Development of a New Storm-Scale 4D-Var Assimilation System

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NHM-4DVAR (Kawabata et al. 2007; 2011; 2013) is upgraded with the adjoint model of **JNoVA** (Honda et al. 2009).

Storm scale, warm rain!
Many observation operator!

NHM-4DVAR is
Research purpose, non-incremental,
full-physics nonhydrostatic model (JMA nonhydrostatic model ver. 2002).
Horizontal resolution: **2 km (storm scale)**
Assimilation window: 10-60 min
Observations
Doppler radial wind and reflectivity by Doppler radar,
GPS precipitable water vapor, GPS zenith total delay,
GPS slant total delay,
Wind profiler, surface wind, surface temperature,
Virtual temperature profile by RASS,
Radial wind by Doppler lidar

Many physics!

JNoVA is
JMA Operational mesoscale nonhydrostatic assimilation system,
incremental with simplified nonlinear model
(JMA nonhydrostatic model ver. 2004).
Horizontal resolution: 15 km
Assimilation window: 3 h

New Formulation

$$J(\mathbf{x}_0,\mathbf{x}_{lbc}) = \frac{1}{2}\left(\mathbf{x}_0{}^b - \mathbf{x}_0\right)^{\mathrm{T}}\mathbf{B}^{-1}\left(\mathbf{x}_0{}^b - \mathbf{x}_0\right)$$

NHM-4DVAR (optimize LBCs)

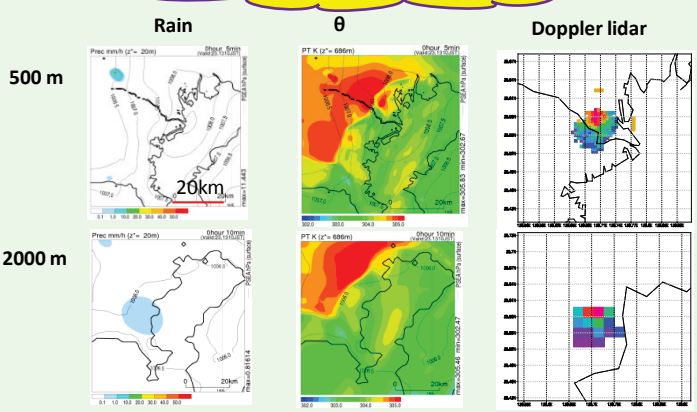
$$+\frac{1}{2}\left(\mathbf{x}_{lbc}{}^b - \mathbf{x}_{lbc}\right)^{\mathrm{T}}\mathbf{B}'^{-1}\left(\mathbf{x}_{lbc}{}^b - \mathbf{x}_{lbc}\right)$$

$$+\frac{1}{2}(H\mathbf{x}_0 - \mathbf{y}^o)^{\mathrm{T}}\mathbf{R}^{-1}(H\mathbf{x}_0 - \mathbf{y}^o)$$

(suppress short waves) $+ J_p$ JNoVA

	Forward model	New NHM-4DVAR	JNoVA	NHM-4DVAR
Resolution	2 km	~2 km	15 km	2 km
Incremental method	--------	No	Yes	No
Moisture process	3-ice bulk	Warm rain	Large scale condensation	Warm rain
Turbulence	Deadorff (1973)	Diagnostic eddy diffusion	Diagnostic eddy diffusion	No
Land-air process	(Sea)Kondo (Land)Louis	(Sea)Kondo (Land)Louis	(Sea)Kondo (Land)Louis	No
soil temperature	heat diffusion	heat diffusion	heat diffusion	No
Radiation	Sugi and Tada	No	No	No
Lateral boundary		Yes	No	Yes
Penalty term		Yes	Yes	No

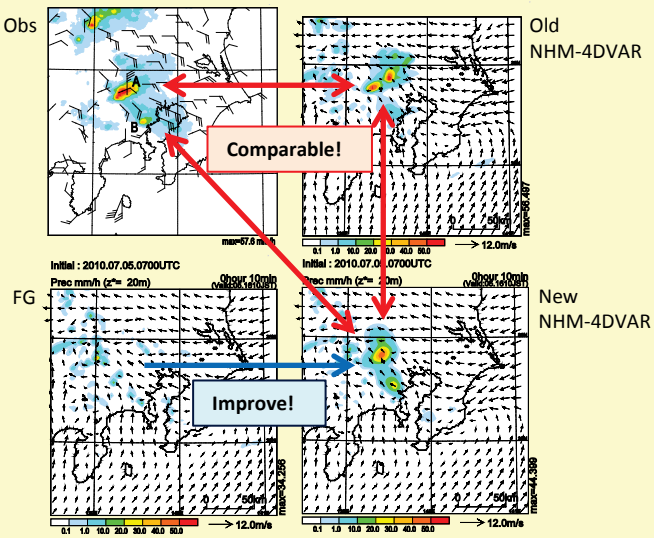
Towards ultra-high resolution 4D-Var
- 500 m grid -



In-depth orography, well-captured small perturbations, close to original resolution of Doppler lidar data

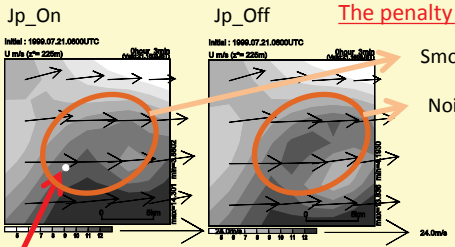
Verification with actual observations

Obs: Doppler radars (radial wind, reflectivity), GPS-PWV, Doppler lidar
Assimilation Window: 10 min Resolution: 2 km



Verification on the penalty term (digital filter)

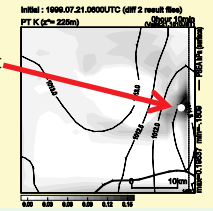
Jp_On Jp_Off The penalty term works well!



Shade: U (m/s), Vector: Wind (m/s)

Assimilation point
Obs: U = 20 m/s, V = 0 m/s, θ = FG + 5 K

Verification on the optimizing the LBCs



Assimilation point
Obs: U = 20 m/s,
V = 0 m/s,
θ = FG + 5 K

Optimizing the LBCs (B) or not (N).
Shades: departure (B - N) of θ
Contours: surface pressure in N
Since the departure (B - N) is large around the lateral boundary, the optimization scheme works well!

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