“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

![Graph showing global average surface temperature change](image)
New methodology synergistically uses NASA observations and model strengths and weaknesses to improve climate projections.
Metric Selection: Earth’s Climate is determined by energy flows.
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.
Performance Evaluation

- Good
- Poor

Models

- ACCESS1-0
- ACCESS1-1
- CanESM2
- CESM1-BGC
- CESM1-WACCM
- CESM1-WACCM
- CNRM-CM5
- CSIRO-MK3-6-0
- GFDL-ESM2G
- GFDL-ESM2M
- GISS-E2-H
- GISS-E2-R
- HadGEM2-AO
- HadGEM2-CC
- IPSL-CM5A-LR
- IPSL-CM5A-MR
- IPSL-CM5B-LR
- MPI-ESM-LR
- MPI-ESM-MR
- NorESM1-ME

Metrics

- OLR all-sky variance test
- OLR all-sky K-S test
- OLR cloudy-sky variance test
- OLR cloudy-sky K-S test
- OLR clear-sky variance test
- OLR clear-sky K-S test
- SW all-sky variance test
- SW all-sky K-S test
- SW cloudy-sky variance test
- SW cloudy-sky K-S test
- SW clear-sky variance test
- SW clear-sky K-S test
- Surface temperature variance test
- Surface temperature K-S test
- SW clear-sky local variance test
- SW clear-sky EMD value
- SW clear-sky K-S test
- SW cloudy-sky local variance test
- SW cloudy-sky EMD value
- SW cloudy-sky K-S test
- SW all-sky local variance test
- SW all-sky EMD value
- SW all-sky K-S test
- OLR/Ts variance test
- OLR(Ts)/Ts variance test
- OLR(Ts)/Ts K-S test
- OLR Ts regression means test
- OLR cloudy-sky/Ts variance test
- OLR cloudy-sky/Ts K-S test
- OLR cloudy-sky/Ts regression means test
- SW/Ts variance test
- SW/Ts K-S test
- SW/Ts regression means test
- Metric mean
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 21\textsuperscript{st}-century projections

"Intelligent" ensemble mean surface shortwave radiation trend (W/m\textsuperscript{2})

US mean decrease in surface solar radiation: -.33 Watts/m\textsuperscript{2}

- **Basin and Range:** -2.4 Watts/m\textsuperscript{2}
- **Fruitful Rim:** -0.5 Watts/m\textsuperscript{2}
- **Prairie Gateway:** 0.7 Watts/m\textsuperscript{2}
- **Northern Great Plains:** -1.9 Watts/m\textsuperscript{2}
- **Heartland:** 0.7 Watts/m\textsuperscript{2}
- **Northern Crescent:** -0.1 Watts/m\textsuperscript{2}
- **Eastern Uplands:** 2.7 Watts/m\textsuperscript{2}
- **Southern Seaboard:** 2.5 Watts/m\textsuperscript{2}
- **Mississippi Portal:** 2.6 Watts/m\textsuperscript{2}
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%.