Emerging Opportunities in Low-Frequency Variability of Renewable Resources: a 7-Year Update

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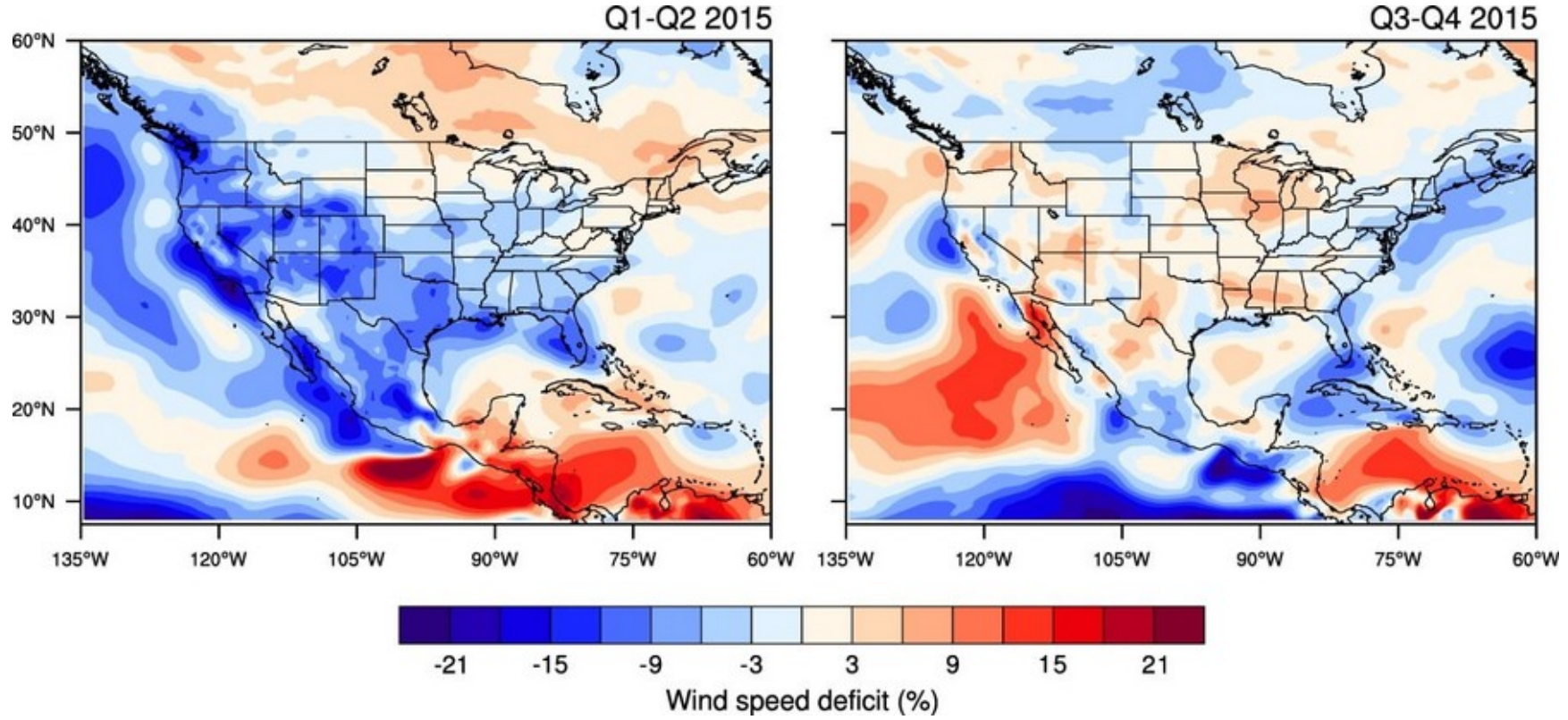
Introduction

- Renewable grid integration offers a significant contact area between climate/weather science and clean energy
- Short-term (minute to day ahead) solar and wind forecasts are well established, longer-term forecasts not yet
- At SOLAR 2016 (San Francisco), I presented on “Emerging opportunities in seasonal forecasting in support of renewable energy systems”
- Here, after summarizing highlights from then, I’ll present findings from a literature review on developments in the area over the past 7 y and some of their implications
  - My proceedings paper has more detail

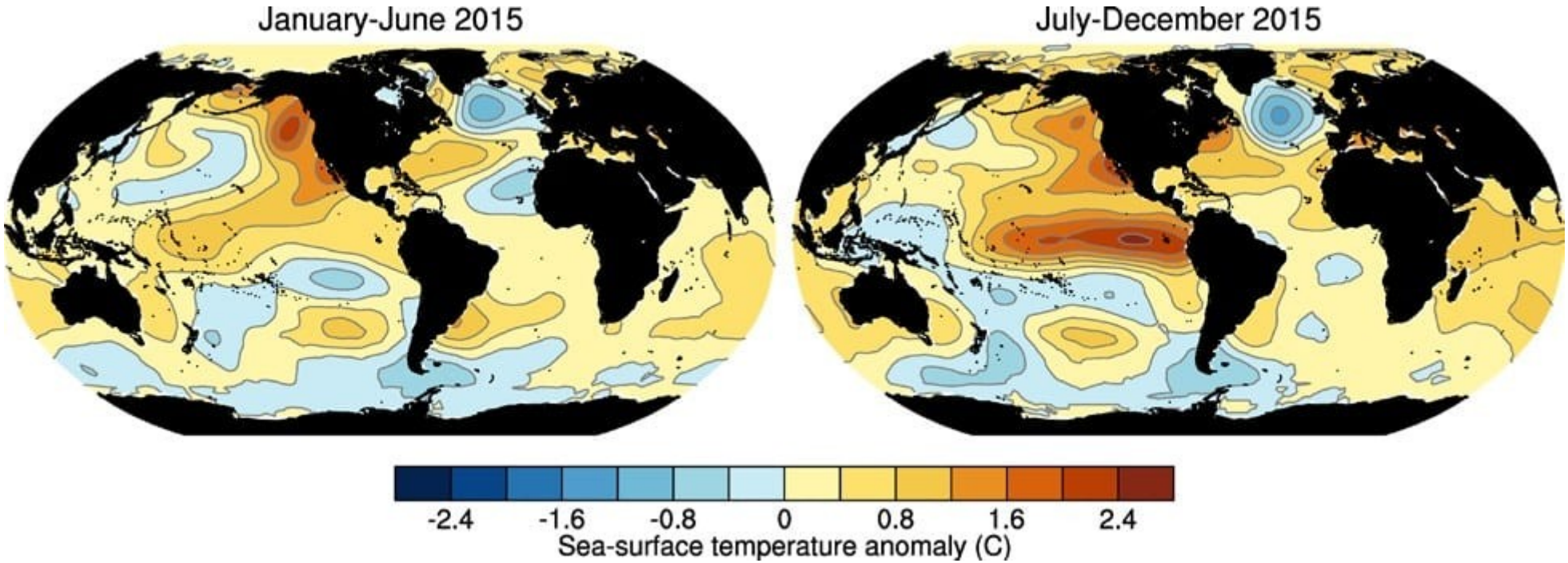
A western wind drought in 2015



This event piqued my interest in long-term variability in wind and solar

Reference: D Rife, NY Krakauer, DS Cohan, JC Collier (2016), A new kind of drought: U.S. record low windiness in 2015, *Earthzine*

A connection with ocean warming



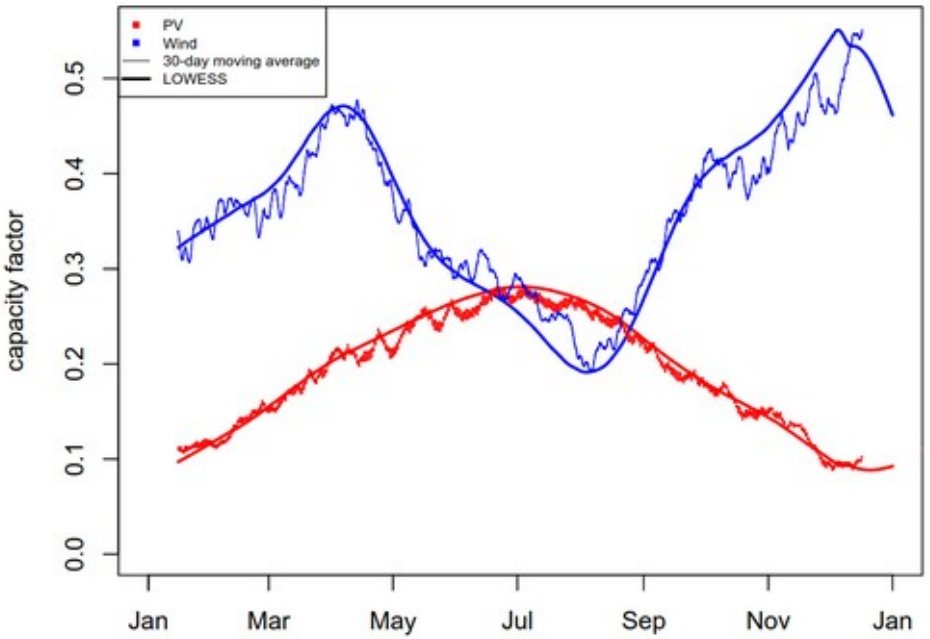
Low windspeed in the western US correlates with particularly warm sea surface temperatures offshore, as was actually seen in 2015

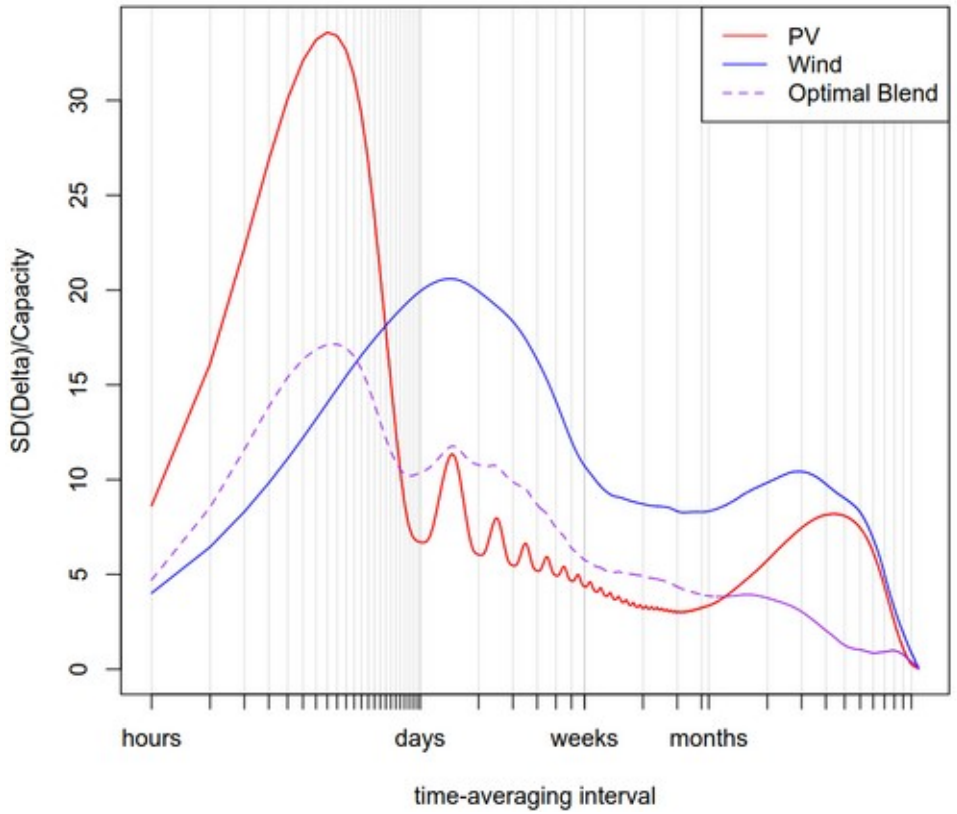
Low windspeed also correlates with (slightly) less sunlight in the region

No connection with El Niño (but such a connection exists for wind elsewhere)

See: NY Krakauer, DS Cohan (2017), Interannual variability and seasonal predictability of wind and solar resources. *Resources*, 6(3): 29

Variance spectrum for wind and solar

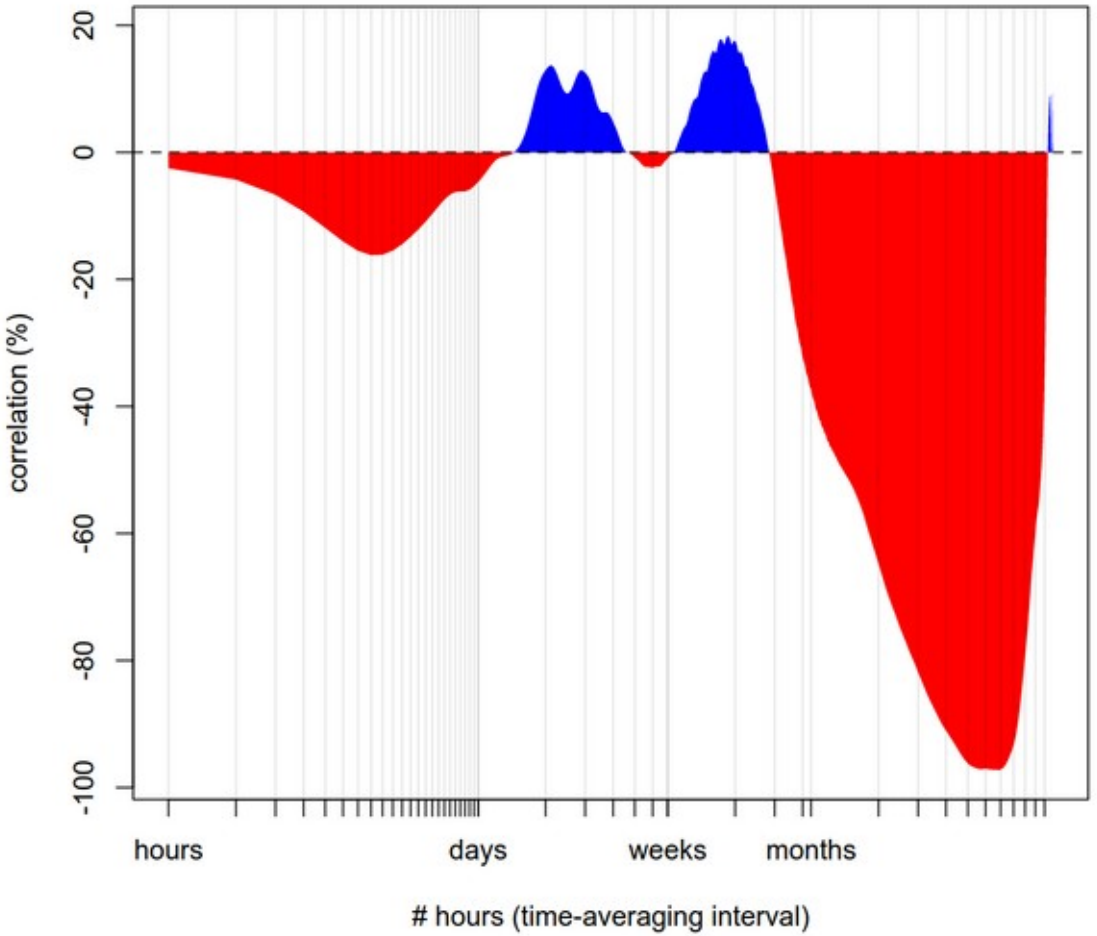




For Minnesota, using actual wind generation data and simulated solar at the same locations over a 3-y period

Reference: Perez, M. & Perez, R. On the complementary variability of wind and solar power, *Proceedings of the ISES Solar World Congress*, 2019

Covariance (complementarity) of wind and solar



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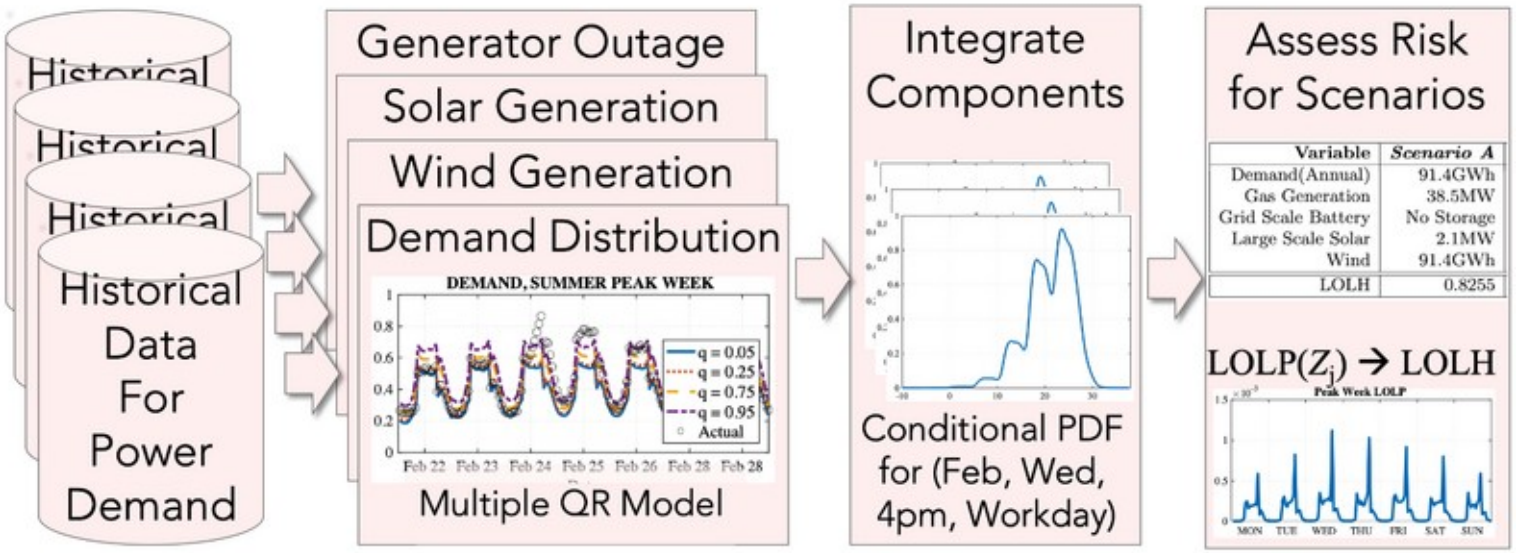
Modeling a multi-source minigrid



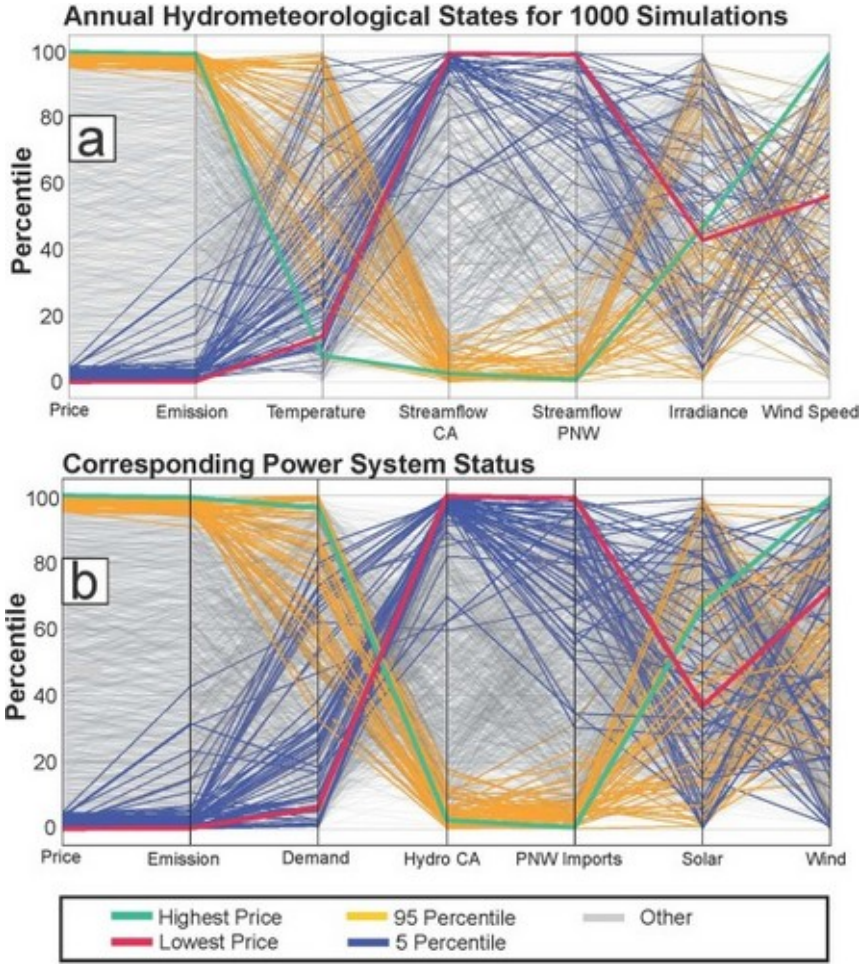
Analytic model for reliability of isolated electric grid of Esperance, Australia under different combinations of gas, wind, solar, and battery storage

Includes empirical associations between solar, wind, and demand

For example, it's found that reliability can be kept the same by replacing one 4.5MW gas turbine out of seven with 8.9MW of extra solar nameplate capacity and 2MW of storage

Reference: Gao, W.; Tayal, D. & Gorinevsky, D. Probabilistic planning of minigrid with renewables and storage in Western Australia, *IEEE Power & Energy Society General Meeting*, 2019

Climate and California energy prices



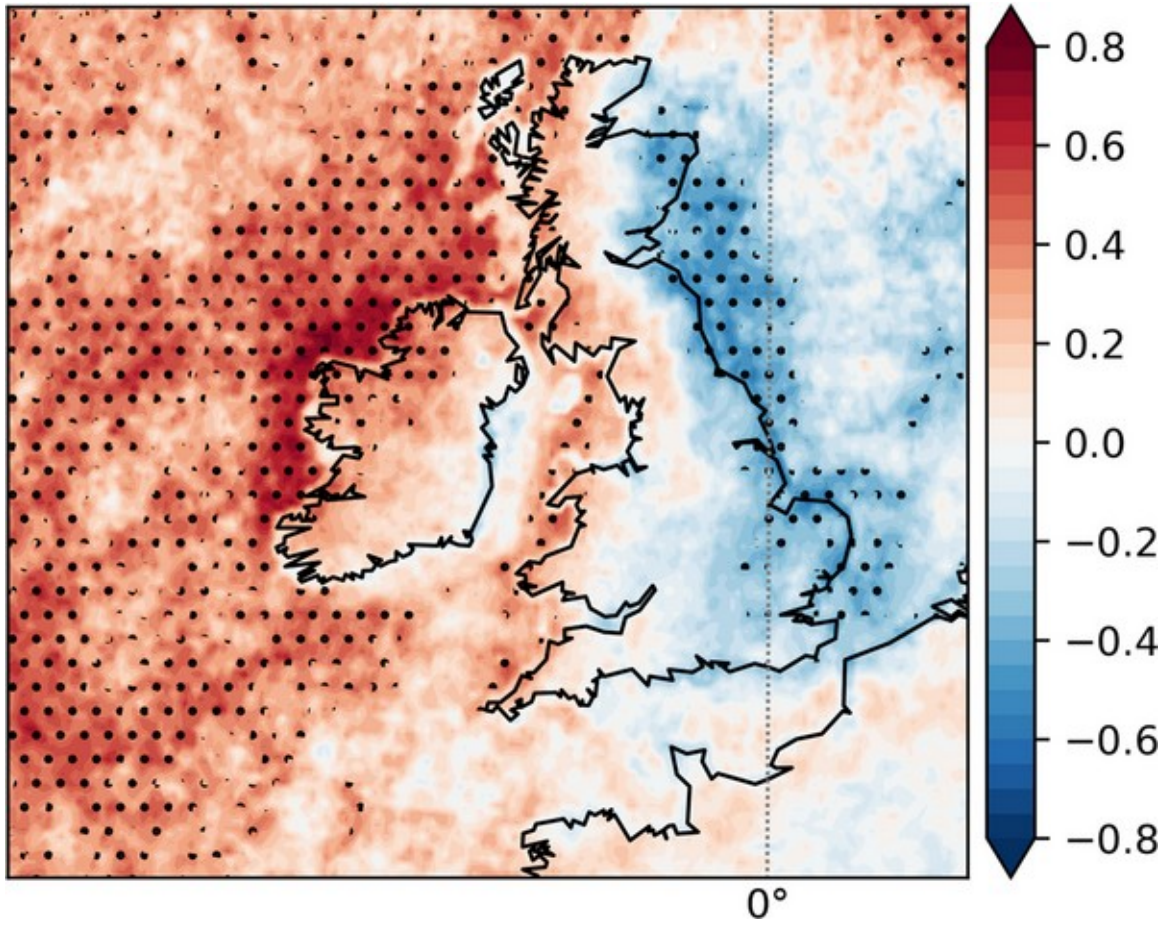
Simulate 1000 years of weather affecting California electricity supply and wholesale price using the California and West Coast Power System (CAPOW) model

Highest prices were associated with hot and dry years that have high energy demand and low hydroelectricity generation

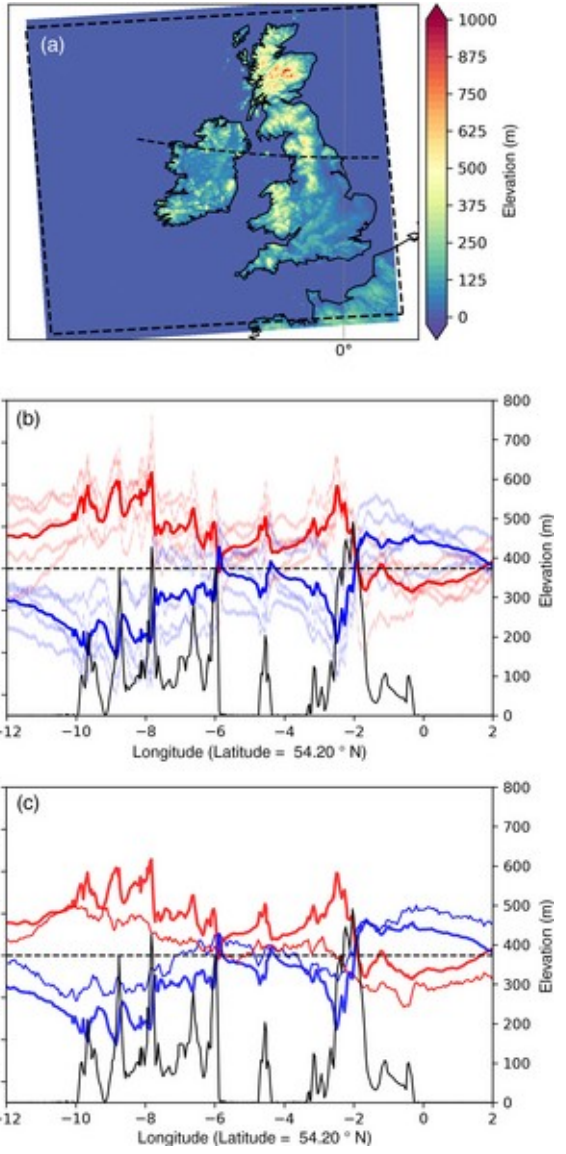
Presumably this can be overcome with additional large solar deployments and diurnal storage that would supply ample energy during summer heatwaves

Su, Y.; Kern, J. D.; Reed, P. M. & Characklis, G. W., Compound hydrometeorological extremes across multiple timescales drive volatility in California electricity market prices and emissions, *Applied Energy*, 2020

British winter sunshine and NAO

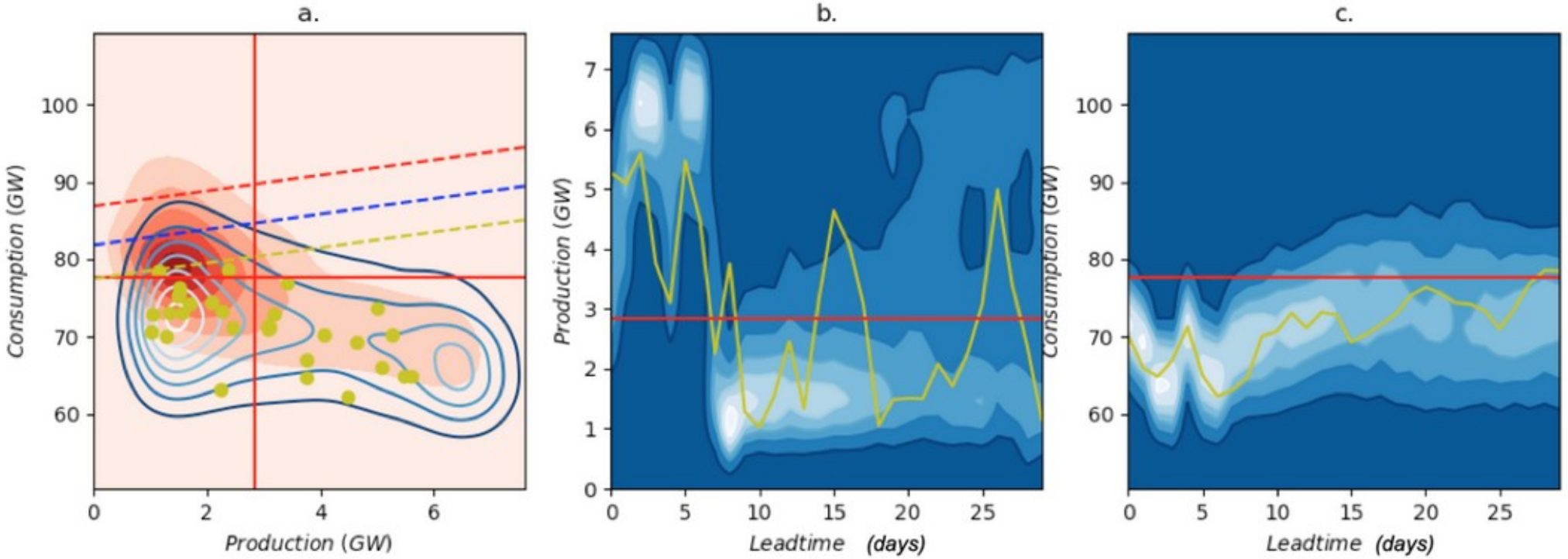


Correlation of winter cloudiness with North Atlantic Oscillation index



Correia, J. M.; McDermott, F.; Sweeney, C.; Doddy, E. & Griffin, S. An investigation of the regional correlation gradients between Euro-Atlantic atmospheric teleconnections and winter solar short wave radiation in northwest Europe, *Meteorological Applications*, 2020

Winter wind in France



Using the ECMWF seasonal forecast ensemble, which predicts NAO well,
both energy demand (based on temperature) and wind energy supply can be forecast,
leading to improved assessment of the risk of electricity shortfall at the evening peak

Alonzo, B.; Drobinski, P.; Plougonven, R. & Tankov, P., Measuring the risk of supply and demand imbalance at the monthly to seasonal scale in France, *Energies*, 2020

Conclusions

- Assessments have progressed of long-term resource variability and complementarity across locations and energy sources
- However, most work has been in Europe and USA
- It’s now feasible to assess the value of long-term forecasting for renewables-dominated grids with storage and demand management

Thanks!

- I’d love to hear your ideas for taking this research area further
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