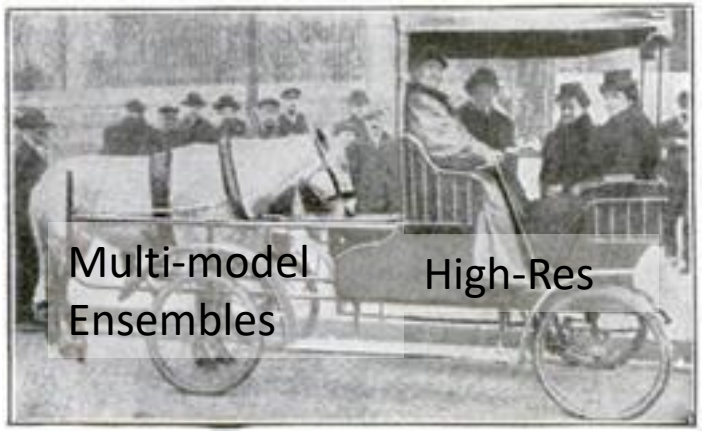
really

What end-users ~~say they~~ want?

Trustworthy High-Resolution local predictions

Prioritization:

1. Large ensemble (Initial condition uncertainty)
2. Multiple models (Structural/parametric uncertainty)
3. High-resolution

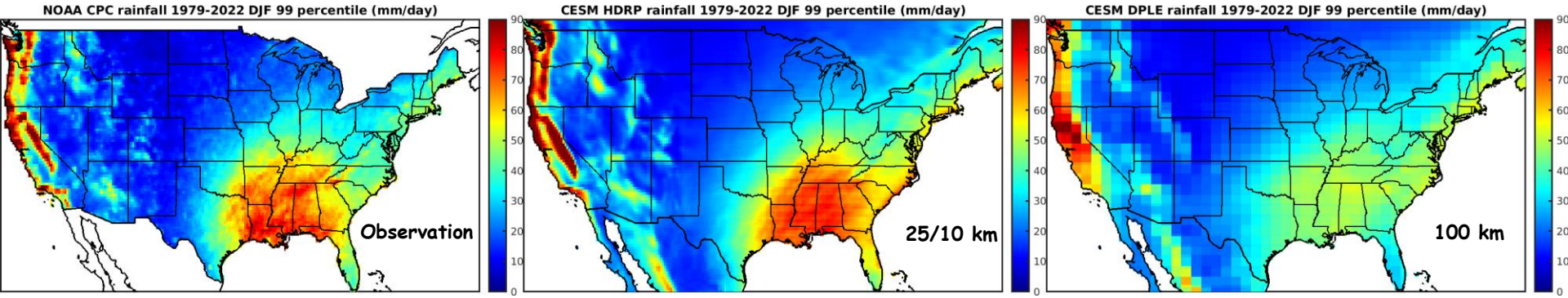


Next 3 slides from Ping Chang: iHESP (NCAR+Texas A&M) simulations

OBS

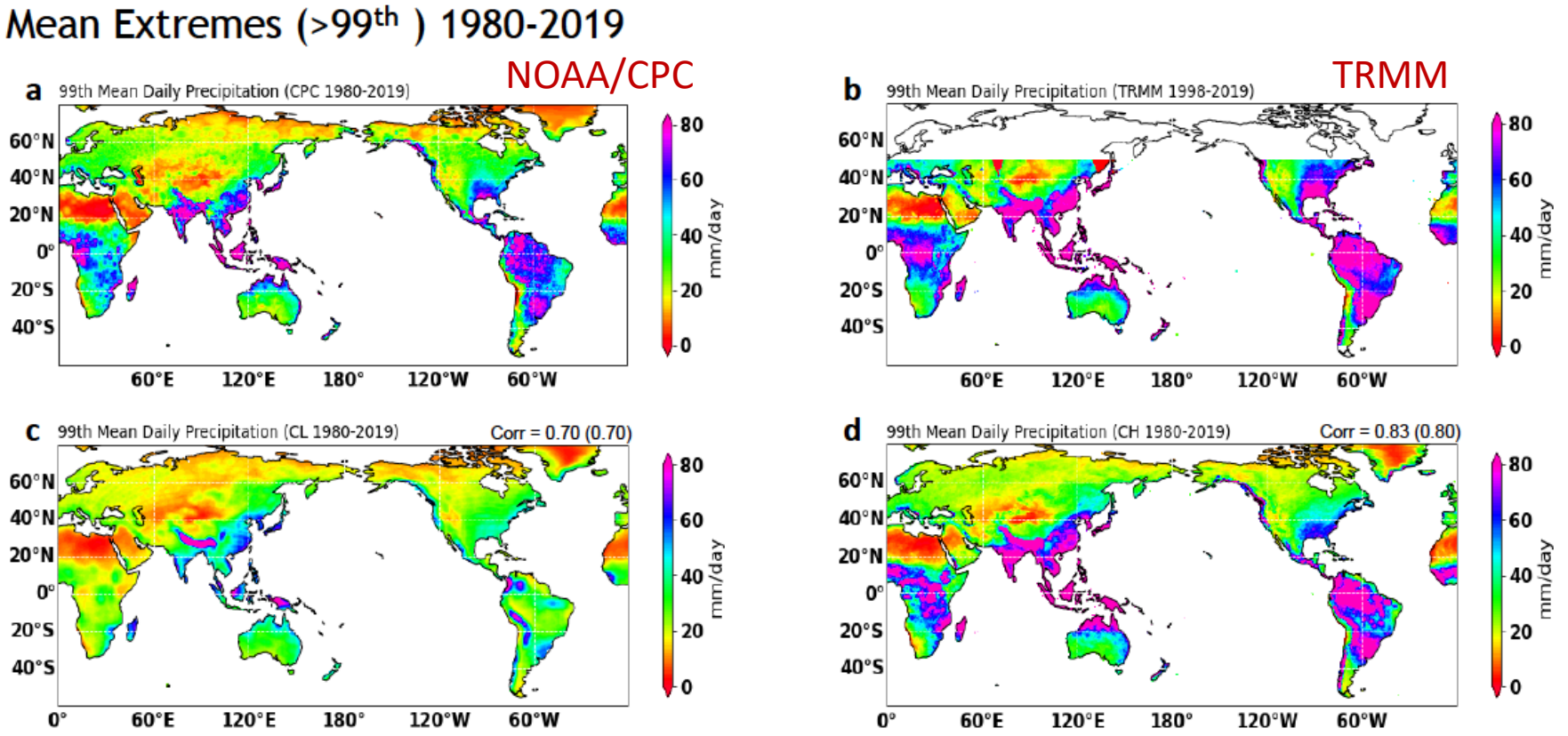
25/10km

100km



DJF 99 percentile rainfall (mm/day)

Global Annual Mean Daily Extreme Precipitation

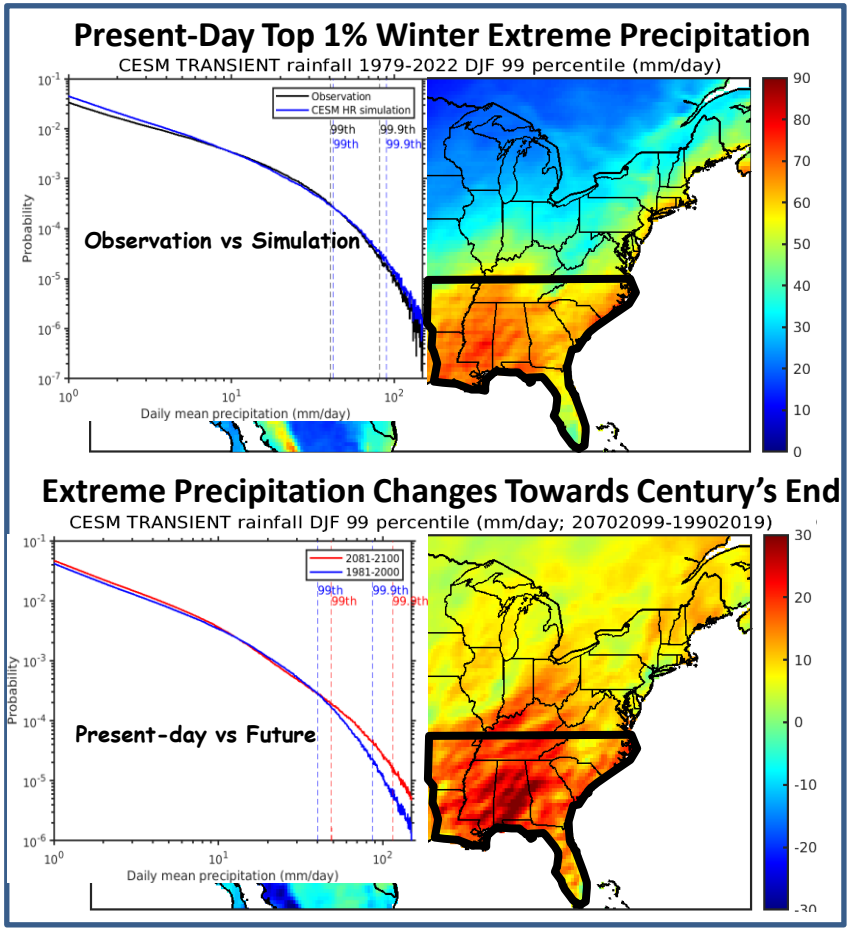


Spatial Correlation (passed significance test), left (with CPC, 60S-80N), right (with TRMM, 50S-50N).
Dry (in red) and Extreme Wet (in magenta)

100km

25/10km

Projection


Present-Day Top 1% Winter Extreme Precipitation
CESM TRANSIENT rainfall 1979-2022 DJF 99 percentile (mm/day)
Observation
CESM HR simulation
99th
99.9th
Observation vs Simulation
Probability
Daily mean precipitation (mm/day)
Extreme Precipitation Changes Towards Century's End
CESM TRANSIENT rainfall DJF 99 percentile (mm/day; 20702099-19902019)
2081-2100
1981-2000
Present-day vs Future

Climate Model Simulations of Wind and Solar Power Resource Droughts

Impact of Model Resolution and Bias

Xue Liu & R. Saravanan

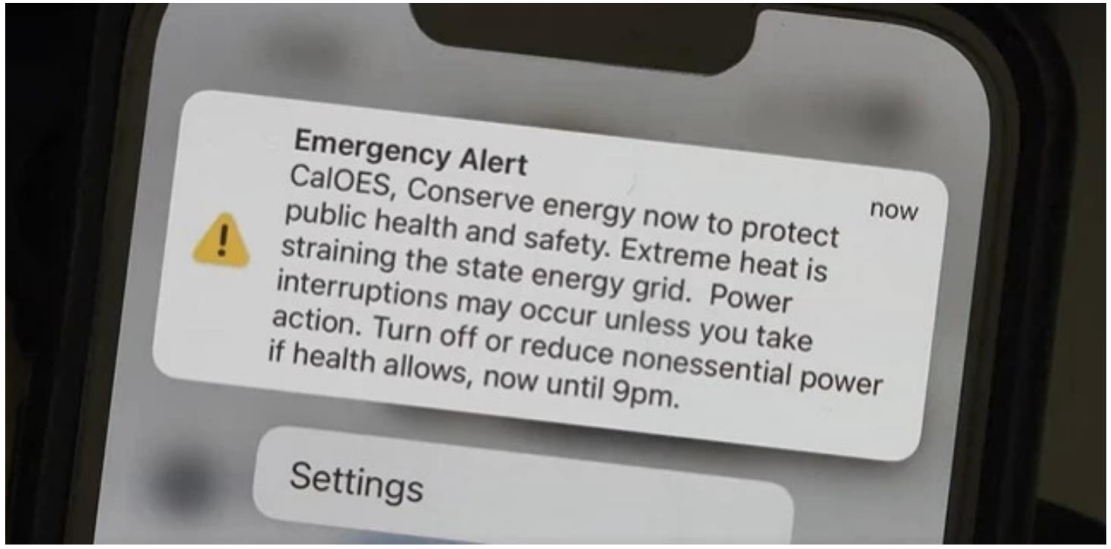
TEXAS A&M UNIVERSITY

CESM Workshop 2023

NEWS › ENVIRONMENT • News

California power outages: How a text message averted major blackouts

State used emergency system for only the third time in 10 years

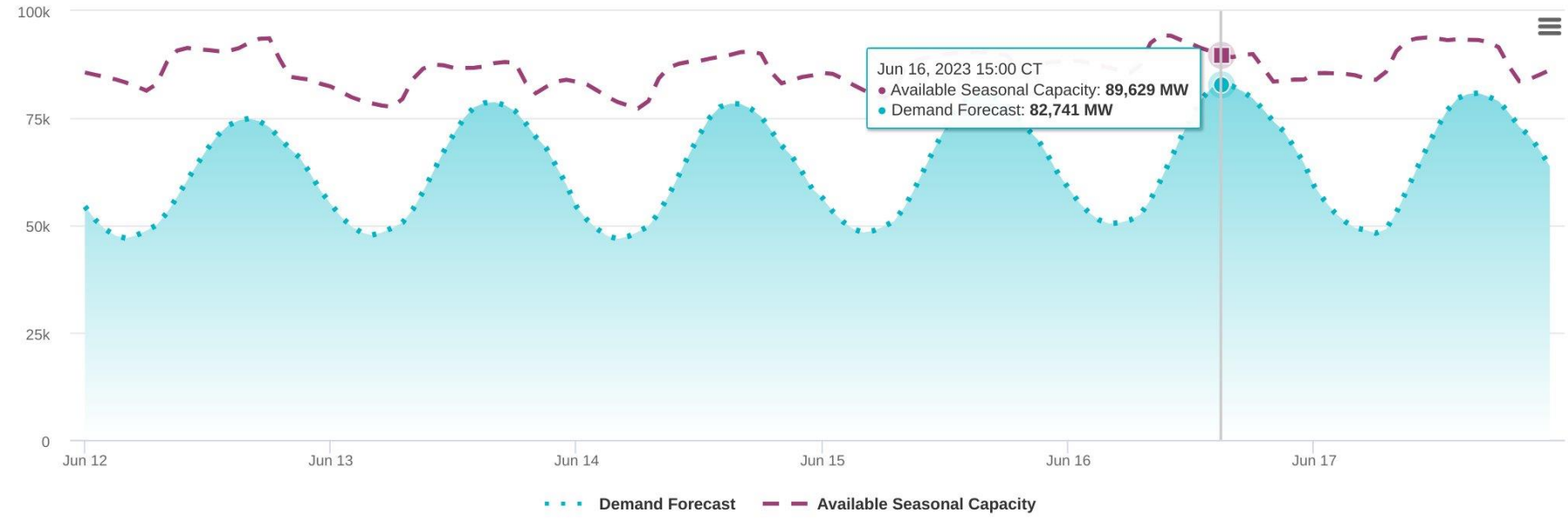


A text sent to 27 million people by the state Office of Emergency Services on Tuesday evening helped dramatically cut electricity demand, saving the state from blackouts, grid officials said Wednesday Sept. 7, 2022. (Photo: California OES)

Supply and Demand

Supply and Demand is a graphical representation of the ERCOT system's current power supply (capacity) and demand using Real-Time data, as well as projected power supply (capacity) and demand from hourly forecasts and seasonal forecasts.

Last Updated: Jun 11, 2023 13:25 CT



Motivations

Net-Zero Energy Future

Wind and Solar Power

Intrinsically variable

Challenges: Robust, continuous generation of electricity!

- Wind and Solar Power are ***Vulnerable to synoptic-scale weather events***
- Extreme low values in power resource availability and their relationship to weather patterns

Meteorology and climatology of historical weekly wind and solar power resource droughts over western North America in ERA5

Patrick T. Brown ✉, David J. Farnham & Ken Caldeira

SN Applied Sciences **3**, Article number: 814 (2021) | Cite this article

- **Definitions:**

"Power Drought": a week in which the averaged wind or the solar power resource (or their sum), is in the first percentile of all weeks considered. (1950-2020).

Compound wind and solar droughts: first percentile weeks after both resources have been normalized and summed.

$$\textit{compound wind and solar droughts}'' = 1\text{st } \textit{percentile}\left[\frac{\textit{wind power}(t)}{\textit{mean}(\textit{wind power}(t))} + \frac{\textit{solar power}(t)}{\textit{mean}(\textit{solar power}(t))}\right]$$

Background and Approach

- Weather Forecast models (high spatial resolution)

  predict large-scale atmospheric flow patterns fairly well

- Climate models (run for longer periods)

  typically have lower resolution and suffer from significant bias

How well can climate models simulate wind and solar power droughts at different resolutions?

How will the wind and solar power droughts change in the future?

- Climate simulations:

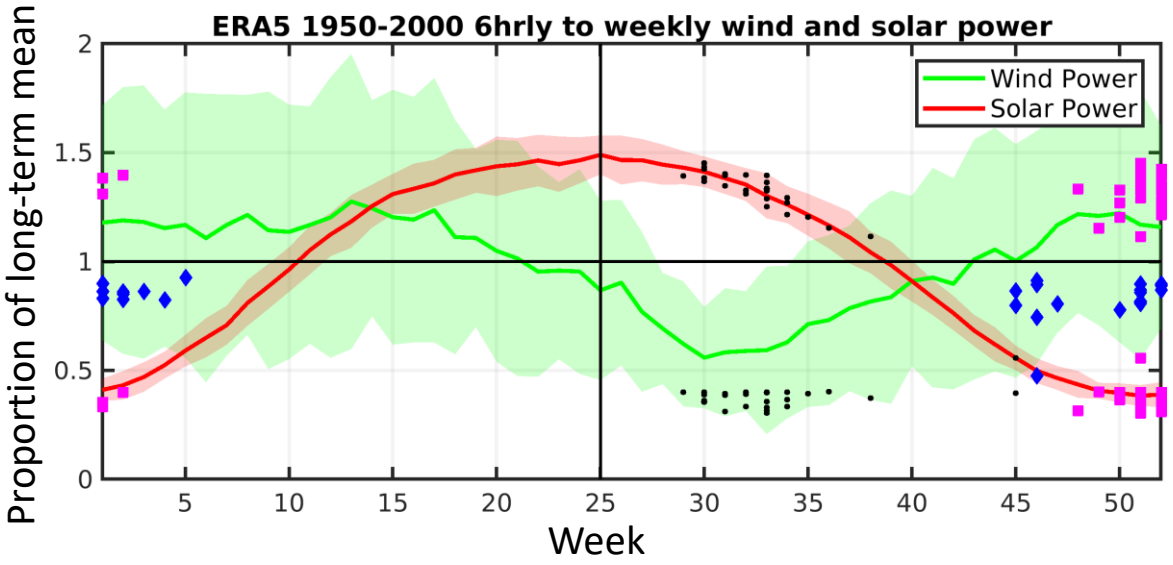
  CESM HR (~0.25^{o} Atmosphere)/LR (1^{o} Atm);1950-2005: historical forcing; 2006-2100: RCP8.5)

- Observations:

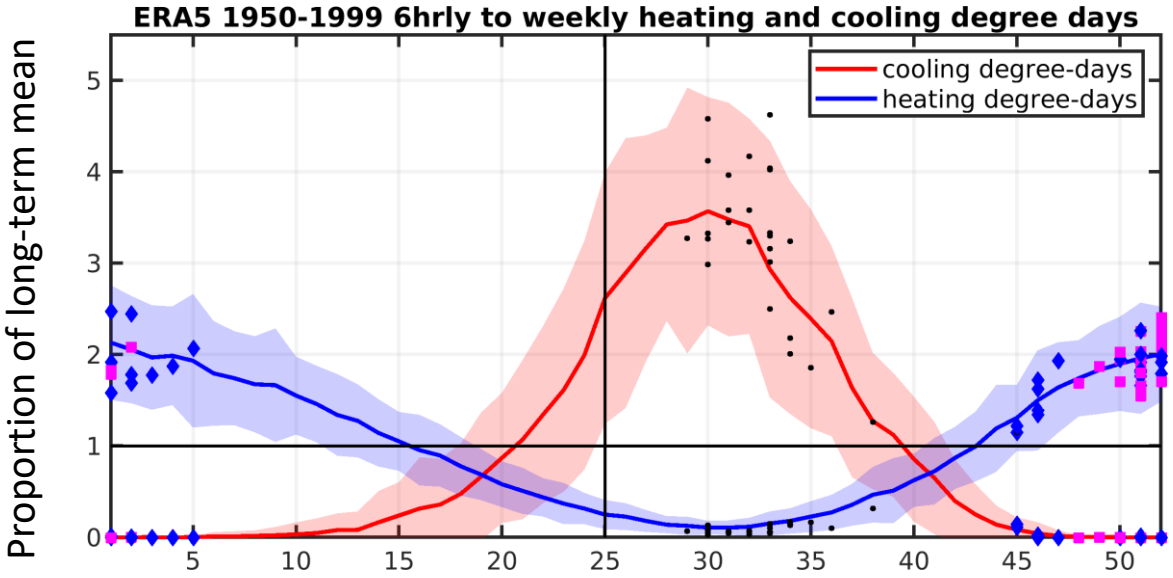
  ERA5 (~0.25^{o} Atm; 1950-2020)

Observed wind and solar power droughts over Western N. America (WNA)

Power Supply



Power Demand



Shading: 2-sigma

Black dots: wind power droughts

Magenta square: solar power droughts

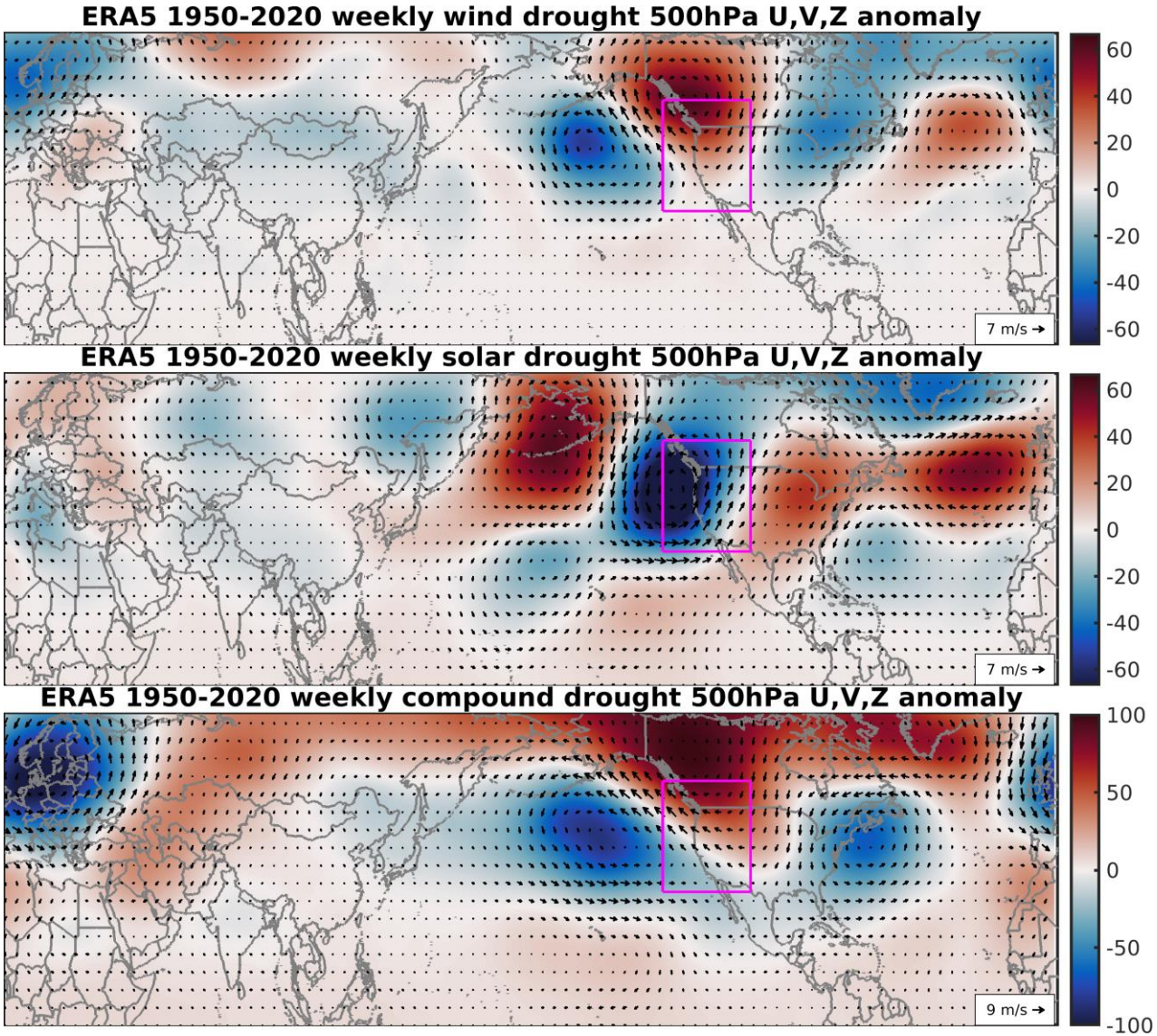
Blue diamond: compound (wind + solar) power droughts

Weather patterns during solar and wind droughts over WNA

Wind droughts

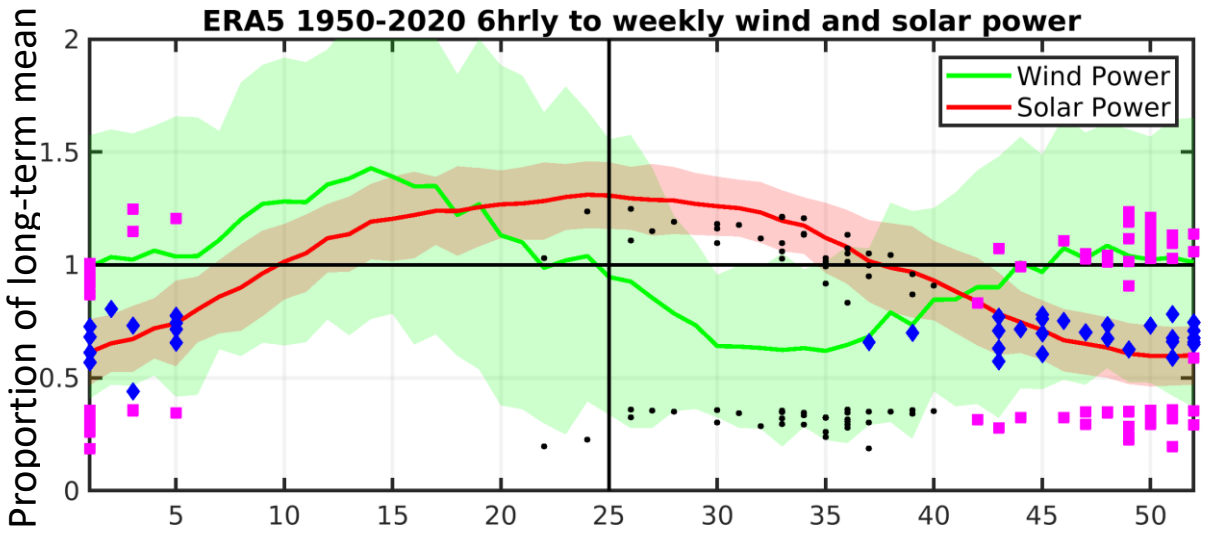
Solar droughts

Compound droughts

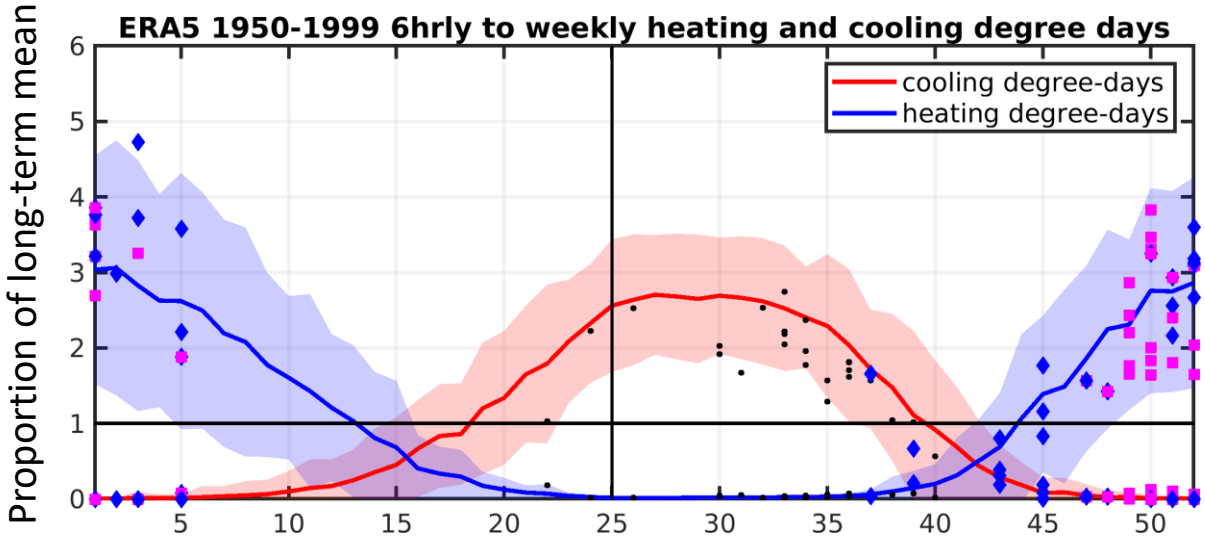


Observed wind and solar power droughts over Texas

Power Supply



Power Demand



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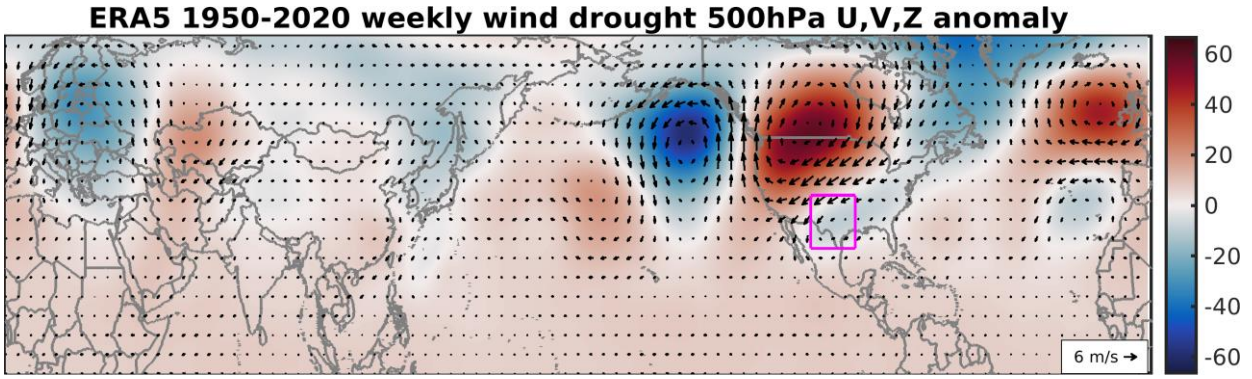
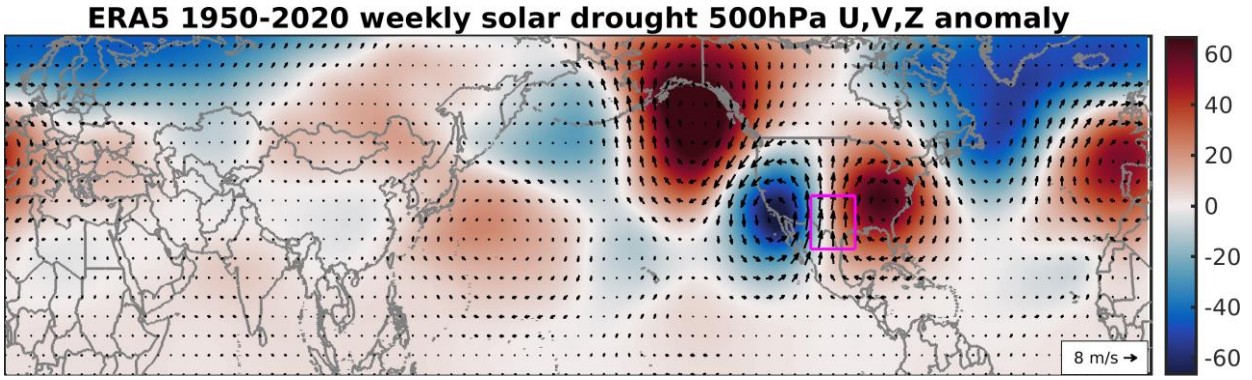
Weather patterns during solar and wind power droughts over Texas

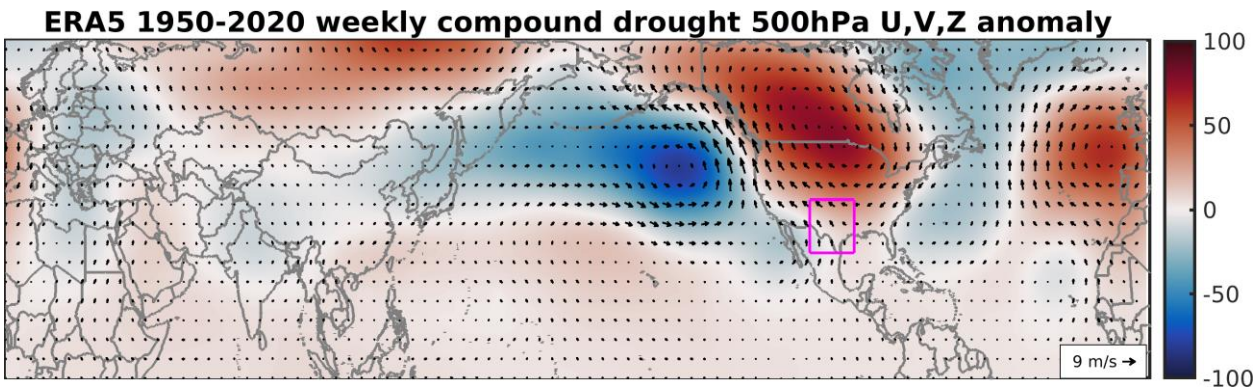
Wind droughts



Solar droughts

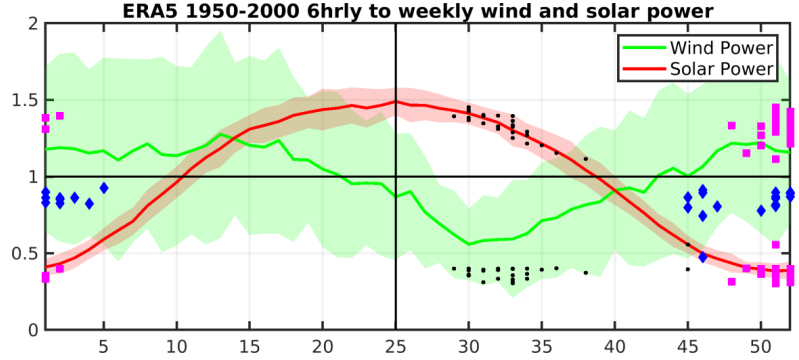


Compound droughts

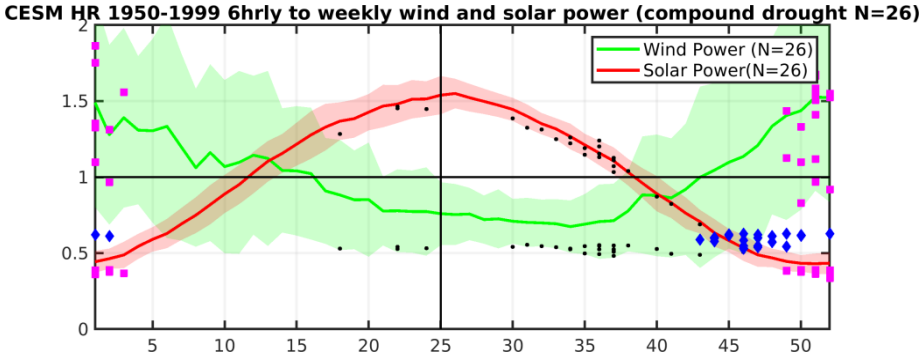


Power supply and power droughts over WNA

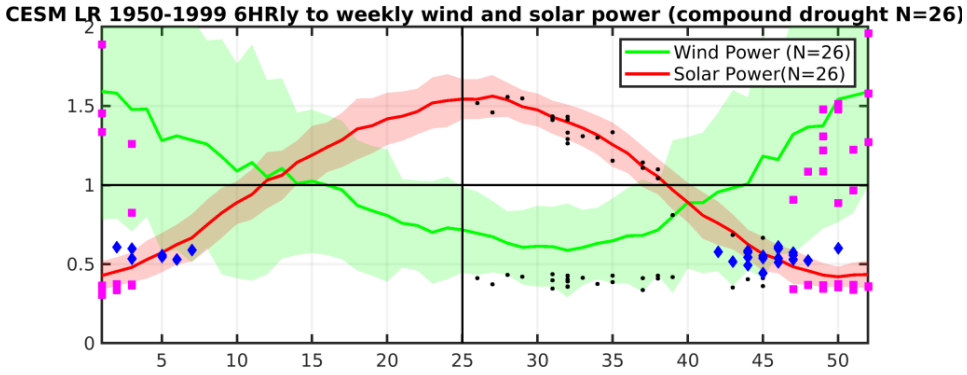
ERA5



CESM HR

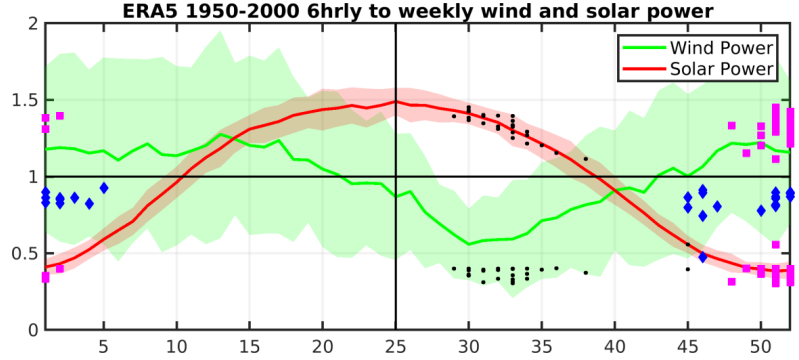


CESM LR

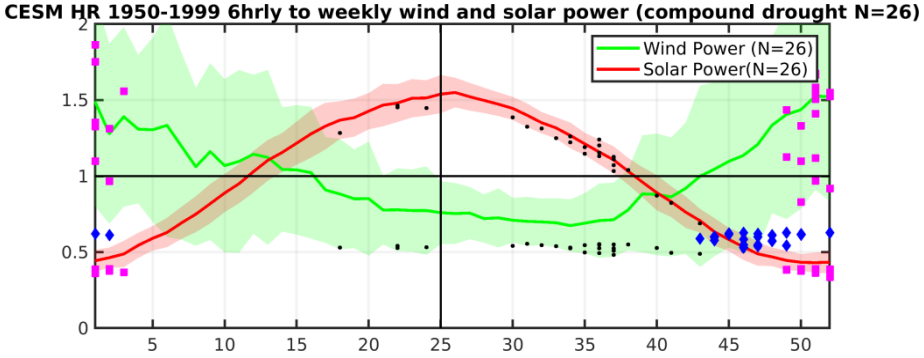


Power supply and power droughts over WNA

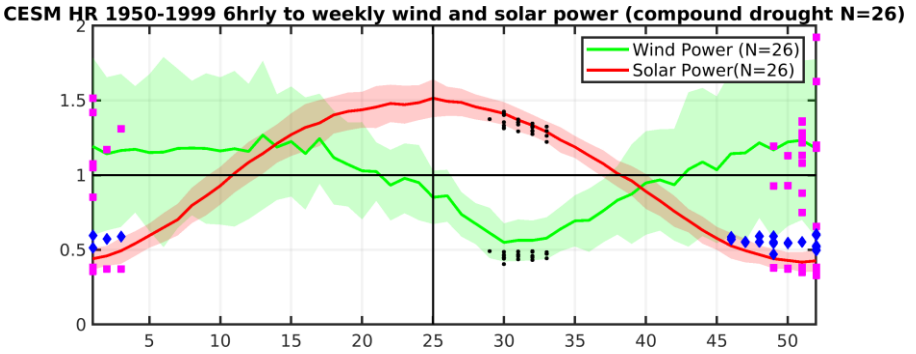
ERA5



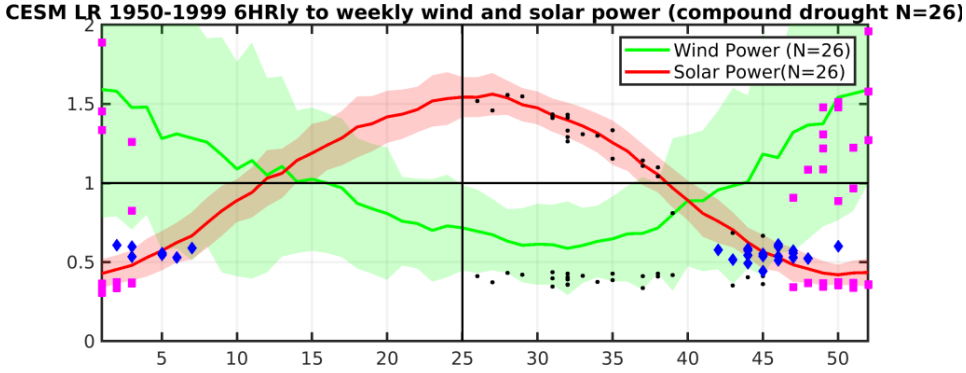
CESM HR



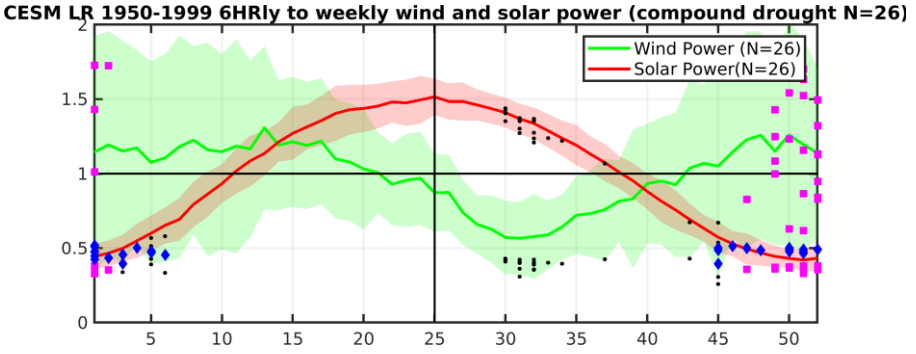
CESM HR– bias corrected



CESM LR



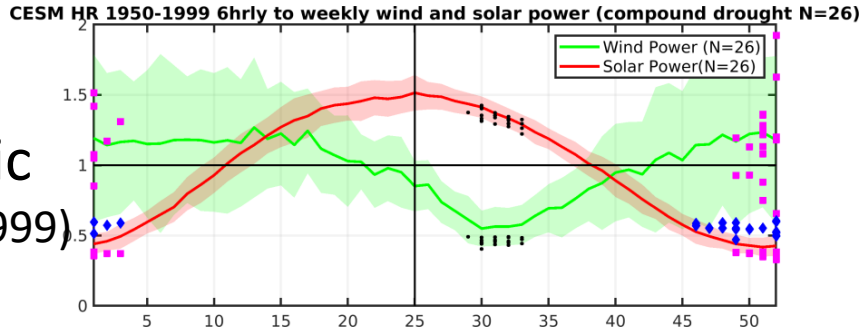
CESM LR- bias corrected



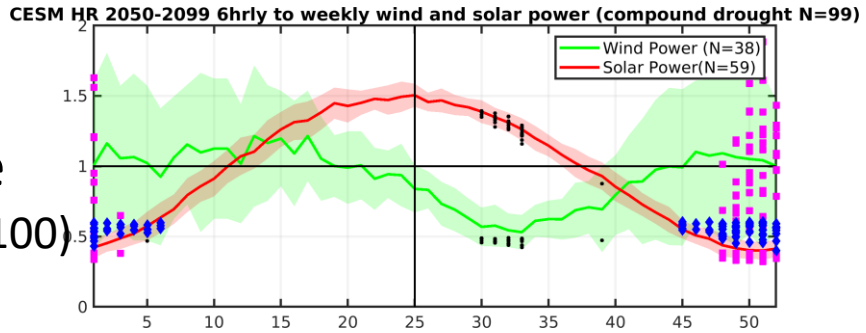
Future wind and solar power supply over WNA

CESM HR- bias corrected

Historic
(1950-1999)



Future
(2050-2100)



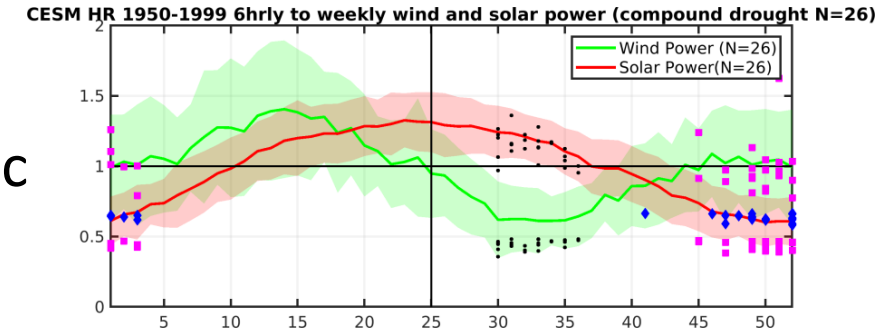
- **Supply**: Increased number of wind and solar droughts in the future.
- **Demand**: (not shown) stress on the energy system during cooling degree days (summer) is much higher.

→ **Big challenges for energy transition to wind and solar power in WNA**

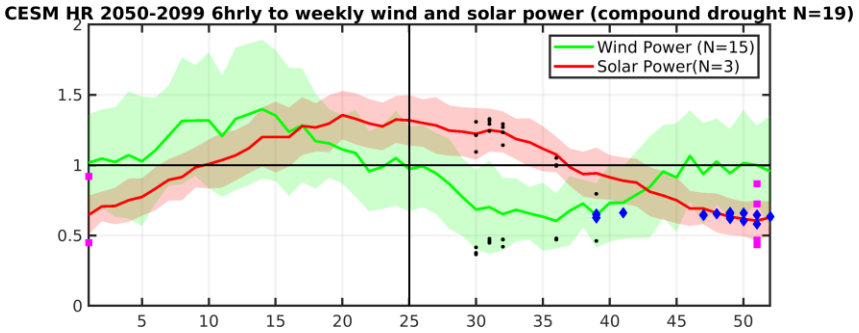
Future wind and solar power supply over Texas

CESM, HR- bias corrected

Historic



Future

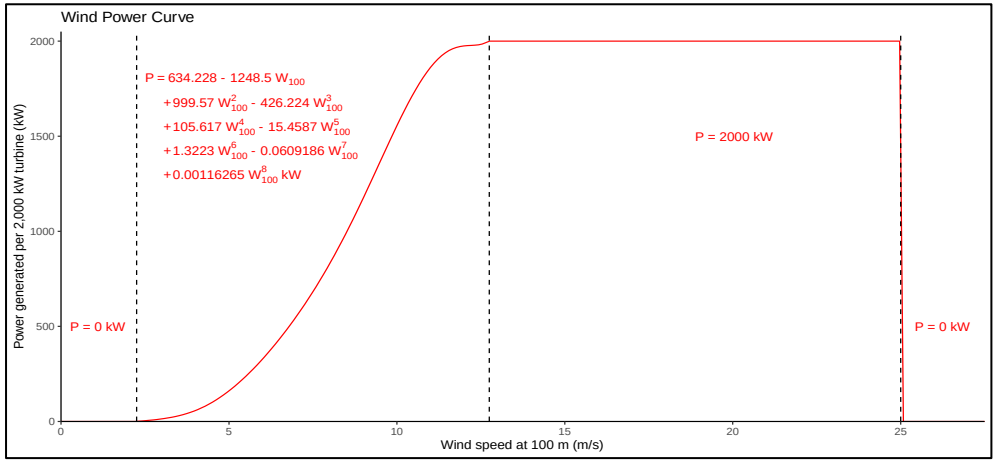


- **Supply**: Decreased number of wind and solar droughts in the future.
- **Demand**: (not shown) Stress on the energy system during cooling degree days (summer) is a little higher in the future, but not as big as is in WNA.

Summary

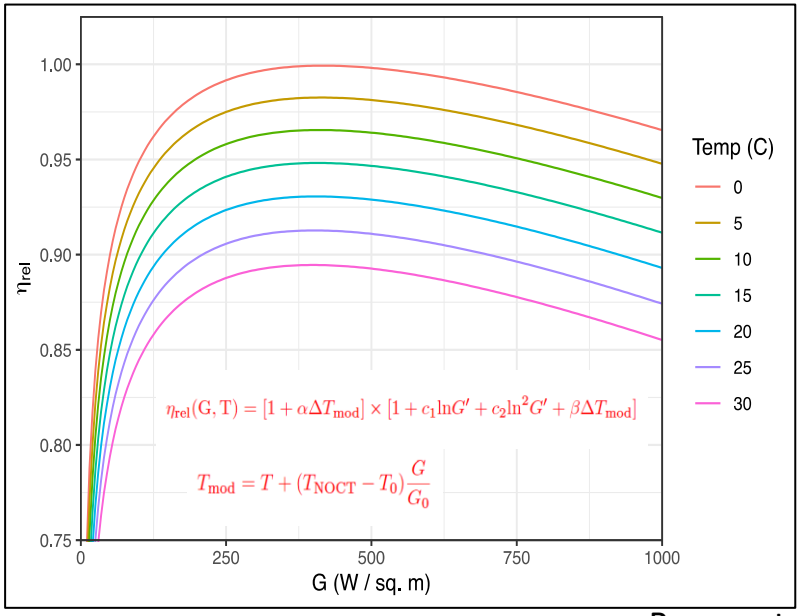
- **Spatial structure** of the relationship between power droughts and weather **varies geographically**
- **Higher resolution may not improve** the model simulations of wind and solar droughts by itself.
  - Need to correct the model bias
- **In WNA, big challenges for energy transition to wind and solar power**
  - energy demands in summer becomes much higher, meanwhile power droughts increase!
- **In Texas, demand will not change a lot, and wind and solar power droughts decrease in the future**

Wind Power Curve from wind turbines



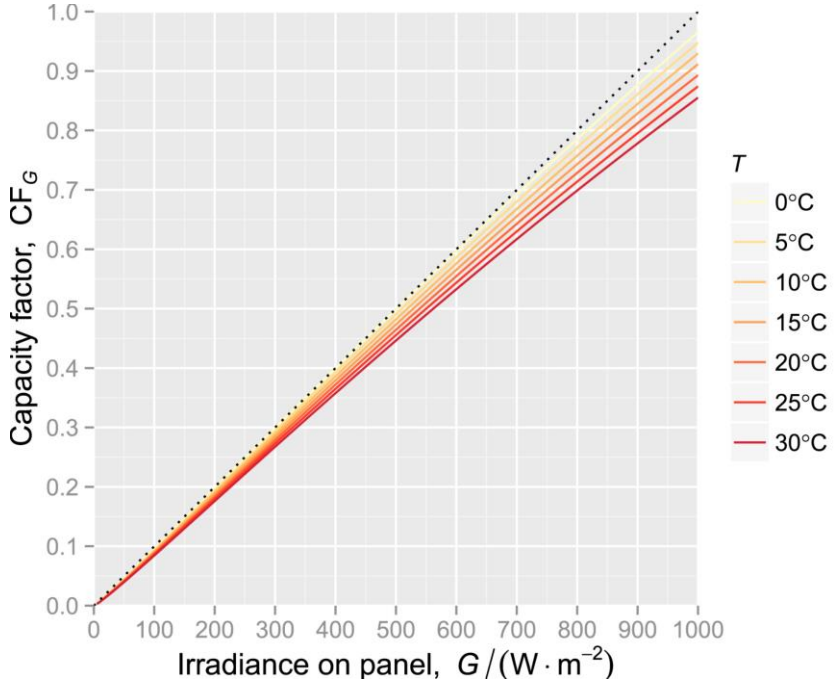
U100 is derived from U10 and Ubot based on the logarithmic law of the wall

The efficiency of hourly radiation depends on temperature



Brown et al. 2021

Power from a solar PV panel

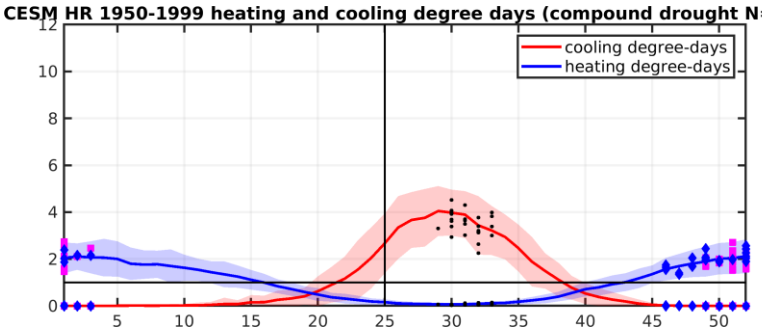


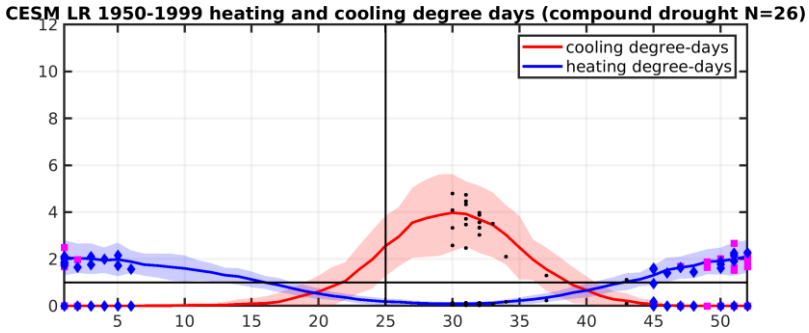
Future wind and solar power demand over WNA

CESM HR- bias corrected

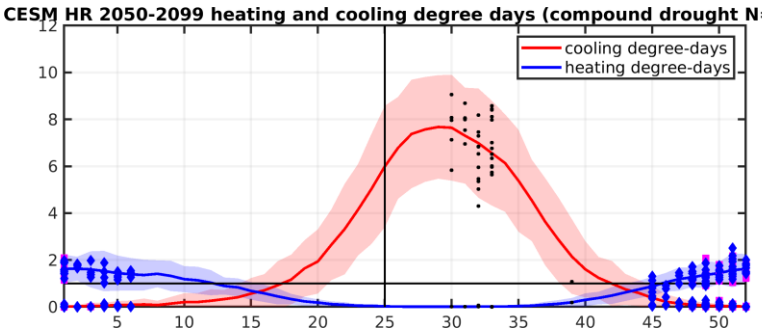
CESM LR- bias corrected

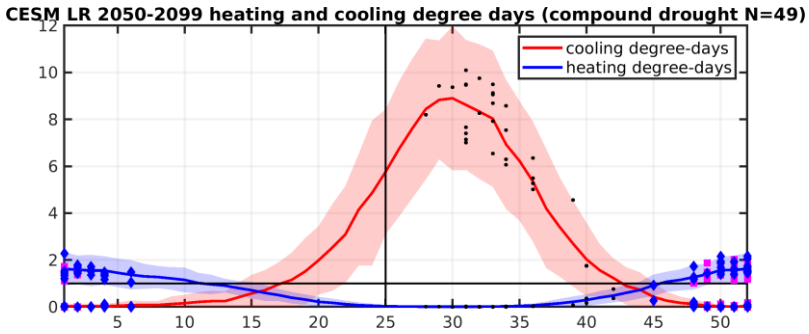
Historic





Future





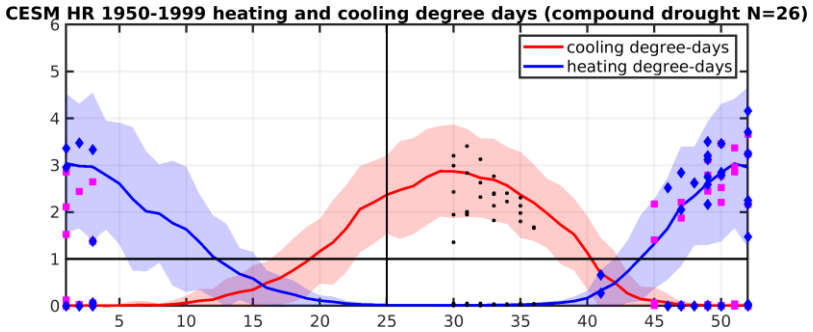
- Increased number of wind and solar droughts in the future.
- Demand-side stress on the energy system during cooling degree days (summer) is much higher.

→ **Big challenges for energy transition to wind and solar power in WNA**

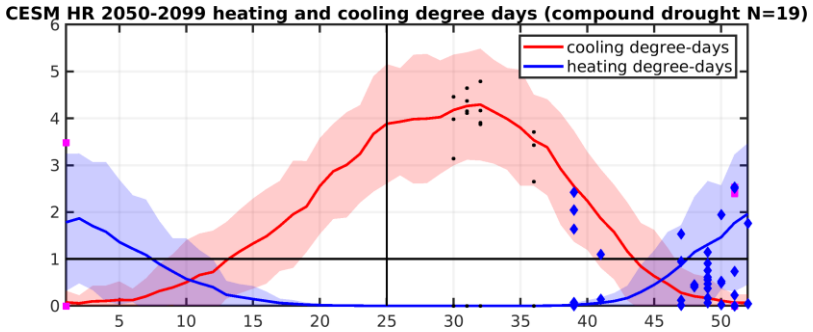
Future wind and solar power demand over Texas

CESM HR- bias corrected

Historic



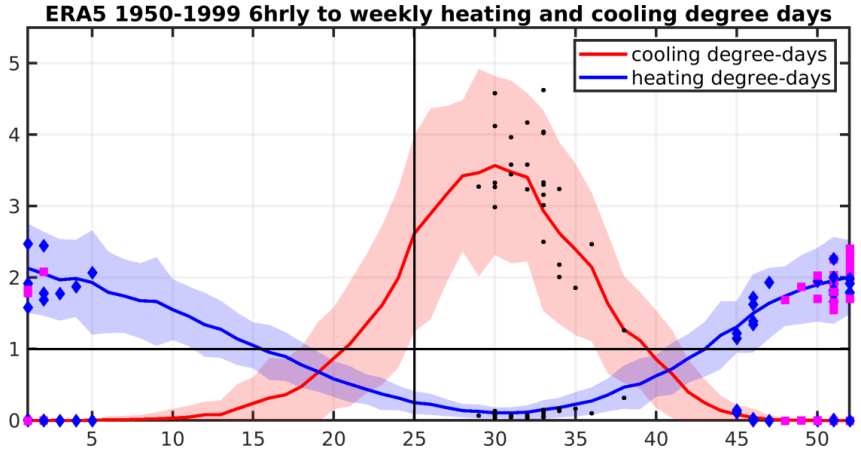
Future

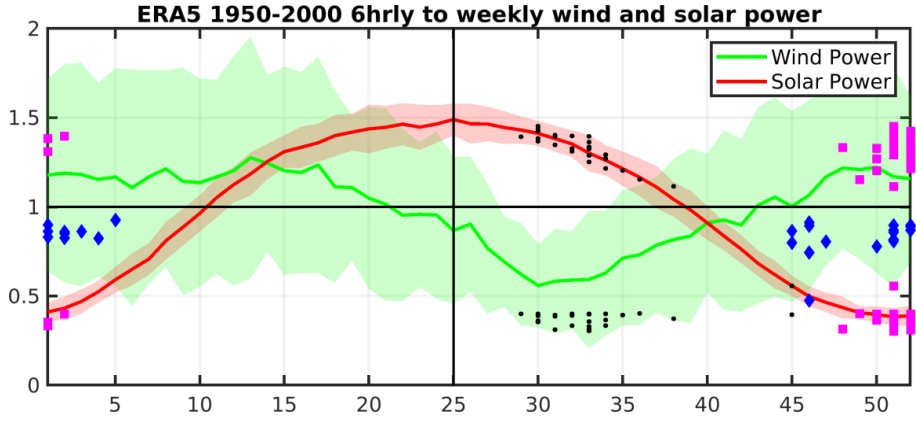


- **Texas**: Demand-side stress on the energy system during cooling degree days (summer) is a little higher in the future, but not as big as what is in WNA.

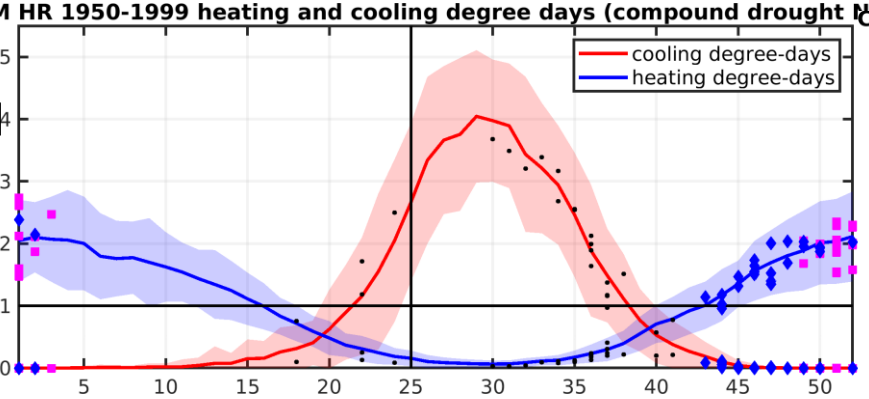
WNA

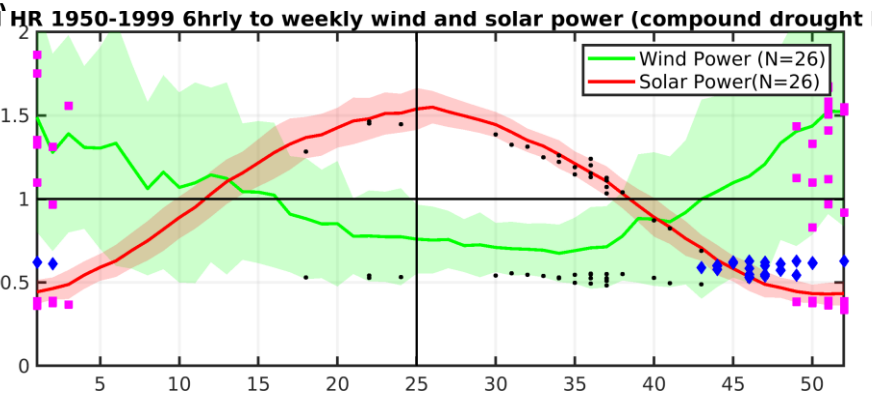
ERA5



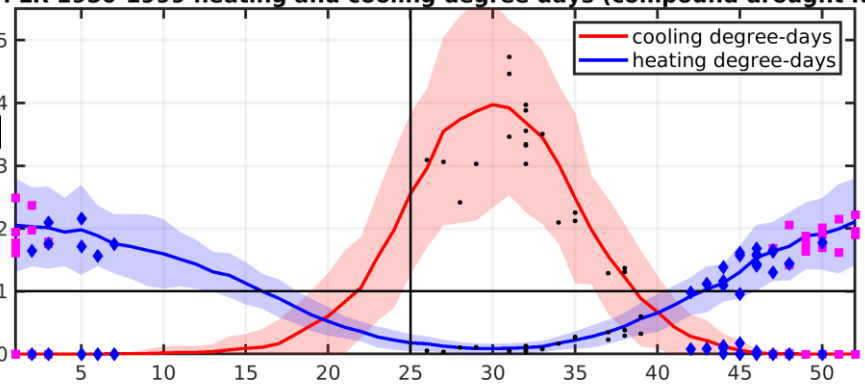


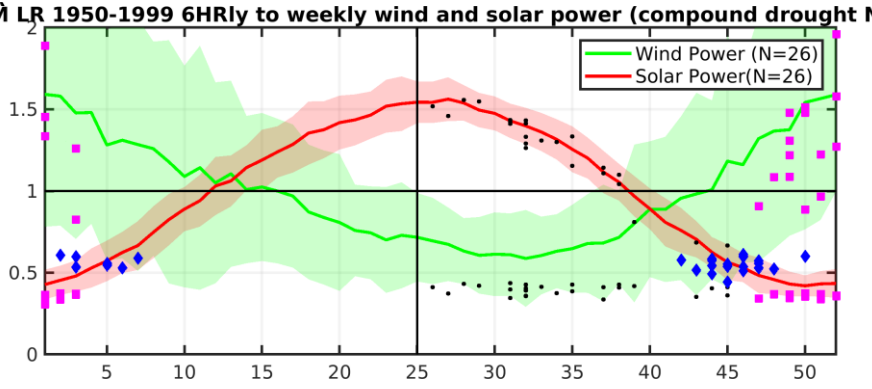
CESM HR





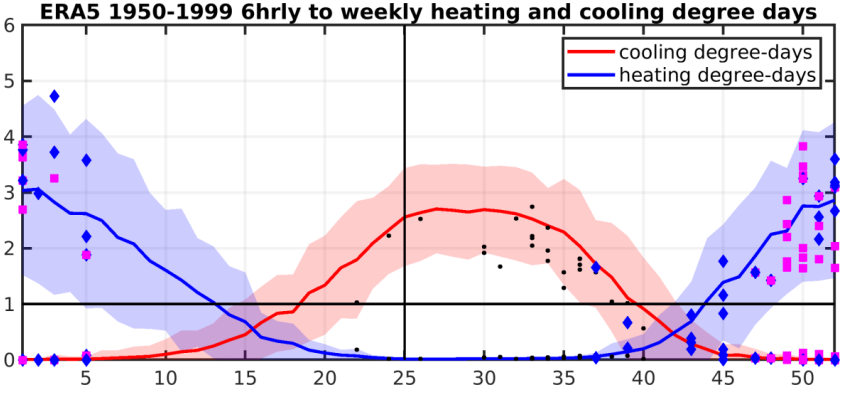
CESM LR

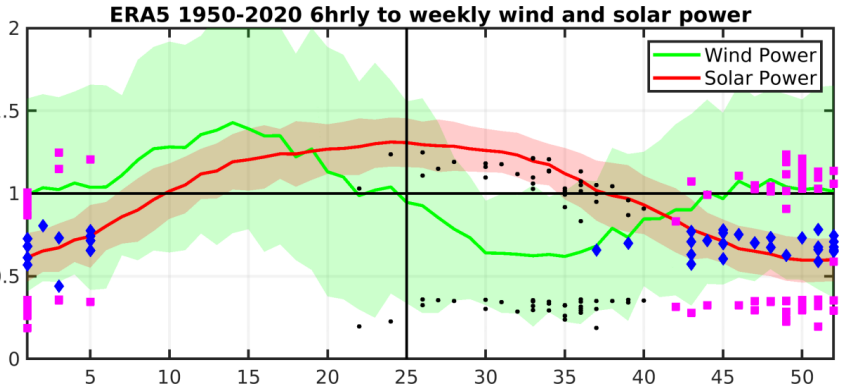




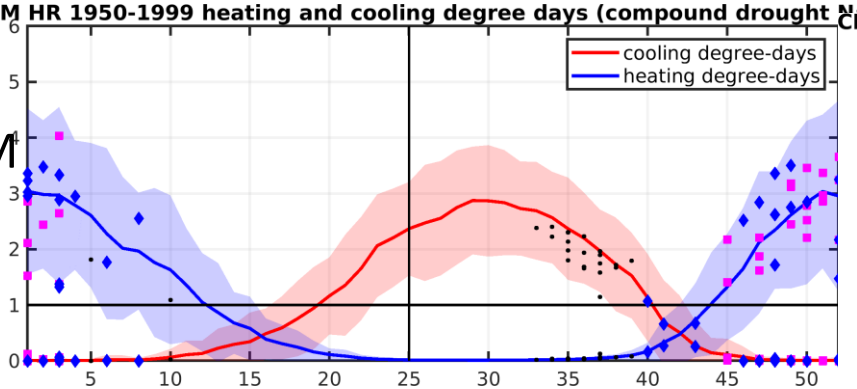
Texas

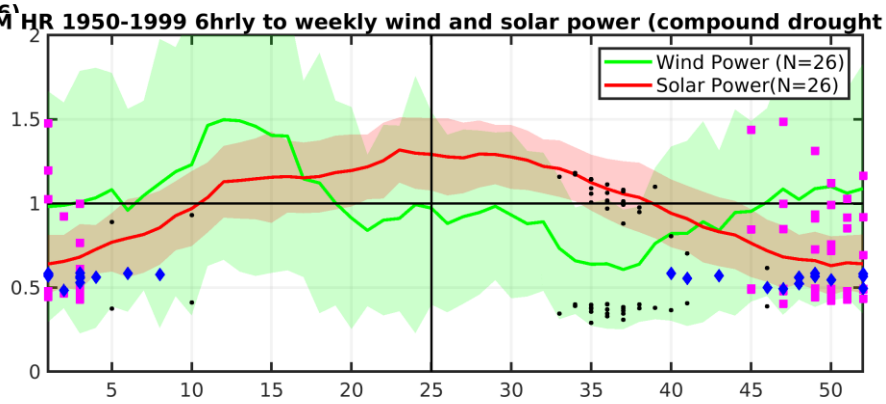
ERA5



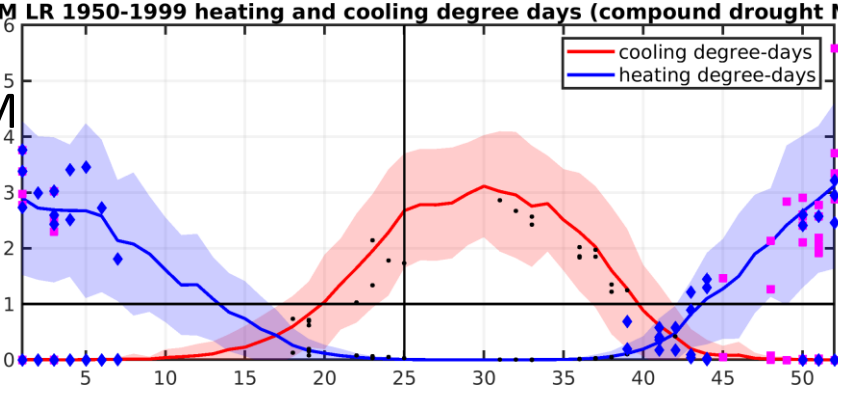


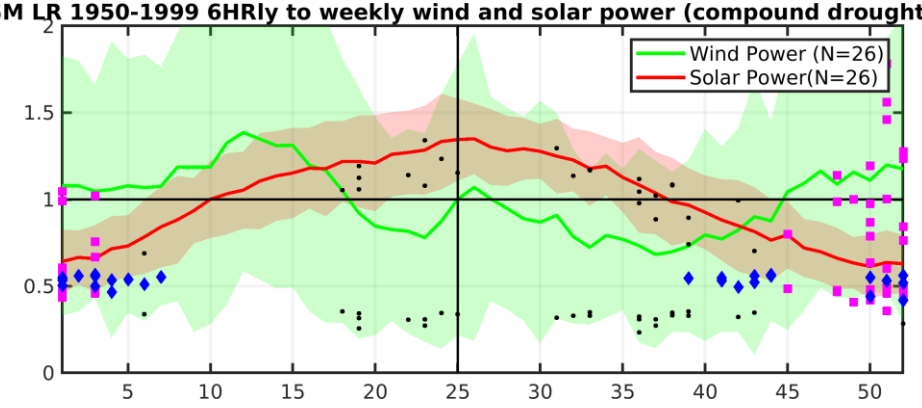
CESM HR





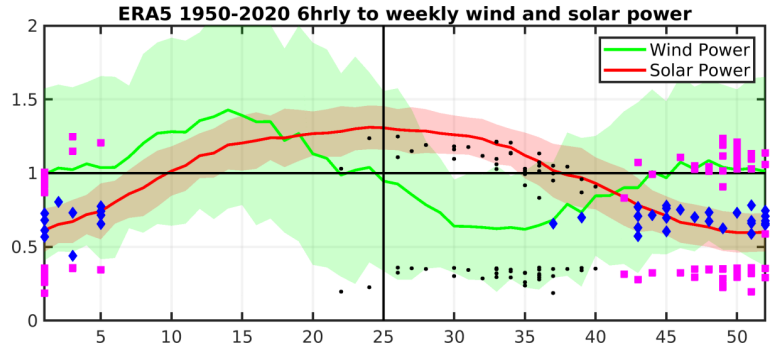
CESM LR



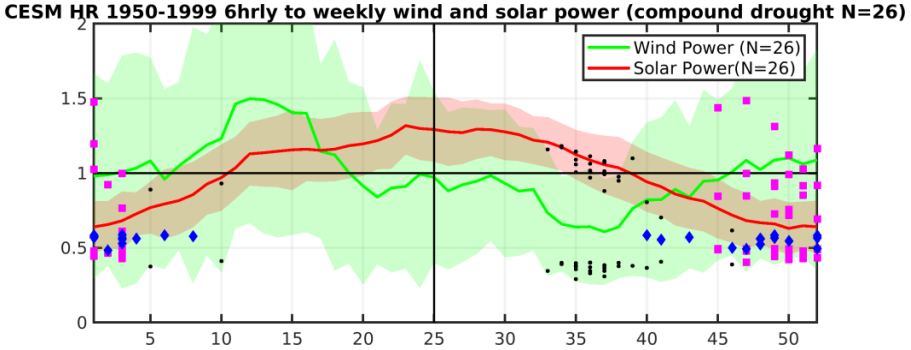


Power supply and power droughts over Texas

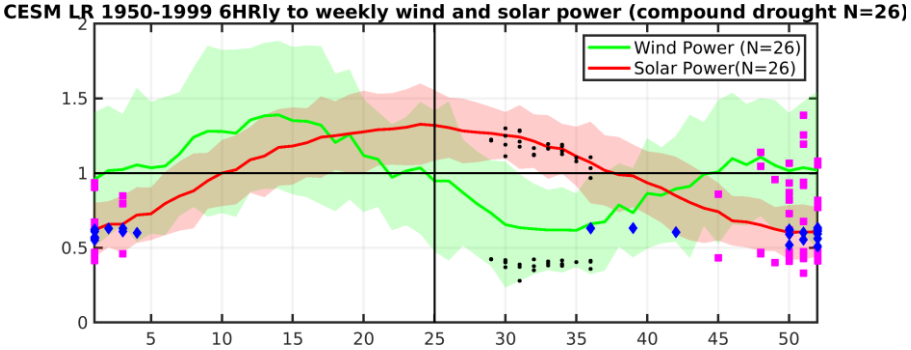
ERA5



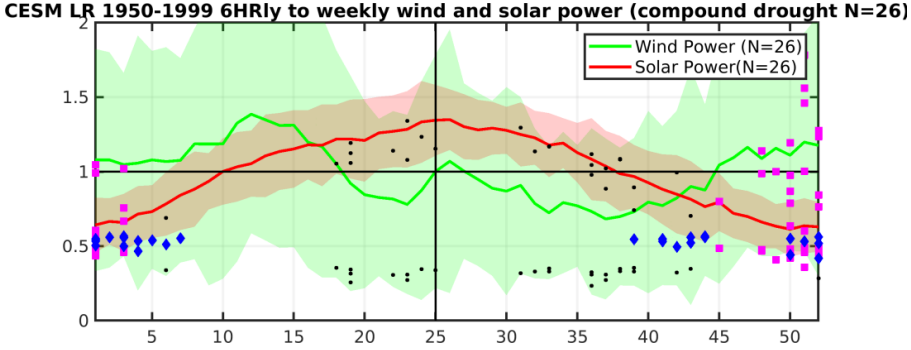
CESM HR



CESM HR– bias corrected



CESM LR



CESM LR- bias corrected