The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals? III. Sedimentation driven coagulation inside the snow-line

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We investigate dust growth due to settling in a 1D vertical column of a protoplanetary disk. It is known from the observed 10 micron feature in disk SEDs, that small micron-sized grains are present at the disk atmosphere throughout the lifetime of the disk. We hope to explain such questions as what process can keep the disk atmospheres dusty for the lifetime of the disk and how does the particle properties change as a function of height above the midplane. We use a Monte Carlo code to follow the mass and porosity evolution of the particles in time. The used collision model is based on laboratory experiments performed on dust aggregates. As the experiments cannot cover all possible collision scenarios, the largest uncertainty of our model is the necessary extrapolations we had to perform. We simultaneously solve for the particle growth and motion. Particles can move vertically due to settling and turbulent mixing. We assume that the vertical profile of the gas density is fixed in time and only the solid component evolves. We find that the used collision model strongly influences the masses and sizes of the particles. The laboratory experiment based collision model greatly reduces the particle sizes compared to models that assume sticking at all collision velocities. We find that a turbulence parameter of alpha = 10^-2 is needed to keep the dust atmospheres dusty, but such strong turbulence can produce only small particles at the midplane which is not favorable for planetesimal formation models. We also see that the particles are larger at the midplane and smaller at the upper layers of the disk. At 3-4 pressure scale heights micron-sized particles are produced. These particle sizes are needed to explain the 10 micron feature of disk SEDs. Turbulence may therefore help to keep small dust particles in the disk atmosphere.

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