Grand Challenges in the Science of Wind Energy

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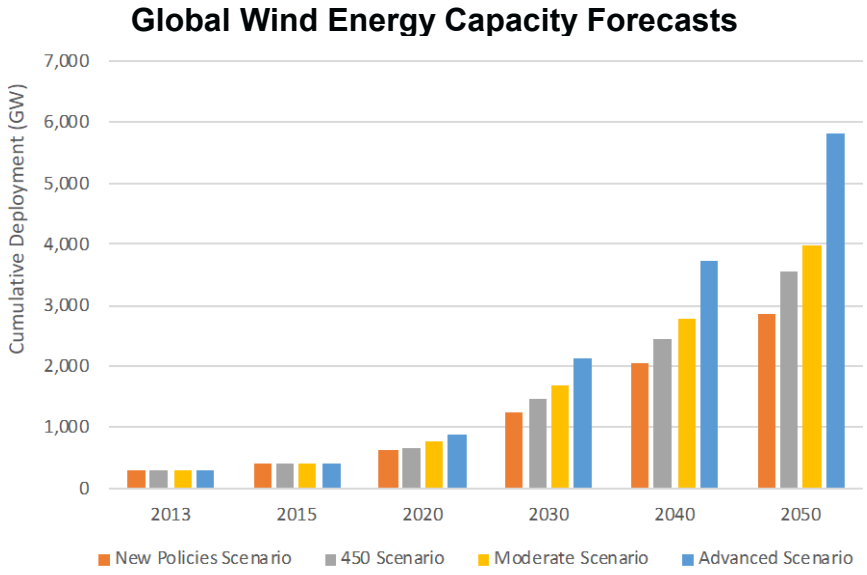
National Renewable Energy Laboratory (NREL)

Torque 2020
September 28, 2020

Today, global wind penetration is estimated at approximately 5%.

Projections suggest global wind capacity could increase from about 0.6 terawatts (TW) today to between 2 TW and 6 TW by 2050.



Source: Global Wind Energy Council (2016)

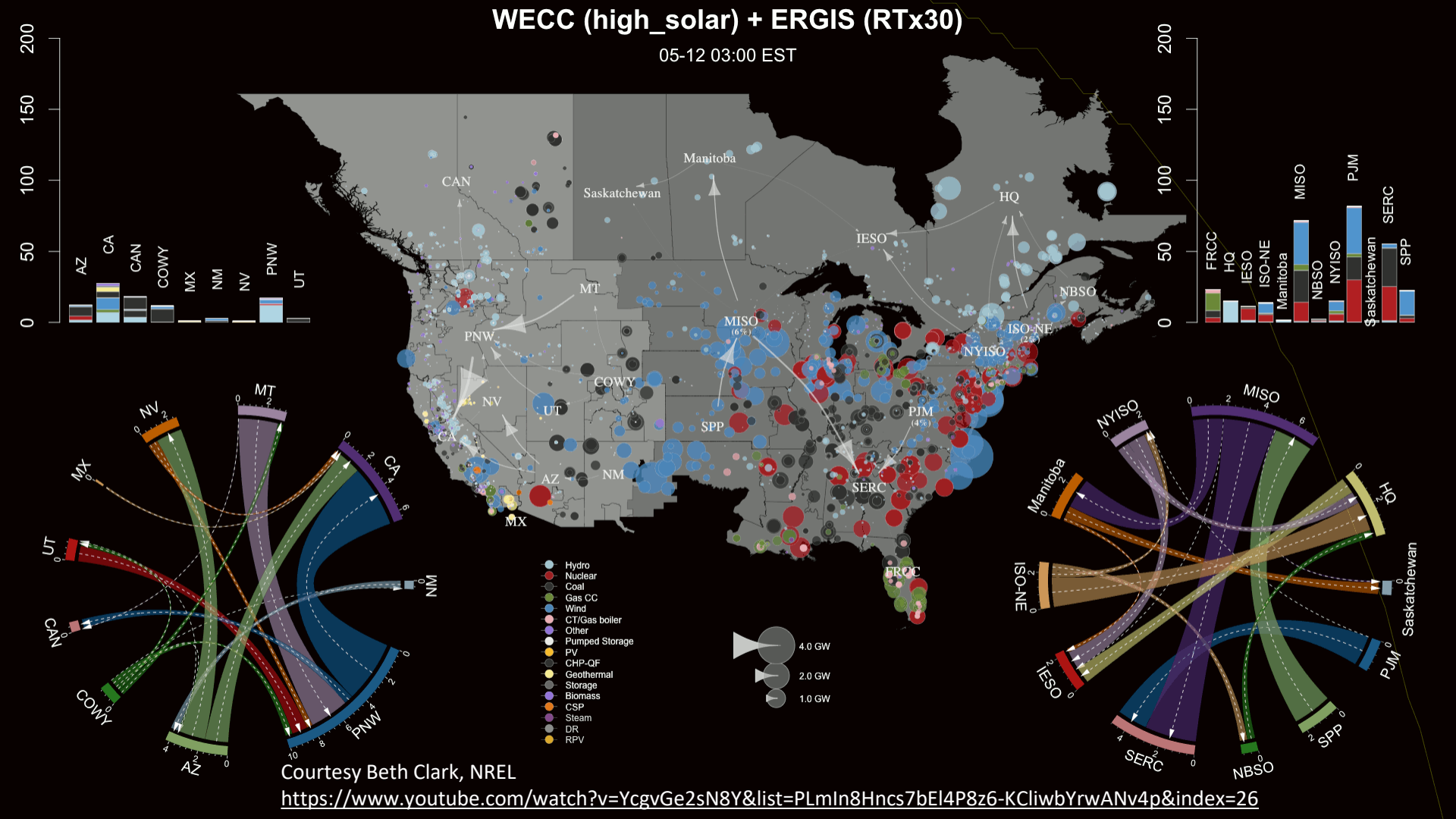
IRENA: Wind could become world's top energy source by 2050

- 35% of the world's installed electrical generation by 2050,
- making it the largest energy source by that time,
- requires the world's installed wind capacity to increase to 6,000 gigawatts. (International Renewable Energy Agency).

Sustainability Times, Jan. 27, 2020

WECC (high_solar) + ERGIS (RTx30)

05-12 03:00 EST

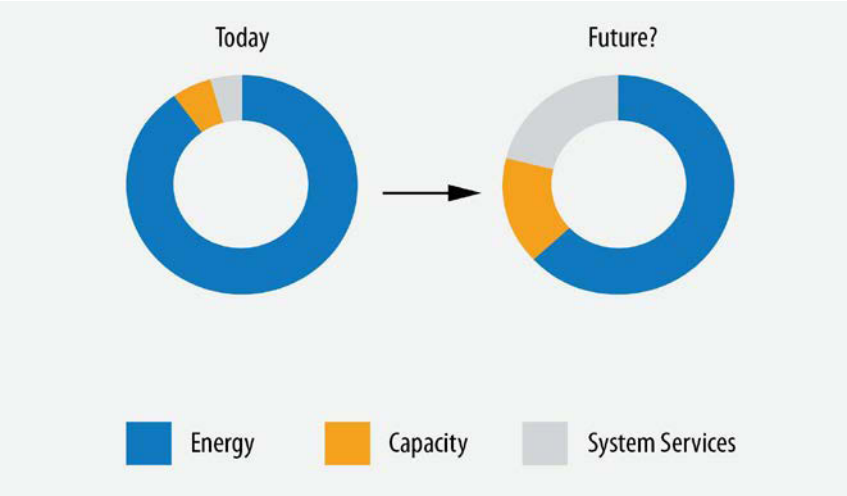


Courtesy Beth Clark, NREL

https://www.youtube.com/watch?v=YcgvGe2sN8Y&list=PLmIn8Hncs7bEl4P8z6-KCliwbYrwANv4p&index=26

A Grand Vision for Renewables

- A future scenario with renewables supplying 80% of the world electricity supply produces a paradigm shift in system architecture, technologies, and markets.



Future electricity system market structure (Source: Dykes et al. 2019 based on Ahlstrom et al. 2015)

What will it take for wind energy to become a foundation of the new energy system and supply up to 50% or more of global electricity?

Science Article Lays out the Challenges

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REVIEW

Grand challenges in the science of wind energy

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Science
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Advertising (PDF)
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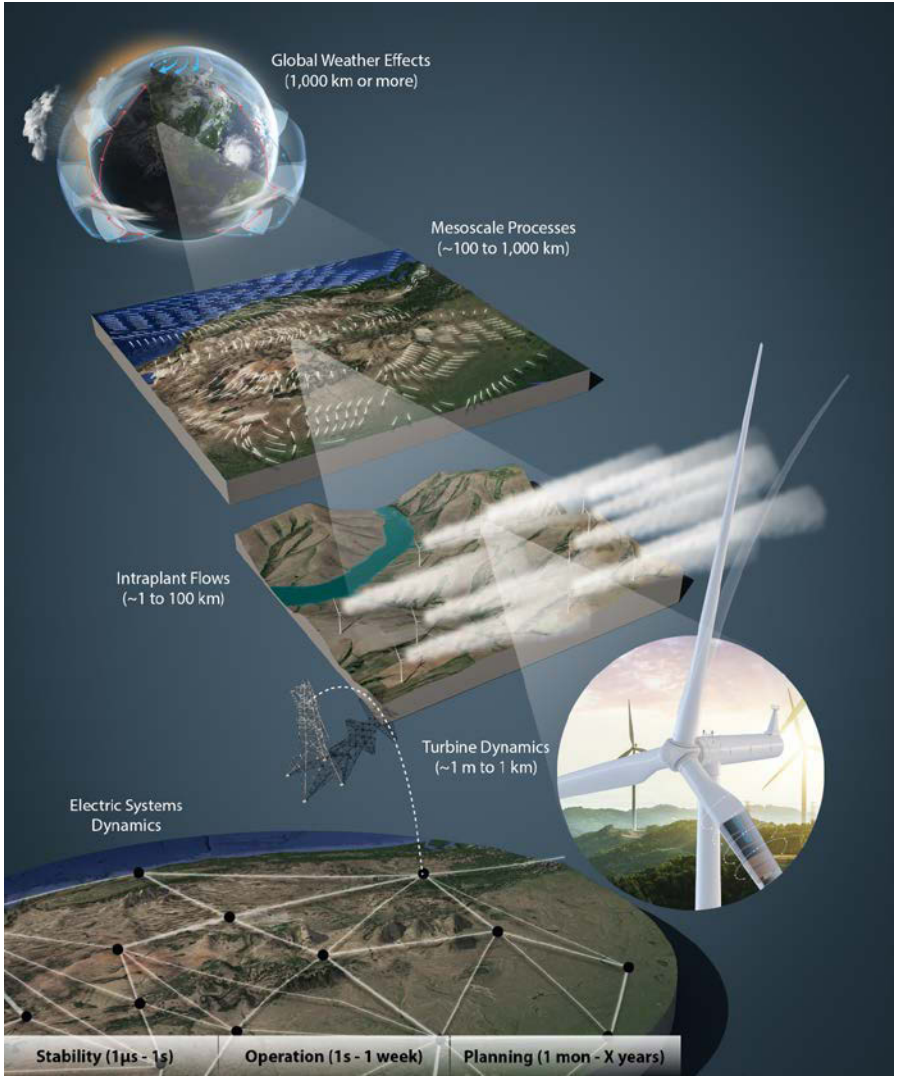
- International Energy Agency (IEA) Wind Technical Experts Meeting, TEM #89, "A Grand Vision for Wind Technology"
- Over 70 experts representing 15 countries met October 2017 in Golden, Colorado
- IEA report, "…Grand Vision for Wind Technology." https://www.nrel.gov/docs/fy19osti/72437.pdf

Article published in *Science*
Oct. 25, 2019
https://dx.doi.org/10.1126/science.aau2027

The Grand Challenges extend from the global weather system to the minutiae of materials science to sub-second power system stability.

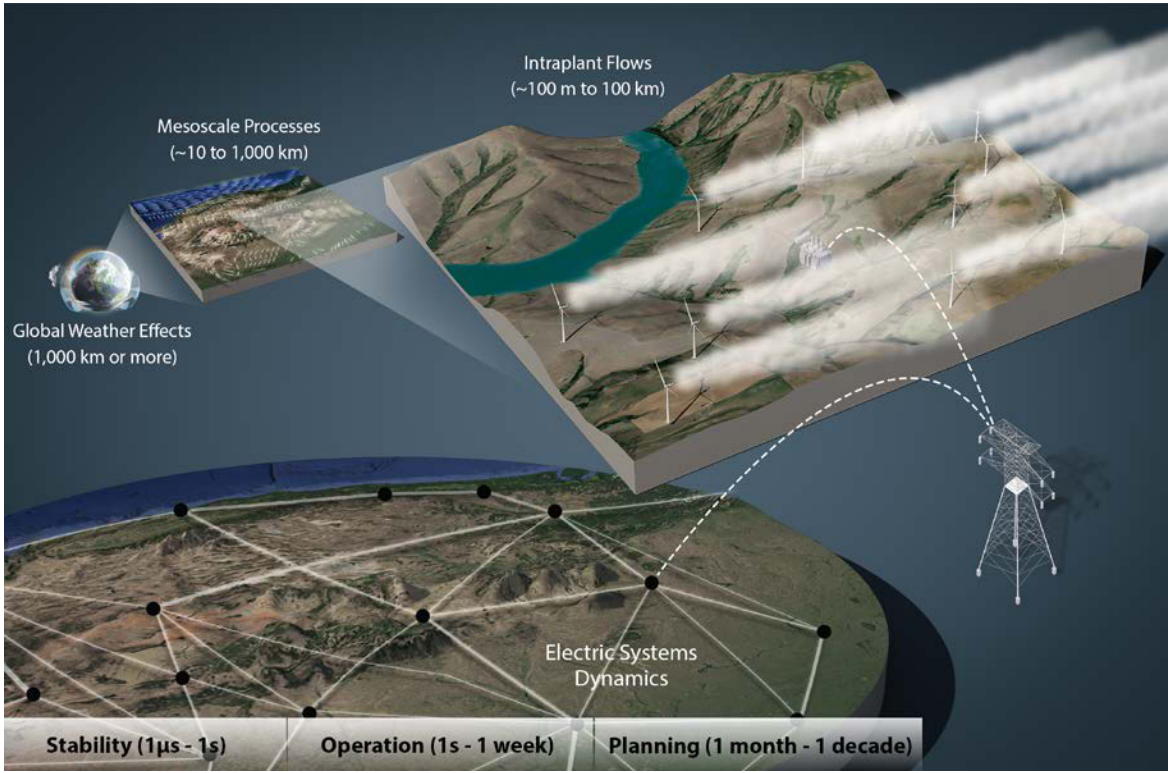
Identified Challenges:

- Control of wind plants to support the future grid
- System dynamics and materials for huge turbines
- Physics of atmospheric flow.

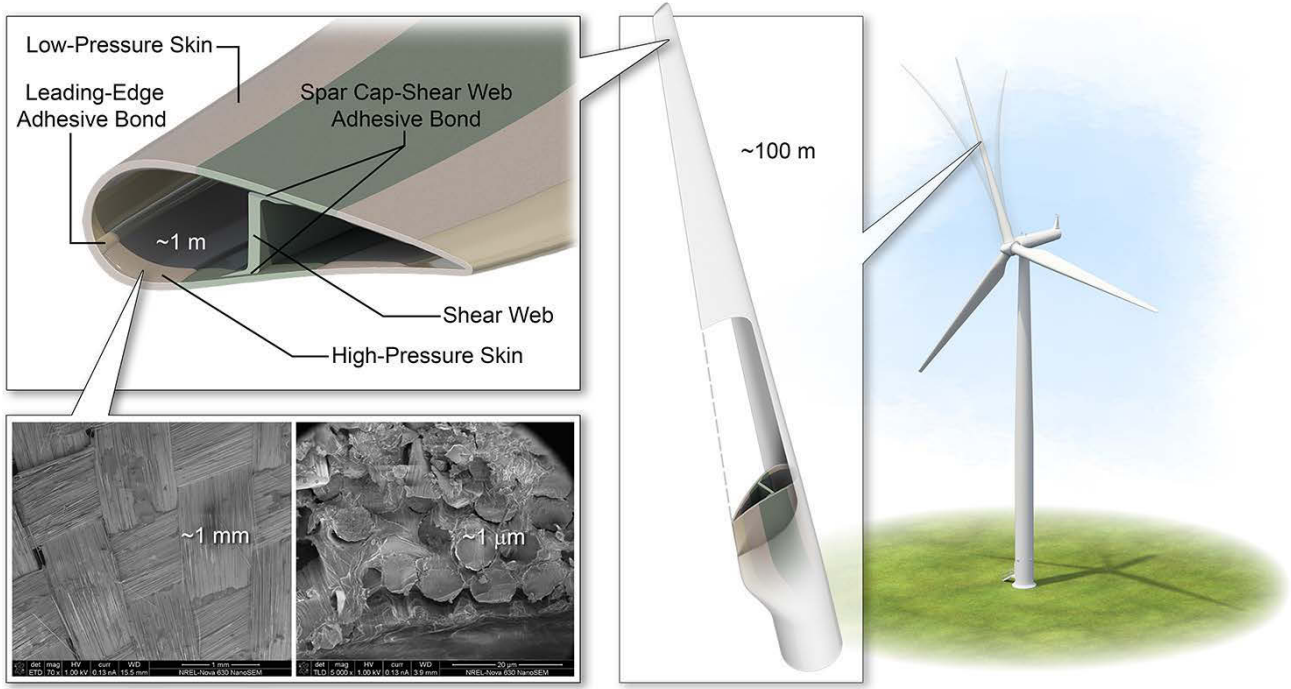


Source: NREL

Grand Challenge #3: Systems science and control of wind power plants to orchestrate wind turbine, plant, and grid formation operations for a future energy system that has stability, resiliency, reliability, and affordability



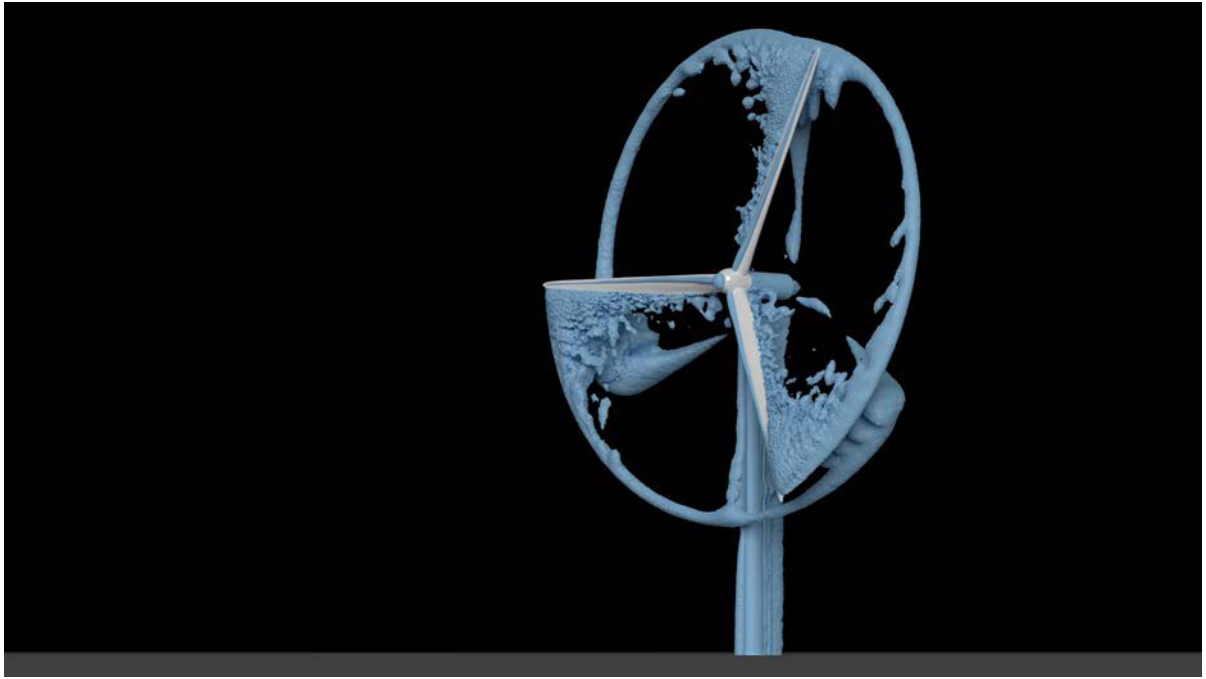
Grand Challenge #2:
Characterizing the structural aerodynamics and hydrodynamics of the largest rotating structures ever manufactured, using advanced materials at commodity prices



Pushing the Boundaries

- Inflow scale & structure
- Re >10 million
- Aerodynamic assumptions
- Large deflections
- Aeroelastic stability
- Floating hydrodynamics
- New control objectives
- Big data analytics
- Transportation constraints
- Manufacturing scale/quality
- Design space dimensionality
- Validation of numerical tools
- Etc.

Blade-resolved simulation of the NREL 5-MW turbine using ExaWind



https://www.nrel.gov/wind/modeling-simulation.html

NREL 5-MW Reference Turbine simulation **("coarse," 25 million-node mesh)** under uniform inflow of 8 m/s. The wake is visualized by contours of velocity magnitude of 5.5 m/s. Simulation performed on the National Energy Research Scientific Computing Center Cori machine.

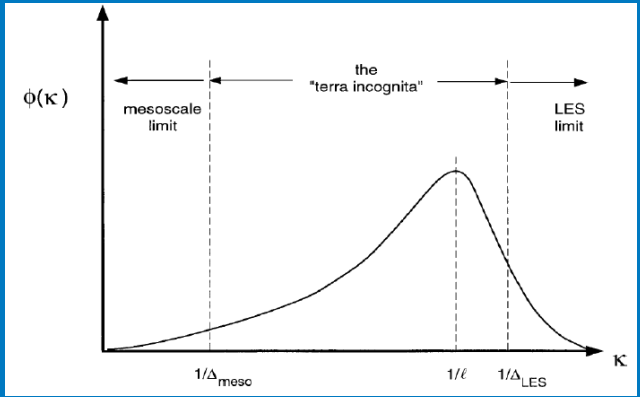
https://www.exascaleproject.org/exawind-project-demonstrates-blade-resolved-simulation-of-the-nrel-5-mw-reference-wind-turbine/

ExaWind Project
(Office of Science)
Participants

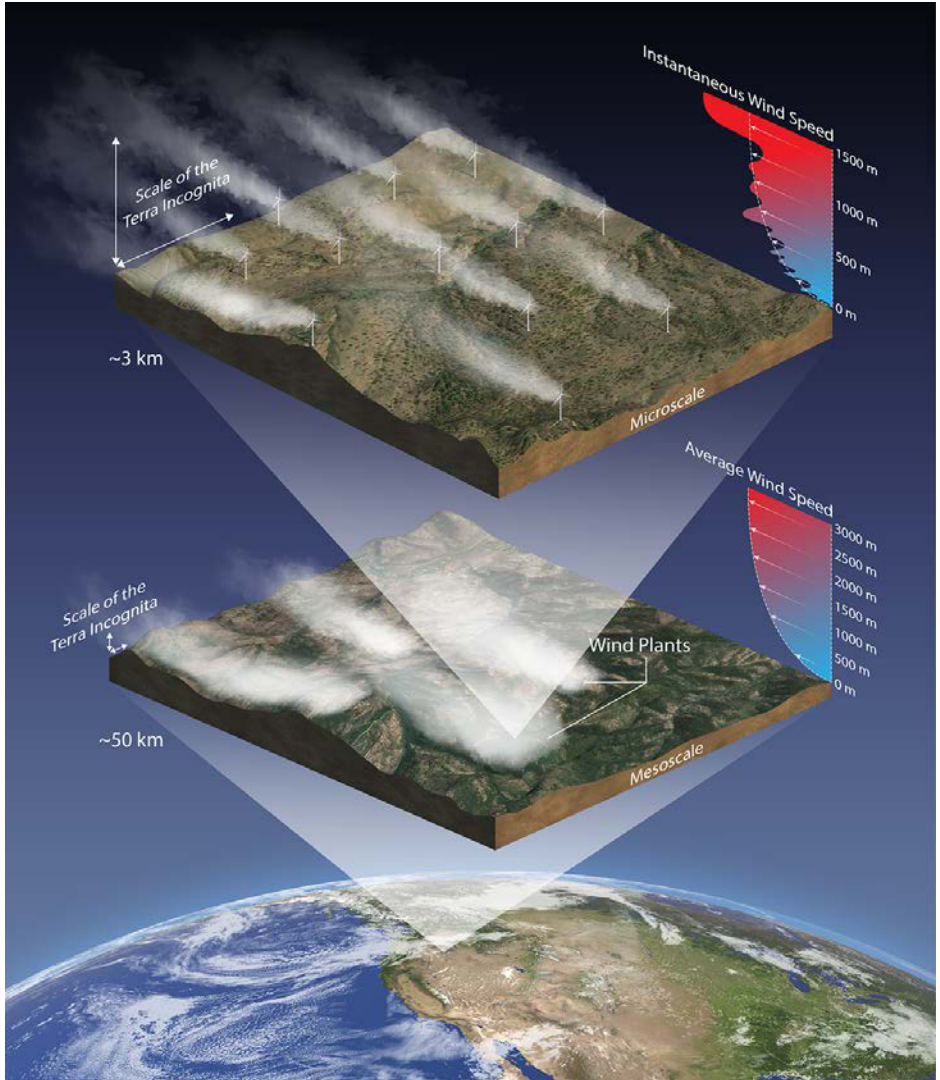
- NREL
- Sandia Labs
- ORNL
- Univ. of Texas

Team: Lawson, Melvin, Ananthan, Gruchalla, Rood, Sprague

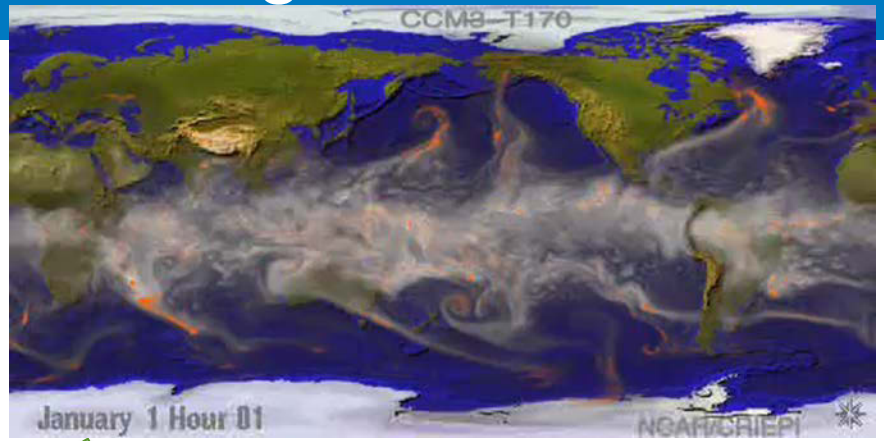
Grand Challenge #1: Mastering the physics of resource from the atmosphere to the intra-plant flows

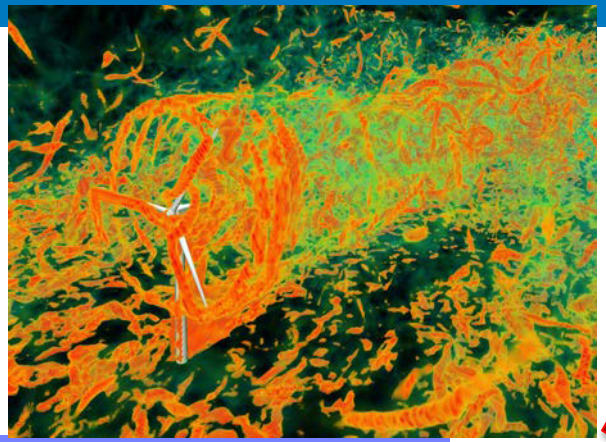


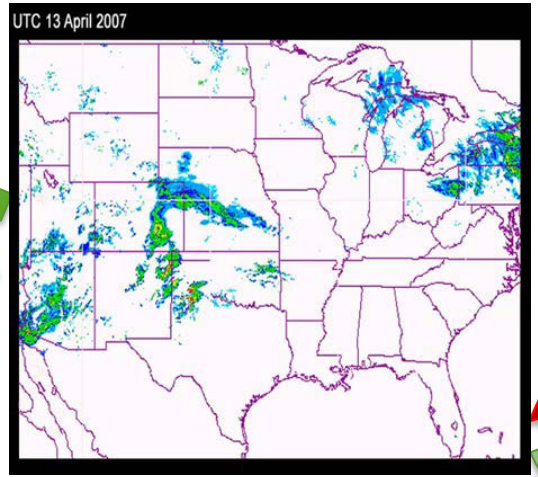
Wyngard, J. (2004). Toward Numerical Modeling in the "**Terra Incognita**." J. Atmospheric Sciences.



Forcing and Transfer of Energy Across Scales



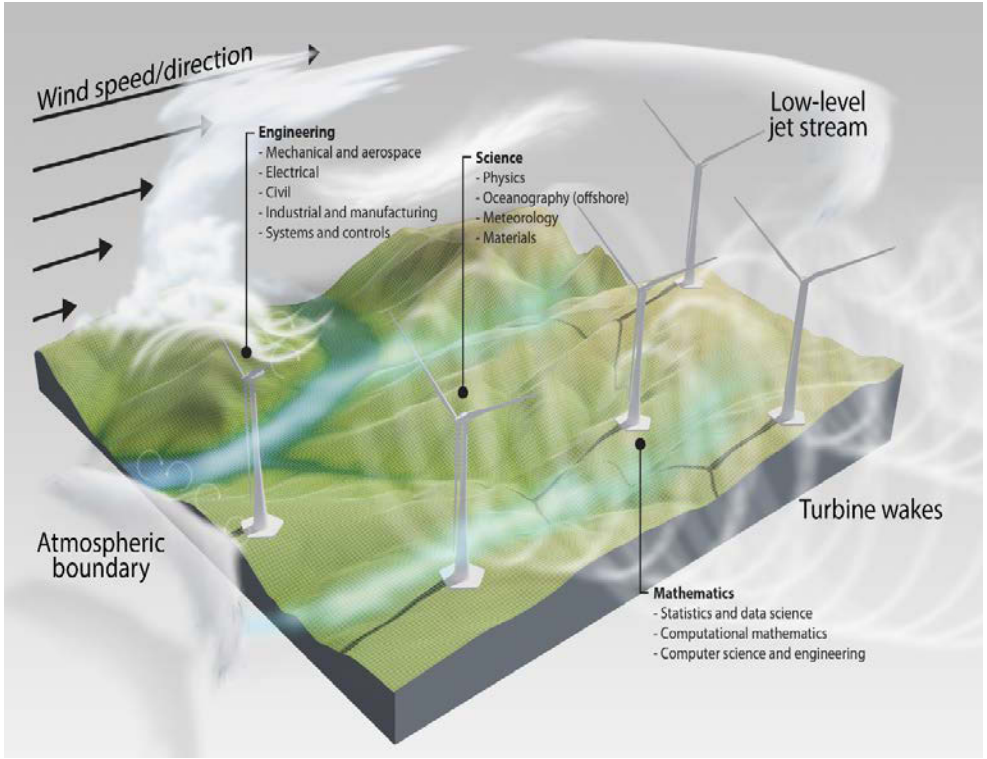




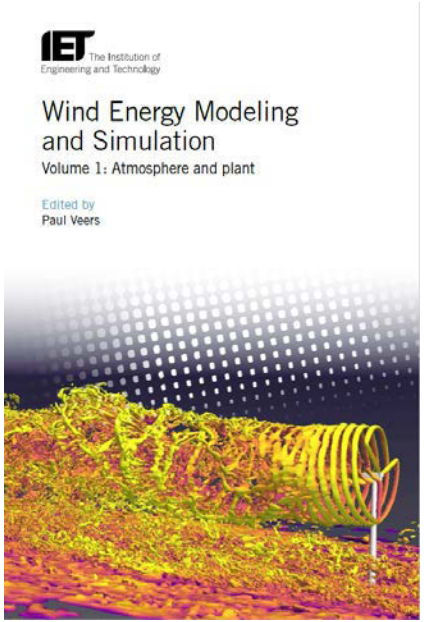
Courtesy Sue Haupt and colleagues, National Center for Atmospheric Research

Courtesy Jeff Mirocha, Lawrence Livermore National Laboratory

Expertise to Achieve Success



The sweep of topics is represented in Wind Energy Modeling and Simulation



2 Volumes
18 Chapters

Atmospheric Science
Wakes & Plants
Aerodynamics
High-Performance Computing
Controls
Drive Trains
Offshore Foundations
Electrical Generators
Grid Integration
Financial Models
Design Optimization
Etc.

Thank You

www.nrel.gov

NREL/PR-4A00-78026

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