

Panel Discussion

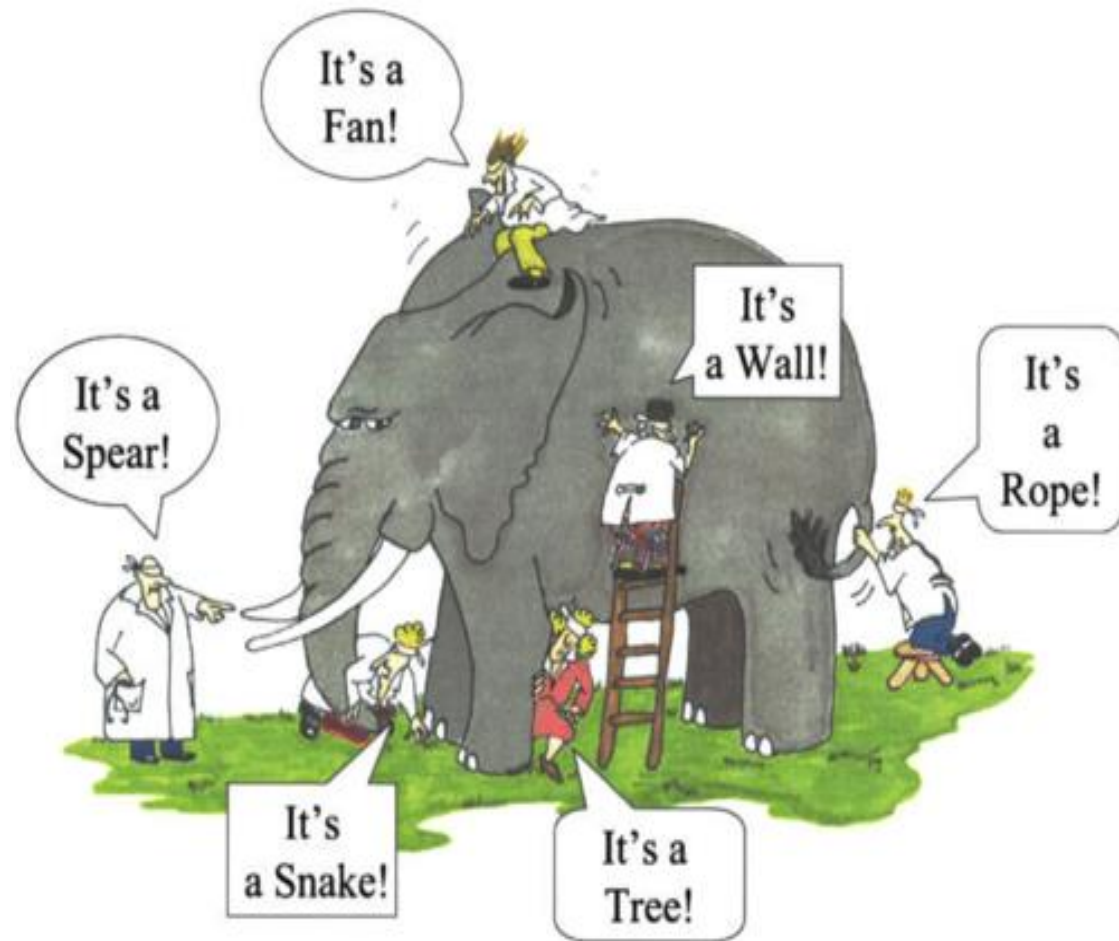
Key Points

- ▶ `Universal' Turbulence Model
 - `One-size' fits all vs. Everything customized
- ▶ Impact of Machine Learning
- ▶ Predictive computation and UQ

Turbulence modeling research

*All models are wrong;
some are useful.*

Everybody is right but
no one is complete



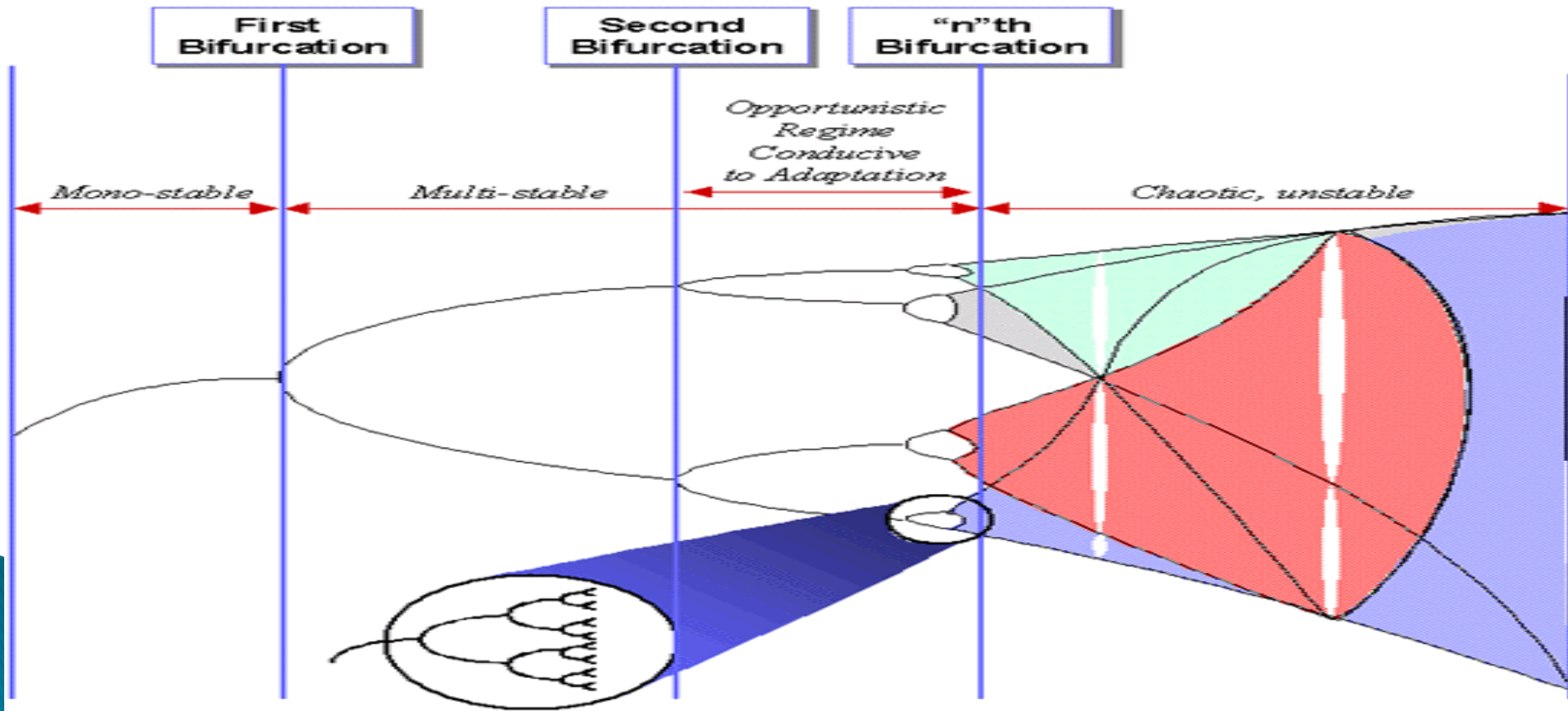
Why do turbulence models fail? What is the way out?

1. Anisotropic eddy viscosity effects
 - *High-order constitutive equations*
2. Non-equilibrium effects: Imbalance between linear and non-linear phenomena
 - *Reynolds stress transport models*
3. Non-local effects of pressure: Distant interactions leading to coherent structures
 - *Scale-resolving simulations → How much to resolve?*
4. Body force effects: Stabilizing or destabilizing

Model choice must match flow physics

Machine Learning and Turbulence

Can ML handle a complex chaotic system



Parting Thoughts

- ▶ Pick right modeling approach for the right problem
- ▶ Seduction of Machine Learning
 - Use ML judiciously
 - Understanding of physics is needed for judicious use
- ▶ *Turbulence physics* \leftrightarrow *Model user*
Chasm must be bridged
- ▶ Truly predictive computation? V&V?

Liepman: *Rise and fall of turbulence models and theories*

