Is 30-second update fast enough??
for convection-resolving data assimilation

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With many thanks to
JMA
UMD Weather-Chaos group
JST CREST “Big Data Assimilation” project
JAXA PMM “Ensemble Data Assimilation” project
Japan’s FLAGSHIP 2020 project
RIKEN Data Assimilation Research Team
Only in 10 minutes!!

(Courtesy of NICT)
Phased Array Weather Radar (PAWR)

3-dim measurement using a parabolic antenna (150 m, 15 EL angles in 5 min)

100x more data!

10x more data in a 1/10 period

3-dim measurement using a phased array antenna (100 m, 100 EL angles in 30 sec)
Phased Array Radar (every 30 sec.)

(Courtesy of NICT)
Pioneering “Big Data Assimilation” Era

High-precision Simulations

Future-generation technologies available 10 years in advance

Mutual feedback
**Revolutionary super-rapid 30-sec. cycle**

- **Obs data processing**
  - DA (4.5PFLOP) → 380GB
  - 3GB

- **30-sec. Ensemble forecasting** (2.6PFLOP)
  - 2.5TB
  - ~2GB

- **30-min. forecasting** (1.6PFLOP)
  - 3GB

- **Obs data processing**
  - DA (4.5PFLOP) → 380GB

- **30-sec. Ensemble forecasting** (2.6PFLOP)
  - 2.5TB
  - ~2GB

- **30-min. forecasting** (1.6PFLOP)

**120 times more rapid** than hourly update cycles
9/11/2014 morning, sudden rain
9/11/2014, sudden local rain
9/11/2014, sudden local rain

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>40,000 views
#9 of RIKEN channel

Simulation (w/o DA)
Simulation (1km DA)
9/11/2014, sudden local rain

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Observation

Simulation (100m Big DA)

Simulation (w/o DA)

Simulation (1km DA)
Another case study (July 16, 2017)

Lien et al. (in prep.)

Resolution | Size | Observation | Cycle length
---|---|---|---
D1 | 18 km | 5760 x 4320 km | PREPBUFR | 6 h
D2 | 5 km | 1280 x 1280 km | PREPBUFR | 6 h
D3 | 1 km | 180 x 180 km | PAWR | 5 m

D4 | 1 km | 120 x 120 km | PAWR

Ensemble size: 50
State variables: U, V, W, P, T, Q, Qc, Qr, Qs, Qi, Qg
Observations superobed to model resolution

NRT system

00:00Z July 15, 2017

Assimilate PAWR data as frequent as every 30 seconds in D4. Reflectivity + Radial velocity

00:00Z July 16

05:00Z July 16 (14:00L)

30-min forecasts every 10 min
30-min forecast: 15:10L – 15:40L

D4_1KM (deterministic)
Radar reflectivity [Z = 3068m] [06:10:00 UTC]

OBS after QC
Radar reflectivity [Z = 3068m] [06:10:00 UTC]

30-sec DA cycle

D4_1KM (deterministic)
Radar reflectivity [Z = 3068m] [06:10:00 UTC]

5-min DA cycle

Lien et al. (in prep.)
30-min forecast: 15:40L – 16:10L

D4_1KM (deterministic)
Radar reflectivity \( [Z = 3068 \text{ m}] \) [06:40:00 UTC]

OBS after QC
Radar reflectivity \( [Z = 3068 \text{ m}] \) [06:40:00 UTC]

30-sec. update certainly helps.

Lien et al. (in prep.)

5-min DA cycle
Impact of update frequency:
30-min-forecast

Threshold = 15 dBZ;
horizontal length scale = 1 km (18-fcst average)

Higher is better

FSS

Forecast time (min)

30 sec
1 min (1/2 data)
2 min (1/4 data)
5 min (1/10 data)

Lien et al. (in prep.)
Impact of update frequency:
30-min-forecast

Threshold = 15 dBZ;
horizontal length scale = 1 km (18-fcst average)

AVERAGE

Higher is better

Forecast time (min)

Lien et al. (in prep.)
Impact of update frequency:
Forecast FSS  

Threshold = 15 dBZ;
horizontal length scale = 1 km (18-fcst average)

Mean FSS in the 10- to 30-min forecasts

Error bars:
95% confidence interval using a pair-difference t-test compared to the 30-sec-cycle experiment

Lien et al. (in prep.)
20-min forecast: 15:30L

OBS after QC

30 sec

5 min (4D)

5 min (1/10 data)

Lien et al. (in prep.)
20-min forecast: 15:30L

Lien et al. (in prep.)
20-min forecast: 15:30L

Lien et al. (in prep.)
OSSE comparing different window lengths of 4D-LETKF

Nonlinear dynamics ➡️ degrading longer window lengths

Maejima et al. (in prep.)
Computational time and Surface rainfall intensity (Analysis)

Nature Run
(a) 3D-LETKF (1min. window)
(b) 4D-LETKF (3min. window)
(c) 4D-LETKF (5min. window)
(d) 4D-LETKF (15min. window)
(e) 3D-LETKF (15min. window)
(f) Forecast

Maejima et al. (in prep.)
Time series of RMSE of water vapor mixing ratio at $z^* = 2$ km.

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Time series of RMSE of water vapor mixing ratio at $z^* = 2$ km.

$Q$(Mixing Ratio) $(z^*=2$km$)$

(a) 3D-LETKF(1min. window)
(b) 4D-LETKF(3min. window)
(c) 4D-LETKF(5min. window)
(d) 4D-LETKF(15min. window)
(e) 3D-LETKF(15min. window)
(f) Forecast

Maejima et al. (in prep.)
Even 30-second update shows strong non-Gaussianity with 1000 members.

1-km-mesh, 1000-member LETKF

contours: 30 dBZ reflectivity

T skewness at z=3845 m

(Ruiz et al. in prep.)
~1000 members good for capturing non-Gaussianity

based on 10240-member SPEEDY-LETKF exp. (*Kondo* & *Miyoshi* 2016)
What do we expect with rapid updates?

based on Lorenz-model exp. (Teramura&Miyoshi 2016)

- Obs interval = 0.08
  - Scatter diag.
  - $K_4$ of PCA1

- Obs interval = 0.25
  - Scatter diag.
  - $K_4$ of PCA1

- Obs interval = 0.50
  - Scatter diag.
  - $K_4$ of PCA1

$K_4$: 4th order cumulant = kurtosis

Heavy tailed ↔ Light tailed
What do we expect with rapid updates? (Teramura & Miyoshi 2016)

Based on Lorenz-model exp.

Obs interval = 0.08

K₄ of PCA1

Obs interval = 0.25

K₄ of PCA1

Obs interval = 0.50

K₄ of PCA1

Frequent obs \implies more Gaussian
1-km-mesh, 1000-member LETKF

Even 30-second update shows strong non-Gaussianity with 1000 members.

30-sec. update may not be fast enough!

(Ruiz et al. in prep.)
Non-Gaussianity and data assimilation frequency
Comparison of KLD for different assimilation frequencies
At 05:15 UTC (15 minutes after the end of the spin-up)

Contours: 30 dBZ

(Ruiz et al. in prep.)
Non-Gaussianity and data assimilation frequency
Comparison of KLD for different assimilation frequencies.

- T 2 min - rain
- T 5 min - rain
- T 1 min - rain
- T 30 sec - rain

More Gaussian with faster cycles

Averaged area > 30 dBZ

(Ruiz et al. in prep.)

w/ 1000 members, 1-km mesh
Summary

30-second update certainly helps, but faster updates may help reduce the non-Gaussianity further (for active convection).

How fast, what performance? – work in progress