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Climate Change for Engineers

AIAA – Houston Annual Technical Symposium

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The Right Climate Stuff Research Team
www.therightclimatestuff.com

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The Right Climate Stuff Research Team

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- **Volunteer group** of primarily retired NASA scientists and engineers - **veterans of the Apollo Program**.
 - **More than 25 active members**
- Formed in February 2012 as **an independent, objective, research team with no funding**
 - **INITIAL GOAL:** Determine the extent to which burning fossil fuels can cause harmful global warming
- **The Bottom Line – We are going to run out of fossil fuels before atmospheric CO2 can rise to levels that could cause harmful warming of the planet**

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- **We aren't climate scientists**
- We do have **education, training, and experience** in the **same scientific disciplines** that **climate scientists use**
- We have **expertise in identifying and mitigating Threats** from **exploring the unknowns of manned space flight**
 - We **define Problems** in terms of a **deviation from "Normal"**
 - Global temperatures **are not deviating from Normal limits** of the **last 10,000 years !**
- We have **bounded the warming that atmospheric CO2 and other GHG** can have
 - **Not a serious nor immediate Threat requiring Global Action**

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- **CONCLUSIONS:** Due to world-wide **rising energy demand** and **rising fossil fuel prices**, as **fossil fuel reserves are consumed**,
 - A **market-driven transition** to **alternative fuels** will be **required before any climate problems can occur**
 - A **USA national energy plan** is **needed** to **ensure our energy future**
 - **Climate alarmism** is **causing irrational energy-related decisions**
 - **Climate alarmism results from complex climate simulation models; not from data!**
 - **Models are not sufficiently accurate to guide public policy decision-making regarding CO2 emissions**
 - **Models are not validated !**

Current Climate Models Not-Validated

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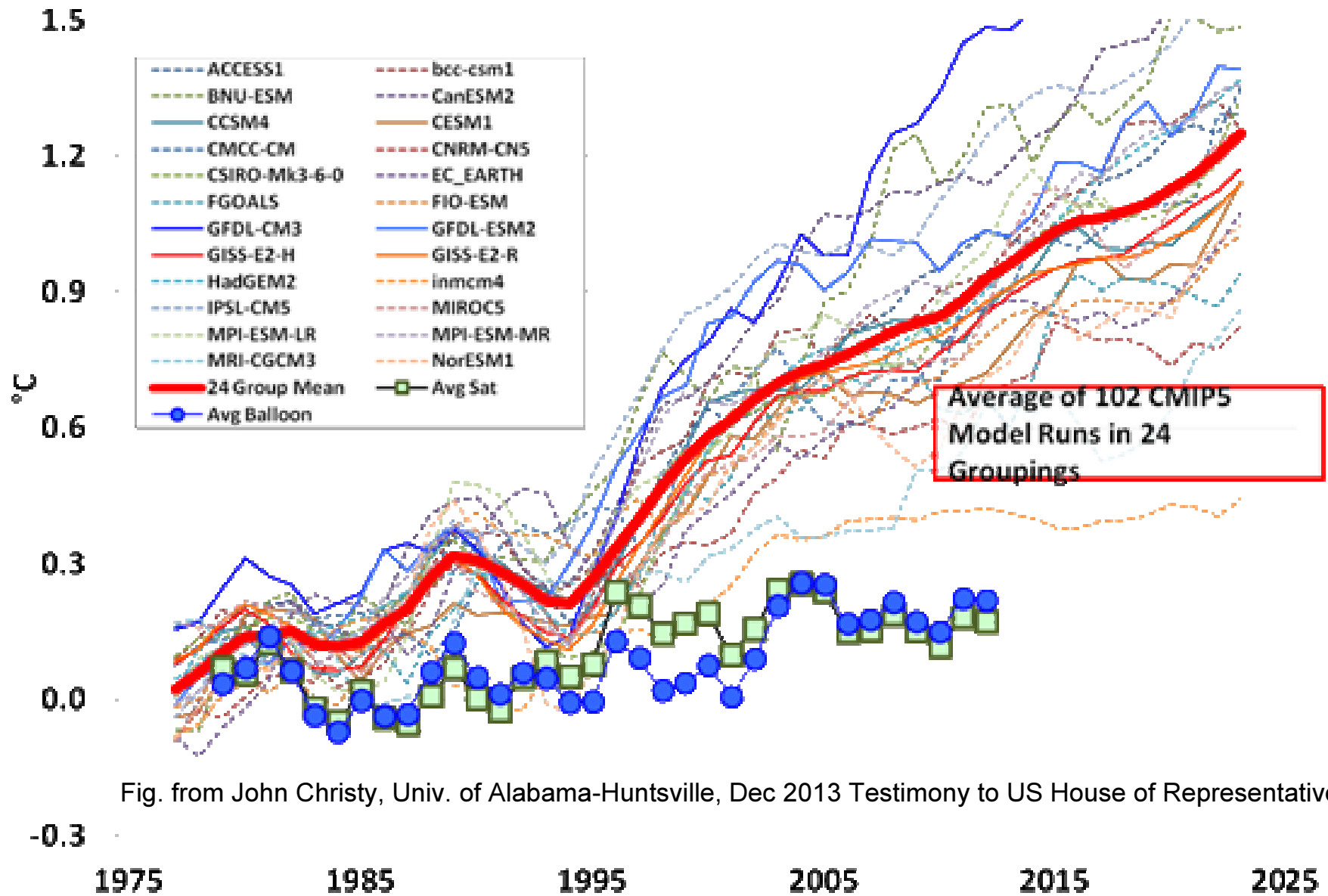


Fig. from John Christy, Univ. of Alabama-Huntsville, Dec 2013 Testimony to US House of Representatives

IPCC Metrics for GHG Climate Sensitivity

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- **Equilibrium Climate Sensitivity (ECS)**
 - Loosely defined as global average temp rise that will eventually result from doubling CO₂ level in the atmosphere
 - Computed by complex, un-validated computer models simulating climate changes over more than 1000 years!
- **Mainstream Climate Science (IPCC) Position**
 - $1.5 < \text{ECS} < 4.5 \text{ deg C}$ (IPCC 2013 AR5 Report)
 - Uncertainty range has not changed in 35 years and \$billions spent on “study” of this issue!
 - Was reduction of uncertainty range ever the research goal?

IPCC Metrics for GHG Climate Sensitivity

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- **Transient Climate Response (TCR)**
 - **Climate model simulation of Global Warming that would result from**
 - **Increasing atmospheric CO₂ levels at a rate of 1% per year until doubled CO₂ level is reached**
 - **Current rate of increase is about 0.5% per year**
 - **TCR climate model simulation more realistic than an ECS simulation**
 - **But still hypothetical!!**

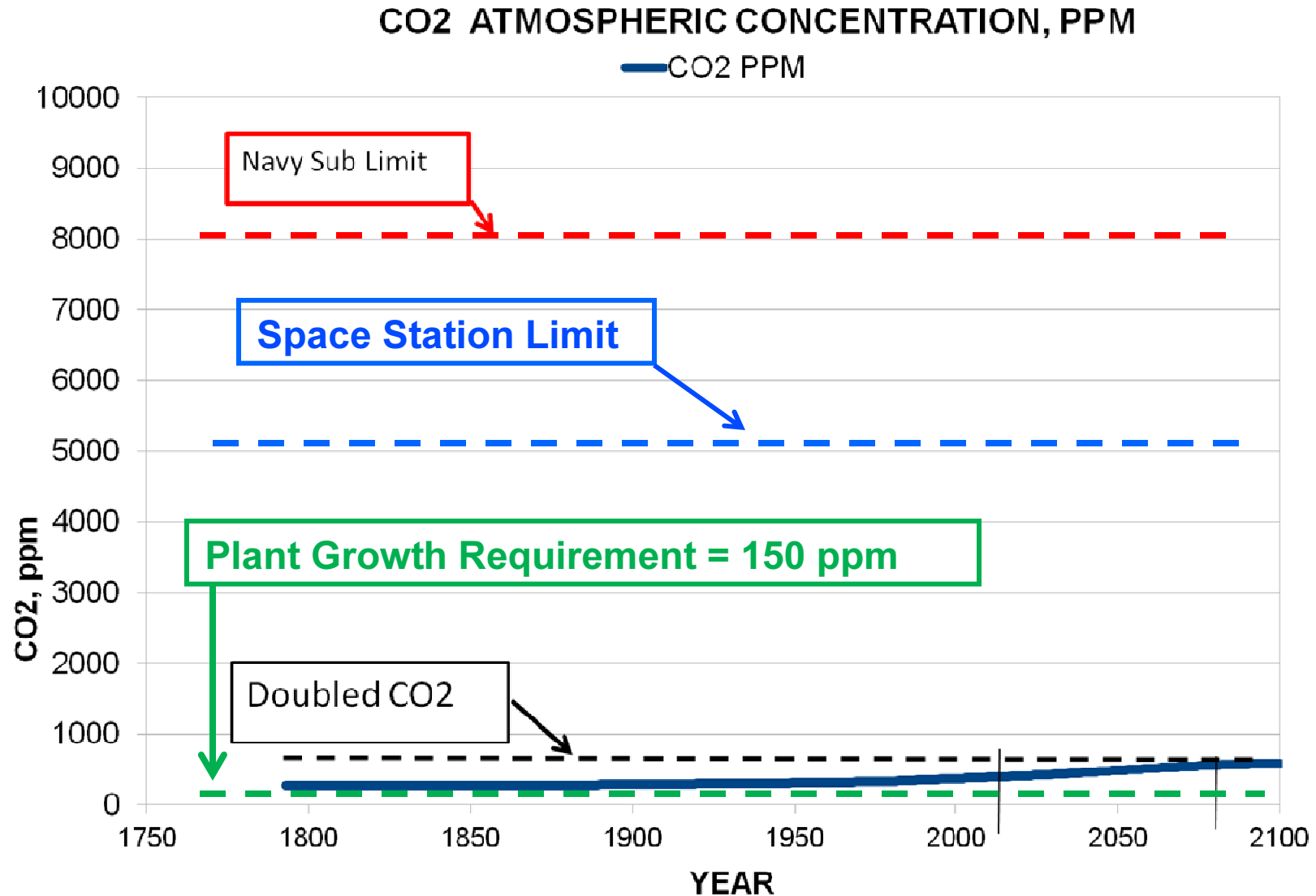
Transient Climate Sensitivity (TCS)

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- To obtain a verifiable GHG climate sensitivity metric, our research team defined a new metric:
 - **Transient Climate Sensitivity (TCS)** – The rise in global average surface temperature due to the actual gradual rise of CO2 in our atmosphere until CO2 levels are doubled
 - **Effects of all GHG are approx. = 1.5x(CO2-only effects)**
- **TCS is a verifiable quantity using actual data**
 - We **determined** conservative value of **TCS from climate data** based on
 - **40 percent rise** in atmospheric **CO2 since 1850**
 - **< 0.8K rise** in **Global Average Temperature since 1850**
- **TCS = 1.2K , K = deg. Kelvin**

CO2 Level In Atmosphere

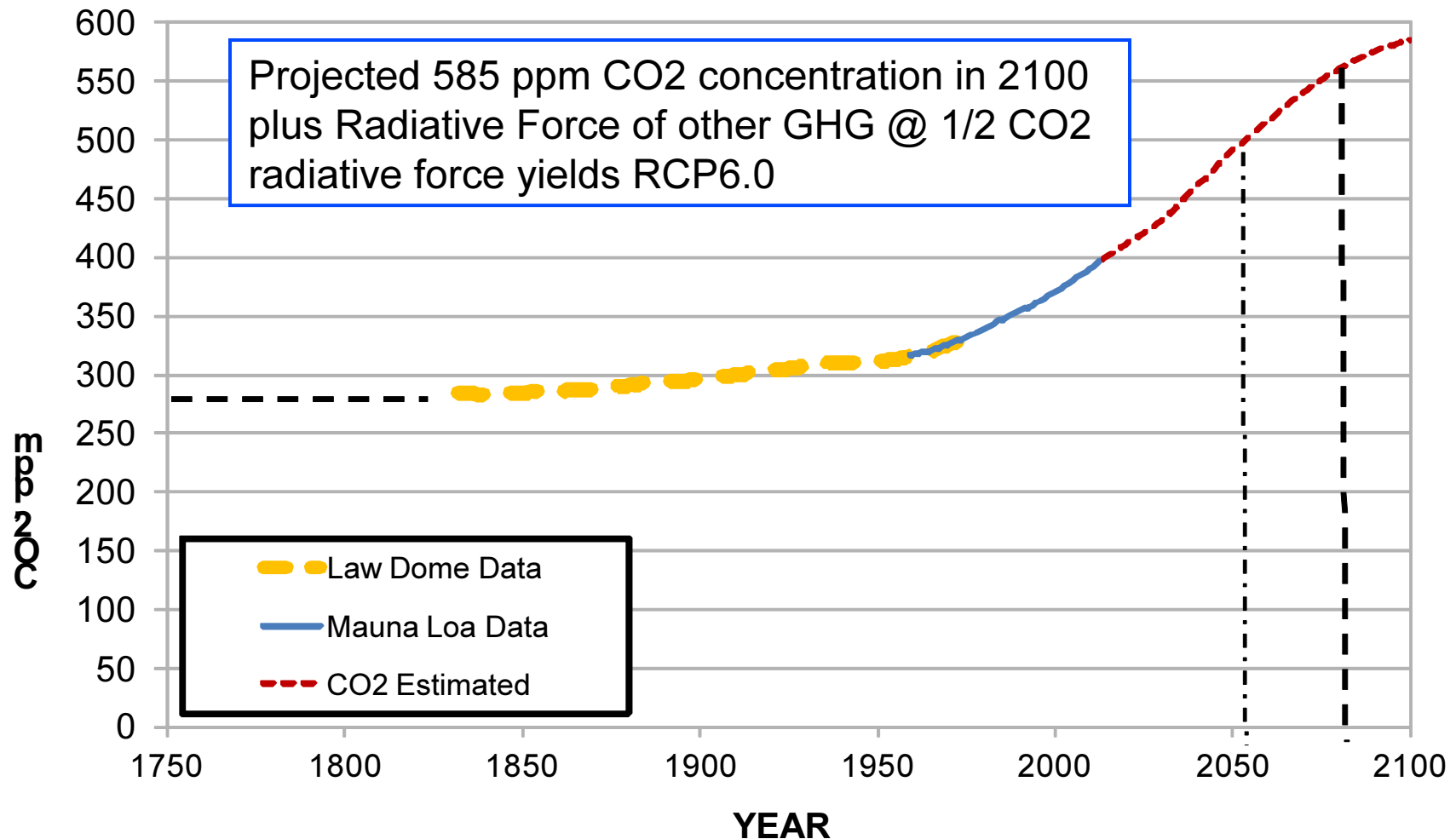
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CO2 TRENDS IN ATMOSPHERE

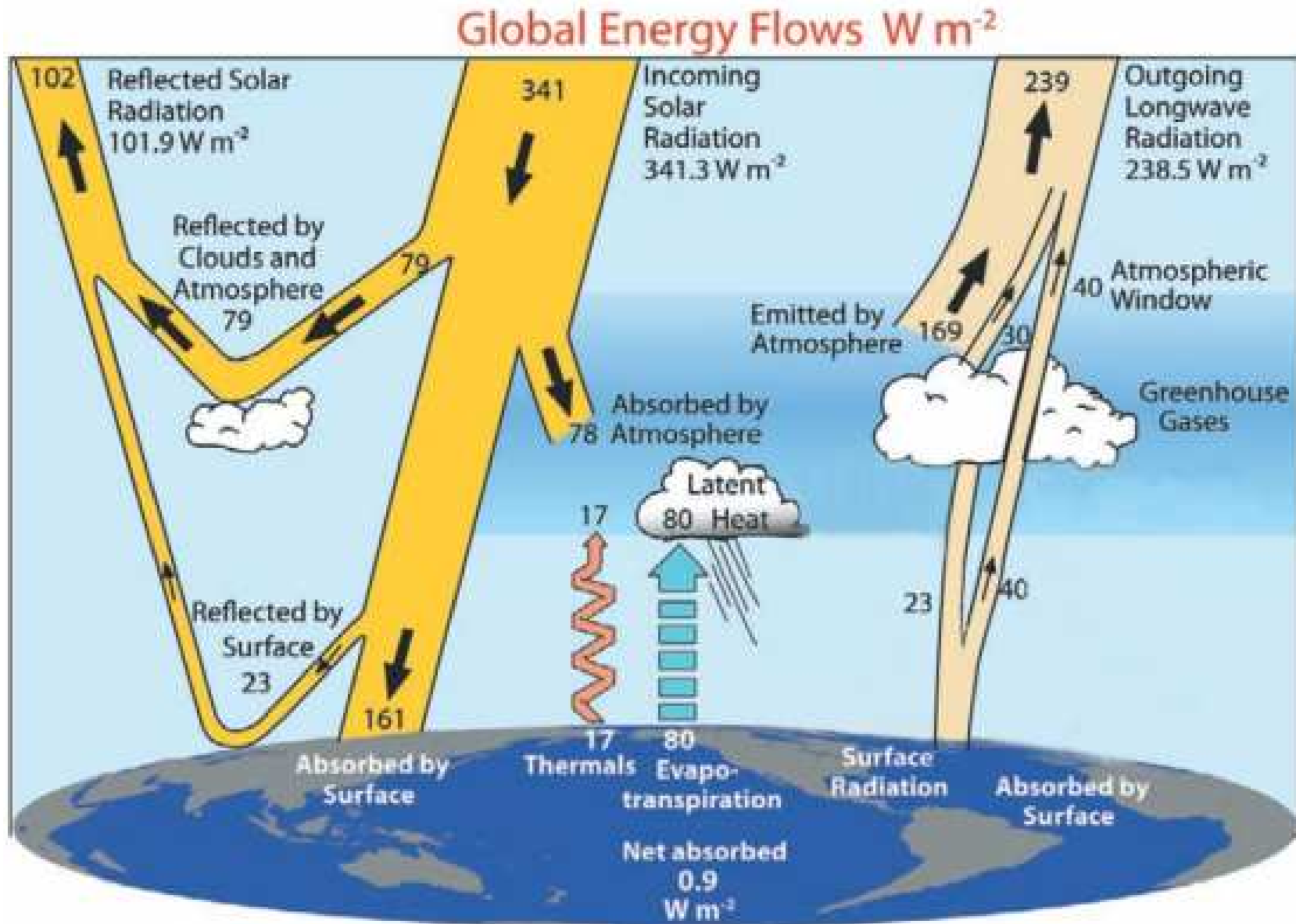
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CO2 ATMOSPHERIC CONCENTRATION, PPM



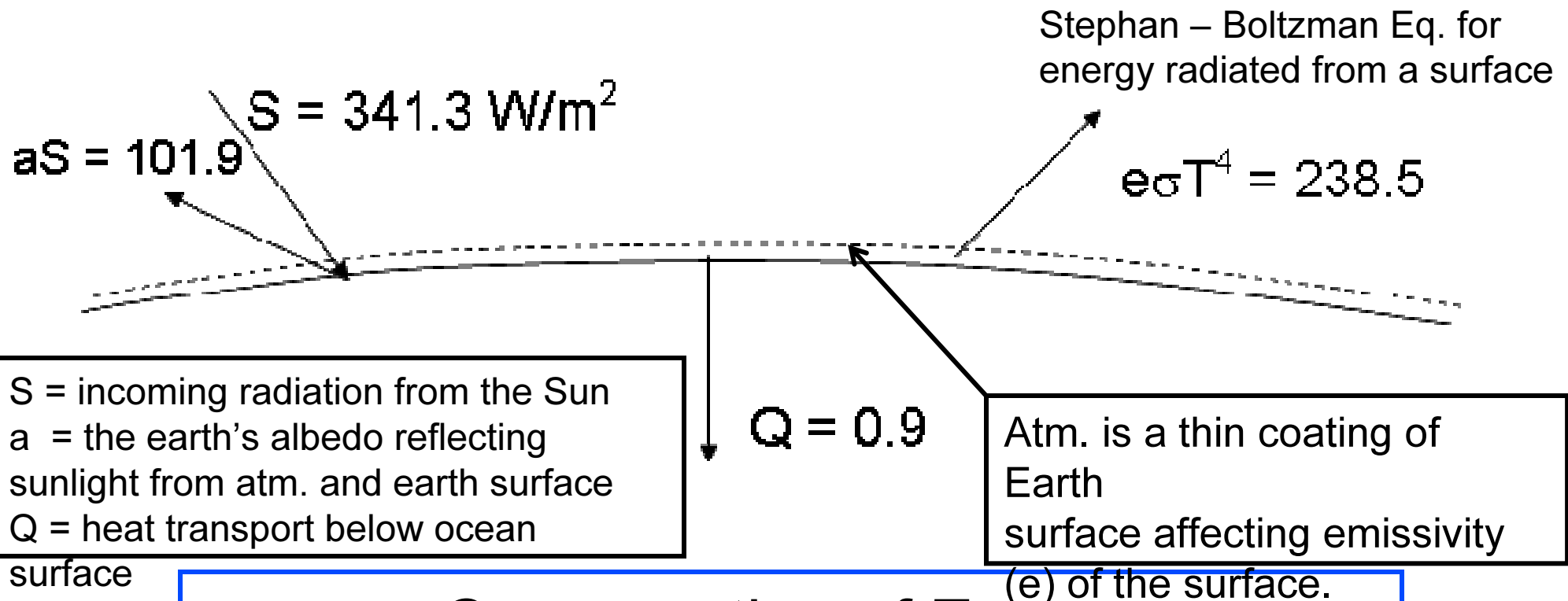
How Does Atm. CO₂ Warm the Earth?

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Earth Surface Energy Balance

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Conservation of Energy

$$e(W, C, G)\sigma T^4 = (1 - a)S - Q$$

W , C and G are atm. concentrations of water vapor, CO_2 and other GHG, respectively

A Simple Model For Temperature Changes

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- Using calculus to form a differential of the Earth Surface Energy Balance Equation

$$\left[\left(\frac{\partial e}{\partial W} \frac{\partial W}{\partial C} + \frac{\partial e}{\partial C} \right) dC + \left(\frac{\partial e}{\partial W} \frac{\partial W}{\partial G} + \frac{\partial e}{\partial G} \right) dG \right] \sigma T^4 + 4e(W, C, G) \sigma T^3 dT = (1-a) dS - S da - dQ$$

$$\sigma = 5.67(10)^{-8} \text{ W/m}^2/\text{K}^4$$

$$\text{For } T = 288\text{K} \quad \text{and} \quad e = 238.5/(\sigma T^4) = 0.611, \quad 4e\sigma T^3 = 1/0.302$$

$$dT = [0.302] \{ - [\text{changes in } e(W, C, G)] \sigma T^4 + (1-a) dS - S da - dQ \}$$

[changes in $e(W, C, G)] \sigma T^4$ are called Radiative Forcing from GHG including water vapor (W) feedback effects

A Simple Model For Temperature Changes

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Radiative Forcing changes from CO₂ concentration in atmosphere relative to the 284.7 ppm concentration in 1850 can be modeled as:

$$\left[\frac{\partial e}{\partial C} dC(\text{year}) \right] \sigma T^4 = 3.71 \{ \text{LOG}[C(\text{year})/284.7] / \text{LOG}[2] \} \quad \text{W/m}^2$$

Radiative Forcing changes from other GHG concentration rise in atmosphere relative to 1850 can be modeled as a fraction, β , of CO₂ radiative forcing

$$\left[\frac{\partial e}{\partial G} dG(\text{year}) \right] \sigma T^4 = (\beta) 3.71 \{ \text{LOG}[C(\text{year})/284.7] / \text{LOG}[2] \} \quad \text{W/m}^2$$

A Simple Model For Temperature Changes

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Radiative Force changes due to water vapor feedback effects can be modeled as a fraction, w , of CO₂ and other GHG forcing

$$\left[\left(\frac{\partial e}{\partial W} \frac{\partial W}{\partial C}\right)dC + \left(\frac{\partial e}{\partial W} \frac{\partial W}{\partial G}\right)dG\right] \sigma T^4 = w(1+\beta)\text{LOG}[C(\text{year})/284.7]/\text{LOG}[2]$$

Using our expressions for radiative force changes since 1850 due to CO₂, other GHG and water vapor feedback

$$dT(\text{year}) = [0.302]\{(1+w)(1+\beta)(3.71)\text{LOG}[C(\text{year})/284.7]/\text{LOG}[2] + (1-a)dS - Sda - dQ\}$$

Using our definition for TCS = $[0.302](1+w)3.71$ deg K

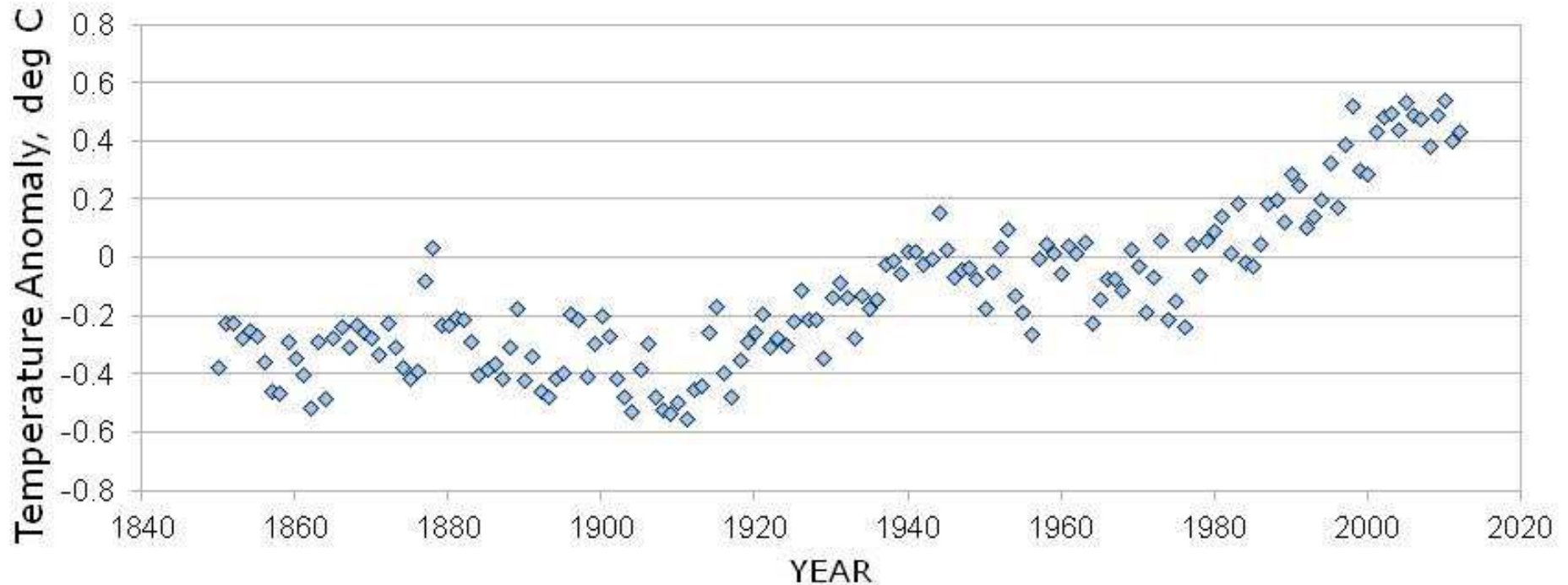
$$dT(\text{year}) = \text{TCS}(1+\beta)\text{LOG}[C(\text{year})/284.7]/\text{LOG}[2] + 0.302\{(1-a)dS - Sda - dQ\}$$

Note: In definition of TCS, w accounts for water vapor feedback and all other feedbacks to CO₂, other GHG, and aerosol radiative forcing

Recent Global Average Temp Variation

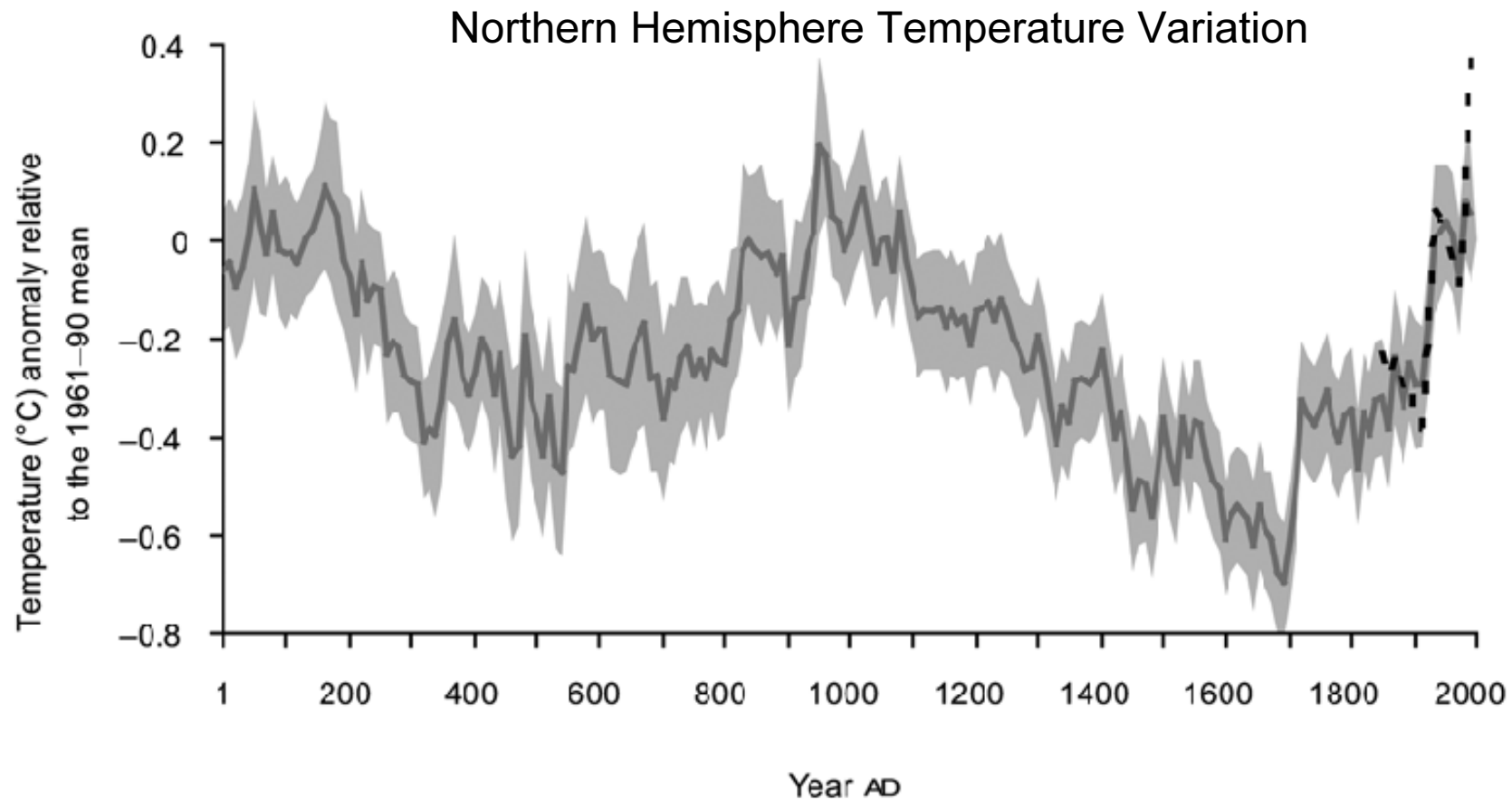
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HADCRUT4 GLOBAL YEARLY AVG TEMPERATURE



Ljungqvist Temp Reconstruction

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Ljungqvist (2010)

Simple Climate Model Fit To Temp Data

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HadCRUT4 Temp(Year) = **(1850 value)**

+ **(TCS)(1+β)** {Log[CO2(year)/284.7]/Log[2]} **(All GHG)**
+ 0.021(year – 1850)/155 **(Solar, dS)**

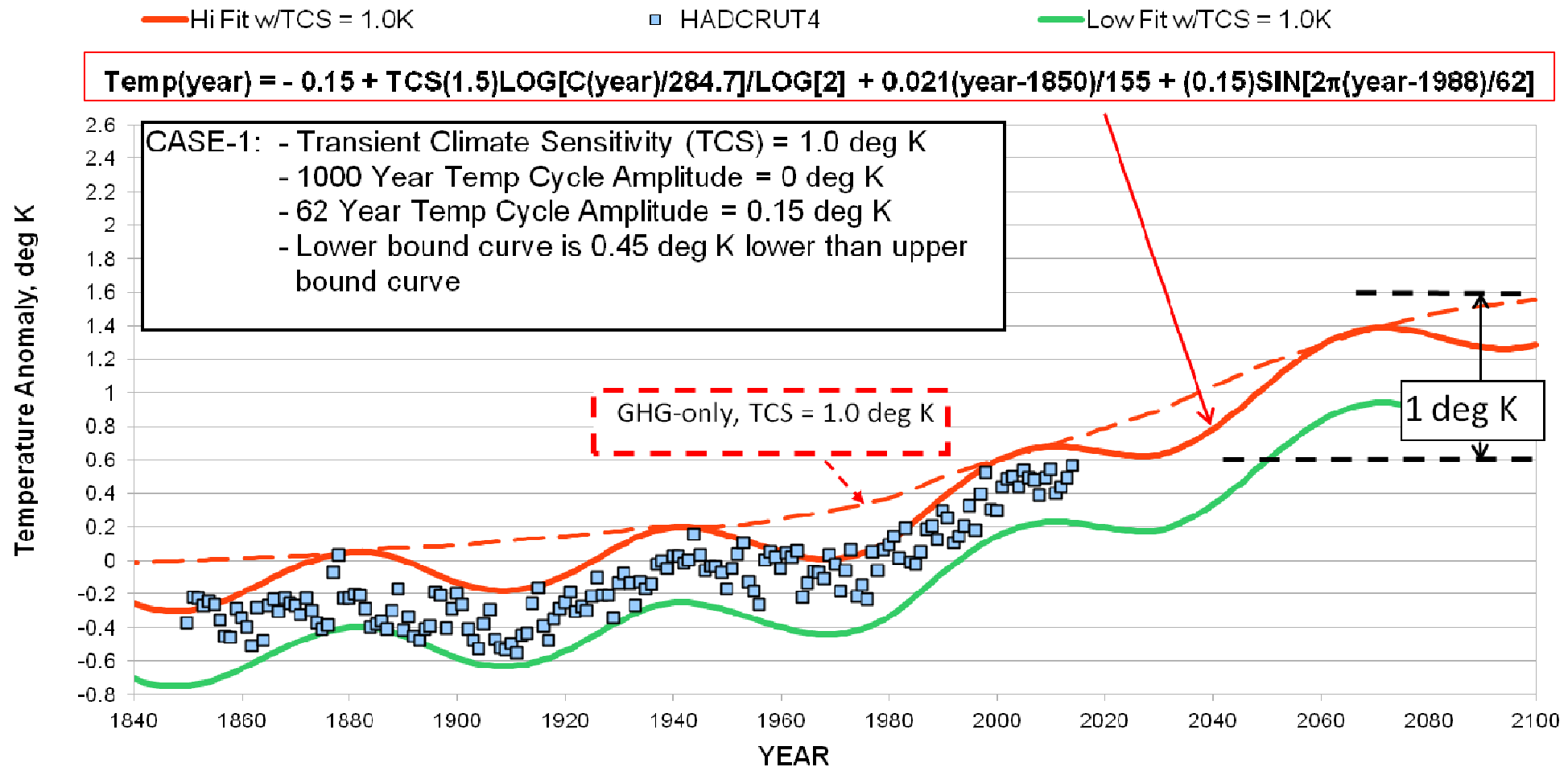
+ **A_L** Sin[2π(Year-1850)/ **1000 yr.**] **(da, dQ)**

+ **A_S** Sin[2π(Year-1988)/**62 yr.**] **(da, dQ)**

TCS(1+β) is a constant determined from function fit to Temp time history data; Nominal value of **β = 0.5** used to determine **TCS**

HadCRUT4 GLOBAL AVERAGE TEMPERATURE ANOMALY

Case 1: No 1000 Year Temperature Cycle, TCS = 1.0 Deg K



With 1000 Year Climate Cycle – TCS = 0.75K

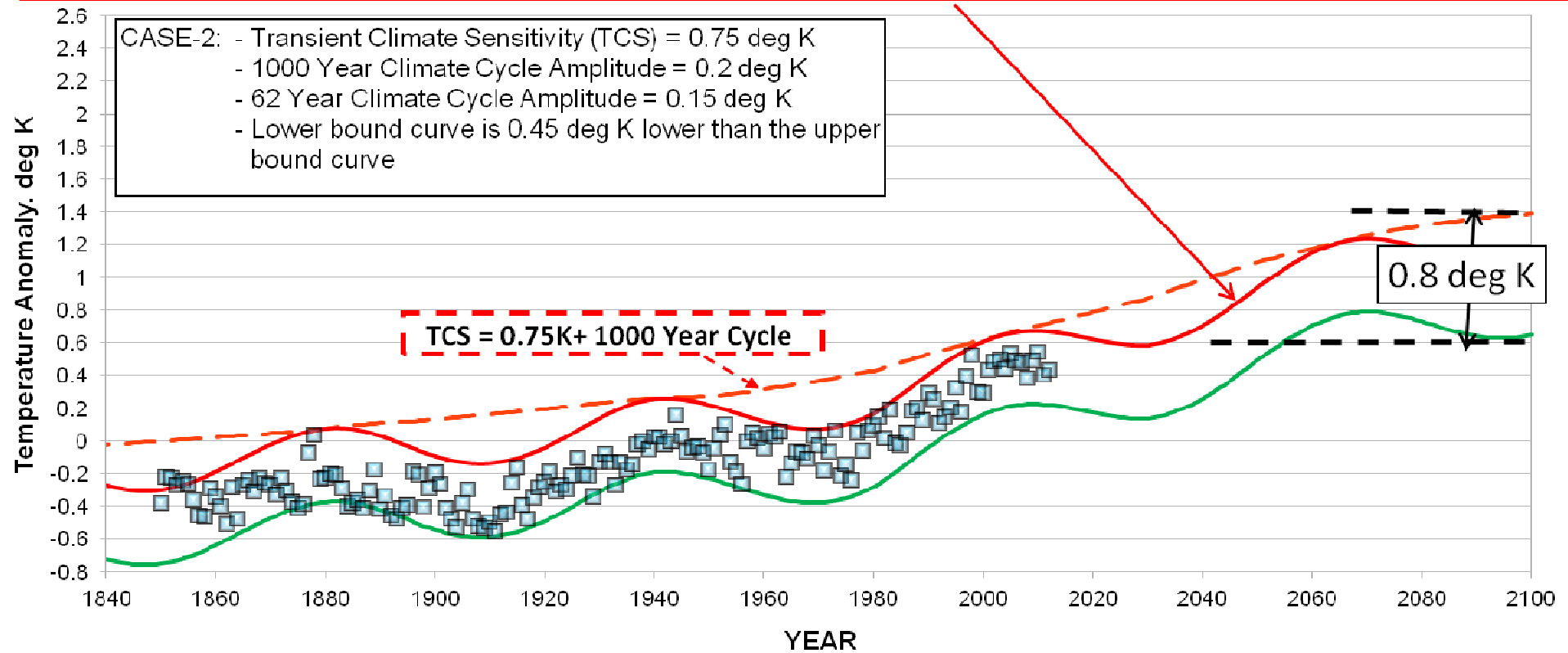
HadCRUT4 GLOBAL AVERAGE TEMPERATURE ANOMALY
CASE 2: With 1000 Year Temp Cycle and TCS = 0.75K

■ HADCRUT4

— Hi Fit w/TCS = 0.75K

— Low Fit w/TCS = 0.75K

$$T(\text{year}) = -0.15 + \text{TCS}(1.5)\text{LOG}[\text{C}(\text{year})/284.7]/\text{LOG}[2] + 0.021(\text{year}-1850)/155 + 0.2\text{SIN}[2\pi(\text{year}-1850)/1000] + 0.15\text{SIN}[2\pi(\text{year}-1988)/62]$$

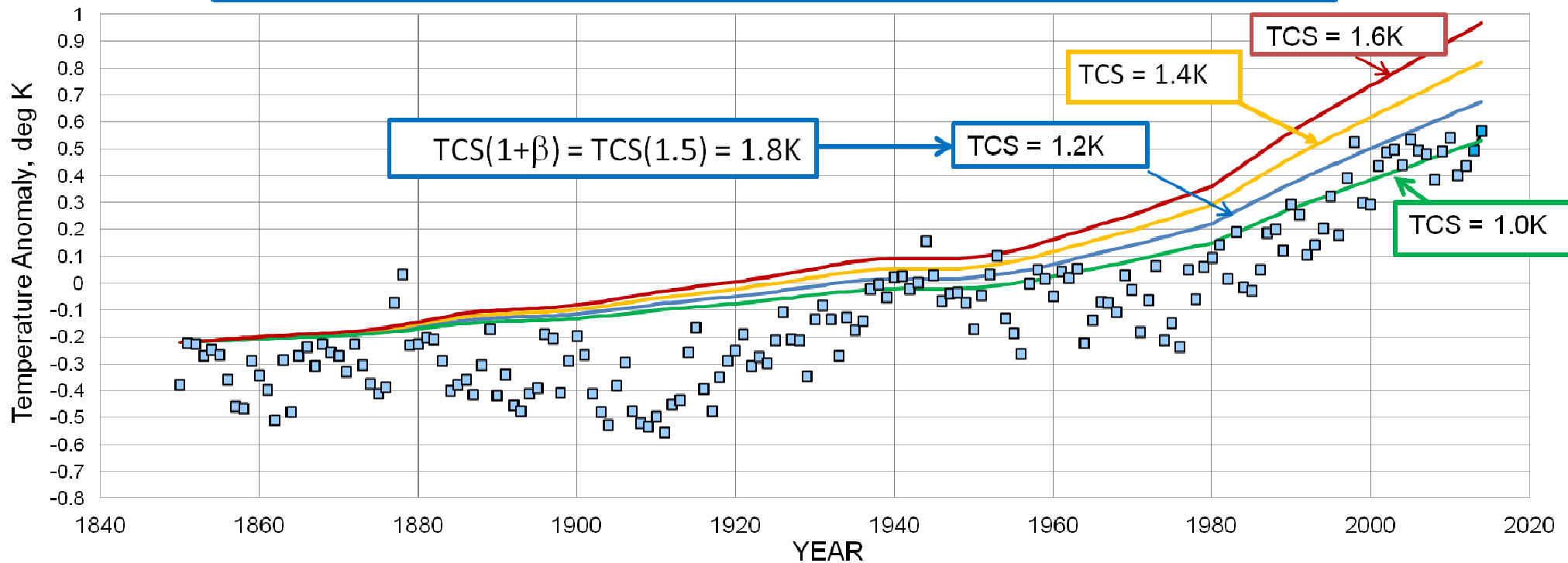


Extracting Most Conservative TCS Value

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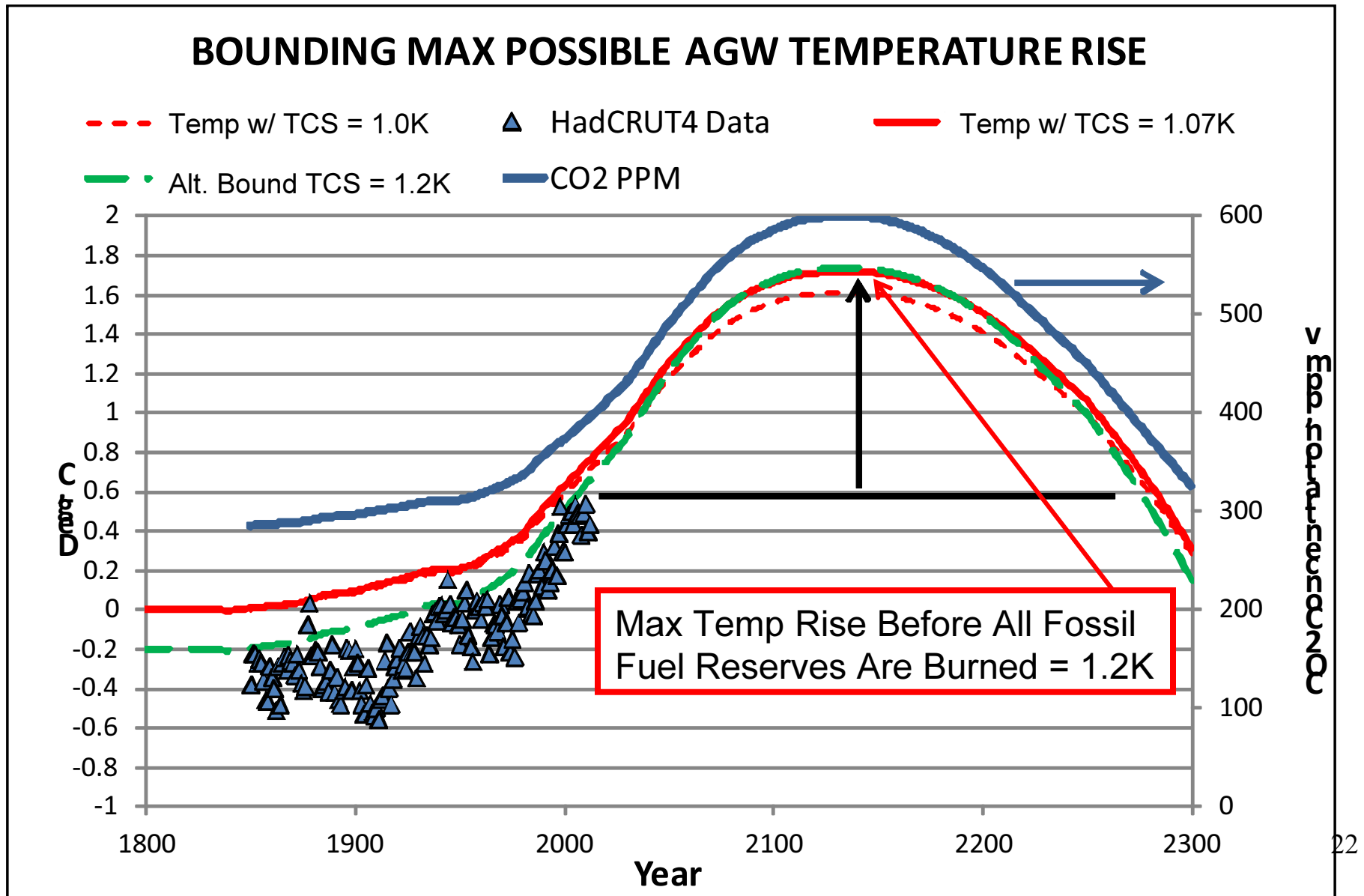
Determining A Conservative Value For Transient Climate Sensitivity (TCS)

$$T(\text{year}) = -0.22 + \text{TCS}(1.5)\text{LOG}[C(\text{year})/284.7]/\text{LOG}[2] + 0.021(\text{year}-1850)/155$$



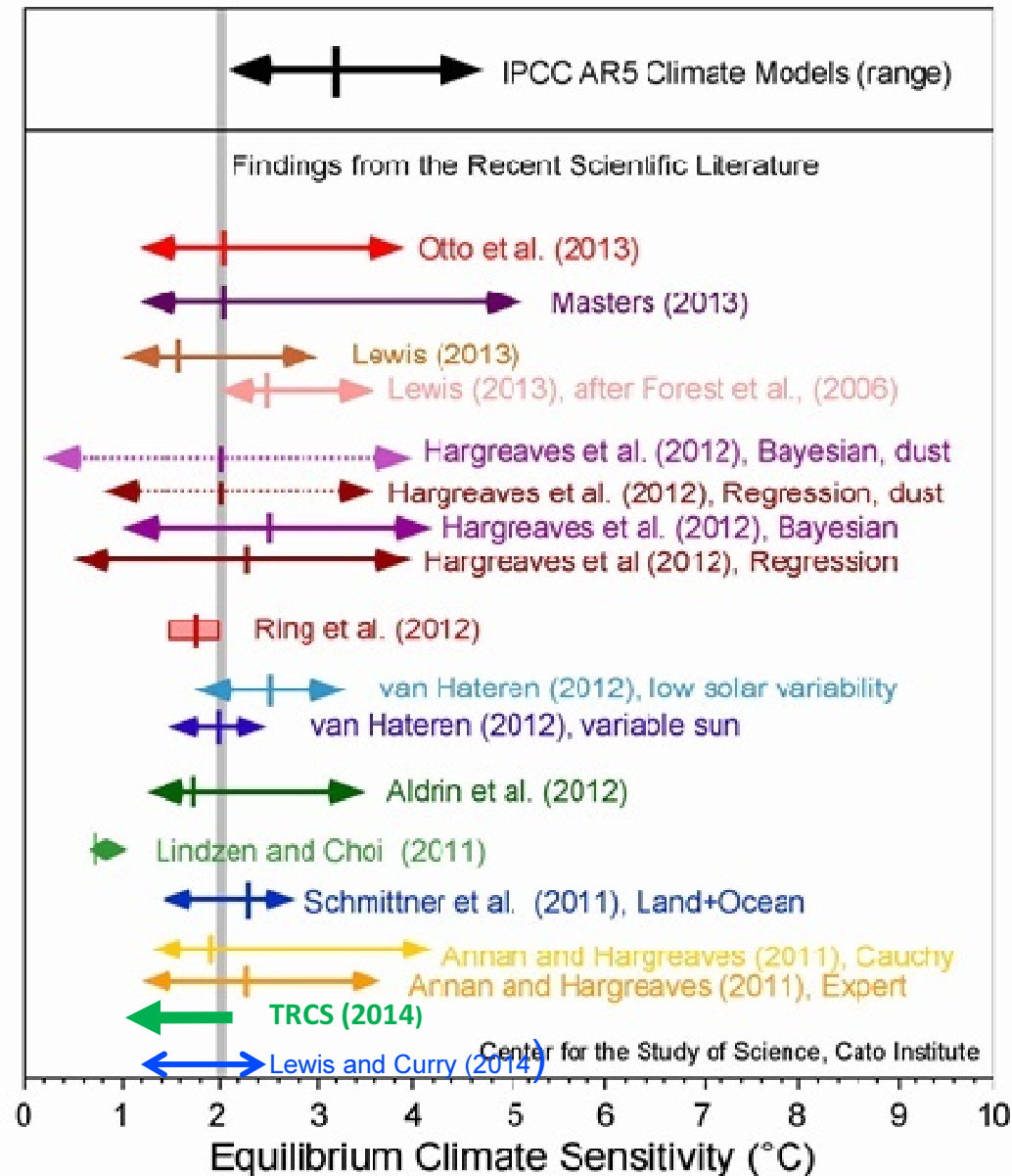
Bounding Future Warming

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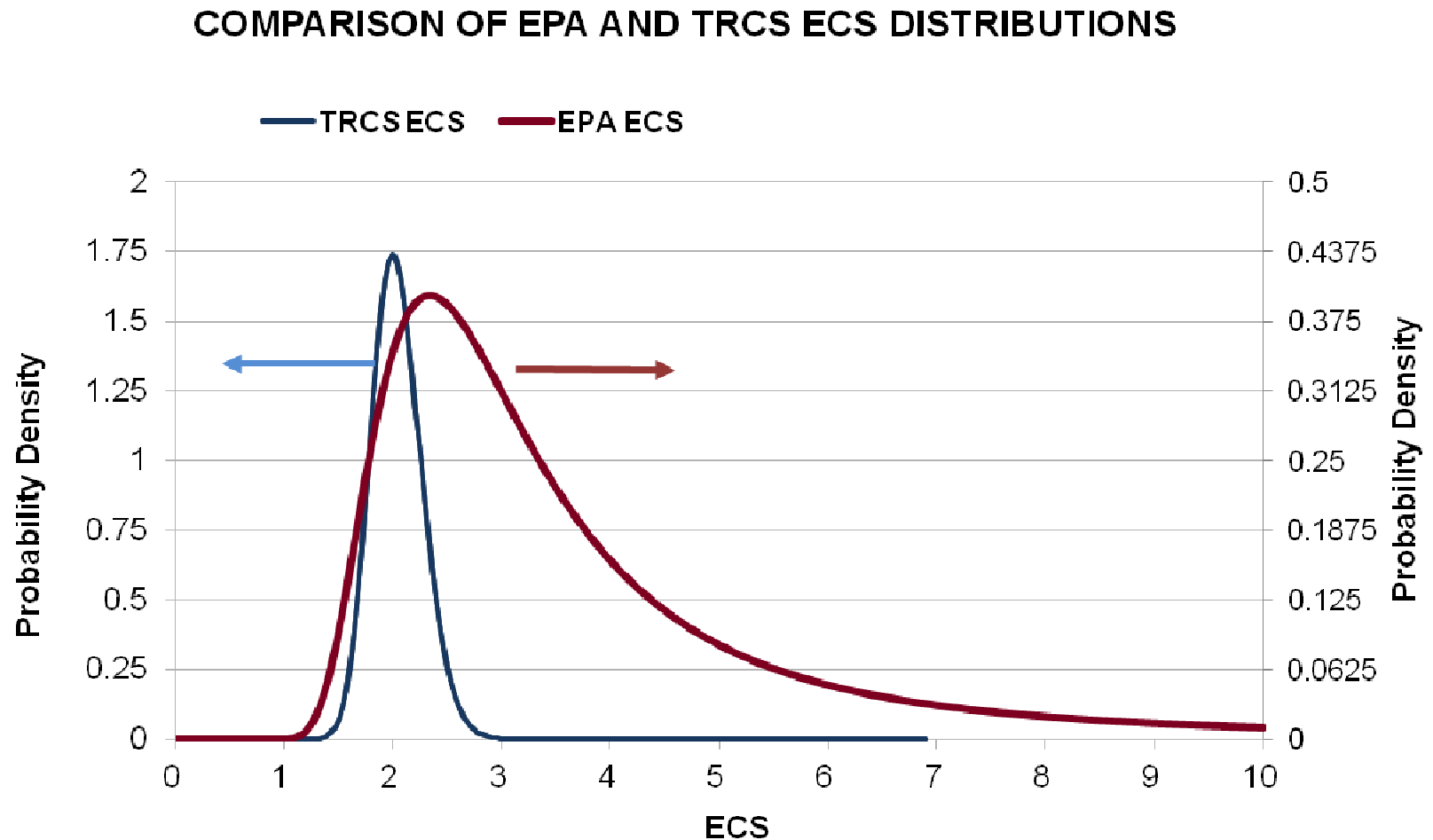
Our ECS Compared to Recent Research

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EPA Probability Distribution for ECS

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Conclusions

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- Climate models are not sufficiently accurate for use in critical public policy decision-making regarding AGW
- AGW can be bounded using available data
 - Should expect a modest amount of continued warming
 - Maximum expected warming may be beneficial, not necessarily harmful
 - More CO₂ in the atmosphere is definitely beneficial as a powerful plant fertilizer
- Current AGW “pause” should continue for about 20 years
- Economic justification for EPA and DoE CO₂ emissions control regulations based on gross distortions of AGW science

Temperature of Planet Earth? – 500 Million years

https://commons.wikimedia.org/wiki/File:All_palaeotemps.svg

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