Modeling the ascent of sounding balloons: Derivation of the vertical air motion

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A new model to describe the ascent of sounding balloons in the troposphere and lower stratosphere (up to 30-35 km altitude) is presented. Contrary to previous models, detailed account is taken of both the variation of the drag coefficient with altitude and the heat imbalance between the balloon and the atmosphere. To compensate for the lack of data on the drag coefficient of sounding balloons, a reference curve for the relationship between drag coefficient and Reynolds number is derived from a dataset of flights launched during the Lindenberg Upper Air Methods Intercomparisons (LUAMI) campaign. The transfer of heat from the surrounding air into the balloon is accounted for by solving the radial heat diffusion equation inside the balloon. The potential applications of the model include the forecast of the trajectory of sounding balloons, which can be used to increase the accuracy of the match technique, and the derivation of the air vertical velocity. The latter is obtained by subtracting the ascent rate of the balloon in still air calculated by the model from the actual ascent rate. This technique is shown to provide an approximation for the vertical air motion with an uncertainty error of 0.5 m/s in the troposphere and 0.2 m/s in the stratosphere. We show that the air vertical velocities and associated air cooling/heating rates derived from the balloon soundings in this paper are in general agreement with small-scale temperature fluctuations related to gravity waves, mechanical turbulence, or other small-scale air motions measured during the SUCCESS campaign (Subsonic Aircraft -Contrail and Cloud Effects Special Study) in the orographically unperturbed mid-latitude middle troposphere.