#### Climate Change, Urbanization, and the Indian Monsoon Rainfall: Toward Informing Climate Science, Adaptation Decisions, and Mitigation Policies with Data-Guided Methods





## -10 0 10 20 30

#### Contributors acknowledged on websites: NSF "Expeditions in Computing" http://climatechange.cs.umn.edu/

ORNL "Climate Extremes"

http://www.ornl.gov/knowledgediscovery/ClimateExtremes/

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#### **PS: We're moving!**

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## Challenge: translate climate model derived insights to decision and policy tools





## Climate extremes: Science, impacts, policy

#### Science

- Extremes characterizations
- Uncertainty assessments
- Enhanced predictions

#### Impacts

- Natural resources
- Hazards risks
- Regional preparedness

#### Policy Relevance

- Emissions policy
- Preparedness decisions
- National security concerns







Temperature and Heat Waves (Ganguly, 2009)





Worst-Case Projected Per Capita Water Availability by 2100\*



Drought Index





Threat and Adaptation

### Indian monsoon rainfall extremes: disagreement over trends in literature



**Fig. 3.** Temporal variation (1951 to 2000) in the number (*N*) of (**A**) heavy ( $R \ge 100$  mm/day, bold line) and moderate ( $5 \le R < 100$  mm/day, thin line) daily rain events and (**B**) very heavy events ( $R \ge 150$  mm/day) during the summer monsoon season over CI. The statistical significance of the trends (dashed lines) was calculated as in Fig. 2.

#### Goswami et al. 2006: Science

Figure 3. Spatial distribution of 25, 75, 95 and 99 percentile rainfall.



Ghosh et al. 2009: Atmos. Sci. Let.

#### Contradictory results over many parts of central India

Study 1

0.3

0.2

0.1

0

-0.1

-0.3

0.06

0.04

0.02

0

-0.02

-0.04

### **EVT - Increasing trends in spatiotemporal** variability





**Diversity in trends of return levels** - more positive than negative contradicts Goswami et al.



Significant increase in spatial variability over time

**Predominance of** regional > global drivers





Starting Year of 30 Years Time Slices



1950 1955 1960 1965 1970 1975 Starting Year of 30 Years Time Slices

# **EVT - Increasing trends in spatiotemporal** variability (2)



### **Global climate model selection for regional climate assessment**

## Recent studies imply overarching benefit of equal-weighted climate model averaging



# Monsoon rainfall periodicity: degradation of results with additional models



## Not as clear for maximum temperature trends



## **Process based evaluations of climate models**

#### Q: How do we know if a model gets it right "by chance"?



## **Going forward**

## **Policy and Science Implications**

- Stakeholders may be better off preparing for increasing variability (uncertainty) than increasing trends
- Regional drivers > "global warming" in some cases
- Definitions of extremes can make a difference
- Importance of physical process evaluation in climate model selection

## Challenges

- Spatial and temporal resolution differences → conflicting results?
- Adaptation/mitigation in the face of increasing variability
- Importance of physical process evaluation in climate model selection
- Regional prediction?

### Thanks to....

## **Collaborators (these 2 studies)**



- Debasish Das (PhD Candidate in CS, Temple University, study 1)
- Subimal Ghosh (Assistant Professor, CEE, IIT-Bombay, studies 1 &2)
- Shih-Chieh Kao (Research Scientist, Environmental Sciences Division, Oak Ridge National Lab, study 1)
- Evan Kodra (GRA, CEE, University of Tennessee, study 2)

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