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4th Research Meeting of Ultra-high Precision Meso-scale Weather Prediction

Challenges in Cloud-Resolving Data Assimilation:

Introduction to SPIRE, Field3, 2-Theme1

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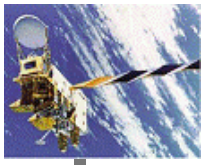
Outline

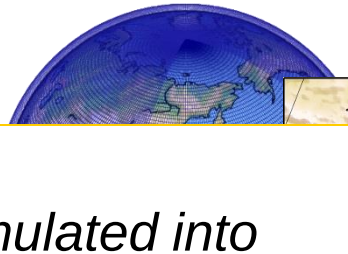
- What is “Data Assimilation”?
- Strategy on data assimilation for mesoscale convective systems
- Development of cloud resolving data assimilation systems
- Some results
- Summary

Definition of Data Assimilation

Data Assimilation System

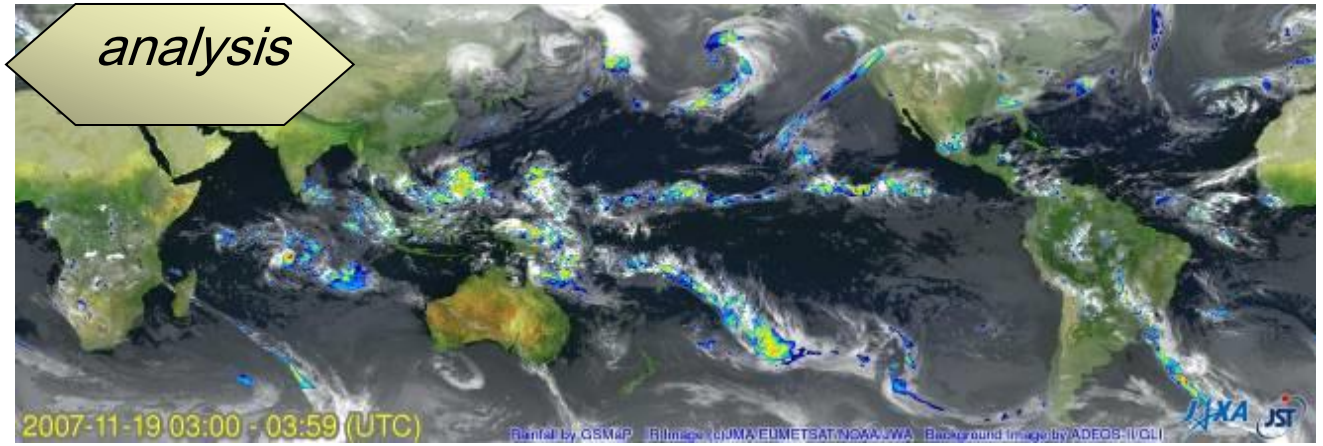
NWP models



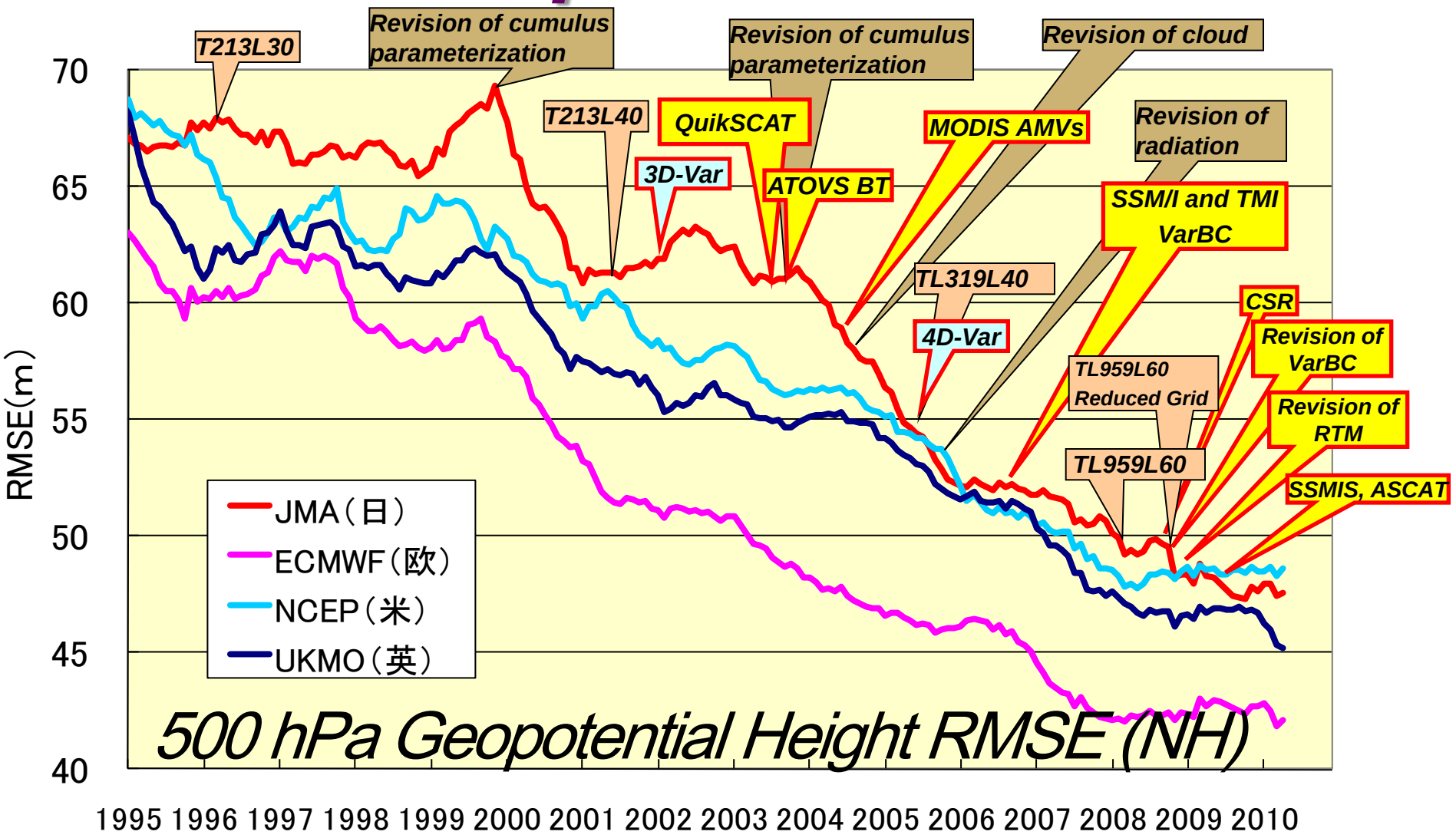

Observe Data

Analysis technique in which the observed information is accumulated into the model state by taking advantage of consistency constraints with the model equations

analysis



DA is important for NWP



Courtesy of Y. Sato (JMA)

Statistical approach to produce analysis data

- Conditional PDF of X given obs. Y:

$$P_{rof}(X \mid Y) \propto P_{rof}(Y \mid X) P_{rof}(X)$$

- Modeling the PDF of first guess and observation error:

$$P_{rof}(X) = P_{rof}(\varepsilon^f)$$

$$\varepsilon^f = X - X^f$$

$$P_{rof}(Y \mid X) = P_{rof}(\varepsilon^o)$$

$$\varepsilon^o = Y - H(X)$$

- Find optimal values that maximize the PDF.

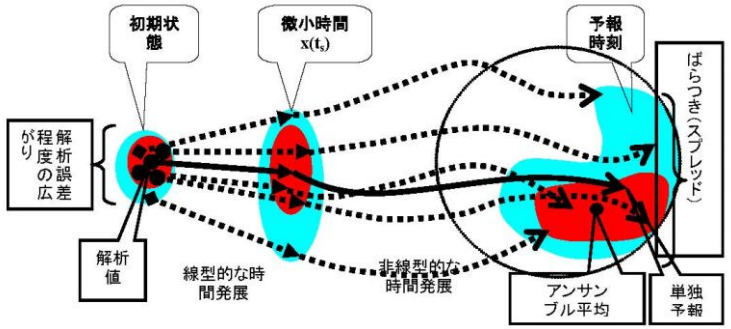
Strategy on data assimilation for mesoscale convective systems

- Ensemble-based data assimilation methods

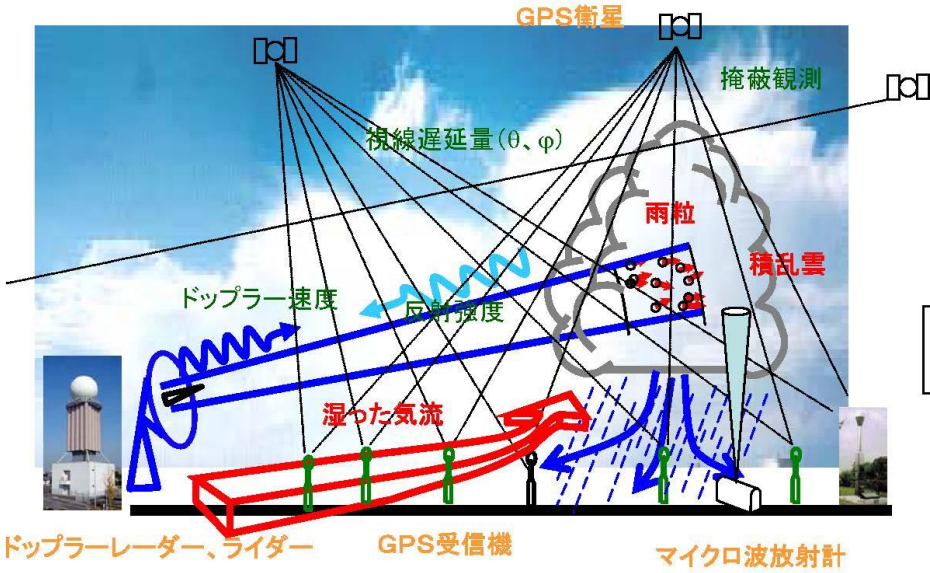
  Nonlinearity or non-Gaussianity.

  Multi-scales:

  cumulus convection vs.environment.

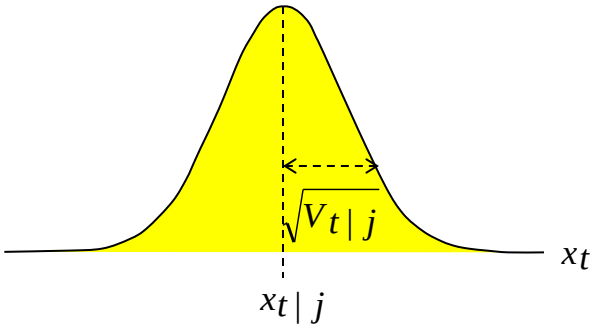


- Assimilation of advanced high-density observational data



Ensemble approximation of PDF (Ueno, 2014)

Gaussian distribution

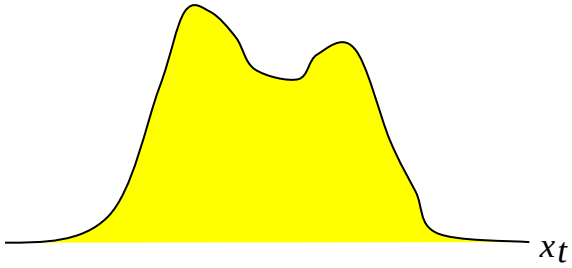


Exactly expressed

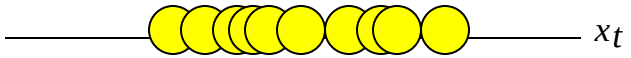
$$N\left(x_{t|j}, V_{t|j}\right)$$

Kalman Filter (KF)

Non-Gaussian



Ensemble/ Particle approximation

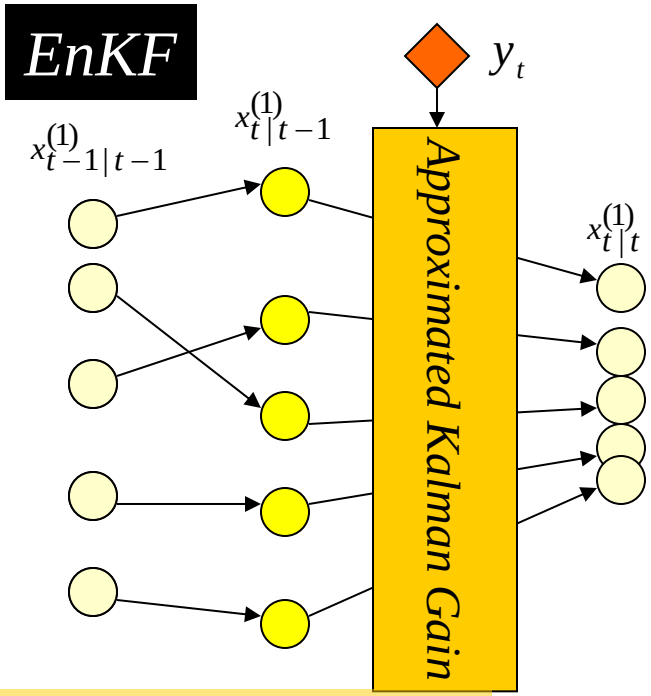


Ensemble Kalman filter(EnKF), Particle filter (PF)

Development of cloud resolving data assimilation systems

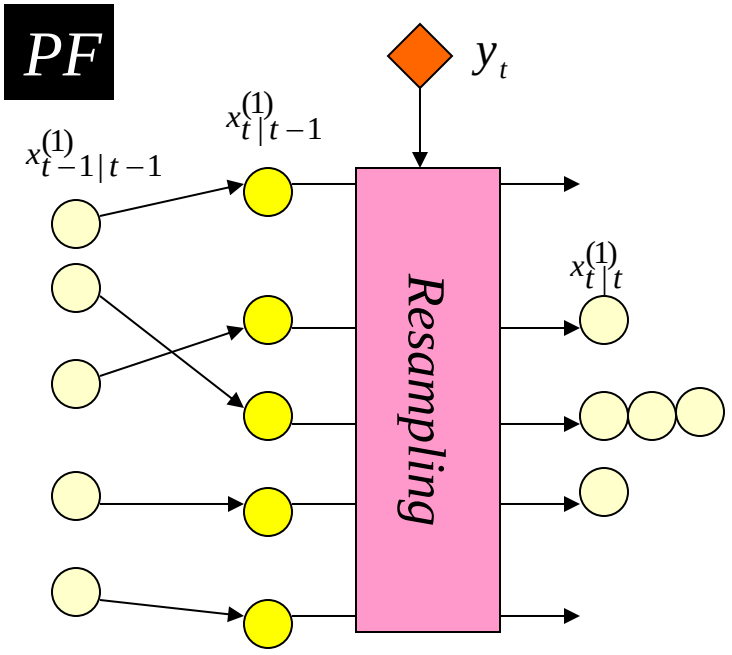
- Development and intercomparison of data assimilation systems for cloud-resolving models
  - NHM-EnVar (MRI)
  - NHM-LETKF (MRI, NPD, JAMSTEC)
  - NHM-Hybrid EnKF-4DVar (MRI, JAMSTEC)
  - NHM-4DVar (MRI, JAMSTEC)
  - CReSS-Hybid (NIED)
  - NHM-PF (ISM)
- Assimilation of advanced observational data
  - Multi-parameter radar data (NIED, DPRI, …)
  - GPS slant total delay data (MRI), …
  - Ground-based microwave radiometer (MRI…)

Development of PF (Ueno, 2014)

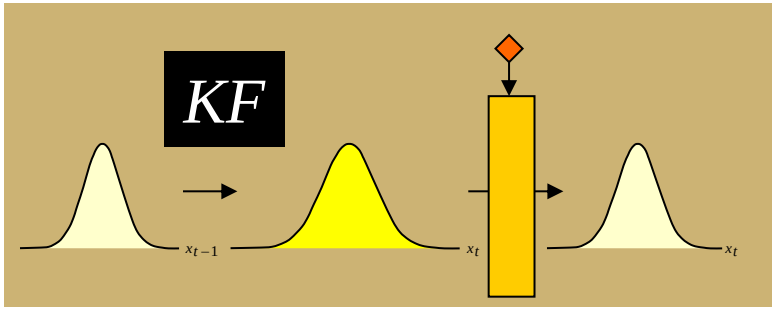


$$K_t = \bar{V}_{t|t-1} H_t \left(H_t \bar{V}_{t|t-1} H_t' + \bar{R}_t \right)^{-1}$$

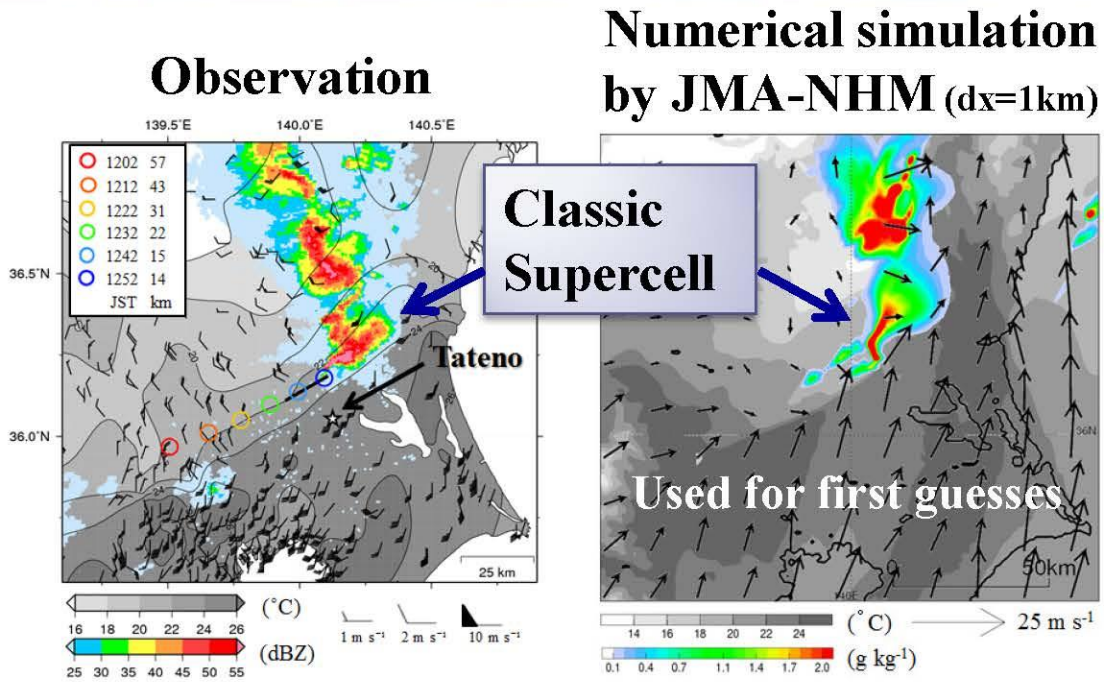
$$x^{(n)}_{t|t} = x^{(n)}_{t|t-1} + \bar{K}_t \left(y_t + w^{(n)}_t - H_t x^{(n)}_{t|t-1} \right)$$



$$p\left(y_t \mid x^{(n)}_{t|t-1} \right)$$



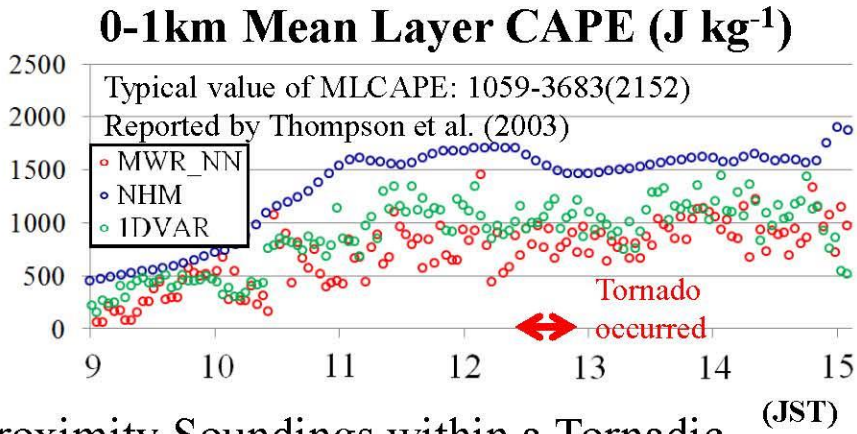
1DVAR using ground-based microwave radiometer



Proximity soundings at intervals of a few minutes and at distances of less than 20 km from a significant tornadic supercell that occurred on 6 May 2012 in Japan were examined.

The **1DVAR technique** successfully reproduced the probable temperature and water vapor profiles during the event.

-> High-frequency thermodynamic profiles would be of benefit in nowcasting severe storms such as significant tornadic supercells.



Araki et al. (2014): Temporal Variation of Close-Proximity Soundings within a Tornadic Supercell Environment. (SOLA, conditionally accepted)