# WRF-LETKF application for flood forecasting on Kyushu torrential rainfall

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# Introduction

- Flood forecasting in Japan usually means hydrological simulations using observed rainfall by weather radars or raingauges, it doesn't mean hydrological simulation using predicted rainfall.
- One reason is that Japanese river catchments are quite small (~10000 $km^2$). It is hard to predict localized torrential rainfall in the right place at the right time.
- Our purpose is to examine the potential of regional ensemble prediction system with convective scale data assimilation for flood forecasting in Japanese small river catchments.

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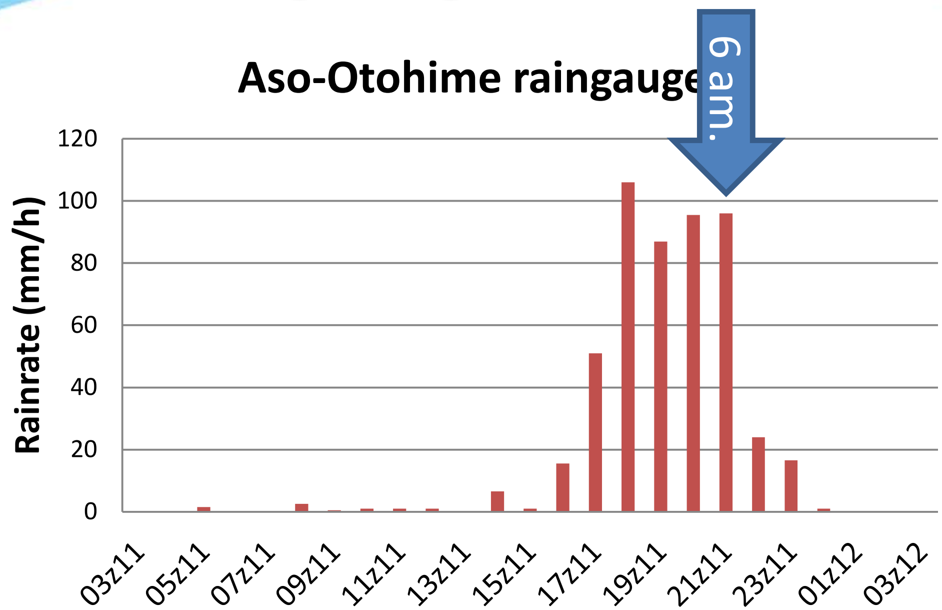
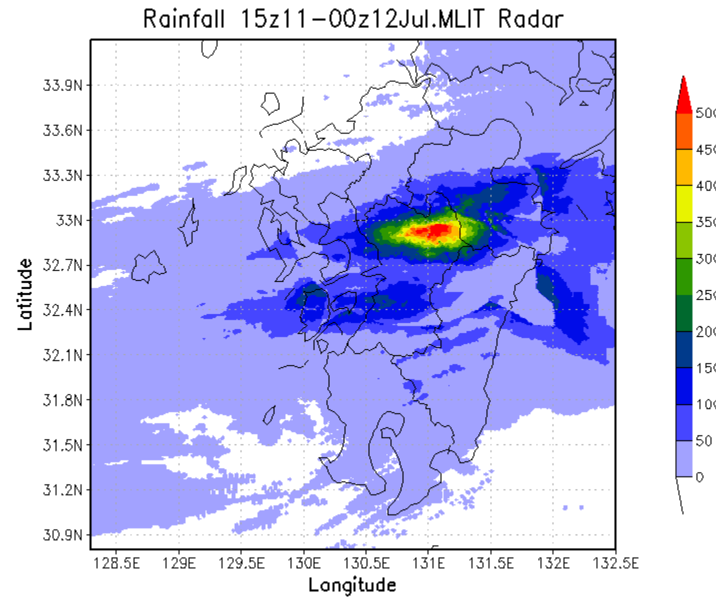
# Examined event

- Northern Kyushu Island suffered localized torrential rainfall and resulted flood disasters on July 2012.
  - Maximum 108.0 mm/hour, 507.5 mm/24 hours at Aso-otohime site broke the record.
  - The resulted river line flood and mudflow caused 34 casualties and economic loss of $2 billion.
- This torrential rainfall occurred before dawn. The prediction of torrential rainfall is crucial to mitigate the disaster.
- We attempted ensemble prediction by WRF-LETKF (Local Ensemble Transform Kalman Filter) and following ensemble flood forecasting for this event to examine its predictability.

Photograph from the report of Japan Society of Civil Engineering

# Raingauge and Radar analysis

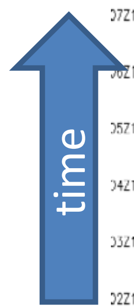


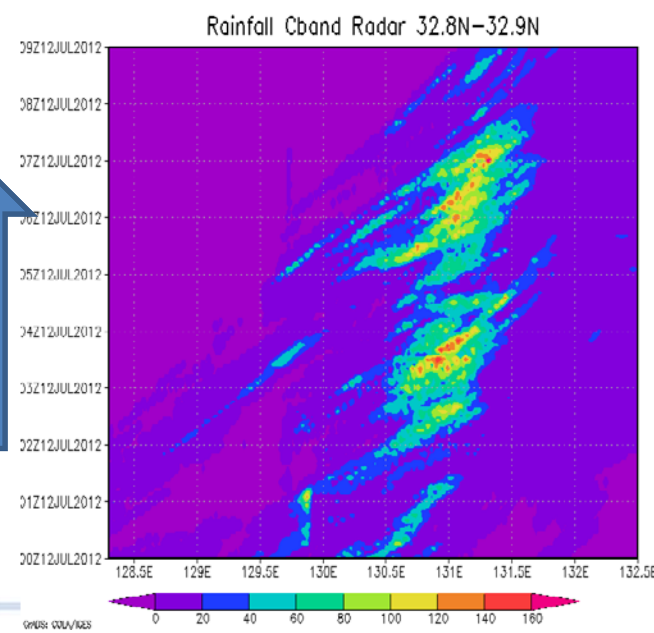




●Rainfall were mainly in 17-22UTC 11 July (02-06LST 12 July) before dawn.

●Radar analysis shows concentration of rainfall in a limited area.

●Rain system went passing eastward once after another.

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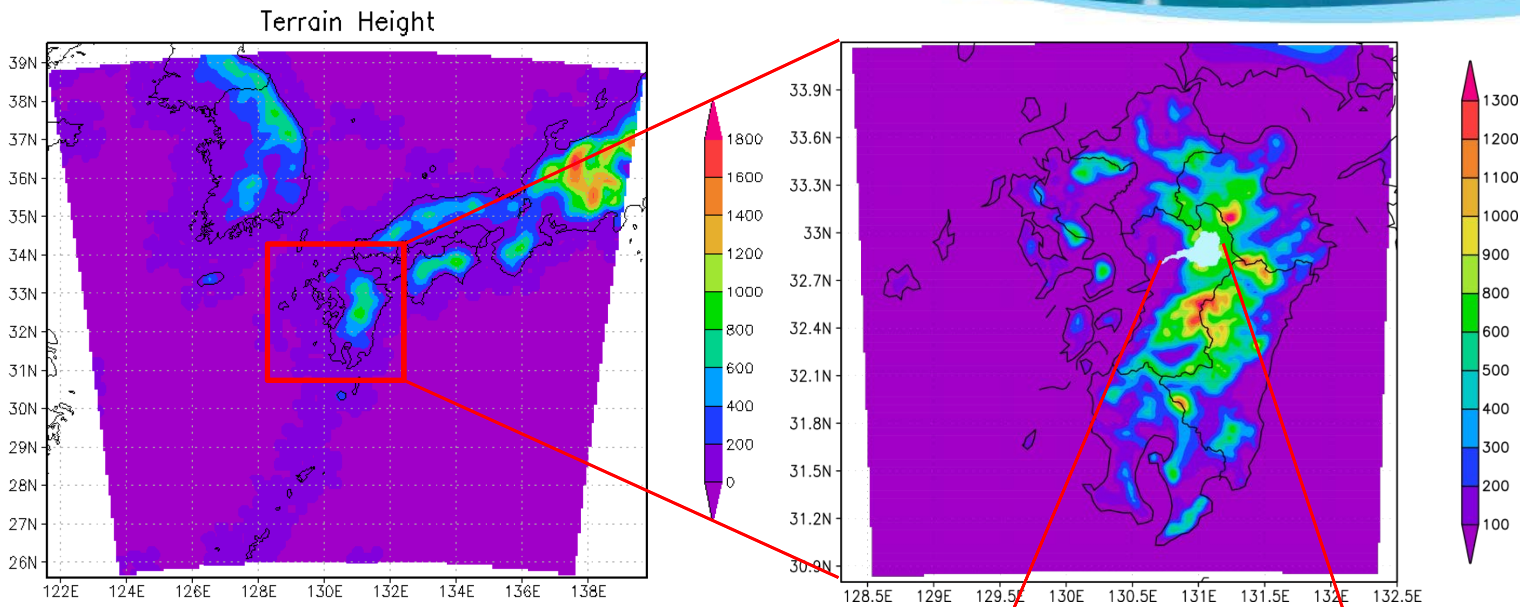
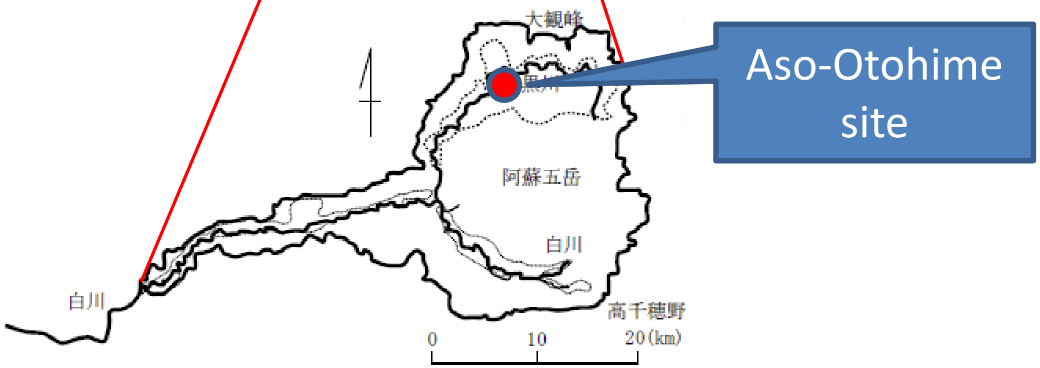
# WRF model design



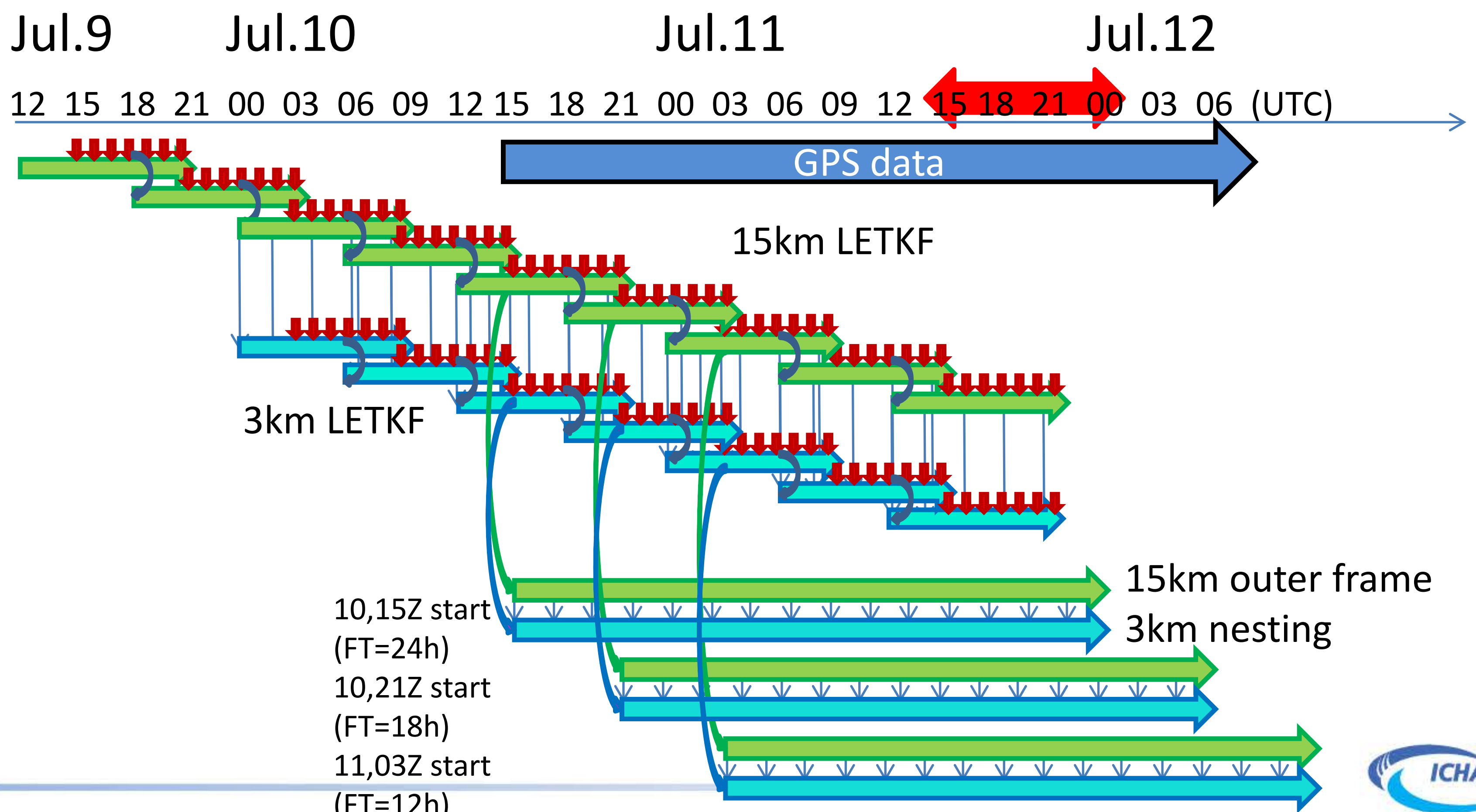

**Outer frame：**
15km mesh, 101x101x40 layers
(1500km x 1500km)
WSM3 microphysics
Kain&Fritsch parameterization
**Inner frame:**
3km mesh, 126x126x40 layers
(375km x 375km)
Lin microphysics
No cumulus parameterization




Shirakawa River catchment
(480 $km^2$ )

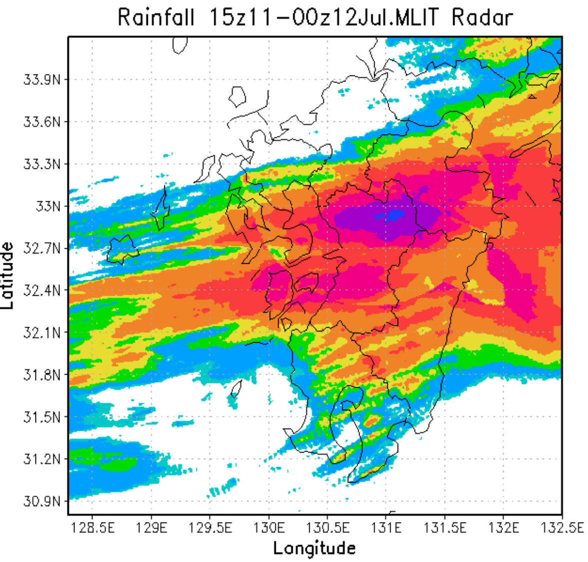
# WRF-LETKF design

- Initial and boundary conditions were by JMA-MSM with NCEP-GFS (50hPa, soil) with lateral boundary perturbation (downscaling of JMA weekly ensemble forecast)
- Assimilated data: PREPBUFR (U, V, T, Q, PS)＋AMeDAS (T, U, V, RH)+GPS PWV hourly, $\sigma_{OBS}$ =200km/50km for 15km/3km mesh, multiplicative inflation factor is 10%.
- 51 members

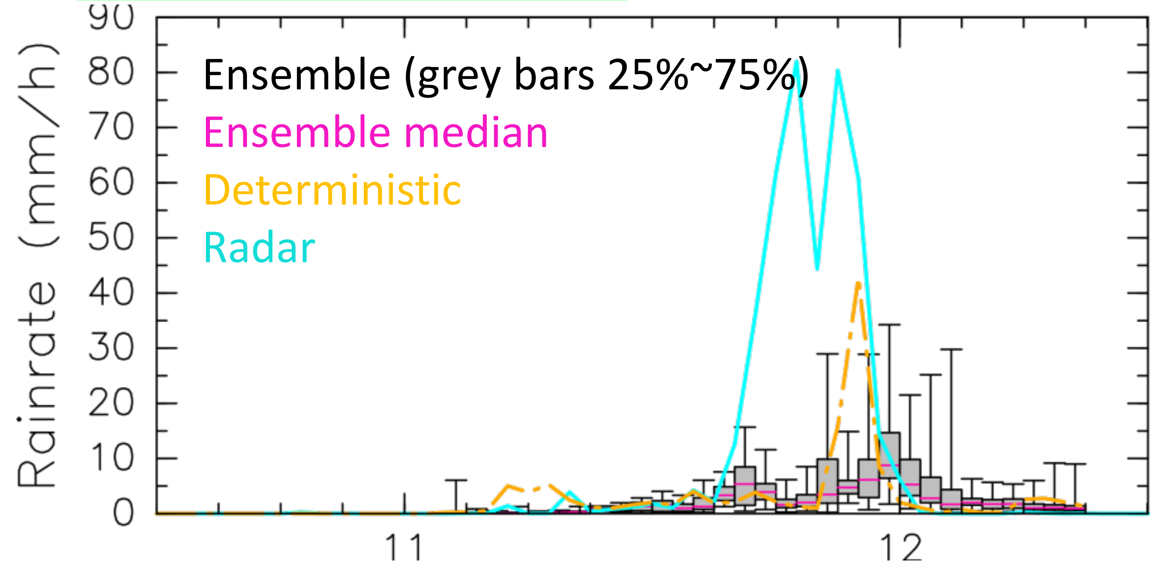


# LETKF analysis

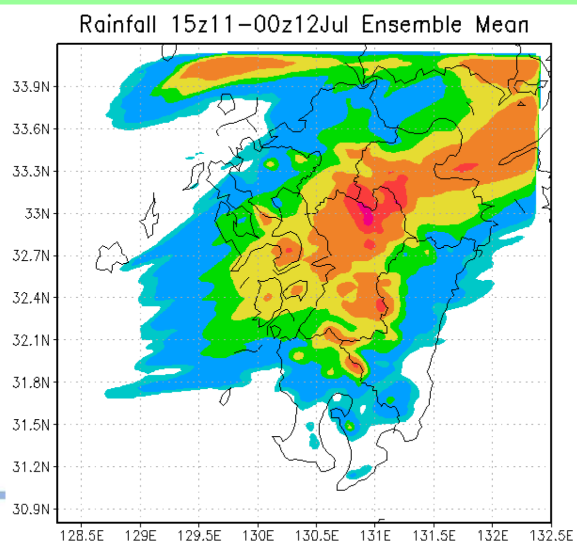
Radar analysis




00Z10Jul.~ 6h update Rainfall

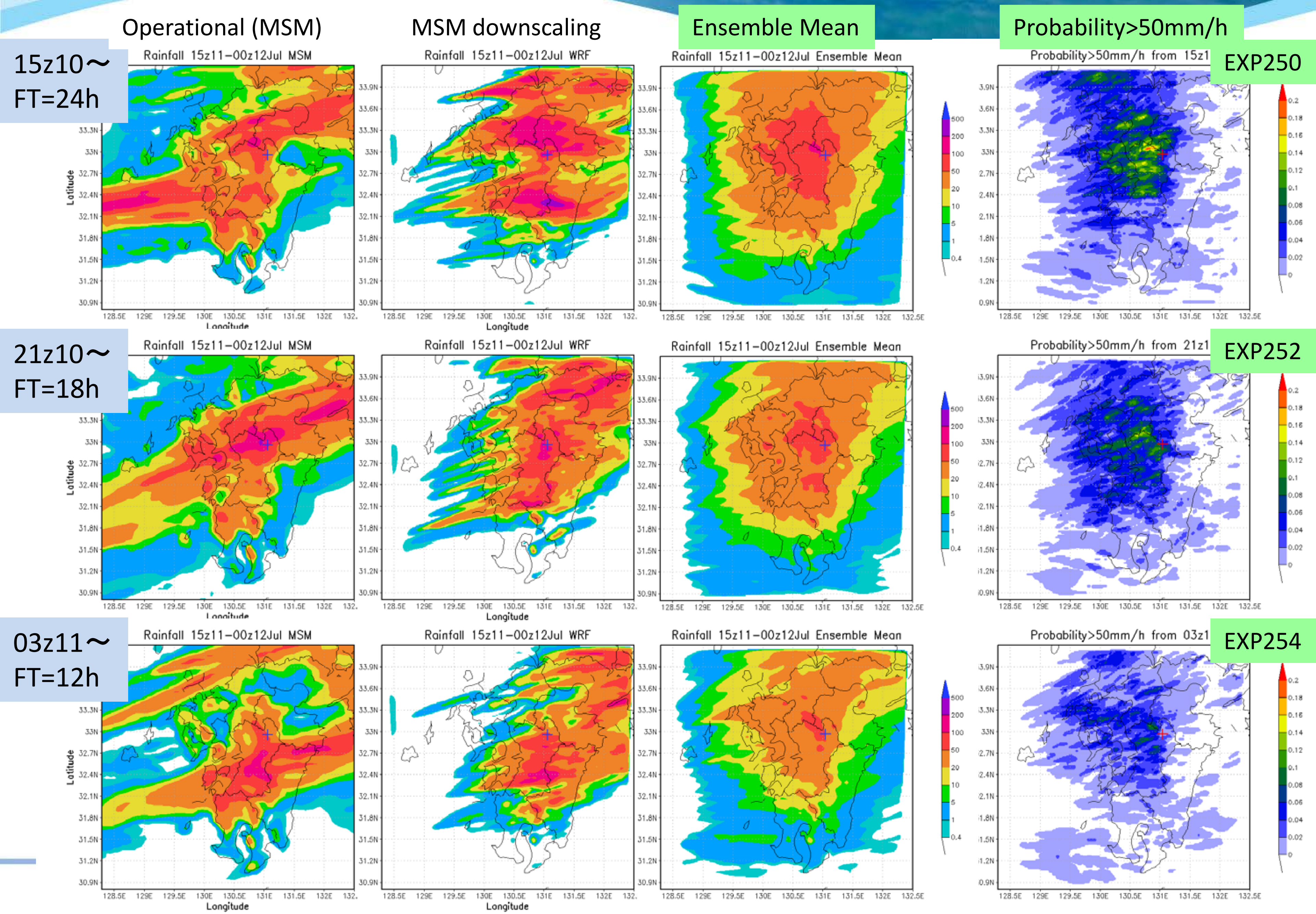



Ensemble mean 00z10~ 6h update



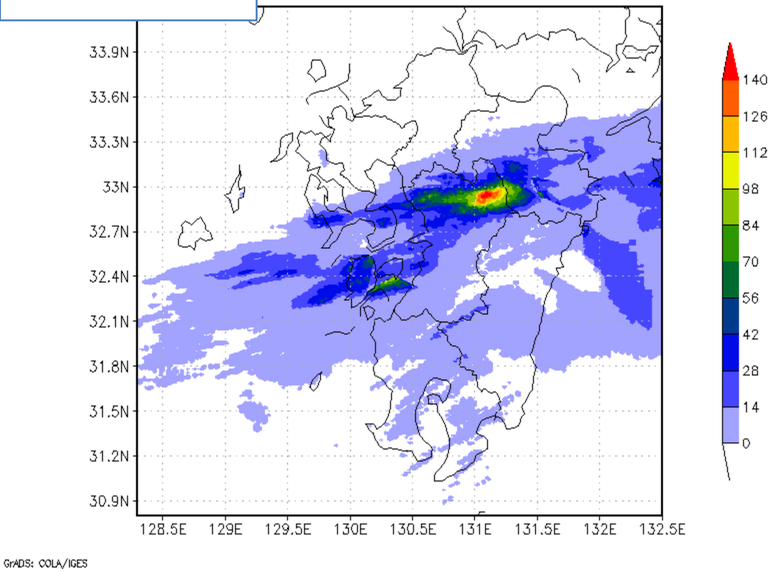

Ensemble mean of LETKF analysis underestimated the total rainfall by about 80%.
Deterministic forecast underestimated as well.

# 33 hour forecast (3km mesh, 51members)

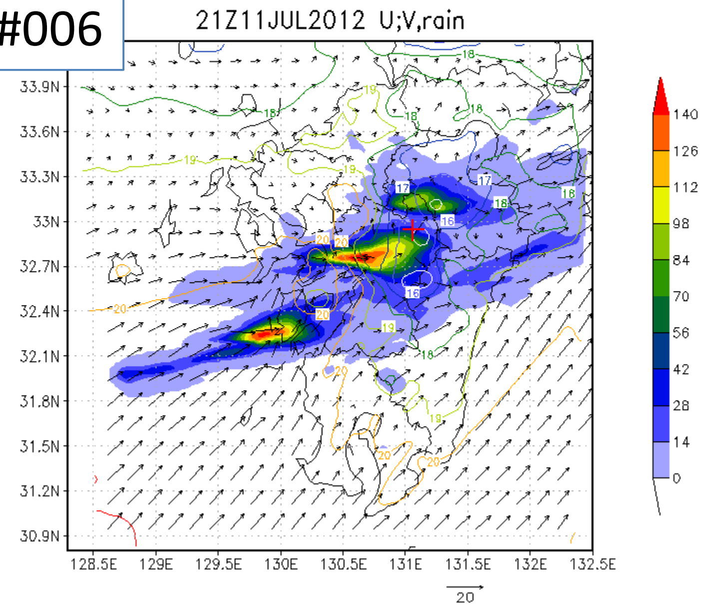


# Torrential rainfall snap shot (FT=24h)

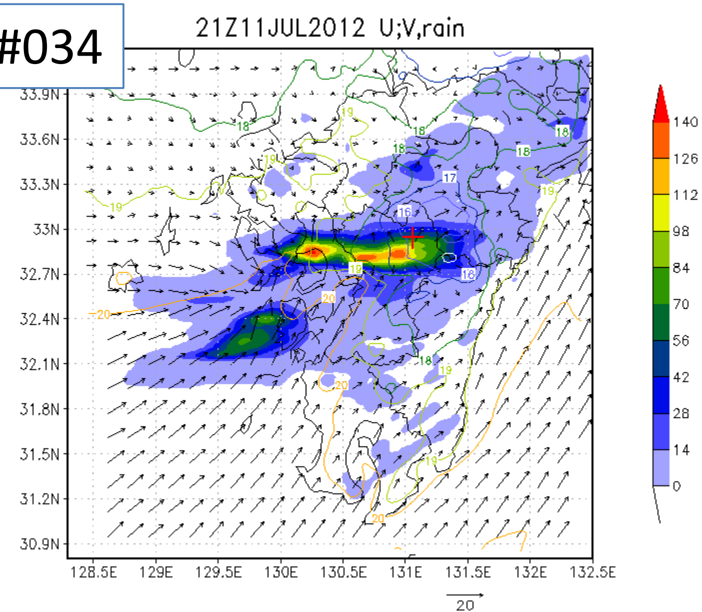
Radar obs



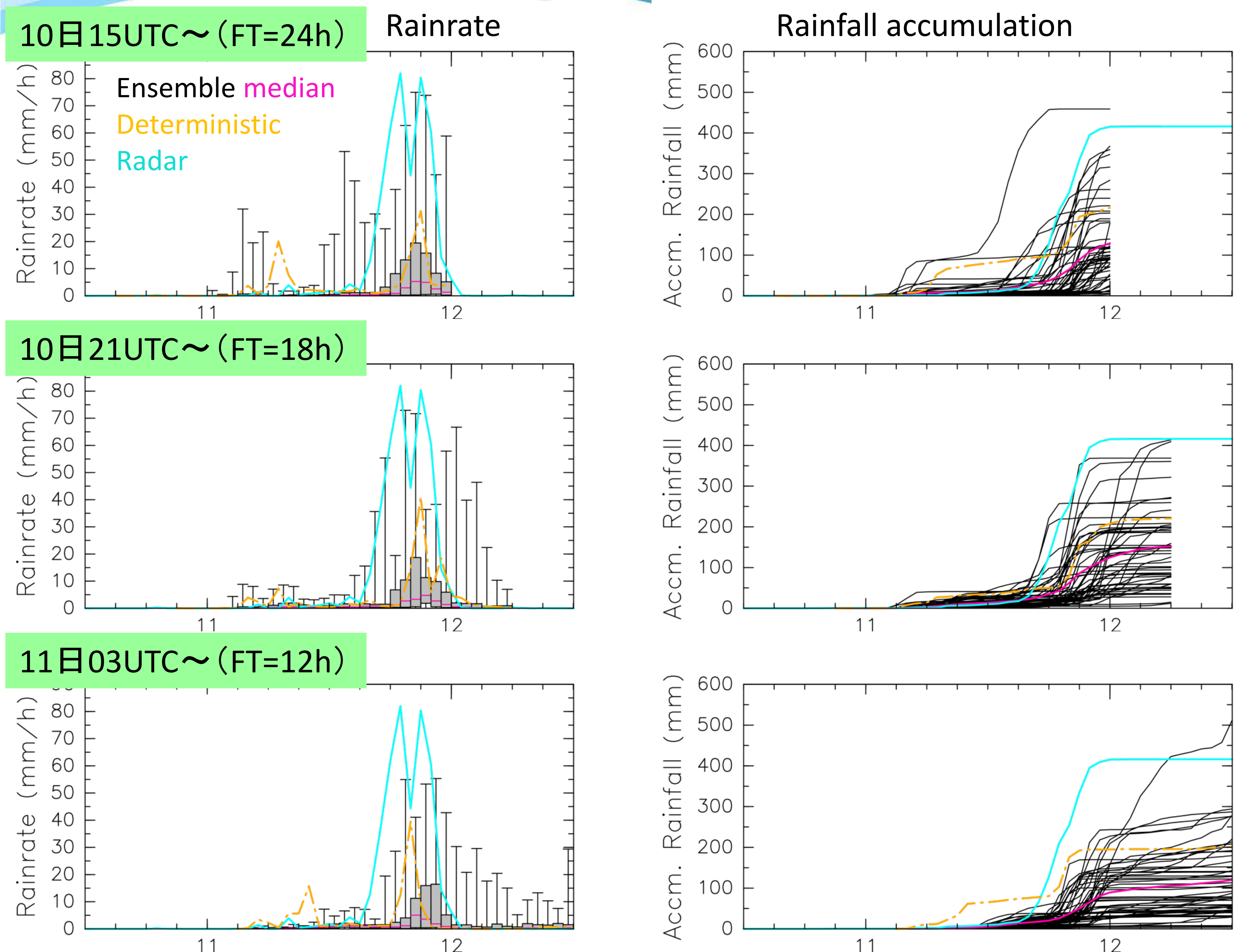

#006




#034

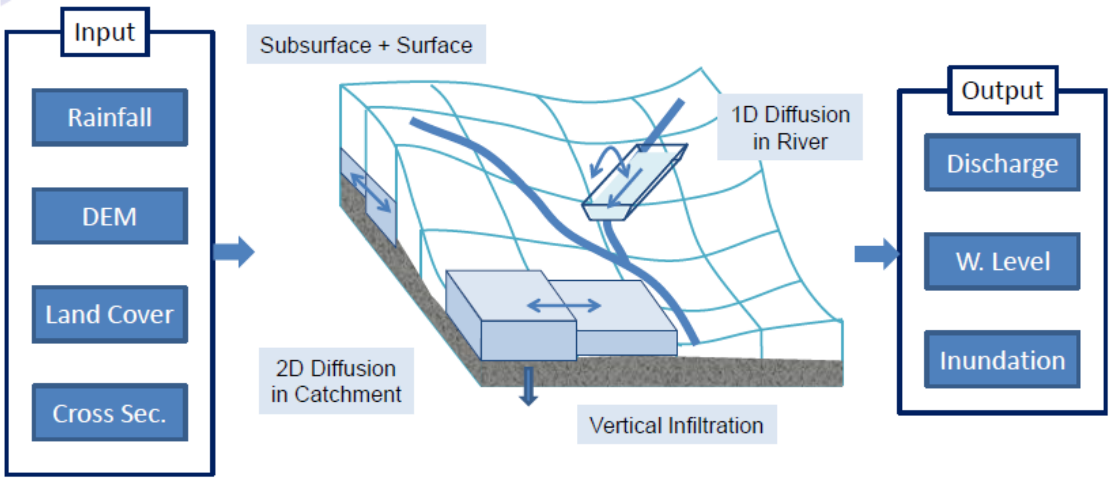


# Catchment average rainfall

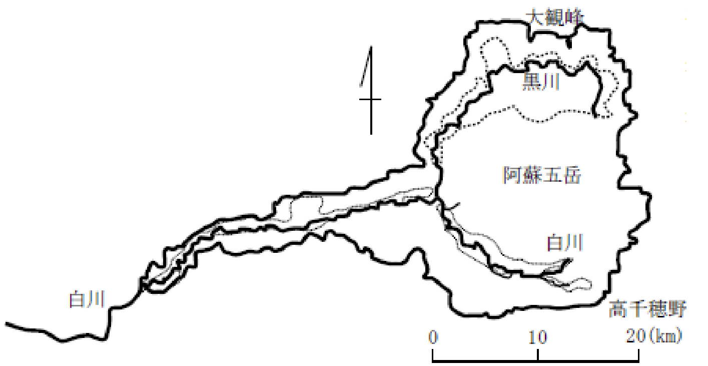


# Streamflow prediction

- Rainfall-Runoff-Inundation (RRI) model

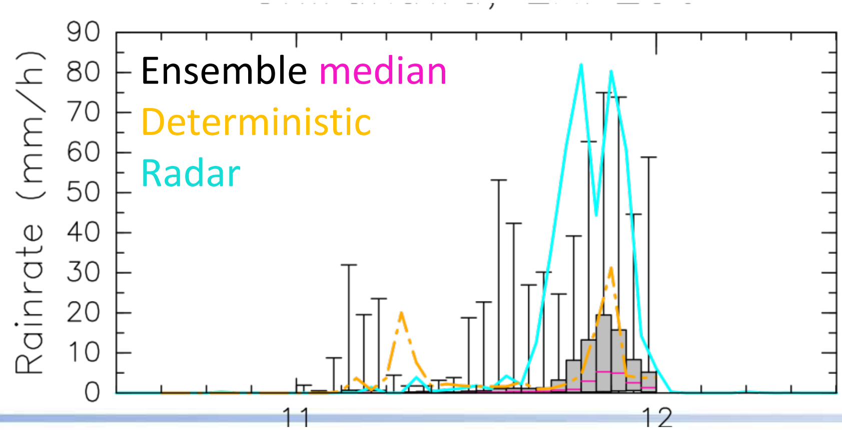



Shirakawa catchment (480 $km^2$ )

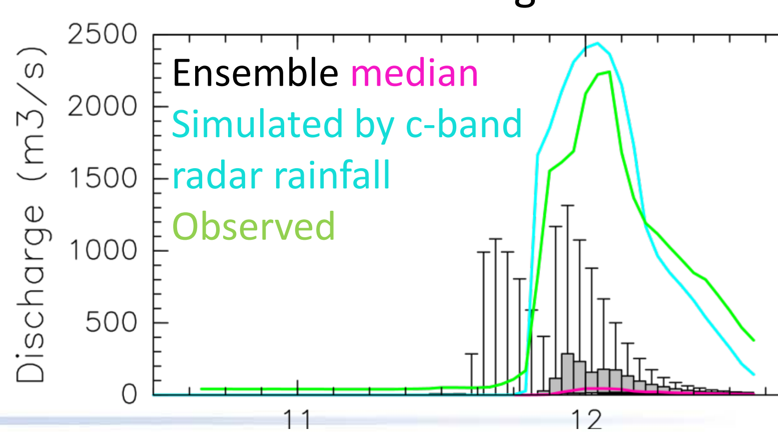



- The streamflow simulation using predicted rainfall couldn't reach observed discharge.

Rainrate




Discharge

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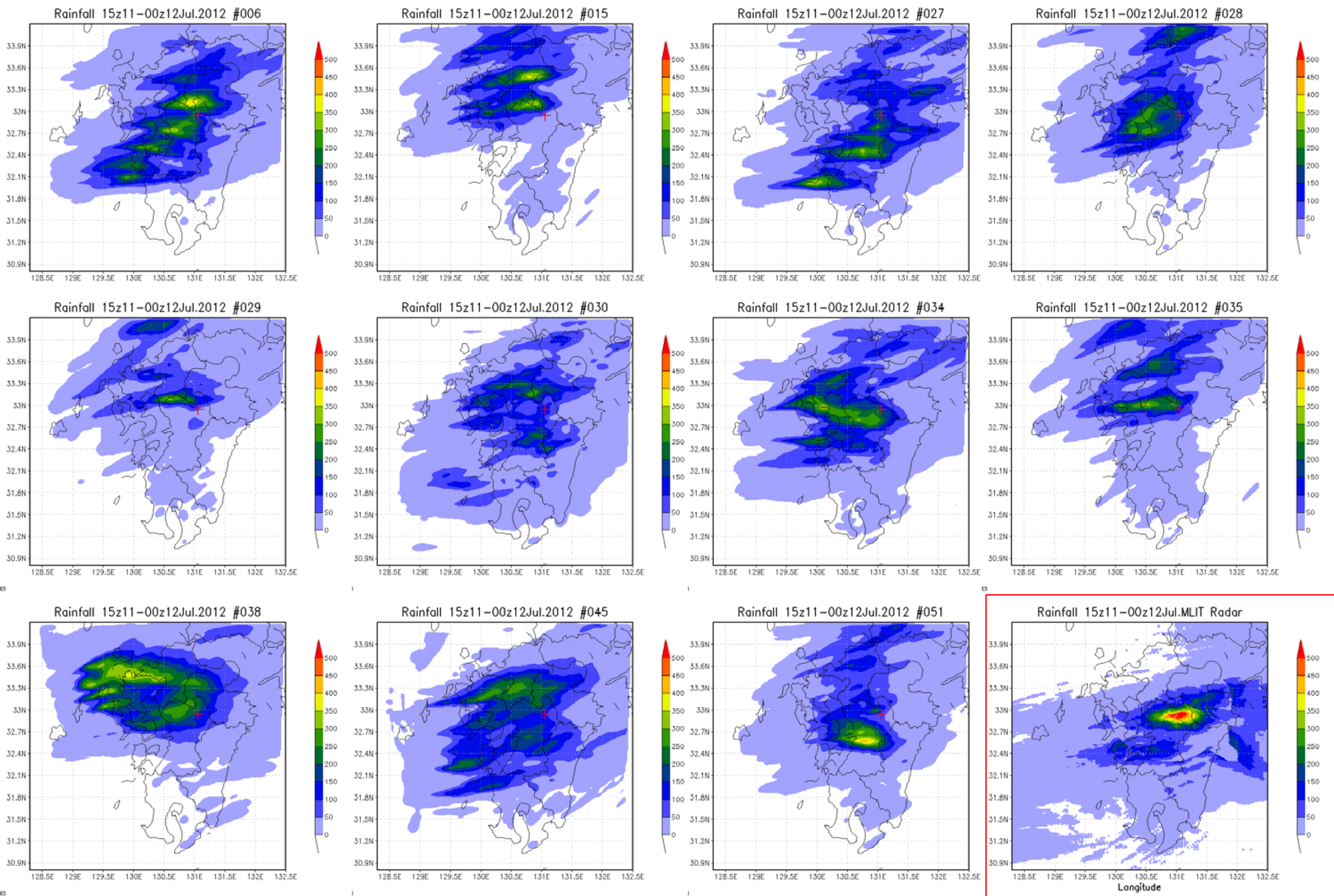
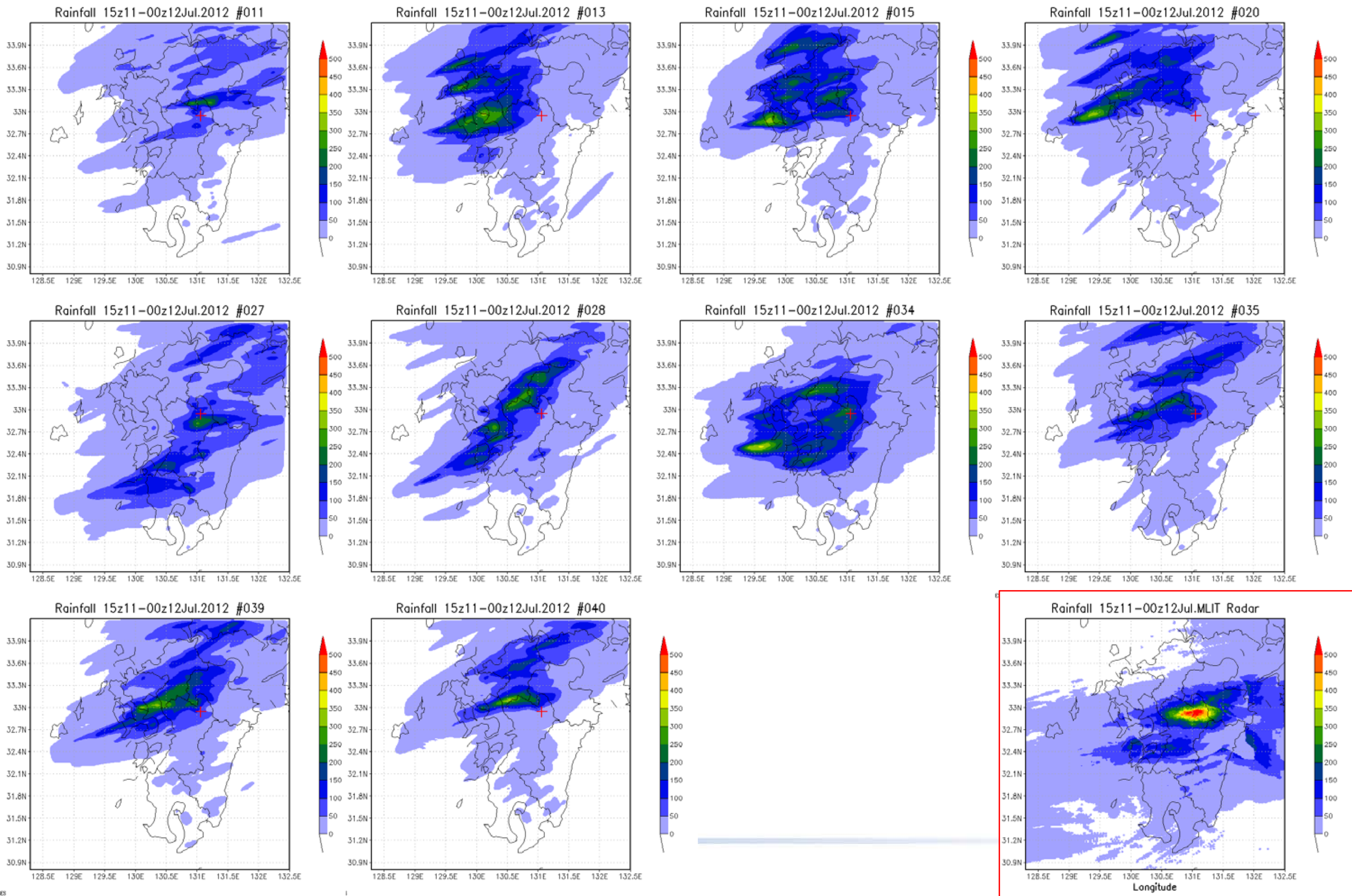
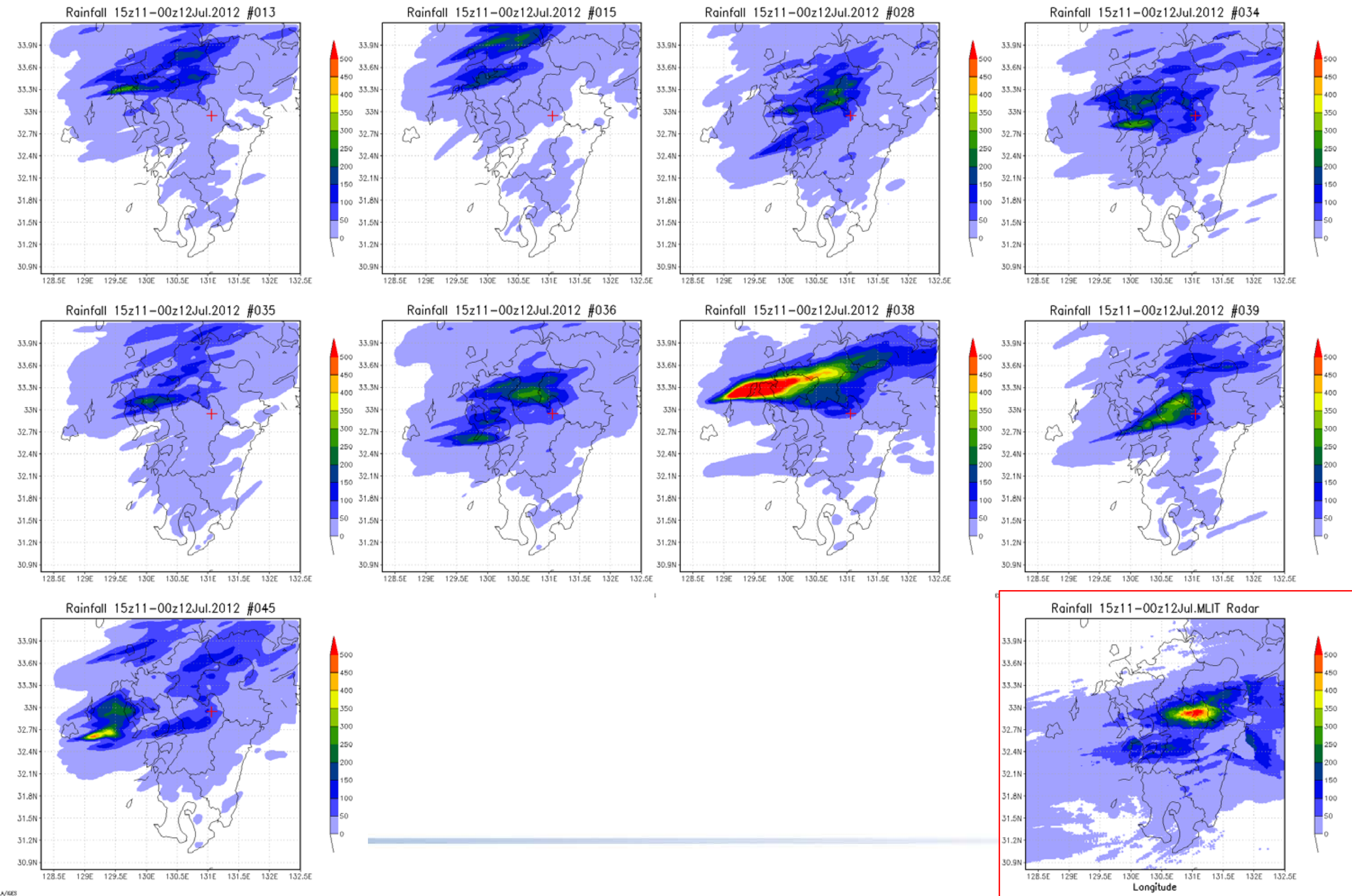
# Large rainfall members (FT=24h)



# Large rainfall members (FT=18h)

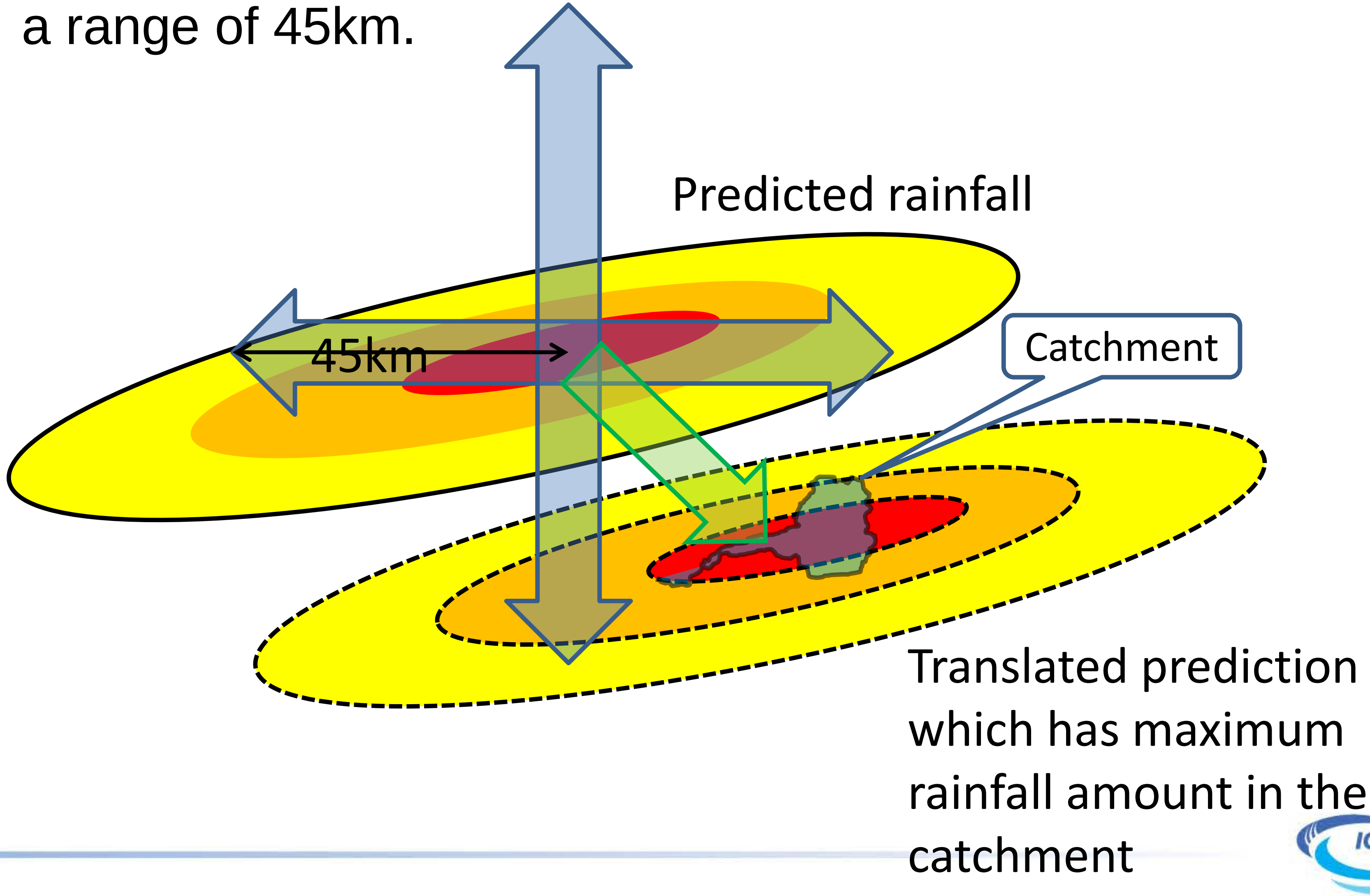


# Large rainfall members (FT=12)



# Translation

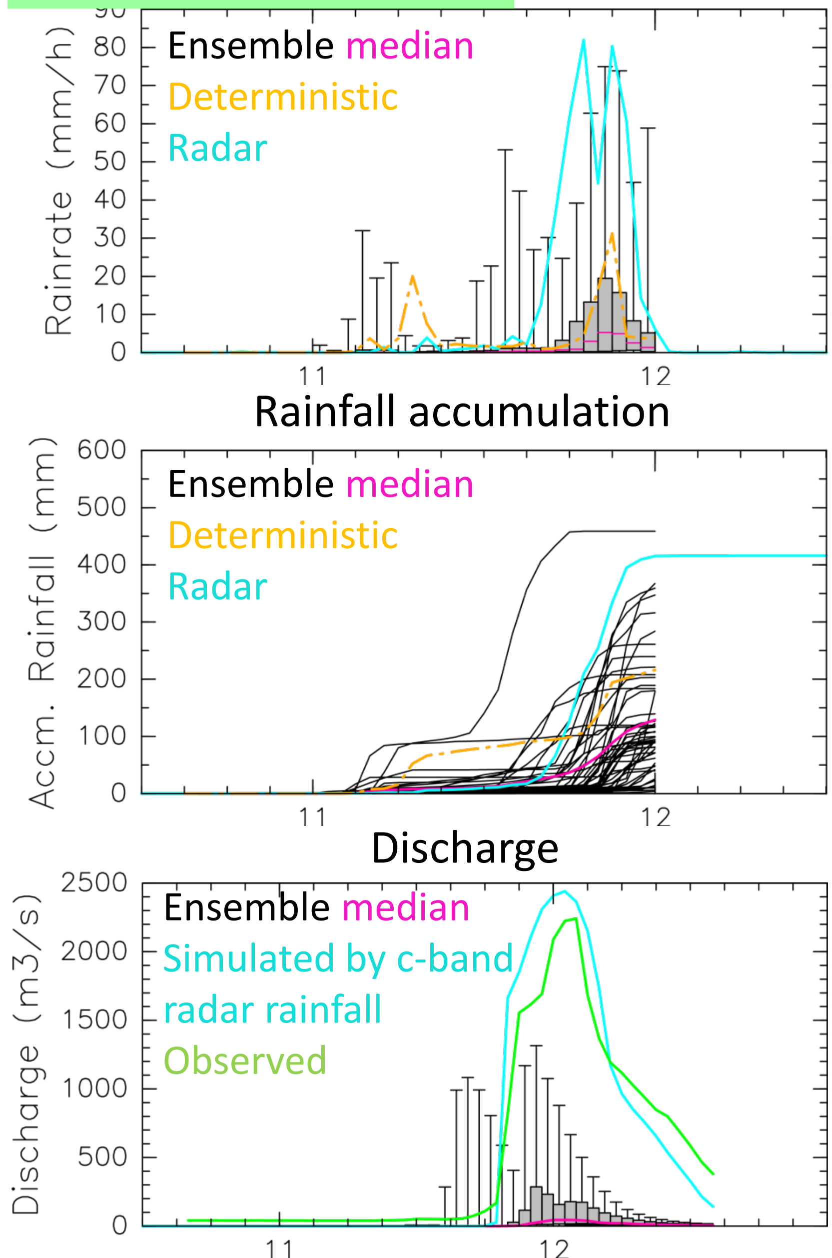
- We translate accumulated rainfall pattern to find possible extreme rainfall in the catchment area within a range of 45km.

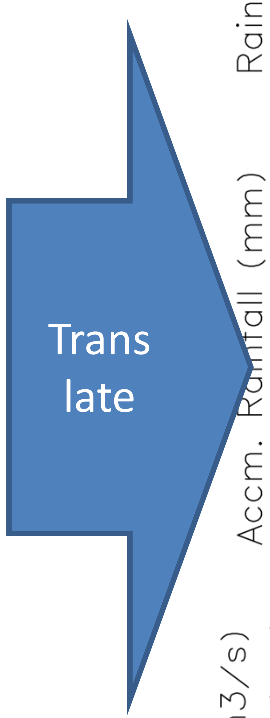


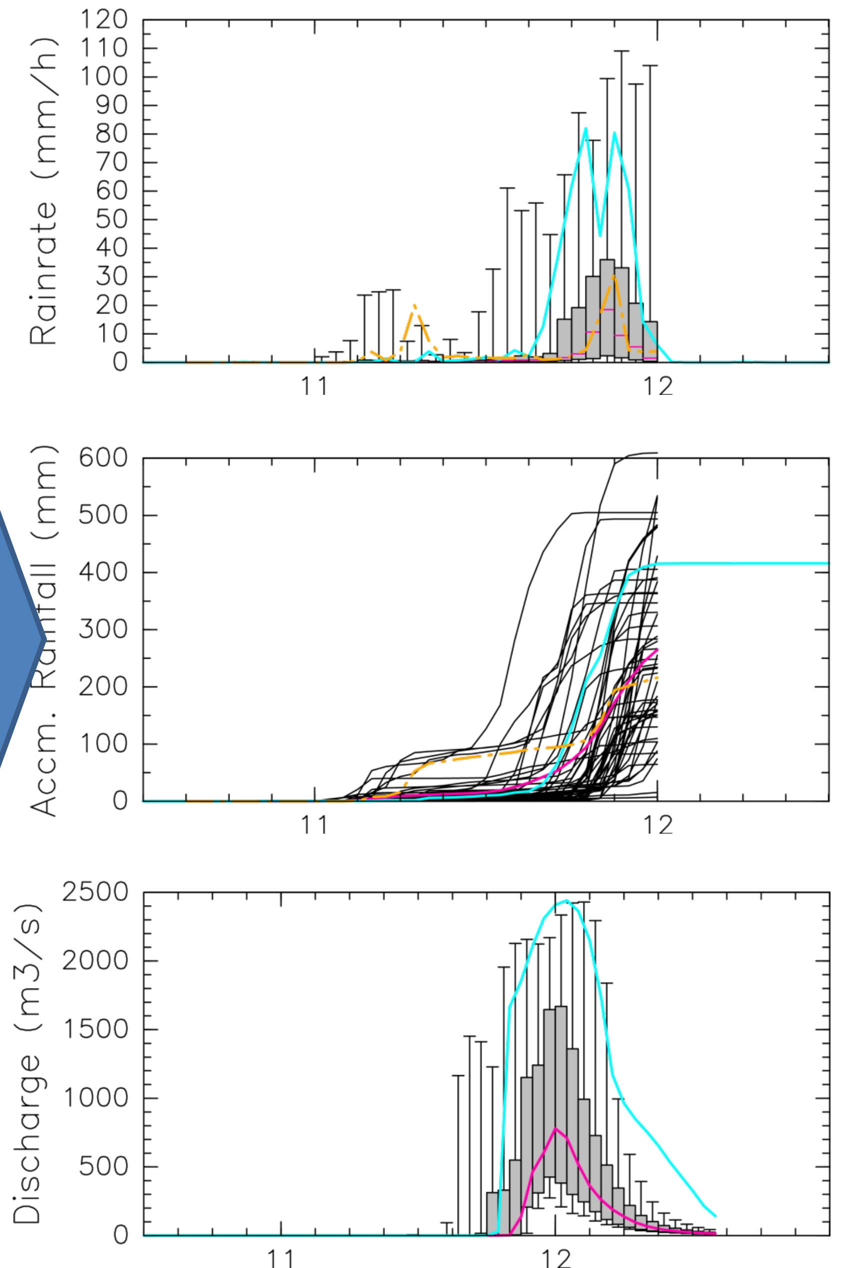
# Translate rainfall and Discharge

10日15UTC～（FT=24h）

Rainrate



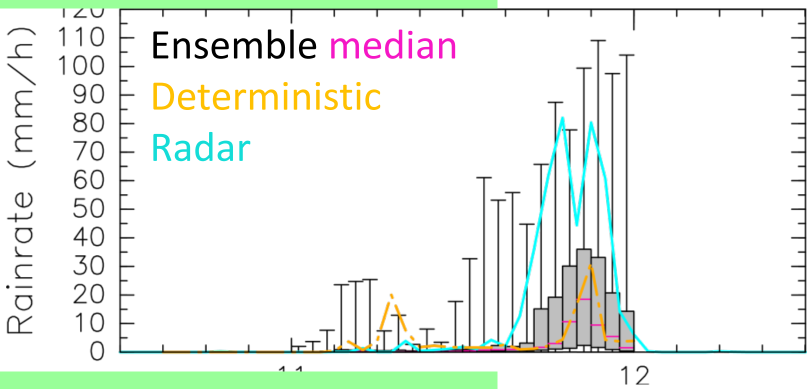



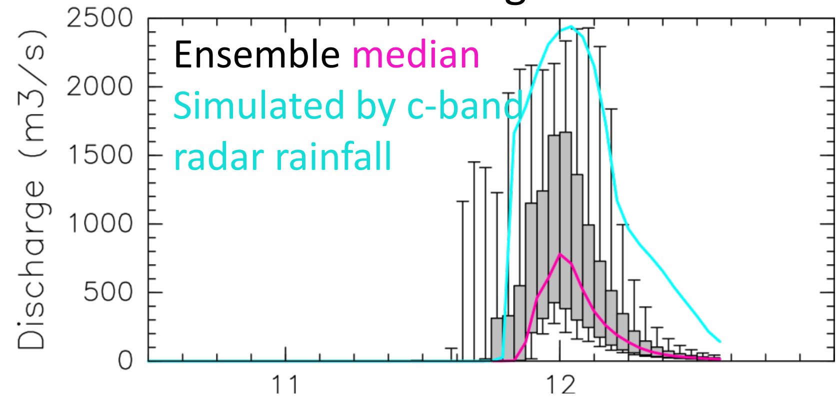
# Translated rainfall and Discharge

10日15UTC～（FT=24h）

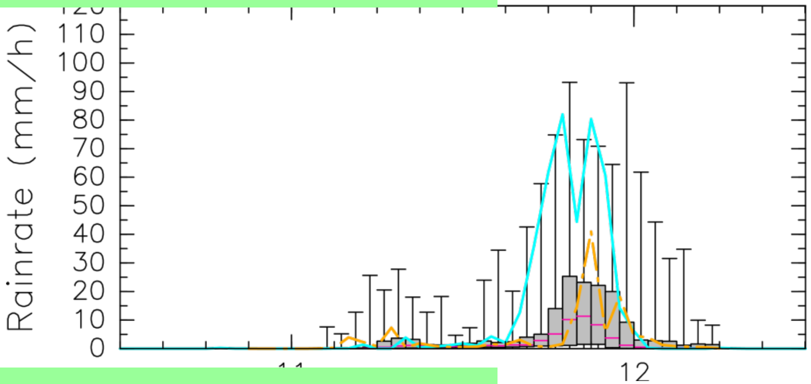
Rainrate

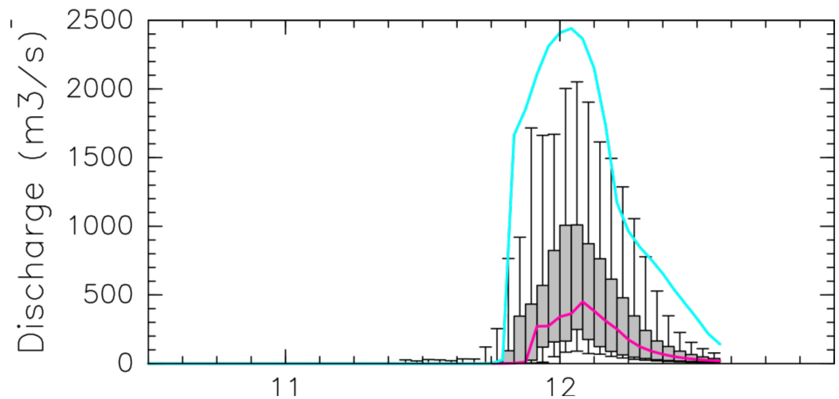



Discharge

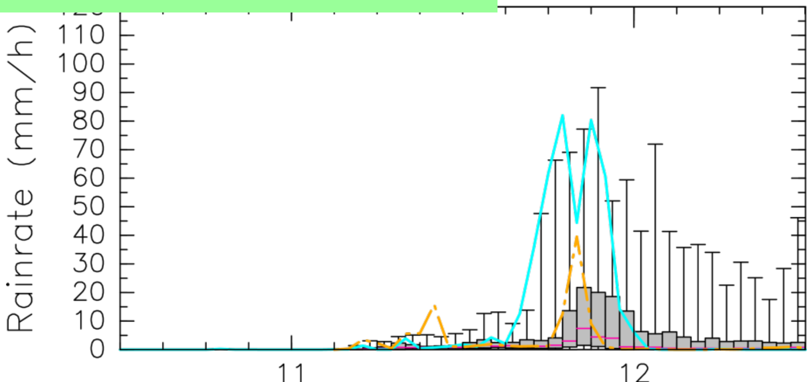


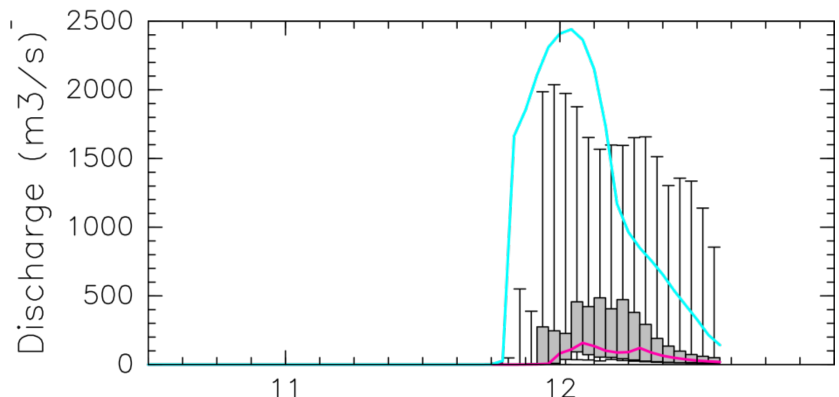

10日21UTC～（FT=18h）




11日03UTC～（FT=12h）

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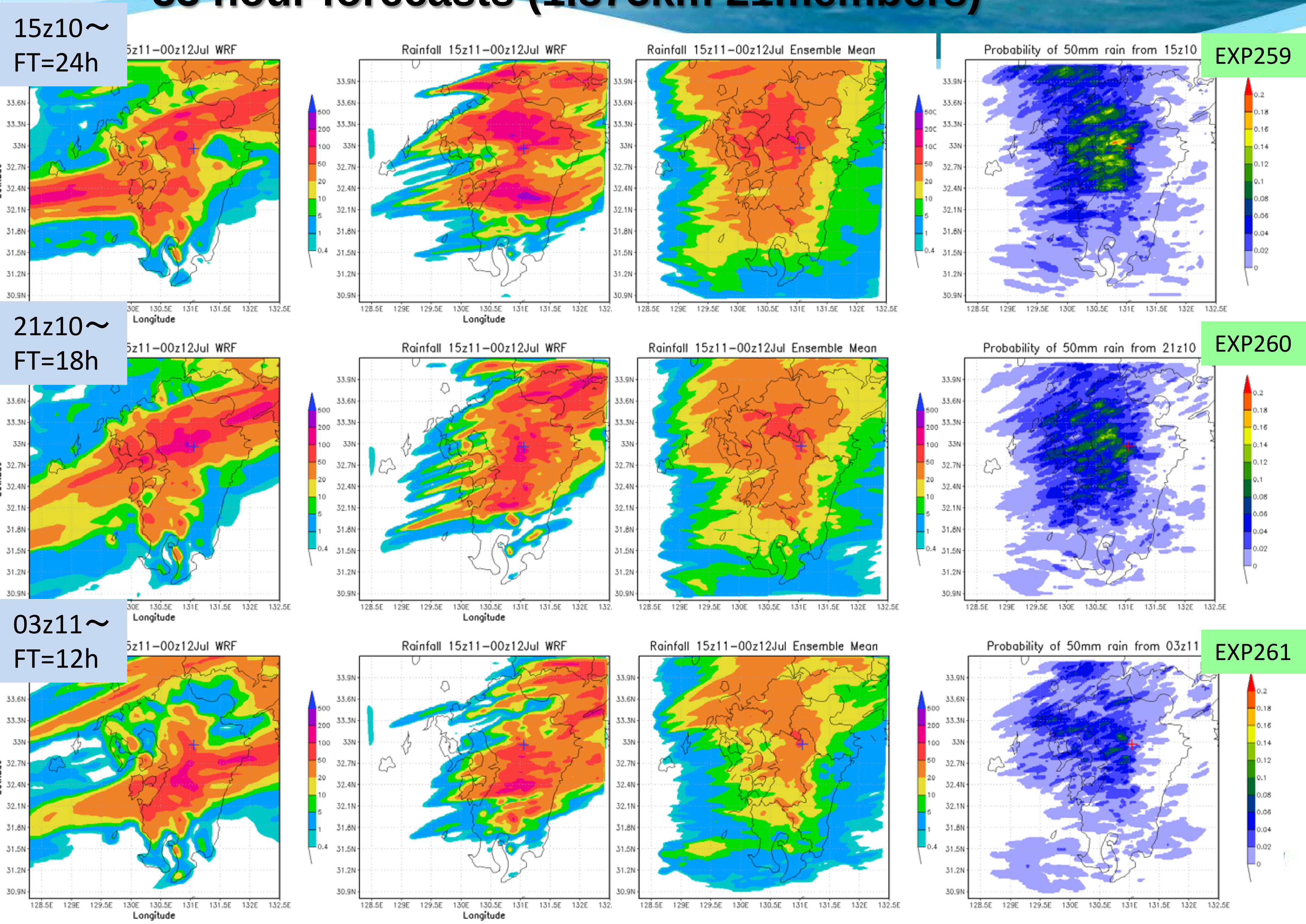
# Summary

- Ensemble weather prediction by WRF-LETKF and ensemble flood forecasting were carried out to examine its predictability for 2012 Northern Kyushu flood event.

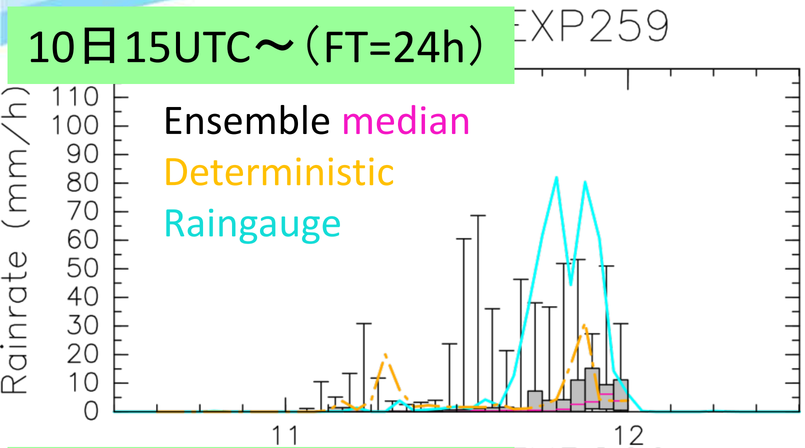
- EPS with 51 member, 15km/3km resolution predicted probability of extreme rainfall, which operational forecast couldn't predict. However, it couldn't predict possibility of the flood. It is still hard to predict rainfall in the river catchment of 480 $km^2$.

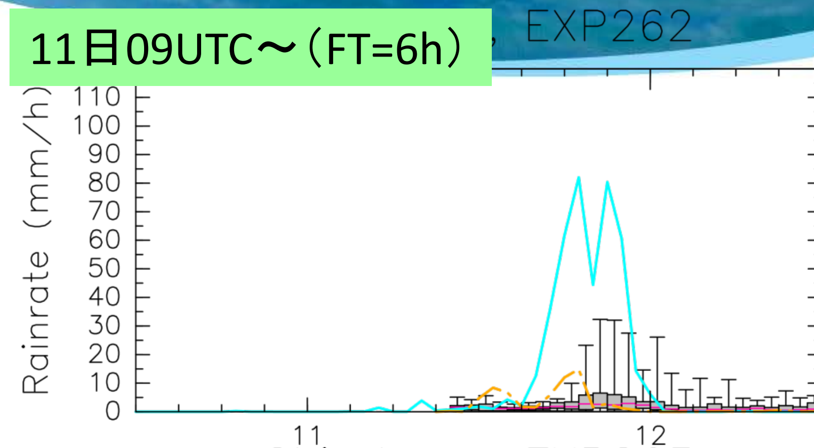
- Translating each member of EPS rainfall could eventually predict the possibility of flood.

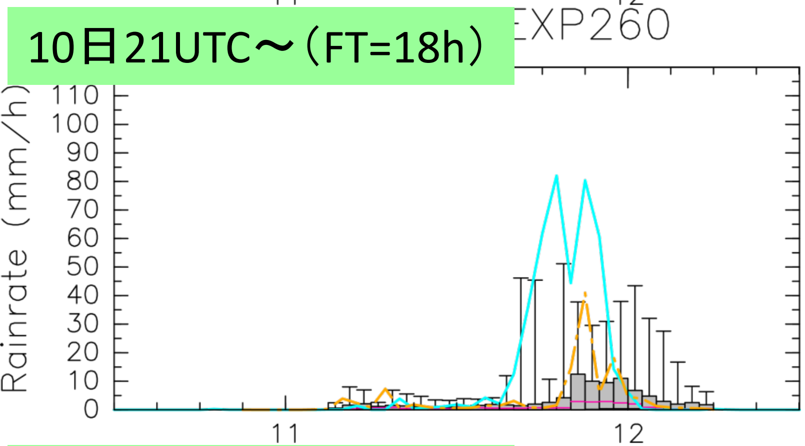
# 33 hour forecasts (1.875km 21members)

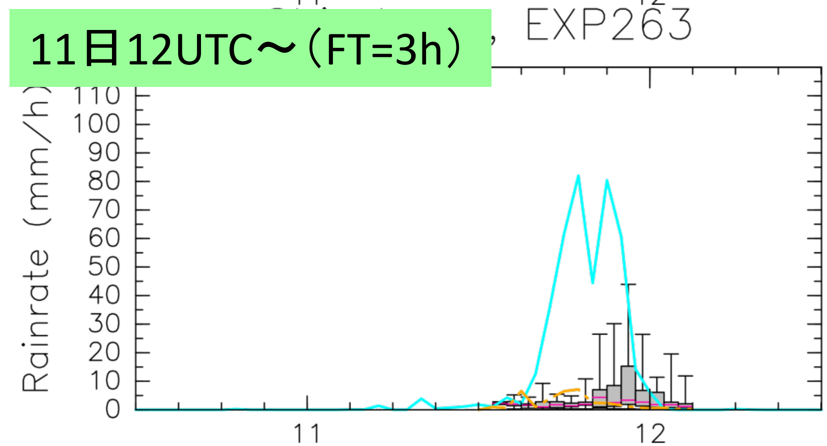


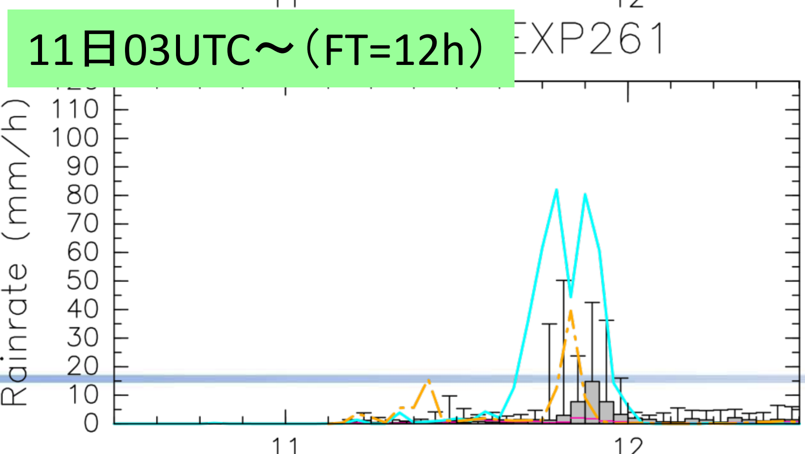
# Original rainfall prediction 1.875km 21members



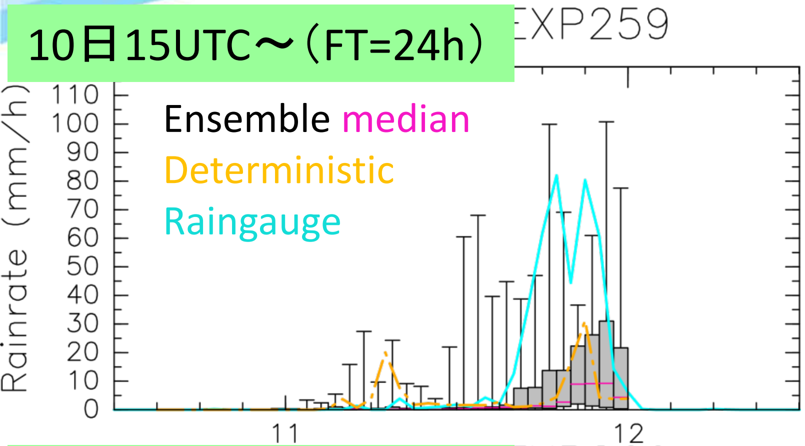



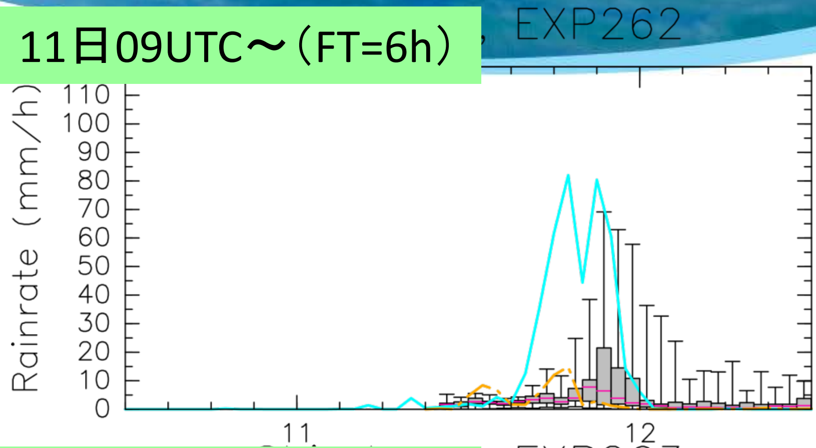



# Translated rainfall prediction 1.875km 21members

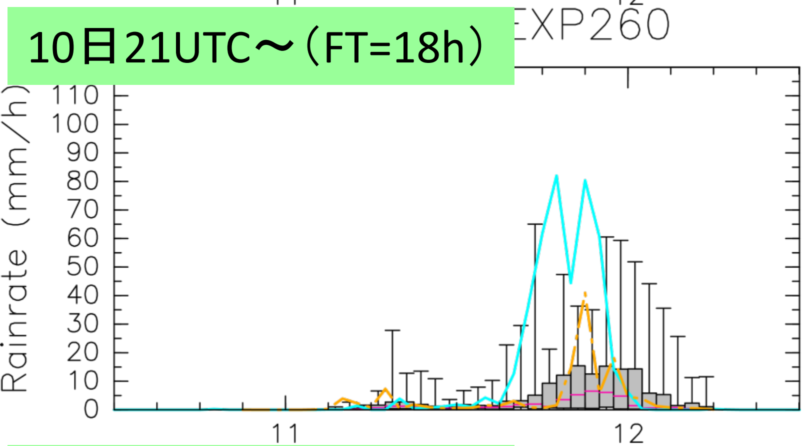
10日15UTC～（FT=24h）



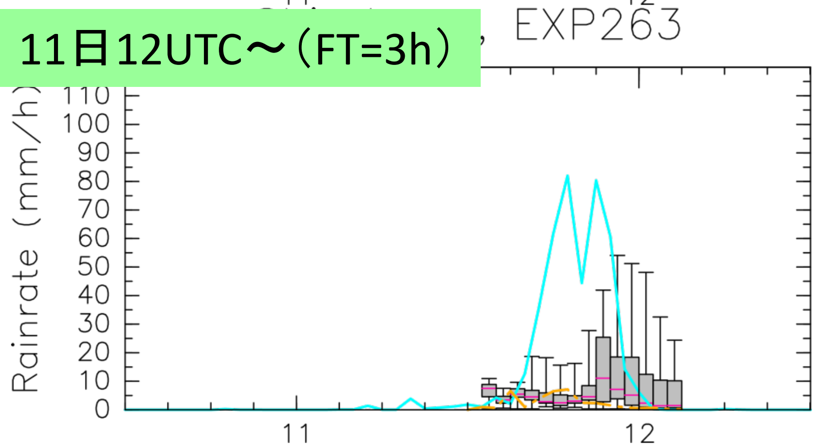

11日09UTC～（FT=6h）



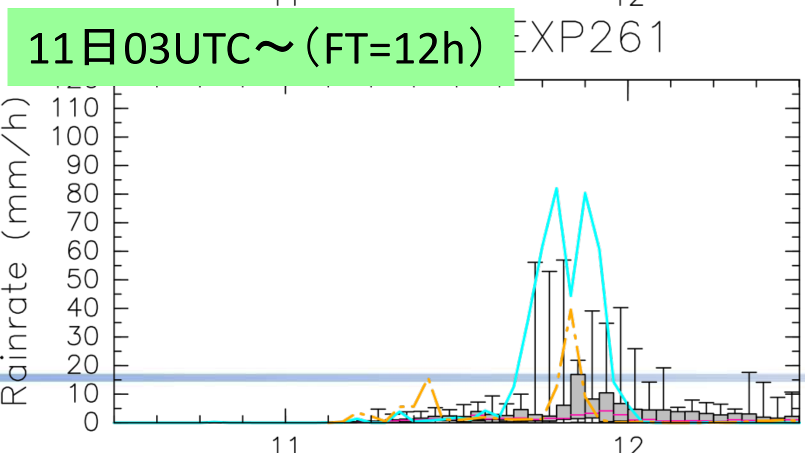

10日21UTC～（FT=18h）



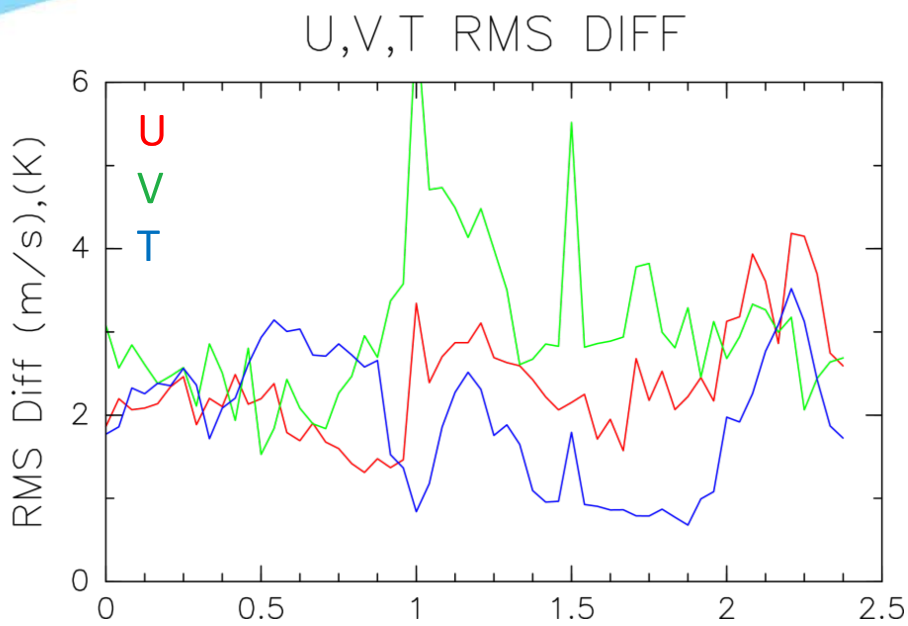

11日12UTC～（FT=3h）



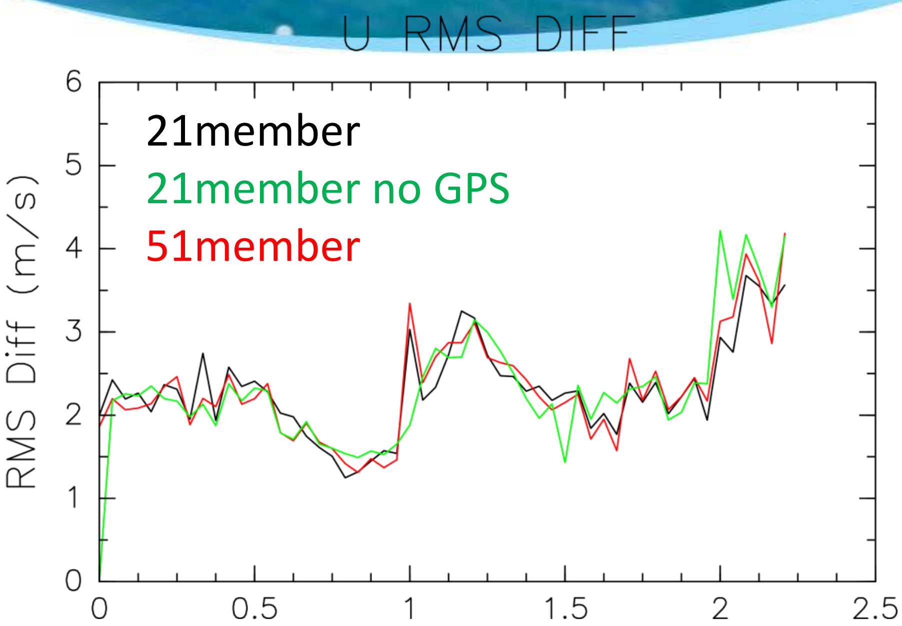

11日03UTC～（FT=12h）



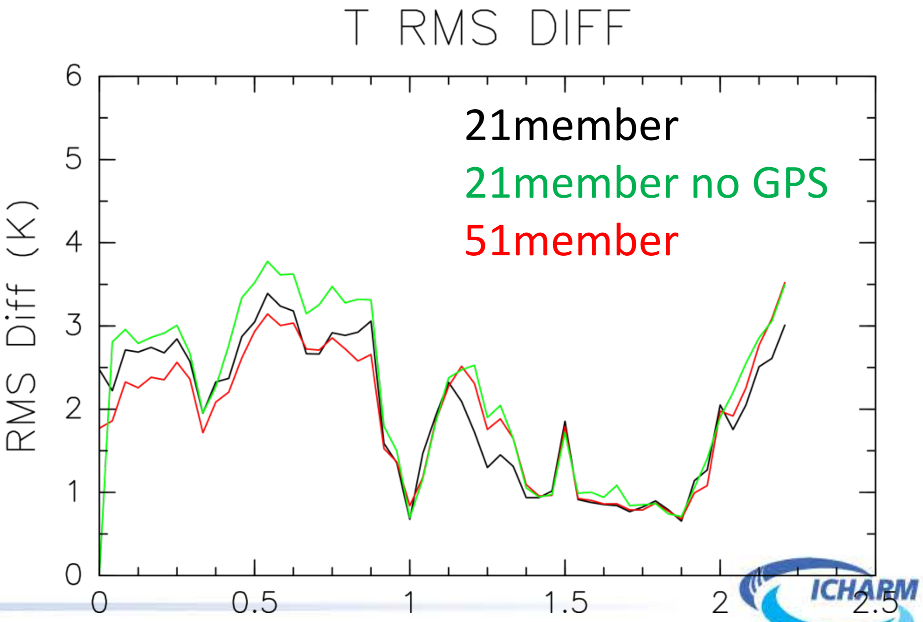
# RMSE



U,V,T RMS DIFF
RMS Diff (m/s),(K)
U
V
T
0
2
4
6
0
0.5
1
1.5
2
2.5

U RMS DIFF
RMS Diff (m/s)
21member
21member no GPS
51member
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5

T RMS DIFF
RMS Diff (K)
21member
21member no GPS
51member
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5