Using Ordinary Kriging to Estimate the Seasonal W126, and N100 24-h Concentrations for the Year 2002

by

Allen S. Lefohn, Ph.D.
A.S.L. & Associates
111 North Last Chance Gulch
Suite 4A
Helena, Montana 59601

H. Peter Knudsen, Ph.D.
Professor
Montana Tech
of the
University of Montana
Butte, Montana 59707

Douglas S. Shadwick
320 Eastwood Road
Chapel Hill, NC 27514

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1.0 Introduction

This report describes how Ordinary Kriging was used to estimate the 6-month W126 and N100 24-h ozone exposure values for the year 2002 for the United States. A.S.L. & Associates has published previously its kriging results in peer-review papers and reports (Knudsen and Lefohn, 1988; Lefohn et al., 1988; Lefohn et al., 1992; Lefohn et al., 1997).

A.S.L. & Associates provided the 2002 ozone hourly data to Mr. Douglas Shadwick for characterizing the 24-hour W126 and N100 monthly values and then summarizing the information into 6-month (April – September) values. In addition, data capture, the second highest daily maximum concentration, and the 4th highest 8-hour daily maximum average concentration were calculated for the EPA's designated ozone season. Following receipt of the data from Mr. Shadwick and checking of the results, A.S.L. & Associates provided Dr. Knudsen with the April – September (6 month) W126 and N100 24-h exposure indices for monitoring sites in 2002. The computer files provided contained summarized air quality data, a monitoring site identification codes, site latitude and longitude, and site characterization code information (i.e., urban, suburban, rural, etc.).

Mr. Shadwick corrected the characterized data for missing values. The estimate of cumulative indices from hourly average data (e.g., the W126 cumulative and N100 ozone indices) will be biased low if a part of the hourly average data is missing. A correction scheme has been adopted to estimate, in particular, a cumulative index for seasonal values of the indices. The correction scheme has two components.

1. A monthly value of each index is calculated. If at least 75% of the hourly data are available for the month, a corrected monthly cumulative index is calculated as the uncorrected monthly cumulative index divided by the data capture (as a fraction).

2. If there are any months with less that 75% data capture and the two chronologically adjacent months each have at least 75% data capture, then a corrected monthly cumulative index for the month with less than 75% data capture is calculated as the arithmetic average of the corrected monthly cumulative indices for the two adjacent months.

If all of the months contained within a season have valid estimates (in the sense described above) of the corrected monthly cumulative index, the corrected seasonal cumulative index is calculated as the sum of the corrected monthly cumulative indices. Otherwise, there is not a valid estimate of the corrected seasonal cumulative index.

In addition to the data provided to Dr. Knudsen, Mr. Shadwick characterized the second highest daily maximum 1-hour concentration and the fourth highest 8-hour average daily maximum concentration that occurred over the EPA-defined ozone season for each monitoring site that experienced sufficient data capture. This information was provided by A.S.L. & Associates to the U.S. Forest Service project manager.

2.0 Scope of Work

Estimate the seasonal W126 and N100 exposure index value for each 1/2^o by 1/2^o cell in the United States excluding Alaska and Hawaii.

Specific tasks performed included:

1. Check and verify the latitude, longitude and elevation of each site.
2. Calculate and model variograms for each exposure index values for each year.
3. Krig the seasonal W126 and N100 values for each year.
4. Prepare files that contain information describing the kriged values, the coordinates, variance, and the 95% error bound for each 1/2 ^{o} by 1/2^o cell.

3.0 Steps in Modeling

In its 1982 Kriging study, NCLAN investigators were concerned about the selection of stations to be included in the air quality analysis (Heck *et al*., 1984). In urban settings, the ozone concentrations were thought to be lower at city-center than at rural locations because of nitric oxide titration in the city. Therefore, NCLAN investigators hypothesized that by using city-center monitoring stations to predict rural ozone levels, the resultant estimations might be biased low. Because of this concern, specific monitoring stations located in large metropolitan areas were not included in the 1982 NCLAN analysis.

Because significant changes have occurred to all metropolitan areas in the last 20 years, the method of filtering city-center sites used in the 1982 NCLAN study was re-examined. Using 2002 data, Table 1 shows statistics for several of the large metropolitan areas of the US. In Table 1, the first line in each case is the mean variance of the N100 values for the city-center sites included in the 1982 study. The second line is a summary of all the sites within the metropolitan area. With the exception of Los Angeles, the1982 set of sites had higher N100 values than the set of values for the entire metropolitan area. In Los Angeles the filtered city center sites are higher than the complete set of sites. Table 2, shows the same information for the W126 index. With the W126 index, the means are much closer in all cases, but the same result is obtained as for the N100 values. With exception of Los Angles, the city-center sites are higher than the complete set of sites.

Based on this test, it was decided to not use the filtering protocol developed in the 1982 NCLAN study, and to instead use all the monitoring data.

Table 1. City Center Site Comparison for N100.

N100 City Center Analysis			

	N	Mean	Variance
Cincinnati			
City Center	9	43.9	198.7
City plus surrounding area	19	30.9	426.3
Charlotte			
City Center	7	39.2	293.2
City plus surrounding area	17	31.5	644.8
St. Louis			
City Center	14	25.4	226.9
City plus surrounding area	19	22.5	245.1
Chicago			
City Center	21	22.1	245.7
City plus surrounding area	25	18.0	355.9
Los Angeles			
City Center	26	39.5	3746.0
City plus surrounding area	43	59.5	6541.5

Table 2 City Center Site Comparison for W126.

W126 City Center			
	N	Mean	Variance
Cincinnati			
City Center	9	39.7	26.8
City plus surrounding area	19	37.8	82.6
Charlotte			
City Center	7	48.6	32.7
City plus surrounding area	17	47.4	86.2
St. Louis			
City Center	14	32.9	54.3
City plus surrounding area	19	32.7	32.7
Chicago			
City Center	21	26.9	66.9
City plus surrounding area	25	26.2	57.7
Los Angeles			
City Center	26	33.8	757.9
City plus surrounding area	43	48.5	1483.4

Ozone exposure indices for California are known to be significantly different (higher) from other areas of the United States. Therefore California was analyzed separately in this study.

The following steps were performed for each exposure index.

1. Data Checking

    a. The latitude, longitude of all the monitoring sites from the AIRS database were compared and updated to coordinates supplied by ASL & Associates. In addition, many of the AIRS sites have incorrect elevations, missing elevations, or elevations listed in feet rather than meters. The elevations of all monitoring sites were checked and update with elevations supplied by Bill Jackson, U.S. Forest Service.
    b. Maps showing monitoring sites and data values were plotted.

2. Calculation of data statistics.

3. Variograms for each exposure index were calculated.

4. Kriged values of W126 for each $1/2^o$ by $1/2^o$ degree cell were determined.

5. A file with kriged values was prepared.

4.0 Data Checking

The latitude, longitude of all the monitoring sites from the AIRS database were compared and updated to coordinates supplied by A.S.L. & Associates. Many of the AIRS sites have latitude and longitude values that are recorded to only 2 decimal places (1/100 of a degree). More precise values are necessary for this study. A.S.L. & Associates provided more precise locations for the monitoring stations. Many of the AIRS sites have incorrect elevations, missing elevations, or elevations listed in feet rather than meters. The elevations of all monitoring sites were checked and update with elevations supplied by Bill Jackson, U.S. Forest Service.

5.0 N100 Exposure Index

Basic statistics and histograms were calculated independently for California and for the rest of the U.S. Table 1 shows summary statistics for the N100 index.

Table 1 N100 Statistics.

AREA	MEAN	VARIANCE	STD.DEV.	MIN	MAX	NUMBER
California	41.46	4880.5	69.9	0.0	372.2	147
Rest of US	16.64	448.62	21.2	0.0	121.1	920

5.1 N100 Variogram Calculation

Experience gained in prior studies of ozone indices was used in determining the parameters for calculating and modeling the variograms of the N100 values. Particular care was used to determine the presence and likely directions of anisotropy. After calculation of the variograms, a theoretical model was fitted to them.

Table 2 Variogram parameters.

AREA	Co	C1	Range1	C2	Range2	Angle	AF ratio
CAL	100	3500	450	0	0	135	3.6
US	200	400	225	200	2250	0	1.5

5.2 Kriging of N100

The N100 exposure for each 1/2^o by 1/2^o cell in California and the rest of US were estimated using ordinary Kriging. The main input to a kriging program is the variogram parameters and the search parameters. The variogram parameters are listed in Table 2. The search parameters are shown below.

Search Radius		California	US
Maximum search radius	=	800 km	1100 km
Max.number of sites used to estimate a cell	=	12	12
Min.number of sites used to estimate a cell	=	1	1

5.3 N100 Results

The Kriging estimates of the N100 exposure value for each 1/2^o by 1/2^o cell by year were written to a file and forwarded to A.S.L & Associates for distribution. A portion of the output file is shown below. The N100estimate for each grid cell is in column 3 and the 95% error bound for the estimate is in column 5. Column 4 contains the kriging variance and column 6 contains the number of values used to make the estimate of the N100 value.

Latitude	Longitude	N100	Krig. Var	95%EB	No. of Samples
44.5	-66.5	17.11	244.9718	31.3	15
45	-66.5	15.62	270.4484	32.89	15
44	-67	19.21	213.7704	29.24	15
44.5	-67	18.05	199.9546	28.28	15
45	-67	15.98	246.2411	31.38	15

6.0 W126 Exposure Index – Basic Statistics

Basic statistics and histograms were calculated independently for California and for the rest of the U.S. Table 3 shows summary statistics for the W126 index.

Table 3 W126 Statistics

AREA	MEAN	VARIANCE	STD.DEV.	MIN	MAX	NUMBER
California	43.99	1583.10	39.79	0.0	161.0	147
Rest of US	30.61	227.34	15.08	0.2	122.1	920

6.1 W126 Variogram Calculation

Experience gained in previous studies was used in determining the parameters for calculating and modeling the variograms of the W126 values. Particular care was used to determine the presence and likely directions of anisotropy. After calculation of the variograms, a theoretical model was fitted to them.

Table 4 Variogram parameters for W126 Index

AREA	Co	C1	Range1	C2	Range2	Angle	AF ratio
CAL	400	1050	550	0	0	135	3.6
US	80	45	415	150	1900	0	1.38

6.2 W126 Kriging

The W126 exposure for each $1/2^o$ by $1/2^o$ cell in California and the rest of US were estimated using Ordinary Kriging. The variogram parameters shown in Table 4 were used and the search parameters used were the same as for the N100 index.

References

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