# Ensemble-based Singular Value Decomposition Analysis to Clarify Relationship between the Atmospheric State and the Hydrometeors

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## 1. Introduction

To improve the accuracy of numerical forecasts of local rainfalls through assimilation of observations associated with rainfall, it is important to understand the relationship between the atmospheric state around the precipitation and the hydrometeors in the precipitation. To investigate such relationship statistically, we performed the singular value decomposition (SVD) of the ensemble-based cross-covariance matrix between the atmospheric state and the hydrometeors using 301-member ensemble forecasts of a local rainfall occurred on the Kanto Plain at about 1430JST on 4 August 2016.

## 2. Data Assimilation with NHM-LETKF System

The 301-member initial states of the ensemble forecasts at 1430JST were created by the JMA nonhydrostatic model-based local ensemble transform Kalman filter (NHM-LETKF[1]) with the 1-km horizontal grid interval. In NHM-LETKF, data observed by four C-band radars, GNSS, and a water vapor Raman Lidar were assimilated with the 10-min assimilation window from 1400JST. The additive ensemble perturbations correlated to the atmospheric state were used for the assimilation of the radar reflectivity[2].

## 3. SVD Analysis for the Local Rainfall

We created the ensemble-based cross-covariance matrix between the atmospheric state and the hydrometeors $\mathbf{X}\mathbf{Y}^T$ and calculated its singular values $d_i$ and singular vectors of the atmospheric state $\mathbf{u}_i$ and the hydrometeors $\mathbf{v}_i$ as $\mathbf{XY}^T = \sum_{i=1}^{301} d_i \mathbf{u}_i \mathbf{v}_i^T$. Here, $\mathbf{X} = [\delta\mathbf{x}_1 \dots \delta\mathbf{x}_{301}]/\sqrt{300}$ is the matrix of 301-member ensemble perturbations of zonal wind ($U$), meridional wind ($V$), vertical wind ($W$), potential temperature (PT), pressure ($P$), and water vapor mixing ratio (QV) and $\mathbf{Y} = [\delta\mathbf{y}_1 \dots \delta\mathbf{y}_{301}]/\sqrt{300}$ is that of mixing ratio of cloud water, cloud ice, rain, snow, and graupel at the time of the rainfall (1450JST). The squared covariance fraction of the first mode was about 50%. The heterogeneous correlation maps of the first mode indicated that the hydrometeors in the rainfall were mainly correlated with the convergence of the horizontal wind and humid air below the 2-km height especially before the rainfall (Figs. 1 and 2). It means that correcting the atmospheric state below the 2-km height through the hydrometeor data assimilation is effective for rainfall forecasts.

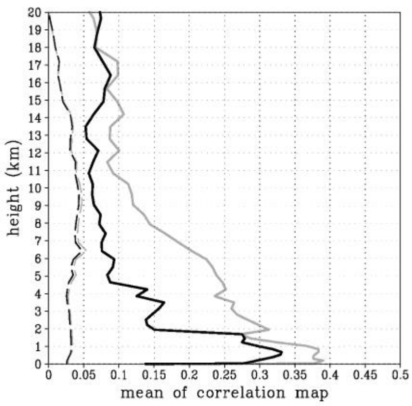


Fig.1. Vertical profile of heterogeneous correlation map of $\mathbf{u}_1$ (solid) and $\mathbf{v}_1$ (dotted) averaged horizontally in the square region (22km × 22km). Black and gray mean the atmospheric states $\mathbf{X}$ at 1430 and 1450JST were used for SVD, respectively.

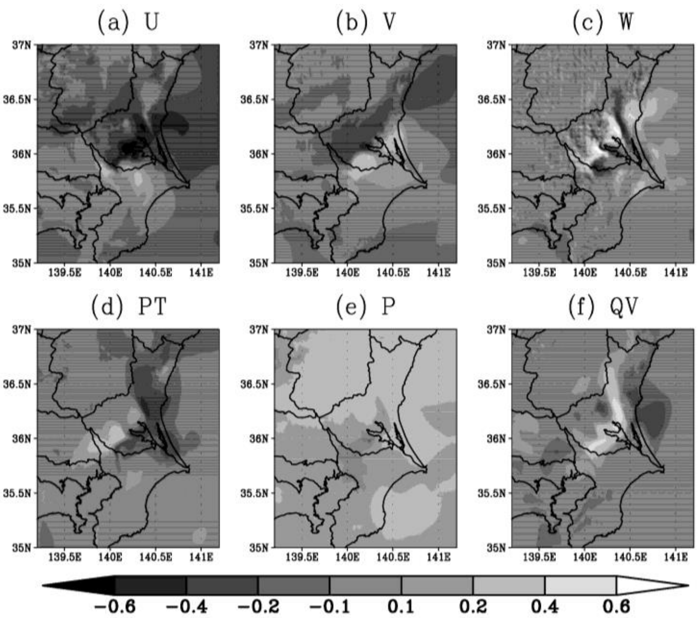


Fig.2. Heterogeneous correlation map of $\mathbf{u}_1$ at 0.4-km height. The atmospheric state $\mathbf{X}$ before the rainfall (1430JST) was used for SVD.

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**References:**

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