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Modeling the Impacts of Climate Change on Crop Production

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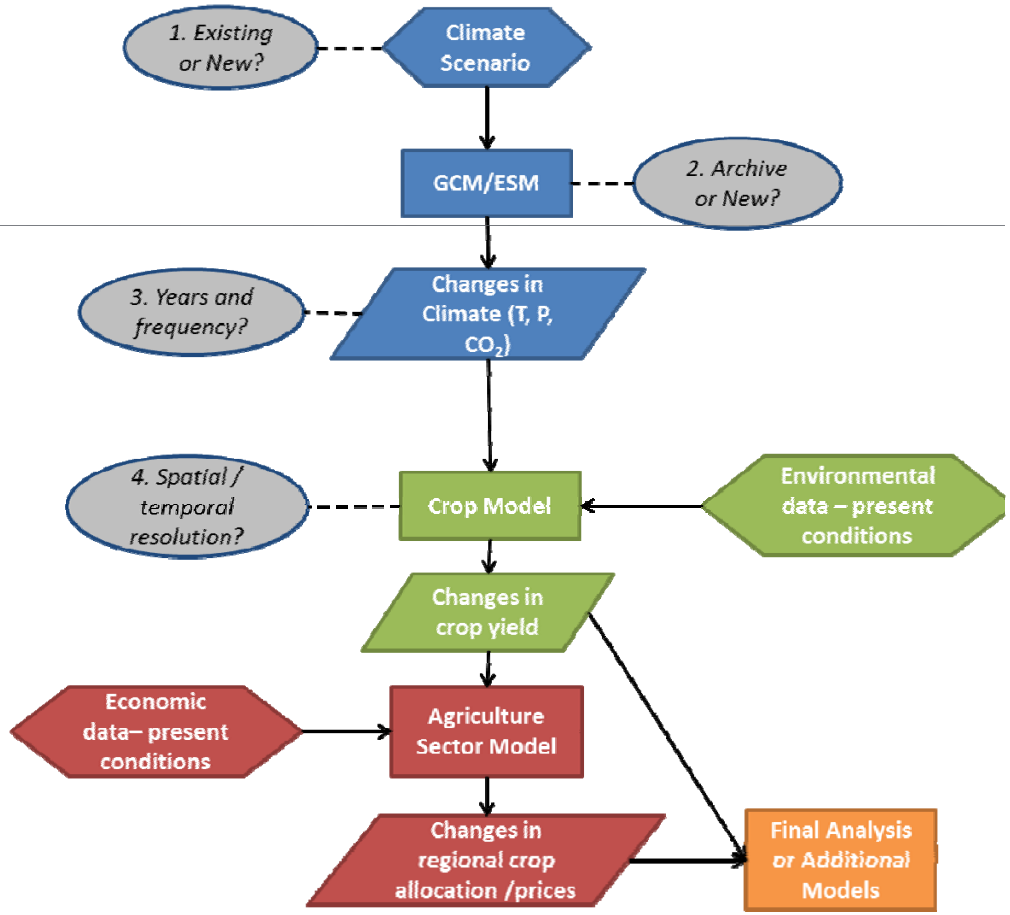
Methodology for Agricultural Impacts Assessments

- Start with scenarios of future climate
  - Baseline: historical conditions
  - Reference: Future projection with no climate policy
  - Mitigation: Future projection with some climate policy
- Acquire projections of key climate variables from these scenarios
  - Direct from climate modelers or from archives
- Conduct simulations in a crop model
- This requires developing appropriate datasets for environmental conditions and management practices in the future
  - Adaptation?
  - Spatial scale and extent?
  - Time period and frequency?

Schematic of models and data for decision support applications and the key questions for stakeholder discussion



Overview of Climate Scenarios

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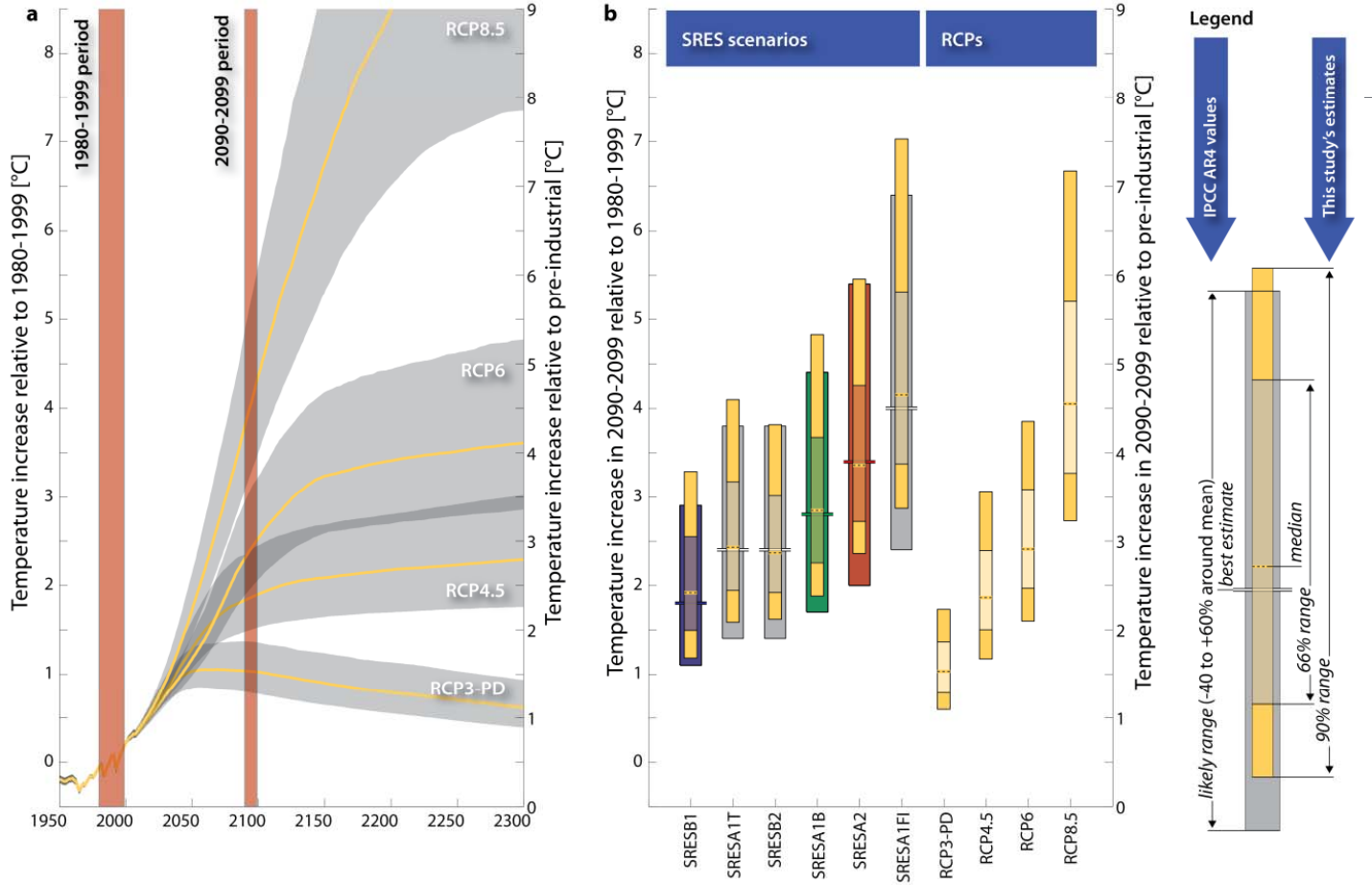
- Main source of future climate scenarios is the Coupled Model Intercomparison Project
  - Coordinated future climate model projections based on scenarios of future human activities from Integrated Assessment Models
  - IS92A, SRES, RCP: refer to different sets of future scenarios assessed by the IPCC



Scenarios are run through dozens of GCMs and ESMs

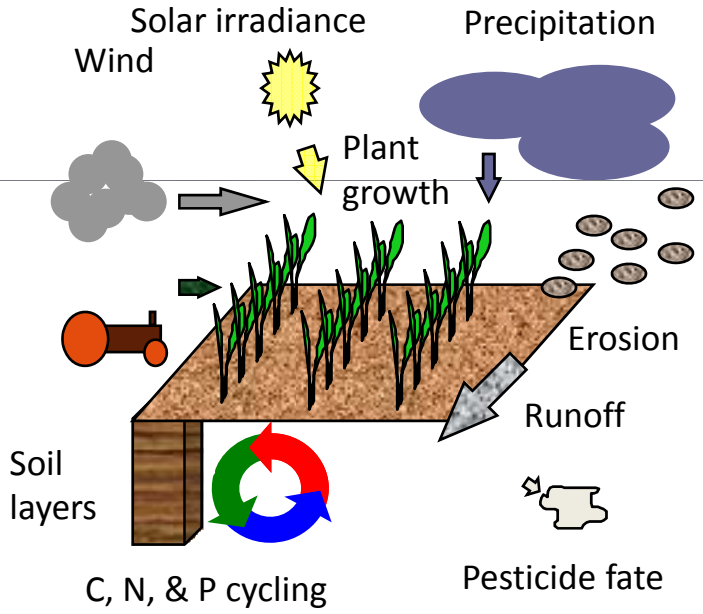
Individual model and ensemble outputs can be used

From Tebaldi et al.

Application of Crop Models to Climate Impacts

- Apply EPIC to assess changes in potential productivity:
  - Grow the crop across the entire region of interest
  - Look at relative changes in crop yields between:
    - Present and future
    - Reference and mitigation scenarios
- Crop model applications are data intensive
  - Spatially explicit **data** on soils, management and other environmental conditions needed for regional analysis
  - **Validation** of the modeling system using historical weather and statistics is critical for assigning confidence to impacts studies

EPIC is a process-based model built to describe climate-soil-management interactions at point or small watershed scales



Representative EPIC modules

Climate Impact Modeling

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- Sources of uncertainty:
  - GCMs and ESMs can vary widely in projections of climate under the same scenarios
  - Recent results show that different crop models are even more variable in their projections of yield using the same climate data
- Eastern China Agricultural Vulnerability
  - Simulate a baseline (1960-1990)and future period using SRES A2 scenario for 2071-2099
- USA Climate Impacts for Risk Analysis
  - Simulate alternative reference and mitigation futures across present day cropping regions
  - Part of a coordinated EPA project to assess the avoided impacts from climate mitigation
- Agricultural Model Inter-comparison Project: Global Gridded Crop Model (GGCM) study

Eastern China: Regional crop production under climate change

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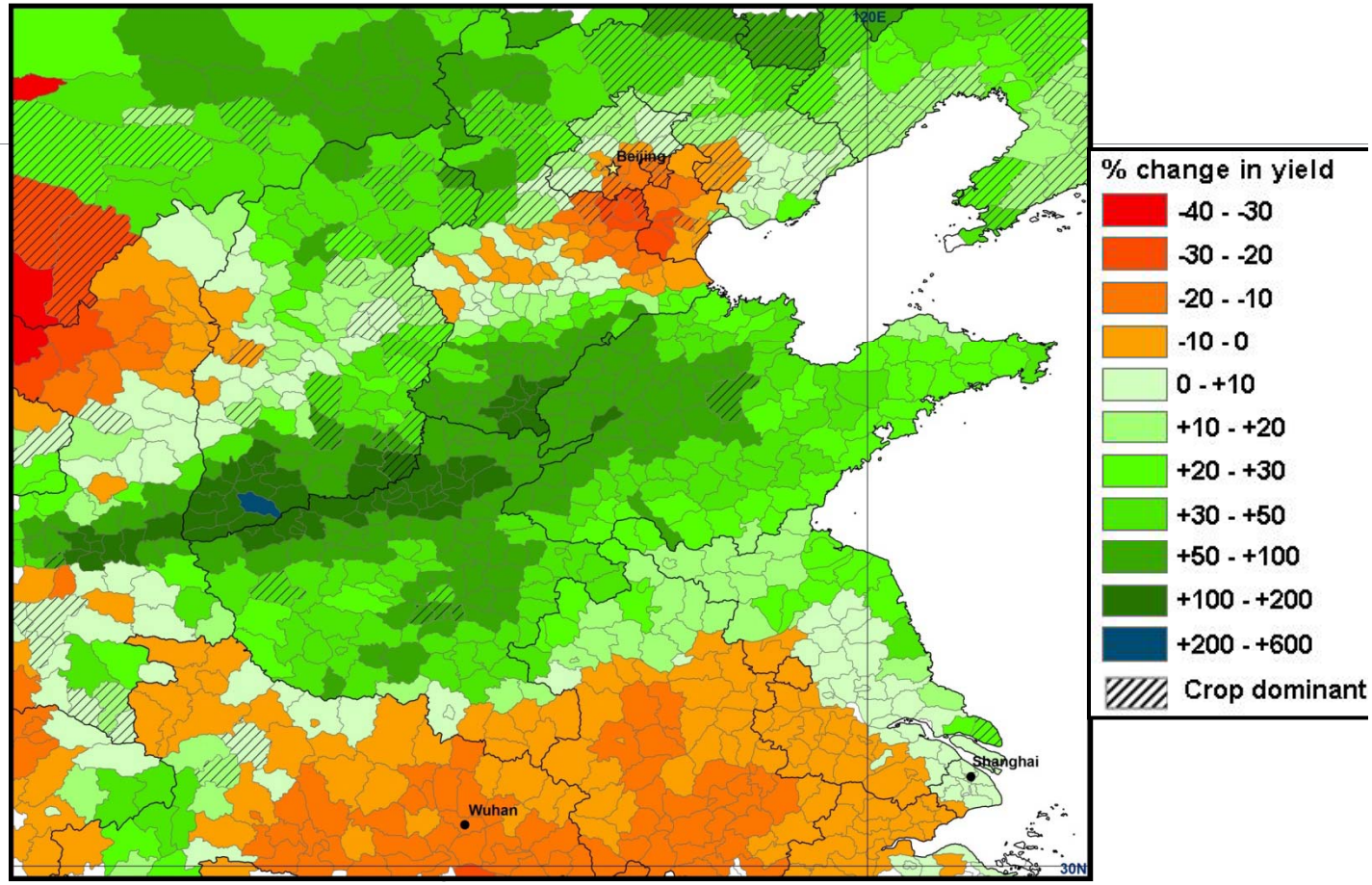
- Climate projection from a Regional Climate Model simulation over China
- SRES A2 scenario: CO_2 increases to 850 ppmv by 2100

Corn yield change: Future – baseline

Used to determine **emergent** production regions or current regions that are **vulnerable** to climate change

Baseline = 1960-1990
Future = 2071-2100



From Chavas et al., 2008

USA: Regional Wheat Yield Difference Due to Climate Policy

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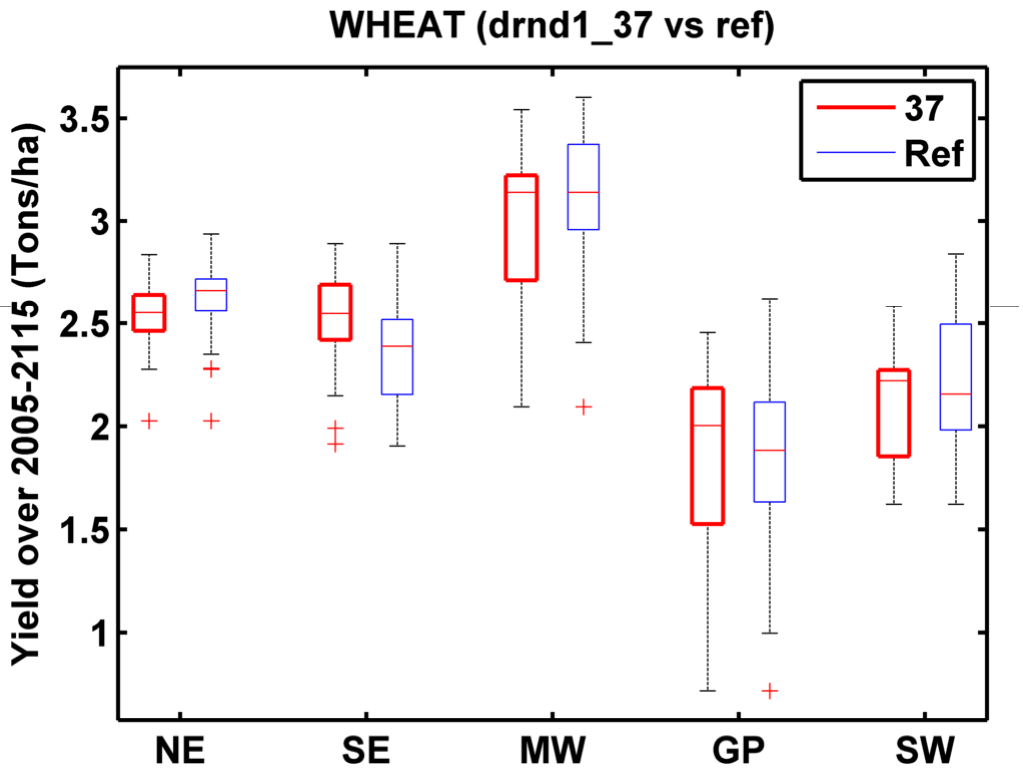
- Applied two customized scenarios from a climate model
  - Reference (no climate policy) – GMT rises by ~4 C by 2100
  - Mitigation 3.7 – GMT rise limited to 2.2 C by 2100
- Simulations with EPIC for present day and extended growing regions in the US
- Results illustrate the consequences of climate mitigation for crop production



AgMIP – Recent community developments

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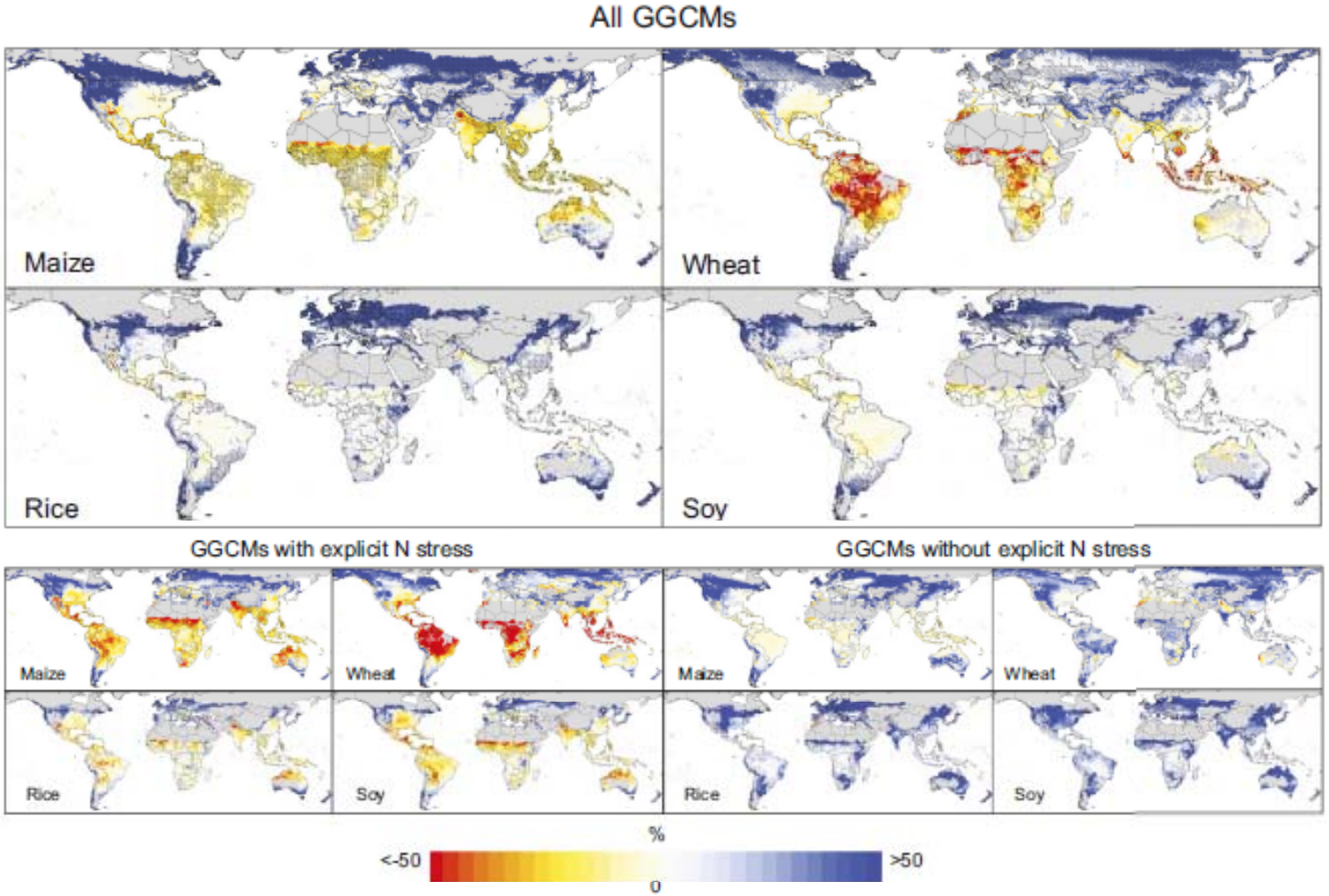

Fig. 3. Median yield changes (%) for RCP8.5 (2070–2099 in comparison to 1980–2010 baseline) with CO_2 effects over all five GCMs x seven GGCMs (6 GGCMs for rice) for rainfed maize (35 ensemble members), wheat (35 ensemble members), rice (30 ensemble members), and soy (35 ensemble members). Hatching indicates areas where more than 70% of the ensemble members agree on the directionality of the impact factor. Gray areas indicate historical areas with little to no yield capacity. The bottom 8 panels show the corresponding yield change patterns over all five GCMs x four GGCMs with nitrogen stress (20 ensemble members from EPIC, GEPIC, pDSSAT, and PEGASUS; except for rice which has 15) (*Left*); and 3 GGCMs without nitrogen stress (15 ensemble members from GAEZ-IMAGE, LPJ-GUESS, and LPJmL).

Resources for scientists

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- Many available crop models can be used in impact studies
- AgMIP: http://www.agmip.org
  - Includes links to publications and information on how to get involved
- The IPCC Data Distribution Center: http://www.ipcc-data.org/
  - Guidelines for Impacts Assessments
- NARCCAP: http://www.narccap.ucar.edu/
  - Regional Climate Data
- CMIP-PCMDI: http://cmip-pcmdi.llnl.gov/
  - Future climate model projections