

# Development of an Observation Operator for Dual Polarimetric Radar

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## 1 Introduction

In recent years, dual polarimetric radar networks have become operational in several countries (e.g., U.S., France, and Japan). The German Meteorological Service (DWD) is also deploying dual polarimetric radars and is planning to expand it to all over Germany. Polarimetric radars are able to provide various kinds of variables and parameters on hydrometeors (e.g.,  $Z_{DP}$ ,  $K_{DP}$ , and  $Z_{DR}$ ). Thus, we can obtain detailed information on precipitation microphysics such as distribution-density, shapes and types of hydrometeors.

Furthermore, we expect that representations of precipitation in numerical weather prediction (NWP) models could be improved using these observations. The goals of this project are (1) to develop and to implement an observation operator for polarimetric radars in the Weather Research and Forecasting (WRF; Skamarock et al. 2005) model, (2) perform model-observation statistics to study the performance of the cloud-precipitation microphysics (in this case the two-moment Morrison scheme; Morrison and Gettelman, 2008), and (3) the direct assimilation of polarimetric radar data for improving initial conditions of hydrometeors in NWP models. Finally, we will investigate whether the assimilation of polarization data will lead to advanced quantitative precipitation estimation (QPE) and forecasting (QPF).

In this study, we present the status of the model forward operator. It consists of a variable converter (Bakhshaii et al., 2014), a space interpolator and super observations. However, the current form of the operator is not combined with the converter, but just includes the interpolator and super observations. The combination will be shown in our poster presentation.

## 2 Super observation

For model-observation statistics and radar data assimilation, observational data are smoothed within a model grid, because the horizontal resolution of the data is much higher than that of NWP models and the data contains sub-grid scale effect such as short waves. This method is called a super observation method which is often adopted (e.g., Sun, 2005; Kawabata et al. 2011). A large number of observations are interpolated to the center of a model grid with a simple averaging method, or the Cressman method in usual super-observations. Instead, we defined the middle of a segment of a radar beam within a model grid as the interpolation point and then averaged the data on the segment (red circle in Fig. 1). This treatment can reduce uncertainty in the assimilation location. If the number of the data is less than a certain threshold, the data is ignored to avoid contamination of noise. The definition of the threshold should take into account both the grid spacing and the observation density. We are also planning to implement an operational noise estimator for each super observation.

## 3 Space interpolator

First, we introduced the Earth's curvature to the space interpolator. The curvature was directly calculated with the Earth's radius instead of using the 4/3 radius (e.g., Wattrelot et al., 2014), however, the Earth is assumed to be a perfect sphere but not a spheroid.

The simplest interpolation from model grids to super observation points is linear interpolation with surrounding 8 grids. Many interpolators adopt this method, however, a few interpolators consider beam broadening (Seko et al. 2004 and Caumont et al. 2006). A radar beam is broadened with distance, and its modelling is usually assumed as Gaussian. Since horizontal grid spacings in former studies were relatively large compared with observational resolutions, they considered the Gaussian weights only in the vertical. In the near future, horizontal grid spacings of our assimilation systems should be sub-kilometer order (e.g., Kawabata et al. 2014), therefore, we have to consider horizontal Gaussian weights in interpolators. In addition, beams at high-elevation angles ( $> 30^\circ$ ) should be broadened in both horizontal and vertical in the model. Since phased array radars can observe  $0 - 90^\circ$  elevation angles simultaneously, for instance, it is beneficial to consider horizontal broadening. First, we defined a certain point as an interpolation point (red circle in Figure 1), and then search grid points, which are used in the interpolation, orthogonally to the beam. After that, these grids (yellow circles in Figure 1) are interpolated with Gaussian weights in distance. In this procedure, we also defined a certain angle as a beam width (typically  $1^\circ$ ).

#### 4 Result

We assumed a virtual radar site under a particular weather condition and calculated rain water distribution with our super-observation and interpolation methods. The configuration of the radar is as follows: it is located at 32N and 77E; its altitude is 100 m; its antenna height is 50 m; its beam resolution is 200 m; its beam width is 1°; its observational range is 300 km. The simulation data was provided by the WRF model with 30-km grid spacing, and the case was a winter storm occurred on 24-25 January 2000 in the U. S.

Using the pseudo radar configuration and simulation data, we examined the sensitivity of interpolation methods. Figure 2 shows that the horizontal distribution of mixing ratio of rain water interpolated on the 0° elevation angle plane of the virtual radar. Two strong convective area can be seen in both Figs. 2a and 2b, however, the intensity in Fig. 2a is stronger than that in Fig. 2b. If a strong convective core exists in a certain layer, this result makes sense, because actual observations far from the radar site include both strong and weak region of convective cores due to beam-broadening.

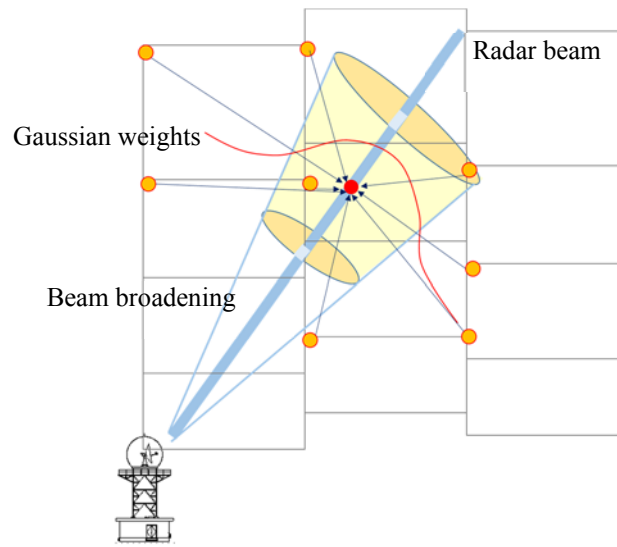


Figure 1: Schematic diagram of the space interpolator. The red circle indicates a super observation, located at the middle of a segment of a beam. Yellow circles show grid points which are used in the interpolation. The red curved line illustrates the Gaussian weights for the interpolation points (yellow circles). Thin yellow area indicates observational volume considered in this interpolation.

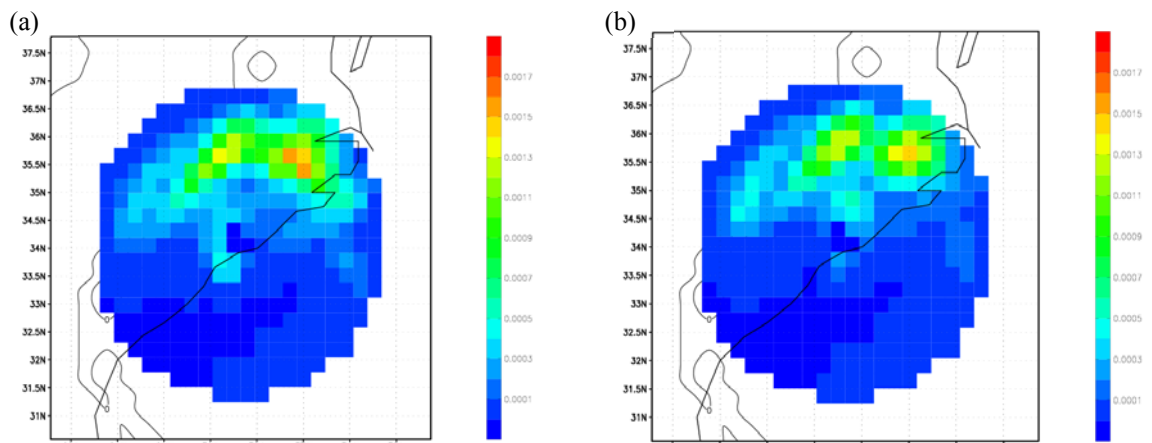


Figure 2: Horizontal distribution of mixing ratio of rain water at a 0° elevation angle plane. (a) Linear interpolation to the center of a model grid. (b) Gaussian-weighted interpolation to the middle of a segment of a radar beam

#### 5 Future plan

Bakhshaii et al. (2014) have already developed a variable converter from the WRF model output to diagnosed polarimetric parameters ( $K_{DP}$  and  $Z_{DR}$ ), which is based on Jung et al. (2008). They compared their method with general characteristics of polarimetric parameters in a super-cell storm. We are planning on developing the combination of our space interpolator with

Bakhshaii et al. (2014). Because their method was only implemented to an S-band radar, we will apply it to other wave length (C- and X-bands). Moreover, we will include a noise estimator and compare predictions by WRF with actual observations and examine model statistics in polarimetric variables and parameters.

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