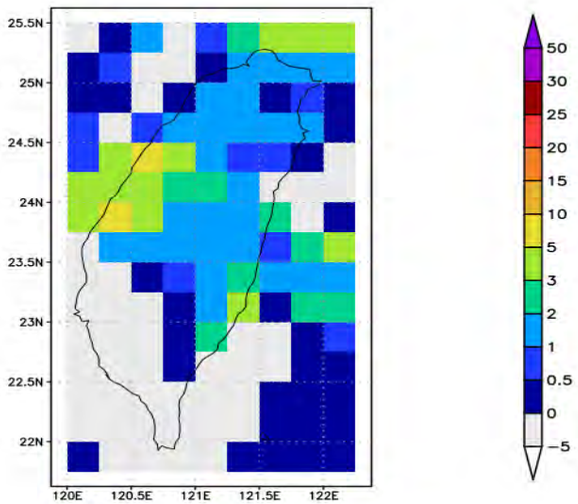

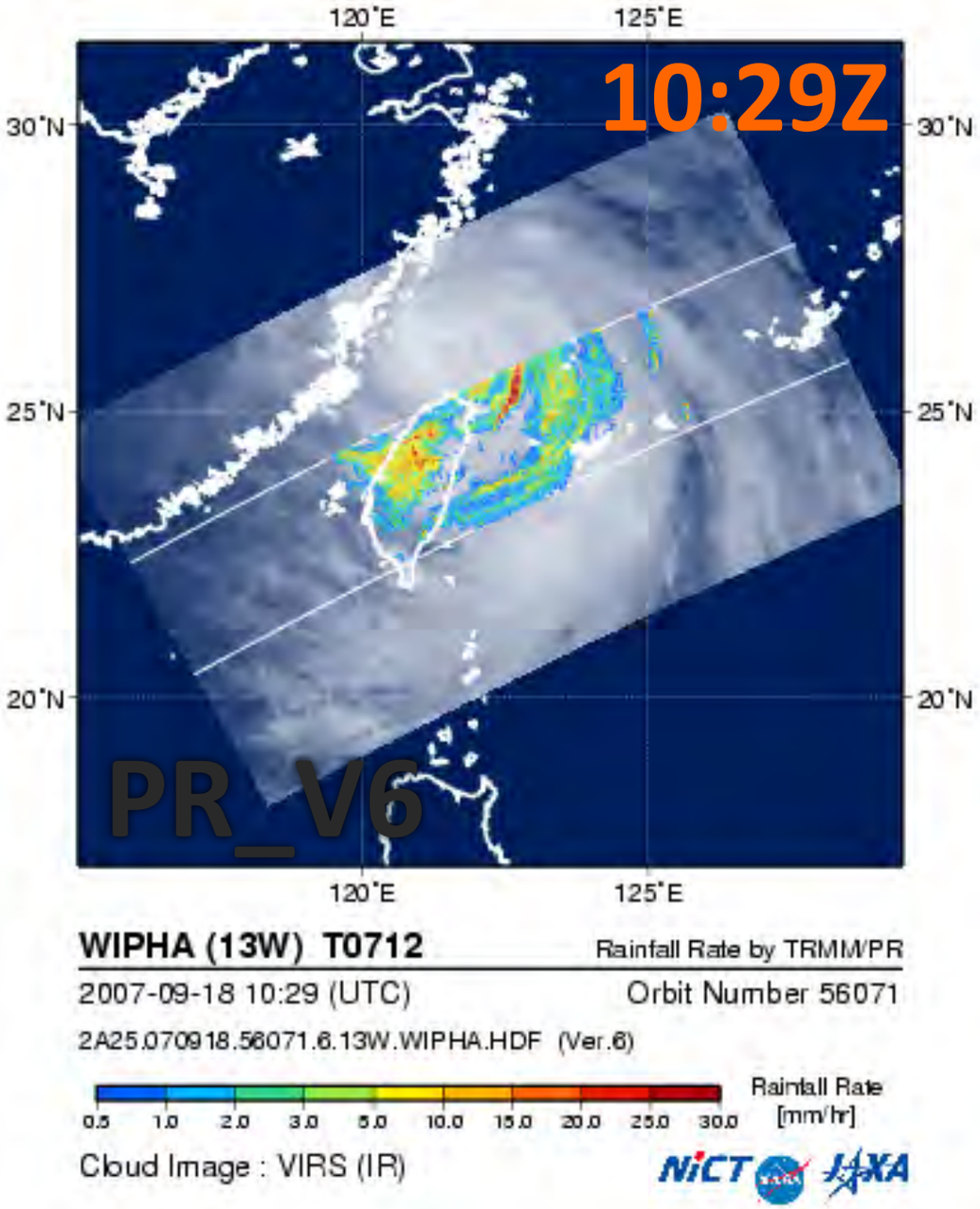

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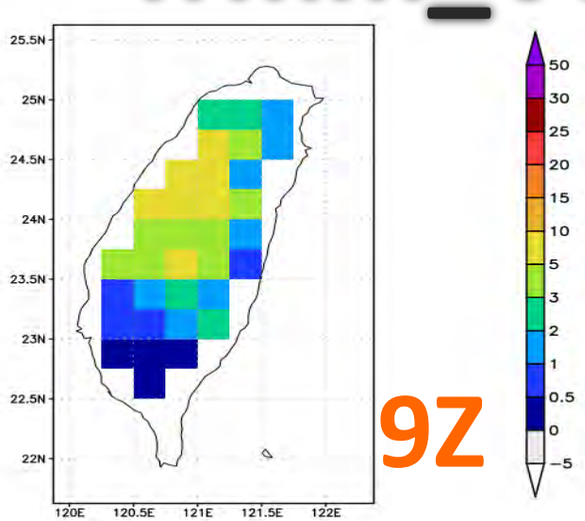

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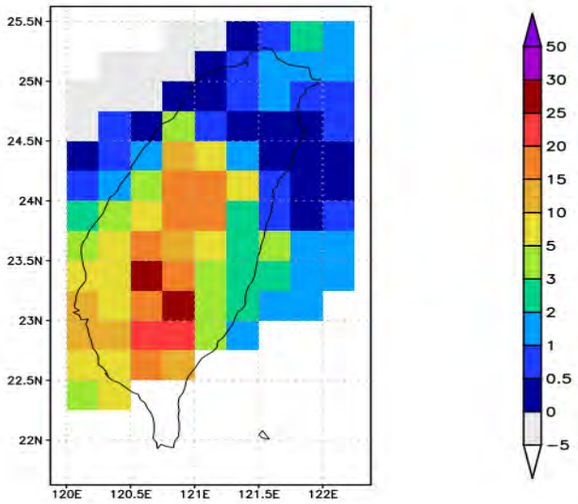

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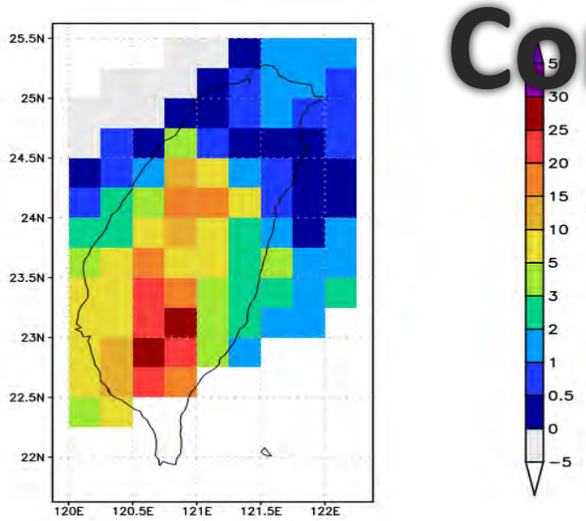

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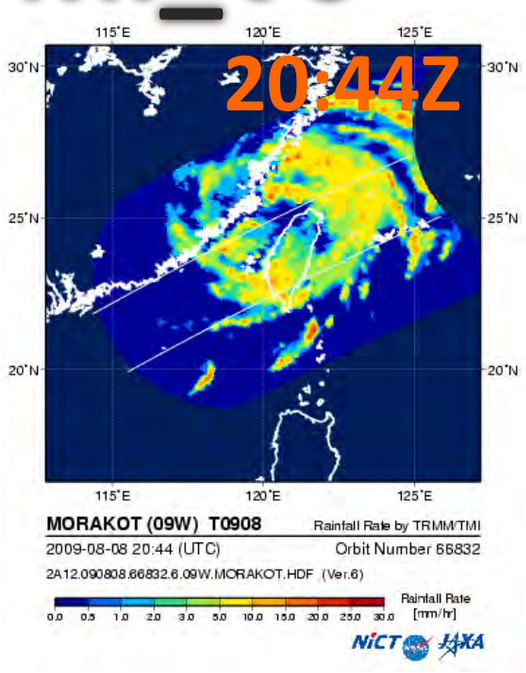

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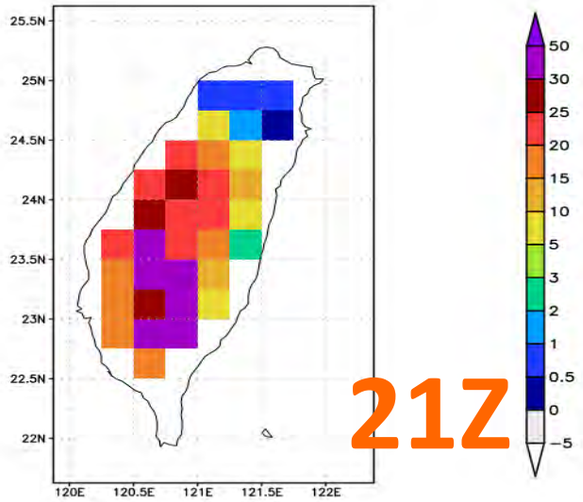

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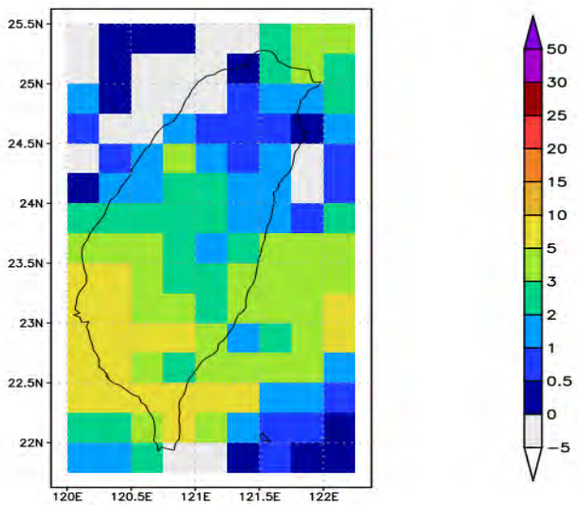

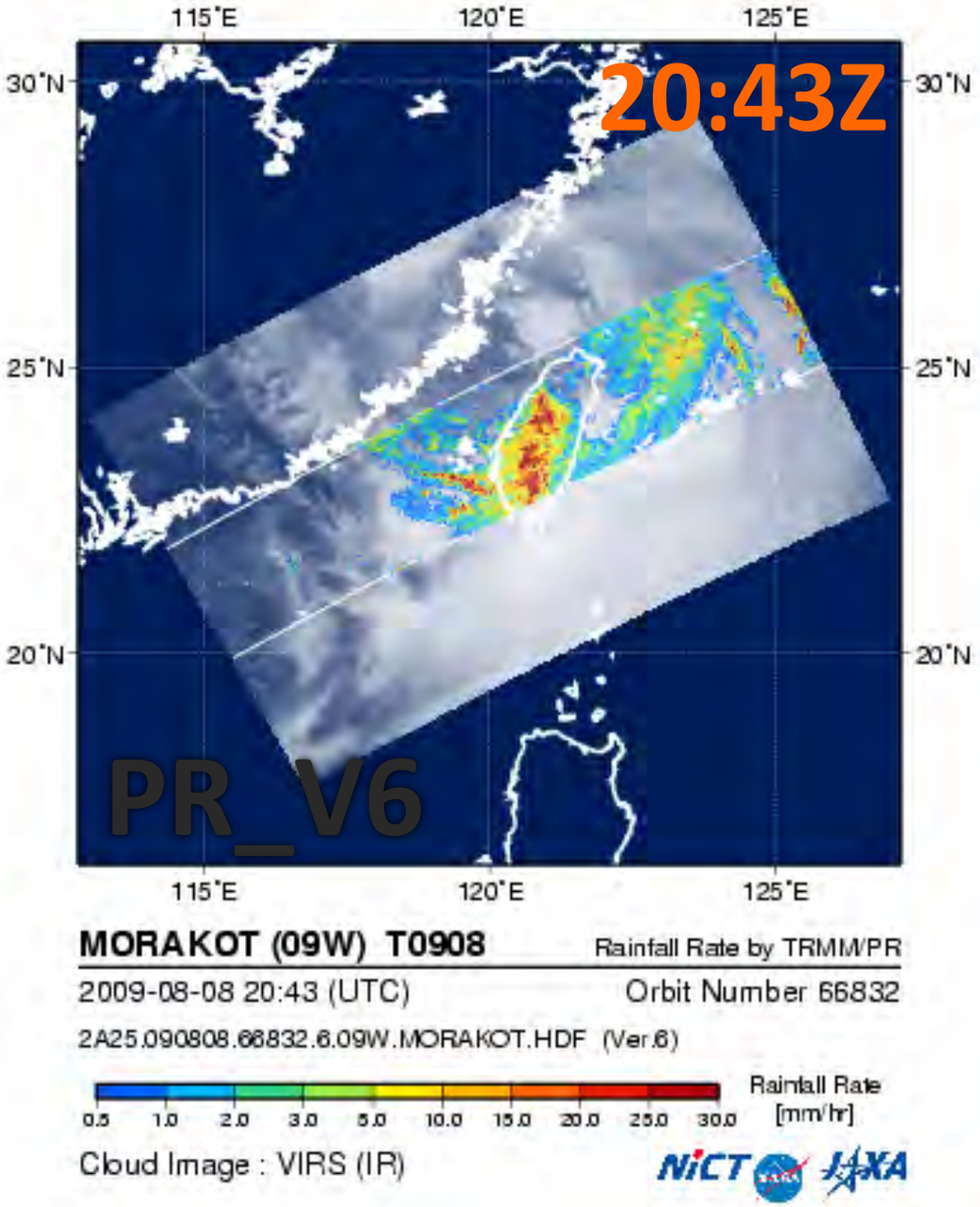

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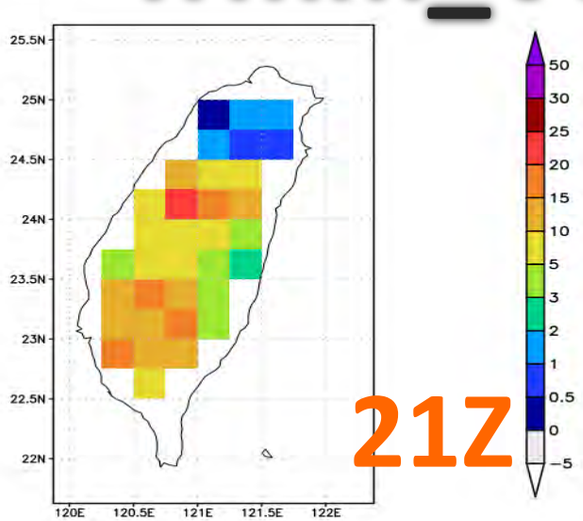
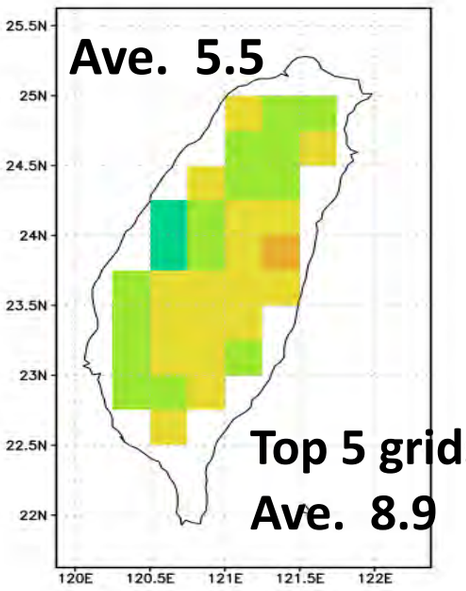


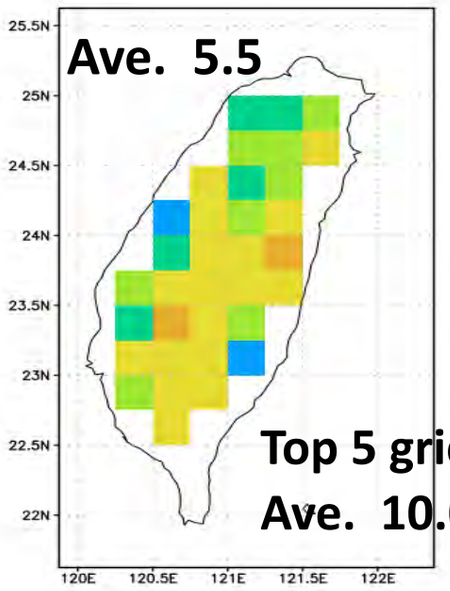
28 Cases Composite with TRMM PR available

TRMM 3B42



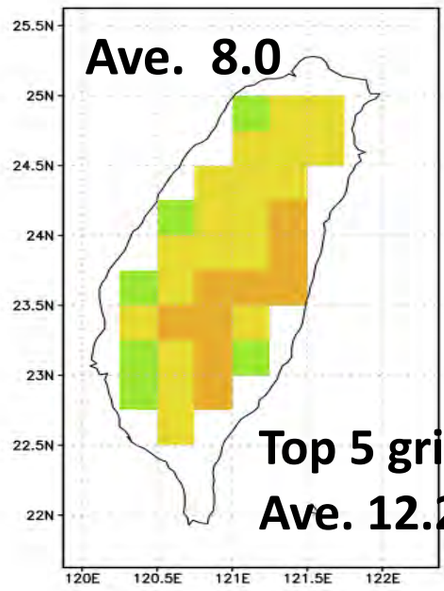
Top 5 grids
Ave. 8.9

TRMM 3G68 PR V7

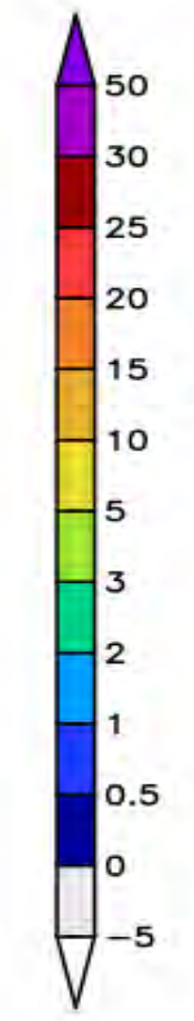


Top 5 grids
Ave. 10.0

Station upscaled



Top 5 grids
Ave. 12.2



mm/hr

Concluding Remarks

- Overestimation of rainfall associated with TC found in the high-resolution climate models (MRI, CAM5, and HiRAM) as compared to TRMM 3B42 data might not be totally attributed as model bias.

- By upscaling the dense surface observation over Taiwan to the data resolution of TRMM, the comparison of the top surface local rainfall events with TRMM estimates indicate that the TRMM data tends to underestimate the local heavy rainfall extreme and enlarge the heavy rainfall area during the period when TC affecting Taiwan. Only slightly improvement (less than 20%) with with hourly and 0.1° time/space grid GSMap data.

- For extreme precipitation associated with TC, the difference between surface observation and TRMM estimate are larger for the heavier local rainfall events.

- Using limited TRMM PR data sample of extreme precipitation associated with TC over Taiwan, TRMM PR(3G68) rainfall estimate are not necessary larger than the merged product (3B42), maybe except the most extremes.

By ranking the mean top 5 rainfall extreme grids of surface observation from all 902 snapshot TC rainfall over Taiwan during 1998-2010 period.
We stratify the different extent of heavy rainfall associated with TC to Top 100, 100-200, 200-400, 400-600 events for comparison.