Study of Road Climate in Cities

Jörgen Bogren and Torbjörn Gustavsson*
Road Climate Centre
Department of Earth Sciences
Box 460, S-405 30 Göteborg University, Göteborg Sweden

BACKGROUND

Road weather information systems are well established as useful tools when performing winter road maintenance activities. Adverse weather conditions during the winter season might give rise to severe road conditions and risk of slipperiness. Geographical and topographical features influences to a great deal temporal and spatial variations in risk of slipperiness along roads. When designing and developing road weather information systems topoclimatological knowledge is essential. Knowledge about local and microclimatological influences on the risk of slipperiness has traditionally been used within models calculating prognoses of temperature development and spatial patterns in rural areas. Lately there has been an increased interest in the possibilities to include the benefits of road weather information systems to be valid for city areas as well.

During the winter season 99/00 a pilot project "road climate in urban areas" will be carried out at different sites in Sweden. It is important to perform a comprehensive analyse of the local and microclimate environments to be able to include the thermal effects of suburban and urban environments into different kinds of road weather related models. The project will use mobile and fixed measurements for recording and analyse of the temperature variations during different weather conditions. One aim of the project is to incorporate the complexity of urban structure and urban heat island effects into the present road surface temperature forecast models. The benefit of this will be to increase the possibilities to issue pre warnings and effective winter road maintenance operations in urban areas.

From earlier work it can be seen that within the study area the city of Stockholm produces an urban heat island which has a mean intensity of 1,4°C for the air temperature, during the winter period November – March, (Bogren et al., 1999). This indicates that there might be a difference in potential for road icing compared to rural conditions. It is of great interest to assess the urban-rural and intra-urban temperature variations that can be significant for the formation of slipperiness on roads and which can be included in model work. Within the pilot project "road climate in urban areas" these urban heat island intensity effects will be analysed in respect of cause for slipperiness.

A focus of the present case study is on the variations in air and road surface temperature that can occur within suburban and urban areas contrasting the rural conditions during a clear night.

DATA

Following study is focused on the Stockholm area in the eastern part of Sweden, Lat. N59°30 and Long E18°00. The study area covers approximately 40*40km and includes urban, suburban and rural environments. Within this area 35 field stations from the Road Weather Information System (RWIS) has been used. Figure 1 shows the City of Stockholm with the field stations in the urban, suburban areas and part of the rural surroundings included in the study. The field stations within the RWIS are equipped with sensors for detection of air temperature and humidity at 2m, road surface temperature, wind speed and wind direction and also an optic sensor for detection of precipitation. The field stations are sited at different topographical locations along the road net work, Table 1.

For the case study which covers the period 16-17 December 1996 the synoptic conditions were characterised by clear sky conditions, Table 2. The weather observations are from the SMHI-stations Arlanda (37km N of City centre), Bromma (8km W of City centre) and City centre.

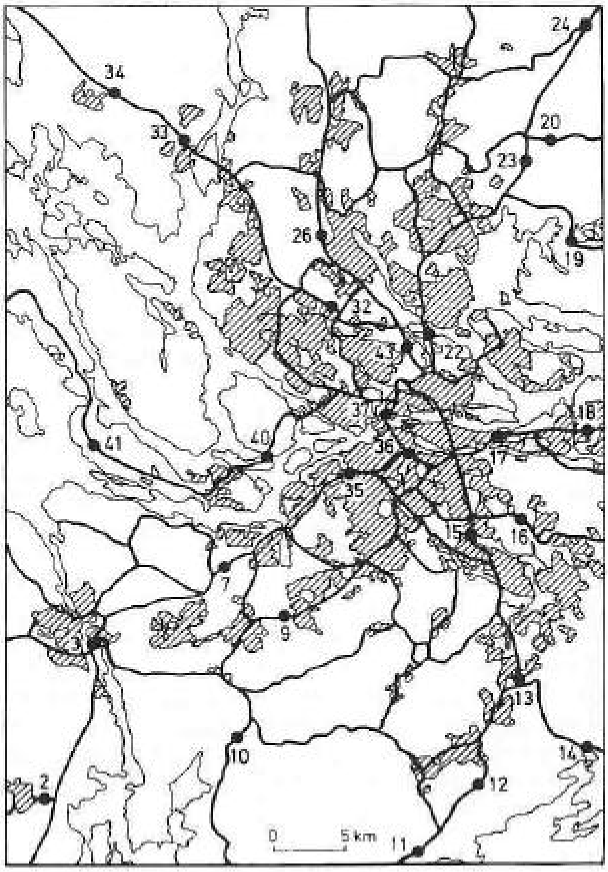

Figure 1. The Stockholm area with the RWIS field stations

RESULTS AND DISCUSSION

Urban areas have the most pronounced effect on the road surface temperature during clear weather conditions (Eliasson, 1993). The road surface minimum temperature in the urban area is successively influenced by the urban heat island, figure 2 illustrates the urban heat island effect on the temperature at an urban (stn 37), a suburban (stn 13) and a rural (stn 31) site following a cross section trough the city of Stockholm and vicinity. The minimum road surface temperature varies from –8,5°C, -10°C and –11,6°C whereas the air temperature varies from –5,7°C, -8,8°C and -12,7°C . This shows that there is a potential effect of an urban heat island to be in the magnitude of 3°C for the road surface temperature and 7- 8°C for the air temperature, see also table 2. This difference in magnitude of the heat island intensity between surface temperature (Tsur) and air temperature (Tair) indicates that there can be a variation in potential for risk of slippery road conditions depending on the intensity of the urban heat island. A criteria for risk of slippery road conditions is when Tsur < Tair and Tsur ≤ 0°C. Using station 17 in the city centre as a reference, the temperature differences to the other stations are calculated and taken as a measure of the urban heat intensity. These values are compared to the temperature difference between surface and air, T(sur-air), figure 3.

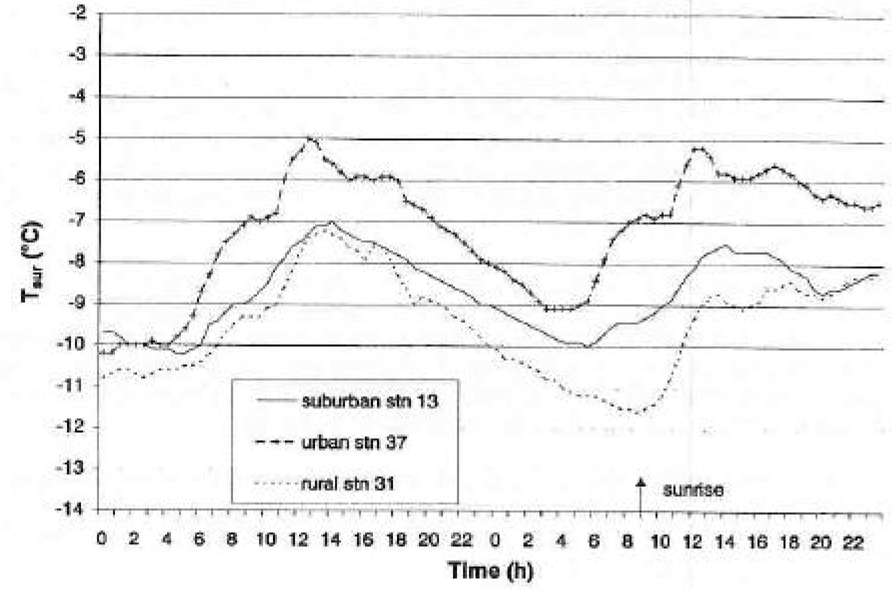

Figure 2a. Road surface temperature at a suburban site (stn 13), an urban site (stn 37) and a rural site (stn 31), during the 16 – 17 December 1996.

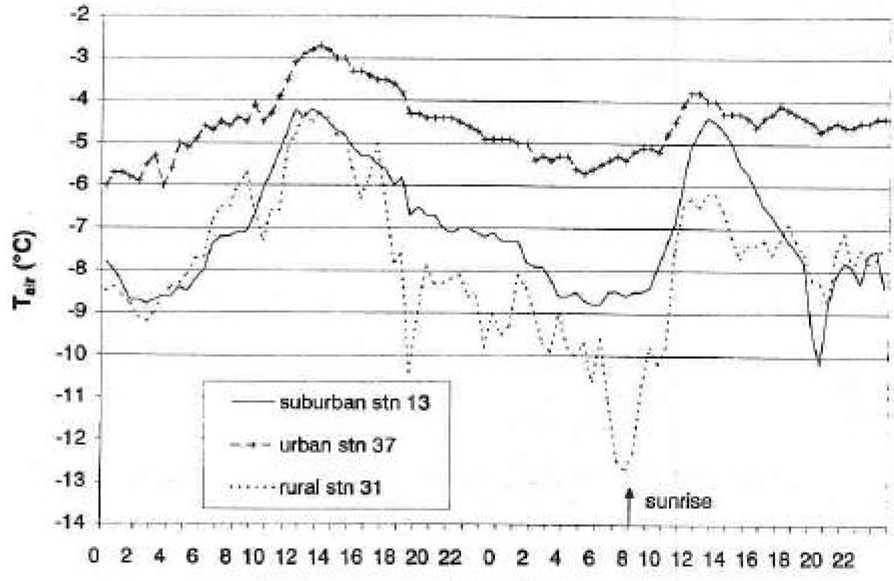

Figure 2b. Air temperature at a suburban site (stn 13), an urban site (stn 37) and a rural site (stn 31), during the 16 – 17 December 1996.

The scatter plot indicates that there is a relation between the intensity of the air temperature urban heat island (TairUHI) and low values of T(sur-air). As a result of urban conditions the air temperature tends to be warmer than the road surface hence giving rise to risk for slipperiness. During the case study all urban locations and almost all suburban locations have values where the road surface temperature is lower than the air temperature. For the rural locations the differences are more diversified where 8 locations have T(sur-air)>0°C. At the rural locations the potential for pooling of cold air can result in that the air temperatures are lower than the surface temperatures. The intensity of the surface temperature urban heat island on the other hand do not tend to influence the magnitude of the T(sur-air). The surface temperature difference between urban, suburban and rural locations are relatively small. From the cluster in the scatter plot of the surface urban heat intensity (TsurUHI) and T(sur-air) a conclusion is that the local site specific features effecting the radiation is most important.

The results of this case study indicates that the effect of the urban heat island must be taken into consideration when modelling the risk of slipperiness along roads. The air temperature urban heat island can have the potential for increased risk of slipperiness. Further studies will be directed towards the effect of different weather conditions on the urban heat island intensity and the influence on the potential for slipperiness on roads. There will also be an analyse of the site specific conditions where exposure for wind, radiation and pooling of cold air are important factors to consider.

Table 1. Characteristics of the RWIS field stations in the Stockholm area and minimum road surface temperatures (minTsur) and minimum air temperatures (minTair) during the 16-17 December 1996.

Stn no	Characteristics	minTsur (°C)	minTair (°C)	Stn no	Characteristics	minTsur (°C)	minTair (°C)
2	Rural, screened	-9,2	-12,4	24	Rural, small valley	-11,3	-13,7
3	Suburban, bridge	-11	-8	26	Urban, city buildings	-8,5	-7,7
7	Suburban, partly screened	-8,4	-9,6	27	Rural, open arable land	-11,2	-12,3
9	Suburban, screened	-9,7	-10	29	Rural, open arable land	-11,7	-13,5
10	Rural, high elevated area, forest	-10,2	-11,3	30	Rural, bridge	-10,9	-7,1
11	Rural, open flat valley	-10,8	-12,2	31	Rural, open	-11,6	-12,7
12	Rural, open neutral	-10,7	-9,1	32	Urban, small houses and field	-8,8	-6,2
13	Suburban, forest	-10	-8,8	33	Suburban, bridge	-10,5	-8,1
14	Rural, screening forest	-8,1	-10,6	34	Rural, elevated area	-11,9	-10,1
15	Urban, open	-9	-6,7	35	Urban, city buildings	-8,3	-6,4
16	Suburban, bridge	-9,7	-7,1	36	Urban, city buildings	-9,3	-5,8
17	Urban, open	-8,2	-5,6	37	Urban, city buildings	-9,1	-5,7
18	Suburban, bridge	-9,9	-5,6	38	Rural, screened forest	-10,4	-9,2
19	Rural, partly screened	-9,3	-7,9	39	Rural, open	-11	-9,2
20	Rural, high elevated area	-10,7	-8,1	40	Rural, partly open/forest	-9,2	-7,3
21	Rural, close to forest	-10,3	-7,6	41	Rural, forest	-8,8	-6,6
22	Urban, bridge	-8,9	-6,5	43	Urban, city buildings	-8,7	-7,2
23	Rural, bridge	-10,1	-9,4				

Table 2. Synoptic weather conditions in the study area. Air temperature and cloudiness at the synoptic stations Arlanda (Arl) a rural location, Bromma (Bro) suburban and Stockholm City (City) an urban location.

Date	Time (h)	Air temperature (°C)					Cloudiness (Octas)		
		Arl	Bro	City	ΔT (Bro-Arl)	ΔT (City-Arl)	Arl	Bro	City
Dec 16	01	-9,3	-6,8		2,5		1		
	07	-7,6	-5,0	-5,0	2,6	2,6	1	0	0
	13	-5,3	-3,6	-3,4	1,7	1,9	1	1	1
	19	-7,9	-6,0	-4,7	1,9	3,2	1	1	0
Dec 17	01	-10,1	-6,8		3,3		0		
	07	-10,9	-5,0	-5,8	5,9	5,1	0	1	0
	13	-6,7	-3,6	-4,6	3,1	2,1	2	5	1
	19	-9,4	-6,0	-4,8	3,4	4,6	7	5	6

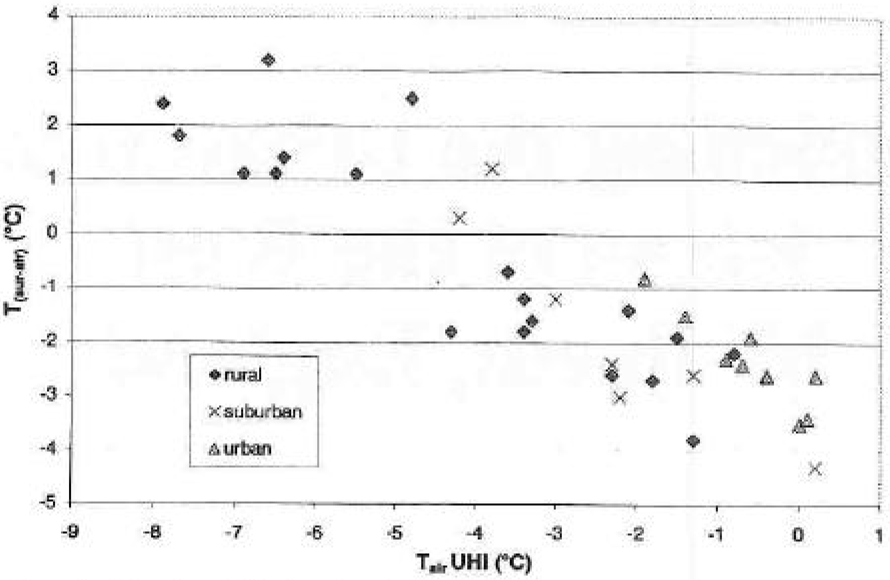

Figure 3a. The effect of the air urban heat island on the difference between air and surface temperature at the different sites.

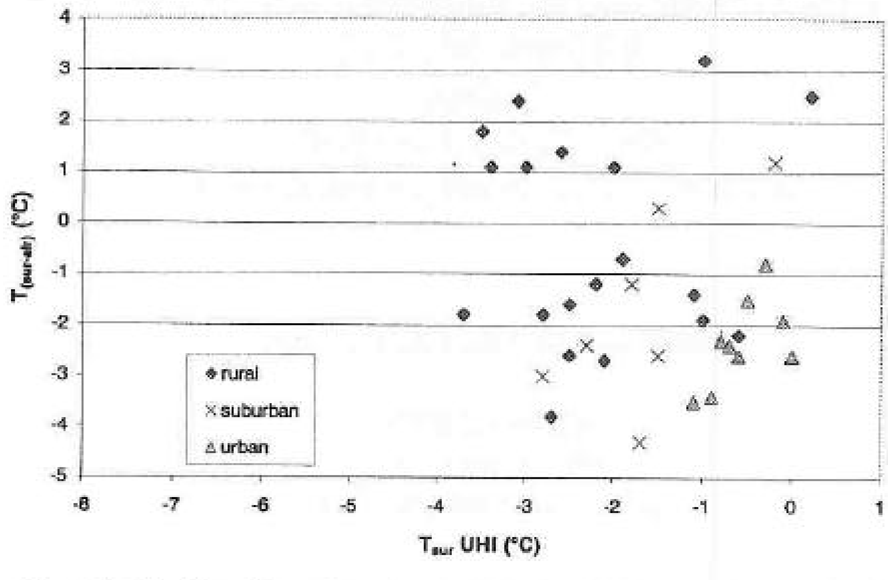

Figure 3b. The effect of the surface urban heat island on the difference between air and surface temperature at the different sites.

REFERENCES

Bogren, J., Gustavsson, T., and Loman G. 1999. Klimatologi – Meteorologi. Studentlitteratur, 326p (in Swedish).

Eliasson, I. 1993. Urban Climate Related to Street Geometry. GUNI report 33. Ph.D. Thesis, University of Gothenburg.

Corresponding author adress: Jörgen Bogren, University of Göteborg, Laboratory of Climatology at Physical Geography, Department of Earth Sciences, Göteborg, Sweden. Box 460, SE – 405 30. Telephone +46–31-773 1964, e-mail jorgen@gvc.gu.se