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Impact of Ambient Temperature and Battery Activity on Internal Battery Temperatures of Electric Vehicles

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Canada

Overview

- Electric Vehicles (EVs) can provide large environmental benefits, cost savings
- General public is still worried about battery longevity

- Battery degradation strongly depends on the battery temperature (Tbatt), which depends on the ambient temperature (Tamb), intensity of battery usage (I^2R), and the operation of the battery thermal management system (TMS)

- 3 EVs were tested on-road in Ottawa, Ontario, Canada, to collect battery temp/ usage data for different types of driving and under various ambient conditions
- Data was used to develop correlations between battery temperature, battery usage and ambient temperatures

- Correlations will be used in EV battery life simulations to forecast degradation

Test Vehicles

2015 Kia Soul EV
(28 kWh, 150 km)

2016 Chevrolet Volt
(18 kWh, 85 km)

2016 Tesla Model S 70D
(70 kWh, 386 km)

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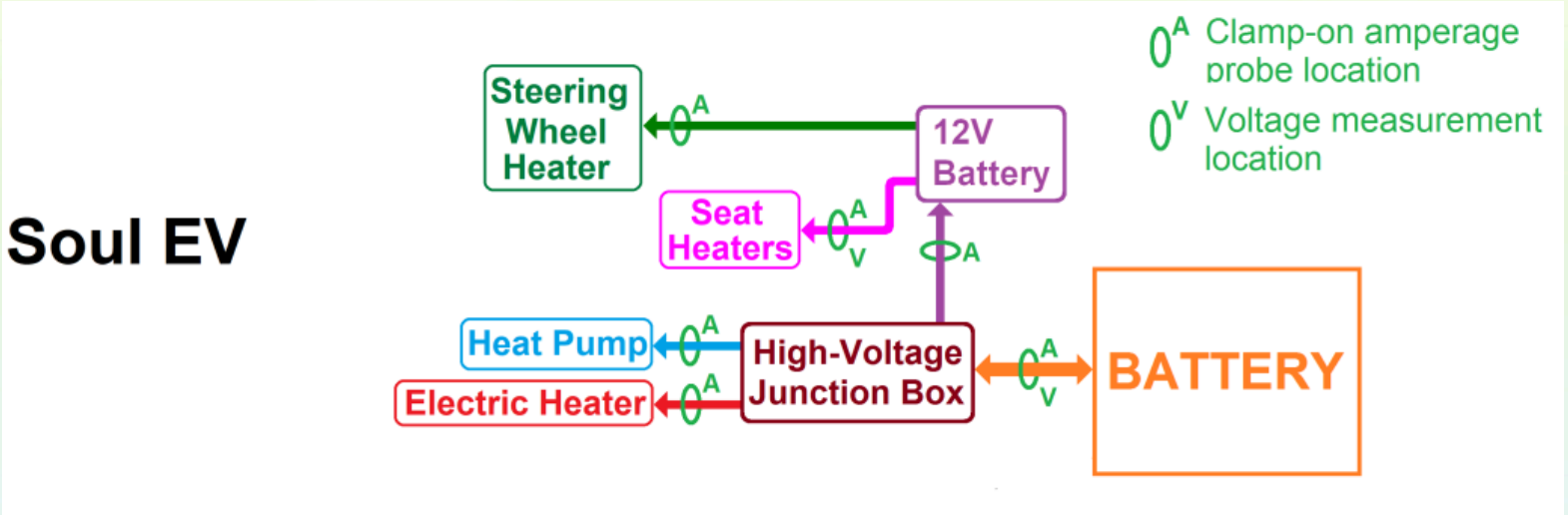
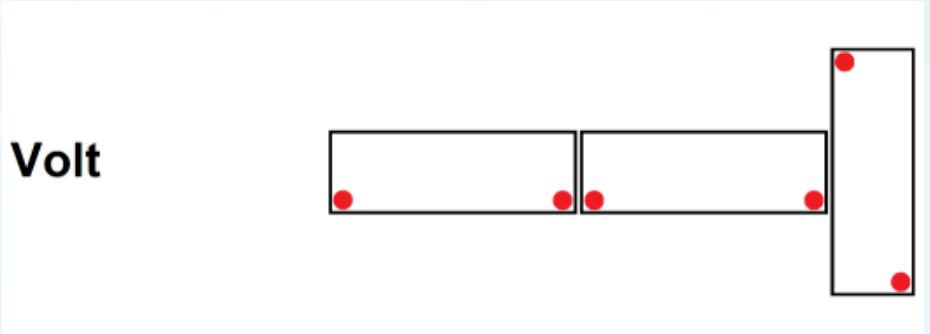
- Test vehicles were instrumented to collect detailed data on battery usage and battery temperatures

Instrumentation

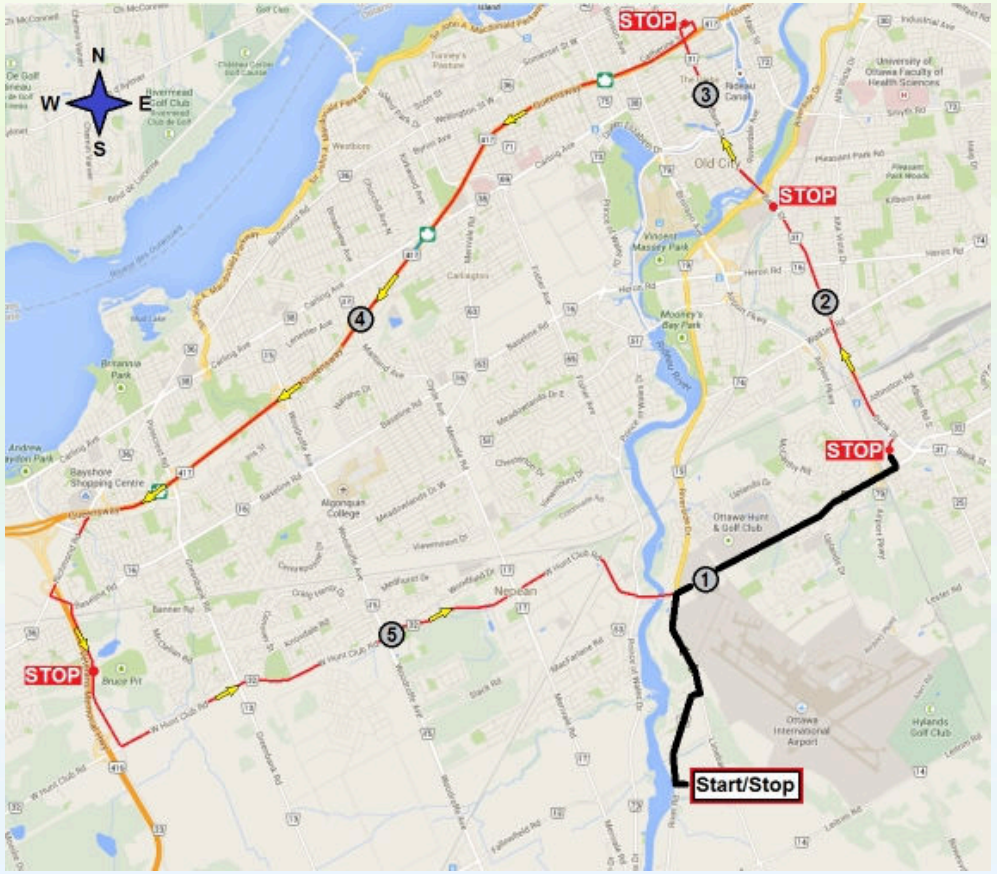
- Vehicles were instrumented to measure currents and voltages



- Battery temperatures were collected from CAN data



Test Route – Different Drive Cycles



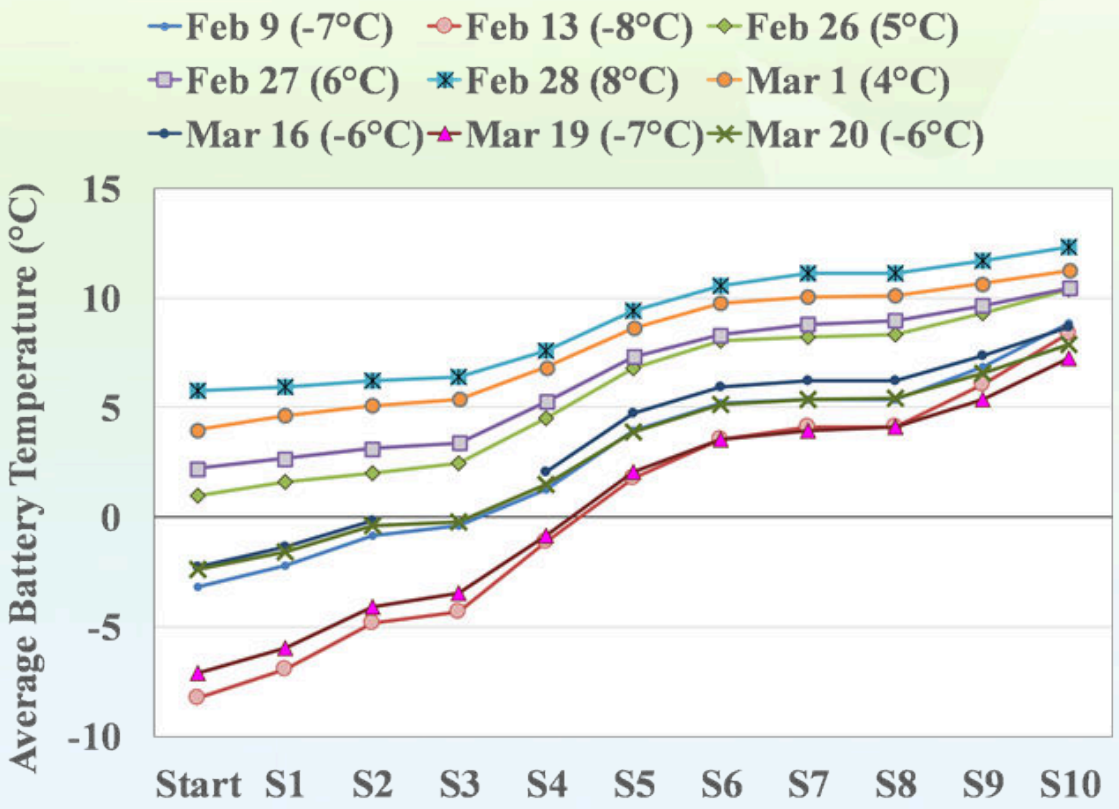
1. Arterial (S1, S6)
2. City (S2, S7)
3. Congested (S3, S8)
4. Expressway (S4, S9)
5. Arterial (S5, S10)

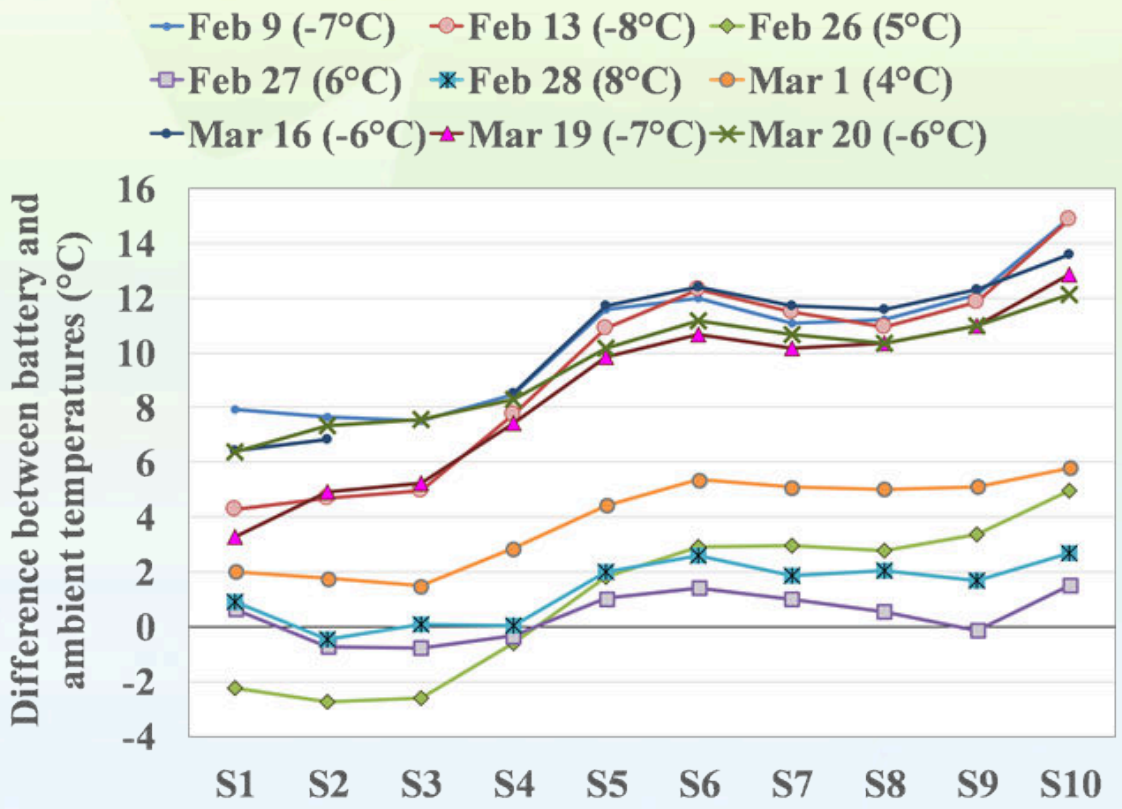
Test Schedule

	Winter		Summer	
Test Vehicle	Test Days	Temperature (°C)	Test Days	Temperature (°C)
Soul EV	9	-8 to +8		
Volt	7	-11 to +3	5	20 to 27
Model S	12	-21 to +2	12	12 to 21

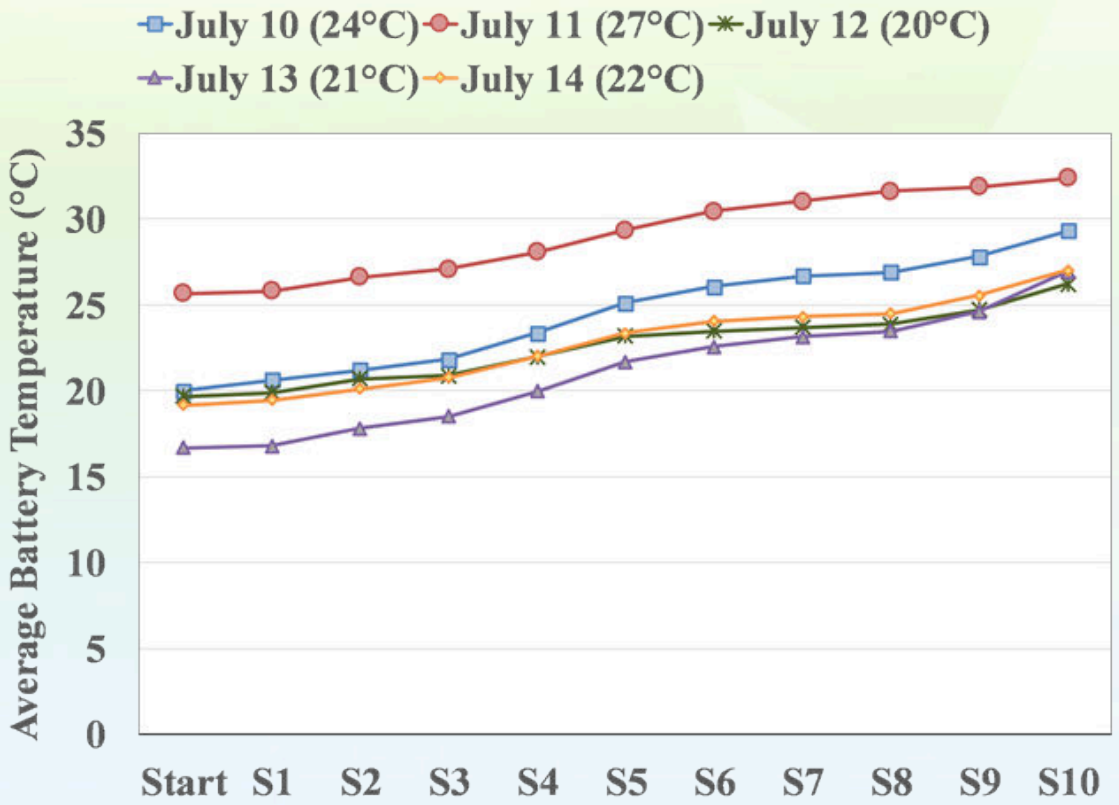
- Test schedule was impacted by weather and driver availability

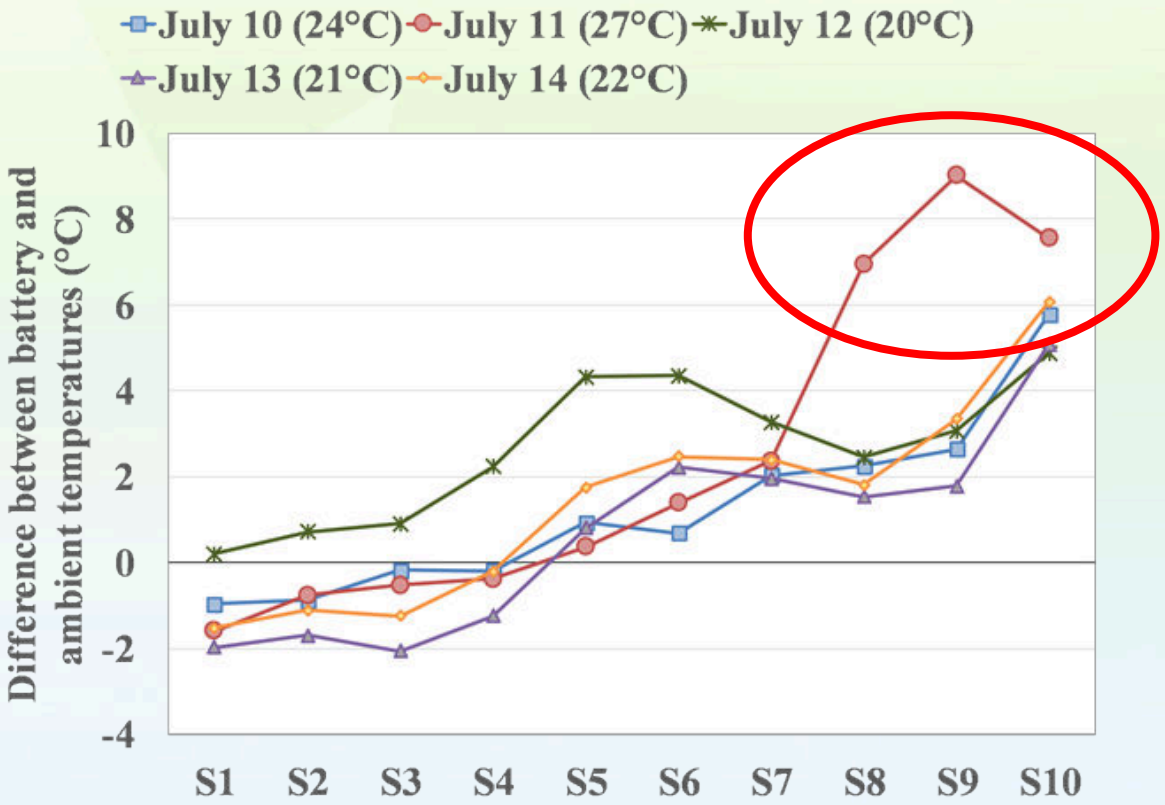
Soul EV Battery Temps (Winter)



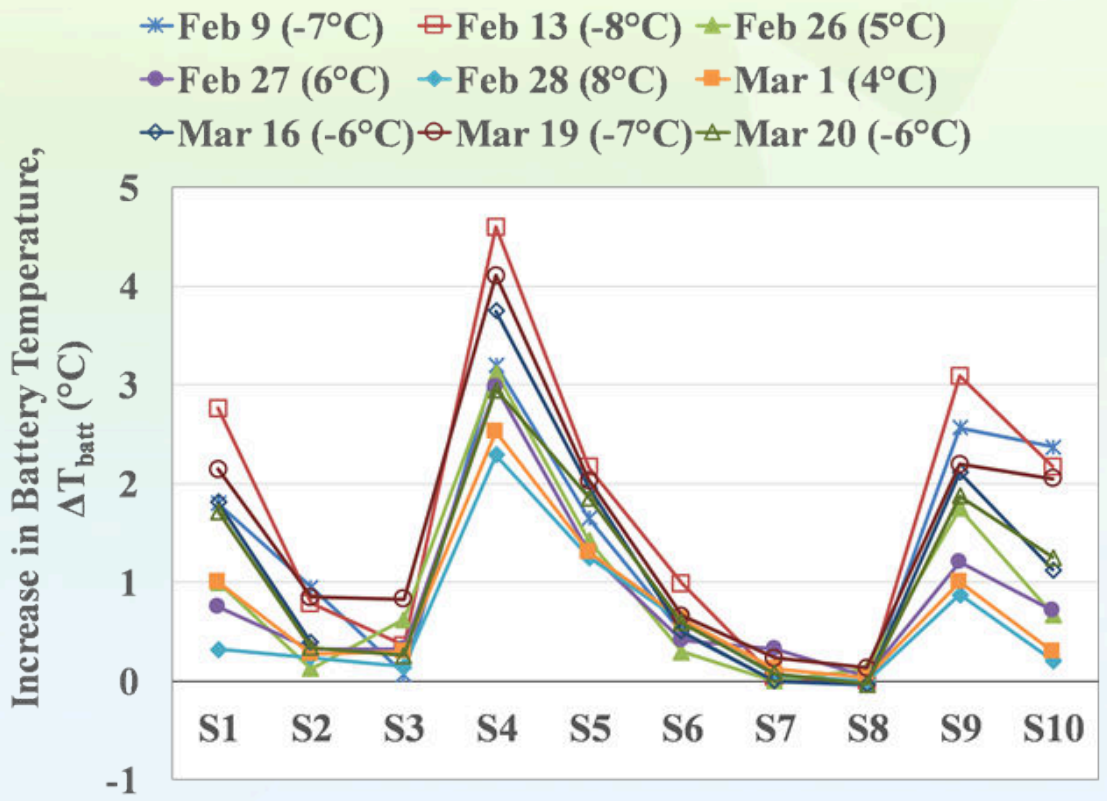


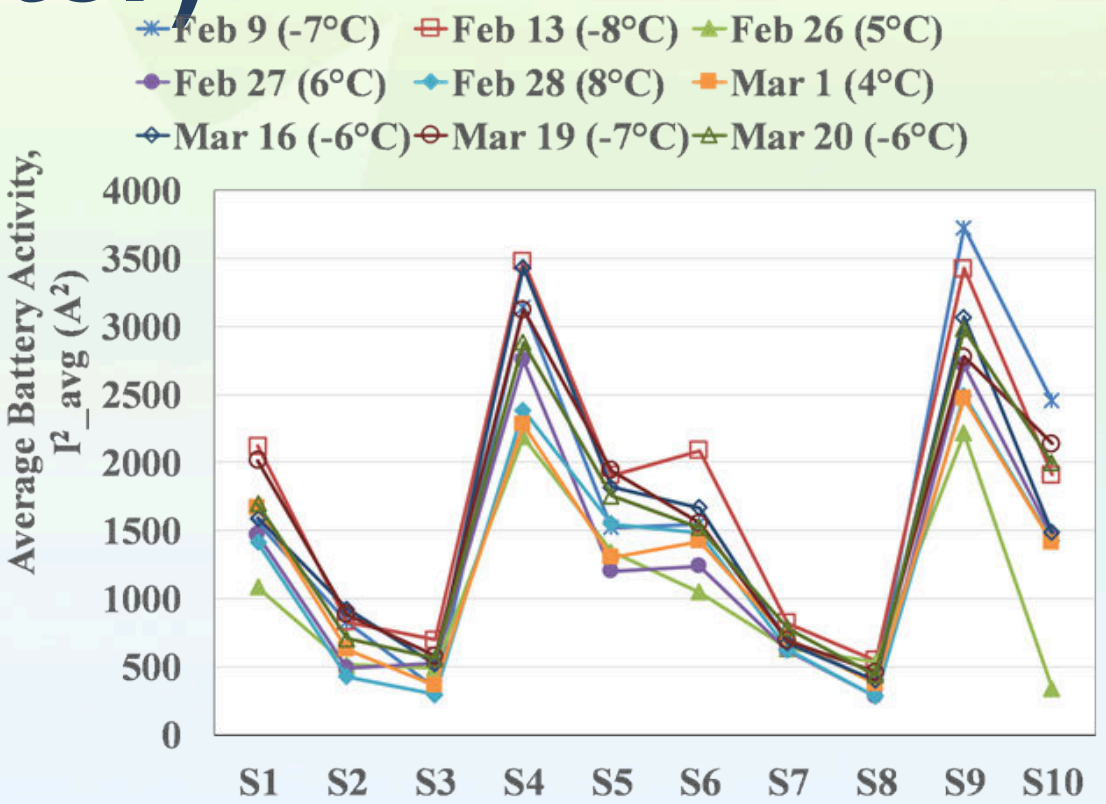
Volt Battery Temperatures (Summer)



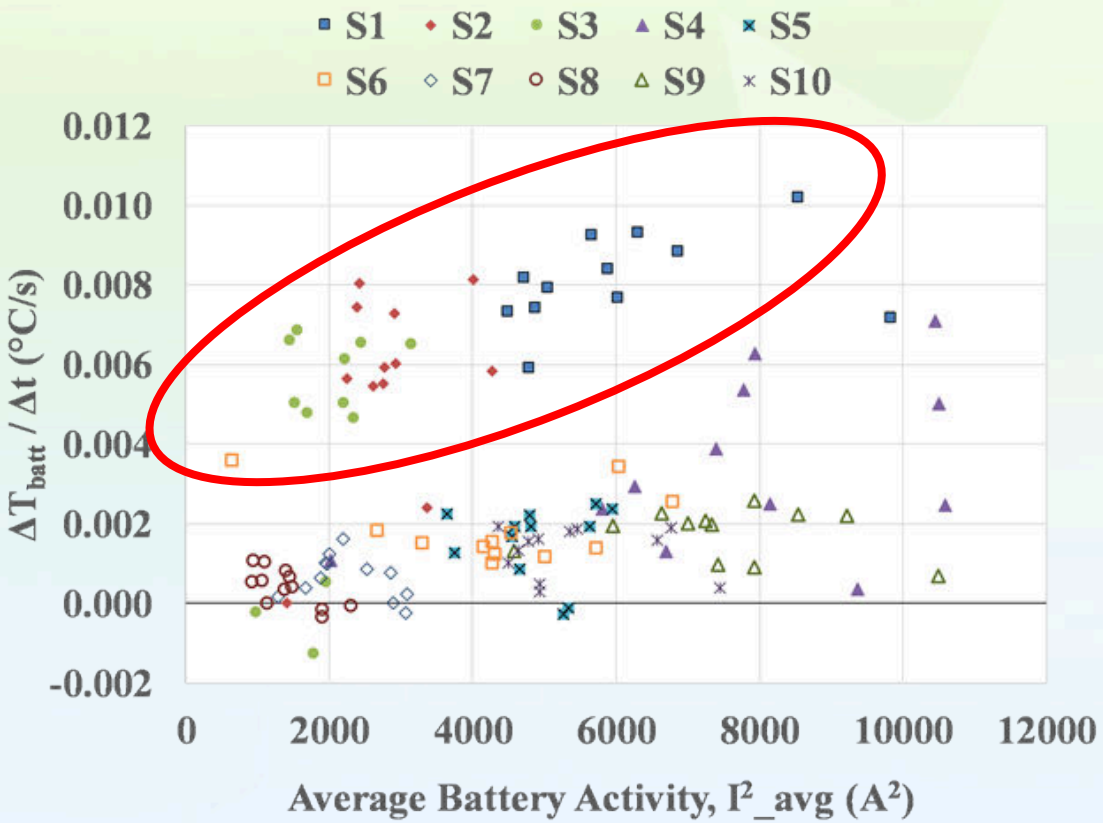


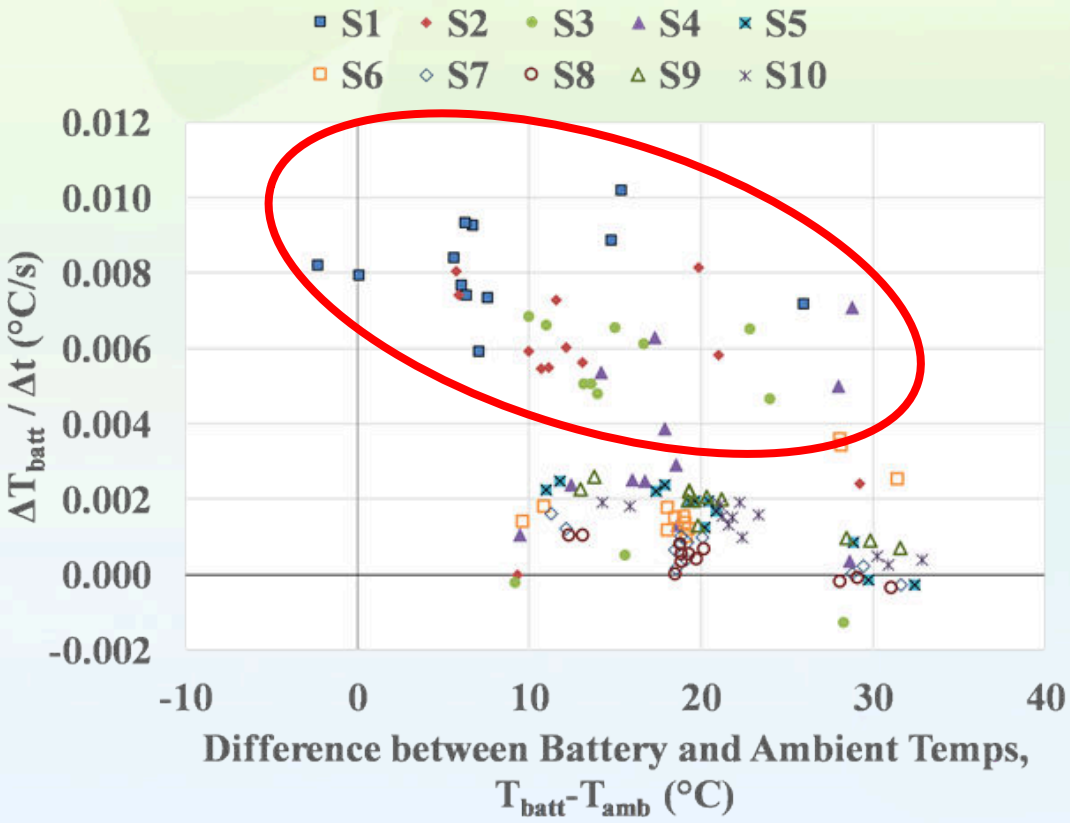
Correlation Between Battery Temp and Battery Activity (Soul EV, Winter)



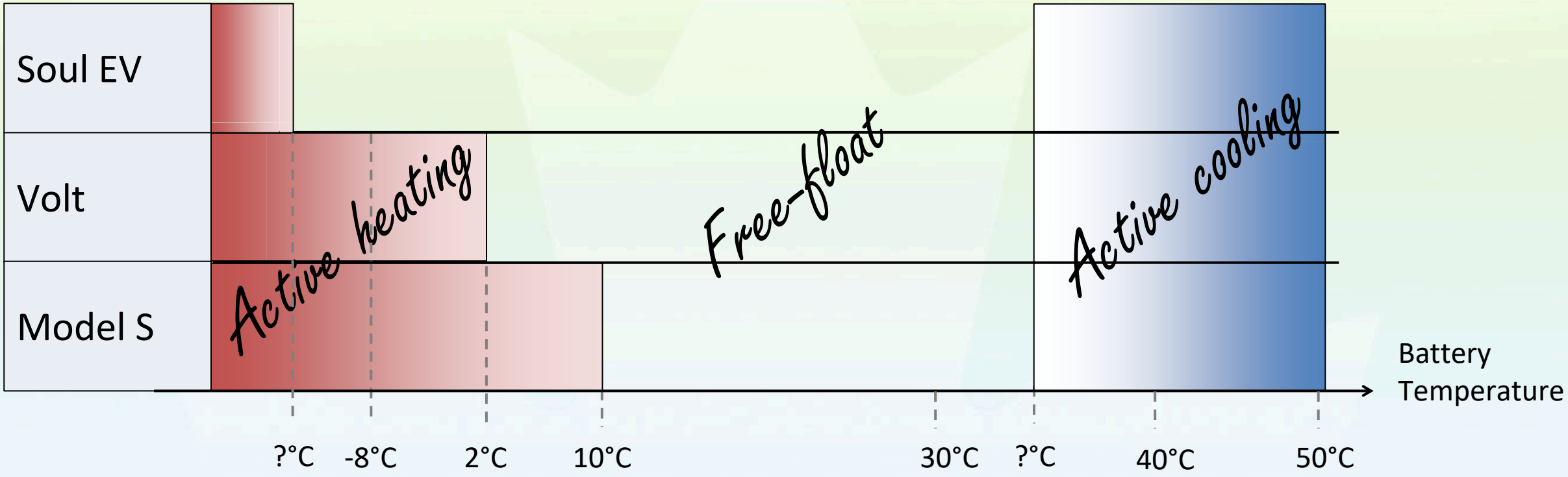


Correlation Between Battery Temps and Battery Activity, Ambient Temp (Model S, Winter)

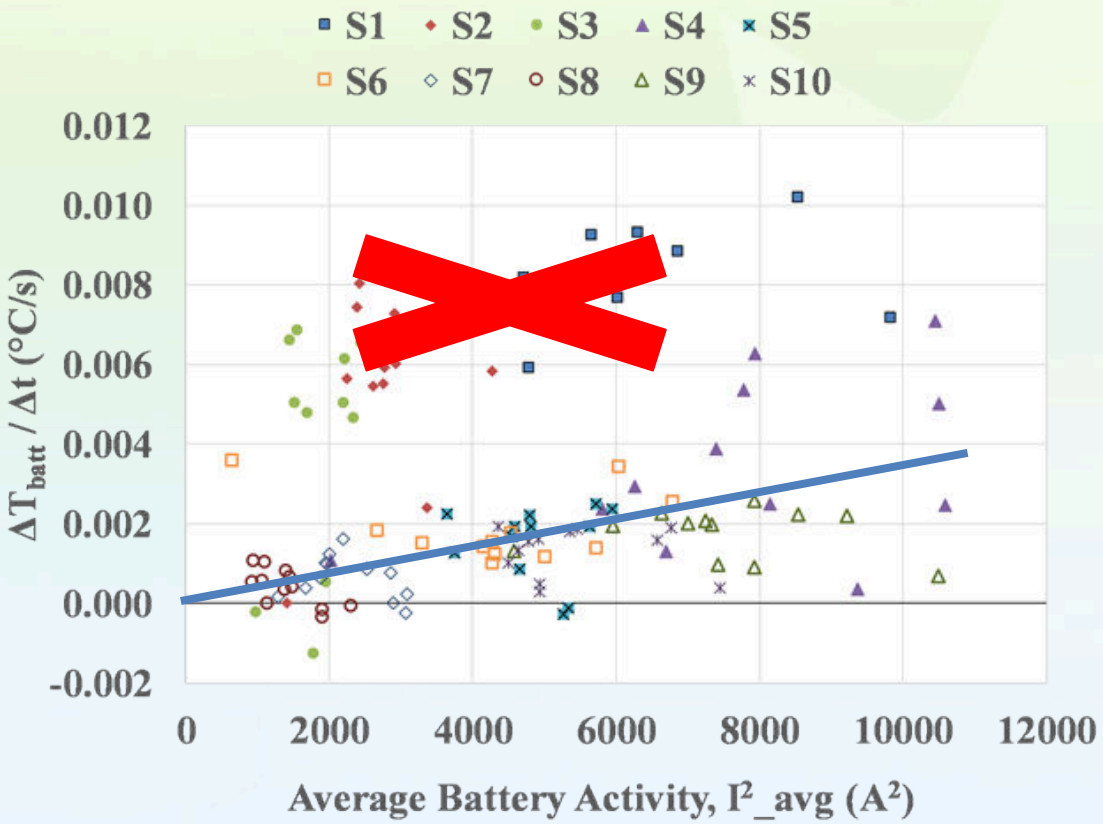


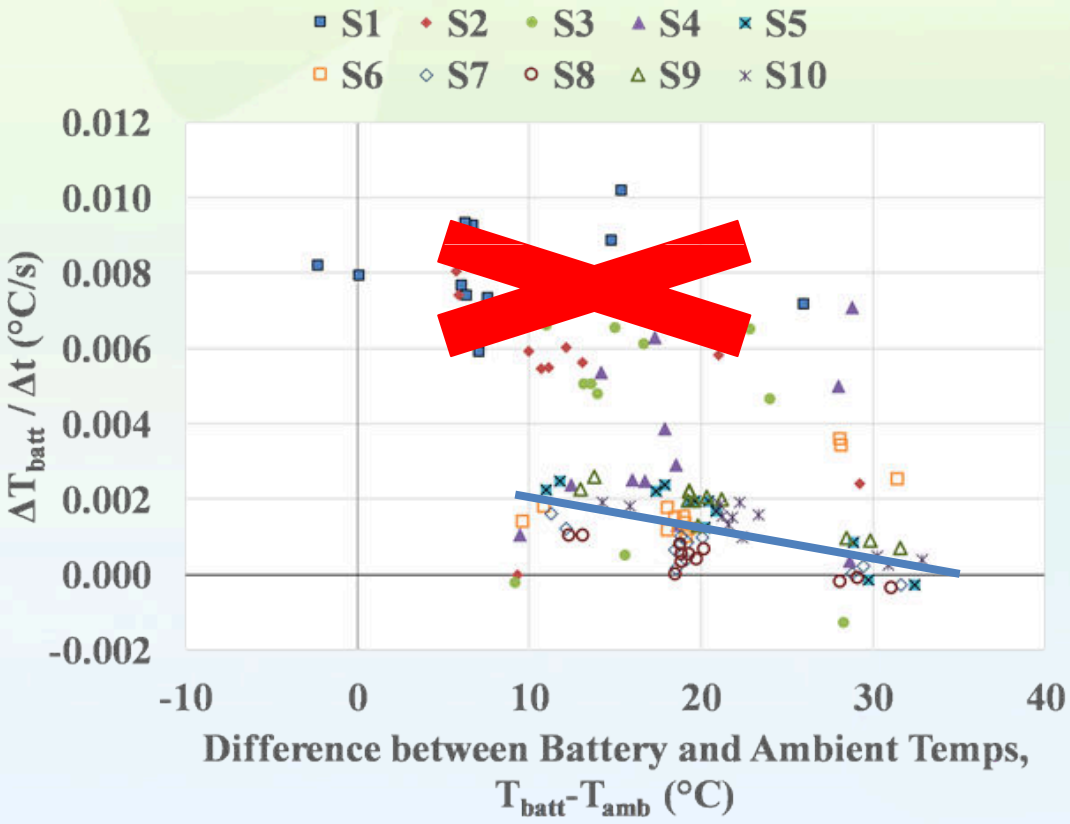


Battery Thermal Management Systems



Correlation Between Battery Temps and Battery Activity, Ambient Temp (Model S, Winter)





Correlation

$$\underbrace{\frac{\Delta T_{batt}}{\Delta t}}_{\text{Change in Tbatt over time}} = \underbrace{w\, I^2}_{\text{Heat generation}} + \underbrace{y * h * (T_{batt} - T_{amb}) * \left(\frac{\Delta t_{mov}}{\Delta t}\right)}_{\text{Heat transfer to ambient}}$$

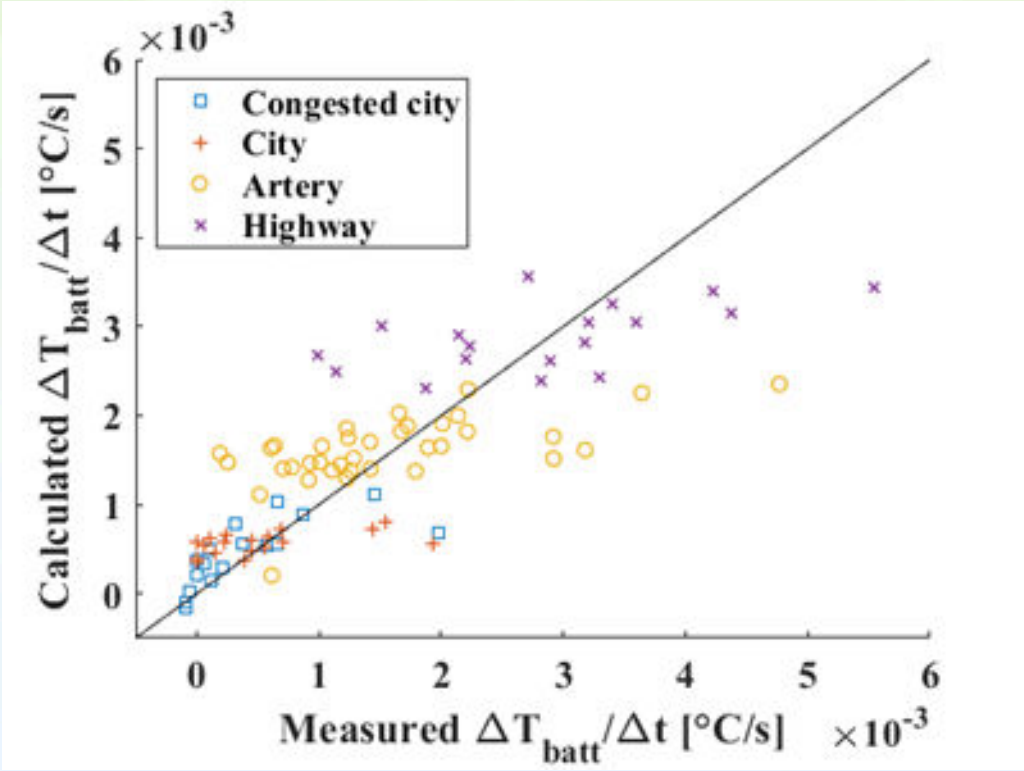
$$h = 10.45 - v + 10v^{1/2}$$

- Values of *w* and *y* for each vehicle, drive cycle and each season: see paper

Covariance Plots

- Calculated value of change in Tbatt graphed against measured value
- Perfect agreement for points on the line y=x
- Results for Soul EV in winter

- Significant differences caused by
  - Variation in traffic flow/traffic lights
  - Variation in weather conditions (wind)
  - Different drivers (drive styles)
  - Tbatt reported in full degrees



Conclusions

- On-road testing of Kia Soul EV, Chevrolet Volt, Tesla Model S provides important insight in Tbatt for various drive cycles and Tamb
- Battery management systems use quite different temperature set points
- Correlations were developed between change in battery temperature, heat generation from battery usage and heat transfer to environment
- Correlations show only reasonable agreement with measurements due to variation in traffic, weather, driver behaviour and low-res temp data
- Additional testing is recommended
  - Summer and winter extremes
  - Higher resolution battery temperature data

Thank you

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