A Statistical Analysis of Model Simulated Extreme Temperature and Precipitation Indices Investigation of Minimum Number of Ensemble Members

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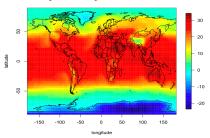
Steve Sain, National Center for Atmospheric Research Claudia Tebaldi, Climate Central

July 27, 2011

Getting to know the Data...

The Indices

- What do you mean "extreme"?
 - "It's very hot/cold"
 - "It rained a lot/very little"
- Analyzed across the globe
- 40 ensemble members
 - Different initial conditions
- Years: 2000-2060
- 2 emission scenarios
 - ► A1B and Commit



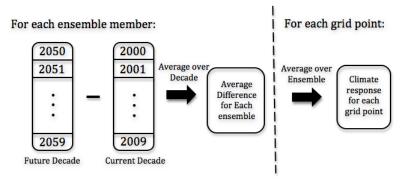
mint3d.grid.A1B, Averaged over Ensemble and Year

Indice	Туре	Definition	Units
mint3d	Temp	Hottest min. temp., three day	°C
hwdi	Temp	Heat wave duration index	Days
sdii	Precip	Simple daily intensity index	<u>mm</u> day
cdd	Precip	Consecutive dry days	Days

Getting to know the Data...

Measuring a Climate Response

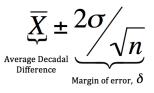
- Climate response: Decadal difference
 - (future decade response) (current decade response)
 - averaged over decade and ensemble members

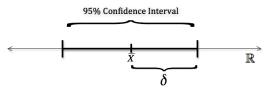


Minimum Number of Ensemble Members

The Idea: Confidence Intervals

- Question: How many ensemble members do we need to show a certain statistical significant difference?
 - Ensemble members are computationally expensive
- The Approach:
 - Confidence Interval Definition:
 - Approximate 95% confidence interval





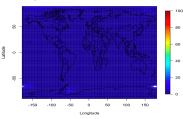
Minimum Number of Ensemble Members

$$\delta = \frac{2\sigma}{\sqrt{n}} \Rightarrow n_{\min} = \frac{4\sigma^2}{\delta^2}$$

Two methods for choosing δ :

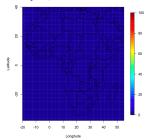
- 2 Let δ be a chosen constant value

Minimum Number of Ensemble Members: Temperature Method 1

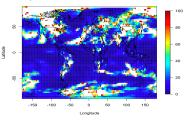


mint3d.grid.A1B , Minimum Number of Ensemble Members

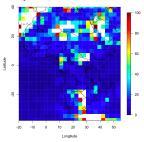
mint3d.grid.A1B , Minimum Number of Ensemble Members



mint3d.grid.Commit , Minimum Number of Ensemble Members



mint3d.grid.Commit , Minimum Number of Ensemble Members

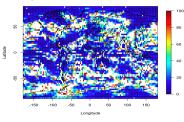


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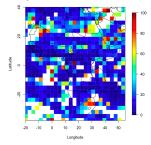
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Minimum Number of Ensemble Members: Precipitation Method 1

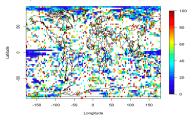
cdd.grid.A1B , Minimum Number of Ensemble Members



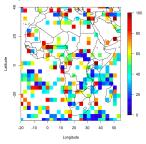
cdd.grid.A1B , Minimum Number of Ensemble Members



cdd.grid.Commit , Minimum Number of Ensemble Members



cdd.grid.Commit , Minimum Number of Ensemble Members



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Analysis of Extremes

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Minimum Number of Ensemble Members

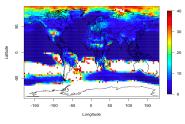
$$\delta = \frac{2\sigma}{\sqrt{n}} \Rightarrow n_{\min} = \frac{4\sigma^2}{\delta^2}$$

Two methods for choosing δ :

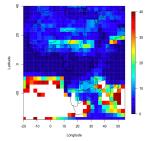
- Let δ be the observed average decadal difference
- 2 Let δ be a chosen constant value \Leftarrow

Minimum Number of Ensemble Members: Temperature Method 2

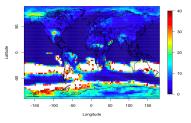
hwdi.grid.A1B , Min. num of ensemble members, sig. diff of 2



hwdi.grid.A1B , Min. num of ensemble members, sig. diff of 2



hwdi.grid.Commit , Min. num of ensemble members, sig. diff of 2



hwdi.grid.Commit , Min. num of ensemble members, sig. diff of 2

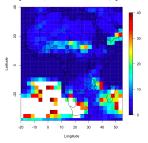


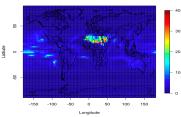
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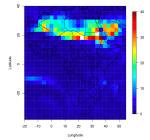
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Minimum Number of Ensemble Members: Precipitation Method 2 *

sdii.grid.A1B, Min. num. of ensemble members, sig. diff of .5

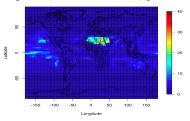


sdii.grid.A1B, Min. num. of ensemble members, sig. diff of .5

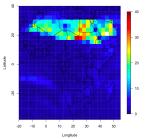


* Ensemble 23 excluded

sdii.grid.Commit , Min. num of ensemble members, sig. diff of 0.5



sdii.grid.Commit , Min. num of ensemble members, sig. diff of 0.5



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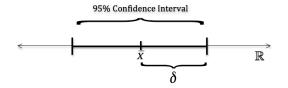
Minimum Significant Difference

New Question... Same Idea

• Same idea, different question

• Recall that,
$$\delta = rac{2\sigma}{\sqrt{n}}$$

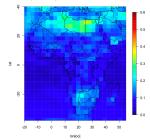
Given that we have 40 ensemble members (n), what is the minimum significant difference (δ) that can be shown?



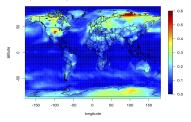
Minimum Significant Difference: Temperature

mint3d.grid.A1B , Significant difference with 40 ensemble members

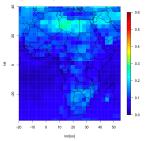




mint3d.grid.Commit, Significant difference with 40 ensemble members



mint3d.grid.Commit, Significant diff. with 40 ensemble members



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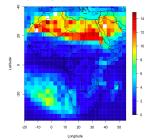
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Minimum Significant Difference: Precipitation

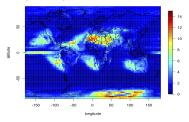
with the second second

cdd.grid.A1B , Significant difference with 40 ensemble members

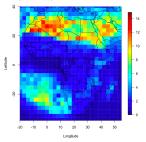
cdd.grid.A1B , Significant diff. with 40 ensemble members



cdd.grid.Commit , Significant difference with 40 ensemble members



cdd.grid.Commit , Significant diff. with 40 ensemble members



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Results

Minimum Number of Ensemble Members

- Precipitation indices generally require more ensemble members than temperature indices
 - cdd requires most ensemble members
- The Commit emission scenario generally requires more ensemble members than A1B
 - The Commit uses emission levels equal to those of the year 2000
- Method 1 requires more ensemble members in areas of high ensemble variance and/or small observed average decadal difference
- Method 2 requires more climate knowledge to determine δ , the specified significant difference

Future Work

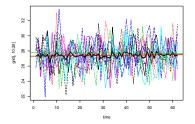
Minimum Number of Ensemble Members

- Type I error correction for multiple comparison
 - false positives
- Investigate temporal correlation structures
- Investigate spatial correlation structures
- Method 1: Investigate areas with a high number of minimum ensemble members when observed average decadal difference is used
- Method 2: Discuss nature and human system implications for specified changes in indices

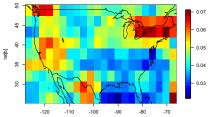
Future Work

A Second Project

- Modeling linear regression slopes for each index
 - Assume two temporal error structures:
 - * Independent
 - ★ Autoregressive model (AR)
 - Investigate spatial dependence structures



Ensemble Members with ensemble average, linear model assuming independence and AR(1)



mint3d.grid.A1B , slopes assuming temporal indep.

Acknowledgments

A special thanks to ...

- Mentor: Steve Sain
- Claudia Tebaldi
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- Doug Nychka
- SIParCS Admin
- NCAR/UCAR
- NSF

Questions?

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