



*Supplement of*

## **Technical note: Nighttime OH and HO<sub>2</sub> chemical equilibria in the mesosphere–lower thermosphere**

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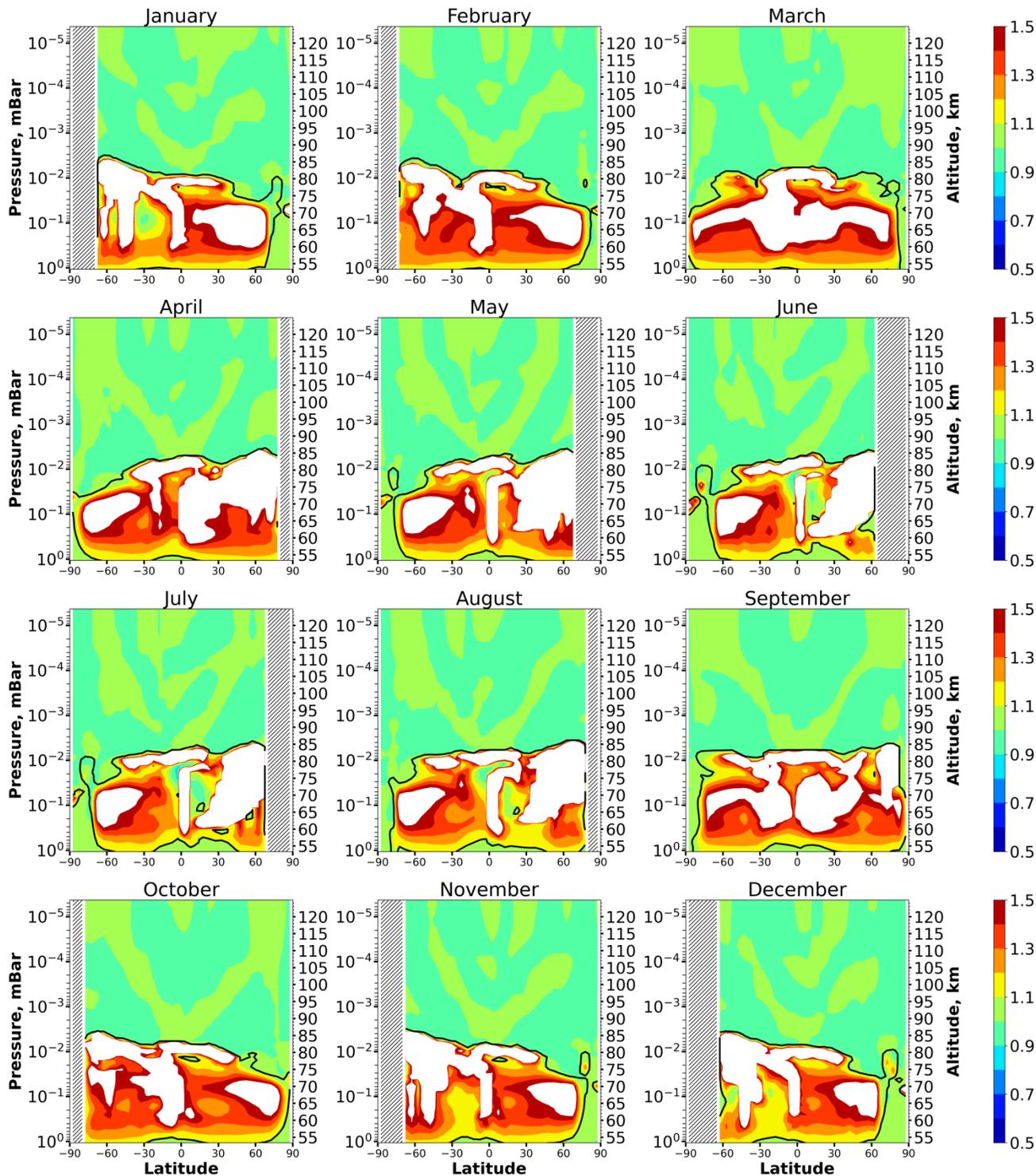


Figure S1. Figure 1 from the paper but with the threshold for the nighttime solar zenith angle is changed to  $95^\circ$ .

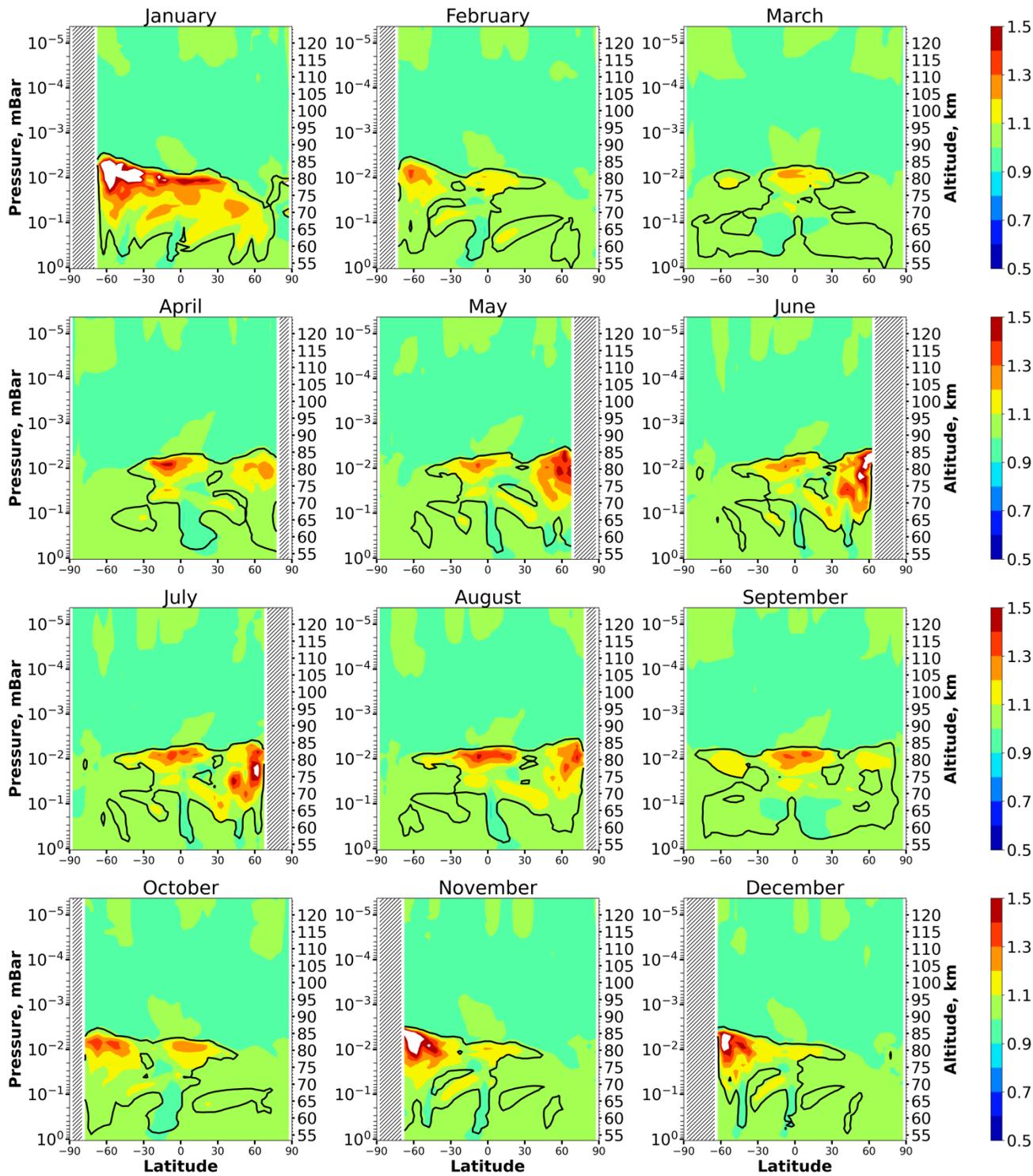


Figure S2. Figure 2 from the paper but with the threshold for the nighttime solar zenith angle is changed to  $95^\circ$ .

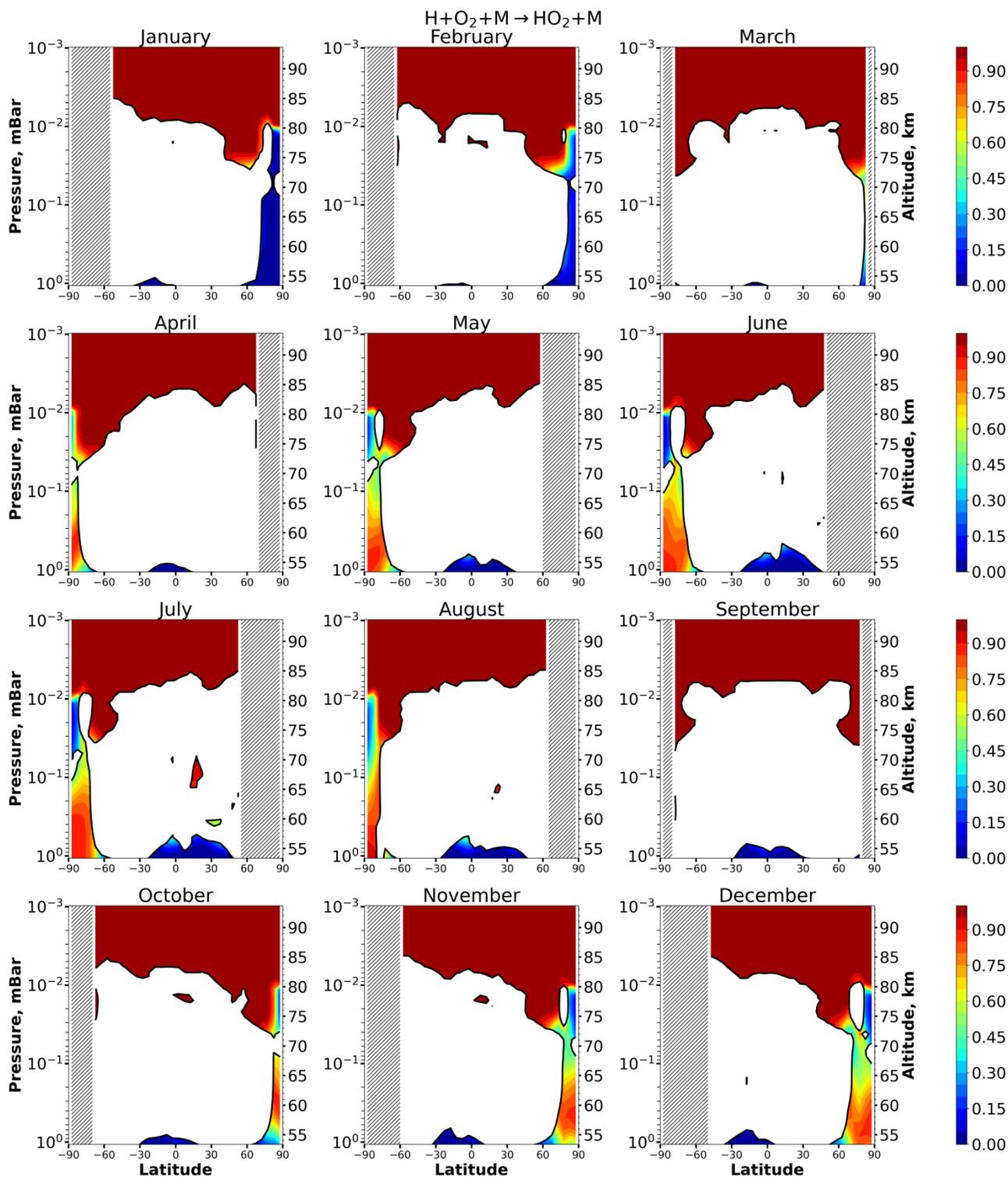


Figure S3. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{H} + \text{O}_2 + \text{M} \rightarrow \text{HO}_2 + \text{M}$  to the total source of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

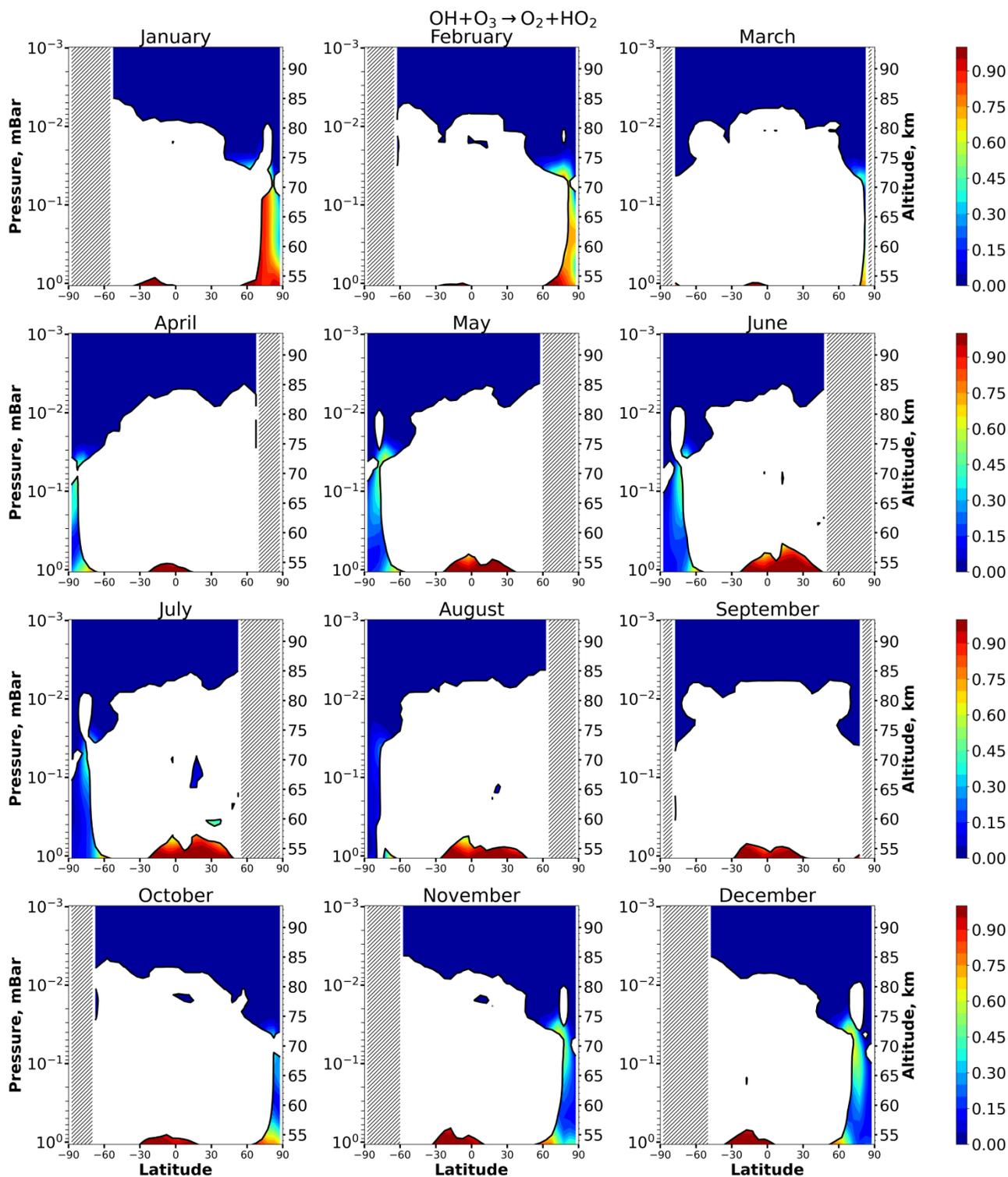


Figure S4. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{OH} + \text{O}_3 \rightarrow \text{O}_2 + \text{HO}_2$  to the total source of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

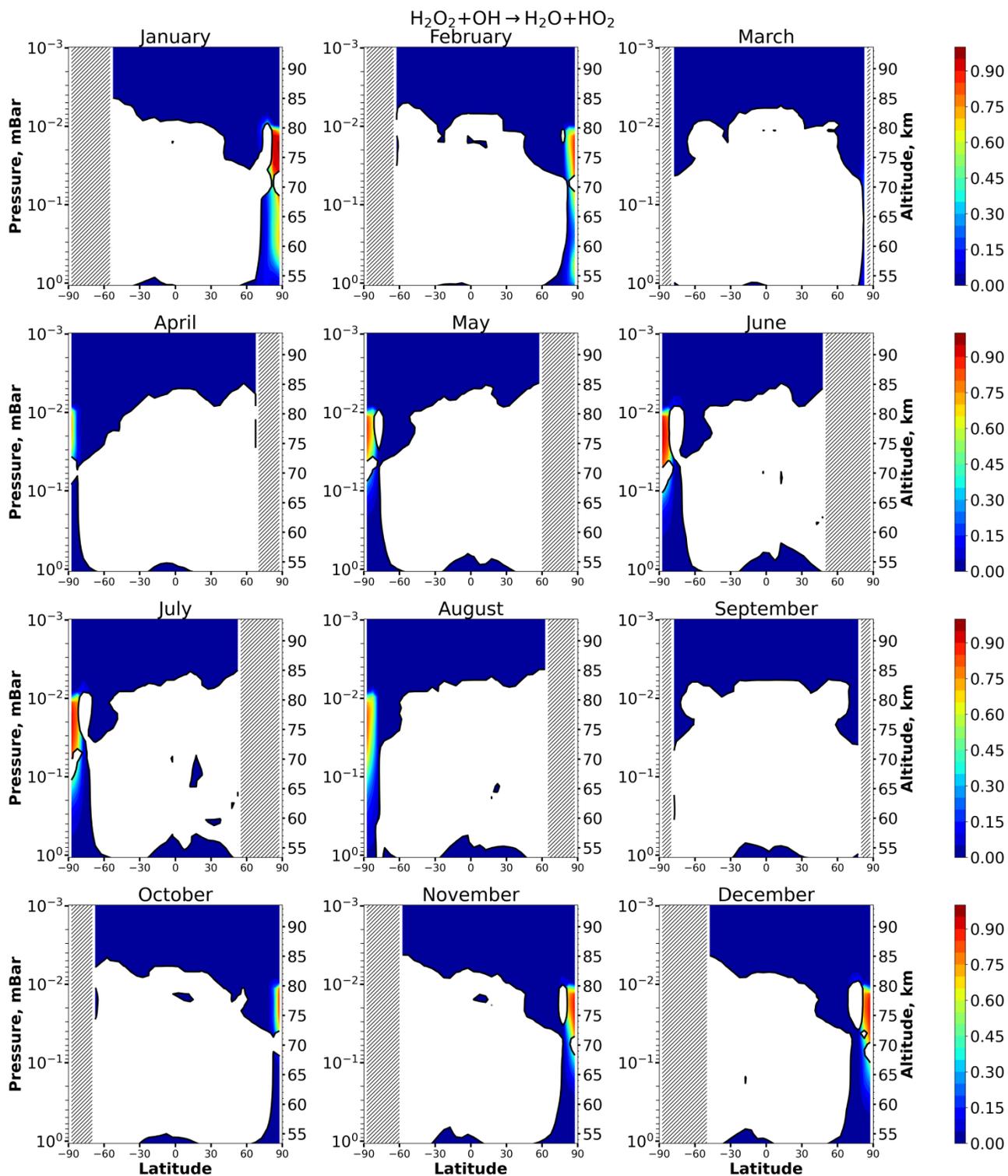


Figure S5. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{H}_2\text{O}_2 + \text{OH} \rightarrow \text{H}_2\text{O} + \text{HO}_2$  to the total source of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

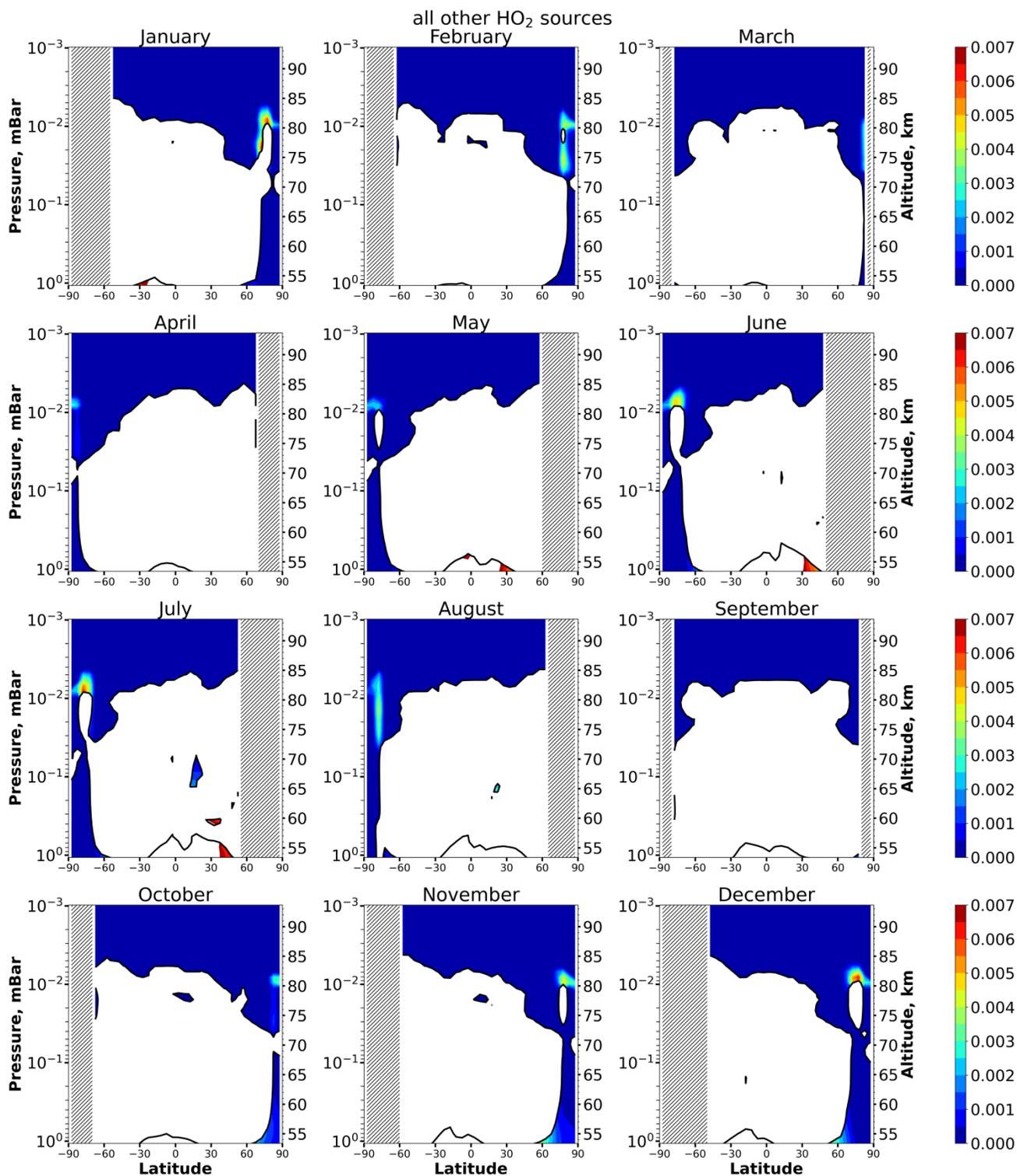


Figure S6. Nighttime mean and monthly averaged relative total contribution of all other reactions (H<sub>2</sub>O<sub>2</sub>+O → OH+HO<sub>2</sub>, CHO+O<sub>2</sub> → HO<sub>2</sub>+CO, and CH<sub>3</sub>O+O<sub>2</sub> → CH<sub>2</sub>O+HO<sub>2</sub>) to the total source of HO<sub>2</sub> in equilibrium areas. White color indicates nonequilibrium areas of HO<sub>2</sub>.

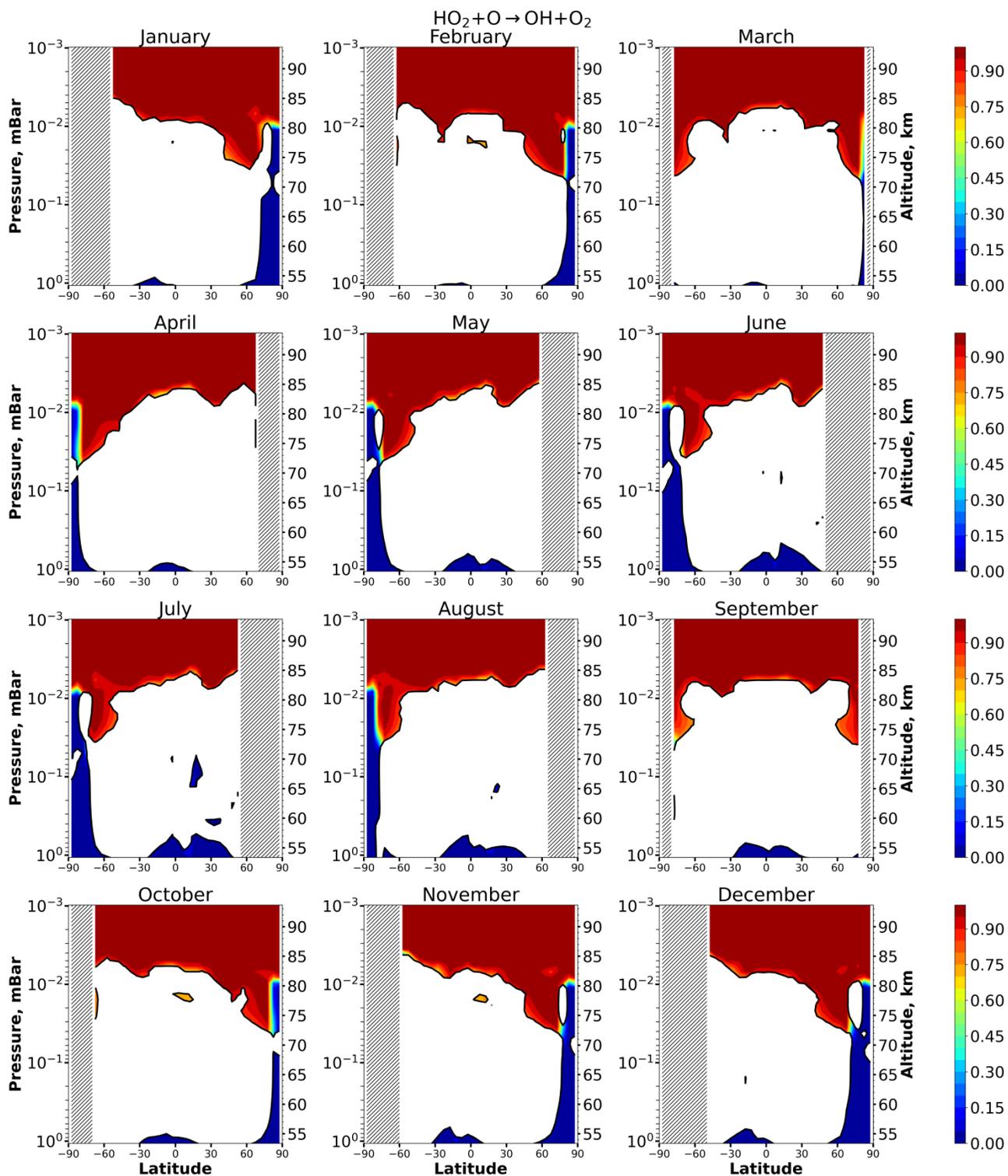


Figure S7. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{HO}_2 + \text{O} \rightarrow \text{OH} + \text{O}_2$  to the total sink of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

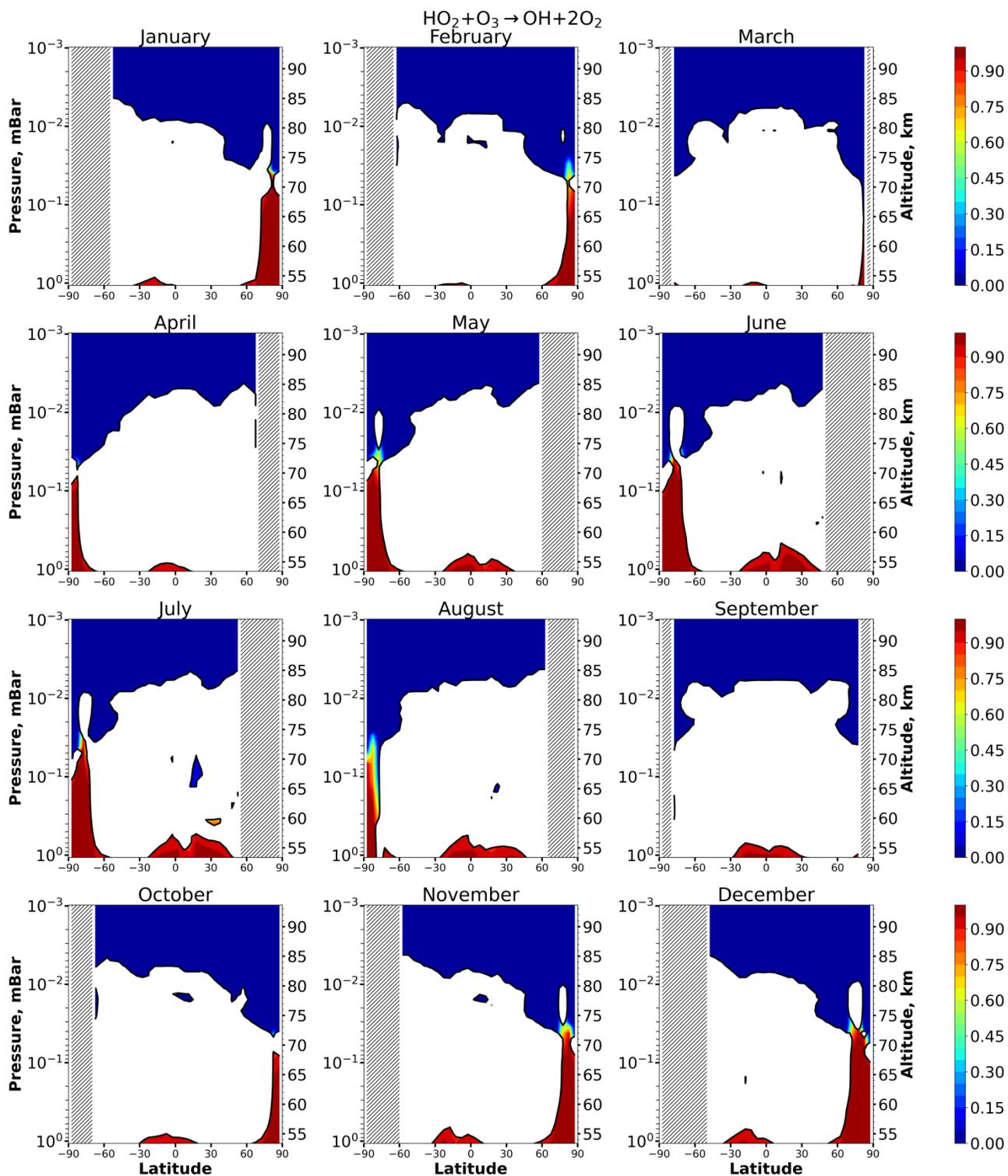


Figure S8. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{HO}_2 + \text{O}_3 \rightarrow \text{OH} + 2\text{O}_2$  to the total sink of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

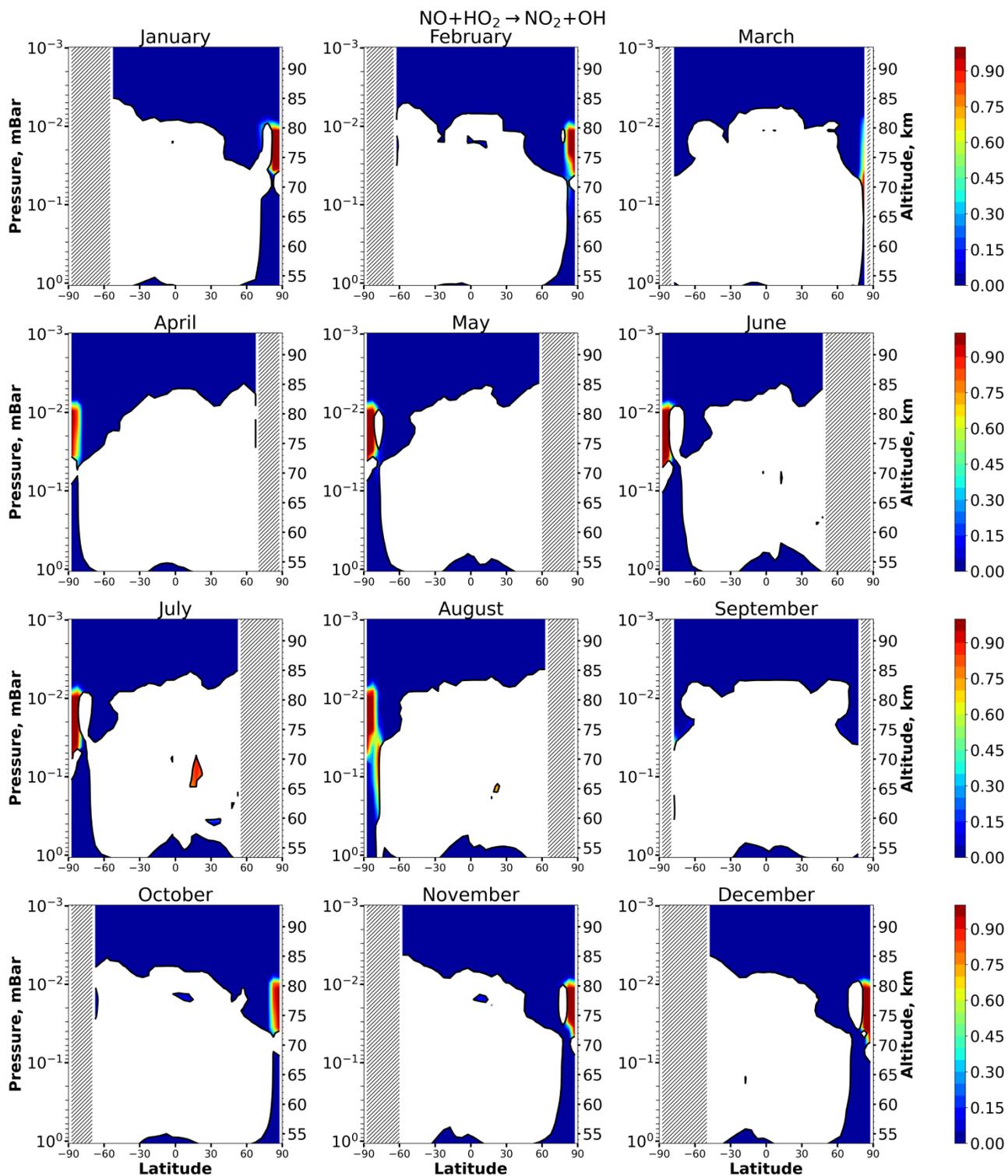


Figure S9. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{NO} + \text{HO}_2 \rightarrow \text{NO}_2 + \text{OH}$  to the total sink of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

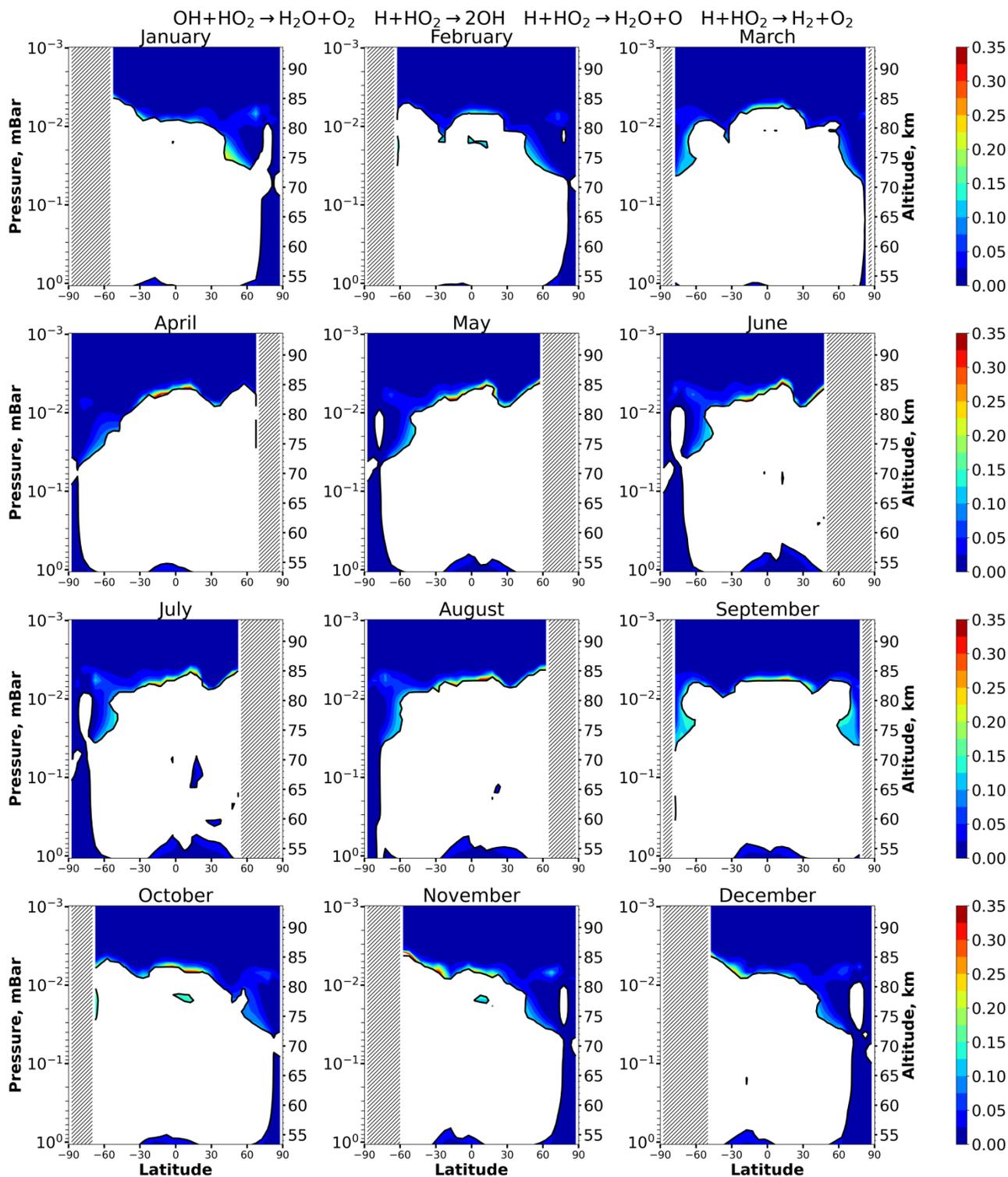


Figure S10. Nighttime mean and monthly averaged relative total contribution of the reactions  $\text{OH}+\text{HO}_2 \rightarrow \text{H}_2\text{O}+\text{O}_2$ ,  $\text{H}+\text{HO}_2 \rightarrow 2\text{OH}$ ,  $\text{H}+\text{HO}_2 \rightarrow \text{H}_2\text{O}+\text{O}$ , and  $\text{H}+\text{HO}_2 \rightarrow \text{H}_2+\text{O}_2$  to the total sink of  $\text{HO}_2$  in equilibrium areas. White color indicates nonequilibrium areas of  $\text{HO}_2$ .

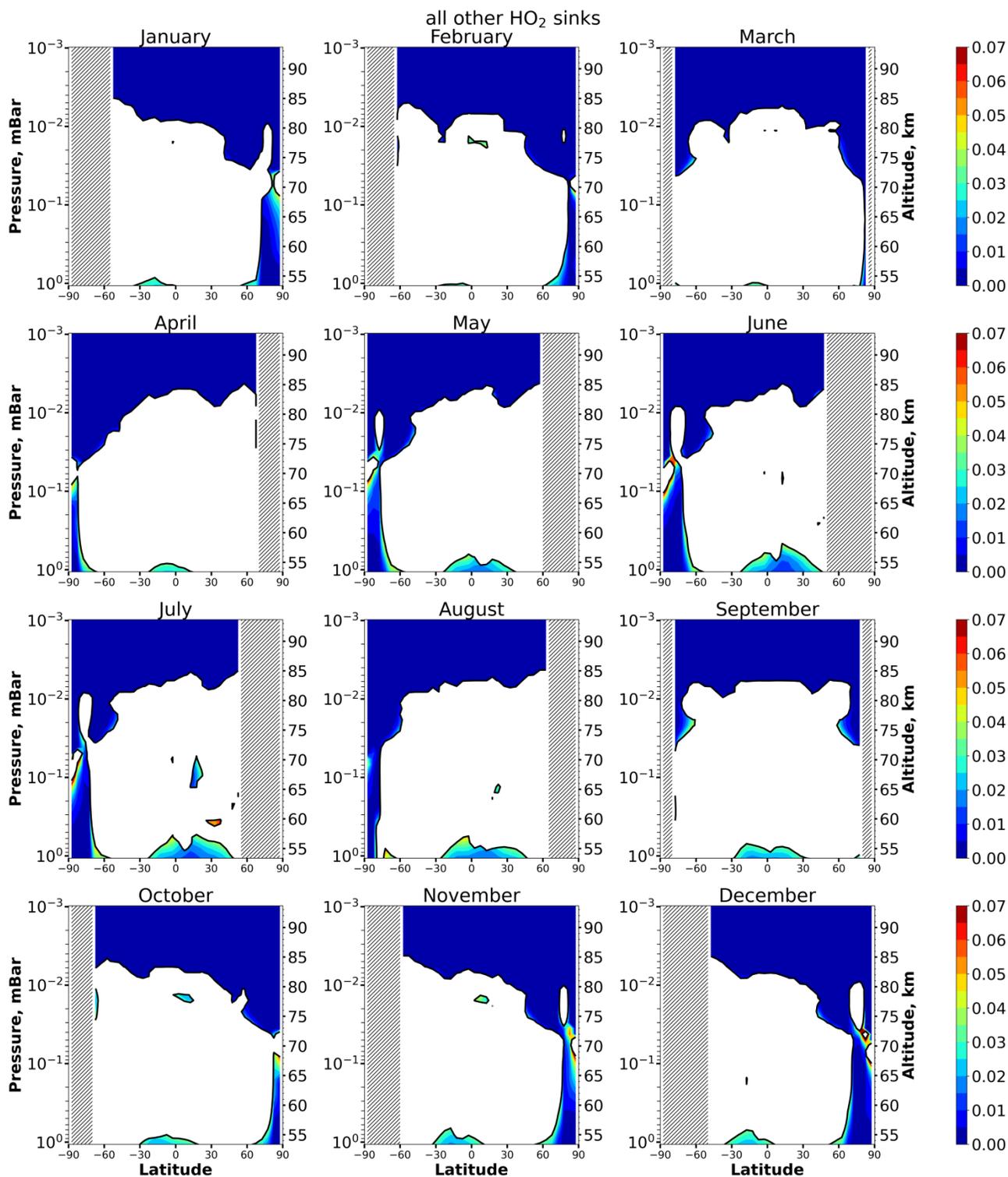


Figure S11. Nighttime mean and monthly averaged relative contribution of total contribution of all other reactions (HO<sub>2</sub>+HO<sub>2</sub> → H<sub>2</sub>O<sub>2</sub>+O<sub>2</sub> and HO<sub>2</sub>+HO<sub>2</sub>+M → H<sub>2</sub>O<sub>2</sub>+O<sub>2</sub>+M) to the total sink of HO<sub>2</sub> in equilibrium areas. White color indicates nonequilibrium areas of HO<sub>2</sub>.

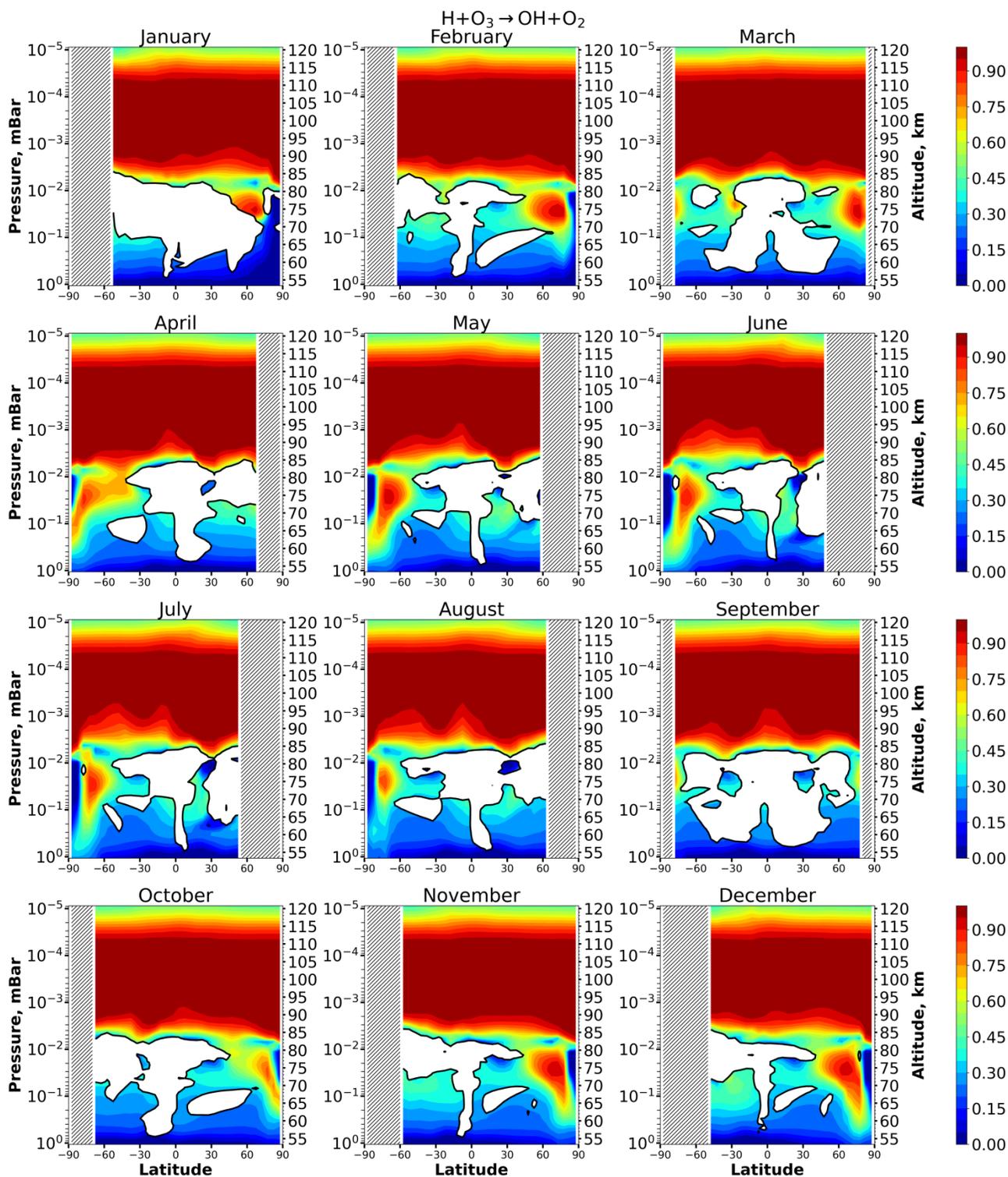


Figure S12. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{H} + \text{O}_3 \rightarrow \text{OH} + \text{O}_2$  to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

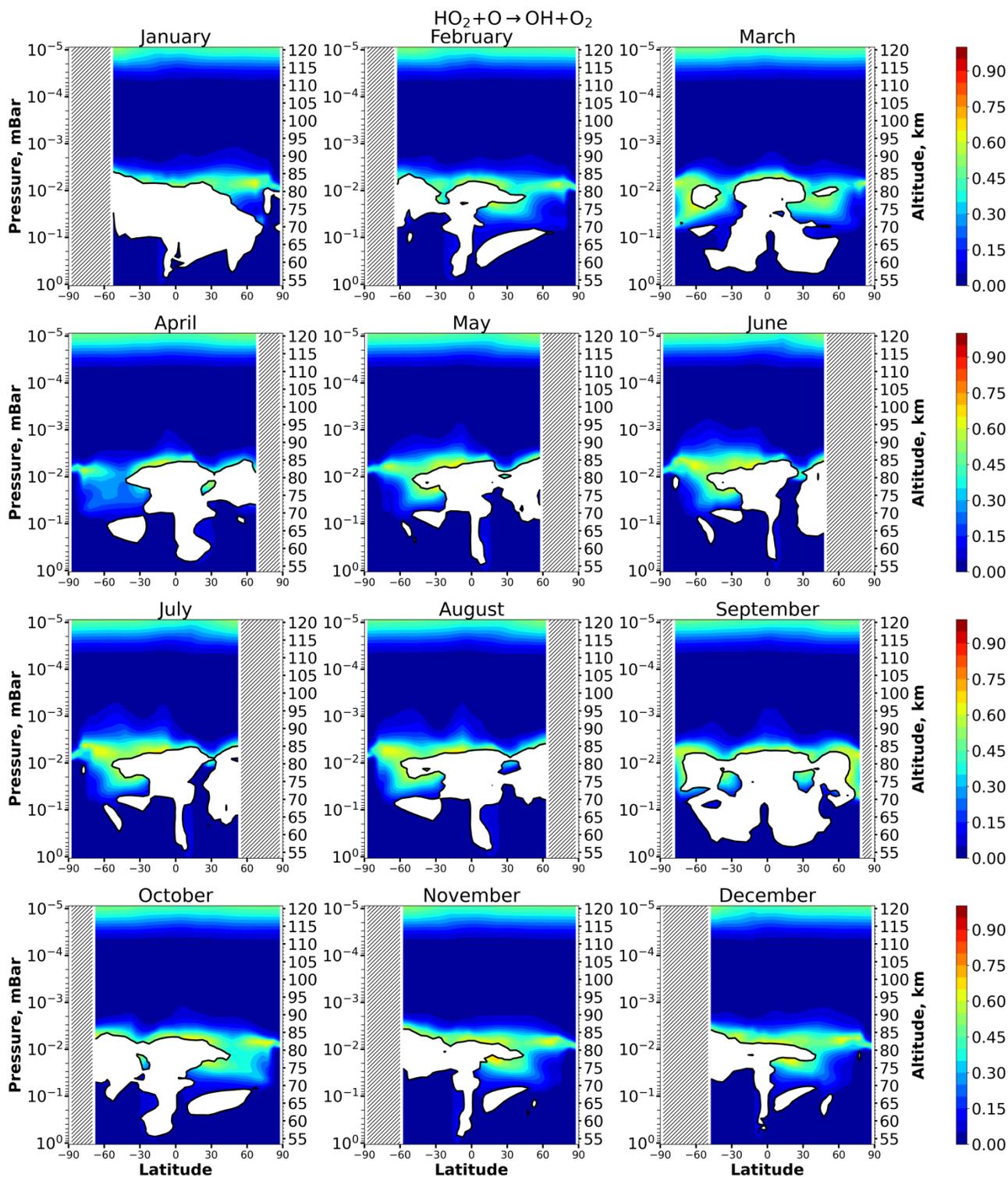


Figure S13. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{HO}_2 + \text{O} \rightarrow \text{OH} + \text{O}_2$  to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

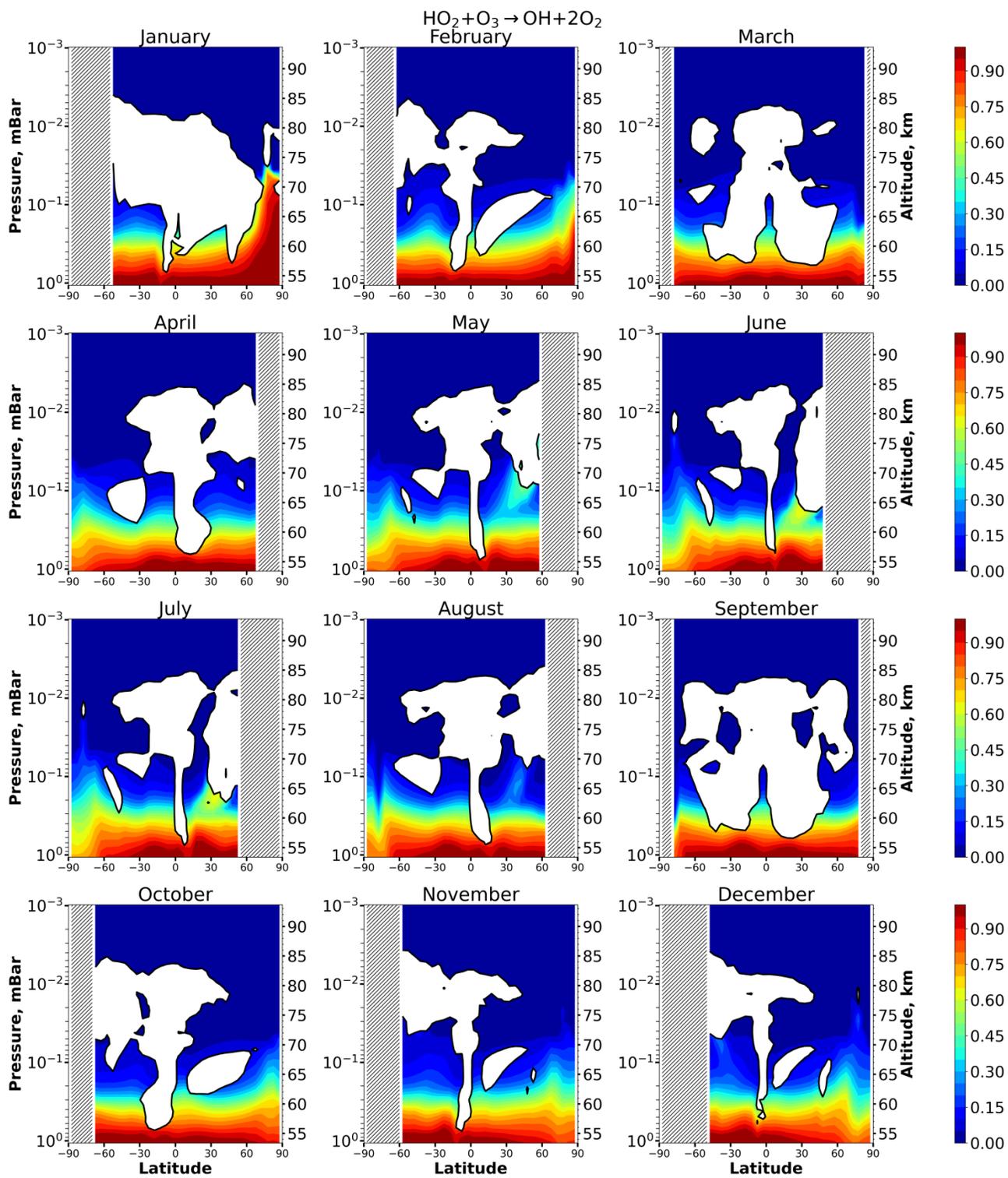


Figure S14. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{HO}_2 + \text{O}_3 \rightarrow \text{OH} + 2\text{O}_2$  to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

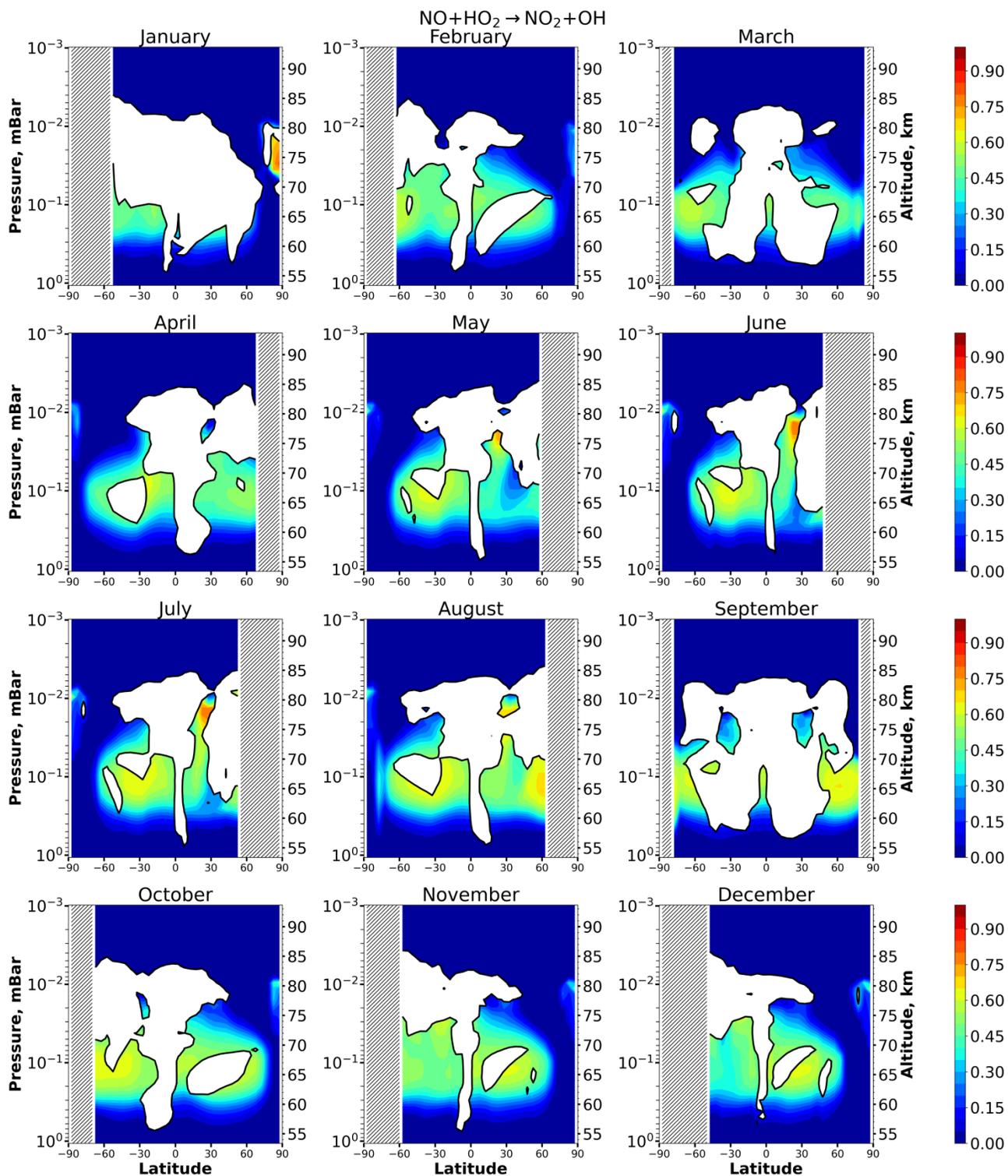


Figure S15. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{NO} + \text{HO}_2 \rightarrow \text{NO}_2 + \text{OH}$  to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

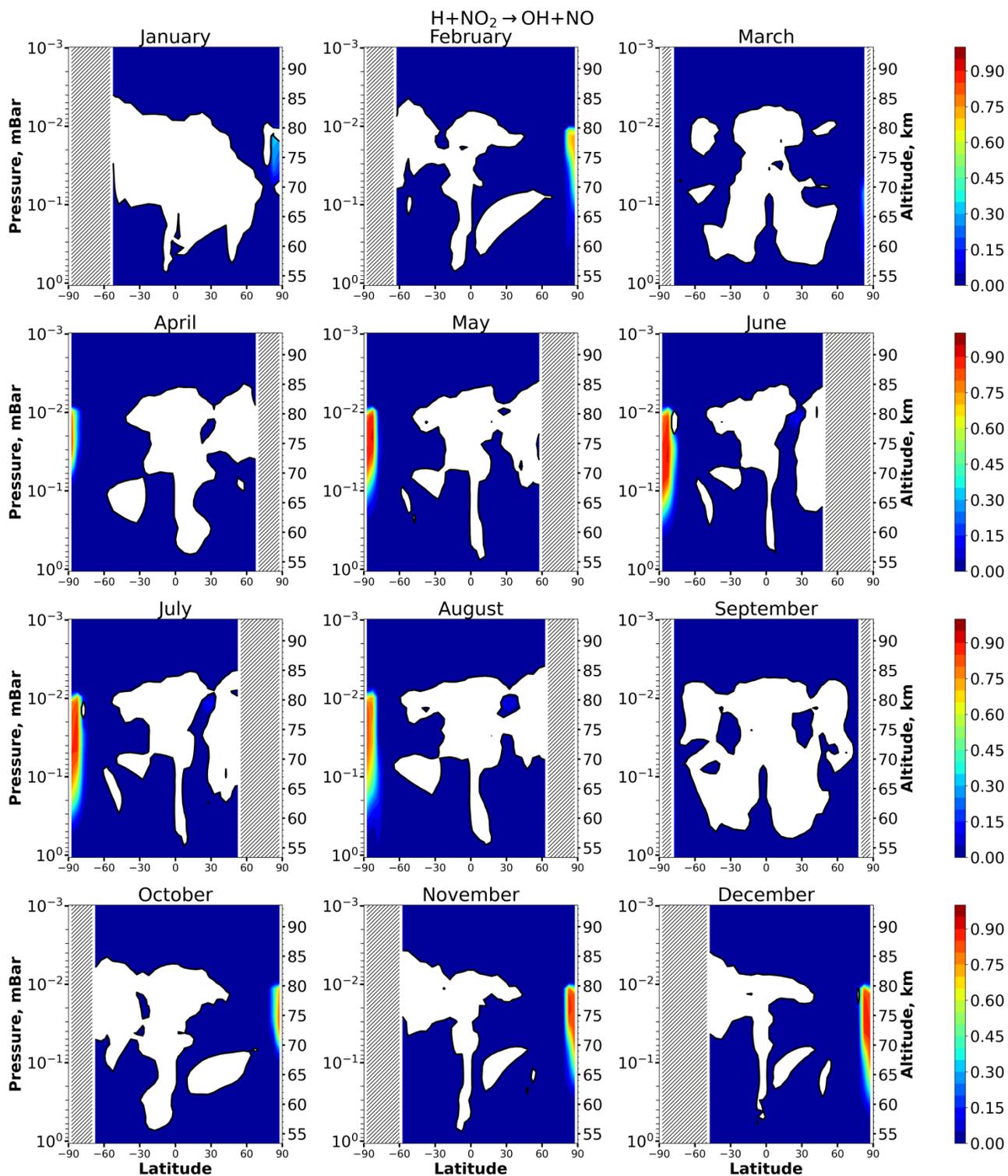


Figure S16. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{H} + \text{NO}_2 \rightarrow \text{OH} + \text{NO}$  to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

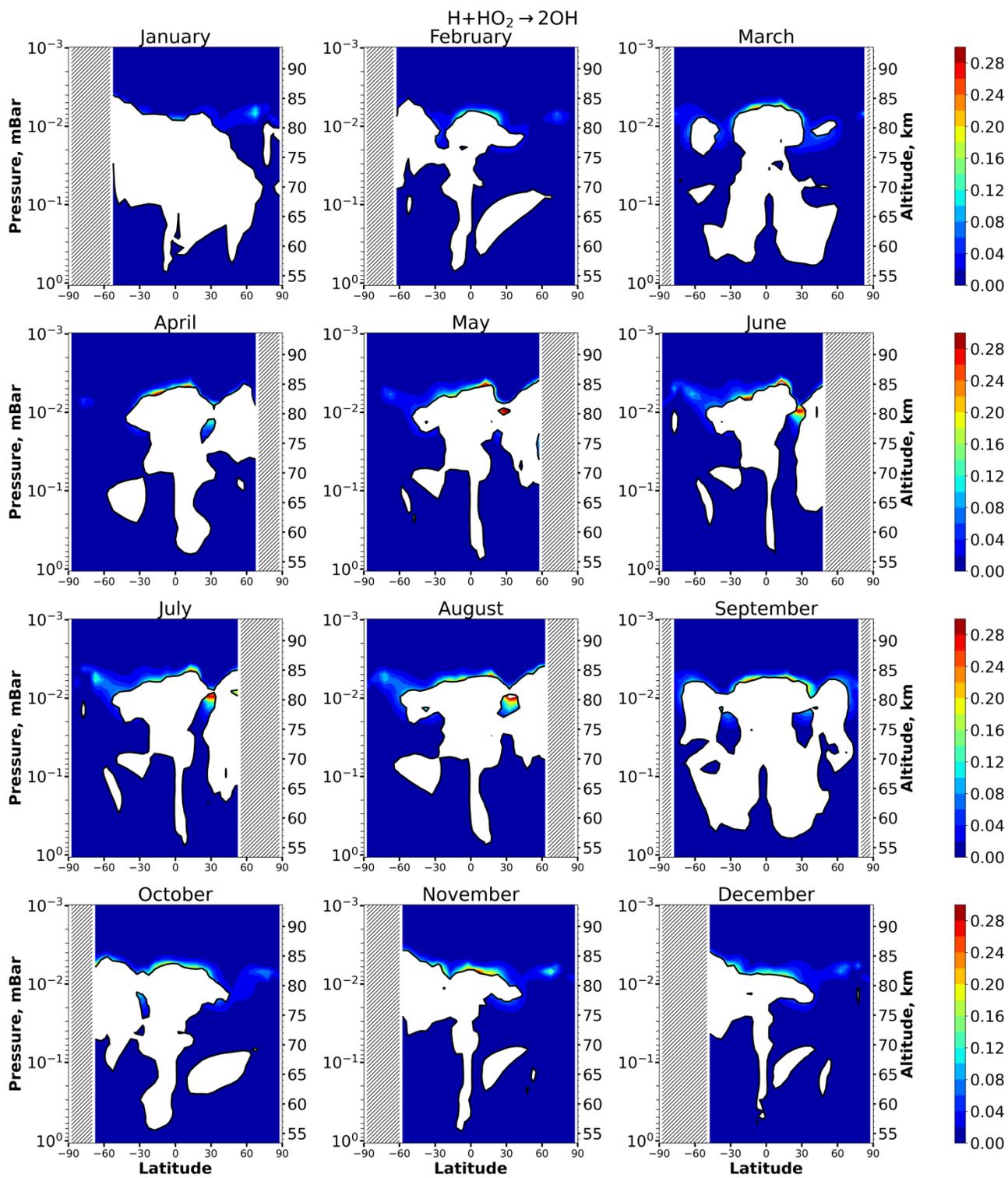


Figure S17. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{H} + \text{HO}_2 \rightarrow 2\text{OH}$  to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

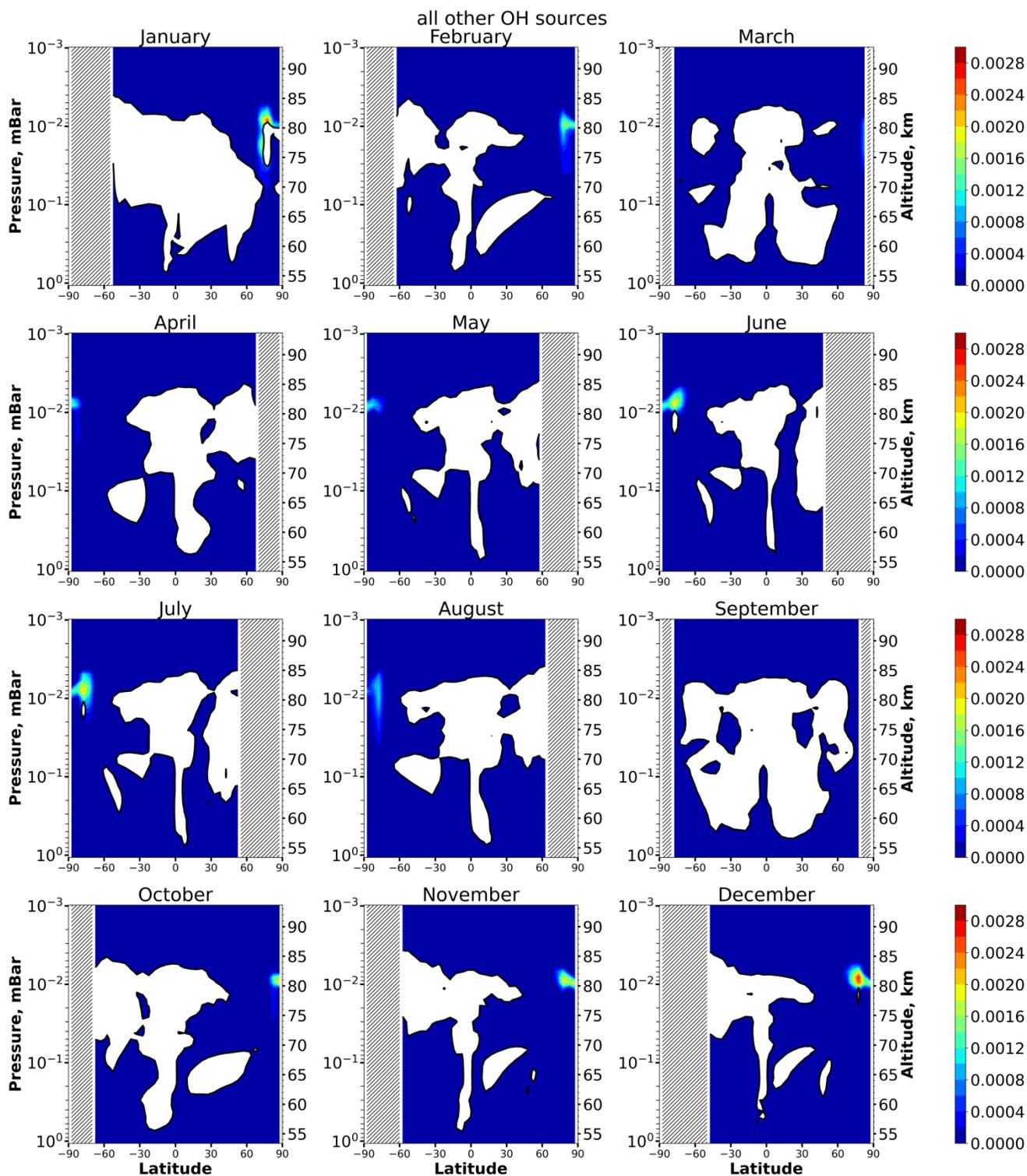


Figure S18. Nighttime mean and monthly averaged relative total contribution of all other reactions ( $\text{H}_2\text{O}_2 + \text{O} \rightarrow \text{OH} + \text{HO}_2$ ,  $\text{H} + \text{NO}_2 \rightarrow \text{OH} + \text{NO}$ ,  $\text{O}(^1\text{D}) + \text{H}_2\text{O} \rightarrow 2\text{OH}$ ,  $\text{O}(^1\text{D}) + \text{H}_2 \rightarrow \text{H} + \text{OH}$ , and  $\text{CH}_4 + \text{O}(^1\text{D}) \rightarrow \text{CH}_3 + \text{OH}$ ) to the total source of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

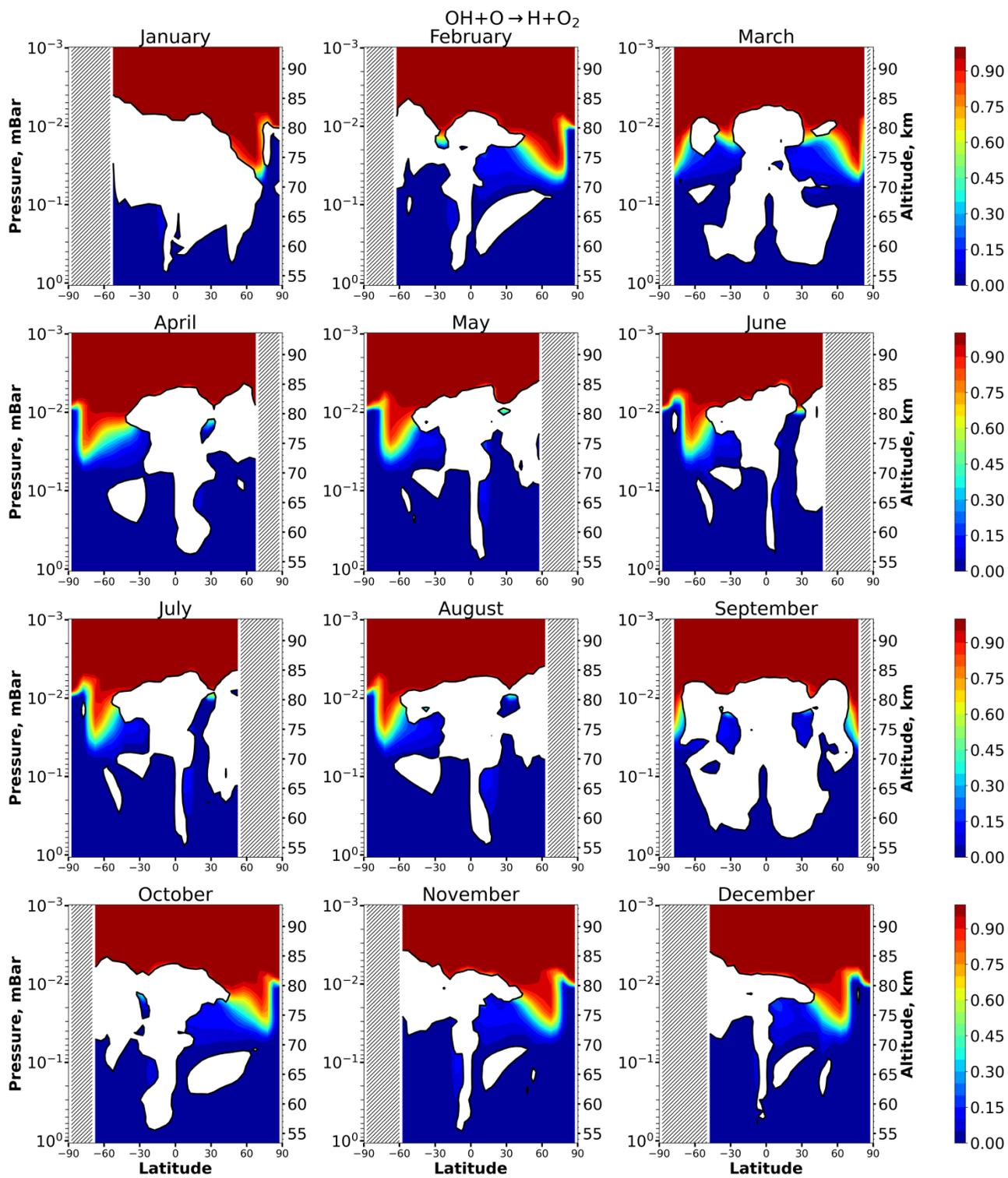


Figure S19. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{OH} + \text{O} \rightarrow \text{H} + \text{O}_2$  to the total sink of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

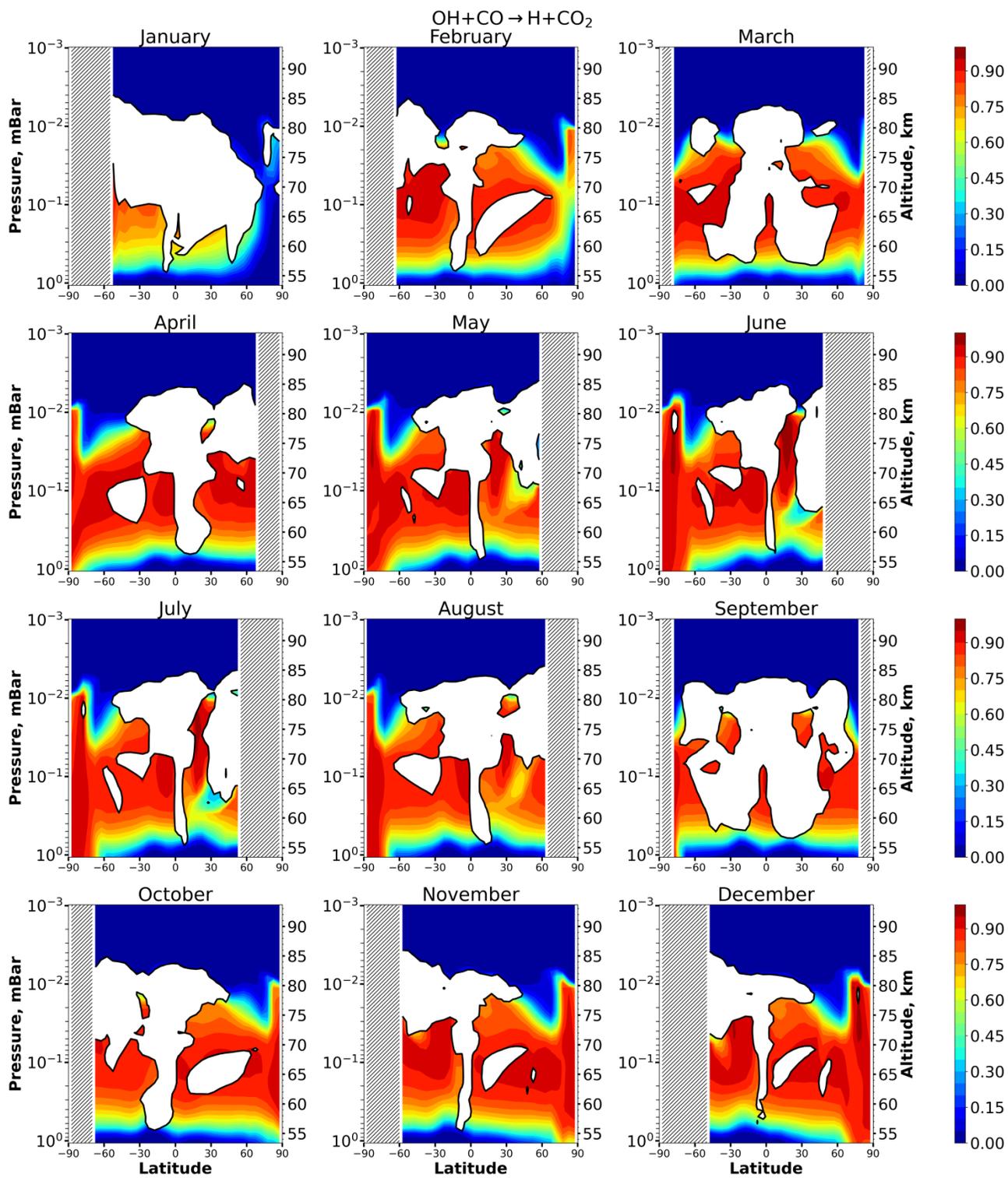


Figure S20. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{OH} + \text{CO} \rightarrow \text{H} + \text{CO}_2$  to the total sink of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

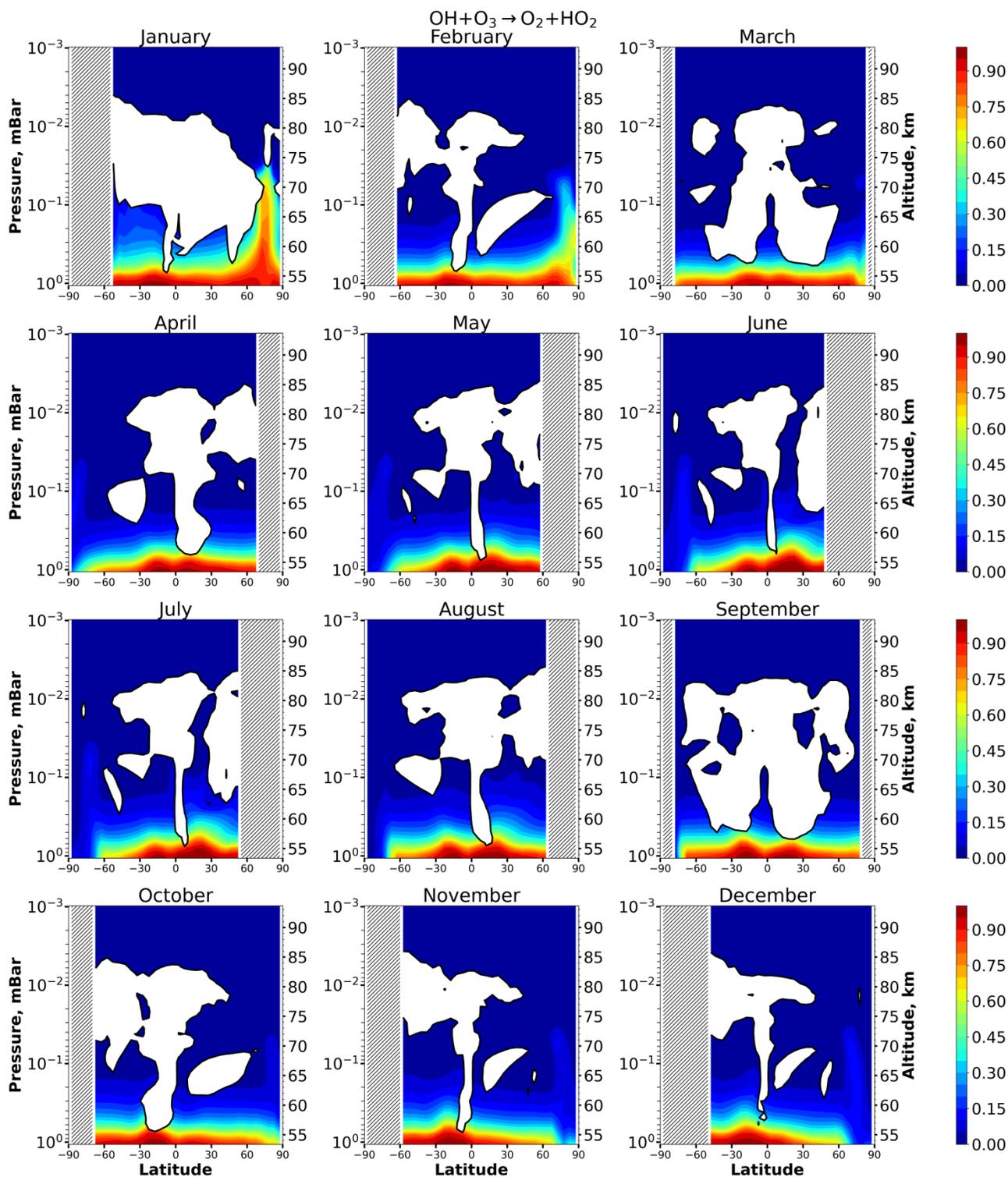


Figure S21. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{OH} + \text{O}_3 \rightarrow \text{O}_2 + \text{HO}_2$  to the total sink of OH in equilibrium areas. White color points nonequilibrium areas of OH.

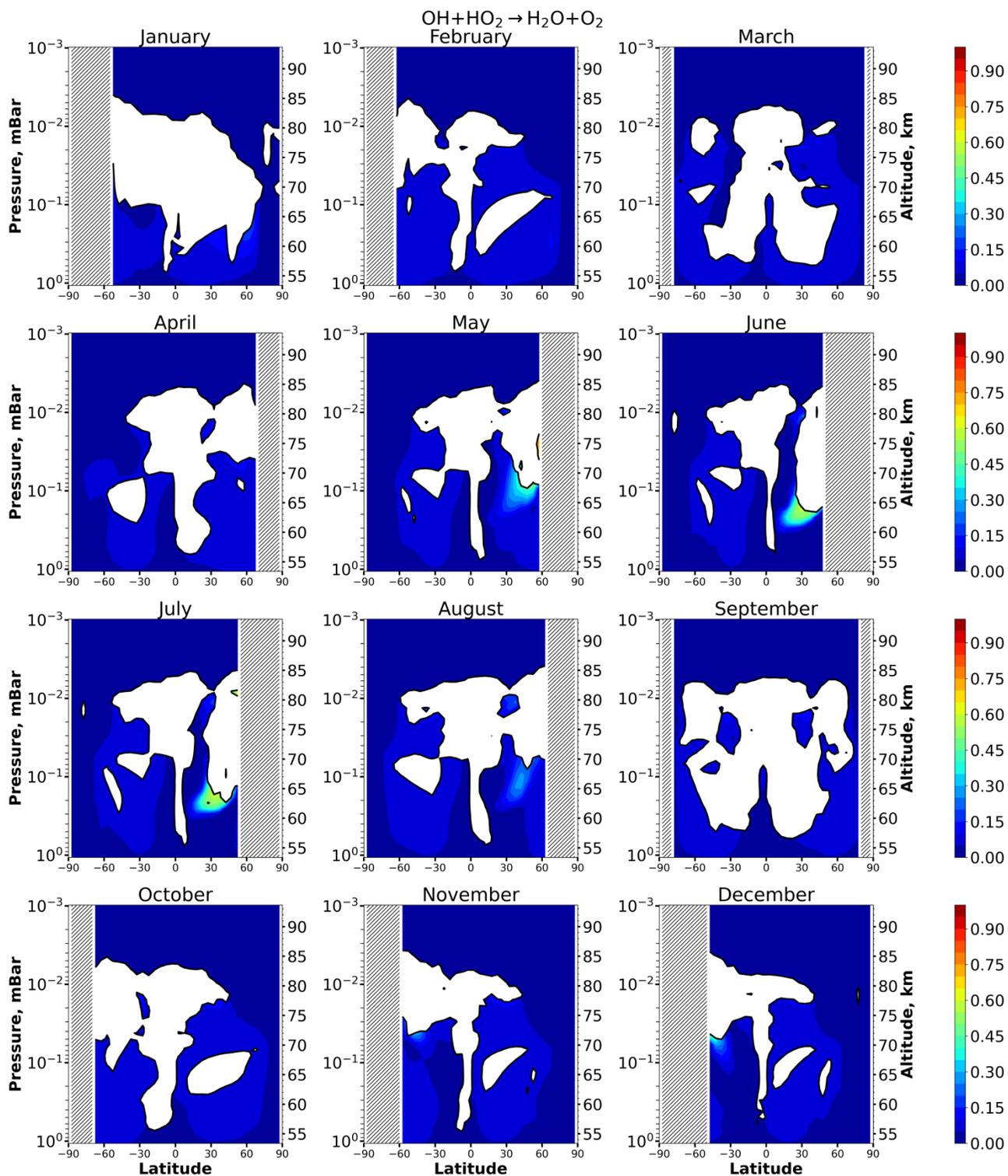


Figure S22. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{OH} + \text{HO}_2 \rightarrow \text{H}_2\text{O} + \text{O}_2$  to the total sink of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

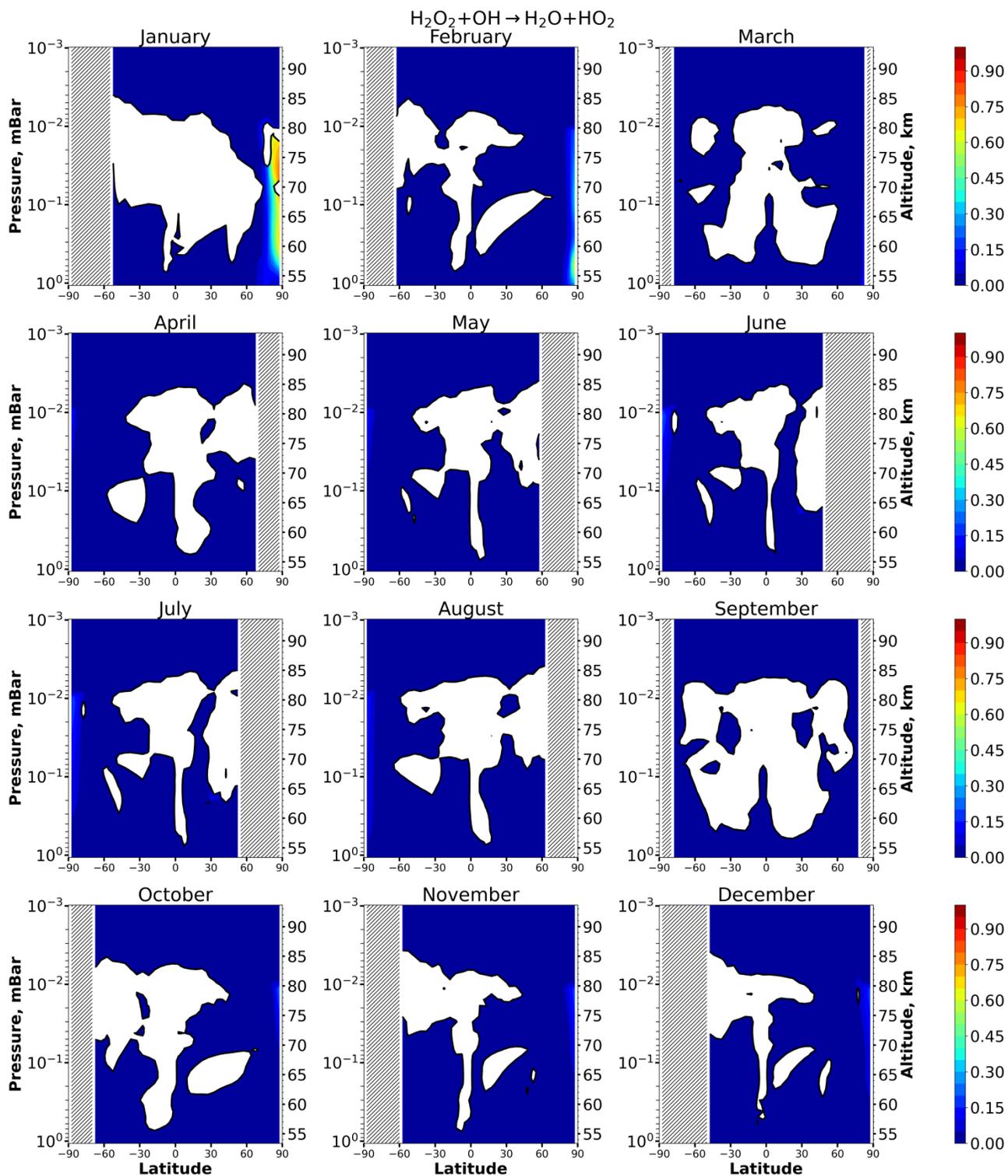


Figure S23. Nighttime mean and monthly averaged relative contribution of the reaction  $\text{H}_2\text{O}_2 + \text{OH} \rightarrow \text{H}_2\text{O} + \text{HO}_2$  to the total sink of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

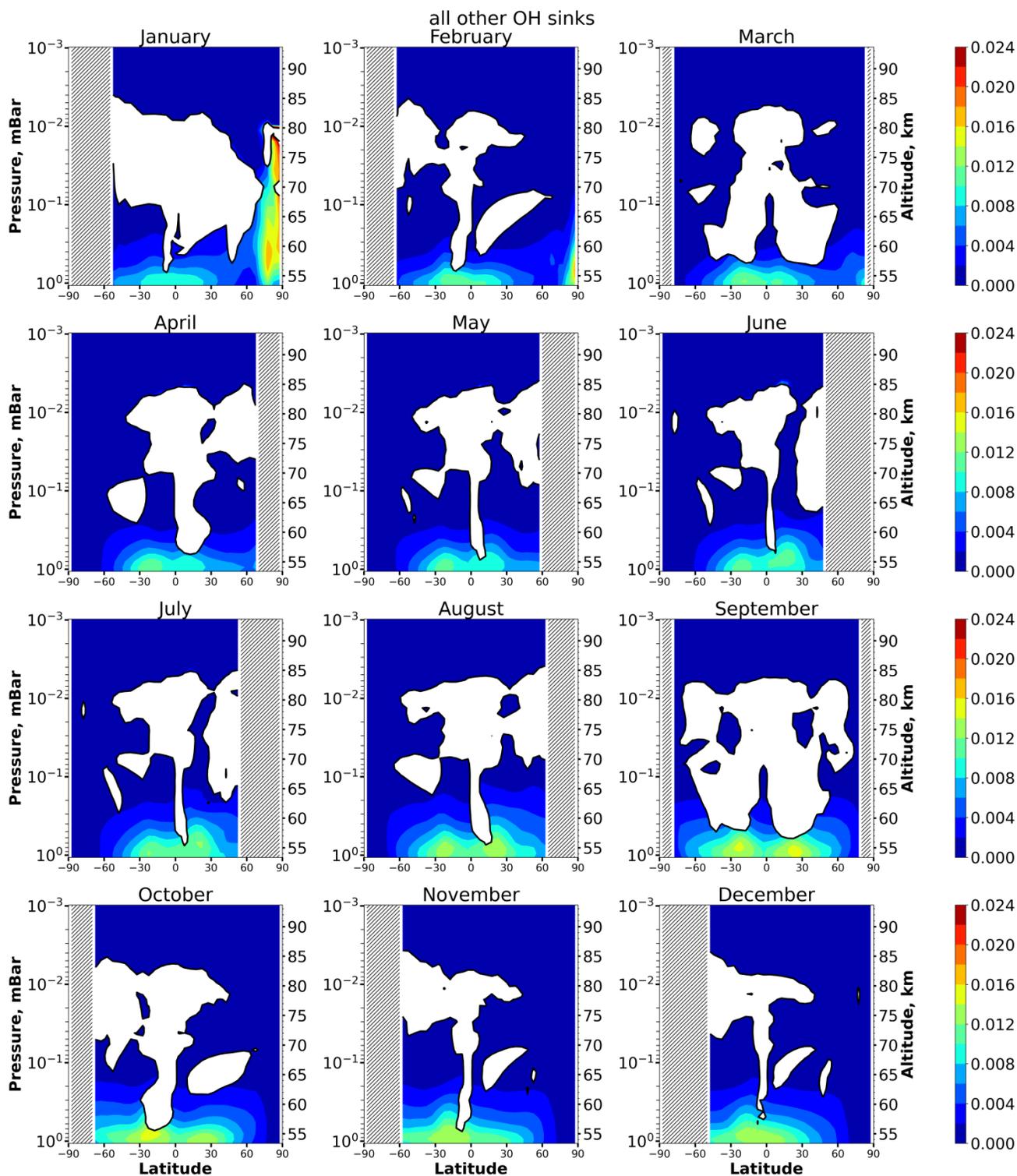


Figure S24. Nighttime mean and monthly averaged relative total contribution of all other reactions ( $\text{OH} + \text{OH} \rightarrow \text{H}_2\text{O} + \text{O}$ ,  $\text{OH} + \text{OH} + \text{M} \rightarrow \text{H}_2\text{O}_2 + \text{M}$ ,  $\text{H} + \text{OH} + \text{N}_2 \rightarrow \text{H}_2\text{O} + \text{N}_2$ ,  $\text{CH}_4 + \text{OH} \rightarrow \text{CH}_3 + \text{H}_2\text{O}$ ,  $\text{OH} + \text{H}_2 \rightarrow \text{H}_2\text{O} + \text{H}$ , and  $\text{N} + \text{OH} \rightarrow \text{NO} + \text{H}$ ) to the total sink of OH in equilibrium areas. White color indicates nonequilibrium areas of OH.

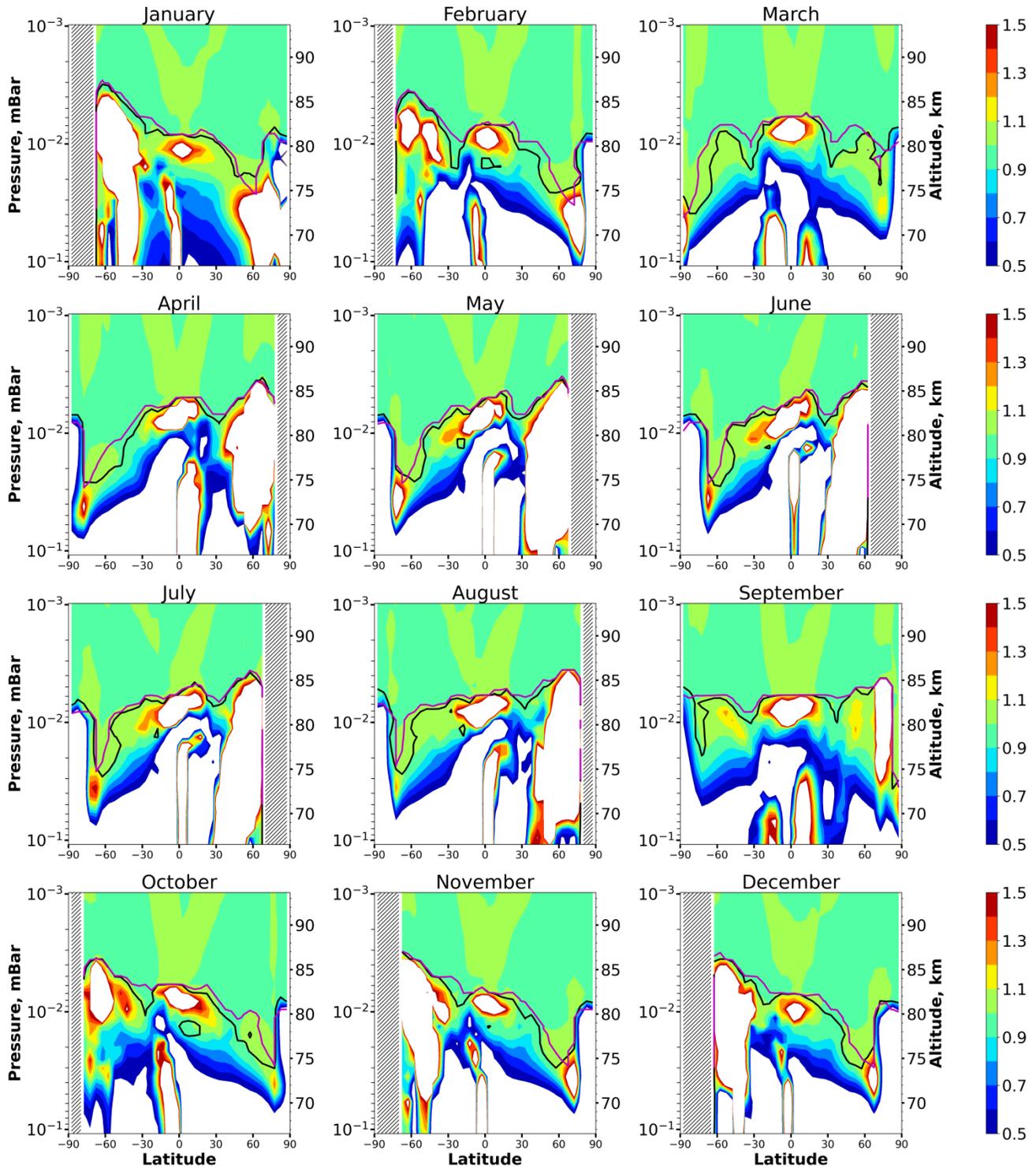


Figure S25. Figure 5 from the paper but with the threshold for the nighttime solar zenith angle is changed to  $95^\circ$ .

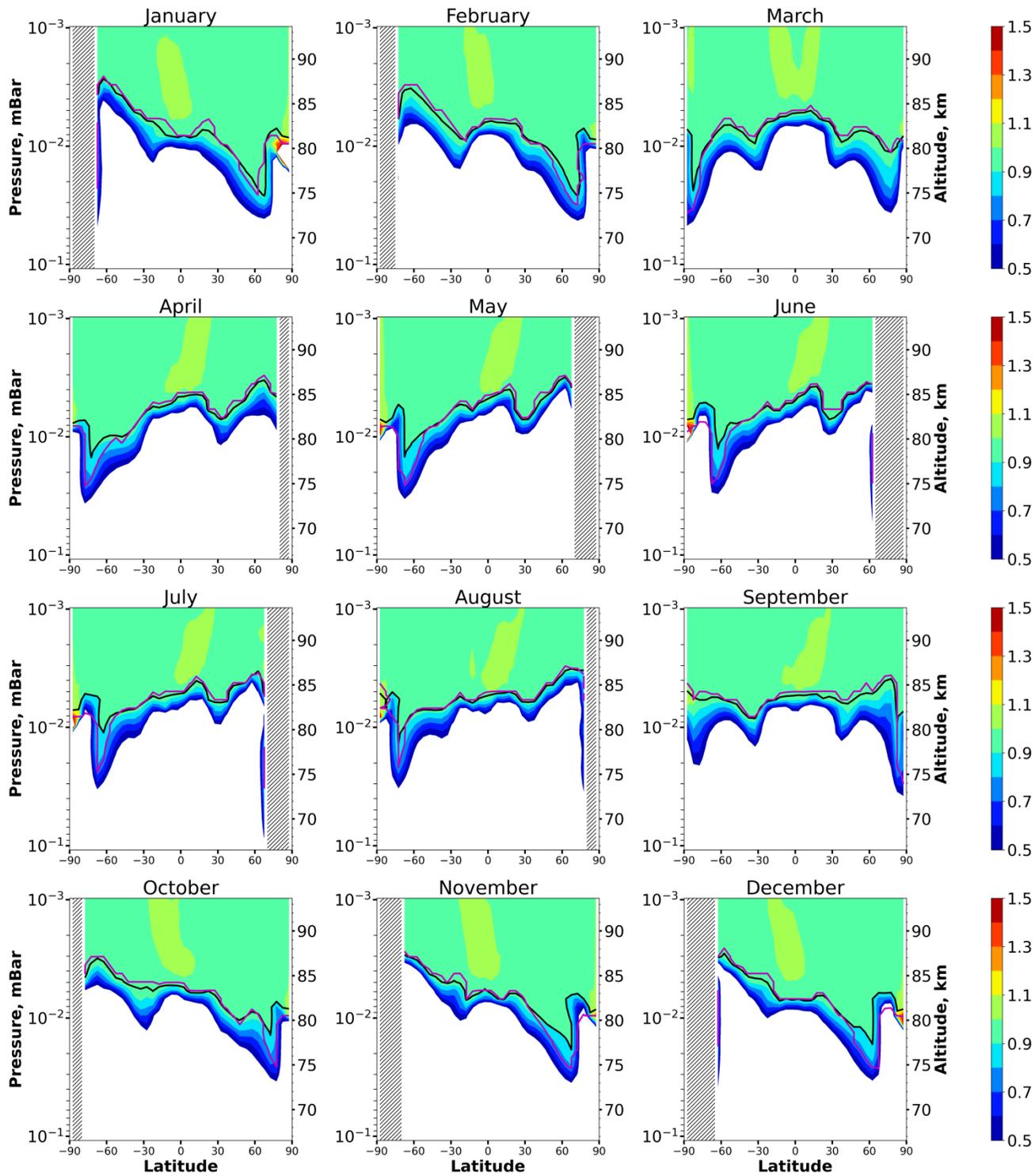


Figure S26. Figure 6 from the paper but with the threshold for the nighttime solar zenith angle is changed to  $95^\circ$ .

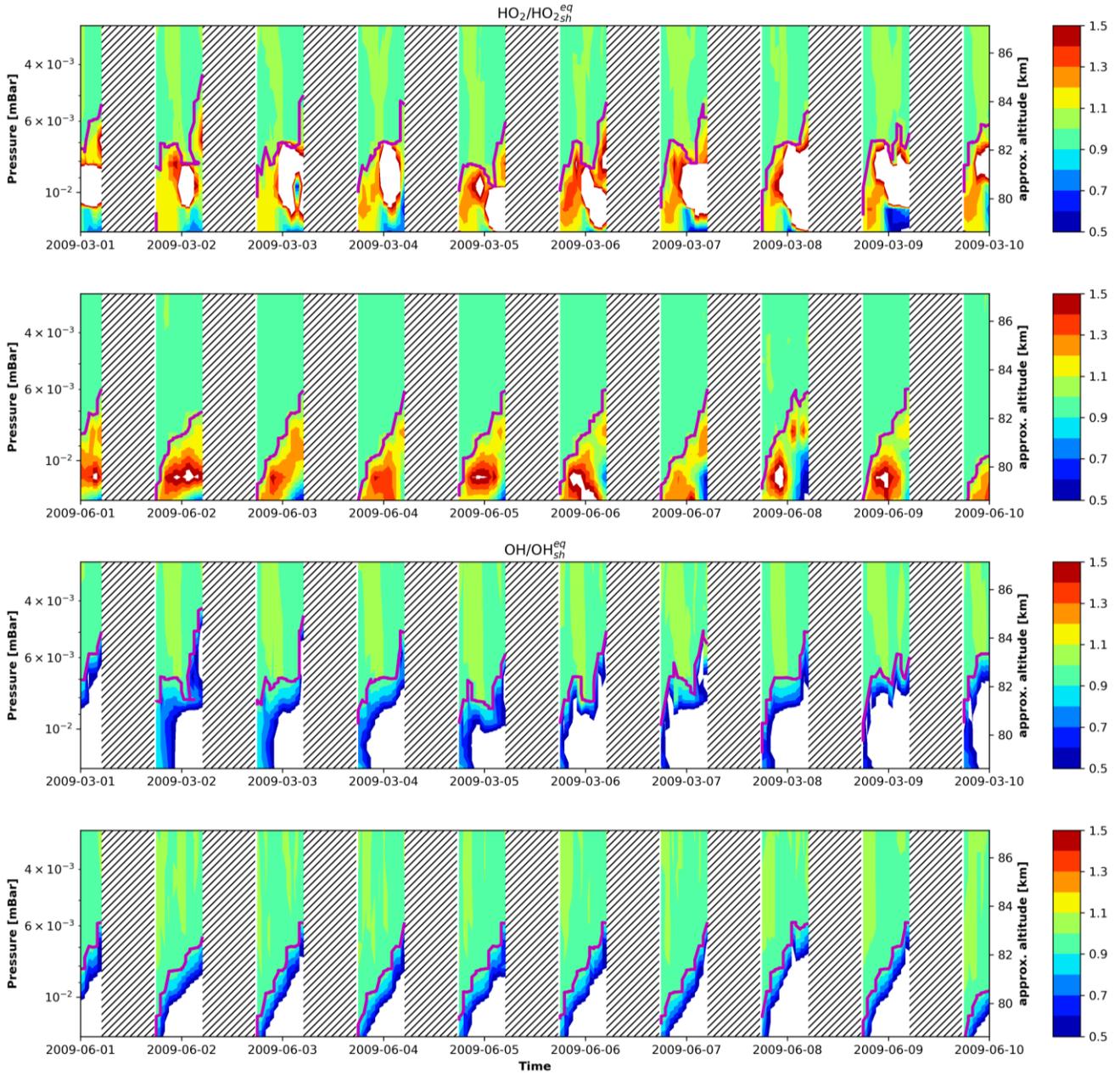


Figure S27.  $HO_2/HO_{2sh}^{eq}$  and  $OH/OH_{sh}^{eq}$  time-height variations above the Equator ( $2.8^{\circ}S, 0^{\circ}W$ ) in March and June 2009 calculated with the use of the temperature and winds distributions from the Canadian Middle Atmosphere Model. The stippling shows daytime. The white area represents the  $HO_2/HO_{2sh}^{eq}$  and  $OH/OH_{sh}^{eq}$  ratios outside the  $[0.5, 1.5]$  interval. Magenta lines indicate the boundary of  $HO_2$  and  $OH$  equilibrium according to criteria (17) and (25) ( $Crit_{HO_2} = 0.1$  and  $Crit_{OH} = 0.1$ ).

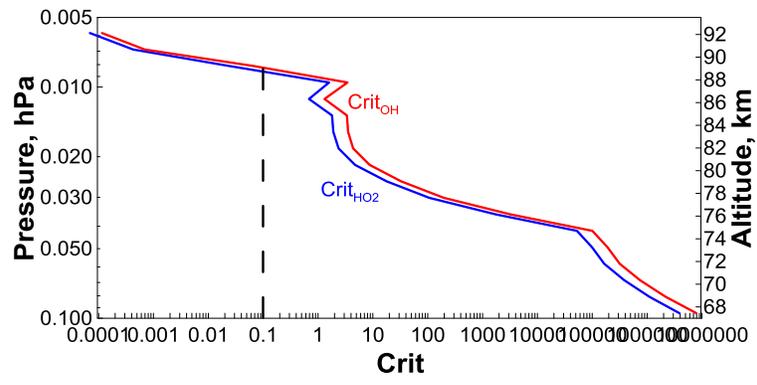


Figure S28. The examples of height-dependence of  $Crit_{HO_2}$  and  $Crit_{OH}$ .