Development of a Method to Estimate Airflow within a Storm

Background

Precipitation forecasting associated with strong wind is important for operations and maintenance of hydropower dams and facilities for transmitting electric power. We have already developed a method of Extended Volume Velocity Processing (EVVP) for estimating a horizontal wind field from single-Doppler radar observations. Data observed by single-Doppler radar, however, have information of wind in the radial direction, so that a three-dimensional wind field basically cannot be estimated only using single-Doppler observations without any assumptions. Thus, several ideas and assumptions are introduced in EVVP method, and this method is demonstrated to estimate a reasonable horizontal wind field qualitatively. Now, quantitative evaluation of EVVP method is remaining. Though an in-situ observation of a three-dimensional wind is difficult to perform, estimation of a wind field is possible by using observations from dual-Doppler radar and fewer assumptions than EVVP method.

Objectives

A dual-Doppler analysis method for estimating a three-dimensional wind field is developed with data from synchronous observations by two Doppler radars. A wind field from dual-Doppler analysis is used to evaluate the performance of EVVP method.

Principal Results

1. Development of a dual-Doppler analysis method

Since three independent observations of radial velocity by Doppler radars are required for estimation of a three-dimensional wind field, an underdetermined problem occurs even when data from two Doppler radars are used. Then, we solve the underdetermined problem by introducing the anelastic continuity equation of air density (Fig.1). A variational adjustment is performed to minimize the error of vertical velocity calculation with the continuity equation.

2. Application of the dual-Doppler analysis to a case of thunderstorm

Application of the dual-Doppler analysis reveals four typical features of a wind field within a thunderstorm as follows (Figs. 2, and 3);

(1) Twin cyclonic and anti-cyclonic vortices exist.
(2) Convergence of wind in the low and middle levels of the atmosphere is found.
(3) Divergence of wind in the upper part of the storm is prominent.
(4) Environmental airflow around vortices is analyzed.

3. Evaluation of EVVP method

EVVP method is a simplified method to estimate a horizontal wind field with data from single-Doppler observation. Comparison of EVVP-derived wind with wind derived from dual-Doppler analysis shows good agreement (Fig.4). Data quality of EVVP-derived wind is good enough to be used for assimilation into a numerical weather forecasting model.

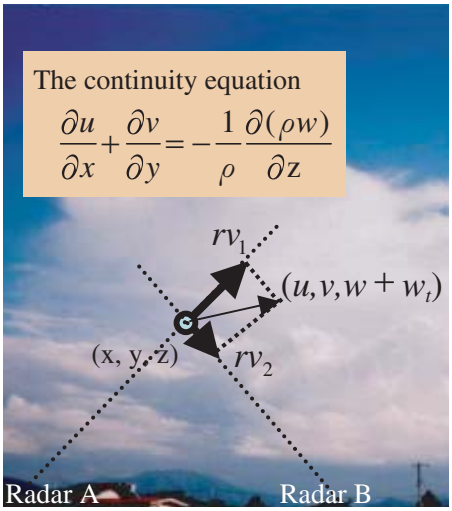
Future Developments

A data assimilation technique will be developed to combine precipitation amount and radial velocities observed by radar with output from a numerical meteorological forecasting model. Such a technique is expected to improve short-term precipitation forecasting with sophisticated initial and boundary conditions for simulation.

Main Researcher: Soichiro Sugimoto,
Research Scientist, Fluid Dynamics Sector, Civil Engineering Research Laboratory

Reference

Sugimoto, S., and Y. Toyoda, 2005, “Development and application of a method to analyze a three-dimensional wind field using data from dual-Doppler observations”, Technical Report N04021 (in Japanese with English abstract)



#1 Hydrometeor moves along the combined component of air motion and the fallspeed of hydrometeor.
#2 Doppler radar observes the radial component of hydrometeor motion.
#3 The fallspeed of hydrometeor is estimated using an empirical relationship with intensity of radar echo.
#4 Unknowns are west-east, north-south, and vertical wind velocities.
#5 Three unknowns are estimated with two radial velocities and the continuity equation.

rv_1	: Radial velocity (by Radar A)	u: West-east wind velocity
rv_2	: Radial velocity (by Radar B)	v: North-south wind velocity
ρ	: Air density	w: Vertical wind velocity
(x,y,z): Location of radar data		w_t: Vertical fallspeed of hydrometeor

Fig.1 Conceptual schematic of dual-Doppler analysis

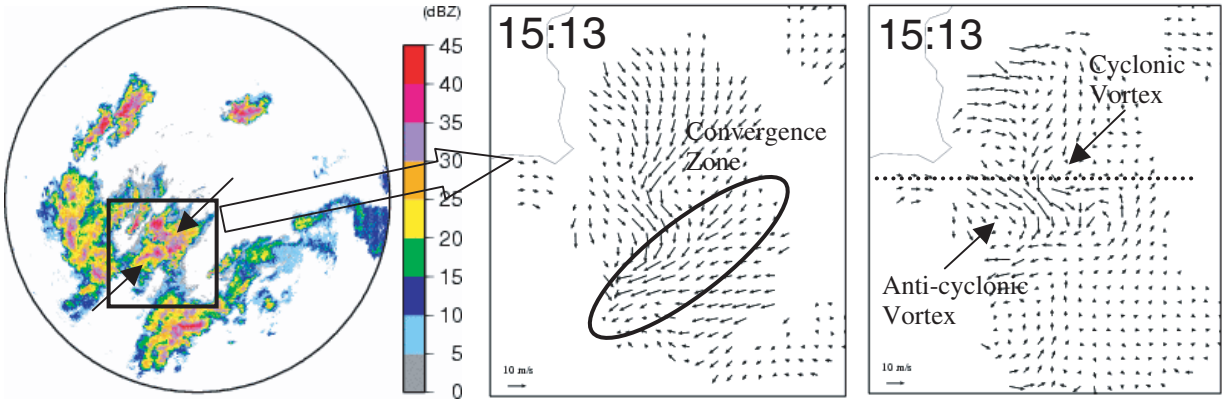


Fig.2 Echo intensity observed by radar (Left) and a horizontal wind field estimated by dual-Doppler analysis (Middle: 2 km height, Right: 3 km height).

Updraft due to a convergence zone (circled line) found at 2 km height is a trigger for lifting vertical circulation in the atmosphere, so that twin cyclonic and anti-cyclonic vortices are developed. Strong precipitation is observed around twin vortices.

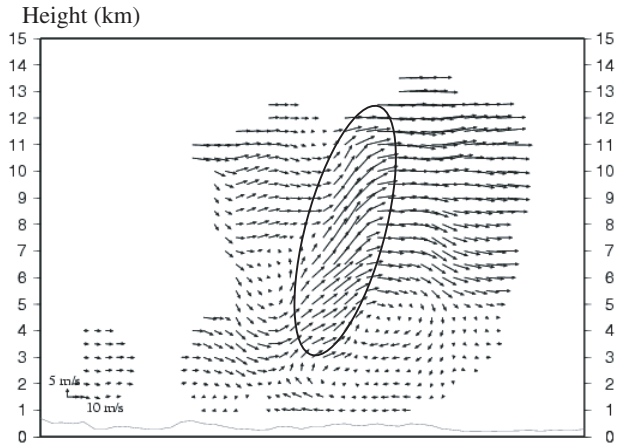


Fig.3 Vertical structure of a wind field (Cross section along a dotted line in Fig. 2)

Updraft above the height of 10 km (circled line) is found around the area where a cyclonic vortex exists, which indicates that a cyclonic storm tends to develop stronger.

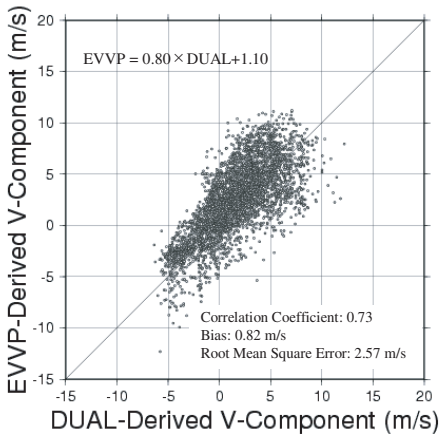


Fig.4 Scatterplot for evaluation of the EVVP method (West-east direction; V-component)

Comparison between winds from two different methods shows good agreement.