A nonlinear photochemical-dynamical model and application for interpreting overturning gravity waves of lidar observations

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A time-dependent, nonlinear, photochemical-dynamical 2-D gravity wave model is developed. The model composed of 4 modules: a dynamical gravity wave model, a middle atmospheric photochemical model, a sodium layer photochemical model and an ionospheric model. We study the evolution of the sodium layer (80 – 110 km) in the presence of an overturning (or convectively unstable) gravity wave using model simulations and Na lidar observations. The observations are a nine-day (210 h) continuous data set of sodium density and temperature lidar measurements from Fort Collins, Colorado (41N, 105W). We model the evolution to large-scale (vertical wavelength of 30 km) and small-scale (vertical wavelength of 10 km) waves and the evolution of the sodium layer. We use filtering methods to identify waves of similar scales in the lidar measurements. The semidiurnal tide is the dominant large scale-wave in the lidar observations. We find that the model and observations show similar behavior in the evolution of the sodium densities, mixing ratios, and potential temperature in response to large- and small-scale waves. The model and observations indicate that the sodium density perturbation has a more pronounced overturning behavior in the bottomside of the layer than the topside of the layer. The sodium density also has a more pronounced overturning behavior than the mixing ratio and potential temperature. At the bottomside of the sodium layer, a gravity wave with a small vertical scale can lead to overturning in the sodium density even when the wave is stable. The study suggests that the evolution of the mixing ratio of atomic sodium is a very good tracer for the overturning of the gravity wave and can give a reliable determination of the atmospheric instability.