Benjamins Mill Wind Project
2022 Radar and Acoustic Monitoring

Prepared for:

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1.0 Introduction

Natural Forces Developments LP (Natural Forces) retained Ausenco Engineering Inc. (Ausenco) (formally known as Hemmera), to conduct spring and fall radar and acoustic monitoring of nocturnal migrating birds at the Benjamins Mill Wind Project (the Project) in 2021 and 2022. The Project is located approximately 13 kilometers (km) southwest (SW) of the Town of Windsor, Nova Scotia (NS).

The *Guide to Preparing an EA Registration Document for Wind Power Projects in Nova Scotia* (Nova Scotia Government 2021) specifies that avian radar studies are required for projects that include turbines greater than 150 m in height. Also, the Canadian Wildlife Service's (CWS) *Wind Energy & Birds Environmental Assessment Guidance Update* (Environment and Climate Change Canada 2022), created in April 2022, specifies that migratory avian radar and acoustic studies be completed for projects that include turbines greater than 150 m in height. Given that the Project turbine will have a maximum total height greater than 150 m, Natural Forces consulted with the CWS and Nova Scotia Environment (NSE) regarding the development and implementation of an avian radar and acoustics study.

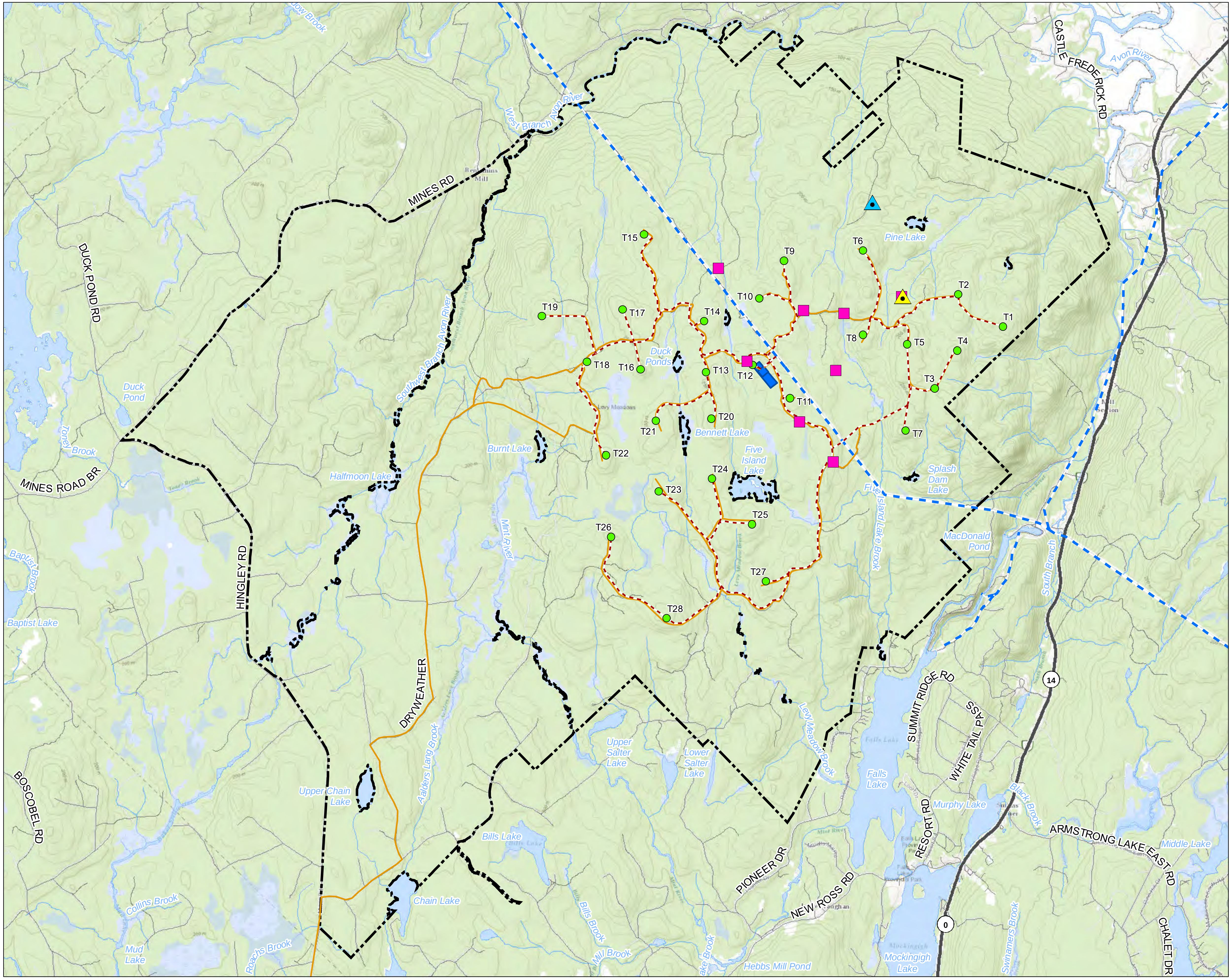
Ausenco, in partnership with Dr. Phil Taylor of Tabanid Consulting and Acadia University, completed spring and fall avian radar and acoustic monitoring at the Project in 2021. In January 2022, Natural Forces submitted an Environmental Registration Document to the Environmental Assessment Branch for Nova Scotia Environment and Climate Change for approval. On March 9, 2022, the Ministers Decision Letter was issued. The letter determined that the Registration Document provided was insufficient to make a decision, and that additional information was required.

This report provides a summary of the additional avian migration information collected during the spring and fall migration season of 2022.

Data presented within this report are inclusive of data collected on the site prior to November 10, 2022. While data collection continued from November 10 until November 23, those data have not been included into this report to meet reporting timelines. As discussed below, we do not believe that these data will change conclusions presented within this report.

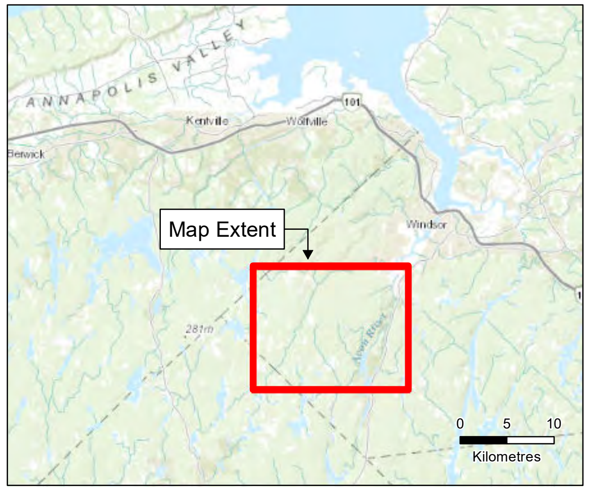
1.1 Project Details

The proposed Project will consist of up to 28 turbines ranging from a size of 4.2 to 6.2 megawatts (MW) for a total nameplate Project capacity between 50 and 150 MW. The final turbine model has not been selected for the Project. The range in turbine specifications being considered include a hub height between 100 and 131 meters (m), rotor diameter between 138 and 170 m, for a total turbine height (i.e., tip of blade) between 170 and 200 m above ground level (agl). The potential rotor swept area (RSA) of the turbines could range from 20 to 200 m agl.



Benjamins Mill Wind Project

Radar and Acoustic Survey Locations



Legend

- ▲ 2022 Radar Location
- ▲ 2021 Radar Location
- ■ Audio Sensor Location
- ● Turbine Location
- — Access Road
- - - Collector Line
- - - Existing Transmission Line
- ■ Substation
- ▭ Project Location

Basemap Layers

- — Highway
- — Road or Trail
- — Watercourse
- ■ Waterbody

Notes

1. All mapped features are approximate and should be used for discussion purposes only.
2. This map is not intended to be a “stand-alone” document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Contains information licensed under the Open Government Licence: Nova Scotia
- Basemap: ESRI World Topographic Map
- Inset Basemap: ESRI World Topographic Map

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NAD 1983 UTM Zone 20N

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Ausenco naturalforces

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2.0 Methods

The following section provides a summary of the methodology used to collect and analyse the radar and acoustic data during spring and fall, 2022.

2.1 Radar Monitoring

The location of the radar was chosen based on access to the Project area, site security and clear sight lines. The radar was deployed within the northern portion of the Project area (See Figure 1.1), approximately 648 m from the nearest proposed turbine.

In 2022 the radar was located approximately 1.3 km SE from the location used in 2021. The change of location was necessitated by access constraints to the 2021 location during the early spring period. The difference in locations from 2021 to 2022 is immaterial to the findings given the detection range of the radar. At both locations, the radar data provides sufficient representation of the movement of nocturnal migrants over the Project area.

The radar technology used during the spring and majority of the fall season was similar to that utilized in 2021. This radar system has been used in the past to assess migratory bird movements at proposed wind energy projects in NS and New Brunswick (NB) (e.g., Burchill Wind Project [Taylor et al. 2020], Westchester Wind Project [Hemmera 2022]) and has been proven to provide an adequate representation of bird passage rates and heights. The radar monitoring system was initially developed through federal (i.e., CWS) grant funding and has been improved upon through multiple iterations over the past 15+ years. The approach used has been implemented on no fewer than 4 wind energy projects in NB and 6 energy projects in NS, along with two successful Master of Science degrees and has been presented in peer reviewed scientific publications.

The radar used for the 2022 spring and majority of the fall season was a Furuno (Camas, Washington, USA) 1962 BB marine radar operating in the microwave X-band (9410 ± 30 Megahertz (MHz), 25 kilowatt (kW)) with a 6-foot XN13A open-array antenna (with a beam width of approximately 22° in the horizontal plane and approximately 1.35° in the vertical plane). The radar was mounted on a custom support framework in a vertical orientation to monitor the altitude of targets and was run in short pulse mode (2100 pulses per second) at 24 revolutions per minute (rpm).

Prior to deployment, the radar was calibrated while in a horizontal orientation using targets at a known distance. The radar signal was digitized at 4.5 m range resolution with an azimuth resolution of 1.35° using a DSPNOR ScanStreamer (Bergen, Norway).

During hurricane Fiona, which passed over the Project area on September 24, the radar was damaged and required replacement. Therefore, there is a gap in data from September 24 to October 13, when a Furuno DRS6A-NXT/DRS25A solid state radar was deployed at the site (as described above) and remained until final retrieval of data on November 10. Data were collected using custom-built software that captured sweeps from the internally digitized data using the Furuno NavNet library. Testing was completed prior to deployment in the field, and based on these tests, it was determined that radar data from the new system would be comparable to the initial system used.

Differences in the processing of radar data are described in Section 2.1.1. Data processing was done in such a way that results were comparable across the two radar models.

Due to the elevation of the Project area and remoteness of the site, the initiation of the spring monitoring period was restricted to snow-free conditions on the site. Therefore, spring radar data were collected from April 23 to June 8. During the 46-day spring monitoring period, the radar functioned properly for 44 nights (96% of the spring monitoring period).

During the fall season, radar data were collected from July 8 to November 10, 2022. During the 125-day monitoring period, the radar functioned properly for 93 nights (74% of the monitoring period). The majority of the interruption in data collect was due to hurricane Fiona. In anticipation of the arrival of the hurricane the radar was removed from the elevated stand and secured. However, regardless of taking steps to protect the radar system from damage, the radar and supporting electronic equipment was impacted, which required the replacement of multiple components. As such, radar data were not collected between September 23 and October 13. However, acoustic data were collected during this time (see Section 2.2.

2.1.1 Radar Data Processing

Data were uploaded to a server via remote cell connection as well and saved an external drive. Data collected prior to 23 September were analyzed using Cognitive Marine Tracker (CMT) radar analysis software, from the Cognitive Radar Corporation (Waterloo, Ontario).

Targets were extracted over background noise if they were at least 6 pixels in size, and the sensitivity to detect targets over the threshold in the CMT software (Pfa setting) was set at 0.02. These settings allowed for weak targets at long range to be identified over background noise, but also were sensitive enough to pick up insects at short range and birds at the edge of the radar beam. To filter out insects and birds on the periphery of the beam at close range, the peak power of the radar return for each target ("peak_val setting") was used and corrected for range, since returned power decreases with range to the fourth power ("scaled intensity"). The numbers of targets in five-minute intervals across the entire season were then correlated with acoustic data, to determine a threshold above which we could be more confident targets were primarily birds. The correlation between acoustic and radar detections plateaued at a scaled intensity of 18, so targets below that threshold were removed from the analysis.

Radar data was visually inspected to determine periods of rain, which were excluded from analysis. Targets below 70 m agl were also eliminated because they are contaminated by ground clutter.

Targets were then extracted from individual "columns" of air starting at a distance along the ground between 300 m and 320 m from the radar. This approach allows for smaller birds to be detected at high altitudes, while sampling low altitudes horizontally from the radar.

Radar data collected after 13 October were processed using program radR (Taylor et al 2010) to extract putative targets (blips) and a measure of target intensity was used to filter out insects. All subsequent processing was as described above, except that the distance along the ground was selected further from the radar (800 to 850 m) to account for apparent higher sensitivity of the solid state radar.

2.2 Acoustic Monitoring

A network of acoustic sensors (Audiomoths™) was deployed across the site with one placed at the radar unit, and 7 throughout the Project area (See Figure 1.1). This distribution of sensors allows for sampling of nocturnal migrants throughout the Project area. The sensors were placed a minimum of 500 m apart to reduce the potential for duplicate sampling of airspace.

The sensors were programmed to begin recording approximately one hour before the end of evening civil twilight and finish recording one hour after the beginning of morning civil twilight and placed in open areas with a clear view of the sky. The sensors were checked approximately every 30 days to replace batteries and download data onto an external hard drive. The detection range of each recording unit is estimated to be up to approximately 100 m for nocturnal flight calls (NFCs) of migratory birds (primarily passerines). Civil twilight was calculated using the suncalc package in R (v 0.5.1; Thieurmel & Elmarchraoui 2022).

2.2.1 Acoustic Data Processing

All acoustic data were either sampled or resampled to 22 kilohertz (kHz) (encompassing the frequency range where most NFCs occur), then subset to encompass only the period of time between the end of evening civil twilight and the beginning of morning civil twilight. It is during this period that birds make NFCs while actively migrating (Evans 2005).

All acoustic files were processed using a custom-built artificial intelligence (AI) NFC detection model developed by Dr. Kitzes' laboratory at the University of Pittsburgh using Open Sound Scape python package. The model was trained using NFCs originally identified by John Kearney of John F. Kearney & Associates (see a summary of these data at nocturnalflightcalls.com).

The NFC model assigns a 'score' to each species group, which is then related to the probability that a specific acoustic detection is actually a member of that species group. NFCs detected by the model were sampled for validation. Each NFC was assigned to one of 3 categories related to the time of night, either 'Dusk', 'Dawn' or 'Night'. NFCs categorized as 'Dusk' and 'Dawn' were detected during 30 min from the beginning or end of the civil twilight period, respectively. For validation, up to 100 NFCs were randomly selected (scores > 2; weighted by score) from the Dusk/Dawn period, and up to 200 calls from the Night period. These calls were visually assessed (by examining a spectrogram) and/or listened to by an expert (Tabanid Consulting Ltd) to verify the identity of the call or call group.

For species with more than 300 calls with scores >2, a statistical model was fit to assess the remaining calls. A binomial model, with the response being valid/not valid was fit to model score and time of night and season. These models were then used to predict the probability that any given call was of a given species or species group.

For plotting and analysis, all NFCs were selected that had been validated, or (for those with >300 calls) had predicted probabilities of greater than 85%. The 85% value was chosen to provide a balance between false classifications and false negatives (i.e., overlooking calls that are truly there). Where applicable, classified calls were further assessed (by visually inspecting additional spectrograms) to check that the false positive rate was near 15%.

Given the few NFCs recorded during the spring, all calls identified by the model (above a score of '2') were validated and were used for analysis. For Canada warbler (*Cardellina canadensis*) all NFCs that were above the 85% threshold for inclusion were visually or acoustically assessed. Similarly, because the AI model works less well with thrush (*Turdidae*) calls, all Thrush calls were manually validated with a score of ‘2’ or greater and included those in the known detections.

2.3 Data Analysis

All analyses were conducted in Rstudio (V. 2021.09.02) running program R (R Statistical Core team; V 4.0.4) and python V.3.8.

2.3.1 Visualization Patterns

All radar and acoustic detections were plotted to visually explore the patterns of bird movement at the site in conjunction with wind direction and strength at the ground level and aloft. Analysis within this report is restricted to a summary of those observations.

Nights from both the spring and fall migration seasons were selected for focus within this report. The selected nights have many radar targets, many acoustic detections, or show different patterns of bird behaviour at the site compared to other nights.

The full set of visualizations for the radar data for the spring and fall are presented in **Appendix A** and **Appendix B**, respectively.

2.3.2 Radar Analysis

The primary objectives of the radar study were to describe the general patterns of migrating birds at the Project site through visualizations, to statistically assess how the number of targets observed below 200 m in altitude relate to those above 200 m, and to assess how the total number of targets observed relate to particular weather variables of interest.

Two response variables were derived from the compiled radar data. The first was the number of targets detected in each hourly period (excluding rain) across all nights. The second was the ratio of the number of targets detected below and above 200 m in altitude. That ratio is positively related to the proportion of targets flying beneath 200 m but does not represent the actual proportion, since the probability of detecting targets decreases with increasing altitude due to changes in the shape and size of the radar beam, and the size of the targets. As such, this ratio overestimates the proportion of targets observed at lower altitudes to some unknown extent. Regardless, the ratio serves as a useful indicator to determine under which conditions and times more targets are flying at relatively lower altitudes.

Weather data (wind speed and direction, pressure, temperature, and humidity) were acquired from the National Centers for Environmental Prediction (NCEP) (https://www.weather.gov/ncep/) and downloaded via the RNCEP package in program R (R Statistical Core Team V 4.0.4) and interpolated to an hourly value at the location using an approach identical to that employed in the function “NCEP.interp”. For this report, wind data from ~700 m altitude were used.

The effect of weather (tailwind assistance, barometric pressure, change in barometric pressure and humidity) on a) the log of the number of targets detected and b) the proportion of targets below 200 m (relative to above 200 m) was modelled using generalized linear models. Model support was assessed using Akaike's Information Criterion (package MuMIn; Barton 2012).

The relationship between targets aloft and weather is complex and nonlinear, and as such, statistical models of such relationships can be difficult to interpret. Therefore, simple models were fit to show the dominant relationships between the two response variables described above and the weather variables. Furthermore, since relationships between wind speed, wind direction and the number of birds aloft can also be complex, a 'tailwind assistance' variable was used to provide a measure of how much the wind would assist a given bird flying in a specific direction. It is known that nocturnal migrants fly with positive tailwind assistance (Peckford and Taylor 2008). Tailwind assistance was calculated assuming migrants are flying in a direction of 45 degrees during spring and 225 degrees in the fall. Therefore, for example in the spring, if the wind was flowing from the direction of 45 degrees, then the birds' tailwind assistance would be negative (a headwind); if the wind was flowing towards 45 degrees, the birds' tailwind assistance would be positive. The strength of the assistance is a function of both the direction of the wind, and its speed.

In addition to the weather variables described above, terms were fit for time of night (categorized into 'sunset', 'sunrise' and 'middle' of the night, with 'sunset' being 90 minutes after the end of evening civil twilight, 'sunrise' being 90 minutes before the beginning of morning civil twilight, and 'middle' representing the remainder of the night). Civil twilight was calculated using the suncalc package in R (v.0.5.1; Thieumel & Elmarchraoui 2022). This variable help assess how total numbers differed at migratory initiation (sunset), cessation (sunrise) and during the night.

The R package 'tidyverse' (Wickham et al. 2019) was used for data manipulation and visualization and the function 'glmer' in package 'lme4' (Bates et al. 2015) was used for statistical modelling. In all cases, mixed effects models were fit, with the day of the year as a random effect. Treating day as a random effect allows the model to account for additional variation in counts that is not fully captured by the weather or timing variables. Models of the total counts were fitted with a 'poisson' family (i.e., the relationship between the response and the predictor variables was on a log scale) and measure of the proportions were filled using a 'binomial' family, which transforms the response using a log-odds ratio. Model fits were assessed by examining residual plots.

2.3.3 Acoustic Analysis

As outlined in Section 2.1.1 , acoustic data were processed to identify NFCs. While the analysis focused on the identification of passerine species, it is known that certain passerines such as vireos, flycatchers and particular species such as catbirds (Evans 2005; Smith et al. 2014) do not call during migration. **Table 2-1** shows the NFC categories for the species and species groups used by the model and provides some context related to particular species that call more rarely than others.

Table 2-1 Nocturnal Flight Call Species and Species Groups

Species / Species Group	Potential Species[(a)]
Cup-Sparrows	· Chipping Sparrow · Field Sparrow · American Tree Sparrow
Fox / Song Sparrow Complex	· Fox Sparrow · Song Sparrow
Zeep	· Bay-breasted Warbler · Blackburnian Warbler · Blackpoll Warbler · Cape May Warbler · Magnolia Warbler · Northern Waterthrush · Yellow Warbler
Single-banded down sweep	· Pine Warbler · Northern Parula · Yellow-throated Warbler (very rare to call) · Prairie Warbler (very rare to call)
Double-up	· Black-throated Green Warbler · Tennessee Warbler · Nashville Warbler · Orange-crowned Warbler
Thrushes	· Hermit Thrush · American Robin · Swainson's Thrush · Veery · Grey-cheeked Thrush (rare) · Bicknell's Thrush (rare) · Eastern Bluebird (rare) · Wood Thrush (rare) · Rose-breasted Grosbeak (rarely calls) · Scarlet Tanager (rare)

Species / Species Group	Potential Species[a]
Full Species	Sparrows: · White-throated sparrow · Savannah Sparrow Warblers: · American Redstart · Black-and-white Warbler · Black-throated Blue Warbler · **Canada Warbler** · Chestnut-sided Warbler · Common Yellowthroat · Mourning Warbler · Ovenbird · Palm Warbler · Yellow-rumped Warbler Other: · **Common Nighthawk** · American Woodcock Poorly detected/classified: · Wilson's Warbler · Red-breasted Nuthatch · Pine Siskin · Golden-crowned Kinglet

(a) Species in bold represent Species at Risk

Following the analysis, the NFCs identified covered a broad range of warbler, sparrow and thrush species found in the region, and are listed below. For auditory and visual examples of these calls, visit nocturnalflightcalls.com.

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- "Zeep"
- "Cup Sparrow" (cupsp)
- "Double-Up" (dubup)
- "Single-banded down sweep" (sbds)
- "Fox Sparrow / Song Sparrow" (fssp)
- "Thrushes" (thrush)
- American Redstart (amre)
- Black and White Warbler (baww)
- Black-throated Blue Warbler (btbw)
- Canada Warbler (cawa)
- Common Yellowthroat (coye)
- Chestnut-sided Warbler (cswa)
- Palm Warbler (pawa)
- Mourning Warbler (mowa)
- Ovenbird (oven)
- Yellow-rumped Warbler (yrwa)
- Savannah Sparrow (savs)
- White-throated Sparrow (wtsp)

3.0 Results

The results presented below are limited to data collected during the 2022 spring and fall migration seasons.

3.1 Spring Migration

3.1.1 Nocturnal Migration Patterns

While there was some level of active migration observed on most nights monitored, the overall intensity of migration was low during the spring season. Most of the migration activity was observed across 6 nights (**Figure 3-2**). The entire dataset of nights for the spring season can be found in **Appendix A**.

Figure 3-2 shows the change in radar target density across the spring season, along with a distribution of density above and below 200 m. On most nights, there were more targets detected above 200 m than below. This pattern is especially true on the nights when most of the seasonal migratory activity occurred.

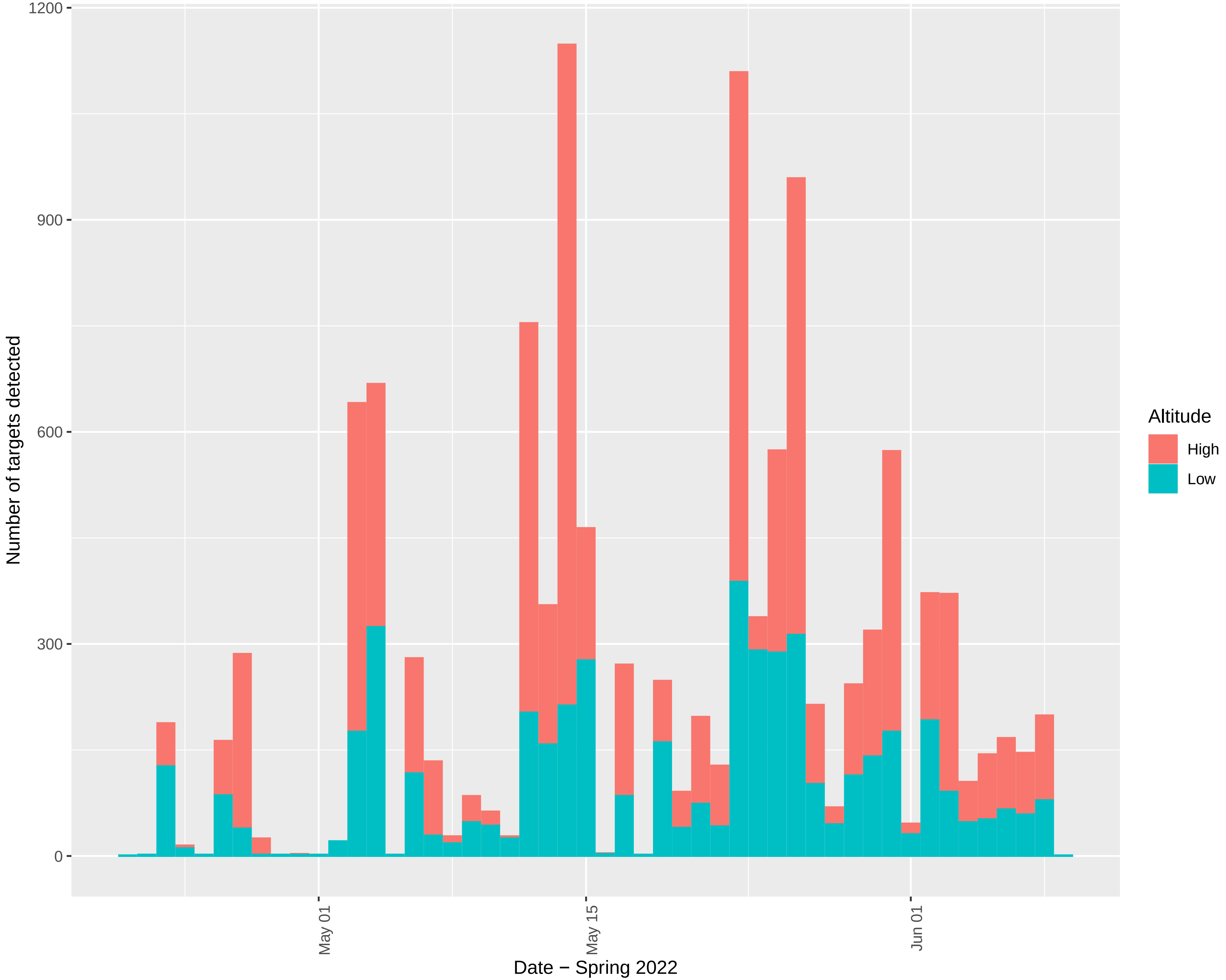

Figure 3-2 Seasonal Change in Radar Detections by Altitude – Spring 2022

Eight nights during the spring were selected for further focus (see Appendix A for the complete spring dataset). The 8 nights selected have either many radar targets, many acoustic detections, or show different patterns of bird behaviour at the site compared to other nights (**Figure 3-3**). Each panel within **Figure 3-3** is a separate night, with the beginning and end of civil twilight indicated by the vertical green and yellow lines, respectively. Time (UTC) is on the x-axis and altitude is on the y-axis. Hexagonal points are radar detections divided into time and altitude bins and are scaled from light grey (few detections) through dark purple, blue, green to yellow (many detections). Wind direction and strength aloft (~700 m) for each hour are displayed at the top of each plot via a red arrow. Light blue boxes represent precipitation events where raindrops could not be distinguished from birds. Red lines represent the approximate altitudinal range of the RSA.

Acoustic detections (a single NFC) are red points along the base of each plot. Generally, more NFCs are detected when radar targets are at lower altitudes (see May 23; **Figure 3-3**); however, that trend is not observed consistently (see May 12; **Figure 3-3**).

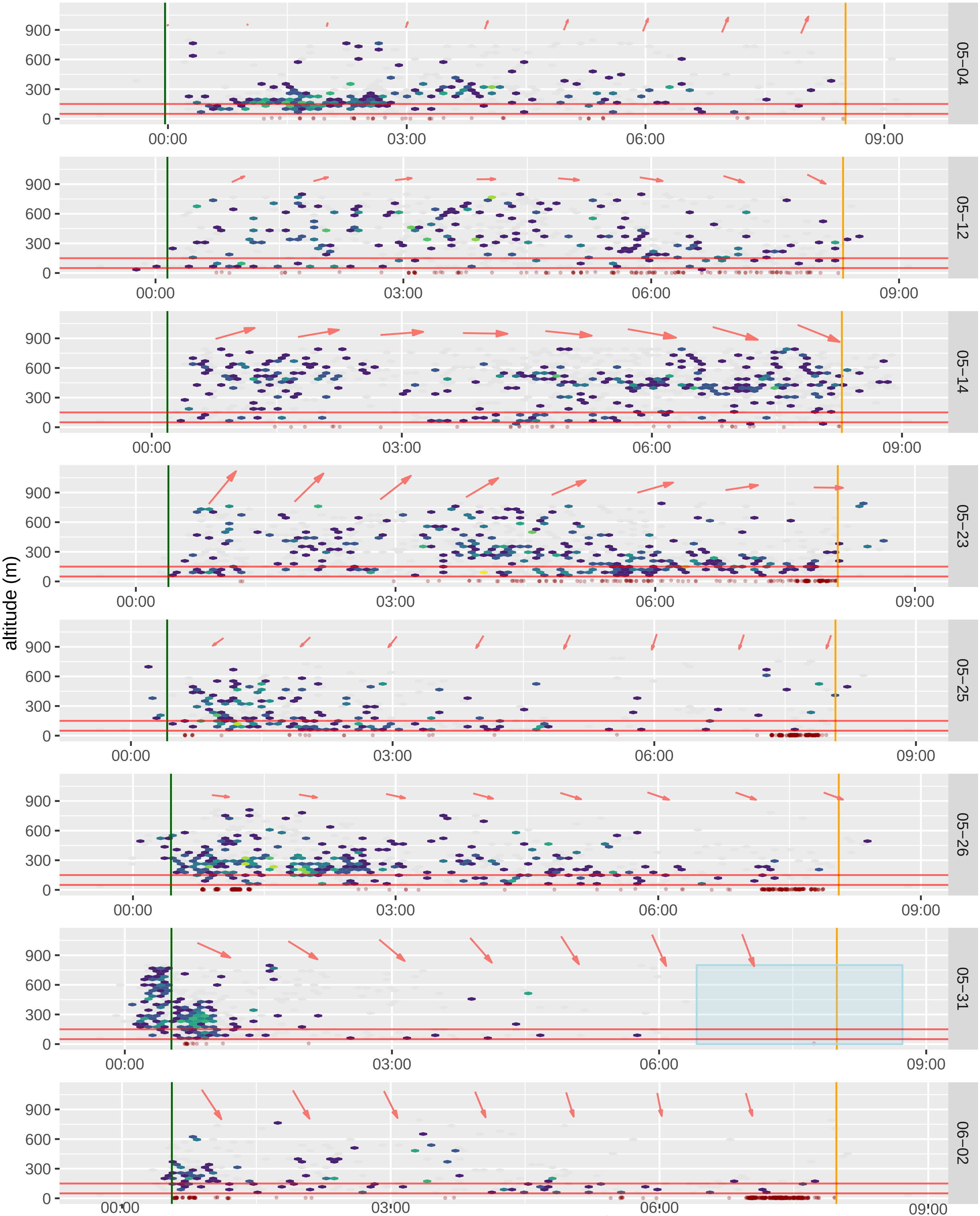

Figure 3-3 Radar and acoustic detections and wind conditions on select nights – Spring 2022

3.1.2 Altitudinal distribution of radar targets

Across all nights, a somewhat uniform decline in targets detected per 50 m altitudinal band (**Figure 3-4**). This decline is due in part due to the declining probability of detecting birds at more distant ranges, and also, potentially, to an actual decrease in the number of birds at increased altitudes. However, it is difficult to separate the effects of these two variables. The red line shown in **Figure 3-4** represents the maximum potential height of the turbines.

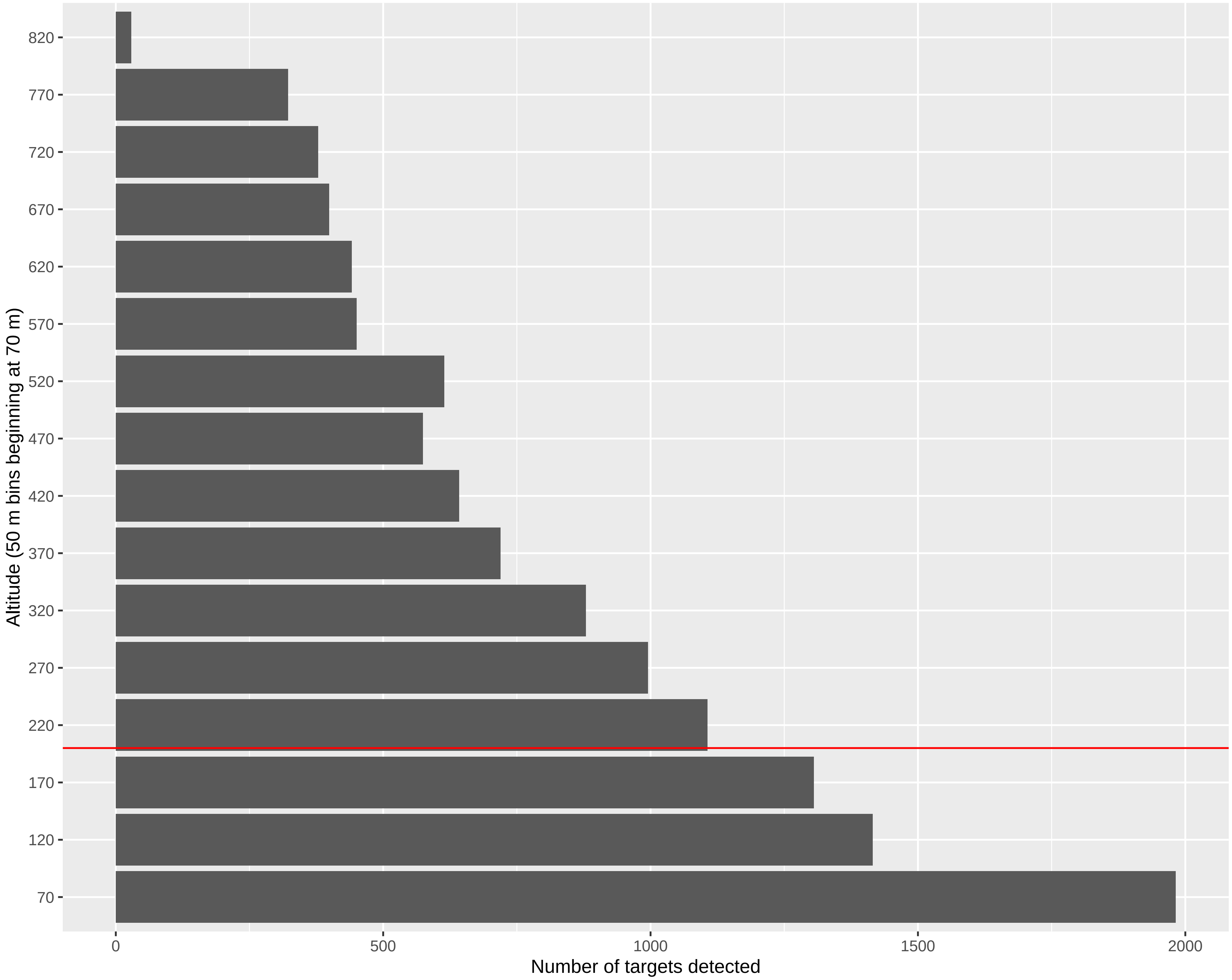

Figure 3-4 Radar Targets by Altitude – Spring 2022

Figure 3-5 shows the density of radar detections by altitude for only the 8 selected nights. The red line indicates the maximum height of the turbines.

The pattern of radar targets by altitude for nights with peak migration show a different pattern than all nights combined, and that pattern varied across nights. On May 14, two distinct altitudinal bands of migrants were observed (see **Figure 3-3** and **Figure 3-5**), one at approximately 400 m, and another near ground level).

During some nights where large numbers of targets were detected (e.g., May 14 and May 12), targets were observed to be primarily at higher altitudes (400 m or greater). On other nights (e.g., May 23 and May 26) the pattern of targets was also different than the average pattern across the season (see **Figure 3-4**), but concentrated at approximately 200 to 300 m in altitude.

Please review **Figure 3-3** to understand how the altitudes below change throughout the night. As can be seen in **Figure 3-3**, May 31 provides an example of a night where rain occurred, and nights May 25, May 31 and June 6 are nights when wind direction was less favorable.

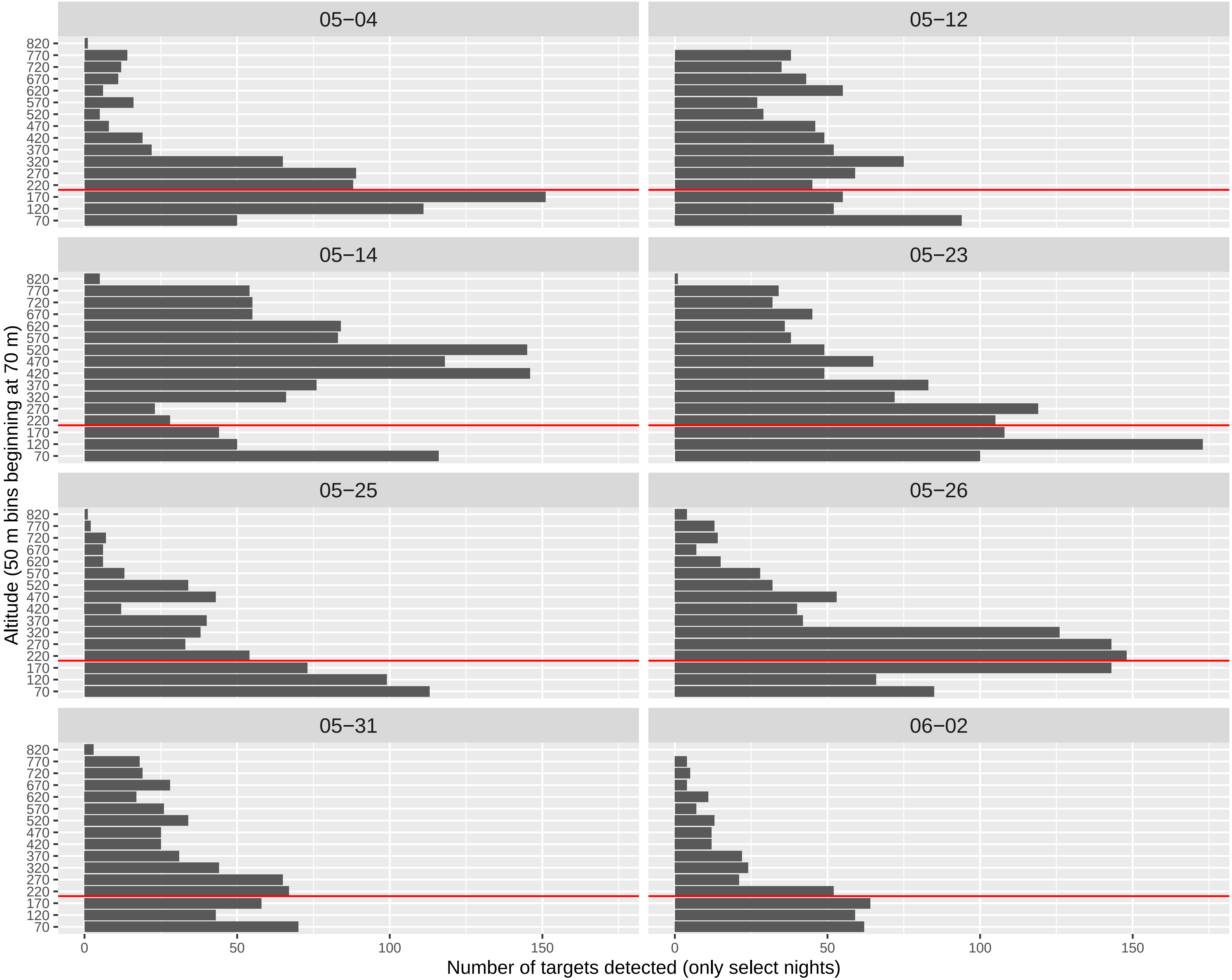

Figure 3-5 Radar Targets by Altitude for Select Nights – Spring 2022

3.1.3 Statistical Analysis of Spring Radar Data

Statistical models provided evidence that the total number of birds per hour was related to tailwind assistance (at ‘surface’), time of night (sunset, sunrise, and middle of the night) and weather (temperature, surface pressure and relative humidity). The most important differences are summarized in **Figure 3-6** and **Figure 3-7** and can be attributed to different behaviours through the night. The radar detected fewer targets around sunset (migration initiation) and sunrise (landing/stopover), compared to the detections observed during the middle of the night (continued migration). The periods immediately following sunset and before dawn seeing comparatively fewer targets may suggest that birds are not using the Project area as a stopover location.

Within **Figure 3-6** each point represents the number of targets in hourly bins, classified by time periods (panels) and month (colours). Tailwind speeds are plotted along the x-axis in km per hour with negative and positive values representing tailwind assistance. To improve data visualization, the total number of targets is represented on the y-axis by taking the log base 10 of the number of targets in hourly bins. The lines are regressions for each group, showing a positive relationship during the middle of the night across the entire season. This means that the number of targets detected is low in strong headwinds (negative tailwind assistance) and increases as tailwind strength increases (**Figure 3-6**). This follows a general pattern that birds prefer to migrate with tailwinds or very light headwinds (e.g., Peckford 2006).

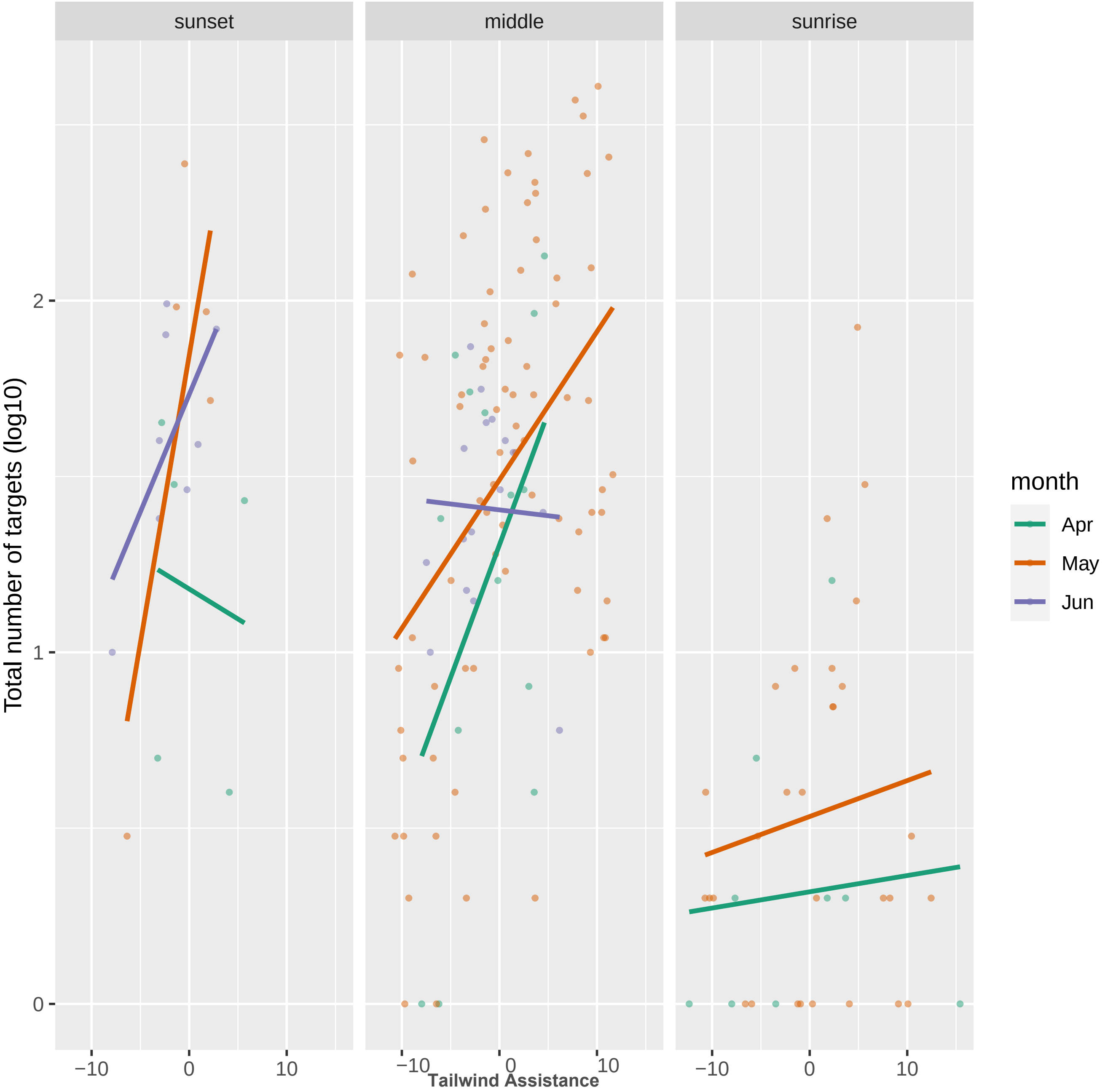

Figure 3-6 Relationship between Tailwind Assistance on Total Number of Targets across Time of Night and Month – Spring 2022

The symbology of **Figure 3-7** is the same as **Figure 3-6** , above, except that the predictor variable is relative humidity, and the smoothed line is a curve, which better depicts how the number of targets increases, then decreases with the predictor. Due to limited data points during sunset, sunrise and during June, focus on **Figure 3-7** should be on data during the middle of the night during April and May (the bulk of the migration observed).

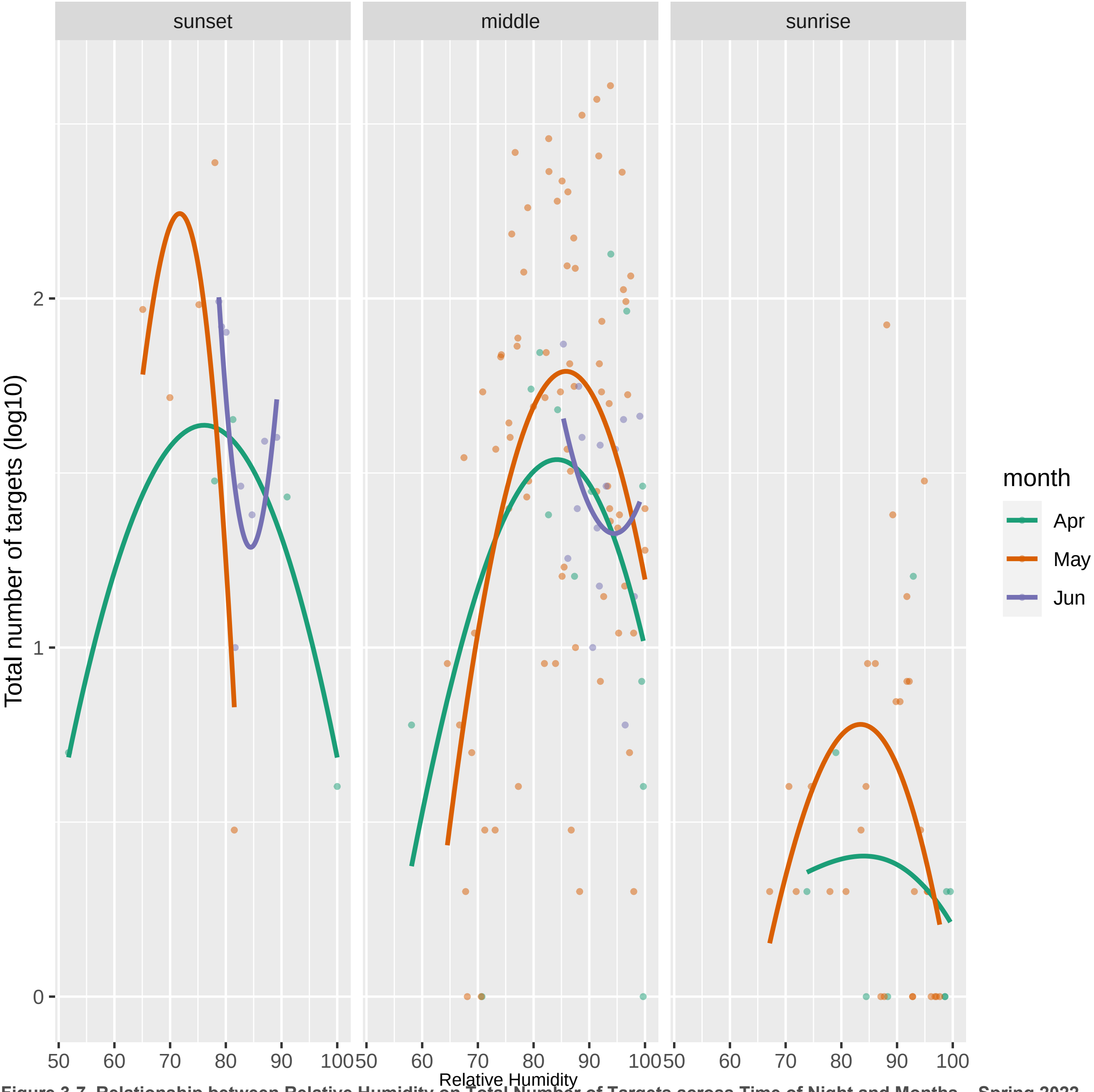

Figure 3-7 Relationship between Relative Humidity on Total Number of Targets across Time of Night and Months – Spring 2022

Relative number of birds at lower altitudes

The index of the proportion of targets flying at low altitudes demonstrates the proportion of targets below a given altitude (i.e., 200 m) in relation to what is detected above that altitude. The index was related to the overall number of migrants, along with all timing and weather variables.

In **Figure 3-8**, each dot represents the number of birds detected below 200 m divided by the total number of birds observed in each hourly bin classified by time of night. The lines are smoothed relationships between the index, and the total number of targets are presented on a log scale.

The primary finding expressed in **Figure 3-8** is that on nights when large numbers of targets were detected, and during the middle part of the night, there tended to be fewer of those targets at lower altitudes. This same pattern is also illustrated in **Figure 3-5**.

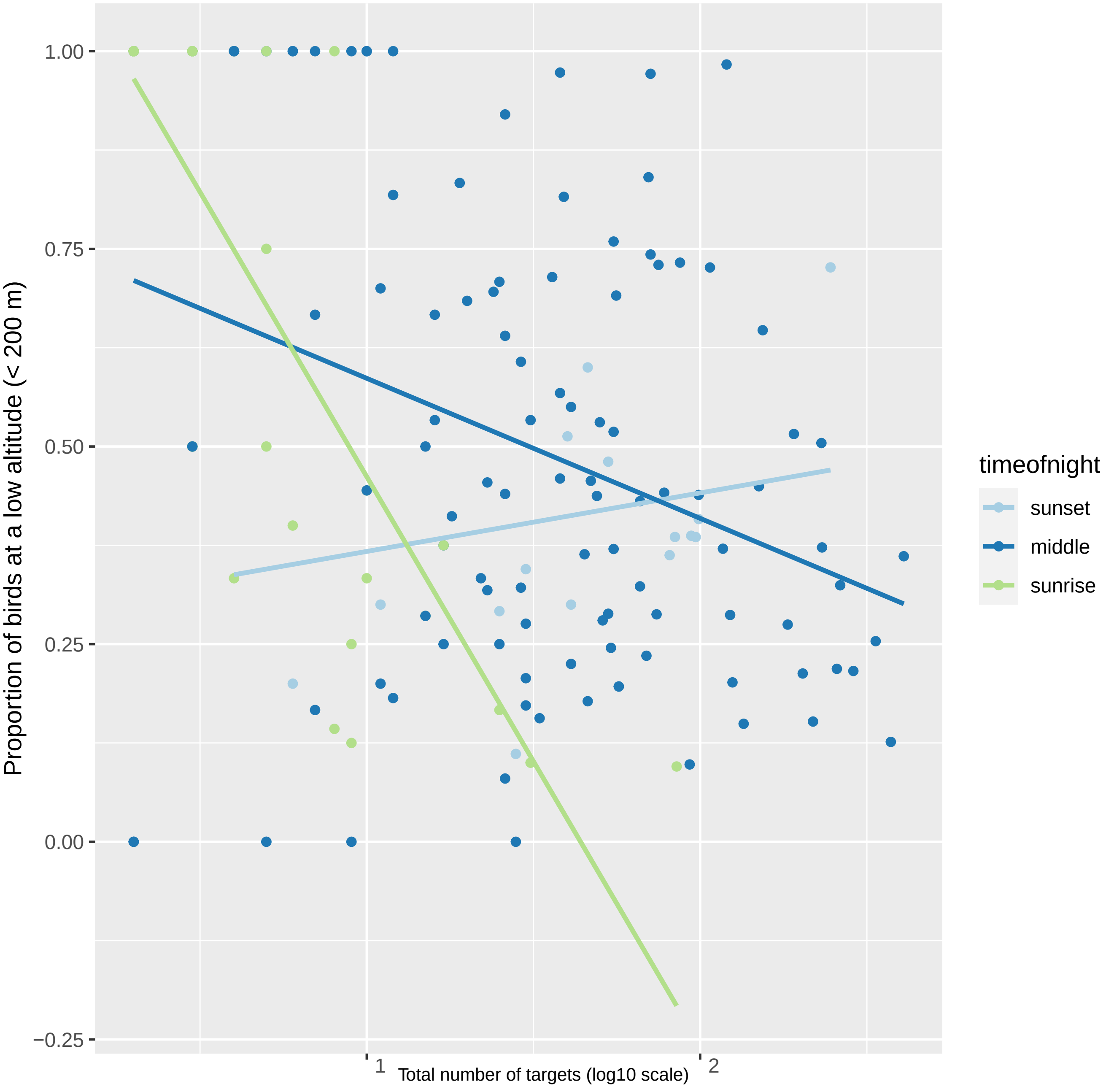

Figure 3-8 Proportion of Targets at Low Altitude in Comparison to Total Number of Targets across Time of Night – Spring 2022.

3.1.4 Nocturnal Flight Call Detections

Overall, few NFCs were detected during the spring season. Flight calls were analyzed and grouped into one of 17 species groups with the majority being sparrows (50.3%), followed by warblers (49.6%). The most common species / species group observed was white-throated sparrow, followed by 'zeeps' and Savannah sparrow. Together, these comprised 63% of the total detections (**Table 3-2**). Common nighthawks were also identified. However, given the species is known to call repeatedly during the night (Brigham et al. 2020), resulting in a high probability of double counting, the counts of NFCs have been excluded from **Table 3-2**. Common nighthawk calls are provided in the figures below to show the trends across the season and time of night.

Table 3-2 Nocturnal Flight Call Detections by Species and Species Group

Species / Species Group(a)(b)	Total Number of Calls Detected	Proportion of Calls Detected
White-throated Sparrow	440	34.7%
Zeep	180	14.2%
Savannah Sparrow	179	14.1%
Ovenbird	176	13.9%
American Redstart	103	8.1%
Black and White Warbler	49	3.9%
Common Yellowthroat	48	3.8%
Double Up	31	2.4%
Single Banded Down Sweep	23	1.8%
Canada Warbler	15	1.2%
Fox / Song Sparrow	12	0.9%
Cup Sparrow	7	0.6%
Mourning Warbler	3	0.2%
Chestnut-sided Warbler	1	0.1
Thrushes	1	0.1
Total	1,268	100

(a) "Zeep" species groups includes bay-breasted warbler, blackburnian warbler, blackpoll warbler, Cape May warbler, magnolia warbler, northern waterthrush and yellow warbler; "Cup Sparrow" species group includes chipping sparrow, field sparrow and American tree sparrow; "Double Up" species group includes black-throated green warbler, Tennessee warbler, Nashville warbler and orange crowned warbler; "Single Banded Down Sweep" species includes pine warbler, northern parula, yellow-throated warbler, and prairie warbler; "Thrushes" includes Hermit Thrush, Swainson's Thrush, Gray-cheeked Thrush, Veery, Rose-breasted Grosbeak and Scarlet Tanager. Common nighthawks were also detected but not displayed within the table.

(b) Species in bold represent Species at Risk.

The majority of the sparrows were detected prior to May 15 (with a peak on May 2), and most warbler NFCs were concentrated on May 14. The peak in warbler NFCs is in alignment with the peak in radar activity described in Section 3.1.1. Nightjar detections occurred in late May and were recorded in similar numbers at dusk, night, and dawn. Given the time of year observed, and because calls were somewhat consistent around dawn and dusk, these are likely individuals that are breeding in the area.

Figure 3-9 Nocturnal Flight Call Detections by Species Group and Time of Year - Spring 2022

Figure 3-10 shows the distribution of acoustic detections by species of sparrows (green), warblers (purple), thrushes (blue) and nightjars (orange) across the entire spring season. The number of detections shown in **Figure 3-10** is the total number of calls detected for that group on that night; also note that the scale differs between groups. Timing of species detections are as expected with most sparrows detected early in the season and warblers concentrated in mid-May.

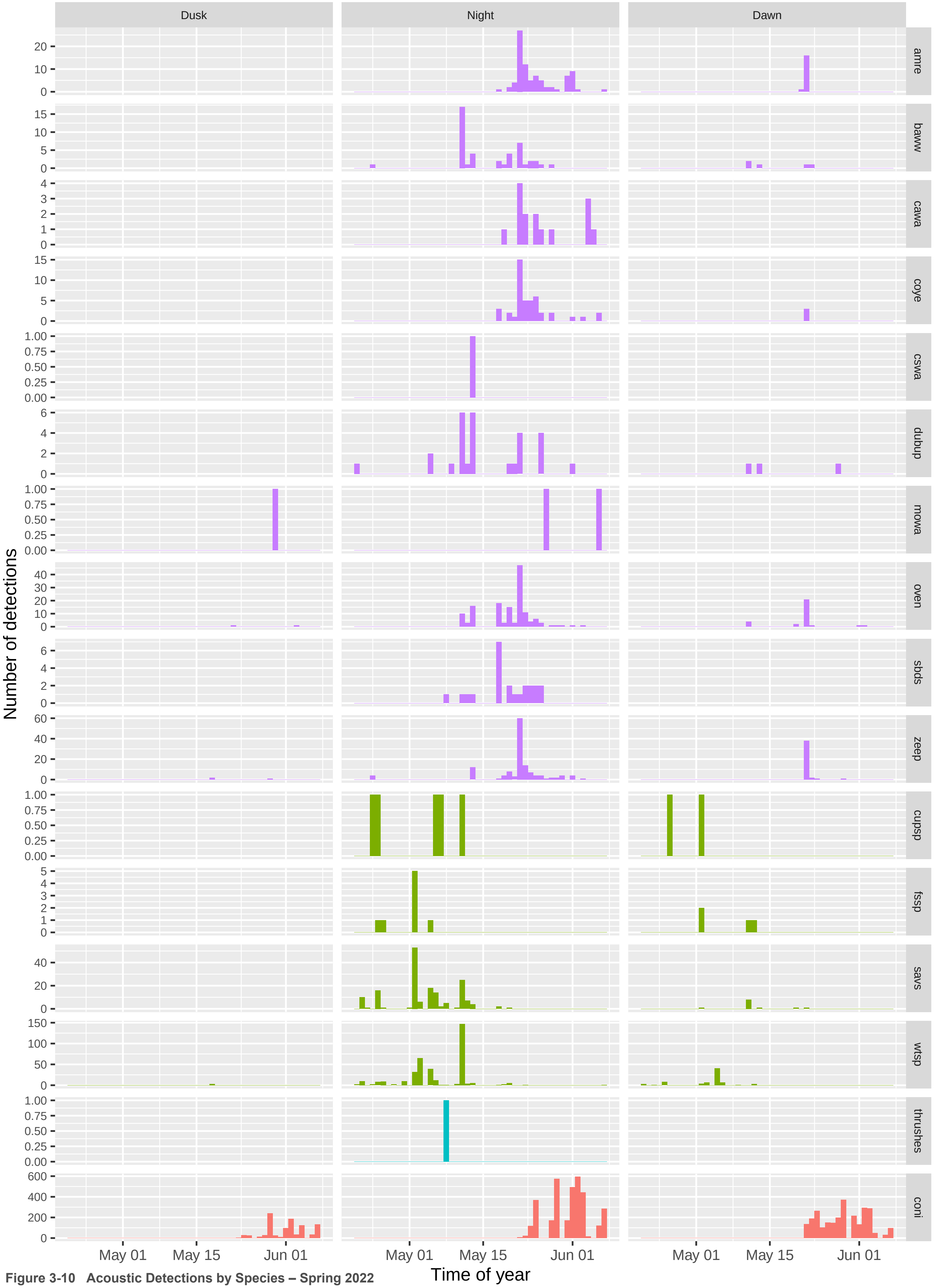

Figure 3-10 Acoustic Detections by Species – Spring 2022

Figure 3-11 shows the occurrence of NFCs detected by time of night during the spring migration season. The majority of sparrow calls were detected at dawn, suggesting that many of these calls were from individuals calling from the ground. The number of warbler NFCs generally increased as time to sunrise decreased. As mentioned above, nightjars (i.e., Common Nighthawk [*Chordeiles minor*]) were generally detected either close to sunrise or sunset.

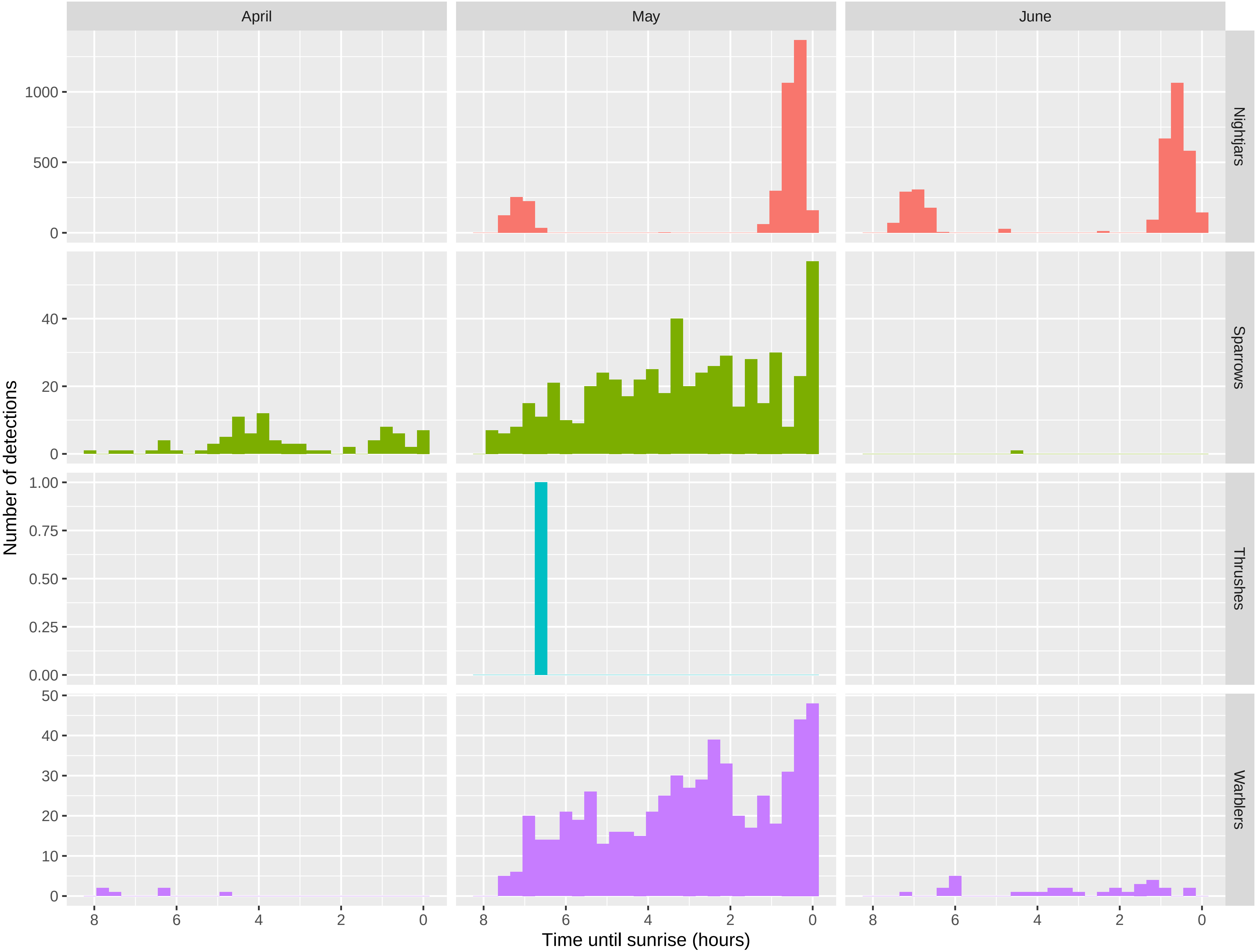

Figure 3-11 Nocturnal Flight Calls by Time until Sunrise – Spring 2022

3.2 Fall Migration

3.2.1 Nocturnal Migration Patterns

As with the spring migration season, active migration was observed on most nights monitored. Nights with the highest number of targets detected occurred through September and in late October. **Figure 3-12** shows the change in radar target density across the fall season, along with a distribution of density above and below 200 m. On most nights, there were more targets detected above 200 m than below. This pattern is especially true for the nights when most of the seasonal migratory activity occurred (i.e., peak nights of activity).

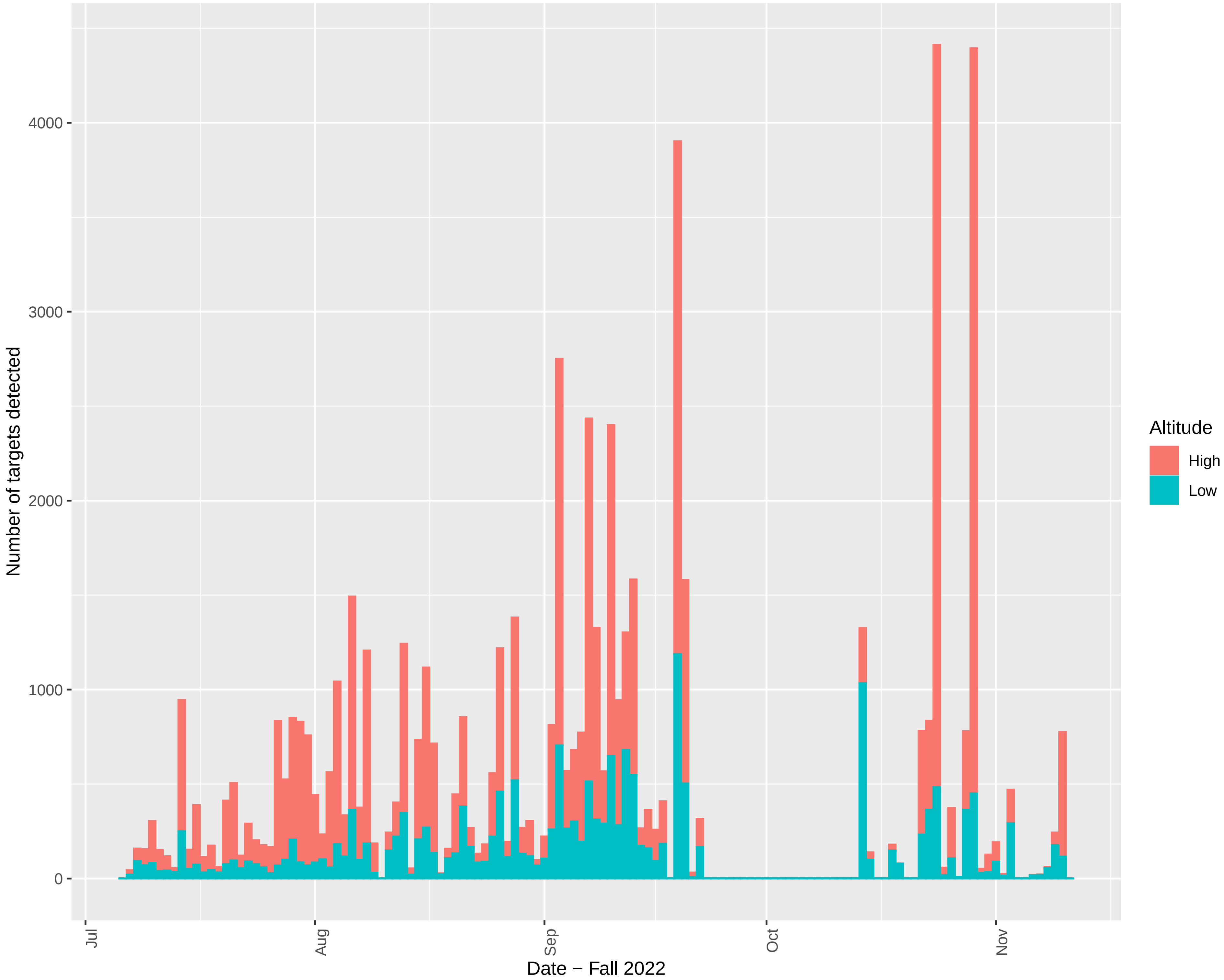

Figure 3-12 Seasonal Change in Radar Detections by Altitude - Fall 2022

Eight nights during the fall were selected for further focus (see Appendix B for the complete fall dataset). The 8 nights selected have either many radar targets, many acoustic detections, or show different patterns of bird behaviour at the site compared to other nights (**Figure 3-13**). Each plot within **Figure 3-13** shows the altitudinal distribution of radar targets for each select night in the fall in relation to wind speed, direction and precipitation. The beginning and end of civil twilight indicated by the vertical green and yellow lines, respectively. Date and time are on the x-axis and altitude is on the y-axis. Hexagonal points are radar detections divided into time and altitude bins and are scaled from light grey (few detections) through dark purple, blue, green to yellow (many detections). Wind direction and strength aloft (700 m) for each hour are displayed at the top of each plot via a red arrow. Light blue boxes represent precipitation events where raindrops could not be distinguished from birds. Red lines represent the approximate altitudinal range of the RSA. Acoustic detections (a single NFC) are red points along the base of each plot. The entire dataset of nights for the fall season can be found in the Appendix B.

During most nights represented in **Figure 3-13** wind direction was from the north. However, October 24 shows a somewhat atypical pattern with high density migration when winds are from the south and also shows a night where rain began during the middle of the night.

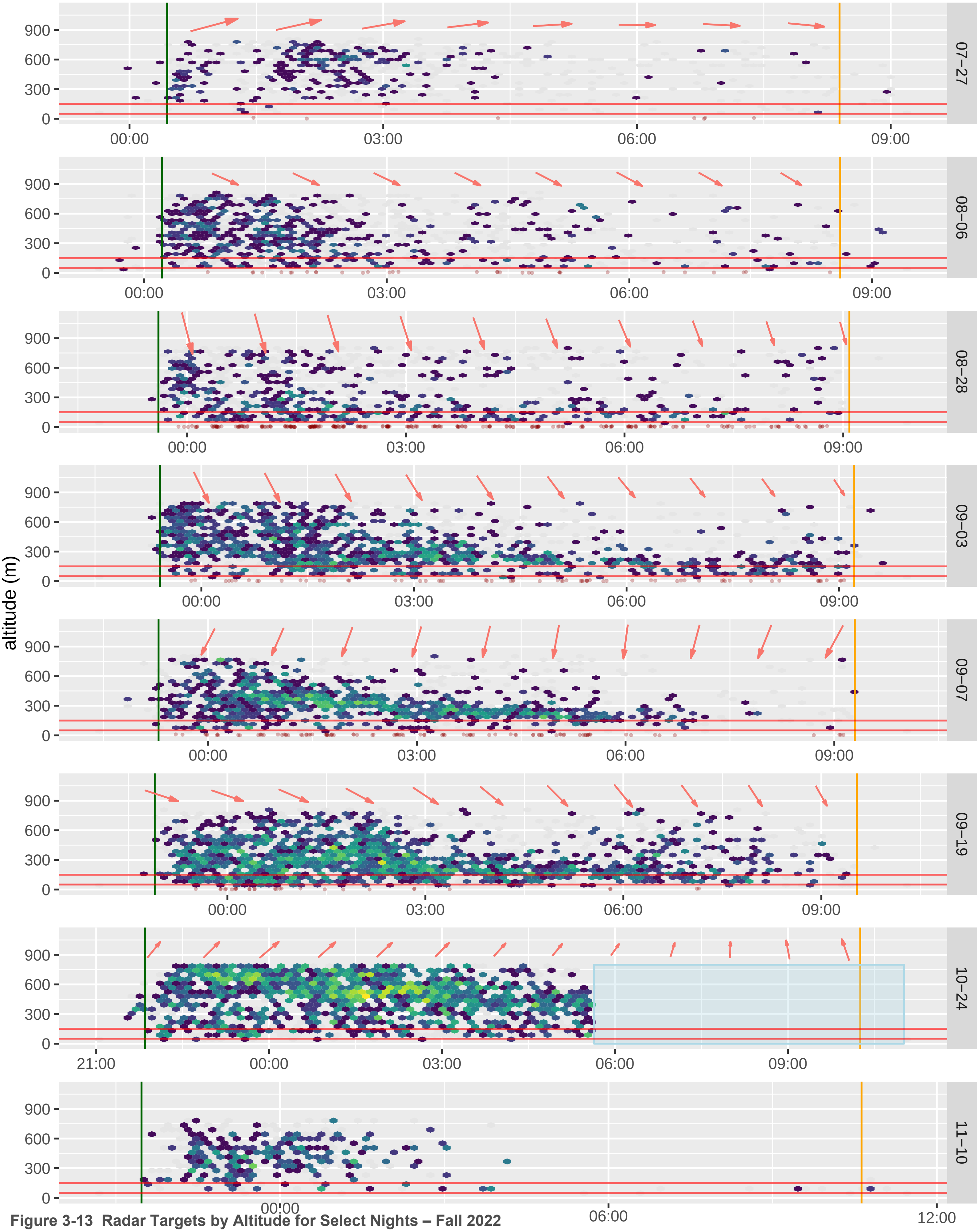

Figure 3-13 Radar Targets by Altitude for Select Nights – Fall 2022

As mentioned in Section 1.0, fall data included in this report extend until November 10 to meet reporting timelines. Based on other data collected by Ausenco and Tabanid Consulting through out the Atlantic region, very little migratory activity is typically observed after November 1 (see Ausenco 2022).

3.2.2 Altitudinal Distribution of Radar Targets

When viewing all radar detections combined during the fall season, the altitudinal band with the most detections is the lowest (approximately 70 m to 120 m). However, at this height local movements of birds are detected and there is a likelihood of ground clutter and insect detections.

Across all nights, a somewhat uniform decline in targets detected per 50 m altitudinal band between approximately 250 and 800 m (**Figure 3-14**) is observed. This decline is due in part due to the declining probability of detecting birds at more distant ranges, and potentially, to an actual decrease in the number of birds at increased altitudes. However, it is difficult to separate the effects of these two variables. The red line shown in **Figure 3-14** represents the maximum potential height of the turbines.

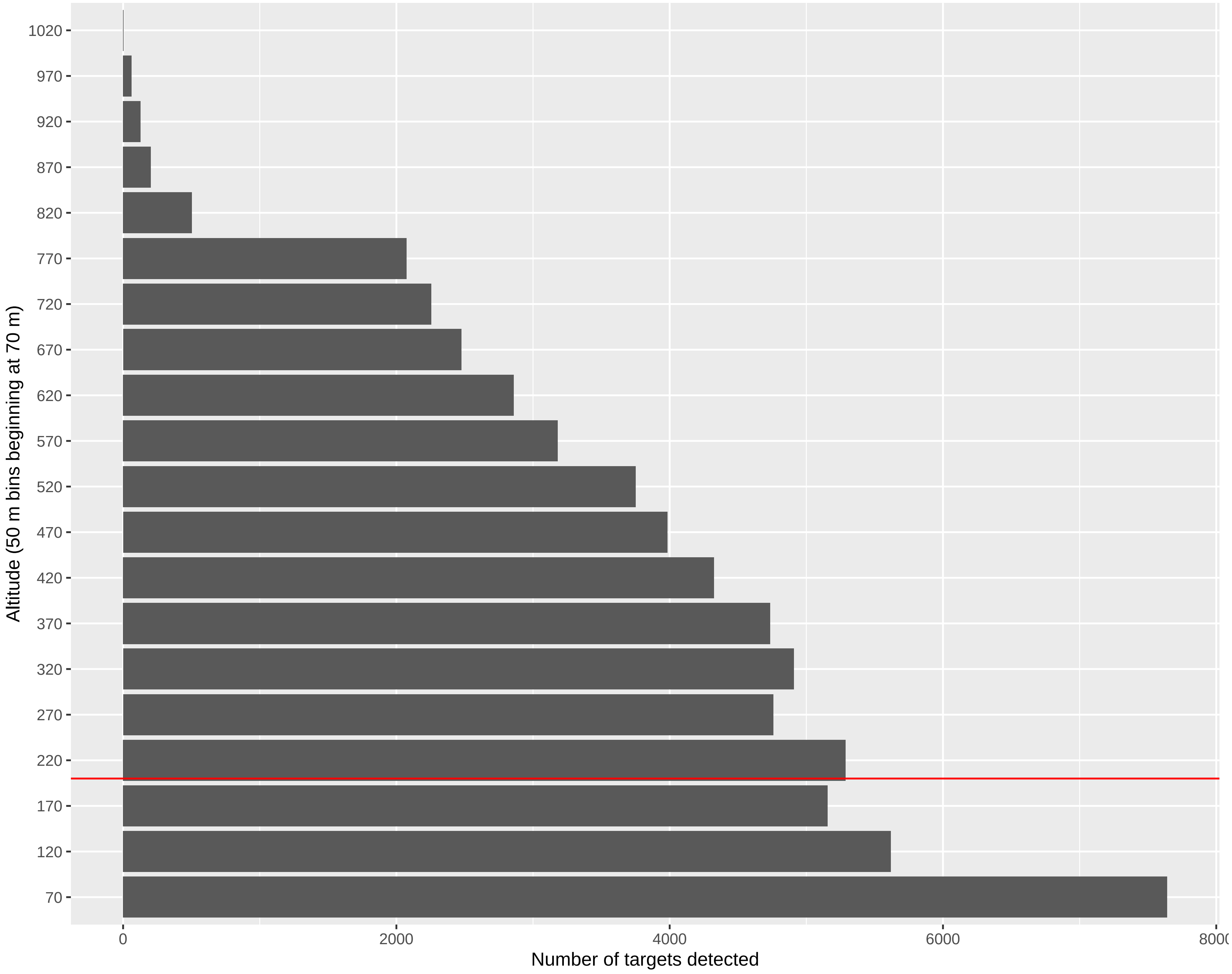

Figure 3-14 Radar Targets by Altitude - Fall 2022

Figure 3-15 shows the density of radar detections by altitude for only the selected nights discussed above. The red line indicates the maximum height of the turbines. The pattern of radar targets by altitude for these nights show different patterns with, generally, most targets being detected at, or above, the proposed turbine RSA.

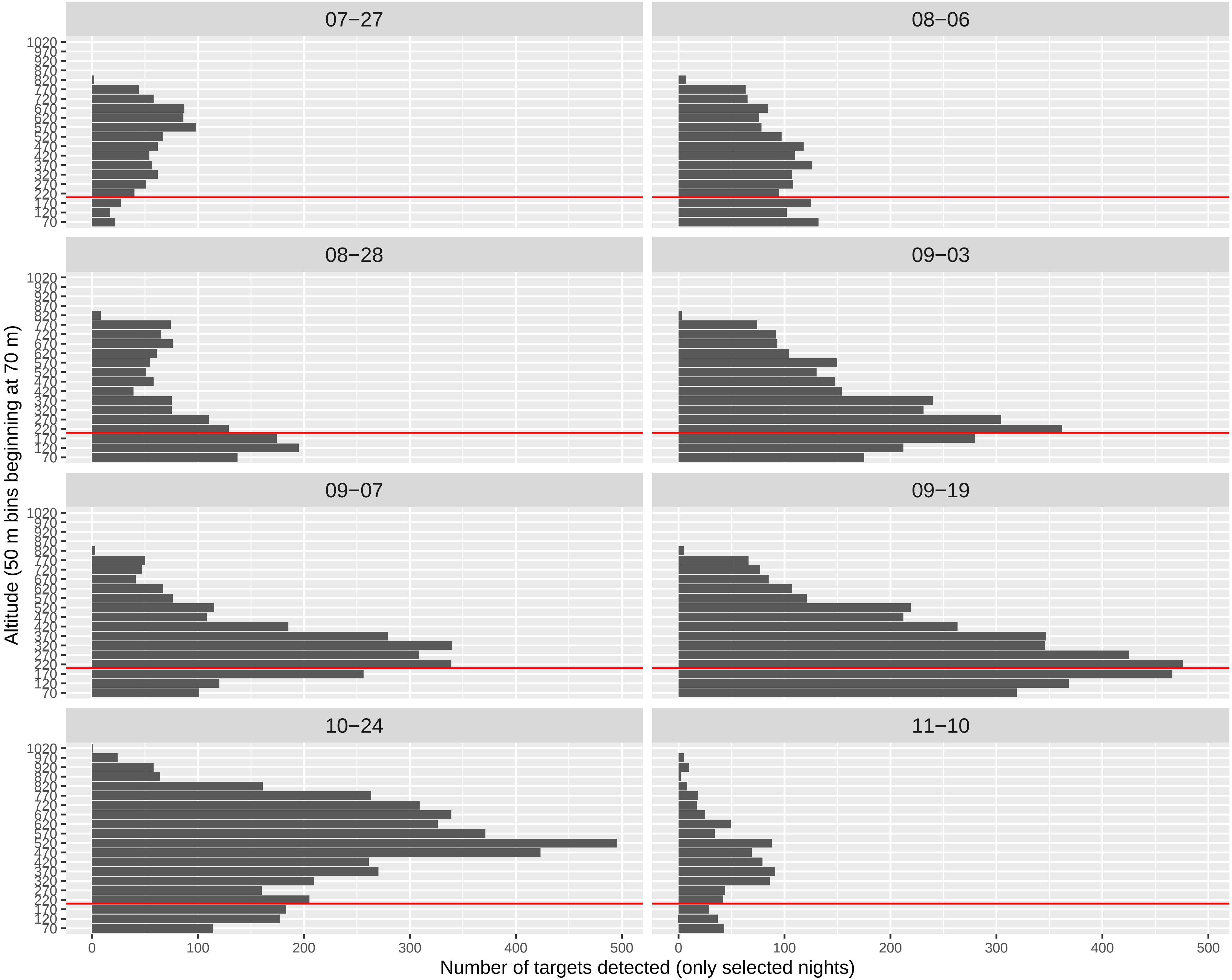

Figure 3-15 Radar Targets by Altitude for Select Nights - Fall 2022 .

3.2.3 Statistical Analysis of Radar Data

The same statistical models completed for the spring migration, described in Section 3.1.3, were completed for the fall data. The same trends observed during the spring, were seen during the fall, with increased targets detected during increased tailwind assistance (**Figure 3-16**), fewer targets detected during increased relative humidity (i.e., increase precipitation) (**Figure 3-17**) and on nights when large numbers of targets were detected, most of those detections were at higher altitudes (**Figure 3-18**). See Section 3.1.3 for a description of the symbology presented in the plots below.

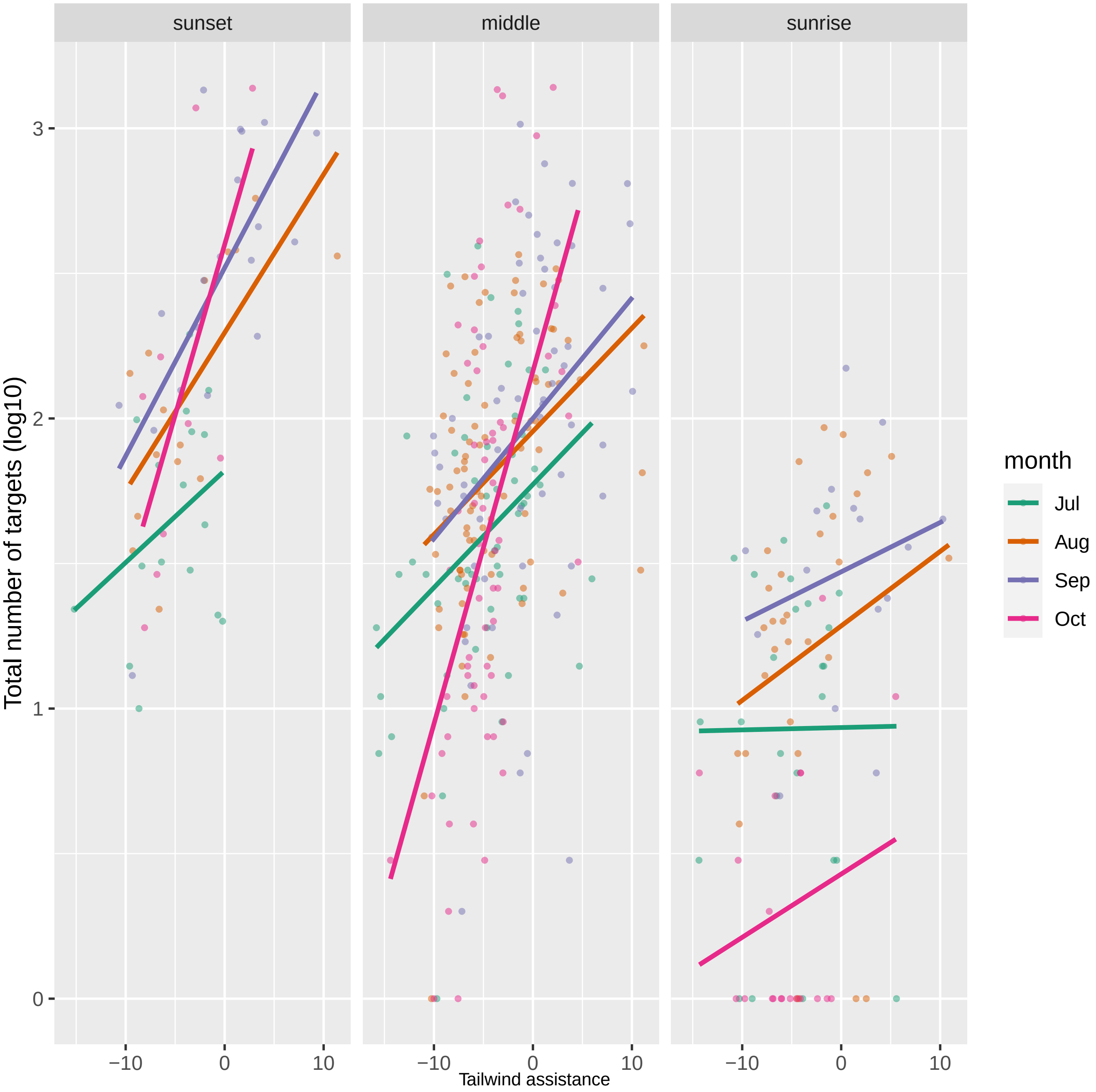

Figure 3-16 Relationship Between Tailwind Assistance on Total Number of Targets across Time of Night and Month – Fall 2022

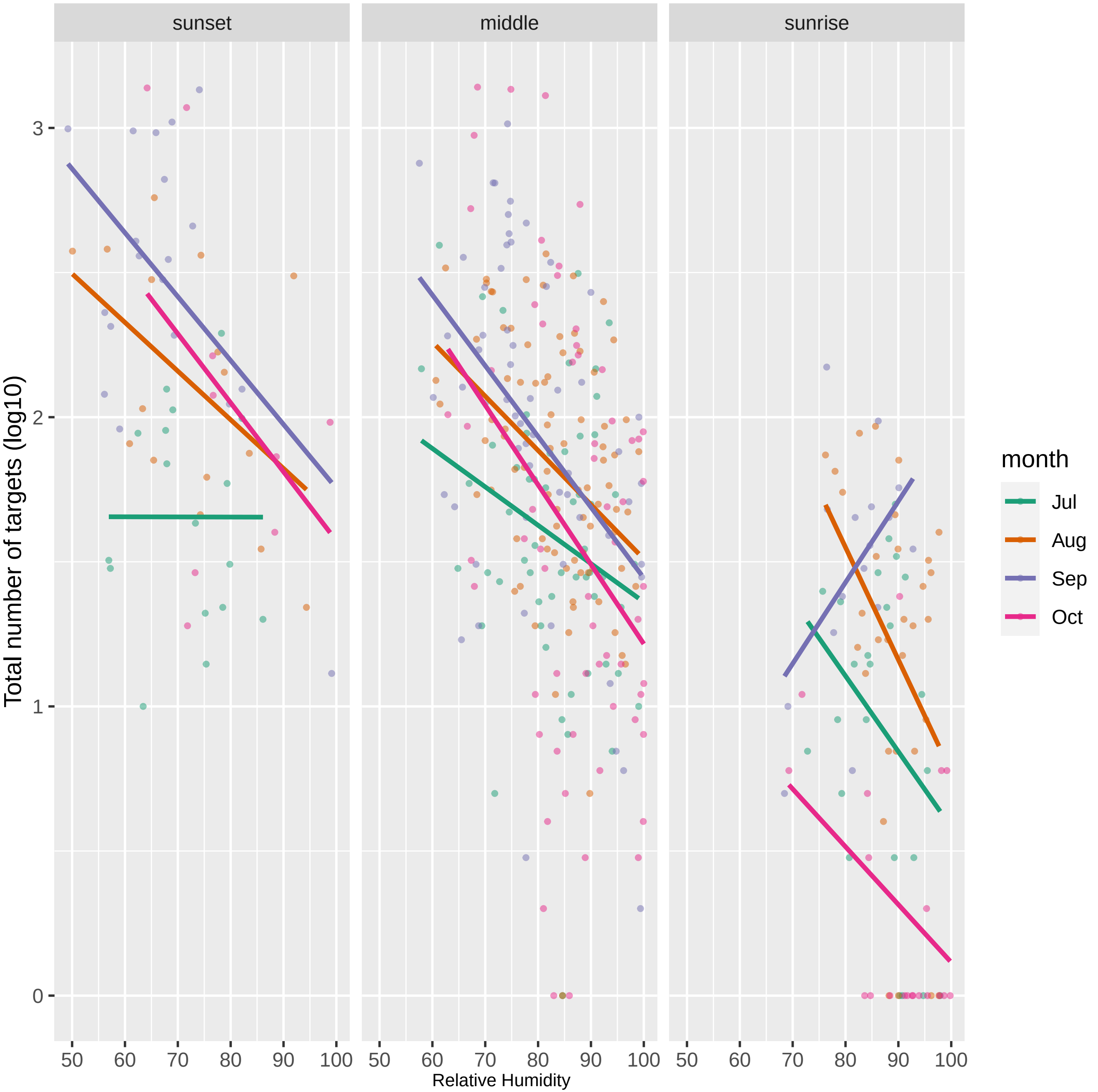

Figure 3-17 Relationship between Relative Humidity on Total Number of Targets across Time of Night and Months – Fall 2022

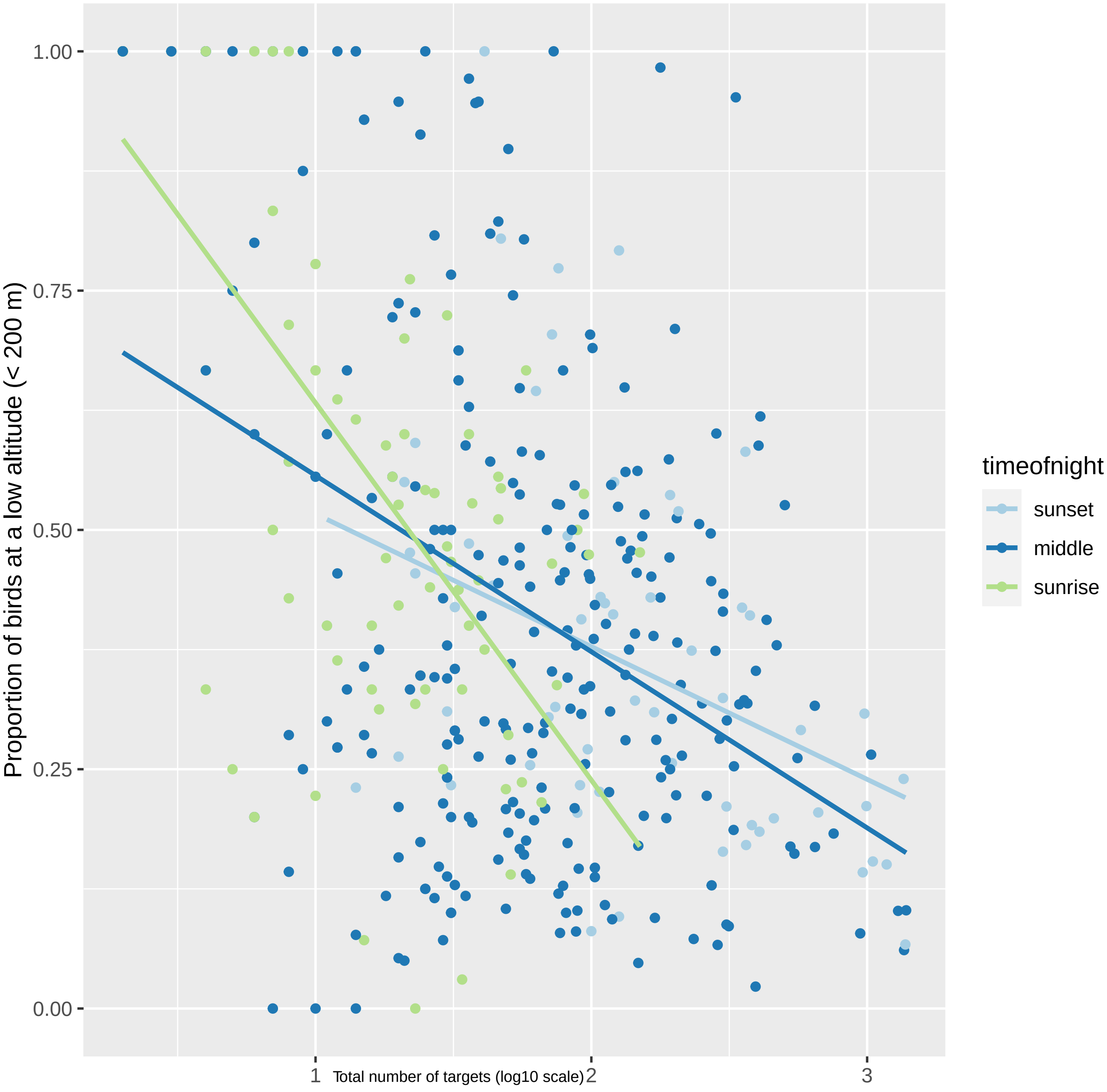

Figure 3-18 Proportion of Targets at Low Altitude in Comparison to Total Number of Targets across Time of Night – Fall 2022

3.2.4 Nocturnal Flight Call Detections

Flight calls were analyzed and grouped into one of 17 species groups. Warblers comprised the majority (89%) of NFCs detected during the fall season. The most common species / species group observed were “zeeps” and ovenbirds which comprised 43.5% of the total detections (**Table 3-3**).

Table 3-3 Nocturnal Flight Call Detections by Species and Species Group

Species / Species Group(a)(b)	Total Number of Calls Detected	Proportion of Calls Detected
Zeep	2,703	24.1
Ovenbird	2,178	19.4
American Redstart	1,253	11.1
Common Yellowthroat	1,182	10.5
Double Up	1,012	9.0
Savannah Sparrow	922	8.2
Black and White Warbler	809	7.2
Single banded Down Sweep	508	4.5
White-throated Sparrow	223	1.98
Canada Warbler	158	1.4
Black-throated Blue Warbler	90	0.8
Chestnut-sided Warbler	63	0.6
Thrushes	62	0.3
Mourning Warbler	31	0.2
Fox/Song Sparrow	24	0.1
Palm Warbler	15	0.1
Cup Sparrow	5	<0.1
Total	11,238	100

(c) “Zeep” species groups includes bay-breasted warbler, blackburnian warbler, blackpoll warbler, Cape May warbler, magnolia warbler, northern waterthrush and yellow warbler; “Cup Sparrow” species group includes chipping sparrow, field sparrow and American tree sparrow; “Double Up” species group includes black-throated green warbler, Tennessee warbler, Nashville warbler and orange crowned warbler; “Single Banded Down Sweep” species includes pine warbler, northern parula, yellow-throated warbler, and prairie warbler; “Thrushes” includes Hermit Thrush, Swainson’s Thrush, Gray-cheeked Trhush, Veery, Rose-breasted Grosbeak and Scarlet Tanager.

(d) Species in italic represent Species at Risk.

Fewer NFCs were detected at the beginning and end of the monitoring period, indicating that the entirety of the migration season was captured. Also, nearly all warbler NFCs were detected during the middle portion of the night (i.e., not during sunrise or sunset) which suggests that most NFCs detected represent migrants passing over the Project area, and not individuals that were stopping over. (**Figure 3-19**).

Thrushes were primarily detected at Dawn, when individuals typically call as they descend from migratory flight. This was observed on the morning of September 13, and to a lesser degree in late August (**Figure 3-19**).

Sparrows, representing 10 % of the NFCs, were detected largely from late September to late October, a shift of approximately 2 weeks compared to the pattern observed with warblers. Similar to warblers, most sparrows were observed during the middle part of the night. While there were few sparrows detected during dusk, there were some detections during dawn around early October. Those calls were primarily white-throated sparrows (see **Figure 3-20**) and are assumed to be individuals calling from the ground. The largest single night of sparrow detections was on September 29 (**Figure 3-19**) which were predominantly savannah sparrows (see **Figure 3-20**).

Common Nighthawk were observed only during the early part of the migration season (**Figure 3-19**) with the vast majority (82%) of calls detected at 2 of 7 sites, and 94% of calls detected at 3 sites. As such, it is assumed that these common nighthawk calls are from individuals breeding in the area. Common nighthawk are known to call frequently during dawn and dusk (Brigham et al. 2020); therefore, the NFCs detected likely represent few individuals calling repeatedly near the acoustic sensors.

Figure 3-19 Nocturnal Flight Call Detections by Species Group and Time of Year - Fall 2022

Figure 3-20 shows the distribution of acoustic detections by species group for: common nighthawk (orange), sparrows (green), thrushes (blue) and warblers (purple), across the entire fall season. The number of detections shown in **Figure 3-20** is the total number of calls detected for that group on that night; also note that the scale differs between species.

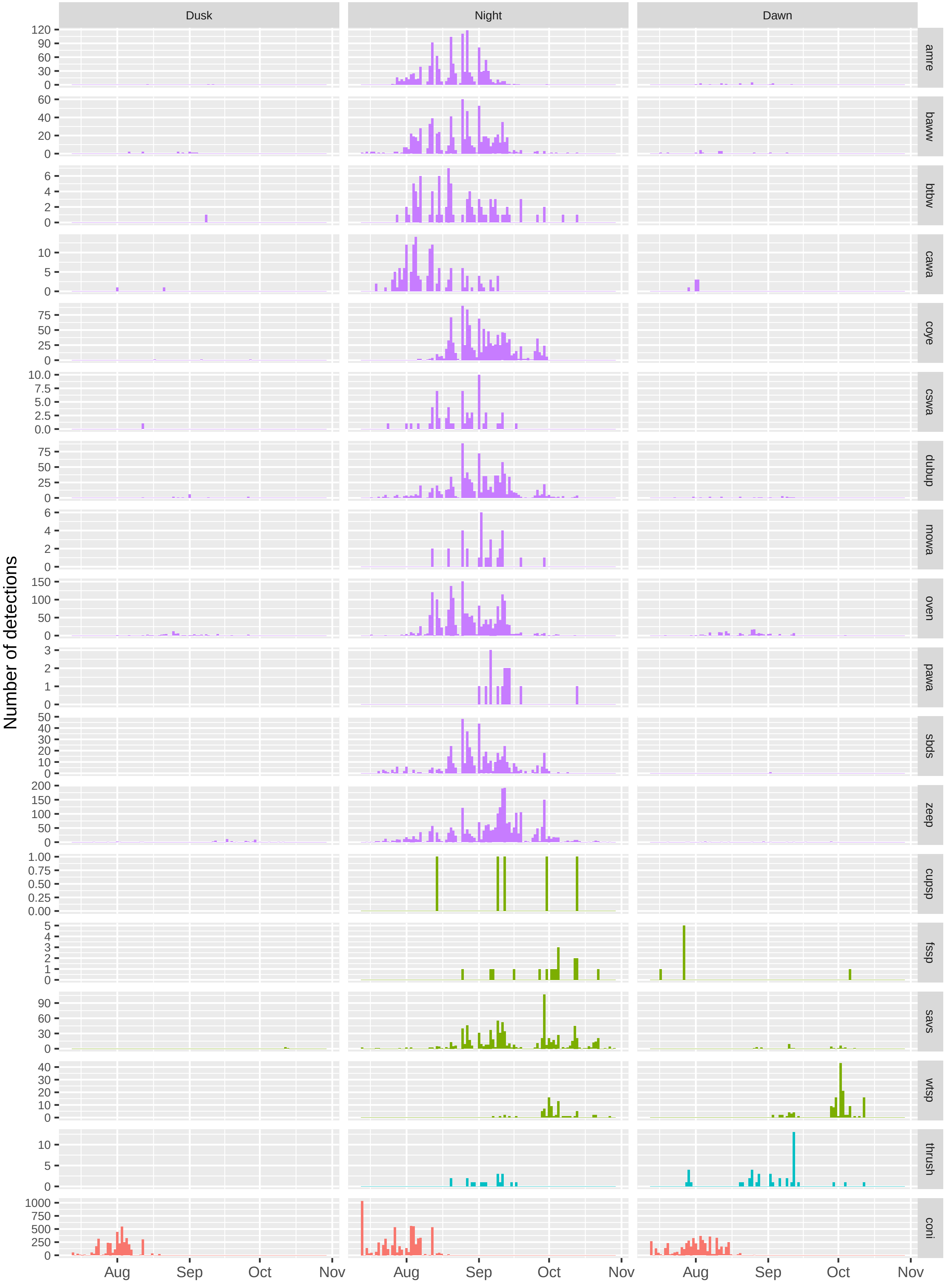

Figure 3-20 Acoustic Detections by Species – Fall 2022

Figure 3-21 shows the occurrence of NFCs detected by time of night during the fall migration season. Common Nighthawk (likely breeding individuals) were active primarily at dawn and dusk. Sparrows were detected throughout the night, indicating that most of the NFCs were from actively migrating individuals. However, a peak in calling activity was detected near dawn in October that is believed to be individuals calling from the ground (primarily white-throated sparrow). Similar to sparrows, most warblers were detected during the middle part of the night, representing individuals in active migration. Most thrushes were detected calling during their dawn decent, as described above.

As discussed in Section 2.1, radar monitoring was not completed between September 23 and October 12 due to damage caused by hurricane Fiona. To understand the extent of migration which occurred during this time, a focused summary of the acoustic data (**Figure 3-22**) shows the number of NFC detections by species during that time period. The majority of species observed during the period when the radar was non-operational was primarily savannah sparrow, which are also captured later in the season with acoustic and radar (see **Figure 3-20**) and “zeeps”, which are observed throughout the season. Given the species observed during this period were also represented during other parts of the season when radar was operational, it is unlikely that the gap in radar data would have provided unique insight into migratory trends at the Project area.

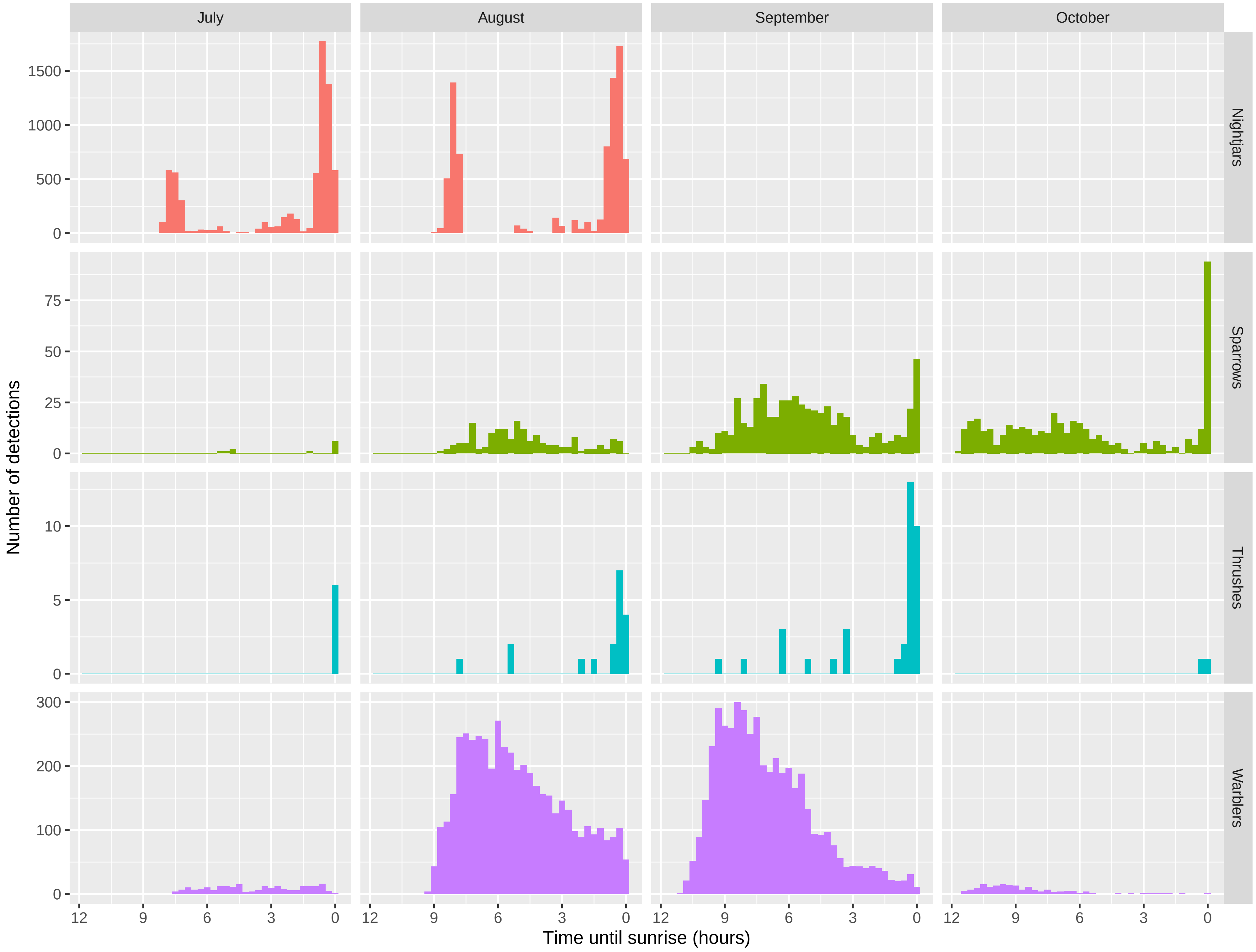

Figure 3-21 Nocturnal Flight Calls by Time until Sunrise – Fall 2022

Figure 3-22 Acoustic Detections by Species between September 21 and October 13 2022

4.0 Summary

Radar and acoustic monitoring were completed at the Project area during the spring and fall 2022 migration seasons with radar data collected within approximately 580 m of the nearest proposed turbine and acoustic data obtained through a network of sensors located across the Project area.

Radar monitoring was nearly continuous throughout the spring (April 23 to June 8) and fall (July 8 to November 10) seasons with the exception of an interruption in radar data due to hurricane Fiona. Acoustic monitoring was conducted continuously through both seasons. Considering these dates, and when examining the number of detections observed across this time period, the entire spring and fall migration seasons were considered to be monitored at the site.

As is typically seen on similar studies in Nova Scotia, the intensity and duration of the spring migration season is much less compared to the fall. Therefore, much of the discussion below is focused on the fall season, when more migrants were observed.

While some level of active migration was observed on most nights, a large proportion of the migratory activity observed was limited to a few nights. Also, most activity was observed when favourable tailwinds were present and with little to no precipitation. These findings are typical to other radar and acoustic studies completed in Nova Scotia (e.g., Peckford and Taylor, 2008).

Targets were detected at heights throughout the area sampled (i.e., between 70 m and approximately 800 m), with most of those being detected above 200 m. However, given that the probability of detecting small birds decreases as distance from the radar increases, the decrease in number of detections of birds higher than 400 m is likely a combination of fewer birds aloft and a decreased detectability. When examining the nights with the largest numbers of targets (i.e., when most of the migration occurred), most of the targets were greater than 200 m, which is above the proposed RSA of the turbines.

When examining differences in detections within nights, most radar and acoustic activity was observed during the middle portion of the night. While some unknown percentage of migrants are likely stopping over at the Project area, given the consistency in distribution of activity within nights, the data suggest that a large proportion of migrants are not utilizing the area for staging during migration. However, it should be noted that it is possible that migrants are landing earlier in the night.

The composition of the species detected via acoustic sensors was consistent with the range of species known to migrate into and through Nova Scotia. The timing of those species was also as expected, with most warblers detected during August and September, and sparrows during September through to mid-October. Other than common nighthawk, which are believed to be local breeders, little to no NFCs were detected in July.

4.1 Species at Risk

While common nighthawk (listed as *Threatened* under the Nova Scotia *Endangered Species Act* (NSESA) and the federal *Species at Risk Act* (SARA)) were detected during the spring and fall migration seasons, the majority of the calls detected are believed to be from local individuals rather than active migrants. Given this species is active at night and calls frequently, the number of calls detected do not provide an accurate representation of the number of individuals at the site, but rather confirms their presence within the Project area.

Canada warblers (listed as endangered under the NSESA and threatened under the SARA) were detected via NFCs throughout August with the majority being detected in early August. Given that Canada warbler NFCs are distinct and detectable from other species, it is assumed that most, or all, Canada warbler NFCs captured by the sensors were identified. Of the 158 Canada warbler calls detected, only 9 were at dusk or dawn, suggesting that the majority of this species are flying over the site during nocturnal migration.

4.2 Assessment of Risk

The assessment of collision risk by migratory birds with turbines using radar and acoustic data is difficult and has not been proven to be effective. In general, mortality associated with windfarms is thought to be low, relative to the effects of other human infrastructure (Zimmerling et al. 2013). While risk may be correlated with volume of migration, without multiple, standardized radar/acoustic studies conducted across a broader region (i.e., across Nova Scotia), it is difficult to make definitive statements about whether the volume of migrants at any particular site is more or less than what might be expected elsewhere.

Risk of migratory bird collisions is also hypothesized to be increased when birds are landing within a project area or if large numbers of birds are “forced” to fly lower due to weather variables such as fog. As indicated above, it appears from the data that large numbers of birds are not using the Project area as a stopover site.

4.3 Comparison with 2021 Results

In 2021, Ausenco completed radar and acoustic monitoring at the Project site using the same approach taken in 2022 (see Hemmera 2021). In 2021, spring monitoring occurred from May 10 through June 3. In 2022 monitoring was initiated on April 23 and continued until June 8. While some levels of migration were observed each night across the 2022 monitoring period, large peaks in migration activity were not detected by the radar prior to mid-May in 2022, suggesting that the bulk of the 2021 spring season was captured. However, acoustic detections of sparrows were observed in early May of 2022 which may have been missed during the 2021 monitoring season.

Fall monitoring was extended later into the season in 2022 compared to 2021. However, no large movements of migrants were detected late in the 2022 season to suggest activity was missed during 2021.

Acoustic analysis techniques improved from 2021. The 2021 analysis only provided detail on the movement patterns of warblers and sparrows. Therefore, additional information related to species composition of migrants was available in 2022. The 2022 data revealed the presence of two species at risk and provided more information on thrushes in the Project area. As discussed in the methods above, the identification of thrushes required a separate analysis compared to warblers and sparrows. This was partly necessitated by the presence of spring peepers (*Hyla crucifer*) located throughout the project area whose calls are similar in frequency to thrushes, making identification difficult.

Overall, the same general pattern of activity was observed in 2022 as in 2021. Most migration was observed during light tailwinds, the activity was detected over relatively few nights, and little activity was observed near the dawn hours.

4.4 Ministerial Information Requests

The ministerial response to the initial Environmental Registration Document submission for the Project provided two additional information requests which are addressed, in part, with these data, and which are discussed below.

Explanation of the discrepancies related to rate of nocturnal passage/migration in research conducted for nearby projects.

The explanations for the differences in the depiction of nocturnal migration at this Project compared to other projects are extensive, and include, but are not limited to, the following:

- Technology:
  - Radar type (e.g., x-band, s-band), antenna type (e.g., open array, parabolic dish), power output, manufacturer, and model all influence the number of targets detected.
  - For NFCs, acoustic sensor manufacturers, microphone type (directional versus omni-directional), sensitivity and configuration influence the range of the sensor which would in turn influence the number of NFCs detected.
- Analysis methodologies:
  - Radar signal processing (the identification of targets), and signal filtering (the elimination of rain and other clutter from the signal) influence the number of radar targets selected as relevant to the study.
  - Methods of identification and classification of acoustic files influence the number individuals and species detected (e.g., manual identification versus AI approaches to species identification).
- Field methodologies:
  - Radar orientation (vertical or horizontal) and line of sight may influence the area of space sampled by the radar. Differences in radar elevation across studies make comparisons problematic.
  - Configuration of sensors in the field influences the number of acoustic files recorded due to factors such as microphone orientation, field placement (i.e., potential for double counting), surrounding vegetation, and presence of background noise.

In addition to the examples above that pertain to the tools used to sample migration, there are also factors that are beyond the control of the study design, such as differences in habitat, topography, and other site-specific factors that may influence the congregation of birds both in flight and during stopover.

Finally, studies conducted in different years sample potentially widely different populations. For example, simple demographic changes, climate change and other factors influence migration patterns and population levels of some species. Therefore, the value in making comparisons among years is limited.

In summary, at present it is not realistic to properly quantify numerical differences observed among different projects, even those that employ the same or similar technology. Rather, it is more appropriate to examine *patterns* of detection (temporally and altitudinally) which provide insight into migration at the site. The patterns of migration observed at the Project area show migration strongest during nights with tailwinds, low precipitation, and focused on few nights across each season. Also, during nights of large migration, most birds are observed to be above the proposed RSA of the Project.

Additional information to support conclusions regarding potential turbine collisions.

This report provides an additional year of data regarding the passage of nocturnal migrants over the Project area (see Section 4.3). These additional data show similar trends in the movements in migrants, particular with respect to the height of migrants. While some level of turbine collisions is anticipated during the operation of the Project, there are no obvious data trends that suggest large movements of migrants will be present within the turbine RSA.

4.5 Limitations

The following are limitations related to the data collected that should be considered when drawing conclusions from the data presented within this report.

Radar Data

Radar data can provide a good understanding of nocturnal avian migration trends at proposed wind energy project sites. However, there are limitations to how the data are collected and can be interpreted, such as:

- While it is assumed that most targets are migratory birds, some proportion of targets may be from insects, bats, clutter and/or precipitation
- Species identification using radar alone is not possible
- As distance from the radar increases, the detection probability of small (i.e., passerine sized) targets decreases. Because we know migration density decreases with increased altitude, the interplay between detection probability and migrant behaviour is difficult to measure.
- Detections at very low altitudes (i.e., below 70 m) is difficult to capture in most onshore wind energy sites due to topography and tree cover which cause clutter in the radar signal.

Acoustic Data

While NFC calling rates provide a good representation of migratory activity (e.g., species present, trends in activity), there are many factors that influence calling rates; several of which are:

- Microphone sensitivity (detection rates may change based on weather, background noise, vegetation cover, and technology)
- Time of year (it is unknown how migratory urgency may impact calling rates)
- Time of night (calling rates may be higher during the early portion of the night to entice stopovers to initiate migratory flight, or in the morning, when individuals are choosing to land for the day). How this influences detection rates is poorly understood.
- Weather conditions (it is unknown how weather conditions may impact calling rates)
- Density of migrants (it is unknown if calling rates increase or decrease with increased migrant density)
- Species composition (while it is known that not all species call, the calling frequency is known for many species that do produce NFCs).

5.0 Closure

This work was performed in accordance with the Purchase Order between Hemmera Envirochem Inc. (Hemmera), a wholly owned subsidiary of Ausenco Engineering Canada Inc. (Ausenco), and Natural Forces Developments LP, dated February 24, 2022 (Contract). This report has been prepared by Hemmera, based on fieldwork conducted by Hemmera, for the sole benefit and use by Natural Forces Developments LP. In performing this work, Hemmera has relied in good faith on information provided by others and has assumed that the information provided by those individuals is both complete and accurate. This work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and Project terms of reference; further, the findings are time sensitive and are considered valid only at the time the report was produced. The conclusions and recommendations contained in this report are based upon the applicable guidelines, regulations, and legislation existing at the time the report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

We sincerely appreciate the opportunity to have assisted you with this Project and if there are any questions, please do not hesitate to contact the undersigned.

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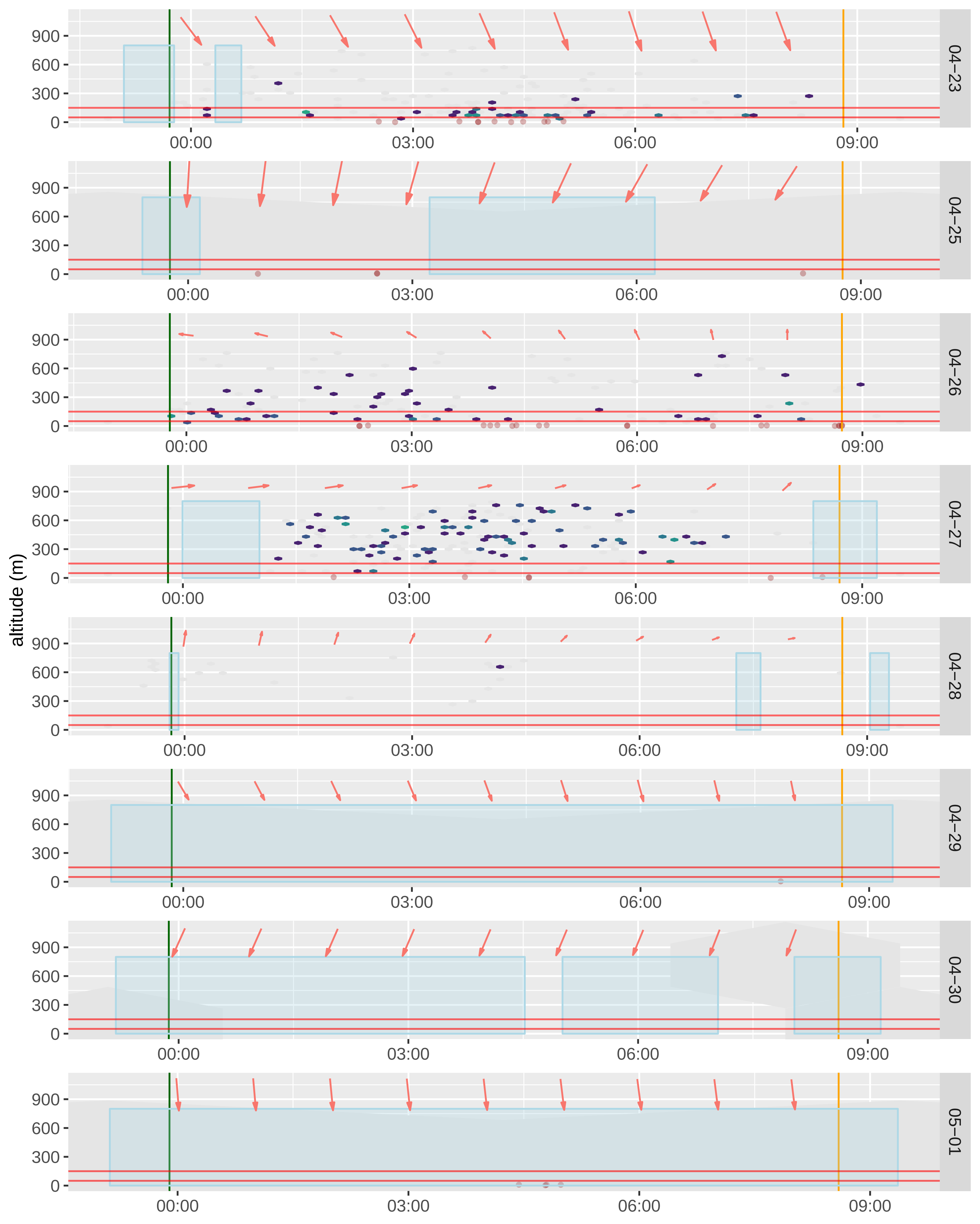
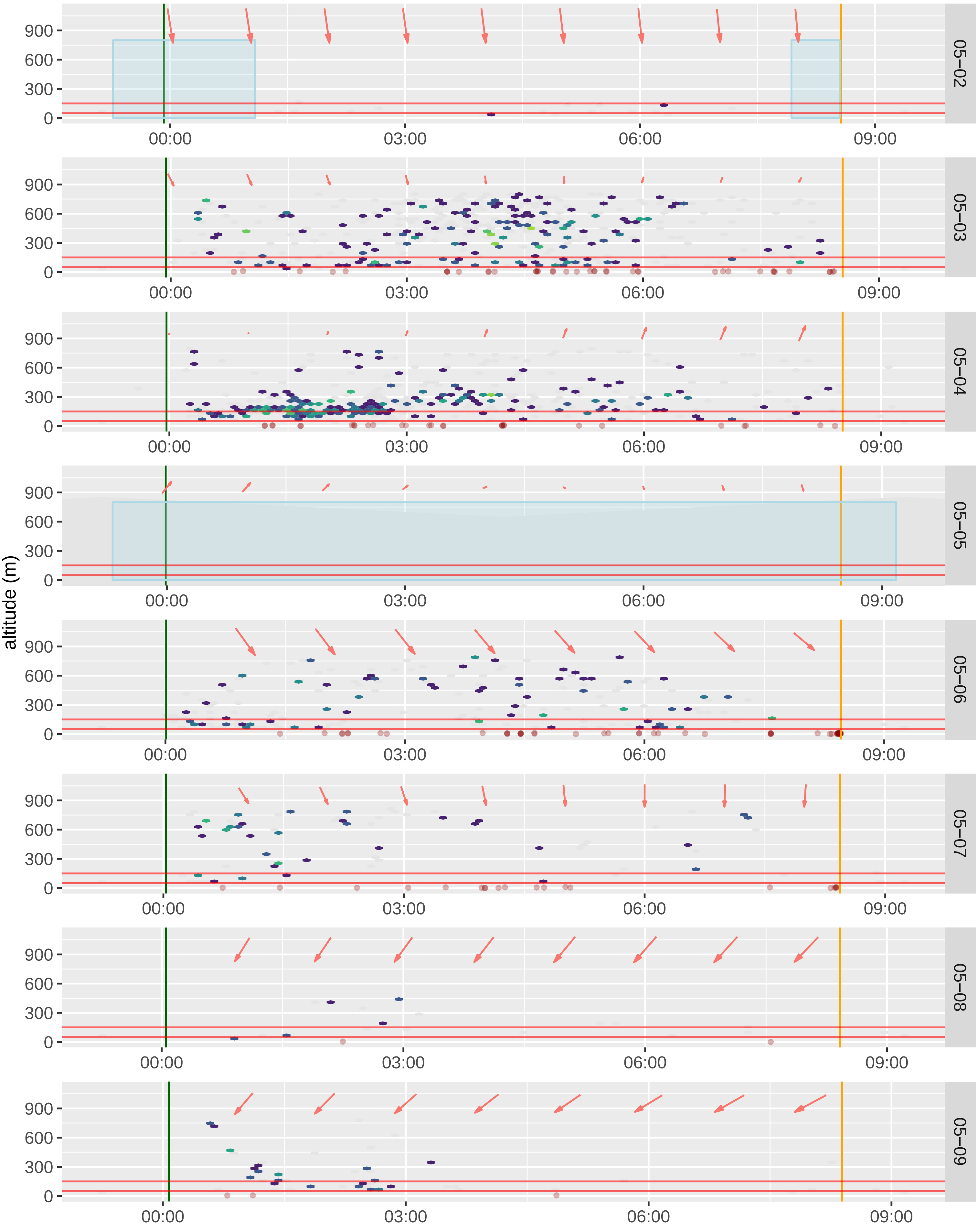
Appendix A

Complete Spring Radar Data

OVERVIEW

The following plots provide the radar and acoustic detections and wind conditions on all nights monitoring at the Project in spring 2022. Each plot is a separate night, with the beginning and end of civil twilight indicated by the vertical green and yellow lines, respectively. Date and time are on the x-axis and altitude is on the y-axis. Hexagonal points are radar detections divided into time and altitude bins and are scaled from light grey (few detections) through dark purple to yellow (many detections). Acoustic detections (a single NFC) are red points along the base of each plot (These have not been processed, and so on some nights may be contaminated by insects, raindrops or other noise). Wind direction and strength at approximately 700 m (red arrow) for each hour are displayed at the top of each plot. The blue box represents a period of rain when we were unable to distinguish between raindrops and bird detections. Red lines represent the approximate altitudinal range of the rotor sweep area


altitude (m)
900
600
300
0
00:00
03:00
06:00
09:00
04–23
04–25
04–26
04–27
04–28
04–29
04–30
05–01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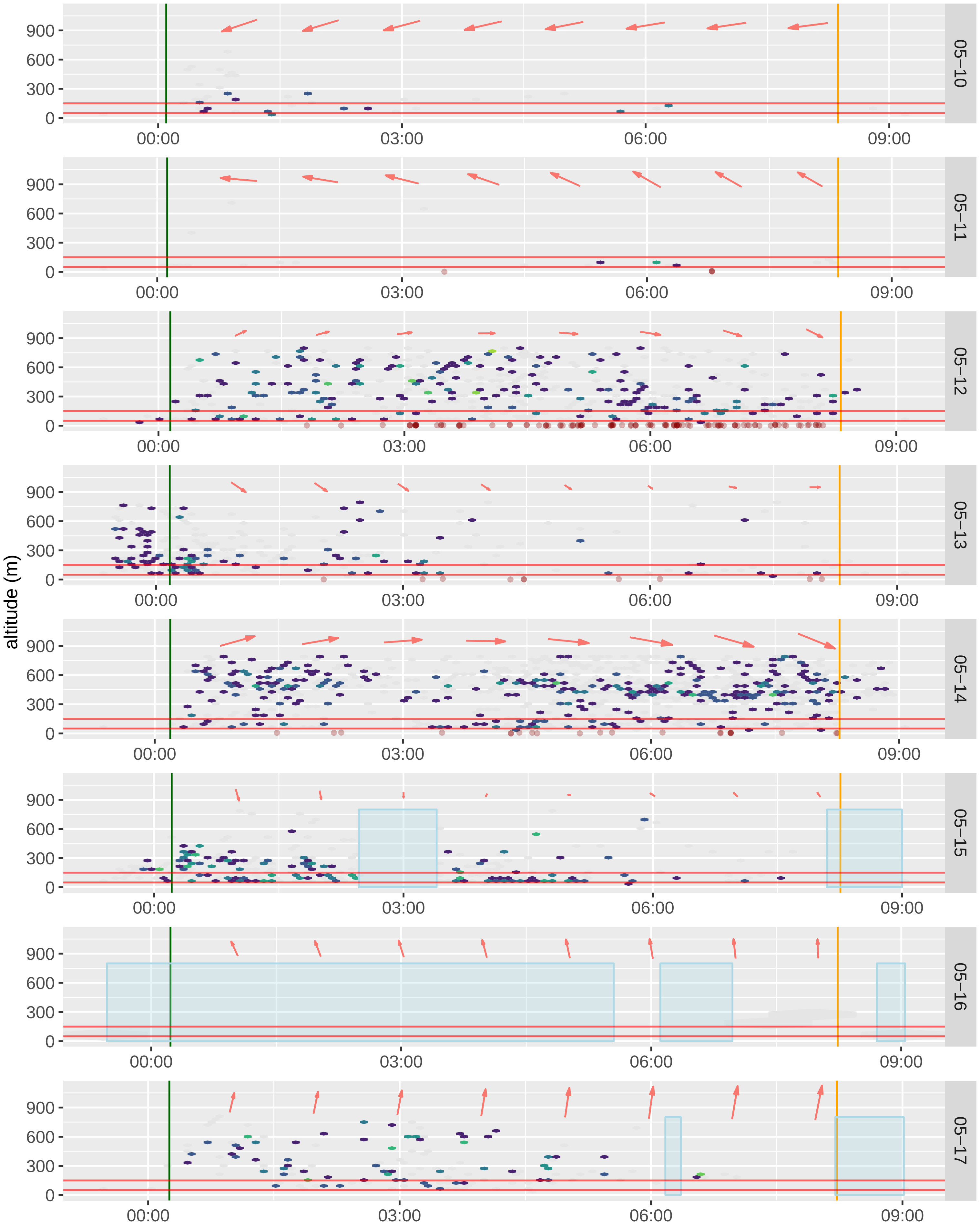
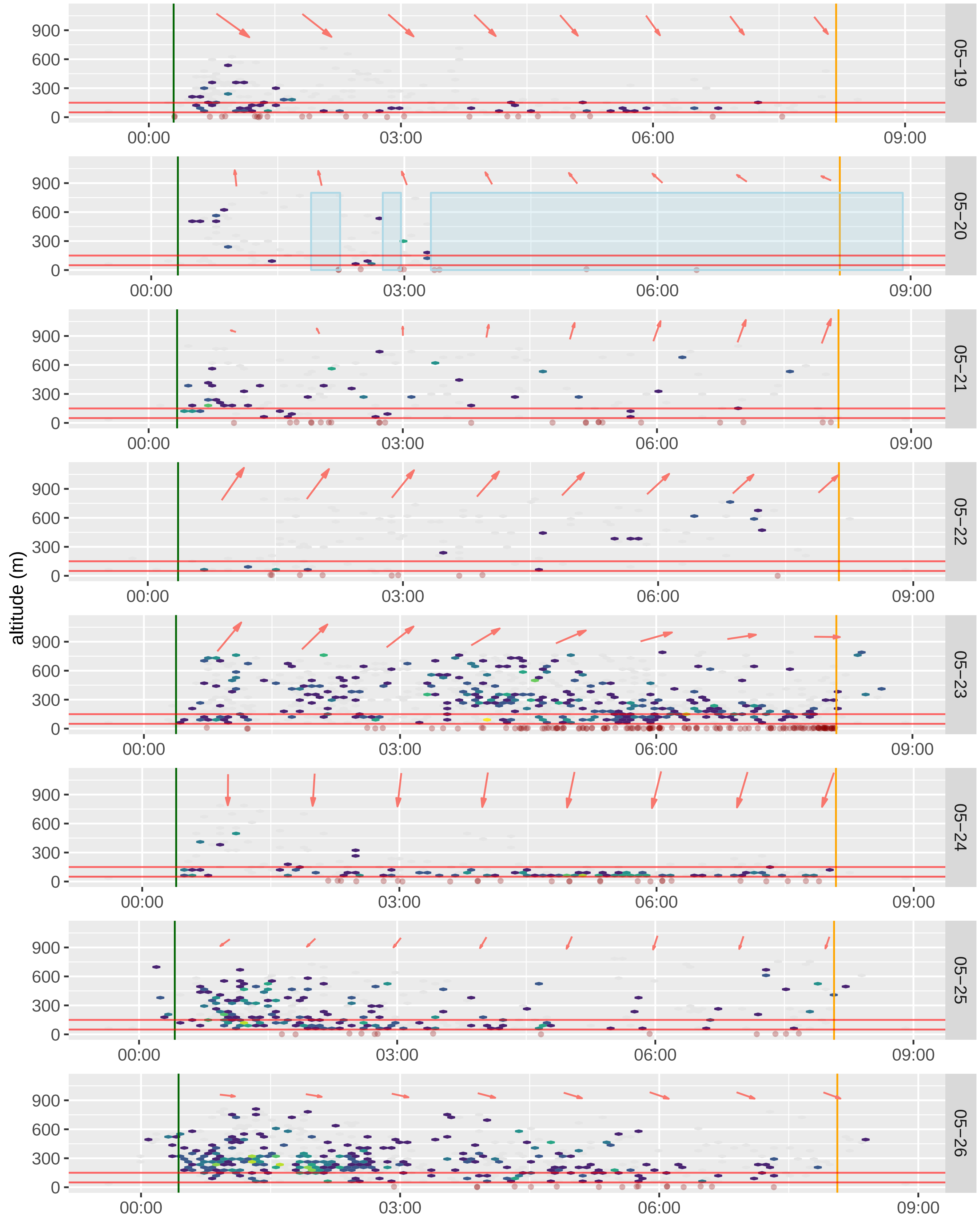
900
600
300
0
00:00
03:00
06:00
09:00
05−02
05−03
05−04
05−05
05−06
05−07
05−08
05−09



altitude (m)
0
300
600
900
00:00
03:00
06:00
09:00
05−10
05−11
05−12
05−13
05−14
05−15
05−16
05−17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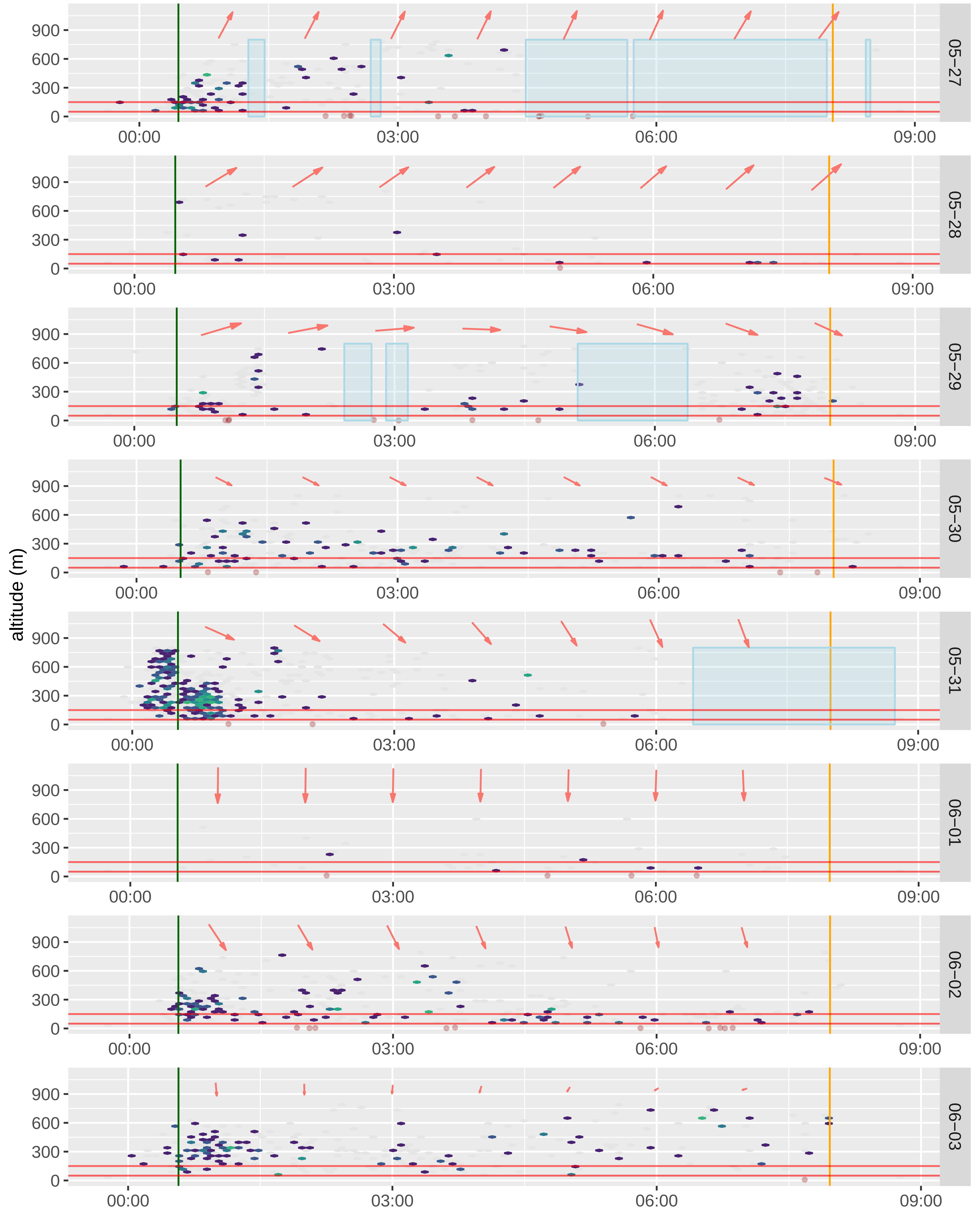
0
300
600
900
00:00
03:00
06:00
09:00
05−19
05−20
05−21
05−22
05−23
05−24
05−25
05−26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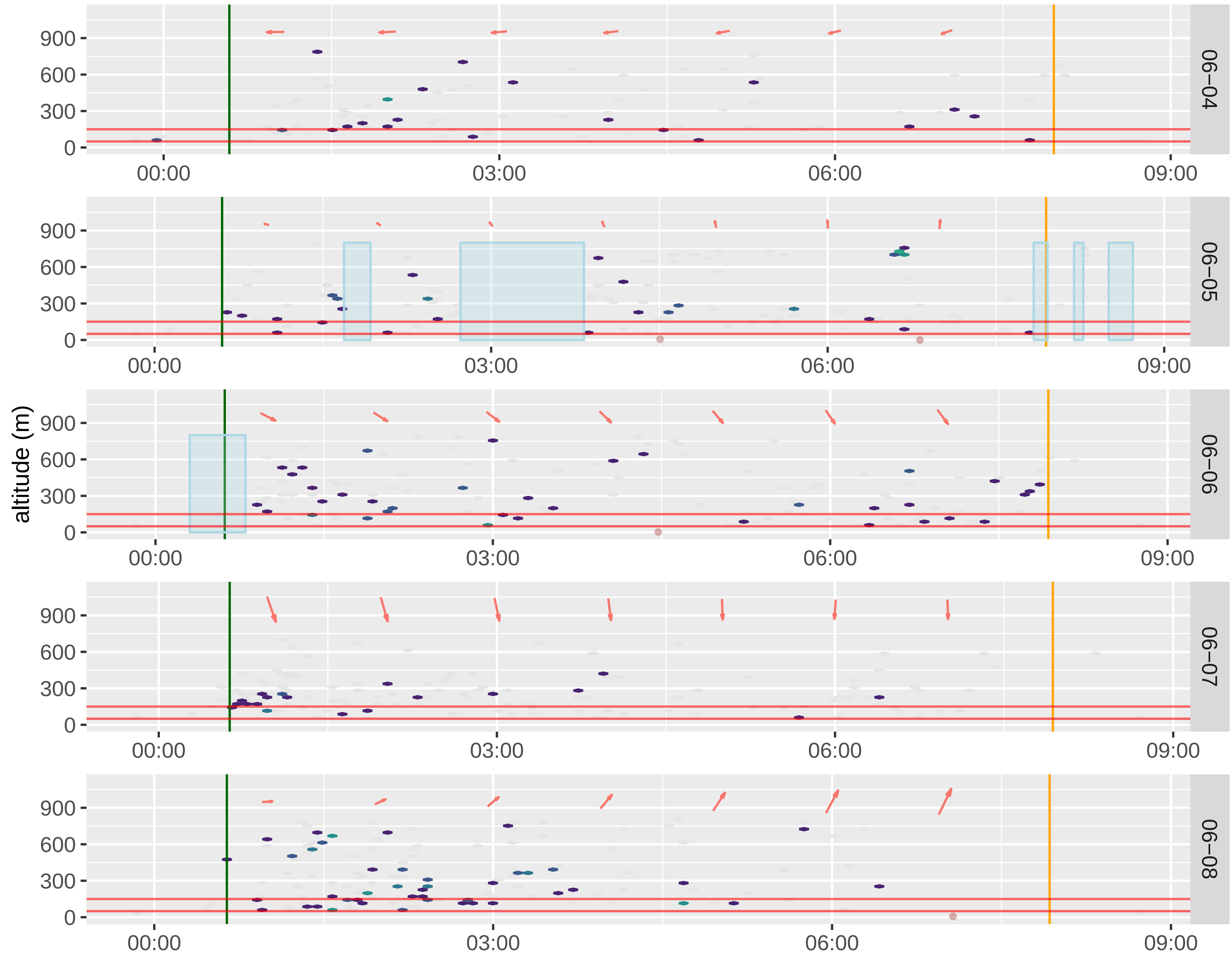
0
300
600
900
00:00
03:00
06:00
09:00
05–27
05–28
05–29
05–30
05–31
06–01
06–02
06–03

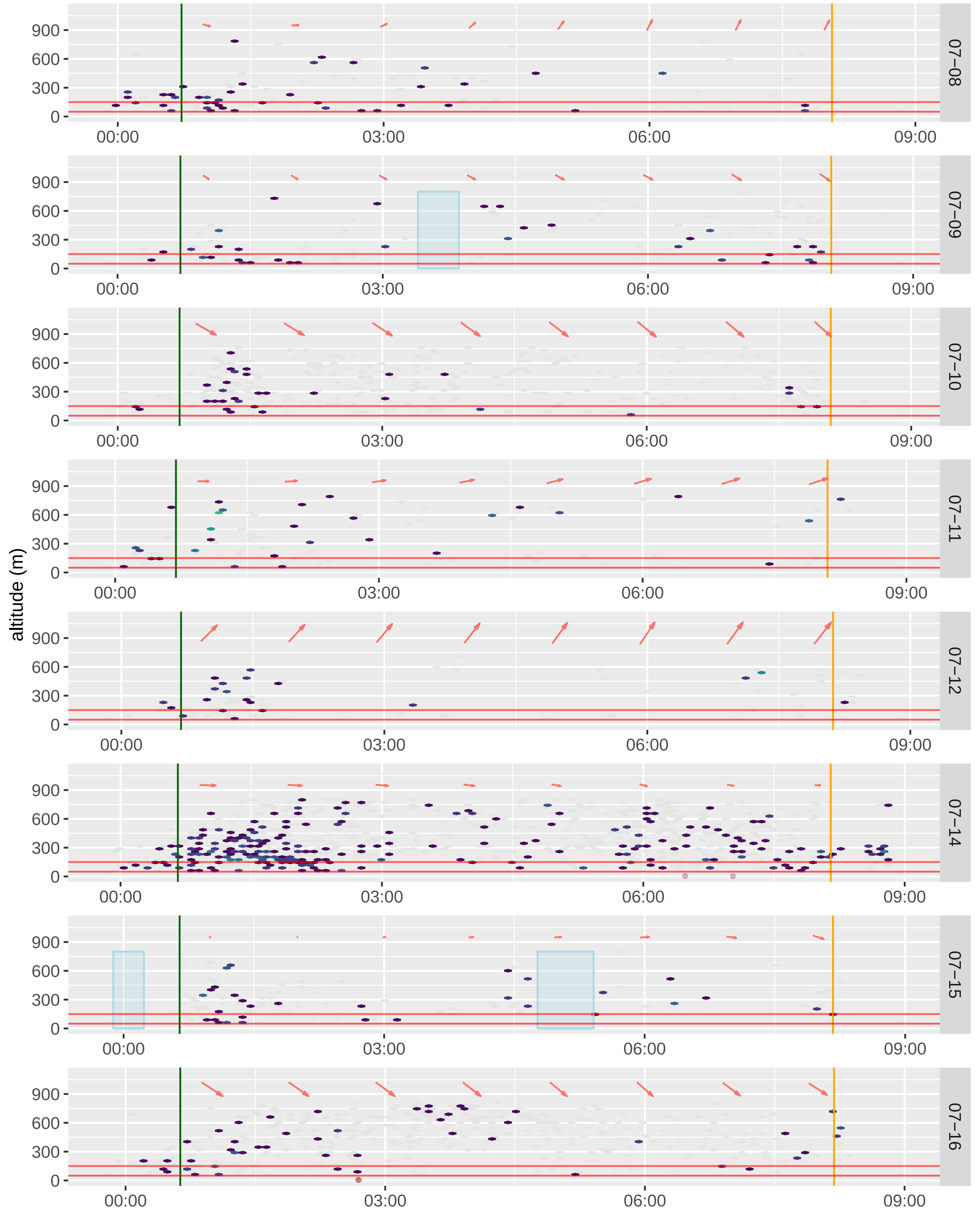

altitude (m)
900
600
300
0
00:00
03:00
06:00
09:00
06−04
06−05
06−06
06−07
06−08

Appendix B

Complete Fall Radar Data

OVERVIEW

The following plots provide the radar and acoustic detections and wind conditions on all nights monitoring at the Project in fall 2022. Each plot is a separate night, with the beginning and end of civil twilight indicated by the vertical green and yellow lines, respectively. Date and time are on the x-axis and altitude is on the y-axis. Hexagonal points are radar detections divided into time and altitude bins and are scaled from light grey (few detections) through dark purple to yellow (many detections). Acoustic detections (a single NFC) are red points along the base of each plot (These have not been processed, and so on some nights may be contaminated by insects, raindrops or other noise). Wind direction and strength at approximately 700 m (red arrow) for each hour are displayed at the top of each plot. The blue box represents a period of rain when we were unable to distinguish between raindrops and bird detections. Red lines represent the approximate altitudinal range of the rotor sweep area.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600
300
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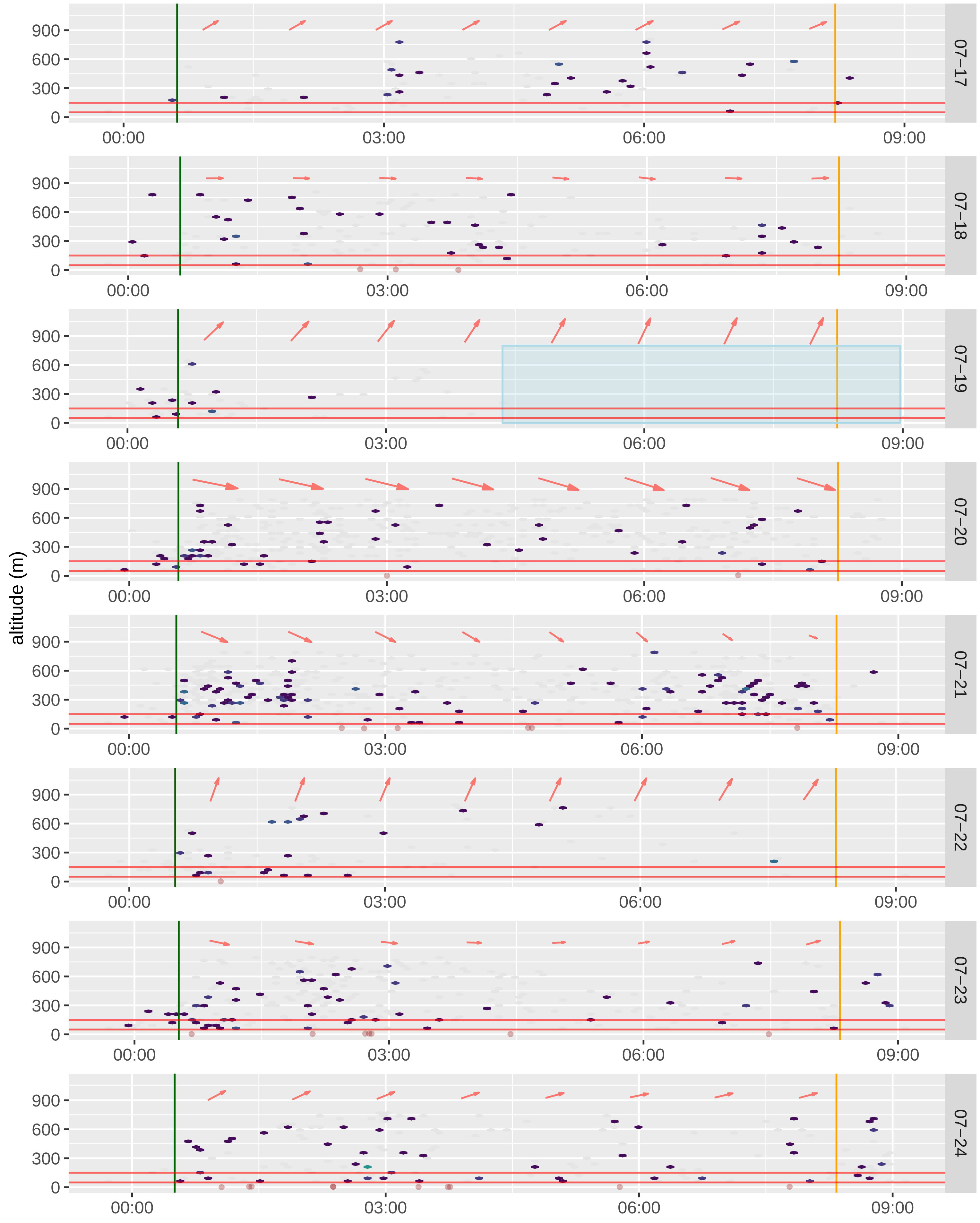
09:00
07−08
07−09
07−10
07−11
07−12
07−14
07−15
07−16


altitude (m)
0
300
600
900
00:00
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07−17
07−18
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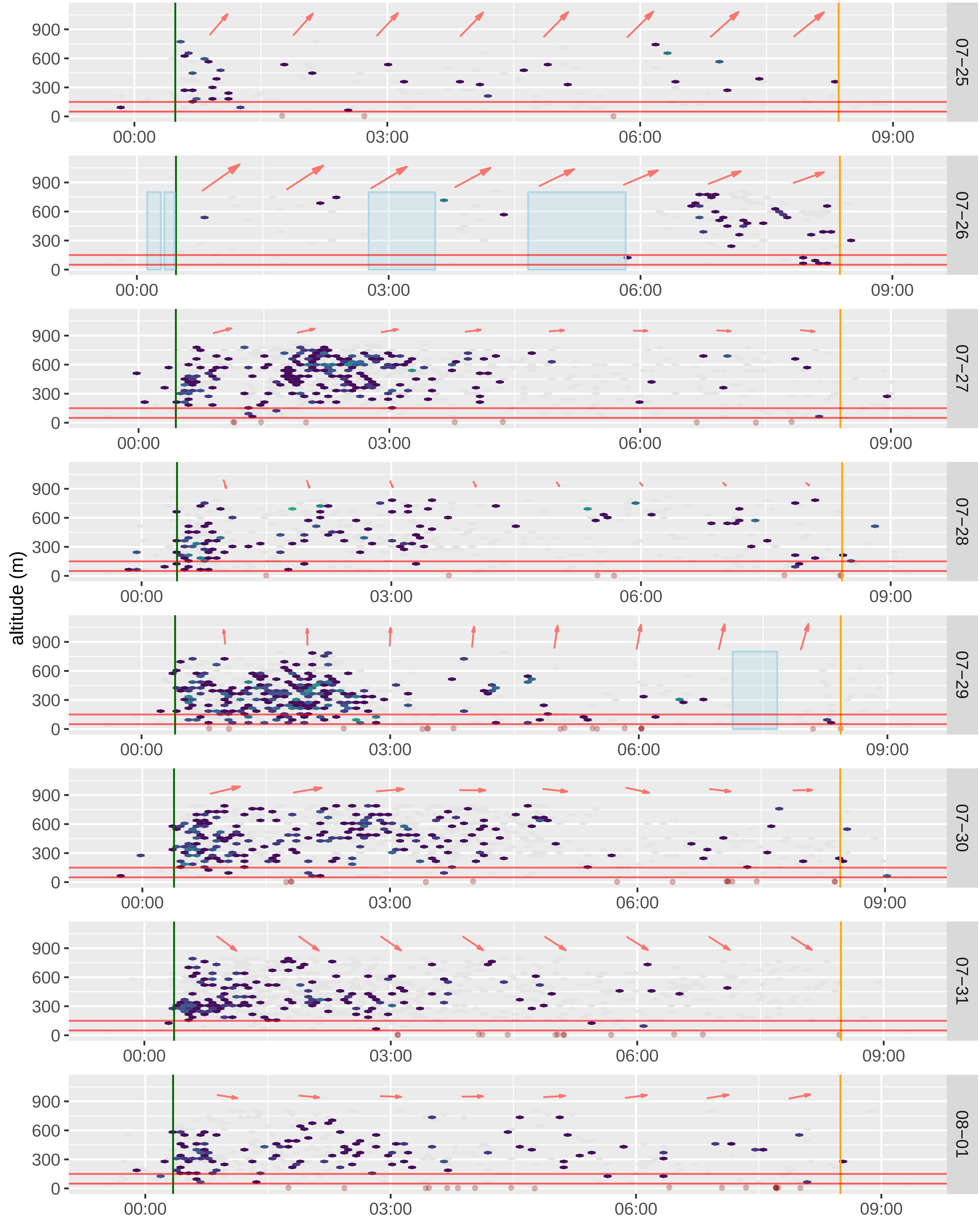
07−20
07−21
07−22
07−23
07−24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300
0
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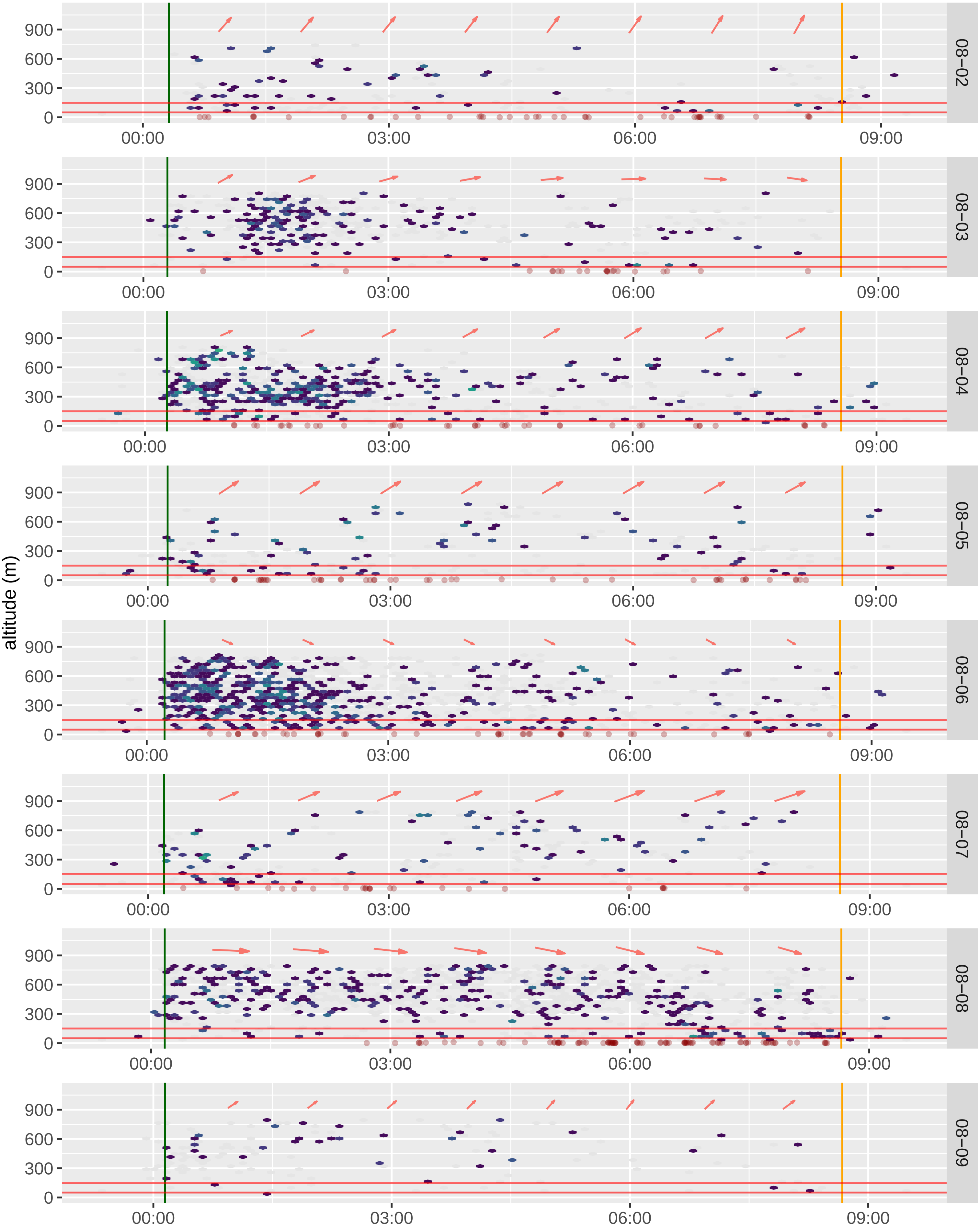
09:00
07−25
07−26
07−27
07−28
07−29
07−30
07−31
08−01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300
600
900
00:00
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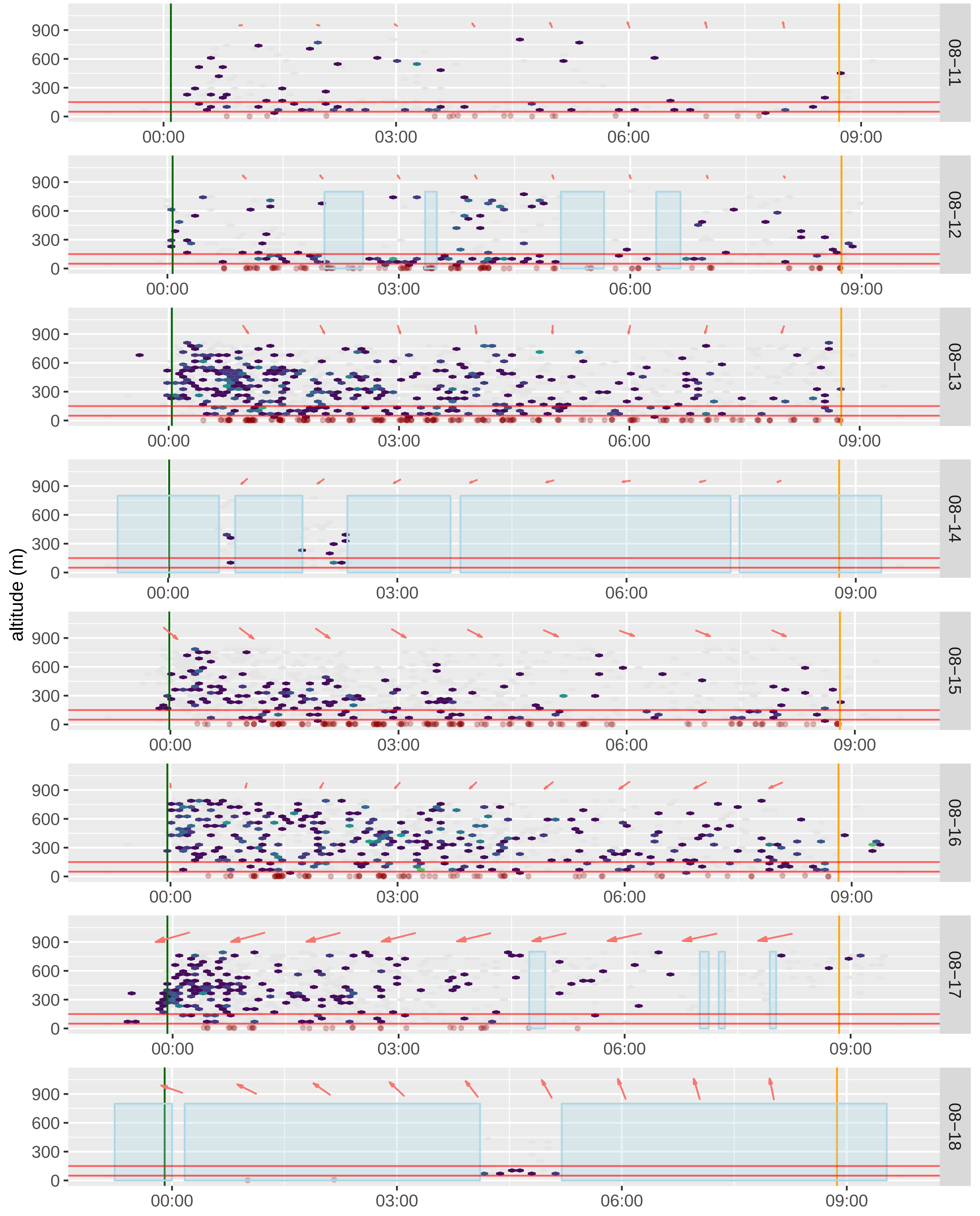
09:00
08−02
08−03
08−04
08−05
08−06
08−07
08−08
08−09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900
600
300
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06:00
09:00
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08−12
08−13
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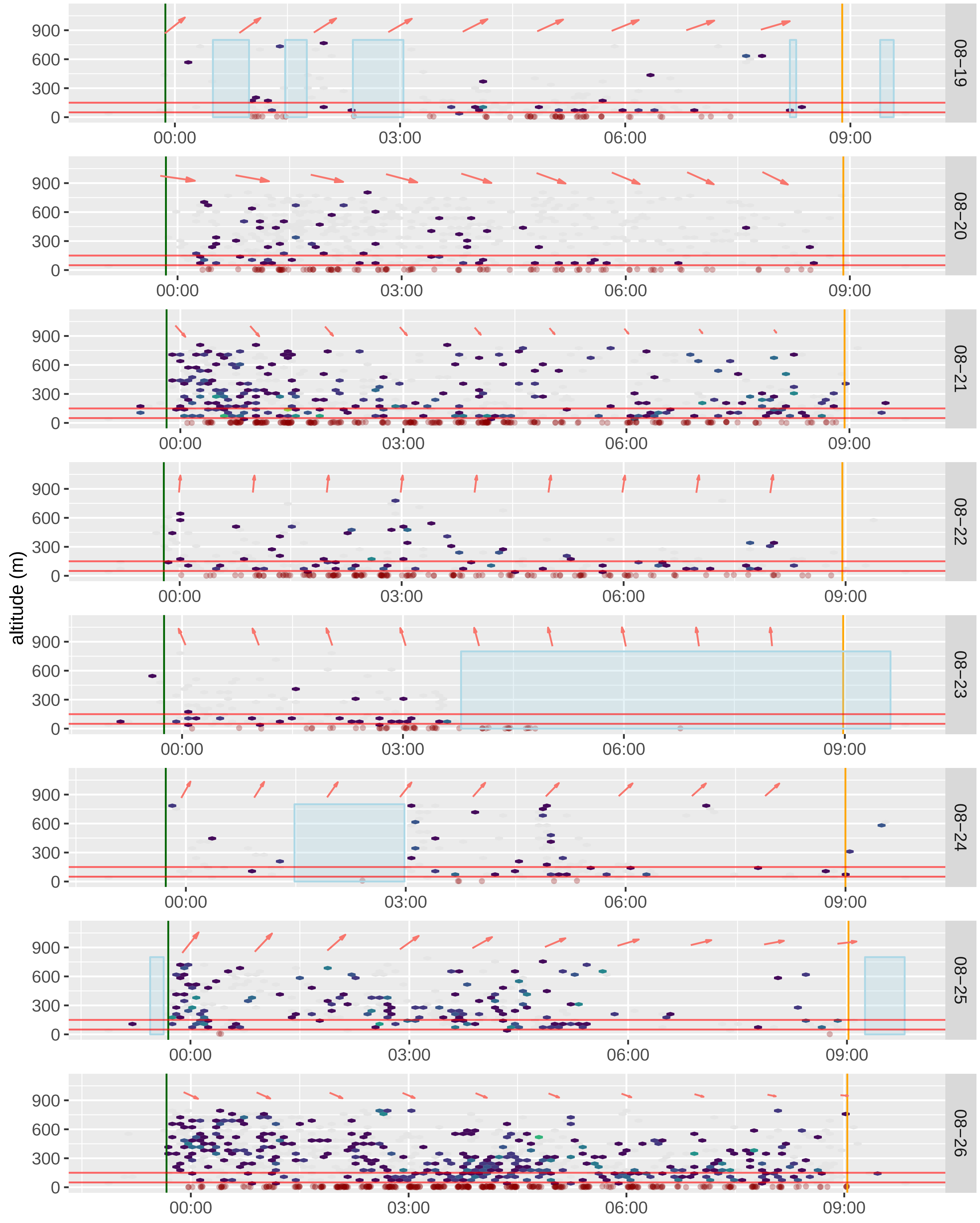
08−15
08−16
08−17
08−18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900
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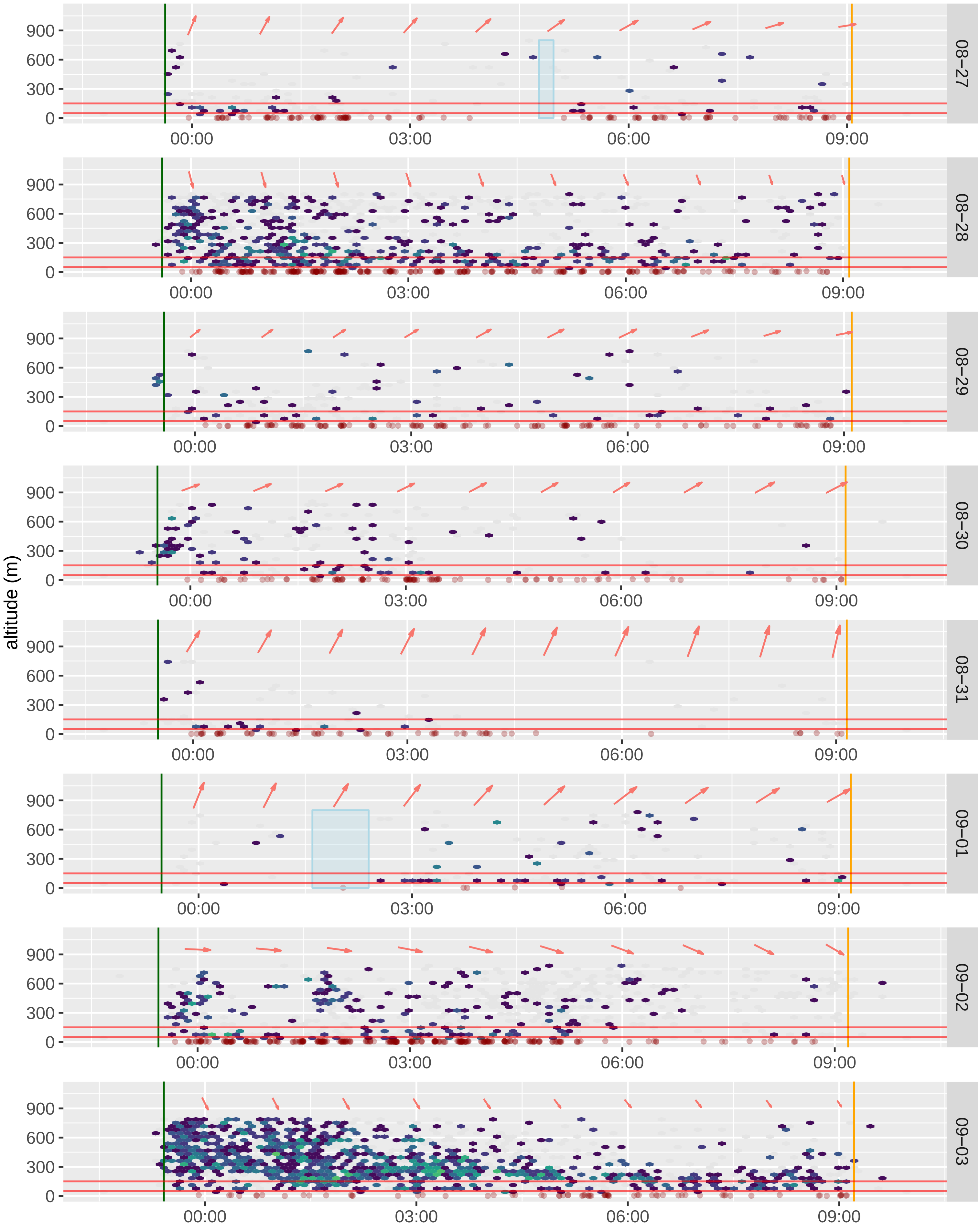
08−19
08−20
08−21
08−22
08−23
08−24
08−25
08−26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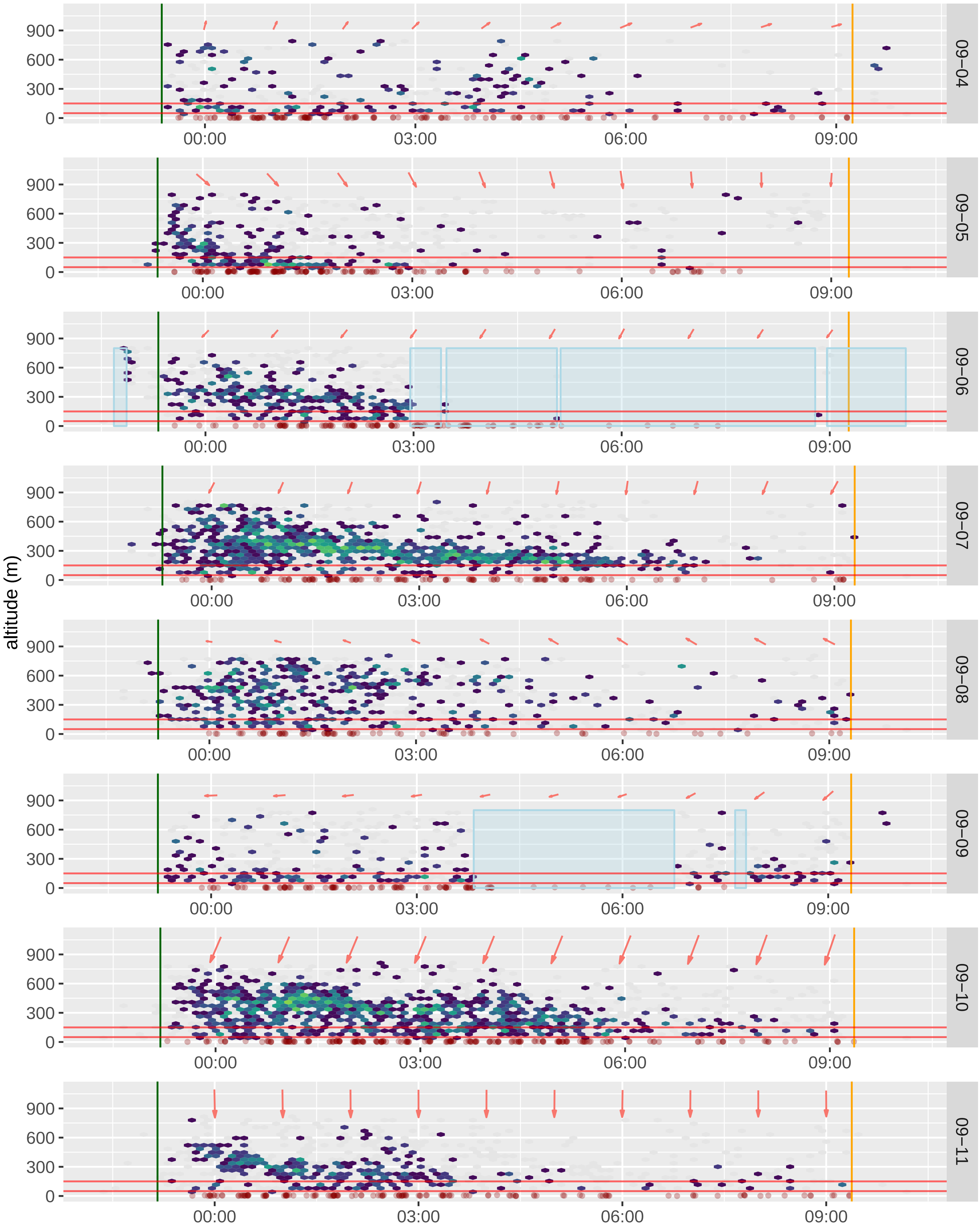
08–28
08–29
08–30
08–31
09–01
09–02
09–03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900
600
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00:00
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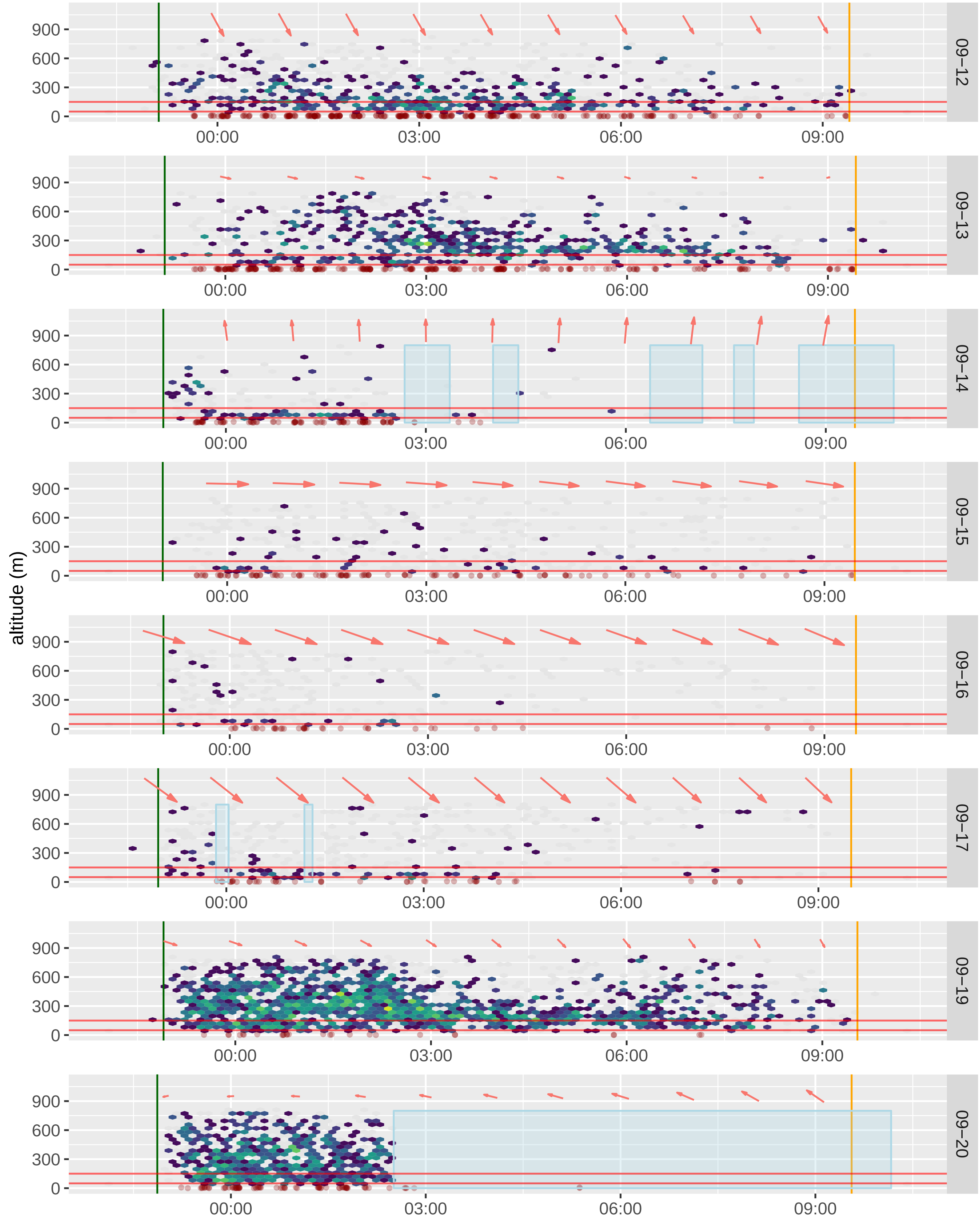
09−07
09−08
09−09
09−10
09−11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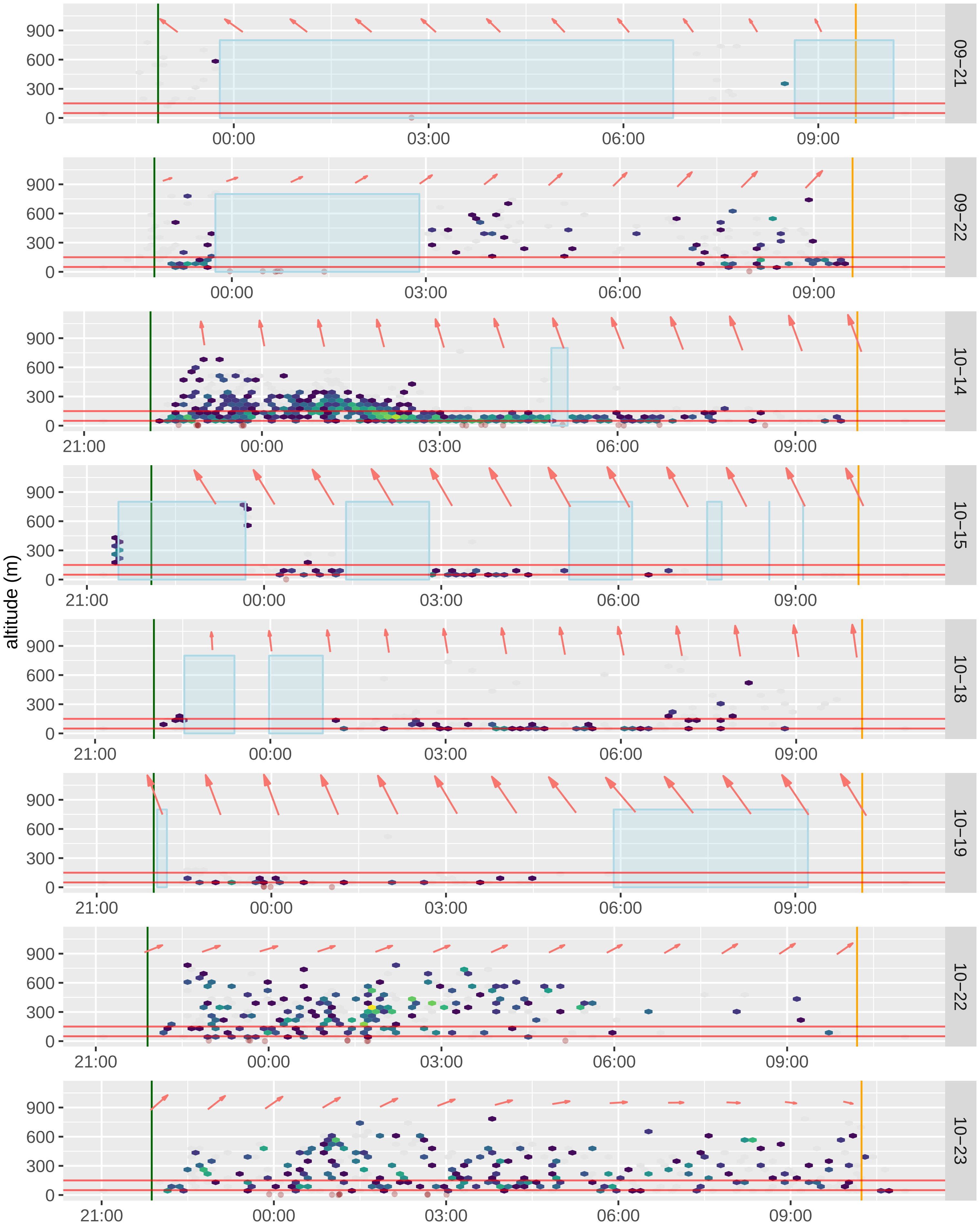
09−17
09−19
09−20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900
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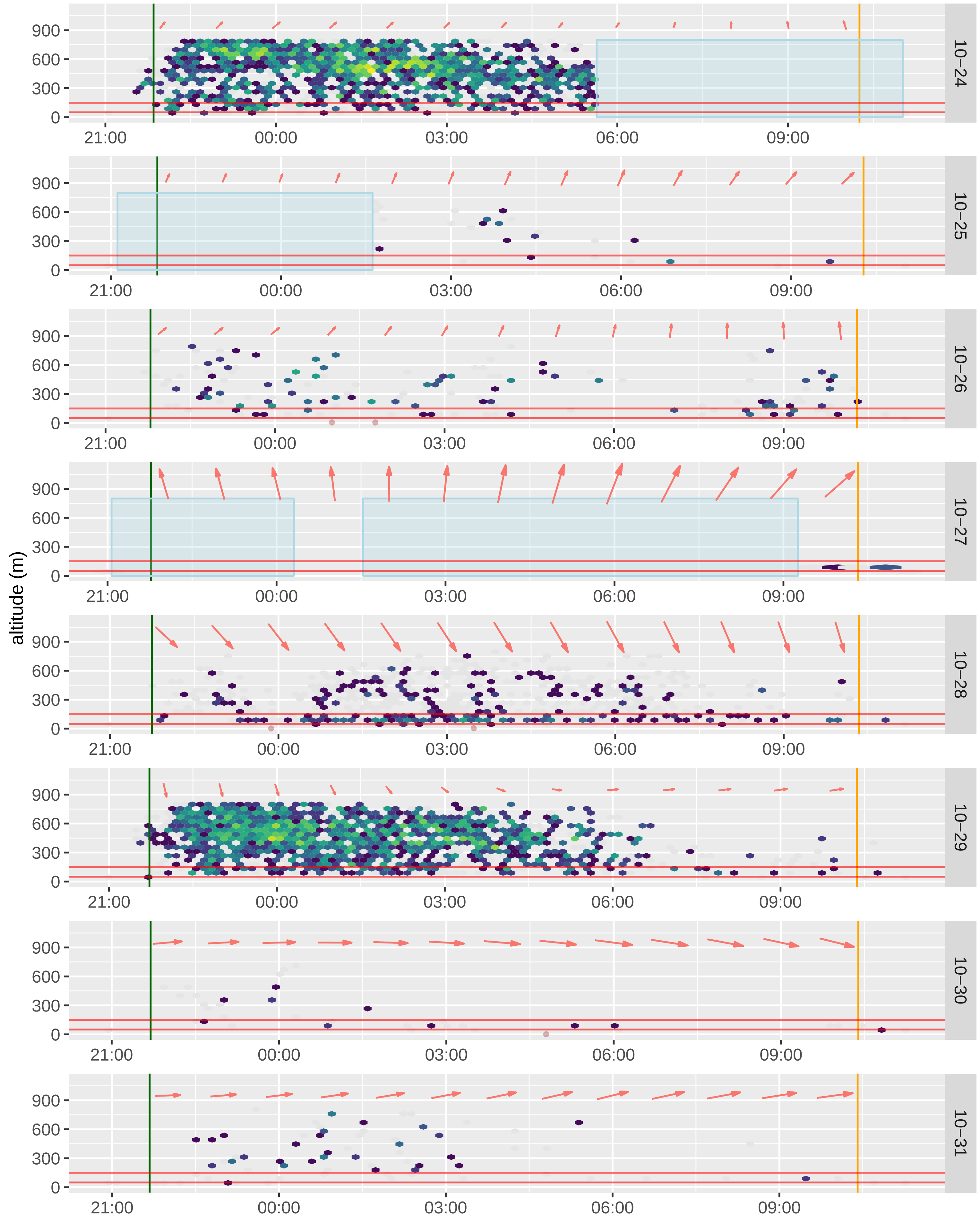
09–21
09–22
10–14
10–15
10–18
10–19
10–22
10–23



altitude (m)
900
600
300
0
21:00
00:00
03:00
06:00
09:00
10−24
10−25
10−26
10−27
10−28
10−29
10−30
10−31


altitude (m)
0
300
600
900
00:00
06:00
12:00
21:00
03:00
09:00
11–01
11–02
11–03
11–07
11–08
11–09
11–10

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