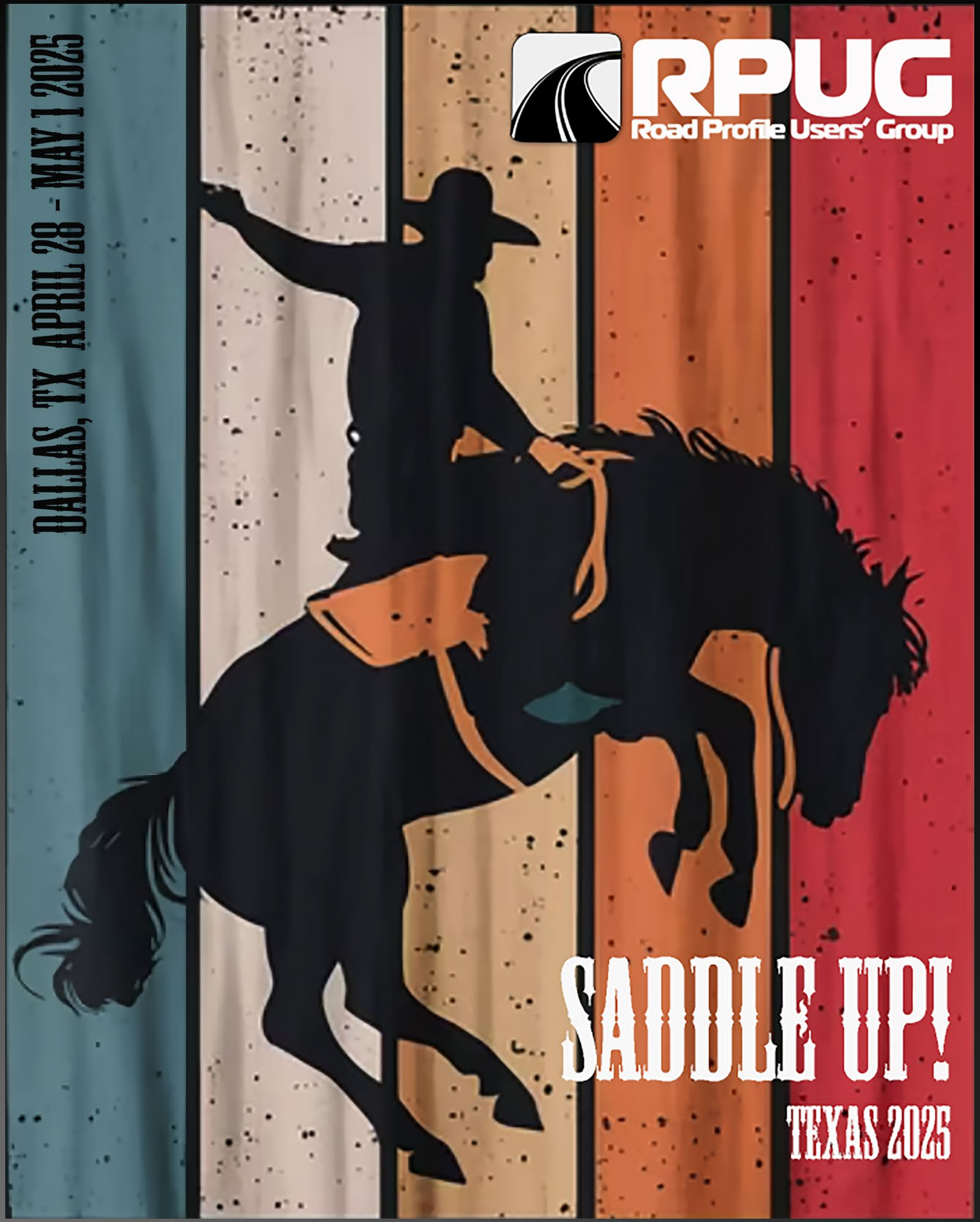


PHYSICAL INTERPRETATION OF CONTACTLESS ENERGY-BASED TIRE-PAVEMENT FRICTION MODELS

AHMAD ALHASAN, PH.D., P.E., HNTB

SENIOR TECHNICAL ADVISOR/PAVEMENTS TEAM LEADER

RPUG
Road Profile Users' Group

OUTLINE

Background

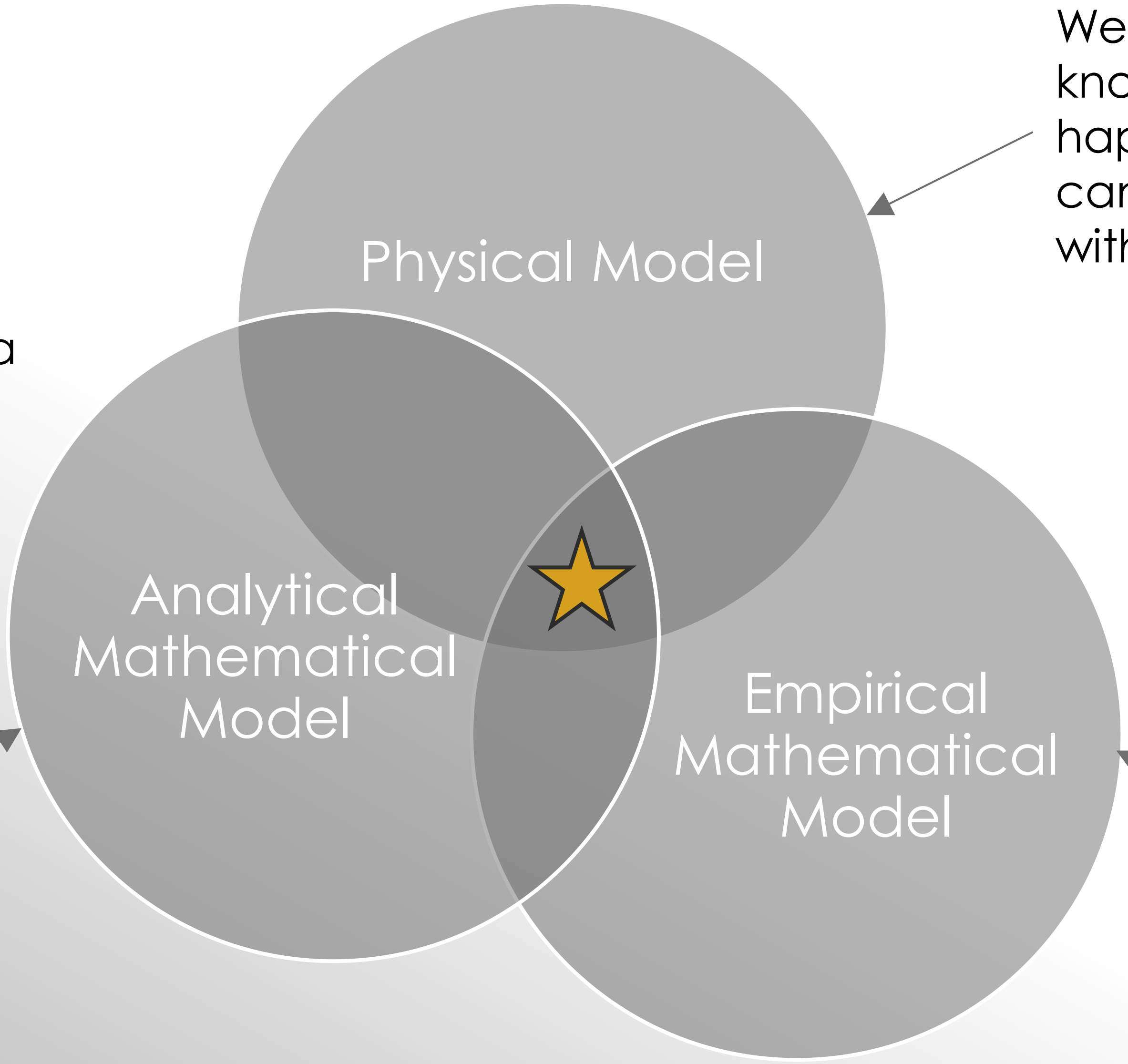
Texture and Friction Measurements

Friction-Texture Models

Concluding Remarks and Future Work

MODELING REALITY

The best model combines good physical description, good mathematical models and rich data



We think we know what is happening but cannot quantify with great details

We have detailed mathematical description. In many cases we have oversimplifying assumptions

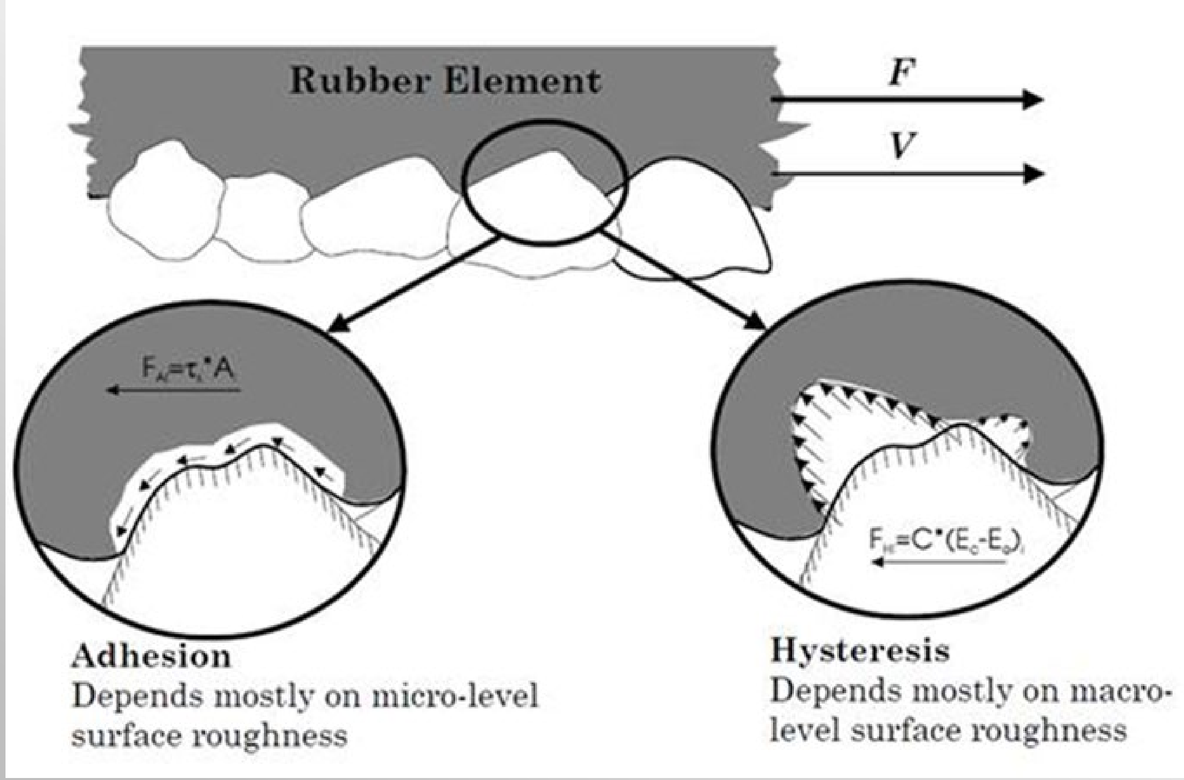
We have quantitative observations and can describe correlations and make predictions if the process is the same

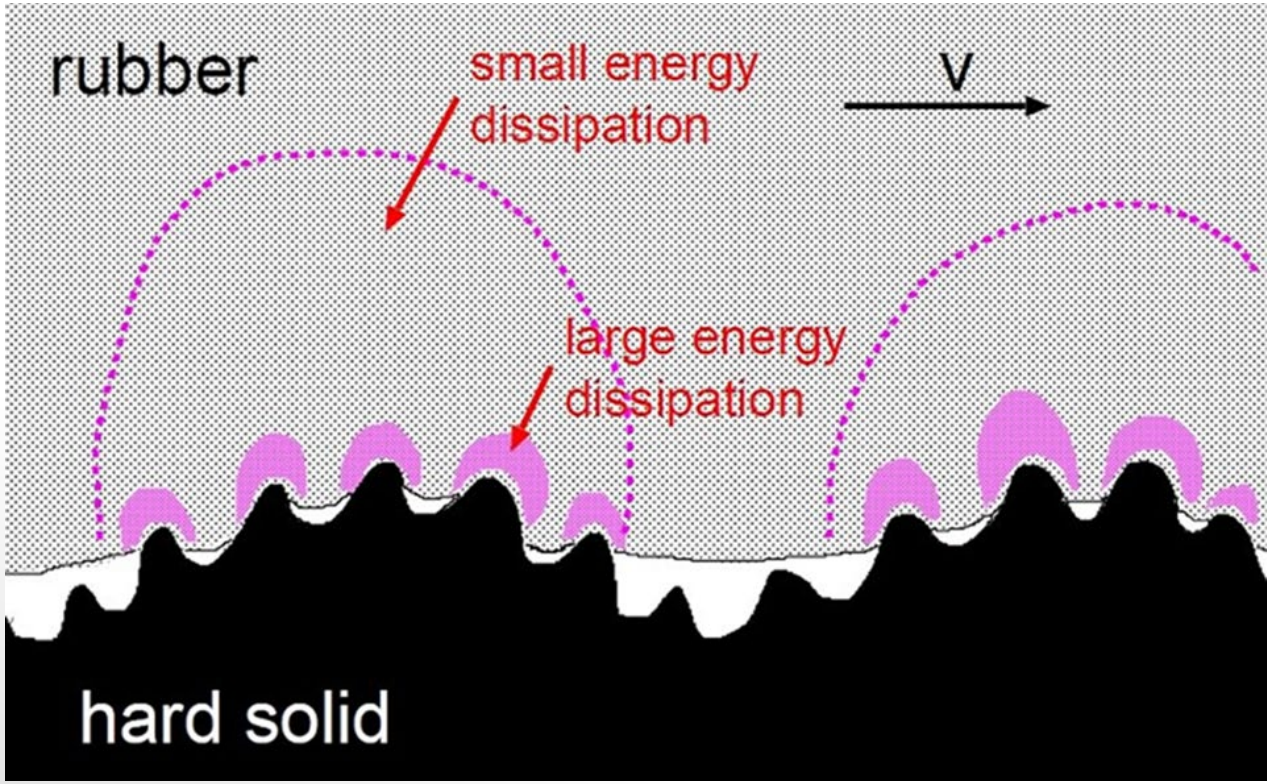
WHY CONTACTLESS FRICTION?

- Friction measurements harmonization
- Measurements at challenging locations
- Relating friction measurements to actual traffic demands
- Better understand the impact of different texture features (engineering mixes in Balance Mix Design)
- Universal measurements less sensitive to testing conditions.

BACK TO THE FUNDAMENTALS

Persson’s friction model provided a robust physical and analytical solutions for a simple rubber block.





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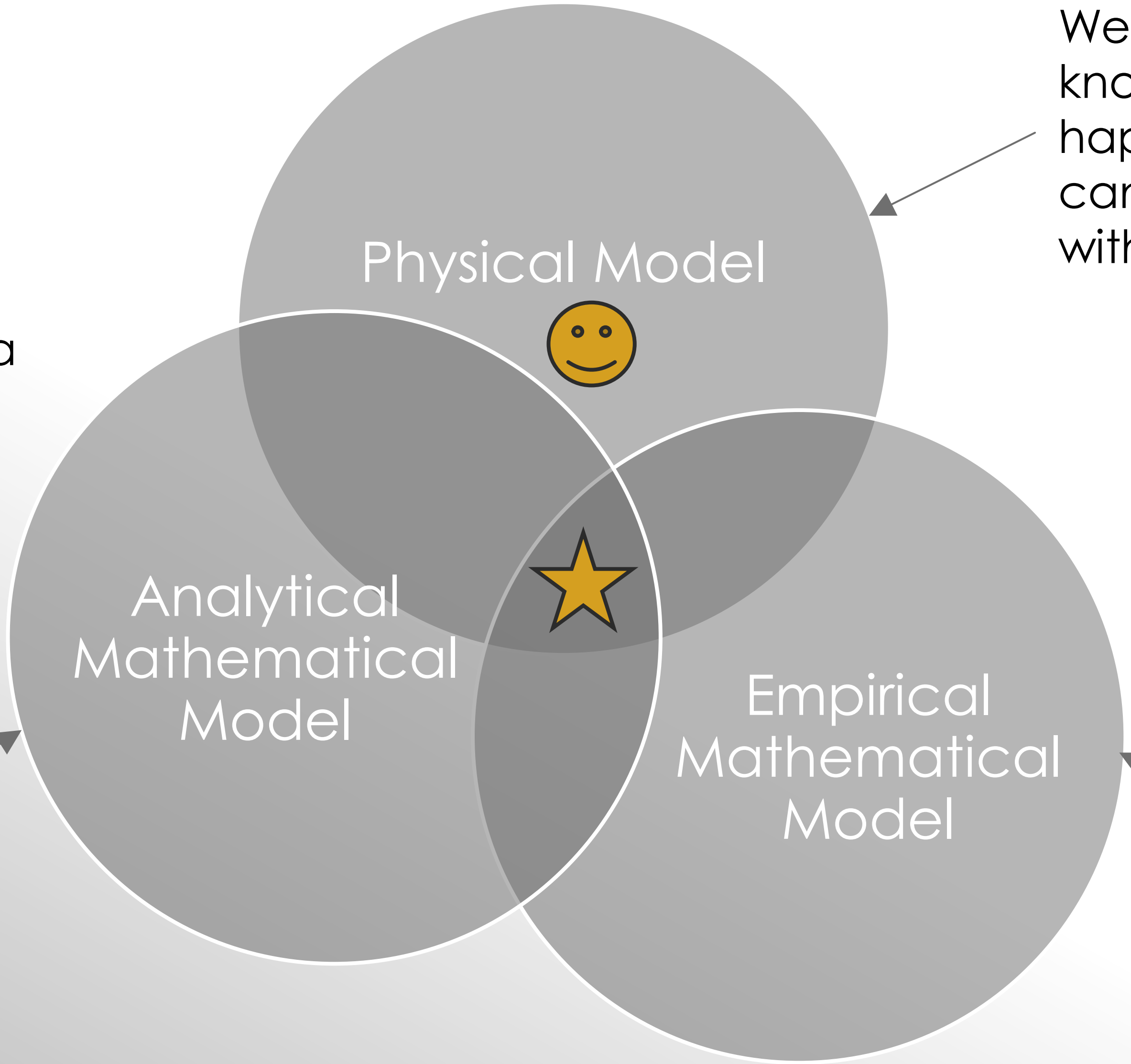

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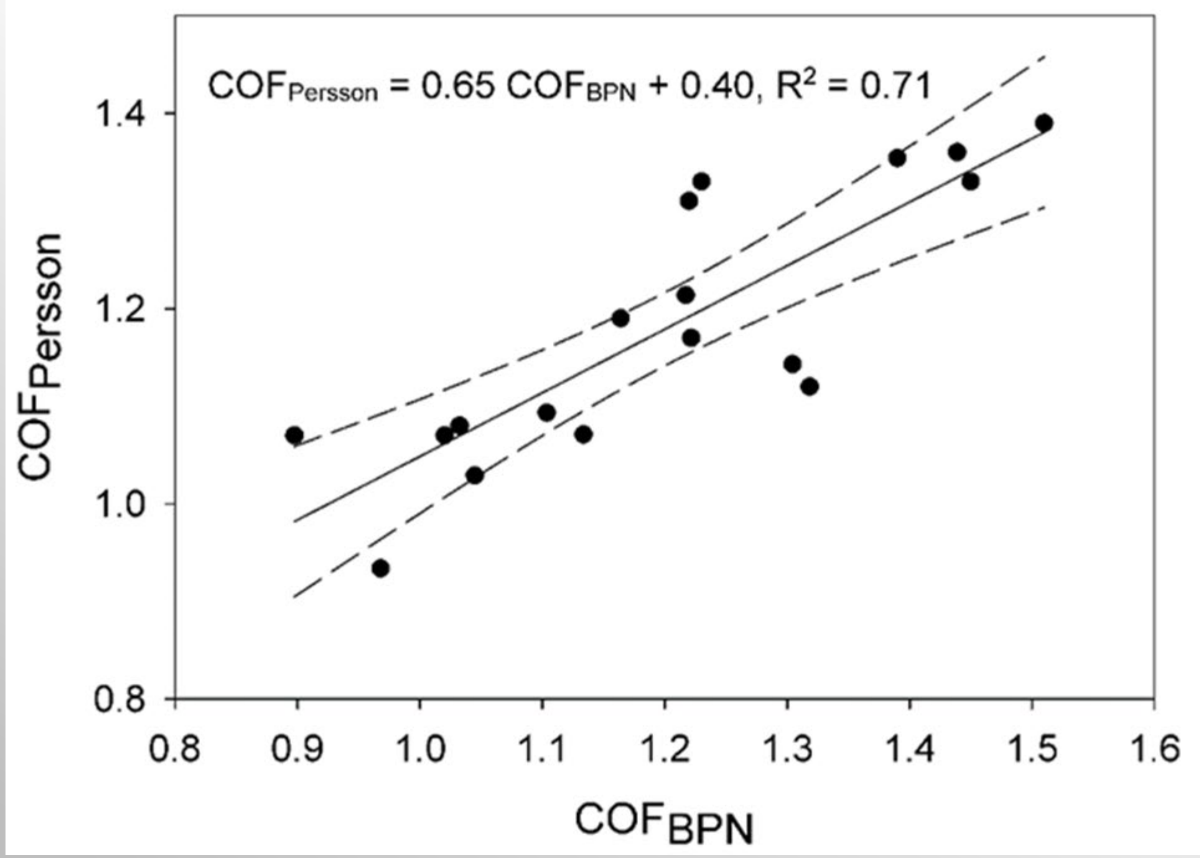
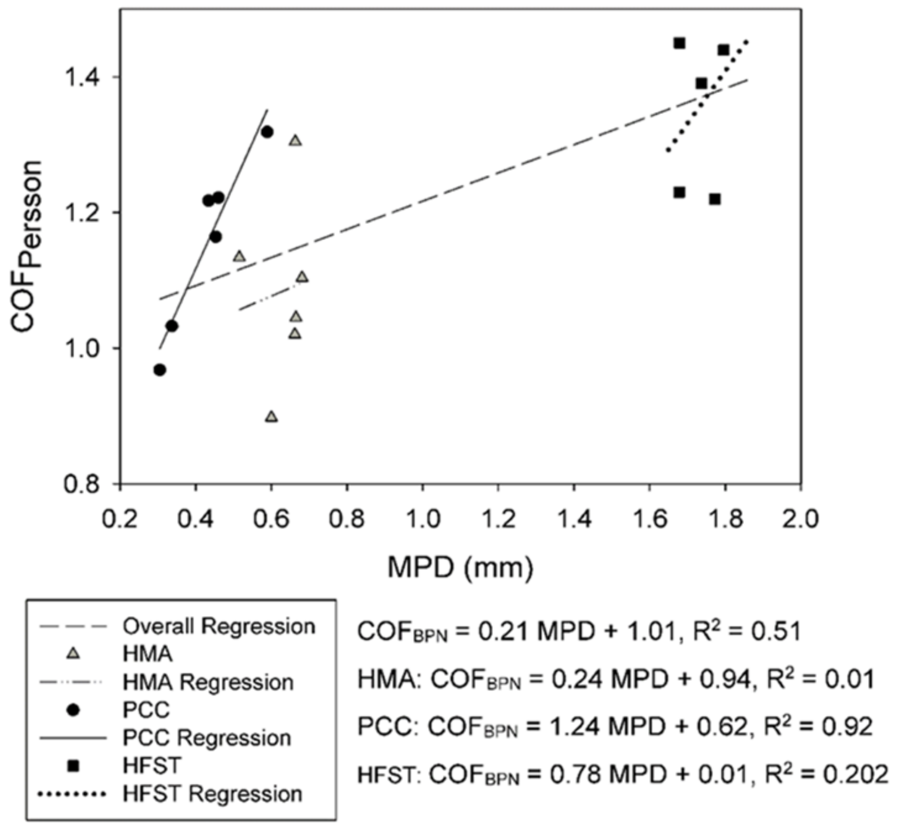
TESTING THE THEORY

The findings were promising, and we learned that the contribution is mostly from hysteresis.





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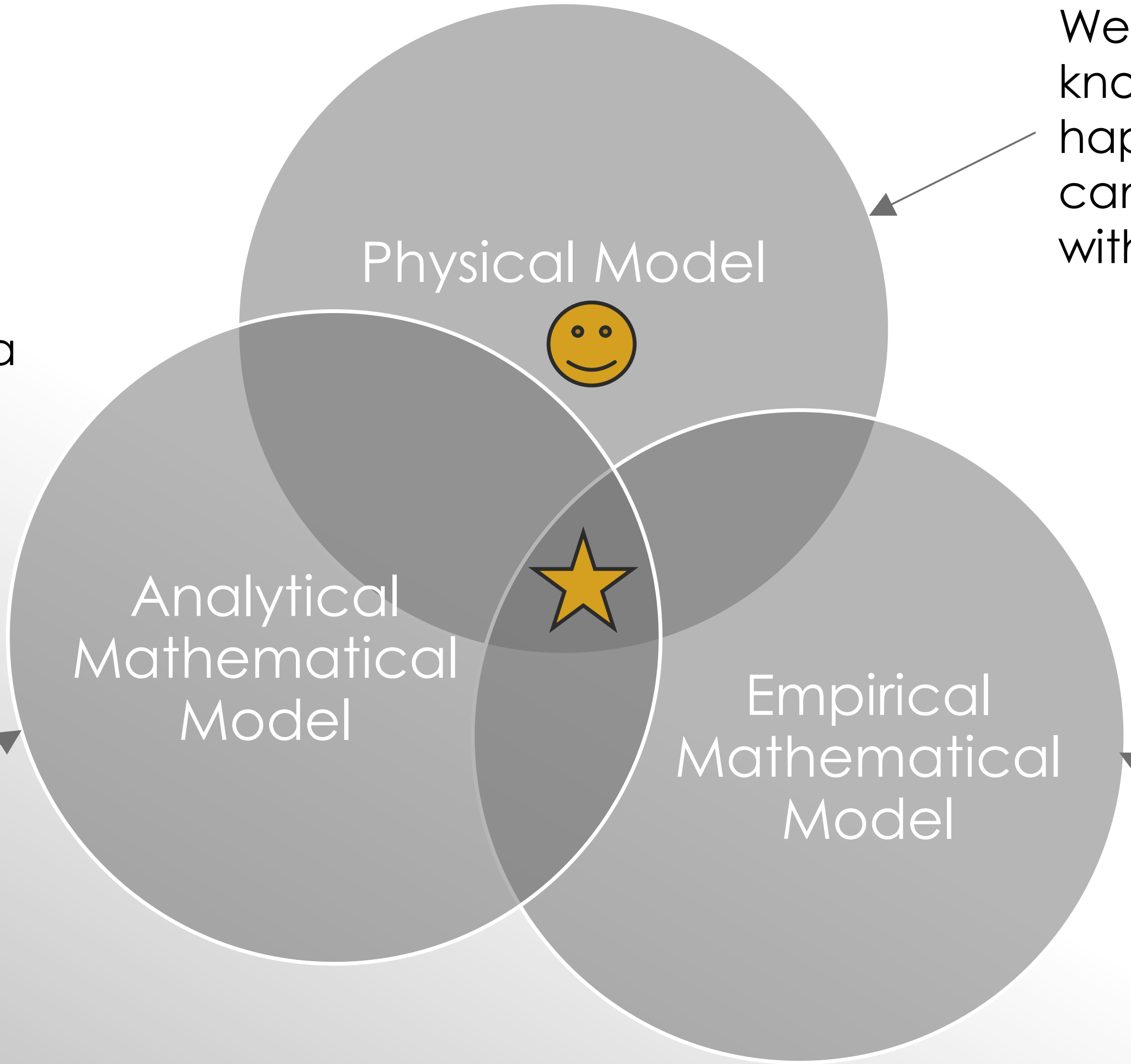

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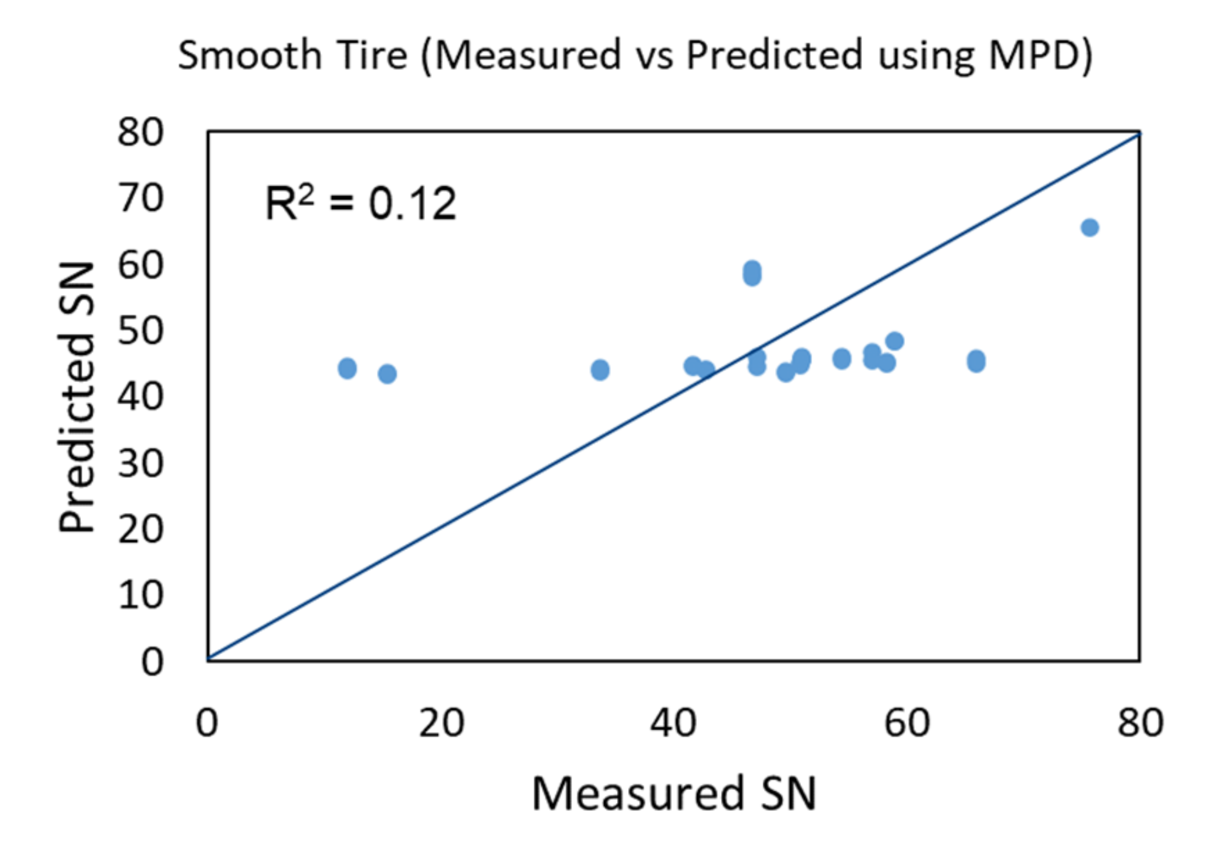
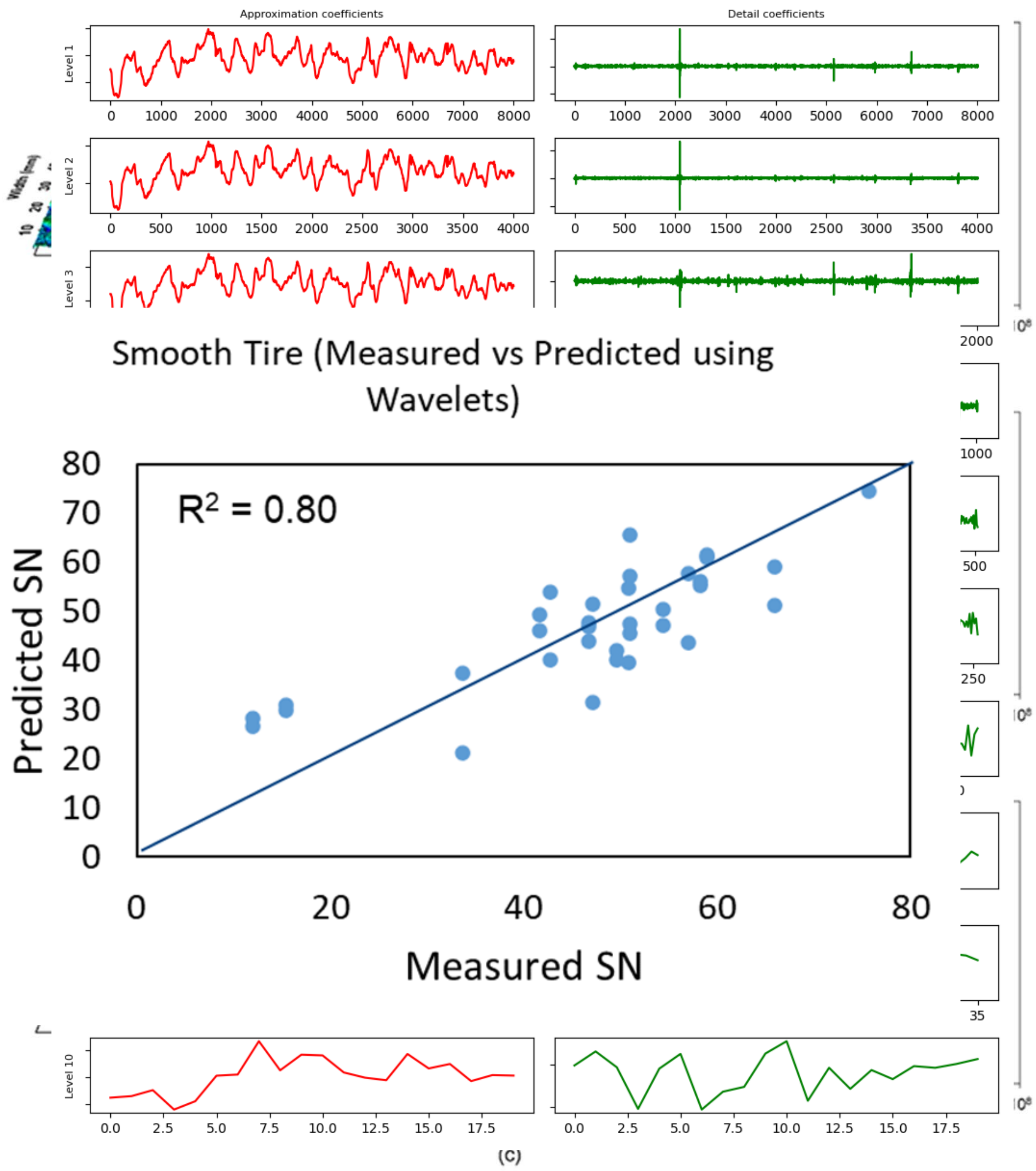
IMPLEMENTING A CONCEPT





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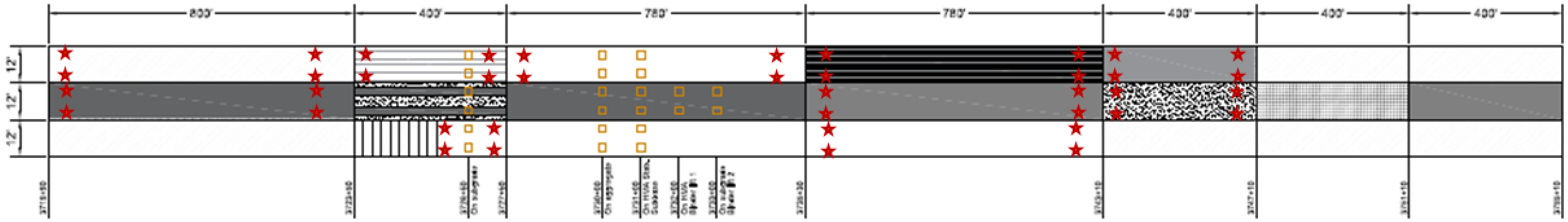
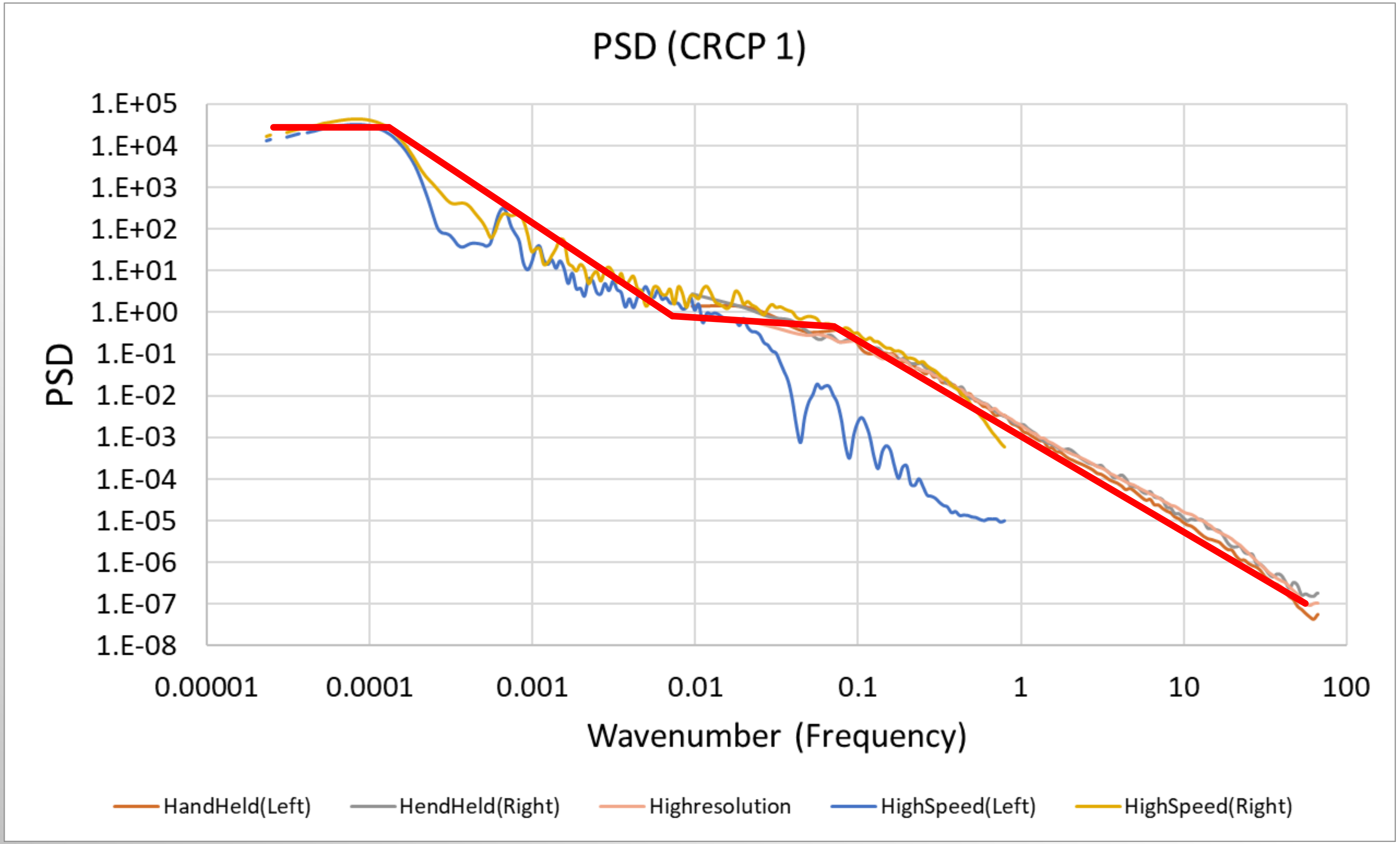
DATA COLLECTION AT ICART

Collected Texture, DFT, and LWST (Smooth and Ribbed)

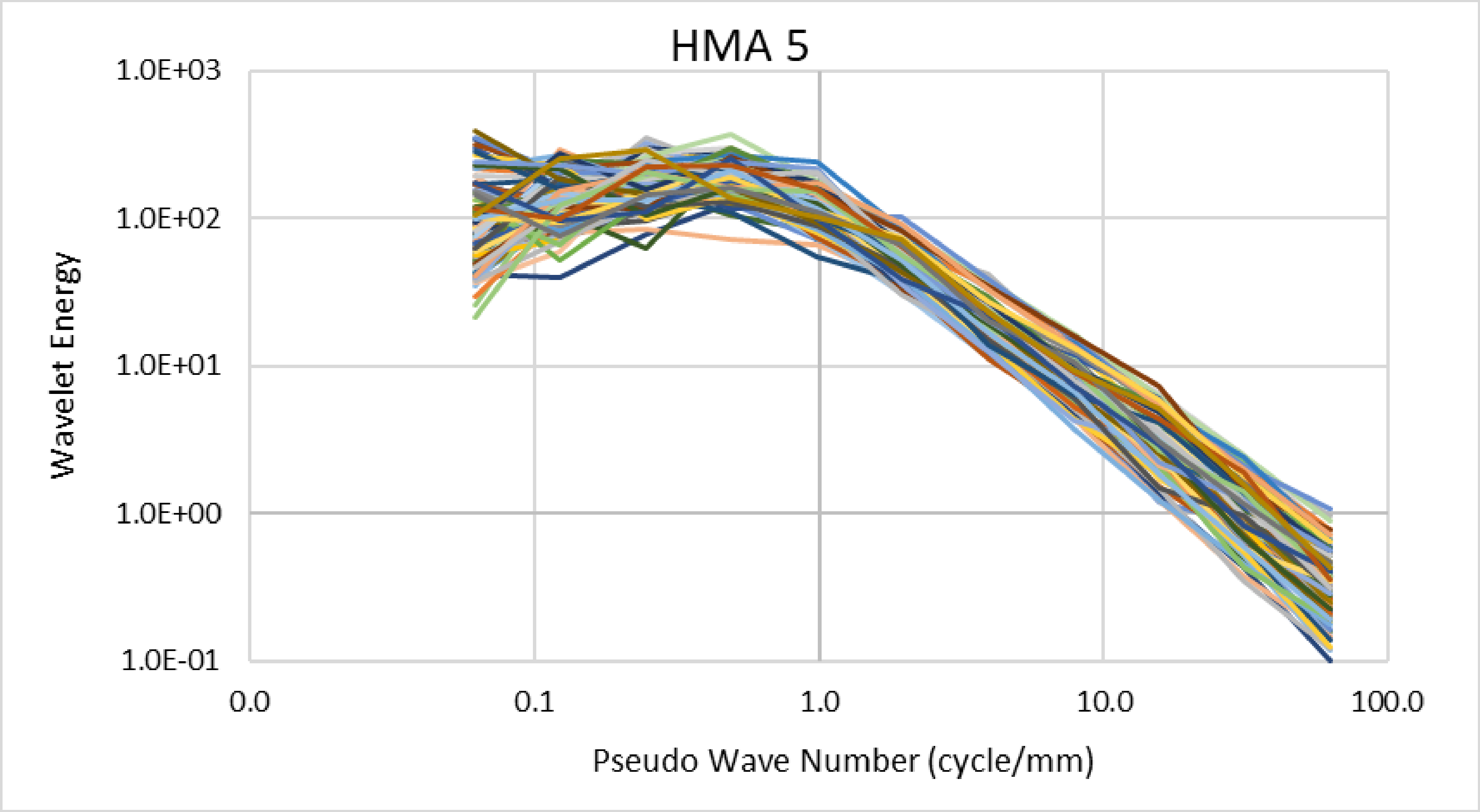


8.5" CRCP - Turf Drag Finish	Smooth Finish with Diamond Grooving	Turf Drag Finish w/ Diamond Grooving	Smooth Finish with Diamond Grinding	Smooth Finish	Turf Drag Finish	Turf Drag Finish
11.5" 12.5 mm SMA	Artificial Rutting	12.5 mm SMA	9.5 mm Dense Graded HMA	Micro surfacing with 30% Calcined Bauxite & 70% Slag	Single Chip Seal	9.5 mm Dense Graded HMA
8.5" JPCP - Turf Drag Finish	Artificial Faulting	Longitudinal Tining	Transverse Tining	Turf Drag Finish	Turf Drag Finish	Turf Drag Finish

SPECTRAL CONTENT (PSD)



SPECTRAL CONTENT (W.E.)



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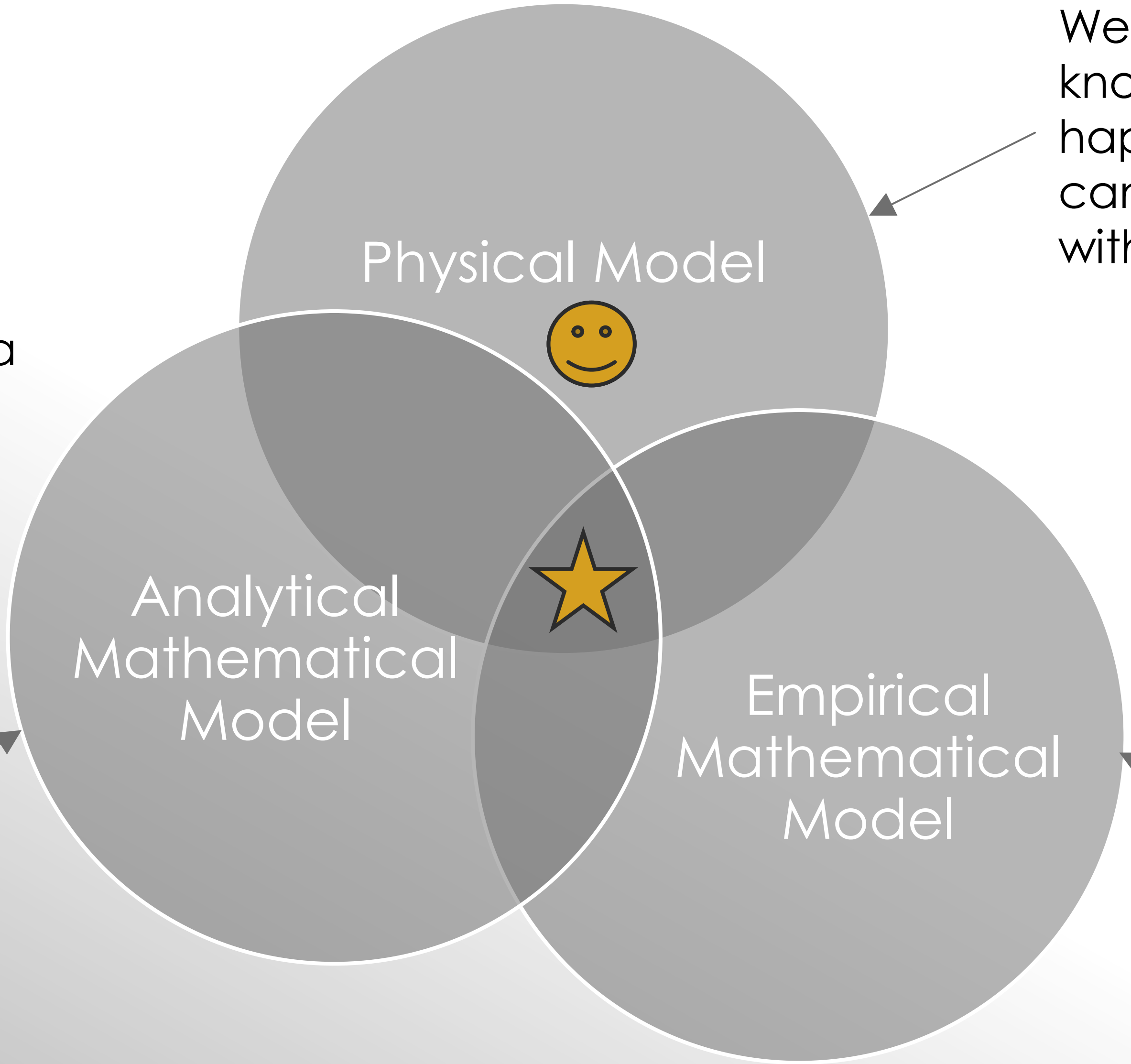

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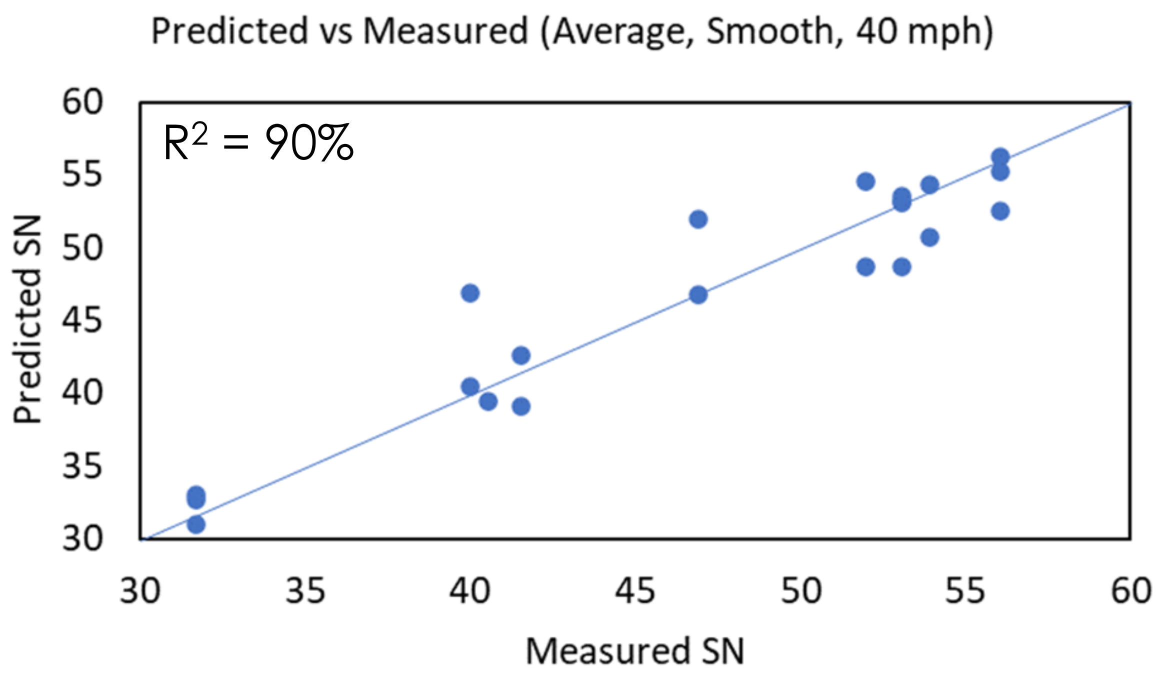
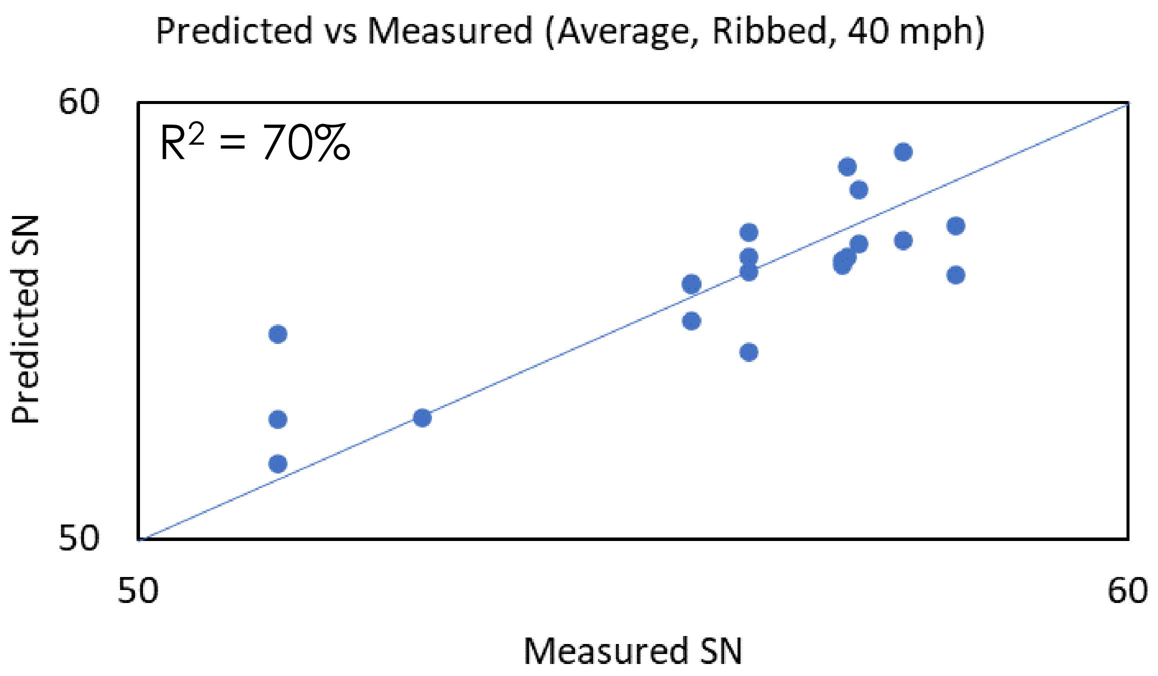
TOWARDS A GLOBAL FRICTION MODEL

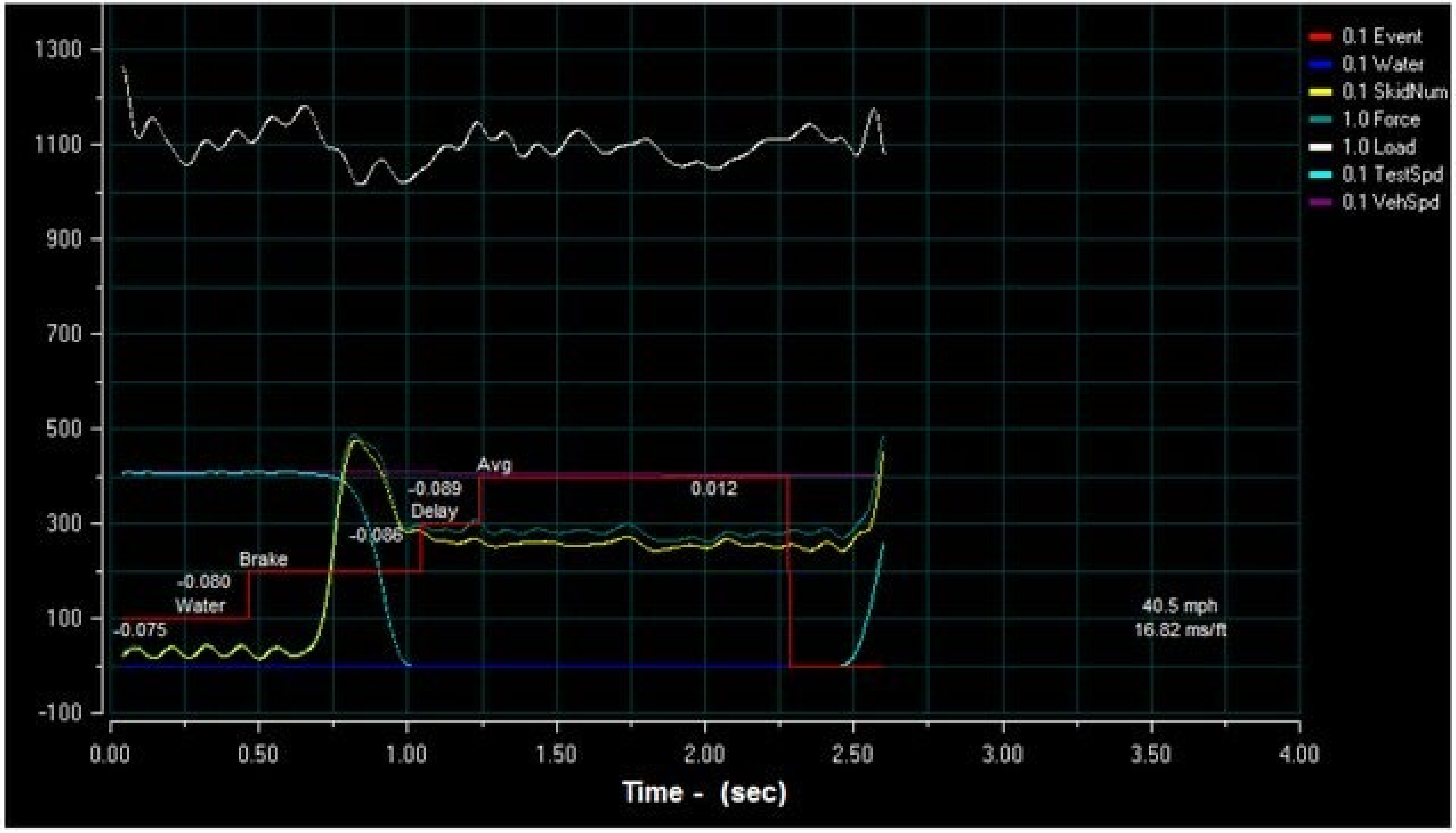
- $F = F[S, V, A, W, T, F_S]$
- F_S is the base friction measurement (used LWST at 40 MPH for now)
- S tire slip ratio operator
- V nominal vehicle speed impact ratio operator
- A tire angle impact
- W wet conditions operator
- T tire characteristics operator

BASE FRICTION MEASUREMENT



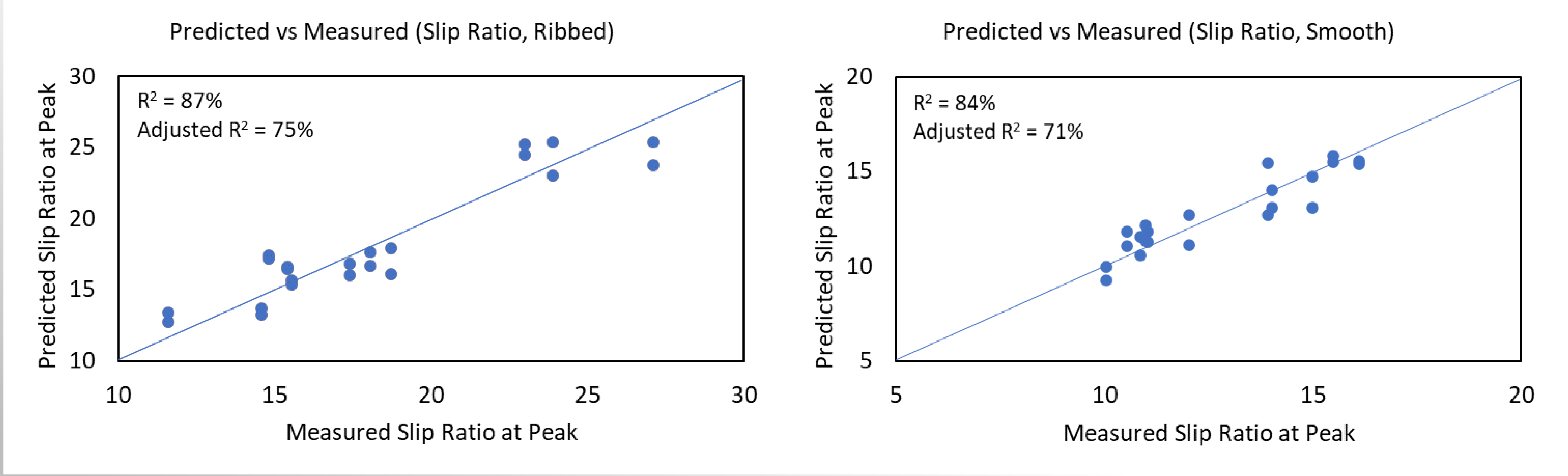


DECOMPOSING LWST MEASUREMENTS



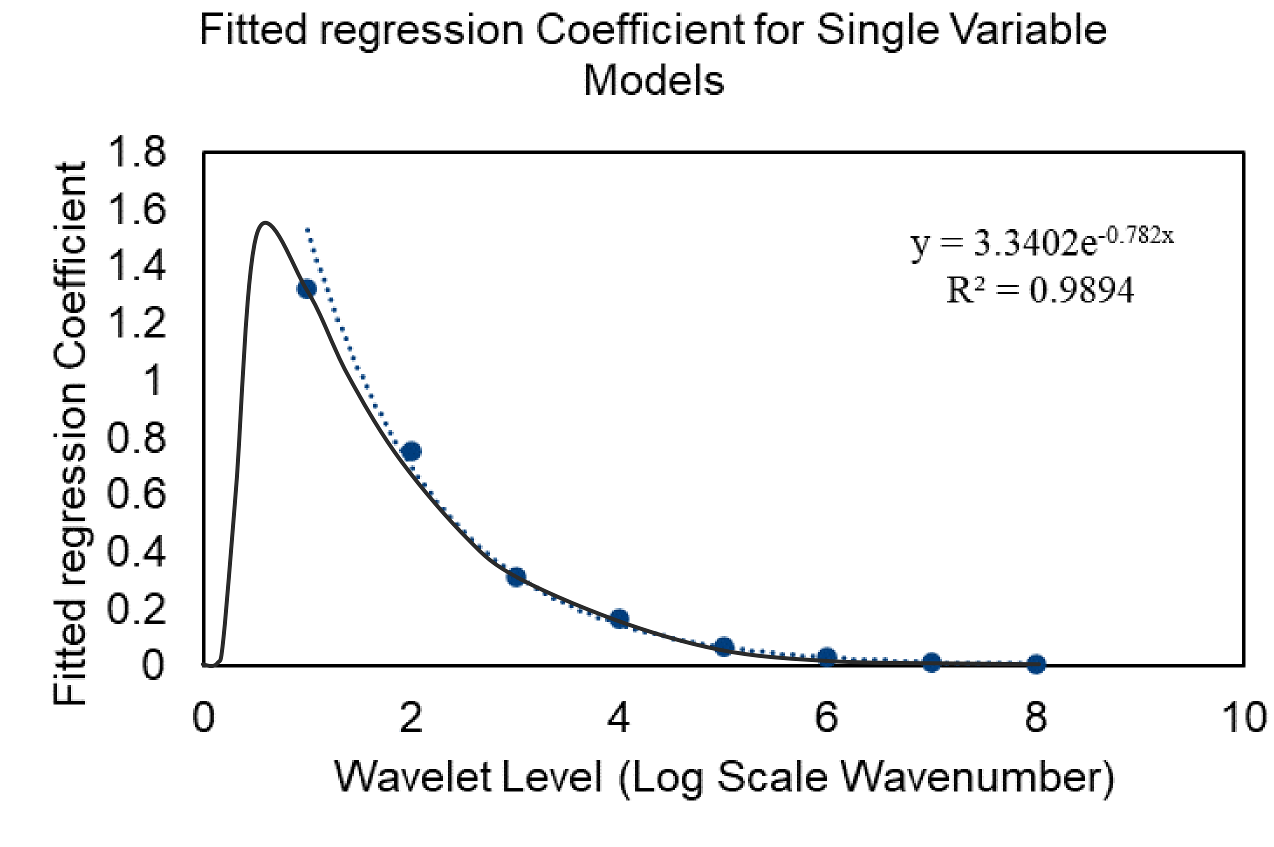
SLIP RATIO IMPACT

- $SR_{Peak} = \sum_{i=1}^{n} a_{SR,i} E_i$

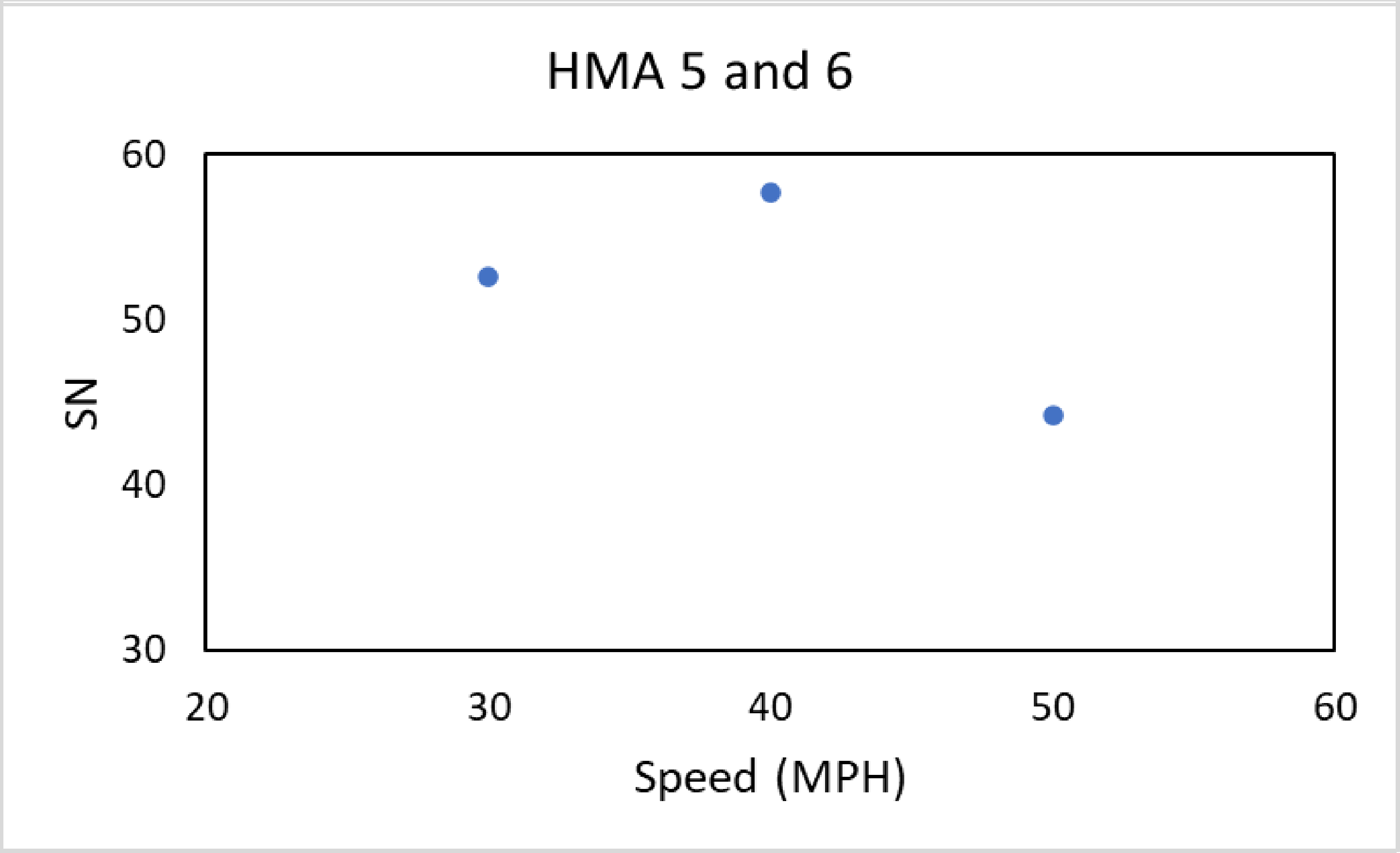


WAVELET ENERGIES CONTRIBUTIONS

Slip ratio operator regression coefficients.

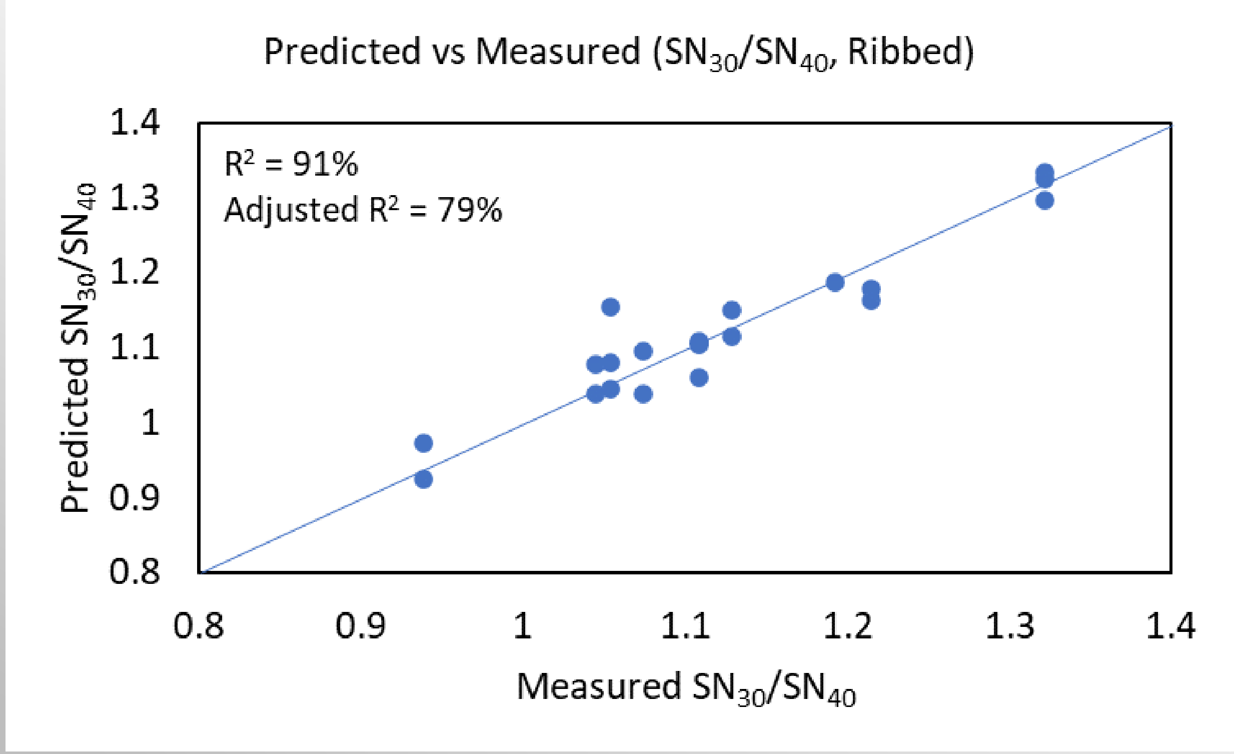


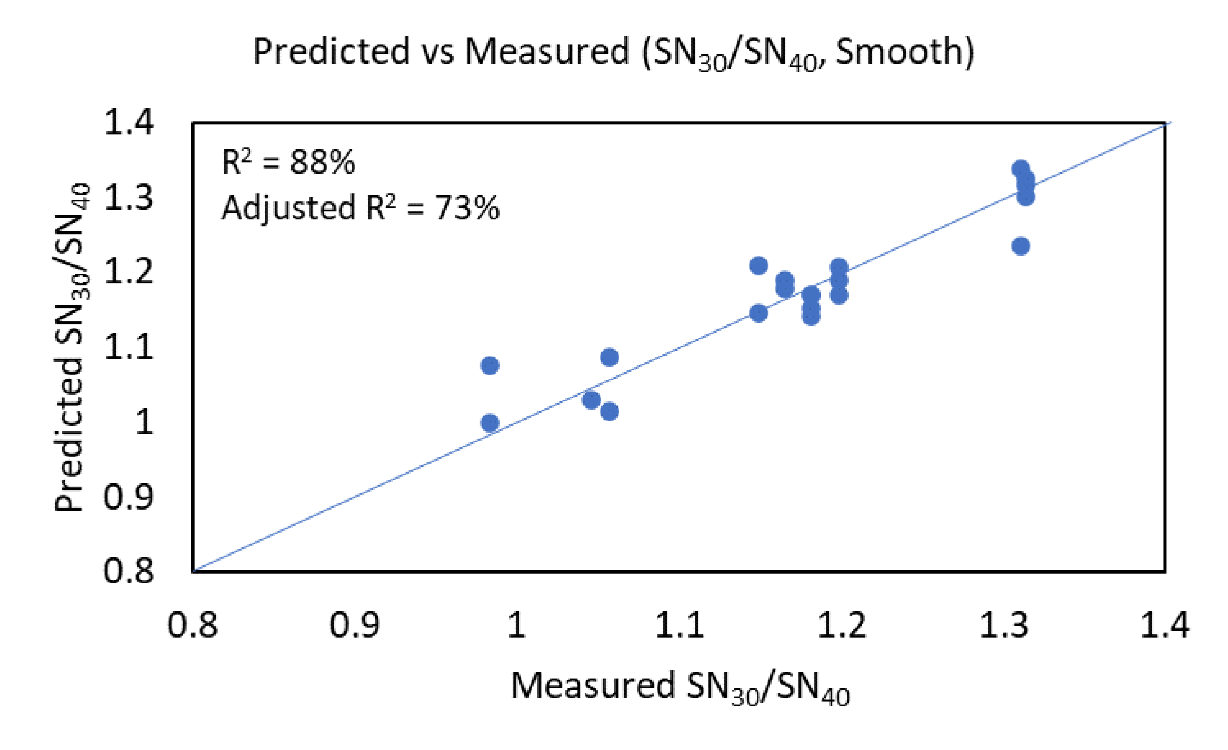
IMPACT OF SPEED



NORMALIZING MEASUREMENTS

- $SN_v = SN_v \sum_{i=1}^{n} a_{v,i} E_i$





CONCLUDING REMARKS AND FUTURE WORK

- We are planning on collecting additional data to cover a wider range of surfaces and conditions.
- It is important to test the models against other devices and technologies.
- The approach can lead to a general model encompassing different tire-pavement traction conditions.