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1. INTRODUCTION

The State of California's diverse and complex topography - its varying mountain range orientations, coastline configurations, basins, and valleys produces a diverse assortment of surface wind climatologies for its numerous meteorological stations. Diurnal and seasonal wind character for some localities may exhibit significant contrasts relative to the large-scale west to northwesterly flow patterns that predominate the free atmosphere overhead [WRCC, 2007].

Given this likelihood, for contingency planning and decision-aid purposes it should be useful to have quick-study individual-hour wind data in hand that characterize this wind variability for stations of interest.

The recent (in the last several years) online availability of hourly observational sets extending back 60 years or more (e.g., the Integrated Surface Hourly data site or "ISH" at the NOAA National Climate Data Center) makes the every-hour option convenient for those who wish to analyze hourly data for many stations. Also, the availability of powerful desktop data analysis and visualization software, itself a fairly recent development, enables results to be presented in a concise and preferably graphical way.

The following analyzes/compares hourly wind climatologies for a collection of Southern California stations, in the process demonstrating a three-chart graphical methodology for presenting results. The graphical scheme is an hour by month climogram approach [Fisk, 2004], analogous to topographic maps. As employed, calendar month replaces the North/South or Y-axis, and hour of the day the East-West or X-axis. The various points on the graph represent wind climatological statistics for a given month/hour, and areas with similar properties can be contoured/colored to further illuminate their features. Sets of these charts (depicting other parameters as well as winds) have been prepared for several Naval Air Station commands in addition to a National Weather Service Forecast office.

To attempt to achieve an organized sampling of stations, the analysis makes use of the NOAA Western Regional Climate Center's California Climate Region delineation (Figure 1), and a selection of sixteen stations with long periods of record. The WRCC regions with stations that could be considered part of Southern California include the South Coast ("H"), the South Interior ("I"), the Sonoran ("K"), the Central Coast ("F"), and the Mohave ("J").

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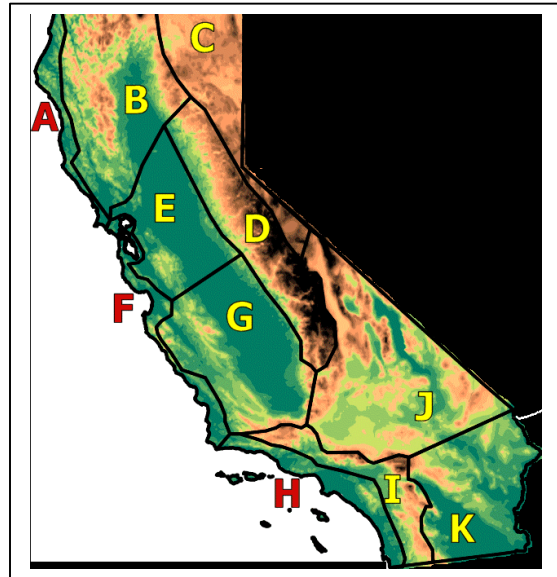


Figure 1. NOAA Western Regional Climate Center (WRCC) California Climate Regions [WRCC, 2007]

2. METHODS AND PROCEDURES

Three types of climograms are presented: 1.) Mean Vector Wind/Constancy, 2.) Prevailing Winds, and 3.) Mean Scalar Wind Speed/Percent of Time with Calms.

The large number of charts presented and space constraints necessitates that supporting interpretations be somewhat brief and occasionally speculative. In any case, the goal of a hopefully effective visual means of presenting data of this kind is to serve as an alternative to voluminous writeups or tabulations.

2.1 - Mean Vector Wind and Vector Wind Constancy

The mean vector wind and vector wind "constancy" characterize overall wind direction and persistence. Calculation is performed by decomposing individual wind observations into their north/south and east/west components, adding the components, and then recombining their arithmetic averages into a single overall "mean vector wind" or "resultant wind". Since individual wind directions almost always show variability from observation to observation, resultant wind speeds will be somewhat less than the corresponding mean scalar wind speeds (mean wind speed irrespective of direction). The ratio of the former to the latter multiplied by 100 measures vector wind "constancy". Constancy

values can range from 100 (individual wind observations unvarying in direction but not necessarily in speed) to 0 (individual wind observations canceling each other out exactly when added vectorially). As the charts to follow will illustrate, mean vector wind directions, speeds, and constancies for a given station can vary considerably on a hour-by-hour basis climatologically, owing to diurnal, seasonal, and of course local topographical influences.

Mean vector winds are depicted in their climogram as arrows, oriented in the direction of flow, with lengths proportional to speed. Constancy values are represented in the graph by color shadings

2.2 - Prevailing Winds

“Prevailing Winds” in this study are the most frequently observed 16-point compass wind directions. The Prevailing Winds climogram depicts for each hour, by calendar month, its direction and mean speed, and like mean vector winds, the arrows are oriented in the direction of flow with their lengths proportional to mean speed. Also represented is prevailing wind frequency, in the form of superimposed color shadings/contour lines.

Prevailing winds information, of course, is less inclusive than that of the mean vector wind, as information on just one direction is considered. However, its interpretation is somewhat more intuitive, and in this regard the two charts complement each other.

Prevailing wind frequencies that are high in magnitude, say >30 percent, are generally associated with mean vector winds of a similar directional orientation accompanied by a high constancy value.

2.3 - “Mean Scalar Wind Speed/Percent of Time with Calms”

“Mean Scalar Wind Speed” and “Percent of Time with Calms” are depicted for each hour and month as solid contours/color for the former and dashed contours for the latter.

3. RESULTS

3.1 - South Coast Stations

Five stations from the “South Coast” region are analyzed for their wind variability: Los Angeles International Airport (LAX), Long Beach FAA Airport, San Diego Lindbergh Field, Point Mugu Naval Base, and Santa Barbara Municipal Airport.

3.1.1 - Los Angeles International Airport (LAX) - Lat: 33° 56 N; Lon: 118° 23 W; Elev: 100 ft.

Figure 1 is the Mean Vector Wind climogram for Los Angeles International Airport (LAX). A symmetric arrangement of like-oriented vectors and constancy regions is shown, the most prominent feature being the area of high magnitude southwesterly vectors encompassing all the months of the year, from 1300

LST at the latest, until well past sunset (rightmost curvilinear trace extending from the top to bottom of the chart) in most cases. This of course reflects the sea-breeze, blowing in from the Pacific coastline 3 miles distant. Highest constancy maxima, depicted by the bright red shadings, are widest for the months with longer daylight hours, the seabreeze generally commencing earlier and persisting longer then.

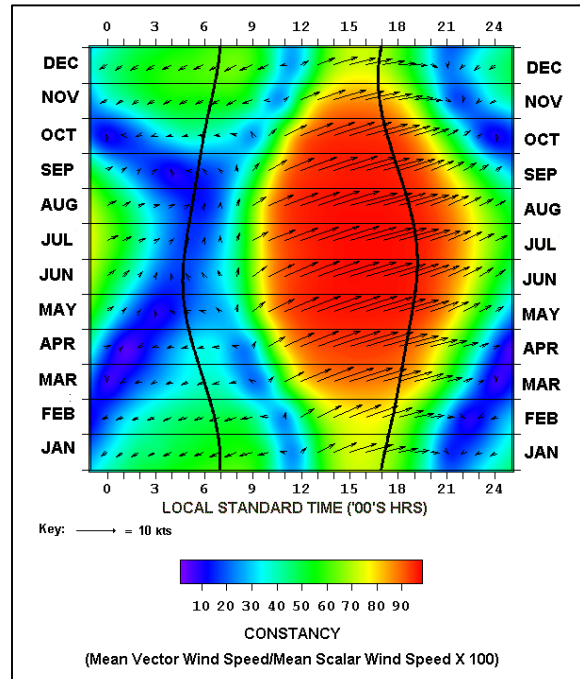


Figure 1. Mean Vector Wind/Constancy Chart for Los Angeles International Airport (LAX)

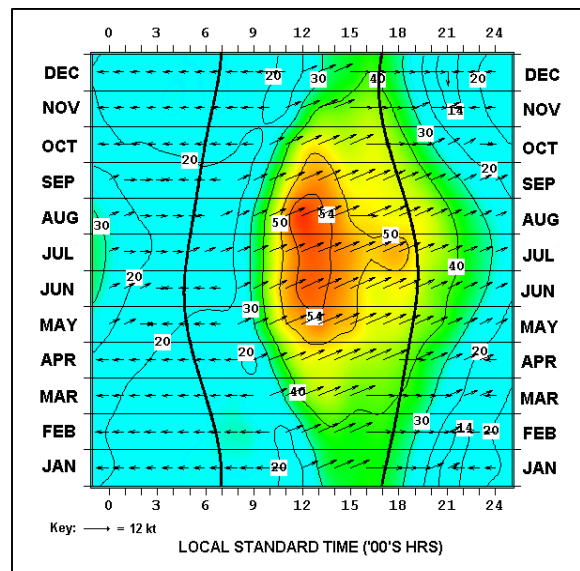


Figure 2. Prevailing Winds' Chart for Los Angeles International Airport (LAX)

The (blue) constancy minima areas reflect diurnal wind changeover periods, the offshore vectors on the nocturnal side having a northeasterly orientation at light magnitudes. Overall resultant wind statistics for LAX are: resultant direction: 252.17 degrees (WSW), resultant speed 3.18 knots, and constancy 48.69.

The LAX Prevailing Winds chart (Figure 2) also shows the prominent southwesterly seabreeze feature. A contour area covering the months June through August from about 1100 to 1300 LST indicates 54 percent or greater southwesterlies' frequencies, a very high statistic when one considers that a completely uniform around-the-compass wind climatology would have just 6.25 percent frequencies for each 16-point direction (assuming no calms).

While the offshore flow vectors in Figure 1 were exclusively northeasterly (at lower, green constancy levels, however), prevailing winds for those same hours are almost all easterly at light speeds (<5 knots).

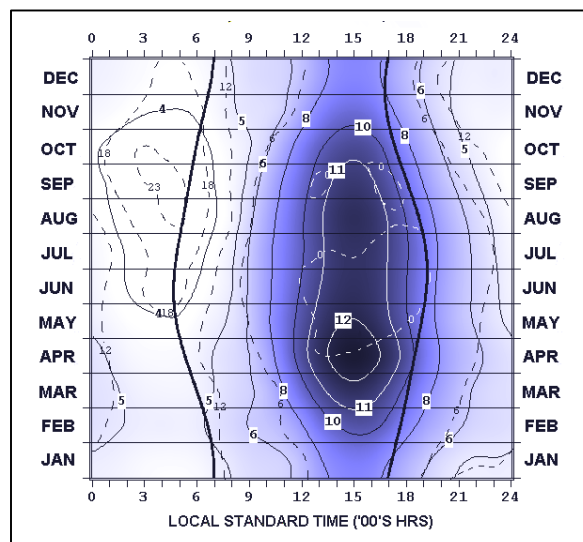


Figure 3. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Los Angeles International Airport (LAX)

The Mean Scalar Wind and Percent of Time with Calms chart (Figure 3) shows clear diurnal and seasonal variation, the highest hourly mean speeds indicated for the mid-to-late afternoon (especially April and May, covered by a 12 knot isopleth). Least average speeds (4 knots and less), are shown for the June through mid-November pre-sunrise hours. Within the 4-knot contour region is the area of greatest calms' incidence, depicted by the 23 percent dashed contour area covering a few individual hours just before sunrise in August, September, and October.

3.1.2 Long Beach FAA Airport Lat 33° 49 N; Lon: 118° 09 ; Elev: 66 ft.

Figure 4 is the Mean Vector Wind/Constancy climogram for Long Beach FAA Airport. Thanks to the local coastline orientation and adjacent topographical features, the pattern is noticeably different and more complex than LAX's.

Overall wind constancy is a reduced 34.32, the associated resultant direction 244.73 degrees (WSW), and magnitude 1.74 knots.

During the warmer months of the year (April-September), highest constancy vectors (orange/red areas), are south to south-southwesterly over the middle to late morning hours, declining in persistency to yellow or green levels in mid-afternoon as the vectors turn clockwise. By the time the vectors become mostly westerly to slightly northwesterly around sunset, a second red/orange area reappears.

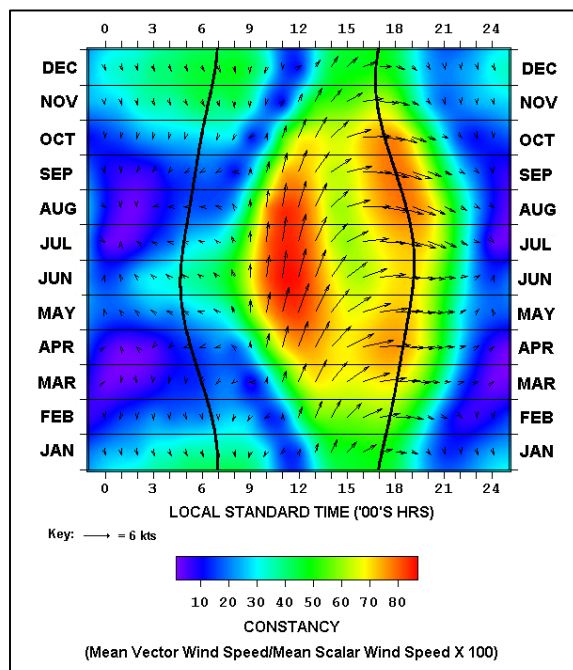


Figure 4. Mean Vector Wind/Constancy Chart for Long Beach FAA Airport

The possible cause of this curious pattern, as the prevailing winds chart (Figure 5 below) hints, is a double sea-breeze pattern – an earlier in the day local southerly flow pattern being overwhelmed later on by a more regional(?) westerly to northwesterly one.

For all the months, prevailing winds are southerly several hours after sunrise, increasing in climatological frequency until just past Noon. A 46 percent maximum frequency isopleth covers the hours 1100 and Noon LST in July. The vectors become mostly westerly by late afternoon, however, and by sunset almost exclusively northwesterly, the climatological frequencies increasing again.

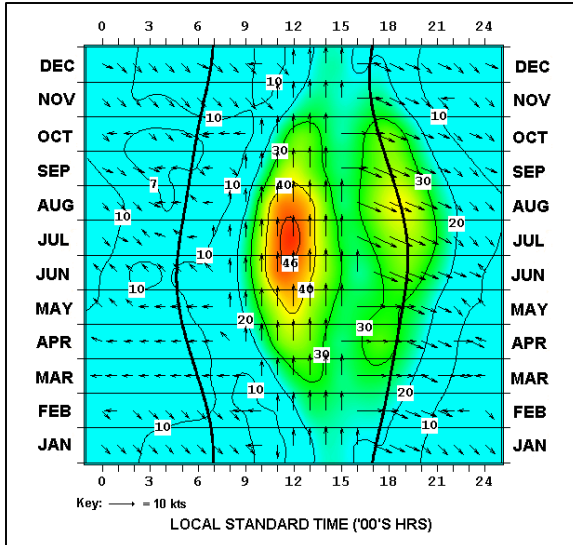


Figure 5. Prevailing Winds Chart for Long Beach FAA Airport

The gradual veering and reduced constancies seen in Figure 4 is probably indicative that the wind shift varies in time from day to day, the early afternoon hours a climatological transition period in this regard.

The Mean Scalar Wind Speed/Percent of Time with Calms chart (Figure 6) shows a late afternoon mean speeds' maximum for the spring months (10 knot isopleth), and a large area of mean speeds at or less than 3 knots covering most of the pre-sunrise hours past midnight for June through December. Incidence of calms is considerably more frequent than at LAX, especially over August to March for the pre-sunrise hours, percentages typically over 40 percent. Overall mean wind speed at Long Beach is 5.08 knots.

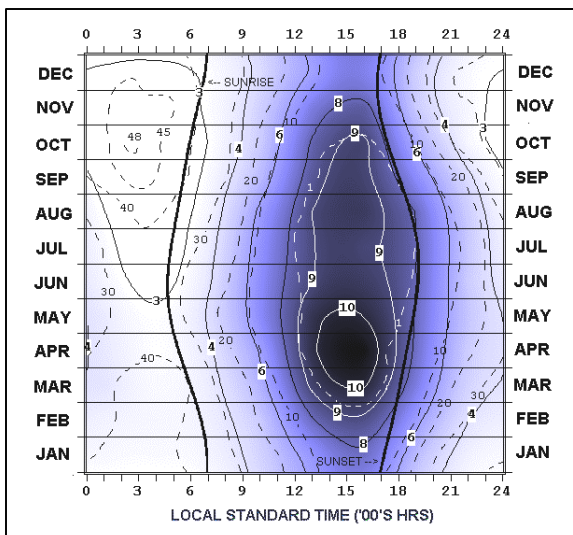


Figure 6. Mean Scalar Wind Speeds and Percent of Time with Calms Chart for Long Beach FAA Airport

3.1.3 San Diego (Lindbergh Field) Lat: 32° 44 N; Lon: 117° 11 W; Elev: 13 ft.

Figure 7 is the Mean Vector Wind/Constancy chart for San Diego Lindbergh Field. Compared to LAX, the sea-breeze vectors are more westerly, attributable no doubt to the configuration of the Pacific coastline in that part of California.

While the diurnal/seasonal constancy pattern is similar to LAX in the relative sense, the highest absolute magnitudes are seldom more than 80. Some of LAX's exceeded 90. Overall wind constancy for San Diego, however, is still 46.31, only slightly less than LAX's 48.69. Resultant direction is 274.47 degrees (W), magnitude 2.83 knots.

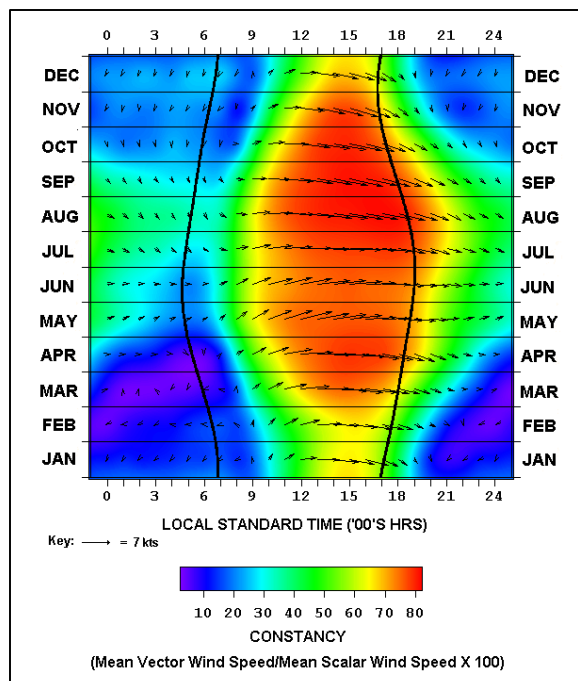


Figure 7. Mean Vector Wind/Constancy Chart for San Diego Lindbergh Field

The Prevailing Winds chart (Figure 8) shows that northwesterlies are by far the most frequently observed individual wind direction for the daylight hours (and those just after sunset), incidence percentages approaching and surpassing 40% for late afternoons during August and September. Nocturnal prevailing winds are mostly light and northerly at incidence percentages typically between 10 to 16 %.

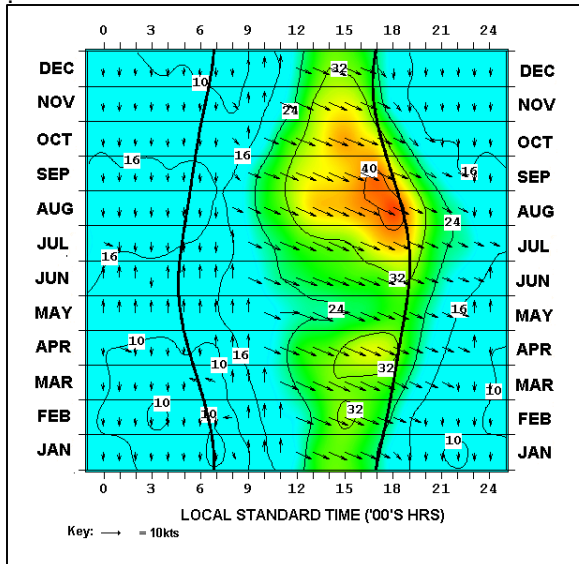


Figure 8. Prevailing Winds Chart for San Diego Lindbergh Field

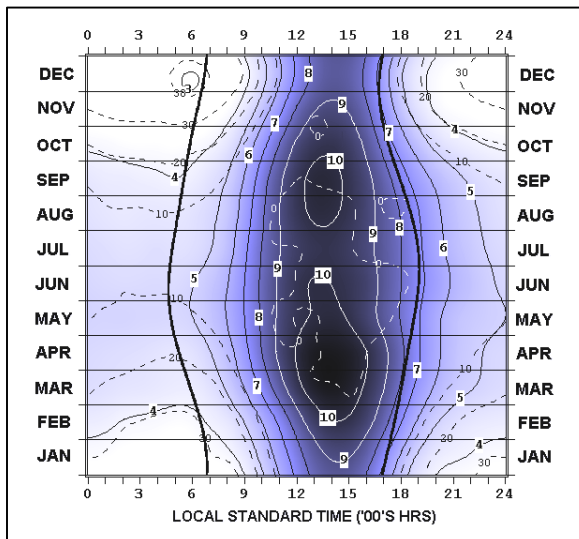


Figure 9. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for San Diego Lindbergh Field

The Mean Scalar Winds/Percent of Time with Calms chart (Figure 9) shows a somewhat different pattern than LAX and Long Beach with two areas of relative maximum mean wind speeds (March-June and August-September), centered a bit earlier in the afternoon. Highest nearest knot contour magnitude is 10 knots. Lowest mean speed isopleth, 3 knots, appears over a small area just before sunrise in December, this also co-located over the isoline area with the most frequent calms: 38 percent. Overall San Diego mean scalar wind speed is 6.11 knots, about 6% less than LAX's figure.

3.1.4 Point Mugu Naval Base (near Oxnard) - Lat: 34° 07' N; Lon: 119° 07' W; Elev: 13 ft.

Point Mugu is a Naval Base situated on the southeastern edge of the Oxnard Plain in Ventura County, adjacent to the Santa Monica Mountains' western terminus.

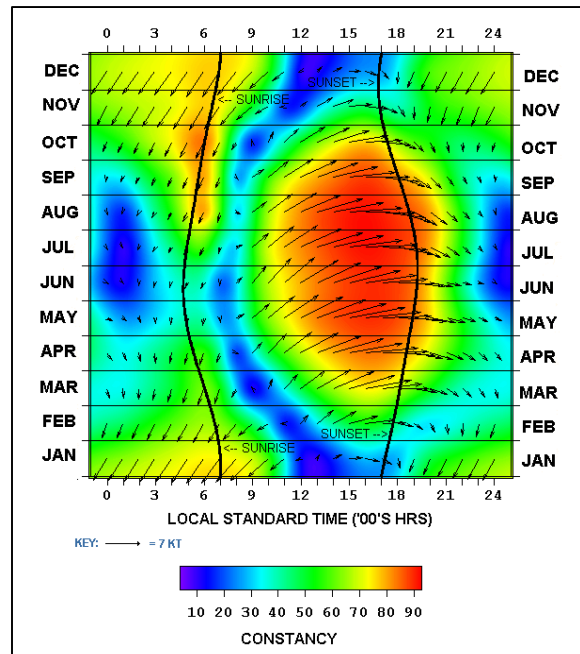


Figure 10. Mean Vector Wind/Constancy Chart for Point Mugu Naval Base, CA.

From Figure 10, the most prominent mean vector feature is the area of relatively high magnitude/high constancy southwesterly to westerly onshore vectors for the mid-morning to late afternoon hours of spring to fall. Not unlike Long Beach, a clockwise turning from morning to afternoon is exhibited, again likely reflecting an initial, southerly component onshore flow pattern that transitions to a more regionally-influenced westerly one as the day progresses.

Another feature is the relatively persistent (yellow/orange areas) and prominent northeasterly vectors for the pre-sunrise hours in November through January, an expression of Santa Ana episodes. Thanks to local topographical channeling, Santa Ana wind flow is frequently enhanced at Point Mugu and the surrounding vicinity. Three miles to the east of Point Mugu, an automatic weather station atop 1450-foot high Laguna Peak has recorded peak wind gusts approaching 100 knots during some exceptionally strong Santa Anas.

The blue constancy minima reflect hourly periods with light and variable wind character (May to September post-midnight hours), or transition hours between

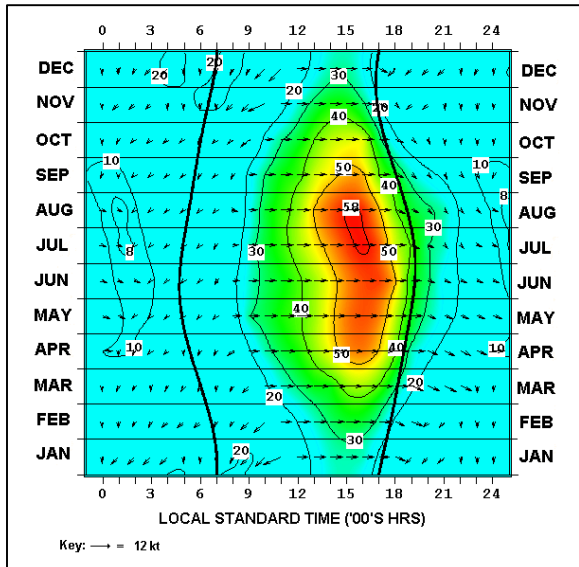


Figure 11. Prevailing Winds' Chart for Point Mugu Naval Base

offshore (onshore) and onshore (offshore) flow (ringed areas).

Point Mugu's Mean Vector Wind constancy (30.24) is 10% lower than Long Beach's, its resultant wind direction 288.50 degrees (WNN), and speed 1.77 knots.

From Figure 11, the most prominent prevailing winds at Pt. Mugu are westerlies, a peak incidence (58 percent) contour indicated for the late afternoons in July and August.

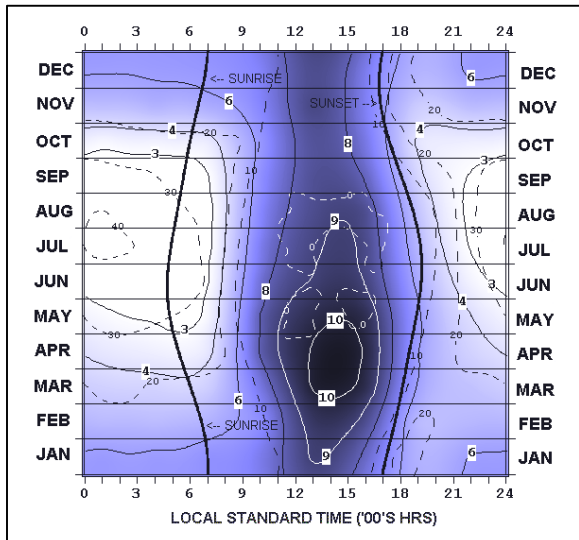


Figure 12. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Point Mugu

Most of the pre-sunrise vectors are light northeasterly, the post-sunset ones prior to midnight, light northwesterly. Noticeable also are some high magnitude northeasterlies positioned for a few late

morning hours in the months November to February, reflecting Santa Anas' relative predominance at those times.

The Mean Scalar Wind Speeds/Percent of Times with Calms chart (Figure 12) shows a March-April late afternoon maximum (10 knot isopleth), and a broad area of 3 knot or less minima covering most nocturnal hours from May through September. Overall mean wind speed at Pt. Mugu is 5.84 knots.

A peak incidence of calms (40 percent isopleth) is shown for the hours just after midnight in July and part of August.

3.1.5 Santa Barbara Municipal Airport Lat : 34° 26 N; Lon: 119° 50 W; Elev. 13 ft.

Figure 13 shows the Mean Vector Wind/Constancy chart for Santa Barbara Municipal Airport. Situated on a comparatively atypical (for the U.S. West coast) south-facing coastline which extends for many miles, the station's mean vector winds exhibit a strong southerly daytime component for all months of the year: almost straight southerly during the mid-morning to more southwesterly in the afternoons. The red/orange constancy maxima areas are not as broad in coverage as LAX and San Diego, and do not extend as late into the day. Nocturnal vectors are very light, mostly northeasterly to easterly. Overall vector wind constancy for Santa Barbara is even less than that for Point Mugu at 24.26, associated with a resultant direction 203.91 degrees (SSW) and speed 1.17 knots.

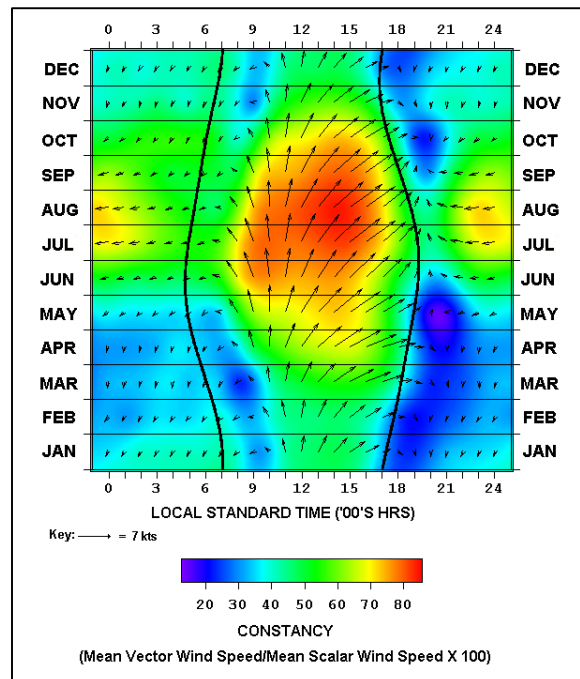


Figure 13. Mean Vector Wind/Constancy Chart for Santa Barbara Municipal Airport

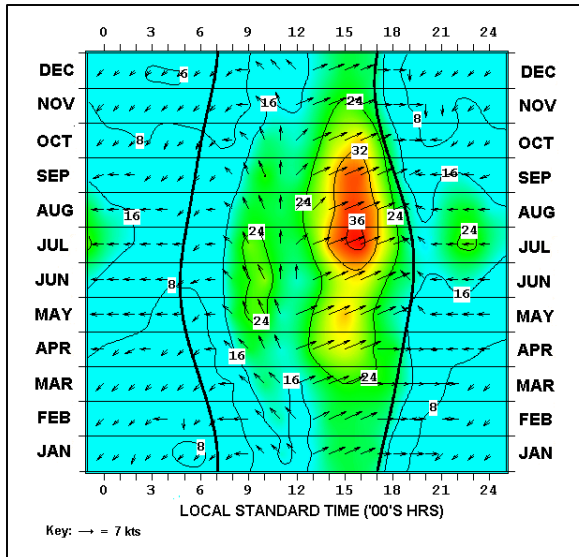


Figure 14. Prevailing Winds' Chart for Santa Barbara Municipal Airport

The Prevailing Winds' chart (Figure 14) shows that from the early morning daylight hours on, the directions are mostly southeasterly, southerly, and then, after mid-day for all months of the year, decidedly southwesterly. A 36 percent maximum incidence contour overlays the southwesterly prevailing wind vector at 1500 LST for July. Nocturnal vectors are either northeasterly or easterly, at light speeds.

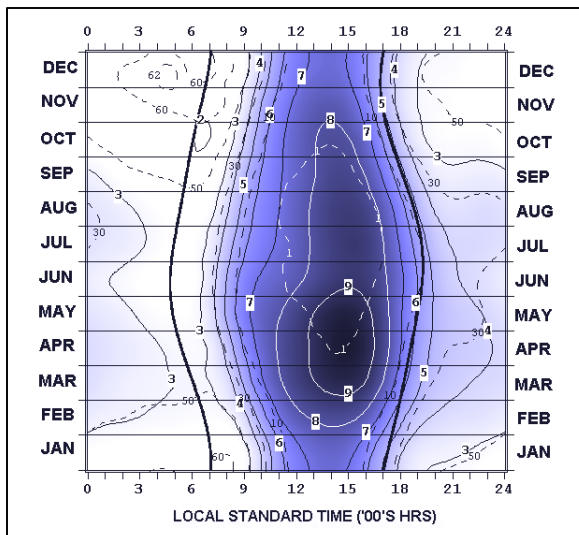


Figure 15. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Santa Barbara

From the Mean Scalar Wind Speeds/ Percent of Time with Calms chart (Figure 15), there is the familiar late afternoon Spring maximum isopleth, indicated for LAX and Long Beach also, but at a lower magnitude for

Santa Barbara (9 knots). Overall mean scalar speed for the station is 4.84 knots, a bit less than Long Beach's.

Santa Barbara's maximum incidence of calms is much higher than those of the other four South Coast stations, climatological percentages exceeding 60 percent for the pre-sunrise hours in November and December.

3.2 - South Interior Stations

Three stations from the "South Interior" region are analyzed for their wind variability: Burbank (Bob Hope) Airport, Ontario International Airport, and March Air Force Base (Riverside)

3.2.1 - Burbank (Bob Hope Airport Lat: 34° 12'; Lon: 118° 21'; Elev: 778 ft.

Burbank (Bob Hope) Airport, at the southeast end of the San Fernando Valley, shows a very high frequency of south-southeasterly resultants (Figure 16), a likely result of the Los Angeles Basin onshore flow being deflected, redirected, and channeled between the Santa Monica and Verdugo Mountains, and an induced circulation of the Valley itself. From May to September, mean vector winds are oriented in this direction for virtually all hours of the day, the remainder of the months October to April showing exclusively south-southeasterlies from around 11AM to sunset. The orange to red (high) constancy area encompasses the May to September south-southeasterlies from a few hours after sunrise all the way in some cases past midnight (July and August).

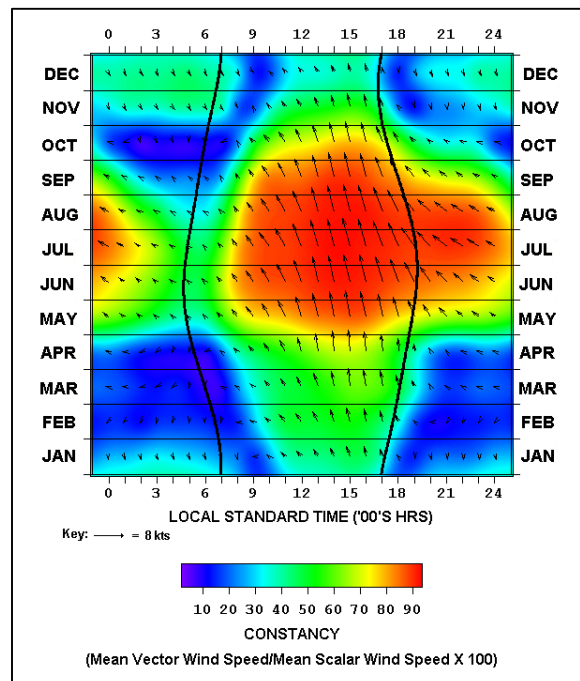


Figure 16. Mean Vector Wind/Constancy Chart for Burbank (Bob Hope) Airport.

Overall Burbank wind constancy is 49.67, slightly higher than LAX's, and associated with a resultant direction of 152.36 degrees (SSE) and magnitude 2.34 knots.

The Prevailing Winds chart (Figure 17) indicates that primary individual wind directions during the high persistency periods are southerly, with some very high frequencies (exceeding 50 percent) for the mid-afternoons, especially in July and August.

The Mean Scalar Wind Speed/Percent of Time with Calms chart (Figure 18) shows a relatively broad area of maximum mean speeds (8 knot contour), essentially encompassing the afternoon hours up to about an hour before sunset.

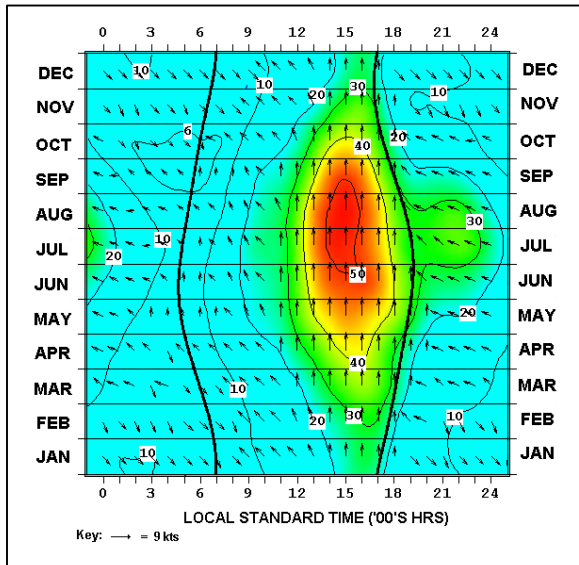


Figure 17. Prevailing Winds' Chart for Burbank Airport

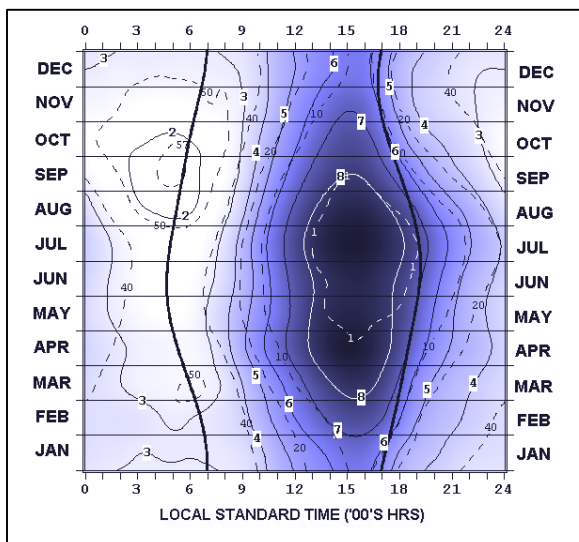


Figure 18. Mean Scalar Wind Speeds and Percent of Times with Calms Chart for Burbank (Bob Hope) Airport

Mean speeds in the pre-sunset hours over August to October are very light (2 knots and below), and a 57 percent calms' contour covers the immediate pre-sunrise hours over September and October.

Overall mean scalar wind speed for Burbank is 4.70 knots, slightly less than that for Santa Barbara.

3.2.2 Ontario International Airport Lat: 34° 03'; Lon: 117° 37'; Elev: 944 ft.

Ontario International Airport, located about 35 miles east of downtown Los Angeles and even farther from the Pacific Coast, nonetheless has a surrounding topography that is still open to the coast. Consequently, its Mean Vector Wind chart (Figure 19) and summary related statistics are quite comparable to LAX's. Overall constancy for Ontario is 53.22, resultant direction 258.22 degrees (W) and resultant speed 3.16 knots.

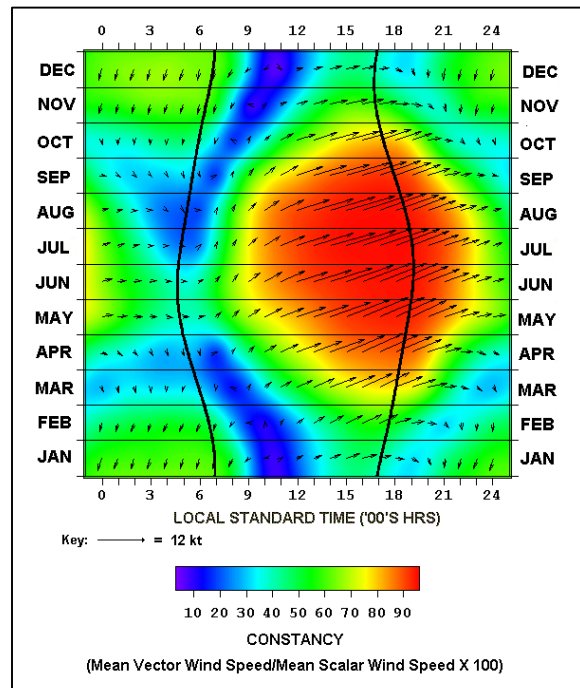


Figure 19. Mean Vector Wind/Constancy Chart for Ontario International Airport, CA.

The prevailing winds' chart (figure 20) also resembles LAX's, although the region of maximum percentages for Ontario is lagged into the hours just before sunset in April to August – 48 percent incidence percentages shown for the prevailing northwesterlies at those hours.

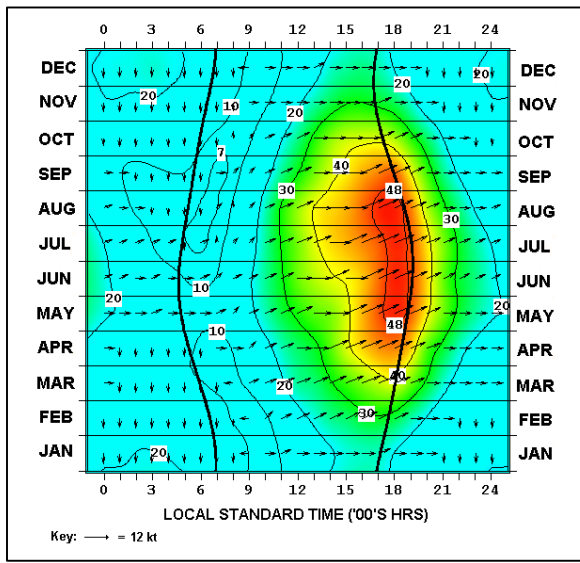


Figure 20. Prevailing Winds Chart for Ontario International Airport, CA.

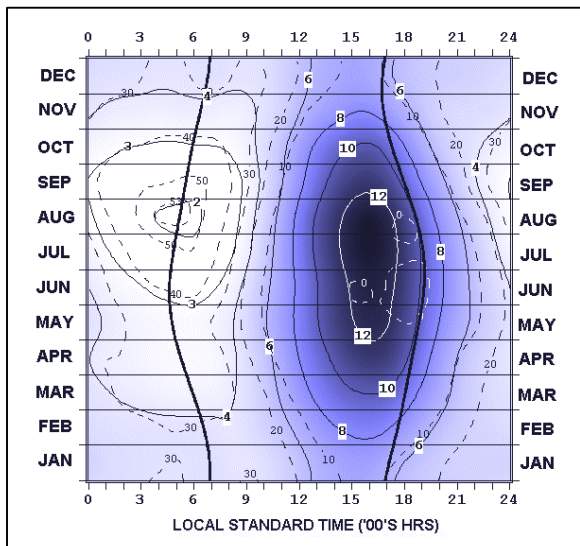


Figure 21. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Ontario International Airport, CA.

Maximum mean scalar wind speeds (Figure 21) for Ontario (12 knot isopleth) are seen for July and August in the late afternoons. Minimum contour (2 knots) is positioned in the early morning hours for August, not coincidentally corresponding to the area of maximum percent calms' incidence (53 percent contour). Overall mean wind speed for Ontario is 5.94 knots, about 10 percent less than that for LAX

3.2.3 March Air Force Base (near Riverside) Lat: 33° 53'; Lon: 117° 16'; Elev: 1538 ft.

Moving to the extreme eastern end of the "Inland Empire", March Air Force Base (Riverside)'s wind variability is examined. This station's hourly record extends back to 1933, the longest of any of the stations considered - some of the individual hours have more than 2000 observations. The station is nearly surrounded to the north and east by the San Gabriel and San Bernardino Mountains, but its topography is still relatively open to flow from the west.

Thus, the resultant constancy pattern (Figure 22) is little different from LAX's and Ontario's, although orientation of the principal high constancy mean vectors is northwesterly. Overall constancy is 47.01, resultant direction 311.33 degrees (NW), and resultant speed 1.98 knots.

The Prevailing Winds chart (Figure 23) indicates that the highest frequencies are also for northwesterlies, absolute maximum percentages approaching or exceeding 45 percent for the immediate pre-sunset hours in July and August.

The Mean Scalar Wind Speeds/Percent of Time with Calms chart (Figure 24) is very similar to Ontario's in pattern, if not magnitudes. Maximum mean speed contour (11 knots and above), a bit lower than Ontario's, covers the late afternoon hours for July and August,

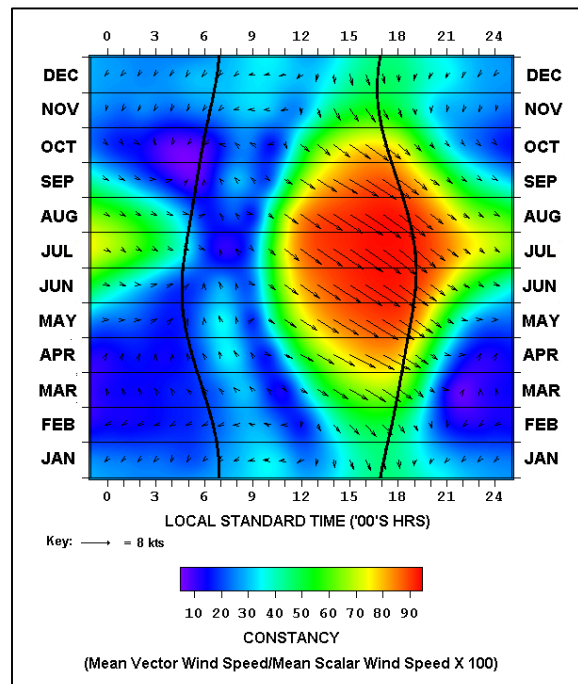


Figure 22. Mean Vector Wind/Constancy Chart for March AFB (Riverside), CA.

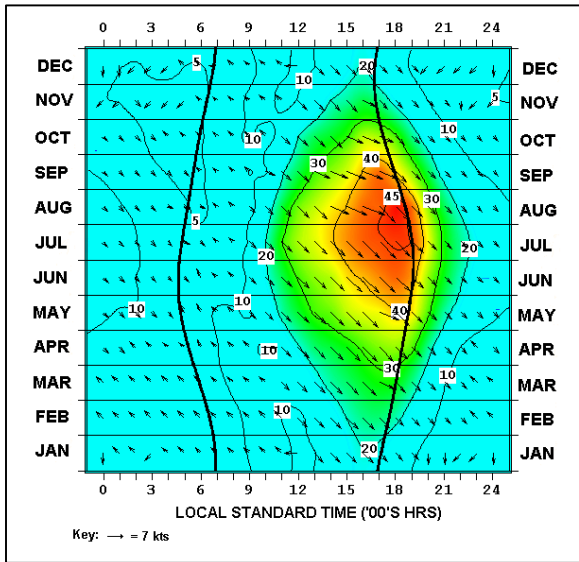


Figure 23. Prevailing winds Chart for March AFB (Riverside), CA.

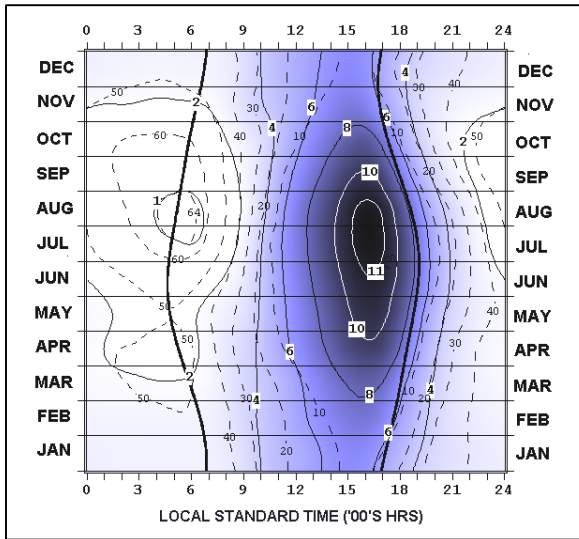


Figure 24. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for March AFB (Riverside), CA.

the minimum isopleth (just 1 knot), positioned almost in the same area as Ontario's 2 knot minimum – in August around sunrise. Again, not coincidentally, this small area is co-located in the area of maximum incidence of calms, in the case of March AFB, 64 percent.

Mean overall wind speed for March AFB is 4.22 knots, the least of any of the sixteen stations considered in this study.

3.3 - Sonoran Stations

3.3.1 - Palm Springs Regional Airport - Lat: 33° 49 N; Lon: 116° 30 W, Elev: 443 ft.

Palm Springs, about 110 miles east of Los Angeles, is located in the upper (above sea-level) portion of the Coachella valley, just southeast of the San Gorgonio Pass. The pass is well-known for its channeling and intensifying of the prevailing westerly windflow that passes through - hundreds of large wind generators are planted in the area taking advantage of this rich power source.

In full-fledged desert country, Palm Springs' mean vector wind patterns assume a different character from those on the coastward side of the San Jacinto Mountains. From Figure 25, most of the mean vectors are northwesterly, and higher in magnitude at night. Also, except for mid-summer, constancy values are usually at their lowest in the mid-afternoon, in direct contrast to the coastward stations.

A major exception to this is the semi-circular, embedded constancy feature covering most of the late-morning to near sunset hours for mid-May to mid-October. Here, constancy values are moderate to high (green to orange-red), accompanied by southeasterly mean vectors, this likely reflecting summertime monsoon influences from the Gulf of California.

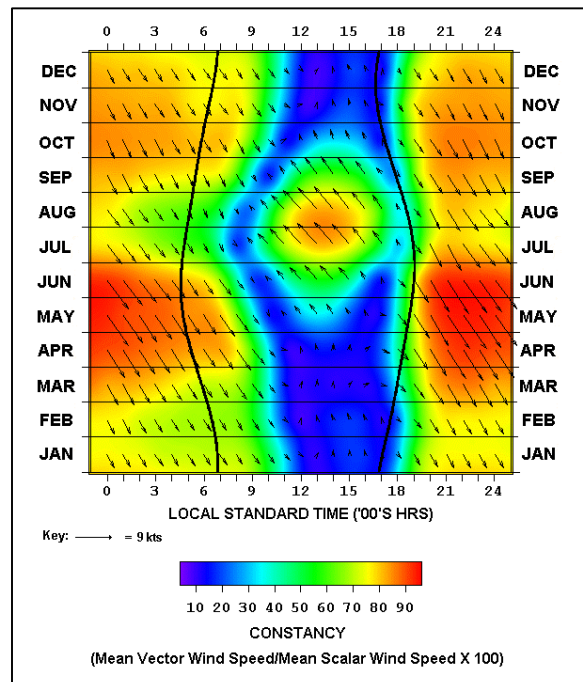


Figure 25. Mean Vector Wind/Constancy Chart for Palm Springs Regional Airport, CA.

Overall wind constancy for Palm Springs is 34.97, associated with a resultant direction of 326.61 degrees (NNW) and speed 2.08 knots.

Maximum prevailing wind incidence (Figure 26) is indicated by the 40 percent isopleth covering June at 2000 and 2100 LST, and May at 2100 LST (all northwesterlies). Daytime prevailing winds are, especially from the late morning on, lighter and mostly southeasterly. The low (blue) constancy values that were shown in Figure 25 for most of those hours probably reflects a vectorial “tug-of-war” between the northwesterlies and southeasterlies, neither predominant enough at those times to produce a clear resultant signal.

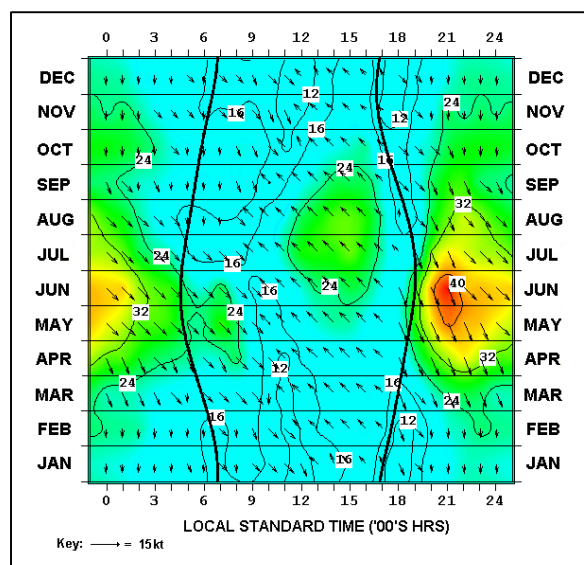


Figure 26. Prevailing winds Chart for Palm Springs Regional Airport, CA.

The Mean Scalar Wind Speed/Percent of Time with Calms chart (Figure 27) reveals a somewhat more complex pattern of isohyets than was shown for the coastward stations. A Spring late-afternoon relative maximum of mean speeds is evident (8 knot contour), not a dissimilar feature compared to the others, but an even higher 9 knot contour is also positioned for the late evening hours over May and June. Lowest mean speeds, as delineated by the 4-knot contour, frequently surround the near sunrise hours in summer, fall, and winter, along with the sunset hours in winter. Overall mean wind speed at Palm Springs is 5.92 knots.

Greatest incidence of calms (32 percent isopleth) has a double positioning: for the hours just after sunrise in July and August, and those just after sunset in December.

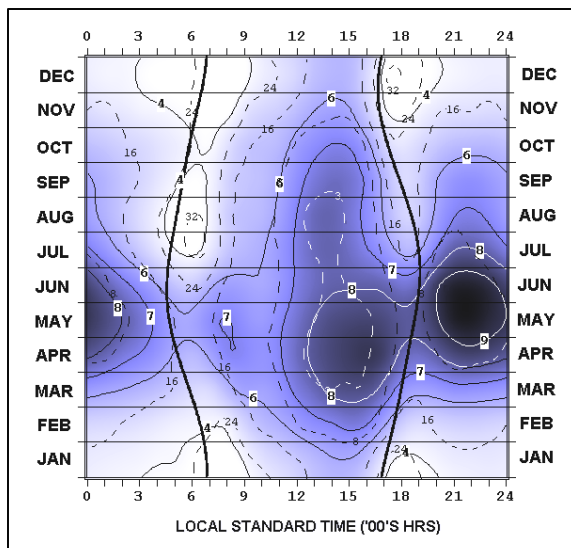


Figure 27. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Palm Springs Regional Airport, CA.

3.3.2 - Blythe Municipal Airport Lat: 33° 37' N; Lon: 114° 43' W; Elev: 397 ft.

Blythe Municipal Airport is located in the California-Arizona border region in the more southern portion of the Colorado Valley.

From the Mean Vector Wind/Constancy chart in Figure 28, the outstanding feature is the high constancy southerly-oriented vectors for the high-sun months of May to September, covering most hours of the day. The only exception to this are a few hours either side of sunrise shaded in green. The low-constancy blue areas, positioned quasi-horizontally, delineate seasonal transition periods, the vectors on colder-season sides being mostly northwesterly. This distribution of essentially opposite-oriented vectors results in a low overall constancy figure for Blythe: 26.70. On balance, though, the southerlies “win out”, and an overall 215.55 degree (SW) resultant direction and speed 1.82 knots is expressed.

The Prevailing Winds chart (Figure 29) further depicts this essentially northerly versus southerly wind pattern. For the months March to October, the vectors are predominantly southerly, northerly from November to February, at lower frequencies, however. A broad green area of 27 percent plus frequencies is indicated for the summer months, likely reflecting the monsoonal circulation, and an absolute maximum 43 percent isopleth is positioned over 0100 LST for July.

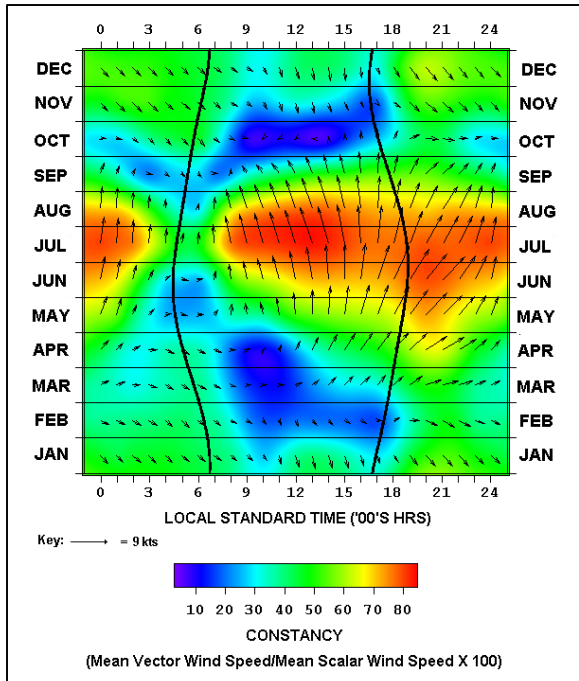


Figure 28 - Mean Vector Wind/Constancy Chart for Blythe Airport, CA.

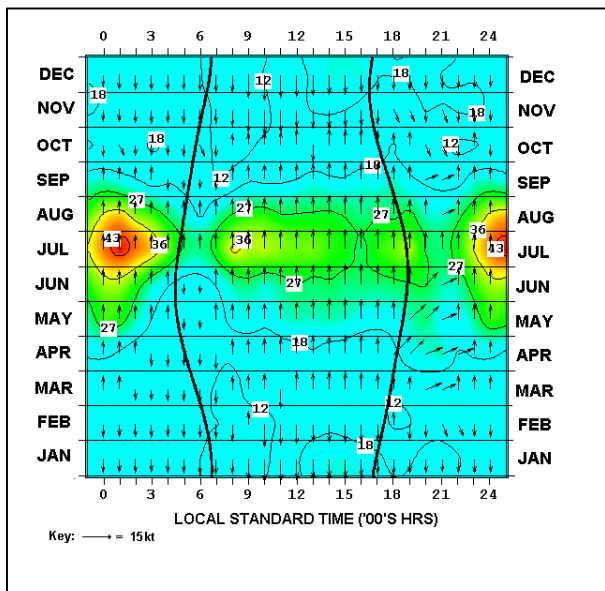


Figure 29. Prevailing Winds' Chart for Blythe Airport, CA.

The Mean Scalar Wind Speeds/Percent of Time with Calms chart (Figure 30) shows a maximum mean speed isopleth (11 knots) for the late afternoon hours in May and June, the minimum speeds' areas (5 knot contours) located, not unlike that for Palm Springs – for the near

sunrise hours. Overall mean scalar wind at Blythe is 6.82 knots, more than 15 % higher than that at Palm Springs.

Maximum calms' incidence at Blythe is depicted by a narrow, elongated 30 percent contour area covering the just-after-sunrise hours from October to March.

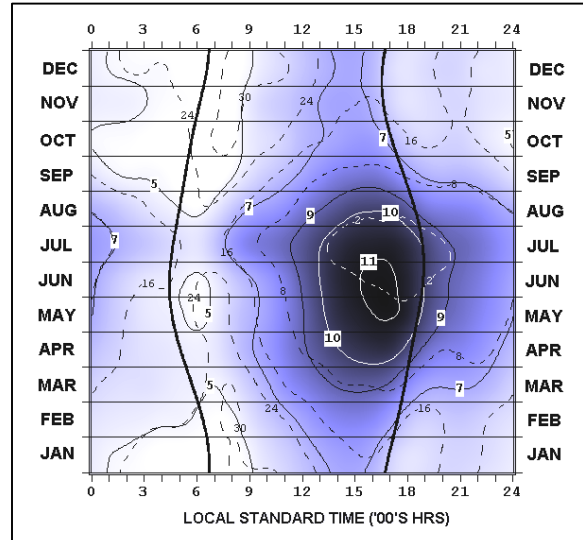


Figure 30. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Blythe Airport, CA.

3.4 - Central Coast Stations

Moving back to the Pacific Coast and farther north just into the lower southern portion of the "Central Coast" region, Pt. Arguello's wind variability is analyzed.

3.1.4 Pt. Arguello (Station PTGC1) Lat: 34° 35' N; Lon: 120° 39' W; Elev: 106 ft.

Pt. Arguello is selected for its unusually highly persistence wind regime, especially in summer. Due to headland topographical forcing, winds are persistent and strongly northerly, parallel to the coast or "side-shore". Figure 31 shows the Mean Vector Wind climogram for Pt. Arguello. A strong northerly vector orientation is noted for virtually all hours of the year. Resultant wind for 2000 LST in August is 359.443 degrees at 19.029 knots, compared to a mean scalar speed for that hour of 19.292 knots. This yields a 98.64 constancy figure, the highest of any of the more than 4600 individual hourly resultants generated for the sixteen stations in this study. This, however, is not a particularly excessive constancy statistic by Arguello standards - eight others for the July and August early evening hours exceed 98! Overall wind constancy for Pt. Arguello is 79.89, associated with a resultant direction of 354.27 degrees (N) and speed 11.10 knots.

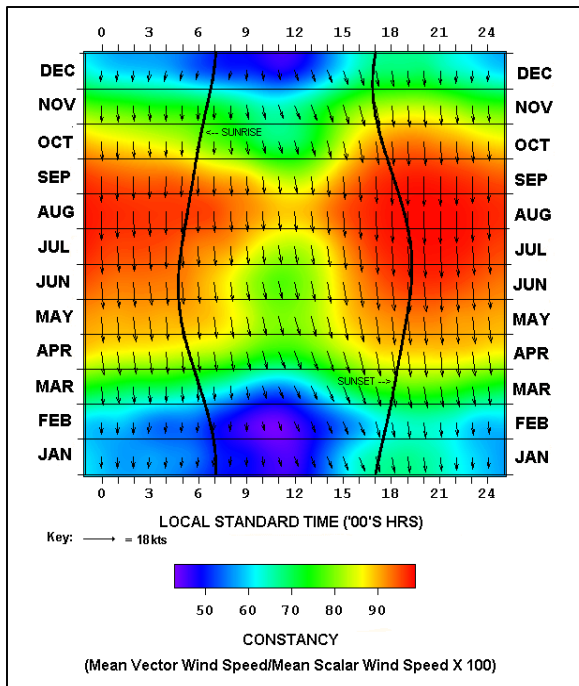


Figure 31 - Mean Vector Wind/Constancy Chart for Pt. Arguello, CA.

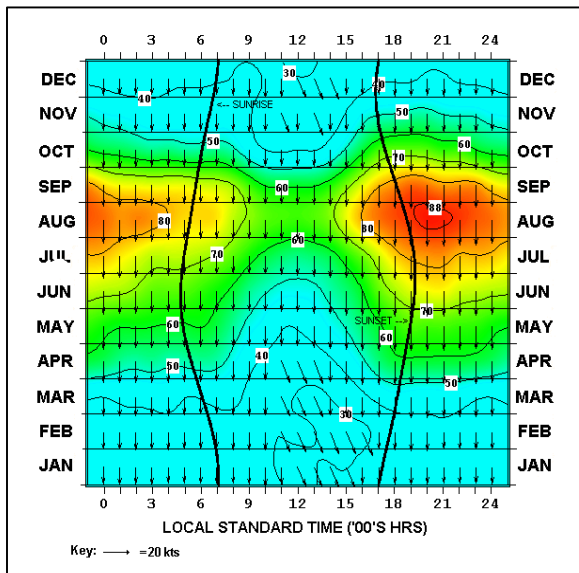


Figure 32. Prevailing Winds Chart for Pt. Arguello, CA.

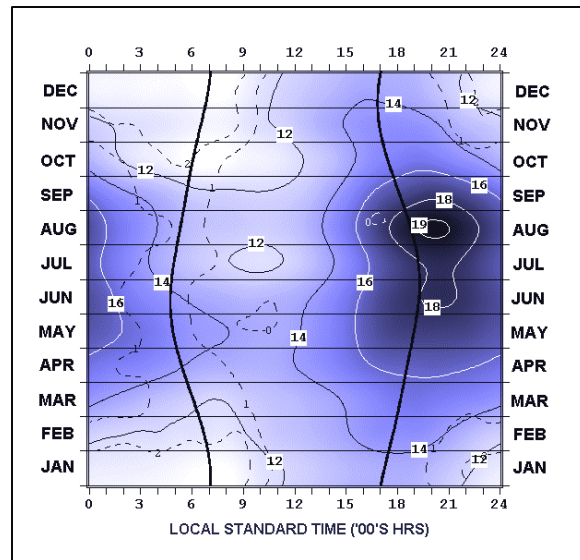


Figure 33 Mean Scalar Wind Speed/Percent of Time with Calms' Chart for Pt. Arguello, CA.

The Prevailing Winds' chart (Figure 32) shows similar orientations, all but a very few of the directions northerly, incidence percentages approaching 90 percent for the early evenings in August. The Mean Scalar Wind Speeds/Percent of Time with Calms chart (Figure 33) shows consistently high winds - overall mean speed is 13.89 knots, the individual averages approaching 20 knots for the June-August hours just after sunset. Lowest individual hourly mean is 10.2 knots, for 0700 LST in October

Not surprisingly, Calms' incidence is almost nil, greatest climatological incidence between 2 and 3 percent, confined mostly to the nocturnal periods in the winter months.

3.5 – Mohave Stations

Five stations' wind variabilities are analyzed from the Mohave region: Sandberg, Palmdale, Lancaster, Victorville (George AFB), and Daggett.

3.5.1 - Sandberg Lat: 34° 45 N; Lon: 120° 42 W; Elev: 4524 ft.

Sandberg, located on a ridgeline that separates the Mojave Desert from the more urbanized areas to the south such as the Santa Clarita, Castaic, and San Fernando Valleys, affords an opportunity to examine wind variability character at a station of high elevation.

Inspection of its mean vector wind chart (Figure 34) shows a mix of mostly northeasterly, northwesterly, and southerly-oriented resultants, the latter showing up with appreciable magnitudes only in July and August for the late-morning to just-before-sunset hours. For the other months on the chart, resultant flow is predominately northeasterly (offshore) in November through February, day and night; and northwesterly (onshore) for March through October, typically from around sunset through

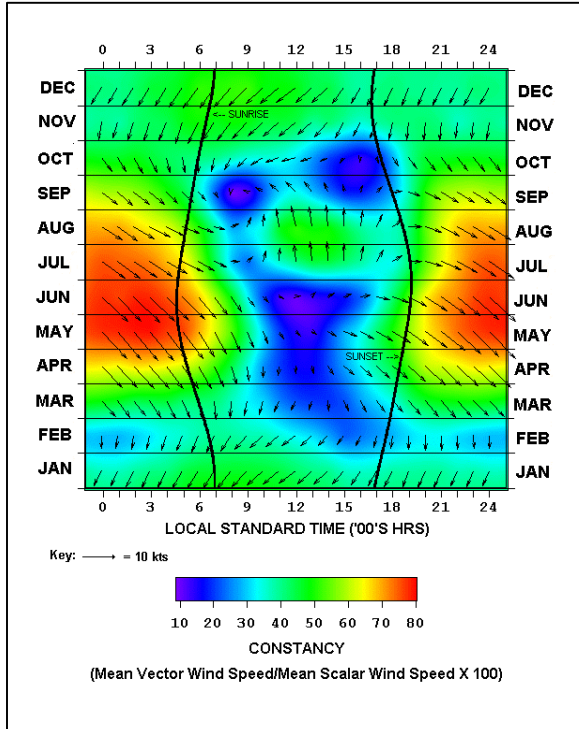


Figure 34. Mean Vector Wind/Constancy Chart for Sandberg, CA..

the following early morning hours. The orange to red (highest) constancy shadings are associated with nocturnal northwesterlies that are expressed during May through August. Overall resultant wind at Sandberg is 343.96 degrees (NNW) at speed 3.23 knots, the constancy figure 26.37, about equally low as Blythe's.

The prevailing winds chart (Figure 35) resembles the mean vector wind chart to a large degree. Among its more noticeable features are the predominant southerlies for June through September mid-morning to late-afternoon hours, the northeasterlies for most hours during the colder months of the year November to February, and the northwesterlies for most of the other hours, especially so for the orange/red areas in May and June. Climatological frequencies for the latter approach 35 percent in these cases.

Thanks to its high altitude and exposed location, mean wind speeds at Sandberg are relatively high for virtually all the hours of the year (Figure 36), the overall average 12.25 knots. The 14-knot maximum mean speed contour covers February, March, and a portion of April for most of the late-morning to mid-afternoon hours, and December from 0500 to 1500 LST in addition to 1700 and 1800 LST.

Percent of Time with Calms is seldom more than 1 percent, the isopleth situated essentially over most of the post-sunset/pre-sunrise hours for September and October.

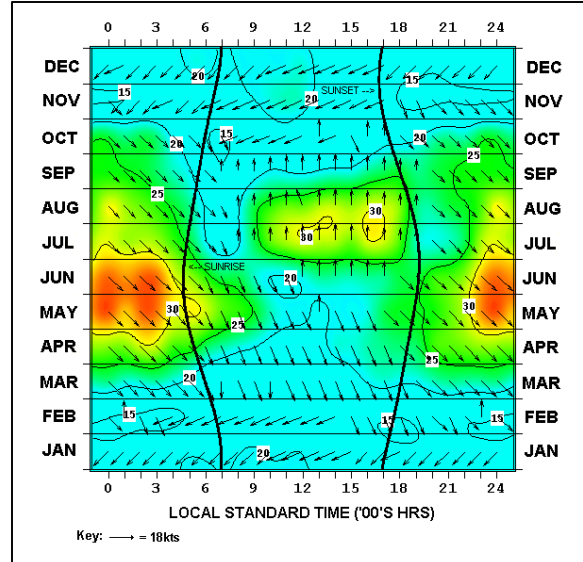


Figure 35. Prevailing Winds Chart for Sandberg, CA.

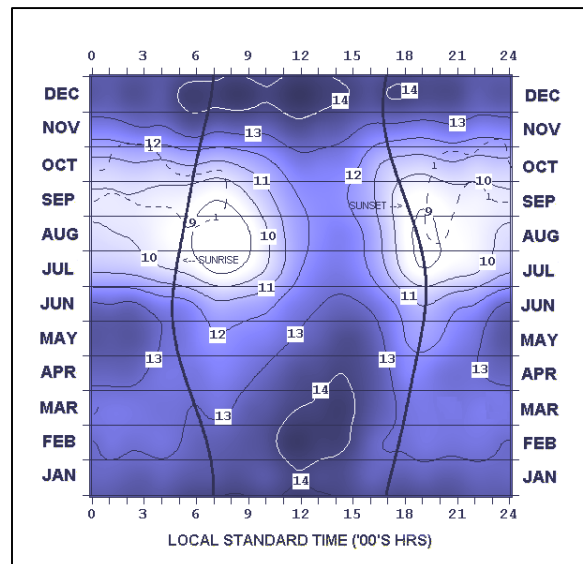


Figure 36. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Sandberg, CA.

3.5.2 - Palmdale Regional Airport Lat: 34° 38 N; Lon: 118° 06 W; Elev: 2543 ft.

Palmdale is located at the west edge of the Mojave Desert just east of Soledad Pass, the adjacent ridgeline trending in a southeasterly direction. Most of its resultants (Figure 37) are oriented southwesterly, at varying constancies and magnitudes, however. The most prominent southwesterlies are exhibited for May to August over the early afternoon hours to about 2100 LST, but thereafter they back slightly, reaching an almost southerly orientation at lower magnitudes by

sunrise. Lowest or “bluest” constancy shadings show up for the colder months of the year, particularly October-February for the late-morning hours to sunset.

Overall resultant wind at Palmdale is 242.55 degrees (WSW) at magnitude speed 5.01 knots. Constancy is 62.10, second highest thus far (to Pt. Arguello).

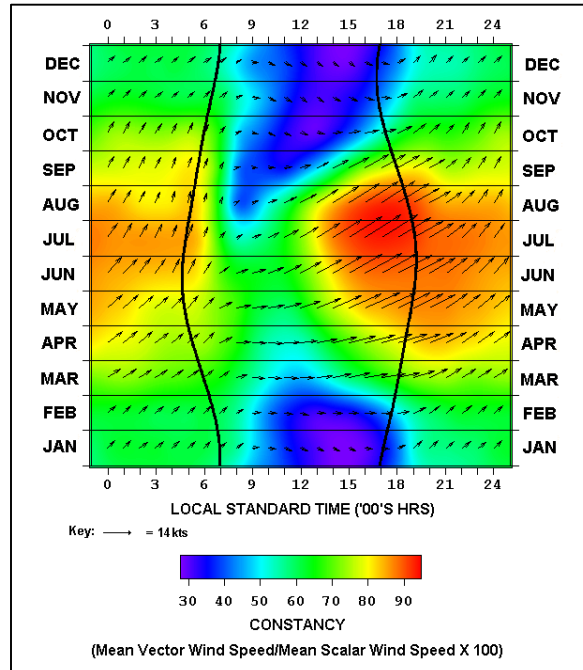


Figure 37. Mean Vector Wind/Constancy Chart for Palmdale, CA..

The prevailing winds chart (Figure 38) shows two main features, an orange-red area of late afternoon to early afternoon high magnitude (~ 15 knots) south-westerlies, covering June to August, and a post-midnight area of relatively frequent but lighter magnitude southerlies (green shadings) encompassing roughly March-October. A 42 percent maximum frequency isopleth is positioned over July and August for the late-afternoon hours' southwesterlies.

A trademark of the Southern California High Desert stations, Palmdale mean wind speeds can reach quite high levels (Figure 39), indicated by the 17 knot contour positioned over mid-May to July for the hours 1500 to 1700 LST. A 4-knot contour area, however, is also located over the hours 0800 to 0900 LST in August and September. Overall mean speed at Palmdale is 9.09 knots.

Incidence of Calms is 40 Percent for around 0800 LST in September.

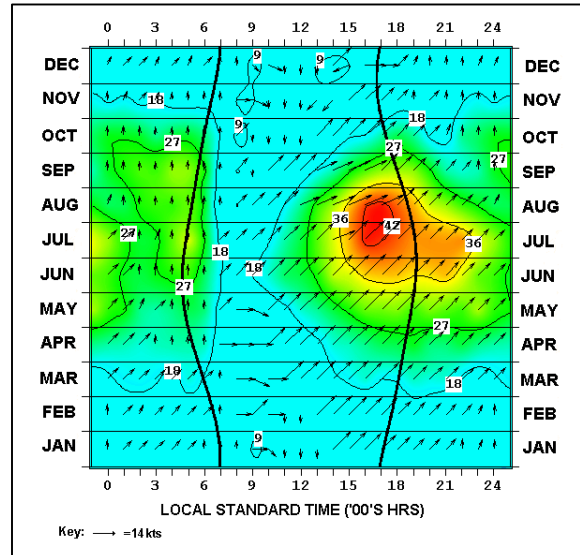


Figure 38. Prevailing Winds Chart for Palmdale, CA.

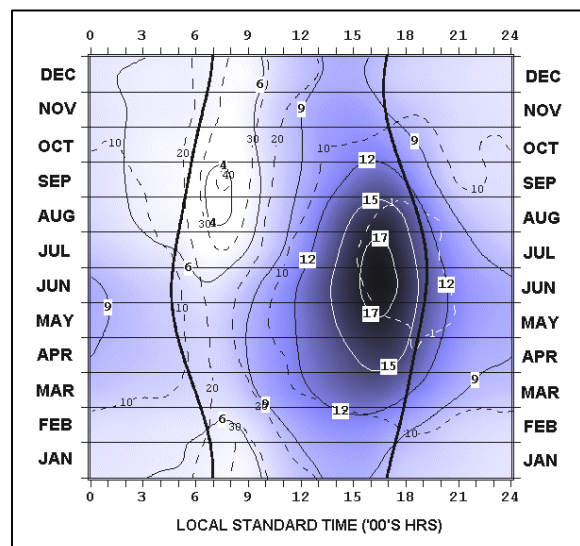


Figure 39. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Palmdale, CA.

3.5.3 - Lancaster (Fox Field) Lat: 34° 41' N; Lon: 118° 10' W; Elev: 2351 ft

Another large High Desert community, Lancaster is located just 10 miles northwest of Palmdale.

Despite the proximity, its mean vector wind chart has some noticeable differences, including generally higher constancies than Palmdale. Also, the warm season vectors are more consistently southwesterly and the cold season ones more westerly. There is a similar, but less extensive positioning of the blue constancy minima – in the case of Lancaster, mostly for the October through February afternoon hours.

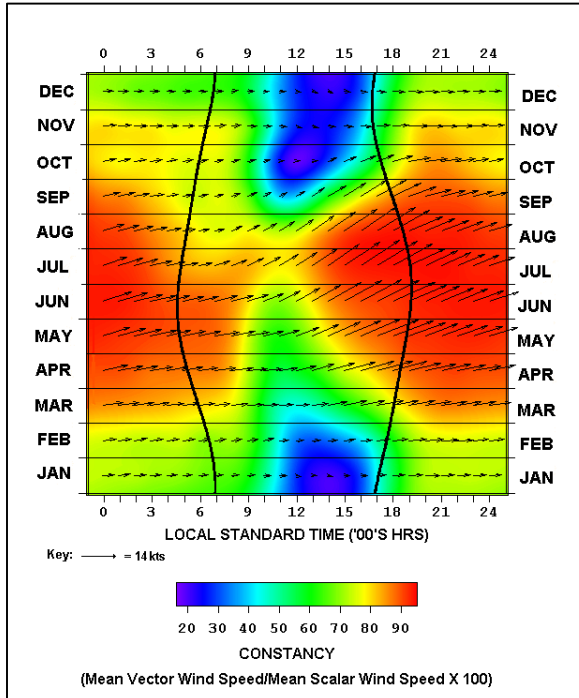


Figure 40. Mean Vector Wind/Constancy Chart for Lancaster (Fox Field), CA..

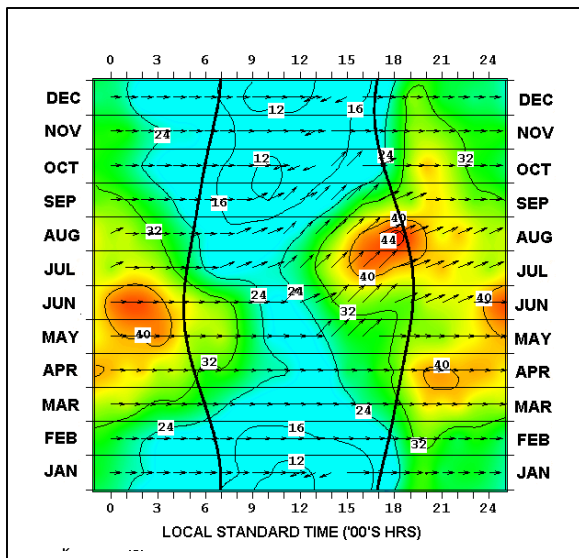


Figure 41. Prevailing Winds' Chart for Lancaster (Fox Field), CA.

Overall vector wind constancy at Lancaster is 73.75 (second only to Pt. Arguello in this regard) and associated with a resultant direction 254.10 degrees (WSW) at 7.26 knots.

The Lancaster Prevailing winds' chart (Figure 41), indicates generally higher percent frequency magnitudes than at Palmdale. There are many more hours

with prevailing westerlies. A 40 percent isopleth covering the first few post-midnight hours in May and June is indicated – no comparable feature is seen on the Palmdale chart, but the 44 percent absolute maximum Lancaster contour, however, positioned just prior to sunset in August (southwesterly prevailing winds at that time) is not much different from Palmdale's 42 percent maximum isopleth placement.

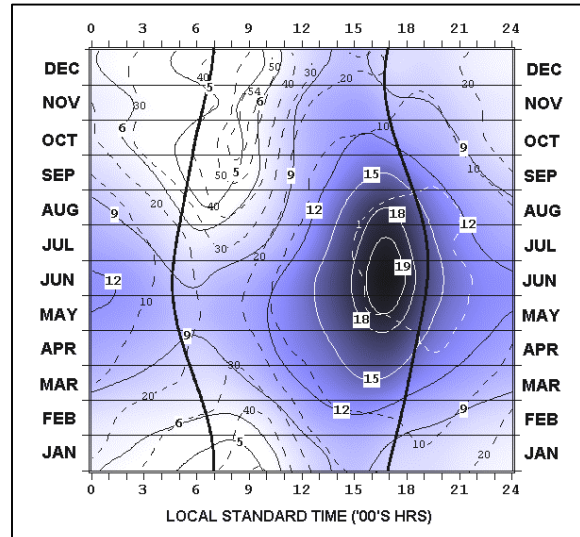


Figure 42. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Lancaster (Fox Field), CA.

From the Mean Scalar Winds/Percent of Time with Calms' chart (figure 42), the Lancaster maximum mean speed isopleth is similarly placed relative to Palmdale's (in the case of Lancaster for the mid-May to late-July late afternoon hours) but higher at 19 knots. The minimum (5-knot) contour is more extensive, covering principally the first several post-sunset hours after sunrise from mid-August through January. Maximum incidence of calms (a narrow elongated 54 percent contour noted for some of the mid-morning hours in October and November) is significantly higher than Palmdale's 40 percent isopleth (at 0800 LST in September).

Still, overall mean scalar wind speed at Lancaster (9.85 knots) is roughly 10 percent higher than Palmdale's figure.

**3.5.4 - Victorville (George AFB) Lat: 34° 35' N;
Lon: 117° 22' W; Elev: 2874 ft**

Victorville, located about 40 miles southeast of Palmdale along the Mojave River just north of the Cajon Pass, exhibits mostly south and south-southwesterly mean vectors (Figure 43). This probably relates to its proximity to nearby topography – the San Gabriel Mountains to the west, the San Bernardino Mountains to the southwest, and the Pass itself.

The orange to red (highest) constancy shadings are confined mostly to the nocturnal hours, although they extend somewhat past sunrise over June to September and in the afternoons during July and August (higher magnitude southwesterlies). For most of the hours after midnight through sunrise, the vectors are principally southerly or south-southwesterly, but a noticeable shift comes several hours after sunrise for all the months - to weak mostly westerly or northwesterlies, the vectors then turning again later in the afternoon to a mostly southwesterly orientation at much stronger magnitudes, especially for the months April-September.

Lowest or “bluest” constancy shadings are again visible for the colder months of the year during daytime, especially October. The latter month seems to be a transition “zone” between the summer season predominant afternoon southwesterlies, and the more prevalent winter northwesterlies at those same hours.

Overall vector wind constancy for Victorville is 46.64, resultant direction: 212.29 (SSW), and resultant speed 3.05 knots.

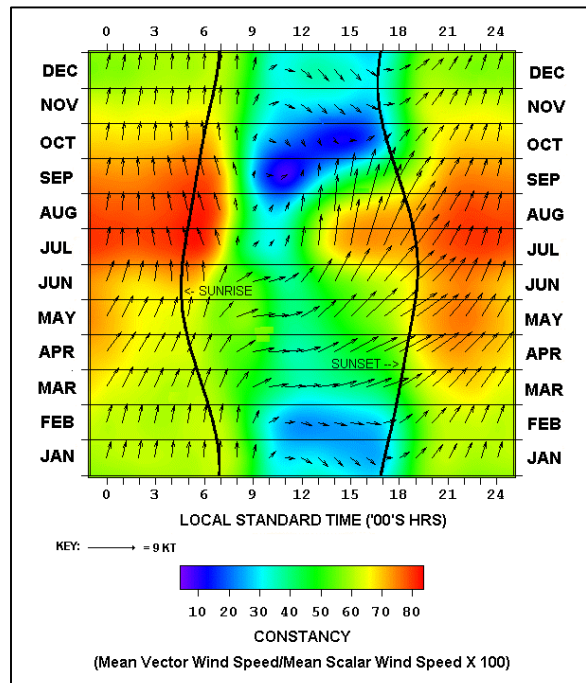


Figure 43. Mean Vector Wind/Constancy Chart for Victorville (George AFB), CA.

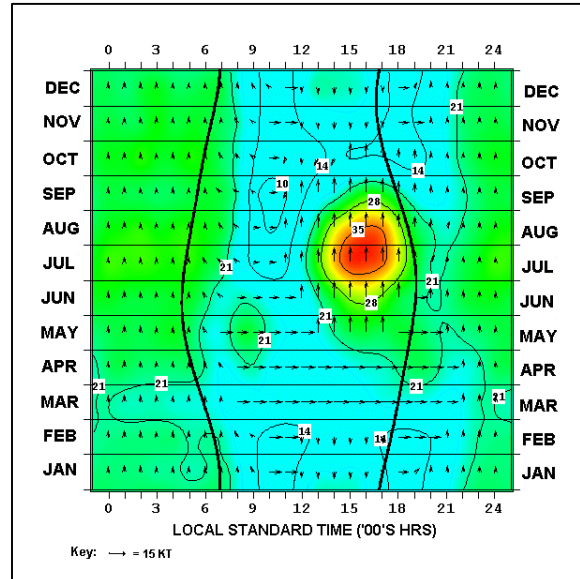


Figure 44. Prevailing Winds Chart for Victorville (George AFB), CA.

In the Prevailing Winds chart (Figure 44), the outstanding feature is the high magnitude (~ 15 knot) southerly flow for at least some of the afternoon hours over May to September, a peak 35 percent isopleth shown that encloses the 1500 to 1700 LST hourly area in July, and the 1600 LST one for August. Most of the other prevailing winds' vectors are southerly, especially at night, and frequently westerly during the daytime, particularly for April and May.

In the Mean Scalar Wind Speed/Percent of Time with Calms chart (Figure 45), there is strikingly little variation in mean speeds throughout the year for most of the nocturnal hours for the non-Spring months, although the familiar late afternoon maximum (12 knot isopleth) is present, especially for May and June. Overall mean scalar wind speed for Victorville (6.53 knots), is much reduced from that at Palmdale and Lancaster.

Greatest incidence of calms (28 percent) is shown for October at around 10AM.

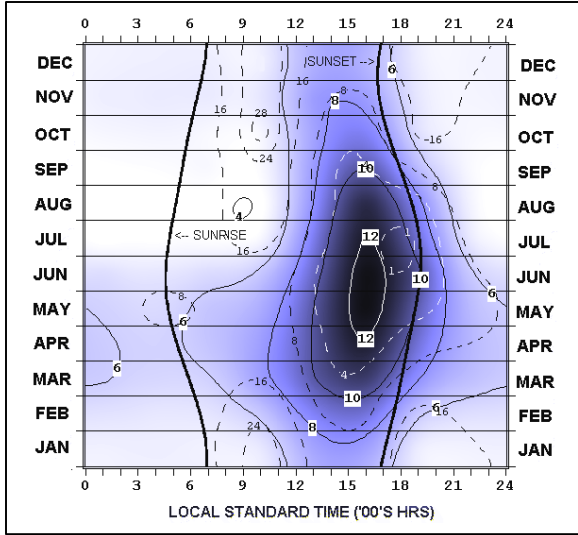


Figure 45. Mean Scalar Wind Speeds and Percent of Time with Calms' Chart for Victorville, CA.

3.5.5 - Daggett Lat: 34° 52' N; Lon: 116° 47' W; Elev: 1927 ft

Daggett, located about 35 miles northeast of Victorville, exhibits highly persistent (orange/red shadings) mean vector winds (Figure 46), especially for the nighttime hours – the orientations, in general, being

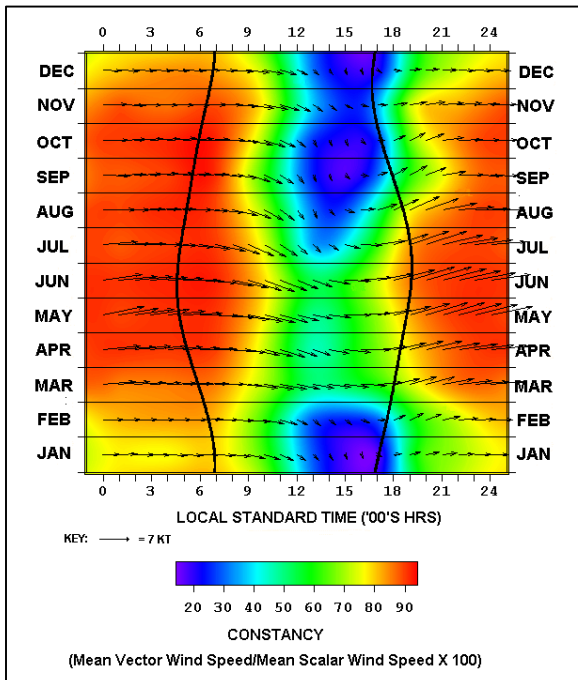


Figure 46. Mean Vector Wind/Constancy Chart for Daggett, CA..

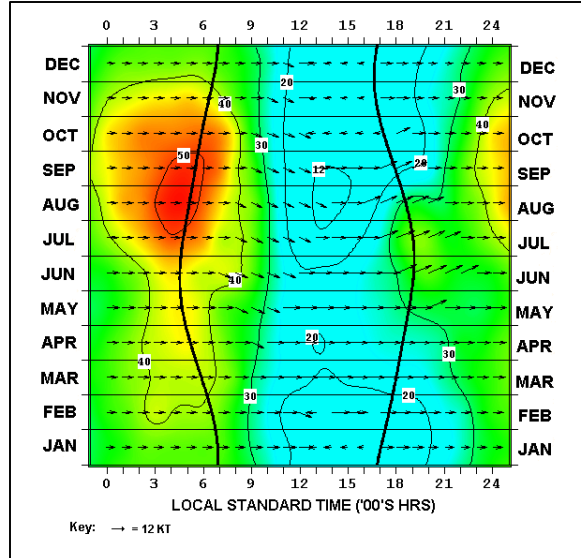


Figure 47. Prevailing Winds Chart for Daggett, CA.

more frequently westerly than those of the other High Desert stations considered. The most prominent resultants, though not much in contrast with the others, are the west-southwesterlies covering the May-August post-sunset hours.

The blue-violet low constancy area is situated generally over the noon to sunset hours in July through February, this feature seemingly marking an apparent transition period between morning west-northwesterly mean flow and that of the afternoon which is more southwesterly. The blue-violet area's extension into the summer season is not seen in the Palmdale or Lancaster charts, but aside from this, the three stations' relative diurnal/seasonal constancy patterns are quite alike. Overall Mean Vector Wind constancy at Daggett is 69.23, at the similarly high levels of Palmdale and Lancaster, the resultant direction 272.19 degrees (W) at speed 6.80 knots.

From Figure 47, nearly all of the prevailing wind directions are westerly, except for some relatively high speed southwesterlies, principally in the early evening hours in June to August, and a few easterlies for the early afternoon hours of October through January. Maximum frequencies are 50 percent or higher (westerlies) for the pre-sunrise hours of August and September.

Mean scalar wind speed for Daggett (9.82 knots) is just a shade less than Lancaster's figure (9.85 knots) but the contour configuration is different (Figure 48). The Daggett maximum contour (14 knots) is considerably less than Lancaster's (19 knot) isopleth, but the latter's relative minimum contour that enclosed several hours either side of sunrise for most months of the year is not present for Daggett. From this it might be generalized that Daggett is more consistently windy than Lancaster or Palmdale but less so in the extreme.

Another noticeable contrast is that the Daggett's oblong-shaped maximum feature reaches into the post-sunset hours. This was not apparent for Lancaster,

Palmdale, or Victorville, the latter three stations right-side contour line separated by at least a few hours from the daytime edge of the sunset demarcation curve.

Finally, Daggett seems to exhibit more of a seasonal concentration of relatively high speeds, the highest level isolines in this regard having a quasi-horizontal track over the months April to June, not unlike Palm Springs.

Greatest calms incidence for Daggett, indicated by the 24 percent isopleth, covers roughly the 1800 to 2100 LST hours for December and January.

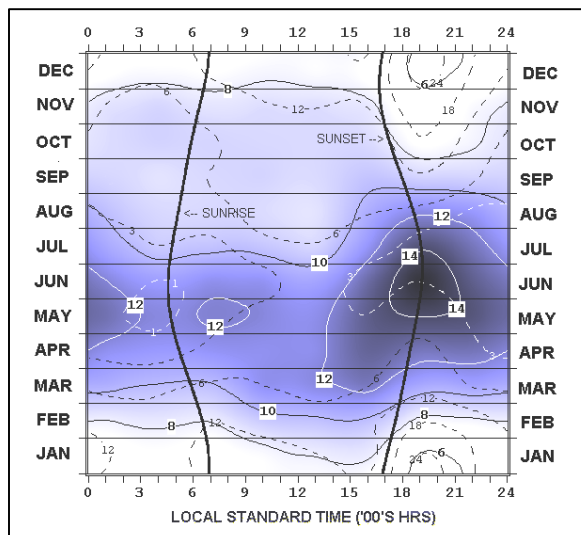


Figure 48. Mean Scalar Wind Speeds/Percent of Times with Calms Chart for Daggett, CA.

4. SUMMARY

Using a triple set of hour-by-month climograms analogous to topographic maps, the foregoing analyzed diurnal and seasonal wind variation landscapes for a sampling of sixteen Southern California stations - along the Pacific Coast, in the Interior Valleys, and within the Mohave and Sonoran Desert areas. The parameters depicted were Mean Vector Wind/Constancy, Prevailing Winds, and Mean Scalar Wind Speeds/Percent of Time with Calms.

The main features of each chart, by station, were described and interpreted with explanations offered as to plausible physical influences.

It should be said that another chart type not used in this analysis is the wind rose. This, of course, would be a useful complement if information on non-primary wind directions was desired.

Visualization charts of these kind may be worth considering as planning and decision-making tools in applications in which wind conditions could have a important impact on activities (e.g. pollution transport scenarios, etc.,)

5. REFERENCES

Fisk, C.J., 2004: Two-way (Hour-Month) Time Section Plots as a Tool for Climatological Visualization and Summarization, 14th Conference on Applied Climatology, American Meteorological Society, 11-15 January 2004, Seattle

<http://ams.confex.com/ams/pdfpapers/69194.pdf>

NOAA Western Regional Climate Center, Desert Research Institute, 2007: Climate of California narrative

<http://www.wrcc.dri.edu/narratives/CALIFORNIA.htm>

NOAA Western Regional Climate Center, Desert Research Institute, 2007: California Climate Tracker page (includes California Climate Regions Map)

<http://www.wrcc.dri.edu/monitor/cal-mon/index.html>