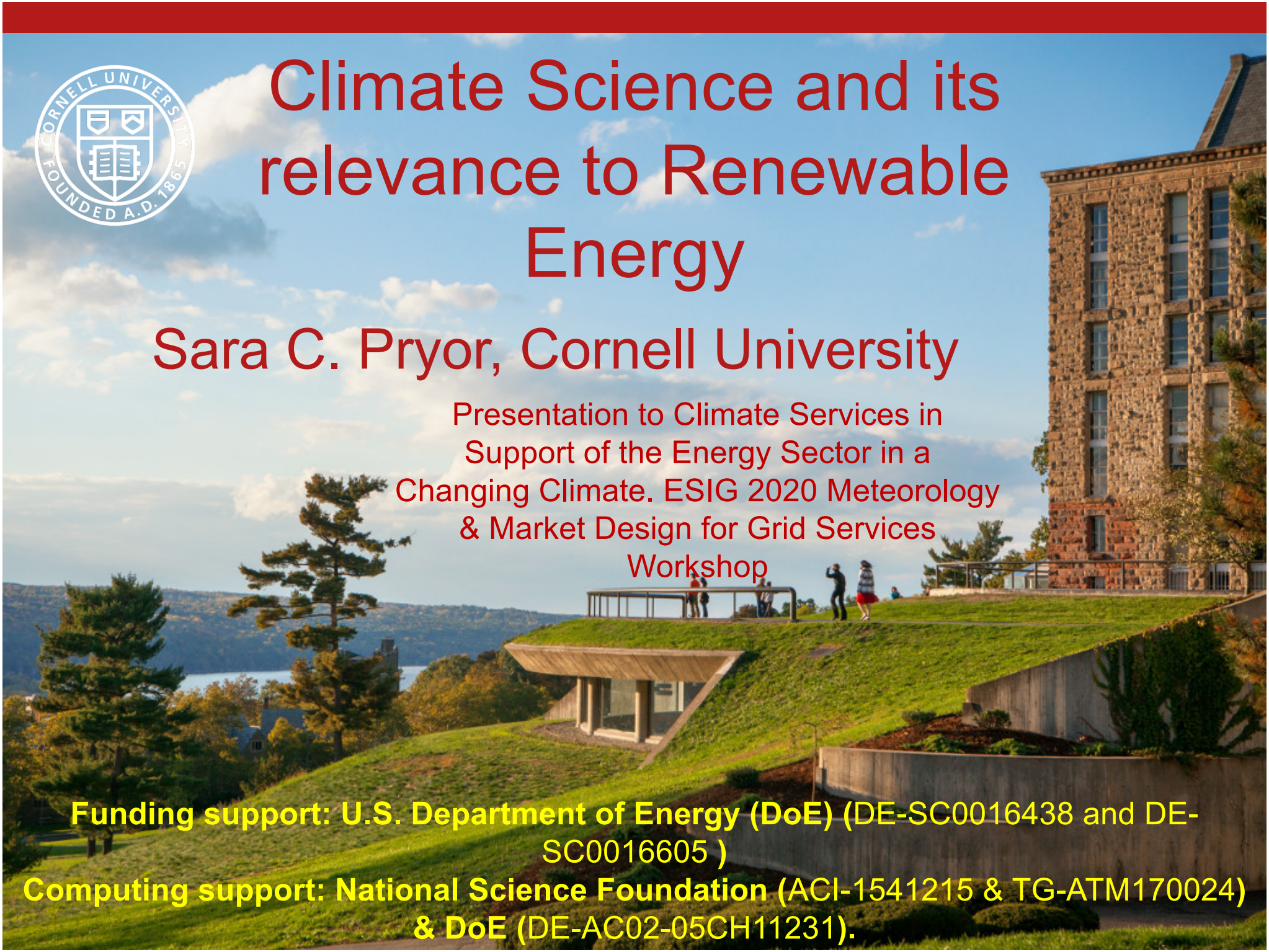

Climate Science and its relevance to Renewable Energy

Sara C. Pryor, Cornell University

Presentation to Climate Services in Support of the Energy Sector in a Changing Climate. ESIG 2020 Meteorology & Market Design for Grid Services Workshop

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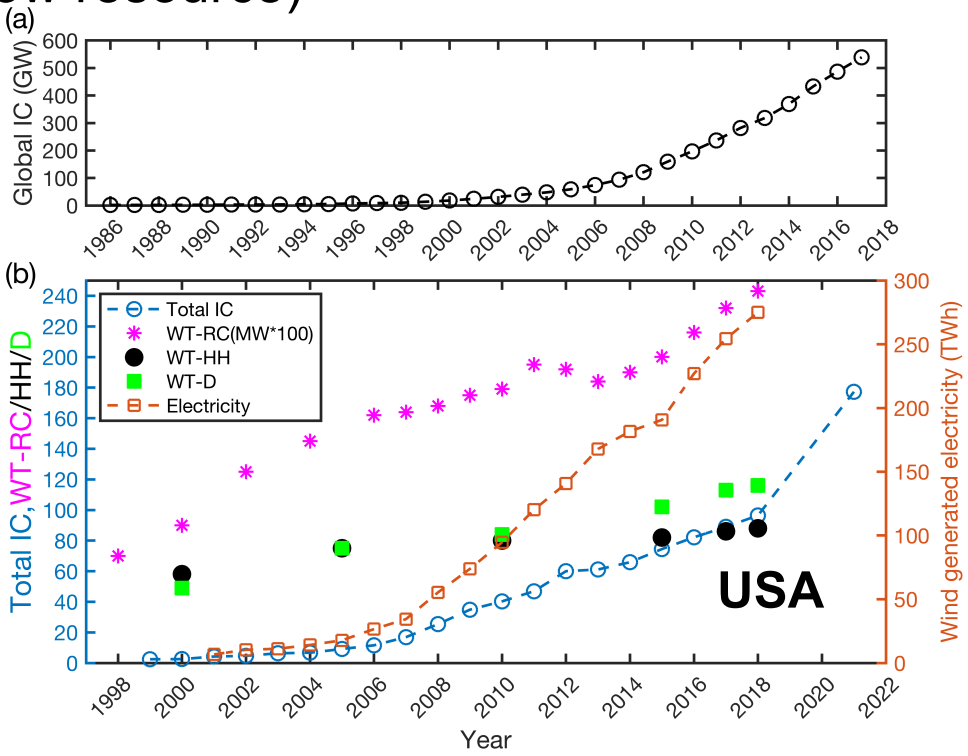
Wind energy & climate change

- Wind energy: LCoE (SGP) < $50/MWh
  - GLOBAL IC: Grew at annualized rate of 20% to approx. 600 GW (2018). Projected +50% inc. 2019-2023.
  - 2017: 6% global electricity. Projections for upto 33% by 2050 (well below resource)

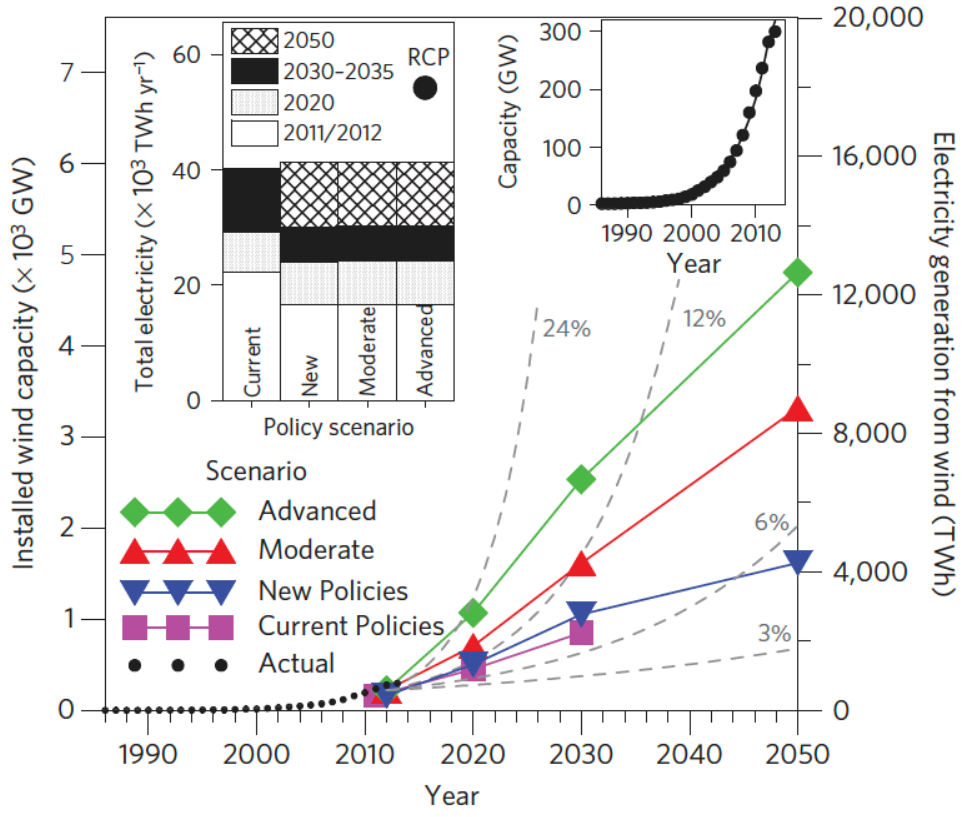


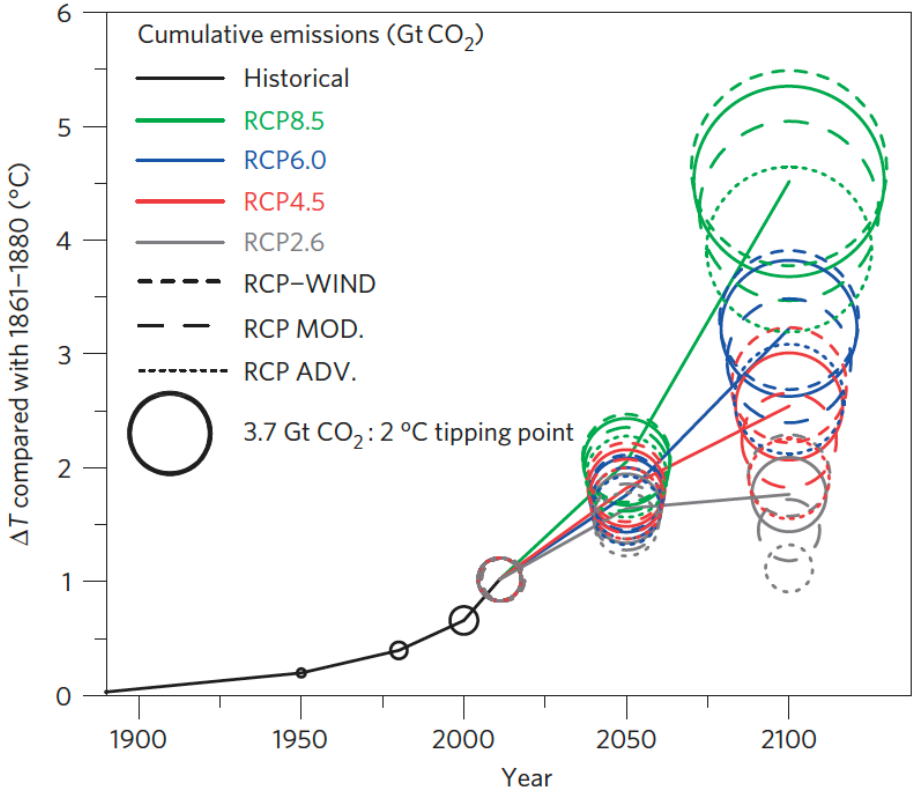
Pryor S.C., Barthelmie R.J. and Shepherd T.J. (2020): 20% of US electricity from wind will have limited impacts on system efficiency and regional climate. *Nature: Scientific Reports* **10** 541

- Reciprocal relationship:
  - Mitigation of climate change (reduce CO_2 emissions)
  - Sensitive to climate change (resource & operating conditions)

Climate change mitigation potential

- Achieving 33% global electricity from wind by 2050 reduces global warming at 2100 by 0.3°C



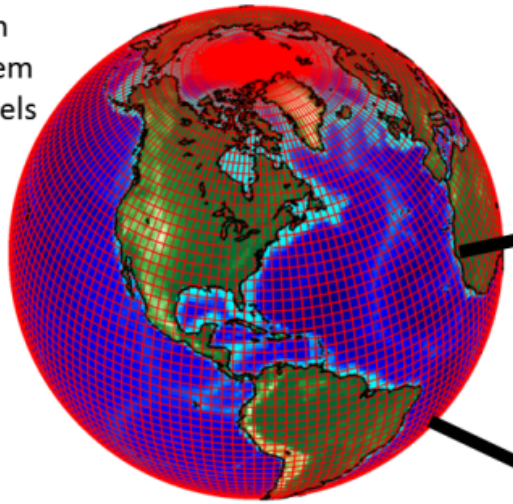


Barthelmie R.J. and Pryor S.C. (2014): The potential contribution of wind energy to climate change mitigation *Nature Climate Change* **4** 684-688.

How might climate change impact wind energy?

Climate forcing: Representative Concentration Pathways (RCP)

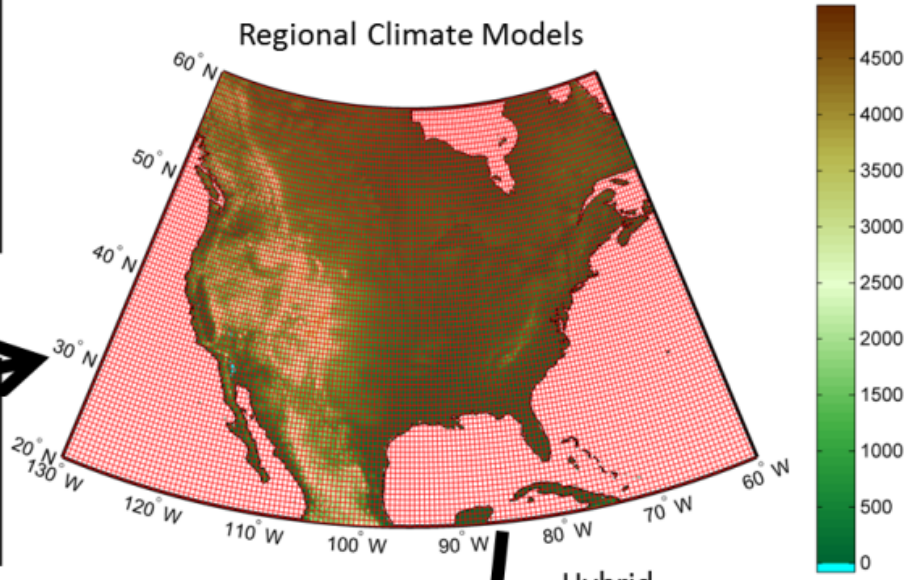
Earth System Models



Multiple RCPs/ESMs ⇒ Uncertainty

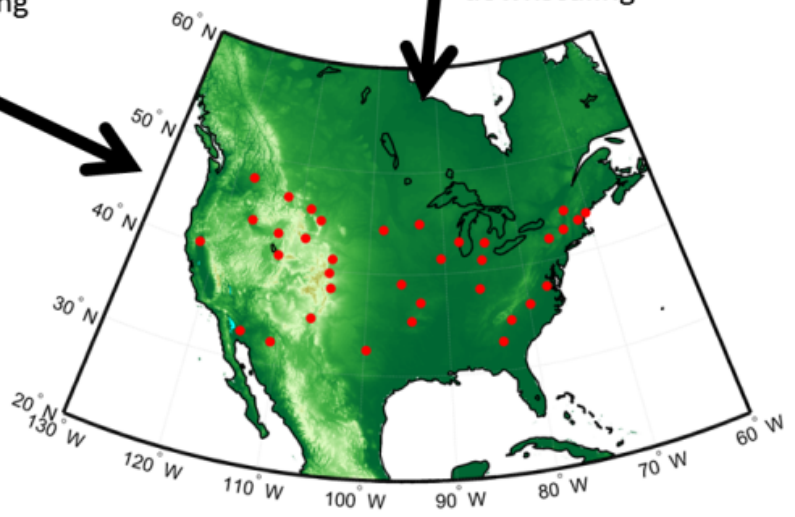
Dynamical downscaling

Regional Climate Models



Statistical downscaling

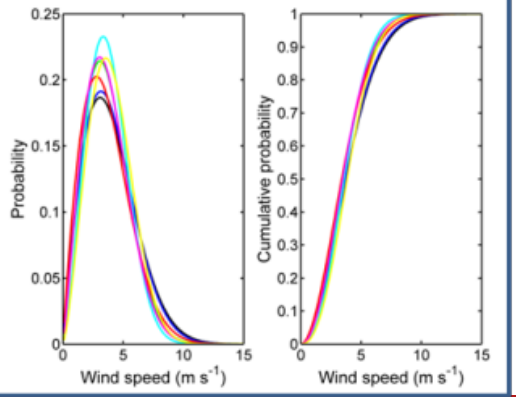
Hybrid downscaling



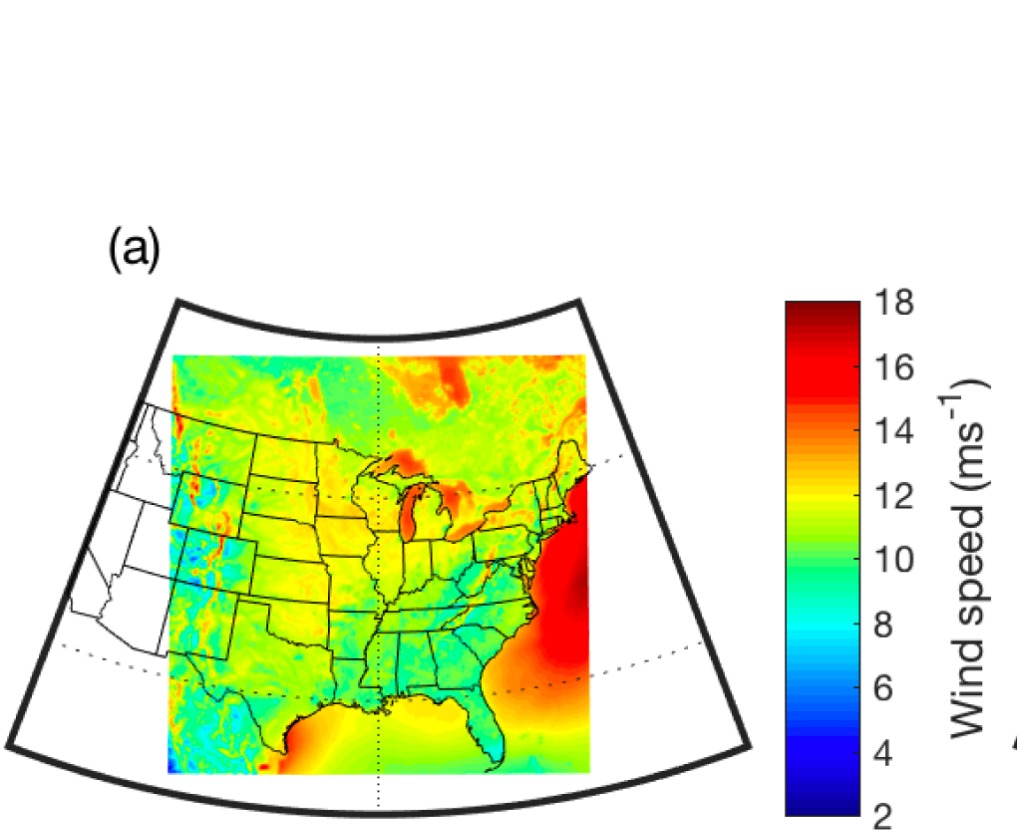
Multiple downscaling approaches in multiple RCP/ESM realizations ⇒ Uncertainty

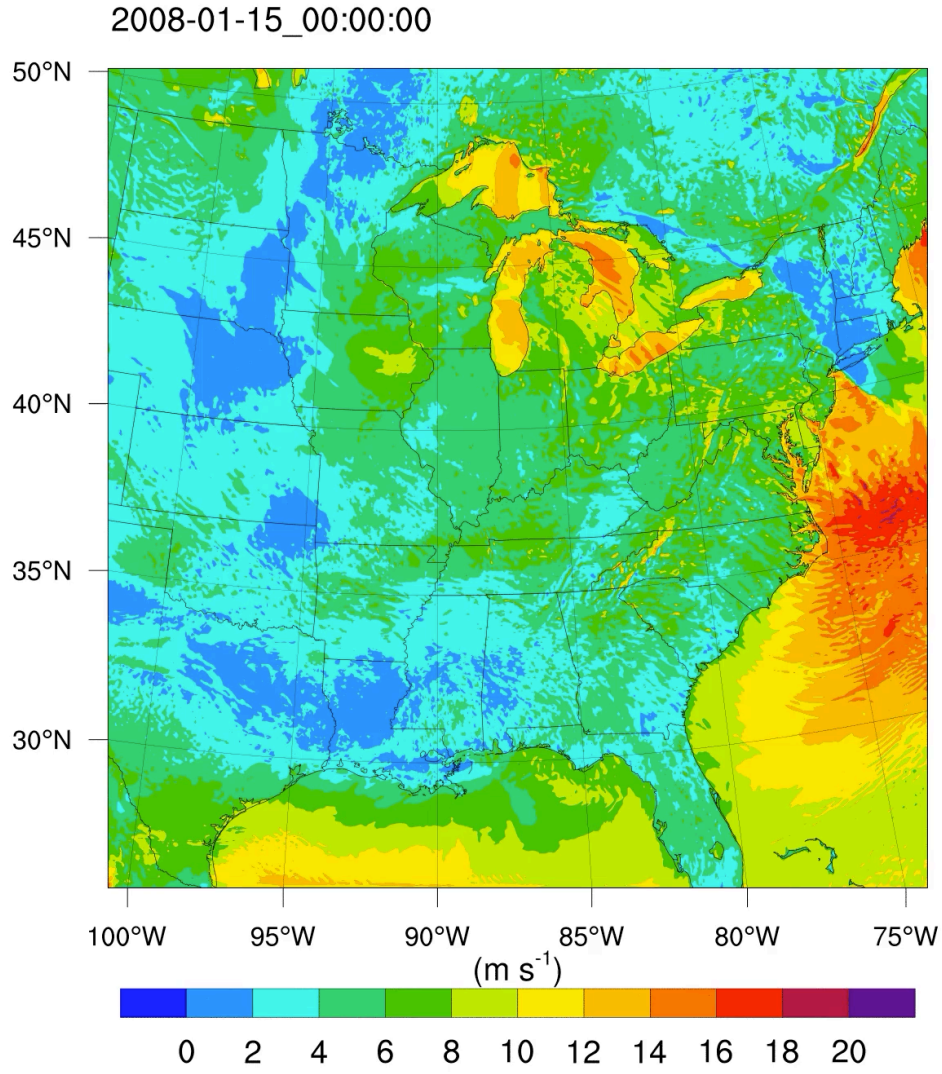
Uncertainty: can't map whole uncertainty space

- Value: *f*(incomplete determination of particular results)
- Structural: *f*(incomplete process understanding)
- Also some from partially chaotic nature of system



Regional climate simulations increasingly high resolution

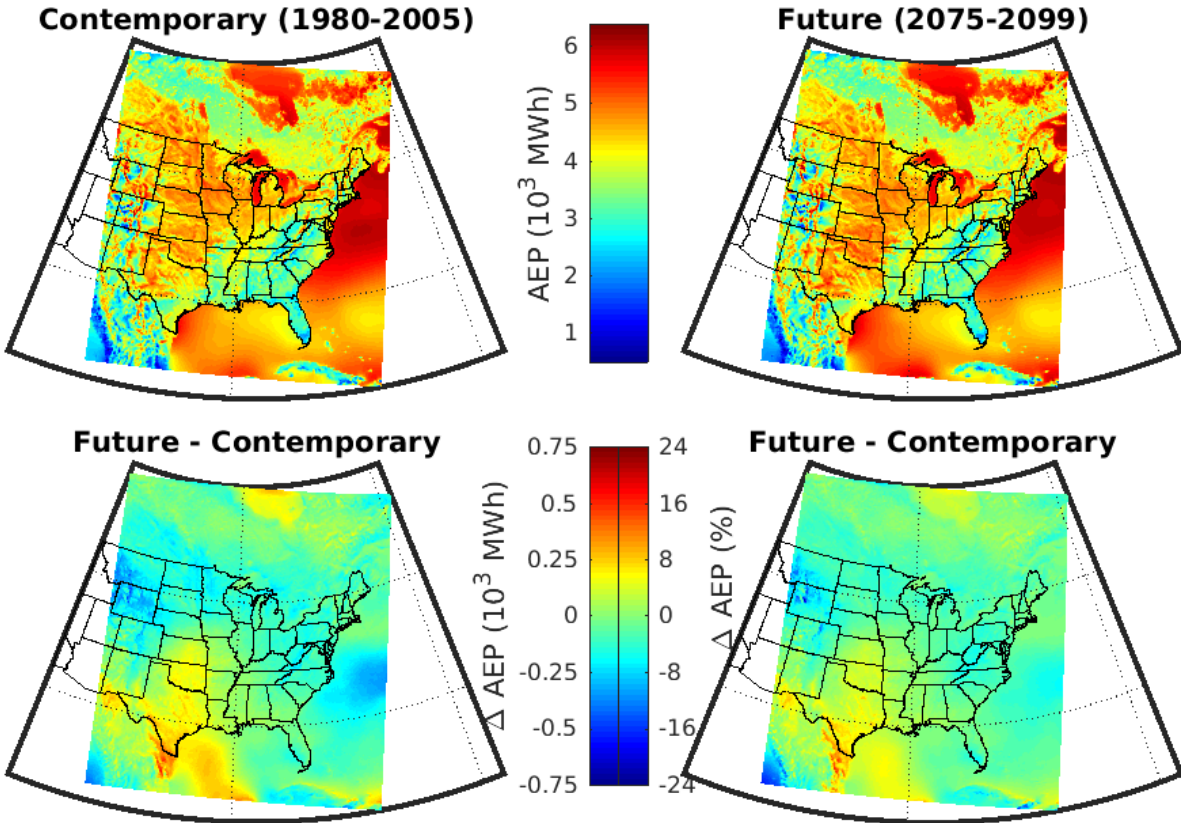


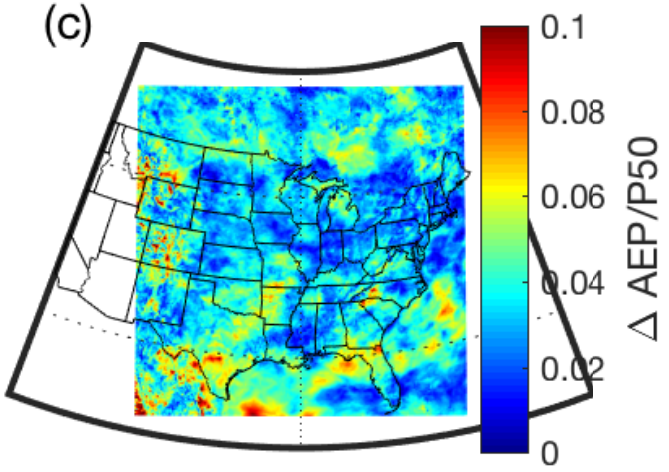


Pryor S.C., Shepherd T.J. and Barthelmie R.J. (2018): Inter-annual variability of wind climates and wind turbine annual energy production. *Wind Energy Science* **3** 651-665

Changing resources? State-of-the-art

- In high resource areas:
  - Change to 2100 < 5%
  - Natural variability ≳ climate change signal
  - Sensitivity (in order): RCM, ESM, res., RCP



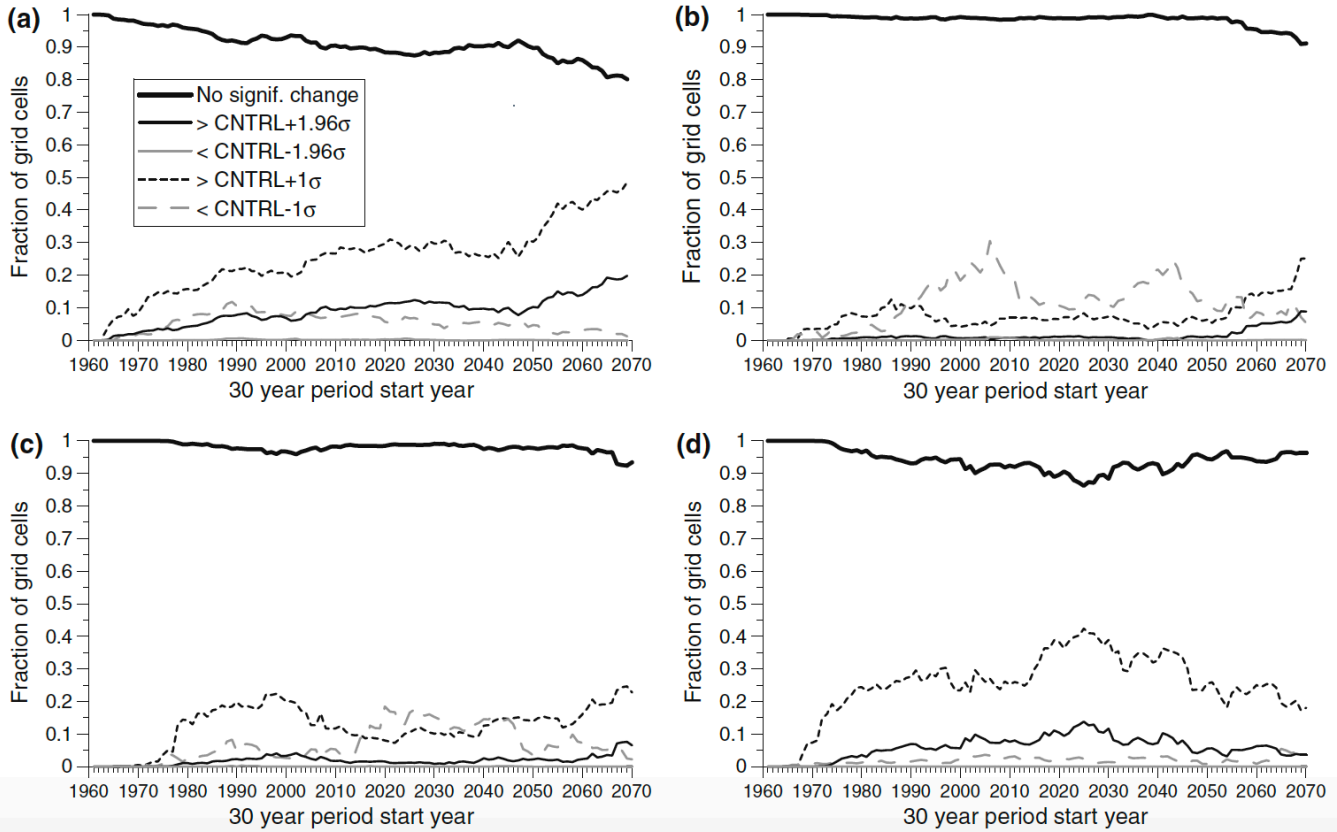


Pryor S.C., Shepherd T.J. and Barthelmie R.J. (2018): Inter-annual variability of wind climates and wind turbine annual energy production. *Wind Energy Science* **3** 651-665

Pryor S.C., Shepherd T.J., Bukovsky M. and Barthelmie R.J. (2020): Assessing the stability of wind resource and operating conditions. *Journal of Physics: Conference Series* **1452** 012084 doi: 10.1088/1742-6596/1452/1/012084.

Changing operating conditions? State-of-the-art

- 50 yr RP wind speed at hub-height.
- In high resource areas
  - Change to 2100 < 5% (< engineering safety margin)
  - Natural variability ≳ climate change signal
  - High sensitivity to model & resolution



Pryor S.C., Barthelmie R.J., Clausen N.E., Drew M., MacKellar I. and Kjellström E. (2012): Analyses of possible changes in intense and extreme wind speeds over northern Europe under climate change scenarios. *Climate Dynamics* **38** 189-208

Partnership to deliver actionable science

- What do we need from renewable energy industry?
  - Access to data (model evaluation & validation)
  - Transparency about challenges
- What are climate scientists doing?
  - Generating and analyzing larger model ensembles to explore resources/operating conditions to describe 'best guess' and probabilistic range of possible futures
  - Accelerating trend to higher resolution (NB computational resources)
  - Interrogating & demonstrating credibility

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