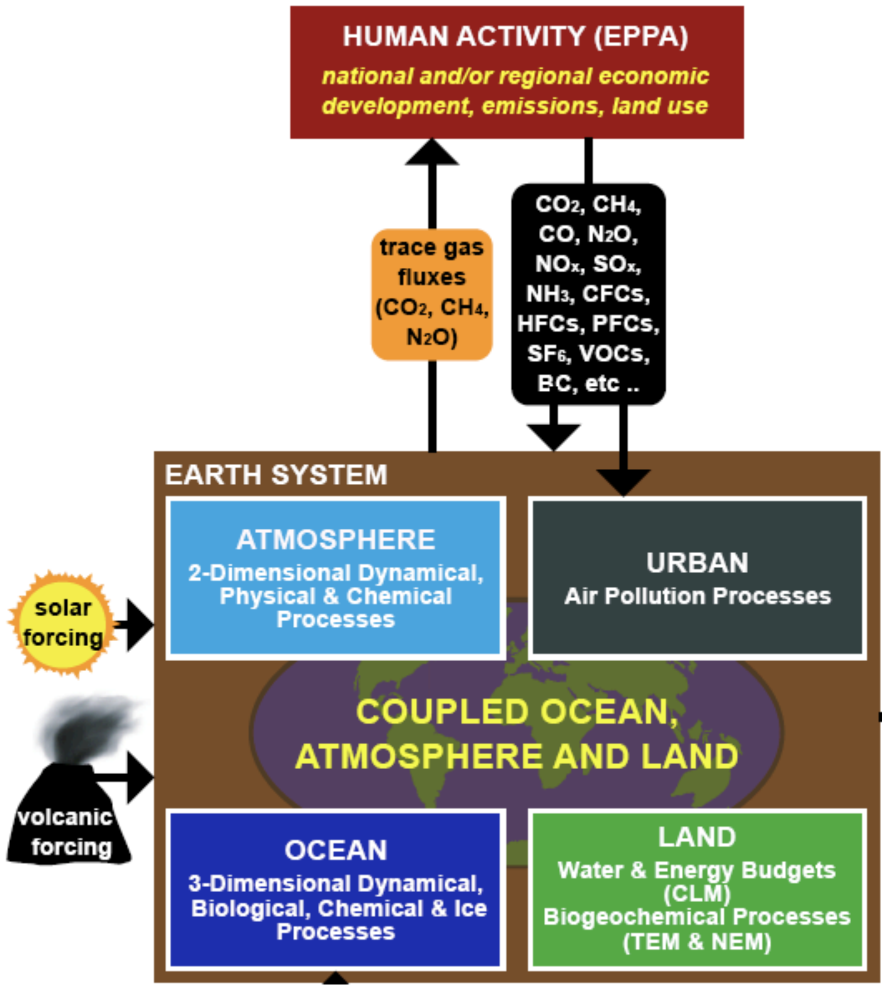
Probabilistic Forecast for 21st Century Climate Based on an Ensemble of Simulations using a Business-As-Usual Scenario

Co-authors: Jeffery Scott, Andrei Sokolov,
Chris Forest, Stephanie Dutkiewicz, Peter Stone

DOE Climate and Earth System Modeling Meeting
Uncertainty Quantification and Metrics
September 22, 2011

Earth System Model Description
(MIT IGSM 2.3)

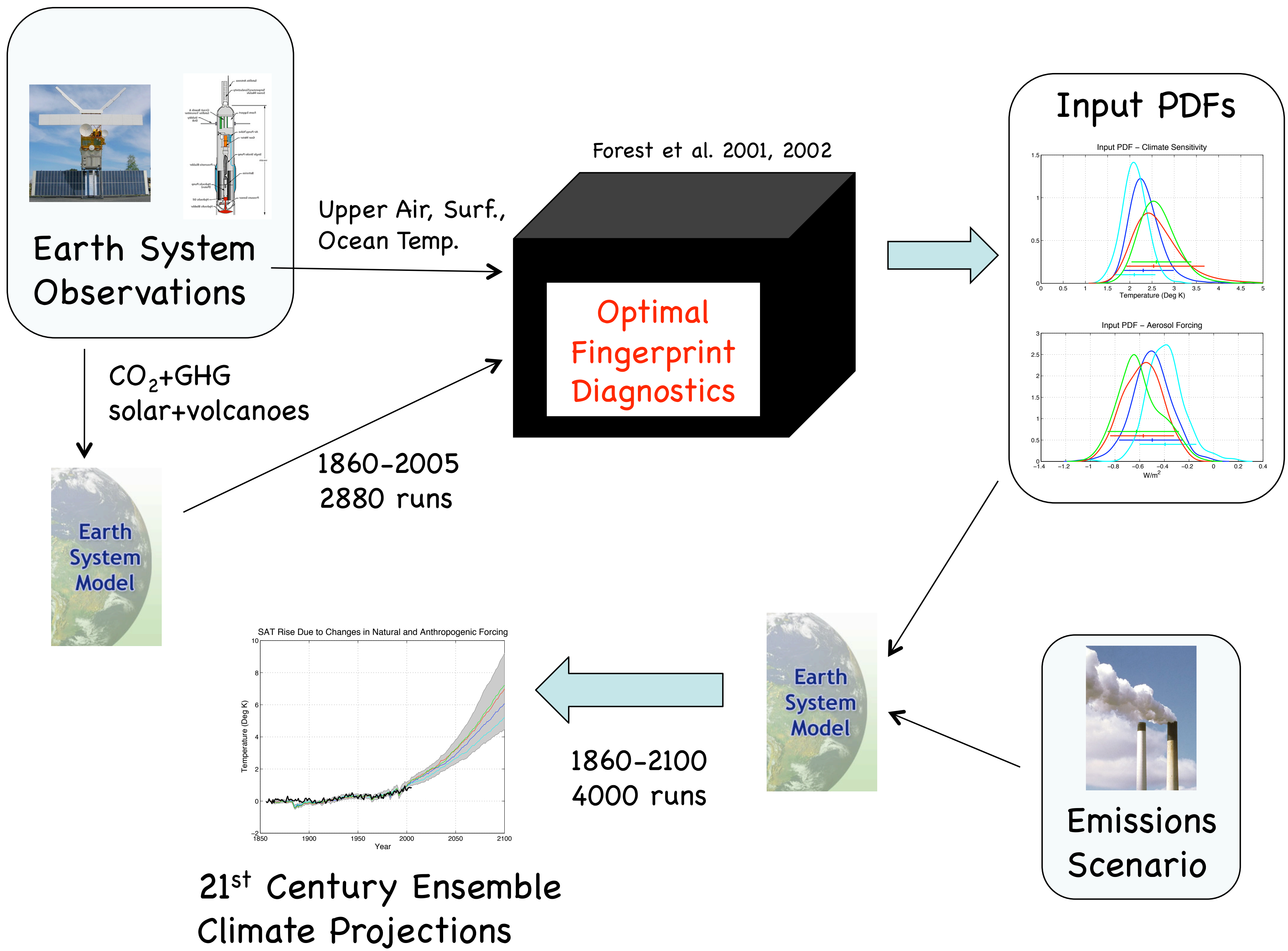


Objective: Can we use historical data to constrain uncertain Earth System Model parameters to generate probabilistic 21st Century simulations?

New in this study: incorporating 3D ocean circulation and biogeochemistry model into the Earth System Model

Research Questions:

- Does including a explicit 3D ocean affect the constraining of model parameters?
- How does including ocean feedbacks (circulation changes, changes in carbon uptake) affect results?
- How is heat and carbon taken up by the ocean?



Earth System Observations
Upper Air, Surf., Ocean Temp.
Forest et al. 2001, 2002
Optimal Fingerprint Diagnostics
Input PDFs
Input PDF – Climate Sensitivity
Temperature (Deg K)
Input PDF – Aerosol Forcing
W/m2
CO2+GHG
solar+volcanoes
Earth System Model
1860-2005
2880 runs
SAT Rise Due to Changes in Natural and Anthropogenic Forcing
Temperature (Deg K)
Year
1860-2100
4000 runs
Earth System Model
Emissions Scenario
21st Century Ensemble Climate Projections

IGSM 2.3 Ensemble

Calibration Runs (20th Century) Parameter Range

- Climate Sensitivity: 0.5 to 10.0 K
- Aerosol Forcing: -1.5 to 0.5 W/m^2
- Ocean Heat Uptake: 4 different ocean states (next slide)
- 4 initial conditions

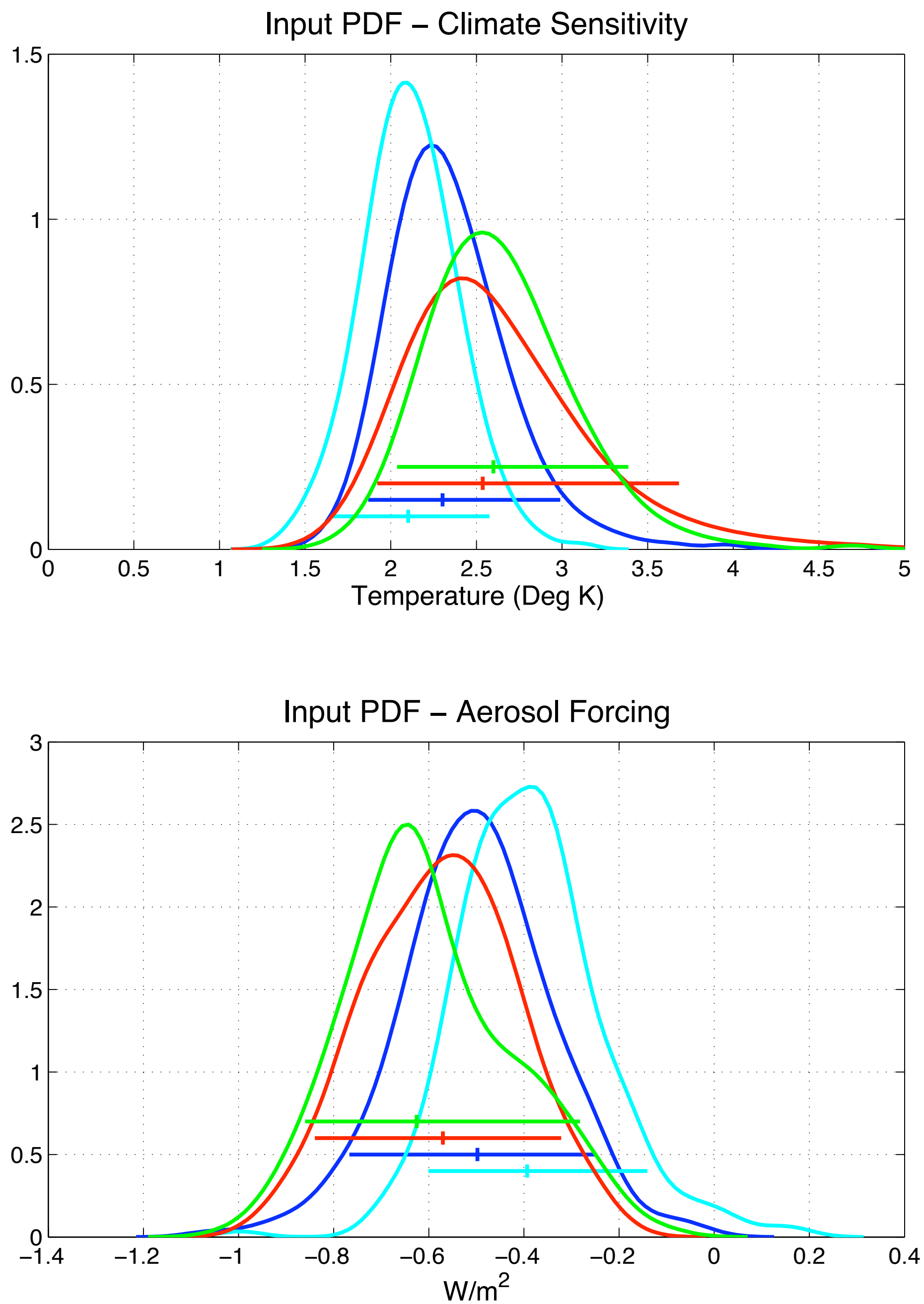
How do we vary ocean heat uptake?

- Previous work: used simple mixed layer anomaly-diffusion ocean model that can represent full range of uncertainty in heat uptake efficiency (via bulk diffusivity parameter)
- Primary physical process for uptake in 3D model is NOT diapycnal (vertical) diffusivity κ_z; however, varying κ_z modifies ocean density and circulation, with resulting different ocean heat uptake properties
- Used four discrete values of κ_z in this study (does not cover uncertain parameter space of heat uptake efficiency)
- Separate pdfs for Climate Sensitivity, Aerosol Forcing generated for each κ_z

Constraining Input PDFs using Observations

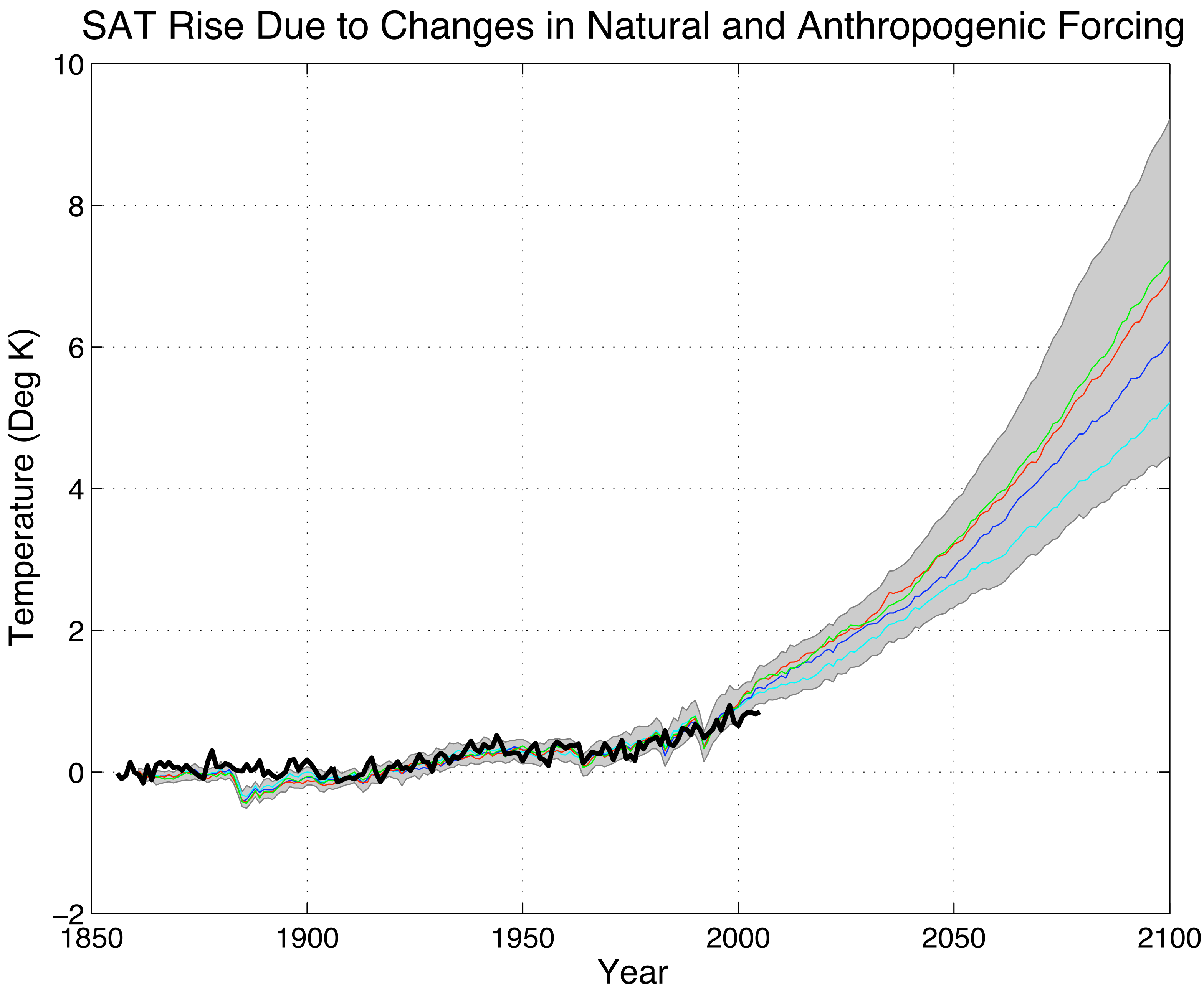
Complicated story here... (Forest et al. manuscript in prep.)

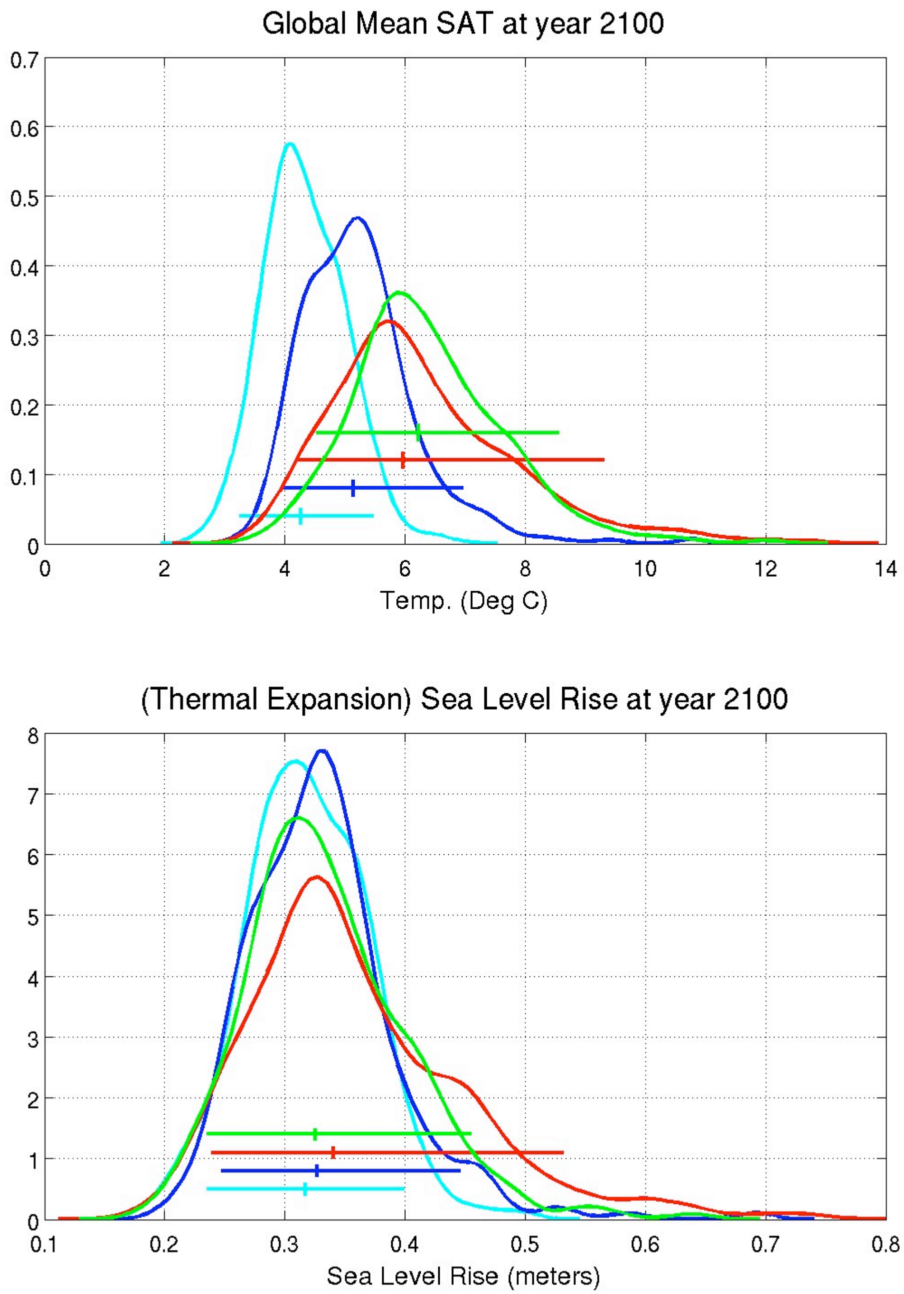
We find: using observed ocean data problematic (overconstrained system? quality of deep ocean data?); ergo, only surface and upper air used in this study



Green: weakest ocean heat uptake efficiency

Cyan: strongest ocean heat uptake efficiency


SAT Rise Due to Changes in Natural and Anthropogenic Forcing
Temperature (Deg K)
Year
10
8
6
4
2
0
−2
1850
1900
1950
2000
2050
2100



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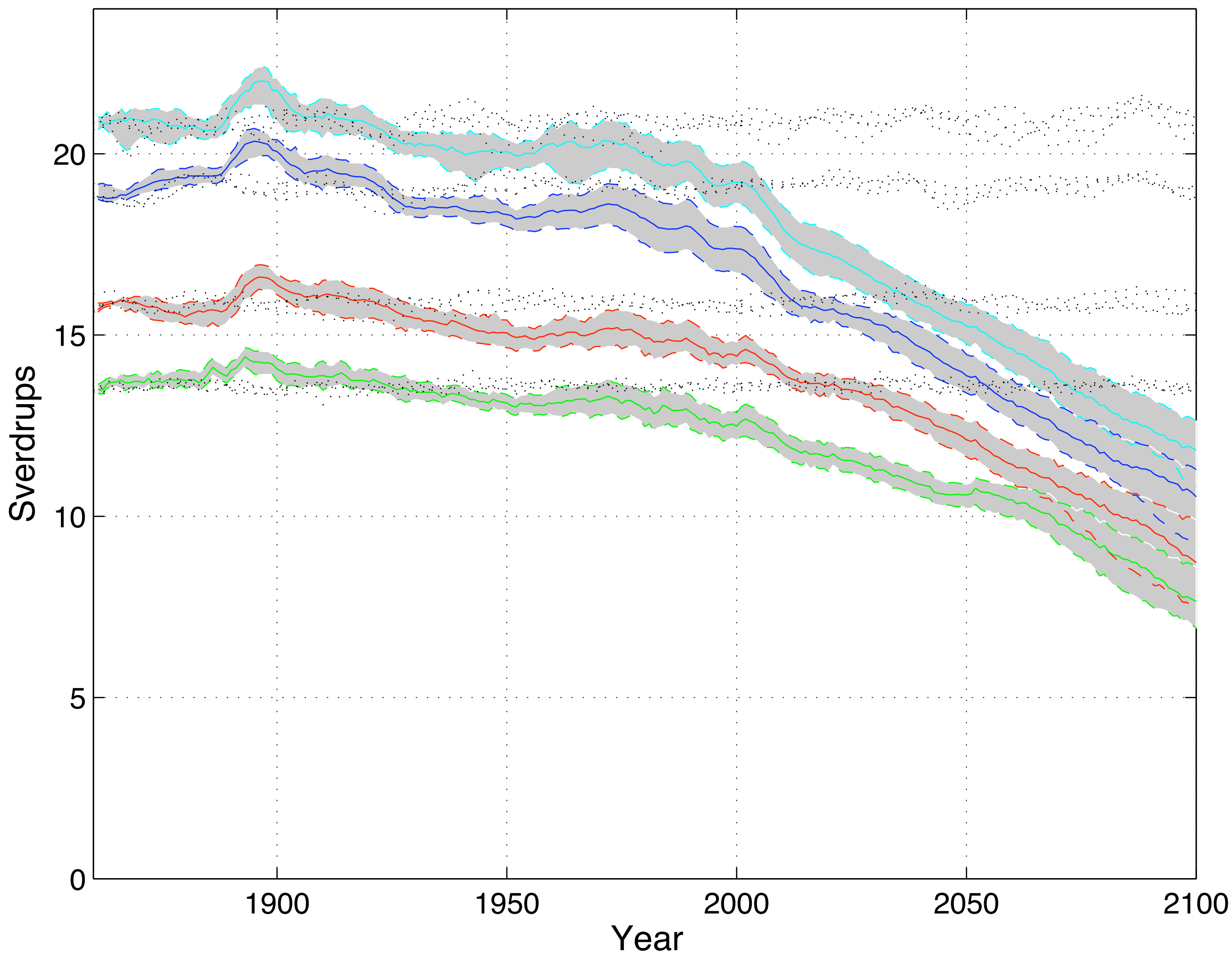
Decrease in
Atlantic Meridional Overturning Circulation



Conclusions:

- Aerosol forcing strongly constrains 20th century behavior; sensitivity "adjusts" to match obs. record
- Median SAT temperature increase over 21st century ranges from 4.3-6.2 K, depending on ocean heat uptake efficiency
- Decrease in the Atlantic meridional overturning circulation seems weekly dependent on the input pdfs

Current work:

- More work needs to be done in understanding and representing ocean heat uptake efficiency in models
- Increased ocean model resolution, improved parameterizations (using DOE Evergreen cluster)
- Expanded observational data set