Answers to the Questions

(3rd day)

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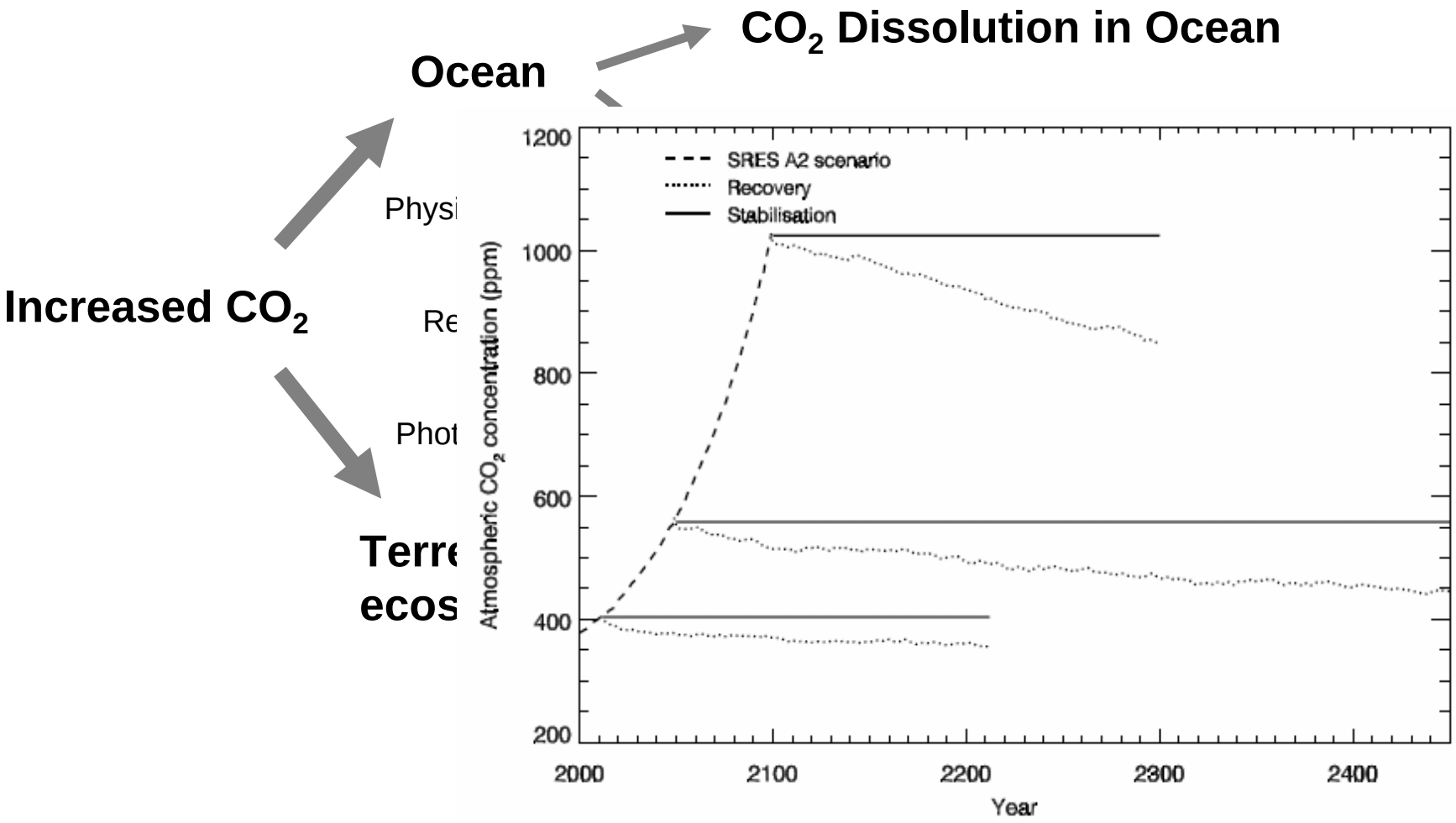
Questions

- What are the natural processes regulating the increase of CO_2 during the fossil-fuel era ?
- What do the observations tell us about these processes ?
- What are the coupling mechanisms between climate and terrestrial carbon fluxes ?
- What are the uncertainties ?
- What is the role of nutrients ?
- What do the IPCC models say ?

1. What are the natural processes regulating the increase of CO_2 during the fossil-fuel era ?



(Jones, 2010, Tellus B)

1. What are the natural processes regulating the increase of CO_2 during the fossil-fuel era ?

Increased CO_2

Ocean

Physical process

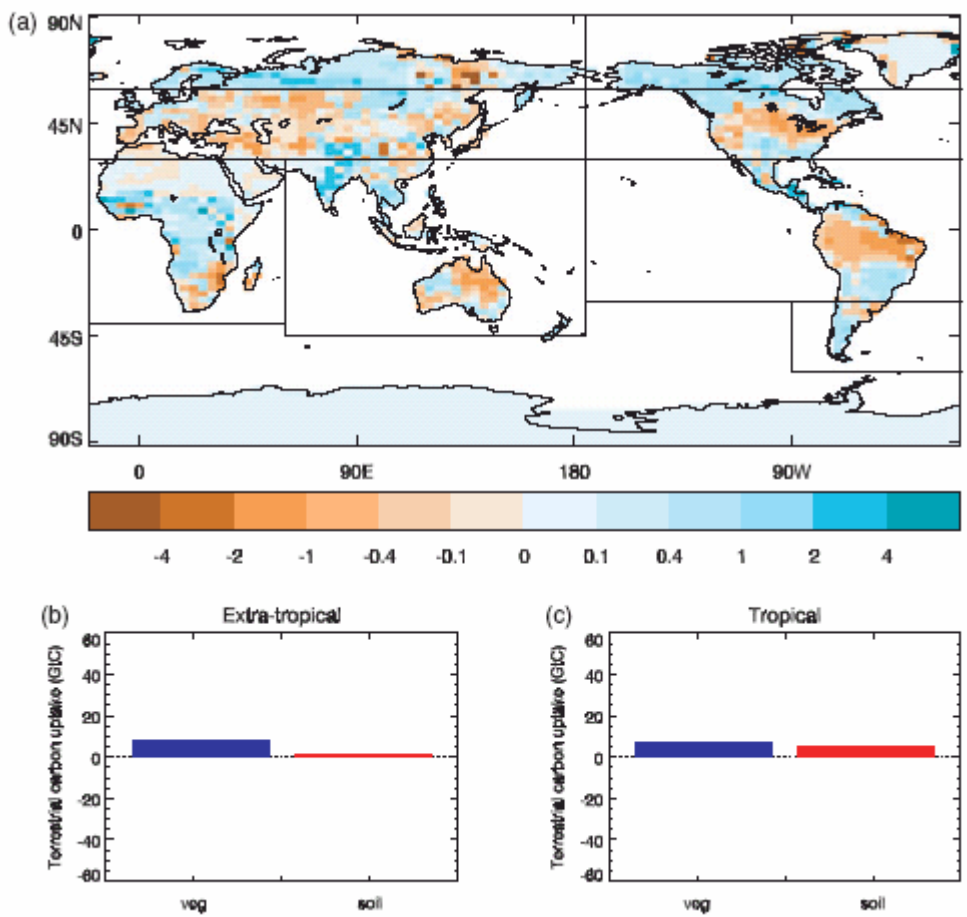
+

Respiration

+

Photosynthesis

Terrestrial ecosystems



(Jones, 2010, Tellus B)

2. What do the observations tell us about these processes ?

1) Ocean is and will continue absorbing CO_2 from the atmosphere

Action point	Duration (yr)	Carbon pool	Carbon uptake by region (GtC)							
			Temperate N. America	Boreal N. America	temperate Eurasia	Boreal Eurasia	S. and tropical America	Africa	Australia	Globe
2012	50	Biomass	1.41	0.36	1.48	1.04	−0.09	6.55	2.11	12.9
		Soil carbon	0.55	2.86	0.43	1.56	−0.96	4.04	0.28	8.8
		ocean								32.1
	100	Biomass	2.26	1.00	2.41	2.14	−1.93	6.14	2.77	14.8
		Soil carbon	−0.37	3.67	−2.70	0.68	1.75	2.43	0.77	6.2
		Ocean								54.4
2050	50	Biomass	7.35	2.16	4.24	3.69	−25.6	4.33	2.30	−1.5
		Soil carbon	4.17	5.19	−2.56	3.68	−10.2	3.70	−4.77	−0.8
		Ocean								80.8
	100	Biomass	9.57	4.01	7.61	6.20	−45.2	1.69	3.08	−13.0
		Soil carbon	0.86	6.31	−10.9	2.68	−22.4	−4.28	−12.26	−40.0
		Ocean								133.8
2100	50	Biomass	6.99	4.80	6.37	5.94	−33.3	−6.65	2.91	−12.9
		Soil carbon	−15.0	3.94	−29.4	−5.12	−6.13	−9.52	−8.68	−69.8
		Ocean								145.1
	100	Biomass	13.5	10.4	14.4	13.1	−40.4	−11.2	4.69	4.5
		Soil carbon	−16.6	4.4	−33.0	−8.01	−6.43	−8.75	−7.03	−75.4
		Ocean								234.8

From Jones *et al*., 2010, Tellus B

2. What do the observations tell us about these processes ?

1) Ocean is and will continue absorbing CO_2 from the atmosphere

2) Experiments almost univocally shows a **stimulation of leaf photosynthesis** when plants are exposed to **elevated CO_2** (Körner, 2006, *New Phytologist*)

3) Experiments with **limited rooting space** have shown a certain degree of **downward adjustment of photosynthetic capacity** under longer-term exposure to **high CO_2 concentrations** (Körner, 2006, *New Phytologist*)

4) **Global warming** may change the role of some ecosystems through affect the tradeoff of photosynthesis vs. respiration (Jones *et al*., 2010, *Tellus B*)

PNAS

Permafrost carbon-climate feedbacks accelerate global warming

Charles D. Koven[a,b,1], Bruno Ringeval[a], Pierre Friedlingstein[c], Philippe Ciais[a], Patricia Cadule[a], Dmitry Khvorostyanov[d], Gerhard Krinner[e], and Charles Tarnocai[f]

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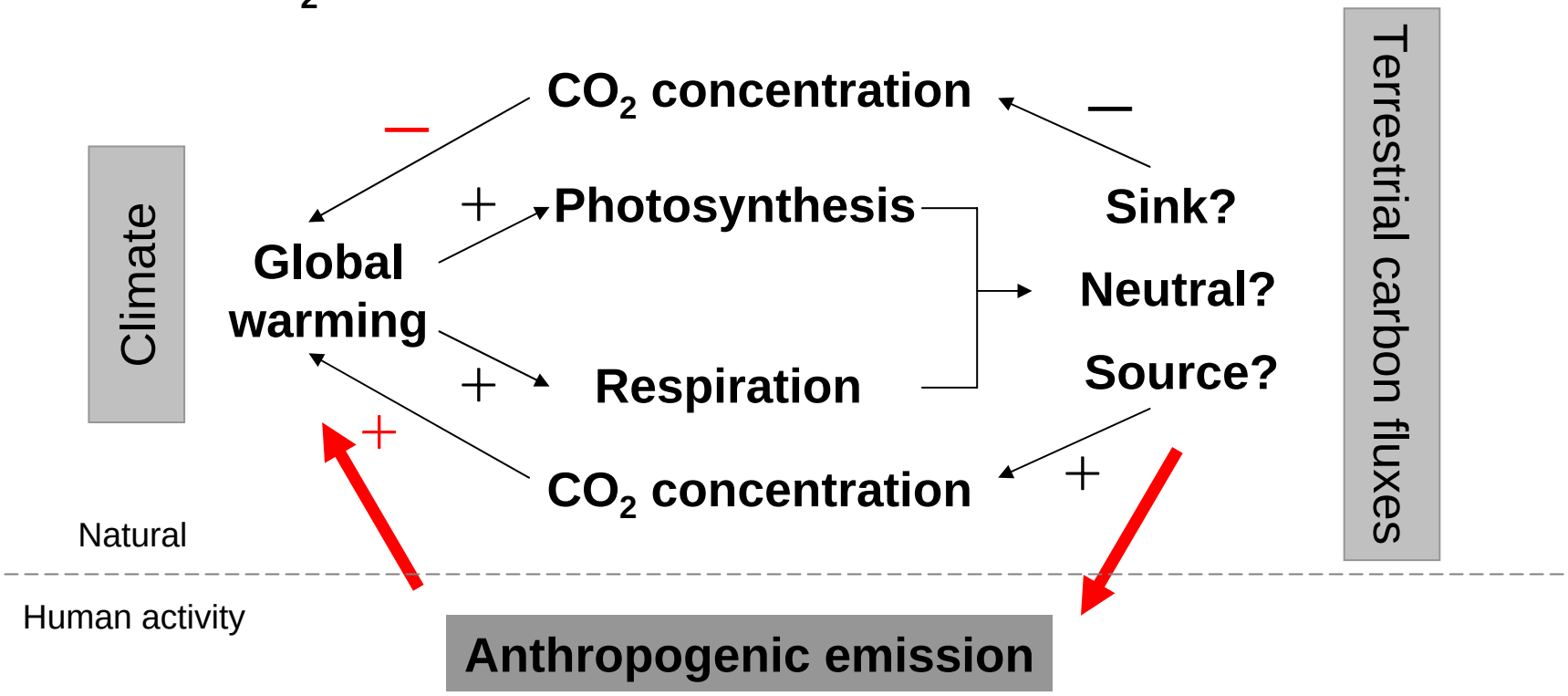
3. What are the coupling mechanisms between climate and terrestrial carbon fluxes ?

Since an increase in CO_2 leads to climatic change, and climatic change in turn affects the CO_2 concentration, the climate, atmospheric CO_2, and the carbon cycle form a feedback loop.

---- Friedlingstein, 2006, Journal of Climate

3. What are the coupling mechanisms between climate and terrestrial carbon fluxes ?

Climate- CO_2 feedback:



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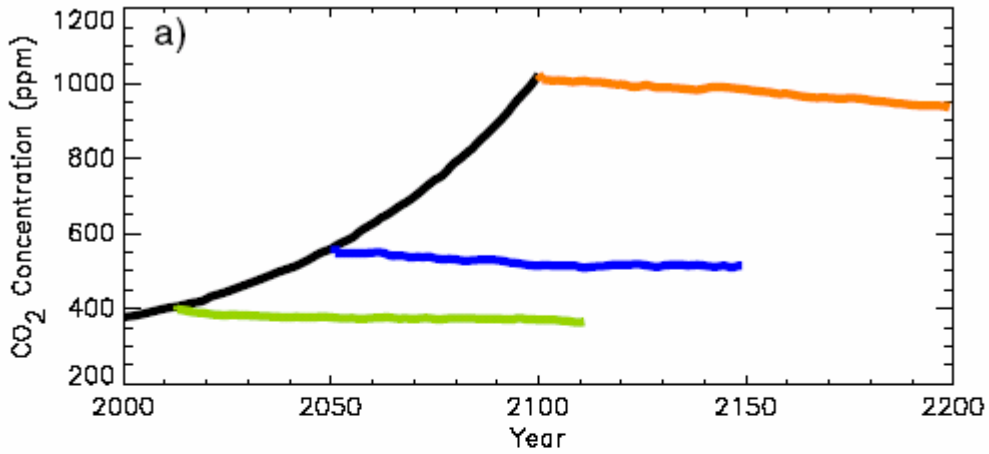

(Lowe, 2009, Environ. Res. Lett)

Under certain scenarios, even if the anthropogenic emission is cut to zero, the temperature will also increase for a long time!

4. What are the uncertainties ?

The sources of uncertainties for future carbon cycle feedbacks:

Greenhouse gas emission storylines

Variations between climate sensitivity of general circulation models

Differences among the parameterization of terrestrial ecosystem models

The uncertainties exist for:

Process formulations vary among models

Parameters and processes include uncertainty for their different theoretical and empirical foundations

Variability nature of ecological systems

(Poulter *et al*., 2010, GCB)

4. What are the uncertainties ?

Global Change Biology

Global Change Biology (2010) 16, 641–656, doi: 10.1111/j.1365-2486.2009.01989.x

Enhanced terrestrial carbon uptake in the Northern High Latitudes in the 21st century from the Coupled Carbon Cycle Climate Model Intercomparison Project model projections

HAIFENG QIAN*, RENU JOSEPH* and NING ZENG*†

PNAS

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Permafrost soils contain enormous amounts of organic carbon, which could act as a positive feedback to global climate change

mental Panel on Climate Change Fourth Assessment Report (IPCC AR4) (6, 7) and other studies (e.g., ref. 8) that examine

5. What is the role of nutrients ?

- Plants require a suite of chemical elements other than carbon to carry out **metabolism** and to **grow** (Körner, 2006, *New Phytologist*).

- Nutrient supply **constrains the productivity** of the terrestrial biosphere (Chapin, 2002, *Principles of Terrestrial Ecosystem Ecology*).

- If noncarbon elements in litter were depleted, this would slow down the **nutrient cycle** (Körner, 2006, *New Phytologist*).

- Nitrogen, phosphorus, and several other elements may play roles in **determining rates of C gain and loss** (Townsend, 2011, *Front Ecol Environ*)

Marine ecosystems:

- Natural **Fe fertilization enhances POC** export by 1.9–7.1 times in the ocean (Bouttes, 2011, GRL)

- The change of nutrient fluxes to coastal areas can lead to widespread **eutrophication, hypoxia** and other ecological damage (Howarth**,** 2011, *Front Ecol Environ*),

6. What do the IPCC models say ?

Future climate change will decrease the carbon uptake ability of terrestrial ecosystems

Additional CO_2 still in the air is between 20 and 200 ppm simulated by 11 models, and the majority lying between 50 and 100 ppm

The higher CO2 levels led to an additional **climate warming** ranging between 0.1° and 1.5° C

Both the land and the ocean carbon cycle are **negative sensitivity** to future climate.

Majority of the models located the reduction of land carbon uptake in the **Tropics**.

Carbon sink in high latitudes is enhanced due to warming, through longer growing seasons and enhanced productivity that offsets the warming-induced increase in heterotrophic respiration.

Friedlingstein, 2006, Journal of Climate

Thank you