“Intelligent Ensemble” Projections of Precipitation and Surface Radiation in support of Agricultural Climate Change Adaptation

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Motivation: Climate influences Society

A location climate influences
- Agriculture
- Energy needs
- Water availability
- Infrastructure
- Building codes
Earth’s climate is changing.

Global mean surface temperature has risen 1.4°F since 1880.

September Arctic sea ice decline at 13% per year.

Global sea level has risen by 7 in. over 100 years.

Record Extremes
Climate change is global but with a regional character.
Adaptation Planning is required

Climate projections are necessary.
Coupled Model Intercomparison Project 5 (CMIP5)

Taylor et al. (2012; BAMS)

Fig. 1. The relationship of CMIP5 to organizations established to coordinate climate research activities internationally and to the IPCC, the modeling centers, and the climate research community.
Expected Changes: Constructing climate projections

Conventional Ensemble Projection Approach: One model, one vote

Projected Temperature Change: 2-6°C (4-10°F) by 2100
New methodology synergistically uses NASA observations and model strengths and weaknesses to improve climate projections.
NASA Earth Science Missions
Current & Planned
Metric Selection: Earth’s Climate is determined by energy flows.

- Reflected Solar Radiation: -100 (-99, -101)
  - Reflected from Cloudy Regions

- Incoming Solar Radiation: 340 (339.9, 340.1)
  - Reflected from Clear Regions

- TOA Imbalance: 0.6 (0.34, 0.86)
  - Absorbed by Atmosphere: 78 (73, 83)
  - Emitted from Clear Regions
  - Emitted from Cloudy Regions
  - Atmosphere LW cooling: -187 (-179, -195)

- NET ATM: -109 (-100, -118)
  - Reflected by Atmosphere
  - Sensible Heat: -24 (-17, -31)
  - Latent Heat: -78 (-74, -85)

- Absorbed at Surface: 162 (157, 167)

- Surface Imbalance: 0.6 (0.34, 0.86)
  - Surface Emission: -398 (-395, -401)

- Absorbed at Surface: 345 (338, 352)

Units: Wm$^{-2}$
Methodology

• Use perfect model approach to determine the quantities whose performance in an unforced variability simulation robustly relates to climate projections

• Then use NASA observations to produce data-constrained climate projections

• The climate model ensemble is used to understand the relationship between variability in Earth’s energy budget and the sensitivity of Earth’s climate to a radiative perturbation.
Producing “Intelligent Ensemble Projections: Selecting “Ideal” Metrics:

Best metrics have both a low standard deviation and $I^2$ value.
Results: 21\textsuperscript{st}-century “Intelligent” projections (regional weights)

"Intelligent" ensemble mean precipitation trend (cm/year)

Difference between "Intelligent" and Equal-weight ensemble means (cm/year)
Results: new 21st-century projections

"Intelligent" ensemble mean temperature trend (°C)

US mean temperature increase: 3.9 °C

- Basin and Range: 3.9 °C
- Fruitful Rim: 3.4 °C
- Prairie Gateway: 3.8 °C
- Northern Great Plains: 4.1 °C
- Heartland: 4.1 °C
- Northern Crescent: 4.3 °C
- Eastern Uplands: 3.8 °C
- Southern Seaboard: 3.5 °C
- Mississippi Portal: 3.6 °C
Results: new 21st-century projections

"Intelligent" ensemble mean precipitation trend (cm/year)

US mean precipitation increase: 3.4 cm/year

- Basin and Range: 0.6 cm/year
- Fruitful Rim: 0.8 cm/year
- Prairie Gateway: -1.8 cm/year
- Northern Great Plains: 2.7 cm/year
- Heartland: 7.2 cm/year
- Northern Crescent: 9.1 cm/year
- Eastern Uplands: 6.8 cm/year
- Southern Seaboard: 6.8 cm/year
- Mississippi Portal: 5.4 cm/year
Results: new 21st-century projections

"Intelligent" ensemble mean surface shortwave radiation trend (W/m²)

US mean decrease in surface solar radiation: -0.33 Watts/m²

- Basin and Range: -2.4 Watts/m²
- Fruitful Rim: -0.5 Watts/m²
- Prairie Gateway: 0.7 Watts/m²
- Northern Great Plains: -1.9 Watts/m²
- Heartland: 0.7 Watts/m²
- Northern Crescent: -0.1 Watts/m²
- Eastern Uplands: 2.7 Watts/m²
- Southern Seaboard: 2.5 Watts/m²
- Mississippi Portal: 2.6 Watts/m²
Summary and Conclusions

• Data constrained climate change projections are one way science an address society’s need for better climate information.
• The “Intelligent” Ensemble method uses model performance to constrain projections.
• The data-constrained projections different from the equal weighted projections by as much as 50%.