Click here to return to Part 1

- Local inversion potential is applied only to grid cells within terrain features that foster the formation of the development of a nighttime inversion. The height of a local inversion is capped at 150 m agl and determined by the amount of potentially accumulating nighttime drainage flow.
- Discontinuities in mapped values of morning mixing height occur when adjacent surface observation stations experience different nighttime conditions, causing the local inversion algorithm to be invoked in one neighborhood and not in the other.

Ventilation Index

The ventilation index has become a useful tool for air pollution management throughout the United States. Fire and smoke managers in the Southeastern United States are most familiar with using a ventilation index, and several states use the index, sometimes called a clearing index, to help regulate outdoor burning (Hardy et al. 2001). Although popular as an assessment and prediction tool, until now there has been no historical review of ventilation potential. This has prevented an understanding of the spatial and temporal variability of ventilation and its associated impact on values of air quality and visibility.

The ventilation index is the product of windspeed and mixing height. Usually, the index is derived from the average value of windspeed in the mixed layer or a local steering wind, which often is well above 10 m, the height of wind derived for this study. Also, we have modified the mixing height to account for local inversions. The local inversion correction creates lower values of ventilation potential at remote sites, which are more applicable than indexes calculated from a central RAOB location. Therefore, values of ventilation index in VCIS are relatively conservative and may best be applied to smoke concerns relatively close to the ground.

To map index values in a meaningful way and help assess the values of air quality and visibility that are at risk from wildland fire, we followed a common procedure of classifying the ventilation index into categories of poor, marginal, fair, and good. We assigned a classification scheme with ventilation index values that are half the values of commonly used classes (Hardy et al. 2001), however, because windspeeds at 10 m agl typically are about half of those at 40 m agl, which is closer to the height of a trajectory wind. The resulting classification scheme is summarized in table 5.

Figure 18 illustrates the monthly mean classifications of ventilation index for October in the contiguous 48 states. Note the large areas of relatively poor ventilation potential in low-lying areas during the morning. During the afternoon, the ventilation potential improves dramatically. Marginal conditions prevail, however, in the lee of several mountain ranges. Monthly mean maps of the ventilation index classes are available on the VCIS Web site (http://www.fs.fed.us/pnw/fera/vent/data.html) for all months and all 50 states. The interactive Web site allows users to plot sensitive receptors, such as hospitals, schools, airports, wilderness areas, and highways as overlays on the ventilation index maps. In addition, users can zoom, pan, add elevation contours, cities, state and county boundaries, and rivers and railroads to help exactly locate areas of potentially high risk.

In addition to maps of ventilation index classifications, the temporal variability of ventilation indexes can be viewed from the VCIS Web site for any point on the landscape through frequency plots of all twice-daily values. The frequencies are shown as box plots, making it possible for users to determine the chance of experiencing a desired ventilation index value on any day of the month. Also available are plots that show the

Table 5—Classification of ventilation potential from ventilation index values in the ventilation climate information system database

Ventilation index	Classification
Square meters per second	
0–1175	Poor
1176–2350	Marginal
2351–3525	Fair
>3525	Good

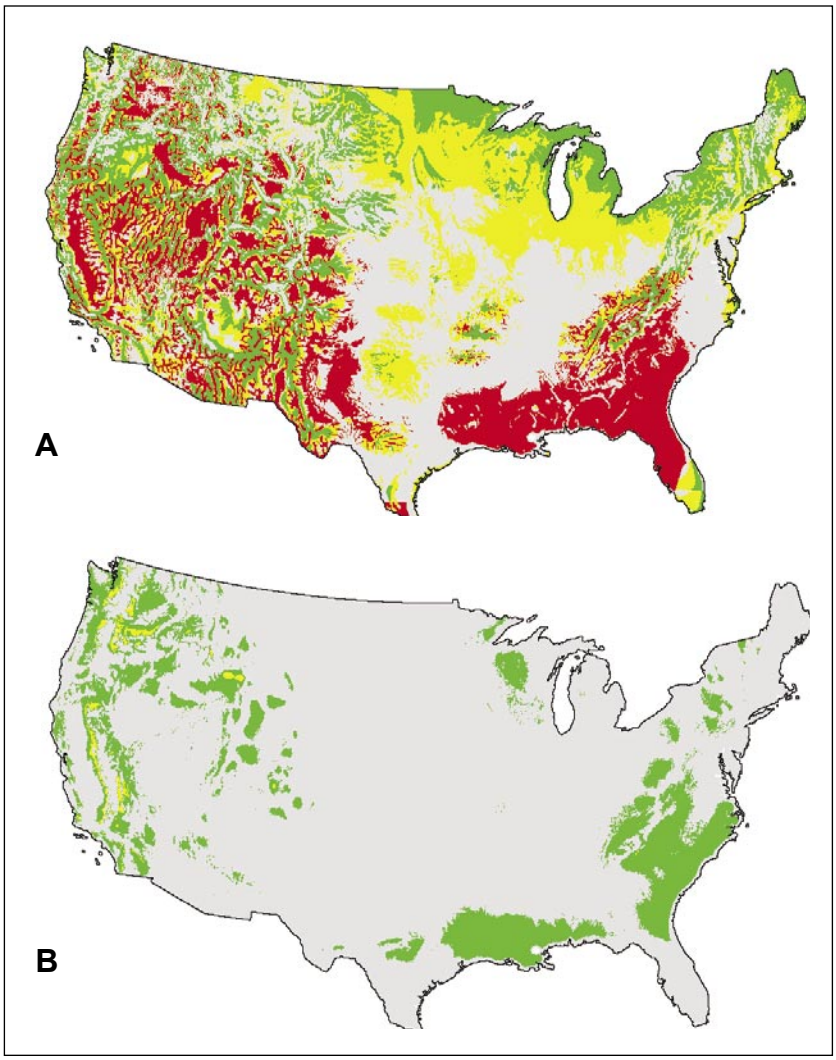

Figure 18—Monthly mean maps of ventilation index classifications for (A) morning and (B) afternoon in October. Red represents potentially poor ventilation conditions, yellow is marginal, green is fair, and gray is good.

year-to-year variability of values for each month. In these plots, the index is not limited to classes, but the full range of actual values can be viewed. Appendix 2 provides examples and explains how to interpret the box-plot time series of ventilation index.

Ventilation Index Verification

As an index, one only can judge its value from its measured components, which are windspeed and mixing height. Modeled winds were shown to be reasonably accurate in many cases, with randomly distributed errors within a range of observation accuracy. There seems to be a relatively consistent slow bias, however, mainly during spring and early summer in high desert regions and flat, grassy areas. Mixing heights always appear reasonably accurate, except within tens of kilometers from Omaha, Nebraska, and Corpus Christi, Texas. It is difficult to determine the accuracy of the local inversion potential, however, because there are so few observations. Also, the relatively coarse grid size (2.5-minute latitude-longitude and 5 km) does not capture many of the small hollows that can trap smoke at night. With the somewhat slow windspeed and inclusion of local valley inversions, we assume that the ventilation index errs conservatively, biasing toward potentially poor ventilation. Although there are missing data in the 40-year record, the long time series ensures reliable interpretation of temporal patterns.

Key Elements of Ventilation Index

- The ventilation index derived for VCIS is most useful for addressing concerns about smoke that stays relatively close to the ground.
- The ventilation index is somewhat conservative but provides a reasonably accurate view of ventilation climate during the last 40 years.
- The VCIS provides the first national coverage of ventilation climate.

Risks to Air Quality and Visibility From Wildland Fire

Development of a fine-resolution database of surface winds, mixing height, and ventilation index affords a unique opportunity to assess the risks to air quality and visibility from wildland biomass burning at various scales. Although model-generated data can only approximate actual conditions, the mapped products and point statistics show reasonable patterns of information and provide the most accurate representation of historical ventilation potential to date. Therefore, conclusions should be used cautiously but not without some confidence.

Risks to air quality occur when ventilation index values are low and harmful pollutants are held close to the ground. Risks to visibility also occur when ventilation index values are low. Light-scattering and absorbing elements of smoke near the ground cause significant degradation of visual range, especially when combined with high atmospheric humidity.

Although we base our estimate of risks to air quality and visibility solely on an index of ventilation potential, more precise estimates can be derived by combining ventilation potential with historical smoke emissions and atmospheric humidity data. Because emissions and humidity data currently are unavailable at a consistent temporal and spatial resolution and they are much more difficult to derive than mixing height and wind, they are not included in this assessment. Where available locally, however, they can be used to help refine the risks identified by ventilation index.

Spatial patterns of the monthly mean ventilation index can be viewed on the VCIS Web site (http://www.fs.fed.us/pnw/fera/vent/data.html). In general, ventilation index data show the greatest risks to air quality and visibility in the Southeastern United

States where marginal to fair ventilation conditions prevail most of the year. This region also has a high concentration of roads, hospitals, and schools. Additionally, the northern plains and deep valleys of the Western United States show risk potential with consistently poor to marginal ventilation during winter and marginal to fair conditions during spring and autumn. Sensitive receptors in the northern plains and western valleys, however, are much more sparse than in the Southeastern United States.

Site-specific information on temporal patterns of ventilation indexes can be viewed from the VCIS Web site by selecting the “Get Stats” button in the “Maps and Graphs” section. At each point, periods of good ventilation potential can be found at times throughout the year. Some places have greater frequency of good ventilation and there are some times that are better than others. There also are places and times when poor ventilation conditions prevail.

To help summarize the data, we divided the country into significant airsheds as defined by the United States Geological Survey hydrologic unit code (HUC) system (Seaber et al. 1987) (fig. 19). The contiguous 48 states were divided according to first-order hydrologic units. The second-order hydrologic units were used to represent airsheds in Alaska. Hawaii is considered a single, separate airshed.

The average ventilation index for each regional airshed is shown in table 6. The table is color coded to highlight values that fall into the range of index classifications of poor (0 to 1175 m^2/s), marginal (1176 to 2350 m^2/s), fair (2351 to 3525 m^2/s), and good (>3525 m^2/s) as red, yellow, green, and white, respectively. During morning hours, marginal to fair ventilation conditions prevail throughout most of the country with relatively poor ventilation potential during summer in the Mississippi regions and South-Atlantic Gulf region. Ventilation potential improves for most of the country during the afternoon. The Mississippi regions, other central U.S. regions, and South-Atlantic Gulf region, however, retain marginal to fair ventilation potential during winter.

Ventilation potential is dominated by wind in the morning, but afternoon ventilation is dominated by mixing height. The highest ventilation potential prevails during spring and early summer in the high desert regions of the country where intense heating causes very high mixing heights. These places include the Rio Grande, Upper and Lower Colorado, and Great Basin airsheds, with high indexes extending well into early autumn in the Rio Grande airshed. The Arkansas-White-Red airshed in the south-central states also experiences high ventilation potential during midsummer when afternoon heating is greatest.

Counter to most of the rest of the country, the highest ventilation indexes in the Pacific Northwest occur during winter. Although the Columbia Basin that is centered in the Pacific Northwest region consistently experiences marginal ventilation potential during winter, high mountains that dominate the remainder of the airshed receive their highest winds in winter, and thus high ventilation potential. Also, high terrain in the Pacific Northwest often rises above interpolated mixing height values in winter, causing the 4000 m agl arbitrary level to dominate mixing height values at this time of year. This may create artificially high ventilation potential in this airshed during winter.

Although prevailing ventilation conditions may indicate the likelihood of risk to values of air quality and visibility in each region, in all places at many times of the year good ventilation conditions can occur. The “Get Stats” button from the “Maps and Graphs” page of the VCIS Web site (http://www.fs.fed.us/pnw/fera/vent/data.html) shows the frequency of potentially good ventilation potential on any day of the month or any

Figure 19—Regional airshed boundaries for the contiguous 48 states and Alaska. Hawaii is a single, separate airshed.

month of the year for individual grid points. To illustrate the regional variability of the ventilation index, we created a series of box plots (figs. 23 through 25 in app. 3) that show the median, standard deviation, and range of values for each month. Although the ventilation index ranges from zero to well over 70 000 m^2/s, the box plots are truncated at 14 000 m^2/s in the afternoon and 7000 m^2/s in the morning to better illustrate the range of management categories, where any value above 3525 m^2/s is considered good ventilation potential.

From the box plots (see app. 3), it appears that all areas can experience good ventilation and low risk to values of air quality and visibility at times during the morning (range bars exceed 7000 m^2/s), but the Great Lakes region clearly experiences the best morning ventilation potential within a standard deviation of its median, especially

Table 6—Average ventilation index values for each regional airshed and each month. Red = poor (<1175), yellow = marginal (1176 to 2350), green = fair (2351 to 3525), and white = good (>3525)

Hour	Regional airshed	January	February	March	April	May	June	July	August	September	October	November	December
							Square meters per second						
Contiguous 48 states													
AM	Arkansas-White-Red	1699	1883	2152	2042	1916	1567	1341	1248	1510	1652	1904	1800
	California	2334	2389	2313	2125	2040	1757	1526	1396	1639	1793	2176	2265
	Great Basin	1826	1927	2038	1882	1677	1398	1353	1282	1449	1513	1862	1881
	Great Lakes	3713	3095	3363	3273	2371	2049	1616	1809	2381	3325	4135	3959
	Lower Colorado	2129	2089	2232	2087	1827	1574	1466	1419	1696	1852	2002	2065
	Lower Mississippi	1578	1795	1896	1661	1541	1101	863	795	1122	1252	1787	1762
	Mid Atlantic	2912	2754	2849	2701	2100	1796	1587	1612	1776	2223	2775	2799
	Missouri	2421	2188	2343	2322	2031	1679	1386	1397	1806	2184	2319	2336
	New England	2965	2784	3164	3033	2396	2151	1834	1883	2092	2553	3215	2954
	Ohio	2752	2386	2536	2522	1809	1413	1190	1175	1451	1836	2505	2636
	Pacific Northwest	2818	2726	2495	2249	1979	1809	1638	1569	1839	2181	2770	2769
	Rio Grande	1887	1928	2174	2004	1840	1549	1319	1252	1482	1647	1923	1863
	Souris-Red-Rainy	1926	1815	2130	1940	1804	1617	1199	1341	1892	2483	2228	1890
	South Atlantic Gulf	1525	1742	1749	1576	1336	1215	1115	1070	1210	1244	1493	1506
	Tennessee	2179	2207	2256	2169	1769	1372	1212	1160	1410	1695	2158	2232
	Texas Gulf	1415	1667	1889	1925	2062	1815	1484	1335	1375	1441	1685	1584
	Upper Colorado	1971	1897	2214	2053	1836	1568	1407	1388	1654	1744	2044	2010
	Upper Mississippi	2003	1773	2216	2109	1669	1391	1058	1097	1462	1959	2129	2008
PM	Arkansas-White-Red	3238	3891	5295	6705	6427	6672	8339	7626	6364	4650	3951	3166
	California	5823	5145	4999	5456	5665	5998	5991	5675	5019	4531	5337	6009
	Great Basin	4454	4092	5415	6413	6764	7795	7768	7021	5985	4352	4203	4402
	Great Lakes	3750	3803	4824	6632	6504	6430	5876	5524	5463	5118	4294	3618
	Lower Colorado	3620	4020	6100	7863	8747	9884	8255	6813	6347	4870	3982	3474
	Lower Mississippi	2930	3526	4516	5160	4952	4907	4815	4725	4661	3898	3558	2973
	Mid Atlantic	4200	4218	4796	5523	5275	5176	4805	4338	4064	4070	4144	4332
	Missouri	4771	4288	5006	6964	6573	6497	6609	6213	5498	4921	4588	4649
	New England	4794	4799	5368	5753	5569	5611	5020	4636	4427	4527	5038	4594
	Ohio	3317	3345	4520	5528	5182	4895	4508	4298	4400	3938	3635	3249
	Pacific Northwest	8715	6438	5010	5237	5231	5618	6041	5694	4651	4451	6980	8756
	Rio Grande	4217	5352	7848	9430	10 673	11 132	9795	7755	7121	5629	4645	4293
	Souris-Red-Rainy	2485	2752	3576	6244	6585	6101	5498	5258	4837	4276	2861	2189
	South Atlantic Gulf	2974	3624	4512	5155	4944	4736	4675	4210	4087	3682	3299	2944
	Tennessee	3791	3982	4778	5489	4962	4735	4414	4123	4213	3850	3831	3913
	Texas Gulf	2969	3586	4863	5873	5899	5769	6969	6971	5483	4291	3689	2959
	Upper Colorado	5863	4809	5626	6810	7336	7861	6919	6219	5838	4375	4926	5749
	Upper Mississippi	2426	2500	3817	5563	5614	5171	4540	4235	4238	3806	2910	2300

Table 6—Average ventilation index values for each regional airshed and each month. Red = poor (<1175), yellow = marginal (1176 to 2350), green = fair (2351 to 3525), and white = good (>3525) (continued)

Hour	Regional airshed	January	February	March	April	May	June	July	August	September	October	November	December
							Square meters per second						
Alaska													
AM	Southeast	3650	3489	3217	3106	2321	2075	1768	1933	2388	3139	3350	3370
	South Central	3266	3064	2890	2529	2129	1986	1714	2033	2526	2768	2941	3131
	Southwest	2997	2856	2810	2569	2461	2007	1988	2415	2920	3068	2893	3025
	Yukon	2710	2588	2443	2156	1971	1806	1908	2118	2386	2489	2532	2634
	Northwest	2965	2883	2896	2667	2341	1965	2234	2548	2911	2901	2905	2895
	Arctic Slope	2112	2052	1894	1896	1871	1770	1804	2064	2525	2294	2067	2090
PM	Southeast	12 007	10 413	7558	6272	4888	4519	4255	5081	6586	8789	11 231	12 182
	South Central	13 107	11 981	9159	5820	4337	4100	4113	5173	7032	9760	11 625	13 047
	Southwest	10 218	8132	5302	4373	4607	4226	3750	4092	4782	5432	8596	10 396
	Yukon	11 740	9829	6303	4687	4820	4596	4329	4374	5023	6919	10 599	11 516
	Northwest	13 143	11 747	9846	6997	6145	4908	4469	4517	5114	7685	12 069	12 390
	Arctic Slope	9351	8565	6968	5222	4386	4191	4393	4664	5061	6640	8834	9082
Hawaii													
AM		2310	2223	2847	2964	2884	2932	3148	2930	2660	2642	2648	2391
PM		4341	4179	5183	5248	5025	5034	5276	4980	4645	4681	4977	4382

during winter. The standard deviations of values generally range from poor to fair during the morning in most regions. This suggests that values of air quality and visibility throughout the country are most likely to be affected during the late night and early morning.

The box plots show that most places have significant potential (within a standard deviation of their median) of reaching good ventilation conditions during the afternoon at any time of the year. Exceptions include the Upper and Lower Mississippi regions, which, while exhibiting some good ventilation occurrences at all times of the year, seldom reach fair conditions in winter. Good conditions occur within a standard deviation only in April and May. Thus, it may be more difficult to find good ventilation conditions in the Mississippi regions than elsewhere.

Another note of interest is the large range of ventilation conditions in California. Its box plot shows that the frequency of good conditions is nearly the same as the frequency of very poor conditions, no matter what time of year. Although other regions may confidently expect good ventilation conditions in July, for example, the chances of finding good conditions in the California region are equal to finding poor conditions. This makes seasonal planning in the California region more difficult than for other regions.

The data suggest that all areas experience times of good ventilation. Therefore, it should be possible to mitigate potential impacts on values of air quality and visibility. In some places, however, good ventilation conditions are less frequent than marginal or poor ventilation conditions, and in most places good ventilation is infrequent during morning hours. At these times and places, balancing the risk to air quality and visibility with other management objectives may be challenging. The data show highly variable conditions, however, in both space and time. The VCIS, which illustrates the frequency and spatial distribution of ventilation conditions that may impact values of air quality and visibility, may help quantify potential risks.

Key Elements of Risks to Air Quality and Visibility From Wildland Fire

- Risks to air quality and visibility from wildland fire can be estimated by assessing spatial and temporal patterns of ventilation index.
- The greatest risks to air quality and visibility from wildland fire occur in the Southeastern United States.
- Risks to air quality and visibility from wildland prescribed fire can be minimized by planning times when good ventilation conditions are most frequent.
- The best ventilation conditions during morning hours occur during winter along the northern coasts of the contiguous 48 states, in southern Alaska, and in the north-central plains.
- The best ventilation conditions during afternoon hours occur in spring and early summer in the Rio Grande airshed.
- The VCIS point statistics allow identification of times of highest or lowest risk at any point on the landscape.
- The VCIS monthly maps show the spatial patterns of potential risk.

Conclusions

The VCIS assists users in assessing values of air quality and visibility at risk from wildland fire by illustrating the spatial and temporal variability of ventilation potential. The 40-year, twice-daily time series at 2.5-minute latitude-longitude and 5-km spatial resolution can be viewed as monthly averaged maps of index classifications or in plots of frequency and magnitude at selected points. The ArcIMS Web-access system allows users to view local to national patterns of ventilation potential. Overlays of sensitive receptors (hospitals, schools, roads, airports, etc.) can help quantify the proximity of risk to poor ventilation conditions.

Creation of such a high-resolution climate information system, with over 100 gigabytes of data, was only possible with high-level computing power. Even so, the amount of smoothing and simplifying assumptions needed to process the data in a reasonable amount of time could be reduced with even more computational energy. Also, whereas the long climate record may compensate for missing data, increased computer resources could reduce the number of missing values in wind by allowing numerical calculations to continue longer before reaching a stable solution and in other variables by using additional algorithms to fill missing data. Nevertheless, the generated values provide a reasonably accurate view of ventilation potential and associated risks to air quality and visibility in the United States. The products include several unique features:

- The first nationally consistent, historical database of surface wind at fine spatial resolution.
- The longest historical record and finest spatial resolution of mixing height.
- The first database of historical ventilation potential.
- The first physically reasonable assessment of historical risks to air quality and visibility.

Because the VCIS offers the first historical perspective of ventilation potential and associated risks to air quality and visibility at a high spatial and temporal resolution on a national scale, the information it holds about patterns and probabilities of risk is just beginning to be explored. As users are being introduced to the products, however, several applications to land management emerge. These include:

- Identification of areas at risk to smoke problems
- Smoke management planning
- Airshed assessments
- Better understanding of the spatial and temporal variability of atmospheric conditions that affect smoke dispersion

Although we adopted a relatively simple approach to assessing values at risk, it was not a trivial task to create the necessary products for analysis. As use increases, however, it may become beneficial to add detail and increase accuracy. For example, the 2.5-minute latitude-longitude and 5-km spatial resolutions are considered extremely fine for such a long history and large domain. Land managers, however, work at resolutions closer to 1 km or less and may desire information more than twice a day. With greater resources it is possible to downscale each product and add accuracy. Until then, we hope users of this first rendition of the VCIS will find value in the information and tools offered from the VCIS Web site.

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English Equivalents

When you know:	Multiply by:	To find:
Meters (m)	3.28	Feet
Kilometers (km)	.6215	Miles
Square kilometers (km^2)	.386	Square miles
Meters per second (m/s)	2.24	Miles per hour
Meters per second (m/s)	1.94	Knots
Square meters per second (m^2/s)	10.76	Square feet per second
KiloPascals (kPa)	10	Millibars
Centigrade (C)	1.8 (and add 32)	Fahrenheit

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Appendix 1: Map Projections

Data Projections

To generate the spatial data components of wind, mixing height, and ventilation index, we used geographic coordinates for the contiguous 48 states and Hawaii, with a grid resolution of 2.5-minute latitude-longitude. The geographic coordinate system creates excessively elongated grid cells above the 50th parallel, however, which cause computational problems for the wind model. Therefore, in Alaska an Albers Conical Equal Area projection was used for generating spatial components, with a grid resolution of 5 km. The following is a summary of map projections used to generate spatial data components of wind, mixing height, and ventilation index:

Contiguous 48 states and Hawaii:

- Projection: Geographic
- Units: Decimal degrees
- Spheroid: WGS84
- Grid size: 2.5 minutes

Alaska:

- Projection: Albers Conical Equal Area
- First standard parallel: 58 00 00
- Second standard parallel: 68 00 00
- Central meridian: -150 00 00
- Origin of the projection: 50 00 00
- False easting: 0
- False northing: 0
- Spheroid: North American Datum 1983
- Grid size: 5000 meters

Web Map Projections

To generate monthly mean maps of the spatial data for display on the Web, we used projections that are common to each region to create maps that look familiar to most users. The following is a summary of map projections used to generate Web maps:

Contiguous 48 states

- Projection: Albers Conical Equal Area
- First standard parallel: 29 30 00
- Second standard parallel: 45 30 00
- Central meridian: -96 00 00
- Origin of the projection: 23 00 00
- False easting: 0
- False northing: 0

- Spheroid: North American Datum 1983
- Grid size: 5000 meters for meteorological data, 2500 meters for background terrain

Alaska

- Projection: Albers Conical Equal Area
- First standard parallel: 58 00 00
- Second standard parallel: 68 00 00
- Central meridian: -150 00 00
- Origin of the projection: 50 00 00
- False easting: 0
- False northing: 0
- Spheroid: North American Datum 1983
- Grid size: 5000 meters for meteorological data, 2500 meters for background terrain

Hawaii

- Projection: Universal Transverse Mercator
- Zone: 4
- Spheroid: North American Datum 1983
- Grid size: 5000 meters for meteorological data, 2500 meters for background terrain

Appendix 2: How to Interpret Graphics

How to Interpret Wind Roses

Wind roses are polar plots that simultaneously display windspeed, wind direction, and relative frequency.

- Windspeeds are shown in meters per second (m/s). One m/s = 1.94 knots = 2.24 miles per hour.
- The percentage of calm winds (<1 m/s) is shown in the center of each wind rose.
- Windspeeds are represented by line thickness and color. Higher windspeeds are indicated by thicker lines and orange to red color.
- The direction that the wind comes from is represented by the angle in which a ray radiates out from the center of the plot. Straight up indicates winds coming from true north.
- Wind frequency is indicated by the length of each line segment of a given thickness and direction. The numerical labels on the concentric circles provide a scale for each graph.

Wind rose example—Figure 20 shows wind frequencies from a site in (a) California and (b) Michigan in August in the afternoon.

- The California site indicates winds predominantly blow from the southwest at this time, and windspeeds frequently exceed 8 m/s. Only 0.32 percent of the winds are calm (less than 1 m/s).
- The Michigan site shows winds prevailing from the south-southeast and south at this time but a significant number of events produce southwest to west winds over the site. Few winds exceed 8 m/s, winds less than 3 m/s occur from all directions, and 4 percent of the winds are calm (less than 1 m/s).

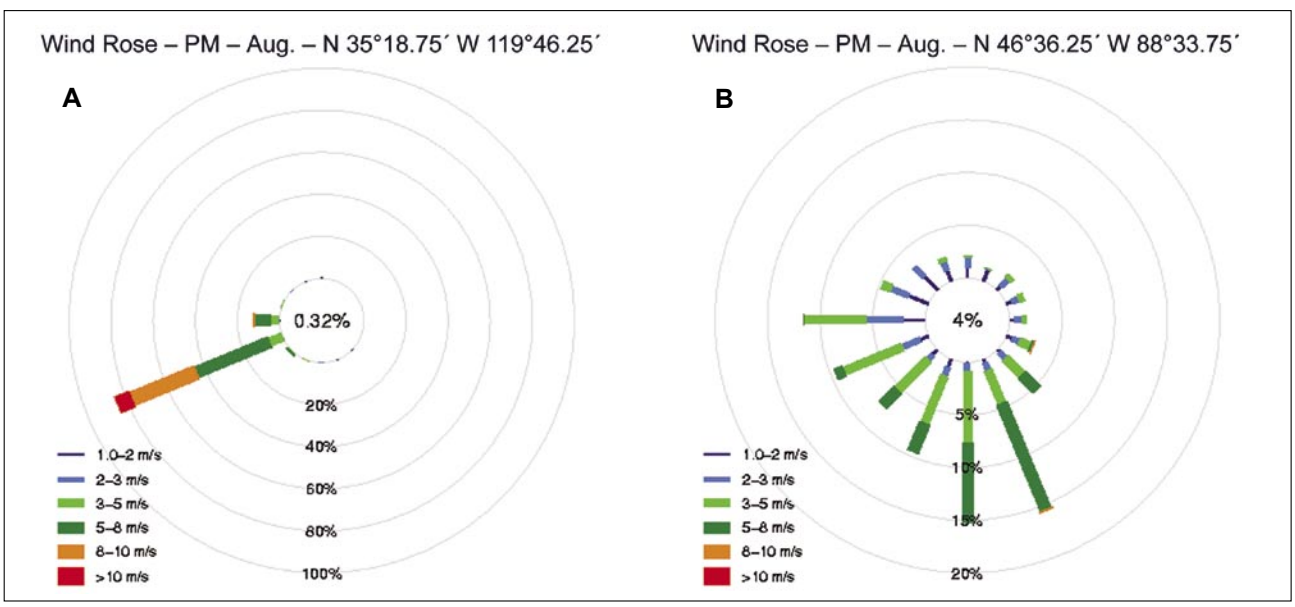


Figure 20—Wind roses from sites in (A) California and (B) Michigan at 0000 universal time coordinated (afternoon) in August. Wind speed is represented by line thickness and color. The direction that the wind comes from is represented by the angle at which the ray radiates out from the center of the plot. Straight up indicates winds coming from the north. The percentage of calm winds (<1 m/s) is shown in the center circle.

How to Interpret Wind Verification Plots

Polar plots of the absolute differences in winds are similar to wind roses in that they simultaneously show differences in speed, direction, and frequency.

- Absolute difference is determined by subtracting each observation from its corresponding modeled value. When observed winds are less than 1 m/s, however, they and the corresponding modeled winds are excluded from difference calculations.
- Some differences may be caused by the model itself, whereas others may be due to the differing resolutions between the model topography and the actual topography. Anemometers are sensitive to small variations in terrain and land use that are not captured in the modeling resolution. See diagrams of surrounding topography and land use that accompany each difference plot to determine this effect.
- Differences between modeled and observed windspeeds are presented as positive values, not distinguishing between overestimation and underestimation. Difference in speed is represented by line thickness and by using the same speed classes as wind roses except that differences (<1 m/s) are not a separate category, causing the thinnest line segments to represent all windspeed differences less than 2 m/s.
- Difference in direction is represented by the angle in which a ray radiates out from the center of the plot. Straight up indicates essentially no difference (within 11.25 degrees). An angle of 90 degrees indicates that the modeled winds differ from the observed winds by 90 degrees in the clockwise direction (i.e., an observed direction of northeast and a modeled direction of southeast).
- Differences are calculated at standard synoptic times of 0Z and 12Z (0000 and 1200 UTC).

Example wind verification—Figure 21 illustrates two sites, one in each row. The top row illustrates a site for which the modeled data match the observed data reasonably well with respect to both direction and speed. This is demonstrated by the long, thin lines pointing toward the top of the absolute differences plot. The second row illustrates a site for which the modeled data do not match the observed data well, as indicated by the shorter, thicker lines pointing in all directions in the absolute differences plot.

- Because 5 percent of the observed winds at the first site were less than 1 m/s, the absolute difference plots correspond to the remaining 95 percent of the observed and modeled winds. Absolute difference at the second site represents 97 percent of the observed and modeled winds.

How to Interpret Box Plots

Box plots simultaneously illustrate variability within and among groups of data.

- The horizontal bar inside each box indicates the median (50th percentile) of the subset.
- The lower and upper limits of the rectangle indicate the quartiles (25th and 75th percentiles, respectively) of the subset.
- The horizontal lines at the ends of the whiskers indicate the extreme values (maximum and minimum) of the subset.

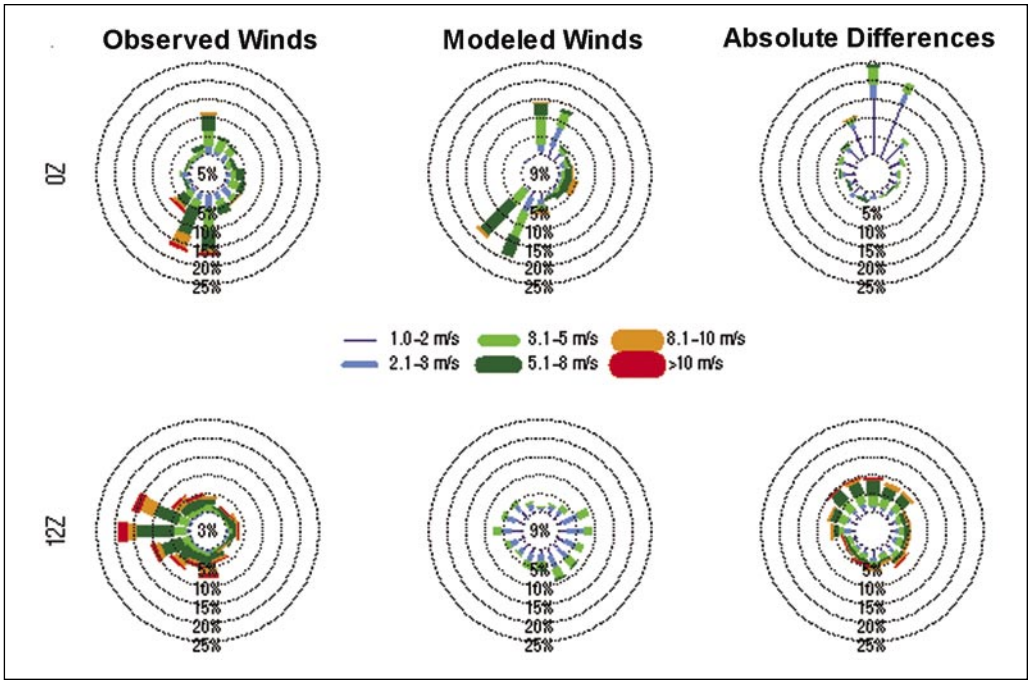


Figure 21—Polar plots of observed and modeled wind, and the absolute difference between modeled and observed for two random sites. The observed and modeled winds are represented as wind roses. The absolute difference shows magnitude of difference by line thickness and angle of difference by the direction in which the ray radiates out from the center of the plot. Straight up indicates direction differences within 11.5 degrees, and a thin line represents speed differences less than 2 m/s.

- The vertical scale of each plot is set to minimize overbearing influence of extreme upper values, and enhance detail in the majority of values. This is done by excluding 0.05 percent of the values that may plot above the highest thousandth tick mark of the graph.

Mixing height—There is a horizontal line at 4000 m on afternoon (PM) box plots and at 1000 m on morning (AM) box plots.

- Interpolated mixing height values sometimes intersect high terrain, creating a belowground value. Mixing can occur to heights well above ground at these places, however, which would allow significant ventilation to occur.
- Because positive mixing height values are needed to calculate ventilation indexes, we set a height to represent the upper limit of mixing whenever interpolated values were less than or equal to zero. The heights were arbitrarily set at 1000 m agl in the morning and 4000 m agl in the afternoon, which approximate maximum values of mixing heights at those times. Unfortunately, the twice-daily time series of historical mixing heights are skewed to these corrected values, especially at high-elevation grid locations.
- Each box plot of mixing height includes a red, horizontal line showing the 1000-m or 4000-m level, where applicable, to help the user determine the effect of the belowground correction.

Example mixing height box plot—Figure 22a illustrates the variability of morning mixing height for a site in Wyoming. The horizontal red line shows the 1000-m correction for belowground mixing height values in the morning. Many times during this month at this site, mixing height is interpolated to a point below ground, and then adjusted to 1000 m. Because there are so many values at 1000 m, at times the 50th percentile and 75th percentile equal 1000 m, causing no box to appear (e.g., April 14 and 16, and 1985, 1987, and 1988).

Figure 22b shows the variability of afternoon mixing height for a site in Minnesota. The horizontal red line shows the 4000 m correction for belowground mixing height values in the afternoon. At this site in this month at this time, mixing height is commonly between 1000 and 3000 m above ground.

- The left side of each figure illustrates the variability within each day of the month across multiple years
- The right side of each figure illustrates the variability within the month from year to year.

Ventilation Index

- Ventilation index box plots use a logarithmic vertical scale. This is to allow more visible detail.
- Color bars on each side of the ventilation index box plots show how the scale relates to mapped categories.
  - Red = poor
  - Yellow = marginal
  - Green = fair
  - White or gray = good

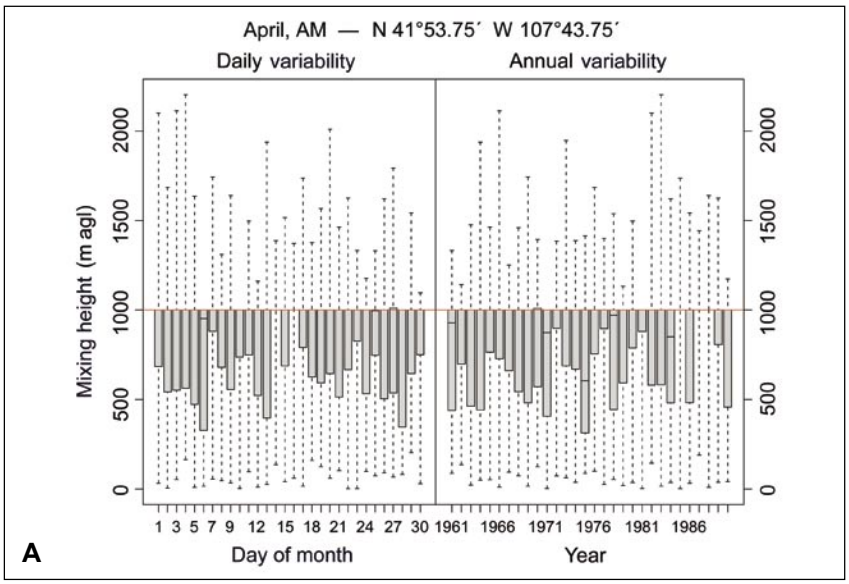


Figure 22—(A) Box plot of morning mixing height in April at a point in Wyoming. The horizontal red line shows the 1000 m correction for belowground mixing height values in the morning. (B) Box plot of afternoon mixing height in April at a point in Minnesota. The horizontal red line shows the 4000 m correction for belowground mixing height values in the afternoon. (C) Box plot of ventilation index for a site in Georgia during the afternoon in April. Color bars indicate poor, marginal, fair, and good classification values (table 4).

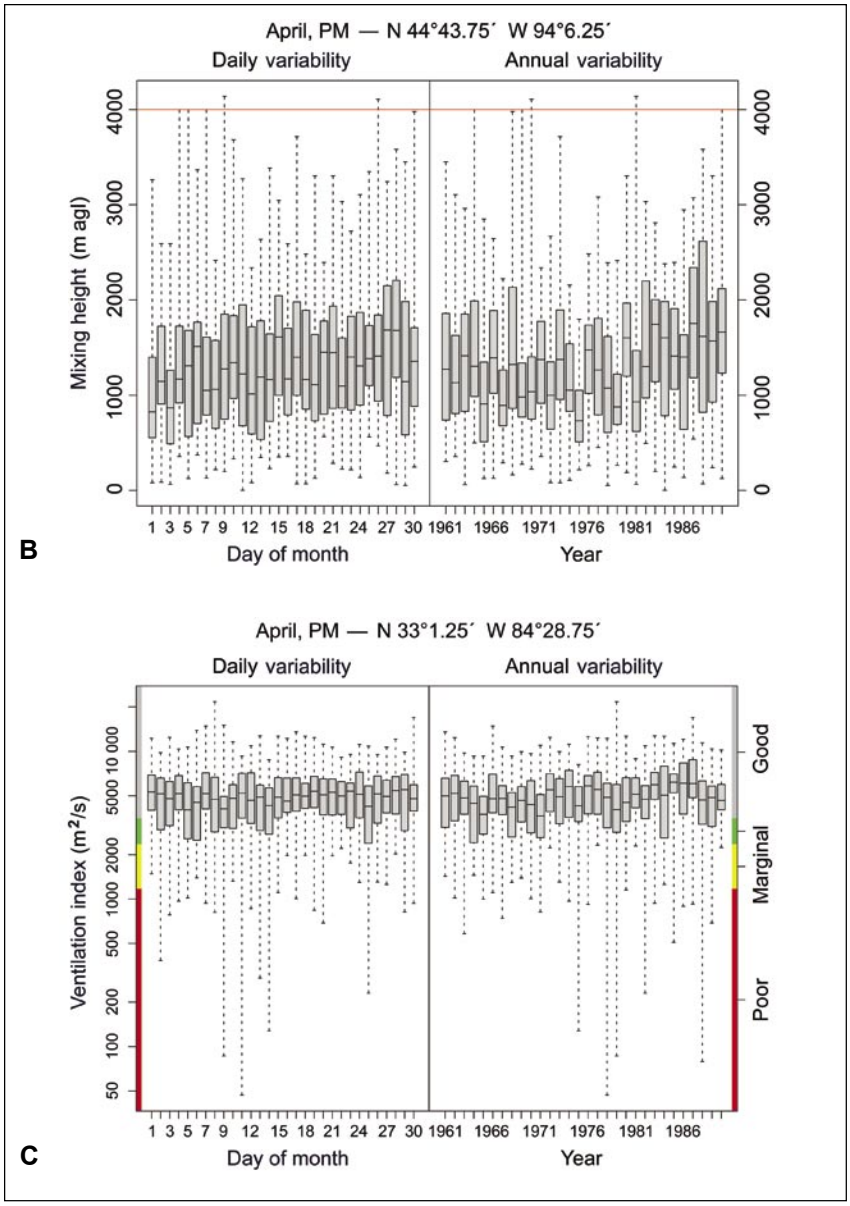


Figure 22—Continued.

Example ventilation index box plot—Figure 22c shows the variability of ventilation index for a site in Georgia in the afternoon. At this site, in this month, and at this time of day, the ventilation index generally is fair, often marginal, and with periods of poor and good ventilation.

- The left side of the figure illustrates the variability within each day of the month across multiple years, whereas the right side of each figure illustrates the variability within the month from year to year.
- Color bars on the figure show that the ventilation index values are mostly good at this site in April.

How to Interpret Maps

Morning monthly mean mixing height—Artifacts in mapped mixing height values appear at the boundaries of local occurrence neighborhoods. This is because local inversion potential is invoked only when certain conditions are met at a nearby surface observation station and adjacent surface stations may have different conditions.

Monthly mean ventilation index—Although ventilation index is calculated as a continuum of values, only four classes are plotted in the monthly mean maps (table 4). This is to facilitate the use of mapped data for assessing potential risk to values of air quality and visibility from wildland fire. The color scale values are half the value of classification schemes commonly used by smoke managers (Hardy et al. 2001). This is because windspeeds at 10 m agl are commonly half of speeds at 40 m agl, a typical height of trajectory winds.

Appendix 3: Summaries of Ventilation Index by Regional Airshed

Box plots show the median, standard deviation, and range of values for each month in each regional airshed in the contiguous 48 states (fig. 23), Alaska (fig. 24), and Hawaii (fig. 25). Airsheds are defined by hydrologic unit code (HUC) code (Seaber et al. 1987) (fig. 19). The contiguous 48 states were divided according to first-order HUC. Second-order HUCs were used to represent airsheds in Alaska. Hawaii is considered a single, separate airshed. Although the ventilation index ranges from zero to well over 70 000 m^2/s, the box plots are truncated at 14 000 m^2/s in the afternoon and 7000 m^2/s in the morning to better illustrate the range of management categories and facilitate cross comparison. Any value above 3525 m^2/s is considered good ventilation potential.

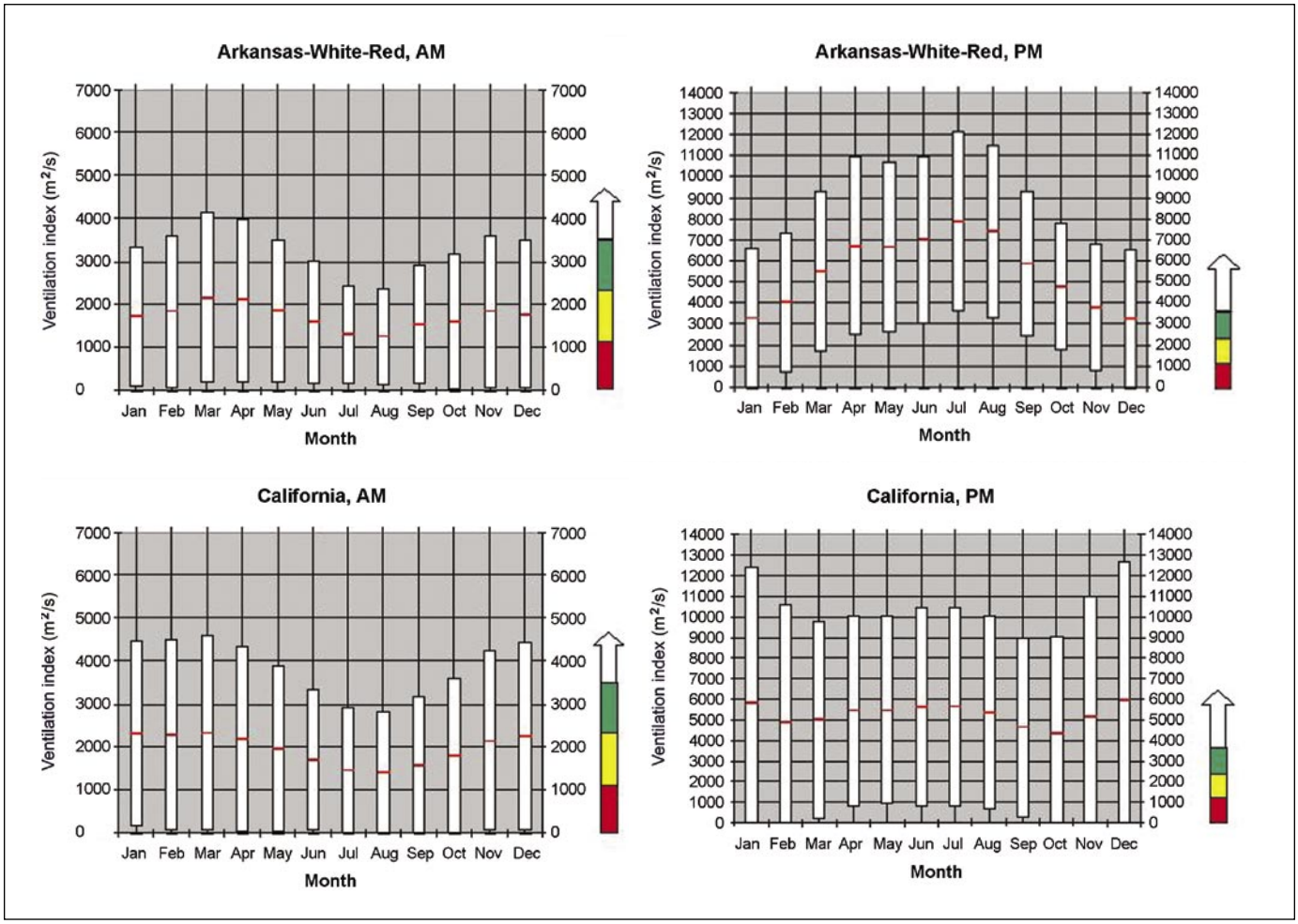


Figure 23—Box plots of ventilation index by month for each regional airshed in the contiguous 48 states. Color bars to the right of each plot indicate categories of poor (red), marginal (yellow), fair (green) and good (white) ventilation potential.

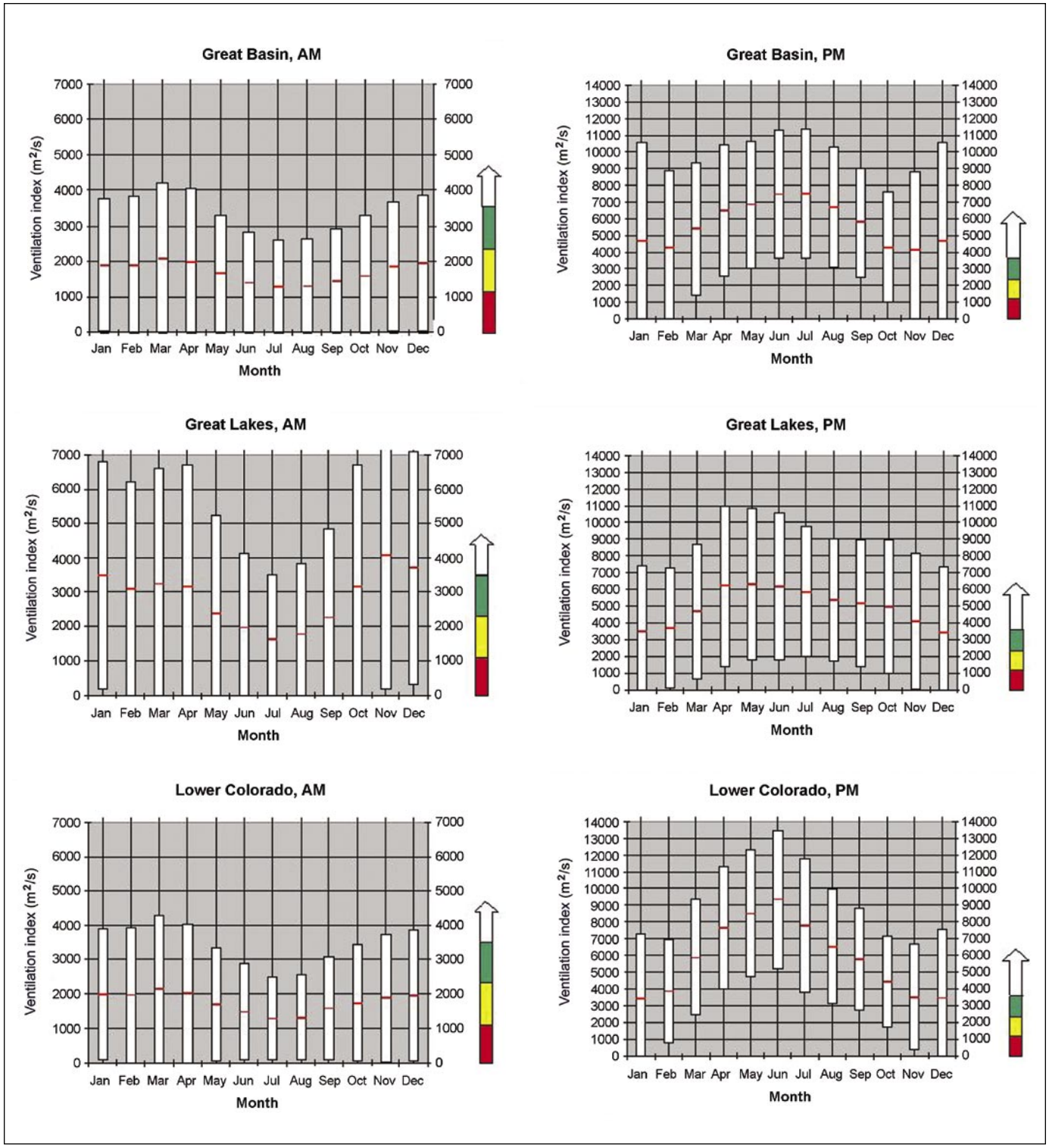


Figure 23—Continued.

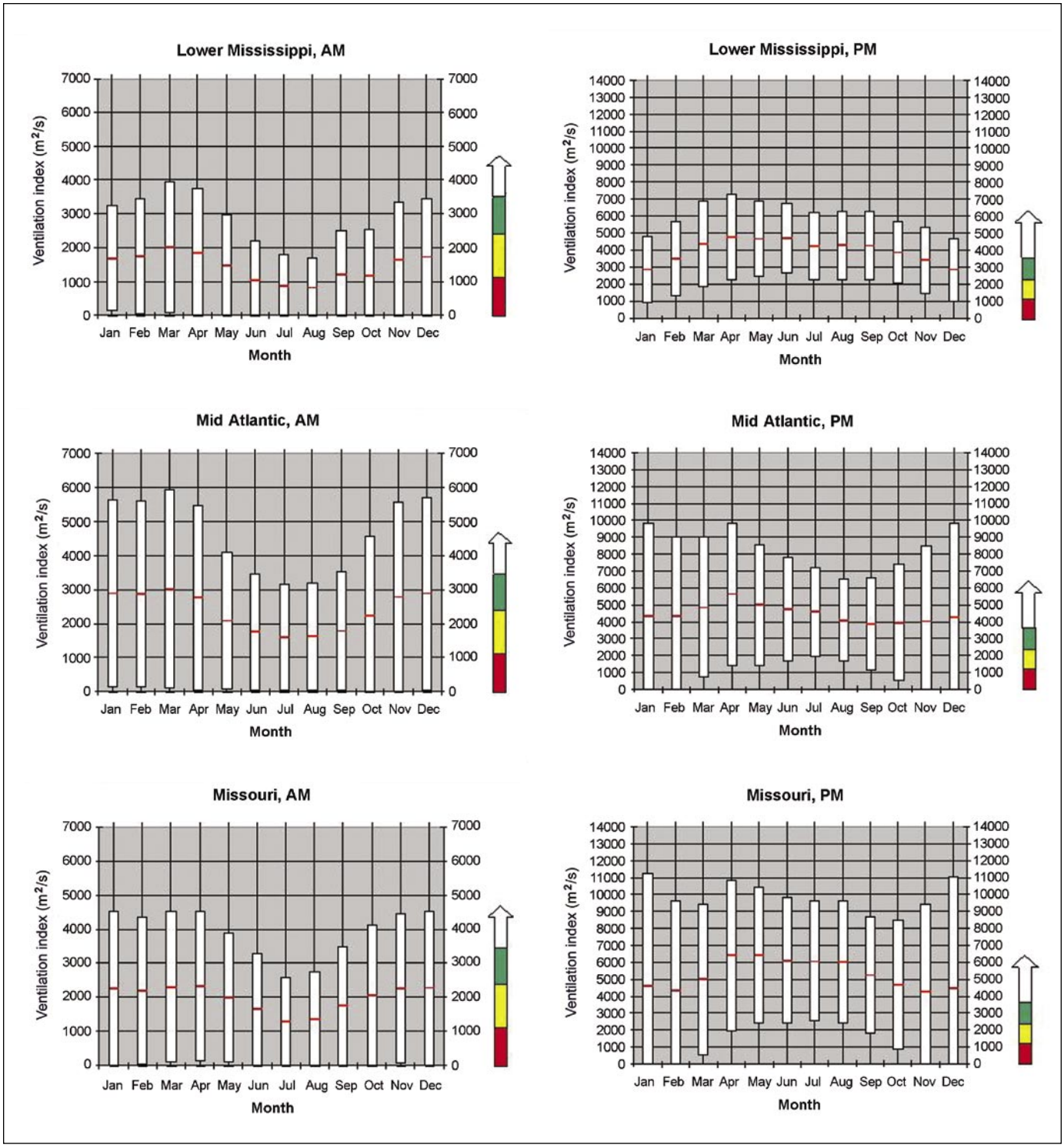
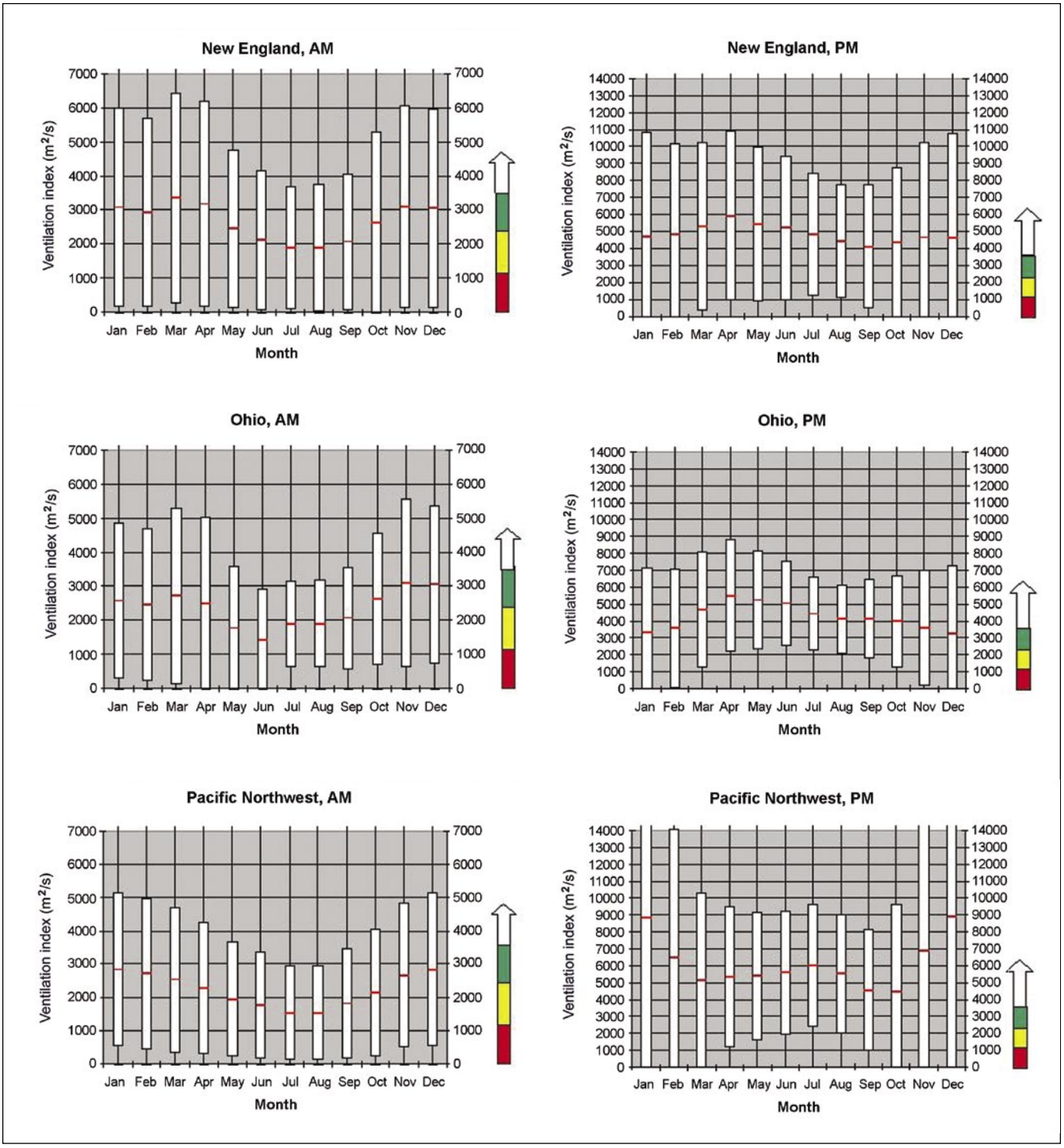


Figure 23—Continued.



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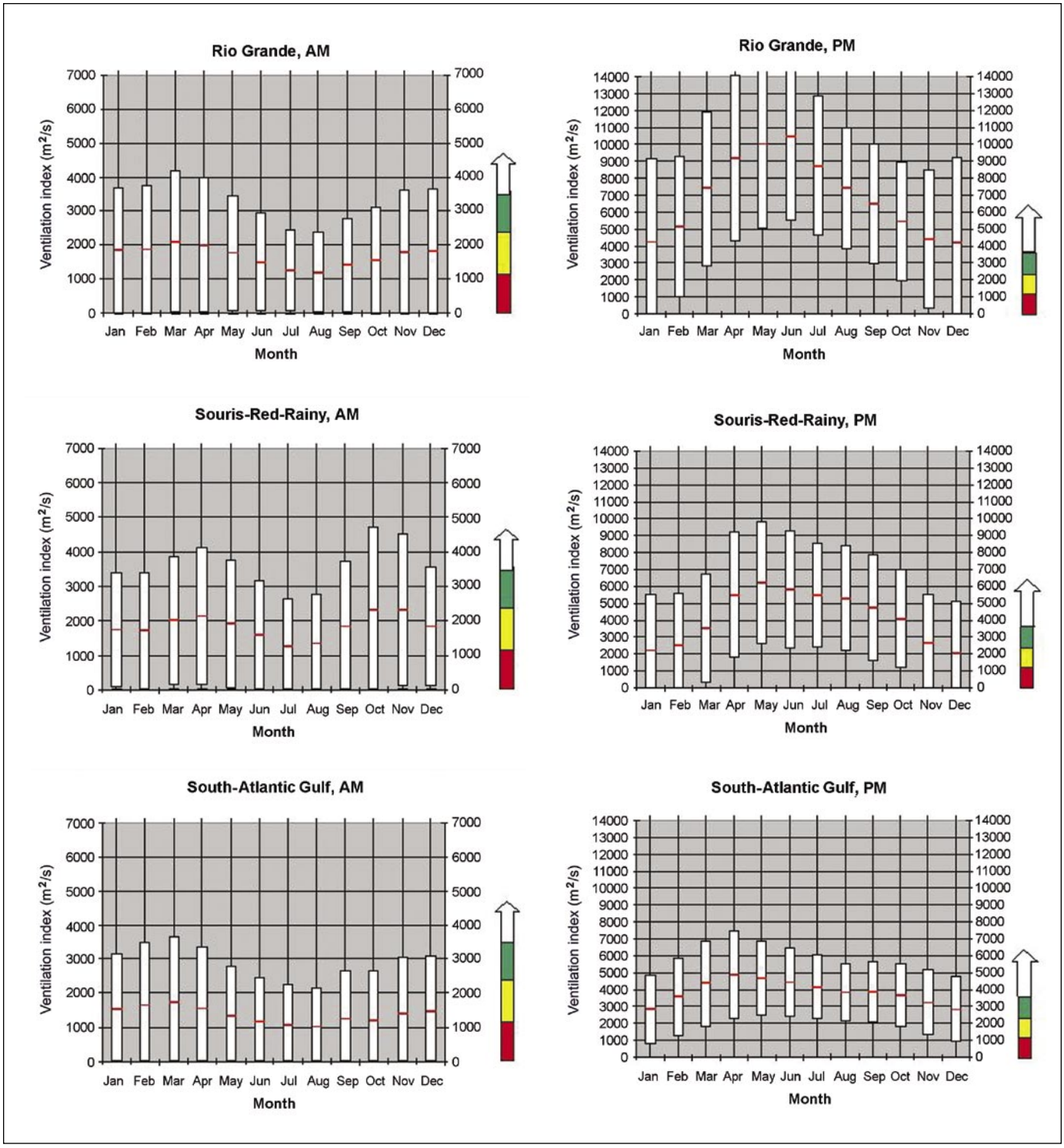

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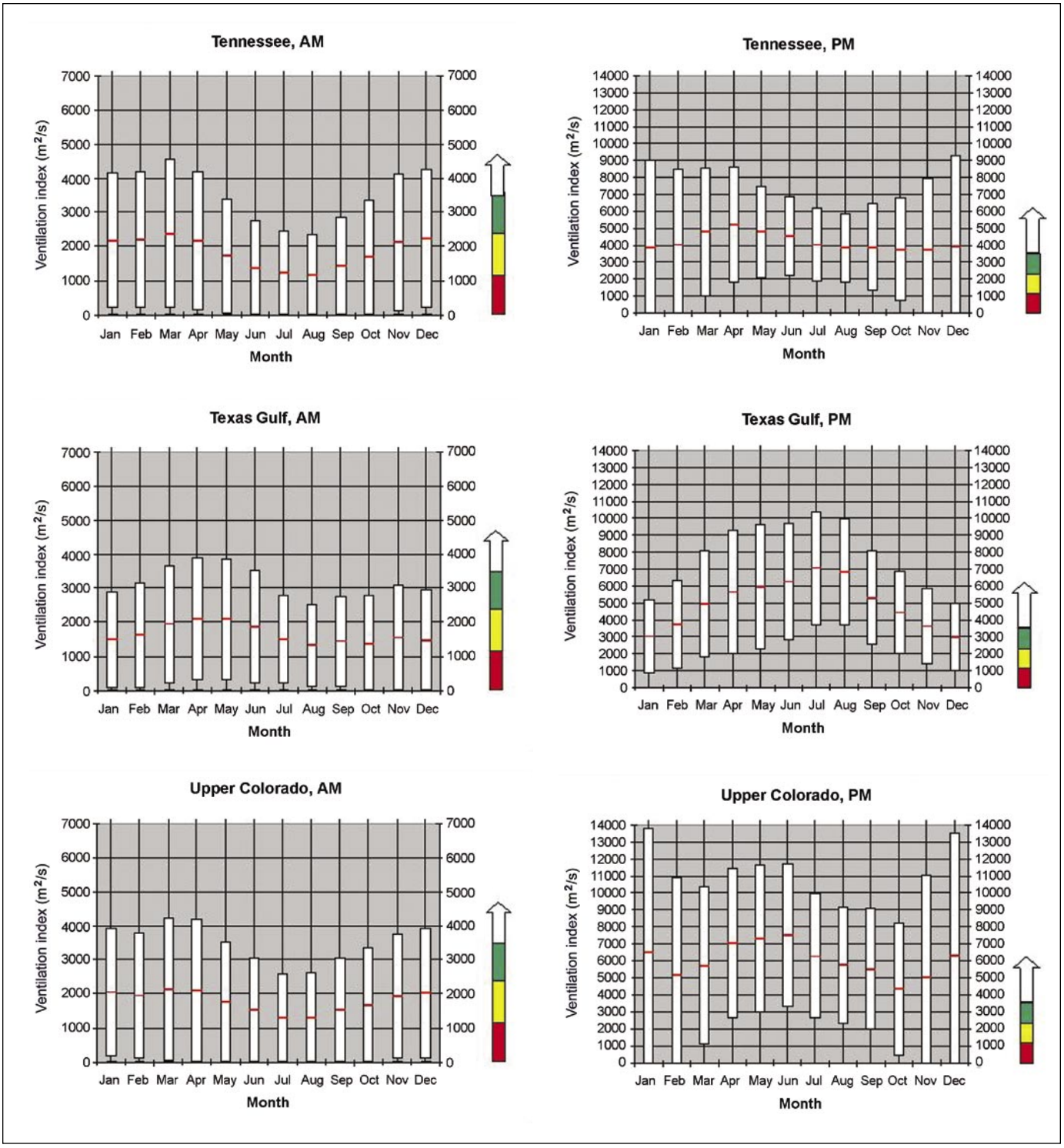

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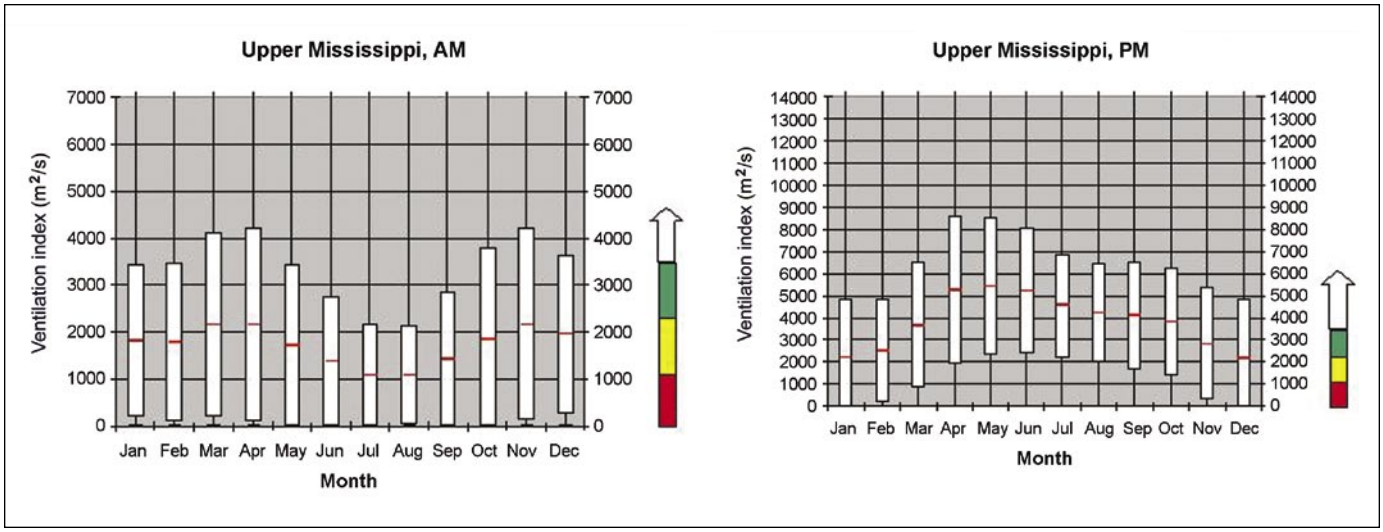

Figure 23—Continued.

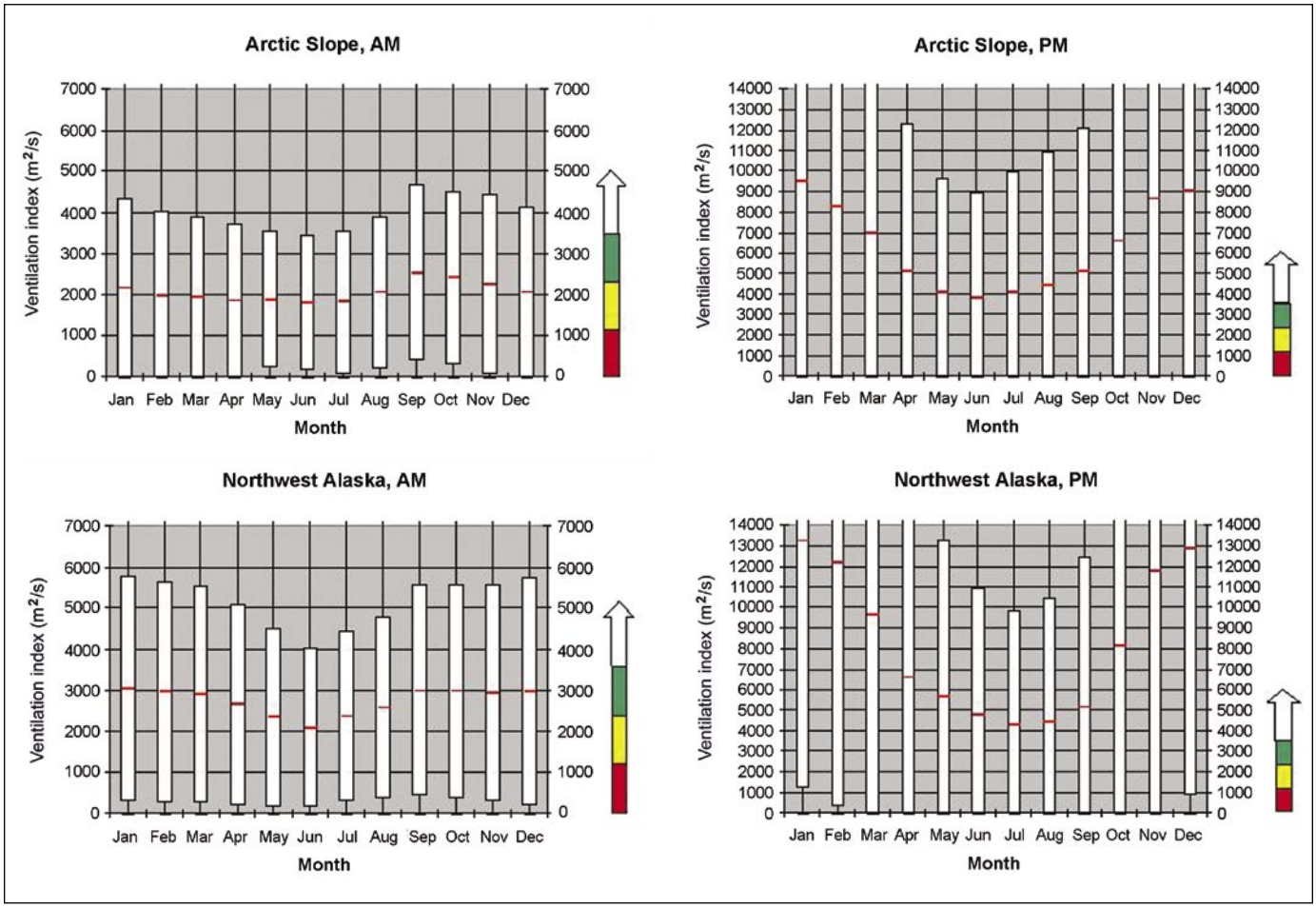

Figure 24—Box plots of ventilation index by month for each regional airshed in Alaska. Color bars to the right of each plot indicate categories of poor (red), marginal (yellow), fair (green) and good (white) ventilation potential.

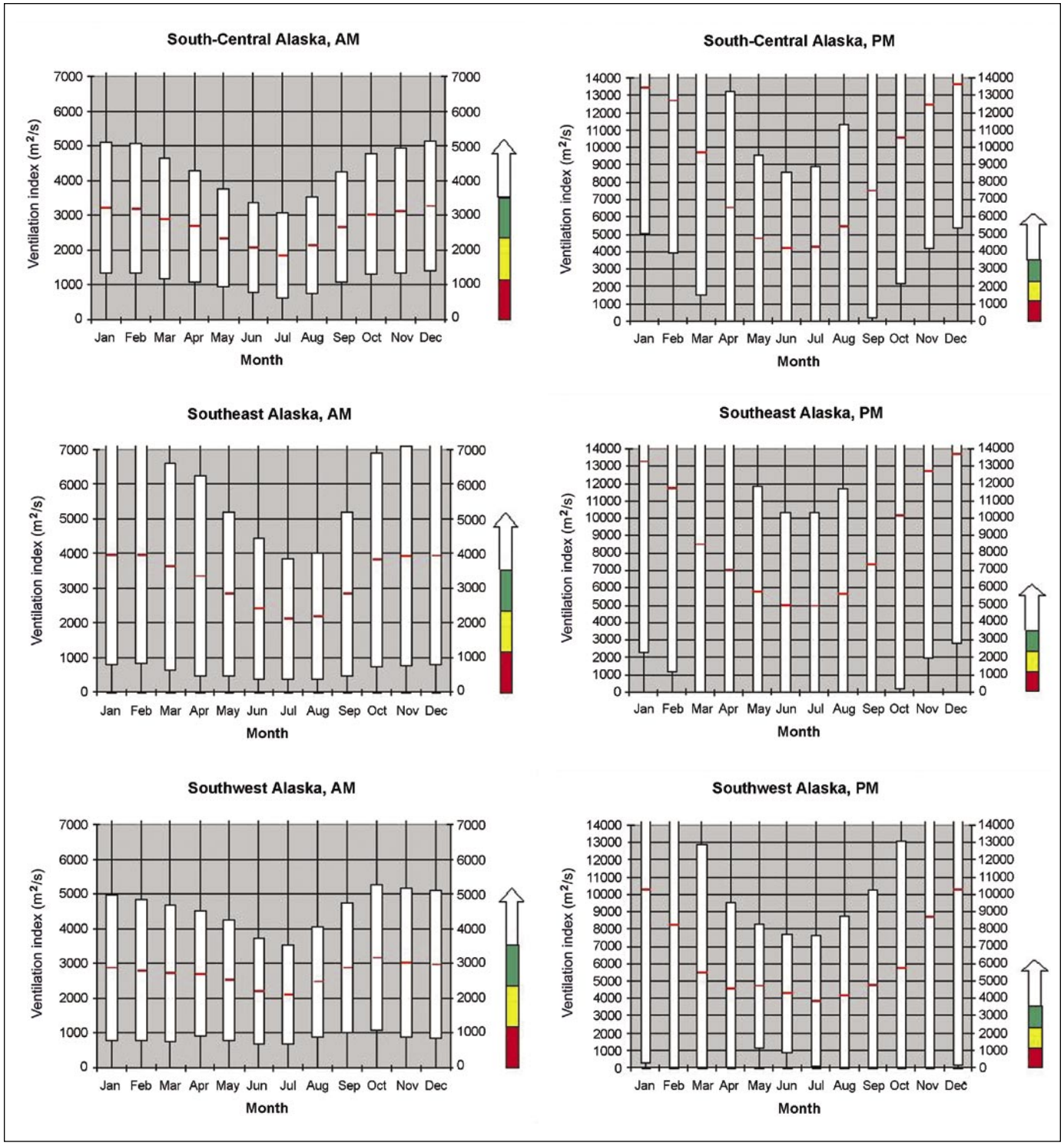

Figure 24—Continued.

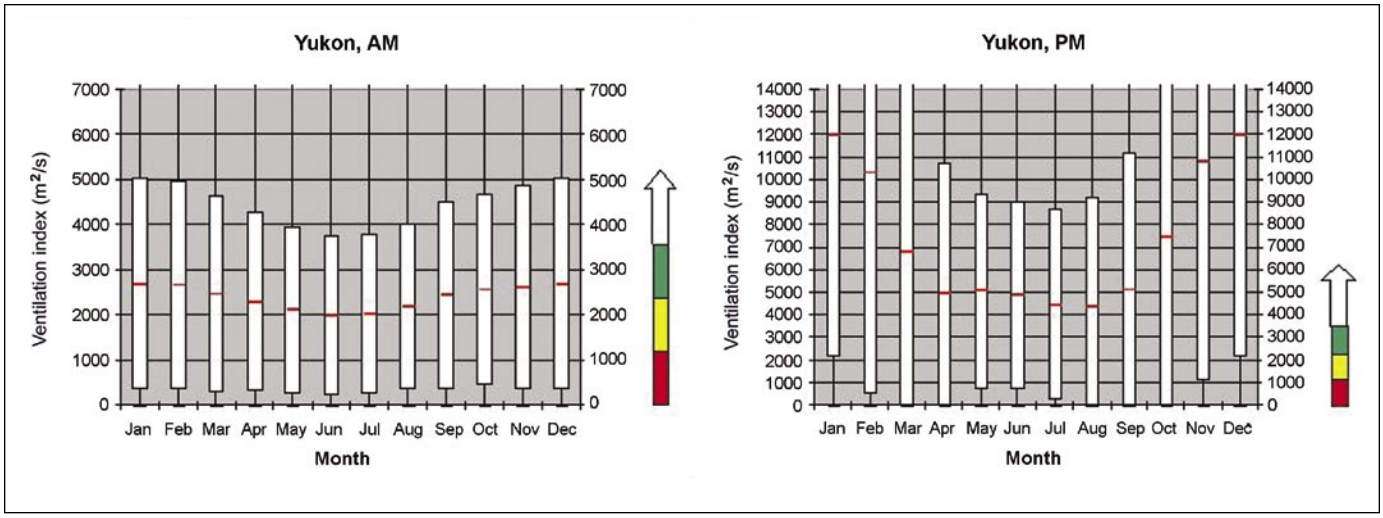

Figure 24—Continued.

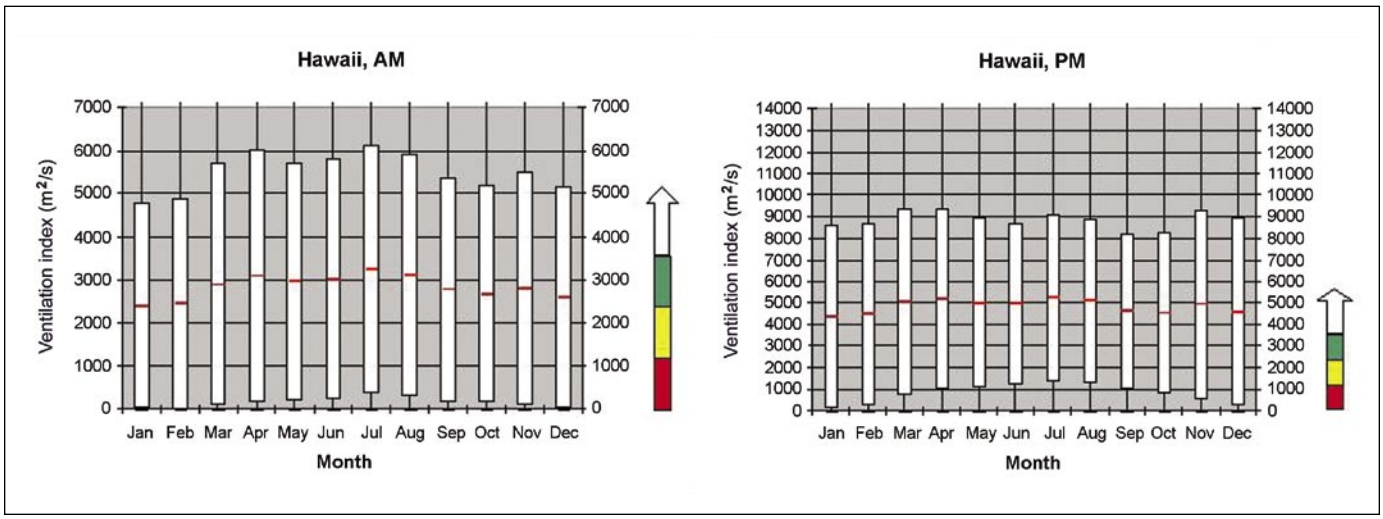

Figure 25—Box plots of ventilation index by month in Hawaii. Color bars to the right of each plot indicate categories of poor (red), marginal (yellow), fair (green) and good (white) ventilation potential.

Appendix 4: The Ventilation Climate Information System Web Site

The ventilation climate information system (VCIS) home page, http://www.fs.fed.us/pnw/fera/vent/, provides access to all documentation, maps, and graphs on ventilation potential in the United States and the associated assessment of air quality and visibility values at risk from wildland fire.

The “Maps and Graphs” button allows access to summary statistics of over 100 gigabytes of data through ArcIMS, the ArcInfo Internet Mapping Service by Environmental Systems Research Institute.[1]

- Alaska, Hawaii, and the contiguous 48 states are separate sites because their maps are projected differently.
- A current browser is needed for the “Maps and Graphs” section (Version 5 or greater of Microsoft Internet Explorer or Version 6 or greater of Netscape Navigator).
- The ArcIMS “Maps and Graphs” opens a separate window from other pages at this site. To return to the VCIS home page, click on the previously open window and use the back button or VENT home link.
- On selecting Alaska, Hawaii, or the contiguous 48 states, enlarge the browser window **before** the site map is loaded. You will be disappointed if you try to enlarge the window after the main map has loaded because the map will remain the size of the opening frame and not fill the extent of the new frame.
- ArcIMS is relatively slow. Therefore, the site works best with a broadband connection to the Internet rather than through a dial-up connection.
- Use the buttons at the top of the “Maps and Graphs” window to navigate through the map frame.

Toggle on or off the inset map.

Zoom in. After selecting this button, you can either (1) click a point on the map to center an interval zoom or (2) define the zoom area by clicking on one corner and holding the left mouse button while dragging open a box. Zooming closer and adding map features allows exact points to be selected. Close zooms also help illustrate the resolution of the data.

Zoom out.

Zoom to full extent.

Go back to last extent.

Pan. Move the map across the screen.

Print. This requires a few moments as it creates a new frame from which you can print just the map and scale or save it to a file.

[1] This use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

GET STATS "Get Stats" opens a table of buttons to retrieve statistics on all meteorological variables and all times for a selected point on the map.

- There are over 100 gigabytes of data that the system processes. Therefore, retrieving statistics may require a few moments, especially if using a dial-up connection.
- Click on a button for a time and variable of interest to view a plot of the historical frequency.
- Click on an open graph to reduce its size.
- You can print or save all open graphs by selecting the "Print" button at the top of the table.

- Use the legend on the right to build a map of interest.
  - Select the meteorological base map, monthly mean surface wind, mixing height, or ventilation index.
    - Select the time and month of interest.
    - Check box next to the meteorological window.
    - Click the "Refresh Map" button.
  - Check box next to any of the list of additional features, then click "Refresh Map" button.
- It may be possible to import a map that was built from VCIS into an ArcInfo application. This feature currently is untested.
- To save a map or graph, right click over the image and select "Save Picture As" or "Save Image As." For maps, this works best from the print window. You can save graphs from any window.

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