

# Supporting Information for ”3D simulation of an extreme SAID flow channel”

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## Contents of this file

1. Figures S1 to S24

## Additional Supporting Information (Files uploaded separately)

1. Captions for Movies S1 to S21

**Introduction** The supporting information aims to help visualize the 3D and 2D simulations in several ways. Figure S1, S6, S11, and S16 show the energy of  $[O_2^+]$  and the threshold important for the analysis. Figures S2 to S5 are field-aligned profiles at the center of the flow channel of the 3D simulations. In contrast, Figures S7 to S10 are field-aligned profiles at LON=80, and Figures S12 to S15 are field-aligned profiles at LON=100 of the 3D simulations. Longitudinal profiles of different plasma parameters are displayed on Figure S16 through S19. 2D simulations also have their supporting figures, from Figure S20 to S25. Movies S01 to S17 are perfect to understand the changes in GEMINI outs

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in time for the 3D simulation. There are movies for every output parameter of GEMINI. Movies from S18 to S21 show the 2D case.

**Movie S1.** Total plasma density ( $N_e$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S2.** Ion temperature ( $T_i$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S3.** Electron temperature ( $T_e$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S4.** Plasma density of  $[NO^+]$  in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S5.** Plasma density of  $[O_2^+]$  in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S6.** Plasma density of  $[O^+]$  in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S7.** field-aligned channel velocity ( $v_1$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S8.** Northward along the L-shell growth channel velocity ( $v_2$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S9.** Zonal east-west channel velocity ( $v_3$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S10.** Northward along the L-shell growth electric field ( $E_2$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S11.** Zonal east-west electric field ( $E_3$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along

the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S12.** Total magnitude of the electric field ( $E_{mag}$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S13.** Pedersen conductivity ( $\sigma_P$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S14.** Hall conductivity ( $\sigma_H$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S15.** field-aligned current density ( $J_1$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S16.** Northward along the L-shell growth current density ( $J_2$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively



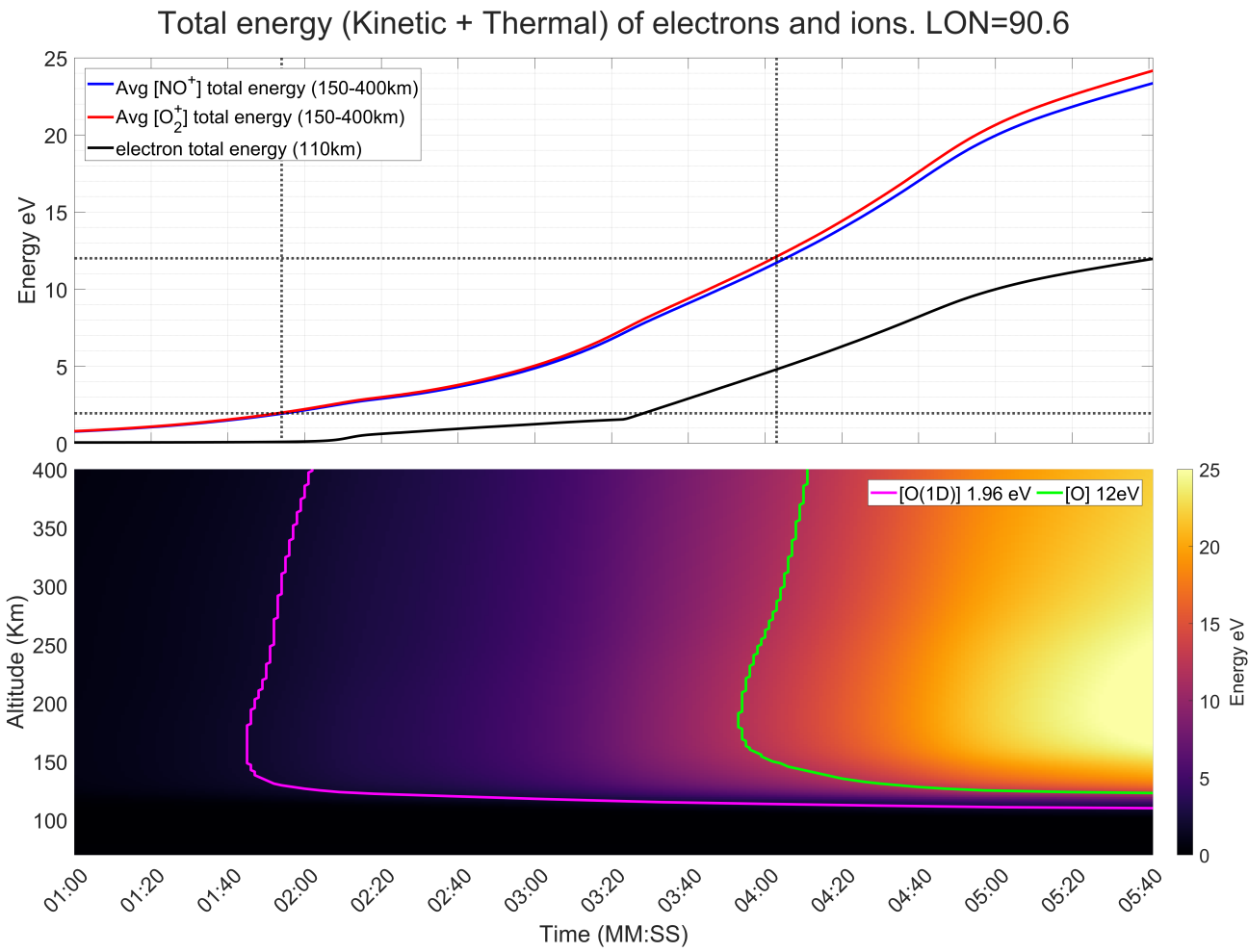
**Movie S17.** Zonal east-west current density ( $J_3$ ) in time for a 3D simulation. Panels a) and b) represent cuts in longitude at  $80^\circ$  and  $100^\circ$ . Panel c) represents a cut in latitude along the magnetic field line. Panels d) through f) represent altitude cuts at 120km, 180km, and 250km respectively

**Movie S18.** Plasma parameters in time for a 2D simulation. Left panel presents total plasma density ( $N_e$ ), center panel is ion temperature ( $T_i$ ), and the left panel is electron temperature ( $T_e$ )

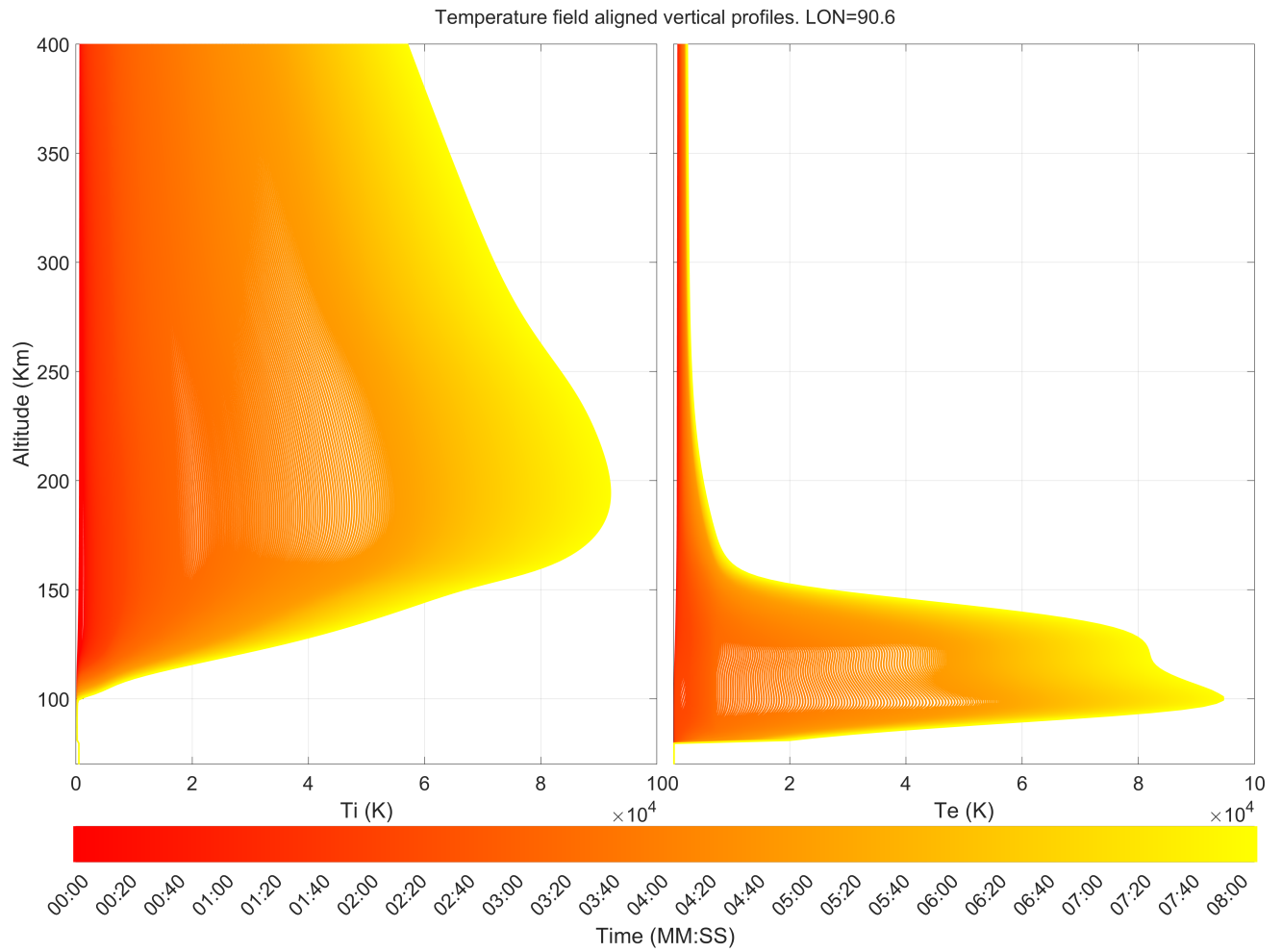
**Movie S19.** Plasma densities of the more important ions for a 2D simulation. Left panel presents the density of  $[O^+]$ , center panel is density of  $[NO^+]$ , and the left panel is density of  $[O_2^+]$

**Movie S20.** Plasma velocities in time for a 2D simulation. Left panel presents field-aligned channel velocity ( $v_1$ ), center panel is northward along the L-shell growth channel velocity ( $v_2$ ), and the left panel is zonal east-west channel velocity ( $v_3$ )

**Movie S21.** Current density in time for a 2D simulation. Left panel presents field-aligned current density ( $J_1$ ), center panel is northward along the L-shell growth current density ( $J_2$ ), and the left panel is zonal east-west current density ( $J_3$ )



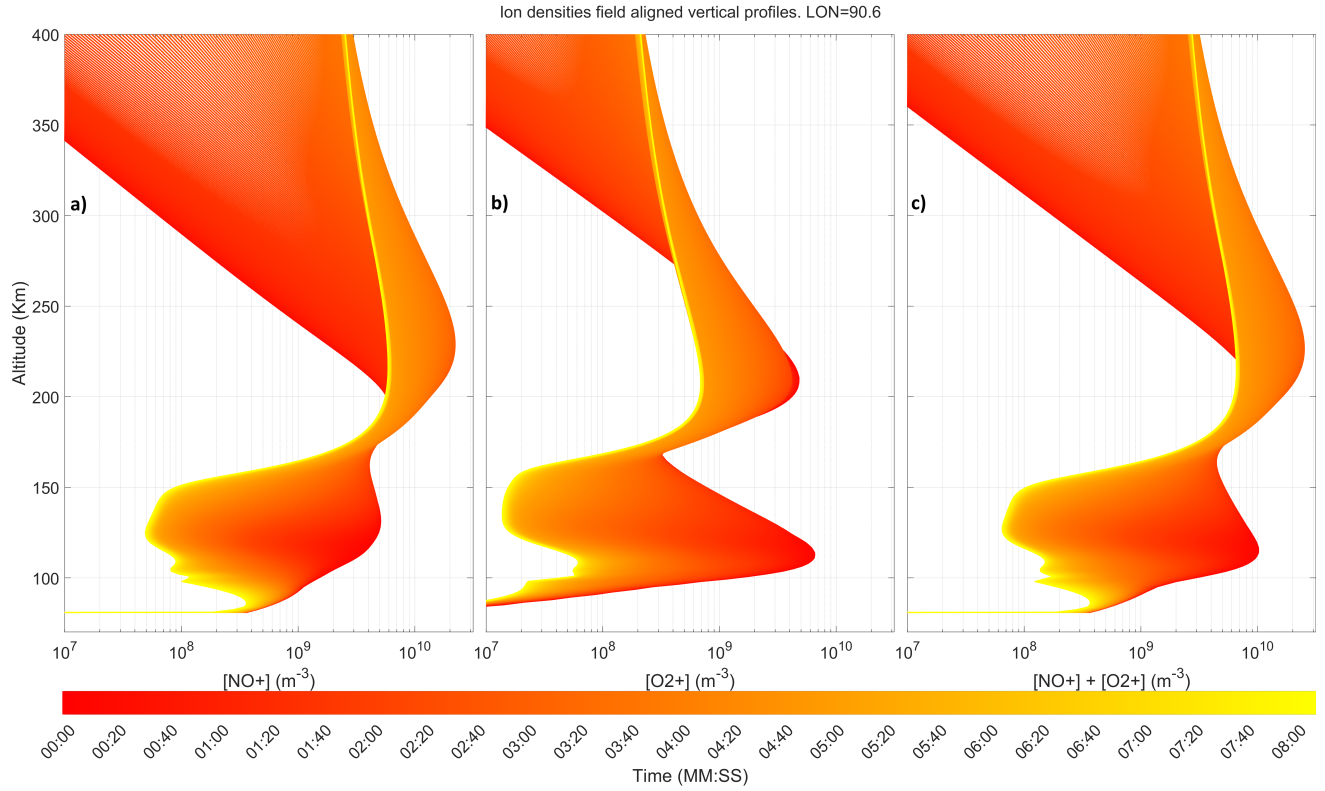
**Figure S1.**  $[O_2^+]$  energy at LON=90.



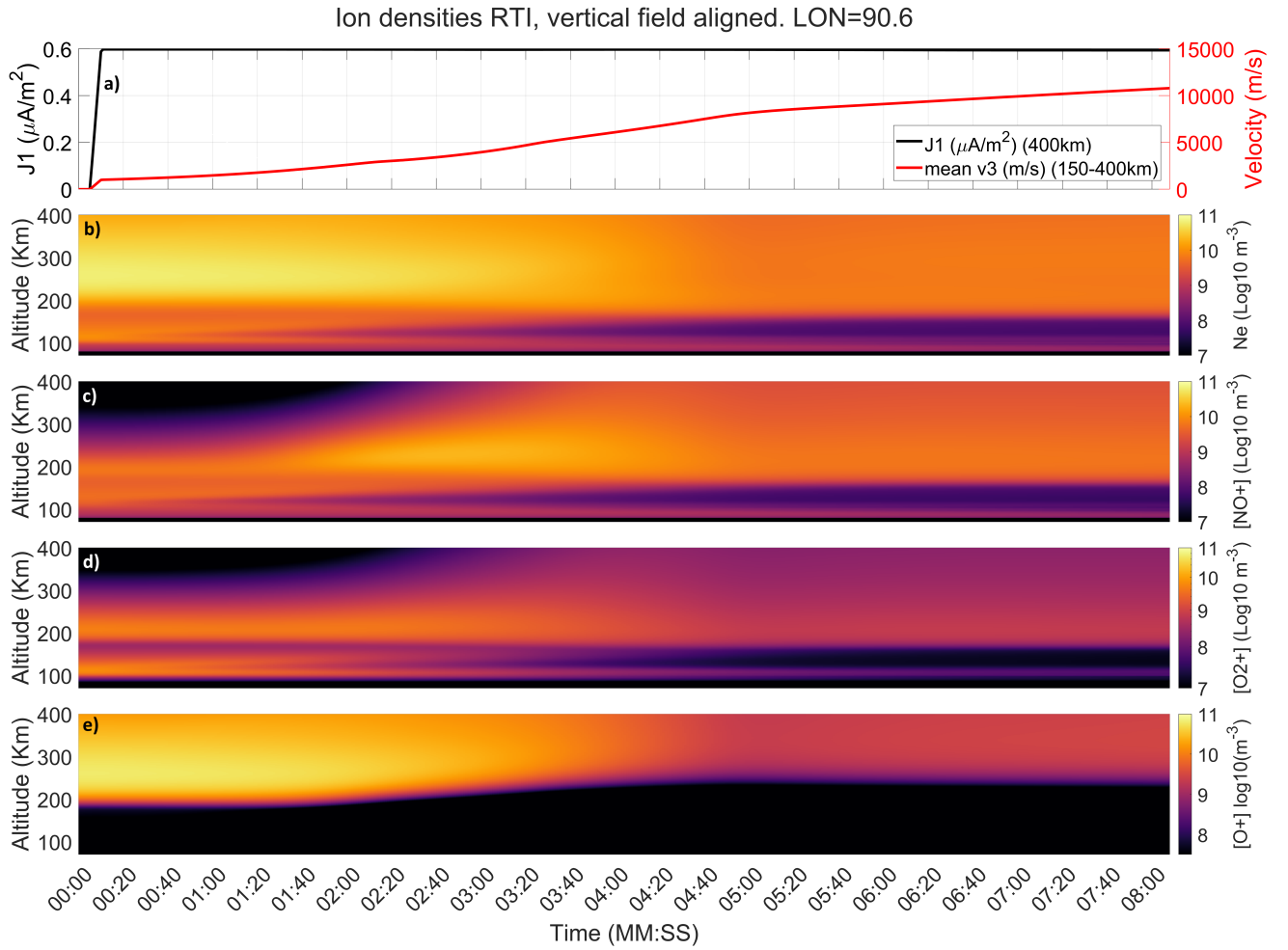
**Figure S2.** Ion and electron temperature field-aligned profiles at LON=90. Time is represented as a gradient from red to yellow as seen on the bottom bar



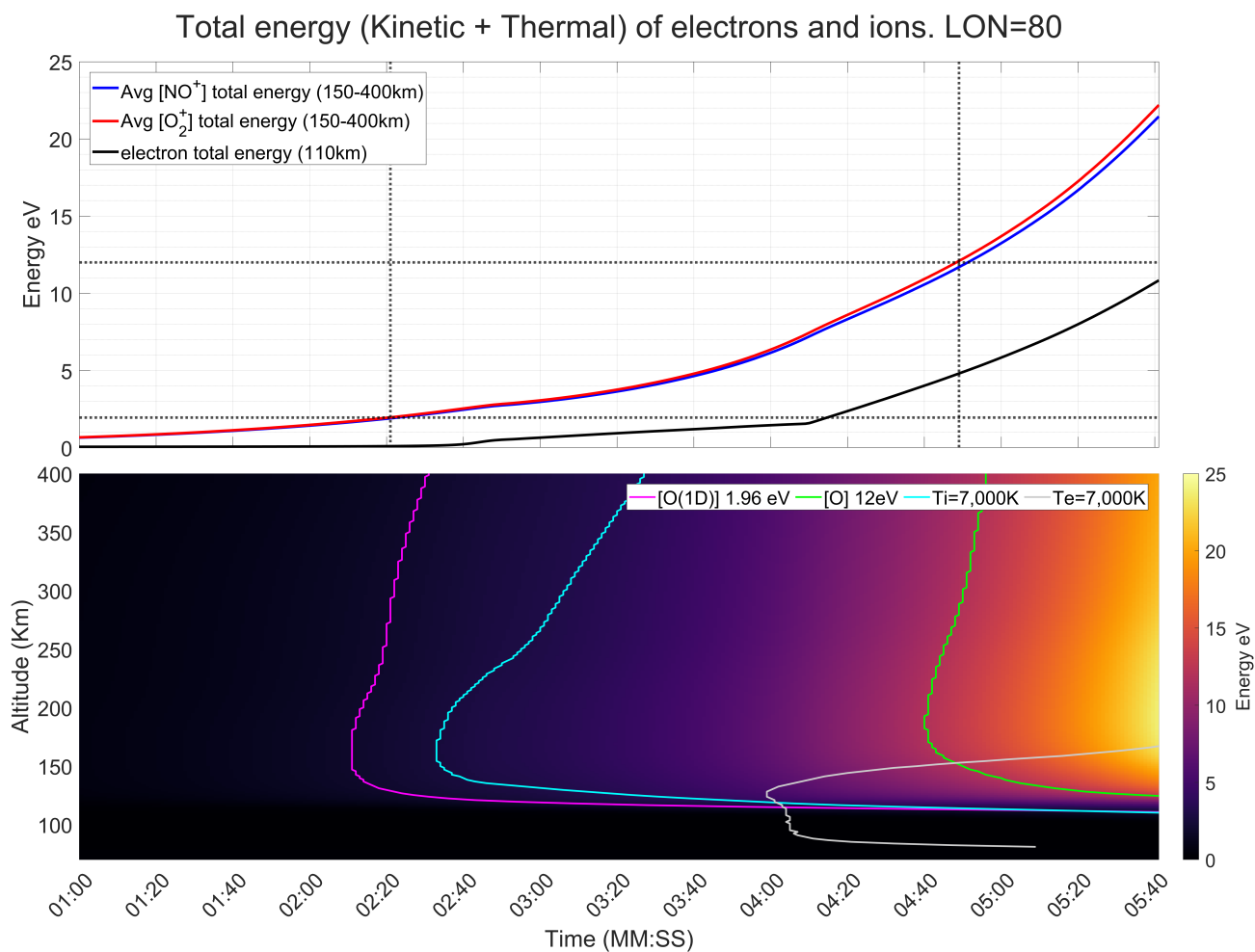
**Figure S3.** Channel velocity and closure current field-aligned profiles at LON=90. Time is represented as a gradient from red to yellow as seen on the bottom bar



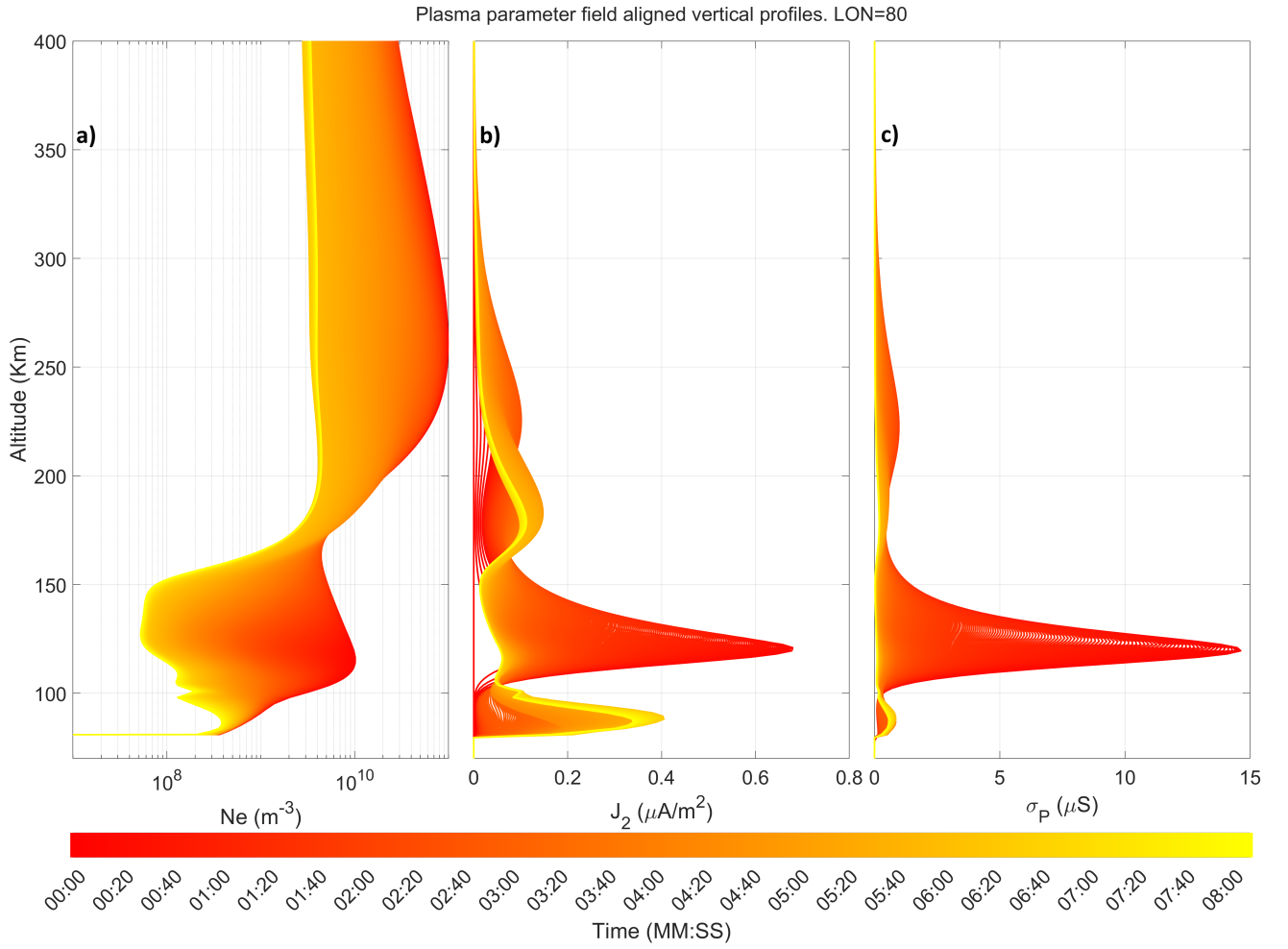
**Figure S4.** Plasma densities of the main ions field-aligned profiles at LON=90. Panel a) represents the density of  $[\text{NO}^+]$ , panel b) represents the density of  $[\text{O}_2^+]$ , and panel c) represents the density of  $[\text{O}^+]$ . Time is represented as a gradient from red to yellow as seen on the bottom bar



**Figure S5.** RTI of plasma densities of the main ions field-aligned profiles at LON=90. Panel a) represents both the channel velocity (red line) and parallel driving current density (black), panel b) represents the total plasma density, panel c) represents the density of  $[NO^+]$ , panel d) represents the density of  $[O_2^+]$ , and panel e) represents the density of  $[O^+]$ .

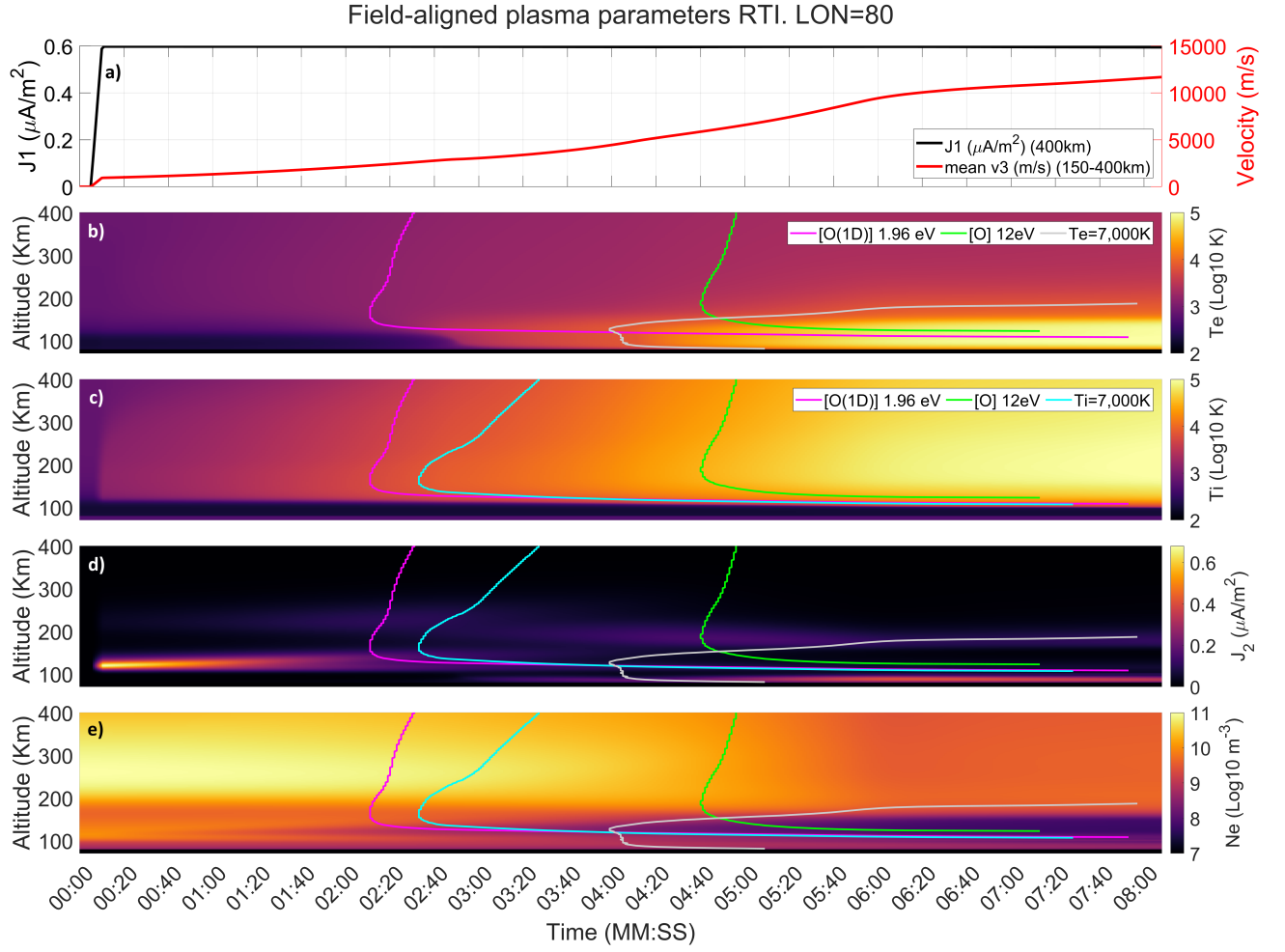


**Figure S6.**  $[\text{O}_2^+]$  energy at LON=80.

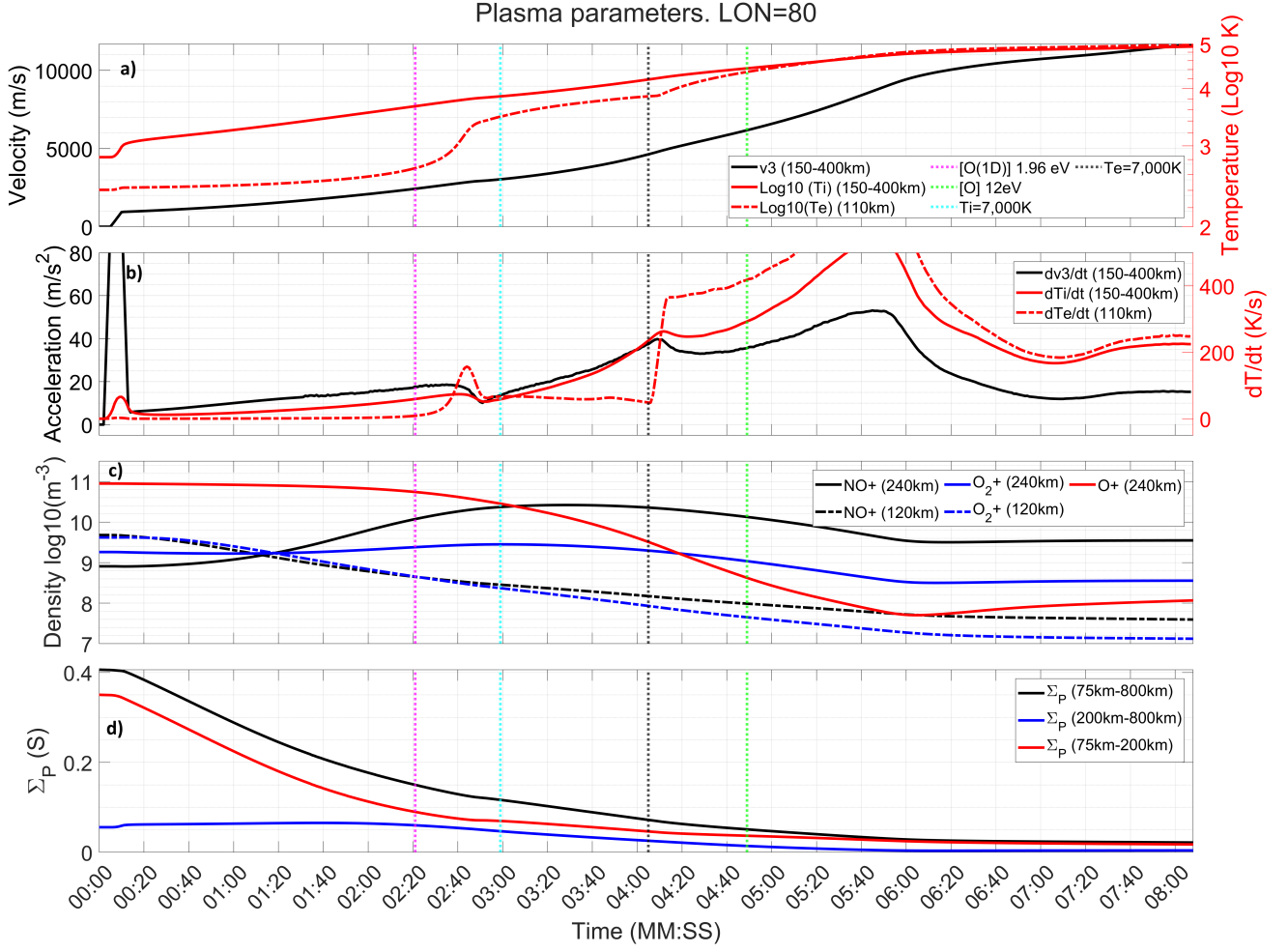


**Figure S7.** Field-aligned plasma parameters at LON=80. Time is represented as a gradient from red to yellow as seen on the bottom bar. Panel a) plasma density at the center of the channel. Panel b) closure current density ( $J_2$ ) at the center of the channel. Panel c) Pedersen conductivity at the center of the channel.

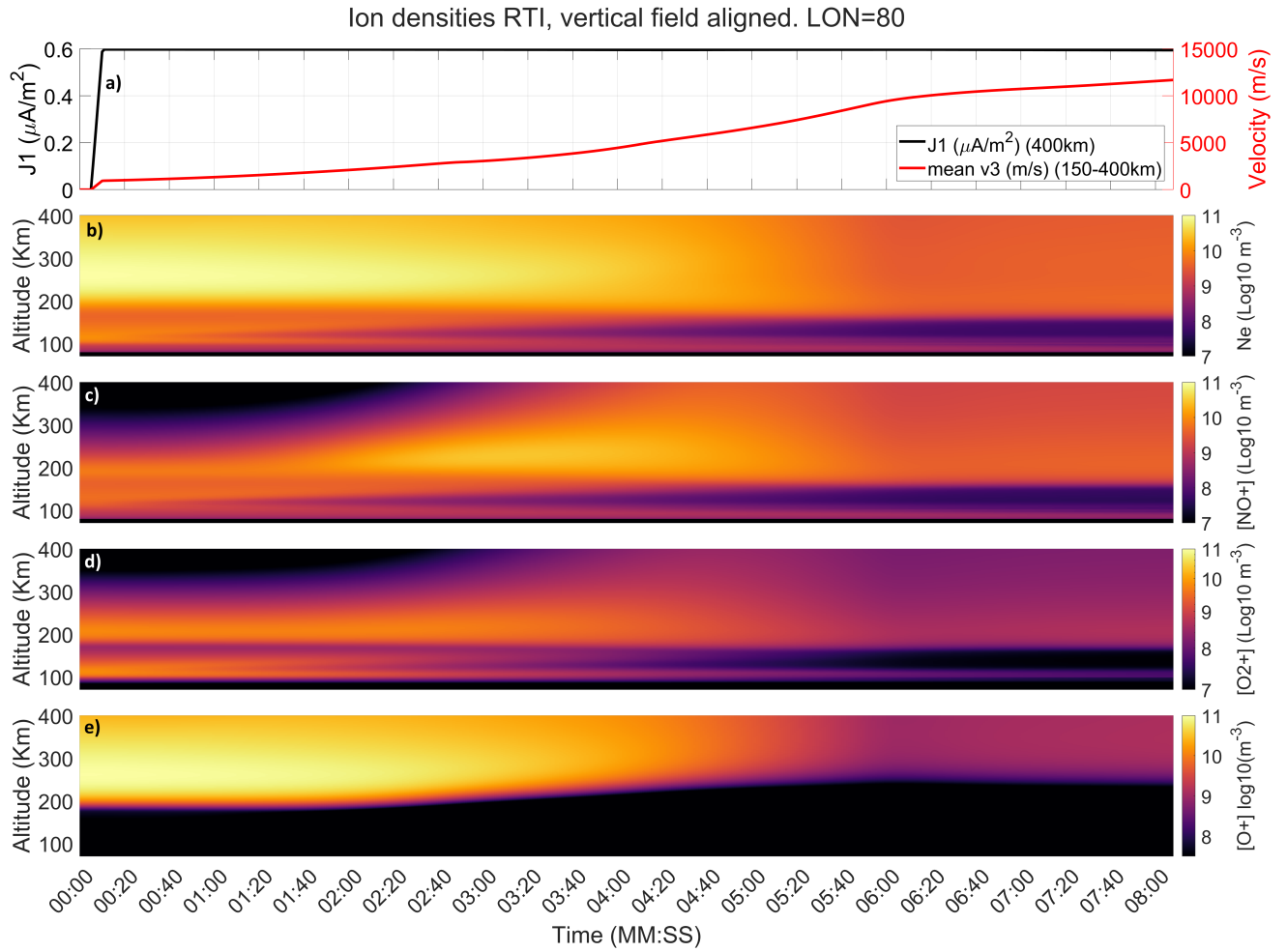




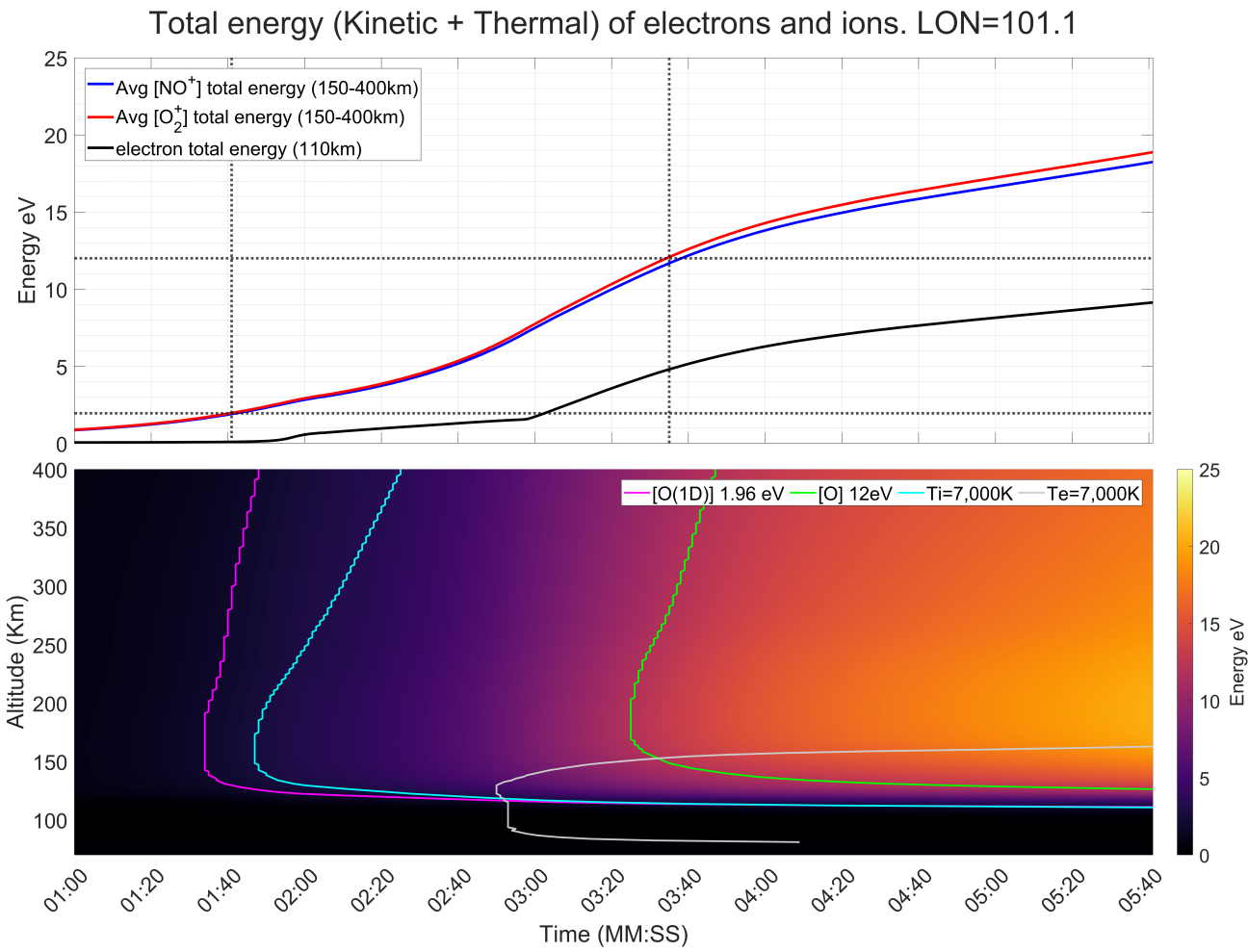
**Figure S8.** Field-aligned RTI taken at LON=80. Panel a) displays values for parallel-to-B current density ( $J_1$ ) and east/west velocity ( $v_3$ ) at averaged from 150 to 400 km. Panels b) and c) showcase electron ( $T_e$ ) and ion ( $T_i$ ) temperatures, respectively. Panel d) depicts the north/south current ( $J_2$ ), while panel e) provides insights into the total electron density ( $N_e$ )



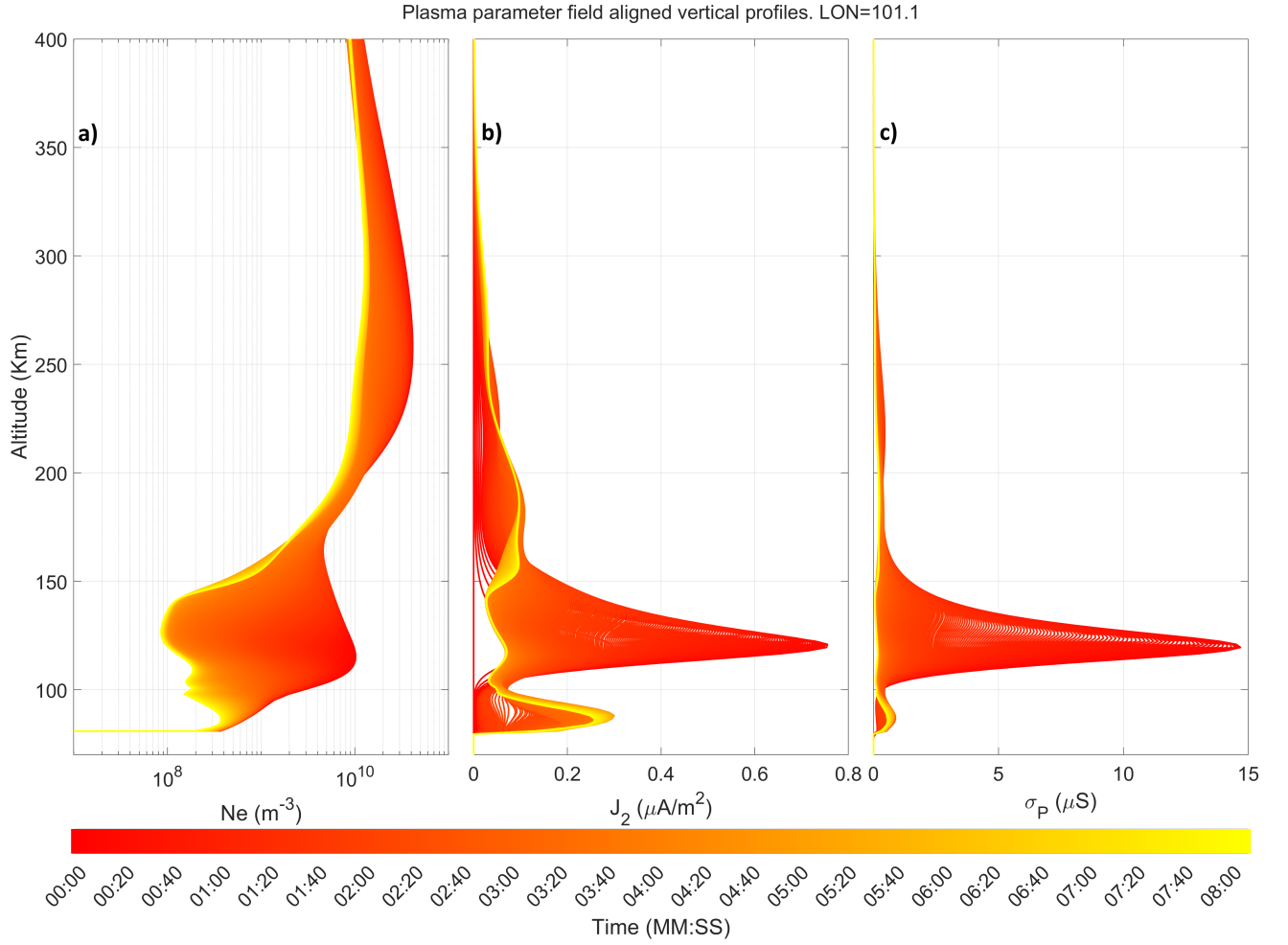
**Figure S9.** Key simulation output parameters at LON=80. Panel a) shows the average channel velocity ( $v_3$ , solid black line) and ion temperature ( $T_i$ , solid red line) between 150-400km, as well as the electron temperature ( $T_e$ , dashed red line) at 100km. Panel b) shows the time derivative of all variables shown on panel a). Panel c) shows the density of the main ions,  $[NO^+]$  and  $[O_2^+]$  at 120km (black and blue solid lines) and 240km (black and blue dashed lines) as well as  $[O^+]$  at 240km (solid red line). Panel d) shows the total height integrated Pedersen conductance ( $\Sigma_p$ , solid black line), as well as the F-region (200-800km, solid blue line) and E-region (95-200km, solid red line) contribution



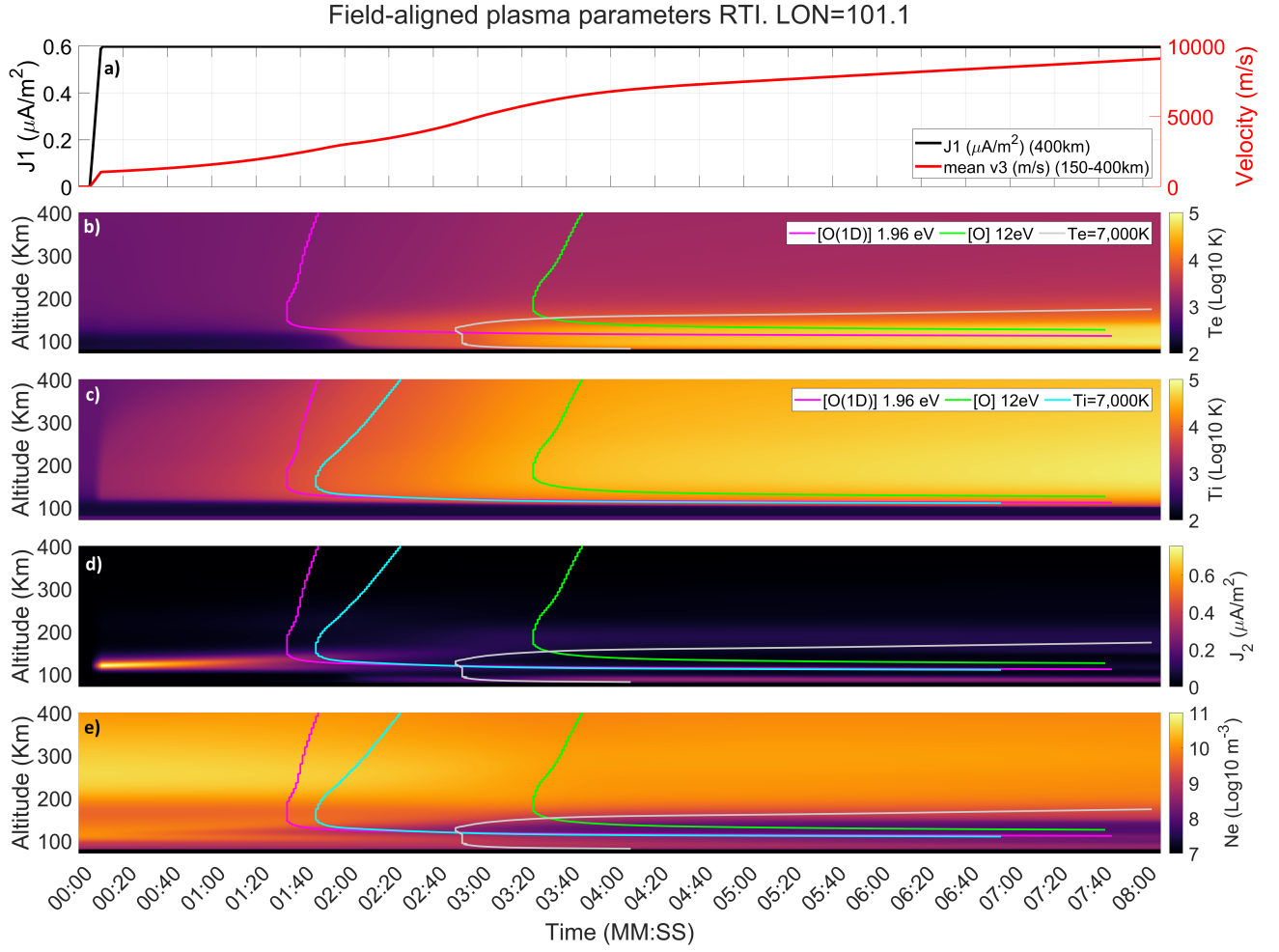
**Figure S10.** RTI of plasma densities of the main ions field-aligned profiles at LON=80. Panel a) represents both the channel velocity (red line) and parallel driving current density (black), panel b) represents the total plasma density, panel c) represents the density of  $[NO^+]$ , panel d) represents the density of  $[O_2^+]$ , and panel e) represents the density of  $[O^+]$ .



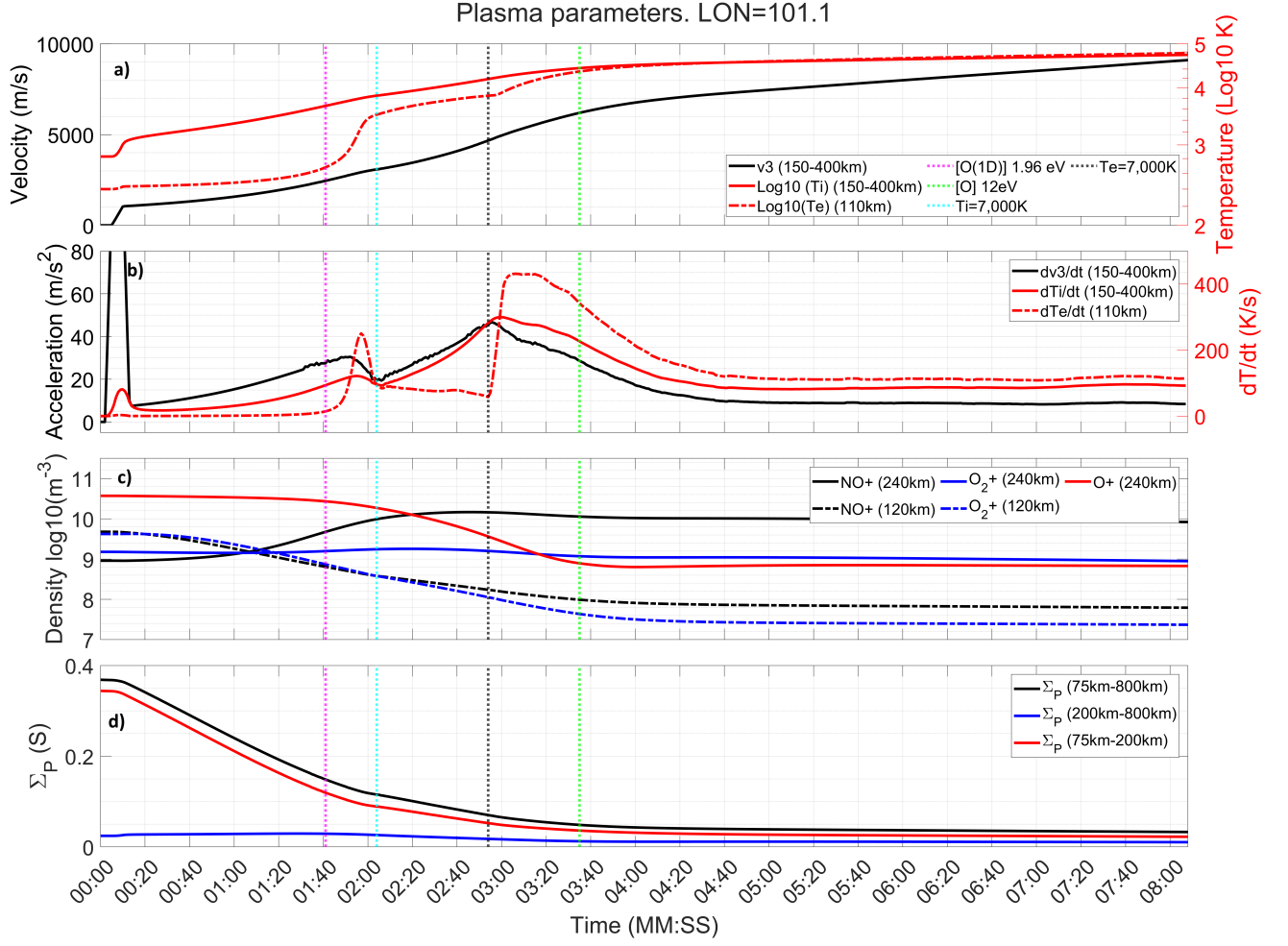
**Figure S11.**  $[O_2^+]$  energy at LON=100.



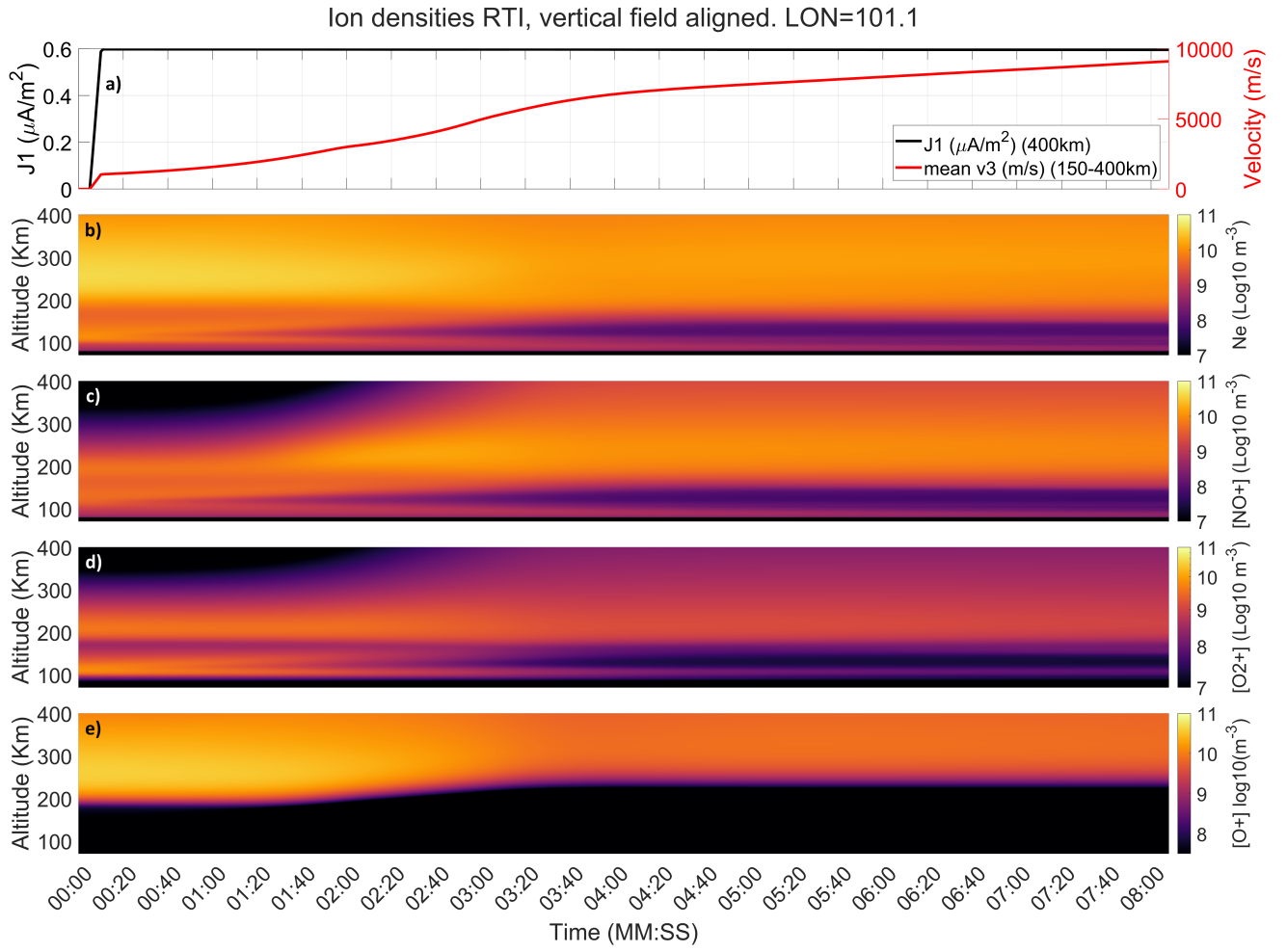
**Figure S12.** Field-aligned plasma parameters at LON=100. Time is represented as a gradient from red to yellow as seen on the bottom bar. Panel a) plasma density at the center of the channel. Panel b) closure current density ( $J_2$ ) at the center of the channel. Panel c) Pedersen conductivity at the center of the channel.



**Figure S13.** Field-aligned profiles are taken at LON=100. Panel a) displays values for parallel-to-B current density ( $J_1$ ) and east/west velocity ( $v_3$ ) at averaged from 150 to 400 km. Panels b) and c) showcase electron ( $T_e$ ) and ion ( $T_i$ ) temperatures, respectively. Panel d) depicts the north/south current ( $J_2$ ), while panel e) provides insights into the total electron density ( $N_e$ )

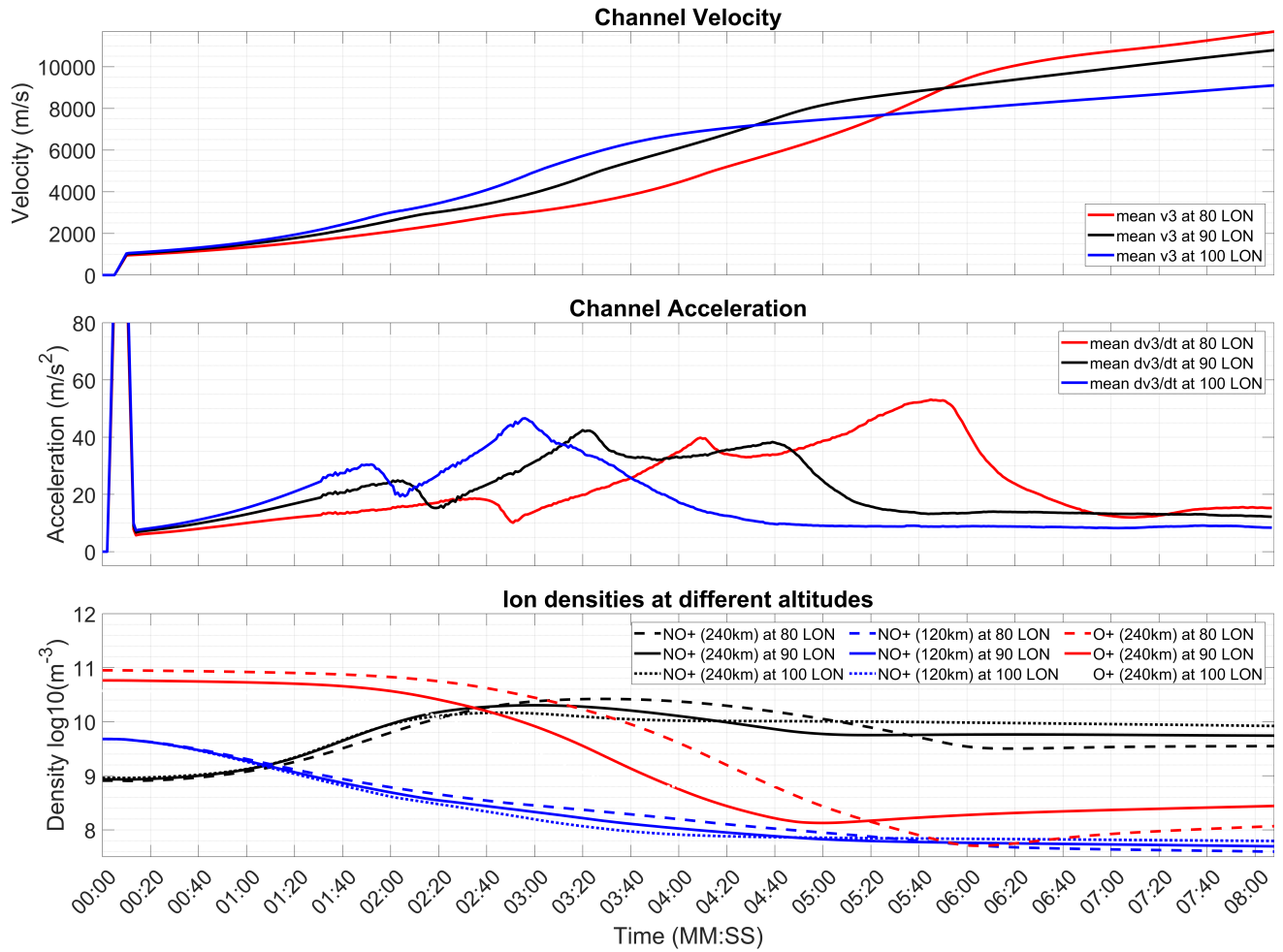


**Figure S14.** Key simulation output parameters at LON=100. Panel a) shows the average channel velocity ( $v_3$ , solid black line) and ion temperature ( $T_i$ , solid red line) between 150-400km, as well as the electron temperature ( $T_e$ , dashed red line) at 100km. Panel b) shows the time derivative of all variables shown on panel a). Panel c) shows the density of the main ions,  $[NO^+]$  and  $[O_2^+]$  at 120km (black and blue solid lines) and 240km (black and blue dashed lines) as well as  $[O^+]$  at 240km (solid red line). Panel d) shows the total height integrated Pedersen conductance ( $\Sigma_p$ , solid black line), as well as the F-region (200-800km, solid blue line) and E-region (95-200km, solid red line) contribution

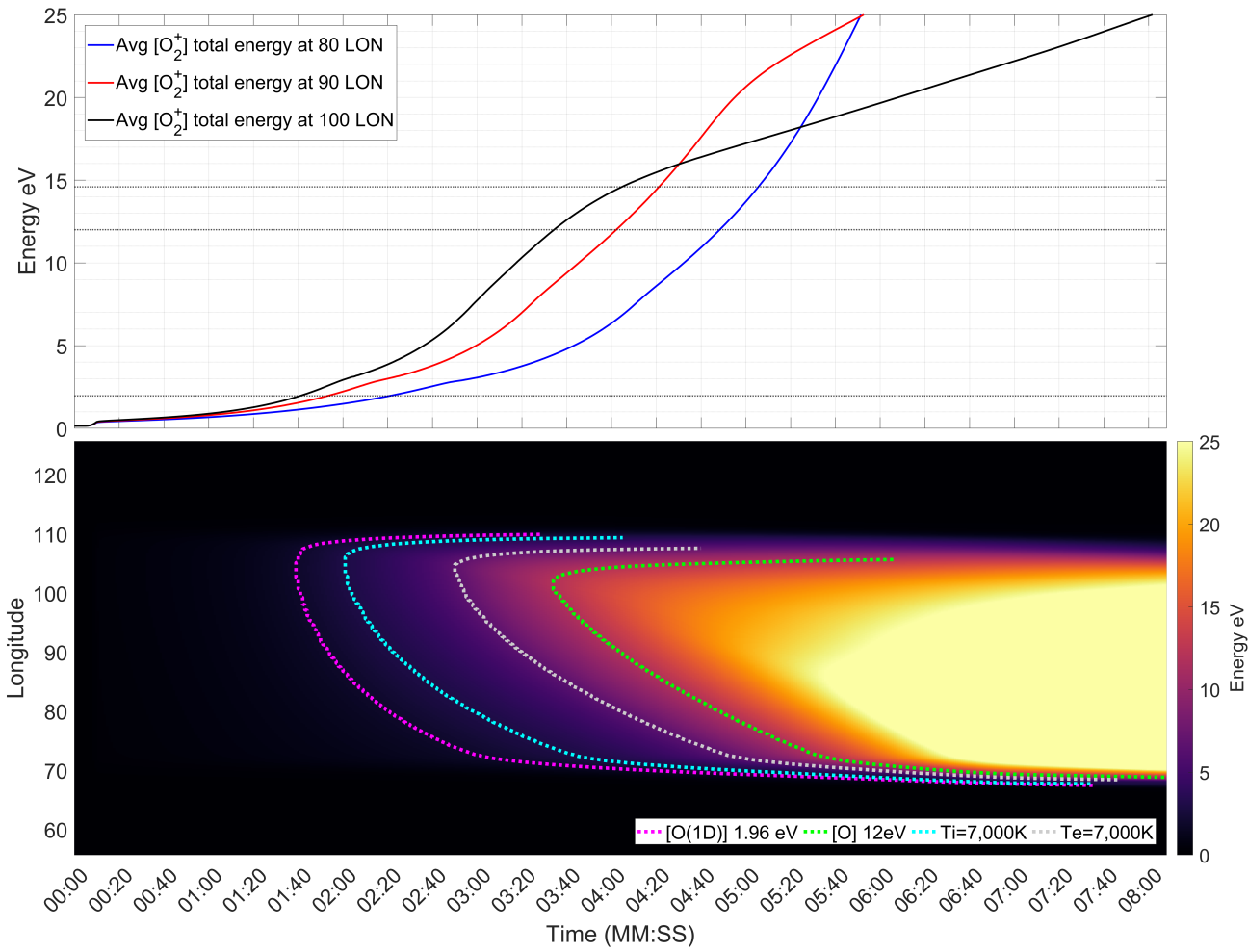


**Figure S15.** RTI of plasma densities of the main ions field-aligned profiles at LON=100. Panel a) represents both the channel velocity (red line) and parallel driving current density (black), panel b) represents the total plasma density, panel c) represents the density of  $[NO^+]$ , panel d) represents the density of  $[O_2^+]$ , and panel e) represents the density of  $[O^+]$ .

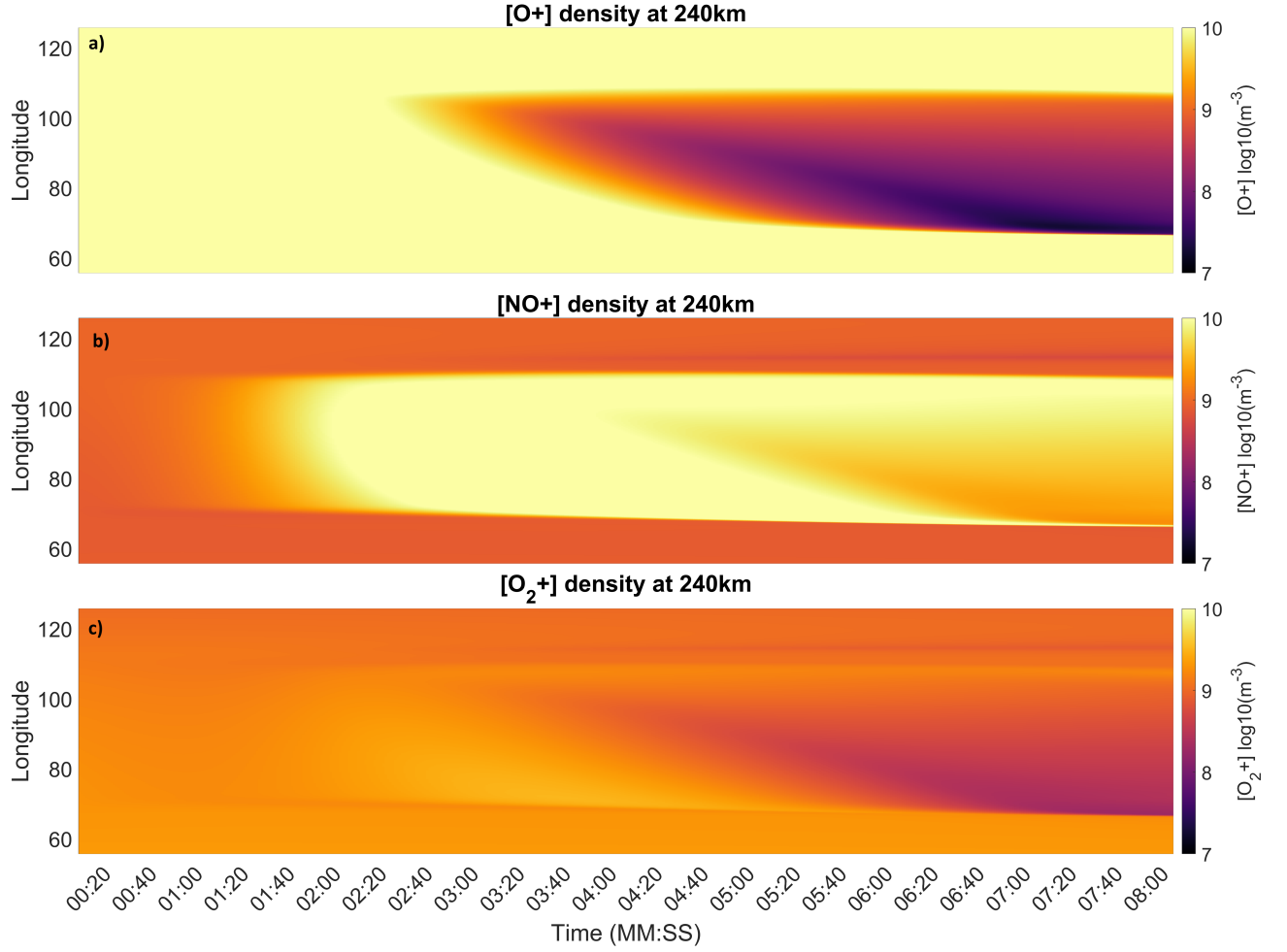




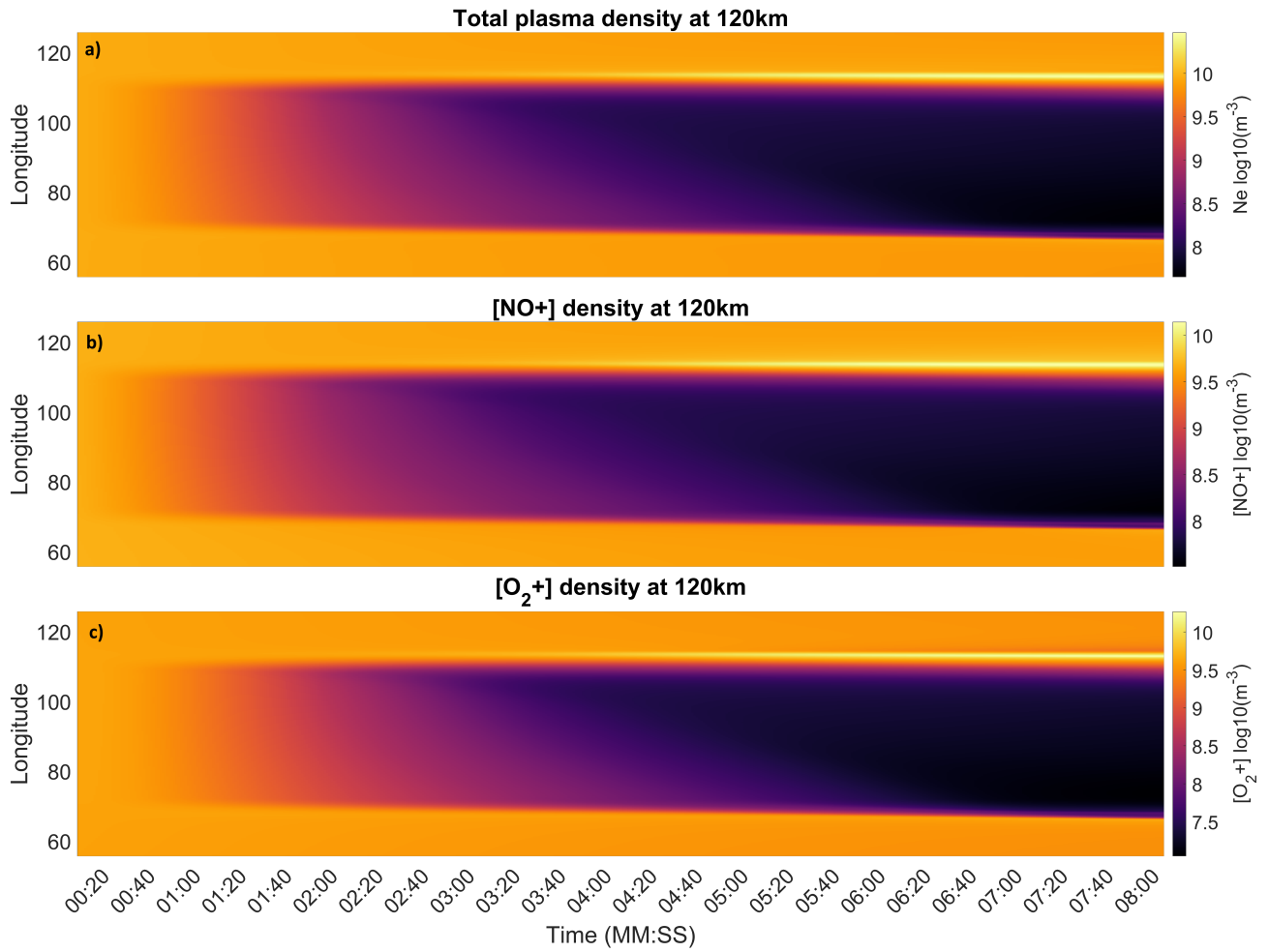
**Figure S16.** Panel a): average channel velocity between 150-400km at three different longitudes (80°, 90° and 100°). Panel b): average channel acceleration between 150-400km at three different longitudes. Panel c) plasma density of  $[NO^+]$  and  $[O^+]$  at different altitudes and longitudes



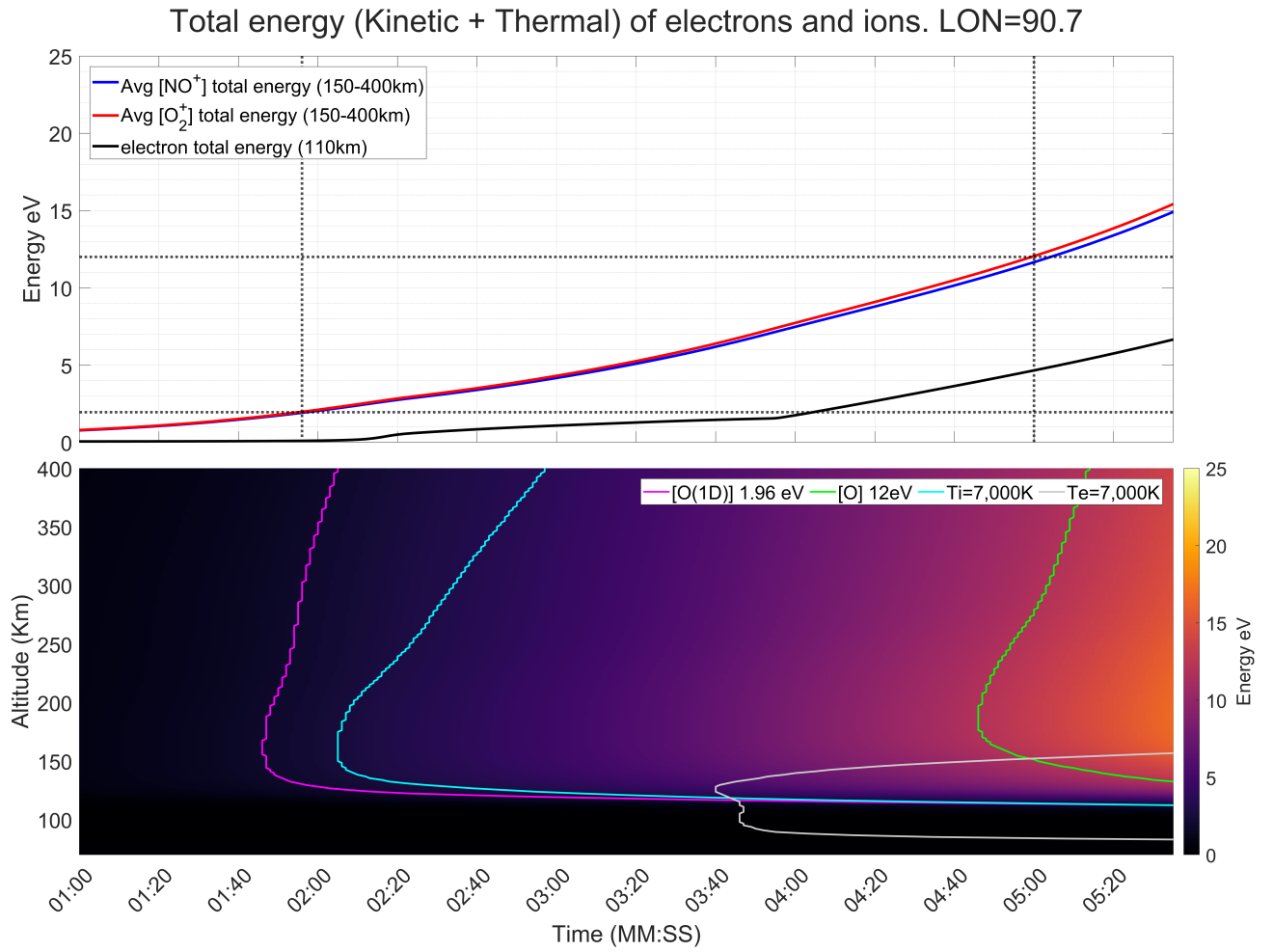
**Figure S17.**  $[O_2^+]$  energy in longitude.



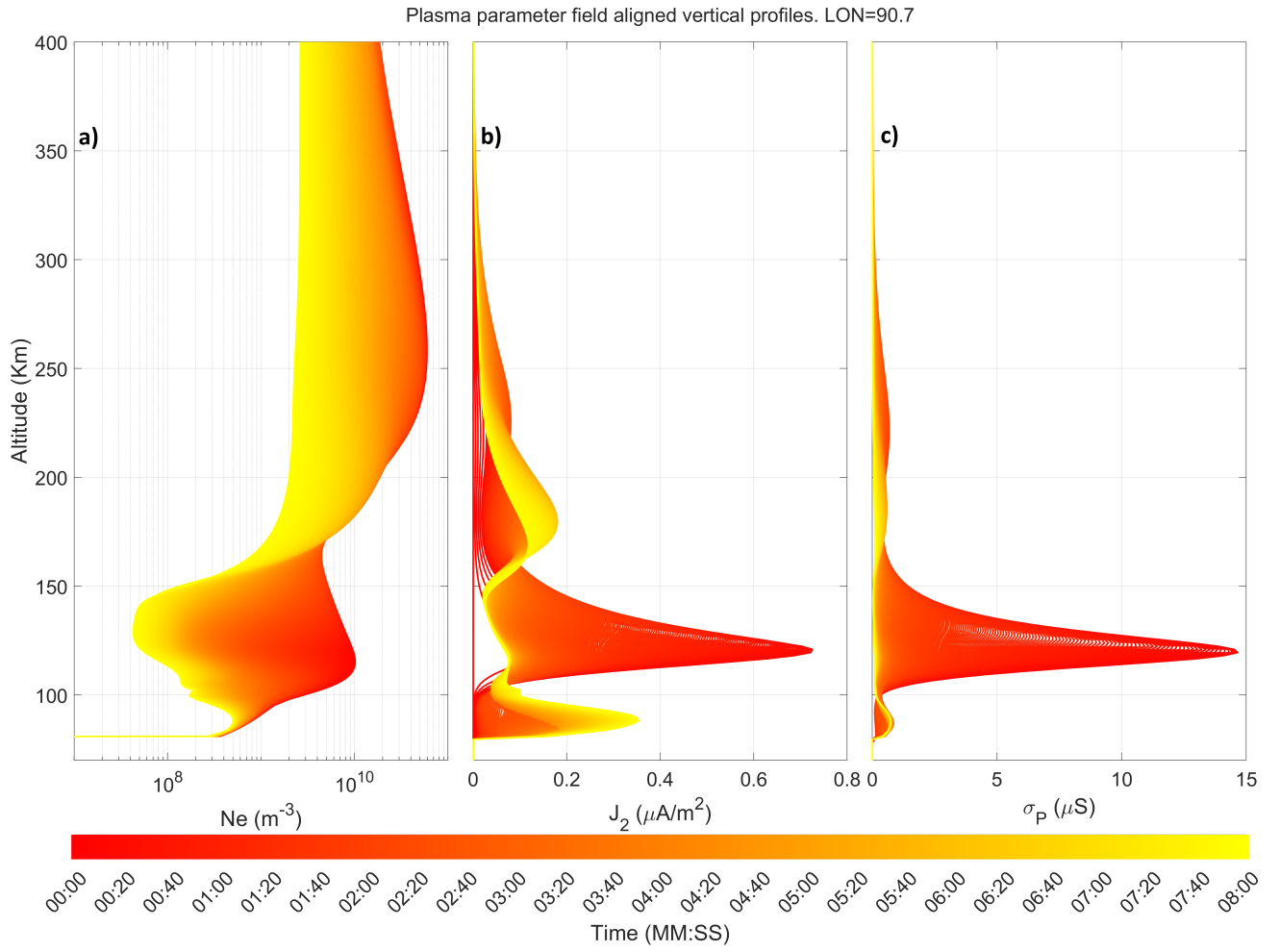
**Figure S18.** Plasma densities of the main ions at 240km in longitude vs time. Panel a) represents the density of  $[O^+]$ , while panel b) and c) represent  $[NO^+]$  and  $[O_2^+]$  respectively



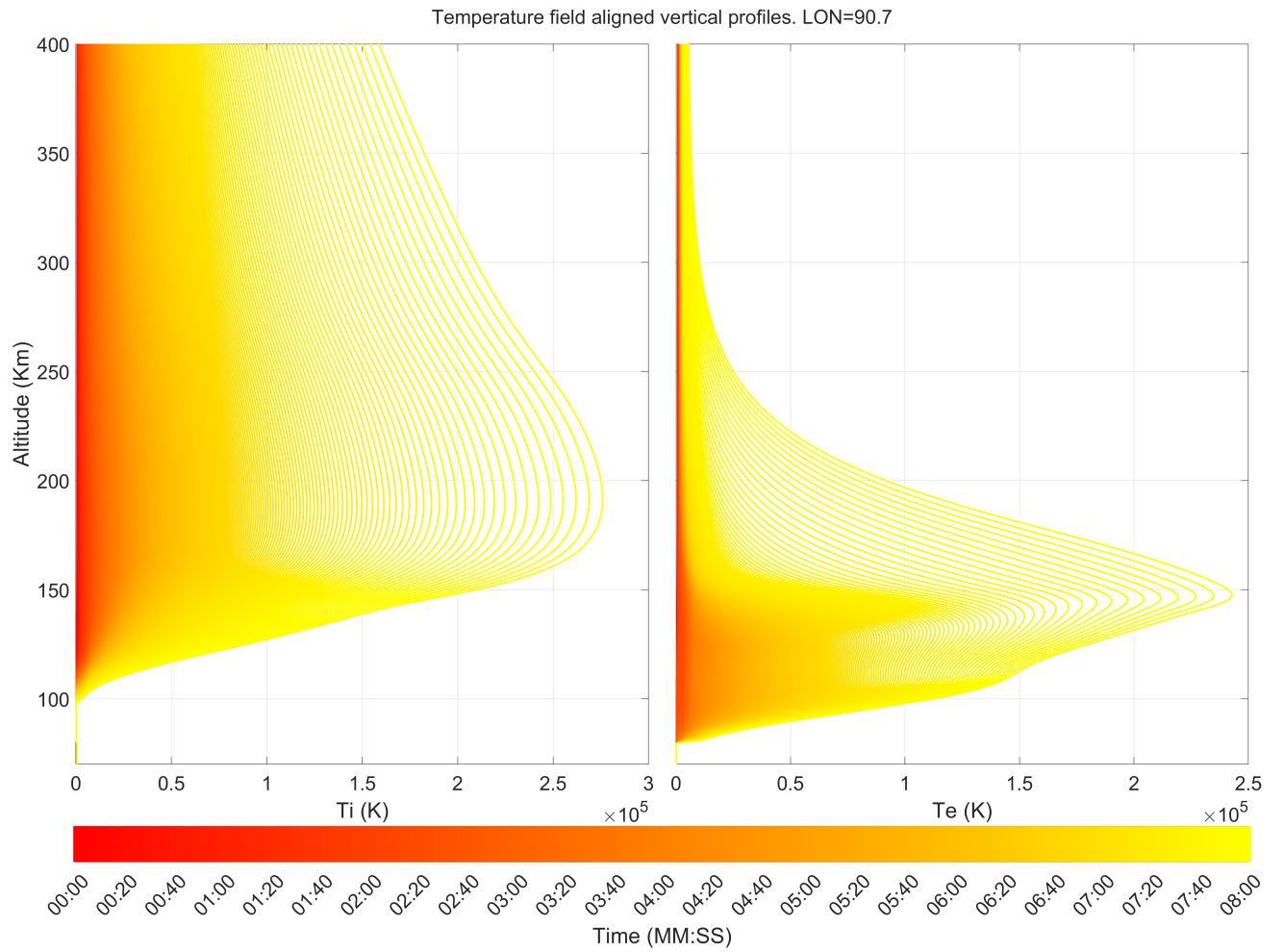
**Figure S19.** Plasma densities of the main ions at 120km in longitude vs time. Panel a) represents the density of  $[\text{O}^+]$ , while panel b) and c) represent  $[\text{NO}^+]$  and  $[\text{O}_2^+]$  respectively



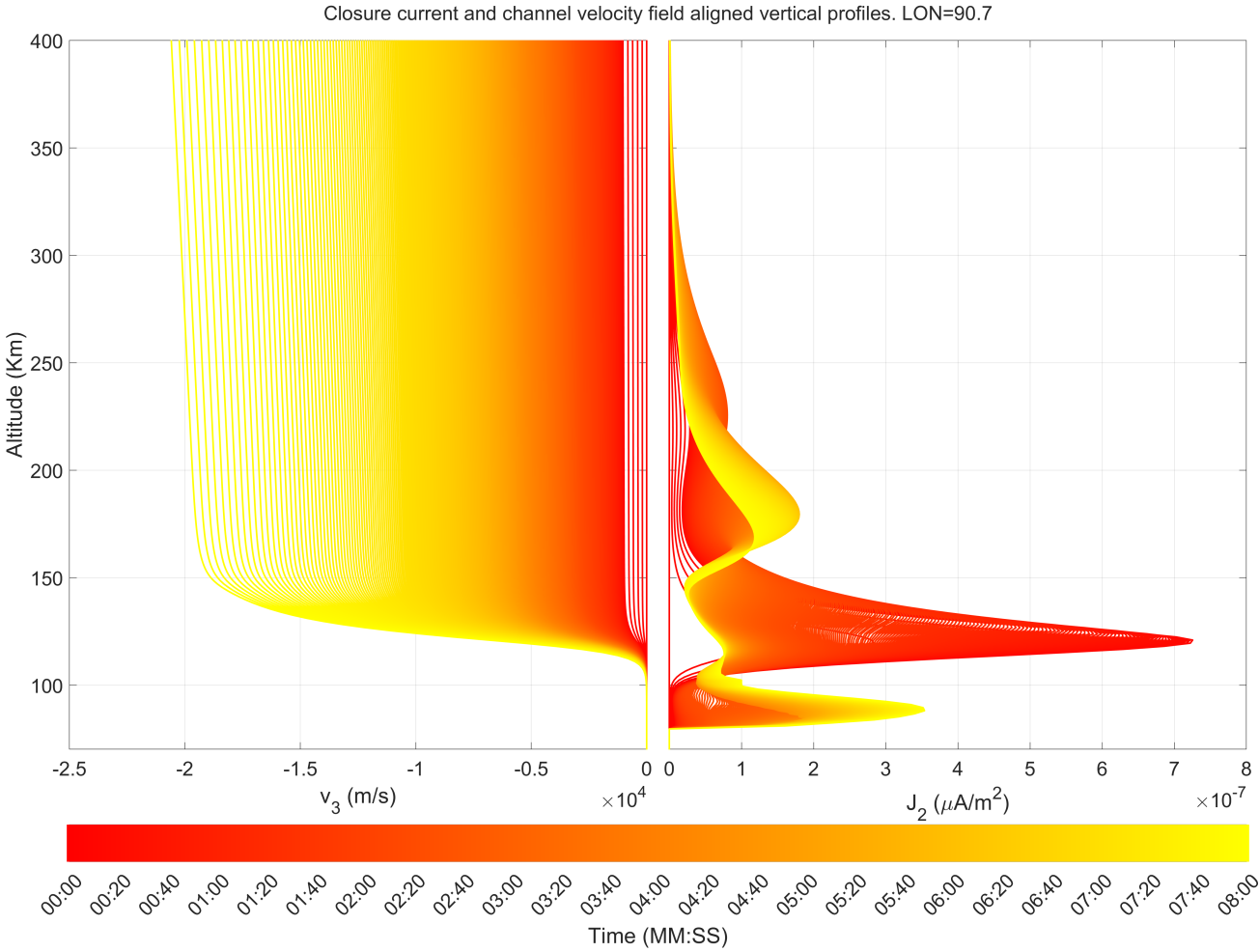
**Figure S20.**  $[\text{O}_2^+]$  energy at LON=90 for a 2D simulation.



**Figure S21.** Field-aligned plasma parameters at LON=90 in a 2D simulation. Time is represented as a gradient from red to yellow as seen on the bottom bar. Panel a) plasma density at the center of the channel. Panel b) closure current density ( $J_2$ ) at the center of the channel. Panel c) Pedersen conductivity at the center of the channel.

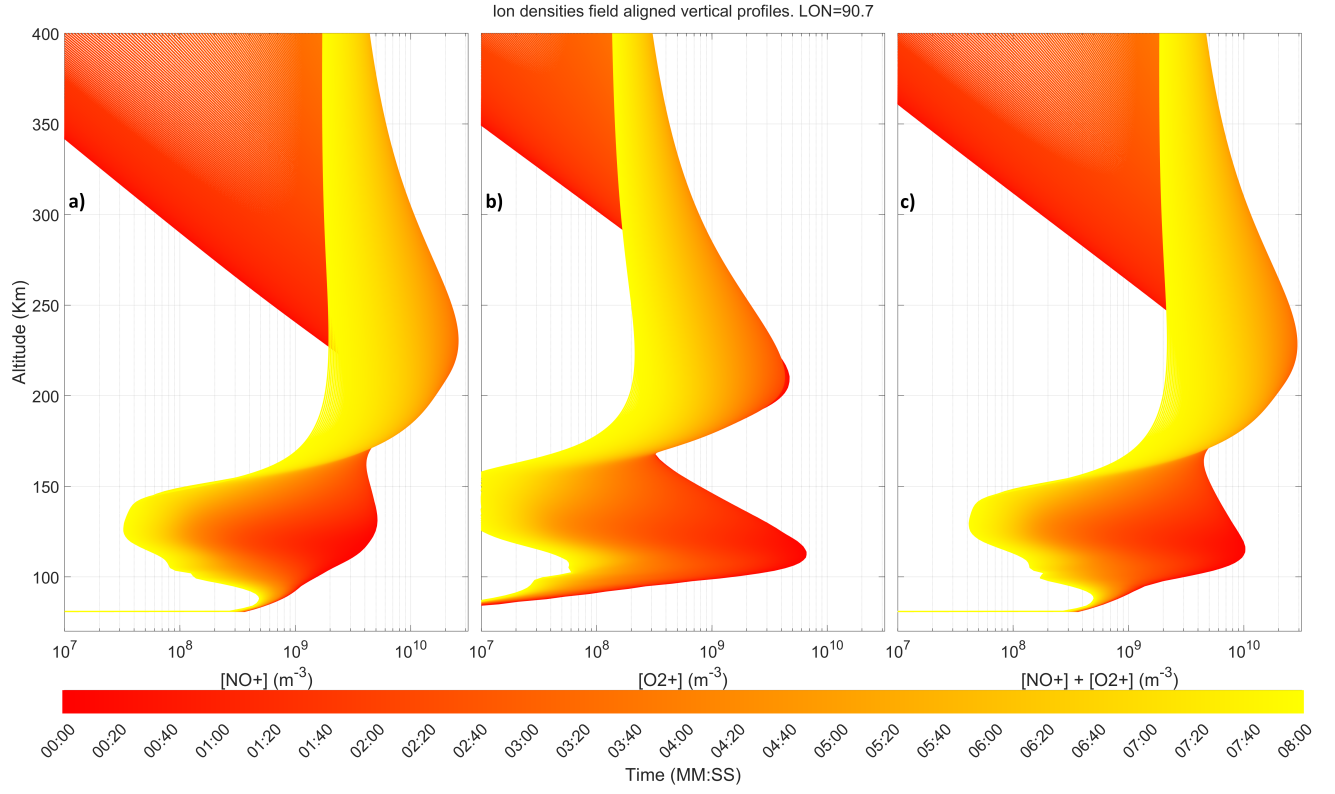


**Figure S22.** Ion and electron temperature field-aligned profiles at LON=90 in a 2D simulation. Time is represented as a gradient from red to yellow as seen on the bottom bar

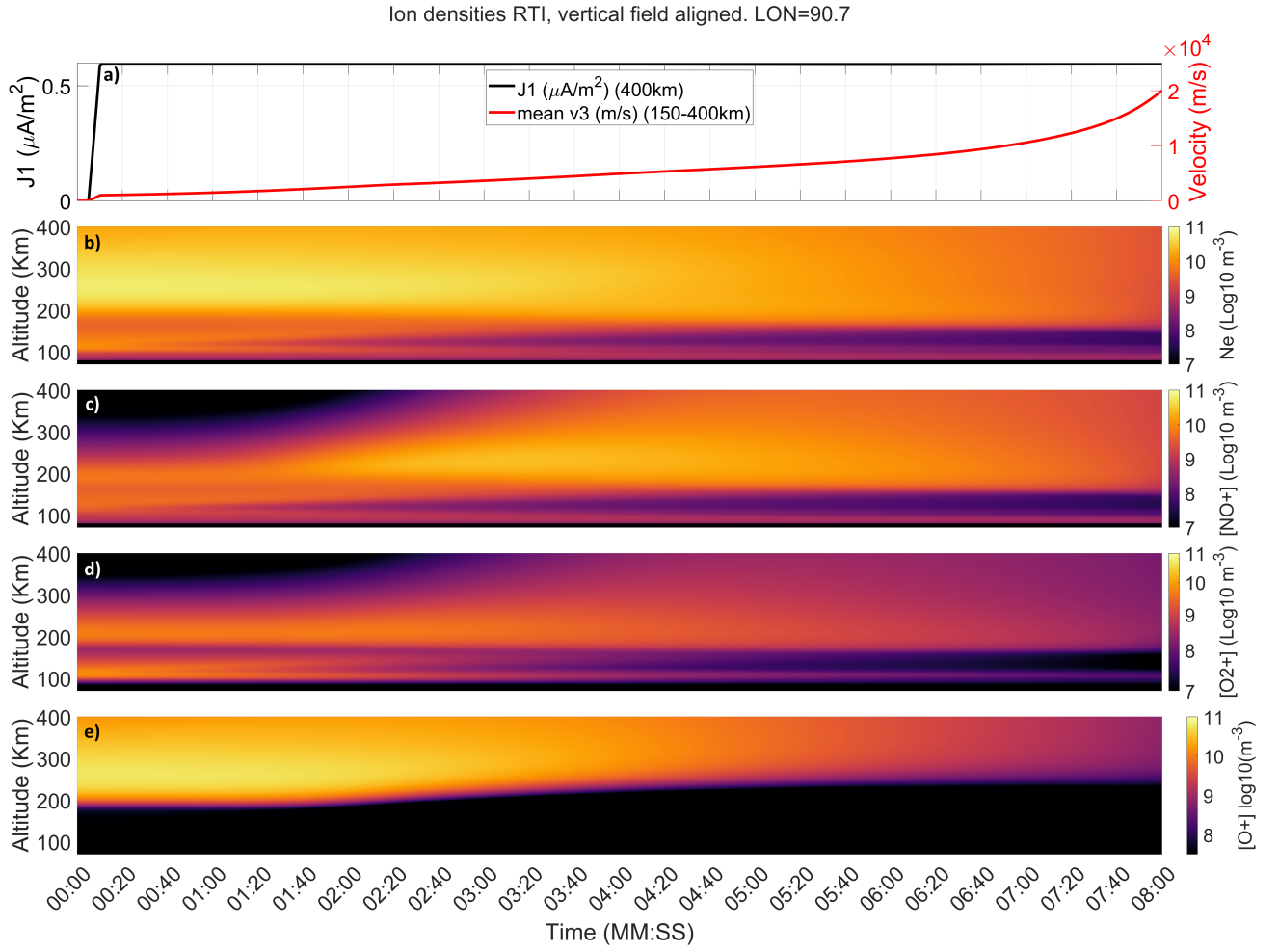


**Figure S23.** Channel velocity and closure current field-aligned profiles at LON=90 in a 2D simulation. Time is represented as a gradient from red to yellow as seen on the bottom bar





**Figure S24.** Plasma densities of the main ions field-aligned profiles at LON=90 in a 2D simulation. Panel a) represents the density of  $[\text{NO}^+]$ , panel b) represents the density of  $[\text{O}_2^+]$ , and panel c) represents the density of  $[\text{O}^+]$ . Time is represented as a gradient from red to yellow as seen on the bottom bar



**Figure S25.** RTI of plasma densities of the main ions field-aligned profiles at LON=90 in a 2D simulation. Panel a) represents both the channel velocity (red line) and parallel driving current density (black), panel b) represents the total plasma density, panel c) represents the density of  $[NO^+]$ , panel d) represents the density of  $[O_2^+]$ , and panel e) represents the density of  $[O^+]$ .