K-MEANS CLUSTERING RESOLUTION OF DIURNAL WIND PATTERN MODES AND PATTERN EXTREMA FOR THREE MAJOR STATIONS IN THE DESERT SOUTHWESTERN U.S. (LAS VEGAS, PHOENIX, AND TUCSON)

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1. INTRODUCTION

Applying K-Means Clustering Analysis on daily 0000 LST to 2300 LST historical wind direction and speed observations for three major metropolitan area stations in the desert Southwest (Las Vegas, Phoenix and Tucson) with lengthy histories, the purpose of the following study is a statistical decomposition of their observations into major sub-patterns or "modes", such modes typically obscured, visually and statistically, in results produced in the more standard composite-type climatological wind analyses . This is a followup to a similar type investigation on nine stations in Southern California area [Fisk,2023], several located in the Mojave and Sonoran deserts, including Daggett, Lancaster, Blythe, and Thermal. The current version has an improved format, with supporting graphics and an additional section on pattern extrema. Three such modes were generated for Las Vegas and four each for Phoenix and Tucson.

Like the previous study, the following steps were executed. First, the hourly wind observations were reduced into north/south ("v") and east/west ("u") components, with creation of a rectangular array of N by 48 cases, where N is the number of complete original daily hourly observations and 48 the number of "u" and "v" parameter values (i.e., 24 pairs of "u"'s and "v"'s). The u's and v's were all reduced to a common scale relative to one another or "standardized". Selecting the "Squared-Euclidean" distance metric, the K-Means clustering routine was then run, integrated with the V-Fold Cross Validation algorithm which produced an "optimal" number of "K" clusters resident in 48-dimensional space. Each of the three or four 48-D "u"/"v" cluster centroids were then transformed via the arctangent function into arrays of hour-to-hour diurnal resultant wind directions, matched up on a one-to-one basis with the hour-to-hour mean scalar wind speeds. The finished results, presented in tables as mean vector wind directions, mean scalar wind speeds, vector wind constancies, and percent frequencies at half-month intervals, together with supporting graphics, are intended hopefully to reveal physically distinct and meaningful patterns, alongside generally smooth climatological frequency progressions over the half-month calendar segments.

Then, as an additional "spin-off"–type exercise, the overall extreme-value aspects of the three stations' diurnal wind patterns are explored. Regarding extremes, among the diagnostics' outputs from the K-Means analyses for the three stations are the Squared Euclidean distance magnitudes for each of the original observations relative to their kth-cluster centroids. Highest magnitudes denote the most distant affinities statistically to a given cluster's properties, but as these distances are just "local", pertaining only to the particular cluster concerned, the information is of limited value. However, the notion of "global" statistical distances, those produced if the observations are not clustered (i.e., a "forced" k=1 treatment, of which the software can perform, can be of some importance). An absolute maximum 48-D, K=1 distance could conceivably be interpreted heuristically as representing the most extreme individual hour-to-hour "u" and "v" daily wind pattern. The fine-scale alternative would seem only to be the intractable task of generating a theoretical, parameter-based application for 48-D data. So, adopting this workaround "strategy" utilizing Squared Euclidean distances from standardized data, not parameter values, the single-most extreme diurnal wind patterns were flagged for each of the three stations, based on examinations of their K=1 statistical distance magnitudes tagged against their original hourly wind directions and scalar speeds.

Such statistical distances would be enhanced by anomalously high standardized u and v magnitudes (i.e., reflecting high wind speeds), unusually placed standardized u and v combinations (i.e., reflecting wind direction anomalies), and uncommon combinations of both wind speeds and directions at atypical hours of the day.

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2. RESULTS

2.1. Las Vegas (McCarran) Int'l Airport - Lat: 36.1 N, Lon: 115.2 W; Elev. 2227 ft.

Las Vegas (McCarren Field) as described in excerpts from its 2017 LCD Annual Summary, is located in a broad desert valley in extreme southern Nevada, almost completely surrounded by mountains that are roughly 2,000 to 10,000 feet higher than the valley floor. The Las Vegas Valley itself slopes roughly downward from the northwest to the southeast and the strongest winds that do occur typically reach the area from the south-west or northwest. Daily data were available from January 1949 thru June 2024, excluding 1965 thru 1972 and 1988, and 69.4% of these or n=16884 were entirely intact on a 24- hour basis.

The cluster analysis resolved three major diurnal

Las Vegas Mode 1 - (64.7%) "Light Nighttime SW'lys/WSW'lys. Light Mid-to-Late Morning NE'lys/ENE'lys"							
HRLST	Resultant Wind Dir	Resultant Wind Dir	Avg Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	SW		6.5	64.2		JA1	82.1
1	SW		6.2	63.3		JA2	77.5
2	WSW		5.9	64.1		FB1	72.3
3	WSW		5.6	64.3		FB2	66.2
4	WSW		5.4	65.7		MR1	61.0
5	WSW		5.3	66.9		MR2	53.5
6	WSW		4.9	65.6		AP1	52.3
7	WSW		4.4	49.8		AP2	48.5
8	W		3.9	13.5		MY1	47.9
9	NE		4.0	30.4		MY2	51.1
10	ENE		4.5	49.8		JU1	51.5
11	ENE		4.9	51.5		JU2	44.5
12	ENE		5.3	46.1		JL1	49.4
13	E		5.7	37.6		JL2	61.4
14	E		6.0	32.1		AU1	61.6
15	ESE		6.2	25.4		AU2	59.8
16	SE		6.4	20.5		SE1	66.0
17	S		6.5	21.9		SE2	67.4
18	SSW		6.8	34.4		OC1	73.7
19	SW		7.2	53.6		OC2	75.8
20	SW		7.6	65.2		NV1	77.6
21	WSW		7.5	67.9		NV2	76.1
22	SW		7.2	66.5		DC1	81.9
23	SW		6.9	65.6		DC2	82.3

Figure 1. Las Vegas Ranked Mode 1 – "Light Nightime SW'lys/WSW'lys. Mid-to-Late Morning NE'lys/ ENE'lys – 64.7% Overall Incidence

wind pattern modes, encompassing (rounded) 64.7%, 25.9 %, and 9.5 % overall incidences, respectively .

Figure 1 above comprises in tabular form the results for Las Vegas Mode #1.

The table consists of eight columns, described as follows: Column 1 is Hour of the Day (LST), Columns 2 and 3: Sixteen Point Compass Mean Resultant Directions (both text and vector form, respectively); Column 4, Mean Scalar Wind Speed (kts), Columns 5 and 6: Vector Wind Constancies (both text and color, respectively); Column 7: Half-month calendar period, and Column 8: Climatological Percent Frequencies for the Half-month period in question.

Constancy values, defined as mean vector wind speed divided by mean scalar wind speed times 100, can range from 0 to100, the colorization scheme shown in Figure 2 ranging in gradations from pure red (0 constancy statistic) to dark blue (100 constancy statistic). Mid-level constancies are depicted in the light green to light blue range, and low constancy values (yellow/orange/brown/ red) indicate relatively low wind direction persistencies climatologically for the hour on question, reflecting preferred directional changeover periods or alternatively, naturally light and variable wind character.

Las Vegas's Mode 1 is mostly a colder season, lower-sun angle feature, the highest frequencies, in excess of 70 percent, noted for the nine consecutive half-month periods "OC1" thru "FB1" (early October thru early February), an absolute maximum 82.3% figure shown for "DC2" (late December). However, the half-month frequencies are never lower than 44.5% ("JU2" or late-June minimum).

Nocturnal mean (resultant) directions are either WSW'ly or SW'ly at relatively light scalar speeds in the 4 to 7 knot range, although the maximum hourly statistic (7.6 knots) is in early evening for 8PM. Daytime wind directions, from roughly 9AM to 2PM, are generally NE'ly to Easterly, higher terrain being present away from those directions relative to the airport, The 8AM red colored constancy minimum (13.5 magnitude) signifies a favored changeover hour for the nocturnal WSW'lys switching to the daytime NE'lys; conversely, later in the mid and late afternoon, the series of orange relative constancy minima encompassing 3PM to 5PM (magnitudes in the 20's) reflects the opposite, the daytime easterly component pattern transitioning back to the SW'ly nocturnal one.

In general, Mode 1 may reflect local topographical influences on Las Vegas winds predominating over more regional synoptic ones.

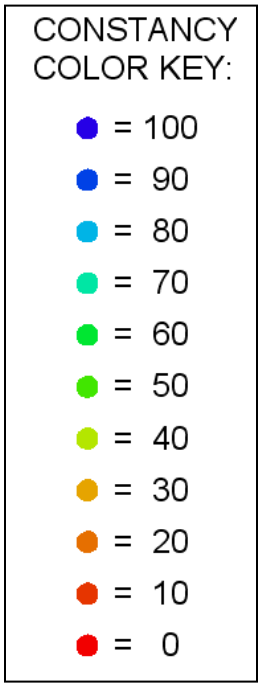


Figure 2 – Color Constancy Key

Figure 3 below shows Las Vegas' second ranking mode, clearly a warm-season predominant pattern with moderate to strong SW'ly quadrant winds at 10 to 16 knots throughout the day (the only exception to the SW'ly "rule" being a Southerly for 10AM). Percent frequencies increase monotonically from "JA1" (early January – 6.1%) to "JU2" (late June – 53.0%), but then exhibit a noticeable drop to 37.7% for "JL2", likely a

Las Vegas Mode 3 - (9.5%) "Moderate to Strong NNW'lys to Northerlies Throughout Day"

HRLST	Resultant Wind Dir	Average Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	NNW		11.5	52.5		JA1	11.8
1	NNW		11.6	58.8		JA2	13.3
2	NNW		11.7	64.2		FB1	15.5
3	NNW		11.7	67.1		FB2	14.6
4	NNW		11.9	70.3		MR1	14.0
5	NNW		11.8	75.0		MR2	17.3
6	NNW		11.9	75.1		AP1	18.4
7	NNW		12.4	78.8		AP2	13.1
8	NNW		13.5	82.7		MY1	10.2
9	N		14.4	85.2		MY2	6.6
10	N		14.7	85.8		JU1	4.8
11	N		14.4	83.8		JU2	2.6
12	N		13.8	82.8		JL1	0.3
13	N		13.4	81.6		JL2	0.9
14	N		13.1	80.4		AU1	0.0
15	N		12.8	79.0		AU2	0.4
16	N		12.3	78.2		SE1	1.7
17	N		11.0	75.8		SE2	6.0
18	N		9.9	71.7		OC1	8.2
19	N		9.2	66.2		OC2	13.1
20	NNW		9.1	63.7		NV1	10.4
21	NNW		9.2	62.2		NV2	16.1
22	NNW		9.0	61.5		DC1	13.2
23	NNW		8.7	60.2		DC2	12.6

Figure 4. Las Vegas Ranked Mode 3 – "Moderate to Strong NNW'lys to Northerlies Throughout Day" – 9.5% Overall Incidence

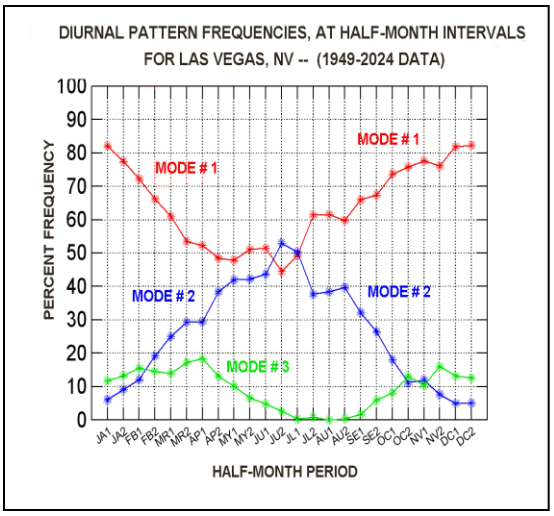


Figure 5. Diurnal Pattern Frequencies at Half-Month Intervals for Las Vegas, NV – (1949-2024 Data)

reflection of circulation changes manifested by the summer monsoon onset. It will be noticed that Mode 1's

Las Vegas Mode 2: (25.9%) "Moderate to Strong SSW'lys to SW'lys Throughout Day"

HRLST	Resultant Wind Dir	Resultant Wind Dir	Avg Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	SSW		10.8	89.8		JA1	6.1
1	SSW		10.8	89.8		JA2	9.2
2	SSW		10.8	89.5		FB1	12.1
3	SSW		10.9	89.3		FB2	19.2
4	SSW		10.6	88.0		MR1	25.0
5	SSW		10.3	86.8		MR2	29.3
6	SSW		10.0	85.4		AP1	29.4
7	SSW		10.2	83.5		AP2	38.4
8	SSW		10.8	81.3		MY1	42.0
9	SSW		11.7	79.2		MY2	42.3
10	S		12.6	80.5		JU1	43.7
11	SSW		13.8	84.7		JU2	53.0
12	SSW		14.7	87.3		JL1	50.3
13	SSW		15.5	89.5		JL2	37.7
14	SSW		15.8	90.6		AU1	38.4
15	SW		16.1	90.4		AU2	39.8
16	SW		16.2	90.8		SE1	32.2
17	SW		15.6	90.0		SE2	26.5
18	SW		14.5	89.4		OC1	18.1
19	SW		12.8	87.8		OC2	11.2
20	SW		12.1	85.5		NV1	12.0
21	SW		11.9	84.5		NV2	7.7
22	SW		12.0	83.4		DC1	5.0
23	SW		12.1	82.2		DC2	5.1

Figure 3. Las Vegas Ranked Mode 2 – "Moderate to Srong SSW'lys to SW'lys Throughout Day" - 25.9% Overall Incidence

percent frequency *increases* over that same interval, from the already mentioned minimum 44.5% for "JU2" (late-June) to 61.4% for "JL2" (late-July). Directional constancies are at "blue" levels throughout, ranging from 79.2 at 10AM to 90.8 at 4PM, the latter hour also displaying the highest mean scalar speed (16.2 knots).

Figure 4 below shows Las Vegas' third and least ranking mode, a relatively uncommon late Fall to mid-Spring post-frontal mode with mostly moderate to strong NNW'ly to Northerlies, maximum mean scalar speeds, curiously, in the mid to late morning.

Highest mean figure (14.7 knots) is shown for 10AM, this hour also indicating the highest constancy figure (85.8). Half-month percent frequencies range from 18.4% for "AP1" (early April), 17.3% for "MR2" (late March), and 16.1% for "NV2" (late November). "AU1" (early August) has a 0.0% statistic (no occurrences).

Finally, Figure 5 summarizes the half-month frequency progressions of Las Vegas' three modes. Interestingly, Mode 2 eclipses Mode 1 in relative frequency for "JU2" (late-June), and nearly matches it for "JU1" (early-July) but then, as previously discussed, it declines markedly for "JU2" (late-July), while Mode 1's shoots upward. This probably reflects the effects of the higher frequency easterlies that comprise the monsoon.

2.2. Phoenix (Sky Harbor) Int'l Airport - Lat: 33.4 N, Lon: 112.0 W; Elev. 1107 ft.

Phoenix (Sky Harbor Airport) also described from excerpts in its 2017 LCD Annual Summary, is located in the flat, oval shaped Salt River Valley of Southern Arizona at an elevation of about 1,100 feet. Scattered mountain ranges, ranging from 1500 to 4500 foot elevations are located to the south, southwest, west, and east at distances varying from 6 to 30 miles'. The Salt River itself flows through Phoenix, and winds at the Airport station are generally light, typically exhibiting a diurnal nocturnal easterlies to daytime westerlies pattern, a valley-type flow influenced by the river channel's gradual downward slope from east to west. The infrequent high winds that do occur are associated predominantly with Monsoonal thunderstorms in summer and episodes related to distant Pacific storms in Spring..

Daily data were available from January 1948 thru June 2024, excluding 1965 thru 1972, and 67.6% of these obs or n=16923 were entirely intact on a 24 hour basis.

The cluster analysis resolved four major diurnal wind pattern modes, encompassing 39.2%, 28.2%, 22.4%, and 10.2% overall incidences, respectively .

Phoenix Mode 1 - (39.2%) - Light Mean Easterlies/ESE'lys thru Mid-Day, Transitioning to Light Mean Westerlies/WNW'lys in Early Afternoon

HRLST	Resultant Wind Dir	Average Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	ESE		3.7	24.4		JA1	46.9
1	ESE		3.6	31.8		JA2	43.7
2	E		3.5	41.3		FB1	41.8
3	E		3.5	50.1		FB2	36.6
4	E		3.4	57.2		MR1	37.4
5	E		3.5	62.6		MR2	31.9
6	E		3.6	67.4		AP1	28.1
7	E		3.8	69.8		AP2	30.8
8	E		4.1	68.8		MY1	27.6
9	ESE		4.2	62.2		MY2	29.7
10	ESE		4.2	49.0		JU1	33.6
11	ESE		4.2	31.1		JU2	36.7
12	SE		4.2	6.3		JL1	38.0
13	W		4.4	22.2		JL2	37.3
14	W		4.8	41.3		AU1	45.5
15	W		5.1	52.1		AU2	43.3
16	WNW		5.4	60.5		SE1	38.4
17	WNW		5.5	64.2		SE2	39.0
18	WNW		4.9	59.9		OC1	38.5
19	W		4.2	39.5		OC2	43.4
20	WSW		3.5	13.9		NV1	44.7
21	SE		3.3	15.5		NV2	50.6
22	ESE		3.3	30.7		DC1	49.0
23	ESE		3.5	41.8		DC2	48.4

Figure 6. Phoenix Ranked Mode 1 – "Light Mean/Easterlies/ESE'lys Thru Mid-Day, Transitioning to Light Mean Westerlies/WNW'lys in Early Afternoon" - 39.2% Overall Incidence

Highest ranking Phoenix Mode #1 (39.2% overall incidence - see Figure 6 above), with a few exceptions, is also the most frequent mode on a individual half-month basis (see Figure 7 below), having this distinction for seventeen of the twenty-four segments. There's also a cold season absolute maximum preference, seven of the eight highest half-month statistics noted for the seven adjacent periods "OC2" (late-October) thru "JA2" (late-January), including the extreme maximum (50.6% shown for "NV2" (late-November). A major exception to the above "rule", a springtime concentration of relative *minima* is also evident, the absolute lowest five statistics recorded for the adjacent segments, "MR2" (late-March) thru "MY2" (late-May), including the absolute minimum (27.6%) for "MY1" (early-May).

Diurnal feature-wise, resultant directions from Midnight through 10AM are predominantly ESE'ly to Easterly at 3-4 knot mean scalar speeds (with "green" to "light blue" constancy levels), but over 11AM through 1PM, (particularly Noon, which shows a red constancy colorization of only 6.3), a transition to Westerlies and WNW'lys sets in. From 2PM thru 7PM, the latter directions hold sway, maximum scalar speed for the day set at 5.5 knots (a WNW'ly), but from 8PM/9PM (both at red constancy levels) there's gradual shift back to predominant ESE'ly flow to close the day.

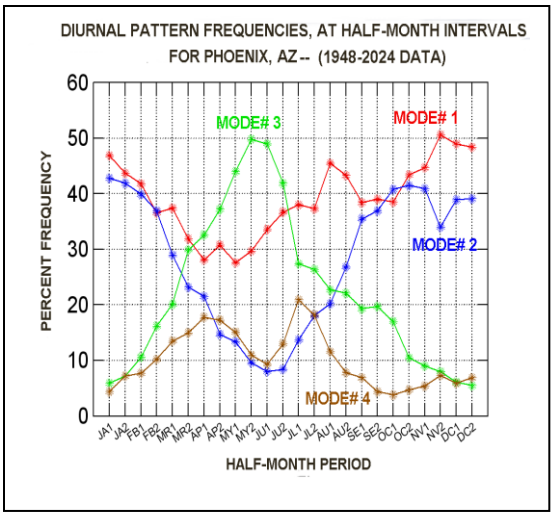
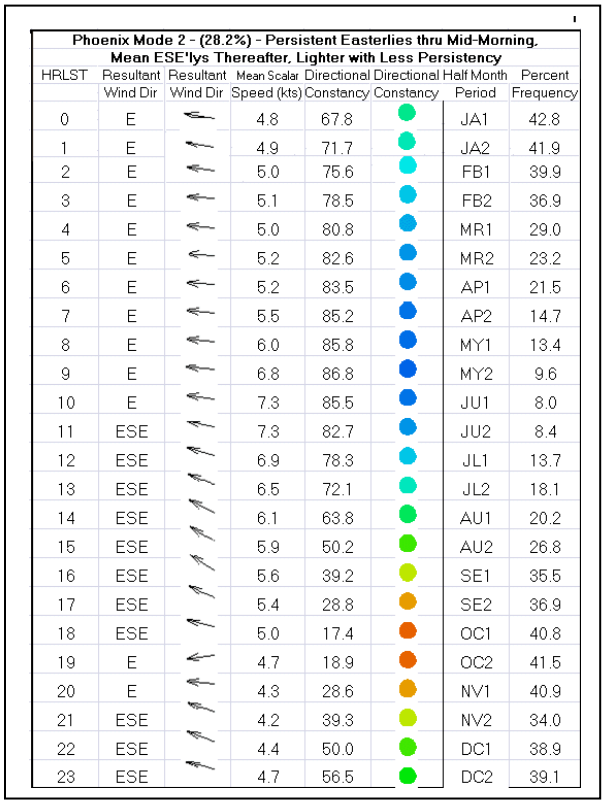


Figure 7. Diurnal Pattern Frequencies at Half-Month Intervals for Phoenix, AZ – (1948-2024 Data)



Phoenix Mode 2 - (28.2%) - Persistent Easterlies thru Mid-Morning, Mean ESE'lys Thereafter, Lighter with Less Persistency

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	E		4.8	67.8		JA1	42.8
1	E		4.9	71.7		JA2	41.9
2	E		5.0	75.6		FB1	39.9
3	E		5.1	78.5		FB2	36.9
4	E		5.0	80.8		MR1	29.0
5	E		5.2	82.6		MR2	23.2
6	E		5.2	83.5		AP1	21.5
7	E		5.5	85.2		AP2	14.7
8	E		6.0	85.8		MY1	13.4
9	E		6.8	86.8		MY2	9.6
10	E		7.3	85.5		JU1	8.0
11	ESE		7.3	82.7		JU2	8.4
12	ESE		6.9	78.3		JL1	13.7
13	ESE		6.5	72.1		JL2	18.1
14	ESE		6.1	63.8		AU1	20.2
15	ESE		5.9	50.2		AU2	26.8
16	ESE		5.6	39.2		SE1	35.5
17	ESE		5.4	28.8		SE2	36.9
18	ESE		5.0	17.4		OC1	40.8
19	E		4.7	18.9		OC2	41.5
20	E		4.3	28.6		NV1	40.9
21	ESE		4.2	39.3		NV2	34.0
22	ESE		4.4	50.0		DC1	38.9
23	ESE		4.7	56.5		DC2	39.1

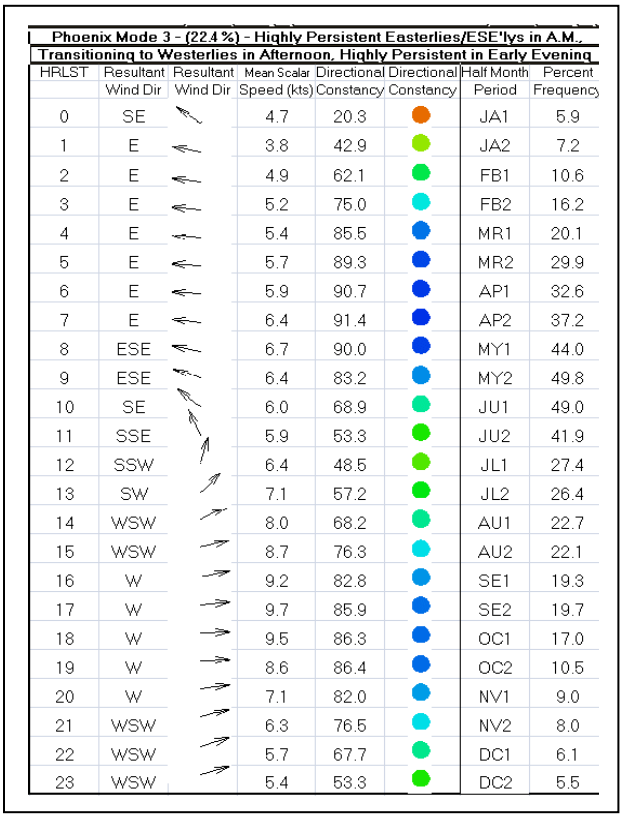
Figure 8. Phoenix Ranked Mode 2 – "Persistent Easterlies thru Mid-Morning, Mean ESE'lys Thereafter, Lighter with Less Persistency" - 28.2% Overall Incidence

Second ranking Phoenix Mode #2 (see Figure 8 above), shows a highly seasonal incidence pattern, with the highest frequencies indicated during the colder months of the year (See Figure 7 above). All of the greater than modal average (28.2%) statistics occur between "SE1" (early September) and "MR1" (early-March), the highest two figures (42.8% and 41.9%) noted for "JA1" (early January) and "JA2" (late January), respectively. – a 41.5% figure also lists for "OC2" (late-October). Minimum figures are each below 10% for "MY2" thru "JU2" (late Spring to early Summer), the absolute lowest: 8.0%, for "JU1" for (early-June).

Thru 10AM, pattern evaluation is relatively straightforward, the resultant directions predominantly Easterly, accompanied by upward trending mean scalar speeds, from 4.8 knots at Midnight to a maximum 7.3 knots for 10AM, coupled with constancies increasing from 80.8 at 4AM to as high as 86.8 at 9AM.

Thereafter, interpretations get more complex, ESE'lys take over at 10AM to predominate the rest of the day (except for the hours 7PM and 8PM, the former with an Easterly resultant, the latter also an Easterly but with a slightly noticeable bent toward the NE- actually to 83 degrees). But In addition, mean scalar speeds begin decreasing from 7.3 knots at 11AM to 4.2 kts by 9PM, constancies declining from 86.8 to less than 20 for both 6PM and 7PM. The late-afternoon/early evening low constancy period likely reflects a low speed high variability regime, although the inter-hour resultant variability is only between the Easterlies and ESE'lys By 11 PM, Mean scalar speeds are back to 4.7 knots with the constancy up to 56.5, conditions approaching those recorded on the previous Midnight

Given this mode's large seasonal variability combined with the somewhat perplexing diurnal trends, such as the mean scalar winds reaching a maximum speed at 11AM, the ESE'lys taking over thereafter, but with declining scalar winds and constancies, this may reflect an interplay of lesser type sub-diurnal modes not distinct enough to be expesssed as standalone ones.



Phoenix Mode 3 - (22.4 %) - Highly Persistent Easterlies/ESE'lys in A.M., Transitioning to Westerlies in Afternoon, Highly Persistent in Early Evening

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	SE		4.7	20.3		JA1	5.9
1	E		3.8	42.9		JA2	7.2
2	E		4.9	62.1		FB1	10.6
3	E		5.2	75.0		FB2	16.2
4	E		5.4	85.5		MR1	20.1
5	E		5.7	89.3		MR2	29.9
6	E		5.9	90.7		AP1	32.6
7	E		6.4	91.4		AP2	37.2
8	ESE		6.7	90.0		MY1	44.0
9	ESE		6.4	83.2		MY2	49.8
10	SE		6.0	68.9		JU1	49.0
11	SSE		5.9	53.3		JU2	41.9
12	SSW		6.4	48.5		JL1	27.4
13	SW		7.1	57.2		JL2	26.4
14	WSW		8.0	68.2		AU1	22.7
15	WSW		8.7	76.3		AU2	22.1
16	W		9.2	82.8		SE1	19.3
17	W		9.7	85.9		SE2	19.7
18	W		9.5	86.3		OC1	17.0
19	W		8.6	86.4		OC2	10.5
20	W		7.1	82.0		NV1	9.0
21	WSW		6.3	76.5		NV2	8.0
22	WSW		5.7	67.7		DC1	6.1
23	WSW		5.4	53.3		DC2	5.5

Figure 9. Phoenix Ranked Mode 3 – "Highly Persistent Easterlies/ESE'lys in A.M, transitioning to Westerlies in Afternoon, Highly Persistent in Early Evening - 22.4% Overall Incidence

Phoenix's third Ranking Mode, as evidenced from inspection of Figure 7's half-month incidence graph, exhibits the most striking feature of the chart, a steep bell-shaped trace of very high relative frequencies, covering almost exclusively the Spring periods. Half-month percentages over the six consecutive segments "AP1" (early-April) thru "JU2" (late-June) are the highest of those particular intervals, ranging as high as 49.8% for "MY2" (late-May) and 49.0% for "JU2" (late-June). Another noticeable feature, though, is the pronounced dip in frequency from 41,9% for 'JU2' (late June) to

27.4% for (‘JL1” or early July), a likely reflection of the Monsoon onset.

Diurnally, Mode 3 consists of two high, “blue” constancy periods with contrasting resultant directions. The first, from 4AM to 9AM, has easterlies through 7AM, ESE’lys for 8AM and 9AM, these accompanied by somewhat elevated mean scalar speeds given the early times of day: (5.4 to 6.7 knots; combined also with constancies between 85.5 and 91.4). Over 9AM to 3PM, there is a very gradual clockwise turning from ESE’lys to WSW’lys, constancies remaining at mostly green levels. Also, mean scalar wind speeds pick up, from the 5.9 knot SSE’lys at 11AM, to the 8.7 knot WSW’lys at 3PM. From 4PM thru 8PM, the second high constancy period, the resultants are all Westerlies at “blue” level constancies between 83 to 86. Maximum mean scalar speed for the day, 9.7 knots, is reached at 4PM. For the last three hours, the resultants return to “WSW’ly” orientations at decreasing mean scalar speeds.

Phoenix Mode 4 - (10.2%) - Prevailing Westerlies Throughout Day, Especially Persistent in Afternoons – Relatively High Speeds

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	WSW	→	6.5	56.7		JA1	4.4
1	W	→	6.4	53.8		JA2	7.2
2	W	→	6.2	52.4		FB1	7.7
3	W	→	5.9	53.4		FB2	10.2
4	W	→	5.6	49.1		MR1	13.5
5	W	→	5.4	47.8		MR2	15.0
6	WSW	→	5.2	42.7		AP1	17.8
7	W	→	5.4	43.2		AP2	17.3
8	W	→	5.9	55.4		MY1	15.1
9	W	→	6.7	69.9		MY2	11.0
10	W	→	7.5	77.6		JU1	9.3
11	W	→	8.1	80.2		JU2	13.0
12	W	→	8.7	82.3		JL1	20.9
13	W	→	9.4	85.4		JL2	18.2
14	W	→	10.1	88.5		AU1	11.6
15	W	→	10.6	87.7		AU2	7.8
16	W	→	10.6	89.1		SE1	6.9
17	W	→	10.5	88.1		SE2	4.4
18	W	→	9.9	85.2		OC1	3.8
19	W	→	8.6	79.2		OC2	4.7
20	W	→	7.3	70.0		NV1	5.4
21	W	→	6.6	58.7		NV2	7.3
22	WSW	→	5.9	49.7		DC1	5.9
23	WSW	→	5.8	38.7		DC2	6.9

Figure 10. Phoenix Ranked Mode 4 – “Prevailing Westerlies Throughout Day, Especially Persistent in Afternoons – Relatively High Speeds - 10.2% Overall Incidence

Phoenix’s fourth Ranking Mode (see Figure 10) is a diurnal regime with almost exclusive Westerlies, twenty of the twenty-hours’ resultants of this orientation. There are two contiguous-segment periods over the year with relative frequency maxima. The first, a Spring feature, covers the five consecutive half-month segments “MR1” (early March) thru “MY1’ (early May), percent frequencies ranging from 13.5% to 17.8%, the maximum for “AP1” (early-April). These undoubtedly relate to early season frontal passages. The second, not as clear as to its nature, is for the two adjacent segments “JL1” (early-July) and “JL2” (late-July). These two have the first and second highest figures of the year: 20.9% and 18.2%, respectively. Only four other segments across the year have percentage frequencies as high as 10.0%

On a diurnal feature basis, mean scalar speeds range from 5.2 knots at 6AM (constancy: 42.7) to 10.6 knots for at both 3PM and 4PM. Constancy values over the 1PM to 6PM period vary from 85.4 to 89.1, the latter at 4PM.

2.3. Tucson Int’l Airport - Lat: 32.1 N, Lon: 110.9 W; Elev. 2549 ft.

According to its 2017 LCD Annual Summary, the Tucson area is “mostly encircled by mountains”, including the Catalina Mountains to the north with elevations exceeding 9000 feet, those to the east and south rising to higher than 5000 feet, and those to the west as high as 4000 feet. Surface winds are generally light, with no major seasonal changes in velocities or directions. Rather they’re influenced by the surrounding mountains and the general slope of the terrain, and locally they tend to be southeasterly, nocturnally and northwesterly during the day. High winds are typically “from the southwest and east to south”.

Daily data were available from January 1949 thru June 2024, excluding 1964-1972, and 61.6% of these daily obs or n=15301 were entirely intact on a 24 hour basis.

The cluster analysis resolved four major diurnal wind pattern modes, encompassing 41.6%, 31.5%, 16.6%, and 10.4% overall incidences, respectively .

Highest ranking Tucson Mode #1 (- see Figure11 below), on an individual half-month basis is the most favored pattern for sixteen of the twenty-four segments, these contiguous with one another (see Figure 12 below). The first four comprise “JA1” (early-January) thru “FB2‘ (late-February), percentage frequencies in the mid 50’s to high 40’s. The magnitudes then trend sharply downward to the teens for the adjacent segments “AP2” (late-April) thru “JU2” (late-June), including the absolute minimum (13.0%) for “JU1” (early June). Thereafter, they surge back upward to 50.9% and 55.6% levels for “JL2” (late-July) and “AU1”,, respectively, coinciding with the summer monsoon arrival. For the year’s remaining segments, the magnitudes persist mainly in the 50’s, the absolute maximum figure (61.4%) attained for “DC2” (late-December).

Tucson Mode 1 (41.6%) - "SE'LYS to SSE'LYS Thru Noon, Mostly NW'LYS Thru Early Evening"

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	SSE		5.9	79.4		JA1	54.3
1	SE		6.0	84.1		JA2	52.9
2	SE		6.1	86.1		FB1	51.7
3	SE		6.1	87.5		FB2	47.4
4	SE		6.2	88.4		MR1	38.3
5	SE		6.2	89.2		MR2	29.7
6	SE		6.4	89.8		AP1	25.7
7	SE		6.7	90.3		AP2	17.9
8	SE		6.8	89.8		MY1	13.9
9	SSE		6.4	85.1		MY2	13.9
10	SSE		5.5	71.1		JU1	13.0
11	SE		4.9	45.2		JU2	15.0
12	SE		5.0	10.1		JL1	33.6
13	NW		5.4	18.2		JL2	50.9
14	NW		6.0	34.2		AU1	55.6
15	NW		6.6	42.7		AU2	53.3
16	NW		7.1	47.2		SE1	45.6
17	NW		7.2	47.1		SE2	40.0
18	NW		6.8	39.9		OC1	48.6
19	WNW		5.8	24.5		OC2	57.4
20	SSW		5.5	22.4		NV1	51.9
21	S		5.6	50		NV2	57.4
22	SSE		5.7	67.7		DC1	59.7
23	SSE		5.9	76.9		DC2	61.4

Figure 11. Tucson Ranked Mode 1 – "SE'lys to SSE'lys Thru Noon. Mostly NW'lys Thru Early Evening " – 41.6% Overall Incidence

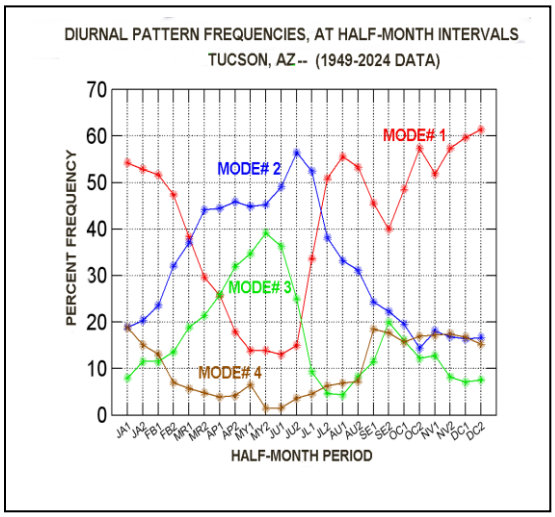


Figure 12 –. Diurnal Pattern Frequencies at Half-Month Intervals for Tucson, AZ – (1949-2024 Data)

The diurnal features of Mode 1 are relatively clear-cut (see Figure 11 above), SSE'lys to SE'lys predominating at high constancies thru 9AM, mostly in the upper 80's to as high as 90.3 at 7AM, mean scalar speeds between 5.9 to 6.8 knots. A gradual directional changeover then develops, especially apparent for Noon and 1PM, with red and red orange constancy colorations showing. From 1PM thru 6PM, the resultants have shifted to NW'lys, constancies, however, indicating more variability, with magnitudes no higher than the 40's, (over 3PM to 5PM). At 5PM, the day's maximum mean scalar speed, a relatively modest 7.2 knots occurs, and at 7PM and 8PM, another changeover period develops (orange/brown constancy colorings), as the SSE'ly nocturnal regime begins to return. At 11PM, the resultant is SSE/ly accompanied by a 5.9 knot mean scalar speed and a 76.9 constancy magnitude.

Tucson second ranking Mode2 (overall incidence 31.5% -see Figure 13 below) is roughly inverse in pattern to Mode 1 (see Figure 12 above). Correlation coefficient between their half-month statistics is -0.860. The contrast is especially evident between the eight contiguous segments "MR2" (late-March) thru "JL1" (early-July), the latter just prior to the full monsoonal onset. The primary reason is attributable to the

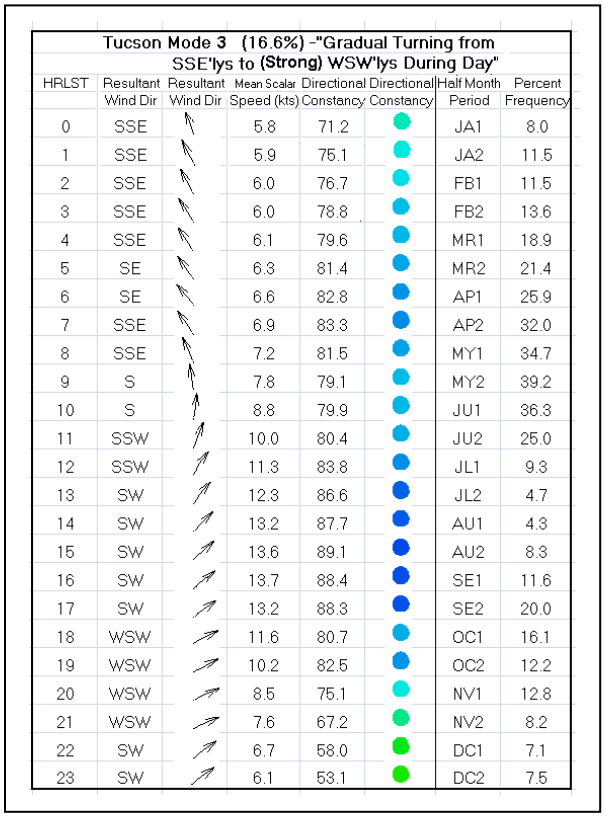
Tucson Mode 2 (31.5%) - WNW'LYS Setting in Mid-Morning

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	SSW		5.7	54.2		JA1	18.9
1	S		5.6	59		JA2	20.4
2	S		5.5	62.8		FB1	23.6
3	SSE		5.5	65.7		FB2	32.1
4	SSE		5.4	68.4		MR1	37.1
5	SSE		5.4	69.8		MR2	44.1
6	SSE		5.4	70.8		AP1	44.5
7	SSE		5.6	70.7		AP2	45.9
8	S		5.1	61.1		MY1	44.9
9	SSW		4.5	34.9		MY2	45.3
10	WNW		4.8	44.1		JU1	49.1
11	WNW		5.8	60.9		JU2	56.4
12	WNW		6.9	69.8		JL1	52.5
13	WNW		8.0	73.8		JL2	38.2
14	WNW		9.0	77.6		AU1	33.2
15	WNW		9.6	80.4		AU2	31.1
16	WNW		10.1	82.5		SE1	24.3
17	NW		10.3	83.1		SE2	22.3
18	NW		9.7	80.4		OC1	19.6
19	NW		8.6	80.4		OC2	14.4
20	NW		7.1	71.1		NV1	18.1
21	WNW		6.3	61.2		NV2	16.9
22	WSW		6.0	50.9		DC1	16.4
23	SW		5.7	50.0		DC2	15.7

Figure 13. Tucson Ranked Mode 2 – "WNW'lys Setting in Mid-Morning " – 31..5% Overall Incidence

longer-duration WNW'lys/ NW'lys at generally stronger speeds than those for Mode 1 (compare Figures 13 and Figures 11, respectively). For Mode 2, the WNW'lys/NW'lys prevail from 10AM thru 9PM (twelve hours), at mean scalar speeds as high as 10.3 knots; in comparison, Mode 1's WNW'lys and NW'lys only appear from 1PM thru 7PM (seven hours), at mean speeds never higher than 7.2 knots.

On a seasonal basis, the contrast in half-month frequency is greatest for "JU2" (late-June), Mode 2 with a 56.4% figure, Mode 1 with 15.0% (see Figure 12).



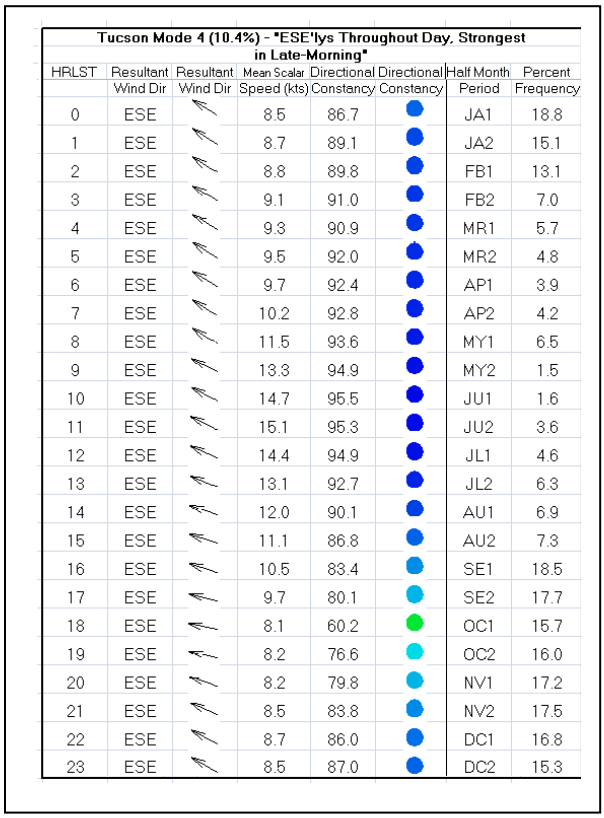
Tucson Mode 3 (16.6%) -"Gradual Turning from SSE'lys to (Strong) WSW'lys During Day"

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	SSE		5.8	71.2		JA1	8.0
1	SSE		5.9	75.1		JA2	11.5
2	SSE		6.0	76.7		FB1	11.5
3	SSE		6.0	78.8		FB2	13.6
4	SSE		6.1	79.6		MR1	18.9
5	SE		6.3	81.4		MR2	21.4
6	SE		6.6	82.8		AP1	25.9
7	SSE		6.9	83.3		AP2	32.0
8	SSE		7.2	81.5		MY1	34.7
9	S		7.8	79.1		MY2	39.2
10	S		8.8	79.9		JU1	36.3
11	SSW		10.0	80.4		JU2	25.0
12	SSW		11.3	83.8		JL1	9.3
13	SW		12.3	86.6		JL2	4.7
14	SW		13.2	87.7		AU1	4.3
15	SW		13.6	89.1		AU2	8.3
16	SW		13.7	88.4		SE1	11.6
17	SW		13.2	88.3		SE2	20.0
18	WSW		11.6	80.7		OC1	16.1
19	WSW		10.2	82.5		OC2	12.2
20	WSW		8.5	75.1		NV1	12.8
21	WSW		7.6	67.2		NV2	8.2
22	SW		6.7	58.0		DC1	7.1
23	SW		6.1	53.1		DC2	7.5

Figure 14. Tucson Ranked Mode 3 – "Gradual Turning SSE'lys to (Strong) WSW'lys During Day – 16.6% Overall Incidence

Tucson's third Ranking Mode (See Figure 14 above), indicating a preferred Spring presence of relatively strong SSW'lys to WSW'ly afternoon winds, shows striking similarities in half-month frequency features to Phoenix's Mode 3 pattern (See Figure 9), both modes highlighting the propensity of relatively high wind episodes during that season. Correlation coefficient between the two patterns is +.831. Maximum half-month frequency for Tucson Mode 3 is 39.2% for "JU1" (early-June), the percent frequency figures for each of the seven contiguous segments, "MR2" thru "JU2" (late-March thru late-June respectively) never exceeded by any of those of the other seventeen.

Following the "JU2"'(late-July) 25.0% figure, that for "JL1" (early-July) plunges to 9.3%, on the way to the absolute minimum 4.3% for "AU1" (early-August). Mode 3's diurnal features are rather eye-catching with monotonic increases and decreases in mean hourly scalar speeds, from 5.8 knots at Midnight to the maximum 13.7 knots at 4PM, back to again 6.1 knots at 11PM. Resultant directions are almost entirely so with only a very gradual clockwide turning displayed during the day from SSE'lys early on, SSW'lys in the late morning, SW'lys by afternoon, and WSW'lys in the evening. There are no significant directional changeover periods (low constancies) during the day, the maximum constancy figure (89.1) seen for 3PM, is associated with a SW'ly resultant at 13.6 knots.



Tucson Mode 4 (10.4%) - "ESE'lys Throughout Day, Strongest in Late-Morning"

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	Half Month Period	Percent Frequency
0	ESE		8.5	86.7		JA1	18.8
1	ESE		8.7	89.1		JA2	15.1
2	ESE		8.8	89.8		FB1	13.1
3	ESE		9.1	91.0		FB2	7.0
4	ESE		9.3	90.9		MR1	5.7
5	ESE		9.5	92.0		MR2	4.8
6	ESE		9.7	92.4		AP1	3.9
7	ESE		10.2	92.8		AP2	4.2
8	ESE		11.5	93.6		MY1	6.5
9	ESE		13.3	94.9		MY2	1.5
10	ESE		14.7	95.5		JU1	1.6
11	ESE		15.1	95.3		JU2	3.6
12	ESE		14.4	94.9		JL1	4.6
13	ESE		13.1	92.7		JL2	6.3
14	ESE		12.0	90.1		AU1	6.9
15	ESE		11.1	86.8		AU2	7.3
16	ESE		10.5	83.4		SE1	18.5
17	ESE		9.7	80.1		SE2	17.7
18	ESE		8.1	60.2		OC1	15.7
19	ESE		8.2	76.6		OC2	16.0
20	ESE		8.2	79.8		NV1	17.2
21	ESE		8.5	83.8		NV2	17.5
22	ESE		8.7	86.0		DC1	16.8
23	ESE		8.5	87.0		DC2	15.3

Figure 15. Tucson Ranked Mode 4 – "ESE'lys Throughout Day, Strongest in Late-Morning – 10.4% Overall Incidence

Fourth Ranking Mode for Tucson has ESE'ly resultants prevailing all day with the highest hourly mean scalar statistics of any of the four modes, including 15.1 knots for 11AM, 14.7 knots for 10 AM, and 14.4 knots for Noon. The reason for the late morning maxima is not clear, but given the seasonal distribution of the half-month maximum percent frequencies: "SE1" (early September" thru "FB2" (late-February), Mode 4 is probably most associated with Monsoon rain episodes (more frequent in Fall) and Pacific Storms. Maximum frequencies are noted for 18.8% for "JA1" (early-January) and "SE1" (early September's 18.5%); the least magnitudes are 1.5% for "MY2" (late-May) and 16% for "JU1" (early-June).

3.1. Las Vegas Extreme-most Daily Hour-to-Hour Wind Pattern Analysis

Figures 16 and 17 present some supporting results involved in determination of the single most extreme hourly wind direction and speed pattern for Las Vegas. As previously noted, the extreme-most statistic is the maximum Squared Euclidean Distance generated from a K=1 cluster analysis of the entire data set as a unit, the 48-D 'u' and v' daily statistics each having been standardized in advance. .

Las Vegas Overall Hourly Resultants & Extrememost Indv Pattern

n= 16884 -- Extrememost --

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	WDIR	WSPD (kts)
0	SW		8.1	60.6		N	6
1	SW		7.9	58.3		NW	30
2	SW		7.7	57.0		NNW	30
3	SW		7.5	55.9		NW	43
4	SW		7.4	54.8		NNW	40
5	SW		7.2	54.2		NNW	25
6	SW		6.9	52.0		NNW	22
7	SW		6.7	41.7		NNW	30
8	SW		6.6	24.4		NNW	32
9	S		6.9	10.7		NW	25
10	SE		7.6	10.7		NW	23
11	SSE		8.1	13.8		NW	34
12	S		8.6	17.2		NNW	25
13	SSW		8.9	21.2		NNW	25
14	SSW		9.2	25.0		NNW	30
15	SSW		9.4	28.9		NNW	33
16	SW		9.4	32.7		NNW	30
17	SW		9.2	39.3		NNW	30
18	SW		9.0	47.7		NNW	25
19	SW		8.8	57.1		NNW	28
20	SW		8.9	62.6		NNW	27
21	SW		8.8	63.5		NNW	17
22	SW		8.6	62.4		NNW	27
23	SW		8.4	61.5		NNW	24

Figure 16. – Las Vegas Overall Diurnal Climatological Wind Character and Extreme-most Individual Event (18 Feb 1955)

From the Figure 16 composite K=1 "Mode" chart above, the format is the same as for the previous decomposed modes' graphs, except that columns 7 and 8, formerly showing the Half-month percent frequency information have been replaced, respectively, by the extreme day's hour-to-hour sixteen point compass directions and the corresponding wind speed. in the case of Las Vegas, that being 18 February 1955.

As Figure 16's data in columns 2 thru 6 are weighted composites of those from Las Vegas' three decomposed modes (Figures 1, 3, and 4) one can get a sense of how the modes are "embedded" or intertwined. A blending of features can be detected from Modes 1 and 2, but the third mode, the post-frontal NNW'lys is totally hidden. However, the extreme wind day featured nearly all NW'lys or NNW'lys, eleven at 30 knots or higher, the strongest, a NW'ly at 43 knots for 3AM, succeeded at 4AM by a NNW'ly at 40 knots.

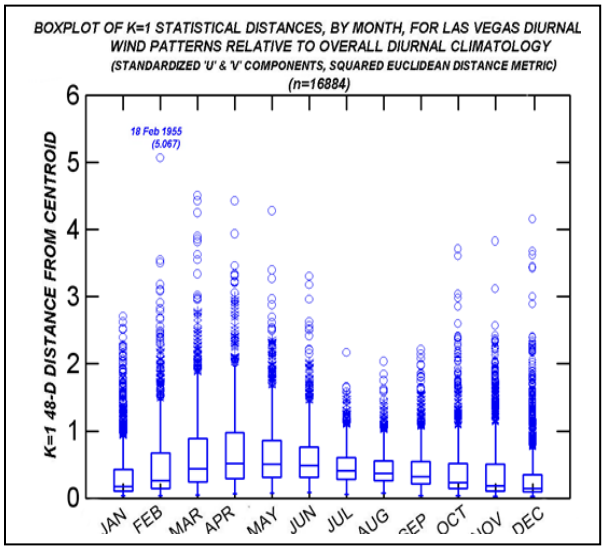


Figure 17 – Boxplot of K=1 Statistical Distances, by Month, for Las Vegas Diurnal Wind Patterns Relative to Overall Diurnal Climatology

Figure 17 above shows month-to-month boxplots of the 48-D Squared Euclidean Distances calculated for each of the 16884 Las Vegas daily observations. The 18 Feb 1955 distance statistic (5.067) is clearly the overall maximum, though, somewhat out of character for February, it's significantly higher than the second ranking statistic for that month, a 3.5 distance magnitude. In general, the distributions for March thru May produce most of these > 3.5 magnitudes, as in general, their diurnal wind speeds are typically stronger, but the Median distances all appear to be all less than 0.5.

Alternatively, in terms of the much simpler calculated "mean daily scalar speeds" statistic, which doesn't consider directions, nor the underlying hour-to-hour patterns of the u and v wind components, 18 Feb 1955 ranks only as the second most extreme. Overall correlation between the 16884 daily mean speeds and the K=1 distances is +.888,

3.2. Phoenix Extreme-most Daily Hour-to-Hour Wind Pattern Analysis

Phoenix Overall Hourly Resultants & Extrememost Indv Pattern

n= 16923 -- Extrememost --

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	WDIR	WSPD (kts)
0	ESE		4.5	26.3		S	14
1	ESE		4.5	35.3		S	16
2	ESE		4.5	44.5		S	26
3	E		4.5	52.1		S	20
4	E		4.5	59.1		S	12
5	E		4.6	63.4		SSW	21
6	E		4.7	66.8		SSW	16
7	E		5.0	68.5		W	31
8	E		5.4	66.3		WSW	17
9	ESE		5.7	59.9		W	28
10	ESE		5.8	49.2		W	26
11	ESE		5.9	36.8		WSW	26
12	SSE		5.9	23.5		WSW	25
13	SSW		6.1	21.2		WSW	18
14	WSW		6.4	31.3		WSW	21
15	WSW		6.7	40.7		WSW	15
16	W		6.8	49.1		WSW	15
17	W		6.9	53.8		WSW	16
18	W		6.5	54.4		SW	19
19	W		5.8	47.0		SW	12
20	W		4.9	33.3		WSW	15
21	SW		4.5	22.8		SSW	8
22	S		4.4	15.0		WSW	6
23	SE		4.5	16.8		SW	4

Figure 18. – Phoenix Overall Diurnal Climatological Wind Character and Extreme-most Individual Event (22 Feb 2023)

Figure 18 above is the Phoenix composite (K=1) "Mode" Chart. Modes 1 (see Figure 6) and 3 (see Figure 9) share the same general resultant features, with the rough dichotomy between the morning easterlies and the afternoon westerlies, but Modes 2 (see Figure 8) and 4 (see Figure 10) are dissimilar with their mostly unidirectional hourly aspects (Easterlies and ESE'lys for #2, Westerlies and SW'lys for #4),.

The extreme wind day, 22 Feb 2023 brought relatively strong (by Phoenix standards) Westerly's to SW'lys for most of the day in particular between roughly 7AM through 2PM. most in excess of 20 Knots, including a 31 knot Westerly at 7AM.

Figure 19 below shows month-to-month boxplots of the distances calculated for the 16923 Phoenix daily observations. The 22 Feb 2023 distance statistic (3.885) is clearly the overall maximum, again somewhat out of character for February; only the maximum for March (3.6 magnitude) approaches this level. Not unlike Las Vegas, the distributions for February thru April produce higher magnitude distances, owing to their higher winds in the mean. Curiously, the median for July (horizontal line drawn thru its box) is the highest for all the calendar

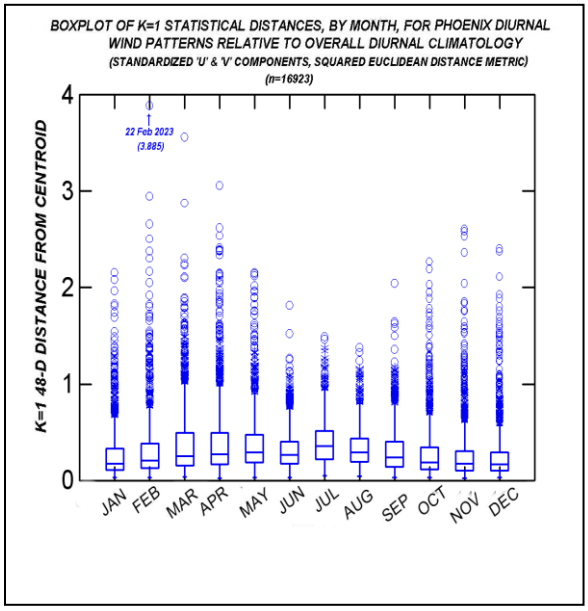


Figure 19 – Boxplot of K=1 Statistical Distances, by Month, for Phoenix Diurnal Wind Patterns Relative to Overall Diurnal Climatology

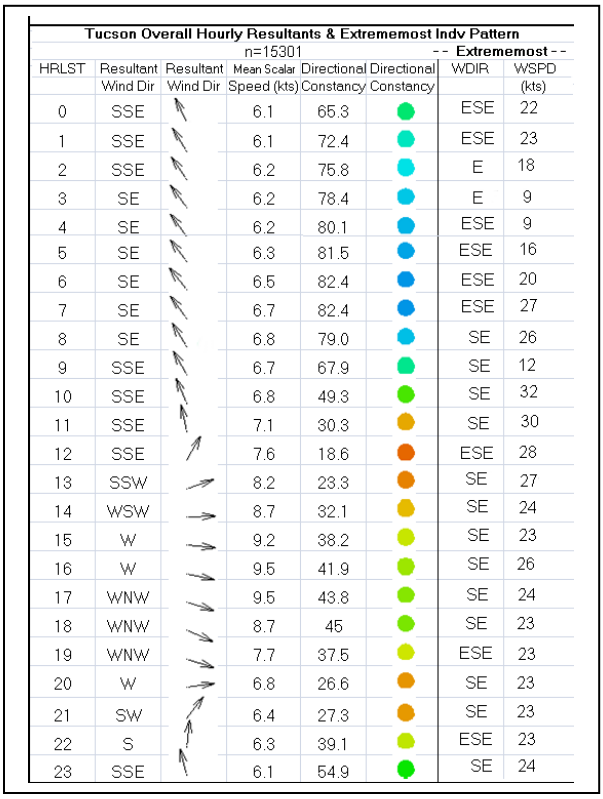
months, possibly reflective of the higher winds accompanying monsoon thunderstorm occurrences at the unaccustomed late evening hours.

Compared with the Mean Hourly Speeds, 22 February 2023 also has the #1 ranking of that variable. Overall correlation between the 16923 daily mean speeds and the daily K=1 distances is +.865,

3.3. Tucson Extreme-most Daily Hour-to-Hour Wind Pattern Analysis

Figure 20 below is the Tucson (K=1) Composite Mode Chart. Comparatively speaking, Modes 1 (See Figure 11) and 2 (See Figure 13), comprising more than 70% of the daily cases, noticeably resemble the composite's SE'lys vs.NW'lys dichotomy although #2's NW'lys set in earlier during the day than #1's and there's no pronounced changeover (low constancy) period. Modes 3 (see Figure 14) and 4 (See Figure 15) are more unidirectional, #3 with SSE'lys to SSW'lys throughout, #4 with ESE'ly's throughout without exception.

The extreme wind pattern day,17 Nov 1951, brought relatively strong SE'lys and SSE'lys throughout, the maximum speed 32 Knots at 10AM, the remaining hours with sustained speeds between 23 and 30 knots.



Tucson Overall Hourly Resultants & Extrememost Indv Pattern

n=15301 -- Extrememost --

HRLST	Resultant Wind Dir	Resultant Wind Dir	Mean Scalar Speed (kts)	Directional Constancy	Directional Constancy	WDIR	WSPD (kts)
0	SSE		6.1	65.3		ESE	22
1	SSE		6.1	72.4		ESE	23
2	SSE		6.2	75.8		E	18
3	SE		6.2	78.4		E	9
4	SE		6.2	80.1		ESE	9
5	SE		6.3	81.5		ESE	16
6	SE		6.5	82.4		ESE	20
7	SE		6.7	82.4		ESE	27
8	SE		6.8	79.0		SE	26
9	SSE		6.7	67.9		SE	12
10	SSE		6.8	49.3		SE	32
11	SSE		7.1	30.3		SE	30
12	SSE		7.6	18.6		ESE	28
13	SSW		8.2	23.3		SE	27
14	WSW		8.7	32.1		SE	24
15	W		9.2	38.2		SE	23
16	W		9.5	41.9		SE	26
17	WNW		9.5	43.8		SE	24
18	WNW		8.7	45		SE	23
19	WNW		7.7	37.5		ESE	23
20	W		6.8	26.6		SE	23
21	SW		6.4	27.3		SE	23
22	S		6.3	39.1		ESE	23
23	SSE		6.1	54.9		SE	24

Figure 20. – Tucson Overall Diurnal Climatological Wind Character and Extreme-most Individual Event (17 Nov 1951)

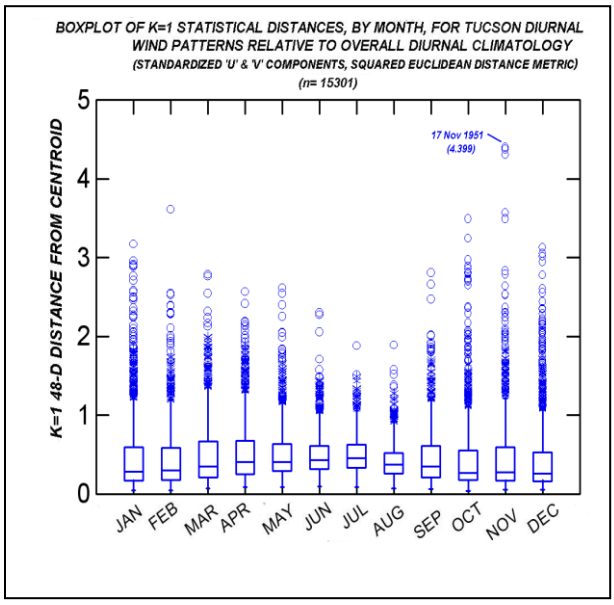


Figure 21 – Boxplot of K=1 Statistical Distances, by Month, for Tucson Diurnal Wind Patterns Relative to Overall Diurnal Climatology

Figure 21 above shows month-to-month boxplots of the 48-D Squared Euclidean Distances calculated for each of the 15301 Tucson daily observations. The 17 Nov 1951 maximum distance statistic (4.399) is marginally higher than two other November cases, (distance statistics 4.375, & 4.301 on successive November days in 1961). November 1951's Mean Hourly Speed statistic is only the second highest on its array

Overall correlation between the 15301 daily mean speeds and the K=1 distances was +.890.

4. SUMMARY

Utilizing K-Means Clustering Analysis, the foregoing identified and described several major diurnal statistical wind pattern modes, each, for Las Vegas, Phoenix, and Tucson, along with their percent climatological frequencies across half-month periods.

As expected, there were a number of interesting patterns, including the less frequent ones that via comparisons with the composite (K=1) "cluster" cloud, were not discernable. The more important modes, conversely, were somewhat entangled feature-wise, but still recognizable, "hindsightwise" in the composite.

As an experiment for each station, composited K=1 daily hourly observational data were utilized, to enable Squared Euclidean distance calculations (in 48-dimensional space), to single out the most "extreme" daily patterns, based on absolute maximum distances. On a strict, abstract, level this was a suitable alternative for hourly wind data, as it was fine-scaled (the individual 'u's and 'v's were considered), and the components were unbiased (the 48 'u's and 'v's reduced to a common scale or standardized). Also, the analysis was heuristic, no high-dimensional type (in this case: n=48) extreme-value parameter-based theorizations required, a likely insurmountable task, to be sure.

However, a much simpler alternative, the single daily mean hourly wind speed statistic, was also discussed and compared. Correlation coefficients between the mean hourlies and the K=1 distances for each of three stations were in the upper.80's, the less than the r=+1.0 resolutions, however, reflecting the differing nature (coarser) of the mean hourly wind speed statistic.

As the Las Vegas, Phoenix, and Tucson stations display, climatologically, generally light winds, a comparatively slight range of preferred hourly directions, and relatively consistent sine-wave-like diurnal patterns, day-after-day, perhaps a K=1 treatment on other more northerly, continental-type stations, with their greater frequencies of fronts and extra-tropical storm passages, plus their generally more variable wind character, would produce greater contrasts in correlations between the mean hourlies and the K=1 distances. Suffice to say, *pattern* in the context of this K=1 treatment is just one of many different statistical attributes that can fashioned to characterize a set of daily hourly wind observations.

Lastly, as noted previously, the clustering analysis could only process daily data which was entirely

complete on a 24-hour basis (no missing hourlies allowed), this reducing the useable sample sizes to 69% of possible for Las Vegas, 68% for Phoenix, and 62% for Tucson. A suitable work-around, especially in cases in which the hourly gaps were not too great, would be preliminary, in advance, linear interpolations of the missing hours' u's and v's, flanking those non-missing components obs. While this wouldn't likely change the decompositions' results significantly, the raw samples sizes already quite large (all in excess of n=1500), it might throw light, in approximate fashion, on even more pronounced daily extreme hourly wind patterns that were otherwise "disqualified" owing to their (few in number) hourly gaps.

5. REFERENCES

Fisk, C., 2023: "K-Means Cluster Analysis of Diurnal Wind Pattern Modes for Nine Climate Stations in the Southern California Area – 103rd American Meteorological Society Annual Meeting – 36Th Conference on Climate Change and Variability – Denver, CO. (PDF) K-MEANS CLUSTER ANALYSIS OF DIURNAL WIND PATTERN MODES FOR NINE CLIMATE STATIONS IN THE SOUTHERN CALIFORNIA AREA (researchgate.net)

Nisbet, R., Elder, J., and Miner, G., 2009: Handbook of Statistical Analysis & Data Mining Applications Elsevier, 824 pp.

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