DETERMINATION OF MIXING HEIGHT IN RIYADH, SAUDI ARABIA

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Abstract: Twice-daily mixing heights, one morning and one afternoon were calculated by using the computational program MIXHTS. MIXHTS utilizes the meteorological data collected from the King Khalid International Airport (KKIA) surface and upper air stations in Riyadh city during the year 2002. Climatic data shows that the city of Riyadh has in general, a hot and dry weather in summer and cold and dry in wintertime, whereas strong insolation is dominant all over the year. Monthly average afternoon mixing heights are ranged from 1629 m to 3971 m, whereas the morning mixing heights are ranged from as low as 935 m to 2920 m. Estimation of mixing heights obtained by this work were found in a good agreement with the daily maximum value obtained from the dry adiabatic temperature method.

Key words: *mixing height, Riyadh, Saudi Arabia, MIXHTS programme.*

1. INTRODUCTION

Mixing height is one of the most important parameters requested by different atmospheric pollution models as an input data for forecasting the air quality. When pollutants emitted into the atmospheric boundary layer (ABL), they dispersed horizontally and vertically because of the action of convection and mechanical turbulences until it becomes completely mixed. In spite of the fact that there is still no unique definition and no general accepted method for calculating the mixing height, however, the depth of the mixed layer is defined as the mixing height, which determines the volume available for the dispersion of pollutants. The greater the depth of the mixed layer the larger the available volume to dilute pollutant emissions.

2. PROCEDURES

Surface and upper air data collected via KKIA stations for the year 2002 were served as a basis for computing the twice-daily mixing heights. The morning and afternoon mixing heights were calculated using vertical temperature profiles known as upper air data and the surface temperature and pressure obtained from the hourly observations.

In this study, the mixing heights were calculated using the MIXHTS model. This model uses three input files. The first input file describes the names, locations, and surface characteristics of the upper air and surface meteorological observation sites. The second contains the hourly values of observed surface meteorological variables. And the third file contains the twice-daily upper air observation data (otherwise known as radiosondes). The output contains the twice-daily mixing height, one morning and the second for the afternoon time. The domain of the study was the extended area of Riyadh meteorological stations in KKIA for the whole year. The model's results were compared with values obtained from the dry adiabatic temperature.

3. RESULTS AND DISCUSSION

The meteorological data used in this study were taken for the period of January to December 2002 in the area of KKIA in the city of Riyadh. This site is located at 24.93 N and 46.72 E with a height of 612 m above the sea level. It is at a distance of about 45 km from the city center, but it is still a representative of an urban environment due to the large extension of the urbanized area of Riyadh city. The available data are profiles of wind speed and direction, and temperature profiles. Besides, the KKIA stations supplied synoptic surface meteorological data (air temperature, wind speed, wind direction, cloud cover, etc.).

Most values of wind speed, observed during the selected period, are lower than 4 ms^{-1}, with the exception of 20% cases where wind speed ranged from 4.5 to 13 ms^{-1}; the sky was generally clear, unless few cases for which cloud cover ranging between 5/8 and 8/8 was observed during winter season.

Table 1: Monthly Mixing Height for Riyadh City, Jan. to Dec. 2002.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM	MAX	2515	2811	3005	3601	4602	3858	4075	3867	4391	3273	2768	2291
	MIN	1326	876	383	1965	3327	3369	3637	3461	2455	2745	1801	1079
	AVE	1864	1796	2191	2855	3939	3627	3883	3670	3971	3080	2359	1629
AM	MAX	2184	1605	2055	2345	3534	2806	2952	2932	3361	2322	2023	1612
	MIN	884	367	596	1219	2108	2298	2487	2445	1743	1743	967	407
	AVE	1386	935	1430	1821	2895	2559	2718	2651	2920	1992	1409	1144

As shown in Table 1 and Figure 1, mixing height values were calculated for the period of January to December 2002. These include the average values of mixing height at 12:00 and 00:00 (UTC). The 00:00 mixing height values calculated are partially in agreement with those obtained from the dry adiabatic method. The better agreement is found for the period from January to March with a mixing height ranged from 912 m to 1357 m by less than 2% difference from the dry adiabatic lapse rate method. The afternoon mixing height values obtained show less consistency with those obtained from the dry adiabatic method for the entire period (Figs. 2 and 3).

Figure 4 shows the calculated mixing height (MH) in Riyadh city for every month from January to December 2002 and in the morning (AM) and in the afternoon (PM), respectively. As shown in the figure, there are very marked differences between the AM and PM mixing height values especially in summer months. On the other hand, during the winter months (January and December), the mixing heights are also quite uniform, but show smaller differences. These observations are related to the sever weather condition, the drastic changes of the surface roughness, and the high level of solar radiation that prevail in Riyadh city. Also, Figure 4 shows that mixing height changes uniformly during the periods of early morning to noon and from early evening to midnight.

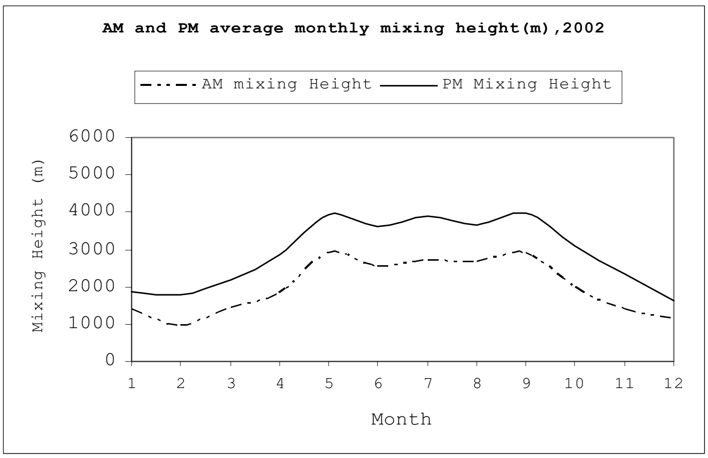

Figure 1. AM and PM average monthly Mixing Heights in Riyadh City, 2002.

4. CONCLUSION

The aim of this study was to calculate mixing height in the city of Riyadh for the year 2002. This approach is adopted using the meteorological conditions observed at the standard height at the surface and upper air stations near to KKIA. The assumption is that these meteorological measurements are representative of the urban area. In some parts of the city of Riyadh associated with complex topography some form of 'downscaling' should be used to define a more realistic wind field, thus calculating reasonable mixing height values.

Our conclusion is that, the Mixing Height in Riyadh city is ranged from 935 m to 2920 m for the early morning period, and from 1629 m to 3971 m in the afternoon time. Besides, the MXHTS model shows a relatively good performance for calculating morning mixing heights in comparison with the Dry Adiabatic Lapse Rate but with some discrepancies for the afternoon mixing height calculations.

For future studies, mixing height derived here should be compared with values derived by using different techniques, e.g. remote sounding systems (lidars, sodars, RASS, wind profiling radars) taking into account the impact of terrain irregularities, changes in the surface roughness and surface heat fluxes.

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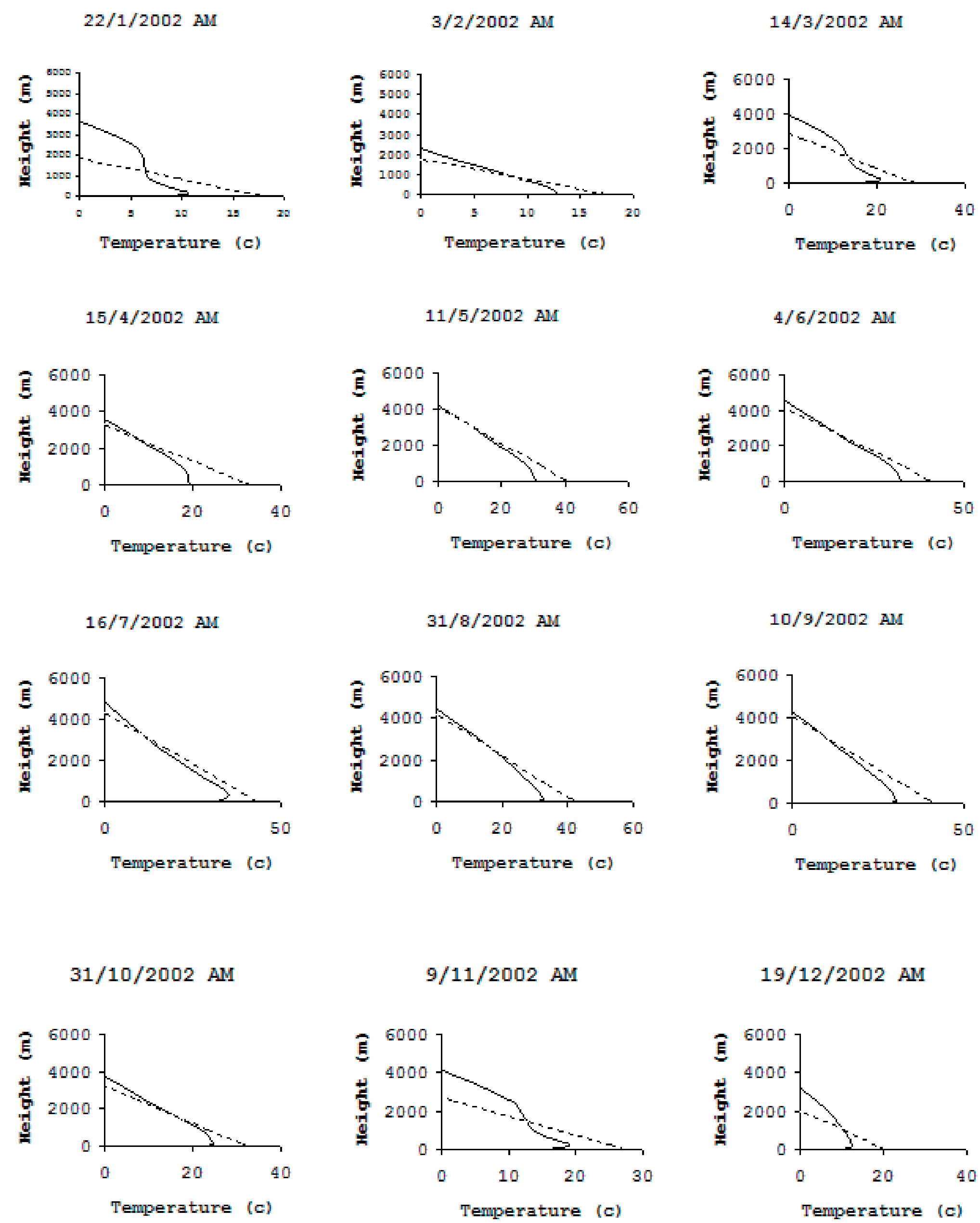

Figure 2. Samples of morning Mixing Heights estimation with the Dry Adiabatic Lapse Rate (--- Adiabatic, —Observed)

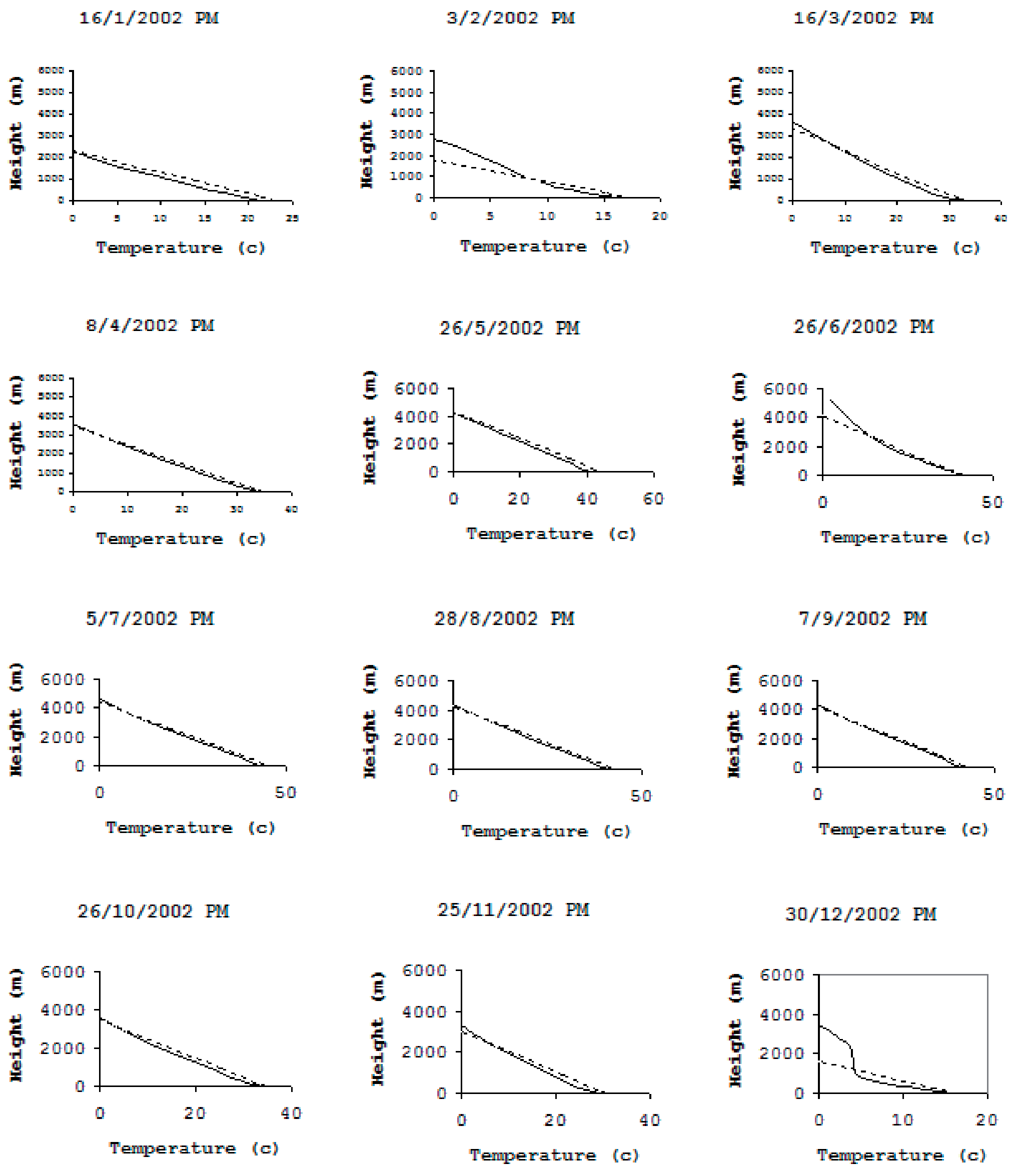

Figure 3. Samples of afternoon Mixing Heights estimation with the Dry Adiabatic Lapse Rate (--- Adiabatic, —Observed)

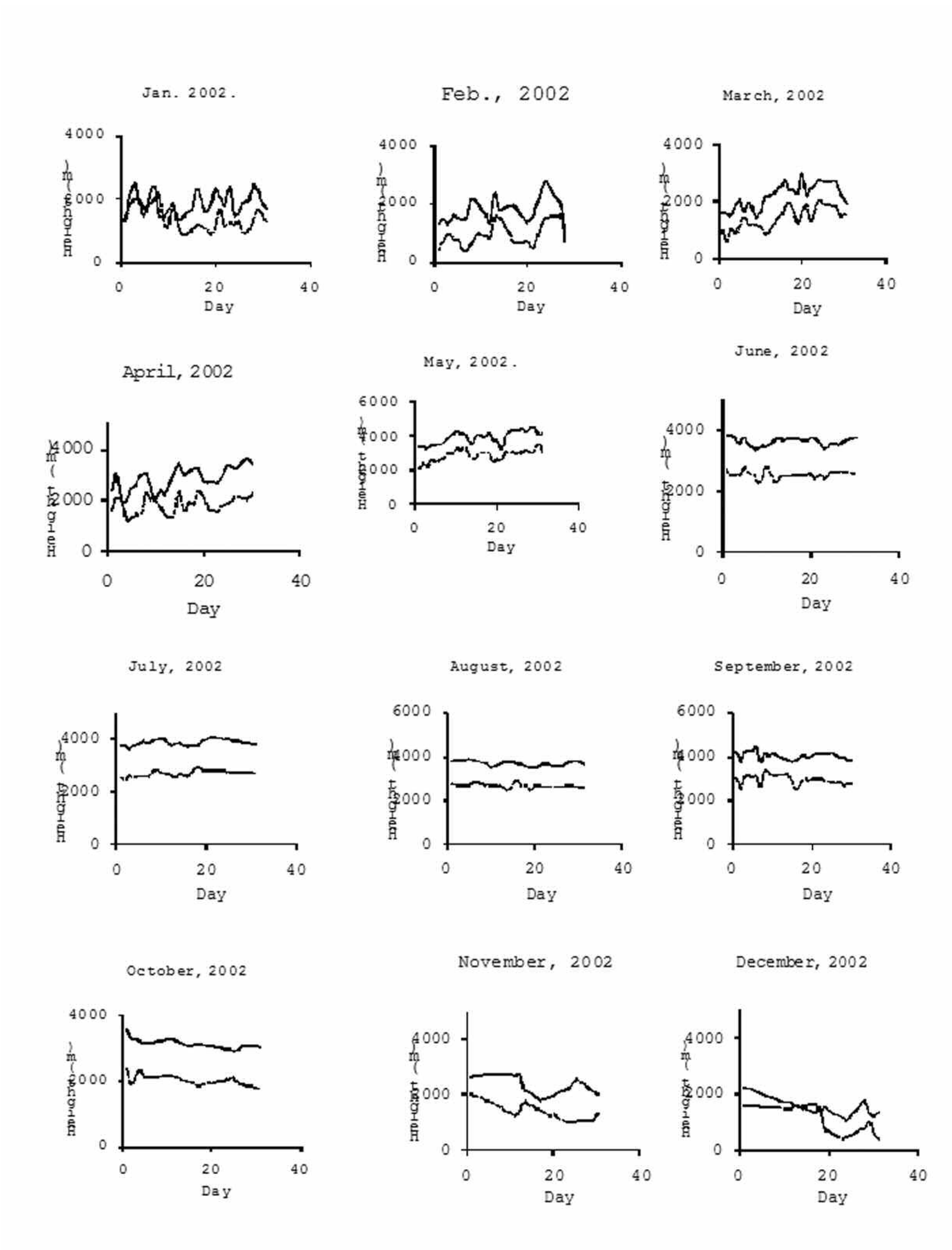

Figure 4. Mixing Heights in Riyadh City, 2002.