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Mean Maximum Mixing Heights for Northern Asia for the Winter of 1978

**W. E. Davis
P. E. Tucker**

August 1984

**Prepared for the U.S. Air Force
under a Related Services Agreement
with the U.S. Department of Energy
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**Pacific Northwest Laboratory
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SUMMARY

Mean maximum mixing heights are used to compute the vertical extent of mixing of an air pollutant released in the surface boundary layer. A past study by Holzworth (1972) has examined mean maximum mixing heights in the United States. This study was confined to northeastern Asia and presents the results of computing maximum mixing heights over a single winter. Also included are mean layer-averaged wind speeds for the same time period. Two regions of low maximum mixing heights and low mean wind speeds were noted.

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MEAN MAXIMUM MIXING HEIGHTS FOR NORTHERN ASIA
FOR THE WINTER OF 1978

INTRODUCTION

One of the parameters affecting the estimation of surface air concentrations of a pollutant is the mean maximum mixing height. Studies of the mean maximum mixing height have been made for the United States by Holzworth (1972). To date no studies have been made of northeastern Asia. Northern Asia is of particular interest in computing maximum mixing heights since this region receives very little solar radiation during the winter. The effect is that the surface will receive little or no solar insolation. With a decrease in heating at the surface, the maximum mixing height will decrease. These low maximum mixing heights combined with low wind speeds will cause a high potential for high surface air concentrations of pollutants. Since this region is under the influence of high pressure, one would expect low maximum mixing heights and low wind speeds would occur in regions of a low-pressure gradient thereby producing a high potential for air pollution (Holzworth 1972).

To determine maximum mixing heights we used the method developed by Holzworth (1972) with some modifications. One necessary modification was due to the assumption that the morning sounding should be used with the afternoon maximum temperature to compute the maximum mixing depth. Our application used the maximum temperature whenever it occurred within the solar day. Also, no allowance was made for an increase in mixing height due to precipitation. The following provides a brief description of the technique used, a description of the data base followed by the results. Two appendixes have been included providing data for individual stations.

TECHNIQUE

Two pieces of information need to be computed before a region can be designated as having a high potential for air pollution. These are a low maximum mixing height and low wind speeds. The maximum mixing height is the maximum height to which a surface parcel may penetrate vertically. The technique used to find this maximum height was, first, to find the time of maximum surface temperature and, second, to compute a potential temperature. Potential temperature is calculated by the following equation.

$$\theta = T \left(\frac{1000}{P} \right)^{0.2857}$$

where: P = pressure in millibars

T = temperature (absolute) in °K.

Once the potential temperature was found, the vertical temperature sounding was used to find the greatest height above the surface where the surface potential temperature intersected the vertical potential temperature profile. This height was designated as the maximum mixing height.

Once the mean maximum mixing height is known, the mean wind speeds also must be calculated. The mean wind speeds were computed using vertical profiles of wind speeds and directions. Rather than computing mean wind speeds over the complete maximum mixed height, separate layer-averaged values for 100 to 500 m and for 500 to 1000 m above the surface were computed. Using two layers will allow some examination of wind shear in regions where the mixing layer extends above 500 m.

DATA BASE

The data base used for this study is the USAFETAC DATSAV data base provided by the U.S. Air Force. Both surface and upper-air data sets were accessed (USAFETAC 1977).

The months selected for the study were January, February and March 1978. This selection was made on the basis of comparisons of mean surface temperatures (Lydolph 1977) at sites throughout northern Asia.

During these months the mean temperatures generally ran normal to two degrees above normal. The upper-air stations used in this study are shown in Figure 1. A list of the stations and their locations is included in Appendix A. It is important to note that the density of stations is somewhat sparse in the extreme northern areas. The quality of data emanating from these stations was poor. Therefore, results in these regions could be improved if additional data were available.

FIGURE 1. Station Locations

RESULTS AND CONCLUSIONS

A comparison of surface temperatures during the 1978 study period indicated the mean values were normal to 2°C above normal for most of the stations. A comparison of surface maps indicated, in general, a normal occurrence of high-pressure systems in Northern Asia during the period of study. This would indicate the results found in this study may be expected for other winters.

The results for the maximum mixing heights have been summarized in Figures 2, 3 and 4 and in Appendix B. Figures 5, 6 and 7 show the mean velocity for a layer 100 to 500 m above surface. The combination of the two sets can provide insight into regions where low mixing heights and low winds would tend to create regions with high potential for air pollution (Holzworth 1972).

FIGURE 2. Mixing Heights (m), January 1978

FIGURE 3. Mixing Heights (m), February 1978

FIGURE 4. Mixing Heights (m), March 1978

FIGURE 5. Wind Speed (m/s), January 1978

FIGURE 6. Wind Speed (m/s), February 1978

FIGURE 7. Wind Speed (m/s), March 1978

Two regions were found that have low mixing heights and low wind speeds. The first is the northeastern USSR with maximum mixing heights no greater than 200 m and a mean wind speed under 2 m/s for January. The second region is the Sikiang Province in China with mixing heights less than 200 m and mean wind speed under 2 m/s. By March, a rather dramatic change occurred as the height for the northeastern USSR increased 300 to 400 m above surface and the wind speed increased 4 to 6 m/s. In Sikiang the wind speed generally remained near 2 m/s; however, the maximum mixing height increased to 1000 to 1600 m above surface. In both cases, the air pollution potential would have decreased from January to March 1978.

REFERENCES

- Holzworth, G. C. 1972. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. Environmental Protection Agency, Raleigh, North Carolina.
- Lydolph, P. E. 1977. Climates of the Soviet Union. Vol. 7. Elsevier Scientific Publishing Company, New York, New York.
- USAFETAC. 1977. DATSAV Data Base Handbook. U.S. Air Force, Scott AFB, Illinois.

APPENDIX A

STATION LOCATIONS

APPENDIX A

STATION LOCATIONS

STATION	LATITUDE	LONGITUDE	STATION	LATITUDE	LONGITUDE	STATION	LATITUDE	LONGITUDE
=====	=====	=====	=====	=====	=====	=====	=====	=====
230220	69.77	-61.70	313000	53.75	-127.25	522030	42.82	-93.53
230780	69.32	-88.23	315100	50.27	-127.52	522670	41.98	-101.88
231460	68.47	-73.62	315380	50.07	-132.15	524180	40.13	-94.80
232050	67.63	-53.03	315610	50.60	-137.10	525330	39.77	-98.53
233300	66.53	-66.55	317070	47.73	-130.98	526810	38.62	-103.12
234180	65.12	-57.12	317350	48.52	-135.18	528890	36.05	-103.90
234720	65.78	-87.97	318730	45.93	-133.73	530680	43.65	-112.02
235520	64.92	-77.83	319090	45.05	-136.63	534630	40.82	-111.70
238040	61.67	-50.87	319600	43.12	-131.92	535130	40.77	-107.42
238840	61.60	-90.02	351080	51.25	-51.42	536140	38.48	-106.23
239210	60.68	-60.45	351210	51.75	-55.12	537720	37.78	-112.57
239330	60.97	-69.08	352290	50.28	-57.17	538450	36.60	-109.52
239550	60.43	-77.88	353610	50.17	-65.22	539150	35.55	-106.68
241250	60.50	-112.45	353940	49.80	-73.15	541020	43.95	-116.08
242660	67.55	-133.40	356710	47.80	-67.73	541350	43.60	-122.28
243430	66.77	-123.42	357460	46.78	-61.68	542180	42.27	-118.98
245070	64.28	-100.25	357960	46.90	-75.02	542920	42.88	-129.48
246410	63.77	-121.63	360030	52.28	-76.97	543370	41.13	-121.13
248170	61.27	-108.03	360960	51.67	-94.40	543420	41.82	-123.57
249080	60.33	-102.28	361770	50.35	-80.27	545110	39.80	-116.48
249440	60.40	-120.43	368590	44.17	-80.08			
249590	62.08	-129.77	380620	44.77	-65.55			
282250	58.02	-56.32	383410	42.85	-71.40			
282750	58.15	-68.20	383530	42.83	-74.60			
284400	56.80	-60.65	383920	41.83	-60.00			
286610	55.47	-65.42	384130	41.73	-64.63			
286980	54.93	-73.42	384570	41.27	-69.28			
287220	54.82	-56.17	385070	40.03	-53.00			
289000	53.25	-50.47	386060	40.55	-70.97			
289520	53.22	-63.63	386870	39.08	-63.62			
292310	58.30	-82.92	388360	38.58	-68.80			
292630	58.45	-92.17	388800	37.97	-58.35			
292820	58.38	-97.50	407450	36.27	-59.65			
295740	56.00	-92.90	442120	49.97	-92.10			
296120	55.37	-78.42	442310	49.63	-100.18			
296340	55.03	-82.92	442590	48.07	-114.52			
296980	54.88	-99.05	442770	46.40	-96.27			
298380	53.33	-83.72	442920	47.93	-107.08			
298650	53.75	-91.42	443540	44.90	-110.13			
300540	59.45	-112.60	443730	43.58	-104.43			
302300	57.77	-108.13	470410	39.93	-127.57			
303090	56.30	-101.72	470580	39.03	-125.80			
303720	56.92	-118.27	471380	36.03	-129.40			
305210	54.80	-105.18	476000	37.38	-136.92			
305540	54.47	-113.60	477440	35.43	-133.37			
306350	53.43	-109.00	505270	49.22	-119.77			
306730	53.73	-119.80	510760	47.73	-88.10			
306920	54.00	-123.98	514310	43.95	-81.35			
307100	52.37	-104.20	514630	43.90	-87.48			
307580	52.02	-113.35	516440	41.72	-82.97			
309350	50.37	-108.77	517090	39.47	-76.00			
309650	50.38	-116.53	517770	39.03	-88.18			
311680	56.45	-138.17	518280	37.13	-79.95			

APPENDIX B

MONTHLY MEAN MIXING HEIGHTS

APPENDIX B

MONTHLY MEAN MIXING HEIGHTS

Mean mixing heights for each station during the months used in the study are listed. The days in the month where mixing occurred are tabulated under the column heading "NM." The column "NS" tabulates those days in each month where data was available but conditions were not appropriate for calculating mixing depths. The third column "NO" contains the count of the days during the month when data were not available at the station.

1978 Mean Monthly Mixing Heights in Meters

STATION	JAN	MM	NS	NO	FEB	MM	NS	NO	MAR	MM	NS	NO	Q1	STATION	JAN	MM	NS	NO	FEB	MM	NS	NO	MAR	MM	NS	NO	Q1
230220	202.	16	4	11	197.	17	9	2	213.	22	4	5	204.	315610	399.	25	0	6	641.	20	0	8	1074.	24	0	7	705.
230780	175.	11	2	18	267.	6	2	20	442.	15	2	14	295.	317070	598.	21	0	10	1139.	17	0	11	997.	7	0	24	911.
231460	97.	18	6	7	108.	14	10	4	148.	10	1	20	117.	317350	481.	27	0	4	611.	28	0	0	671.	29	1	1	587.
232050	93.	10	14	7	144.	17	9	2	154.	17	1	13	130.	318730	546.	25	0	6	759.	23	0	5	1041.	23	0	8	782.
233300	112.	10	8	13	95.	11	5	12	214.	20	4	7	140.	319090	1028.	19	0	12	1452.	21	0	7	1426.	26	0	5	1302.
234180	156.	17	9	5	298.	20	6	2	428.	26	2	3	294.	319600	730.	26	0	5	1208.	27	0	1	1288.	30	0	1	1075.
234720	197.	20	7	4	389.	23	3	2	542.	21	2	8	376.	351080	168.	12	10	9	220.	23	4	1	308.	26	3	2	232.
235520	163.	20	7	4	205.	15	7	6	383.	17	3	11	250.	351210	158.	24	5	2	294.	20	3	5	378.	29	1	1	276.
238040	178.	15	11	5	261.	21	4	3	407.	21	7	3	282.	352290	135.	9	3	19	394.	15	0	13	350.	24	0	7	293.
238840	221.	20	5	6	464.	23	1	4	835.	27	1	3	506.	353610	233.	16	2	13	258.	18	1	9	252.	15	0	16	248.
239210	253.	24	3	4	428.	18	3	7	721.	21	2	8	467.	353940	387.	10	0	21	315.	22	4	2	438.	28	1	2	380.
239330	140.	10	6	15	185.	18	6	4	530.	18	2	11	285.	356710	139.	8	1	22	228.	15	0	13	314.	4	0	27	227.
239550	175.	19	9	3	412.	21	3	4	510.	28	3	0	366.	357460	220.	22	2	7	343.	26	0	2	663.	28	0	3	409.
241250	24.	9	13	9	68.	10	7	11	421.	25	2	4	171.	357960	146.	17	0	14	192.	21	1	6	480.	26	0	5	272.
242660	82.	13	3	15	202.	17	0	11	512.	1	0	30	265.	360030	242.	4	0	27	280.	21	2	5	555.	20	0	11	359.
243430	68.	13	12	6	175.	20	4	4	368.	15	1	15	203.	360960	226.	22	0	9	422.	13	0	15	985.	21	0	10	544.
245070	111.	16	6	9	433.	17	0	11	850.	12	0	19	465.	361770	213.	6	1	24	416.	22	1	5	567.	27	1	3	399.
246410	96.	20	2	9	266.	18	1	9	637.	21	1	9	333.	368590	472.	5	0	26	594.	21	0	7	1329.	25	0	6	798.
248170	255.	18	2	11	450.	18	2	8	980.	8	0	23	562.	380620	280.	20	2	9	320.	20	0	8	738.	28	0	3	446.
249080	263.	17	0	14	376.	8	1	19	1095.	10	0	21	578.	383410	649.	5	1	25	398.	20	4	4	788.	23	2	6	612.
249440	244.	17	1	13	450.	15	0	13	1038.	13	0	18	577.	383530	379.	15	2	14	474.	17	2	9	951.	25	0	6	601.
249590	192.	25	1	5	342.	22	0	6	519.	24	0	7	351.	383920	464.	20	1	10	494.	25	3	0	874.	30	0	1	611.
282250	193.	3	2	26	138.	5	1	22	333.	12	1	18	222.	384130	189.	2	0	29	140.	3	1	24	1063.	5	0	26	464.
282750	165.	18	3	10	319.	22	5	1	543.	25	1	5	342.	384570	522.	20	2	9	548.	21	2	5	1171.	24	3	4	747.
284400	256.	21	4	6	486.	25	0	3	677.	23	0	8	463.	385070	422.	22	4	5	575.	21	2	5	803.	25	1	5	600.
286610	138.	10	3	18	305.	14	0	14	413.	19	0	12	285.	386060	446.	10	0	21	318.	4	0	24	1226.	1	0	30	663.
286980	135.	22	8	1	249.	22	4	2	388.	28	1	2	257.	386870	596.	18	1	12	617.	17	2	9	1309.	16	0	15	841.
287220	253.	22	5	4	343.	22	3	3	461.	25	0	6	353.	388360	524.	20	4	7	716.	22	2	4	1481.	30	1	0	907.
289000	201.	20	10	1	415.	24	1	3	423.	29	1	1	346.	388800	377.	10	0	21	388.	11	6	11	1030.	18	1	12	599.
289520	152.	4	0	27	248.	26	1	1	320.	29	0	2	240.	407450	617.	7	1	23	957.	6	0	22	2130.	4	0	27	1235.
292310	363.	26	3	2	366.	23	2	3	669.	30	1	0	466.	442120	296.	22	0	9	383.	19	0	9	572.	16	0	15	417.
292630	407.	19	1	11	390.	16	2	10	823.	22	0	9	540.	442310	1279.	8	0	23	1219.	5	0	23	1632.	9	0	22	1383.
292820	409.	19	3	9	438.	22	0	6	1061.	19	1	11	636.	442590	512.	18	0	13	852.	14	0	14	1292.	18	0	13	885.
295740	603.	20	2	9	628.	18	0	10	1018.	14	0	17	750.	442770	682.	18	0	13	1088.	11	1	16	1411.	14	1	16	1061.
296120	205.	28	1	2	246.	21	1	6	486.	25	2	4	312.	442920	673.	18	0	13	816.	12	0	16	1944.	20	1	10	1144.
296340	249.	17	6	8	377.	27	1	0	552.	27	2	2	393.	443540	554.	16	0	15	852.	14	0	14	1405.	22	0	9	937.
296980	135.	6	0	25	744.	4	0	24	1270.	19	0	12	716.	443730	975.	5	0	26	1269.	7	0	21	1937.	8	0	23	1394.
298380	213.	11	6	14	444.	17	4	7	588.	20	1	10	415.	470410	1068.	11	1	19	1024.	3	0	25	1478.	16	0	15	1190.
298650	527.	16	0	15	592.	12	0	16	1150.	15	0	16	756.	470580	958.	24	0	7	962.	24	0	4	1324.	28	0	3	1081.
300540	275.	12	1	18	494.	16	0	12	1405.	6	0	25	725.	471380	931.	22	0	9	1192.	24	0	4	1043.	26	0	5	1055.
302380	301.	16	2	13	492.	13	1	14	1386.	10	0	21	726.	476000	1083.	28	3	0	925.	27	1	0	1415.	30	1	0	1141.
303090	243.	12	6	13	261.	2	0	26	925.	17	2	12	477.	477440	874.	26	3	2	823.	21	7	0	1102.	27	3	1	933.
303720	261.	19	1	11	815.	13	0	15	1281.	15	0	16	786.	505270	371.	28	0	3	528.	20	0	8	705.	25	1	5	535.
305210	398.	19	0	12	460.	9	0	19	1462.	11	0	20	773.	510760	280.	25	2	4	369.	25	1	2	541.	29	1	1	397.
305540	622.	13	0	18	1081.	13	1	14	1546.	21	0	10	1083.	514310	358.	15	0	16	475.	19	2	7	1086.	27	1	3	640.
306350	687.	24	2	5	746.	17	0	11	989.	20	0	11	807.	514630	204.	19	1	11	286.	19	1	8	842.	22	1	8	444.
306730	423.	5	0	26	1113.	6	0	22	1324.	14	0	17	954.	516440	353.	26	0	5	643.	23	0	5	1651.	30	0	1	882.
306920	475.	14	0	17	1003.	10	0	18	1116.	17	0	14	865.	517090	368.	23	1	7	514.	24	0	4	1223.	28	0	3	702.
307100	430.	18	0	13	571.	10	0	18	810.	16	1	14	604.	517770	535.	27	0	4	795.	22	0	6	1629.	23	0	8	986.
307580	590.	15	0	16	1140.	10	0	18	1896.	17	0	14	1209.	518280	346.	26	0	5	460.	22	0	6	1530.	27	0	4	779.
309350	529.	6	0	25	739.	11	0	17	1439.	13	1	17	903.	522030	458.	24	0	7	639.	25	0	3	1727.	28	0	3	942.
309650	293.	12	0	19	871.	6	0	22	1536.	17	0	14	900.	522670	792.	10	0	21	1054.	8	0	20	1664.	15	0	16	1170.
311680	372.	26	1	4	643.	27	0	1	930.	29	0	2	648.	524180	612.	20	0	11	715.	18	0	10	1737.	22	0	9	1021.

STATION	JAN	MM	NS	NO	FEB	MM	NS	NO	MAR	MM	NS	NO	Q1
*****	****	xx	xx	xx	****	xx	xx	xx	****	xx	xx	xx	*****
522670	792.	10	0	21	1054.	8	0	20	1664.	15	0	16	1170.
524180	612.	20	0	11	715.	18	0	10	1737.	22	0	9	1021.
525330	570.	11	0	20	1108.	18	0	10	1574.	21	0	10	1084.
526810	1030.	11	0	20	997.	13	1	14	1081.	19	0	12	1036.
528890	1095.	17	0	14	1436.	18	1	9	1471.	21	1	9	1334.
530680	329.	28	0	3	432.	19	0	9	1403.	29	0	2	721.
534630	977.	21	1	9	987.	17	1	10	1776.	25	0	6	1246.
535130	954.	27	0	4	1117.	23	0	5	1825.	28	0	3	1298.
536140	1025.	18	0	13	858.	21	0	7	1310.	28	0	3	1064.
537720	1380.	18	0	13	1103.	18	1	9	1710.	26	1	4	1397.
538450	1376.	11	0	20	1150.	18	0	10	1277.	18	1	12	1268.
539150	1165.	16	1	14	997.	19	0	9	1240.	26	1	4	1134.
541020	341.	27	1	3	437.	27	0	1	732.	28	1	2	503.
541350	829.	8	0	23	874.	16	0	12	1324.	5	0	26	1009.
542180	1176.	22	0	9	1130.	21	1	6	1823.	24	2	5	1376.
542920	992.	5	0	26	1488.	16	0	12	1364.	5	0	26	1281.
543370	997.	22	0	9	1044.	25	1	2	1206.	25	1	5	1082.
543420	644.	22	3	6	827.	25	1	2	1114.	29	1	1	862.
545110	1026.	23	1	7	1006.	22	1	5	1318.	27	2	2	1117.

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