Statistical Evaluation of Potential Redundancies in Everglades National Park's Network of Marsh Hydro-Stations.

Katharine M. Banner* Eliot Liucci* Bradley A. Strickland† Kelly R. McCaffrey†

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*Montana State University, Department of Mathematical Sciences
†Everglades National Park, South Florida Natural Resources Center

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1 Executive summary

This report presents a purely statistical clustering approach to assess redundancies within the network of marsh hydro-stations based on their observed stage (water elevation) data recorded between January 1, 2000 (beginning of Comprehensive Everglades Restoration Plan, CERP) and December 31, 2020. Using only a statistical analysis to determine whether two marsh hydro-stations might be considered redundant or not is dependent on the various choices made during the analysis, which we thoroughly explain in Section 4. We summarize general patterns of similarities among regional cluster-results and all-region results in Subsection 1.1 and similarities within each region's results in Subsection 1.2. The ultimate decision for whether stations should no longer be maintained should be based on best professional judgement and domain knowledge provided by the Data Sciences Branch and others at South Florida Natural Resources Center (SFNRC).

We used hierarchical agglomerative clustering (HAC) to generate by-region cluster results within Long Pine Key, Lower C111, Road, Rocky Glades, Shark Slough, and Taylor Slough, and an all-region analysis that included all stations. We included stations with time-series observations of daily average stage measurements with less than 10% missingness, which excluded SPARO, RG1, RG4 (see Section 4). We applied HAC for three different seasons: *entire time series* or *overall* (Jan. 1, 2000 - Dec. 31, 2020), *dry season* (Nov. 1, and April 30), *wet season* (May 1 - October 31). We computed pairwise Euclidean- and correlation-based distances (Pearson or Spearman) that distinguish time-shifted, value-shifted, time-warped, and scaled differences in hydrological time series, but to different extents (discussed in Section 4.1). Both metrics are used and compared because agreement in clustering results regardless of metric chosen provides more evidence of redundancy. We created cluster solutions based on cutting the Euclidean-based dendrograms at three different cut-heights based on 1-cm, 2-cm, and 3-cm daily average differences, as potential practically meaningful differences among water-stage time series (see Section 4.3). Our approach for cutting the Euclidean-based

dendrograms provides a consistent criteria for determining the cluster solutions regardless of which stations were included in the clustering (by-region or all-region).

In addition to this report, the provided R code can be used to explore potential station redundancies based on less stringent criteria (> 3-cm average daily difference) along with best professional judgment. The code repository (EVER-Stage-Analysis Github repository, URL: https://github.com/kbanner14/EVER-Stage-Analysis/tree/main) delivered to SFNRC is intended to make it easier to broaden or adjust the investigations presented herein to support informed decision making for hydrology stations in EVER. Furthermore, all graphics and reproducible code are included in the repository, such that minor adjustments (e.g., jittering labels or modifying maps and summary figures) can be made by the Data Sciences Team at SFNRC after the conclusion of this project.

1.1 General findings across regions and seasons

- Differences in daily average stage measurements among stations appeared to be mostly value-shifted, time series were consistently shifted higher or lower over the survey period. Differences were obvious visually in regions with more variability in daily average stage values (e.g., Shark Slough, Road, Rocky Glades).

- Rankings of similarity were mostly consistent within a specific distance metric (Euclidean or correlation-based) across seasons (overall, wet, dry) and tended to differ when comparing across metrics within a season. When two metrics indicate the same (or very similar rankings) there is more evidence for similarity (low rankings for both metrics) or dissimilarity (high rankings for both metrics).

- Cluster dendrograms were relatively consistent across seasons within a distance metric but differed in construction across metrics (holds for by-region and all-region results). For most regional results, the two most similar stations (similarity rank = 1) were the same across metrics.

- Clustering solutions that suggest possible station redundancies were only observed

for Long Pine Key and Lower C111. Road, Rocky Glades, Shark Slough, and Taylor Slough all resulted in each station being its own cluster. Therefore, best professional judgement along with a less stringent criteria for cutting the dendrograms is required to determine statistical redundancies among observed stage measurements for the Road, Rocky Glades, Shark Slough, and Taylor Slough stations.

- Marsh stations at similar elevations and closer in geographic space were most likely to be clustered together.

- All-region results were generally consistent with by-region results across metrics and seasons, indicating some consensus for potentially redundant and "most similar" stations.

1.2 General findings within regions

- Long Pine Key: Value-shifted differences were visually apparent. Using HAC with the Euclidean metric resulted in DO1 and D03 being clustered together at the 3-cm cut-height in all seasons and the 2-cm cut-height in the dry season (Figure 8). There was very little visual difference between daily average stage observations from these two stations (Figure 6). Also, DO1 and DO3 were the closest in geographic space and most similar in elevation of all pairs of stations (see Figure 9). Only one of the clustered stations, D03, was proposed to be hibernated and these results suggest it is potentially redundant with DO1 which was proposed to remain active.

- Lower C111: Using HAC with the Euclidean metric resulted in CT50R and CV5NR, and CT27R and EVER6 being clustered together at the 3-cm cut-height in all seasons. Only CT50R was proposed to remain active and EVER6, CV5NR, CT27R were all proposed to be hibernated. Based on dendrogram results (see Figure 14) and visual inspection of the four station's time series (Figure 12), these

stations measure very similar daily average stage.

- Road: Daily average stage values showed obvious value-shifted differences among the three stations (Figure 17). Using HAC with the Euclidean metric resulted in no clustering at 1, 2, or 3-cm daily difference cut-heights (Figure 19). The NMP station was proposed to remain active, whereas NP46 and SP were proposed to be hibernated. However, based on the clustering results these three stations were dissimilar and possibly not redundant with each other.

- Rocky Glades: Daily average stage values showed obvious value-shifted differences among stations with NP62 having far lower daily average stage measurements than the others (Figure 22). Using HAC with the Euclidean metric resulted in no clustering at 1, 2, or 3-cm daily difference cut-heights. However, CR2 and RG2 were consistently clustered together first (Figure 24). The station RG2 was proposed to be hibernated, and CR2 proposed to remain active. Best professional judgement would be required to determine that these stations are redundant.

- Shark Slough: Daily average stage values showed obvious value-shifted differences among stations with NP201 showing far higher daily average stage measurements than the others and pretty clear separation among most stations within the region aside from those that record the lowest daily average stage (Figure 27). Using HAC with the Euclidean metric resulted in no clustering at 1, 2, or 3-cm daily difference cut-heights (Figure 29). However, NP203 and P33 were consistently grouped together as the first cluster, where NP203 was proposed to be hibernated and P33 was proposed to remain active. However, a best professional judgement would be required to determine that these stations are redundant as they failed to meet the threshold of 3-cm daily difference (Figure 29).

- Taylor Slough: Daily average stage values showed value-shifted differences were visually apparent among stations but showed less obvious separation among stations than value-shifted differences in Shark Slough, Road, or Rocky Glades (Fig-

ure 32). Using HAC with the Euclidean metric resulted in no clustering at 1, 2, or 3-cm daily difference cut-heights (Figure 34). Both metrics agreed that the CP station should be in the first cluster in the overall and wet seasons, but differed in which station CP should be joined with (CP:E146 Euclidean, CP:NCL Spearman). During the dry season, the first cluster was determined to be NCL:P37 for Euclidean distance and CP:NCL for Spearman. Across all seasons and metrics, the stations that were most similar were comprised of one station proposed to be hibernated (E146, NCL) and one station that was proposed to remain active (CP, P37). Further interrogation of these results, in conjunction with best professional judgment, is required to determine which stations in Taylor Slough can be considered redundant as these cluster results were less consistent and failed to meet the threshold of 3-cm daily average difference (Figure 34).

- All region: Many of the stations clustered together based on HAC with a Euclidean distance metric in the by-region analyses were also clustered together in the all-region analysis, and at the same cut-heights. Specifically, D01:D03, EVER6:CT27R, CT50R:CV5NR clustered together at the 3-cm daily-difference cut-height. We also observed D01:D03 clustering together at the 2-cm daily-difference cut-height during the dry season. The other station pair that was most similar based on the Euclidean dendrograms across all seasons was NCL:P37, which was consistent with the by-region analysis of Taylor Slough. The Spearman distance metric showed high similarity among D01:D03, CP:NCL, and EVER6:CV5NR :CT27R:EVER6 during the overall and wet seasons. During the dry season the most similar stations were E112:TSB, CP:NCL, and EVER6:CV5NR:CT27R:EVER6 using the Spearman metric (Figure 38-40). Defining a practically meaningful threshold for cutting the dendrogram is not as straightforward for correlation metrics. Therefore, the decision to hibernate any of these stations based on their similarity using the Spearman metric should be based on best professional judgment.

2 Introduction

Marsh hydrology stations within the Everglades National Park (EVER) are used to obtain daily average stage (water elevation) measurements at their locations. In the spring of 2023 a subset of marsh stations were proposed to be hibernated to reduce workload and costs associated with maintenance of the system (details provided in Appendix A). This report provides visualizations and cluster analyses to inform potential similarities among stations based on their daily average stage measurements between January 1, 2000 and December 31, 2020. We explored clustering based on three different seasons: *entire time series* or *overall* (complete cases between Jan. 1, 2000 - Dec. 31, 2020), *dry season* (complete cases between Nov. 1, and April 30), *wet season* (complete cases from May 1 - October 31).

3 Description of data

The EVER data analyzed consist of stage measurements for 58 fresh water monitoring stations within South Florida (Figure 1). For each station, the stage (water elevation) is recorded as a mostly continuous time series, ranging back as far as 1952. The daily stage observations used in this analysis are the average water elevations for each day (measured in feet). Stage values were transformed to the centimeter scale (Stage_cm variable) to afford conceptualization of meaningful differences in daily average water elevation (based on professional judgment of sensor measurement error). Measurement error is considered any daily difference less than 0.6 cm, and we started with 1 cm being the smallest meaningful difference for our work assessing redundancy. We combined the raw time-series data for a station (EVER-Stage-Analysis/Client Documents/Raw Data/EVER_HydroData_20230414) with the meta-data (EVER-Stage-Analysis/Client Documents/Raw Data/EVER_Hydro_MetaData.csv), providing the spatial coordinates (latitude and longitude in degrees), the regional location, the elevation (feet), and observation date for each station. Additional variables, such as the hydrological season

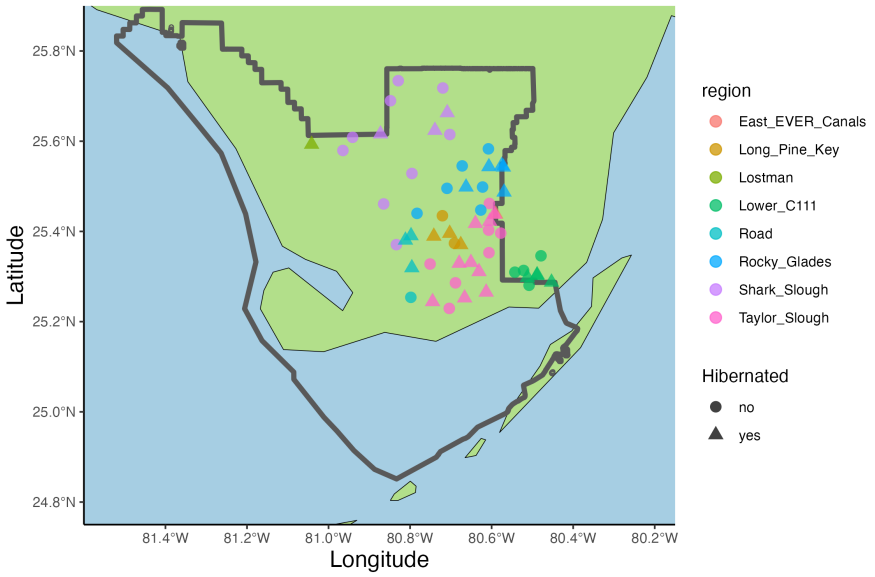


Figure 1: The spatial distribution of marsh stations to be analyzed, colored by the region provided by the EVER Research Team. The shape of each point represents whether the station was proposed to be hibernated (triangle) or not (circle). The black outline indicates the border of EVER

(wet, dry), were created by defining measurements taken between May 1st and October 31st as coming from the 'wet' season, and measurements taken between November 1st and April 30th for the 'dry' season. Hibernation status was included by assigning a 'yes' to the stations that were suggested for hibernation by Damon Rondeau in April, 2023 and a 'no' to stations that were suggested to remain active (see Appendix A). The last 6 days of data available within Taylor Slough are provided in Table 1.

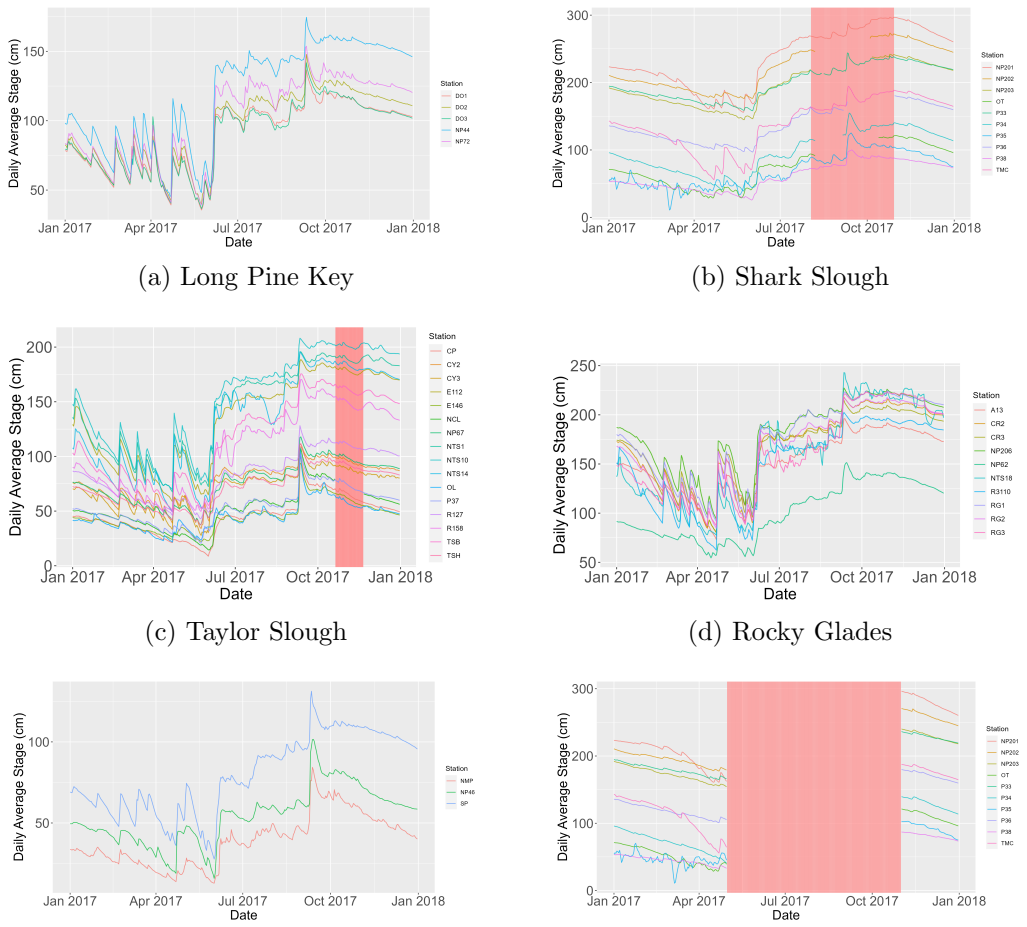
Missing values occur when a sensor 'turned off' (e.g., equipment failure or stage

X.stn	date	season	Stage_cm	Hibernated	lat	long	elev	region
TSH	2020-12-26	dry	90.93	yes	25.31	-80.63	1.41	Taylor_Slough
TSH	2020-12-27	dry	90.60	yes	25.31	-80.63	1.41	Taylor_Slough
TSH	2020-12-28	dry	90.38	yes	25.31	-80.63	1.41	Taylor_Slough
TSH	2020-12-29	dry	90.29	yes	25.31	-80.63	1.41	Taylor_Slough
TSH	2020-12-30	dry	90.06	yes	25.31	-80.63	1.41	Taylor_Slough
TSH	2020-12-31	dry	89.81	yes	25.31	-80.63	1.41	Taylor_Slough

Table 1: The information for station TSH within the Taylor Slough region is provided from December 26, 2020 to December 31, 2020. The response variable analyzed in this report was Stage_cm, which is a stage (water elevation) measurement rather than depth of water.

measurements were above/below measurable thresholds). It is assumed that these values are missing completely at random, meaning there is no systematic event related to the measures of water elevation which caused these data to be unavailable. The assumption of "missing completely at random" is reasonable as missingness does not occur systematically, either across various stations or within a single time-series. Missingness summaries for stations in each region across the entire period of interest (Jan 1, 2000 - Dec 31, 2020) are provided in their respective results sections (Section 5).

Natural disasters such as hurricane Irma (occurred in 2017) could cause missingness that is not completely at random. An investigation into the missingness present due to hurricane Irma can be seen in Figure 2, where each region's missingness within 2017 is displayed. Shark Slough, Taylor Slough, and Lower C111 appear to experience large portions of missingness around the time that Hurricane Irma hit Southern Florida (Figure 2). Therefore, results in Shark Slough, Taylor Slough and Lower C111 may only apply to periods of time when there was not a hurricane. Although this was not done for this particular analysis, one could subset the regional data sets to exclude dates around severe storm events from all stations, effectively restricting the scope of inference to non-storm times.



(a) Long Pine Key

(b) Shark Slough

(c) Taylor Slough

(d) Rocky Glades

(e) Road

(f) Lower C111

Figure 2: Line plots displaying the observed missingness in 2017. Within each region's plot, the color of the line represents the station. The vertical red bars indicate a day where at least 1 station in that region observed a missing value.

4 Methods

We used Hierarchical Agglomerative Clustering (HAC) to identify potential redundancies within hydrology stations in the regions of EVER. To implement HAC, the user must define a distance metric quantitatively assessing pairwise differences among stations, a linkage rule for re-defining distances among stations/clusters at each interaction of the HAC algorithm, and a decision rule for creating cluster solutions. Our choices are outlined in Sections 4.1, 4.2, and 4.3, respectively. To conduct HAC all stations must have observations of daily average stage in order to compute pairwise distances. There-

fore, we used only complete-cases in our subsequent analyses. We define a complete-case as an observation date with stage observations at *all* stations of interest.

4.1 Choice of Distance Metrics

A distance metric summarizes the pairwise similarity between two station's time series of daily average stage as one number, with smaller numbers indicating more similarity between stations. There are several popular distance metrics for time series (See Aghabozorgi et al., 2015), but it is important that the metric corresponds with a hydrologically meaningful definition of 'different' when comparing two stations. Prakaisak and Wongchaisuwat (2022) demonstrate that HAC with Euclidean distance is an effective combination when clustering hydrological time-series data. Euclidean distance (pictured in Figure 3) allows us to consider two stations as different if their maximum and minimum observations are measured at different times (time-shifted and time-warped) or if one measures higher values than another, on average (value-shifted and scaled differences).

Following Soares et al. (2018), we chose to use two distance metrics for all station pairs (Euclidean and correlation-based). If two metrics that measure different aspects of dissimilarity (or measure the same aspect but to different extents) agree for a comparison, that provides more support for the decision to remove a potentially redundant station. Correlation-based distances summarize how similar the pattern in the time series is across the time-period of interest, and picks up differences in time-shifted and time-warped series, but not in value-shifted series when the patterns are similar. Another popular distance metric for clustering of time-series data is dynamic time warping (DTW). We did not consider DTW because two time series that are time-shifted or time-warped (have similar patterns but different seasonal max and min values) are similar with respect to DTW, but we wanted to treat stations offset in time (time-shifted, time-warped) as different in our analysis (See Distance_Metric_Investigation.pdf).

4.1.1 Euclidean metric

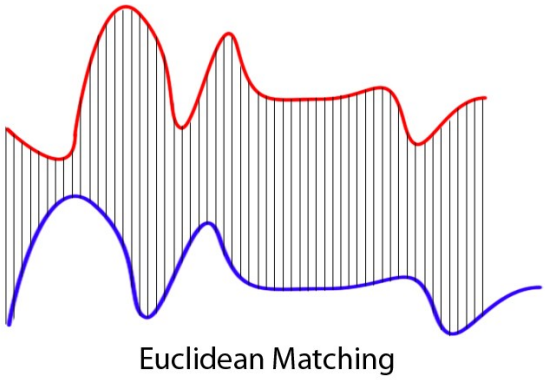


Figure 3: Visualization of how Euclidean Distance works for 2 time series, from Wikimedia Commons https://commons.wikimedia.org/wiki/File:Euclidean_vs_DTW.jpg

Euclidean distance between time-series A and time-series B, $d(A, B)$, can be calculated using Equation 1. In Equation 1, A_i and B_i represent the measured daily average water elevation at time i for station A and B, respectively; t represents the number of complete cases available within a specific region. (I.e., t is the total number of observations for which all stations have stage measurements within a specific region).

$$d(A, B) = \sqrt{\sum_{i=1}^{t} (A_i - B_i)^2} \tag{1}$$

4.1.2 Correlation-based metrics

Pearson distance, $r(A, B)$ is calculated by finding the Pearson correlation between two time-series (A and B) and then subtracting that value from 1 (Equation 2). This results in stations with higher linear correlations — more similar patterns in stage measurements within the time period of interest — having a Pearson distance closer to 0.

$$r(A, B) = 1 - \frac{\sum_i^t (A_i - \bar{A})(B_i - \bar{B})}{\sqrt{\sum_i^t (A_i - \bar{A})^2 \sum_i^t (B_i - \bar{B})^2}} \tag{2}$$

In Equation 2, A_i and B_i represent the measured daily average water elevation at

time i for station A and B, respectively, t the number of complete cases available within a specific region, and $\bar{A}$ and $\bar{B}$ represent the sample average of the daily average water elevations for stations A and B, respectively.

The Pearson distance measure *assumes there is a linear relationship between the two observed time series being compared.* The assumption of linearity could be severely violated if there are outliers present with high leverage (high distance from the average stage measurement of either station), or if there are severe non-linear relationships observed between points in series A and B. When severe violations of linearity were present for at any pairs of stations within a region, we used *Spearman distance*. We used pairwise scatterplots of stage observations between all station pairs to visually assess the linearity assumption within each region (See linearity plots in regional figures folders in EVER-Stage-Analysis)

Spearman distance is a non-parametric measure of the correlation between two stations, requiring only that values are on the same scale between compared stations. *Spearman distance*, $r_s(A, B)$, is defined in Equation 3. In Equation 3, A and B represent stations, t represents the number of complete-case observations in the region, and d_i^2 represents the square of the difference in ranks of the two observed measurements (ranked lowest to highest, including negative numbers).

$$r_s(A, B) = 1 - \frac{6 \sum_{i=1}^{t} d_i^2}{t(t^2 - 1)} \tag{3}$$

4.1.3 Practical Implications of Choice of Distance Metric

In practical terms, if two time-series have an identical pattern but one observes 10 centimeter higher stage every day (value-shifted difference), the Euclidean distance would be high (indicating dissimilar time series that are likely not redundant information) but the correlation-based distance would be low (indicating similar time series with potential redundancy). If two time-series have an identical pattern but one is offset by a few days (time-shifted differences), the correlation-based metric will be high and

the Euclidean distance will also pick up this difference (but potentially to a lesser extent than the correlation-based metric). If two time-series are different both in stage value (value-shifted) and when the maximums or minimums occur (time-shifted differences), both Euclidean and correlation-based metrics will be high. A high value for both Euclidean and correlation-based metrics may suggest that pairwise time series are dissimilar and likely not redundant in terms of their time series features (time-shifted and value-shifted), which could be explored through additional visualizations of the time series. (See Distance_Metric_Investigation.pdf for a complete treatment of the different distance metrics considered and the types of differences they can pick up.)

4.2 HAC Algorithm and Choice of Linkage

In the context of a redundancy analysis within regions of EVER, the HAC algorithm starts by treating each station within a specific region as its own cluster. At the first iteration, HAC assigns the two most similar stations (similarity based on chosen distance metric) together into a cluster of size 2. Distances are then recomputed among all remaining singletons and the initial cluster and the smallest of those distances is used to join a singleton with the first cluster or a "closer" singleton to create a new cluster of size 2. This process repeats until all stations are assigned to a single cluster (James et al., 2013).

A linkage defines the "closeness" between two groups of observations determining how distances are recomputed at each step of the HAC algorithm. Three common choices of linkage are (1) 'complete' (furthest neighbor), which records the largest dissimilarity between all pairwise dissimilarities of stations in the two clusters, (2) 'single' (nearest neighbor), which records the smallest dissimilarity between all pairwise dissimilarities of stations in the two clusters, and (3) 'medoid' (group average), which records the averages of all pairwise dissimilarities of stations in the two clusters. We chose the complete linkage to ensure the largest similarity within clusters, effectively minimizing the maximum redundancy (James et al., 2013). To change the choice of

linkage one would need to change the specified linkage in all calls to `hclust` within the Code repository (EVER-Stage-Analysis/Code/).

4.3 Choice of Cluster Solutions

The results from HAC can be summarized in a dendrogram (tree diagram) for each metric (e.g., Figure 8). Cluster heights correspond to how similar the stations within the resulting cluster are. (The heights across Euclidean and correlation-based metrics are not directly comparable on the scales we created them on, but see Appendix C describing the relationship between Euclidean- and Pearson-based metrics.) We conceptualized meaningful cut-heights for Euclidean-based dendrograms using 1, 2, or 3 times the smallest meaningful difference in stage censor measurements as the distance between observations from two stations within the Euclidean distance formula. Let, Cut_height_l be the practically meaningful cut-height for $l = 1, 2, 3$ times the smallest meaningful difference (m, where $m = 1 - cm$ for stage censors in EVER), and t be the total number of complete case observations within the region-season of interest. Then, $Cut\_height_l = \sqrt{\sum_{i=1}^{t}(lm)^2} = \sqrt{\sum_{i=1}^{t} l^2} = l\sqrt{t}$ for $l = 1, 2, 3$ (because $m = 1 - cm$). We created cluster solutions by cutting the Euclidean dendrogram at each of the practically meaningful daily differences defined by $l = 1, 2, 3$ and t for each region-season of interest (Table B). Defining a practically meaningful threshold for cutting the dendrograms for correlation metrics is not as straightforward as the measure is more difficult to translate to practically meaningful values. Therefore, the decision of where to cut the dendrograms for the correlation-based metrics should be based on best professional judgement of domain experts.

In addition to clustering results, we explore the relative rankings of station pairs by distance metric. Comparing the pairwise station ranks based on the two metrics can be helpful because when they indicate the same (or very similar rankings) there is more evidence for similarity (low rankings for both metrics) or dissimilarity (high rankings for both metrics). This extends to cluster results as well (i.e., comparing dendrograms

across metrics). Finally, to understand factors that might explain similarities among marsh station time series, we graphically explore whether pairs of stations are similar because they are similar in elevation and/or close together in geographic space.

4.4 Implementation and Reproducibility

We used R Statistical Software (R Core Team, 2023) for all statistical computation, the `tidyverse` (Wickham et al., 2019) for data processing and plotting, and the `hclust` function within the base-R `stats` package for HAC. All code is available in the EVER-Stage-Analysis Github repository (URL: `https://github.com/kbanner14/EVER-Stage-Analysis/tree/main`). Users should begin by working through Vignette.pdf and its accompanying script file to learn how to use all functions in the repository and learn how to adjust code to investigate how results would change if different choices were made (i.e., different daily difference and associated cut-height, distance metric, or linkage). Code to generate comparison figures in Sections 5.1 - 5.6 are provided in the by-region-report_analysis.R script file within the EVER-Stage-Analysis repository.

5 Regional Results

We implemented HAC with complete-case observations from time series recorded by hydro-stations within the Long Pine Key, Lower C11, Road, Rocky Glades, Shark Slough, and Taylor Slough regions within EVER. For each region, we obtained cluster results within each season (overall, wet season, dry season) using the Euclidean dissimilarity metric and the most appropriate correlation-based summary metric for the region. Following Soares et al. (2018), stations with more than 10% missingness between Jan 1, 2000 and Dec 31, 2020 (time period of interest) were excluded from regional analyses (SPARO, RG1 and RG4). LO2 from Lostman and L31W from East EVER Canals were not included in the by-region analysis because they were singletons within their regions.

In the following subsections, the spatial context for where stations are situated within a region and within EVER, time-series plots of observed daily average stage measurements (cm) for included stations, and a summary of missingness within each region-season combination are provided. To interpret the HAC results with the goal to inform which stations may be redundant and candidates for hibernating, we include figures that compare metrics (Euclidean or correlation-based) and seasons (overall, wet, and dry) in terms of dissimilarity-based pairwise rankings, dendrograms, and biplots. These and other graphics are provided in region-season specific folders within the GitHub repository EVER-Stage-Analysis. And reproducible code included in the repository can be used for minor adjustments (e.g., jittering labels or modifying maps and summary figures) as needed.

5.1 Long Pine Key

Stations within Long Pine Key are shown on a map of EVER in Figure 4, and observed daily average stage measurements (cm) are shown with missingness (indicated by red bars) between Jan 1, 2000 and Dec 31, 2020 in Figure 5. Station NP44 appears to have higher (value-shifted) stage measurements than other stations within the Long Pine Key Region, but there are no other obvious patterns in Figure 5. Table 2 provides a summary of the total number and % of missing observations for each station in decreasing order within each season. In Long Pine Key the total % missingness was highest during the dry season and DO3 was the station with the most missingness across all seasons.

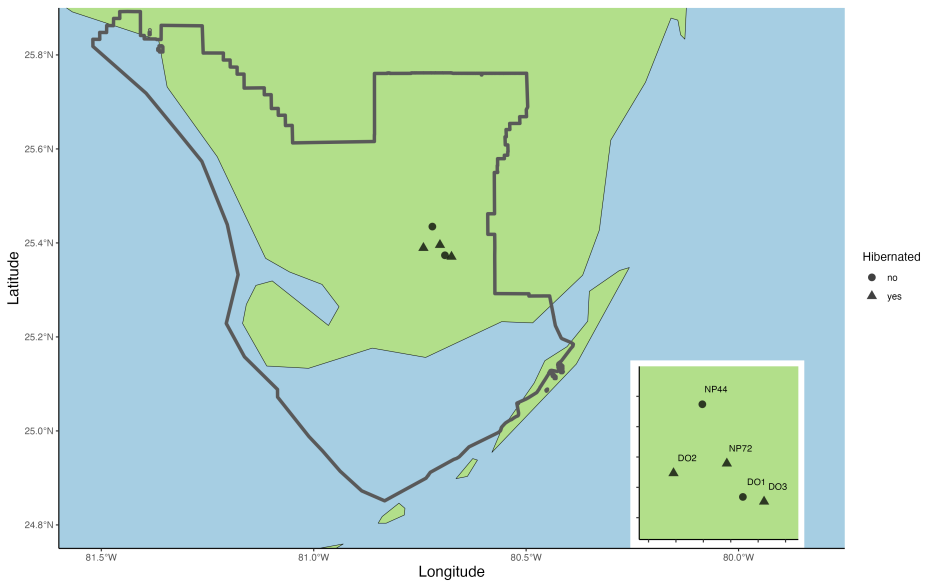


Figure 4: A map of the stations within the Long Pine Key region situated in the boundary of EVER. Stations that were proposed to be hibernated in May 2023 are marked with a triangle.

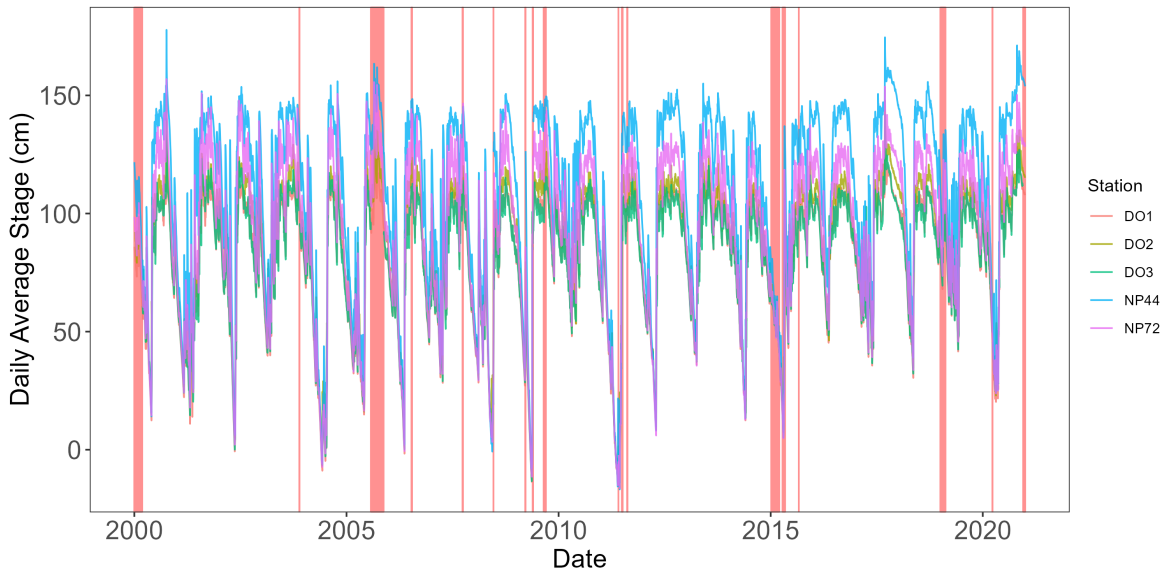


Figure 5: A line plot highlighting the observed stage (cm) measurements and missingness within the Long Pine Key region from 2000 to 2020, colored by station. Red vertical bars indicate a day where at least 1 station has a missing stage value.

Pearson correlation was a reasonable metric to use for Long Pine Key (See linearity plot, EVER-Stage-Analysis). Comparing pairwise dissimilarity across the Euclidean and Pearson distance metrics for all seasons (overall, wet, dry) revealed that Stations D01 and D03 were most similar regardless of metric-season comparison and stations

Region	Station	End Date	N	n	Missing	% Missing
Long Pine Key	DO3	2020-12-13	7671.00	7470.00	201	2.62
Long Pine Key	DO1	2020-12-31	7671.00	7577.00	94	1.23
Long Pine Key	DO2	2020-12-31	7671.00	7608.00	63	0.82
Long Pine Key	NP72	2020-12-31	7671.00	7653.00	18	0.23
Long Pine Key	NP44	2020-12-31	7671.00	7663.00	8	0.10
Total (overall)			7671.00	7287.00	378	4.93
Long Pine Key (wet)	DO3	2020-10-31	3864.00	3770.00	94	2.43
Long Pine Key (wet)	NP72	2020-10-31	3864.00	3846.00	18	0.47
Long Pine Key (wet)	DO2	2020-10-31	3864.00	3852.00	12	0.31
Long Pine Key (wet)	DO1	2020-10-31	3864.00	3858.00	6	0.16
Long Pine Key (wet)	NP44	2020-10-31	3864.00	3859.00	5	0.13
Total (wet)			3864.00	3729.00	135	3.49
Long_Pine_Key (dry)	DO3	2020-12-13	3807.00	3700.00	107	2.81
Long_Pine_Key (dry)	DO1	2020-12-31	3807.00	3719.00	88	2.31
Long_Pine_Key (dry)	DO2	2020-12-31	3807.00	3756.00	51	1.34
Long_Pine_Key (dry)	NP44	2020-12-31	3807.00	3804.00	3	0.08
Long_Pine_Key (dry)	NP72	2020-12-31	3807.00	3807.00	0	0.00
Total (dry)			3807.00	3558.00	243	6.38

Table 2: A table highlighting the missingness within the Long Pine Key region-season combinations. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

NP44 and D03 were most dissimilar (Figure 7). This can also be seen in the dendrograms resulting from applying HAC with both distance metrics in each season by noting that D01 and D03 join at the lowest height regardless of metric or season; additionally, NP44 is always the last station to join clusters (Figure 8).

We applied HAC and obtained cluster solutions for the Euclidean dissimilarity metric for $l = 1, 2, 3$ cut-heights within all seasons. Clustering was observed at the $l = 3$ cut-height for all seasons with stations D01 and D03 being clustered together. The stations D01 and D03 were also clustered together at the $l = 2$ cut-height within the dry season (left column, Figure 8). This cluster appears in blue in the biplots investigating the relationship between pairwise Euclidean or Spearman dissimilarity and absolute difference in elevation or physical space (Figure 9 top and bottom, respectively). Figure 9 shows moderate to strong linear associations between dissimilarity and absolute

difference in elevation and absolute distance in physical space regardless of dissimilarity metric, indicating a relationship between cluster results and stations that are close in elevation and space. We can also see from Figure 9 that the stations clustered together were most similar in elevation and physical space, and only one of the clustered stations was proposed to be hibernated. None of the stations that are most dissimilar were both proposed to be hibernated.

A time series plot of the two clustered stations shows similar patterns (apparent redundancy) in the time-series observed at DO1 and DO3 (Figure 6). Station D03 was proposed to be hibernated and DO1 was not.

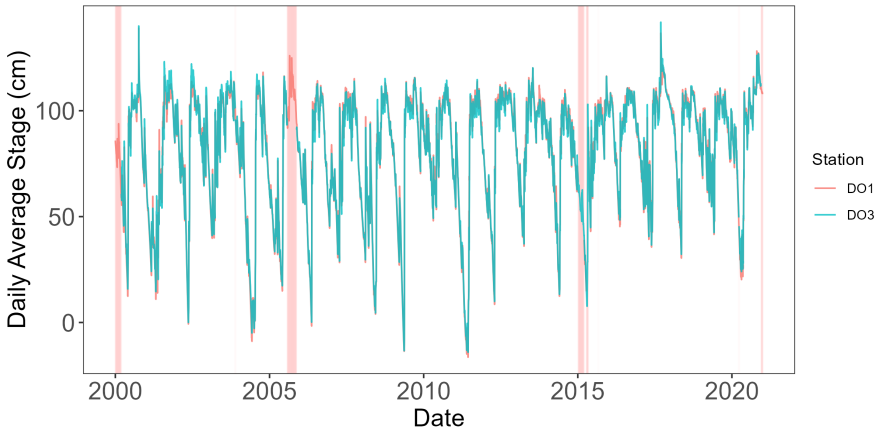


Figure 6: Raw time-series plot of observed daily average stage measurements by stations DO1 and DO3 from 2000 to 2020.

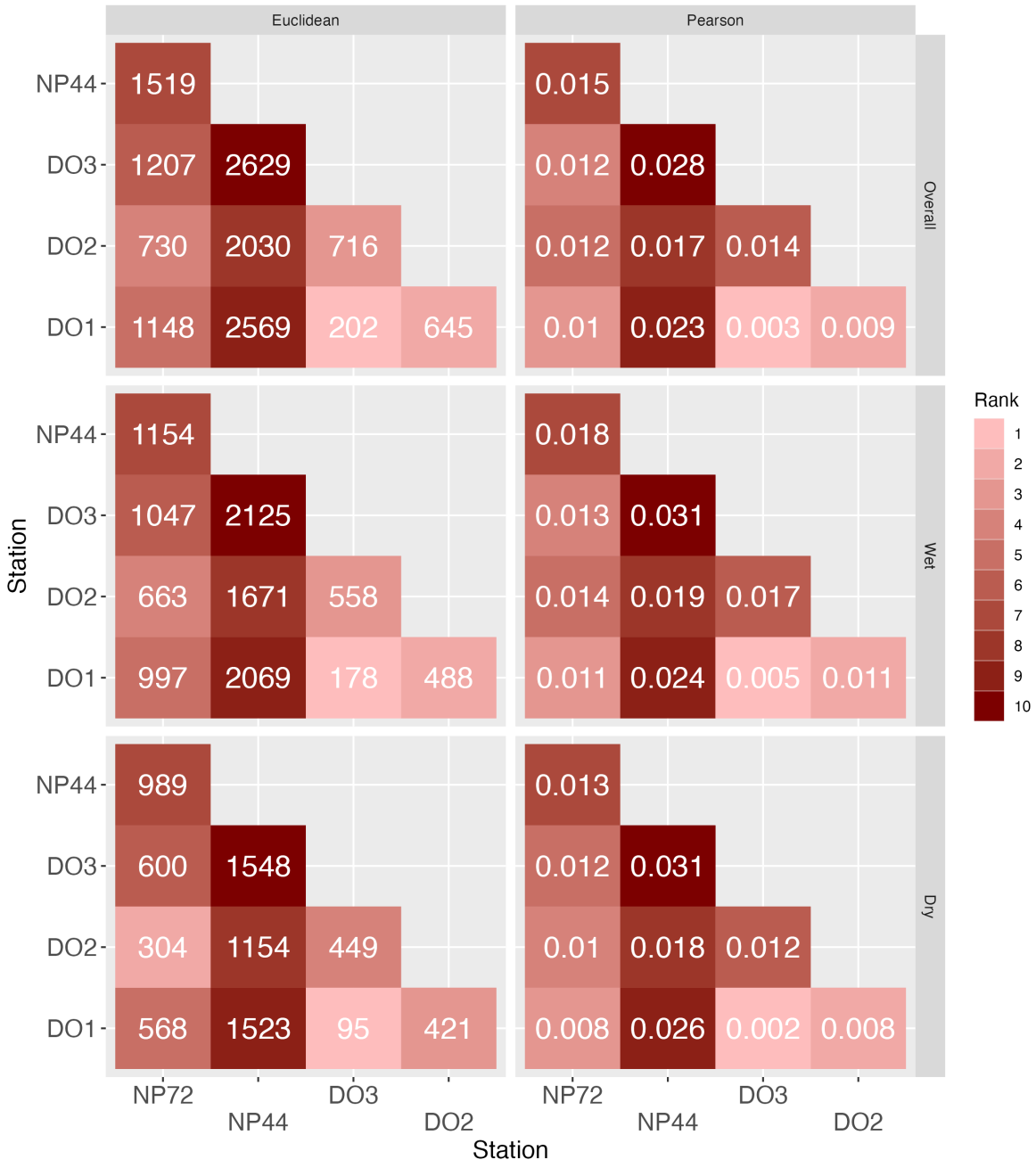


Figure 7: Tile plots of the ranked dissimilarity between stations using Euclidean and Pearson metrics for the Long Pine Key region. Low ranks indicate similarity, whereas high ranks indicate dissimilarity (1 = most similar, 10 = most dissimilar).

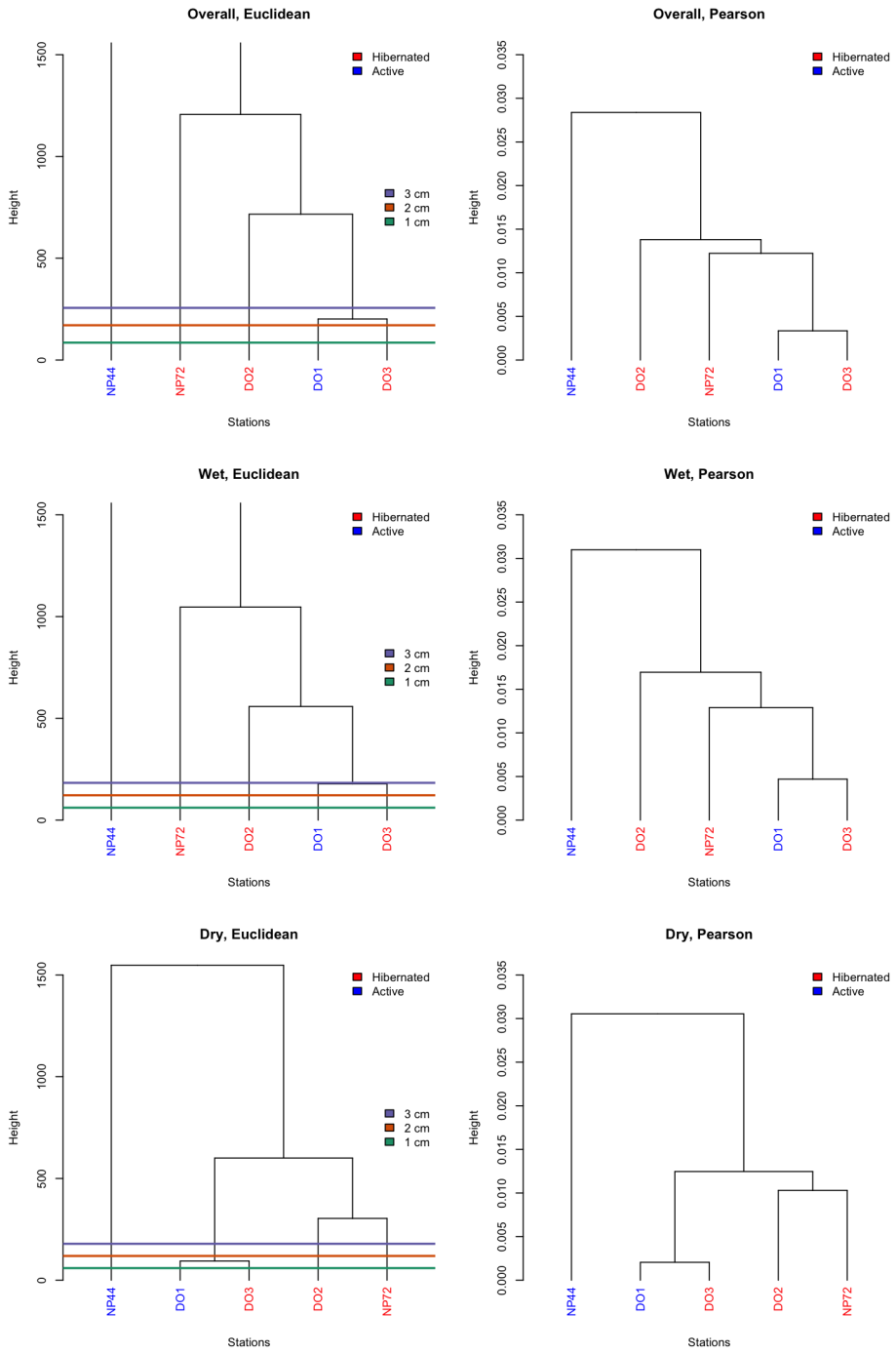


Figure 8: Dendrograms of the HAC results using both Euclidean and Pearson distance for the Long Pine Key region during the entire time series (top), wet season (middle), and dry season (bottom). For Euclidean distance, the horizontal lines indicate Euclidean distances for the practically meaningful differences of 1 cm (green), 2 cm (orange), and 3 cm (purple) in daily average water elevation. Red stations were proposed to be hibernated, whereas blue stations were not.

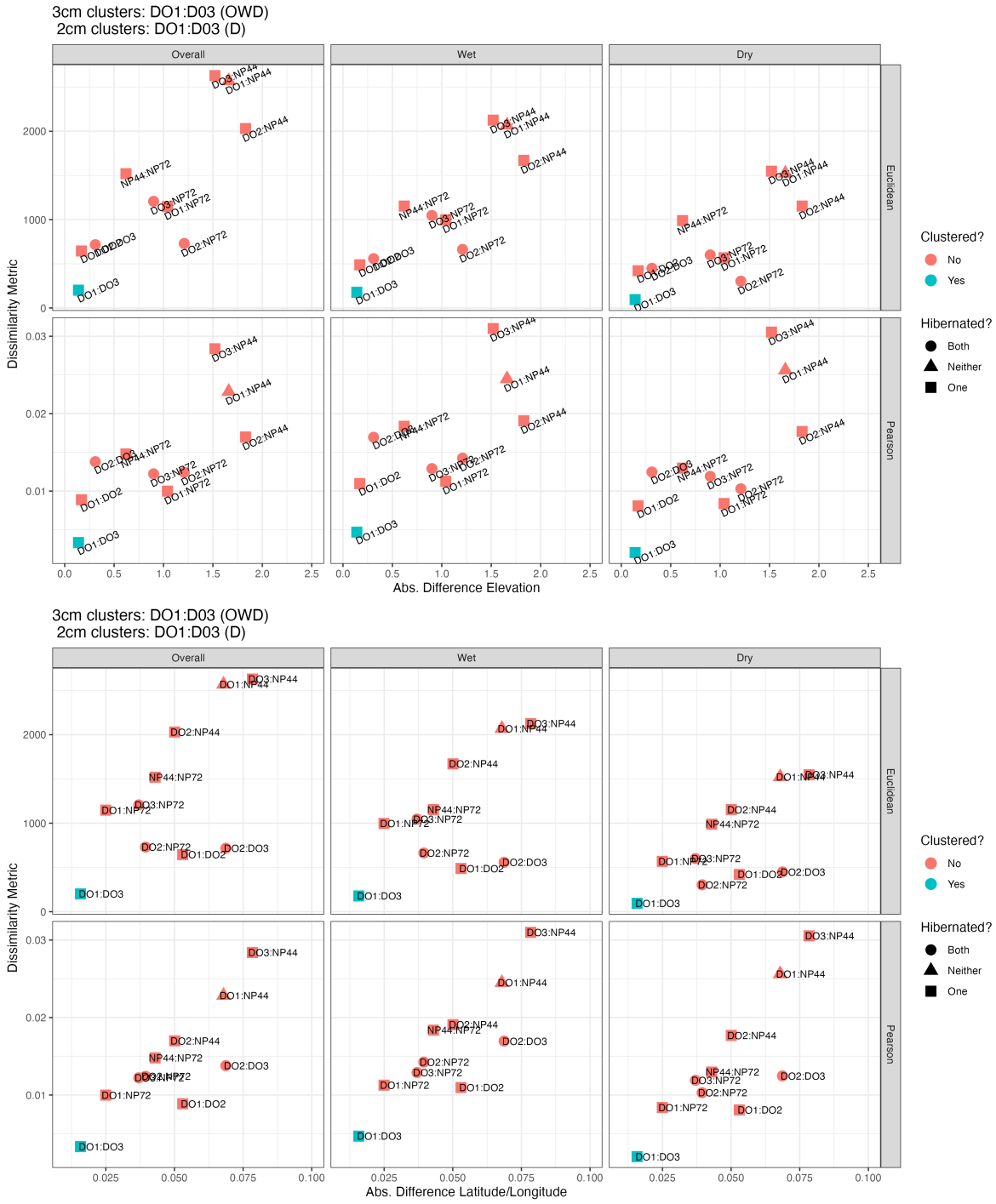


Figure 9: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair within the Long Pine Key region. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

5.2 Lower C111

Stations within Lower C111 are shown on a map of EVER in Figure 10, and observed daily average stage measurements (cm) are shown with missingness (indicated by red bars) between Jan 1, 2000 and Dec 31, 2020 in Figure 11. None of the station's time series in this region have an obvious visually distinct pattern from the others (Figure 11). Table 3 provides a summary of the total number and % of missing observations for each station in decreasing order within each season. In Lower C111 the total % missingness was highest during the wet season and CT50R and EVER7 were the stations with the most missingness across all seasons.

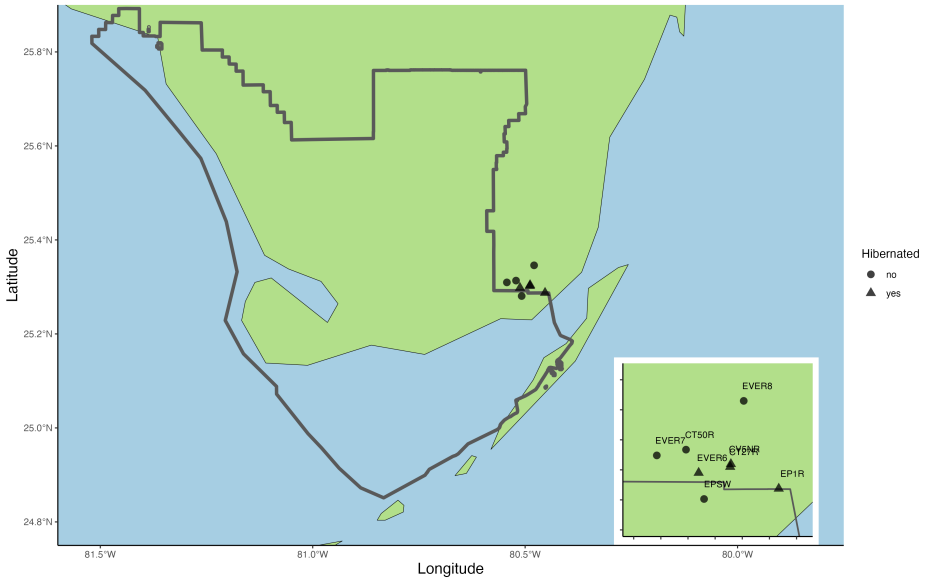


Figure 10: A map of the stations within the Lower C111 region plotted with the boundary of EVER (black line). Stations that were proposed to be hibernated in May 2023 are marked with a triangle.

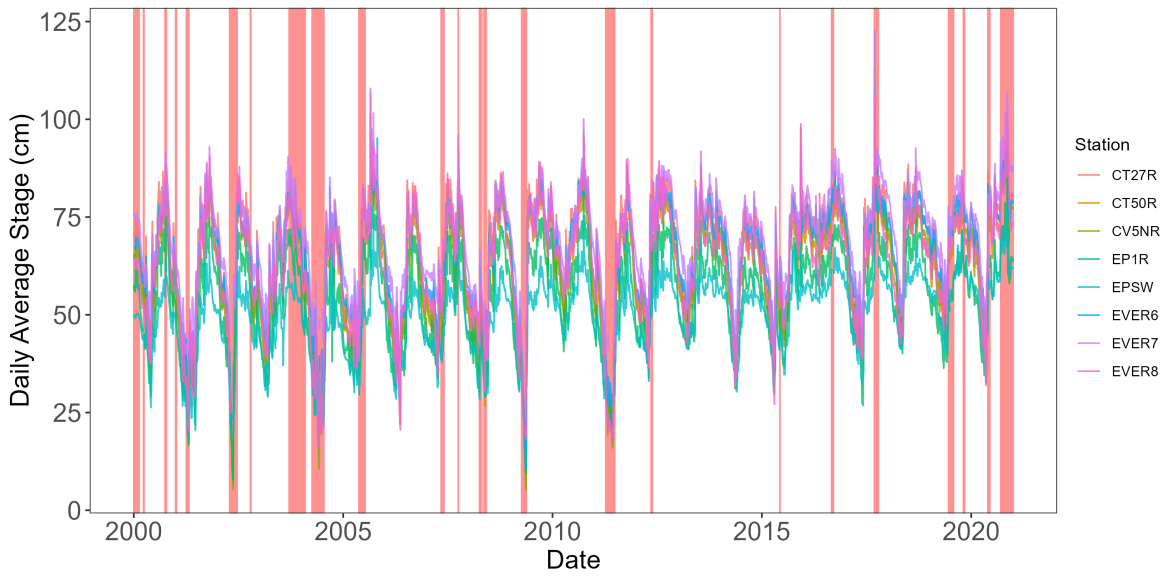


Figure 11: A line plot highlighting the observed stage (cm) measurements and missingness within the Lower C111 region from 2000 to 2020, colored by station. Red vertical bars indicate a day where at least 1 station has a missing stage value

Spearman correlation was the most reasonable metric to use for Lower C11 (See linearity plot, EVER-Stage-Analysis). Comparing pairwise dissimilarity across the Euclidean and Spearman distance metrics for all seasons (overall, wet, dry) revealed relatively consistent rankings across seasons within each metric (blocks/columns of dark red are similar within columns of Figure 13), and different patterns in the ranking within season when comparing metrics (blocks/columns of dark red are not the same within rows of Figure 13). Stations CT50R and CV5NR are most similar with respect to Euclidean dissimilarity and CT50R and CT27R are most similar with respect to Spearman dissimilarity, regardless of season. Similarly, EPSW and EVER7 are most dissimilar with respect to Euclidean dissimilarity across all seasons whereas EPSW and EVER8 are most dissimilar with respect to Spearman dissimilarity (Figure 7). The same patterns in the tile plots can be observed in the HAC dendrograms, in that the stations included in the first cluster formed varies depending on the metric (Figure 14).

We applied HAC and obtained cluster solutions for the Euclidean dissimilarity metric for $l = 1, 2, 3$ cut-heights within all seasons. The only cut-height resulting in any clustering based on the Euclidean dissimilarity metric was the $l = 3$ cut-height. At

Region	Station	End Date	N	n	Missing	% Missing
Lower_C111	CT50R	2020-09-14	7671.00	7236.00	435	5.67
Lower_C111	EVER7	2020-12-31	7671.00	7417.00	254	3.31
Lower_C111	EPSW	2020-12-31	7671.00	7486.00	185	2.41
Lower_C111	CT27R	2020-12-31	7671.00	7497.00	174	2.27
Lower_C111	EP1R	2020-12-31	7671.00	7564.00	107	1.39
Lower_C111	EVER8	2020-12-31	7671.00	7606.00	65	0.85
Lower_C111	EVER6	2020-12-31	7671.00	7634.00	37	0.48
Lower_C111	CV5NR	2020-12-31	7671.00	7647.00	24	0.31
Total (overall)			7671.00	6390.00	819	10.68
Region	Station	End Date	N	n	Missing	% Missing
Lower_C111 (wet)	CT50R	2020-09-14	3864.00	3633.00	231	5.98
Lower_C111 (wet)	EVER7	2020-10-31	3864.00	3704.00	160	4.14
Lower_C111 (wet)	EPSW	2020-10-31	3864.00	3708.00	156	4.04
Lower_C111 (wet)	CT27R	2020-10-31	3864.00	3742.00	122	3.16
Lower_C111 (wet)	EP1R	2020-10-31	3864.00	3762.00	102	2.64
Lower_C111 (wet)	EVER8	2020-10-31	3864.00	3803.00	61	1.58
Lower_C111 (wet)	CV5NR	2020-10-31	3864.00	3840.00	24	0.62
Lower_C111 (wet)	EVER6	2020-10-31	3864.00	3841.00	23	0.60
Total (wet)			3864.00	2985.00	500	12.94
Lower_C111 (dry)	CT50R	2020-04-30	3807.00	3603.00	204	5.36
Lower_C111 (dry)	EVER7	2020-12-31	3807.00	3713.00	94	2.47
Lower_C111 (dry)	CT27R	2020-12-31	3807.00	3755.00	52	1.37
Lower_C111 (dry)	EPSW	2020-12-31	3807.00	3778.00	29	0.76
Lower_C111 (dry)	EVER6	2020-12-31	3807.00	3793.00	14	0.37
Lower_C111 (dry)	EP1R	2020-12-31	3807.00	3802.00	5	0.13
Lower_C111 (dry)	EVER8	2020-12-31	3807.00	3803.00	4	0.11
Lower_C111 (dry)	CV5NR	2020-12-31	3807.00	3807.00	0	0.00
Total (dry)			3807.00	3405.00	319	8.38

Table 3: A table highlighting the missingness within the Lower C111 region-season combinations. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

the $l = 3$ cut-height, two clusters of size two were created in all seasons (CT50R and CV5NR, CT27R and EVER6; See Figure 12). These two clusters appear as blue points in the biplots investigating the relationship between pairwise Euclidean or Spearman dissimilarity and absolute difference in elevation or physical space (Figure 9 top and bottom, respectively). Weak positive linear associations are apparent between both

types of dissimilarity and absolute difference in elevation and physical space, with the strongest positive linear association being observed during the dry season for both metrics (Figure 15). Three of the four stations ending up in clusters were proposed to be hibernated, but CT50R was proposed to remain active.

A time series plot of the two clusters is provided in Figure 12. Patterns among all four stations are nearly identical and do not appear to be value-shifted, indicating potential redundancies within (and between) the clusters.

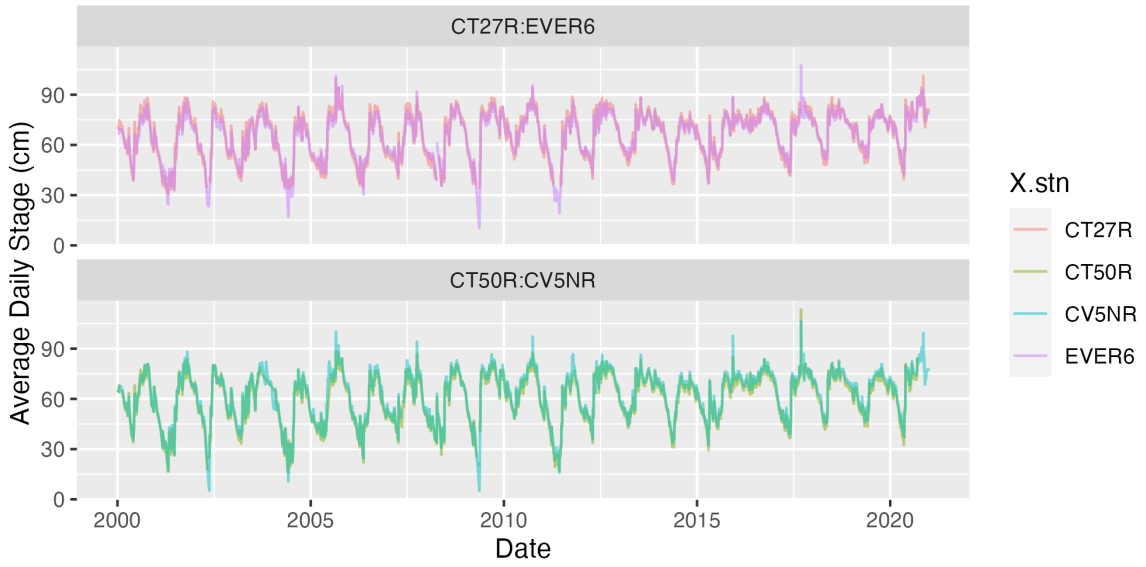


Figure 12: Raw time-series plot of observed daily average stage measurements for the two two-station clusters formed by cutting the dendrogram at a daily average stage difference of 3-cm. Missingness is not represented on this plot. Station CT50R was proposed to remain active and all others were proposed to be hibernated.

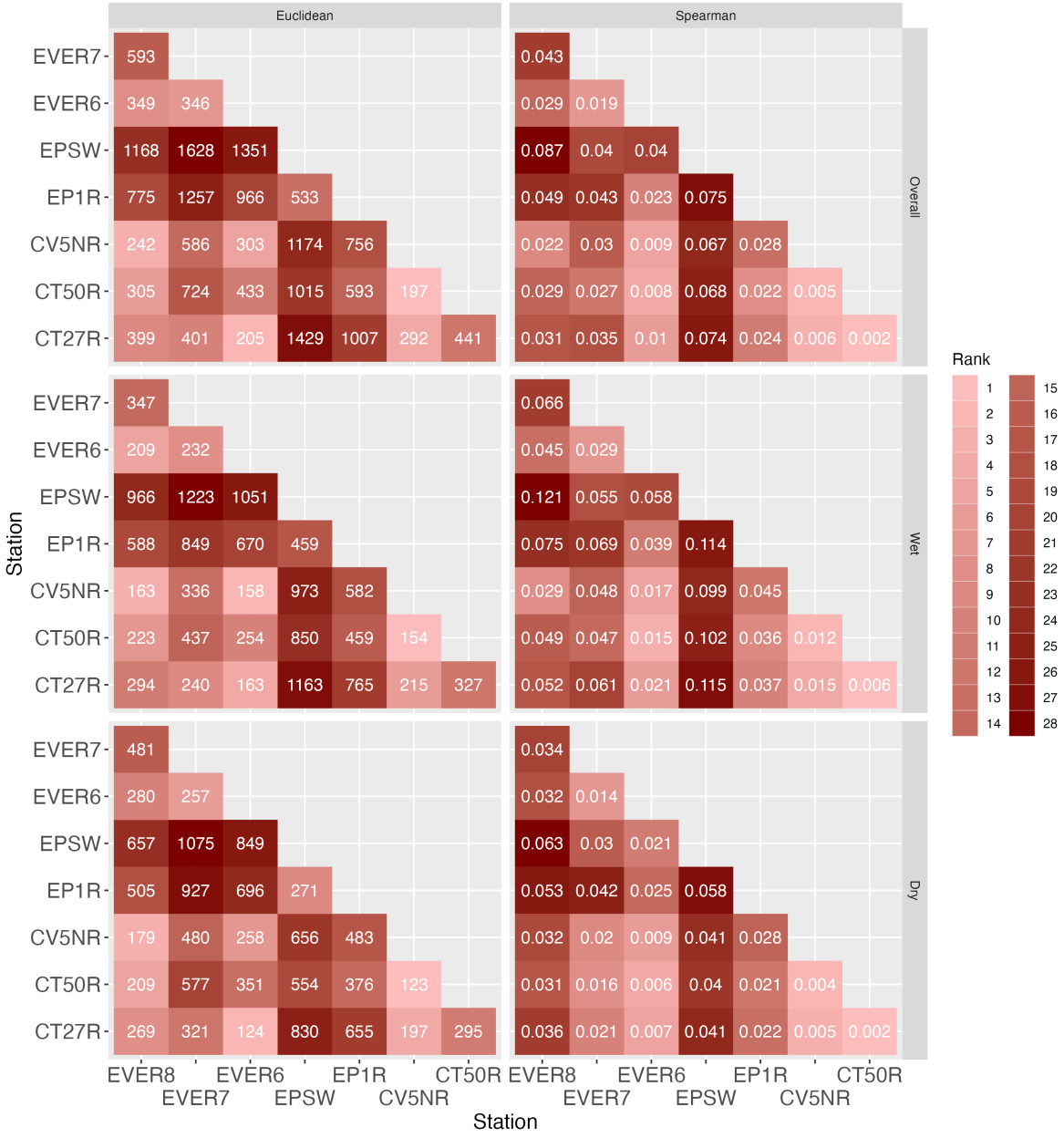


Figure 13: Tile plots of the ranked dissimilarity between stations using Euclidean (left) and Spearman (right) metrics within the overall (top), wet (middle), and dry (bottom) seasons for the Lower C111 region. Low ranks are depicted with lighter red/pink and indicate higher similarity, whereas high ranks are depicted in darker red and indicate higher dissimilarity (1 = most similar, 28 = most dissimilar).

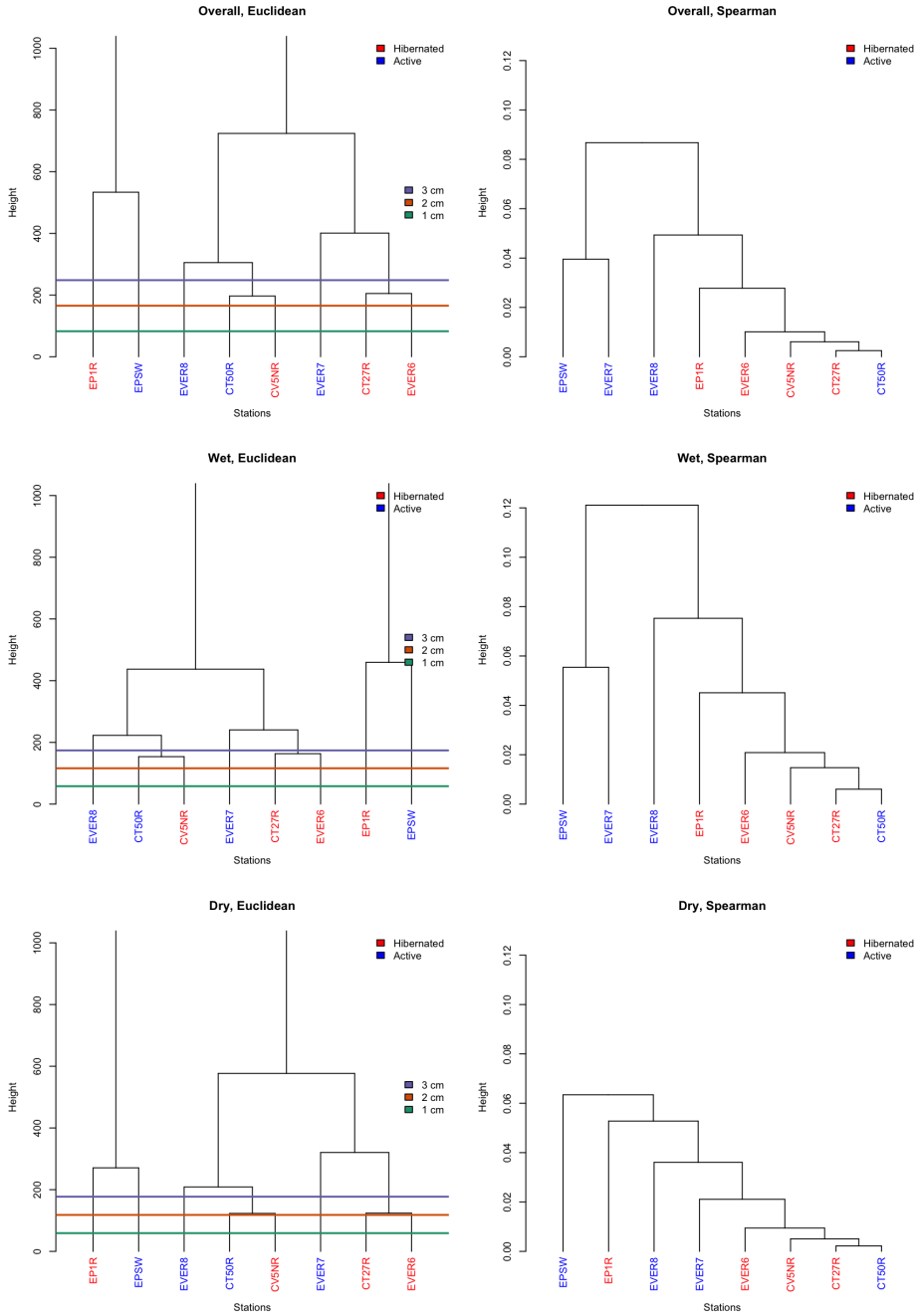


Figure 14: Dendrograms of the HAC results using both Euclidean and Spearman distance for the Lower C11 region during the entire time series (top), wet season (middle), and dry season (bottom). For Euclidean distance, the horizontal lines indicate Euclidean distances for the practically meaningful differences of 1 cm (green), 2 cm (orange), and 3 cm (purple) in daily average water elevation. Red stations were proposed to be hibernated, whereas blue stations were not.

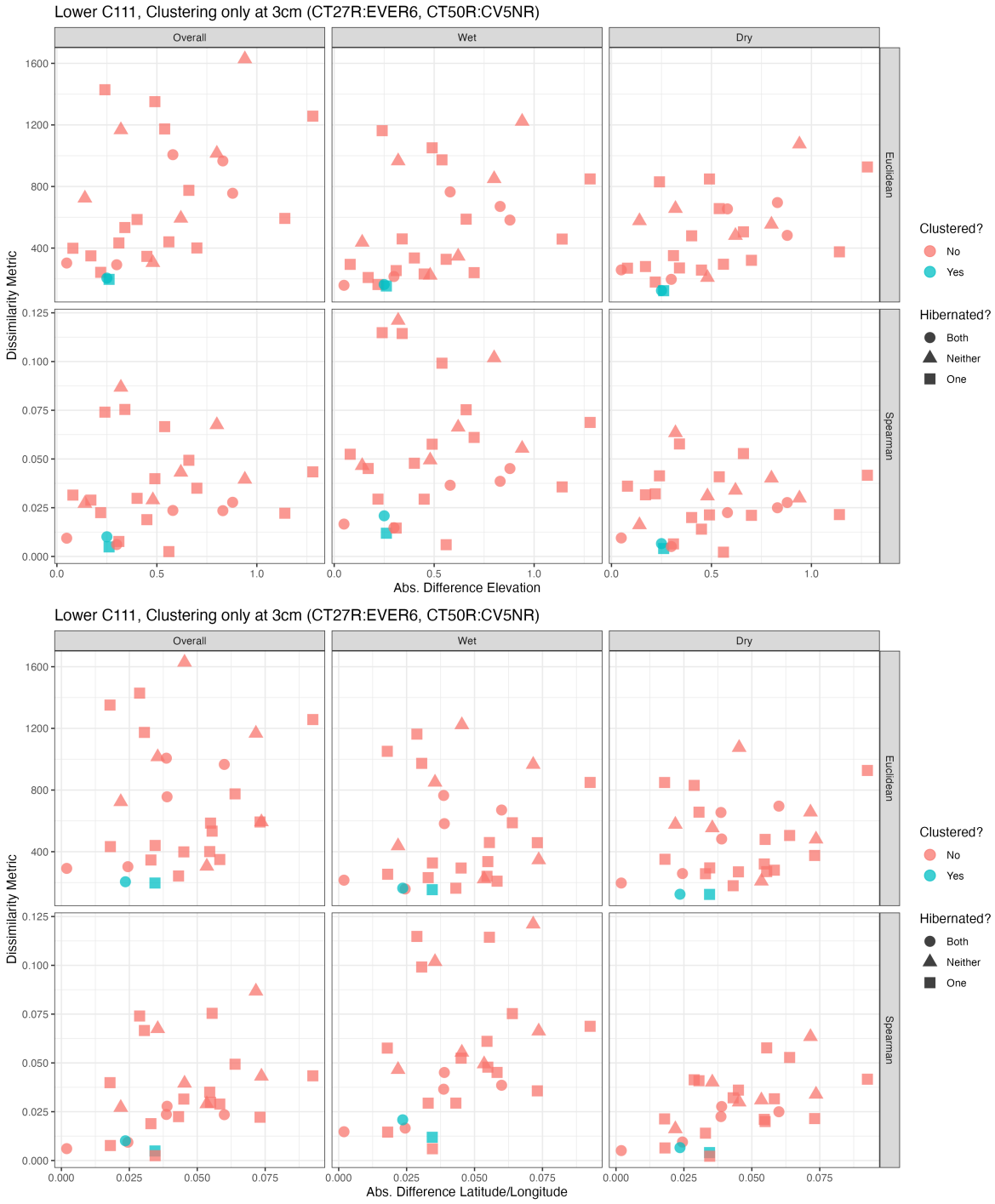


Figure 15: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair within the Lower C111 region. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

5.3 Road

Stations within Road are shown on a map of EVER in Figure 16, and observed daily average stage measurements (cm) are shown with missingness (indicated by red bars) between Jan 1, 2000 and Dec 31, 2020 in Figure 17. Missingness is defined as any day in which at least one station did not record a daily average stage measurement. There are clear value-shifted differences in the three time series within the Road region with station SP showing the highest daily average stage measurements, followed by station NP46 and then station NMP (Figure 17). The patterns across the 3 Road stations appear similar aside from the value shift and there is very little missingness present in this region regardless of season (See, Figure 17 and Table 4, respectively). Station SR1 was excluded from analysis within this region due to having greater than 10% missingness.

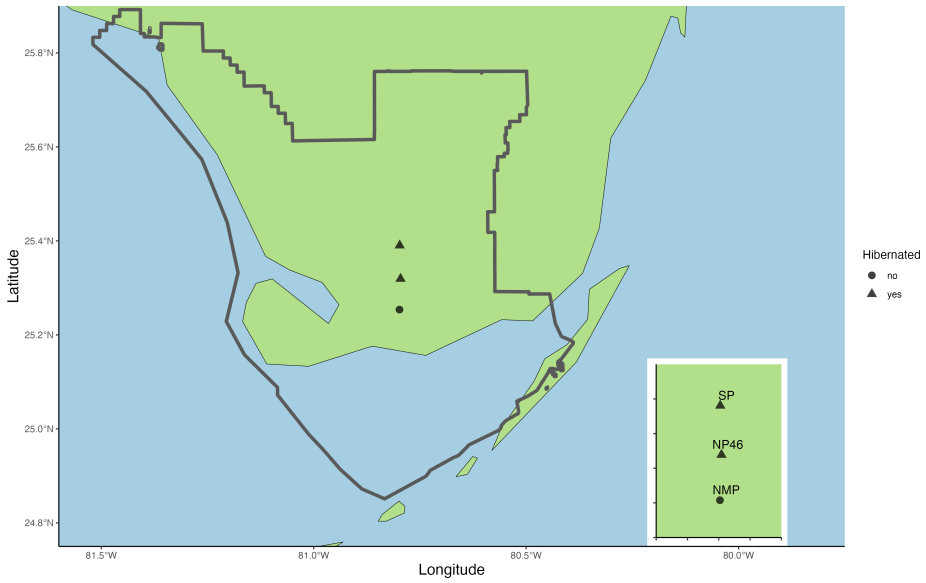


Figure 16: A map of the stations included in the analysis within the Road region (plotted with the boundary of EVER, black line). Stations that were proposed to be hibernated in May 2023 are marked with a triangle.

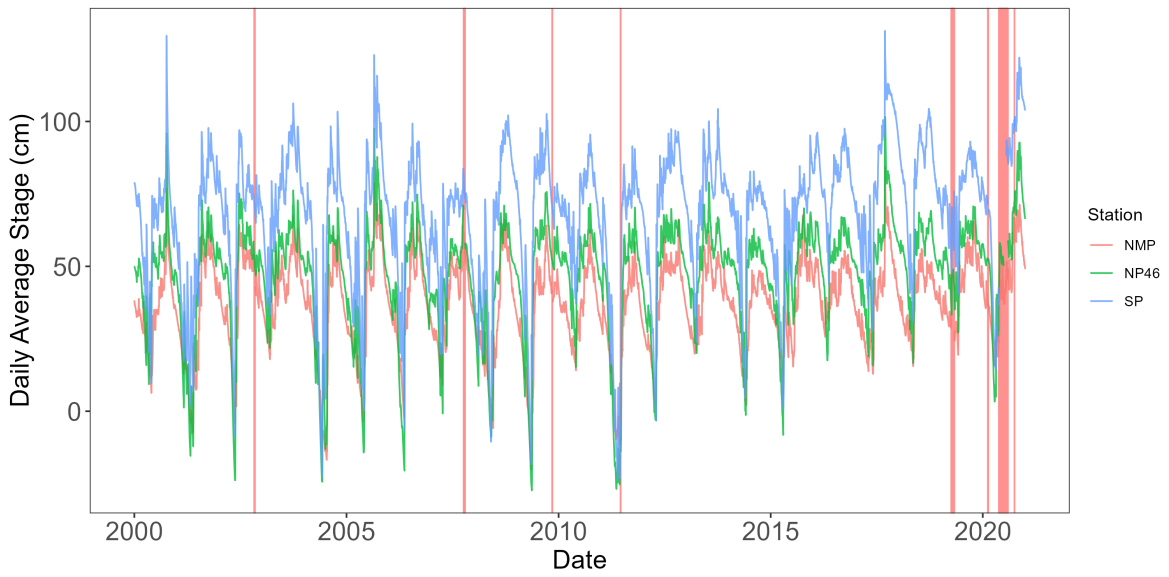


Figure 17: A line plot highlighting the observed stage (cm) measurements and missingness within the Road region from 2000 to 2020, colored by station. Red vertical bars indicate a day where at least 1 station has a missing stage value

Region	Station	End Date	N	n	Missing	% Missing
Road	SR1	2020-12-31	7671.00	6560.00	1111	14.48
Road	SP	2020-12-31	7671.00	7602.00	69	0.90
Road	NP46	2020-12-31	7671.00	7622.00	49	0.64
Road	NMP	2020-12-31	7671.00	7637.00	34	0.44
Total (overall, excluding SR1)			7671.00	7519.00	131	1.71
Road (wet)	SR1	2020-10-31	3864.00	3193.00	671	17.37
Road (wet)	SP	2020-10-31	3864.00	3799.00	65	1.68
Road (wet)	NP46	2020-10-31	3864.00	3815.00	49	1.27
Road (wet)	NMP	2020-10-31	3864.00	3862.00	2	0.05
Total (wet, excluding SR1)			3864.00	3748.00	95	2.46
Road (dry)	SR1	2020-12-31	3807.00	3367.00	440	11.56
Road (dry)	NMP	2020-12-31	3807.00	3775.00	32	0.84
Road (dry)	SP	2020-12-31	3807.00	3803.00	4	0.11
Road (dry)	NP46	2020-12-31	3807.00	3807.00	0	0.00
Total (dry, excluding SR1)			3807.00	3771.00	36	0.95

Table 4: A table highlighting the missingness within the Road region-season combinations. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

Spearman correlation was the most reasonable metric to use for Road (See linearity plot, EVER-Stage-Analysis). Comparing pairwise dissimilarity across the Euclidean and Spearman distance metrics for all seasons (overall, wet, dry) revealed consensus for the most dissimilar stations, but not for the most similar stations (Figure 18). All three stations also appear dissimilar based on the dendrograms and remained their own cluster at all three Euclidean cut-heights considered (Figure 19).

With only three pairwise comparisons among the stations in road, there are very few observations in the biplots comparing pairwise dissimilarity based on Euclidean and Spearman distance to absolute pairwise difference in elevation and physical space, but there does appear to be a generally positive association between each dissimilarity metric and each absolute difference across all three seasons (Figure 20).

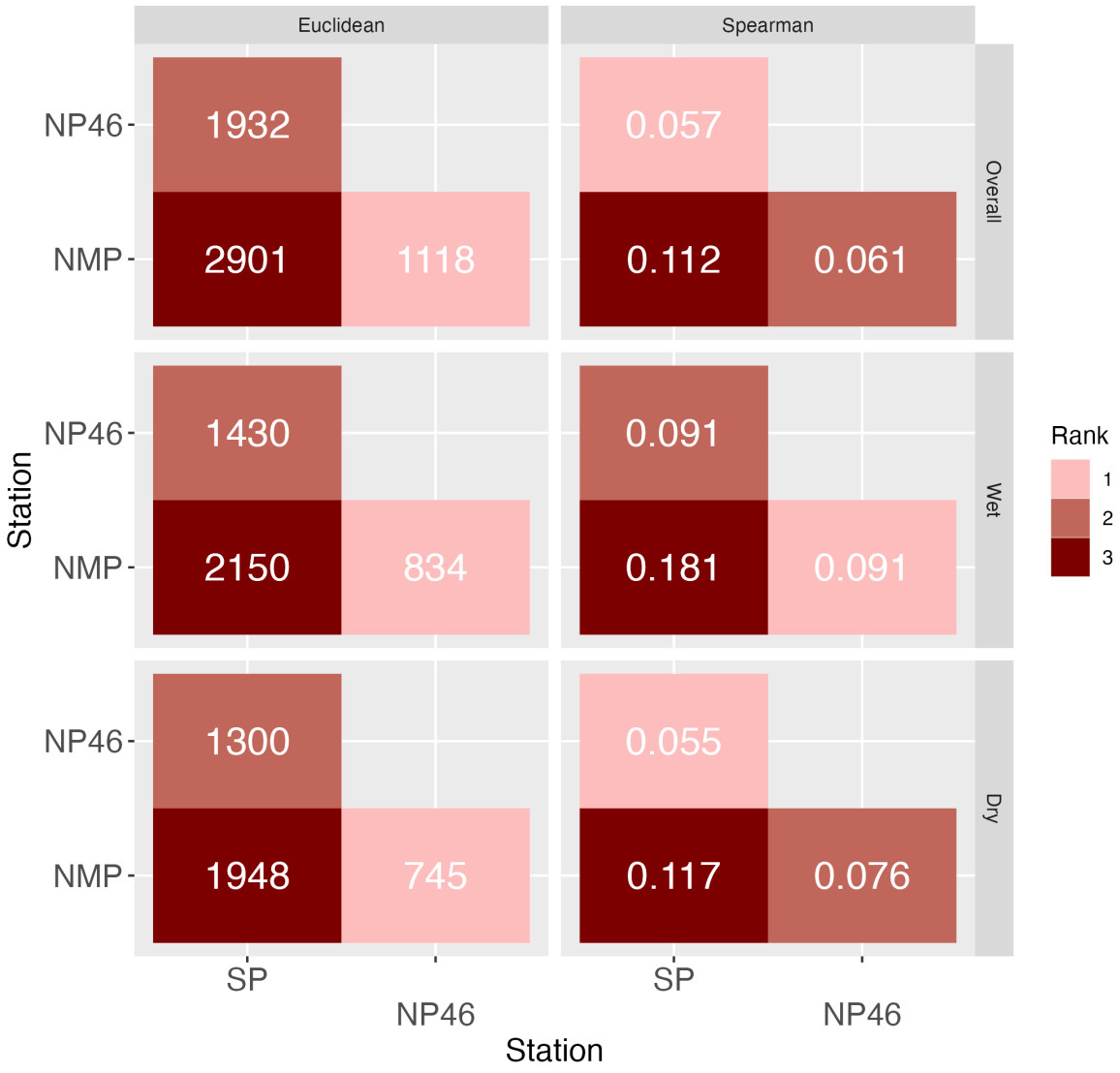


Figure 18: Tile plots of the ranked dissimilarity between stations using Euclidean (left) and Spearman (right) metrics within the overall (top), wet (middle), and dry (bottom) seasons for the Road region. Lighter red and lower rank indicates similarity, whereas darker red and higher rank indicates dissimilarity (1 = most similar, 3 = most dissimilar).

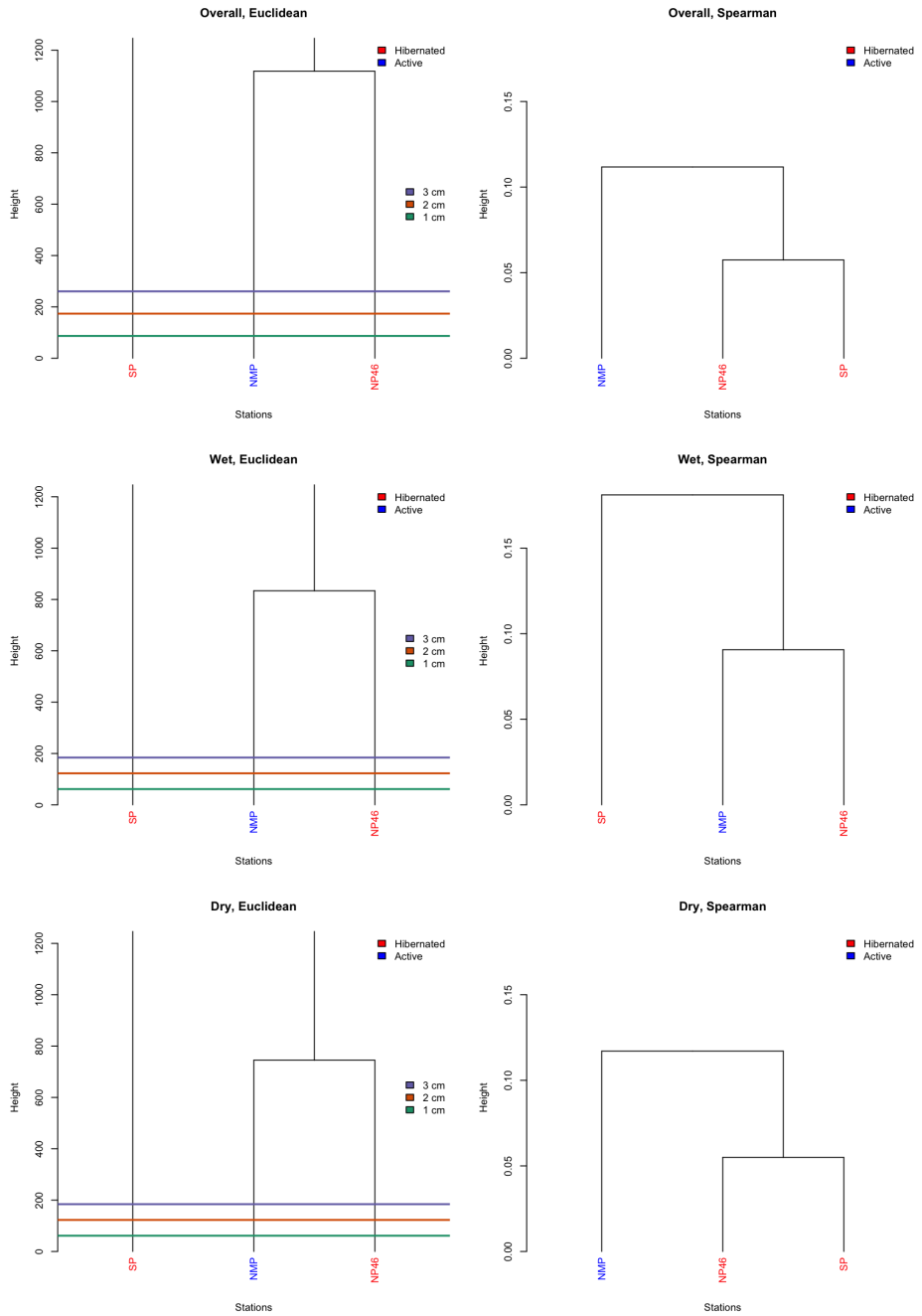


Figure 19: Dendrograms of the HAC results using both Euclidean and Spearman distance for the Road region during the entire time series (top), wet season (middle), and dry season (bottom). For Euclidean distance, the horizontal lines indicate Euclidean distances for the practically meaningful differences of 1 cm (green), 2 cm (orange), and 3 cm (purple) in daily average water elevation. Red stations were proposed to be hibernated, whereas blue stations were not.

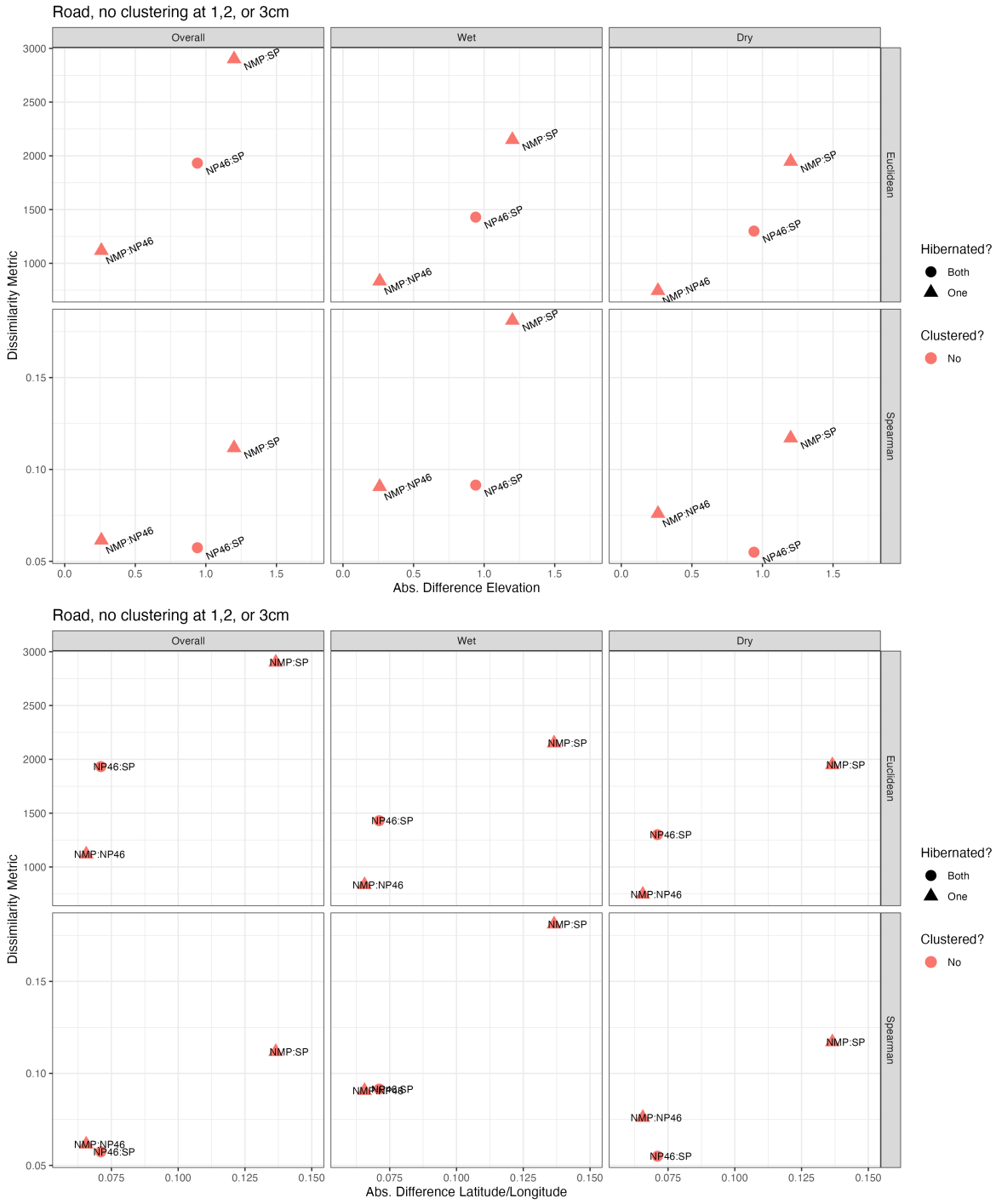


Figure 20: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair within the Road region. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

5.4 Rocky Glades

Stations within Rocky Glades are shown on a map of EVER in Figure 21, and observed daily average stage measurements (cm) are shown with missingness (indicated by red bars) between Jan 1, 2000 and Dec 31, 2020 in Figure 22. There are visible value-shifted differences among the stations in Rocky Glades with NP62 showing substantially lower daily average stage measurements than other stations in the region (Figure 22). There is also visible separation in the values of daily average stage measurements among the stations that are substantially higher than NP62 with some having higher/lower values than the others but all exhibiting a relatively similar pattern over time. Table 5 provides a summary of the total number and % of missing observations for each station in decreasing order within each season. In Rocky Glades the total % missingness was highest during the wet season, and RG3, CR3, and RG1 all had high missingness across all seasons (Table 5). Station RG4 was excluded from analysis within this region due to having greater than 10% missingness.

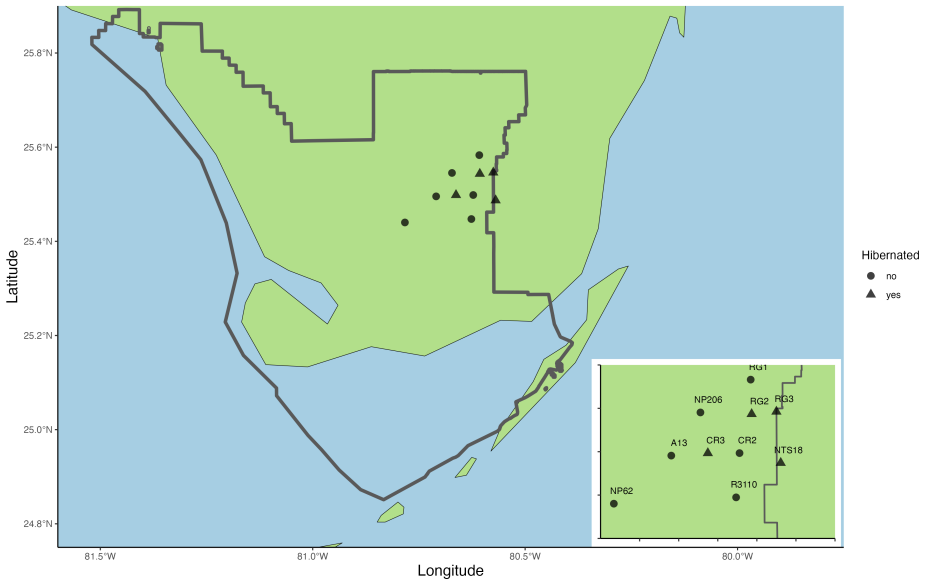


Figure 21: A map of the stations included in the analysis within the Rocky Glades region (plotted with the boundary of EVER, black line). The station RG4 was excluded because more than 10% of stage observations were missing. Stations that were proposed to be hibernated in May 2023 are marked with a triangle.

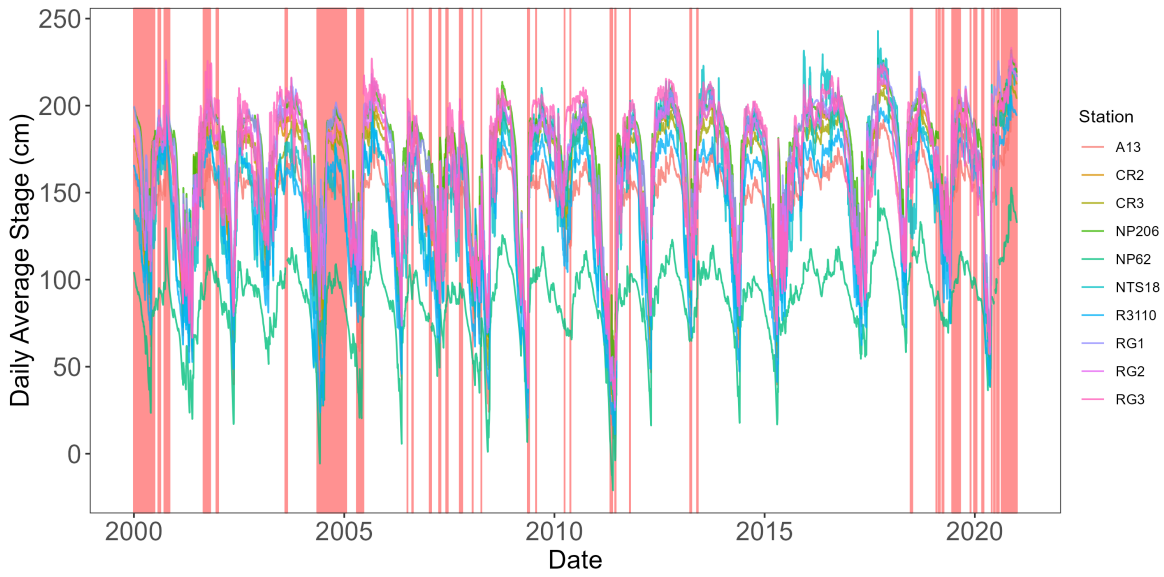


Figure 22: A line plot highlighting the observed stage (cm) measurements and missingness within the Rocky Glades region from 2000 to 2020, colored by station. Red vertical bars indicate a day where at least 1 station has a missing stage value

Region	Station	End Date	N	n	Missing	% Missing
Rocky_Glades	RG4	2020-12-31	7671.00	6754.00	917	11.95
Rocky_Glades	RG3	2020-12-31	7671.00	7158.00	513	6.69
Rocky_Glades	CR3	2020-12-31	7671.00	7509.00	162	2.11
Rocky_Glades	RG1	2020-12-31	7671.00	7512.00	159	2.07
Rocky_Glades	NP62	2020-12-31	7671.00	7569.00	102	1.33
Rocky_Glades	NTS18	2020-12-31	7671.00	7579.00	92	1.20
Rocky_Glades	A13	2020-12-31	7671.00	7607.00	64	0.83
Rocky_Glades	CR2	2020-12-31	7671.00	7632.00	39	0.51
Rocky_Glades	NP206	2020-12-31	7671.00	7641.00	30	0.39
Rocky_Glades	RG2	2020-12-31	7671.00	7649.00	22	0.29
Rocky_Glades	R3110	2020-12-31	7671.00	7671.00	0	0.00
Total (excluding RG4)			7671.00	6488.00	1049	13.67
Rocky_Glades (wet)	RG4	2020-10-31	3864.00	3369.00	495	12.81
Rocky_Glades (wet)	RG3	2020-10-31	3864.00	3562.00	302	7.82
Rocky_Glades (wet)	CR3	2020-10-31	3864.00	3757.00	107	2.77
Rocky_Glades (wet)	RG1	2020-10-31	3864.00	3779.00	85	2.20
Rocky_Glades (wet)	NP62	2020-10-31	3864.00	3786.00	78	2.02
Rocky_Glades (wet)	NTS18	2020-10-31	3864.00	3794.00	70	1.81
Rocky_Glades (wet)	RG2	2020-10-31	3864.00	3842.00	22	0.57
Rocky_Glades (wet)	CR2	2020-10-31	3864.00	3846.00	18	0.47
Rocky_Glades (wet)	NP206	2020-10-31	3864.00	3860.00	4	0.10
Rocky_Glades (wet)	A13	2020-10-31	3864.00	3862.00	2	0.05
Rocky_Glades (wet)	R3110	2020-10-31	3864.00	3864.00	0	0.00
Total (wet, excluding RG4)			3864.00	3176.00	661	17.11
Rocky_Glades (dry)	RG4	2020-12-31	84381	83959	422	11.08
Rocky_Glades (dry)	RG3	2020-12-31	3807.00	3596.00	211	5.54
Rocky_Glades (dry)	RG1	2020-12-31	3807.00	3733.00	74	1.94
Rocky_Glades (dry)	A13	2020-12-31	3807.00	3745.00	62	1.63
Rocky_Glades (dry)	CR3	2020-12-31	3807.00	3752.00	55	1.44
Rocky_Glades (dry)	NP206	2020-12-31	3807.00	3781.00	26	0.68
Rocky_Glades (dry)	NP62	2020-12-31	3807.00	3783.00	24	0.63
Rocky_Glades (dry)	NTS18	2020-12-31	3807.00	3785.00	22	0.58
Rocky_Glades (dry)	CR2	2020-12-31	3807.00	3786.00	21	0.55
Rocky_Glades (dry)	R3110	2020-12-31	3807.00	3807.00	0	0.00
Rocky_Glades (dry)	RG2	2020-12-31	3807.00	3807.00	0	0.00
Total (dry, excluding RG4)			3807.00	3312.00	388	10.19

Table 5: A table highlighting the missingness within the Rocky Glades region-season combinations. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

Spearman correlation was the most reasonable correlation-based metric to use for Rocky Glades (See linearity plot, EVER-Stage-Analysis). When comparing to Euclidean dissimilarity, we observed some differences in the Euclidean- and Spearman-based ranks within a season (comparing within a row of Figure 23). When conditioning on a metric (i.e., within Euclidean or Spearman) rankings across seasons are relatively consistent (comparing within a column of Figure 23). Both metrics consistently ranked RG2 and CR2 as the most similar stations across all seasons, but there was no consistency across metrics when comparing the most dissimilar stations within a season. The consistency in most-similar stations is also observed in the dendrograms; CR2 and RG2 are always the first stations to be joined as a cluster regardless of metric and season (Figure 24).

Implementing HAC with the Euclidean metric resulted in no clustering at any of the three practically meaningful Euclidean cut-heights considered ($l = 1, 2, 3$). We observed strong positive linear associations between pairwise Euclidean dissimilarity and the absolute difference in elevation and physical space across all seasons (Figure 25). The same relationships are not as strong for Spearman dissimilarity. These relationships indicate that stations close in space, elevation, or both in the Rocky Glades will be most similar with respect to Euclidean and Spearman dissimilarity.

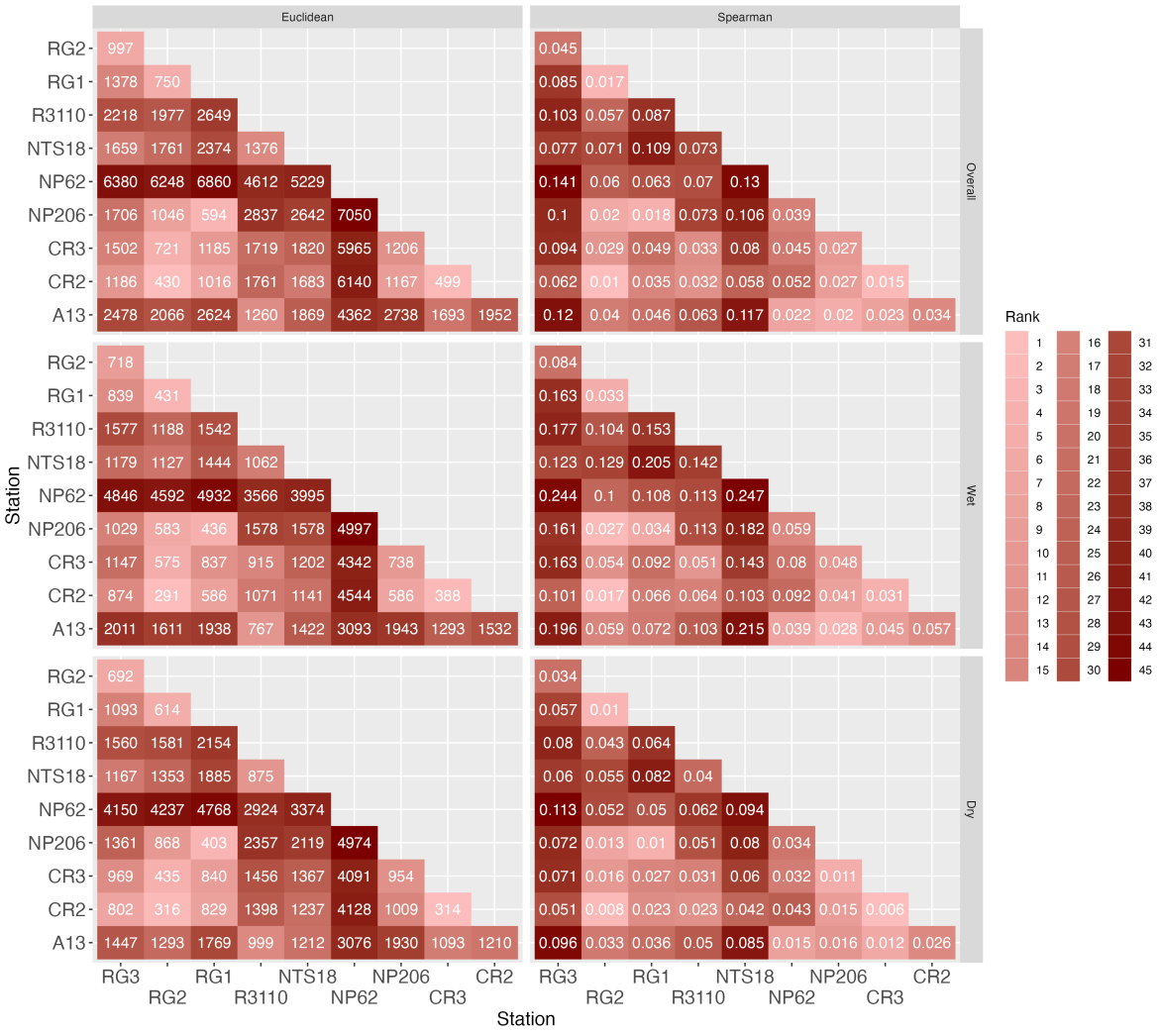


Figure 23: Tile plots of the ranked dissimilarity between stations using Euclidean (left) and Spearman (right) metrics within the overall (top), wet (middle), and dry (bottom) seasons for the Rocky Glades region. Lower ranks and lighter red color indicates similarity, whereas higher ranks and darker red color indicates dissimilarity (1 = most similar, 45 = most dissimilar).

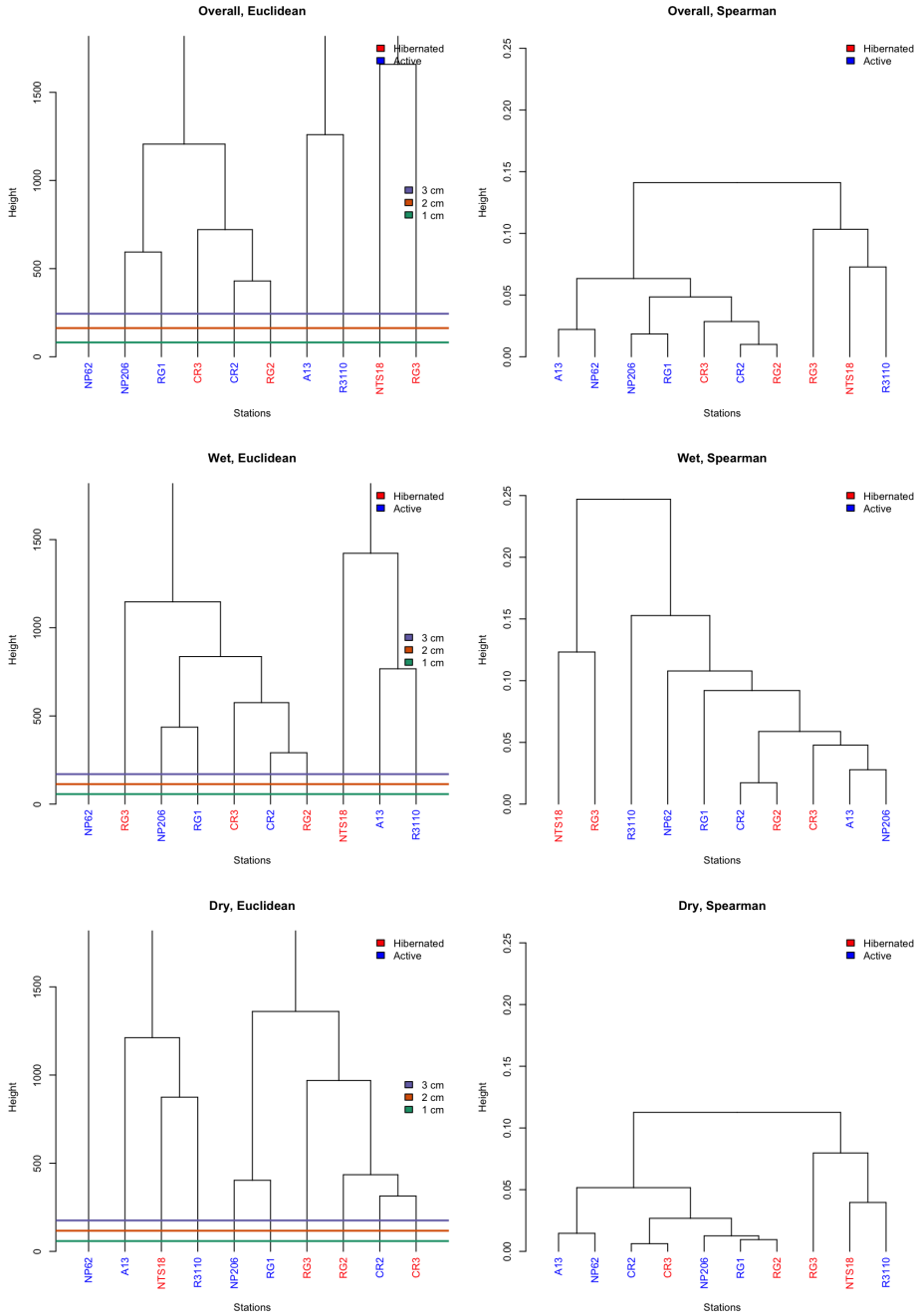


Figure 24: Dendrograms of the HAC results using both Euclidean and Spearman distance for the Rocky Glades region during the entire time series (top), wet season (middle), and dry season (bottom). For Euclidean distance, the horizontal lines indicate Euclidean distances for the practically meaningful differences of 1 cm (green), 2 cm (orange), and 3 cm (purple) in daily average water elevation. Red stations were proposed to be hibernated, whereas blue stations were not.

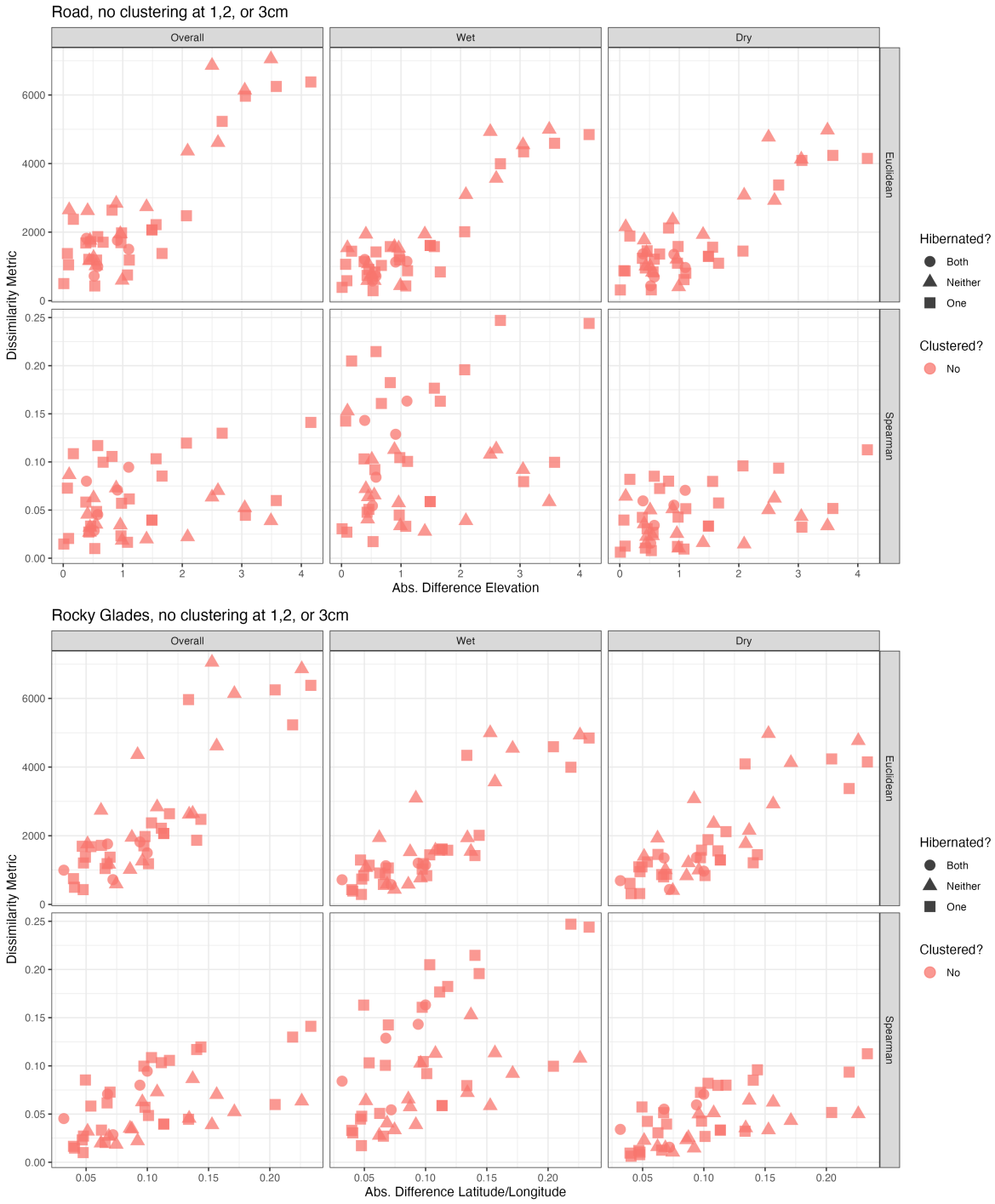


Figure 25: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair within the Rocky Glades region. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

5.5 Shark Slough

Stations within Shark Slough are shown on a map of EVER in Figure 26, and observed daily average stage measurements (cm) are shown with missingness (indicated by red bars) between Jan 1, 2000 and Dec 31, 2020 in Figure 27. There are visible value-shifted differences among the stations in Shark Slough with all "NP" stations showing consistently higher daily average stage measurements than other stations in the region (Figure 27). There is visible separation in the values of daily average stage measurements among most stations in Shark Slough. Table 6 provides a summary of the total number and % of missing observations for each station in decreasing order within each season. In Shark Slough the total % missingness was highest during the wet season, and RG3, CR3, and RG1 all had high missingness across all seasons (Table 6). Station SPARO was excluded from analysis within this region because it did not become active until November 2011.

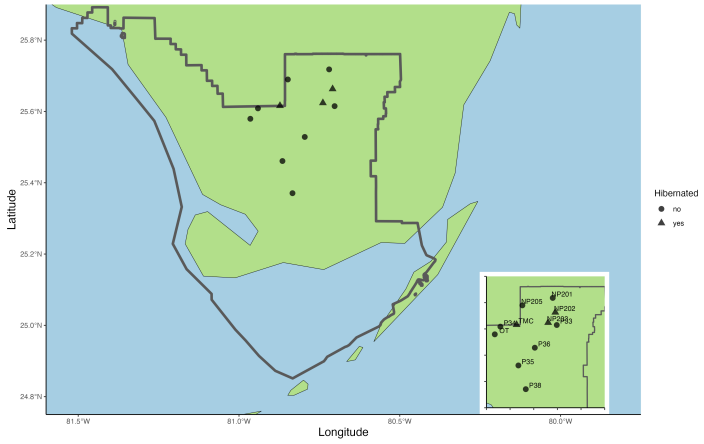


Figure 26: A map of the stations included in the analysis of the Shark Slough region. Stations are plotted with the boundary of EVER (black line). Stations that were proposed to be hibernated in May 2023 are marked with a triangle.

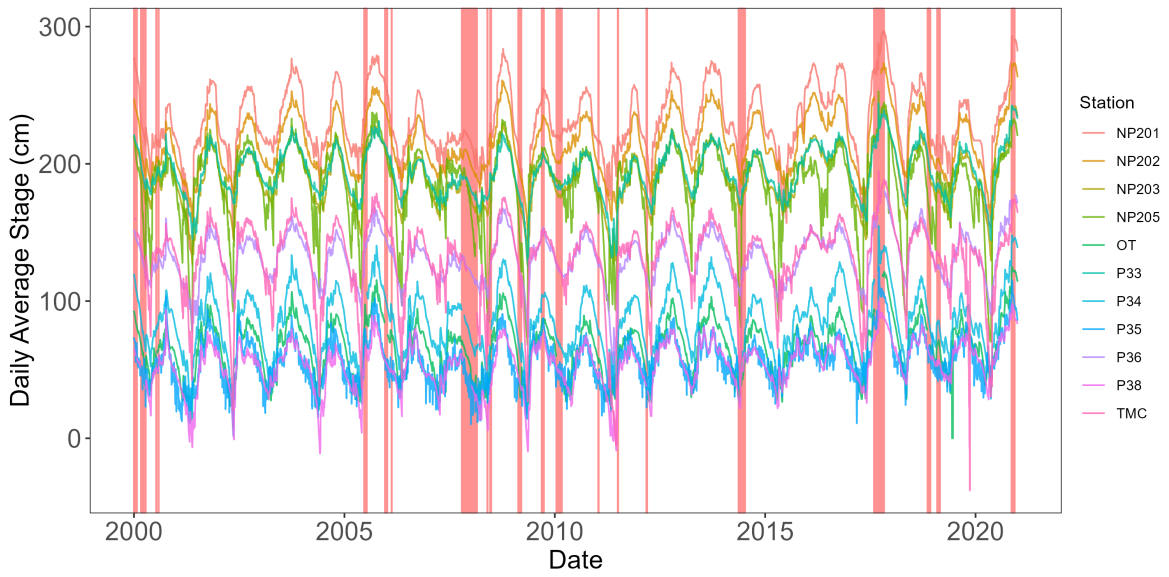


Figure 27: A line plot highlighting the observed stage (cm) measurements and missingness within the Shark Slough region from 2000 to 2020, colored by station. Red vertical bars indicate a day where at least 1 station has a missing stage value

Region	Station	End Date	N	n	Missing	% Missing
Shark_Slough	SPARO	2020-12-31	7671.00	3227.00	4444	57.93
Shark_Slough	OT	2020-12-31	7671.00	7501.00	170	2.22
Shark_Slough	P38	2020-12-31	7671.00	7529.00	142	1.85
Shark_Slough	TMC	2020-12-31	7671.00	7563.00	108	1.41
Shark_Slough	NP203	2020-12-31	7671.00	7564.00	107	1.39
Shark_Slough	P35	2020-12-31	7671.00	7578.00	93	1.21
Shark_Slough	P34	2020-12-31	7671.00	7589.00	82	1.07
Shark_Slough	P36	2020-12-31	7671.00	7595.00	76	0.99
Shark_Slough	NP202	2020-12-31	7671.00	7610.00	61	0.80
Shark_Slough	NP201	2020-12-31	7671.00	7630.00	41	0.53
Shark_Slough	P33	2020-12-31	7671.00	7670.00	1	0.01
Shark_Slough	NP205	2020-12-31	7671.00	7670.00	1	0.01
Total (excluding SPARO)			7671.00	6789.00	596	7.77
Shark_Slough (wet)	SPARO	2020-10-31	3864.00	1535.00	2329	60.27
Shark_Slough (wet)	NP203	2020-10-31	3864.00	3783.00	81	2.10
Shark_Slough (wet)	P34	2020-10-31	3864.00	3787.00	77	1.99
Shark_Slough (wet)	OT	2020-10-31	3864.00	3793.00	71	1.84
Shark_Slough (wet)	NP202	2020-10-31	3864.00	3803.00	61	1.58
Shark_Slough (wet)	P35	2020-10-31	3864.00	3806.00	58	1.50
Shark_Slough (wet)	P36	2020-10-31	3864.00	3813.00	51	1.32
Shark_Slough (wet)	P38	2020-10-31	3864.00	3842.00	22	0.57
Shark_Slough (wet)	P33	2020-10-31	3864.00	3863.00	1	0.03
Shark_Slough (wet)	NP201	2020-10-31	3864.00	3864.00	0	0.00
Shark_Slough (wet)	TMC	2020-10-31	3864.00	3864.00	0	0.00
Shark_Slough (wet)	NP205	2020-10-31	3864.00	3864.00	0	0.00
Total (wet, excluding SPARO)			3864.00	3442.00	227	5.87
Shark_Slough (dry)	SPARO	2020-12-31	3807.00	1692.00	2115	55.56
Shark_Slough (dry)	P38	2020-12-31	3807.00	3687.00	120	3.15
Shark_Slough (dry)	TMC	2020-12-31	3807.00	3699.00	108	2.84
Shark_Slough (dry)	OT	2020-12-31	3807.00	3708.00	99	2.60
Shark_Slough (dry)	NP201	2020-12-31	3807.00	3766.00	41	1.08
Shark_Slough (dry)	P35	2020-12-31	3807.00	3772.00	35	0.92
Shark_Slough (dry)	NP203	2020-12-31	3807.00	3781.00	26	0.68
Shark_Slough (dry)	P36	2020-12-31	3807.00	3782.00	25	0.66
Shark_Slough (dry)	P34	2020-12-31	3807.00	3802.00	5	0.13
Shark_Slough (dry)	NP205	2020-12-31	3807.00	3806.00	1	0.03
Shark_Slough (dry)	NP202	2020-12-31	3807.00	3807.00	0	0.00
Shark_Slough (dry)	P33	2020-12-31	3807.00	3807.00	0	0.00
Total (dry, excluding SPARO)			3807.00	3347.00	369	9.69

Table 6: A table highlighting the missingness within the Shark Slough region-season combinations. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

Spearman correlation was the most reasonable metric to use for Shark Slough (See linearity plot, EVER-Stage-Analysis). Comparing Spearman and Euclidean dissimilarity within a season (overall, wet, or dry) we observed that the most similar stations were always NP203 and P33, and that the most dissimilar stations were not consistent (comparing tileplots within a row of Figure 28). Comparing pairwise dissimilarity across seasons within a metric (Euclidean or Pearson) revealed similar rankings across seasons (comparing tileplots within a column in Figure 28). The consistency in most-similar stations is also observed in the dendrograms; NP203 and P33 are always the first stations to join regardless of metric and season (Figure 29).

Implementing HAC with the Euclidean metric resulted in no clustering at any of the three practically meaningful Euclidean cut-heights considered ($l = 1, 2, 3$). We observed strong positive linear associations between pairwise Euclidean dissimilarity and the absolute difference in elevation across all seasons, but the relationship was not as strong between Euclidean dissimilarity and physical space (Figure 30). A much noisier association was observed for Spearman dissimilarity. These relationships indicate that stations close in space, elevation, or both in Shark Slough will tend to be most similar with respect to Euclidean dissimilarity.

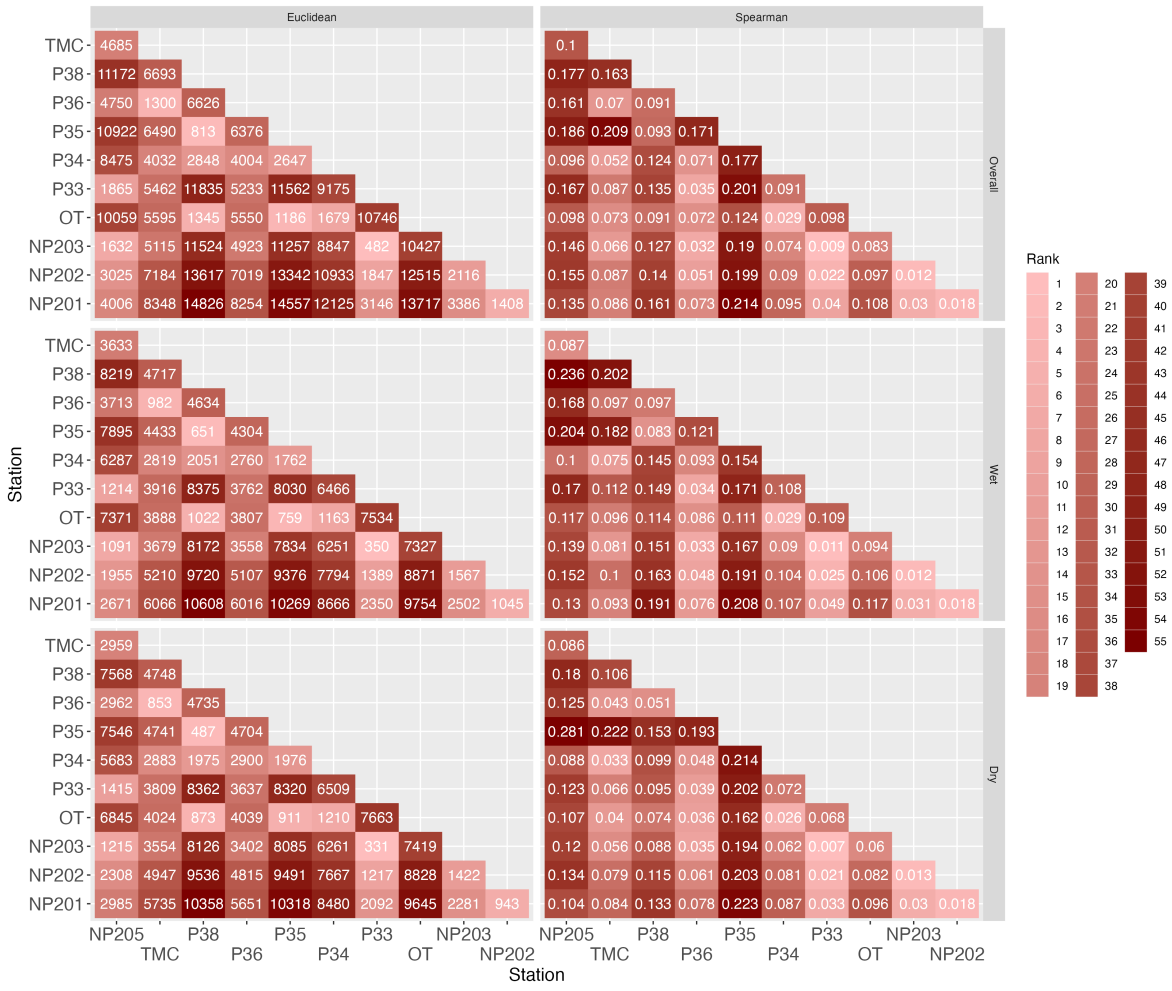


Figure 28: Tile plots of the ranked dissimilarity between stations using Euclidean (left) and Spearman (right) metrics within the overall (top), wet (middle), and dry (bottom) seasons for the Shark Slough region. Darker red indicates stations are more dissimilar (highest rank = 55), whereas lighter red/pink colors represent similarity between stations (lowest rank = 1).

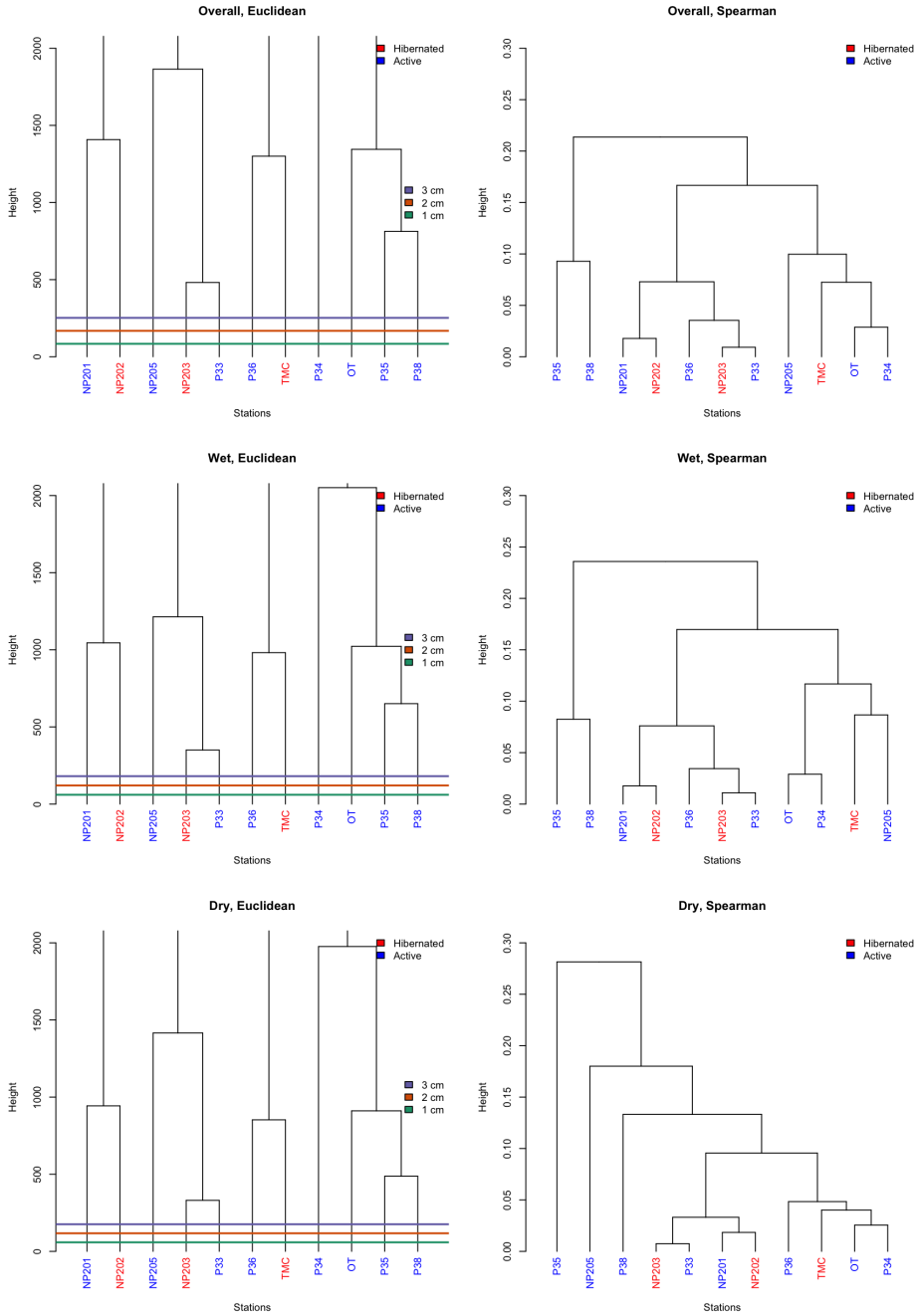


Figure 29: Dendrograms of the HAC results using both Euclidean and Spearman distance for the Shark Slough region during the entire time series (top), wet season (middle), and dry season (bottom). For Euclidean distance, the horizontal lines indicate Euclidean distances for the practically meaningful differences of 1 cm (green), 2 cm (orange), and 3 cm (purple) in daily average water elevation. Red stations were proposed to be hibernated, whereas blue stations were not.

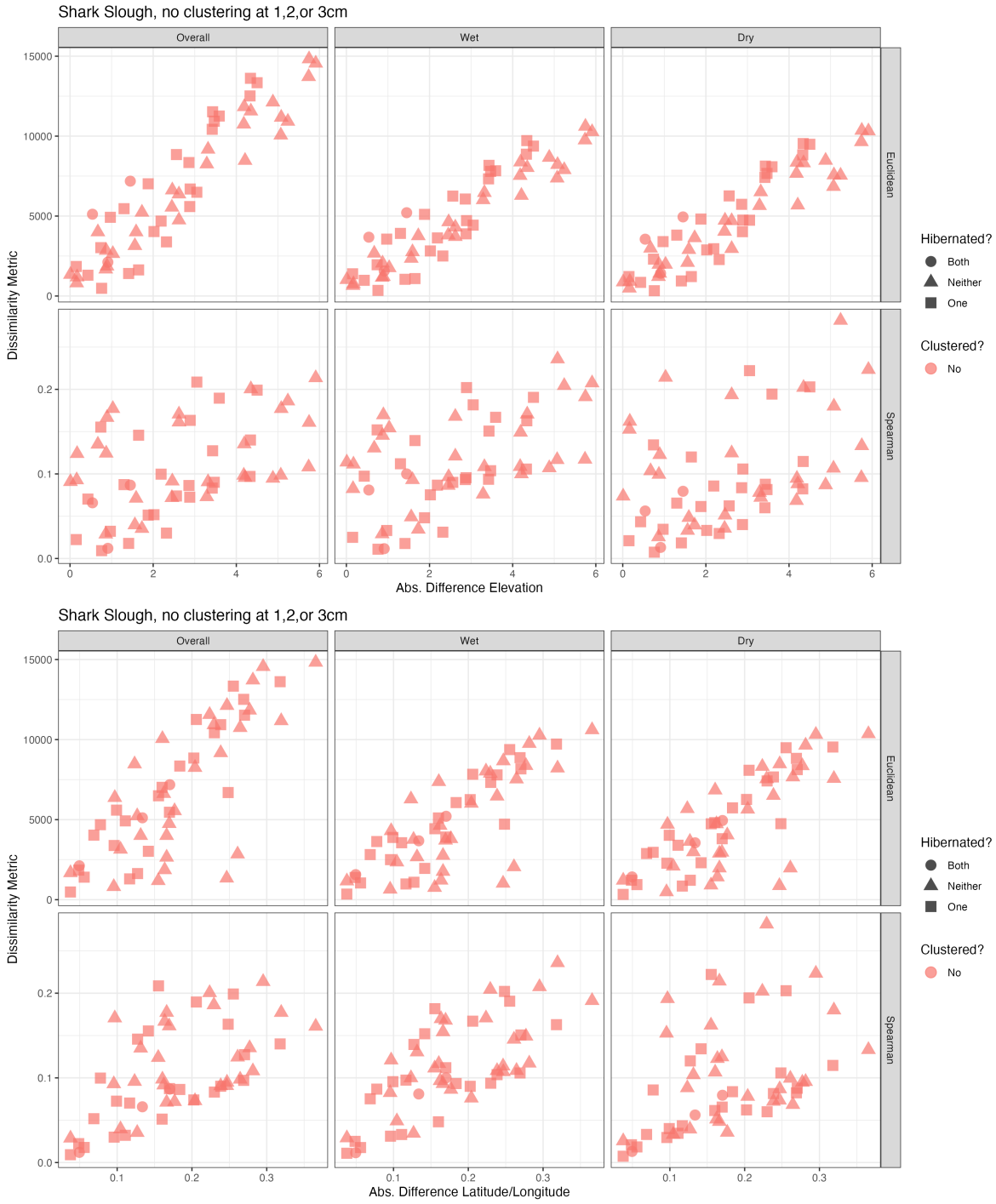


Figure 30: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair within the Shark Slough region. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

5.6 Taylor Slough

Stations within Taylor Slough are shown on a map of EVER in Figure 31, and observed daily average stage measurements (cm) are shown with missingness (indicated by red bars) between Jan 1, 2000 and Dec 31, 2020 in Figure 32. There are visible value-shifted differences among the stations in Taylor Slough, but it is difficult to identify which stations record the highest/lowest daily average stage measurements within the region (Figure 32). Tables 7 and 8 provide summaries of the total number and % of missing observations for each station in decreasing order within each season. In Taylor Slough the total % missingness was highest during the wet and overall seasons, and CY2, NTS1, and NTS14 all had high missingness within the wet and overall seasons (Table 7), whereas CY2 and E146 had the highest missingness in the dry season (Table 8).

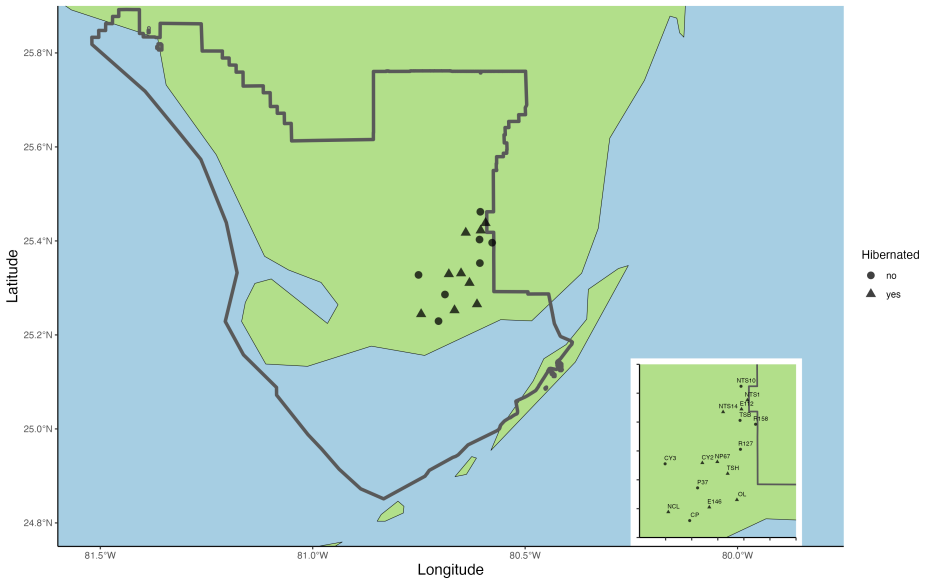


Figure 31: A map of the analyzed stations within the Taylor Slough region, plotted with the boundary of EVER (black line). Stations that were proposed to be hibernated in May 2023 are marked with a triangle.

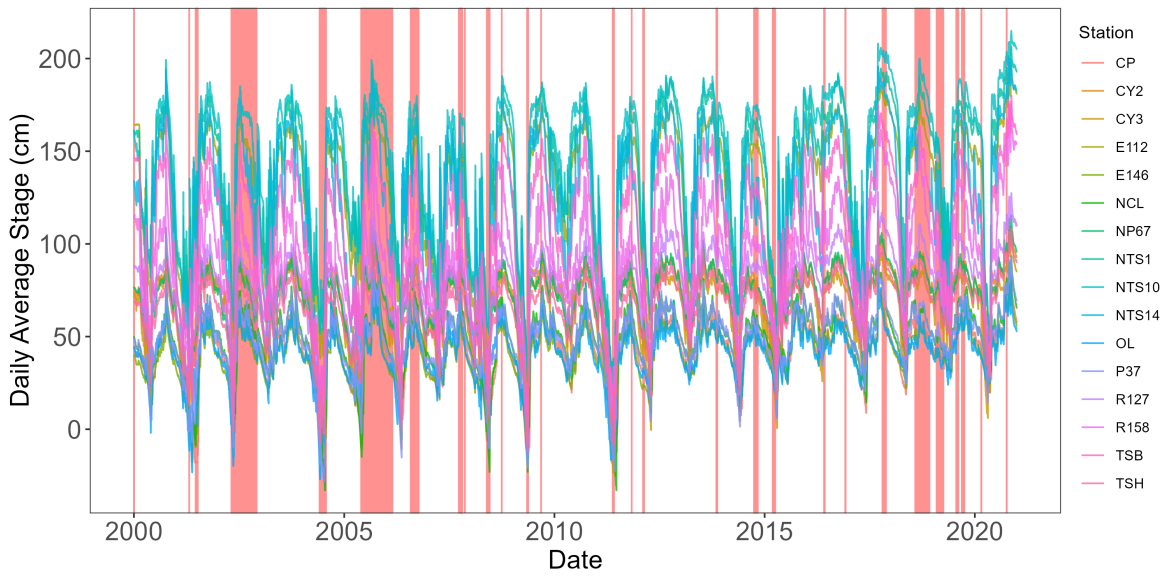


Figure 32: A line plot highlighting the observed stage (cm) measurements and missingness within the Taylor Slough region from 2000 to 2020, colored by station. Red vertical bars indicate a day where at least 1 station has a missing stage value

Region	Station	End Date	N	n	Missing	% Missing
Taylor_Slough	CY2	2020-12-31	7671.00	7378.00	293	3.82
Taylor_Slough	NTS1	2020-12-31	7671.00	7426.00	245	3.19
Taylor_Slough	NTS14	2020-12-31	7671.00	7530.00	141	1.84
Taylor_Slough	E146	2020-12-31	7671.00	7563.00	108	1.41
Taylor_Slough	CP	2020-12-31	7671.00	7583.00	88	1.15
Taylor_Slough	NP67	2020-12-31	7671.00	7587.00	84	1.10
Taylor_Slough	R158	2020-12-31	7671.00	7606.00	65	0.85
Taylor_Slough	NCL	2020-12-31	7671.00	7616.00	55	0.72
Taylor_Slough	R127	2020-12-31	7671.00	7660.00	11	0.14
Taylor_Slough	OL	2020-12-31	7671.00	7664.00	7	0.09
Taylor_Slough	TSH	2020-12-31	7671.00	7668.00	3	0.04
Taylor_Slough	CY3	2020-12-31	7671.00	7670.00	1	0.01
Taylor_Slough	NTS10	2020-12-31	7671.00	7670.00	1	0.01
Taylor_Slough	E112	2020-12-31	7671.00	7671.00	0	0.00
Taylor_Slough	P37	2020-12-31	7671.00	7671.00	0	0.00
Taylor_Slough	TSB	2020-12-31	7671.00	7671.00	0	0.00
Total (overall)			7671	6569	1011	13.18
Taylor_Slough (wet)	NTS1	2020-10-31	3864.00	3654.00	210	5.43
Taylor_Slough (wet)	CY2	2020-10-31	3864.00	3707.00	157	4.06
Taylor_Slough (wet)	NTS14	2020-10-31	3864.00	3755.00	109	2.82
Taylor_Slough (wet)	NP67	2020-10-31	3864.00	3783.00	81	2.10
Taylor_Slough (wet)	CP	2020-10-31	3864.00	3784.00	80	2.07
Taylor_Slough (wet)	E146	2020-10-31	3864.00	3795.00	69	1.79
Taylor_Slough (wet)	R158	2020-10-31	3864.00	3804.00	60	1.55
Taylor_Slough (wet)	NCL	2020-10-31	3864.00	3844.00	20	0.52
Taylor_Slough (wet)	R127	2020-10-31	3864.00	3853.00	11	0.28
Taylor_Slough (wet)	OL	2020-10-31	3864.00	3857.00	7	0.18
Taylor_Slough (wet)	CY3	2020-10-31	3864.00	3863.00	1	0.03
Taylor_Slough (wet)	E112	2020-10-31	3864.00	3864.00	0	0.00
Taylor_Slough (wet)	NTS10	2020-10-31	3864.00	3864.00	0	0.00
Taylor_Slough (wet)	P37	2020-10-31	3864.00	3864.00	0	0.00
Taylor_Slough (wet)	TSB	2020-10-31	3864.00	3864.00	0	0.00
Taylor_Slough (wet)	TSH	2020-10-31	3864.00	3864.00	0	0.00
Total (wet)			3864.00	3059.00	714	18.48

Table 7: A table highlighting the missingness within the Taylor Slough region-season combinations. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

Region	Station	End Date	N	n	Missing	% Missing
Taylor_Slough (dry)	CY2	2020-12-31	3807.00	3671.00	136	3.57
Taylor_Slough (dry)	E146	2020-12-31	3807.00	3768.00	39	1.02
Taylor_Slough (dry)	NCL	2020-12-31	3807.00	3772.00	35	0.92
Taylor_Slough (dry)	NTS1	2020-12-31	3807.00	3772.00	35	0.92
Taylor_Slough (dry)	NTS14	2020-12-31	3807.00	3775.00	32	0.84
Taylor_Slough (dry)	CP	2020-12-31	3807.00	3799.00	8	0.21
Taylor_Slough (dry)	R158	2020-12-31	3807.00	3802.00	5	0.13
Taylor_Slough (dry)	NP67	2020-12-31	3807.00	3804.00	3	0.08
Taylor_Slough (dry)	TSH	2020-12-31	3807.00	3804.00	3	0.08
Taylor_Slough (dry)	NTS10	2020-12-31	3807.00	3806.00	1	0.03
Taylor_Slough (dry)	CY3	2020-12-31	3807.00	3807.00	0	0.00
Taylor_Slough (dry)	E112	2020-12-31	3807.00	3807.00	0	0.00
Taylor_Slough (dry)	OL	2020-12-31	3807.00	3807.00	0	0.00
Taylor_Slough (dry)	P37	2020-12-31	3807.00	3807.00	0	0.00
Taylor_Slough (dry)	R127	2020-12-31	3807.00	3807.00	0	0.00
Taylor_Slough (dry)	TSB	2020-12-31	3807.00	3807.00	0	0.00
Total (dry)			3807.00	3510.00	297	7.80

Table 8: A table highlighting the missingness within the Taylor Slough during the dry season. Station order is determined by % missingness (highest to lowest, top to bottom), N corresponds to the total number of days in the analyzed time period, n corresponds to the actual number of observations, Missing corresponds to how many values are missing, and % Missing corresponds to the percent of the entire time-series that is missing.

Spearman correlation was the most reasonable metric to use for Taylor Slough (See linearity plot, EVER-Stage-Analysis). Comparing Spearman and Euclidean dissimilarity within a season (overall, wet, or dry) we observed different patterns across metrics (comparing within a row of Figure 33). Both metrics agreed that the CP station should be in the first cluster in the overall and wet seasons, but differed in which station CP should be joined with; E146 using Euclidean or NCL using Spearman (Figure 34). During the dry season the first cluster was determined to be NCL:P37 for Euclidean distance and CP:NCL for Spearman. Across all seasons and metrics, the stations that were most similar were comprised of one station proposed to be hibernated (E146, NCL) and one station that was proposed to remain active (CP, P37). However, implementing HAC with the Euclidean metric resulted in no clustering at any of the three practically meaningful Euclidean cut-heights considered ($l = 1, 2, 3$; Figure 34).

We observed a moderate to strong positive linear associations between pairwise Euclidean dissimilarity and the absolute difference in elevation and physical space across all seasons (Figure 35). The same relationships are more moderate for Spearman dissimilarity. Taken together, these relationships indicate that stations close in space, elevation, or both in the Taylor Slough will be most similar with respect to Euclidean and Spearman dissimilarity.

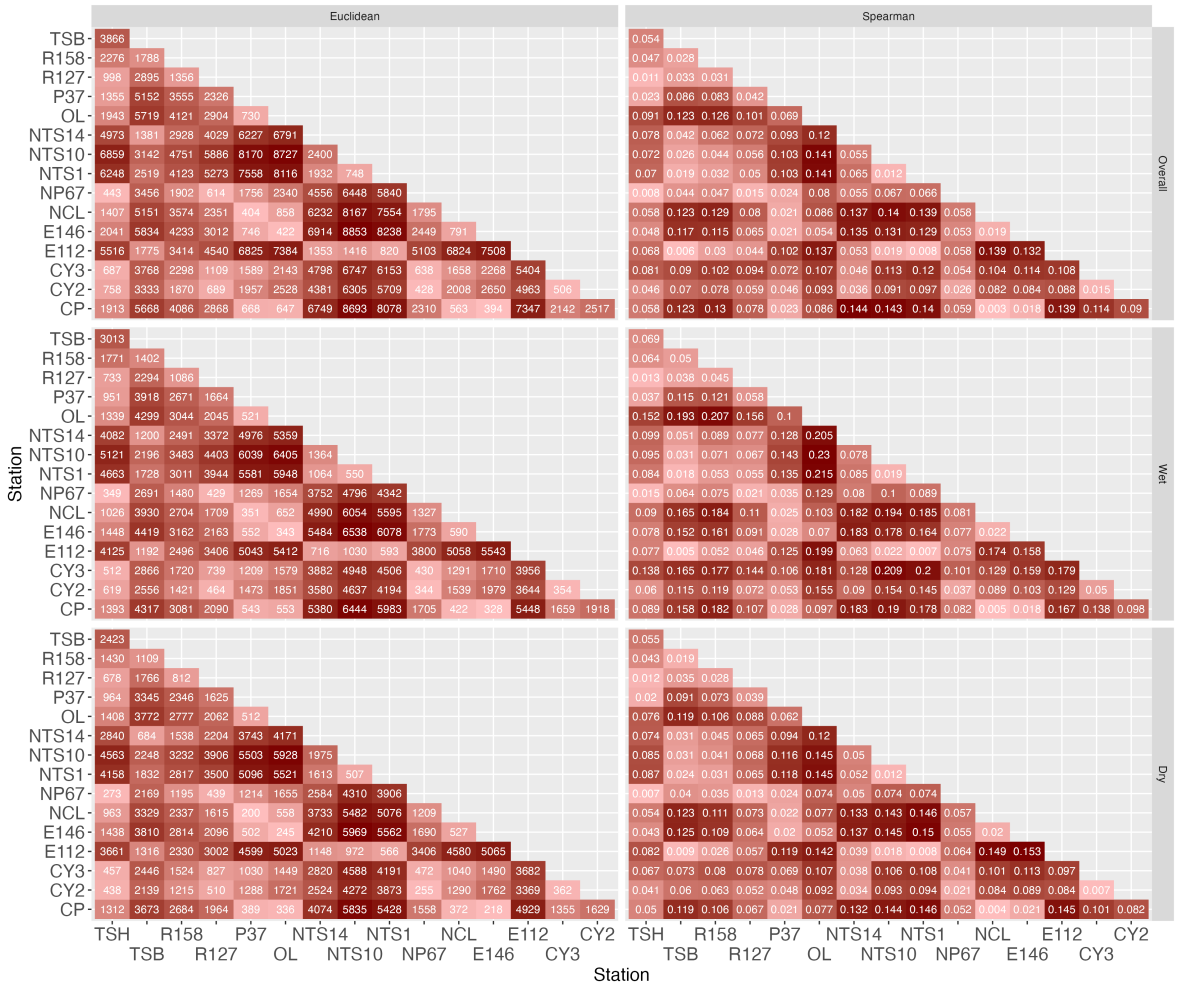


Figure 33: Tile plots of the ranked dissimilarity between stations using Euclidean (left) and Spearman (right) metrics within the overall (top), wet (middle), and dry (bottom) seasons for the Taylor Slough region. Darker red indicates stations are more dissimilar (highest rank), whereas lighter red/pink colors represent similarity between stations (lowest rank = 1). The rank legend was removed for this plot due to the large number of stations in the region.

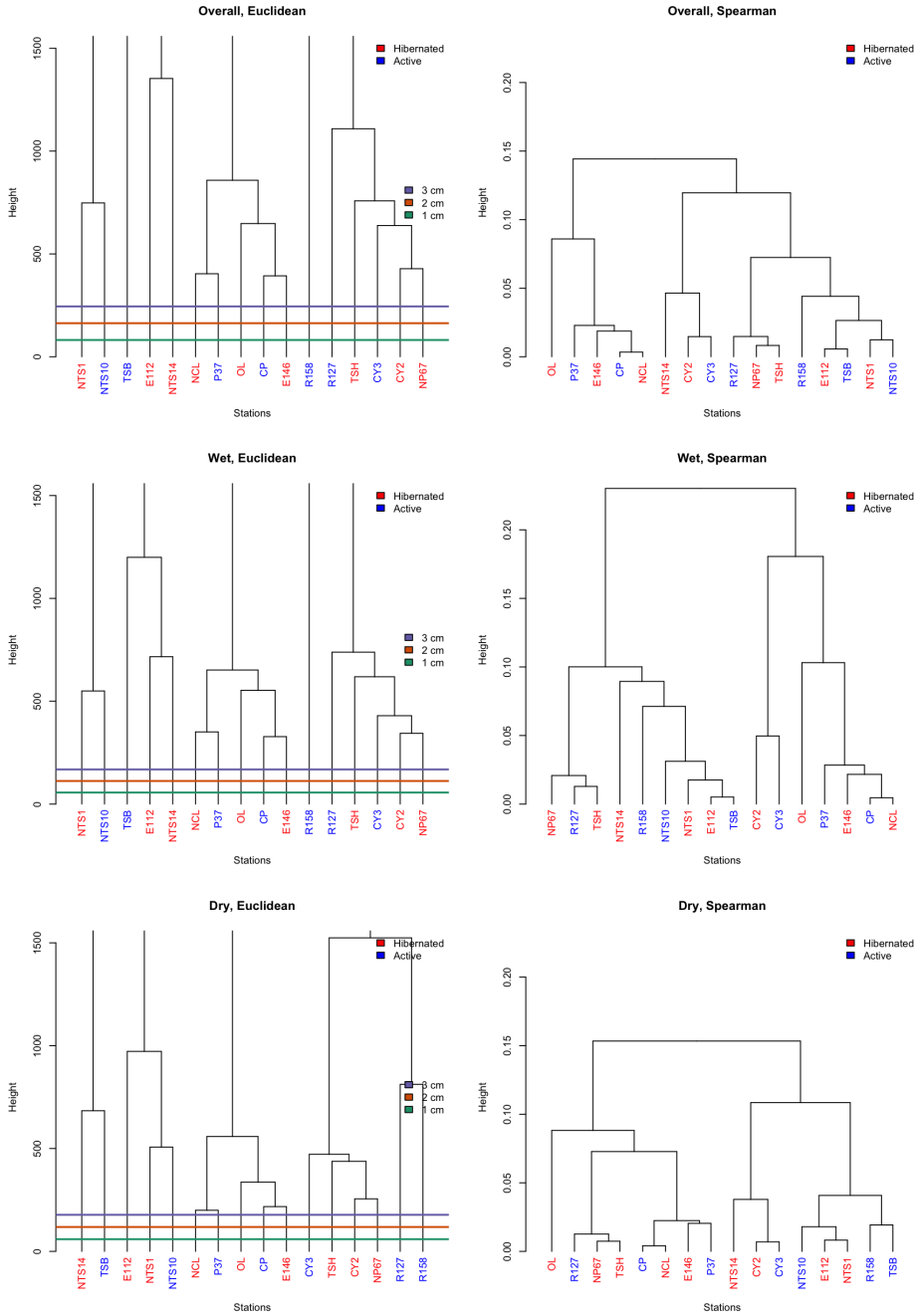


Figure 34: Dendrograms of the HAC results using both Euclidean and Spearman distance for the Taylor Slough region during the entire time series (top), wet season (middle), and dry season (bottom). For Euclidean distance, the horizontal lines indicate Euclidean distances for the practically meaningful differences of 1 cm (green), 2 cm (orange), and 3 cm (purple) in daily average water elevation. Red stations were proposed to be hibernated, whereas blue stations were not.

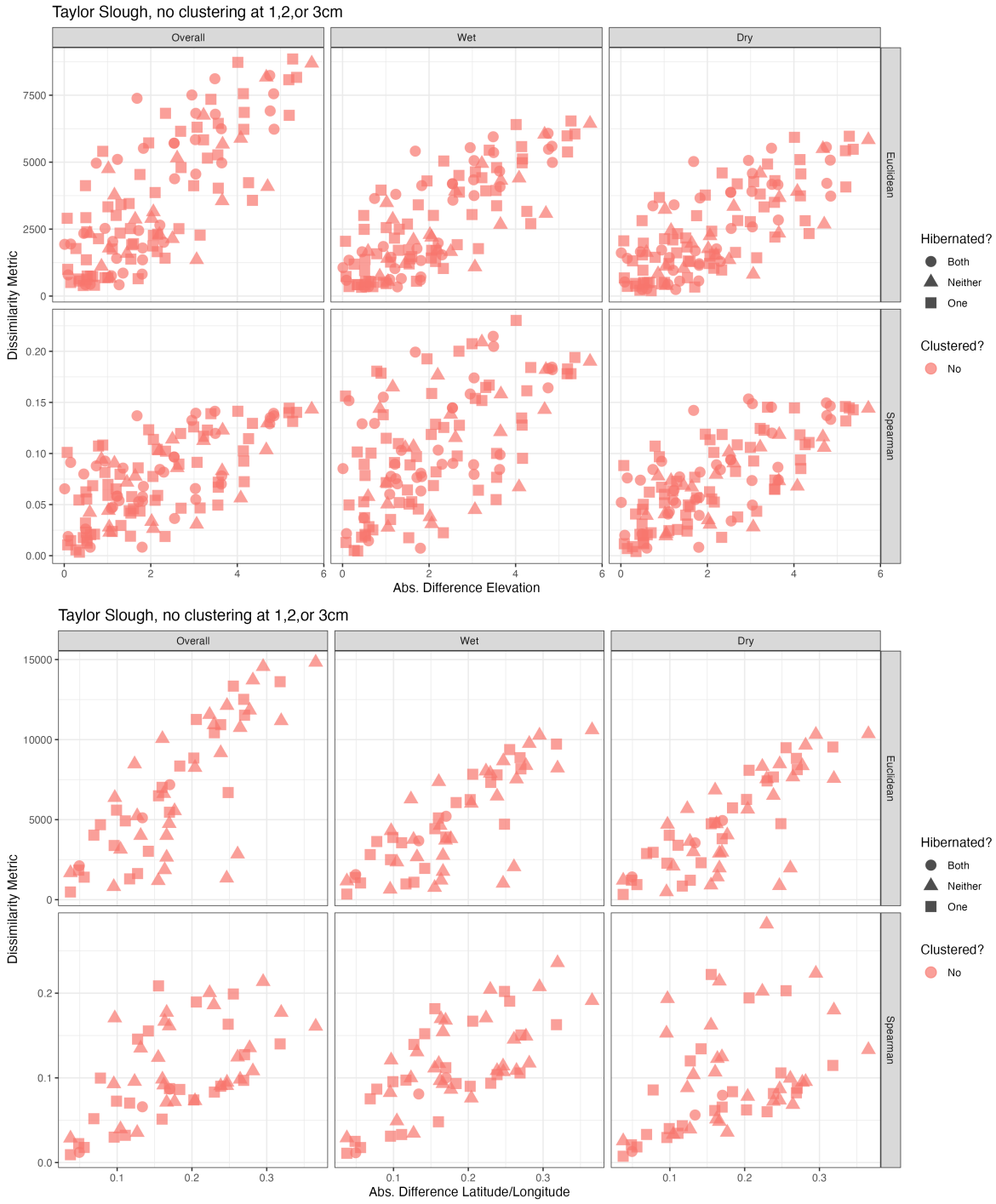


Figure 35: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair within the Taylor Slough region. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

6 All-region results

For completeness, we also consider an all-region analysis of complete cases among all hydrology stations within EVER. The missingness present within each station during the entire time series is summarized in Tables 9 – 10. We excluded stations SPAR0, SR1, and RG4 based on the 10% missingness criterion, and this resulted in 56.9% of the dates between January 1, 2000 and December 31, 2020 providing complete-case data (see Figure 37). Note that decreasing the missingness criterion to 5% resulted in about 32.6% missingness, which is still substantial, so we chose to use the 10% for consistency with the by-region analysis. We included two additional stations, LO2 (from Lostman) and L31W (from East EVER Canals) in the all-region analysis that were not included in the by-region analysis because they were singletons within their regions.

We perform a complete-case HAC analysis on the 52 stations meeting the missingness criterion using Euclidean and Spearman dissimilarity metrics during three seasons of interest (overall, wet, dry). This option is consistent with the by-region analyses, but will draw inference from using just over half of the observations in the time period of interest. The appropriateness of drawing inference about all dates in the time period from this relatively low percentage of complete cases hinges on whether it is appropriate to assume missingness is completely at random and requires careful thought by the domain experts.

To afford comparisons to the by-region results presented in Sections 5.1 - 5.6, we provide a high-level summary of results focusing on dendrograms and biplots (though see by-region-report_analysis.R for more figure ideas). The same stations that were clustered together in the Euclidean-based HAC in the by-region analysis also clustered together in the all-region analysis (Figures 38, 39, 40). When HAC was applied to the Euclidean distance metric, we observed clustering of D01:D03 from Long Pine key, and EVER6:CT27R and CT50R:CV5NR from LowerC111 during all seasons at the 3-cm daily-difference cut-height. We also observed D01:D03 clustering together at the 2-cm daily-difference cut-height during the dry season, which is consistent with the

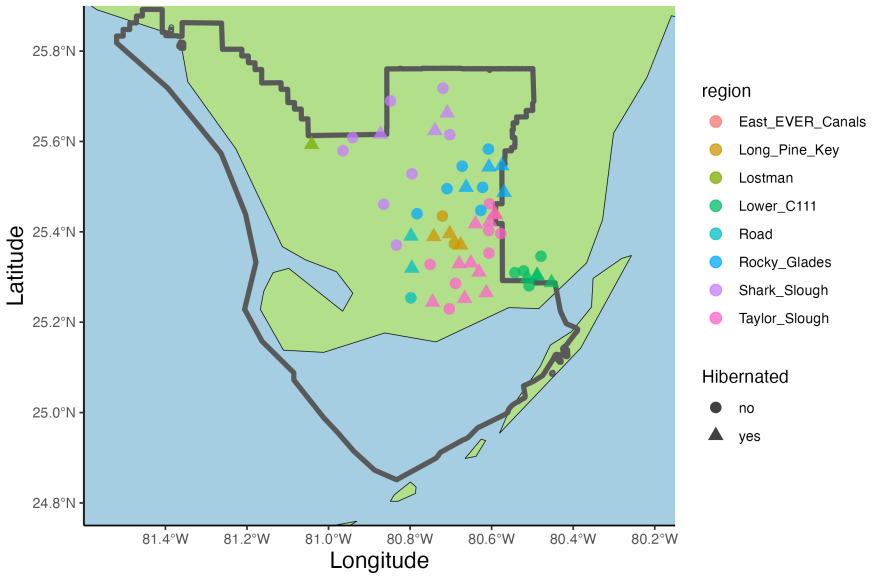


Figure 36: Spatial distribution of the stage stations to be analyzed displayed within the boundary of EVER (colored by assigned region). Three stations with more than 10% missingness were excluded from the plot (SPARO, RG1, SR1). The shape of each point represents proposed hibernation status for the station (circle = "no", triangle = "yes"). Tea

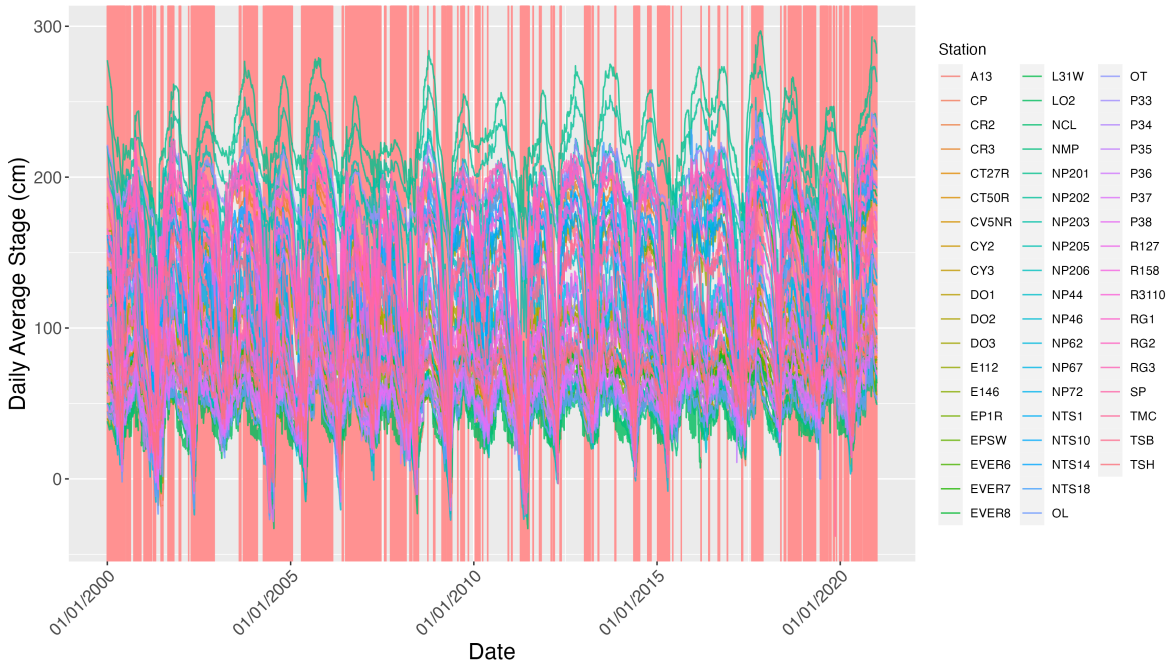


Figure 37: A line plot displaying the missingness present across all stations between Jan. 1, 2000 and Dec. 31, 2020. Three stations with more than 10% missingness were excluded from the plot (SPARO, RG1, SR1). The red vertical bars indicate a day where at least 1 of the 56 stations experienced a missing value.

Long Pine Key results. Other station pairs that do not cluster together at the 3-cm cut-height on the Euclidean dendrograms, but that do cluster into pairs just above the 3-cm cut-height in most seasons are NCL:P37. Similar to the Euclidean-based HAC results, the dendrograms based on HAC applied to the Spearman distance metric show high similarity among D01:D03, CP:NCL, and EVER6:CV5NR:CT27R:EVER6 during the overall and wet seasons. During the dry season we see the most similarity among E112:TSB, CP:NCL, and EVER6:CV5NR:CT27R:EVER6. Regardless of metric or season, the stations that are identified as most similar based on the dendrograms tend to be a mix of stations that were proposed to be hibernated and those that were not.

Biplots show positive associations between pairwise dissimilarities and absolute difference in elevation and physical space (lat, long) among stations across both metrics and all three seasons (Figure 41, strongest linear association for Euclidean and elevation). We see increasing variation in the dissimilarity metric for both Euclidean and Spearman metrics as the absolute difference in elevation and absolute distance increase (more pronounced for Spearman, Figure 41). These findings are consistent with the by-region analyses and suggest that stations closer in space or elevation will tend to have smaller dissimilarity values (and may tend to cluster together).

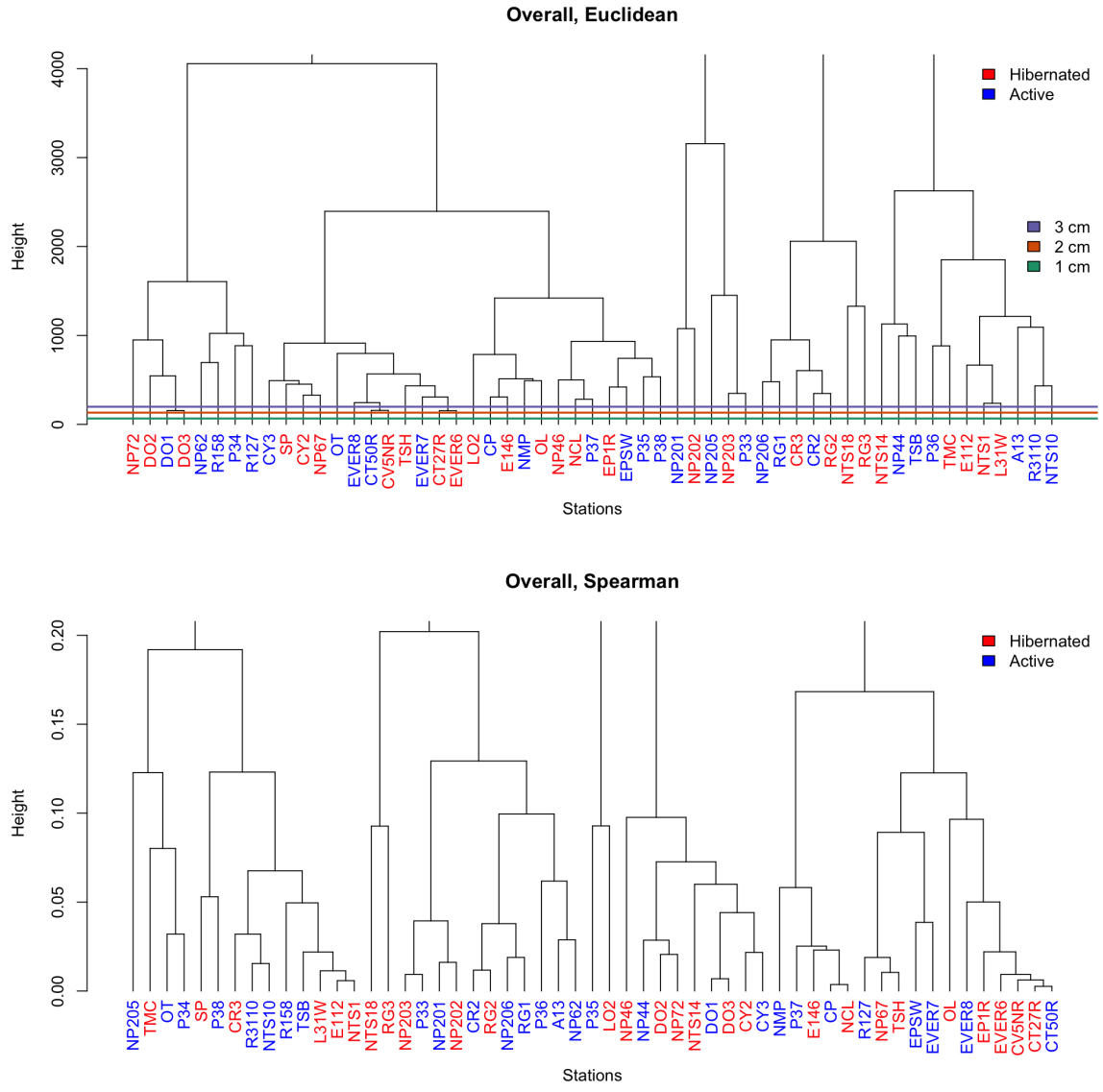


Figure 38: Dendrograms resulting from applying HAC with a Euclidean distance metric (top) and Spearman metric (bottom) to all stations with less than 10% missingness during the entire time period of interest (Jan 1, 2000 - Dec 31, 2020). Stations are colored by hibernation status (red if proposed to be hibernated, blue if proposed to remain active), and the 3 horizontal lines in the Euclidean dendrogram represent 1-cm (green) 2-cm (orange) and 3-cm (purple) daily-difference cut-heights.

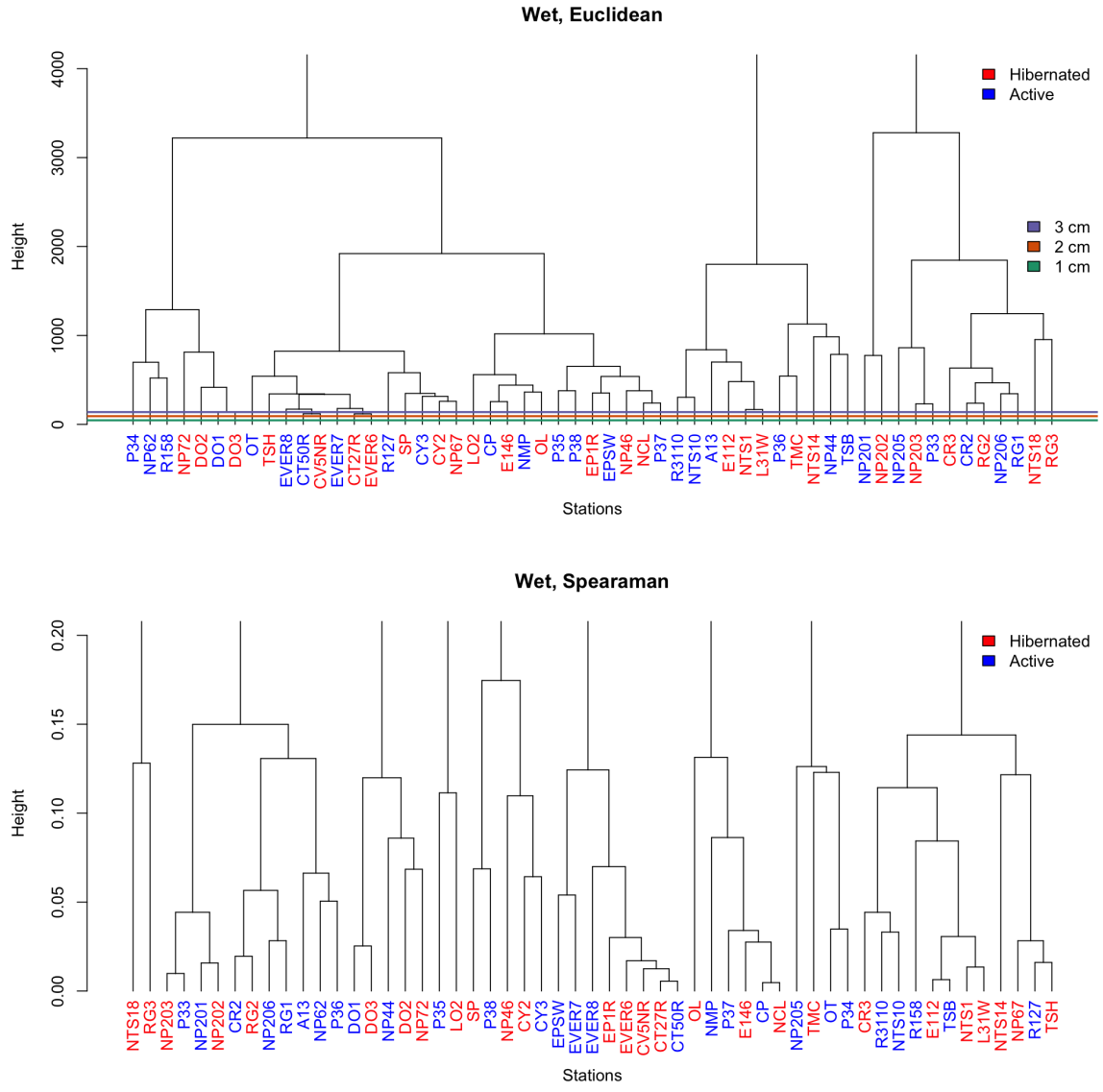


Figure 39: Dendrograms resulting from applying HAC with a Euclidean distance metric (top) and Spearman metric (bottom) to all stations with less than 10% missingness during wet season. Stations are colored by hibernation status (red if proposed to be hibernated, blue if proposed to remain active), and the 3 horizontal lines in the Euclidean dendrogram represent 1-cm (green) 2-cm (orange) and 3-cm (purple) daily-difference cut-heights.

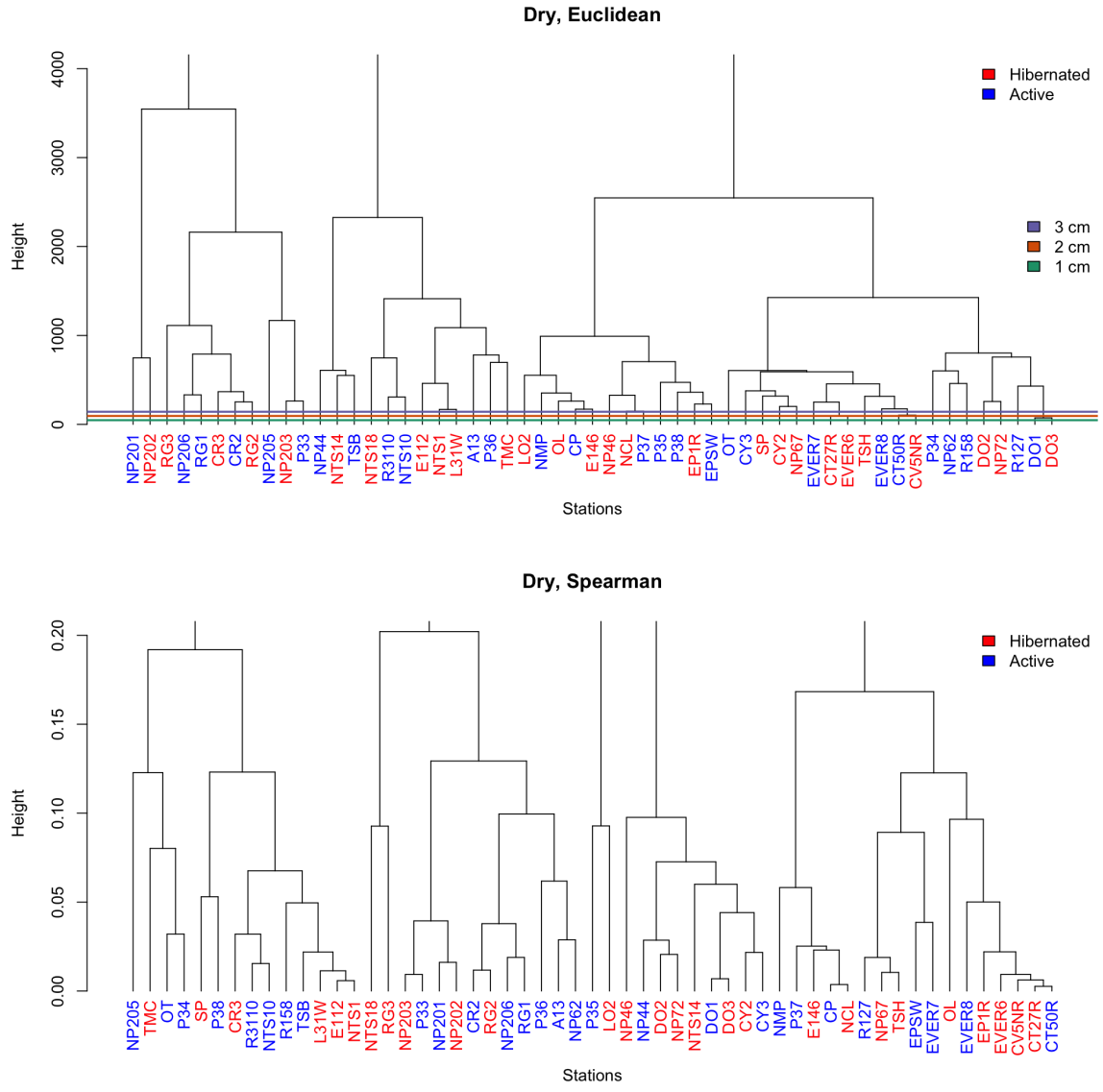


Figure 40: Dendrograms resulting from applying HAC with a Euclidean distance metric (top) and Spearman metric (bottom) to all stations with less than 10% missingness during the dry season. Stations are colored by hibernation status (red if proposed to be hibernated, blue if proposed to remain active), and the 3 horizontal lines in the Euclidean dendrogram represent 1-cm (green) 2-cm (orange) and 3-cm (purple) daily-difference cut-heights.

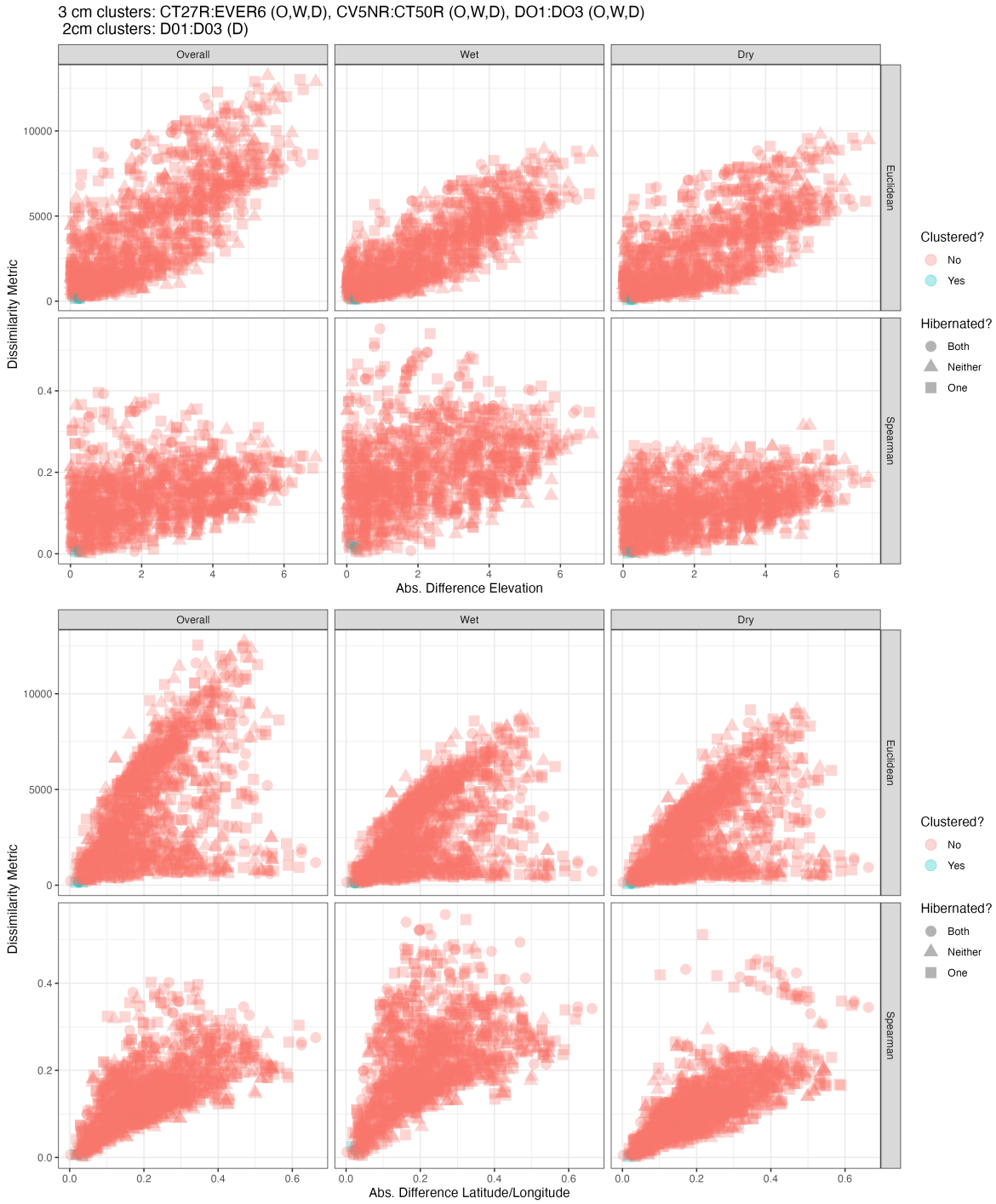


Figure 41: Scatterplots of the calculated pairwise dissimilarity against the observed absolute difference in elevations (top) and distance in physical space using latitude and longitude (bottom) for each station pair included in the all-region analysis. For each set of scatterplots, results from different dissimilarity metrics are shown in rows (Euclidean = top, Correlation-based = bottom) and results from different seasons across columns (overall = leftmost, wet = middle, dry = rightmost). The shape indicates the hibernation status of the station pair (circle = both proposed for hibernation, triangle = neither proposed for hibernation, square = one proposed for hibernation) and color indicates if the stations were clustered together based on the Euclidean cut-height indicated in the title (blue = yes, red = no).

Region	Station	End Date	N	n	Missing	% Missing
Shark_Slough	SPARO	2020-12-31	7671.00	3227.00	4444	57.93
Road	SR1	2020-12-31	7671.00	6560.00	1111	14.48
Rocky_Glades	RG4	2020-12-31	7671.00	6754.00	917	11.95
Lostman	LO2	2020-12-31	7671.00	7065.00	606	7.90
Rocky_Glades	RG3	2020-12-31	7671.00	7158.00	513	6.69
Lower_C111	CT50R	2020-09-14	7671.00	7236.00	435	5.67
Taylor_Slough	CY2	2020-12-31	7671.00	7378.00	293	3.82
Lower_C111	EVER7	2020-12-31	7671.00	7417.00	254	3.31
Taylor_Slough	NTS1	2020-12-31	7671.00	7426.00	245	3.19
Long_Pine_Key	DO3	2020-12-13	7671.00	7470.00	201	2.62
Lower_C111	EPSW	2020-12-31	7671.00	7486.00	185	2.41
Lower_C111	CT27R	2020-12-31	7671.00	7497.00	174	2.27
Shark_Slough	OT	2020-12-31	7671.00	7501.00	170	2.22
Rocky_Glades	CR3	2020-12-31	7671.00	7509.00	162	2.11
Rocky_Glades	RG1	2020-12-31	7671.00	7512.00	159	2.07
Shark_Slough	P38	2020-12-31	7671.00	7529.00	142	1.85
Taylor_Slough	NTS14	2020-12-31	7671.00	7530.00	141	1.84
Shark_Slough	TMC	2020-12-31	7671.00	7563.00	108	1.41
Taylor_Slough	E146	2020-12-31	7671.00	7563.00	108	1.41
Lower_C111	EP1R	2020-12-31	7671.00	7564.00	107	1.39
Shark_Slough	NP203	2020-12-31	7671.00	7564.00	107	1.39
Rocky_Glades	NP62	2020-12-31	7671.00	7569.00	102	1.33
Long_Pine_Key	DO1	2020-12-31	7671.00	7577.00	94	1.23
Shark_Slough	P35	2020-12-31	7671.00	7578.00	93	1.21
Rocky_Glades	NTS18	2020-12-31	7671.00	7579.00	92	1.20
East_EVER_Canals	L31W	2020-12-31	7671.00	7580.00	91	1.19
Taylor_Slough	CP	2020-12-31	7671.00	7583.00	88	1.15
Taylor_Slough	NP67	2020-12-31	7671.00	7587.00	84	1.10
Shark_Slough	P34	2020-12-31	7671.00	7589.00	82	1.07
Shark_Slough	P36	2020-12-31	7671.00	7595.00	76	0.99
Road	SP	2020-12-31	7671.00	7602.00	69	0.90
Lower_C111	EVER8	2020-12-31	7671.00	7606.00	65	0.85
Taylor_Slough	R158	2020-12-31	7671.00	7606.00	65	0.85
Rocky_Glades	A13	2020-12-31	7671.00	7607.00	64	0.83
Long_Pine_Key	DO2	2020-12-31	7671.00	7608.00	63	0.82
Shark_Slough	NP202	2020-12-31	7671.00	7610.00	61	0.80
Taylor_Slough	NCL	2020-12-31	7671.00	7616.00	55	0.72

Table 9: A table of Missingness percentages presented in decreasing order for each station in EVER. The table includes the region each station is a member of, the name of the station, the date of the last recorded observation, the total number of dates within the date range, the number of measurements observed within the date range, the number of measurements missing within the date range, and the percentage of missing observations. Continued on next page.

Region	Station	End Date	N	n	Missing	% Missing
Road	NP46	2020-12-31	7671.00	7622.00	49	0.64
Shark_Slough	NP201	2020-12-31	7671.00	7630.00	41	0.53
Rocky_Glades	CR2	2020-12-31	7671.00	7632.00	39	0.51
Lower_C111	EVER6	2020-12-31	7671.00	7634.00	37	0.48
Road	NMP	2020-12-31	7671.00	7637.00	34	0.44
Shark_Slough	NP206	2020-12-31	7671.00	7641.00	30	0.39
Lower_C111	CV5NR	2020-12-31	7671.00	7647.00	24	0.31
Rocky_Glades	RG2	2020-12-31	7671.00	7649.00	22	0.29
Long_Pine_Key	NP72	2020-12-31	7671.00	7653.00	18	0.23
Taylor_Slough	R127	2020-12-31	7671.00	7660.00	11	0.14
Long_Pine_Key	NP44	2020-12-31	7671.00	7663.00	8	0.10
Lower_C111	OL	2020-12-31	7671.00	7664.00	7	0.09
Taylor_Slough	TSH	2020-12-31	7671.00	7668.00	3	0.04
Shark_Slough	P33	2020-12-31	7671.00	7670.00	1	0.01
Shark_Slough	NP205	2020-12-31	7671.00	7670.00	1	0.01
Taylor_Slough	CY3	2020-12-31	7671.00	7670.00	1	0.01
Taylor_Slough	NTS10	2020-12-31	7671.00	7670.00	1	0.01
Rocky_Glades	R3110	2020-12-31	7671.00	7671.00	0	0.00
Taylor_Slough	E112	2020-12-31	7671.00	7671.00	0	0.00
Taylor_Slough	P37	2020-12-31	7671.00	7671.00	0	0.00
Taylor_Slough	TSB	2020-12-31	7671.00	7671.00	0	0.00
Total			7671.00	2150.00	5521	71.97

Table 10: Continued from previous page. A table of Missingness percentages presented in decreasing order for each station in EVER. The table includes the region each station is a member of, the name of the station, the date of the last recorded observation, the total number of dates within the date range, the number of measurements observed within the date range, the number of measurements missing within the date range, and the percentage of missing observations. The final row summarizes the missingness within the complete-case.

We outline two additional approaches for an all-region analysis in the face of 43.1% missingness that could be considered in future investigations.

1. Apply an imputation method to "fill in" missing values for all stations (if possible). Use HAC on all stations (with missing values imputed) using Euclidean and Spearman dissimilarity metrics during three seasons of interest (overall, wet, dry). Imputing missing values can be very effective if only a small period is missing (for example, a few days), but stations with large portions of sequential missingness will still need to be excluded from the analysis (e.g., SPARO, which did not come online until Nov. 2011). A popular imputation method is the Kalman filter algorithm (Agbailu et al., 2020), which could provide a way forward for data imputation in this context.

2. Consider an entirely different approach to the redundancy analysis than HAC. This option would involve a continuous model (for example, splines) being fit to each station's discrete time-series within a time-series modeling framework. This would require imputation to be done as a model cannot be fit effectively to time-series with large levels of missingness. Once imputation is performed, clustering occurs on the coefficients obtained from the continuous model. An example is provided in, Bouveyron and Jacques (2011) and more references can be found in Aghabozorgi et al. (2015).

7 Conclusion

This report is meant to help identify potential redundancies in the hydrology stations within EVER and make informed decisions about which stations to hibernate (if needed due to budget constraints). Results from the all-region analysis were generally consistent with the by-region analysis, providing evidence of some consensus between the two approaches.

Overall, only Long Pine Key and Lower C111 had stations identified as potentially

redundant based on cutting the HAC Euclidean-based dendrograms at 1-cm, 2-cm, or 3-cm difference in average daily stage. In Long Pine Key, stations D01 and D03 were clustered together during all seasons at the 3-cm cut-height and during the dry season at the 2-cm cut-height. DO3 was proposed to be hibernated. In Lower C111, stations CT27R:EVER6 and CT50R:CV5NR were clustered together at the 3-cm cut-height during all seasons. Only CT50R was proposed to remain active and EVER6, CV5NR, CT27R were all proposed to be hibernated. Based on Spearman correlation these four Lower C111 stations could be considered one cluster—suggesting potential redundancies among them, see Figure 14. Visual inspection of time-series of daily average stage measurements provide additional evidence for potential redundancies.

Best professional judgement is required to determine redundancies among stations in Rocky Glades, Shark Slough, Taylor Slough, or the Road region because none of the clustering results using the Euclidean metric met the threshold of a 3-cm, on average, daily difference. However, there may be additional stations to consider for hibernation by choosing a less stringent cut-height for Euclidean-based dendrograms or using an informed decision-rule for cutting correlation-based dendrograms (Figures 8, 14, 24, 29, 34, 38, 39, 40). The code repository accompanying this report is intended to make it easier for researchers to broaden or adjust our investigations presented herein (i.e., consider different cluster solutions based on different practically meaningful daily differences) to support informed decision making for hydrology stations in EVER. Specifically, see line 903 in by-region-report_analysis.R for an example of how to use `cluster_custom` for these types of investigations.

A Hibernation status variable

Damon Rondeau shared *Hydro_Station_List_20230423.xlsx* with MSU researchers in April, 2023. (This file is located within the Client Documents directory within the Ever-Stage-Analysis repository). Damon assigned the value "keep" to stations for which the answer to any of the following questions was "Yes."

- Has the station been active for at least 50 years?
- Is there recorded funding for the station?
- Is the station a WQ site? WQ = water quality. Separate monitoring program.
- Does the station monitor Chlorophyll concentrations?
- Is the station used for Critical Usage? Critical usage is defined as a station monitored for legal (e.g., endangered species) or critical park functions.

Damon then assigned a number [0,1,2,3] to stations not marked as "Keep"; the number corresponds to the number of networks the station belongs to. Those networks are:

- Everglades Depth Estimation Network (EDEN)
- Southern Florida Water Management District Eco (SFWMD Eco)
- Southern Florida Water Management District Weather (SFWMD Weather)
- National Oceanic and the Atmospheric Administration (NOAA)
- Biscayne National Park (BISC)
- Fish and Wildlife Service (FWS)
- US Army Corps of Engineers (USACE)

That is, Damon assigned a value of "keep," "0," "1," "2," or "3" to each station in the monitoring network. Damon also assigned each station a hibernation status of "yes"

(proposed hibernation) or "no" (proposed to remain active). A by-station summary of the notes associated with both of these variables is provided by Damon is in Table 11 – 13.

Station	Hibernated	Status	Comments
A13	no	2	
CP	no	3	
CR2	no	Keep	
CR3	yes	1	A13 to be used in it's stead
CT27R	yes	1	Drops SoTay East airboat run into a half day
CT50R	no	1	
CV5NR	yes	1	No other reason to go out that far (EVER8 now on Helicopter run)
CY2	yes	1	Monuments/canopy cover/OIH Culverts to CY3
CY3	no	Keep	
DO1	no	Keep	
DO2	yes	Keep	Reducing helicopter run, poisonwood, check with JT about HID Needs
DO3	yes	Keep	Can only be run with 4x4 truck, even then we have to be VERY careful, check with JT about HID needs
E112	yes	2	Reducing helicopter run, compares VERY well with many stations
E146	yes	2	Drops SoTay West airboat run into a half day
EP1R	yes	1	Drops SoTay East airboat run into a half day
EPSW	no	Keep	
EVER6	yes	2	Drops SoTay East airboat run into a half day
EVER7	no	2	
EVER8	no	2	
L31W	yes	2	Station is a pain in the but and with removal of NTS1, drops a half day

Table 11: Hibernation status assignments for all marsh stations in EVER National Park. Continued on next page.

Station	Hibernated	Status	Comments
LO2	yes	1	Reduce helicopter time, SW goes dry, grabbed from Gordon and should have NOT absorbed
NCL	yes	1	Zach wants to keep for Lakes, drops SoTay West into a half day run
NMP	no	1	
NP201	no	Keep	
NP202	yes	2	Reduces SRS to one airboat day
NP203	yes	2	Reduces SRS to one airboat day
NP206	no	Keep	
NP44	no	Keep	
NP46	yes	Keep	Reducing road run stations and data management
NP62	no	Keep	
NP67	yes	Keep	Reducing road run stations and data management
NP72	yes	Keep	Reducing road run stations and data management
NTS1	yes	2	Reducing road run stations and data management
NTS10	no	2	
NTS14	yes	1	Reducing road run stations and data management
NTS18	yes	1	Reducing road run stations and data management
OL	yes	1	Drops SoTay West airboat run into a half day
OT	no	2	
P33	no	Keep	
P34	no	Keep	
P35	no	Keep	
P36	no	Keep	
P37	no	Keep	
P38	no	Keep	
R127	no	Keep	

Table 12: Hibernation status assignments for all marsh stations in EVER National Park. Continued on next page.

Station	Hibernated	Status	Comments
R158	no	1	
R3110	no	Keep	
RG1	no	Keep	
RG2	yes	2	Reducing helicopter run, compares VERY well with many stations
RG3	yes	1	Reducing road run stations and data management
RG4	yes	0	Reducing road run stations and data management, bad walk
SP	yes	1	Reducing road run stations and data management
SPARO	no	Keep	
SR1	yes	1	Reducing road run stations and data management, station is in a hole, needs rebuilt - was part of a comparison with SR2 - which was removed a long time ago
TMC	yes	1	Reduces BICY run to one airboat day easy, and allows helicopter support for OT and P34
TSB	no	Keep	
TSH	yes	0	Drops SoTay West airboat run into a half day
NP205	no	Keep	

Table 13: Hibernation status assignments for all marsh stations in EVER National Park.

B Meaningful difference cutoffs (by region-season)

Region	Season	$l = 1$	$l = 2$	$l = 3$
Long_Pine_Key	Overall	85.40	170.80	256.20
Long_Pine_Key	Wet Season	61.07	122.13	183.20
Long_Pine_Key	Dry Season	59.70	119.40	179.10
Lower_C111	Overall	82.78	165.55	248.33
Lower_C111	Wet Season	58.00	116.00	174.00
Lower_C111	Dry Season	59.06	118.12	177.18
Road	Overall	80.23	160.46	240.69
Road	Wet Season	55.70	111.39	167.09
Road	Dry Season	57.75	115.50	173.25
Rocky_Glades	Overall	78.87	157.75	236.62
Rocky_Glades	Wet Season	54.85	109.71	164.56
Rocky_Glades	Dry Season	56.67	113.35	170.02
Shark_Slough	Overall	54.77	109.54	164.32
Shark_Slough	Wet Season	37.31	74.62	111.93
Shark_Slough	Dry Season	40.10	80.20	120.30
Taylor_Slough	Overall	81.61	163.22	244.83
Taylor_Slough	Wet Season	56.12	112.25	168.37
Taylor_Slough	Dry Season	59.25	118.49	177.74
All-Region	Overall	66.1	132	198
All-Region	Wet Season	46.1	92.2	138
All-Region	Dry Season	47.3	94.6	142

Table 14: Cut-heights for $l = 1, 2, 3$ and $m = 1 - cm$ for each region-season combination investigated in the EVER hydrology station redundancy analyses. Values correspond to 1-, 2-, and 3-cm daily average difference in stage for all complete cases within a region-season.

C Euclidean-Pearson comparison

In order to compare Euclidean distance and Pearson distance directly, the observed time series must be scaled to have a mean values of 0 and a variance of 1. Let A^* and B^* represent scaled versions of two stations A and B, respectively. Then, the following is true.

$$r(A^*, B^*) = 1 - \frac{d^2(A^*, B^*)}{2t} \tag{4}$$

Where r is the Pearson metric defined in Equation 2 and d is the Euclidean metric defined in Equation 1.

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