Tropical Cyclone Intensity Change in a Uniform Flow

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1. Introduction

In recent tropical cyclone (TC) modeling studies, much efforts have been devoted to the effect of environmental vertical wind shear on TC intensity change (e.g. Bender 1997; Frank and Ritchie 1999, 2001; Wong and Chan 2004). It is generally concluded that the vertical wind shear has a negative impact for TC intensification. However, discrepancies of results are found for a simple case of a TC under the influence of a uniform flow. Frank and Ritchie (2001) found that a TC in a 3.5 m s^{-1} uniform background flow slightly intensifies compared with a no-flow case while Peng et al. (1999) showed that a TC weakens in a uniform flow of 5-10 m s^{-1}. This study therefore attempts to investigate the effect of uniform flow on TC intensity changes.

2. Model configuration

The Pennsylvania State University / National Center of Atmospheric Research Mesoscale Model version 5 (MM5) is used in this study. The domain size is 301 x 301 grid points with 24 sigma levels, and the grid resolution is 15 km. The Betts-Miller (Betts and Miller 1986) cumulus parameterization scheme is used to spin-up the vortex for 24 h of model time. Uniform flow with 0 – 8 m s^{-1} is imposed on both *f* and beta planes with the Betts-Miller scheme turned off.

3. Results

A stronger uniform flow imposed on an *f* plane results in a weaker vortex (Fig. 1a), which is due to the development of vertical wind shear induced by an asymmetry in vertical motion. Wavenumber-1 asymmetries in vertical motion and a rotation of the upper-level anticyclone appear to reduce the secondary circulation of the vortex, which introduces a vertical wind shear. The induced vertical wind shear further weakens the secondary circulation of the vortex as described by Wong and Chan (2004) so that the vortex under a strong uniform flow weakens with time. For a weak uniform flow, the asymmetric vertical motion is not strong enough to reduce the secondary circulation so that vertical wind shear cannot develop.

For the cases on a beta plane, the TC in the no-flow case weakens significantly by the beta-induced shear relative to that on an *f* plane. Moreover, a westerly flow is more favorable for TC intensification than easterly flow (Fig. 1b). It is because the beta-induced shear vector is towards the southeast, so a westerly uniform flow enhances TC development by canceling part of the beta-induced shear whereas an easterly flow strengthens it by altering the magnitude and direction of the shear vector (Fig. 2).

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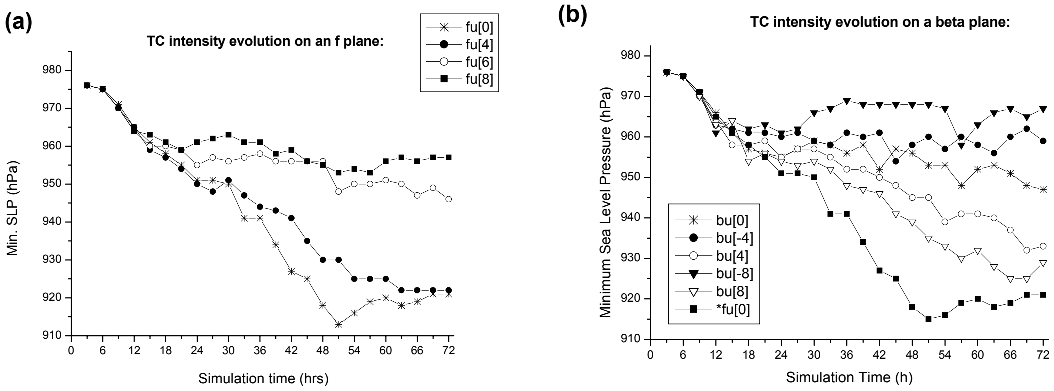

Fig. 1. Intensity evolution of vortices on (a) f plane and (b) beta plane, (symbol fu[x] & bu[x] represent f-plane and beta-plane experiments respectively, the number insides the brackets denote the uniform flow speed, positive number indicates a westerly flow while negative number indicates an easterly flow).

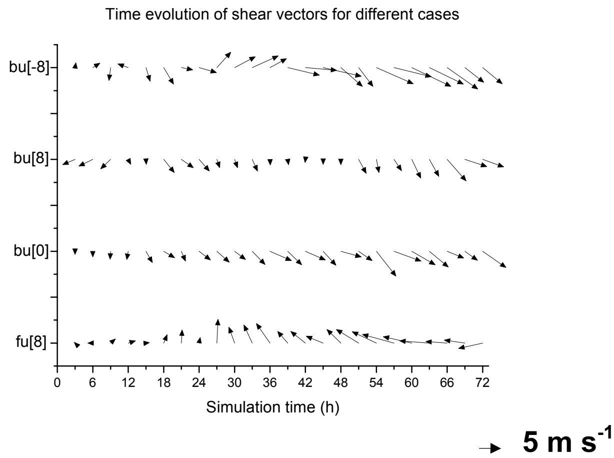

Fig. 2. Time evolution of the vector shear for the fu[8], bu[0], bu[8] and bu[-8] cases respectively.