Offshore Wind Modeling Opportunities and Challenges: Microscale Modeling

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Atmospheric Challenges for the Wind-Energy Industry
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Initial Questions

- **What do we mean by microscale modeling?**
  - LES comes to mind first, but it also can be…
  - RANS, linearized flow models + engineering wake models

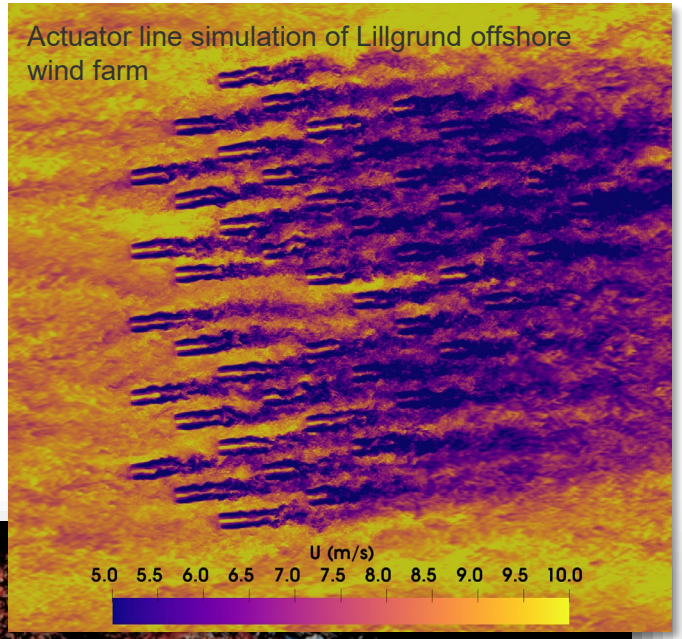
- **What is microscale modeling used for?**
  - Very localized wind resource assessment, but don't forget…
  - Wake physics discovery to inform engineering models
  - Advanced control/operational systems virtual laboratory
  - Understanding mechanical loads

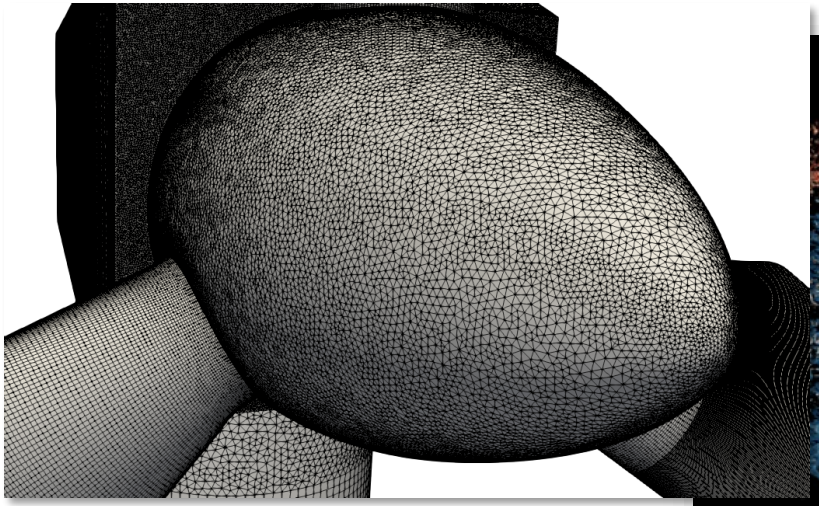
Initial Questions

- **What is different about offshore microscale modeling?**
  - Coupling with waves
    - Waves modify the flow in the turbine layer
    - Wind modifies the waves
    - How do waves affect wakes?
  - Different atmospheric phenomena than used to on land
    - Land-sea breeze
    - Coastal low-level jet
    - Hurricanes
  - Moisture and its effect on heat transfer

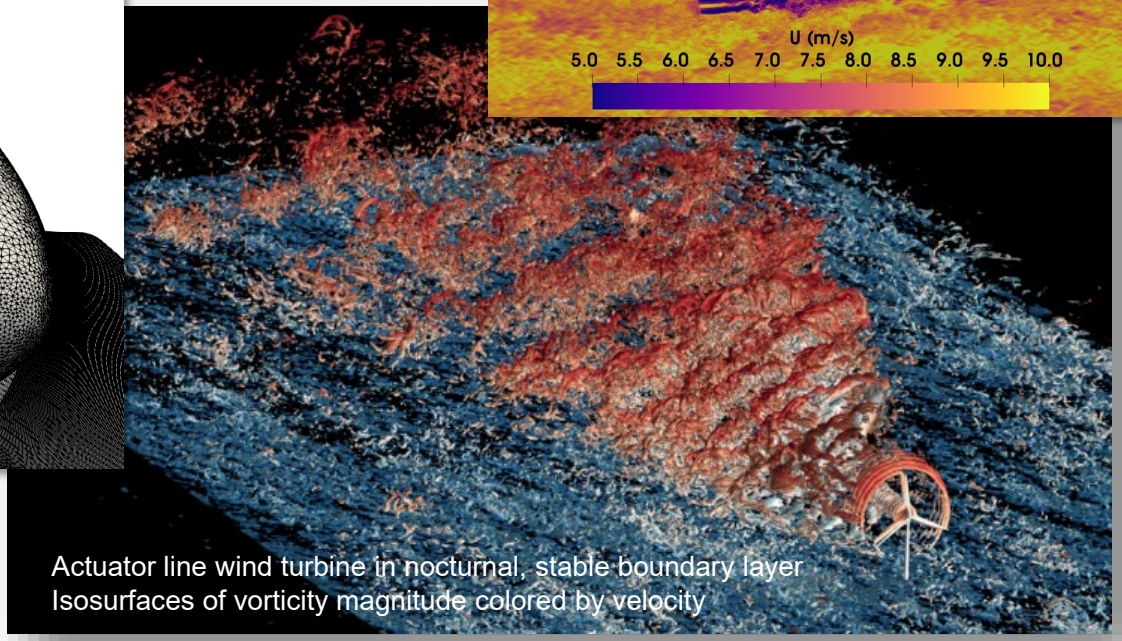
What A Hi-Fi Wind-Energy Microscale Model Looks Like at NREL

- **Use of microscale modeling extends beyond resource assessment:**
  - Need for microscale solver that blends atmospheric+engineering world
  - Need a range of capability from actuator disks to blade resolved, from flat surface with proper stress model to two-phase flow





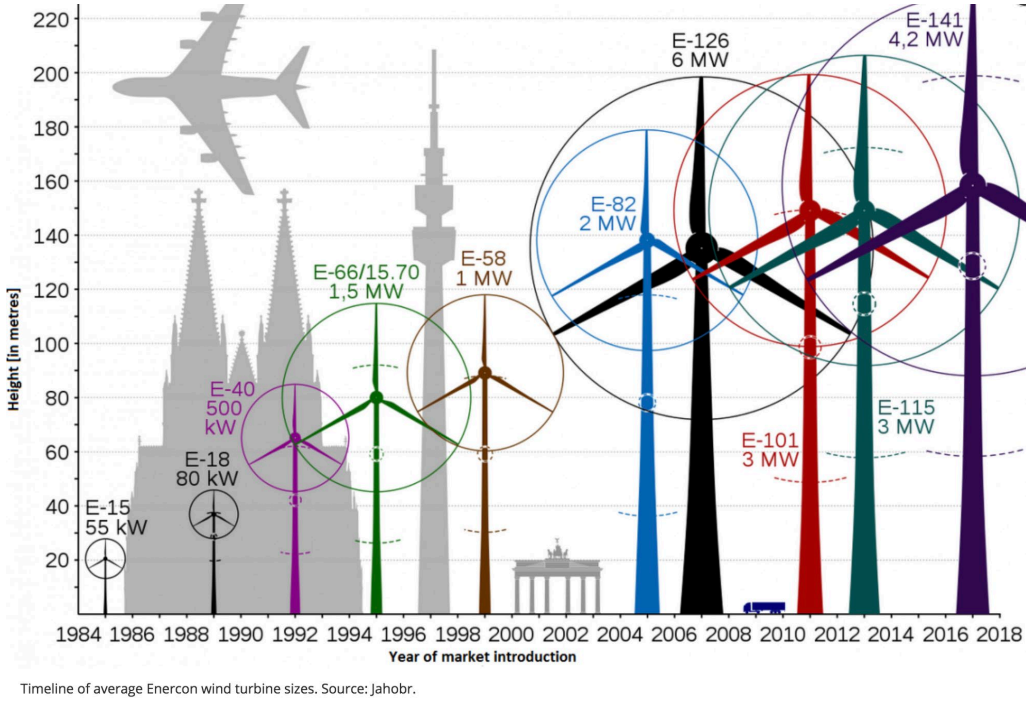
Turbine-geometry resolving computational mesh



Actuator line wind turbine in nocturnal, stable boundary layer
Isosurfaces of vorticity magnitude colored by velocity

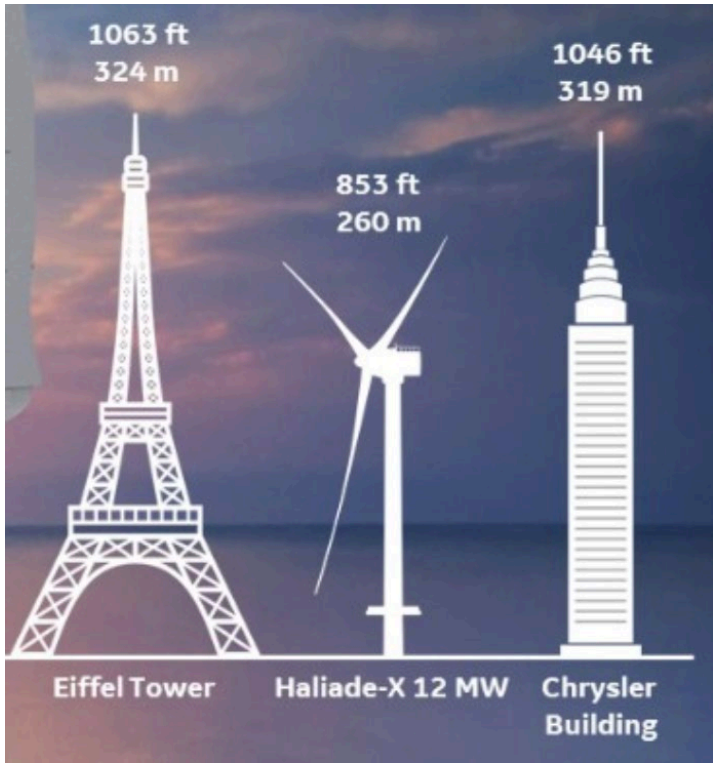
Offshore Wind Turbines are BIG!

- Turbine sizes are growing (especially offshore turbines)



Timeline of average Enercon wind turbine sizes. Source: Jahobr.

History of Enercon onshore wind turbine size



General Electric's planned Haliade-X offshore wind turbine:

- 220 m rotor diameter
- 12 MW rated power

Offshore Wind Turbines Are Complex!

- Offshore wind

The GE-Alstom Block Island Wind Farm off the coast of Rhode Island CREDIT: ERIC THAYER/BLOOMBERG

The first U.S. offshore wind plant off of Block Island, RI

The last of five 6 MW floating turbines being towed to Scotland for the first floating offshore wind plant

The last Hywind turbine sailing away from Stord in Norway for the coast off Abderdeenshire. Photograph: PA

Flow From Turbine Point of View

Conclusions

- **Not advocating for industry adopting hi-fi microscale models for wind-turbine/farm design**
  - Caveat 1: remember that faster-than-real time LES is now reality
  - Caveat 2: remember that a high-end GPU is like a small supercomputer
- **Use hi-fi as a discovery tool to improve lightweight tools**
  - Difficulty: Lightweight tool needs are vast; prioritize
- **My personal top picks for use of hi-fi microscale offshore**
  - Understanding adequacy of design standard turbulence models and improving them if required
  - Improving surface stress/flux modeling for waves
  - Next-generation wake models
    - More physics, but fast enough for controls
    - Both individual wakes and farm wake
  - Understanding new issues
    - Wind farm blockage
  - Planning field campaigns

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