Radar data assimilation at sub-kilometer scales

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K computer

Computer simulations create the future

Introduction

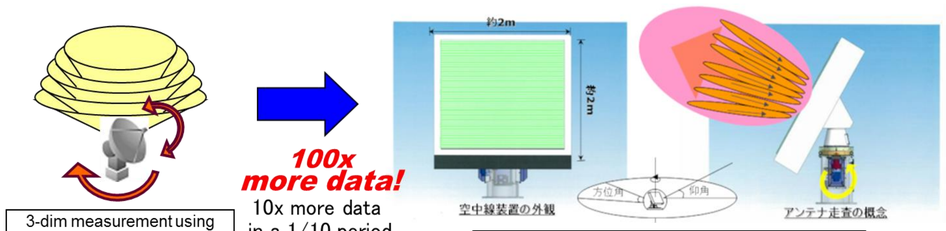
Scalable Computing for Advanced Library and Environment

- SCALE: A open-source basic library for weather and climate models (Nishizawa et al. 2015; Sato et al. 2015).
- SCALE-RM (SCALE-Regional Model): A regional numerical weather prediction model based on the SCALE.
- http://scale.aics.riken.jp/

SCALE-LETKF

- A LETKF data assimilation package with the SCALE model.

Phased Array Weather Radar (PAWR)



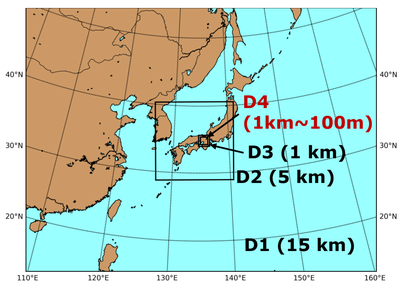
3-dim measurement using a parabolic antenna (150 m, 15 EL angles in 5 min)

100x more data!
10x more data in a 1/10 period

Courtesy of NICT

3-dim measurement using a phased array antenna (100 m, 100 EL angles in 30 sec)

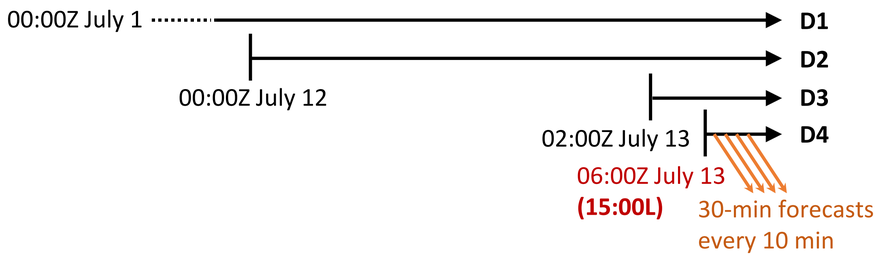
Experimental setup



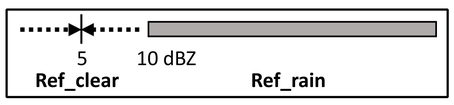
	Resolution	Size	Observation	Cycle length
D1	15 km	5760 x 4320 km	PREPBUFR	6 h
D2	5 km	1280 x 1280 km	PREPBUFR	6 h
D3	1 km	180 x 180 km	PAWR	5 m
D4	1 km 500 m 250 m 100 m	120 x 120 km	PAWR	30 s

Ensemble size: 100

State variables: U, V, W, P, T, Q, Qc, Qr, Qs, Qi, Qg

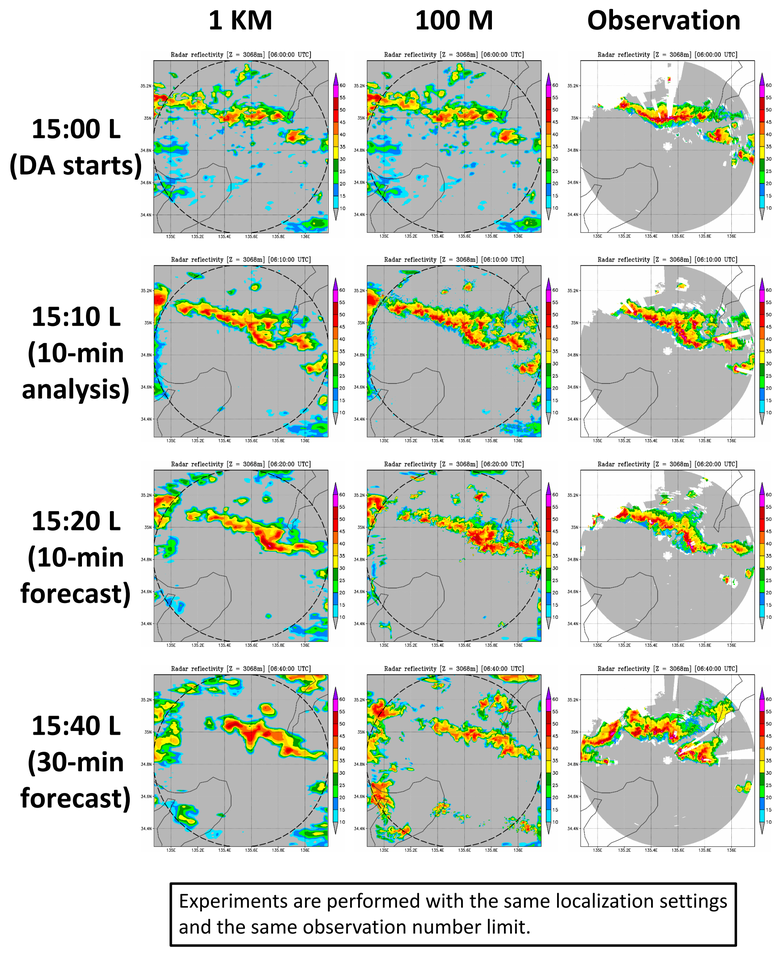


- Assimilate both reflectivity (**Ref**) and radial velocity (**Vr**) data.
- Radar data QC (Ruiz et al. 2015): remove ground clutter and attenuated data.
- Superob to model resolution (use only the data below 11 km).
- Define **Ref_rain**: raw Ref >= 10 dBZ
  Ref_clear: raw Ref < 10 dBZ
- Set all **Ref_clear** (both observation and background) to 5 dBZ.
  (Similar to Aksoy et al. 2009 but leave a 5-dBZ gap between minimum **Ref_rain** and **Ref_clear**)
- Observation errors: **Ref**: 5 dBZ
  Vr: 3 m/s



- Reject data when [y – H(x)] > 10 x obs error
- Reject data when there are too few "raining" (**Ref_rain**) background members:
  (similar to Lien et al. 2013, 2016 for precipitation assimilation)
  Ref_rain obs: require >= 1 (out of 100) background members having **Ref_rain**
  Ref_clear obs: require >= 20 (out of 100) background members having **Ref_rain**
- Limit number of observations used per grid (Hamrud et al. 2015): Max = 100
- Relaxation to prior spread (Whitaker and Hamill 2012): α = 0.95
- Covariance localization:
  Horizontal (**Ref_rain** and **Vr**): 4 km
  Horizontal (**Ref_clear**): 2 km
  Vertical (all): 2 km

Results

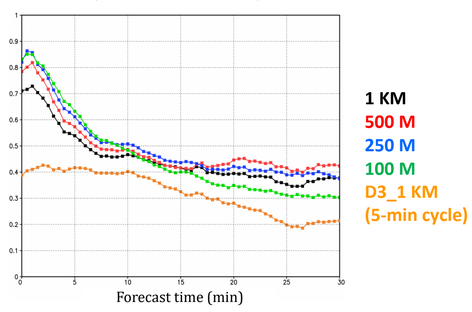


Experiments are performed with the same localization settings and the same observation number limit.

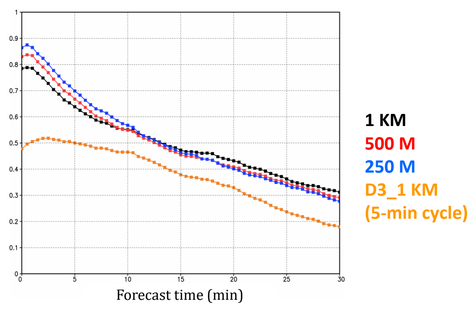
Threat scores are compared to the PAWR reflectivity observation and calculated in 3 dimensions (entire domain, 2.5–4 km height) at 1-km grids; higher resolution data are averaged to the same 1-km grid.

Threat scores – 10 dBZ

(0610Z; **1 forecast**)



(0610Z - 0700Z; **6 forecasts**)

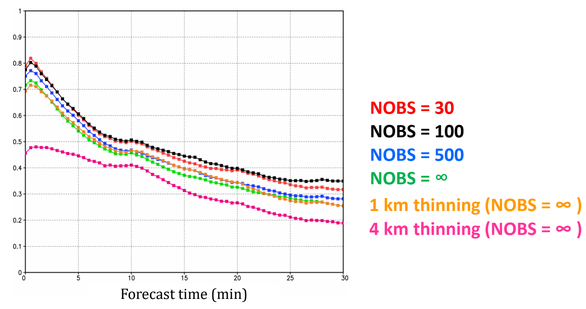


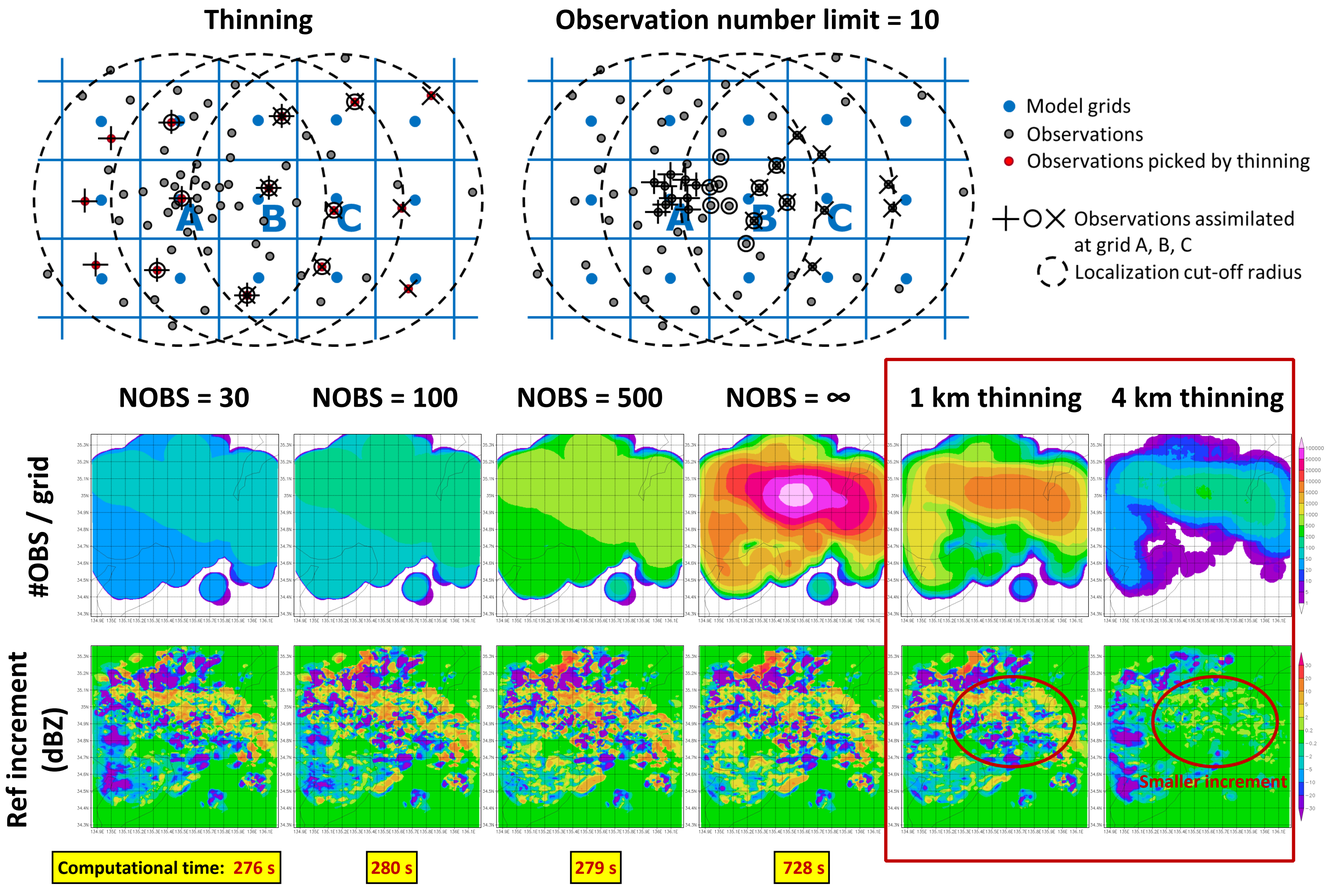
Observation number limit

- Hamrud et al. 2015: Limit the number of observations assimilated per grid point for each combination of different report types (e.g., radiosonde) and variables (e.g., U-wind).
- Observations spatially closest to the analyzed grid are selected.
- Advantages:
  – Improve the results.
  – Save the computational time.

250 M experiments
Threat scores – 10 dBZ

(0610Z - 0620Z; **2 forecasts**)





Summary

- We explore the assimilation of Phased Array Weather Radar (PAWR) data at 1-km – 100-m model resolution with a 30-s rapid-update cycle using the K computer.
- The sub-kilometer radar data assimilation using the LETKF can work!
  – Higher resolution assimilation up to 100 m leads to a better fit to observation, although the benefit does not last beyond 10 minutes in our current experiments.
  – The 30-second update cycle is advantageous over the 5-minutes update cycle.
- Observation number limit (Hamrud et al. 2015) is one of the keys to assimilate such dense observation data.

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