Modeling to Determine the Condition of Excess Emissions for 2023 ODSVRA

J.A. Gillies and J. Mejia, Division of Atmospheric Sciences, Desert Research Institute, Reno, NV

Staff, Oceano Dunes State Vehicular Recreation Area, Oceano, CA

The second amendment to the Stipulated Order of Abatement (SOA), adopted in October 2022, modified the key mass emissions and concentration reduction requirements from the original SOA that had formed the basis for State Parks' Dust Control Program and 2019-2022 ARWP documents. Specifically, the October 2022 SOA amendments replaced the requirement to reduce baseline PM_{10} emissions by 50% and achieve absolute ambient air quality standards with a new requirement that is "designed to eliminate emissions in excess of naturally occurring emissions from the ODSVRA that contribute to downwind violations of the state and federal PM_{10} air quality standards".

To determine if the ODSVRA is, or is not, in a condition of excess emissions required major modifications to the DRI emissions modeling process (Mejia et al., 2019) and model inputs. The changes to the model were developed principally by the Scientific Advisory Group (SAG) and were presented to California Department of Parks and Recreation (CDPR) on December 19th, 2023*.

These recommendations were:

1. In the model, the ODSVRA is to be divided into emissivity zones based on location (non-riding area north, riding south, etc.) instead of using the 21 m by 21 m grid that had been used in the past.
2. All PI-SWERL data from 2013 to 2022 will be used for both the current and pre-disturbance modeling scenarios (Table 1, below).
3. The median of the emissivity values (E, mg m^{-2} s^{-1}) from the distribution of emissivity values for each of the (three) PI-SWERL test friction velocities (u_* m s^{-1}) will be used to derive an emissivity relation of the form $E = a\, u_*^{b}$ that characterizes the emissivity in the designated zones for both the current and the pre-disturbance scenarios.
4. The pre-disturbance scenario will be based on the non-riding area emissivity overlain on the riding area for three defined zones identified in Table 1 and as shown in Fig. 1 (below). The current year scenario will be based on the emissivity of the zones identified in Table 1 and as shown in Fig. 2 (below).

On Feb. 8, 2024, the SLOCAPCD conditionally approved the SAG recommendations and CDPR instructed DRI to carry out a modeling exercise based on application of these recommendations within the emission model to evaluate the condition of being in excess of emissions between the current year ODSVRA (i.e., emissivity zones, dust emission control zones, and vegetation cover as of 2023) and 1939, representing the naturally occurring emissions case.

This report describes the changes to the DRI emission model that were required to estimate the emissions in metric tons per day from the defined zones (Table 1) and the total emissions, i.e., the summation of emissions from the zones representing the current conditions and the

* Document can be found at: https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/SAG%20Memo_Emissivity%20Grids%20for%20Future%20Modeling%20of%20Excess%20Emissions%20-%2020231219.pdf

Table 1. The defined zones of emissivity and the data source for deriving the emissivity relations.

Zones for Current Year	**Emission Source Data for Emissivity Relation**
Non-Riding Area (NRA) North	All 2013-2022 PI-SWERL measurements located in NRA North Zone
Non-Riding Area (NRA) Central	All 2013-2022 PI-SWERL measurements located in NRA Central Zone (not including FRA, PE, SE)
Non-Riding Area (NRA) South	All 2013-2022 PI-SWERL measurements located in NRA South Zone
Riding Area (RA) Central-North	All 2013-2022 PI-SWERL measurements located in RA Central-North Sub-Region
Riding Area (RA) Central-South	All 2013-2022 PI-SWERL measurements located in RA Central-South Sub-Region
Foredune Restoration Area (FRA)	Only 2022 PI-SWERL measurements located in the FRA
Plover Exclosure (PE)	Only 2022 PI-SWERL measurements located in the PE
Seasonal Exclosure (SE)	Weighted average of riding and non-riding measurements in SE areas
Zones for Pre-Disturbance (1939)	
North (same as NRA North)	All 2013-2022 PI-SWERL measurements located in NRA North Zone
Central (same as NRA Central but also including footprint of RA areas between the north and south boundaries, and the FRA, PE, and SE areas)	All 2013-2022 PI-SWERL measurements located in NRA Central Zone (not including measurements from FRA, PE, SE)
South (same as NRA South)	All 2013-2022 PI-SWERL measurements located in NRA South Zone

conditions of 1939. The difference in the total mass emissions is used to evaluate if the current condition is, or is not, in a state of excess emissions.

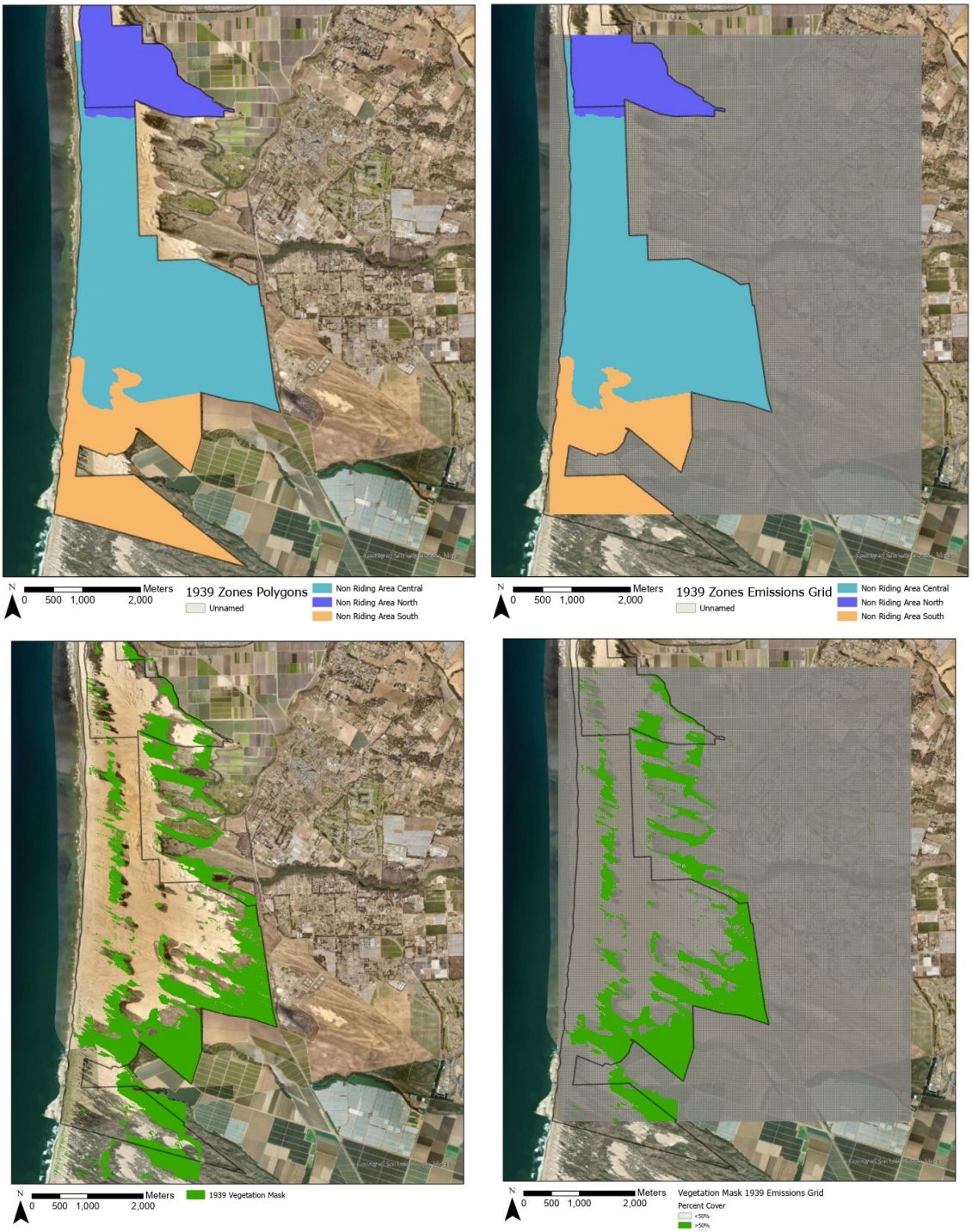

Figure 1. The emissivity zones (upper panels) and vegetation cover zones (lower panels representing conditions in 1939. Maps show the SAG-provided polygons (left) compared with the grid-defined zones (right). Gray rectangle shown in the maps on the right defines the modeling domain.

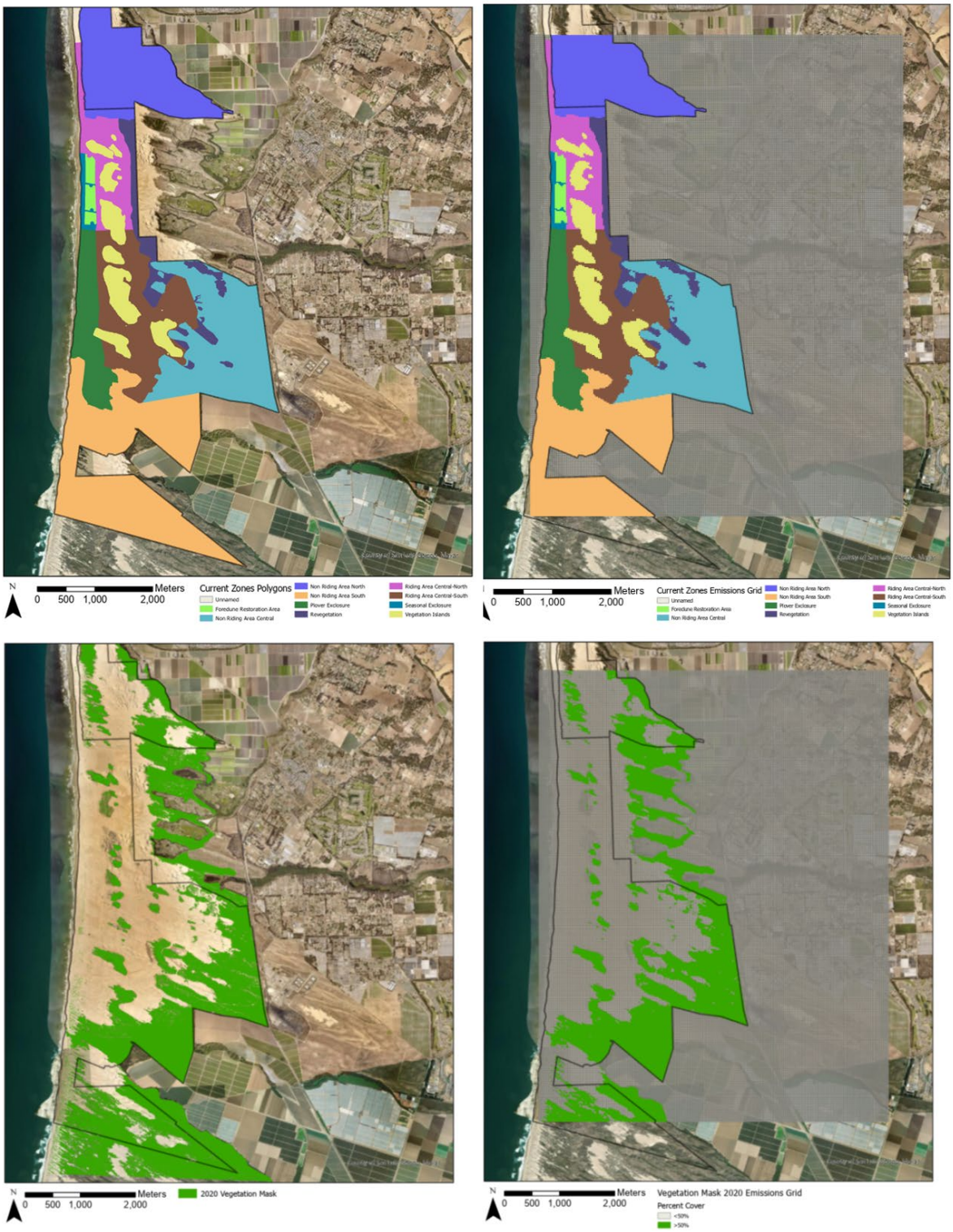

Figure 2. The emissivity and dust control zones (upper panels), and vegetation cover zones (lower panels) of the current ODSVRA. Maps show the SAG-provided polygons (left) compared with the grid-defined zones (right). Gray rectangle shown in the maps on the right defines the modeling domain.

Defining the Zones within the DRI Emission Model

The switch to zones with different emissivity relations as opposed to the interpolated/extrapolated scheme used previously for modeling mass emissions from the ODSVRA created an unforeseen challenge to define the zones within the DRI emission model. The emission model written in Python could not handle the conversion to a zone-based approach basically for lack of Geographic Information System (GIS)-capability to deal with the complexity of zones within zones (e.g., a vegetation zone embedded within an emission zone), which caused the model to crash. To rectify the problem, it was necessary to convert the SAG-provided polygons created in a GIS program to an emissions grid using ArcGIS Pro.

To accomplish this the following steps were taken:

1) Using the X, Y coordinates of the underlying 21 m × 21 m grid cells (see Fig. 1 or 2) and associated tabular data from the DRI emission model, a projected point file was created in WGS1984 UTM Zone 10 N so that the points were equidistant.
2) A polygon file was created and the edges were snapped to the four distal corners of the domain grid to create a single large rectangle.
3) Each of the grid cells in the original DRI emission model has a defined center point for each 21 m × 21 m square. The Fishnet Tool in ArcGIS Pro was used to create a set of identical square polygons that filled the large rectangular polygon (step 2), and each square within the polygon had a coordinate referenced to the middle position of the original domain.
4) A "spatial join" in ArcGIS was used to label each square grid polygon with associated tabular data (e.g., emissivity coefficients, dust control status, etc.) for the point coordinates from the DRI emission model to create a shapefile.
5) To create the SAG-defined zones for the current and 1939 landscapes the SAG-provided polygon files were modified using the Intersect tool in ArcGIS Pro that assigned the square grids to an associated polygon zone.
6) As the underlying grid was composed of squares, at known borders (e.g., park boundary) it was necessary to define whether a square was interior or exterior to the park. If a grid square, by area, was ≥50% within the defined boundary that cut across the square, the square was considered to be in the park and within its specified zone.
7) The same process needed to be undertaken for the vegetation masks (current and 1939). The vegetation cover polygons (from UCSB and as modified by the SAG) were modified using the Intersect tool in ArcGIS Pro to estimate the percent cover in each square grid. If a grid square, by area, was ≥50% covered by vegetation it was considered to be non-emitting. If a grid square was <50% covered it was assigned the emissivity of the zone it was within. This 50% grid square area threshold has been used in previous reports and tested for uncertainty.
8) The fully attributed grids (i.e., zones, vegetation, dust control areas, etc.) were exported from ArcGIS Pro in the form of a shapefile and CSV that could be used within the DRI emission model.

This GIS processing of the SAG-provided polygons defining the zones and the vegetation cover polygons (UCSB with SAG modifications) results in different sized zones once converted to the square grid format that can be brought into the DRI emission model. Table 2 shows the change in area in each of the zones that results from the GIS processing of the original polygons. The processing results in the total area decreasing by approximately 8.8% for GIS modified grid cell zones compared with the SAG-provided polygons.

Table 2. The area of the zones as provided by the SAG compared with the GIS modified grid cell zones by area and % difference. The area of each GIS-modified Grid Cell zone minus the vegetation cover is also provided, based on the Grid Cell zones and vegetation layer.

	Original Polygons	GIS Modified Grid Cell Zones	% Difference	After Removing Vegetation Cover
Zone Designation (1939)	**Acres**	**Acres**		**Acres**
Non Riding Area Central	2526.3	2525.8	-0.02	1915.5
Non Riding Area North	729.6	595.5	-18.38	498.7
Non Riding Area South	1169.3	914.0	-21.84	464.0
Sum	4425.2	4035.3	-8.81	2878.2
	Original Polygons	**GIS Modified Grid Cell Zones**	**% Difference**	
Zone Designation (current)	**Acres**	**Acres**		
Foredune Restoration Area	48.0	49.3	2.62	49.3
Non Riding Area Central	819.4	820.1	0.09	269.7
Non Riding Area North	729.6	595.5	-18.38	389.6
Non Riding Area South	1169.3	914.0	-21.84	303.5
Plover Exclosure	309.7	309.5	-0.08	309.5
Revegetation	207.7	207.3	-0.19	200.6
Riding Area Central-North	251.1	249.3	-0.72	249.2
Riding Area Central-South	546.8	547.2	0.07	546.7
Seasonal Exclosure	34.5	34.0	-1.54	34.0
Vegetation Islands	309.1	309.2	0.01	194.2
Sum	4425.2	4035.3	-8.81	2546.3

There is an underlying model domain issue that remains to be addressed as the new excess emission framework is adopted. This issue is the areal extent of the model domain (gray polygon shown in Figs. 1 and 2), which was initially adopted for evaluating the total emissions from the ODSVRA riding area and estimation of mass concentration of PM_{10} at the SLOCAPCD monitoring stations CDF and Mesa2. This model domain does not cover the entire area of the ODSVRA as designated by the zones listed in Table 2. The size of the original domain was limited due to computational issues related to memory restrictions for running CALMET to generate the wind field. This is not a hardware limitation, but a software limitation to allocate memory within the Fortran code that was used to construct CALMET. The fidelity of the original grid (i.e., individual grid cell size and total number of cells) was balanced against exceeding the memory allocation restrictions to arrive at the size of the original domain.

The size of the domain can be changed to include all the zones, but it will require investigating how to expand CALMET capacity for the larger domain while keeping the 21 m × 21 m grid cell size, or the grid cells will have to be greater than 21 m × 21 m. Changing the size of the domain will also have consequences for other parts of the model output, with the greatest impact on the wind field that drives the emissions. Increasing the size of the domain and introducing new topography will influence the development of the modeled wind field. The model will need to calculate the wind friction velocity (i.e., u_*) for each grid cell in the newly included areas in the larger domain. Adding new areas may also result in changes in wind speed and direction, most prominently at the borders where the newly incorporated areas bound the older domain area, which could also affect the calculation of u_* in these previously defined border zones. DRI acknowledges that these changes can be undertaken, but it will require significant resources to make these modifications and require agreement by the stakeholders (i.e., Parks, APCD, and SAG) on the model modification process. It was not feasible to make these changes in the time frame of reporting the model results in the excess emissions framework by March 2024. Given the directive, these changes could be accomplished before the end of 2024.

The Emissivity Relations Associated with the Zones

The emissivity relations, of the form $E = a\ u_*^b$, associated with the defined zones used for the modeling were drawn from the SAG (2023) memo represented in their Table 4. The non-linear regression used to calculate the *a* and *b* coefficients was carried out using the agreed upon software package SigmaPlot. The coefficients for the power relations for the zones used in the DRI emission model are reproduced from SAG (2023) Table 4 in this report as Table 3.

Zones identified as being under re-vegetated dust control or are identified as grid cells with ≥50% vegetation cover are assigned an emissivity of zero under all wind conditions.

Table 3. Data used in developing the emissivity relations. The number of available PI-SWERL tests (n), the u_* values for the three PI-SWERL test settings, the median emissivity values as a function of u_* are shown in the top half of the Table. The power function coefficients (*a*, *b*) for the zones are shown in the bottom half of the Table with the correlation coefficient (r^2) indicating the goodness of fit of the power relation in each case.

	Non-Riding Areas			Riding Areas		FRA	PE	Avg. SE
	North	Central	South	Central-North	Central-South			
n=	111	221	67	403	574	110	23	103
u_* (m s^{-1})								
0.381	0.039	0.021	0.001	0.094	0.024	0.006	0.003	0.028
0.534	0.307	0.193	0.142	0.640	0.432	0.068	0.032	0.180
0.607	0.932	0.610	0.388	1.349	0.964	0.192	0.107	0.439
E (mg m^{-2} s^{-1})=$a\ u_*^{\ b}$								
a	66.376	51.649	20.786	24.34	24.395	10.71	11.416	13.042
b	8.547	8.893	7.972	5.795	6.466	8.060	9.355	6.798
r^2	0.999	0.999	0.999	1.000	0.999	1.000	1.000	0.999

The Wind Field Driving the Emissions Model

This aspect of the modeling has remained unchanged in the excess emission framework. The development of the wind field is described in detail in Mejia et al. (2019). The wind field applied to the current and 1939 model runs are representative of the amalgamation of the wind field data generated for the 10 highest PM_{10} emitting days that occurred in May 2013. This wind field has been used in the model estimates provided in all the Annual Report and Work Plans (ARWP) through to the 2023 ARWP.

Modeling Results

Maps of emissions created by the meteorology of the 10 highest emission days from May 2013 applied to the zones for the current year and 1939 are shown in Fig. 3. Table 4 provides the model-derived estimates of total mass emissions in metric tons per day for each of the zones in the current year and 1939 and for the sum of total emissions for the equivalently sized areas (4035.3 acres), i.e., the three zones of 1939 and the ten zones of the current year. Note that the vegetation cover is different between the two years, so different sized areas within the total area (i.e., 4035.3 acres) have zero emissions due to the difference in vegetation cover (Table 2).

Based on the summation of the polygons, for equivalent areas for the two scenarios, the current ODSVRA is not in excess of emissions compared to 1939. The pre-disturbance landscape had a modeled emission of 166 metric tons per day whereas the current landscape had a modeled emission of 148 metric tons per day, with a difference buffer of 18 metric tons per day.

Next Phase

In 2024 additional PI-SWERL emissivity data will be collected in May covering as much as possible the test locations that were sampled in 2019 in the riding and non-riding areas. The foredune restoration area and plover exclosure will be sampled in October duplicating the sampling points of October 2022 as much as possible. In October DRI will also select a subset of the May 2024 sampling grid and repeat PI-SWERL measurements at these locations as controls.

The May and October 2024 PI-SWERL data will be QA/QCed by DRI and the emissivity (mg m^{-2} s^{-1}) for each PI-SWERL test for the three u_* set points will be provided to the SAG to add to the PI-SWERL emissivity database as a function of the established zones. Using SigmaPlot, the SAG will update the emissivity relations (Table 2). These updated emissivity relations and any other updated model input data (e.g., current vegetation cover, changes in dust control areas) will be used as input into the model to determine if compliance with the SOA excess emissions mandate is achieved for the conditions of 2024. This could likely be accomplished by the end of December 2024.

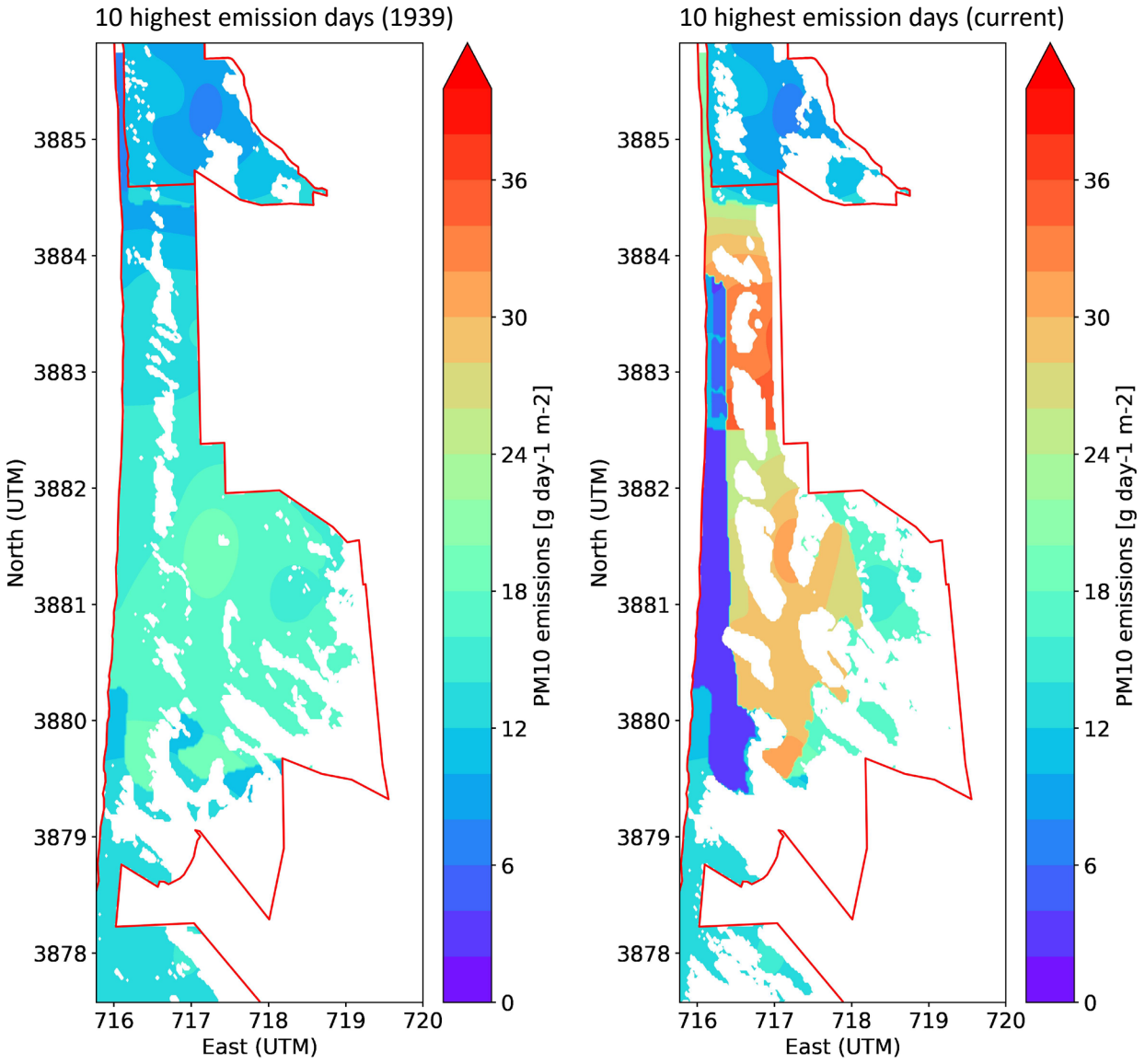

Figure 3. The distribution of emissivity (E= g m^{-2} day^{-1}) for 1939 (left panel) and the current year (right panel) based on the meteorology of the 10 highest PM_{10} emission days, May 2013.

Table 3. Model-derived estimates of total mass emissions in metric tons per day for each of the zones in the current year and 1939 and for the sum of total emissions for the equivalently sized areas.

Zone	Total Emissions metric tons/day (10 Highest Emissivity Days May 2013)
1939	
Non Riding Area Central	122
Non Riding Area North	20
Non Riding Area South	24
Total	**166**
Current	
Foredune Restoration Area	1
Non Riding Area Central	18
Non Riding Area North	16
Non Riding Area South	16
Plover Exclosure	4
Riding Area Central-North	30
Riding Area Central-South	63
Seasonal Exclosure	1
Vegetation Islands	0
Revegetation	0
Total	**148**

References

Mejia, J.F., J.A. Gillies, V. Etyemezian, R. Glick (2019). A very-high resolution (20 m) measurement-based dust emissions and dispersion modeling approach for the Oceano Dunes, California. *Atmospheric Environment*, 218, 116977, doi: 10.1016/j.atmosenv.2019.116977.

SAG (2023). *Updated SAG Recommendations for Establishing Emissivity Grids to be used in Modeling of Pre-Disturbance Conditions and Future Excess Emissions Reductions*. Memo from SAG to California Department of Parks and Recreation and San Luis Obispo County Air Pollution Control District, December 19, 2023.

SLOCAPCD (2024). *Approval of California Department of Parks and Recreation's Modeling Assumptions to be used in their 2024 Annual Report and Work Plan in Response to Stipulated Order of Abatement Number 17-01*. Memo from San Luis Obispo County Air Pollution Control District to California Department of Parks and Recreation, February 8, 2024.