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The Meteoric Ni Layer in the Upper Atmosphere

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The ablation of cosmic dust particles is a source of metallic vapours in planetary upper atmospheres. Recently, ground-based lidars have made the first observations of a layer of Ni atoms peaking around 86 km in the terrestrial atmosphere (in contrast, the layers of Na and Fe have been observed for several decades). In order to understand these Ni layer observations, we have developed a new version of the Leeds Chemical Ablation Model (CAMBOD) to include a Ni-Fe-S metallic phase in addition to the bulk silicate phase. The validity of the new model was tested using our laboratory Meteoric Ablation Simulator, where micron-size meteoritic particles were flash heated to temperatures as high as 2700 K to simulate their atmospheric entry, and the ablating Ni atoms monitored by fast time-resolved laser induced fluorescence.

The first global atmospheric model of Ni (WACCM-Ni) was then developed with three components: the Whole Atmosphere Community Climate Model (WACCM6); a meteoric input function derived by coupling an astronomical model of dust sources in the solar system with CABMOD; and a comprehensive set of neutral, ion-molecule and photochemical reactions pertinent to the chemistry of Ni in the upper atmosphere. The kinetics of these reactions were mostly measured in our laboratory, or else modelled theoretically using ab initio quantum calculations combined with statistical rate theory. WACCM-Ni simulates satisfactorily the observed neutral Ni layer peak height and width, as well as Ni^+ ion measurements from rocket-borne mass spectrometry. The Ni layer is predicted to have a similar seasonal and latitudinal variation as the Fe layer, and its unusually broad bottom-side compared with Fe is caused by the relatively fast NiO + CO -> Ni + CO_2 reaction. The quantum yield for photon emission from the reaction between Ni and O_3, which has been observed in the nightglow from space-based spectrometers, is estimated to be between 6 and 40%.