Long-range predictability of fluctuations in solar and wind resources

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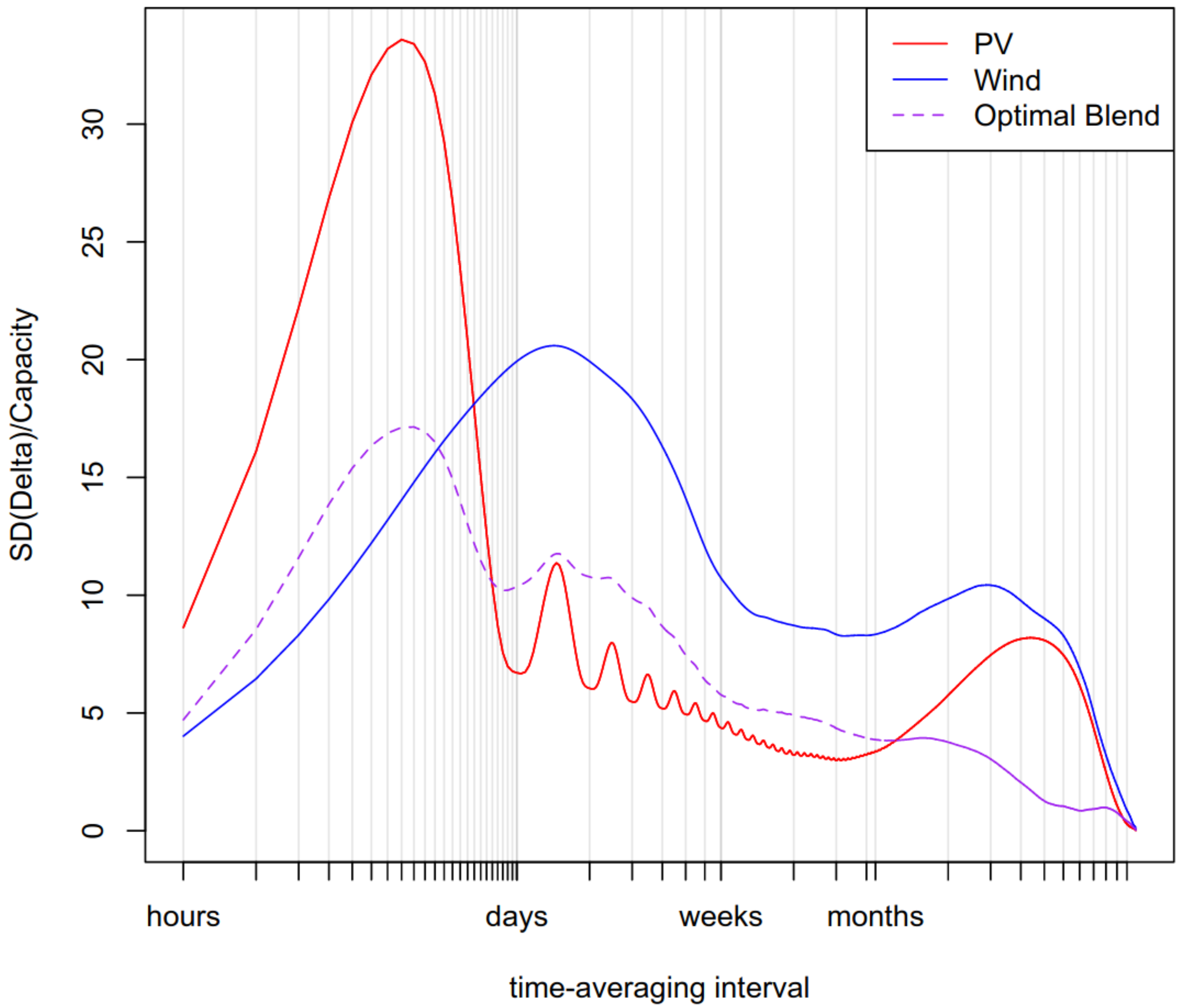
Solar and wind resources both depend on weather

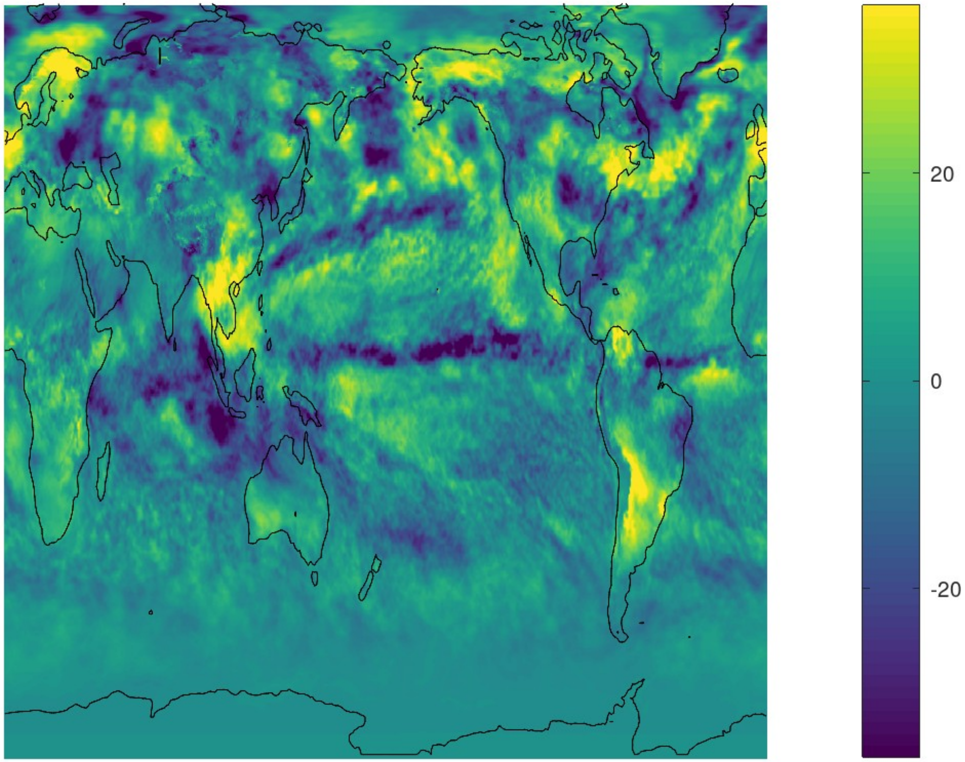
- As does energy demand!
- Because of weather, we can have more or less of these resources than usual over a given day, week, month, ...

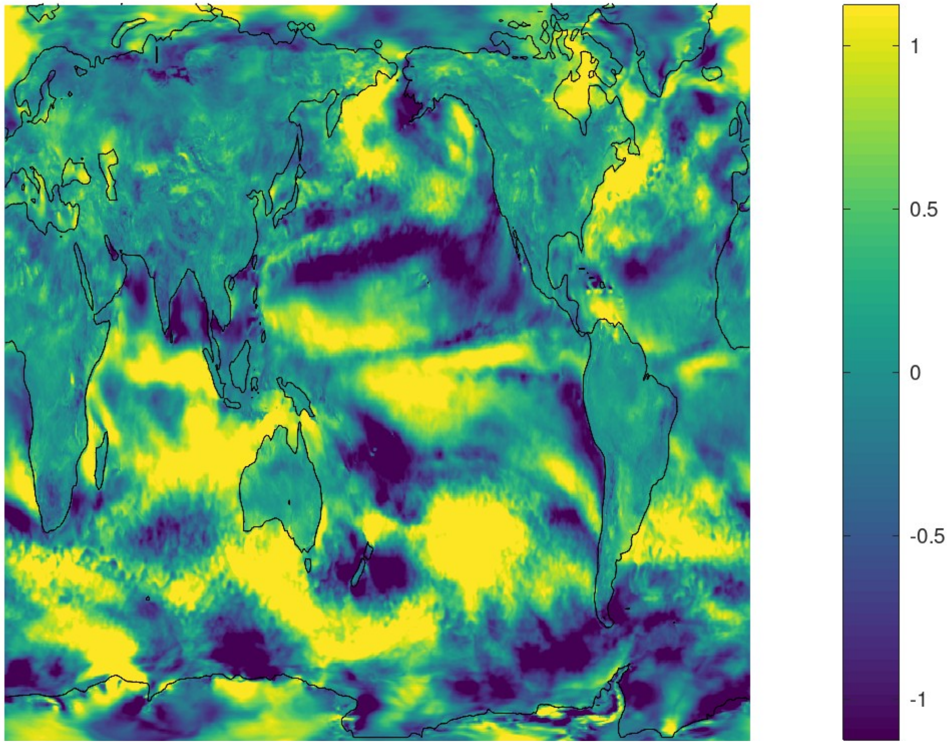
Variability of wind, solar generation across timescales (Minnesota)



Perez and Perez, 2019

Example: May 2020 sunlight and surface wind, compared to average





Reanalysis (ERA5)
Surface insolation (W m^{-2}, above)
and windspeed (m s^{-1}, left),
2020 minus 1979-2019 average

Example: a wind drought in 2015

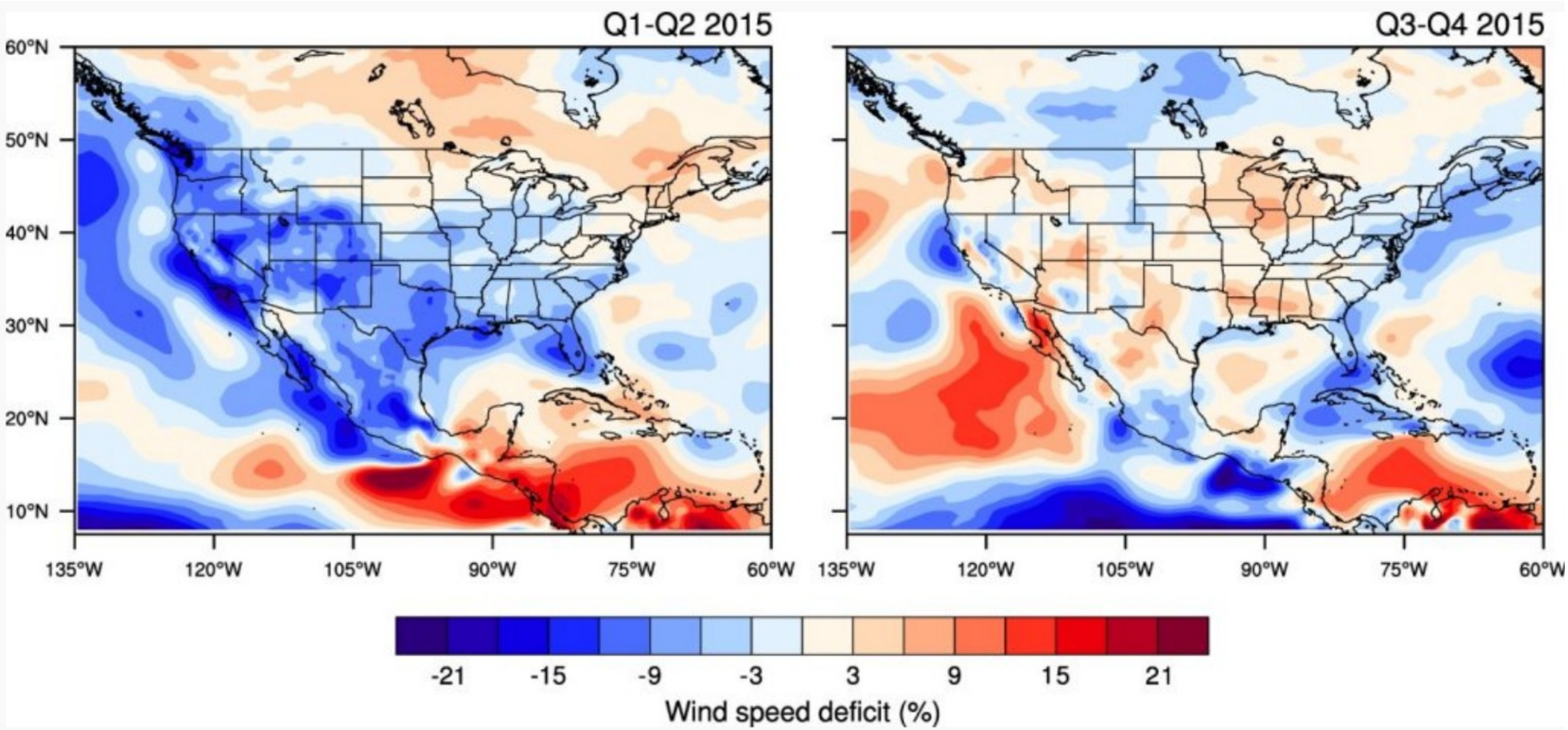
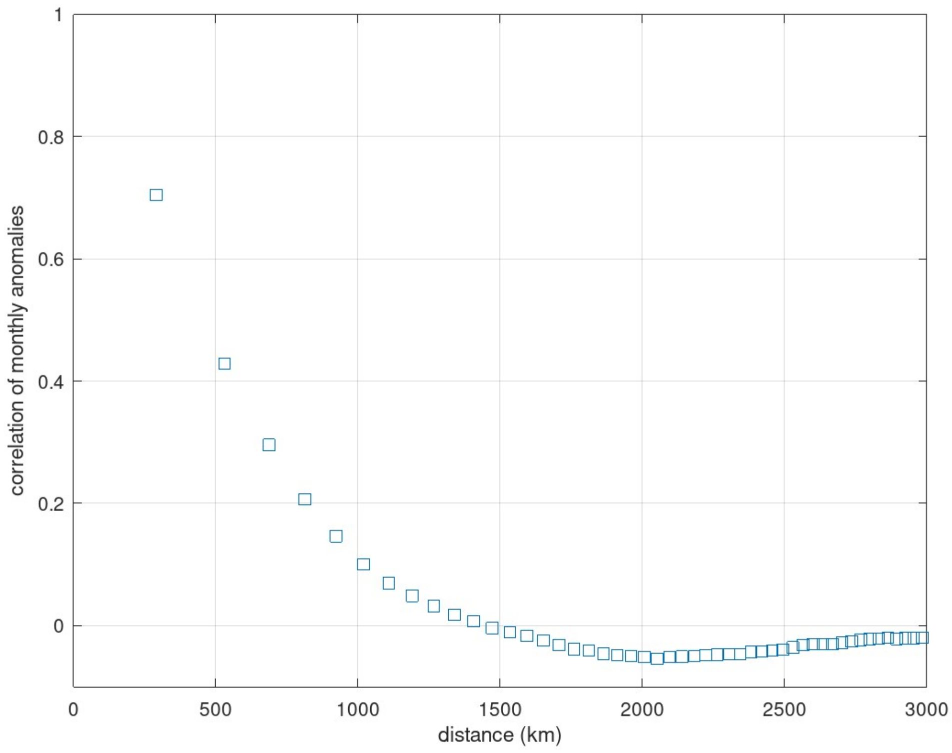


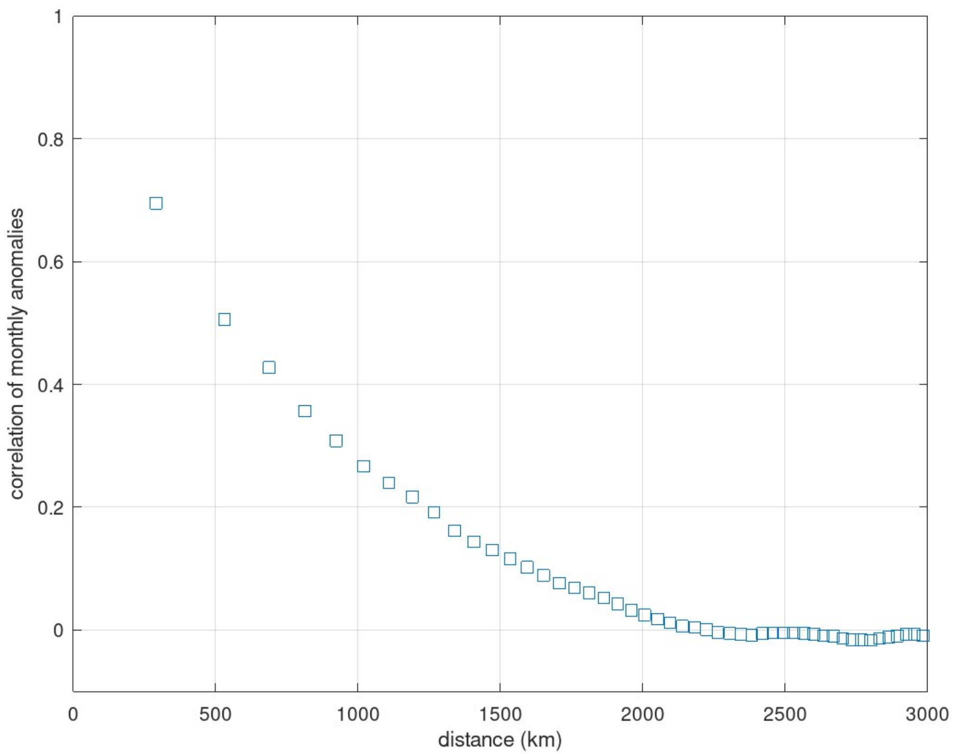
Figure 1. Windiness levels for the first and second quarters and the third and fourth quarters of 2015 compared to the 1979-2014 average. During the first and second quarters, many locations in California, Florida, Oregon, Washington, and Texas reported their lowest wind speeds in more tha[n] 30 years. Image Credit: DNV GL, 2016

Wind generation down ~20% over much of W and S USA in first half of year

See
Rife, Krakauer, et al. (2016), "A new kind of drought: U.S. record low windiness in 2015"

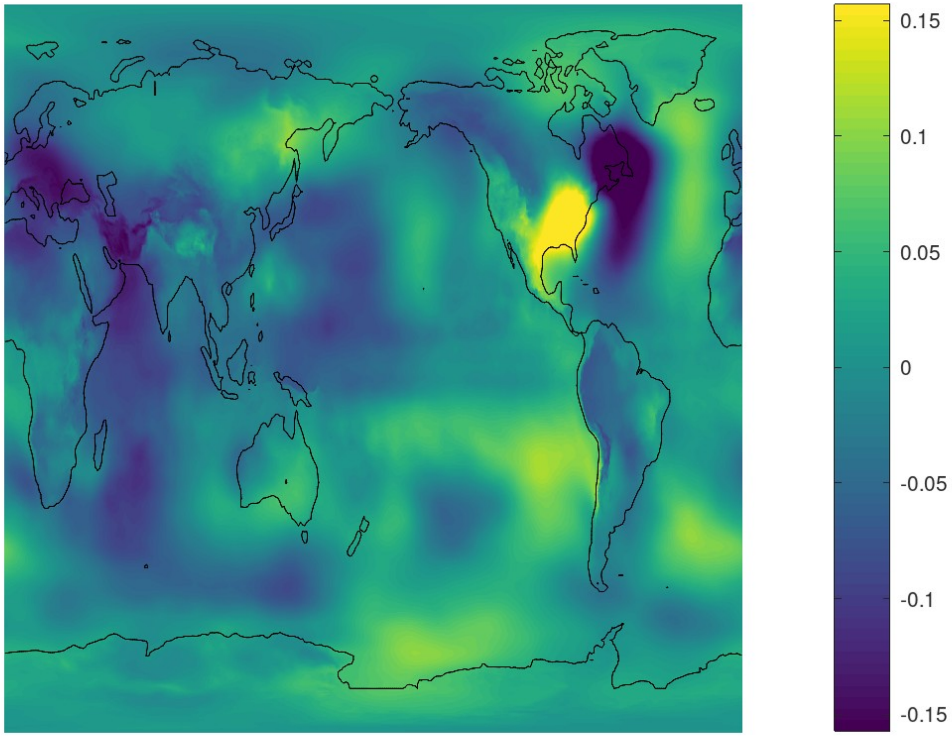
Typically, monthly anomalies have spatial scales of hundreds of km

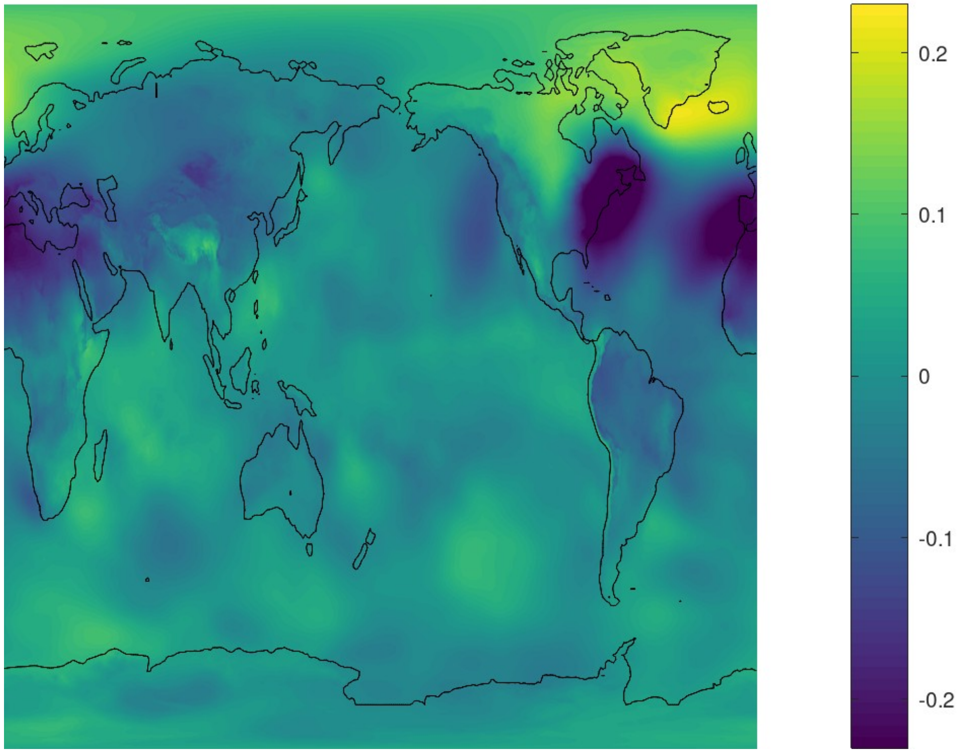




Mean correlation of monthly anomalies in surface insolation (above) and windspeed (left),
from ERA5, 1979-2019,
centered at 40.75 °N, 74 °W

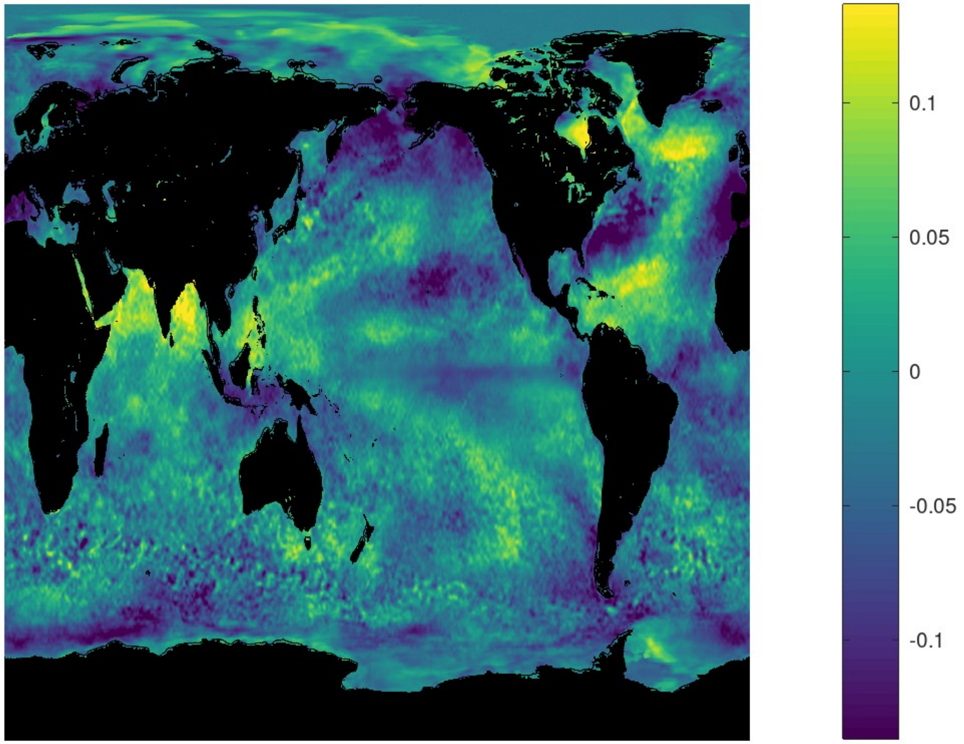
Such anomalies typically correlate with other aspects of weather, like surface pressure

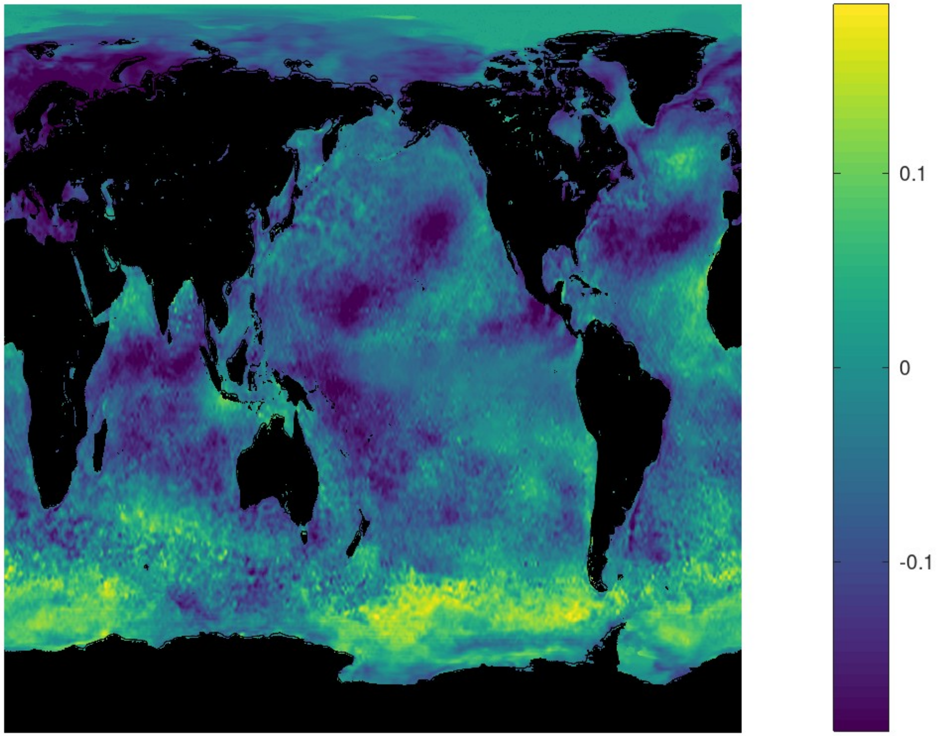




Anomaly correlation with each point in the sea-level pressure field of surface insolation (above) and windspeed (left), both at 40.75 °N, 74 °W from ERA5, 1979-2019

And, to a lesser extent, with sea-surface temperature





Anomaly correlation with each point in the SST field
of surface insolation (above)
and windspeed (left),
both at 40.75 °N, 74 °W
from ERA5, 1979-2019

As did, e.g., the 2015 wind drought

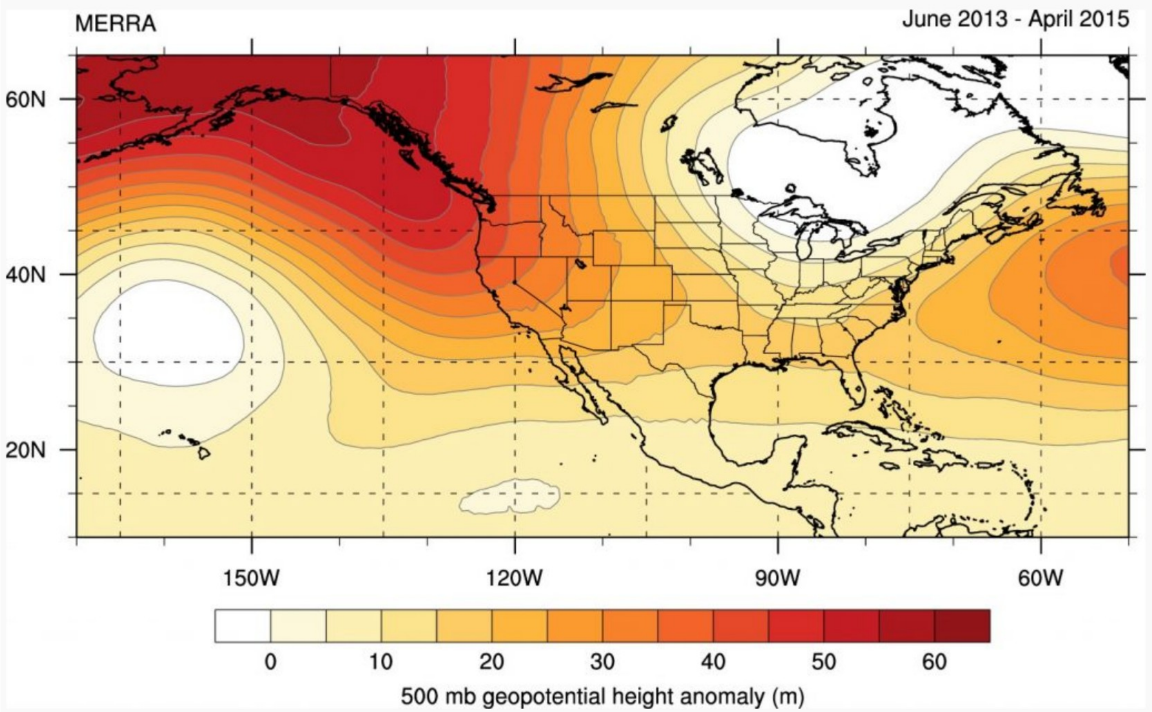
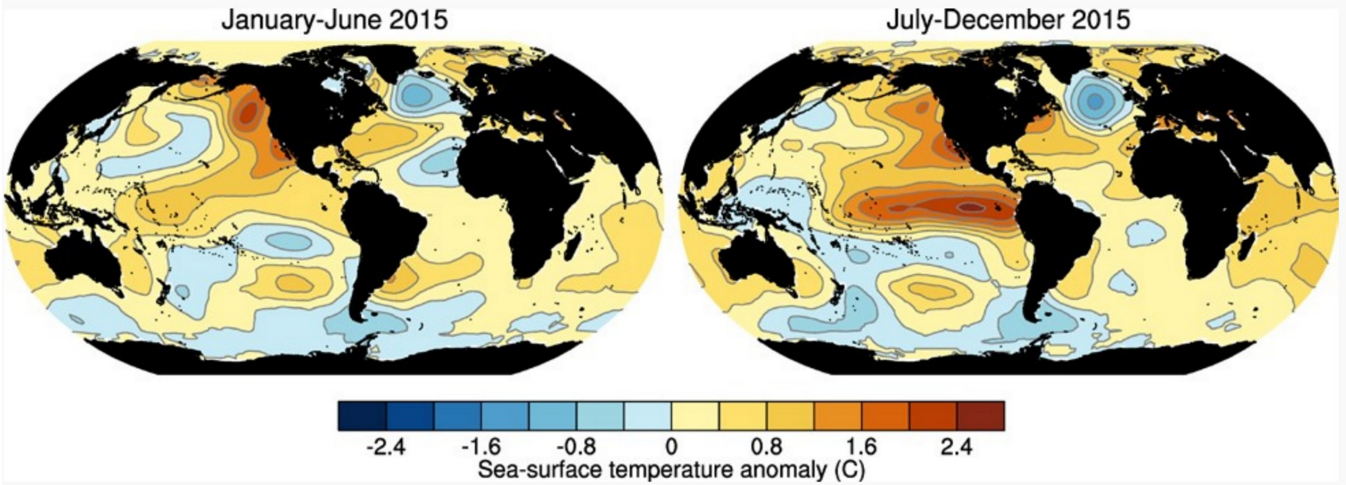


Figure 2. Atmospheric height anomalies in the mid troposphere (500-mb geopotential height) for June 2013-April 2015 compared to the 1981-2010 average. Positive values are indicative of high pressure. Image Credit: Data Source: NASA MERRA project. Analysis performed by: Daran Rife



SST anomalies for the first and second quarters (left) and the third and fourth quarters (right) of 2015, compared to the 1981-2010 average. Derived from Extended Reconstructed SST Version 4 data. Image Credit: Data Source: Huang et al.,2014; Liu et al., 2014. Analysis performed by: Daran Rife

Sea-surface temperature is one of the influences on weather that's predictable months in advance

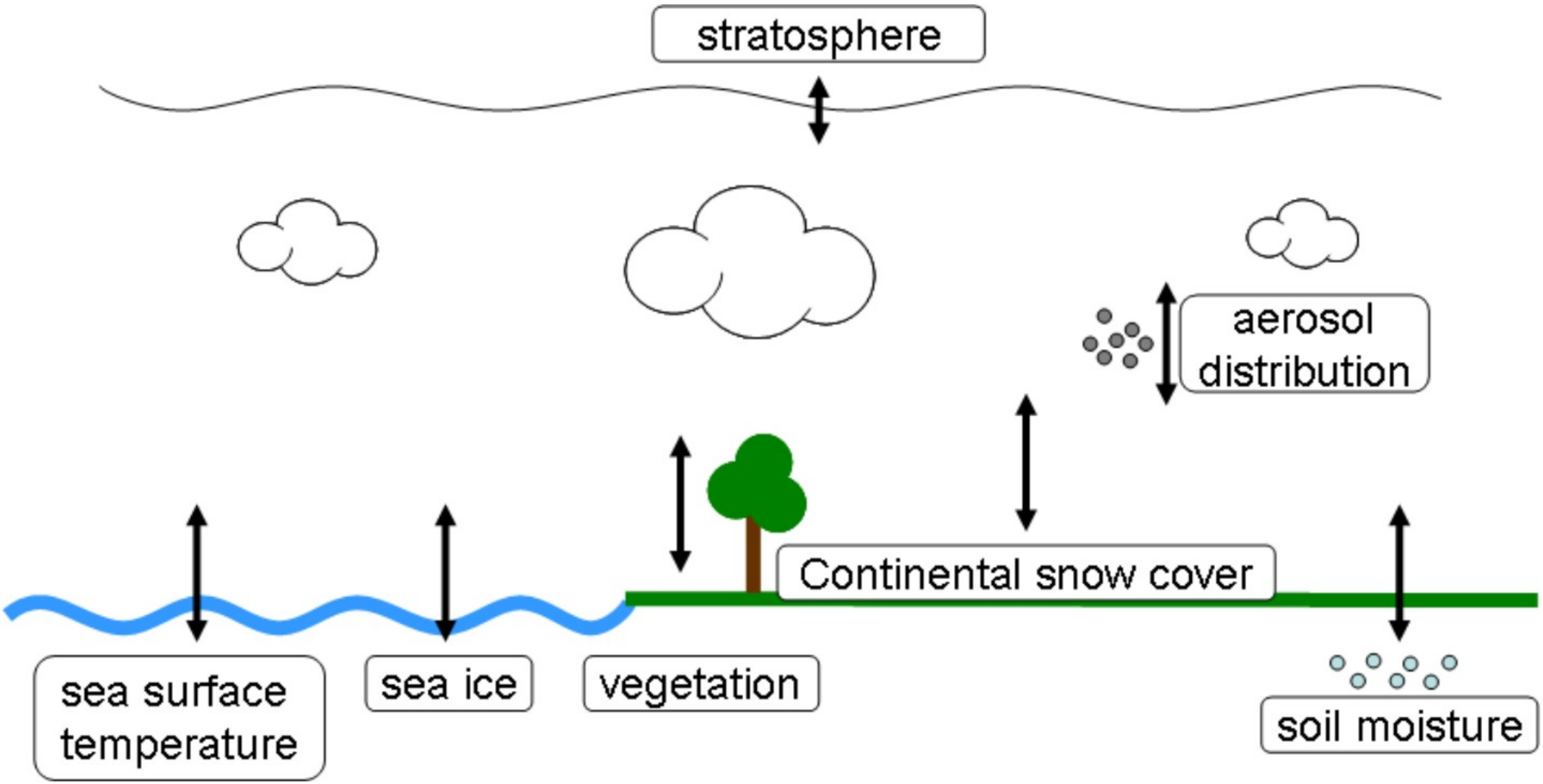


Figure 1.3: Boundary conditions and other factors with potential impacts on the variability of weather on seasonal time scales (see text for details).

Renggli (2011), "Seasonal predictability of wintertime windstorm climate over the North Atlantic and Europe"

SST patterns affect weather via several known teleconnection modes

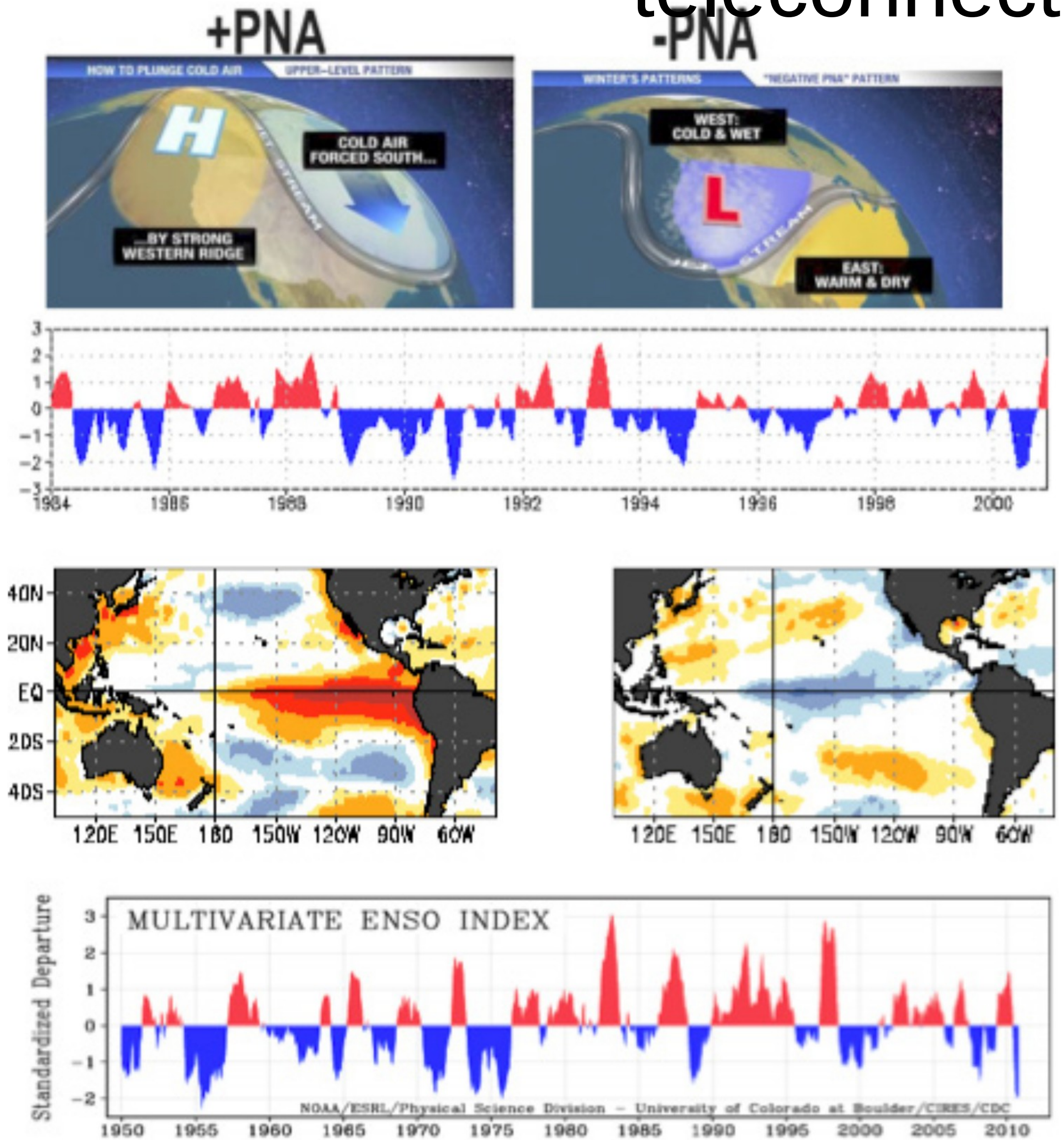
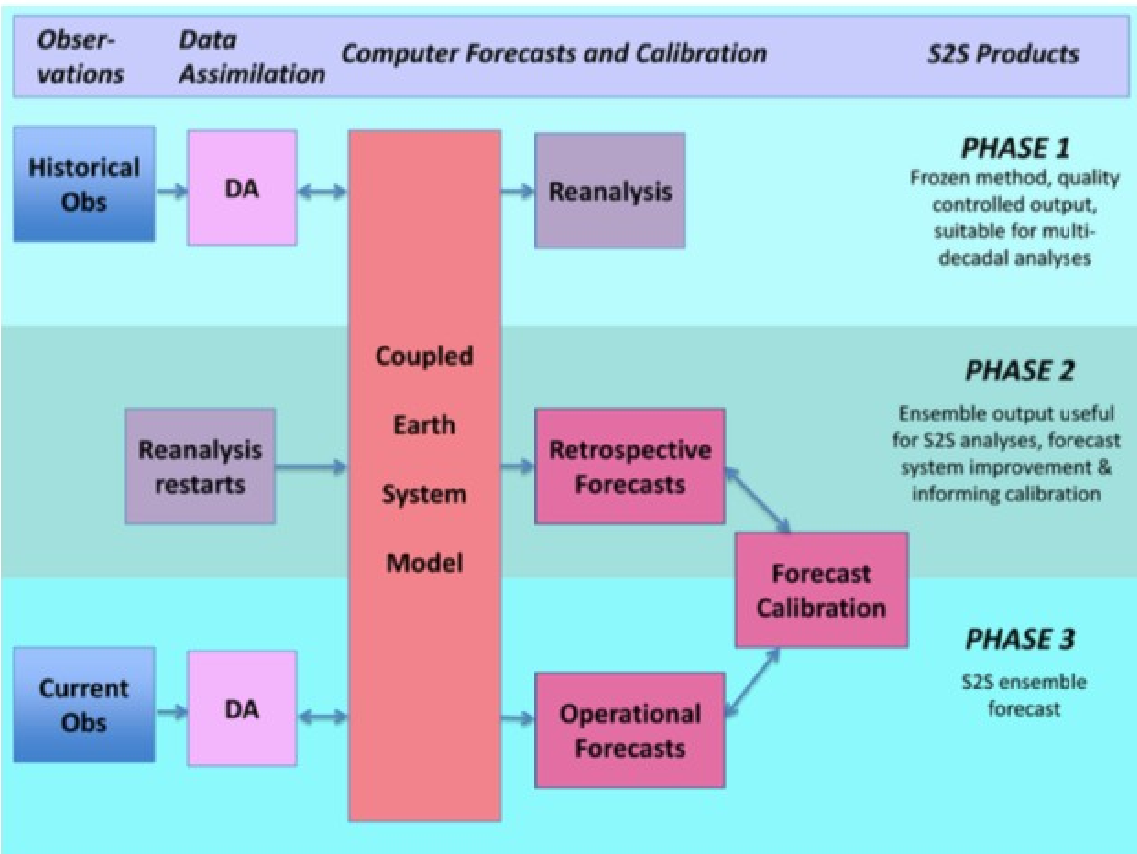


FIGURE 4.4 Two examples of common and impactful "natural modes of variability." NOTES: Top panels illustrate the atmospheric circulation anomalies associated with the PNA pattern in its positive (left) and negative (right) phases. Bottom panels illustrate the SST anomalies associated with the ENSO phenomenon, showing both El Niño (left) and La Niña (right) phases. SOURCE: Top panel from njweatherblogs.com, other panels from NOAA.

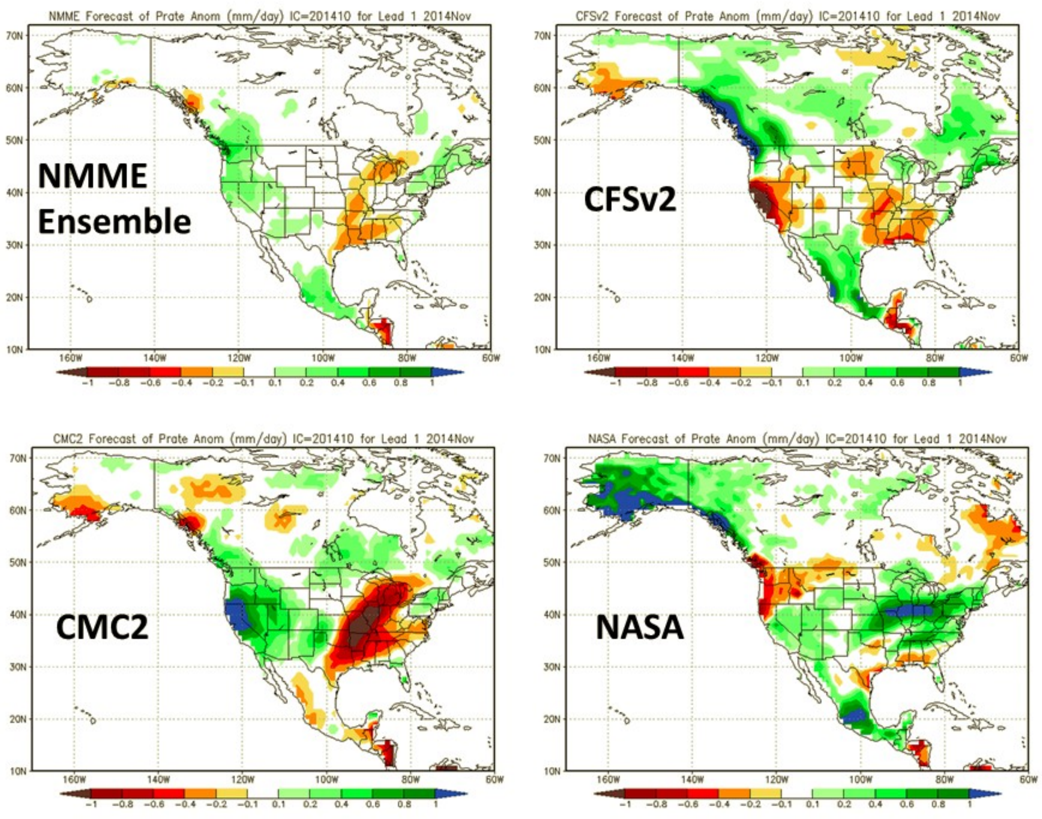
NAS (2016), "Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts"

Dynamical prediction for seasonal forecasting



- Global numerical climate models run starting with present conditions to simulate the next few months
- Ensemble of runs to get a range of possible outcomes
- Potentially include ocean, land dynamics

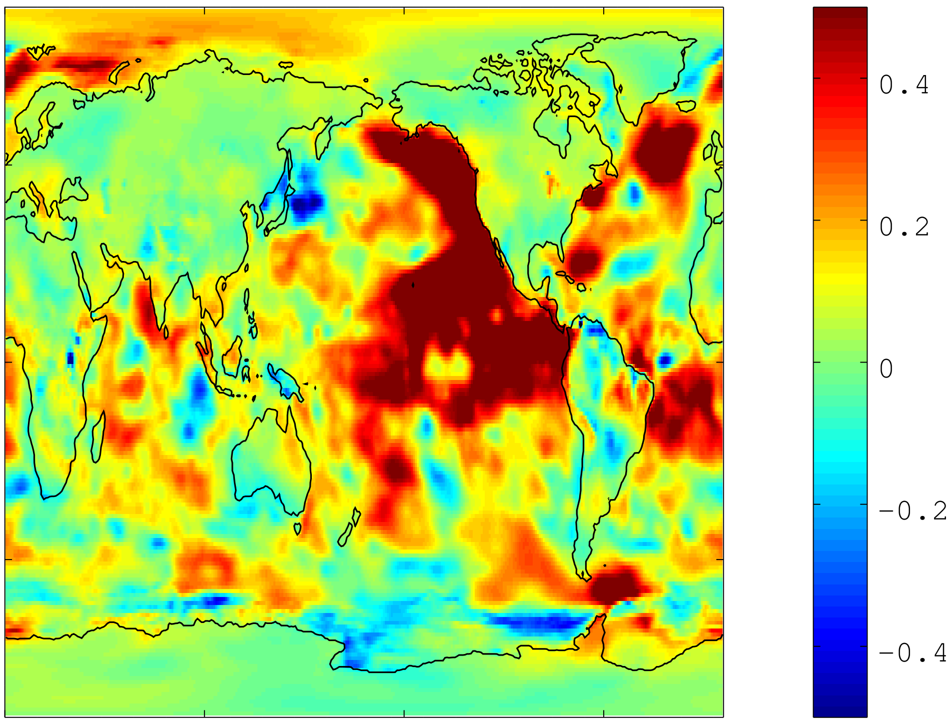
North American Multi-Model Ensemble (NMME)

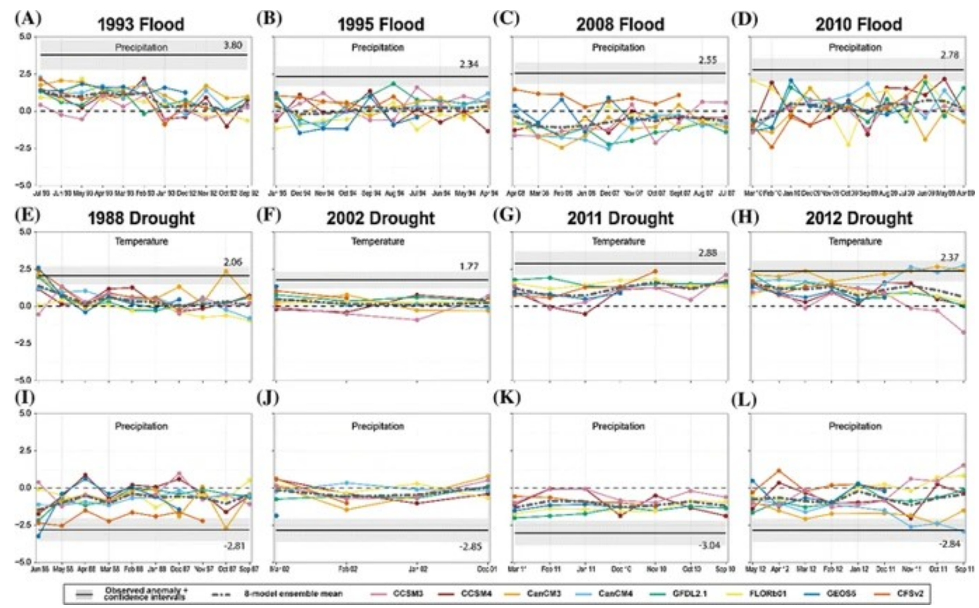


Example precipitation forecast for N America from individual NMME models and the multi-model mean

- Several state of the art climate models; several ensemble members from each model
- Monthly forecasts extending to 12 months, since 2011 (retrospectively since 1982)
- Output 1-degree forecast temperature, precipitation... posted online on the 8th of each month

Some NMME skill results





Left: Next-month temperature prediction skill map, from Krakauer (2019), “Temperature trends and prediction skill in NMME seasonal forecasts”

Right: Forecasts of precipitation and temperature for major USA floods and droughts, from Slater et al. (2016), "Evaluation of the skill of NMME Global Climate Models in predicting average and extreme precipitation and temperature over the continental USA"

Conclusions

- For a given month and location, the wind and solar resource may vary substantially between years
- This variability is associated with other aspects of weather, including atmospheric pressure and sea surface temperature
- NMME provides forecasts of temperature, precipitation, and eventually other fields, which can be potentially used to help predict some of these fluctuations and aid in operating renewables based power grids

Thanks!

- For more info:
  - nirkrakauer.net (full text of publications)
  - mail@nirkrakauer.net
- Questions?