Kinetics of CO_2 and nitrogen oxides in air plasmas produced by the action of sprites and halos in the Earth mesosphere

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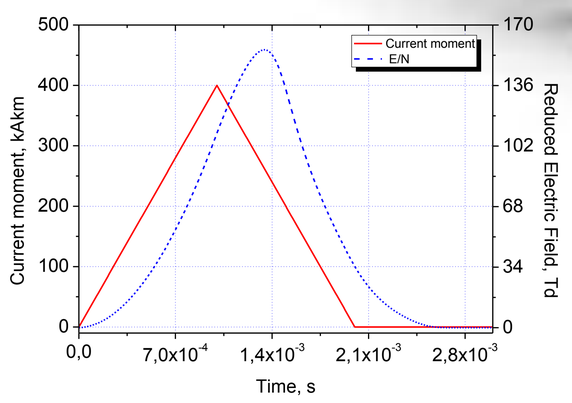
ABSTRACT

We present results related to a kinetic model of air plasmas generated in the presence of sprites and halos. The model includes a detailed scheme of the vibrational kinetics of CO_2 , which has allowed us to calculate the concentrations of the (ground electronic state) vibrational levels of CO_2 , responsible for its major optical emissions in the IR and, among others, of those observed at 4.3 μm and 14.9 μm. In addition, we have identified the main collision mechanisms responsible for the excitation/deexcitation of CO_2 by considering the electric fields associated with halos and the plasma filaments (streamers) of sprites. We have found that sprite activity in the mesosphere produces a considerable enhancement (of more than five orders of magnitude) in the concentration of the vibrational level $CO_2(00^01)$. Our results indicate that the CO_2 emission enhancement in the 4.3 μm lasts for more than 100 seconds after the passage of the sprite streamers, which suggests that this IR emission could be detected by dedicated sensors in space platforms. We have also found an increase in over five orders of magnitude of the concentration of N_2O and an increase of more than 1K mesosphere temperature under the action of sprites.

MOTIVATION AND GOALS

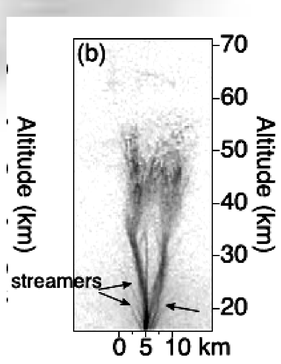
The impact of sprite streamers and halos in the background electron desity are studied. This is very important because the electron density affects to the atmospheric conductivity and this in turn to the propagation of the streamers.



The contribution of sprite streamers and halos to the IR emission (14.9 μm and 4.23 μm) due to vibrational CO_2 deactivation are analized. Picard et al. (GRL 1997) estimated the posibility of detection of the IR emission from space platform. We include a more detailed vibrational kinetics of CO_2 and we present a possible IR spectra.

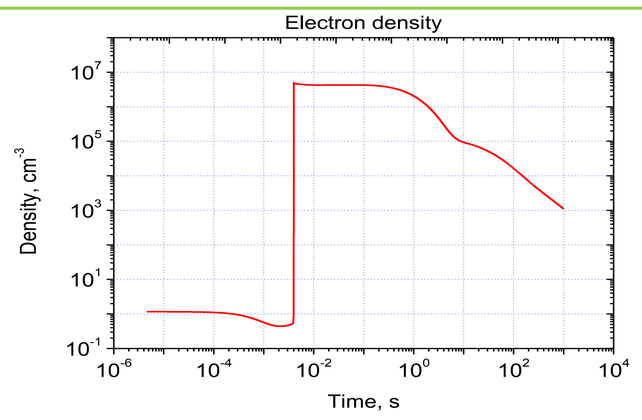
Nitrogen oxides are very important species in the mesospheric chemical evolution (N_2O particularly). Gordillo-Vázquez (JPD 2008) obtained a significant increase in the concentration of the NO_x and two orders of magnitud in the N_2O concentration under the streamer electric field influence. Sentman et al.(JGR2008) predicted an increase of the 50% in the NO density.

Gas heating mechanisms in the mesosphere under the sprite influence are not well known. In 1998, Pasko et al. (GRL 1998a) estimated a heating of $\Delta T/T \approx 2 - 0.2$ % (50-60 km) under the action of streamer electric field. We think that this gas heating is also possible in lower mesosphere under the action of Blue Jets and Gigantic Jets.

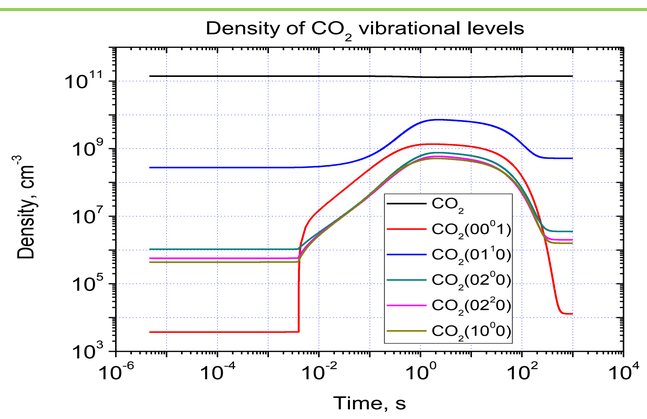


Riousset et al. (JGR 2010)

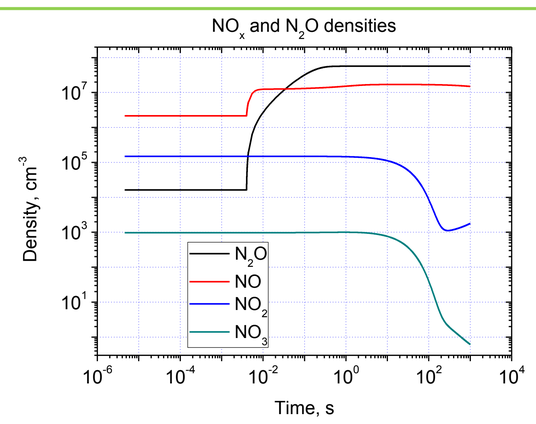
RESULTS FOR SPRITE STREAMERS (75 km)



$e + N_2 \rightarrow N_2^+ + e + e$
$e + O_2 \rightarrow O_2^+ + e + e$
$O^- + N_2 \rightarrow N_2O + e$
$e + O_2 + N_2 \rightarrow O_2^- + N_2$
$e + O_2 + O_2 \rightarrow O_2^- + O_2$
$e + O_2 \rightarrow O + O^-$

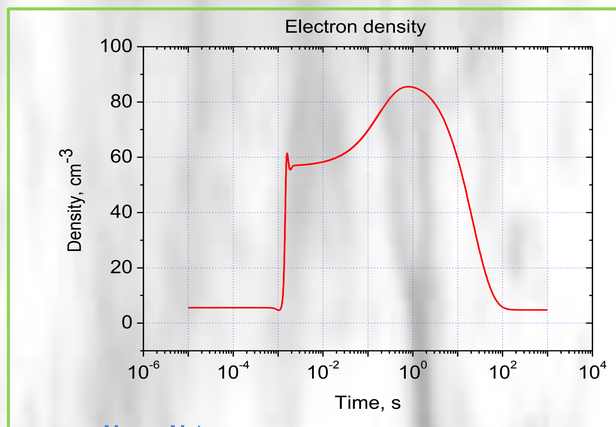


$e + CO_2 \rightarrow CO_2(00^01) + e$
$e + CO_2 \rightarrow CO_2(01^10) + e$
$CO_2(00^01) \rightarrow CO_2 + 4.26\ \mu m$
$CO_2(01^10) \rightarrow CO_2 + 14.9\ \mu m$

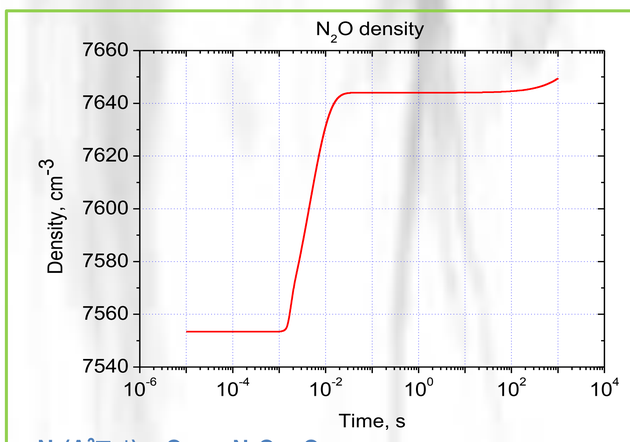


$O^- + N_2 \rightarrow N_2O + e$
$e + N_2O_2^+ \rightarrow NO + NO$
$e + N_2O \rightarrow N_2 + O + e$
$N + NO \rightarrow N_2 + O$

RESULTS FROM HALO ACTIVITY (80 km)



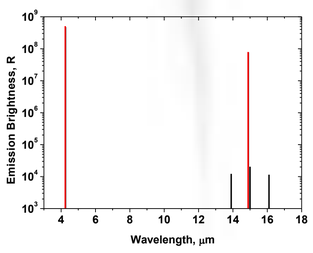
$e + N_2 \rightarrow N_2^+ + e + e$
$e + O_2 \rightarrow O_2^+ + e + e$
$O^- + N_2 \rightarrow N_2O + e$
$e + O_3 \rightarrow O^- + O_2$



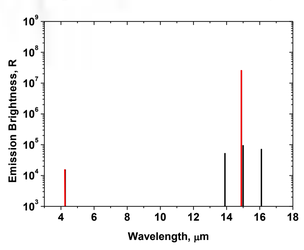
$N_2(A^3\Sigma_u^+) + O_2 \rightarrow N_2O + O$
$N + NO_2 \rightarrow O + N_2O$
$O^- + N_2O \rightarrow NO^- + NO$

Possible IR spectra obtained with a 30 fps camera *in situ*

Sprite IR emission (75 km)

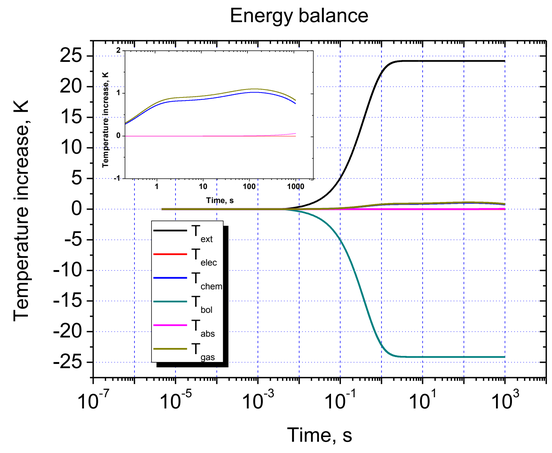


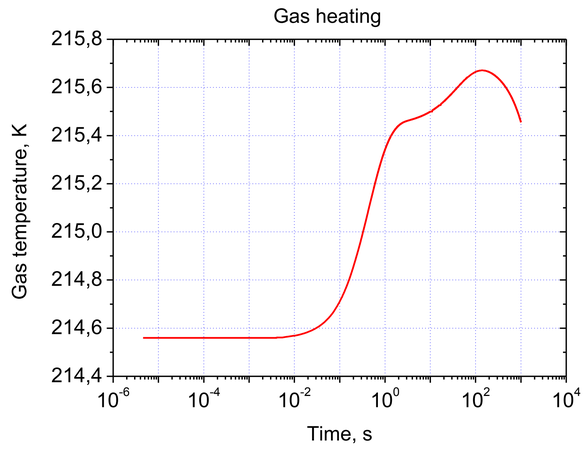
Background IR emission (80 km)



The emission of 4.26 μm under the action of sprite is four orders of magnitude higher than background

MESOSPHERIC GAS HEATING (75 km)





$N_2(rot) + M \rightarrow N_2 + M$

provides almost 60% of the total temperature increase experienced by the mesosphere by the influence of sprites

The role of the characteristic time (τ) of the field decay