Digital Twinning of a Drilling Rig

Calgary Geothermal and UNWASTE Workshop

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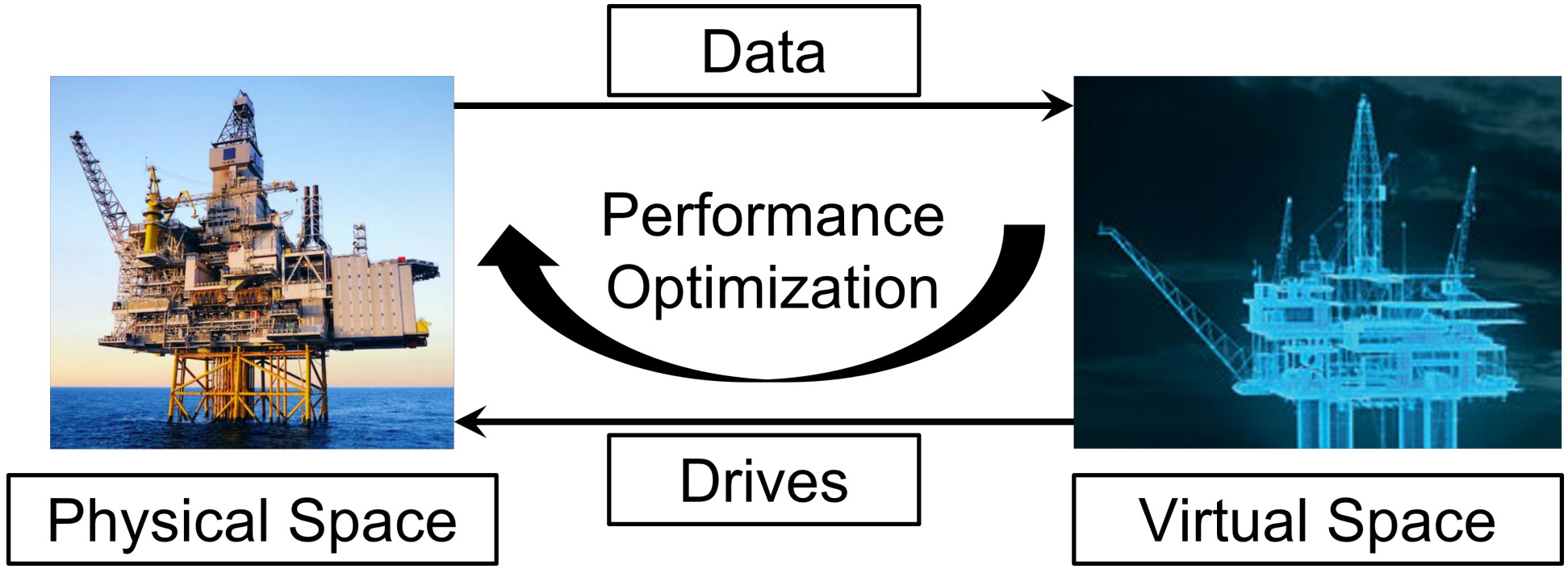
Background & Motivation



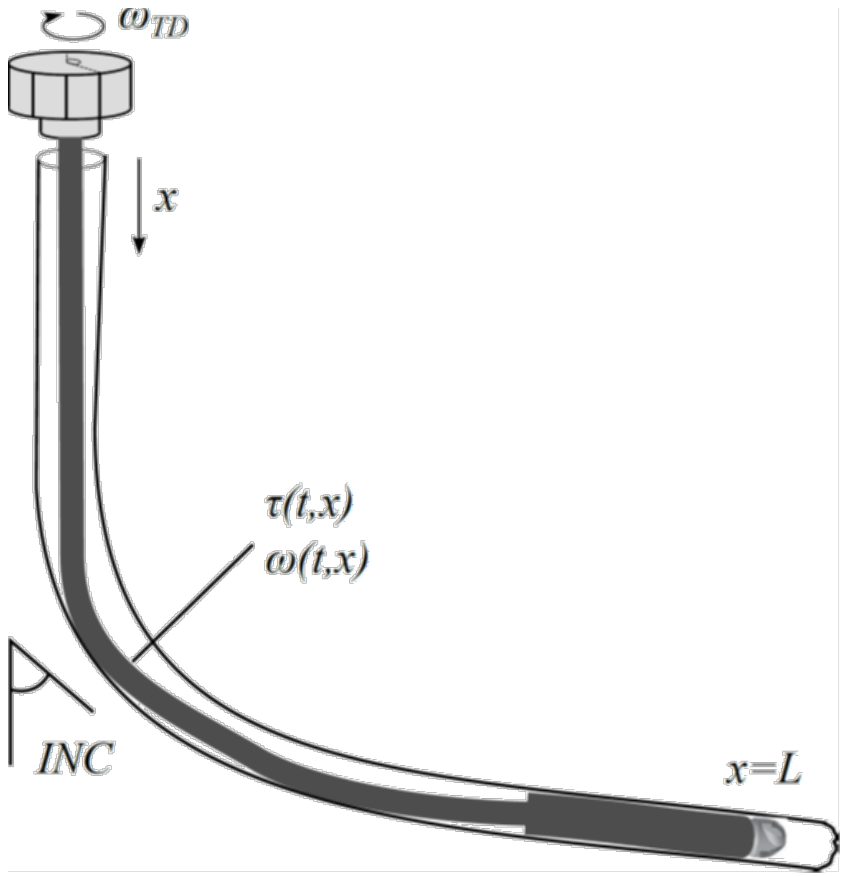
- Drillstring dynamics
- Challenge
  - Occurrence of unwanted vibrations

- Realtime data/performance analysis
- Digital model of a physical system
  - To better understand and optimize

https://ieeexplore.ieee.org/ielx7/6287639/8948470/09104682.pdf?tag=1&tag=1

Background & Motivation

- Model – Field validated distributed model
  - Aarsnes (2016, 2018)
- Captures higher modes
- Model – 1–D wave equation with a soft-sensor
- Soft sensor advantage
  - Uses topside measurements
- Estimates
  - Kinematic and static friction coefficients
  - Angular velocity, torque



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Mathematical Model

Off-Bottom Dynamics

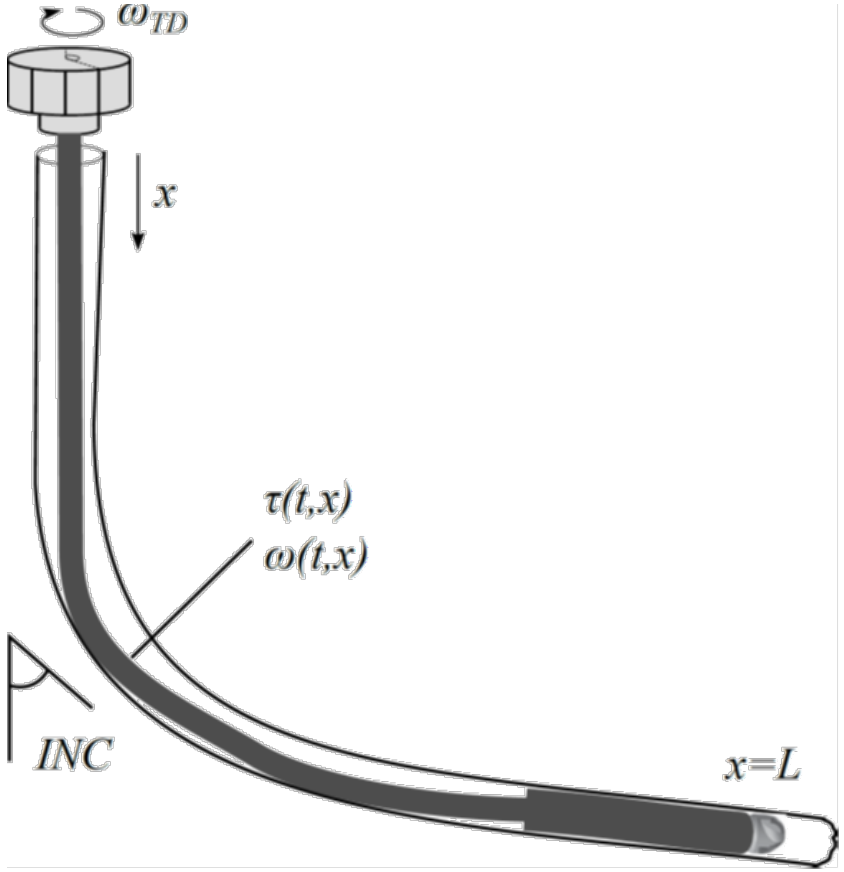
$$\frac{\partial \tau(t,x)}{\partial t} + JG\frac{\partial \omega(t,x)}{\partial x} = 0$$

Bit-rock Interaction

$$\tau_b = \alpha_1 * DOC + \alpha_2 * WOB$$

DOC – Depth-of-cut

WOB – Weight-on-bit



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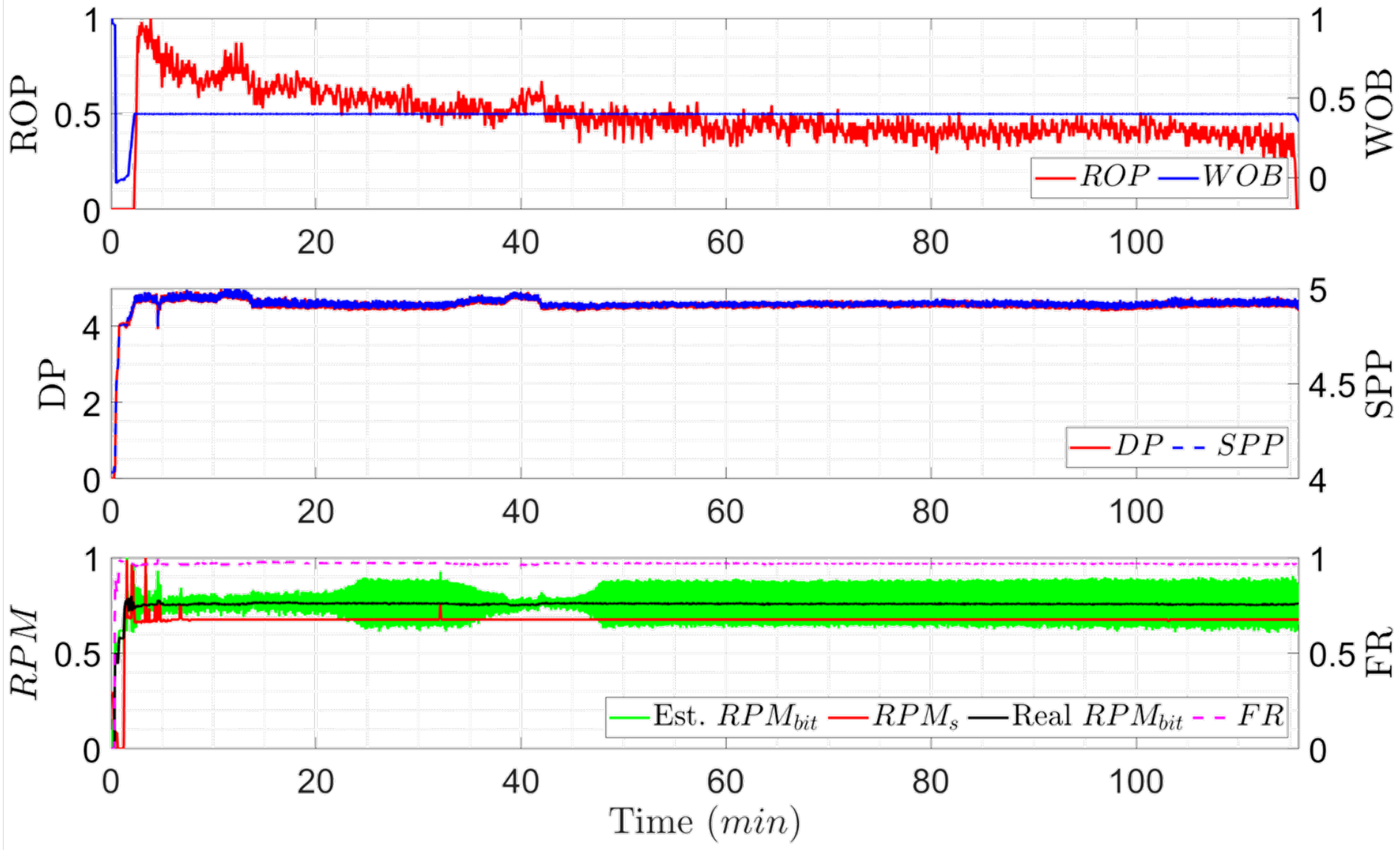
Results and Discussion

- Web-based application – PyRoDrill
- Built using widgets
  - Instructions
  - Import column X – store as Parameter 1 – Convert to SI units
- CSV data, data can be read from the database
- Output – Display using interactive graphs

Evolution of Drilling Parameters



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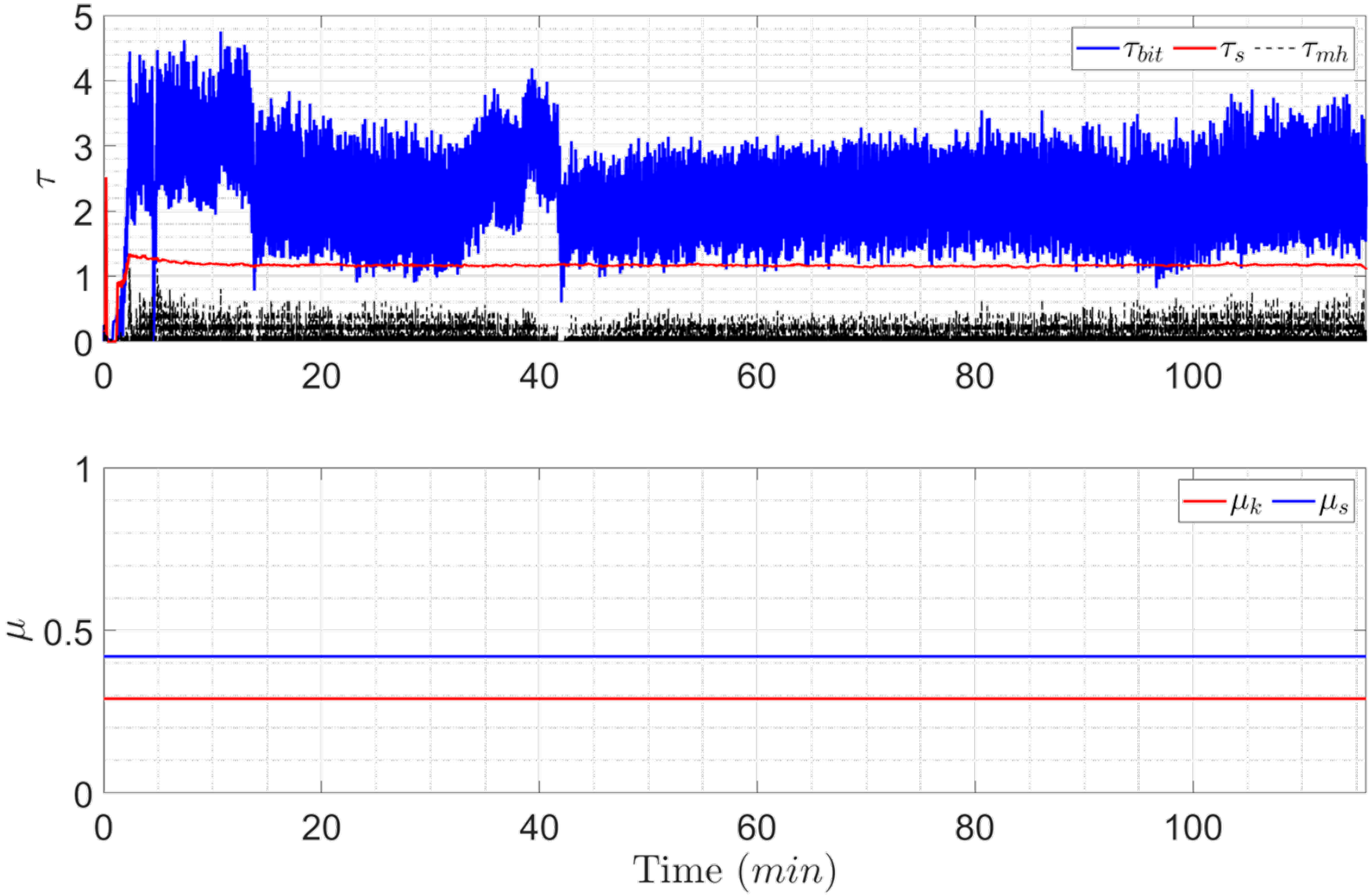
Evolution of Drilling Parameters



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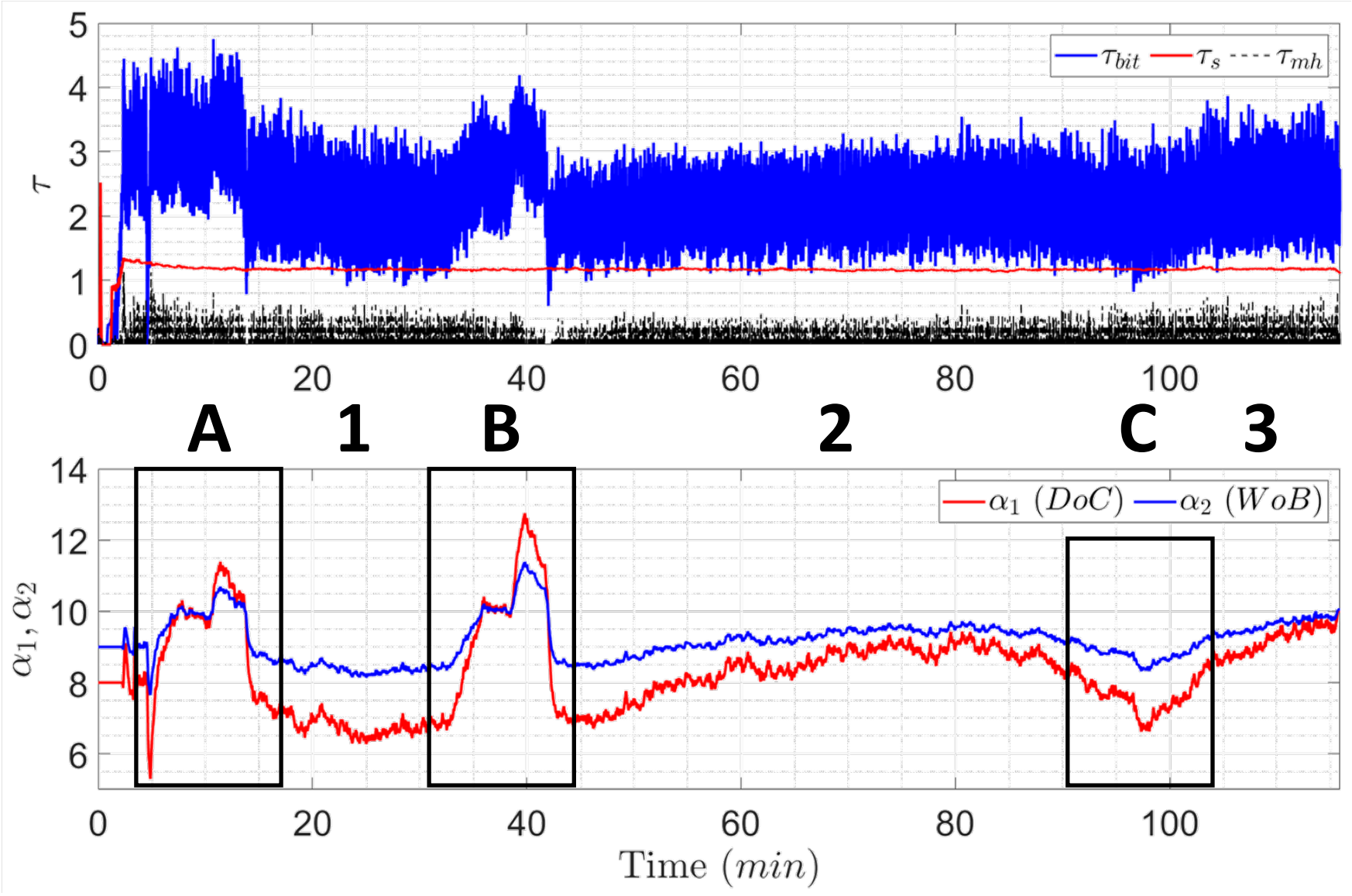
Evolution of Drilling Parameters



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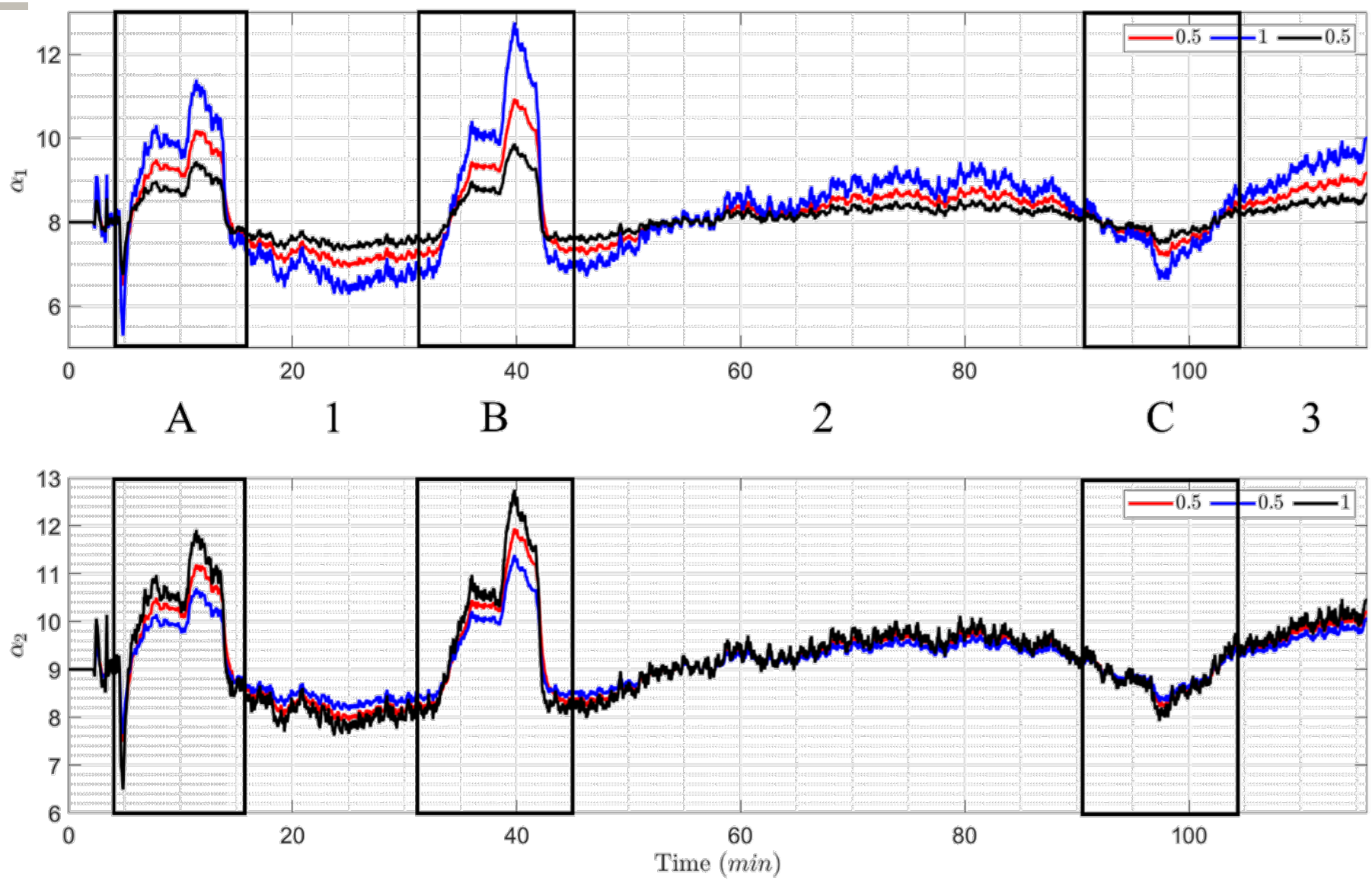
Evolution of α_1 (DOC) and α_2 (WOB)



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Future Work

- Include the hydraulics
- Underlying parameters in α_1 and α_2
- Physics-based models for bit-torque
- Coupled axial and torsional drillstring dynamics.

Conclusions

- Proposed an integrated digital twin model
- Bit-torque as function of weight-on-bit and the depth-of-cut.
- Evolution of α_1 and α_2
  - Bit wear and/or damage
  - Formation change
- Insights – Downhole conditions
- Absence of the hydraulics model
  - Multiple solutions for the bit-rock interaction parameters.
- Bit-rock interaction parameters
  - Monitoring and optimizing

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Questions?

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