Towards Improved Projections

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Messages from the draft White-paper

- This initiative aims at improving the ESMs used for projecting future climate change based on the work in the land, ocean, and observation initiatives.

- Investigate prospects for improving and potentially extending the (β, γ) framework.

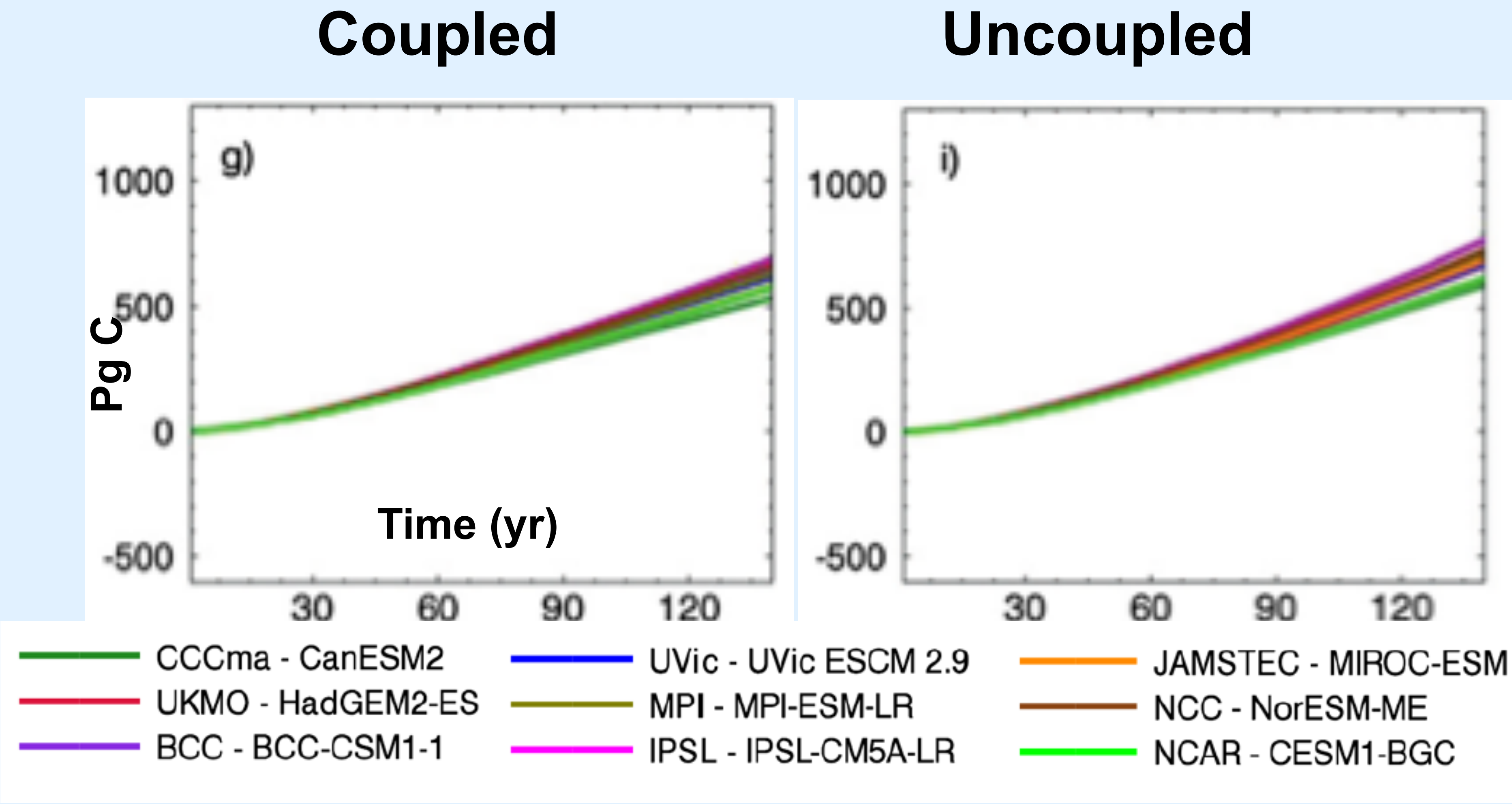
- Particular focus on the response of the carbon cycle to regional forcing.

- Investigate processes contributing to non-linearity of the carbon cycle.

- New scenarios (e.g. 1.5 ^{o}C and BECCS-driven land-use)

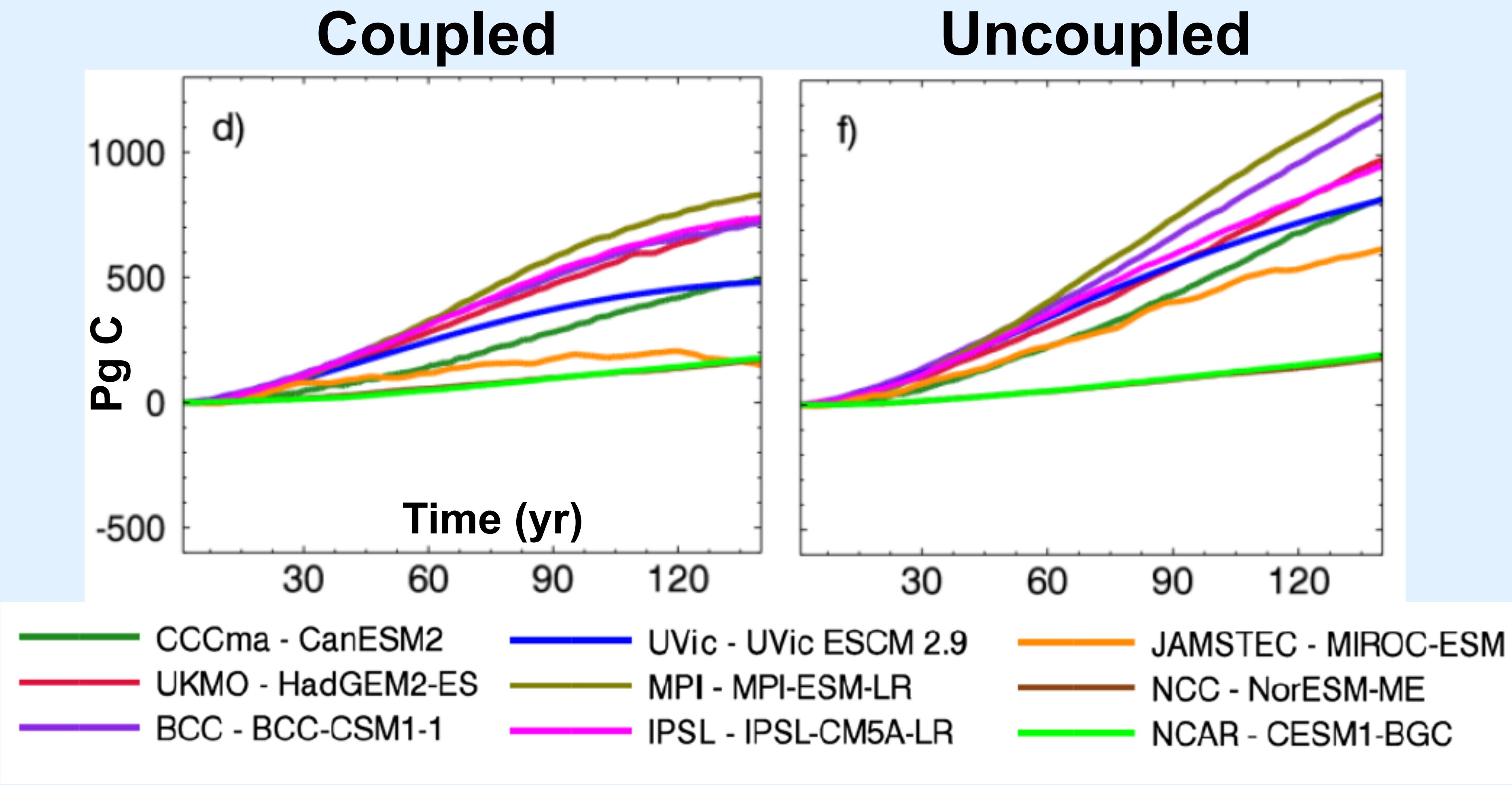
Uncertainties in Future Climate-Carbon Cycle Feedbacks

Ocean Carbon Change in CMIP5 Models (1% per year increase in CO_2)



Arora et al., 2013

Land Carbon Change in CMIP5 Models
(1% per year increase in CO_2)



Arora et al., 2013

Discussion Groups

- GROUP A (Thomas): What defines an improved projection? What do we want our projections to deliver?
- GROUP A/B : What new projections are likely to be required over the next 5-10 years (e.g. negative emissions scenarios, SRM geoengineering, Trump World) ?
- GROUP B (Peter): Do we need a feedback analysis that extends beyond (β, γ) ?

Beyond (β, γ)

- Yes, we would like an improved conceptual model to understand and analyze carbon cycle feedbacks!
- Design criteria:

  Should ideally build-on (β, γ) approach;

  Should recognise different system timescales (i.e. difference between quasi-equilibrium and transient responses), especially for the ocean;

  Should reduce scenario-dependence of (β, γ);

  Will ideally connect to other conceptual models of (a) TCRE (e.g. Williams & Goodwin, 2016, 2016); (b) linear response theory (impulse-response functions).

  May provide a theoretical basis for Emergent Constraints…☺️

Beyond (β, γ) Workshop ?

- **Proposal:** We would like to run a focused workshop (<20 people) to derive an extension to the (β, γ) approach, which includes turnover times and other system timescales, and which makes connections to other recent analyses.
- **Length:** 2-3 days.
- **Potential invitees:** this working group plus Rick Williams (Liverpool), Phil Williamson (Southampton), Jonathan Gregory (Reading), Martin Heimann (Jena), Vivek Arora (UVic), Damon Mathews (Concordia), Jean-Louis Dufresne (IPSL).
- **Output:** hands-on testing of extended frameworks against ESM time-series; Conclusion on the best way forward; review paper.

QA: What defines an improved projection? What do we want our projections to deliver?

QA1) What are the sources of uncertainty in future projections?

QA2) How do we improve our confidence in future projections of land and ocean carbon sinks?

1. Scenario uncertainty
    - Different scenario (SSPs)
    - New scenarios are required (Negative emissions, SRM technologies, Trump world)

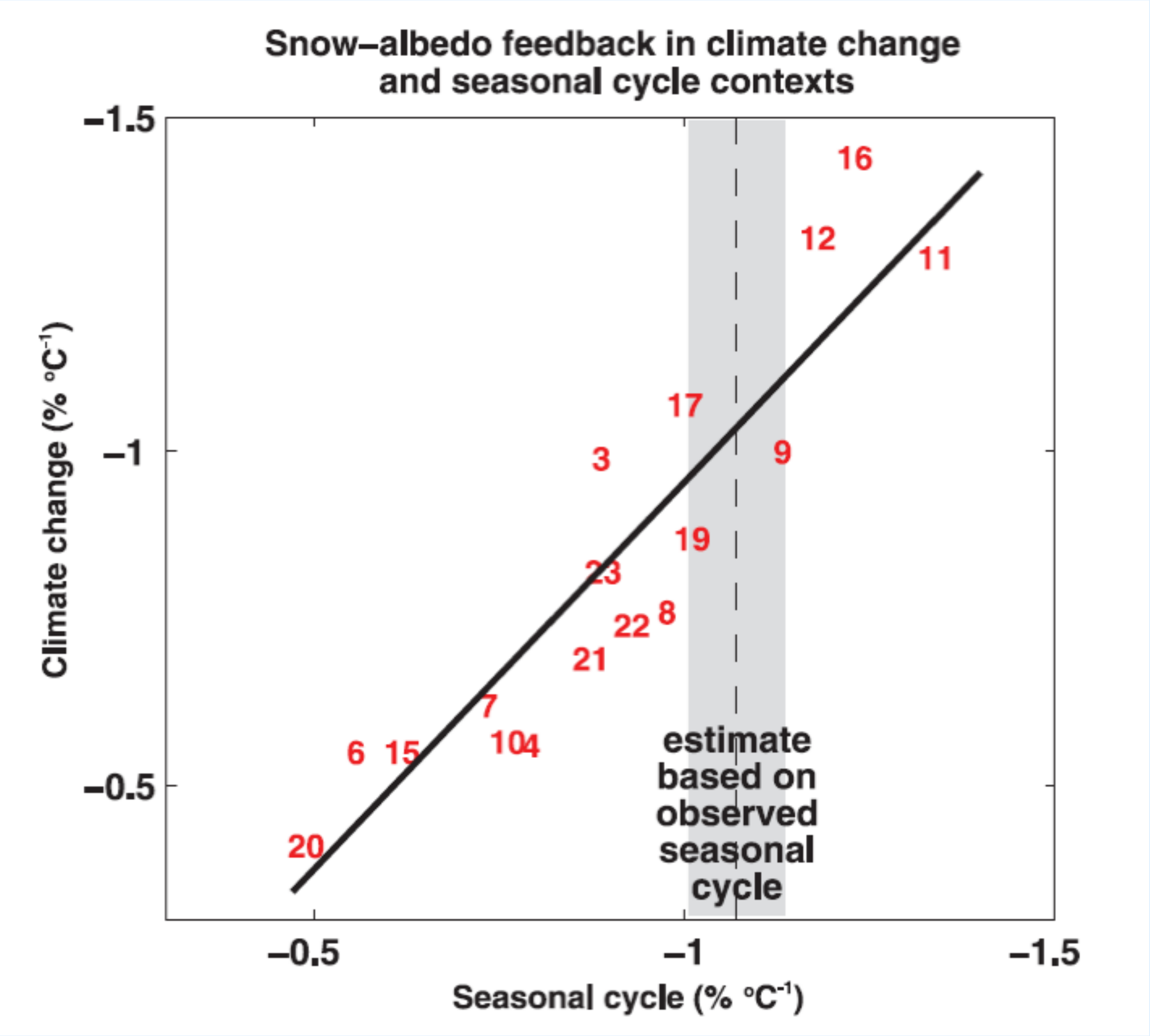
1. Model structural uncertainty
    - Different MIPs (C4MIP, OMIP/LUMIP, PMIP, LongrunMIP) → Link to R1/R2/R3
    - Sensitivity simulations (changes in remineralization depth scales, variable stoichiometry, changes in land-ocean carbon exchange; different model resolutions)
    - Use existing and emerging datasets (paleo/contemporary) to constrain models.
    - New feedback analysis

1. Internal variability
    - Large ensemble simulations to assess predictability → Link to R3
    - Decadal climate predictions of land and ocean carbon sink (10 years, 20-30 years); DCPP; Can we predict the evolution of the carbon sink over the next decades?

Emergent Constraints:

Using Earth System Models
to identify the relationships between
observable contemporary variations
and future sensitivity

Archetypal Example of an *Emergent Constraint*



Hall & Qu (2006)

Emergent Constraints

- **Emergent** because it a relationship that emerges from the ensemble of ESM projections.
- **Constraint** because it enables an observation to constrain the estimate of the ES sensitivity in the real world.
- *Allow model ensembles to be more than the sum of the parts.*
- *Identify metrics of current system which are most relevant to projected changes.*

Recipe for Finding Emergent Constraints

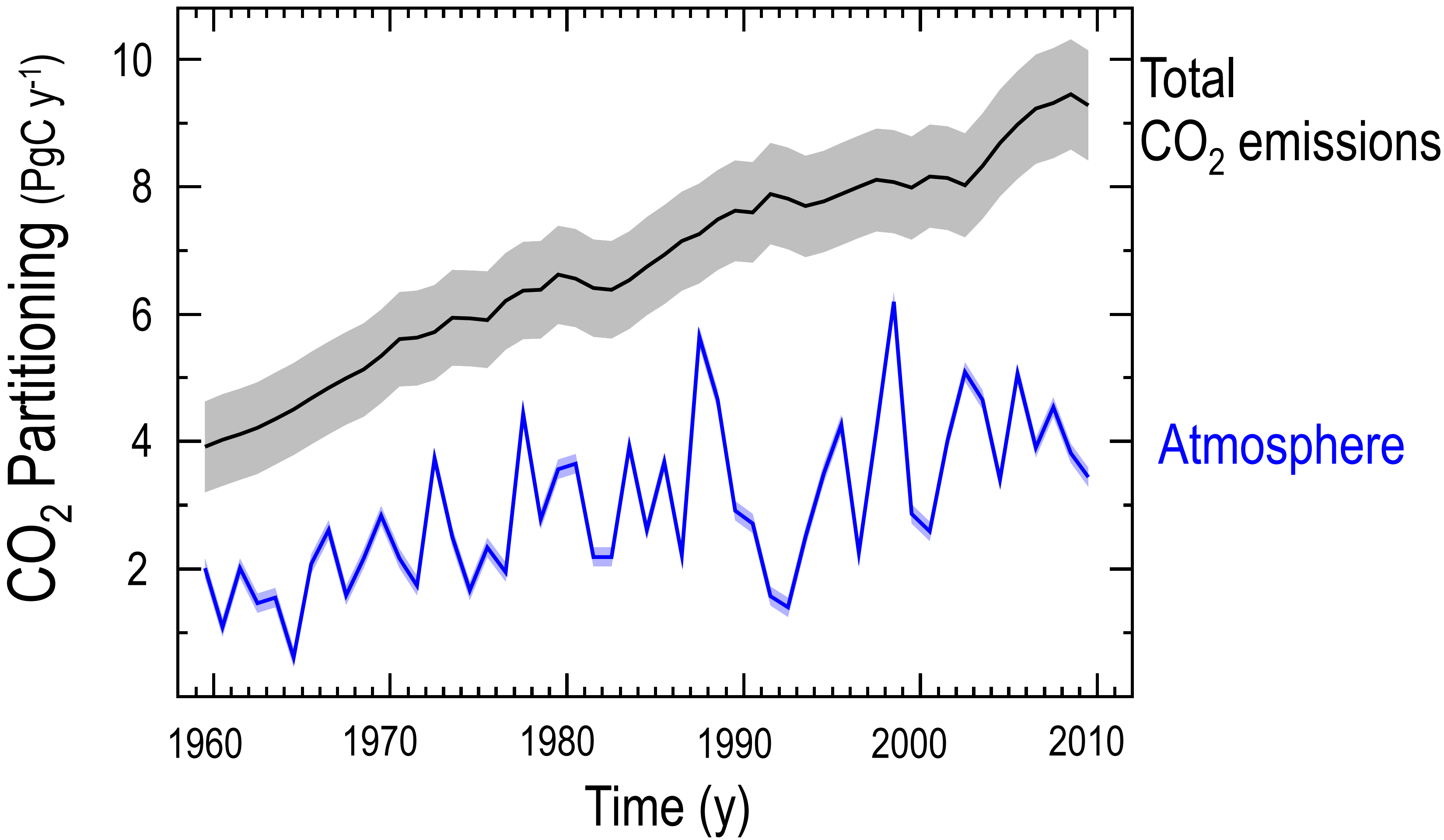
1. Identify a key uncertainty in future projections.
2. Identify an observed variation that could plausibly be related to that uncertainty.
3. Check for an *Emergent Relationship* between the Uncertainty and the Observation, across the ESM ensemble.
4. Apply the *Observational Constraint* to the *Emergent Relationship*, to derive an *Emergent Constraint* on the key uncertainty in future projections.

Emergent Constraints on Carbon Cycle Sensitivities

(some recent examples)

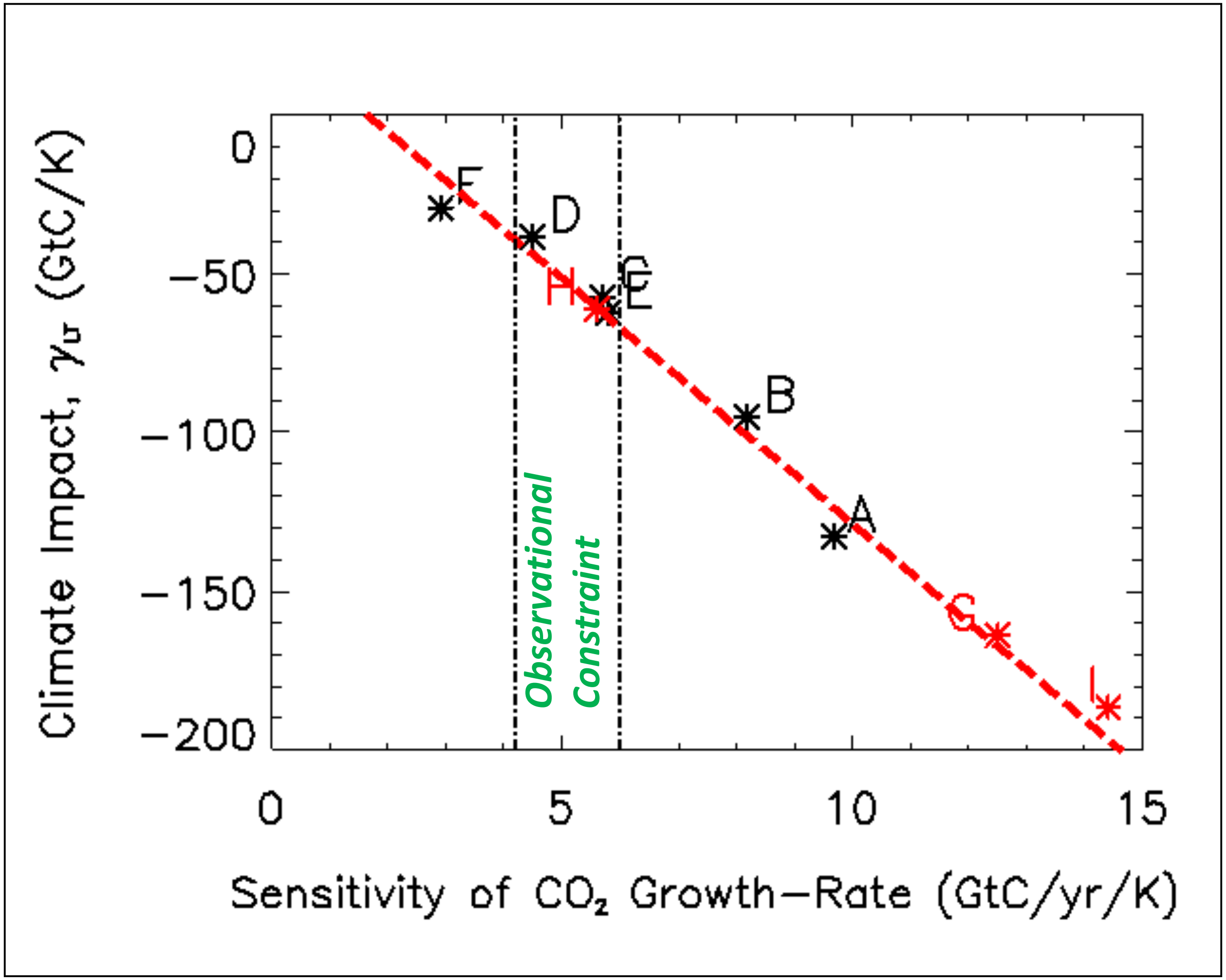
Interannual Variability in CO_2 Growth-rate

Evolution of the fraction of total emissions that remain in the atmosphere



Updated from Le Quéré et al. 2009, Nature Geoscience; Data: NOAA 2010, CDIAC 2010

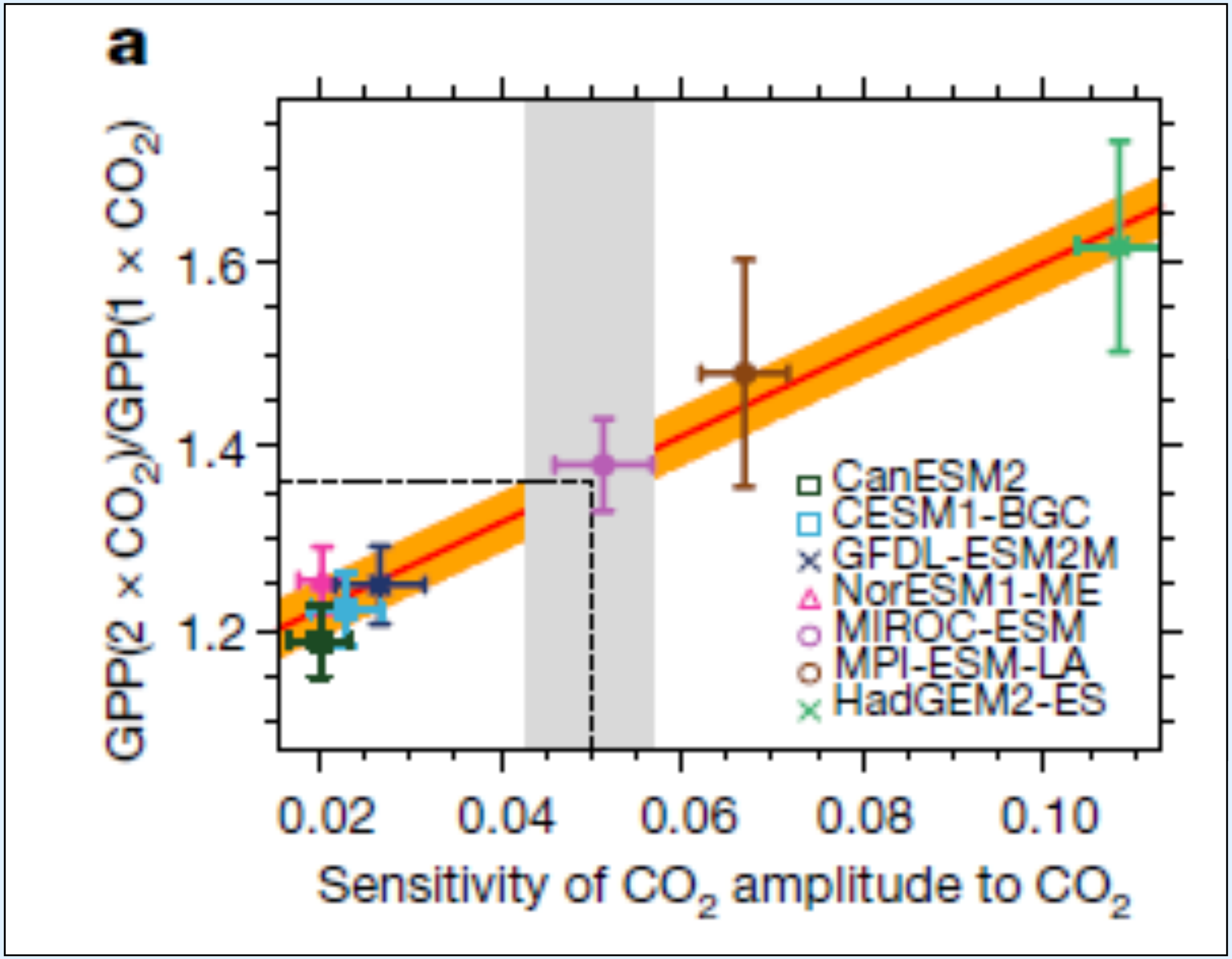
Emergent Constraint on Tropical γ
from Interannual Variability in CO_2



Cox et al., 2013

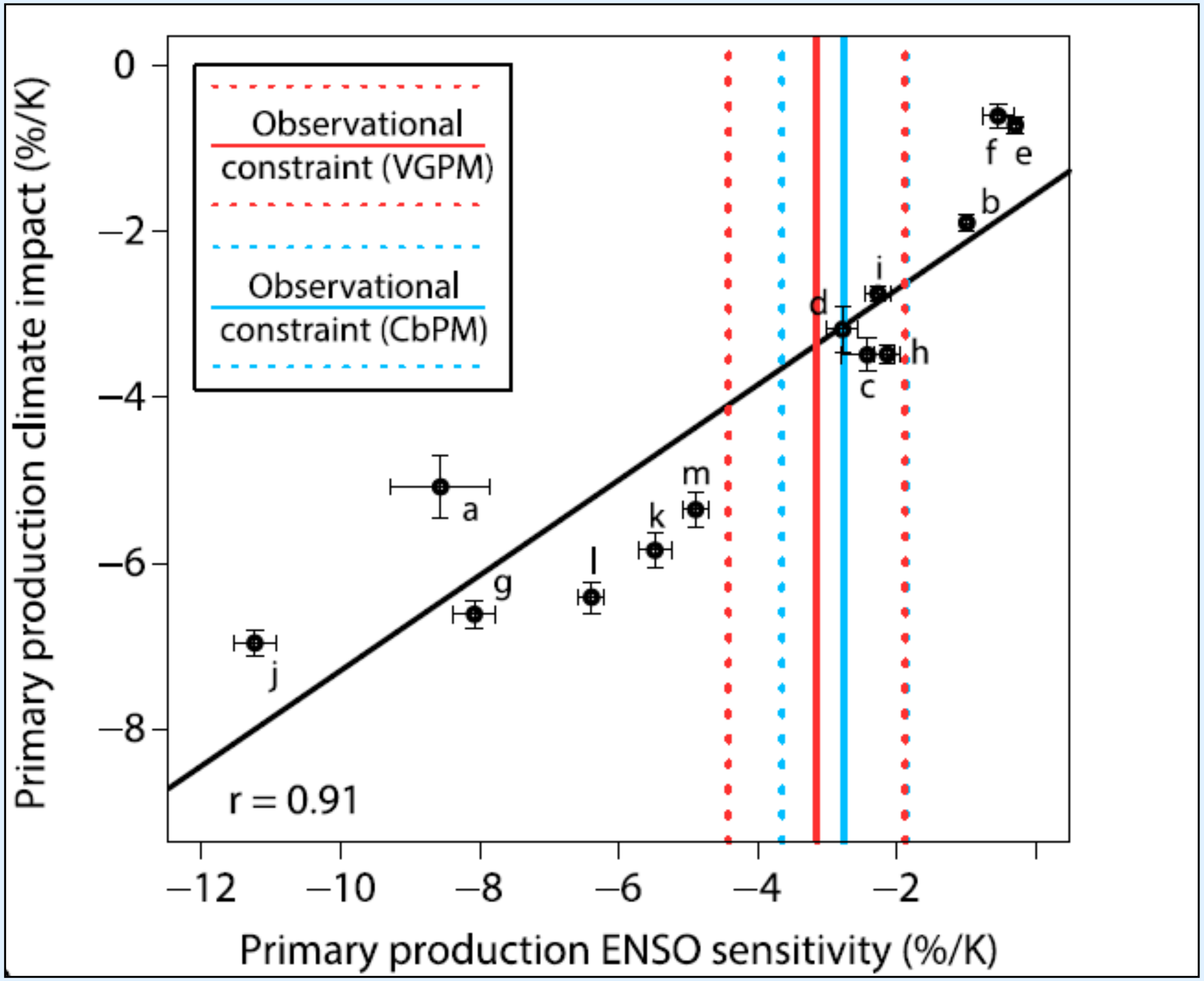
Emergent Constraint on CO_2 Fertilization

from trends in the seasonal cycle of CO_2



Wenzel et al., 2016

Emergent Constraint on T sensitivity of Tropical Ocean PP
from Interannual Variability in Chlorophyll



Kwiatkowski et al., submitted