Building climate resilience in the winter road maintenance sector. *Change is coming…*

Lee Chapman
Professor of Climate Resilience & Met Office Joint Chair
University of Birmingham, UK
l.chapman@bham.ac.uk

A little about me…

- Interested in the impact of weather and climate on the built environment
  - Urban Climate Impacts
  - Infrastructure Meteorology
    - Railway Buckling
    - Leaves on the line
    - Winter Road Maintenance
  - Climate Change
- Hold a joint chair with the UK Met Office

- Been at UoB since 1998!
  - PhD in Winter Road Maintenance
  - Run two university start-ups
  - Involved in all four UK Climate Change Risk Assessments

UNIVERSITY OF BIRMINGHAM

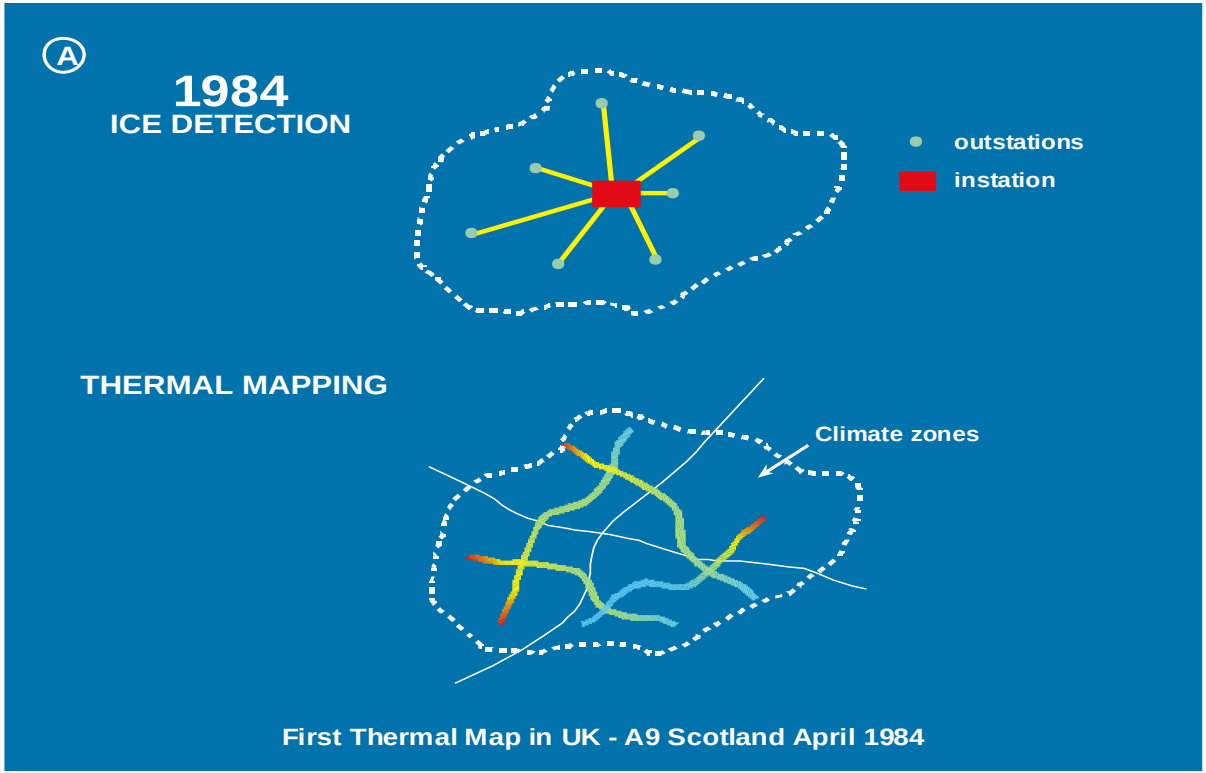
The importance of winter road maintenance

- Estimated UK spend is £1500m+ in a normal winter
- Salt corrodes £200m+ of structures each year
- Disruption in Winter 2010/11 was estimated to cost the economy over £600m per day.
- Cost:Benefit is estimated at 1:9

- Where would we be without road weather forecasts?

40 years ago

1980s
1990s
2000s
2010s
2020s
2030s
2040s



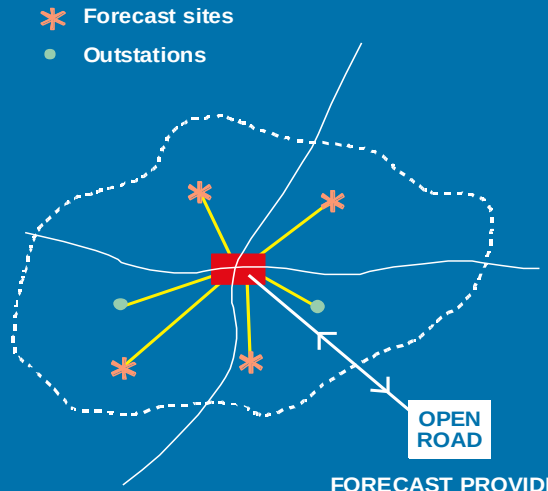
40 years ago

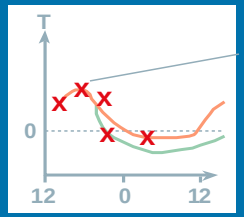
1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

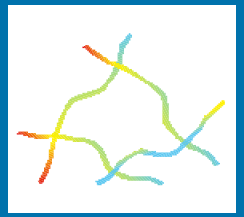
"*Road surface temperatures are expected to fall below zero at 2 a.m. and ice is expected to form on most of the roads in the region.*"

1980s
1990s
2000s
2010s
2020s
2030s
2040s

Ⓑ 1986 ICE PREDICTION





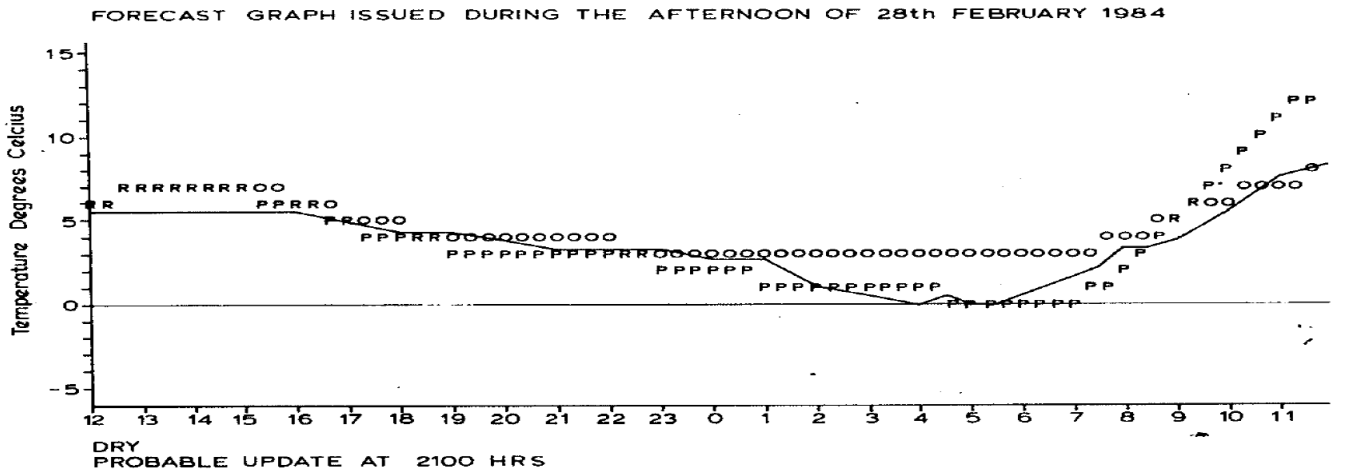


Minimum Road Surface Temperature

Forecast Thermal Maps

Probabilistic Forecasting (1980s style)

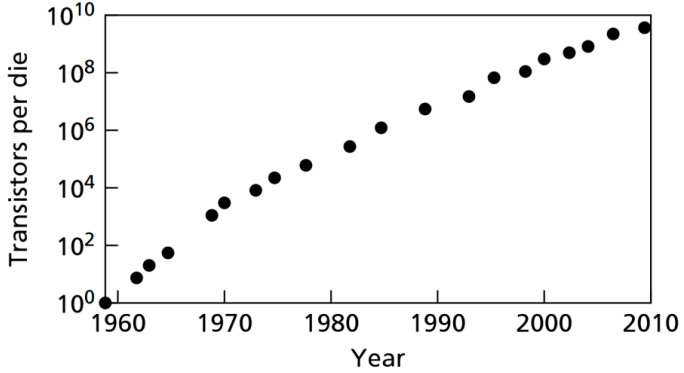
1980s
1990s
2000s
2010s
2020s
2030s
2040s



Deterministic Forecasts

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

- It was the best we could do
  - 30 mins to run a forecast for one site

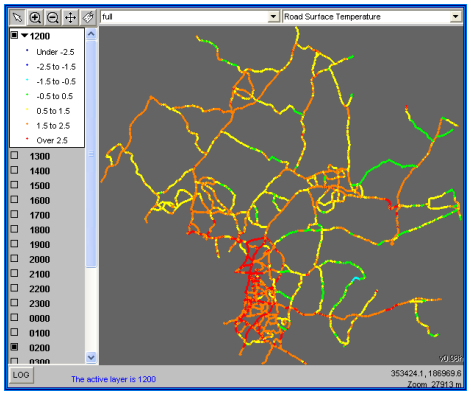


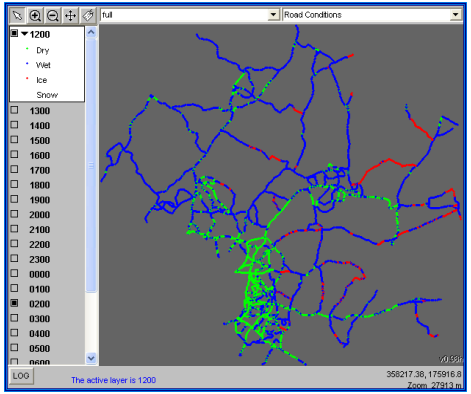
- Despite increasing computer power, road weather forecasts have remained deterministic in nature but...
- ...large advances in mesoscale models which drive the downscaling

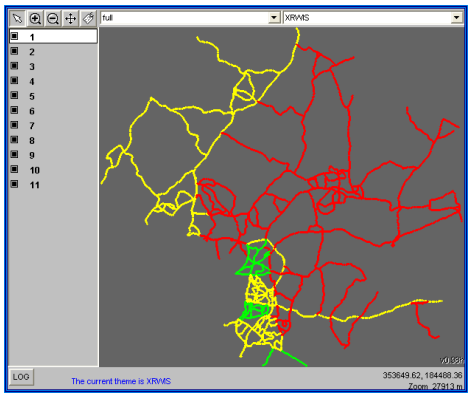
20 years ago

1980s
1990s
2000s
2010s
2020s
2030s
2040s

- Increasing computer power was instead been used by the winter road maintenance community in other ways:
  - Salting Route Optimisation }
  - Decision Support Systems } Selective Salting
  - Route Based Forecasting }







UNIVERSITY OF BIRMINGHAM

Route-based forecasting

1980s
1990s
2000s
2010s
2020s
2030s
2040s

- This is where I entered the fray…
- Invented route based forecasting for my PhD.
- Set up a spin-out company

entice technology

- We ran that for 4 years before selling to the then largest private weather company in the world
- Rival route-based forecasting products now mainstream
- Why did the idea prove popular?
- The savings were tantalising -
  - Selective Salting was now a real possibility but…


US007089115B2

(12) **United States Patent**
Chapman et al.

(10) **Patent No.: US 7,089,115 B2**
(45) **Date of Patent: Aug. 8, 2006**

(54) **ROAD WEATHER PREDICTION SYSTEM AND METHOD**

(75) Inventors: **Lee Chapman**, Birmingham (GB); **John Edward Thornes**, Worcestershire (GB)

(73) Assignee: **Entice Technology Limited**, Birmingham (GB)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 138 days.

(21) Appl. No.: **10/485,430**

(22) PCT Filed: **Jul. 31, 2002**

(86) PCT No.: **PCT/GB02/03521**

§ 371 (c)(1),
(2), (4) Date: **Aug. 16, 2004**

(87) PCT Pub. No.: **WO03/012485**

PCT Pub. Date: **Feb. 13, 2003**

(65) **Prior Publication Data**

US 2005/0010365 A1 Jan. 13, 2005

(30) **Foreign Application Priority Data**

Aug. 2, 2001 (GB) 0118853.1

(51) **Int. Cl.**
G01W 1/00 (2006.01)

(52) **U.S. Cl.** **702/3**

(58) **Field of Classification Search** 702/2, 702/3, 4, 5

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,675,081 A 10/1997 Solheim et al. 73/170.28
6,085,152 A * 7/2000 Doerfel 702/3
6,990,410 B1 * 1/2006 Boright et al. 702/3

FOREIGN PATENT DOCUMENTS

JP 09114371 5/1997
JP 11064536 3/1999
JP 2001051069 2/2001

OTHER PUBLICATIONS

XP-002240949; Site-specific Road Condition Forecast for Maintenance Services; J. Heierli; pp. 1-6.

(Continued)

Primary Examiner—Donald McElheny, Jr.
(74) *Attorney, Agent, or Firm*—Wells St. John P.S.

(57) **ABSTRACT**

In one aspect, the present invention relates to a method of determining the sky-view factor at a location. The method comprises the steps of receiving data from at least one global positioning satellite at the location, and comparing the data so obtained with a mathematical function. The function is derived from corresponding data obtained from reference locations at which the sky view factor is known, whereby to arrive at an approximation of the sky view factor at said location. In another aspect, the invention relates to a method for predicting the variation in temperatures over time at locations along a survey route, particularly a road network. The method comprises the steps of establishing a database for the survey route containing location specific geographical parameters, obtaining actual and forecast meteorological data and separately predicting the temperature at each location using energy balance equations. The predicted temperature calculated for each location is dependent upon the meteorological and the geographical parameters for the location whose temperature is being predicted. The invention also discloses systems which relate to the above methods.

21 Claims, 12 Drawing Sheets

Now

- Despite all the technologies, selective salting is still not happening
- In an age of litigation, engineers are wary about relying on forecasts at this level of resolution

- Observations remain key…

Internet of Things

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

- Low-cost option for RST measurement that has the potential to be deployed at the same resolution as a route-based forecast
  - Based on the Internet of Things
  - Game Changing in network densification and confidence building

UNIVERSITY OF BIRMINGHAM

Wintersense

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

- My second winter road maintenance spin-out company.

- Sold in 2019 to Campbell Scientific Ltd who now market the product worldwide
- The market has finally caught up and rival products now exist from many providers

Many other sophisticated sensing options…

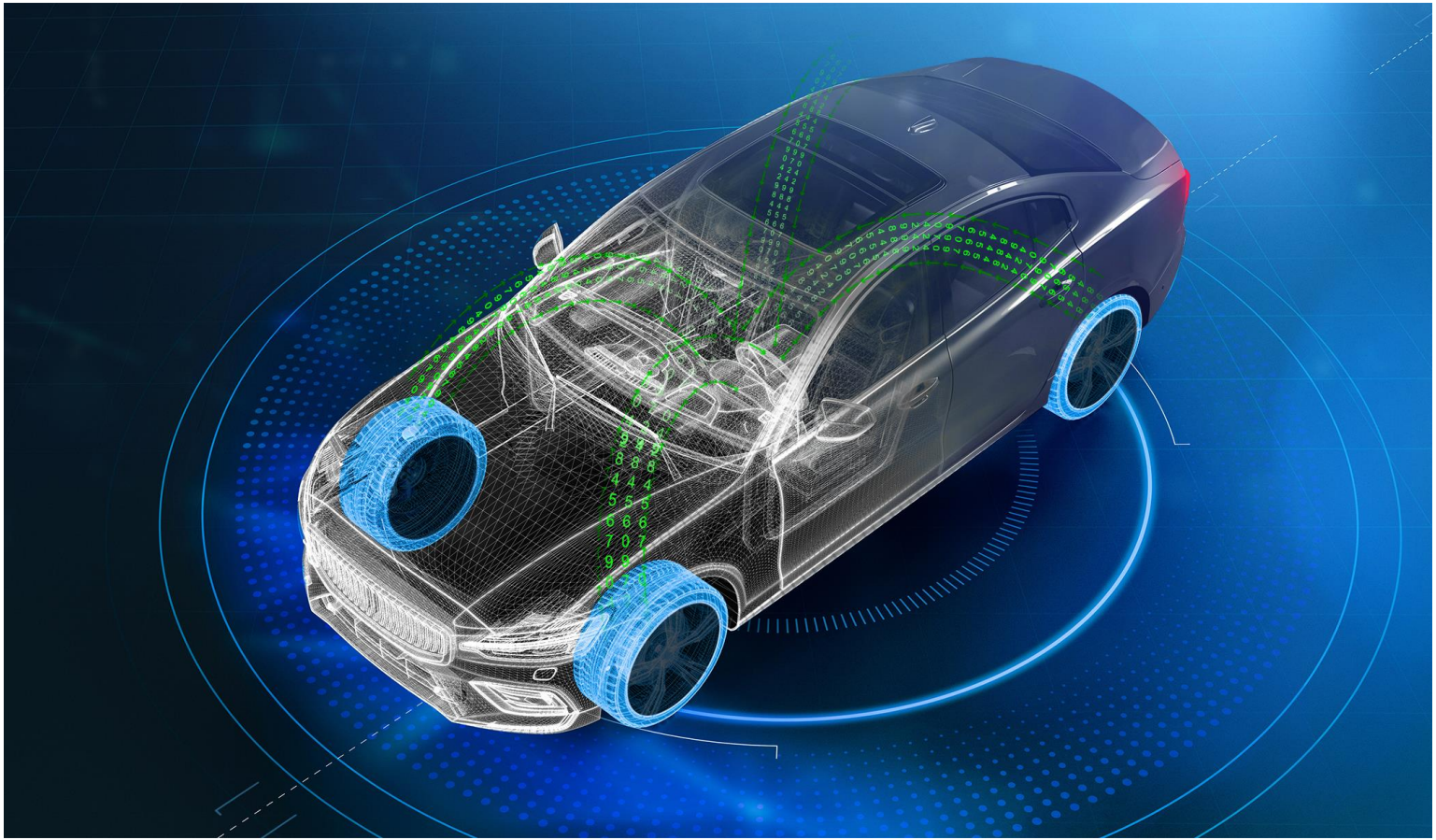
1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

Mobile

In Situ

Data from connected vehicles…

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	



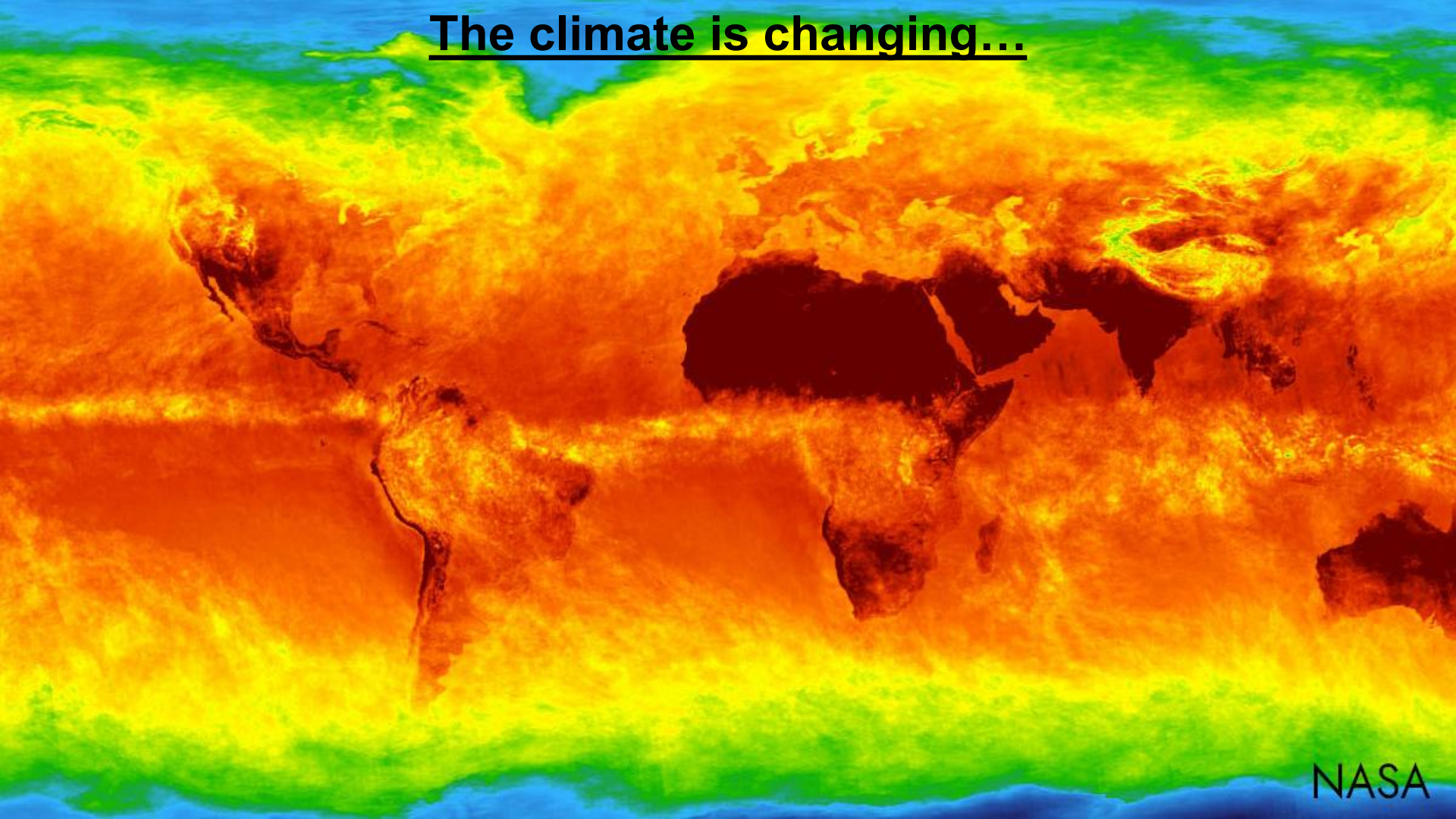
UNIVERSITY OF BIRMINGHAM

The rise of AI

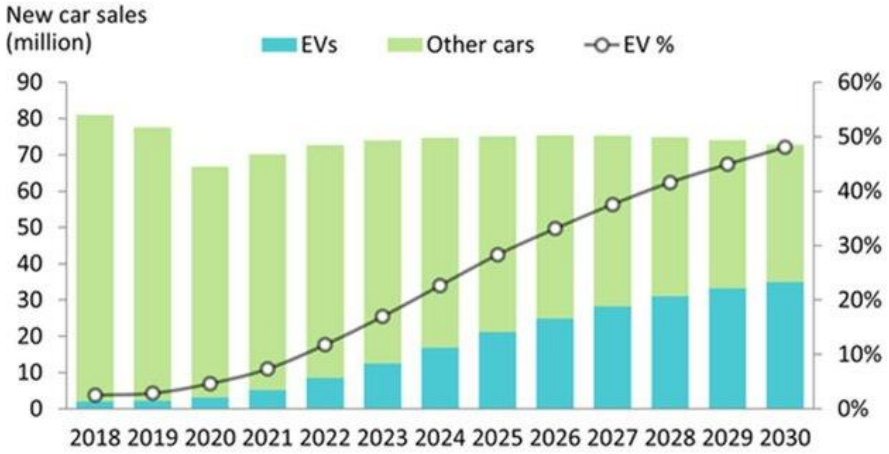
- All these new approaches are producing data at an unprecedented scale
- Not all the data is well structured
  - Lot of noise
- AI is unlocking the potential of this mass data collection
  - Nowcasting on the edge (IoT sensors)
  - Object recognition on sophisticated sensors
  - Making sense of Big Data collected from connected vehicles
- AI is already more than capable of replacing human weather forecasters…

- Has the pace of change ever been faster in the winter road maintenance sector?
- But it isn't the only thing changing…

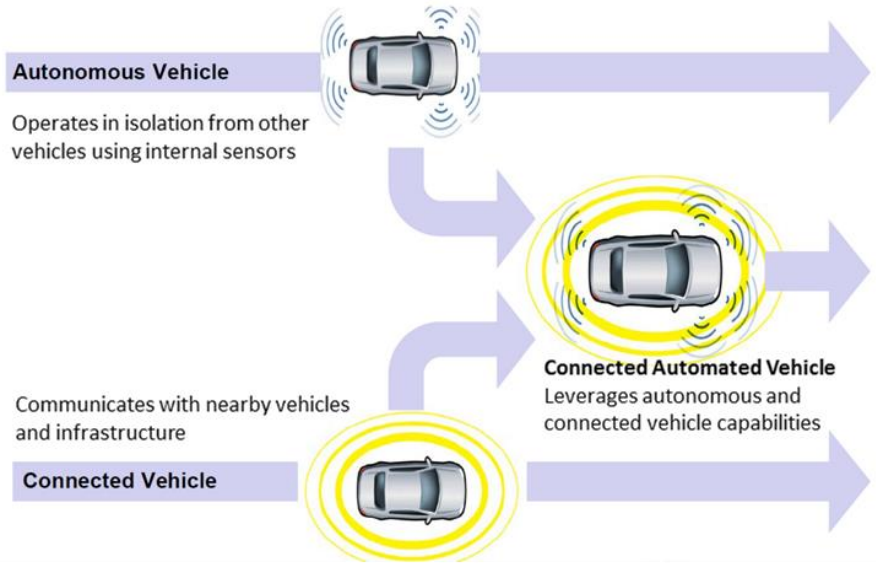
The climate is changing…



…and so are our vehicles



Latyshev et al (2021)



https://www.nevadadot.com/mobility/avcv

"As of the end of April 2024, there are now 1,100,000 fully electric cars on UK roads and a further 655,000 plug-in hybrids."
https://www.zap-map.com/

UNIVERSITY OF BIRMINGHAM

Autonomous Vehicles

1980s
1990s
2000s
2010s
2020s
2030s
2040s

- ECVs are just the precursor to AVs
- Not a case of if, but when…
  - Change will be quick – like flipping a switch
- A lack of data will no longer be a problem
  - Every vehicle on the road will be a data goldmine
- But what are the other implications?

What does this mean?

- The climate will undoubtedly be more variable and extreme

- However, the capabilities of vehicles are markedly different to today
- Taken together – the management of the risk is going to need to evolve…

What will a future winter road maintenance service look like?

Are electric and autonomous vehicles more or less resilient to the weather than their fossil fuel predeccesors?

Weather Risks on ECAV's

	Electric / Connected Vehicle Risks	Additional Issues for AV	Considerations / Mitigations *
High Temperatures	• Reduced range due to cabin cooling • Melting roads will impact roll resistance also reducing range • Increased cooling of components requiring further drain (overheating risks) • Battery degradation in heat, reducing their lifespan • Increased demand on energy grid for cooling may impact supply.		• Battery thermal management systems may help, but will also require increased power. • Parking / charging in covered areas during extreme weather, • Preconditioning to cool the vehicle while it's plugged in • Ecological driving to increase range in adverse conditions.
Rain / Fog / Visibility	• Communication challenges in poor weather	• Reduced sensor performance (especially LIDAR) • Extreme rainfall (e.g. Freezing Rainfall) may be beyond training envelopes. • Hail can damage on-board vehicle sensors	
Flooding	• Water ingress into electric systems. • Charging infrastructure and substations susceptible to flooding.	• Shallow floodwater can obscure lane markings, deep floodwater can hide hazards.	• Lack of an air-intake potentially increases wading depth, therefore increasing resilience
Wind & Storms	• Impact on aerodynamics and energy consumption • Gusts may impact vehicle stability • Charging infrastructure susceptible to flying debris • Storms may impact electricity supplies • Low winds will impact on renewable generation		

Winter Risks for ECAV's

	Electric / Connected Vehicle Risks	Additional Issues for AV	Considerations / Mitigations *
Low Temperatures	• Reduced battery performance and range (up to 36%). Compounded by the increased need for cabin heating. • Batteries take longer to charge • Heavier vehicles can cause more damage to the road in freeze-thaw cycles (potholes) • Increased demand on energy grid for heating may impact supply.		• Preconditioning to warm the vehicle while it's plugged in • Ecological driving to increase range in adverse conditions.
Snow and Ice	• Accretion of snow on wheel arches may reduce efficiency and range • Frozen charging infrastructure. • Accretion of snow and ice may impeded energy generation and supply. • Communication challenges in poor weather	• Snow obscure / obstruct sensors • Snow on road infrastructure can impact navigation (lane markings and signs) • Interactions with winter maintenance fleet may be challenging. • Rapidly changing weather conditions can be challenging for AV algorithms	• Trends to move to AWD by manufacturers will increase resilience • Heavier vehicles with a lower centre of gravity will increase traction • Better engine torque • Reduced risk of skidding from regenerative breaking • Simpler mechanics promote resilience. • Data from sensors will facilitate improved real-time decision making

Implications for winter road maintenance delivery?

- Does the risk actually decrease?
  - Heavy vehicles with a lower centre of gravity
  - Improved torque and regenerative braking
  - Driver assistance systems
- All reduce skid risk and improve safety
- Are we confident to move to a white road policy if this is case?

- Greater autonomy does lead to problems though:
  - Obscuring of lane markings and signage (i.e. white road!)
  - This can be fixed with quantum sensing / positioning

- Reduced ranges in cold weather will lead to more stranded vehicles
- Does a duty of care extend to charging infrastructure?

Electric & Connected Gritters

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

- Connected Gritters have long been used since the advent of GPS
  - Tracking & Logging
  - Dynamic Routing
- Electric Gritters are also starting to enter service:
  - ECON E-QCB
  - Range: 170 miles
- Range suitable for average use
  - Operating in non-optimal conditions (i.e. cold)
  - Resilience issues for extreme events

Implications for winter road maintenance support systems?

- Data from connected vehicles already underpinning significant progress here:
  - Real time friction measurements
  - Communications between vehicles, re-routing algorithms etc
  - Nira Dynamics

- A good example of how Artificial Intelligence has the capability to make sense of noisy data from
  - Connected vehicles
  - Dense distributed sensor networks (IoT)
  - Real time treatment updates
  - Pattern / object recognition from sophisticated sensors

The elephant in the room

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

- Are we collecting / developing middling technologies that are based on what we have needed for the last 40 years and not the next 40?
  - Nice tech, but how long is the shelf life?
- If we decide we do still need a winter service, how different does it need to look?

Autonomous Gritters

- It isn't data from autonomous cars that will be transformative, it will be autonomous gritters.
- An autonomous gritter short circuits the entire system:
  - Collects it's own on-board road weather data
  - Takes real-time actions based on what it is sensing
  - No weather forecast required!
  - No decision maker required!
- The only reason weather forecasts are issued at midday is due to working time directives and forward planning
- A fleet of autonomous gritters can patrol 24/7 with no issues.

It’s already happening (at least on sidewalks)…

1980s	
1990s	
2000s	
2010s	
2020s	
2030s	
2040s	

https://www.swaprobotics.com/snow-plowing

A new paradigm

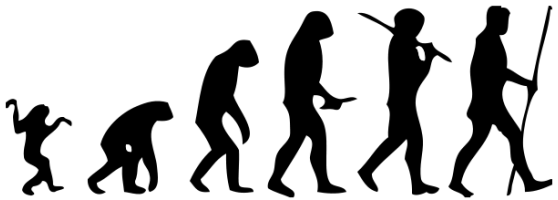
- Very little of our current RWIS is needed
- We will have gone full circle back to ice detection of the early 1980's

- Research Targets:
- Still need to improve our mobile measurement capabilities
  - Low latency temperature / condition sensing
  - Residual Salt detection
- A network of in-situ sensors still needed:
  - Spot check /calibrate mobile sensors in real time
  - Early warning system to deploy the fleet

Conclusions

- Winter service will need to evolve to both the changing climate and the changing vehicle fleet

- The latest fleet of ECV's has the potential to reduce the burden of winter maintenance
  - Increased safety
  - White Roads are perhaps a step too far…



- We are embarking on a period of rapid change in the sector
  - The sector has the chance to show leadership in embracing the benefits, even if it does mean ripping up the rule book.
  - Counter-intuitive to think tomorrows technologies will take us back to approaches from 40 years ago!