# CGRA Climate

## Historical Data, Scenarios, and Extreme Events

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AgMIP The Agricultural Model Intercomparison and Improvement Project

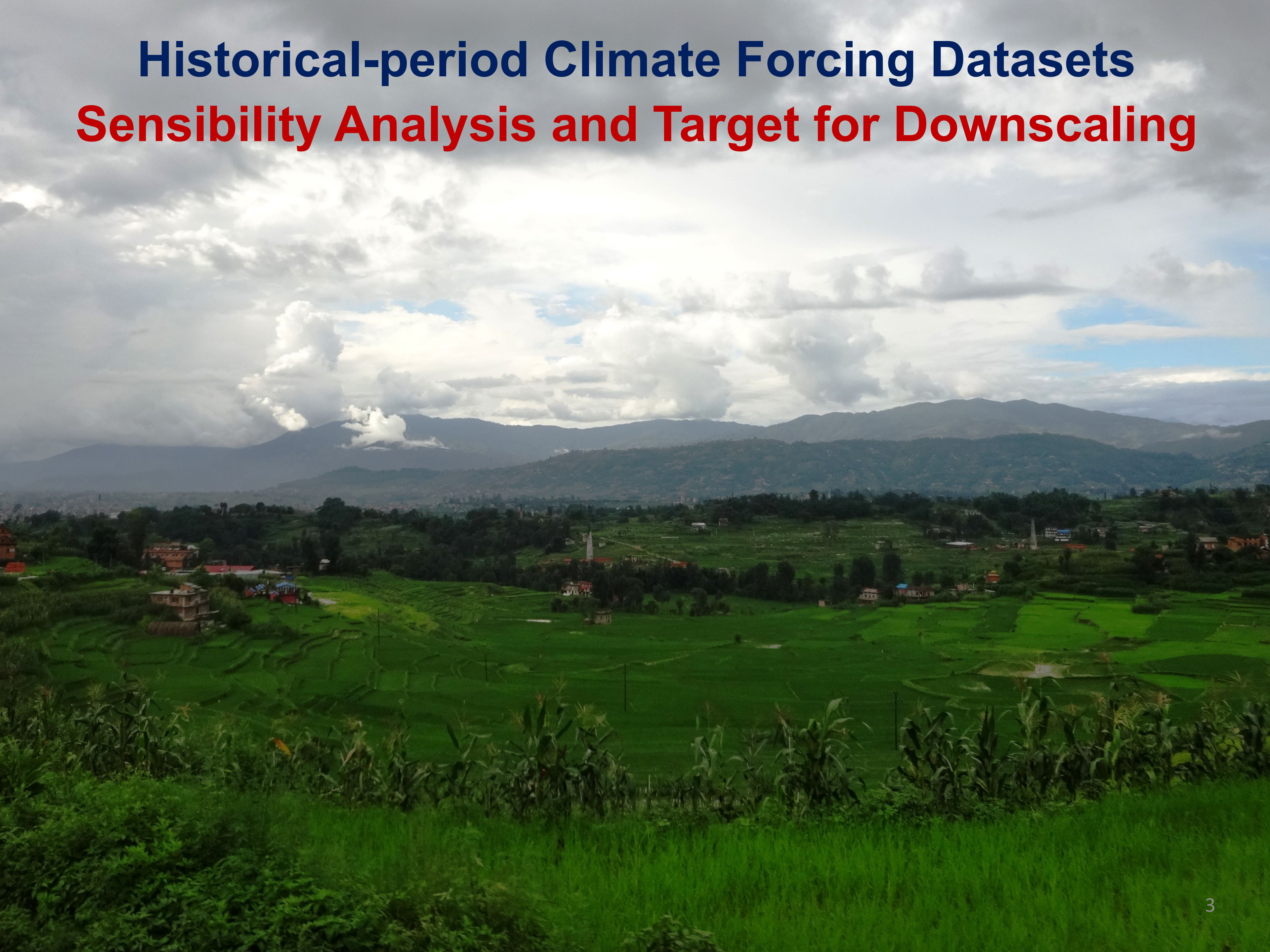
# Continuum of Climate Time Periods of Interest

| | 1980 | 2015 | 2040 | 2070 | 2100 |
|---|---|---|---|---|---|
| Pre-Satellite Era | Satellite Era | Near-term | Mid-Century | End-of-Century | Distant Future |

- **Pre-Satellite era**: Uncertainty stems from distribution of observational stations and data loss over the years
- **Satellite era**: Improvement in observational coverage and reduction in uncertainty, particularly in areas of low observational density (e.g., many developing countries).
- **Near-term**: Climate variability dominates over climate change, low skill in prediction of this variability
- **Mid-Century**: Climate change signal begins to emerge from climate variability
- **End-of-Century**: Mitigation regimes really separate out climate signal (large differences between RCPs)
- **Distant Future**: Time doesn't stop in 2100!  Difficult to create societal scenarios and expect economic simulations to run this far out

# Historical-period Climate Forcing Datasets

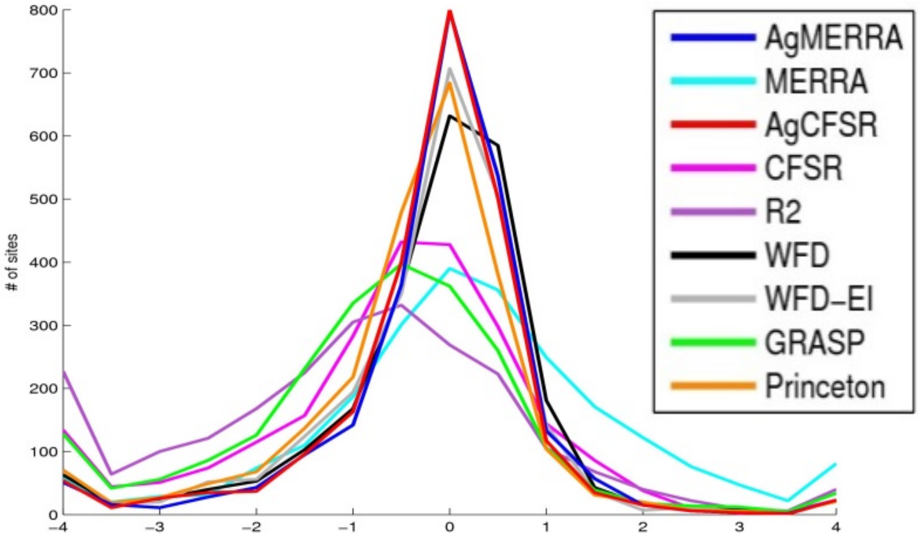
## Sensibility Analysis and Target for Downscaling



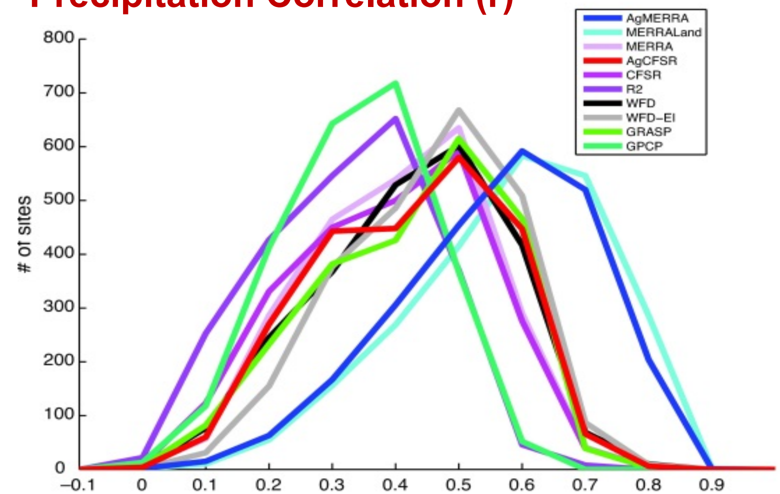
# AgMERRA Historical Climate Data

## Global land, 0.25$^0$x0.25$^0$, daily from 1980-2010

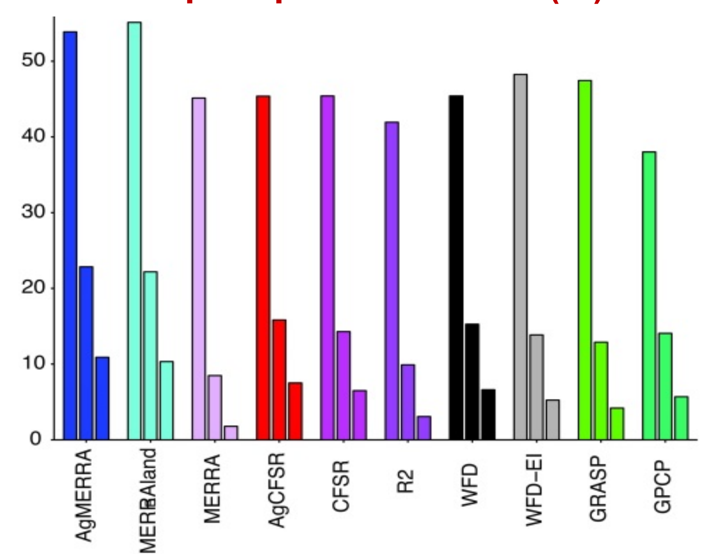
**Avg of Tmax and Tmin Biases ($^0$C)**




**Precipitation Correlation (r)**




**Threat score for 1, 25, and 50mm precipitation events (%)**



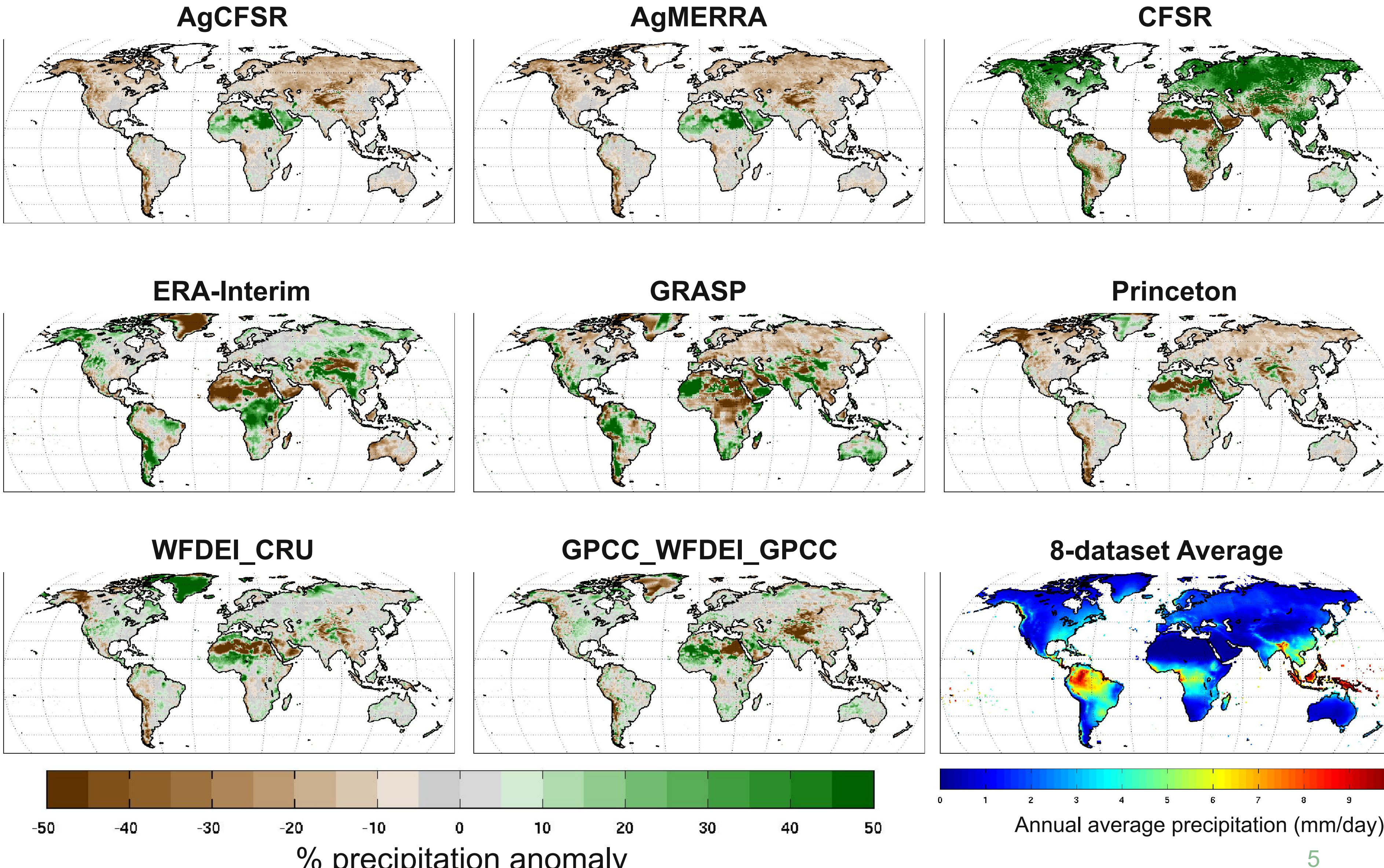

**AgMERRA and AgCFSR features:**

- ➢**improved solar radiation**
- ➢**Improved precipitation variability**
- ➢**fine spatial patterns of rainfall from satellites**
- ➢**an adjustment to diurnal temperature range**
- ➢**relative humidity at Tmax**

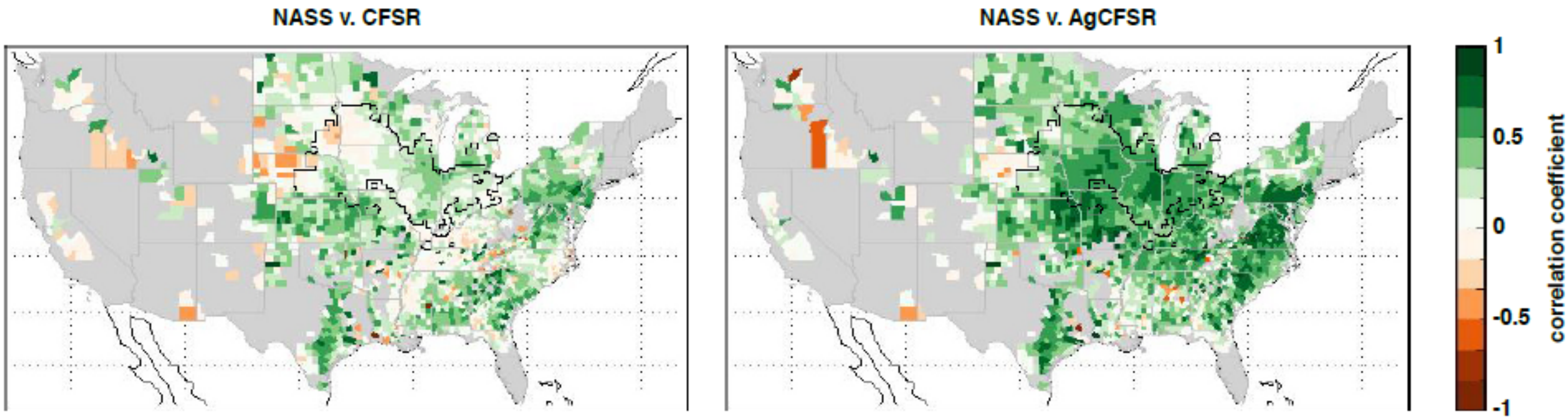
- **Tools developed to easily create .AgMIP-formatted time series**
- **Bias correction and gap-filling applications protocols developed and demonstrated.**

**http://data.giss.nasa.gov/impacts/agmipcf**

# Differences in Climate Datasets
## Mean Precipitation (mm/day)

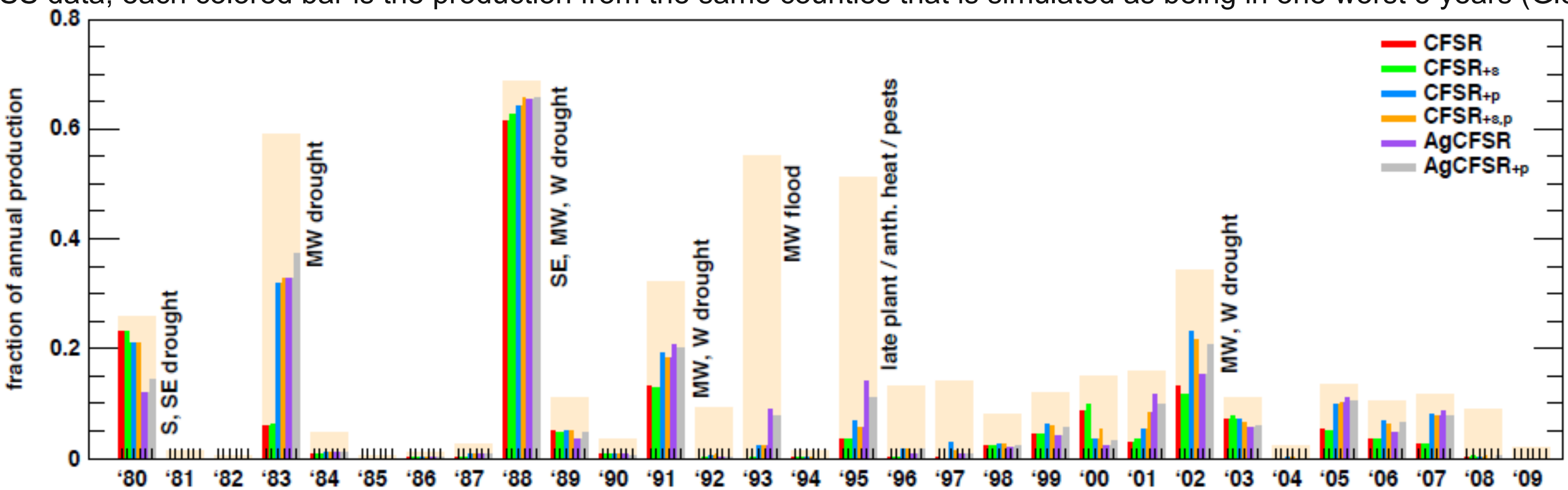


# AgCFSR vs. CFSR in US Maize



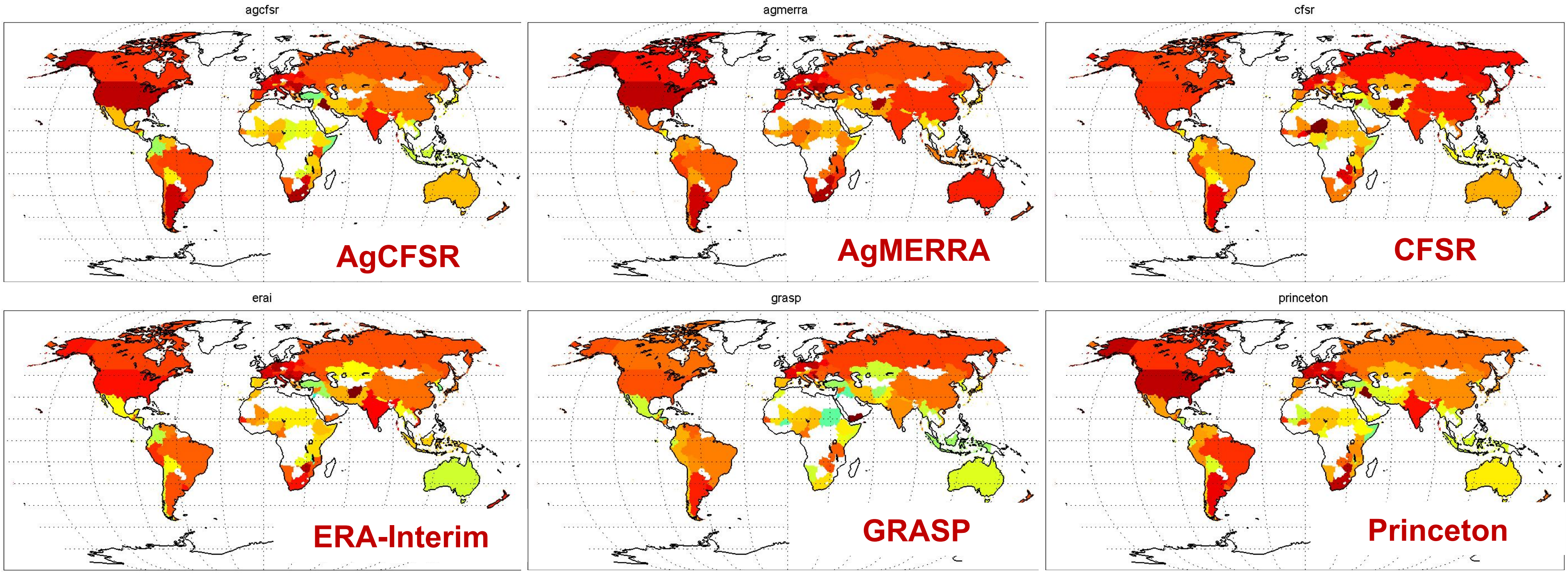

**Above**: Correlations between NASS County-level production and that simulated by pDSSAT using CFSR (left) and AgCFSR (right) climate data (from Glotter et al., in preparation)

**Below**: Probability of detecting extreme events. Tan bar shows fraction of US maize production experiencing one of 5 worst years in NASS data, each colored bar is the production from the same counties that is simulated as being in one worst 5 years (Glotter et al.)



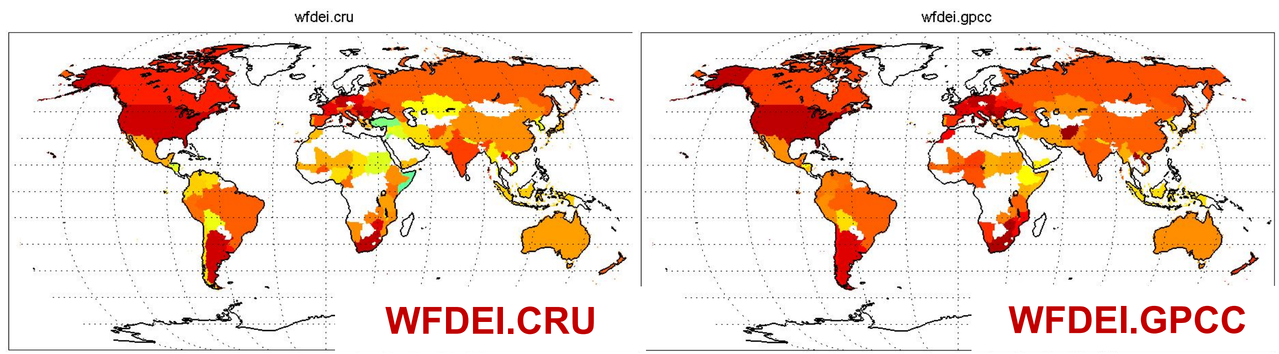
# Differences in Climate Datasets

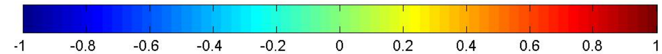
## Correlation (r) of Simulated Maize Yield with FAO Data




**Highest correlation for each country shown from ensemble of 7 GGCMs**

Scenario: default
Time range: 1980-2009

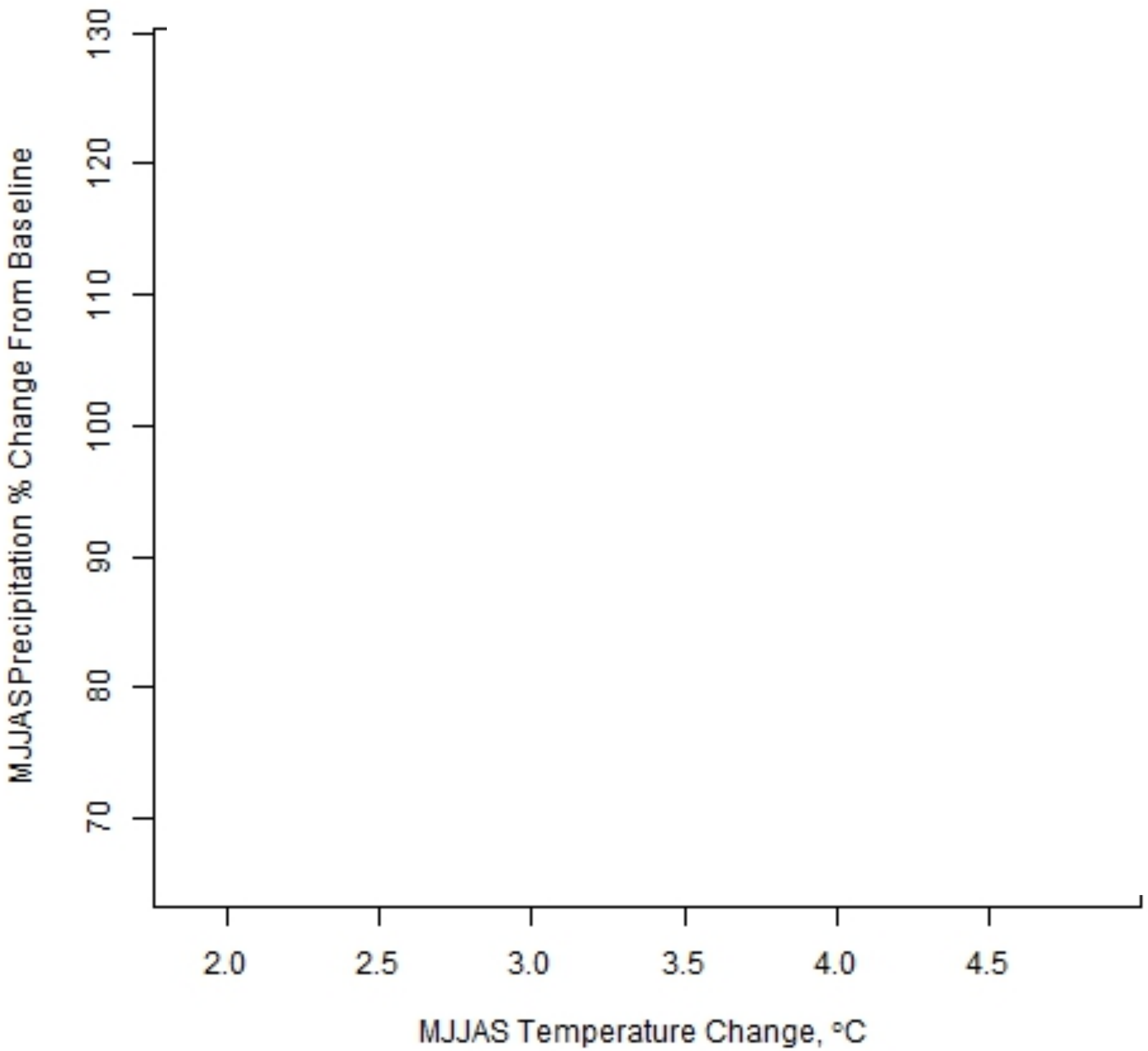



Correlation (r)
between simulated crop yields and FAO yield data

# Climate Scenarios for Integrated Assessment

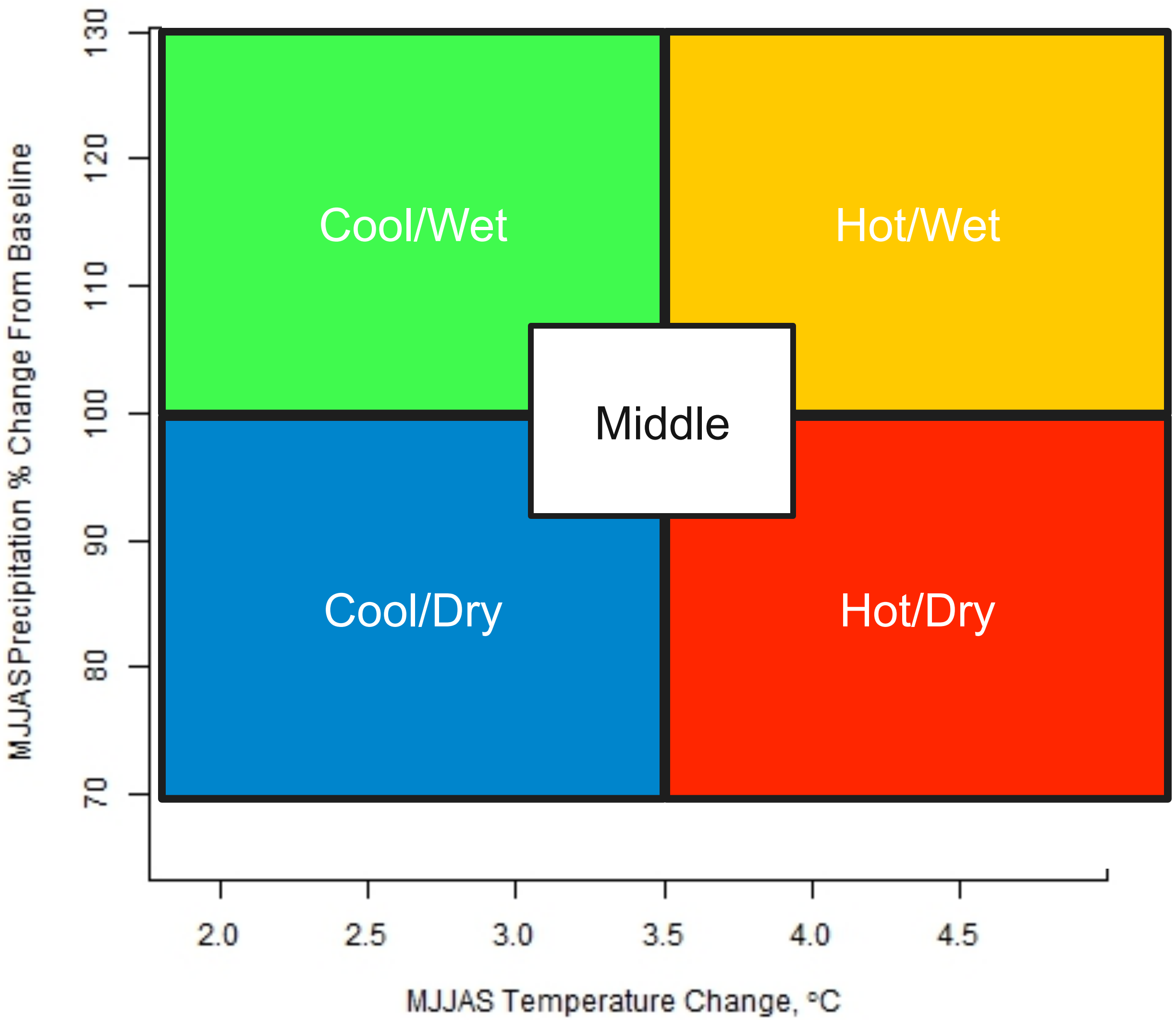
# Selecting 5 GCMs for full analysis




**Focus on Mid-Century as this includes climate changes that we can distinguish from climate variability**

**Basic approach is to choose 5 GCMs that represent the full ensemble of GCM projected changes in temperature and rainfall within growing season.**

# Selecting 5 GCMs for full analysis

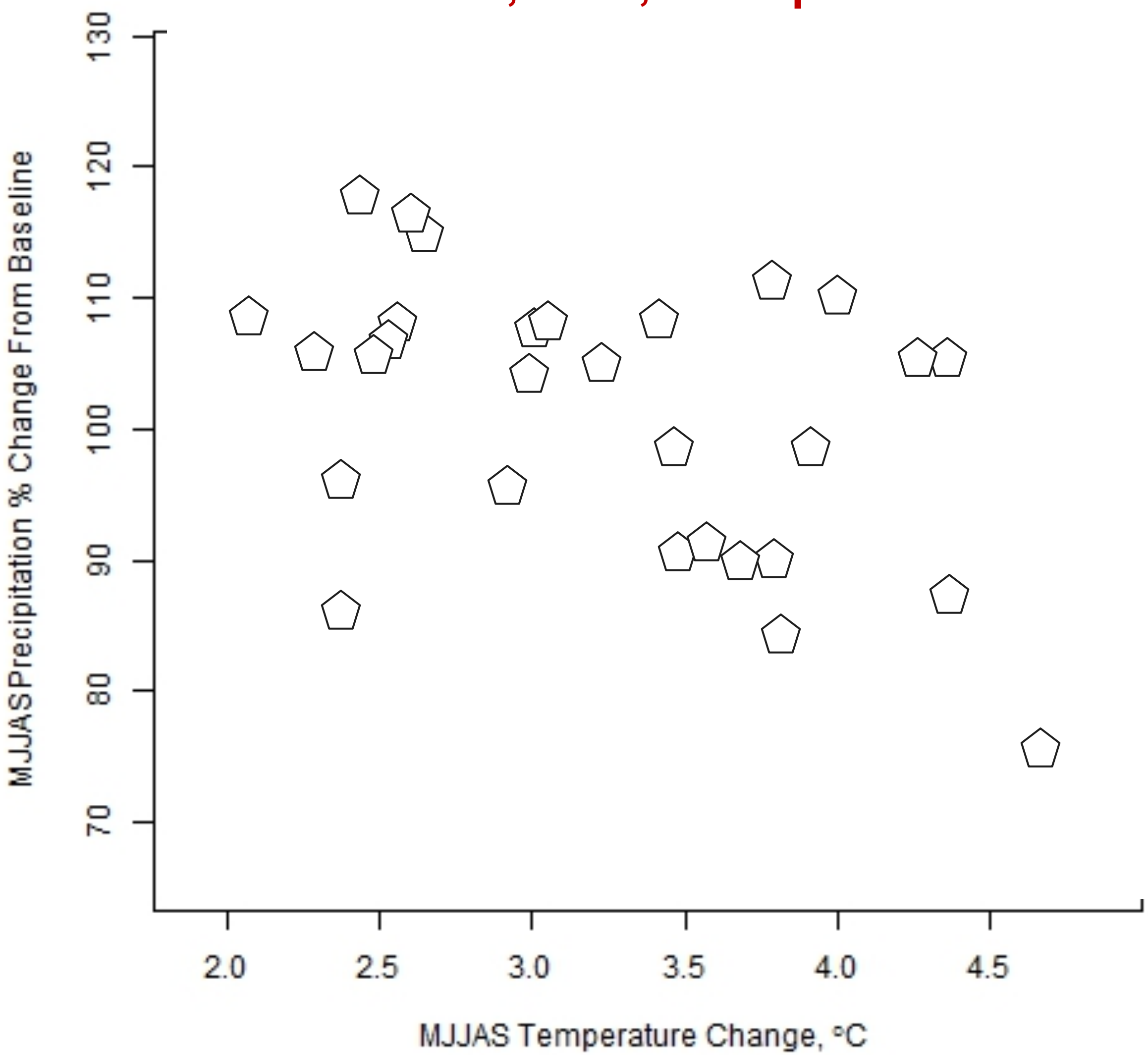



**Identify 5 types of relative change:**

**Middle**
**Cool/Wet**
**Cool/Dry**
**Hot/Wet**
**Hot/Dry**

# Selecting 5 GCMs for full analysis

## Ames, Iowa, Example




**Look at spread of GCMs to understand basic response within growing season (using Ames, USA, Example – MJJAS = May-Sept.)**

**29 CMIP5 GCMs from RCP8.5 Mid-Century**

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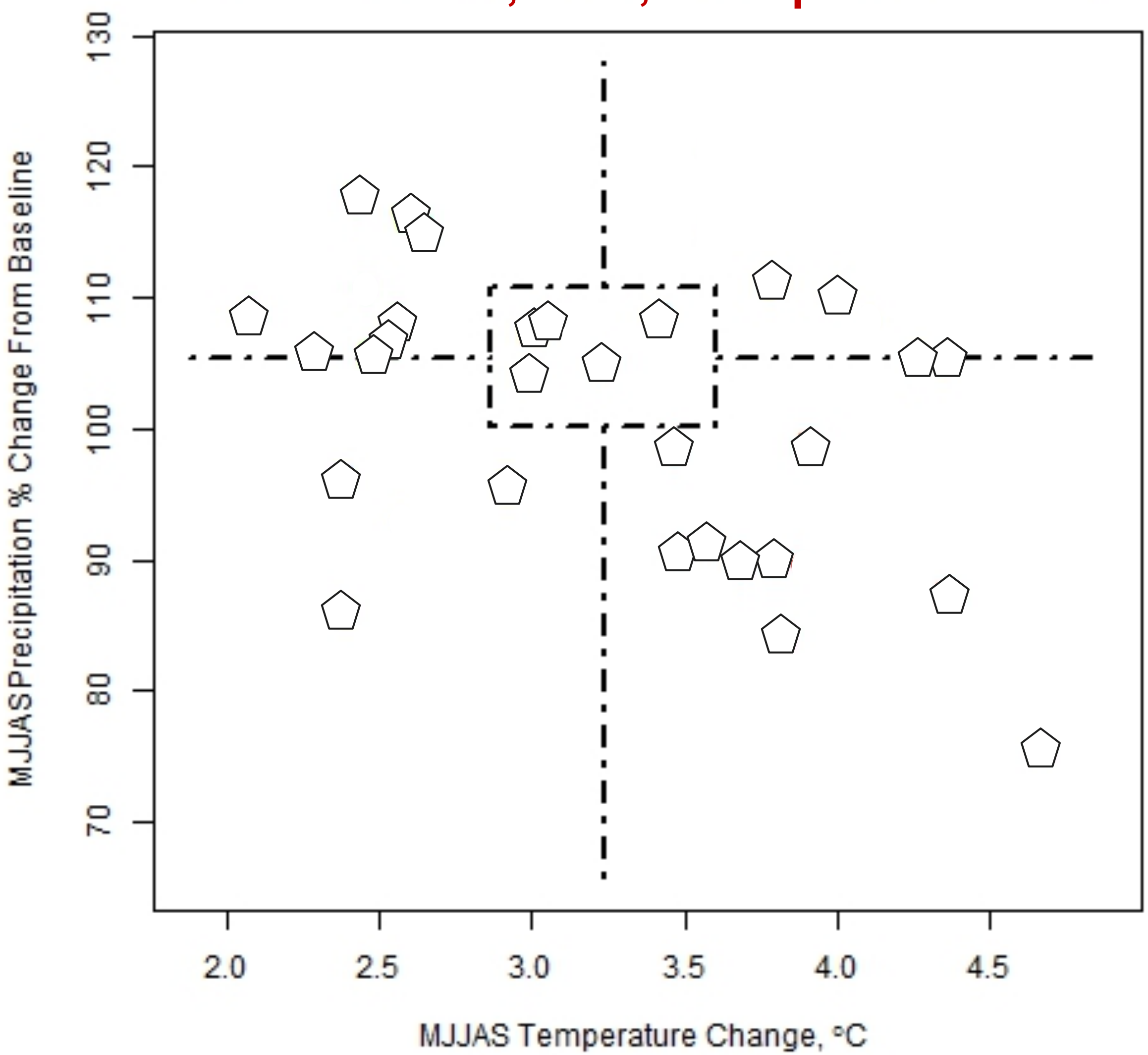
# Selecting 5 GCMs for full analysis

## Ames, Iowa, Example



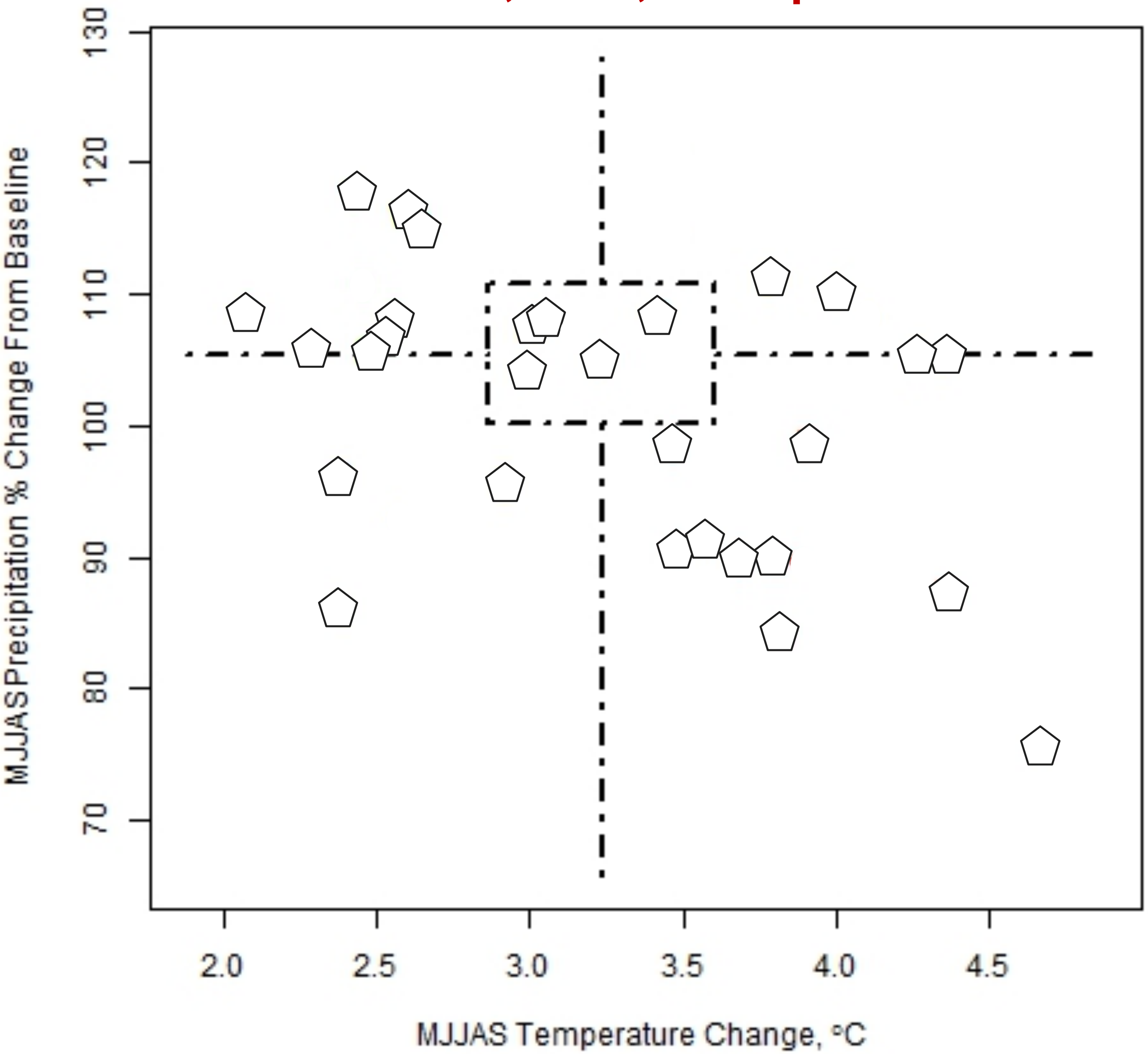

**Identify median temperature and precipitation changes to define hot/cool or wet/dry as relative from middle of GCM projections**

**Middle section is one standard deviation wide in each direction.**

- Note that this is relative warming and relative dryness.
- Compares against median of all models, not current period.

# Selecting 5 GCMs for full analysis

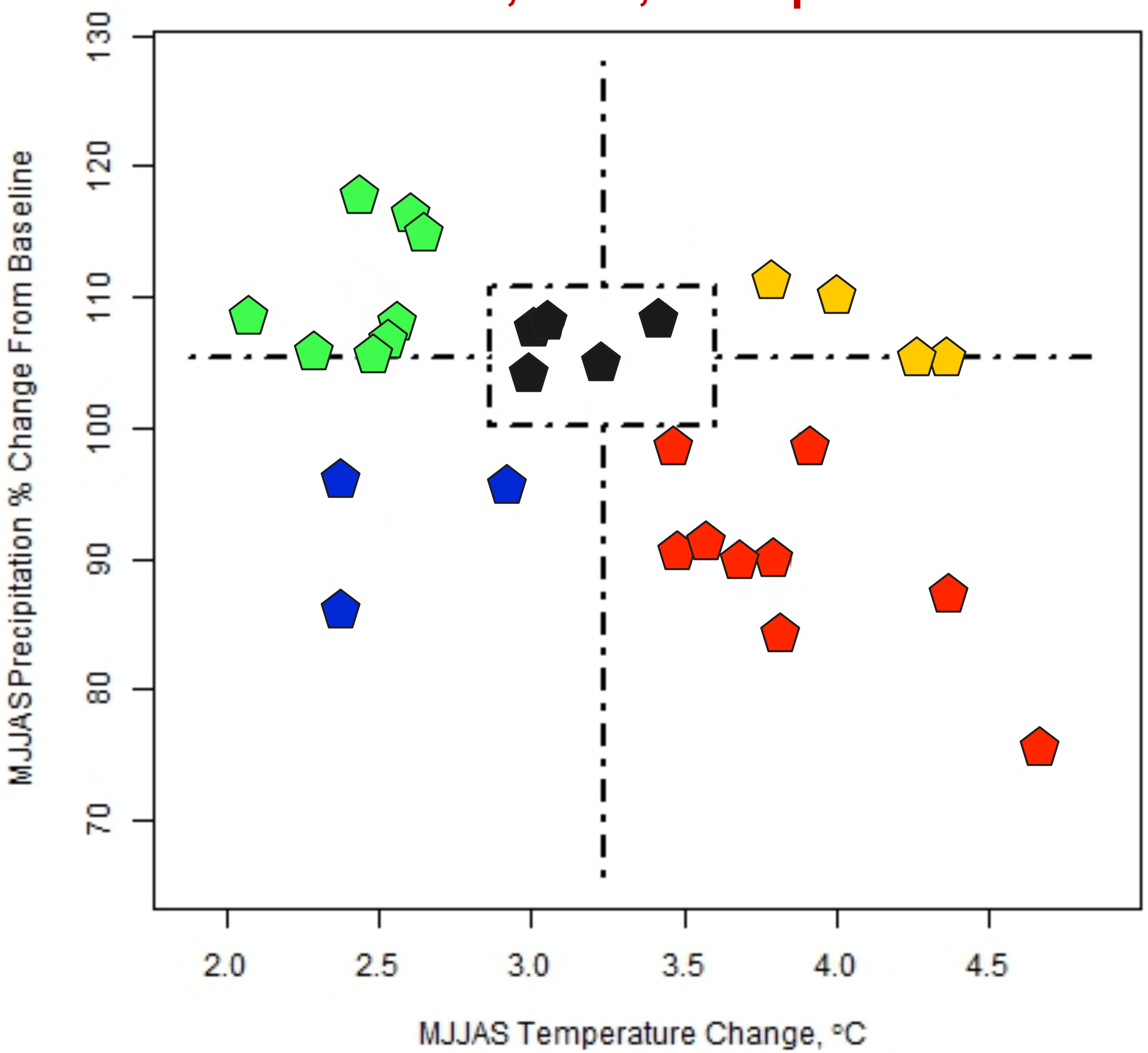
**Ames, Iowa, Example**




**Identify which models fall in which quadrants**

# Selecting 5 GCMs for full analysis

## Ames, Iowa, Example

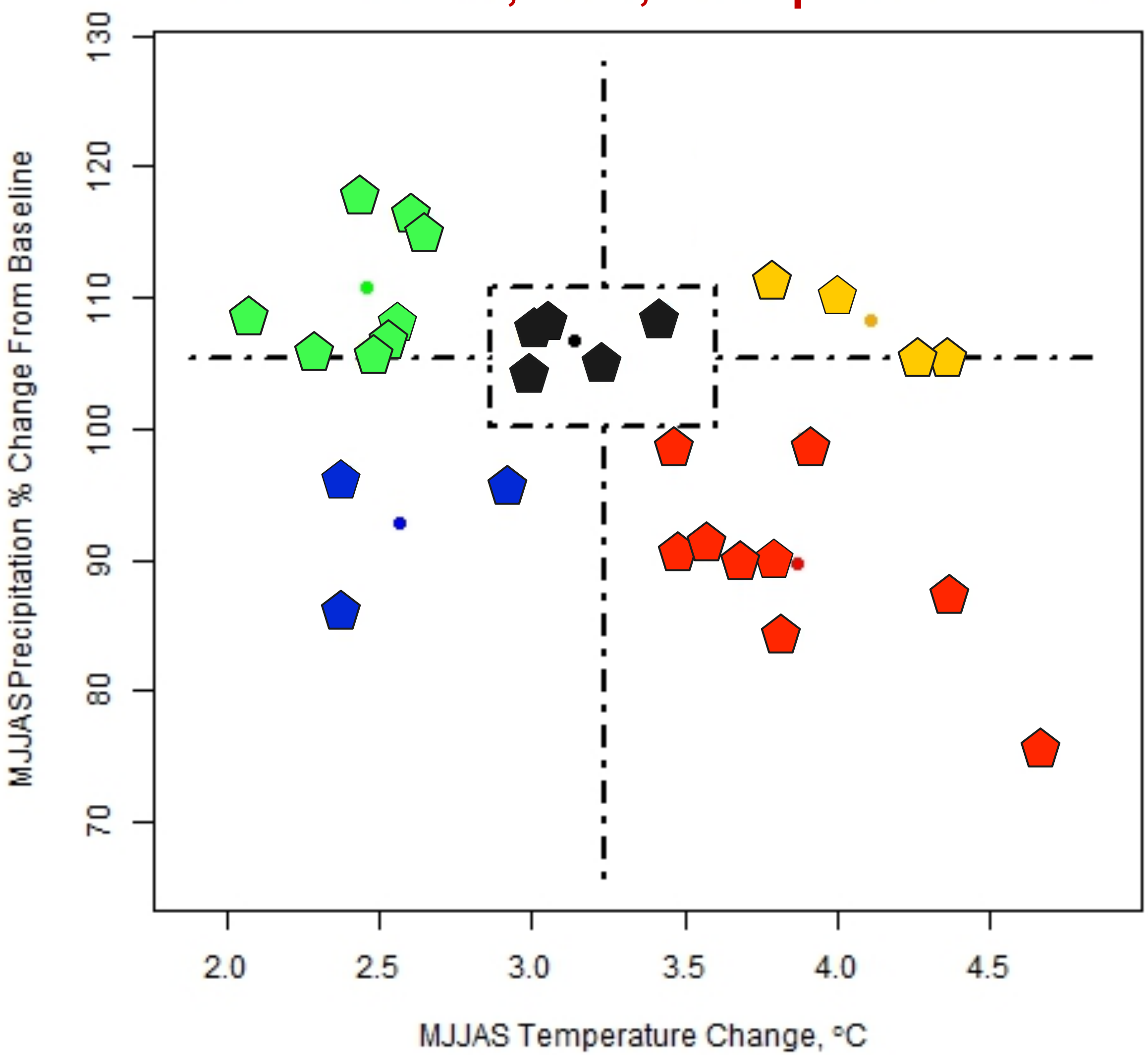



**Identify which models fall in which quadrants**

**Then identify the average projected change in each quadrant to help identify most representative model of that quadrant.**

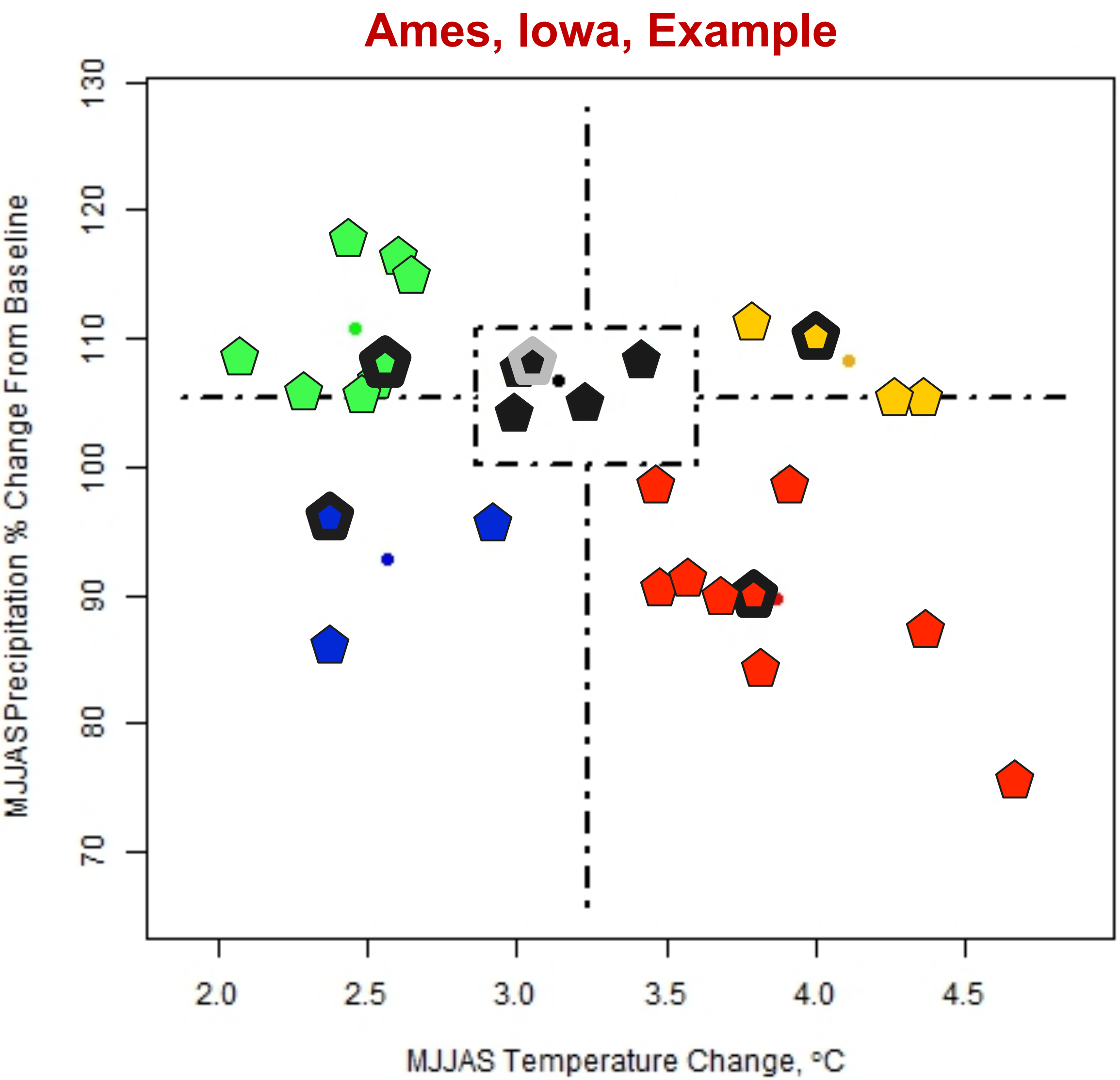
# Selecting 5 GCMs for full analysis

## Ames, Iowa, Example




**Choose model from each quadrant that is most representative.**

# Selecting 5 GCMs for full analysis




Choose model from each quadrant that is most representative.

Note number of models that fall in each quadrant for reports and communications related to uncertainty or risk management.

# Selecting 5 GCMs for full analysis

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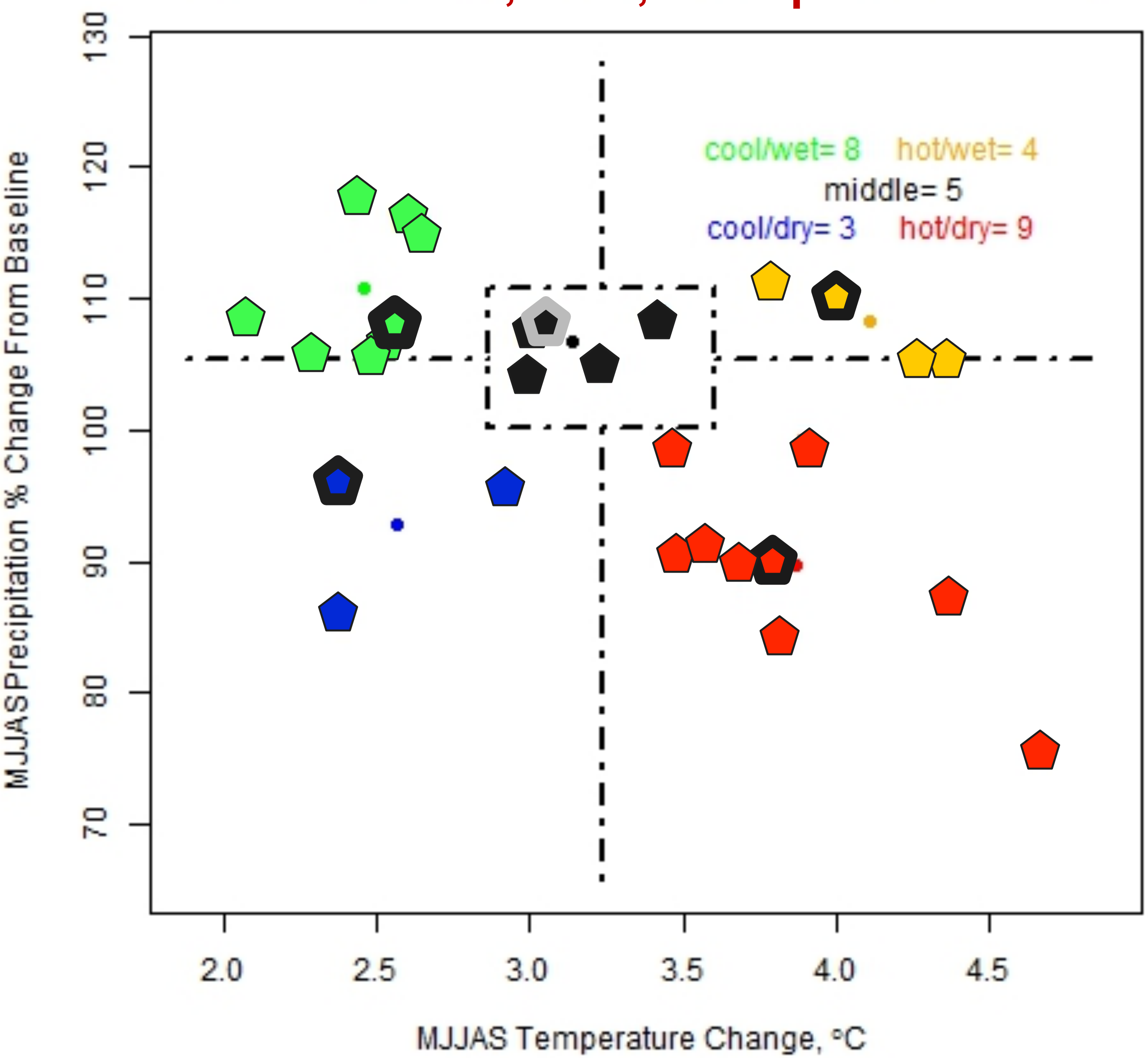
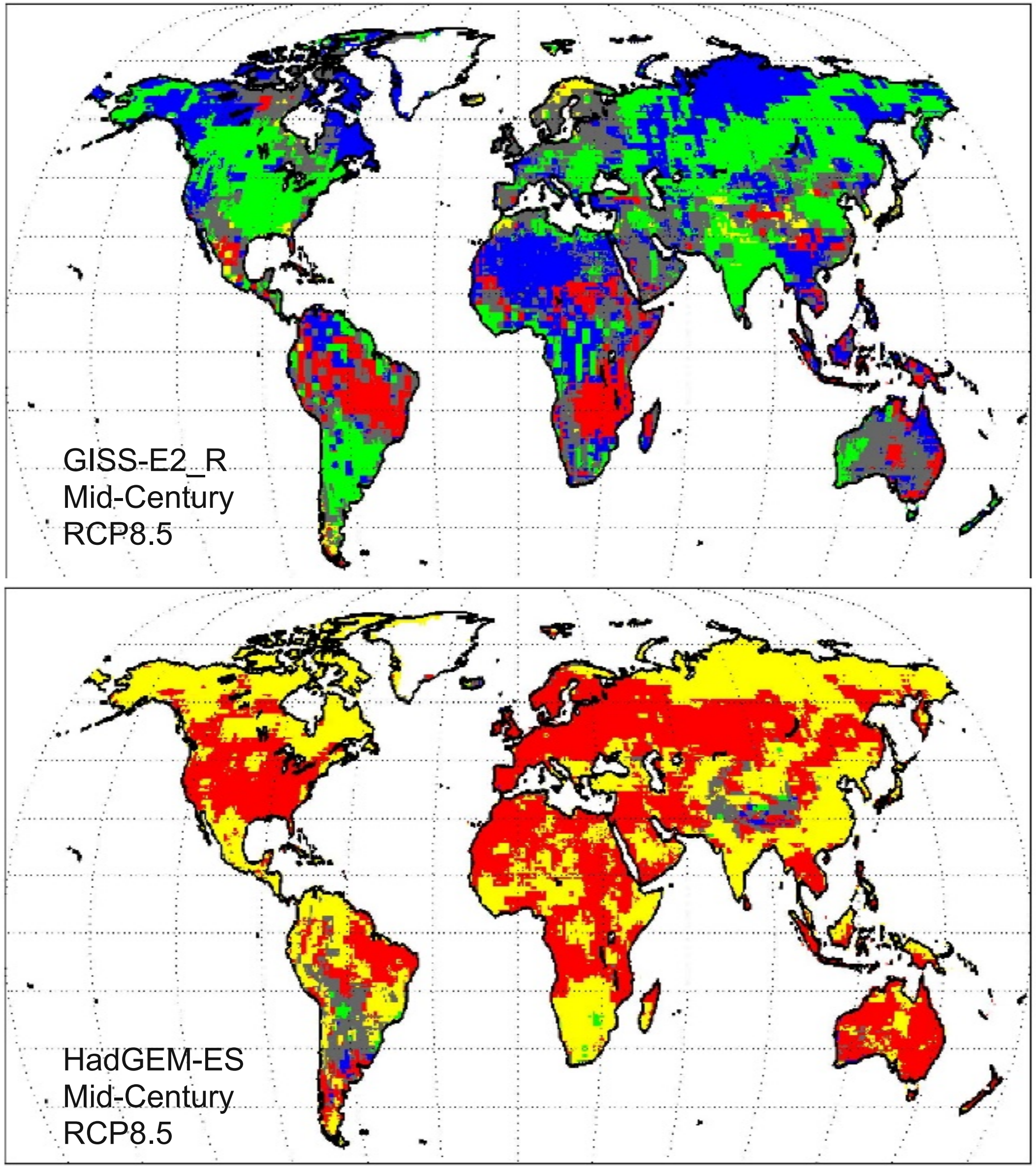
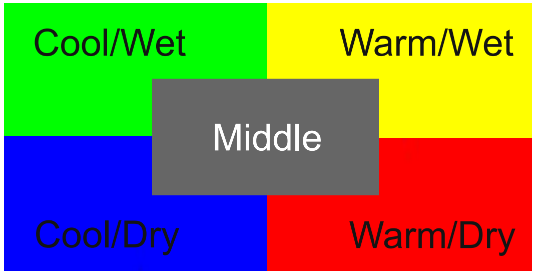
## Ames, Iowa, Example




These 5 GCMs can then be used for full climate-crop-livestock-economics assessment.

# Can apply globally




Ruane and McDermid, in preparation

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# Creating future scenarios

**AgMIP Approach in Regional Integrated Assessments:**

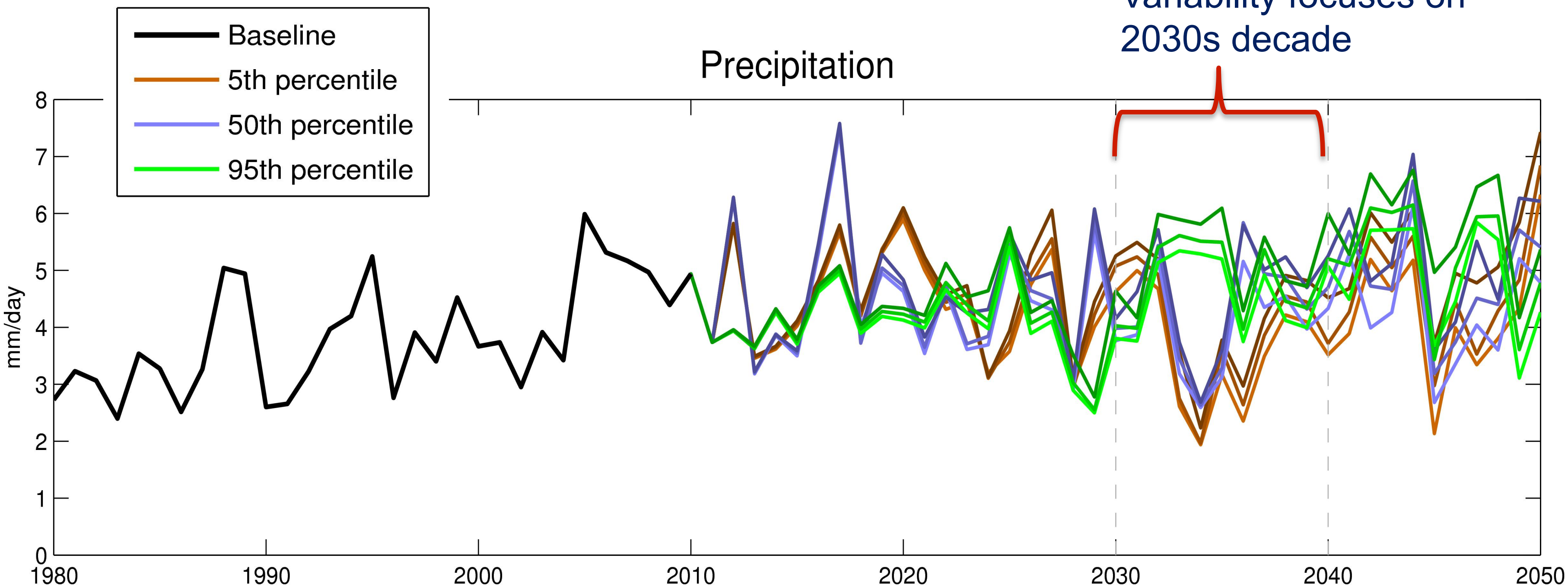
**Enhanced Delta Approach – quantile mapping from observations based upon GCM changes in fitted distributions and number of rainy days.**
- Built on quality-controlled historical dataset (observations/AgMERRA)
- limited to 30-year time slices based upon 1980-2010 period.
- focused on climate variables needed for agricultural models, missing other variables that may be needed in other sectors

**Other common approaches:**
- **Dynamical Downscaling** (e.g., CORDEX)
  - challenges in consistency/coverage; difficult to determine added value added
- **Statistical Downscaling** (e.g., BCSD, ISI-MIP, NEX)
  - quantile mapping from GCMs to observations
  - depends on gridded historical observations and GCM weather sequences
  - much more history on monthly scale, daily statistical downscale relatively recent
  - ISI-MIP provides variables needed for other sectors as well as 1980-2100 set
- **Empirical Statistical Downscaling**

# Constructing Near-term Climate Scenarios with focus on Extremes

Ruane and Greene, in prep.

2030s Precipitation Extremes




Diourbel, Senegal probabilistic projections to 2050s factor in mean changes and internal variability using statistical disaggregation and uncertainty in GCM projections.

Allows us to estimate likelihood of extreme interannual events

(work done in collaboration with Arthur Greene and James Chryssanthacopoulos)

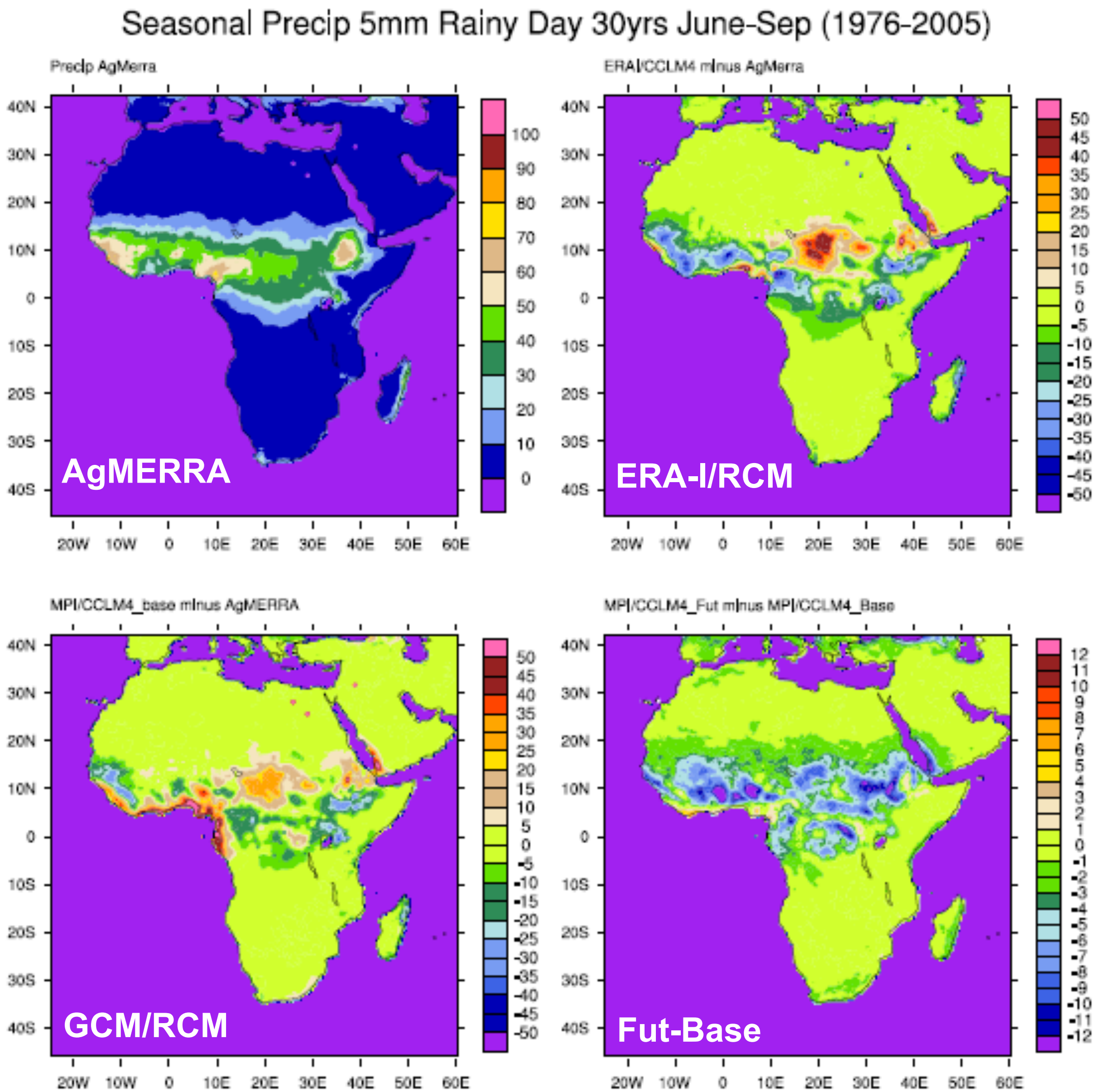
# Starting Proposals for CGRA Climate

# Proposals for CGRA Climate

- Use CMIP5 outputs rather than wait for CMIP6
  - 1980-2010 forms suitable baseline with potential for climate and ag sector validation data
  - Mid-century provides sweet spot of climate signal and plausible scenario building
- Use ISI-MIP or NEX climate approach to keep doors open for extensions and aggregate evaluations with other impact sectors
  - Provides gridded data from many GCMs, we should request that more GCMs processed
  - Compare AgMERRA and statistical approach's baseline during calibration/validation
- Use the best possible local climate data whenever possible, as this is part of the potential benefit of linking with site-based crop/livestock modeling and regional integrated assessments.
  - We can still make future climate scenarios using same statistical methods on these local climate data, enabling consistency in method even as benefit of local focus remains
- Use regional analysis to determine GCM subsets
  - Build international picture using representative quadrants
- Use sensitivity analyses/scenarios to address potential for climate extremes
  - Low skill in GCM prediction, but we can create artificial scenarios that cover interesting possibilities
  - Potential to associate probabilities with particular near-term scenarios


Extra Slides for Further Description

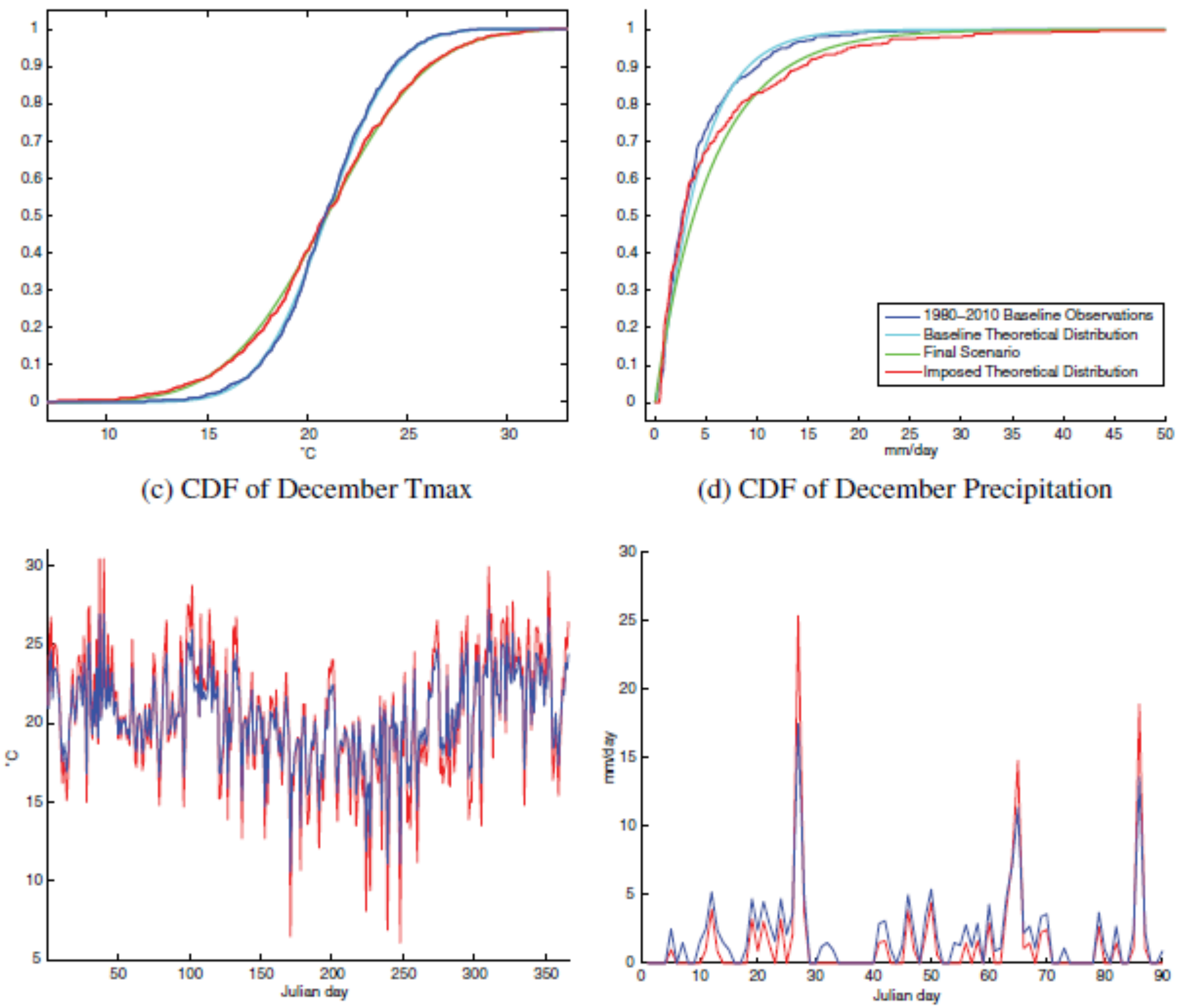
# Dynamical Downscaling




- Tremendous potential of downscaled climate models
- Simulations at scales capable of better resolving extreme events and fine-scale patterns
- Need to simulate historical conditions sensibly but then information comes from simulation of climate changes
- CORDEX appealing due to international consistency

- Difficult to obtain all results from CORDEX
- Need more analyses of strengths/weaknesses
- Important to justify mean changes from GCM

# Enhanced Delta Method




(c) CDF of December Tmax

(d) CDF of December Precipitation

(e) Mean and Variability ΔT Example

(f) Mean and Variability ΔP Example

**Recognizable historical time series adjusted to impose climate changes drawn from CMIP5 models.**

**Adjusts each month's:**

- Mean Tmax, Tmin
- Standard deviation of daily temperatures
- Mean precipitation
- # rainy days
- Shape of rainfall distribution

**Does not adjust:**

- Solar radiation
- Wind speed
- Relative humidity at Tmax (although vapor pressure and VPD changes)

GCM Δvariability is less reliable than Δmeans

Shizukhuishi, Japan, hypothetical scenarios from Ruane et al., 2015