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Corporate Strategic Research
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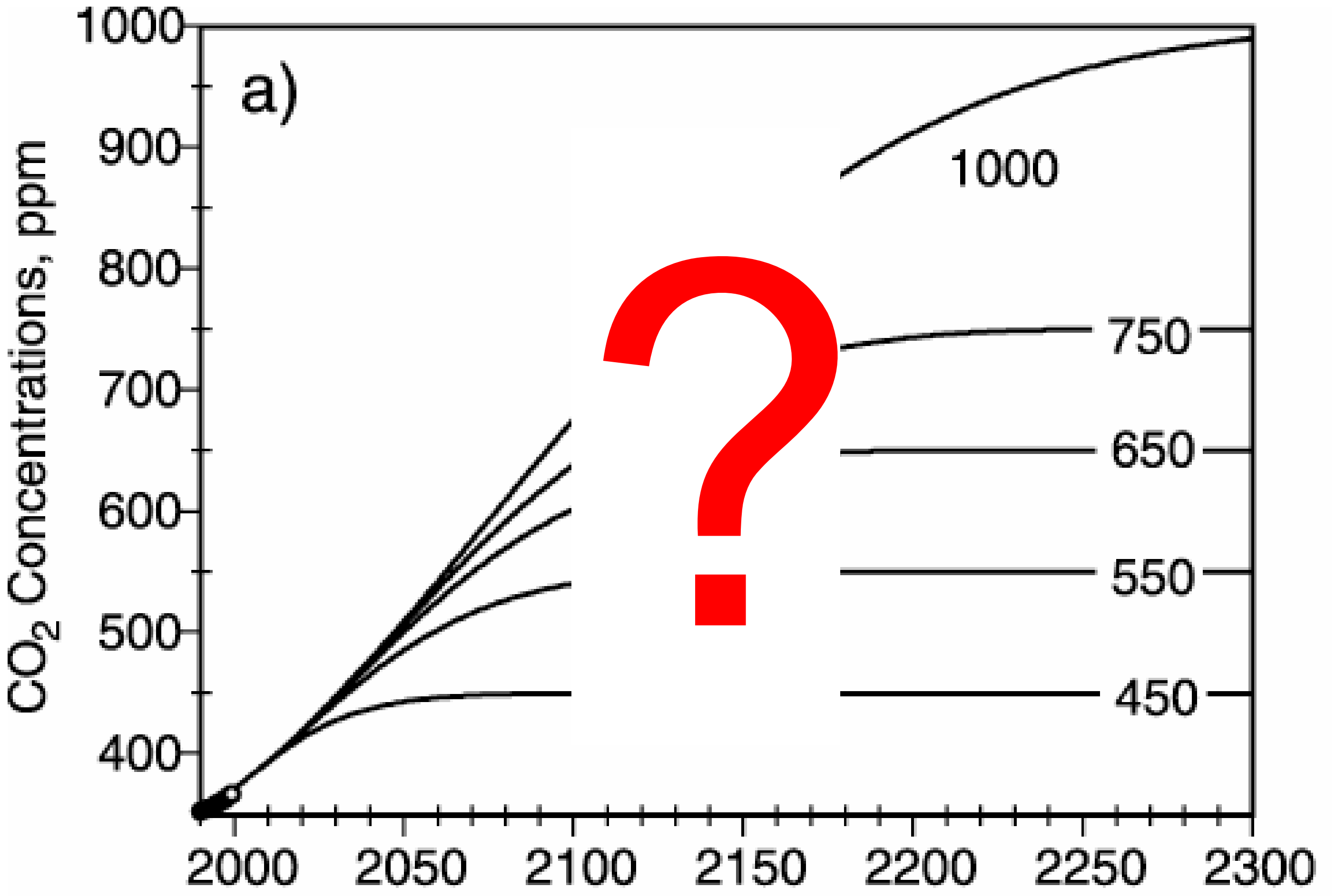
STABILIZATION SCENARIOS WORKSHOP
Tsukuba, Japan



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“STABILIZATION SCENARIOS” WORKSHOP

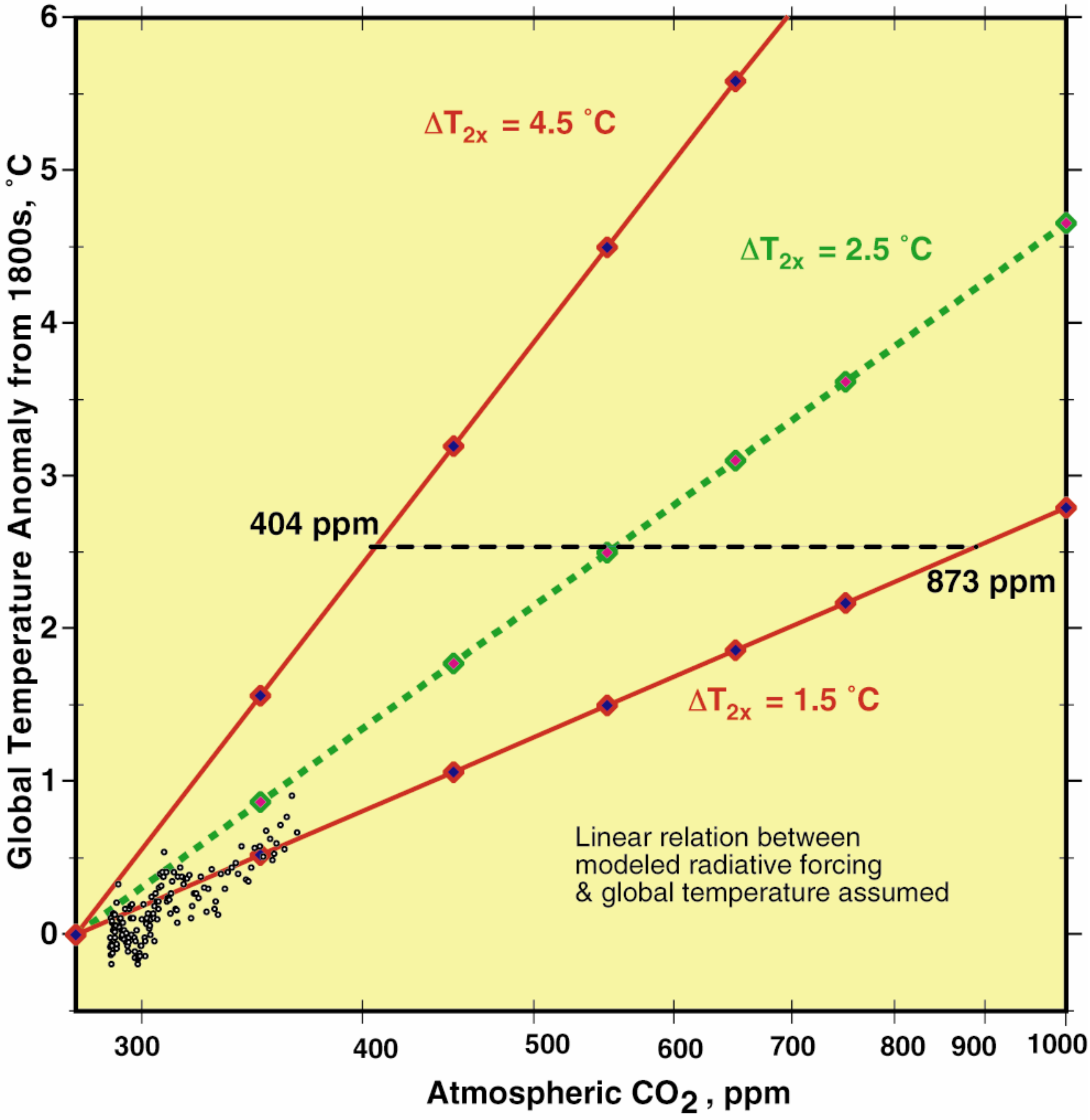
- Objective: provide sound advice on near-term actions to address long-term risks
  - Key insights or spurious messages
- Long-term scenarios
  - who is the consumer of the scenarios/what is the purpose
- “What to stabilize”
  - “stabilization targets” paradigm
    - Key insights or spurious messages
  - uncertainties
    - Key insights or spurious messages
  - near-term metrics Vs long-term objectives
    - Key insights or spurious messages

CLIMATE CHANGE SCIENCE PERSPECTIVE FOR THE IPCC WORKSHOP ON DANGEROUS LEVELS OF GHGs

- **Modeled equilibrium global temperature Vs CO2 and climate sensitivity**
- **Quest for objective estimates of climate sensitivity**
- **Abrupt climate change**
- **Carbon cycle estimates of CO2 emissions for stabilization**
- **Trajectories of CO2 concentration**
- **Summary**

MODELED EQUILIBRIUM GLOBAL TEMPERATURE Vs CO2 AND CLIMATE SENSITIVITY

- **Range of ΔT_{2x} = 1.5 to 4.5 °C leads to a wide range of modeled CO2 levels for a specified equilibrium temperature**
  - **Other factors to consider:**
    - + **Other GHGs**
    - + **Aerosols**
    - + **Solar, volcanoes**
    - + **Variability**



QUEST FOR OBJECTIVE ESTIMATES OF CLIMATE SENSITIVITY

- **Approach: Theory and modeling**
  - **Obstacles: gaps in understanding, e.g., of cloud feedbacks**

- **Approach: Ranges of model results**
  - **Obstacles: model validation/invalidation; no probability assigned to a given model parameterization and structure**
  - **Characteristics: range of plausible model results must be contained in the range of uncertainty -- range is a lower bound on the width of the range of uncertainty**

- **Approach: Climate sensitivity estimation through climate model calibration**
  - **Obstacles: gaps in understanding, e.g., of forcing (aerosol indirect effects, ice condensation nuclei etc.), and century time scale variability; limited observational records (accumulating with time)**

- **Approach: Paleo-analogues (deducing climate sensitivity from past climate epochs)**
  - **Obstacles: imperfect analogue for future (e.g. LGM and roles of sea ice, solar insolation patterns, etc.), accuracy of reconstructions of past climate systems**

ABRUPT CLIMATE CHANGE

- **Indications of rapid change in climate from paleo-records**
  - **Hypotheses for causes under active research -- currently difficult to simulate abrupt behavior…far from predictable**
  - **Pre-Holocene changes may not be good analogies for future change**
  - **Causes were, of course, not anthropogenic**

- **Potentially important mechanisms for abrupt change, for example:**
  - **Shift in thermohaline circulation**
    - \+ **Response differs between models**
    - \+ **Could have strong regional effects**
    - \+ **Appropriate monitoring prudent**

"SAFE LEVELS" SUMMARY

- The commonly used range of climate sensitivity results in a wide modeled range of CO2 levels for a specified equilibrium temperature
- Fundamental obstacles for the scientific determination of the probability distribution of climate sensitivity
- Abrupt climate change could lead to serious impacts, but research is at an early stage in determining mechanisms and what might trigger abrupt change, whether anthropogenic or not

Currently there is very little ability to make probabilistic forecasts of climate limiting determination of safe levels of greenhouse gases.

Ability will improve over the time-scales of concern?

LONG-TERM CARBON CYCLE CONSIDERATIONS

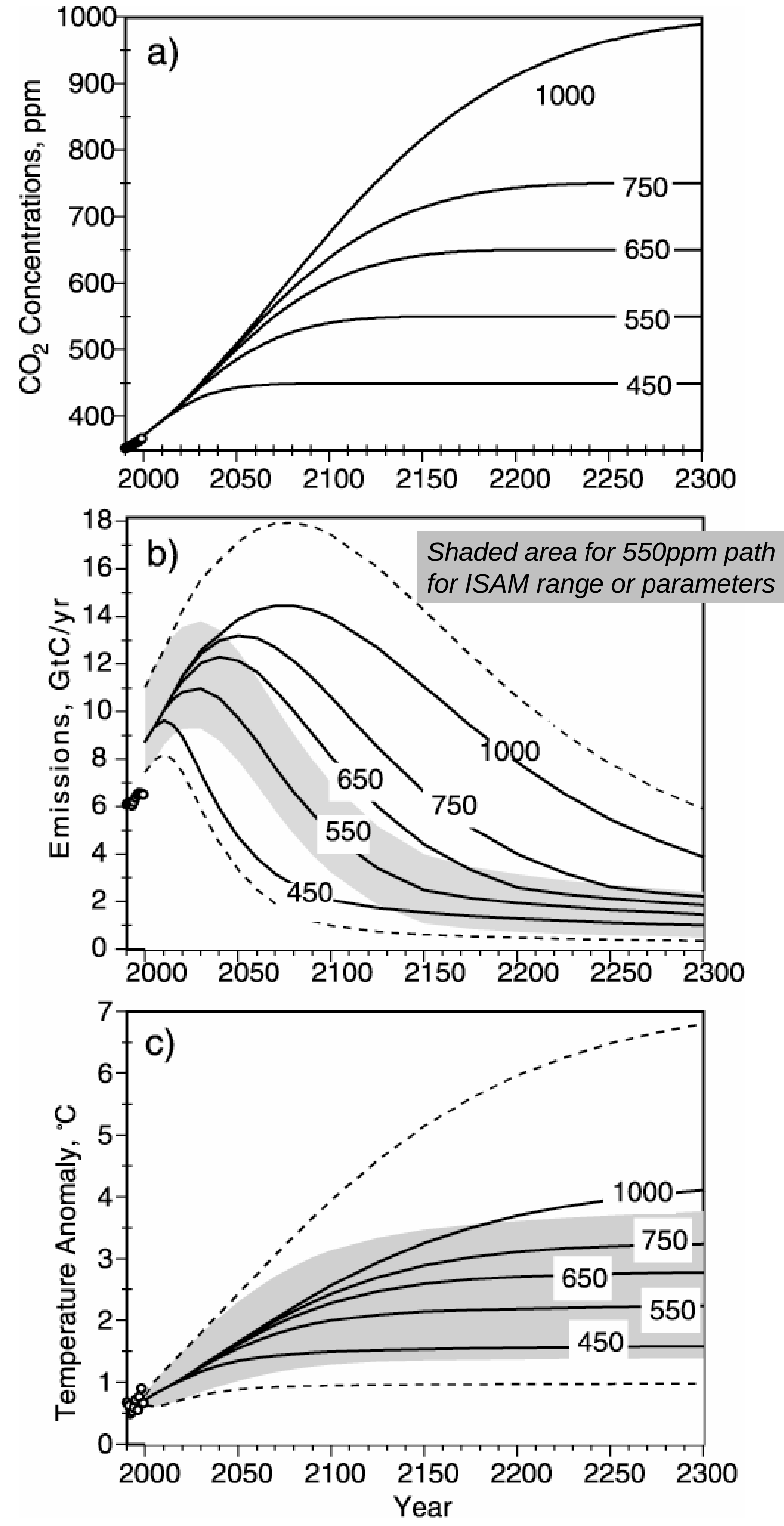
- **Carbon cycle characteristics**

- **“Stabilization scenarios”**

CARBON CYCLE ESTIMATES OF CO2 EMISSIONS FOR STABILIZATION

Kheshgi and Jain (GBC, 2003)

- **Arbitrary trajectories leading monotonically to constant CO2 levels specified (WRE trajectories)**
- **Deduced net anthropogenic emissions including modeled interactions with climate**
  - **Based on responses of a range of models**
  - **Differences in responses due mostly to biosphere response to changed CO2, and climate**
  - **Long-term, the ocean sink dominates natural uptake**
- **Long-term, modeled temperature rise primarily dependent on equilibrium climate sensitivity parameter**
- Factors in addition to CO2 could modify results



CARBON CYCLE ESTIMATES OF CO2 EMISSIONS FOR STABILIZATION

Kheshgi and Jain (GBC, 2003)

- **Arbitrary trajectories leading monotonically to constant CO2 levels specified (WRE trajectories)**
-

Models assume no substantial management of plants and soils...ever.

  - **climate**
  - **Long-term, the ocean sink dominates natural uptake**
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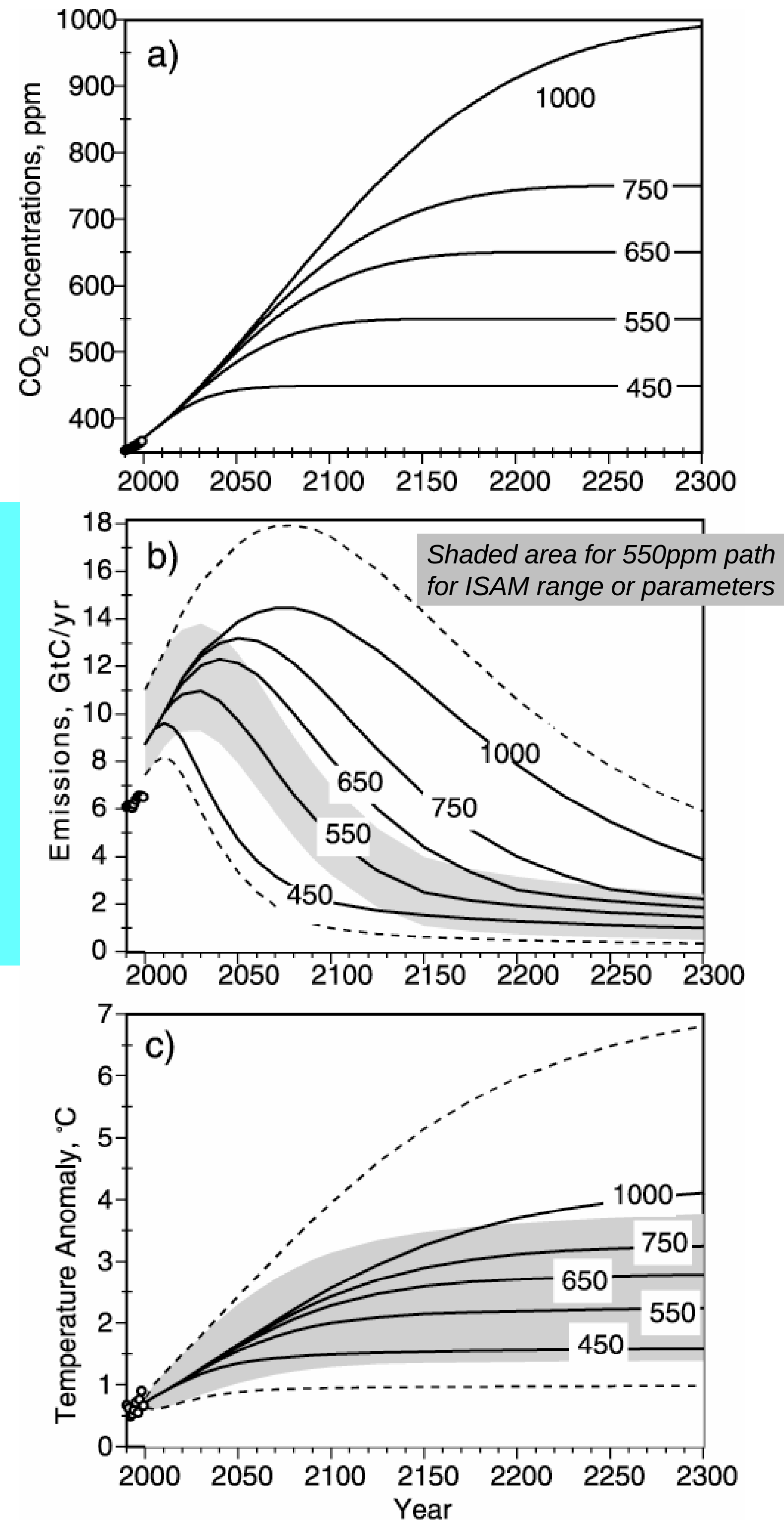
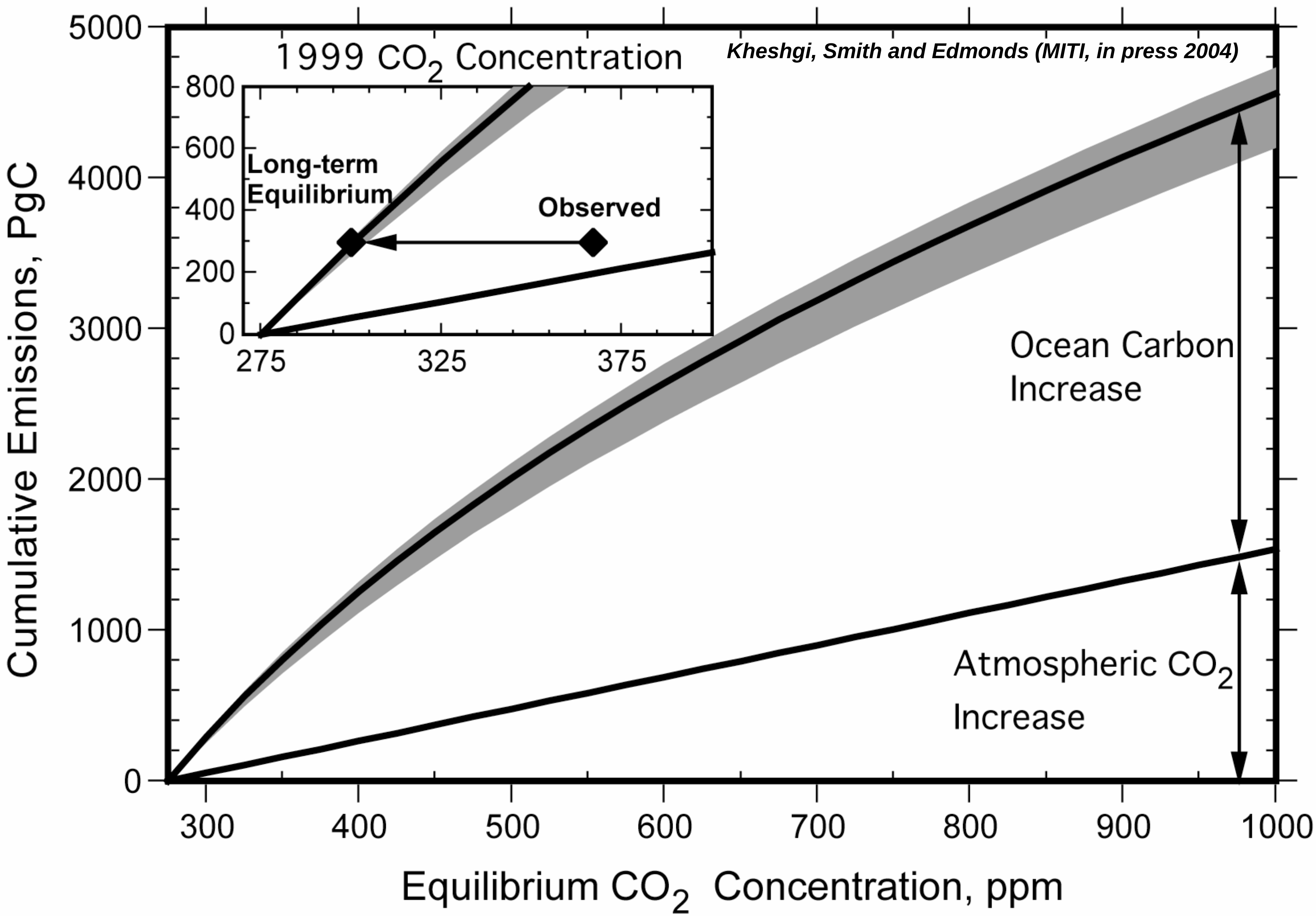


EQUILIBRIUM PARTITIONING OF ADDED CO2 TO THE OCEAN/ATMOSPHERE SYSTEM

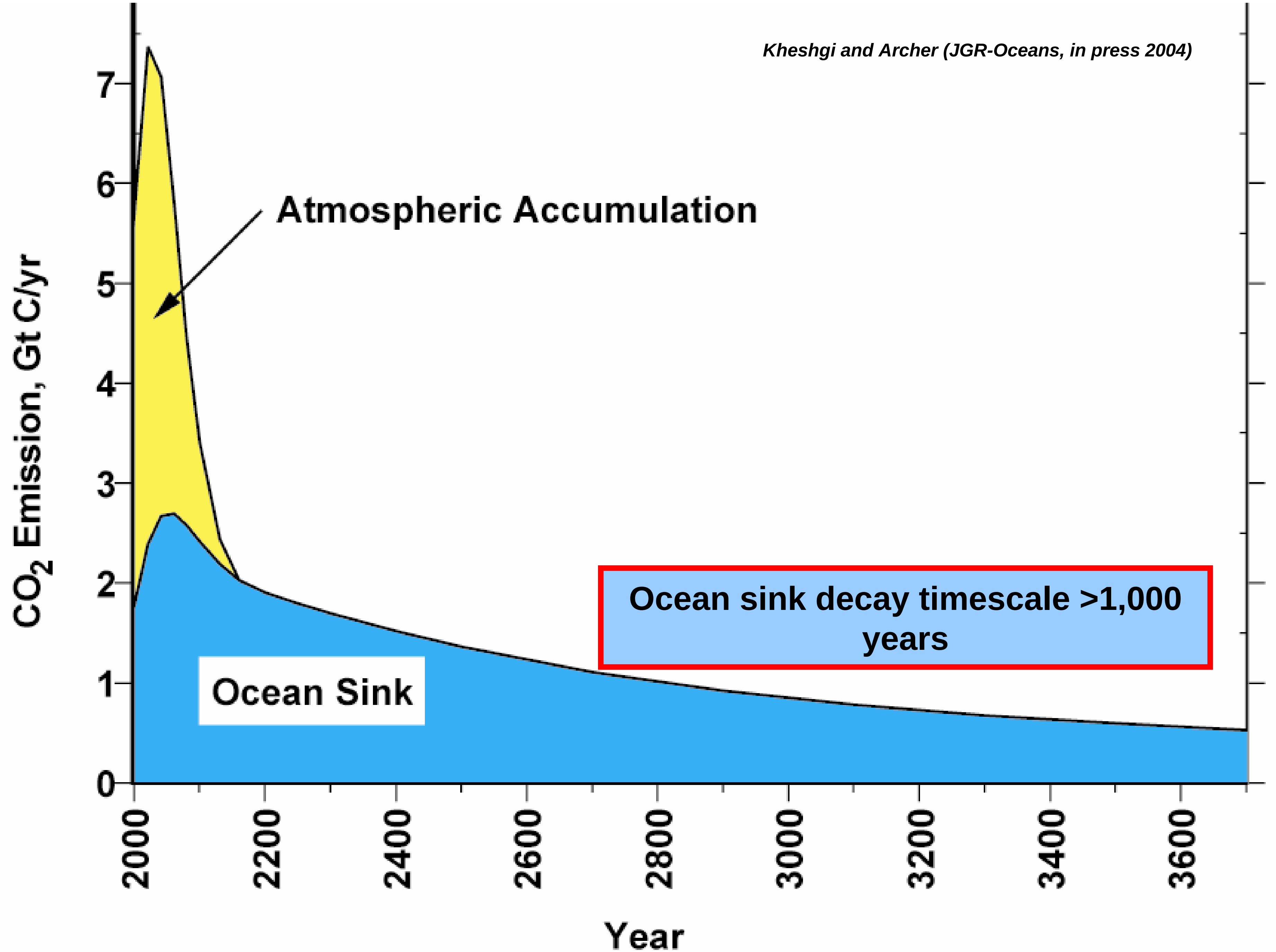
(no sediment neutralization)

$$CO_2(g) + H_20 \Leftrightarrow H_2CO_3(aq) \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2H^+$$

Total Carbon = TC(pCO2, Titration Alkalinity, Salinity, Temperature)

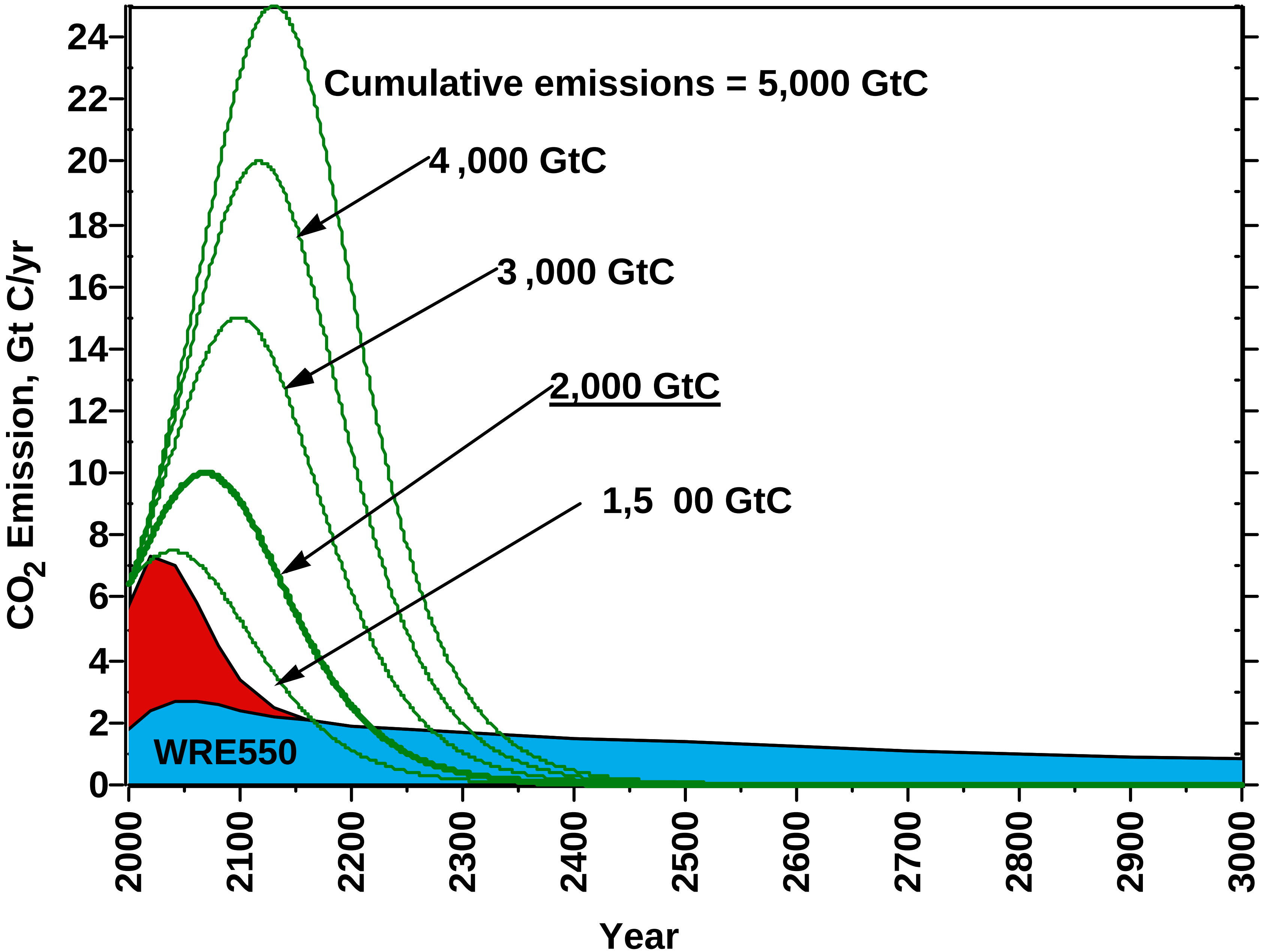


CARBON UPTAKE BY OCEAN/ATMOSPHERE SYSTEM: WRE550 CASE



CO_2 EMISSIONS: LOGISTIC FUNCTIONS

Kheshgi (Energy, in press 2004)

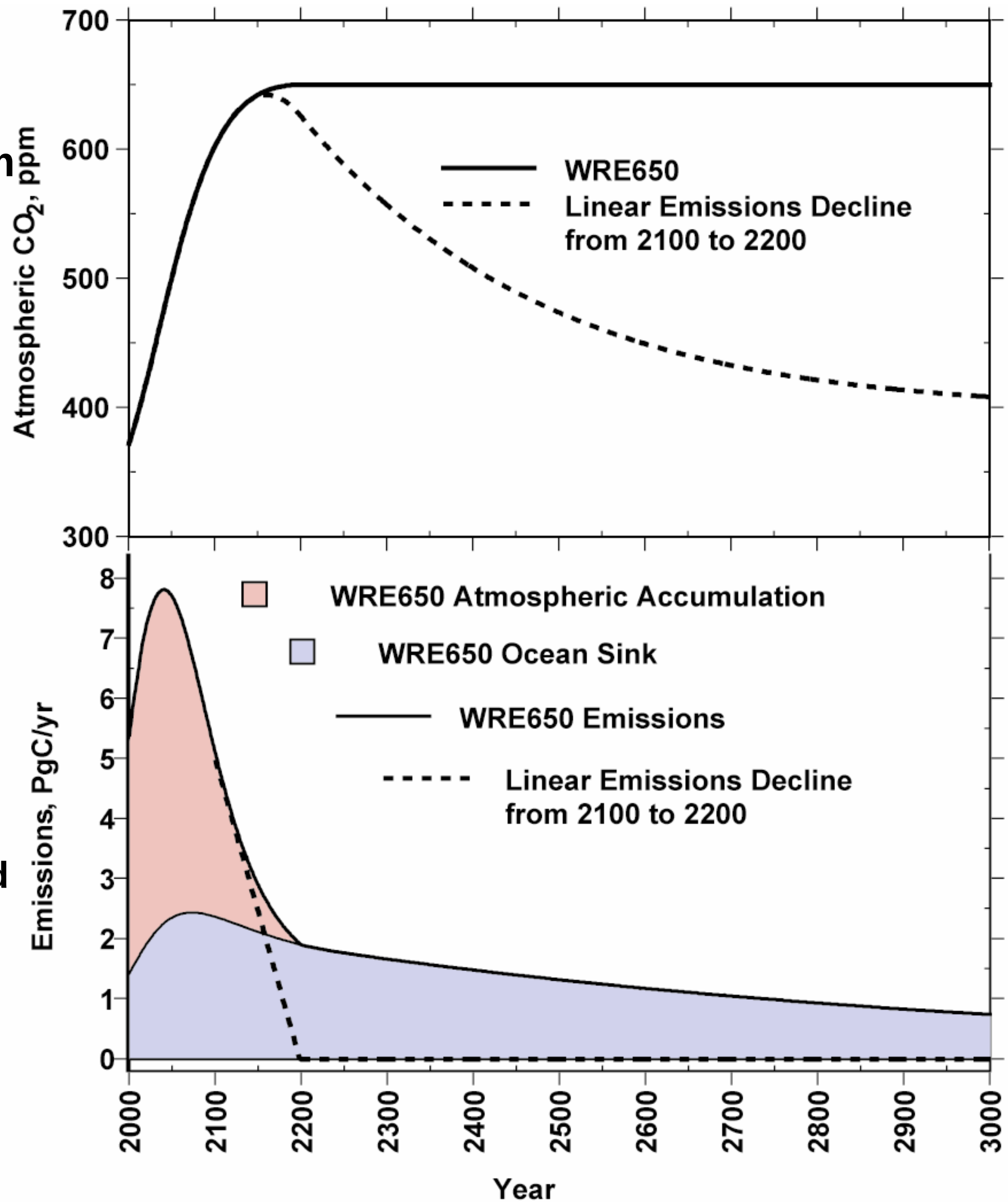


TRAJECTORIES OF CO2 CONCENTRATION

Kheshgi, Smith and Edmonds (MITI, submitted 2003)

- **Example: two alternative trajectories**
  - **Monotonic approach to 650 ppm**
  - **Non-monotonic trajectory peaking near 650 ppm and declining to about 400 ppm**

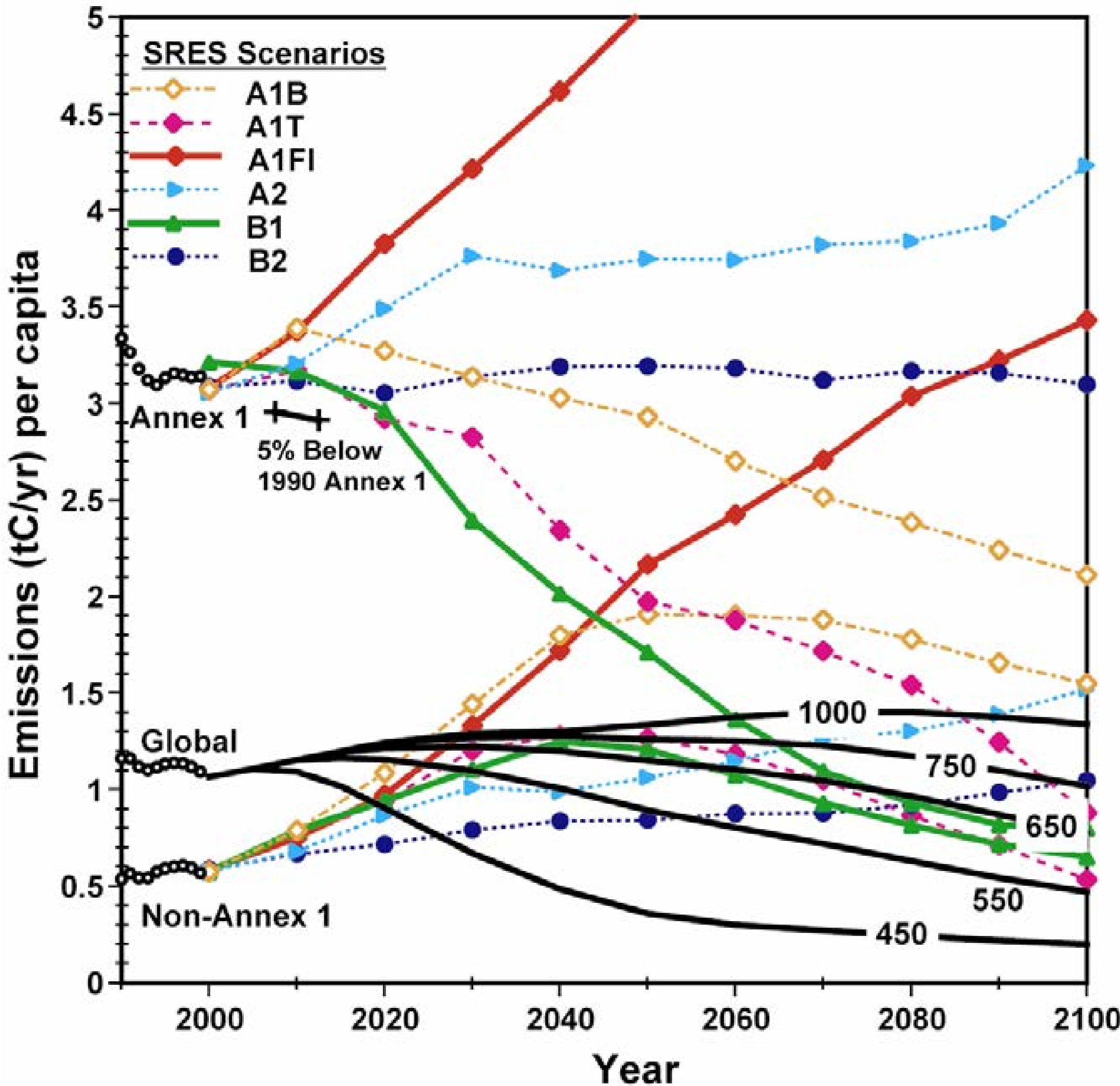
- **Deduced emissions for ocean/atm system (biosphere sources/sinks part of "emissions" in this case)**
  - **For monotonic approach to 650 ppm:**
    - **Atm only accumulates carbon prior to 650 ppm being reached**
    - **Ocean sink persists for 1000+ years**
  - **A linear decline in emissions after 2100 results in the non-monotonic trajectory**



ON STRATEGIES FOR REDUCING GREENHOUSE GAS EMISSIONS

Bolin and Kheshgi, Proc Nat Academy Sci, 2001,

- **Target stabilization level not known**
- **Scenarios diverge over decades**
- **Vast differences in per capita emissions**
- **Lack of affordable energy for many -- development priority**



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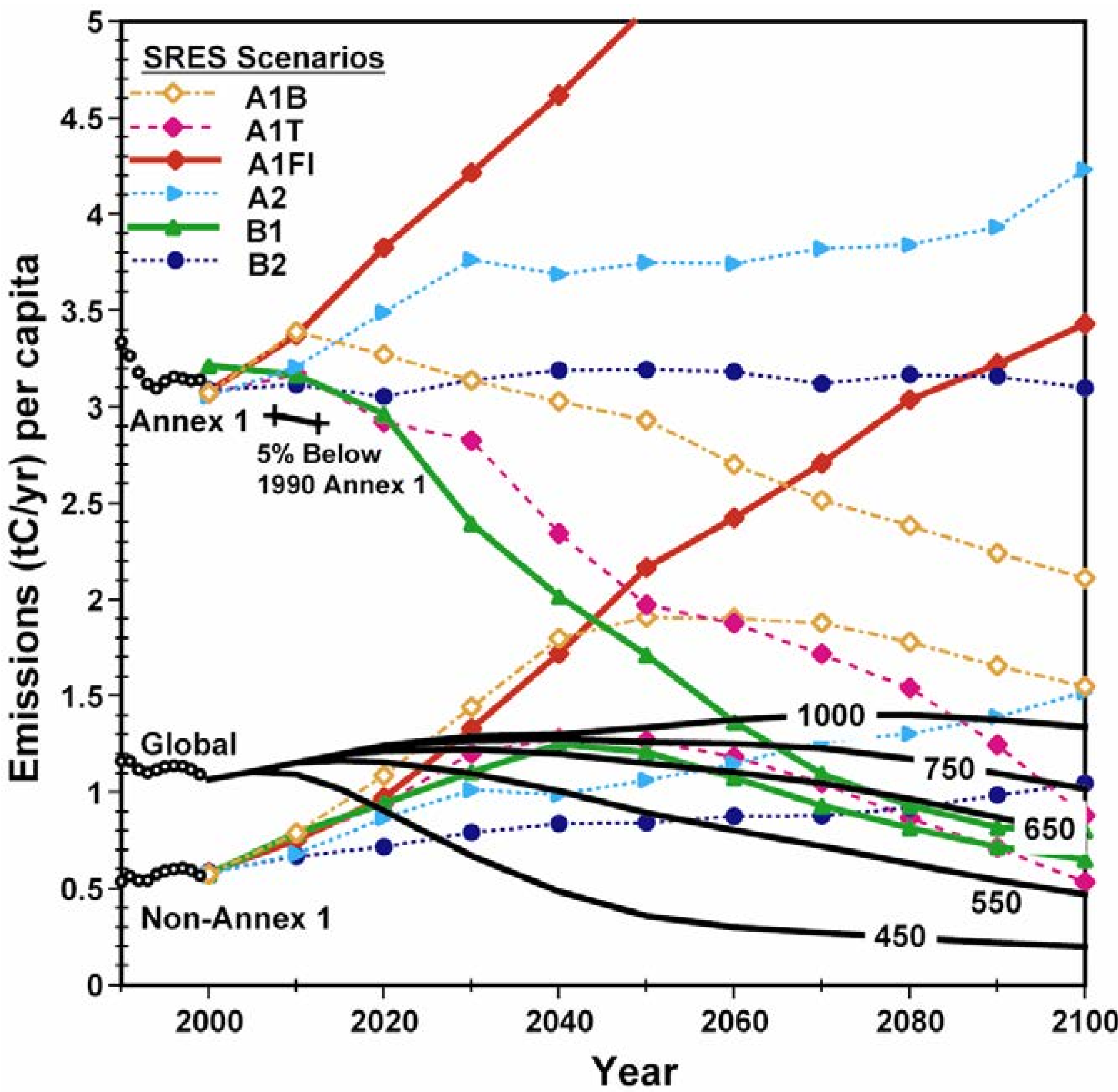
How can the advice enabled with these scenarios be improved?



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  - **uncertainties**
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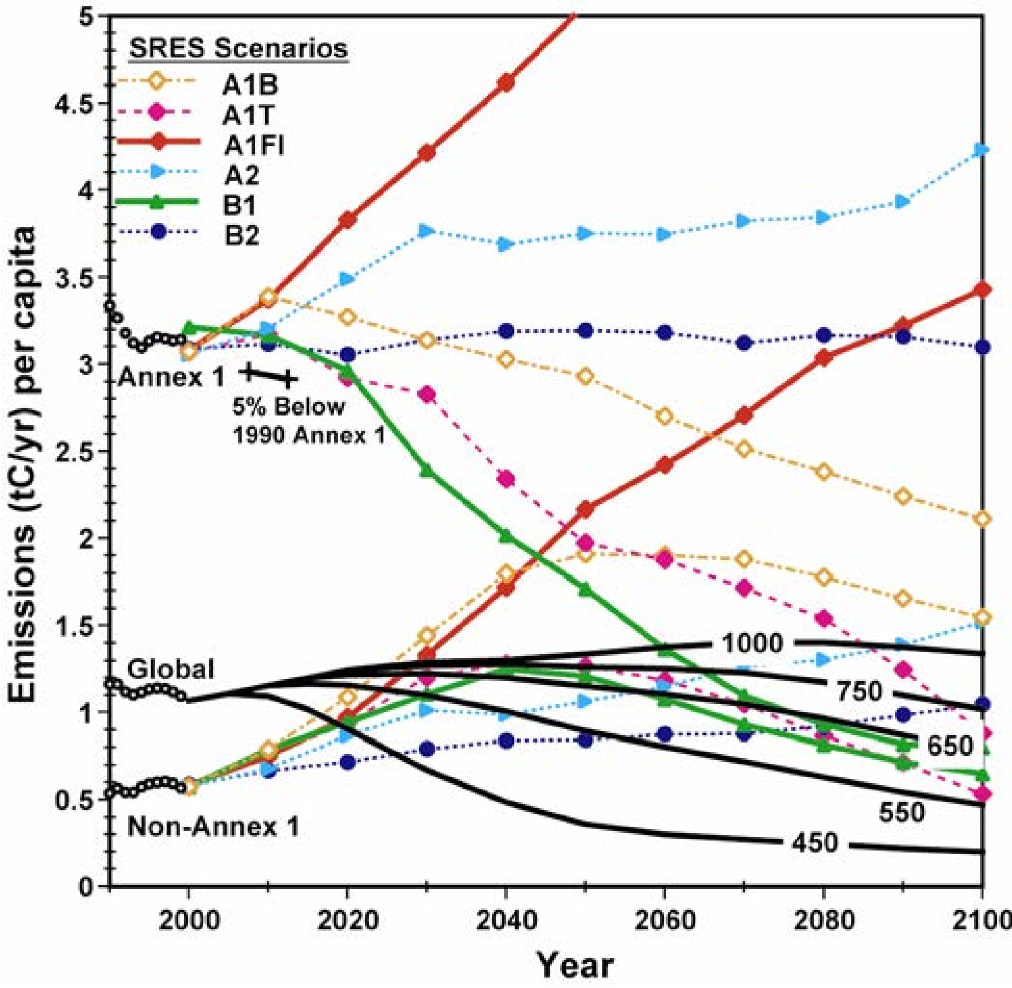

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⇐ modeling or decision making?

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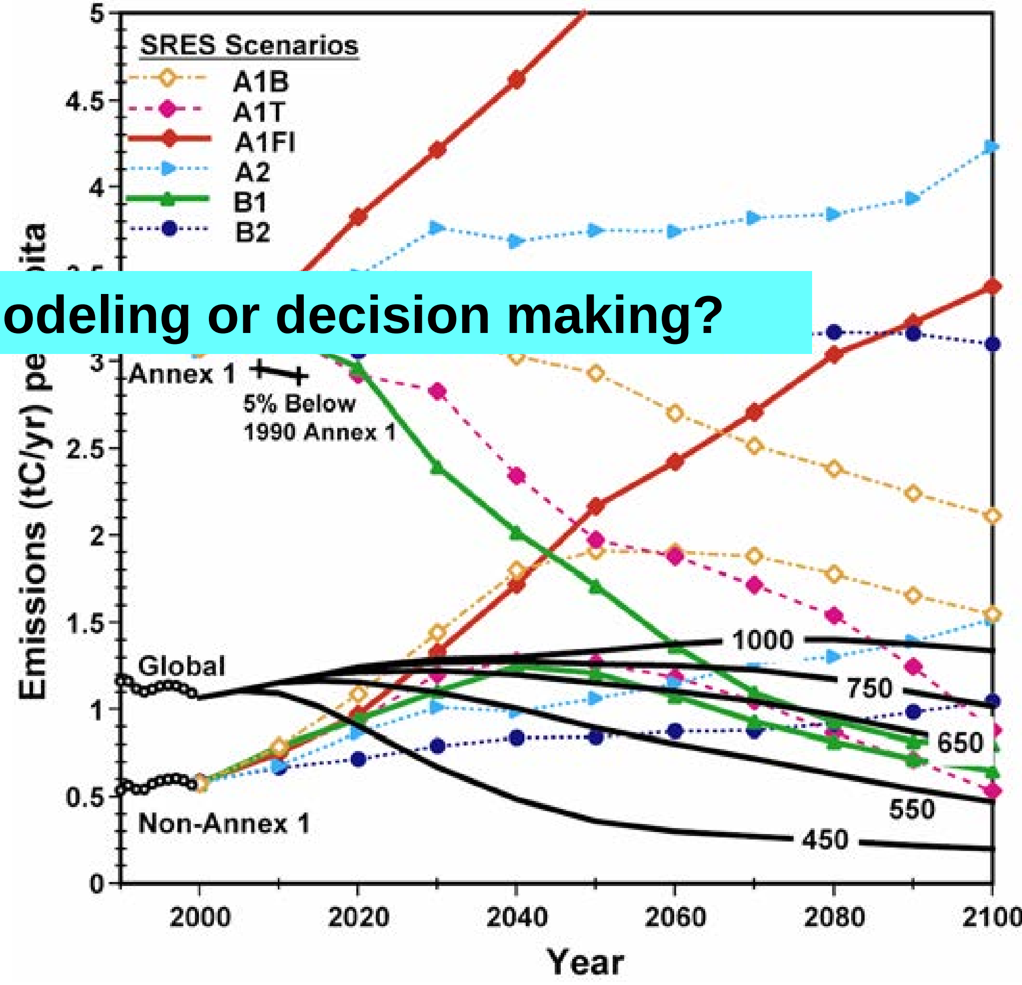

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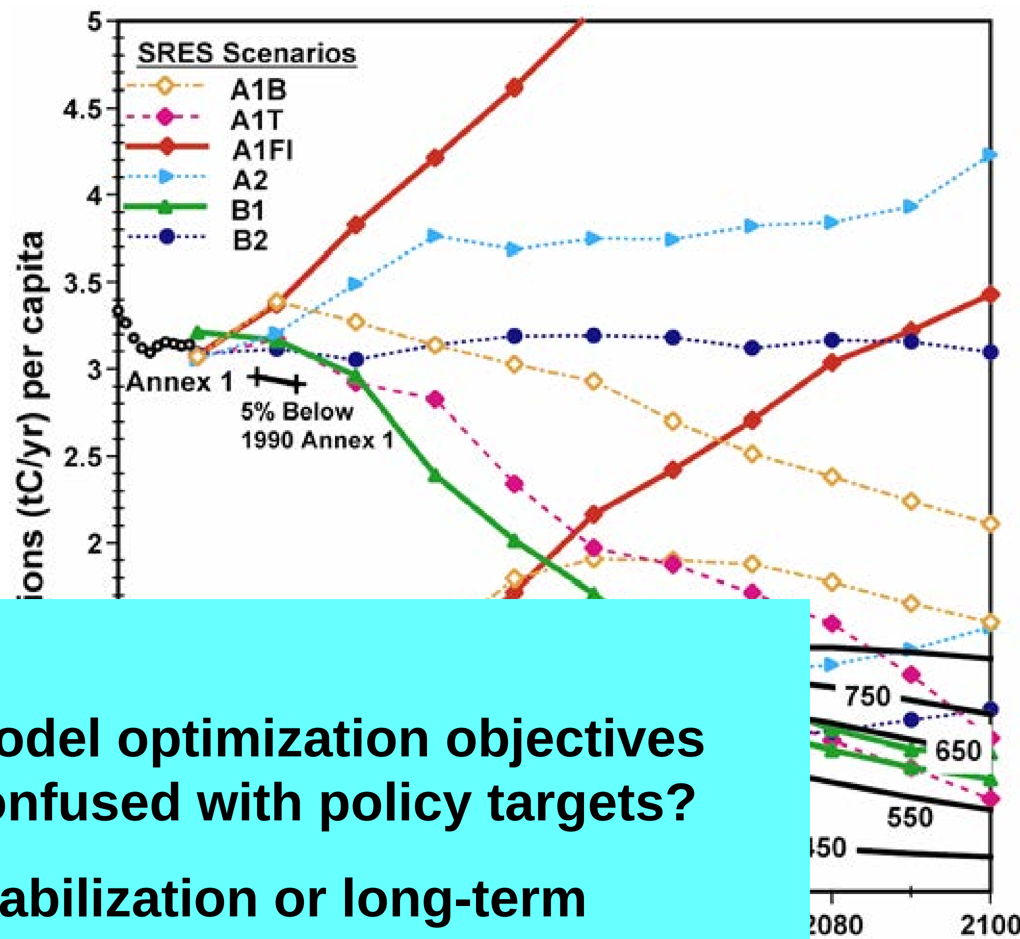

⇐

- **model optimization objectives confused with policy targets?**
- **Stabilization or long-term development?**
- **What's included and what is hidden?**
- **How is it communicated?**

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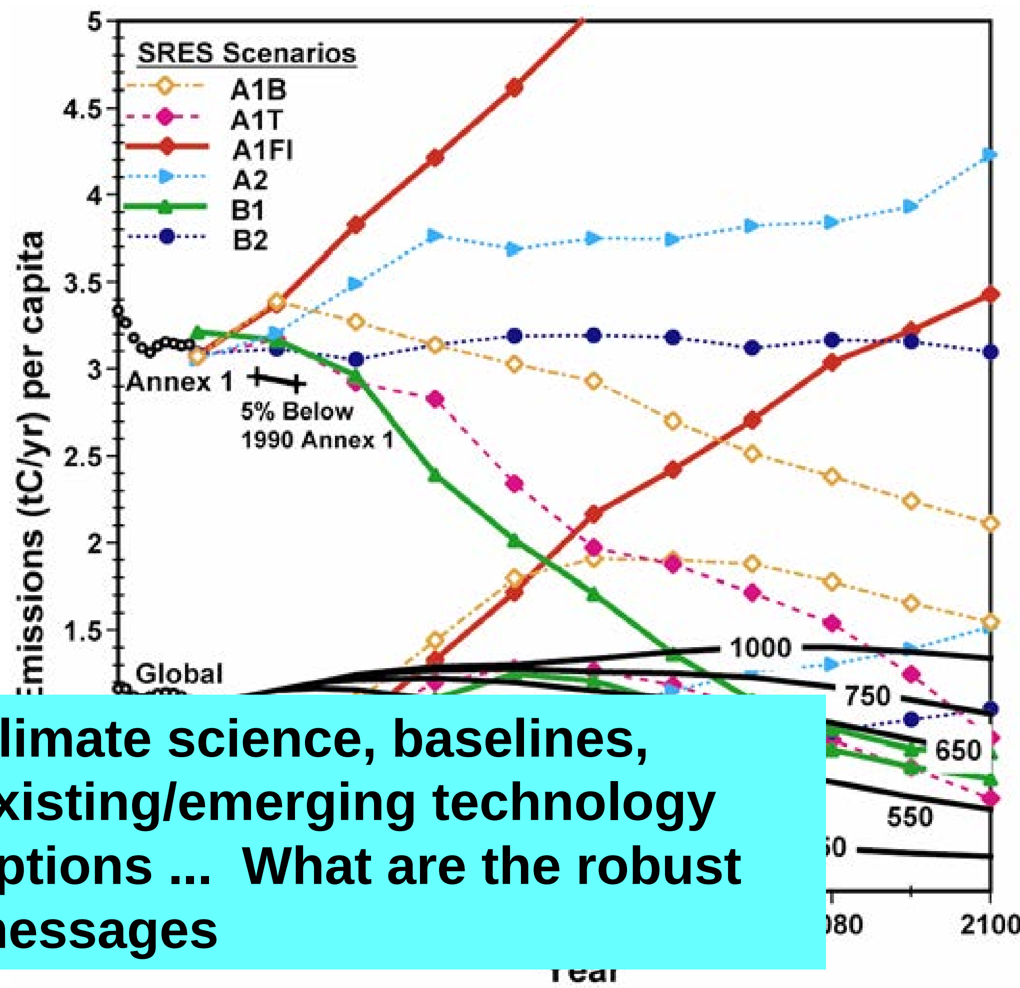

⇐ climate science, baselines, existing/emerging technology options ... What are the robust messages

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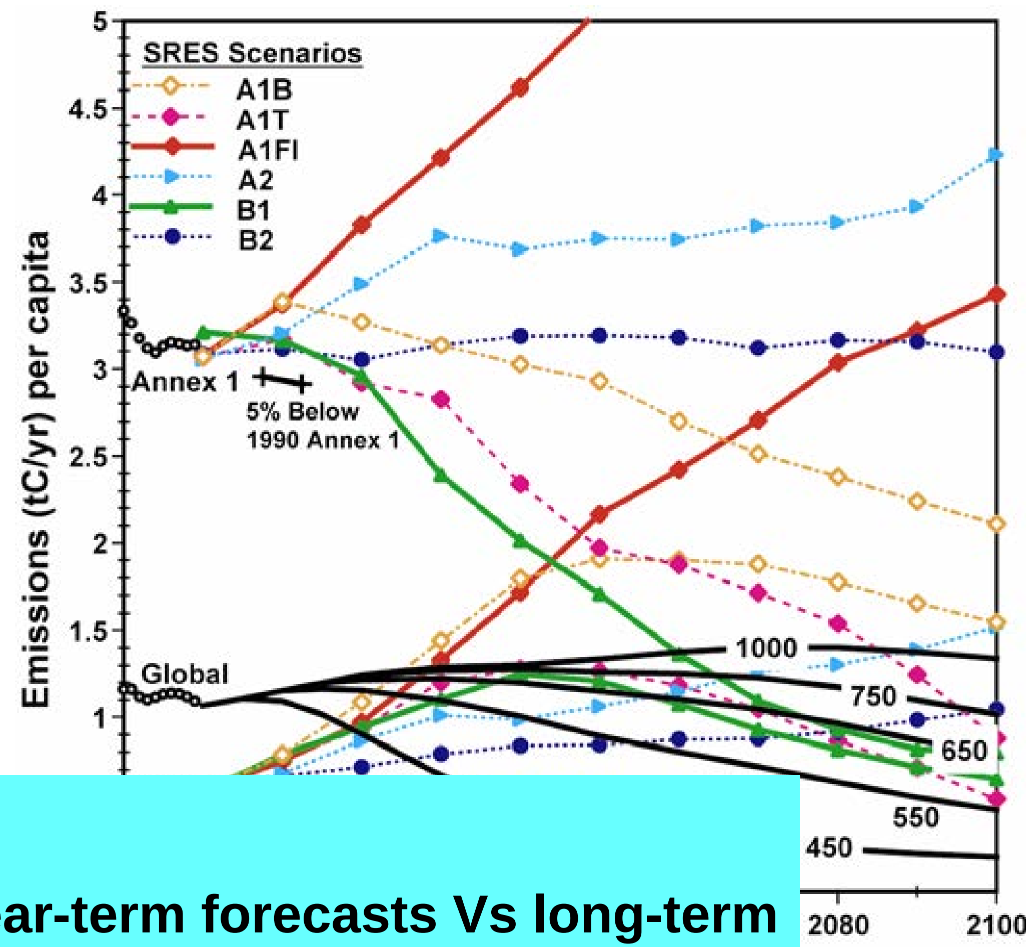

⇐

- **Near-term forecasts Vs long-term scenarios**
- **observable metrics Vs model objectives**