A REAL-TIME MOTORCYCLE THERMAL AND INTERACTION TIRE MODEL FOR MOTORSPORT APPLICATIONS

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<u>UniNa Vehicle Dynamics research group</u>

MEGARIDE®

APPLIED VEHICLE RESEARCH

an official UniNa spinoff company

MULTI-PHYSICAL TIRE MODELS

MODULAR SIMULATION PLATFORM

SCIENCE APPLIED TO RACES

WHAT WE DO - FOR BIKE&TIRE MAKERS

FROM VEHICLE DATA
TO ROAD GRIP

SAFETY LOGICS
AND SMART MOBILITY

PATENTED

COST AND TIME SAVINGS IN
DEVELOPMENT STAGES

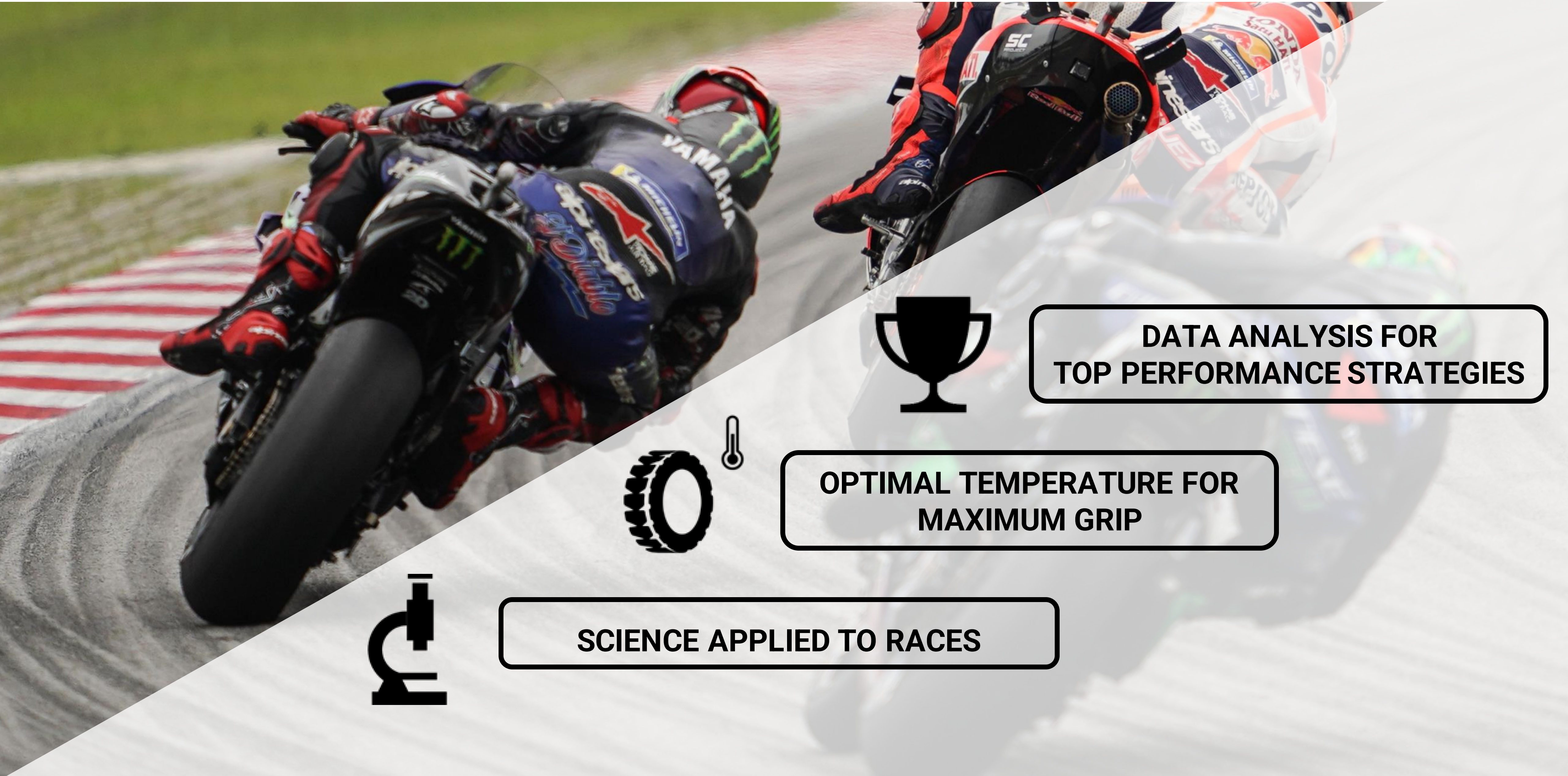
WHAT WE DO - IN REALTIME SIMULATIONS

ADVANCED DRIVING EXPERIENCE

VEHICLE DIGITAL TWIN

VIRTUAL TIRES DEV

WHAT WE DO - FOR MOTORSPORT



DATA ANALYSIS FOR
TOP PERFORMANCE STRATEGIES

OPTIMAL TEMPERATURE FOR
MAXIMUM GRIP

SCIENCE APPLIED TO RACES

RESEARCH HIGHLIGHTS

- TEAM AWARDED AS “M.I.T. YOUNG INNOVATORS UNDER 35”
- 1ST PROJECT IN ITALY FOR TECH-TRANSFER (IMSA AWARD) IN 2021
- 14 PhD / 20+ MSc / 35+ BSc PER YEAR ON VD AND TIRE SIMULATION TOPICS
- SUPPORT OF “TYRE LAB” UNIVERSITY FACILITY FOR EXPERIMENTAL ACTIVITIES

COMPANY HIGHLIGHTS

- “TIRE TECHNOLOGY OF THE YEAR” AND "VD DEVELOPMENT TOOL OF THE YEAR"
- GROWING TEAM (45 PPL) AND BUSINESS (EBITDA > 20%) IN 6 YEARS WITH NO DEBT / NO EQUITY GIVEN
- BECOME A TECH-HOLDING GROUP INVOLVING 4 STARTUPS (MEGARIDE, VESEVO, RIDESENSE, GRIP ADVISOR)
- 5 F1 / 2 MOTOGP / 1 MOTO2 / 2 SBK / 4 FOE / 2 WEC / 2 NASCAR / 2 WRC / 3 F2-F3 / 5 TIREMAKERS / 4 CARMAKERS

Innovazione 23

ECOSISTEMI

NAPOLI TECH UNA SCIA DI START UP DIETRO APPLE & CO.

Cupertino ha cominciato nel 2015, poi a ruota altri big: la prossima sarà Tim. Hanno creato acceleratori di imprese e trovato l'ambiente favorevole, grazie anche alla Federico II. I casi di MegaRide, Sophia High Tech ed E-LISa. E anche la Bbc tifa per la svolta tecnologica sul Golfo

di Greta Schaunich

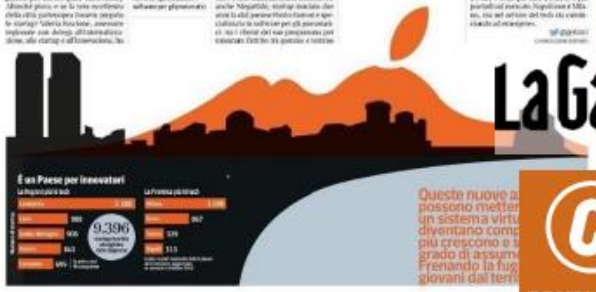
Caccia all'unicorno

MotoGp La Rossa ha vinto l'appello ma ha svelato il progetto di tre ingegneri partenopei: "Ora vediamo chi saprà copiarci"

Ducati senza segreti dietro il cucchiaio il genio napoletano

MASSIMO CALANDRI, TERMAS DE RIO HONDO

La Gazzetta dello Sport



È un Paese per innovatori

INNOVAZIONE

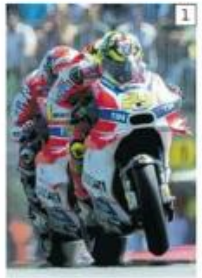
MegaRide, la startup ha grip sul mercato

MASSIMO CALANDRI, NAPOLI

Studia soluzioni innovative per aumentare l'efficienza dei pneumatici. E ora sta passando dalle corse, dove lavora con Ducati e Audi, ai veicoli da strada

Due anni fa scarabocchiavano il futuro logo sui tovagliolini da bar, la start up non era ancora nata. E adesso...». Adesso quella di MegaRide è una storia esemplare: tre amici geniali, l'Università Federico II, l'orgoglio di poter fare da soli reinvestendo gli utili nelle idee. Nove dipendenti, un fatturato che oggi sfiora il milione di euro ma continua a crescere. Le collaborazioni con Maserati, Pirelli, Audi e Ducati, che in MotoGP ha ricominciato a vincere esattamente il giorno in cui ha scelto di affidarsi a questi - ispiratissimi - ragazzi napoletani. Tre giovani ingegneri, soprattutto tre amici veri. I fondatori: Flavio Farroni, Francesco Timpone e Alexandr Sakhnevych. Aggiungete un fisico proveniente dalla Apple Academy di San Giovanni a Teduccio. E ora anche un ingegnere novarese, che ha scelto di lasciare la Ferrari di Formula Uno per "crescere con loro". Benvenuti al Sud.

E' cominciato tutto dalla tesi di laurea di Farroni, dieci anni fa, su un modello di "grip" per la Ferrari in Formula Uno. Studiando come ottimizzare le prestazioni dei pneumatici. "Ci hanno subito cercato in molti, proponendoci di prendersi le diverse licenze. Ho pensato che sarebbe stato meglio far nascere una start up in un ambiente vivace come quello napoletano, a stretto contatto col polo di San Giovanni dove ci sono Academy come Apple, Deloitte e Ferrovie dello Stato. Il posto giusto, nel momento giusto". MegaRide, ovvero: applied vehicle research. Ricerca applicata al veicolo. La start up comincia a collaborare con Ducati Corse. Esordio perfetto: il 14 agosto 2016, in Austria, la Rossa di Borgo Panigale realizza una doppietta storica vincendo con Iannone e Dovizioso secondo. "Abbiamo allargato le collaborazioni: oltre a Ducati, abbiamo l'esclusiva con Audi Sport in Formula E. Lavoriamo con Maserati, Pirelli". Il software è fondamentale per capire quale sarà il miglior set up da adottare per ogni gara, però anche per un'azienda che vuole progredire nelle prestazioni della propria gomma, evolvere nello sviluppo delle vetture. "E' solo 'inizio'", conferma Farroni, premiato dalla rivista italiana del Mit di Boston tra i 10 giovani innovatori dell'anno. "La nostra tecnologia può offrire importanti prospettive ai grandi player dell'automotive". Dicono che una start up non possa andare avanti senza un grande investitore. Invece. "Ci siamo autofinanziati, reinvestendo gli utili delle collaborazioni in risorse e strutture, restando titolari al 100% delle quote". Un esempio che ha finito per attirare delle eccellenze come Damiano Capra, 35 anni, di Novara, per 6 stagioni alla Ferrari in Formula Uno. "Volevo crescere da un punto di vista personale", spiega. "Scommettere su di una realtà giovane però con grandi prospettive, in cui potessi portare la mia esperienza. Conoscevo la qualità di questo ambiente. E non ho esitato un secondo, ad andare a Sud".



1 La Ducati ha adottato le soluzioni di MegaRide dal 2016 nel Gp d'Austria

la Repubblica A&F AFFARI&FINANZA

STARTUP DI GENI

E ad aiutarli c'è MegaRide: dall'università a maghi del grip

di Andrea Cremonesi

Harvard Business Review ITALIA

START-UP INTERVIEW

MegaRide, il futuro della smart mobility tra mito e innovazione

INTERVISTA DI CRISTINA CAPECE A FLAVIO FARRONI, CEO E CO-FOUNDER DI MEGARIDE

30 Novembre 2018

SERVIZIO | AUTOMOTIVE

MegaRide dalla MotoGp alle strade: la startup napoletana vi testa le gomme

–di Francesco Prisco

The Trust Project

Il Sole 24 ORE TECNOLOGIA

Development Tool of the Year:

MegaRide Simulation pack

From simulation to durability assessment, software to lab machinery, the Development Tool of the Year category recognizes innovation in creating tools that help vehicle dynamicists achieve automotive excellence.

In 2018 the startup company MegaRide (a spin-off of the University of Naples) launched a modular system to enhance real-time driver-in-the-loop (DIL) simulation for tire performance and vehicle setup optimization, with a view to helping automotive and motorsport companies improve safety and performance. The company may be new, but it is reporting success, having already had its systems implemented in the vehicle and tire development programs of several tire manufacturers, as well as the simulation systems of several motorsport teams from Formula E, MotoGP and DTM – and it has now won a VDI award.

DIL simulators are certainly useful, especially with the real-world testing limitations and costs of motorsport, but if the theoretical limits applied in the system are not accurate, then the drivers' sensations and feeling of the car setup, as well as their responses to the model and feedback to engineers, are not truly representative of the real world.

To help solve this issue, the MegaRide pack comprises three main elements to enhance simulation: a physical thermal model to predict, in real-time, the temperature of different tire layers; a formula that takes into account tread wear phenomena, road roughness, compounds' viscoelasticity and grip/temperature relationship; and a multicontact tire/road envelope model, to enhance the reliability of the driver's feeling in driving simulations, reproducing the ride dynamics caused by curbs, bumps and road roughness.

This cooperation between the models in real-time simulation environments increases the reliability and the physicality of testing sessions performed using driving simulators and vehicle dynamics platforms.

Padraic Deane, managing editor,

Все о мире MotoGP

Why here today

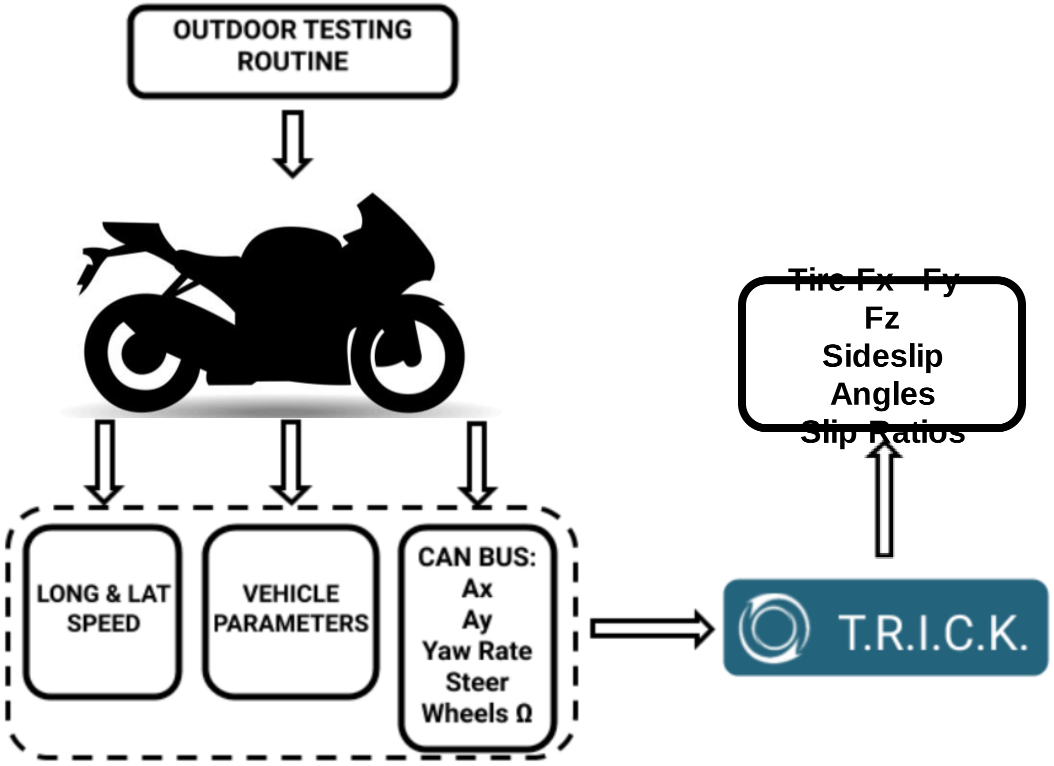
The activities of the **Vehicle Dynamics UniNa research group** and of the related companies concerning the development of **models** and **procedures** aimed to support subjects playing a role in **vehicle dynamics** field have been extended in several projects to "**two-wheeled vehicles**" field, for:

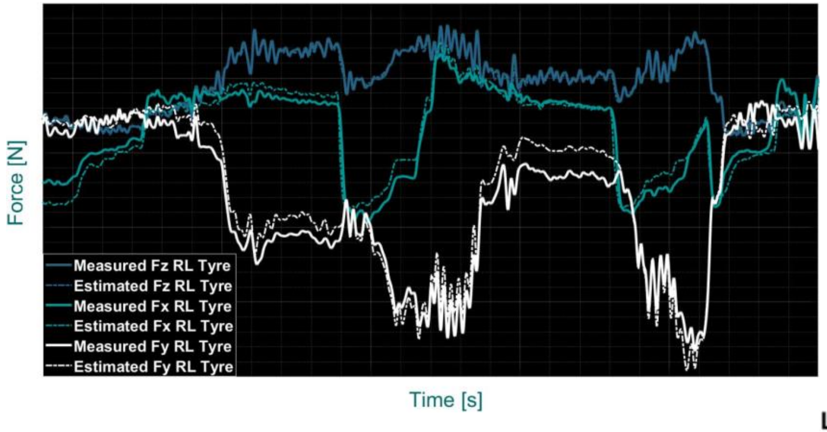
- DEVELOPMENT OF **PHYSICAL MODELS** CONCERNING WITH RIDE, COMFORT, HANDLING AND TIRE/ROAD INTERACTION PHENOMENA
- DEVELOPMENT OF PROCEDURES FOR THE **IDENTIFICATION OF PARAMETERS** CHARACTERIZING VEHICLES AND THEIR SUBSYSTEMS

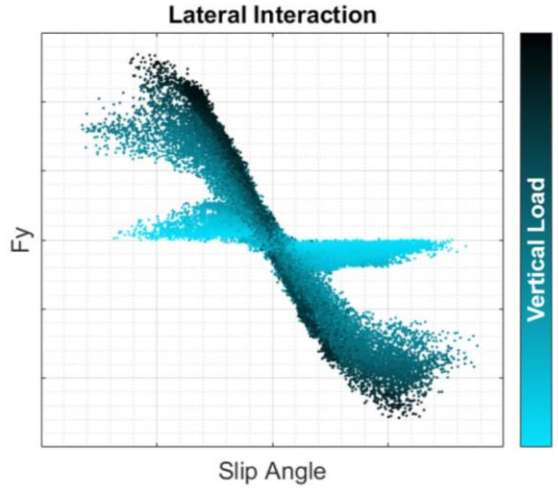
- DEVELOPMENT OF **SOFTWARE PACKAGES** FOR THE EVALUATION AND THE OPTIMIZATION OF THE VEHICLE PERFORMANCES BOTH IN ROAD AND IN TRACK APPLICATIONS
- DEVELOPMENT OF INNOVATIVE METHODOLOGIES FOR **EXPERIMENTAL TESTING ACTIVITIES**, INDOOR AND OUTDOOR

STEP 1: from Vehicle Data to Models Input

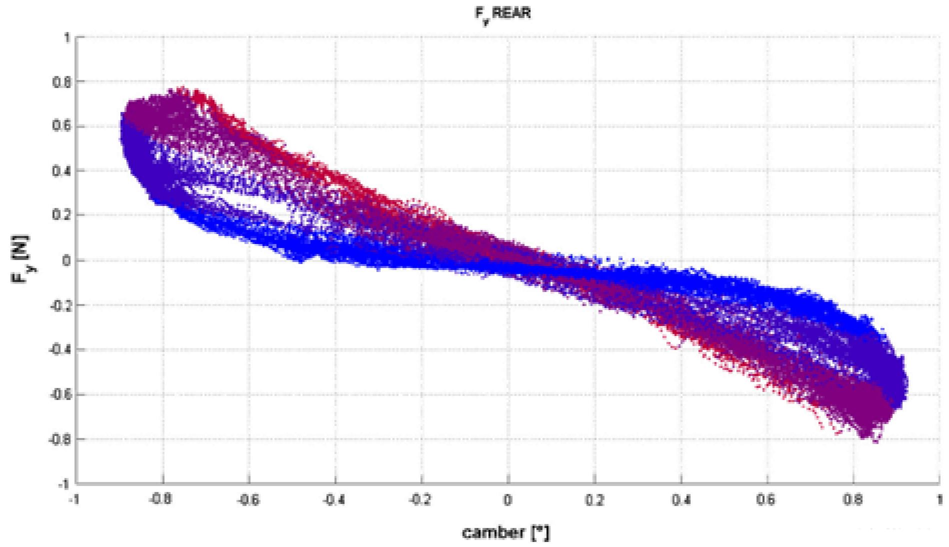
T.R.I.C.K. (Tire/Road Interaction Characterization & Knowledge) is a tool for the evaluation of tire forces from standard onboard signals, born for vehicle design target, grown for grip real-time evaluation



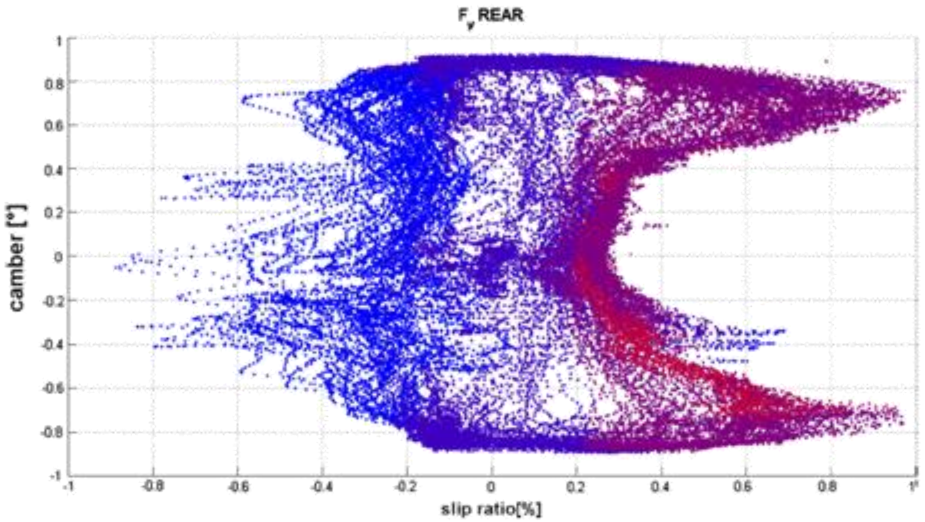


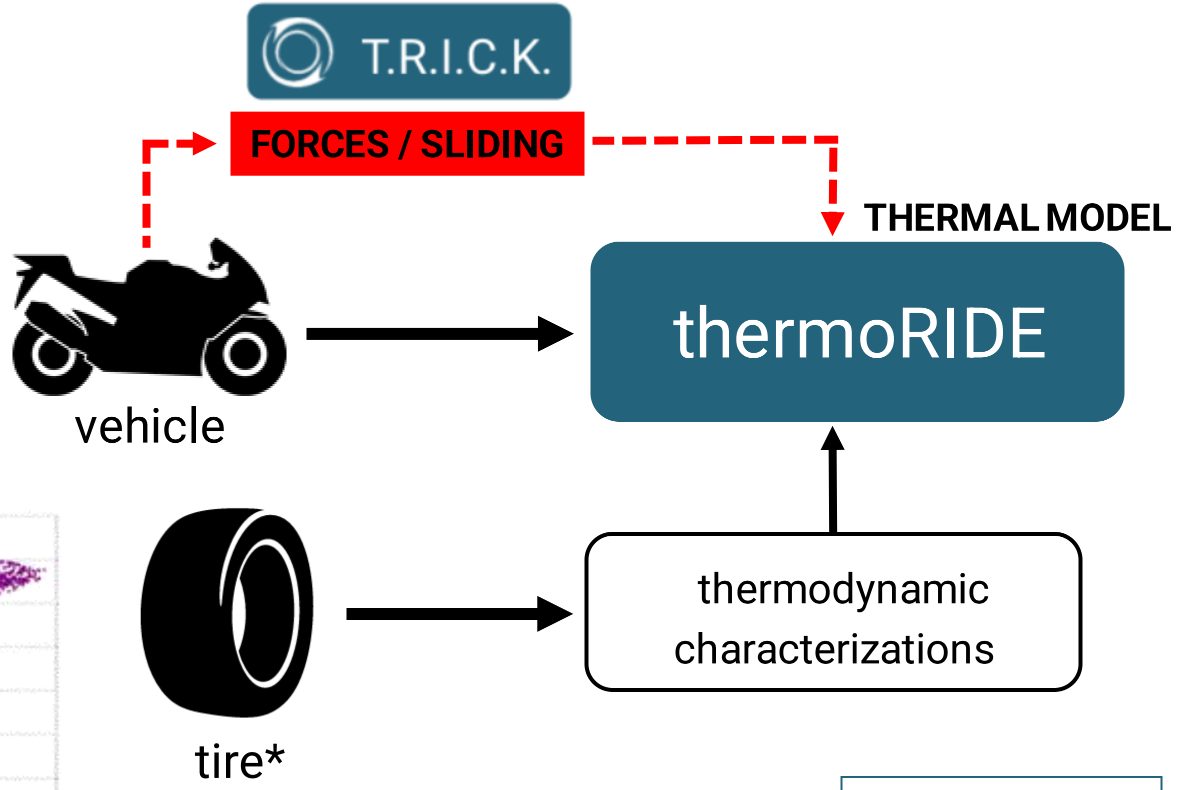


STEP 1: from Vehicle Data to Models Input



- Tangential Forces
- Vertical Forces
- Slip Angles
- Slip Ratios
- Camber Angles
- Wheel Speeds





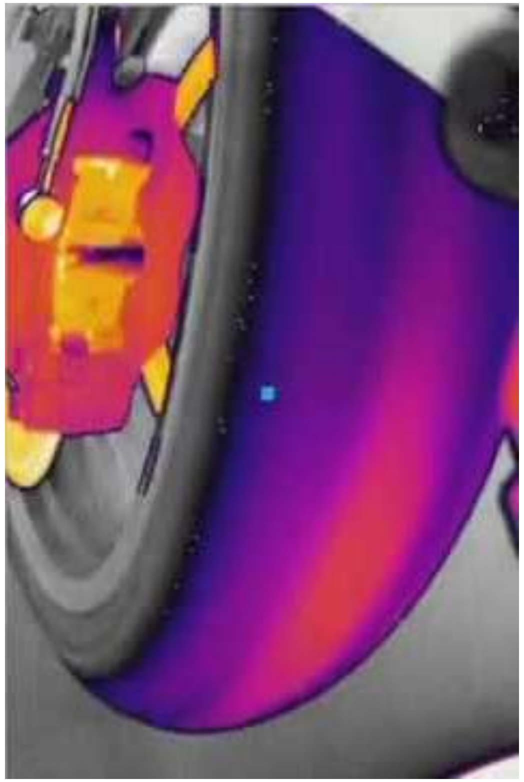
* Model Parameters Characterization in cooperation with UniNa Tire Lab

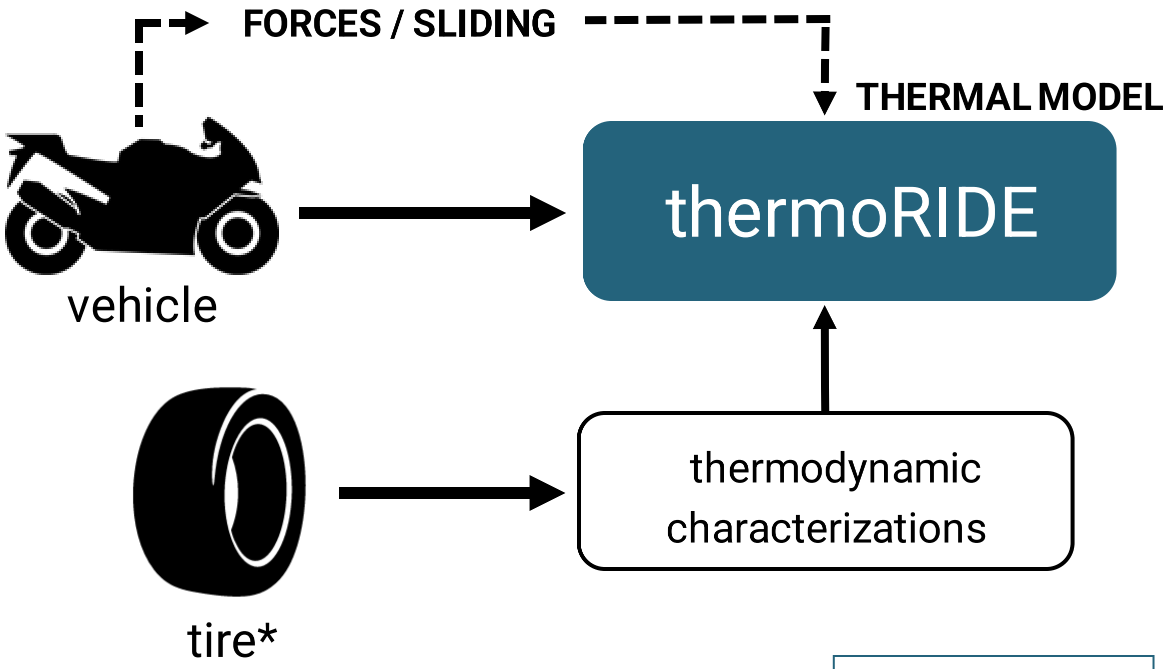
STEP 2: Motorcycle Real-Time Tire Thermal Modelling

an overview

TARGET:

- Availability of thermal info on inner layers (not measurable)
- Advanced analysis & sim concerning grip/stiffness correlation with tire temperature
- Prediction of tire temperature local distribution in next events
- Setup development for thermal working range optimization



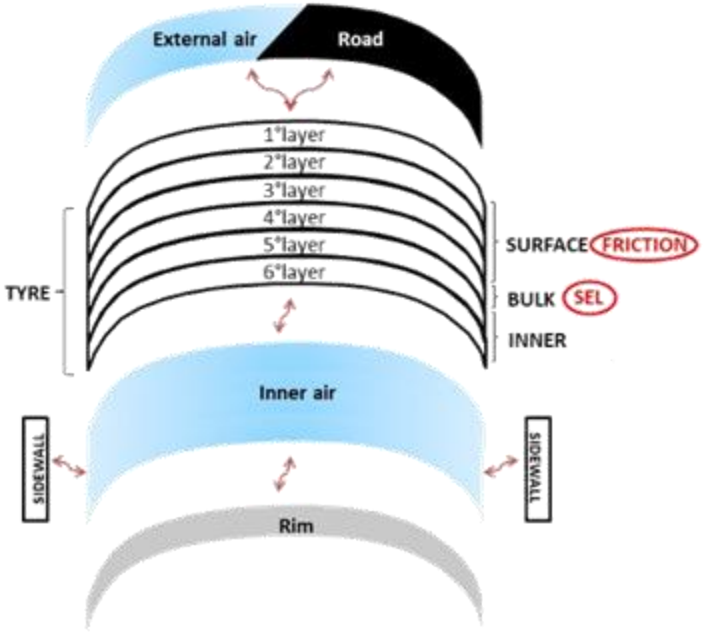


*** Model Parameters Characterization in cooperation with UniNa Tire Lab**

STEP 2: Motorcycle Real-Time Tire Thermal Modelling

physical modelling - basic concepts

The tire is represented as a parallelepiped, constituted by **6 layers (+ inner air and sidewalls)** along the **radial** direction z, discretized in a number of nodes defined by user according to the desired level of **detail** and **computational load** for real-time running



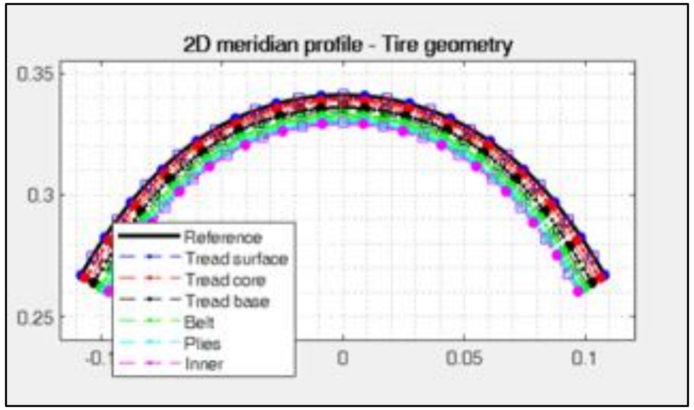
- Tread Surface
- Tread Core
- Tread Base
- Belt
- Plies
- Inner Liner

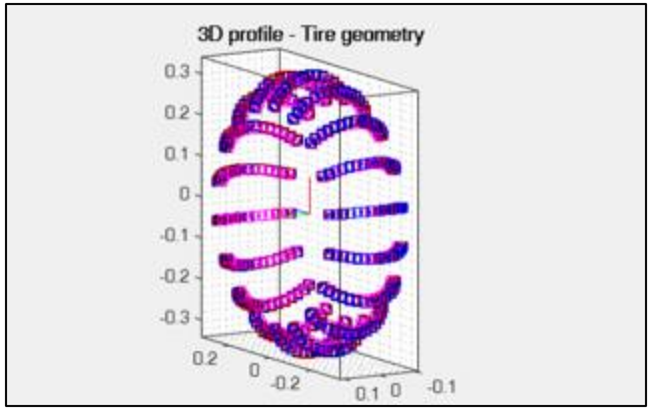
STEP 2: Motorcycle Real-Time Tire Thermal Modelling

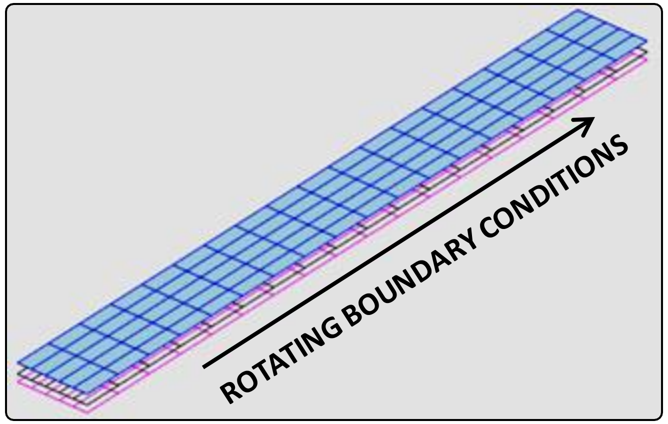
physical modelling - tire structure

The tire is represented as a parallelepiped, constituted by **6 layers (+ inner air and sidewalls)** along the **radial** direction z, discretized in a number of nodes defined by user according to the desired level of **detail** and **computational load** for real-time running

Along the **lateral** direction the nodes are grouped in **up-to-16** ribs in order to take into account contact patch position due to steering and camber variations



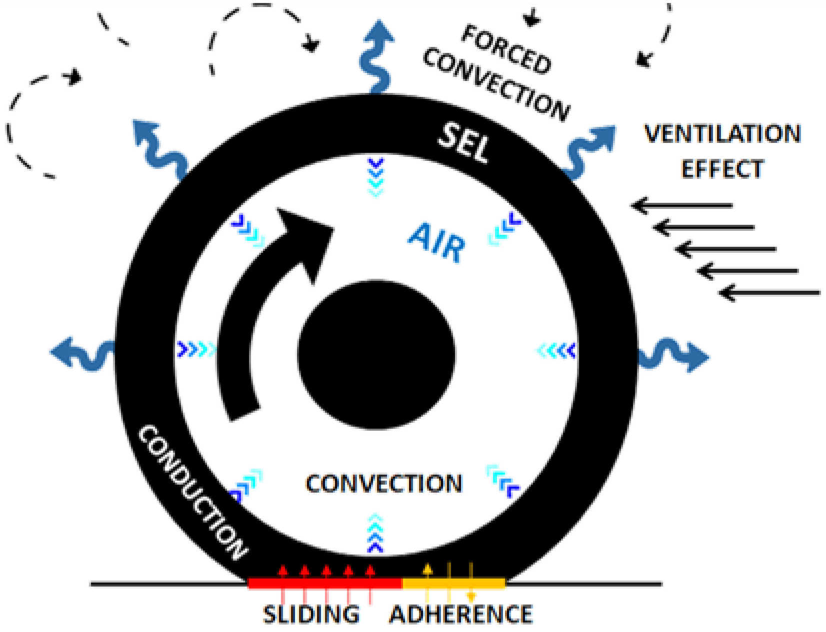




STEP 2: Motorcycle Real-Time Tire Thermal Modelling

physical modelling - thermal phenomena

The model takes into account the physical phenomena concerning tire thermal behaviour:



- the **heat generations** due to:
  - Friction Power - tire/road tangential interaction
  - SEL (Strain Energy Loss) - effect of deformations due to rolling

- the **heat exchange with the external environment** due to:
  - forced convection of the tire surface layer with the outside air
  - thermal conduction between the tread and the road
  - natural/forced convection of the inner liner with the inner air

- the **heat conduction** between the tire layers due to temperature gradients

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

MEGARIDE

VI-GRADE

2024 ZERO PROTOTYPES SUMMIT

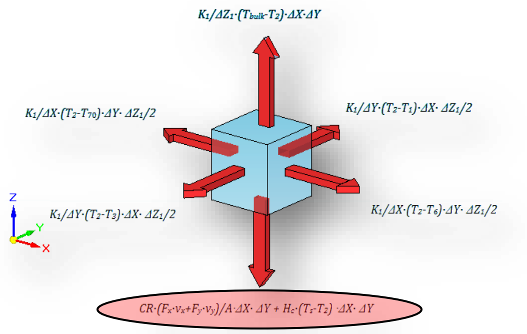
STEP 2: Motorcycle Real-Time Tire Thermal Modelling

physical modelling - formulations

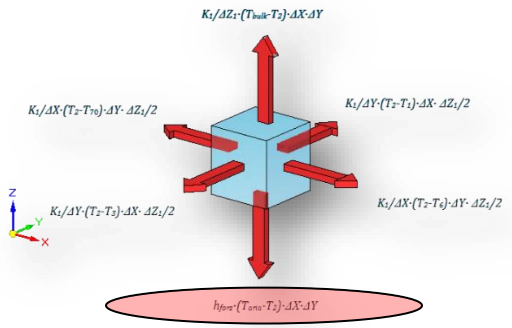
The model is based on **heat balance differential equations**, carried out for each node and integrated with time-varying boundary conditions, depending on their position around the axis of the wheel

The developed thermodynamic tire model is based on the use of the **diffusion equation of Fourier** applied to a **three-dimensional domain**

$$\frac{\partial T}{\partial t} = \frac{\dot{q}_G}{\rho \cdot c_v} + \frac{1}{\rho \cdot c_v} \cdot \left(\frac{\partial^2 k(z,T) \cdot T}{\partial x^2} + \frac{\partial^2 k(z,T) \cdot T}{\partial y^2} + \frac{\partial^2 k(z,T) \cdot T}{\partial z^2} \right)$$



NODE IN CONTACT WITH ROAD



NODE IN CONTACT WITH EXTERNAL AIR

Writing the balance equations for each generic node needs the modelling of heat **generation** and of heat **exchanges** with the external environment

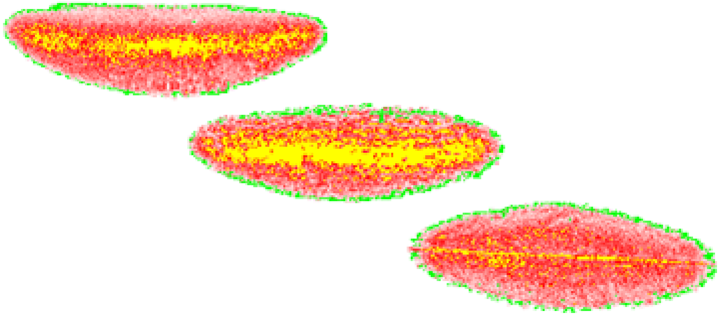
STEP 3: Model Parameterization

our nondestructive approach

In order to provide tire temperature distribution from telemetry data the model has to be properly characterized by means of a specific "LAB" version, reproducing tire behaviour under testing conditions

The tire parameters are experimentally characterized at UniNa TireLab:

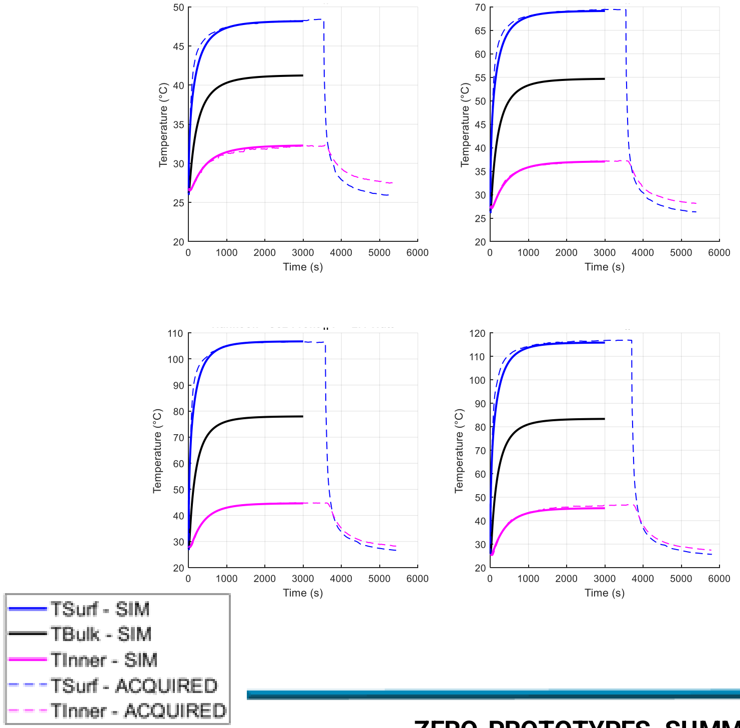
- THERMAL: evaluation of the **Thermal Characteristics** (Conductivity and Specific Heat) by means of a specifically developed laser and thermal cameras test bench
- STRUCTURAL: **evaluation of the SEL** (Strain Energy Loss) contribution due to rolling cyclic deformations of tread and carcass structure, and **measurement of the Contact Patch area** at different values of camber and vertical load

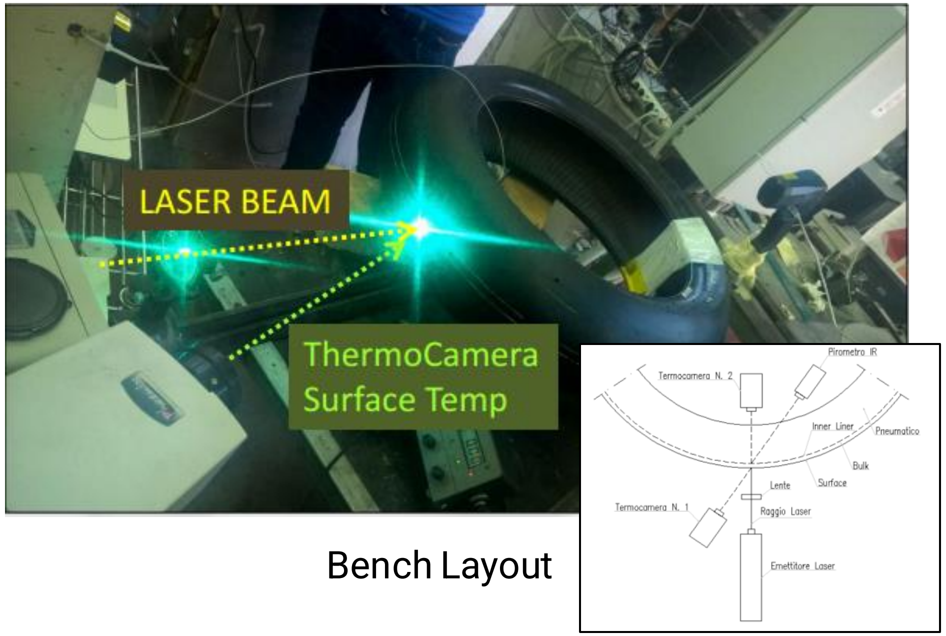


STEP 3: Model Parameterization

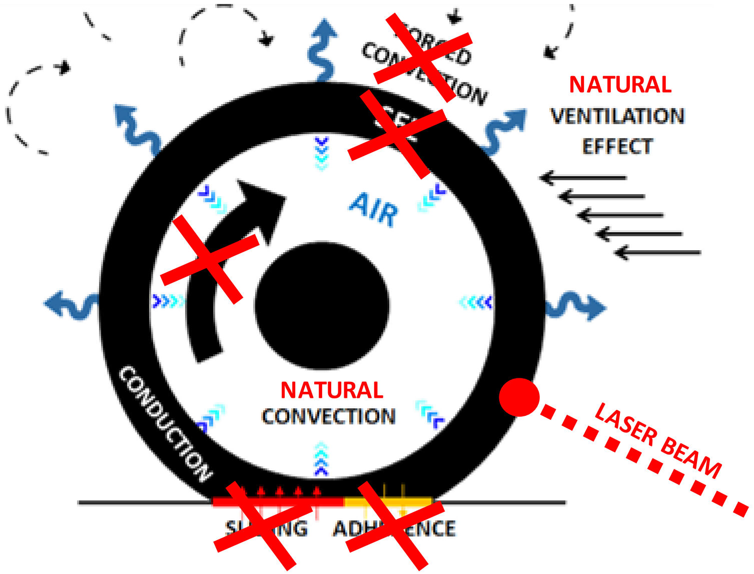
Thermal Diffusivity Characterization

A fundamental parameter for the tires thermodynamic characterization is the **thermal diffusivity**, which embraces together **thermal conductivity**, **density** and **specific heat**. Its estimation is quite complex to determine, due to variability among tires and to temperature dependence





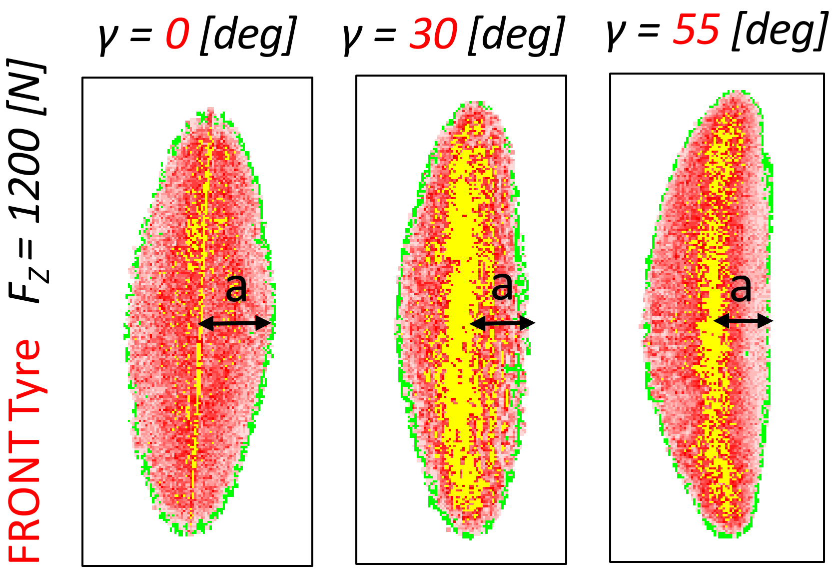
Bench Layout

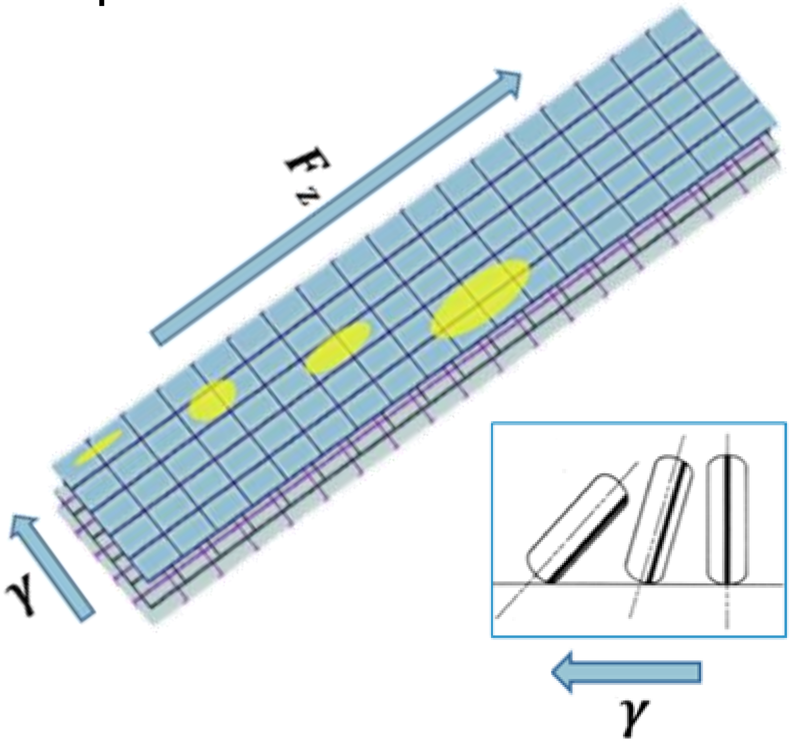


STEP 3: Model Parameterization

Footprints Characterization

A specific test bench equipping contact pressure sensors is adopted with the aim to quantify **contact patch extension** under variable values of vertical load, camber angle and inflation pressure.

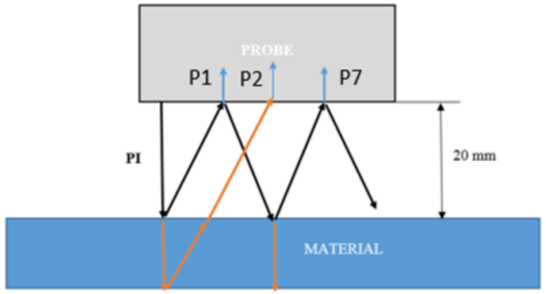


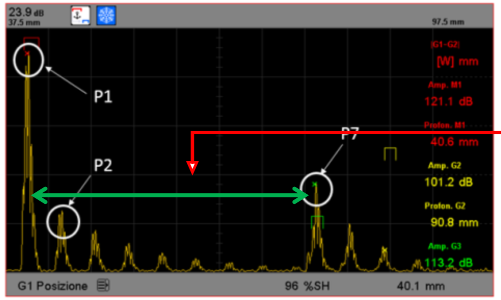


STEP 3: Model Parameterization

Inner Layers Thickness Evaluation

The estimation of tire layers **thickness** is performed thanks to the elaboration of signals acquired by **ultrasonic probes**



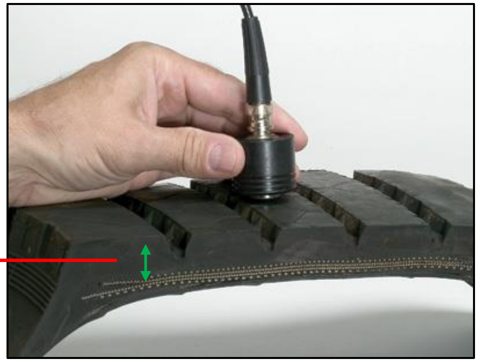


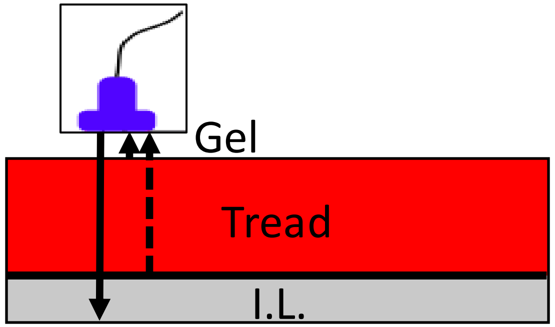
P1 = P$_i$*D20***R***D20*T$_{probe}$
P7 = P$_i$*D20***R***D20*R$_{probe}$*D20***R***D20*T$_{probe}$

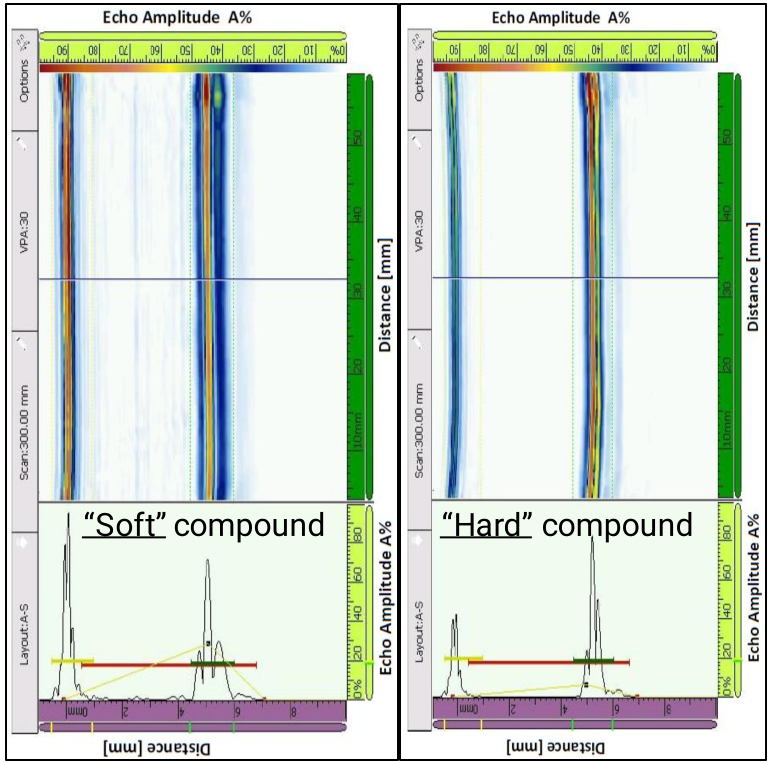
$$\mathbf{R} = \frac{Z_2 - Z_1}{Z_1 + Z_2}$$

$$Z_2 = \left(\frac{\rho * c}{1 + r^2}\right) + i * \left(r * \frac{\rho * c}{1 + r^2}\right)$$

TREAD THICKNESS
TAN(δ)







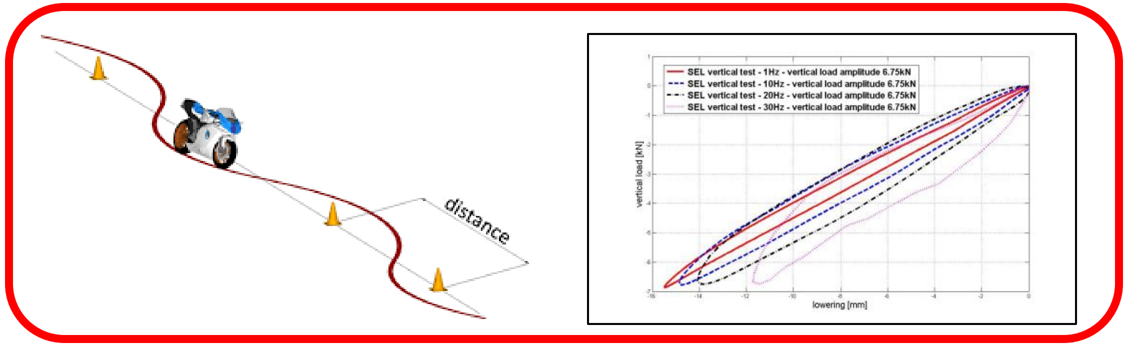
STEP 3: Model Parameterization

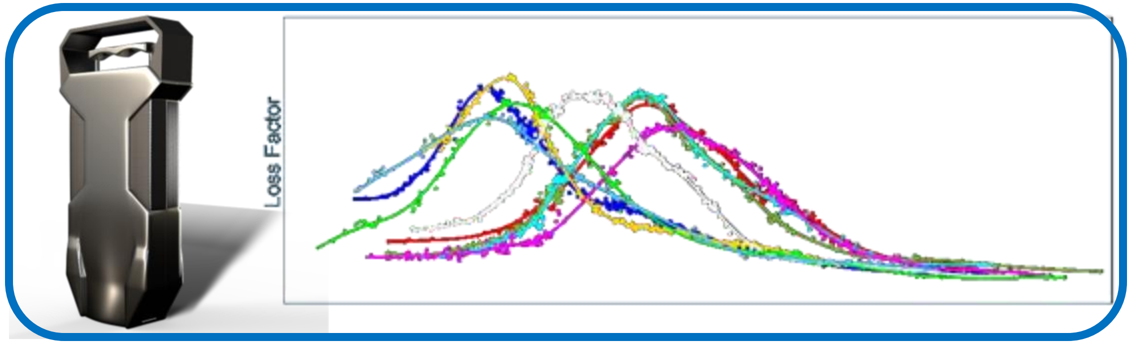
Strain Energy Loss Characterization

The **SEL (Strain Energy Loss)** is the energy dissipated by the tire as a result of the deformations due to rolling and road interactions. This dissipation is caused by a superposition of several phenomena, such as **intra-plies friction**, non-linear **visco-elastic behaviour** of rubber components and **sidewall deflections**

In order to determine the above mentioned macro and micro mechanical characteristics, 2 different identification procedures have been developed:

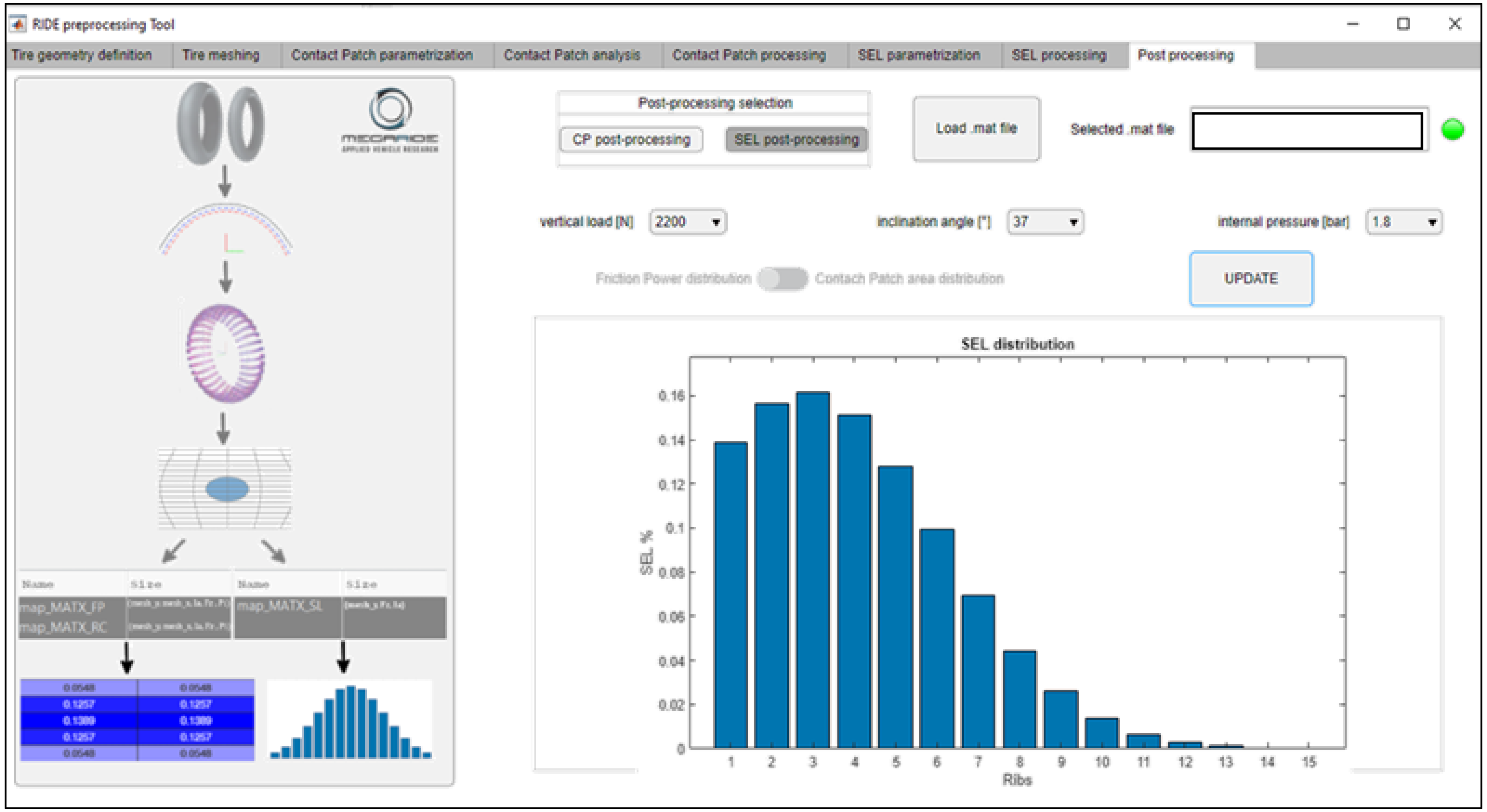
- **macro-SEL**, identified from track data, acquired under specific testing conditions
- **micro-SEL**, identified from compound viscoelastic characteristics, measured by VESevo





STEP 3: Model Parameterization

Strain Energy Loss Modelling



The macro and micro SEL data collected are analysed and distributed along lateral ribs by means of a dedicated processing tool

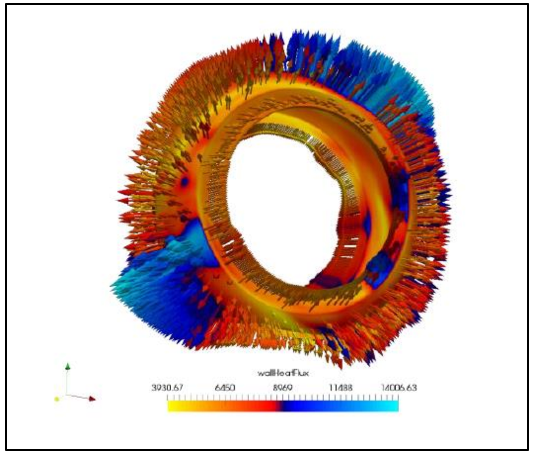
Example:
Fz: 2000N
Camber: 37°
Inner Pressure: 1.8bar

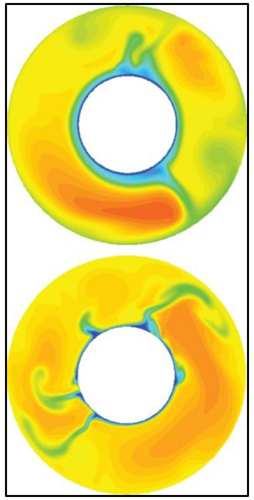
STEP 3: Model Parameterization

Special Customizations

thermoRIDE Model – BOUNDARY CONDITIONS & FURTHER IMPLEMENTATIONS

- **Convection with external air** is modelled by physical analytic expressions or CFD aero-maps

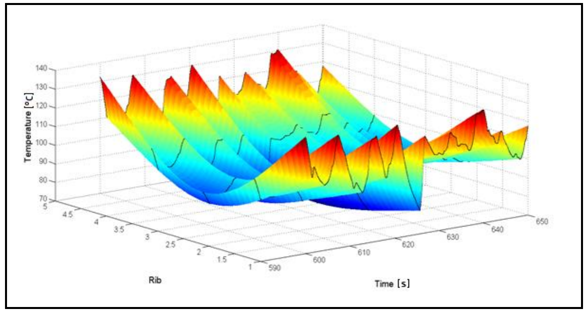




- **Inflation chamber airflow** is supposed as being characterized by natural, laminar or turbulent forced convection depending on wheel speed (studied with CFD and modelled by proper analytic expressions)

- Modelling of effects due to **local heat sources** (exhaust-blown diffusers & local overheatings)

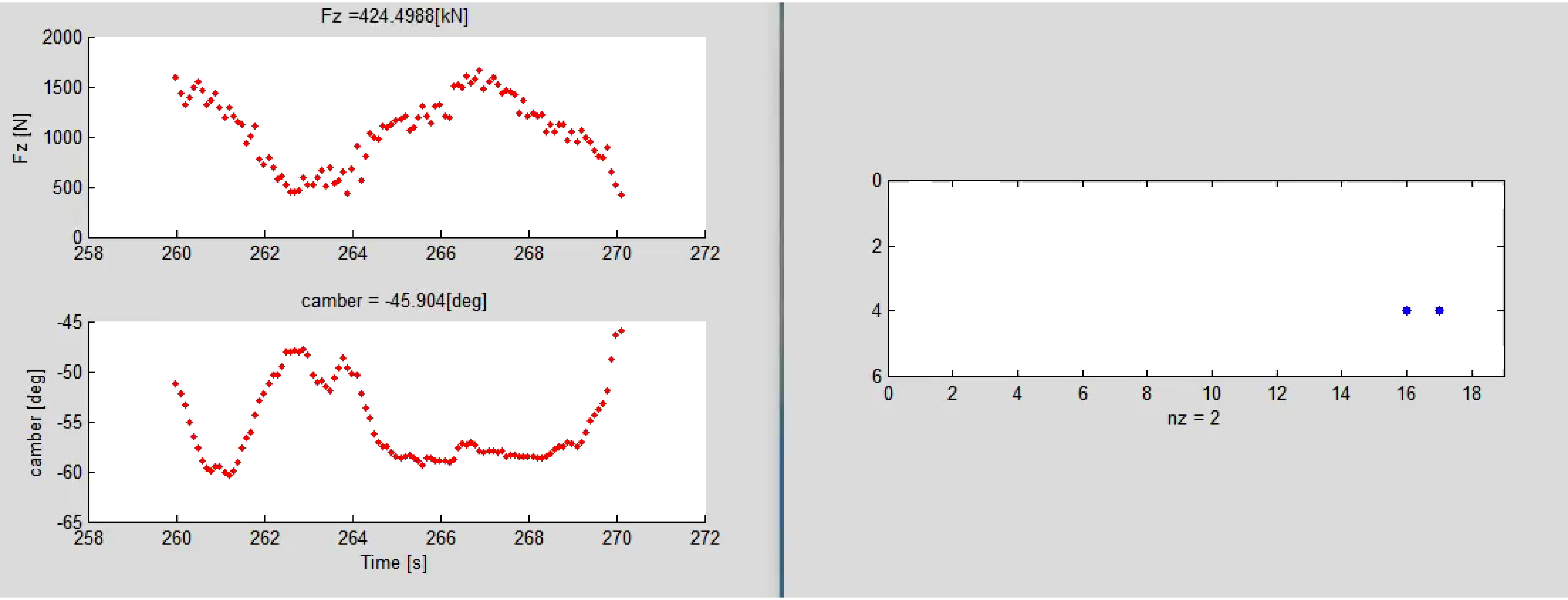
- **Under/over inflation** thermal effects



STEP 4: Running the Model

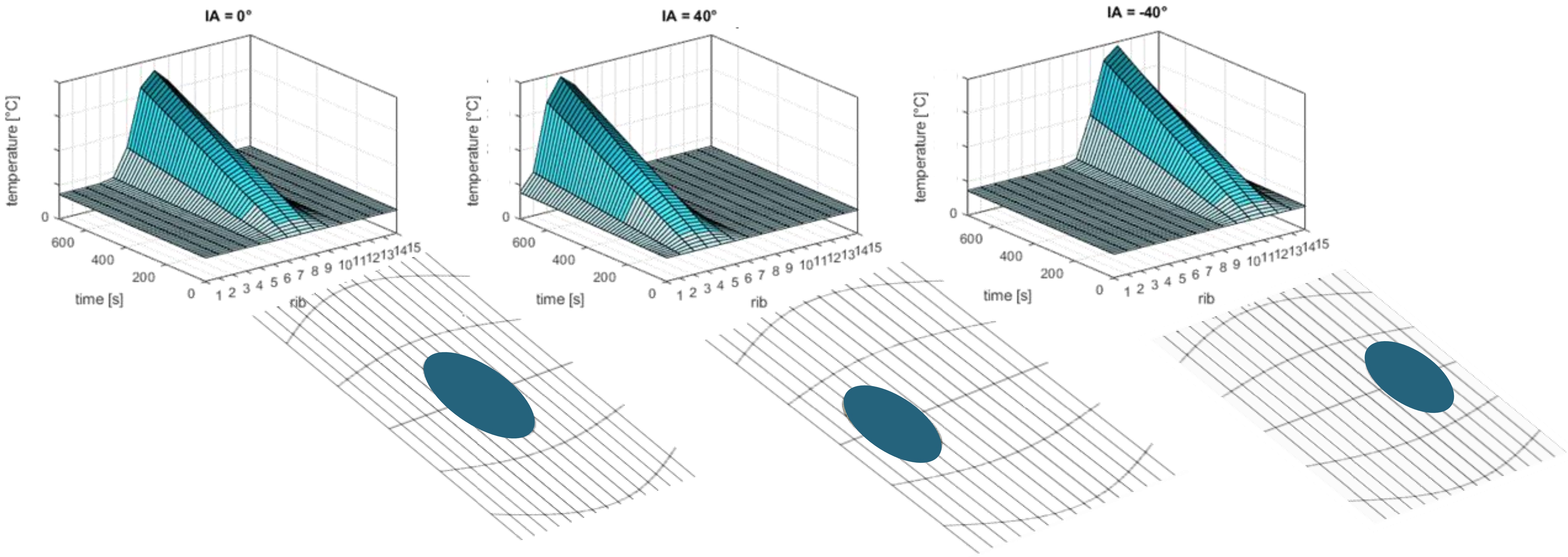
Working Principle

Contact Patch nodes motion within the unrolled tire surface grid due to Fz and camber variations



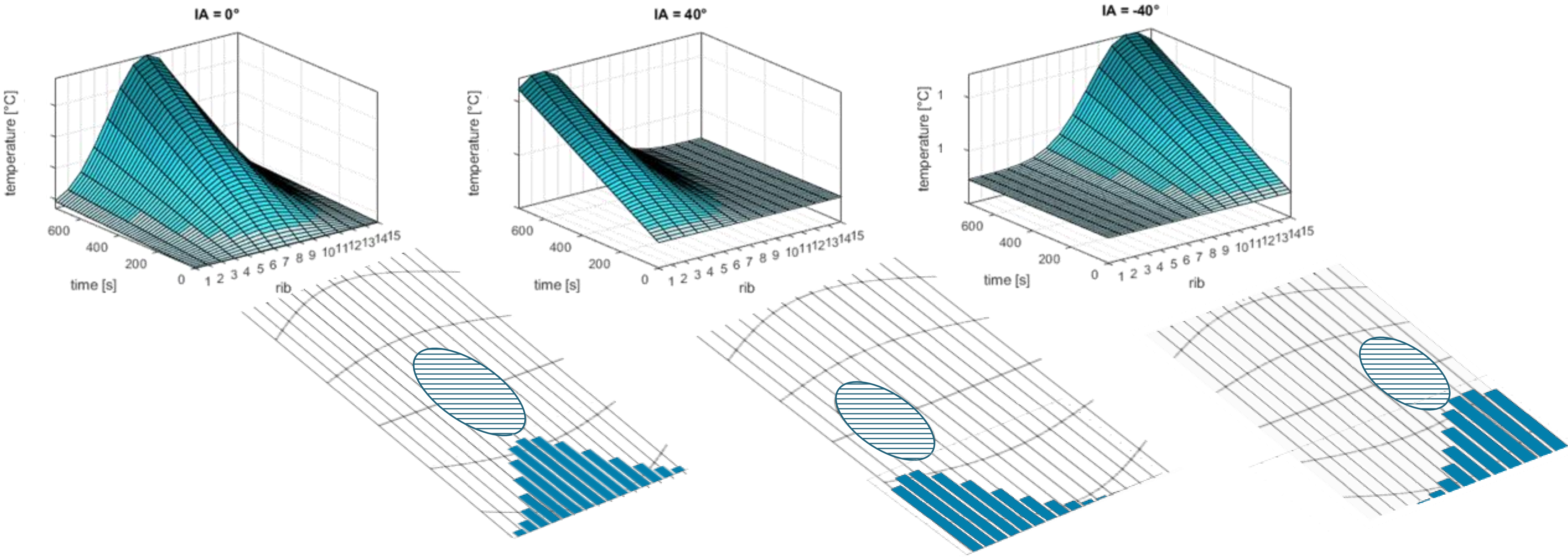
STEP 4: Running the Model

Friction Power Consistency and Validation Tests



STEP 4: Running the Model

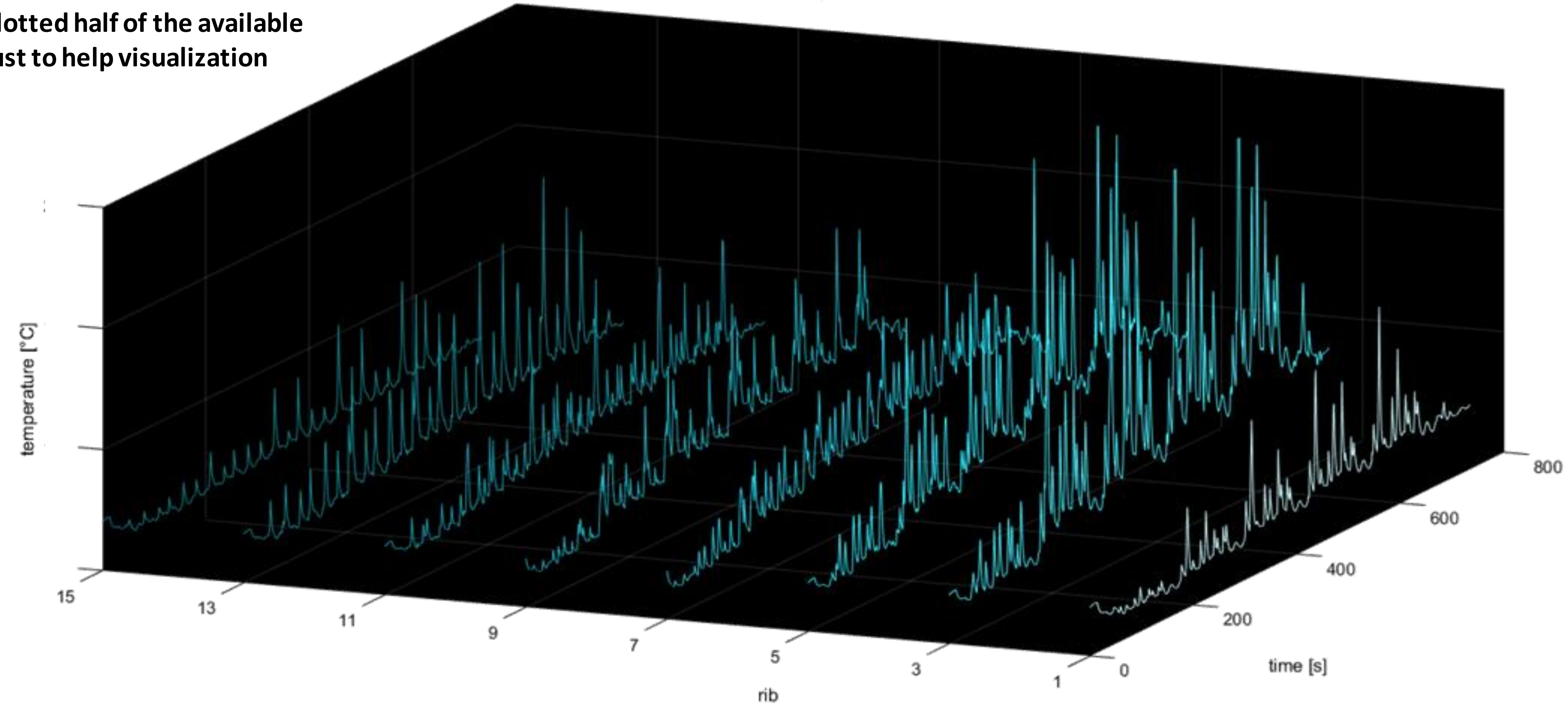
SEL Consistency and Validation Tests



STEP 4: Running the Model

Whole Lap Tire Surface Simulation Rib by Rib

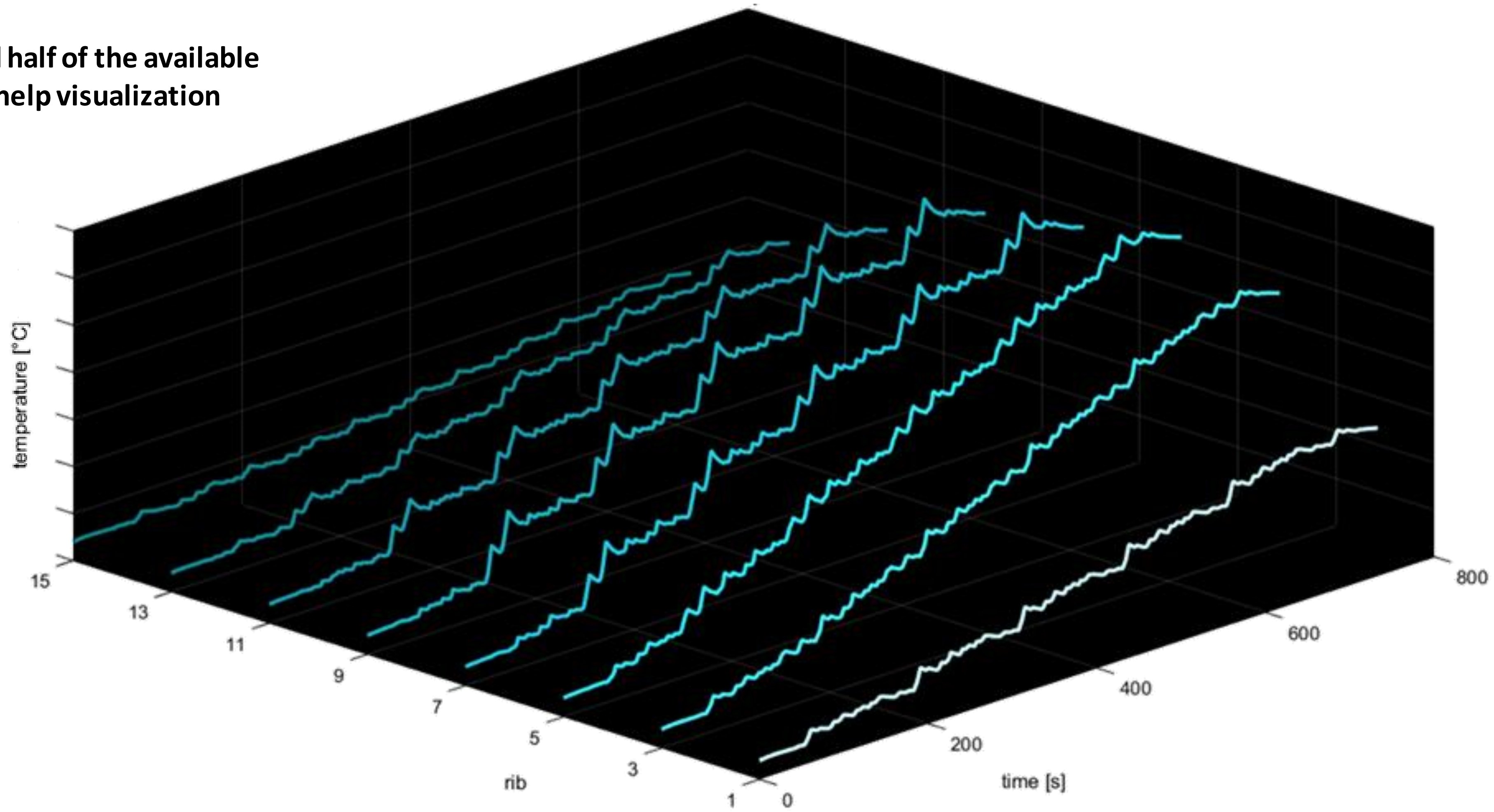
*** plotted half of the available ribs just to help visualization



STEP 4: Running the Model

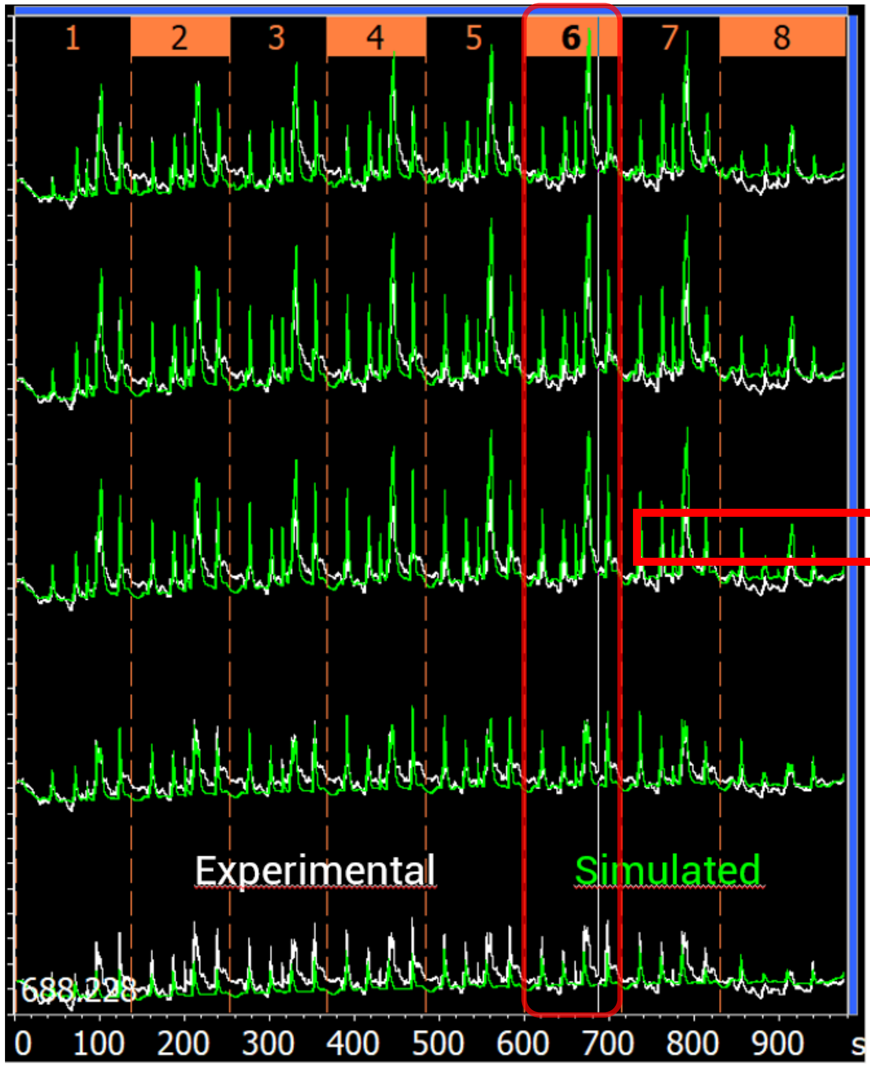
Whole Lap Tire Tread Core Simulation Rib by Rib

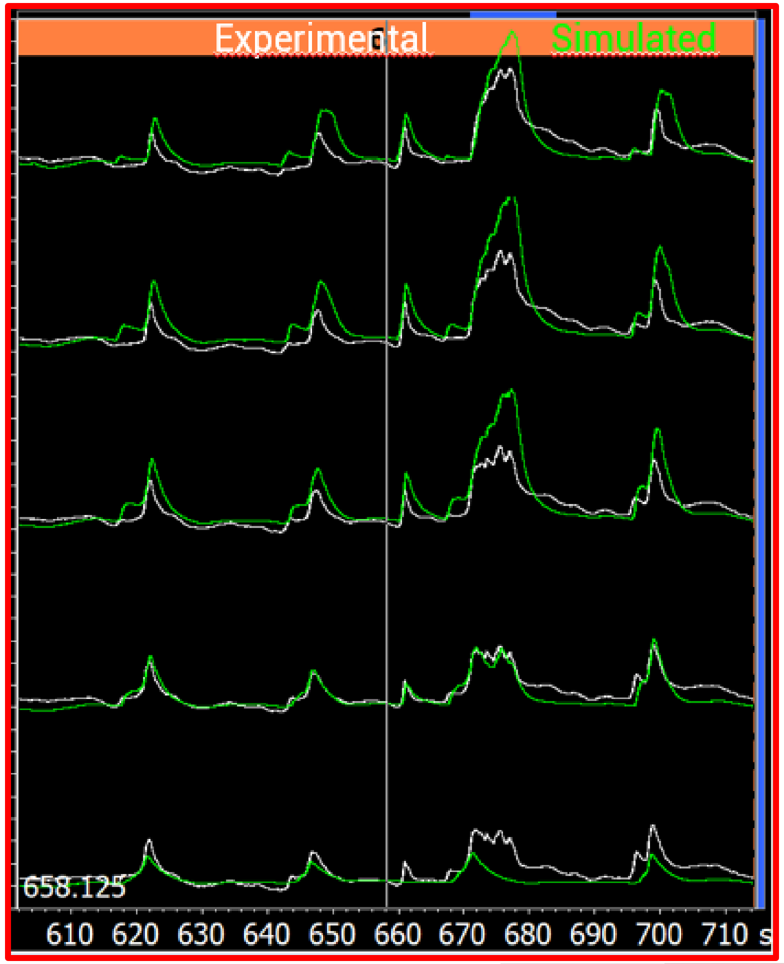
***** plotted half of the available ribs just to help visualization**



STEP 4: Running the Model

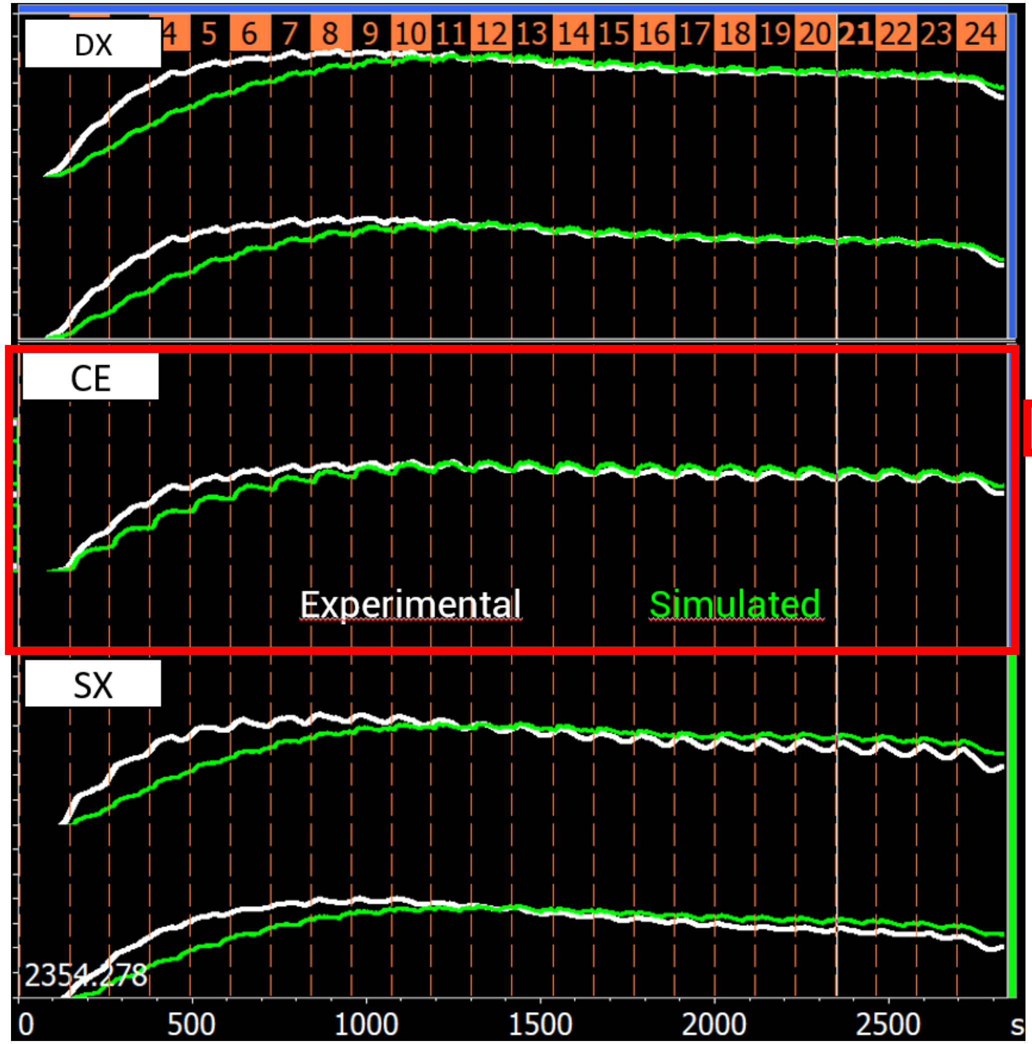
External Surface Validation

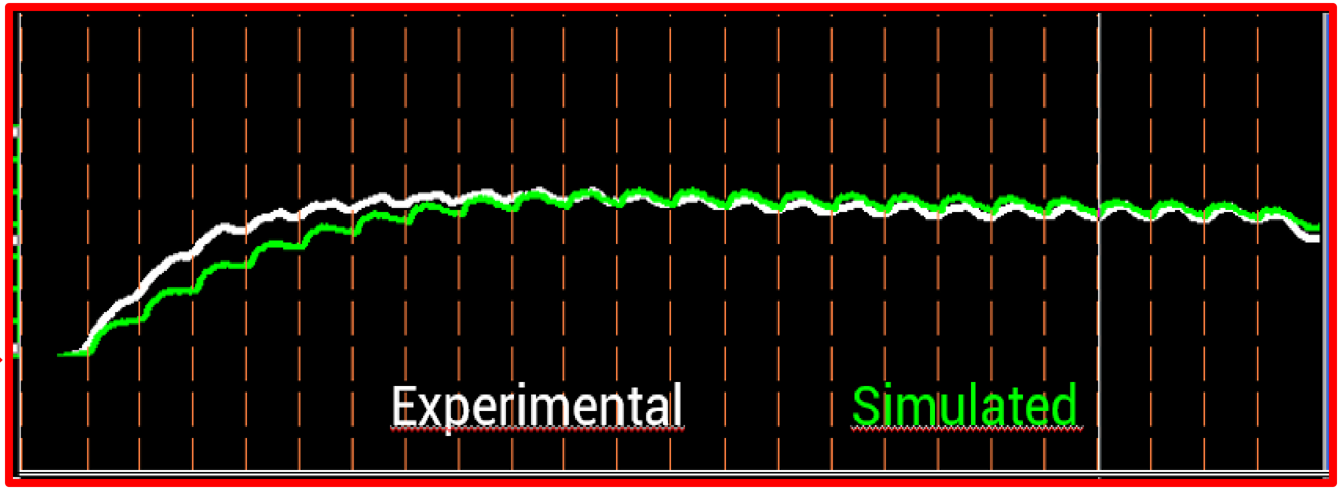




STEP 4: Running the Model

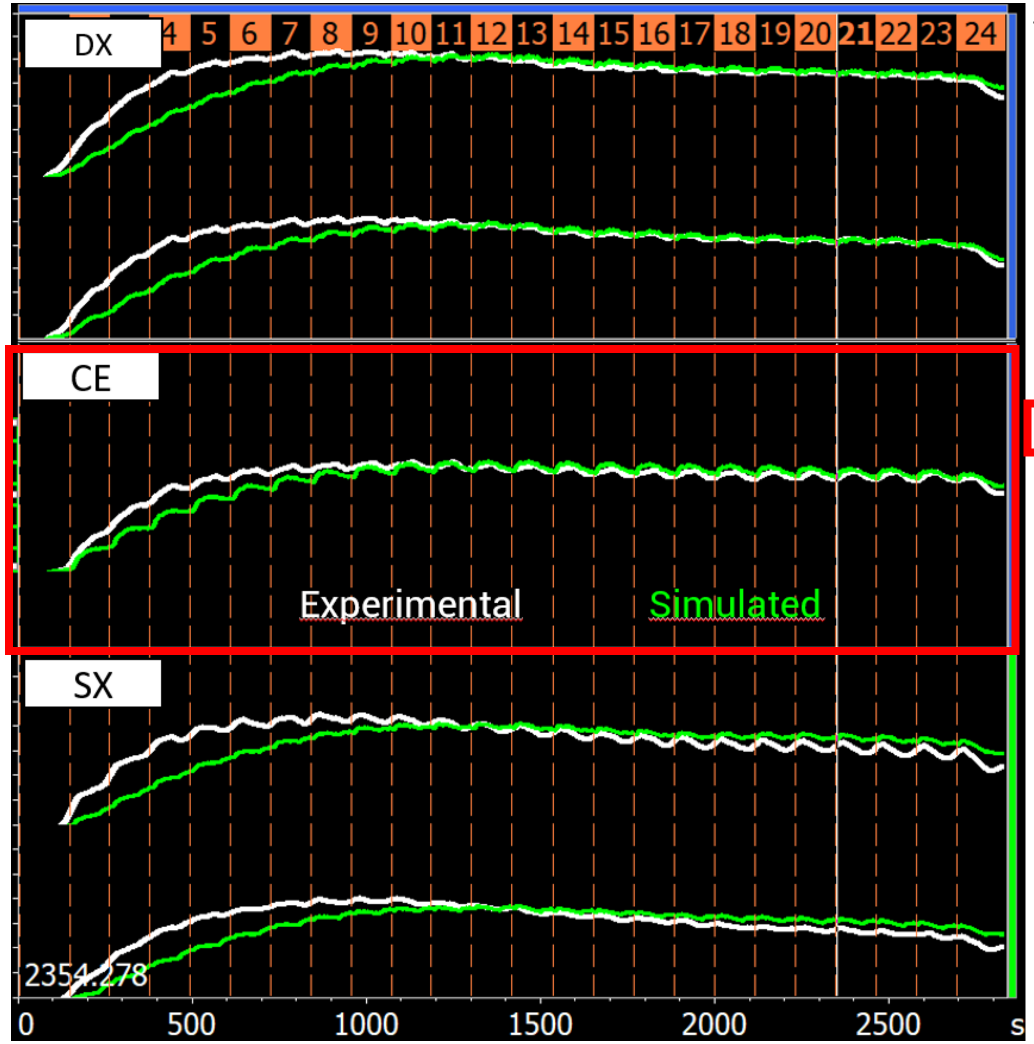
Inner Liner Validation

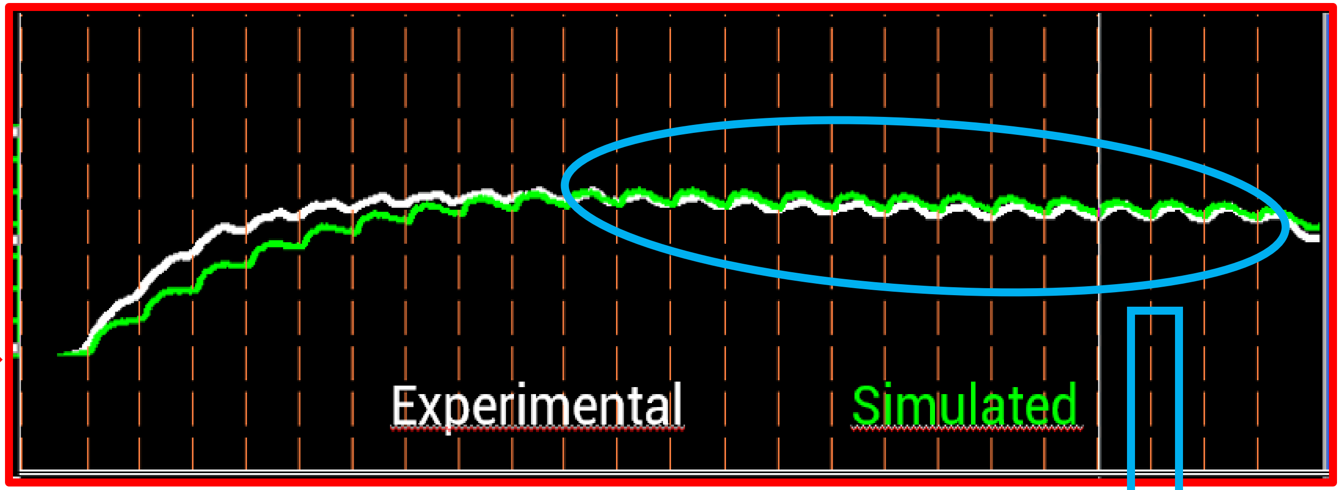




STEP 4: Running the Model

Inner Liner Validation

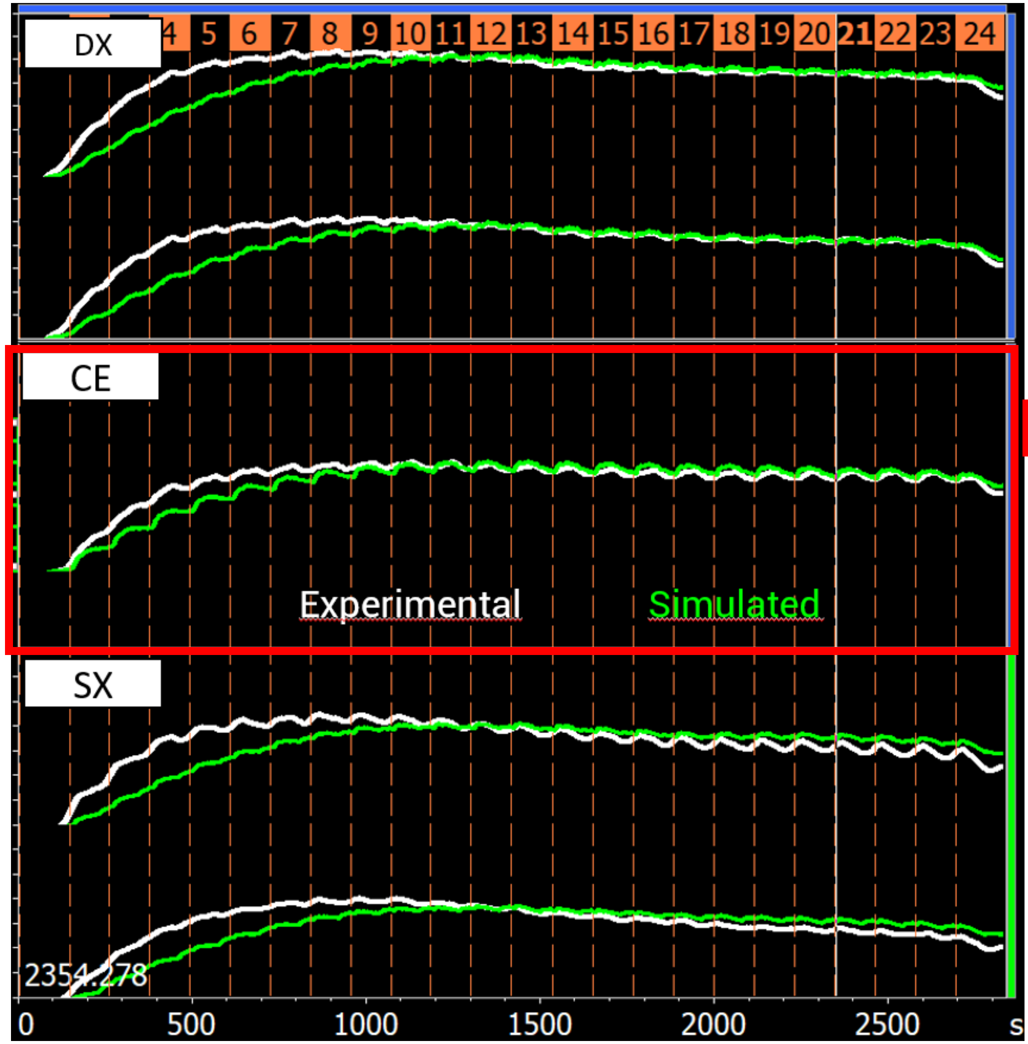


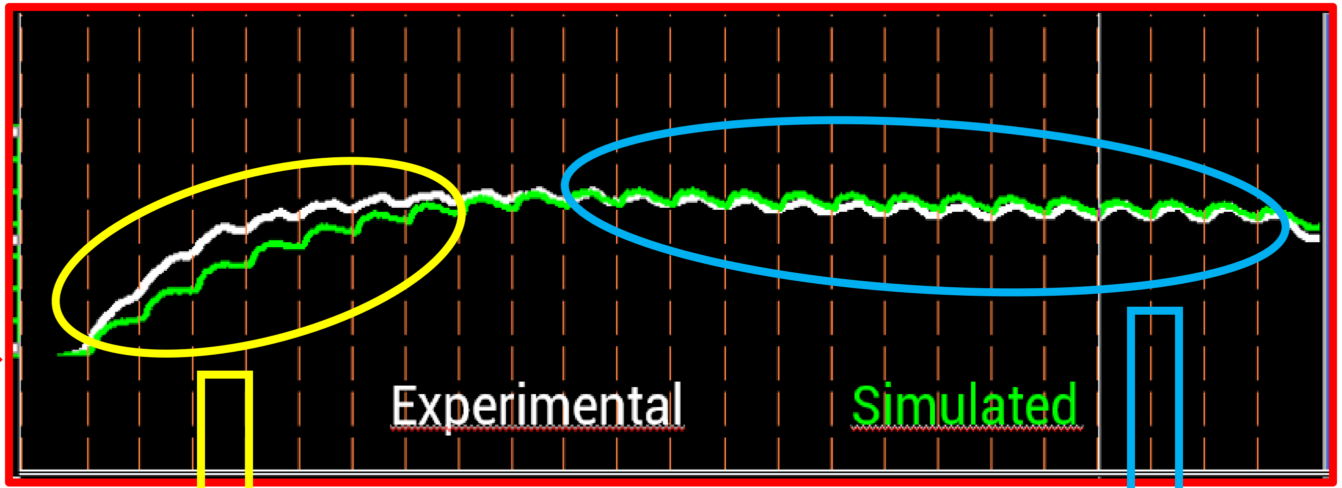


Good fitting in stabilized conditions, replicating temperature decrease thanks to new **weaRIDE WEAR MODEL**

STEP 4: Running the Model

Inner Liner Validation





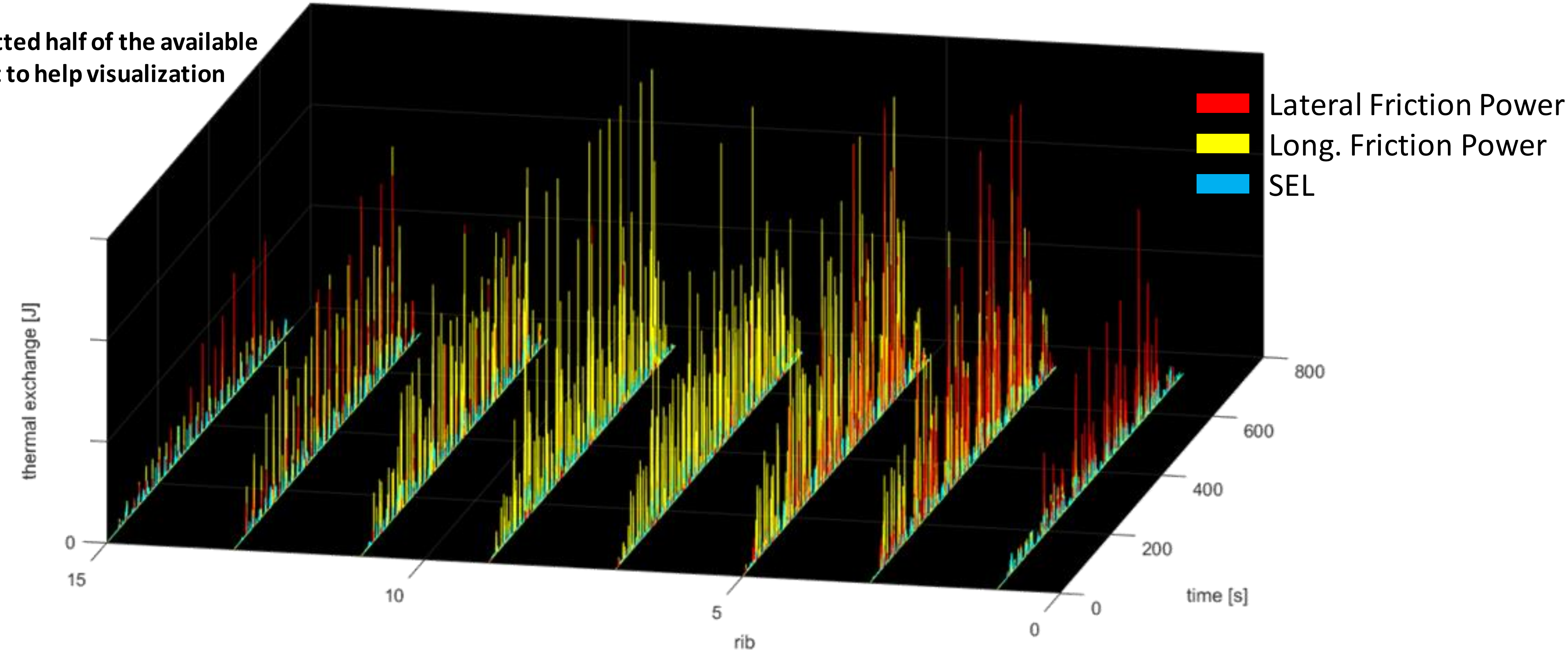
Transient dynamics in inner gas turbulences (due to **AIR MODEL, still** in progress at the time of the analysis)

Good fitting in stabilized conditions, replicating temperature decrease thanks to new **weaRIDE WEAR MODEL**

STEP 4: Running the Model

Heating Sources Analysis

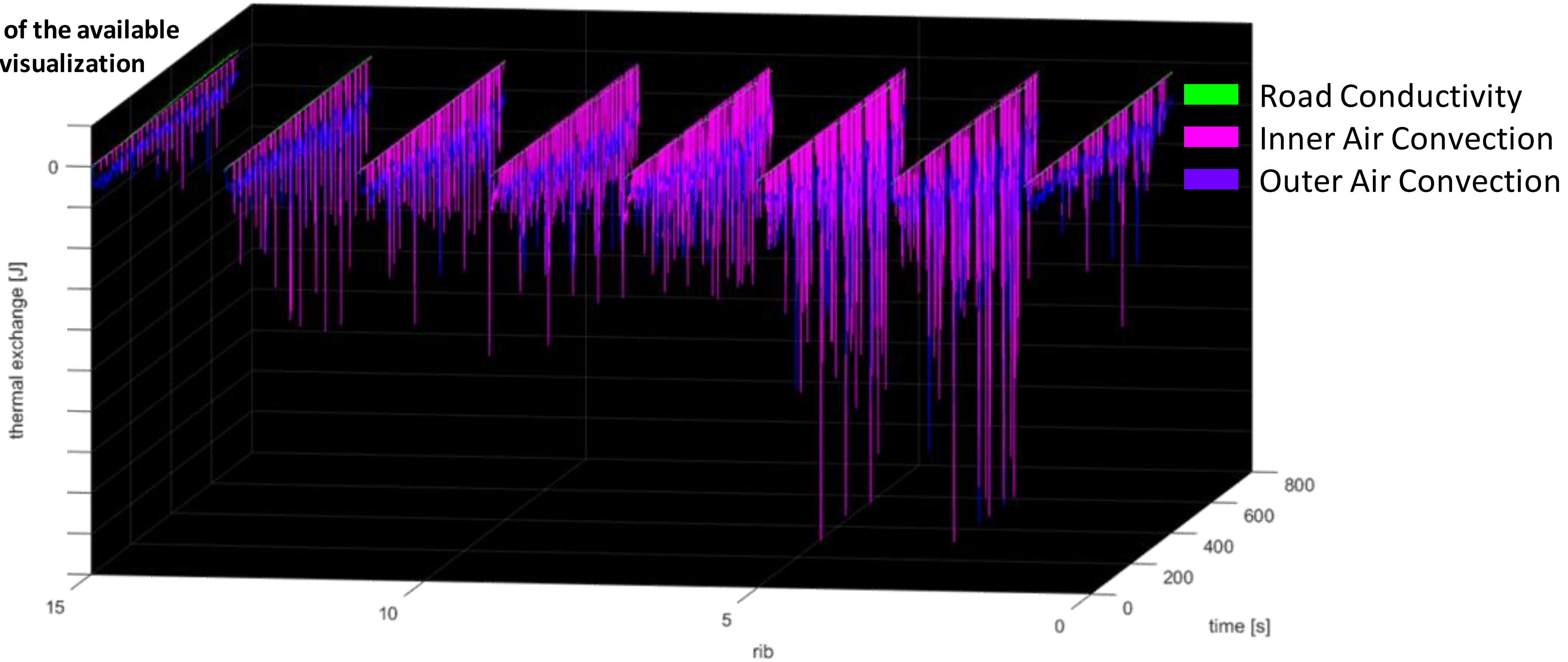
***** plotted half of the available ribs just to help visualization**



STEP 4: Running the Model

Cooling Sources Analysis

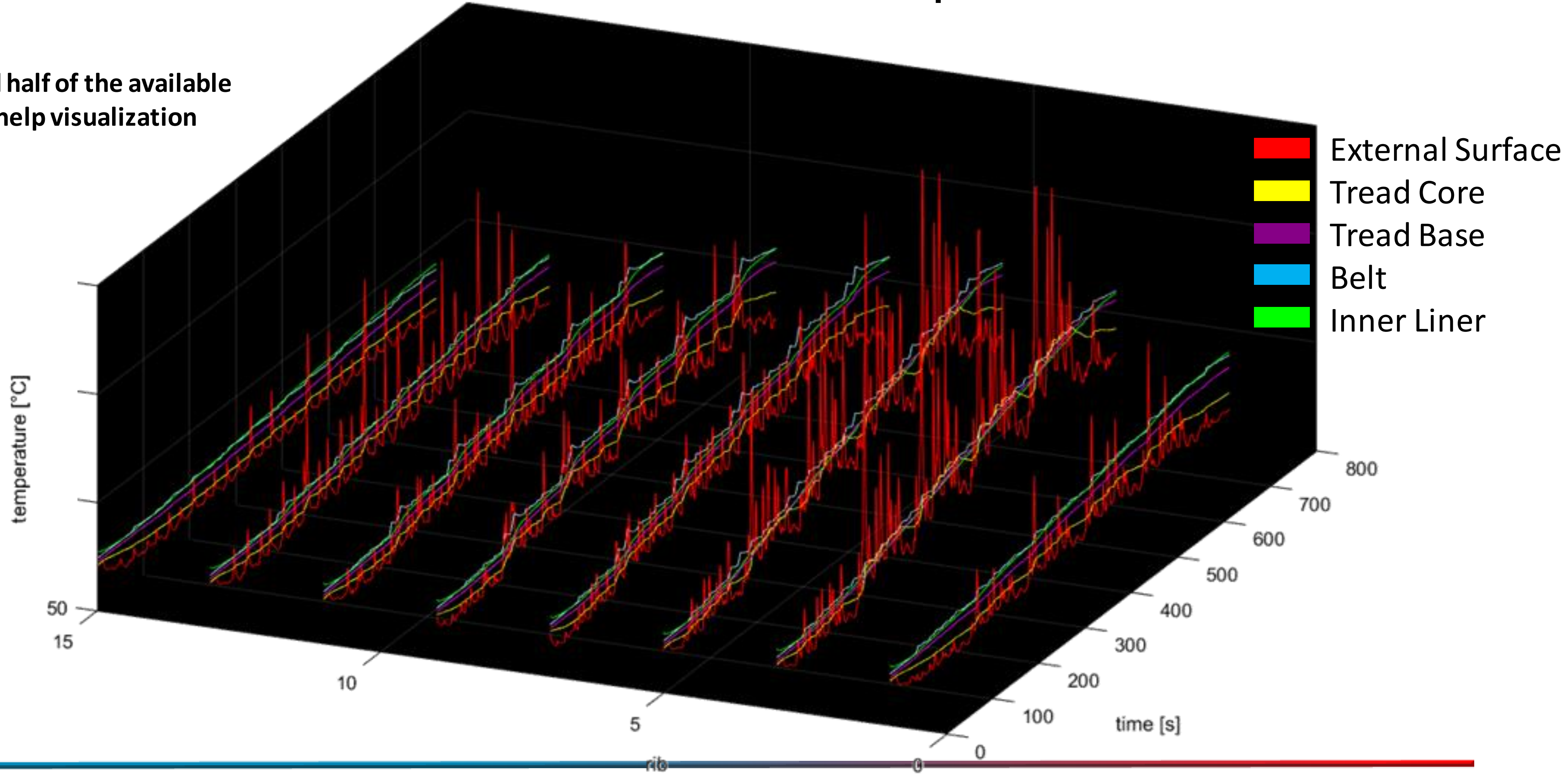
*** plotted half of the available ribs just to help visualization



STEP 4: Running the Model

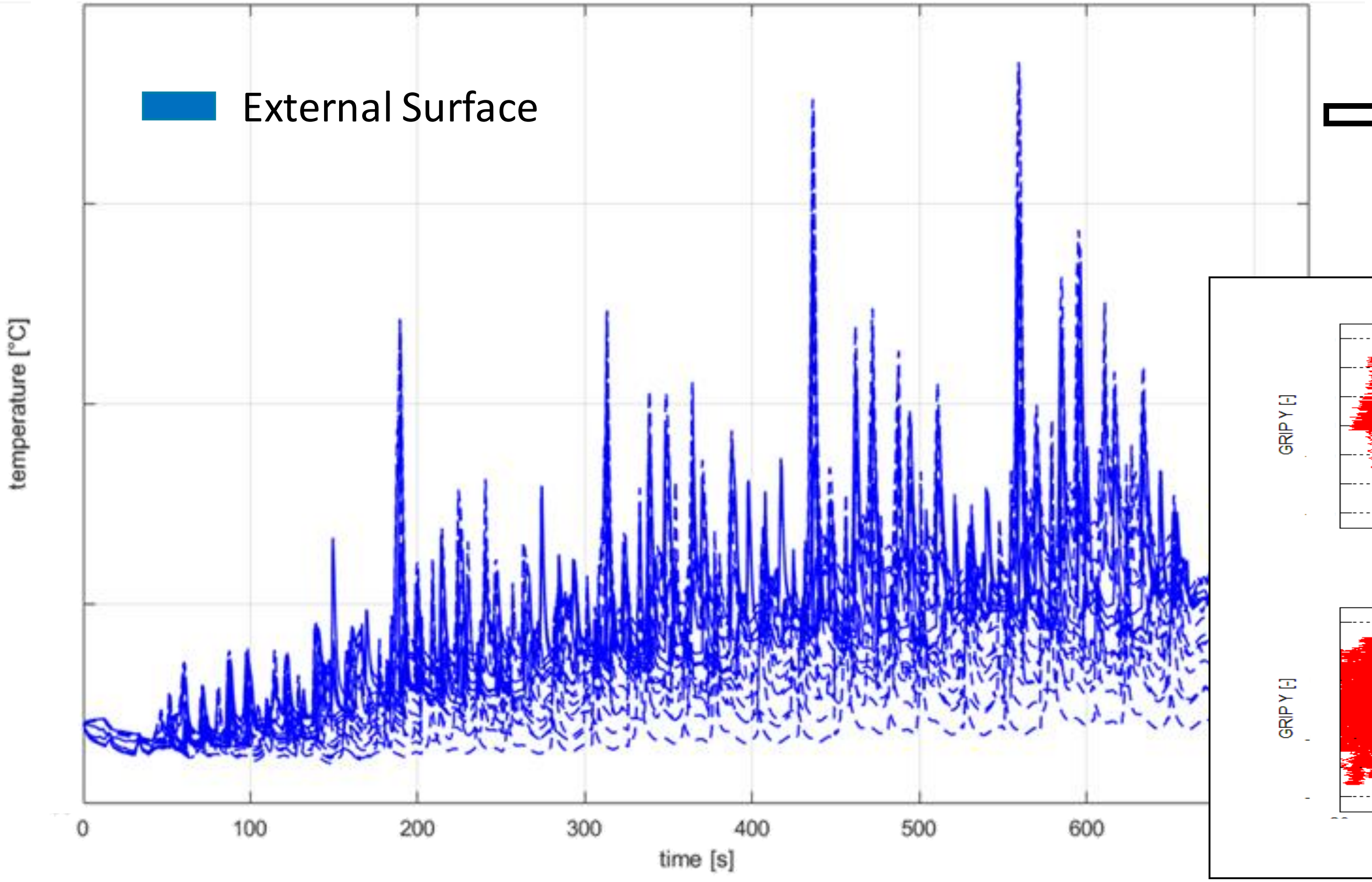
The "Virtual Sensors" Concept

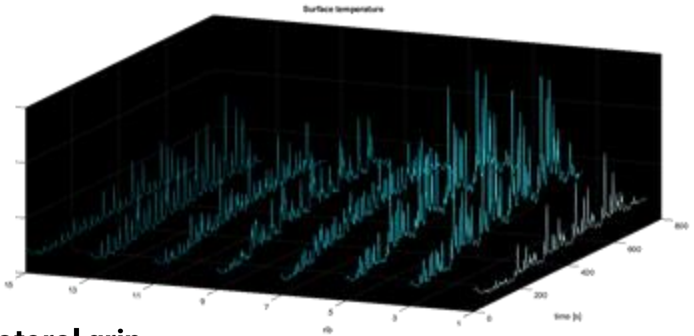
*** plotted half of the available ribs just to help visualization



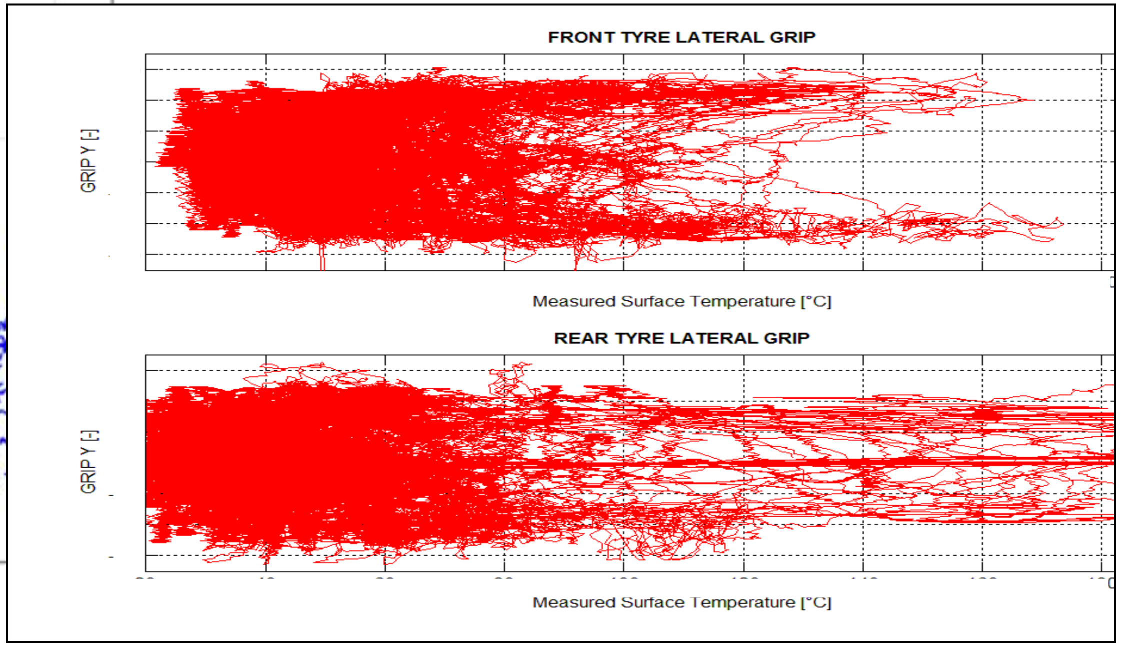
STEP 4: Towards Multiphysics

Temperature / Grip correlations



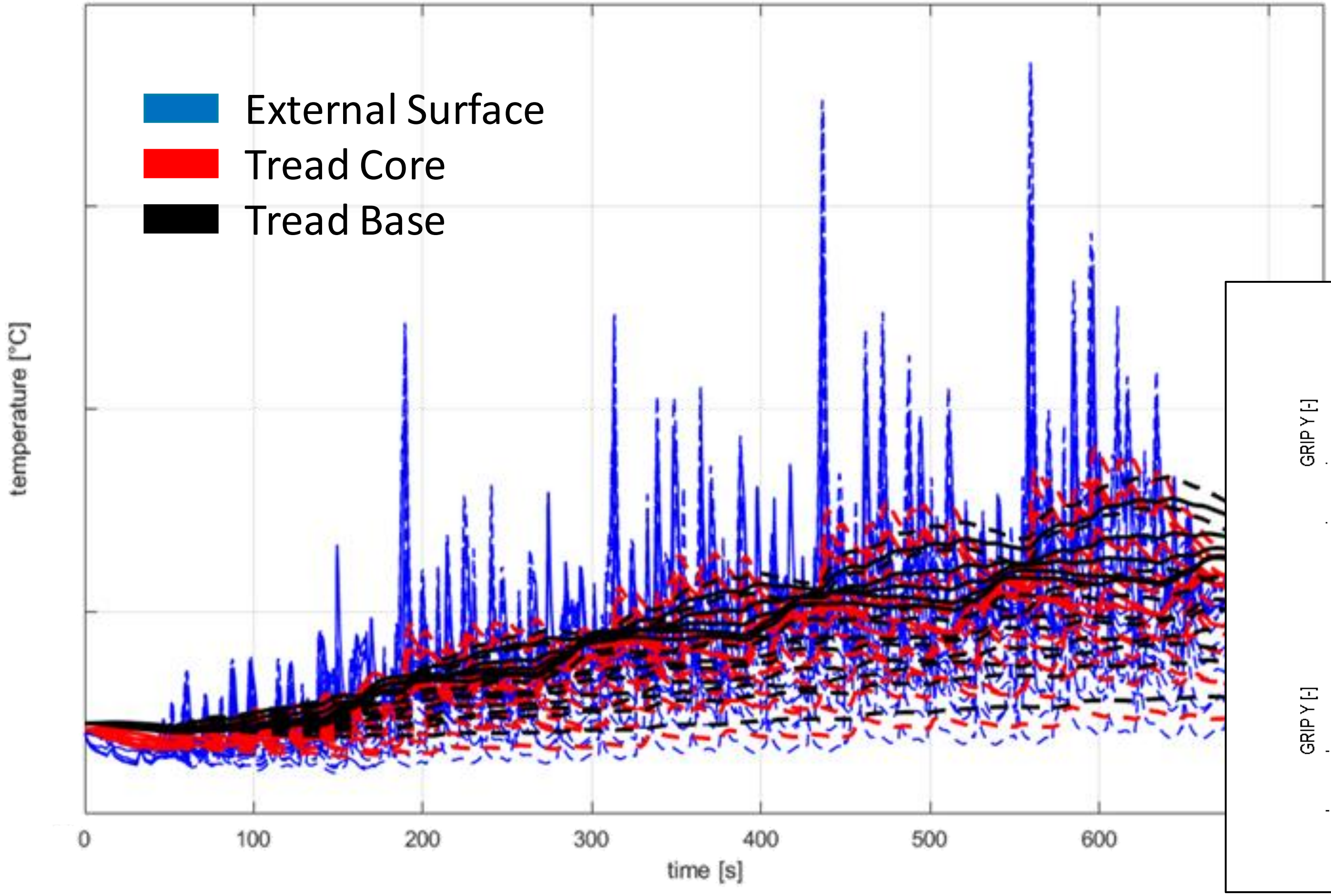


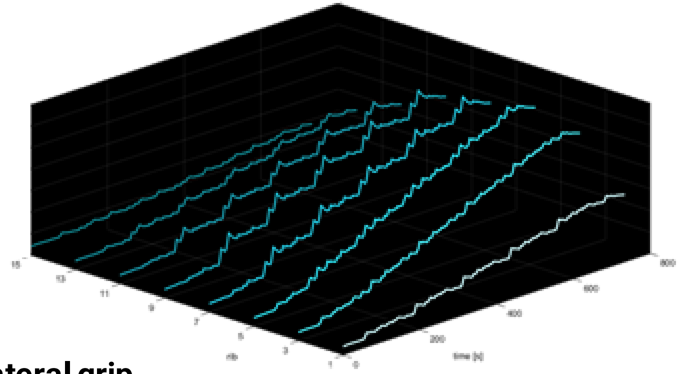
Y-axis: lateral grip
X-axis: surface temperature



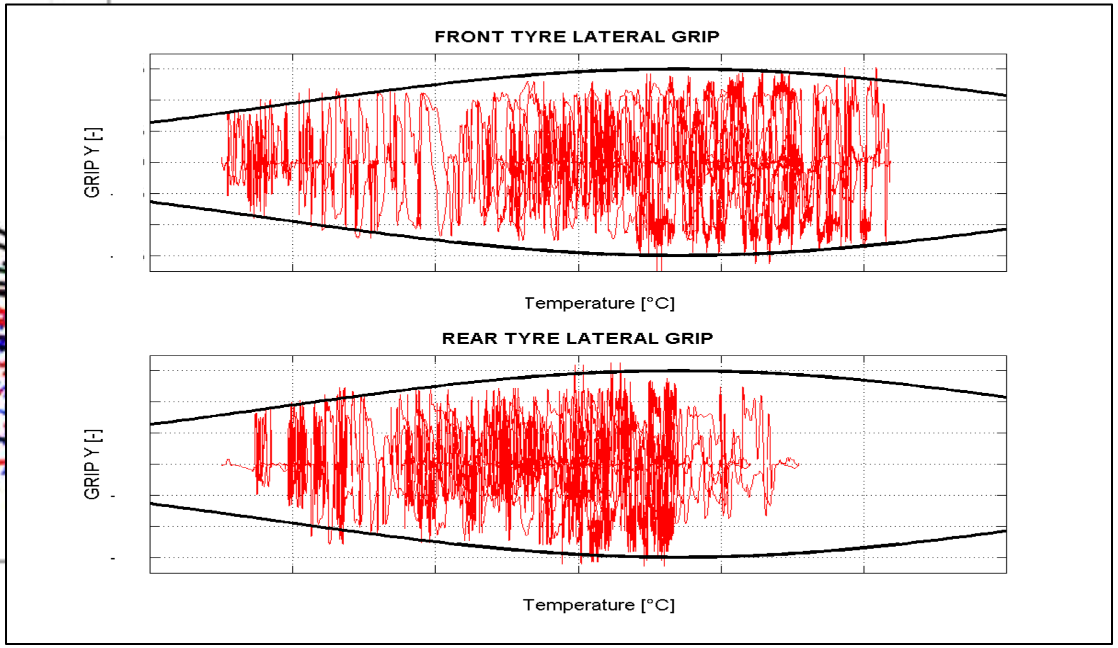
STEP 4: Towards Multiphysics

Temperature / Grip correlations



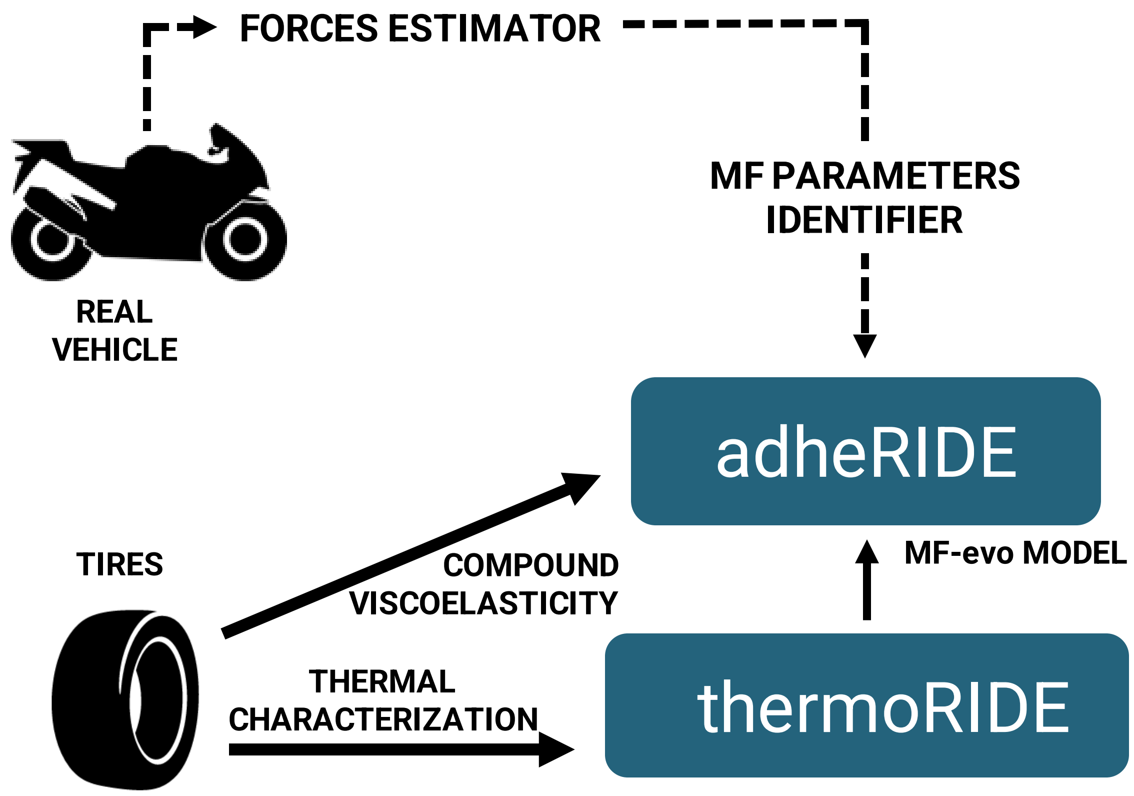


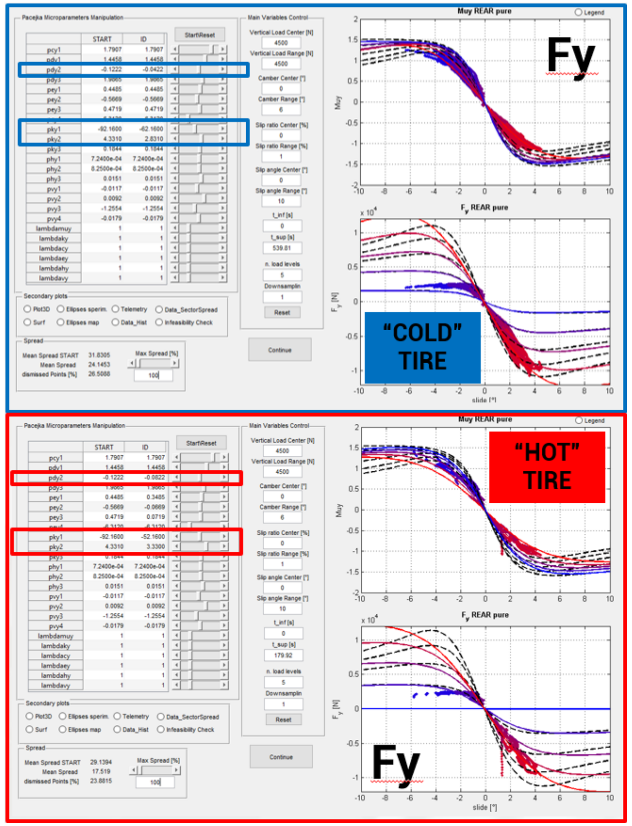
Y-axis: lateral grip
X-axis: surf/core/base mixed temperature

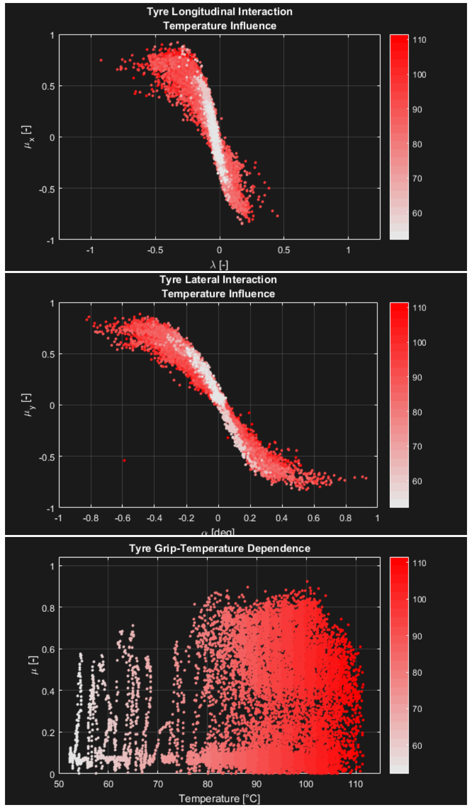


STEP 4: Towards Multiphysics

Advanced Motorcycle MF Model

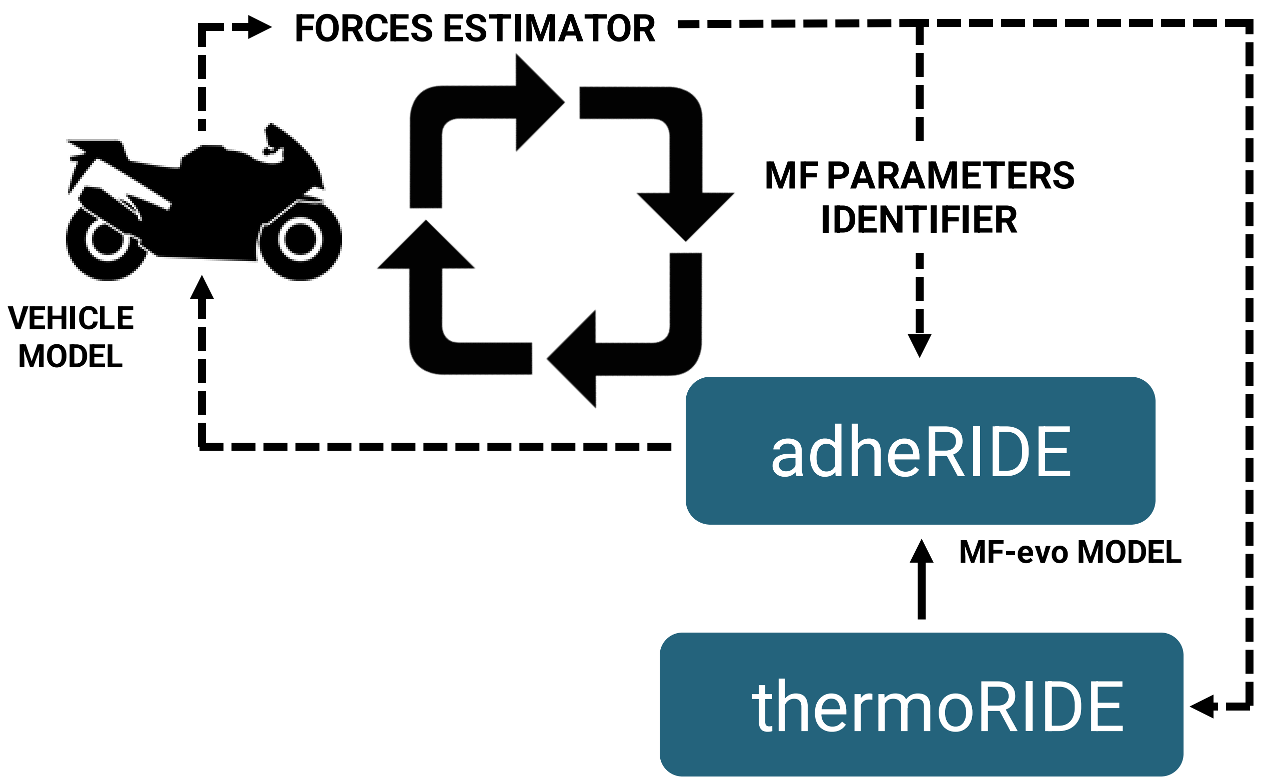






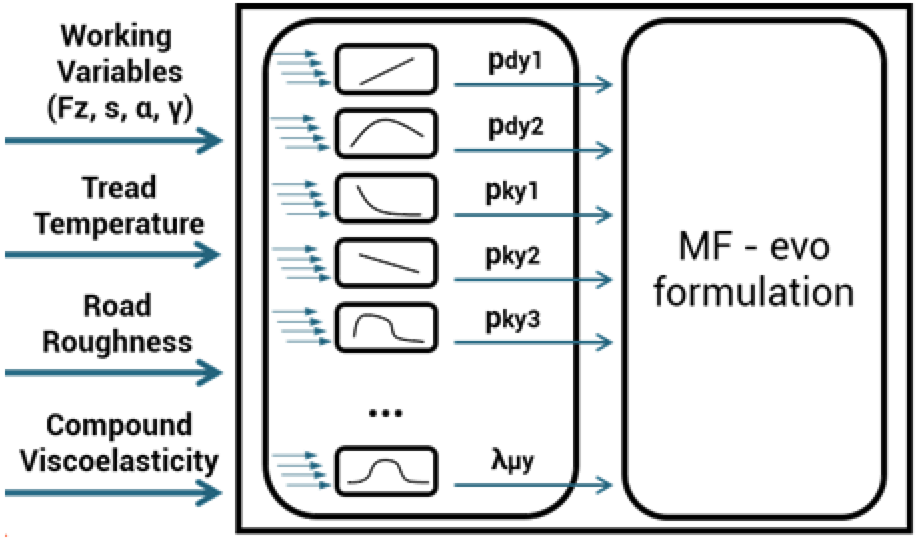
STEP 4: Towards Multiphysics

Advanced Motorcycle MF Model



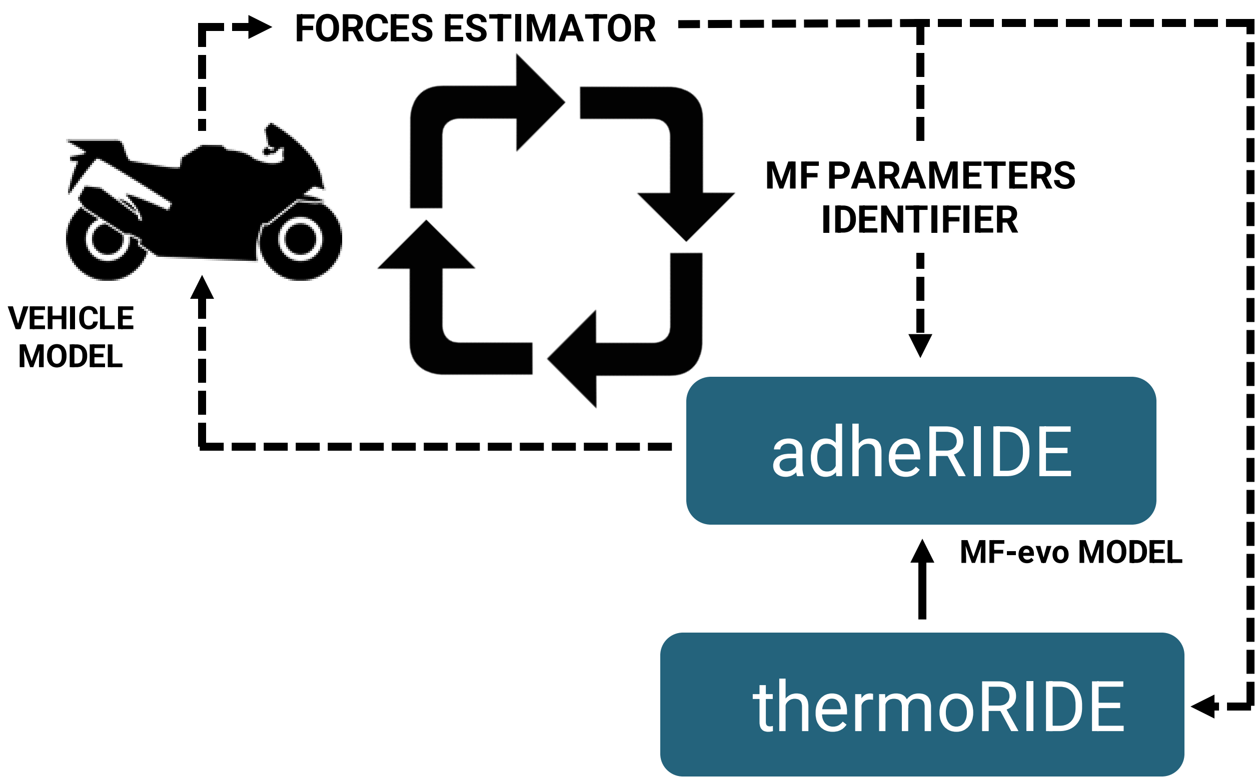
- an innovative Pacejka's MF model sensitive to:

- TIRE TEMPERATURE
- COMPOUND VISCOELASTICITY
- ROAD ROUGHNESS



STEP 4: Towards Multiphysics

Advanced Motorcycle MF Model



APPLICATIONS:

- Vehicle Setup Optimization
- Motorcycle Vehicle Dynamics Development
- Laptime Predictors accounting for grip/temperature relationship
-

***** AWARDED AS TIRE TECHNOLOGY OF THE YEAR AND VEHICLE DYNAMICS DEVELOPMENT TOOL OF THE YEAR**

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