Numerical weather forecast and Digital forecast at KMA

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Outline

- Overview of KMA's NWP Systems
- Medium-range forecast
  - Recent Changes in KMA's EPS
  - TIGGE : Multi-model test
- Digital Forecast System

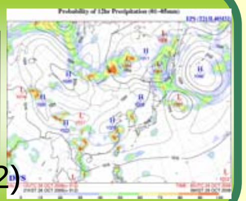
KMA Digital Forecast

Data Acquisition & Q.C

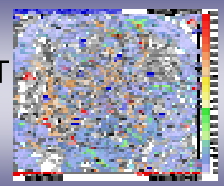
NWP system

TIGGE

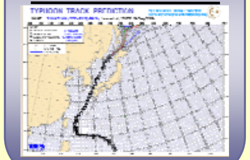
EPS
(T213L40, 16members, 10days,00/12)



GDAPS
(3dVar, FGAT T426/L40, 10days)



Typhoon Model
(30km, 72hrs)

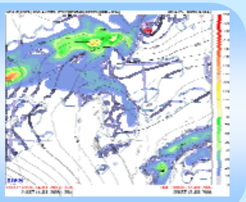


GWAM
(wave model, 1.25º, 10days)

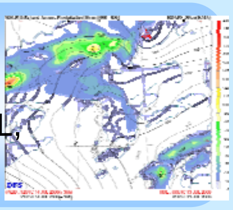
GDLM
(statistical model ,10days)

Digital Forecast
TMN
TMX
PoP
PTY
SKY

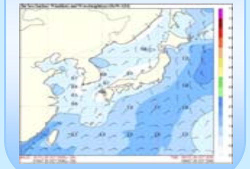
KWRF
(3dVar 10km/30L, 60hrs)



RDAPS
(Downscale, FDDA, 30km/33L, 66hrs)



RWAM
(0.25º,66hrs)



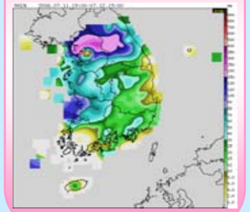
RTSM
(1/12º,48hrs)

Temp, POP
(statistical model)

Digital Forecast
MIN/MAX T
PoP
3Hr T
RH
Wave Height
Wind S/D
Prep. Typ.
Sky Cond.
Rain/Snow

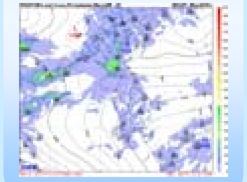
On-Going Project

Storm-Scale Model



- 1~5Km grid model
  Radar assimilation
  Intensify model physics

RDAPS
(3dVar,1day 10km/33L)



KWAM
(1/12º, 66hrs)

KLAPS
(15/5km, 18hrs)

RDAPS
(Downscale, 5km/33L, 1day)

EPS (Ensemble Prediction System)

	GBEPS 1.1.1 ~ GBEPS 1.2.1	GBEPS 2.1.1 ~ GBEPS 2.3.1	GBEPS 3.3.1
Operation period	2001.3.1 ~	2003.11.1 ~	From 2006.7.
Data assimilation	2dOI → 3dOI	3dOI → 3dVar	3dVar
Model	GDAPS T106L21	GDAPS T106L30	GDAPS T213L40
Vertical resolution	21 levels	30 levels	40 levels
Perturbation method	Breeding	Breeding + Factor Rotation	Breeding + Factor Rotation
Target area (BV)	Global	Northern Hemisphere	Northern Hemisphere
Run per days	1 (12UTC)	1 (12UTC)	2 (00, 12UTC)
Lead time	10 days	8 days	10 days
Ensemble members	16 (16 members + 1 control)		(16+1)*2 members

KMA Digital Forecast

Recent Changes

- Increasing resolution and ensemble size
  - T106L30M16 → T213L40M32
  - once a day (12Z) → twice a day (00Z, 12Z)

- Statistical Post-Processing : Bias Correction
  - Decaying averaging bias estimate (from Bo cui)

- EPS does not produce enough spread
  - Bred vectors seem to have similarity

    → Introduce factor rotation
  - Growth rate of perturbation is small

    → Test stochastic perturbation

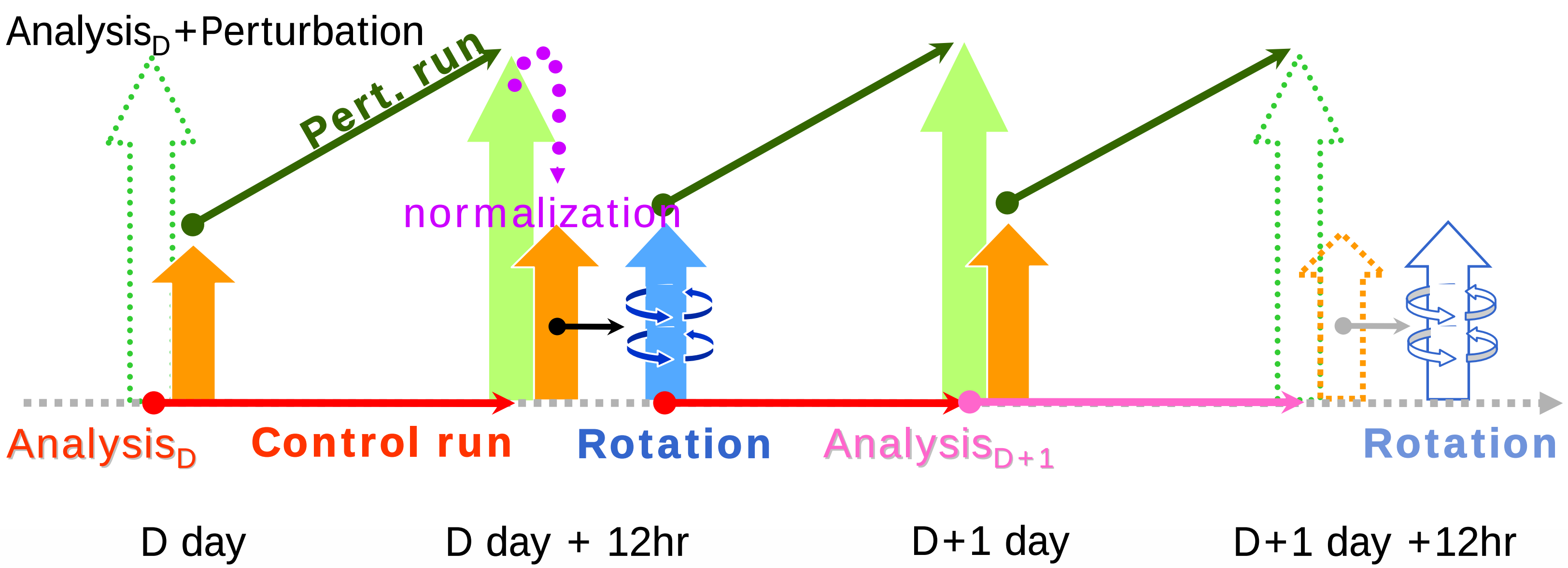
Factor Rotation

- What is the Factor analysis?
  - □ Use relationship among variables
  - □ Find the structure of the relationship and
  - □ Tie to similar variables → Factors

- How to produce perturbation with factors?
  - □ Rotate the factors obtained from factor analysis
  - □ With keeping orthogonal feature among factors
  - ⇒ New perturbations

Breeding+Factor Rotation

Breeding + Rotation



Bias Corr. & Stochastic Pert.

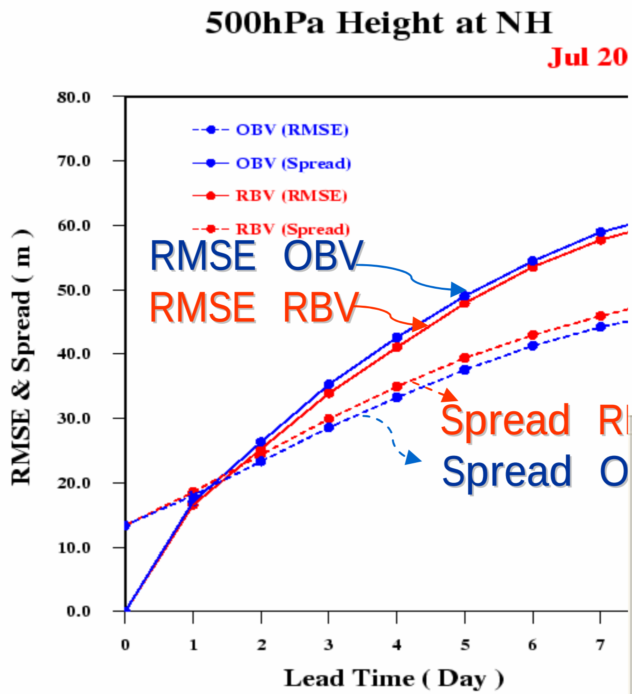
Bias Correction

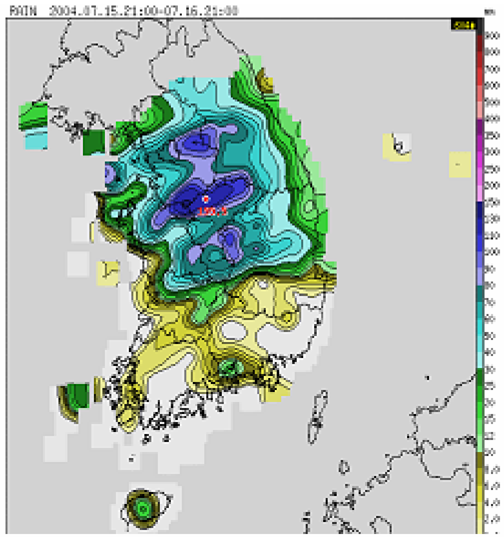
- Motivation: strong +bias over east Asia
- Method: Decaying averaging bias estimation (Bo Cui)

Stochastic Perturbation

- Estimate error of model physics from background error covariance used in 3dVar.
  - random (stochastic) forcing << model error
- Apply stochastic perturbation to tendency every hour

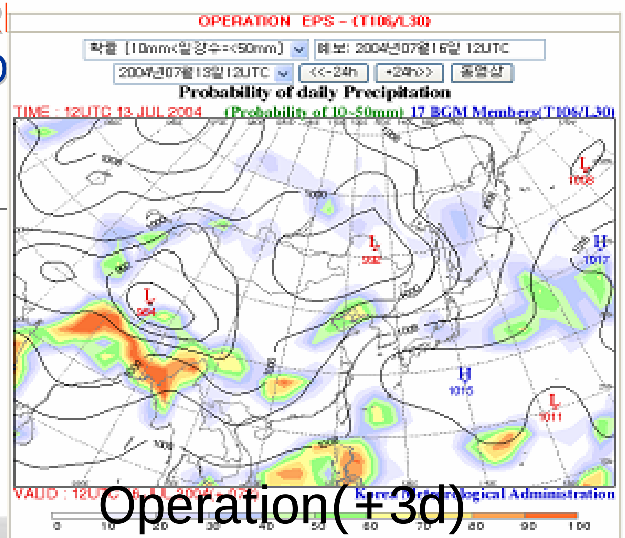
Impact of Factor rotation

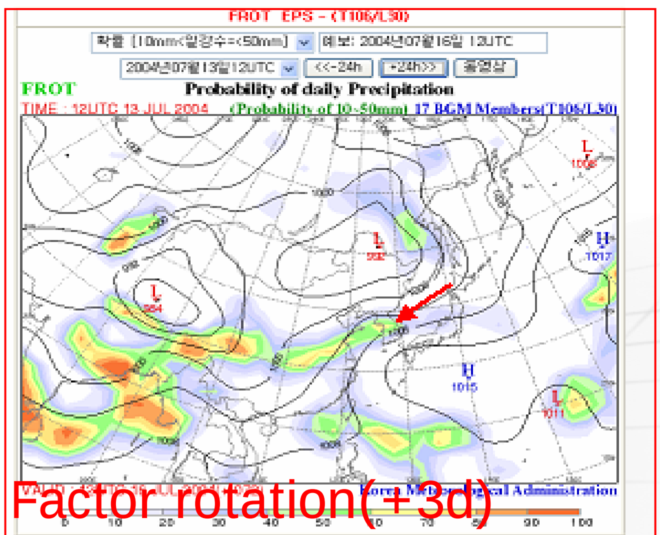




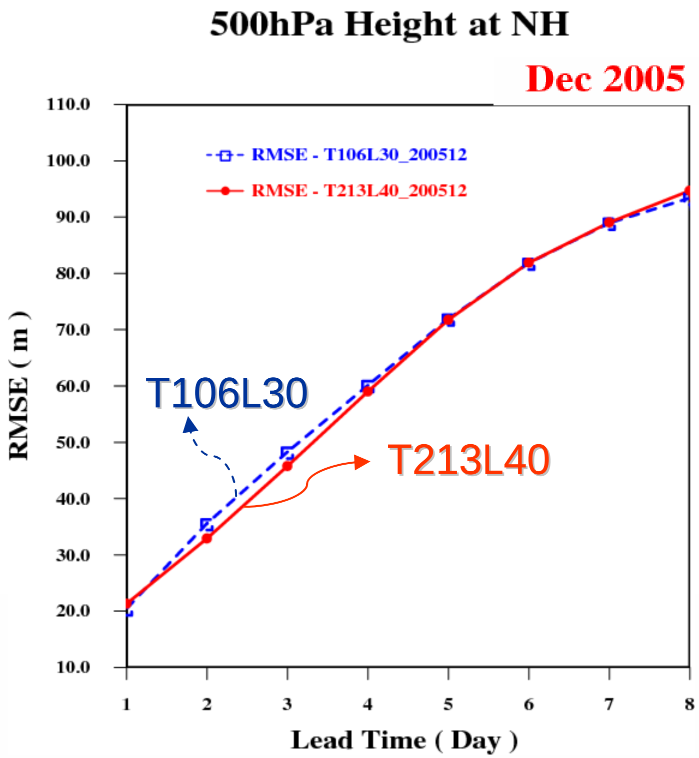
IC: 2004 July 13 12UTC

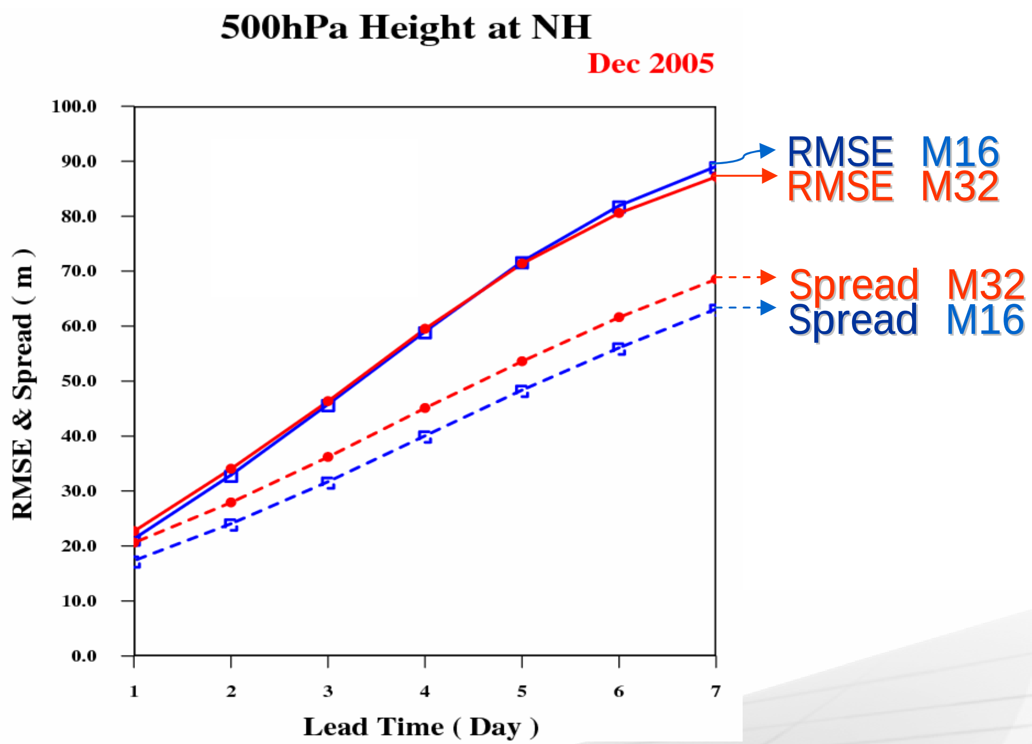
PoP : July 16 12UTC (+3d)
After factor rotation, probability of precipitation successfully reproduces the heavy rainfall as observed.



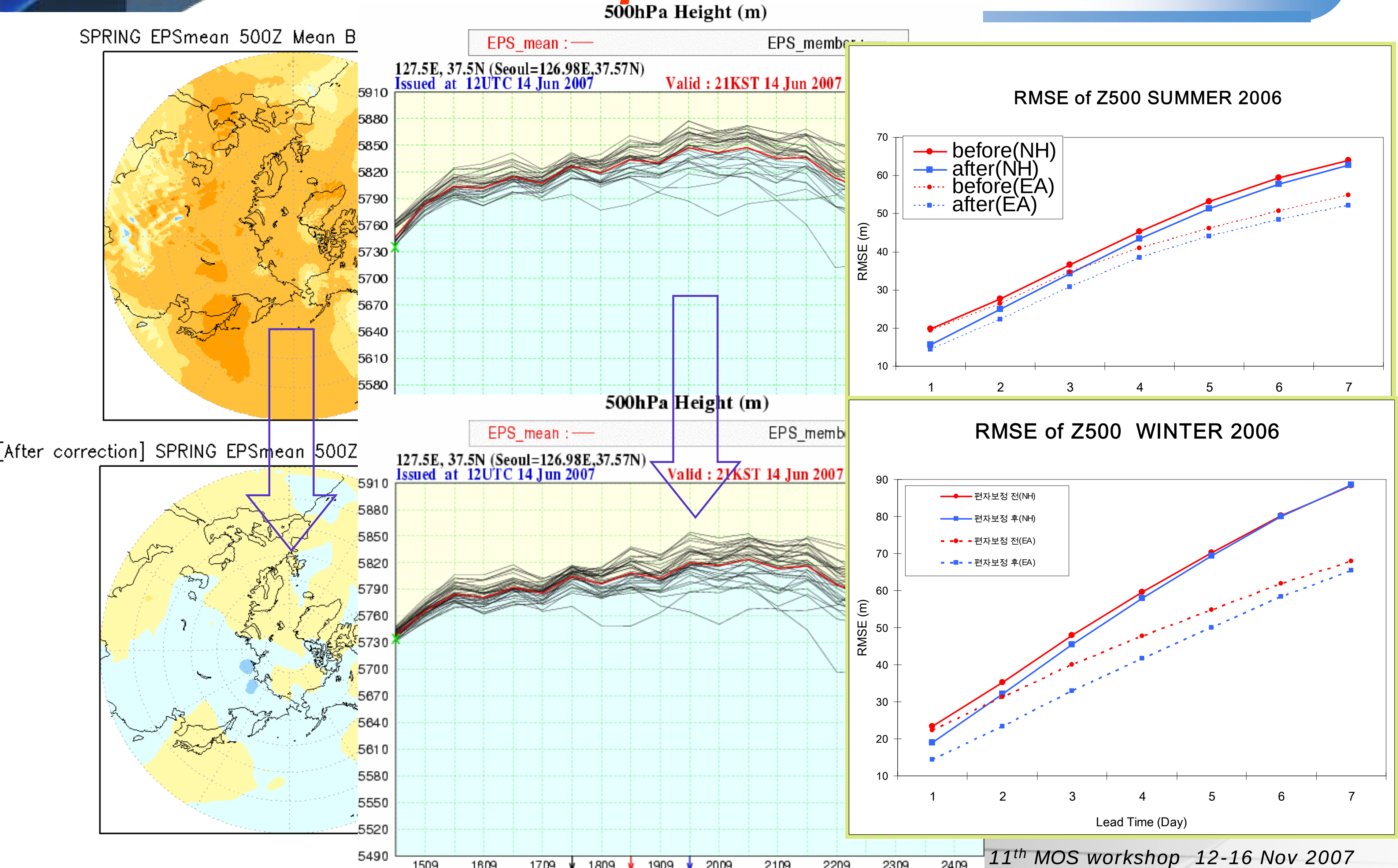


Impact of Resolution & Membership





Impact of Bias Correction



TIGGE: Multi-model test

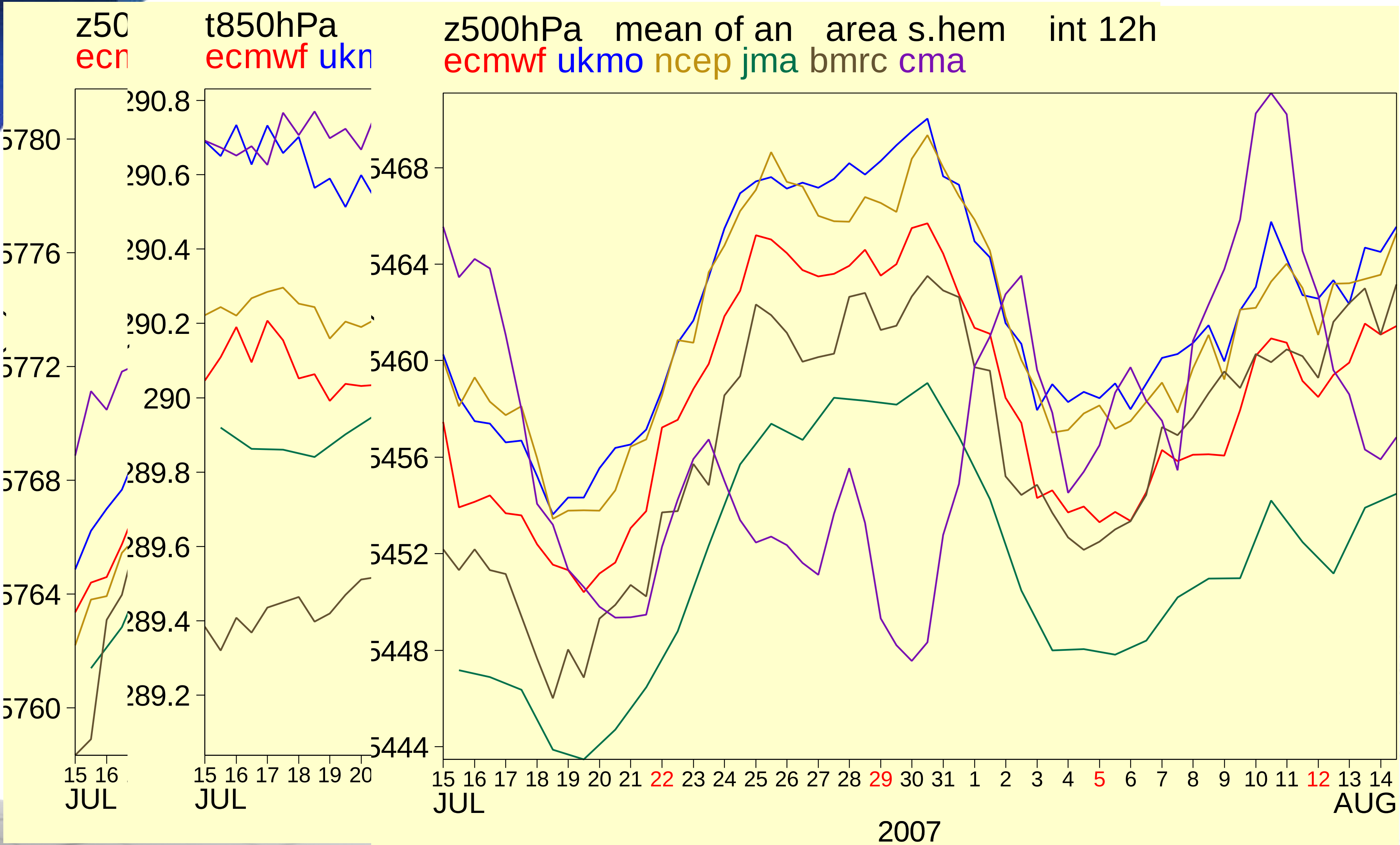
Many Questions/Choices

- Which analysis to use
- How to combine ?
  - Use all the centers/members or only good centers/members?
  - Simple or weighted combine➔ How to determine the weight ?
  - Using calibration? ➔ How to calibrate?

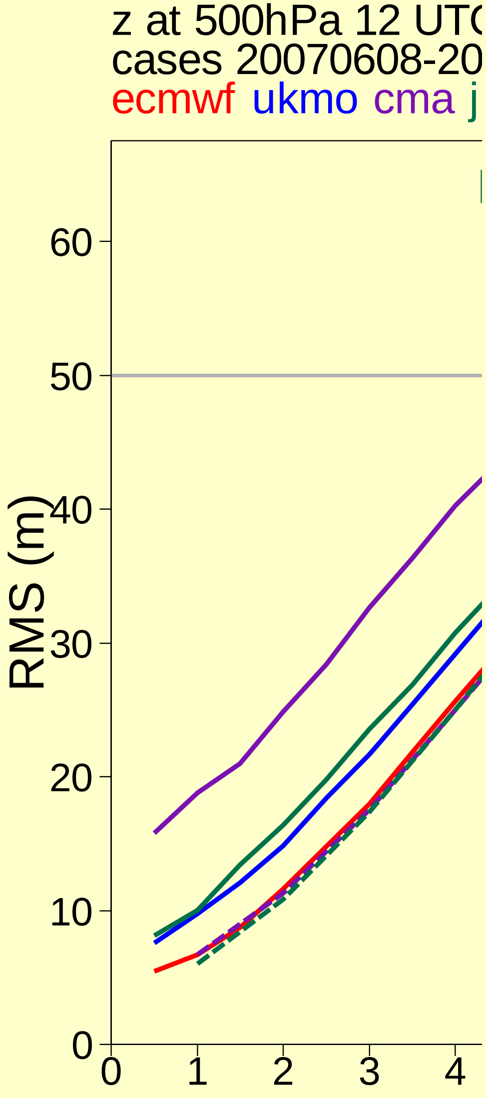
Multi-model ensemble test

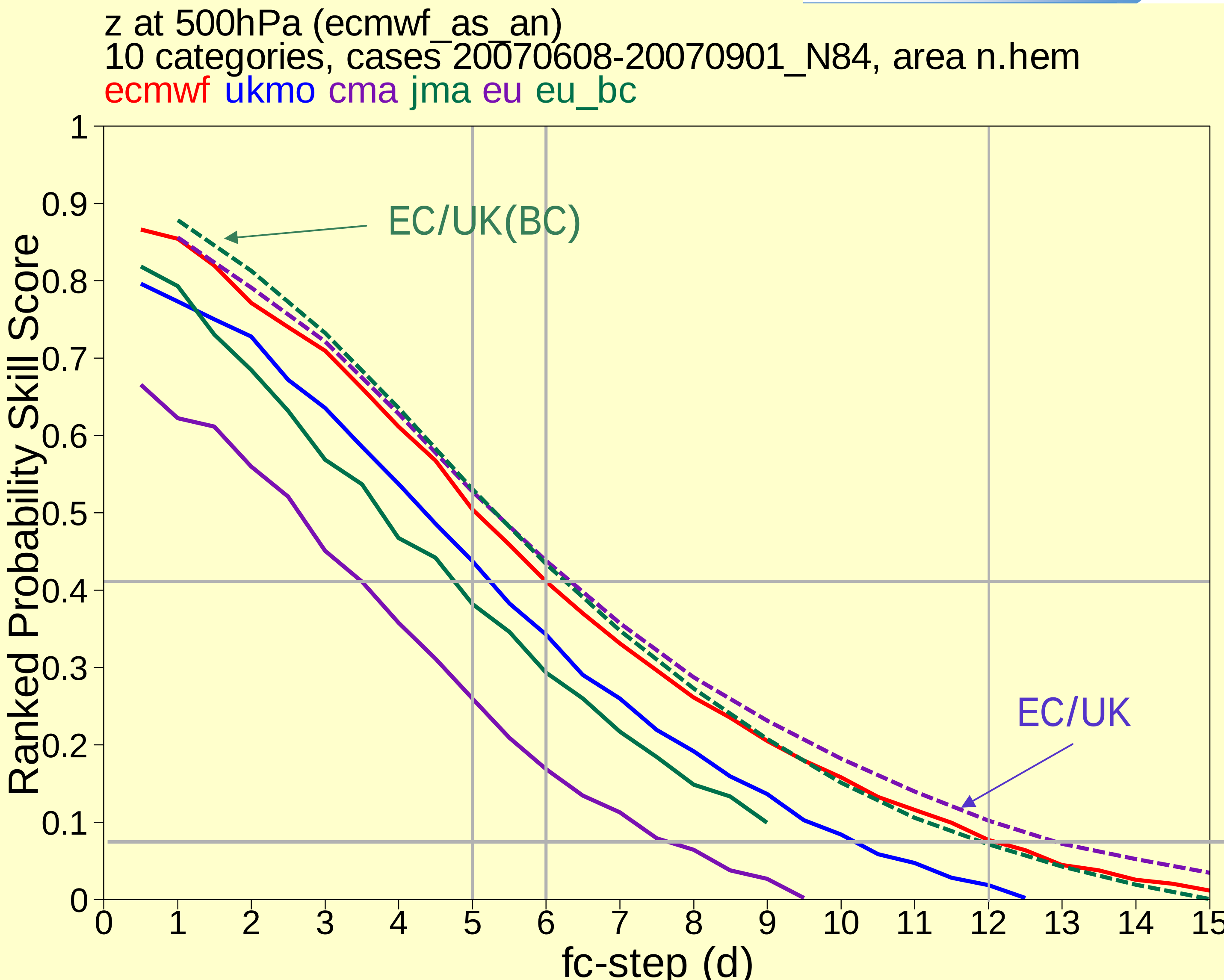
- Combine test period: 8 Jun – 1 Sep (84 cases)
- Centres: ECMWF, UKMO, JMA, CMA
- Method:
  - Simply combine all the members
  - With/without bias-correction (use previous 30 days)
  - Calculate bias for each centres, cf/pf separately

Which an ? (Area mean of an)

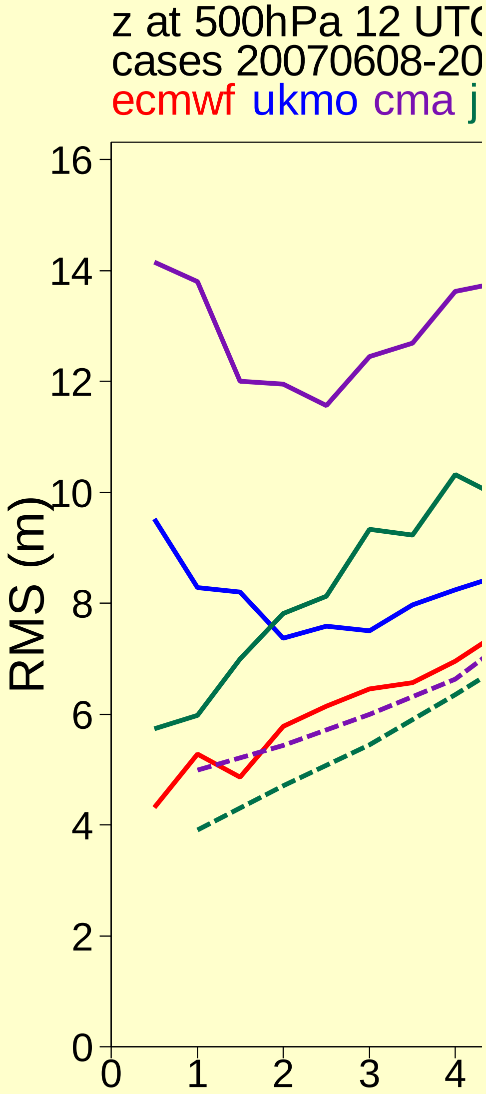


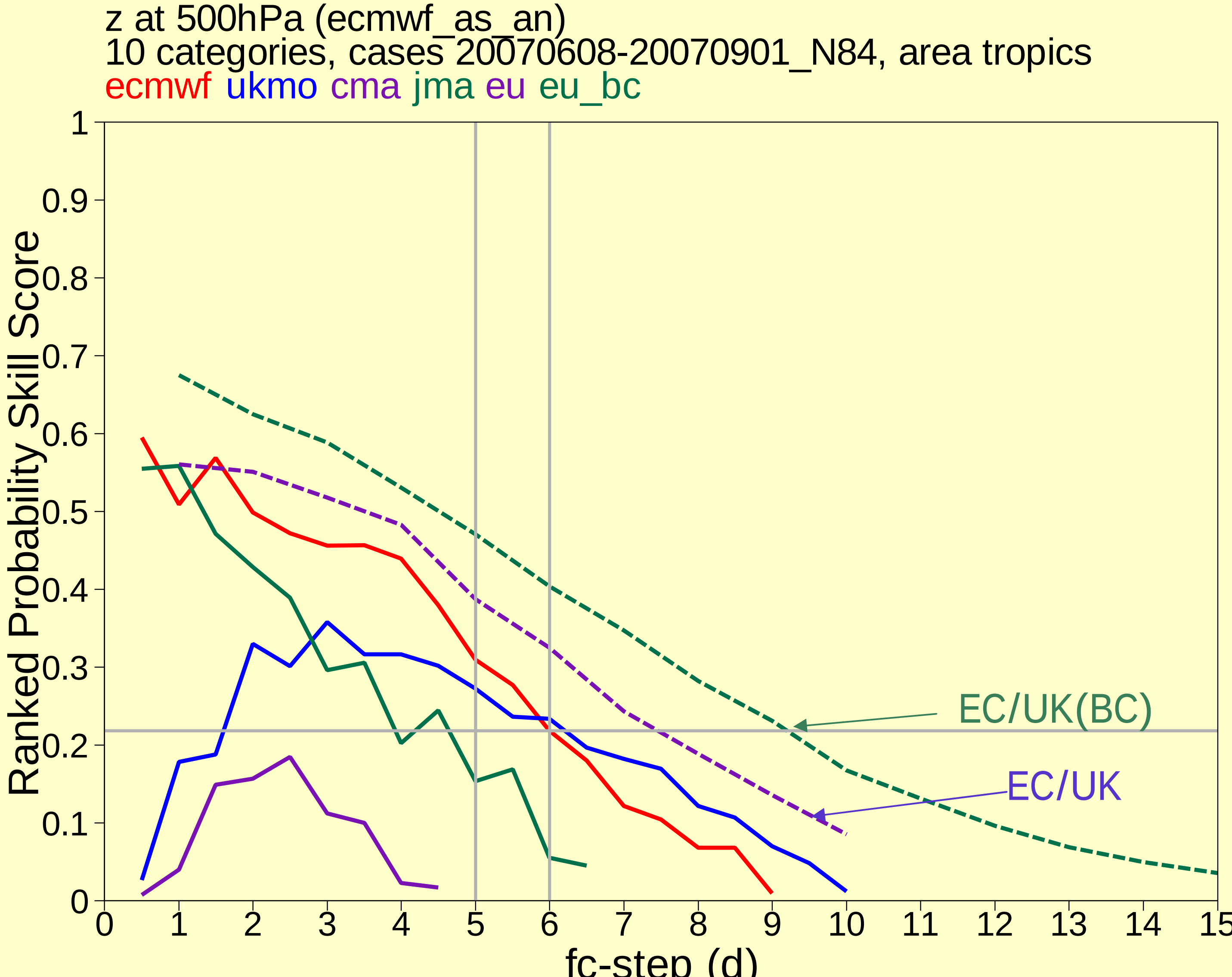
Raw/Cal data ? (RMSE/RPSS : Z500 NH)



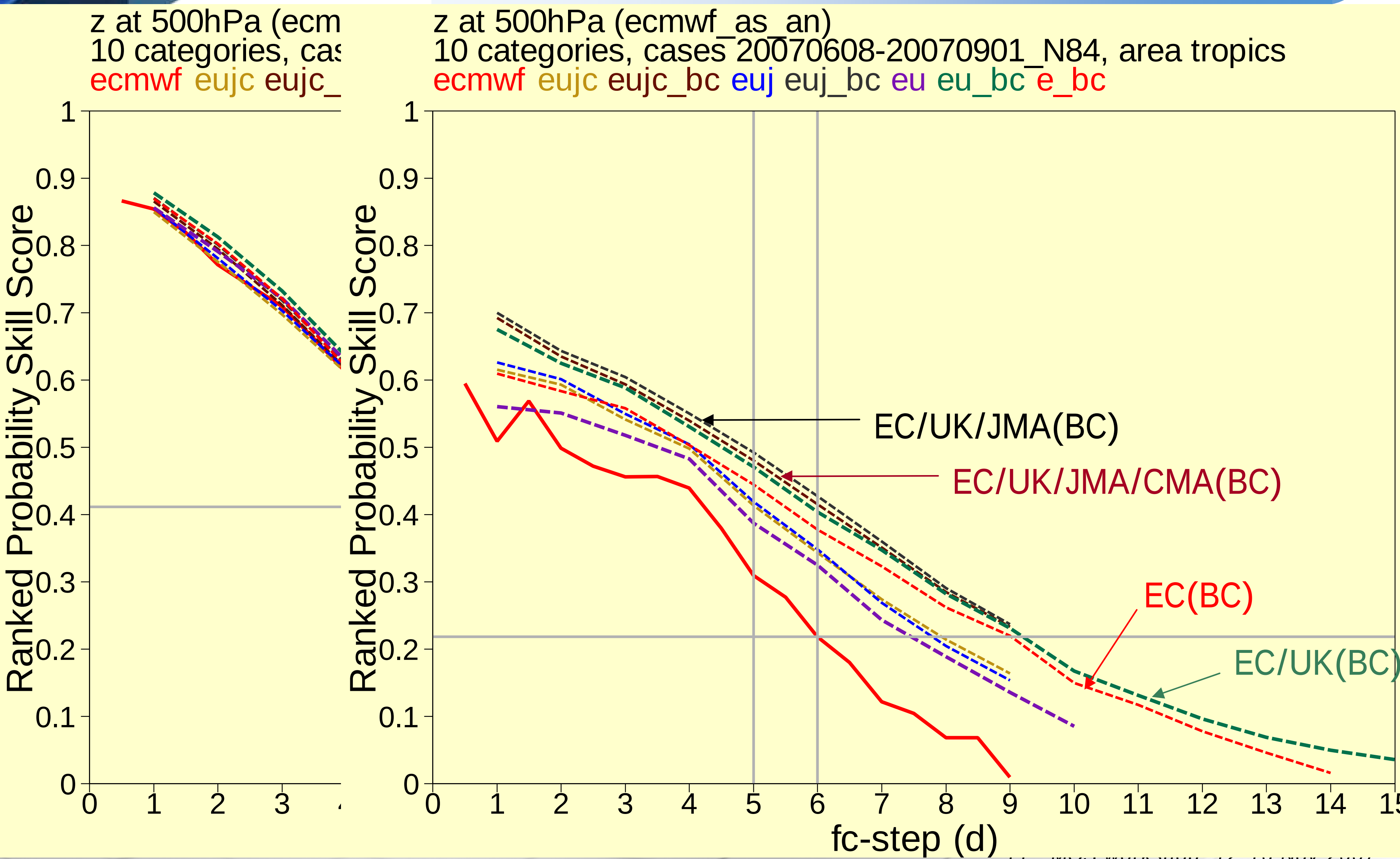


Raw/Cal data ? (RMSE/RPSS : Z500 TR)

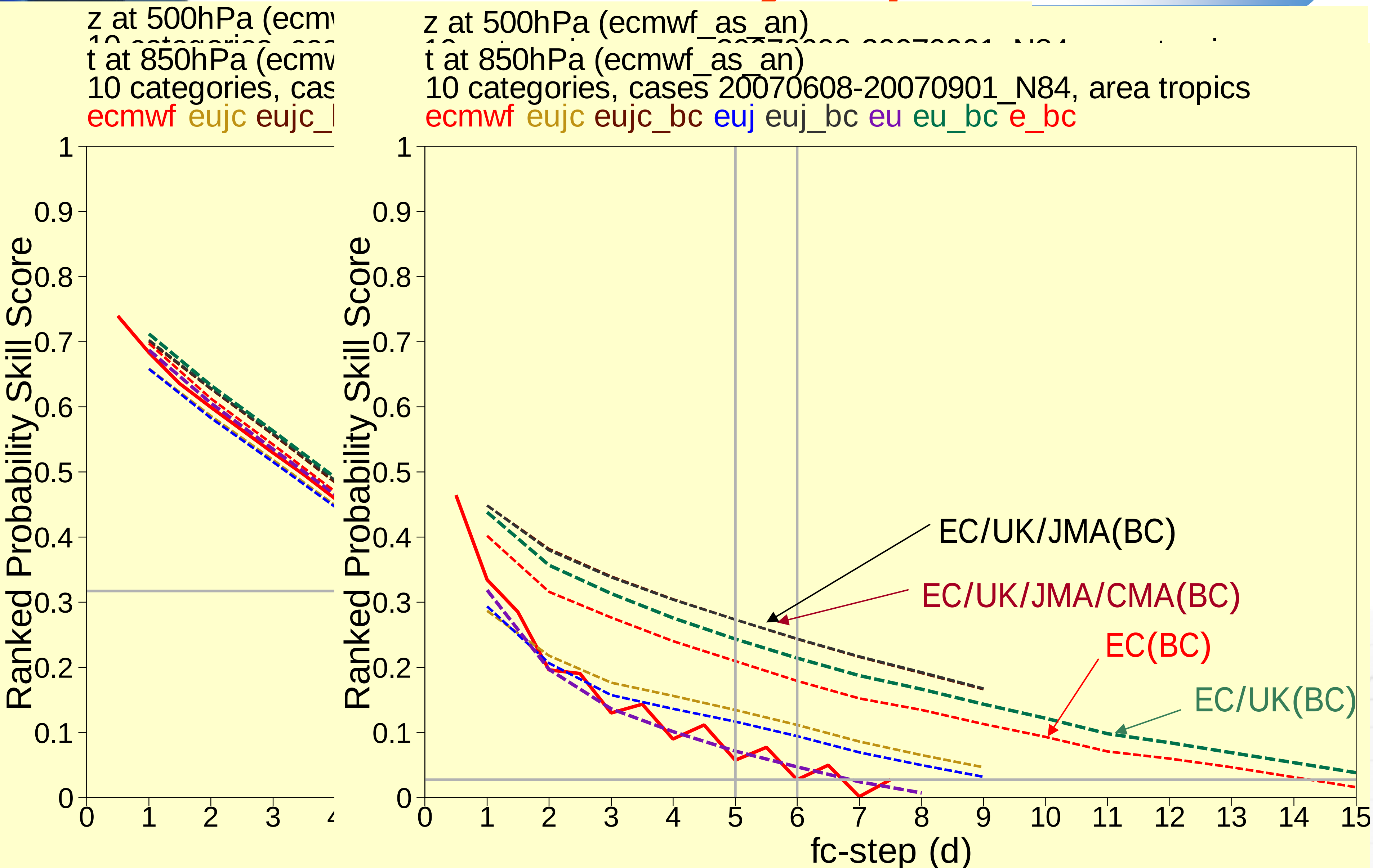




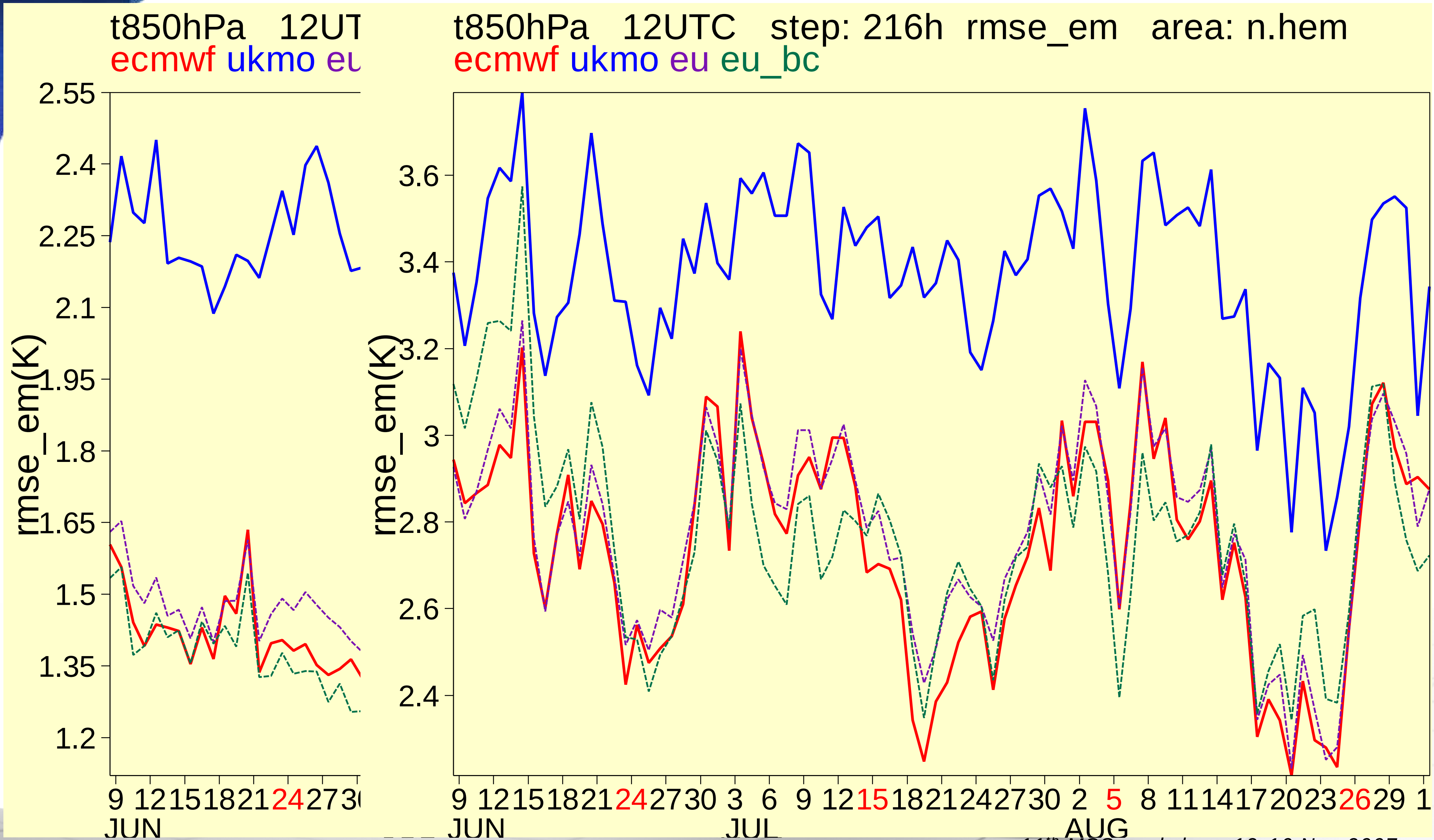
Which centers ? (RPSS – Z500 NH/TR)



Sensitivity to parameters ?



Daily RMSE – t850 +3d/+9d NH



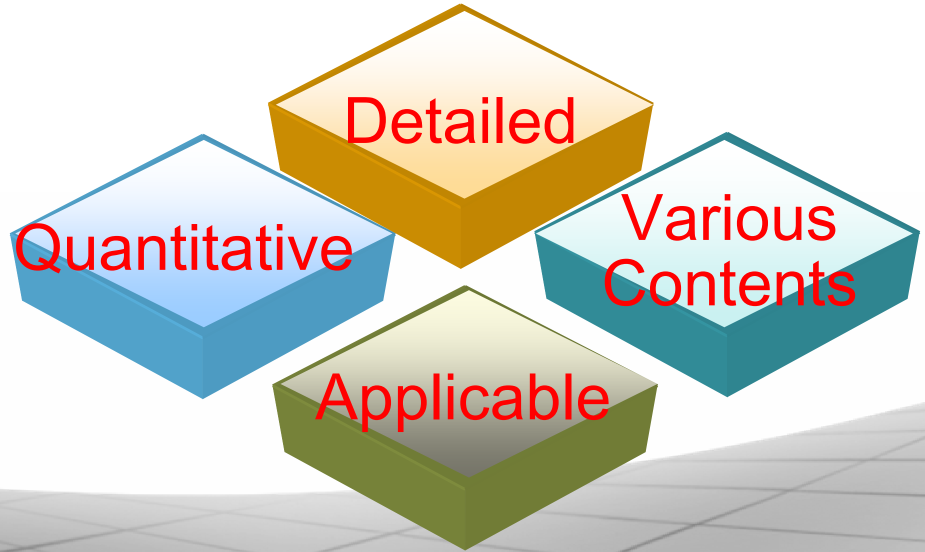
Summary of Preliminary Result

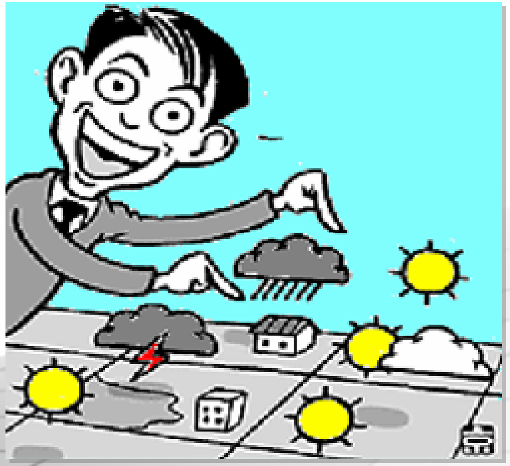
- More gains on probabilistic scores than deterministic scores
- AS, NA, NH: small gains, distinctive gains over tropics (where ecmwf shows under-dispersion)
- Difference btn parameters and areas
- Bc better in early period, but nbc better in the later period of forecast
- Larger benefit of multi-model over strong bias area
- Decision should be made on the bases of areas, parameters of interest
- Lower level parameter (T2m, precipitation) ?
- Advanced calibration ?
- Optimum weight for each centers?

Digital Forecast : Motivation

- Strong demand for detailed, quantitative meteorological services
- Public does not want weather at station, but at their house
- The use of meteorological data is too difficult
  - Private sector requires easy to handle data to reproduce new application information
  - Nwp output is used by only very limited area

← one of important barrier to develop application information





KMA Digital Forecast

Current Forecast

Change

Digital Forecast

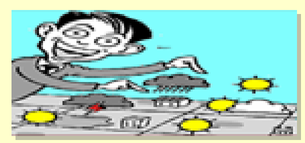
Goal of Digital Forecast

Detailed

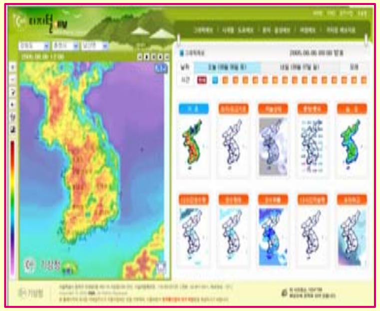
Quantitative

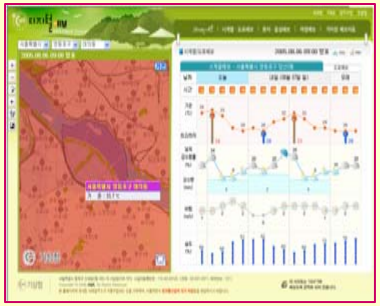
Various Contents

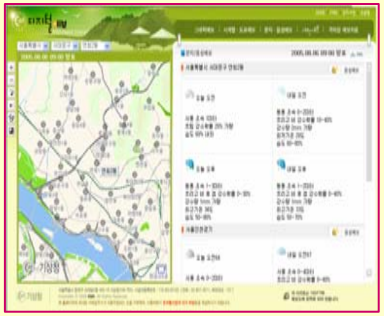
Applicable



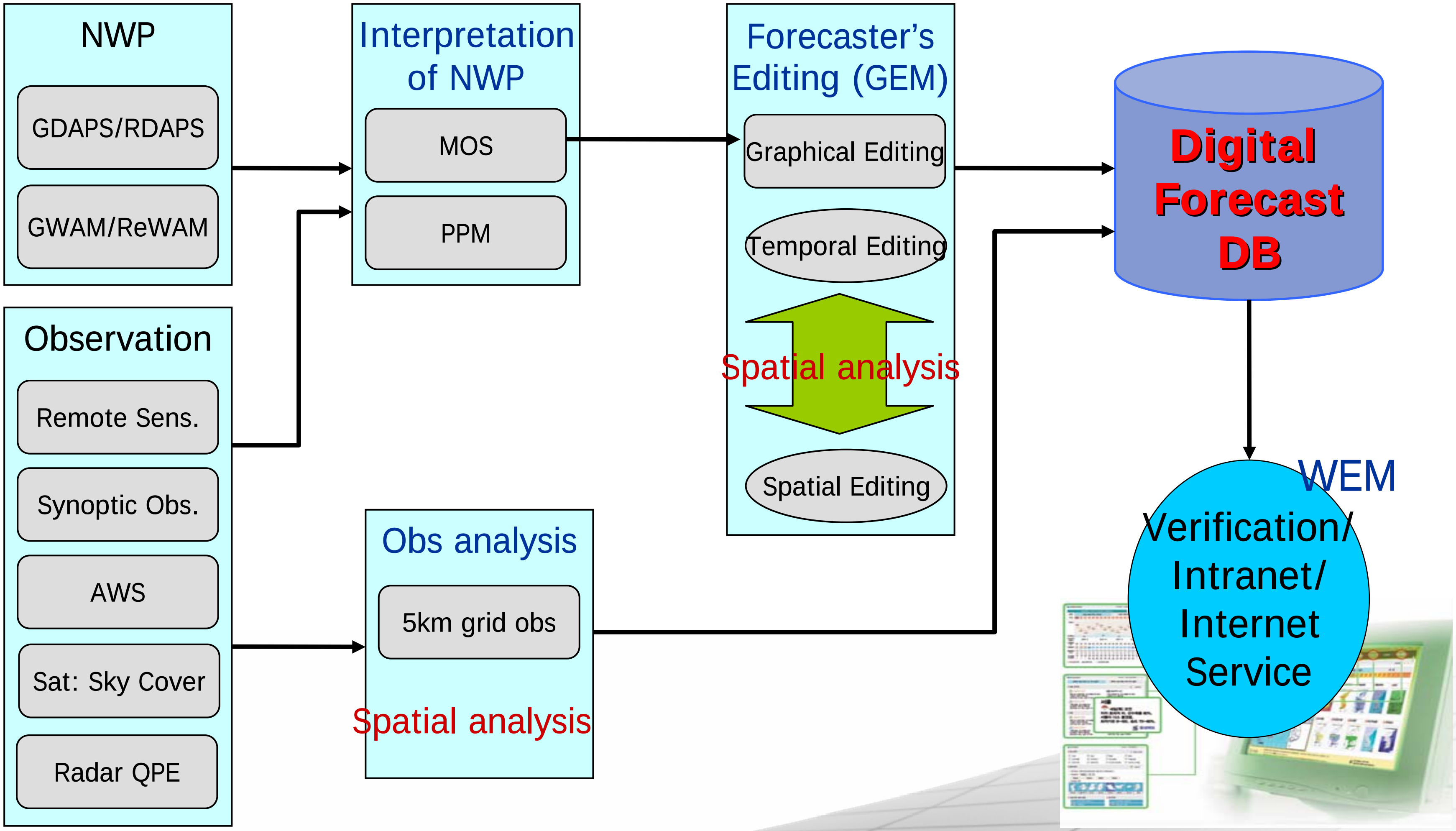
When, Where, How Much, Computer Friendly form







Conceptual Structure

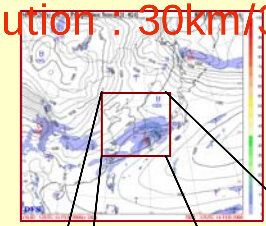


Status of Digital Forecast

Digital Forecast range	Short range	Medium range
NWP Model	RDAPS	GDAPS
Forecast length/interval	48hours/3hours	10.5day/12hours
Resolution	5km	30km
Frequency (per day)	8	2
Forecast parameter	12	5
Grid/element transform module	11	5
Statistical analysis module (MOS)	MOS 8(/9)	developing
Spatial analysis module (2d-OI)	apply, improvement	not apply
Graphical editing module (GEM)	semi-operation, improvement	
Web service module (WEM)	semi-operation, improvement	
Verification system	operation, improvement	

Interpretation of Model Output : shortDFS

RDAPS:
Forecast 66hour
Resolution : 30km/3hour



T, WIND, HUMIDITY
PRESSURE, RAIN,

MOS

$$Y_t = F_t\left(\frac{\tilde{X}_{00h} + \tilde{X}_{03h} + \tilde{X}_{06h}}{3}\right) + F_{climate}(T_t) + T_{obs}$$

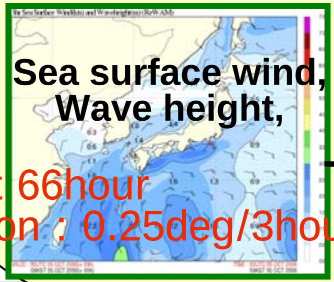
MOS models
at 103 stations

3-hour/Max/Min Temp.,
Probability of Precip., RH,
Wind,
single-station eq.

Precip.

PPM

Sky cover, Precip. Type
Snow-depth
Generalized-operator eq.



Sea surface wind,
Wave height,

ReWAM
Forecast 66hour
Resolution : 0.25deg/3hourly

Effective wave height

- Combine NWP Model and statistical methods
- Generate 5 km-grid forecast, Predict every 3 hour up to 48 hours

MOS Tool

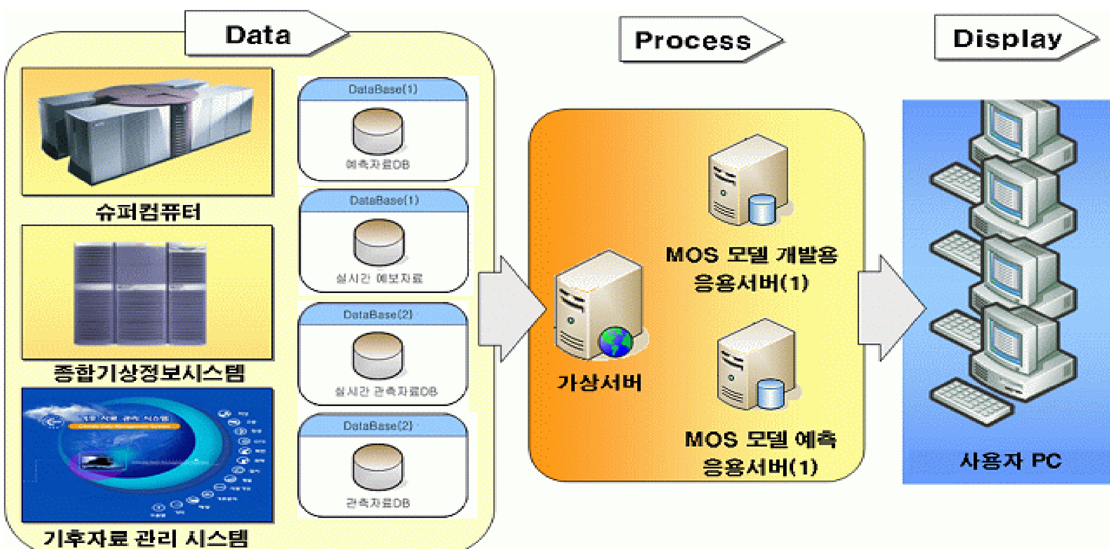
- Need tool that mange and produce MOS eq. efficiently according to the changes of NWP models
- Using this tool, make the indicator for MOS model

o Speed up for developing and improving MOS eq.

o Standardization of MOS model

o Total system of development/verification/management of MOS

→ efficiency, accuracy, convenience

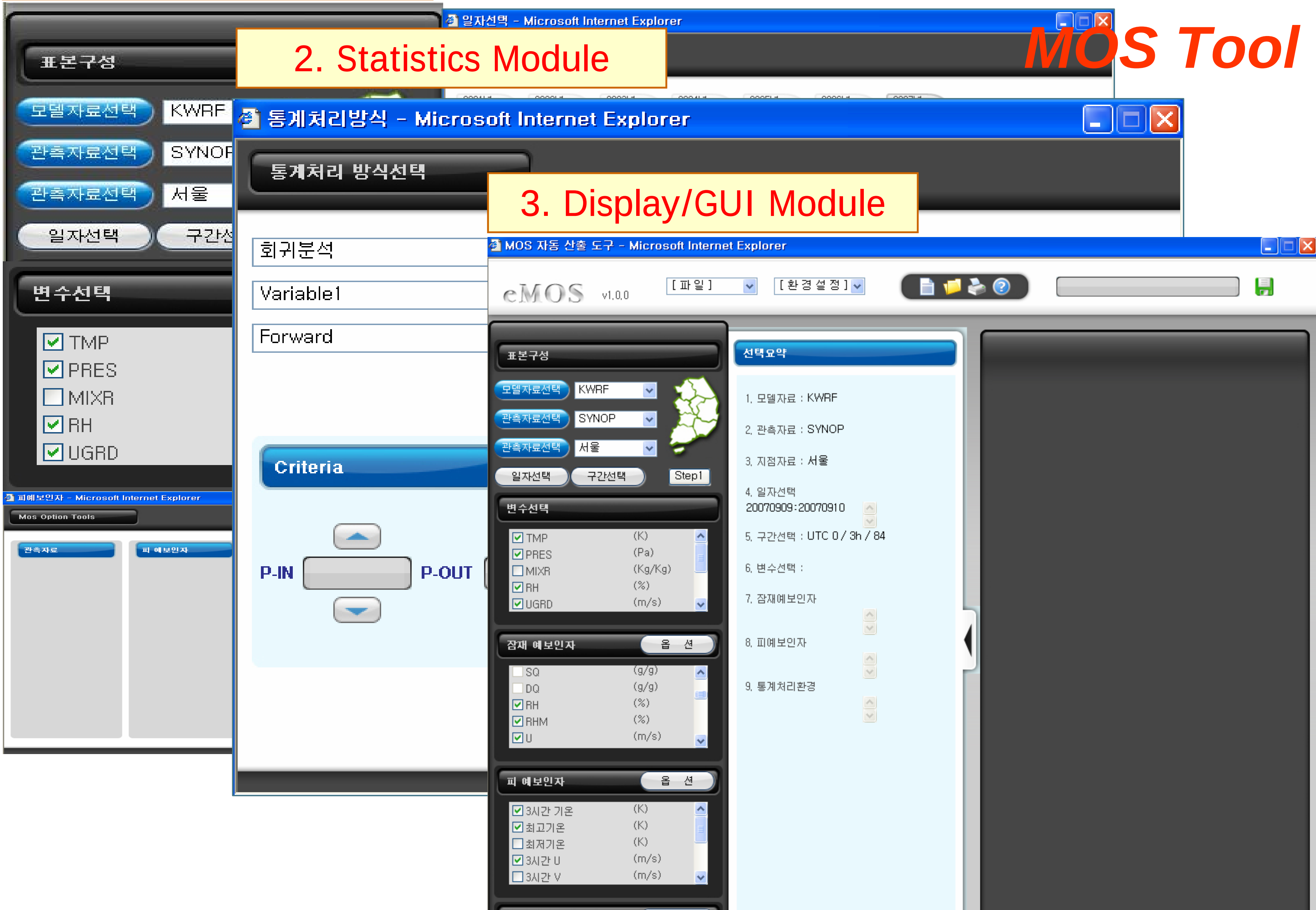


MOS Tool

1. Sampling Module

2. Statistics Module

3. Display/GUI Module

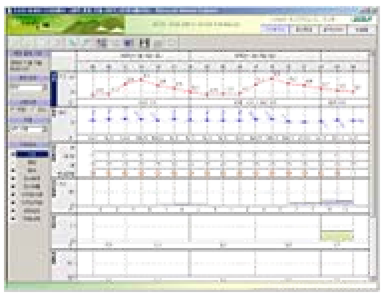


Forecaster's Editing (GEM)

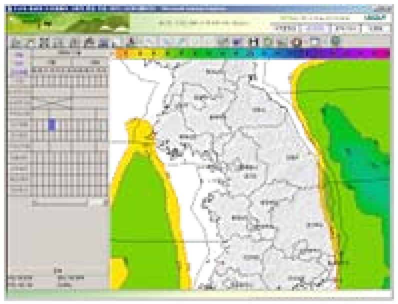
Weather Station

Regional Met. Office

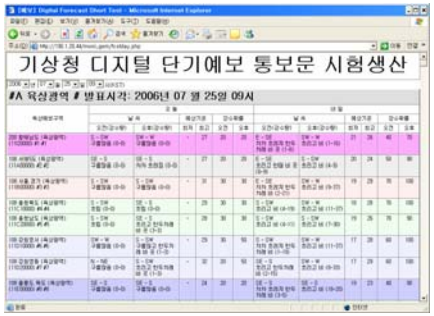
KMA Headquarter



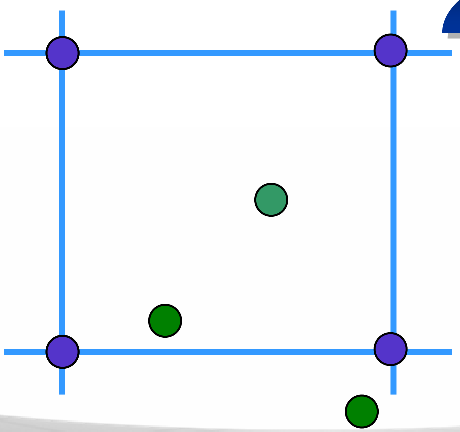
Time Series Editing



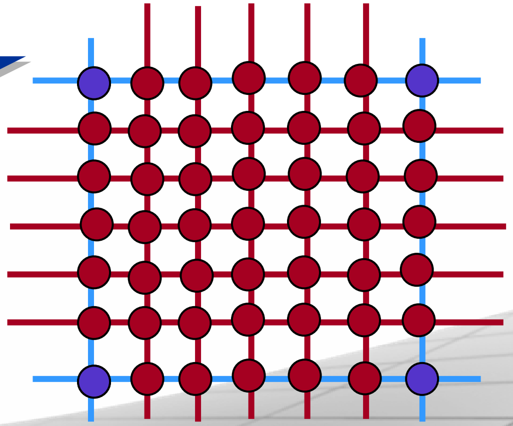
Spatial Editing



Issue Forecast

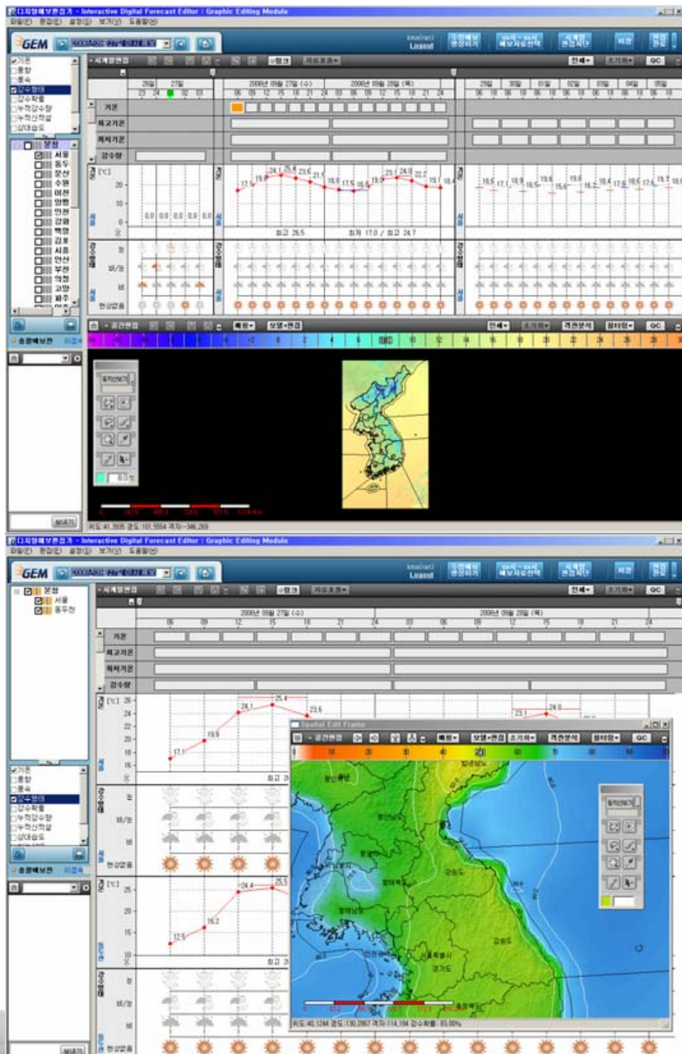


Objective Analysis

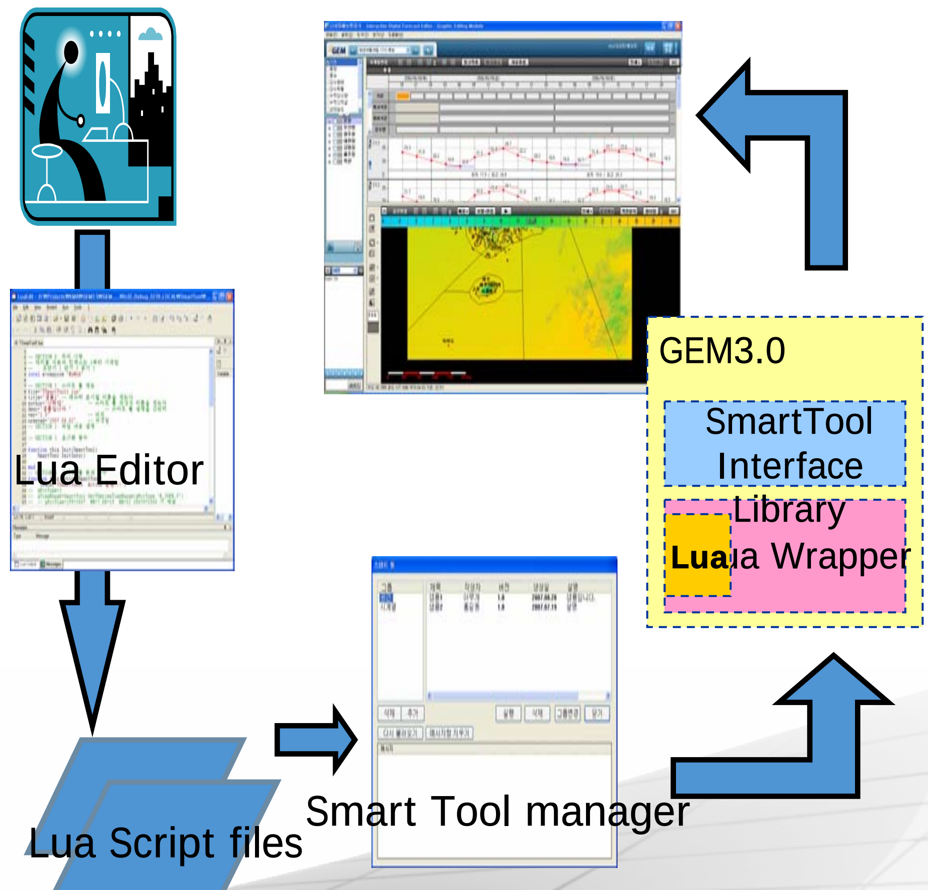


GEM

GEM Editing Window

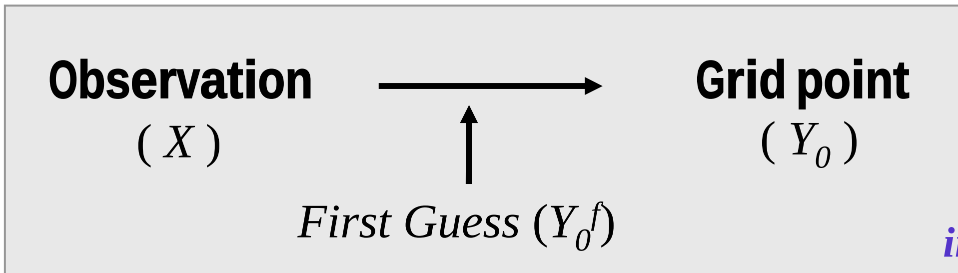


Apply Smart Tool



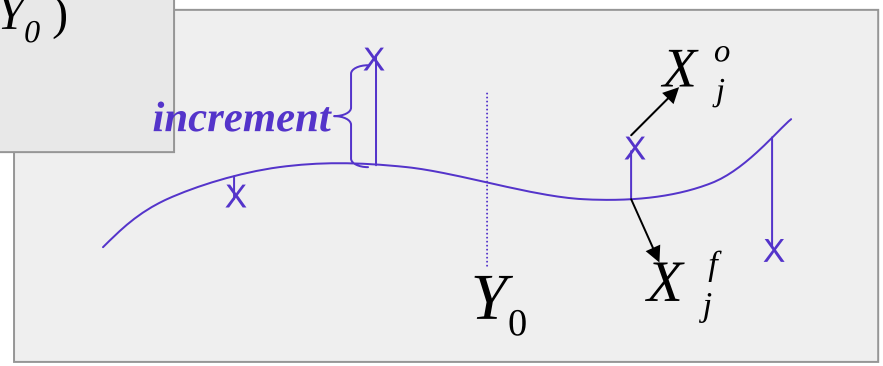
Spatial analysis module (2d-OI)

2 dimensional-Optimal Interpolation



determine weight that minimize

$(Y_0 - X_0)$



$$Y_0 = \sum_{j=1}^{m} hj(X_j^o - X_j^f) + Y_0^f$$

$$= \sum (weight \times increment) + First \quad guess$$

Weight determine the reliability of analysis (Y_0)

Weight in 2d-OI

Weight (h) : 2dOI

$$\sum_{j=1}^{7}(\mu_{ij}^{P} + \mu_{ij}^{0}\lambda_i\lambda_j)H_j = \mu_{ig}^{P} \qquad \lambda = \frac{\sigma_o}{\sigma_b}$$

i,j : station g: digital grid

μ_{ij}^{P} : BE covariance μ_{ij}^{o}: OE covariance

μ_{ig}^{P} : BE covariance between grid & station

assume OE covariance ~ 0

(Forecaster editing ~ true)

Weight (h): DFS 2dOI

$$\sum_{j=1}^{N}(\mu_{ij}^{P})H_j = \mu_{ig}^{P}$$

$$\begin{pmatrix} h_1 \\ h_2 \\ \cdot \\ \cdot \\ \cdot \\ h_m \end{pmatrix} = \begin{pmatrix} \sigma_{11}, \sigma_{12}, \cdots, \sigma_{1m} \\ \sigma_{21}, \sigma_{22}, \cdots, \cdot \\ \cdot \quad \cdot \quad \cdot \\ \cdot \quad \cdot \quad \cdot \\ \cdot \quad \cdot \quad \cdot \\ \sigma_{m1}, \cdots\cdots, \sigma_{mm} \end{pmatrix}^{-1} \begin{pmatrix} \sigma_{01} \\ \sigma_{02} \\ \cdot \\ \cdot \\ \cdot \\ \sigma_{0m} \end{pmatrix}$$

Weight co-variance of obs to obs (fixed) co-variance of obs to grid (alter)

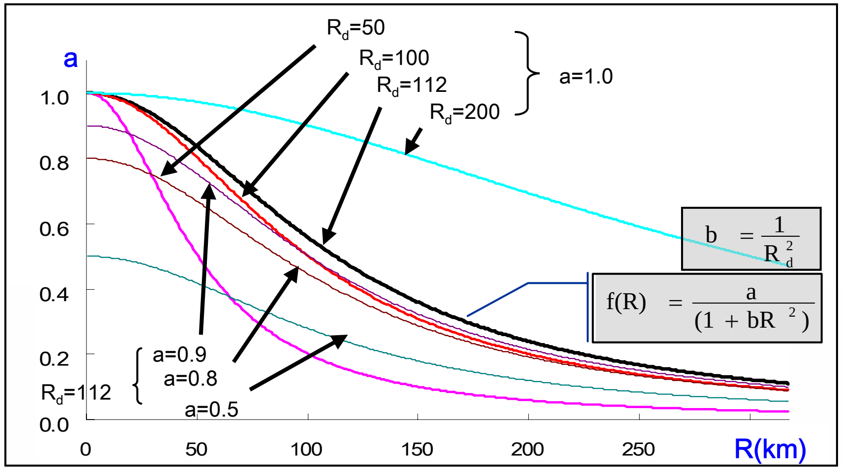
Correlation between obs stations

OLD

$$\mu_{ij}^{P} = \frac{a}{1 + br^{2}}$$

r : distance a : error ratio (fixed, 1)

b : error cov wrt r (fixed, 1/1600)



Lorentz's type function fitting

NEW

Use BE cov between stations

$$\rho_{ij} = \frac{\sigma_{ij}}{\sqrt{\sigma_{ii}\sigma_{jj}}} \qquad \sigma_{ij} \text{ : covariance}$$

- Construct full matrix
  - isotropic ⇒ anisotropic
  - homogeneous⇒ inhomogeneous

$$\mu_{ij}^{P} = \begin{pmatrix} \rho_{11}, \rho_{12}, \cdots, \rho_{1m} \\ \rho_{21}, \rho_{22}, \cdots, \cdot \\ \cdot \quad \cdot \quad \quad \cdot \\ \cdot \quad \quad \cdot \quad \cdot \\ \cdot \quad \quad \quad \cdot \quad \cdot \\ \rho_{m1}, \cdots\cdots, \rho_{mm} \end{pmatrix} \quad (75\text{x}75)$$

Correlation between grid and station

OLD

$$\mu_{ig}^{P} = \frac{a}{1+br^{2}}$$

r : distance a : error ratio (fixed, 1)

b : error cov wrt r (fixed, 1/1600)

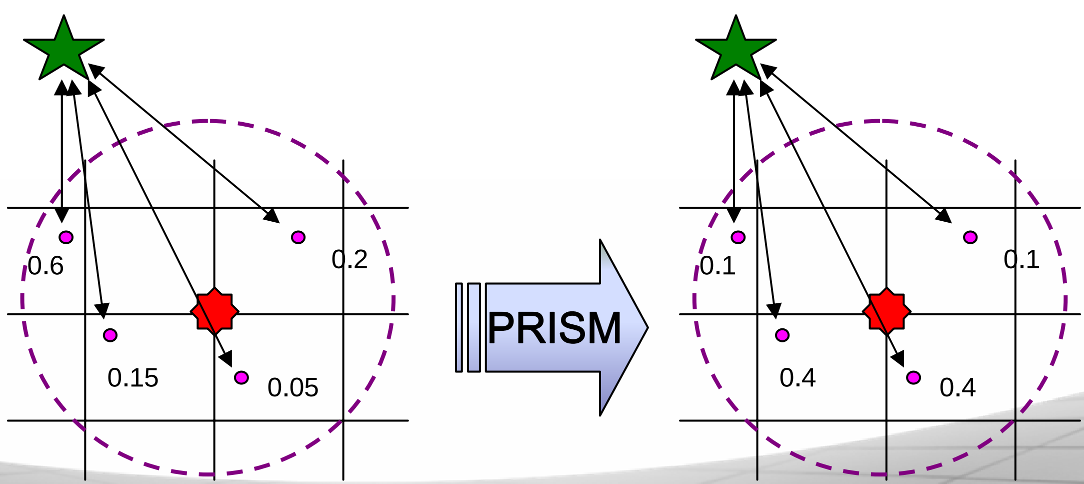
NEW

assume: correlation of spatial error
~ correlation of geographic information

1.Use BEC between stations

2.Use BEC between station and AWS

3. Use grid GIS (PRISM :weight wrt distance, altitude, slope, ,)



$$\mu_{ig}^{P} = \frac{\sum_{k=1}^{K} \omega_{gk} \rho_{ki}^{P}}{\sum_{k=1}^{K} \omega_{gk}}$$

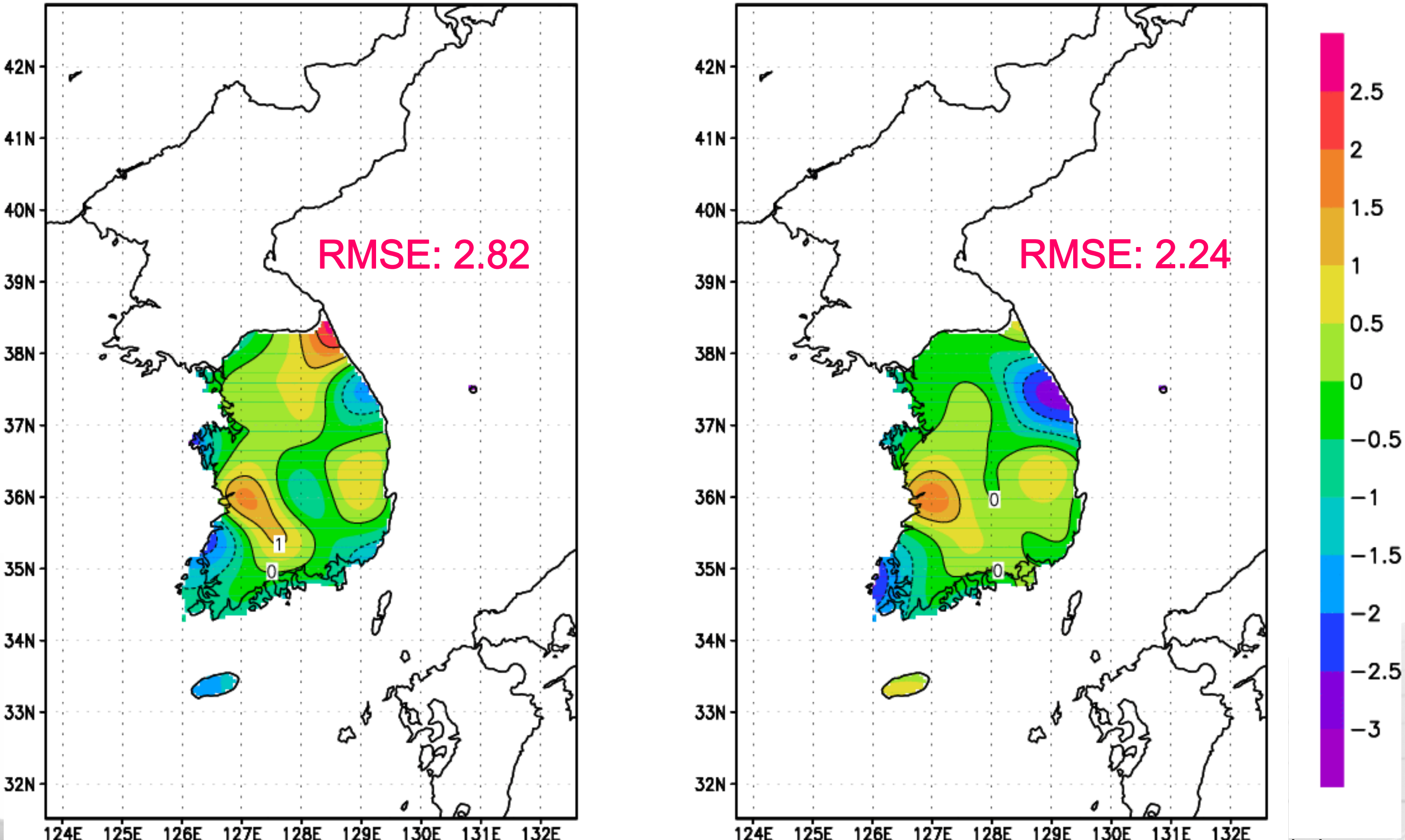
ρ_{ik}^{P} : BEC of neighboring station

ω_{gk}^{P} : weight of neighboring stations

Impact: ERROR

Temperature (06UTC 5 OCT 2007)

OLD - OBS | NEW - OBS



KMA Digital Forecast

WEB SERVICE MODULE (WEM)

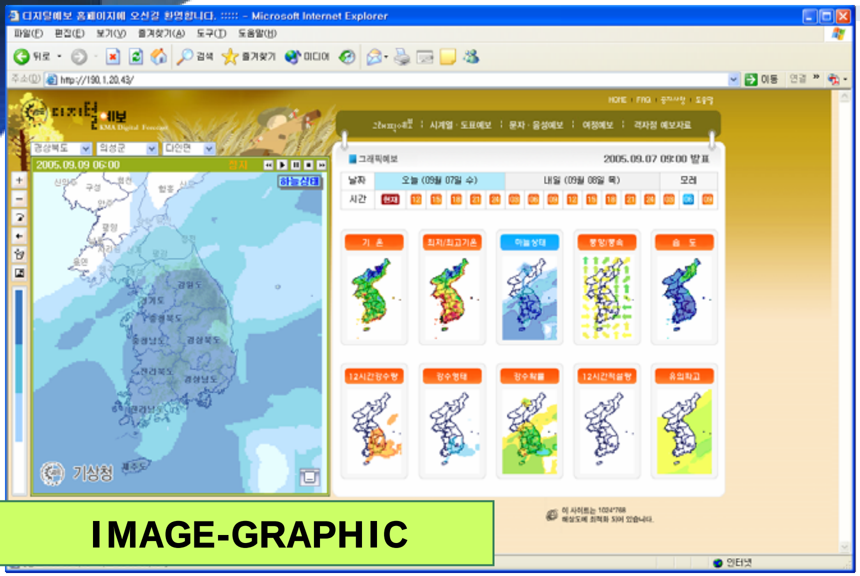
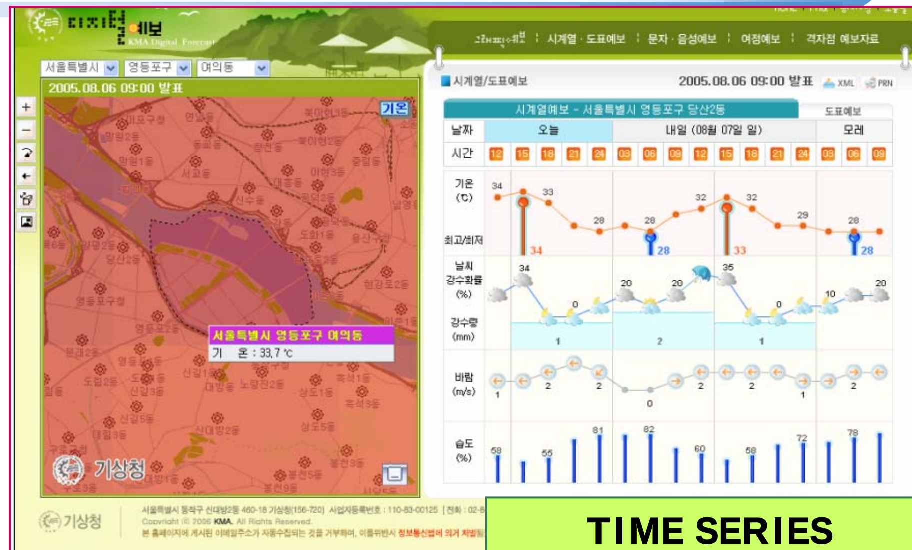
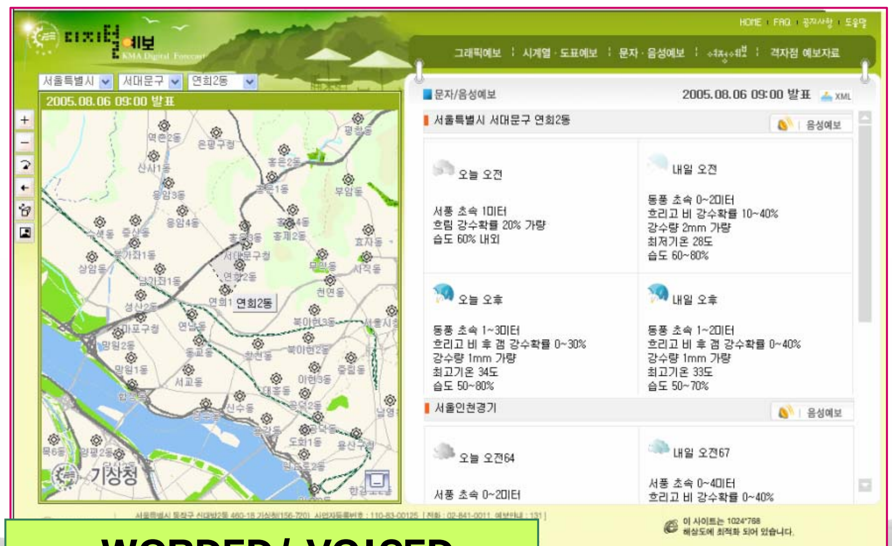


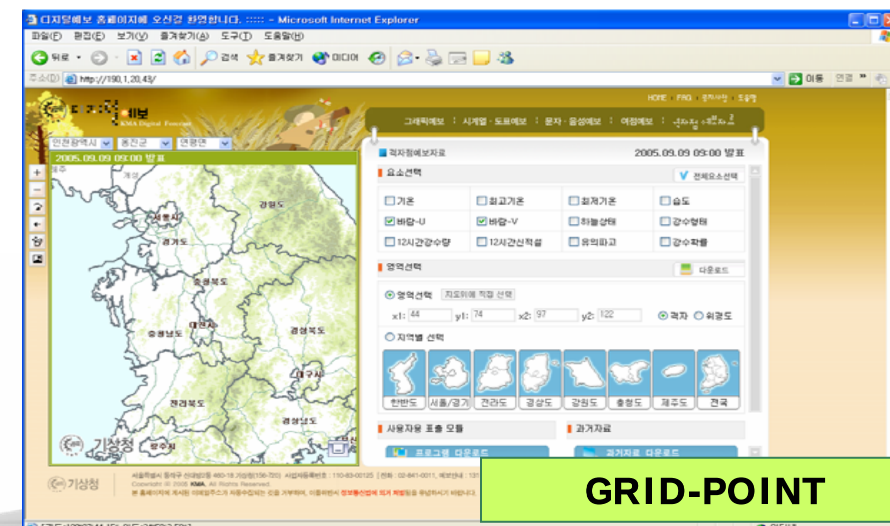
IMAGE-GRAPHIC



TIME SERIES



WORDED / VOICED



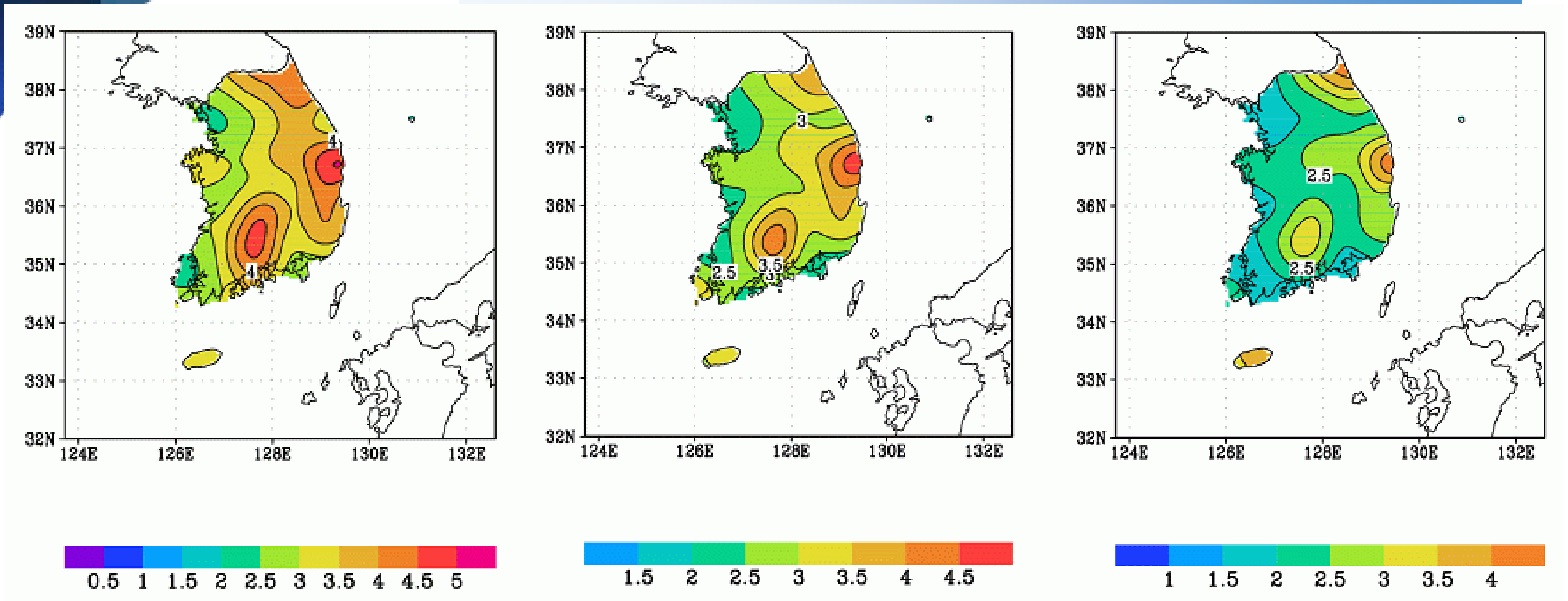
GRID-POINT

Accuracy : Short range DFS

DEC 2005 - SEP 2006

Verification items	FCST	MOS	NWP	IMPROVEMENT % (NWP vs.FCST)	Remarks
RMSE TMP(C)	2.1	2.0	2.7	22.2	
RMSE TMAX(C)	2.4	2.4	2.9	17.2	
RMSE TMIN(C)	2.4	2.4	3.0	20.0	
RMSE PPTN(mm)	10.5	-	11.7	11.1	
ACC PPTN IDF	0.86	-	0.87	1.5	
RMSE WS (m/s)	2.8	-	2.9	3.4	
RF WD (deg)	0.45	-	0.44	2.27	
ACC2 SKY	0.77	-	0.74	4.05	Comparison with PPM
RMSE RH (%)	14.0	12.4	18.0	22.2	MOS since March 2006

Distribution of RMSE

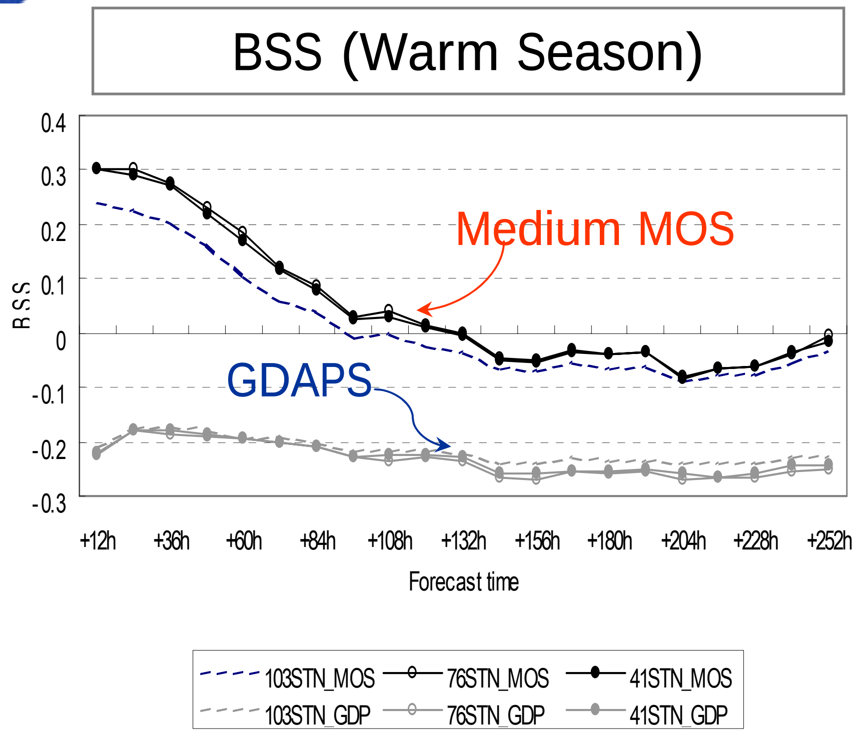


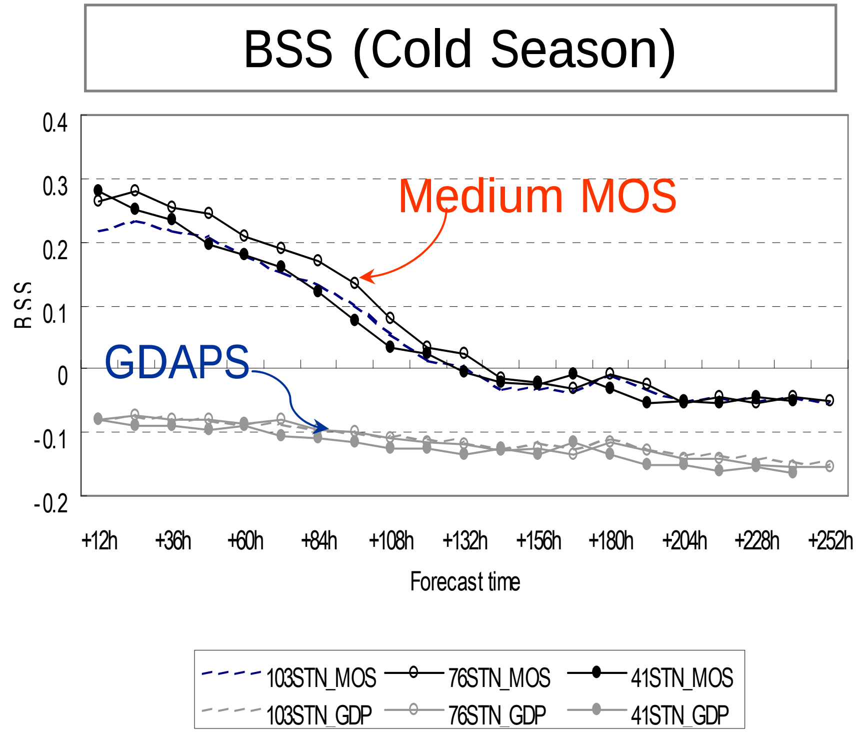
WINTER SPRING SUMMER

Mountainous area large error

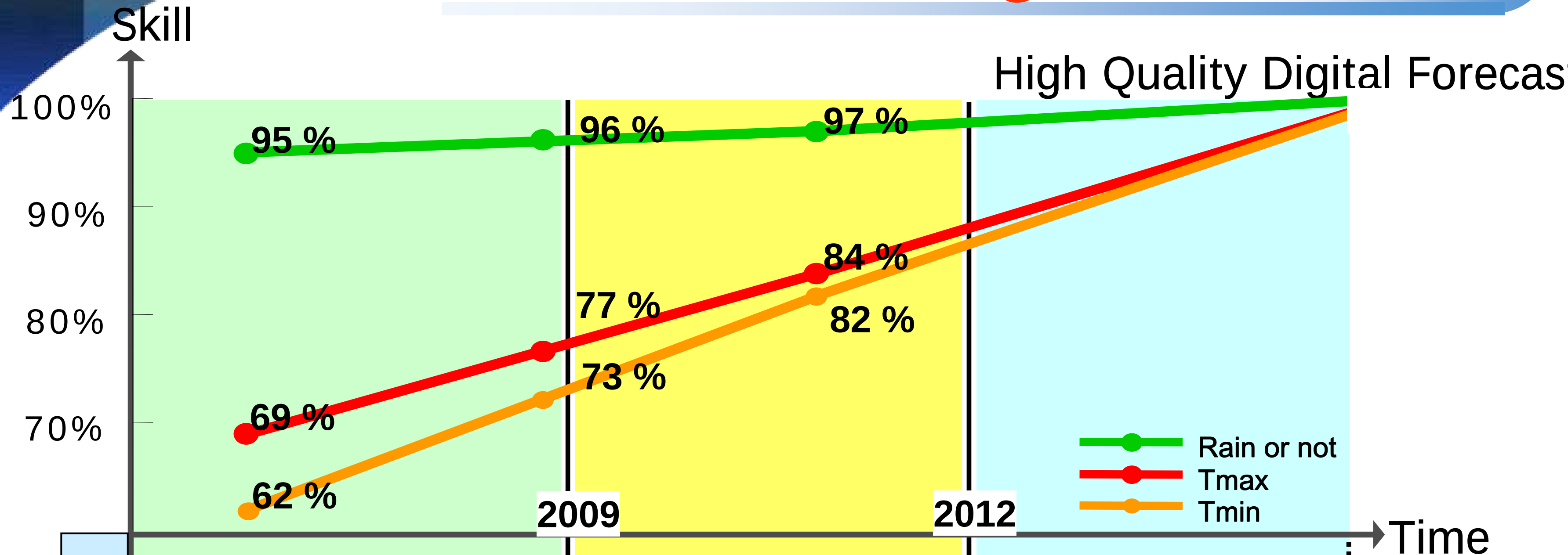
Summer better than winter

Accuracy: Medium range DFS





Plan : Digital Forecast



development	Short term ('07-'09) -Smart tool -MOS improvement -Editing module imp.	Medium term('10-'12) -5km KWRF -linkage with special weather system -short, medium range unified system	Long term ('13-'15) -unified NWP system -dynamic time-space editing -seamless WID
Application plan	Service for life benefit -life index, fire index -Service of 3hr forecast	Service of industry -management of water source -management of energy and harvest	Extended public service -quantitative and detail forecast -support to disaster prevension

Thank You~