An Integrated Rapid Multi-Scale Analysis and Prediction System (RMAPS-IN) in Beijing Area and its Preliminary Performance Evaluation

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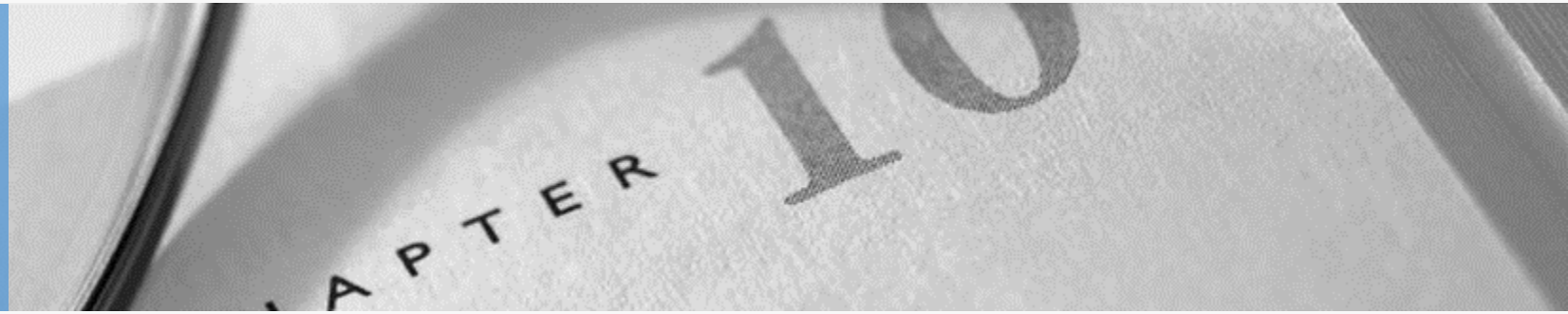
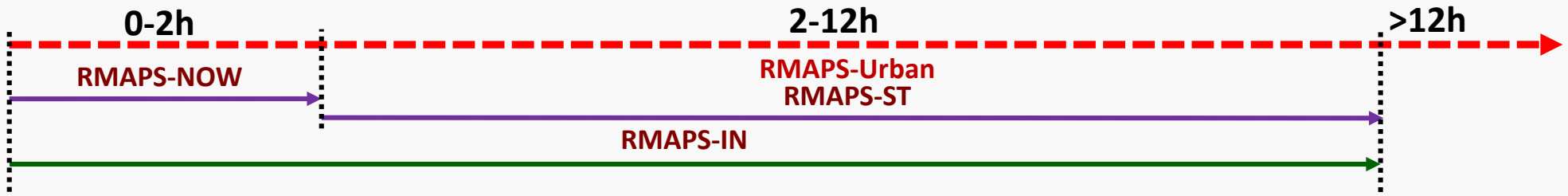


WHAT'S RMAPS and RMAPS-IN

- RMAPS: ***R**apid updated **M**ulti-scale **A**nalysis and **P**rediction **S**ystem*
  - 4 Components:
    - ST(***S**hort-**T**erm): WRF+WRFDA (0-24h)*
    - NOW(***NOW**casting): AutoNowcasting+VDRAS (0-2h)*
    - Urban
    - IN(***IN**tegration): **IN**CA (Beijing Version, 0-12h)*
      - *To provide 10-min updated unified 0-12h output*
- What to INTEGRATE:
  - DATA
    - RADAR QPE: RMAPS-NOW
    - Analysis Background: RMAPS-ST
    - AWS OBSERVATIONS
  - TECHNIQUES
    - Wind analysis background: RMAPS-NOW
    - Motion Vector: RMAPS-NOW
    - Blending Weight: RMAPS-NOW



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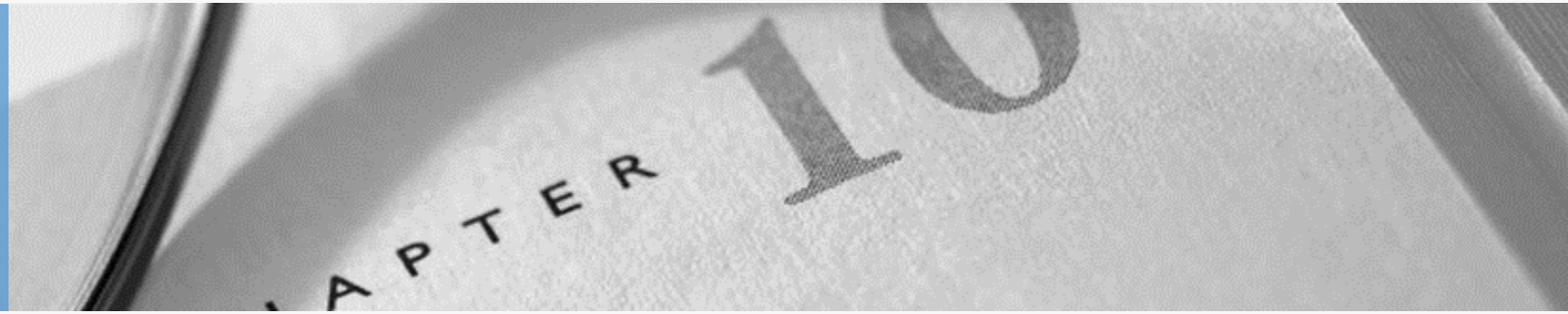
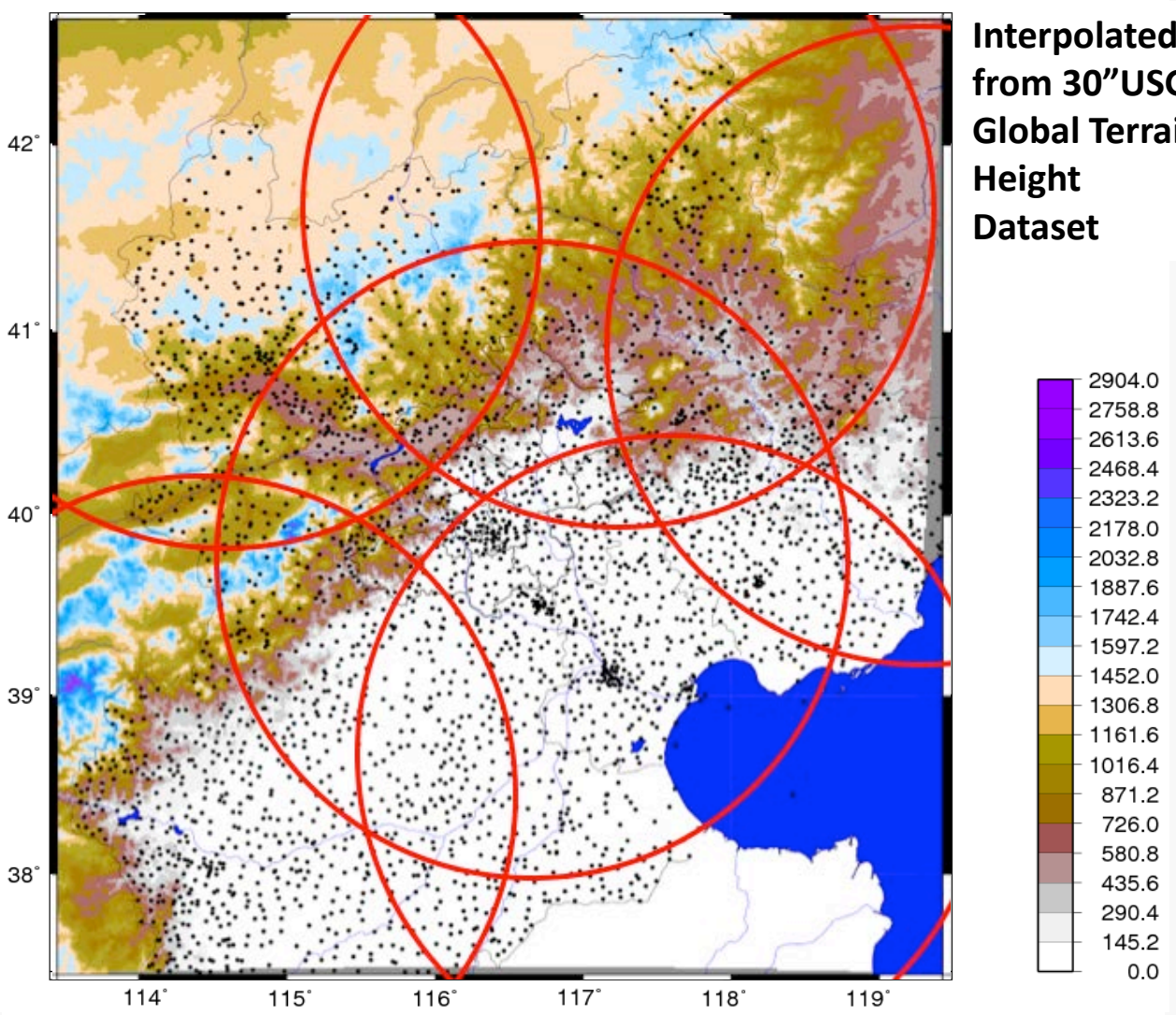


Domain Configuration and Downscaling to 1km



Interpolated from 30”USGS Global Terrain Height Dataset

- Grid points: 511*581
- Grid distance: 1km
- 3223 AWS stations
- 6 Doppler Radars

RMAPS-INv1.0 Features

Horizontal

- Lambert projection
- 1x1 km

Vertical

- True z-coordinate
- 0-4000m
- TQ: dz=200m, 20 layers
- UV: dz=125m, 32 layers

3-D Analysis

- Temperature
- Humidity
- Wind

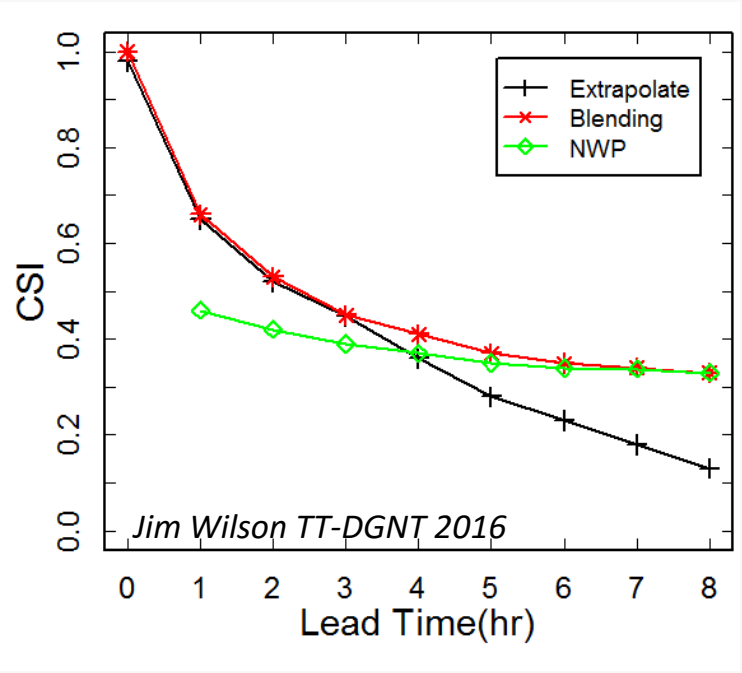
2-D Convective Parameters

- CAPE, CIN, LCL, LFC
- Instability Indices (LI, Showalter, ..)
- Trigger-Temperature-Deficit
- Equivalent Potential Temperature
- Moisture convergence
- Mass convergence

2-D Analysis and Forecasts

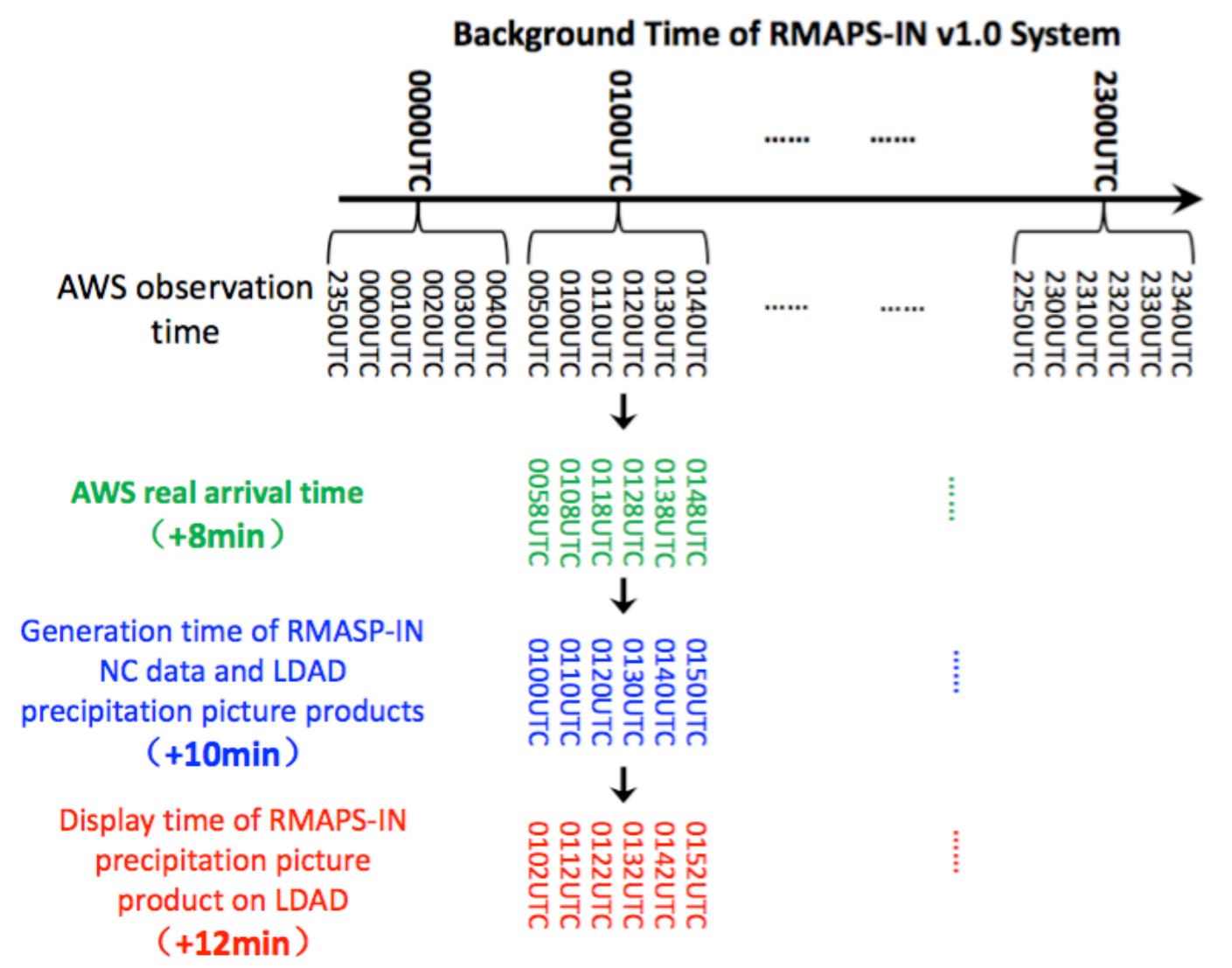
- 2-m Temperature
- 2-m Relative Humidity
- 10-m Wind
- Precipitation
- Precipitation type
- Snowfall line
- Icing potential
- Wind chill
- Visibility

RMAPS-IN STRATEGY

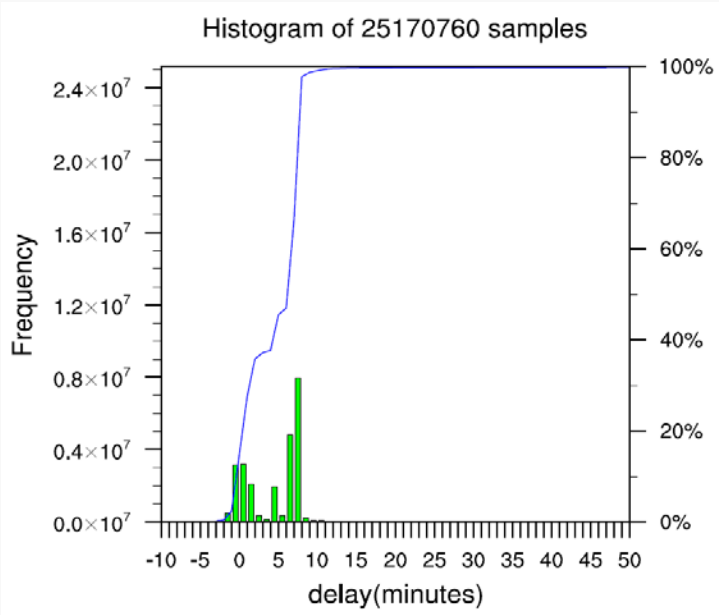


	PRECIPITATION	T/Q/WIND
ANALYSIS BACKGROUND	RADAR QPE $P_{ANA}(i,j) = P_{STAT}(i,j) + v\left[P^{**}_{RADAR}(i,j) - P^{**}_{RADSTAT}(i,j)\right]$	NWP (RMAPS-ST) $X_{ANA}(i,j,m) = X_{ST}(i,j,m) + \Delta X(i,j,m)$ $\Delta X = X_k^{OBS} - X_k^{ST}$
NOWCASING	EXTRAPOLATION $P_{EXTRAP}(t_i)$	PERSISTENCE+NWP FORECASTED TENDENCY $X_{IN}(t_i) = X_{IN}(t_{i-1}) + f_T\left[X_{ST}(t_i) - X_{ST}(t_{i-1})\right]$
FORECAST LENGTH AND BLENDING STRETEGY	12 hours $P_{IN}(t_i) = gP_{EXTRAP}(t_i) + (1-g)P_{ST}(t_i)$	12hours $X^*_{IN}(t_i) = g\,X_{IN}(t_i) + (1-g)\,X_{ST}(t_i)$

AWS cut-off time and Running Time Table



- Timetable
  - 7*24
  - Updated time interval: 10-min
- RMAPS-IN products delay time: 8+2+2 minutes
  - 8-min: AWS observation cut-off time
  - 2-min: RMAPS-IN running
  - 2-min: Products distribution
- Strategies to accelerate the running
  - Compilation optimization
  - OPENMP



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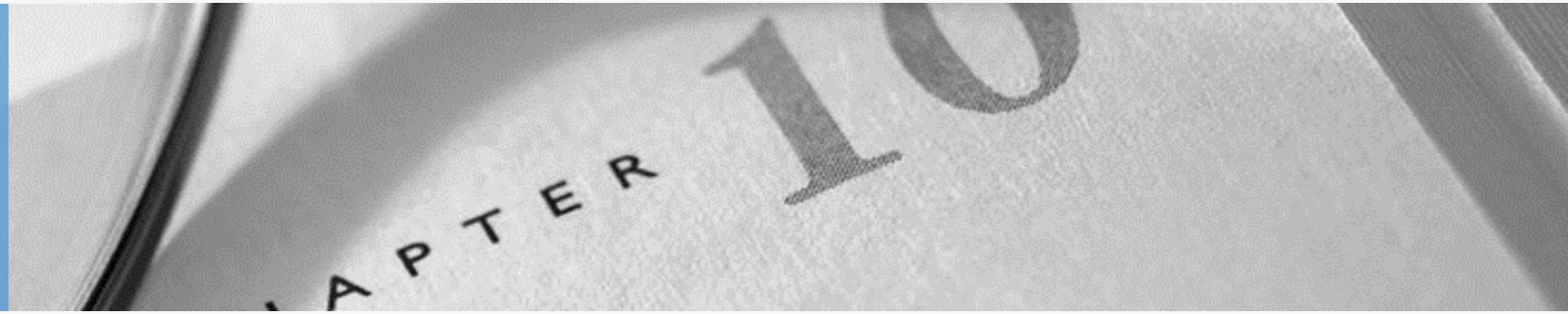


QPE of RMAPS-IN

Rain-Gauge Observations

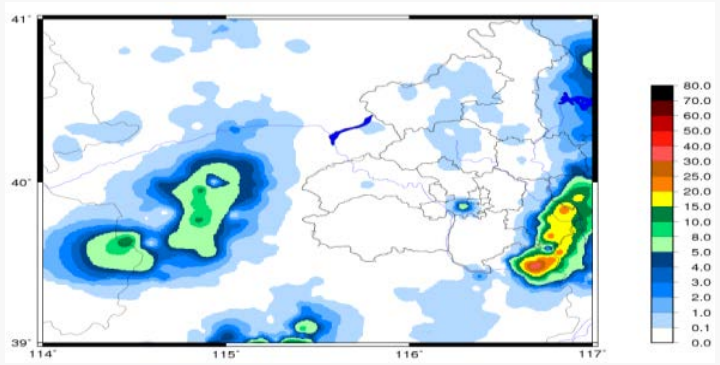
Distance-weighted interpolation;
Elevation Dependent
Parameterized

Radar QPE

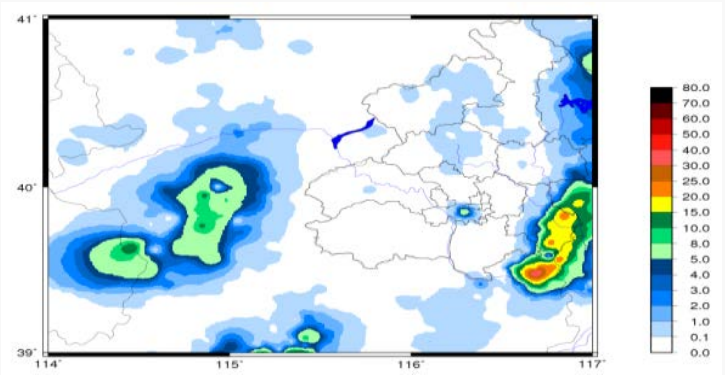
Downscaling

Bi-linear Interpolation;
QPE scaled;
2-D smooth

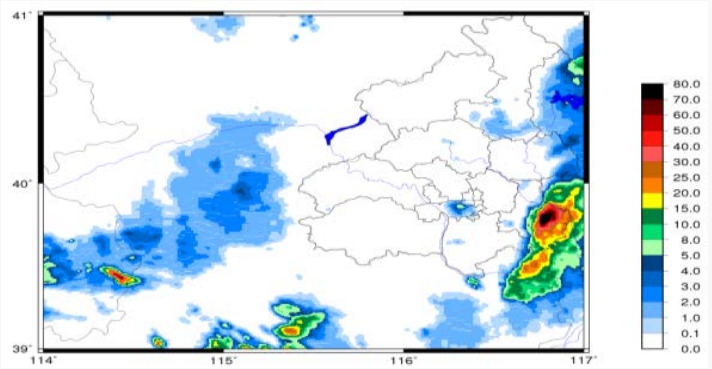
Precipitation Analysis



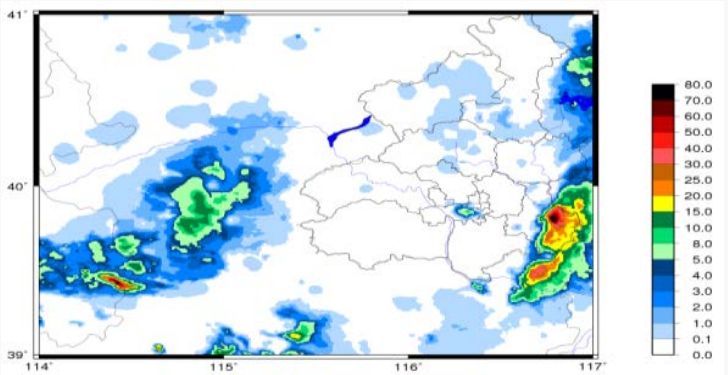
Interpolated
AWS precipitation



Topography corrected AWS
precipitation



Scaled Radar QPE



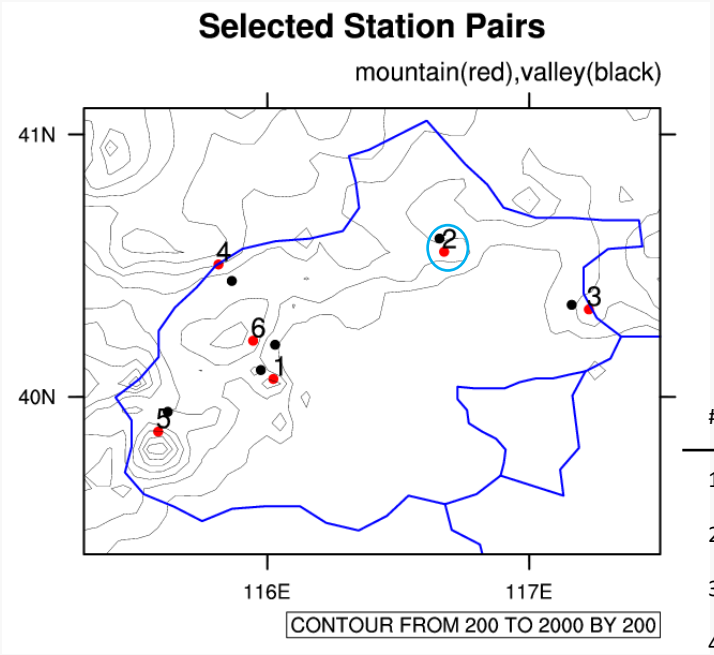
Blended QPE

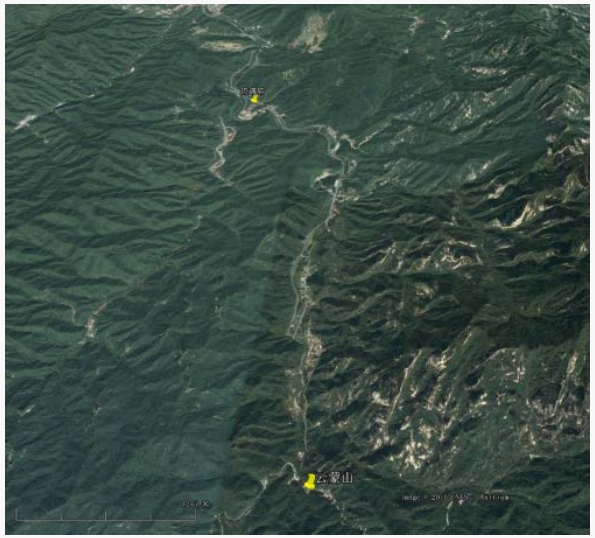
22:00BJT, 28th August 2014

Parameterization of elevation effects on precipitation in Beijing area

- complicated variability of precipitation-elevation gradients
- an intensity-dependent parameterization algorithm of elevation effects applied on hourly precipitation in Beijing area
- the mountain precipitation is derived as a function of valley precipitation
- the physics of the orographic precipitation process called the seeder-feeder mechanism

- DATA:
  - AWS rain-gauge observations
  - 2008.8.1-2015.5.31
  - 12-hour accumulated rainfall observation (00-12UTC, 12-00UTC)
- mountain-valley station pairs are required
  - Elevation difference < 500m
  - Horizontal distance < 6km
  - Good historical archived consistency
- Six representative station pairs





$$P_{mtn}=\begin{cases}P_{val}(a-bP_{val}) & P_{val}\le P_c\\ P_{val}+(a-1-bP_c)P_c & P_{val}\ge P_c\end{cases}$$

$$P_c=(a-1)/(2b)$$

$$P_{mtn}=\begin{cases}P_{val}\left[1+(a-1)\left(1-\frac{P_{val}}{2P_c}\right)\right] & P_{val}\le P_c\\ P_{val}+\frac{a-1}{2}P_c & P_{val}\ge P_c\end{cases}$$

RMSE of 12-hour accumulated precipitation → minimum

#	站点对	a值	b值	参数Pc值 (mm)	弱降水临界Pcc值 (mm)	最小RMSE(mm)
1	妙峰山-菩萨鹿	1.59	0.5	0.59	0.5	31.3212
2	云蒙山-琉璃庙	2.09	0.8	0.68	0.5	110.931
3	玻璃台-镇罗营	1.60	0.4	0.76	0.5	109.181
4	松山-野鸭湖	1.79	0.7	0.56	0.5	33.6355
5	百花山-清水	2.65	1	0.82	0.5	47.195
6	禾子涧-古将	1.86	0.8	0.54	0.5	31.1186

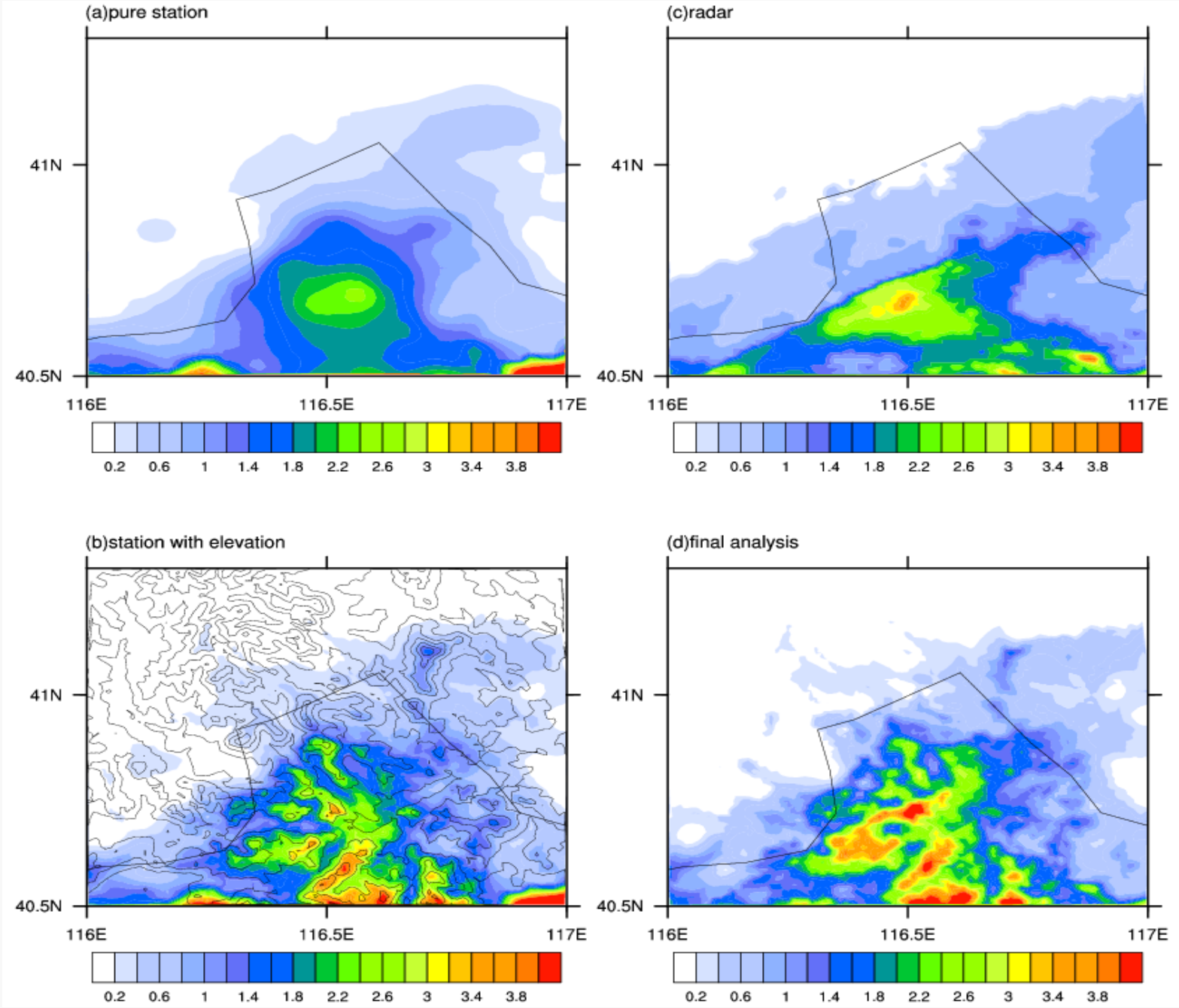
$$G_{ELEV}\equiv\frac{1}{P}\frac{\Delta P}{\Delta z}\approx\frac{1}{P_{VAL}}\frac{P_{MTN}-P_{VAL}}{\Delta z}=\frac{1}{\Delta z}\left(\frac{P_{MTN}}{P_{VAL}}-1\right)$$

Empirically

$$\hat{z}_H=\begin{cases}Z_{MAX}-\Delta Z\exp\left(-\frac{z_H-Z_{MAX}+\Delta Z}{\Delta Z}\right) & z_H>Z_{MAX}-\Delta Z\\ z_H & z_H\le Z_{MAX}-\Delta Z\end{cases}$$

Zmax=2000m
ΔZ=500m

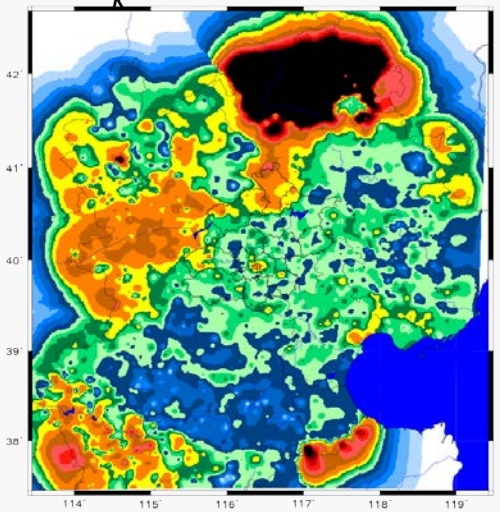
$$\Delta P_{ELEV}=G_{ELEV}(\hat{z}_H-z_{ST})P_{VAL}$$


(a)pure station
(c)radar
(b)station with elevation
(d)final analysis
41N
40.5N
116E
116.5E
117E
0.2
0.6
1
1.4
1.8
2.2
2.6
3
3.4
3.8

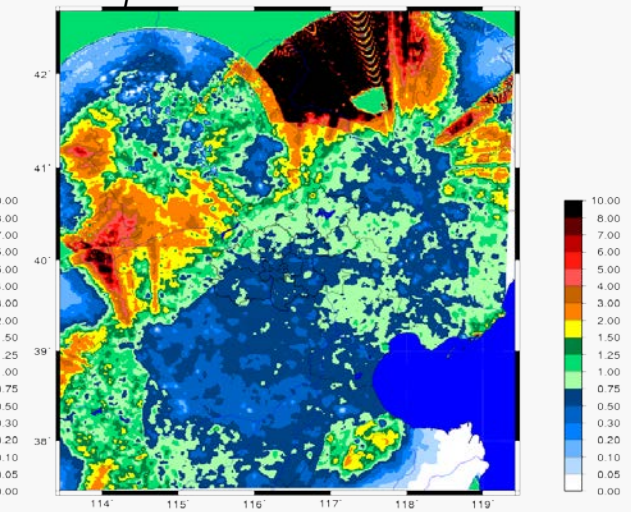
Climatological scaling of radar data

- Since the radar field is strongly range-dependent and contains biases due to topographic shielding it must be scaled before used in the precipitation analysis.
- 2787 AWS stations
- 1-hr accumulated AWS precipitation from 2 warm seasons (2014-2015)
- Totally 2157 time samples

RFC_k



RFC_l



Station Scaling:

$$RFC_k = \frac{\sum_{month} P_k}{\sum_{month} P_{RADAR,k}} .$$

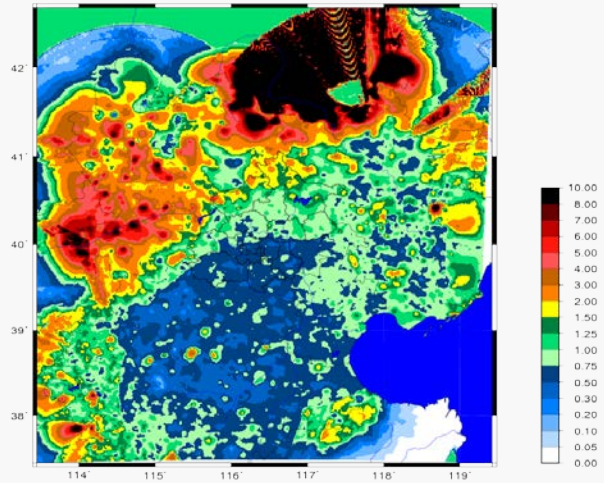
Grid-point Scaling:

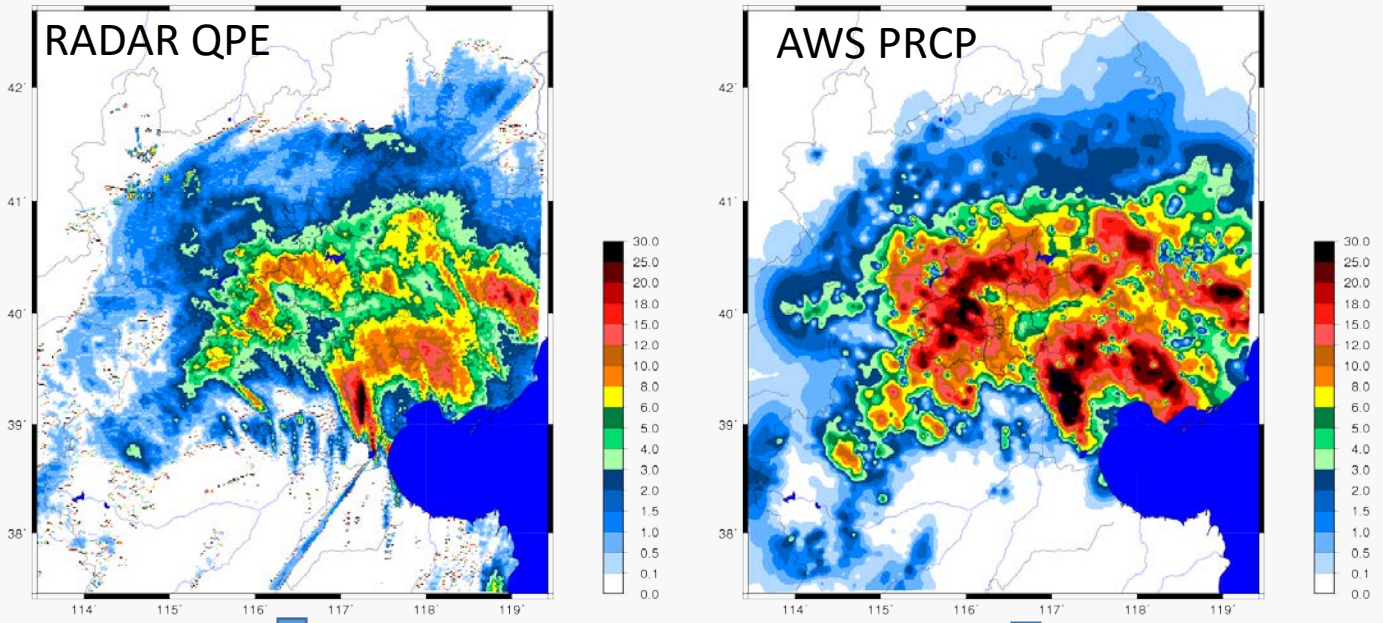
$$RFC_l(i,j) = \frac{\sum_{month} P_{STAT}(i,j)}{\sum_{month} P_{RADAR}(i,j)}$$

Scaled Radar QPE：

$$P^*_{RADAR}(i,j) = \max\left[RFC(i,j), RFC_l(i,j)\right] P_{RADAR}(i,j) .$$

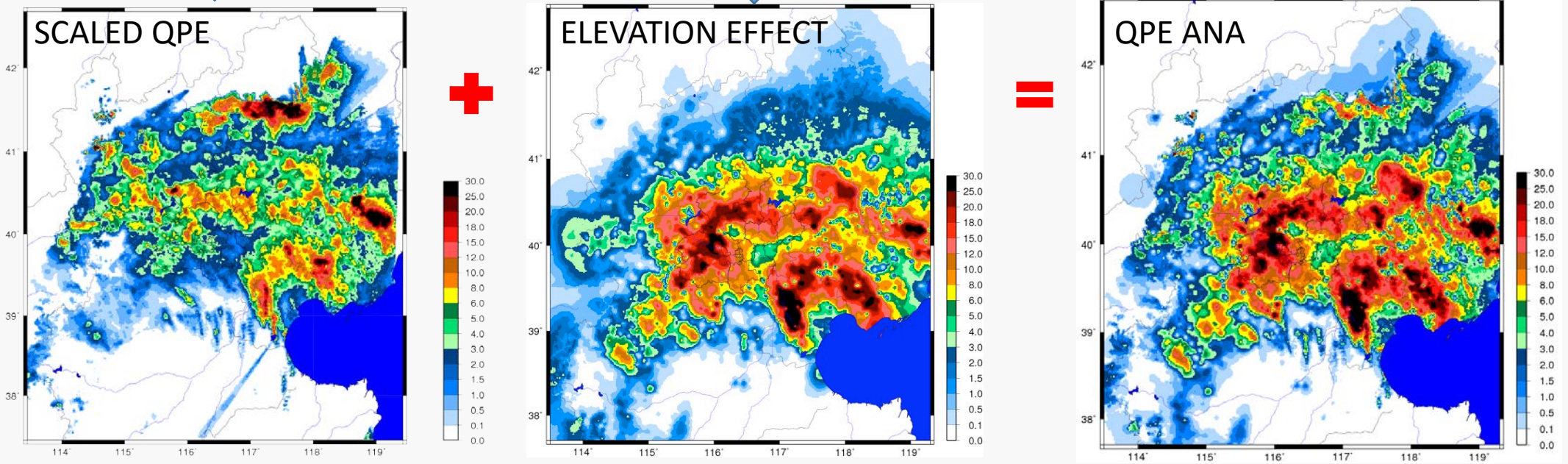
FINAL RFC





$$P_{INCA}(i,j) = P_{STAT}(i,j) + v\left[P^{**}_{RADAR}(i,j) - P^{**}_{RADSTAT}(i,j)\right]$$

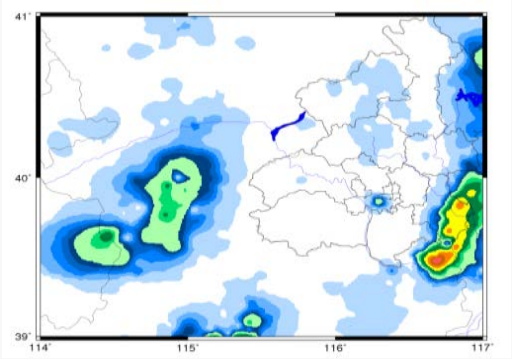
$$v(i,j) = \begin{cases} 1 & RFC < RFC_0 \\ \exp\left[-\ln(2)\left(\dfrac{RFC - RFC_0}{RFC_H - RFC_0}\right)^2\right] & RFC \geq RFC_0 \end{cases}$$



QPF by moving vector extrapolation

STEP I

10-min accumulated AWS precipitation interpolated with elevation correction



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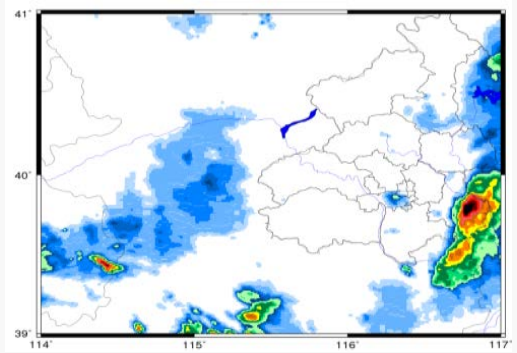
10-min accumulated radar QPE with climatological scaling correction



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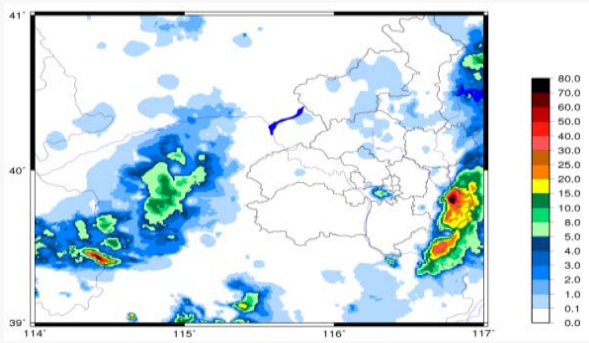
10-min accumulated blending precipitation analysis

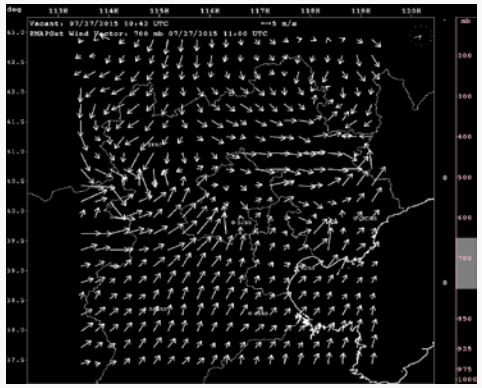


STEP II

Moving vector defined with two consecutive 10-min precipitation analysis

+

500/700hPa Wind Constraint from NWP



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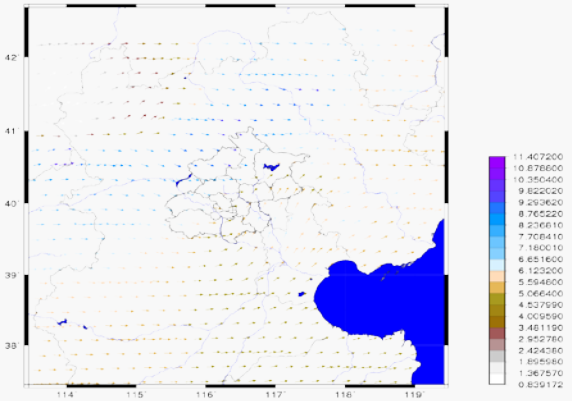
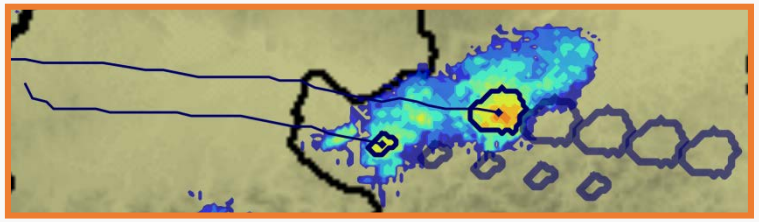
RMAPS-In Gridded extrapolated moving vectors



STEP III

Extrapolation Forecast



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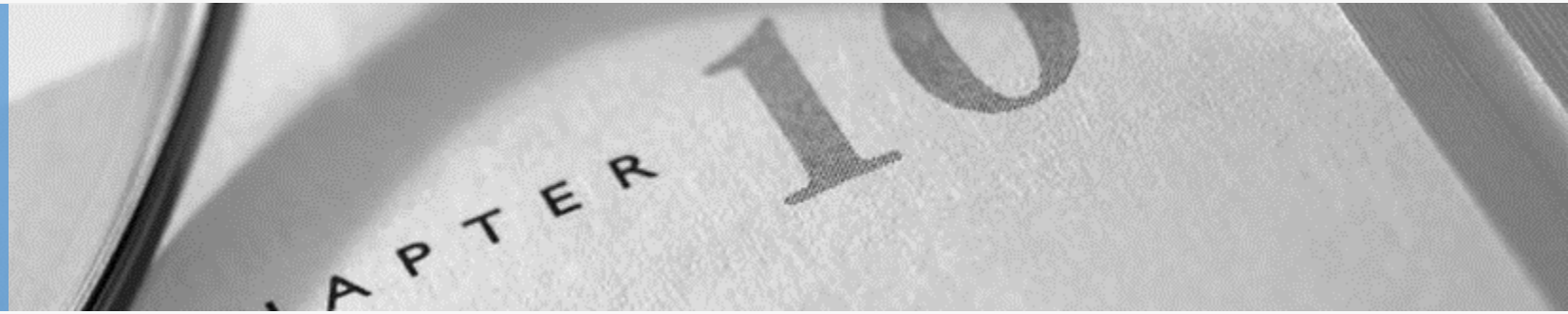
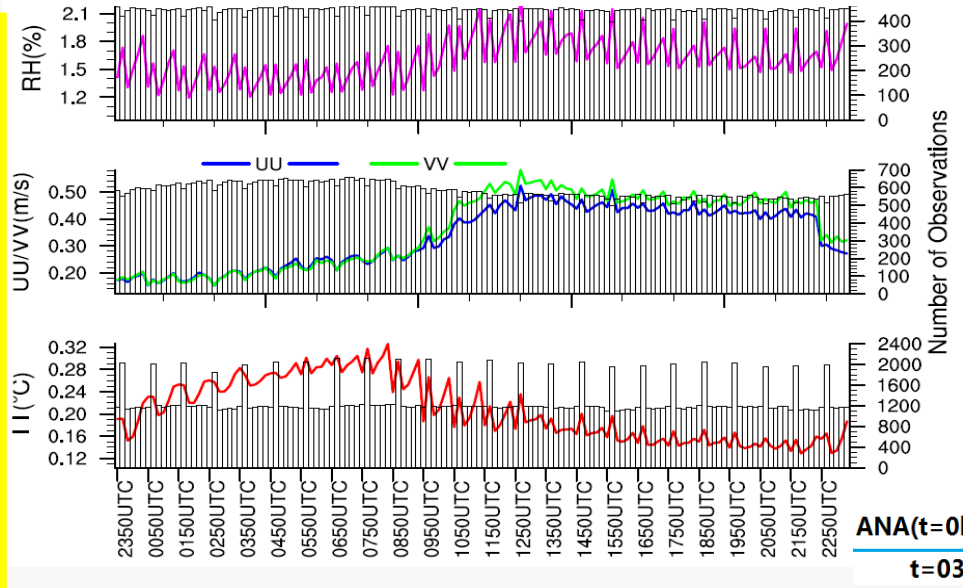
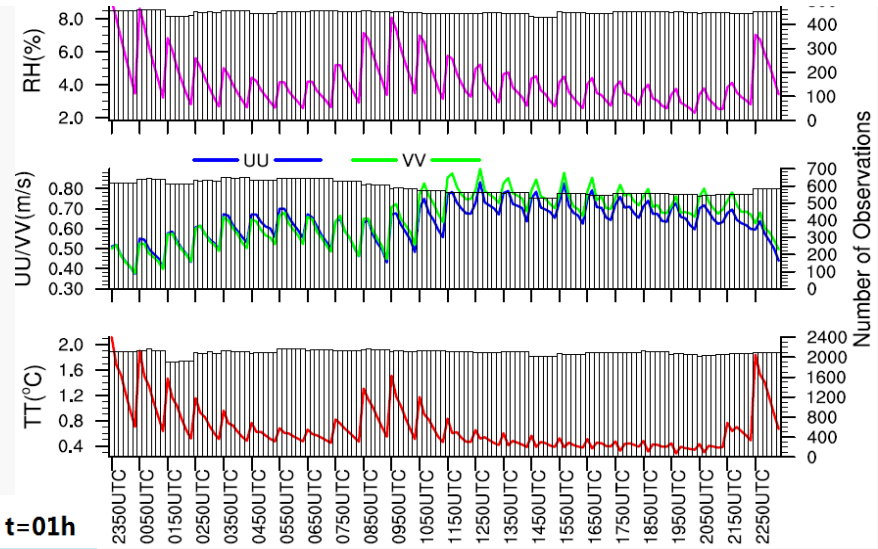


Absolute error of the analysis and forecasts during 10 July – 10 Oct 2015 of RMAPS-IN

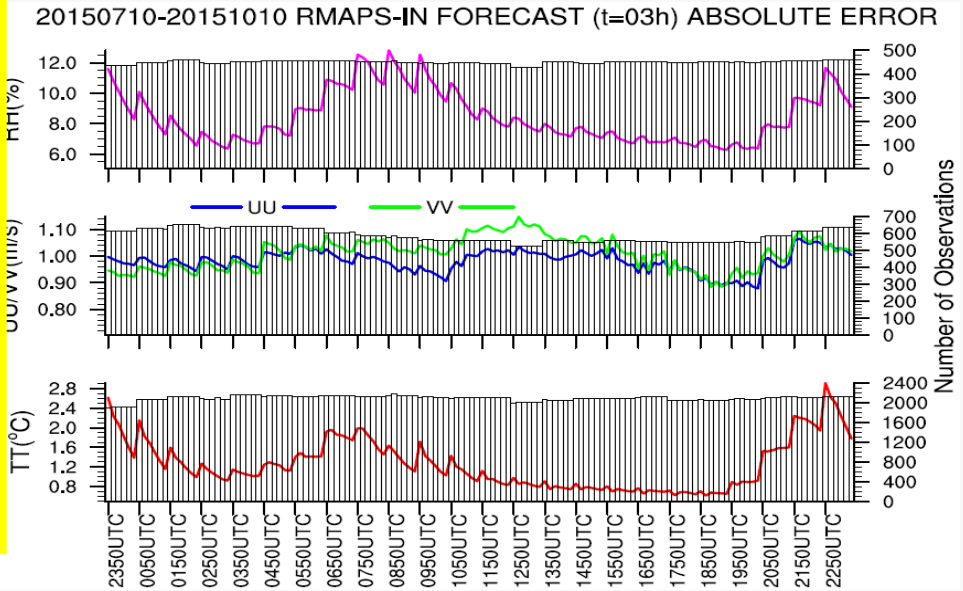
- Absolute Error of RMAPS-IN 10-min updataed analysis:
  - Temperature:
    - <0.35°C daytime
    - <0.20°C nighttime
  - U/V:<0.6m/s
  - Relative Humidiry:<2.3%

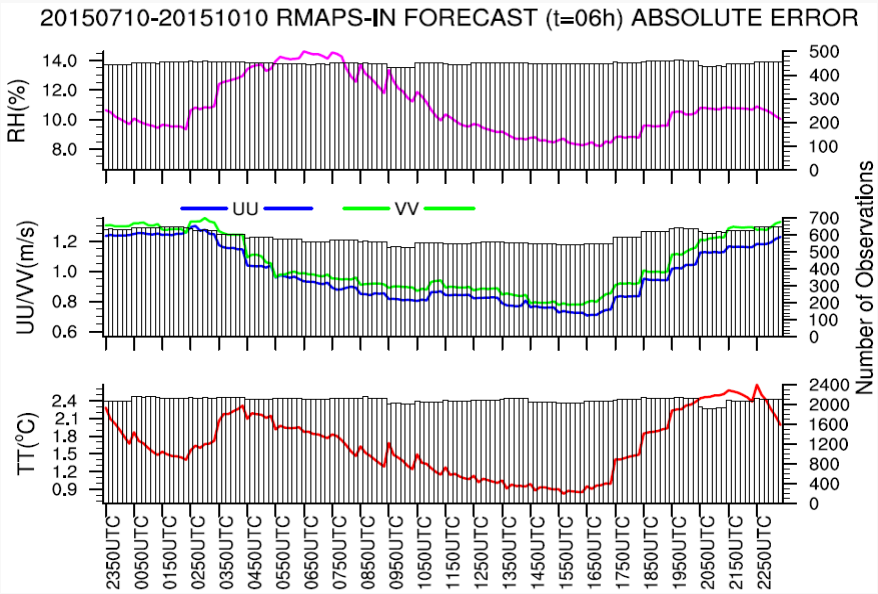
- Absolute Error of RMAPS-IN 10-min updataed forecasts:
  - The blending effect of NWP+AWS may last longer than 6 hours
  - Temperature:<2.5°C
  - U/V:<1.3m/s
  - Relative Humidity:<14%



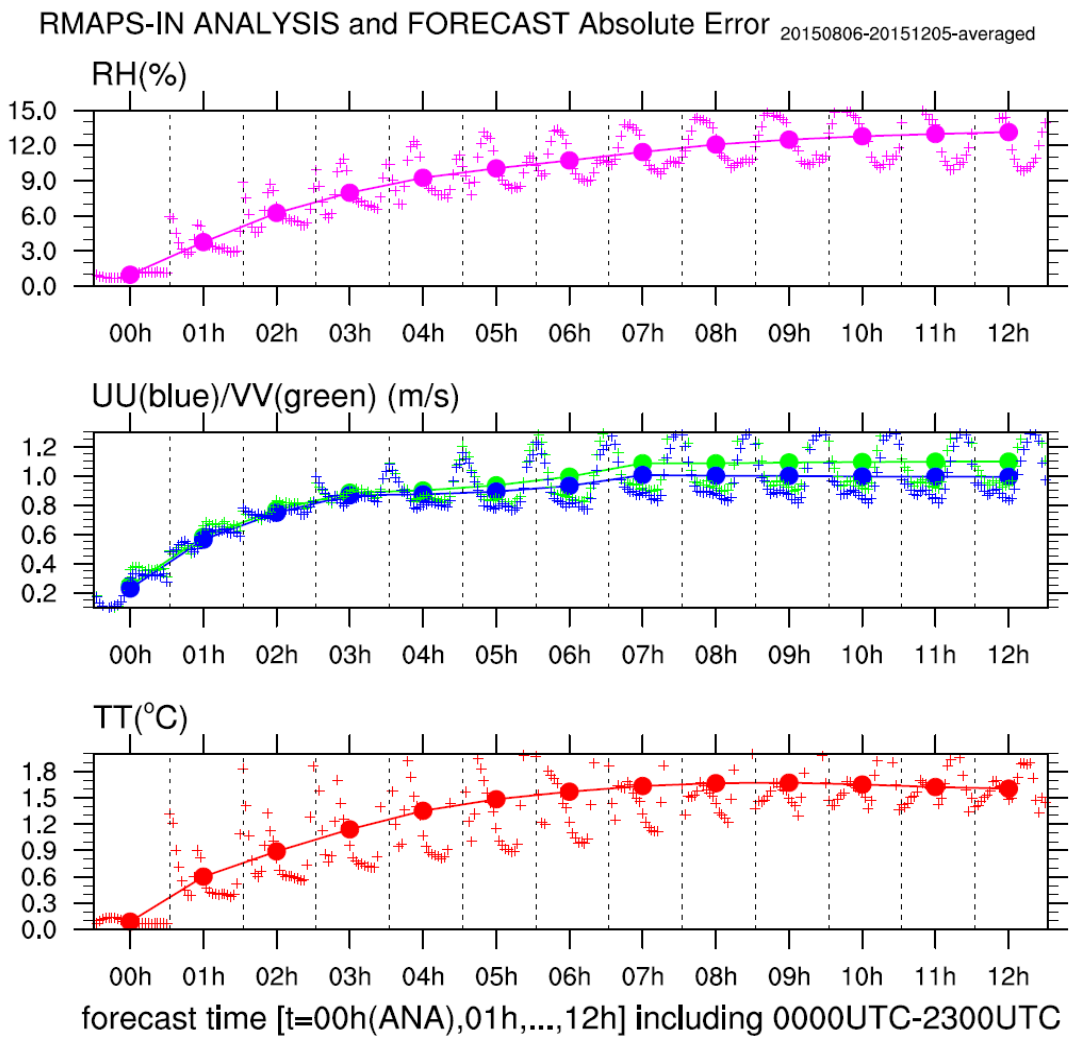


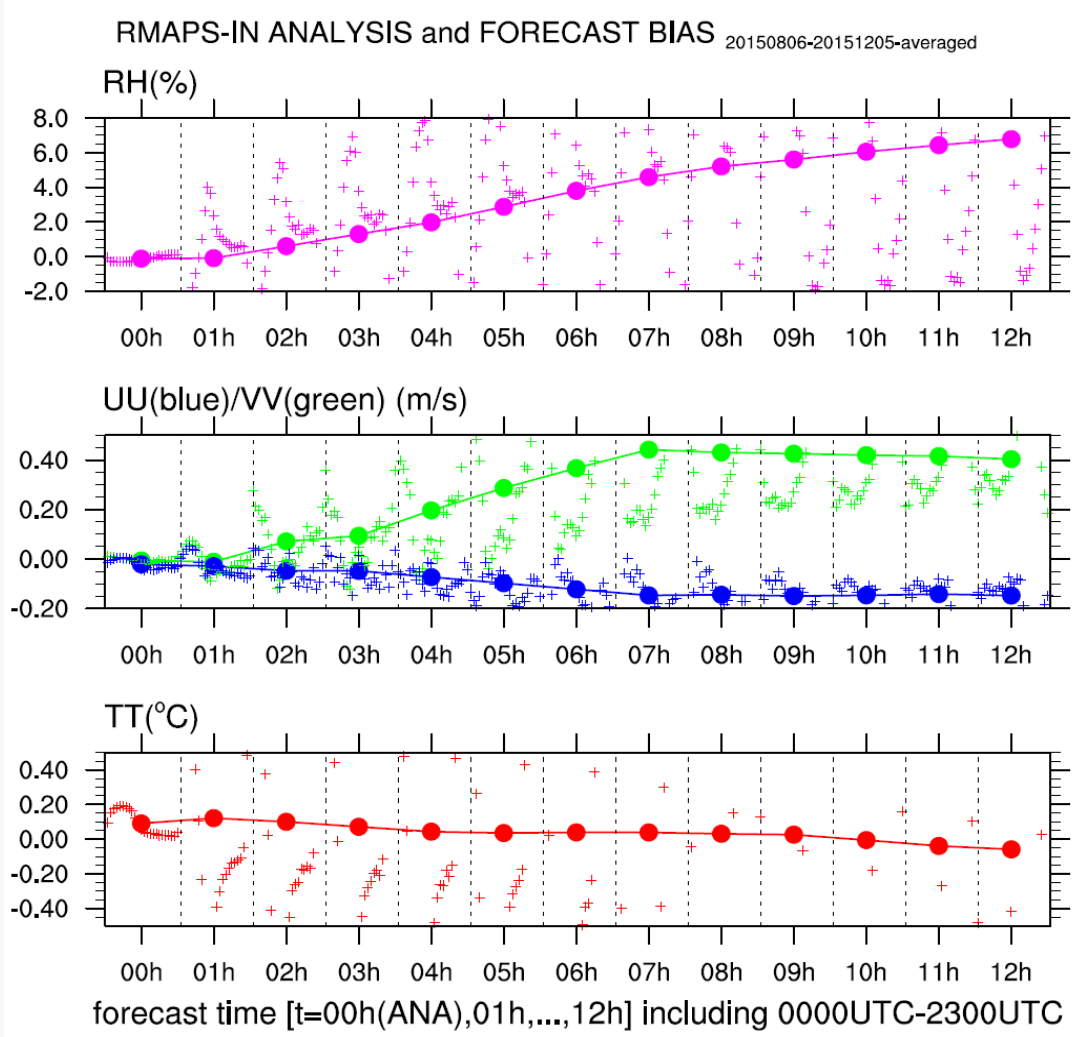
ANA(t=0h) t=01h
t=03h t=06h



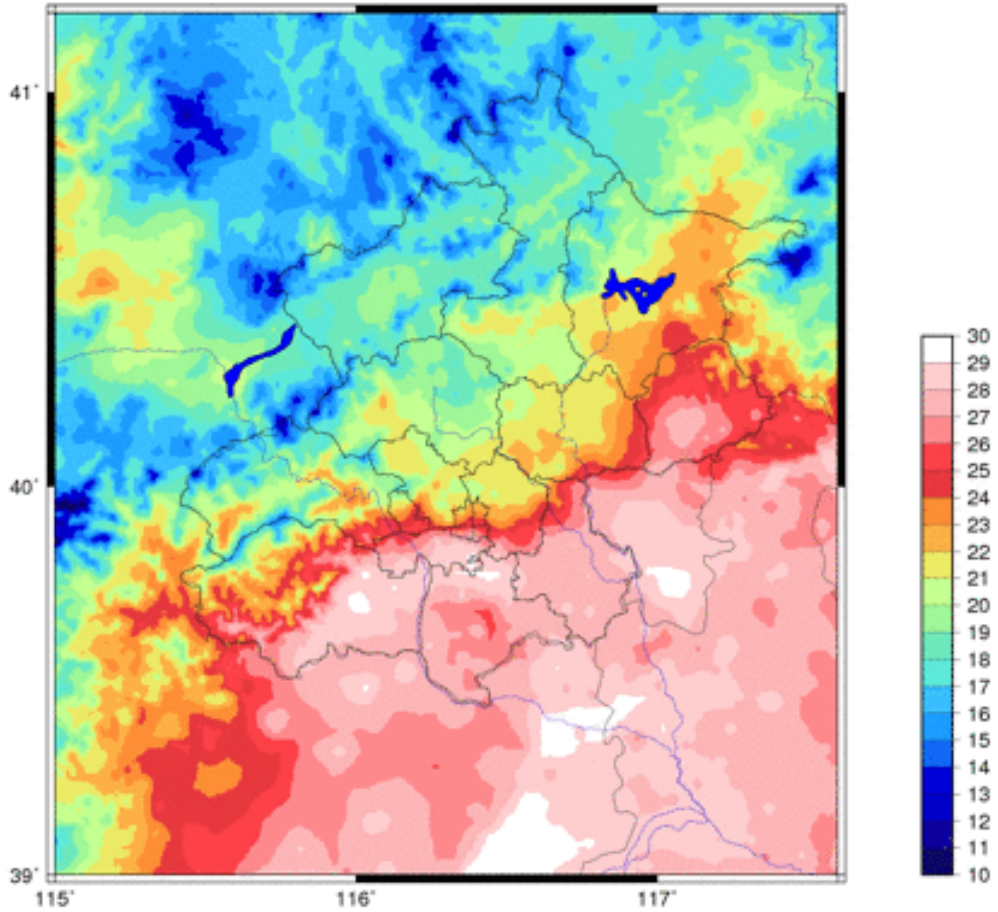


RMAPS-IN ANALYSIS AND FORECAST Absolute Error



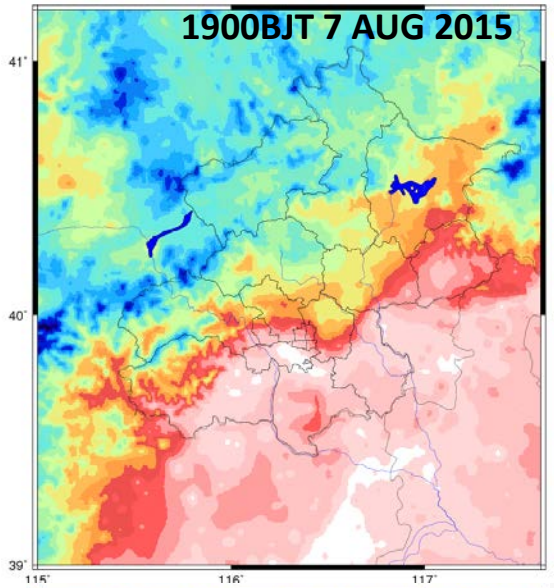


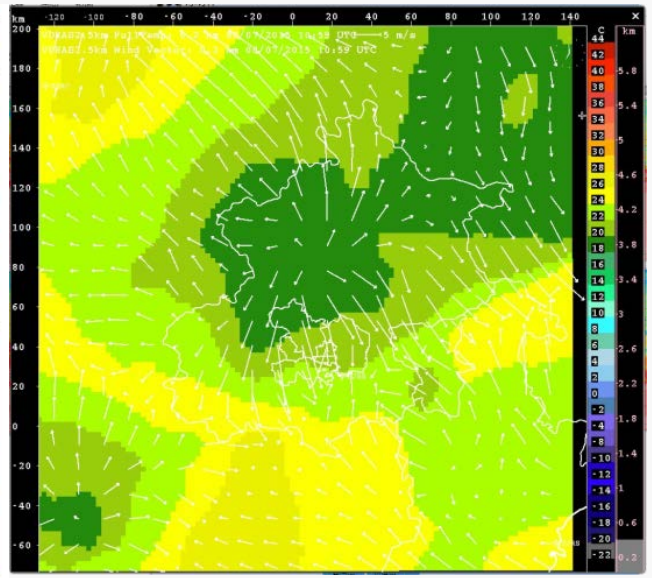
10-minute updated 2-m Temperature Analysis (19:00-20:50BJT, 7th August 2015)

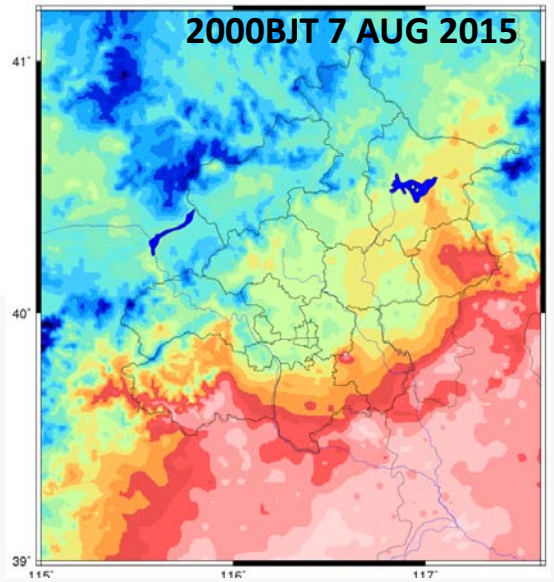


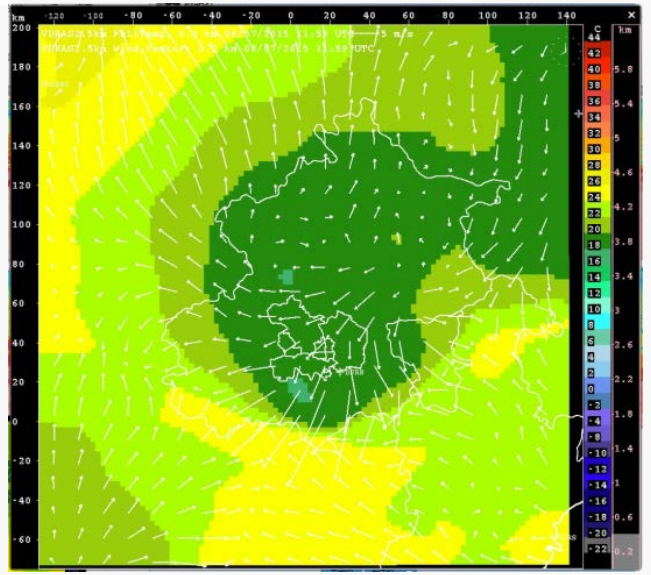
RMAPS-IN

VDRAS

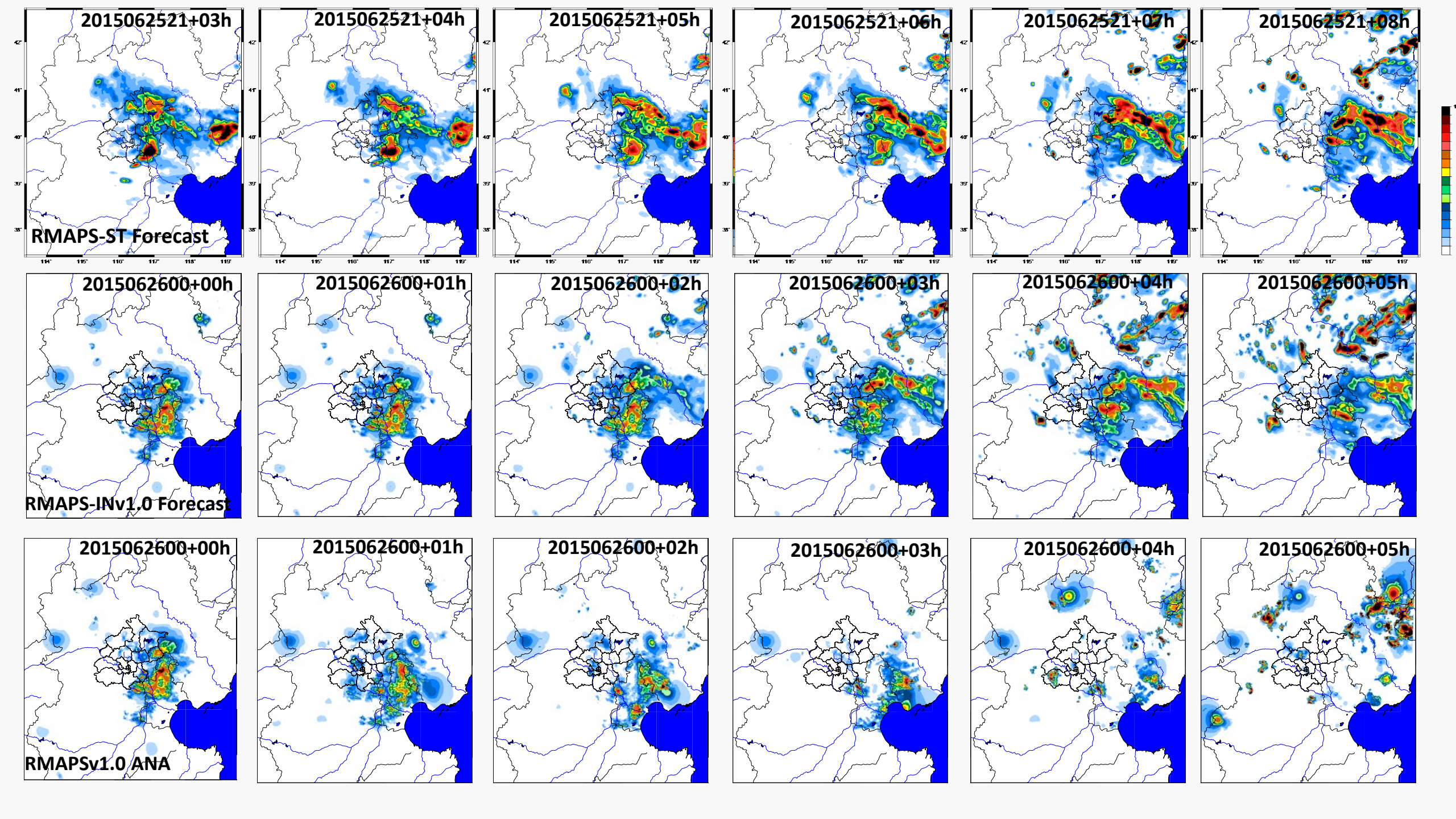






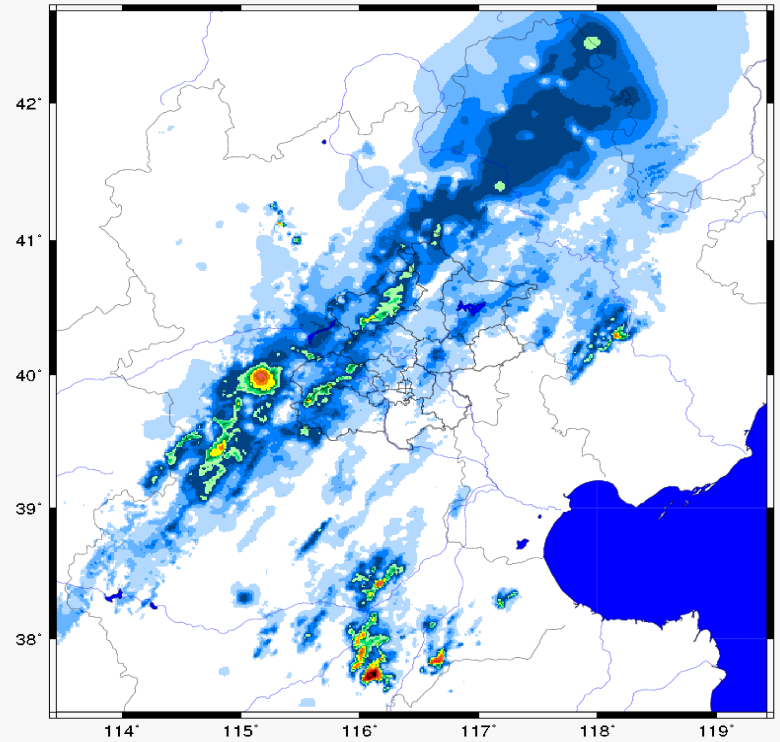


- A heavy convective storm case in Beijing Area
- The boundary of cold pool incurred by convection easily identified
- Well matched with the analysis from VDRAS but with more detailed structures


2015062521+03h
2015062521+04h
2015062521+05h
2015062521+06h
2015062521+07h
2015062521+08h
RMAPS-ST Forecast
2015062600+00h
2015062600+01h
2015062600+02h
2015062600+03h
2015062600+04h
2015062600+05h
RMAPS-INv1.0 Forecast
2015062600+00h
2015062600+01h
2015062600+02h
2015062600+03h
2015062600+04h
2015062600+05h
RMAPSv1.0 ANA

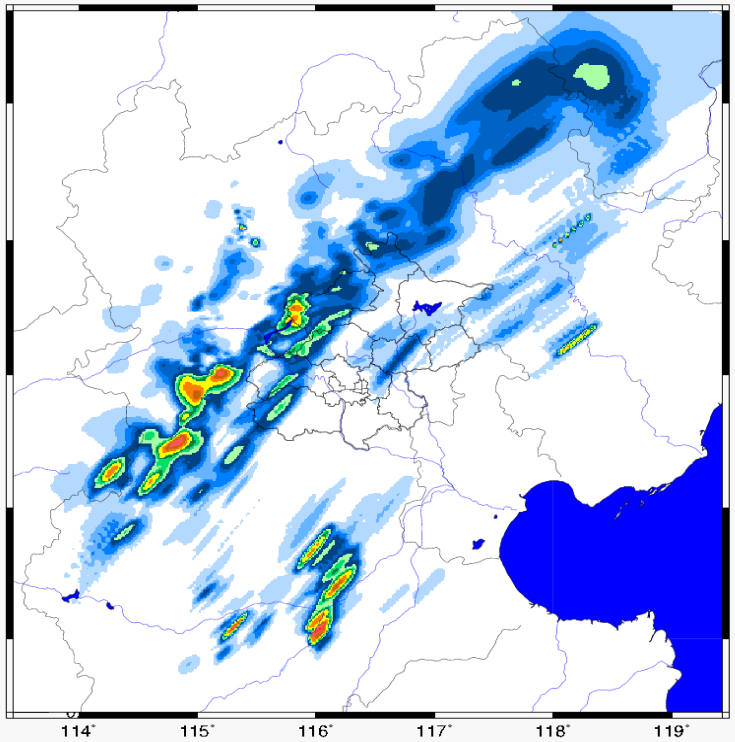
09BJT 2nd - 00BJT 3rd May, 2016

ANALYSIS



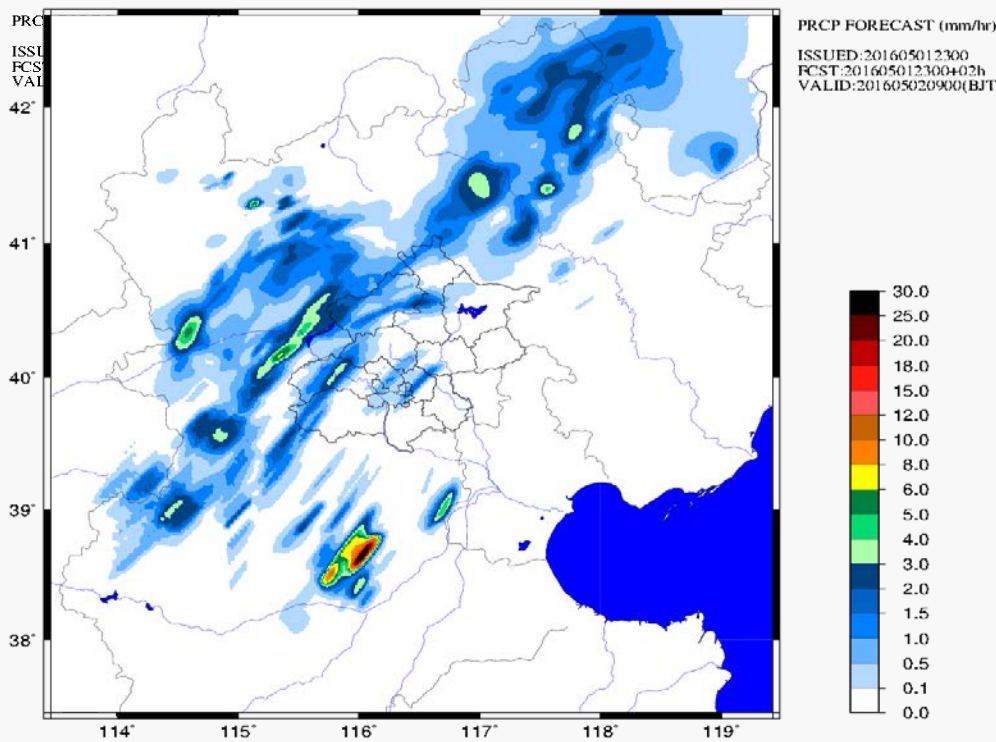
2016年5月2日09时-5月3日00时(BJT)
逐小时累积QPE

0-1hr



RMAPS-IN系统在2016年5月2日08时-5月2日23时(BJT)起始的0-1hr定量降水预报

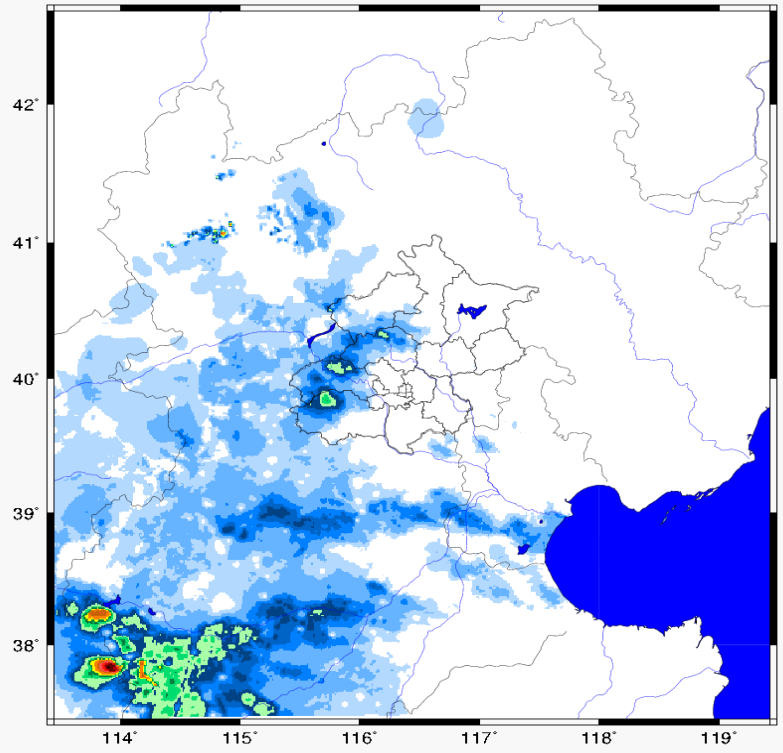
1-2hr



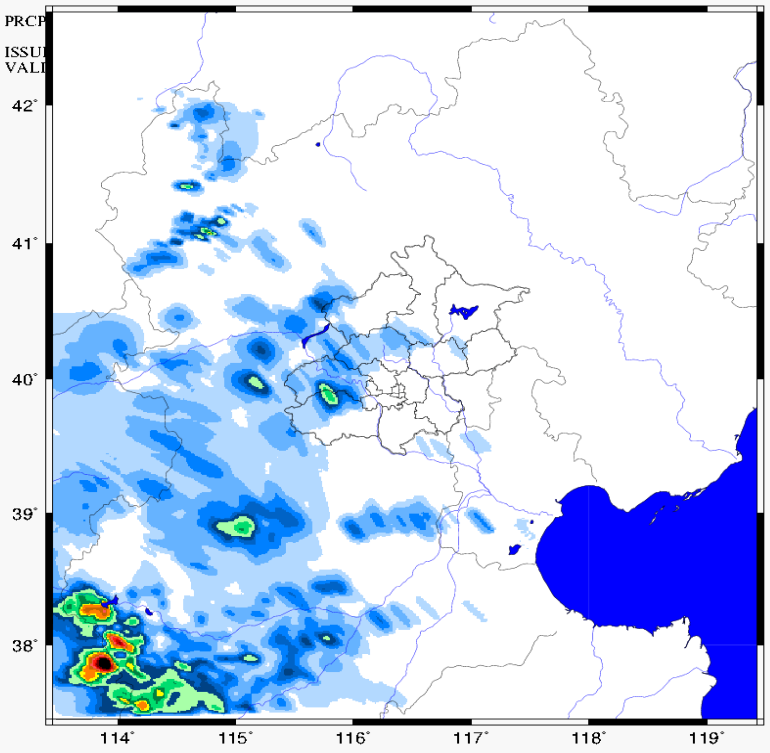
RMAPS-IN系统在2016年5月2日07时-5月2日22时(BJT)起始的1-2hr定量降水预报

23BJT 19th July – 21BJT 20th July, 2016

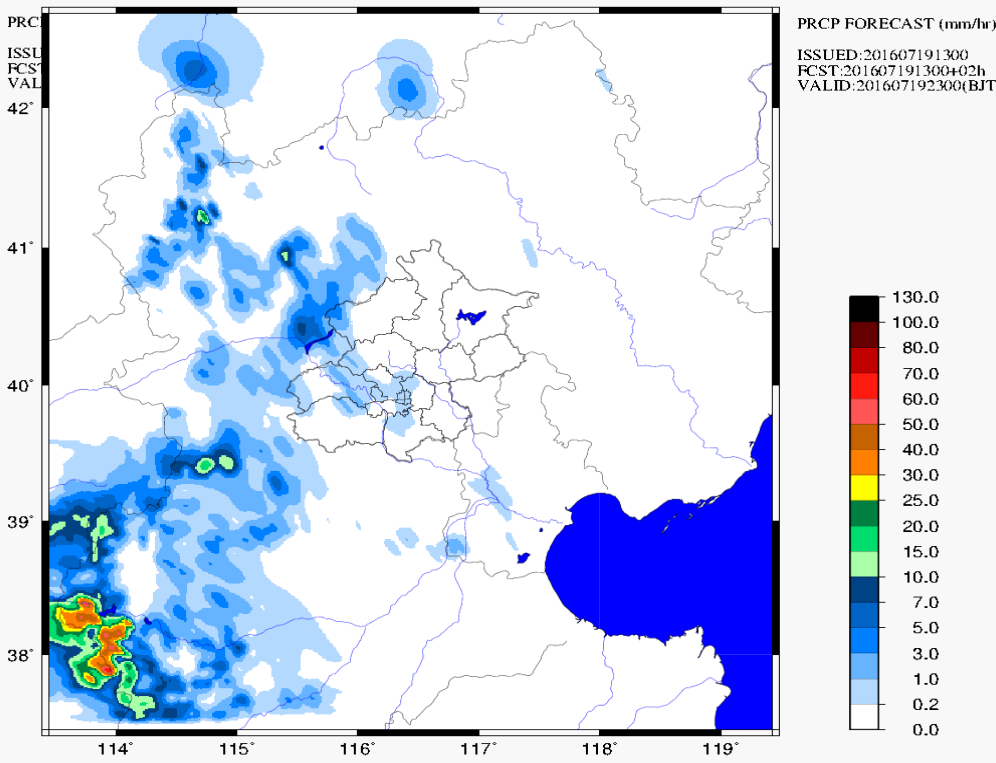
ANALYSIS



0-1hr



1-2hr

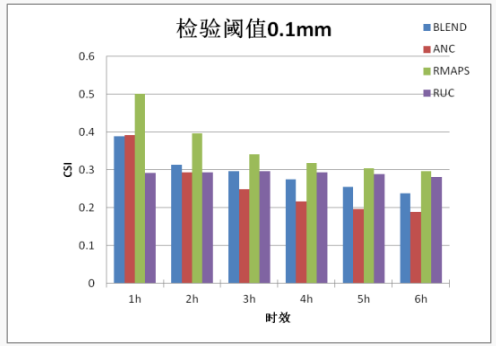


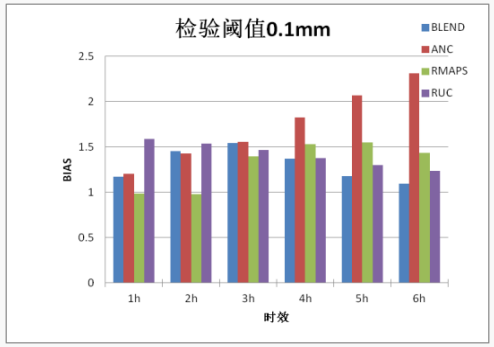
INTERCOMPARISON of RMAPS-IN with BLENDING*

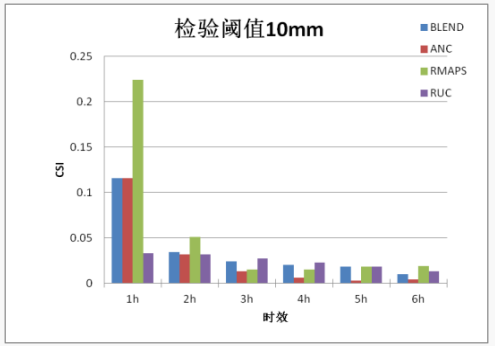
	RMAPS-IN	BLENDING
Data	AWS Rain Gauge Observation/Radar QPE/NWP QPF	Radar QPF/Radar QPE/NWP QPF
Products	**Gridded Precipitation Analysis/0-6h Nowcasting/0-12h Blended QPF**	**0-6h Blended QPF**
Precipitation Analysis	Y	N
Nowcasting	Y	N
Blending Forecast	Y	Y
Resolution	1km	1km
Updated Interval	10-min	10-min
Nowcasting Method	**Motion Vector Extrapolation**	**Nowcasting products dependent**
Blending Time Length	0-6h	0-6h
Blending Forecast Output Interval	**Per 10-min**	**Per 1 hour**
Blending Forecast Method	Time Weighted Blending of Extrapolation with NWP	Time Weighted Blending of Extrapolation with NWP
Blending Weight	**Time Weighted**	**Hyperbolic tangent curve**
NWP Treatment	**Averaged into per 10-min**	**Phase Correct and Intensity Calibration**

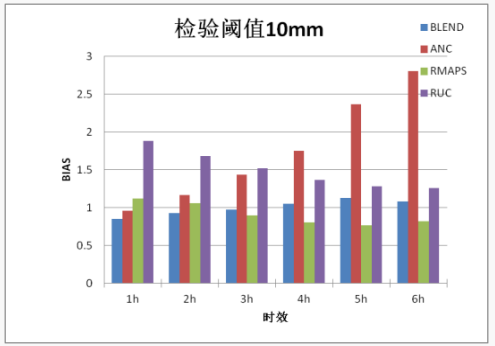
**PROTOTYPE IS FROM RAPIDS*

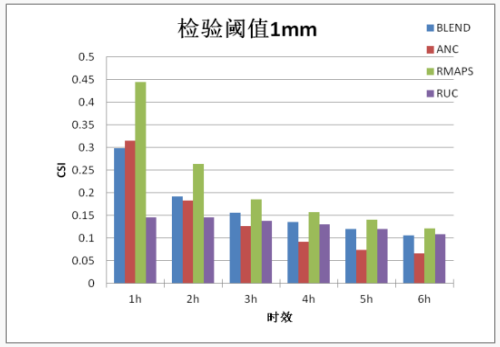
CSI/BIAS of the operational forecasting systems during the warm season (20150716-20150905)

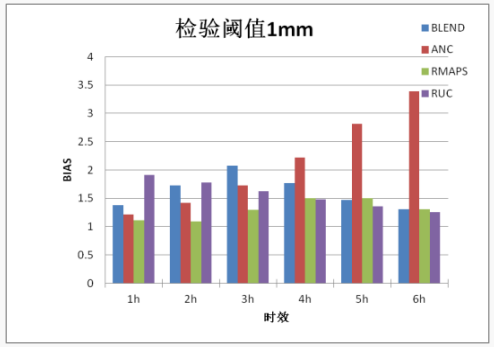


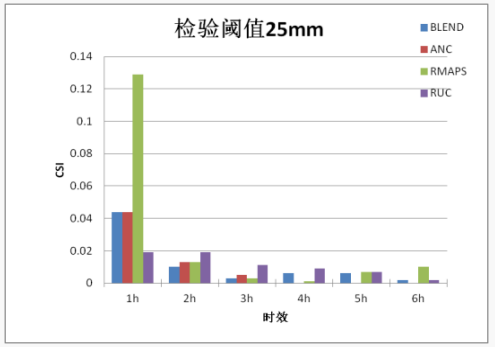


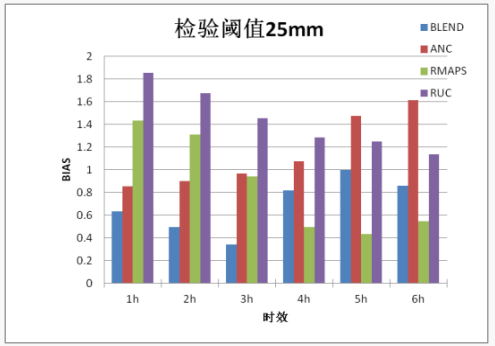


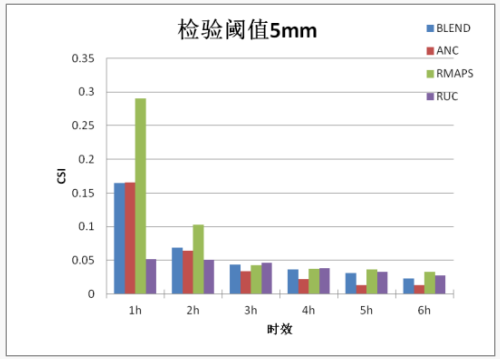


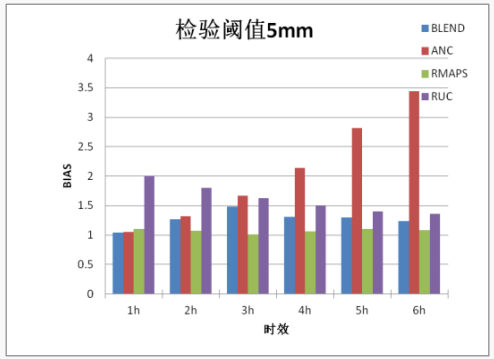










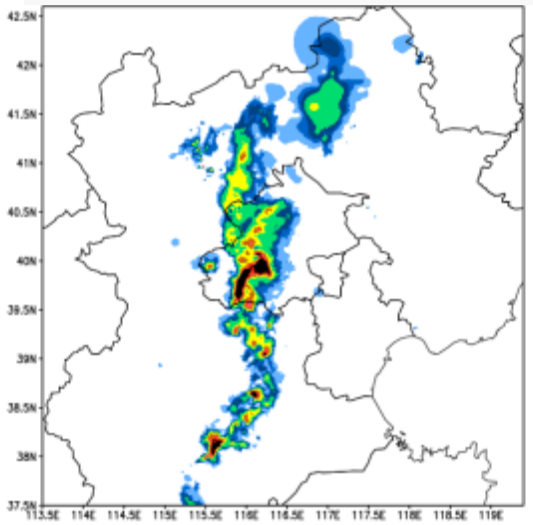


- **1-2h: RMAPS-IN>BLENDING~RMAPS-NOW>RMAPS-ST**
- **>3h: RMAPS-IN~BLENDING~RMAPS-ST>RMAPS-NOW**

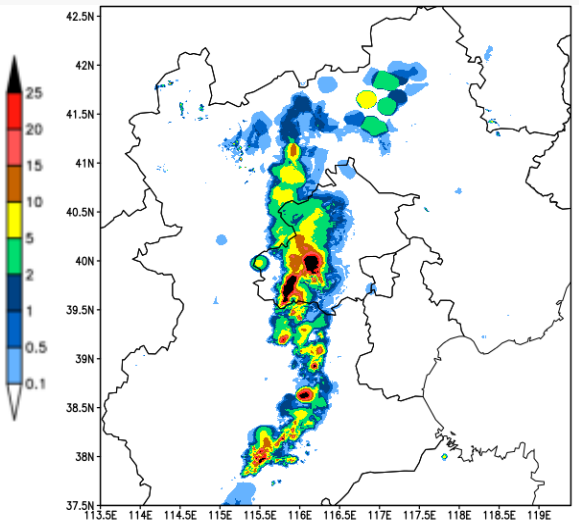
CASE1: Precipitation Analysis and 0-1h Forecasts (2015071622UTC+1h, Valid at 2015071623UTC)

- Structures well matched

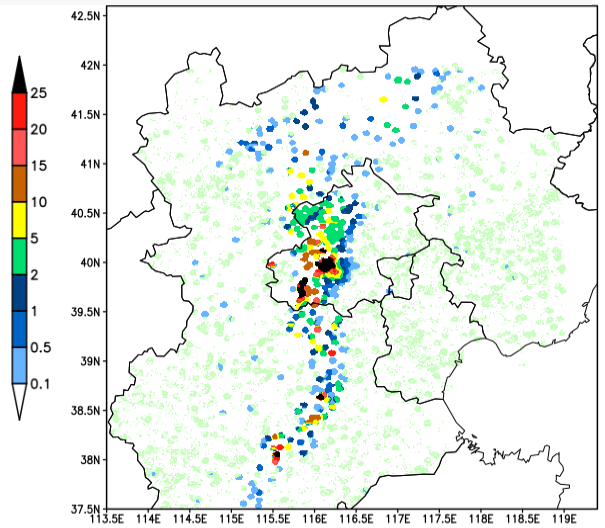
RMAPS-IN ANA



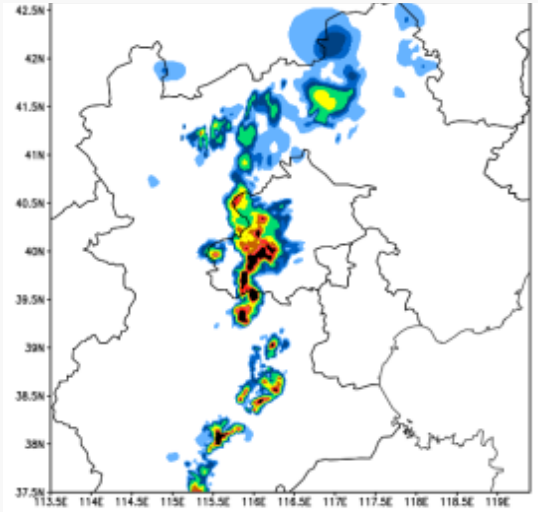
BLENDING ANA



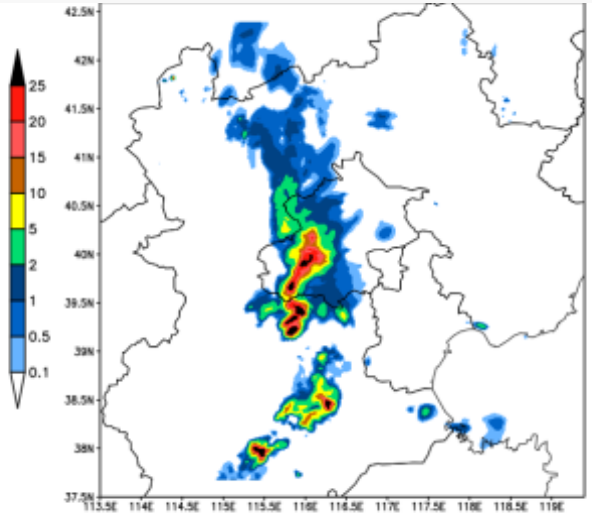
AWS RAIN-GAUGE



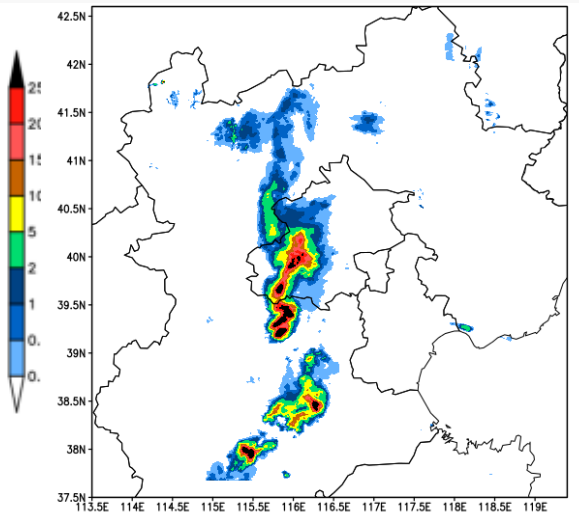
RMAPS-IN 0-1hr FORECAST



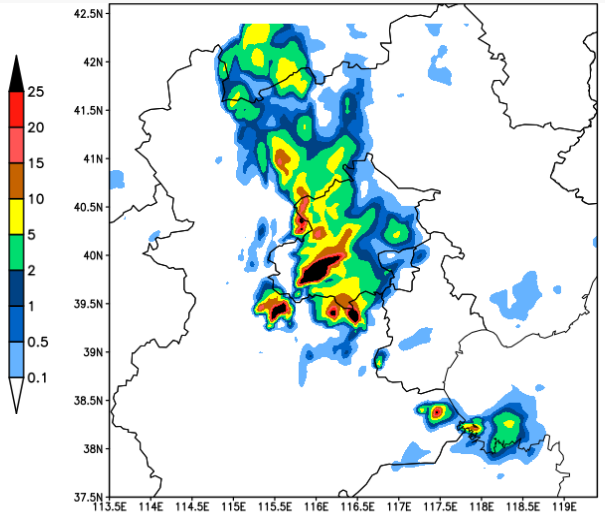
BLENDING 0-1 hr FORECAST



RMAPS-NOW 0-1hr FORECAST

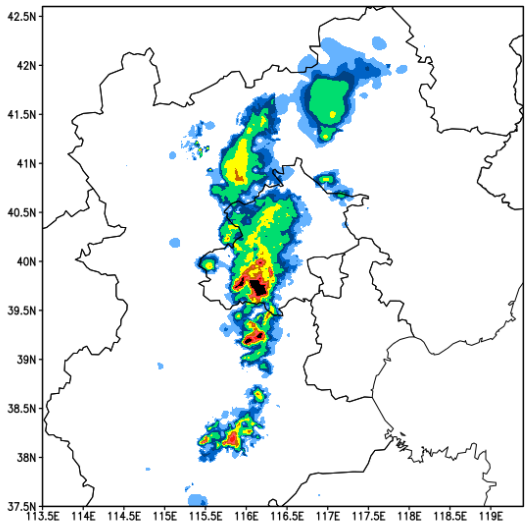


RMPAS-ST FORECAST

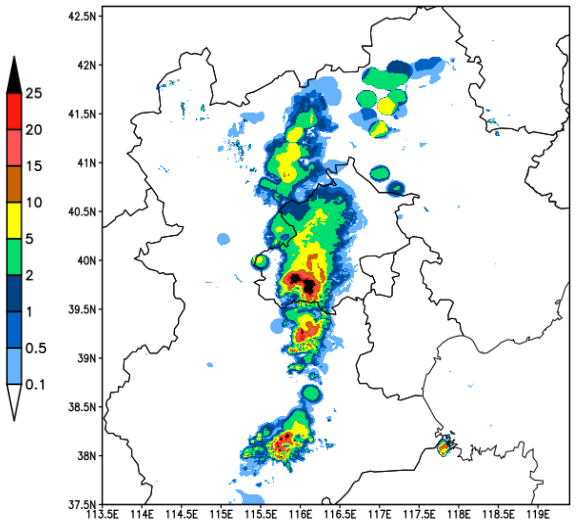


CASE1: Precipitation Analysis and 1-2h Forecasts (2015071622UTC+2h, Valid at 2015071700UTC)

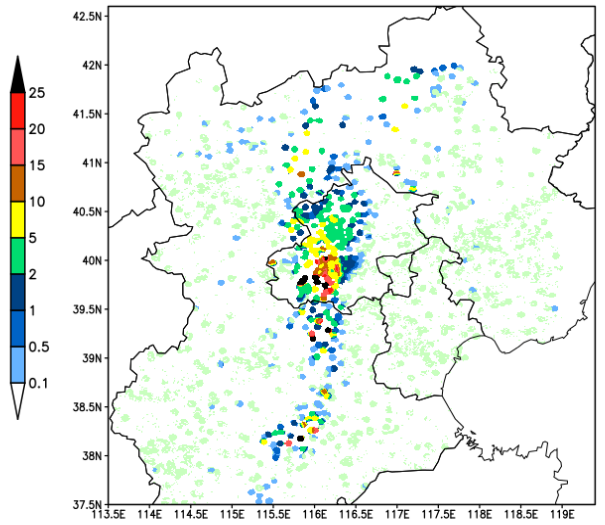
RMAPS-IN ANA



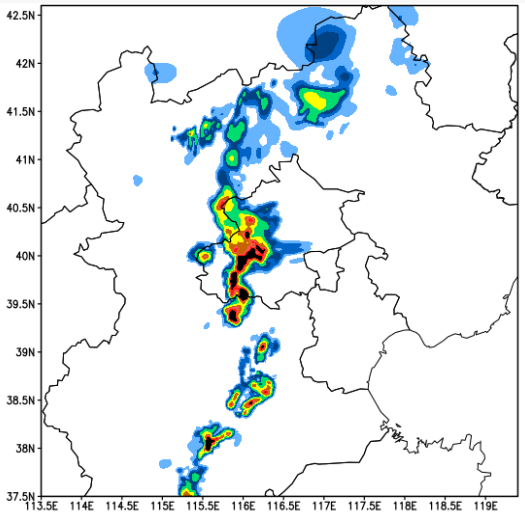
BLENDING ANA



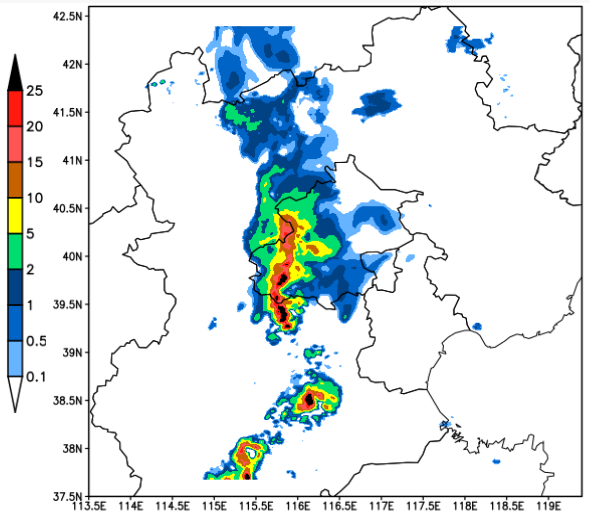
AWS RAIN-GAUGE



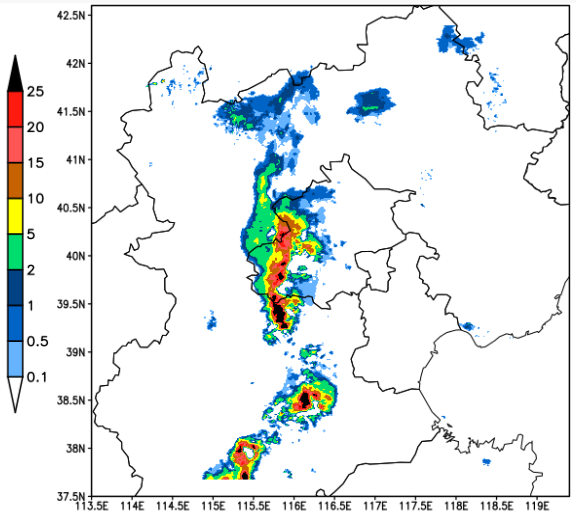
RMAPS-IN 1-2hr FORECAST



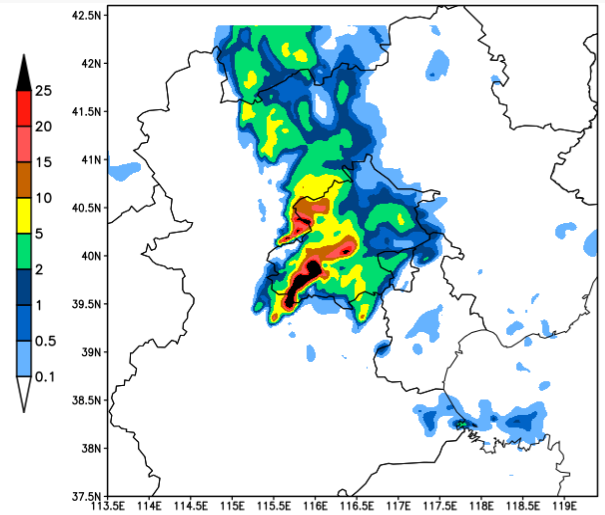
BLENDING 1-2hr FORECAST



RMAPS-NOW 1-2hr FORECAST



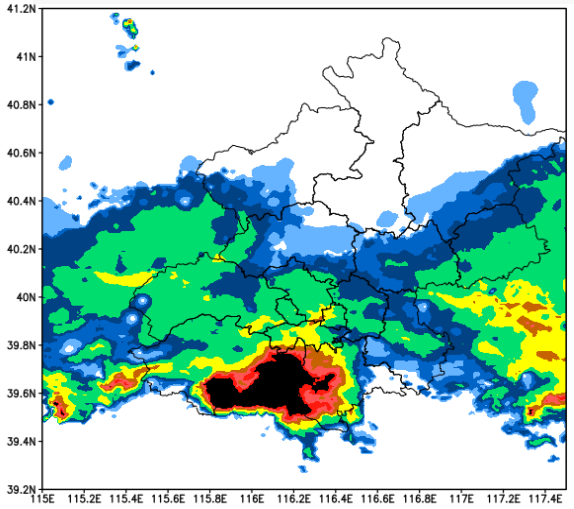
RMAPS-ST FORECAST



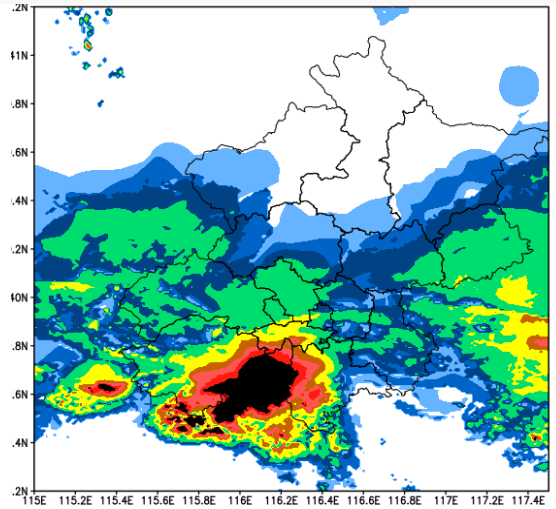
CASE2: Precipitation Analysis and 0-1h Forecasts (2015072714UTC+1h, Valid at 2015072715UTC)

- ONLY Beijing Area
- The False-Alarm comes of BLENDING system comes from BJANC and BJRUC respectively

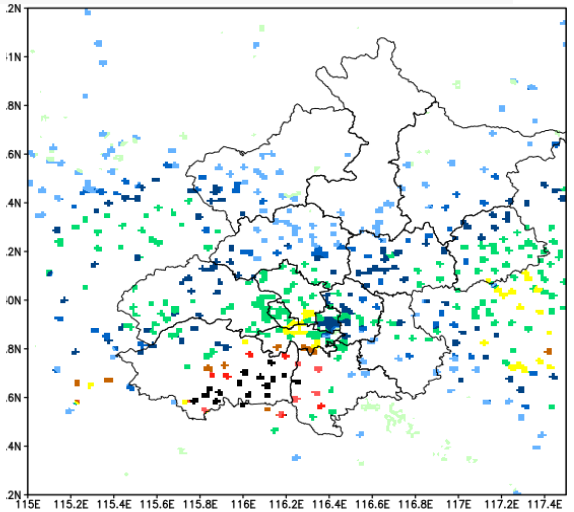
RMAPS-IN ANA



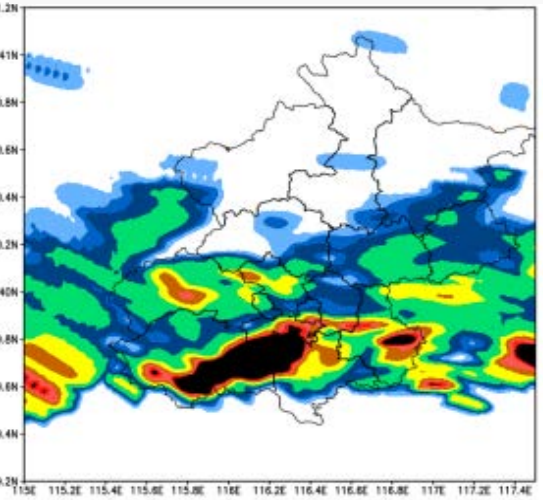
BLENDING ANA



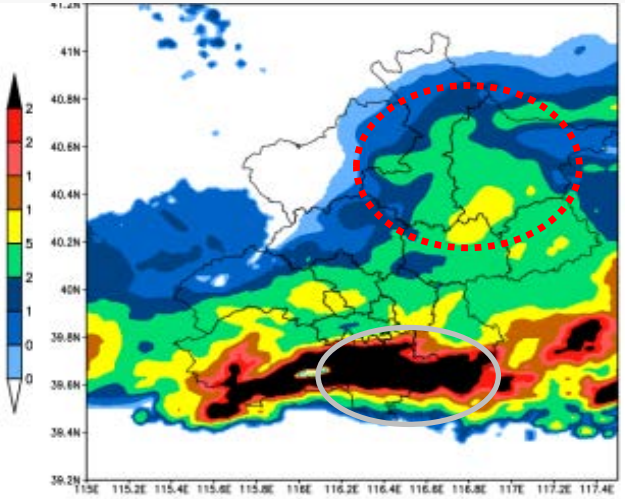
AWS RAIN-GAUGE



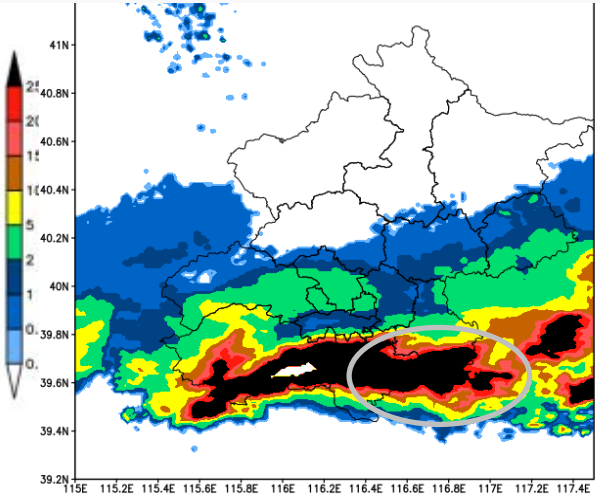
RMAPS-IN 0-1hr FORECAST



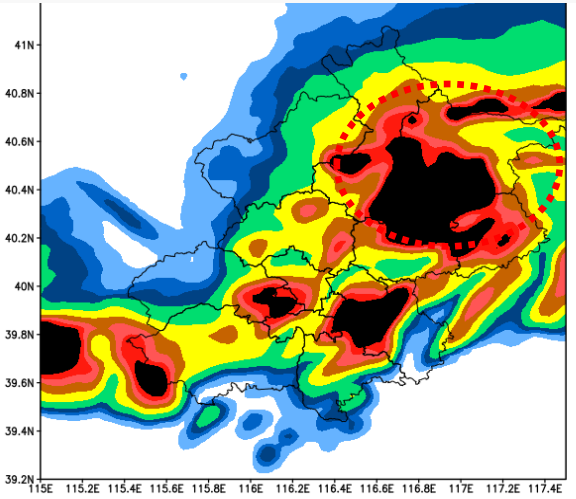
BLENDING 0-1 hr FORECAST



RMAPS-NOW 0-1hr FORECAST

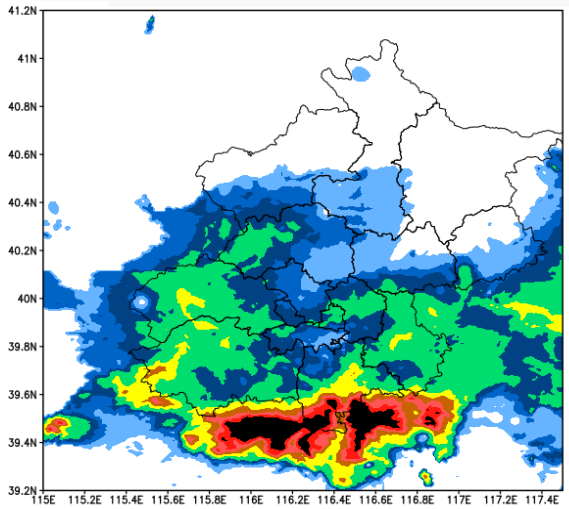


RMPAS-ST FORECAST

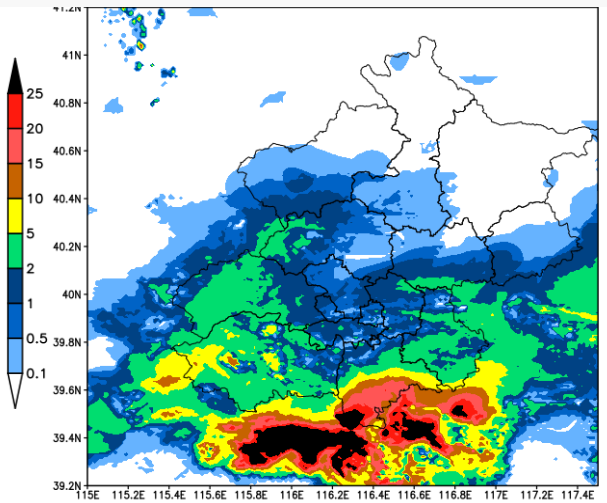


CASE2: Precipitation Analysis and 1-2h Forecasts (2015072714UTC+2h, Valid at 2015072716UTC)

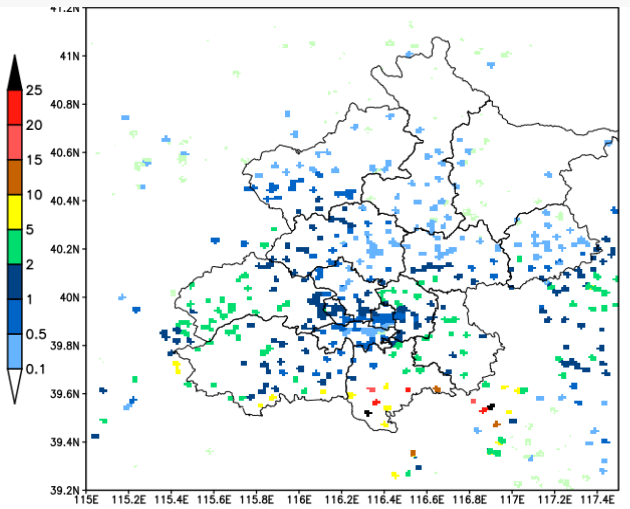
RMAPS-IN ANA



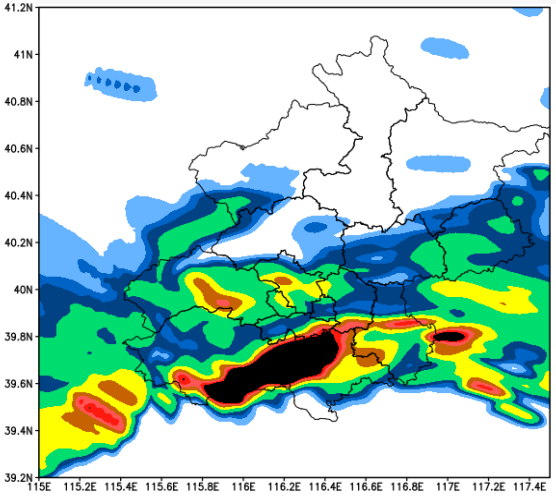
BLENDING ANA



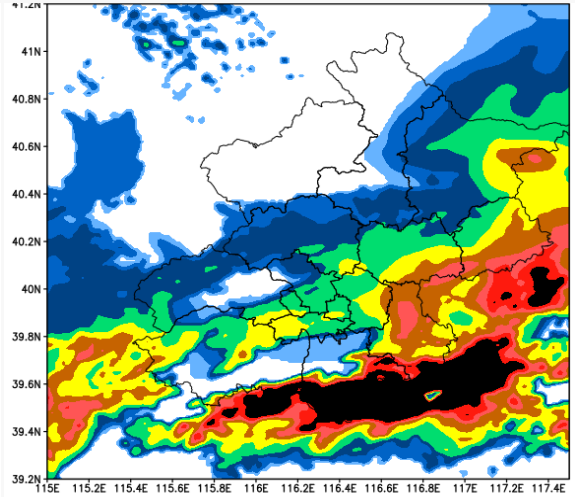
AWS RAIN-GAUGE



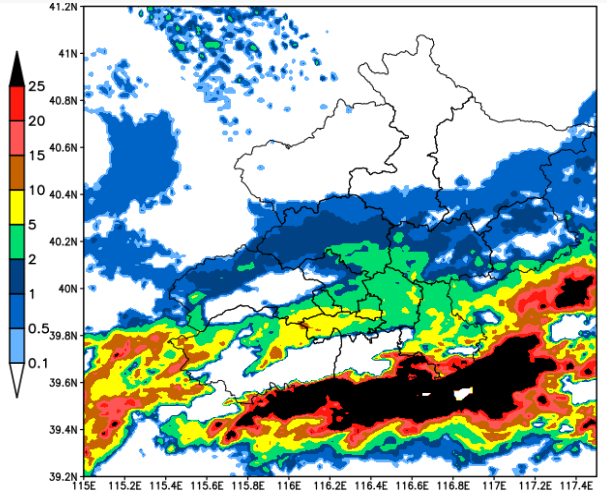
RMAPS-IN 1-2hr FORECAST



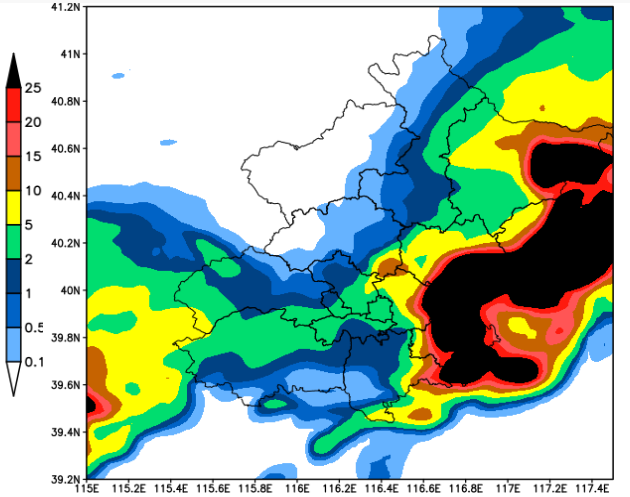
BLENDING 1-2hr FORECAST



RMAPS-NOW 1-2hr FORECAST



RMAPS-ST FORECAST



ACKNOWLEDGEMENTS to ZAMG COLLEAGUES

THANKS

FOR YOUR WATCHING