Designing Decadal Experiments for Common IPCC AR5 Experiments

Based on: Aspen Meeting White Paper and Input from a wide group

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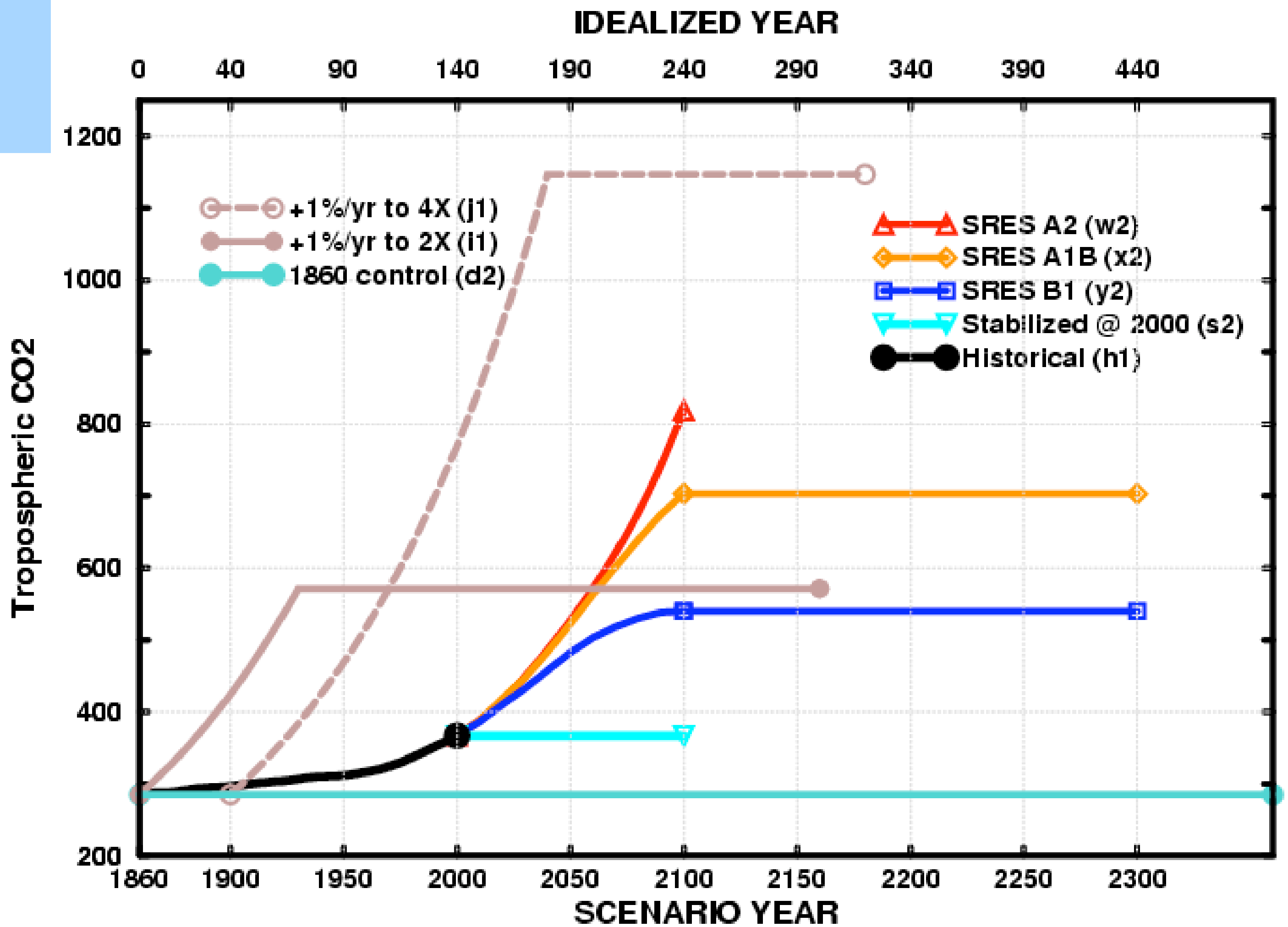
*Karl has not seen or approved this talk!

AR4 Experiments



Each of the two sets of IPCC experiments represents ~2,600 model years of integrations.

The CM2.0 & CM2.1 experiments required 30% to 60% of GFDL's computing resources for ~12 months and generated >300 TB of model output files.

AR5 Timeline

- Publication: Jan-Feb 2013
- Runs: 2009 and early 2010
  - Need time for analysis by WG1 authors
  - Hand off to WGII and WGIII authors
- Experiment design – specs must be finished this fall.

Groups with Input

- Aspen Meeting summer 2006
  - WG1, 2, 3 representatives
- IPCC Scenarios group
  - Netherlands meeting & summary
- WGCM
  - Stockdale et al.
- TGCIA
  - Large group of WGII and some WGIII
- Detection/Attribution Folks (IDAG)
- Others

For coordinated climate change projection experiments to be run by the international climate modeling community for assessment in the IPCC AR5, two classes of climate change experiments are proposed, each focused on defined scientific questions:

1. **Near-Term (2005-2040)**
   Decadal predictability, atm chemistry, regional climate change/extreme events
2. **Longer term (2005 to 2300)**
   Close carbon cycle, stabilization scenarios

Long term Forecasts

- Close carbon cycle
- Investigate carbon feedback on climate
- Make long term climate projections
- Allow WGIII to explore uncertainty in their ESMs

Short term Forecasts
3 Foci

- Higher resolution
  - Changes in extreme events and regional info
- More complex atmospheric chemistry
  - Relationship to air quality, regional climate change
- Decadal prediction
  - How much “prediction” does present day “warming commitment” buy you?
  - What parts of natural variability are predictable?

Problems

- CPU time is a big issue
  - Long term runs more than for AR4
  - Short term runs could be larger than long term
  - Resolution, ensemble number, complexity trade offs
- Lots of science questions in short term area
  - If groups pick and choose from a wide spread of “mandatory” runs, we may lose the MIP and the benefit of basing predictions on wide range of models which increases skill + spans uncertainty (somewhat)

Short term Forecasts
3 Foci

- Higher resolution
- More complex atmospheric chemistry
- Decadal prediction

Problem: How to design a set of experiments that are scientifically meaningful, societally relevant, allows groups a wide range of options and a still is a MIP?

Our solution

- Focus on 2030 to 2040 time period and present day
  - Allows common time period for MIP
- Propose combination of AOGCM and atmosphere-only time-slice runs
  - Allows cpu dollars to be spent on items of interest
- Explicitly discuss the 3 foci
- Encourage others to form more detailed/focused MIPs and ensure that they map well together

Decadal Prediction Experimental Design

- Goal: Predictions of the 1st kind plus boundary changes (radiative forcing)
  - Initial value forecasts
  - 2005 to 2040
  - Is this a good period
- What would it take to convince ourselves/others that we have skill?
  - Stockdale et al. paper

Questions

- Are the observations good enough to initialize models? What is needed?
  - XBTs period
  - ARGO period
  - Land, sea ice, …
- Role of hindcasts?
  - How many hindcasts are needed?
  - How long?
  - Relative value of a long control versus many hindcasts
    - Biases
- Are the models good enough?
  - Atmosphere and ocean normally focus of thought
  - What is role of other components/processes (land, sea ice, aerosols, etc.)?
  - Over what period do the ICs matter
- What timeslices (present?) should be used

Questions

- Ensemble size?
- What is processes are predictable?
  - THC/MOC, warming commitment, others?
- Does it matter to where people live?
- How to verify predictions?
  - Develop metrics to measure skill?
  - Attribution methods
- Forcings
  - Solar, volcano, …

More questions

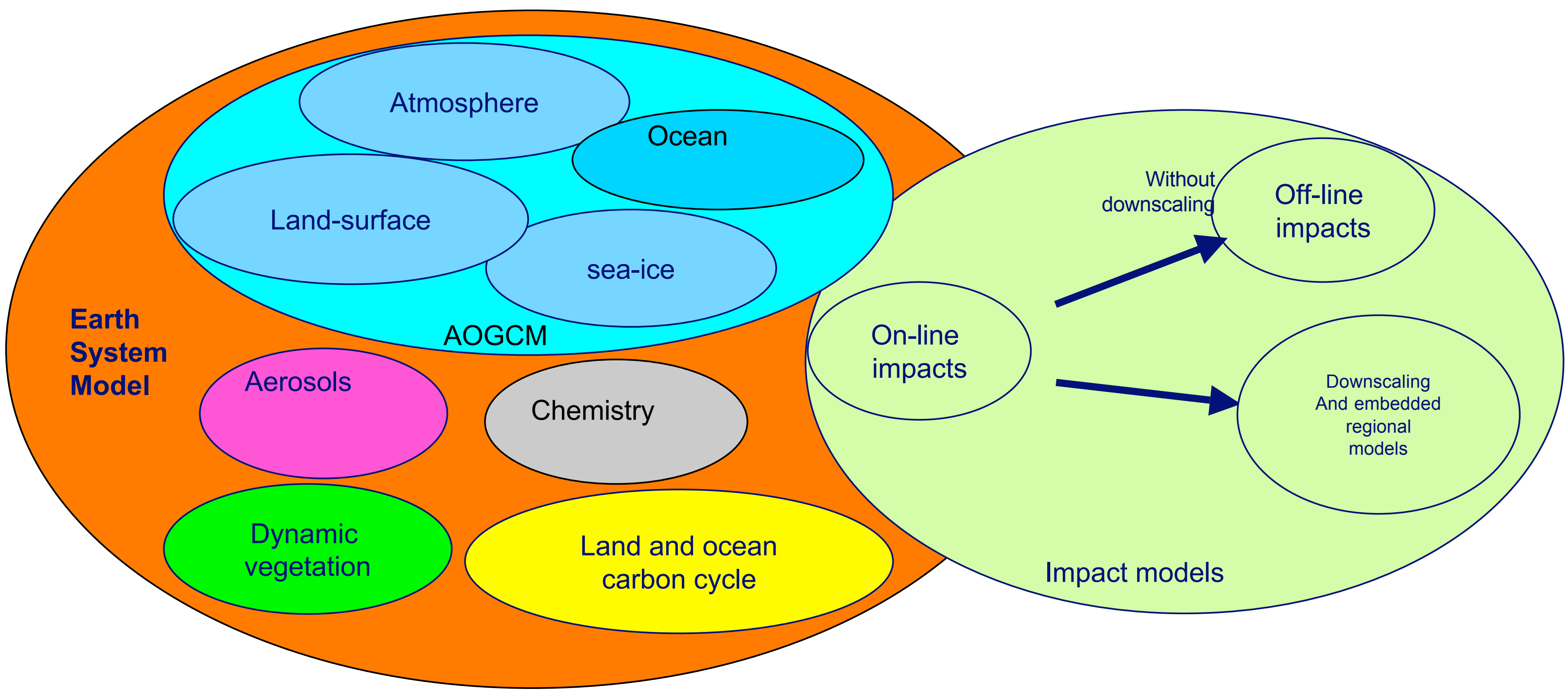
- How do we know a model's sensitivity and transient climate response (1%CO2 run and ctl needed?)
- What do we compare IC runs against (see comparison right now against AR4 ensemble, do we need something other than concatenated 20thC runs/longterm future?
- Would 1 run running 1960-2040 through help (would definitely help for attribution based prediction)

Practical questions

- How do we document forcings (TOA long/shortwave stored?)
- What variables will be saved
- What is minimum configuration

- - can be decided later but needs to be decided soon!

Earth System Model Definition: Closed carbon cycle



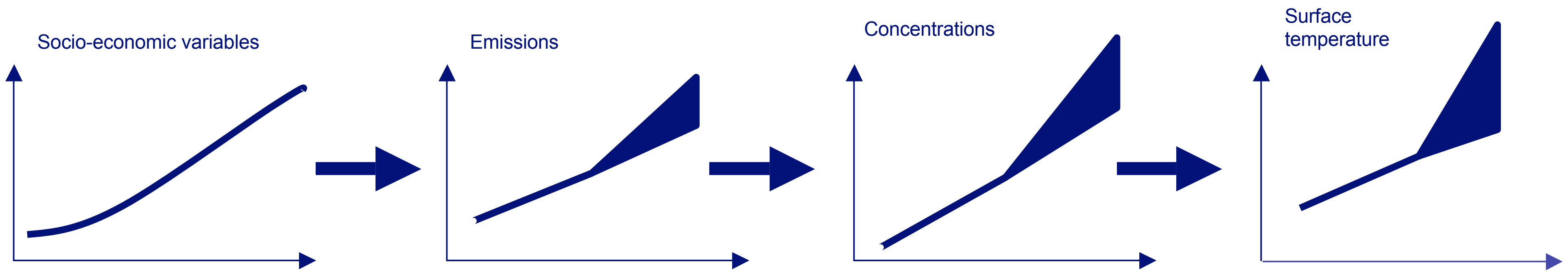
Long-Term Experimental Design (2100 and Beyond)

WHAT ARE CARBON CYCLE FEEDBACKS ON CLIMATE SYSTEM?

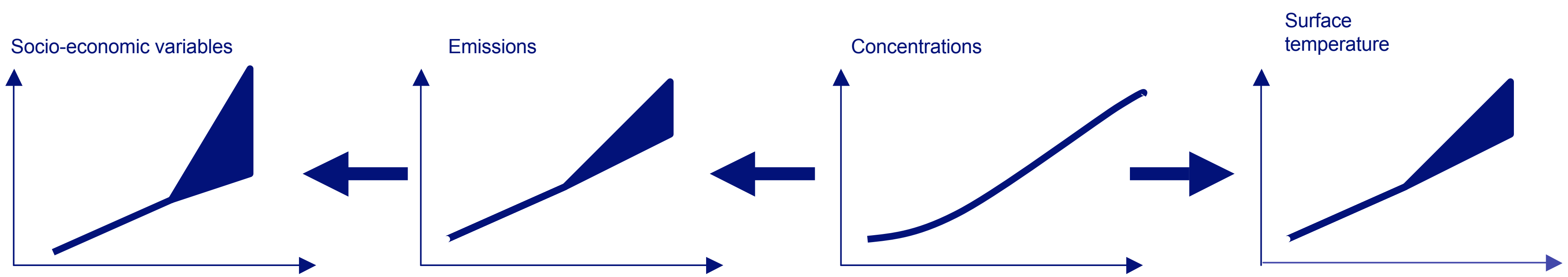
- Long-term runs provide an opportunity to contribute to a policy perspective on avoiding consequences of climate change (e.g. mitigation/stabilization)
- Lower resolution AOGCM and/or ESM (roughly 2^o) w/pre-industrial spinup including 20th century experiments with natural and anthropogenic forcings (at least 10 ensemble members).

- WG3 to provide CO2 concentration stabilization benchmark scenarios: (1) high case ~700 ppm, (2) low case ~400 ppm, and possibly (3) midrange ~550 ppm. At least one ensemble per scenario; models to include terrestrial and ocean carbon cycle, dynamic vegetation as available, chemistry and aerosols prescribed to 2100, stabilized after 2100 to 2300; WG3 would derive policy options to attain permissable emissions

Forward approach: start with socio-economic variables



Reverse approach: start with stabilization scenario concentrations



Long-Term Experimental Design (continued)

Experiment 1: Carbon cycle responds to increasing CO2 concentrations and temperature changes

- An AOGCM or ESM-type model w/time series of specified GHG concentrations provided by WG3

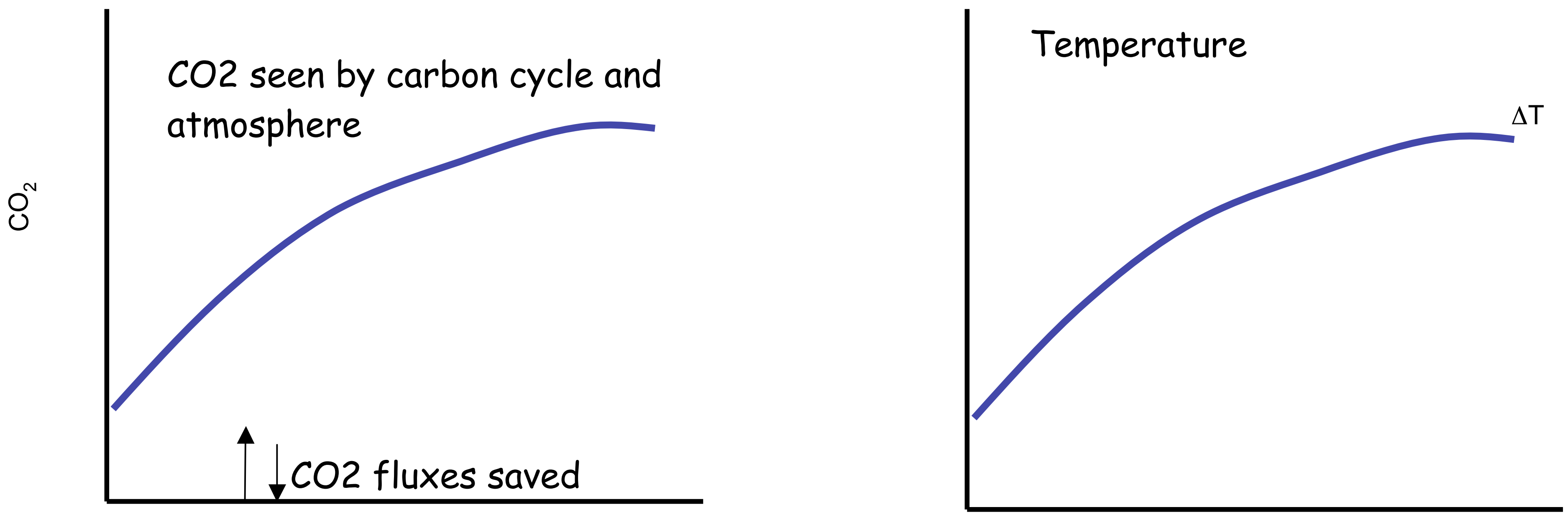
- Carbon cycle model produces a time-series of CO_2 fluxes that are saved

  Note: CO_2 fluxes do not enter the atmosphere to change climate system response to specified concentration time series.

- The CO_2 fluxes from this experiment (e.g., land/ocean CO_2) are used to derive emissions that are returned to WG3 to derive mitigation policies to achieve the desired emissions

(emissions = rate of change of concentrations + CO2 flux).

Experiment #1:
Carbon Cycle sees increasing CO2 Concentrations and ΔT;
Land/Ocean CO2 fluxes saved to derive emissions for WG3



Land/Ocean CO_2 fluxes are NOT interactive with atmosphere

Experiment 2: Carbon cycle responds only to increasing CO2 concentrations

- Atmospheric CO_2 is fixed for radiation code in the model only, therefore, temperature will remain about the same (but includes internal climate variability).

- Time-evolving CO2 concentrations from Experiment 1 are input to the carbon cycle, and land-ocean CO2 fluxes are saved

- The derived emissions between Experiments 1 and 2 can be compared to infer the magnitude of carbon cycle feedback

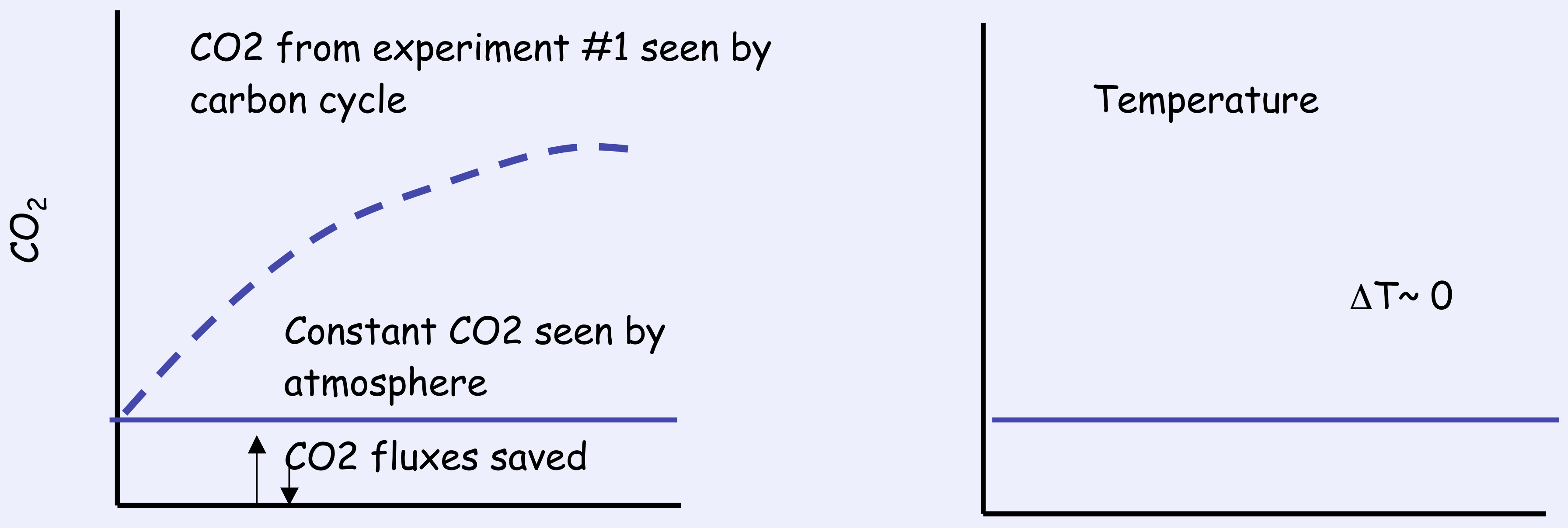
- The derived emissions will be noisy and WG3 will need to fit, or smooth the time series emissions pathways.

- Open question: start from end of historical integration as in Exp 1 or start from control?

Experiment #2:

Carbon Cycle sees CO_2 Concentrations from Experiment #1; atmospheric CO_2 and T are constant;

Land/Ocean CO_2 fluxes saved to derive emissions for WG3



Land/Ocean CO_2fluxes are NOT interactive with atmosphere

Experiment 3 (optional): Magnitude of carbon cycle feedback in terms of temperature

- Determine the magnitude of the carbon cycle AND climate feedback in terms of temperature change

- Diagnosed emissions in the absence of climate effects on the carbon cycle (from Experiment 2), will be used to drive the ESM (coupled carbon cycle-climate model) in Experiment 1.

- In this experiment, CO_2 will evolve distinctly from the original prescribed CO_2 scenario (of Experiment 1).

- The temperature difference between experiments 1 and 3 defines the magnitude of the carbon cycle feedback on temperature

Experiment #3 (optional): Derived emissions in the absence of climate change from Exp. #2 are used to drive carbon cycle-climate model from Experiment #1