Wind profiling to support renewable energy development

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U.S. mission: Increase Renewable Energy input into U.S. energy portfolio

Reduce CO_2 emissions to mitigate climate change

NOAA mission: Support Renewable Energy by weather and wind forecast

Lower risk for wind plant siting and operations

- What is the accuracy of these models?
- How Boundary Layer processes may impact turbine operations?

There is need for quality measurements at turbine heights

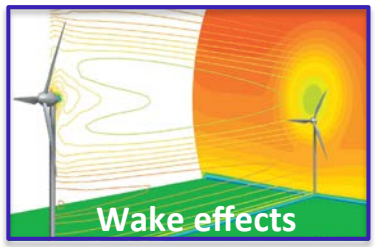
Doppler lidar addresses this need

Provides accurate information on wind and turbulence profiles with high temporal and vertical resolution

CSD scientists use lidars as a new tool to support Wind Energy development inland and offshore

- Estimate wind resources at the heights of turbine rotors
- Evaluate and improve NOAA Weather Prediction models
- Study turbine wake dynamics

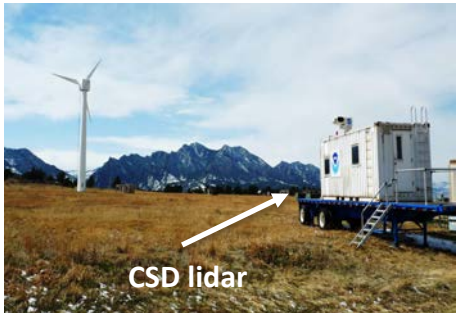
Turbine wake dynamics (2011-2012)



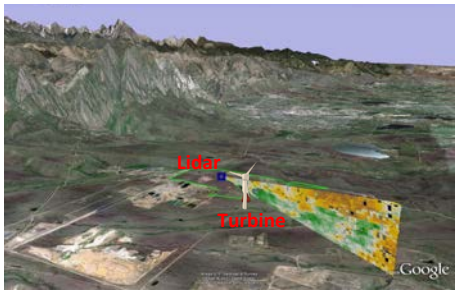
Major wake effects are ***reduced wind and increased turbulence*** downwind of operating turbine

Accounting for wakes is an important issue for optimal siting of turbines in a wind farm

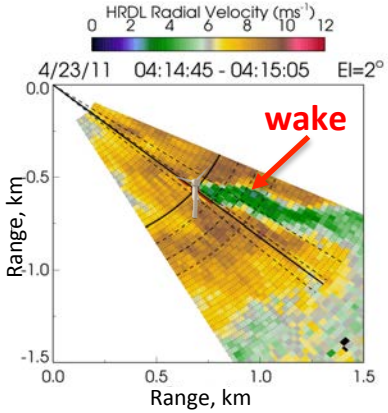
CSD scientists used lidar measurements to obtain wind flow features, both upwind and downwind of a research turbine to study wake

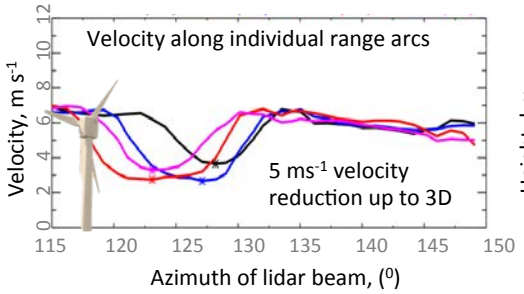


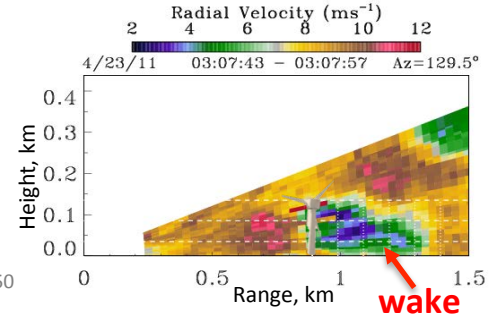
Lidar deployment at the National Wind Technology Center



Simultaneous lidar measurements upwind and downwind of a 2.5 MW turbine

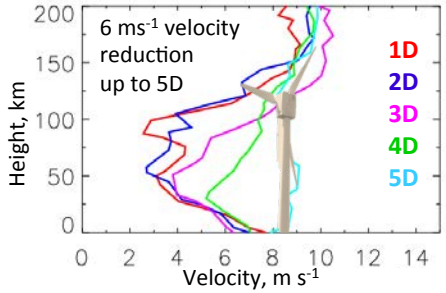






Reference: Banta, Pichugina, Brewer, et al., 2015: JTECH, in press

- Velocity deficits of 6-8 m s^{-1} extending up to 10-12 rotor diameters (D)
- Max deficit ranges from 10% to 64%

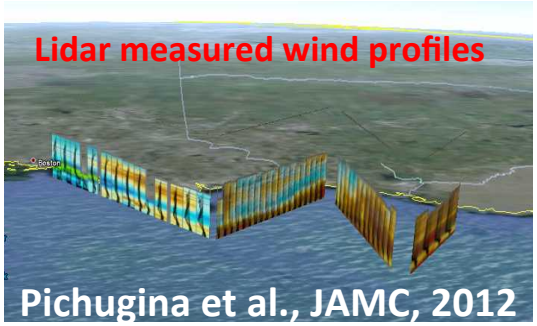


Collaboration: *Department of Energy (DOE), CU Boulder, the Lawrence Livermore National Laboratory (LLNL), the National Renewable Energy Laboratory (NREL), and SIEMENS*

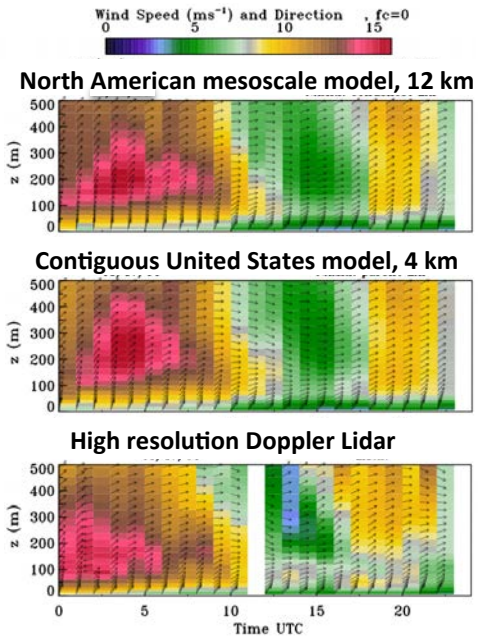
Validation and Improvement Numerical Weather Prediction models for offshore Wind Energy (2013-14)

Scientific questions:

- What is the accuracy of operational models offshore? (for initial conditions and for different lead hours)
- How models perform under different atmospheric conditions? (stable/unstable, Low Level Jet, frontal passages)



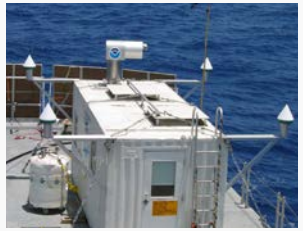
We used ship-borne lidar data to validate and improve NOAA forecast models



Comparing modeled and observed wind flow

- All models capture major trends in wind field well
- Models show 10% improvement for the first 2-5 lead hours
- Larger discrepancies between observed and modeled winds found:
  - below 200m;
  - during nocturnal Low Level Jet events;

illustrating need to improve Boundary Layer physics



CSD engineers developed **unique** motion-compensating system to operate lidar offshore and obtain highly accurate measurements even under rough sea conditions

Collaboration:

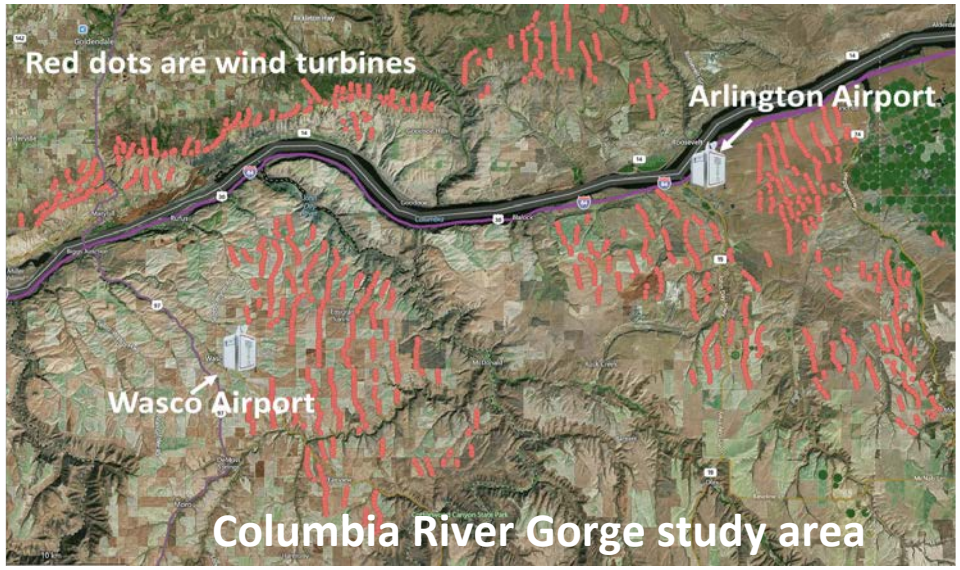
Department of Energy, National Weather Service (NWS/NCEP), NOAA Physical Science and Global Systems divisions

Wind Forecast Improvement Project-WFIP 2 (2015-2016)

Objectives:

- Characterize complex terrain atmospheric phenomena that impact model accuracy
- Validate and Improve weather prediction models

CSD scanning Doppler lidar



Variety of instruments will be deployed for 18-month period to observe mountain wind flow phenomena:

- Frontal Passages
- Gap Flows
- Mountain Waves
- Topographic Wakes
- Marine Pushes
- Convective outflows

CSD will provide real-time measurements from 2 scanning Doppler lidars for the whole duration of the experiment to validate NOAA models. The 3^{d} lidar will be used for short-term case studies

Partnership

- US Department of Energy (DOE)
- NOAA divisions (PSD,GSD and ARL)
- CU Boulder, Notre Dame University
- National Centers for Environmental Prediction (NCEP)
- DOE National Laboratories (NREL, PNNL, LLNL, and Argonne)
- VAISALA, LEOSPHERE, Lockheed Martin, NCAR, and local wind energy companies