How do we verify a route based forecast?

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

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Introduction

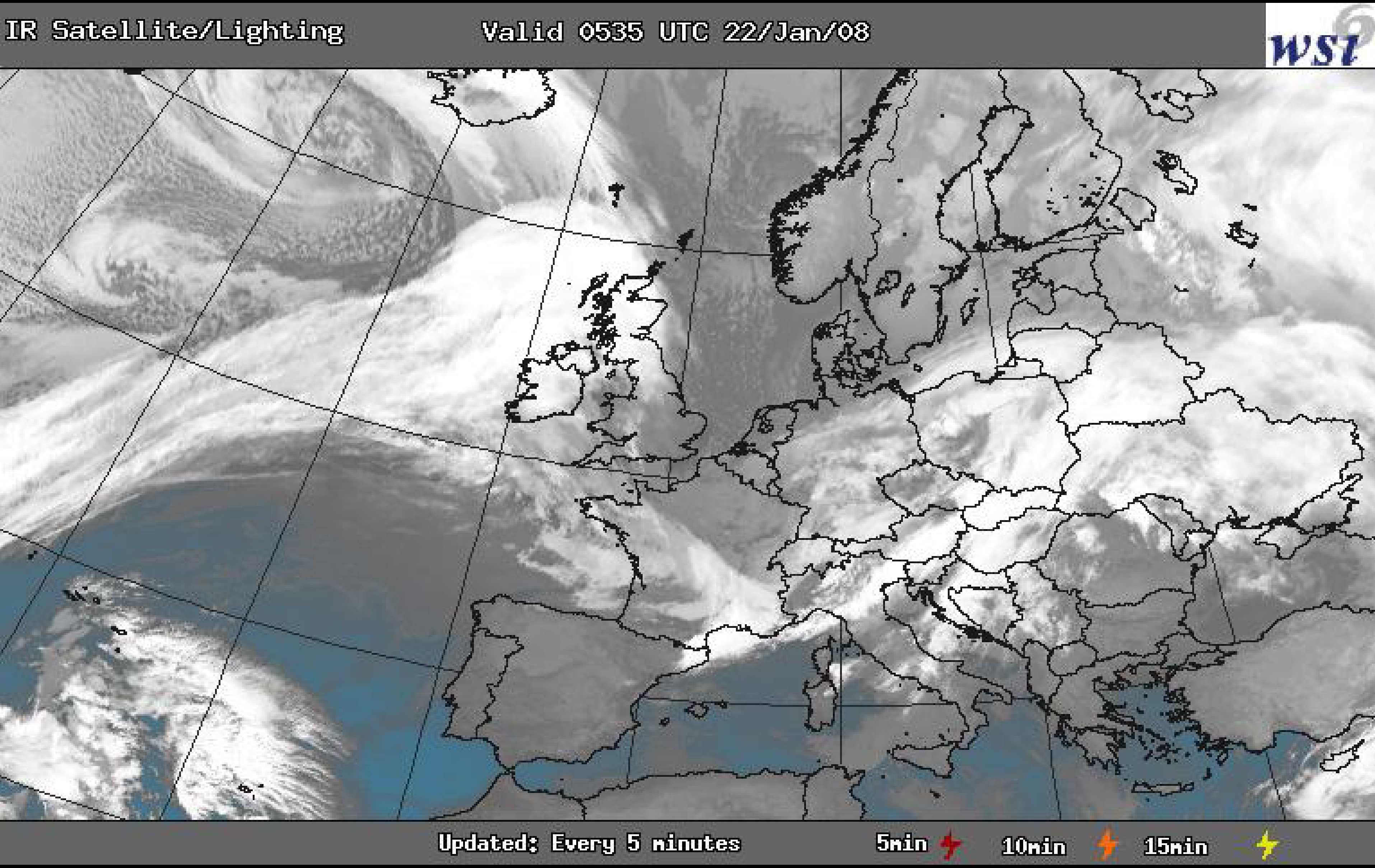
- What is route based forecasting
- Existing Verification Techniques
- Incorporating Existing Verification Technology into the new route based forecasting paradigm
- Statistical Technique using Hierarchical Clustering – Case Study from Leicestershire, UK

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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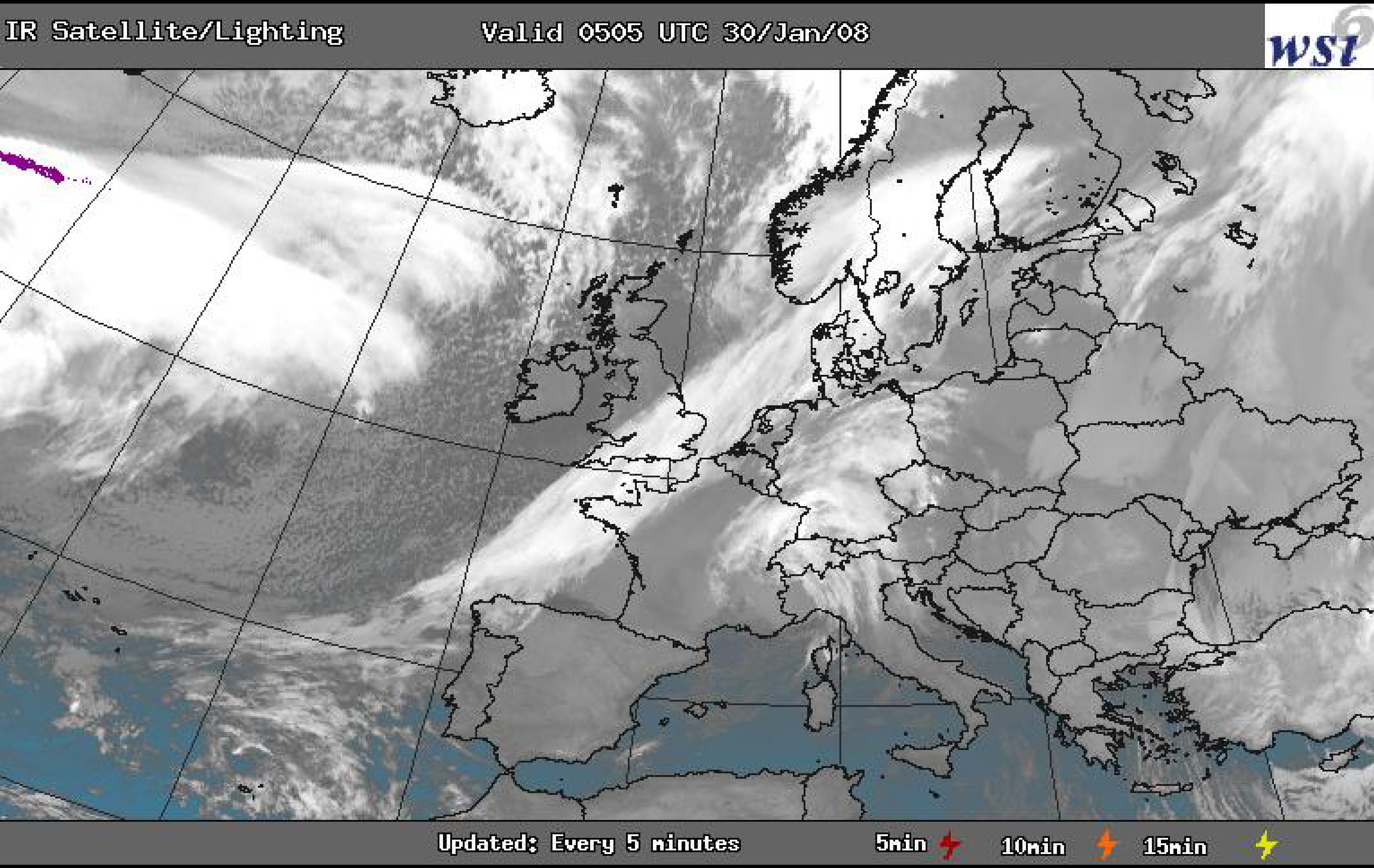
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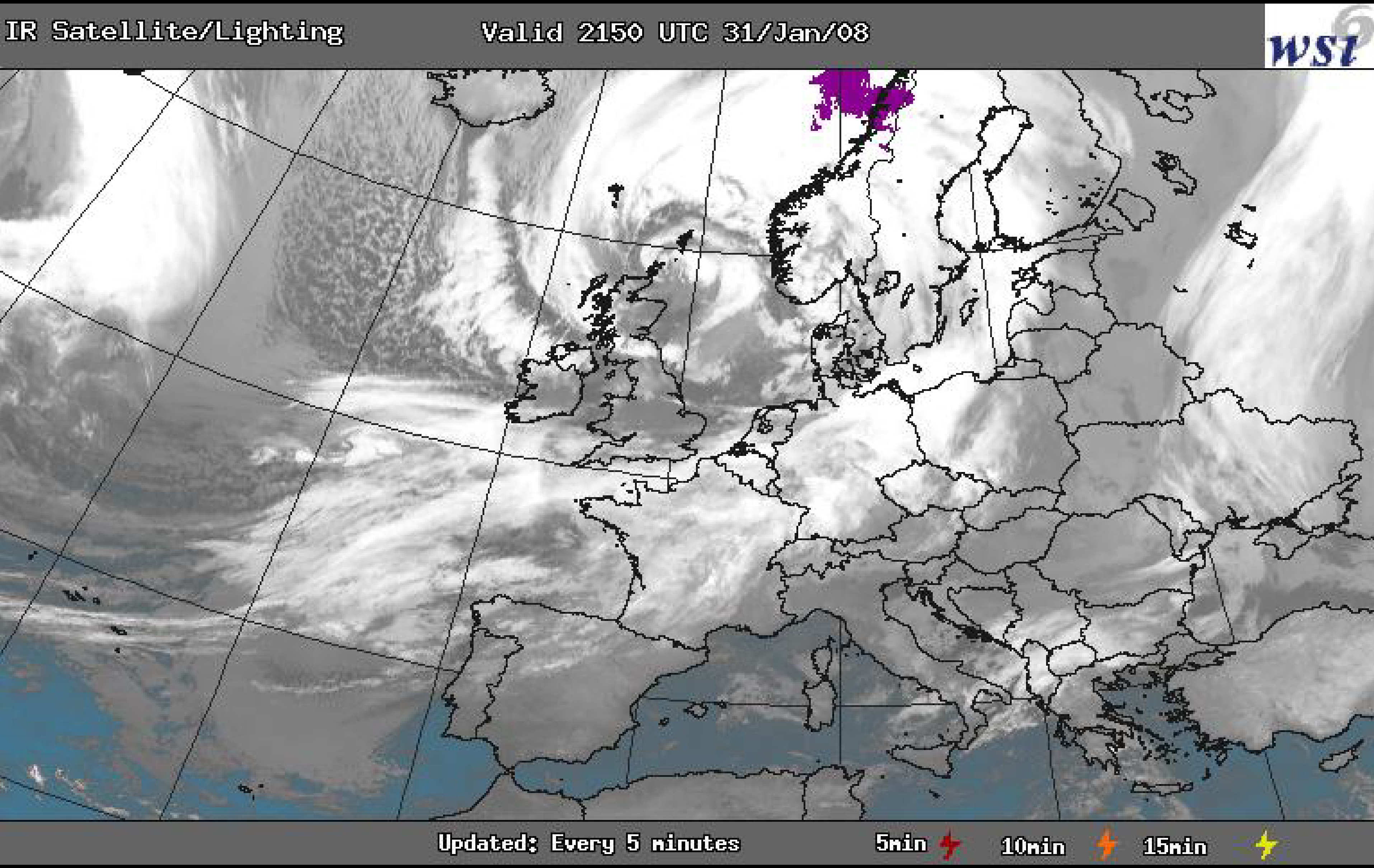

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What is route based forecasting?

- 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

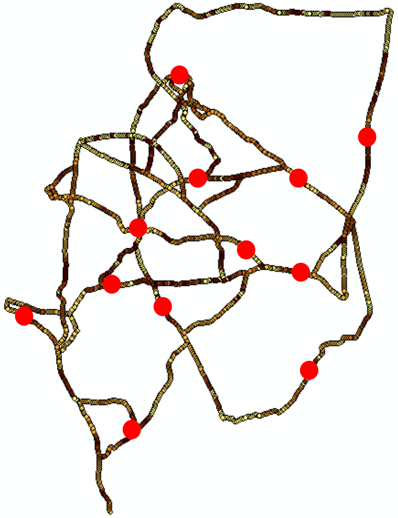
Existing Verification Techniques

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

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- Increased strain on current resources
- A new robust, reliable, rapid and cost effective verification technique is required

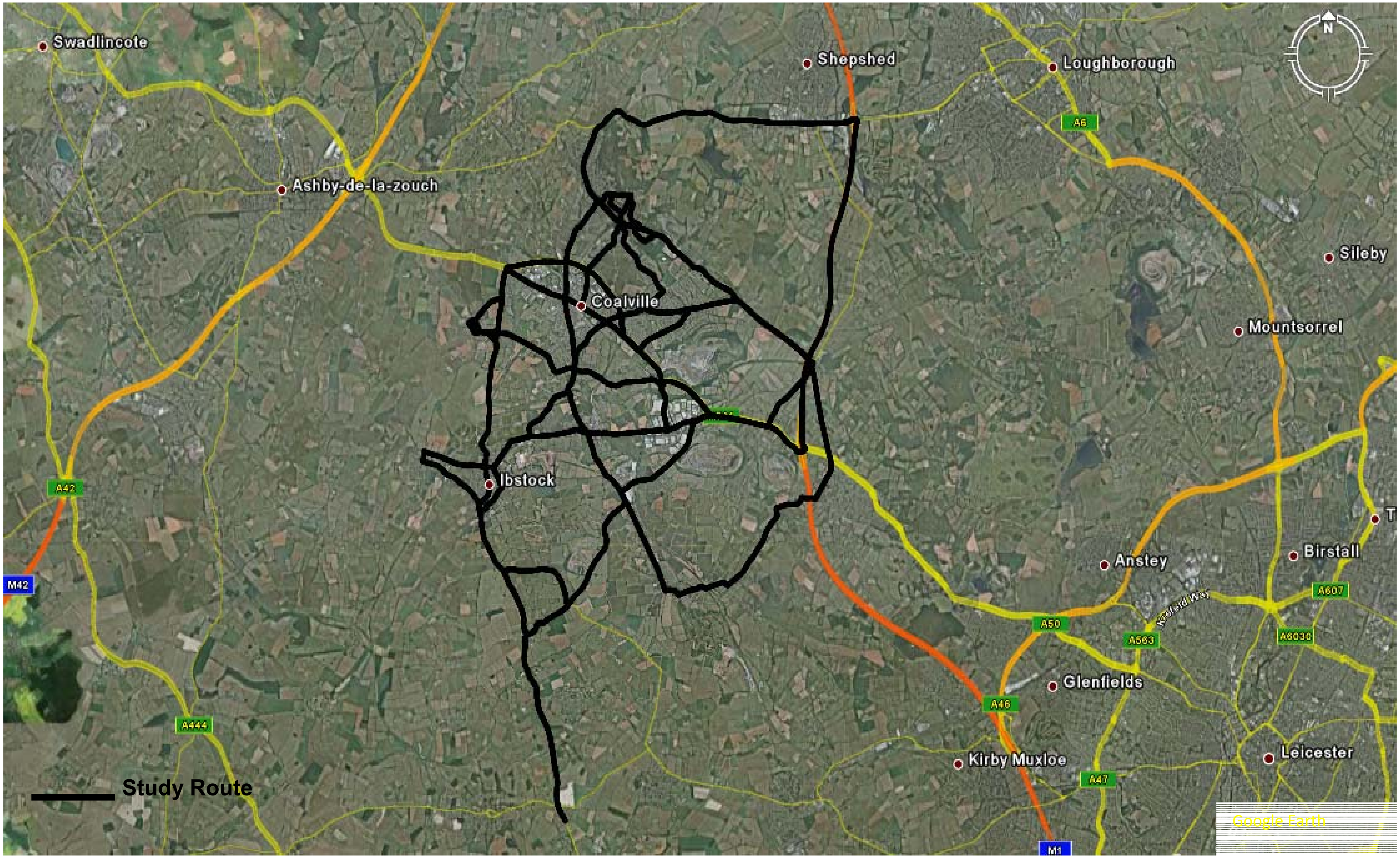
Incorporating existing verification technology into the new route based forecasting paradigm

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



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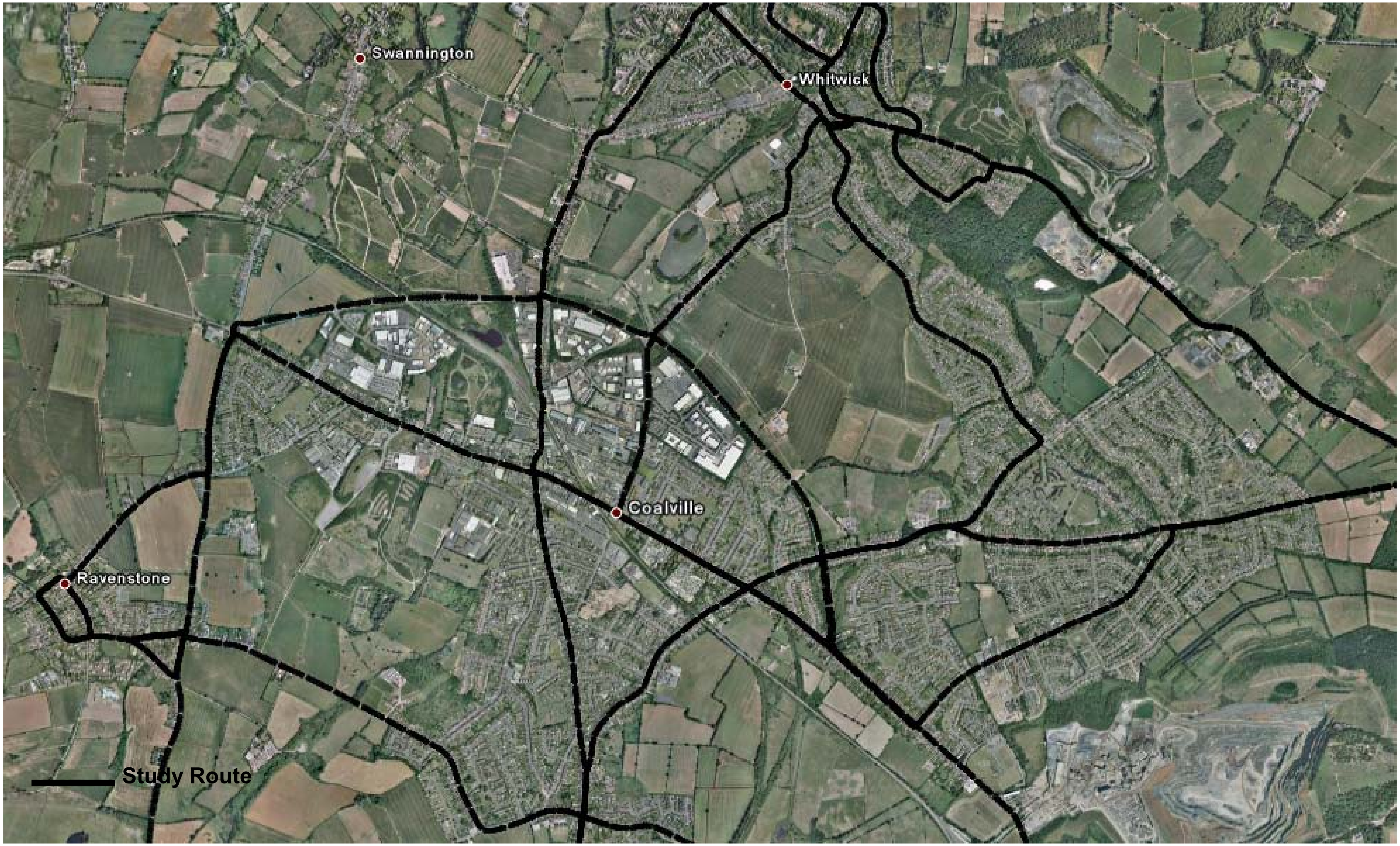
The Study Route



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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

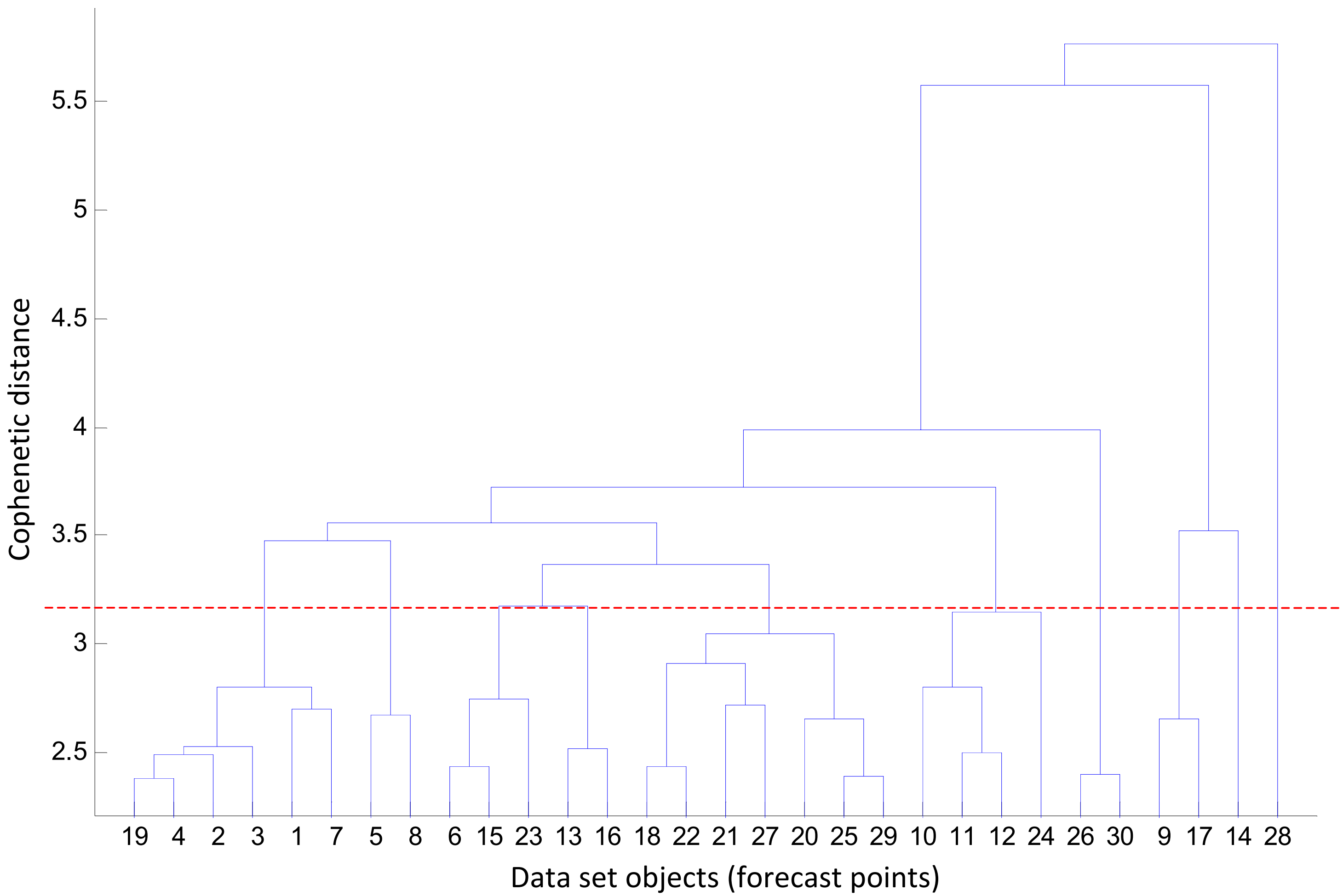
Summary Statistics

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

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



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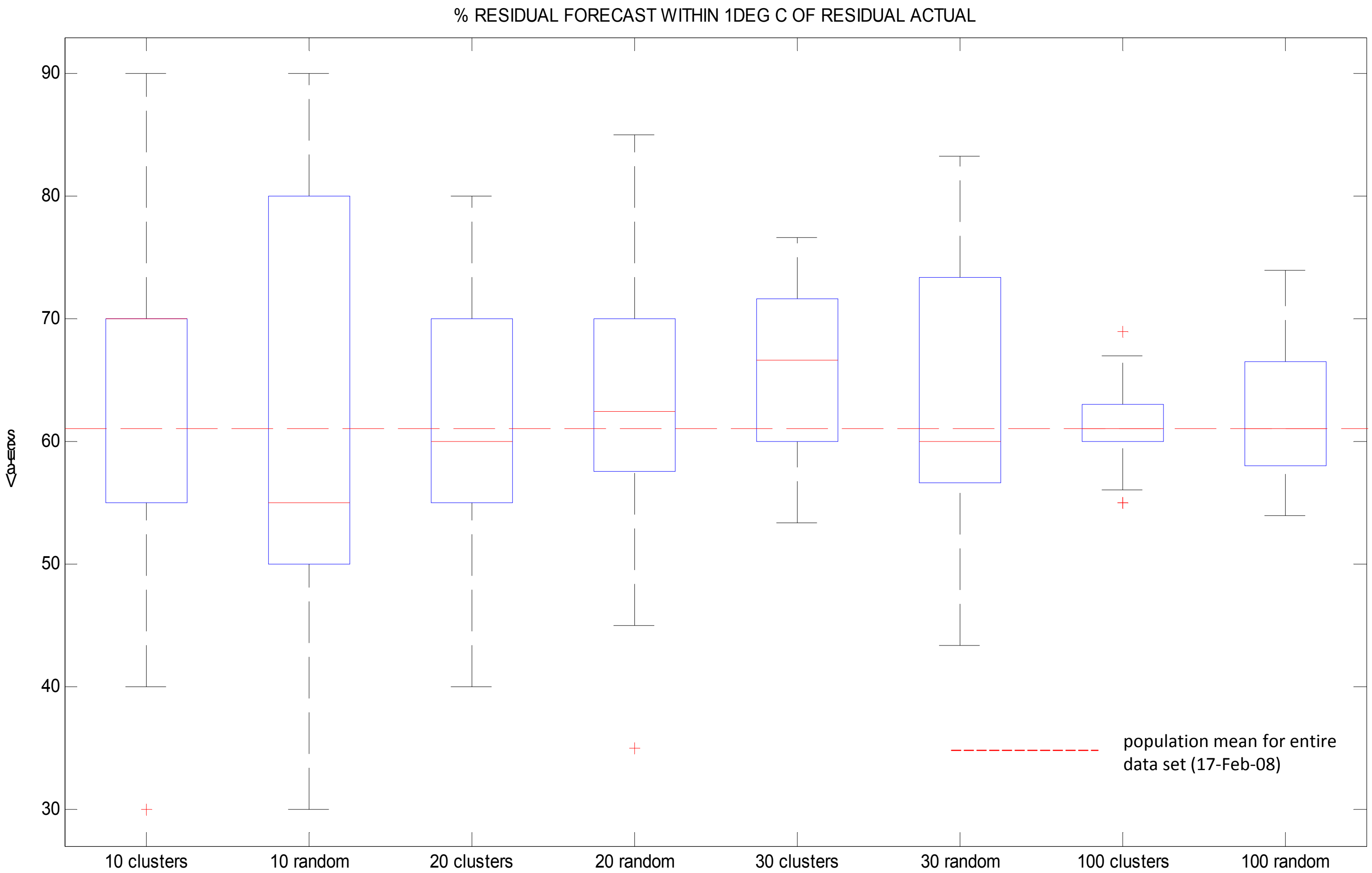
Hierarchical Clustering

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



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

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