Recent Wind Farm Modelling Enhancements in FAST.Farm

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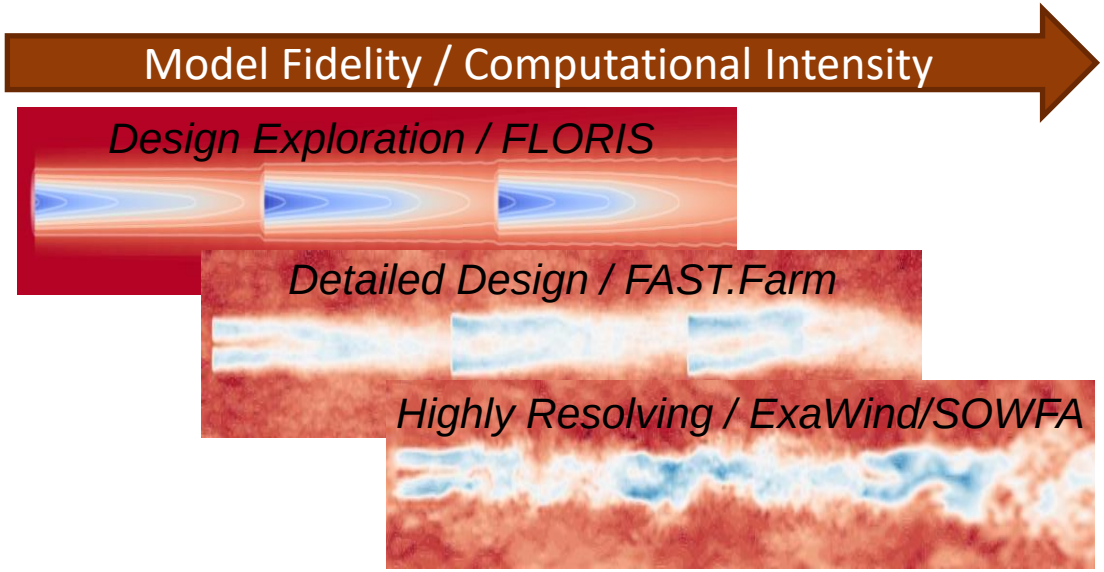
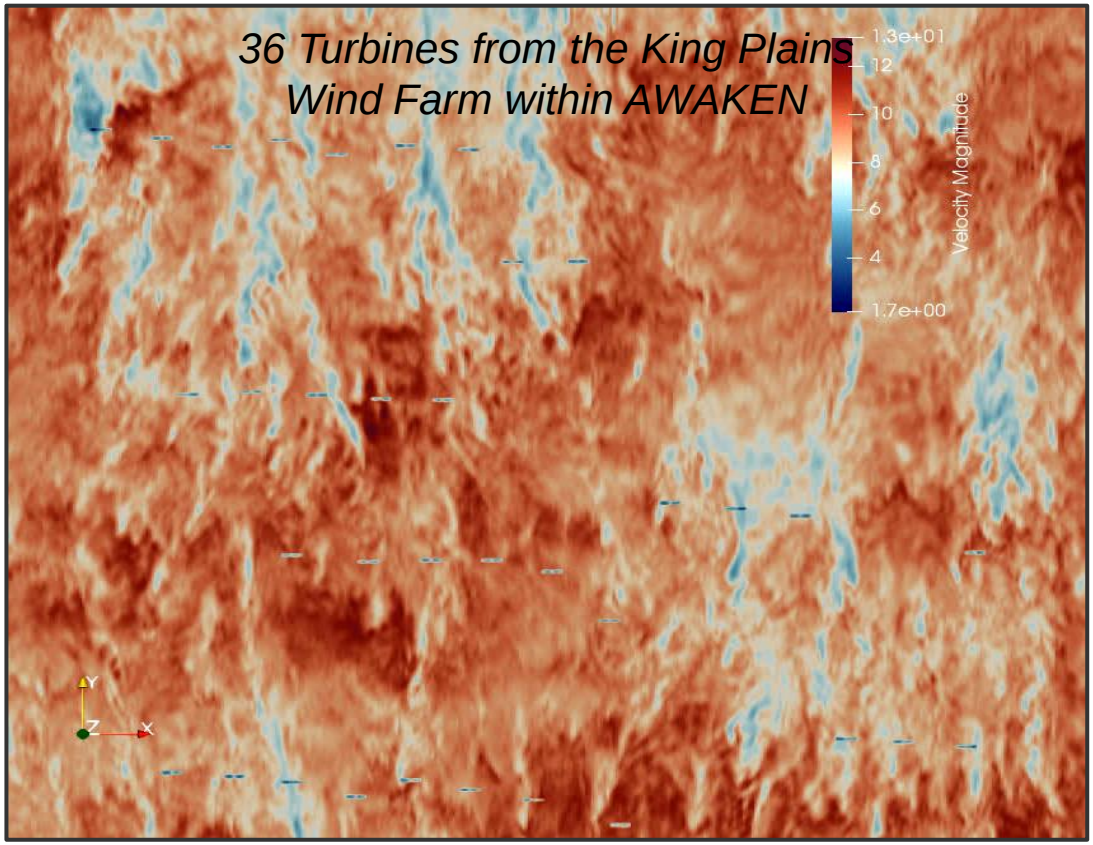
FAST.Farm Overview

FAST.Farm extends the capabilities of OpenFAST to provide physics-based engineering simulation of multi-turbine land-based, fixed-bottom offshore, and floating offshore wind farms with the ability to:

- Simulate each wind turbine in the farm with an OpenFAST model
- Capture relevant physics for prediction of wind farm power performance and structural loads, including wind farm-wide ambient wind, super controller, and wake advection, meandering, and merging
- Maintain computational efficiency through parallelization to enable loads analysis for predicting the ultimate and fatigue loads of each wind turbine in the farm





Background – FAST.Farm Submodel Hierarchy

FAST.Farm Driver
Calls individual modules, derives module inputs from outputs, & drives time-domain solution forward

Super Controller (SC)
Solves wind plant super controller dynamics

OpenFAST (OF)
(One instance per turbine; subcycled; many modules)
Solves aero-hydro-servo-elastic dynamics for an individual wind turbine

Wake Dynamics (WD)
(One instance per rotor)
Calculates wake dynamics for an individual rotor

Ambient Wind & Array Effects (AWAE)
Processes ambient wind & wake interactions across the wind plant

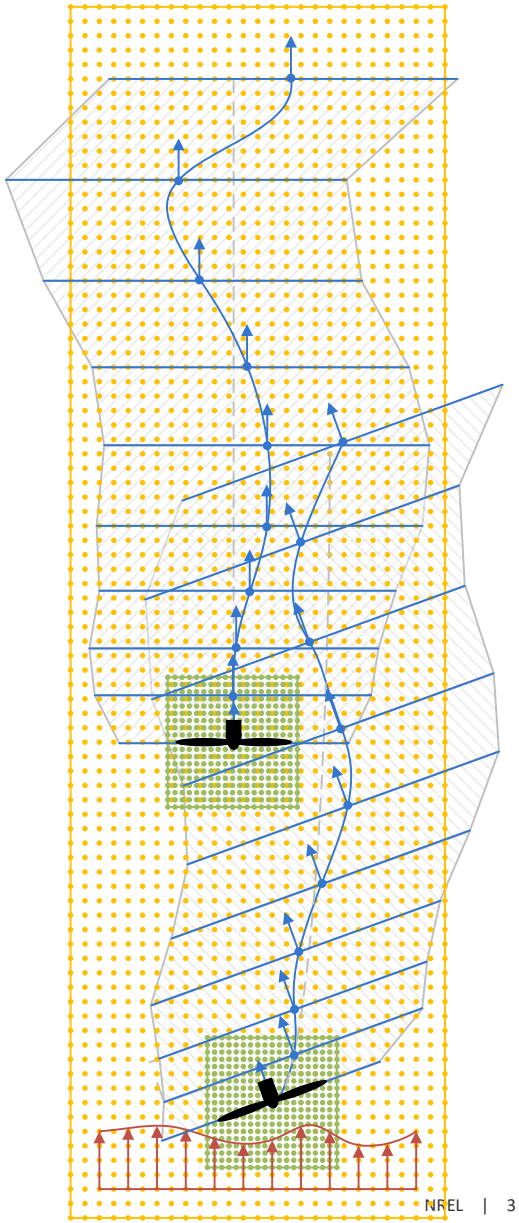
Wake Advection, Deflection, & Meandering
Solves dynamic wake advection, deflection, & meandering for an individual rotor

Near-Wake Correction
Calculates near-wake (pressure-gradient-zone) correction to wake deficit for an individual rotor

Wake-Deficit Increment
Increments the quasi-steady axisymmetric wake deficit downwind for an individual rotor

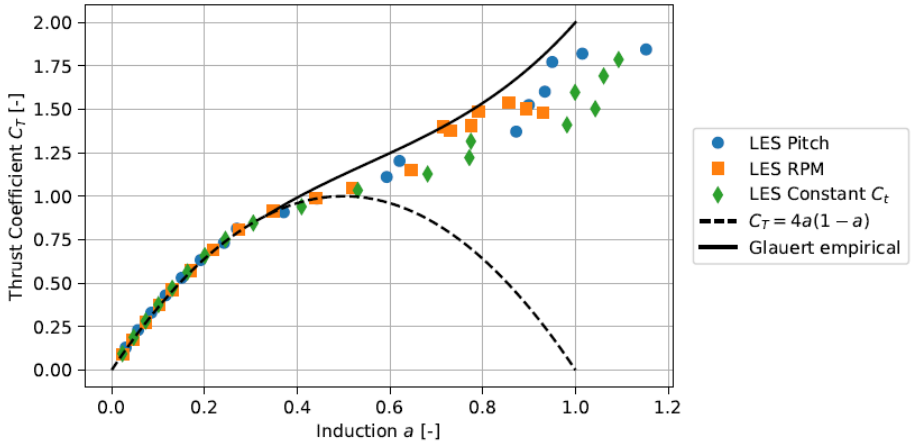
Ambient Wind
Processes ambient wind across the wind plant from a high-fidelity precursor or an interface to **InflowWind**

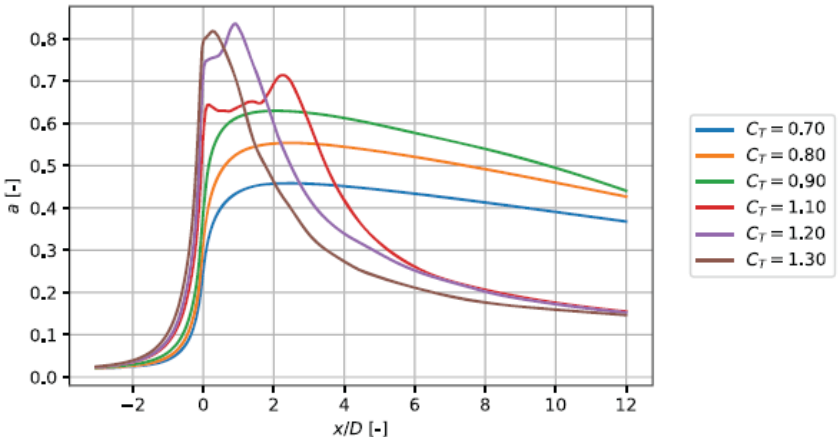
Wake Merging
Identifies zones of overlap between all wakes across the wind plant & merges their wake deficits

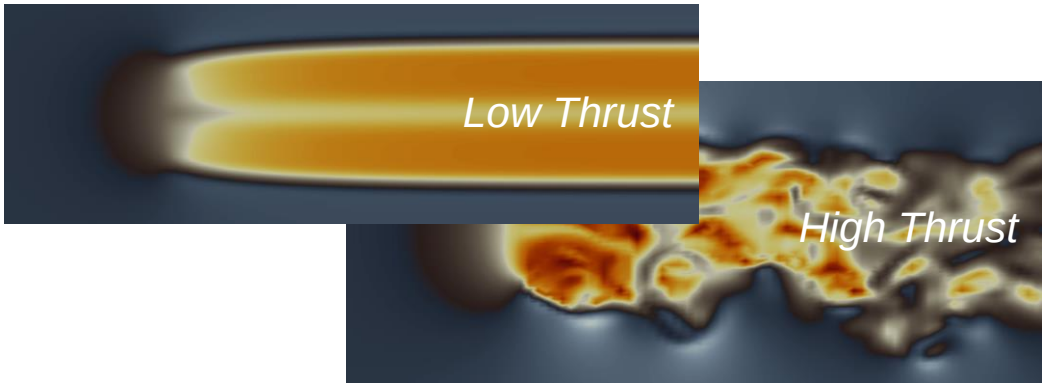


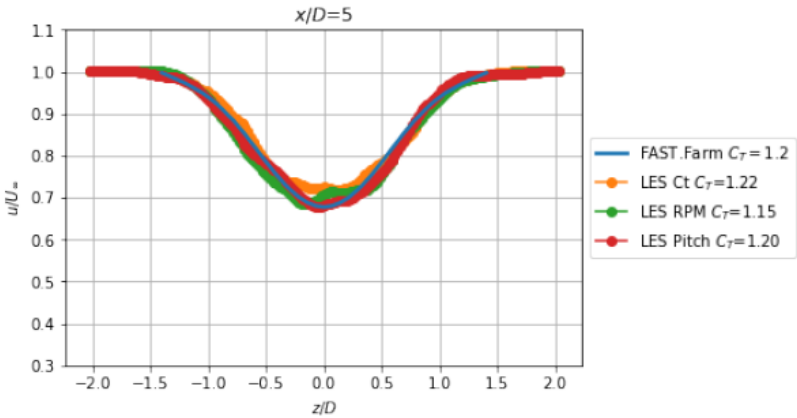
Near-Wake Correction

- Problem: Momentum theory and original model invalid at high thrust (C_T >≈ 1)
- Solution: Fit Gaussian wake profile at high thrust from LES; blend between
- Impact: Model now valid at low wind speeds for typical soft-stiff towers









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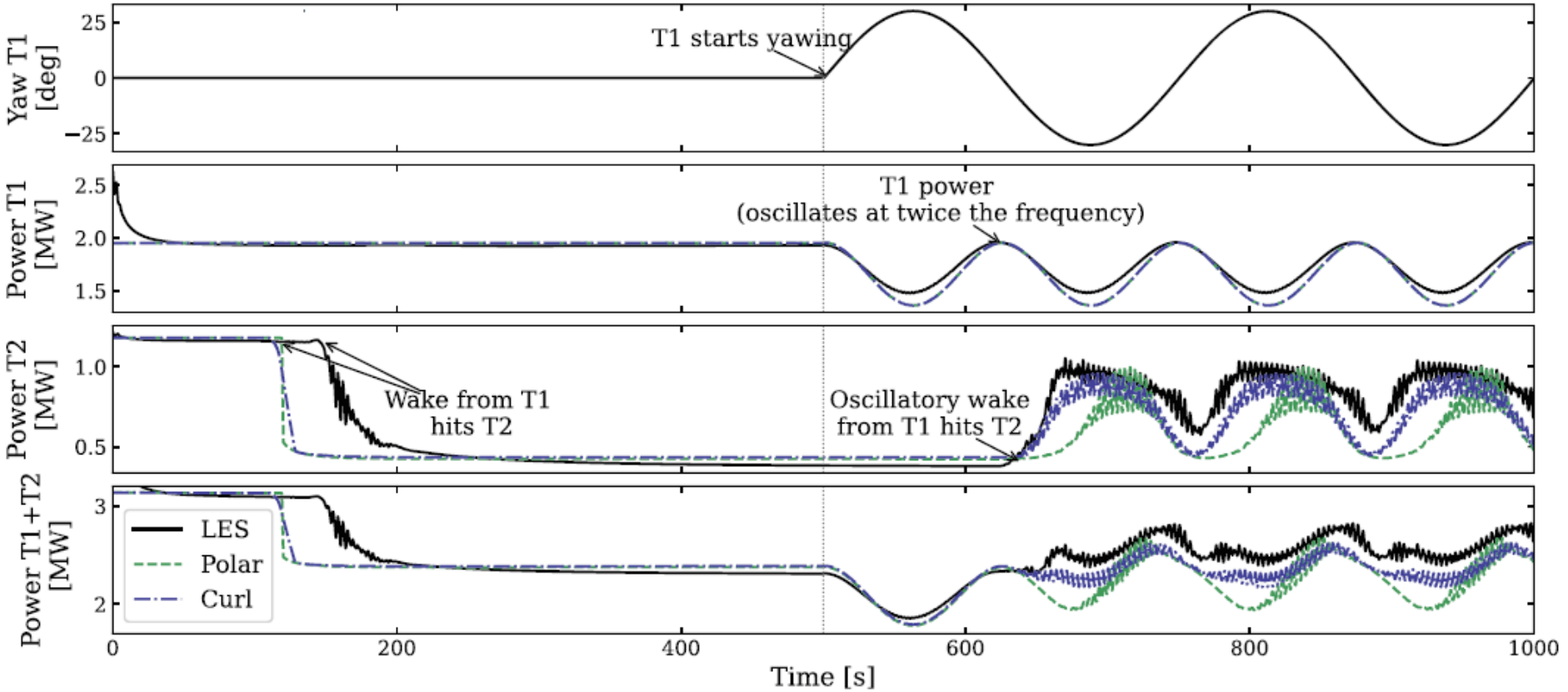
Curled Wake

- Problem: Original model had axisymmetric wake with deflection in skewed flow
- Solution: Develop time-varying formulation of the FLORIS curled wake model
- Impact: Model now valid for skewed flow and wake steering applications



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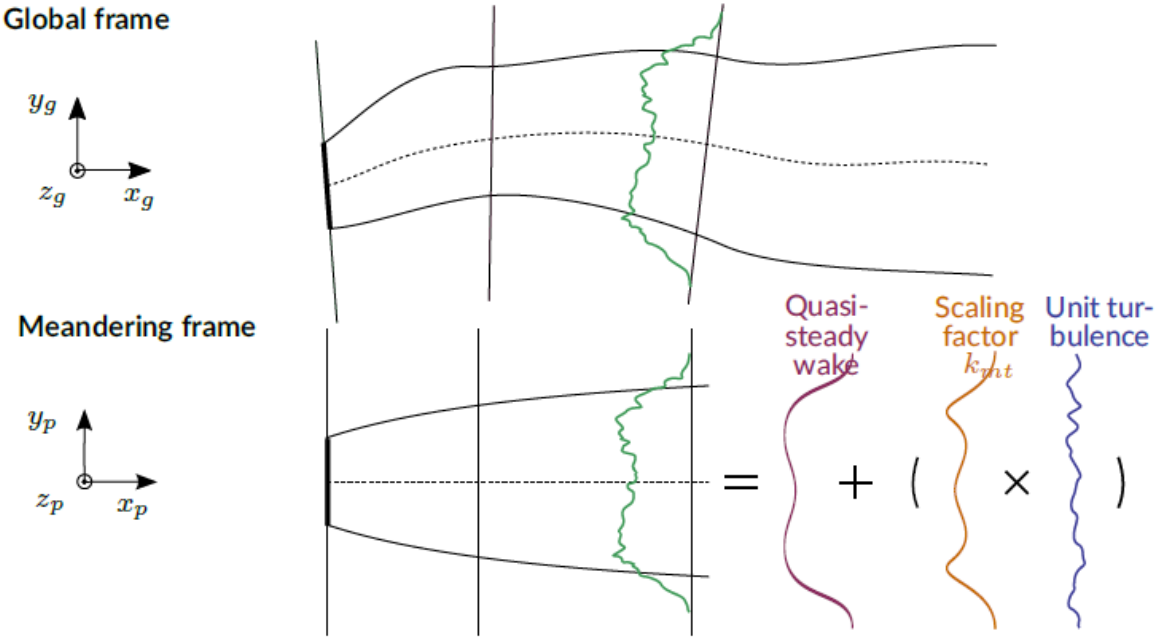
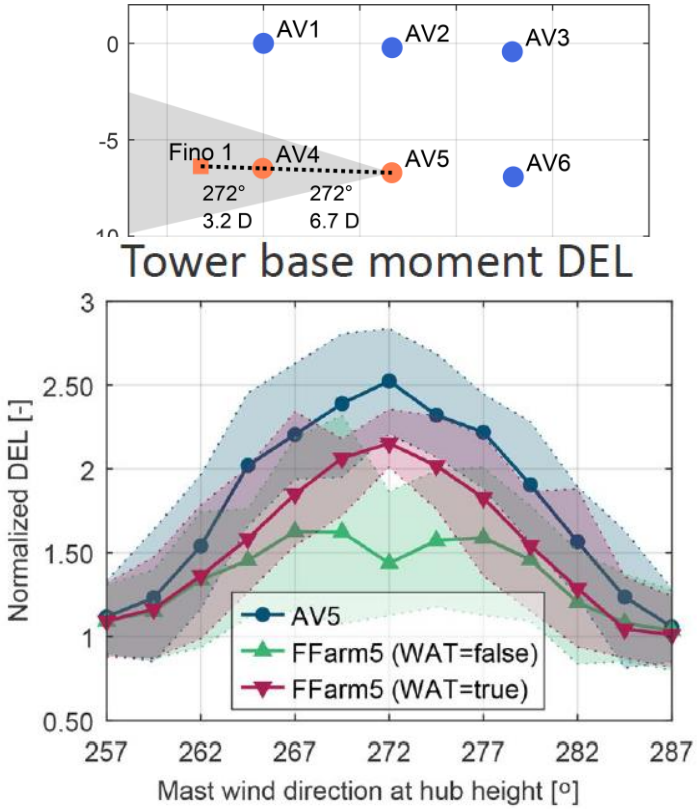
Wake-Added Turbulence

- Problem: Original model underpredicted downstream turbine loads at low TI
- Solution: Develop a wake-added turbulence model adopted for FAST.Farm
- Impact: Model now valid in stable atmospheric stability





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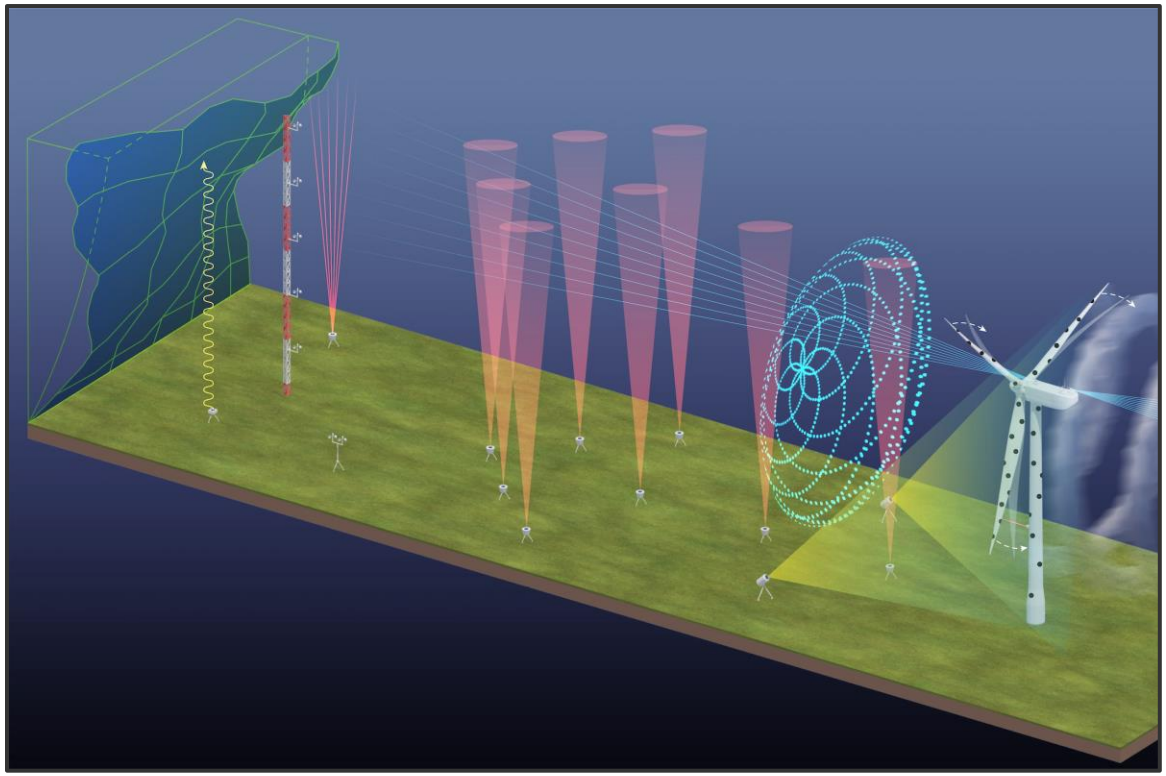
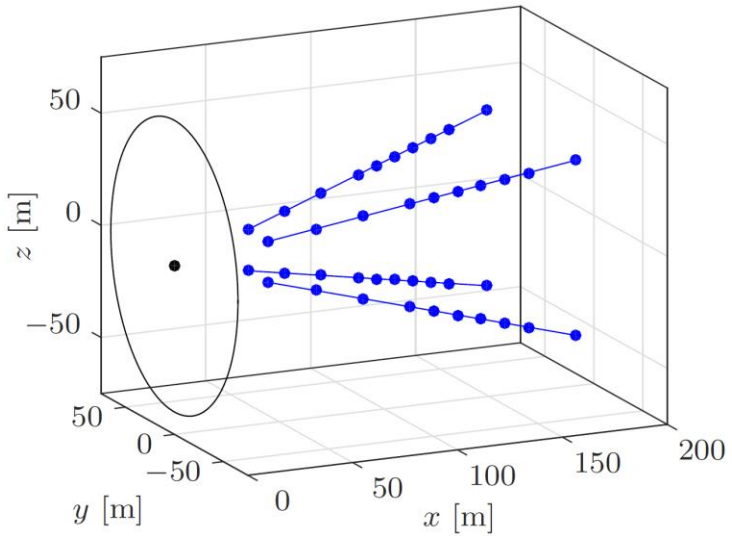
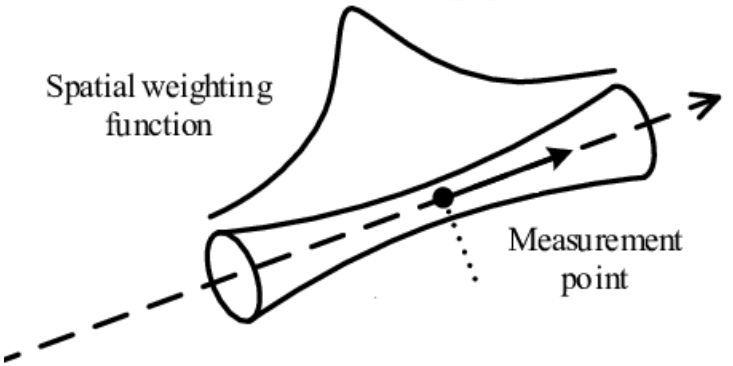
LiDAR Simulator

- Problem: Original wind outputs do not capture line-of-sight weighting of LiDARs
- Solution: Interface externally developed module LidarSim to FAST.Farm
- Impact: LiDAR measurements can be passed to controllers or used in validation







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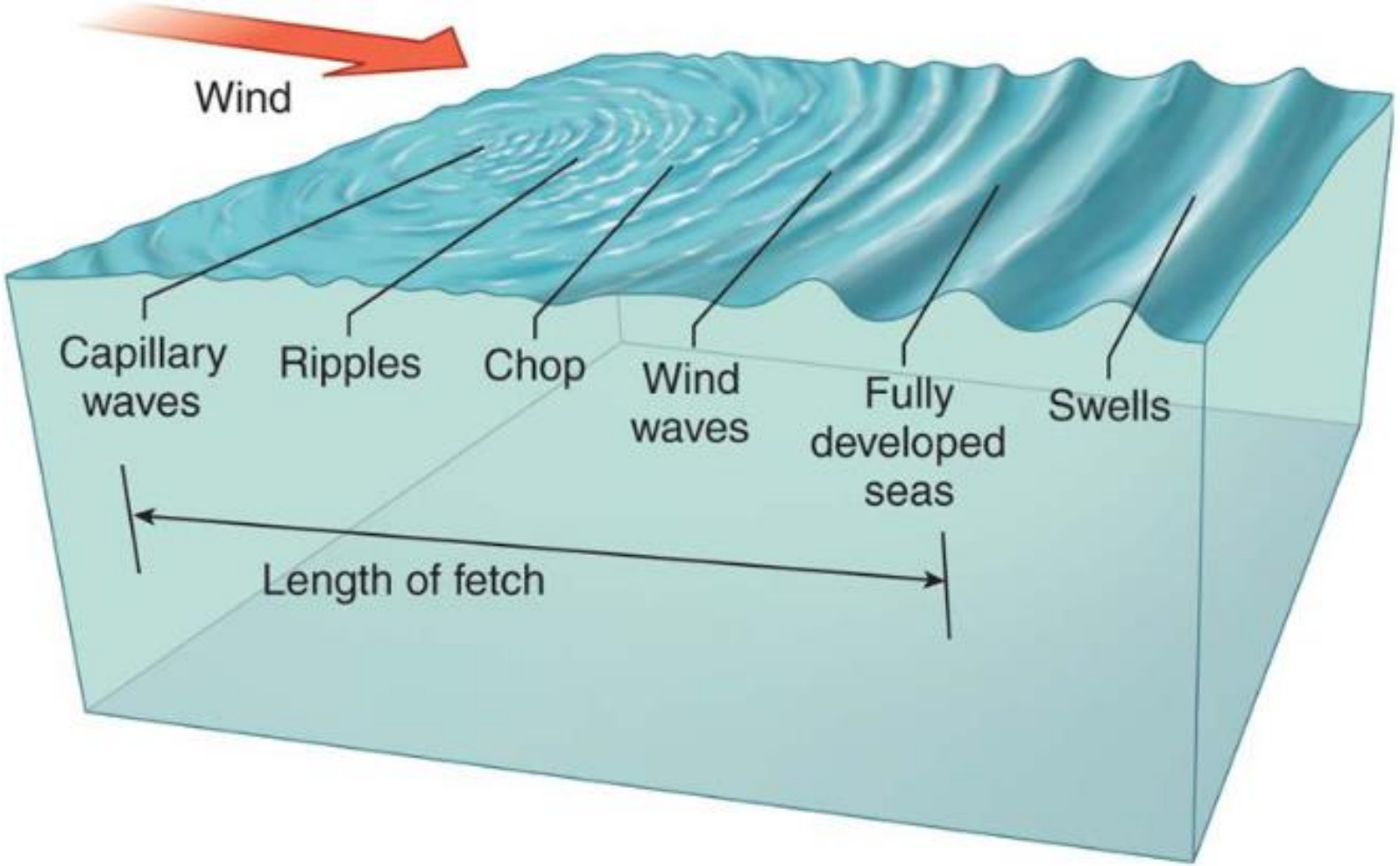
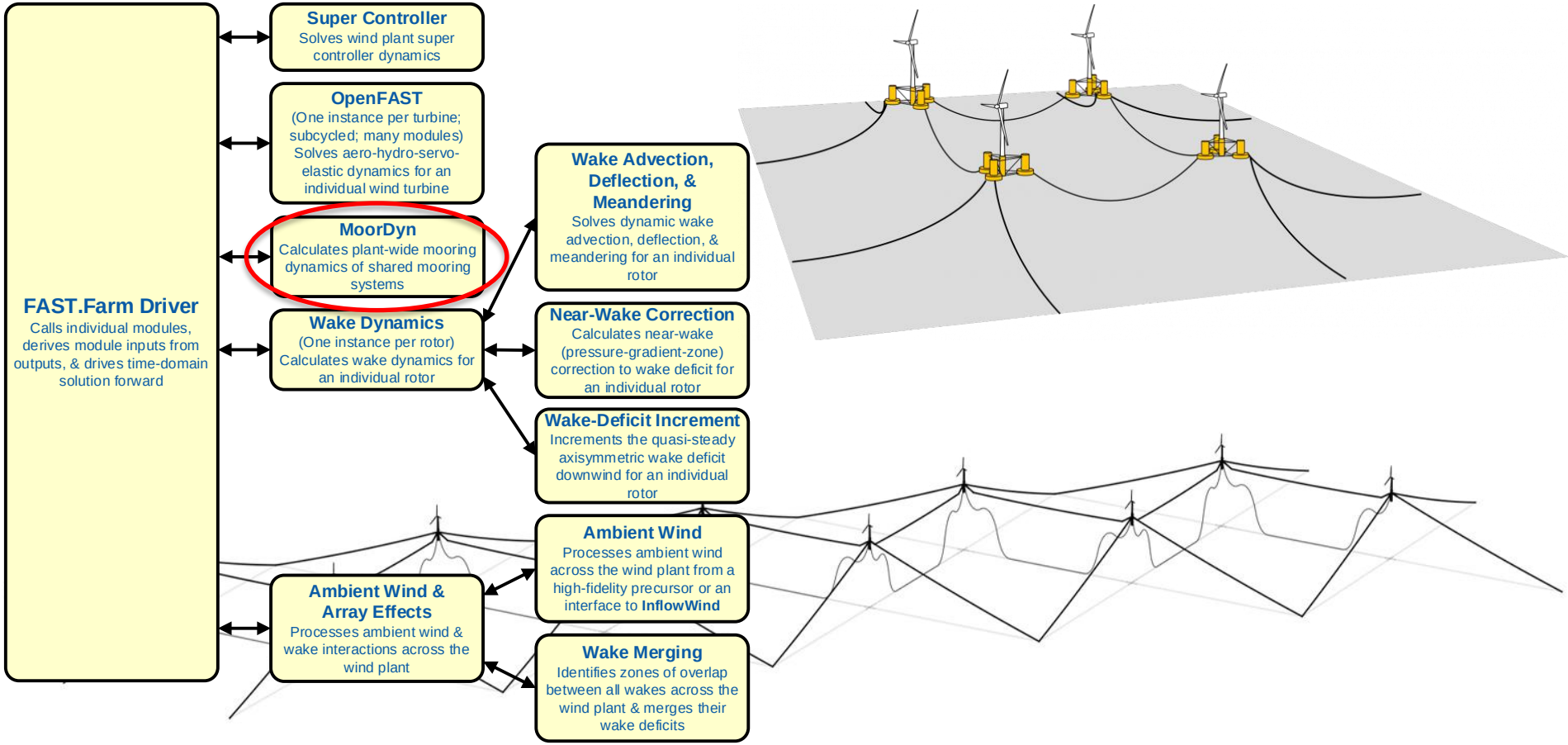
Farm-Wide Offshore Wave Field

- Problem: Original surface waves were independently defined at each turbine
- Solution: Apply dispersion relationship farm-wide based on turbine positions
- Impact: Ensures consistent wave phasing from wave propagation across farm



Offshore Shared Mooring Systems

- Problem: Original moorings were independently defined at each turbine
- Solution: Interface instance of mooring module MoorDyn at the FAST.Farm level
- Impact: Model now supports floating offshore wind farms with shared moorings



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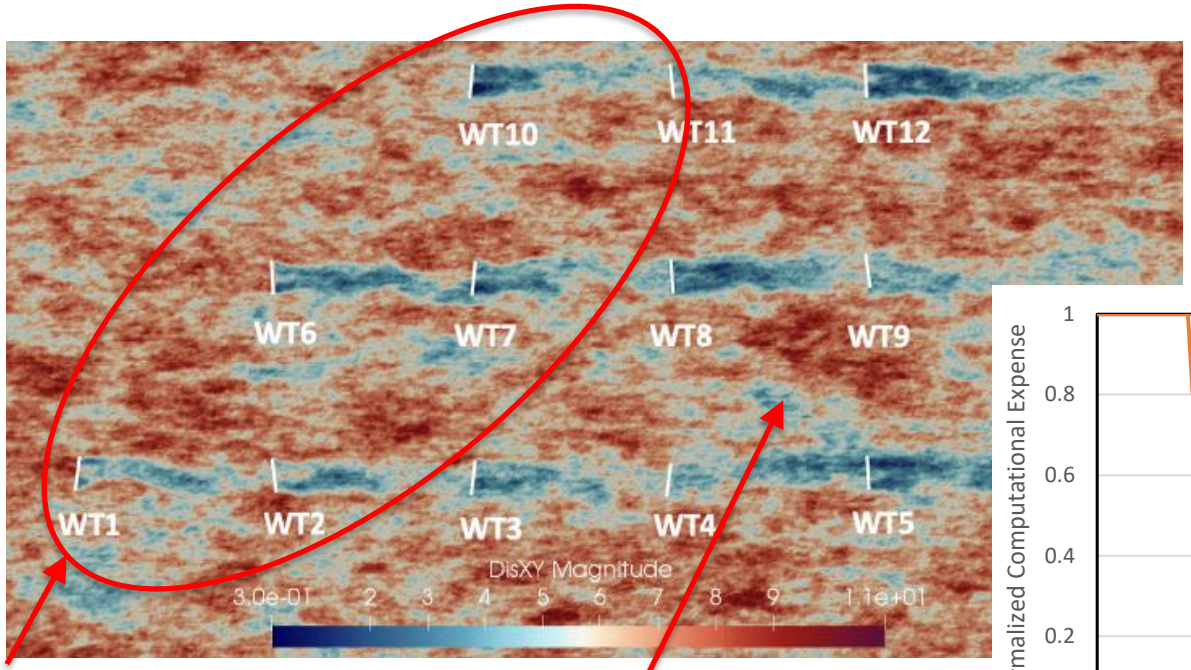
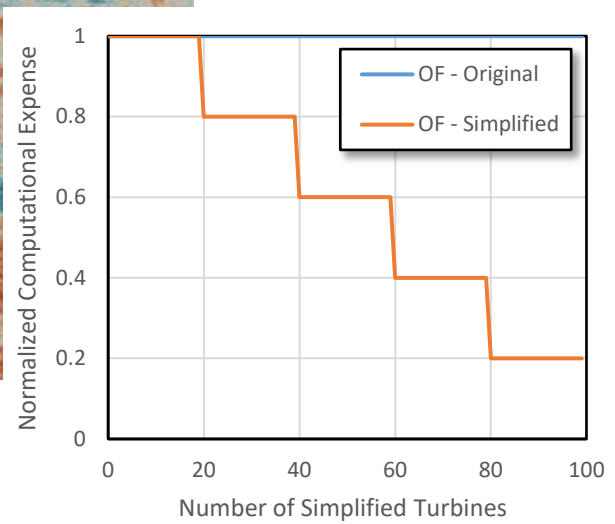
Simplified Turbine Modeling

- Problem: Computational bottlenecks and memory requirements for large farms
- Solution: Introduce options for simplified turbine modeling (rigid, actuator disk)
- Impact: Computationally tractable simulations of large wind farms



Simplified OpenFAST models with wakes and control

Full OpenFAST models with wakes, control, and structural loads



Normalized Computational Expense with N_t = 100 and N_{Th} = 20

Jonkman, J.; Branlard, E.; Platt, A.; Thedin, R.; Shaler, K.; and Sirnivas, S. "Simplified Turbine Modeling in FAST.Farm for Improved Computational Performance." *NAWEA / WindTech 2022, 20–22 September 2022, Newark, DE (USA)*.

Carpe Ventum!

Combined, these improvements will facilitate more accurate and computationally tractable simulations not previously possible with FAST.Farm, enabling further advancements in wind farm design and analysis!

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