Development of the operational visibility data assimilation system at KMA

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Outline

- Motivation
- New Very-Short Range Forecast system
- Quality control
- Data Assimilation
- Experiment results
- Summary and plans

Motivation

Deaths per 100 car accidents (in Korea)

clear=3.3, cloudy=4.4, rain=4.1, **fog=11**, snow=4.2

Test operation of Fog special report (since 2010)

expected less than 200 meter visibility for more than 2hours

Visibility observation network

238 over South Korea

→ **Data Assimiiation**

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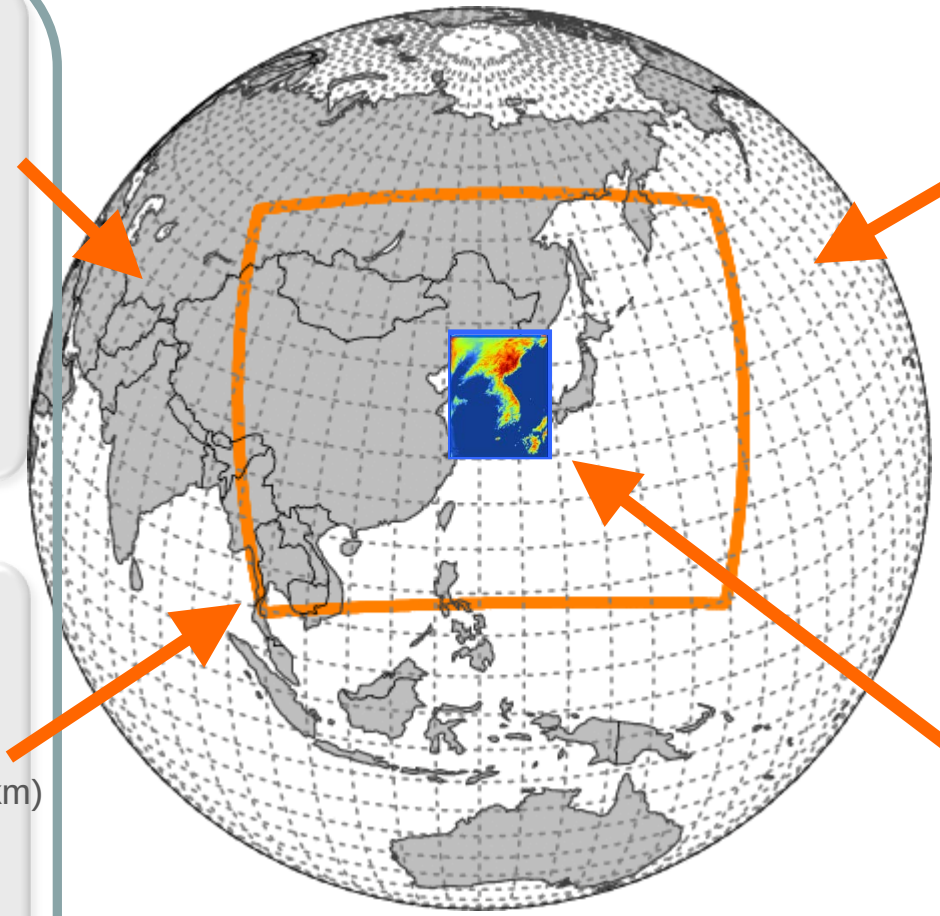
Main Operational NWP Systems at KMA

GLOBAL

- Resolution
  N512 → N768L70
  (~25 → 17km
  / top = 80km)
- Target Length
  252hrs (00/12UTC)
  72hrs (06/18UTC)
- 4DVAR

E-ASIA

- Resolution
  12kmL70
  (0.11°x0.11° / top=80km)
- Target Length
  72hrs (6 hourly)
- Initialization : 4DVAR



Main NWP Suites in KMA

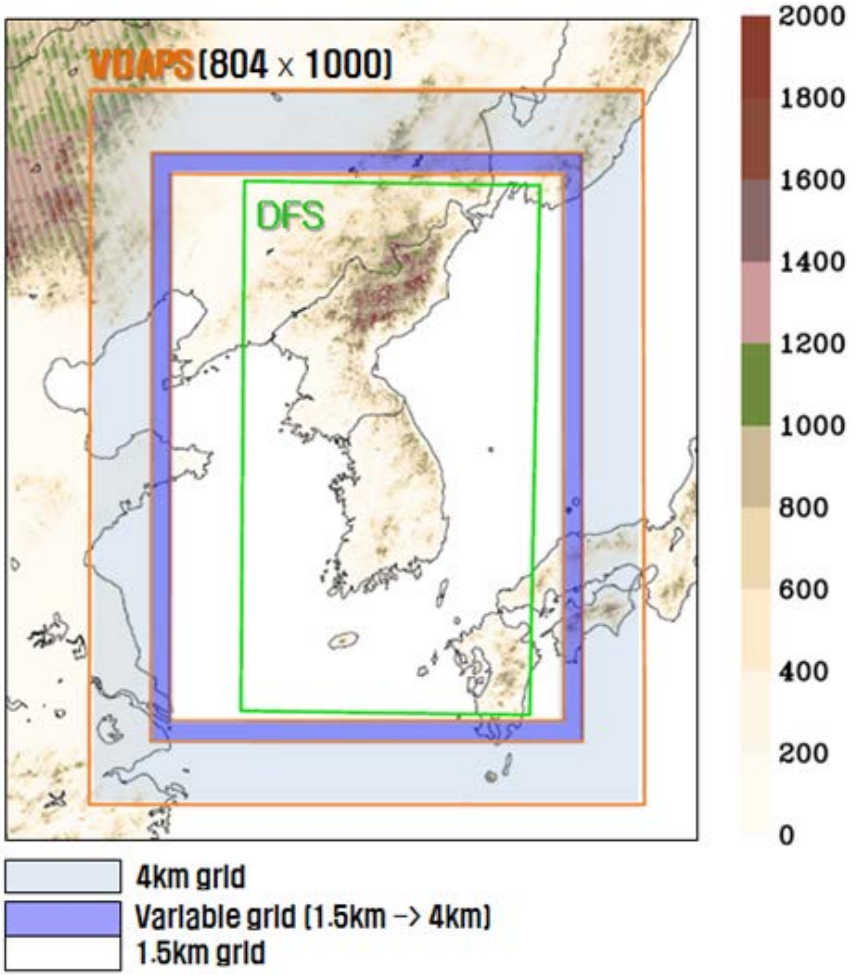
Global EPS

- Resolution
  N320L70
  (~40km/ top =80km)
- Target Length
  240hrs
- IC : GDAPS
- # of Members : 24

LOCAL

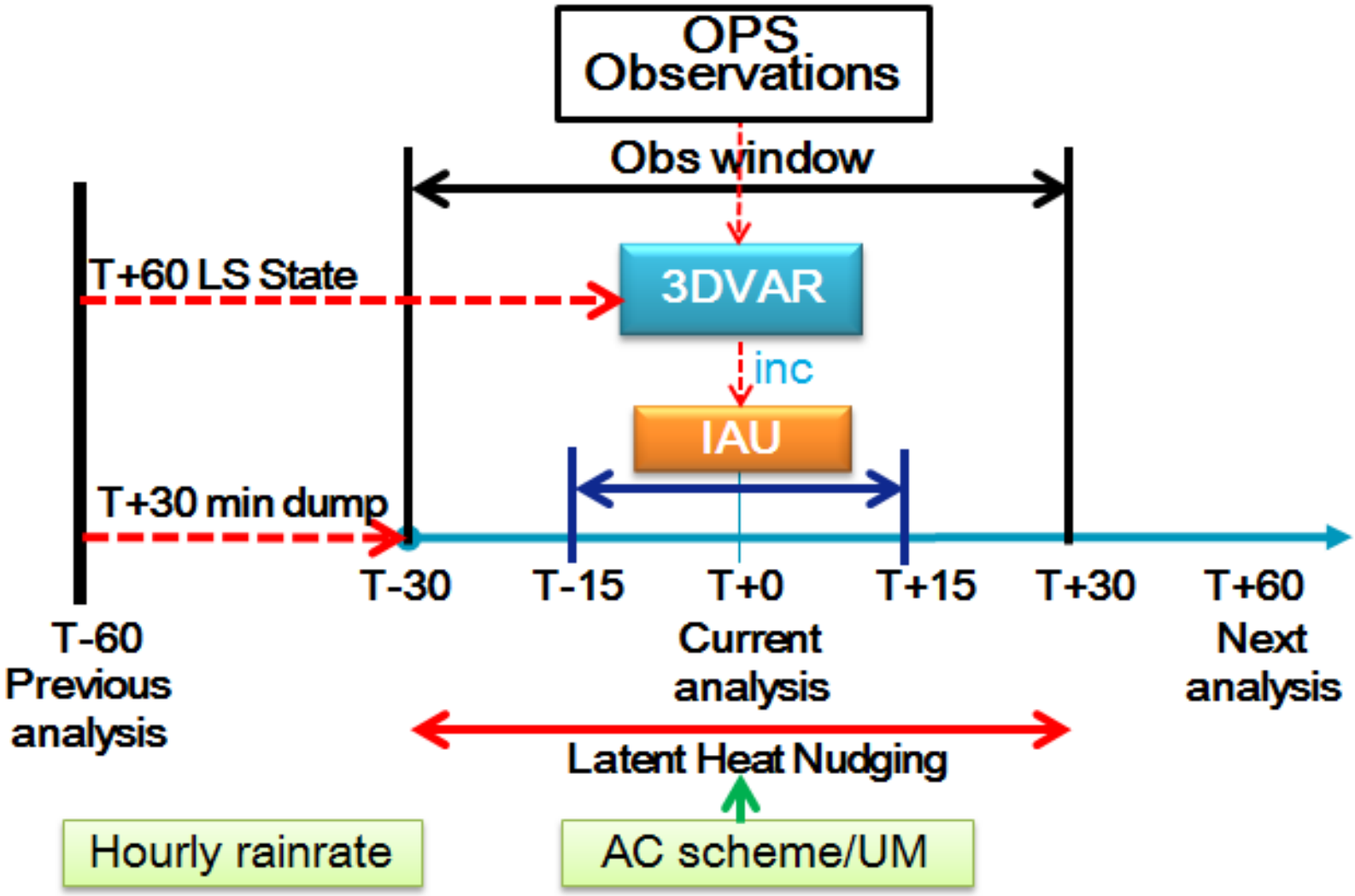
- Resolution
  1.5kmL70
  (744×928 / top =39km)
- Target Length
  36hrs
- Initialization : 3DVAR

Very-Short Range Forecasting System



Model	VDAPS V1.0
Horizontal grid spacing	1.5km
Dimension	804×1000
Vertical layers/ model top	70/40km
Time step	50 seconds
Data assimilation	3DVAR, IAU, LHN
Lateral boundary condition	Global Data Assimilation and Prediction System (GDAPS N768)
Cycle/DA window/cutoff	1hour / -30~30min / 2h50m (0h25m)
Observations	Surface(SYNOP, AWS, METAR, Ship, Buoy), SONDE (TEMP, PILOT, Windprofiler, Drop-Sonde), Aircraft (AMDAR), Rain rate, Radar radial winds, Visibility

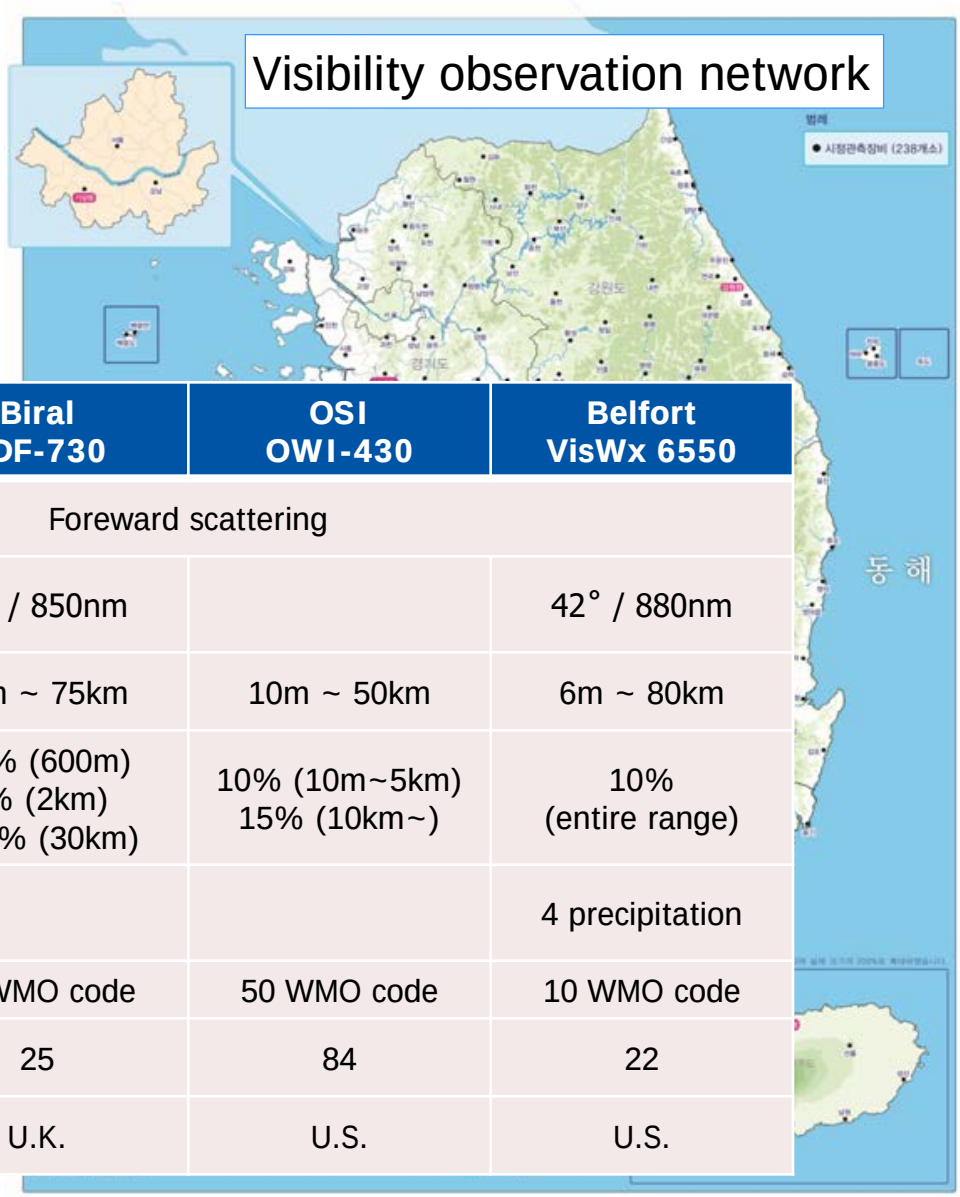
Very-Short Range Forecasting System : Time windows



Visibility : Observation

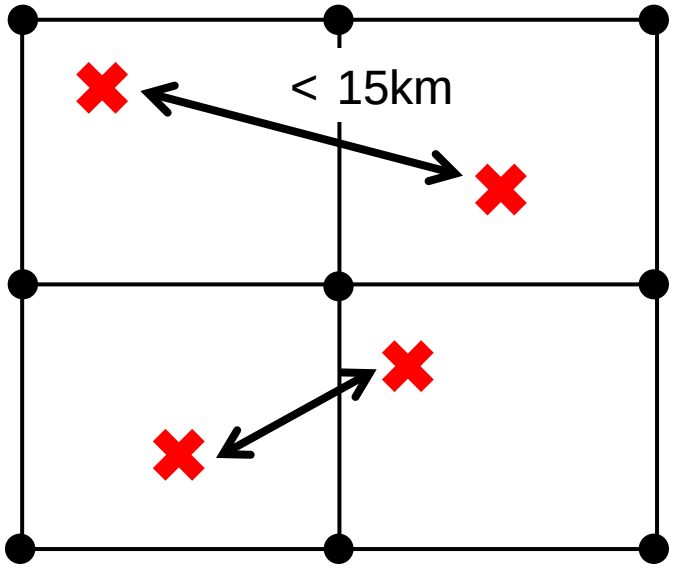
instrumental measurement :

238 points including 22 regional office



Instrument	Vaisala PWD22	Biral VDF-730	OSI OWI-430	Belfort VisWx 6550
Measurement method	Foreward scattering			
Scattering angle / wavelength		45° / 850nm		42° / 880nm
Range of measurment	10m ~20km	10m ~ 75km	10m ~ 50km	6m ~ 80km
Measurement error	10% (10m~10km) 15% (10~20km)	1.3% (600m) 2% (2km) 10.5% (30km)	10% (10m~5km) 15% (10km~)	10% (entire range)
Present weather detection	7 precipitation 3 aerosol			4 precipitation
	49 WMO code	15 WMO code	50 WMO code	10 WMO code
Num. of instrument	52	25	84	22
Made in	Finland	U.K.	U.S.	U.S.

Visibility : Observation error



1.3 ~ 15%

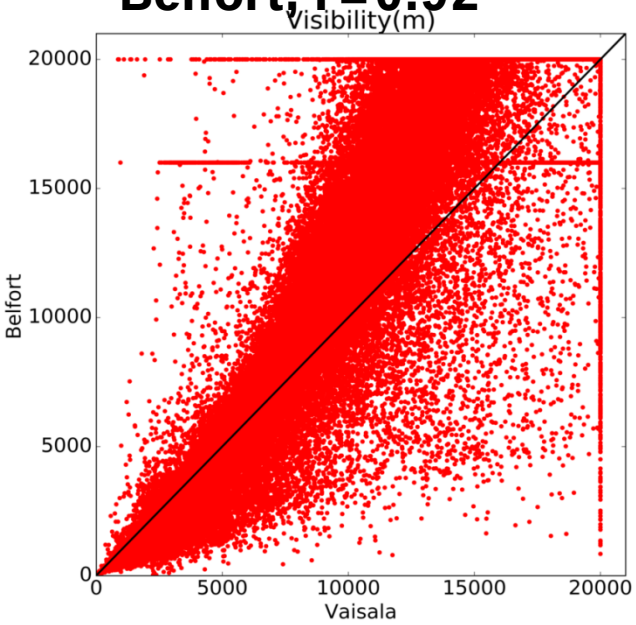
root mean square visibility ratio : 1.5-2

$|\log(VIS_{obs}) - \log(VIS_{true})| \sim 0.25$

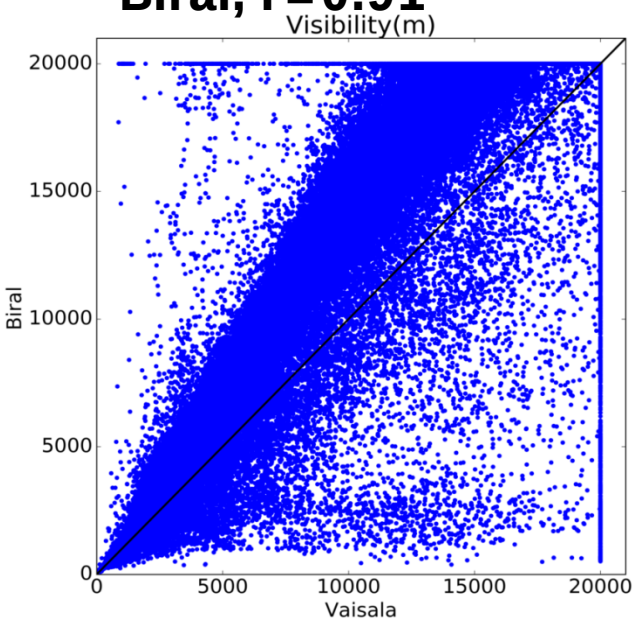
REF: Prediction of visibility and aerosol within the Met office UM, Clark et al., 2008, QJRMS

Vis observation : correlation with Vaisala

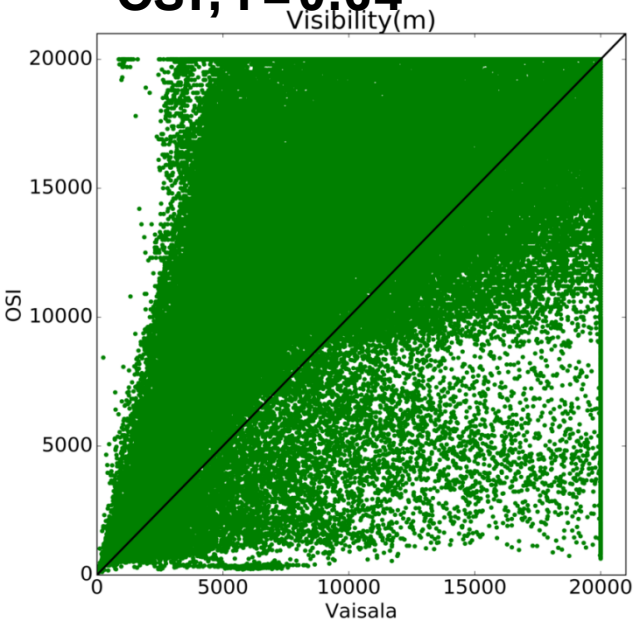
Belfort, r=0.92



Biral, r=0.91



OSI, r=0.64



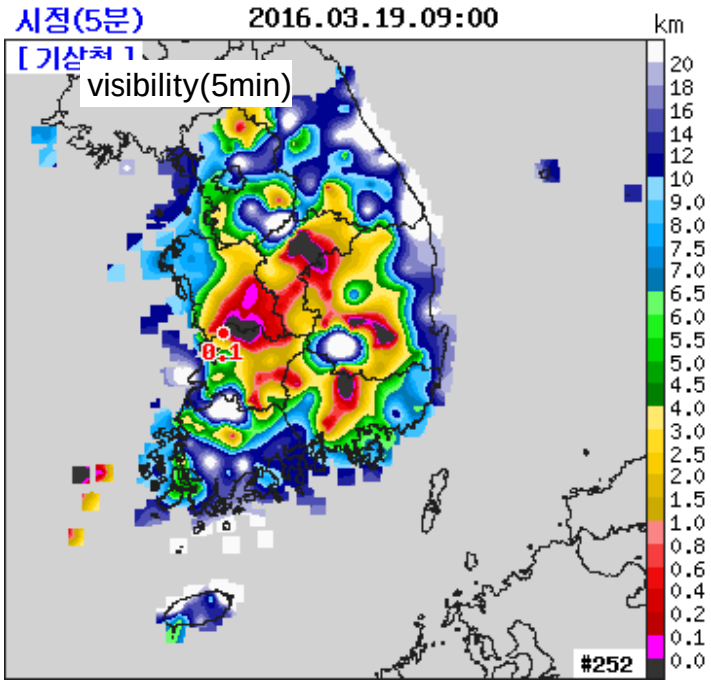
Samples (#187,980)	Belfort	Biral	OSI
Bias(m)	753.6	1759.2	1896.3
RMSD(m)	2748.8	3178.1	5507.7
Corr	0.92	0.91	0.64

REF: Analysis of visibility observations,
Y Lee, K Kim, J Ha, and E Lim (2016)

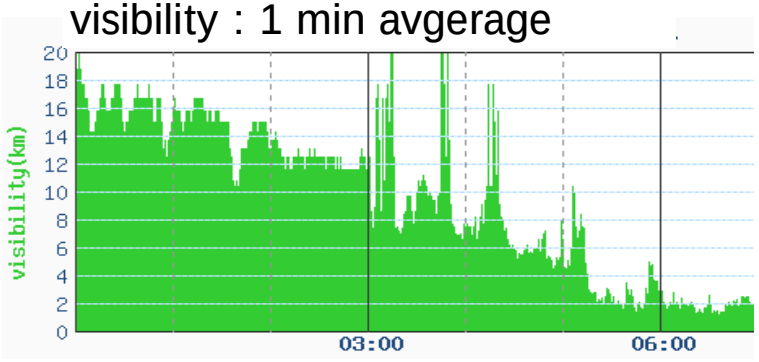
Spatial / temporal variabilities

temporal variability

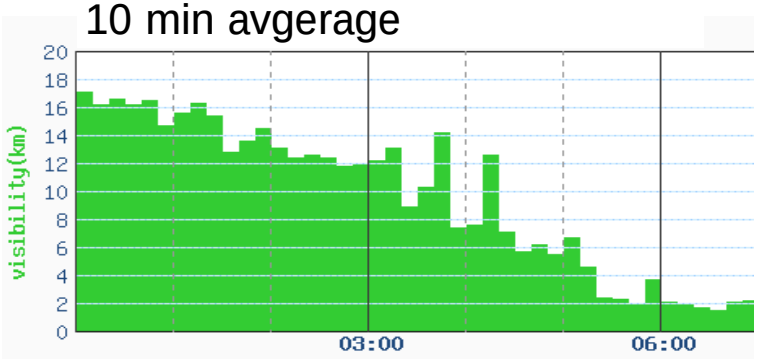
spatial variability



visibility : 1 min avgerage

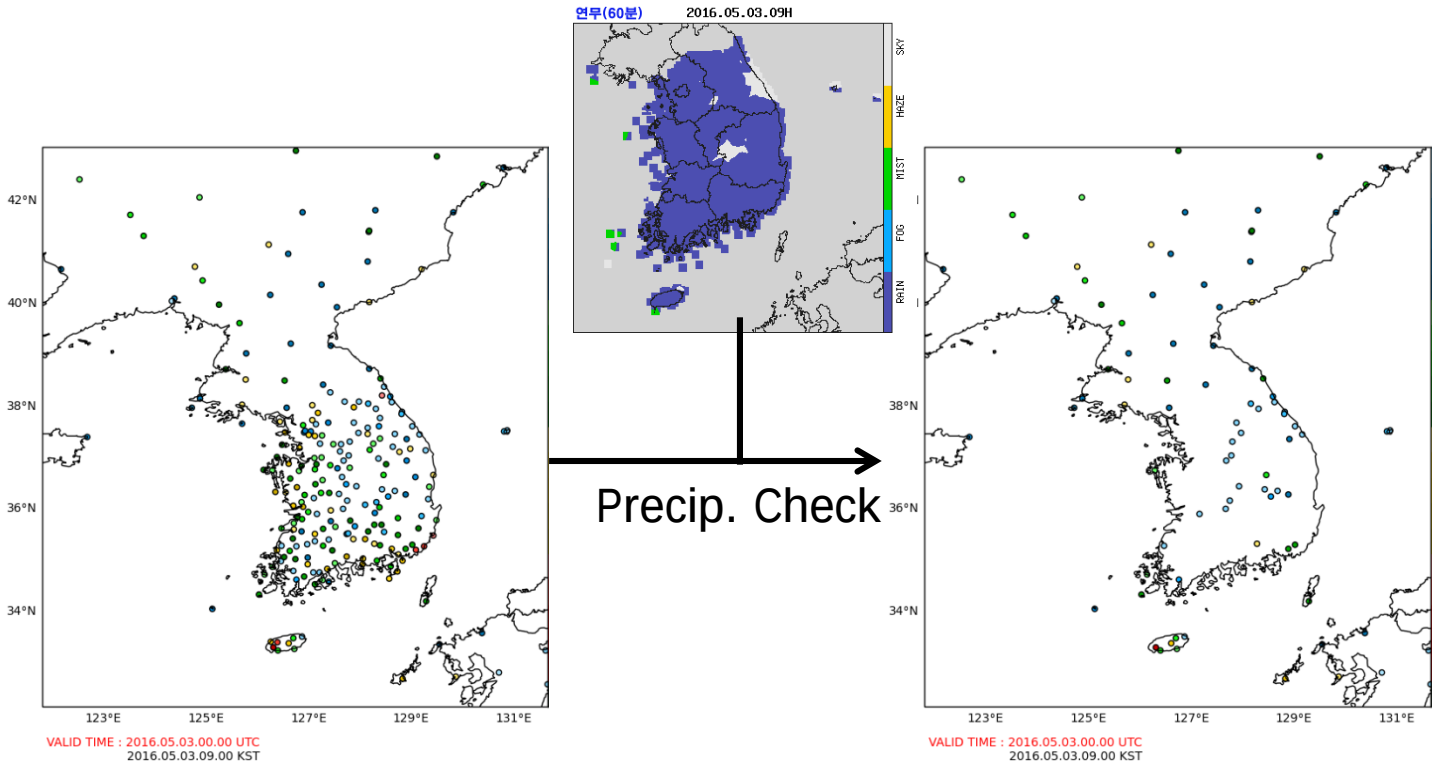


10 min avgerage



No background, buddy, consistency check !!!

Visibility Q.C. : Precipitation check

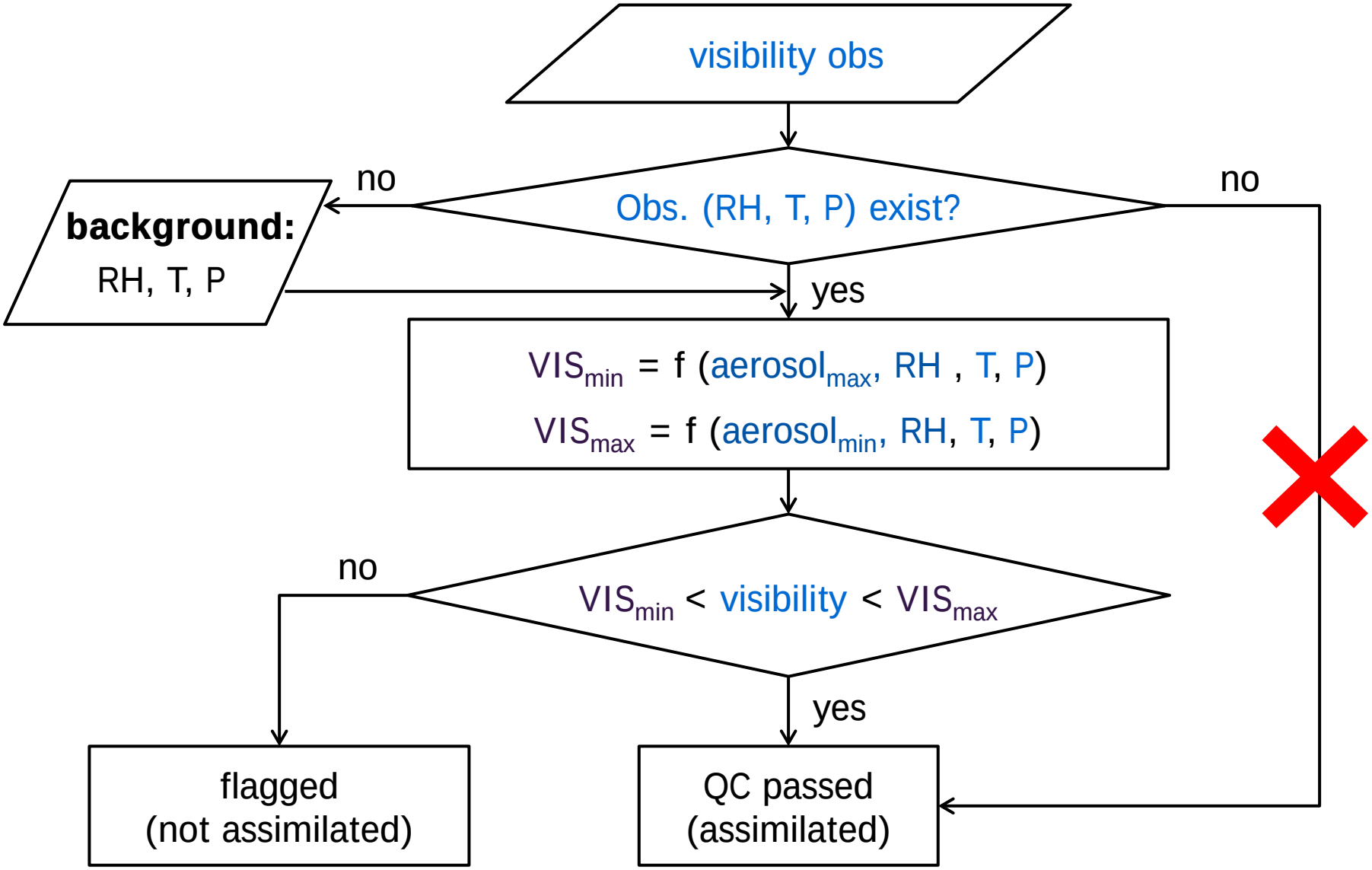


In case of precipitation, reliability of visibility observation decreases.

The model does not consider precipitation in the calculation of visibility.

→ Visibility data must be removed if there is precipitation.

Visibility Q.C. : Range check



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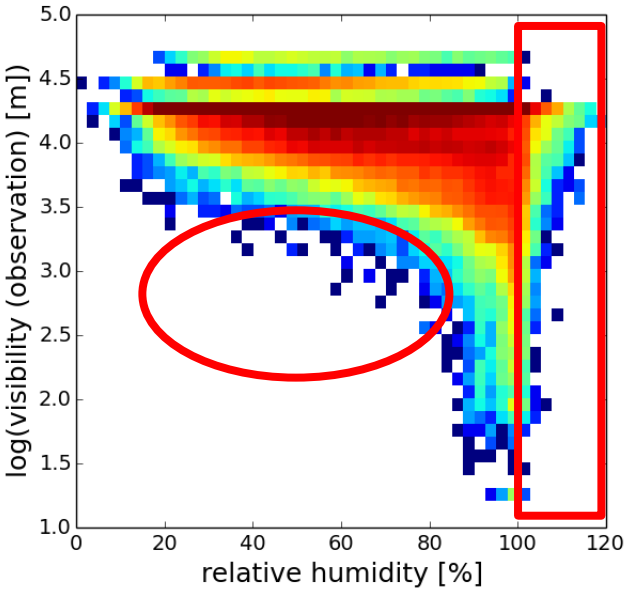
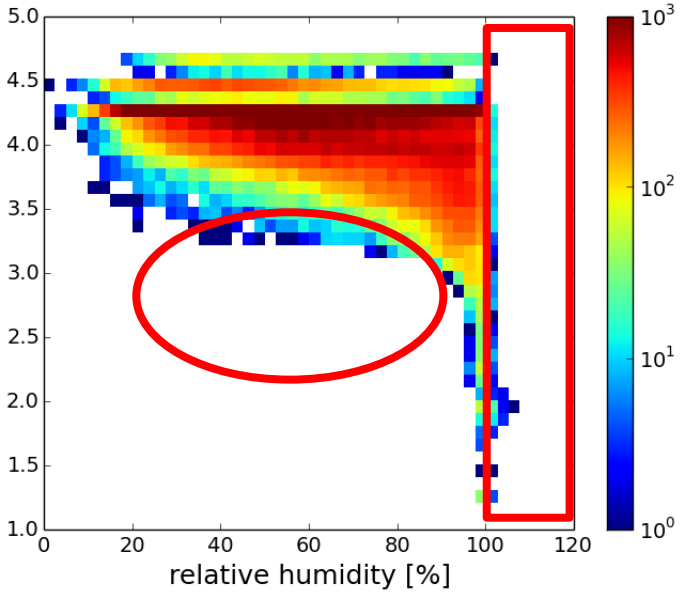
Visibility Q.C. : Range check

Period : Feb (1 month) + Mar (22 days) 2016

old QC



modified QC



- All visibility data must pass range check using obs. or background RH, T, P.

Visibility D.A. : visibility operator

$$vis = \frac{\ln \varepsilon}{Nr^2\beta_0 + \beta_{air}}$$

a fog droplet radius (r), and number density (N),
ε is the liminal contrast,
β_0 is the scattering coefficient
β_{air} is the clear air scattering term.

$$N = N_0\left(\frac{m}{m_0}\right)^{1-3p}$$

•. The number density, N N_0, is the standard number density of the aerosol, p is the mass loading power, and m_0 is the standard mixing ratio of aerosol.

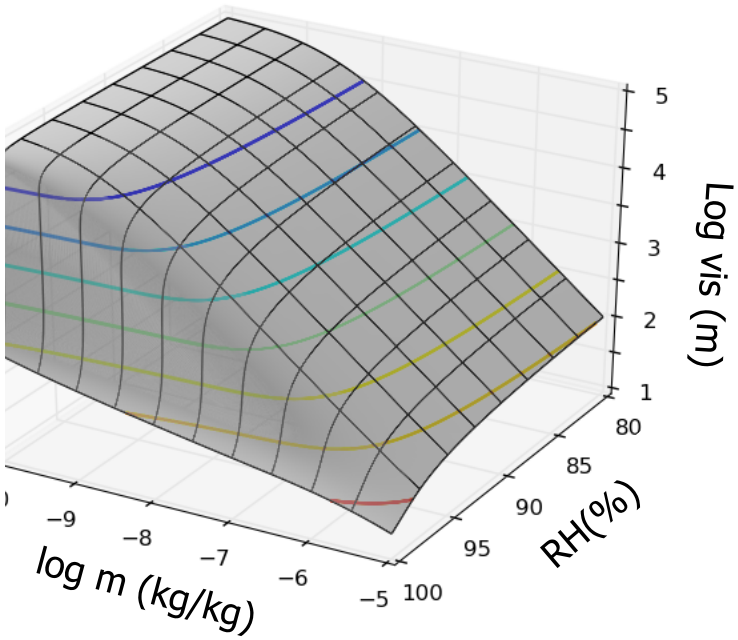
$$q_t = \left(RH(r,m) - k\right)q_s(T) + q_l(r,m)$$

$$RH = \exp\left(\frac{A_0}{r} - \frac{B_0}{(r/r_d)^3 - 1}\right)$$

• q_t is the sum of a relative humidity term and a liquid water term. The constant k is used to modify q_t to account for its distribution across a grid square

•A_0, B_0, r_0, m_0 and p are constants

$$r_d = r_0\left(\frac{m}{m_0}\right)^p \qquad q_l = \tfrac{4}{3}\pi(r^3 - r_d^3)\rho_w N$$

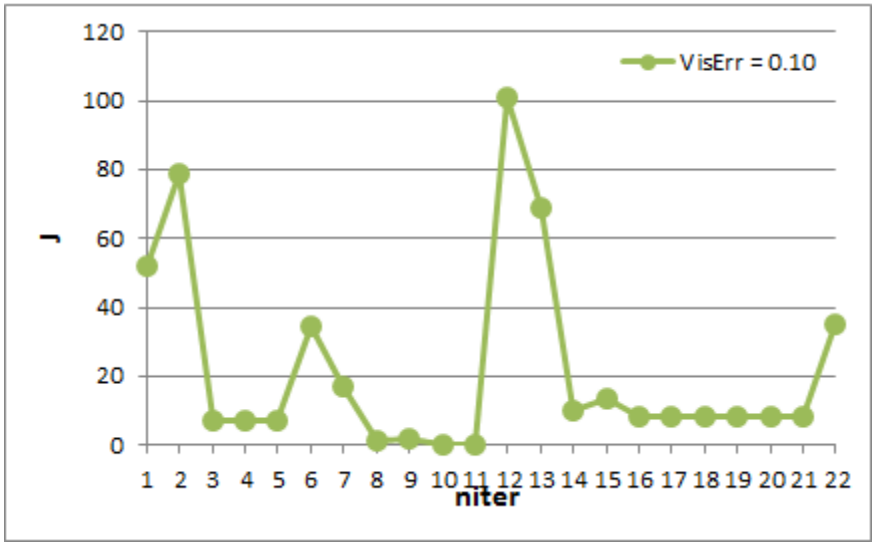


$$\log_{10} vis = \log_{10} vis_g + \log_{10} m'\left(\frac{d\log_{10} vis}{d\log_{10} m}\right)_g + q'\left(\frac{d\log_{10} vis}{dq}\right)_g + T'\left(\frac{d\log_{10} vis}{dT}\right)_g$$

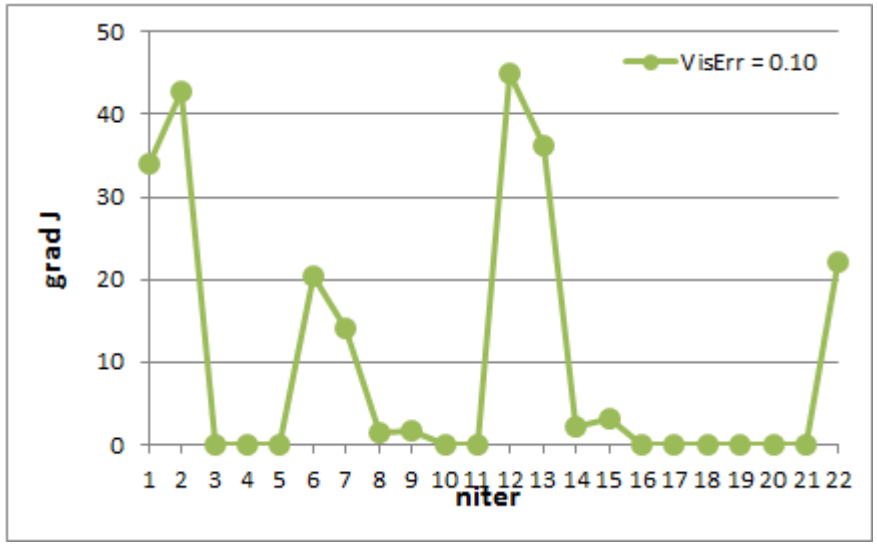
Visibility D.A. : minimization (single obs. Exp)

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mathbf{x}_b)^{\mathrm{T}} \mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}_b) + \frac{1}{2}[H(\mathbf{x}) - \mathbf{y}]^{\mathrm{T}} \mathbf{R}^{-1}[H(\mathbf{x}) - \mathbf{y}]$$

Cost function



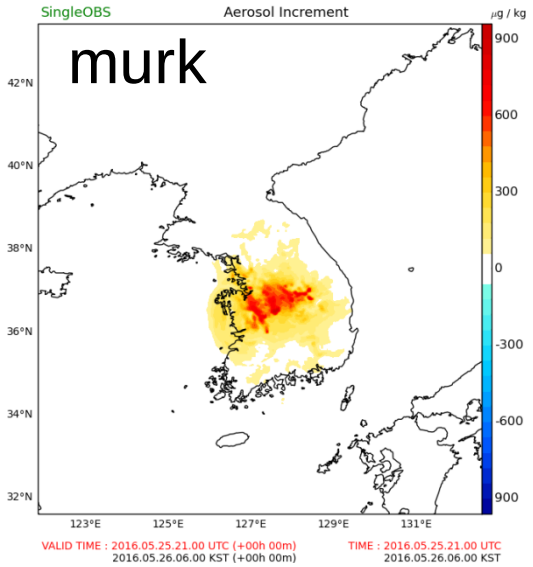
Gradient

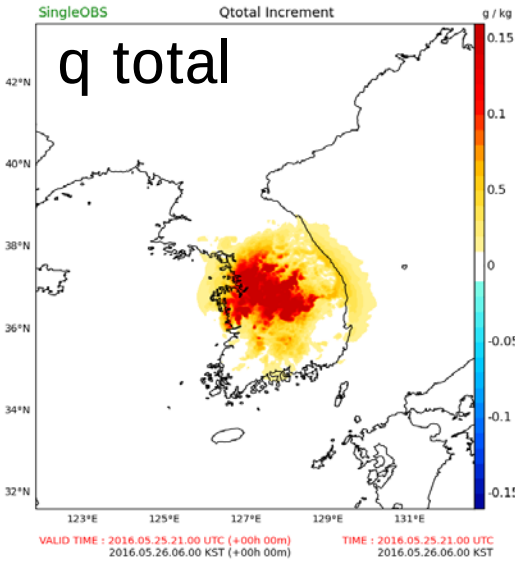


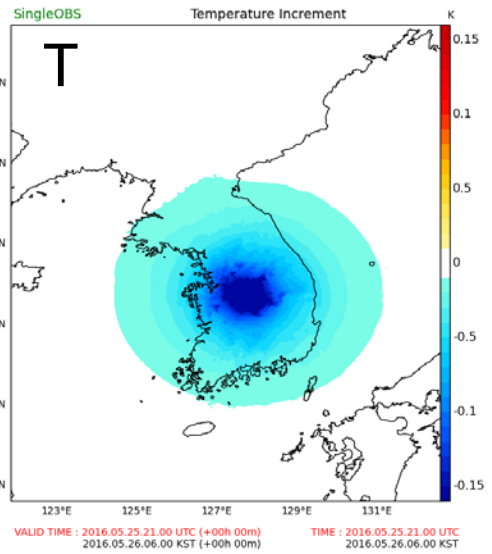
- Nonlinear visibility operator basic state is updated during minimization

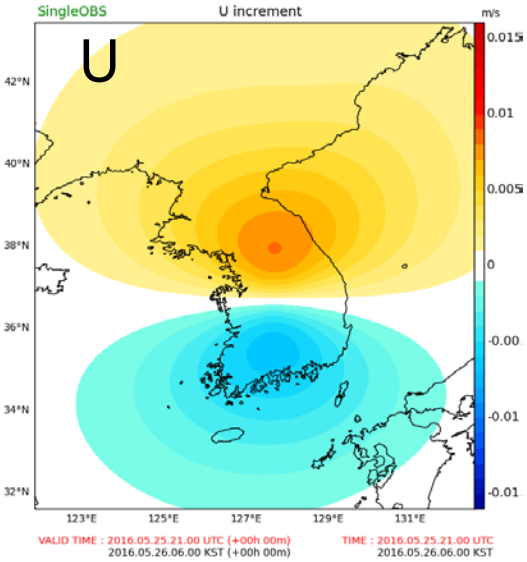
  ➔ working well ??

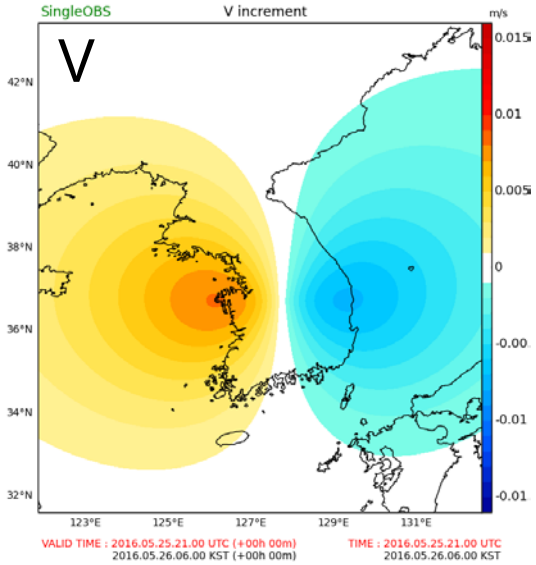
Visibility D.A. : Single Observation Test











- Issues
  - Decorrelation length scale?
  - murk correlation

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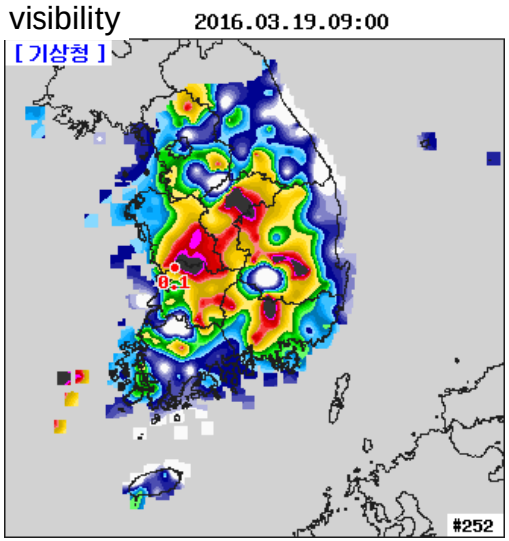
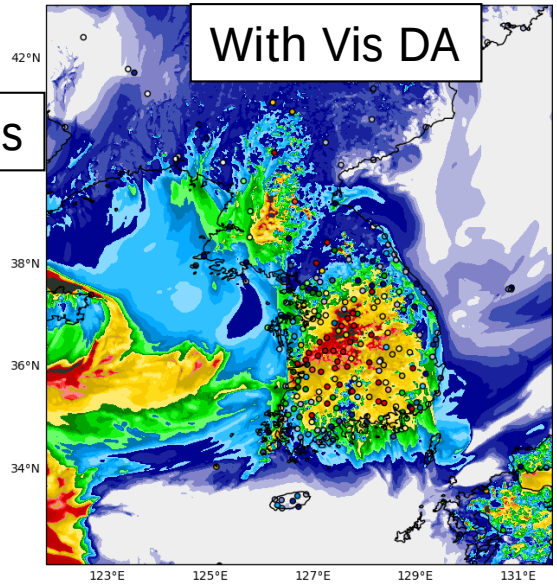
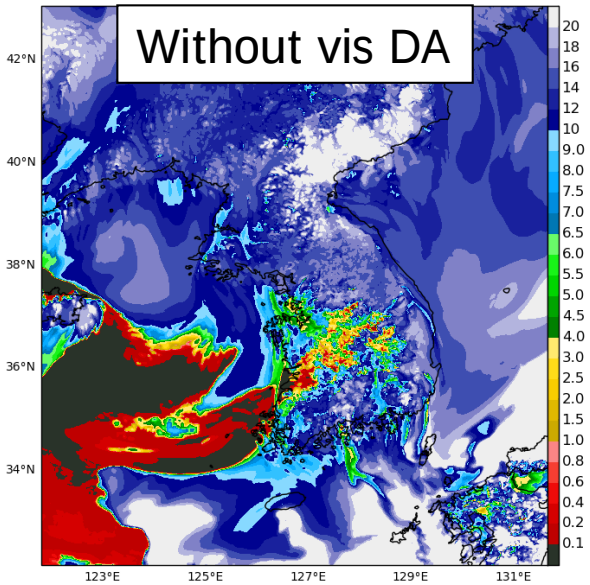
Case study

OBS



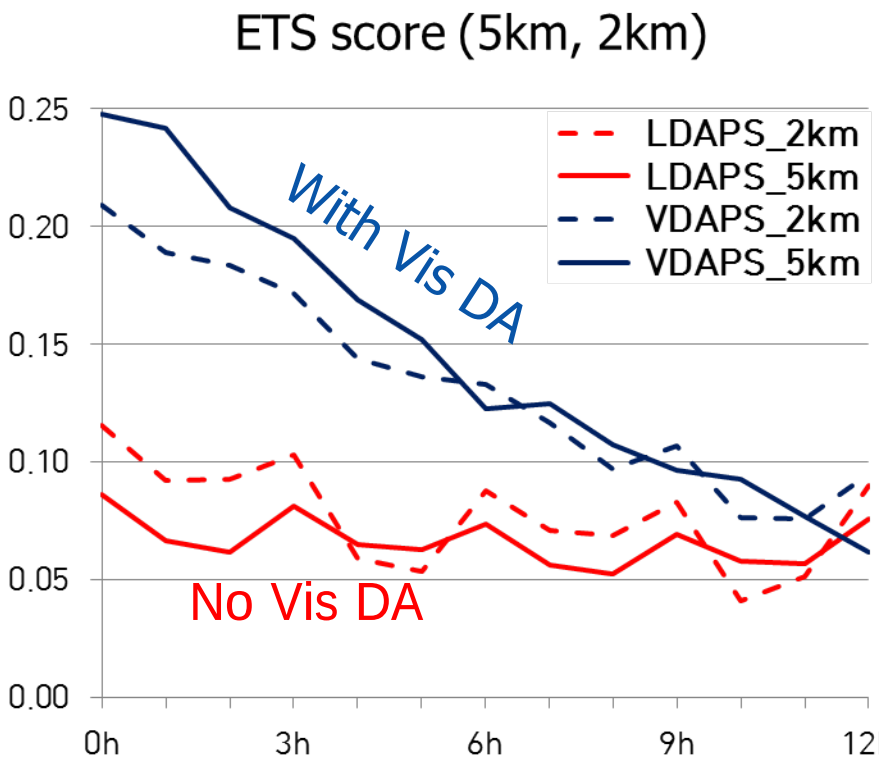
analysis

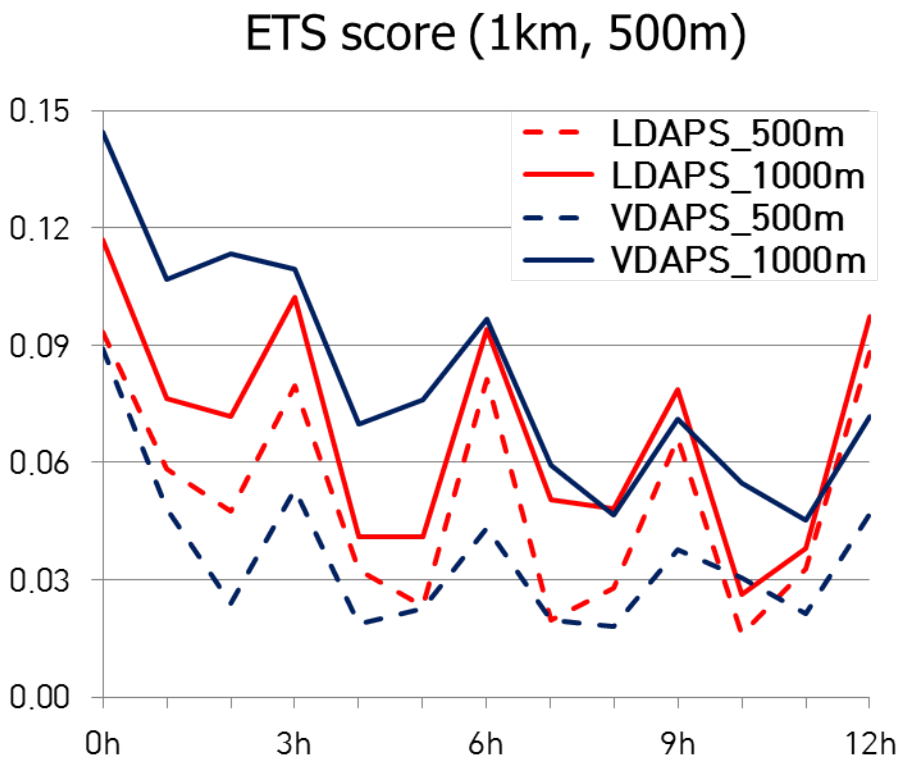




Equitable Threat Scores

Period : Feb (1 month) + Mar (1 week) 2016





VDAPS : 1-hour cycling with VIS DA, LDAPS : 3-hour cycling without VIS DA

- VDAPS shows higher ETS for the events with visibility under 2 and 5 km.
- For fog events (visibility less than 1 km), both models show poor ETS

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Summary and plans

Summary
- implemented operational visibility DA into VDAPS at KMA
- developed the background based quality control
- case/cycling experiments
  improve vis forecast but still low ETS scores for low vis.
- Issues
  aerosol (one total aerosol, no LBC), measurements errors,
  background error covariance, double loop performance

On-going works
- operation (Oct. 2016)
- Improvement of low vis DA (errors, aerosol , double loop, B)

Future plan
- 4DVAR
- aerosol sources
- lateral boundary conditions (Global: 2 species, VDAPS: 1 specie)
- vis. obs. operator (more than 2 species)