Introduction: Climate Services in Support of the Energy Sector in a Changing Climate

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WEMC
World Energy & Meteorology Council

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NCAR
National Center for Atmospheric Research

Meteorology/Climate Impact on Energy Systems

Impact on Energy System

Flickering	Decrease Solar Power	Disruption to Energy Transport	Disruption in Oil Rig Operations	Reduced Hydo Power	Changes in Demand	Maintenance	Changes in Renewable Resources

Example Event

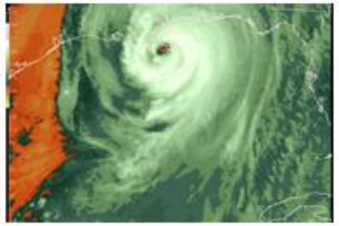

Lightning


Thunderstorms

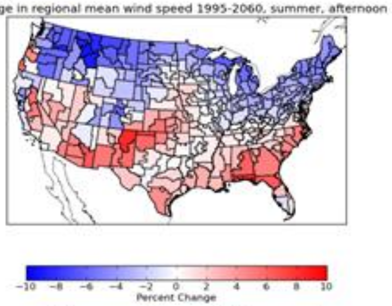

Drought

El Nino


Passing Clouds


Hurricanes


Cold Spells / Heat Waves



Changing Climate

Time scale

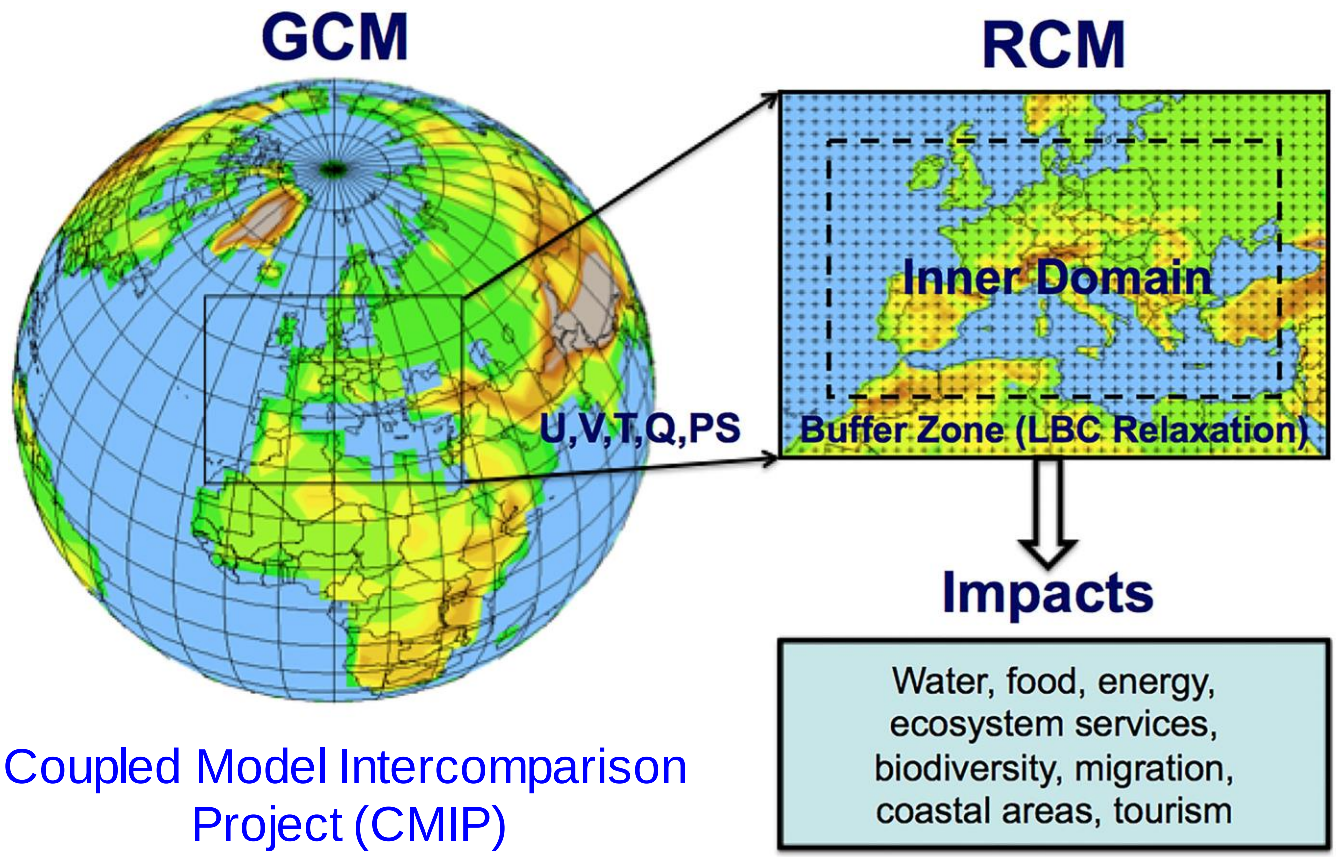
Seconds — Minutes — Hours — Days — Months — Seasons — Years — Decades

Intergovernmental Panel on Climate Change (IPCC)

- IPCC is the UN body for assessing the science related to climate change.
- Established in 1988 to provide policymakers with regular scientific assessments concerning climate change, its implications and potential future risks, and to put forward adaptation and mitigation strategies.
- Comprised of 195 member states.
- Assesses thousands of scientific papers published each year to inform policymakers about the state of knowledge on climate change.
- Identifies where there is agreement in the scientific community, where there are differences and where further research is needed.

- Assessment reports periodically (5-7 years)
- Conclusions of 2014 report:
  - Human influence on the climate system is clear.
  - The more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts.
  - We have the means to limit climate change and build a more prosperous, sustainable future.

Climate Modeling



Coupled Model Intercomparison Project (CMIP)

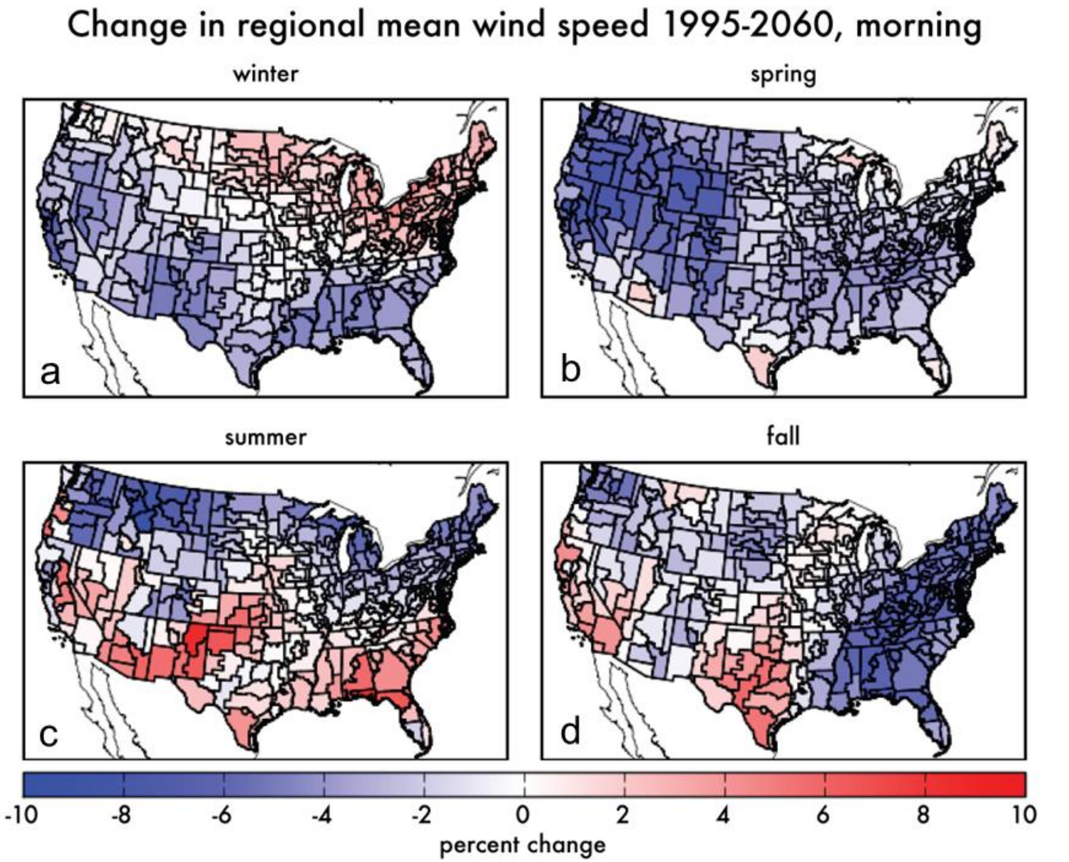
COordinated Regional climate Downscaling EXperiment - CORDEX

- Global Climate Models (GCMs) run for long periods of time at coarser resolution (~ 50-350 km)
- Regional Climate Models (RCMs) used to downscale to regional information (~ 10 – 50 km)
- Used to infer specific impacts.
- Quantify uncertainty through running ensembles of coupled GCMs/RCMs.
- Run over recent time periods and compare under forcing scenarios
  - Special Report on Emission Scenarios (SRESs)
  - Representative Concentration Pathways (RCPs)

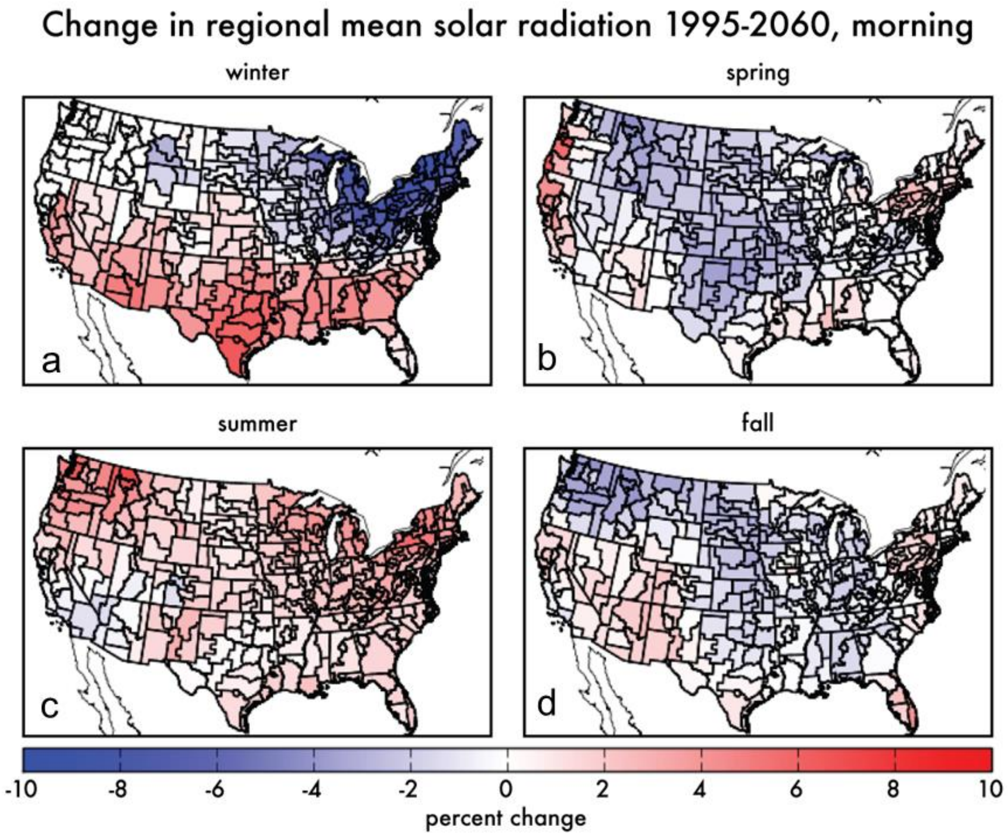
Filippo Giorgi/AGU: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018JD030094

Using Output to Determine Energy Impacts

Is **Wind Speed** likely to change over the U.S. in a changing climate and will it vary by time of day and season?



Is **Solar Irradiance** likely to change over the U.S. in a changing climate and will it vary by time of day and season?



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Haupt, S.E., J. Copeland, W.Y.Y. Cheng, C. Amman, Y. Zhang, and P. Sullivan, 2016: Quantifying the Wind and Solar Power Resource and their Inter-annual Variability over the United States under Current and Projected Future Climate, *Journal of Applied Meteorology and Climatology*, **55**, pp. 345-363. DOI: 10.1175/JAMC-D-15-0011.1

Changing Climate

Table S1: Mean and likely range of temperature changes by 2100 for SRESs and RCPs and emissions pathway label used in this review to facilitate comparisons between sets of scenarios.

Emissions Scenario		Temperature Change (°C) by 2100		
		Mean	Likely Range	Emissions Pathway Label in this Review
RCP[a]	2.6	1.0	0.3–1.7	Low
	4.5	1.8	1.1–2.6	Medium
	6.5	2.2	1.4–3.1	Medium
	8.5	3.7	2.6–4.8	High
SRES[b]	B1	1.8	1.1–2.9	Low
	B2	2.4	1.4–3.8	Medium
	A1B	2.8	1.7–4.4	Medium
	A2	3.4	2.0–5.4	High

[a] Mean temperature changes given for 2081–2100 relative to 1986–2005. Likely range of temperature change based on 5%–95% interval across GCM outputs. Source: [1].

[b] Mean temperature changes given for 2090–2099 relative to 1980–1999. Likely range of temperature change based on +/- 1 standard deviation of model averages. Source: [2].

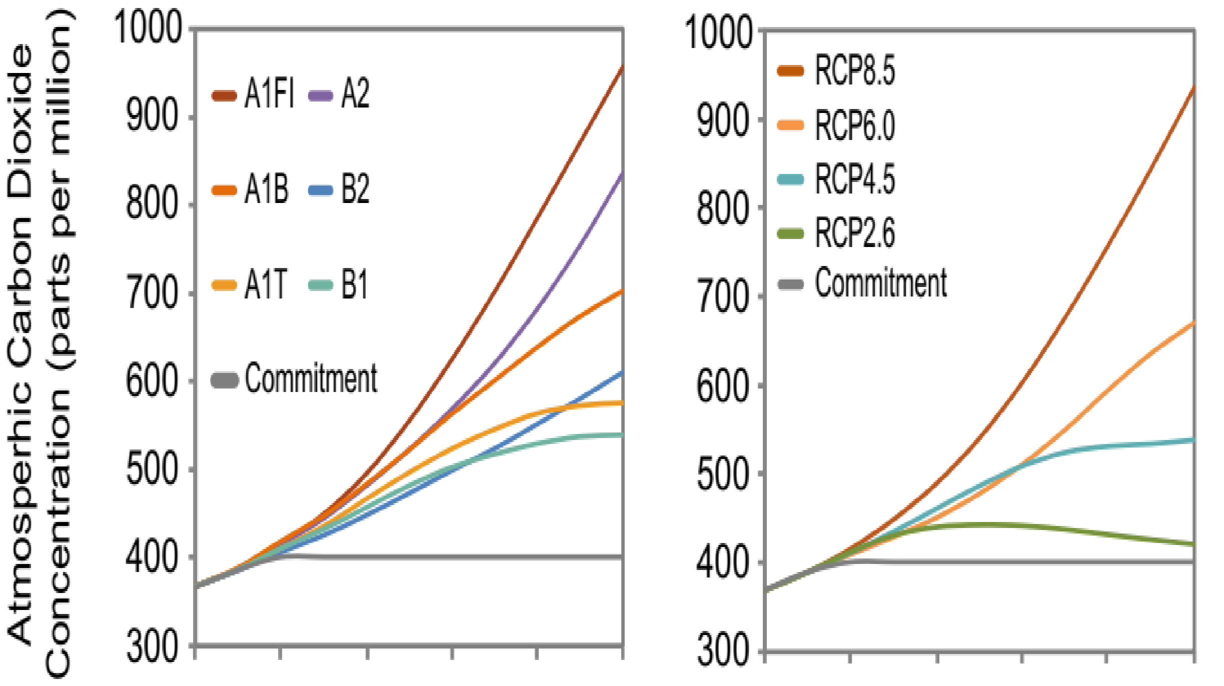

Figure S1: Atmospheric CO_2 concentrations under SRES (left) and RCP (right) emission scenarios. "Commitment" indicates a hypothetical scenario where CO_2 concentrations stabilize at roughly 400 ppm

NCAR UCAR | Craig, M.T., S. Cohen, J. Macknick, C. Draxl, O.J. Guerra, M. Sengupta, S.E. Haupt, B.-M. Hodge, and C. Brancucci, 2018: A Review of the Potential Impacts of Climate Change on Bulk Power System Planning and Operations in the United States, *Renewable and Sustainable Energy*, DOI: 10.1016/j.rser.2018.09.022

Energy Sector Implications

Power System Component	Component-Level Impacts (Agreement among Studies, Quality of Evidence, and Confidence in our Evaluation)	Potential Power System Planning and Operations Implications
Electricity demand	Increased annual total and, to a greater extent, peak electricity demand (high, robust, high)	Increased total generation Increased investment requirement in generation or demand response and more peaked electricity prices
Thermal generators	Increased summertime curtailments largely contingent on enforcement of thermal discharge regulations (high, robust, high)	Reduced capacity value of thermal units, requiring additional capacity investments If curtailments correlated, increased operational reserve requirements
Transmission	Reduced transmission capacity during peak demand periods (medium, low, medium)	Increased transmission investment Exacerbated congestion and contingencies

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Energy Sector Implications

Hydropower	Reduced summertime hydropower resource in California and the Pacific Northwest (medium, medium, medium) Reduced annual hydropower resource across South (medium, medium, medium)	Reduced capacity value, depending on release schedule and head height, requiring additional capacity investments Increased dispatching of other units
Wind	Decreased wind resources on average across US (low, medium, low) Large regional and temporal (seasonal and time of day) heterogeneity in wind resource changes (medium, medium, medium)	Increased wind investment or reliance on other zero-carbon technologies to meet decarbonization targets Regional changes in capacity values, requiring increased capacity investments
Solar	Decreased solar PV resource in California (medium, low, low) Increased solar PV and CSP resource in the Southeast (high, medium, medium) Greater average increases in CSP than solar PV resource across US (high, medium, high) Large regional and temporal (seasonal and time of day) heterogeneity in solar resource changes (medium, medium, medium)	Increased solar investment or reliance on other zero-carbon technologies to meet decarbonization targets Regional changes in capacity values, requiring increased capacity investments Increased investment in CSP relative to PV plants

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