Climate Scenarios for the California Energy System: Expected Outcomes

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Outline

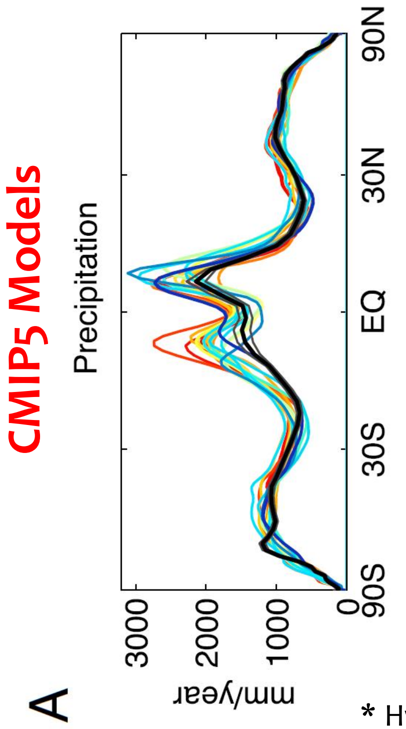
* Background information about global and regional climate models
* Selecting global climate models
* Selecting “representative” climate scenarios for the energy system
* Expected outcomes

Background Information: Global Climate Models

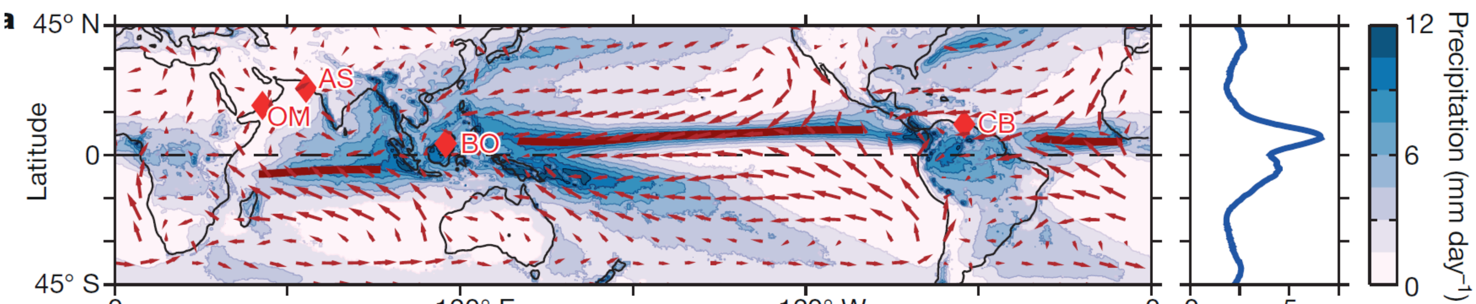
* Global climate models are extraordinarily complex and they do a remarkable job simulating planet Earth
* However, we should be cognizant of their limitations: two examples
  * Artificial double-intertropical convergence zone is a common problem in all the models. It is "perhaps the most significant and most persistent bias of global climate models."
  * The simulation of clouds and, in particular, the interactions of aerosols (small particles in the air) with clouds are not very well represented

Background Information: Global Climate Models

- The artificial double-intertropical convergence zone is “perhaps the most significant and most persistent bias of global climate models.” *



Observations

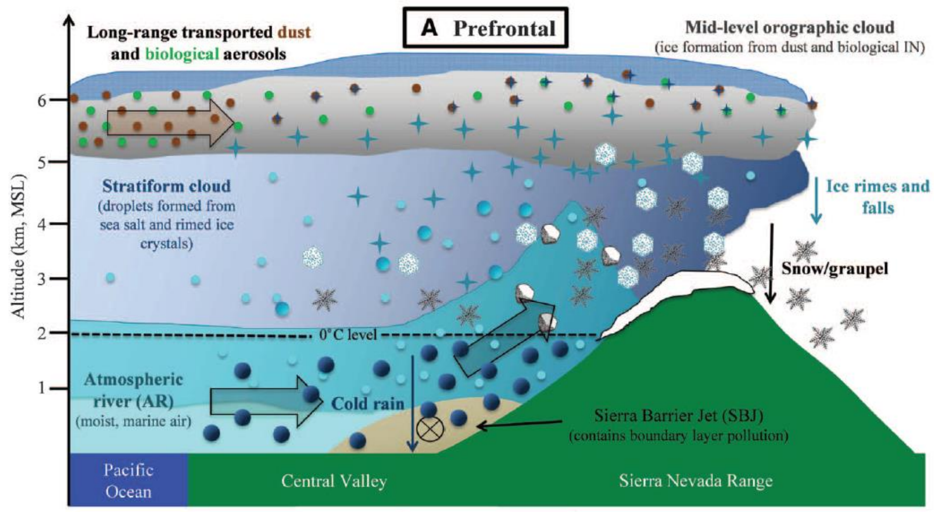


Schneider, Bischoff & Huang. Nature 2014

* Hwang & Frierson, PNAS 2013

Background Information: Global Climate Models

- The simulation of clouds and, in particular, the interactions of aerosols (small particles in the air) with clouds are not very well represented
  - Recent Northern Hemisphere tropical expansion primarily driven by black carbon and tropospheric ozone. Allen, R. J., S. C. Sherwood, et al., Nature 2012
  - CalWater has shown that aerosols from California and transported aloft from Asia and Africa have a major influence on precipitation in California. Creamean et al. Science 2013



Creamean et al., Science 2013

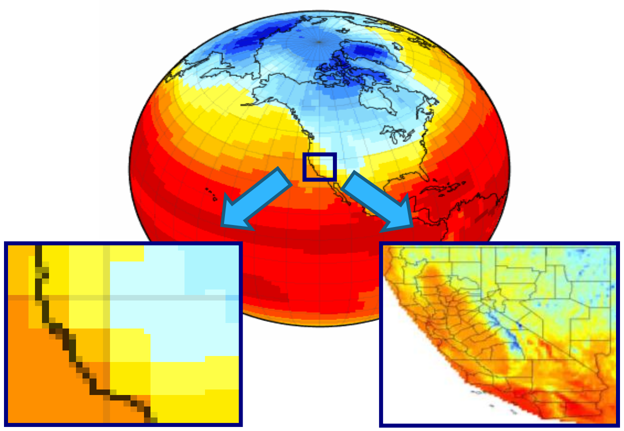
Selecting Global Climate Models

* One option is to select the best performing models, but we face the following problems:
  * What are the appropriate metrics? We get different results depending on the evaluation method/metric used
  * The historical period may be too short
  * Models can be "right" for the wrong reasons
* For practical reasons, however, researchers studying impacts/adaptation can only handle a handful of scenarios. The Climate Change Technical Advisory Group created by DWR has selected 10 global climate models. Thank you!

Regional Climate Models

Lessons from prior work for California*

- Statistical regional climate models, by design, reproduce historical conditions very well. However, we don't know if the statistical relationships are valid under future conditions
- Dynamic regional climate models produce serious biases if driven directly by boundary conditions provided by the global climate models



Franco & Pittiglio
Data Sources: Scripps and CMIP3

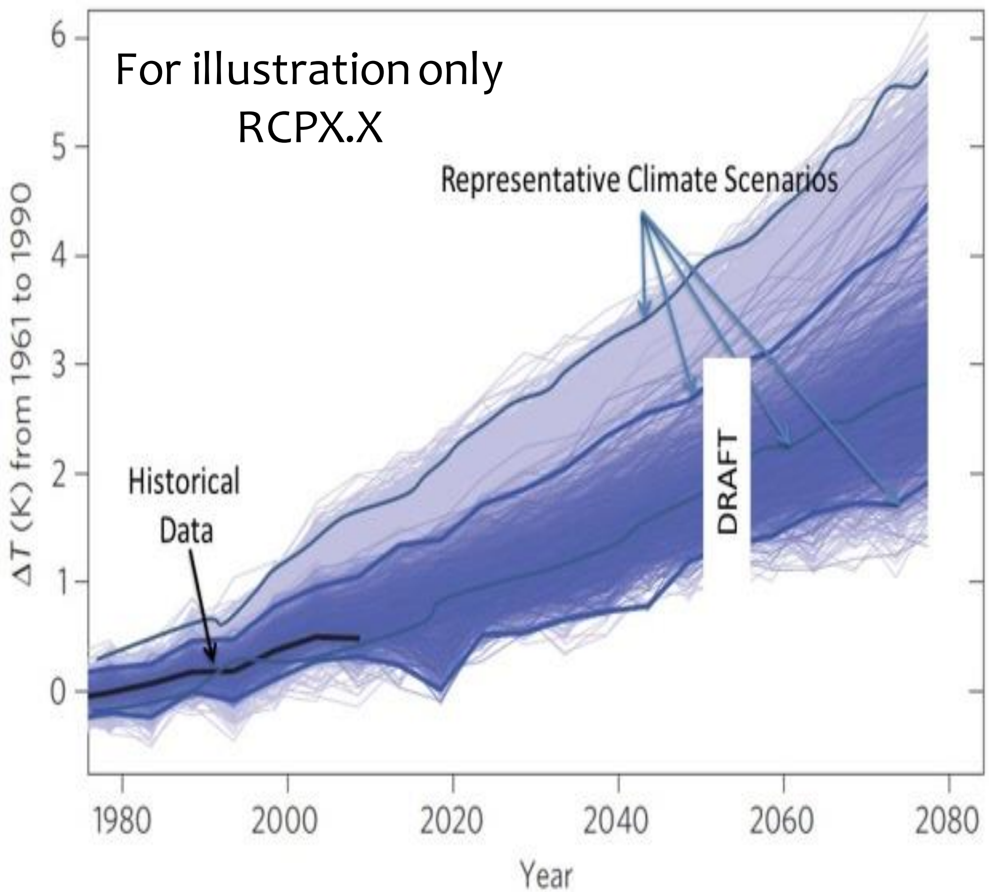
* See 1) Pierce, D. W. et al., 2013: Probabilistic estimates of future changes in California temperature and precipitation using statistical and dynamical downscaling. Climate Dynamics, v. 40, 839-856. doi 10.1007/s00382-012-1337-9; 2) CAT Climate Change Research Plan 2015: Appendix by Franco (CEC) and Anderson (DWR).

Desired characteristics of climate scenarios for the energy system

- **Electricity and natural gas demand**
  - Minimum and maximum daily temperatures, with spatial distribution of T fields
  - Relative humidity
  - Delta Breeze and other regional phenomena
- **Hydropower generation**
  - Meteorological and hydrological parameters that determine streamflows (e.g., precipitation, solar radiation) and reservoir storage
  - Daily and, if possible, hourly streamflows in areas if importance for power generation (at more than 12 locations)
- **Wind power**
  - Wind fields with sufficient spatial and temporal resolution to gauge impacts to wind generation, i.e., winds at 80 m, in the range of importance for wind turbines.
- **Solar energy**
  - Ground-level solar radiation
- **Bioenergy**
  - Suite of additional parameters (e.g., soil moisture, RH, solar radiation, wind fields)
- **Large-scale (utility-scale) solar and wind**
  - Perhaps higher spatial and temporal resolution (e.g., DRECP is using climate scenarios to estimate ecological impacts)

Selecting "representative" climate scenarios for the energy system

- Let's assume for a moment that we have a perfect downscaling technique
- The representative climate scenarios should span the range of all the downscaled CMIP5 scenarios. But for what parameters? Only temperature and precipitation? The entire State? Climatic zones?



Selecting "representative" climate scenarios for the energy system (cont.)

* But there is no such a thing as a perfect downscaling technique. What shall we do?
* One approach is to use as many downscaling techniques as possible, but this can tremendously increase the number of scenarios.
* We can select downscaling techniques that simulate well extreme events, produce realistic distribution of precipitation, can handle multiple variables, etc. **LOCA** satisfies these requirements.
* We can also use dynamic downscaling techniques that correct the substantial biases produced by these models when driven directly by the outputs from global climate models (Alex Hall's work).

Does CMIP5 define the potential range of outcomes very well?

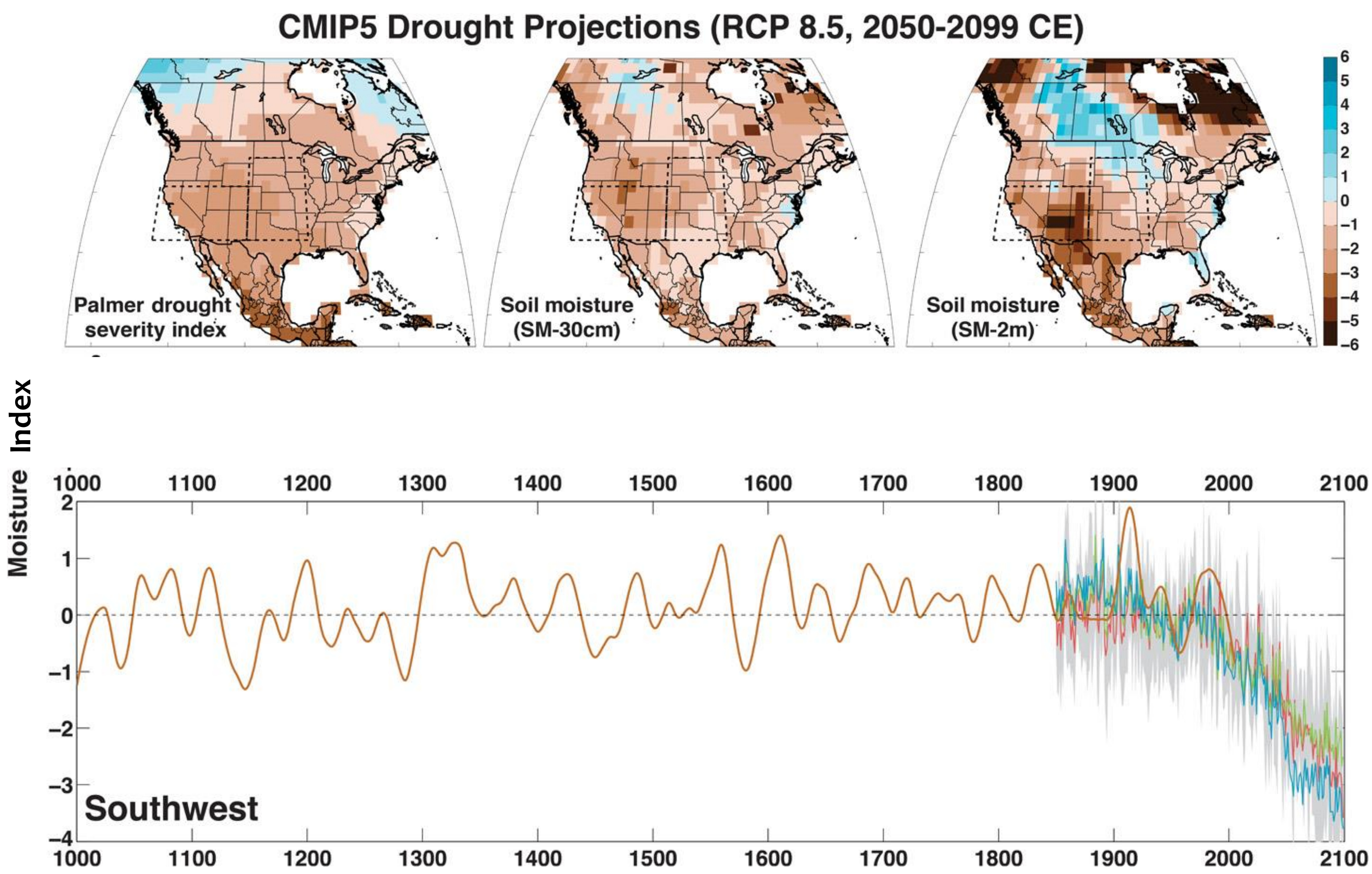
* **Tentatively YES for temperature but it seems like the answer is NO for precipitation**
  * Presentation by Dr. Mark Snyder last May suggests that the global climate models can produce prolong droughts, but long integration times are needed (1000 years+).
  * Ault et al., 2014 argue that there are not enough CMIP5 runs
  * However, CMIP5 shows an increased risk of prolonged droughts if we look at metrics such as soil moisture (Cook et al., 2015)

Ault et al., 2014. Assessing the risk of persistent drought using climate model simulations and paleoclimate data. JCLIM

Top: Multimodel mean summer (JJA) PDSI and standardized soil moisture (SM-30cm and SM-2m) over North America for 2050–2099 from 17 CMIP5 model projections using the RCP 8.5 emissions scenario.SM-30cm and SM-2m are standardized to the same mean and variance ...

Adapted from

Science Advances

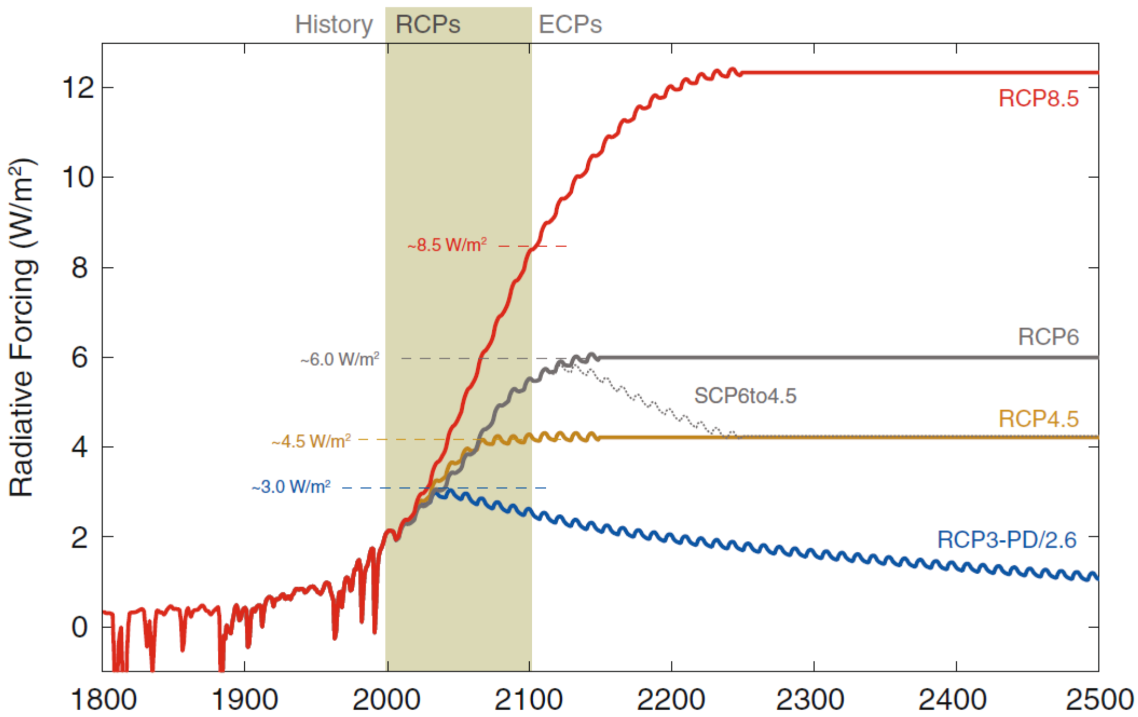


Benjamin I. Cook et al. SciAdv 2015;1:e1400082

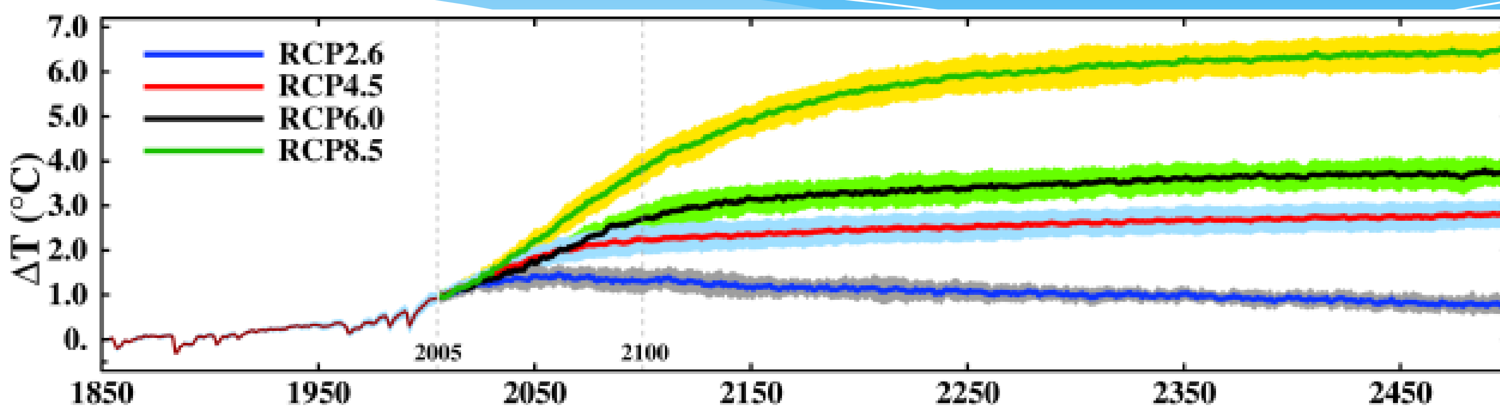
Representative (Global) Concentration Pathways (RCPs)

[Climatic Change](#)
November 2011, Volume 109, [Issue 1-2](#), pp 213-241

- New global "emission" scenarios from the IPCC
- We will **not** use RCP6
- We will use RCP8.5 and RCP4.5 and explore RCP2.6



Are we committed to a certain level of warming in the next 30 years?



Future climate change under RCP emission scenarios with GISS ModelE2

- Global annual mean surface air temperature anomalies relative to 1850–1880 base period for all RCP scenarios
- Historical period ends in 2005
- It looks like all the models produce more or less the same warming for about 30 years after 2005. As was done by Pierce et al. 2013, shall we assume that for the next 35 yrs the scenarios do not depend on the RCPs? Yes for RCP4.5 and RCP8.5

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Climate Scenarios for the Energy Sector: expected outcomes

* Downscaling using LOCA for temperature and precipitation (David Pierce's presentation). Future results for at least relative humidity and wind fields
* Hydrological modeling using the most recent version of the Variable Infiltration Model (VIC) (Pierce). Scripps will add up to 12 sites where streamflows will be estimated. We need your input.
* Dynamic downscaling (Alex Hall). Late this year.
* Most used outputs to be available via Cal-Adapt (UC Berkeley and Susan Wilhelm)
* "Probabilistic" sea level rise projections (Dan Cayan)
* Wildfire scenarios (Westerling - UC Merced; David Stoms) – Late this year to 2nd quarter in 2016.
* All the scenarios to be available soon after the energy part of California's Fourth Climate Change Assessment starts its research activities. Scenarios will be available for the non-energy part of the Assessment

Thank you!

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