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Title page: Heathrow Airport photographed looking toward the north-west across runway 09L/27R with and aircraft having taken off from runway 27R and the British Airways headquarters building in the background.

ABOUT THE AUTHOR

Michael Pierre de Villiers was born in Durban, South Africa. He was trained to World Meteorological Organization class one meteorologist and multi-discipline weather forecaster in the South African Weather Service where he reached the rank of Director. He served on a weather ship in the South Atlantic. He served on World Meteorological Organization expert teams and was World Meteorological Organization rapporteur for the Africa region. He was also a commercial pilot and flying instructor. More recently he was a weather forecaster in the United Arab Emirates, then in England. Now retired.

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INTRODUCTION

Forecasting the runway surface temperature (RST) at airports is crucial to the efficient and safe operation of an airport in cold climes in winter. The closure of an airport due to settling snow and ice on runways and taxiways causes annoying delays for passengers and financial costs to the airport operator and airlines using the airport. Prior warning of these events allows airport operators to take preventative measures.

For a trial period during the winter of 2008 to 2009 the British Airports Authority (Heathrow) placed a Campbell Scientific mobile weather station on an unused part of a taxiway at Heathrow airport (Figure 1) in order to fine tune and verify the Weather Services International (WSI) neXt generation Road Weather Information System (XRWIS, Thornes et al 2005), which was used to provide hourly forecast RST thermal maps and hourly forecast RST on the WSI Heathrow Hubcast web site. An example of a runway temperature map is shown in an appendix.

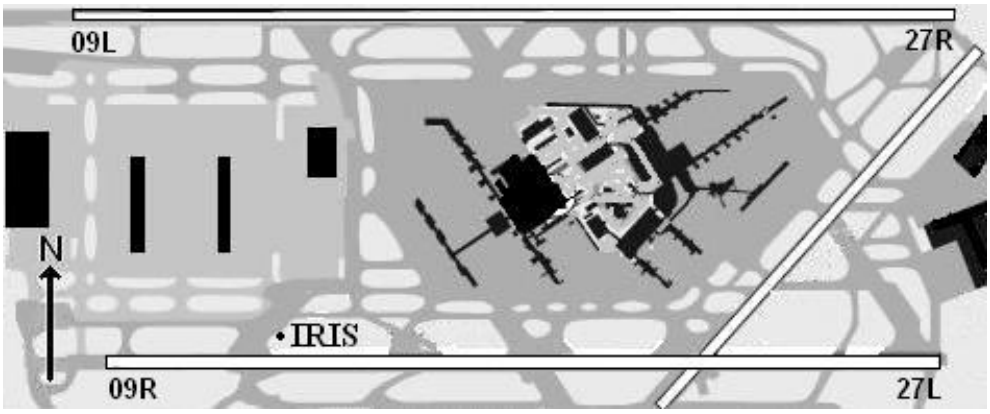

Figure 1. The location of the Campbell Scientific mobile weather station in relation to runway 09R.

This article presents RST graphs, from this trial period (for six nights, prior to, during and after a snow the snow event of the 1 to 3 February 2009) and discusses the effect of the changing weather on the RST.

METHOD

A Campbell Scientific Infra-red Road Information System (IRIS) weather station automatically registered 10 minute intervals of RST, air temperature and dew-point temperature 1.5m above the taxiway while receiving equipment calculated the humidity. An nfra-red sensor was positioned pointing downward to the concrete surface. This surface was made of large stone chips with an albedo similar to the nearby 09R runway. The data were presented on a Campbell Scientific web site, as well as on the WSI Heathrow Hubcast website and archived by WSI. These observations were then compared with the Heathrow half-hourly Meteorological Aviation Report (METAR) observations (ICAO 2005 and WMO 1995) and the United

Kingdom Meteorological Office surface analysis charts (Eden 2009a and b) for analysis and discussion.

Factors that influence the RST can be divided into meteorological and non-meteorological. Meteorological factors are cloud cover, air temperature, wind speed, precipitation and humidity. Non-meteorological factors are latitude, altitude, geographical position, runway construction and aircraft traffic frequency (Karlsson 2001, Bogren 2001 and Chapman et al 2001). As the study is of a single fixed RST observation point at one airport isolated from nearby traffic and not being compared with other sites, non-meteorological aspects were ignored.

GENERAL REVIEW

Sky view and cloud cover (within 1980 m of the runway surface) are crucial with respect to RST. Postgard and Nunez (2000, from Chapman et al 2001) found that the sky view accounted for up to 61% of the variation in RST. Due to its position on flat and open terrain the IRIS equipment at Heathrow had a 100% unobstructed sky view. During daylight hours the amount of cloud cover dictates the amount short wave solar radiation reaching surface. High cloud amount reduces surface heating with a lower RST than could be achieved under a clear sky. At night cloud cover restricts the escape of long wave radiation from the earth's surface resulting in a higher RST than could be achieved under a clear sky (Viskanta and Daniel 1980).

Air temperature at the runway surface is a function of the ground temperature, which is influenced by incoming and outgoing radiation, which in turn is controlled by the sky view. Daylight ground heating by short wave radiation is quickly conducted to the air immediately above the ground, while night cooling cools the air (Anadakumar 1999). Air temperature is therefore of less importance than cloud cover, unless it is associated with a change of air mass. For example, warmer air associated with a warm front and cold air following a cold front.

Cooling, or warming, of the runway surface is also a function of wind, the rate of cooling being more rapid during a clear night with a calm, or light, wind. A calm, or light, wind allows persistent cooling of stagnant, or slowly replaced, air. Increased wind speed allows continual replacement of warmer near surface air, which slows runway cooling. However, if the air is colder than the runway surface the increased wind will encourage runway cooling and therefore lower RST. In addition, if the surface is wet, such as after recent rain, or dew formation in high near surface humidity, evaporative cooling in a stronger wind will increase surface cooling. Precipitation, in any form when evaporating, or melting, absorbs latent heat from the air. The resultant cooling of the air in turn lowers the RST (Weller and Thornes 2001).

DISCUSSION

Change of air mass

High pressure (1026 hPa) was centred over southern Scandinavia at 0000 UTC on the 29th with low pressure to the west of Ireland (Eden 2009a). During the preceding day post-warm front overcast low cloud (±100-300 m above ground) and drizzle, borne by a 5-7 kn south-south-easterly wind, had moved northward over England. The insulating blanket of low cloud kept air temperature and RST well above freezing and a frost free night (Figure 2). During the early hours of the 29th, a cold front from the east passed over London and between 0440 and 0450 UTC a post-cold front wind increased to 11 kn, bringing with it drier and colder continental air. The air temperature lowered from 5°C to 3°C, while the dew-point depression increased from about 1°C to 2-3°C and the cloud base rose from 122 to 300 m and later 490 m. Coincident with these changes, the RST lowered from 5°C to 3°C and it was briefly down to 2.5°C. Throughout the period the RST remained higher than the dew-point and well above 0°C. Consequently, the runway surface remained dry with no frost.

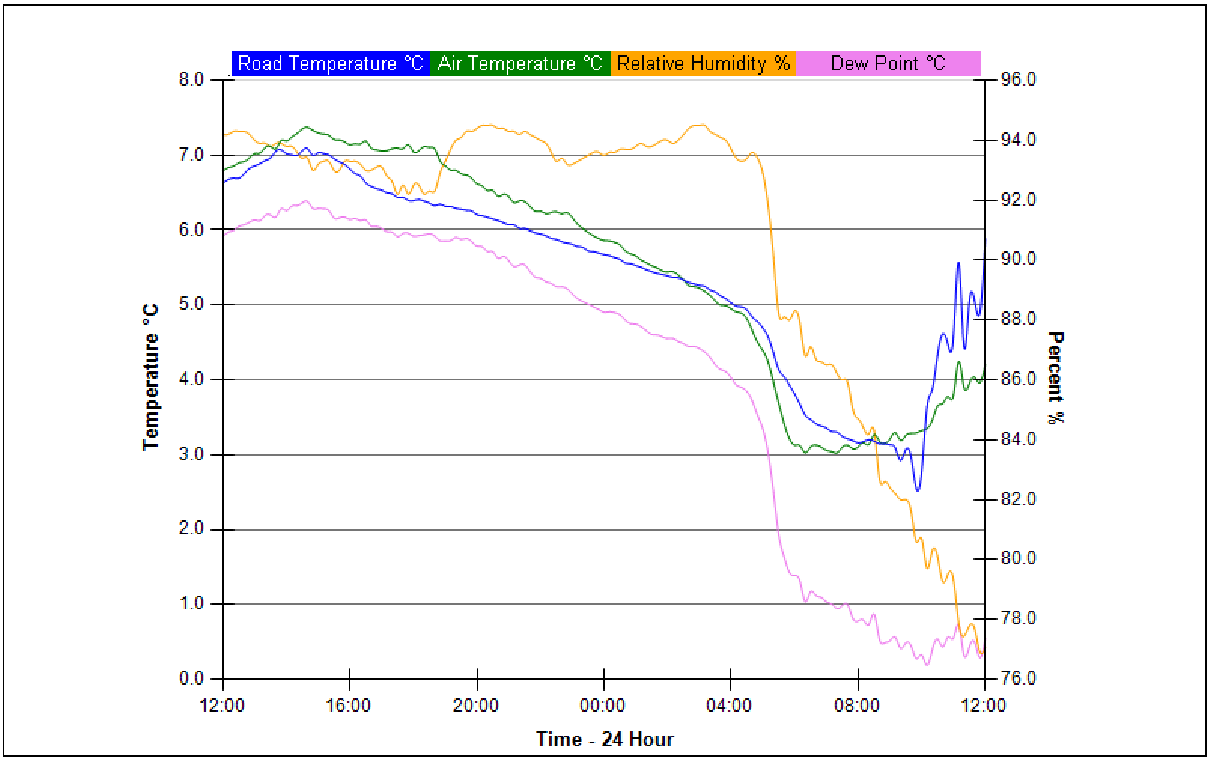

Figure 2. Observations on the 28th/29th January 2009. The different traces are; runway surface temperature (RST) blue (°C), air temperature green (°C), relative humidity orange (%) and dew-point temperature pink (°C).

Radiation cooling night

From 12 noon on the 29th to the 30th, drier, continental air, from the south-east, was in circulation about high pressure centred over Scandinavia. Apart from a brief spell of broken cloud at about 457 m (1850 to 2020 UTC), there was little in the way of cloud and what there was, was above 1524 m. As a result of the clear sky and increased radiation to space, the air temperature fell rapidly through the evening to 0°C overnight and the RST to almost -2°C (Figure 3). Prior to 2100 UTC the RST was above freezing and above the dew-point temperature and a dry runway surface. However, at 2100 UTC the RST dropped below freezing and below the dew-point temperature, an ideal condition for hoar frost that existed until about 1000 UTC on the 30th.

Dry radiation cooling night

Although there was no significant cloud (that is, no cloud below 1524 m) during the 24 hour period from 1200 UTC on the 30th to 1200 UTC on the 31st, the near surface air, in an 8-11 kn east-south-easterly to easterly wind, was much drier with dew-point depressions of 6°C during the afternoon and 3°C overnight. The RST reached a minimum of -1°C at about 0600 UTC, but remained warmer than the dew-point temperature throughout and too dry for frost (Figure 4).

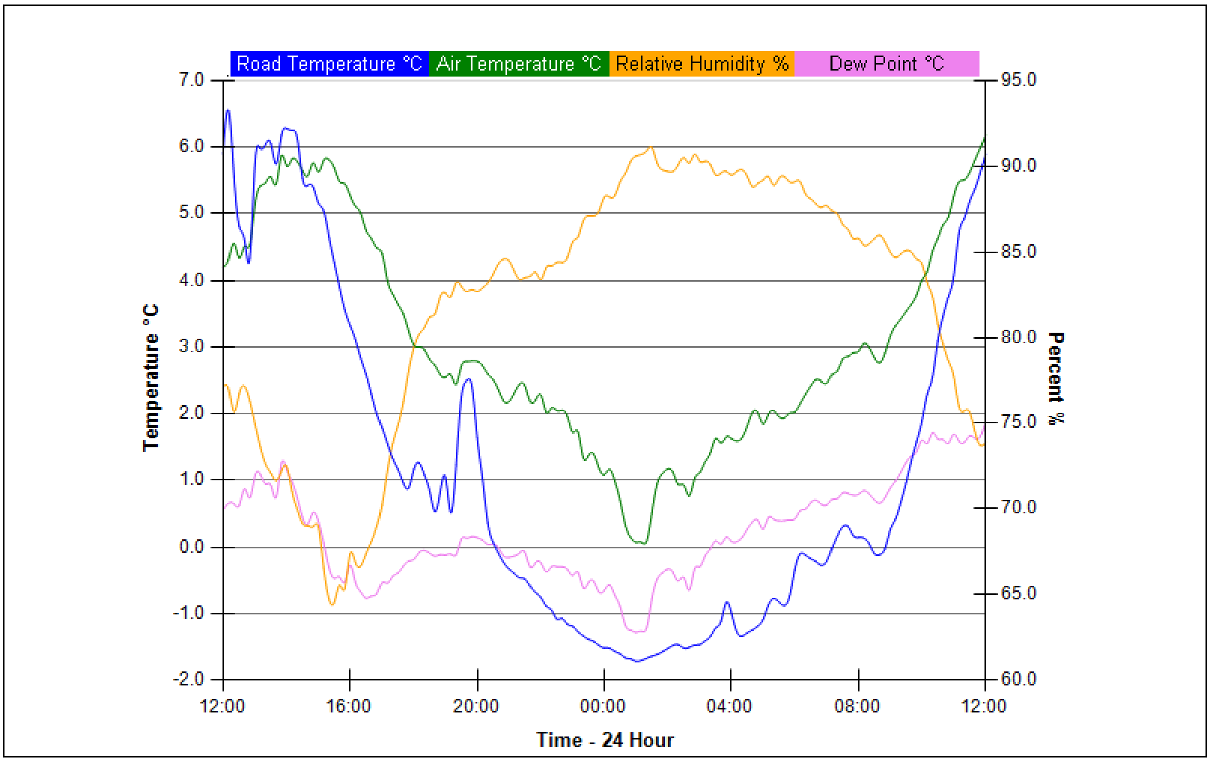

Figure 3. As for figure2, but observations on the 29th/30th January 2009.

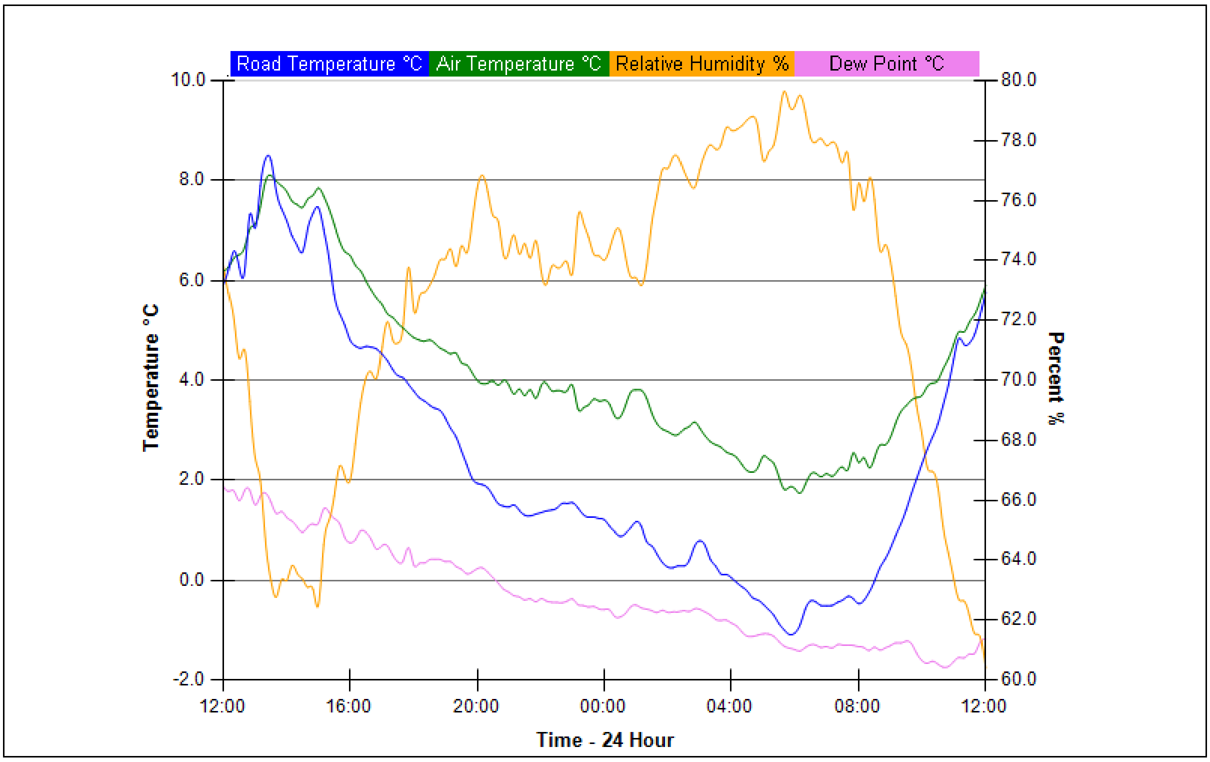

Figure 4. As for figure 2, but observations on the 30th/31st January 2009.

Varying cloud cover

During the late afternoon and early night of the 31st January and the 1st February, when there was no significant cloud, the RST fell rapidly to -2°C, but it rose slightly around 2400 UTC when there was brief broken cloud at 518 m. At about 0200 to 0330 UTC it rose to above zero in more prolonged broken cloud at 549 m and again after 0600 UTC when a persistent broken layer at about 914 m arrived (Figure 5). Although the RST was below 0°C for the most part of the night, it was also, for the most part, warmer than the dew-point temperature. This can be attributed to the persistent 10-12 kn easterly wind. However, between 2100 to 2300 UTC the RST was slightly below the dew-point temperature and hoar frost could have formed. The frost probably melted when the RST rose above freezing at 0200 to 0330 UTC, but the wet surface would have frozen again, this time as ice, when the RST again dropped below freezing under a clear sky and it would not have melted until the warmer temperatures under the persistent cloud cover and warming after dawn occurred.

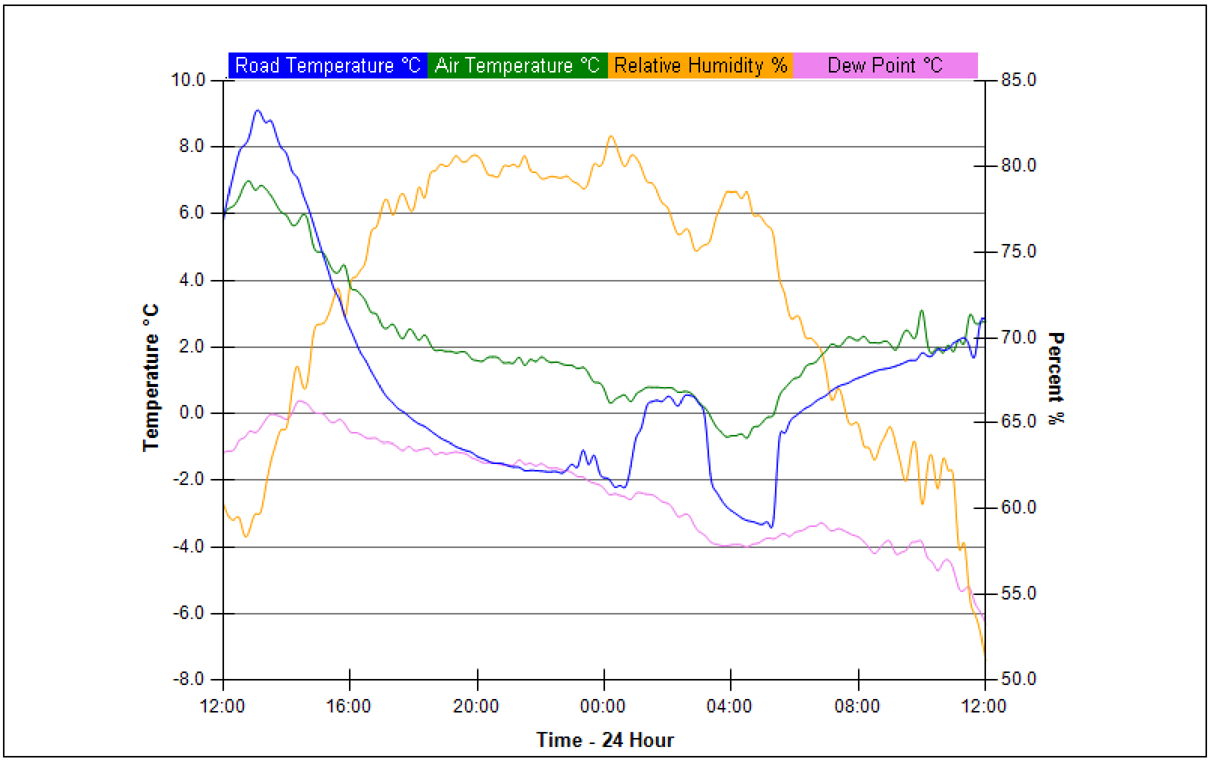

Figure 5. As for figure 2, but observations on the 31st January to 1st February 2009.

Snow and cloud cover

Broken cloud at 914 m preceded a cold front that passed over Heathrow from the east at about 1600 UTC on the 1st February (Eden 2009b) The passing of the front was accompanied by Cumulonimbus cloud, snow showers and a 17 kn east-north-easterly wind. The RST fell below freezing about 1700 UTC and reached -3°C two hours later (Figure 6). Light and at times moderate snow fell continuously in a north-easterly to north-north-easterly wind of 6-9 kn after 2100 UTC on the 1st and the snow finally ended at 2020 UTC on the 2nd. The visibility was down to 600m, while broken to overcast cloud descended to 60 m with zero vertical visibility at times. The METARs indicate that, at its worst, the depth of dry snow on runways 09L and 09R was 20 mm between 2050 and 0350 UTC, with 51-100% over the runway covered and medium to poor braking action. After 0350 the snow depth varied between 5 and 10 mm, with wet snow after 0550 UTC. There was briefly 10mm of slush around 1050 UTC, followed by damp runways. However, during the afternoon and evening of the 2nd, at various times and on different runways, there was 1mm of compacted, or rolled, snow covering less than 10% of the runway and between 2250 and 2350 UTC this amounted to 51-100% of the runways. To their credit, BAA kept Heathrow open throughout the inclement weather (verbal communication D. Whittington, BAA, 2010).

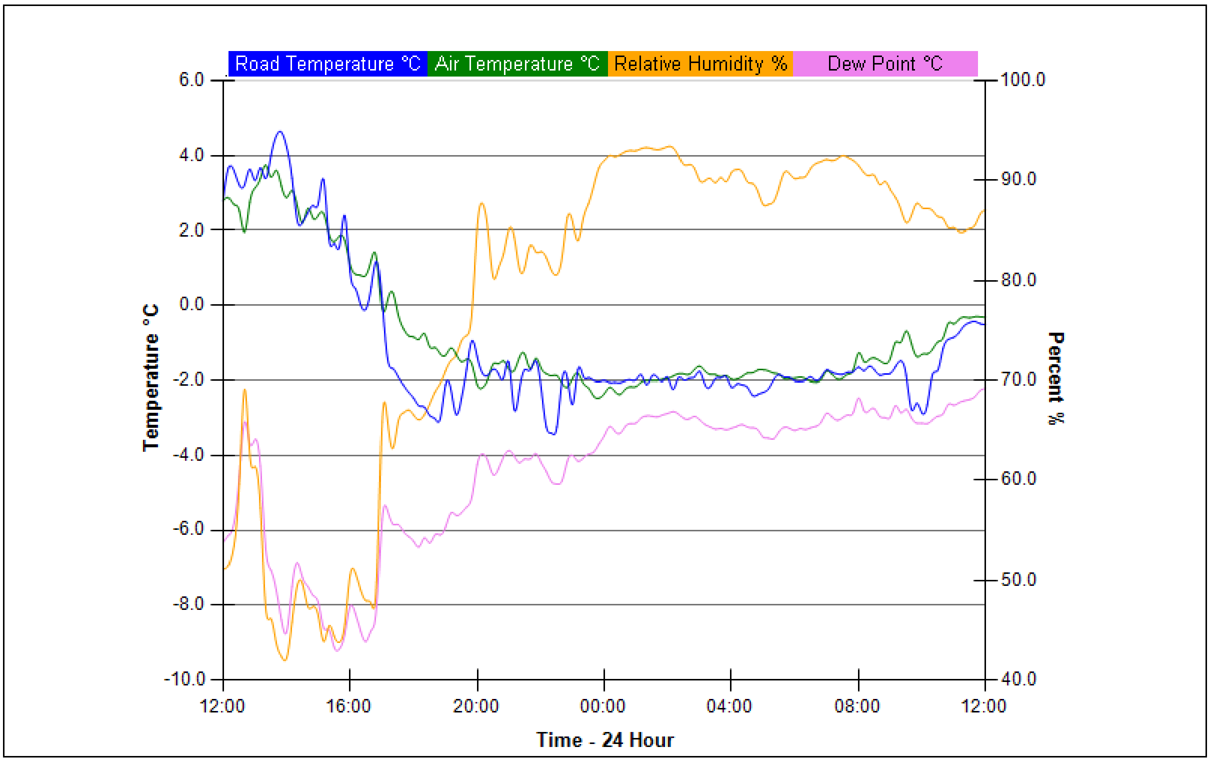

Figure 6. As for figure 2, but observations on the 1st/2nd February 2009.

Under the snowfall and accompanying low cloud, the RST was reasonably steady at about -2°C with colder and warmer fluctuations being related to lifting and lowering of the cloud base, respectively and weather changes. For example, at 1850 and 1920 UTC there was scattered cloud at 853 m, good visibility and no weather. At this time the RST was about -3°C, while at 1950 there was overcast cloud at 152 m, visibility 1000 m and a snow shower and the RST rose to -1°C. Another marked drop in the RST, to about -3.5°C, occurred at about 2150 UTC when there was a period of lifted and scattered to broken cloud at about 610 m with improved visibility to 5000 to 7000 m and light snow showers. The last big RST dip on the chart at 1020 UTC also coincided with the cloud base briefly rising to 1064 m.

The most marked change in RST occurred from noon to noon on the 2nd to the 3rd (Figure 7). While still in continuous light to moderate snow, but with the cloud base frequently 300 to 610 m, the air temperature and RST hovered around freezing. At 1950 UTC light snow gave way to mist with brief light rain at 2120 UTC, which probably resulted in ice on the runway surface after about 2300 UTC when the RST dropped below zero. Between 0050 and 0150 on the 3rd the cloud cleared from broken at 300 m to no significant cloud, that is, cloud base above 1524 m. The mist cleared and the wind dropped from southerly 9 kn to 3-4 kn. At the same time the RST fell rapidly from -0.5°C to about -6°C, while the air temperature steadily fell to -4°C during the early hours of the 3rd. There were moments when drifting patches of cloud caused the RST to warm up to around -4°C and after 0800 UTC there was a steady rise in RST and air temperature in conjunction with a wind of 6-8 kn from the south-east. For the most part, between 0100 and about 0900 UTC, the RST was also below the dew-point temperature and therefore favourable for hoar frost.

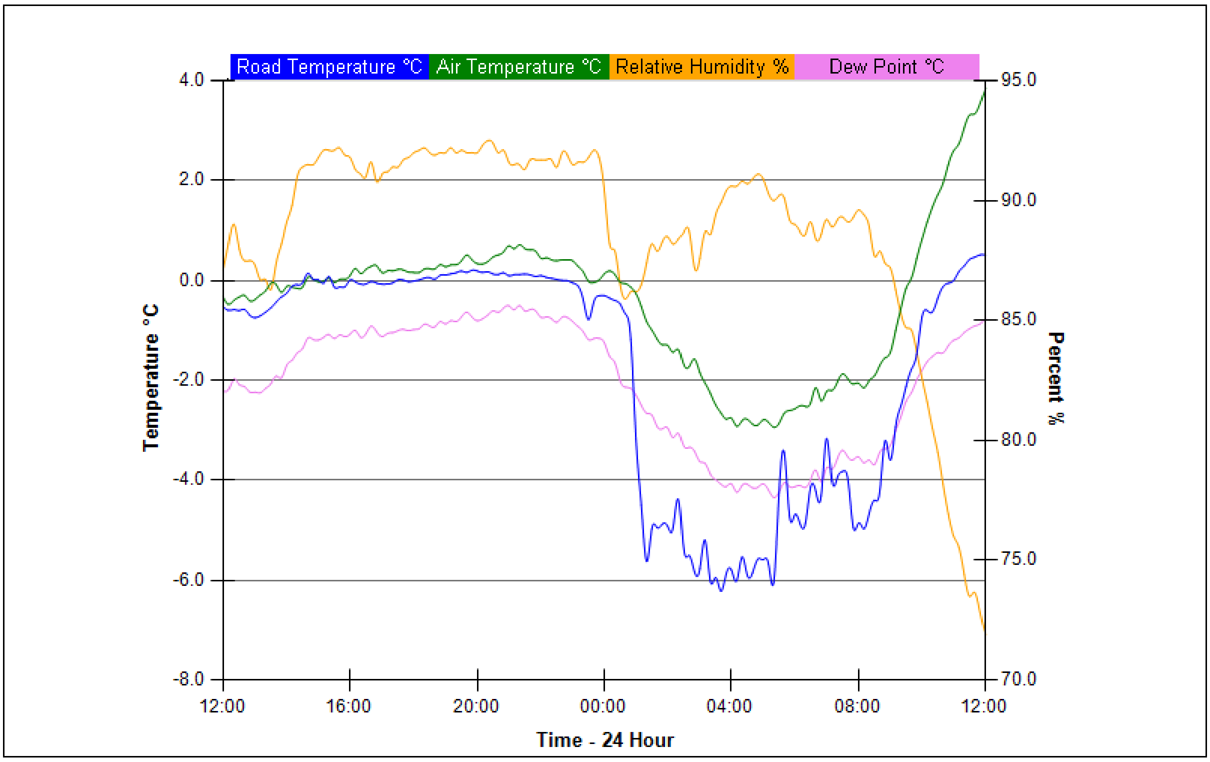

Figure 7. As for figure 2, but observations on the 2nd/3rd February 2009.

CONCLUSIONS

The IRIS weather station provided interesting insight into the RST changes that took place at the Heathrow test site in changing synoptic and weather conditions in association with the snow event.

In accord with prior research cloud base and cloud (and therefore sky view) was the main driver of RST changes. A higher the cloud base and decrease in cloud amount resulted in colder RST and varying cloud amounts resulted in fluctuating RST. The coldest RST occurred under a clear sky. This was clearly evident after the cold spell on the last of the six nights. The opposite effect was evident on the first night when a layer of low cloud kept air temperature and RST well above freezing and a frost free night, even though a cold front brought colder air from the European mainland.

Wind effect was evident during the night of the 30th to 31st when there was no significant cloud, but a persistent gentle to moderate wind prevented the RST from falling lower than -1°C. The wind and turbulent mixing also prevented the RST from falling below the dew-point temperature of the air and therefore a frost free surface.

Under snowfall (and low cloud) the RST remained consistently steady by night and day. There was also markedly little difference between the RST and air temperature under a layer of low cloud and snow, while the greatest variation between the two was under a clear sky when the RST was much colder by night and warmer by day.

Clear radiation nights were also clearly favourable for hoar frost. The exceptions being when there was low cloud cover, or snow and when turbulent mixing in a moderate wind maintained the RST above the dew-point temperature. Excluding early on the 1st, when melted frost could refreeze as ice, the RST was never lower than the dew-point temperature when both were above freezing. Therefore, the situation did not arise where surface dew could form, which would turn to ice once the RST fell below °C.

ACKNOWLEDGEMENTS

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REFERENCES

Anandakumar K. 1999. A study on the partition of net radiation into heat fluxes on a dry asphalt surface. Atmospheric Environment, 33: 3911-3918.

Bogren J, Gustavsson T, Karlson M. 2001. Temperature differences in the air layer close to a road surface. Meteorological Applications 8: 385-395.

Chapman L, Thornes JE, Bradley AV. 2001. Modelling of road surface temperature from a geographical parameter database. Part 2: Numerical. Meteorological Applications 8: 409-419.

Eden P. 2009a. Weather Log. Weather. Vol 64 No3 i-iv.

Eden P. 2009b. Weather Log. Weather. Vol 64 No4 i-iv.

International Civil Aviation Organization (ICAO). 2004. Meteorological Service for international Air Navigation, Annex 3. Geneva. 4-1 to 4.4

Karlsson M. 2001. Prediction of hoar-frost by use of a road weather information system. Meteorological Applications 8, 95-105.

Thornes E, Cavan G, Chapman L. 2005. XRWIS: The use of geomatics to predict winter road surface temperatures in Poland. Meteorological Applications 12:83-90. (Number 1 March 2005).

Viskanta R, Daniel RA. 1980. Radiative effects of elevated pollution layers on temperature structure and dispersion in an urban atmosphere. Journal of Applied Meteorology 19: 53-70.

Weller J, Thornes JE. 2001. An investigation of winter nocturnal air and road surface temperature variation in the West Midlands, UK under different synoptic conditions. Meteorological Applications 8: 461-474.

World meteorological Organization (WMO). 1995. Manual on Codes. Volume I.1 (Annex II to WMO Technical Regulations. Geneva. FM 15 A-25 to A-36.

APPENDIX