Attachment D

Visibility-Related PM Analyses.

General / Background:

This attachment describes the SP visibility-related PM analyses. The following analyses were undertaken to address statements made in, and subsequent comments to, the first draft (2003) EPA Particulate Matter (PM) Staff Paper (SP). Specifically, the draft PM SP noted in Chapter 6, that "EPA recognized that the selection of an appropriate level for a national secondary [$PM_{2.5}$] standard to address visibility protection was complicated by regional differences in visibility impairment due to several factors, including background and current levels of PM, the composition of PM, and average relative humidity." Preliminary analyses seem to indicate that these regional differences are not as significant when considering urban areas and daylight averaging periods. A rapidly growing national database of Federal Reference Method (FRM) $PM_{2.5}$, continuous $PM_{2.5}$ and $PM_{2.5}$ chemical speciation measurements now provides better opportunities to explore these factors.

General Goals:

Some fundamental goals of these analyses were:

- Compare regional levels (including East versus West) of urban $PM_{2.5}$ mass, all hours and select daylight periods.
- Compare regional composition (including East versus West) of urban $PM_{2.5}$.
- Compare regional relative humidity (including East versus West) for select time periods (e.g., 24-hour average and shorter daylight periods).
- Compare regional relationships of urban visibility versus $PM_{2.5}$ mass levels for select time periods (using reconstructed extinction as the indicator for visibility).
- Estimate levels of $PM_{2.5}$ needed to meet various visual range goals
- Estimate the rate of exeedance for various $PM_{2.5}$ levels for various different time periods.

Formulae and Assumptions:

The visibility analyses carried out make wide use of several formulas and assumptions:

- Reconstructed light extinction formula from IMPROVE:

b_{ext} = [(3) * *f(RH)* * $PM_{2.5}$ mass of sulfates] +
[(3) * *f(RH)* * $PM_{2.5}$ mass of nitrates] +
[(4) * $PM_{2.5}$ mass of OCM] +
[(10) * $PM_{2.5}$ mass of EC] +
[(1) * $PM_{2.5}$ mass of 'soil' or 'crustal'] +
[(0.6) * $PM_{10-2.5}$ mass, a.k.a. PMc] +
10 (Rayleigh scattering by gases)

Where …….

- b_{ext} is the calculated total light extinction in inverse megameters (Mm^{-1}). Also referred to as reconstructed light extinction (RE).
- $PM_{2.5}$ component masses are in units of $\mu g/m^3$.
- 'Sulfates', 'nitrates', 'OCM', 'EC', and 'crustal' defined as specified in Attachment C. Assume the 5 components estimate total $PM_{2.5}$ mass.
- *f(RH)* is the relative humidity adjustment factor that accounts for the relative humidity effects on hygroscopic aerosols. See Output A.i for a table of conversions. RH levels were capped at 95%, reflecting the lack of accuracy in higher relative humidity values and their highly disproportionate impact on reconstructed light extinction; hence, *f(RH)* was capped at 7.4.

- Koschmieder relationship between visible range (VR) and RE:

  VR (km) = 3912 / RE (Mm^{-1})

  Or, restated

  RE (Mm^{-1}) = 3912 / VR (km)
- Assumption 1: Speciation profiles are fairly consistent over time (i.e., on a daily basis). Hence, a 24-hour speciation profile can be applied to corresponding hourly mass data. This assumption was made due to: a) the desire to evaluate sub-daily time periods (i.e., hourly increments) of visibility and PM relationships, and b) the lack of sufficient amount and quality of hourly speciation data. Continuous speciation instruments are still undergoing further development and refinement. Continuous speciation data from a pilot study were evaluated (on a limited basis) to check this assumption. The nominal evaluation found some credibility in the assumption.
- Assumption 2: Speciation profiles are fairly consistent over space (e.g., within 50 miles). Hence, a speciation profile from a 'nearby' site can be applied to a non-source-oriented $PM_{2.5}$ continuous site (for the same day). Previous analyses by OAQPS have shown that multiple speciation sites in the same metropolitan area have similar profiles. In fact, there are considerable similarities at regional levels.
- Assumption 3: Hourly $PM_{10-2.5}$ levels can be estimated by applying regional ratios of 24-hr size cut ratios to hourly $PM_{2.5}$ data. Because of the desire to conduct the visibility analyses on an hourly (or multi-hour) time block, hourly $PM_{10-2.5}$ data were needed (per the RE formula). Nationally, there are *some* collocated hourly PM10 and hourly $PM_{2.5}$ monitors, but to limit the analyses to those sites would have produced a considerably small database. Thus, to make a more robust database, where collocated (PM10 and$PM_{2.5}$) hourly measurements were not available, the coarse fraction mass was estimated from hourly $PM_{2.5}$ using 24-hour based size fraction ratios. These ratios were computed via Analyses 6 (and corresponding Output A.6) in Attachment A.

<u>Construction of visibility database</u>

When this visibility analysis was first initiated (early 2004), the most current available urban $PM_{2.5}$ speciation and PM continuous data (that represented at least a full year, and was seasonally unbiased) were for the timeframe April 2002 through March 2003. (RH data were available for longer and more current periods but the PM data needs drove the time period selection). The first visibility database (db) was constructed

for that noted period. Later, around October 2004, the database was updated to represent the full year 2003 (January through December). A minor portion of the analyses referenced in this attachment reflect the older (3/2002 - 4/2003) db, but the majority reflects the newer db (1/2003 – 12/2003). If not otherwise specified, assume the newer db was utilized. The following statements document the creation of the newer db (though the processing steps taken for the early db were almost identical):

- EPA speciation network (ESpN) data for 2003 were provided by Tesh Rao of OAQPS on 9/21/2004. Data were retrieved from the EPA's national ambient air quality database, the Air Quality System (AQS), on May 17, 2004. See Attachment C for more details. For the visibility analyses, only the major profile component *percentages* (of the total of those 5 major components) were used. [The component percentages were multiplied by the $PM_{2.5}$ hourly data in order to estimate an hourly speciated dataset.] Henceforth, let CP represent the component percentage (in mass) of the major component mass sum. I.e., CP_sulf = component percentage of sulfates; CP_nit= component percentage of nitrates; CP_ocm = component percentage of organic carbon mass; CP_ec = component percentage of elemental carbon; and CP_cr = component percentage of crustal material.]
- $PM_{2.5}$ continuous data for 2003 were polled from AQS on August 24, 2004. [Data with method codes of 740 or 741 were excluded, per Tim Hanley of OAQPS.]
- PM_{10} continuous data for 2003 were retrieved from AQS on August 24, 2004.
- Raw National Weather Service (NWS) hourly data for 2003 (and also for 2001 and 2002; the additional 2 years were used in Analysis 4) were obtained from Bill Cox of OAQPS on March 19, 2004. Utilized fields were relative humidity (RH), barometric pressure (BP), and temperature (T).
- 10-year meteorological (relative humidity-related) database constructed by Ken Walsh of Science Applications International Corporation (SAIC) was received on February 18, 2004 and an addendum on October 5, 2004. The 10-year database contains averaged NWS site-level hourly RH and *f(RH)* (by site X month X hour). The 10 years of data encompassed 1988-1997.
- Database estimates for visibility (RE) were anchored at the continuous $PM_{2.5}$ sites.
- Hourly $PM_{2.5}$ and hourly PM10 data (for $PM_{10-2.5}$ estimation) were matched by site X date X hour; collocation was required. As noted above (assumption 3), if a continuous $PM_{2.5}$ site did not have collocated continuous PM_{10}, then hourly $PM_{10-2.5}$ value were estimated using regional 24-hour ratios of size fractions. Regional size fraction ratios were matched to the hourly $PM_{2.5}$ data by region.
- Hourly $PM_{2.5}$ data and daily speciation data were matched by site X date; either the speciation monitor had to be collocated or within 50 miles of the continuous $PM_{2.5}$ monitor. Note implementation of assumptions 1 and 2. [More than half of the observations in the visibility db had either collocated speciation data or speciation data from within 3 miles.]
- Raw meteorological (met) data and 10-year average NWS RH-related data *from the nearest NWS site* were matched to the $PM_{2.5}$ continuous data by date X hour. [More than 75% of the NWS data used were within 21 miles of the $PM_{2.5}$ continuous monitor; More than 50% of the NWS data used were within 11 miles of the $PM_{2.5}$ continuous monitor.]
- Using the merged inputs identified above and the RE formula also specified above, RE was computed (for each site-date-hour of 2003 where all components were available) according to the following general formula:

  RE = [(3) * *f(RH)* * (hourly $PM_{2.5}$ * CP_sulf)] +

[(3) * *f(RH)* * (hourly $PM_{2.5}$ * CP_nit] +
[(4) *(hourly $PM_{2.5}$ * CP_ocm)] +
[(10) * (hourly $PM_{2.5}$ * CP_ec)] +
[(1) * (hourly $PM_{2.5}$ * CP_cr)] +
[(0.6) * (hourly PMc)] +
10

Where …….

- The *f(RH)* used in the formula either corresponded to the actual, same date-hour *f(RH)* value (from RH table look-up), or to the 10-year average *f(RH)*.

- In addition to computing hourly RE with either 'actual' *f(RH)* or 10-year average *f(RH)*, additional variations of the RE formula were also calculated. Examples of RE computational variations utilized in SP visibility analyses include:
  - RE_real = RE as above using the 'actual' *f(RH)*.
  - RE_avg10 = RE as above using the 10-year average *f(RH)*.
  - RE_real_avgc = same as RE_real except that regional size fraction ratios were always used to estimate hourly PMc (not just when collocated hourly PM_{10} was available).
  - RE_avg10_avgc = same as RE_avg10 except that regional size fraction ratios were always used to estimate hourly PMc (not just when collocated hourly PM_{10} was available).
  - RE_real_NC = same as RE_real except that the $PM_{10-2.5}$ component was omitted.
  - RE_avg10_NC = same as RE_avg10 except that the $PM_{10-2.5}$ component was omitted.
- SAS code was used to create the db's:
  - 'match hourly to nws and spec - 1b.sas' was used to ascertain a list of available collocated and/or nearby sites for $PM_{2.5}$ continuous, $PM_{2.5}$ speciation, and NWS.
  - 'merge espn nws cont - 2b.sas' merged the three input data files noted above and derived *f(RH)* for 'actual' RH.
  - 'pm10 - 3b.sas'merged continuous PM10 data (to estimate hourly $PM_{10-2.5}$ when available)
  - 'add regional pmc ratio - 4b.sas' added the regional ratios of 24-hour size fractions (to estimate hourly $PM_{10-2.5}$ if hourly data PM10 were available at the site.
  - 'final calcs - 5b.sas' made the RE computations.

Analysis 1 – Comparison of regional levels (including East versus West) of urban $PM_{2.5}$ mass and components

Goals:

- ? To characterize and compare regional and East and West urban $PM_{2.5}$ concentration levels.

Outputs:

- o Annual averages of $PM_{2.5}$ (24-hour and shorter time-frame) were calculated from different networks and/or portions of networks. Various tables and graphs show the comparisons. See Output D.1.

Methods:

- SAS procedures (MEANS and SUMMARY) were used to compute averages. Freelance Graphics was used to make the plots.

Analysis 2 – Evaluation of relative humidity (RH) data.

Goals:

- ? To characterize the diurnal pattern of RH and FRH in various areas (e.g., East versus West).
- ? To compare RH and *f(RH)* from different db's

Outputs:

- o Various plots and tables were generated. See Output D.2.

Methods:

- SAS code ('rh boxplots.sas' and 'RH boxplots for visdb.sas') was used to generate the diurnal distribution box-plots.
- SAS code ('diurnal final.sas') generated the diurnally summarized *average* data; corresponding line plots were created in Freelance Graphics.
- The RH table was created in Excel.

Analysis 3 – Evaluation of relationship between RE and $PM_{2.5}$; evaluation of diurnal patterns in RE and model components; and evaluation of different averaging time blocks

Goals:

- ? To assess the relationship between RE and $PM_{2.5}$
- ? To characterize the diurnal patter of RE and related components by region.
- ? To ascertain the cause of diurnal/model variations ('outliers').
- ? To investigate different time periods as possible candidates for an averaging time.

Outputs:

- o Various line-plots and tables were generated; see Output D.3.

Methods:

- SAS code ('diurnal final.sas') generated the diurnally summarized *average* data.
- The line-plots were created with Freelance Graphics
- Tables were made in Excel.

Analysis 4 – Estimation of $PM_{2.5}$ levels needed to achieve various visual range goals

Goals:

- ? Help inform decision regarding 'level' of possible secondary standard (i.e., estimate the $PM_{2.5}$ levels needed to achieve various visual ranges).

Outputs:

- Regional boxplots for various visual range goals were generated; see Output D.4.

Methods:

- The methodology utilized: a) the formulas identified above for 'construction of visibility database'; b) estimates of annual regional speciation profiles as percents of total (using all available 2003 ESpN data, not just sites used in the visibility database); c) estimates of regional ratios of $PM_{10-2.5}$ to $PM_{2.5}$ (from Analysis A.6 in Attachment A; term 'ratio_pmc/pmf')); and estimates of the regional distributions of hourly RH (from all NWS site for the period 2001-2003, not just sites in the visibility db). Given those formulae and inputs, we then solved for hourly $PM_{2.5}$ for various visual range targets. SAS code ('target pmf for visual range goals.sas') was used to process the inputs and generate the boxplots. Below is a walk-through of the formulae; the underlined fields are the 'knowns' (using inputs b, c, & d):

As above …	RE =	[(3) * *f(RH)* * (hourly $PM_{2.5}$ * CP_sulf)] + [(3) * *f(RH)* * (hourly $PM_{2.5}$ * CP_nit] + [(4) *(hourly $PM_{2.5}$ * CP_ocm)] + [(10) * (hourly $PM_{2.5}$ * CP_ec)] + [(1) * (hourly $PM_{2.5}$ * CP_cr)] + [(0.6) * (hourly $PM_{10-2.5}$)] + 10
As above …	RE =	3912 / VR
Substituting …	'PM$_{2.5}$ * ratio_pmc/pmf' for 'PM$_{10-2.5}$'	
Hence …	$PM_{2.5}$ =	(RE -10) / (3* *f(RH)* * CP_sulf) + (3 * *f(RH)* * CP_nit) + (4 * CP_ocm) + (10 * CP_ec) + (1 * CP_cr) + (.6* ratio_pmc/pmf))
Thus …	For each hour and each region, 100 estimates of $PM_{2.5}$ were calculated (f(RH) being the varying field, $f(RH)_1$ to $f(RH)_{100}$ representing the regional distribution. Hourly $PM_{2.5}$ estimates were then averaged to the desired averaging time (24-hours or 4-hour block, 12 p.m. - 4 p.m.)	

Analysis 5 – Estimation of the exceedance levels of various $PM_{2.5}$ levels

Goals:

- Estimate county exceedance levels (as percentage of days) for varying $PM_{2.5}$ levels for different timeframes.

Outputs:

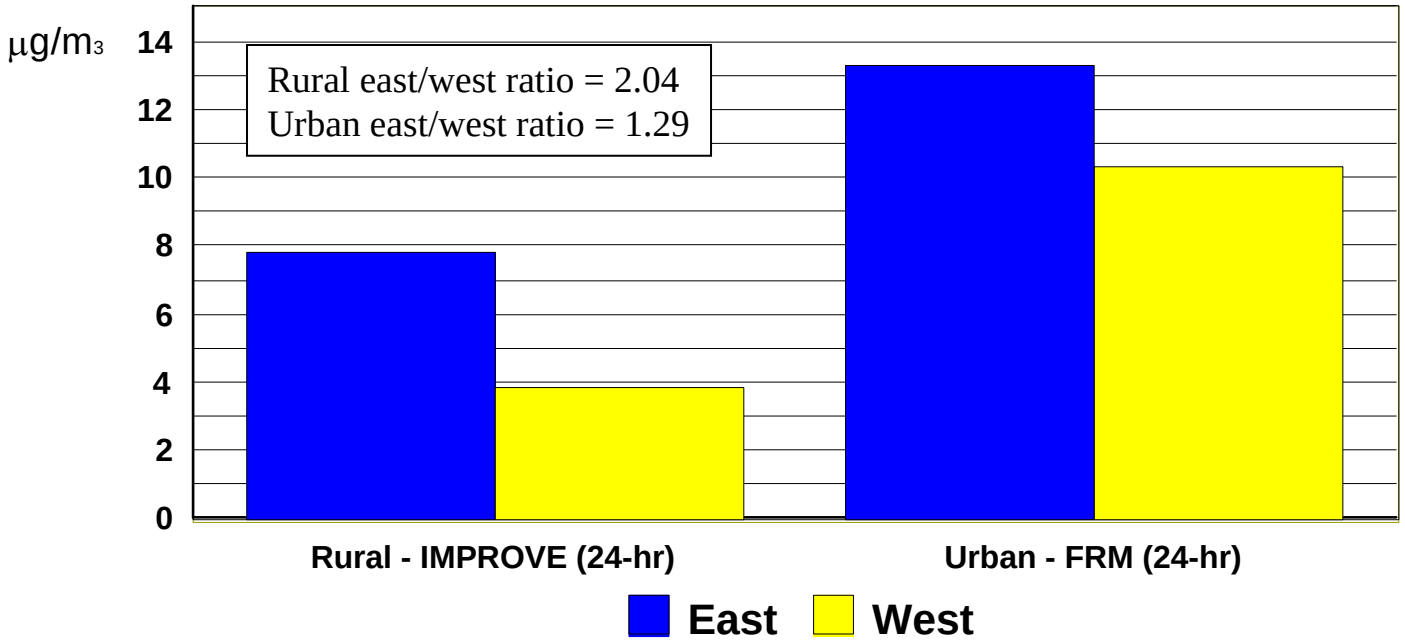
- Line-plots, distinguishing between 'eastern' and western' counties, were generated for a 24-hour period and 12 p.m. - 4 p.m. block; see Attachment D.5.

Methods:

- All available continuous 2001-2003 $PM_{2.5}$ data were used. Data were aggregated to desired averaging time (by sit-day). The county level maximum for each day (of the possible 1095 days) for the specified time-frame was identified. This maximum was compared to $PM_{2.5}$ levels from 5 to 65 $\mu g/m^3$ in 5 $\mu g/m^3$ increments. The results were plotted as a percentage of the total available (monitored in the county)

days. SAS code (‘violating thresh bigdb.sas’) for the data manipulation and plotting.

Year 2003 (1/'03-12/'03)

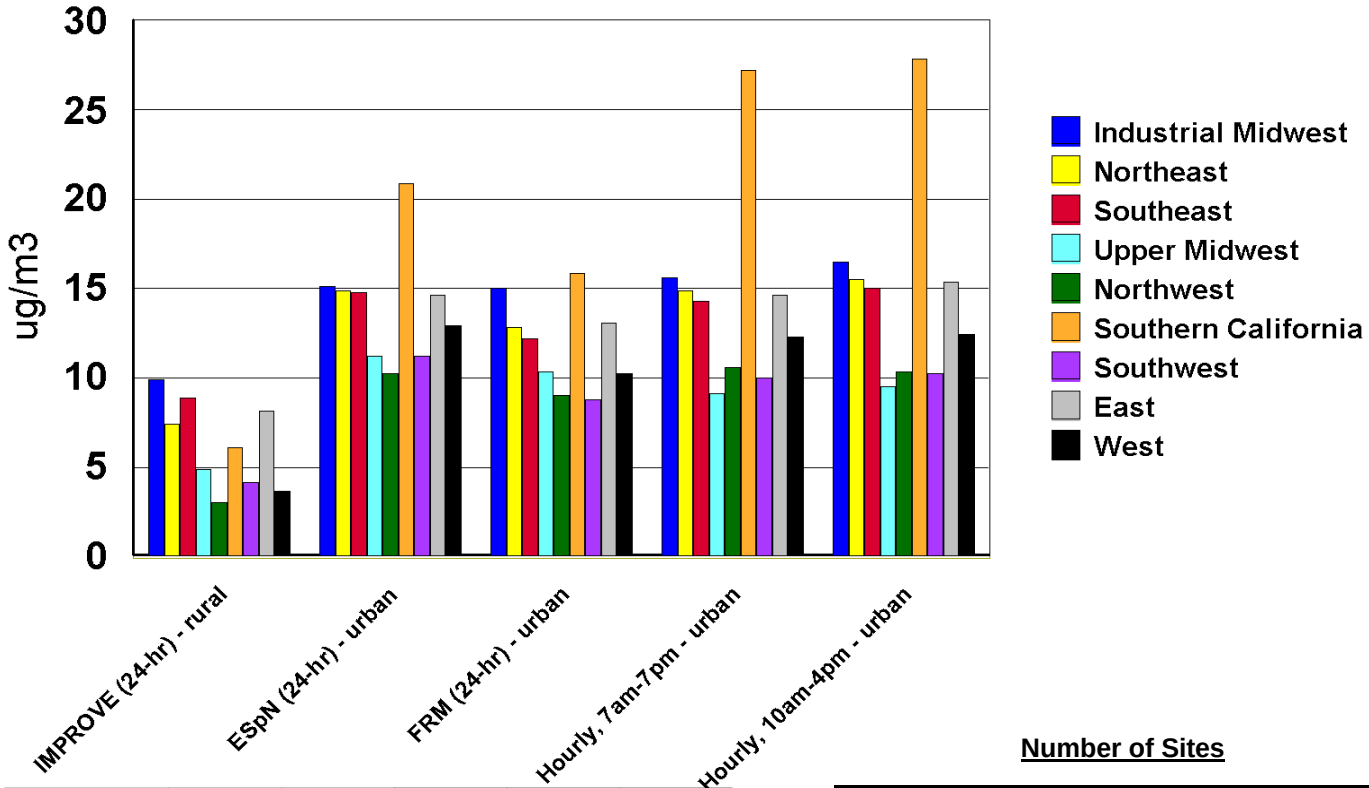


Note: Urban IMPROVE sites and rural FRM sites excluded.

$PM_{2.5}$ concentration differences between eastern and western areas and between rural and urban areas for 2003

PM2.5 Concentrations, Annual Averages

(4/01/02 - 3/31/03) ('old' vis. db)



east/west ratio =	2.23 IMP	1.13 ESpn	1.27 FRM	1.19 Hrly 7-7	1.24 Hrly 10-4

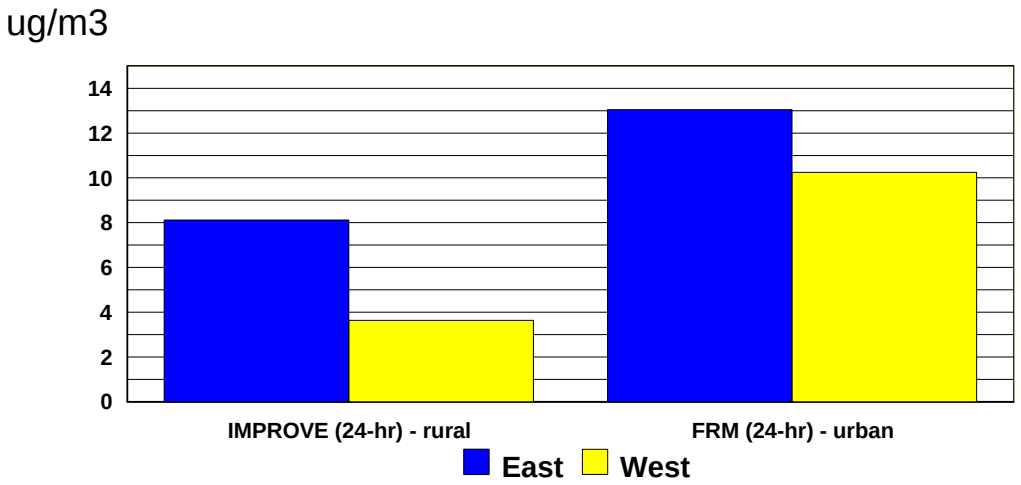
Larger differences in rural east/west mass than urban east/west mass!

Number of Sites

Region	IMPROVE	Speciation	FRM	Continuous
Industria	12	35	249	19
Northeast	15	26	191	25
Southeast	13	37	264	33
Upper Mid	6	8	79	2
Northwest	49	13	154	9
Southern	9	5	48	2
Southwest	22	2	56	6
East	46	106	783	79
West	80	20	258	17

East/West Rural/Urban differences in PM2.5 Mass

(4/01/02 - 3/31/03)



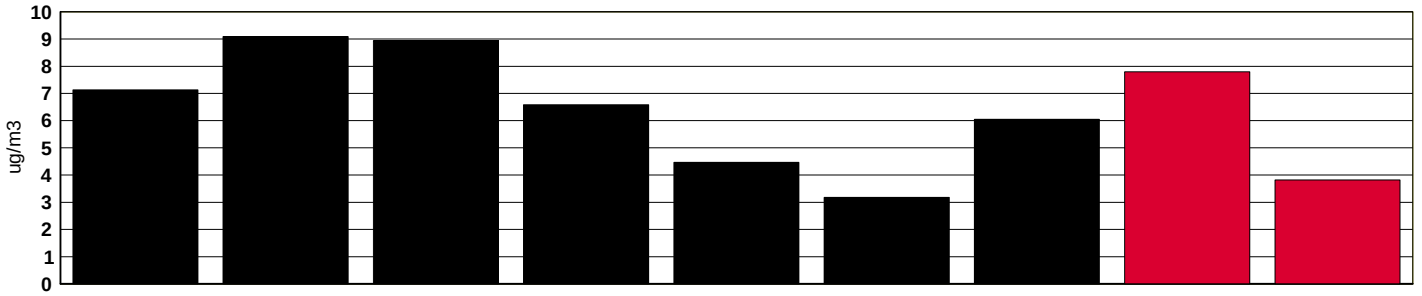
East/West urban PM2.5 concentrations more similar than rural east/west concentrations.

Rural east/west ratio = 2.23
Urban east/west ratio = 1.27

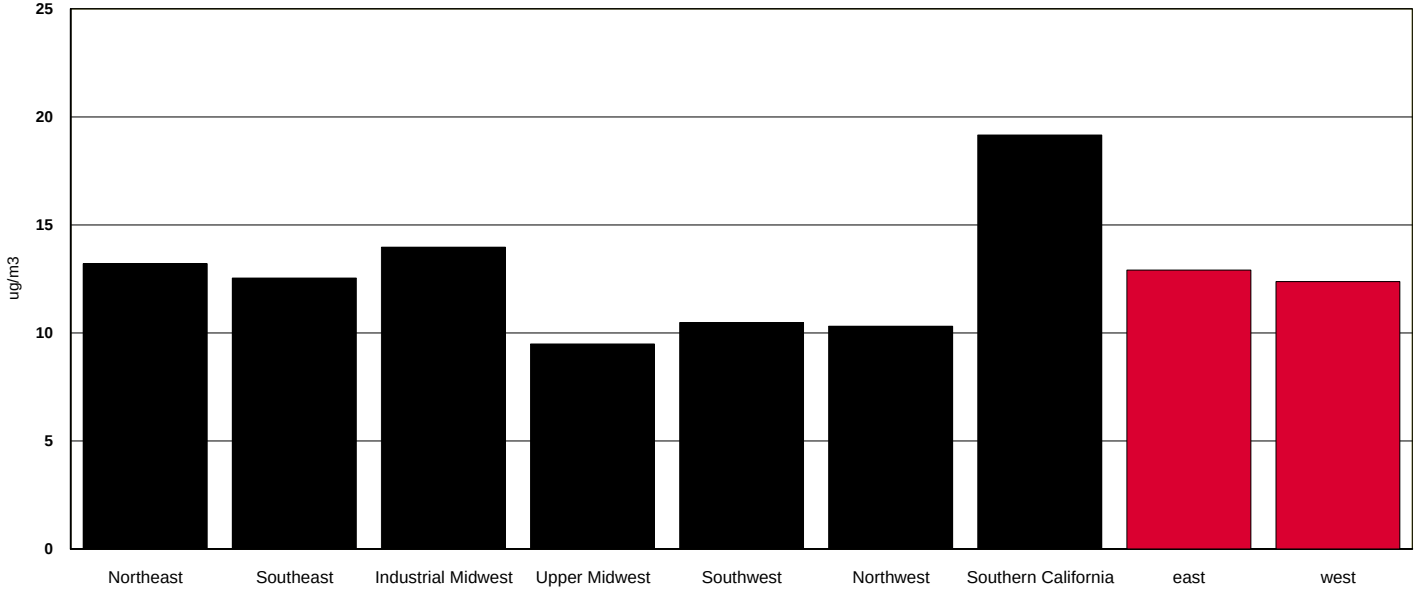
Note: Urban IMPROVE sites and rural FRM site excluded.

Urban East / West $PM_{2.5}$ Mass Levels are More Similar than Rural East / West Mass Levels

2003 Annual average PM2.5 at rural IMPROVE sites East/West=2.04

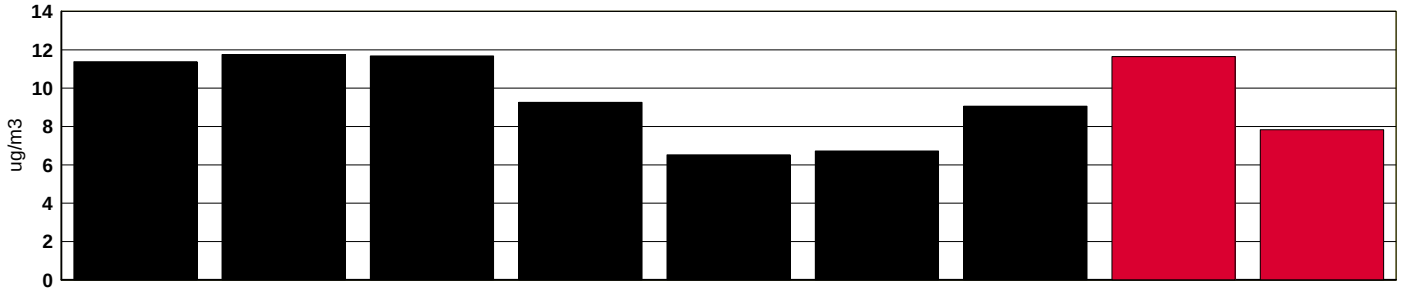


2003 Annual average PM2.5 at urban ESpN sites East/West=1.04

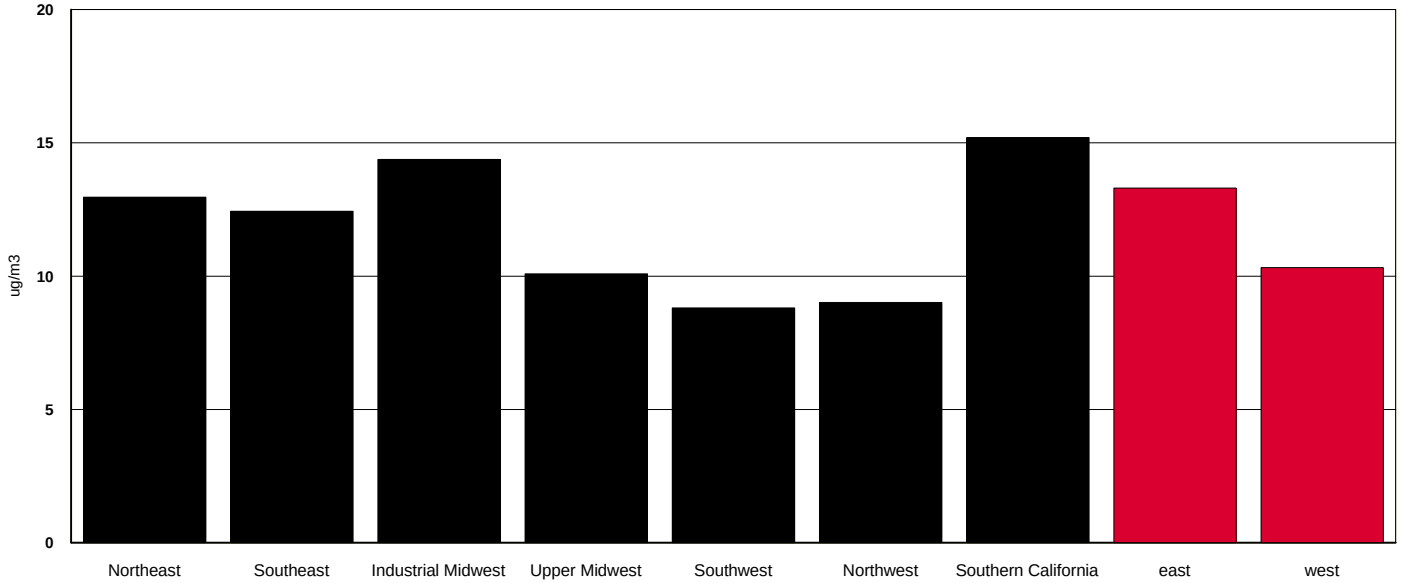


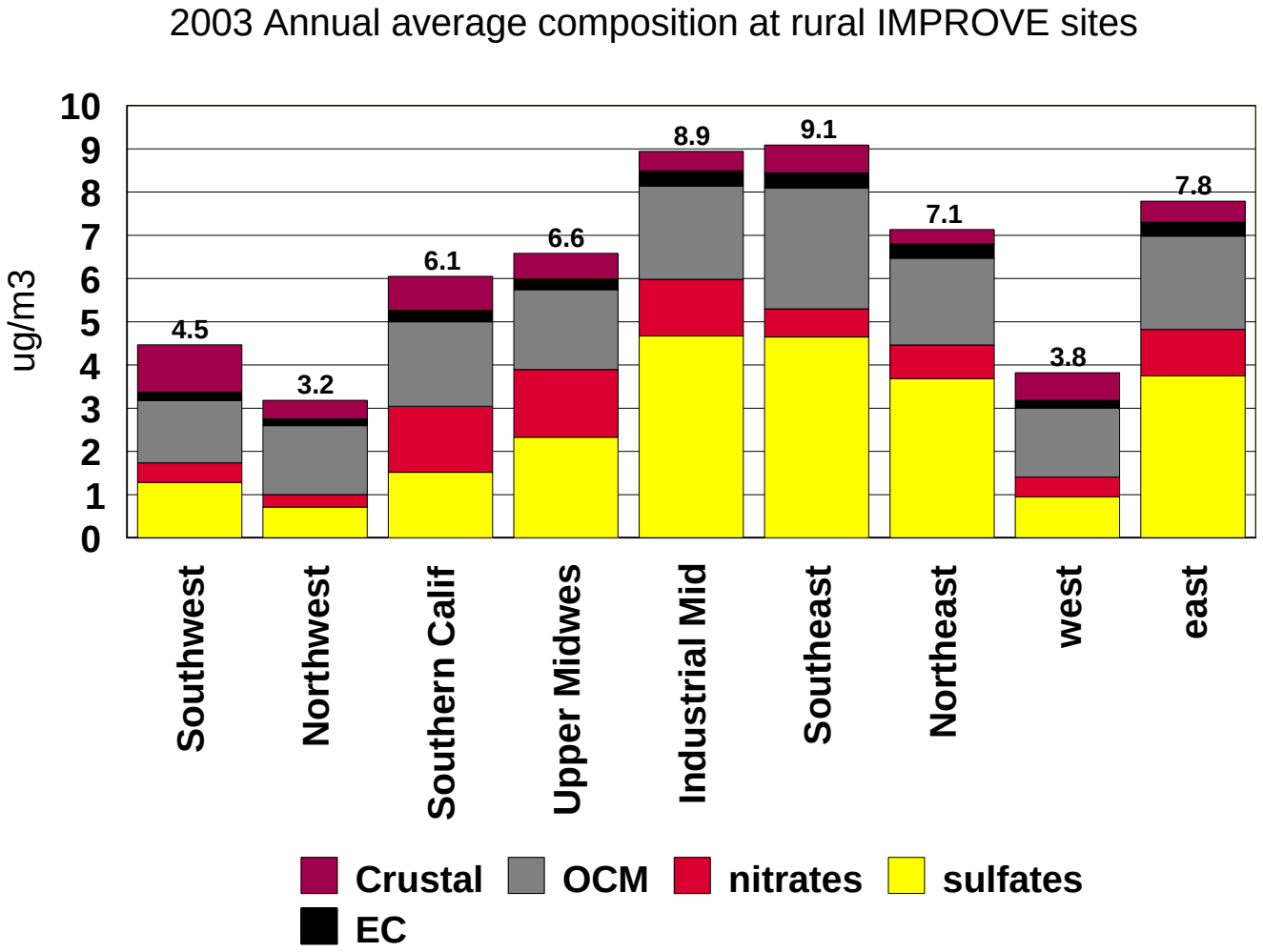
Urban East / West $PM_{2.5}$ Mass Levels are More Similar than Rural East / West Mass Levels

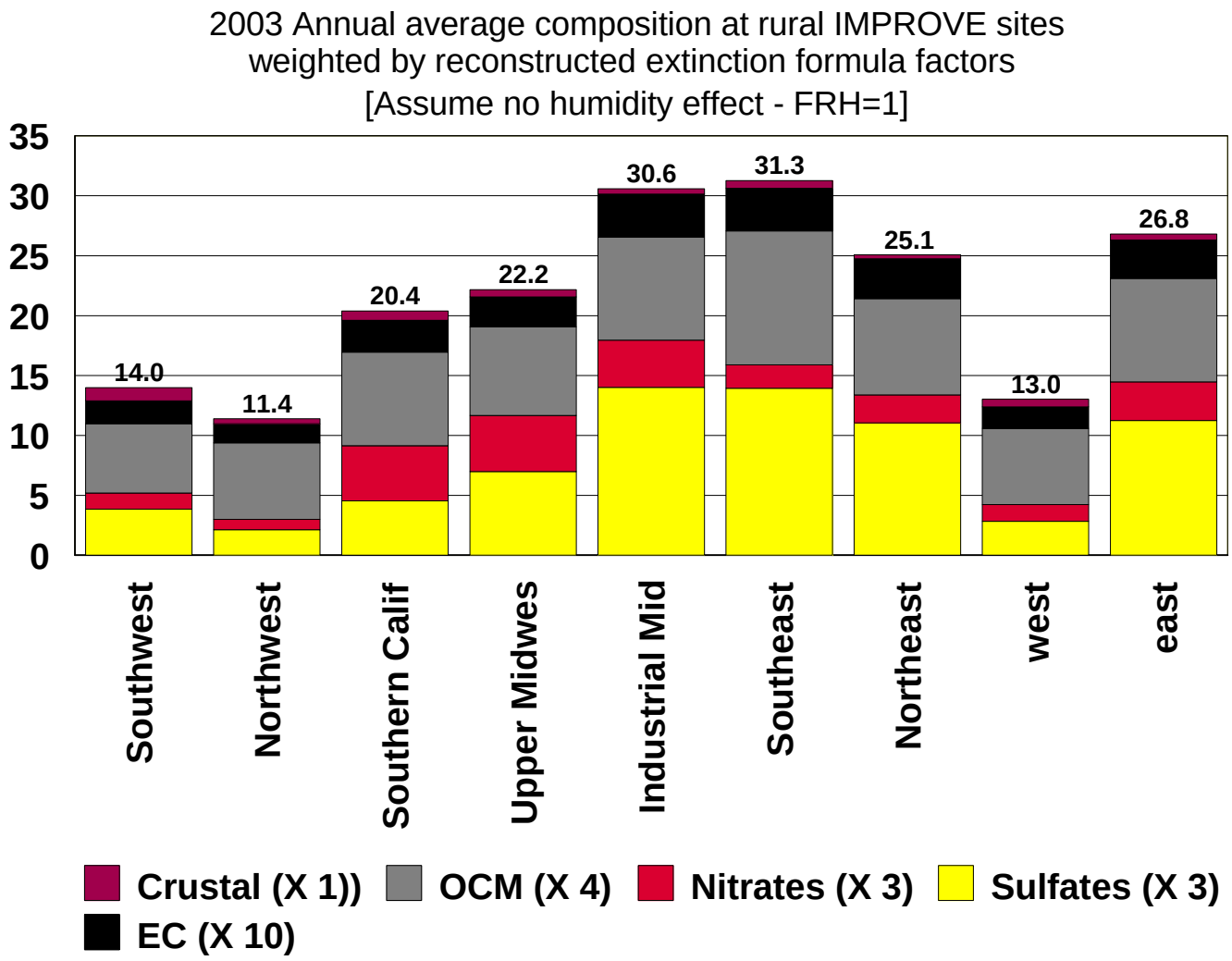
2003 Annual average PM2.5 at rural FRM sites East/West=1.48

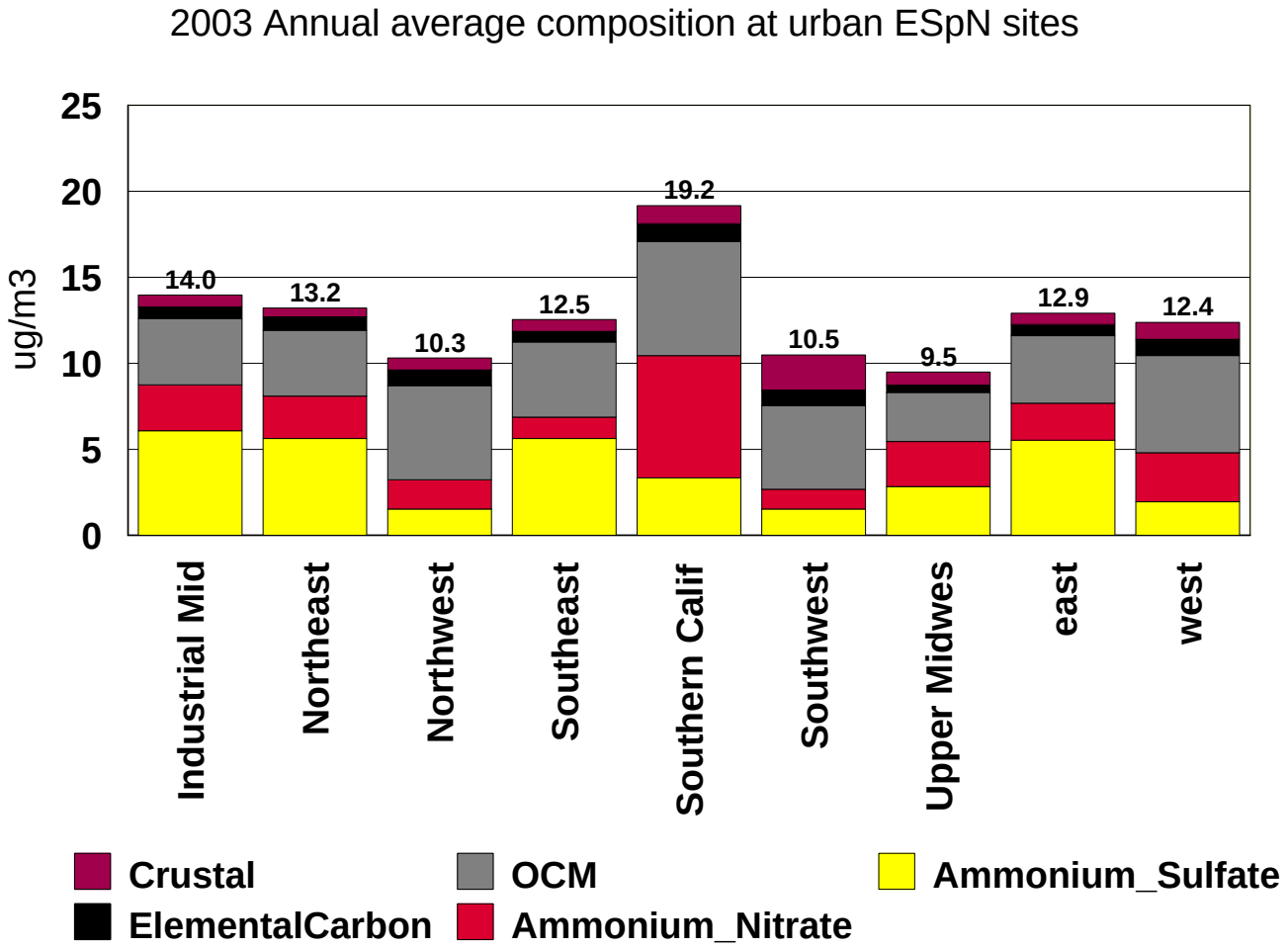


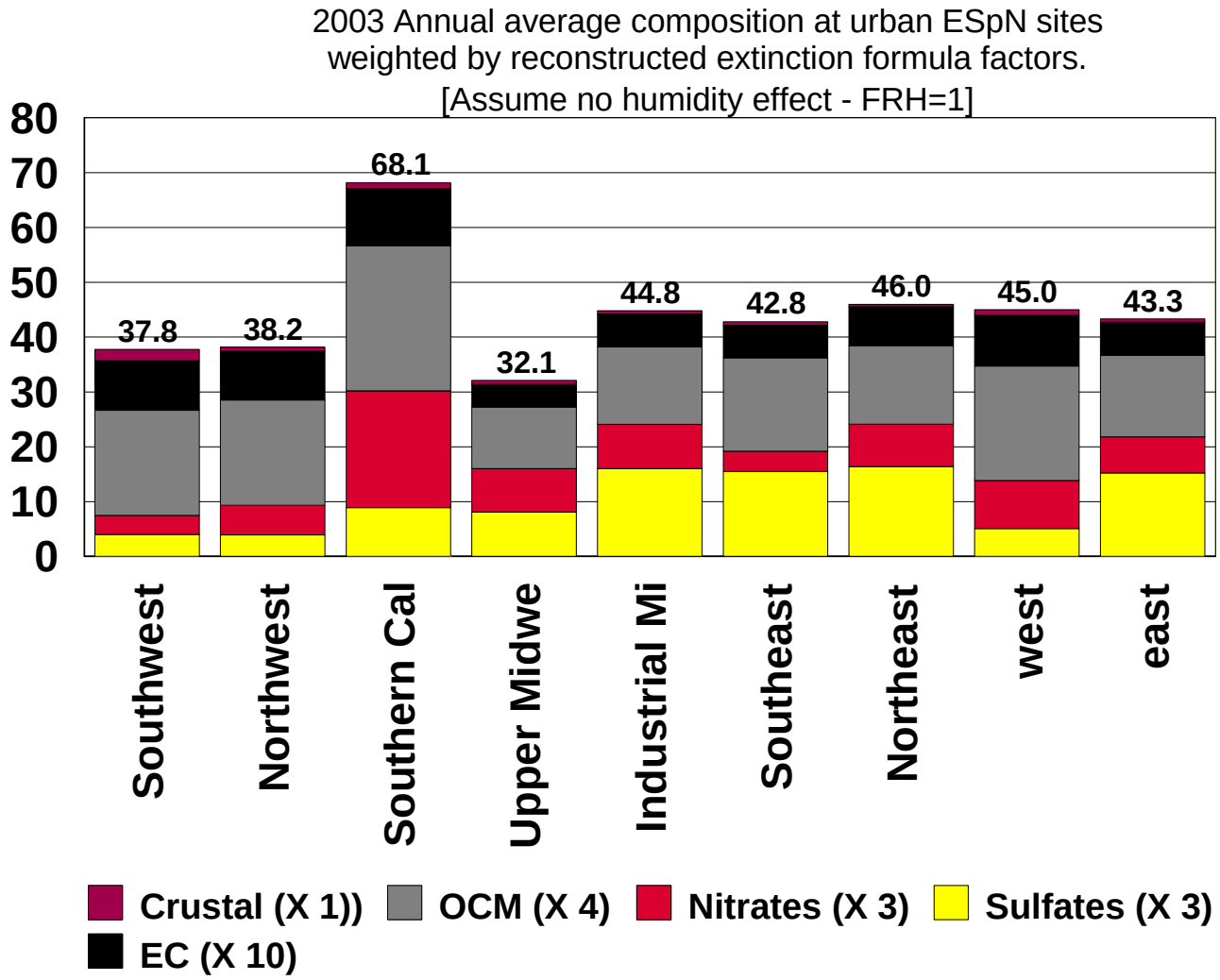
2003 Annual average PM2.5 at urban FRM sites East/West=1.29




2003 Annual average composition at rural IMPROVE sites
ug/m3
10
9
8
7
6
5
4
3
2
1
0
4.5
3.2
6.1
6.6
8.9
9.1
7.1
3.8
7.8
Southwest
Northwest
Southern Calif
Upper Midwes
Industrial Mid
Southeast
Northeast
west
east
Crustal
OCM
nitrates
sulfates
EC


2003 Annual average composition at rural IMPROVE sites
weighted by reconstructed extinction formula factors
[Assume no humidity effect - FRH=1]
35
30
25
20
15
10
5
0
14.0
11.4
20.4
22.2
30.6
31.3
25.1
13.0
26.8
Southwest
Northwest
Southern Calif
Upper Midwes
Industrial Mid
Southeast
Northeast
west
east
Crustal (X 1))
OCM (X 4)
Nitrates (X 3)
Sulfates (X 3)
EC (X 10)

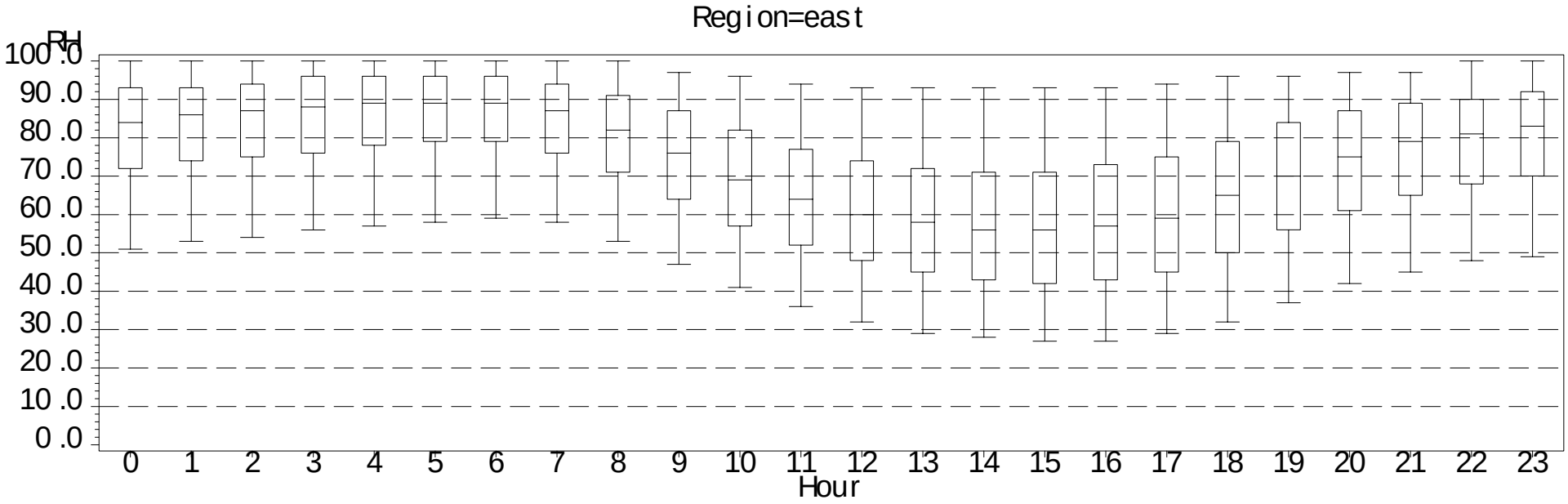

2003 Annual average composition at urban ESpN sites
ug/m3
25
20
15
10
5
0
14.0
13.2
10.3
12.5
19.2
10.5
9.5
12.9
12.4
Industrial Mid
Northeast
Northwest
Southeast
Southern Calif
Southwest
Upper Midwes
east
west
Crustal
ElementalCarbon
OCM
Ammonium_Nitrate
Ammonium_Sulfate

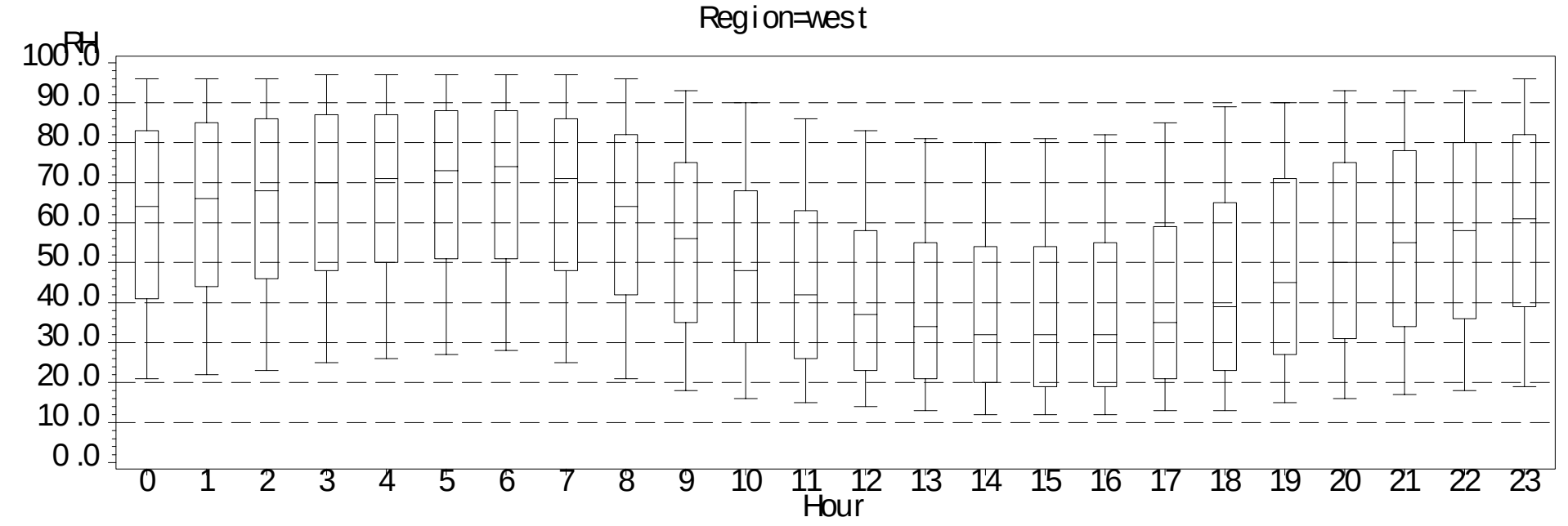

2003 Annual average composition at urban ESpN sites
weighted by reconstructed extinction formula factors.
[Assume no humidity effect - FRH=1]
80
70
60
50
40
30
20
10
0
37.8
38.2
68.1
32.1
44.8
42.8
46.0
45.0
43.3
Southwest
Northwest
Southern Cal
Upper Midwe
Industrial Mi
Southeast
Northeast
west
east
Crustal (X 1))
OCM (X 4)
Nitrates (X 3)
Sulfates (X 3)
EC (X 10)

Average 12-4pm PM2.5,PM2.5 profile, and PM10-2.5 in 2003 visibility db

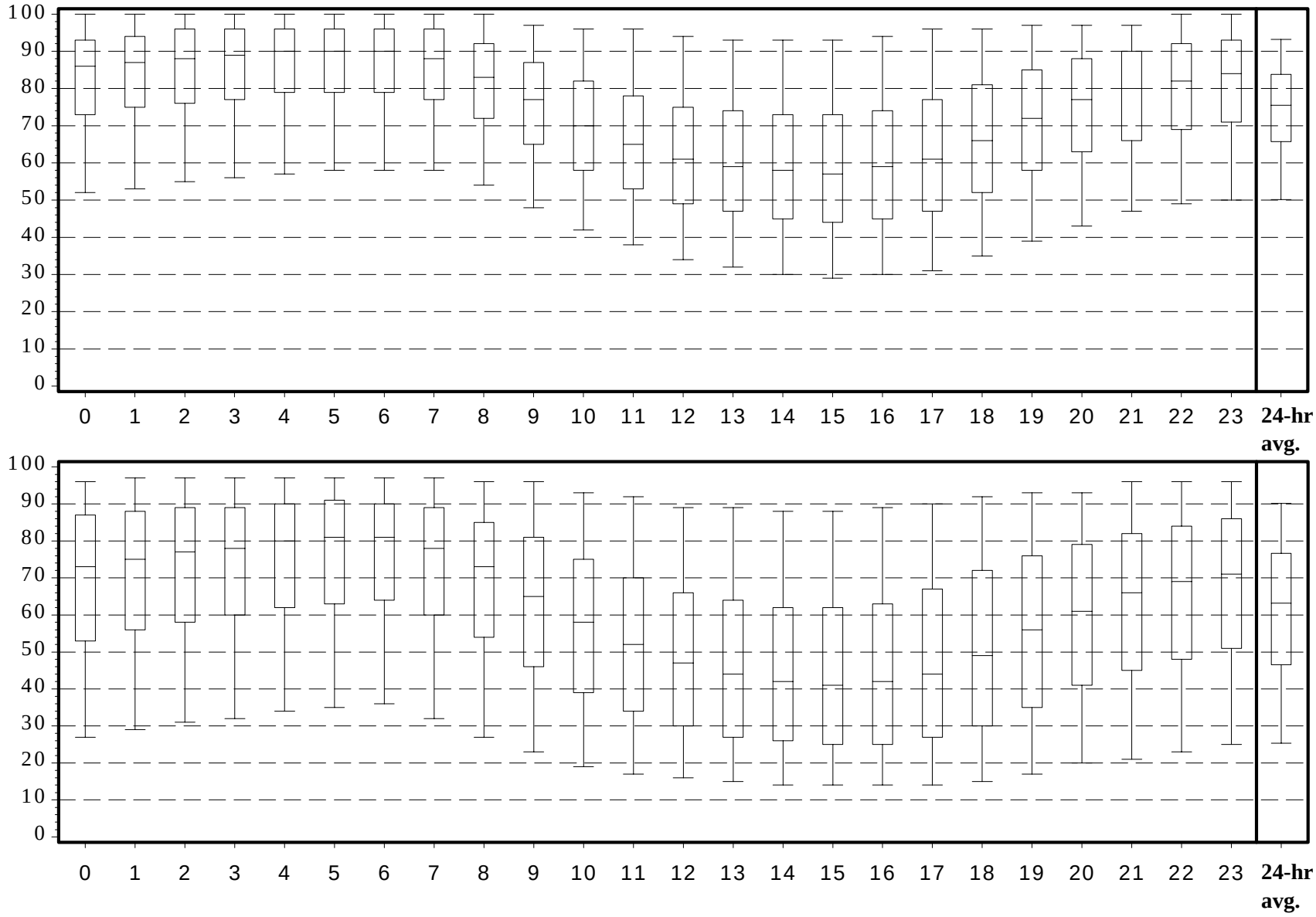
PM profile 12-4pm	Industrial Midwest	Northeast	Southeast	Upper Midwest	Northwest	Southern CA	Southwest
	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
PM2.5	13.3	13.1	11.3	9.7	9.2	21.5	10.3
PM25_ocm	3.65	3.70	3.85	3.38	4.80	8.46	3.38
PM25_ec	0.67	0.90	0.53	0.45	0.67	0.93	0.61
PM25_nitrates	2.86	2.35	1.07	2.36	1.73	5.79	0.51
PM25_sulfates	5.46	5.65	5.02	2.83	1.36	2.86	1.61
PM25_crustal	0.63	0.52	0.84	0.66	0.65	3.42	4.18
PM10-2.5	8.0	6.9	7.2	10.6	10.3	31.3	44.0

2003 RH at NWS sites, by region and hour

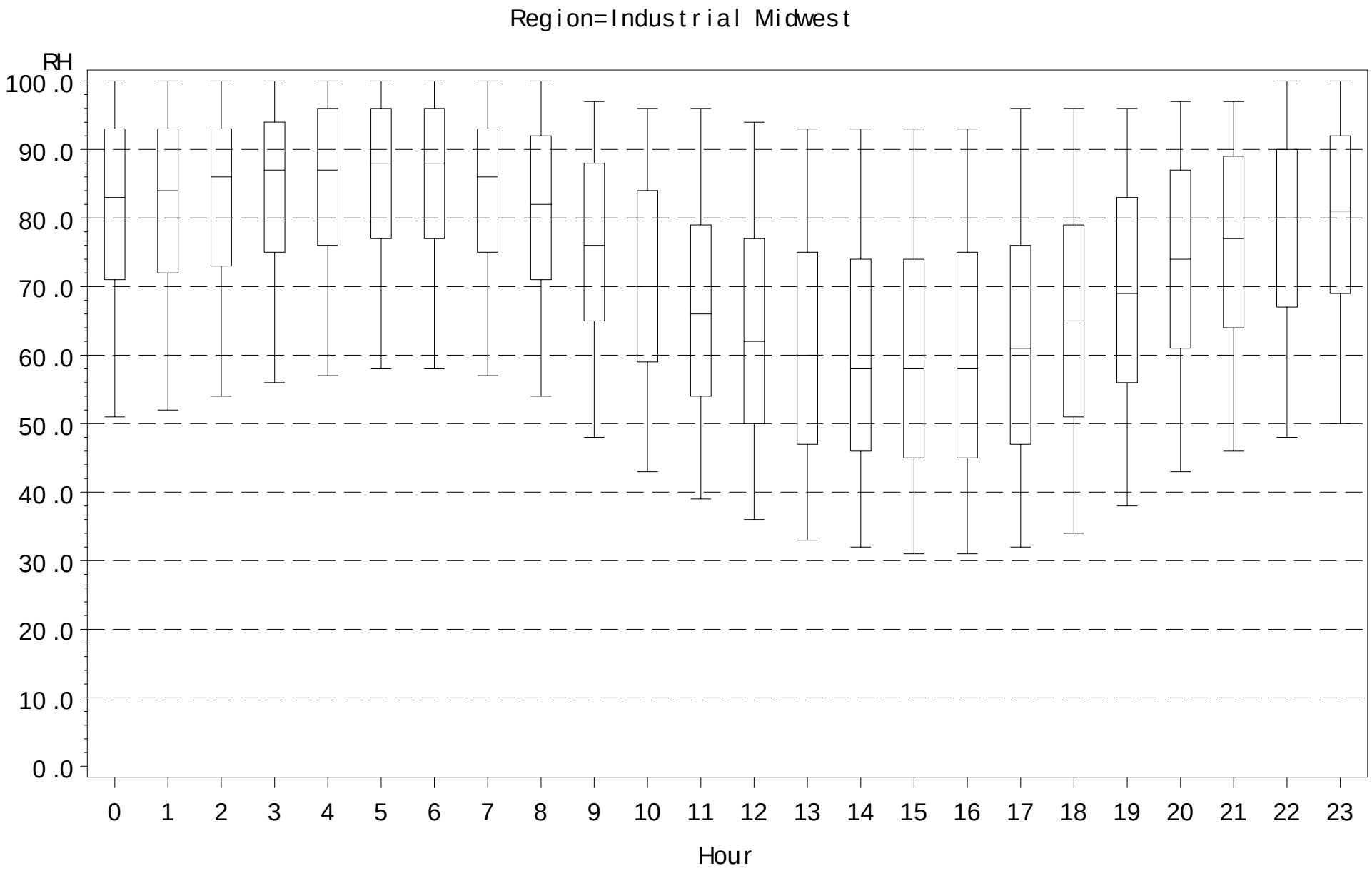




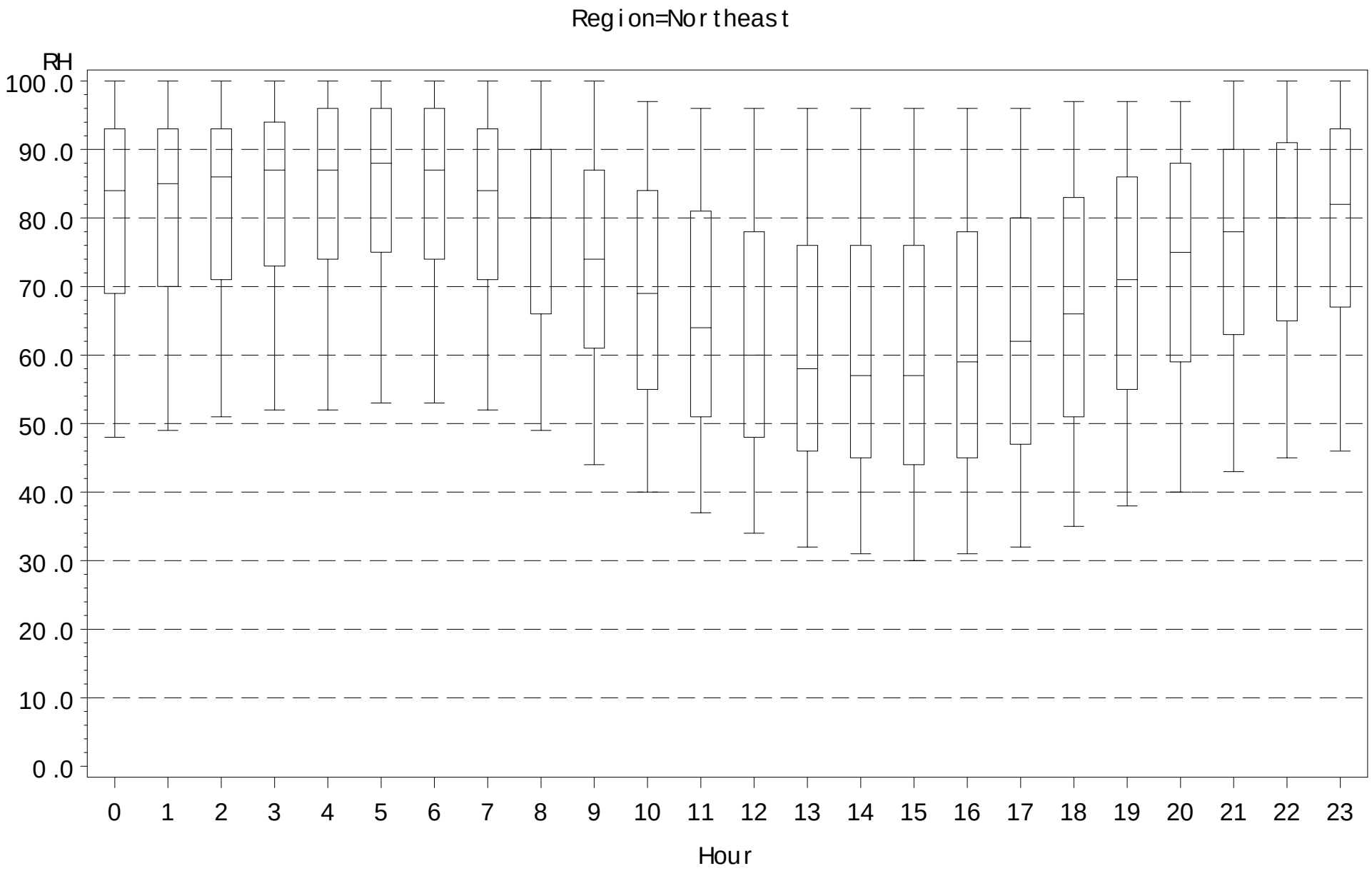
2003 RH at NWS sites, by region and hour - add 24-hr avg



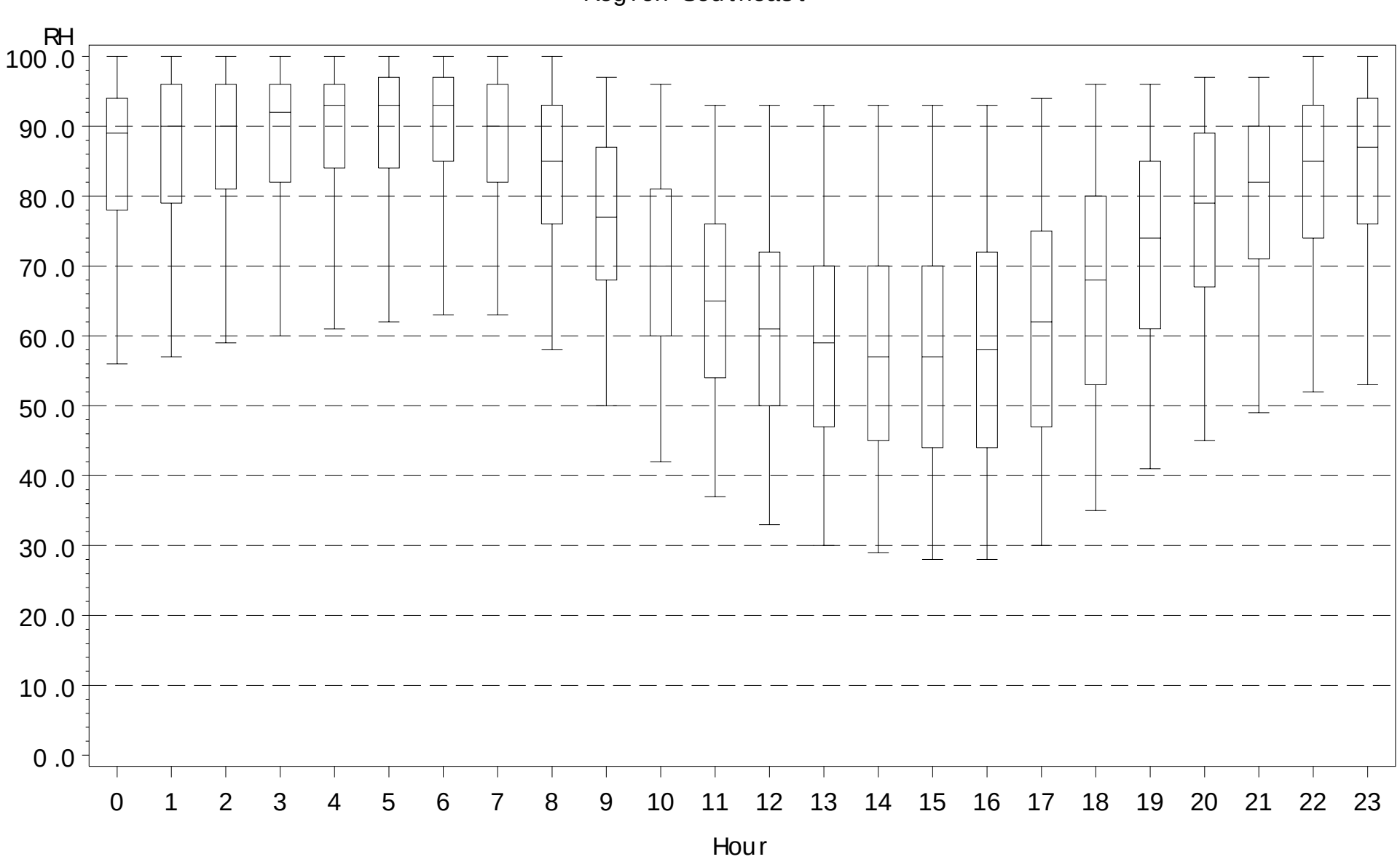
2003 RH at NWS sites, by region and hour



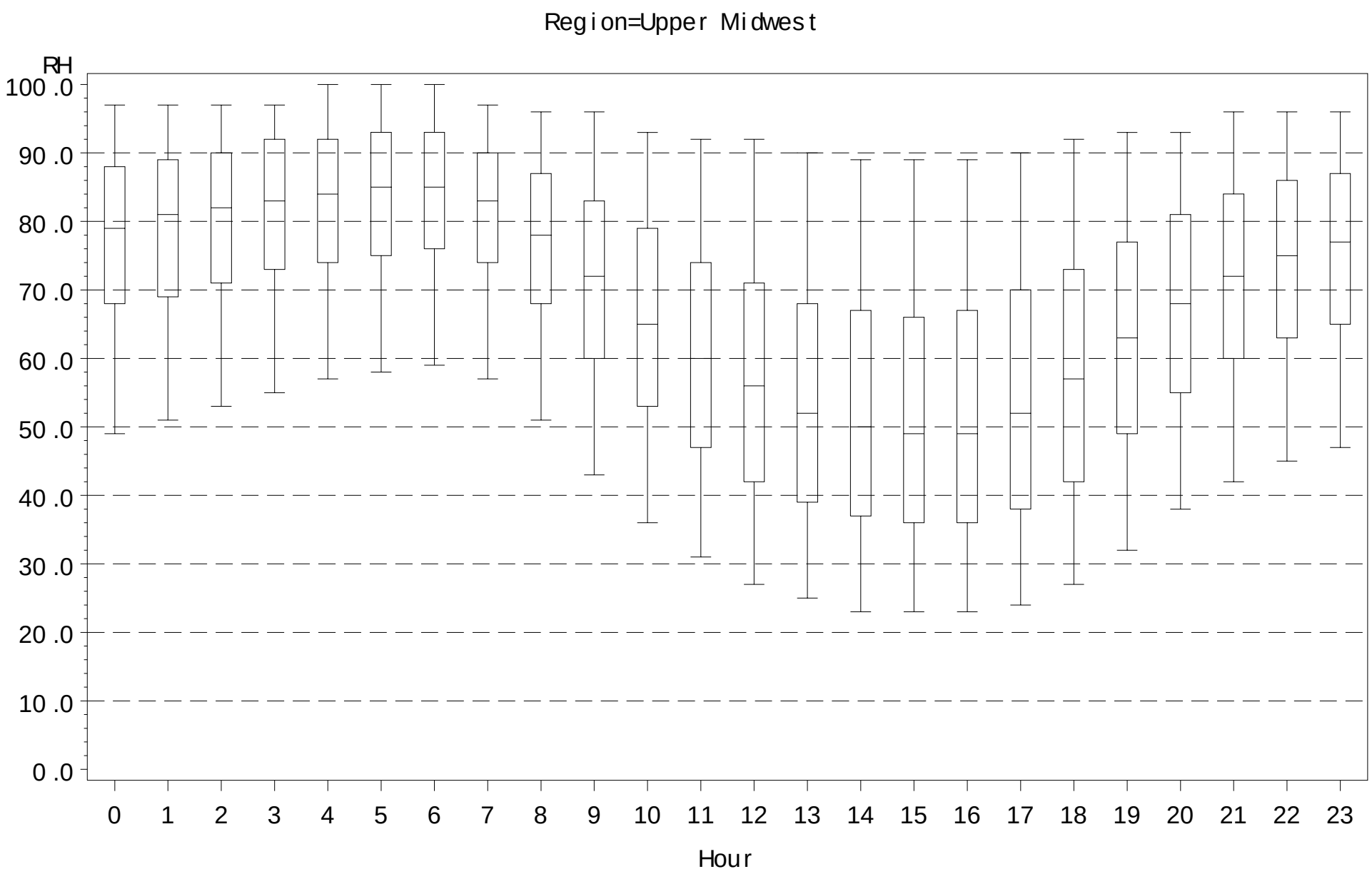
2003 RH at NWS sites, by region and hour



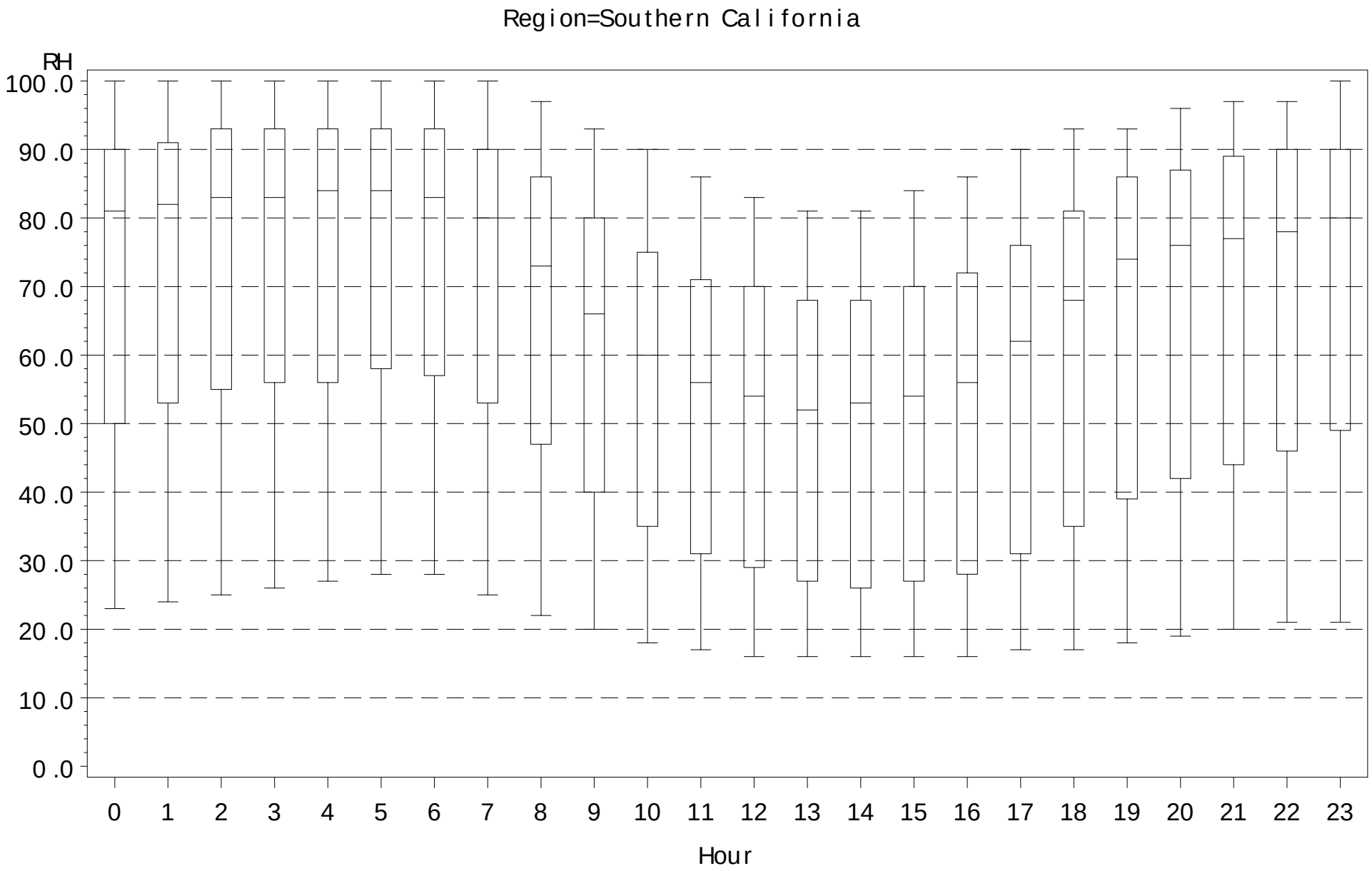
2003 RH at NWS sites, by region and hour



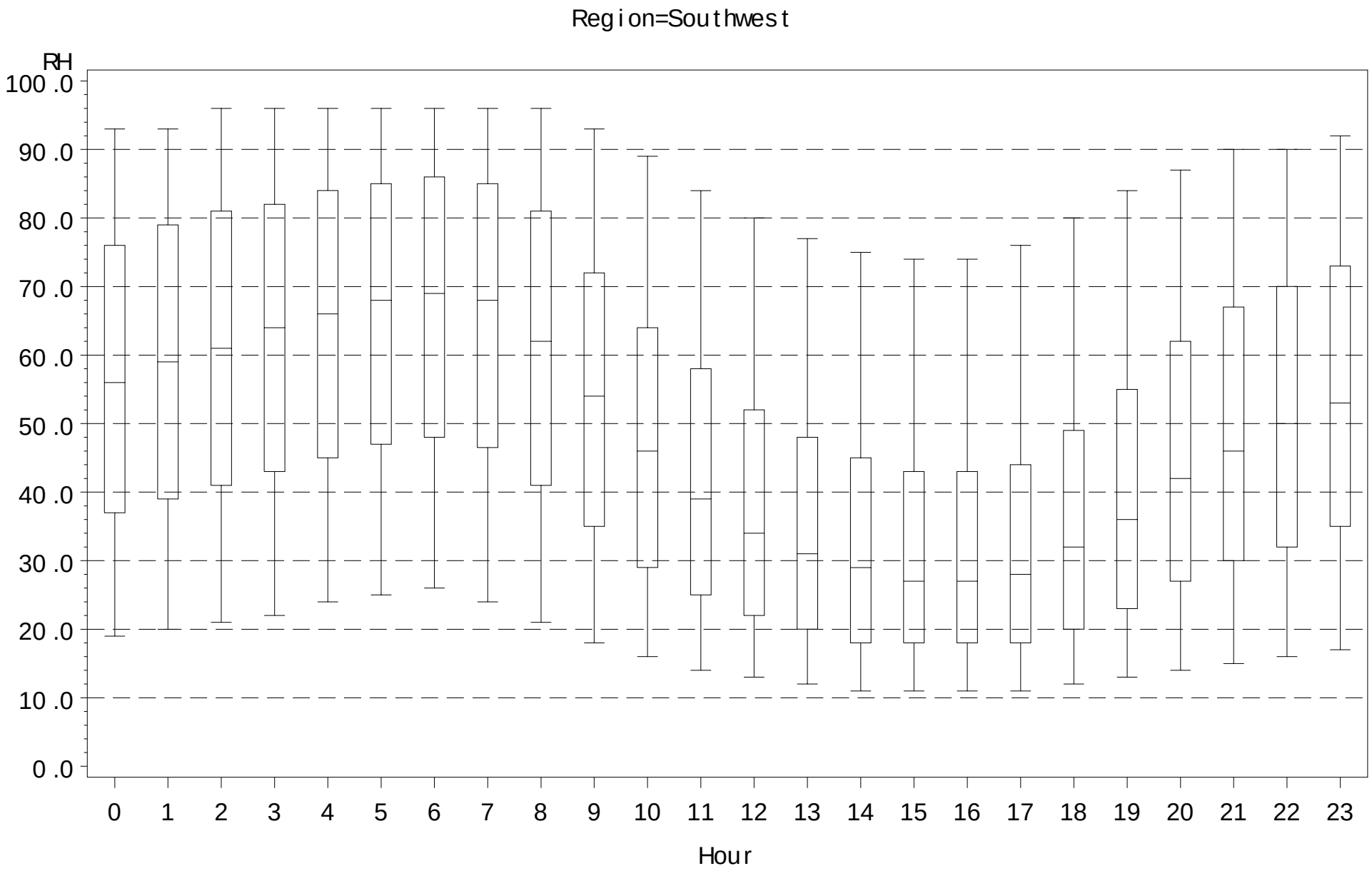
2003 RH at NWS sites, by region and hour



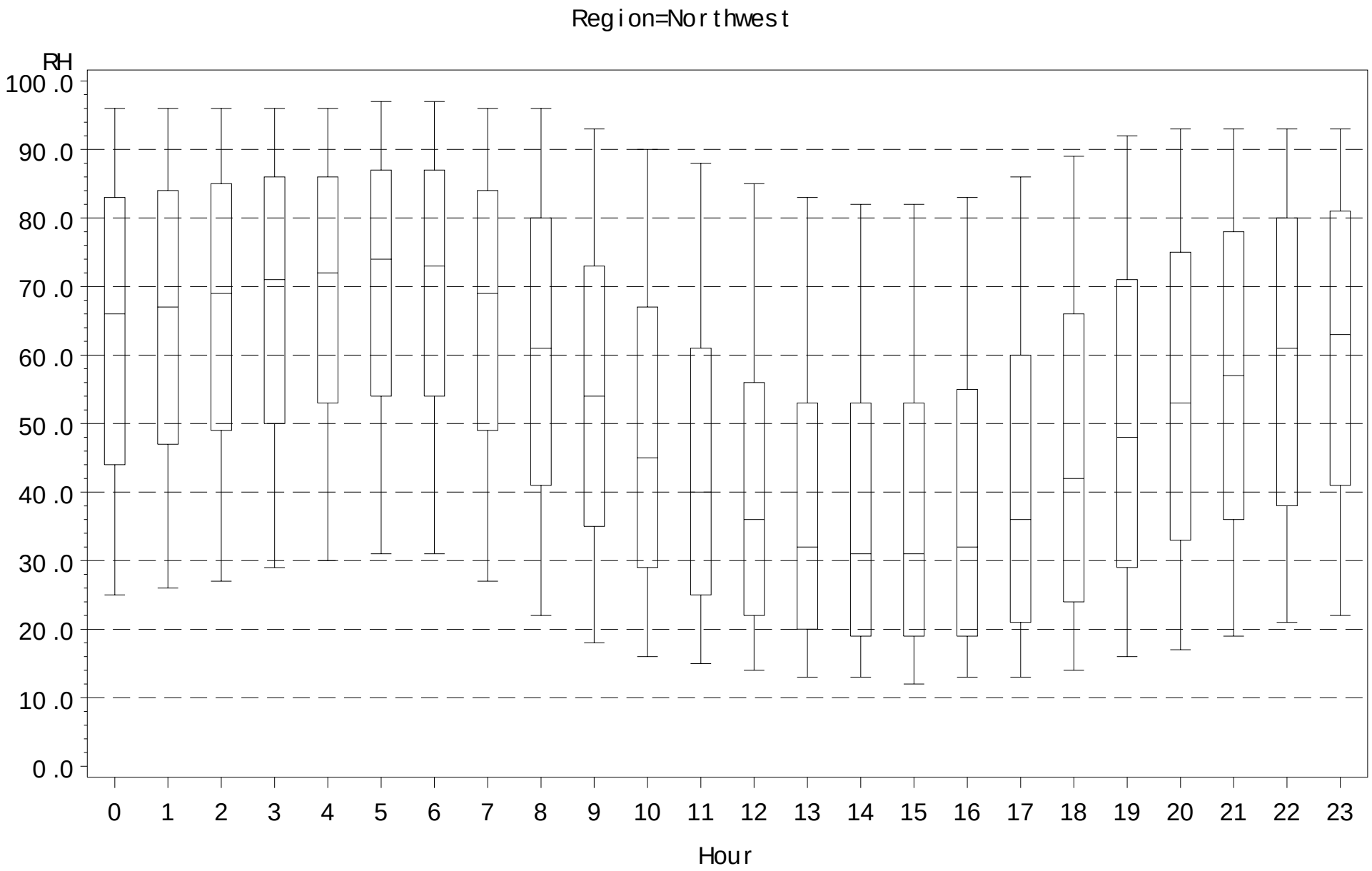
2003 RH at NWS sites, by region and hour



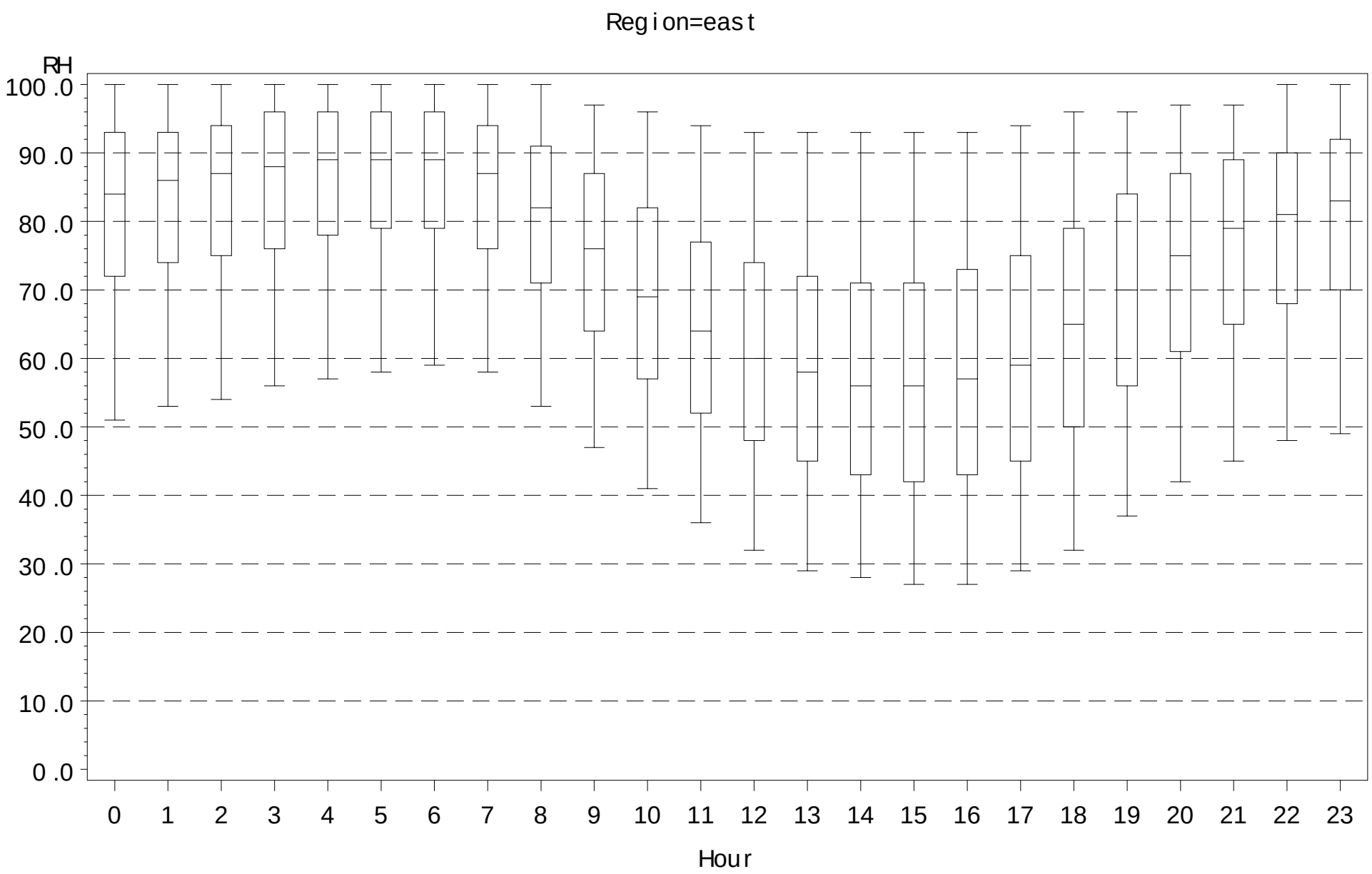
2003 RH at NWS sites, by region and hour



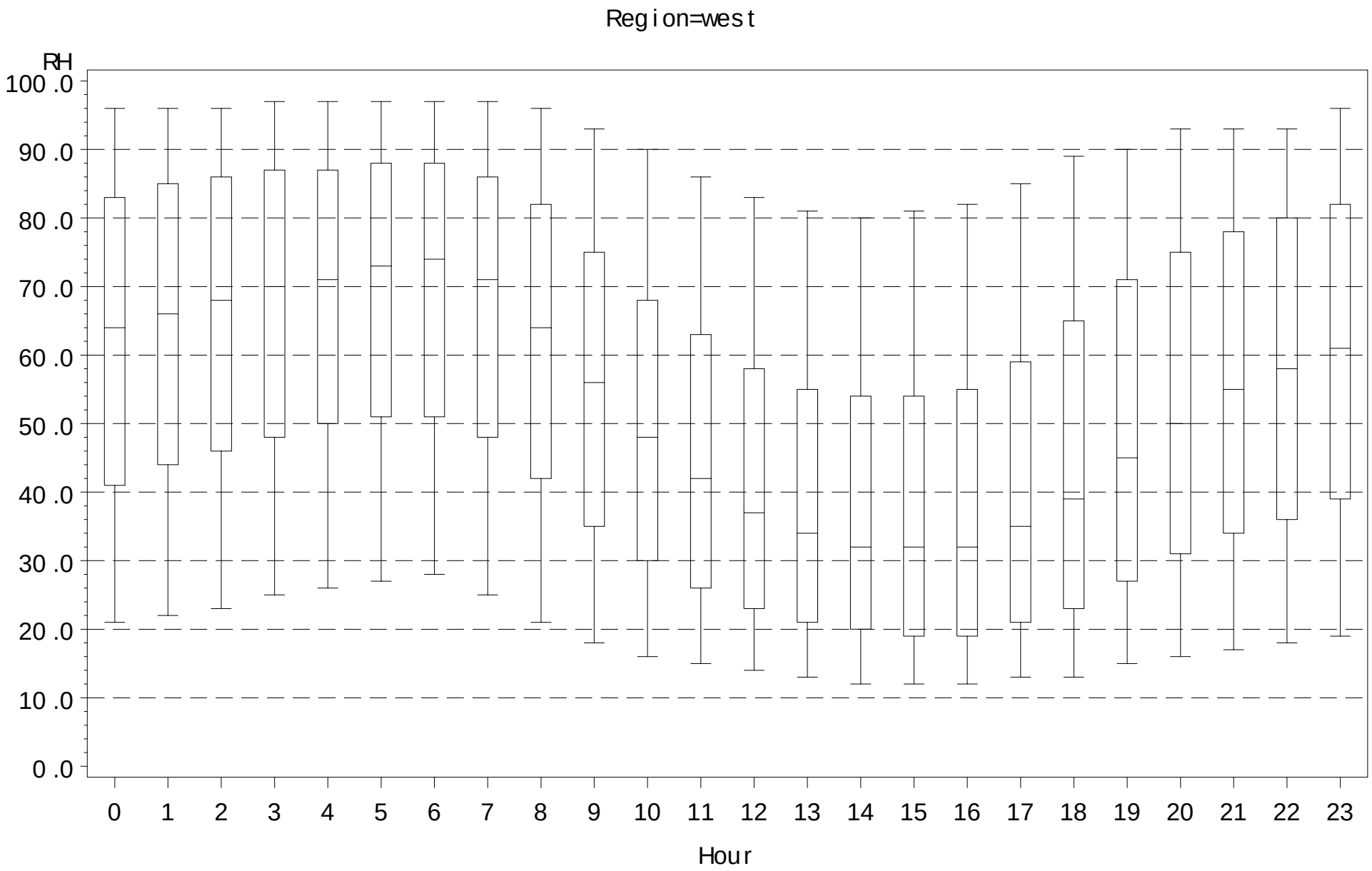
2003 RH at NWS sites, by region and hour



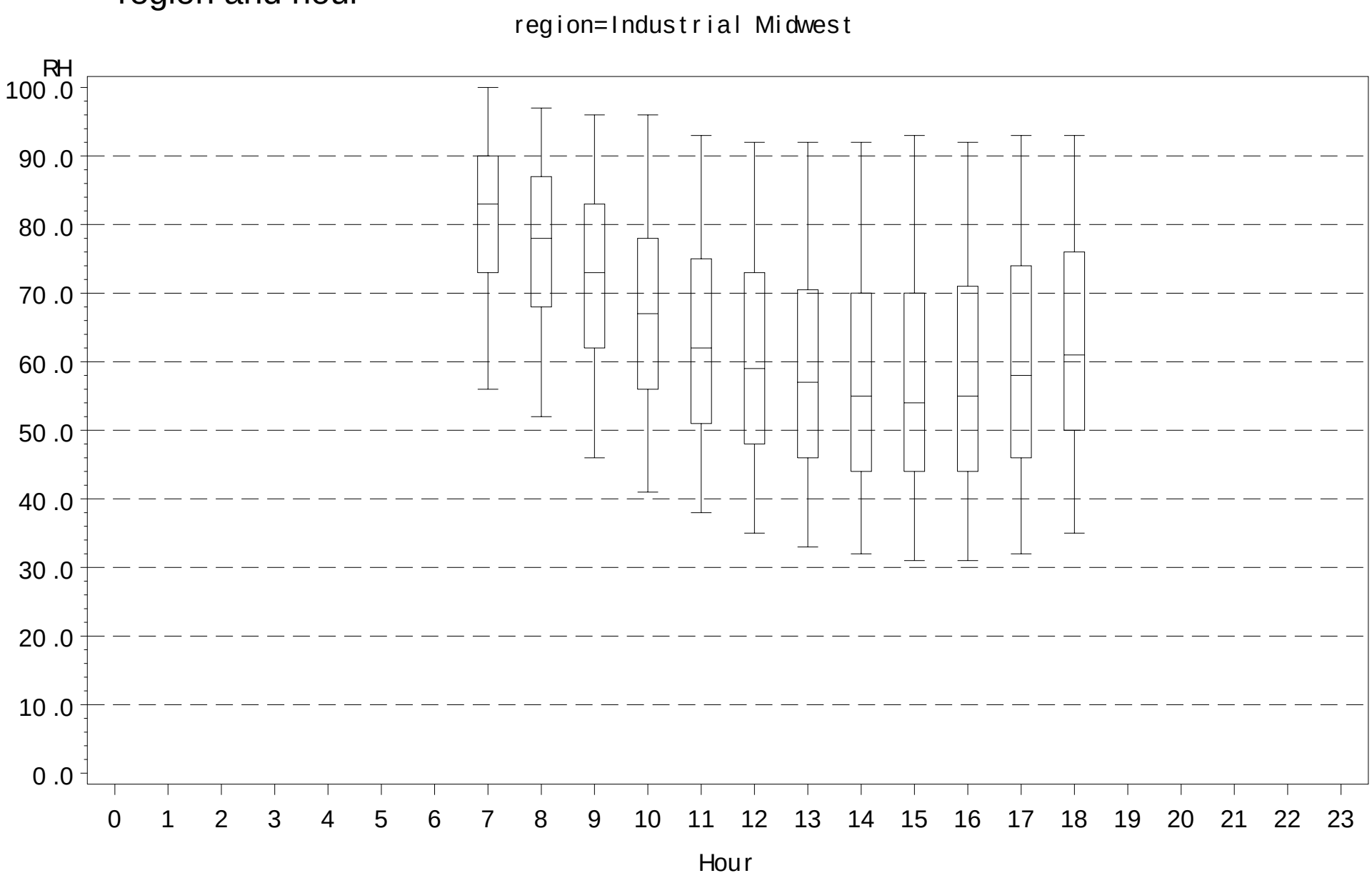
2003 RH at NWS sites, by region and hour



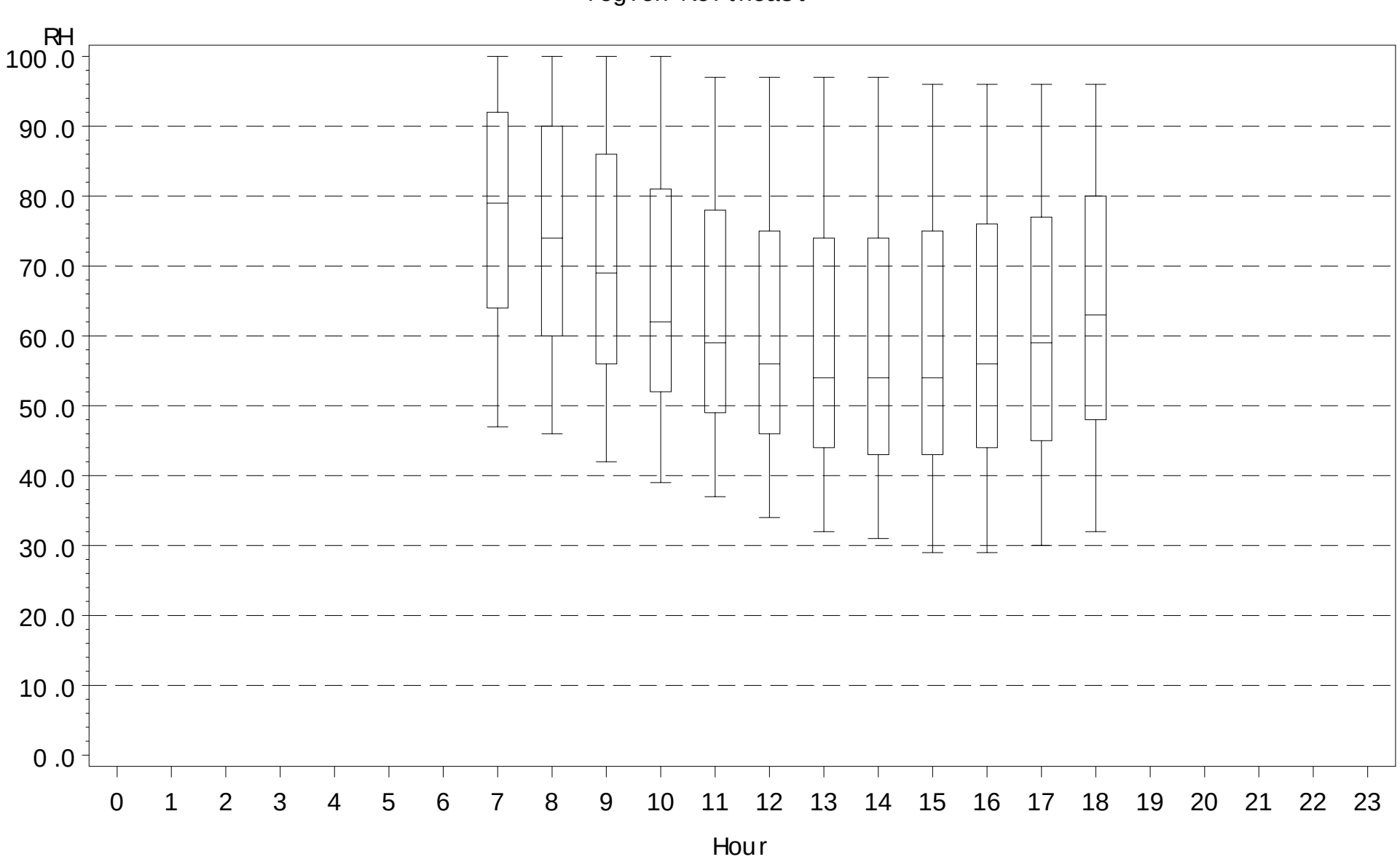
2003 RH at NWS sites, by region and hour



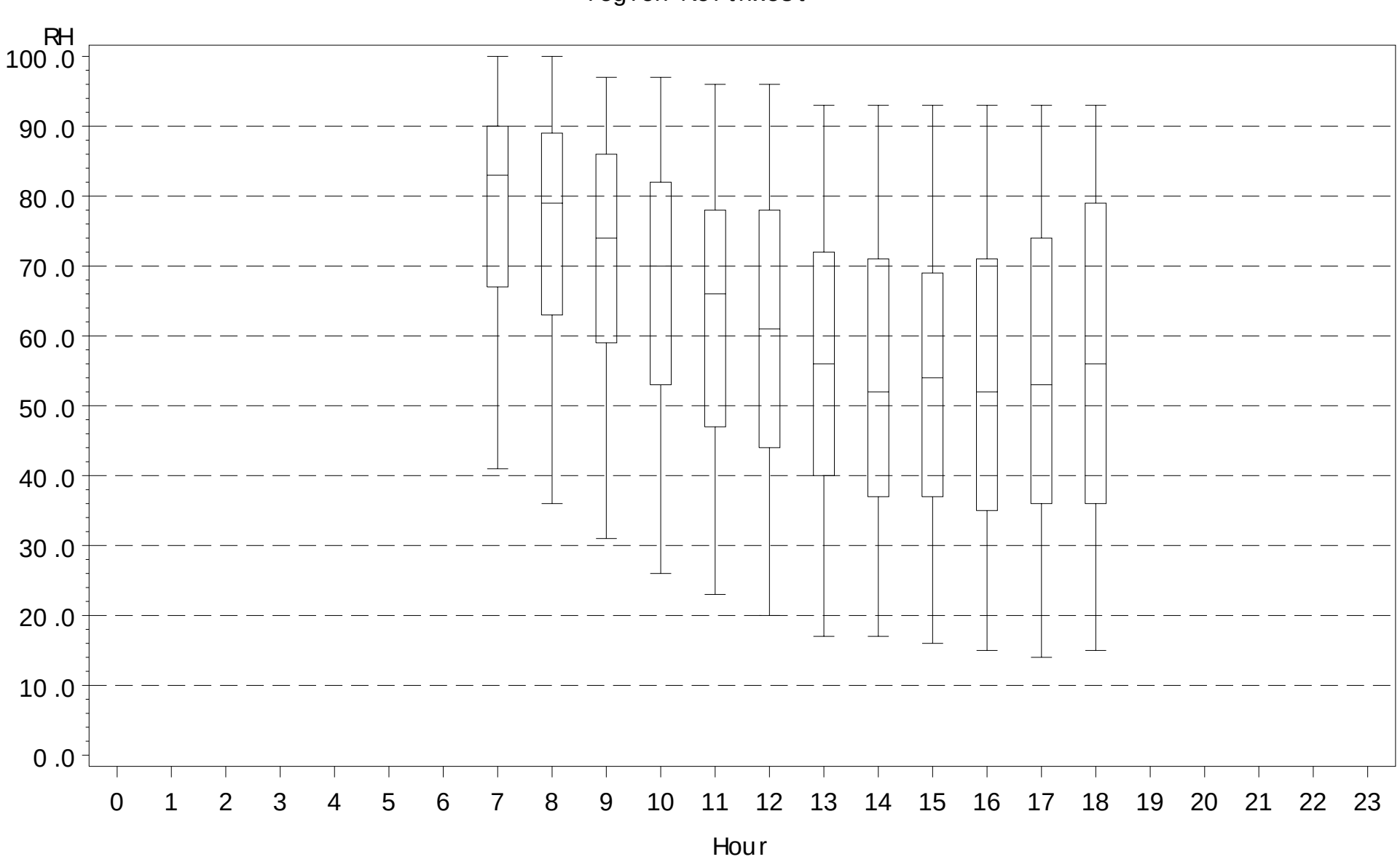
2003 RH at NWS sites for site-days used in visibility analyses (new db), by region and hour



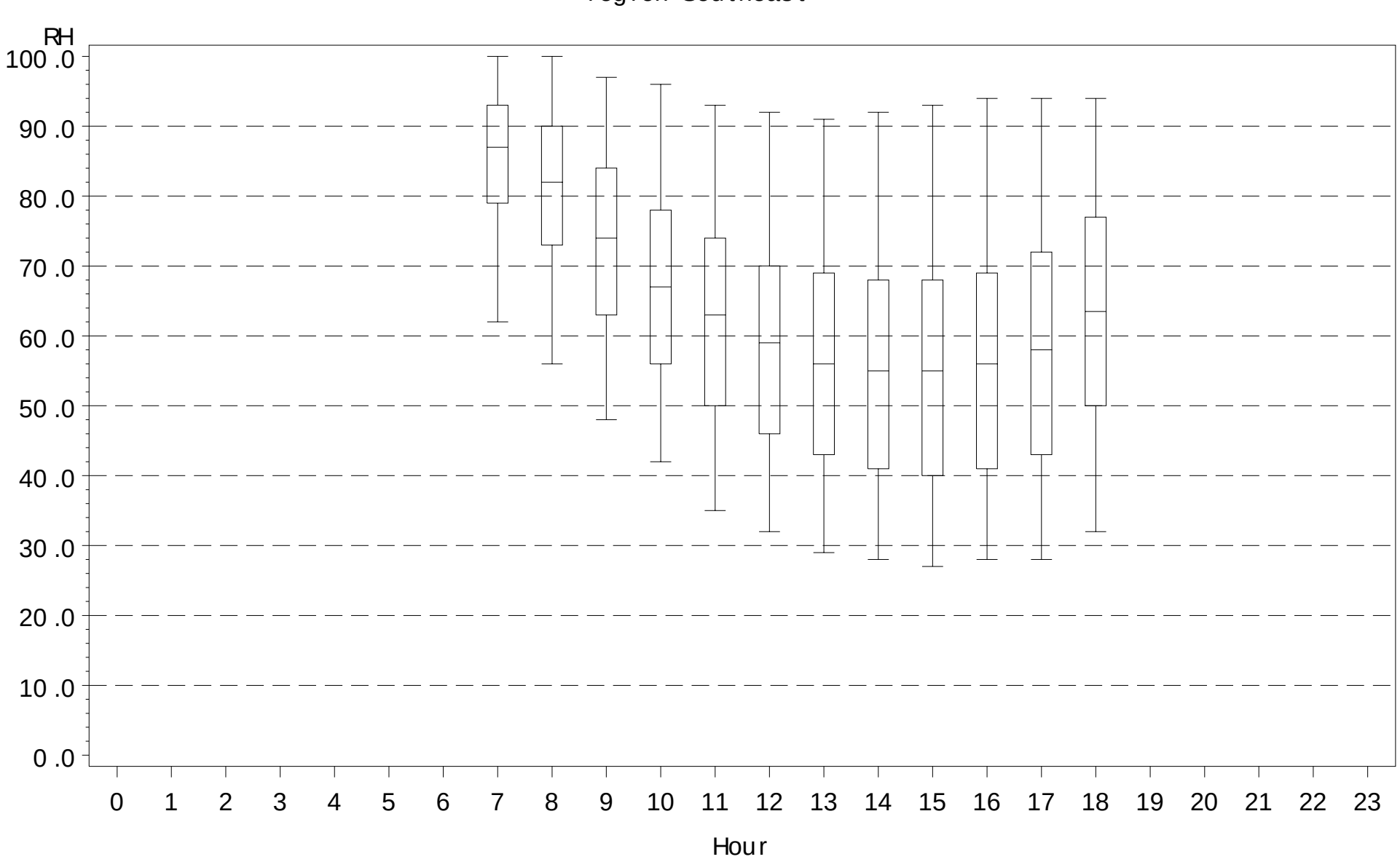
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



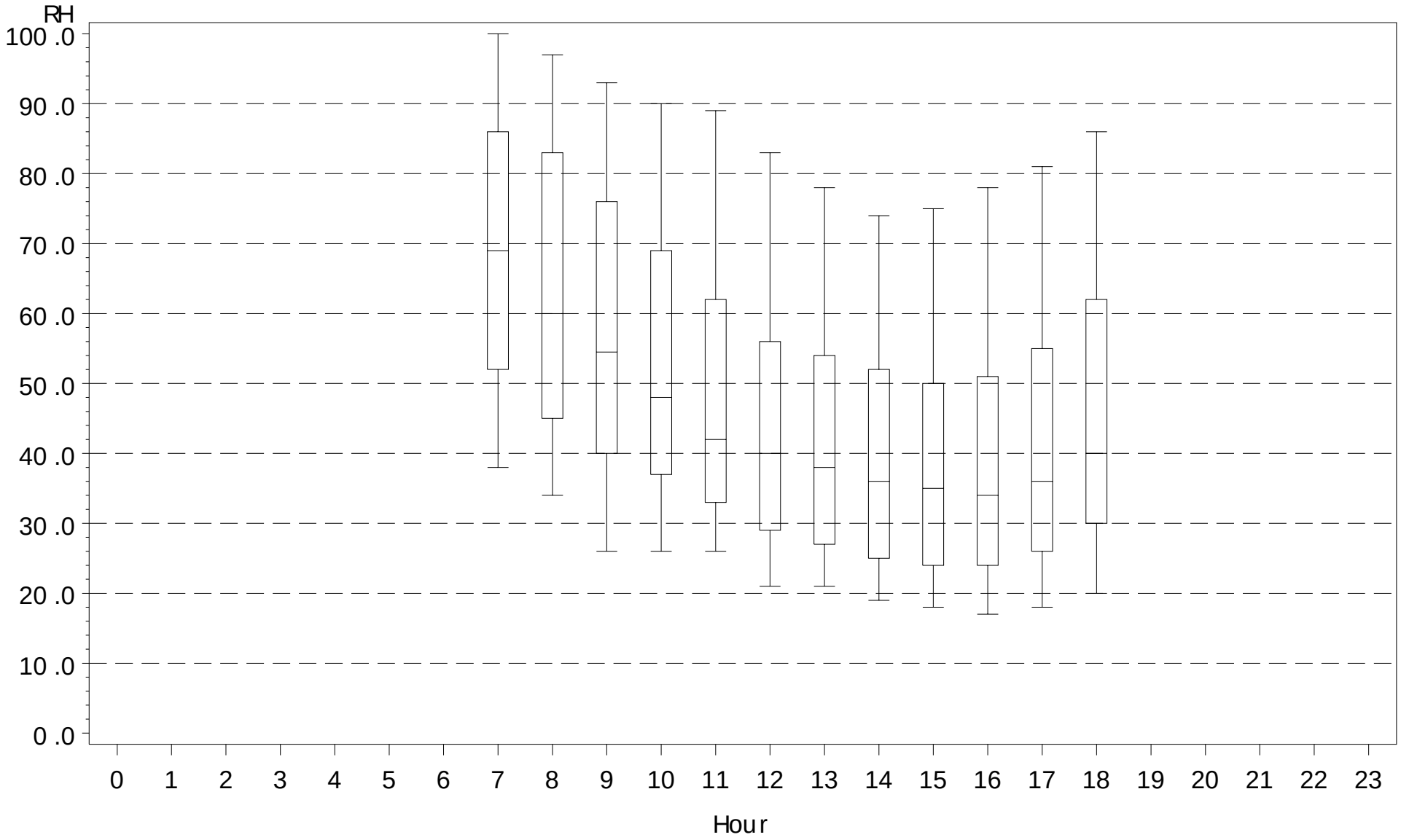
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



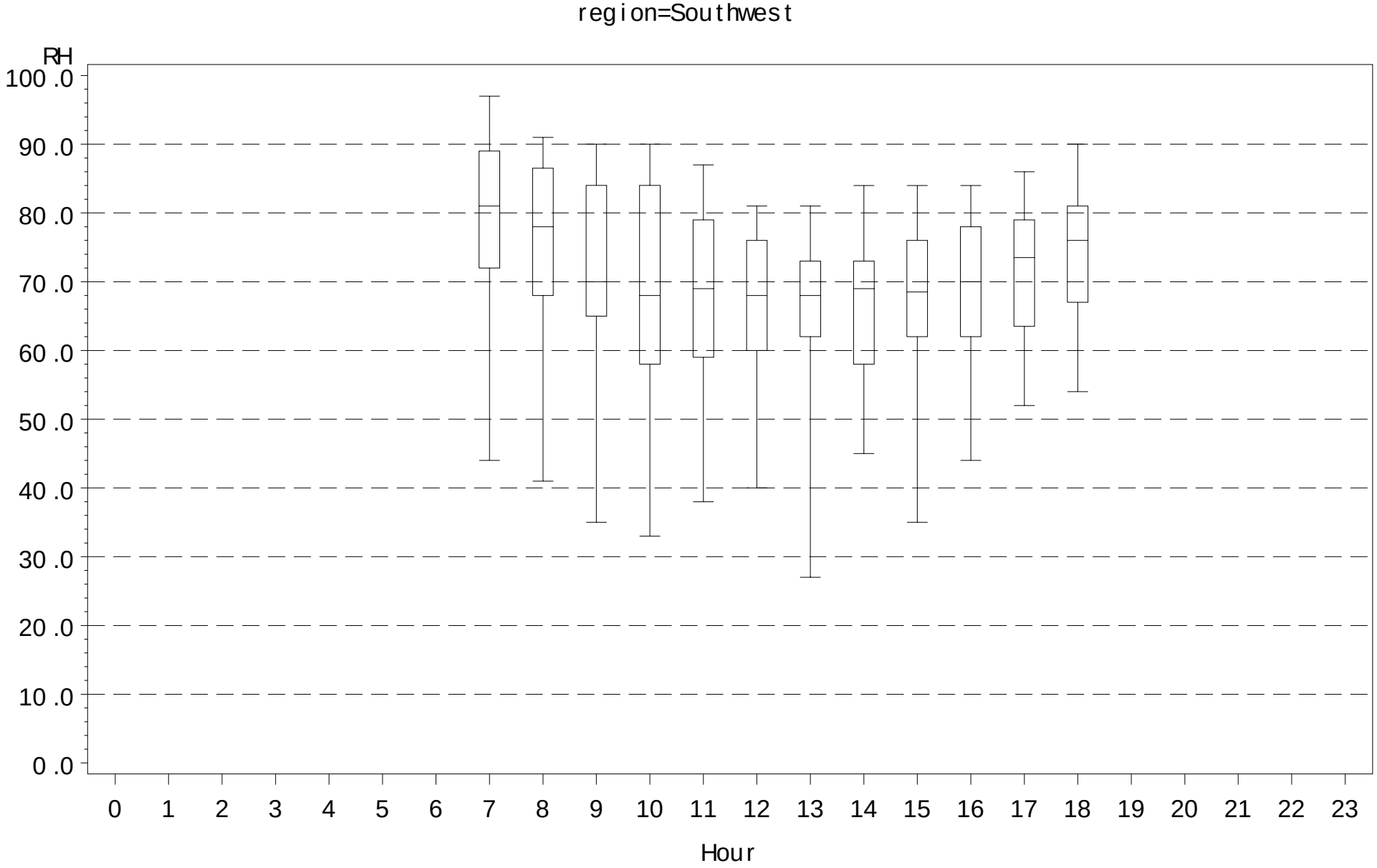
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



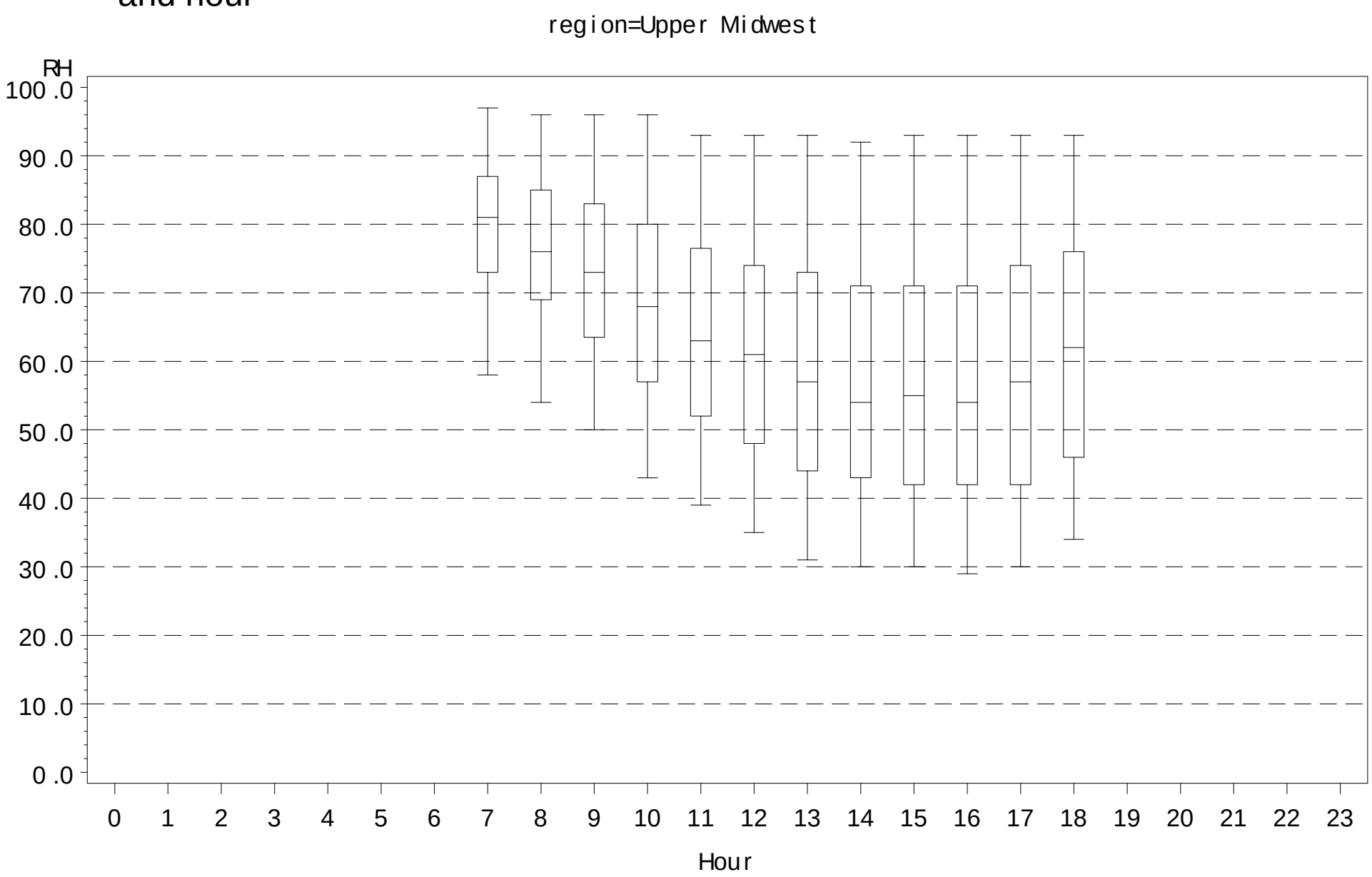
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



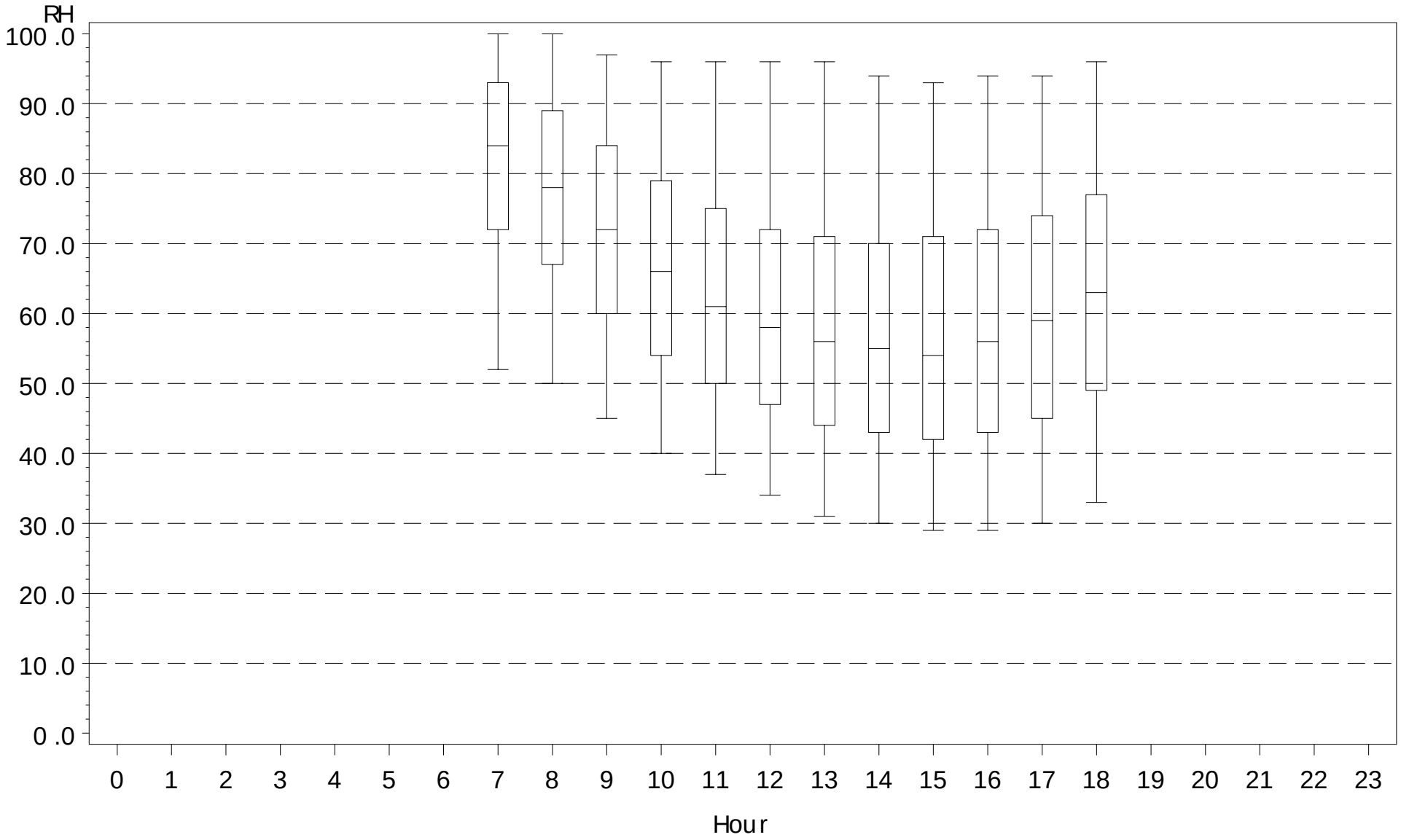
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



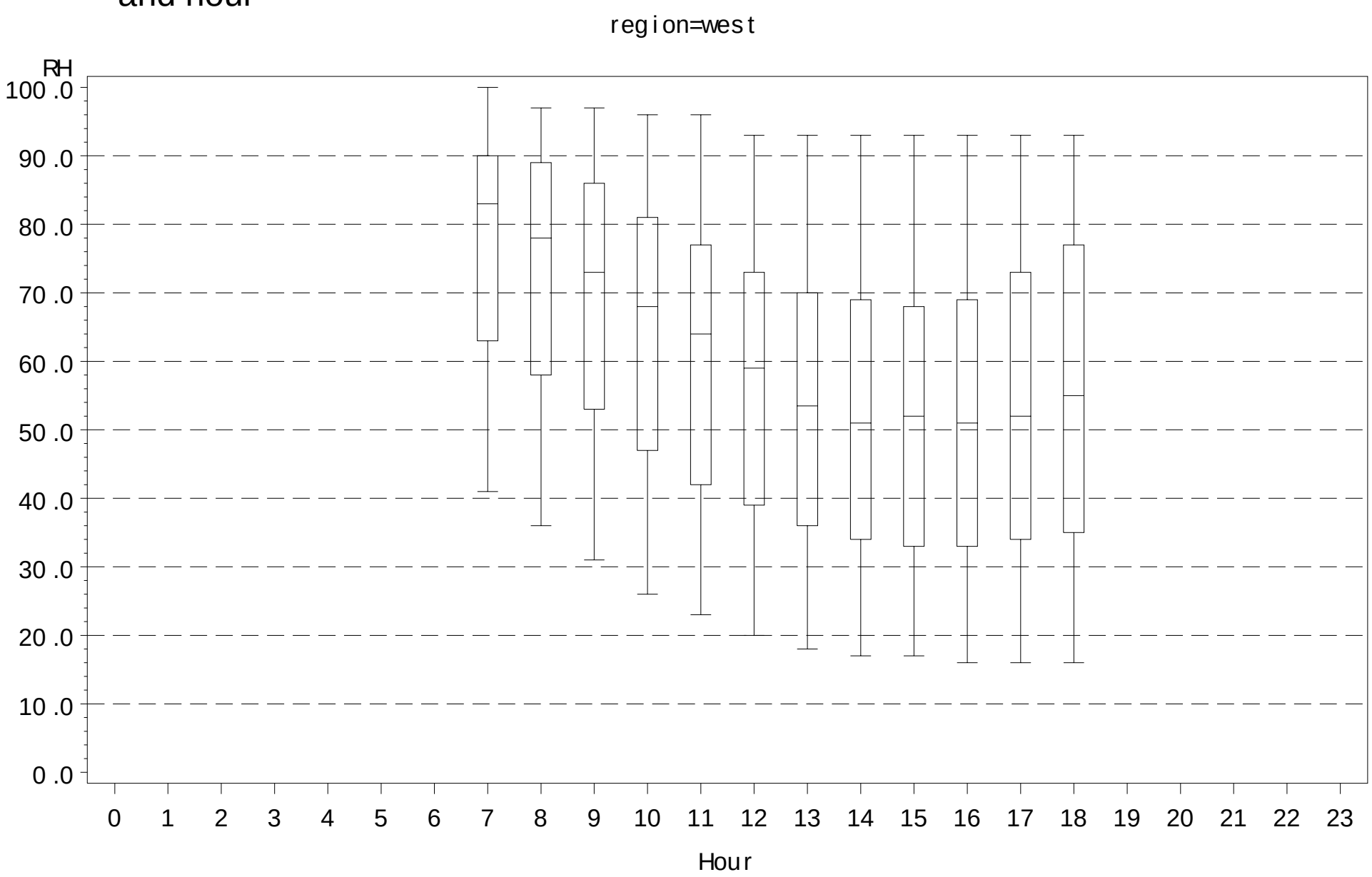
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



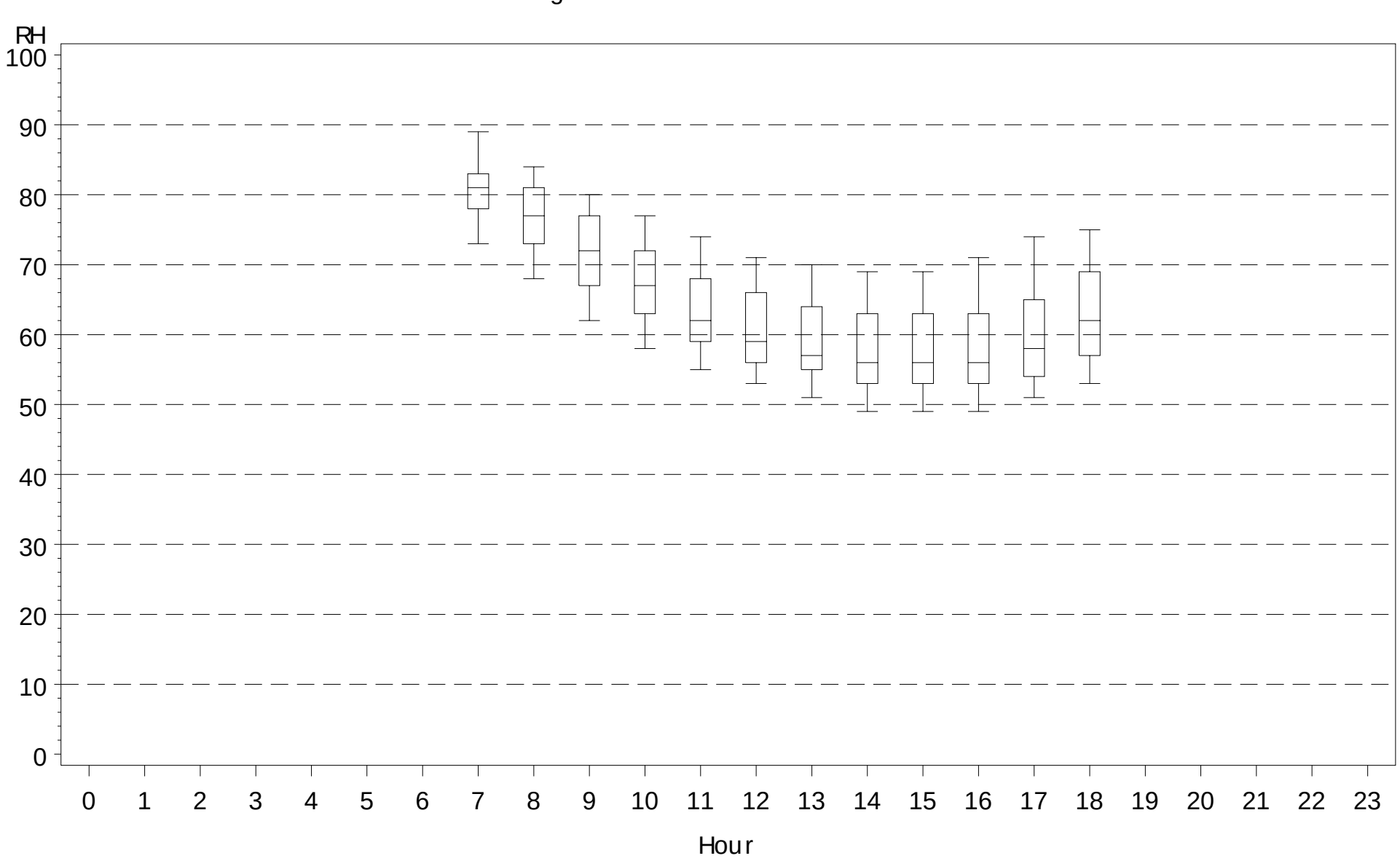
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



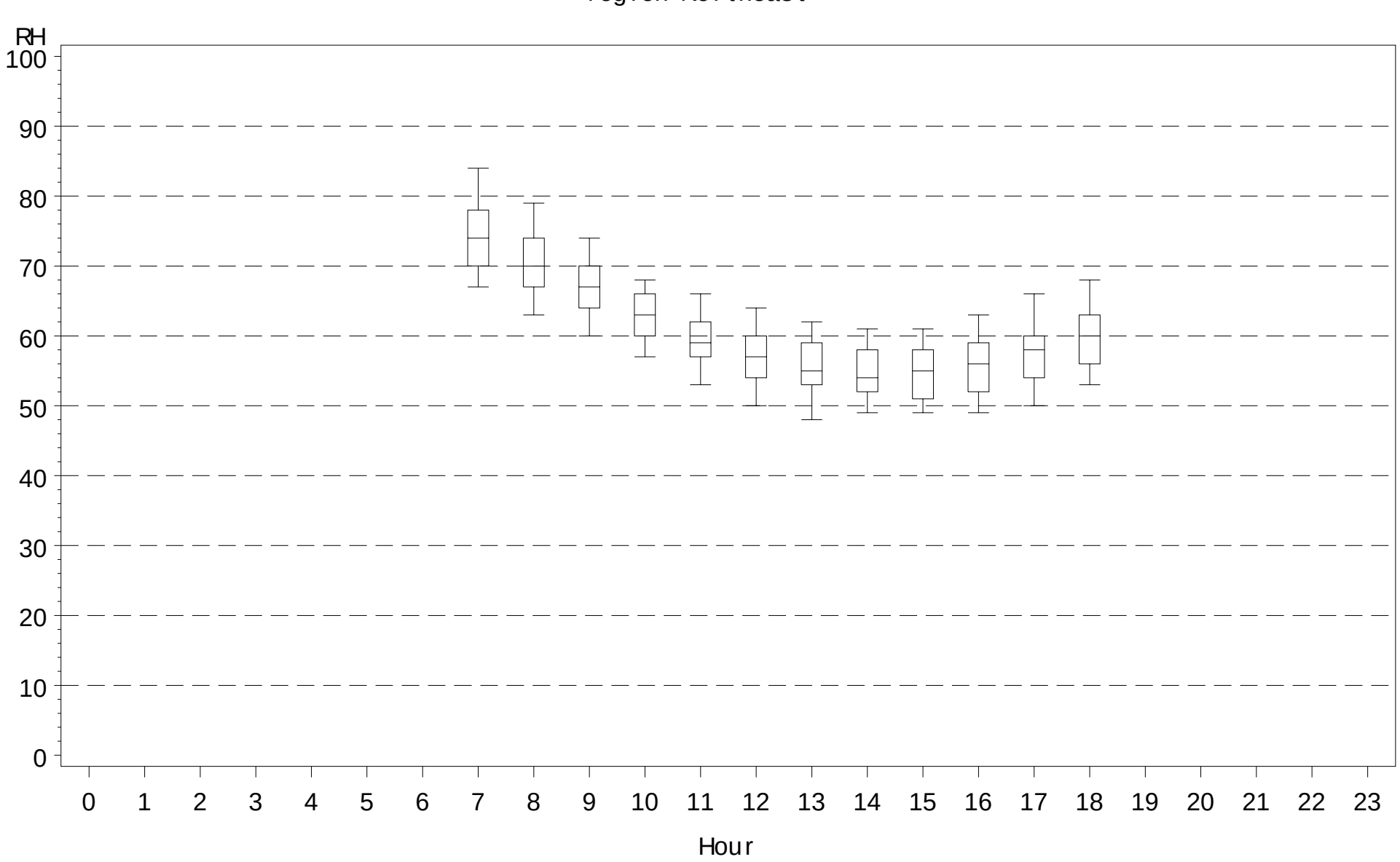
2003 RH at NWS sites for site-days used in visibility analyses, by region and hour



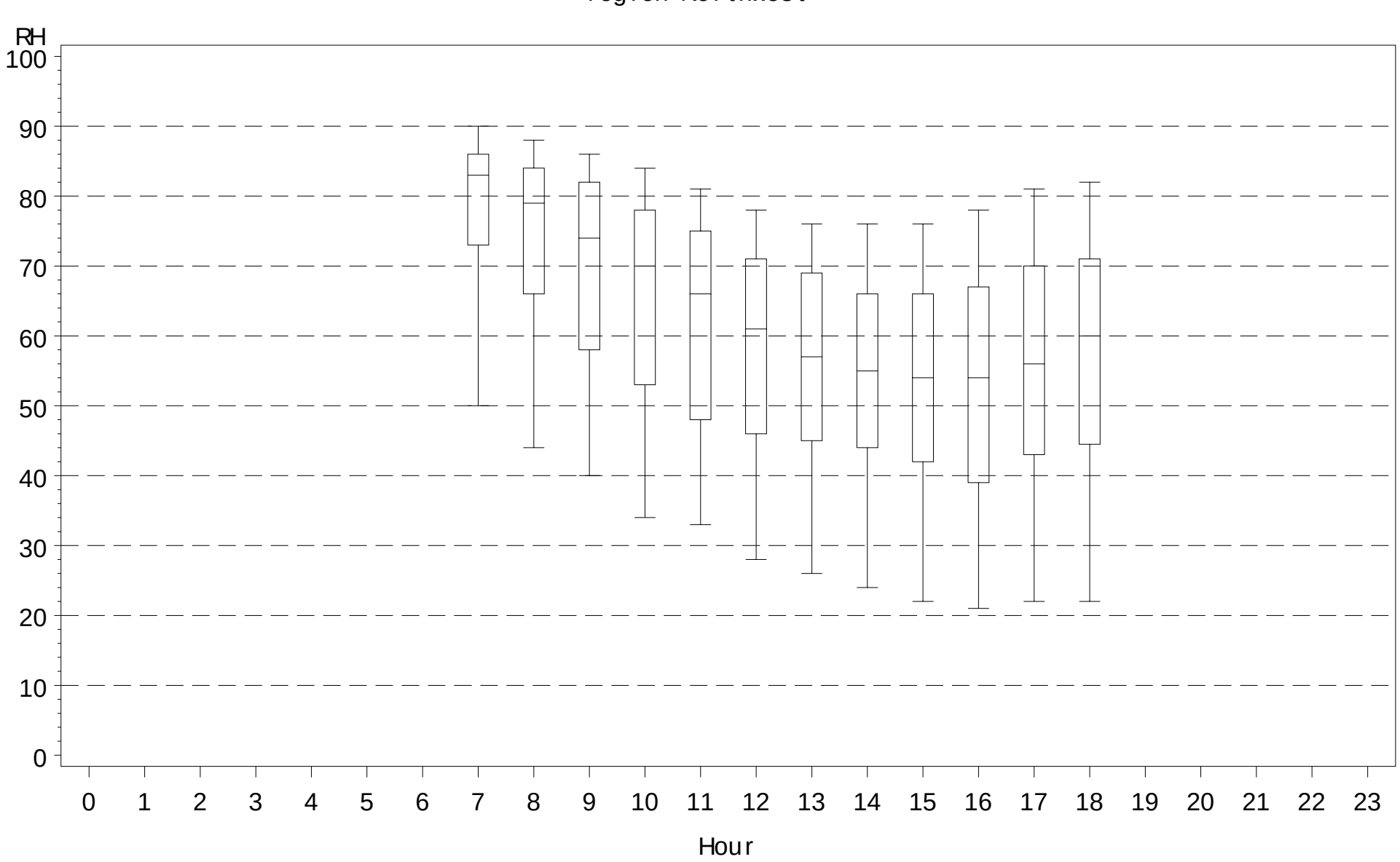
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



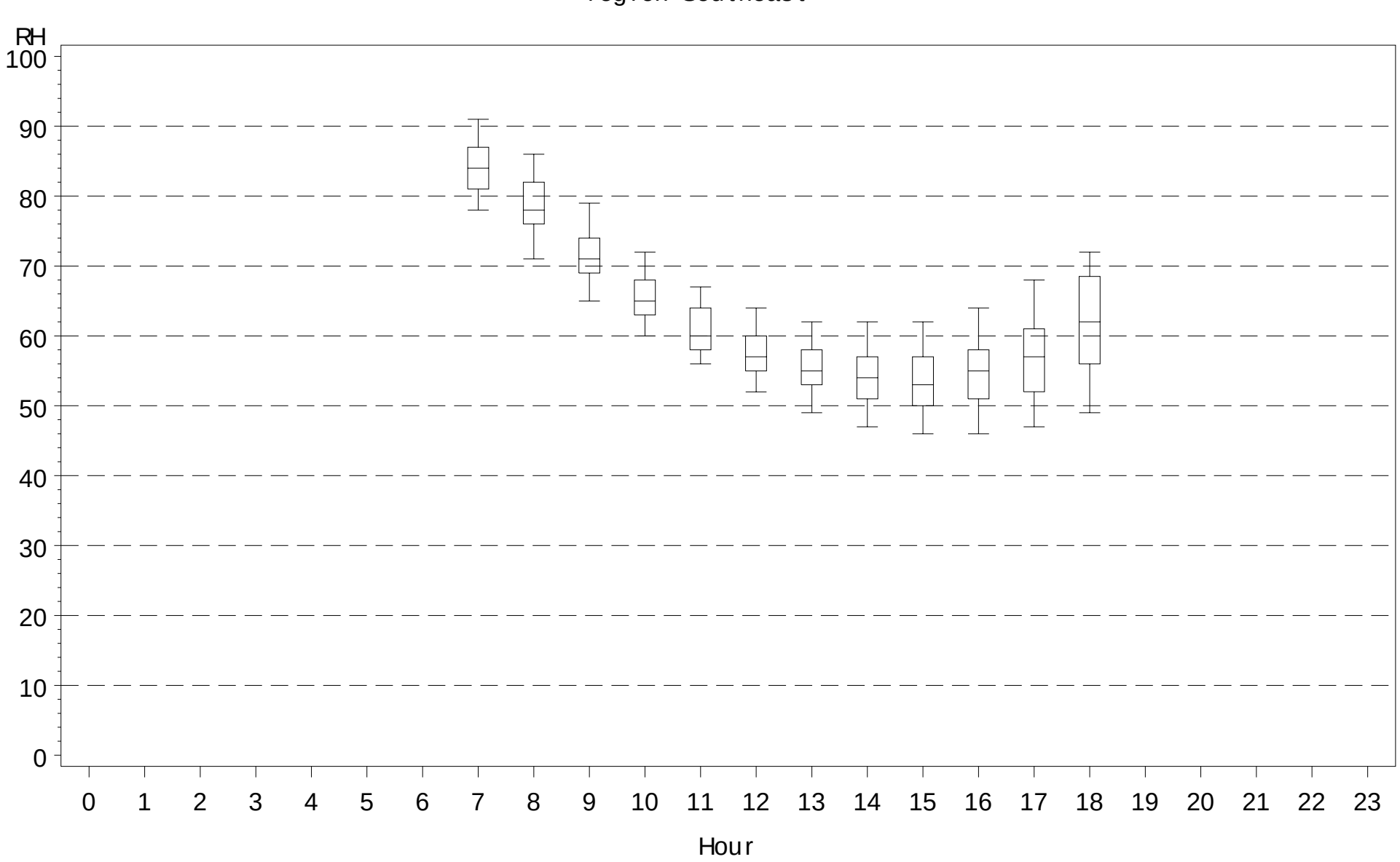
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



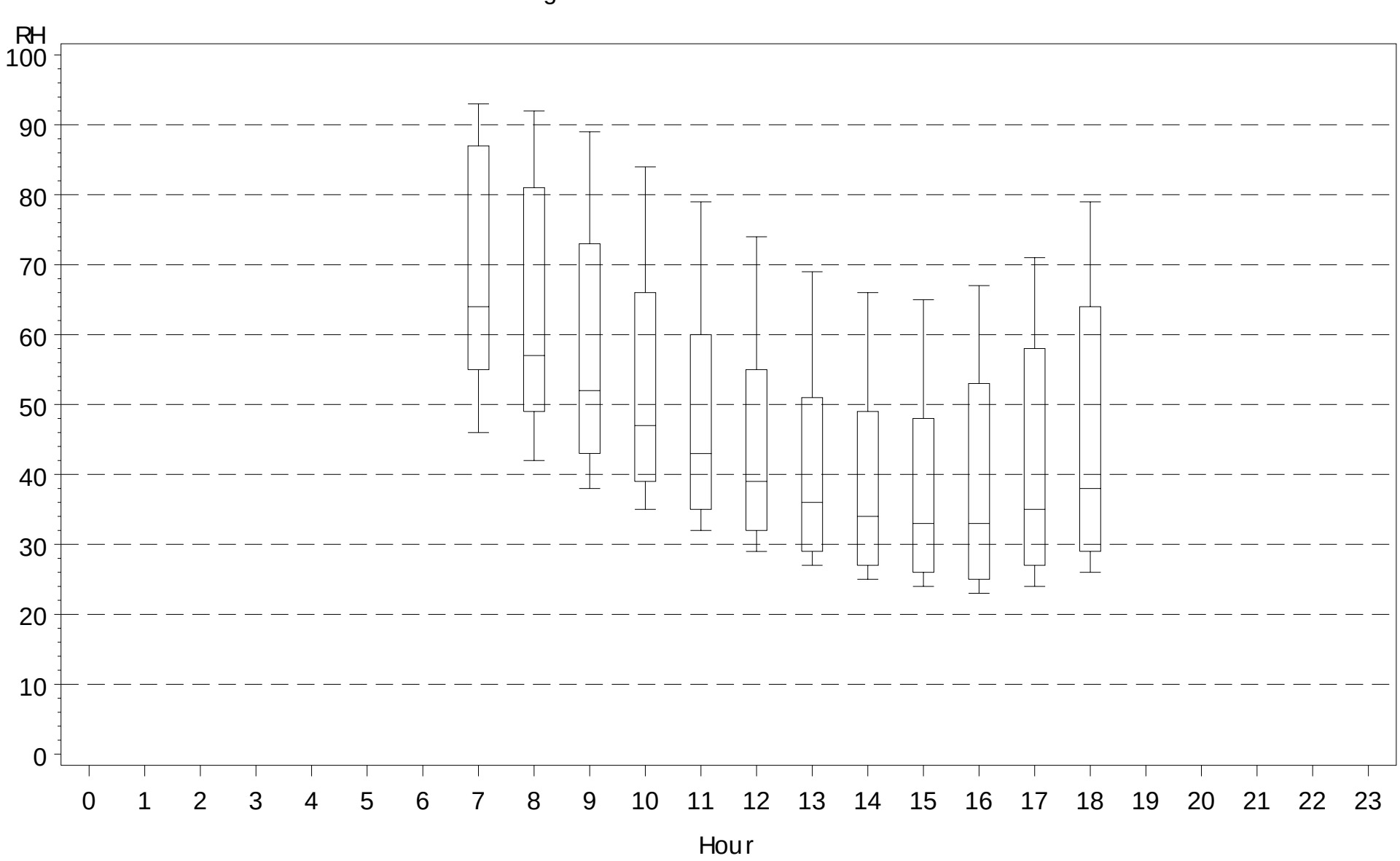
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



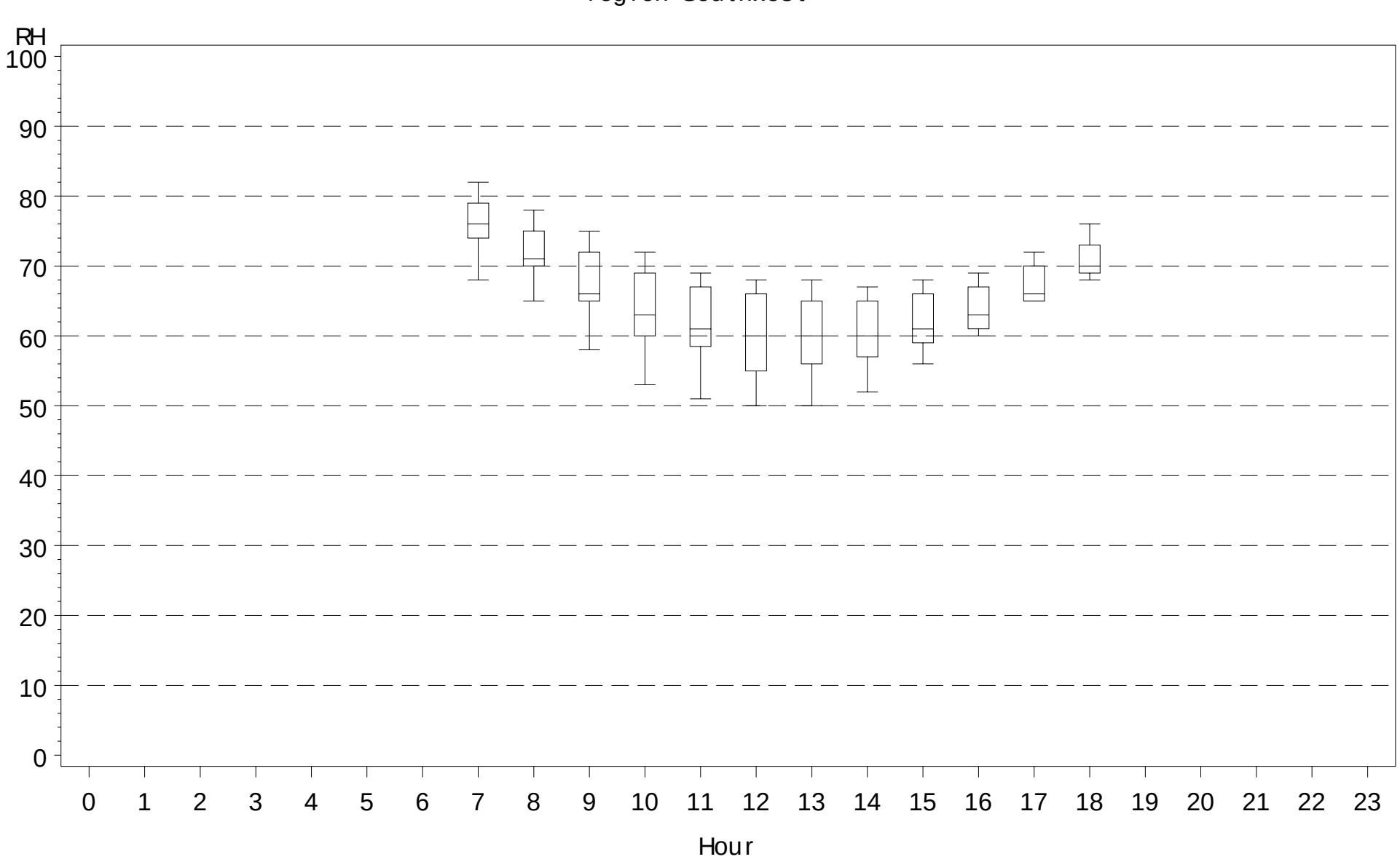
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



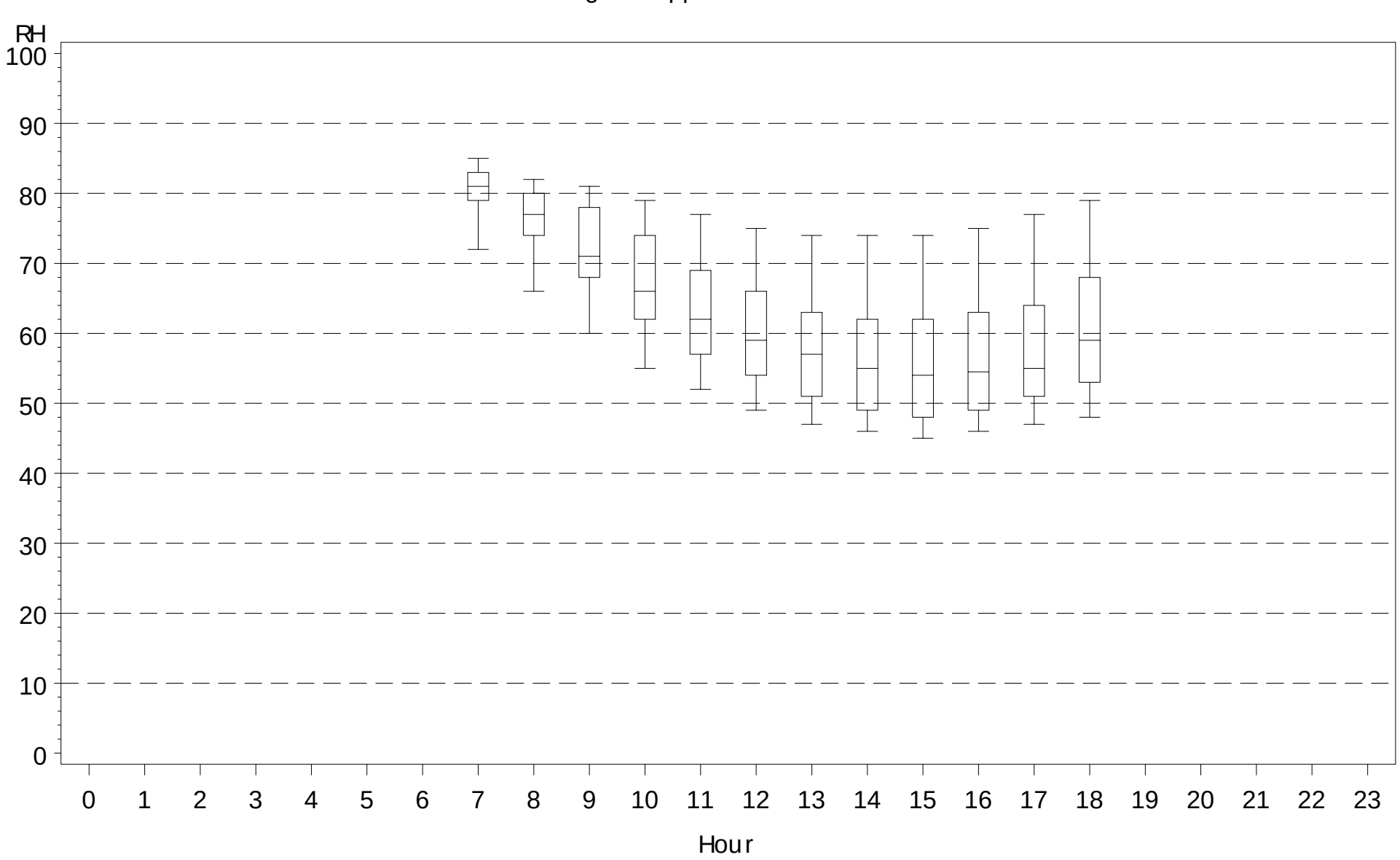
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



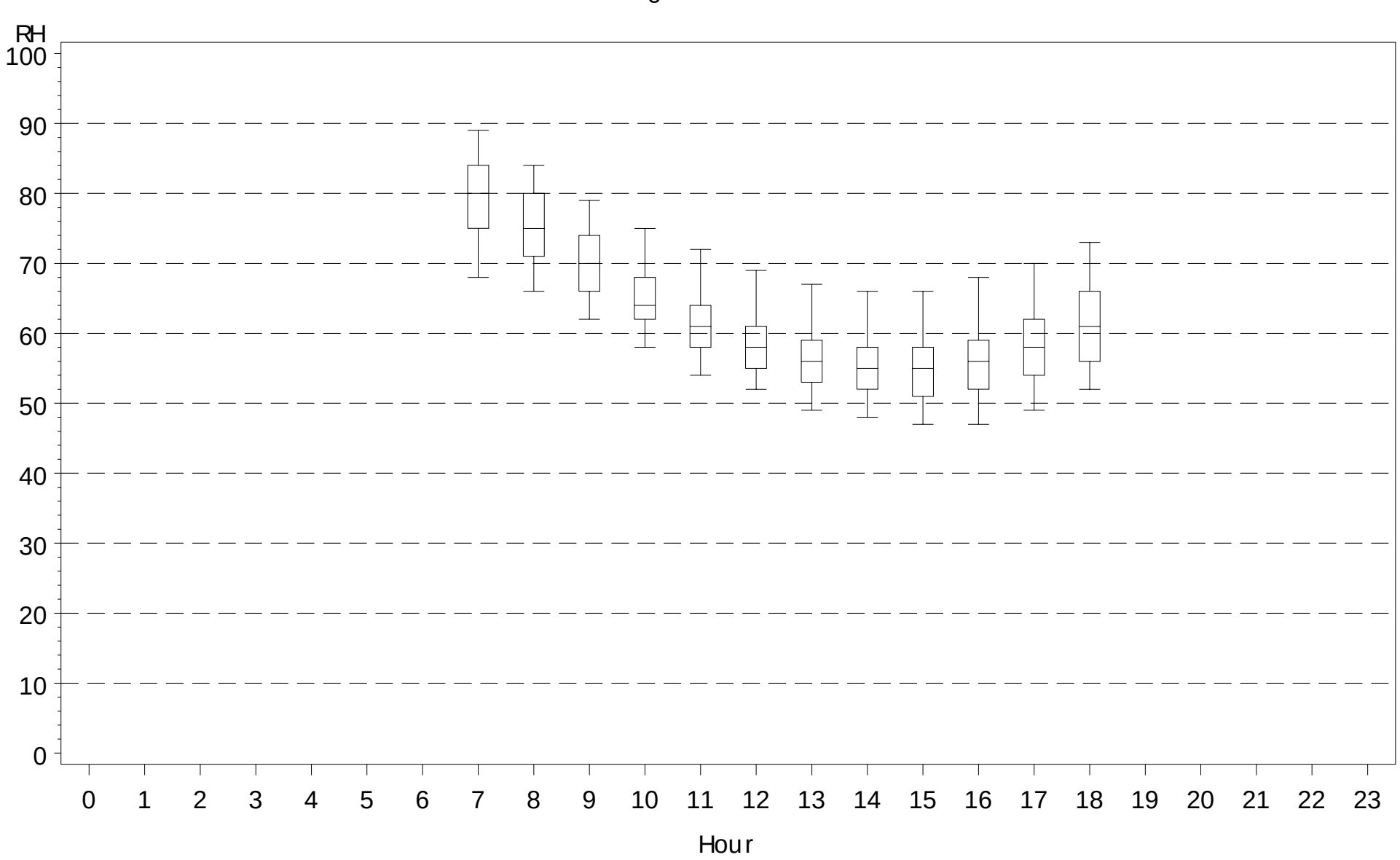
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



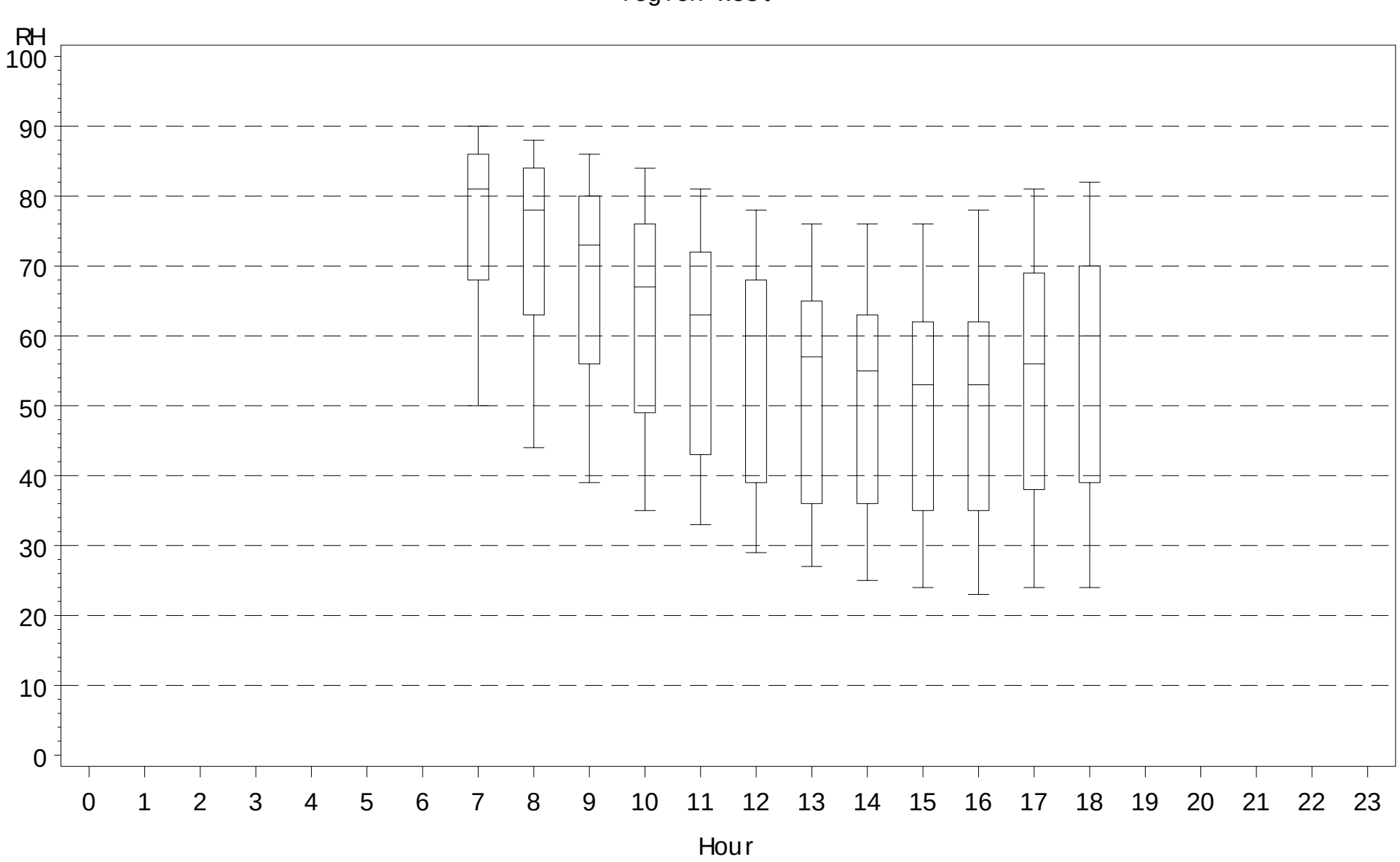
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



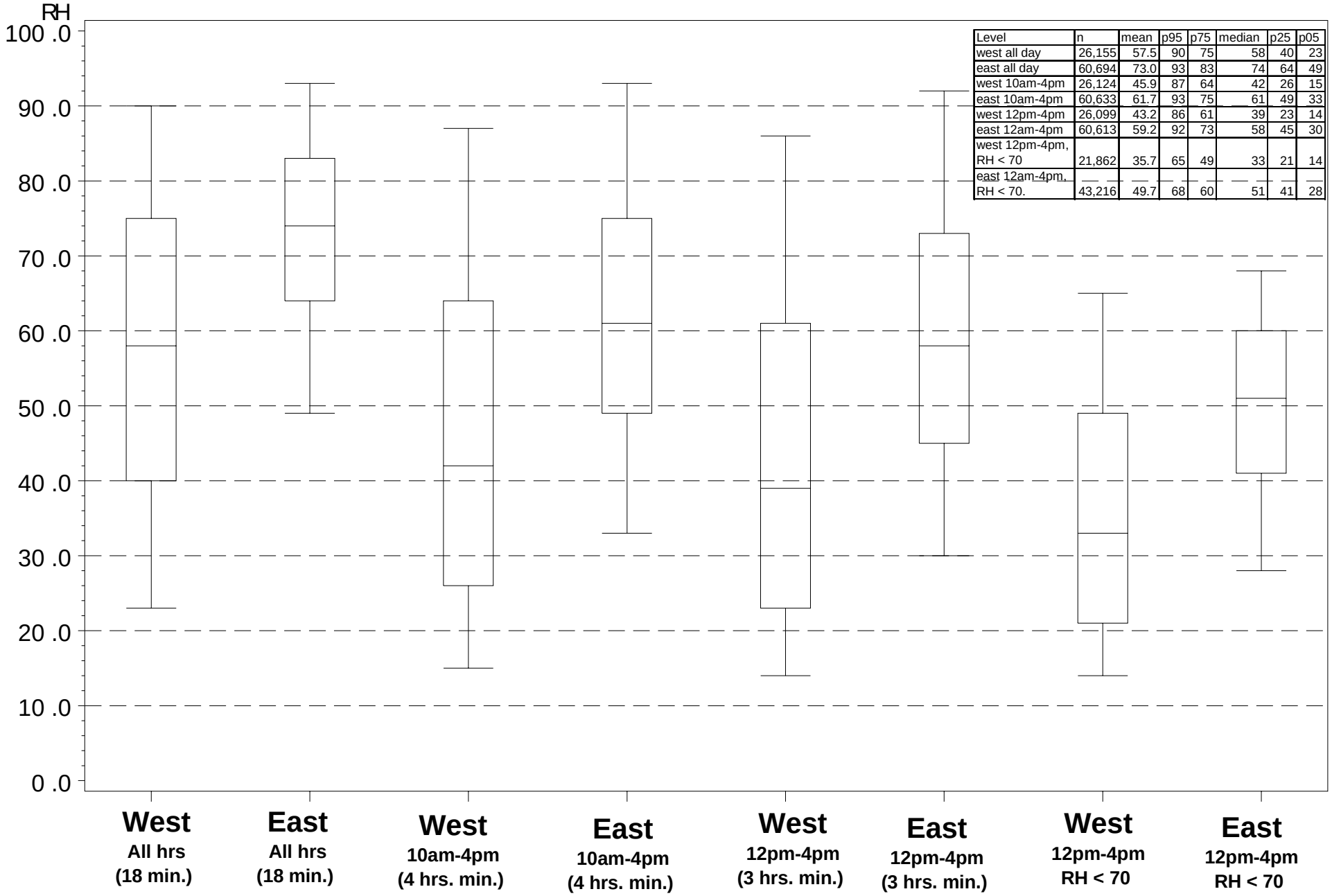
10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour



10-year average month-hour RH at NWS sites for site-days used in visibility analyses, by region and hour

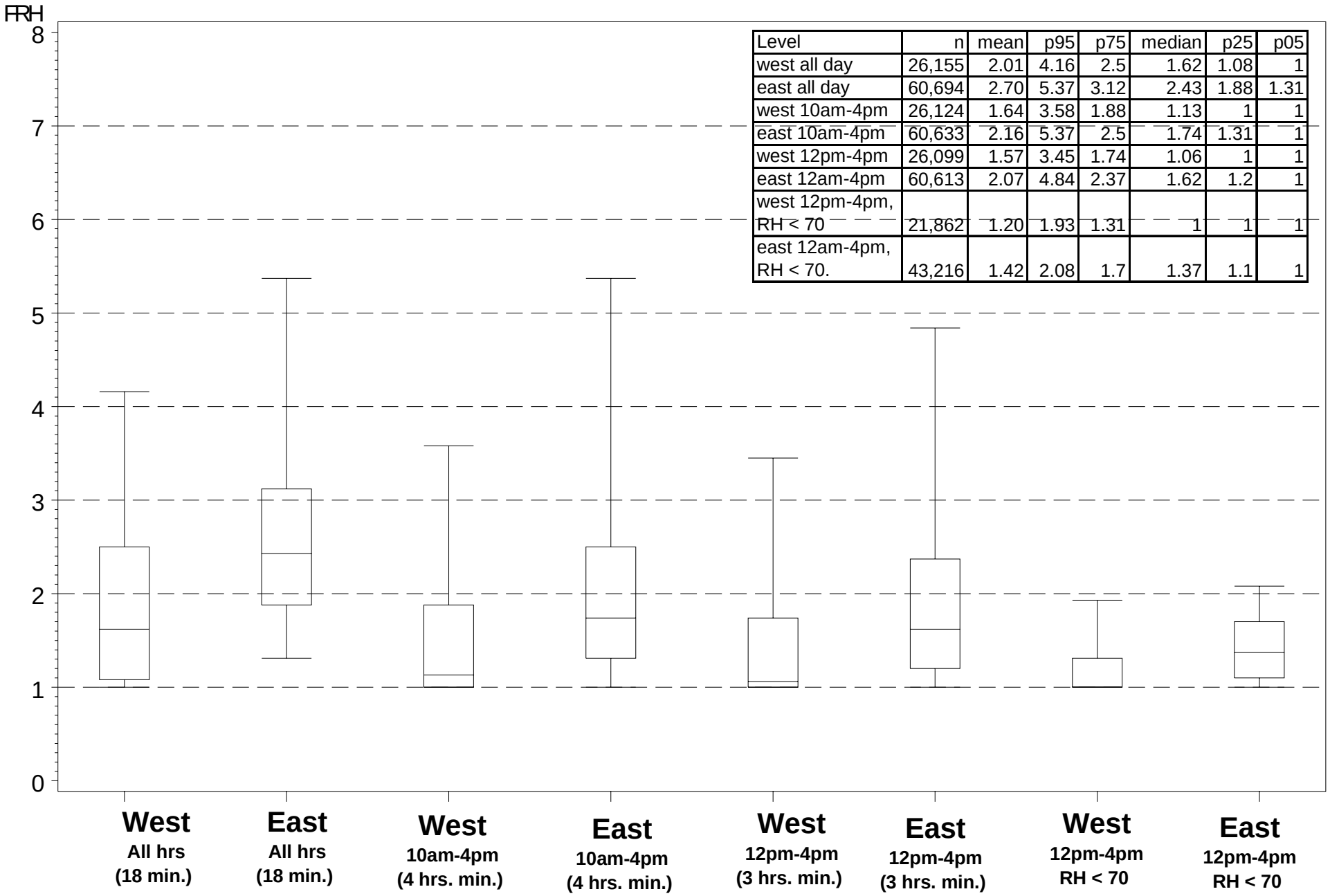


2003 NWS average RH for east and west, various time periods



Level	n	mean	p95	p75	median	p25	p05
west all day	26,155	57.5	90	75	58	40	23
east all day	60,694	73.0	93	83	74	64	49
west 10am-4pm	26,124	45.9	87	64	42	26	15
east 10am-4pm	60,633	61.7	93	75	61	49	33
west 12pm-4pm	26,099	43.2	86	61	39	23	14
east 12am-4pm	60,613	59.2	92	73	58	45	30
west 12pm-4pm, RH < 70	21,862	35.7	65	49	33	21	14
east 12am-4pm, RH < 70.	43,216	49.7	68	60	51	41	28

2003 NWS average FRH for east and west, various time periods



Level	n	mean	p95	p75	median	p25	p05
west all day	26,155	2.01	4.16	2.5	1.62	1.08	1
east all day	60,694	2.70	5.37	3.12	2.43	1.88	1.31
west 10am-4pm	26,124	1.64	3.58	1.88	1.13	1	1
east 10am-4pm	60,633	2.16	5.37	2.5	1.74	1.31	1
west 12pm-4pm	26,099	1.57	3.45	1.74	1.06	1	1
east 12am-4pm	60,613	2.07	4.84	2.37	1.62	1.2	1
west 12pm-4pm, RH < 70	21,862	1.20	1.93	1.31	1	1	1
east 12am-4pm, RH < 70.	43,216	1.42	2.08	1.7	1.37	1.1	1

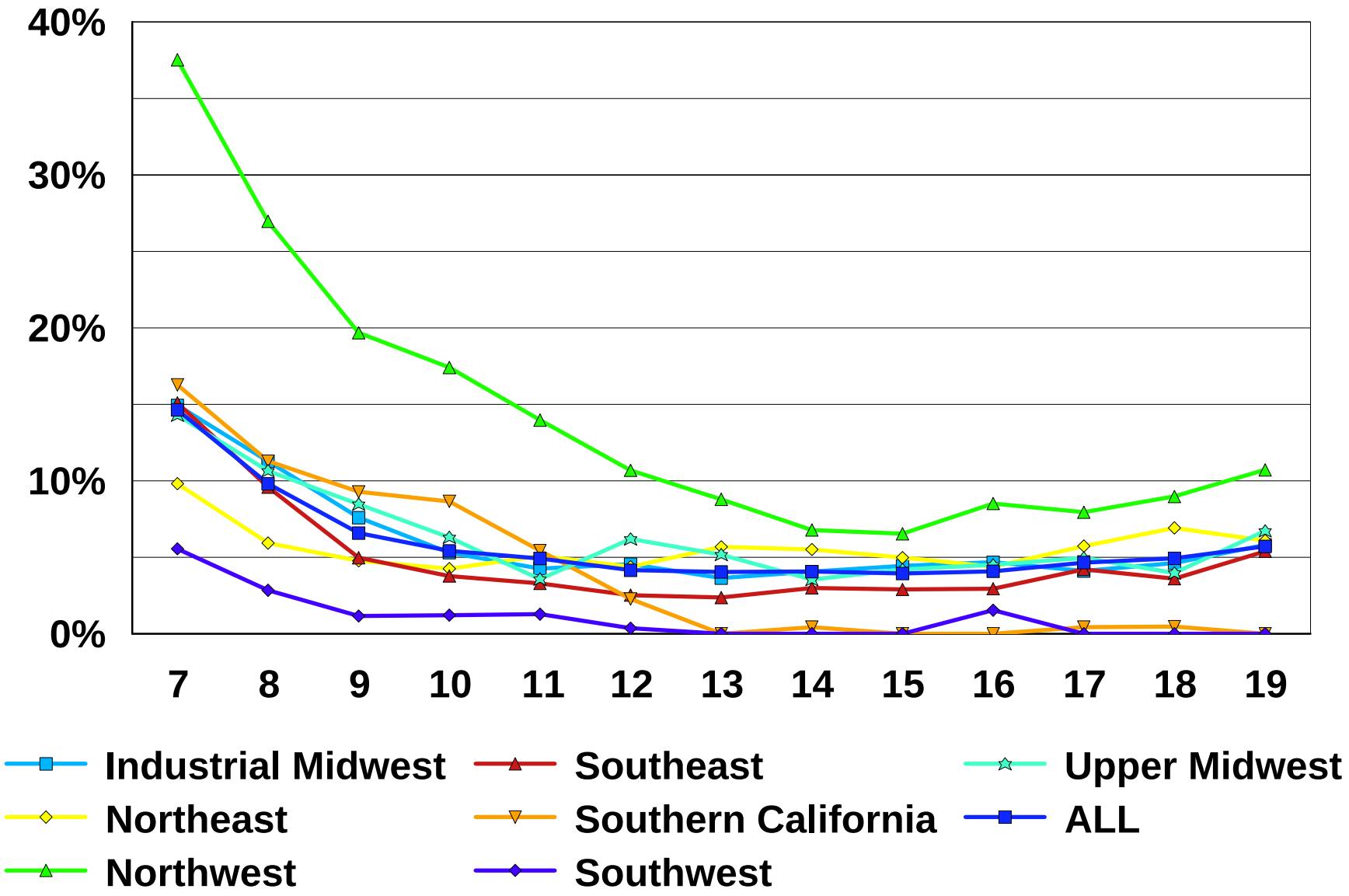
Percent of Hourly NWS RH Observations Under Select RH Thresholds, 2003

	Northwest				Southern CA				Southwest				Upper Midwest				Industrial Midwest				Northeast				Southeast			
	% N where RH less than				% N where RH less than				% N where RH less than				% N where RH less than				% N where RH less than				% N where RH less than				% N where RH less than			
Hour	95	90	80	70	95	90	80	70	95	90	80	70	95	90	80	70	95	90	80	70	95	90	80	70	95	90	80	70
0	90%	81%	62%	47%	88%	71%	49%	39%	97%	90%	79%	67%	91%	79%	52%	29%	83%	68%	43%	23%	79%	63%	41%	26%	76%	51%	28%	15%
1	89%	79%	59%	45%	86%	69%	48%	38%	96%	89%	76%	63%	90%	76%	48%	25%	81%	65%	39%	20%	76%	60%	39%	24%	72%	47%	25%	13%
2	88%	78%	57%	42%	86%	68%	47%	37%	95%	87%	74%	60%	88%	73%	44%	22%	79%	62%	36%	18%	75%	59%	37%	23%	69%	43%	22%	11%
3	87%	76%	54%	39%	84%	67%	46%	36%	94%	86%	71%	57%	87%	71%	41%	20%	77%	59%	33%	17%	73%	57%	35%	21%	66%	40%	21%	10%
4	86%	74%	52%	37%	83%	65%	45%	34%	93%	84%	68%	55%	85%	69%	38%	18%	75%	57%	31%	15%	72%	55%	33%	20%	63%	38%	19%	9%
5	85%	73%	50%	35%	83%	65%	45%	34%	92%	82%	66%	52%	83%	66%	35%	16%	74%	55%	30%	14%	71%	54%	32%	19%	61%	36%	18%	9%
6	86%	74%	52%	37%	83%	66%	45%	33%	92%	81%	64%	50%	84%	66%	34%	15%	74%	56%	29%	14%	73%	56%	34%	19%	61%	36%	17%	8%
7	88%	78%	57%	42%	86%	73%	50%	37%	93%	83%	66%	52%	88%	73%	41%	18%	79%	62%	33%	15%	78%	63%	40%	23%	70%	43%	20%	9%
8	90%	82%	65%	50%	91%	82%	62%	45%	94%	88%	74%	59%	92%	82%	55%	29%	85%	71%	44%	22%	84%	71%	49%	30%	82%	63%	33%	14%
9	93%	87%	73%	60%	95%	90%	75%	57%	96%	93%	84%	71%	94%	87%	68%	46%	90%	80%	58%	35%	88%	78%	61%	42%	90%	79%	57%	28%
10	95%	90%	79%	68%	97%	94%	83%	66%	98%	95%	90%	81%	96%	91%	77%	59%	92%	85%	69%	48%	91%	83%	69%	52%	94%	87%	73%	47%
11	97%	93%	84%	74%	99%	96%	89%	72%	99%	97%	93%	86%	97%	93%	82%	68%	94%	88%	75%	58%	92%	86%	74%	59%	96%	90%	81%	62%
12	97%	94%	86%	78%	99%	98%	92%	76%	99%	98%	95%	90%	97%	94%	85%	73%	95%	90%	79%	64%	93%	87%	76%	64%	97%	92%	84%	69%
13	98%	95%	88%	81%	99%	98%	93%	78%	99%	98%	96%	92%	98%	95%	87%	76%	96%	91%	81%	68%	93%	88%	78%	66%	97%	93%	86%	73%
14	98%	96%	89%	82%	99%	98%	93%	78%	99%	98%	96%	93%	98%	96%	88%	78%	96%	92%	82%	70%	93%	87%	78%	67%	97%	93%	86%	74%
15	98%	95%	89%	82%	99%	98%	92%	76%	99%	98%	96%	94%	98%	95%	88%	78%	96%	92%	82%	70%	93%	87%	77%	66%	97%	92%	86%	73%
16	98%	95%	88%	80%	99%	97%	89%	71%	99%	98%	96%	94%	98%	95%	87%	77%	96%	91%	81%	69%	93%	87%	76%	64%	96%	92%	84%	70%
17	97%	94%	85%	77%	99%	95%	82%	64%	99%	98%	96%	93%	98%	94%	85%	74%	95%	90%	80%	66%	92%	85%	73%	60%	96%	91%	81%	65%
18	96%	92%	82%	72%	98%	90%	72%	55%	99%	98%	95%	91%	97%	93%	83%	69%	94%	89%	76%	60%	90%	83%	68%	54%	95%	88%	74%	53%
19	95%	90%	78%	67%	96%	85%	62%	48%	99%	97%	93%	87%	96%	92%	78%	62%	93%	86%	71%	52%	89%	79%	62%	46%	93%	82%	63%	40%
20	94%	88%	74%	62%	94%	80%	57%	46%	99%	96%	91%	83%	95%	90%	72%	52%	91%	82%	63%	42%	87%	75%	56%	39%	90%	75%	51%	29%
21	93%	86%	71%	57%	92%	77%	55%	44%	98%	95%	88%	78%	94%	87%	66%	44%	89%	78%	57%	35%	84%	72%	51%	34%	87%	68%	43%	23%
22	92%	84%	68%	53%	91%	75%	53%	42%	98%	94%	85%	74%	93%	84%	61%	38%	87%	74%	51%	30%	83%	69%	47%	30%	83%	62%	37%	19%
23	91%	83%	65%	50%	89%	73%	51%	41%	97%	92%	81%	70%	92%	82%	56%	33%	85%	71%	47%	26%	81%	66%	44%	28%	80%	57%	32%	17%

Red indicates less than 75%

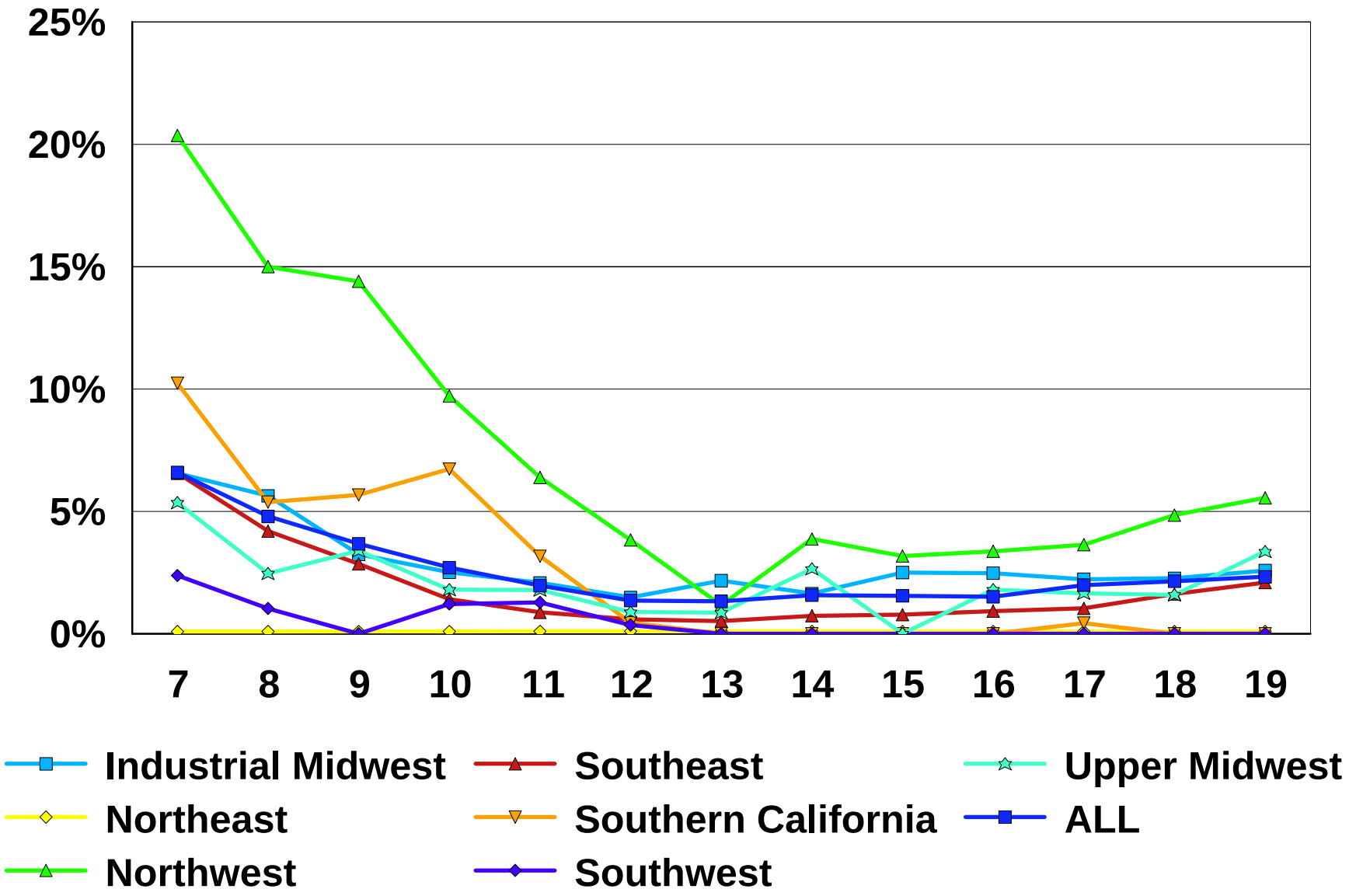
Percent of Hours Where RH ≥ 95

(for 'old' visibility db: 4/02-3/03)



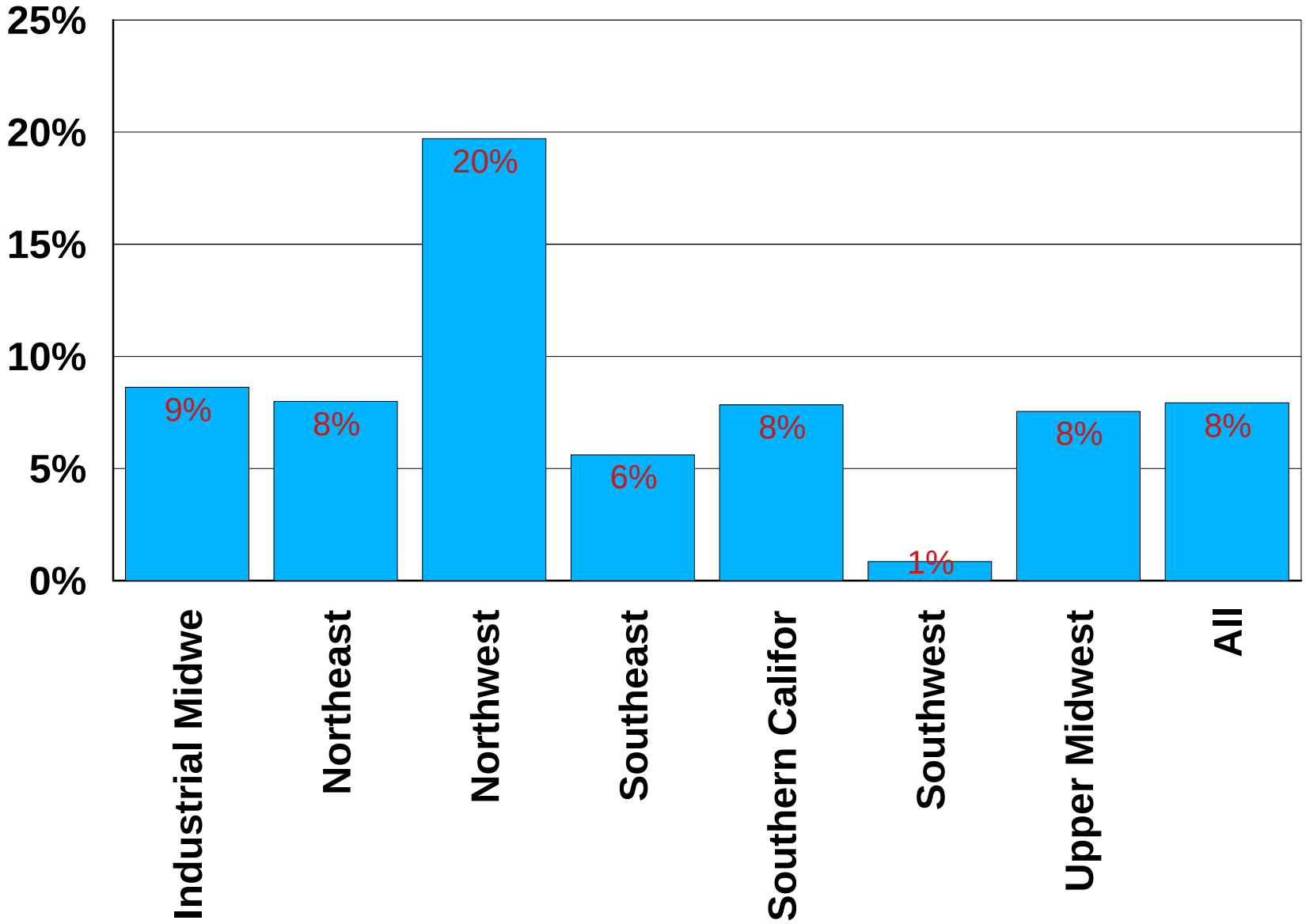
Percent of Hours Where RH ≥ 98

(for 'old' visibility db: 4/02-3/03)

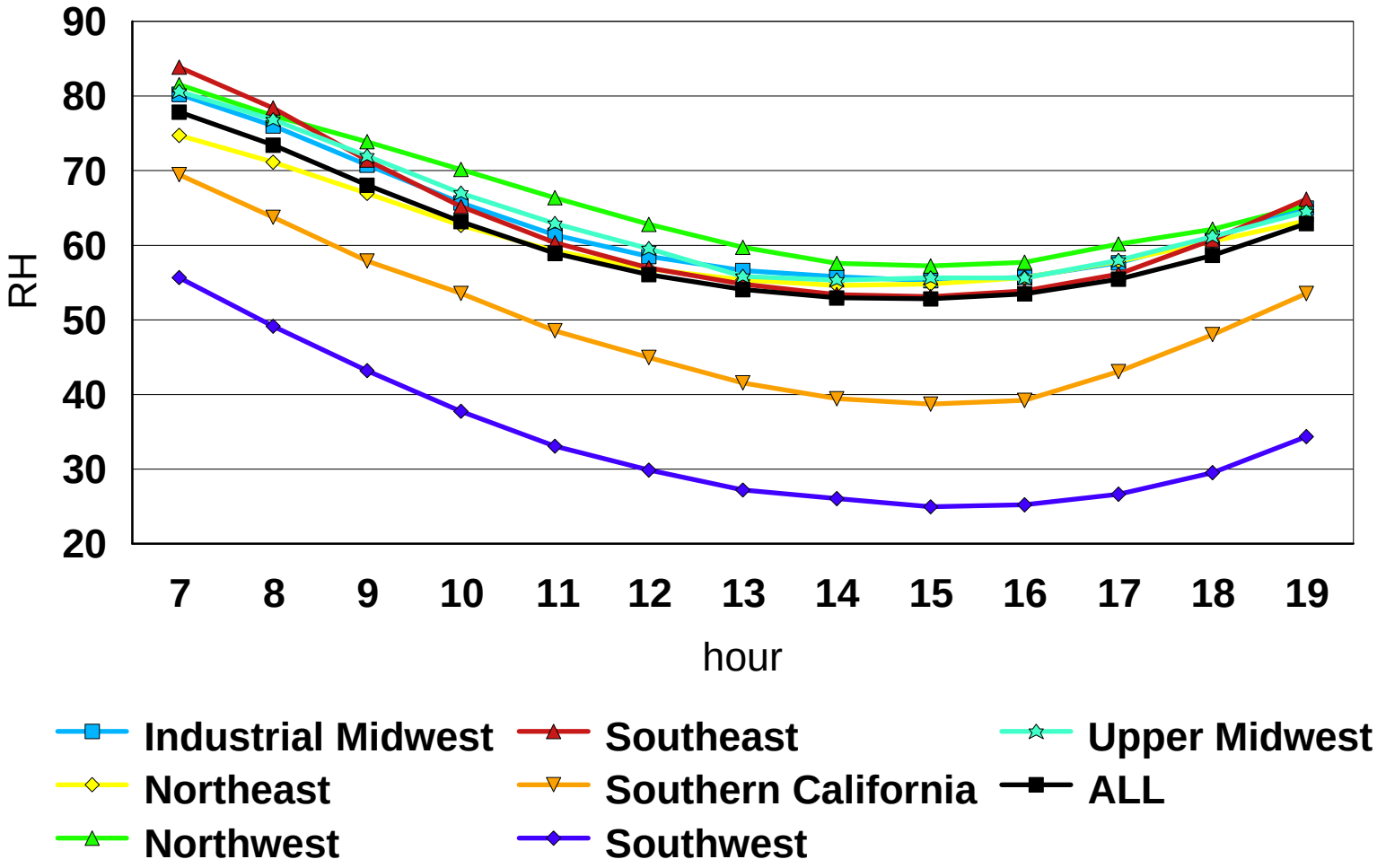


Percent of 10am-4pm blocks where RH ≥ 95 (for 1+ hrs)

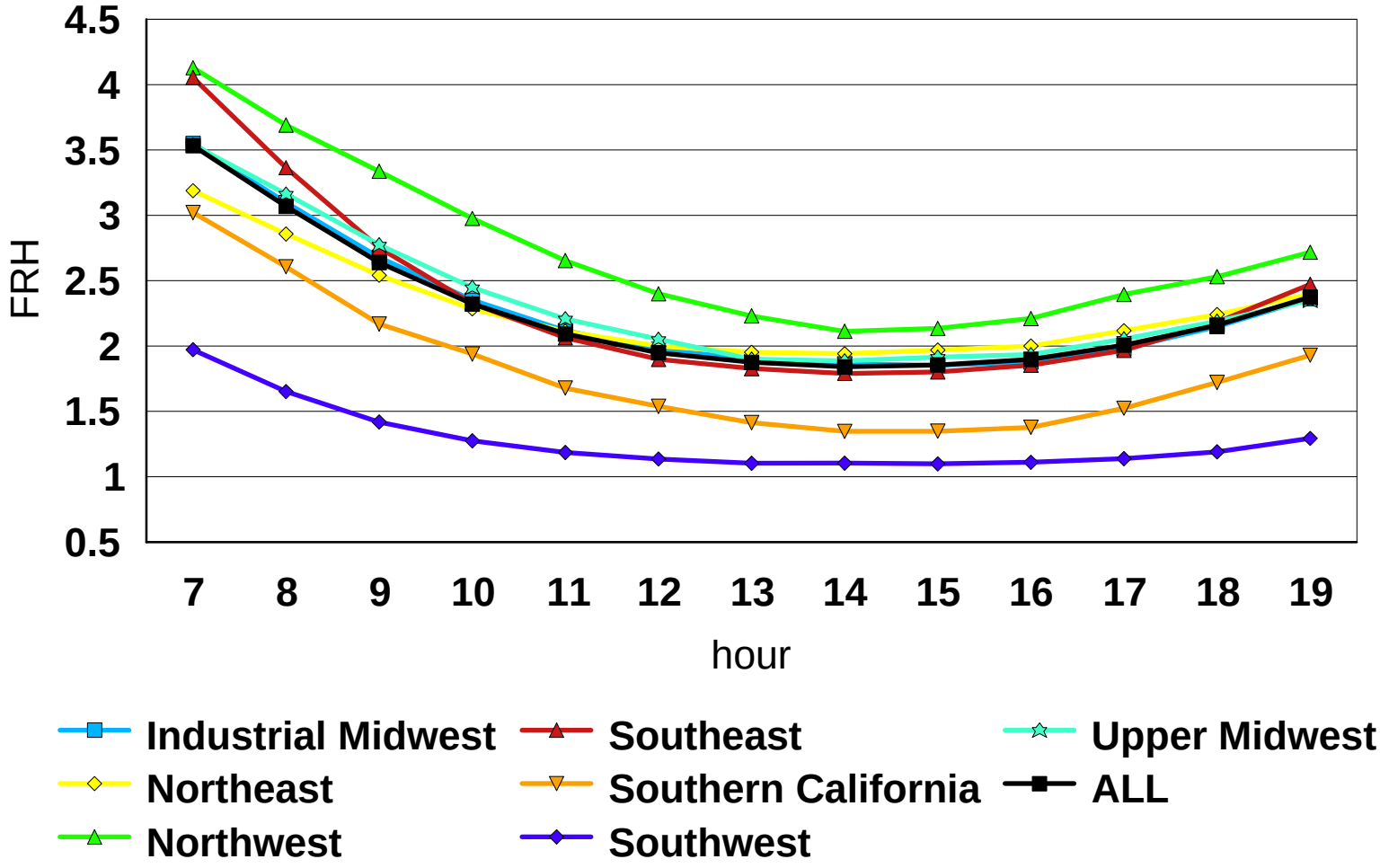
(for 'old' visibility db: 4/02-3/03)



RH - 10yr Avg
(for 'old' vis. db)



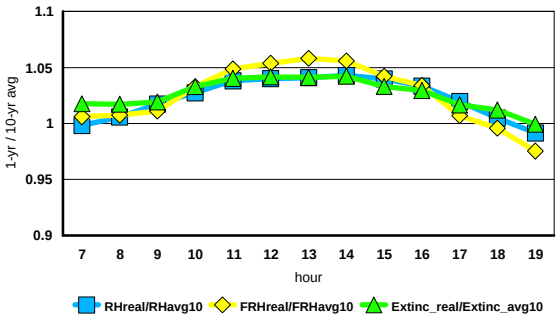
FRH - 10yr Avg
(for 'old vis. db)



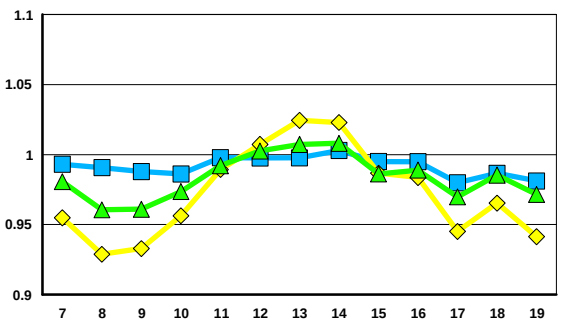
RH, FRH, Recon Extinction: Actual RH vs. 10yr Avg

How Representative was 4/02 - 3/03 ('old' vis db) ..... compared to 10-yr avg?

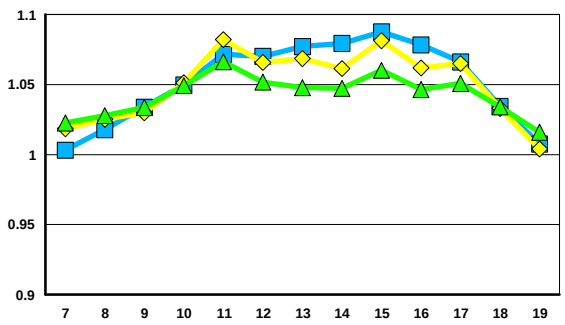
All Regions



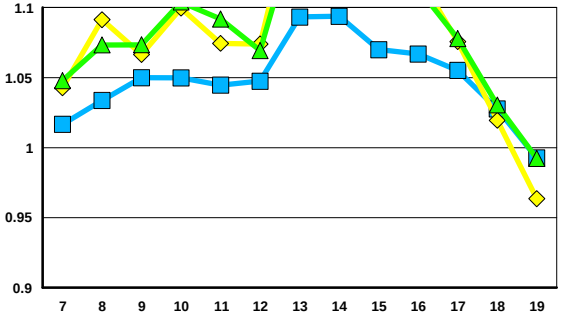
Northeast



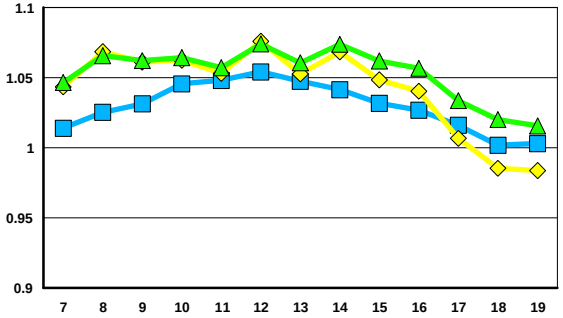
Southeast



Upper Midwest

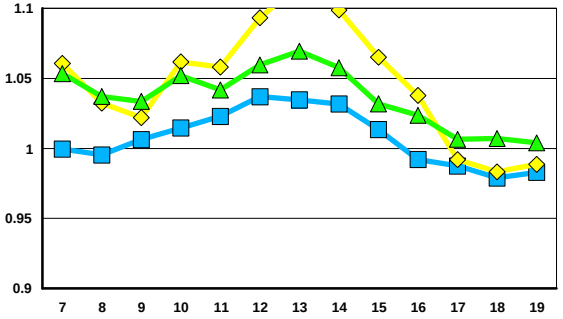


Industrial Midwest

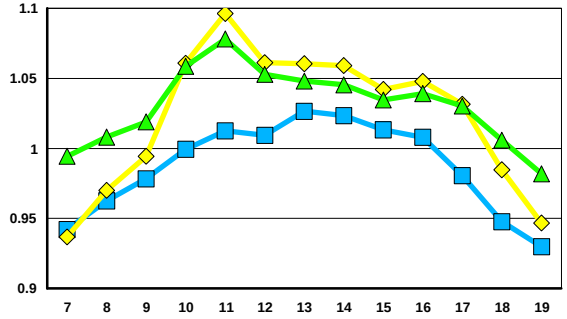


- Most areas had higher midday humidity during 4/02-3/03 than 'average' (~4% higher for all regions). Hence, FRH and reconstructed extinction values are higher than those calculated w/ 10-yr avg FRH's.... for same PM2.5 levels. Slopes for Recon. Extinc. = PM2.5 would be greater

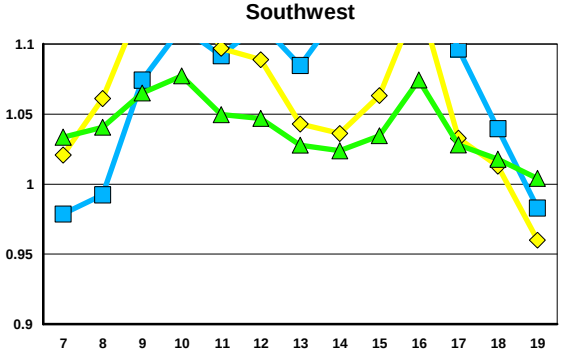
Northwest

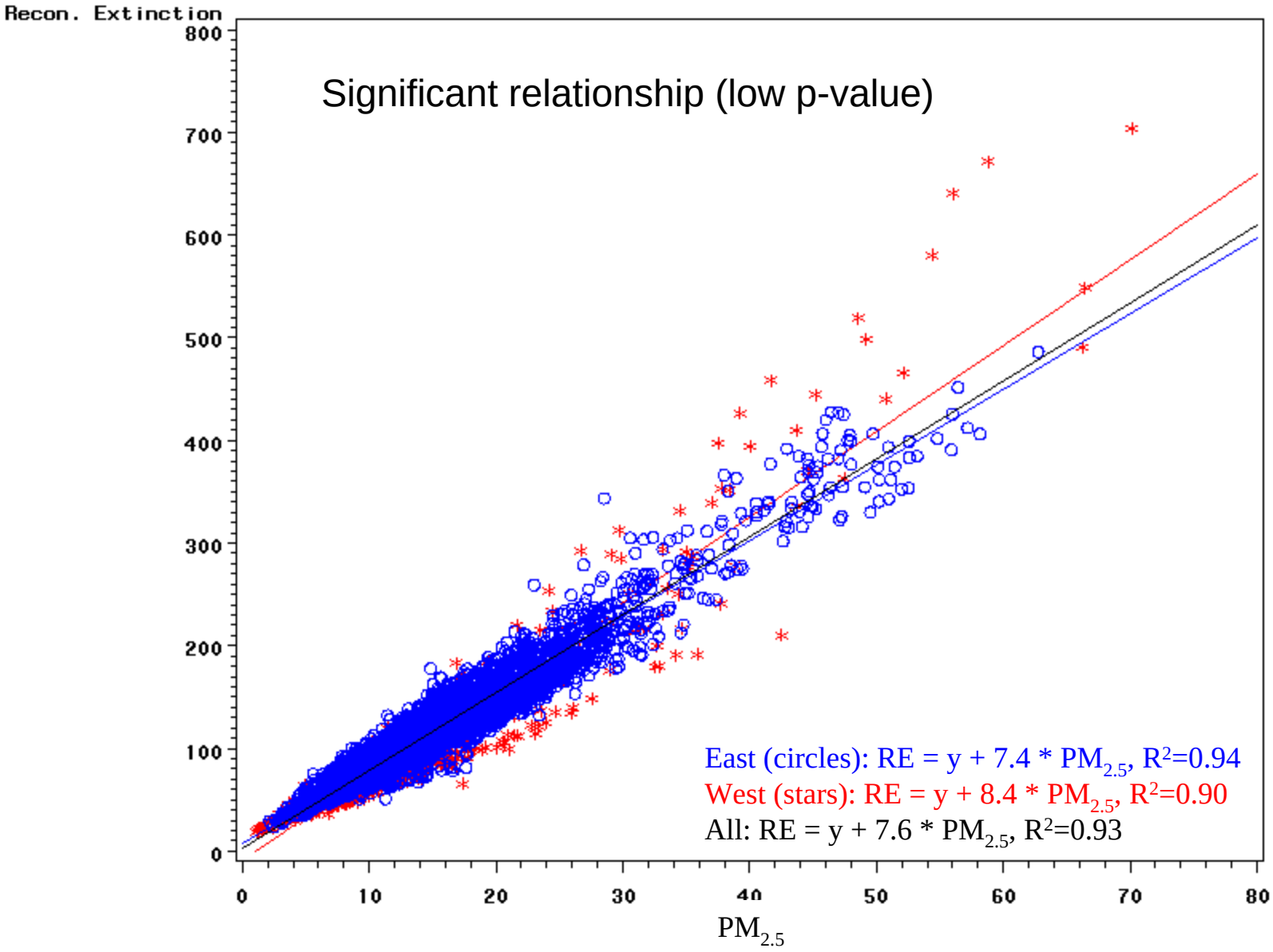


Southern CA

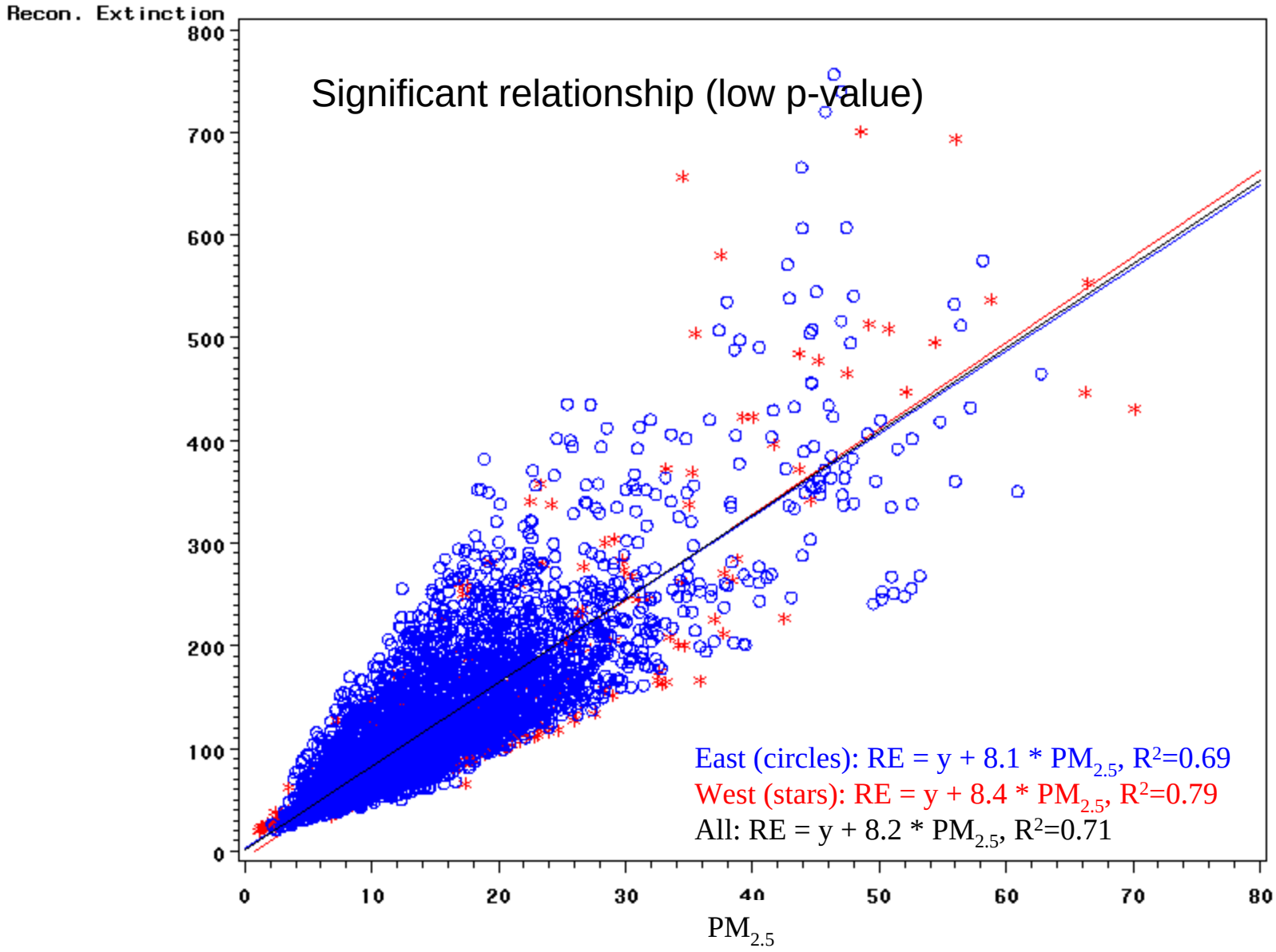


Southwest





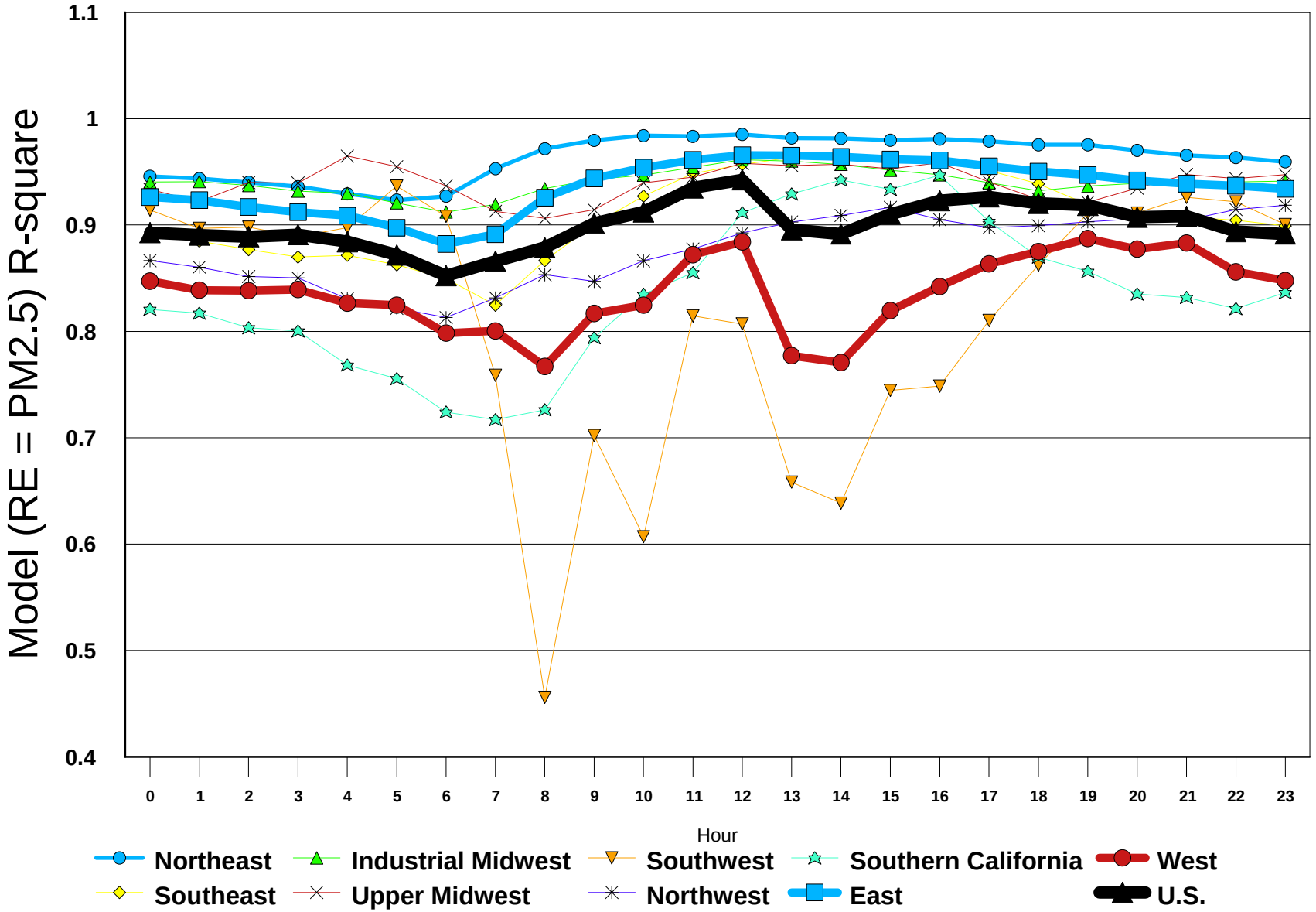
Relationship between reconstructed light extinction (RE) and 24-hour average $PM_{2.5}$. 2003.
Using 10-year average *f(RH)*.



Relationship between reconstructed light extinction (RE) and 24-hour average $PM_{2.5}$, 2003. Using actual *f(RH)*

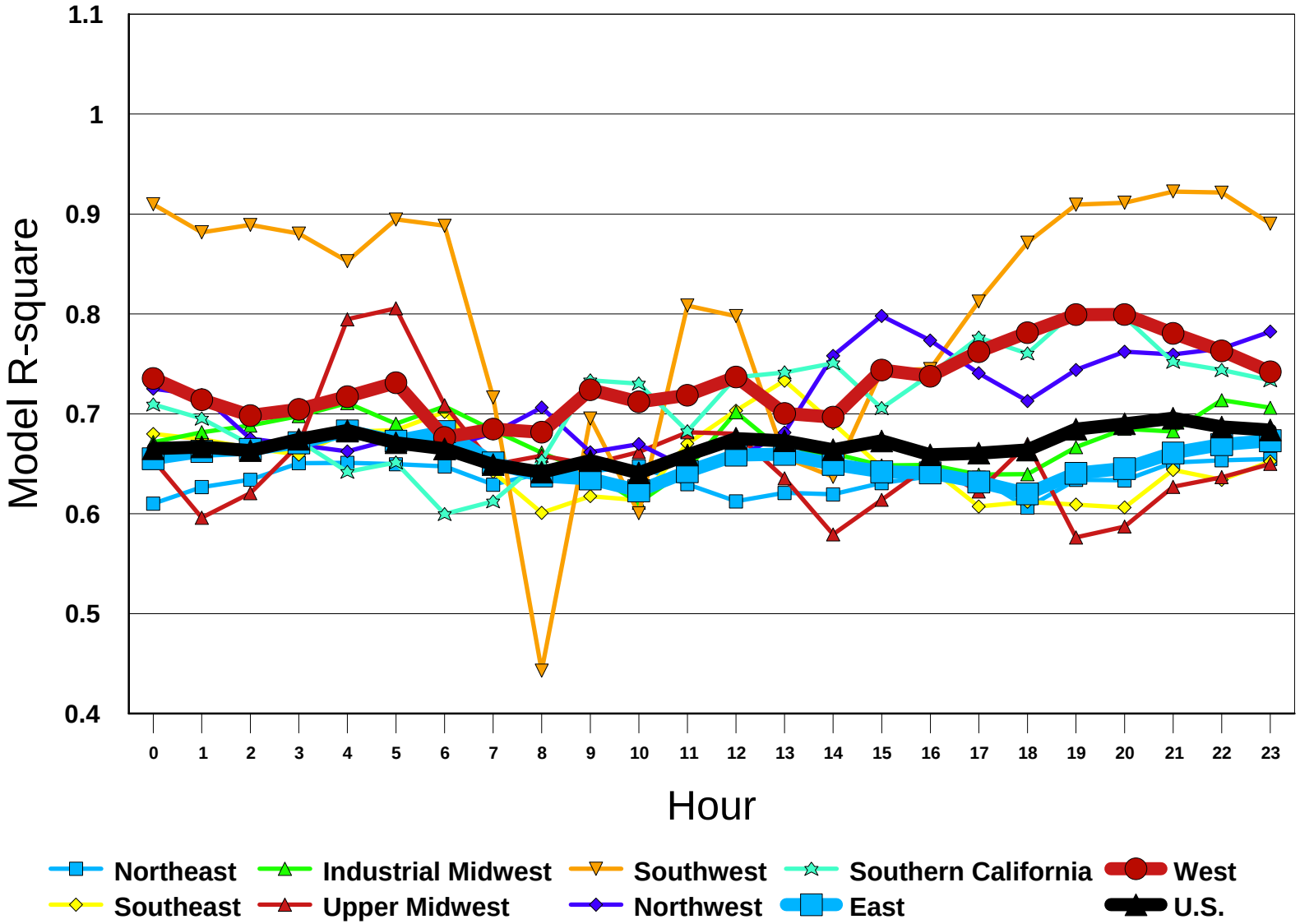
Model R^2 for relationship between reconstructed light extinction (RE) and hourly PM2.5 (increase in RE due to incremental increase in PM2.5), 2003.

RE computed using 10-year average *f(RH)*.



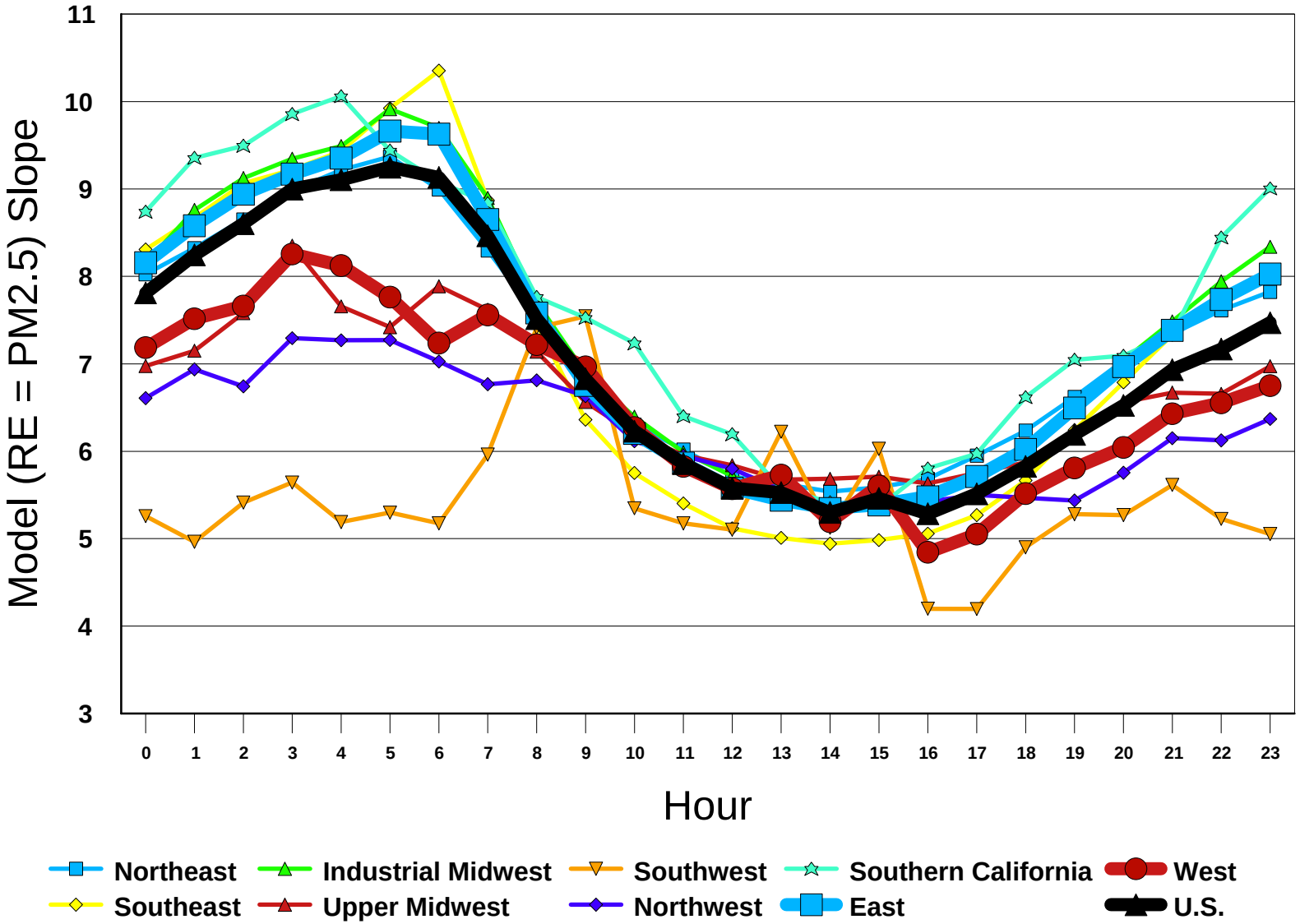
Model R^2 for relationship between reconstructed light extinction (RE) and hourly PM2.5 (increase in RE due to incremental increase in PM2.5), 2003.

RE computed with actual *f(RH)*.



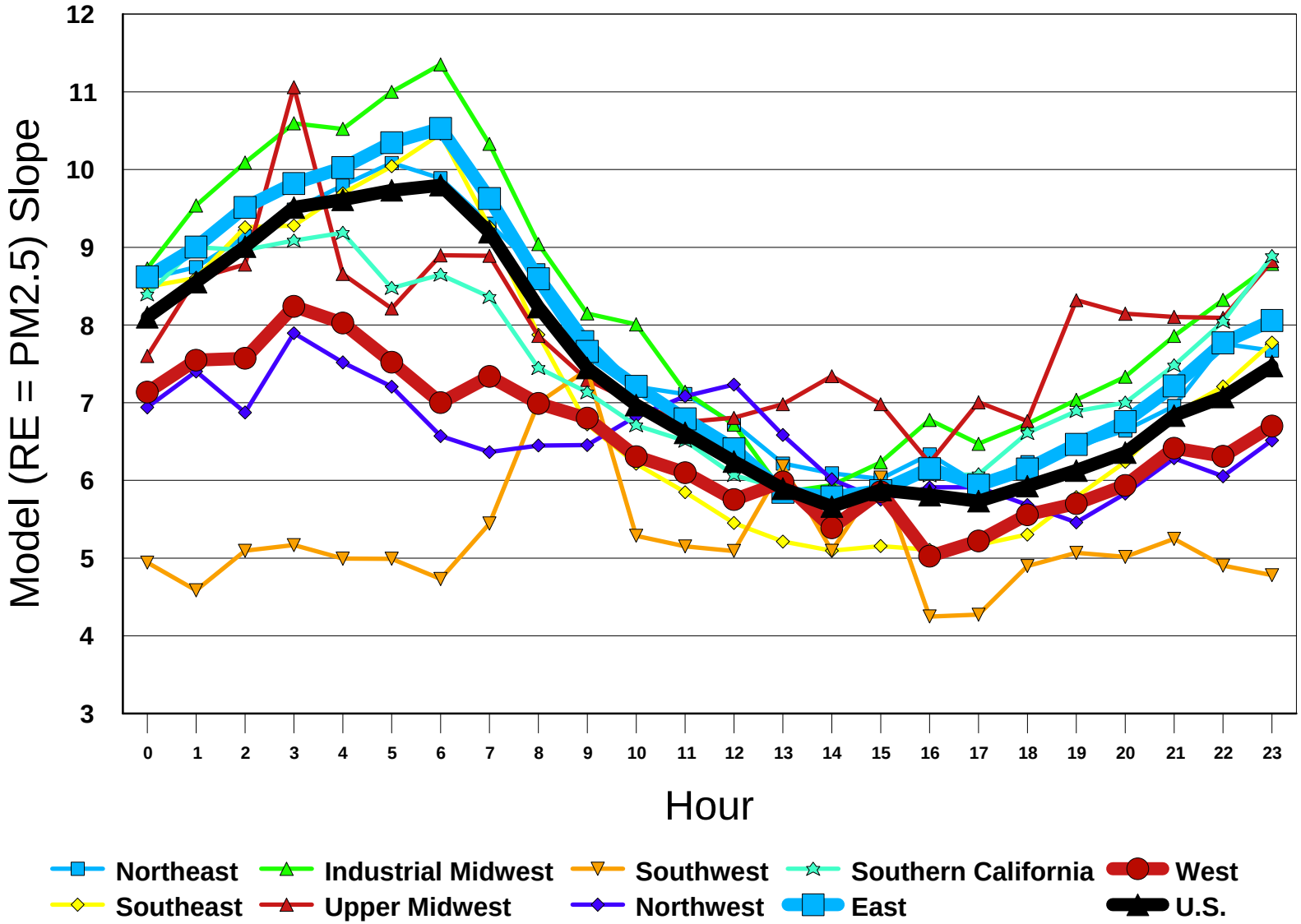
Model slope for relationship between reconstructed light extinction (RE) and hourly PM2.5 (increase in RE due to incremental increase in PM2.5), 2003.

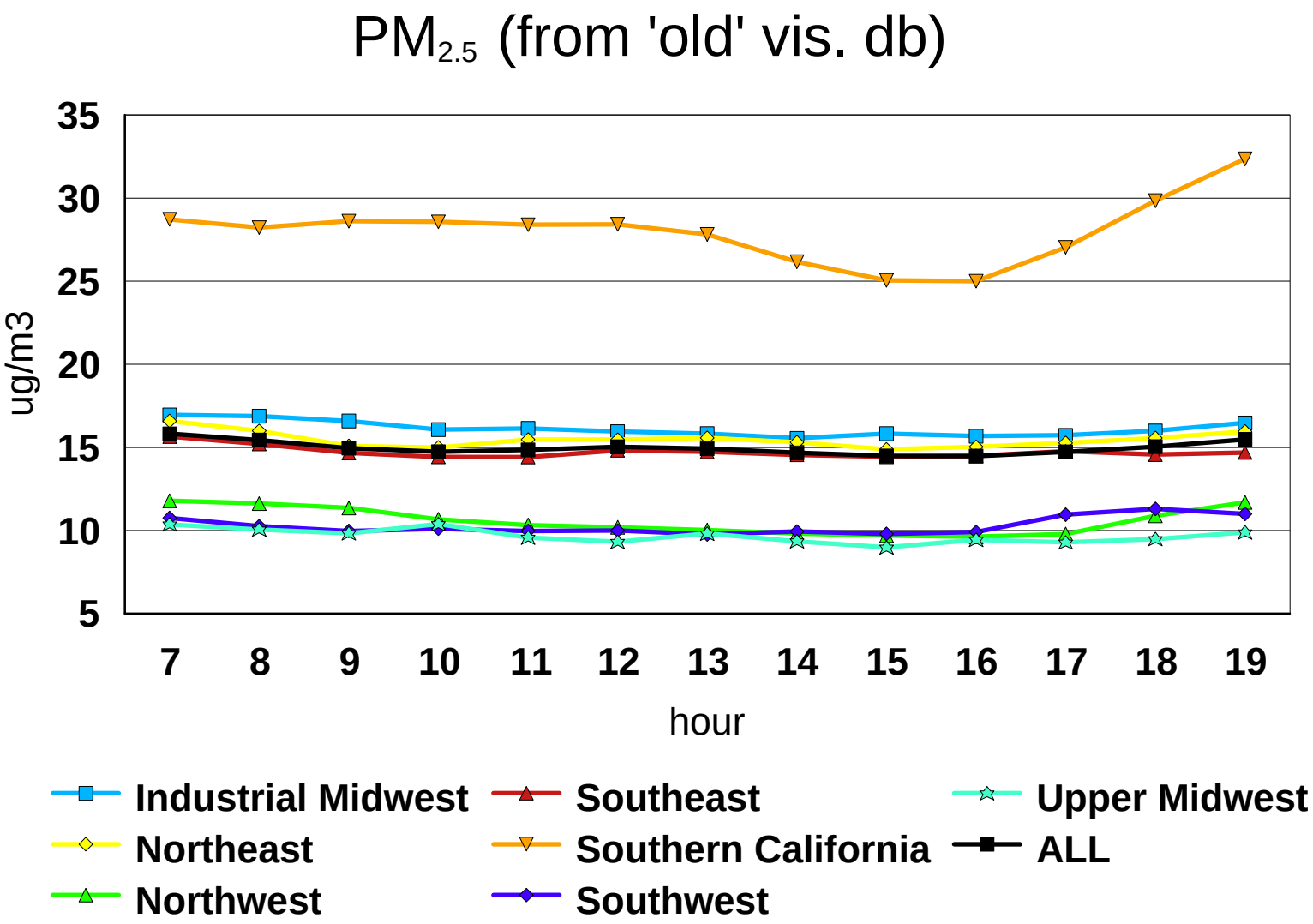
RE computed with 10-year average *f(RH)*.



Model slope for relationship between reconstructed light extinction (RE) and hourly PM2.5 (increase in RE due to incremental increase in PM2.5), 2003.

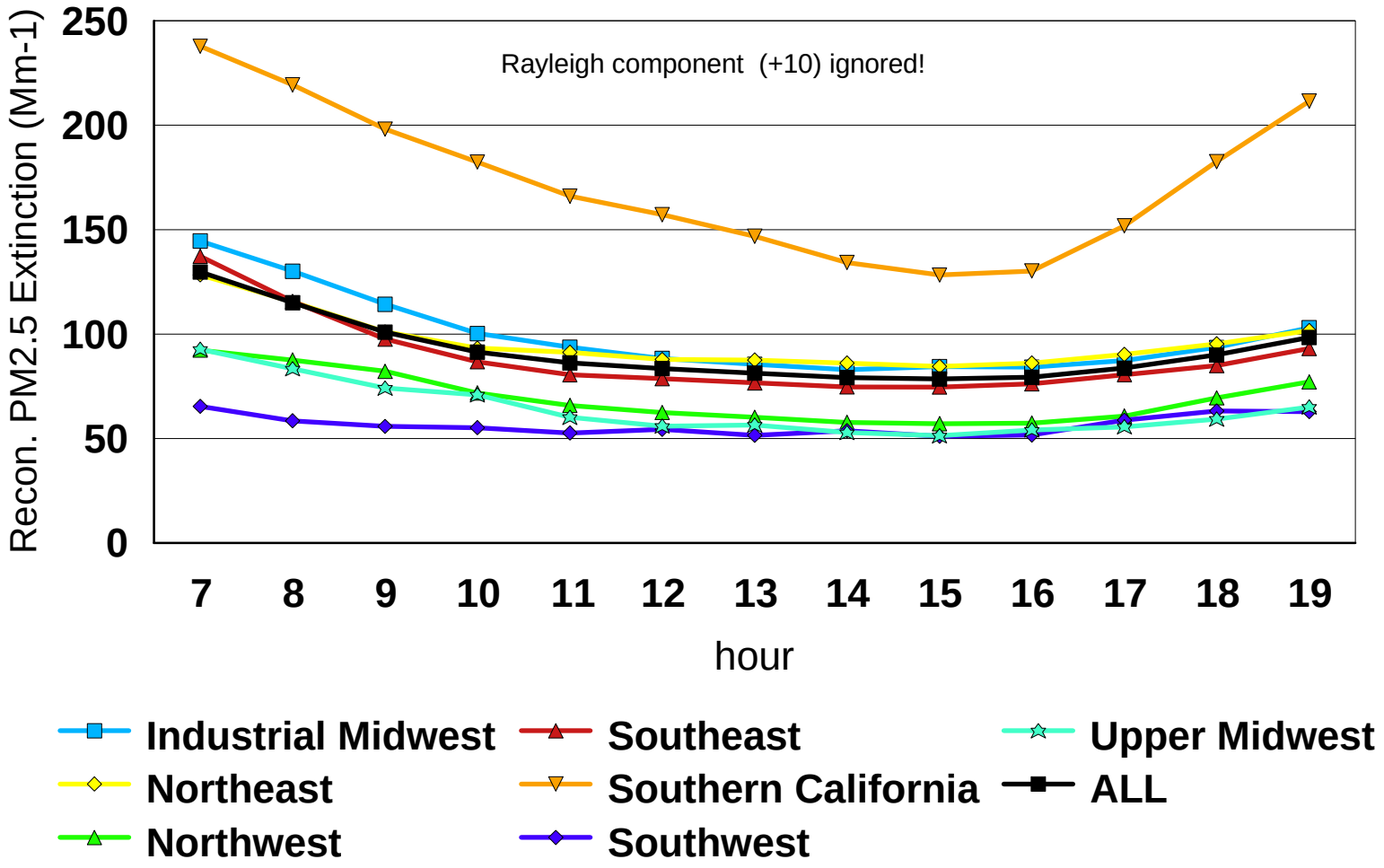
RE computed with actual *f(RH)*.





Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

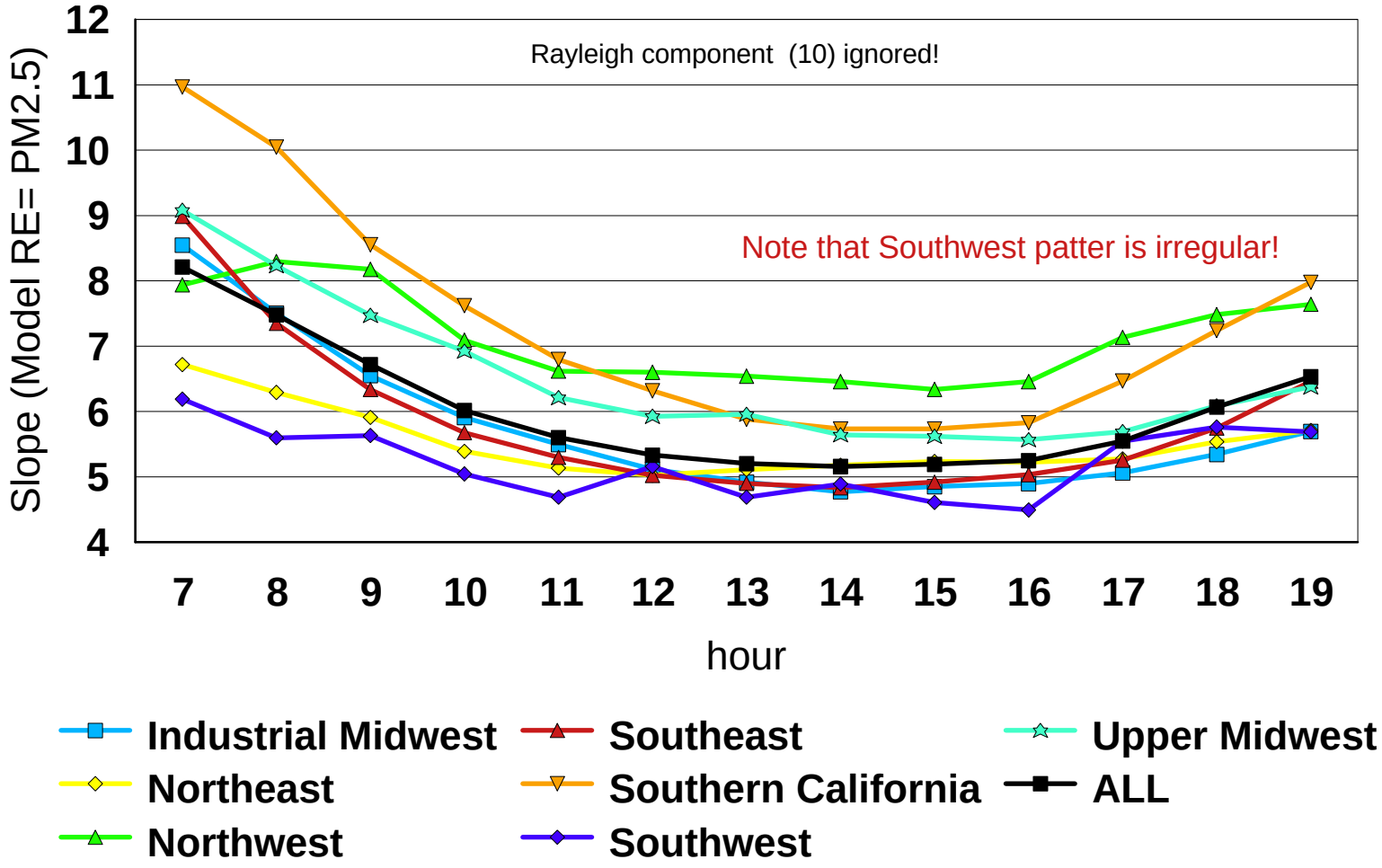
Reconstructed Extinction ('old' db) - using 10-year avg. met and combo PMc*



[*If collocated hourly PM10 was not present (for a site-day), a PMcoarse value was estimated using regional PM2.5-to-PM10 ratios]

Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

Slope (Recon. Extinction = $PM_{2.5}$) - using 10-year avg. met and combo PMc*

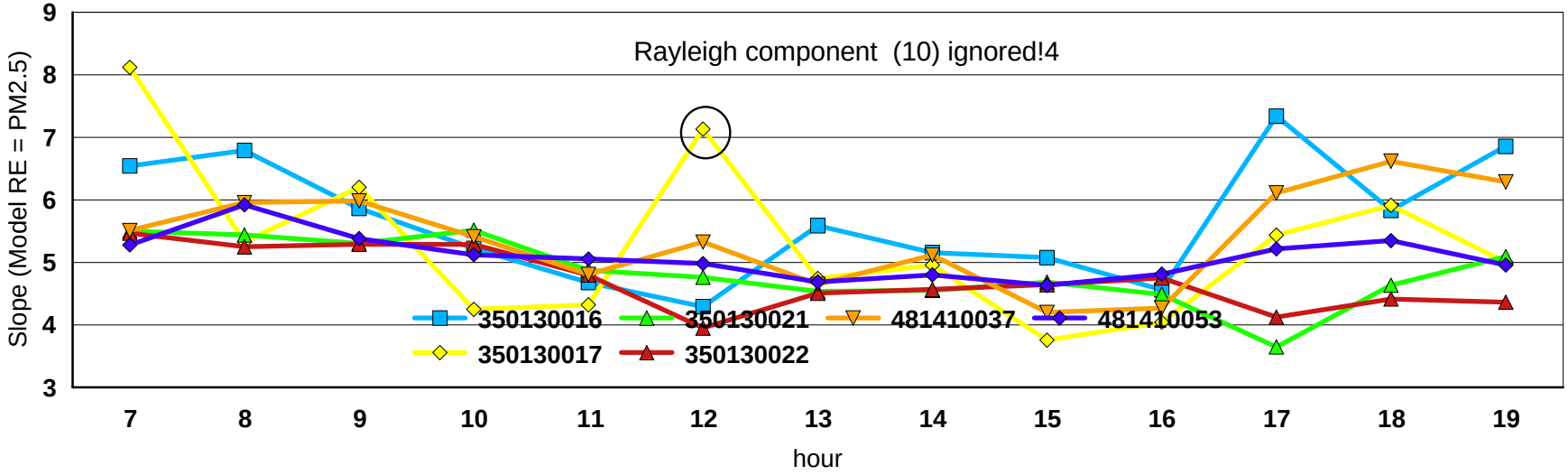


[*If collocated hourly PM10 was not present (for a site-day), a PMcoarse value was estimated using regional PM2.5-to-PM10 ratios]

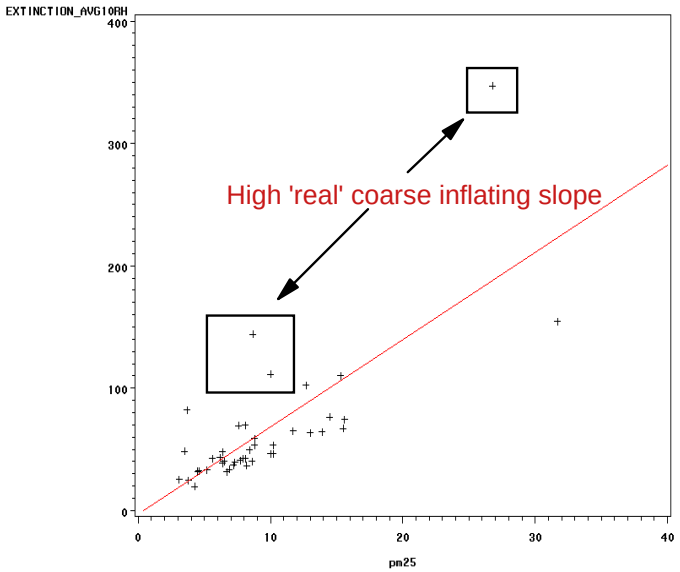
Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

Slope (Recon. Extinction = $PM_{2.5}$) - using combo PMc

Southwest Sites



Site 350130017 (yellow above), Hr=12

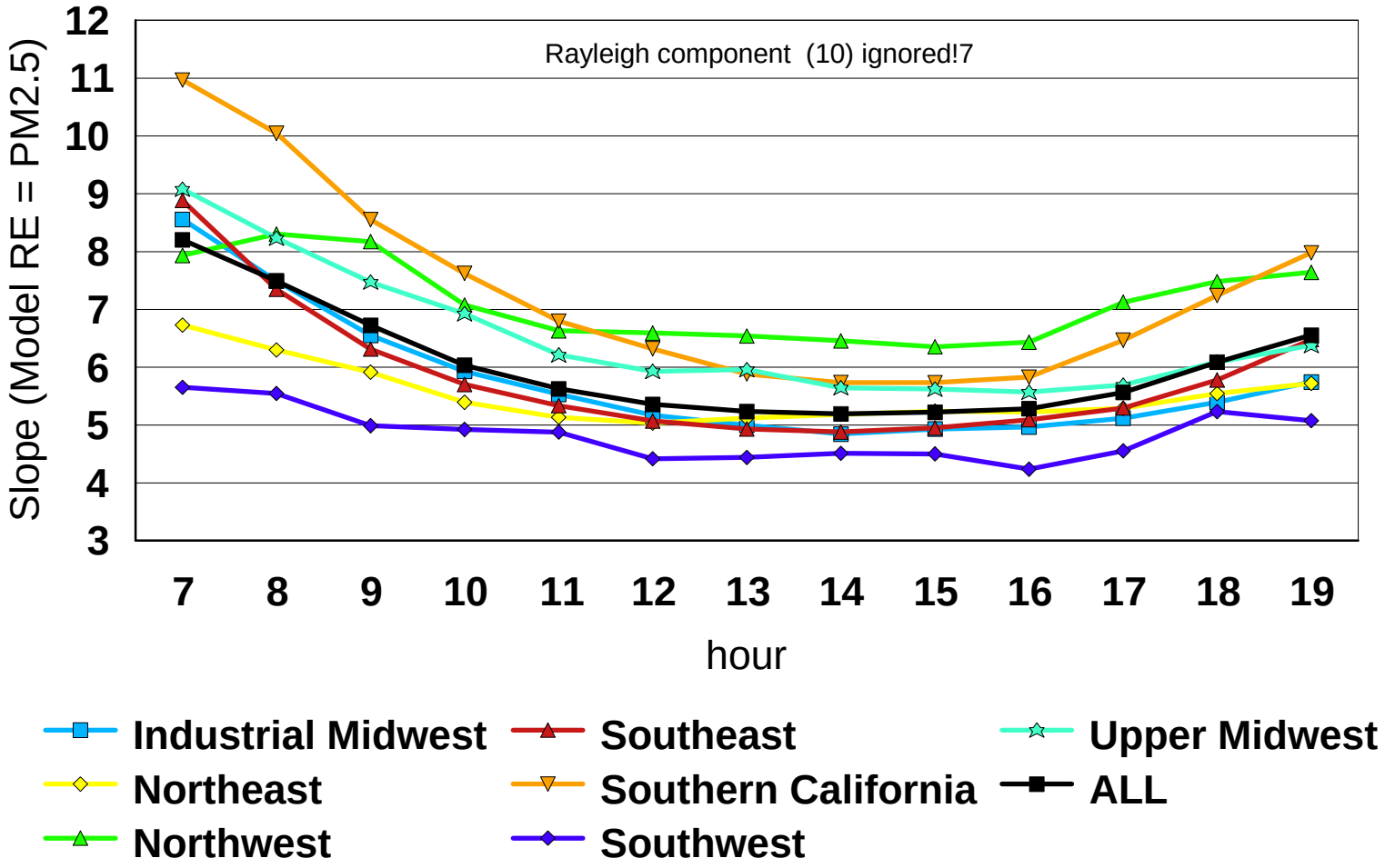


EXTINCTION_AVG10RH=
(3*FRH10AVG*PM25_NITRATES) +
(3*FRH10AVG*PM25_SULFATES) +
(4*PM25_OCM) +
(10*PM25_EC) +
(PM25_CRUSTAL) +
(.6* PMC);

Rayleigh component (10) ignored!

Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

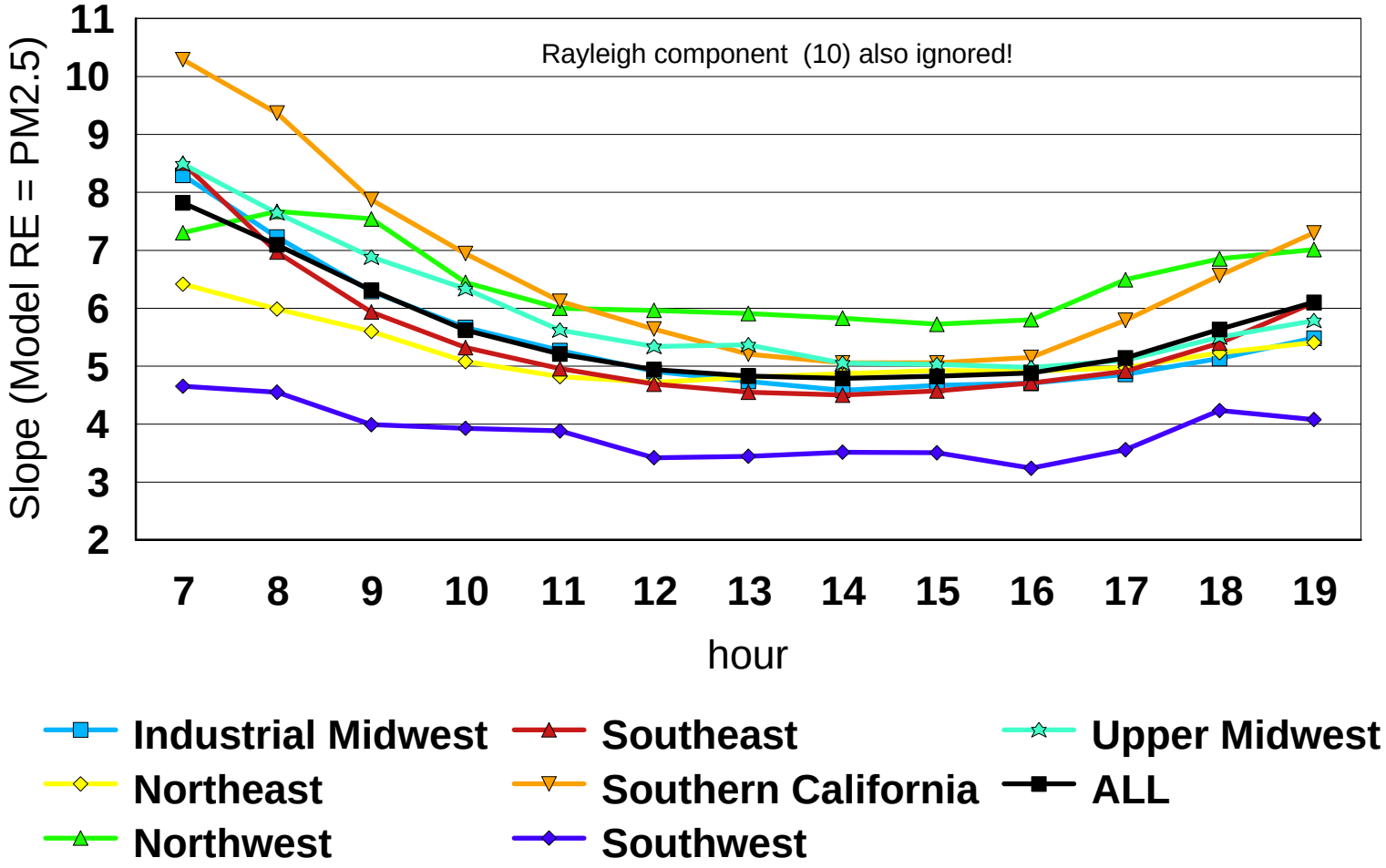
Slope (Recon. Extinction=$PM_{2.5}$) - using PMC from Reg. Ratios*



[* All PMcoarse data were estimated using regional PM2.5-to-PM10 ratios]

Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

Slope (Recon. Extinction = $PM_{2.5}$) - ignoring PMc component

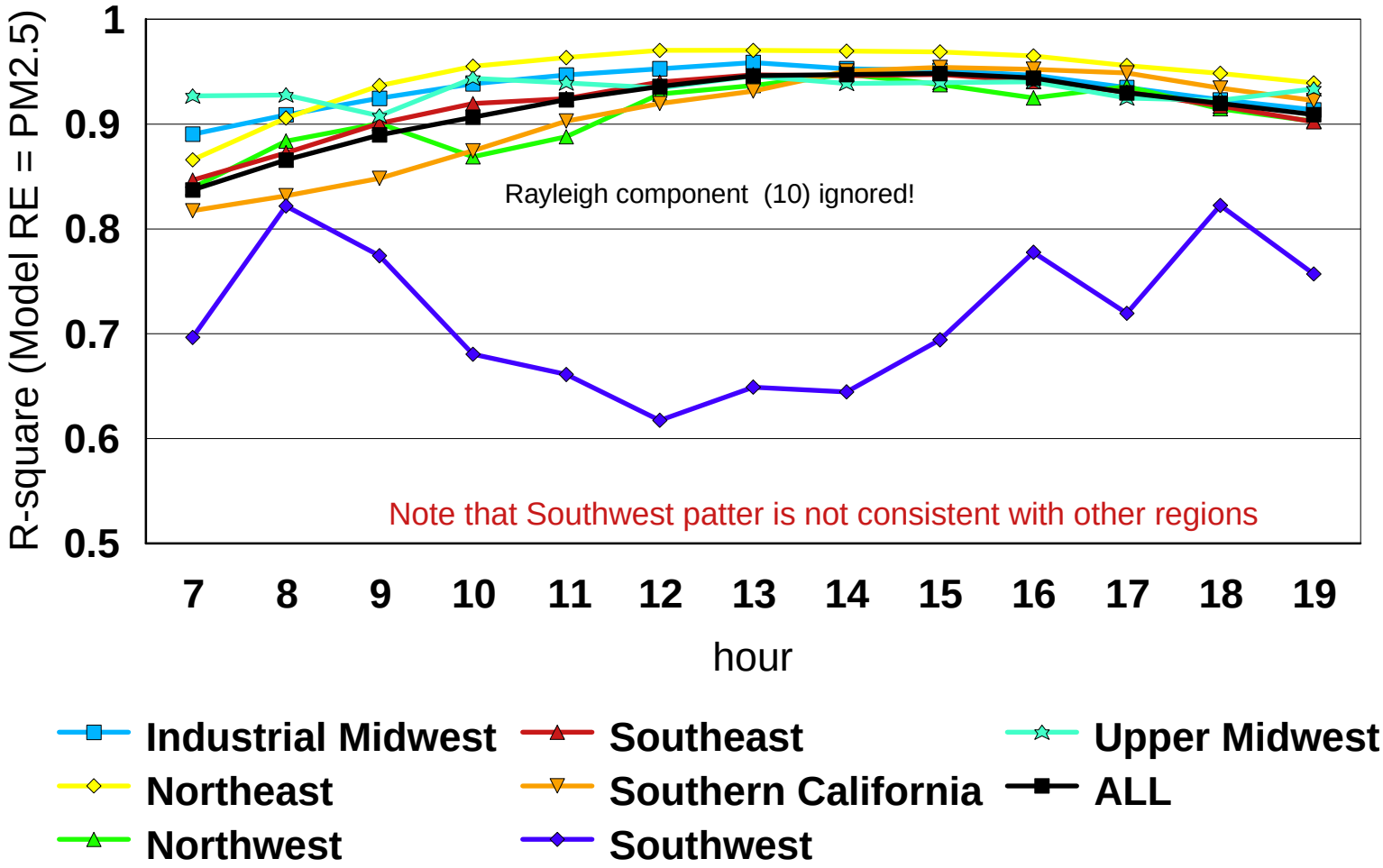


EXTINCTION_AVG10RH=
(3*FRH10AVG*PM25_NITRATES) +
(3*FRH10AVG*PM25_SULFATES) +
(4*PM25_OCM) +
(10*PM25_EC) +
(PM25_CRUSTAL) +
~~(.6* PMC);~~

Rayleigh component (10) ignored!

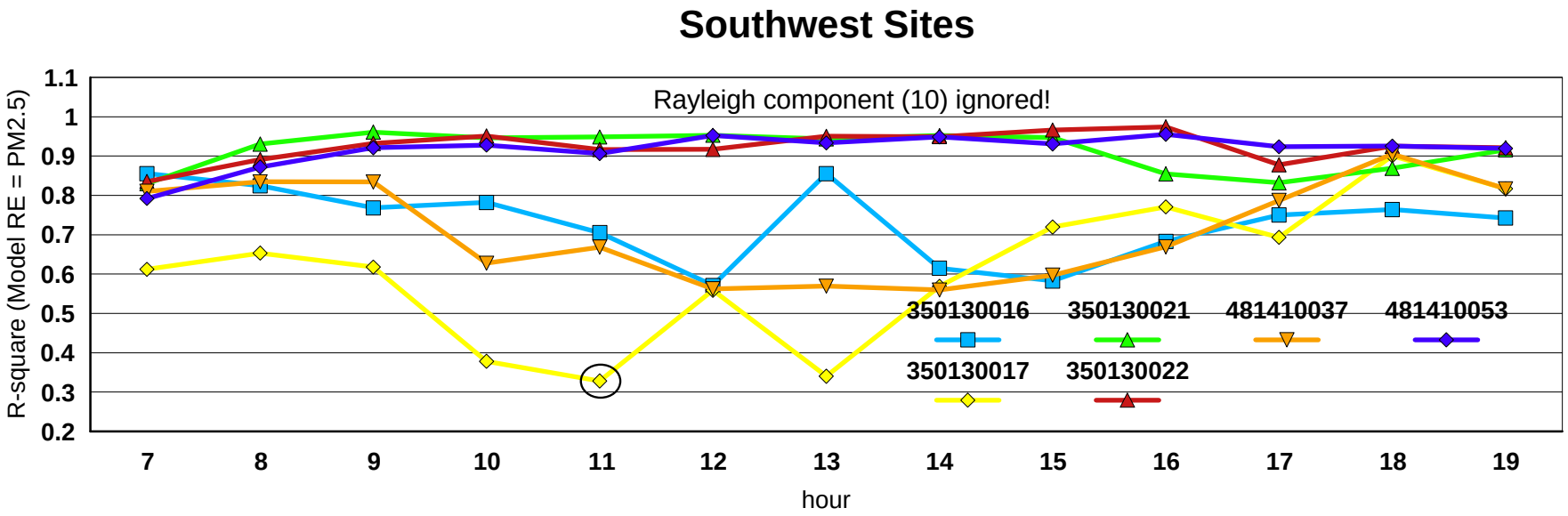
Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

R^2 (Recon. Extinction = $PM_{2.5}$) - using combo PMc

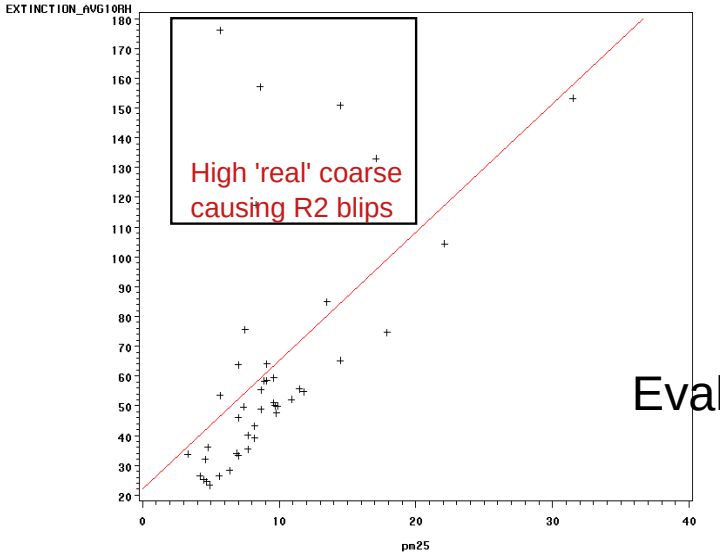


Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

R^2 (Recon. Extinction = $PM_{2.5}$) - using combo PMc



Site 350130017 (yellow above), Hr=11

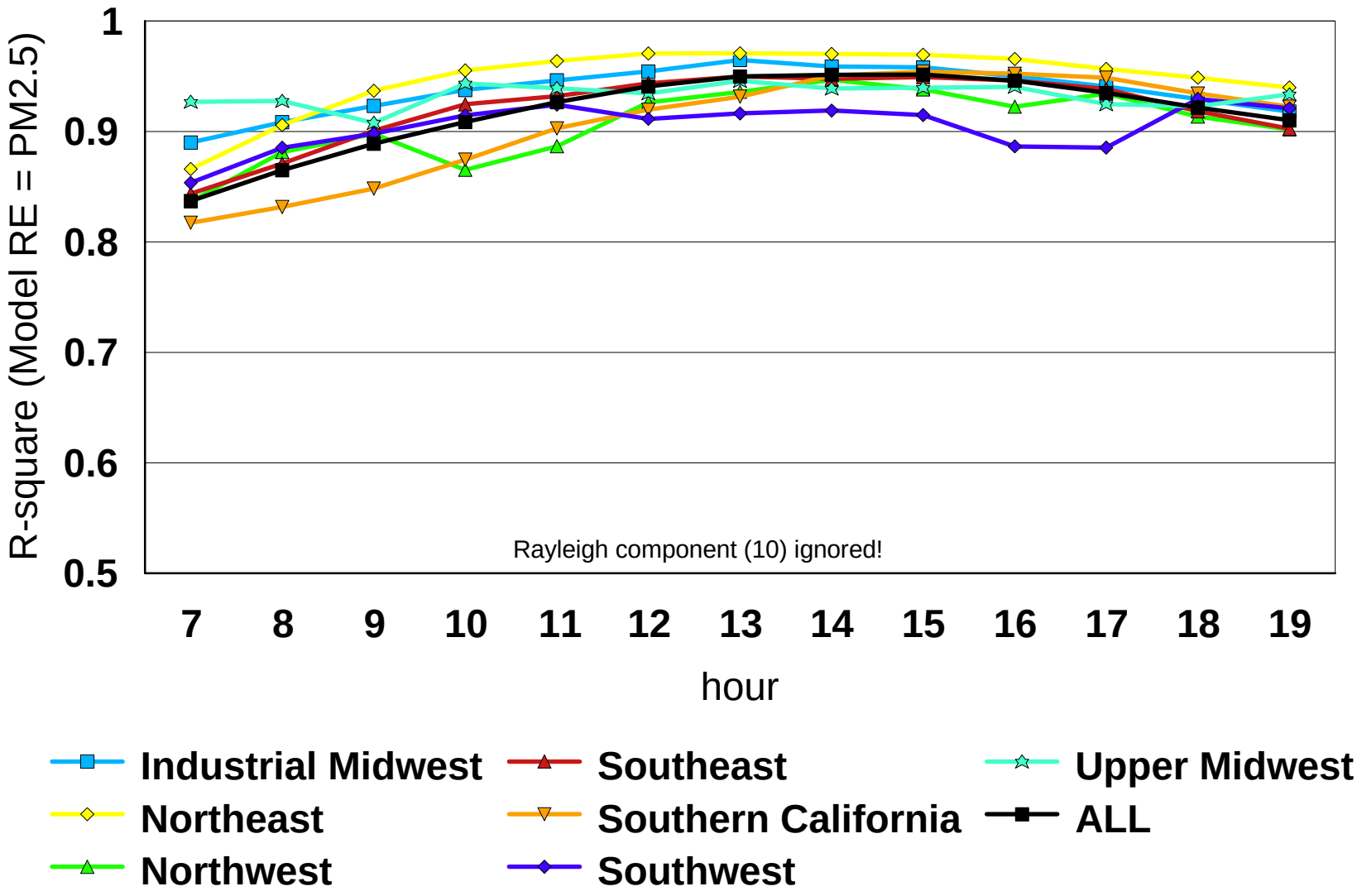


EXTINCTION_AVG10RH=
(3*FRH10AVG*PM25_NITRATES) +
(3*FRH10AVG*PM25_SULFATES) +
(4*PM25_OCM) +
(10*PM25_EC) +
(PM25_CRUSTAL) +
(.6* PMC);

Rayleigh component (10) ignored!

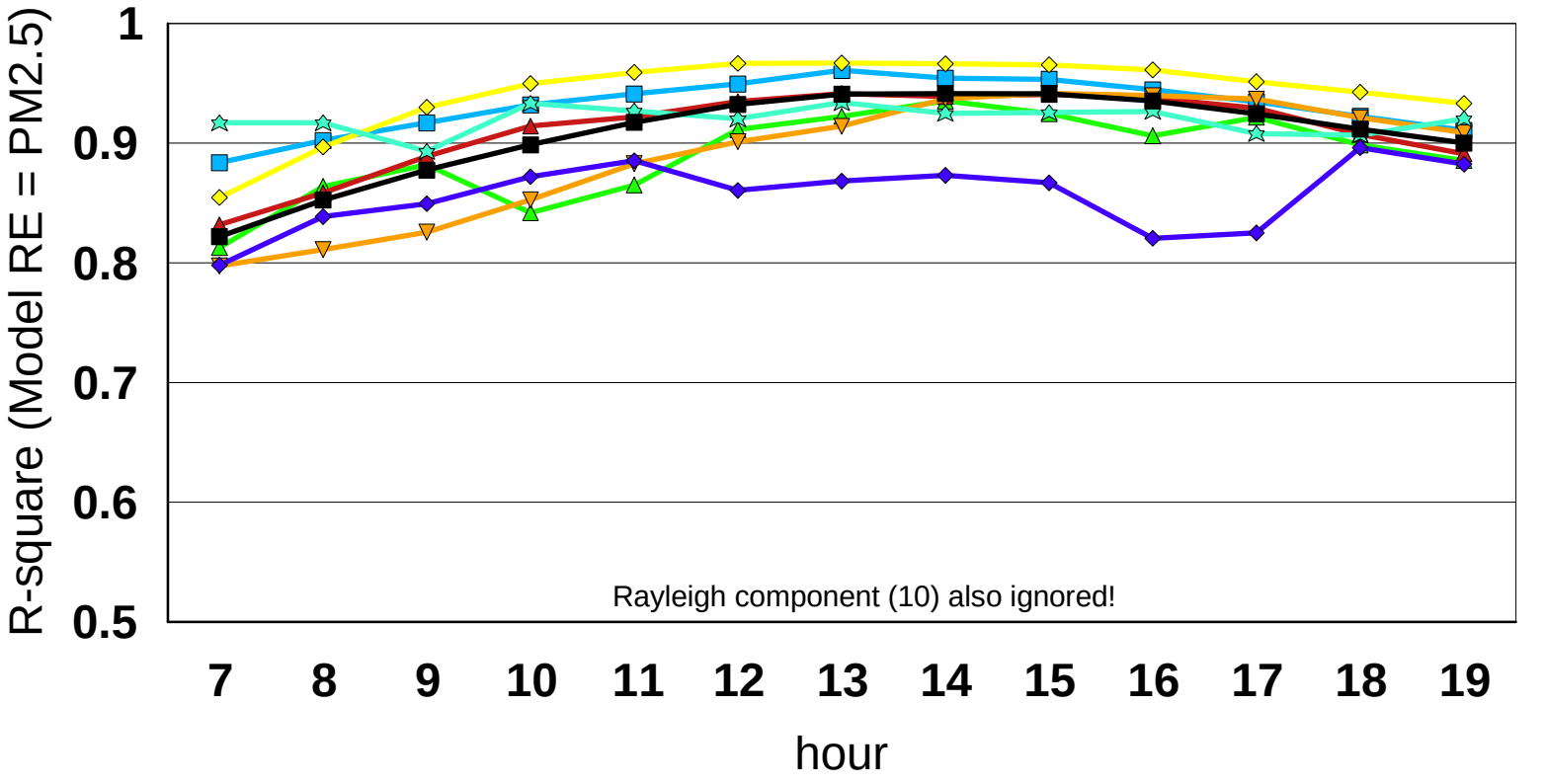
Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

R^2 (Recon. Extinction = $PM_{2.5}$) - using PMc from Reg. Ratios



Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

R^2 (Recon. Extinction = $PM_{2.5}$) - <u>ignoring PMc component</u>



EXTINCTION_AVG10RH=
(3*FRH10AVG*PM25_NITRATES) +
(3*FRH10AVG*PM25_SULFATES) +
(4*PM25_OCM) +
(10*PM25_EC) +
(PM25_CRUSTAL) +
~~(.6* PMC);~~

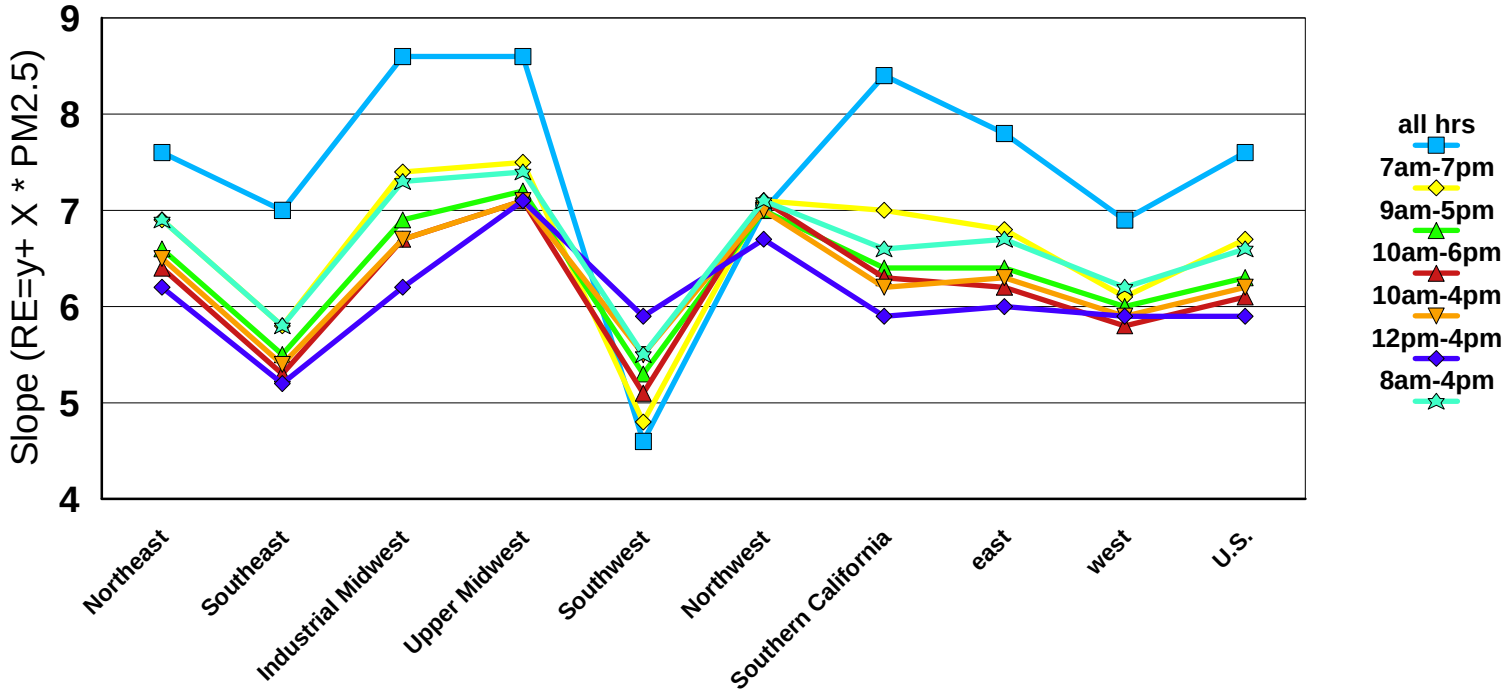
Rayleigh component (10) ignored!

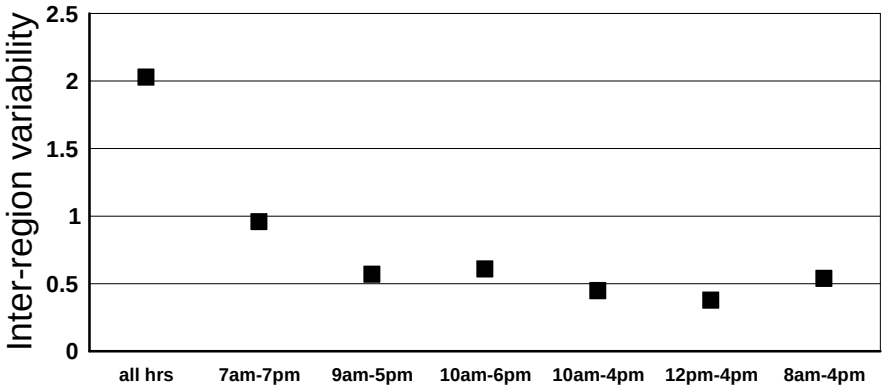
Evaluation of diurnal patterns -'old' (4/'02 -3/'03) db

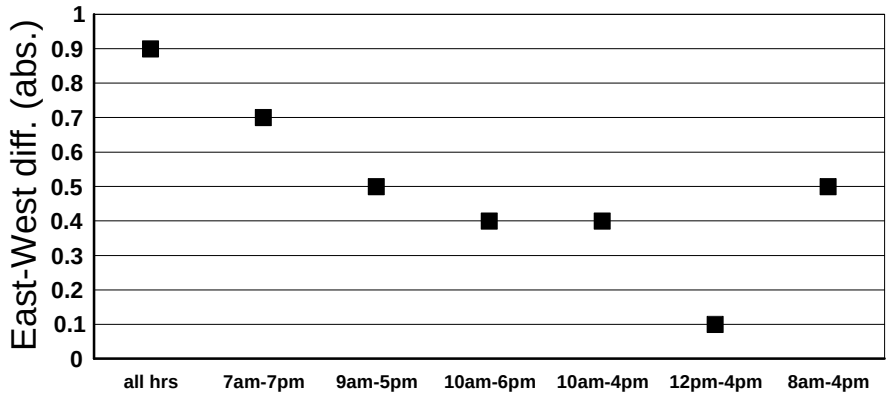
Comparison of Different Averaging Periods – 2003 db 10-year average *f(RH)*

				All hours (all RH)						
Timeframe	# Hours	Min. Hrs Rqrd	Area	Mean 10-yr Avg. RH	Mean 10-yr Avg. FRH	Mean PM2.5	Mean RE	Corr.	Inter-cept	Slope
All hrs	24	18	Northeast	66.2	2.66	14.0	108	0.98	5.5	7.3
			Southeast	71.2	3.05	12.1	98	0.94	12.0	7.1
			Industrial Midwest	71.1	2.88	14.6	118	0.97	8.1	7.5
			Upper Midwest	69.7	2.74	10.2	80	0.96	8.8	7.0
			Southwest	41.0	1.51	11.3	73	0.86	19.1	4.8
			Northwest	67.0	2.84	10.1	76	0.91	9.4	6.6
			Southern California	61.7	2.39	24.1	168	0.91	-37.4	8.5
			east	69.5	2.88	13.4	106	0.97	8.5	7.3
			west	60.1	2.43	12.3	88	0.91	4.5	6.8
			Total	67.8	2.80	13.2	103	0.95	7.8	7.2
			Inter-region variability	113.45	0.27	23.78	1109.6	0.002	346.19	1.30
7a.m. to 7p.m.	12	9	Northeast	60.8	2.28	14.1	99	0.99	10.6	6.3
			Southeast	62.9	2.39	12.0	84	0.96	16.0	5.7
			Industrial Midwest	64.7	2.41	14.3	103	0.97	13.3	6.3
			Upper Midwest	63.6	2.32	9.8	72	0.96	10.1	6.3
			Southwest	34.3	1.29	10.8	70	0.83	17.9	4.8
			Northwest	59.9	2.37	9.2	67	0.92	9.4	6.2
			Southern California	53.7	1.93	22.7	142	0.92	-14.3	6.9
			east	62.7	2.36	13.2	94	0.97	12.4	6.1
			west	53.3	2.04	11.5	78	0.91	11.0	5.9
			Total	61.0	2.30	12.9	91	0.96	12.2	6.1
			Inter-region variability	114.52	0.17	21.17	715.1	0.003	116.14	0.43
9a.m. to 5p.m.	8	6	Northeast	58.2	2.12	13.7	92	0.99	11.3	5.9
			Southeast	59.2	2.10	11.4	74	0.97	14.4	5.2
			Industrial Midwest	62.0	2.21	13.9	95	0.97	13.6	5.8
			Upper Midwest	61.1	2.15	9.5	67	0.97	10.1	6.0
			Southwest	31.4	1.19	9.8	64	0.85	12.6	5.3
			Northwest	57.1	2.17	8.6	61	0.93	9.8	6.0
			Southern California	50.3	1.72	22.4	133	0.94	-7.5	6.3
			east	59.6	2.13	12.8	85	0.98	11.9	5.7
			west	50.4	1.87	10.9	73	0.92	10.5	5.7
			Total	57.9	2.08	12.5	83	0.96	11.6	5.7
			Inter-region variability	115.84	0.14	22.29	646.8	0.002	57.04	0.15
10a.m. to 6p.m.	8	6	Northeast	57.1	2.07	13.8	92	0.99	11.4	5.8
			Southeast	57.2	1.99	11.3	72	0.97	13.6	5.1
			Industrial Midwest	60.5	2.13	13.8	92	0.97	13.7	5.7
			Upper Midwest	59.4	2.06	9.3	64	0.97	10.2	5.9
			Southwest	29.3	1.15	10.2	66	0.86	13.9	5.1
			Northwest	55.1	2.06	8.5	59	0.94	9.7	5.8
			Southern California	48.7	1.65	22.0	128	0.95	-6.1	6.1
			east	58.0	2.05	12.8	83	0.98	11.6	5.6
			west	48.6	1.79	10.8	71	0.92	11.2	5.5
			Total	56.3	2.00	12.4	81	0.96	11.6	5.6
			Inter-region variability	119.08	0.13	21.09	583.6	0.002	50.35	0.15
10a.m. to 4p.m.	6	4	Northeast	57.3	2.07	13.6	90	0.99	11.5	5.8
			Southeast	57.9	2.01	11.2	71	0.97	13.6	5.1
			Industrial Midwest	61.0	2.15	13.7	92	0.97	13.4	5.7
			Upper Midwest	60.1	2.08	9.3	65	0.97	10.2	5.9
			Southwest	30.3	1.16	9.6	64	0.85	10.6	5.6
			Northwest	55.6	2.08	8.3	59	0.93	10.2	5.8
			Southern California	49.1	1.66	22.3	130	0.94	-4.5	6.0
			east	58.5	2.06	12.6	83	0.98	11.7	5.6
			west	49.2	1.80	10.6	70	0.92	10.1	5.7
			Total	56.8	2.01	12.2	80	0.96	11.3	5.6
			Inter-region variability	115.45	0.13	22.80	626.3	0.002	38.84	0.08
12p.m. to 4p.m.	4	3	Northeast	55.4	1.99	13.7	89	0.99	12.0	5.6
			Southeast	55.0	1.88	11.1	68	0.98	13.0	5.0
			Industrial Midwest	58.8	2.03	13.7	89	0.98	13.5	5.5
			Upper Midwest	57.4	1.96	9.1	62	0.98	9.8	5.7
			Southwest	27.6	1.12	10.3	68	0.85	7.3	5.9
			Northwest	52.8	1.93	8.0	55	0.95	10.6	5.6
			Southern California	46.4	1.55	21.4	121	0.96	-0.9	5.7
			east	56.1	1.95	12.6	80	0.98	11.7	5.4
			west	46.4	1.68	10.5	68	0.90	8.6	5.7
			Total	54.3	1.90	12.2	78	0.96	10.8	5.5
			Inter-region variability	118.26	0.11	20.19	508.8	0.002	25.06	0.08
8a.m. to 4p.m.	8	6	Northeast	60.2	2.23	13.8	95	0.99	11.0	6.1
			Southeast	62.4	2.29	11.7	80	0.96	15.6	5.5
			Industrial Midwest	64.3	2.35	14.2	100	0.97	13.4	6.1
			Upper Midwest	63.6	2.29	9.9	72	0.97	10.3	6.2
			Southwest	34.3	1.26	9.6	65	0.82	11.4	5.5
			Northwest	59.9	2.34	8.9	65	0.92	9.5	6.2
			Southern California	52.9	1.86	23.0	141	0.92	-9.9	6.6
			east	62.1	2.29	13.0	90	0.98	12.3	6.0
			west	53.2	2.01	11.1	76	0.91	9.6	6.0
			Total	60.5	2.24	12.6	88	0.96	11.7	6.0
			Inter-region variability	112.73	0.16	23.43	742.5	0.003	72.12	0.15

Comparison of Slopes (RE=y + X * PM2.5) for Select Timeframes, by Region Using actual FRH

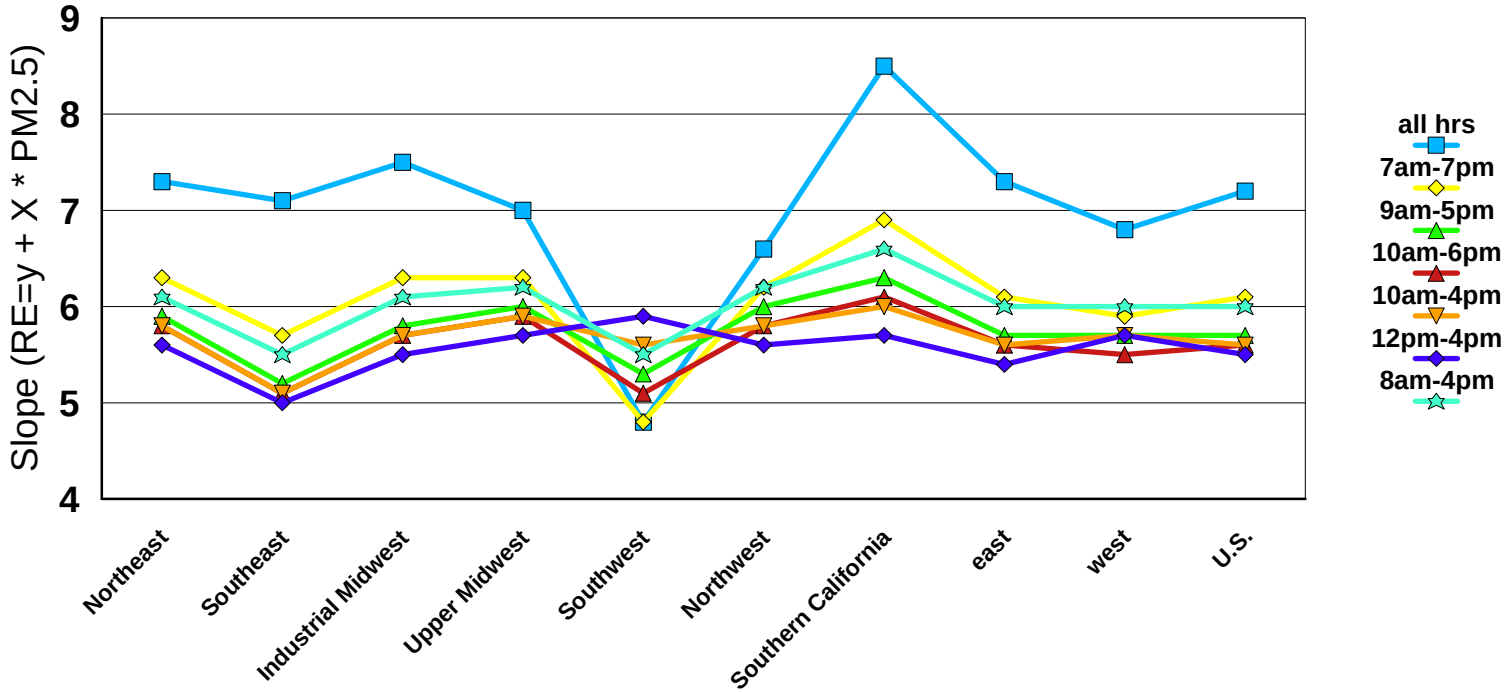


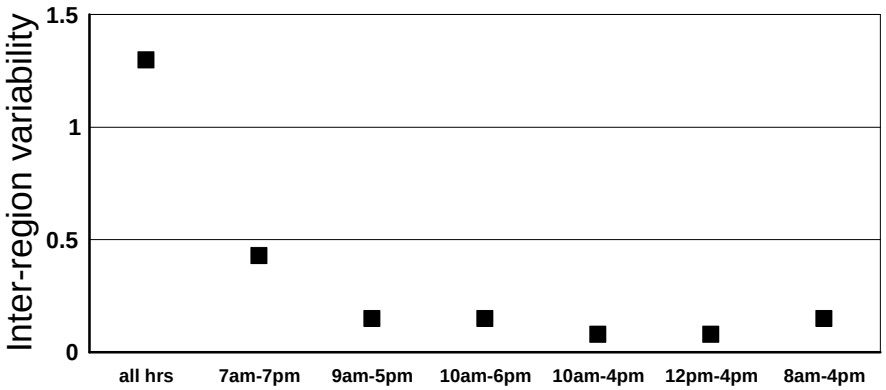


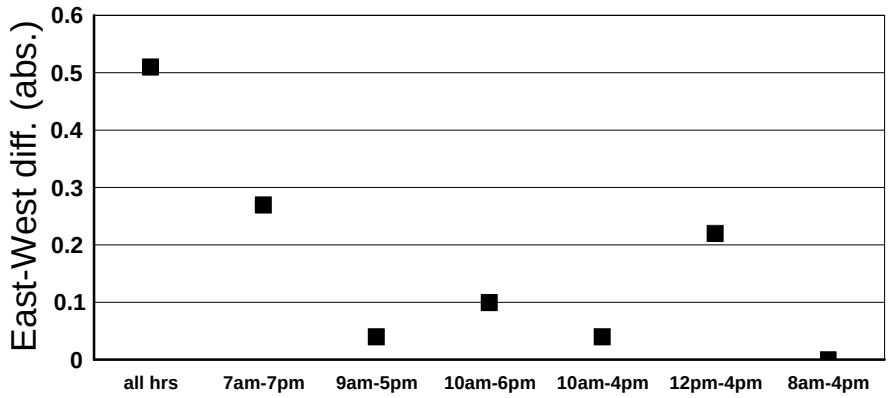


Source: 2003 visibility database.

Comparison of Slopes (RE=y + X * PM2.5) for Select Timeframes, by Region Using 10-Year Avg. FRH

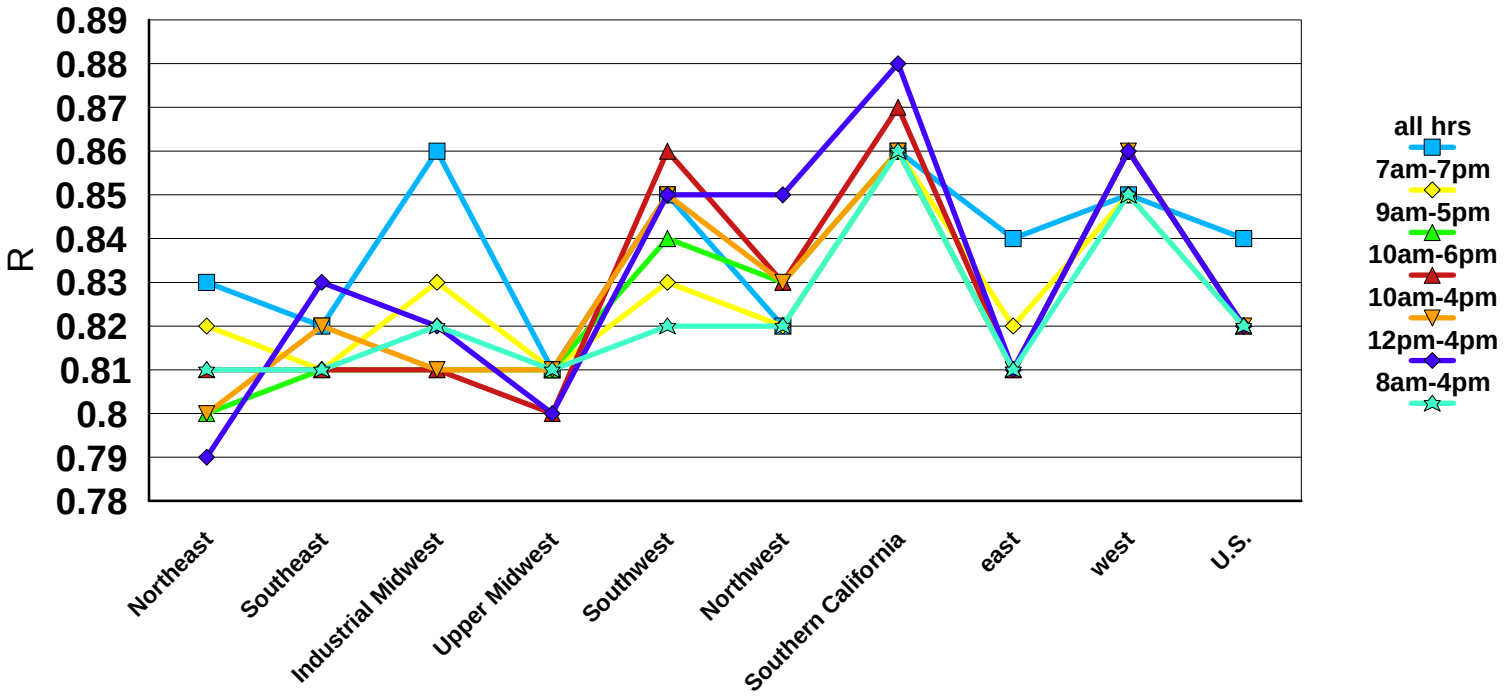


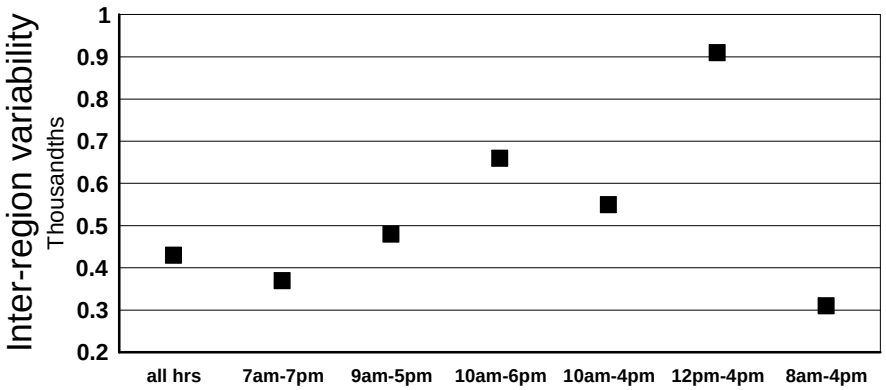


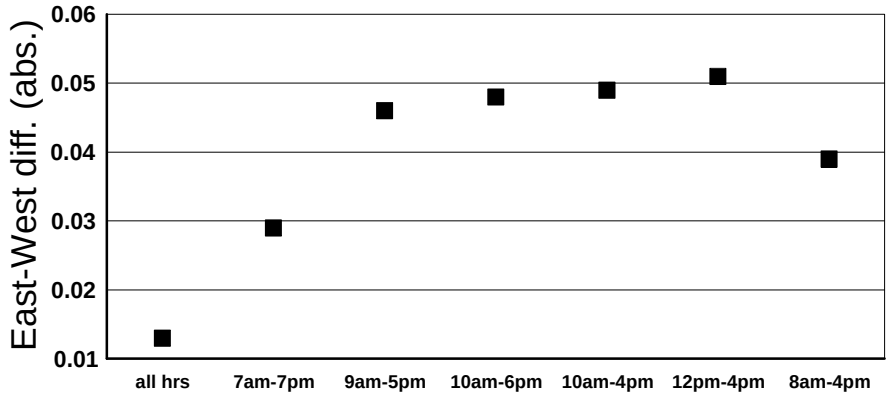


Source: 2003 visibility database.

Comparison of Correlations (RE vs. PM2.5) for Select Timeframes, by Region Using Actual FRH

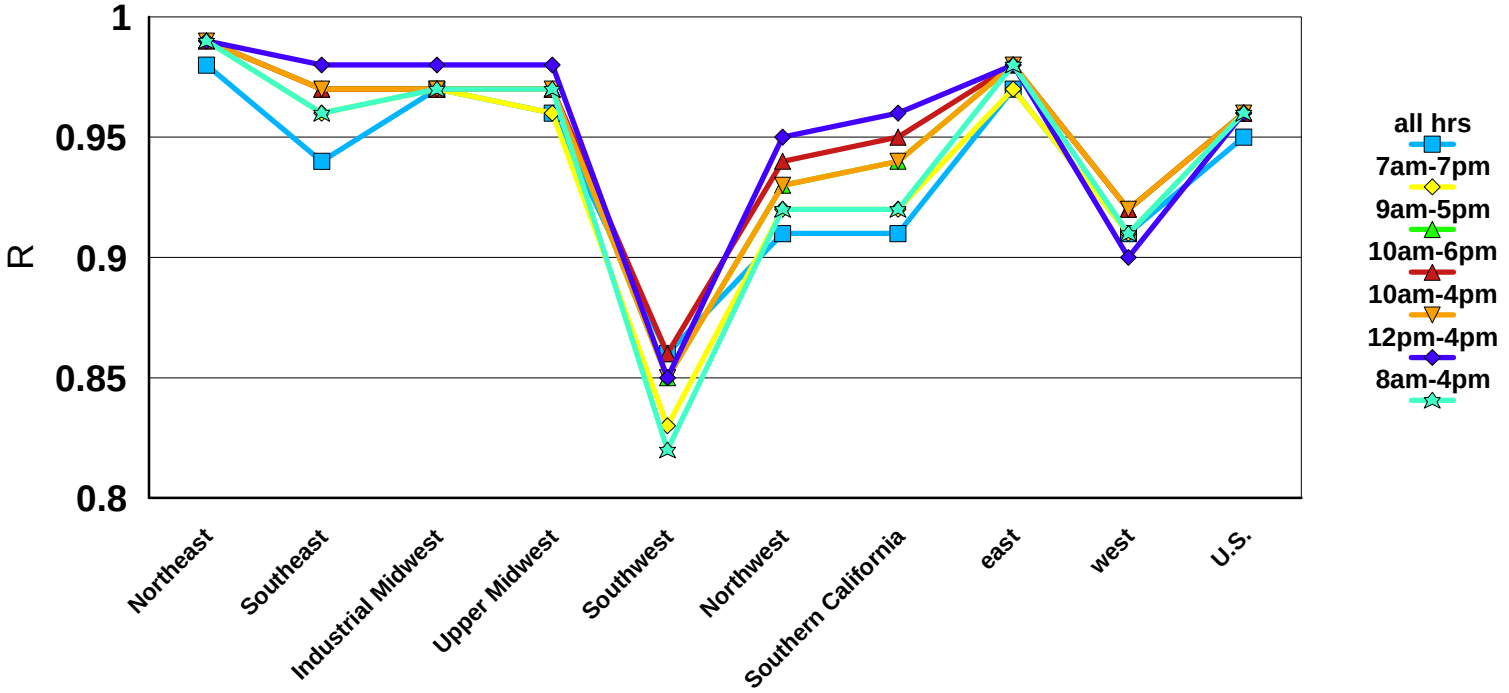


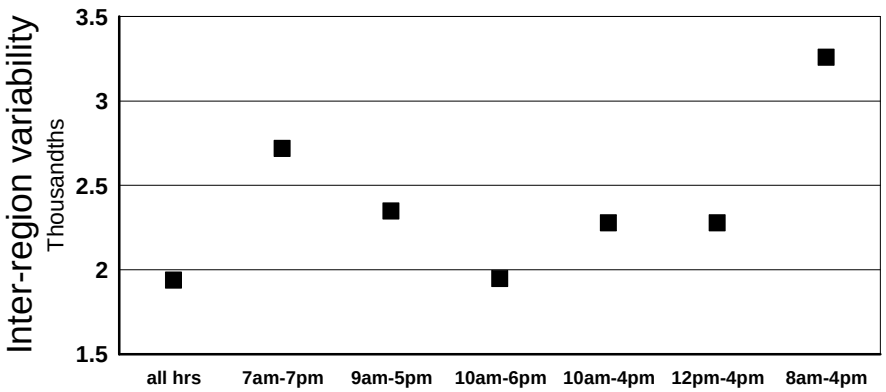


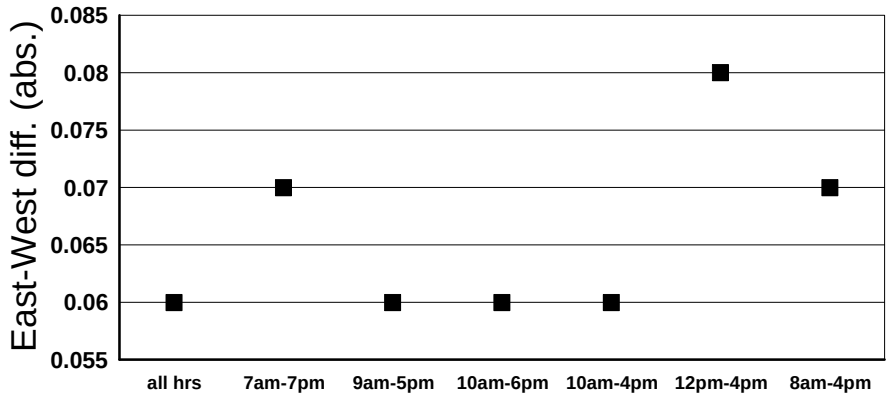


Source: 2003 visibility database.

Comparison of Correlations (RE vs. PM2.5) for Select Timeframes, by Region Using 10-Year Avg. FRH







Source: 2003 visibility database.

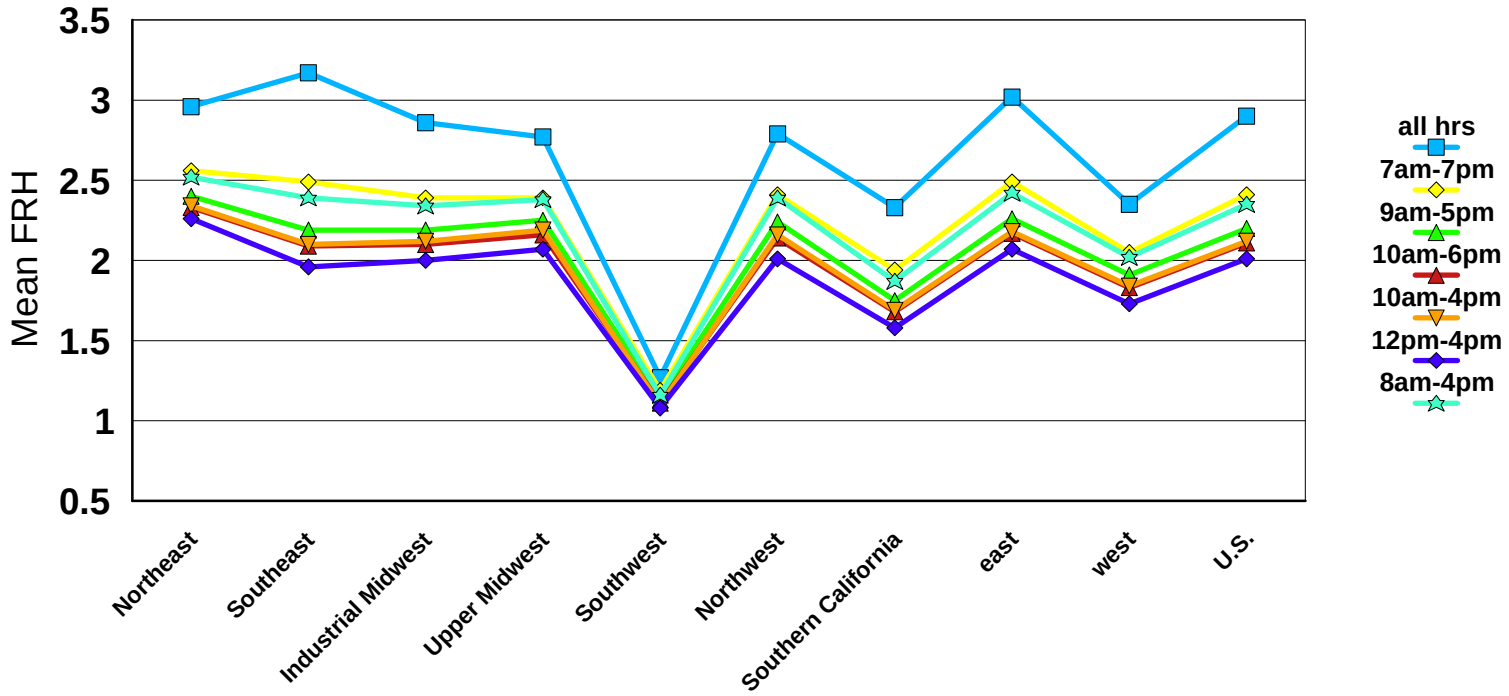
Comparison of Different Averaging Periods – 2003 db, using actual *f(RH)*

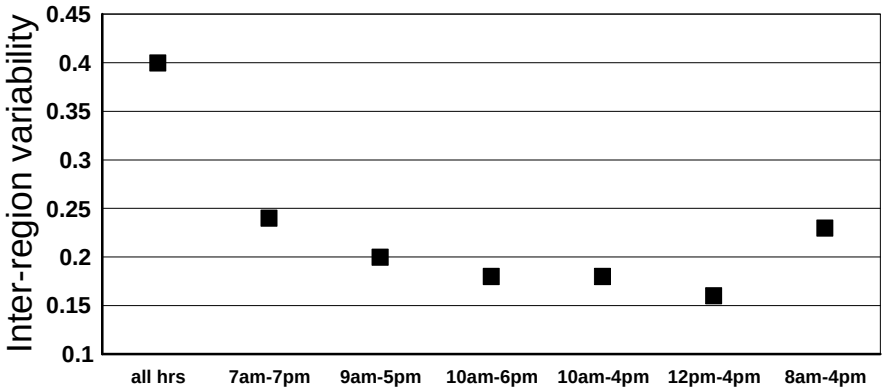
Ranking of time-periods based on slope and r-square

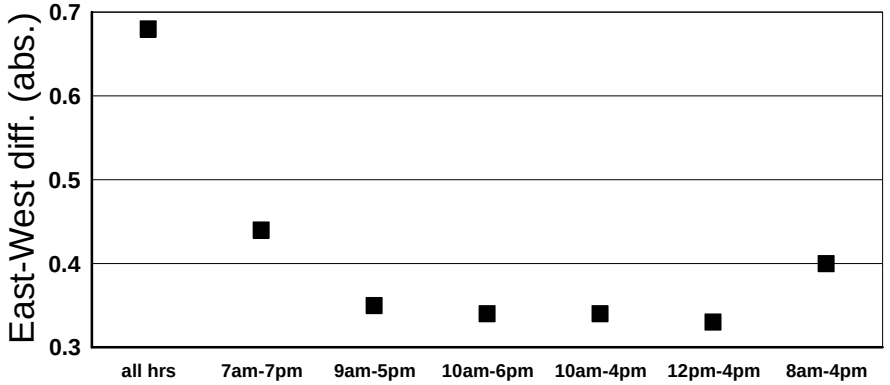
	national slope		inter-region slope variability		east-west slope diff		national corr		inter-region corr variability		east-west corr diff		
	national slope	rank (low to high)	inter-region slope variability	rank (low to high)	east-west slope diff	rank (low to high)	national corr	rank (high to low)	inter-region corr variability	rank (low to high)	east-west corr diff	rank (low to high)	6-Factor Average
all hrs	7.6	7	2.03	7	0.9	7	0.84	1	0.000	3	0.01	1	4.3
7am–7pm	6.7	6	0.96	6	0.7	6	0.82	2	0.000	2	0.03	2	4.0
9am-5pm	6.3	4	0.57	4	0.5	4	0.82	5	0.000	4	0.05	4	4.2
10am-6pm	6.1	2	0.61	5	0.4	3	0.82	4	0.001	6	0.05	5	4.2
10am-4pm	6.2	3	0.45	2	0.4	2	0.82	7	0.001	5	0.05	6	4.2
12pm-4pm	5.9	1	0.38	1	0.1	1	0.82	3	0.001	7	0.05	7	3.3
8am-4pm	6.6	5	0.54	3	0.5	5	0.82	6	0.000	1	0.04	3	3.8

Based on this analysis, the 12-4 period is ‘best’!

Comparison of RH Effects (Avg. FRH) for Select Timeframes, by Region Using Actual RH/FRH

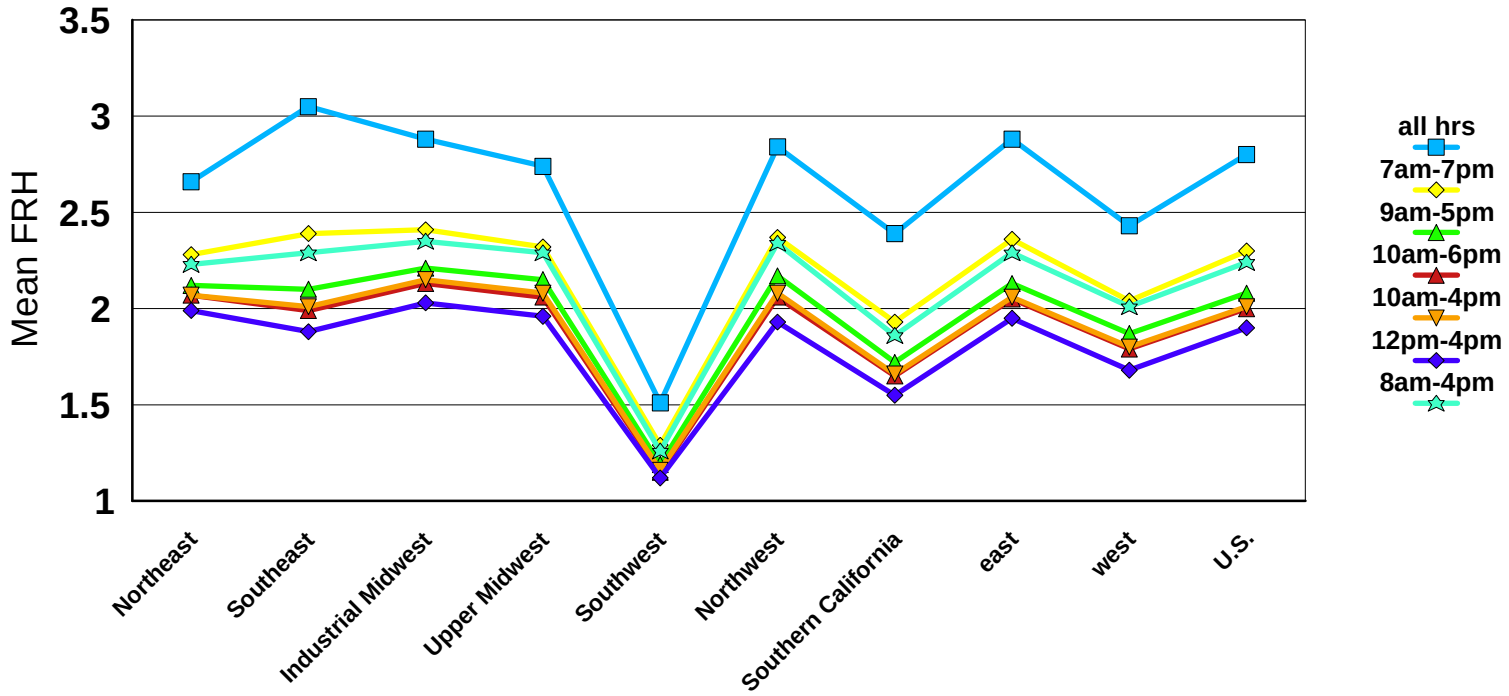


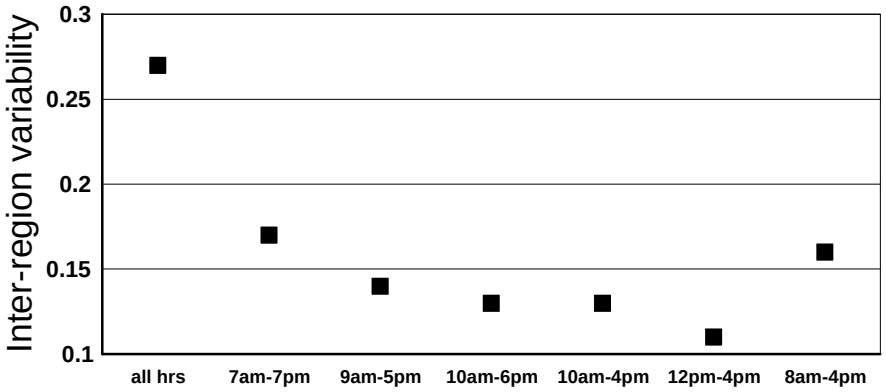


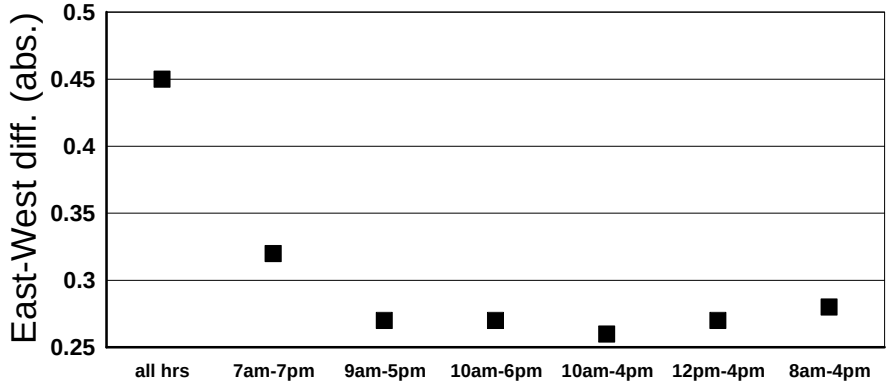


Source: 2003 visibility database.

Comparison of RH Effects (Avg. FRH) for Select Timeframes, by Region Using 10-Year Avg. FRH

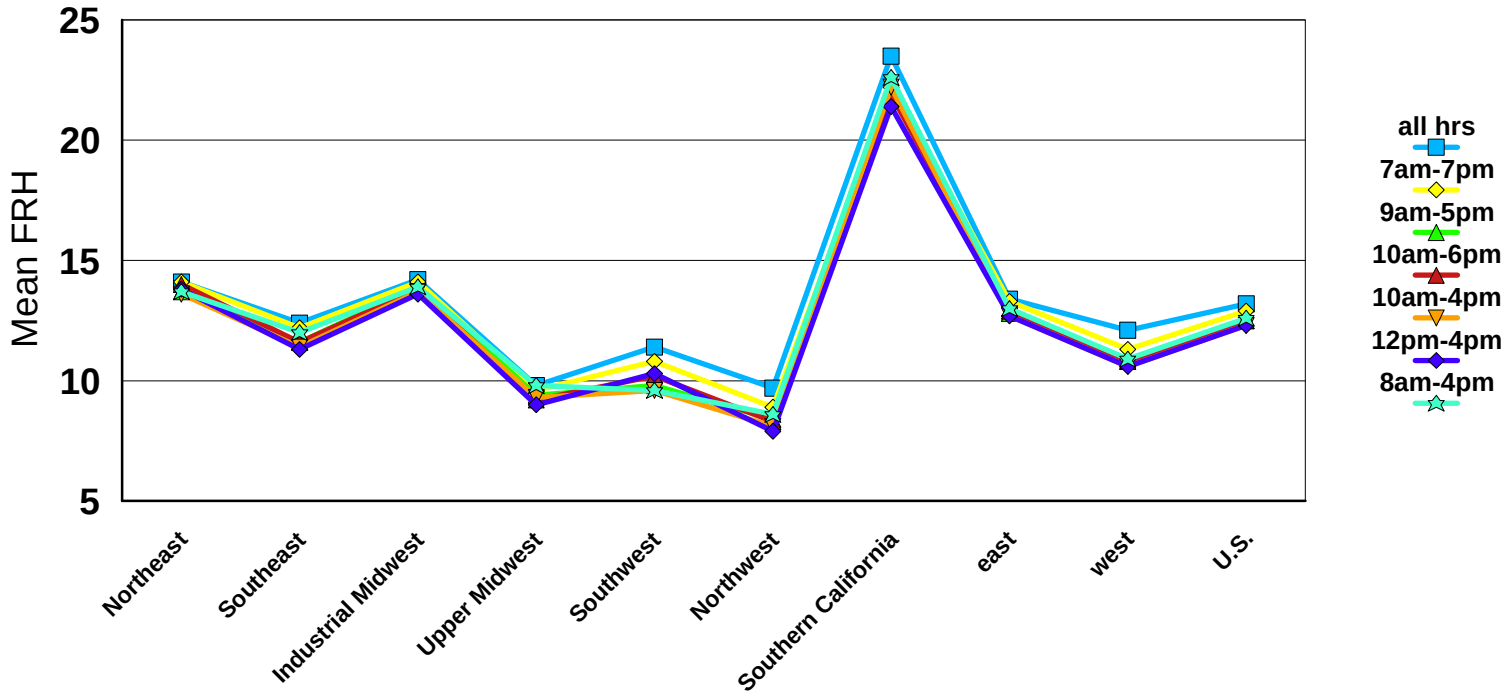


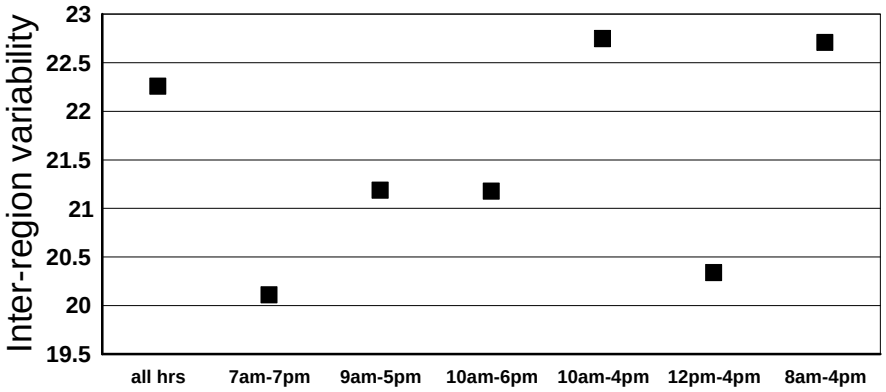


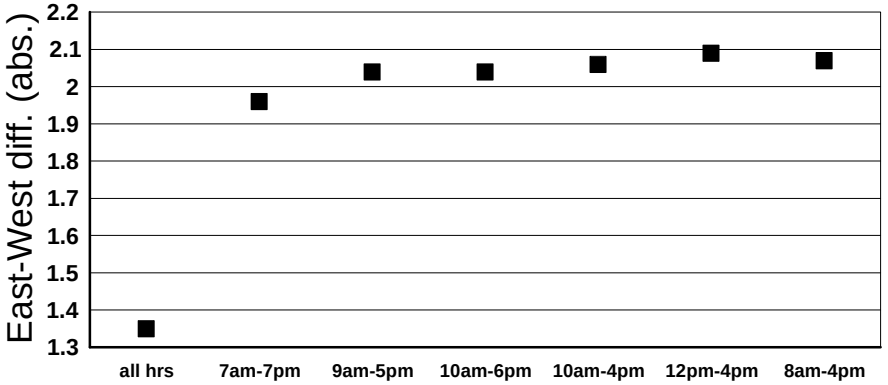


Source: 2003 visibility database.

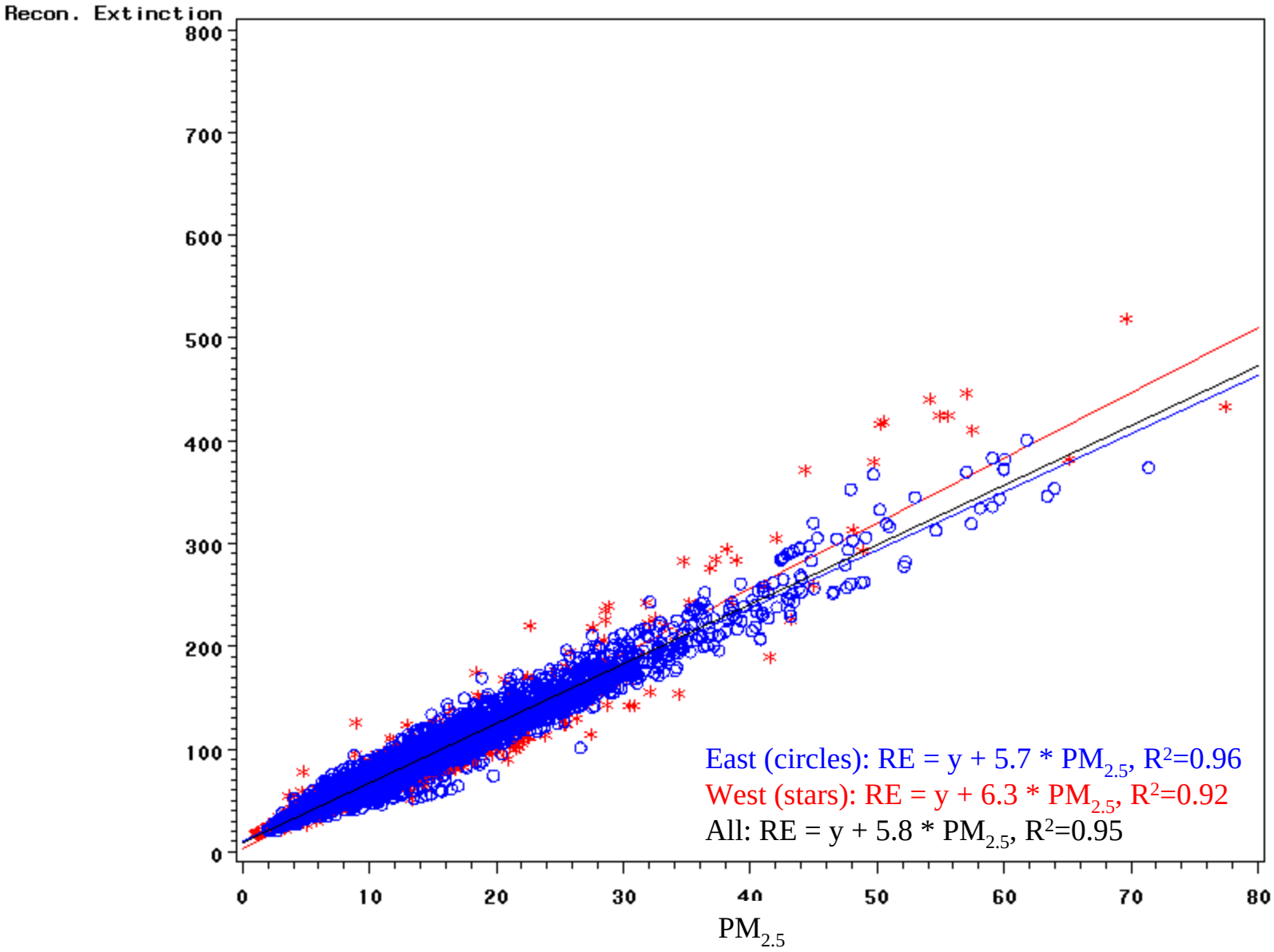
Comparison of PM2.5 Select Timeframes, by Region



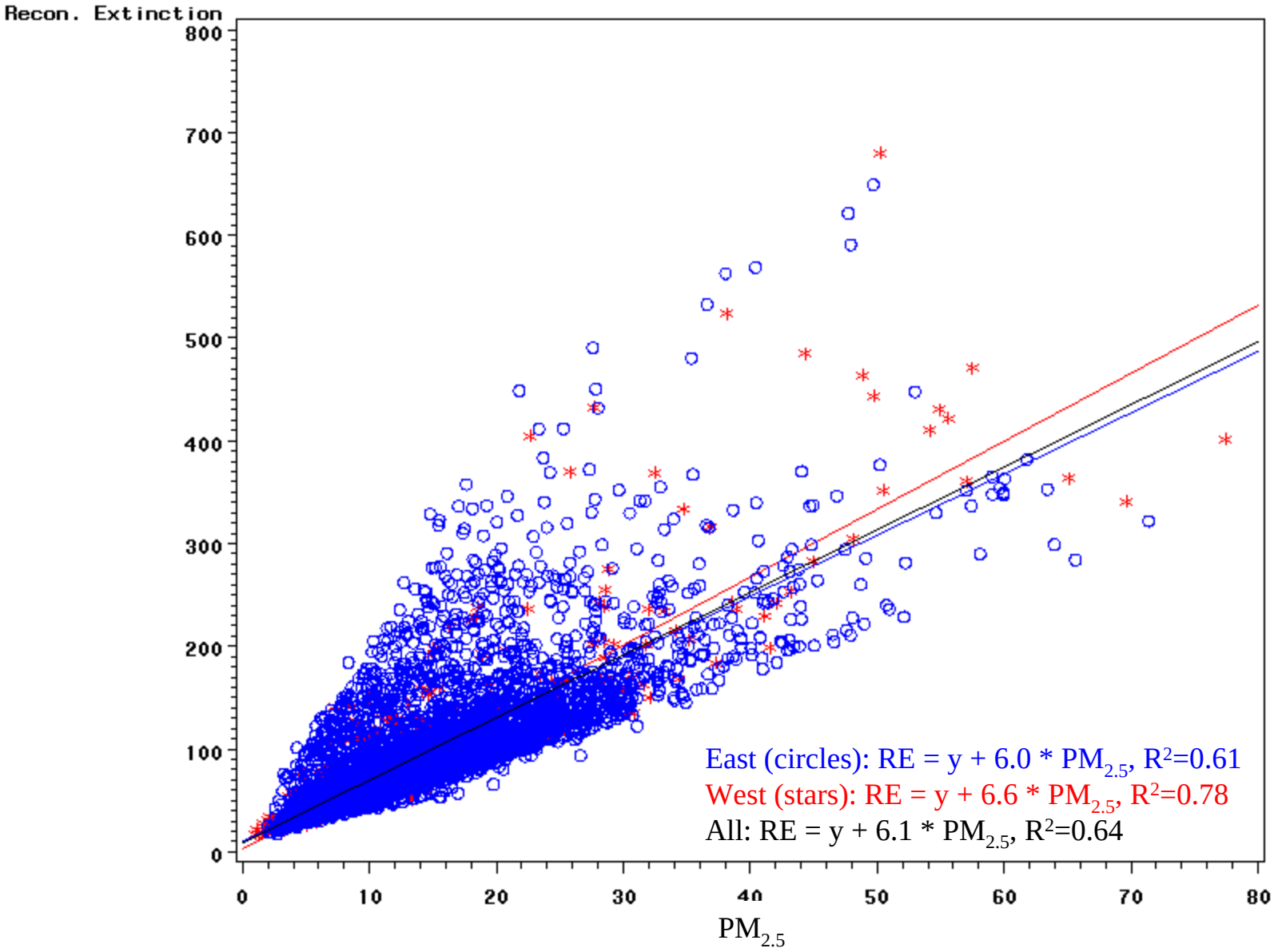




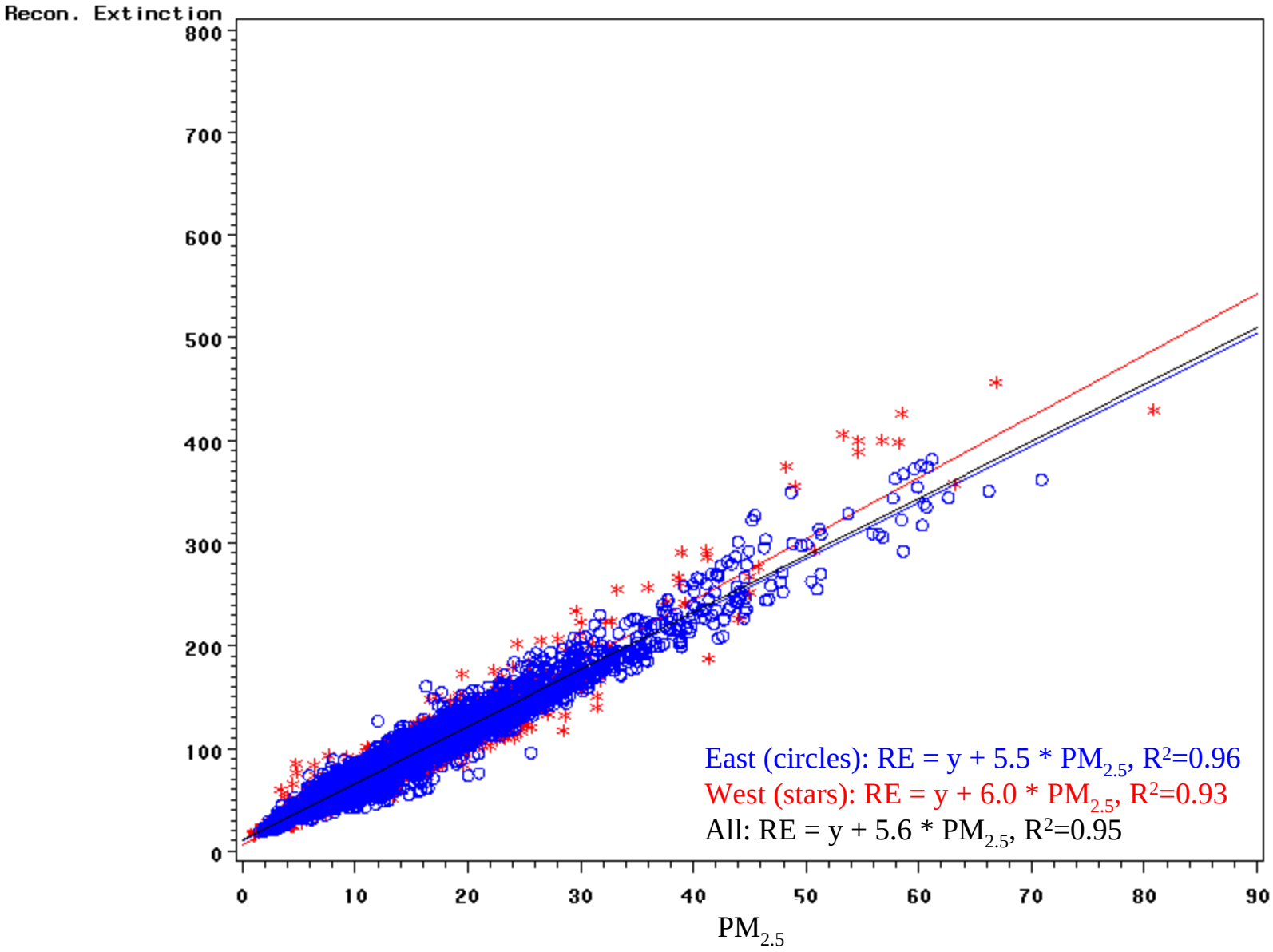
Source: 2003 visibility database.



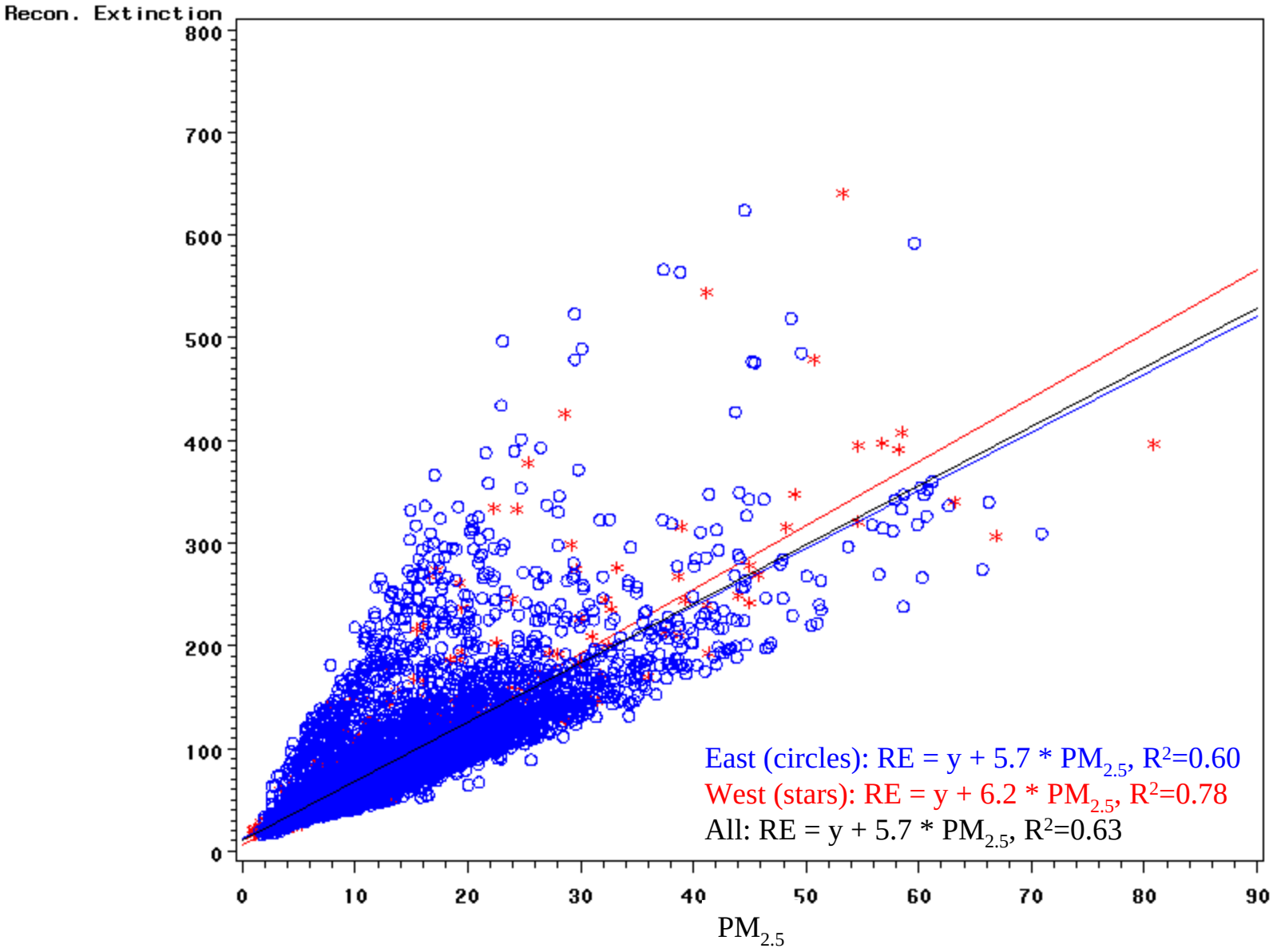
Relationship between reconstructed light extinction (RE) and 10 a.m. – 6 p.m. average $PM_{2.5}$, 2003.
Using 10-year average *f(RH)*.



Relationship between reconstructed light extinction (RE) and 10 a.m. – 6 p.m. average $PM_{2.5}$, 2003.
Using actual *f(RH)*



Relationship between reconstructed light extinction (RE) and 12 p.m. – 4 p.m. average $PM_{2.5}$, 2003.
Using 10-year average *f(RH)*.



Relationship between reconstructed light extinction (RE) and 12 p.m. – 4 p.m. average $PM_{2.5}$, 2003.
Using actual *f(RH)*.

Correlations for 12-4pm Average PM2.5 Concentration and Reconstructed Extinction, 2003

Area	N	Correlation
All Regions	97,563	.767
East	80,413	.746
West	17,150	.848
Northeast	26,592	.759
Southeast	32,791	.710
Ind. Midwest	19,142	.748
Upper Midwest	1,888	.786
Southwest	3,112	.793
Northwest	10,789	.822
Southern CA	3,249	.831

Source: 2003 visibility database.

SP Visibility Analyses

‘Level of Secondary Standard’

Goal: Help inform decision regarding 'level of standard'

- Outputs: Show/summarize $PM_{2.5}$ levels needed to meet various visual range goals
- Focus:
  - 24-hr & 12pm-4pm timeframes
  - VR's of 10, 20, 30, 40, 50, 60 kilometers
- Method: Assume most variation in RE caused by RH. Used fixed composition - use average regional PM2.5 composition; PMc as function of PM2.5 (from regional ratios); vary RH using regional (hourly-specific) distribution.
- Inputs / Processing:
  - 1 year ('03) complete ESpN $PM_{2.5}$ speciation data: EC, OCM, Sulfates, Nitrates, Crustal. Sites needed 4 quarters of 11+ samples.
    - Components (in ug/m3) averaged by site X quarter; then by site (annual), then across PMreg.
    - Regional component percentages (of Remass) computed from PMregion average mass compositions
  - PMc/PMf ratio, by PMregion, from 'regular' SP $PM_{10-2.5}$ db.
    - Db represents most recent consecutive 12-, 8-, or 4-quarter period from '01-'03.
    - Regional ratios (of PMc/PMf) computed at site level then averaged by PMregion
  - 3-year average ('01-'03) hourly RH data from all NWS sites
    - Assigned NWS sites to PMregion
    - Averaged RH by ID X month X day X hr. [Average of 3 years] NOTE THAT THIS STEP WAS SUBSEQUENTLY CHANGED TO USE THE 3-YEAR (RAW) DISTRIBUTION INSTEAD OF THE DISTRIBUTION OF THE 3-YEAR AVERAGES.
    - Computed univariate distribution p1-p100, by PMregion X hr. [Dist. of all sites' 365/6 hrly avgs.]
    - For each percentile value of RH (by PMregion V hr), identified table-look-up value for FRH. RH capped at 95. ([.e., Same FRH value (7.4) assigned to all RH's $\geq$ 95.]

Inputs / Processing - Continued

- Converted VR levels (10-60) to Reconstructed Extinction (RE) levels by formula

  RE = 3912 / VR

- Using RE formula of:

  RE =
  (**3** * FRH * PM25_NITRATES) +
  (**3** * FRH * PM25_SULFATES) +
  (**4** * PM25_OCM) +
  (**10** * PM25_EC) +
  (PM25_CRUSTAL) +
  (**.6** * PMc)
  +**10** [Rayleigh l.s.]

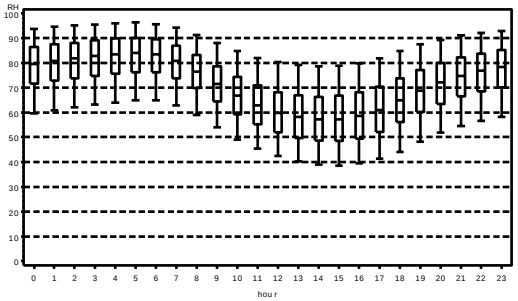
  Solved for $PM_{2.5}$ for each VR level, each hour, each percentile, by PMregion, using formula:

  PM_{25} =
  (RE -**10**) / ((**3***frh*sulfates%)+(**3***frh*nitrates%)+ (**4***ocm%)+(**10***ec%)+(**1***crustal%)+(**.6***$ratio_{pmc/pmf}$))

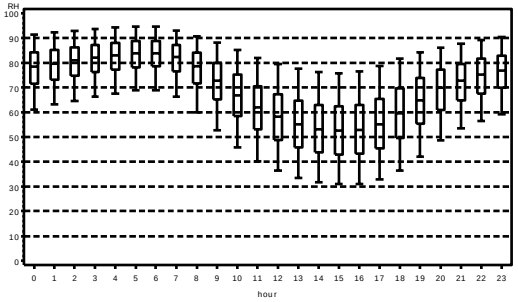
- Averaged computed hourly $PM_{2.5}$ values (by VR level, by PMregion, by percentile)… for 4-hr and 24-hr periods.

Regional Distributions of RH, by Hr

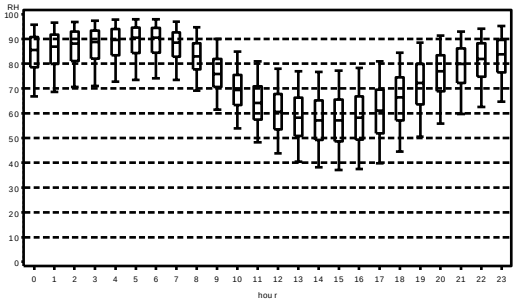
Northeast



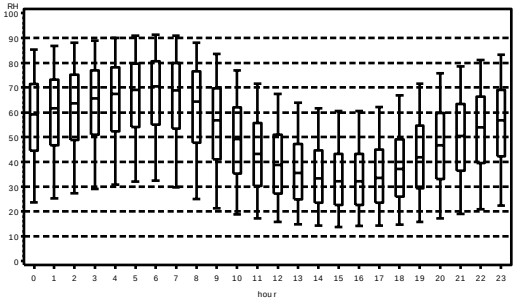
Upper Midwest



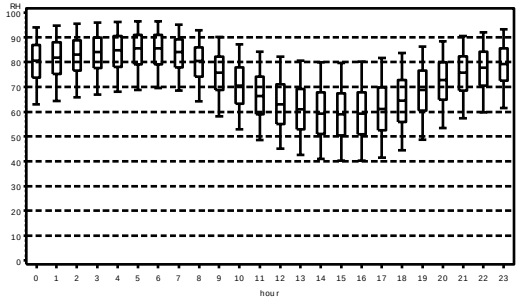
Southeast



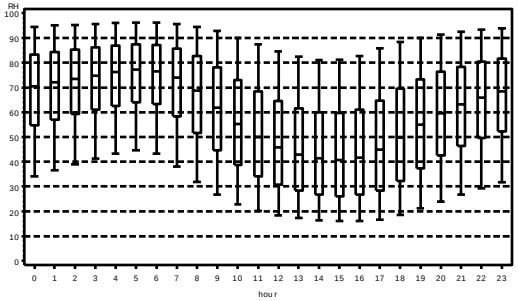
Southwest



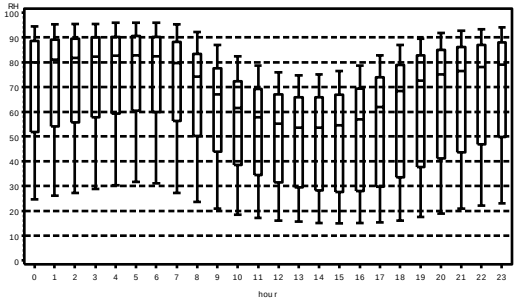
Industrial Midwest

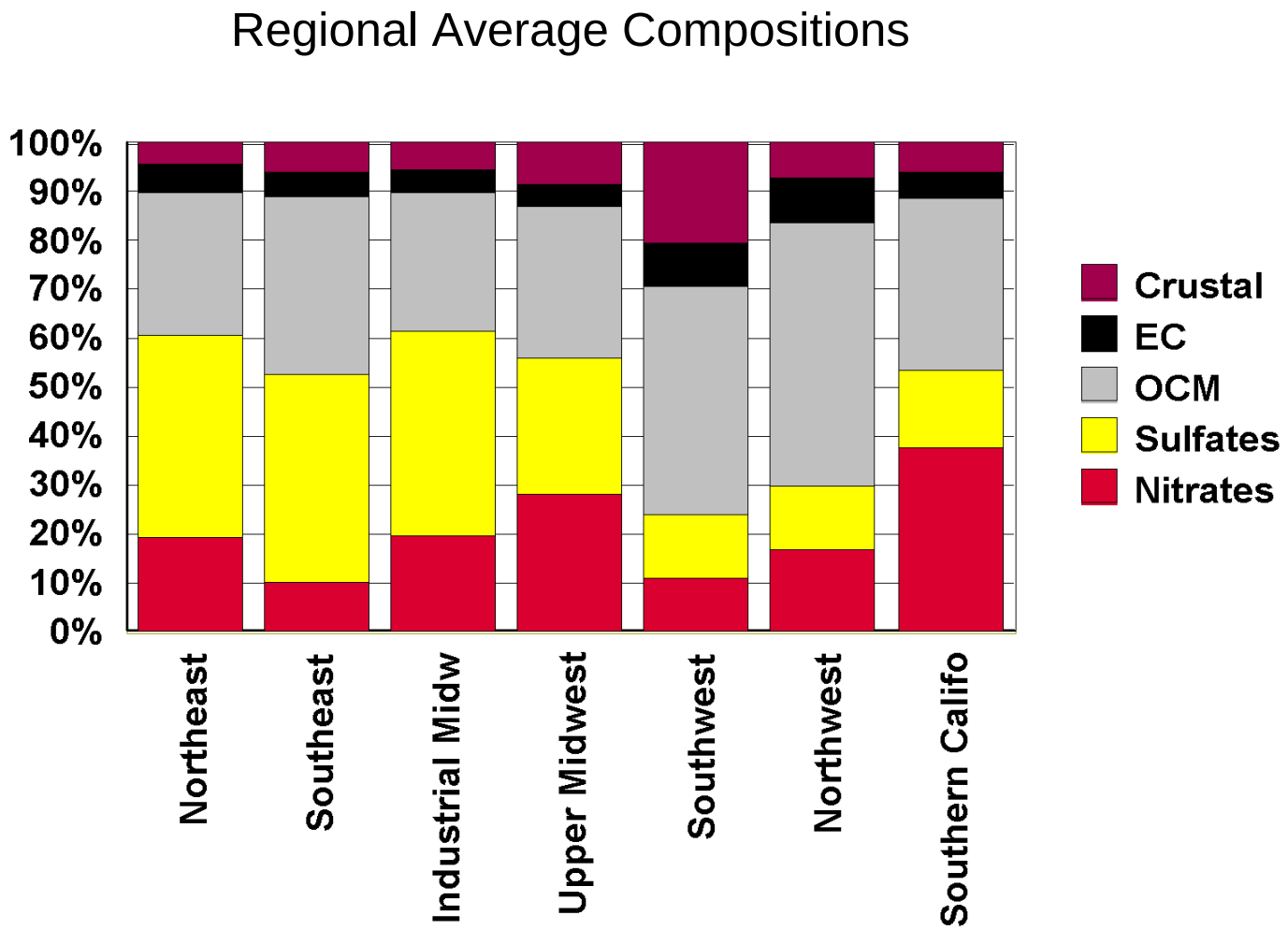


Northwest



Southern California

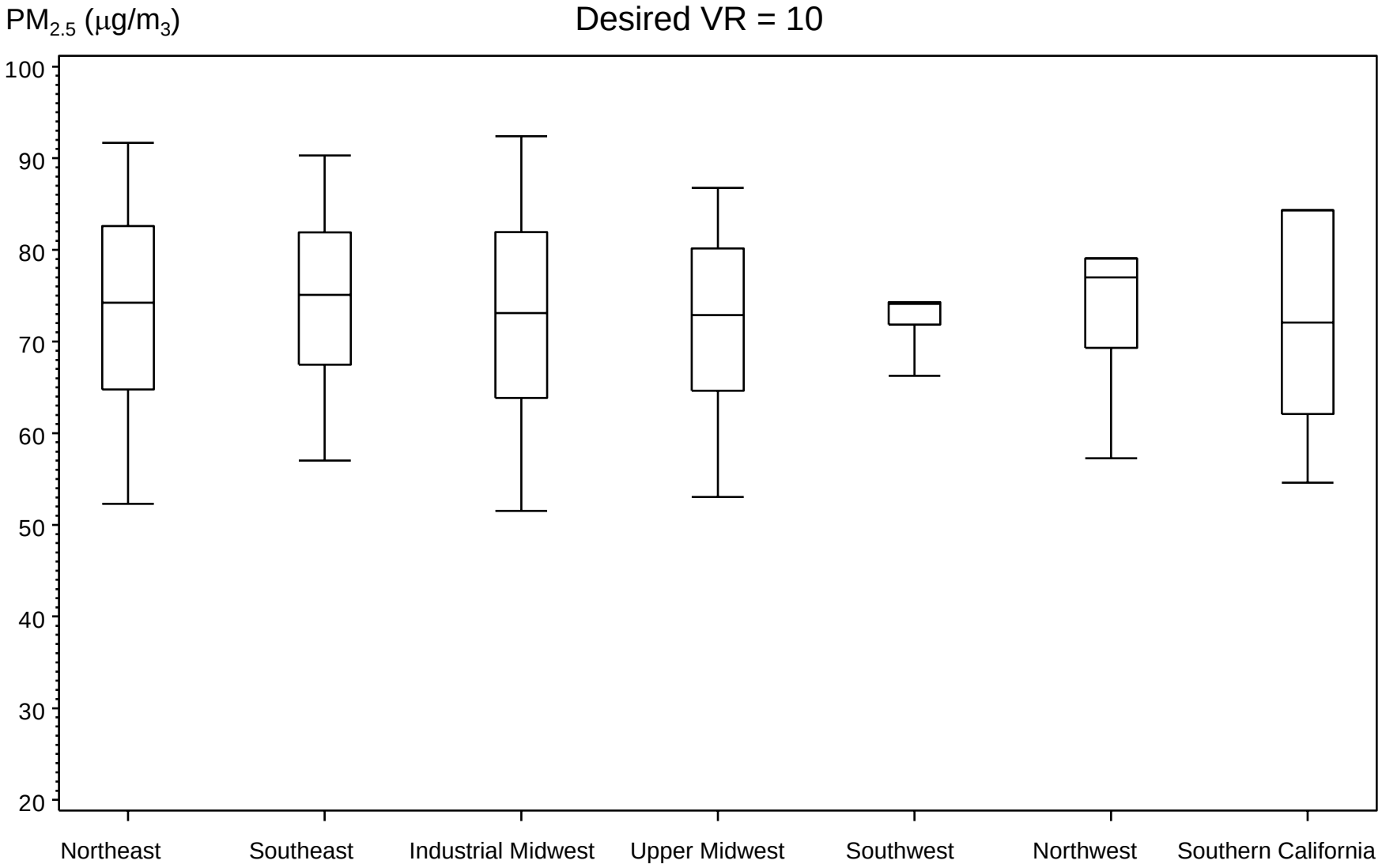



Regional Average Compositions
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Northeast
Southeast
Industrial Midw
Upper Midwest
Southwest
Northwest
Southern Califo
Crustal
EC
OCM
Sulfates
Nitrates

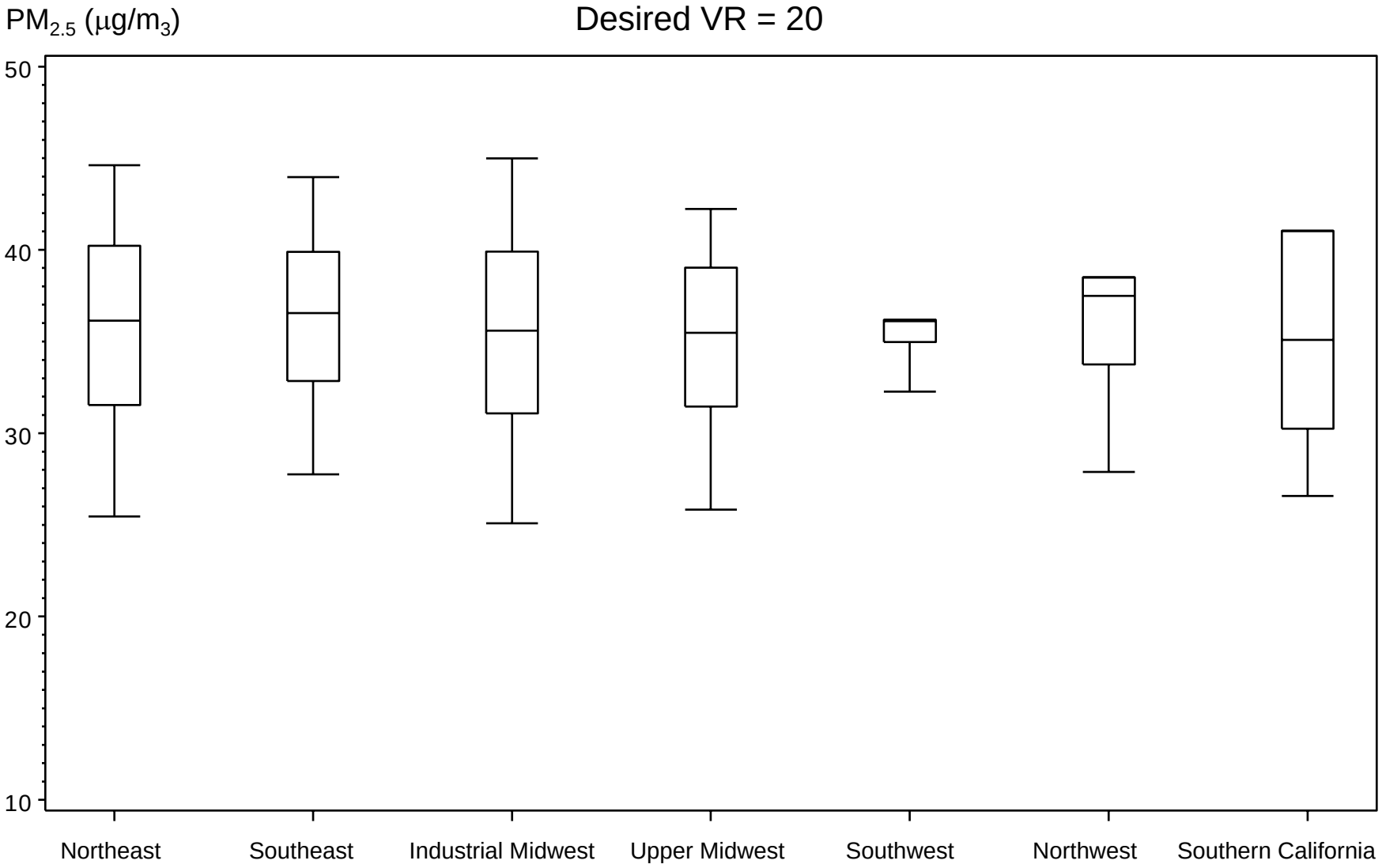
Regional PMc / PMf Ratios

Northeast	0.620
Southeast	0.794
Industrial Midwest	0.587
Upper Midwest	1.545
Southwest	2.417
Northwest	1.305
Southern California	1.485

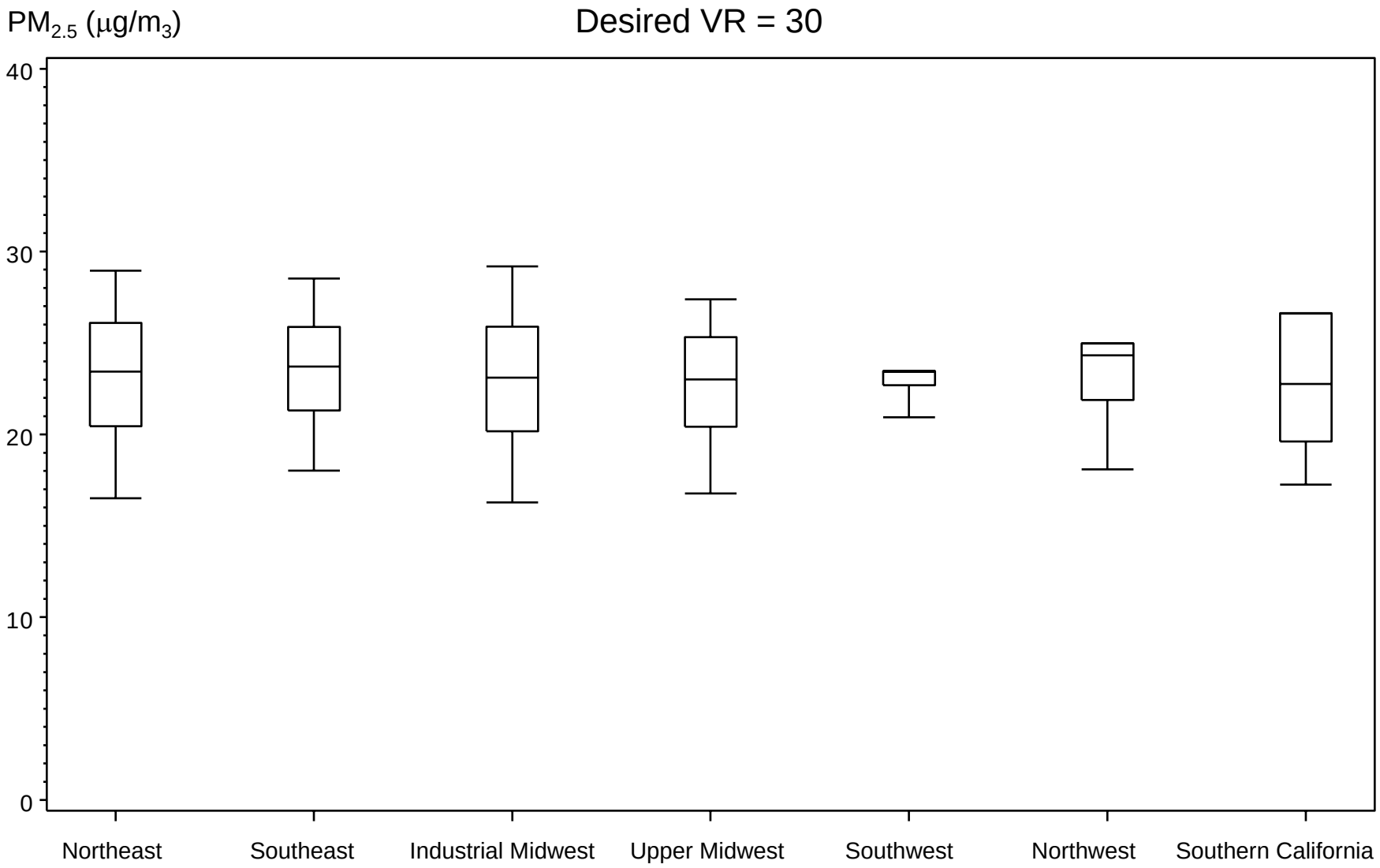
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



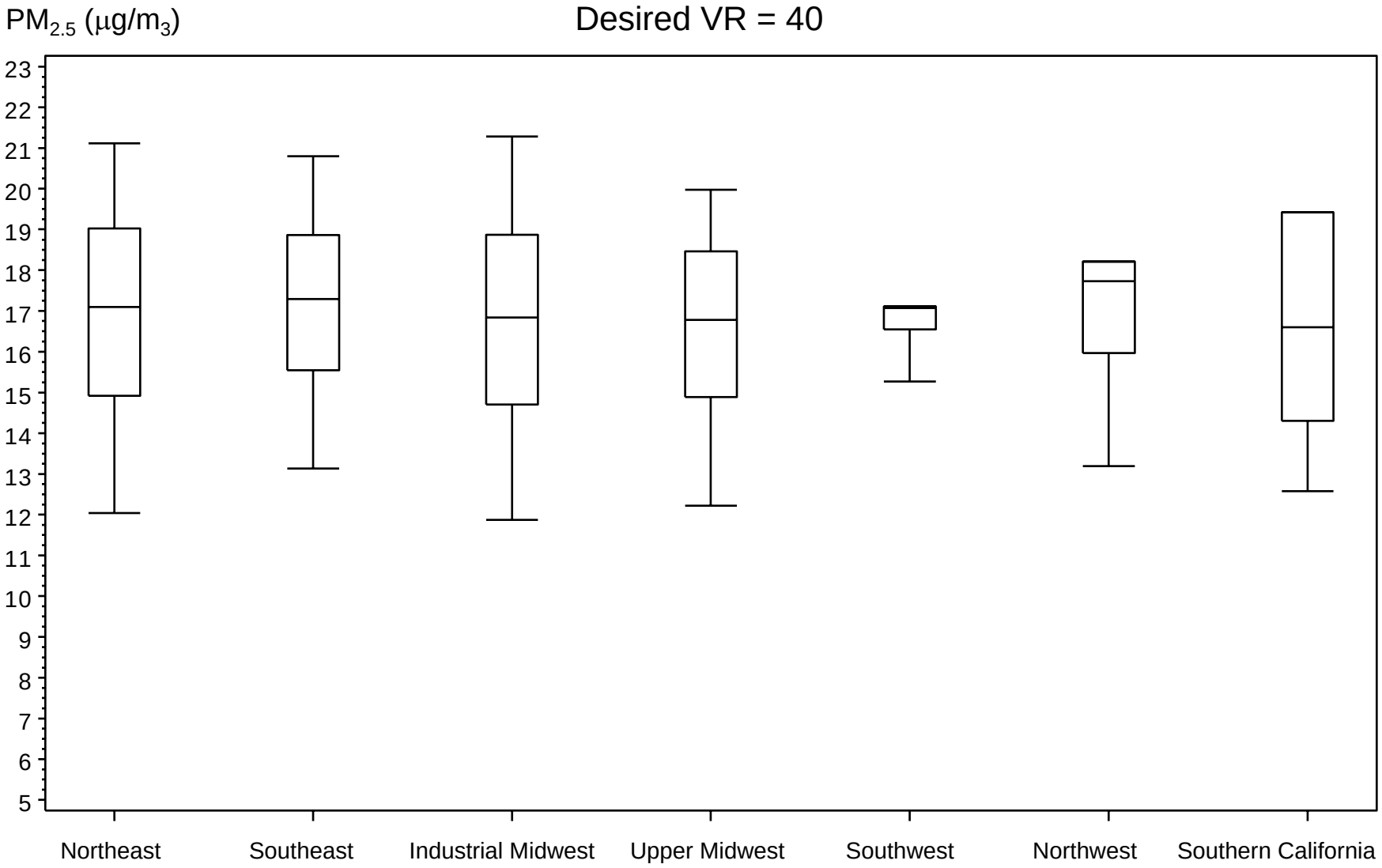
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



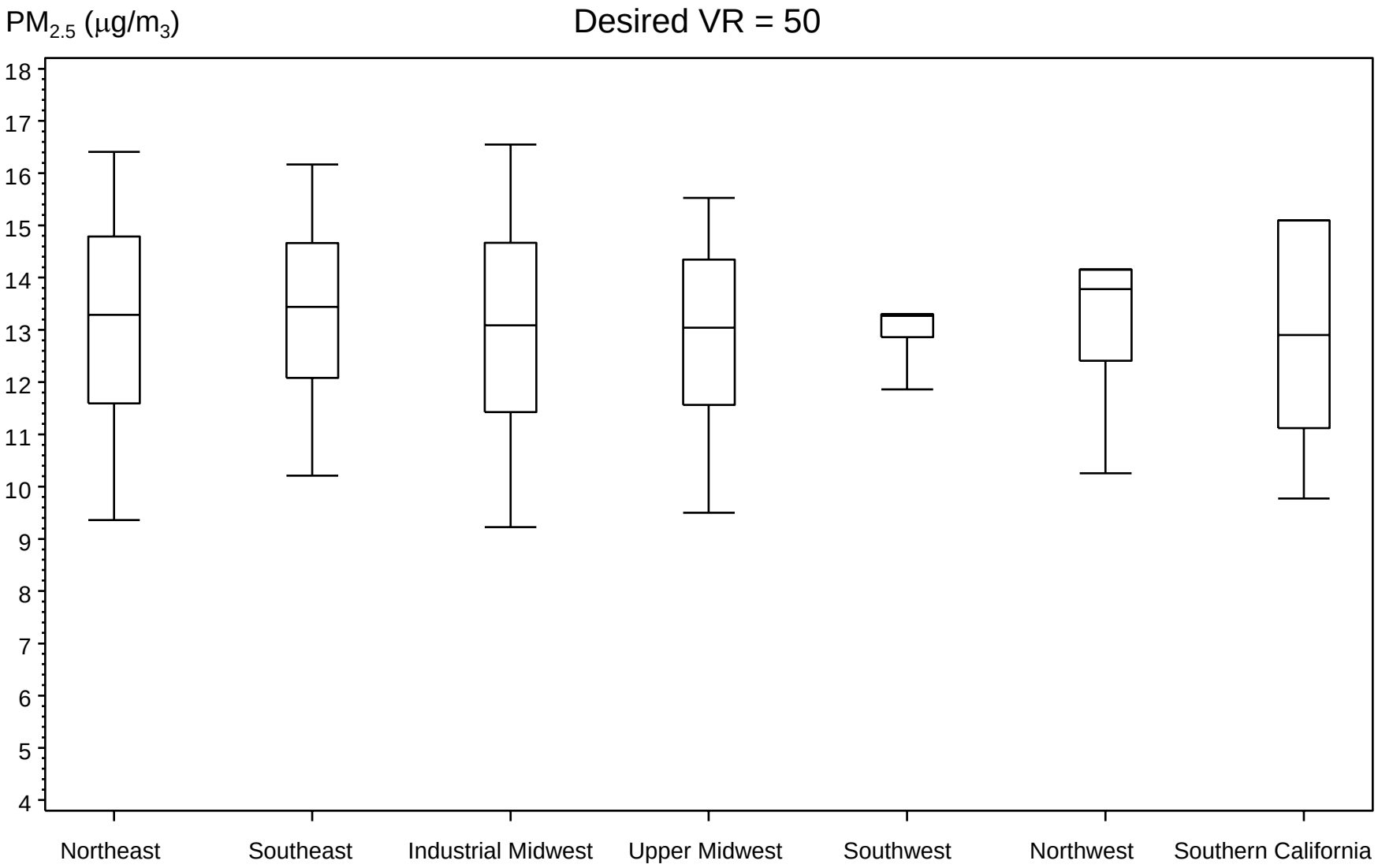
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



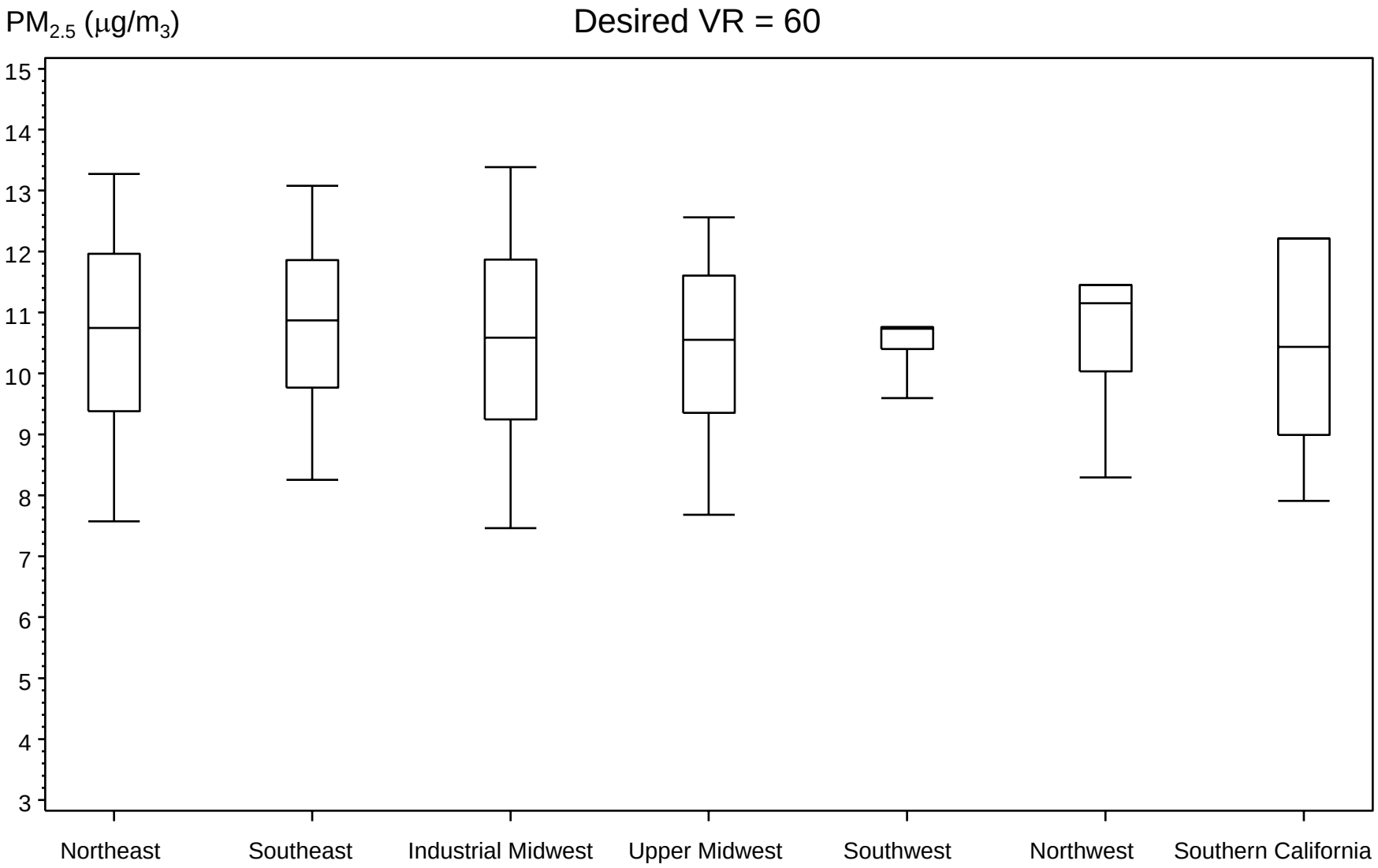
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



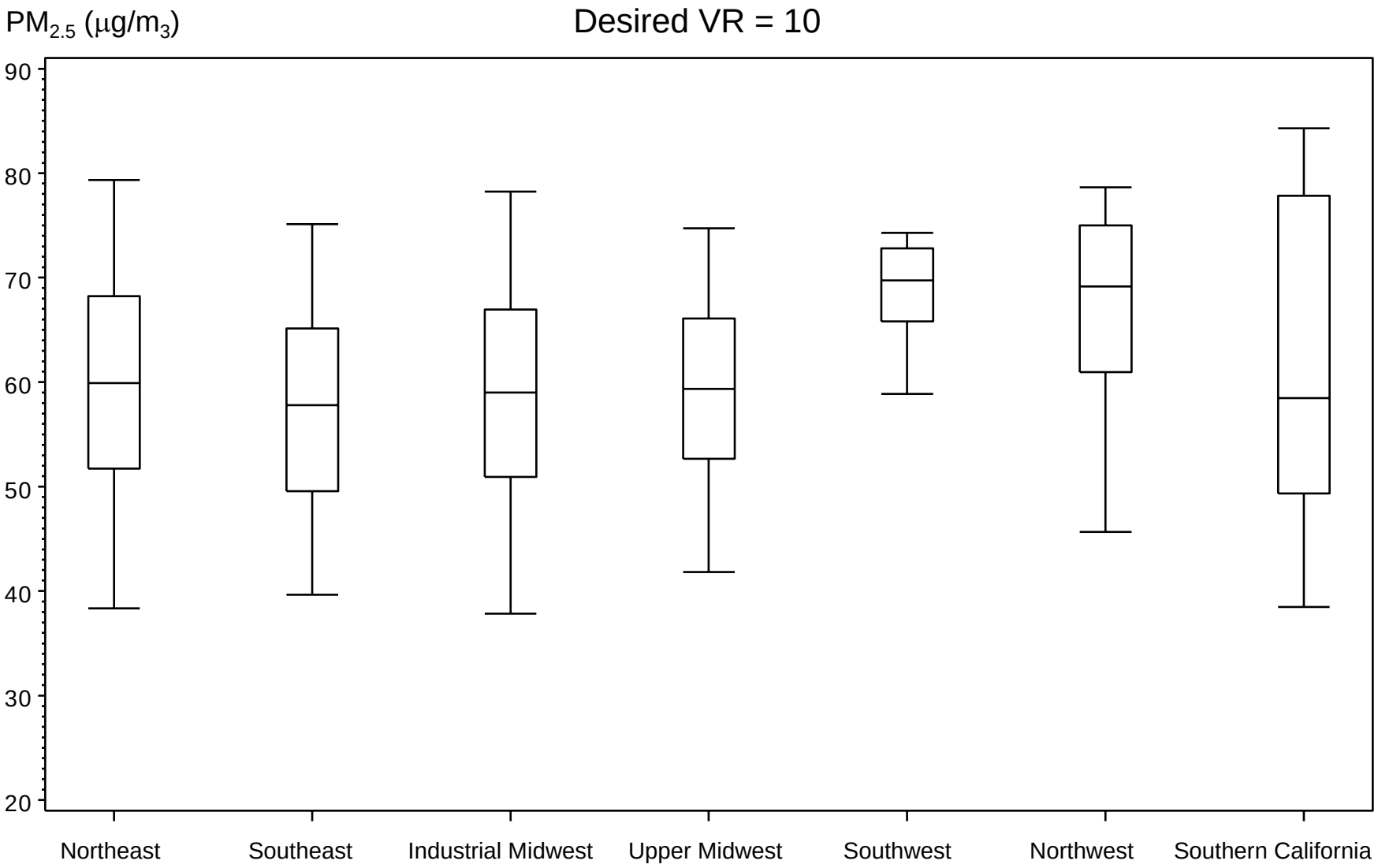
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



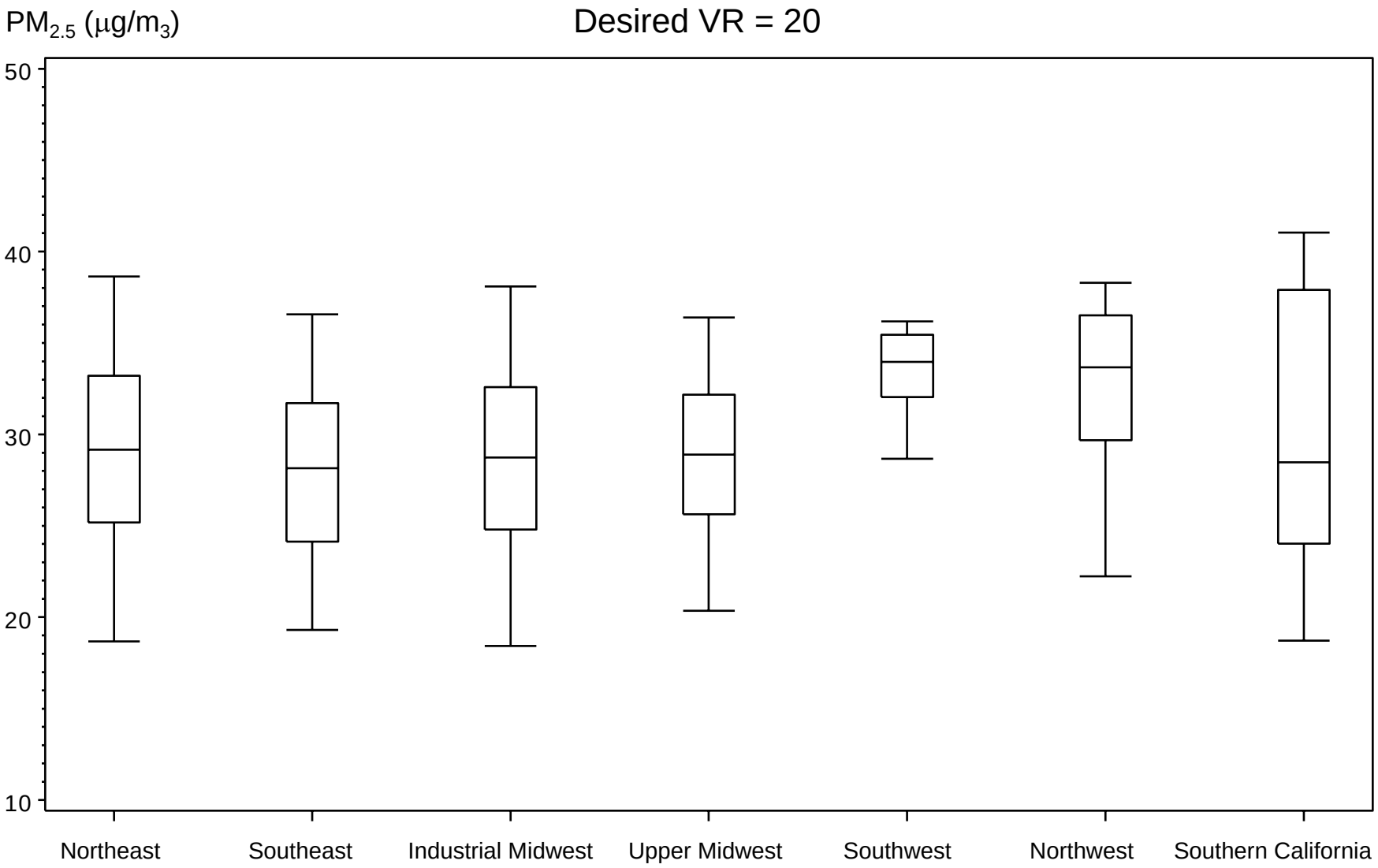
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



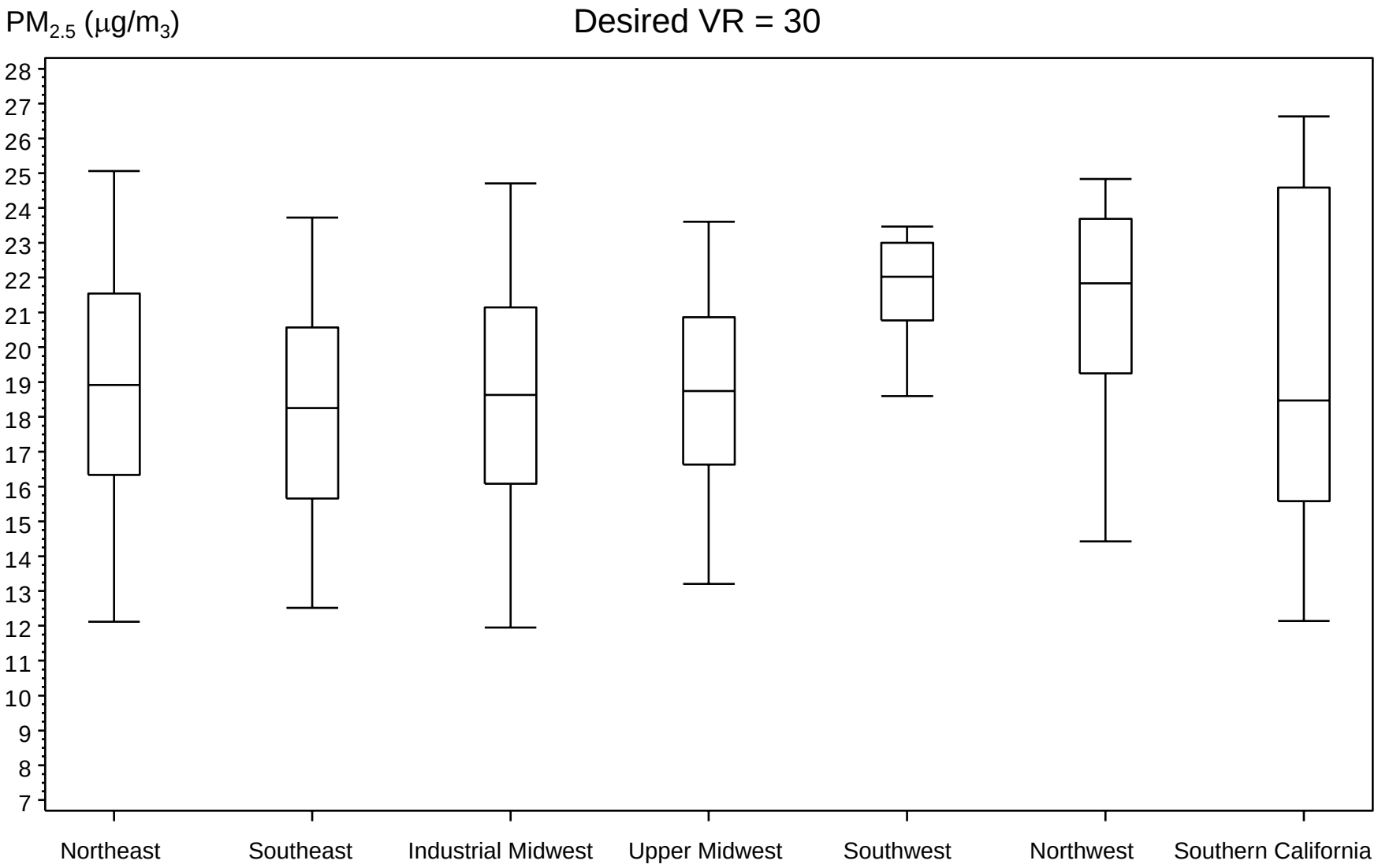
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-hr Timeframe



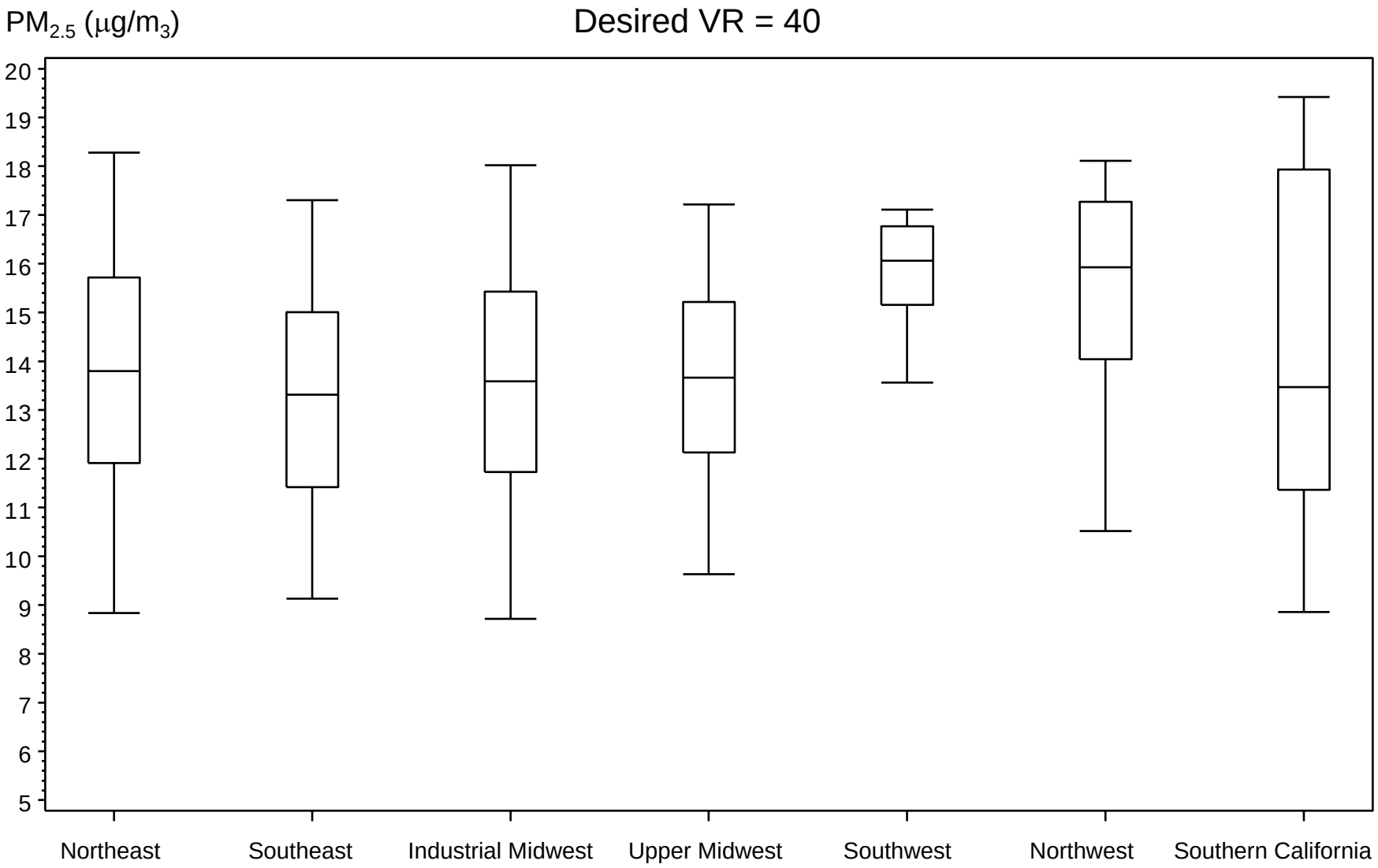
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-hr Timeframe



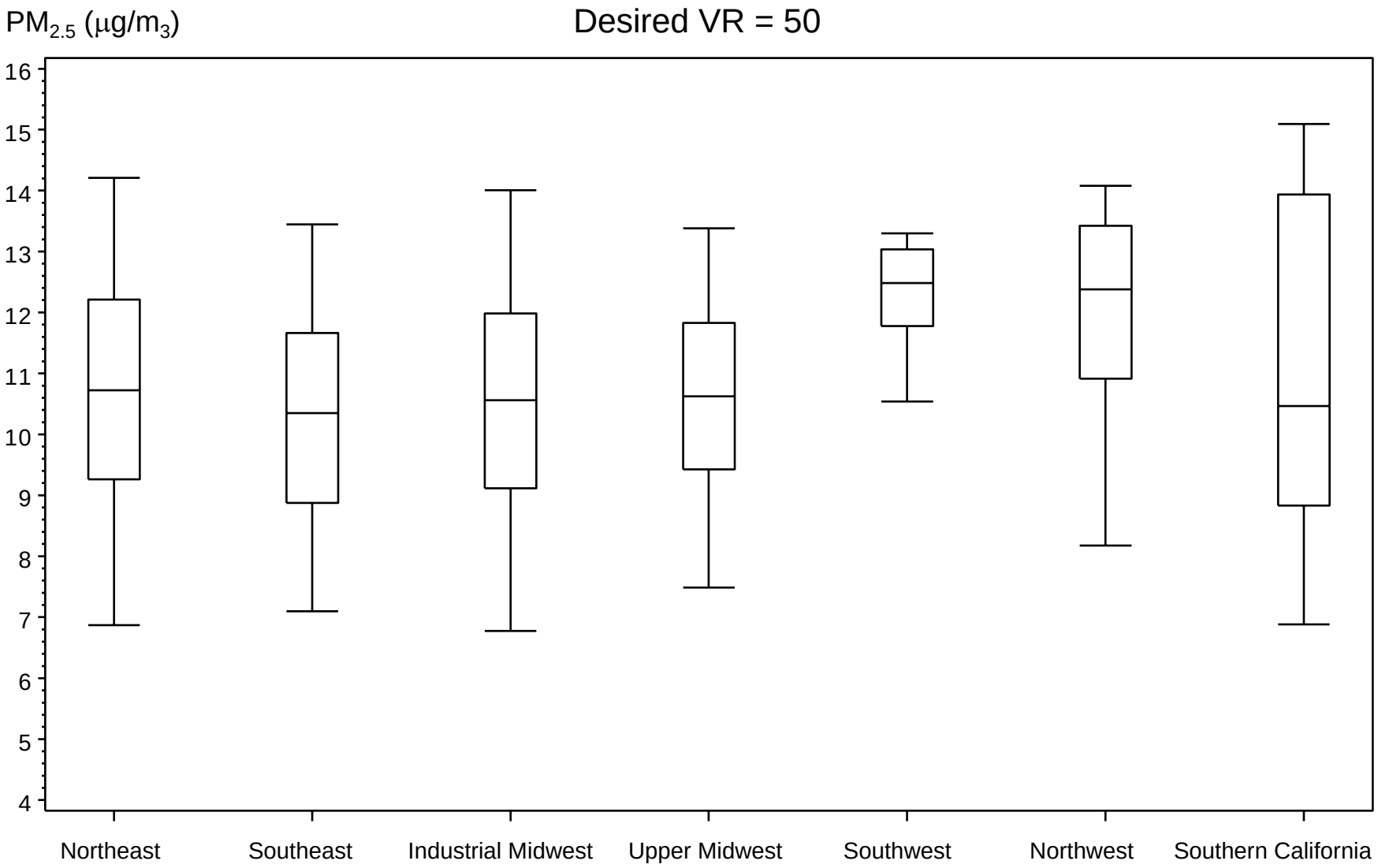
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-hr Timeframe



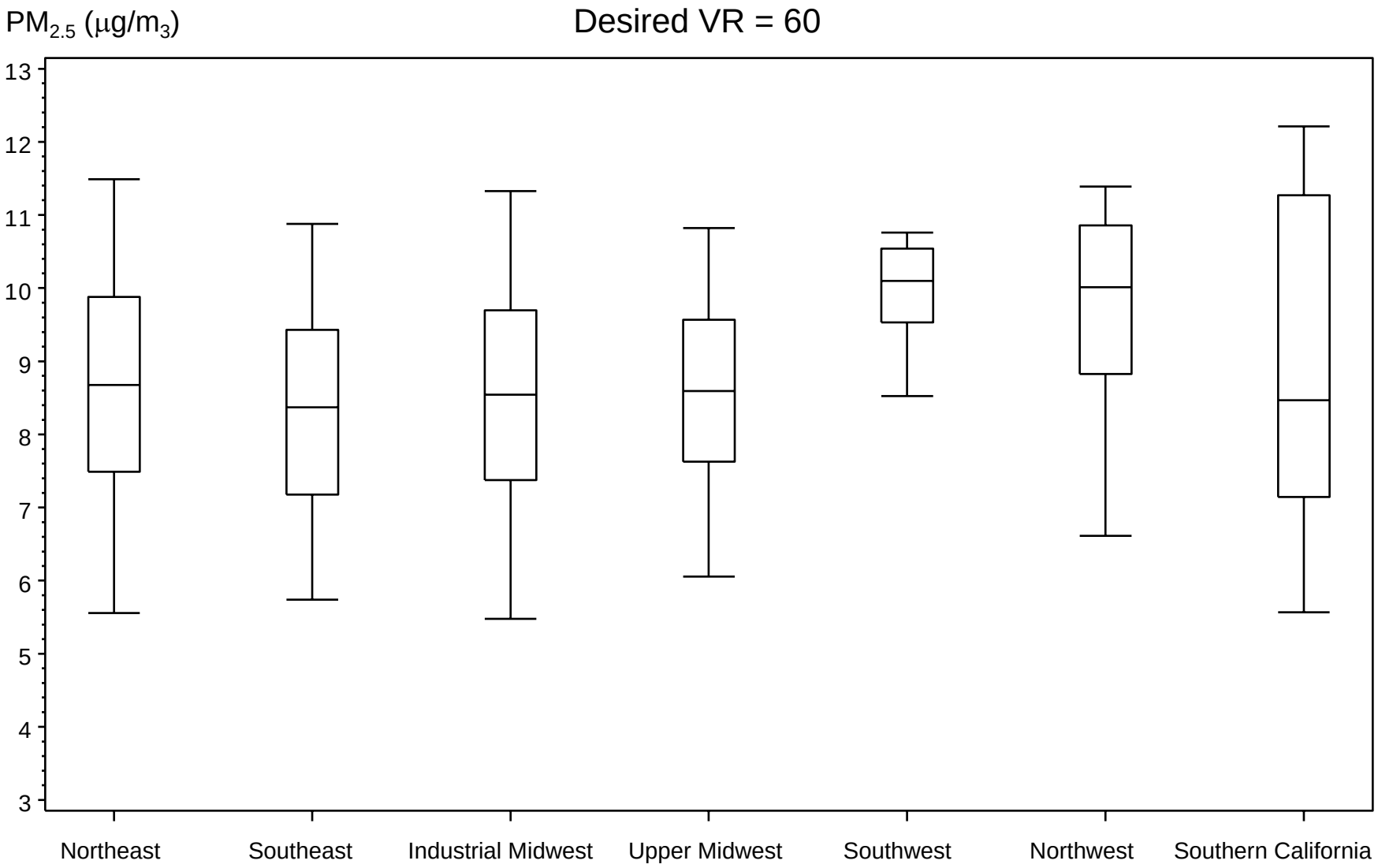
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-hr Timeframe



$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-hr Timeframe



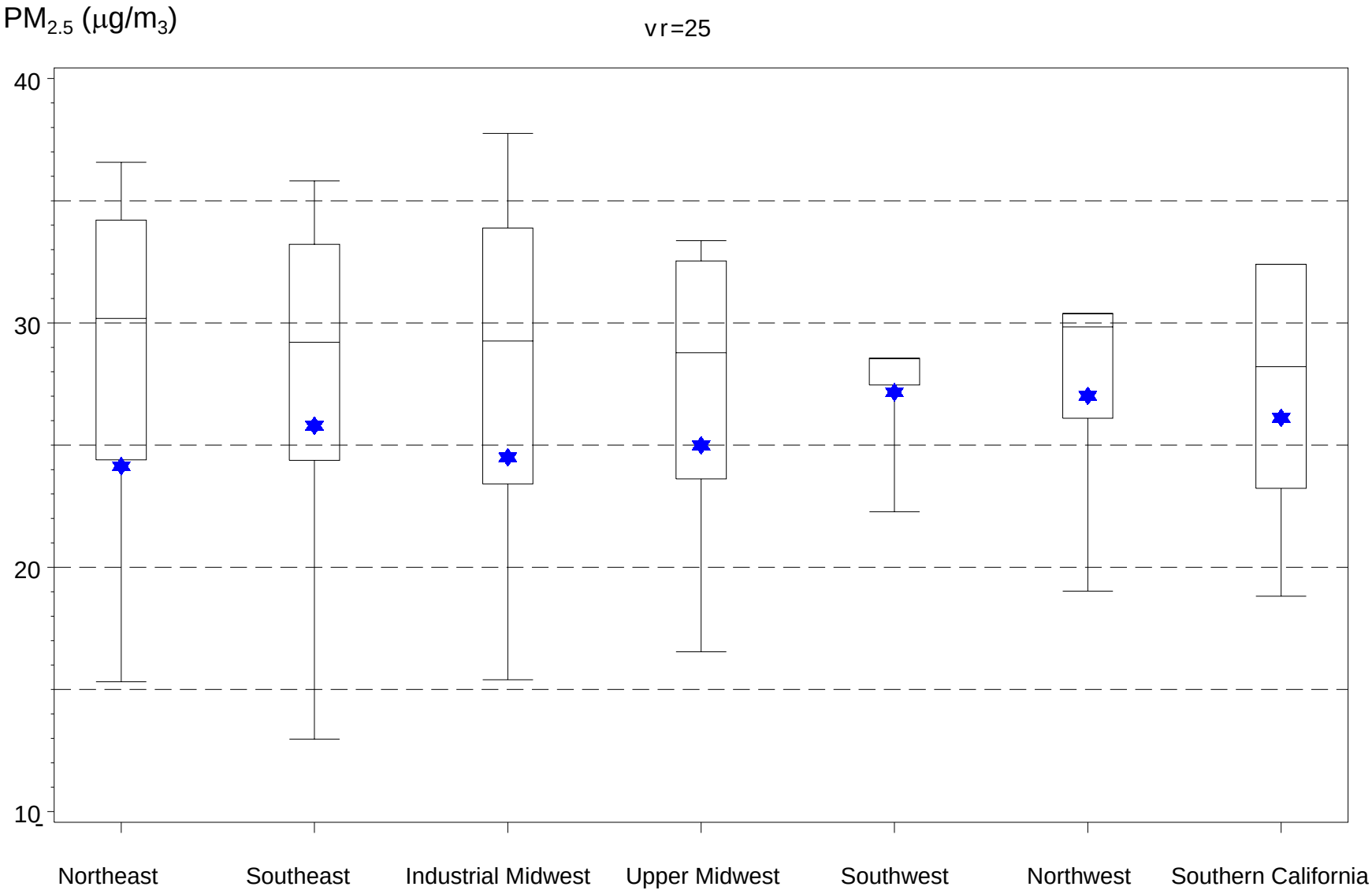
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-hr Timeframe



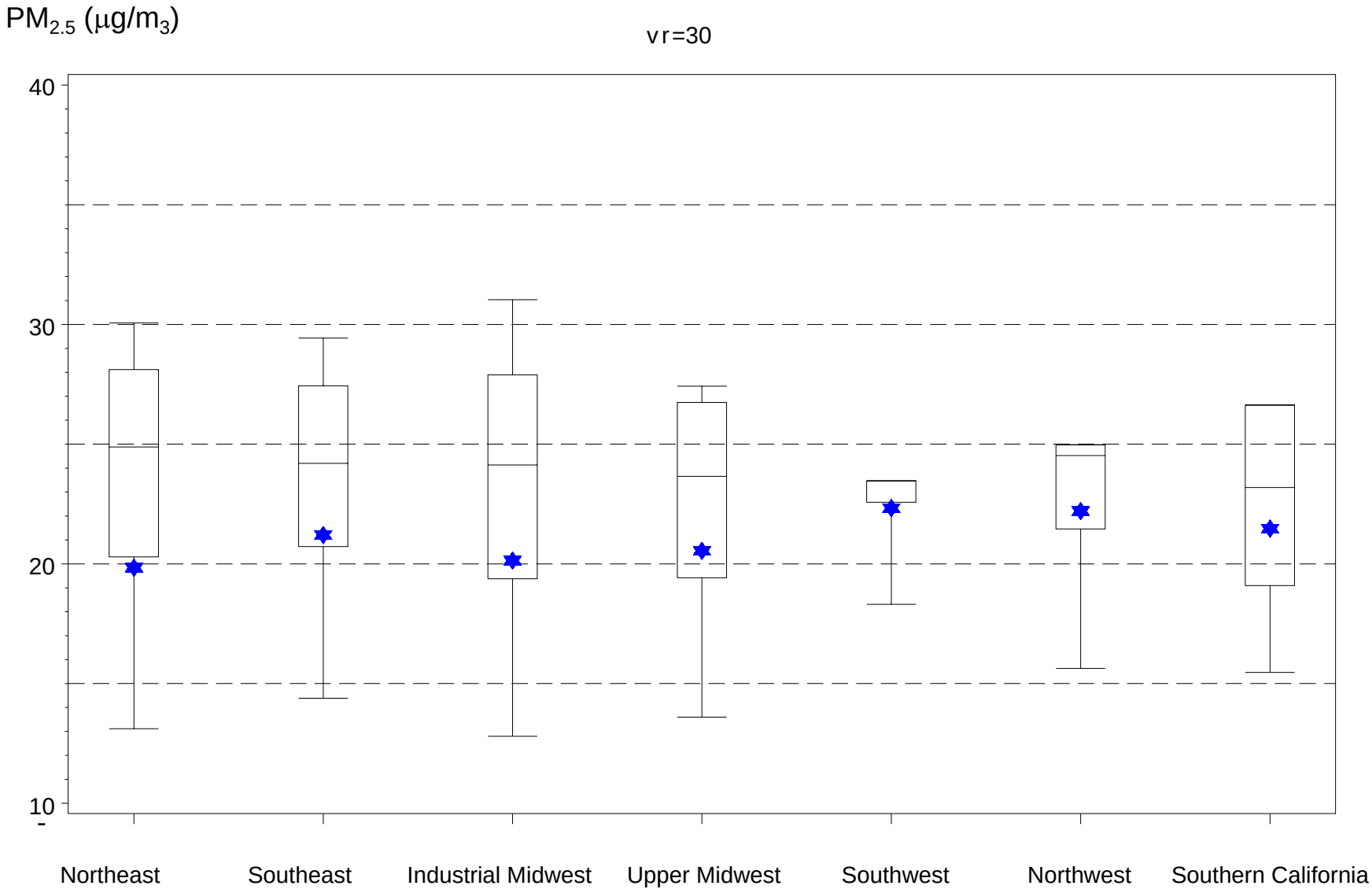
Methodology was tweaked to:

1. Use 3-year regional (raw) distribution of hourly NWS RH values instead of distribution of 3-year averages of hourly NWS RH.
2. Solve for visual range targets of 25, 30, and 35 km.
3. Add mean (utilizing regional, hourly FRH means) to graphs. Shown as an asterisk.
4. Scales were made common.

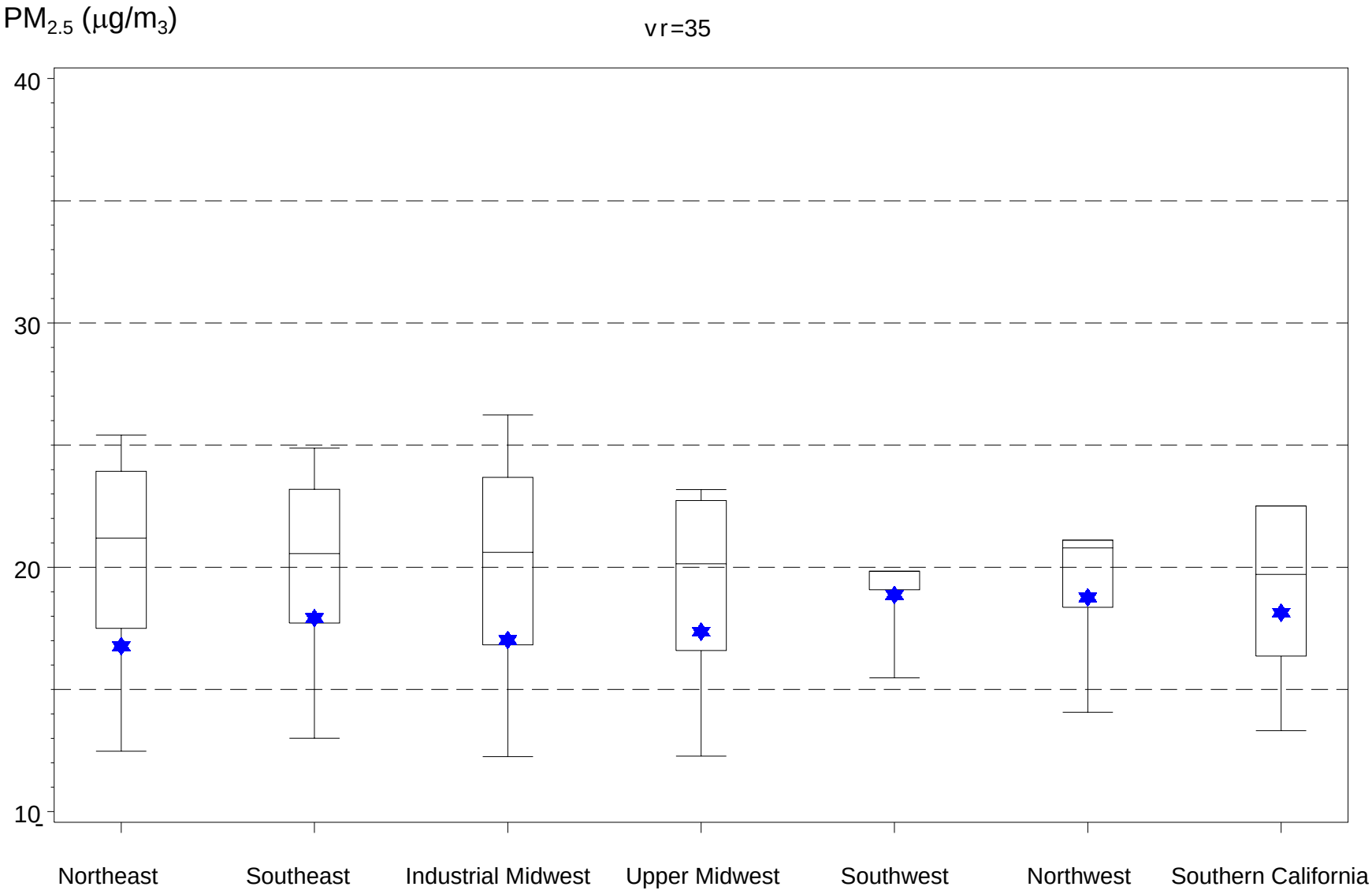
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



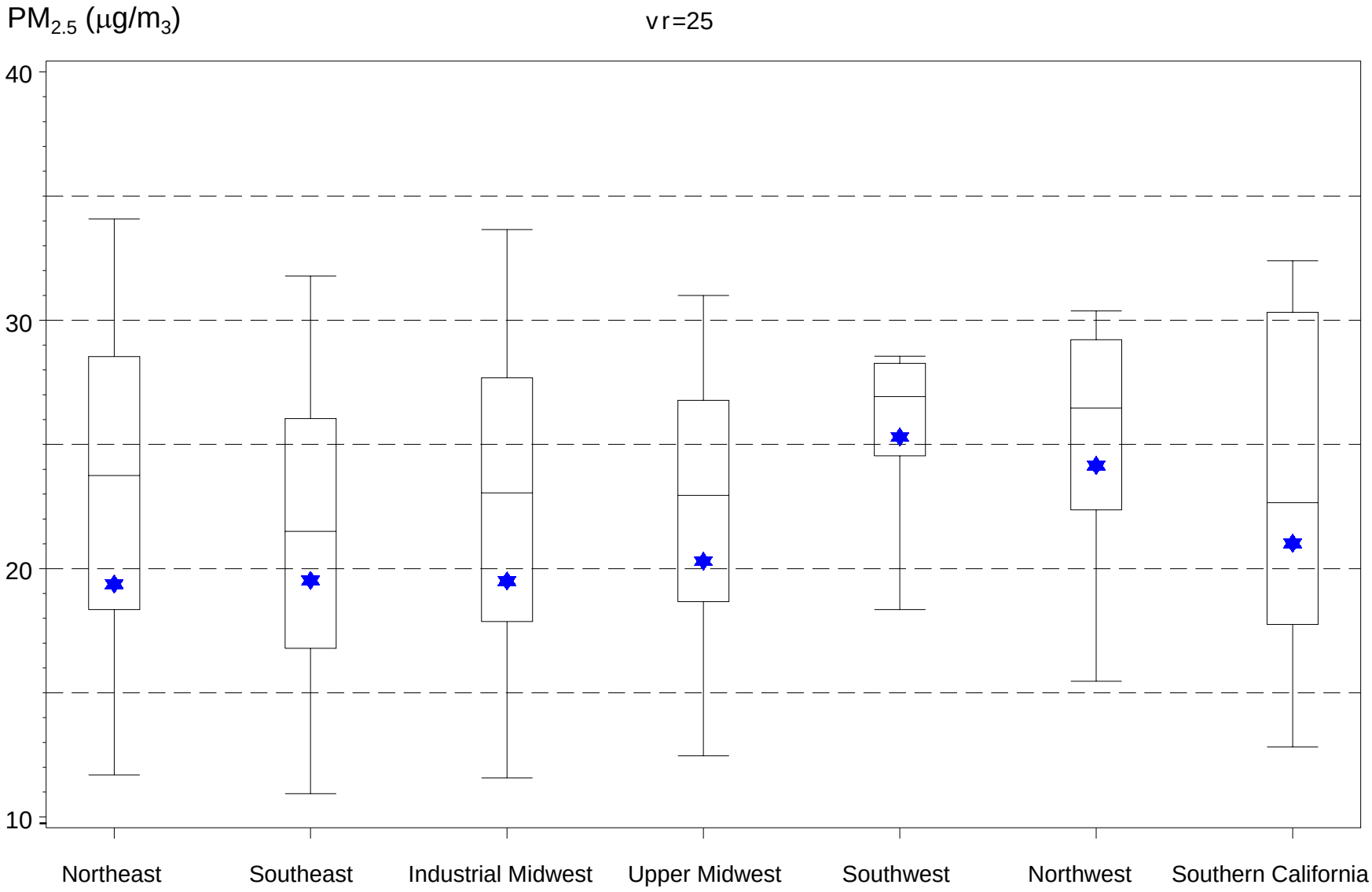
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



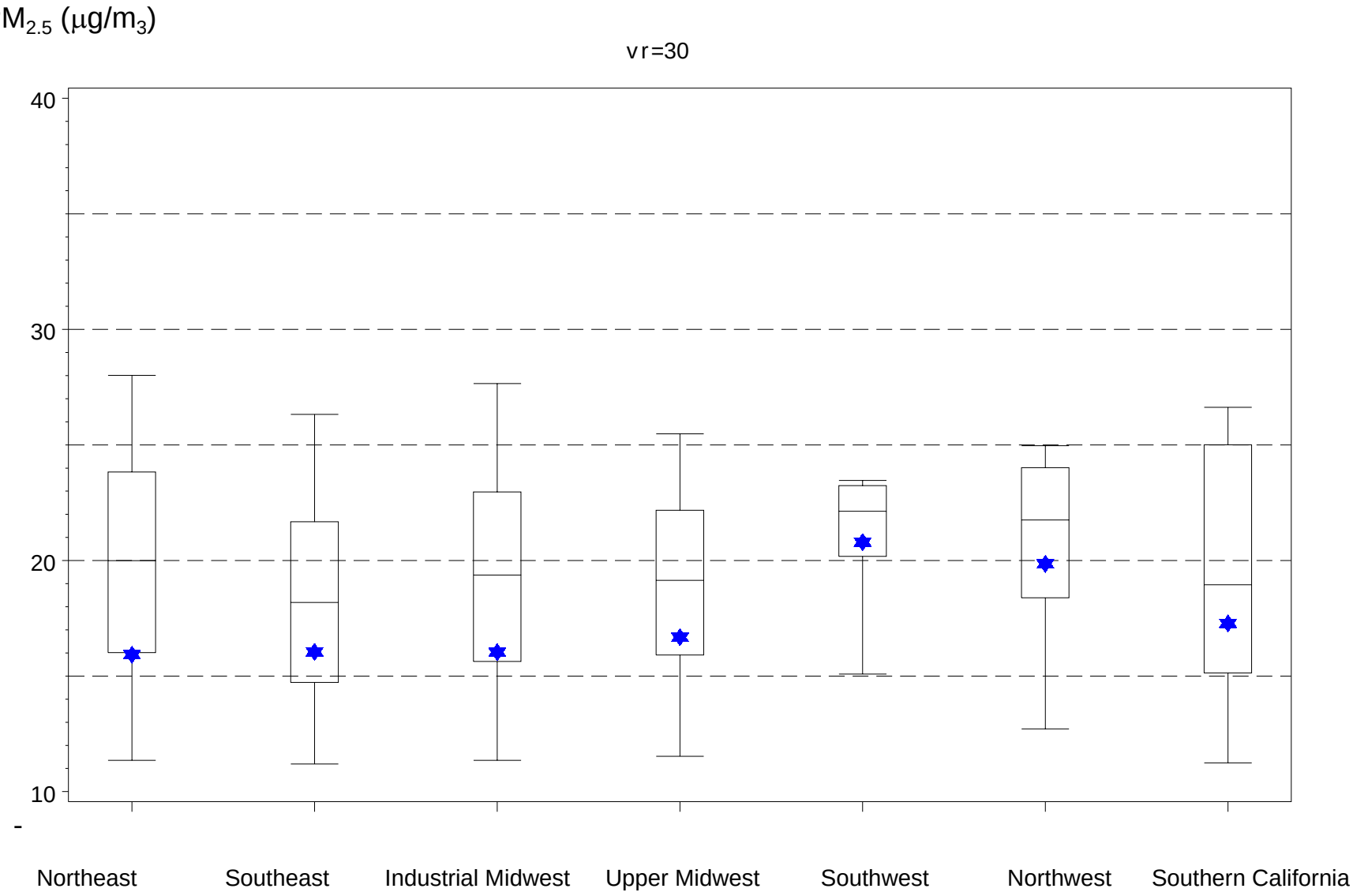
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
12pm-4pm Timeframe



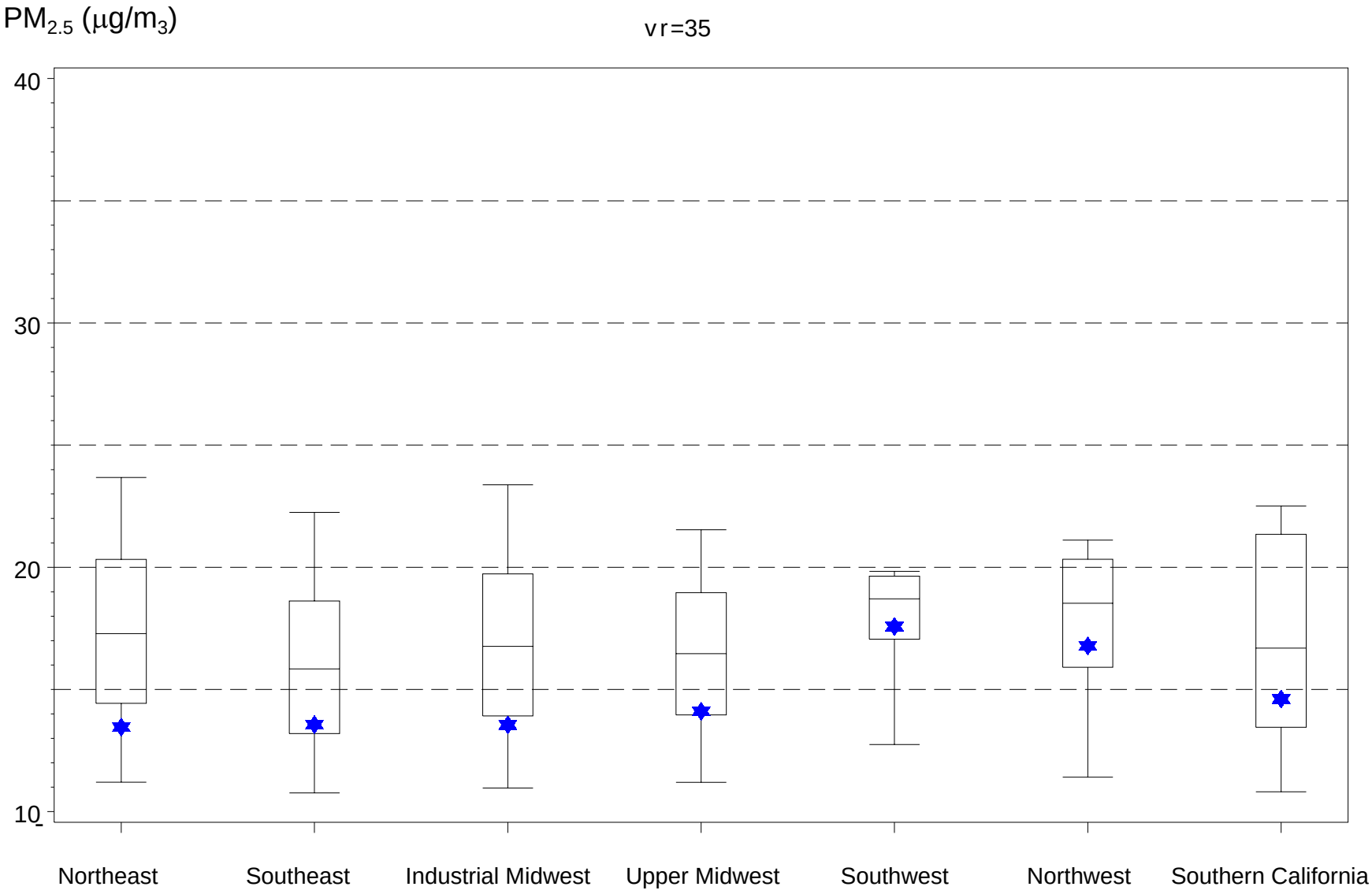
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-Hour Timeframe



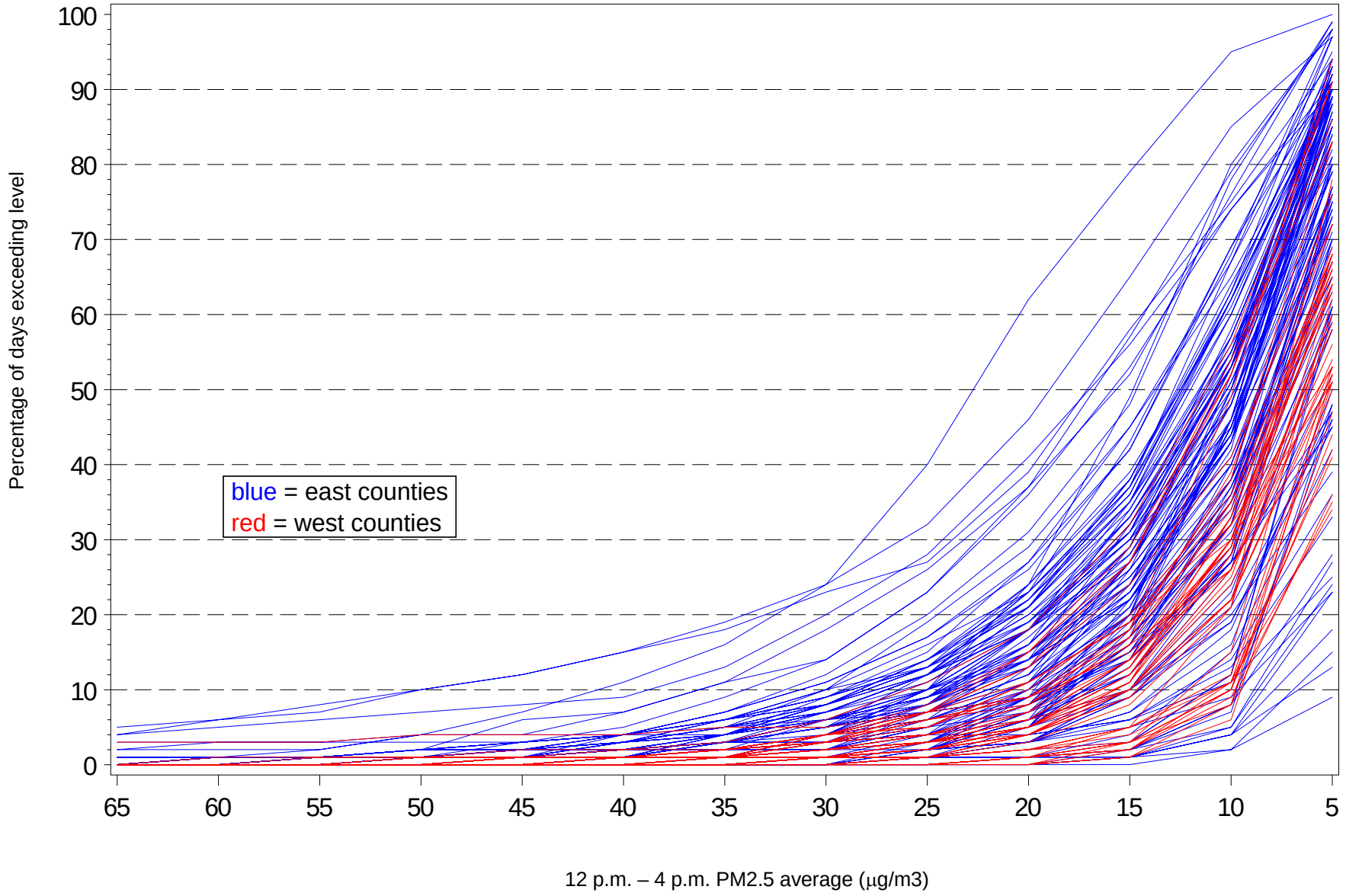
$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-Hour Timeframe

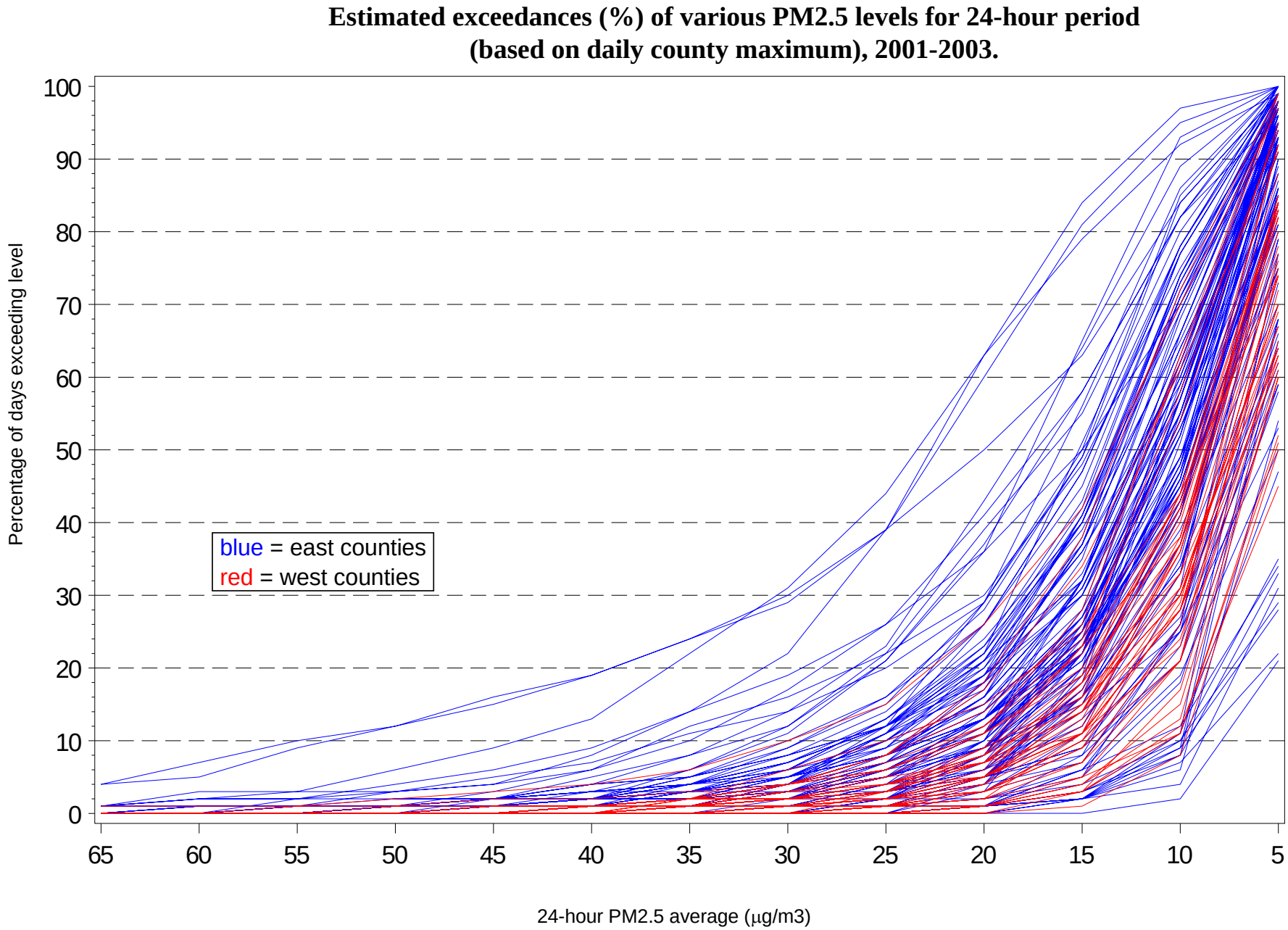


$PM_{2.5}$ Levels Needed to Meet Various Visual Range Goals
24-Hour Timeframe



Estimated exceedances (%) of various PM2.5 levels for 12 p.m. - 4p.m. (based on daily county maximum), 2001-2003.




Estimated exceedances (%) of various PM2.5 levels for 24-hour period
(based on daily county maximum), 2001-2003.
Percentage of days exceeding level
100
90
80
70
60
50
40
30
20
10
0
blue = east counties
red = west counties
65
60
55
50
45
40
35
30
25
20
15
10
5
24-hour PM2.5 average (μg/m3)