Gas heating and chemical impact of Sprite streamer channels in the Earth mesosphere

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We present results obtained through a kinetic model of air plasmas generated in the presence of sprite streamer channels. The model includes a sophisticated chemical scheme as well as the resolution, in a self-consistent way, of the energy conservation equation to investigate the thermal impact of sprite streamers in the surrounding gas. We have identified the main kinetic mechanisms responsible of the gas heating as well as the evolution of the chemical species in the air plasma. We have found that the activity of sprite streamers in the mesosphere considerably affects not only the electron density but also the concentration of neutral key species such as NO and N_2O, both responsible of the mesospheric ozone balance. Our results also show an increase, of about 1 K at 65 km, in the gas temperature that becomes less important as altitude grows

1. Introduction

Sprites are huge electrical discharges in the Earth mesosphere due to positive cloud to ground lightning strokes in the troposphere. The chemical evolution of the mesospheric species due to the action of sprite streamers is still being studied. Sentman *et al.* [1] and Gordillo-Vázquez [2], both in 2008, proposed two different kinetic models which can explain the important chemical evolution of a great set of atmospheric components, i.e. neutral species like NO or N_2O.

The possibility of the gas heating in sprite streamer channels is still a subject of ongoing research. In 1998, Pasko *et al.* [3] estimated a gas heating between 2 – 0.2 % of the gas temperature at altitudes from 50 km to 60 km and in a time scale of 10 ms under the action of sprite streamers. Later, in 2014, da Silva and Pasko [4] proposed that fast heating could be the mechanism responsible of the gas heating in the first stages of the sprite streamer.

2. Variation of the concentration of nitrogen oxides (N_2O and NO_x, x = 1,2,3) in the mesosphere due to the action of sprite streamers

Through simulations, we have estimated the temporal evolution of a large number of chemical species within the streamer channel [5]. The N_2O concentration increases by more than two orders of magnitude [Figure 1.] at 65 km of altitude (red solid line) and almost two orders of magnitude at 75 km (dashed red line) remaining high in time. On the other hand, the NO concentration has an increase of four orders of magnitude (solid black line) at 65 km of altitude and, in the case of 75 km of altitude this increase is negligible. Another important issue is that the temporal evolution of NO_3 at 65 km and 75 km has a different behaviour for long times (> 10 s). Namely, at 65 km and for long times, the concentration of NO_3 has a decreasing trend while at 75 km, this trend is growing.

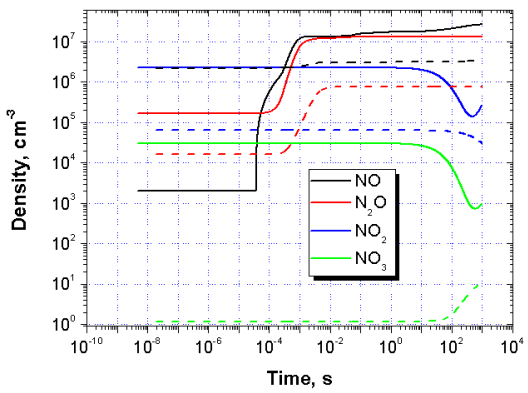

Figure 1: Calculated nighttime N_2O and NO_x (x=1,2,3) density variation under the action of a sprite streamer in the Earth mesosphere. The solid line refers to 65 km of altitude and the dashed line refers to 75 km of altitude.

The main production mechanism of N_2O, under the action of a sprite streamer electric field, is the associative detachment (AD) of the O^- by N_2, which has an important dependence with the electric field [6]. In the case of NO and NO_3, the different behaviour at different altitudes could be explained by the great difference in the initial background densities of these species since their production and

destruction mechanisms are the same for the two altitudes considered.

3. Gas heating within the streamer channel

We have estimated the variation of the gas temperature within the streamer channel solving the gas energy conservation equation [7] in a self-consistent way. We can see [Figure 2.] how the gas temperature variation changes with the altitude. At 65 km, the variation from the background value is almost 1 K for large times while, at 70 km, the increase in the gas temperature is a little higher than 0.2 K. The more substantial increase occurs at the low reduced electric field stage of the streamer, mainly due to the energetic balance of the vibrational-translational (V-T) reactions which involve vibrationally excited CO_2 and N_2 species. However, at the moment of the sprite streamer head, we have a negligible increase in the gas temperature (a few mK) caused by the rotational deexcitation of N_2 and the fast quenching processes (fast heating) of electronically excited species (mainly metastable species). Finally, at the time in which the gas temperature begins to grow (between 1 ms and 100 ms), the mechanisms responsible of this increase are a mix between V-T and fast quenching processes together with rotational deexcitation of N_2.

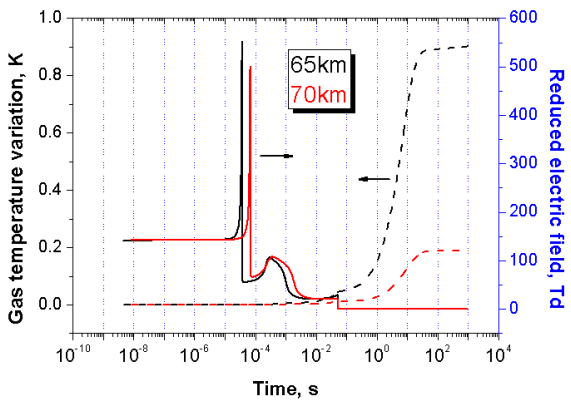

Figure 2: Calculated nighttime reduced electric field (solid line) and gas temperature variation (dashed line) in the sprite streamer channel.

We have obtained these results through simulations, in an array of 20 altitudes (between 65 km and 85 km) using a sophisticated kinetics model [8] based in Gordillo-Vázquez's scheme [2,9], that allowed us to obtain the reduced electric field and the plasma gas temperature of sprite streamers in a self-consistent way.

4. Aknowledgments

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5. References

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