Transport and Environment Committee

10.00am, Thursday 9 August 2018

Winter Maintenance Review

Item number	8.2
Report number	
Executive/routine	Routine
Wards	All
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Executive Summary

This report provides a progress report on the Winter Maintenance Plan.

Report

Winter Maintenance Review

1. Recommendations

1.1 It is recommended that Committee notes the progress made with implementing the actions contained within the Winter Maintenance Improvement Plan.

1.2 It is recommended that Committee receives a Winter Maintenance readiness report in October 2018.

2. Background

2.1 At the Transport and Environment Committee on 17 May 2018 information was provided on the current service arrangements together with the improvement plan developed.

2.2 This report provides a progress report on the actions detailed in the Winter Maintenance Improvement Plan.

3. Main report

Winter Operations Update

3.1 An outcome report on the Thermal Mapping exercise has been received and the contractor has discussed this with the working group. A copy of this is attached at Appendix 1. An update on the outcomes from this report will be provided to Committee in October 2018.

3.2 The findings of the Thermal Mapping exercise propose that the city is split in to three gritting domains.

3.3 Work is underway to optimise priority gritting routes for pavements, cycleways and roads, based on the Thermal Mapping findings and the principals that were approved at the March 2018 Committee.

3.4 A suite of optimised routes for each of the three 'domains' will allow winter weather forecasts to identify routes that could receive freezing conditions. The Duty Manager would use this 'route forecast', combined with other factors such a dew point, existing salt levels on surfaces, precipitation timings, to make a treatment decision.

3.5 It is anticipated that significant treatment efficiency savings will be achieved by operating route based forecasting and decision making, targeting areas that need treatment.

3.6 New Road Priority routes, covering the existing treatment network as a minimum, are being developed, based on the findings of the Thermal Mapping exercise and applying Route Smart software to optimise route efficiency:

3.6.1 Road Priority 1 (P1) will have some minor changes to reflect recent city developments;

3.6.2 Road Priority 2 (P2) will include key linking and access roads to the P1 network and roads that are part of the priority cycle network;

3.6.3 Road Priority 3 (P3) will be created and include roads linking residential roads with P2 and P1 roads; and

3.6.4 Residential roads will include all other residential areas. These will be roads that are not P1, P2 or P3 and likely to be adjacent to homes.

3.7 Winter operations have been staffed by Edinburgh Road Services (Roster A) to undertake gritting of road routes and park and ride sites, and Roster B, staffed by volunteers from across the Council undertaking the gritting of pavements and cycleways.

3.8 Resourcing for the treatment of road routes and park and ride sites (Roster A) will remain and similar levels of volunteers will be sought (Roster B) to treat a P1 pavements and cycleways.

3.9 Local priority areas, which will be absorbed into P2 and P3 routes, were and will continue to be staffed by Council staff. They carry out winter weather duties during their normal working hours.

3.10 The P2 and P3 pavement and cycleway routes will be treated however there will be on other non-essential Council services as these duties are carried out instead of normal operations. This impact is acknowledged and will be communicated to increase community understanding. For example, street cleansing and litter bin servicing activities are likely to cease or at least be significantly reduced while staff carry out winter weather duties. If cold weather continues for several days, the impact will be noticeable and therefore managers will assess priorities and allocate resources accordingly.

3.11 During periods of extreme snow or ice conditions this impact can increase however the ability of services to undertake their normal duties is also affected by the severe weather conditions. It is therefore paramount that resources are focused on winter operations in the first instance, to allow normal day to day service operations to be undertaken where possible. An example of this, would be access hampered by snowy conditions preventing bin lorries access residential streets to collect household waste.

3.12 The Council's Grit Bin policy is being reviewed and influenced by the findings from the Thermal Mapping exercise. The main change to this policy will be that grit bins will be filled in reverse priority in respect of pavement, cycleway and road priorities treatment. Grit bins on non-priority pavements, cycleways and roads will be afforded first priority for refilling to ensure residents have a supply of salt to allow for self-help.

3.13 Grit bin filling on priority treatment routes will be monitored to evaluate the extent of their use. Grit bins that are infrequently used during cold spells will in time be removed.

3.14 As detailed in the March 2018 report to this committee, refilling grit bins is resource intensive. Reducing the servicing of grit bins on Priority routes will reduce resource pressure and costs

3.15 As a result of these changes, the Council's website will be updated to provide revised information on the new treatment domains and changes to the priority routes and grit bins.

3.16 Progress is also being made with developing procedures with business support colleagues to respond to correspondence and support performance targets.

Customer and Information Technology Services

3.17 Discussions are ongoing with Customer and Information Technology Services to develop procedures to provide customer support during the winter period. Dedicated mailboxes will be provided to manage correspondence and the information on the Council's website will be updated to reflect the improvements to the service and from feedback.

Depot Operations

3.18 A review of salt stocks has been completed. A stock of 13,000 tonnes will be in place for the start of winter 2018/19 and replenished as required. 5,000 tonnes will be held between Bankhead and Blackford roads depots.

3.19 A further strategic supply of 8,000 tonnes will be in place. Arrangements are currently being made to have this strategic supply at the Council's Braehead depot.

3.20 Orders for salt stocks have been placed for 2018/19.

Fleet

3.21 The provision of new fleet to support winter weather operations is being progressed. Due to the condition of the current aging fleet, it is necessary to replace a number of vehicles to ensure appropriate capability for this coming winter. Fleet will utilise a hire arrangement to provide a core of vehicles pending implementation of a more comprehensive procurement process.

3.22 A key finding from the review of this winter was the support needed to keep the winter fleet operational. Mechanical and Fitter support is required 24/7 during winter operations. The provision of new vehicles will reduce the pressure on maintenance services however cover arrangements are being reviewed to ensure adequate arrangements are in place prior to the start of winter operations in October.

Contract Management

3.23 The Council has a contract in place to recruit additional support to cover staff absence, vehicle breakdown or extreme conditions. The current provision is to hire a gritter with driver.

3.24 Consideration has been given to the possibility of hiring drivers only to drive the Council's gritters however this is not currently possible therefore the current arrangement will be continued.

3.25 A performance review of the current contractor was carried out as part of the full winter maintenance review and issues/concerns identified have been addressed. This contract will continue for the forthcoming winter period.

3.26 The Council also has a contract in place with a farmer located in the rural Balerno area. This contract is working well and will continue for the forthcoming winter.

Technological Improvements

3.27 A GPS vehicle tracking system was installed in gritters last winter. Hire vehicles and subcontracted gritters were provided with mobile trackers. The information available from the trackers supported the Duty Team Leaders in managing the gritting fleet and the provision of real-time information to the Council's Independent Claims Handler in defence of any public liability claims. All new/hire vehicles will be fitted with this tracking system.

3.28 Routing technology is being used to create optimised routes. Good progress is being made and routes will be created within each of the new thermal domains.

3.29 The aim is to have these routes uploaded to sat-nav type devices. While it is hoped to trial this for winter 2018/19, it is likely to be 2019 and later before we have this on the entire fleet.

3.30 This technology will replace the current arrangement which is a manually created paper based system and will reduce the pressure on the gritter driver when undertaking an unfamiliar route.

4. Measures of success

4.1 The Thermal Mapping exercise will provide three domains, allowing targeted gritting to be undertaken in the coldest parts of the city when the weather forecast permits this approach.

4.2 Optimising gritting routes using Routesmart software is estimated to achieve a 17% to 20% route efficiency.

4.3 The Edinburgh community will have clarity on which pavements, cycleways and roads will be treated, and when.

4.4 There will be clear timescales for refilling grit bins.

4.5 The downtime of the gritting fleet will reduce with the provision of newer vehicles.

5. Financial impact

5.1 The budget to provide a winter weather service is based on a seven year average spend and was £2.88m for 2017/18. Budget underspends following milder winters create a reserve to fund severe winters with high costs.

5.2 The budget and reserve level will be reviewed to ensure the contingency reserve is maintained but only to an amount sufficient to fund a severe winter such as experienced in 2009/10 and 2010/11.

5.3 The improvements and changes outlined in this report will enable the Council to deliver winter weather services effectively and efficiently. Any year on year savings from efficiency or milder weather will add to the reserve.

5.4 To deliver the improvements outlined in this report, especially for pavements and cycleways, there will be an impact on services that supply staff to carry out winter weather duties during their normal working hours. This does not have a direct financial impact but additional costs may be incurred as services return to normal.

6. Risk, policy, compliance and governance impact

6.1 The City of Edinburgh Council has a statutory duty (under Section 34 of the Roads (Scotland) Act 1984) to take such steps as it considers reasonable 'to prevent snow and ice endangering the safe passage of pedestrians and vehicles over public roads". The intention of this duty is not that the Council will take immediate and simultaneous steps to clear and/or treat every road whenever ice or snow exists. It is recognised by the Courts that this would be impossible and beyond the limits of available resources. Failure to fulfil these duties could result in action being taken against the Council.

6.2 ERS provides the Winter Maintenance Service with support from other Council services; some provide drivers for the gritting fleet. Failure to secure this support could have significant reputational risks if the pavement, cycleway and road network is not treated during wintry weather. It would also increase the requirements to use sub-contractors, and could expose the Council to legal challenge.

6.3 Failure to replace the existing fleet could result in an insufficient number of available vehicles to manage the gritting requirements in accordance with Section 34 of the Roads (Scotland) Act 1984.

7. Equalities impact

7.1 It is recognised that the Winter Maintenance service impacts upon everyone in the city to a greater or lesser degree. It is acknowledged that people with mobility difficulties are likely to experience significant disruption to their working and/or personal lives.

7.2 The major Winter Weather Working Together review conducted in 2011 focussed on the identification of groups who may be more adversely affected by severe winter weather including sheltered housing, special schools and care homes. The changes made to gritting routes were developed from these findings.

7.3 Reviews of gritting routes undertaken since that date take in to account the location and needs of these groups and the services they need to access.

7.4 During periods of severe winter weather, the Council's Emergency Plan has provisions in place to cater for those from within the protected characteristics.

7.5 Edinburgh's winter weather review proposes using three main groups of staff to treat all Priority 1 pavements, cycleways and roads at the same time. The Priority 1 roads are selected to provide emergency service access and a public transport network.

8. Sustainability impact

8.1 Reduction in mileage, gained through the thermal mapping exercise when gritting only the coldest domain, will result in a reduction of vehicle emissions.

8.2 Reduction in mileage, gained through Routesmart route optimisation will result in a reduction of vehicle emissions.

8.3 Any reduction in salt usage, obtained through the thermal mapping exercise, will reduce the amount of salt entering rivers and water courses.

8.4 Renewal of the gritting fleet will provide more efficient engines and reduce emissions.

9. Consultation and engagement

9.1 ERS staff have, and continue to be, consulted on the depot rationalisation project and the replacement of fleet.

9.2 Consultation and engagement with staff is taking place in relation to the wider Roads Improvement Plan which includes some aspects of Winter Maintenance.

9.3 Specialist groups such as Sustrans, Living Streets, SPOKES and some community groups will be engaged and consulted.

10. Background reading/external references

10.1 Roads Service Improvement Plan at Transport and Environment Committee on 1 March 2018.

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11. Appendices

Appendix One Thermal Mapping Report

Thermal Mapping Report

Vaisala Transportation Weather Services

The City of Edinburgh Council
June 2018
(updated for publication August 2018)

VAISALA

Table of Contents

Summary

For: The City of Edinburgh Council

Data collected: January 2018 to March 2018

Road Network Surveyed: 625km

Number of Nights Mapped:

Type of night	No. of mapped nights	Weather conditions
Extreme	12	Little to no cloud cover throughout (0-2 oktas), little to no wind
Damped	7	Heavy cloud cover, moderate to strong winds

Main Findings

On a regional scale, the urban/rural variation displayed under all three conditions (Extreme, Intermediate, and Damped) is the main controlling factor on road surface temperature (RST) distribution. The vast majority of above average RSTs are located in close proximity to the city centre, with a relatively uniform decrease in temperature moving away from the city. It is likely under certain weather conditions that a coastal to inland variation in RSTs will also occur.

Under Extreme and Intermediate conditions, it is evident that factors such as sky-view, road construction, and reflectivity of the road surface influence RSTs on a localised scale, in some cases presenting exceptions to the general urban to rural trend. The influence of these features is much less apparent under Damped conditions.

The range in RSTs shown in the Thermal Mapping results, and the fact that there are distinctive areas of RSTs above or below the network average allows that the region can be divided into Climatic Domains. Primarily based on the Extreme Map, but also taking into consideration the current weather station distribution and topography, it is recommended that the region be divided into three domains – Urban, Northwest, and Southern.

Next Steps

Before the 2018/2019 winter season, The City of Edinburgh Thermal Maps will be uploaded to Vaisala's RoadDSS Navigator Software. Utilising the daily weather forecast supplied from the forecast provider the Thermal Maps will display dynamically for each night giving decision makers an insight into expected Forecast Minimum RSTs across the region. It is possible for decision makers to take part in a full day (Winter Services Workshop) or a half-day (RoadDSS Workshop) of training. These courses are designed to provide decision makers with a full understanding of the functionality of the Vaisala Manager Decision Support Software, including the thermal maps, and give a refresher of some of the day-to-day challenges faced when making decisions. A new Thermal Mapping e-learning module will also be available in the Decision Support Software.

The Thermal Mapping results indicate a significant range in RSTs across the network. In instances where the network average is close to 0°C, it is probable that there will be large sections of the road network remaining above freezing and therefore not requiring treatment. Under these 'marginal' conditions, selective treatment can yield significant savings over the course of a winter season.

The division of the region into Climatic Domains allows treatment to be carried out on a domain-by-domain basis if gritting routes are designed accordingly. Alternatively, based on the Thermal Mapping results, a designated Cold Network could be created, allowing reduced network coverage in marginal conditions.

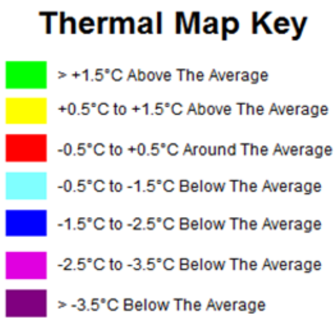
1. Introduction

This report presents findings from the Thermal Mapping survey undertaken to assess temperature variations across the road network. The report explains both the theory behind Thermal Mapping and the results of the Thermal Mapping survey. The thermal characteristics of any section of road are unique and can differ widely across a given area due to variations in weather, climate and multiple non-weather related factors. This report explains the reasons for the differences in temperature across the network. The results of the survey can be used to optimize treatment routes, find suitable weather station locations or, when combined with a forecast, provide an effective decision support tools for winter decision makers.

An explanation of the theory behind Thermal Mapping can be found in Appendix A and B.

2. Thermal Mapping

Thermal Maps display a representation of the relative spatial variation in minimum RST of a surveyed highway network. Deviations in RST from the overall survey average are denoted by differing colours for each 1.0°C of variation. This section introduces the Thermal Maps produced during this survey and provides analysis for variations found within the maps.



2.1. Extreme Thermal Map

The Extreme Thermal Map exhibits the maximum night time RST variation across the road network. This will occur under calm, clear conditions, typical of an anticyclonic (high pressure) system, allowing maximum radiative cooling of the road, cold air drainage and the likely development of a temperature inversion.

Comment from our expert

When adjusted to a mean average of 0°C, the Extreme dataset has a range from -2.9°C to 8°C. This maximum figure of 8°C indicates that there are values in the dataset that are considerably higher than the mean average, likely to be located close to the city centre. These warm 'spikes' in temperature, which often occur at locations where a bridge crosses over a road and cooling is offset by a low sky view factor, will increase the overall range displayed in the dataset. Without the influence of these warm 'spikes', a range of ~6-7°C might be a more accurate representation of the temperature variation exhibited on the Extreme Map.

There are some exceptions to the urban to rural, warmer to colder trend displayed on the Extreme Map, and the reasons behind some of these instances are explained in the relevant sections of Chapter 3. One obvious example of colder temperatures close to the city centre can be seen on Queen's Drive (Holyrood Park), which displays mostly cyan (0.5°C to 1.5°C below average) and blue (1.5°C to 2.5°C below average) colouring on the Extreme Map.

It is worth noting that the Extreme Map displays the temperature relationship that would be expected if weather conditions are uniform 'Extreme' (i.e. calm and clear) across the entire region, and there may often be instances where this is not the case. This is the main reason behind dividing the region into Climatic Domains in order to use the map operationally.

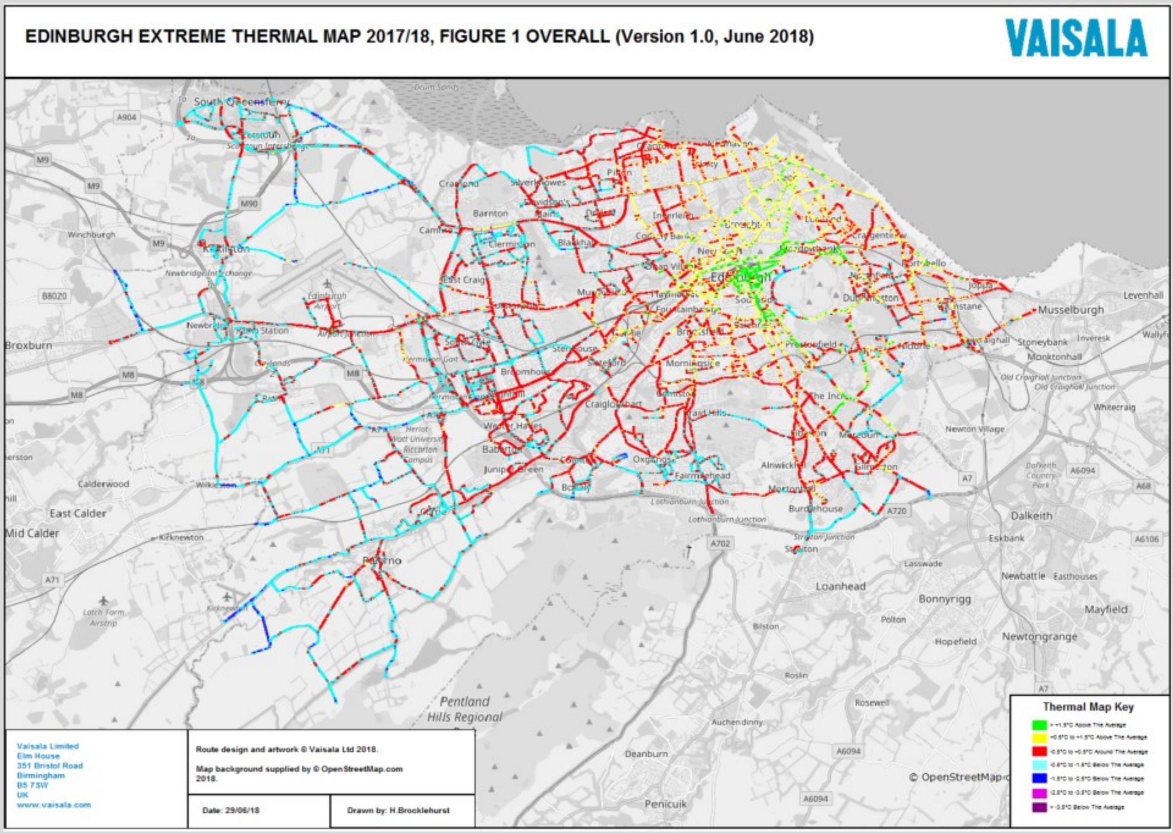


Figure 2.1. The Extreme Thermal Map. Higher definition maps provided separately. Map: © OpenStreetMap, CC-BY-SA.

2.2. Intermediate Thermal Map

The Intermediate Thermal Map depicts the relationship of RSTs that develop under clear, windy (>12km/h) or calmer, overcast conditions where cloud coverage is medium to high level. These result in a narrower temperature range due to increased mixing of air layers reducing cold air drainage and restricting frost hollow formation, or cloud cover reducing the effects of radiative cooling. The overall result of either of these scenarios is to reduce the amplitude of the temperature differences and therefore the temperature range of the road surface.

Whilst Extreme and Damped conditions are easily defined, and by their nature tend to remain consistent throughout a survey night, Intermediate surveys are associated with nights where changeable conditions are experienced. Therefore, an algorithm developed by Vaisala, was used to ensure the consistency of the map in comparison with the result of the other conditions.

Comment from our expert

The overall range in the Intermediate dataset is reduced to 7.6°C. There are still significant sections of the network displaying below average (cyan colour) RSTs but perhaps the most obvious difference from the Extreme Map is that there are now very few roads displaying temperatures more than 1.5°C below the average (blue colour category). There is no data in the purple and magenta colour categories (more than 2.5°C below average) as the minimum value is -2°C when adjusted around a network average of 0°C. The majority of roads in close proximity to the city centre continue to display above average RSTs, but there is an overall shift towards the network average temperature and subsequently a far greater amount of the map appears in the red (average) category.

The distribution of colour categories on the Intermediate Thermal Map is generally consistent with those on the Extreme Map. However, the influence on RST development of many localised factors is not as marked as they were under Extreme conditions, with an apparent shift toward the relative average as a result. Overall, the Intermediate Map supports the findings of the Extreme Map, in that the same general trends in RSTs are present.

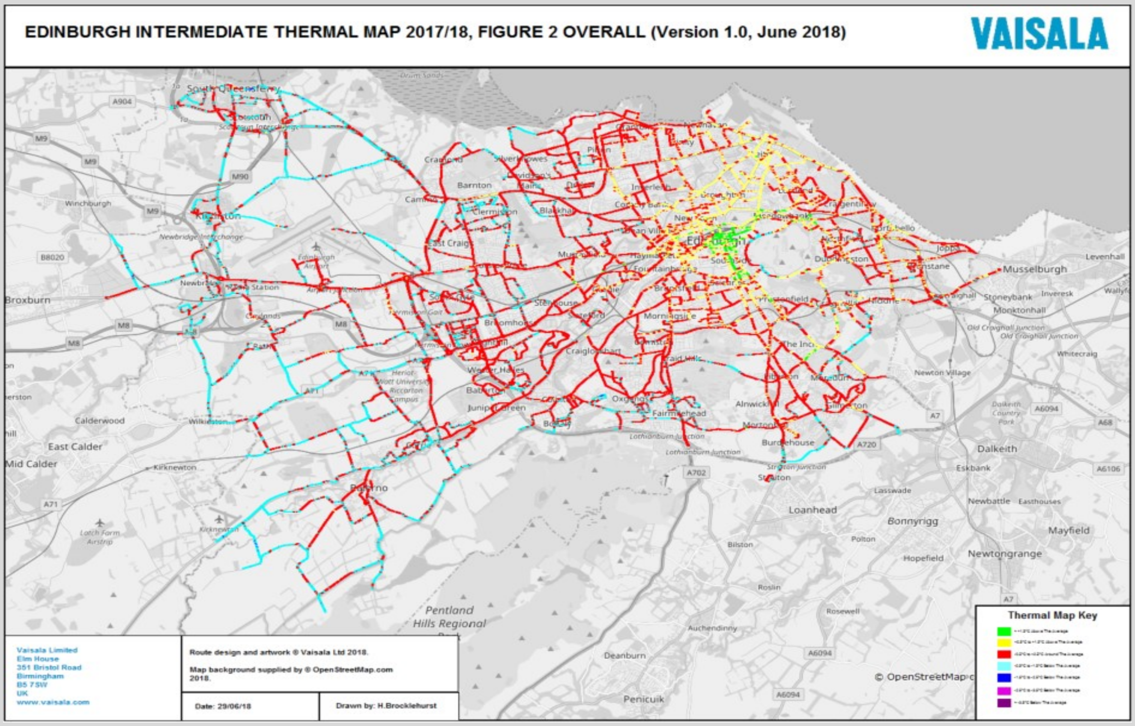


Figure 2.2. The Intermediate Thermal Map. Higher definition maps provided separately. Map: © OpenStreetMap, CC-BY-SA.

2.3. Damped Thermal Map

The Damped Thermal Map demonstrates the pattern of RSTs that develop under increased cloud cover (particularly cloud height <2000m) that offsets radiative cooling of the road surface, and higher wind speeds that mix the air layers and reduce temperature inversions. Consequently, the importance of localised features is reduced, while larger effects such as proximity to the sea and changes in altitude are dominant. As a result, the Damped Thermal Map displays a significantly reduced amount of variation in RST from the overall average. The majority of the road network falls within 1.0°C either side of the network average.

Comment from our expert

The overall range in the Damped dataset is just 4°C, as many of the warmer and colder 'spikes' in temperature are removed. Many of the permanent features of the road infrastructure (e.g. bridge decks, construction type) that cause variations in RST on a localised scale are much less apparent on the Damped Map as their effects are largely mitigated by the unstable weather conditions.

The most noteworthy finding from the Damped Map is the volume of below average RSTs displayed in the southeast of the network, indicated by the cyan colouring in the Oxgangs, Buckstone and Gracemount areas. The main significance of this is that it supports the division of the network into three Climatic Domains rather than two – discussed further in Chapter 5.

The roads around Balerno continue to display below average RSTs under Damped conditions, confirming that this is likely to be a cold section of the network in all weather conditions. Marine Drive and Silverknowes Road also display below average RSTs, even though the majority of roads in that area are in the red (average) colour category.

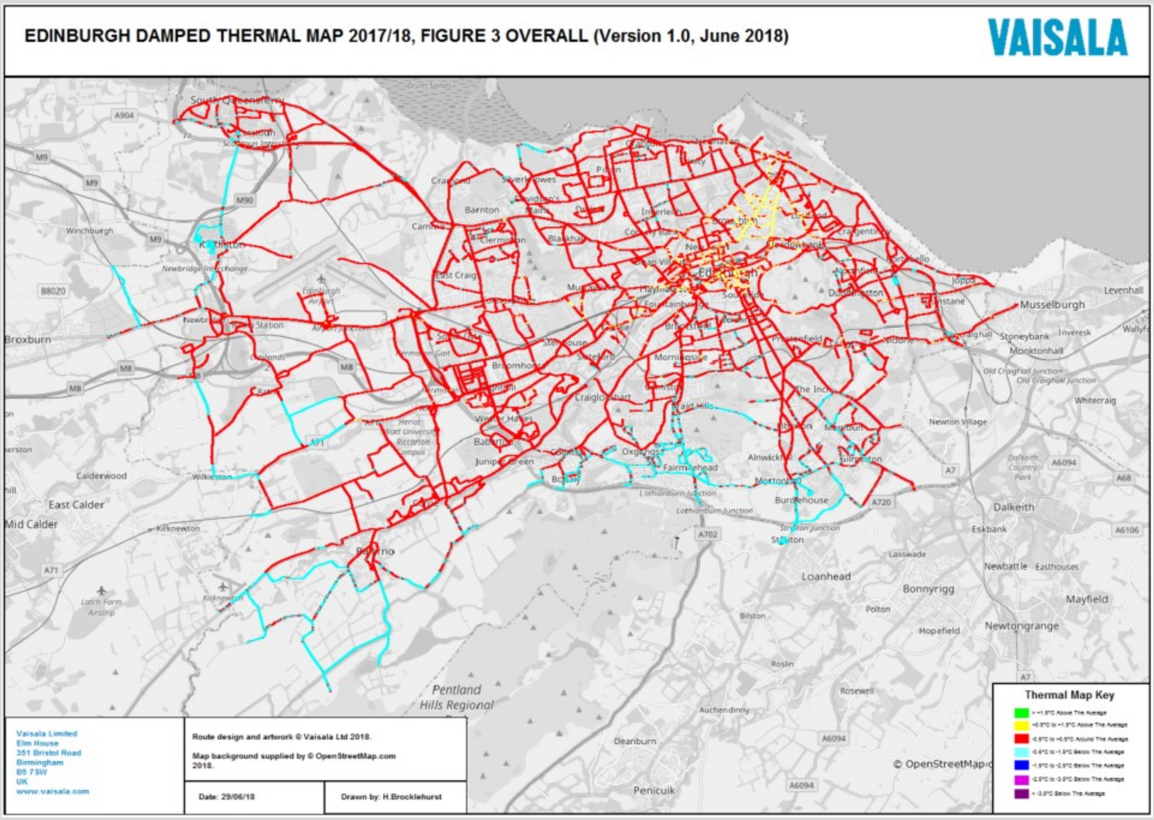


Figure 2.3. The Damped Thermal Map. Higher definition maps provided separately. Map: © OpenStreetMap, CC-BY-SA.

3. Analysis of Temperature Variations

Following the Thermal Mapping survey, the data was analysed to discover the reasons for variations in temperature across the mapped network. It's possible to attribute certain warm and cold sections of road to different permanent, non-meteorological factors. In this section, the maps are analysed and discussed to establish the reasons for the variations in temperature found across the extreme, intermediate and damped maps.

3.1. Altitude and Topography

Comment from our expert

There is an altitudinal range of ~200m across the road network, with the city centre lying relatively close to sea level and a general increase in altitude with distance inland. This increase in altitude is likely to have contributed to the colder RSTs displayed further inland, as a decrease in temperature is generally observed with an increase in altitude. However, the effect of the urban heat island is undoubtedly the main controlling factor behind the temperature variation shown on a regional scale.

The usual decrease in temperature with height can be reversed on a localised scale, when a phenomena known as *katabatic* air drainage (or a temperature inversion) occurs. Cold air is relatively dense in comparison to adjacent warmer air mass, which can cause cold air to flow downslope under calm weather conditions. It is probable that this has contributed to the cold temperatures displayed on Queen's Drive, as cold air is likely to have flowed downslope from the hills in Holyrood Park.

3.2. Water Bodies

Comment from our expert

During the winter months, significantly large water bodies are generally warmer than adjacent landmasses, and have the capacity to maintain heat for longer after dark as less longwave radiation is emitted. As a result, roads that are located in close proximity to water bodies have the potential to display warmer RSTs. Across the Edinburgh network, many of the roads that are near the coast are also close to the city centre and it is likely that urbanisation has had a more significant warming effect on RSTs in these locations.

Further out of the city, there are locations on the network close to the coast that actually display below average RSTs, most notably Marine Drive and the B924 (Queensferry). Therefore, the coastal to inland warming to cooling trend that might be anticipated in a coastal region is not thought to be hugely significant in this case. However, it is again worth considering that the Thermal Maps show the temperature relationship assuming uniform weather conditions across the region. It is possible that the coastal areas of the network will experience different weather conditions than further inland. In which case a coastal to inland trend could be observed under certain weather conditions, and could be accounted for by dividing the network into appropriate Climatic Domains.

3.3. Sky View Factor

Comment from our expert

Although receiving a greater amount of solar input during the day, roads with a high sky-view factor are likely to lose more heat after dark through reflected shortwave radiation. Conversely, on roads with a lower sky-view factor, a greater amount of the outgoing radiation will be trapped in close proximity to the road surface, reducing the amount of heat loss. Differences in sky-view factor can cause significant variation in RSTs on a very localised scale.

On the north section of Queen’s Drive there is a clear transition from colder to warmer RSTs in alignment with a reduction in sky-view factor where trees line the roadside. This is because on the section of road lined with trees, a greater proportion of outgoing radiation will be trapped closer to the road surface, reducing heat loss. The result is a difference in temperature of up to 4°C, over a distance of ~250m.

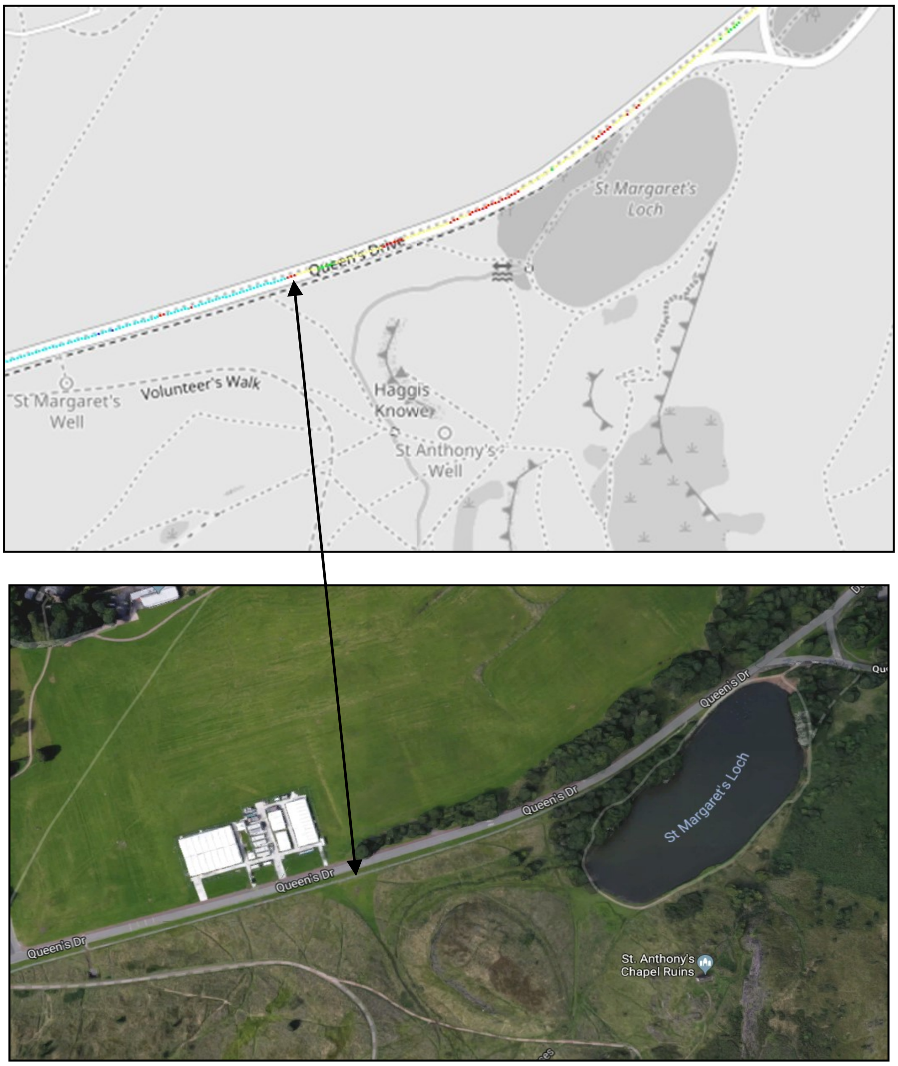


Figure 3.3. Sky View factor example from the Extreme Thermal Mapping. Map: © OpenStreetMap, CC-BY-SA. Satellite Imagery: © Google 2018.

3.4. Urbanisation

Comment from our expert

Urbanisation is the main influencing factor on regional scale RST distribution under all three weather conditions. The temperature difference between urban and rural areas is the result of heat sources within the city, allied to the fact that the fabric of the urban environment will retain heat to a greater degree than rural areas. This is the result not only of the construction materials but also the urban architecture and lower sky view factor. Higher traffic volumes in urban areas will also have a warming influence on the road surface.

The urban heat island is most pronounced on the Extreme Map, extending southwest from Leith to the roads around Haymarket, Fountainbridge, and Sciennes. Under Damped conditions, the urban area displaying above average RSTs is reduced in size, particularly in an easterly direction towards Duddingston and Northfield, and in a westerly direction towards Comely Bank and Pilton, which now display RSTs closer to the average (red).

3.5. Road Construction

Comment from our expert

Both construction type and surface colour will have an effect on RST at a given location. On Redford Bank (off the B701) there are RSTs in the blue and magenta categories (up to 3.5°C below average) on the Extreme Map, despite this location being a residential cul-de-sac. On inspecting the road on Google Street View, it appears that the road construction has significantly degraded, which could cause increased heat loss from the road surface. The road surface in this area is also light in colour, reducing the amount of heat that will be absorbed through solar input during daytime hours. This location is noteworthy as there is a primary school at the end of the road.

Figure 3.5. Sky View factor example from the Extreme Thermal Mapping. Map: © OpenStreetMap, CC-BY-SA. Street View Imagery: © Google 2018.

The colour of a surface is the main controlling factor behind its reflectivity (*albedo*). Lighter colours are more reflective and therefore absorb less heat through solar input and are likely to be displayed as relatively cold sections of the network in the Thermal Mapping results. The restricted access (buses only) section of The Jewel (between the A1 and A6106) is painted green in colour and is lighter than the adjacent roads. Under Extreme conditions, this section of road is in the blue category (1.5°C to 2.5°C below average). The increased reflectivity of the surface and the fact that this section of road is likely to have lower traffic volumes are both likely to have contributed to the cold RSTs displayed here.

Figure 3.6. Sky View factor example from the Extreme Thermal Mapping. Map: © OpenStreetMap, CC-BY-SA. Satellite, Street View Imagery: © Google 2018.

4. Weather Station Locations

Road weather stations provide information about atmospheric and road weather conditions at selected points across the road network. This allows winter maintenance decision makers to know precisely what's happening at each location on the network. Weather stations are positioned to represent a cross section of temperature regimes and a good geographical spread across the area.

When weather stations are being located it is good practise to consider climatic differences across the road network, the range of temperature differences, temperature anomalies such as bridge decks and overhanging vegetation and areas of different road surface. These features can be determined based upon the thermal mapping.

Stations can be sited using Thermal Mapping in order to provide both the optimum number of stations but also ensure that they are positioned in areas with stable temperature profiles.

Weather stations combined with Thermal Mapping then give an overview of the entire network RSTs rather than just receiving site-specific information from individual sensor locations.

4.1. Current Weather Station Locations

Weather Station Name	Location	Extreme Thermal Map Colour Band	Location Notes
A1 Duddingston	55.943611, -3.131667	Yellow (0.5 to 1.5 above network average)	Representative of the average for Urban Domain, possible interference from trees
A71 Dalmahoy	55.911667, -3.355278	Cyan (0.5 to 1.5 below network average)	Suitable forecast location for Northwest Domain
A772 Gilmerton	55.896944, -3.140833	Cyan (0.5 to 1.5 below network average) / Red (average)	Unstable section of Thermal Map near roundabout – not ideal forecast site
A90 Davidsons Mains	55.960833, -3.260278	Red (average)	Suitable forecast site for Urban or Northwest Domain, depending on exact boundary
A90 Dolphinton	55.979167, -3.346389	Red (average)	Appropriate site for monitoring A90, not currently forecast enabled
A901 Trinity	55.980222, -3.205556	Red (average)	Coastal location – possible interference so might not be preferable as a forecast site
Balerno	55.875556, -3.340278	Cyan (0.5 to 1.5 below network average)	Appropriate forecast location for South Domain

Comment from our expert

The current weather stations are well distributed across the network and are in alignment with the proposed Domain setup (Chapter 5). Almost all of the weather stations are currently set up to receive forecasts, there is at least one option for a forecasting site within each Domain, assuming that the instruments currently on the weather stations are up to date and working effectively. The only locations of any concern are Duddingston (A1), where trees currently overhang the weather station and Trinity (A901), as this could experience erratic weather conditions due to its proximity to the seafront, so might not be ideal as a forecast station.

In alignment with the Thermal Mapping results, no additional weather station locations are considered necessary.

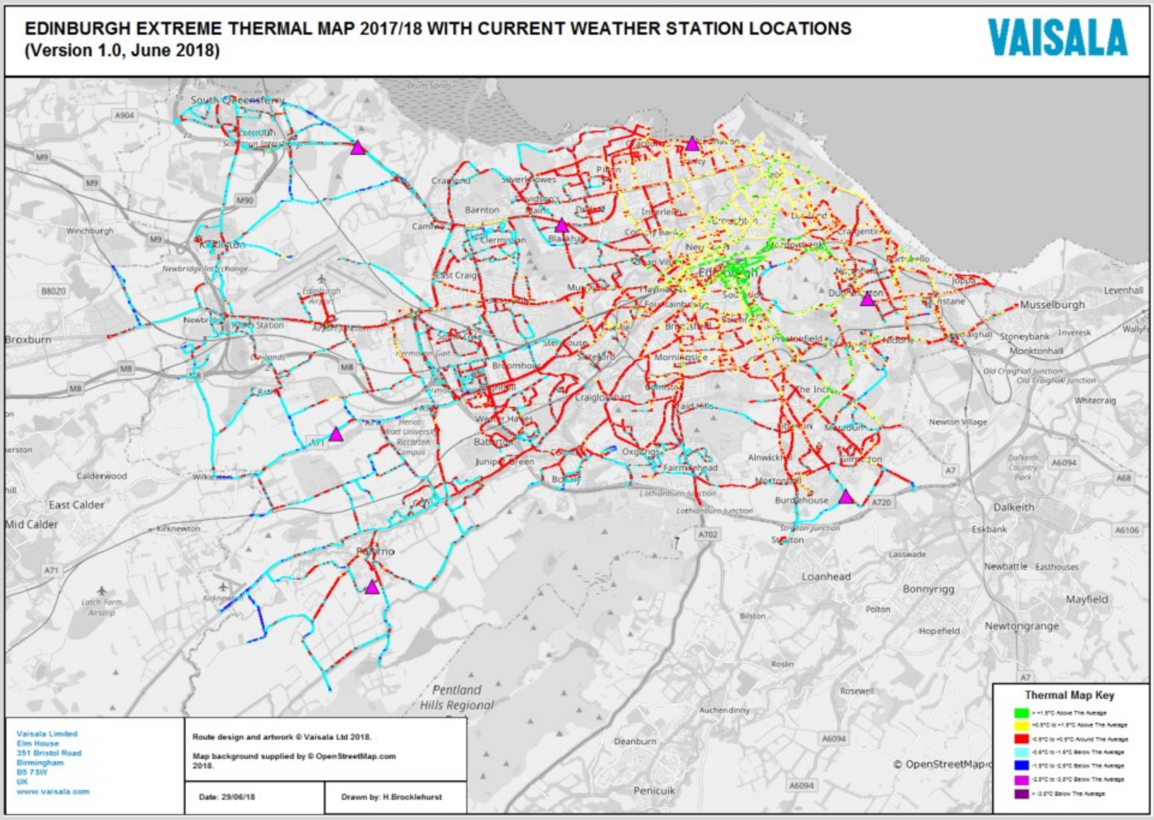


Figure 4.1. The Extreme Thermal Map showing the current weather station locations. Map: © OpenStreetMap, CC-BY-SA.

5. Climatic Domains

5.1. Recommended Climatic Domains

Comment from our expert

Upon analysing the Extreme Thermal Mapping results, it was thought that the network could be divided into either two (Urban and Rural) or three Domains (Urban, Northwest, and South). As discussed on page 12, the Extreme Map shows the temperature relationship assuming uniform weather conditions across the entire region and on some winter nights, a significant difference in temperature between the north-western and southern areas might not transpire. However, mainly due to the varying topography, it is probable that the southern area of the network will regularly experience differing weather conditions to the northwest. The Damped Thermal Map also supports the division of the network into three Domains rather than two; as more below average RSTs are in the South Domain compared to the Northwest (see Figure 5.2). In addition, there are adequate weather stations distributed across the network to support three Climatic Domains.

Consequently, the Domain set up shown in Figures 5.1 and 5.2 is the only option that Vaisala are currently recommending. Vaisala are happy to discuss alternative options based on The City of Edinburgh Council's feedback.

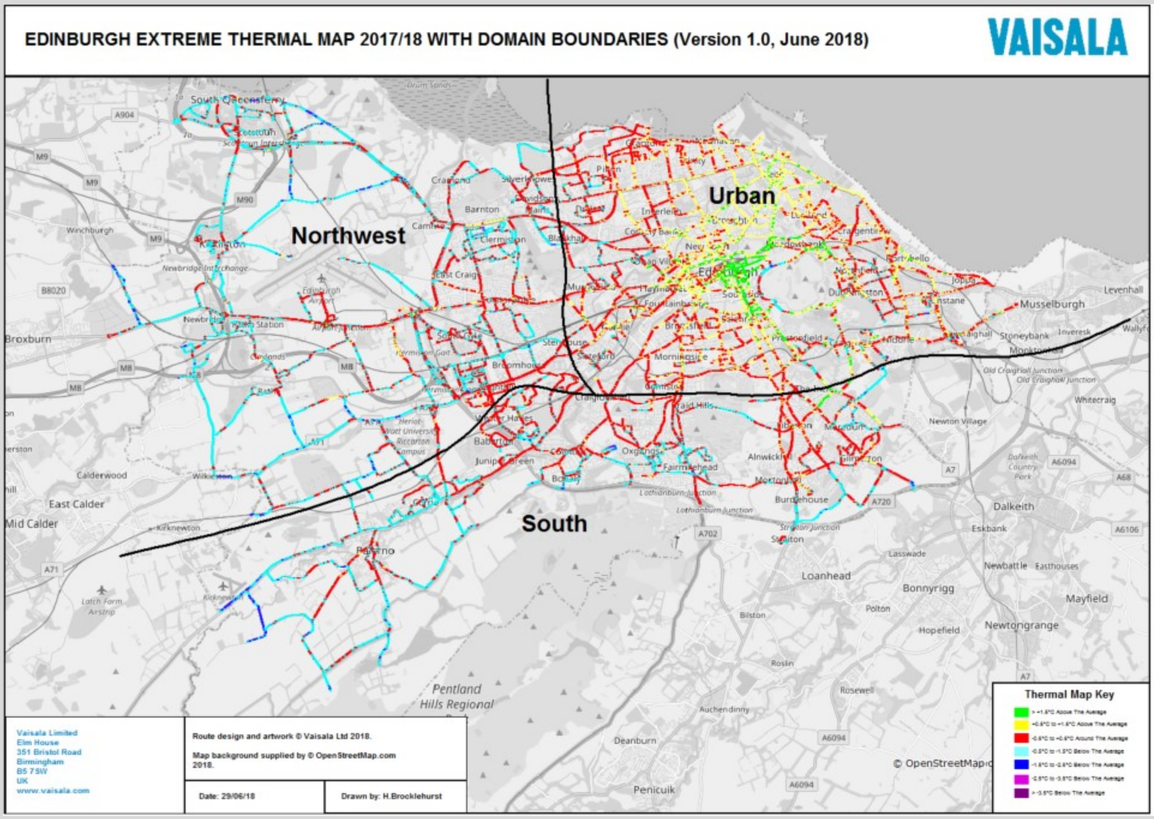


Figure 5.1. The Extreme Thermal Map showing the current weather stations along with recommended Climatic Domain boundaries. Map: © OpenStreetMap, CC-BY-SA.

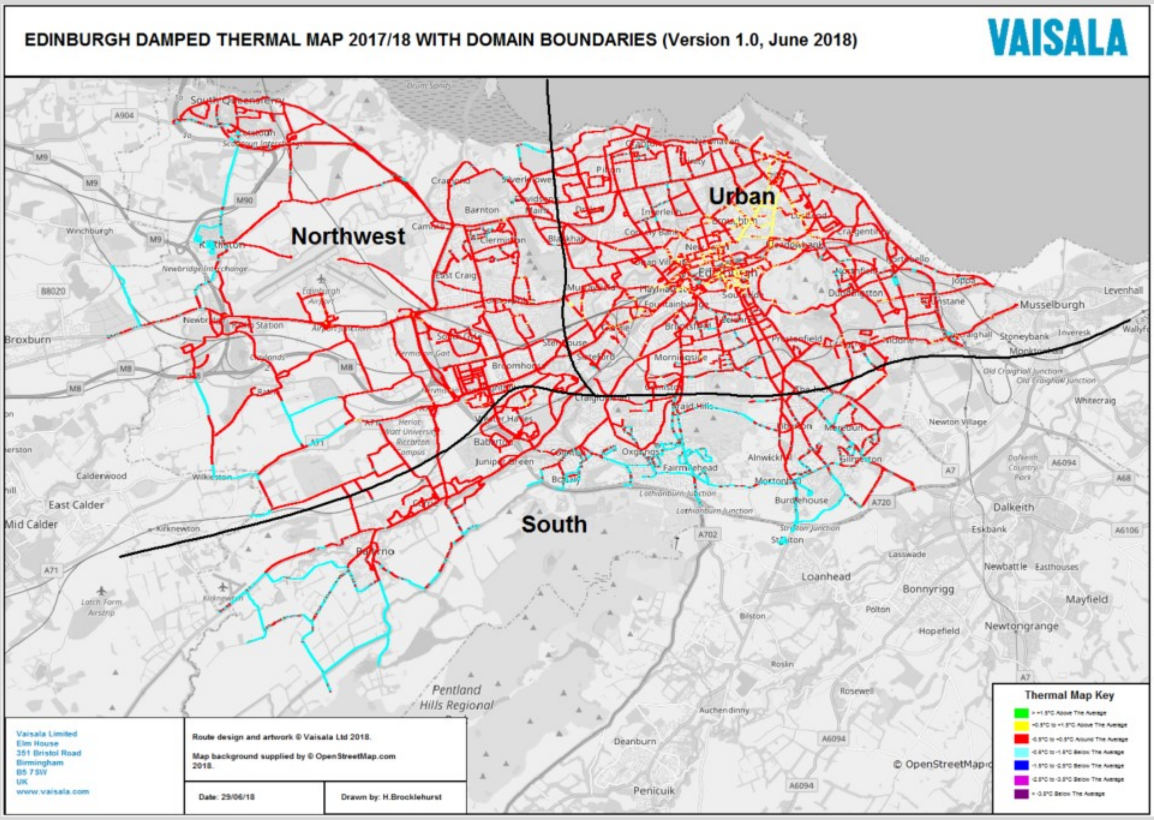


Figure 5.2. The Damped Thermal Map showing the current weather stations along with recommended Climatic Domain boundaries. Map: © OpenStreetMap, CC-BY-SA.

Appendix A: Thermal Mapping Theory

Thermal Mapping is a process by which the variations in minimum night time road surface temperatures (RSTs) are measured using a thermopile (an infrared temperature sensor). The sensor is mounted to a vehicle and connected to a data logger and GPS unit. Once the data has been collected and analysed the resulting Thermal Maps provide a representation of the variations in minimum RST along the road under different weather conditions, therefore revealing a pattern of warm and cold sections across the road network.

Variations in Road Surface Temperature

RSTs vary across the road network for a number of reasons. The weather is one of the overriding influences on RSTs, but other more permanent, non-meteorological factors also play a significant part, especially when looking at overnight temperatures. Even if two sections of road are experiencing the same weather, RSTs can still vary based upon these permanent factors. This section will look at the causes of variations in temperature and the influence of weather on RSTs.

Meteorological Variations

On a clear day heat is absorbed by the road surface in the form of incoming solar radiation. This heat is then slowly released overnight once the warming influence of the sun has disappeared. This creates a diurnal cycle of RSTs, with maximum temperatures normally occurring in the early afternoon and the minimum temperatures occurring just after dawn. The amount of incoming solar radiation will vary depending on, not only the time of day, but also the time of year and the amount of cloud.

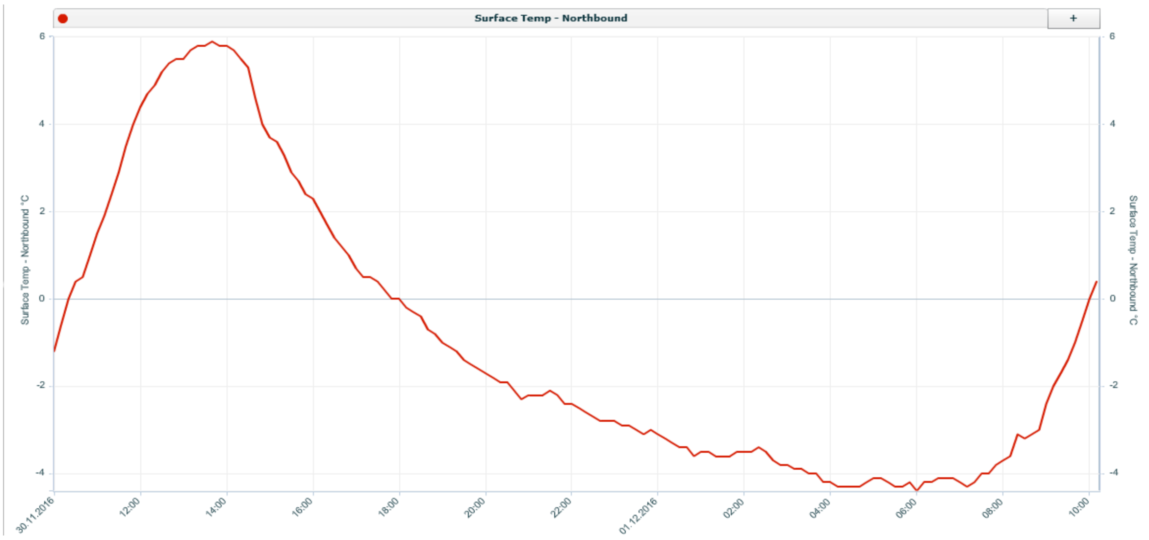


Figure A.1. RST graph showing extreme conditions with maximum daytime heating and maximum night time cooling

Clouds reflect and absorb solar radiation, thereby reducing the amount of direct solar radiation reaching the surface. They absorb heat not only from above, but also from below, due to re-radiation from the earth's surface. This absorbed heat is then re-radiated and at night this can prevent RSTs from falling as low as they would on a clear night when maximum heat can escape back into the atmosphere.

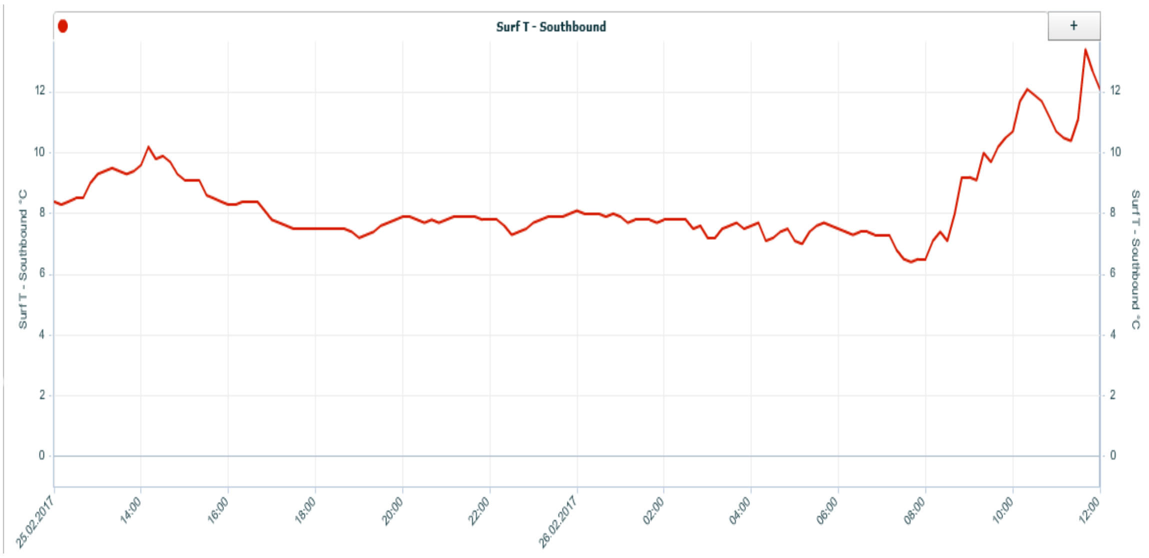


Figure A.2. RST graph showing damped conditions with minimal daytime heating and minimal night time cooling

These different weather conditions are categorised into three types: Extreme, Intermediate and Damped. Roads are surveyed on a selection of nights to assess to what degree the temperature varies in each of these weather conditions.



Extreme Nights

Extreme conditions produce the greatest degree of variation in RSTs. It occurs when skies are clear and wind speeds are very low. The absence of cloud and wind allow for maximum heat loss from road surfaces. In addition, the lack of any significant mixing of air layers allows katabatic drainage (cold air pooling) to occur and the generation of temperature inversions as cooler ground surfaces chill the air immediately above them so that the usual decrease of temperature with height is reversed. This weather scenario is usually associated with anticyclonic (high pressure) systems.

Damped Nights

These conditions represent the opposite end of the weather spectrum, consisting of total low level (below 2000m) cloud cover and moderate or stronger wind speeds. This produces a significantly reduced (or damped) variation in RST. Similar results can also be obtained with lower wind speeds if conditions have remained cloudy throughout the preceding day. This kind of weather is commonly associated with low pressure systems, which often bring associated bands of precipitation.

Intermediate Nights

Intermediate conditions are typically the result of either: a) medium to high level cloud cover with the absence of significant wind, or b) clearer skies with moderate wind speeds. These two situations produce similar results in that the degree of variation of RST is reduced from that found under Extreme conditions but is greater than that found under Damped conditions. Intermediate surveys are associated with nights where changeable conditions are experienced. Therefore, an algorithm that has been developed by Vaisala is used to ensure the consistency of the map in comparison with the result of the other conditions.

Non-Meteorological Factors

As well as the weather, there are a number of permanent factors that can affect the spatial variation of night time RSTs. Each of these factors have a bearing on the distribution of RSTs but they rarely act in isolation and the RST at any given point is a complex interaction of a number of factors.

Sky View Factor

Sky view factor relates to the amount of “visible sky” and is used to determine the maximum incoming solar radiation that could reach the road surface. It ranges from 0 when none of the sky is visible (e.g. inside a tunnel) to 1 when there are no obstructions visible (e.g. an open hilltop).

The sky view factor depends upon the presence of trees, building cover and topography, which reduce the incoming solar radiation to the surface via shading. At night, low sky view will allow heat to be trapped close to the road surface, keeping the surface temperatures a little warmer.

Altitude

Normally, the higher the altitude, the lower you would expect the minimum road temperature to be. This is the result of the environmental lapse rate (the fall of air temperature with height) which is usually about 6°C per 1000m in altitude. On calm, clear nights, it is possible for lower temperatures to be found at lower altitude in valley bottoms. This is due to the formation of inversions or the pooling of cold dense air, which sinks under the influence of gravity through the process of katabatic drainage.

Water Bodies

Water has the capacity to maintain heat for a longer period of time after sunset than land. The influence that a water body can have on an adjacent air mass, and subsequently on RSTs in the nearby area is most apparent in coastal regions, where RSTs tend to be warmer in close proximity to the shoreline. The same trend can be noted on a more localised scale in the presence of lakes and rivers.

Road Construction

Changes in road construction provide a significant contribution to the varying characteristics of RSTs. Different construction materials, age and surface dressing type across carriageways will result in differing relative RSTs. Concrete, for example, retains heat stored through the day and gradually emits the heat over night, as a result concrete sections of road can be warmer than other surfaces.

Bridge Decks

Where a road crosses a bridge it is likely to be cooler due to its shallower construction and as a result it will possess a smaller thermal memory. The bridge deck will lose heat upwards into the atmosphere, like a normal road surface, but will also be cooling from below as air circulates under the bridge. In addition, bridges contain a large amount of metal, which loses heat quickly overnight.

Urban Heat Island

The urban heat island effect is the name given to the phenomenon observed in towns and cities whereby the built-up area can be several degrees warmer than the suburbs or surrounding rural area. The temperature difference between urban and rural areas is the result of industrial and domestic heat sources within the town or city, allied to the fact that the fabric of the urban environment, including roads, will retain heat to a greater degree than a rural area. This is the result not only of the construction materials but also the urban architecture and lower sky view factor. Within the city, the heat island effect means that topography, weather and traffic are usually less influential on RST than on other non-urban roads.

Traffic

Traffic tends to keep roads warm at night, offsetting the loss of heat by radiation. Traffic also stirs the air above the surface, promoting the mixing of warmer air with colder layers nearby, limiting cooling on calmer nights. In addition, frictional heat generated by vehicle tyres and the gaining of heat from engines and exhausts helps to keep roads with higher traffic flows warmer than less heavily trafficked roads. Minimum RSTs can also vary across the carriageways on motorways and dual carriageways. Differences between lanes of up to 1.5°C can occur due to the differences in the volume of traffic in each carriageway. Vehicles tend to concentrate in the nearside lane and at night these lanes are generally warmer than the outside lanes and slip roads. This phenomenon is most significant on roads with high traffic volumes at night.

Climatic Domains


Due to the large size of many road networks, it cannot be assumed that the weather will be the same across the entire region. It is therefore possible that whilst one part of the region may be experiencing Extreme conditions, another may be experiencing Intermediate, or even Damped conditions, due to a changing meteorological situation.

In order to represent this variation it is necessary to sub-divide the road network into smaller areas referred to as Climatic Domains. The extent of a Climatic Domain and the number of climatic areas covering a particular network is dependent upon the proximity of geographical features likely to influence the weather over the network. These could include the proximity to large bodies of water, such as lakes and sea or high ground, and the prevailing wind direction. In each Climatic Domain it would be expected that similar weather conditions could be experienced at any one time.

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