## Decription for the general public

Clouds are an integral component of the Earth's atmosphere and play an important role in weather and climate. The way clouds interact with the climate system depends on sizes of liquid water droplets that make up a cloud. Cloud droplets are formed on tiny aerosol particles. They grow by condensation of water vapor and, once their sizes are of the order of tens of micrometers, they collide and coalesce with each other, what produces rain drops. The process of collision and coalescence is of tremendous importance for rain formation. As unlikely as it seems, there are still many unresolved questions regarding the collision-coalescence process. For example, it is still not known why some clouds quickly produce rain, within 20 minutes from their formation.

The process of collision-coalescence, although relatively simple from the perspective of a single droplet, is impossible to be treated directly on the scale of a cloud, because of the vast number of droplets involved (one cubic meter contains around a hundred million of droplets). Therefore cloud studies use approximate representations of the collision-coalescence process.

Our understanding of clouds is largely based on numerical modeling. The most detailed numerical models capable of modeling whole clouds simulate collision-coalescence using an equation proposed by Marian Smoluchowski at the beginning of the XX century. This equation predicts a mean result of the essentially random collision-coalescence process. Therefore the Smoluchowski equation cannot capture the "lucky droplets" effect. The idea of the "lucky droplets" is that a small fraction of droplets (one in a million) collide much more often than other droplets. The hypothesis that "lucky droplets" are responsible for quick production of rain is still on the table, although it was proposed more than half a century ago. Another source of doubt regarding the use of the Smoluchowski equation in cloud modeling is that the equation is based on some assumptions that are poorly understood in the context of cloud modeling.

Many studies conducted in the past did not give a definite answer to the question of correctness of the Smoluchowski equation for modeling collision-coalescence in clouds. There are many reasons for that. One is that there were no better numerical models known that could be used to validate the Smoluchowski equation. Another problem was the lack of sufficient computational power to conduct large-scale simulations. New numerical techniques for modeling cloud droplets, in particular the Super-droplet Method introduced to cloud physics in 2009 by the Japanese researcher Shin-ichiro Shima, allow us to revisit the problem of correctness of the Smoluchowski equation, i.e. to find an answer to the fundamental question – is rain formation **deterministic or stochastic**? Within the proposed project we will look for an answer to this question using numerical modeling over many scales: from single cubic meters of air to cloud fields over an area of hundreds of square kilometers. It is worth to note that the Super-droplet Method is a very promising novel approach to modeling cloud droplets, that has many advantages over the more traditional methods. Institute of Geophysics at the University of Warsaw is one of few research centers that is already using this method.

The proposed project will advance our understanding of fundamental cloud physics processes, and will help develop improved representations of clouds in weather and climate models.