Supporting Information for

Heat flux assumptions contribute to overestimation of wildfire smoke injection into the free troposphere

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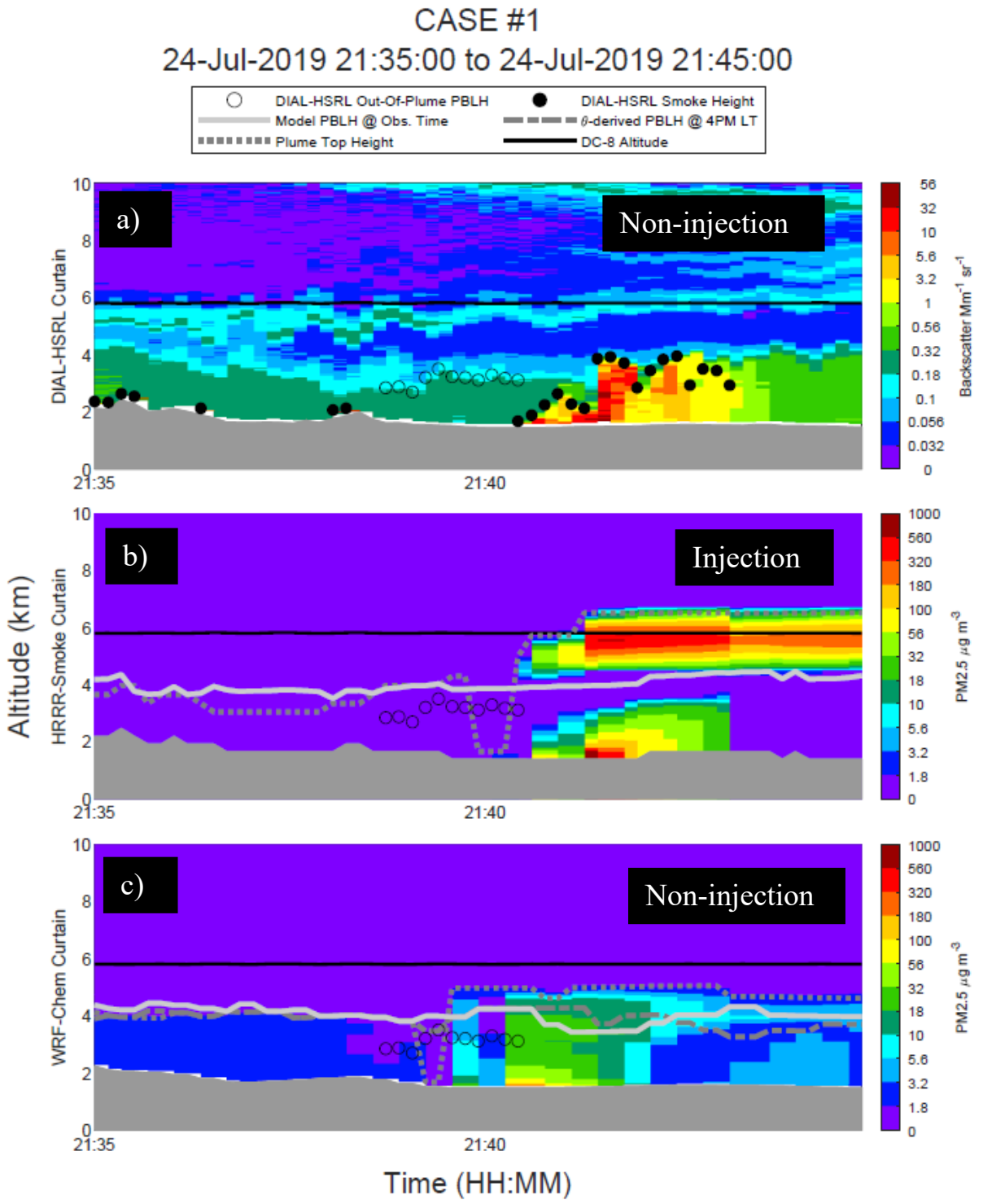
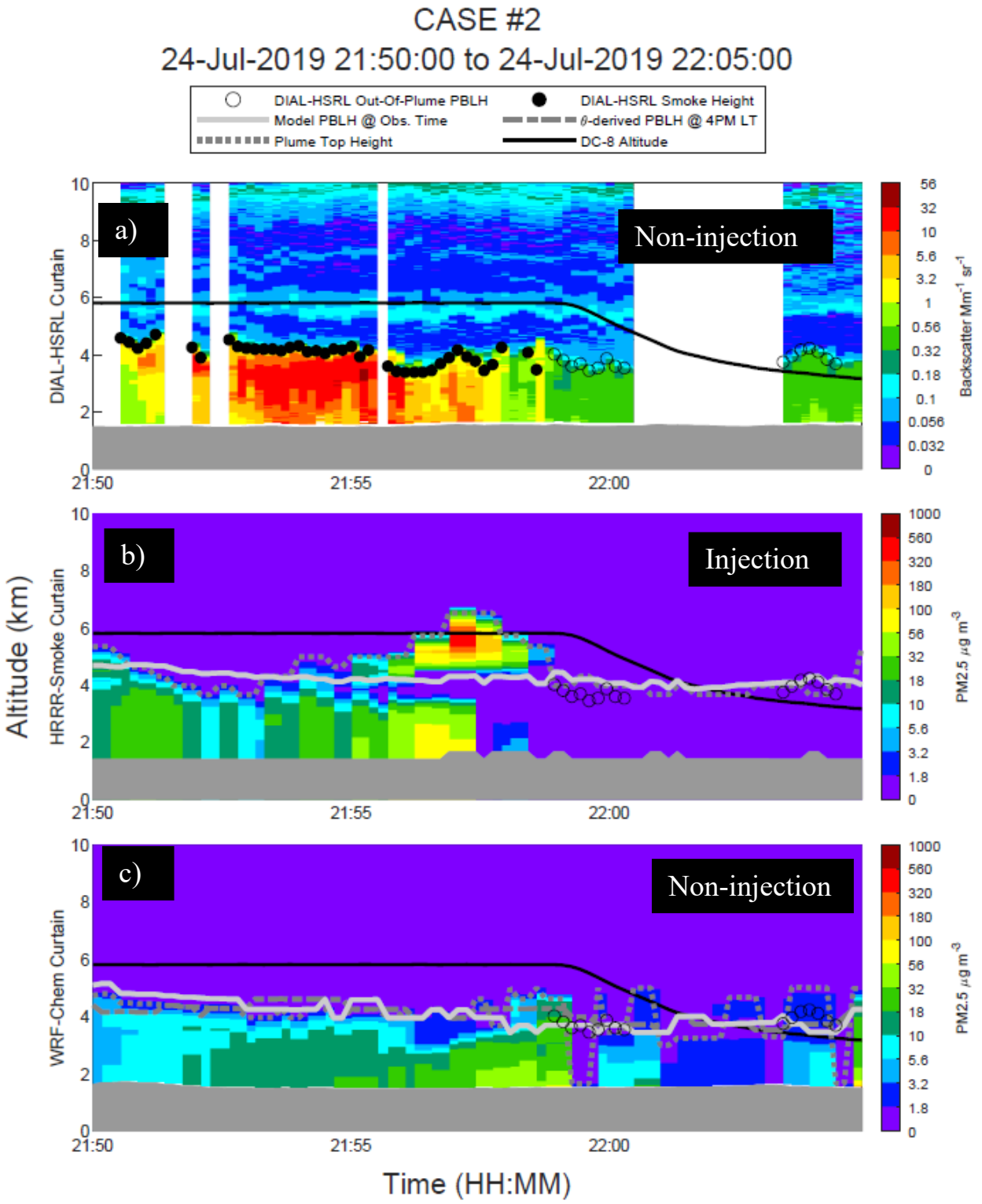
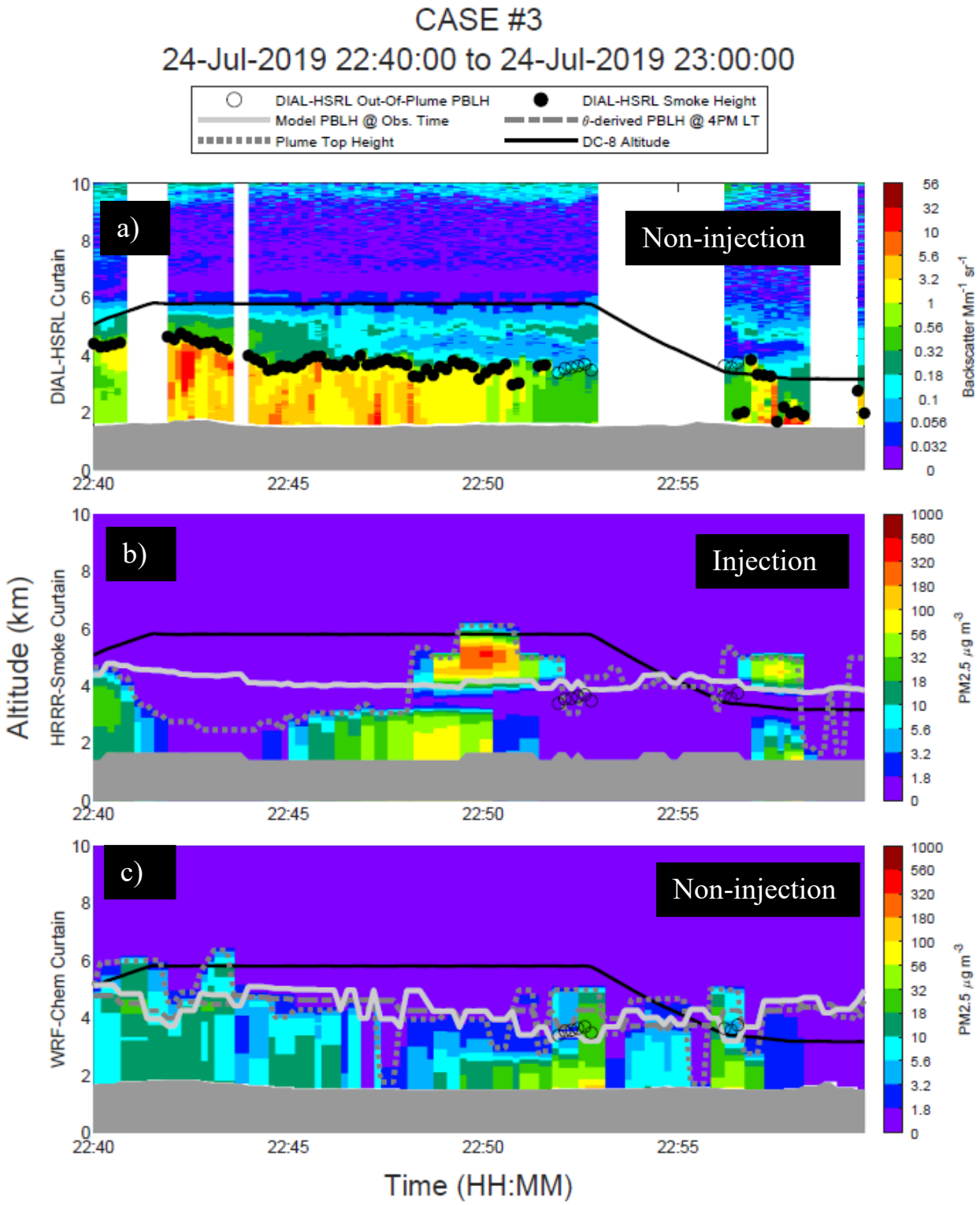


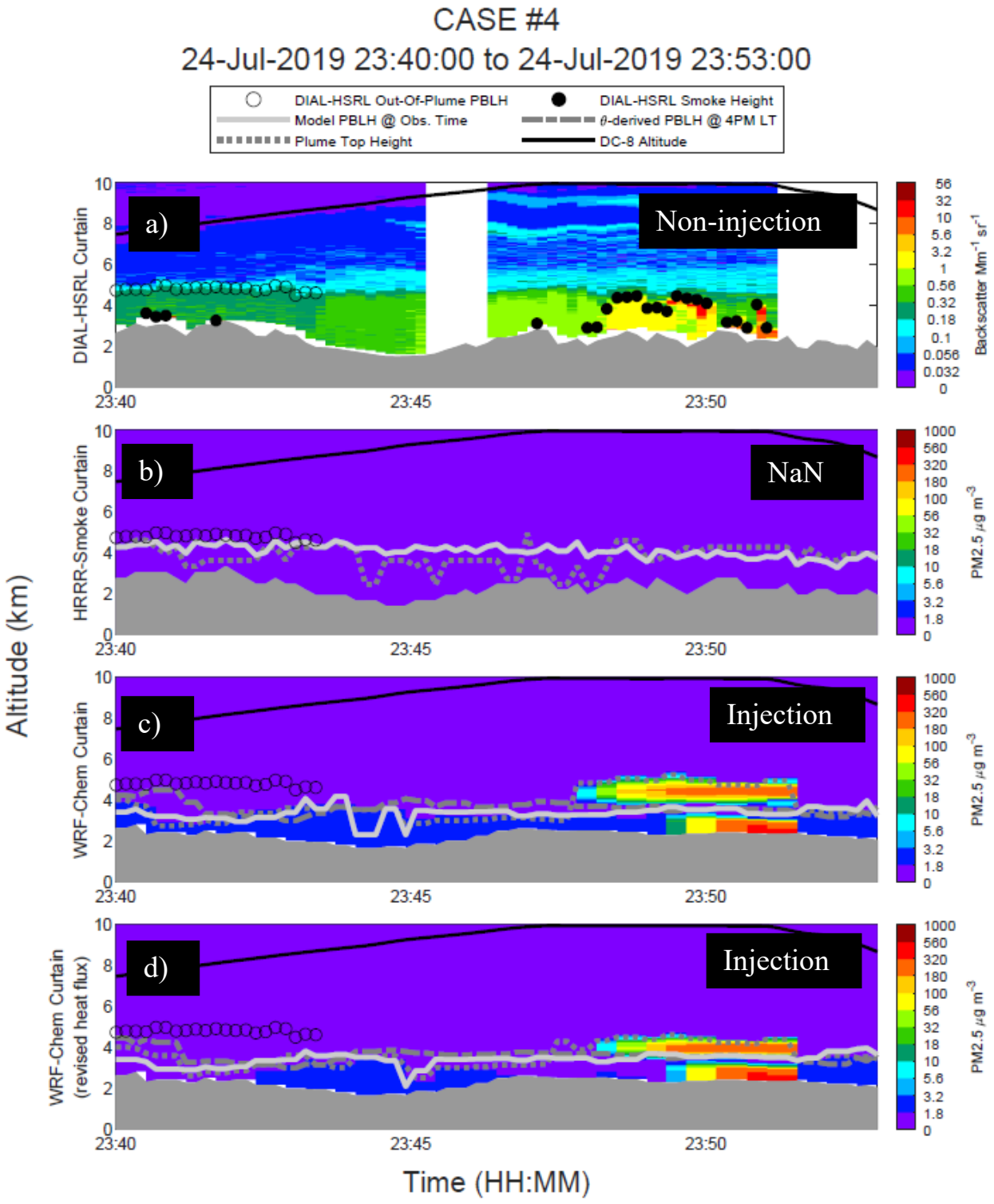
Supplementary Fig. 1: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheep Fire on 2019-07-24 21:35-21:45 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



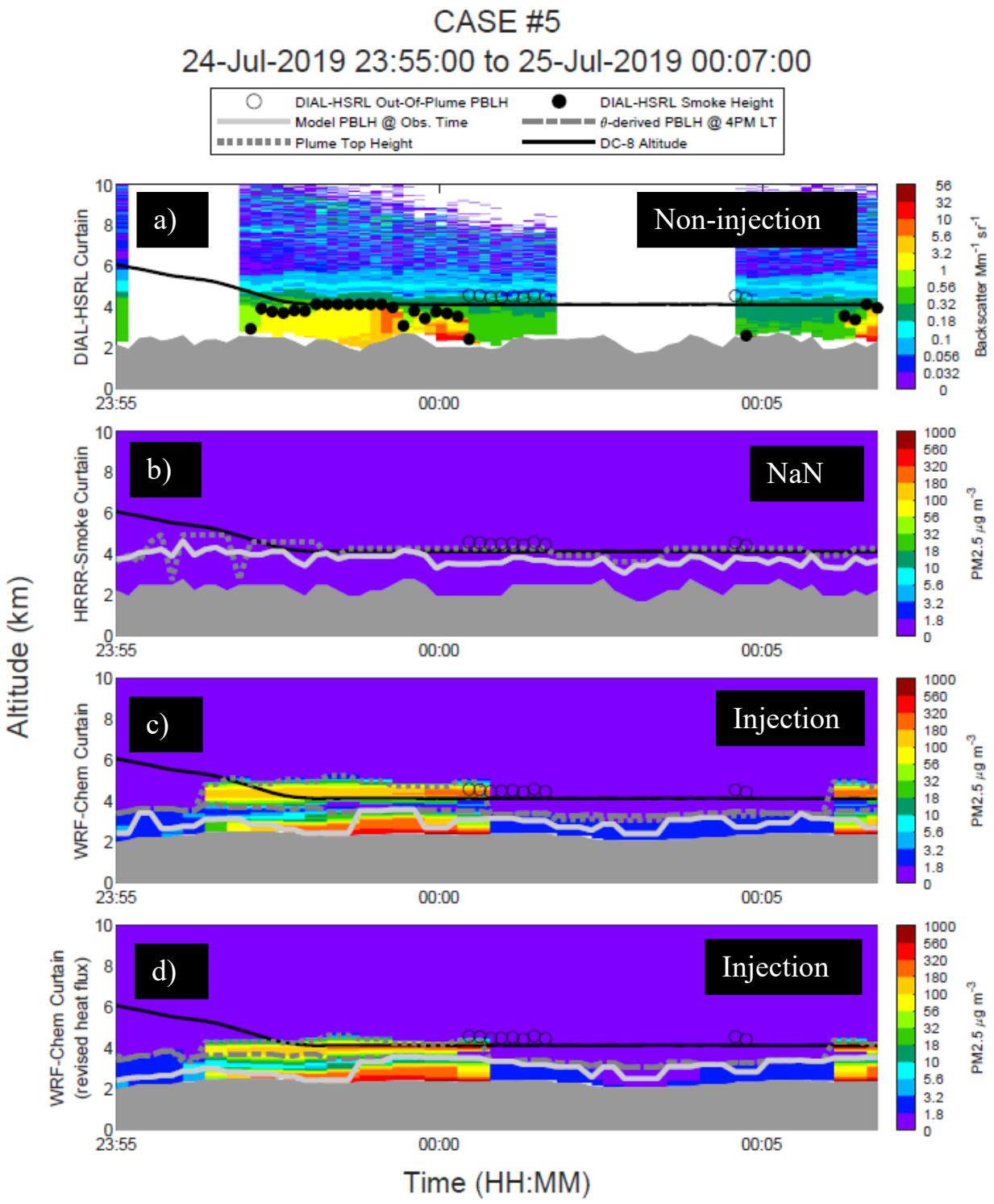
Supplementary Fig. 2: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheep Fire on 2019-07-24 21:50-22:05 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



Supplementary Fig. 3: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheep Fire on 2019-07-24 22:40-23:00 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



Supplementary Fig. 4: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Shady Fire 2019-07-24 23:40-23:53 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



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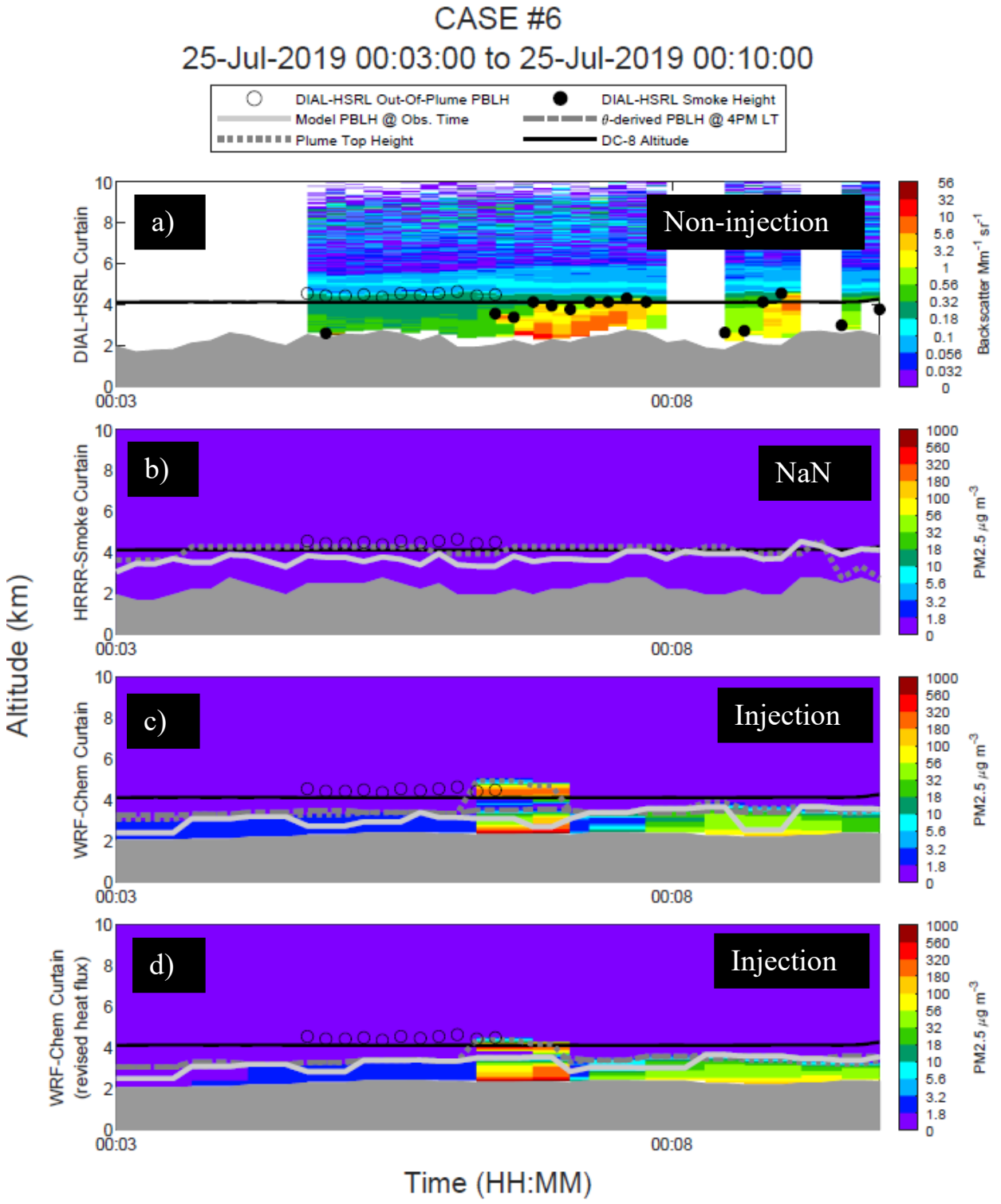

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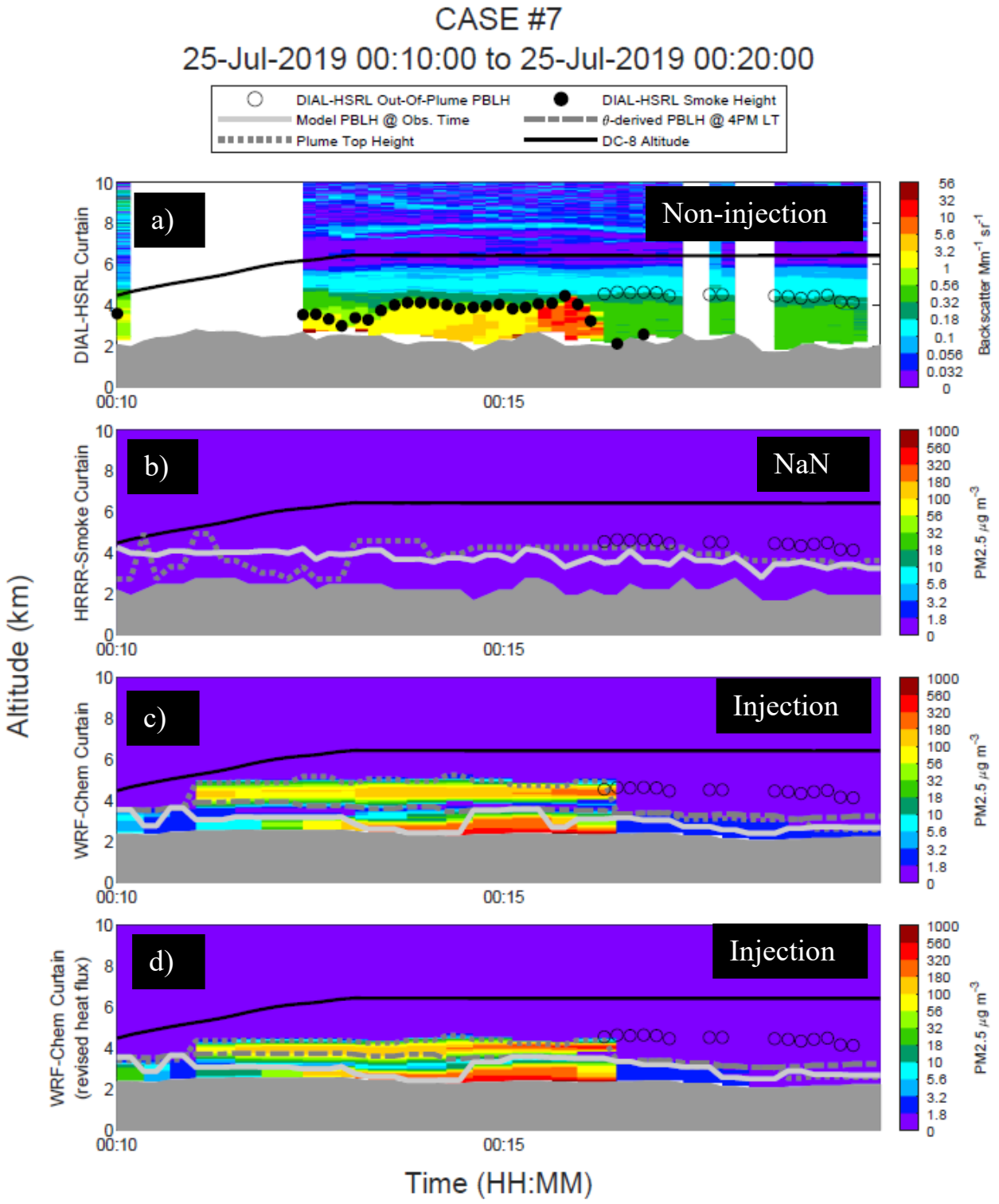

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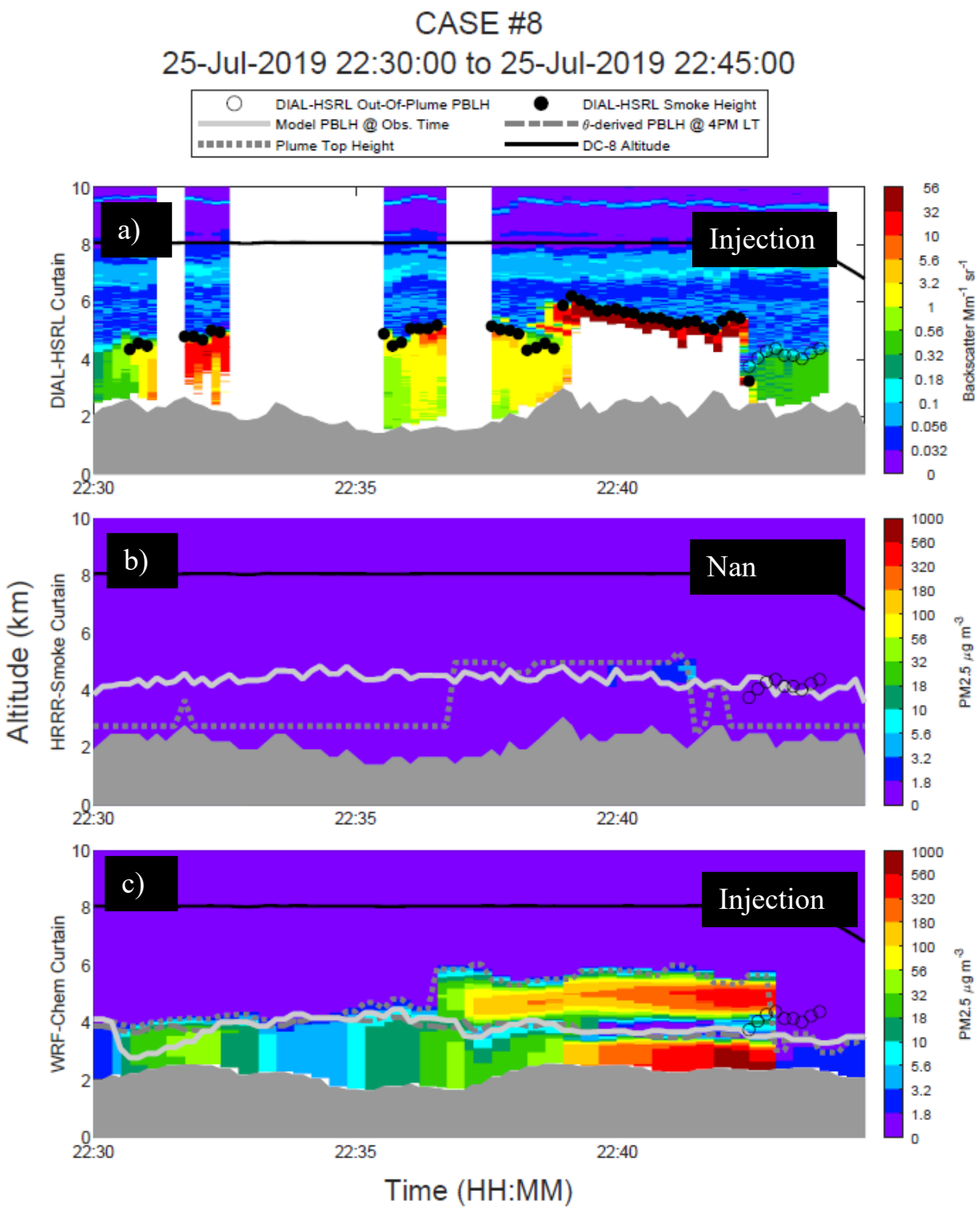
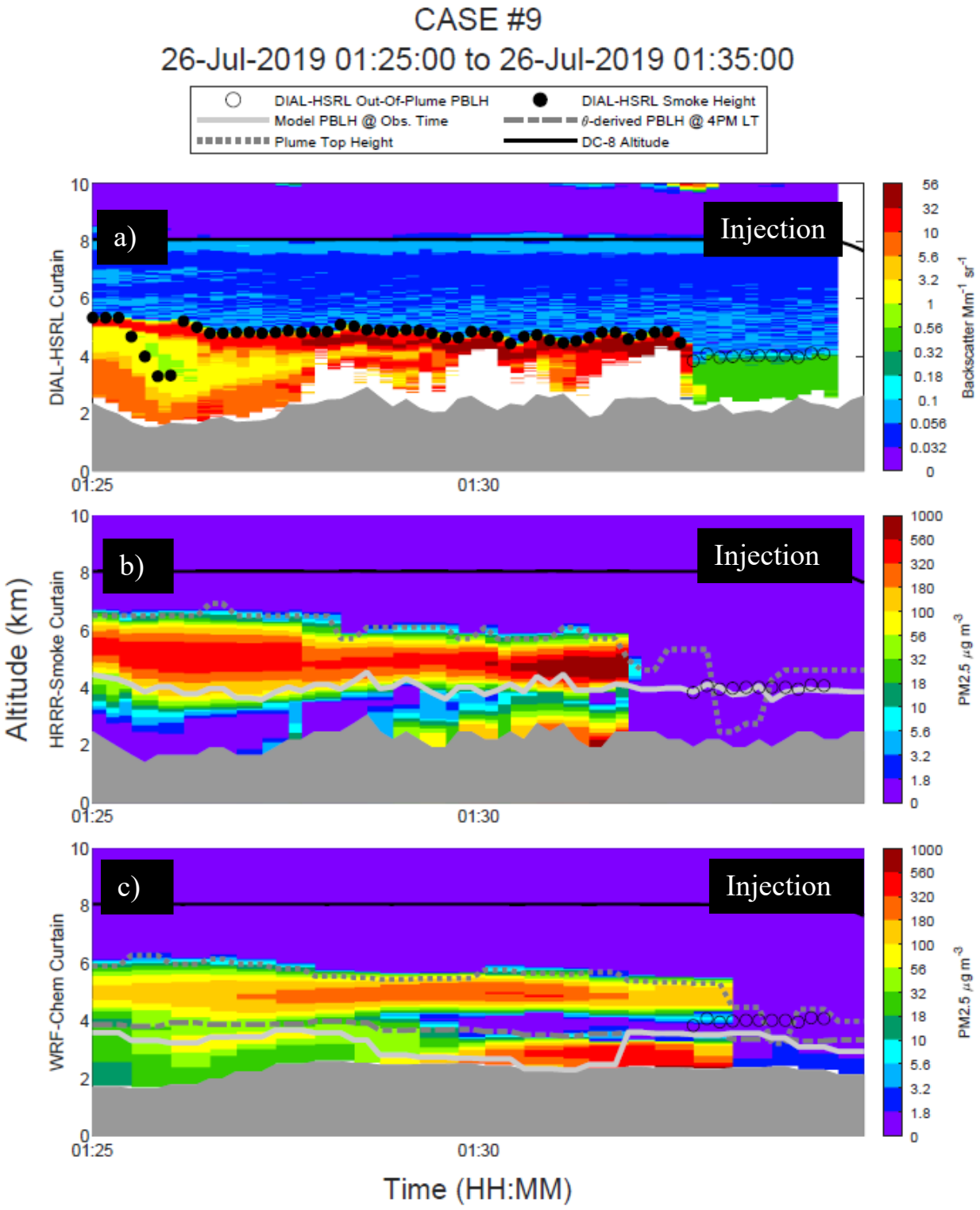


Supplementary Fig. 8: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Shady Fire on 2019-07-25 22:30-22:45 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



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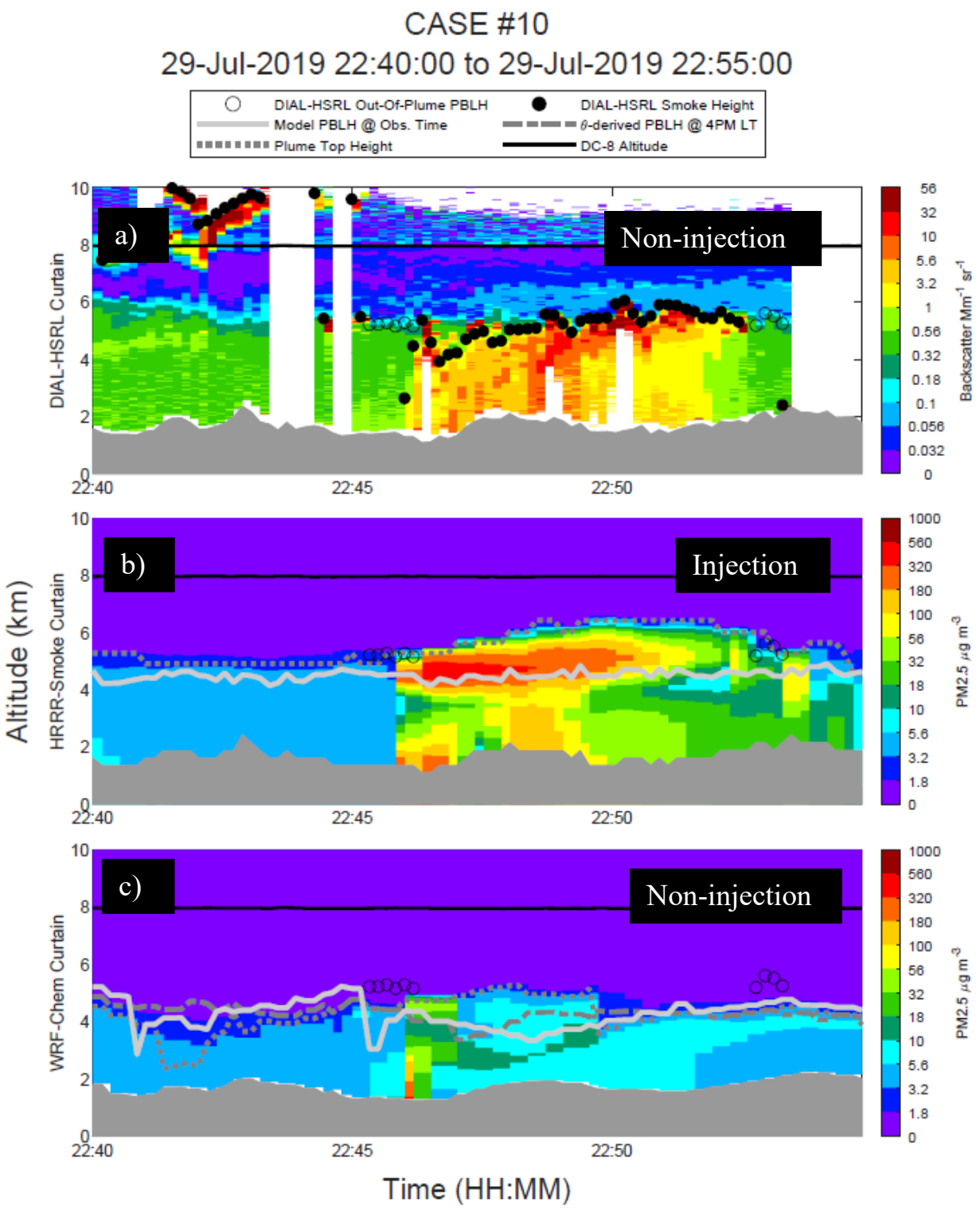

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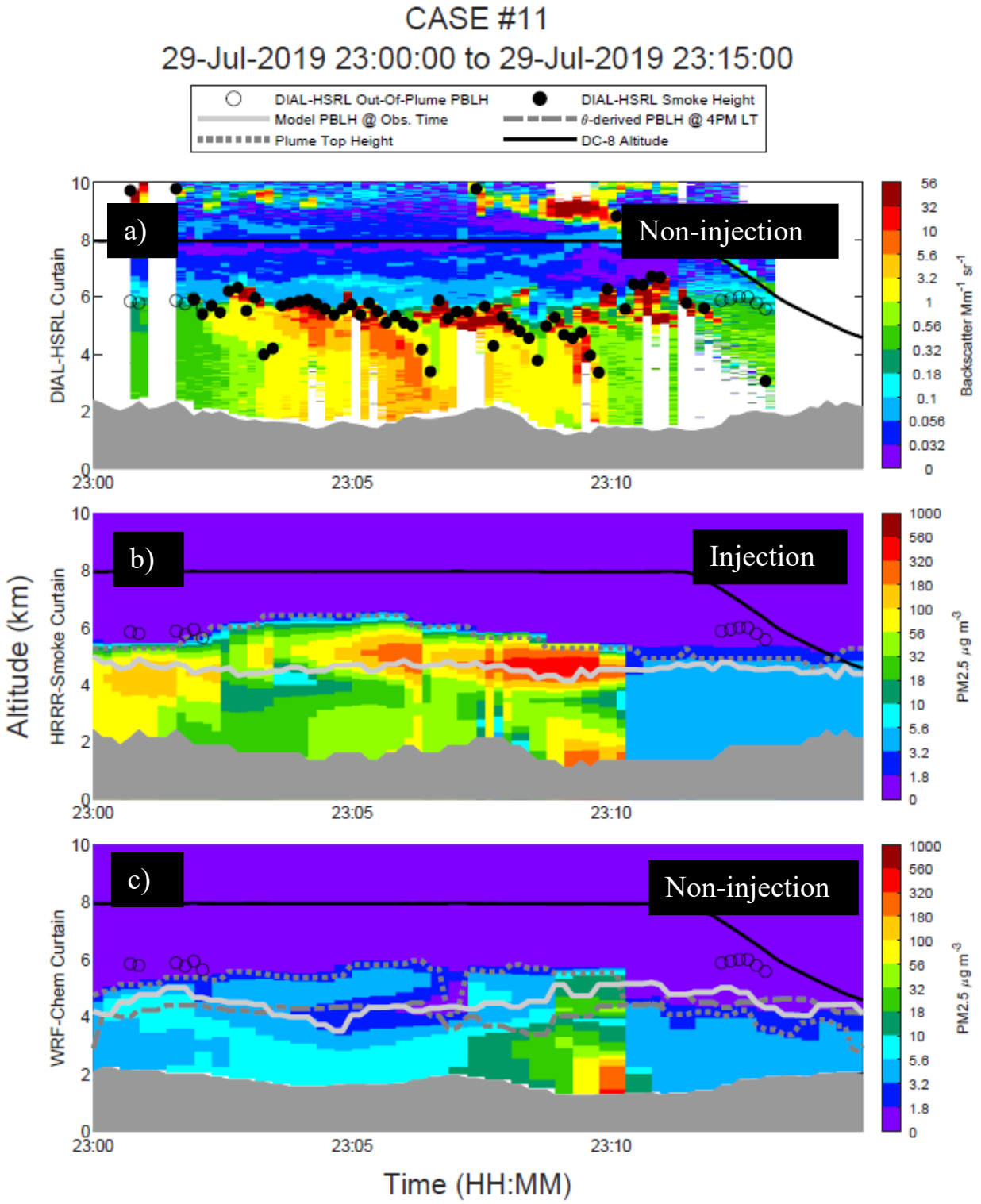

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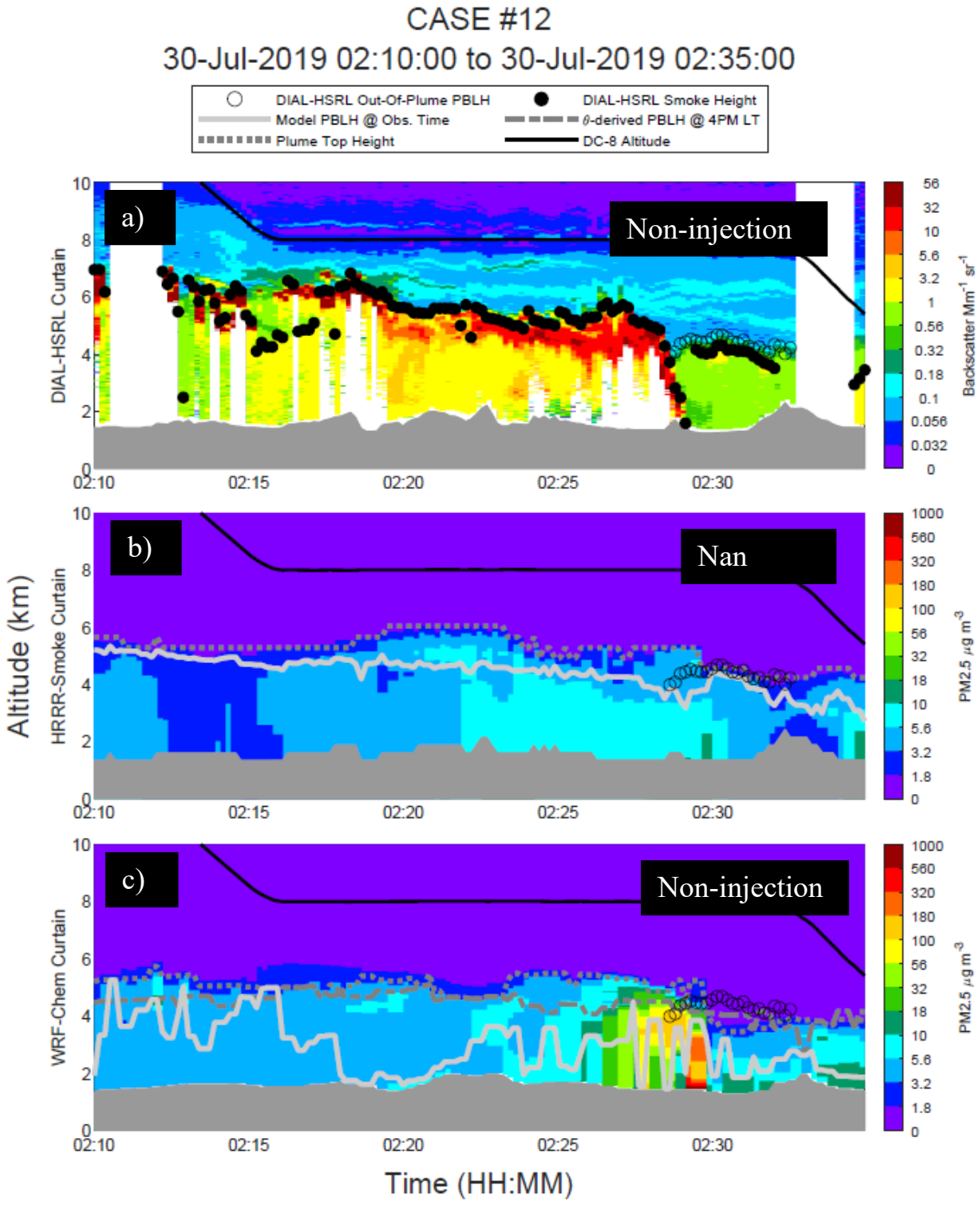
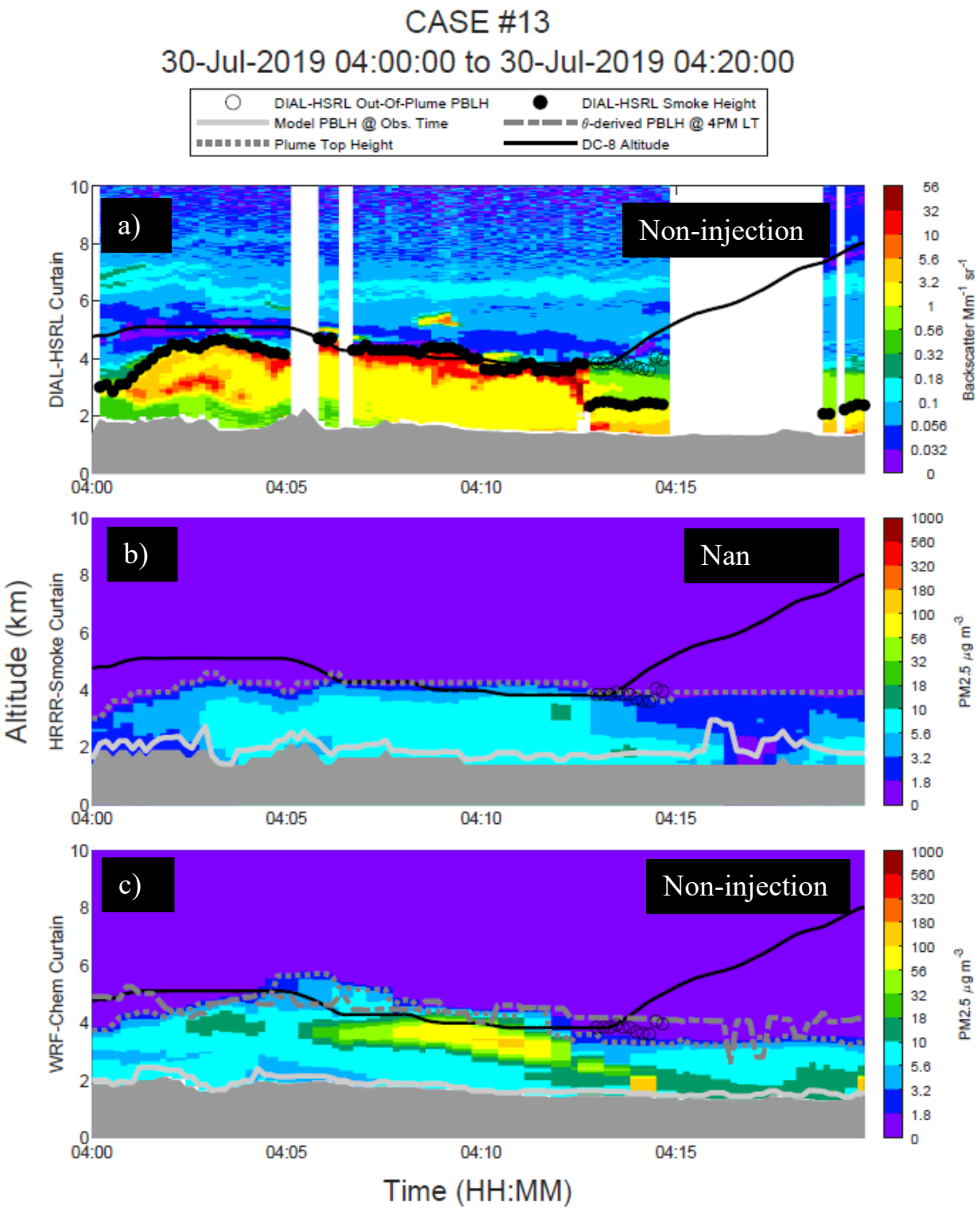


Supplementary Fig. 12: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Tucker Fire on 2019-07-30 02:10-02:35 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



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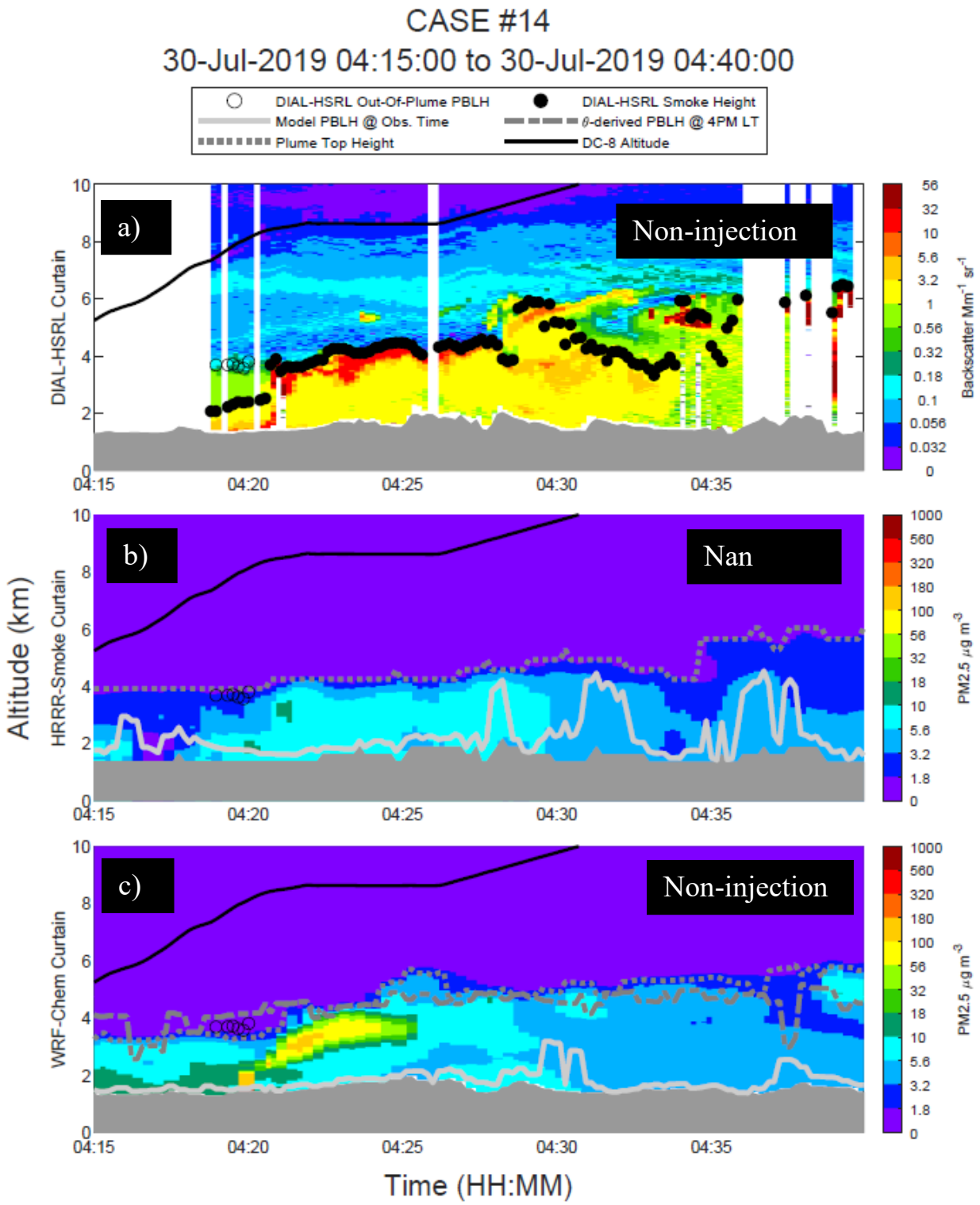

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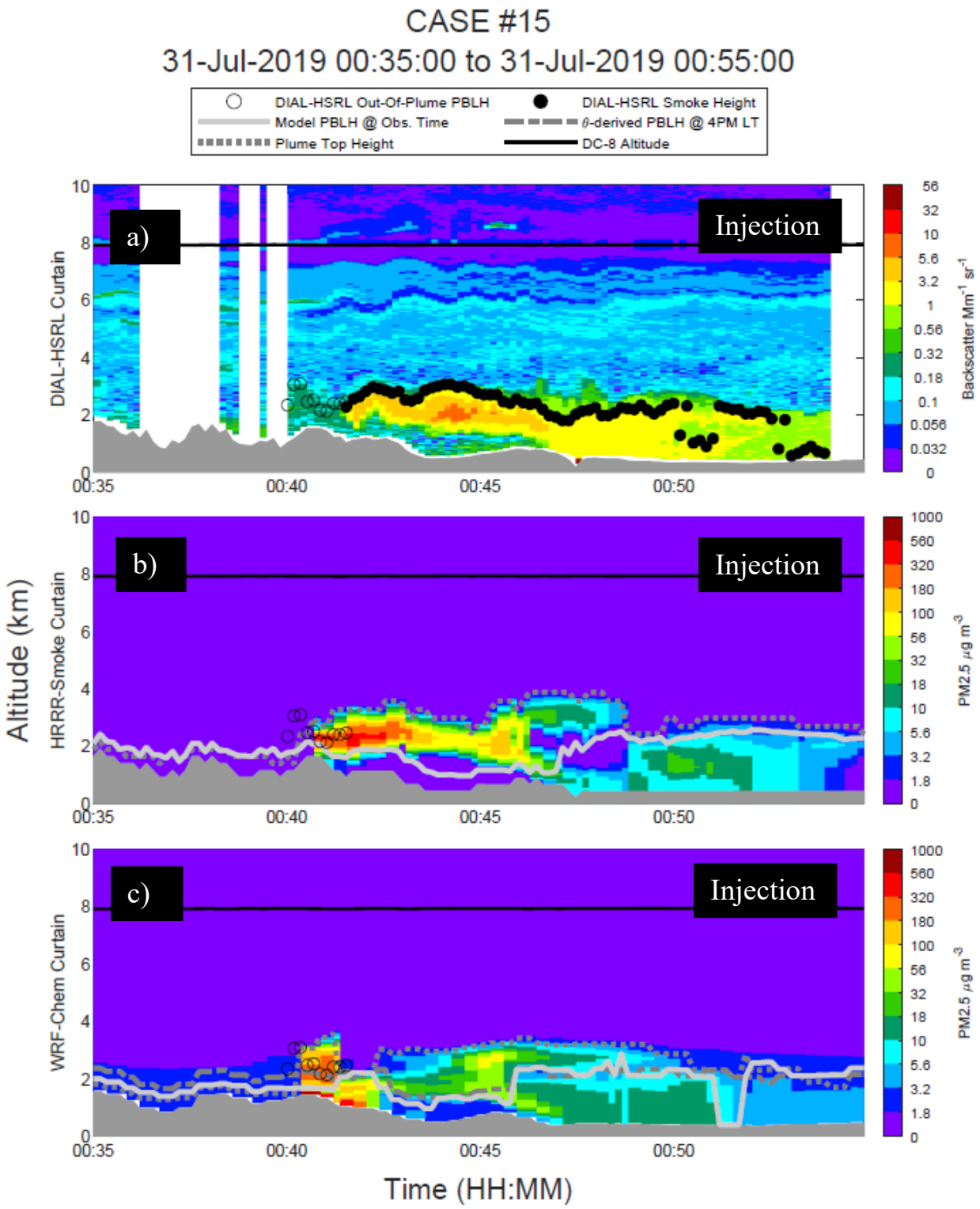
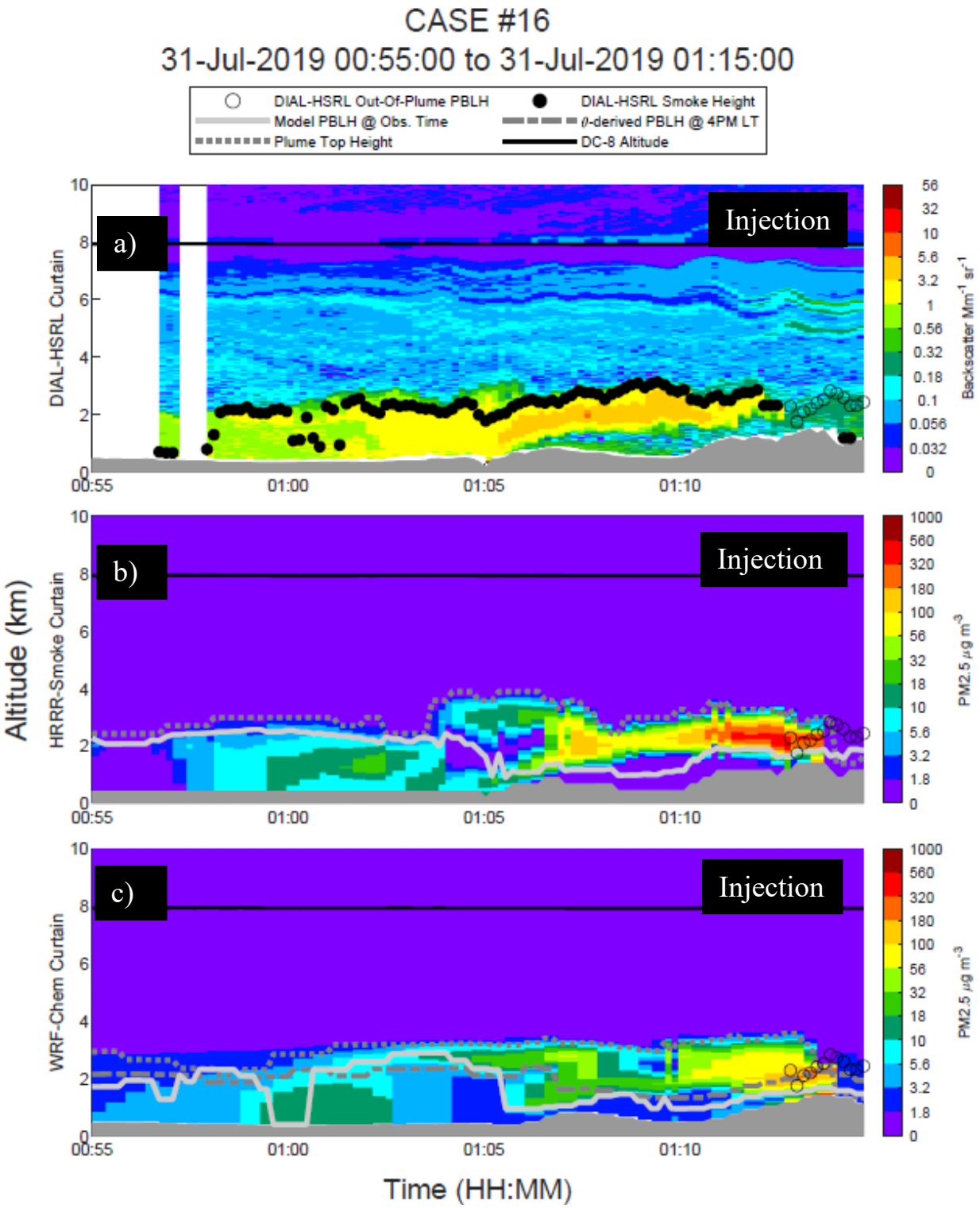
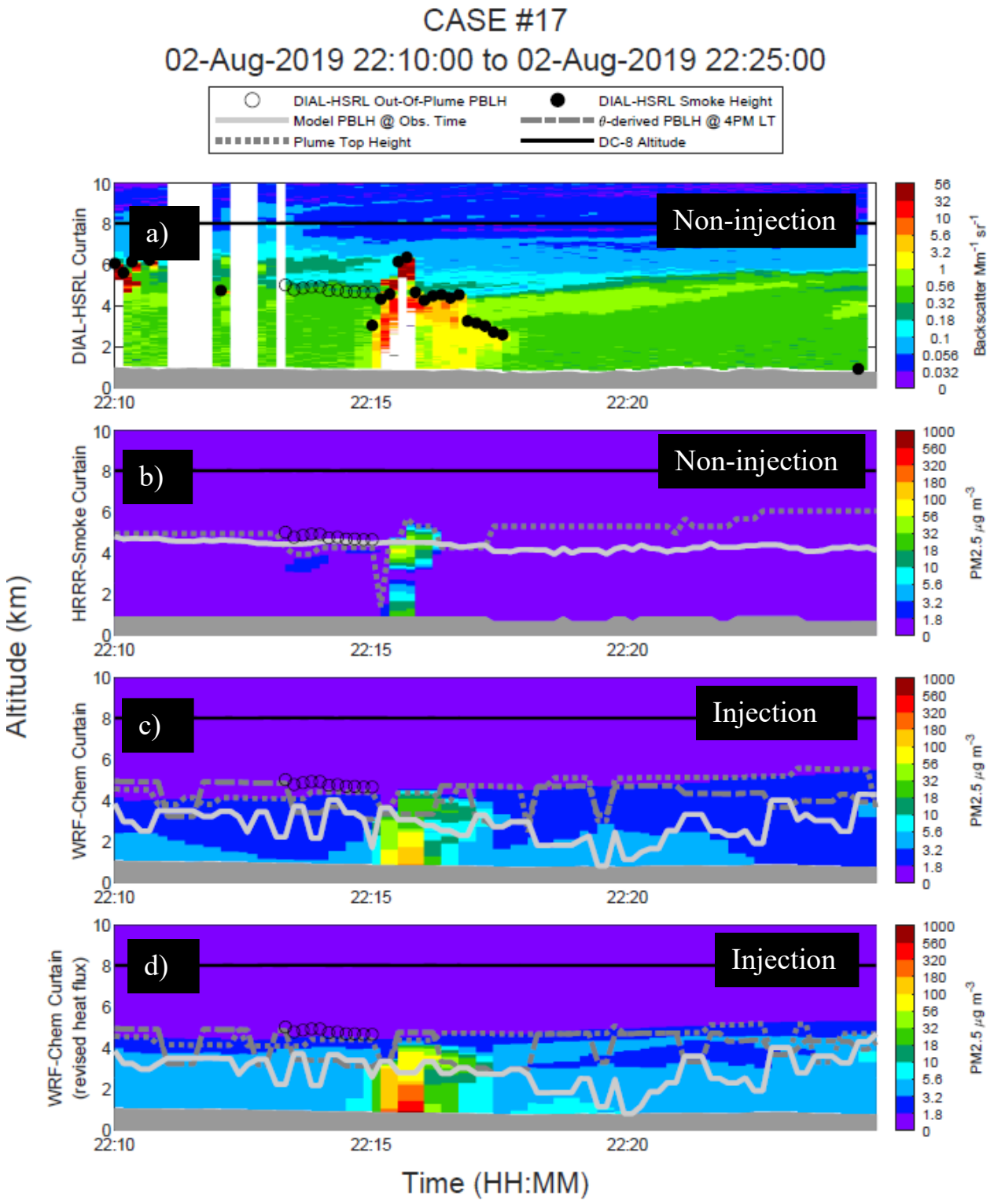


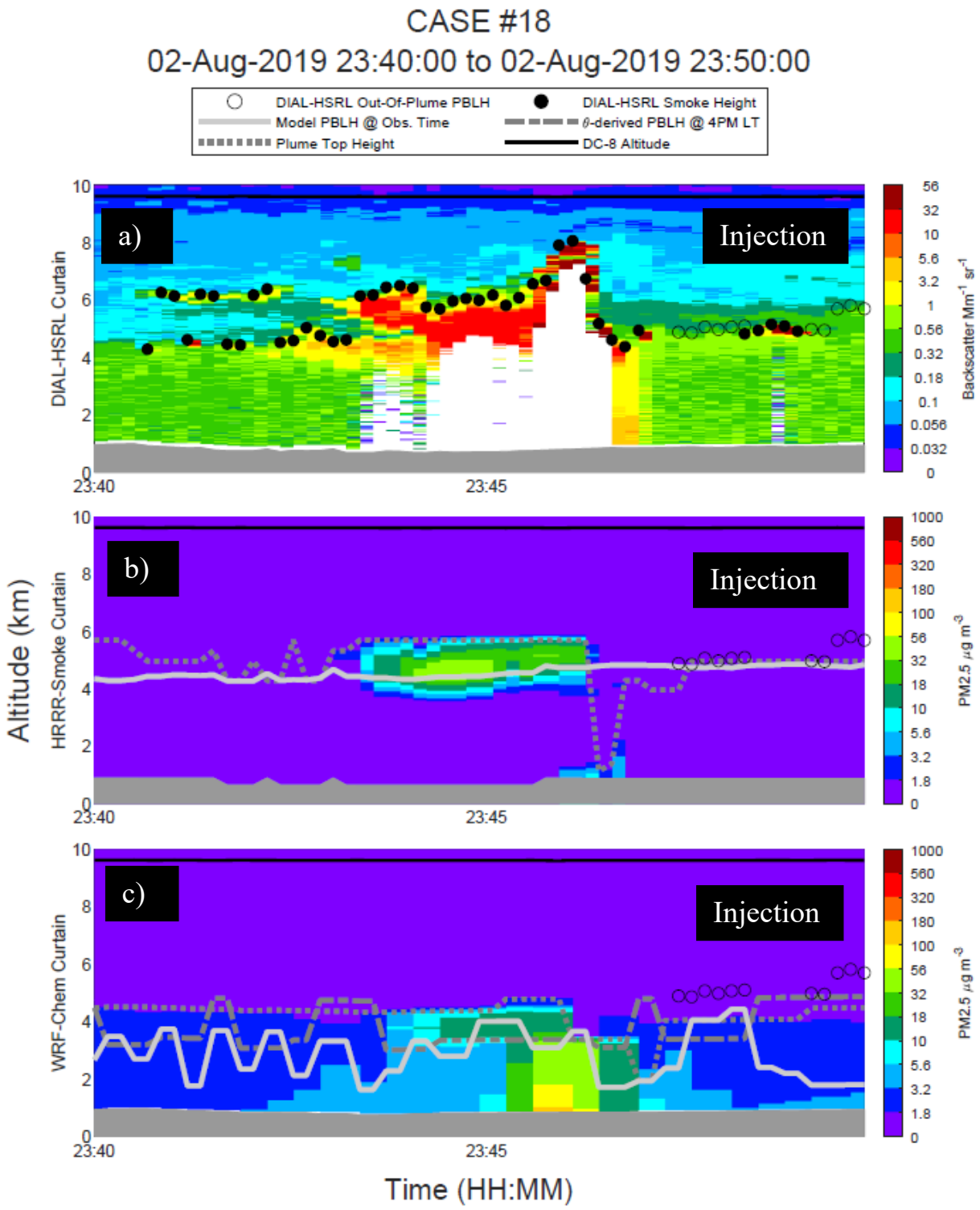
Supplementary Fig. 15: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Left Hand Fire on 2019-07-31 00:35-00:55 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



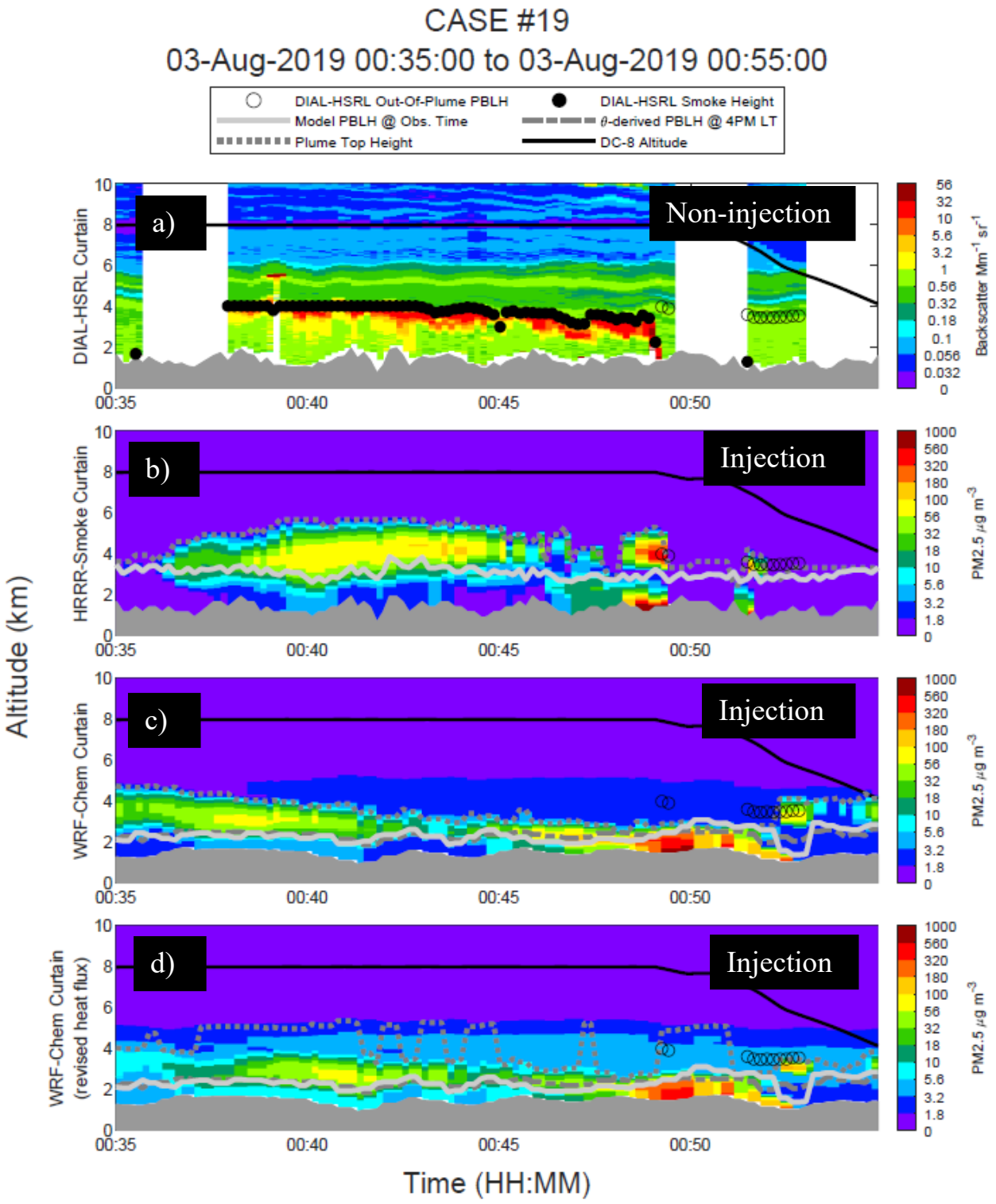
Supplementary Fig. 16: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Left Hand Fire on 2019-07-31 00:55-01:15 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



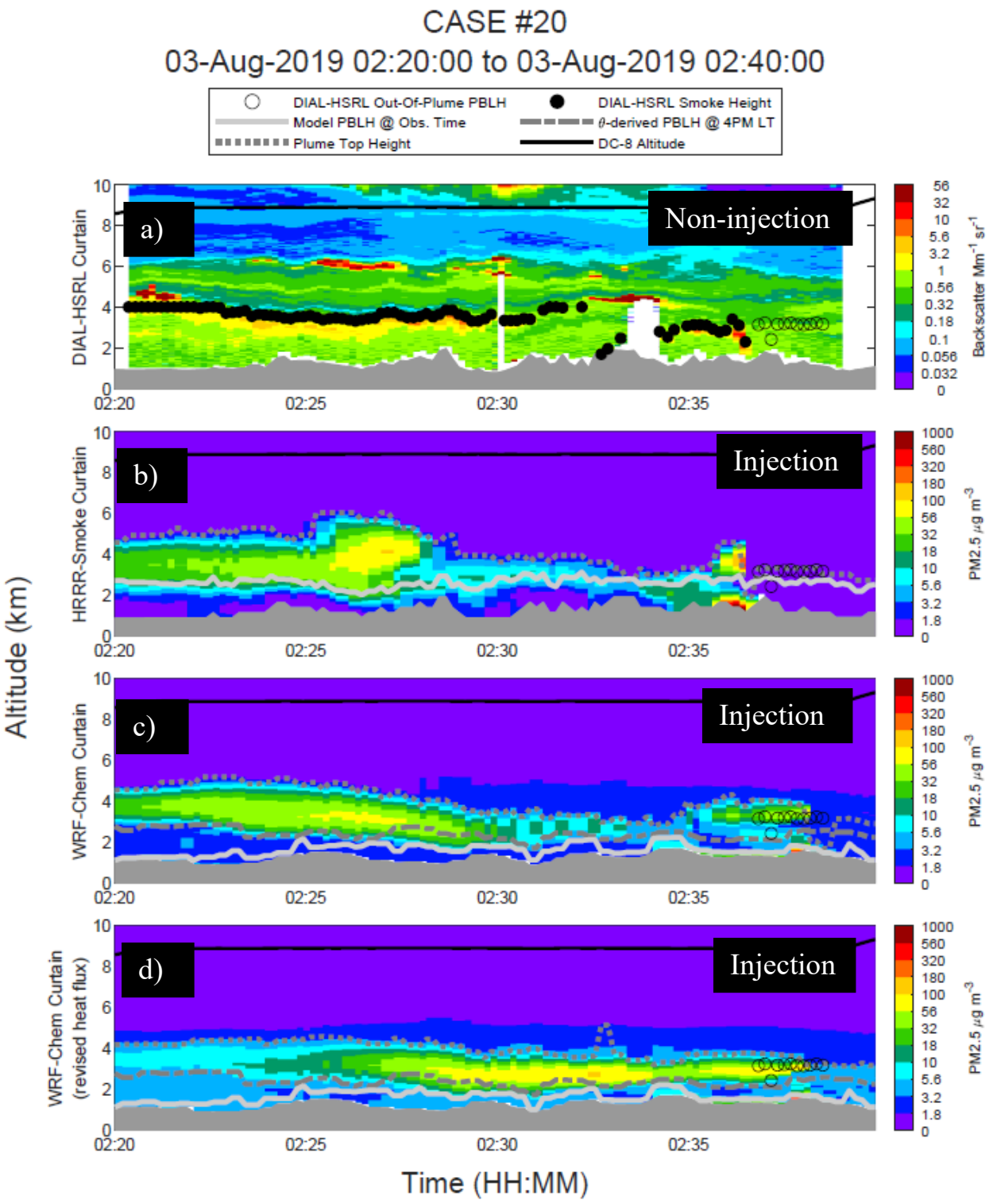
Supplementary Fig. 17: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Ridge Top Fire 2019-08-02 22:10-22:25 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



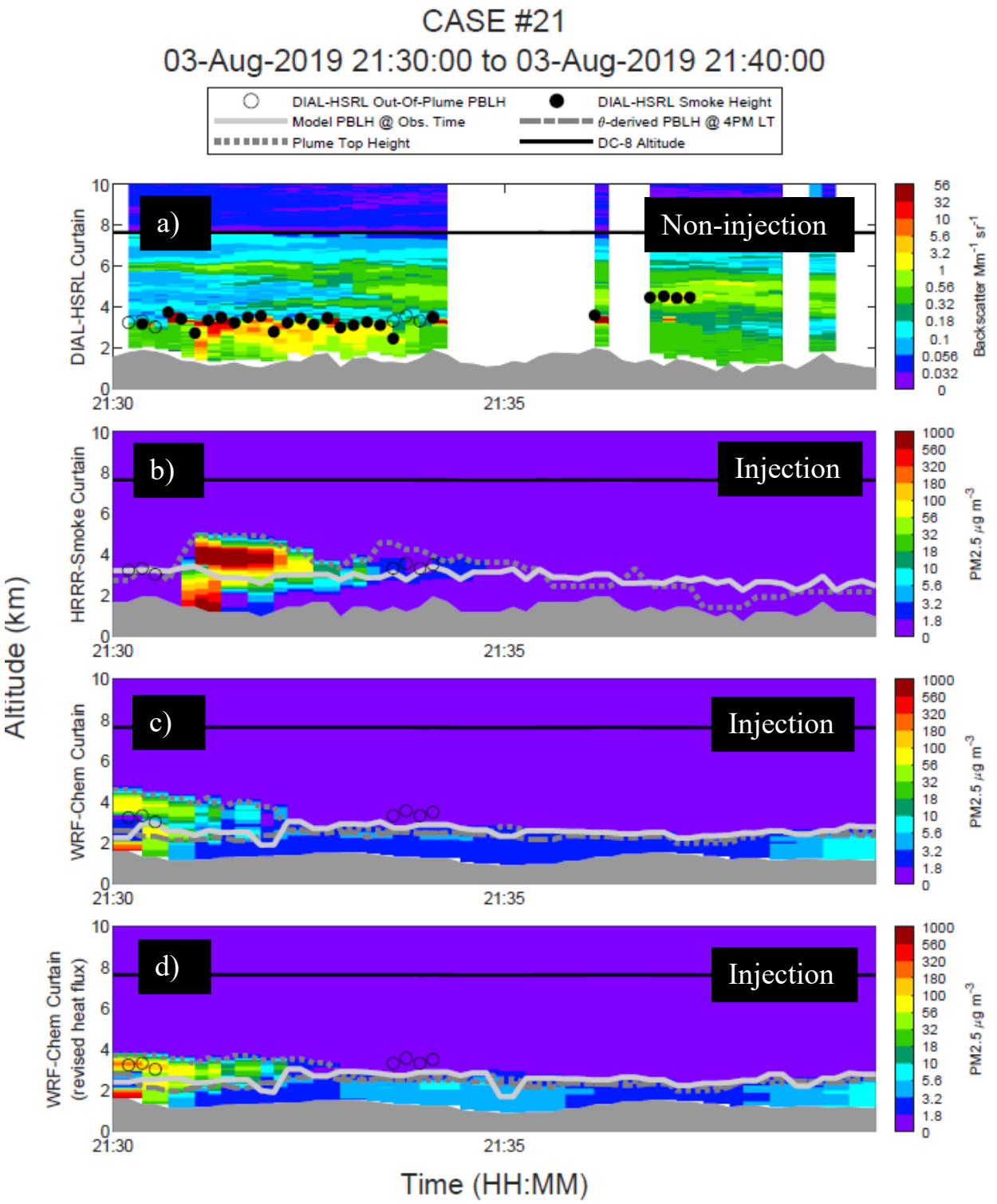
Supplementary Fig. 18: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Ridge Top Fire on 2019-08-02 23:40-23:50 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



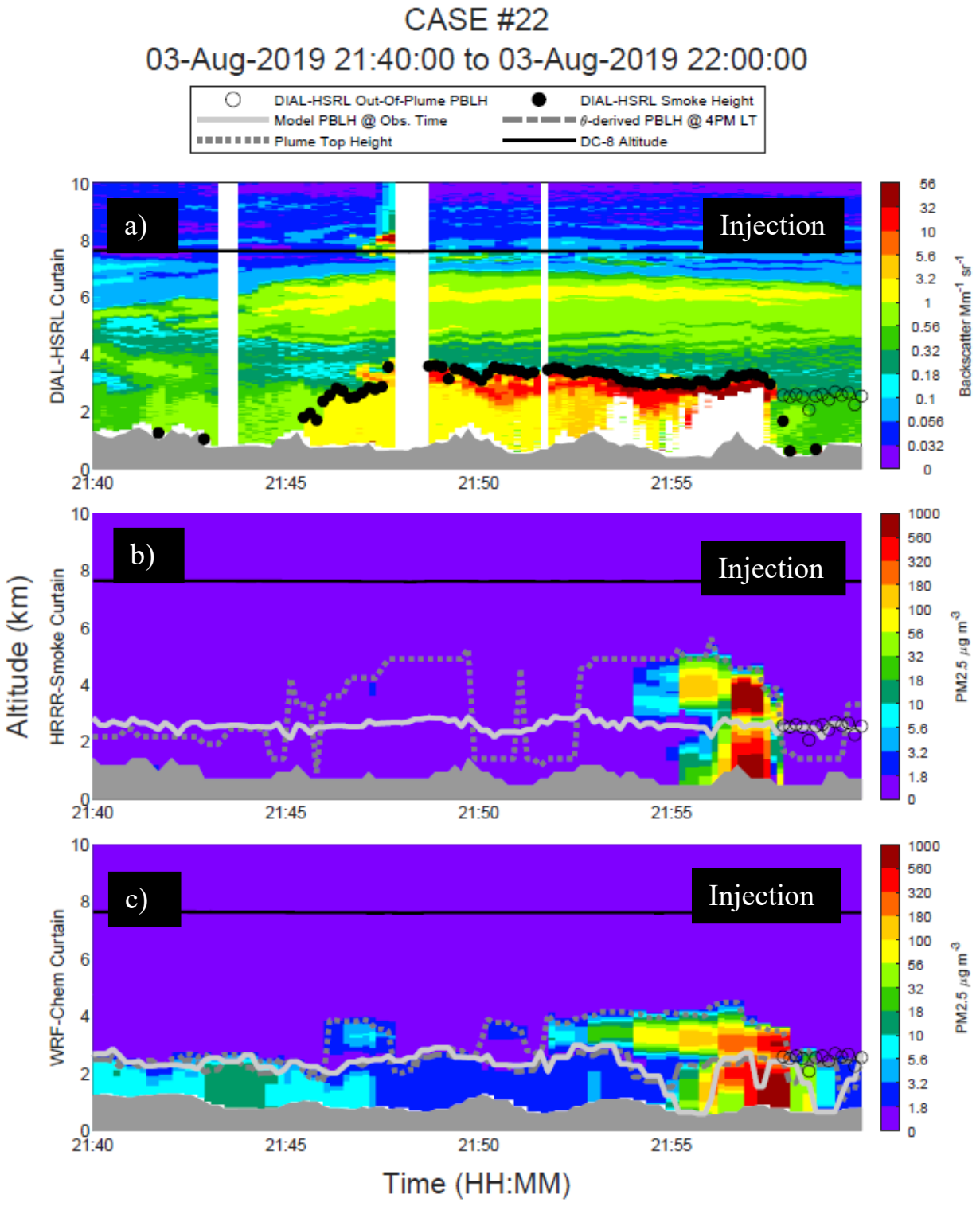
Supplementary Fig. 19: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Mica/Lick Creek Fire 2019-08-03 00:35-00:55 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



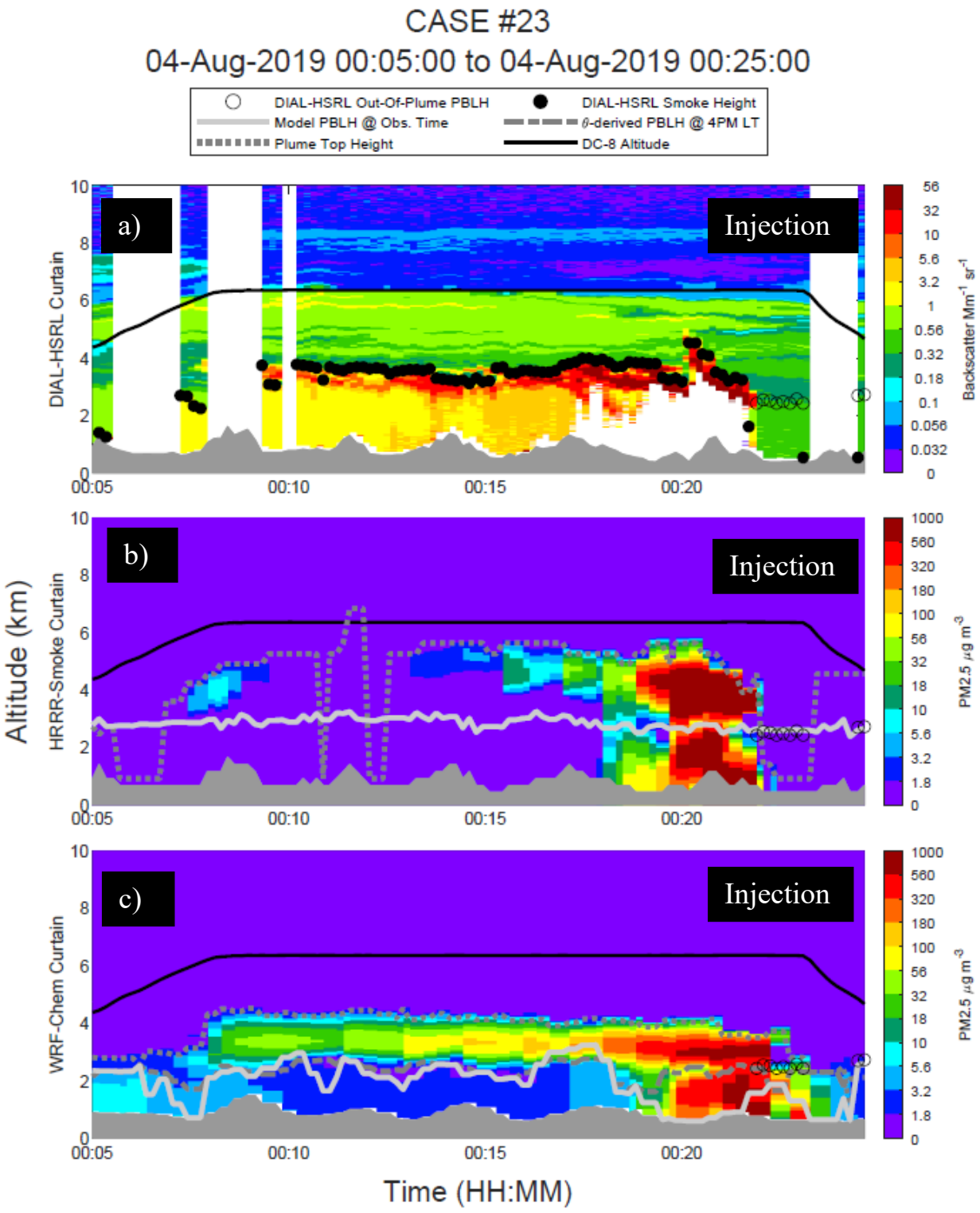
Supplementary Fig. 20: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Mica/Lick Creek Fire 2019-08-03 02:20-02:40 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



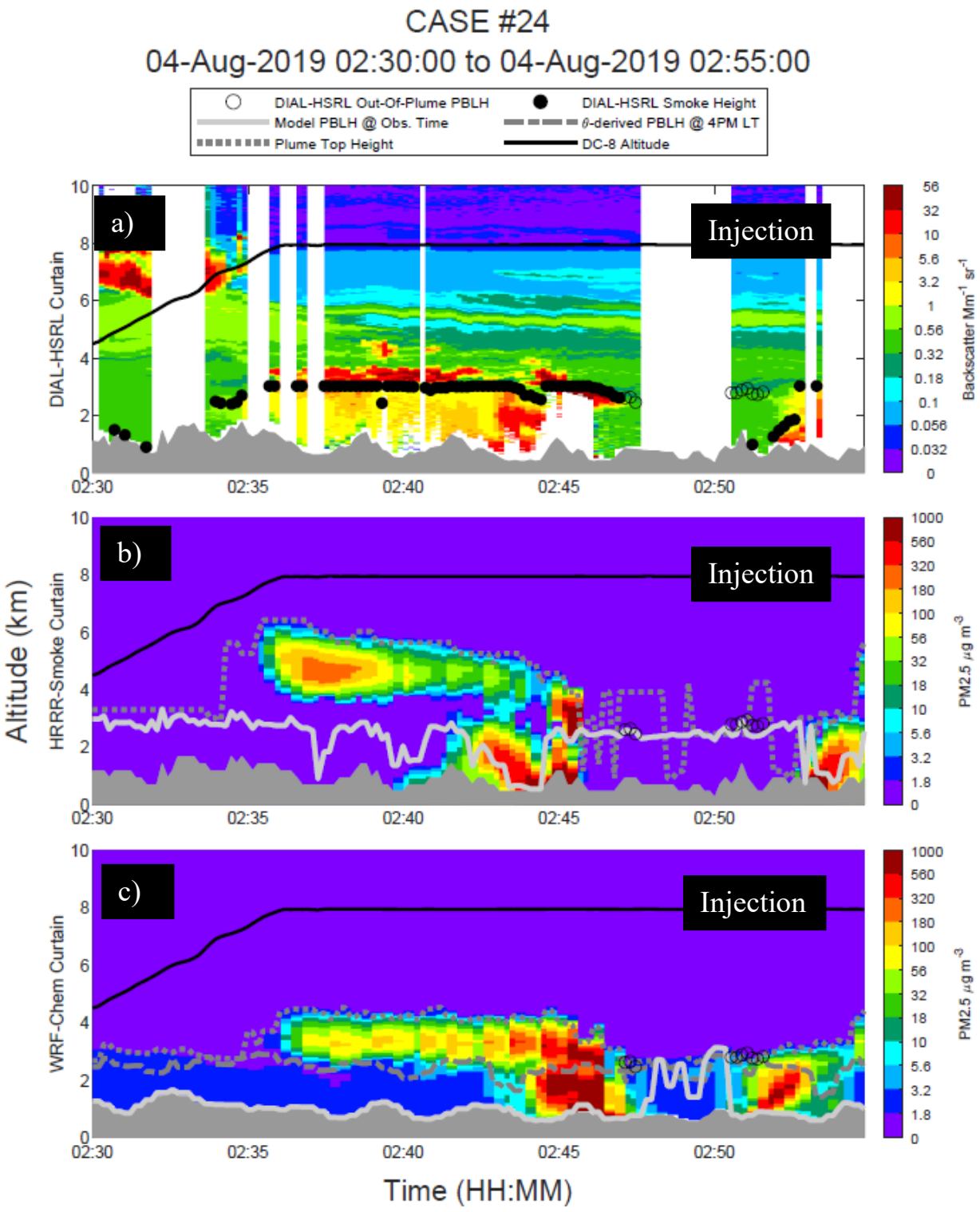
Supplementary Fig. 21: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Mica Creek Fire 2019-08-03 21:30-21:40 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



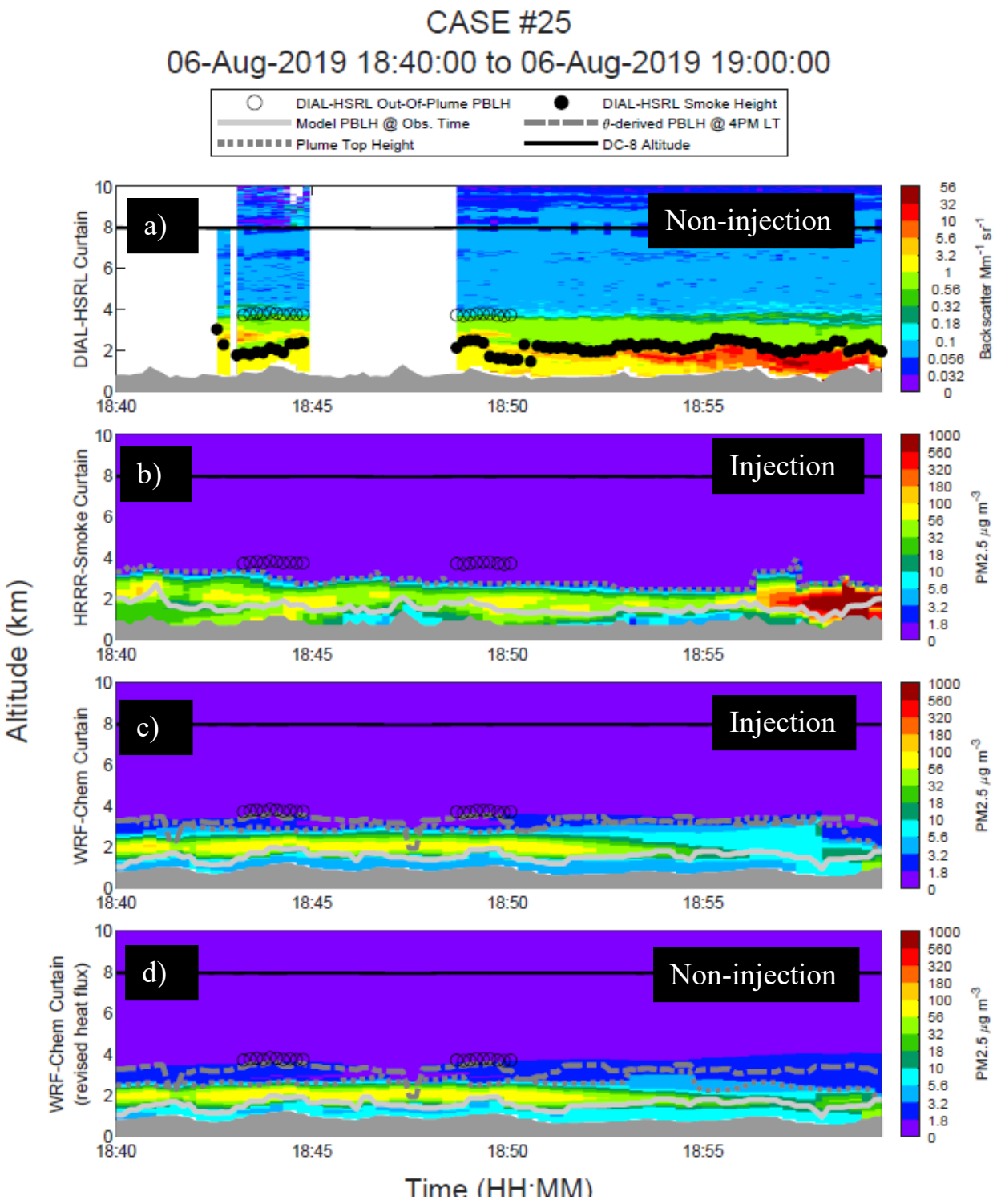
Supplementary Fig. 22: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-03 21:40-22:00 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



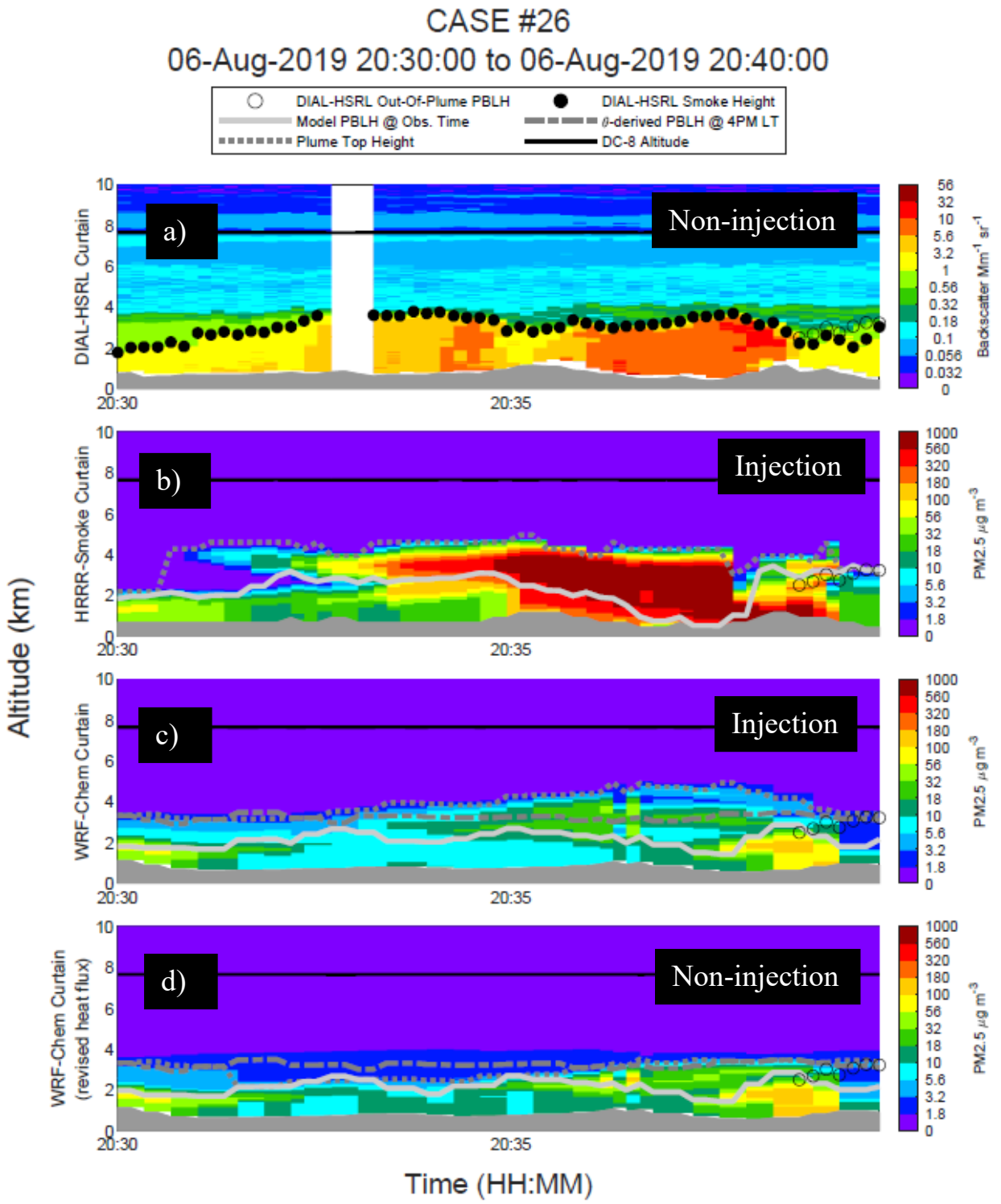
Supplementary Fig. 23: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-04 00:05-00:25 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



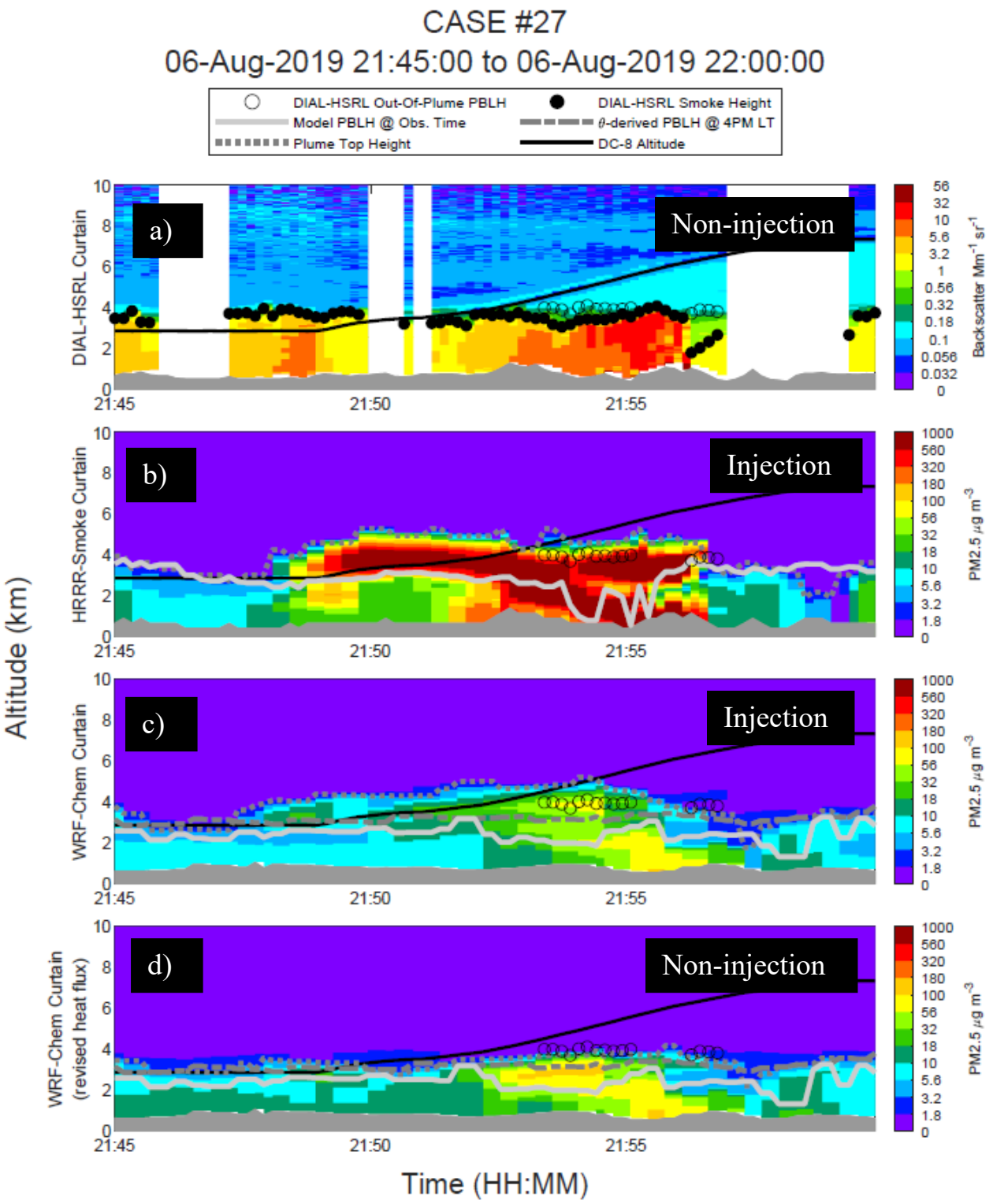
Supplementary Fig. 24: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-04 02:30-02:55 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



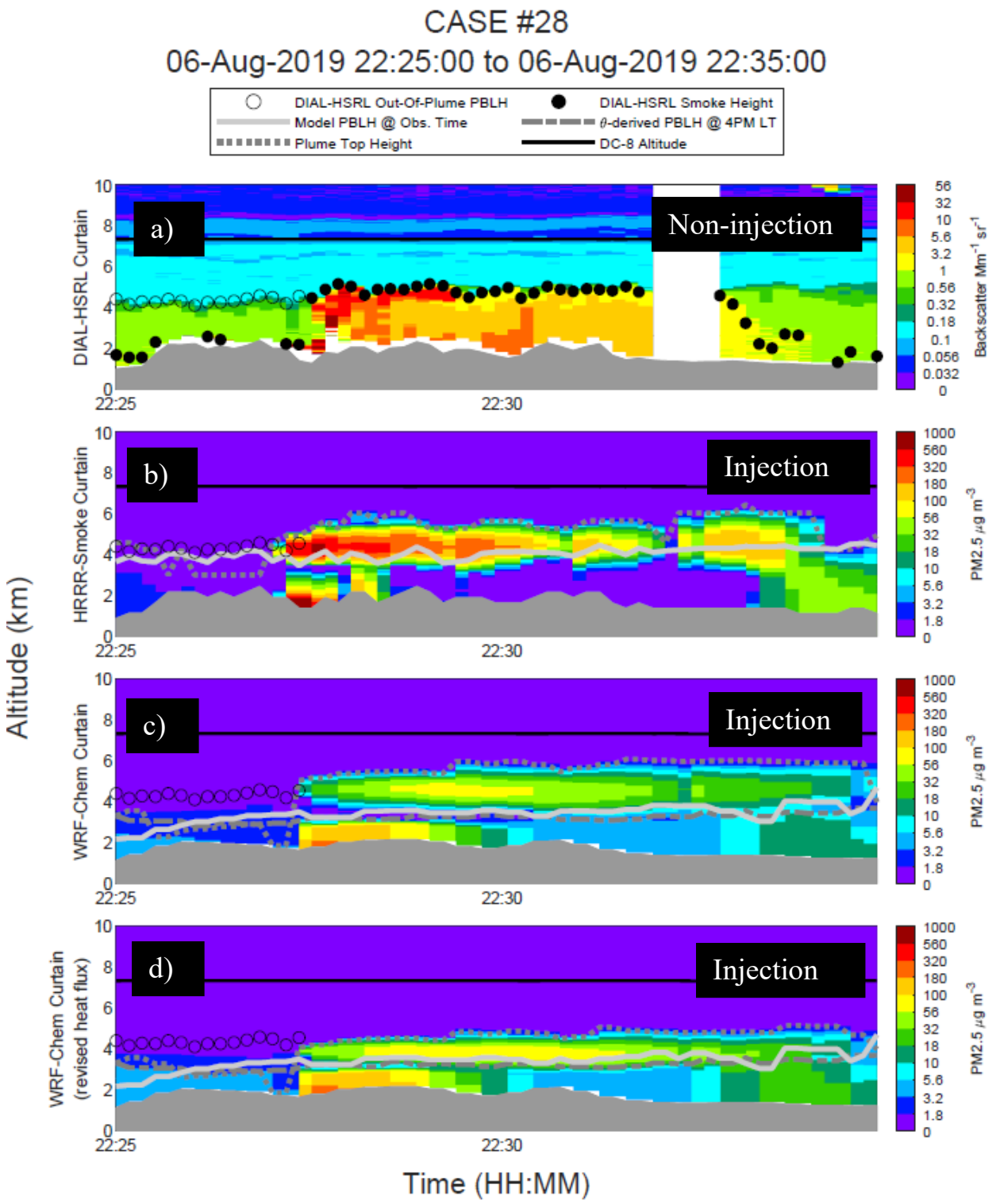
Supplementary Fig. 25: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Williams Flats Fire 2019-08-06 18:40-19:00 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



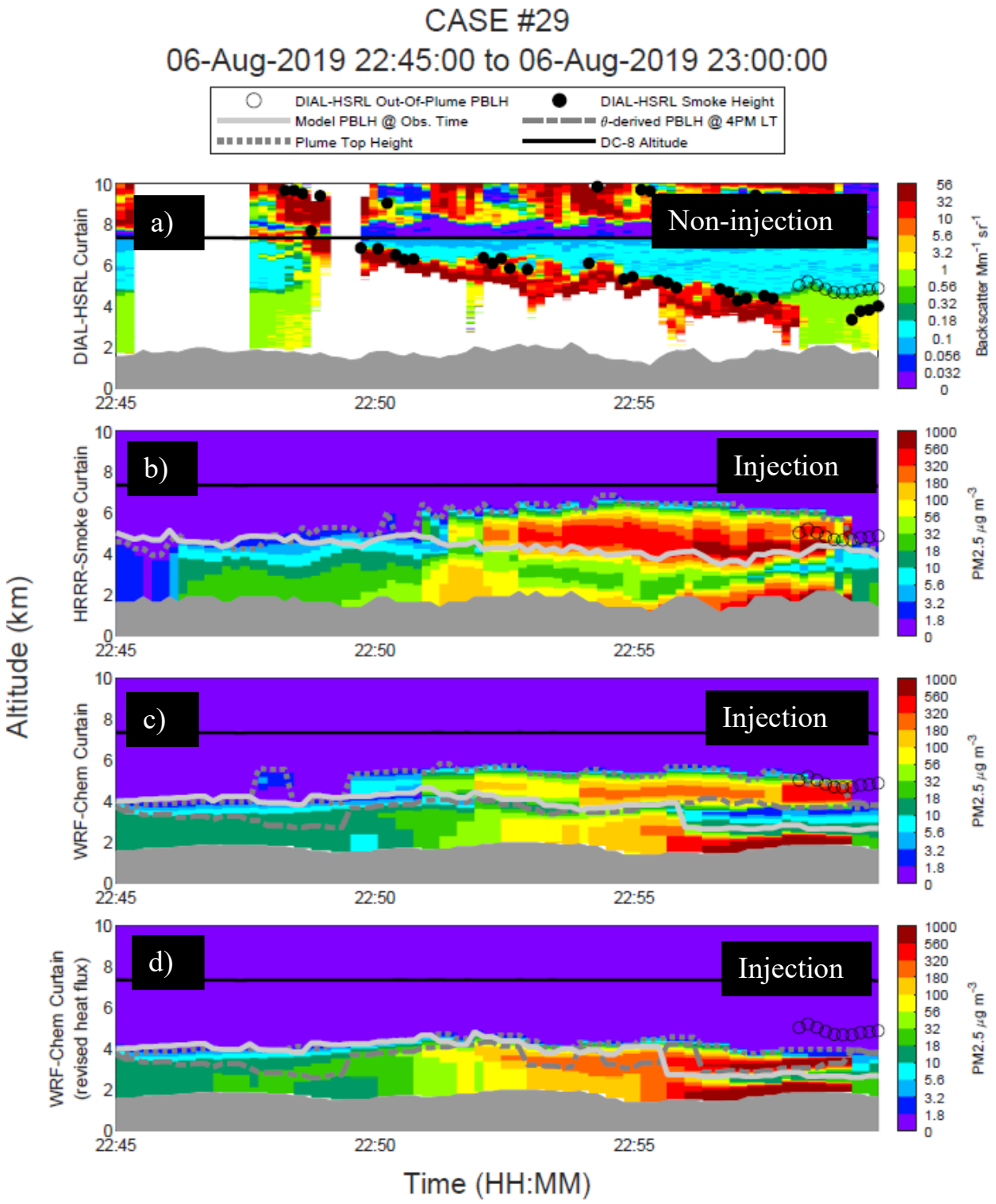
Supplementary Fig. 26: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Williams Flats Fire 2019-08-06 20:30-20:40 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



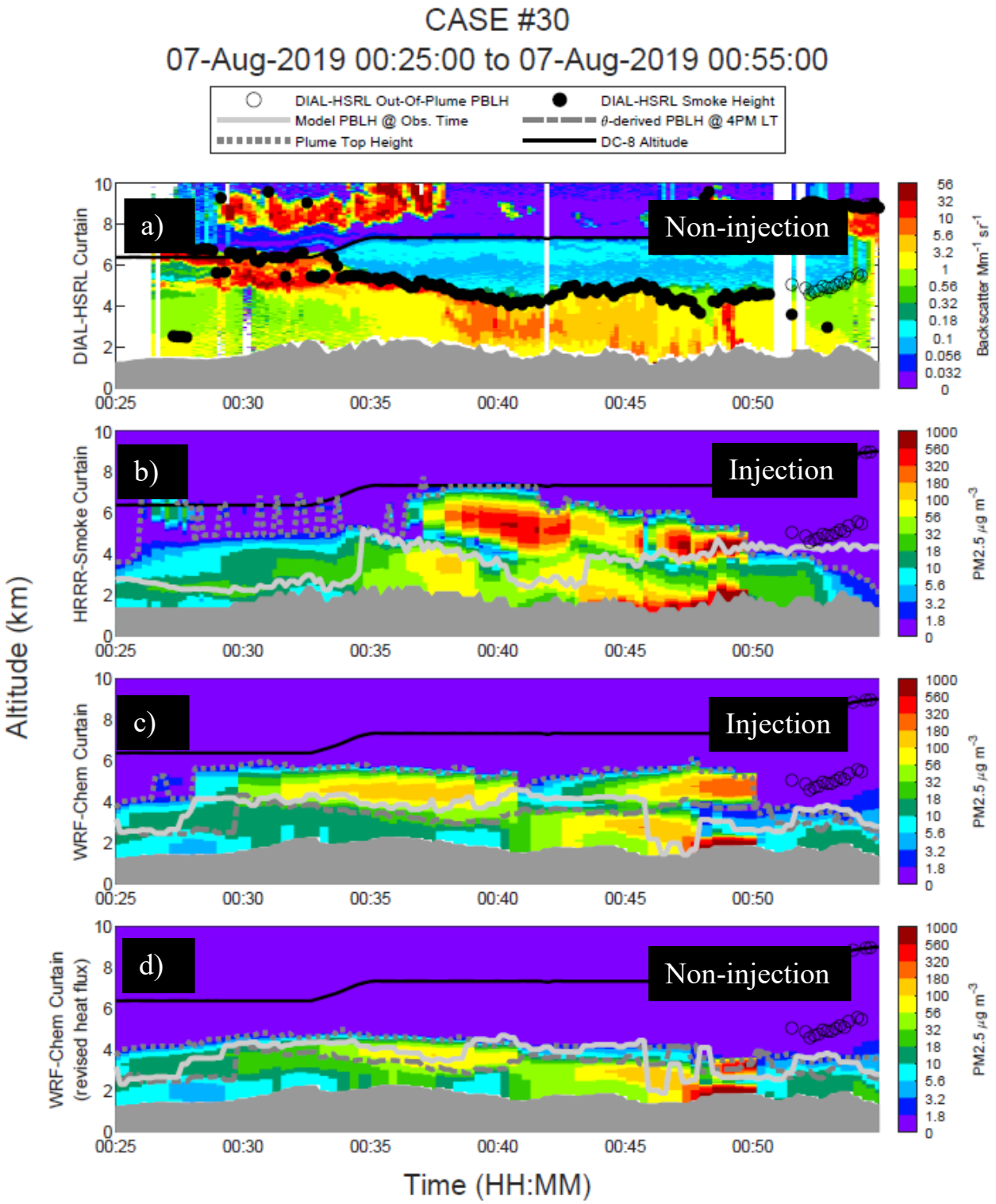
Supplementary Fig. 27: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Williams Flats Fire 2019-08-06 21:45-22:00 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



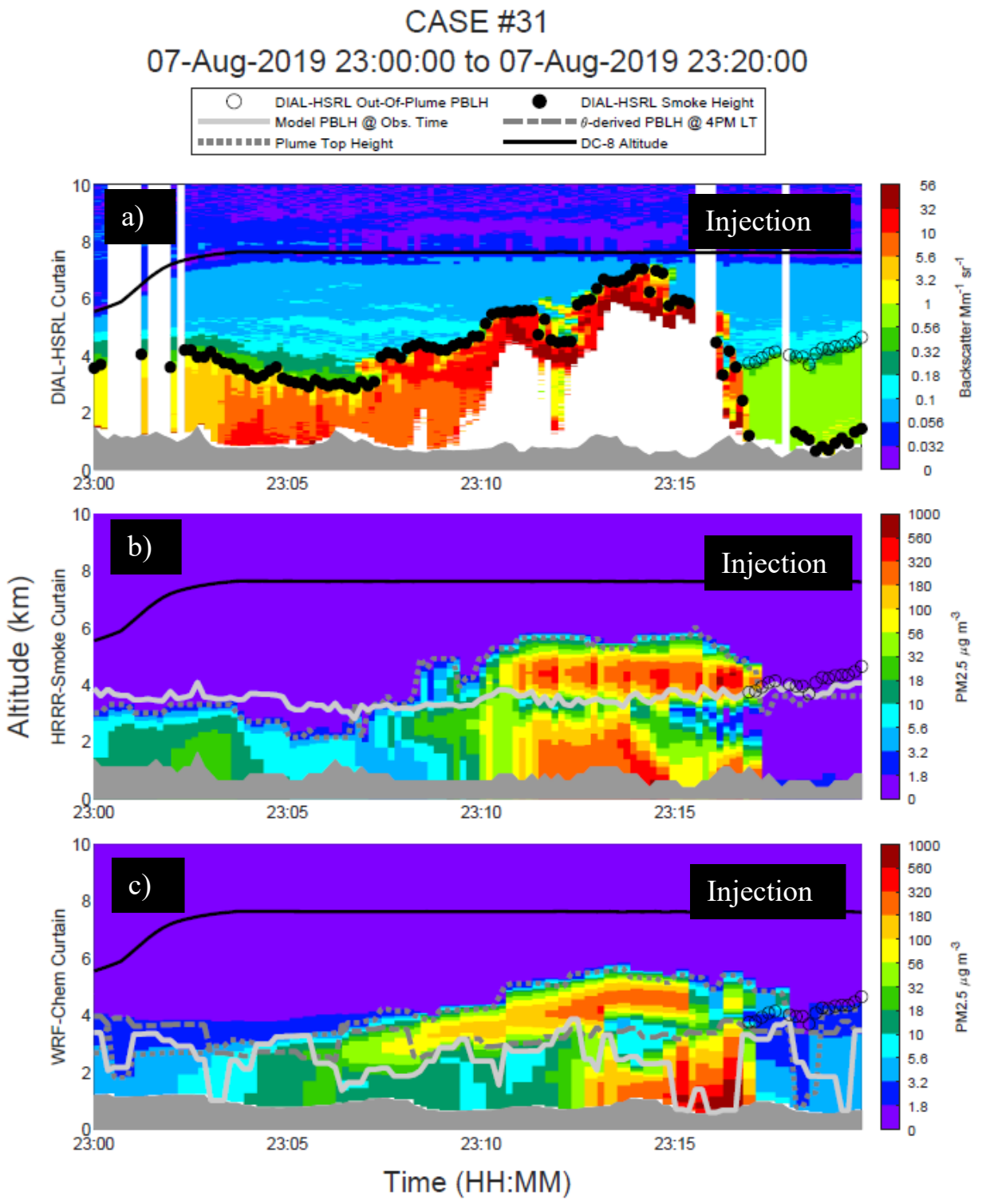
Supplementary Fig. 28: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Snow Creek Fire 2019-08-06 22:25-22:35 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



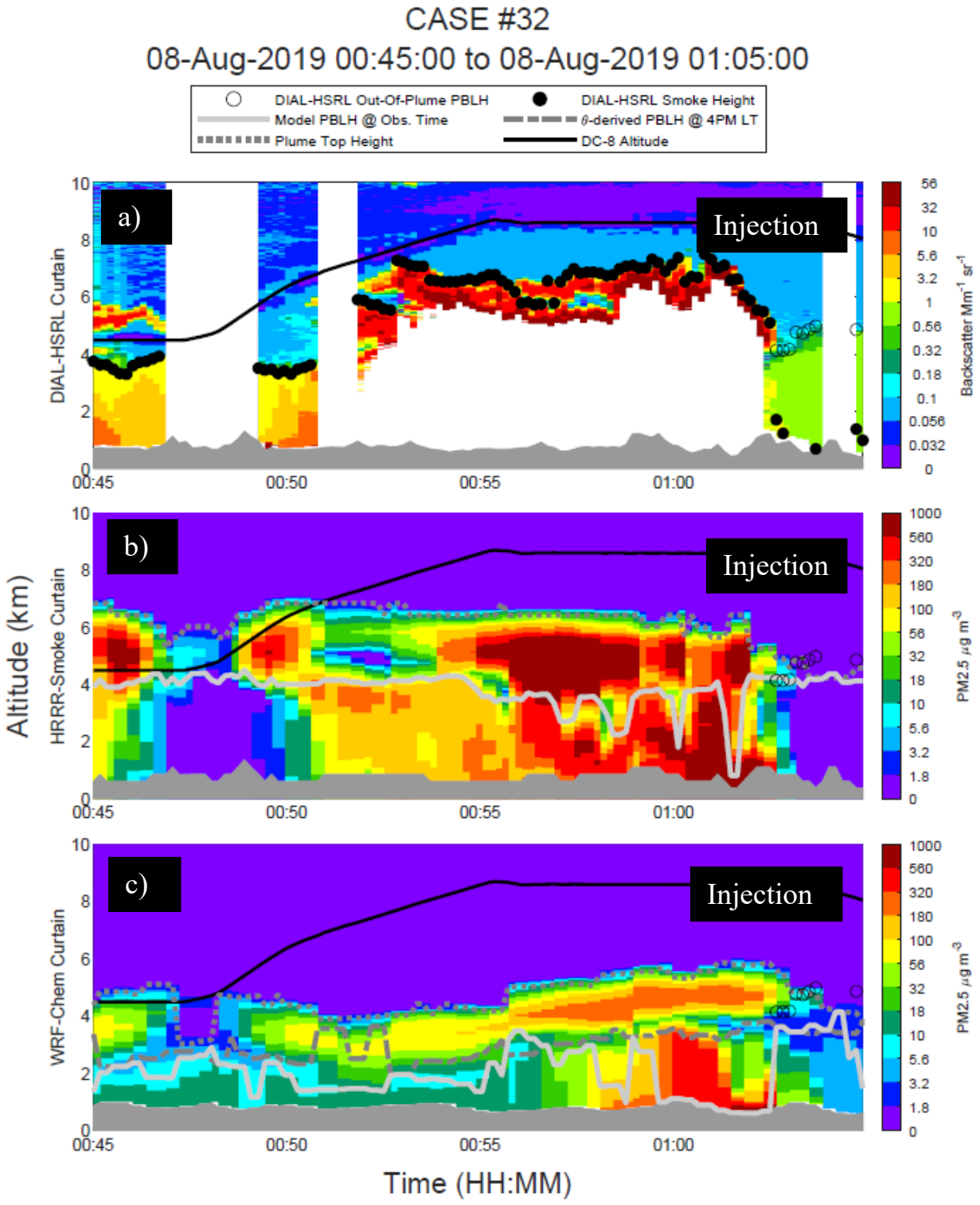
Supplementary Fig. 29: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Horsefly Fire 2019-08-06 22:45-23:00 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



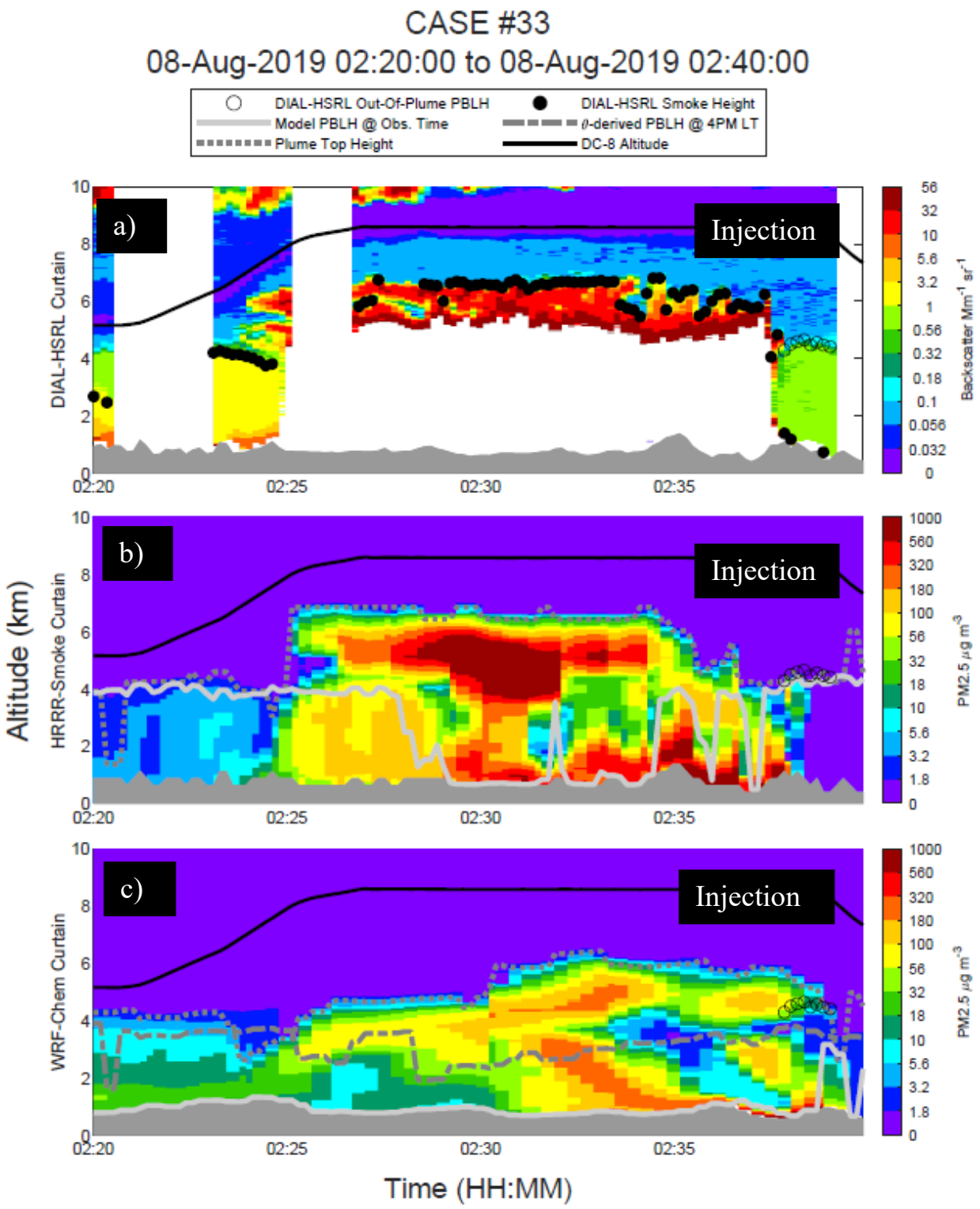
Supplementary Fig. 30: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Horsefly Fire 2019-08-07 00:25-00:55 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



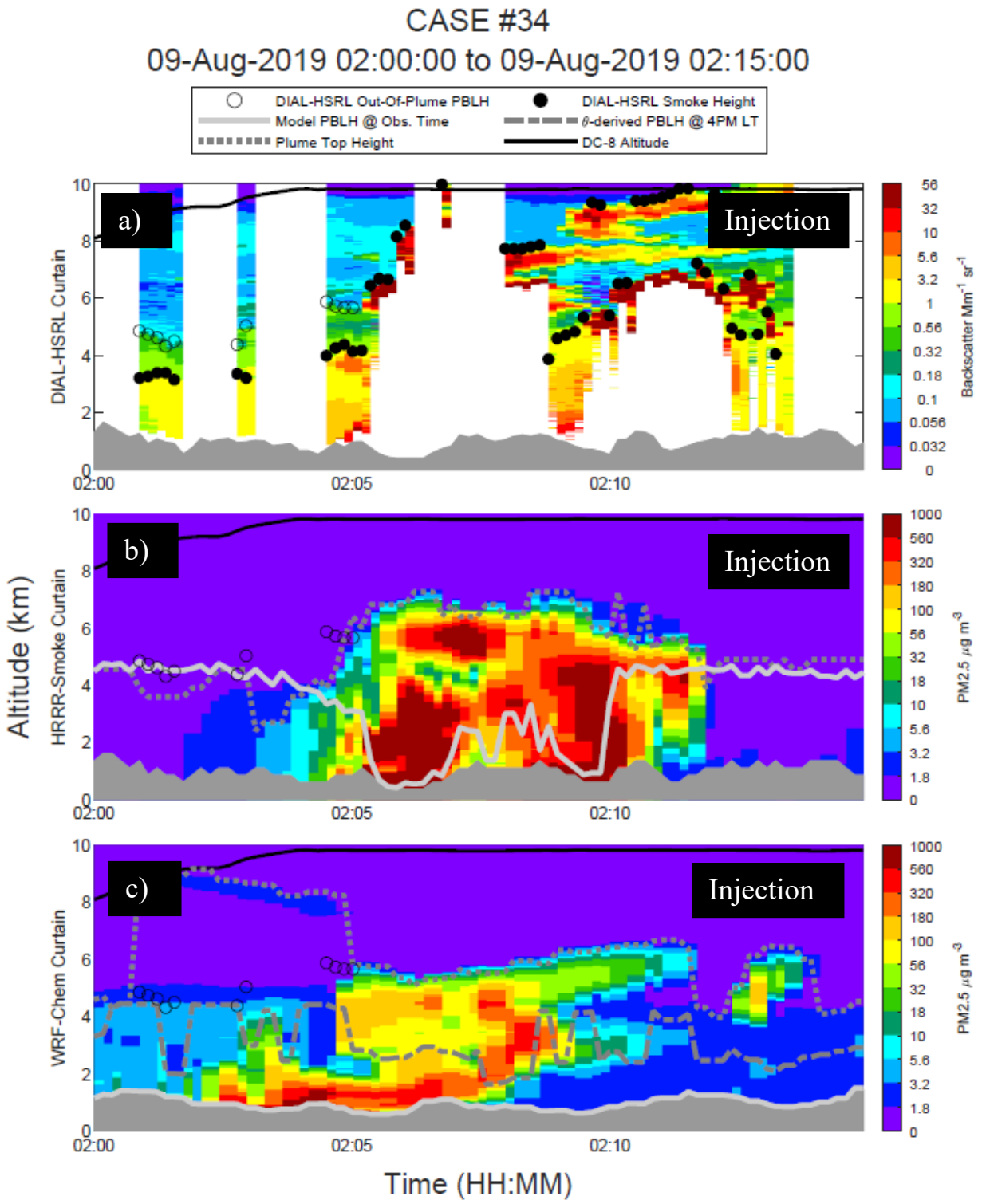
Supplementary Fig. 31: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheep Fire on 2019-08-07 23:00-23:20 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



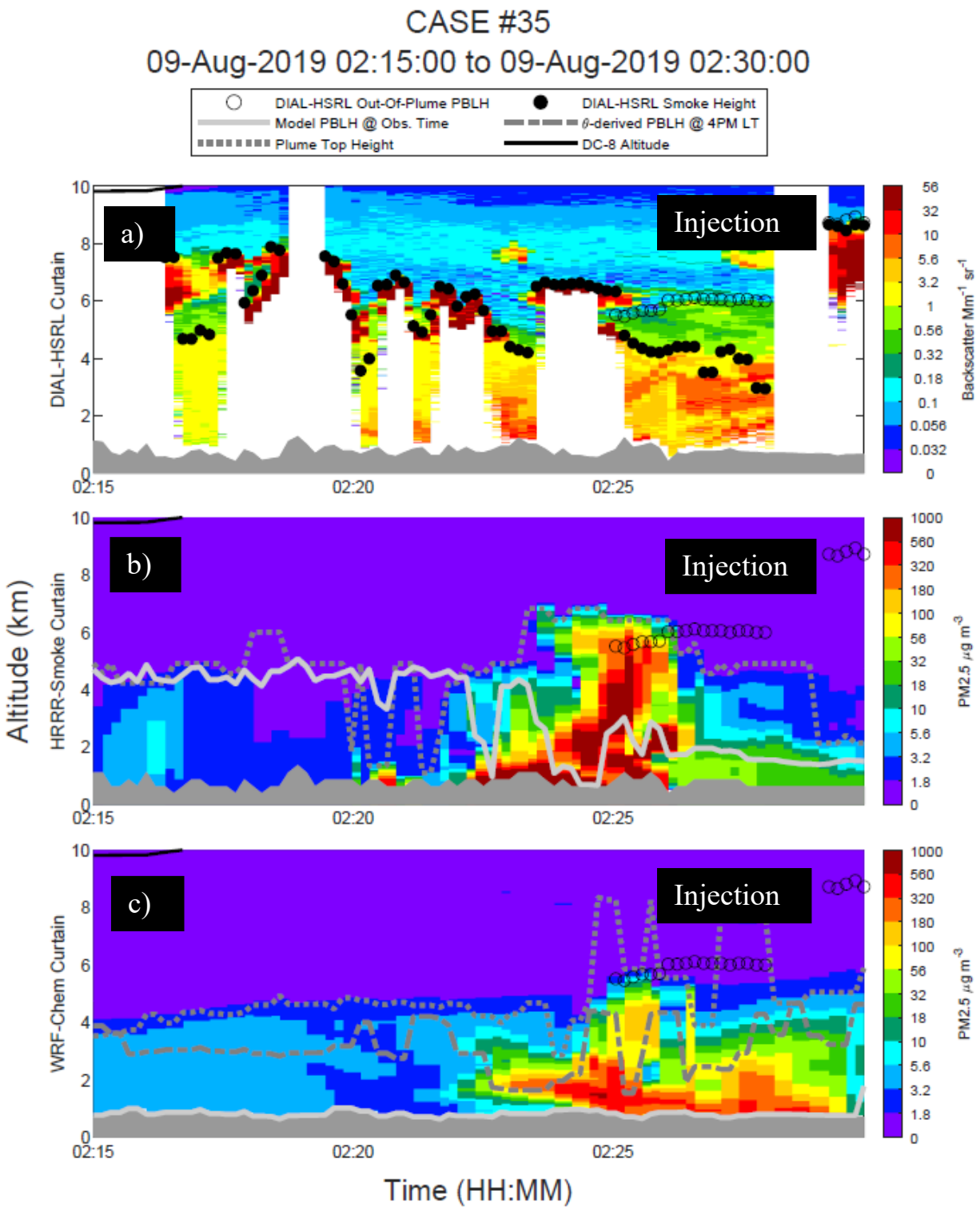
Supplementary Fig. 32: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-08 00:45-01:05 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



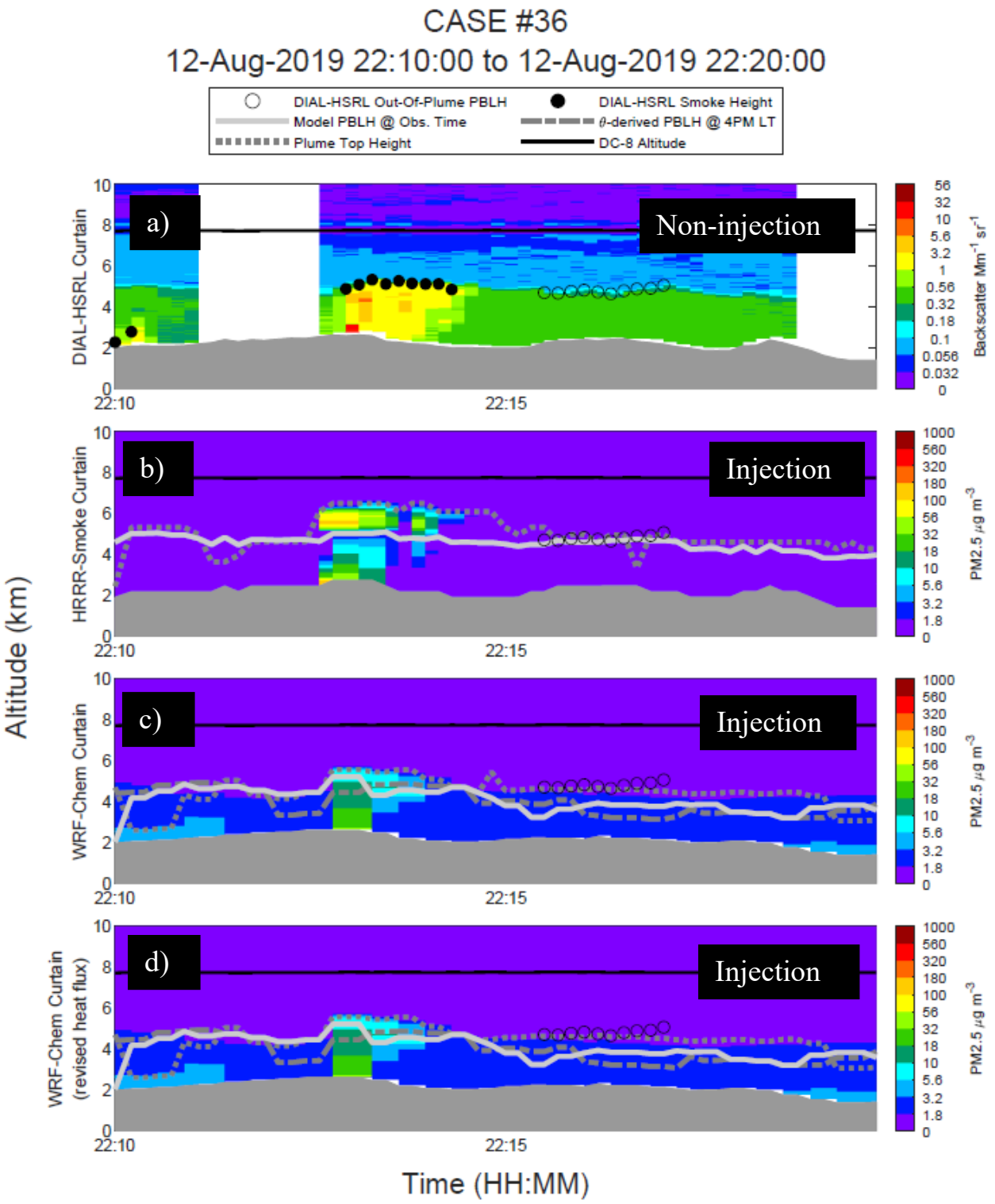
Supplementary Fig. 33: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-08 02:20-02:40 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



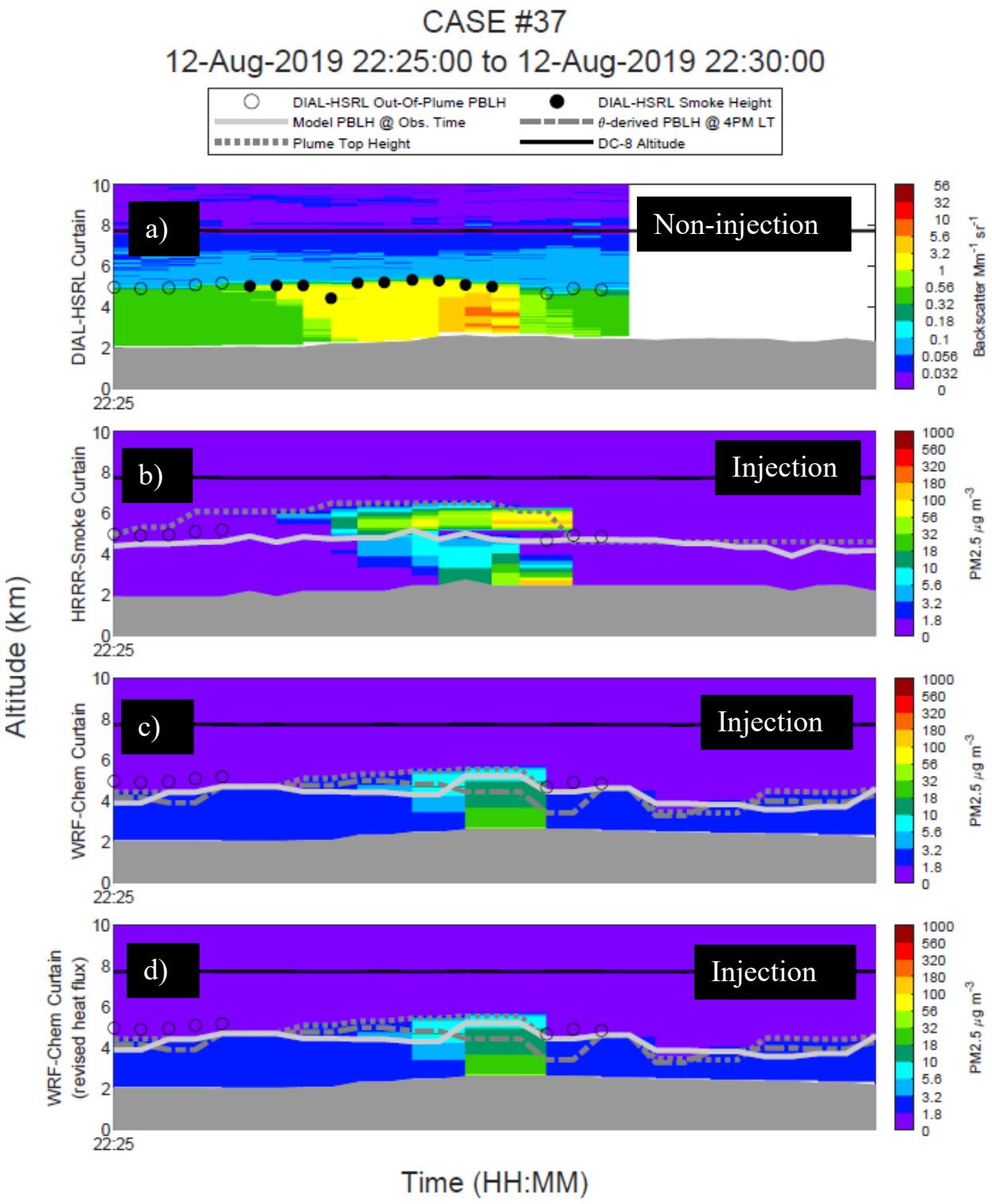
Supplementary Fig. 34: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-09 02:00-02:15 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



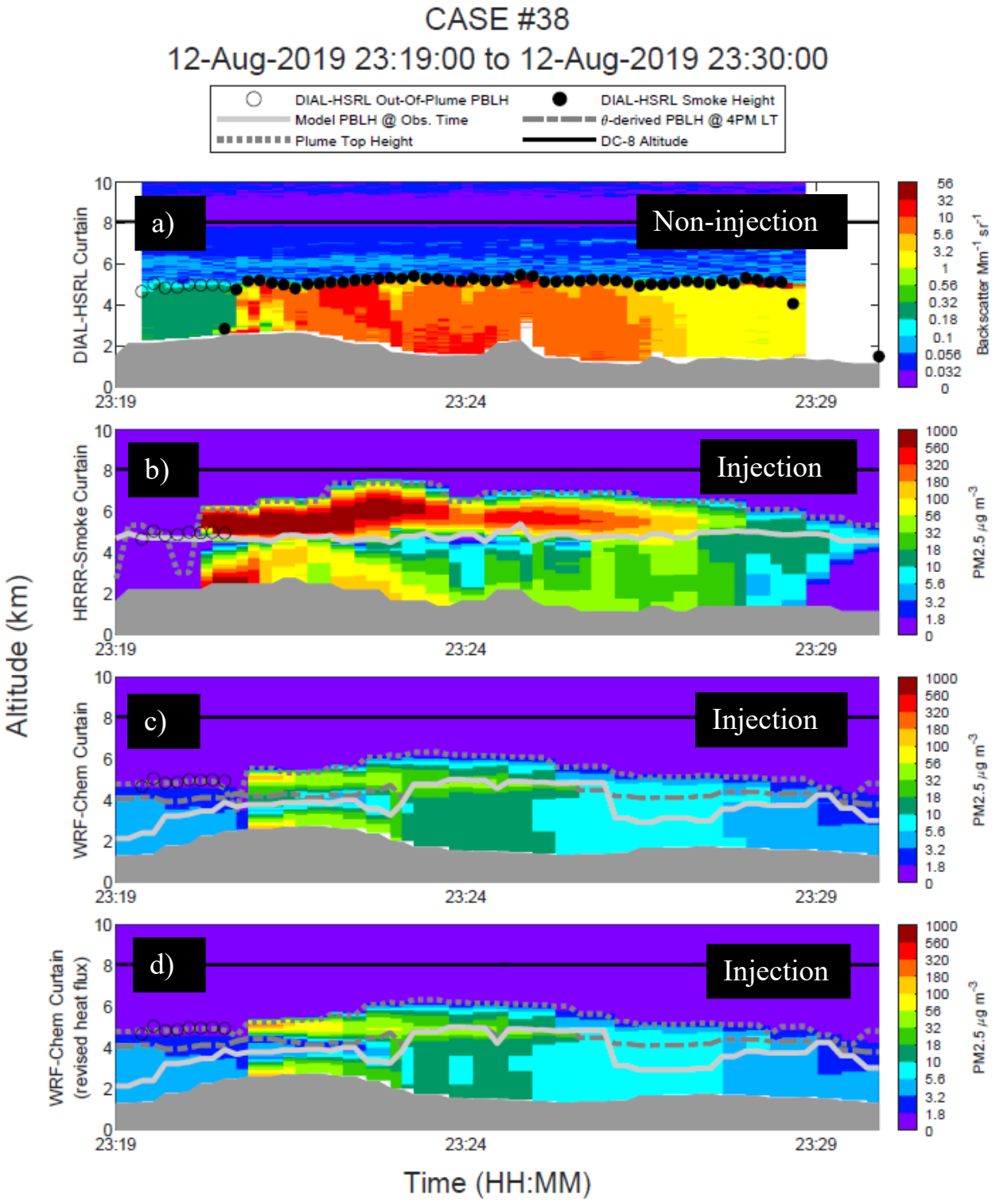
Supplementary Fig. 35: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Williams Flats Fire on 2019-08-09 02:15-02:30 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



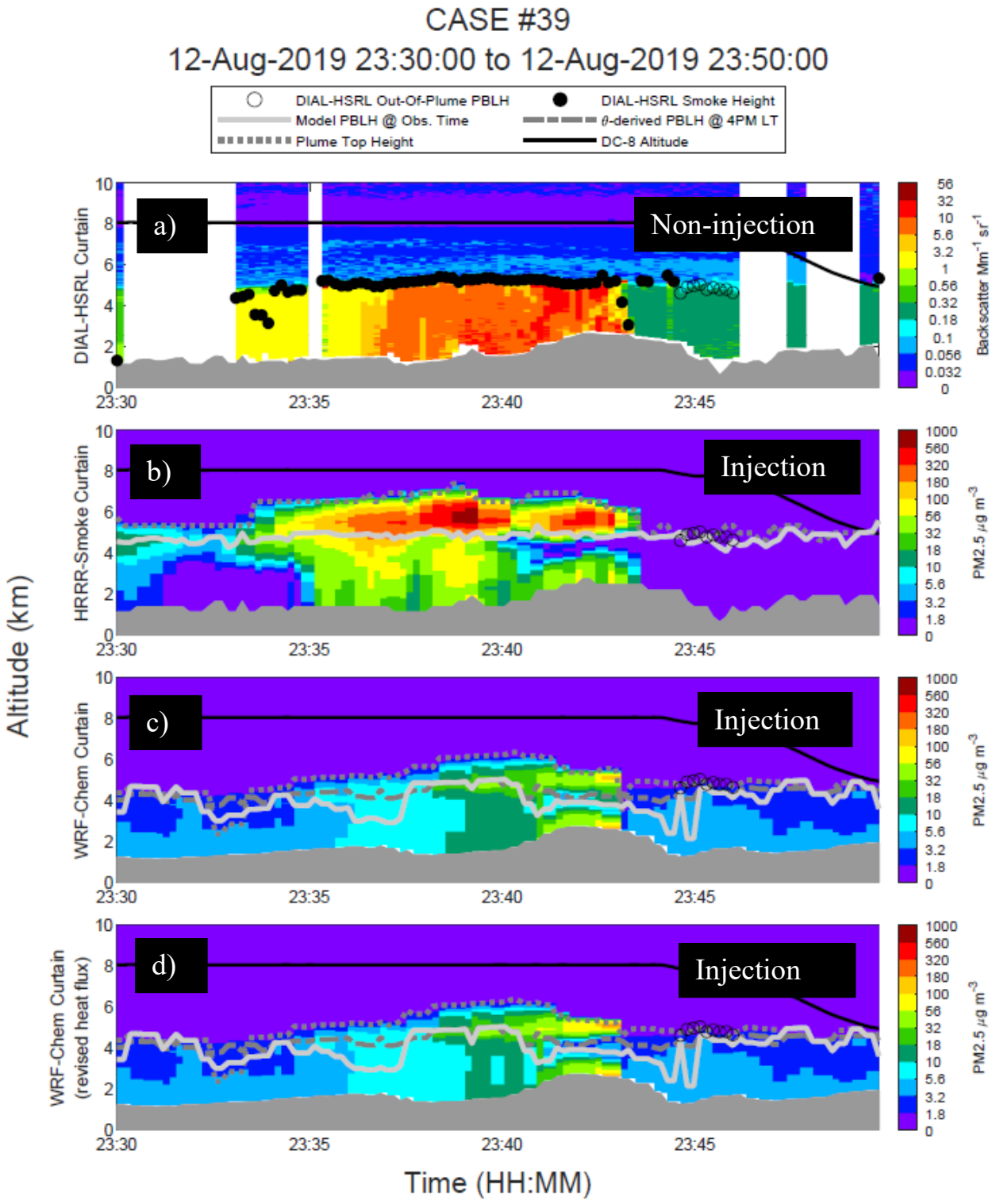
Supplementary Fig. 36: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Srings Fire 2019-08-12 22:10-22:20 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



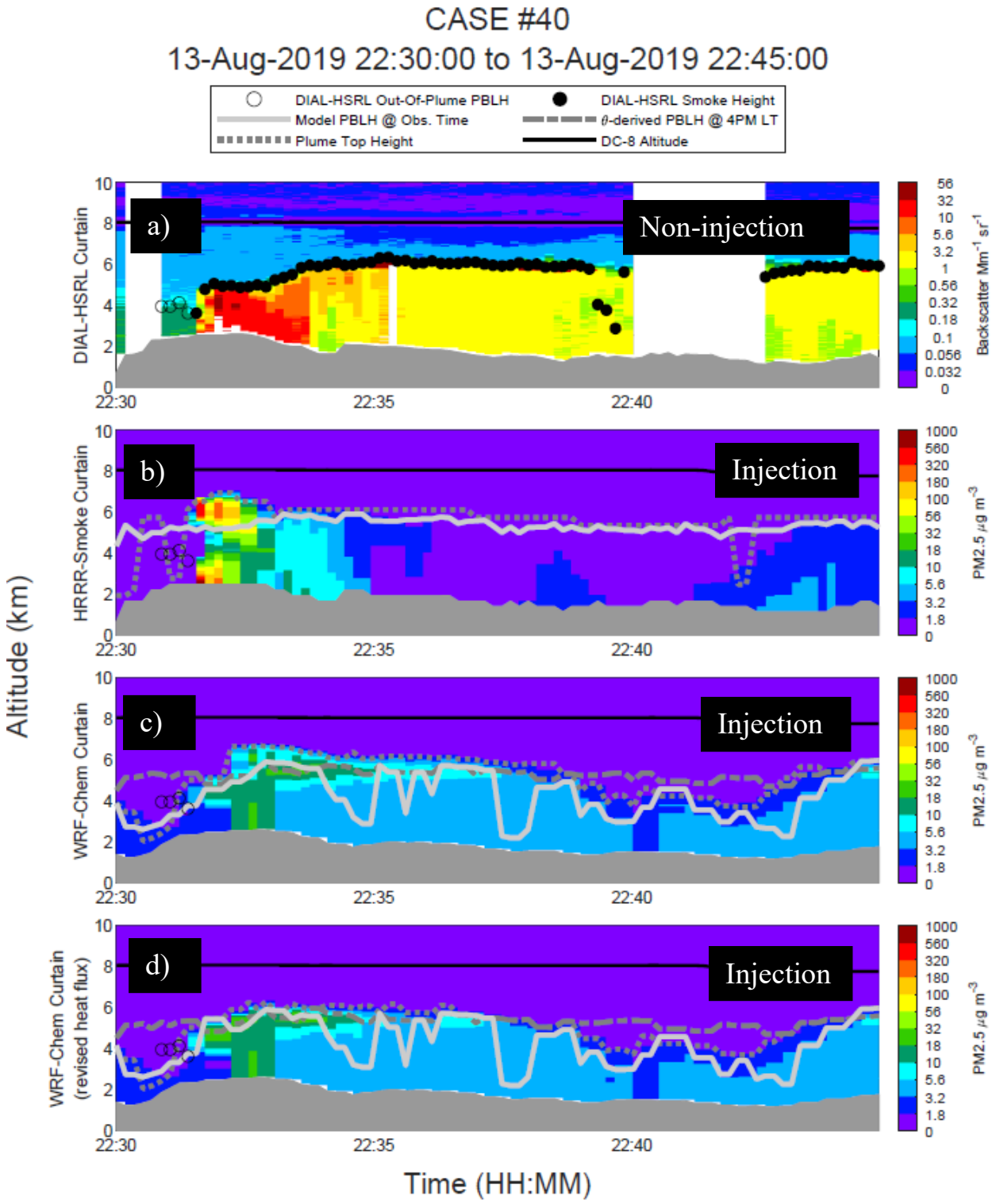
Supplementary Fig. 37: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Springs Fire 2019-08-12 22:25-22:30 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



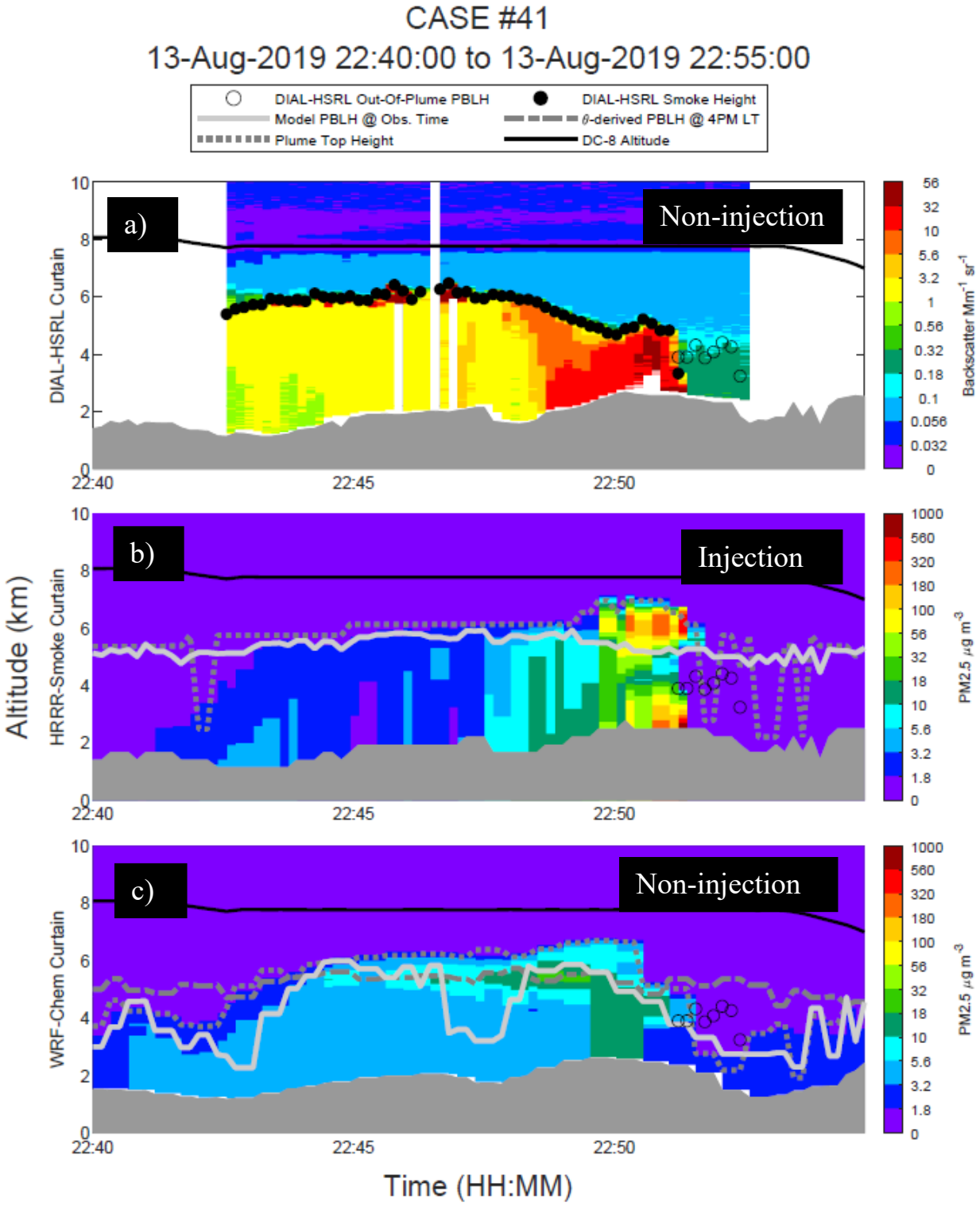
Supplementary Fig. 38: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Castle Fire 2019-08-12 23:19-23:30 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



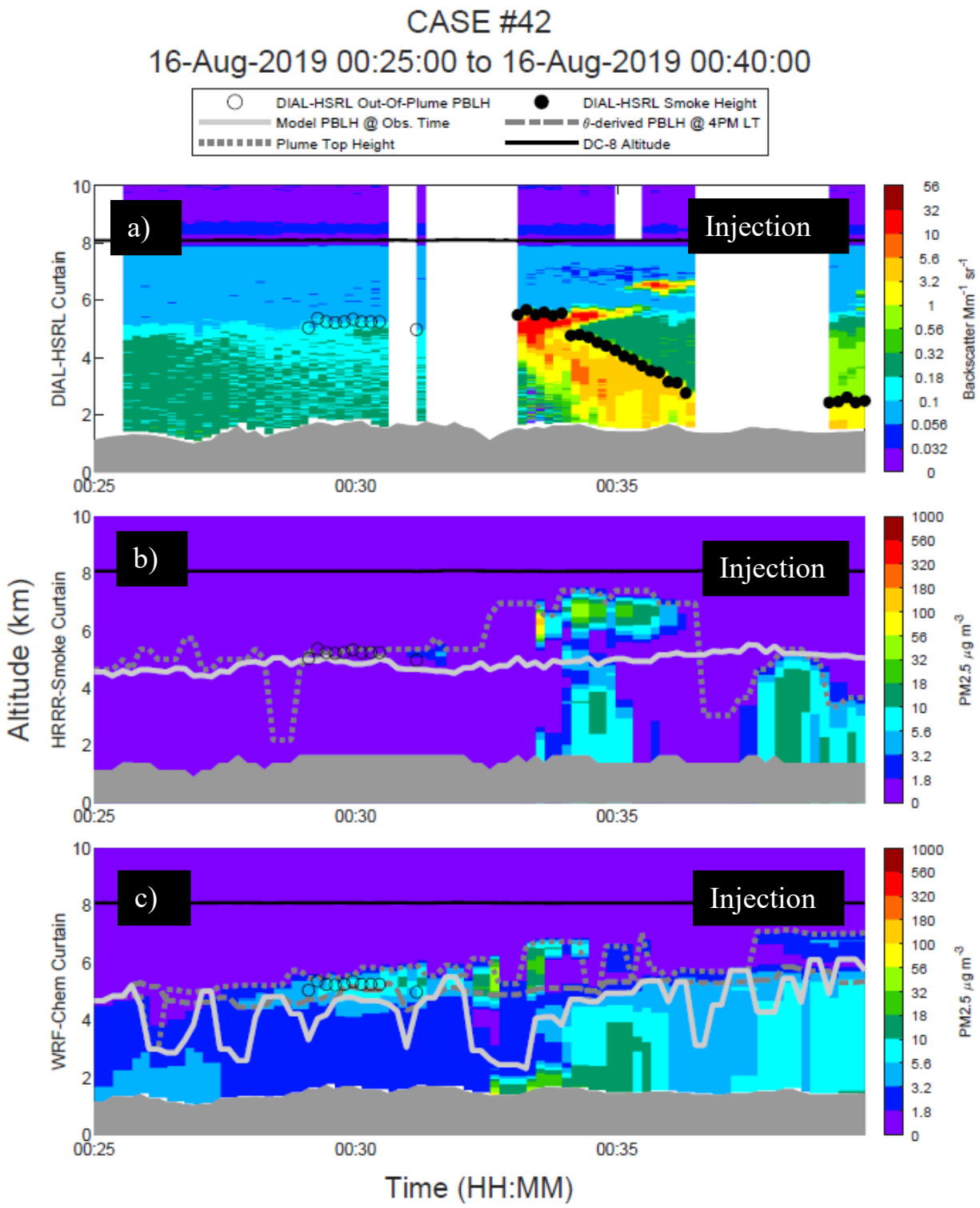
Supplementary Fig. 39: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Castle Fire 2019-08-12 23:30-23:50 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



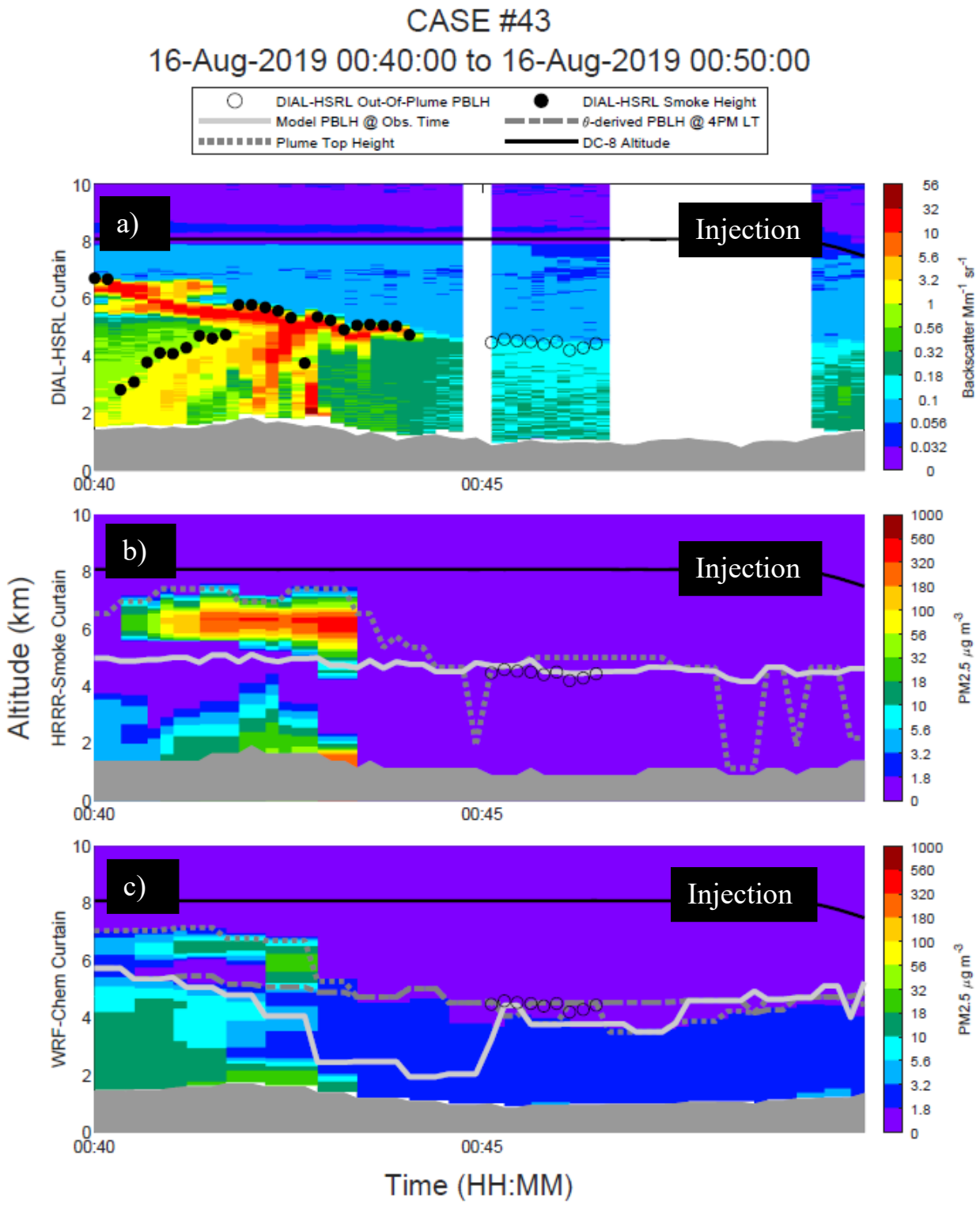
Supplementary Fig. 40: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Castle Fire 2019-08-13 22:30-22:45 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



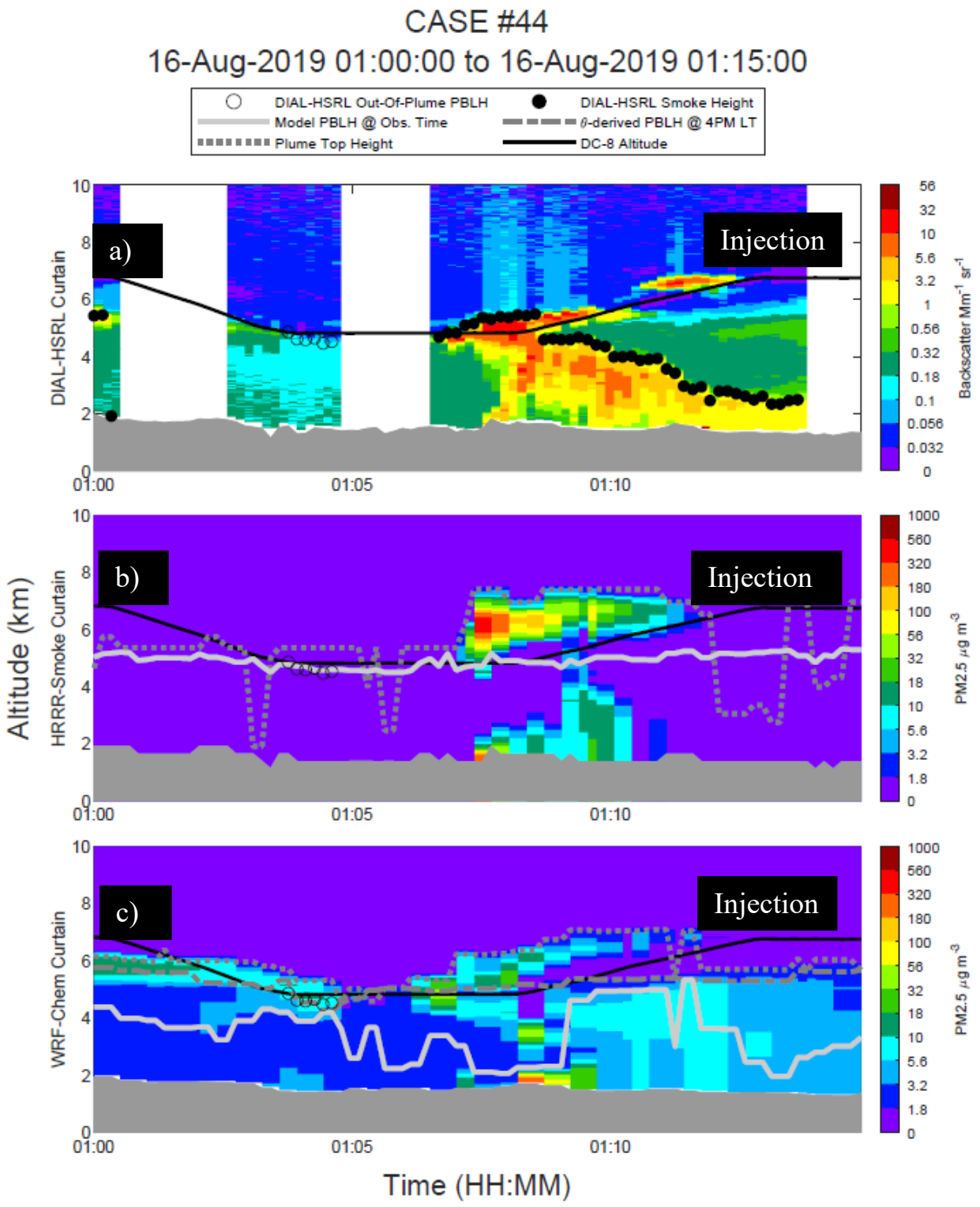
Supplementary Fig. 41: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Castle Fire on 2019-08-13 22:40-22:55 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



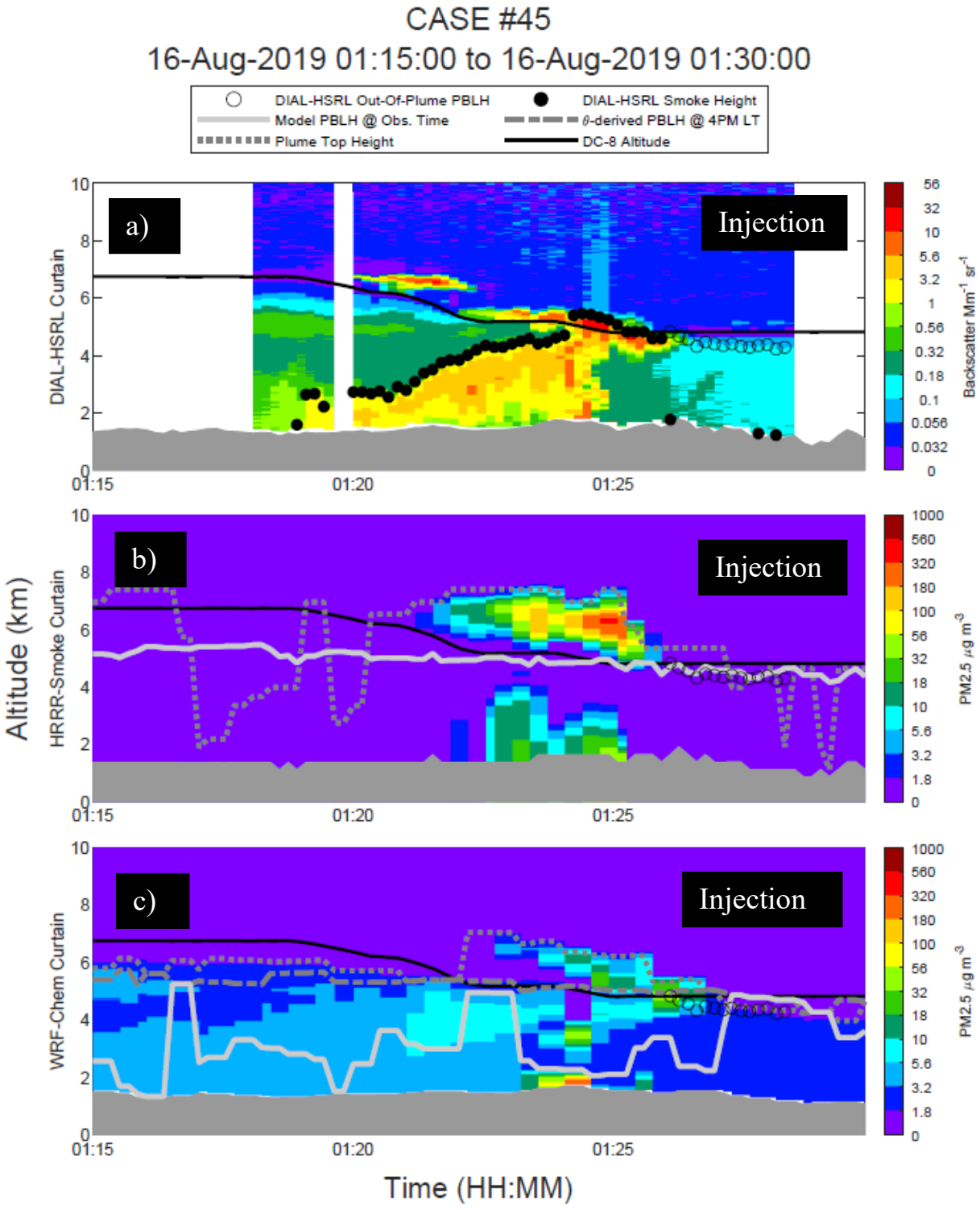
Supplementary Fig. 42: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheridan Fire on 2019-08-16 00:25-00:40 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



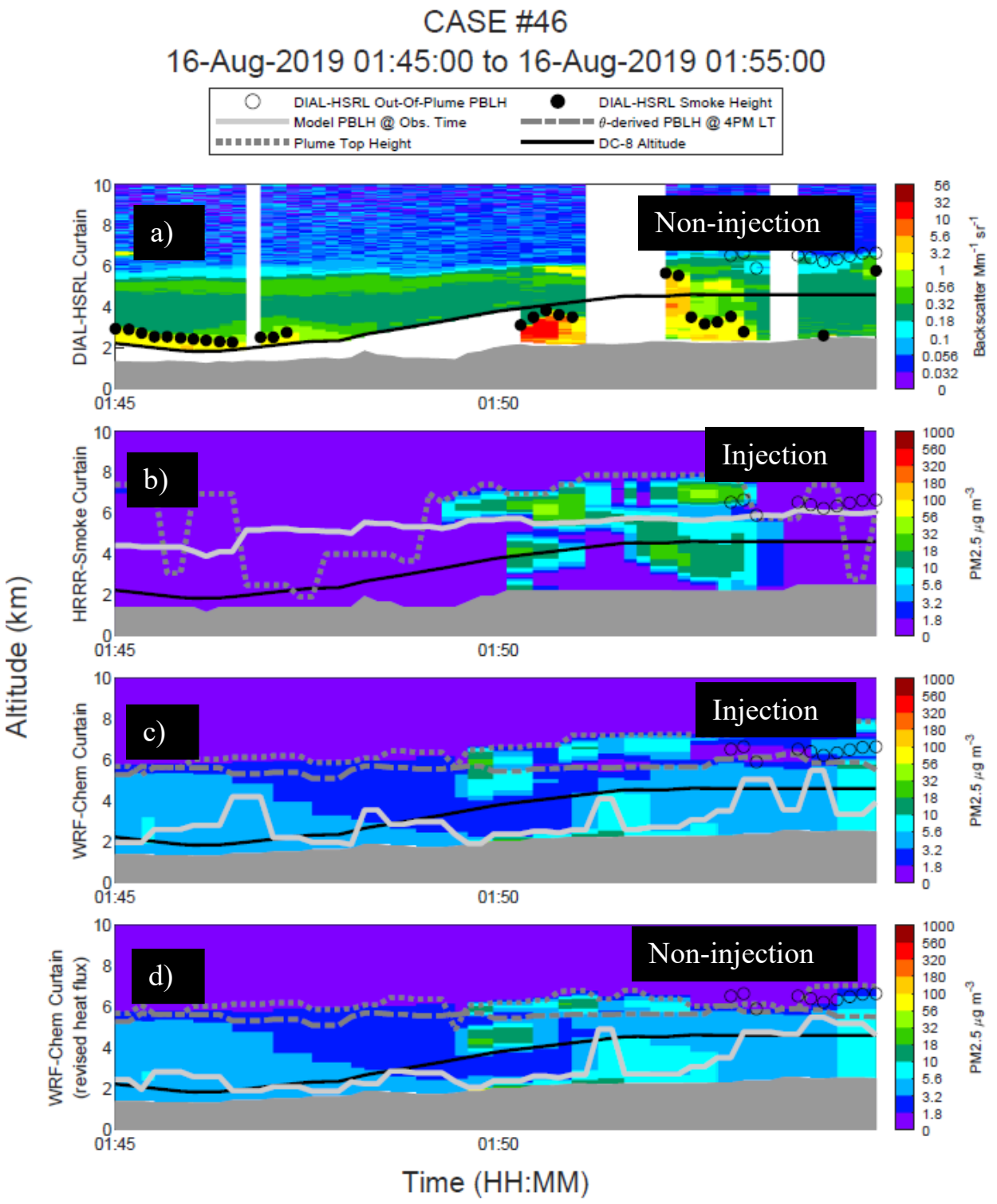
Supplementary Fig. 43: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheridan Fire on 2019-08-16 00:40-00:50 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



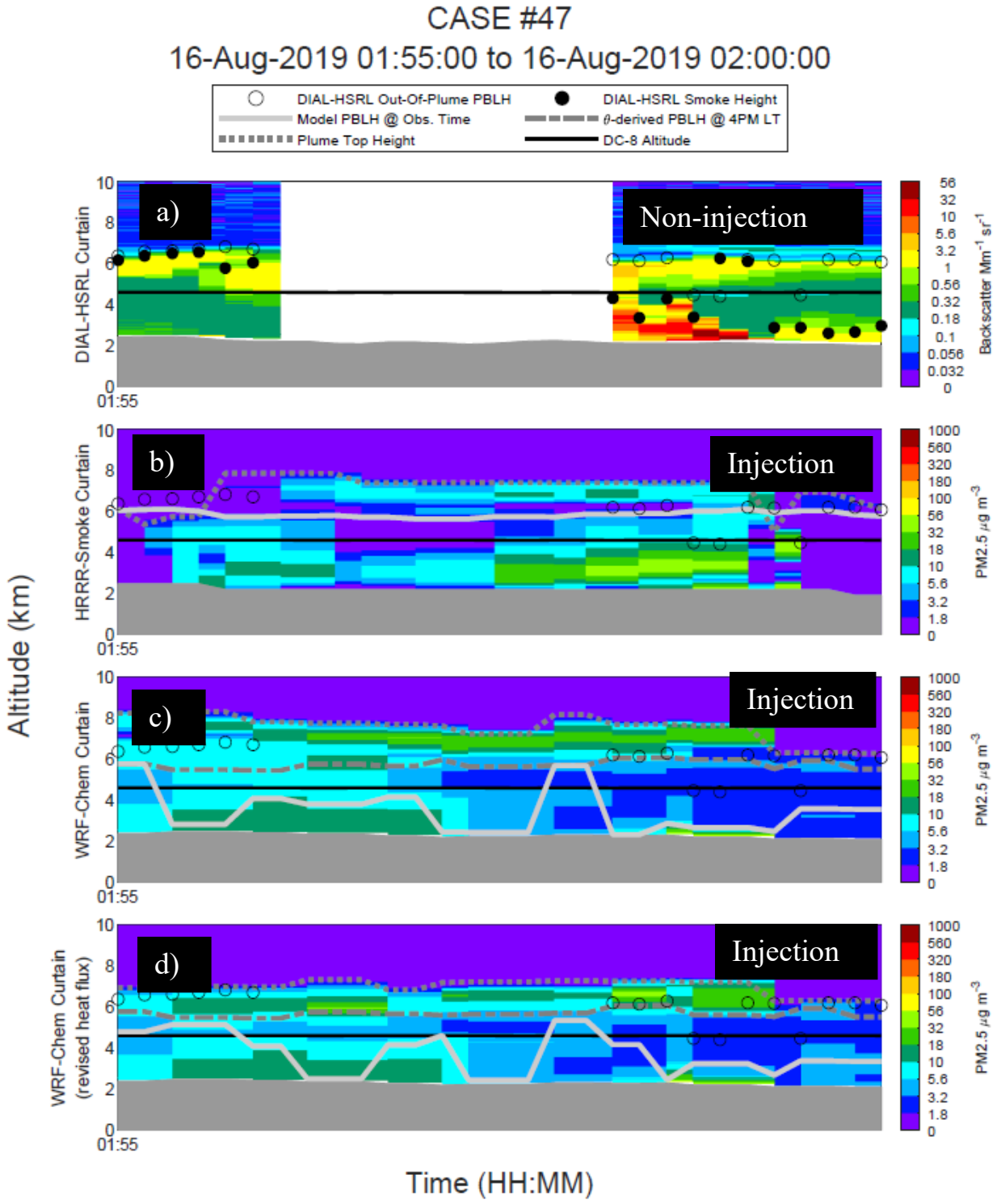
Supplementary Fig. 44: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheridan Fire on 2019-08-16 01:00-01:15 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



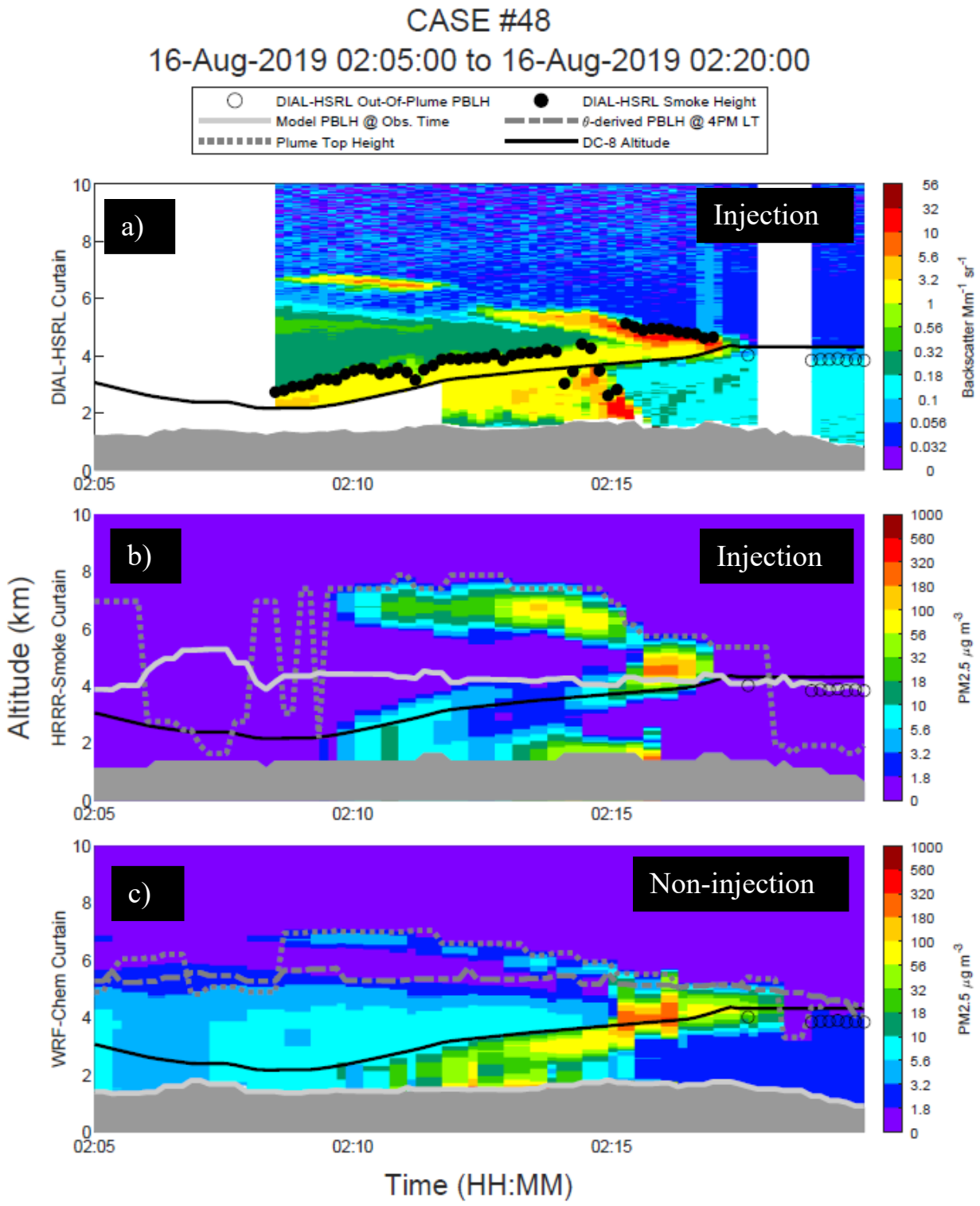
Supplementary Fig. 45: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b) and WRF-Chem (c) for the Sheridan Fire on 2019-08-16 01:15-01:30 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



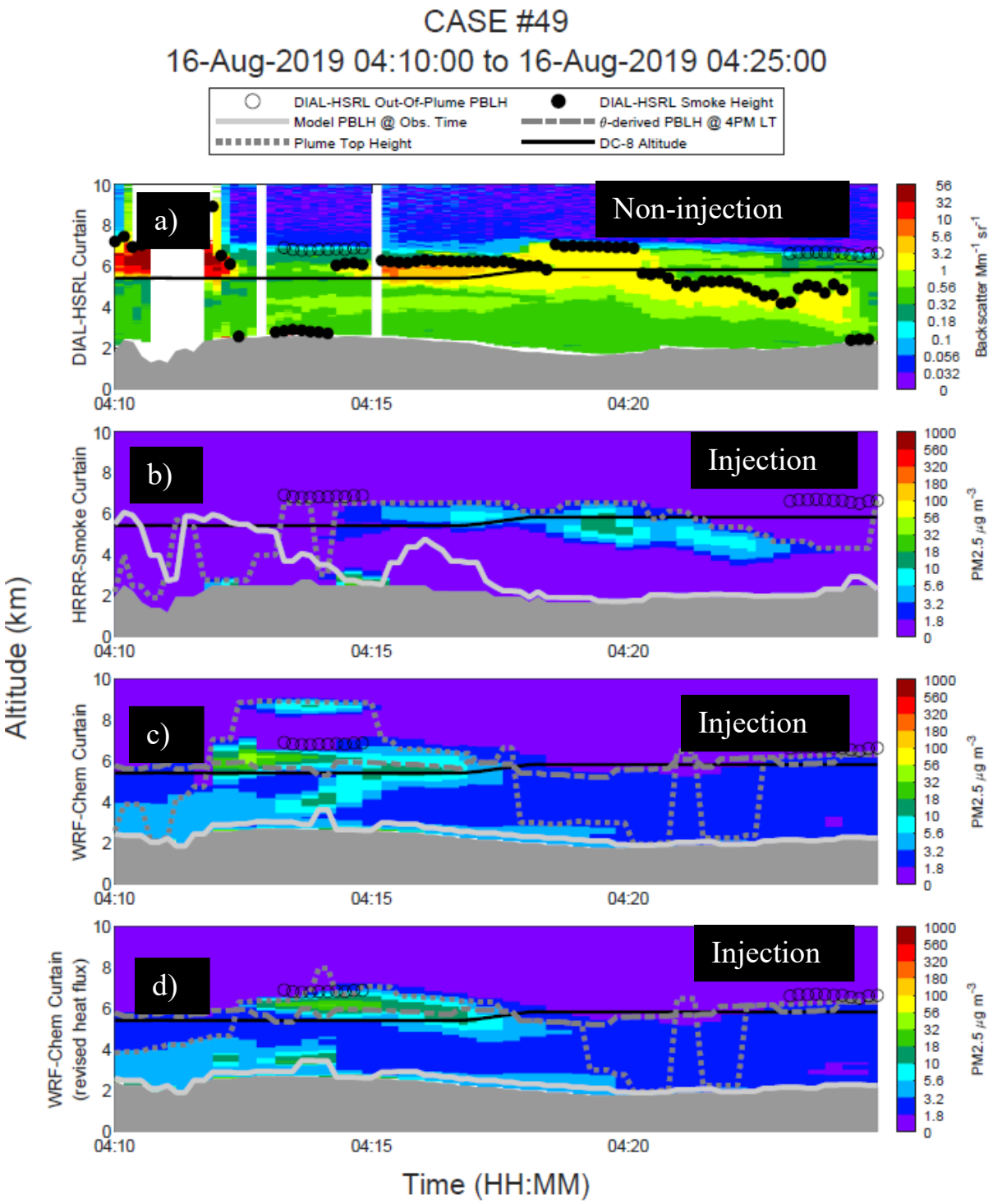
Supplementary Fig. 46: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Saber Fire 2019-08-16 01:45-01:55 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



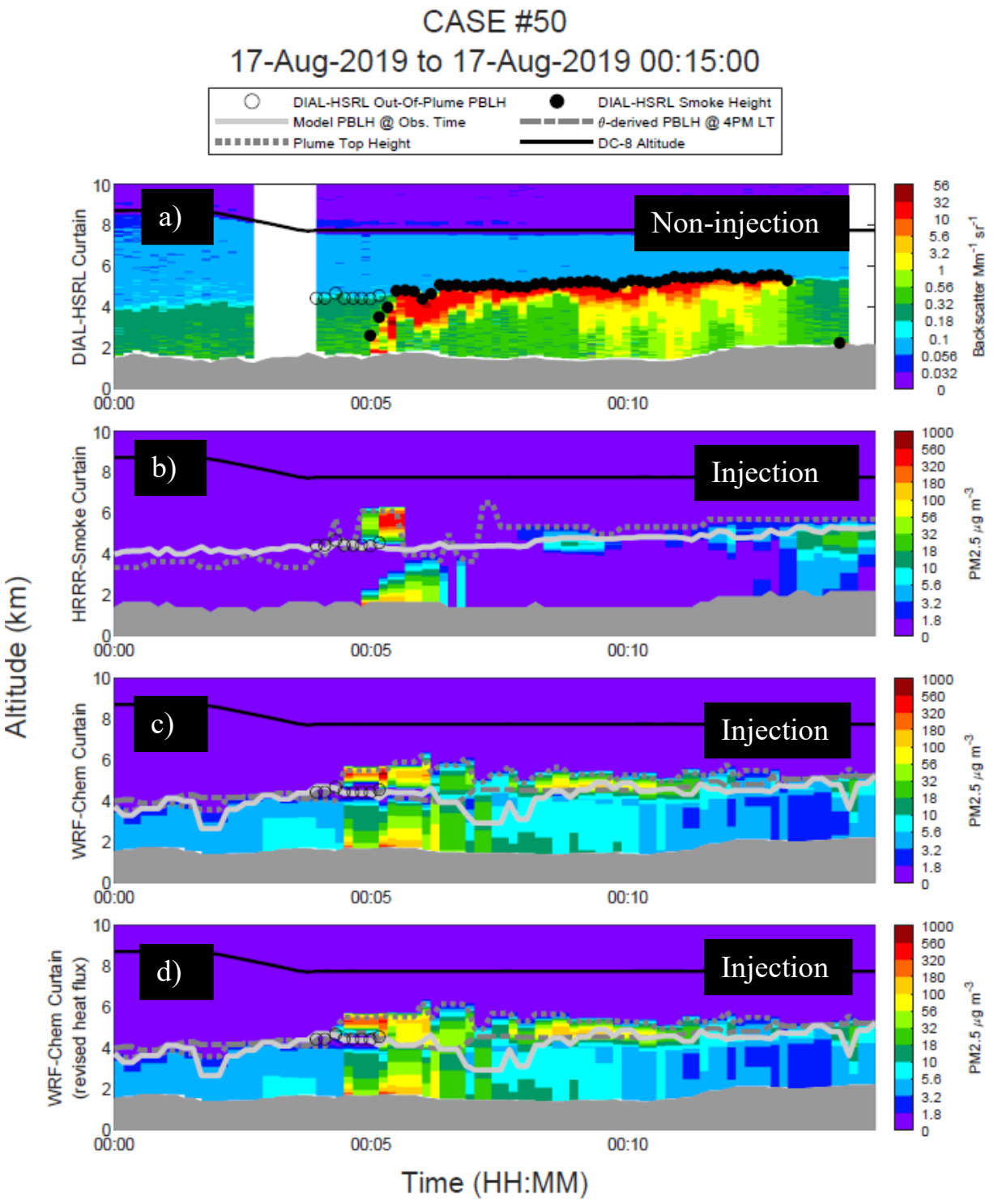
Supplementary Fig. 47: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Boulin Fire 2019-08-16 01:55-02:00 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



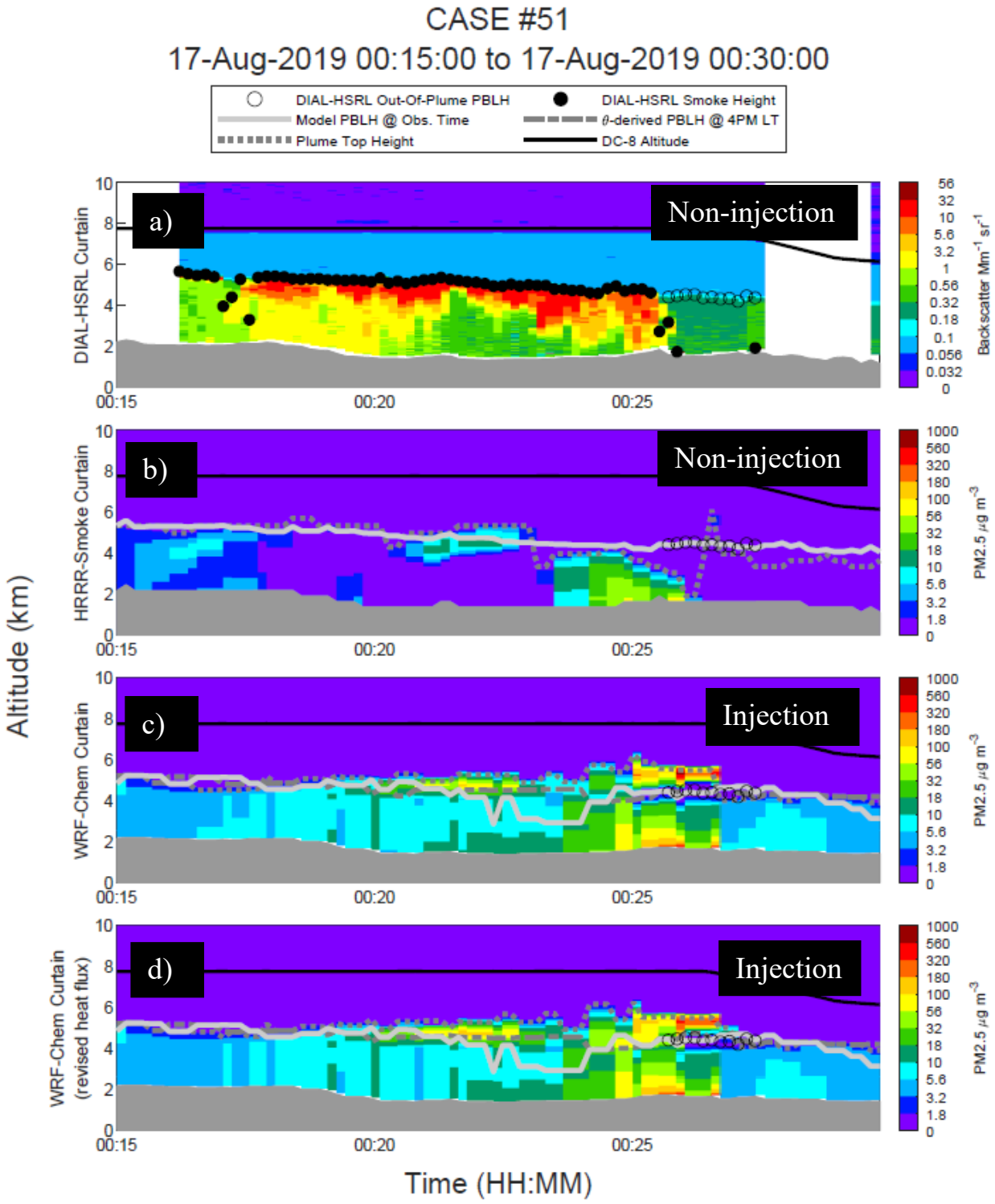
Supplementary Fig. 48: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Sheridan Fire 2019-08-16 02:05-02:20 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



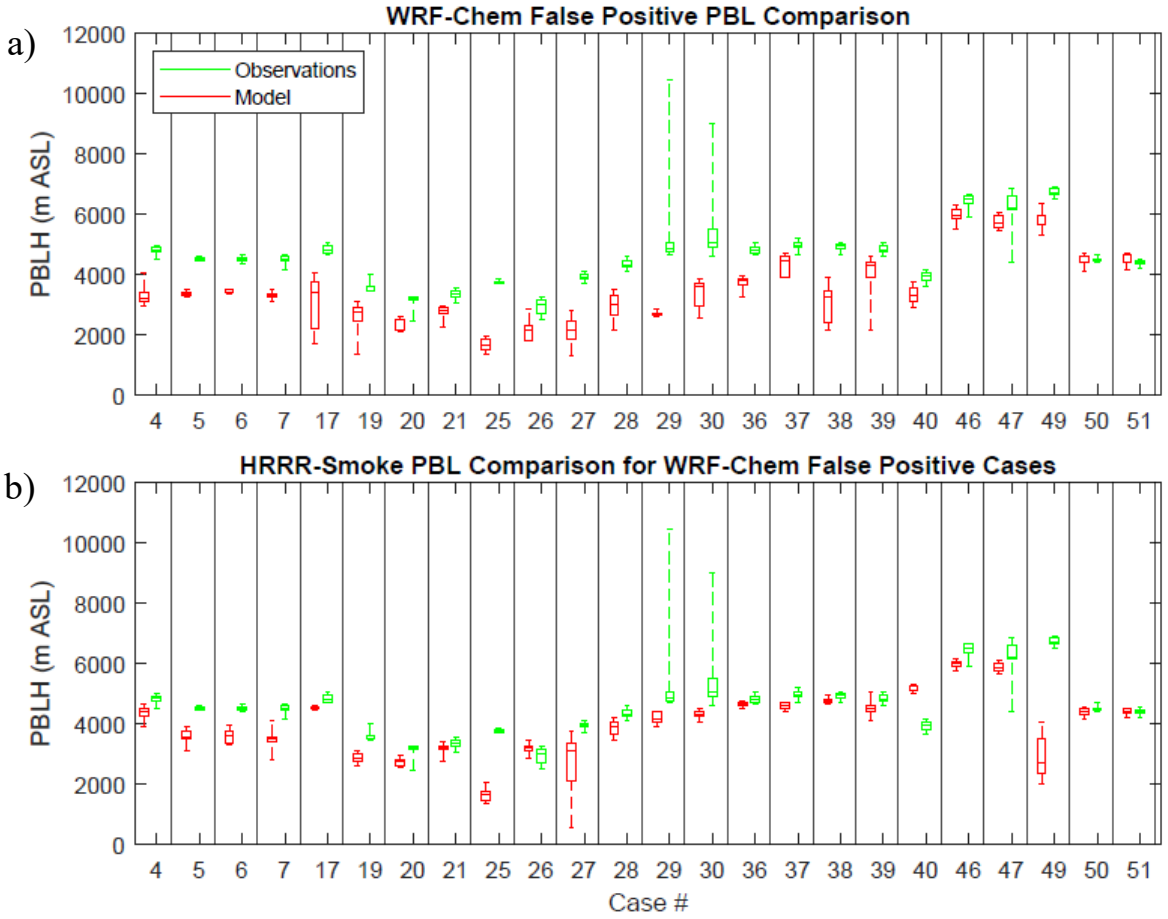
Supplementary Fig. 49: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Ikes Fire 2019-08-16 04:10-04:25 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



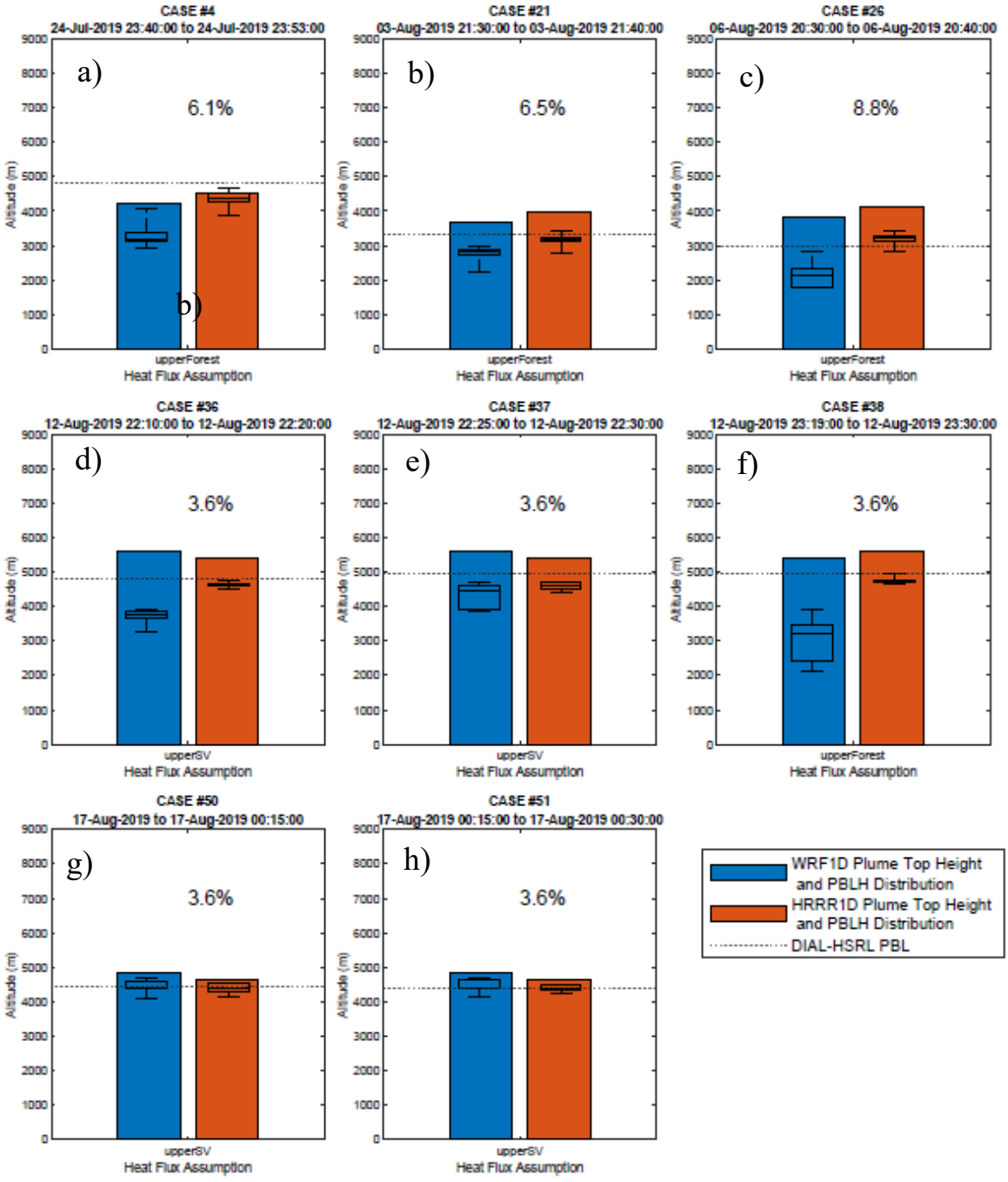
Supplementary Fig. 50: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Sheridan Fire 2019-08-17 00:00-00:15 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



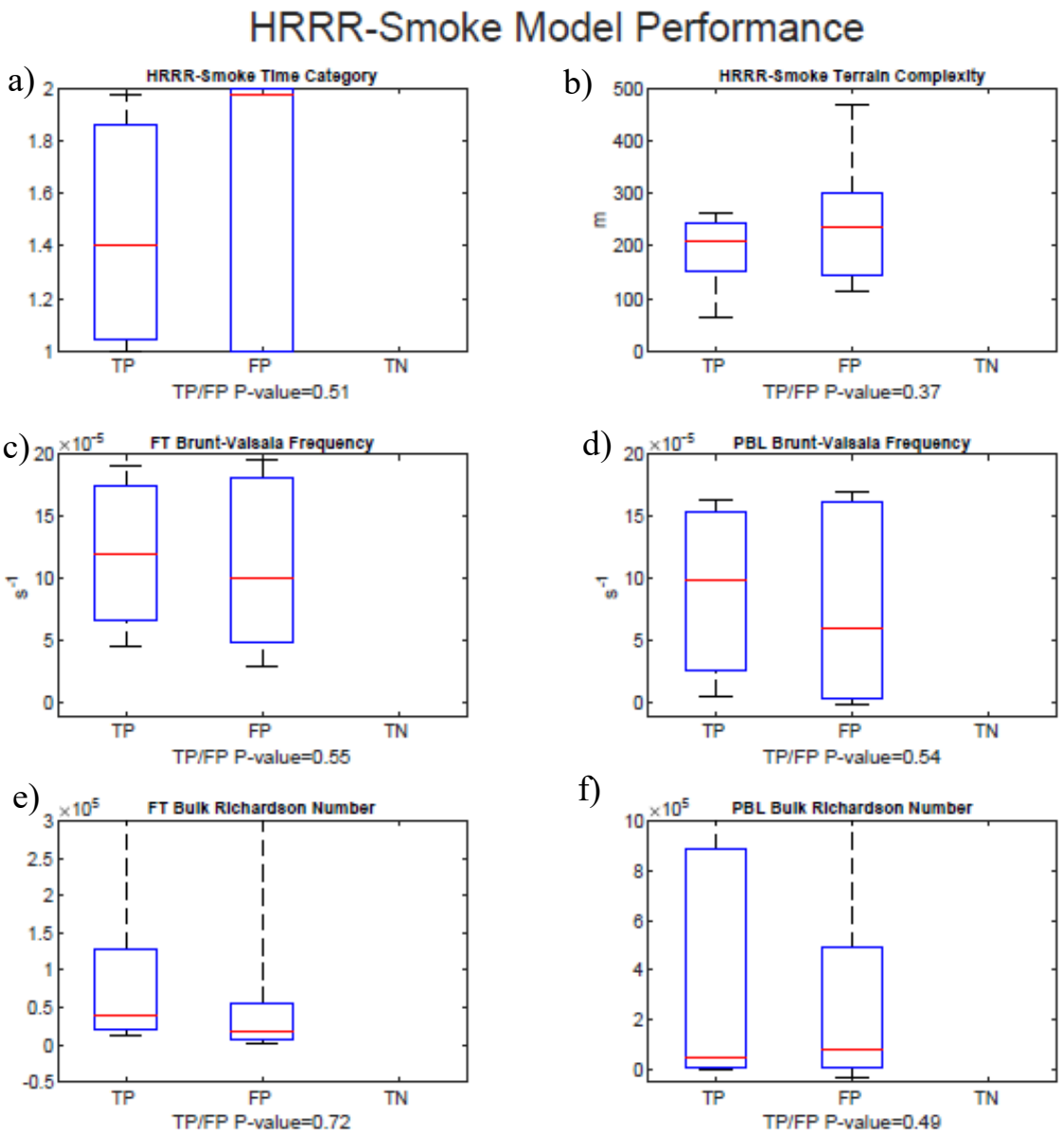
Supplementary Fig. 51: Vertical profiles of backscatter from the DIAL-HSRL (a) and PM2.5 from HRRR-Smoke (b), WRF-Chem with default heat fluxes (c), and WRF-Chem with adjusted heat fluxes (d) for the Sheridan Fire 2019-08-17 00:15-00:30 UTC. In panel a, open circles show the top of the PBL and filled circles are the smoke top heights. In panels b and c, the modeled PBL height is shown as the light gray line, and the smoke top height is shown as the dotted dark gray line. In panel c, the dark gray dashed line shows the PBL top at 4pm local time, assumed to be the time when the PBL height is at its maximum.



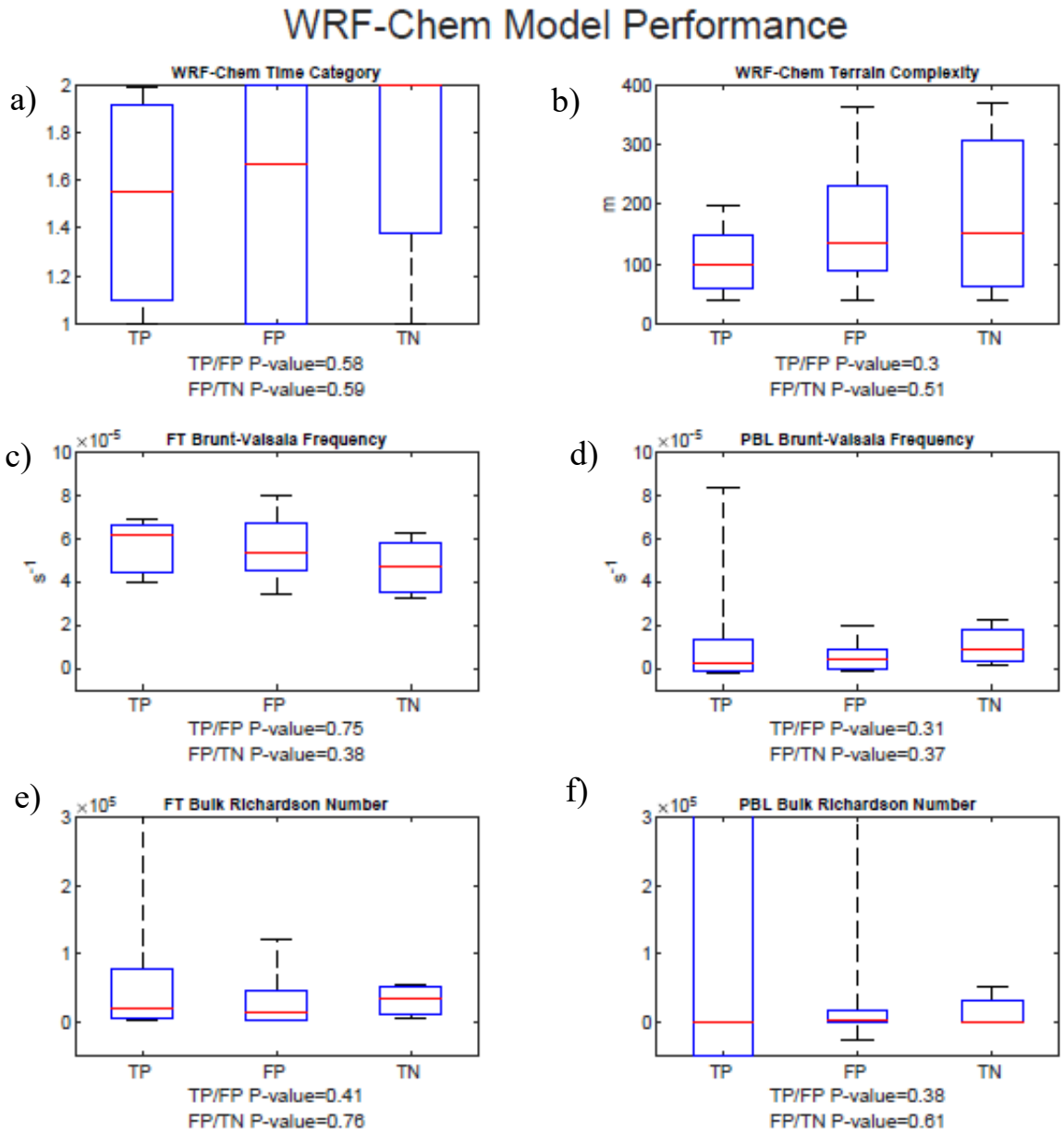
Supplementary Fig. 52: Comparison of observed (green) and modeled (red) planetary boundary layer height (in m above sea level) distributions for the WRF-Chem (a) and HRRR-Smoke (b) models. Cases for which these plots were generated are the WRF-Chem false positives.



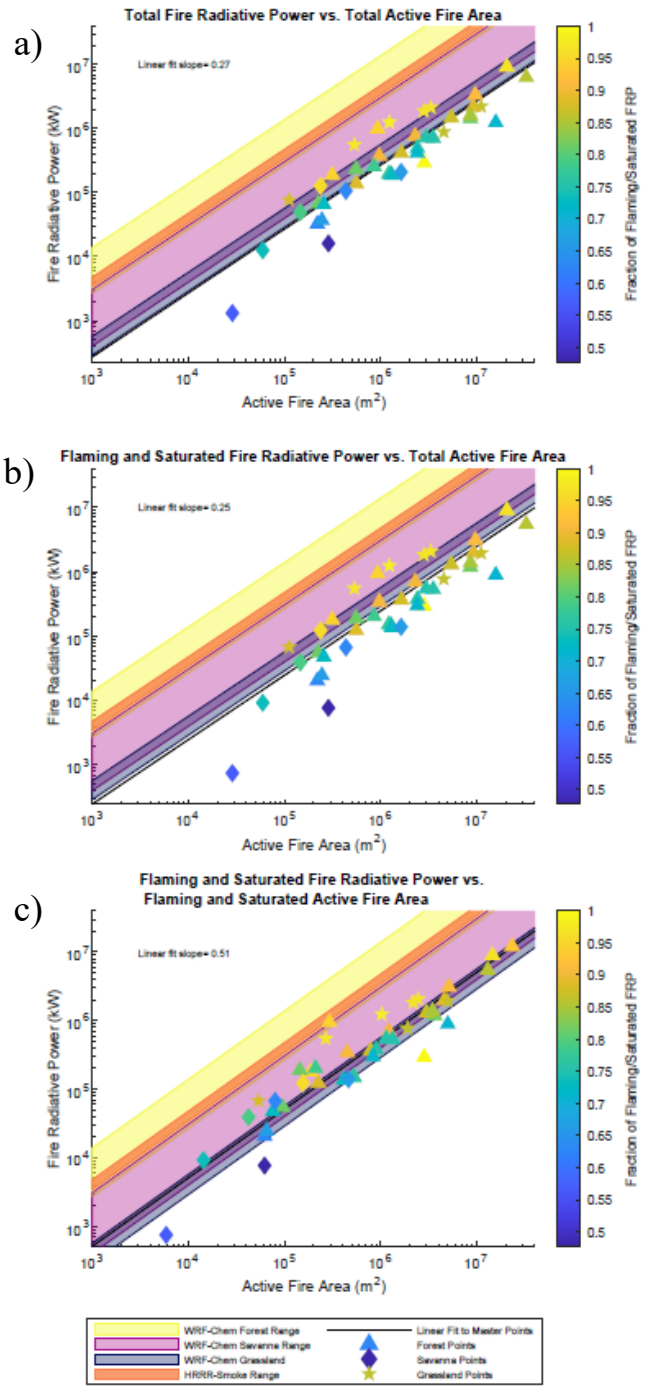
Supplementary Fig. 53: Plume top heights from the 1D Freitas forced by 1D WRF-Chem meteorology (blue bars), and 1D Freitas forced by 1D HRRR-Smoke meteorology (red bars) for cases where WRF-Chem underpredicted the PBLH and HRRR-Smoke accurately captured the PBLH. PBLHs associated with each meteorology configuration are overlaid as box and whisker plots over their corresponding bar, and the PBLH derived from the DIAL-HSRL is given as a dotted line. Selected fires include a) Shady, b) Mica Creek, c) Williams Flats, d-e) Spring, f) Castle, g-h) Sheridan



Supplementary Fig. 54: Box and whisker plots of (a) HRRR-Smoke time of day, (b) HRRR-Smoke terrain variability (standard deviation in 3x3 grid box around fire), (c) FT Brunt-Vaisala Frequency, (d) PBL Brunt-Vaisala Frequency (e) FT bulk Richardson number, (f) PBL bulk Richardson number. Red line denotes medians, blue box denotes the interquartile range, and whiskers denote the 1.5x interquartile range. TP, FP, and FN are defined as in Fig. 1 caption.

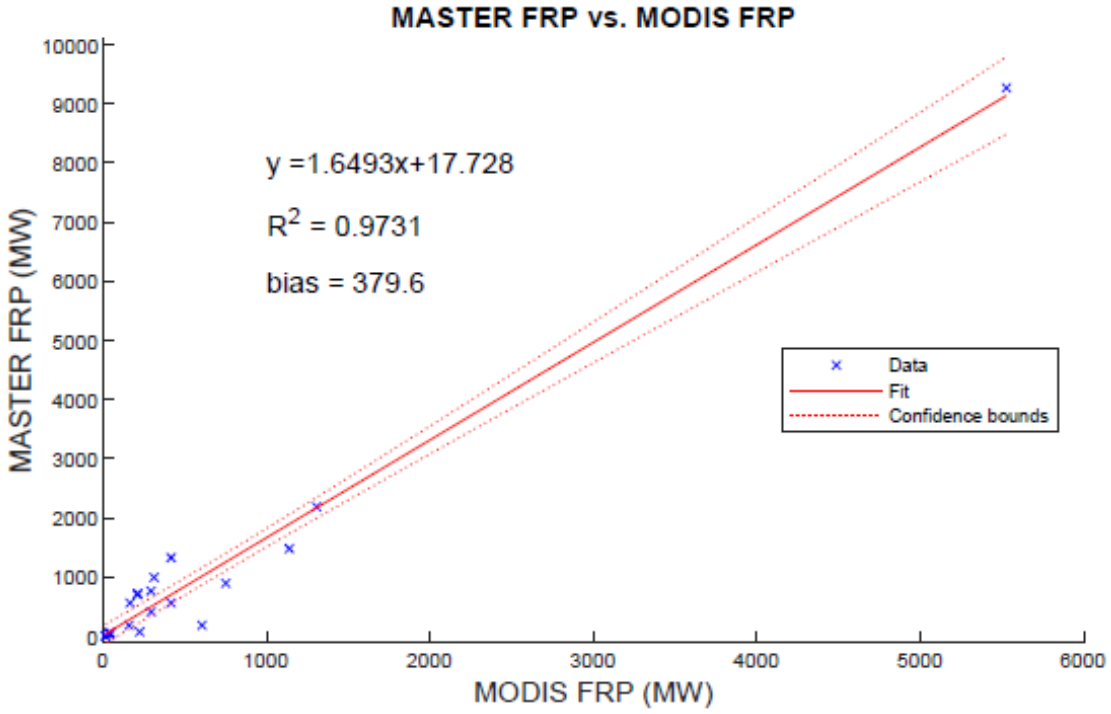


Supplementary Fig. 55: Box and whisker plots of (a) WRF-Chem time of day, (b) WRF-Chem terrain variability (standard deviation in 3x3 grid box around fire), (c) FT Brunt-Vaisala Frequency, (d) PBL Brunt-Vaisala Frequency (e) FT bulk Richardson number, (f) PBL bulk Richardson number. Red line denotes medians, blue box denotes the interquartile range, and whiskers denote the 1.5x interquartile range. TP, FP, and FN are defined as in Fig. 1 caption

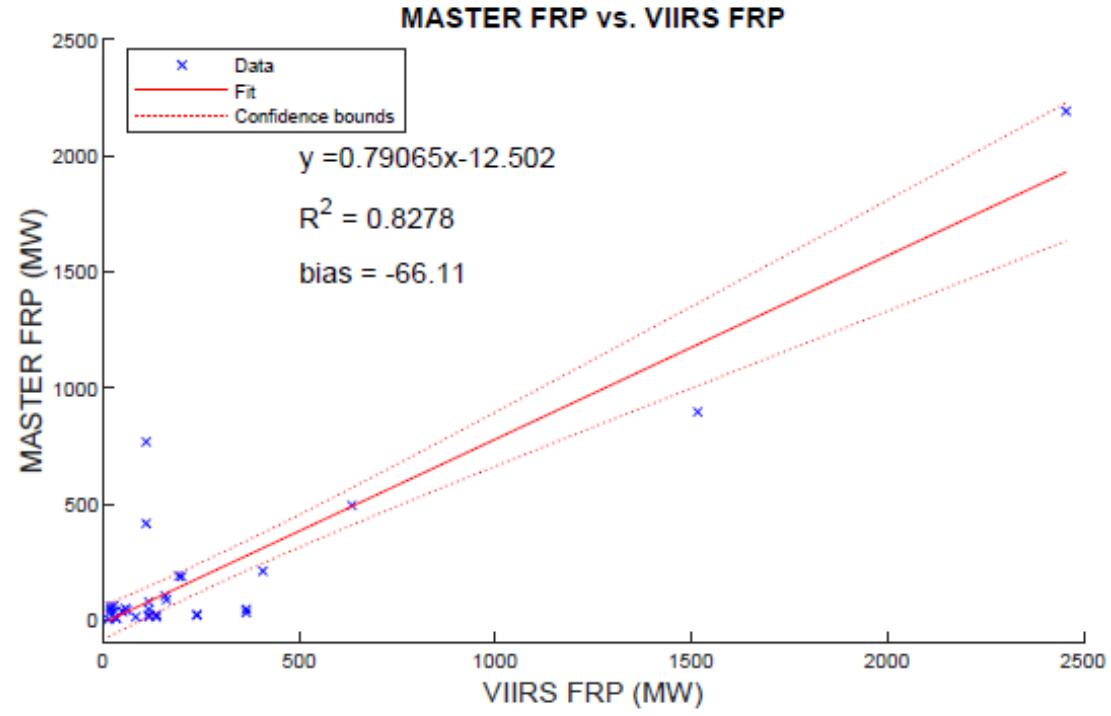


Supplementary Fig. 56: Analogous to Fig. 1, but for different combustion phases: (a) total FRP and total area, (b) flaming/saturated FRP and total area, and (c) flaming/saturated FRP and flaming/saturated area

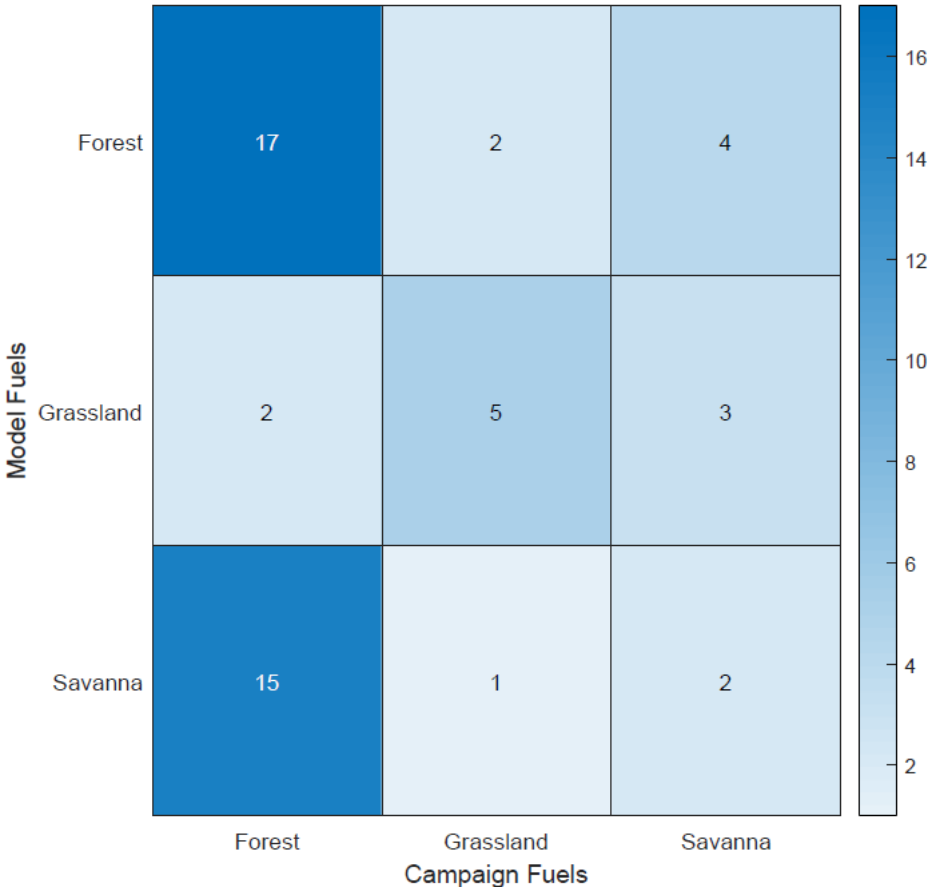
a)



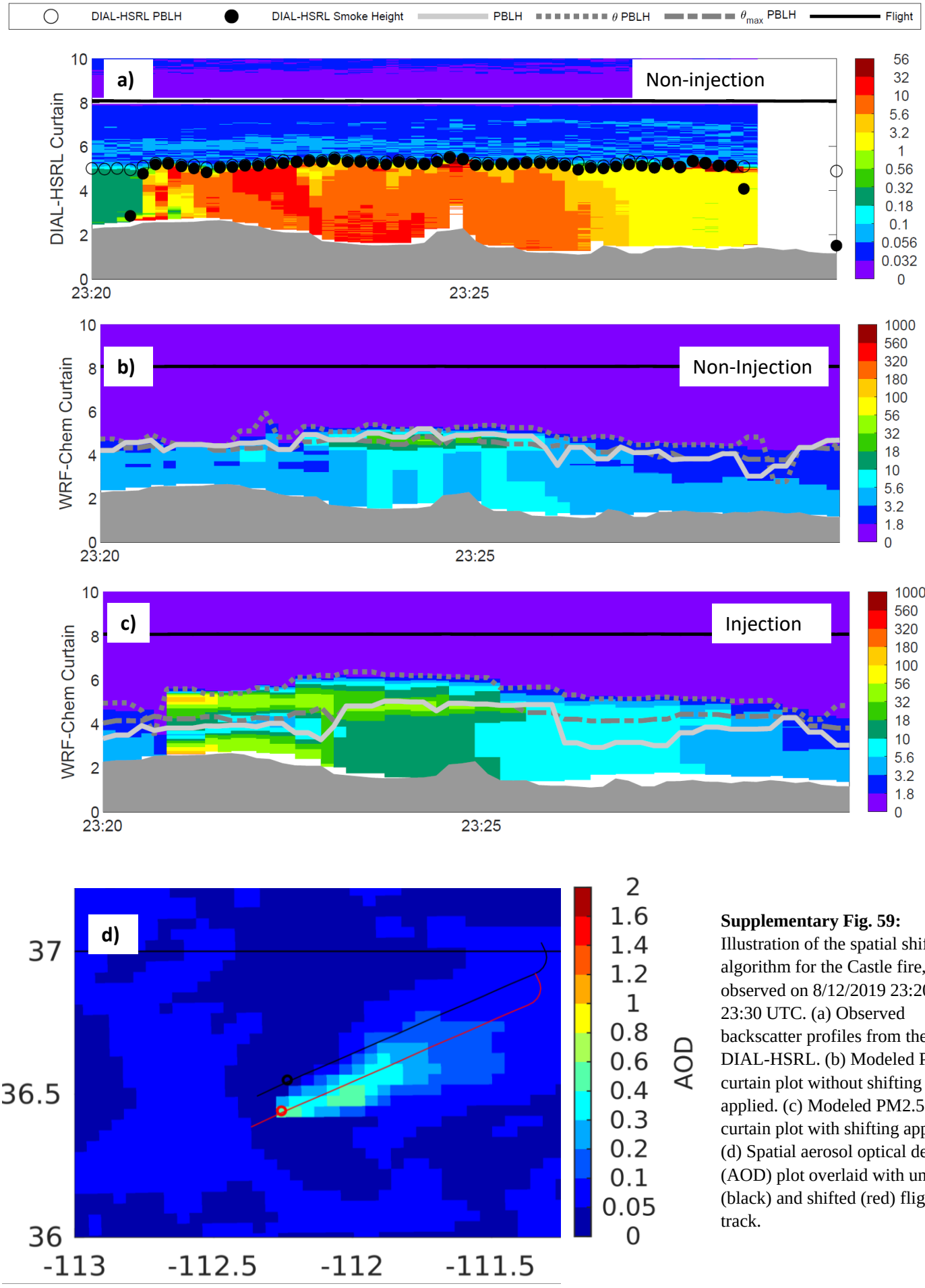
b)



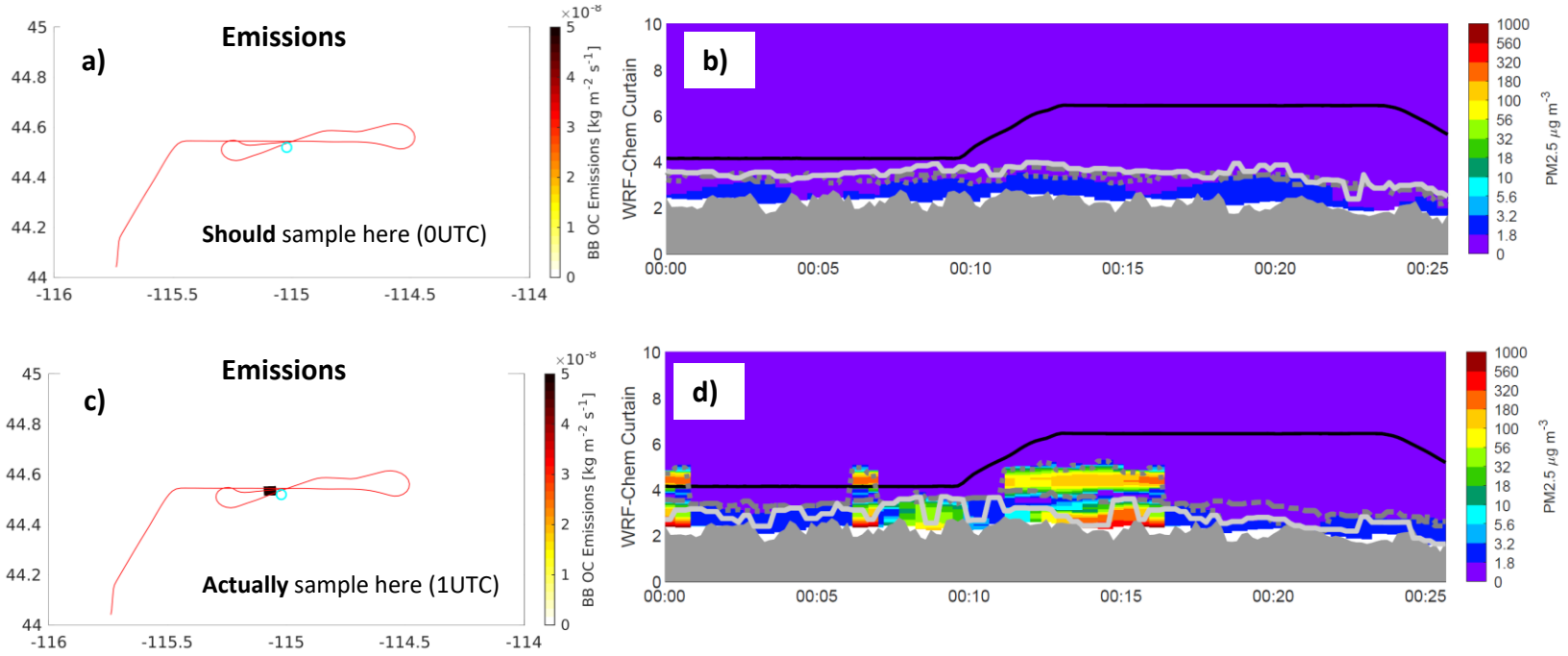
Supplementary Fig. 57: MASTER FRP vs (a) VIIRS FRP and (b) MODIS FRP determined using VIIRS and MODIS overpasses within +/- 2hrs from MASTER overpasses. MASTER values tend to be higher than MODIS values and lower than VIIRS values. Red dashed lines are 95% confidence bounds on the best fit line.



Supplementary Fig. 58: Comparison of campaign fuels and model fuels covering three broad fuel categories for the 51 test cases in this study: grassland, savanna, and forest. Entries along the main diagonal represent cases where the model and the campaign fuel type agreed, and off diagonals represent cases where the model and campaign fuel type disagreed.



Supplementary Fig. 59: Illustration of the spatial shifting algorithm for the Castle fire, observed on 8/12/2019 23:20-23:30 UTC. (a) Observed backscatter profiles from the DIAL-HSRL. (b) Modeled PM2.5 curtain plot without shifting applied. (c) Modeled PM2.5 curtain plot with shifting applied. (d) Spatial aerosol optical depth (AOD) plot overlaid with unshifted (black) and shifted (red) flight track.



Supplementary Fig. 60: Illustration of time shift for the Shady Fire, observed 7/29/2019 00:00-00:38 UTC. (a) spatial emissions plot and (b) vertical curtain of PM2.5 sampled at the model time matching the observed time. Note how emissions are not present in the spatial or the vertical plot. (c) spatial emissions plot and (d) vertical curtain plot sampled at the model time shifted to one hour after the observed time. Emissions are now present in the spatial plot and vertical plume structure is developed.

		Overpass Time (UTC)		DIAL-HSRL		WRF-Chem		WRF-Chem Observed PBL		WRF-Chem Sensitivity		WRF-Chem Sensitivity Observed PBL	
Fig.	Fire	Start Time	End Time	Injection	End Node	Injection	End Node	Injection	End Node	Injection	End Node	Injection	End Node
S1	Sheep	7-24 21:35	7-24 21:45	0	B2	0	B2	1	D2	nan	nan	nan	nan
S2	Sheep	7-24 21:50	7-24 22:05	0	B2	0	B2	0	B2	nan	nan	nan	nan
S3	Sheep	7-24 22:40	7-24 23:00	0	B2	0	C2	0	C2	nan	nan	nan	nan
S4	Shady	7-24 23:40	7-24 23:53	0	B2	1	D2	0	B2	1	D2	0	B2
S5	Shady	7-24 23:55	7-25 00:07	0	B2	1	F2	0	B2	1	F2	0	B2
S6	Shady	7-25 00:03	7-25 00:10	0	B2	1	F2	0	B2	1	D2	0	B2
S7	Shady	7-25 00:10	7-25 00:20	0	B2	1	F2	0	B2	1	F2	0	B2
S8	Shady	7-25 22:30	7-25 22:45	1	D2	1	D2	1	D2	nan	nan	nan	nan
S9	Shady	7-26 01:25	7-26 01:35	1	D2	1	D2	1	D2	nan	nan	nan	nan
S10	North Hills	7-29 22:40	7-29 22:55	0	B2	0	B2	0	B2	nan	nan	nan	nan
S11	North Hills	7-29 23:00	7-29 23:15	0	B2	0	B2	0	B2	nan	nan	nan	nan
S12	Tucker	7-30 02:10	7-30 02:35	0	E2	0	E2	0	E2	nan	nan	nan	nan
S13	Tucker	7-30 04:00	7-30 04:20	0	B2	0	F1	0	B2	nan	nan	nan	nan
S14	Tucker	7-30 04:15	7-30 04:40	0	B2	0	F1	0	B2	nan	nan	nan	nan
S15	Left Hand	7-31 00:35	7-31 00:55	1	E1	1	E1	1	E1	nan	nan	nan	nan
S16	Left Hand	7-31 00:55	7-31 01:15	1	E1	1	E1	1	E1	nan	nan	nan	nan
S17	Ridge Top	8-02 22:10	8-02 22:25	0	B2	1	D2	0	B2	1	D2	0	B2
S18	Ridge Top	8-02 23:40	8-02 23:50	1	D2	1	F2	0	B2	nan	nan	nan	nan
S19	Mica/Lick Creek	8-03 00:35	8-03 00:55	0	B2	1	D2	0	B2	1	D2	0	B2
S20	Mica/Lick Creek	8-03 02:20	8-03 02:40	0	B2	1	F2	1	D2	1	F2	0	B2
S21	Mica Creek	8-03 21:30	8-03 21:40	0	B2	1	D2	1	D2	1	D2	0	B2
S22	Williams Flats	8-03 21:40	8-03 22:00	1	D2	1	D2	1	D2	nan	nan	nan	nan
S23	Williams Flats	8-04 00:05	8-04 00:25	1	D2	1	F2	1	D2	nan	nan	nan	nan
S23	Williams Flats	8-04 02:30	8-04 02:55	1	D2	1	F2	1	D2	nan	nan	nan	nan
S25	Williams Flats	8-06 18:40	8-06 19:00	0	B2	1	D2	0	B2	0	E2	0	B2
S26	Williams Flats	8-06 20:30	8-06 20:40	0	B2	1	D2	1	D2	0	E2	0	E2
S27	Williams Flats	8-06 21:45	8-06 22:00	0	B2	1	D2	0	B2	0	E2	0	B2
S28	Snow Creek	8-06 22:25	8-06 22:35	0	B2	1	D2	1	D2	1	D2	0	B2
S29	Horsefly	8-06 22:45	8-06 23:00	0	B2	1	D2	0	B2	0	E2	0	B2
S30	Horsefly	8-07 00:25	8-07 00:55	0	B2	1	D2	0	B2	0	E2	0	B2
S31	Williams Flats	8-07 23:00	8-07 23:20	1	D2	1	E1	1	E1	nan	nan	nan	nan
S32	Williams Flats	8-08 00:45	8-08 01:05	1	D2	1	D2	1	D2	nan	nan	nan	nan
S33	Williams Flats	8-08 02:20	8-08 02:40	1	D2	1	D2	1	D2	nan	nan	nan	nan
S34	Williams Flats	8-09 02:00	8-09 02:15	1	D2	1	F2	1	D2	nan	nan	nan	nan
S35	Williams Flats	8-09 02:15	8-09 02:30	1	D2	1	F2	0	B2	nan	nan	nan	nan
S36	Springs	8-12 22:10	8-12 22:20	0	B2	1	D2	1	D2	1	D2	1	D2
S37	Springs	8-12 22:25	8-12 22:30	0	B2	1	D2	0	B2	1	D2	1	D2
S38	Castle	8-12 23:19	8-12 23:30	0	B2	1	D2	1	D2	1	D2	1	D2
S39	Castle	8-12 23:30	8-12 23:50	0	B2	1	D2	1	D2	1	D2	1	D2
S40	Castle	8-13 22:30	8-13 22:45	0	C2	1	D2	1	D2	1	D2	1	D2
S41	Castle	8-13 22:40	8-13 22:55	0	C2	0	B2	1	D2	nan	nan	nan	nan
S42	Sheridan	8-16 00:25	8-16 00:40	1	D2	1	D2	1	D2	nan	nan	nan	nan
S43	Sheridan	8-16 00:40	8-16 00:50	1	D2	1	D2	1	D2	nan	nan	nan	nan
S44	Sheridan	8-16 01:00	8-16 01:15	1	D2	1	F2	1	D2	nan	nan	nan	nan
S45	Sheridan	8-16 01:15	8-16 01:30	1	D2	1	F2	1	D2	nan	nan	nan	nan
S46	Saber	8-16 01:45	8-16 01:55	0	B2	1	F2	0	B2	0	E2	0	B2
S47	Boulin	8-16 01:55	8-16 02:00	0	B2	1	F2	1	D2	1	F2	1	D2
S48	Sheridan	8-16 02:05	8-16 02:20	1	D2	0	F1	1	D2	nan	nan	nan	nan
S49	Ikes	8-16 04:10	8-16 04:25	0	B2	1	F2	0	B2	1	F2	0	B2
S50	Sheridan	8-17 00:00	8-17 00:15	0	B2	1	D2	1	D2	1	D2	1	D2
S51	Sheridan	8-17 00:15	8-17 00:30	0	B2	1	D2	1	D2	1	D2	1	D2

Supplementary Table 1: Details for each case, including the figure number, fire name, date, and time of the measurements, WRF-Chem modeled and observed injection behavior (0=non-injection, 1=injection), and terminal node of the decision tree that results in each classification. Not-a-Number (Nan) means that the model missed the fire and therefore the injection behavior could not be evaluated.

		Overpass Time (UTC)		DIAL-HSRL		HRRR-Smoke		HRRR-Smoke Observed PBL	
Fig.	Fire	Start Time	End Time	Injection	End Node	Injection	End Node	Injection	End Node
S1	Sheep	7-24 21:35	7-24 21:45	0	B2	1	D2	1	D2
S2	Sheep	7-24 21:50	7-24 22:05	0	B2	1	D2	1	D2
S3	Sheep	7-24 22:40	7-24 23:00	0	B2	1	D2	1	D2
S4	Shady	7-24 23:40	7-24 23:53	0	B2	nan	nan	nan	nan
S5	Shady	7-24 23:55	7-25 00:07	0	B2	nan	nan	nan	nan
S6	Shady	7-25 00:03	7-25 00:10	0	B2	nan	nan	nan	nan
S7	Shady	7-25 00:10	7-25 00:20	0	B2	nan	nan	nan	nan
S8	Shady	7-25 22:30	7-25 22:45	1	D2	nan	nan	nan	nan
S9	Shady	7-26 01:25	7-26 01:35	1	D2	1	D2	1	D2
S10	North Hills	7-29 22:40	7-29 22:55	0	B2	1	D2	0	B2
S11	North Hills	7-29 23:00	7-29 23:15	0	B2	1	D2	0	B2
S12	Tucker	7-30 02:10	7-30 02:35	0	E2	nan	nan	nan	nan
S13	Tucker	7-30 04:00	7-30 04:20	0	B2	nan	nan	nan	nan
S14	Tucker	7-30 04:15	7-30 04:40	0	B2	nan	nan	nan	nan
S15	Left Hand	7-31 00:35	7-31 00:55	1	E1	1	E1	0	B2
S16	Left Hand	7-31 00:55	7-31 01:15	1	E1	1	E1	0	B2
S17	Ridge Top	8-02 22:10	8-02 22:25	0	B2	0	B2	0	B2
S18	Ridge Top	8-02 23:40	8-02 23:50	1	D2	1	D2	1	D2
S19	Mica/Lick Creek	8-03 00:35	8-03 00:55	0	B2	1	D2	1	D2
S20	Mica/Lick Creek	8-03 02:20	8-03 02:40	0	B2	1	D2	1	D2
S21	Mica Creek	8-03 21:30	8-03 21:40	0	B2	1	D2	1	D2
S22	Williams Flats	8-03 21:40	8-03 22:00	1	D2	1	D2	1	D2
S23	Williams Flats	8-04 00:05	8-04 00:25	1	D2	1	D2	1	D2
S23	Williams Flats	8-04 02:30	8-04 02:55	1	D2	1	D2	1	D2
S25	Williams Flats	8-06 18:40	8-06 19:00	0	B2	1	D2	0	B2
S26	Williams Flats	8-06 20:30	8-06 20:40	0	B2	1	D2	1	D2
S27	Williams Flats	8-06 21:45	8-06 22:00	0	B2	1	D2	0	B2
S28	Snow Creek	8-06 22:25	8-06 22:35	0	B2	1	D2	1	D2
S29	Horsefly	8-06 22:45	8-06 23:00	0	B2	1	D2	0	B2
S30	Horsefly	8-07 00:25	8-07 00:55	0	B2	1	D2	0	B2
S31	Williams Flats	8-07 23:00	8-07 23:20	1	D2	1	D2	1	D2
S32	Williams Flats	8-08 00:45	8-08 01:05	1	D2	1	D2	1	D2
S33	Williams Flats	8-08 02:20	8-08 02:40	1	D2	1	D2	1	D2
S34	Williams Flats	8-09 02:00	8-09 02:15	1	D2	1	D2	1	D2
S35	Williams Flats	8-09 02:15	8-09 02:30	1	D2	1	D2	0	B2
S36	Springs	8-12 22:10	8-12 22:20	0	B2	1	D2	1	D2
S37	Springs	8-12 22:25	8-12 22:30	0	B2	1	D2	1	D2
S38	Castle	8-12 23:19	8-12 23:30	0	B2	1	D2	1	D2
S39	Castle	8-12 23:30	8-12 23:50	0	B2	1	D2	1	D2
S40	Castle	8-13 22:30	8-13 22:45	0	C2	1	D2	1	D2
S41	Castle	8-13 22:40	8-13 22:55	0	C2	1	D2	1	D2
S42	Sheridan	8-16 00:25	8-16 00:40	1	D2	1	D2	1	D2
S43	Sheridan	8-16 00:40	8-16 00:50	1	D2	1	D2	1	D2
S44	Sheridan	8-16 01:00	8-16 01:15	1	D2	1	D2	1	D2
S45	Sheridan	8-16 01:15	8-16 01:30	1	D2	1	D2	1	D2
S46	Saber	8-16 01:45	8-16 01:55	0	B2	1	D2	1	D2
S47	Boulin	8-16 01:55	8-16 02:00	0	B2	1	D2	1	D2
S48	Sheridan	8-16 02:05	8-16 02:20	1	D2	1	D2	1	D2
S49	Ikes	8-16 04:10	8-16 04:25	0	B2	1	D2	0	B2
S50	Sheridan	8-17 00:00	8-17 00:15	0	B2	1	D2	1	D2
S51	Sheridan	8-17 00:15	8-17 00:30	0	B2	0	B2	0	B2

Supplementary Table 2: Details for each case, including the figure number, fire name, date, and time of the measurements, HRRR-Smoke modeled and observed injection behavior (0=non-injection, 1=injection), and terminal node of the decision tree that results in each classification. Not-a-Number (Nan) means that the model missed the fire and therefore the injection behavior could not be evaluated.

Fig.	Fire	Out of plume MLH Identified?	Assumptions (unless stated differently. 0.32 is the MLH cutoff, whole air column is searched, and upwind only is used)
S1	Sheep	Yes (11pts)	Get points closest to fire, where terrain is similar to fire
S2	Sheep	Yes (16pts)	Added points post turn
S3	Sheep	Yes (9pts)	Added points post turn
S4	Shady	Yes (21pts)	Used the downwind region with similar terrain
S5	Shady	Yes (10pts)	Added points post turn
S6	Shady	Yes (11pts)	
S7	Shady	Yes (15pts)	
S8	Shady	Yes (9pts)	Not enough points, even post turn or downwind
S9	Shady	Yes (11pts)	
S10	North Hills	Yes (11pts)	Chose some upwind no clouds, some downwind
S11	North Hills	Yes (12pts)	Chose some upwind no clouds, some downwind
S12	Tucker	Yes (24pts)	
S13	Tucker	Yes (11pts)	
S14	Tucker	Yes (6pts)	Not enough points, even post turn or downwind
S15	Left Hand	Yes (10pts)	
S16	Left Hand	Yes (12pts)	
S17	Ridge Top	Yes (11pts)	Look for light green 0.56 below 11km, dark green may be pyroCu outflow?
S18	Ridge Top	Yes (11pts)	Look for light green 0.56 below 11km, dark green may be pyroCu outflow?
S19	Mica/Lick Creek	Yes (11pts)	Look for light green 0.56 below 4km, lofted smoky layer
S20	Mica/Lick Creek	Yes (11pts)	Look for light green 0.56 below 4km, lofted smoky layer
S21	Mica Creek	Yes (7pts)	Chose some upwind no clouds, some downwind
S22	Williams Flats	Yes (13pts)	Look for medium green 0.32 below 4.5km, lofted smoky layer
S23	Williams Flats	Yes (10pts)	Look for medium green 0.32 below 4.5km, lofted smoky layer
S23	Williams Flats	Yes (11pts)	Look for medium green 0.32 below 3km, lofted smoky layer
S25	Williams Flats	Yes (19pts)	Chose downwind with similar terrain
S26	Williams Flats	Yes (7pts)	Look for light green 0.56 below 11km
S27	Williams Flats	Yes (15pts)	Chose some upwind no clouds, some downwind
S28	Snow Creek	Yes (15pts)	
S29	Horsefly	Yes (11pts)	
S30	Horsefly	Yes (17pts)	Chose a smaller time window, shaved off that edge that was catching high clouds
S31	Williams Flats	Yes (17pts)	
S32	Williams Flats	Yes (8pts)	Not enough points, even post turn or downwind
S33	Williams Flats	Yes (8pts)	Not enough points, even post turn or downwind
S34	Williams Flats	Yes (11pts)	
S35	Williams Flats	Yes (23pts)	
S36	Springs	Yes (10pts)	Used the downwind region with similar terrain
S37	Springs	Yes (8pts)	Chose some upwind no clouds, some downwind
S38	Castle	Yes (8pts)	
S39	Castle	Yes (9pts)	Filtered out clouds just upwind of the fire
S40	Castle	Yes (4pts)	Not enough points, even post turn or downwind
S41	Castle	Yes (8pts)	
S42	Sheridan	Yes (10pts)	Expanded the time window, looked for blue 0.18
S43	Sheridan	Yes (9pts)	Expanded the time window, looked for blue 0.18
S44	Sheridan	Yes (6pts)	Expanded the time window, looked for blue 0.18
S45	Sheridan	Yes (14pts)	Looked for blue 0.18
S46	Saber	Yes (10pts)	Saber is observed right before Boulin, and LATE, use light blue
S47	Boulin	Yes (17pts)	Use whole thing, assume it's mixed layer
S48	Sheridan	Yes (18pts)	Looked for blue 0.18
S49	Ikes	Yes (21pts)	Chose some upwind no clouds, some downwind
S50	Sheridan	Yes (8pts)	
S51	Sheridan	Yes (11pts)	

Supplementary Table 3: Assumptions for selecting the out-of-plume observed PBLH