Climate Sensitivity: Uncertainties & Learning

Workshop on GHG Stabilization Scenarios
Tsukuba, Japan, 23 January 2004

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Introduction

- Climate sensitivity, ΔT_{2x}: The change in global-average near-surface temperature resulting from a doubling of the preindustrial carbon dioxide concentration.
- If ΔT_{2x} is small, then the problem of human-induced climate change may not be acute. If ΔT_{2x} is large, then human-induced climate change may be one of the most severe problems of the 21st century.

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Outline

- **Primer on Climate Sensitivity, ΔT_{2x}**
- **Estimates of Climate Sensitivity, ΔT_{2x}**
- **Uncertainty in ΔT_{2x} due to uncertainty in the radiative forcing**
- **Causes of temperature changes from 1856 to present**
- **Learning ΔT_{2x} over time**

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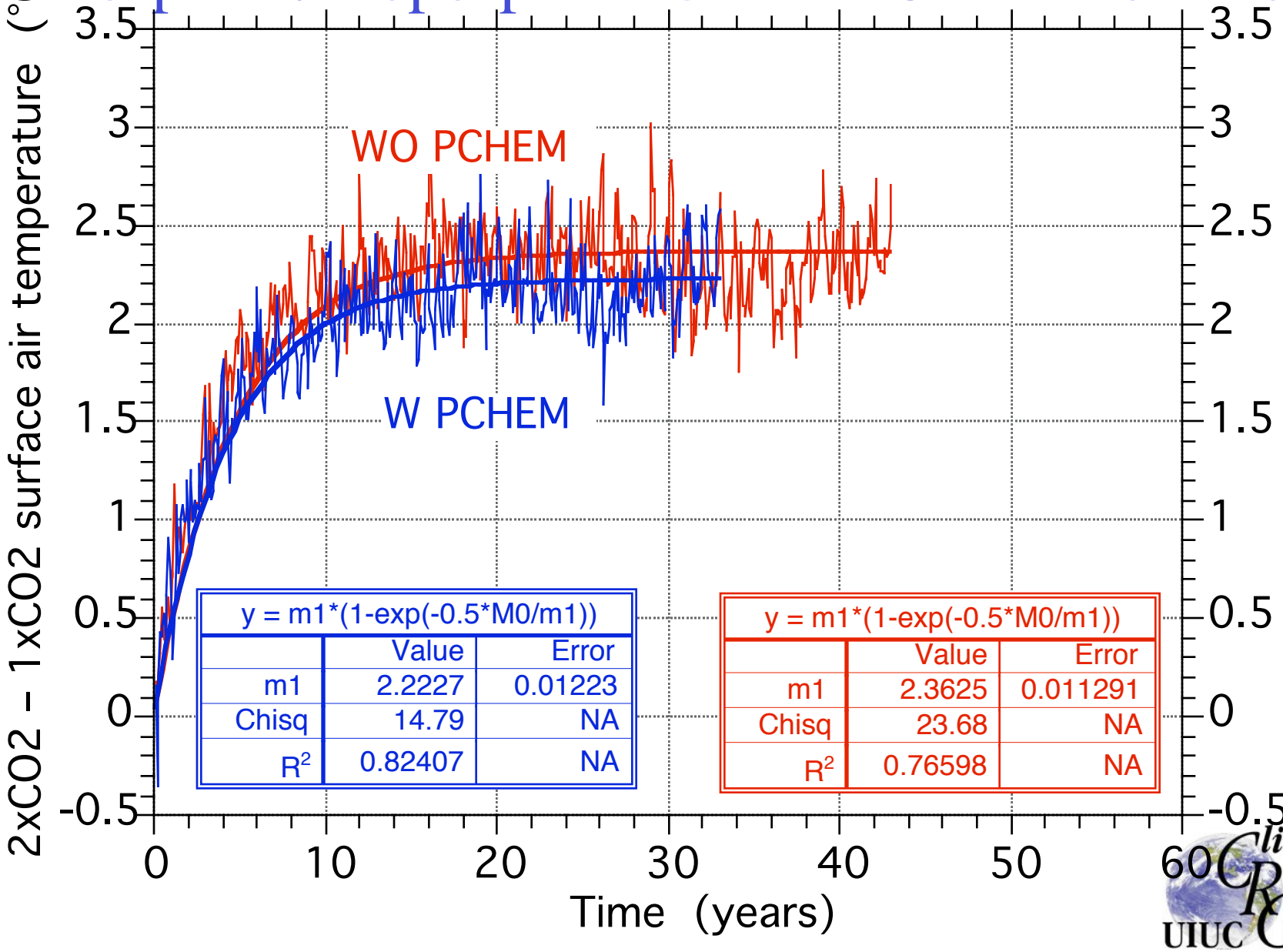
$$\frac{dH(t)}{dt} = -\frac{\Delta T(t)}{\lambda} + F(t)$$

- F(t): Radiative Forcing
  - The change in the net downward radiative flux at some level in the atmosphere, usually the tropopause, caused by some "external" factor, such as changed solar insolation or GHGs.
- Instantaneous Radiative Forcing
  - Radiative forcing before any temperature changes.
- Adjusted Radiative Forcing
  - Radiative forcing after temperatures above the tropopause change, with tropospheric temperatures held constant.

$$\frac{dH(t)}{dt} = -\frac{\Delta T(t)}{\lambda} + F(t)$$

- dH(t)/dt – The change in heat storage of the climate system; on earth, essentially the heat taken up or lost by the ocean.
- λ – Climate Sensitivity
- Equilibrium Climate Sensitivity , λ_{eq}
  - F(t) = constant and sufficient time elapsed for dH/dt = 0. $\Delta T = \Delta T_{eq}$.
  - $\lambda = \lambda_{eq} = \Delta T_{eq}/F$; e.g., $\lambda_{eq} = \Delta T_{2x}/F_{2x}$. $F_{2x} = 3.71$ W/m^2. ΔT_{2x} taken as a synonym for λ_{eq}.

ΔT_{2x} Simulated By The UIUC Stratosphere/Troposphere General Circulation Model



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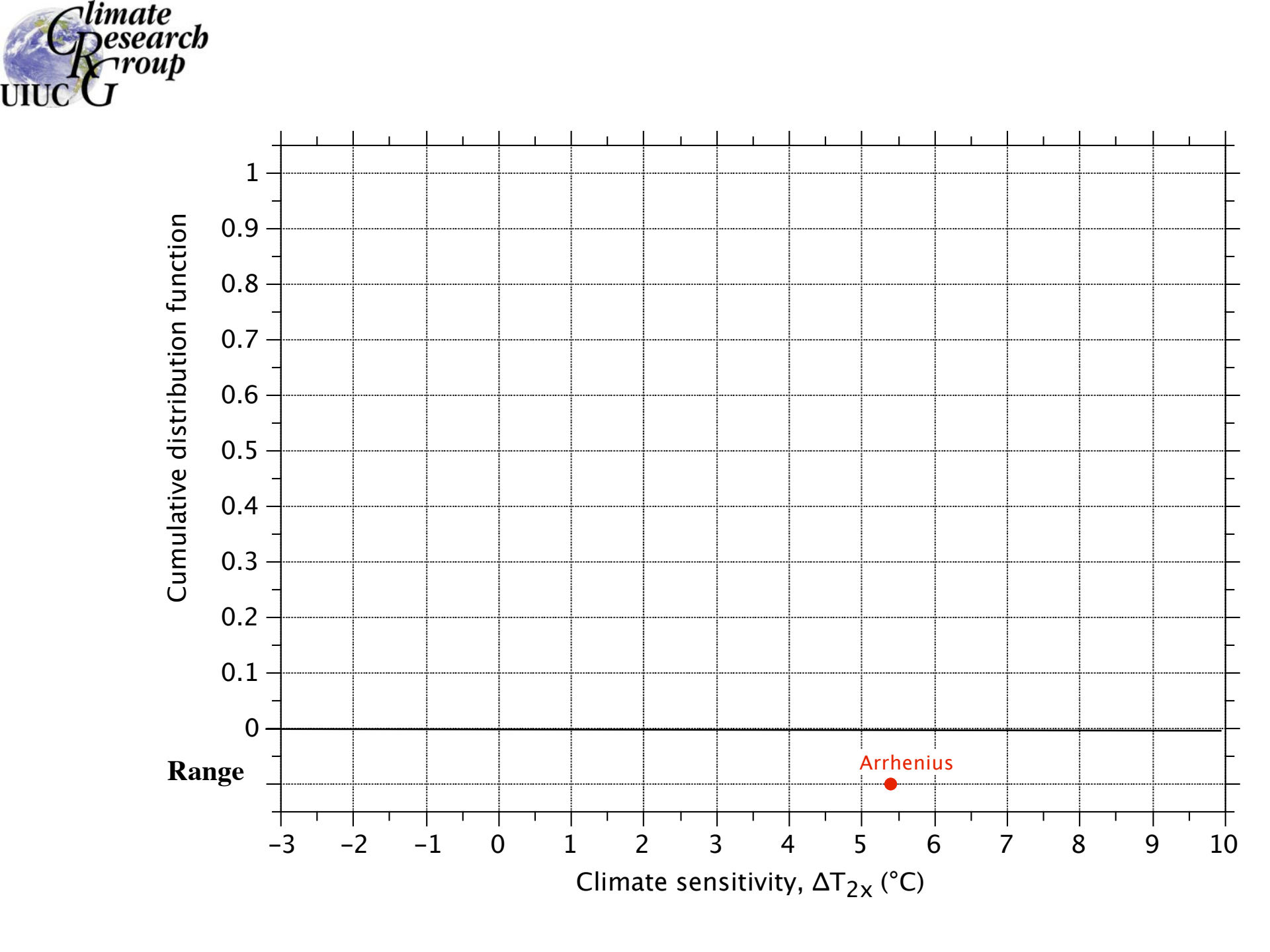
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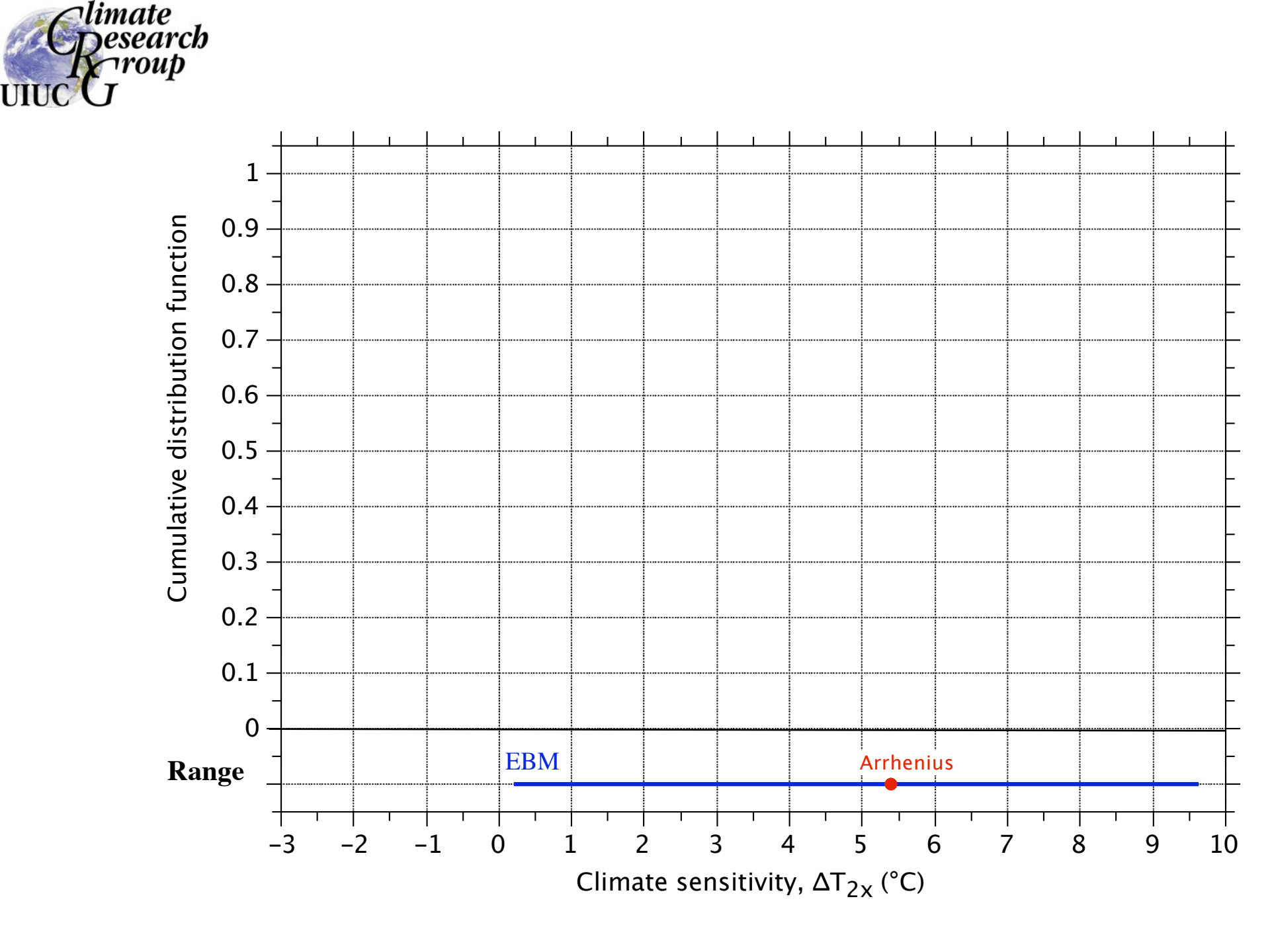
Climate sensitivity, ΔT2x (°C)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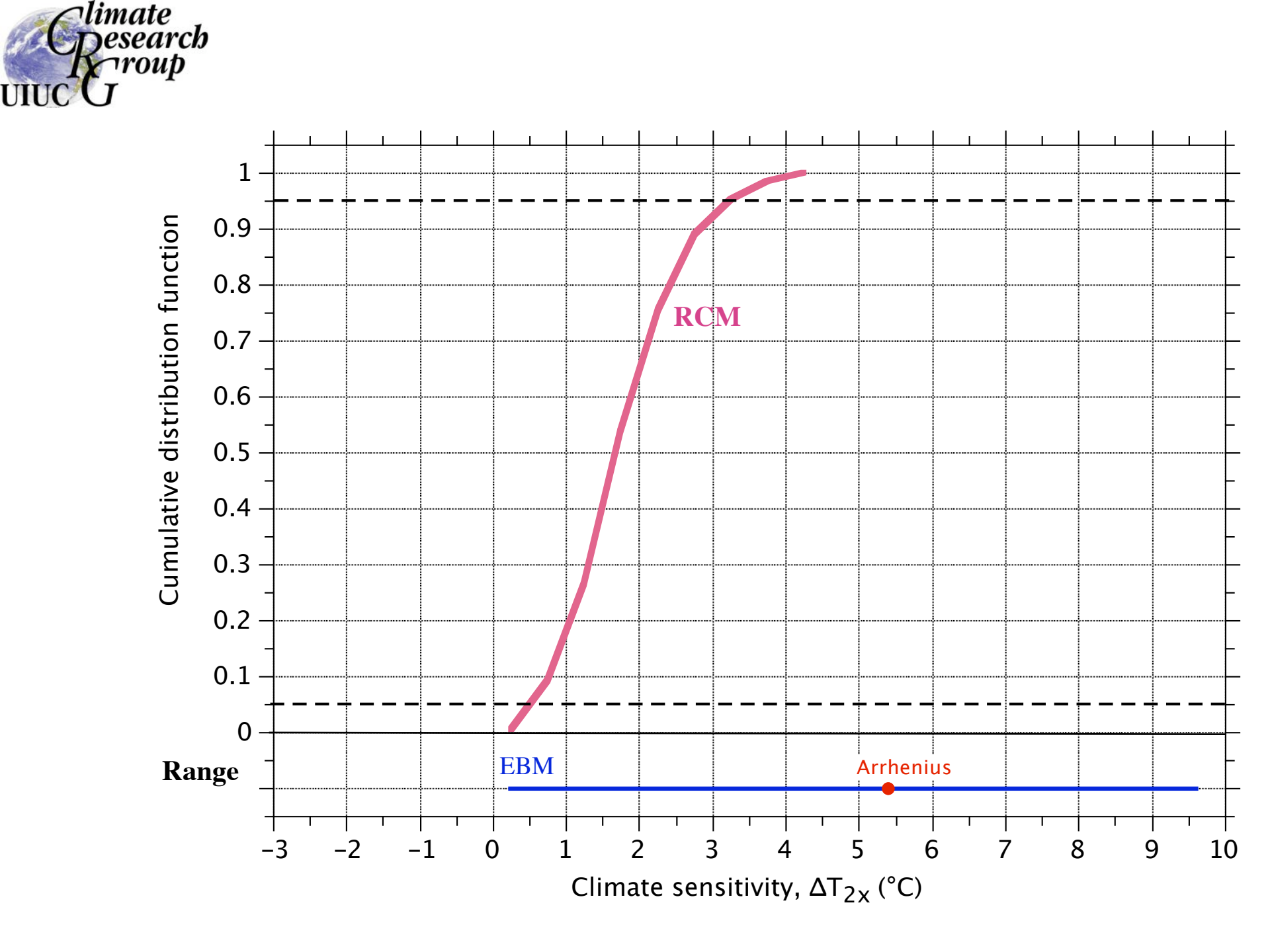
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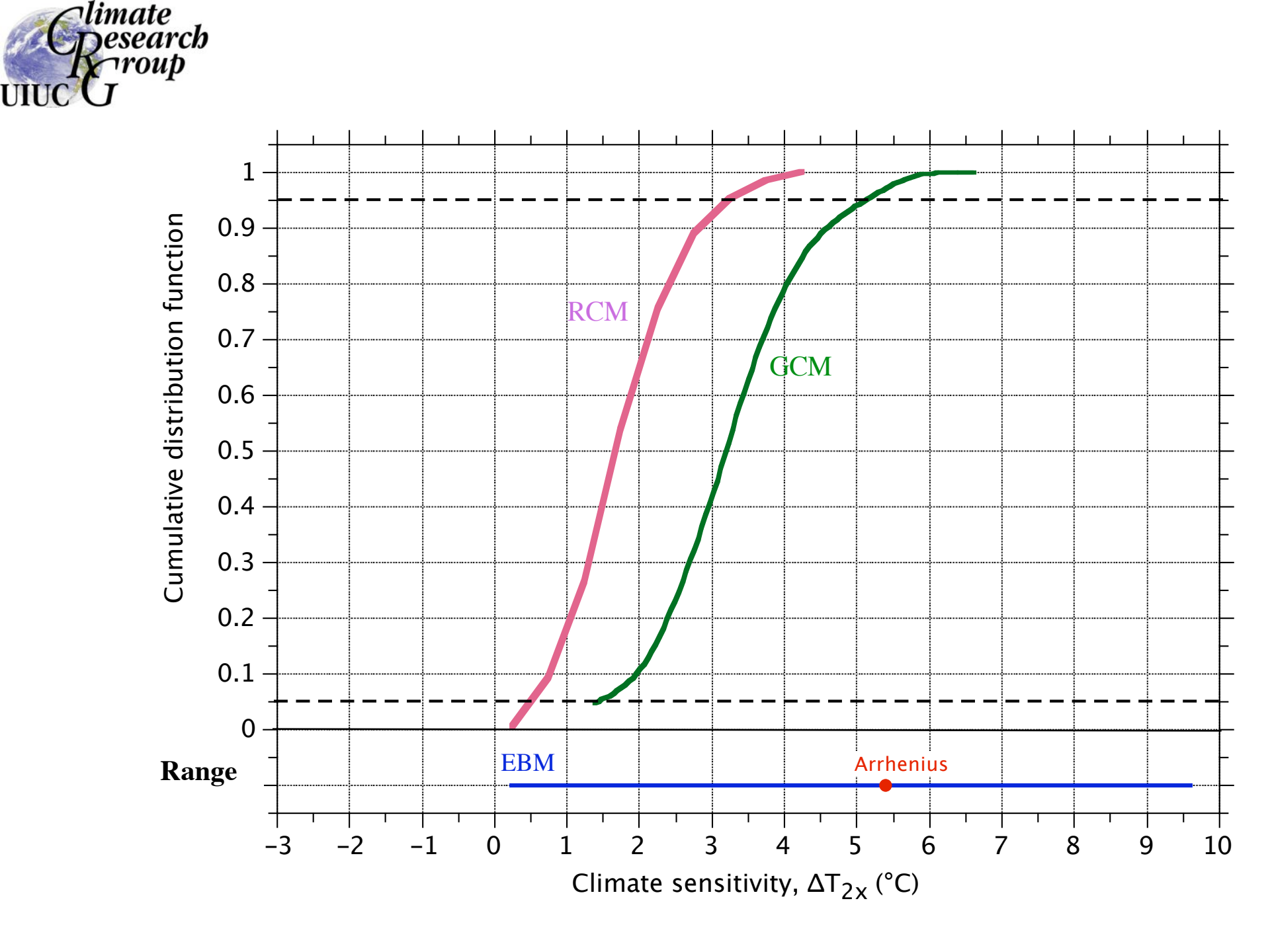
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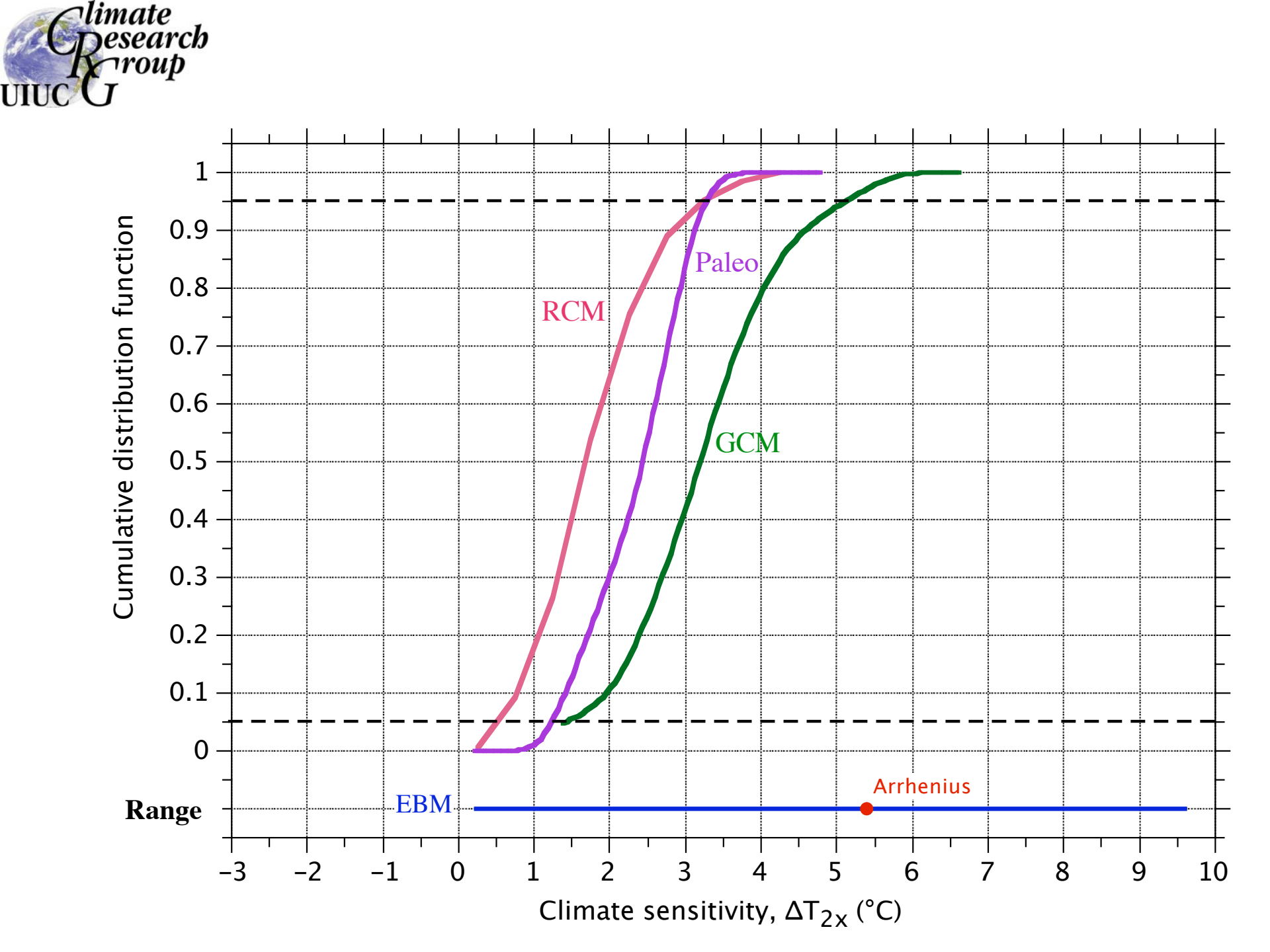
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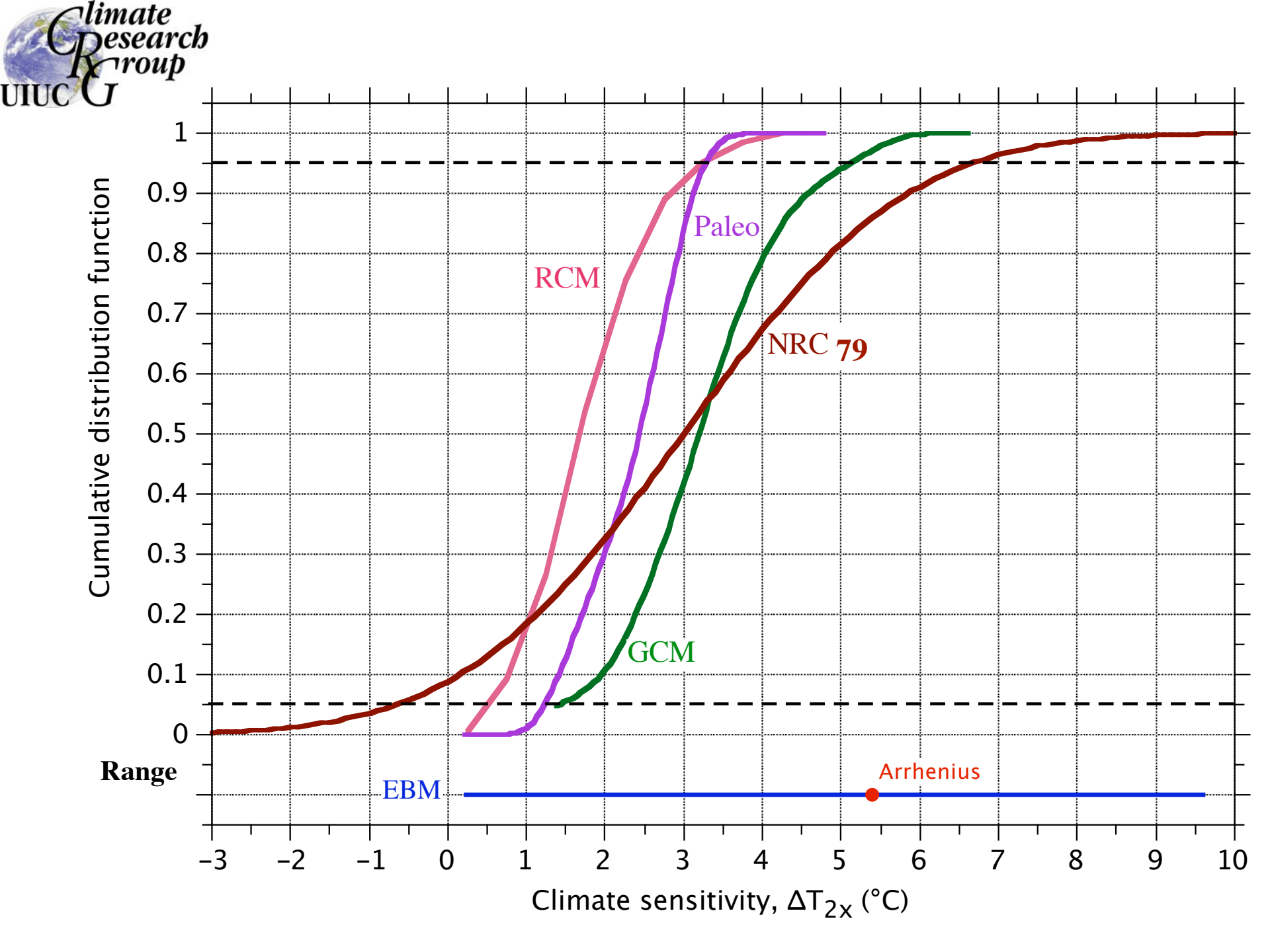
Climate sensitivity, ΔT2x (°C)

- U.S. National Research Council study chaired by Jule Charney wrote: "We estimate the most probable global warming for a doubling of CO_2 to be near 3°C with a probable error of ±1.5°C".
- The Intergovernmental Panel on Climate Change interpreted the findings of the Charney report to mean that $1.5°C \leq \Delta T_{2x} \leq 4.5°C$.
- We assert that this interpretation is incorrect and that the correct interpretation is that there is only a 50% likelihood that ΔT_{2x} lies within 1.5° to 4.5°C.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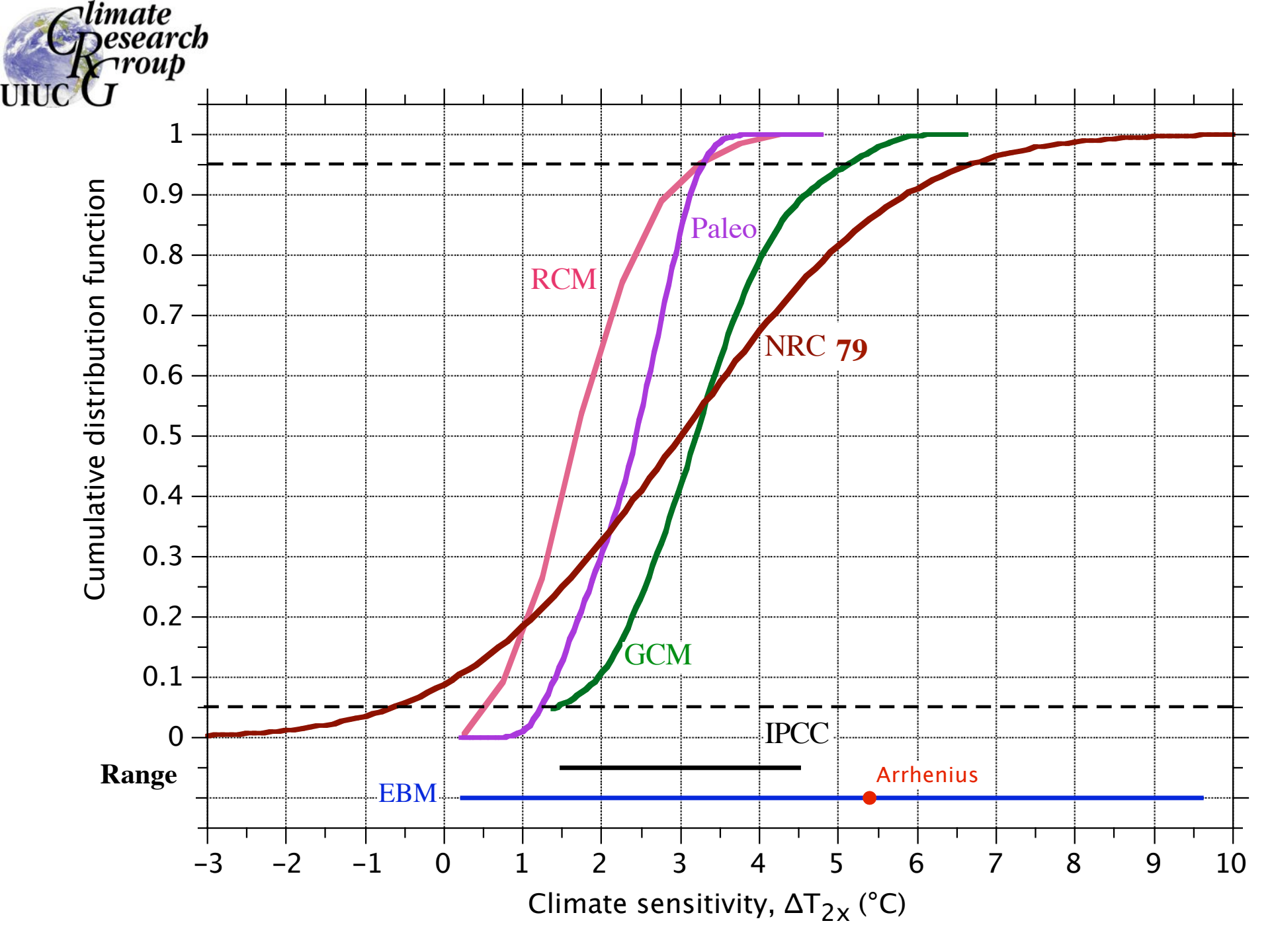
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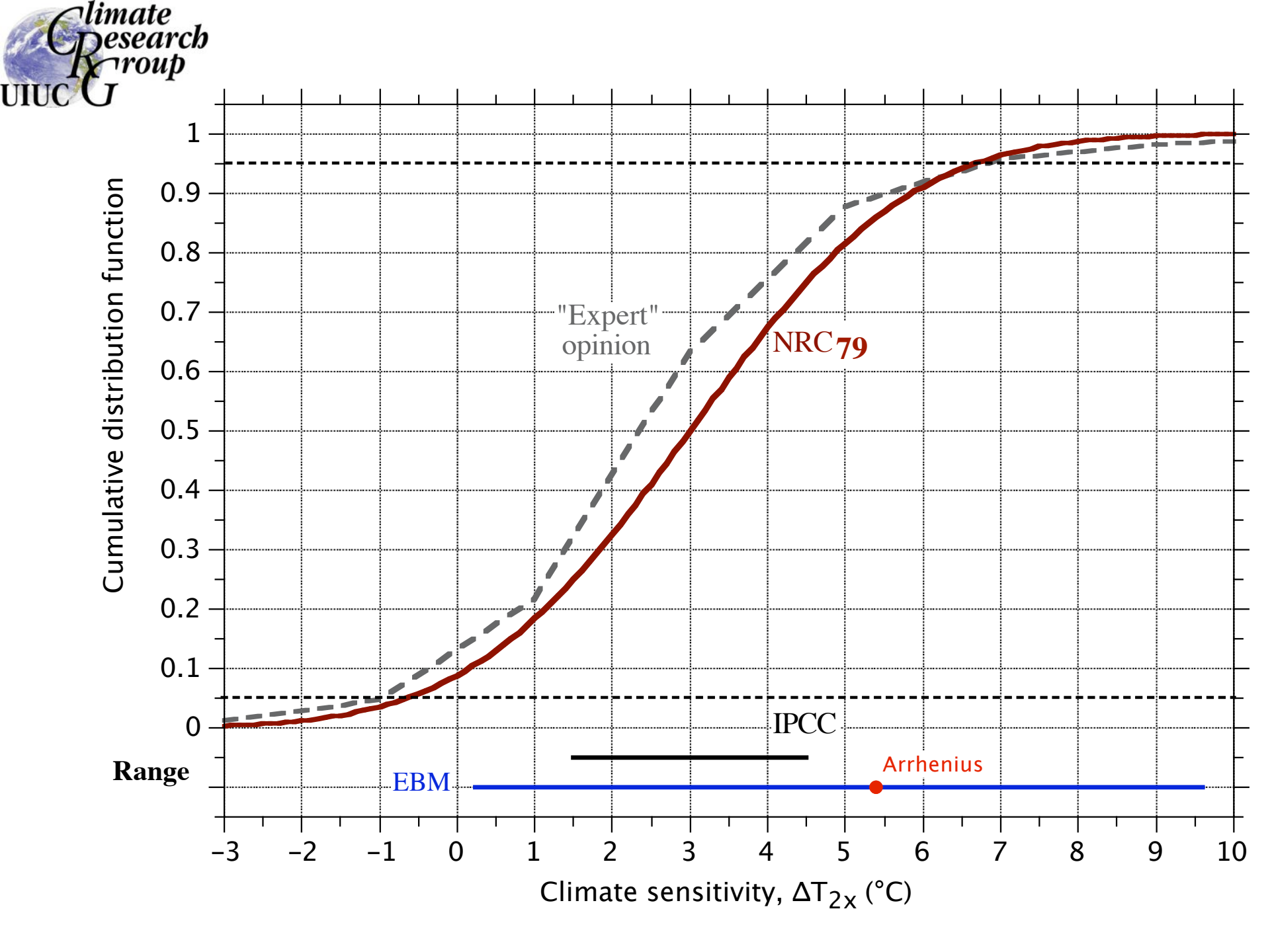
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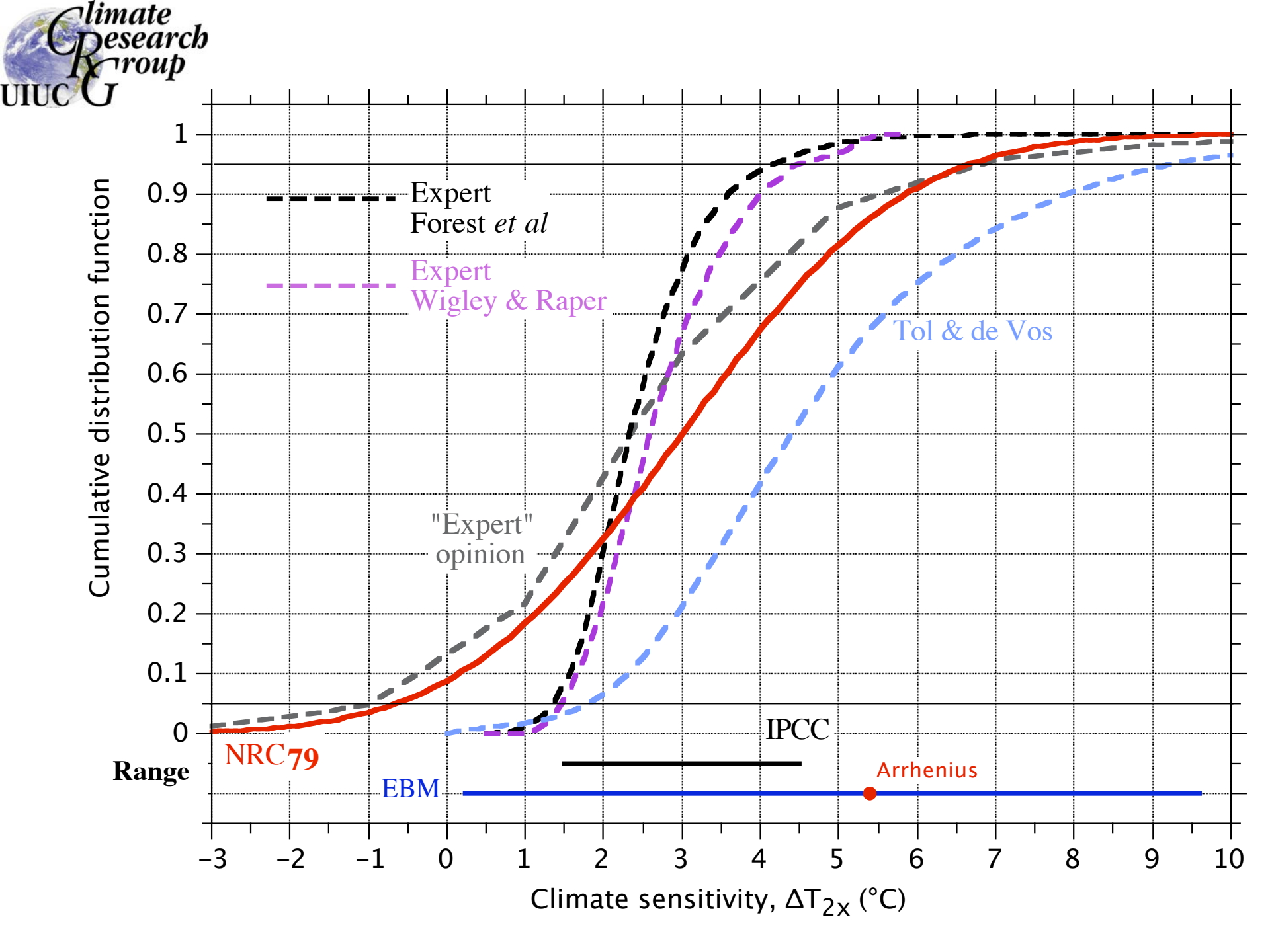
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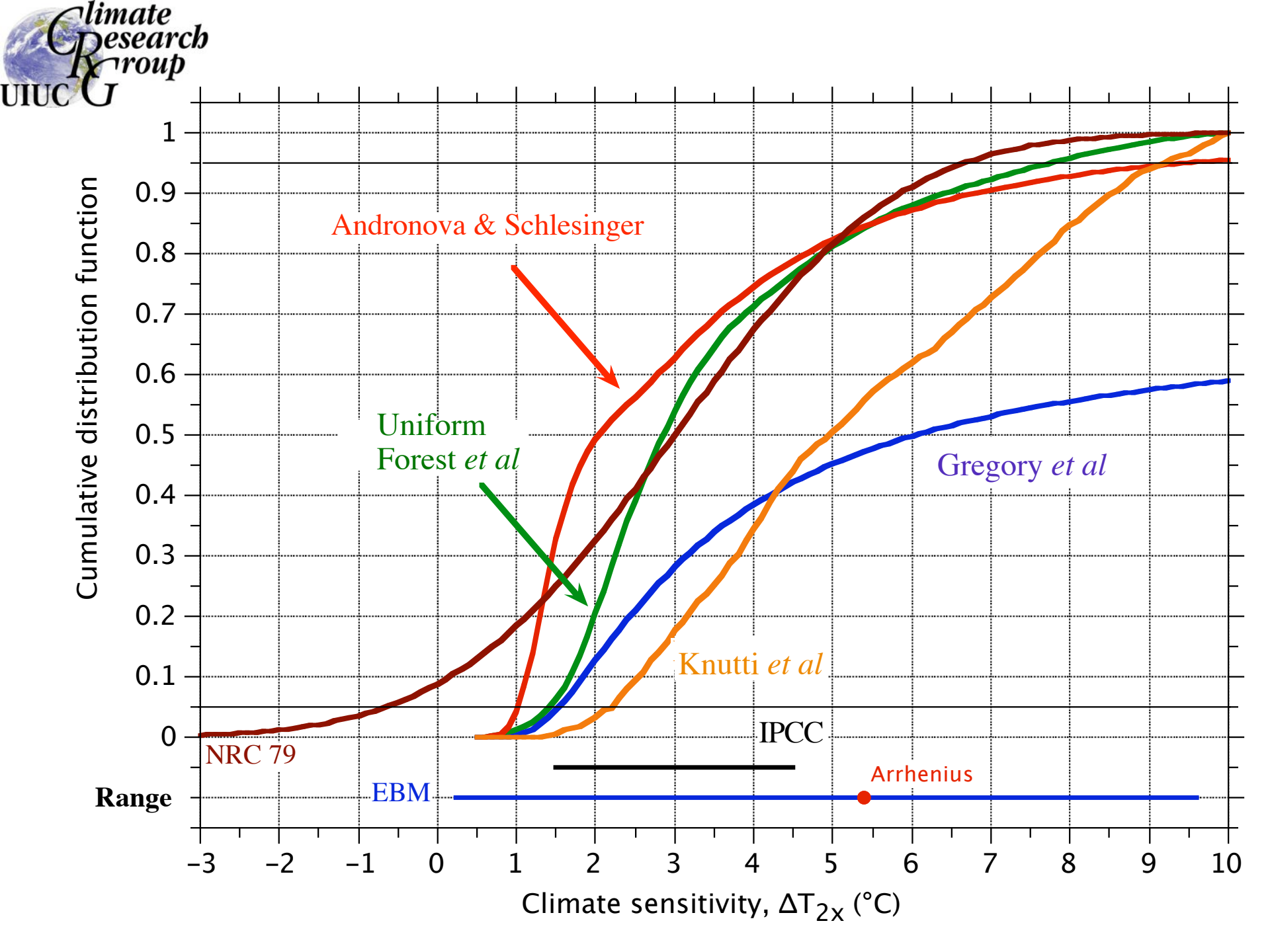
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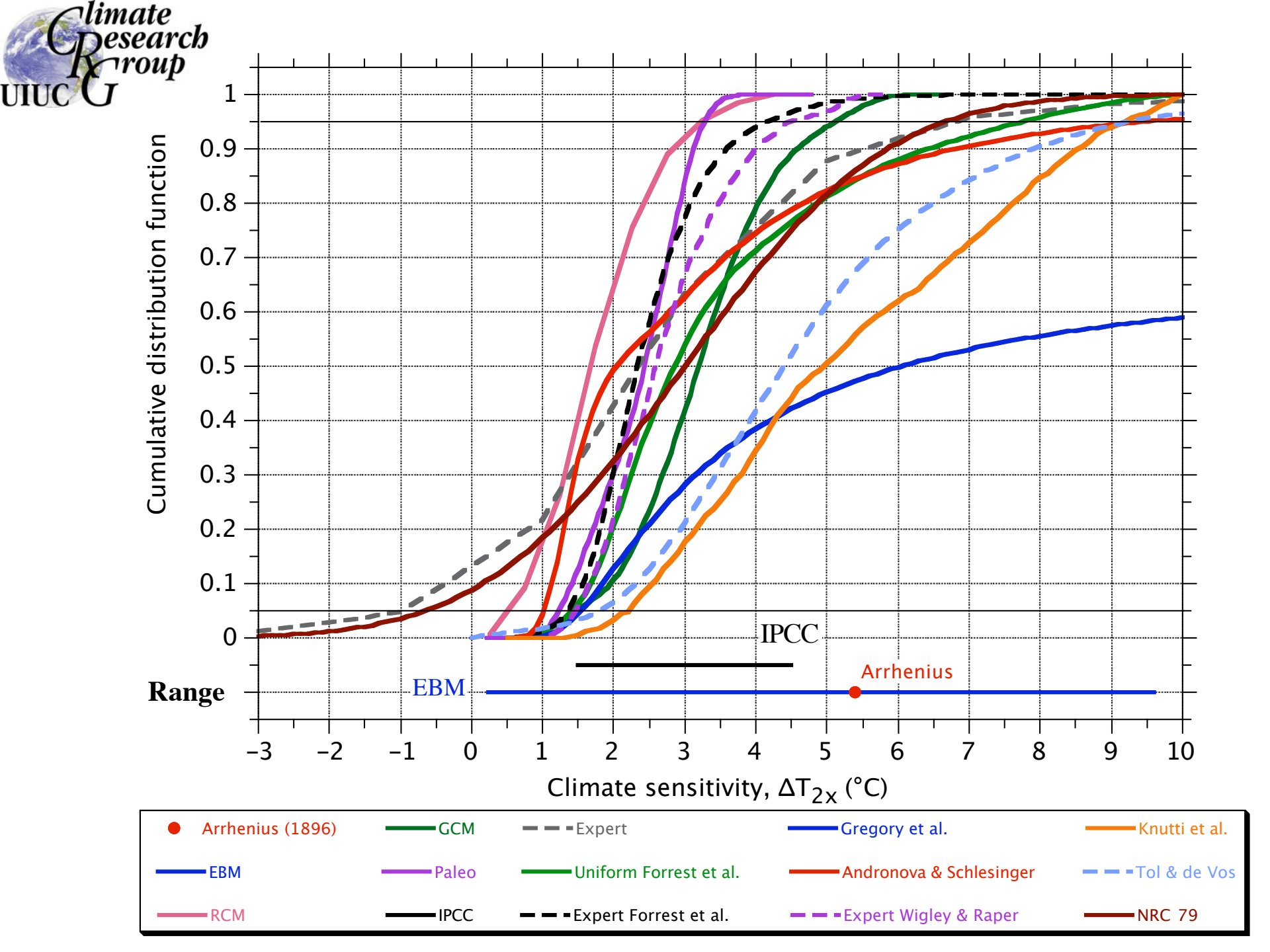
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Climate sensitivity, ΔT2x (°C)
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Expert Forrest et al.
Expert Wigley & Raper
NRC 79

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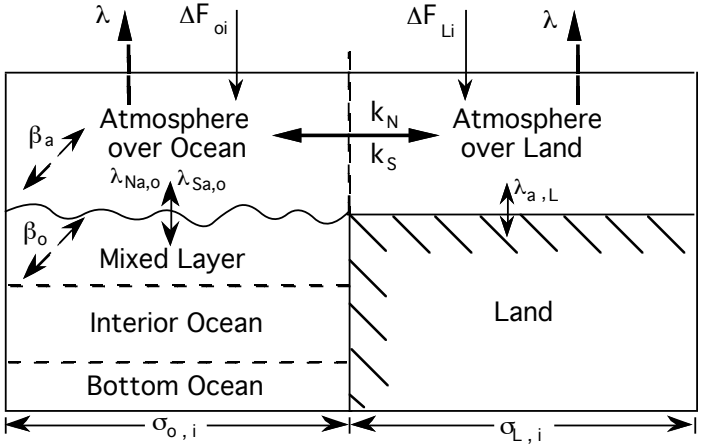
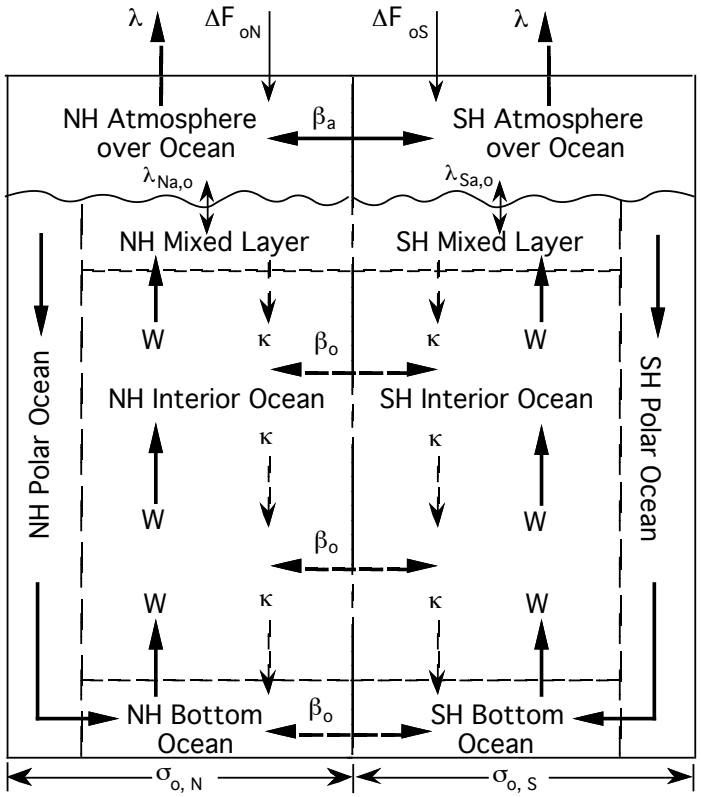
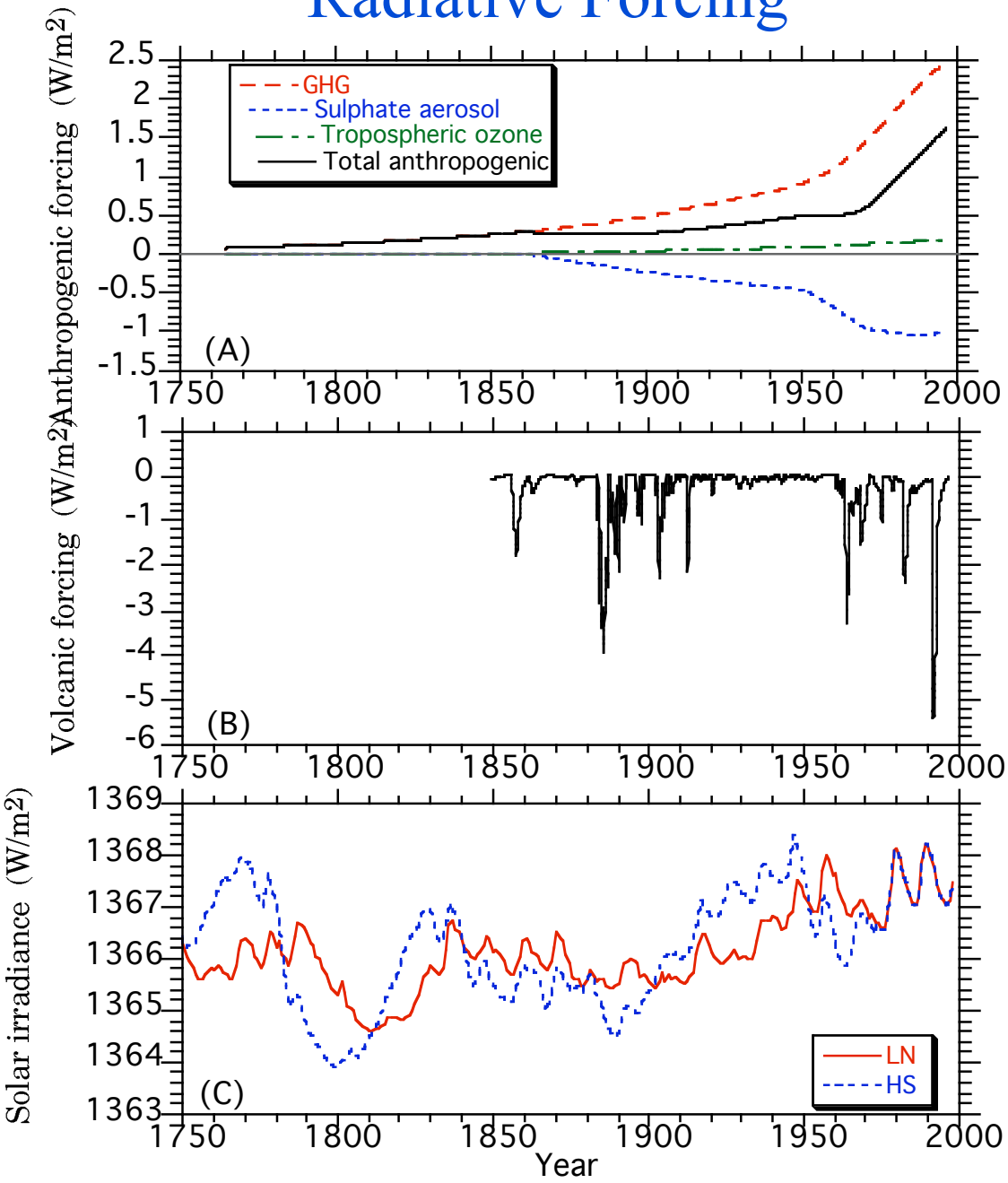
Simple climate/ocean model

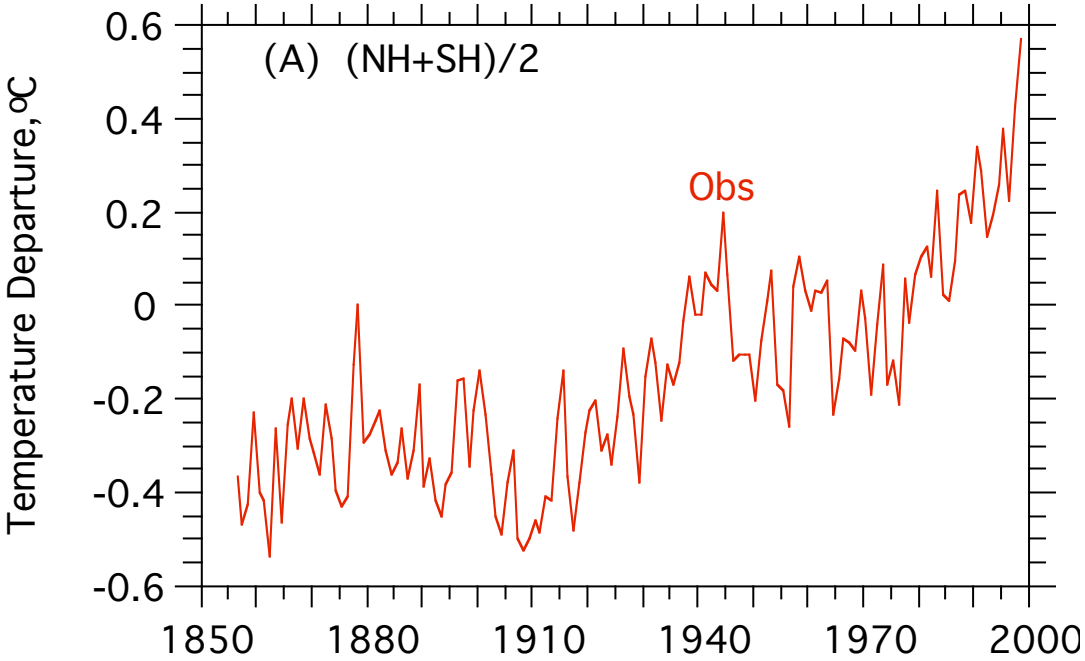


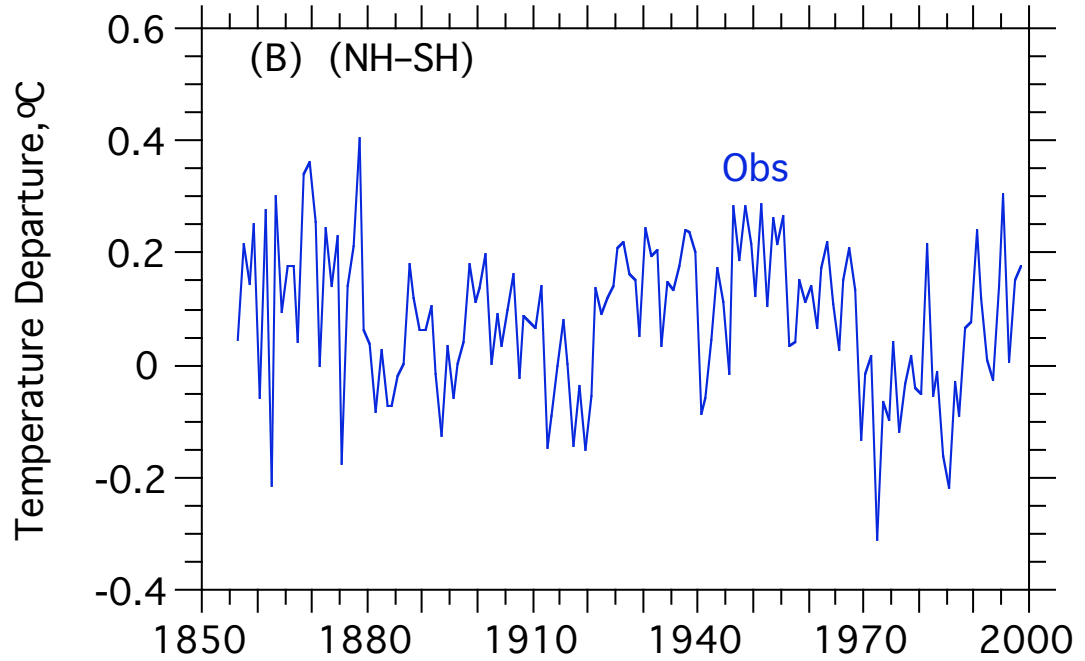


Radiative Forcing



Observed Surface Air Temperature Changes





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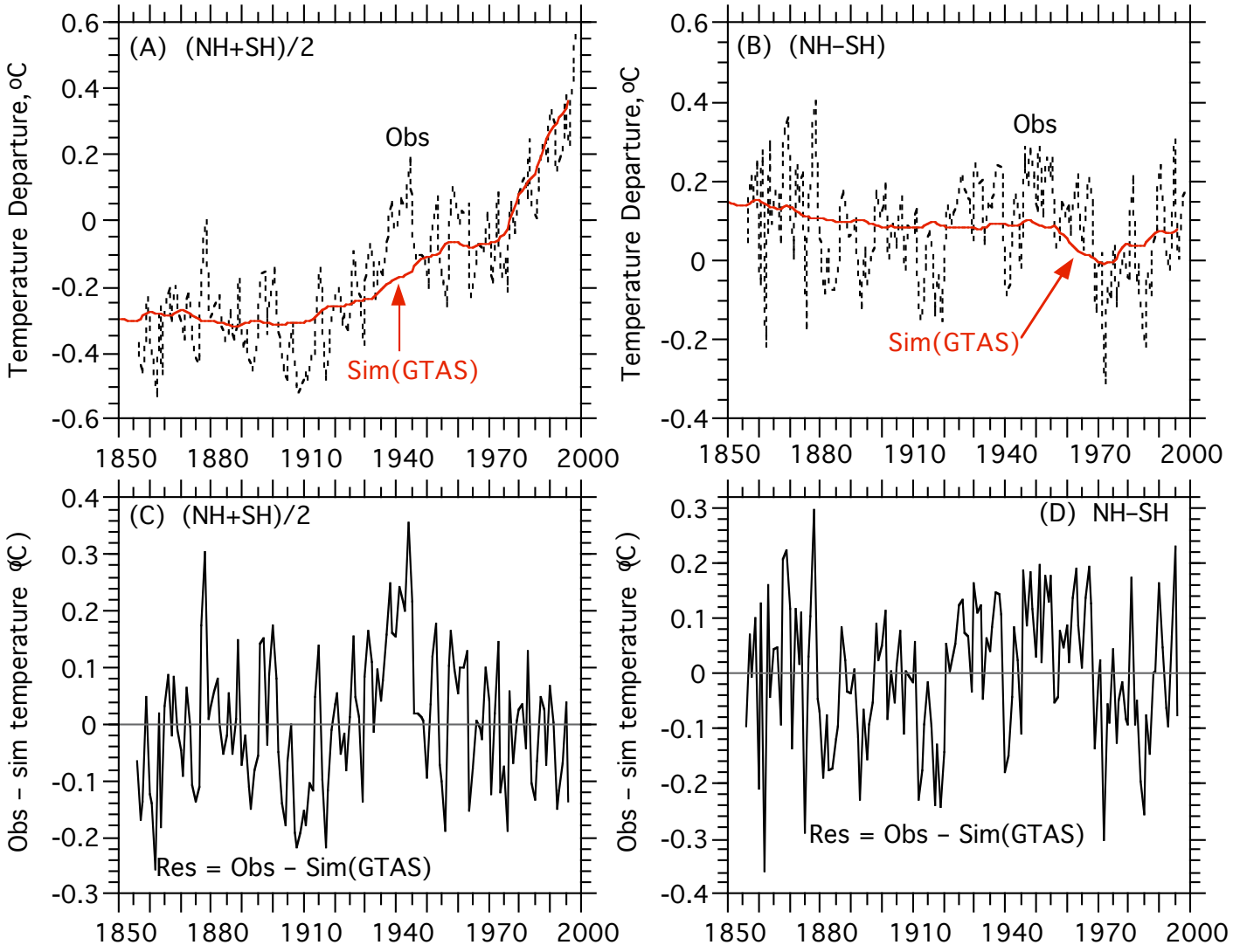
Simulated Vs. Observed Surface Air Temperature Change



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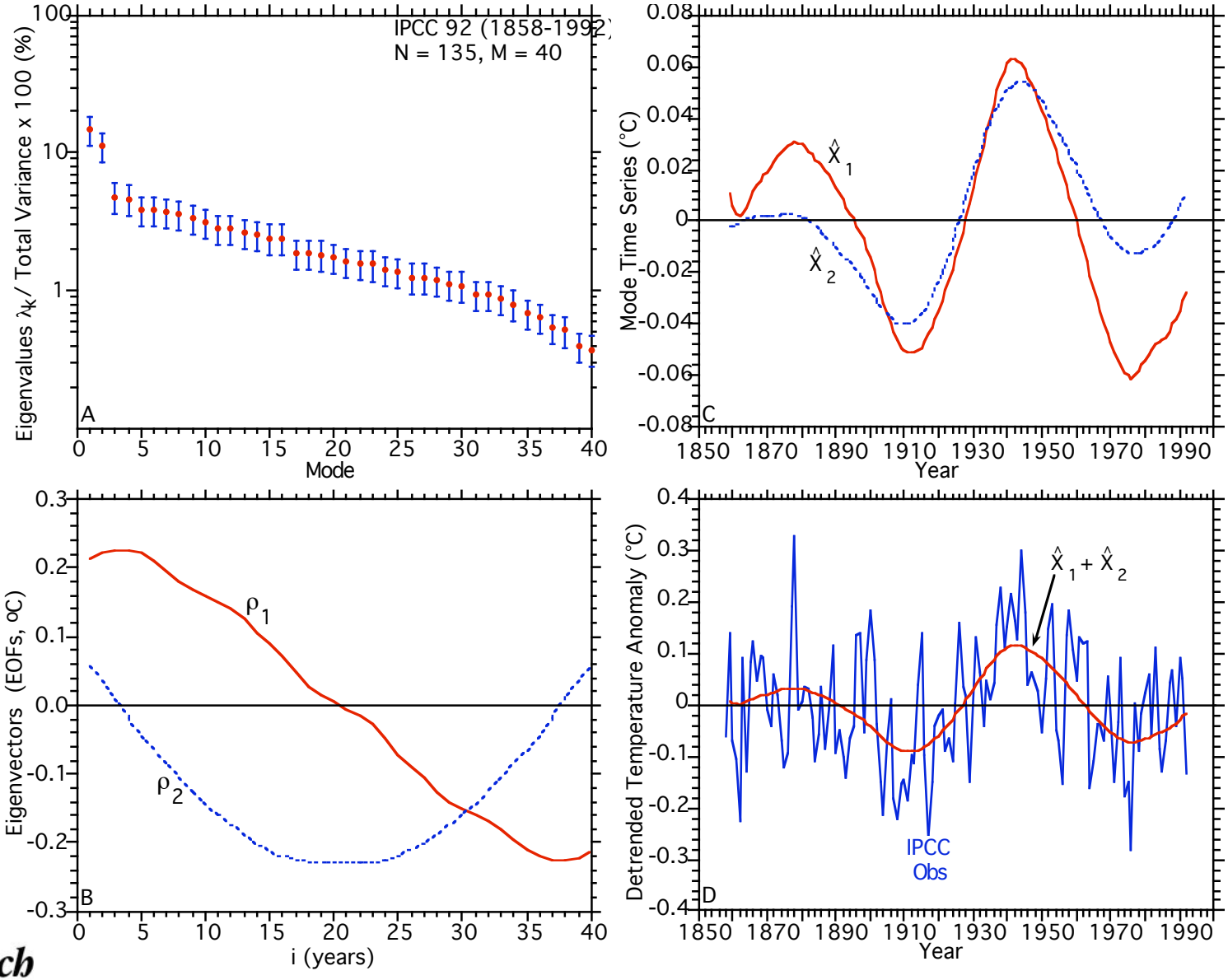
Schlesinger & Ramankutty (1994)



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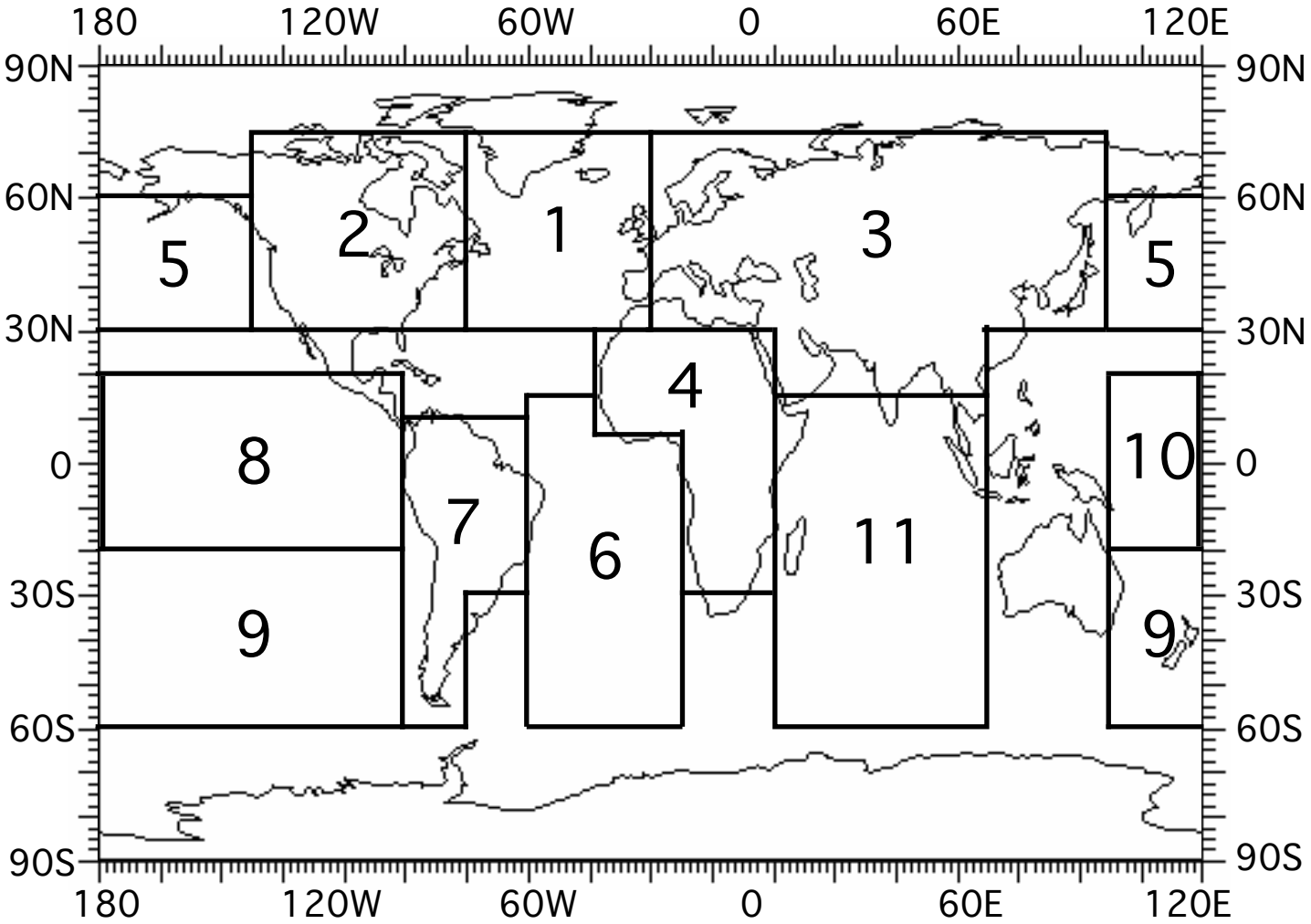

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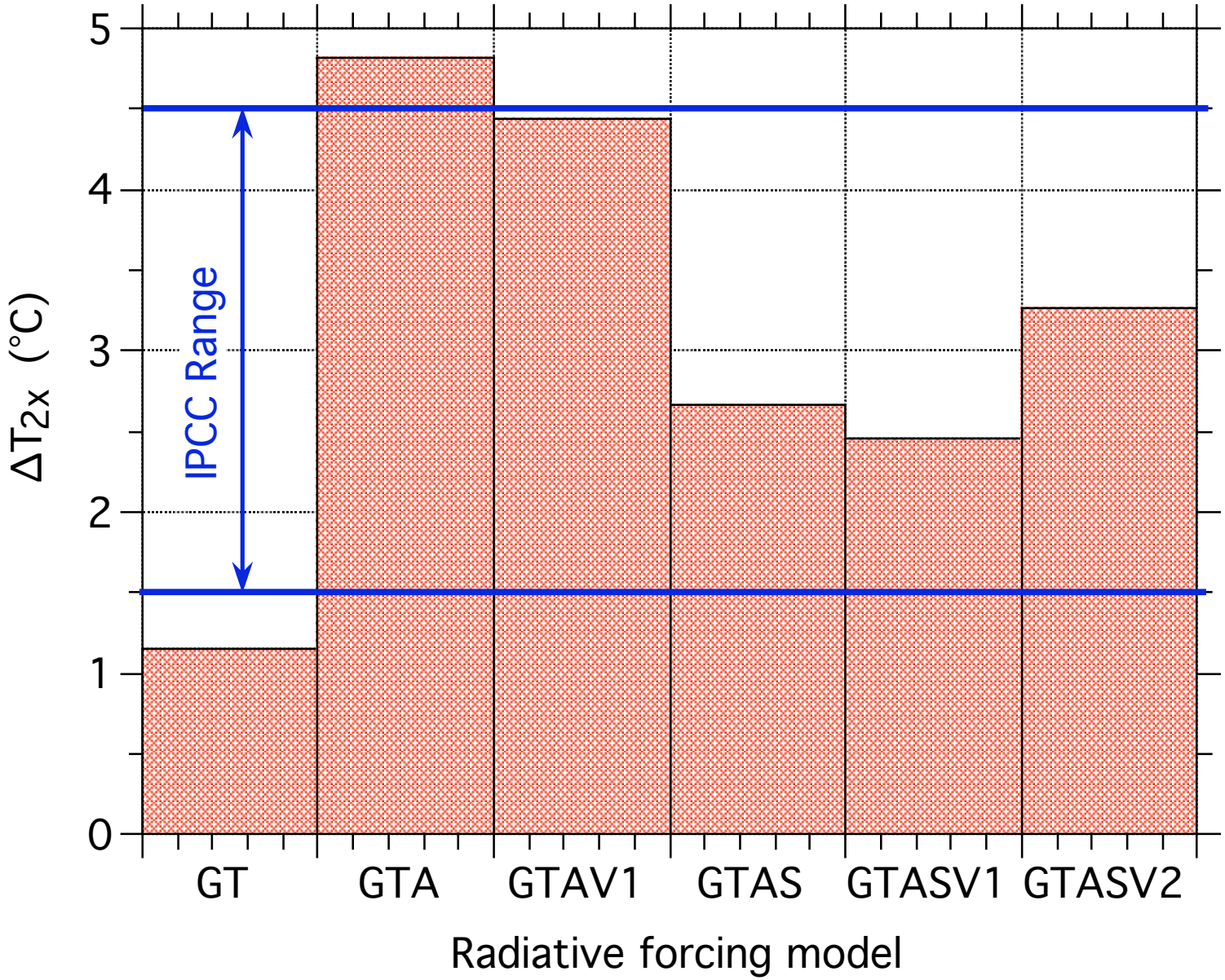
ΔT_{2x} Versus Radiative Forcing



Conclusion 1

- To reduce the uncertainty in climate sensitivity requires reducing the uncertainty in the radiative forcing, not only by aerosols, but also by the Sun and volcanoes.

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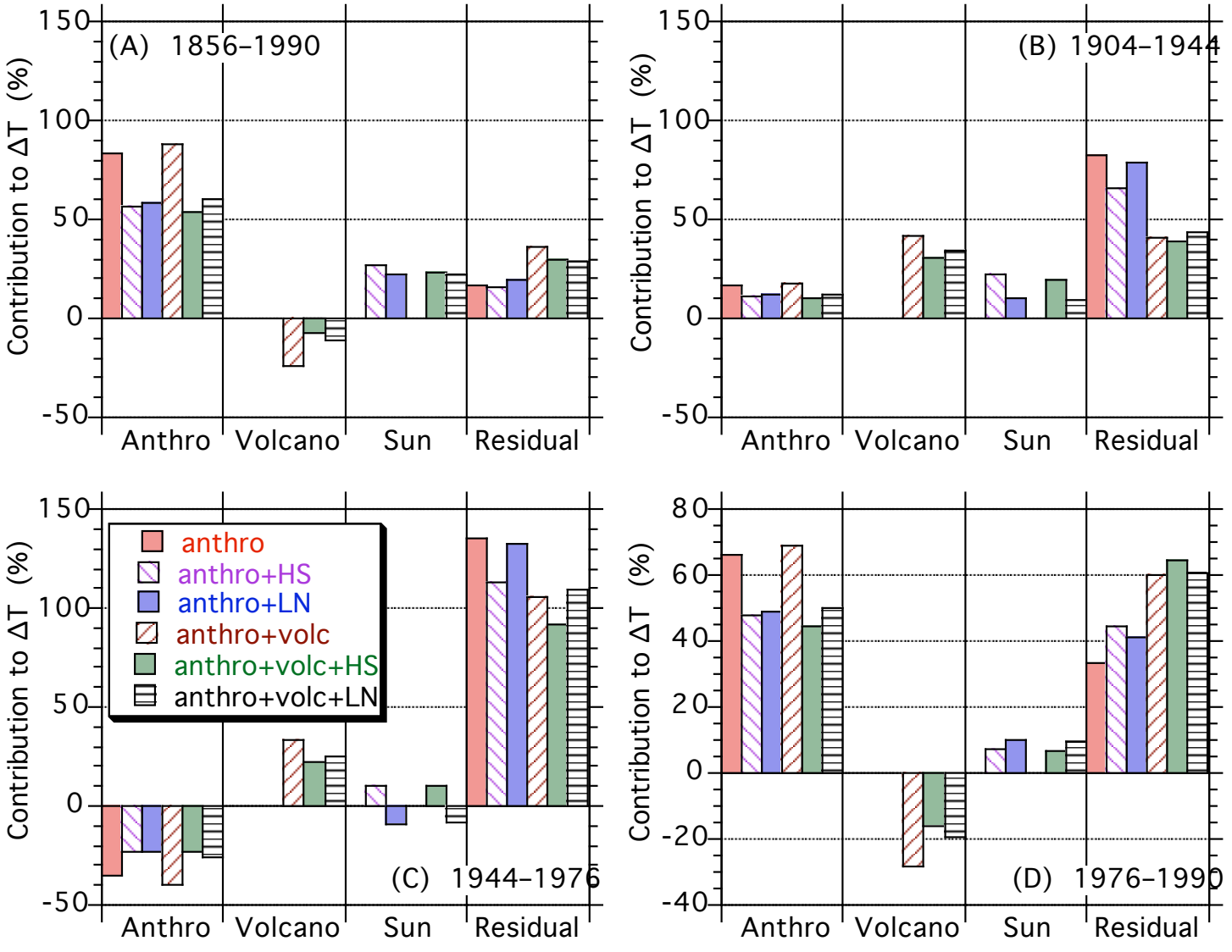
Contributions to the Observed Temperature Changes



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Conclusions 2

- The observed warming during 1904-1944 and cooling during 1944-1976 were not human induced.
- The observed warming during 1976-1990 was equally due to humans and the residual.

Conclusions 2

- The observed warming during 1856-1990 was mostly human induced.

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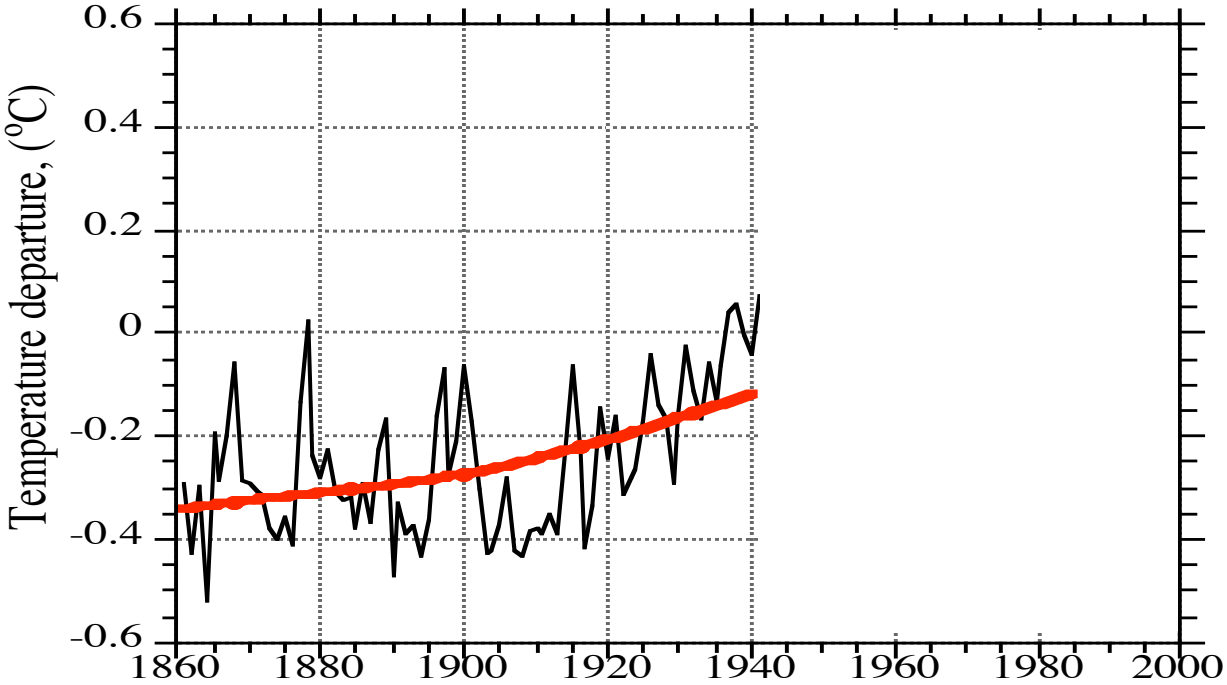

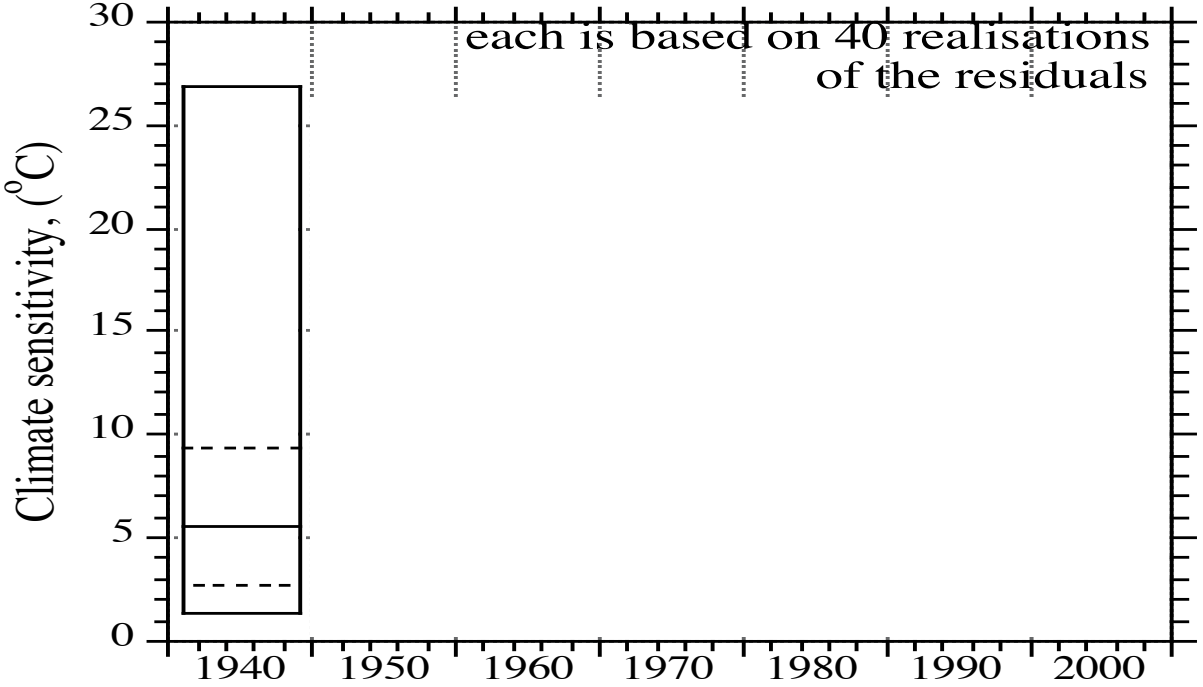

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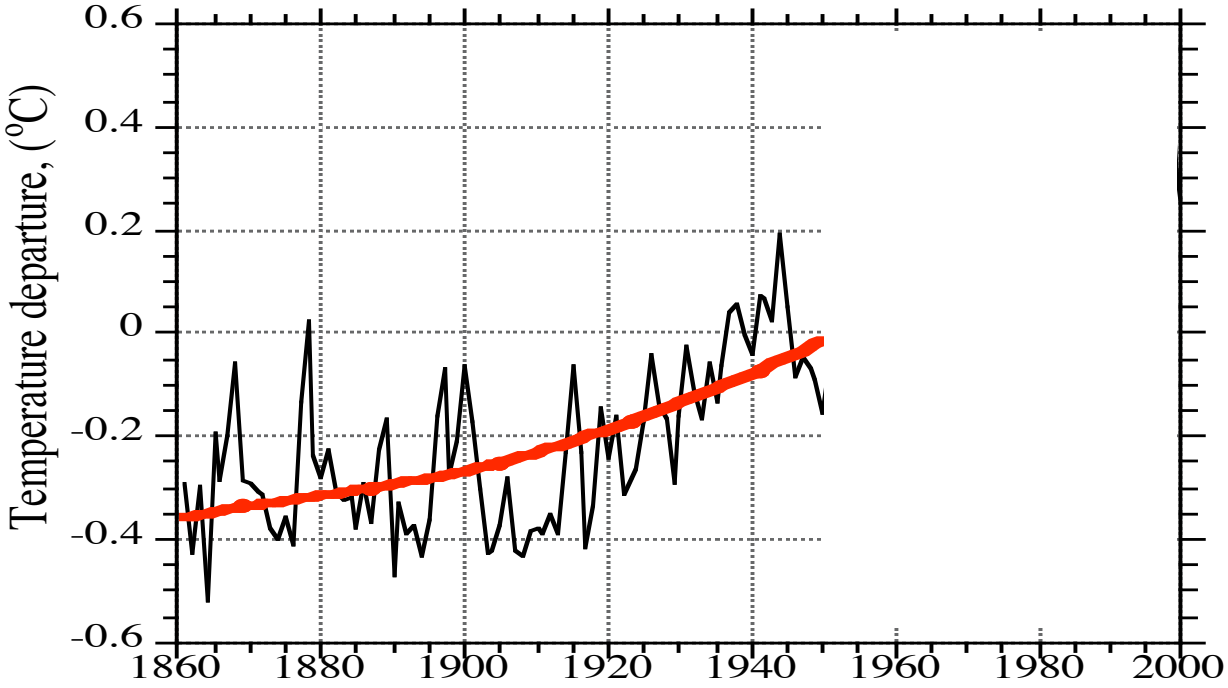

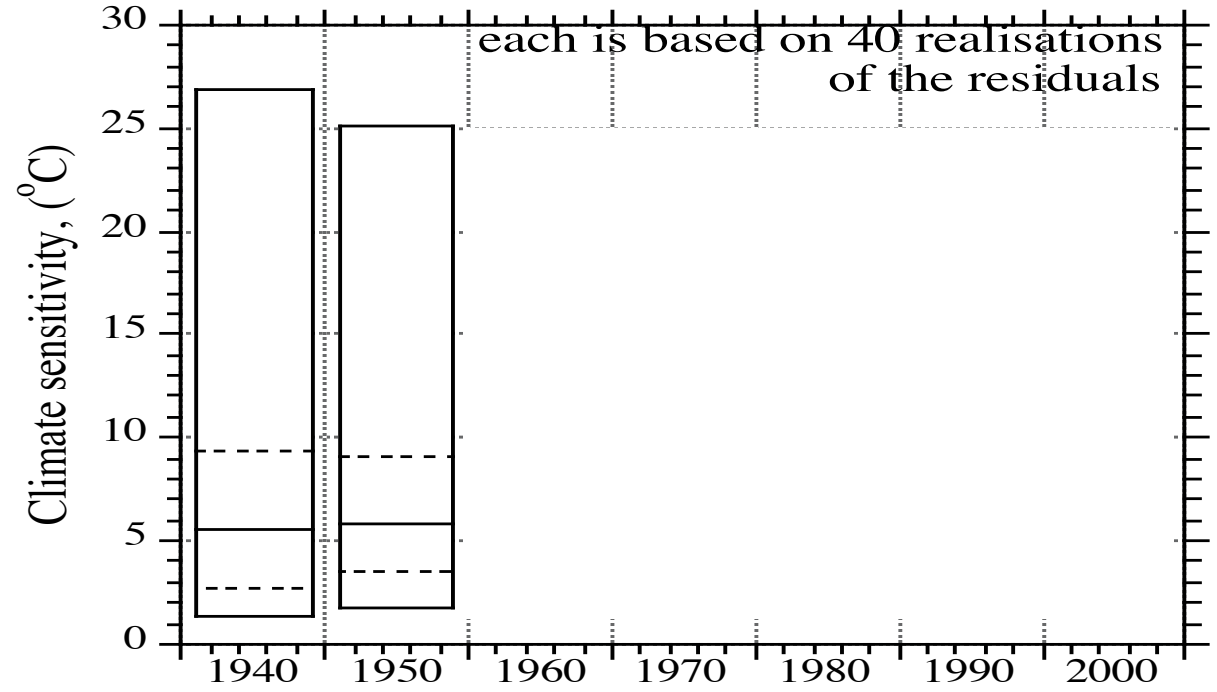

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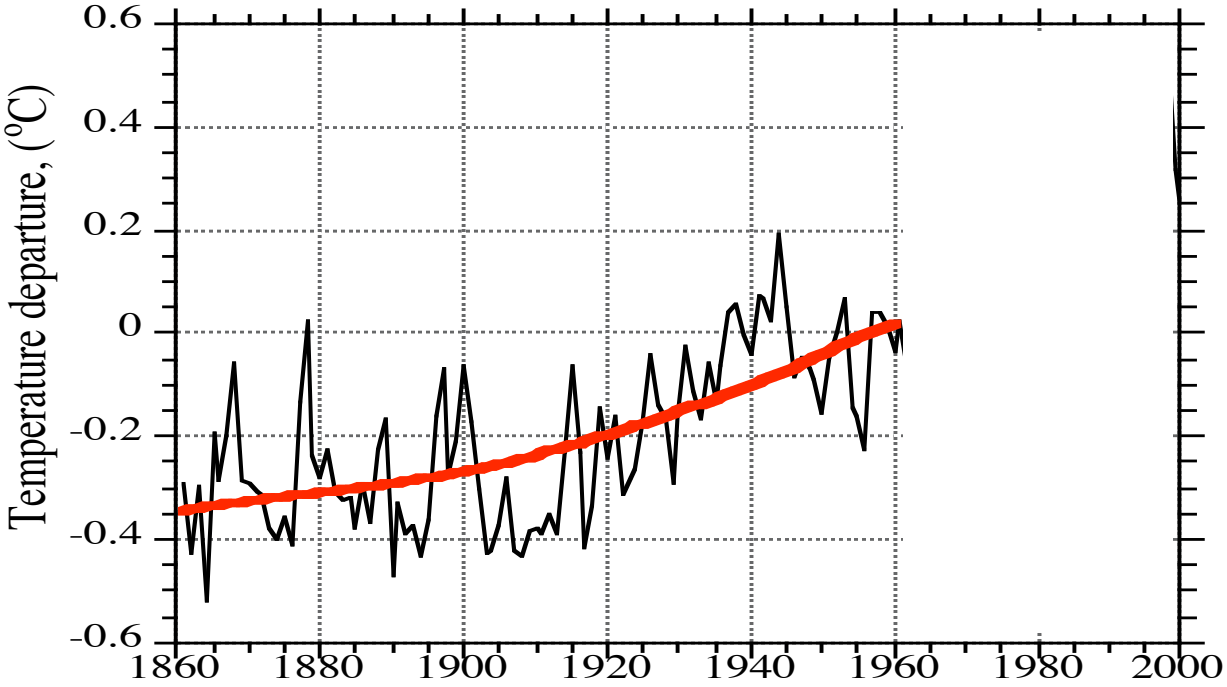

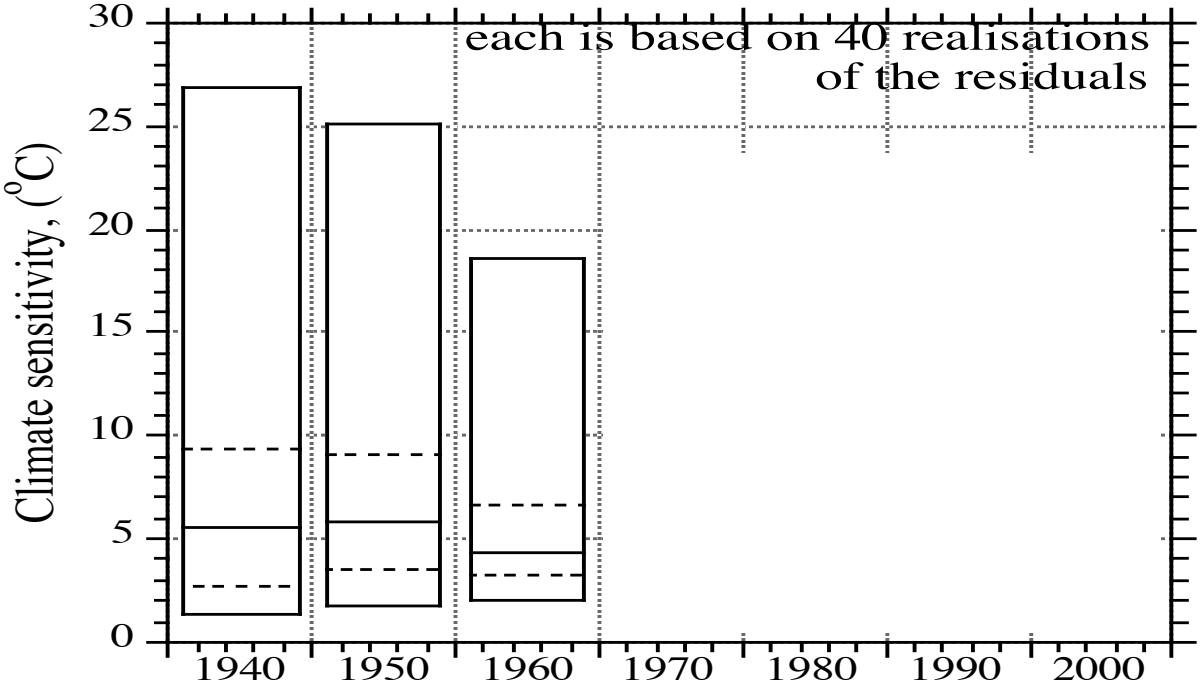

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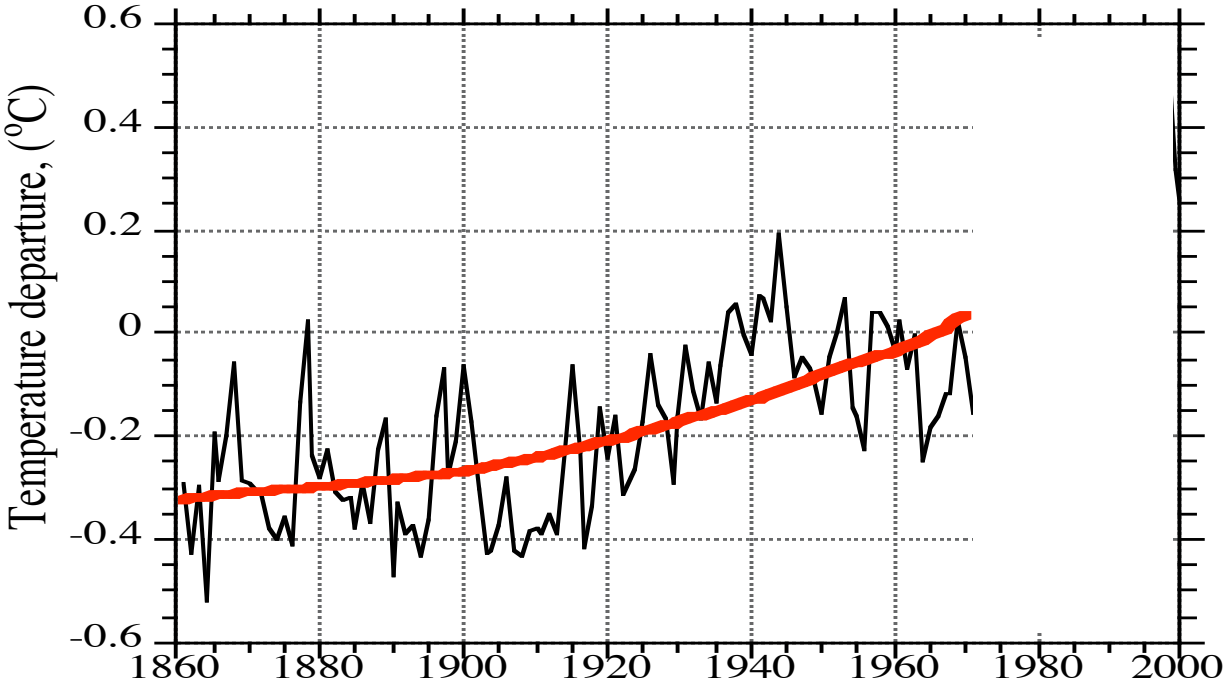

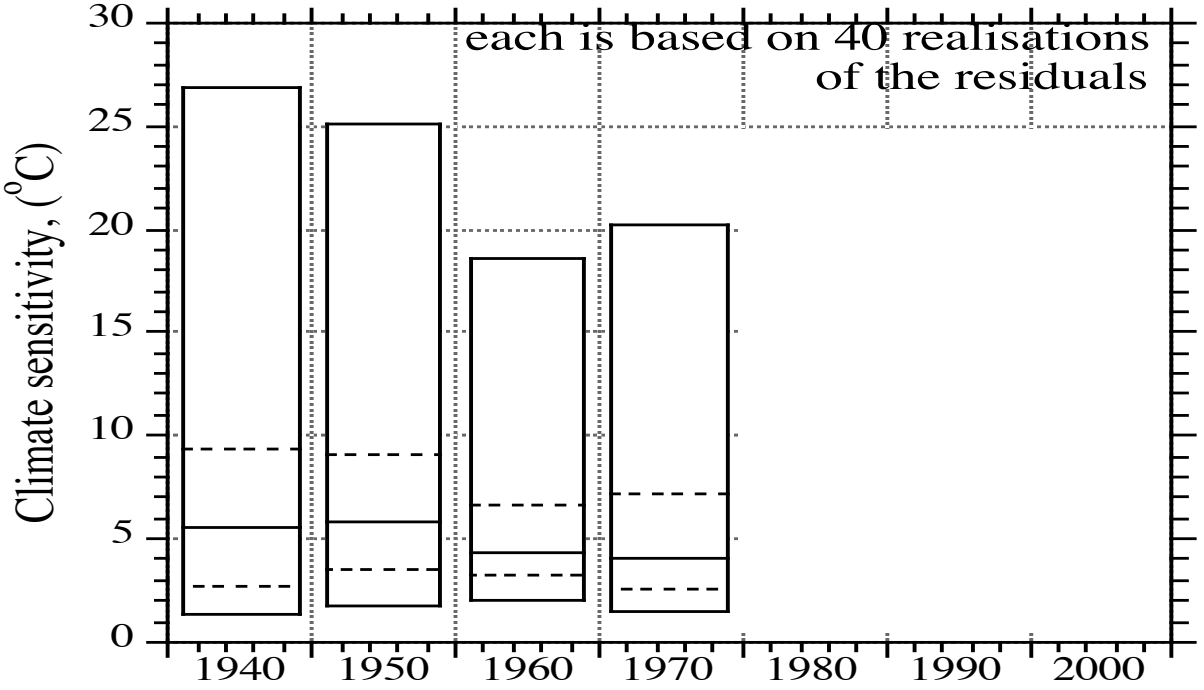

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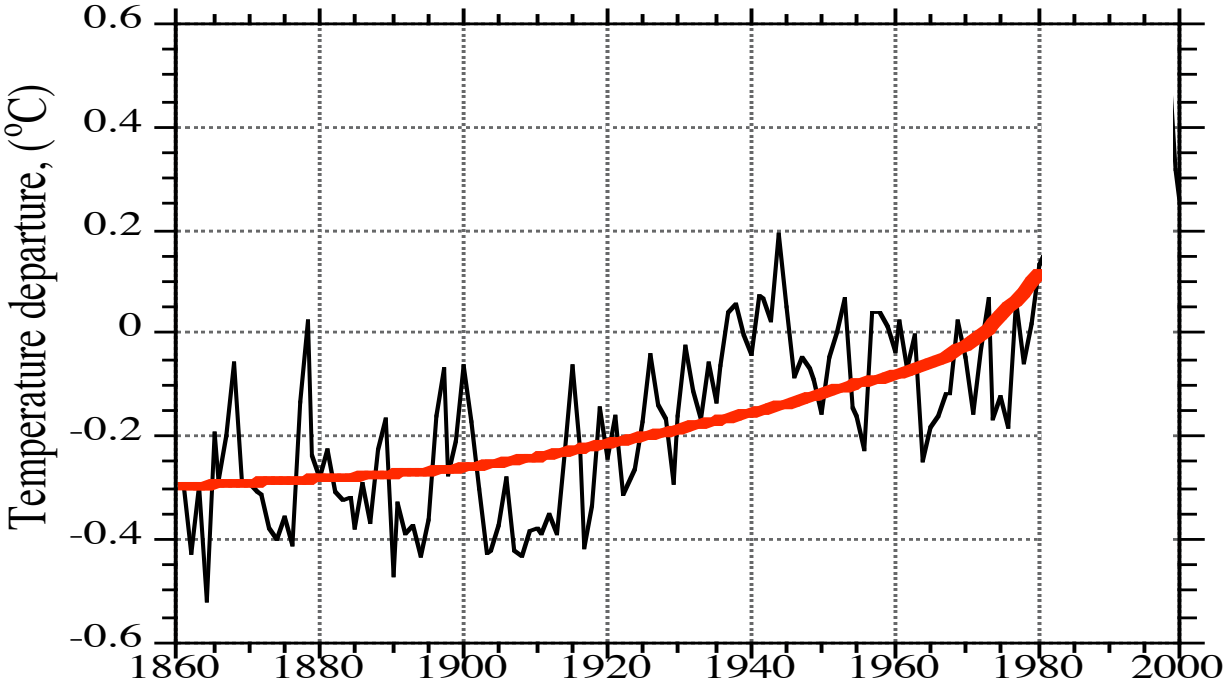

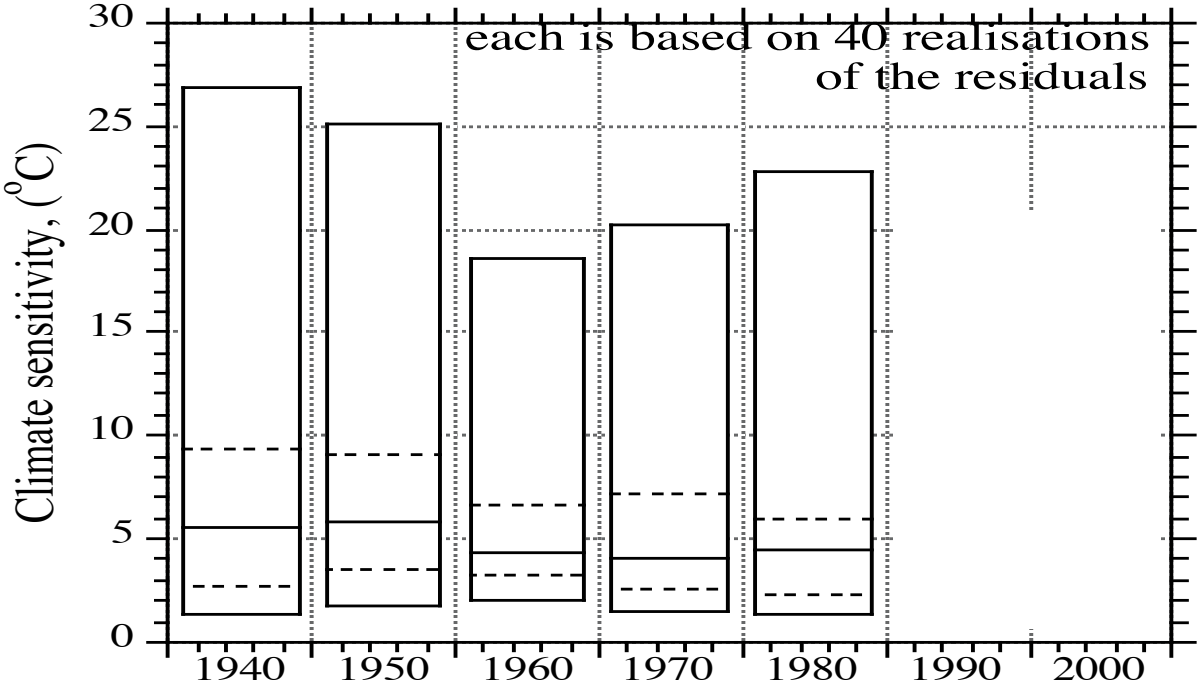

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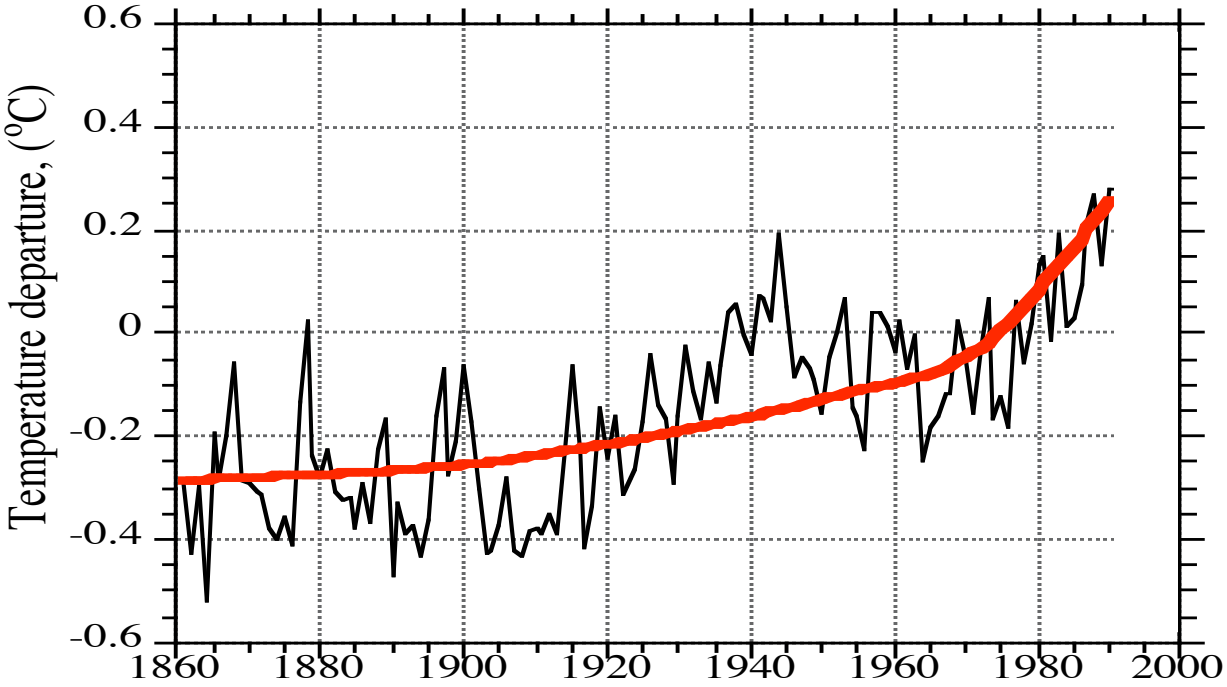

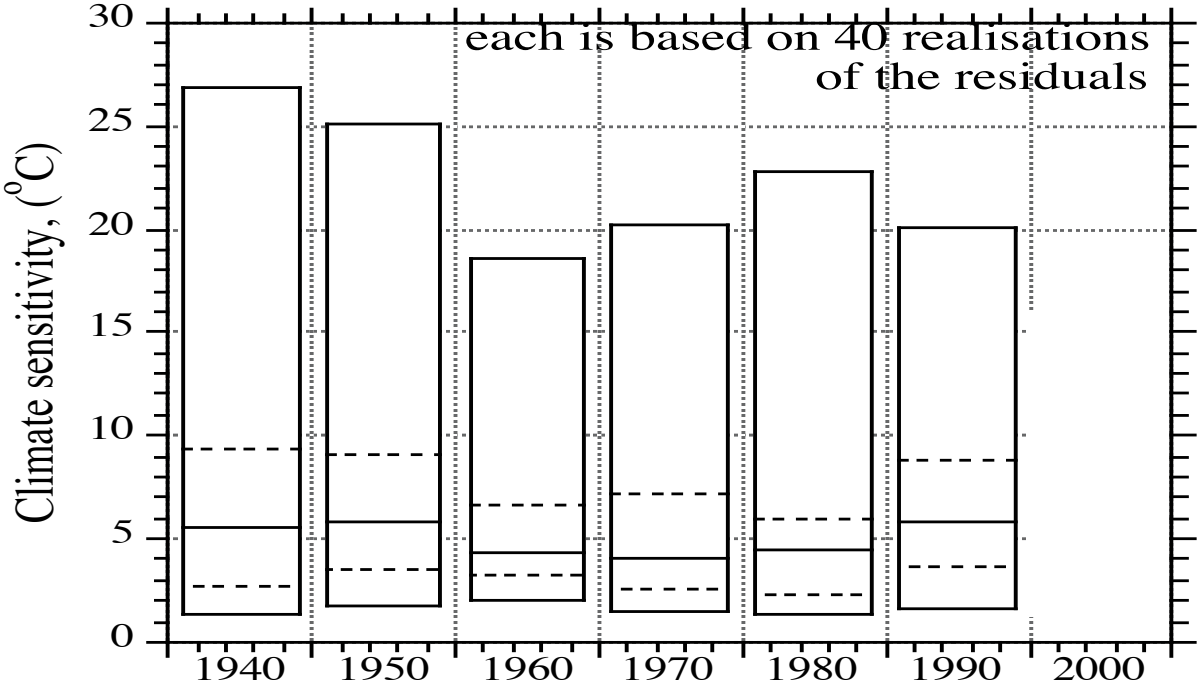

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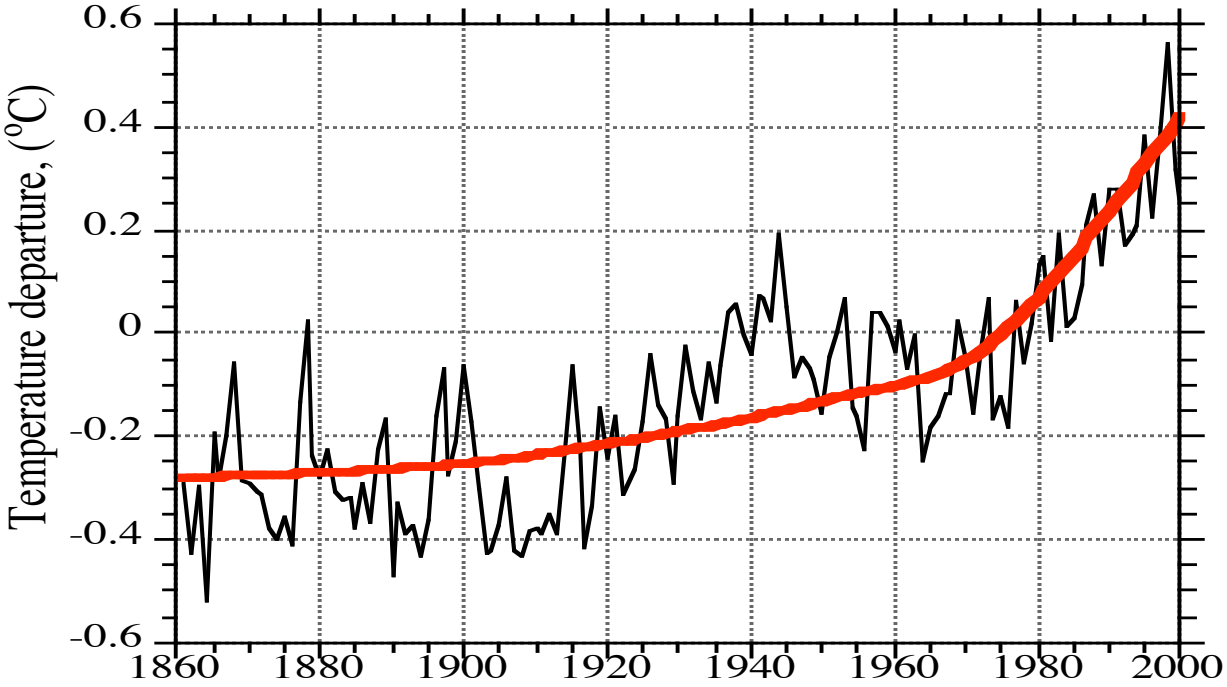
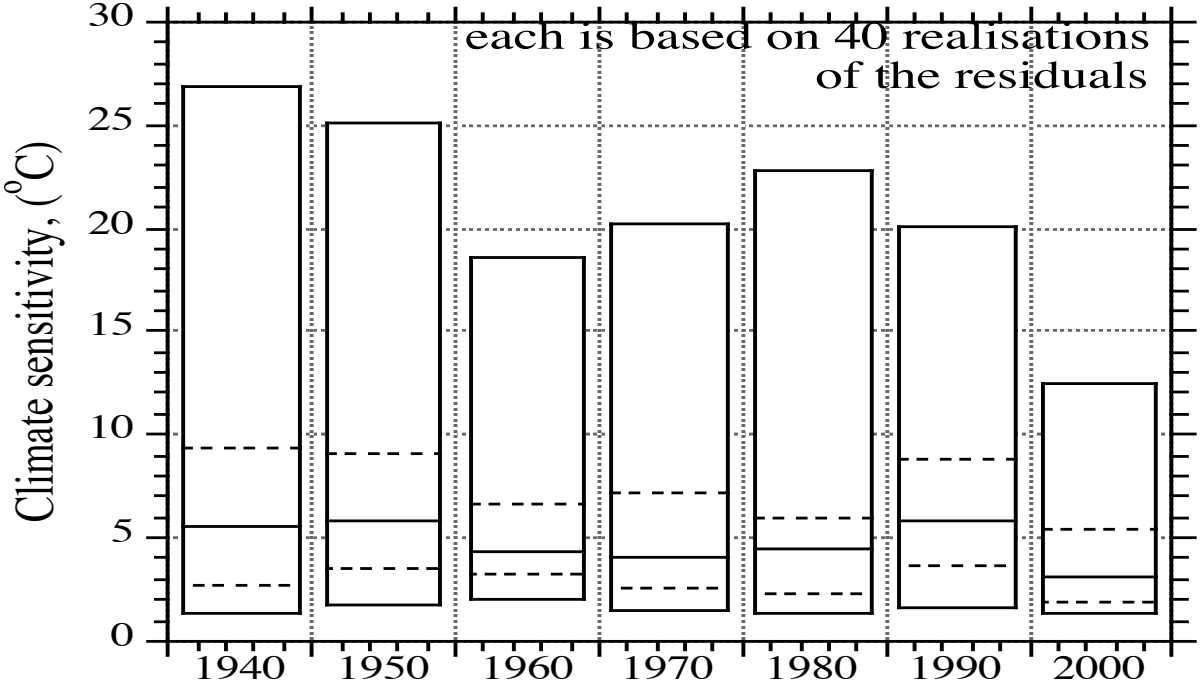




Conclusion 3

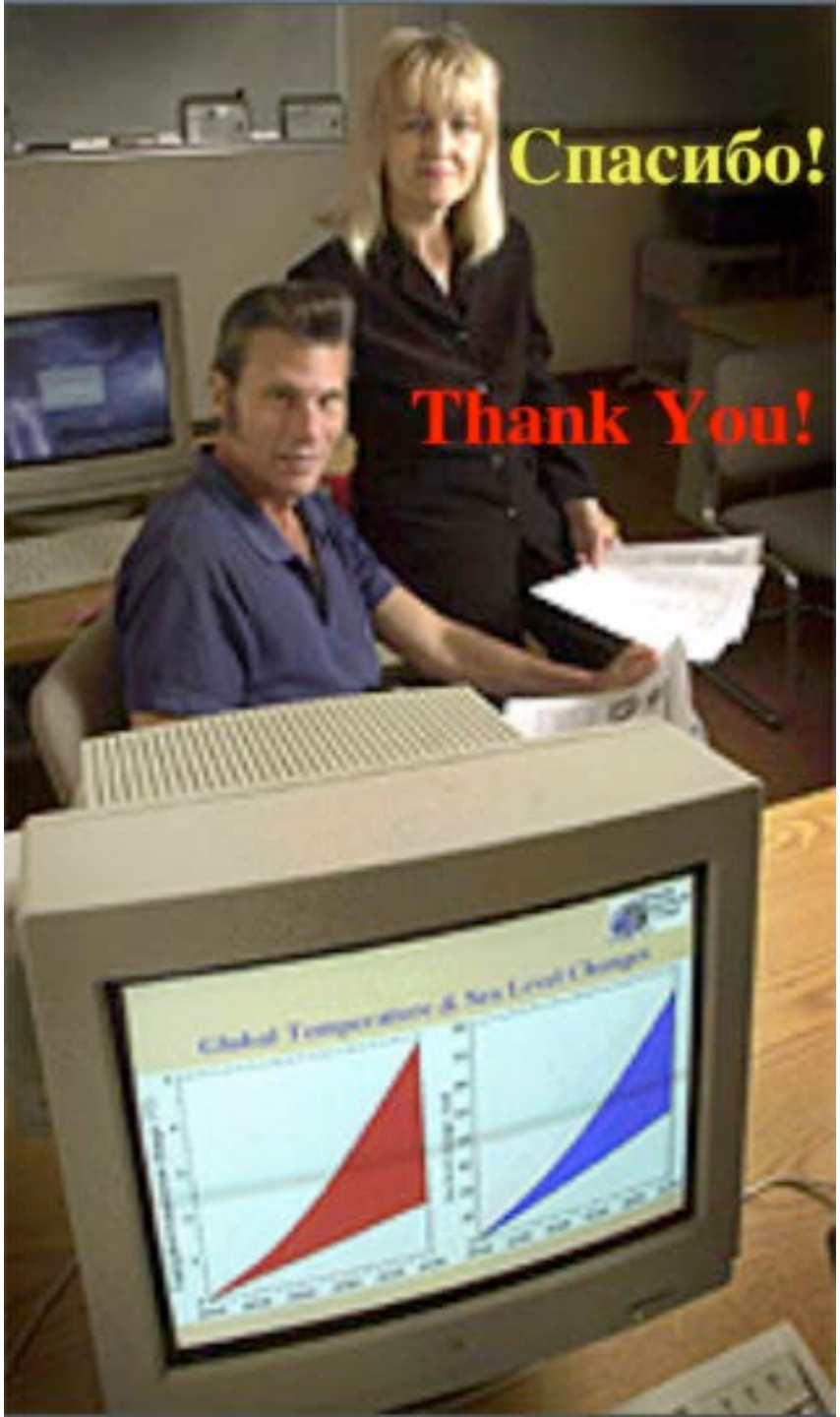
- The uncertainty in climate sensitivity due to climate noise can be reduced by learning over time, that is, by performing future estimations using longer observational records.

Conclusions 4

- It is quite likely that the formulation and negotiation of policies to abate human-induced climate change will, for the foreseeable future, continue to be made against a backdrop of deep uncertainty.

Recommendation

- Focus not only on where we end, but also on *how we can begin*.
- Thus, need to develop near-term hedging strategy(ies) that will get buy-in by the US and Australia.



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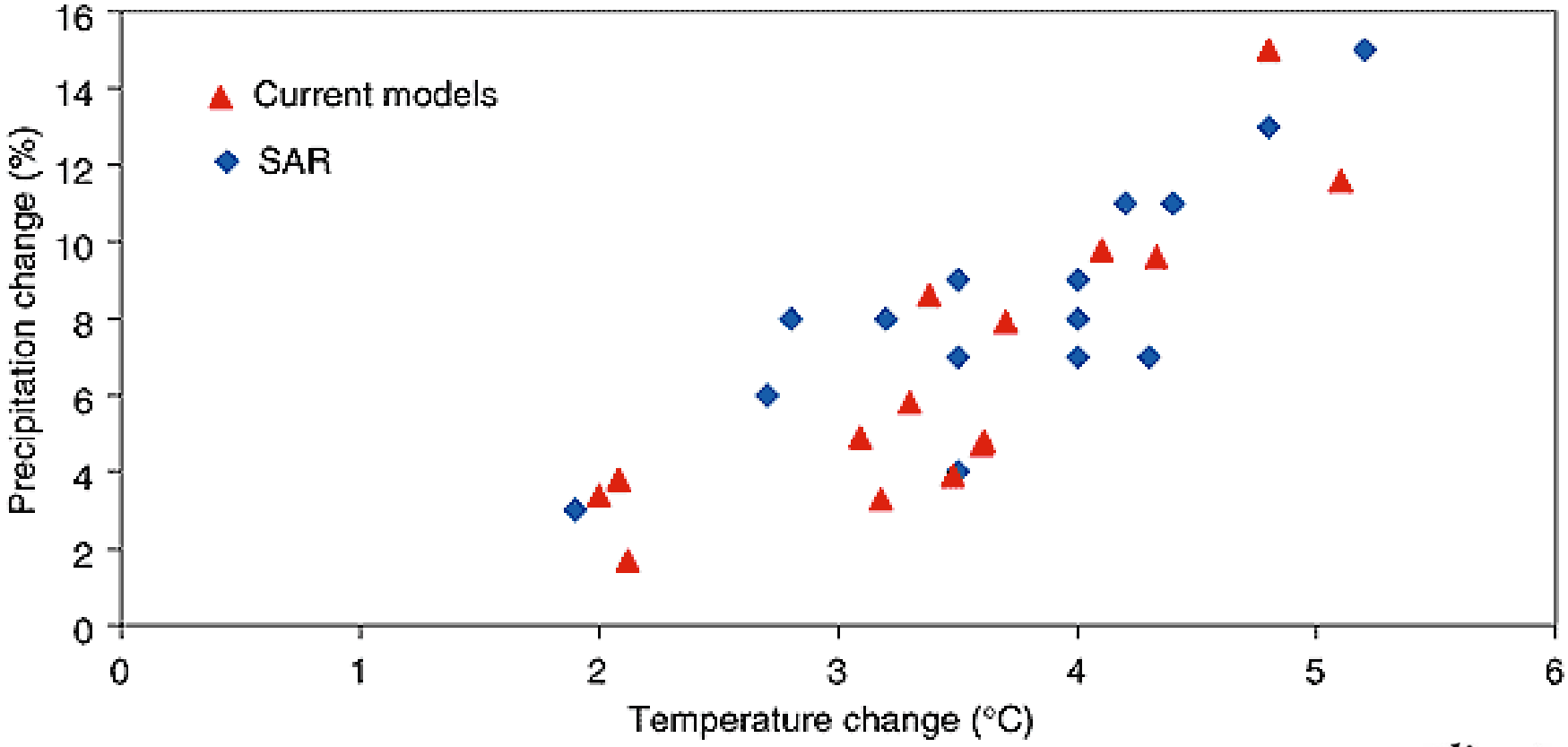
$$\frac{dH(t)}{dt} = -\frac{\Delta T(t)}{\lambda} + F(t)$$

- Effective Climate Sensitivity, $\lambda_e(t)$
  - F(t) need not be constant and/or equilibrium achieved.
  - $\lambda(t) = \lambda_e(t) = \Delta T(t)/[F(t) - dH(t)/dt]$.
  - If F = constant, then $\lambda_e(t)$ –> λ_{eq} as t –>infinity; for $F > 0$, from above, $\lambda_e(t) \geq \lambda_{eq}$.
- Transient Climate Response
  - Change in global-mean surface air temperature for a transient climate forcing at the time of doubling of the CO_2 concentration.

ΔT_{2x} Simulated By Some General Circulation Models



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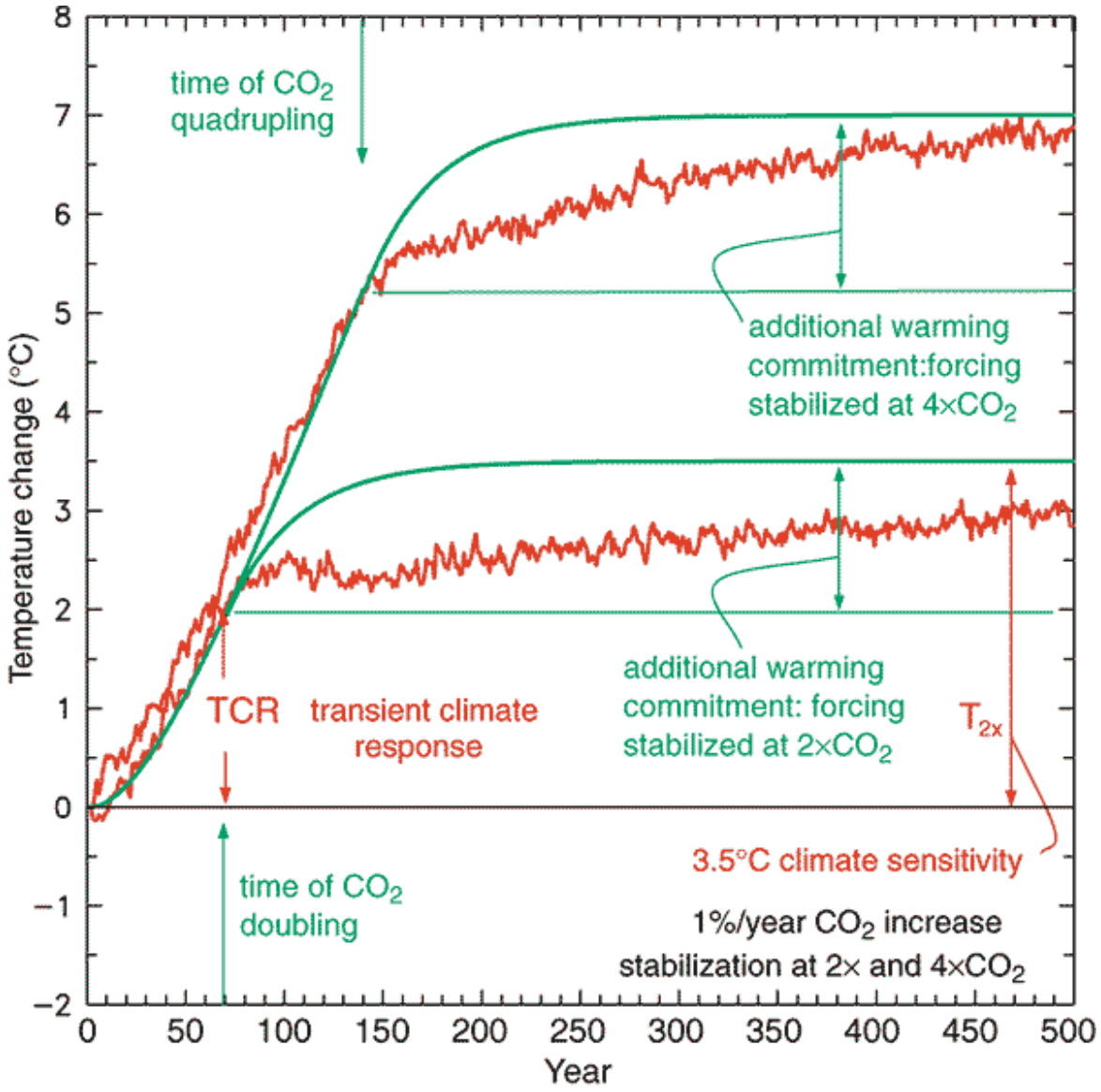
Transient Climate Response



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Outline

- **Primer on Climate Sensitivity, ΔT_{2x}**
- **Estimates of Climate Sensitivity, ΔT_{2x}**
- **Uncertainty in ΔT_{2x} due to uncertainty in the radiative forcing**
- **Causes of temperature changes from 1856 to present**
- **Uncertainty in ΔT_{2x} due to uncertainty in the temperature data**
- **Learning ΔT_{2x} over time**

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Estimates of ΔT_{2x} and ΔF_{SO4} from three datasets for GA

Dataset/Quantity	ΔT_{2x} (°C)	ΔF_{SO4} (Wm^{-2})
Jones et al. [1999]	4.8564	–0.2183
Jones and Moberg [2003]	4.2437	–0.2068
Folland et al. [2001a]	1.2771	+0.0095

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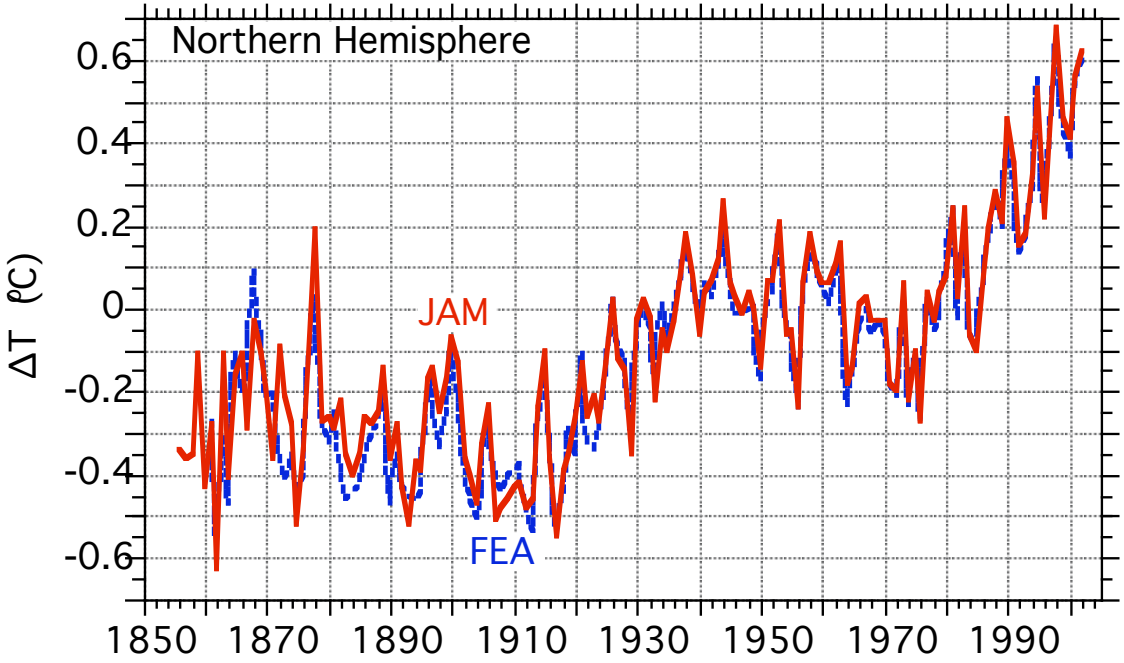

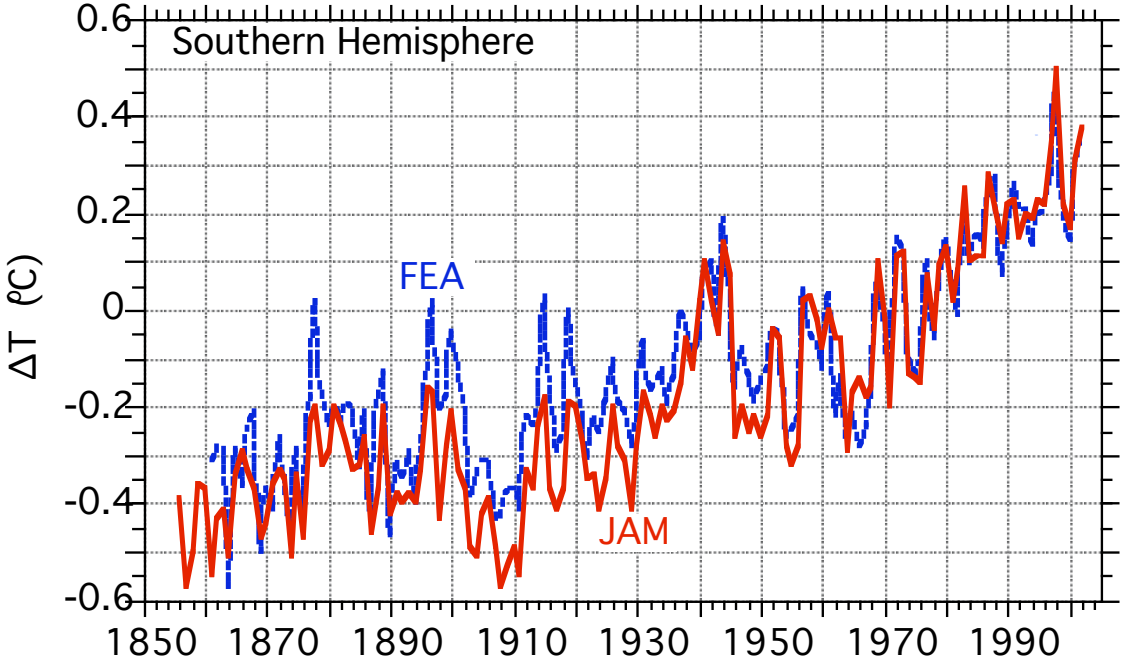

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Conclusion 3

- The uncertainty in the southern hemisphere temperatures must be reduced.

Conclusions 5

- Such policy formulation can be aided by the tool of robust adaptive decision analysis. But, that is a topic for a future lecture.