The generation mechanism of upper vortex street seen in water vapor image

Yasumitsu Maejima[1]; Keita Iga[2]; Hiroshi Niino[3]

[1] Ori, Univ. of Tokyo; [2] ORI, Univ. of Tokyo; [3] Div. of Marine Meteor., Ocean Res. Inst., Univ. of Tokyo

Vortex streets are often found in atmosphere and many cases have been reported until now. For example, meso-beta-scale vortex street along convergent cloud band is often observed in winter western Japan Sea. This vortex street is generated in strong horizontal shear zone of convergent cloud band, and Nagata (1993) concluded that barotropic instability is dominant generation mechanism of these vortices by calculating linear stability of two-dimensional barotropic flow

The genesis of a vortex street along cold front was also examined by Toyoda and Niino (1999). They simulated the characteristic weak wind region in mid-troposphere, and correspondingly horizontal shear zone, and showed that it was formed by vertical advection of momentum in convective clouds along cold front. They also calculated the linear stability of simulated field, and showed that the vortex street was generated by barotropic instability.

Many other vortex streets have been observed, but the genesis of vortex street have not been analyzed in most cases because of the luck of observational data. In resent years, water vapor images are used in analyzing upper layer phenomena in addition to infrared images, and new upper vortex streets are found. However, vortices in upper troposphere are scarcely, and little information has been obtained on the genesis.

In this study, we investigate the vortices observed in water vapor images on 6 July 2005, and elucidate the genesis of upper vortex street by linear stability analysis. First, we examine the environmental field by analyzing the forecast data of JMA regional spectrum model (RSM) and discuss the predictability of upper vortex street. Second, we calculate linear stability of the basic field of the RSM data. We compare the features of observed upper vortex street with those of the unstable modes. In addition, we examine energy conversion in these unstable modes.

Water vapor image show that upper vortex street was started to form around 06UTC 6 July 2005. Wave length is about 300km or 400km and estimated phase speed is about 8.5m/s. The RSM data of the cross section at longitude 143 degrees east at 00UTC 6 July show that strong horizontal shear zone is formed around latitude 44 degrees north from 200 hPa to 400hPa. It seems that the upper vortex street is generated along this horizontal shear. Thus we consider cross section at longitude 143 degrees east of RSM data as characteristic basic field, and calculate linear stability of the field under quasi geostrophic system. Upper and lower boundary conditions are no horizontal gradient of perturbation potential temperature. As a result, characteristic unstable modes whose wave lengths are about 400km are generated. Their e-folding times are about 11 hours and their phase speeds are about 8.0m/s: these values agree with those of observed vortex streets in both spatial scale and time scale. Next, we examined the features of these unstable modes. They have large amplitude in upper horizontal shear zone and positive momentum is transported from strong wind area to weak wind area. In addition, energy conversion analysis shows that energy conversion from mean kinetic energy to eddy kinetic energy is much larger than other conversion terms. In the result, upper vortex street is generated by barotropic instability.