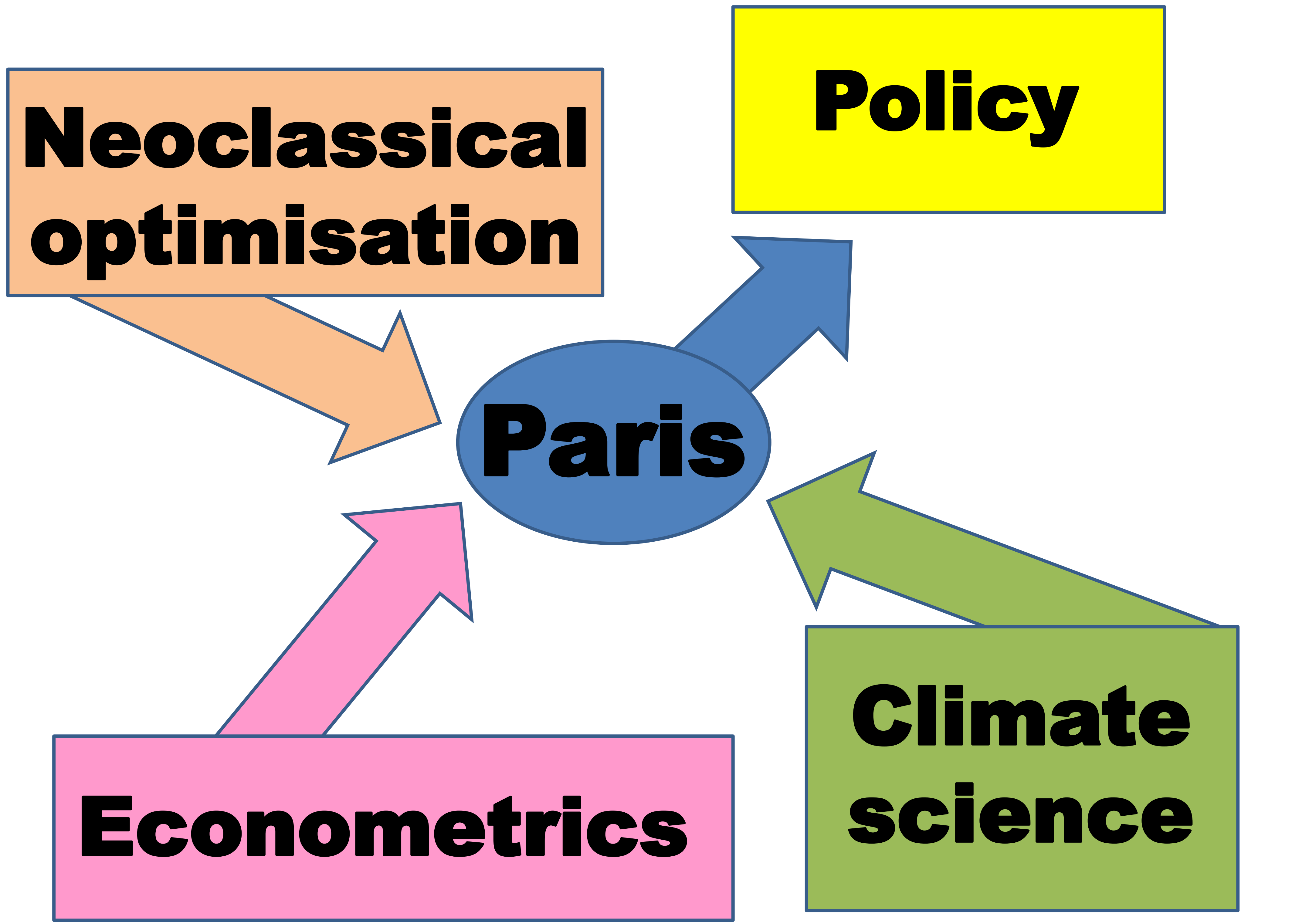
The Paris Climate Agreement – grounds for optimism, or for grim foreboding?

Prof. Roy Thompson, FRSE


Neoclassical optimisation
Policy
Paris
Econometrics
Climate science

"…pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels…"

Article 2.1(a)

1. Seminal turning point

2. Meaningful progress

3. Phenomenally expensive

4. Unfeasible

5. Legal cynicism

Web-based reports of reactions to the Paris Agreement

1. Seminal turning point

Coca-Cola MR

SIERRA CLUB

SHELL

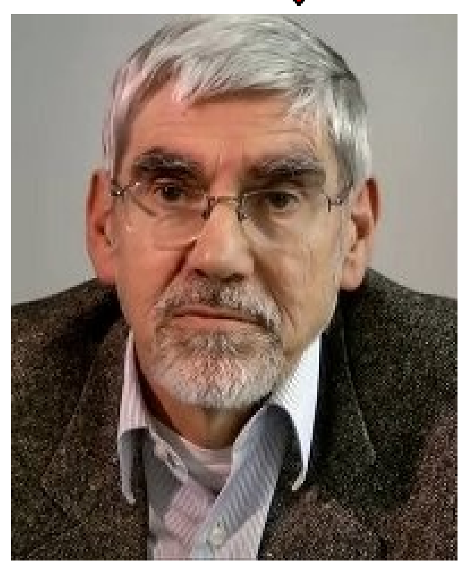
2. Meaningful progress

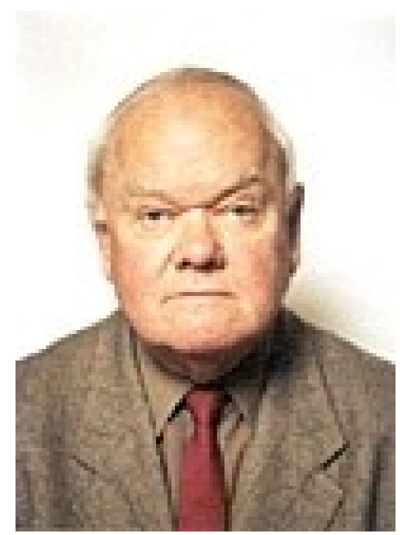
ExxonMobil

1. Seminal turning point

2. Meaningful progress

3. Phenomenally expensive





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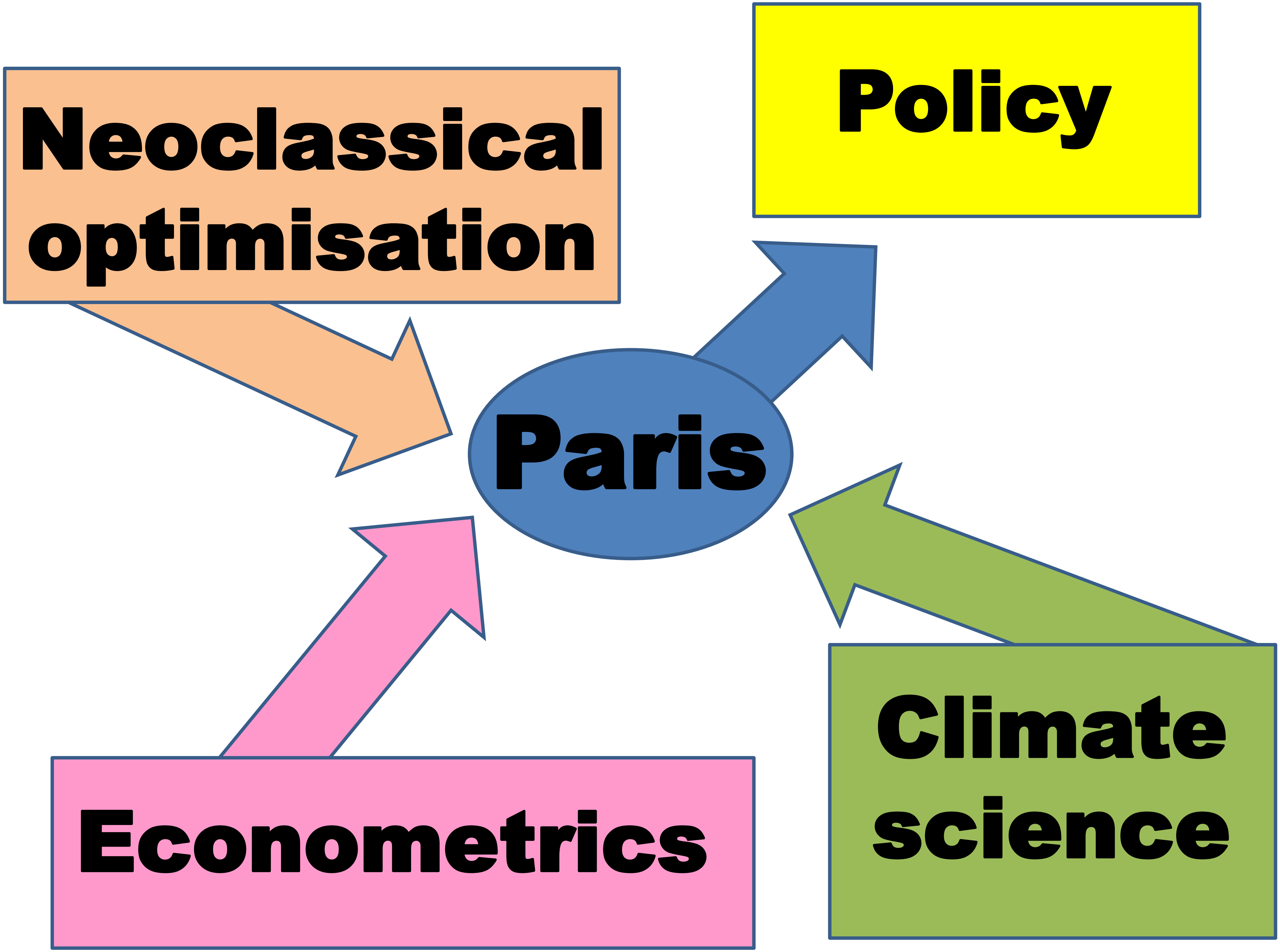
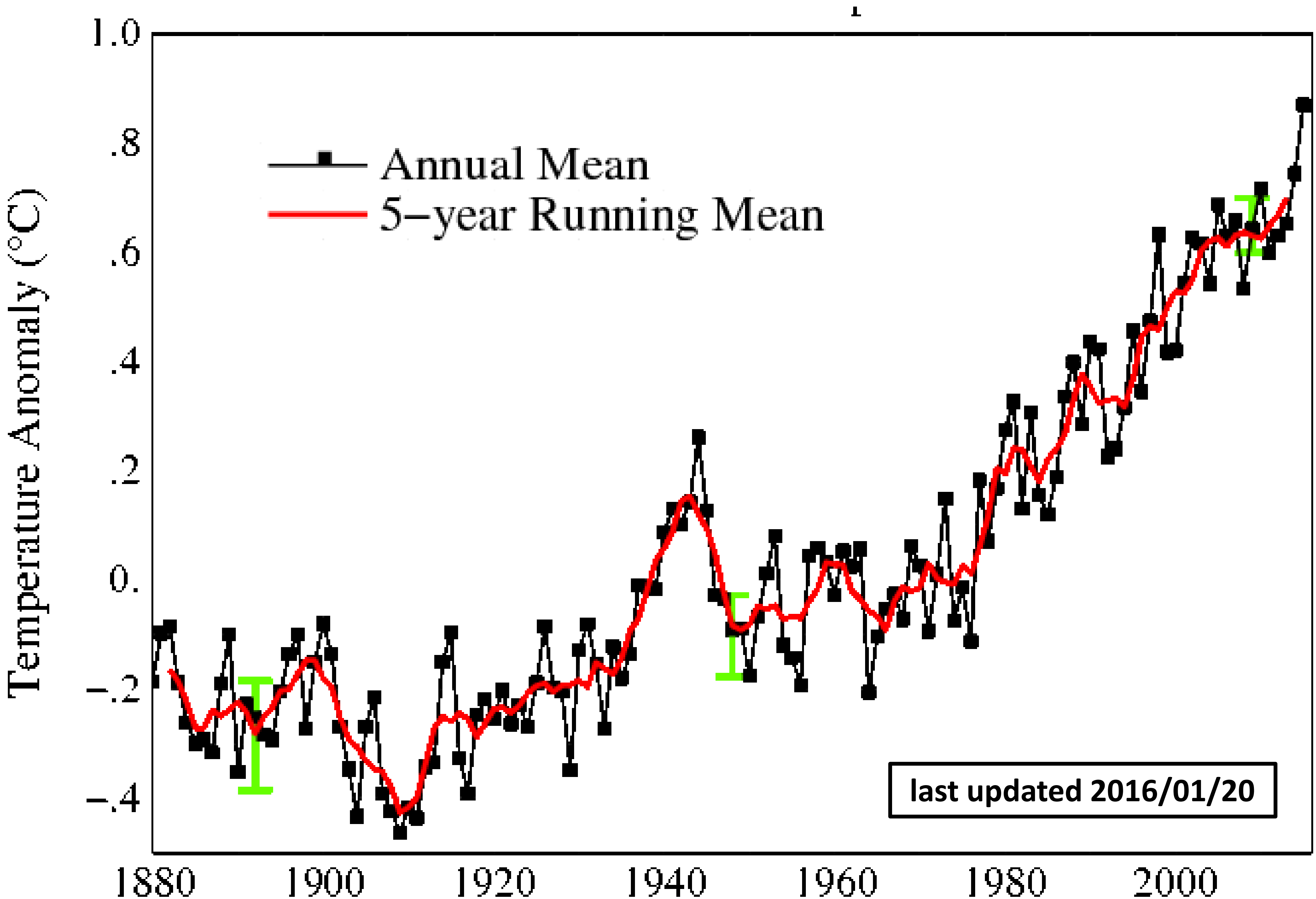


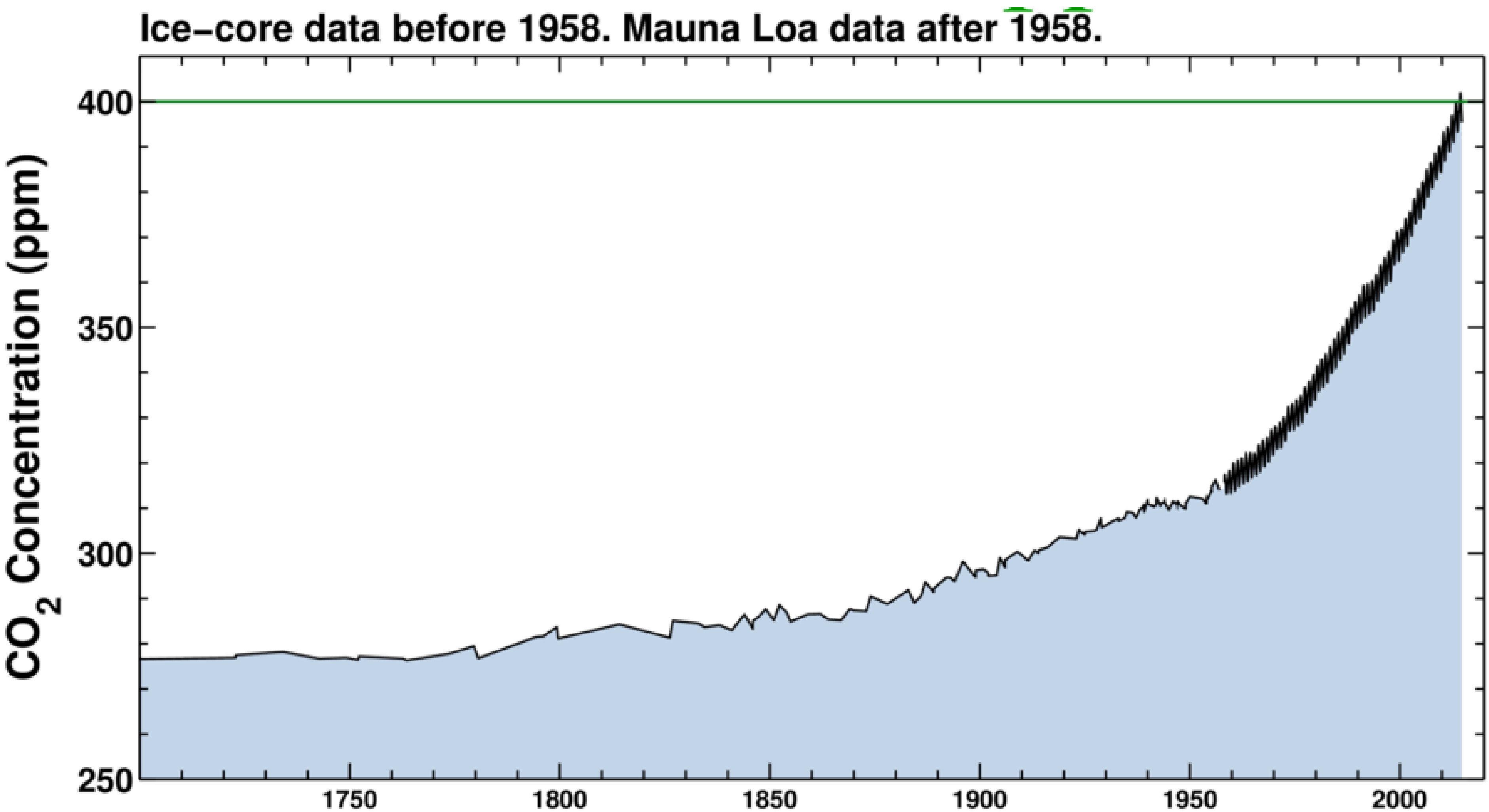
Policy
Neoclassical optimisation
Paris
Econometrics
Climate science


Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990
2006

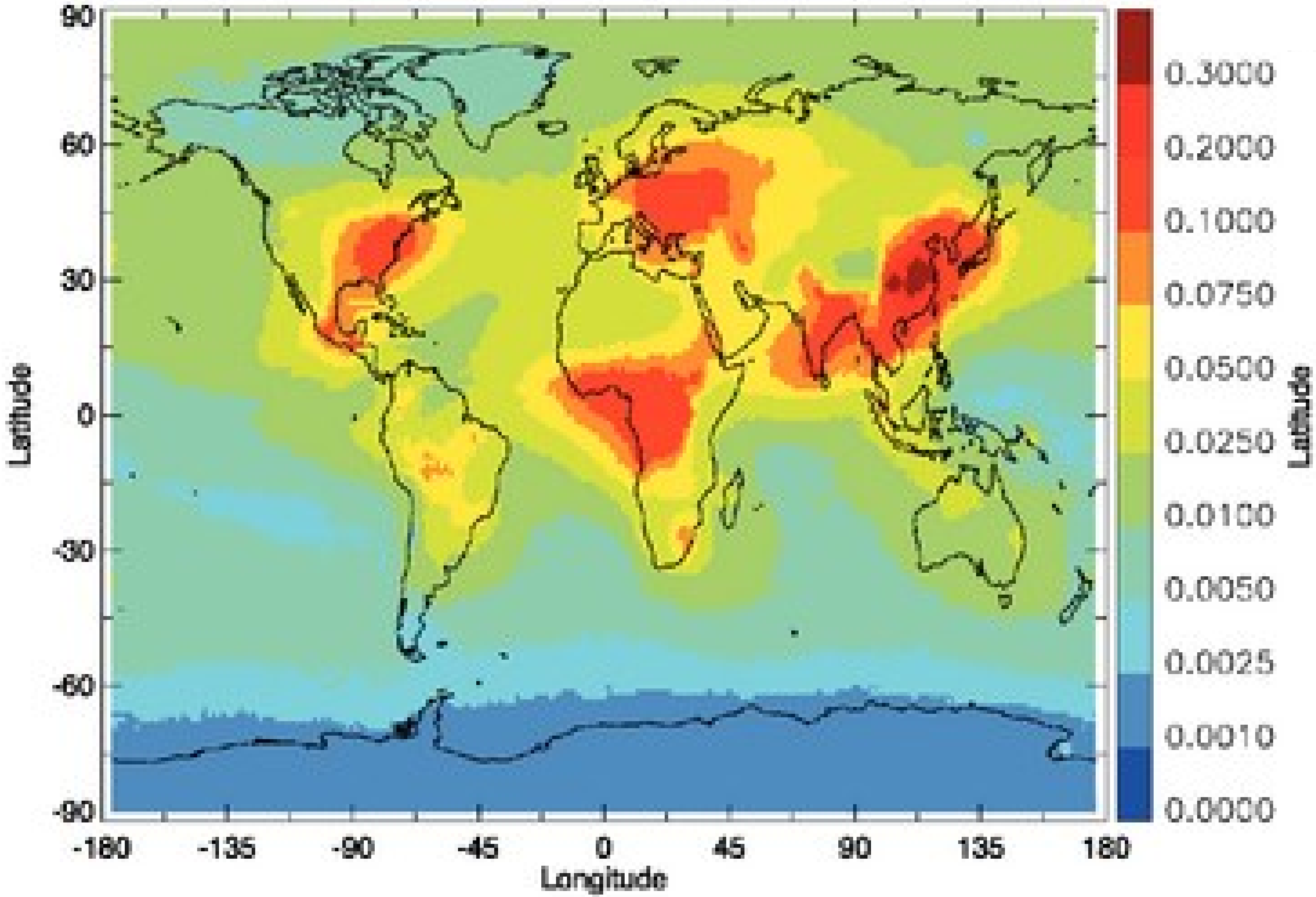
Global temperatures



CO_2 concentration February 08 406.27 ppm

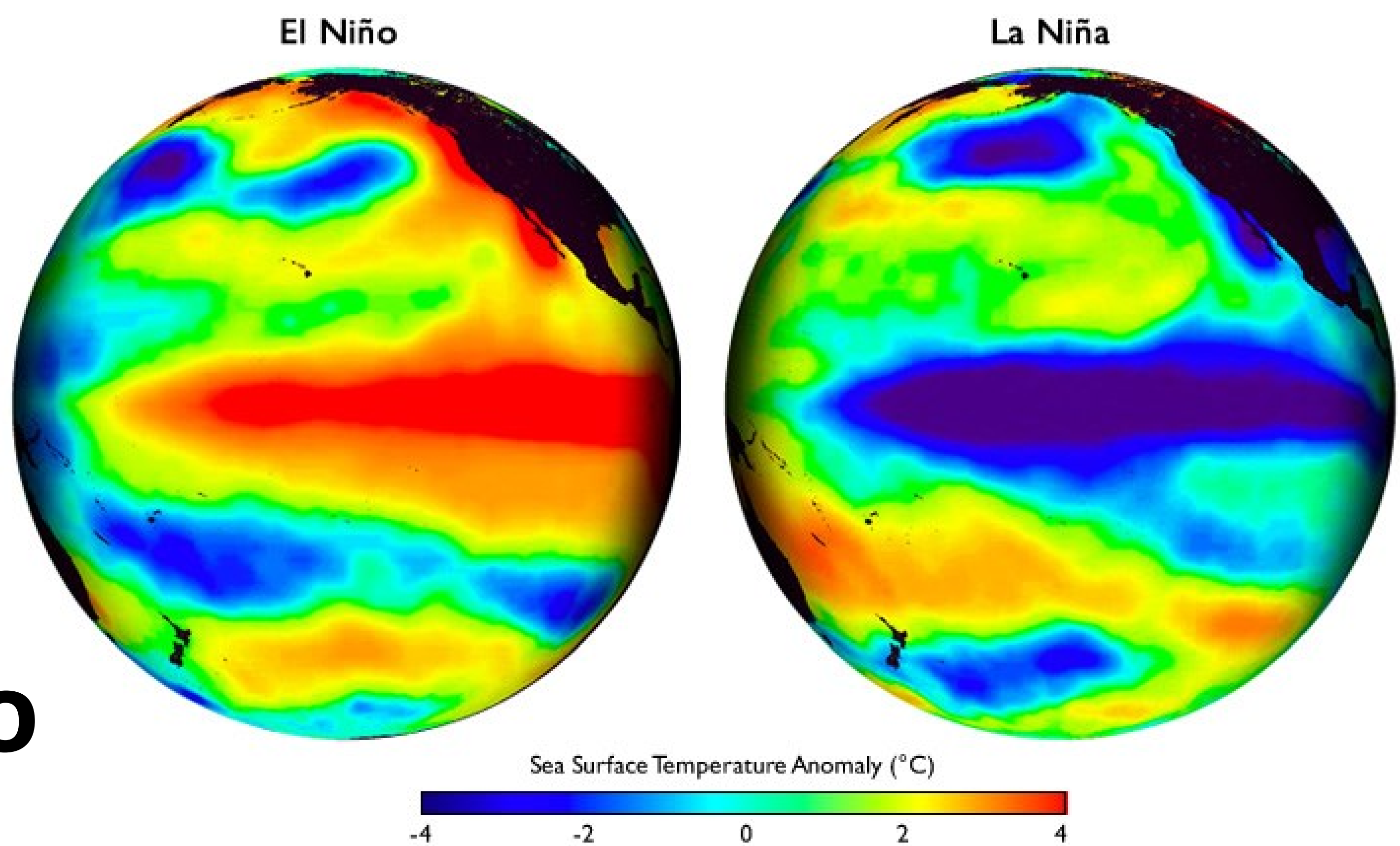


Aerosol optical depth



Characteristic aerosol properties related to their radiative effects, derived as the mean of the results from the nine AeroCom models.

Volcanoes

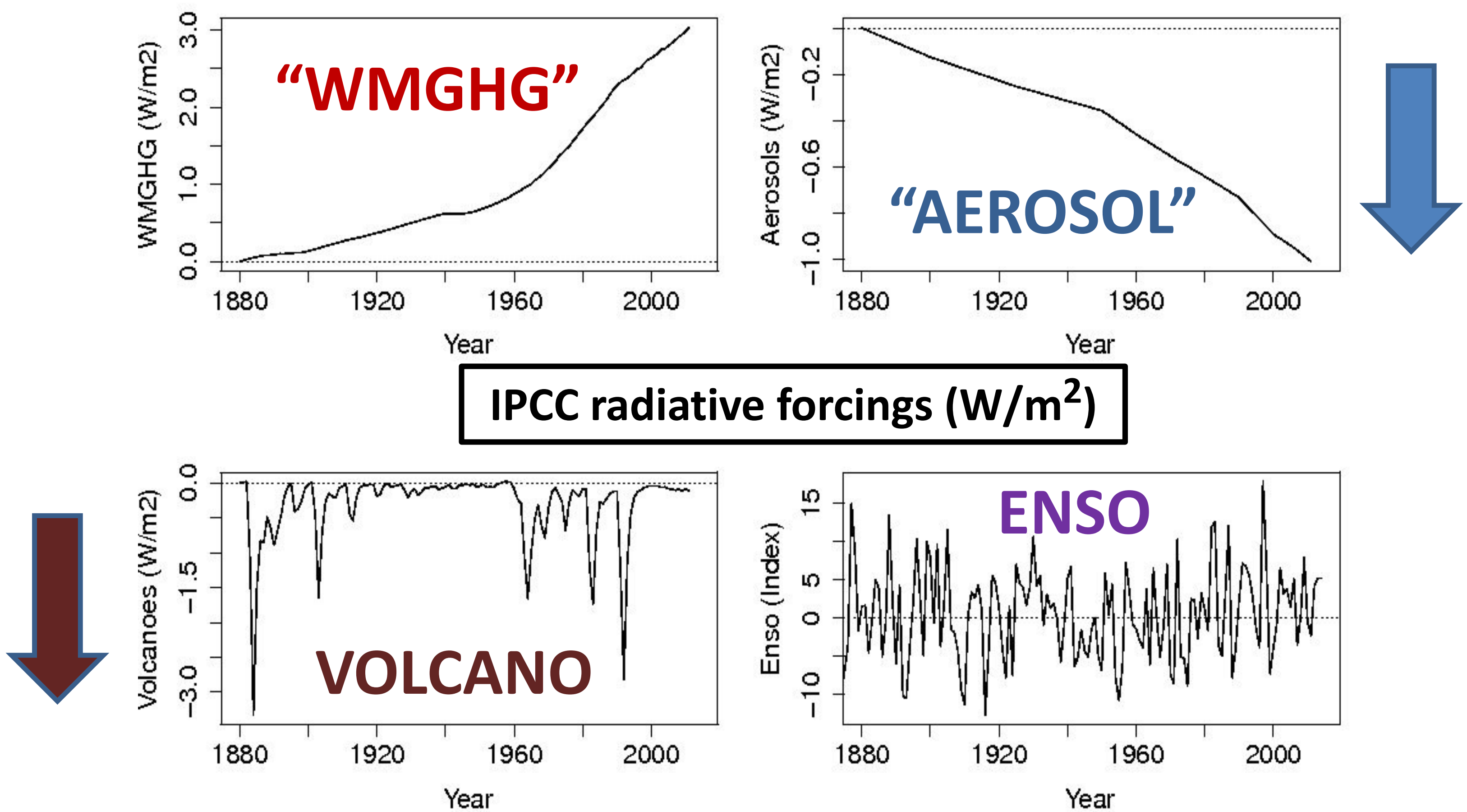


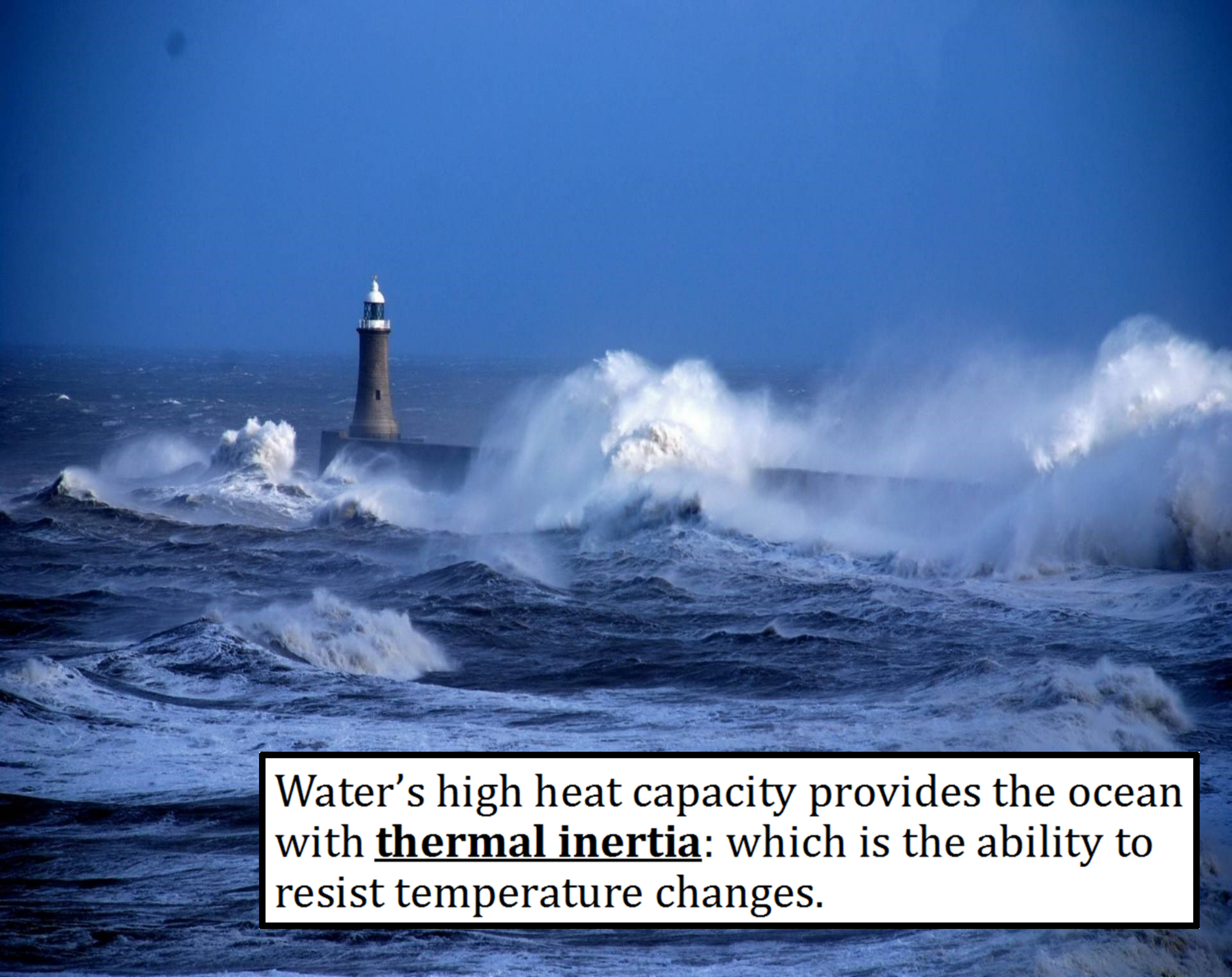
El Niño

Heat balance in terms of a time-series analysis

Multiple regression:

$$y_i = \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij} + e_i \, ,$$

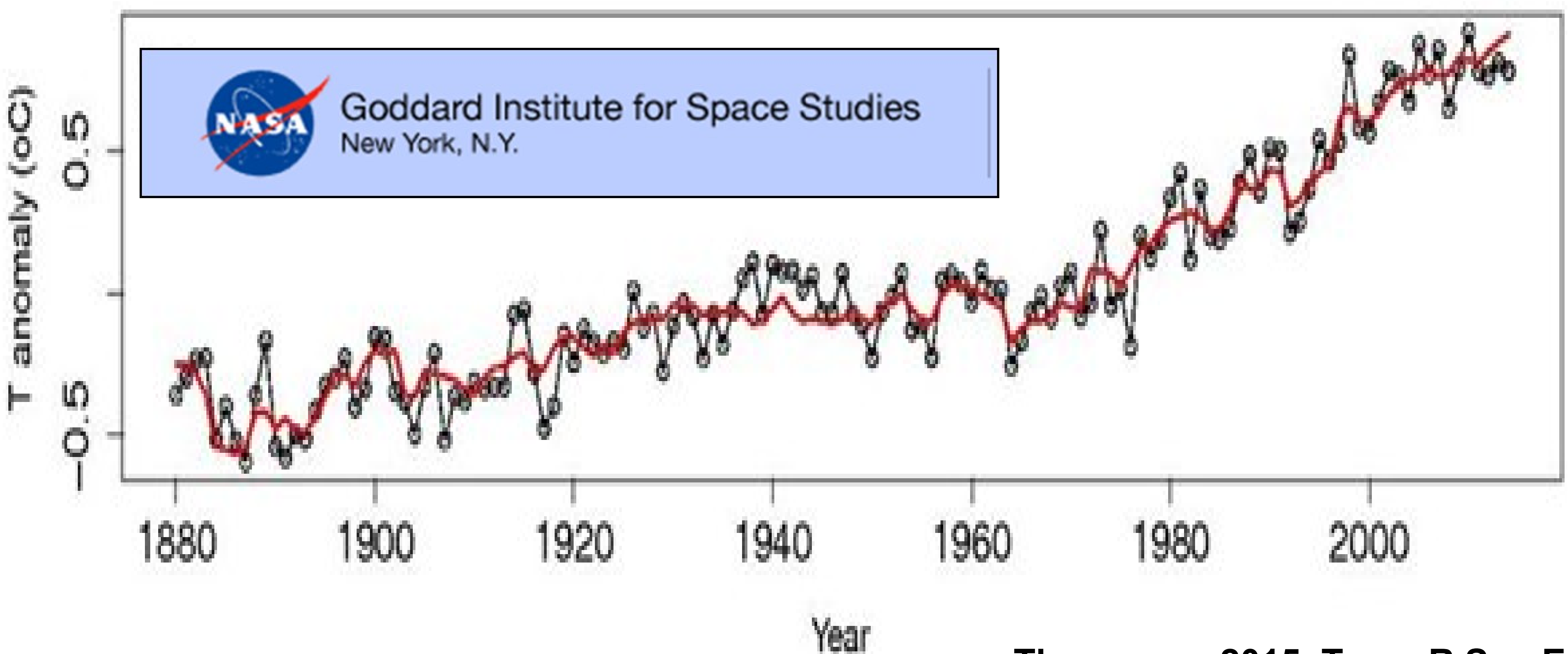



Water's high heat capacity provides the ocean with **thermal inertia**: which is the ability to resist temperature changes.

An empirically based heat-balance calculation

(non-steady state)

Temperature ~ Greenhouse gases + aerosols + volcanoes + ENSO



Thompson, 2015, Trans R Soc Ed

“Just One Damned Thing After Another”

Climate sensitivity

Roy Thompson

School of GeoSciences, Crew

$$y_i = \beta_0 + \sum \ldots + e_i \qquad (3)$$

Where f_j represents unspecified sm… (commonly natural cubic, or B-splines; see Hastie … …rani (1986) for examples). Here the well-known exp…tial smoothing technique, which assigns exponentially …sing weights over time, is used as the smoother.

Thirdly, and lastly, we recast the …egression approach (Equations 2 & 3) in terms of a tim… analysis, by allowing for correlations in the observa… taken at times i and $i-1$. That is, in practical terms …ack of statistical independence of the observation… …relations) is allowed for by modelling the residuals a… …regressive (AR), or moving-average (MA) process (as i… …quation 4).

$$\mathrm{AR1}(\rho) = \begin{bmatrix} 1 & \rho & \rho^2 & \cdots & \rho^n \\ \rho & 1 & \rho & \cdots & \vdots \\ \rho^2 & \rho & 1 & \cdots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^n & \cdots & \cdots & \cdots & 1 \end{bmatrix} \qquad (4)$$

In practice the parameter(s) of the ARMA process (e.g., Equation 4, where ρ is the lag-1 autocorrelation, and n the number of observations) can be estimated simultaneously to the coefficients of Equation 2; or Equation 3, using the R-function gnls() (see section 7 – Appendix), which fits a non-linear model using generalised least squares whilst allowing the errors to be correlated (Pinheiro & Bates 2000).

The aerosol dilemma

Correlation between regression parameter estimates:

0.972

	WMGHG	Aerosol			
WMGHG					
Aerosol	**0.972**	x			
Volcano	-0.175	-0.179			
ENSO	-0.048	-0.035			
Solar	0.102	0.133			x
Thermal Response Time	0.064	0.060	-0.456	-0.802	-0.113

Redundancy in WMGHG vs Aerosol

==

Approximate 95% confidence intervals:

Coefficients:

	lower	est.	upper
Constant	-0.50	-0.38	-0.27
WMGHG	0.02	0.35	0.69
Aerosol	**-0.69**	**0.21**	**1.10**
Volcano	0.03	0.08	0.14
ENSO	0.003	0.005	0.007

-0.69 +/- +1.10

Correlation structure:

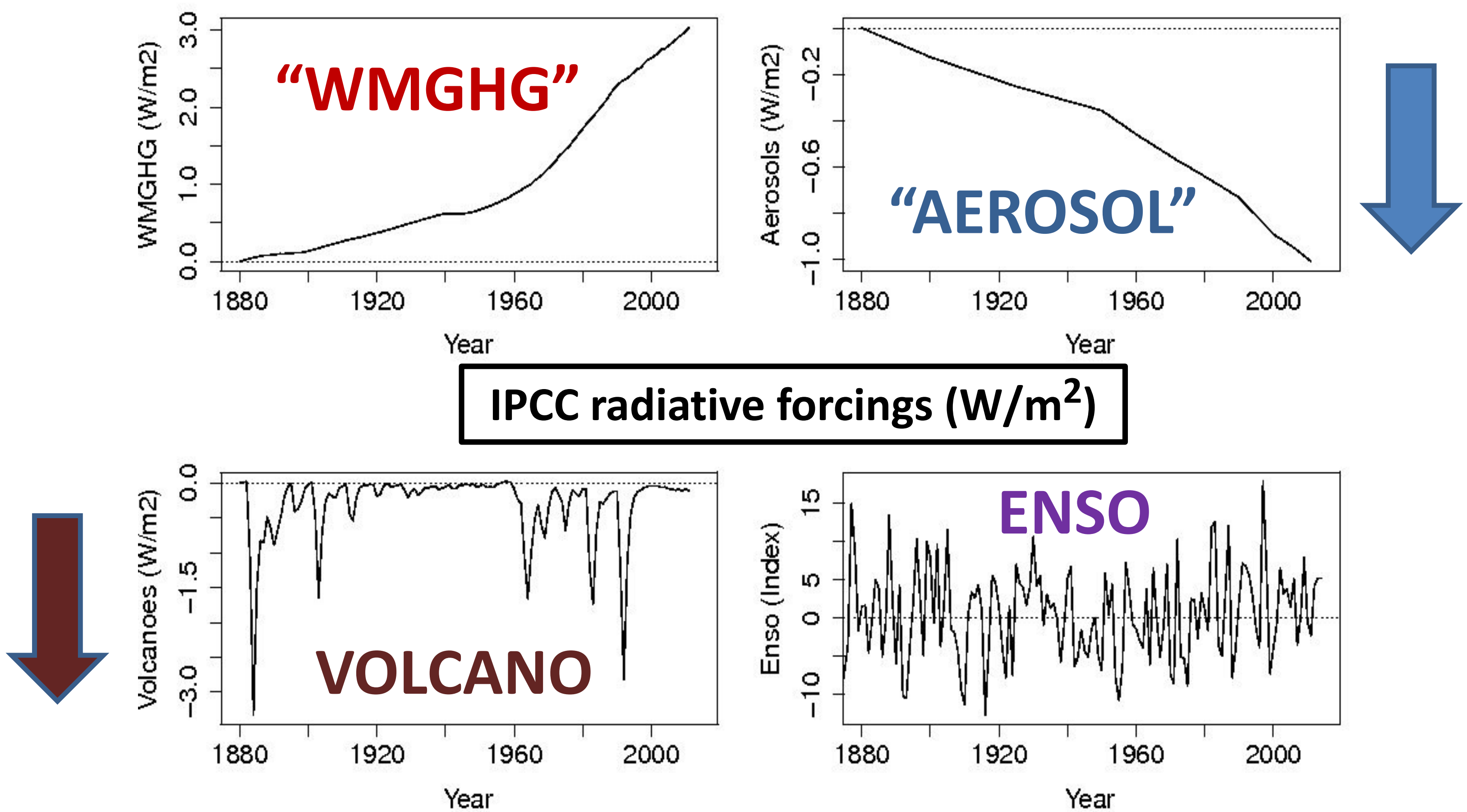
	lower	est.	upper
Phi	0.51	0.65	0.76

Aerosol not significant

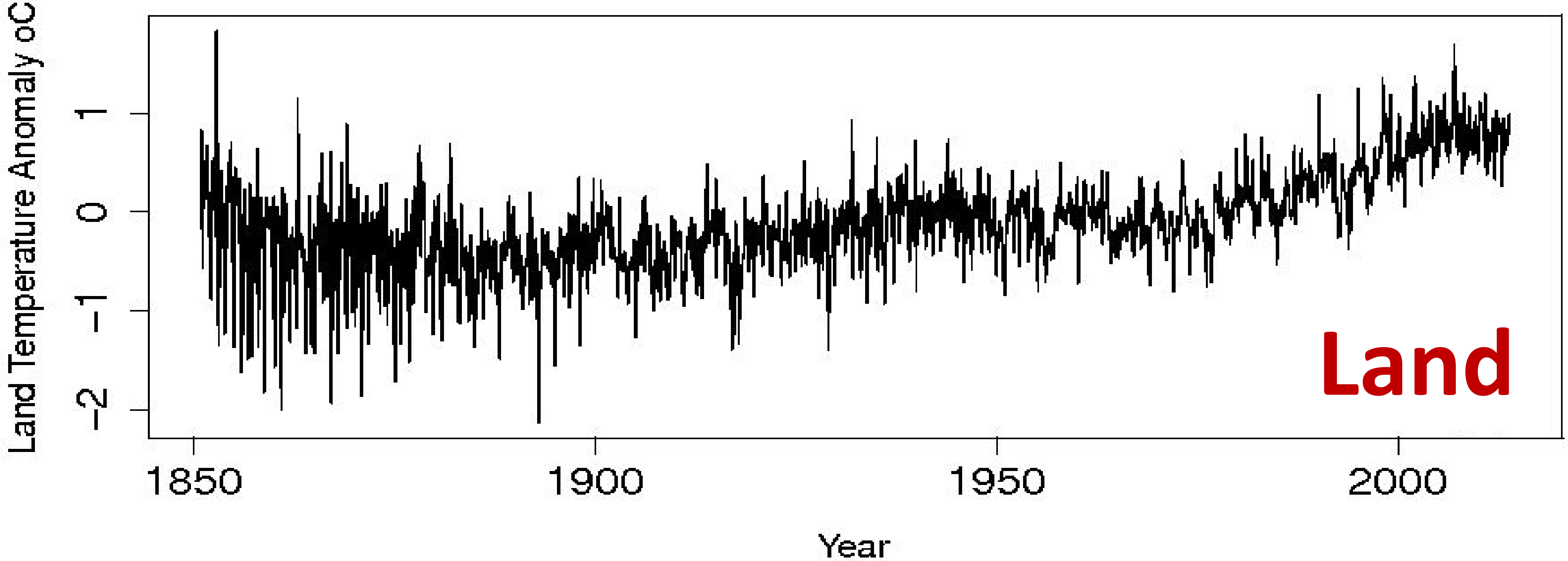
Heat balance in terms of a time-series analysis

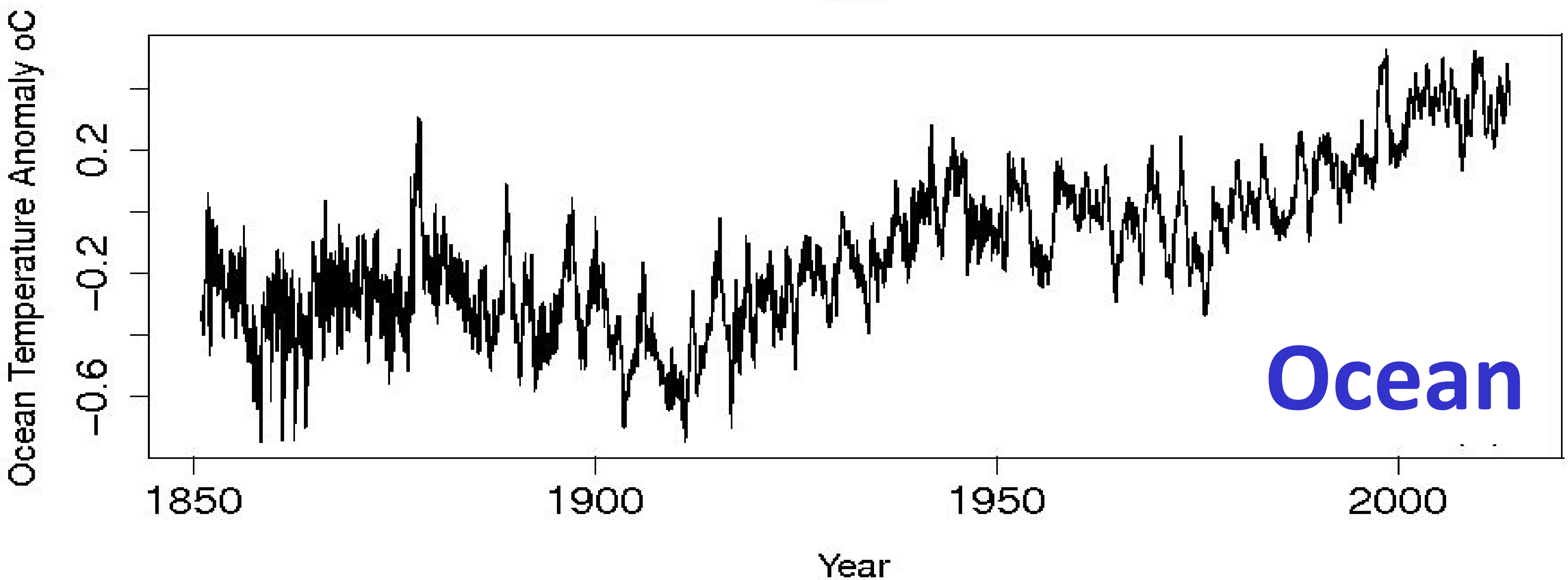
Multiple regression:

$$y_i = \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij} + e_i ,$$

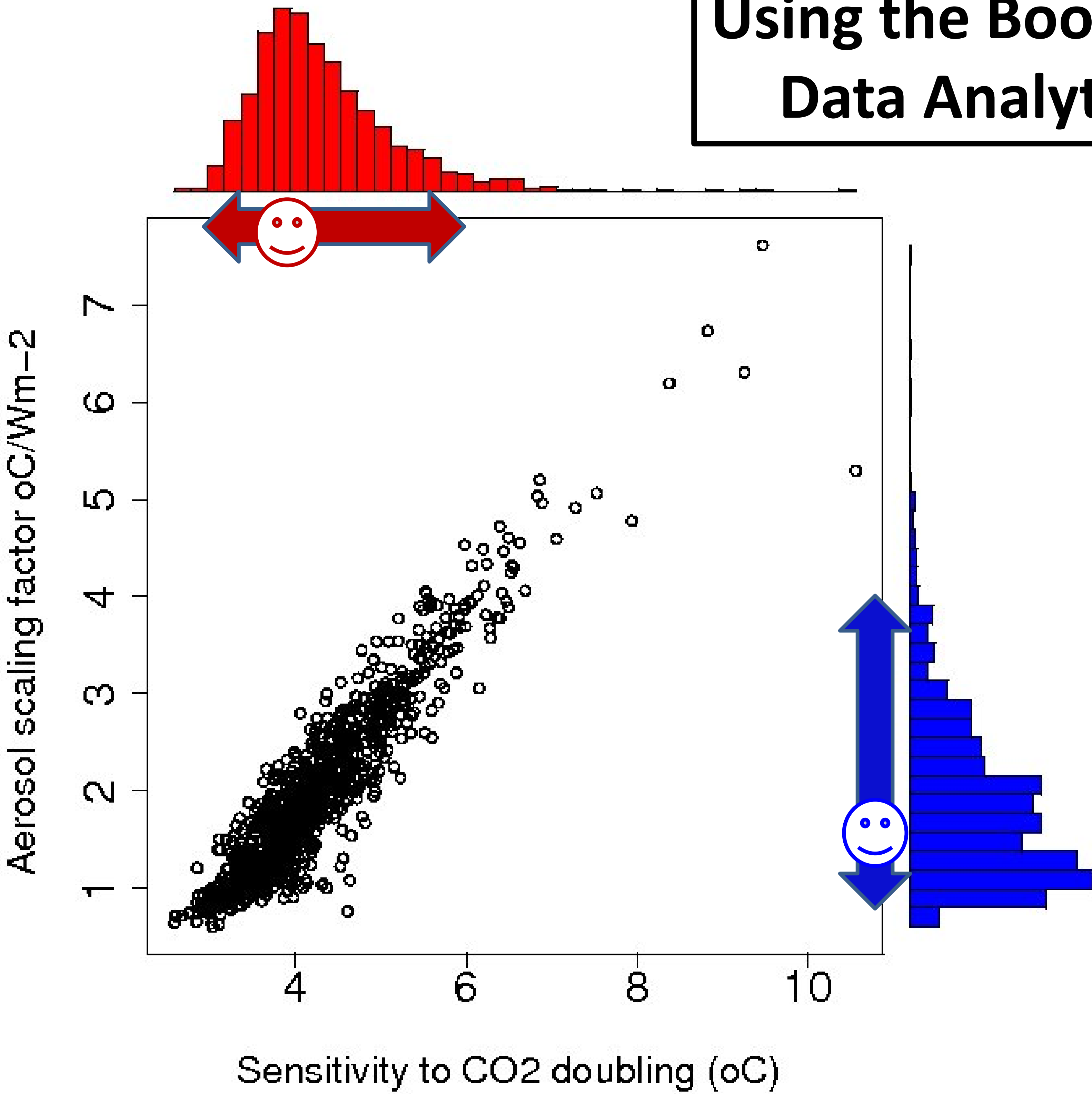


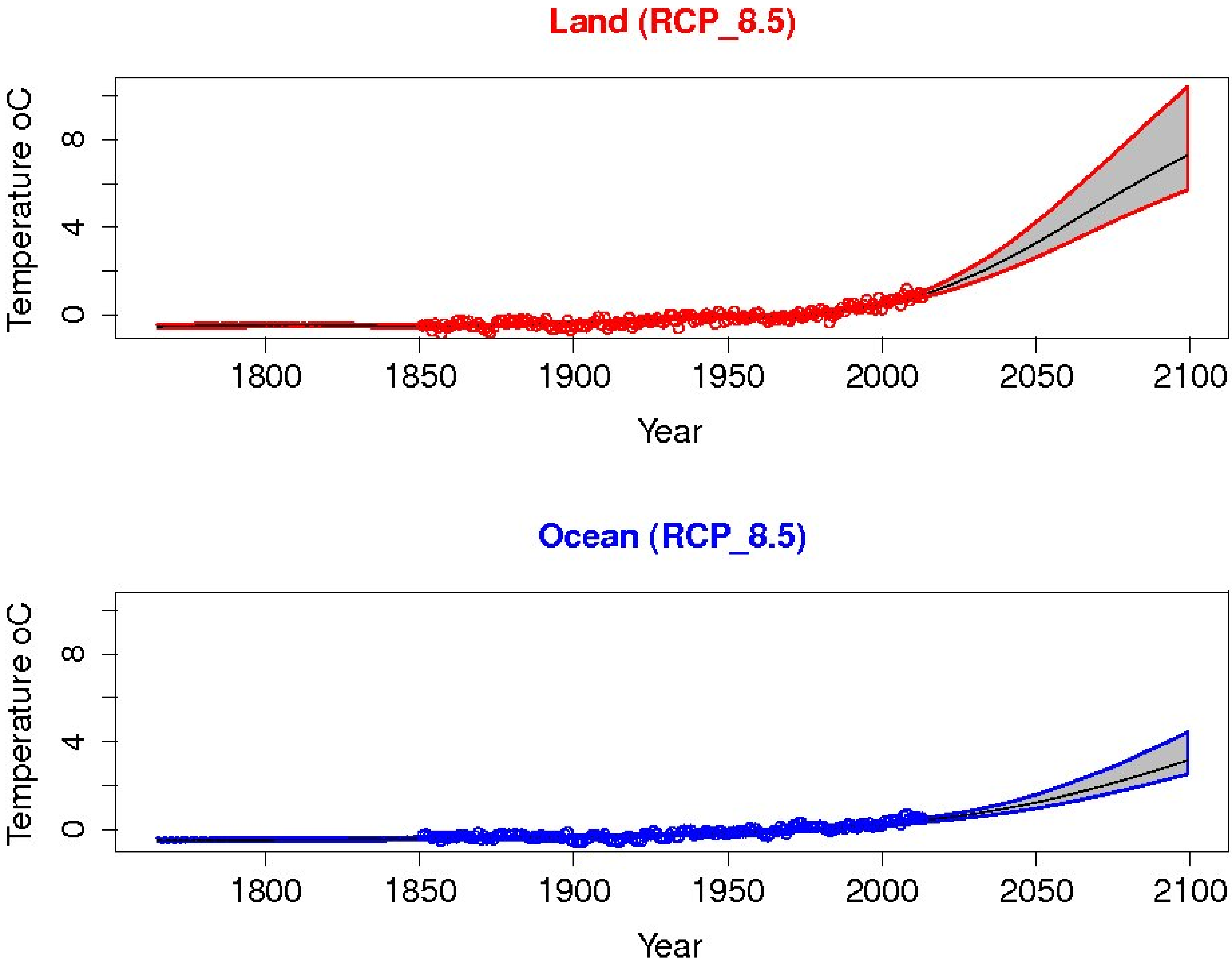
2nd attempt


Land Temperature Anomaly oC
1
0
−1
−2
1850
1900
1950
2000
Year
Land


Ocean Temperature Anomaly oC
0.2
−0.2
−0.6
1850
1900
1950
2000
Year
Ocean

Using the Bootstrap as a Data Analytical Tool




Land (RCP_8.5)
Temperature oC
0
4
8
1800
1850
1900
1950
2000
2050
2100
Year
Ocean (RCP_8.5)
Temperature oC
0
4
8
1800
1850
1900
1950
2000
2050
2100
Year


KIEV

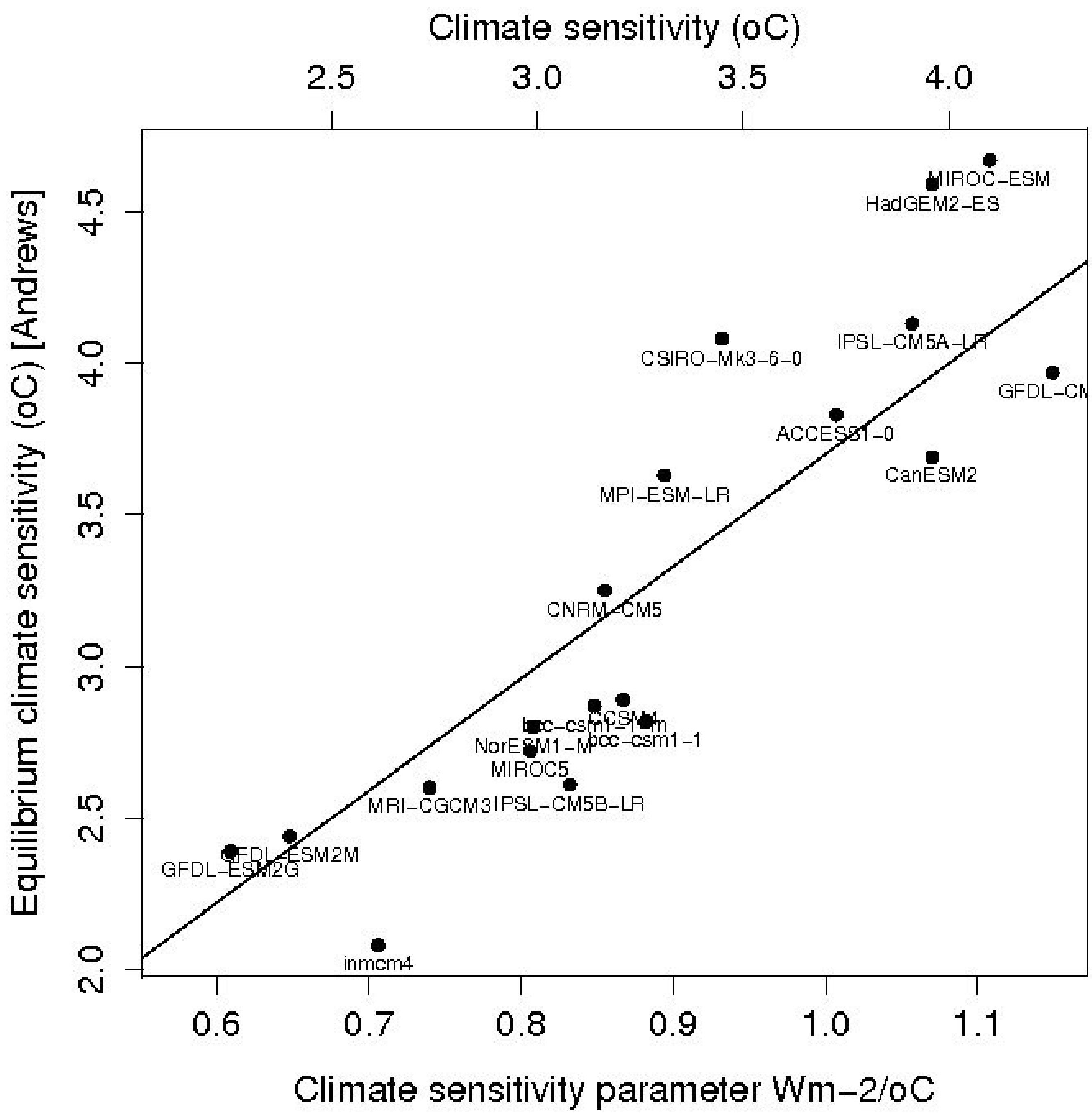

MINNEAPOLIS


WINDHOEK

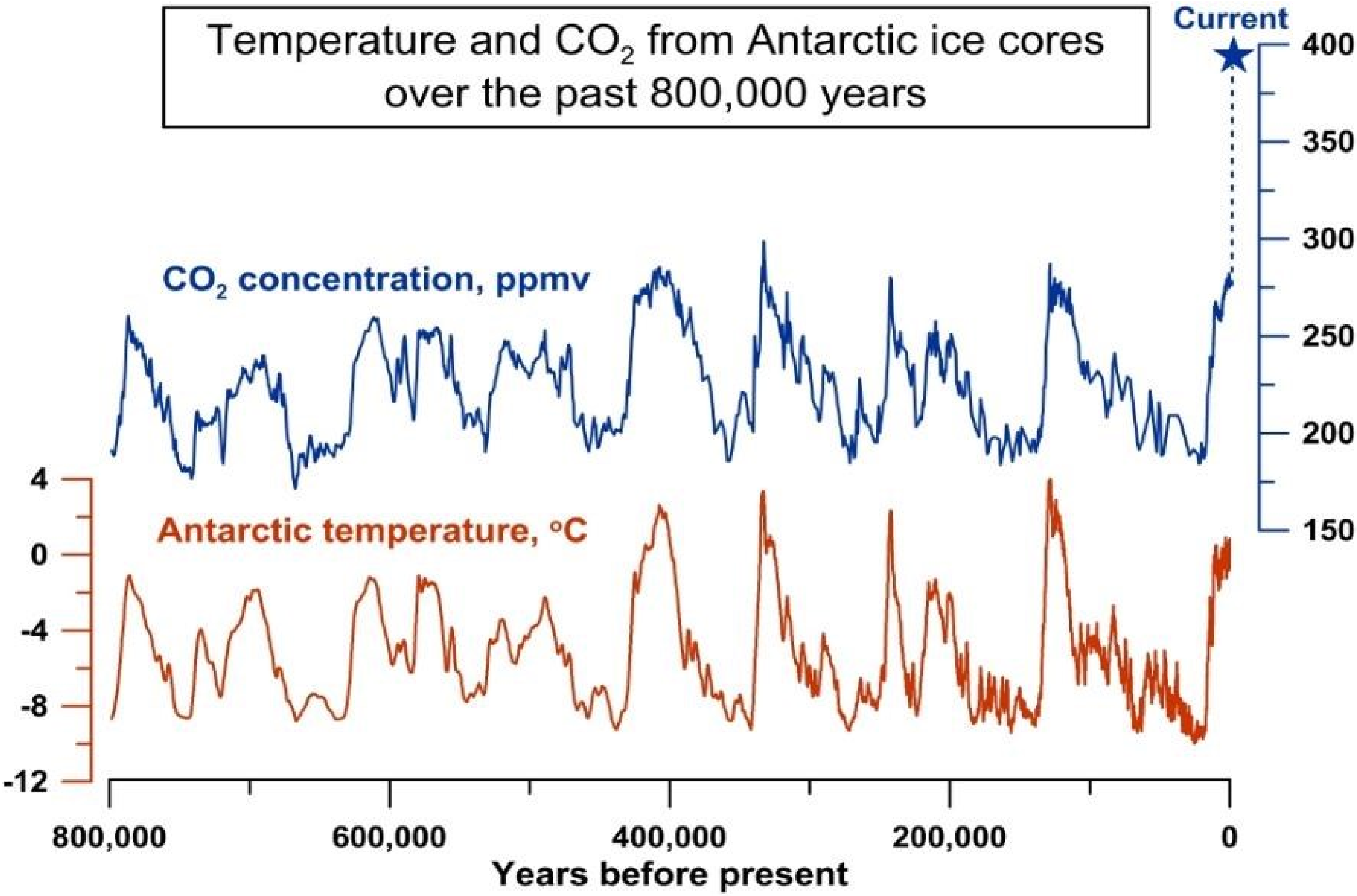

I'VE FINALLY OVERCOME MY OBSESSIVE NEED FOR EXTERNAL VALIDATION.

CMIP | Coupled Model Intercomparison Project

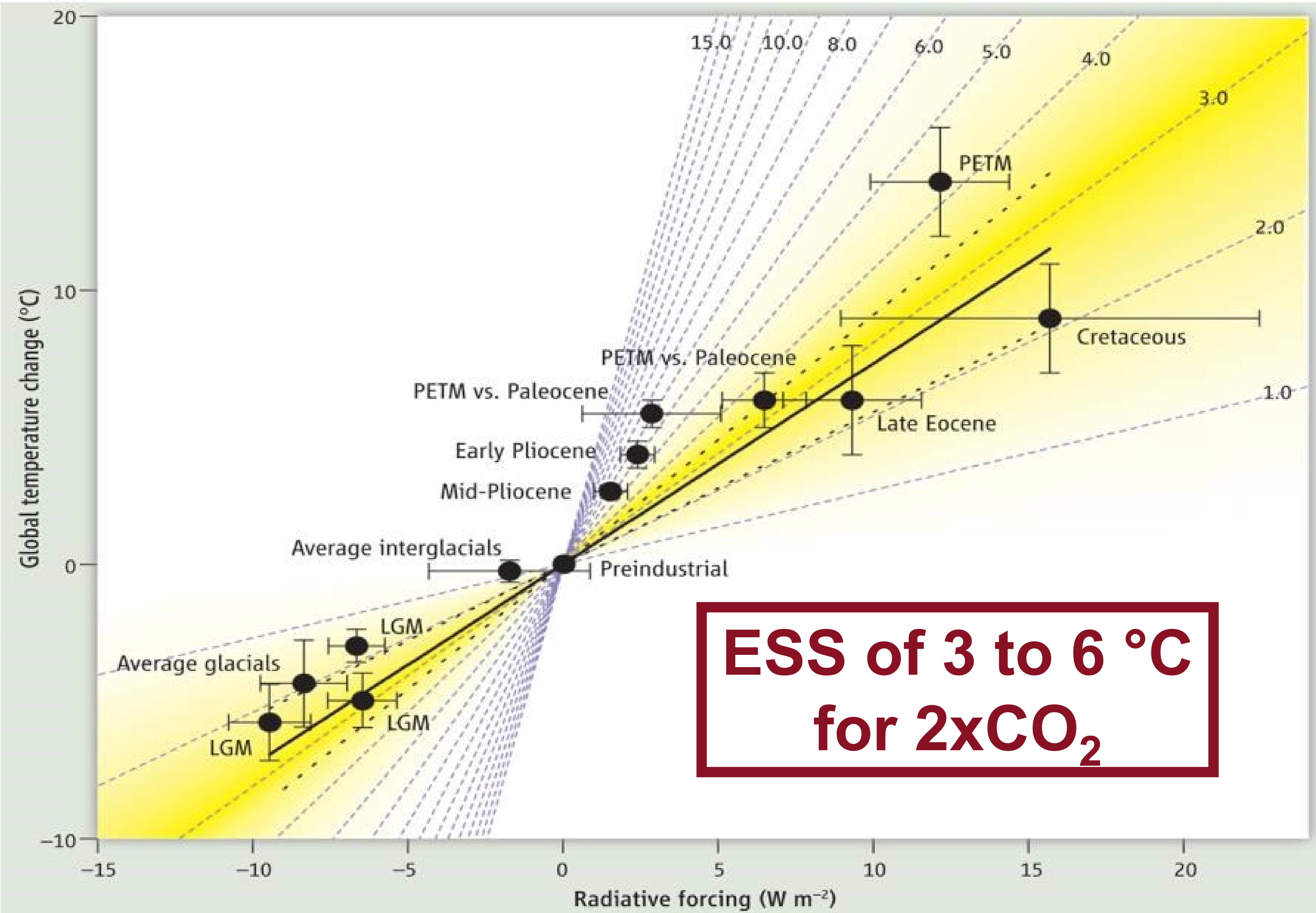
CMIP5: the most ambitious coordinated multi-model climate change experiment ever attempted



Antarctic ice: the world's air museum

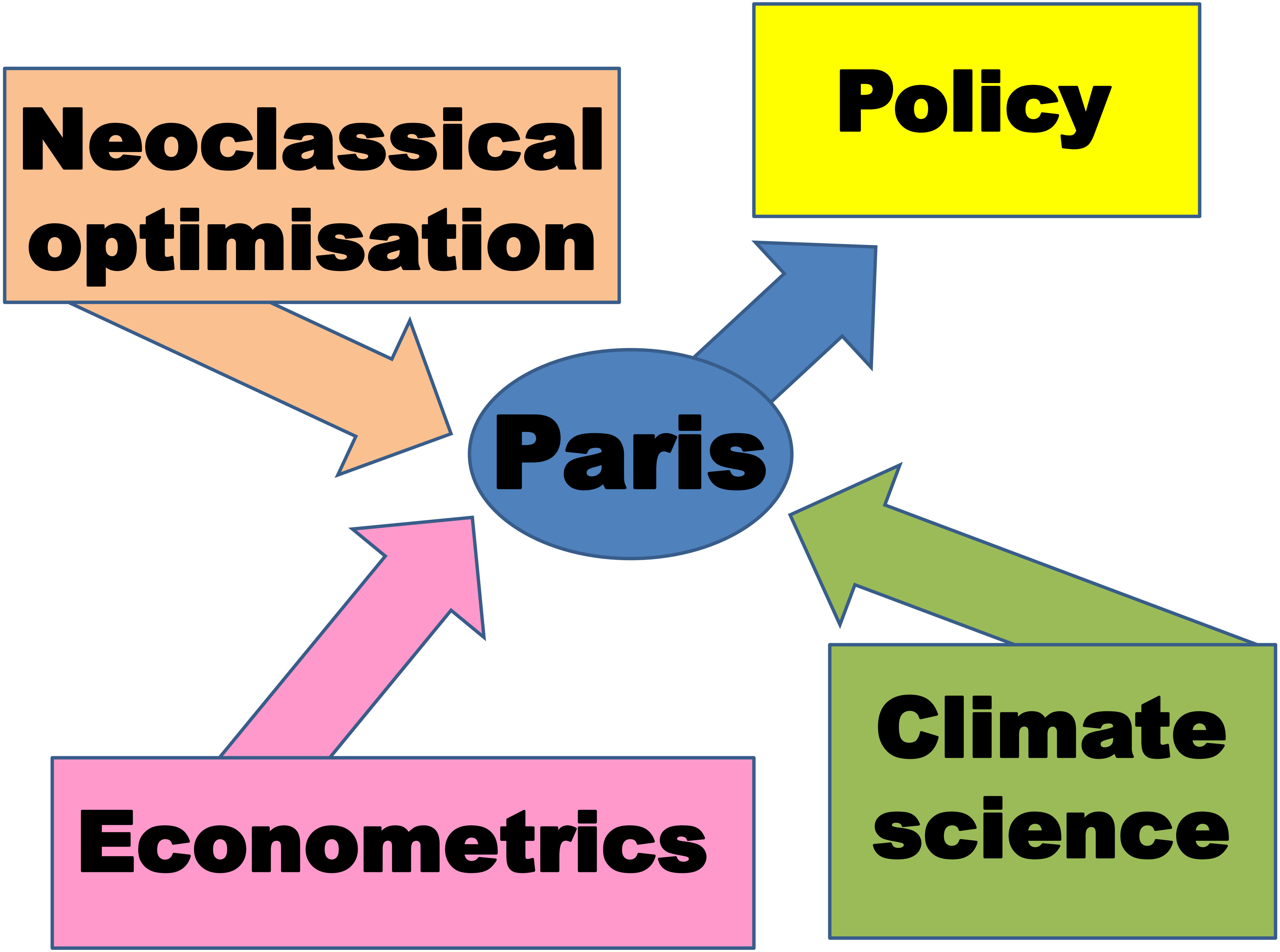


Climate Sensitivity Estimated From Earth's Climate History



CONCLUSIONS (CLIMATE SCIENCE)

- The simple heat-balance approach has been validated on GCMs.
- WMGHG, Aerosols, Volcanoes and ENSO are all found to be significant forcings.
- While the sum of the anthropogenic forcings sensitivity is well determined, individual sensitivities are highly correlated and need to be carefully disentangled.
- My ‘purely’ data-driven estimate of climate sensitivity is high, +4 ^{o}C, with 95% confidence intervals of 3.0 to 6.3 ^{o}C.
- Business-as-usual yields a 7.9 ^{o}C rise over land by 2100.
- Typical cities (Riga/Minneapolis/Windhoek) will experience 500-year heatwaves, in most years, by 2100 on a BaU trajectory.
- The 1.5 ^{o}C Paris guardrail will be breached before 2030.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Disentangling the Nordhaus/Stern controversy

Lord Stern:

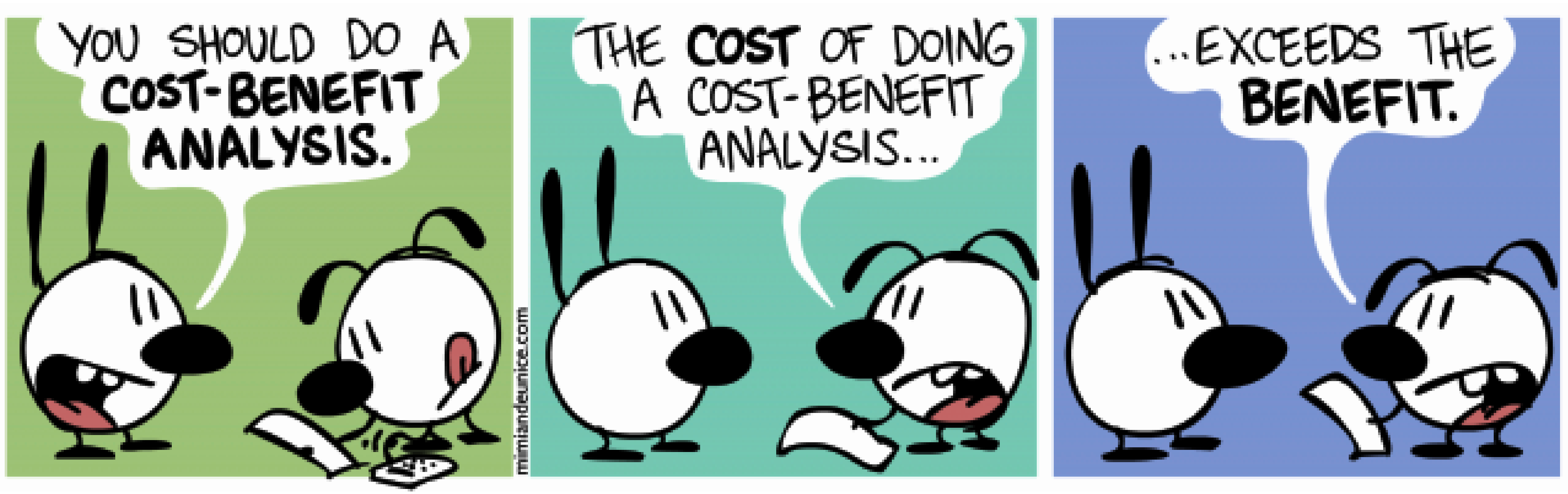
Claims the benefits of strong, early action outweigh the costs. Prefers cap and trade. Champions a low discount rate

Carbon Tax, or Cap & Trade?

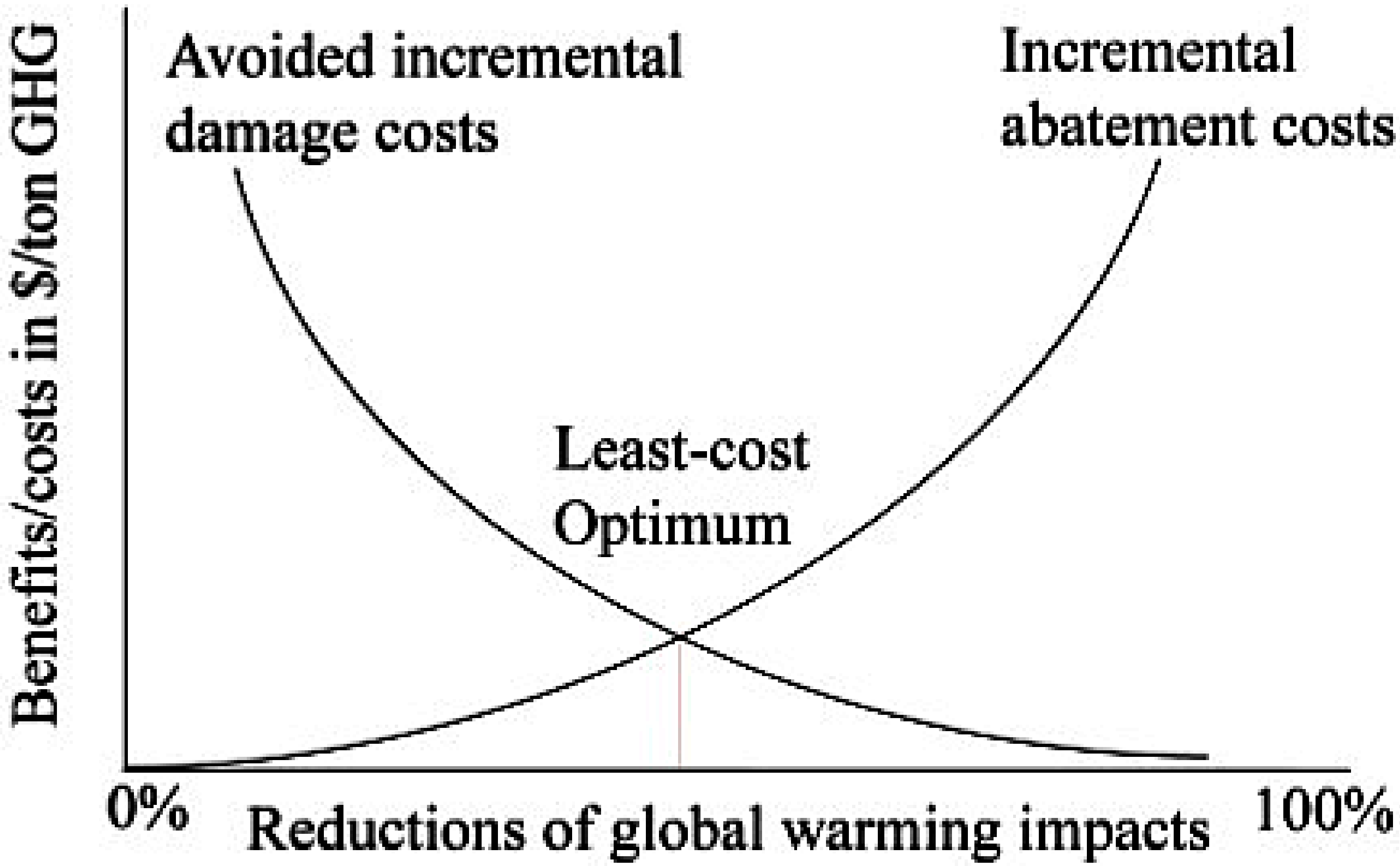
Nordhaus:

Strongly favours a carbon tax (initially around $10/ton), and has criticised the Stern Review for its use of a low discount rate.

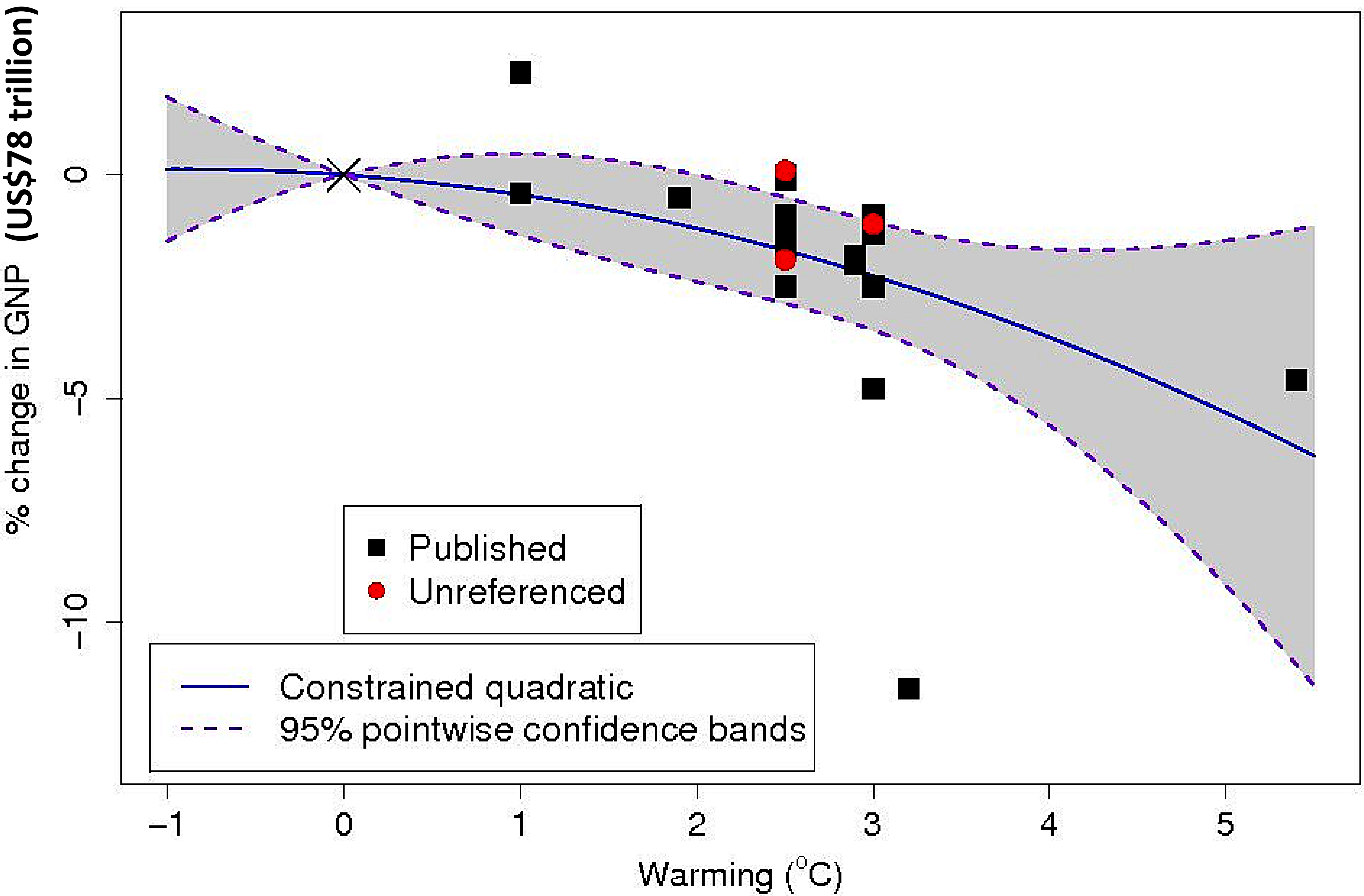
Cost-benefit analysis



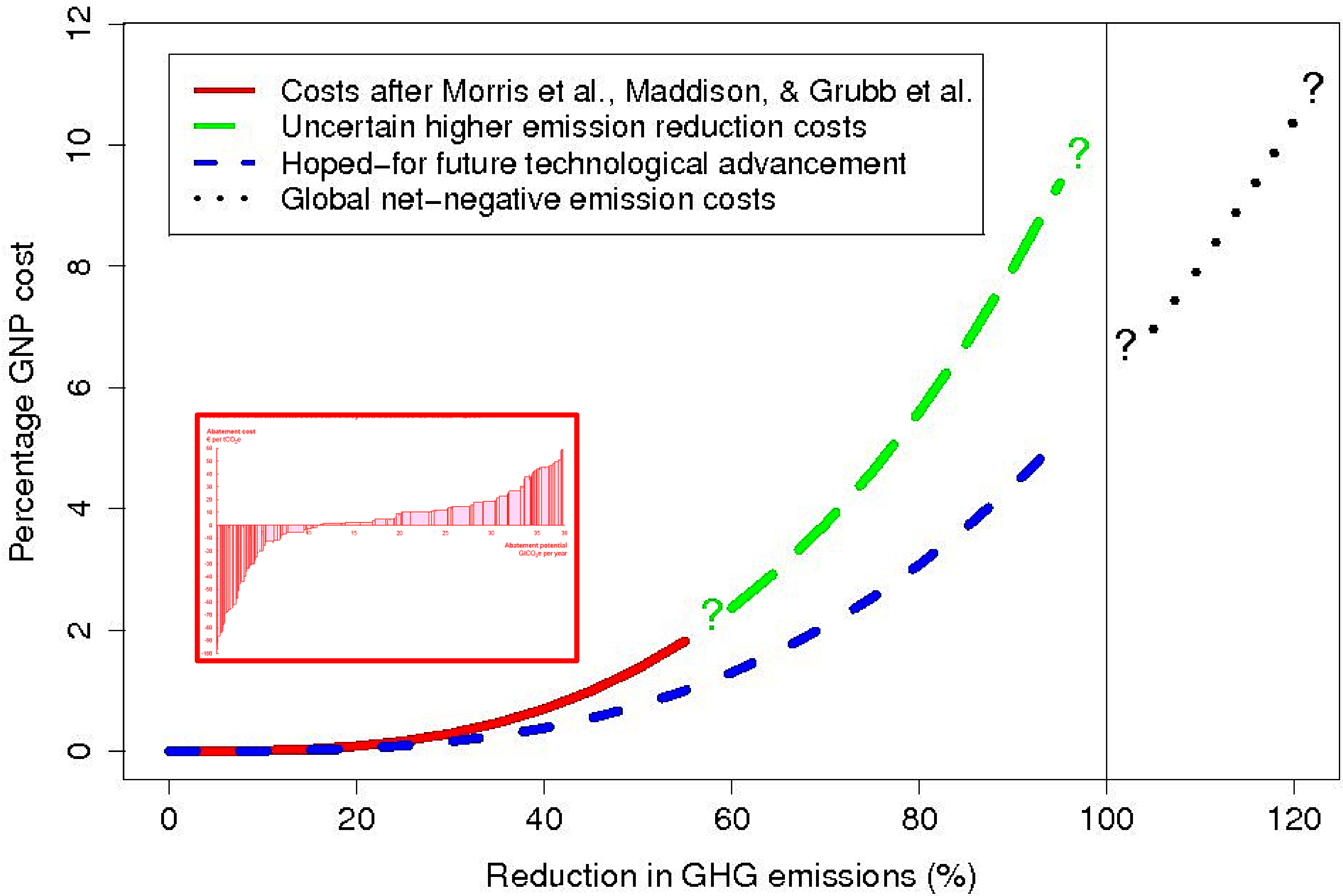
Cost-benefit analysis: the standard approach

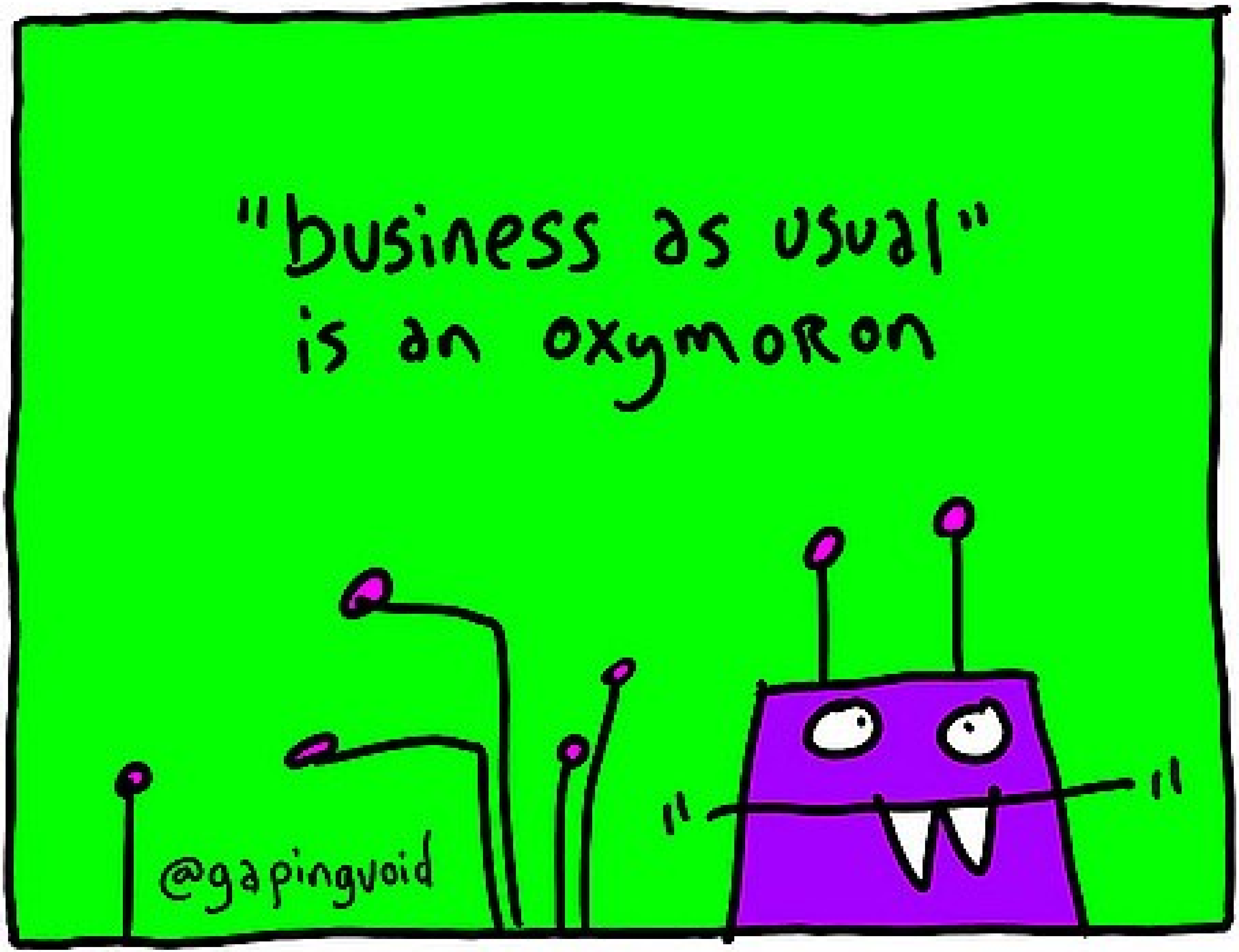


Damage function

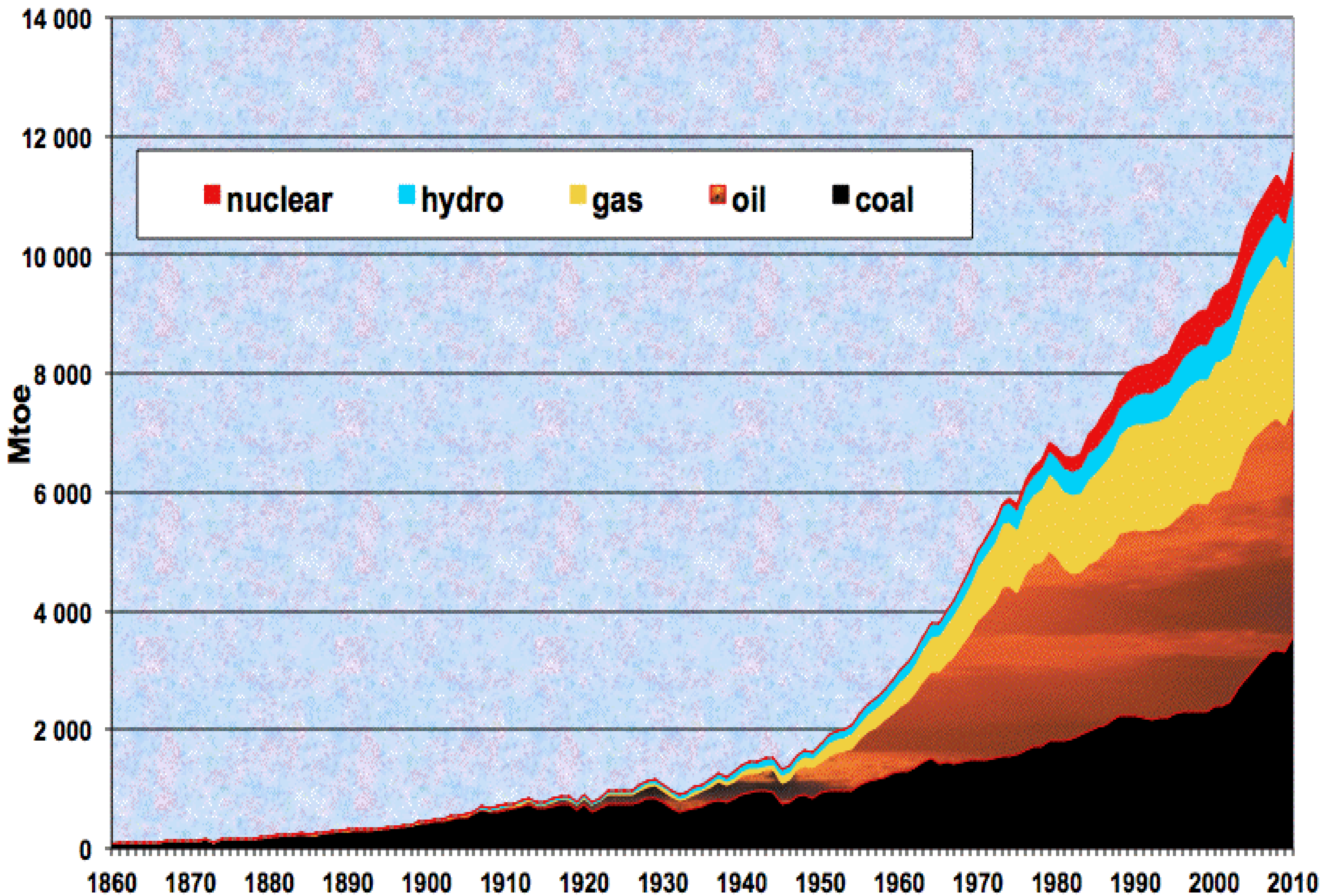


Costs of global emissions reduction

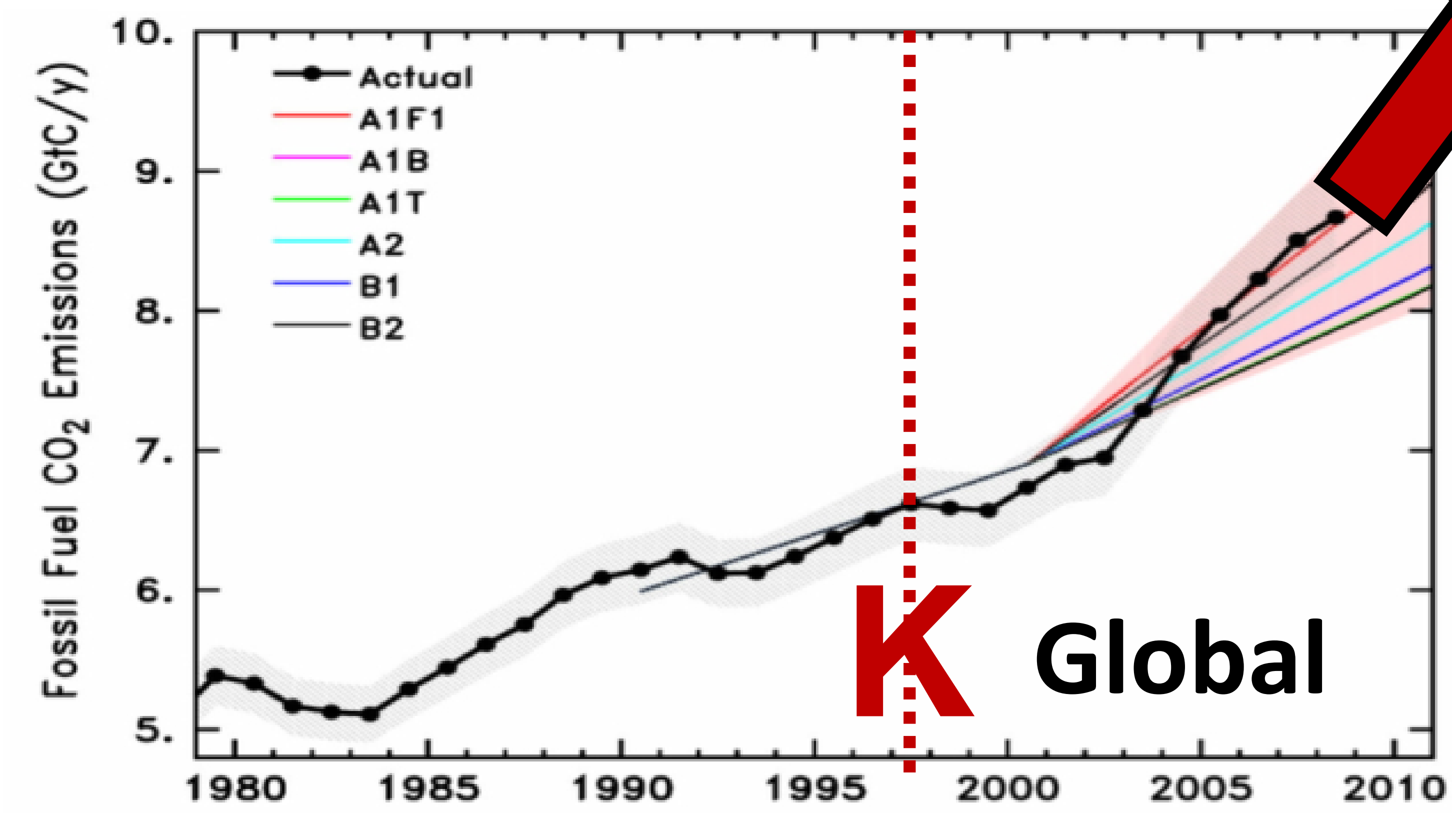



"business as usual"
is an oxymoron
@gapingvoid

Rise in global energy production



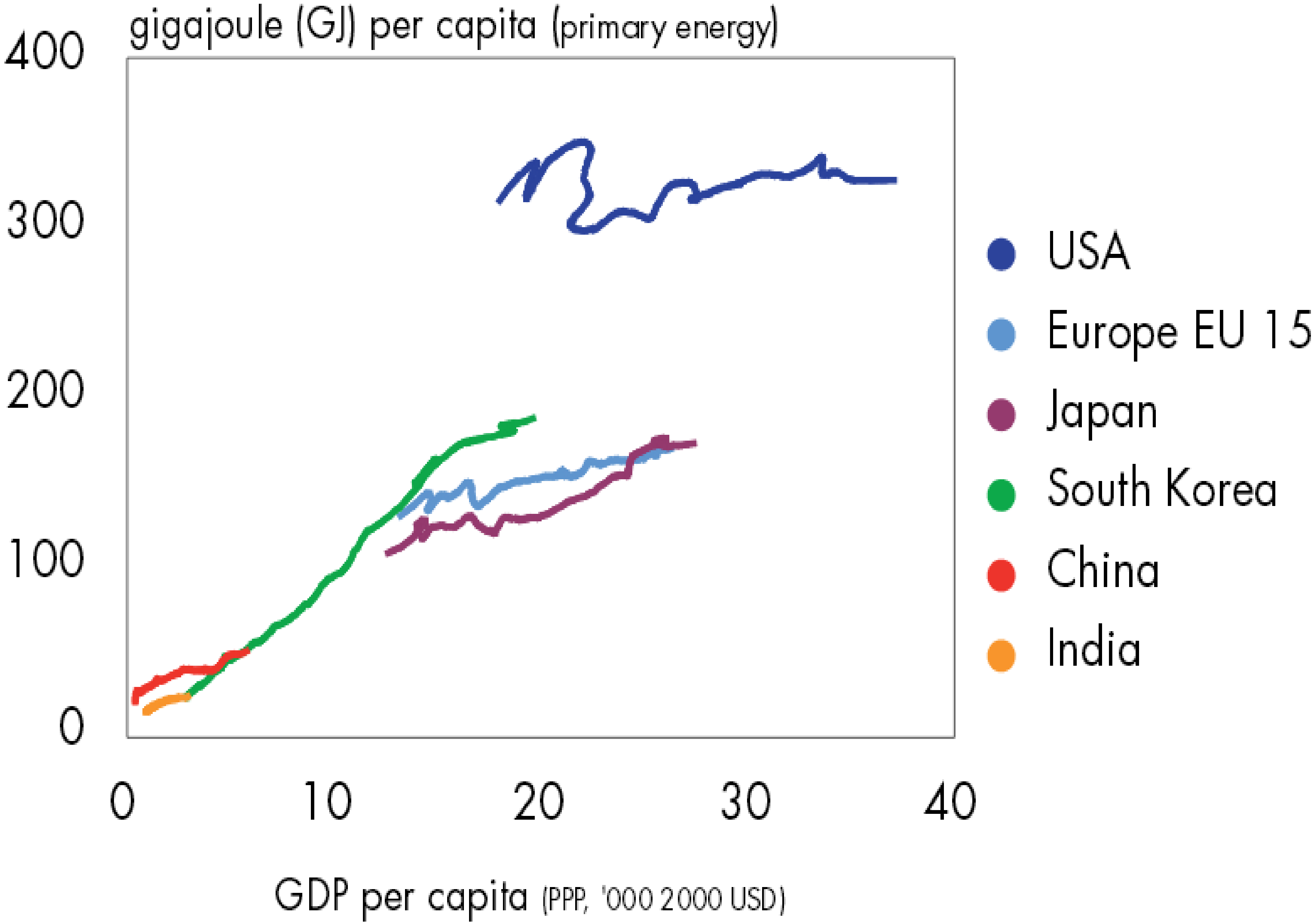
Where are we now?



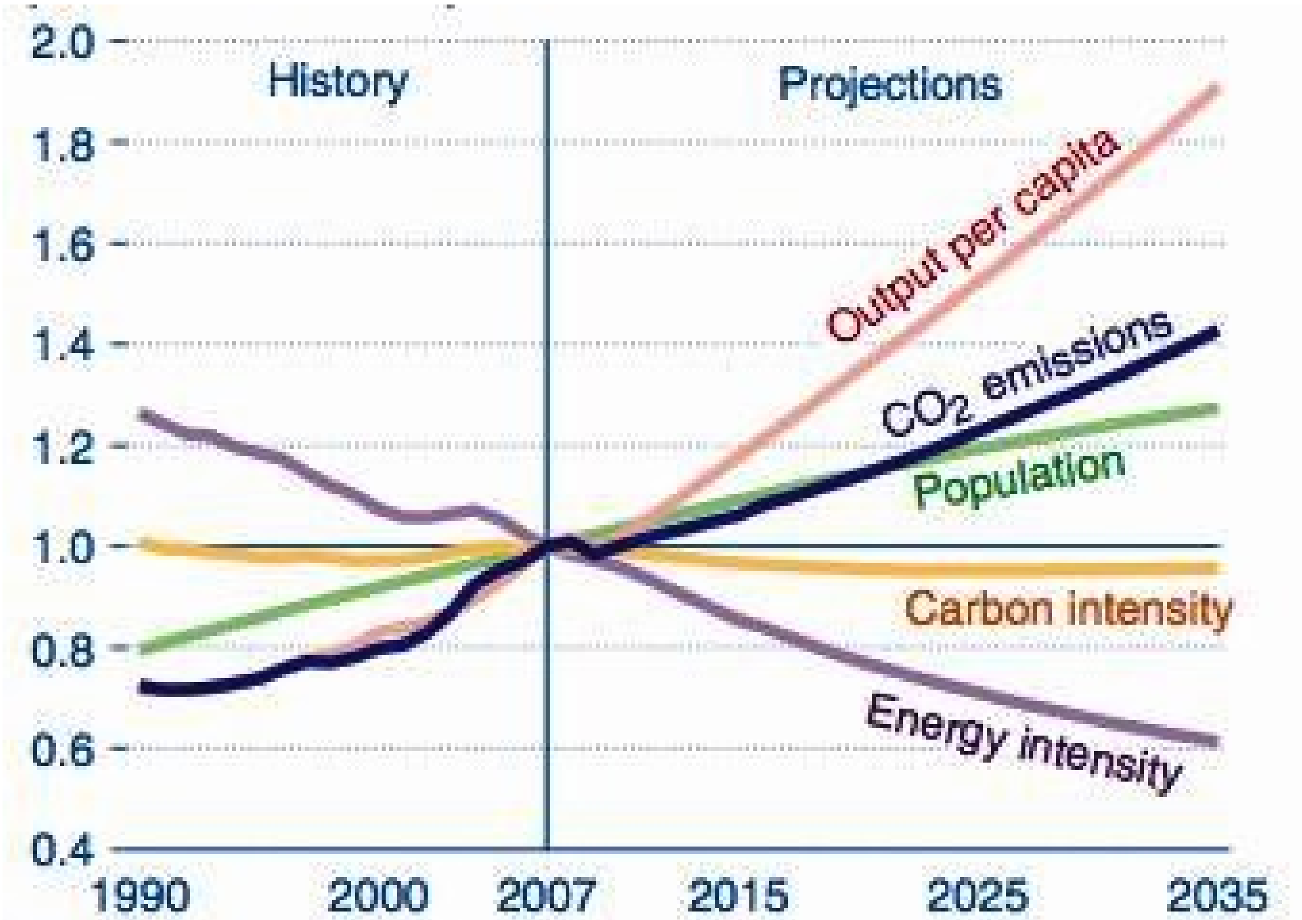
spite Kyoto, global CO_2 emissions are rising even faster than business-as-usual projections.

Climbing the energy ladder

Data shown 1970-2005



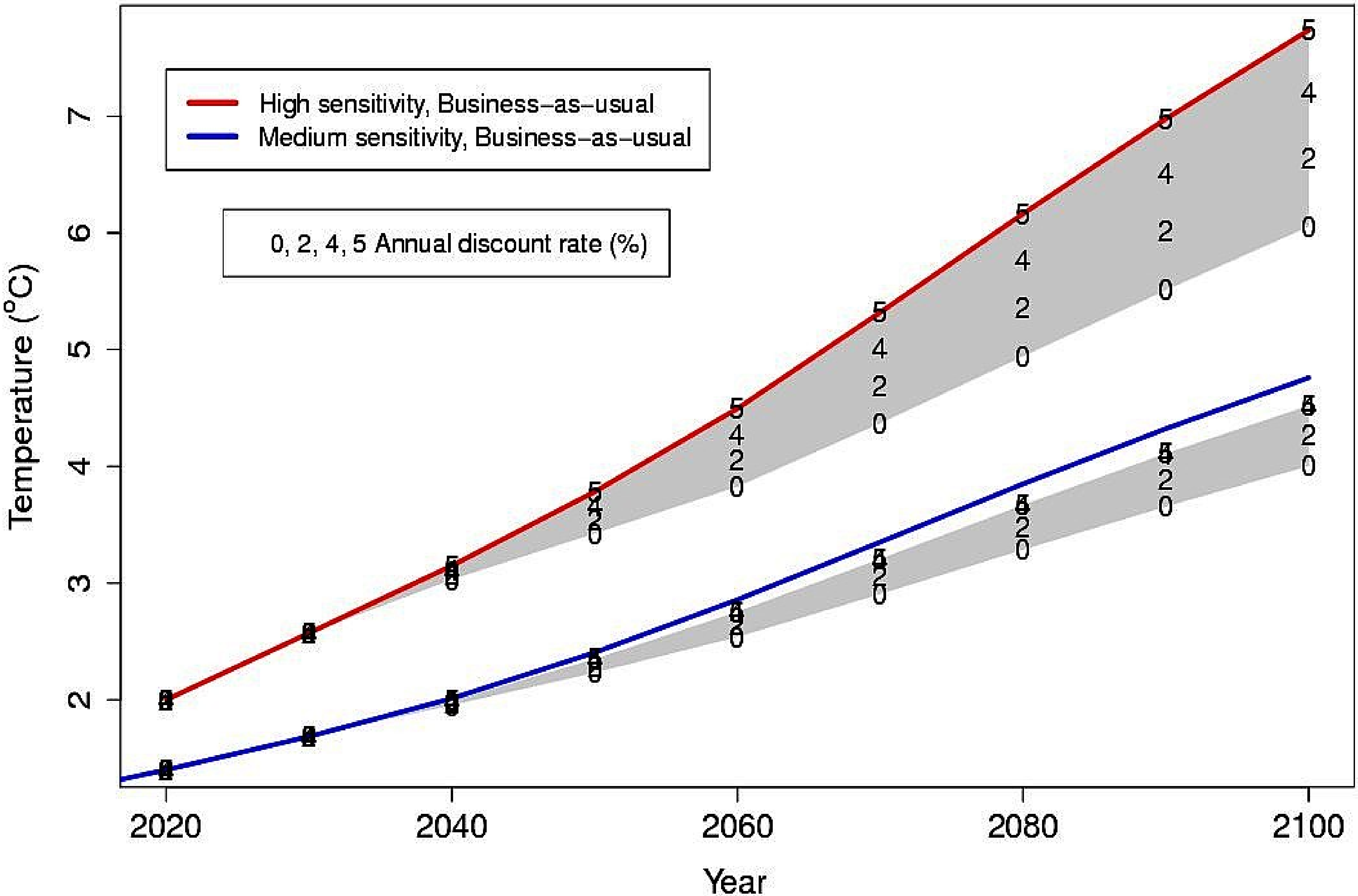
Kaya identity and global CO_2 emissions

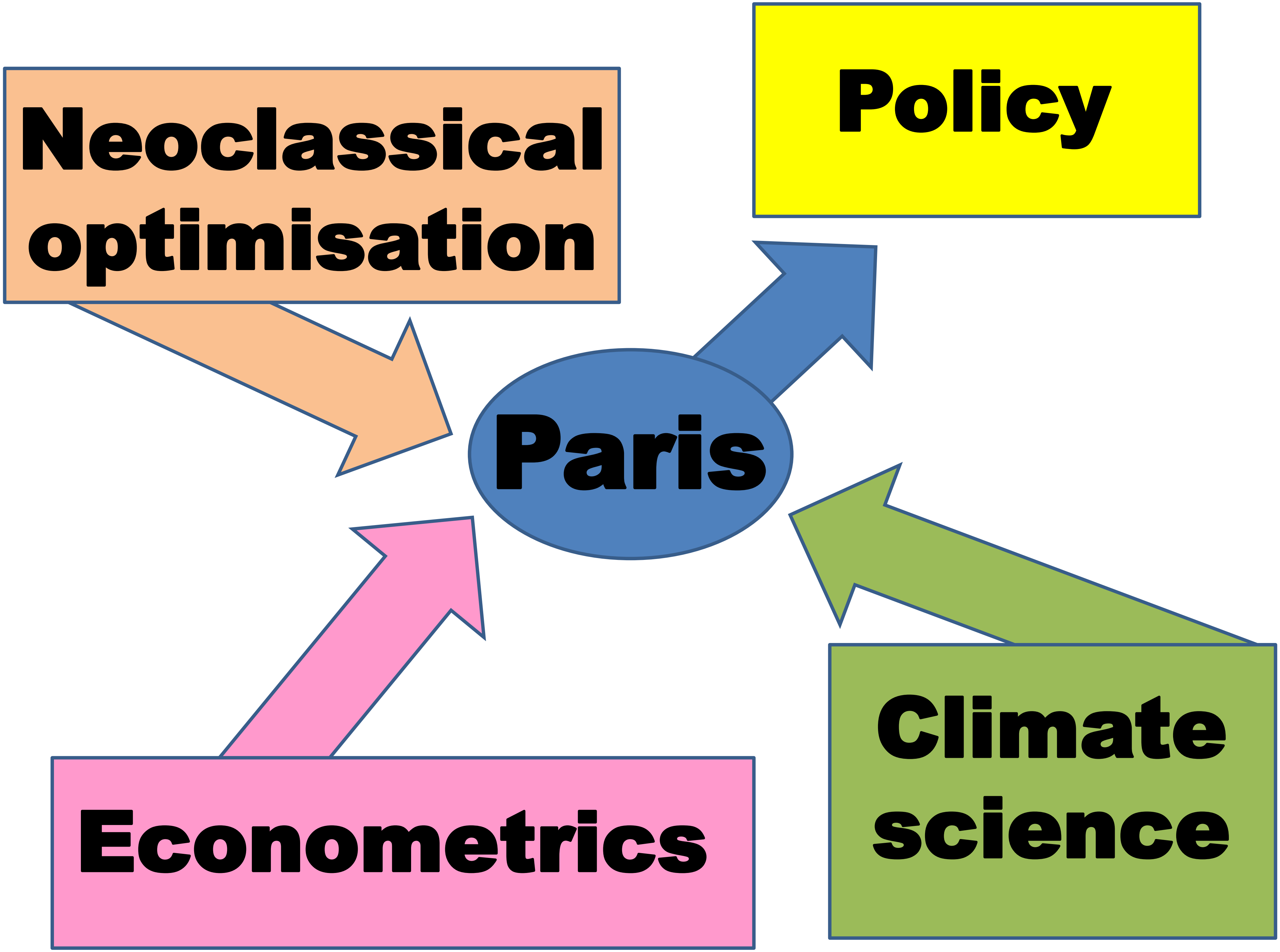


Yoichi Kaya
Japanese energy economist

$$CO2\ emissions = People \times \frac{GDP}{Person} \times \frac{Energy}{GDP} \times \frac{CO2}{Energy}$$

Optimisation of the economic/energy-balance analysis





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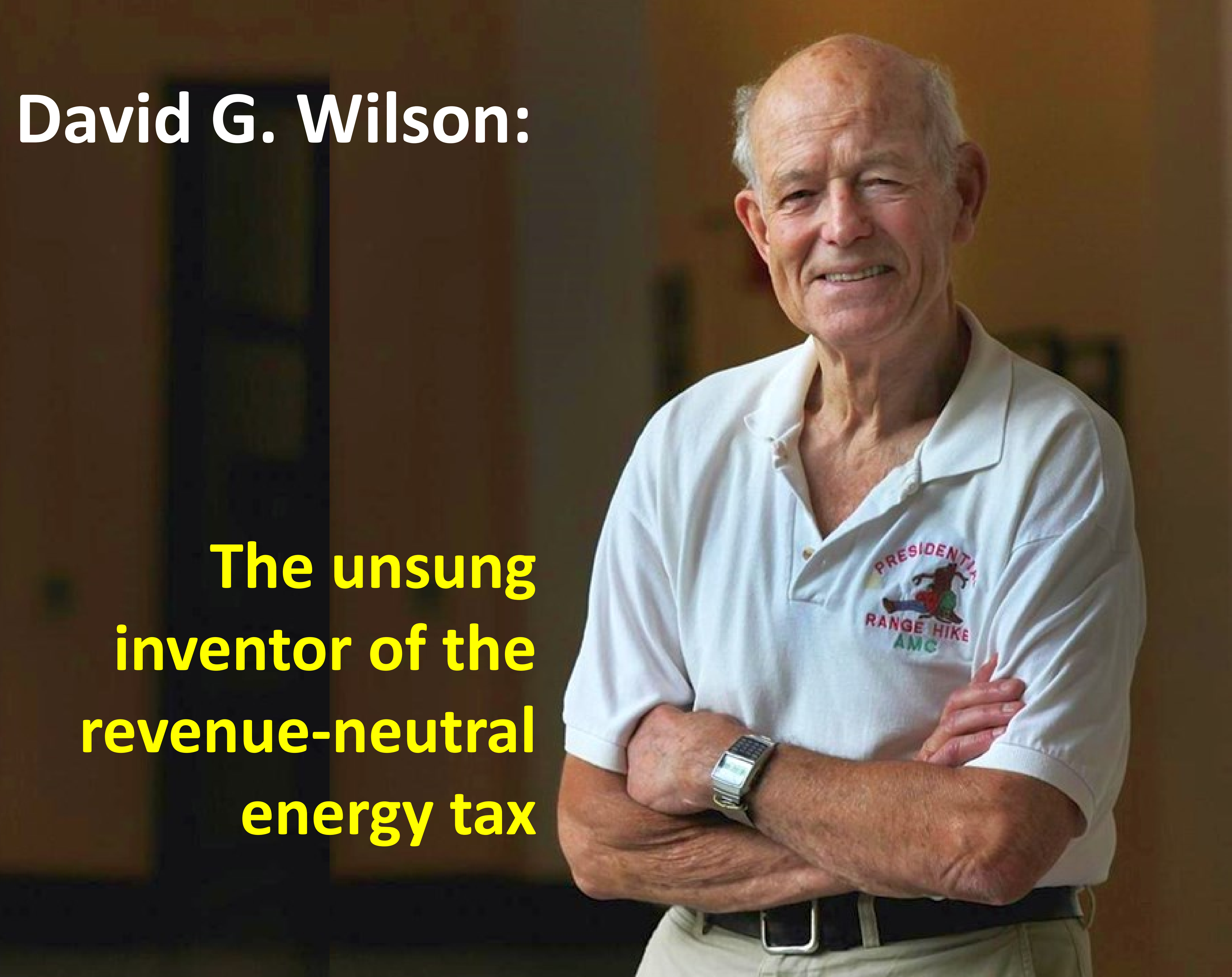
David G. Wilson:

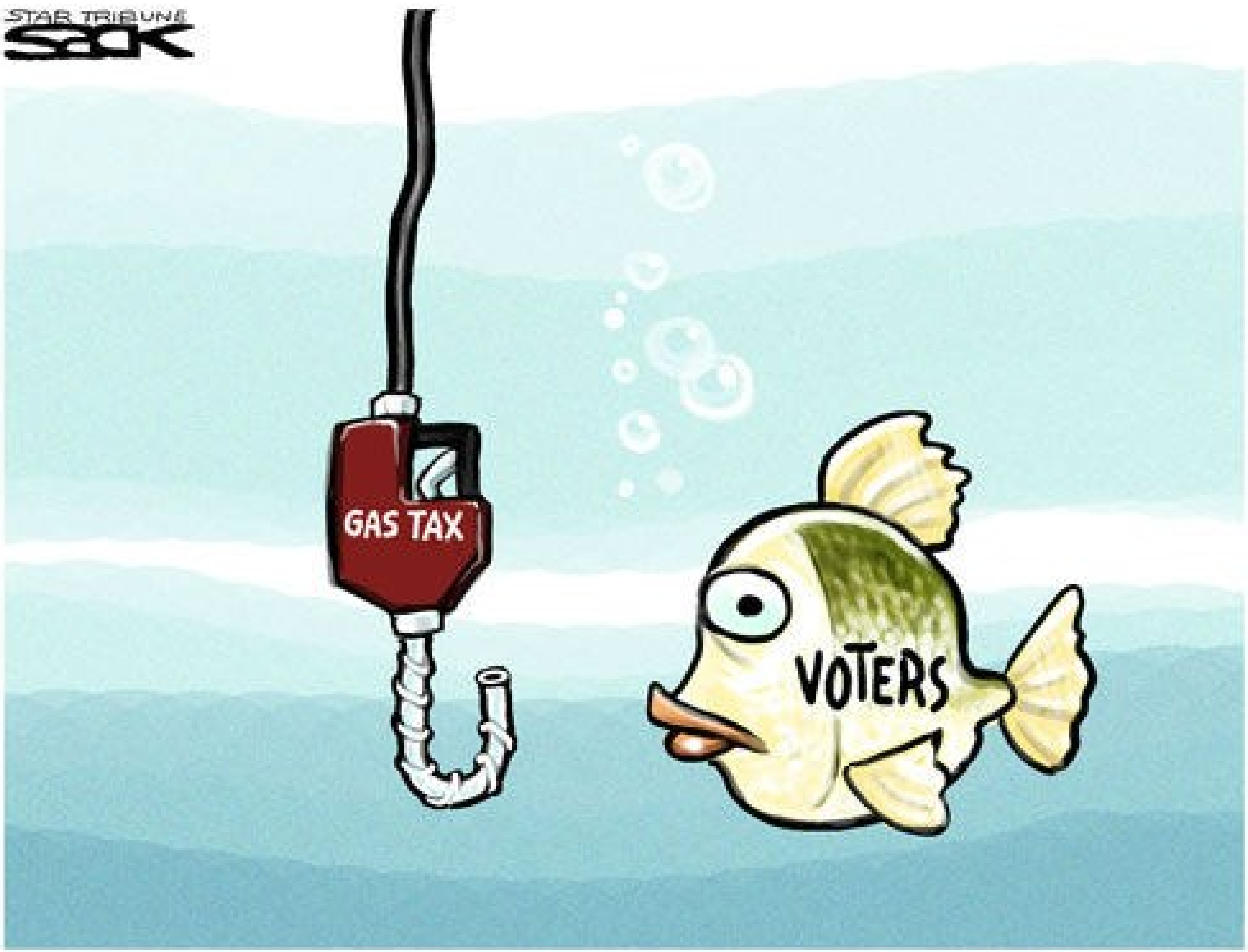
The unsung inventor of the revenue-neutral energy tax



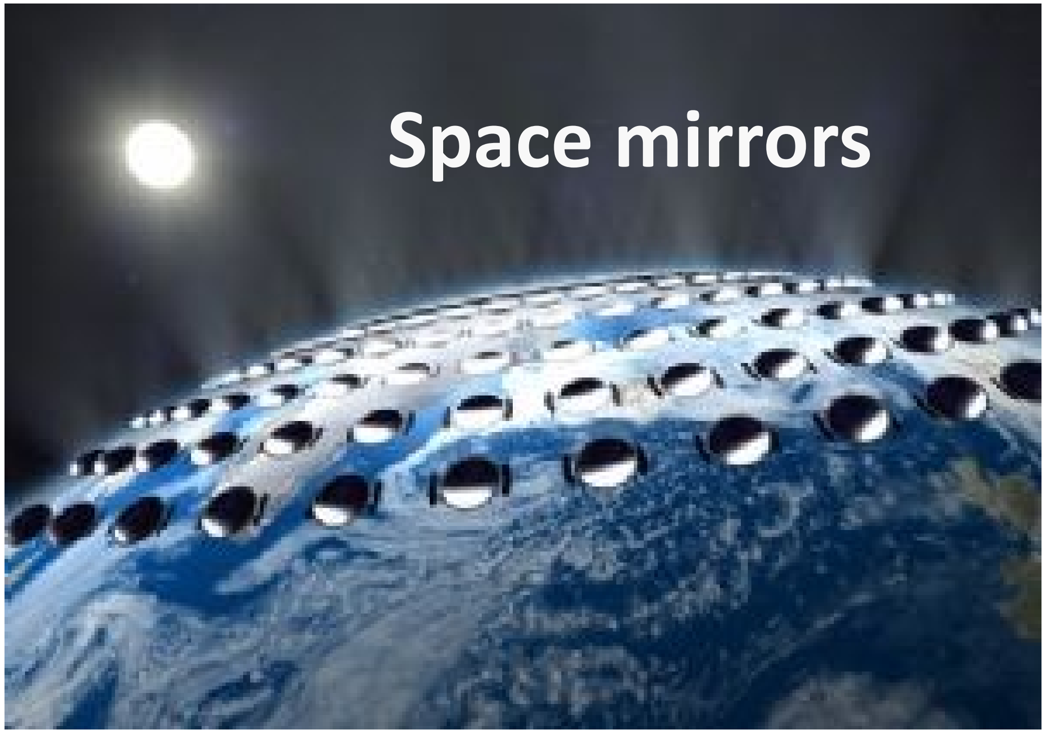
Carbon Rebate

(A 'revenue neutral' carbon tax)

- All money collected is returned to households.
  (None goes to the politicians)
- Innovation and investment in low-carbon technology stimulated by Adam Smith's invisible hand.
- Simple and inexpensive to administer.
- Scope for corruption greatly reduced.
- Gradual, so predictable for business.
- Can receive bipartisan political support.


STAR TRIBUNE
SACK
GAS TAX
VOTERS

Geoengineering



CONCLUSIONS

- **The basic economic-climate analysis manages to reproduce the results of more complex IAMs.**

- **The dominant economic-climate parameter is climate sensitivity.**

- **The 1.5^{o} C Paris guardrail is naïve, ambiguous and unattainable.**

- **Neither the Paris pledges, nor the Paris ratchet, nor ‘optimal economics’ will suffice to stabilize global warming.**