TOWARDS BETTER UNDERSTANDING OF PREFERENTIAL CONCENTRATION IN CLOUDS:
DROPLETS IN SMALL VORTICES
Katarzyna Karpińska *, Szymon Malinowski *
* Institute of Geophysics, Faculty of Physics, University of Warsaw

1. INTRODUCTION
Recent studies attribute the evolution of droplet size distribution in warm convective clouds to enhancement of collision-coalescence by turbulence. The aim of this study is a better understanding of enhanced collisions and preferential concentration from numerical analysis of droplet motion in vortex tubes: small coherent structures characteristic for high Reynolds number turbulent flows. Former research of such effects by Hill 1 and by Markowicz et al.2 was limited to horizontally oriented vortex tubes only. Herein we analyse tubes which are parallel or oblique to the direction of gravity.

2. DROPLET DYNAMICS
Motion of droplet governed by the Stokes equation was calculated in predefined velocity field. 3D numerical simulations were done for two sets of field parameters.

3. DROPLET MOTION ANALYSIS

3.1. Z direction
Motion in plane perpendicular to vortex axis separates from the direction parallel to it.

Analytical solution for $z(t) = z_0$, $z(t) = 0$:

$$z(t) = \frac{\lambda}{\lambda_+ - \lambda_-} \left( \lambda_+ \exp(\lambda_- t) - \lambda_- \exp(\lambda_+ t) \right) + z_0$$

$\lambda = \lambda(K_1)$, $\lambda_+ > 0$, $\lambda_- < 0$

Motion in 2 direction depends only on initial position of a droplet:

- $z_0 < z_{0b}$
- $z_0 > z_{0b}$

- exponential decrease
- exponential increase

3.2. XY plane
Motion in XY plane depends on initial position of droplet:

- $v_x(t) = \frac{\gamma}{(1-\sin^2\theta)^{1/2}} \sqrt{R_0 - R}$
- $v_y(t) = 0$

Simple case: vortex parallel to gravity
Droplet gets on its stable, steady orbit, where radial viscous and centrifugal forces equalize.

Orbit radius $r_{st} = \frac{\lambda_1}{\lambda_-}$ unstable, steady position
Orbit angular velocity $\omega_{st} = \frac{\Gamma}{2R}$

Existence conditions:

$\frac{\lambda}{\lambda_+} \leq 1$
$\sin \theta \geq \frac{\sqrt{\lambda/\lambda_+}}{\lambda_-}$

4. NUMERICAL SIMULATIONS
Equation of motion for droplet in predefined velocity field:

$$m\ddot{r} = m\gamma \left( \mathbf{v}_0 - \mathbf{r} \right) + mg$$

Solutions of equations depend on 3 nondimensional parameters:

- motion in plane XY depends on $K_1$ and $K_3$,
- in Z-direction - on $K_1$ and $K_2$.

4.1. Trajectories of droplets of uniform size in XY plane

4.2. Frames of motion of randomly distributed droplets

5. CONCLUSIONS
Features such as stationary orbits, stationary points and limit cycles were identified as three-dimensional structures leading to enhancement of preferential concentration. Their conditions of existence were described. Theoretical results were in a good agreement with numerical simulations.

6. REFERENCES