Scientist:

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Model Name and History:

- Long name : Vector Vorticity Model
- Acronym (to be used in graphics & data files naming) : CSUVVM
- Short/conversational name (other than acronym, if any) : VVM, VVCM
- Generic predecessor or relative (name/variant, and acronym,
whether or not it also takes part in this study) : VVCRM, VVCRM V1.0, VVCM V1.1

Model Type: 3D

Numerical Domain:

- Domain size in x-direction: 176 km
- Domain size in y-direction: 176 km
- Domain size in z-direction: 24593.78 m
- Number of grid points in x-direction: 177
- Number of grid points in y-direction: 177
- Number of grid points in z-direction: 40
- Grid size in x-direction: 1 km
- Grid size in y-direction: 1 km
- Grid size in z-direction (if stretched please specify): Stretched vertical grid following Krueger, S. K., 1988: Numerical simulation of tropical cumulus clouds and their interaction with the subcloud layer. *J. Atmos. Sci*., **45**, 2221-2250.

- Time step : 5 sec

Numerical Technique:

- Numerical method (finite-difference, spectral, etc.): Finite Difference
- Advection scheme and its order of accuracy: Eulerian upstream-weighted partially 3rd order, quadradically bounded scheme for scalar and vorticity components (3rd order accuracy when flow is uniform)
- Time scheme and its order of accuracy: Adams-Bashforth 2nd order
- Dynamical equations (elastic, anelastic, etc.): anelastic - Lipps, F. B., and R. S. Hemler, 1982: A scale analysis of deep moist convection and some related numerical calculations. *J. Atmos.*

Sci., **39**, 2192–2210.
- Numerical diffusion (type, order, magnitude of coefficient) Richardson-number-dependent non linear diffusion, minimum of 10 m^2 s^-1,
- Lateral boundary conditions: cyclic
- Upper boundary condition (Sponge layer, specification, ...): w and horizontal vorticity components=0, Rayleigh type gravity wave damping, sponge layer - Modified for TWP-ICE, SIN^2 VERTICAL DEPENDENCE 20-24KM

Physical Parameterizations:

- Surface flux parameterization for heat, moisture, momentum: Deardorff, J. W., 1972: Parameterization of the planetary boundary layer for use in general circulation models. *Mon. Wea. Rev*., **100**, 93–106.

- Longwave radiation parameterization: RRTMG http://rtweb.aer.com/rrtm_frame.html
- Shortwave radiation parameterization: RRTMG http://rtweb.aer.com/rrtm_frame.html

- Microphysical (2D/3D models) or cloud/convective (1D model) parameterization: Microphysical processes are parameterized with a bulk method essentially following Lord *et al.* (1984) and Lin *et al.* (1983). Major modifications have been made by Krueger *et al.* (1995) on the growth of cloud ice by the Bergeron process, the conversion of cloud ice to snow, and the characteristics of graupel.

- Turbulence closure scheme (turbulence closure type, variables predicted and diagnosed by - - the turbulence closure, closure for turbulent length scale, ...) First order turbulence closure scheme that uses eddy viscosity and diffusivity coefficients depending of deformation and stability is used. Shutts, G. J. and M. E. B. Gray, 1994: A numerical modeling study of the geostrophic adjustment process following deep convection. *Q. J. R. Meteor. Soc*., **120**, 1145-1178.

Documentation:

Please provide references that more fully describe your model.
- Documentation (present model), if available.
- Documentation (predecessor or relative) – optional if the preceding is available.

Jung, J.-H., and A. Arakawa, 2008: A three-dimensional anelastic model based on the vorticity equation. *Mon. Wea. Rev.*, **136**, 276-294.
http://kiwi.atmos.colostate.edu/pubs/joon-hee-tech_report.pdf

TWP-ICE Deviations and Notes:
-Sensitivity Test
-Missing data fields: number concentrations, projected areas, dBZ, Doppler velocities, mean mass diameter, optical properties (model does not compute these fields)
-Missing Input: Model lacks ability to specify aerosols.