Portland State
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"I'm Convinced that 2050 will be Warmer than 2020, Now tell me Something Actionable."

An Introduction to Climate Projections: What Information is out There and How to Interpret it for a Specific Application

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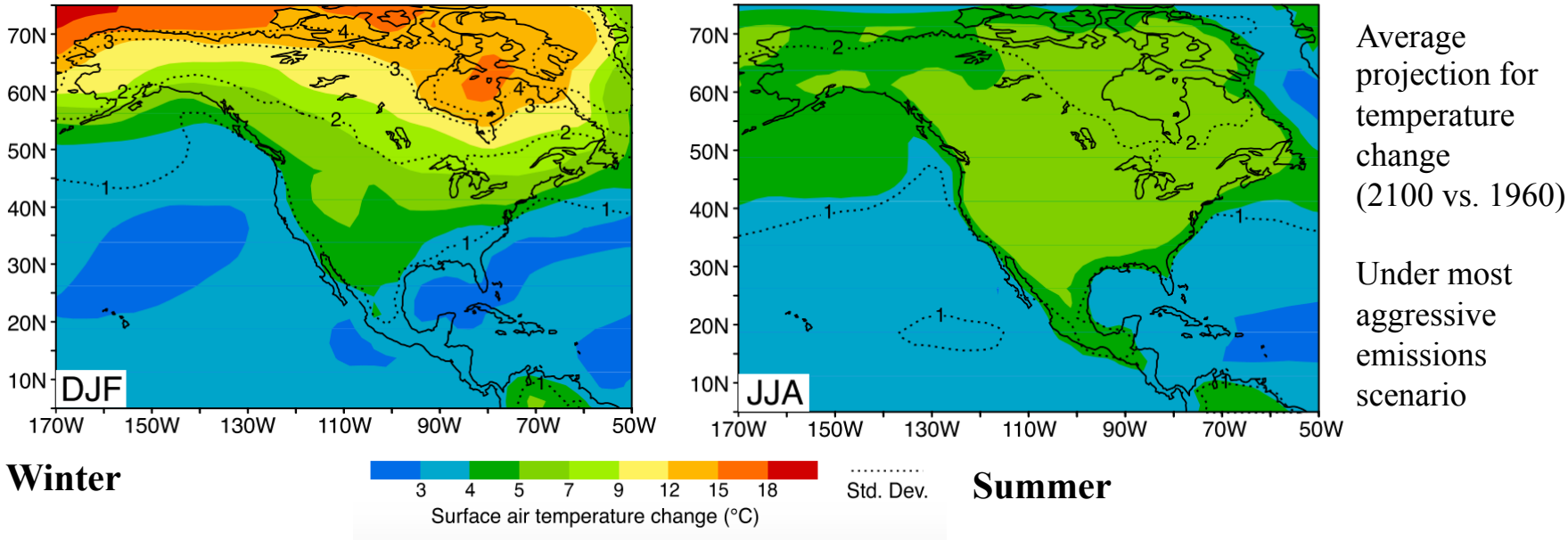
What is a Climate Projection?

- A: The likely state of the Earth System in the future given its state in the past and some assumptions about how humans will influence it.
- The Earth System includes 4 main components, the *Atmosphere*, *Ocean*, *Cryosphere* and *Biosphere* and their "external forcings".
- Here we will focus on two parts of the Earth System that are important for agriculture: temperature and precipitation.



Winter

Summer

Average projection for temperature change (2100 vs. 1960)

Under most aggressive emissions scenario

Figure from Maloney et al. (2014 – J. Climate)

Why Projection and not Prediction?

- A: This is a tacit acknowledgement that future human activities are unknown. Because human activities are such a key part of the external forcings on the Earth System, climate modelers can only "project" by assuming *scenarios* for what humans might do.
- Scenarios are primarily formulated around greenhouse gas emission trajectories. There are two commonly investigated scenarios:
  - RCP 8.5, referred to as "business as usual" assumes no global emissions stabilization, corresponds to 5 deg. C warming on average.
  - RCP 4.5 is considered to represent a conservative scenario for stabilization of greenhouse forcing by 2100, corresponds to 2.5 deg. C warming on average.

How many Climate Models are there and Which one is Best?

- A: Relatively few. Projecting the entire Earth System for multiple scenarios 50 – 100 years in the future is **expensive**. Most highly developed countries that also have meteorological agencies have 1-2 climate models that fit this definition.

- Beginning in the 1990s the World Climate Research Programme (WCRP) began a framework to establish climate model best practices and encourage comparison: CMIP

- In 2019, we will age out of the 5th generation Climate Model Intercomparison Project (CMIP5) and enter CMIP6. Projection *fidelity* (level of detail) and *sophistication* (example: how are glacial meltwater pools simulated?) generally increase with each generation.

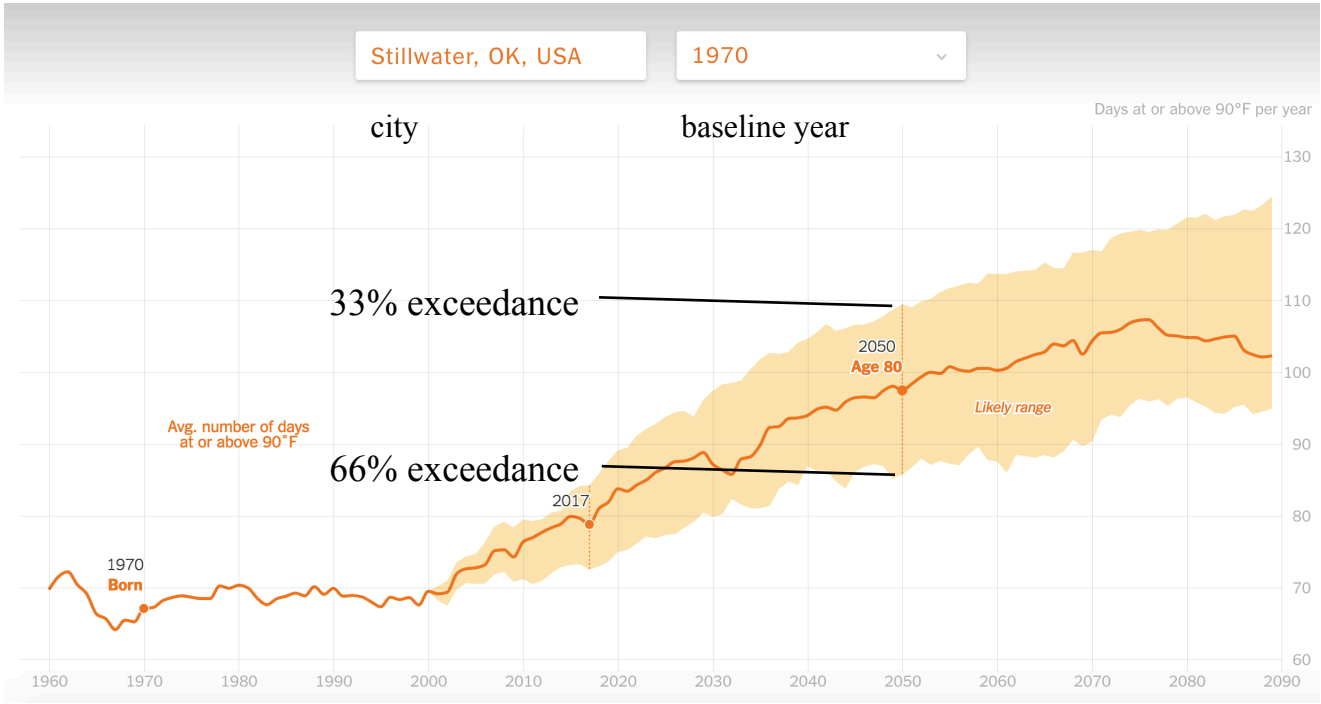
- It is common to treat all individual CMIP model projections as equally likely. Doing so allows an ensemble of projections and thus an estimate of probability of outcome.

Getting Started with CMIP5/CMIP6

- The CMIP5 (and CMIP6) datasets are too variable to address in a single presentation.
- Researchers interested in using CMIP5 should visit https://cmip.llnl.gov/cmip5/ to get started, or https://pcmdi.llnl.gov/CMIP6/.
- Some consistent metadata:
  - Output is produced on a gridded sphere (regularly spaced latitudes and longitudes) in most cases.
  - Data is disseminated in NetCDF format, a variant of Heirarchical Data Format.
  - Horizontal resolutions (CMIP5) are typically near 2.0 degrees lat-lon
  - Temporal resolution is one record per day at minimum, but monthly and yearly averaged fields are also often available.
  - Where one record per day, Temperature diurnal cycle is handled by split variables T_{max}/T_{min}.

Example: Exceedance Probability of 90 Degree Days

- A perfectly comfortable question to ask in February: "What's the chance the high temperature in my location will exceed 90 F now, and what will it be circa 2050?"
- The CMIP5 ensemble of projections is well-suited for this question ***for most locations***



The graph shows the 21 year running mean of number 90 F days. After 2000, the upper/lower terciles of same is shown from CMIP5 ensemble with RCP4.5 + some correction for *representativeness*.

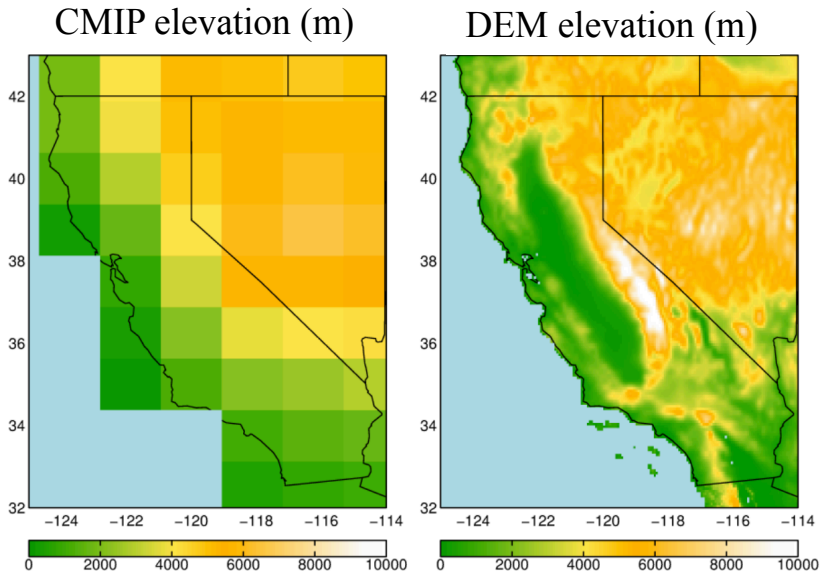
Generated using online tool at https://www.nytimes.com/interactive/2018/08/30/climate/how-much-hotter-is-your-hometown.html

Limitations

1. Representativeness

   CMIP computational grid resolution
   Means that realistic spatial structures are not captured.

   Shown is an example of surface elevation in CA/NV as it appears natively in a CMIP5 model (left) and from a high-resolution digital elevation map (right).

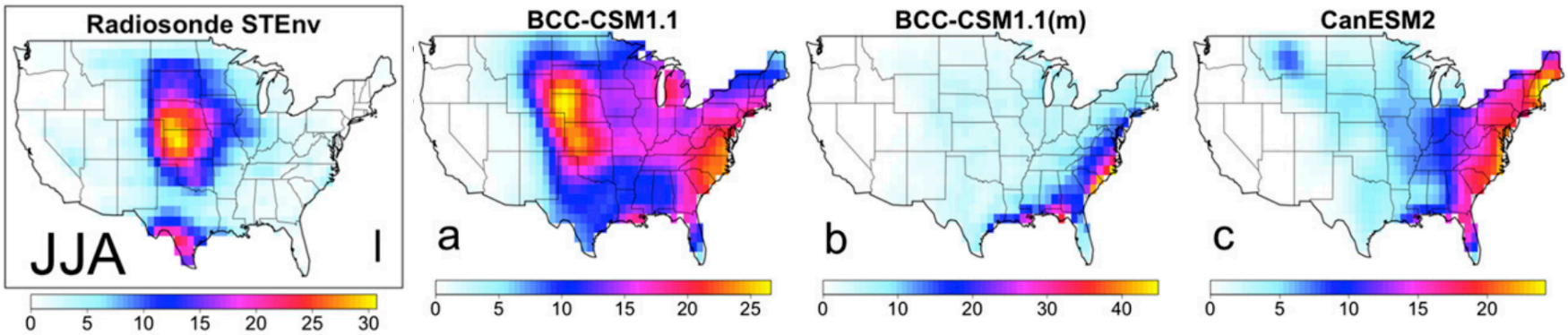


2. Physical Realism: In some locations, seasonal cloud cover (Southern CA), rain (monsoon regions) or land surface dryness (drought in the Southern Plains) are highly influential on daytime high temperature. The CMIP models simulate analogs to these, but reality is much more sophisticated.

Figure Courtesy David Pierce, UCSD-SIO

Example: Will Planting/Growing/Harvest Seasons be Wetter or Drier by 2050?

- The CMIP ensemble can generally estimate the sign of seasonal accumulated precipitation change in the future, for most regions.
- Limitations: Representativeness (same as 90 degree days); Physical realism gets more problematic for precipitation. Example:



Left: Summer average of **observed** potential for severe thunderstoms. **Right**: 3 CMIP **projections** of same quantity.

- For these reasons, **quantitative** changes in precipitation from CMIP **should probably not be** transformed to actionable information without deeper analysis.

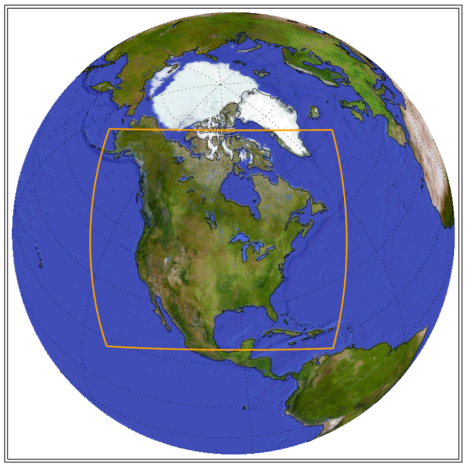
Example: Will 2048 be a wet year or drought?

- A: Impossible to say.
- The CMIP projections represent *probability densities* that account for human activity scenarios and the past/present Earth System.
- The probability of any state changes with time, but following *Chaos Theory* their sequence in time is unknowable more than ~ 2 weeks in the future.

I've Decided my Application Falls in a Grey Area Between 90 F Exceedance and Quantitative Trends in Precipitation. CMIP Cant tell me the whole story, what can I do?

- A: This branch of Climate Science is called "Downscaling"
- Researchers use CMIP models as input and apply full physics models at higher spatial resolution **or** statistical methods to develop higher fidelity information for a sub-region or sub-timespan.
- While CMIP is centralized, downscaling efforts can be more boutique.

Conceptual map of a set of CMIP model boundaries used to generate a downscaling over North America (http://www.cordex.org)



Regional Climate Models

- CORDEX – World Climate Research Programme's Regional Downscaling Group. For North America:

  http://www.cordex.org/domains/region1-north-america/

  Dynamic (full physical differential equations solved forward in time)

  And Statistical downscaling is performed through CORDEX

- North American Regional Climate Change Assessment Program (NARCCAP): http://www.narccap.ucar.edu/

  Functions similarly to CMIP to compare high-resolution, regionally bounded model dynamical projections over North America

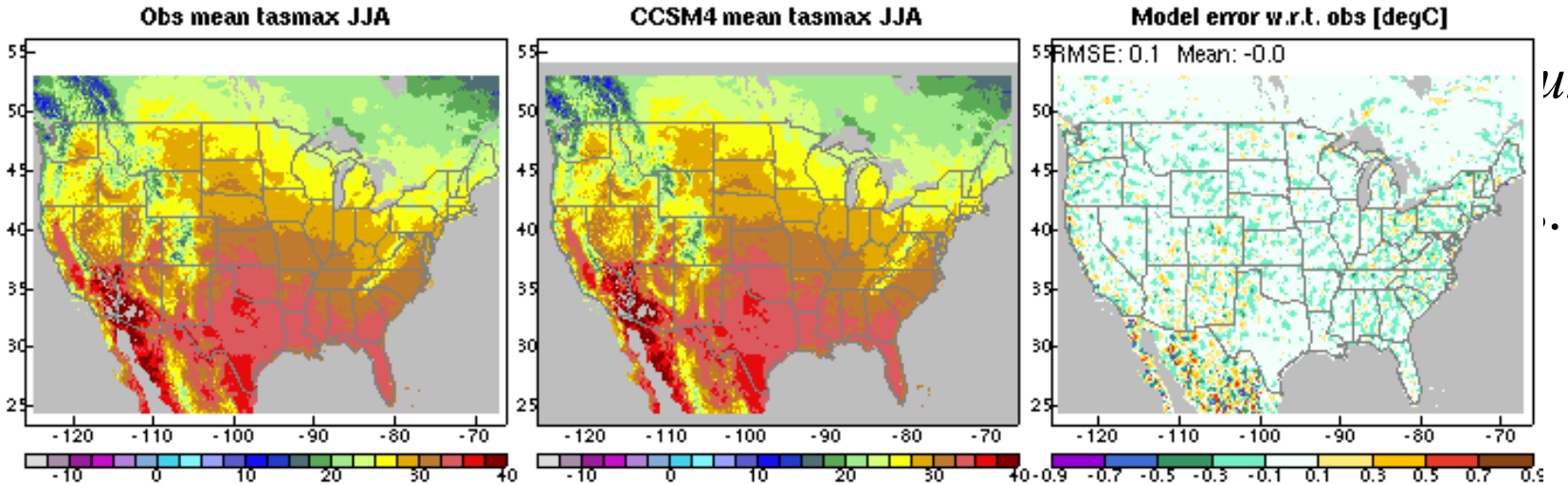
Statistical Downscaling

- Example - LOCA: http://loca.ucsd.edu/what-is-loca/

- A technique to match analog days from the observational record to CMIP projection by searching for similar patterns. Can be applied to long-term weather stations **or** where stations are dense can be used to create gridded maps.

Example of Summer Mean US T_{MAX} from observations (left) and generated by LOCA (middle) all are deg. C

- *um*



Contact Info

- I'm happy to answer questions at anmarti2@pdx.edu

- Affiliated Group Websites for More on Climate and Extremes:
  - Center for Western Weather and Water Extremes @ UC San Diego
    http://cw3e.ucsd.edu/
  - Climate Science Laboratory @ Portland State University
    https://sites.google.com/pdx.edu/portland-state-climate-science/