Fine Forecast of Road Surface Temperature in Beijing City

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ABSTRACT

A road surface temperature fine forecast model is built and tested using road stations observed data in Beijing city. The model is developed based on the Common Land Model (CoLM) and Beijing Rapid Update Cycle Model (BJ-RUC). The observed data is measured by ROSA, Vaisala Company of Finland. The temporal resolution of the model is 1h and forecast time span is 24 h and update frequency is 3h. This model considers the physical characteristics of road surface sufficiently such as the imperviousness, relatively low albedo, low heat capacity, high heat conductivity and nearly no evaporation etc. The model uses the variational data assimilation system to assimilate the observational road surface data and the influences of the anthropogenic heat and urban boundary layer are also considered. The verification results indicate that the fine forecast model can simulate the diurnal variation and the maximum value of road temperature very well comparative to the observation. Using the numerical forecast model can forecast road temperature more accurate especially when the road temperature is extremely high; the error would be reduced about 70-80% comparative to only using the BJ-RUC model. The accurate prediction of the road surface temperature can not only greatly reduce the occurrence probability of road traffic accident such as the tire burst effectively, but also can make the road snow and icing forecast more accurately.

Keywords: fine forecast model, road surface temperature, variational data assimilation, anthropogenic heat, urban boundary layer

1. Introduction

Road surface temperature is a key parameter in road weather forecast, for it is not only a crucial parameter for tire burst in summer, but have a decisive role in road snow melt and freezing in winter. But in China at present [5], no special model or method is used in road surface temperature prediction, and the meso-scale meteorological model such as the Beijing Rapid Update Cycle Model (BJ-RUC) [2] has relatively low prediction accuracy. Now, along with the building of road meteorology monitor stations in Beijing city which using the apparatus from Rosa Vaisala company in Finland, the fine forecast and examination of road surface temperature becomes available. In this paper, a road surface temperature fine forecast model is built and tested using road stations observed data in Beijing city. The model is developed based on the Common Land Model (CoLM) [1] and Beijing Rapid Update Cycle Model (BJ-RUC). This model considers the physical characteristics of road surface sufficiently such as the imperviousness, relatively low albedo, low heat capacity, high heat conductivity and nearly no evaporation etc. The model uses the variational data assimilation system to assimilate the observational road surface data and the influences of the anthropogenic heat and urban boundary layer are also considered.

2. Data and Methodology

The road surface temperature fine forecast model which this paper developed is based on the Common Land Model (CoLM) and the Beijing Rapid Update Cycle Model (BJ-RUC). The temporal resolution of the model is 1h and forecast time span is 24 h and update frequency is 3h. CoLM is a global land surface model and the characteristics of road surface are not amply considered. The fine forecast model considers the physical characteristics of road surface sufficiently such as the imperviousness, relatively low albedo, low heat capacity, high heat conductivity and nearly no evaporation etc, and the surface energy balance model and water balance model are also modified according to these characteristics.

The influences of the anthropogenic heat [4] and urban boundary layer [6] on the road surface temperature are also considered in the fine forecast model. Figure1 is the anthropogenic heat variation diagram in summer Beijing during a whole day. The anthropogenic heat data at 0, 4, 8, 12 and 18 o'clock is defined at first using investigational and statistical method, and then at other times, the data is interpolated linearly.

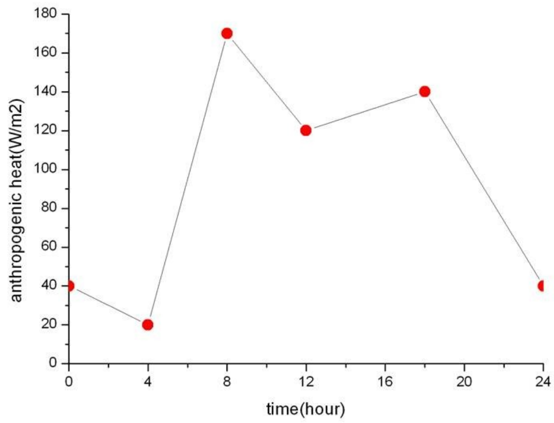


Figure1 The anthropogenic heat variation diagram in summer Beijing during a whole day

The observation data from the 325m meteorological tower of the Institute of Atmospheric Physics is used to fit the profile of the atmosphere in the boundary layer. The wind profile and temperature profile are represented as follows:

$$\frac{\sigma_u}{u_*} = 1.73\left(1 - 1.0\frac{z'}{L}\right)^{\frac{1}{3}} \qquad (1)$$

$$\frac{\sigma_T}{T_*} = 0.88\left(-\frac{z'}{L}\right)^{-\frac{1}{3}} \qquad (2)$$

In order to acquire an accurate initial field, the model uses a variational data assimilation system [3] to assimilate the observational road surface data. The observed data is measured by ROSA, Vaisala Company of Finland. The variational data assimilation method uses the surface energy balance model in the fine forecast model as the adjoint physical constraint, and the tuned factor in the assimilation system is the road surface heat transfer coefficient. Figure 2 and 3 are ROSA monitoring network in Beijing city and ROSA Vaisala road surface observation instrument respectively.

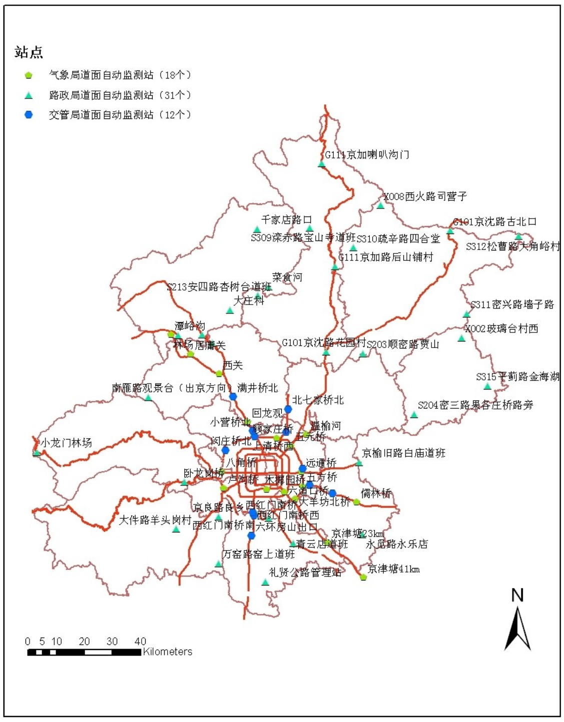


Figure2 ROSA monitoring network in Beijing city

Figure3 ROSA Vaisala road surface observation instrument

Figure 4 depicts the schematic of the road surface fine forecast model. Table 1 summarizes the main parameters which the fine forecast model considered that control road surface temperature.

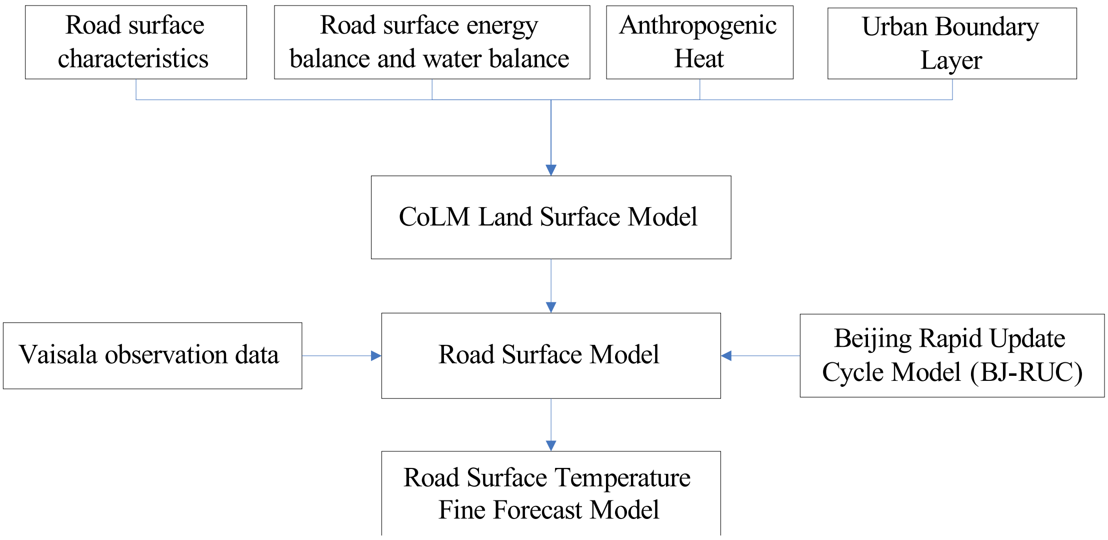


Figure 4 Schematic of the road surface fine forecast model

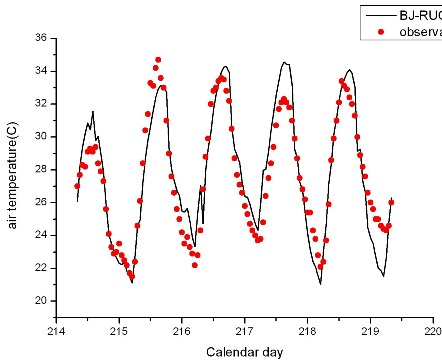
Table 1 The main parameters which the fine forecast model considered that control road surface temperature

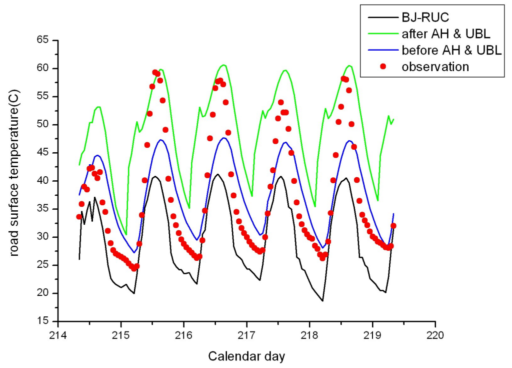
Time-invariant parameter	Urban Boundary Layer	Energy balance equation	Water balance equation
Albedo	Roughness length	Anthropogenic heat	Water conductivity
Heat conductivity	Wind profile	Latent heat flux	Evaporation
Heat capacity	Temperature profile	Initial surface temperature	Infiltration
	Water vapor profile		

3. Result and Discussion

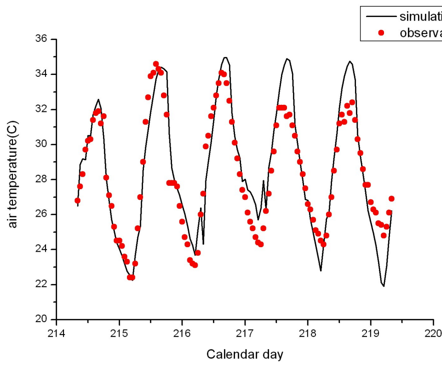
Five sites are chosen to accomplish the road surface temperature forecasting. Each of these five sites is located in one main express way which linked Beijing to other cities of China. These five sites are Jingjintang41, Lugouqiao, Xiguan, Xihongmennan, and Yuantong respectively; and they are located in Jinjingtang, Jingshi, Badaling, Jingkai, and Jingtong express way respectively. The forecast time span is from 1st to 6th August, 2008. The meteorological forcing data is from BJ-RUC, the observed air temperature near the road surface and the road surface temperature from Vaisala instrument is used for the comparison.

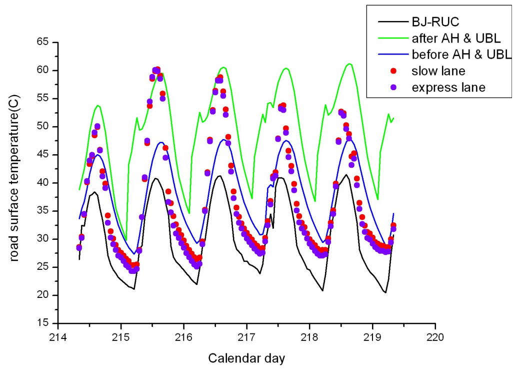
Two road surface model runs were carried out for each of the 5 sites: one with and another without considering the anthropogenic heat (AH) and the urban boundary layer (UBL). Time series of the resulting road surface temperature (RST) estimate from these runs for each of the 5 sites are plotted in Fig. 5b. The red dots in Fig. 5b are RST measurements conducted at different times, while the black lines in Fig. 5b are RST simulations of BJ-RUC. Time series of the resulting air temperature estimate from BJ-RUC compared with the observation for each of the 5 sites are plotted in Fig. 5a. From figure 5 (1)-(2), and (4)-(5), we can see that in the daytime, especially from 10am to 3pm, when the road traffic accident most frequently happened because of the extremely high RST, in day 215 and 216, when the air temperature prediction is fairly well, after considering the AH and UBL, the RST could be simulated perfectively, and the error is less than 5K, while without considering the AH and UBL, the error could be about 10K, and the error of BJ-RUC could be 15-20K. While in day 217 and 218, when the air temperature is overestimated, after considering the AH and UBL, the RST could be overestimated too. From figure 5 (3), we can see that in the daytime, in day 217 and 218, when the air temperature prediction is fairly well, after considering the AH and UBL, the RST could be overestimated. While in day 215 and 216, when the air temperature is underestimated, after considering the AH and UBL, the RST could be estimated perfectly. We also can see that in all the 5 sites, after considering the AH and UBL, the RST prediction at night is overestimated, while before considering the AH and UBL, the RST prediction at night is simulated perfectly well, this is because in all the 5 sites, the AH is overestimated at night. Figure 5 (6) is the mean value of the RST and air temperature of all the 5 sites.



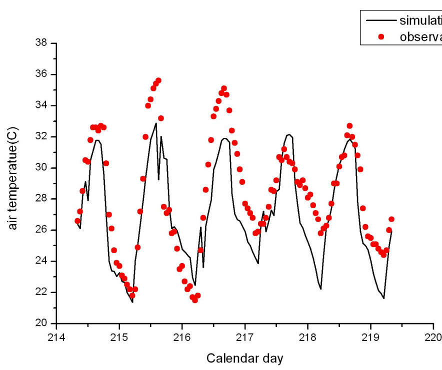


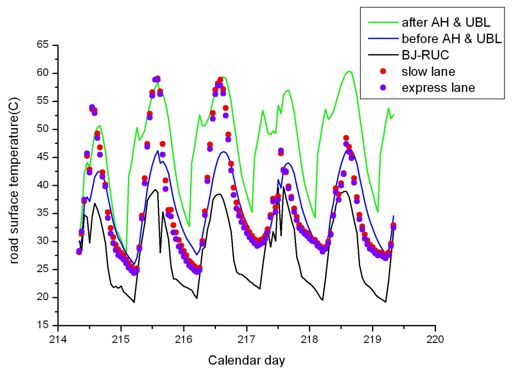
(a1) (b1)



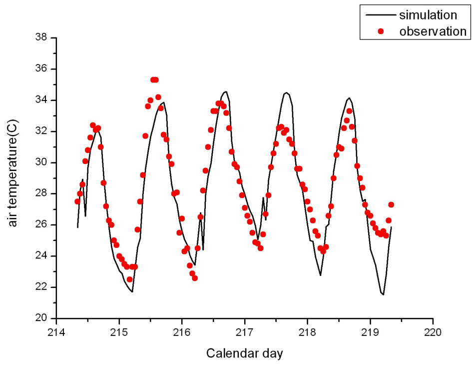


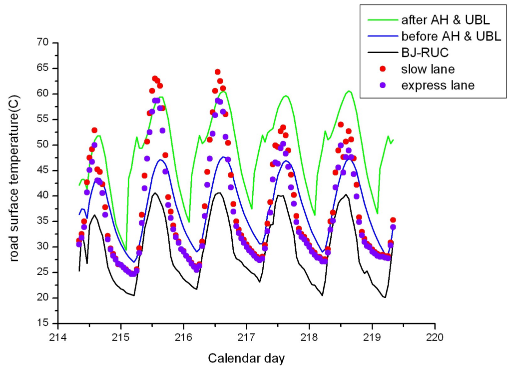
(a2) (b2)



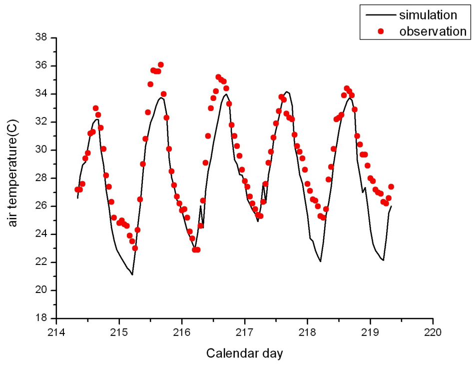


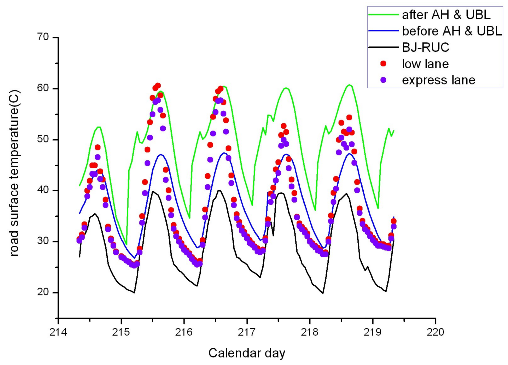
(a3) (b3)



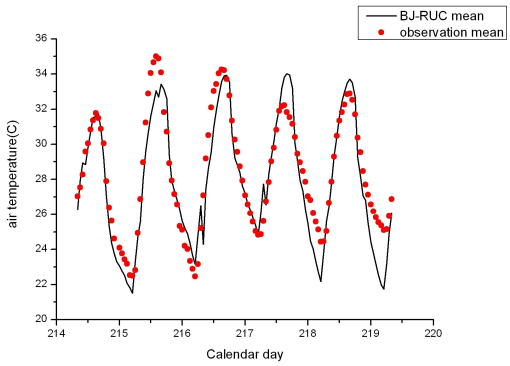


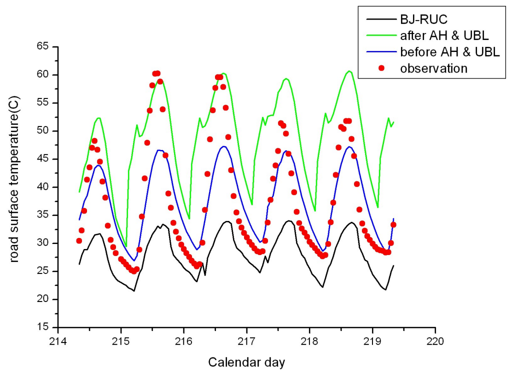
(a4) (b4)





(a5) (b5)





(a6) (b6)

Figure 5 Comparison of the road surface temperature (RST) results between the observed, BJ-RUC simulated and the two road surface model runs for each of the 5 sites: one with and another without considering the anthropogenic heat (AH) and the urban boundary layer (UBL) (Figure 5(b)). Comparison of the time series of the resulting air temperature estimate from BJ-RUC and measurements (Figure 5(a)). (1) Jingjintang41, (2) Lugouqiao, (3) Xiguan, (4) Xihongmennan, (5) Yuantong. (6) Mean value of all the 5 sites

4. Conclusions and future study

From the study of this paper, we can draw several conclusions:

1) The road surface model could forecast the RST very well compared with the BJ-RUC.
2) In the daytime, after considering the AH and UBL, the RST is forecast quite well, while at

night, before considering the AH and UBL, the RST is forecast quite well.

3) The accuracy of the RST forecast is also depending on the forecast of the air temperature too.

In the near future, in order to forecast the RST more accurately in the whole year, the AH and UBL of the model would be reconsidered and the road surface parameters such as the albedo, heat capacity and heat conductivity etc. would be adjusted too. The other important parameters in road meteorology such as the snow and ice depth and melting would be forecasted in the future too.

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