

The 7<sup>th</sup> International Workshop on Air Quality Forecasting Research

# A study of accuracy improvement for national air quality forecasting

2015.9.1

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# PM pollution episodes are increasing in Korea?

Beijing smog day( 14 Jan., 2013)



Korean smog day( 17 Jan., 2013)

스모그 원인 물질의 이동경로

출한다. 또 기하급수적으로 늘어나는 자동차에서 배기가스가 배출되기 때문이다. 베이징만 하더라도 자동차 대수가 지난해 500만대를 넘어섰다. 자동차 배기가스에서 나오는 납(Pb)·비소(As) 등이 대기의 중금속 수치를 높인다.

이같이 오염된 중국의 공기가 연중 편서풍을 타고 한반도로 이동하기 때문에 중국이 오염되면 한국 상공도 '안전지대'가 될 수 없다. 이달 초 중

환경부, 5월 한·중·일 회의서 실시간 자료 공유 제안하기로

중, 자국민에도 오염 공개안내 관련자료 받을 수 있을지 의문

중국 등에서 바람을 타고 온 황사·스모그가 한국 대기오염에 미치는 영향 국내 대기오염에서 차지하는 비율(%)

황산화물	29.7%
초미세먼지(PM-2.5)	32-60
미세먼지(PM-10)	30-50
납	30
카드뮴	50
비소	40

※미세먼지와 중금속(납·카드뮴·비소) 오염도는 황사가 발생했을 때의 비율

출처: 환경부



"스모그 대책 마련하라" 전국 곳곳에 중금속 스모그가 발생한 가운데 16일 오전 서울 중로 단체 회원들이 '베이징 스모그'에 대한 대책 마련을 촉구하는 기자회견을 하고 있다.

국에서 발생한 최악의 스모그 속 대기오염 물질도 고스란히 한국으로 이

이다. 이 때문에 스모그가 발생한 12~15일 서울 은평구 불광동에서 비

에 중금속 농도 등 오염도 자료를

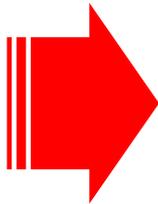
공유하지는 의견을 전달할 계획이

민을 상대로도 환경오염 수치를 공

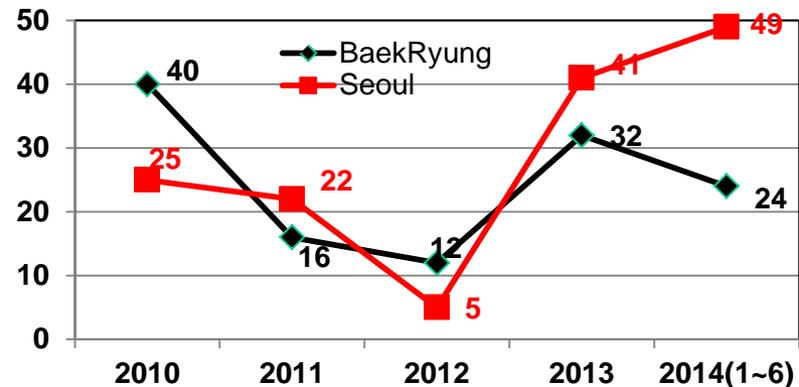
개하지 않고 있어 우리 정부에 자료

해배

## National air quality forecasting service commenced since 30 Aug. 2013



PM Pollution Episode in Seoul ('13.12)



Number of Excess Days over PM<sub>10</sub> 24hr Standard (100µg/m<sup>3</sup>)

# NAQF overview

## Outline

✓ **Target pollutants**      **PM<sub>10</sub>, PM<sub>2.5</sub>, Ozone**

✓ **Target Area**

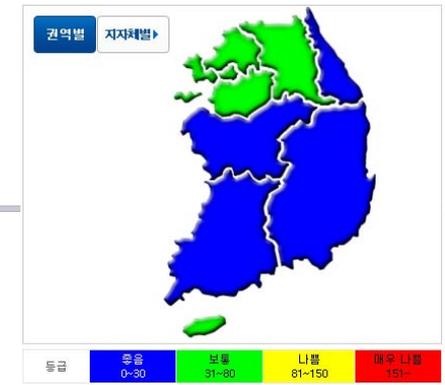
- Past : six regions
- Present : 10 regions
- Future : 17 regions

✓ **Time**

- Four times per day
- 5, 11, 17, 23 LST

✓ **Evaluation**

- Periodic report: Weekly and monthly evaluation of forecast accuracy
- Spot report: Intensive analysis of pollution event



# First step- Observation

## Observation, collection and analysis of National and Asian air quality

Obs.

Monitoring

Mod.

Analysis

Fore.

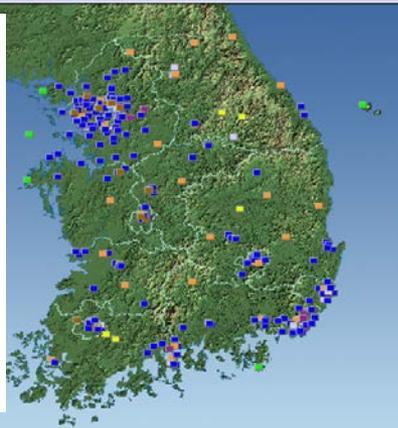
Production

Comm.

Application

### Korean surface observation

■ Background	6
■ Rural	15
■ Urban	233
■ Roadside	29
■ Photochemical pol.	15
■ Hazardous pol.	31
■ Acid Deposition(ATM)	38
■ Acid Deposition(wet)	38
■ Acid Deposition(dry)	38
■ Visibility	4
■ Greenhouse Gas	1
■ Heavy Metal	48
● Multi-pollutant	
★ Super Site	



Monitoring network  
(11 network/469 sites)

### Asian real time data collection

Real time data collection from  
1000 sites in 74 Chinese cities

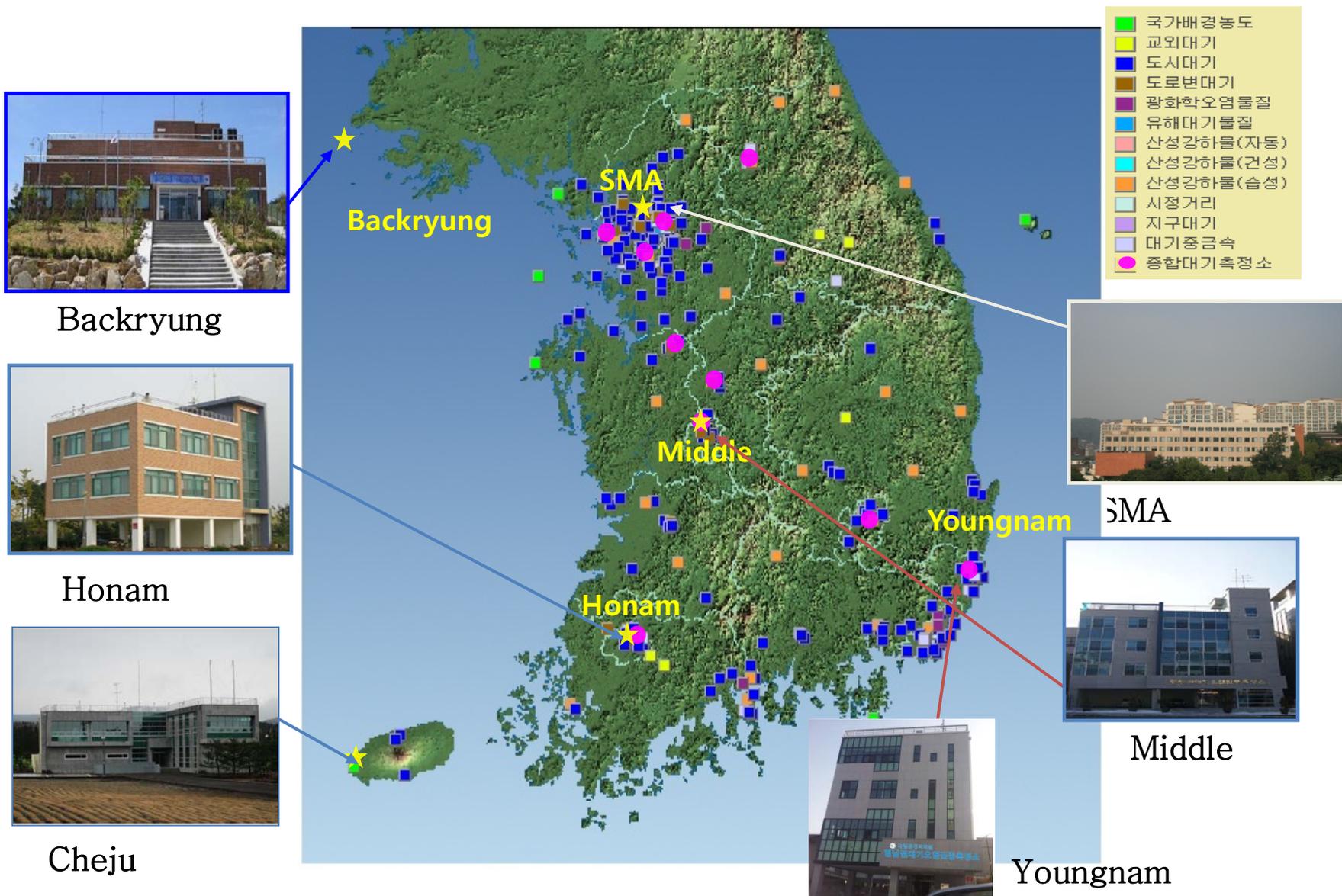


AD-Net LIDAR (20 units)



Satellite observation  
(COMS, MODIS,  
MTSAT, NOAA)

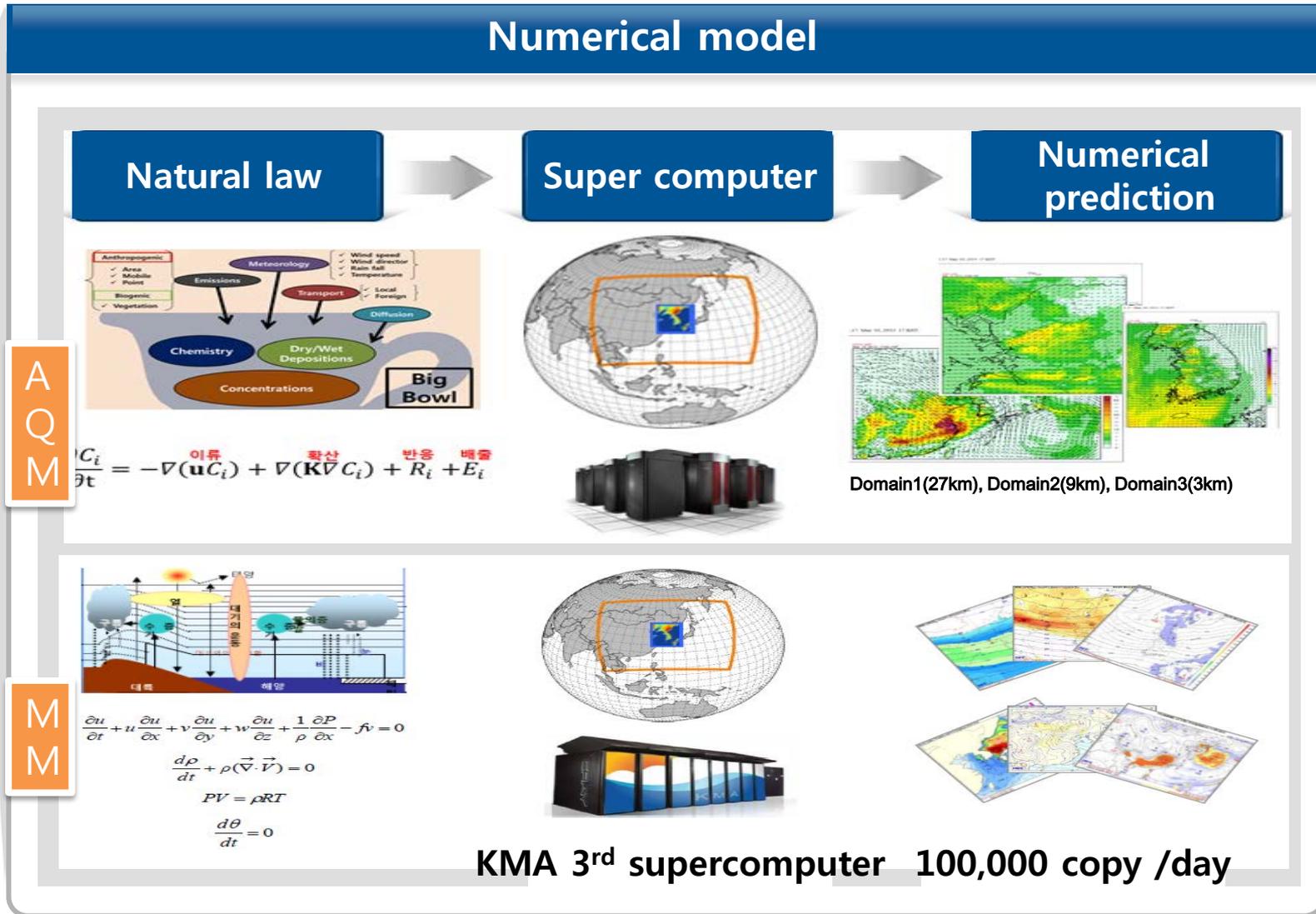
# Super site network (6 supersites)



# Operational monitoring items (Aerosol Mass & Composition)

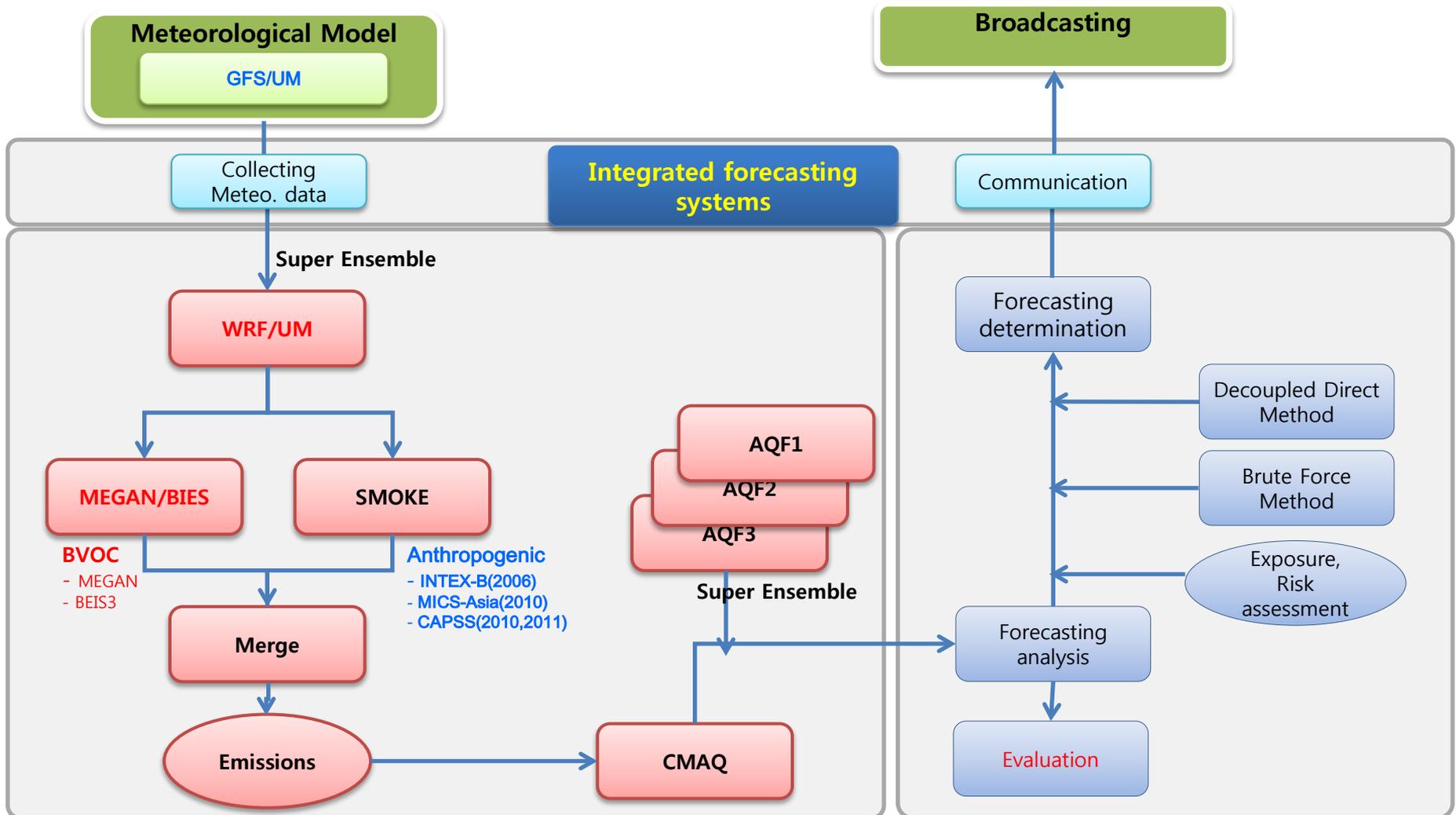
PM <sub>10</sub>	Mass (MetOne, BAM1020)	Aerosol Profile	LIDAR (IfT, Polly) Sunphotometer (NASA) PANDORA (NASA)
PM <sub>2.5</sub>	Mass (MetOne, BAM1020) Ion (URG, AIM9000D) OC/EC (Sunset, OCEC analyzer) BC (Magee, AE31) Element (Cooper, Xact620)	Manual Sampling	PM <sub>2.5</sub> (APM, PMS-103) PM <sub>2.5</sub> (Sibata, Hi-Vol) PM <sub>10</sub> (APM, PMS-103) TSP (Tisch, TE-5000) MOUDI (MSP, 110)
Size Distr.	0.002~0.020um (HCT, Nano DMA) 0.01~0.5um (TSI, SMPS 3080) 0.5~20um (TSI, APS 3321)		
Single Particle analysis	Size, Ion, Organics etc. (Aerodyne, ToF-AMS) Soot (DMT, SP2)		
Optical Property	B <sub>sca</sub> (TSI, Nephelometer 3563) B <sub>abs</sub> (Magee, AE31)		

# Second step- Model

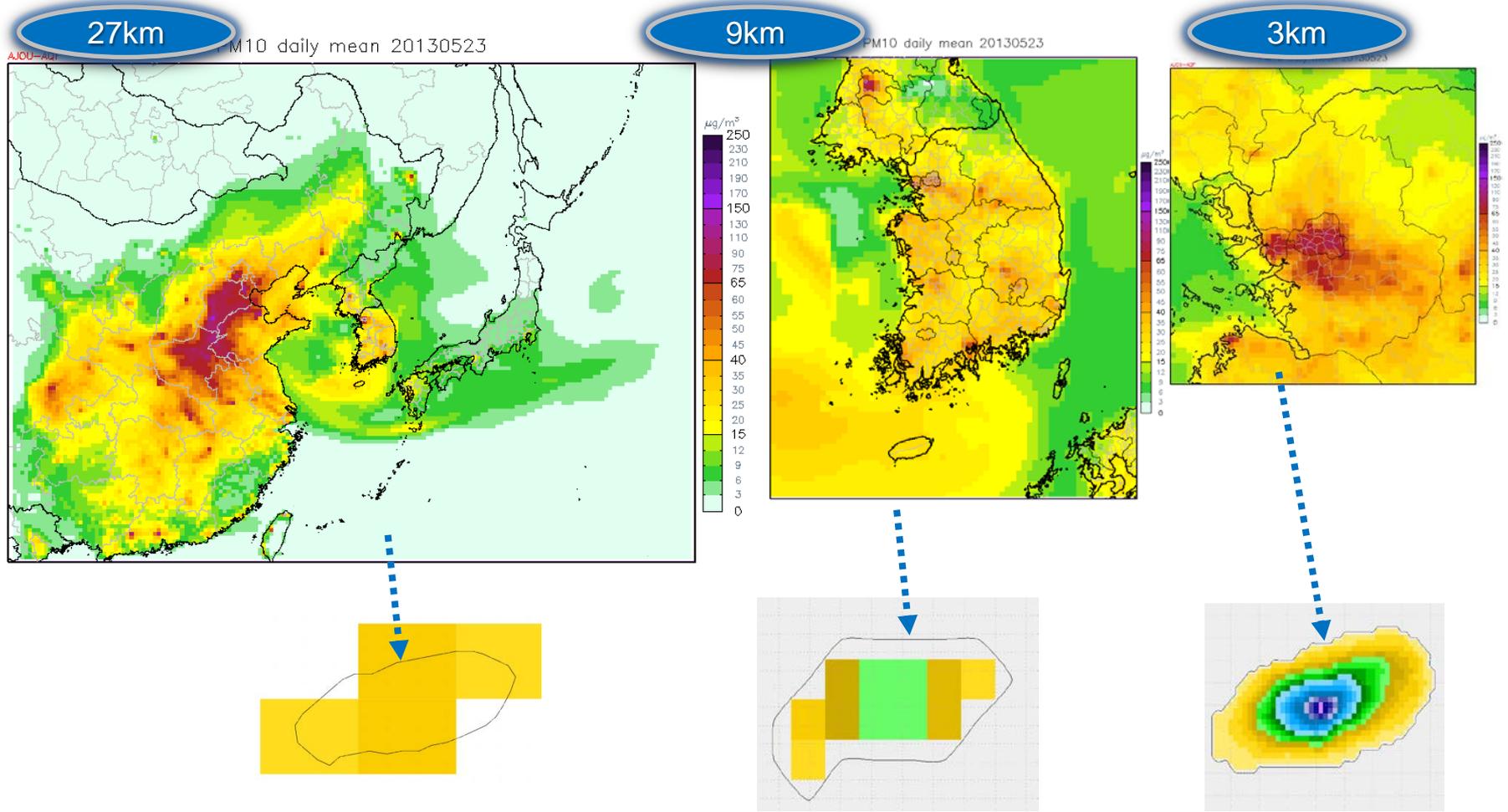


# Model operation (Meteo. + Emis. + Air chem.)

- Starting from data collection of global meteorological forecast data, we are operating a regional meteorological model, emission processing model and regional air quality model followed by source apportionment model

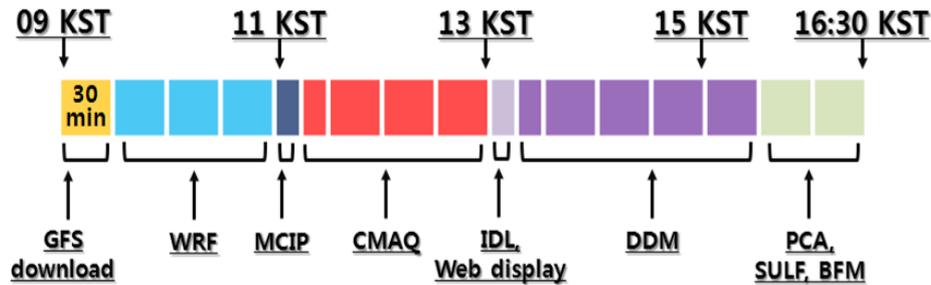


# Modeling domain(NE Asia, Korea, SMA)

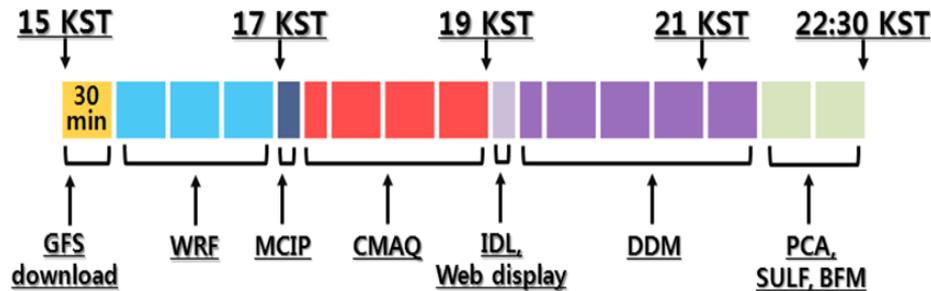


# Modeling schedule (at least 4 hours required)

## Afternoon 17-o'clock forecast



## Morning 11-o'clock forecast



# Third step- Forecast

Obs.  
Monitoring

Mod.  
Analysis

Fore.  
Production

Comm.  
Application

Forecast using numerical prediction with knowledge, experience and knowhow

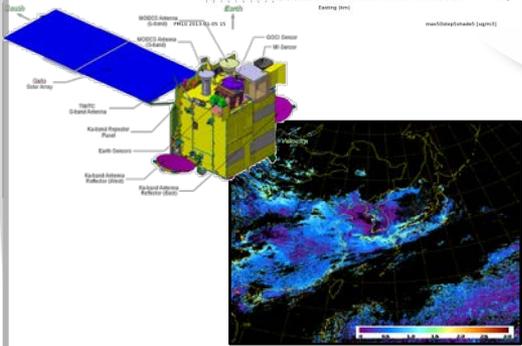
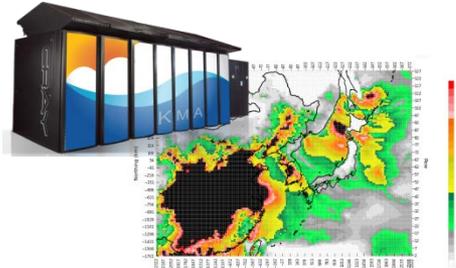
Numerical prediction



Forecaster's subjective judgment



Forecast



Current status

Knowledge, experience, knowhow

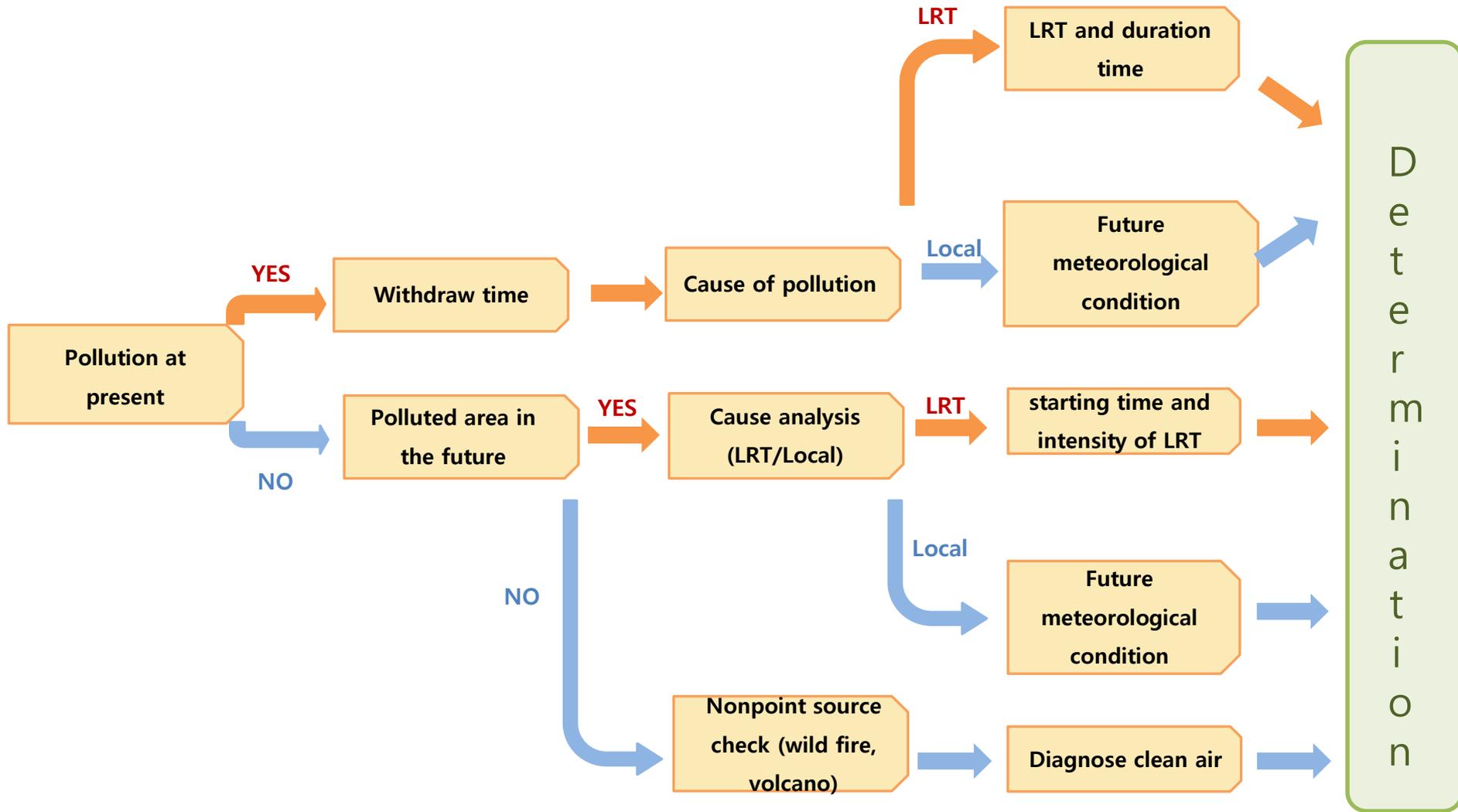


대한민국 기상청  
기상예보

구분	시간	구분	시간	구분	시간
기온	12.0	강수량	0.0	습도	65%
강풍	없음	해상풍속	1.0	해상습도	75%
해상기온	13.0	해상강수량	0.0	해상습도	75%
해상기온	13.0	해상강수량	0.0	해상습도	75%



# Forecasting decision making



# Comparison with other forecast

**ARL**  
Air Resources Laboratory  
Advancing Atmospheric Science and Technology through Research

**HYSPLIT Topics**

- Emission
- Model Outputs
- Publications
- Tutorial, Ash
- User
- Smoke Plume/Cloud
- Data
- Webshop
- Examples
- Support Services
- READY Site
- Global HYSPLIT
- Publications Search

## ■ HYSPLIT

(Hybrid Single-Particle Lagrangian Integrated Trajectory)

[http://www.arl.noaa.gov/HYSPLIT\\_info.php](http://www.arl.noaa.gov/HYSPLIT_info.php)

## ■ MACC

<http://www.gmes-atmosphere.eu/>

**MACC** Monitoring atmospheric composition & climate

**Latest** Copernicus services - Information Day

**Today's Forecasts**

- Reactive Gases
- Aerosols
- European Air Quality
- UV Index
- Ozone Layer
- CO2

**Latest Analyses**

- Fire Monitoring
- Reactive Gases
- Aerosols
- European Air Quality

**SPRINTARS**  
Spectral Radiation-Transport Model for Aerosol Species

**SPRINTARS aerosol forecast**

Updated around 4:00JST (19:00UTC) every day.  
(Data policy)

1. Asia  
2. surface concentration  
3. PM10  
4. [PLAY Mode]

SPRINTARS is based on the simulation with a global aerosol climate model, SPRINTARS. Horizontal resolution of the simulation is about 50km.

## ■ SPRINTARS

<http://sprintars.riam.kyushu-u.ac.jp/forecast2.html>

## ■ CFORS

Forecast for distributions of Asian dust and anthropogenic aerosols in east Asian region

**CFORS**

Realtime forecasting by RIAM/CBERS/NIES-CFORS (Chemical weather Forecasting System) until the day after tomorrow

**Dust distribution**

U-V&Dust total m/s&ug/m3 JST  
2015/01/13 09:00:00

UNIT = 0.000E+01, UNIT = 0.000E+01

九州大学応用化学研究所(RIAM)/国立環境研究所(NIES)

<http://www-cfors.nies.go.jp/~cfors/>

# Fourth step-communication



### Media

- TV, radio, newspaper
- Webpage  
Airkorea, KMA
- Smart phone (Appl, SMS)  
131 call
- Prevention meteorology database
- Internal report and related organization

### Recipient

- MOE
- KMA  
기상청
- Public
- Press
- Local Gov.

# Fourth step-communication

## KMA homepage

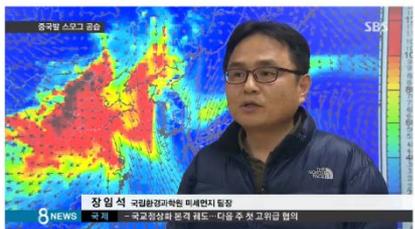
The screenshot shows the KMA homepage with a navigation bar at the top. The main content area features a '특보' (Special Report) section with a map of South Korea and a table of forecasts. A red box highlights the '특보' section.

## Airkorea homepage

The screenshot shows the Airkorea homepage with a navigation bar at the top. The main content area features a '대기질 예보' (Air Quality Forecast) section with a table of forecasts. A red box highlights the '대기질 예보' section.

## TV/radio/newspaper reporter

채널	인물사	소속부서	기자명	취재분야
KBS	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
HBC	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
SBS	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
YTH	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
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	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치



채널	인물사	소속부서	기자명	취재분야
KBS	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
HBC	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
SBS	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치
YTH	김현수	사회부	김현수	정치
	김현수	사회부	김현수	정치

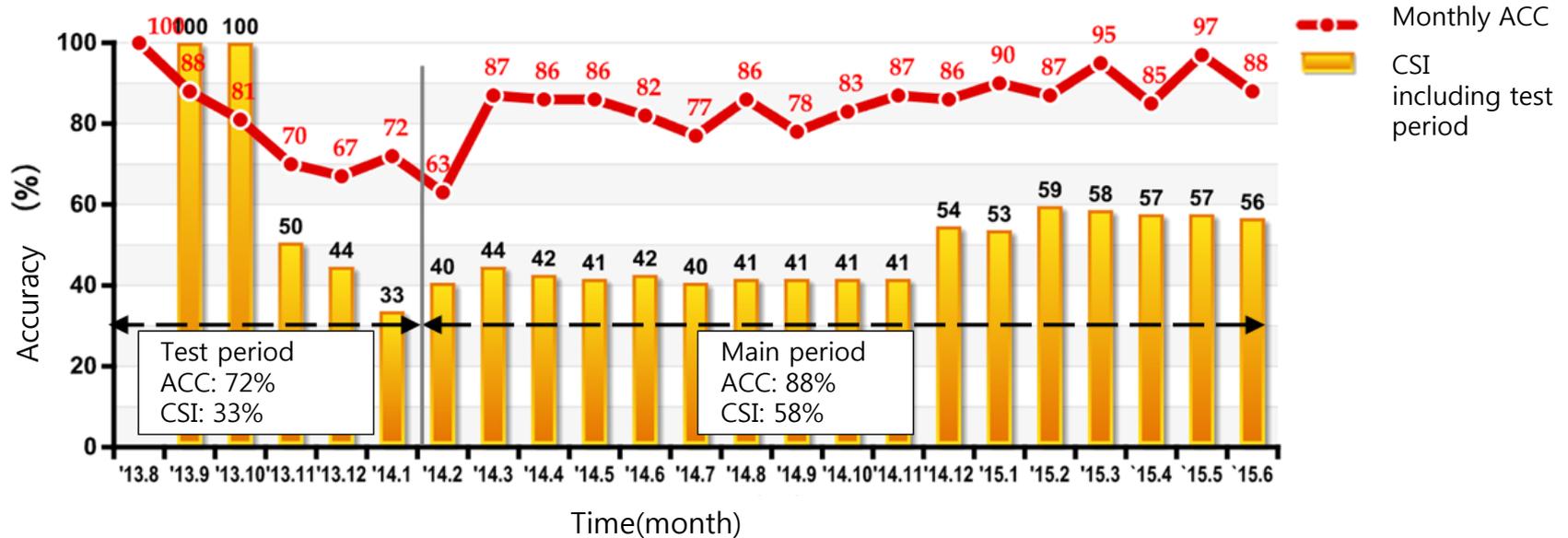
# Weather + Air quality Consultation Service

Month	Total Call	Total Response	Air quality Consultation	Ratio
2014. 1	63,169	60,859	11,124	<b>18.3%</b>
2014. 2	68,163	65,605	11,100	<b>16.9%</b>
2014. 3	98,214	94,224	16,198	<b>17.2%</b>
2014. 4	103,266	99,224	16,024	<b>16.1%</b>
2014. 5	98,954	95,037	15,376	<b>16.2%</b>
2014. 6	119,423	110,340	8,048	7.3%
2014. 7	136,059	123,101	4,179	3.4%

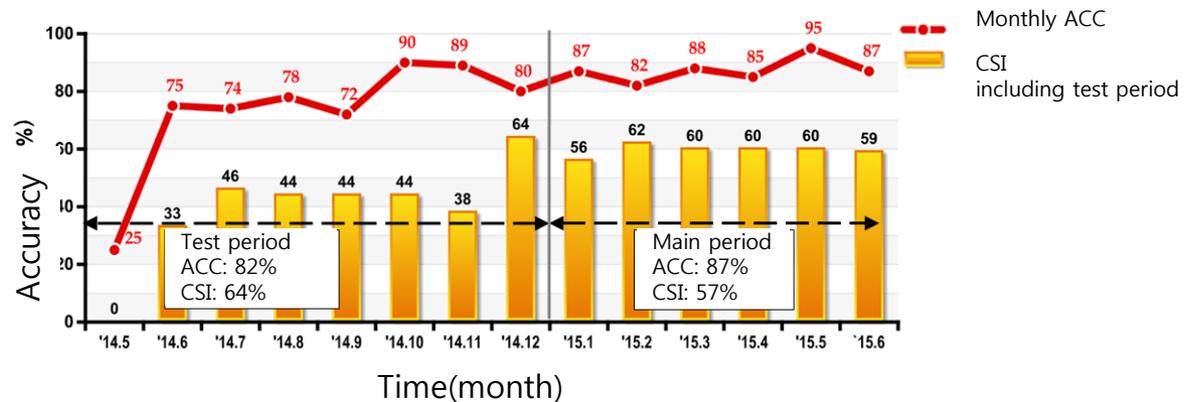
Month	Call	Response	Air quality Consultation	Ratio
2015. 1	60,868	59,113	6,806	<b>11.5%</b>
2015. 2	60,335	58,616	12,663	<b>21.6%</b>
2015. 3	77,685	75,599	18,026	<b>23.8%</b>
2015. 4	117,933	110,987	12,503	<b>11.3%</b>
2015. 5	94,157	90,479	10,045	<b>11.1%</b>
2015. 6	117,977	112,367	4,309	3.8%
2015. 7	143,623	132,756	2,322	1.7%

# Overall evaluation of Korean forecasting accuracy

## PM10



## PM2.5



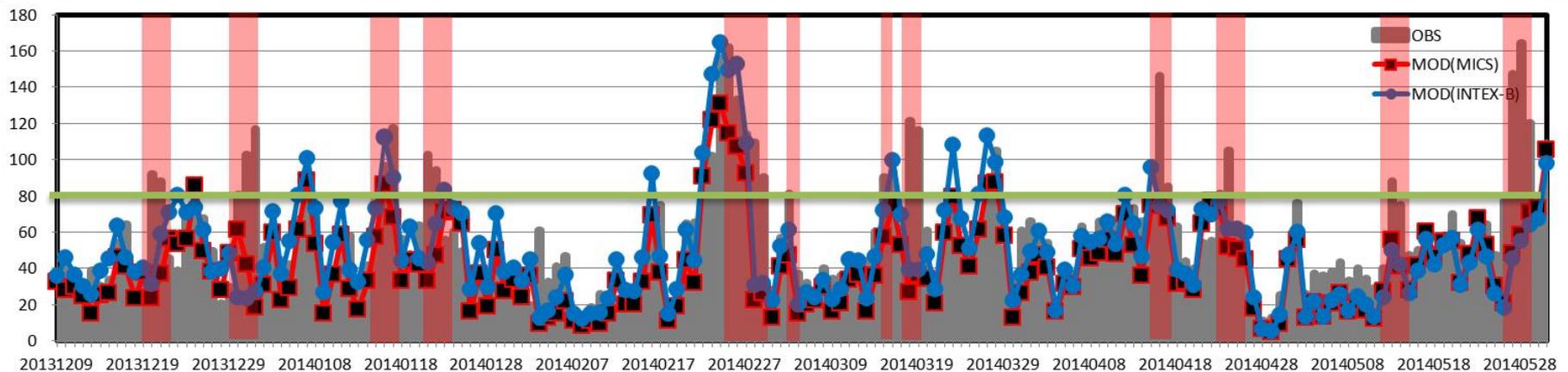
# Major causes of forecasting uncertainty

Analysis period : 2013.12.9.~ 2014.05.31

Site : Seoul Metropolitan Area(SMA), Method: on the grid

Model: WRF-SMOKE-CMAQ with two emission inventories (MICS-ASIA and INTEX-B)

Generally AQM agreed with observation but failed in capturing high pollution episodes The correlation between AQM and observation is in the range of 0.75~0.77. The bad forecasting was due to incompleteness of emission, uncertainty of meteorology, missing of Asian dust, the lack of experienced forecasters

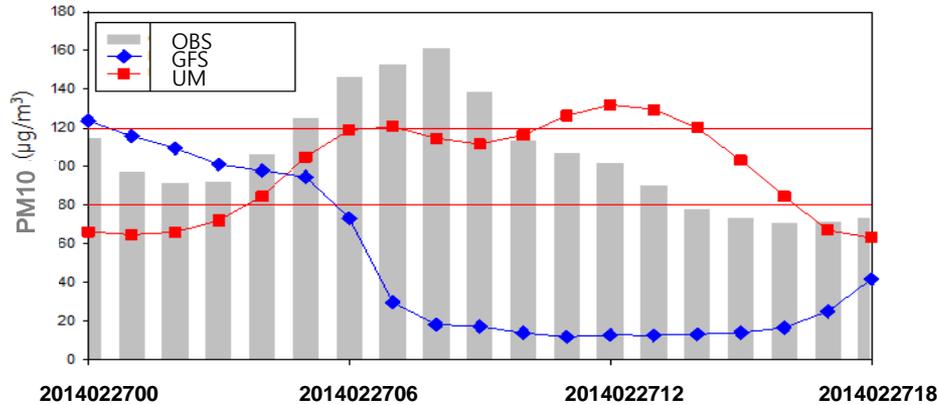


# High PM pollution episodes

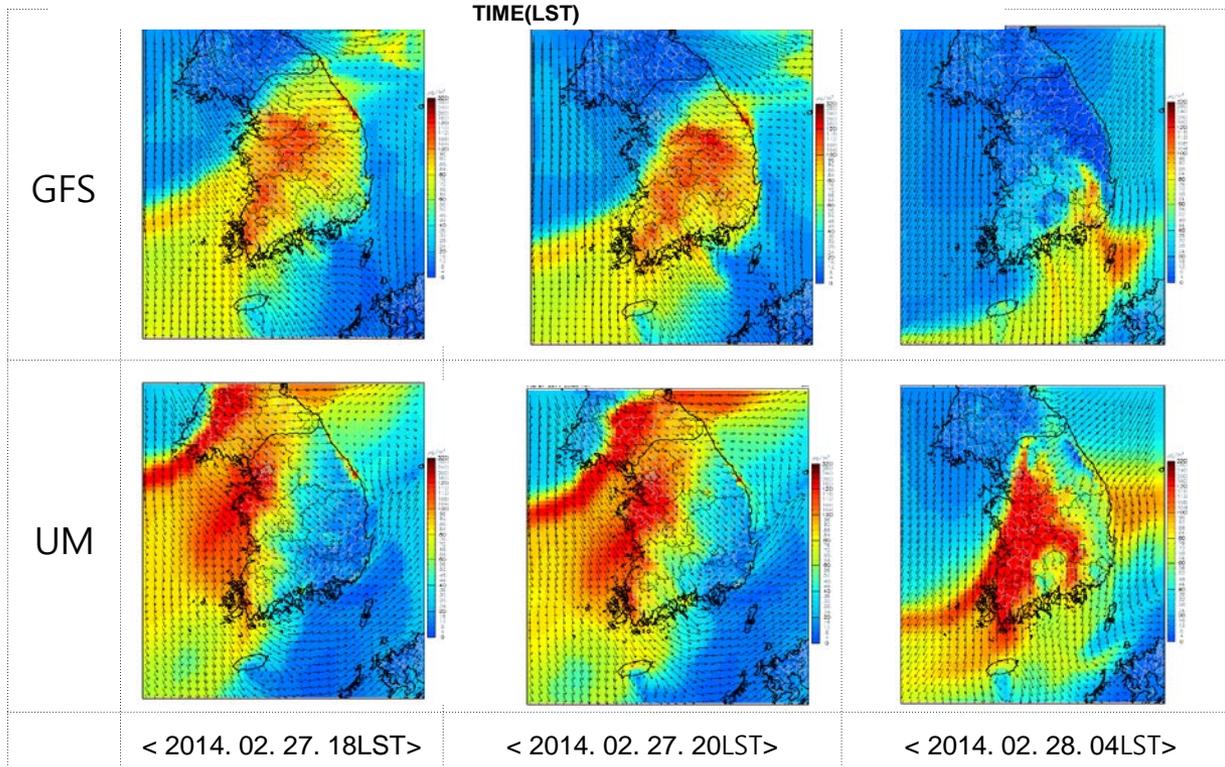
YEAR	MON/DAY	OBS	MOD	HIT
2014	1/17	IV	III	FALSE
	1/25	II	III	FALSE
	2/27	III	II	FALSE
	4/16	IV	III	FALSE
	4/17	III	III	TRUE
	5/31	III	III	TRUE
	12/29	IV	II	FALSE
	12/30	IV	IV	TRUE
2015	2/22	V	II	FALSE
	2/23	V	V	TRUE
	2/24	IV	V	FALSE
	3/16	V	II	FALSE
	3/17	IV	IV	TRUE
	3/20	IV	II	FALSE
	3/21	V	IV	FALSE
	3/22	IV	IV	TRUE
	3/30	V	IV	FALSE
	3/31	IV	IV	TRUE

I: Good, II: moderate III: unhealthy for sensitive group, IV: very healthy, V: Hazardous

# Meteorology uncertainty (Case 1: 27 Feb. 2014, Site: Seoul)

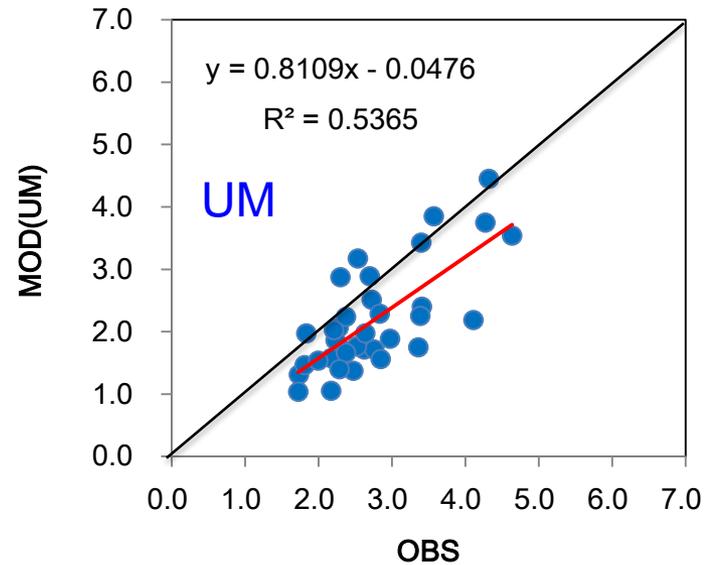
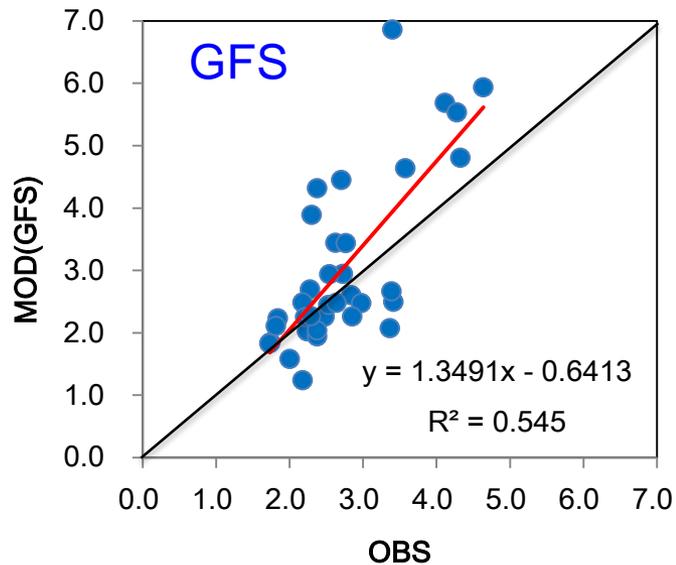


- GFS-CMAQ predicted the ending time of high PM conc. earlier than OBS on 27 Feb. 2014.
- Better simulation of ending time of high PM conc. was obtained by UM-CMAQ



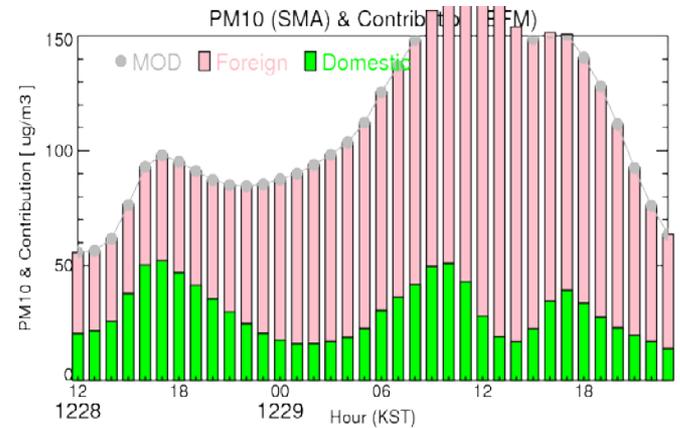
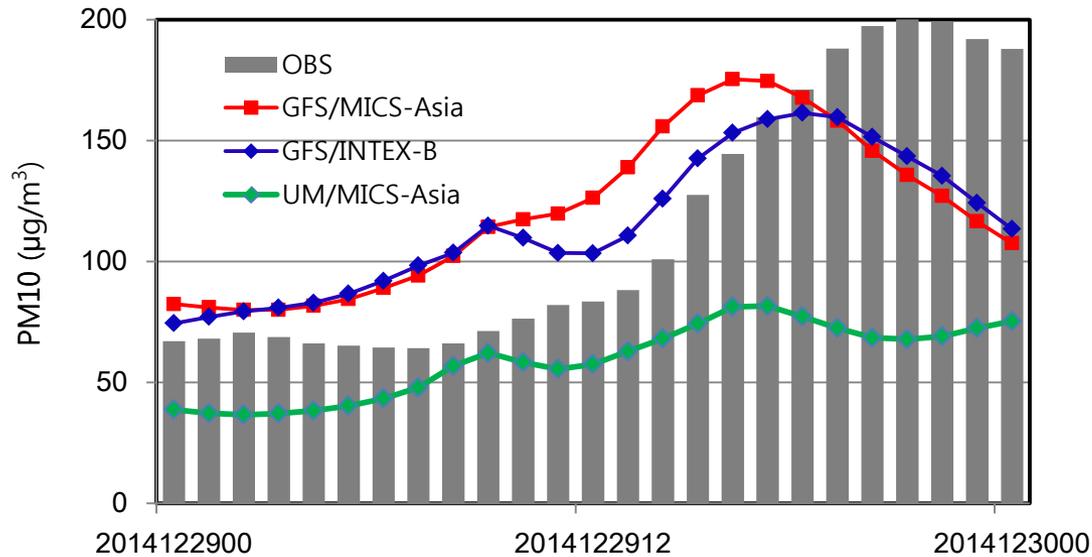
- Two separate plumes arrived at Korea and then merged, which were simulated by both UM and GFS
- The latest plume moved slowly in UM-CMAQ than in GFS-CMAQ

# GFS vs UM

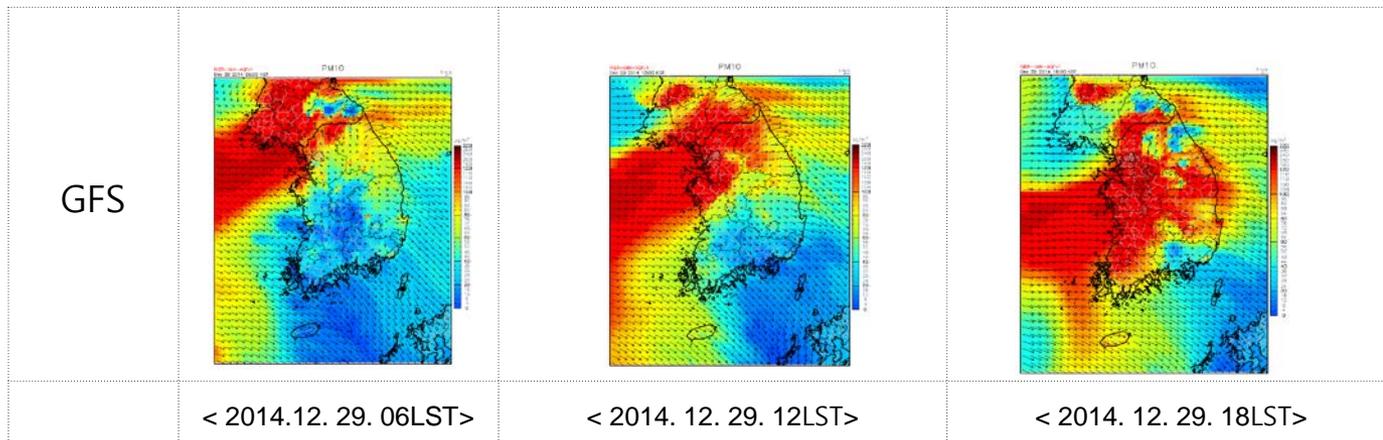


- Simulated surface wind speeds by UM and GFS were both biased in high PM pollution episodes. The bias was negative in UM while positive in GFS
- But UM and GFS were much alike in correlation coefficients
- This may cause the difference of the arriving and leaving time of long-range transported PM to Korea.

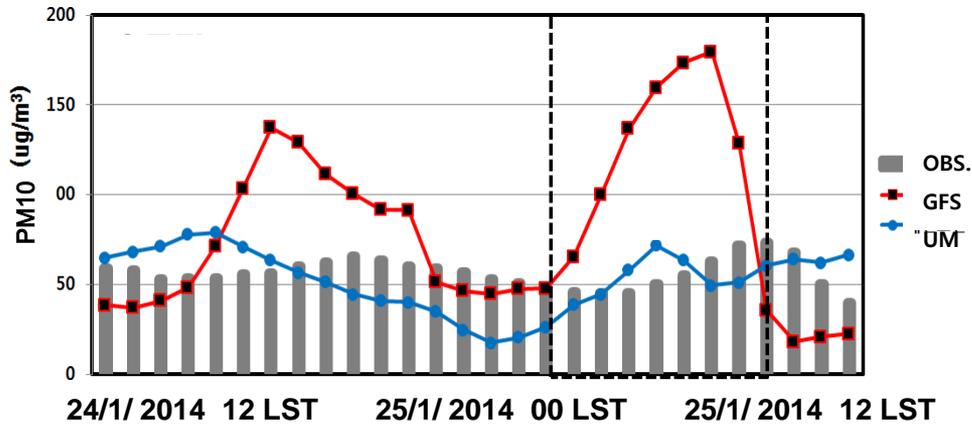
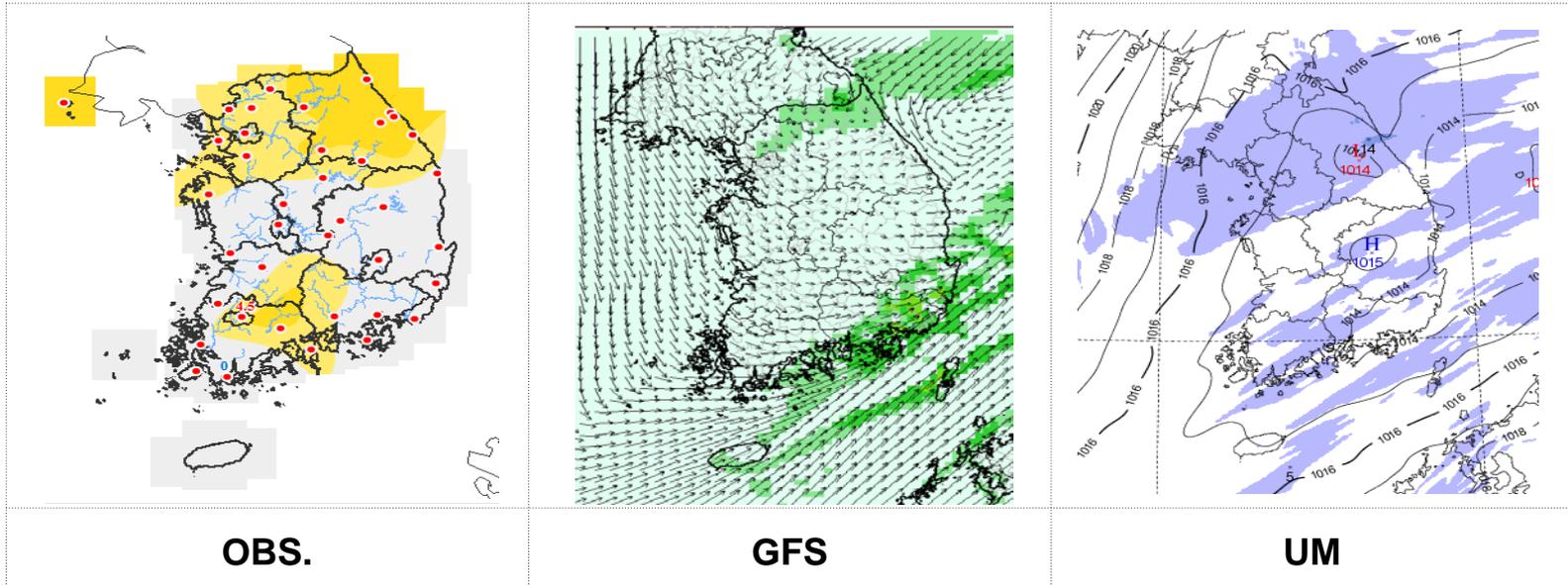
# Meteorology uncertainty (Case 2: 29 Dec. 2014, Site: Seoul)



A probing tool(BFM) showed that high PM conc. in Seoul was caused mainly by long-range transport on 29 Dec. 2014. In this case GFS-CMAQ showed better performance than UM-CMAQ.

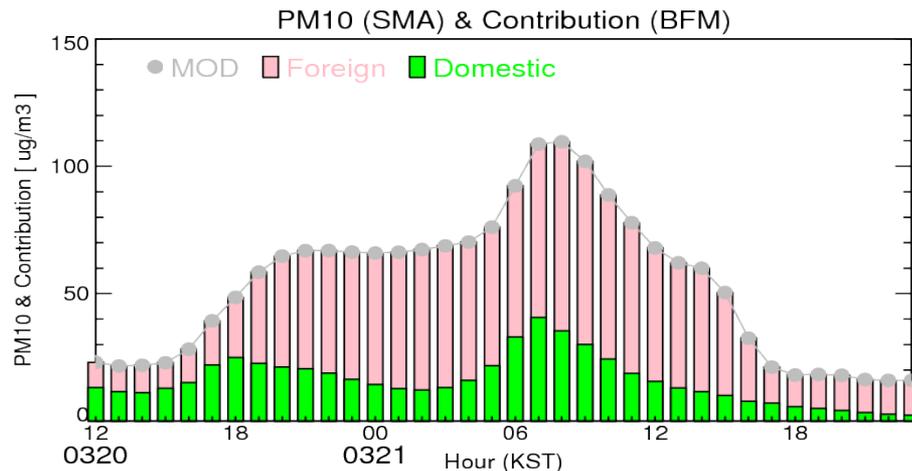
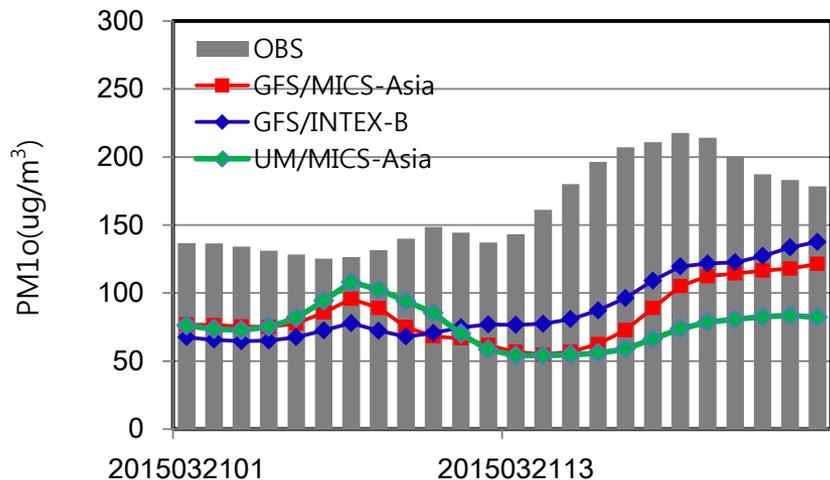


# Meteorology uncertainty (Case 2: 25 Jan. 2014)

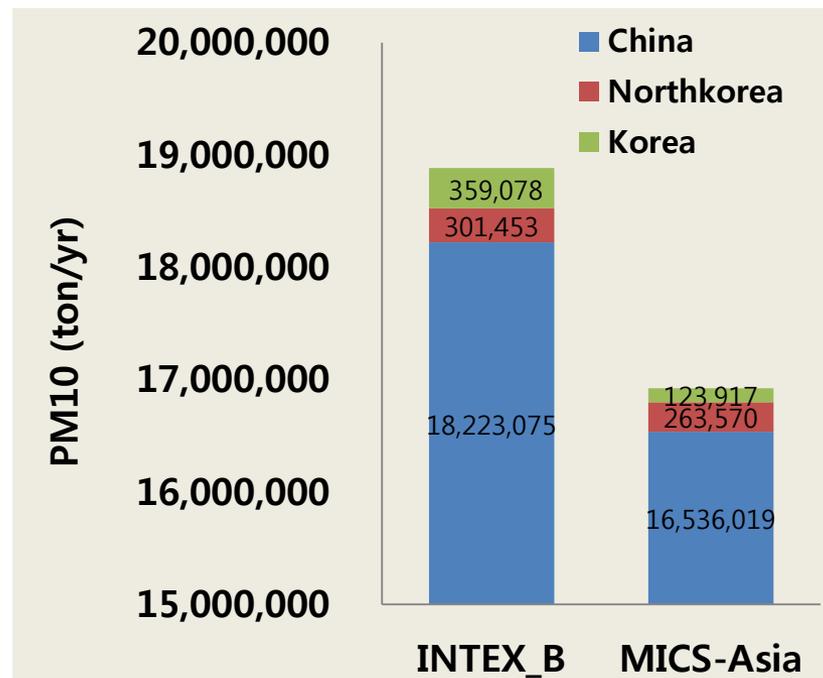


GFS-WRF showed poor performance on simulating the spatial distribution of precipitation. Under-prediction of scavenging caused over-prediction of PM concentration in SMA

# Emission incompleteness (Case 3: 21 Mar. 2015, Site: SMA)

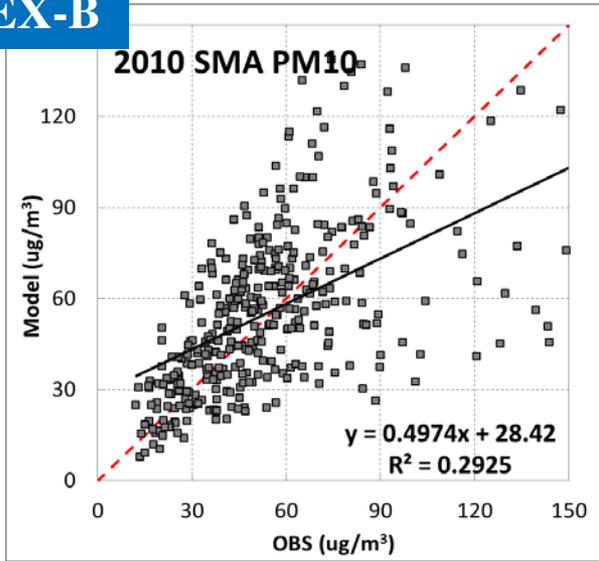


- BFM illustrated that high PM was long-range transported to SMA.
- All AQMs with GFS/UM/MICS-Asia/INTEX-B failed to capture high PM conc.

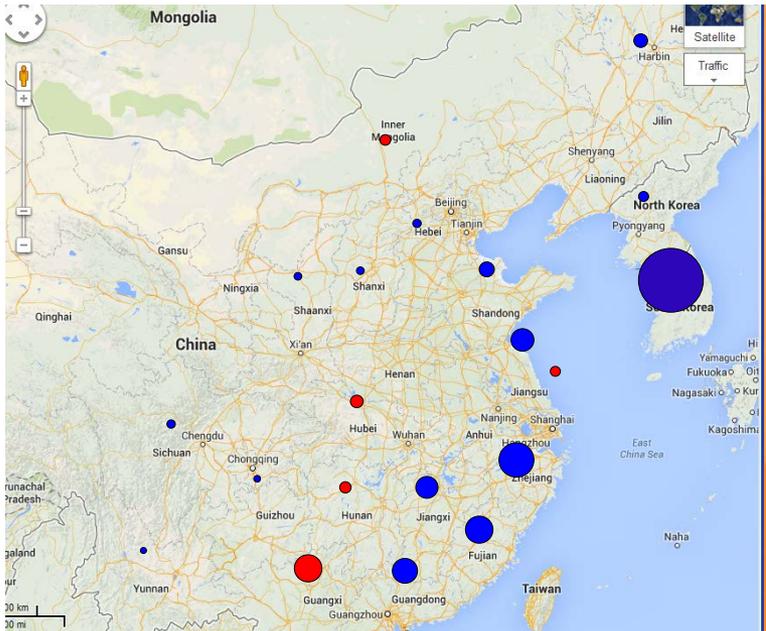
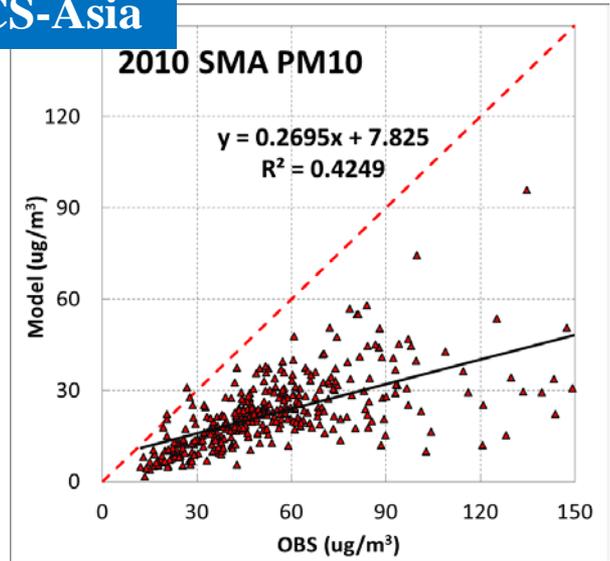


# INTEX-B(2006) vs MICS-ASIA(2010)

w/ INTEX-B



w/ MICS-Asia

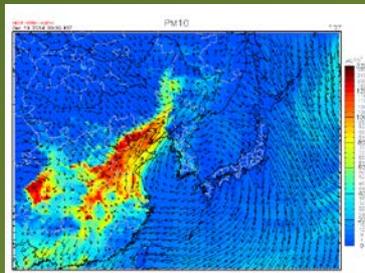


Courtesy, Ajou University  
Air Quality research Lab.

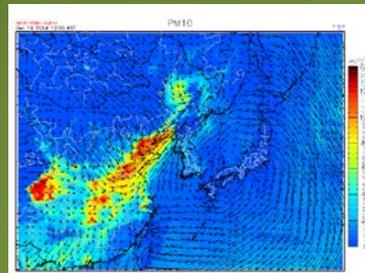
Spatial distribution of PM10 emission rate difference between MICS and INTEX-B emission inventories  
(MICS-INTEX)/INTEX\*100,  
red: positive, blue: negative)

# Emission incompleteness

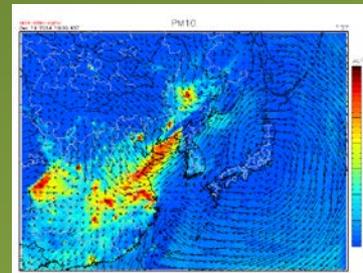
(Case 4: 19~20 Dec. 2014. Site: Backryung island)



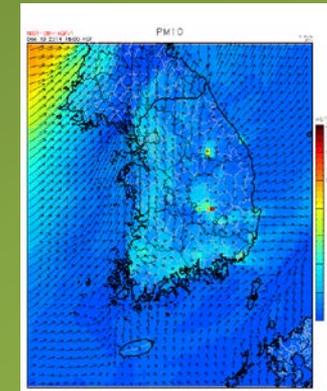
2014/12/19/06



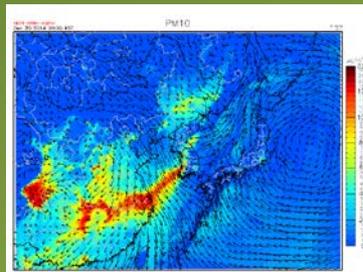
2014/12/19/12



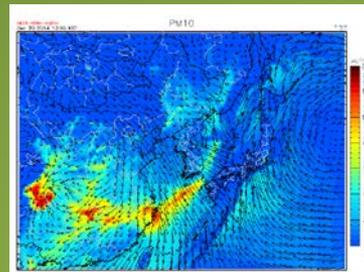
2014/12/19/18



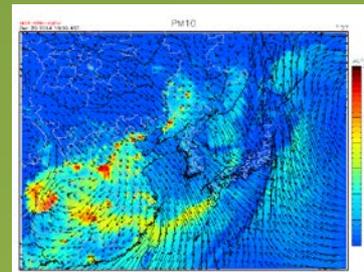
2014/12/19/18



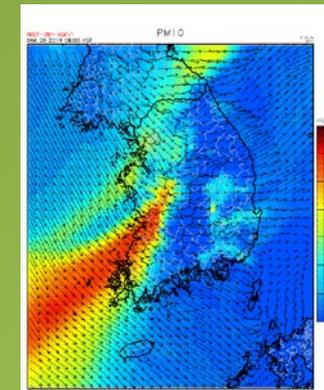
2014/12/20/06



2014/12/20/12



2014/12/20/18

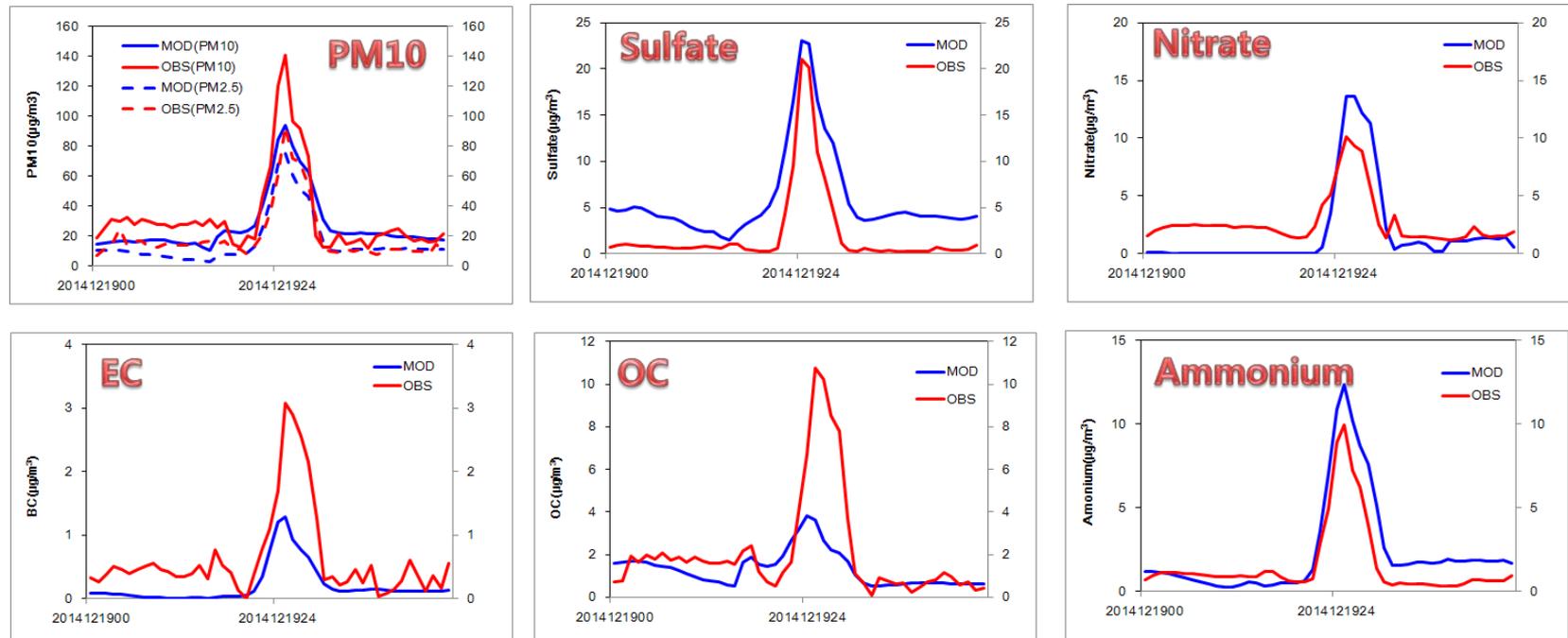


2014/12/20/06

- A strong northwest wind blew around Siberian high on the northeast China
- This wind pushed a thin PM plume from China to Korean peninsular at night on 19 Dec., 2014

# Emission incompleteness

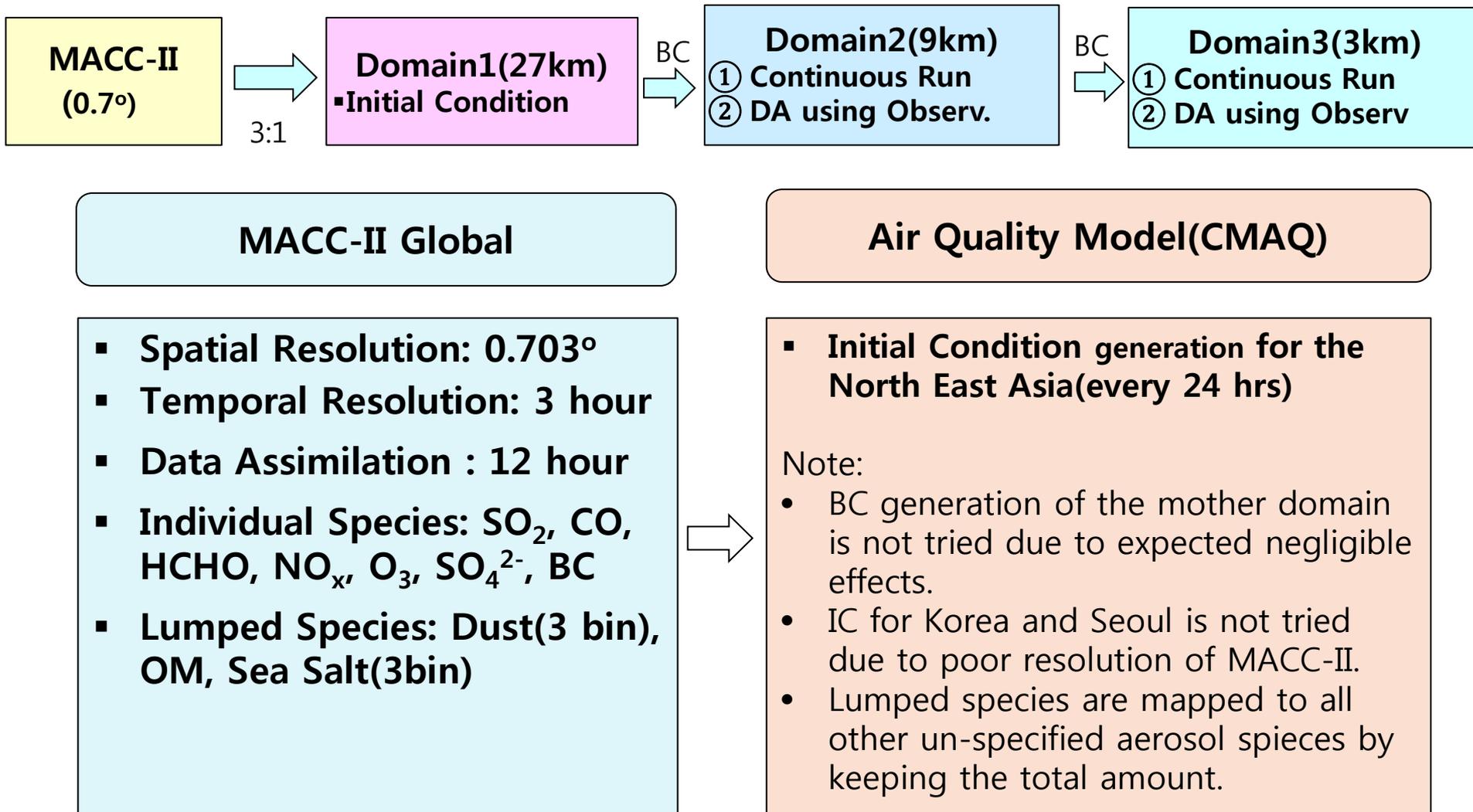
(Case 4: 19~20 Dec. 2014. Site: Backryung island)



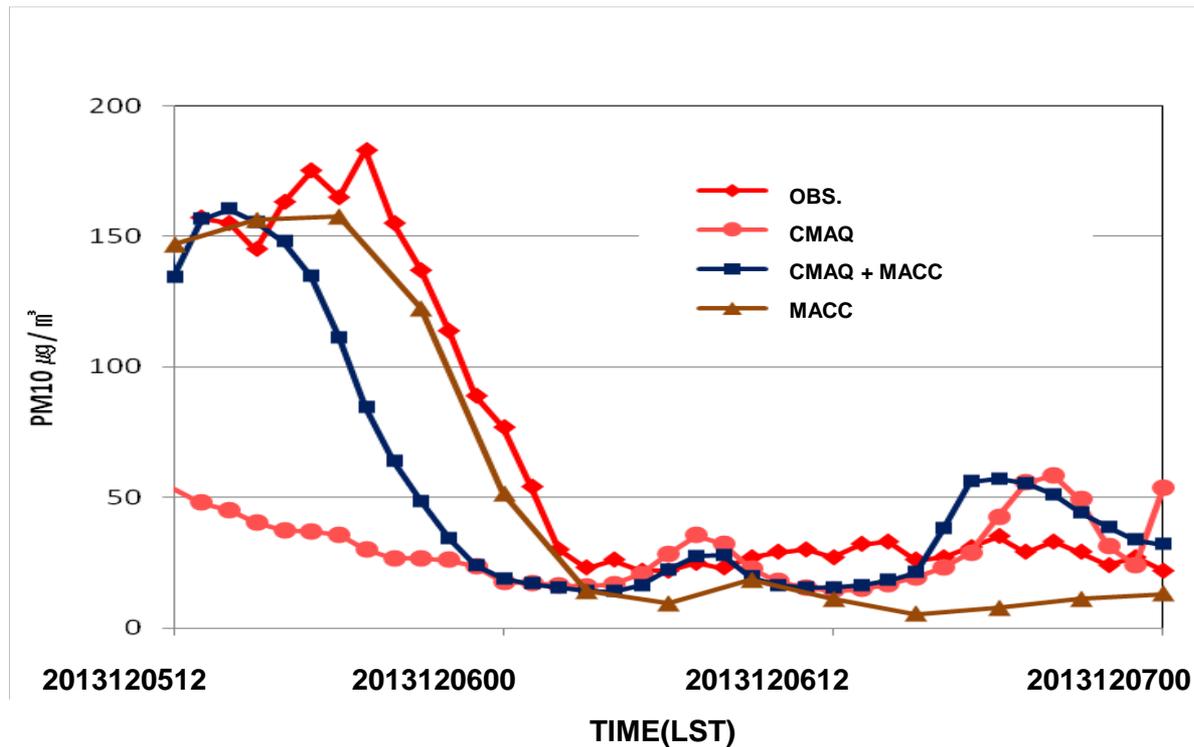
- High PM was transported from the Northern China to South Korea via North Korea. AQM captured the starting and ending time of it but under-predicted its magnitude.
- The composition comparison showed that AQM under-predicted organic particles as well as primary coarse particles. It implies uncertainty of SOC formation mechanism and the existence of unknown coarse particle source in Northeastern China and North Korea.

# One possible solution to emission incompleteness

## data assimilation



# MACC data assimilation (Case 5: 5 Dec. 2013)



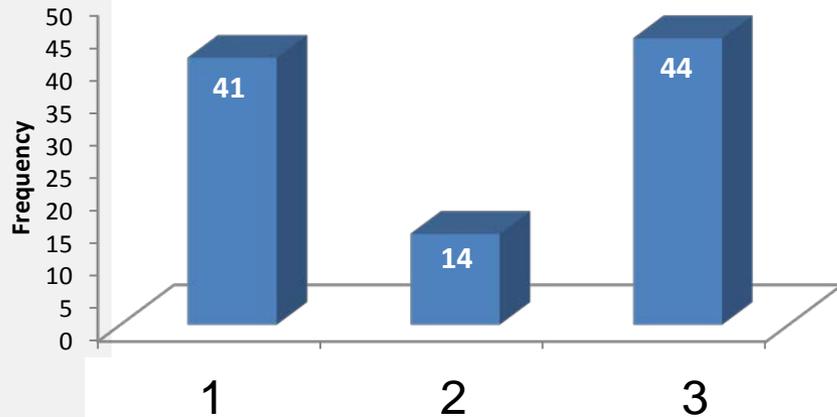
- Good match with observation was shown not in CMAQ but in MACC and CMAQ+MACC
- MACC simulated the starting, ending and peak appearing time of high PM pollution at Seoul



# Cause of False Alarm

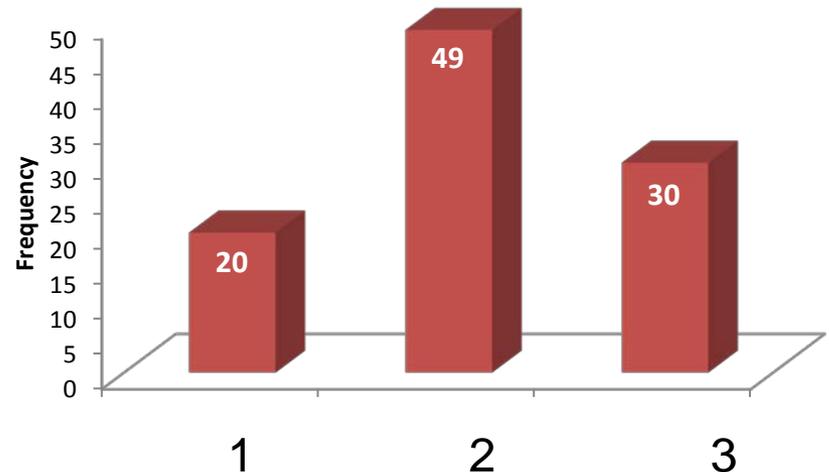
## Cause of FAR

1. Concentrated in boundary
2. Model over-prediction
3. Decision making problem



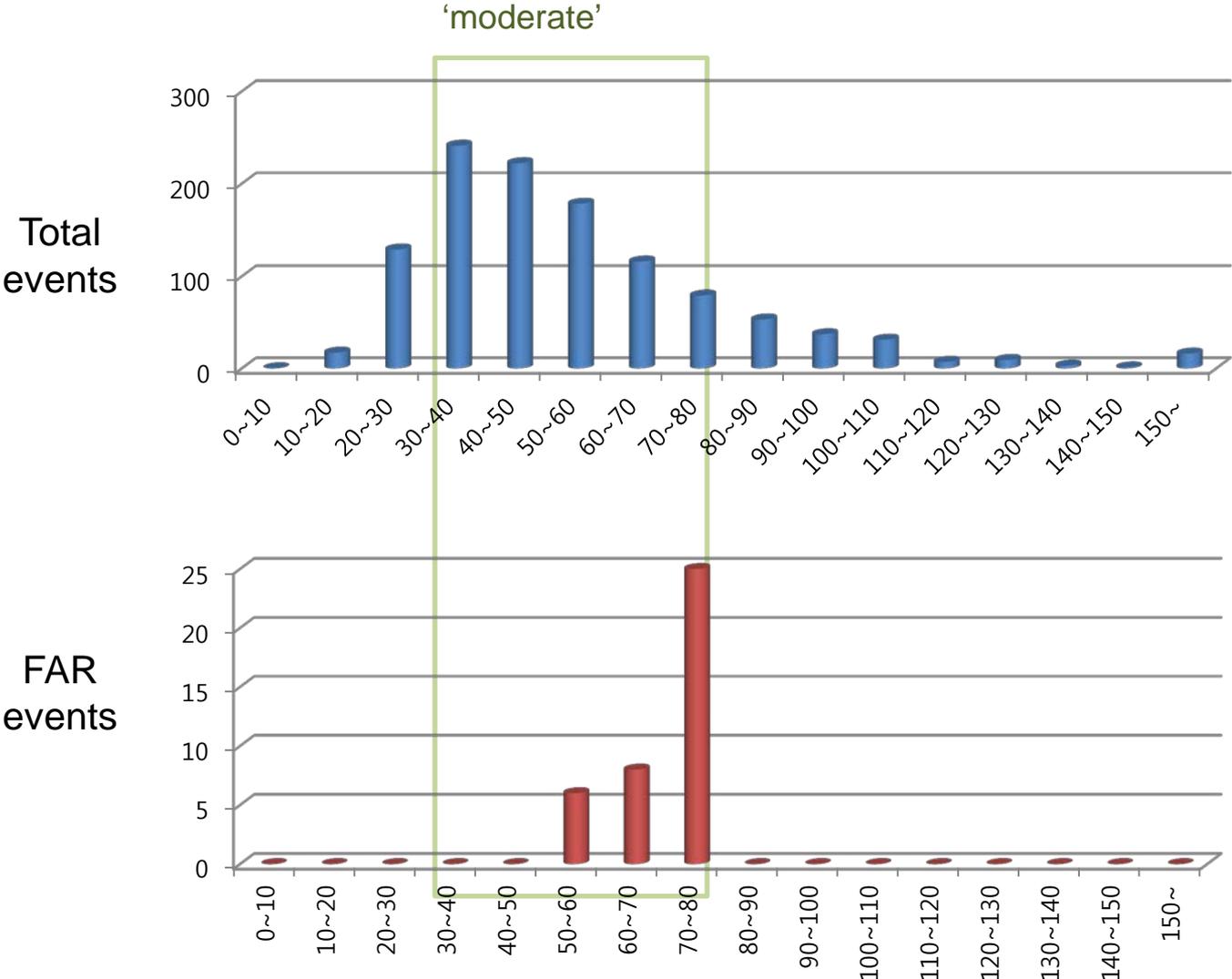
## Cause of Events

1. Local pollution  
: Miss the time and strength of stagnation
2. LRT pollution  
: Miss inflow and outflow timing
3. Local + LRT pollution  
: Miss inflow time of LTP and stagnation



# Boundary problem of AQI categories

## Frequency distribution of observed AQI and FAR



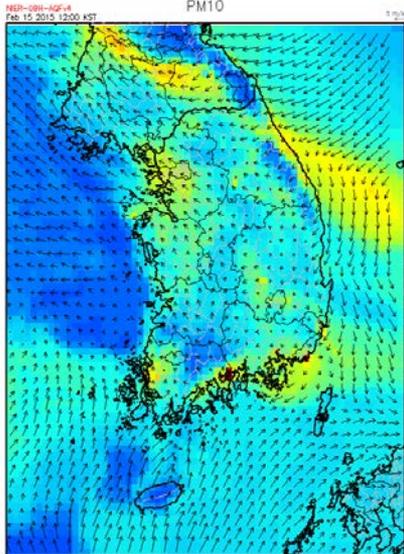
# Boundary problem (Case 7: 2015.2.15)

Forecast in 15 Feb. 2015 was the category of 'Unhealthy for Sensitive Group(USG)' in SMA, Gangwon, Chungcheong, Youngnam, while 'Moderate' in others

Model prediction was  $67.5 \mu\text{g}/\text{m}^3$  (GFS),  $77.1 \mu\text{g}/\text{m}^3$  (UM) in Seoul

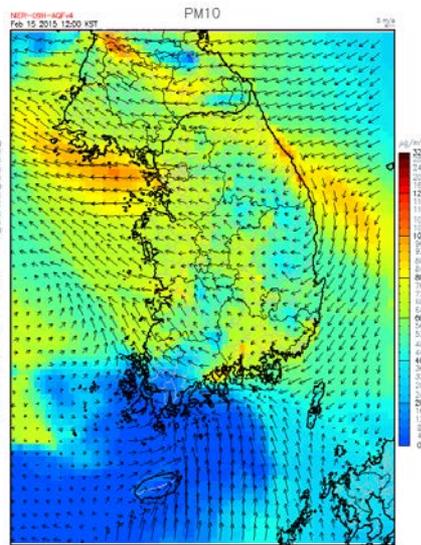
→ but it turned out to be 'Moderate ( $77.6 \mu\text{g}/\text{m}^3$ )'

Feb. 15 2015 12LST



GFS-CMAQ

Feb. 15 2015 12LST



UM-CMAQ

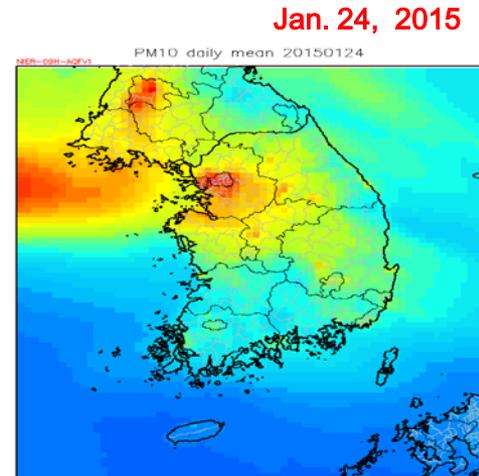
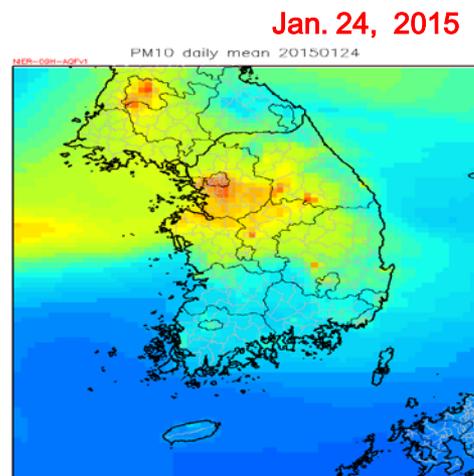
연월일	시	서울	인천	경기북부	경기남부	수도권	강원영서	강원영동	강원권	충청권	호남권	영남권	제주권
2015-02-15	1	73	80	98	89	86	95	107	100	91	95	83	102
	2	76	82	98	93	88	96	109	102	91	95	84	93
	3	77	81	97	90	87	100	109	104	92	92	82	88
	4	77	83	94	88	86	95	103	98	90	91	82	96
	5	77	82	95	87	85	99	89	95	89	91	84	99
	6	76	81	95	85	84	94	86	91	90	92	87	106
	7	76	82	95	86	85	95	83	90	91	92	90	105
	8	81	84	97	87	87	97	91	95	93	94	93	102
	9	84	86	103	88	89	99	96	97	102	98	101	98
	10	83	90	107	93	92	109	108	109	111	104	113	118
	11	83	93	112	94	94	110	109	109	115	111	122	124
	12	81	89	106	95	93	113	95	105	117	116	121	118
	13	79	85	95	92	89	120	93	108	107	115	116	100
	14	76	81	86	86	83	114	97	107	97	115	115	87
	15	74	82	86	86	83	103	99	101	90	123	119	86
	16	73	80	86	86	82	100	94	98	88	130	122	75
	17	70	80	82	83	79	93	97	95	87	123	123	63
	18	68	79	92	83	80	98	98	98	86	101	117	62
	19	69	81	95	83	82	101	99	100	85	82	113	65
	20	76	84	102	85	85	105	89	98	87	67	110	58
	21	82	83	100	86	87	105	79	93	88	61	106	43
	22	85	81	99	84	86	101	69	87	87	61	101	35
	23	84	84	96	85	86	97	70	85	86	57	95	28
	24	82	82	94	86	86	86	94	66	82	83	48	87

# Model over-prediction (Case 8: 24 Jan. 2015)

Forecast in 24 Jan. 2015 was in the category of 'USG' in SMA, western Gangwon, Chungcheong while 'Moderate' in others

➔ But it turned out to be 'USG' only in western Gangwon.

※ (OBS) Seoul : 53.0, Incheon : 57.2, Northern Kyunggi : 69.8, Southern Kyunggi : 60.4, **Western Gangwon : 88.9**, Eastern Gangwon : 52.1, Chungcheong : 54.6, Honam : 42.6, Youngnam : 60.5, Cheju : 29.8)



# Summary

- AQM agreed with observation but failed in capturing high pollution episodes which were due to incompleteness of emission, uncertainty of meteorology, missing of Asian dust, the lack of experienced forecasters
- Generally UM-CMAQ tends to predict higher surface PM concentration than GFS-CMAQ in high PM pollution episodes
- Unknown source of coarse particle in Northern China may be one of reason for under-prediction of PM10 in Korea
- Global data assimilation(MACC) is helpful to improve the model accuracy in regional scale in the sense that it is global air quality model
- False alarms were issued mostly when a predicted PM concentration was in the boundary of “moderate” and “USG” categories

Thank you for  
your attention