How do we verify a route based forecast?

D.S. Hammond, L. Chapman & J.E. Thornes
University of Birmingham, UK

14th Standing International Road Weather Conference
14th May 2008, Prague
Introduction

• What is route based forecasting

• Existing Verification Techniques

• Incorporating Existing Verification Technology into the new route based forecasting paradigm

• Statistical Technique using Hierarchical Clustering – Case Study from Leicestershire, UK
What is route based forecasting?

“Route based forecasting is a service that delivers individual forecasts of Road Surface Temperature and Road Surface Condition for each salting route within a client’s road network.” (Hammond, 2008)
What is route based forecasting?

• No longer a site specific forecast with interpolation from thermal maps

• No two nights are the same – e.g. the extent to which cloud cover is present at a given geographic location
What is route based forecasting?

- Route based forecasts model the influence of meteorological, geographical and infrastructure parameters on RST and RSC on a night by night basis.
- Route based forecasts aim to resolve rather than simplify a complex reality.
Verifying route based forecasts – the current problem

- WSI route based forecasting service - forecasts RST and RSC every 50m → 32 forecast points per mile of road!
- Users need confidence that the model can accurately predict RST and RSC at every forecast point
- Requires the accuracy of forecasts around routes and away from sensor sites to be verified
- Need to verify the **spatial variation of RST** around routes
Existing Verification Techniques

Road Outstations

- Traditional verification source for site specific forecasts
Existing Verification Techniques

Road Outstations

• Calibration issues

• Spot measurement – no information on spatial variation of RST

• Spot measurements can be useful for verifying problematic sites within a route based forecast – thermal singularities

• Not economically viable to install outstations at all thermal singularities
Existing Verification Techniques

Remote Infrared Temperature Sensors

- Lower cost
- Solar powered / mobile communications
- Greater network coverage possible
Existing Verification Techniques

Remote Infrared Temperature Sensors

- Measurement errors due to traffic
- Clear sky algorithms not perfect
- Spot measurement
- Thousands needed to achieve required spatial resolution
Existing Verification Techniques

Thermal Mapping

• Thermally mapping the road network with a vehicle mounted IR sensor provides a data set describing the variation of RST around a road network

• With strict quality control most errors associated with the technique can be minimised or eliminated altogether

• Technique successfully used for verifying route based forecasts since 2001
**Existing Verification Techniques**

**Thermal Mapping**

- Thermal mapping is time consuming!
- Surveys restricted to a small time window
- Growing demand for verification data as more highway authorities adopt route based forecasting services
- Increased strain on current resources
- A new robust, reliable, rapid and cost effective verification technique is required
Incorporating existing verification technology into the new route based forecasting paradigm

A statistical approach using Hierarchical Clustering
Why choose clustering?

• WSI’s spatial modelling approach takes into account numerous meteorological, geographical and infrastructure parameters

• Possible to group forecast points into clusters

• All points within a single cluster share similar geographical and thermal characteristics

• Potential for shorter survey routes for verification, leading to significant cost and time savings for thermal surveying
The Study Route
The Study Route
The Study Route
Verification Data Set

• Study route thermally surveyed on 20 nights between January and March 2008

• Route based forecasts then generated for the study route using WSI’s spatial modelling approach
### Summary Statistics

<table>
<thead>
<tr>
<th>Date</th>
<th>Bias</th>
<th>SD of Bias</th>
<th>RMSE</th>
<th>% residual forecast within ±1°C of residual actual</th>
<th>SD of thermal data (Stability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-Jan-08</td>
<td>1.04</td>
<td>0.78</td>
<td>1.30</td>
<td>82.94</td>
<td>0.78 (Intermediate)</td>
</tr>
<tr>
<td>24-Jan-08</td>
<td>0.15</td>
<td>0.93</td>
<td>0.94</td>
<td>67.69</td>
<td>1.09 (Extreme)</td>
</tr>
<tr>
<td>29-Jan-08</td>
<td>-2.23</td>
<td>0.66</td>
<td>2.33</td>
<td>88.53</td>
<td>0.70 (Intermediate)</td>
</tr>
<tr>
<td>31-Jan-08</td>
<td>0.44</td>
<td>0.80</td>
<td>0.91</td>
<td>79.35</td>
<td>0.87 (Intermediate)</td>
</tr>
<tr>
<td>03-Feb-08</td>
<td>-2.44</td>
<td>0.62</td>
<td>2.52</td>
<td>90.49</td>
<td>0.37 (Damped)</td>
</tr>
<tr>
<td>08-Feb-08</td>
<td>1.05</td>
<td>0.88</td>
<td>1.37</td>
<td>77.81</td>
<td>0.97 (Extreme)</td>
</tr>
<tr>
<td>09-Feb-08</td>
<td>0.68</td>
<td>1.18</td>
<td>1.36</td>
<td>63.73</td>
<td>1.19 (Extreme)</td>
</tr>
<tr>
<td>10-Feb-08</td>
<td>0.63</td>
<td>1.21</td>
<td>1.36</td>
<td>60.75</td>
<td>1.23 (Extreme)</td>
</tr>
<tr>
<td>11-Feb-08</td>
<td>0.16</td>
<td>1.18</td>
<td>1.19</td>
<td>61.07</td>
<td>1.19 (Extreme)</td>
</tr>
<tr>
<td>12-Feb-08</td>
<td>0.15</td>
<td>1.38</td>
<td>1.39</td>
<td>52.45</td>
<td>1.42 (Extreme)</td>
</tr>
<tr>
<td>14-Feb-08</td>
<td>-4.24</td>
<td>0.55</td>
<td>4.27</td>
<td>93.38</td>
<td>0.47 (Damped)</td>
</tr>
<tr>
<td>15-Feb-08</td>
<td>-0.35</td>
<td>0.89</td>
<td>0.96</td>
<td>73.89</td>
<td>0.75 (Intermediate)</td>
</tr>
<tr>
<td>16-Feb-08</td>
<td>-2.75</td>
<td>1.19</td>
<td>2.99</td>
<td>61.68</td>
<td>0.95 (Extreme)</td>
</tr>
<tr>
<td>17-Feb-08</td>
<td>-1.12</td>
<td>1.20</td>
<td>1.64</td>
<td>61.07</td>
<td>1.14 (Extreme)</td>
</tr>
<tr>
<td>20-Feb-08</td>
<td>-1.40</td>
<td>0.59</td>
<td>1.52</td>
<td>91.00</td>
<td>0.73 (Intermediate)</td>
</tr>
<tr>
<td>26-Feb-08</td>
<td>0.94</td>
<td>0.72</td>
<td>1.19</td>
<td>85.78</td>
<td>0.86 (Intermediate)</td>
</tr>
<tr>
<td>27-Feb-08</td>
<td>-0.56</td>
<td>0.96</td>
<td>1.11</td>
<td>70.26</td>
<td>1.00 (Extreme)</td>
</tr>
<tr>
<td>12-Mar-08</td>
<td>1.44</td>
<td>0.69</td>
<td>1.60</td>
<td>87.09</td>
<td>0.73 (Intermediate)</td>
</tr>
<tr>
<td>17-Mar-08</td>
<td>-4.25</td>
<td>0.92</td>
<td>4.35</td>
<td>69.70</td>
<td>0.62 (Intermediate)</td>
</tr>
<tr>
<td>18-Mar-08</td>
<td>-1.10</td>
<td>0.98</td>
<td>1.47</td>
<td>68.16</td>
<td>1.08 (Extreme)</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.69</td>
<td>0.92</td>
<td>1.79</td>
<td>74.34</td>
<td></td>
</tr>
</tbody>
</table>
Hierarchical Clustering

• Forecast & actual RST values for each 50m forecast point were grouped into 10, 20, 30 and 100 clusters

• Metric and clustering algorithms used to link pairs of objects with similar characteristics into binary clusters

• Newly formed binary clusters then linked to other objects to create larger clusters until all objects in the original data set are linked together in a hierarchical tree
Hierarchical Clustering

Cophenetic distance

Data set objects (forecast points)
Hierarchical Clustering

For each set of clusters (10, 20, 30 & 100):

- 20 corresponding forecast and surveyed RST values were chosen from each cluster at random – clustered values

- A further 20 corresponding forecast and surveyed RST values were chosen at random from the entire data set – random values

- Statistical analysis of forecast accuracy then carried out for the clustered and random values and compared with the statistics for the entire data set
Hierarchical Clustering

% RESIDUAL FORECAST WITHIN 1DEG C OF RESIDUAL ACTUAL

---

Values

% RESIDUAL FORECAST WITHIN 1DEG C OF RESIDUAL ACTUAL

population mean for entire data set (17-Feb-08)
Conclusions

• With 100 clusters a route based forecast can be verified with a good degree of accuracy – potential cost savings for thermal surveying

• Further research required to fully test the robustness of such a technique

• Outstations / remote infrared sensors useful for verifying forecast models at locations identified as thermal singularities

• Statistical techniques are certainly worth further investigation – clustering, dimensionality reduction
References


