Attributing the increase of atmospheric CO_2 to historical emitters and absorbers

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Global Carbon Cycle

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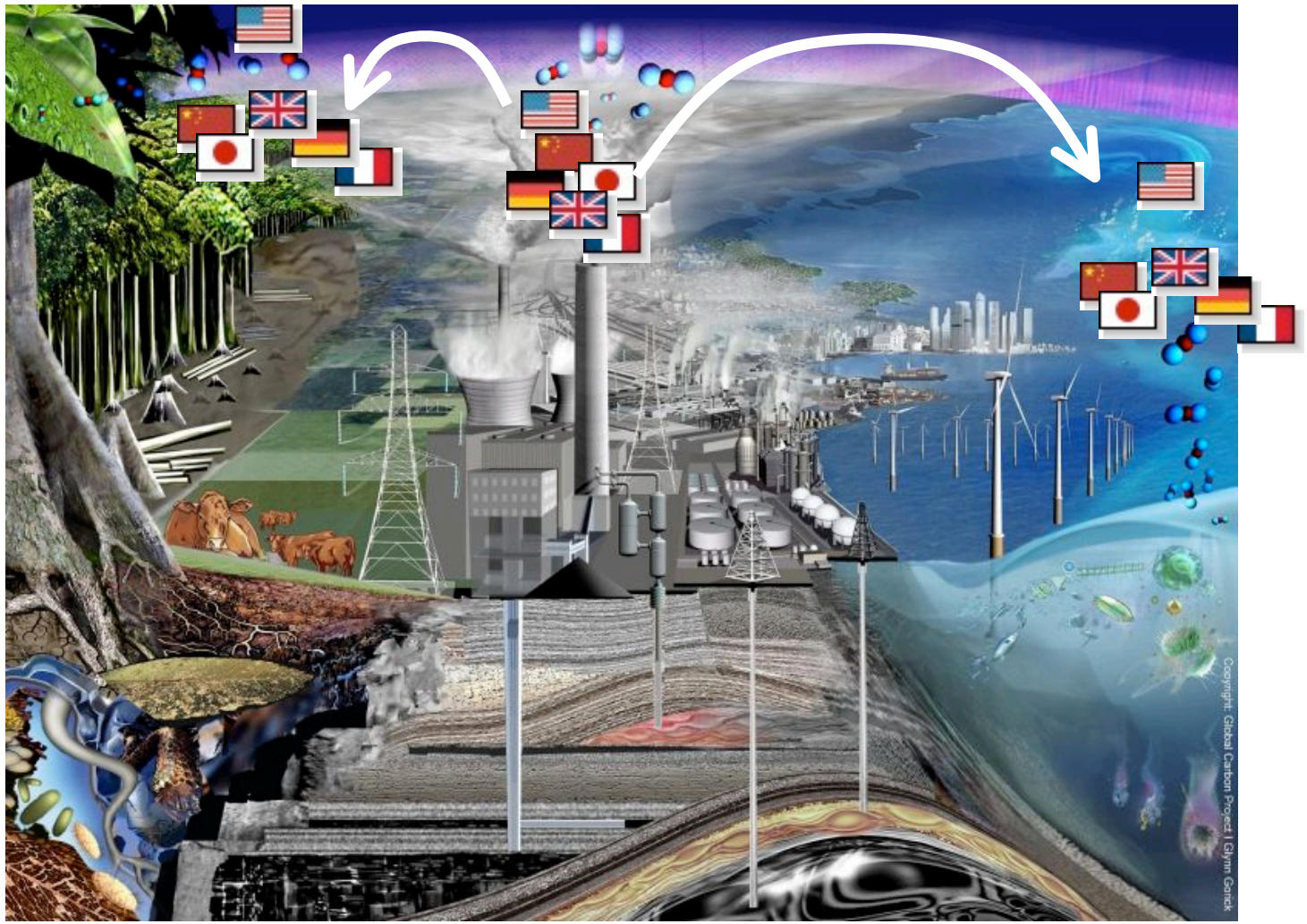
Tracing the fate of emissions



A tree growing in Buckingham Palace garden

How many CO2 molecules from China and the US did it absorb to grow ?

Usual research question :
What is responsible for C sinks ?

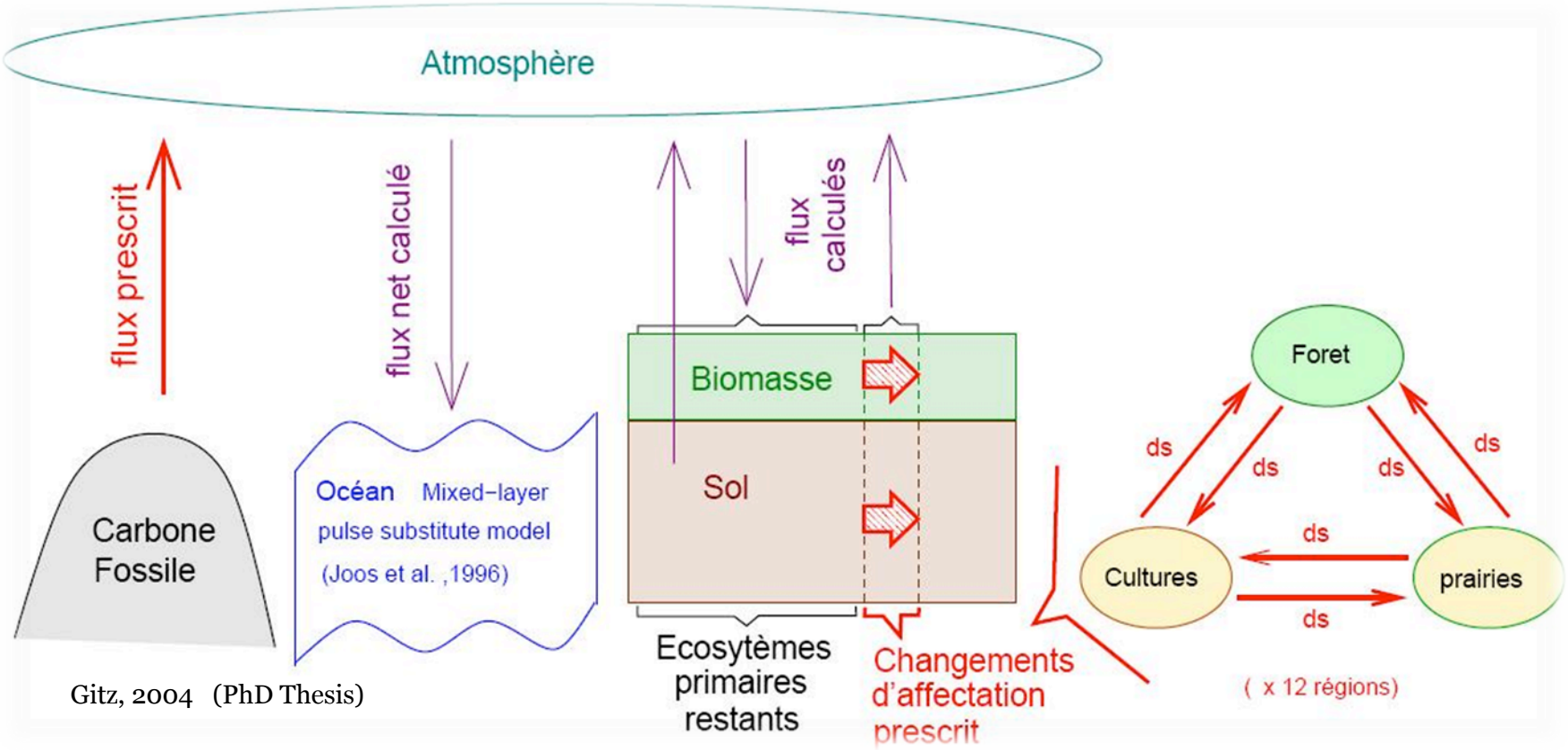
This talk research question :
Who is responsible for C sinks ?

Regional carbon budgets

- Fossil fuel emissions (FF) and land use change emission estimates (LUC) are available for diverse regions.
- The atmospheric ‘sink’ (AS) is global.
- The ocean sink (OS) and land biosphere sink (BS) are regional.
- Question : how to split the global atmospheric sink into regional sinks ?

OSCAR

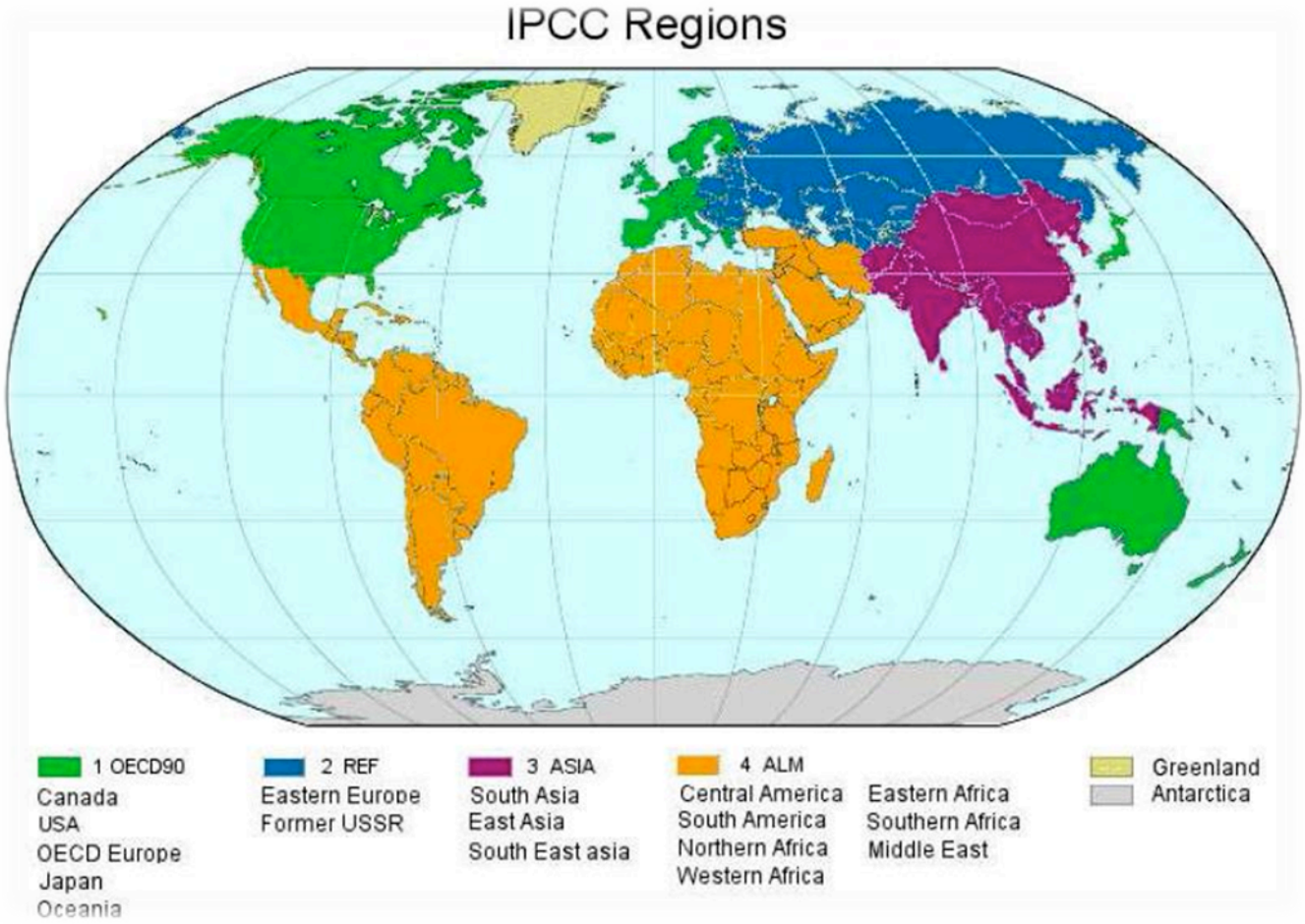
A global carbon cycle model (idealized but useful for testing)



Gitz, 2004 (PhD Thesis)

OSCAR has been modified to 'tag' carbon emitted and absorbed in each region

Four IPCC economic regions



Sink processes

Ocean sink

- Calculated as a global number
- Depends on total CO_2
- OS = *ocean*(C_{tot})

Land biosphere sink

- Calculated as regional numbers (i)
- Depends on total CO_2 via NPP_i fertilization
- BS_i = *land*(N_i,C_{tot}) = $land_i$(C_{tot})

The idea : obtain regional details on sinks

absorbers	Sink provided	total
	by OECD	BS_1
	by REF	BS_2
	by ASIA	BS_3
	by ALM	BS_4
	by Ocean	OS_{tot}

The idea : regional details on sinks

emitters

absorbers

Sink provided	to OECD	to REF	to ASIA	to ALM
by OECD	$BS_{1\leftarrow1}$	$BS_{1\leftarrow2}$	$BS_{1\leftarrow3}$	$BS_{1\leftarrow4}$
by REF	$BS_{2\leftarrow1}$	$BS_{2\leftarrow2}$	$BS_{2\leftarrow3}$	$BS_{2\leftarrow4}$
by ASIA	$BS_{3\leftarrow1}$	$BS_{3\leftarrow2}$	$BS_{3\leftarrow3}$	$BS_{3\leftarrow4}$
by ALM	$BS_{4\leftarrow1}$	$BS_{4\leftarrow2}$	$BS_{4\leftarrow3}$	$BS_{4\leftarrow4}$
by Ocean	$OS_{\leftarrow1}$	$OS_{\leftarrow2}$	$OS_{\leftarrow3}$	$OS_{\leftarrow4}$

The CAT = Crossed Attribution Table

Non linearity issues

- Ocean sink : results from a non linear system with 3 equations and 3 unknowns.
- Land sink : log function of atmospheric CO_2.
- Implies that : $S_{tot} \neq \Sigma\, sink(C_i)$ et $S_i \neq sink(C_i)$
- Solution ?

Linearization

- Linearizing means : define ϱ_i shares such as : $S_{\leftarrow i} = \varrho_i \, . \, S_{tot}$
- If normalization, then $\Sigma \, \varrho_i = 1$
- Otherwise, allow a non-attributed (n/a) sink to conserve the mass
- Linearization method applied at each time step
- 4 different methods were tested so that 100% of the excess CO_2 can be attributed, their results are similar to the second digit

Attribution experiments

Covering the period 1850 to 2006

Only emissions (E0)	Absorber's (E1)
• Ocean sink not attributed.	• Ocean sink not attributed.
• Land sink **not attributed**	• Land sinks attributed to each **absorber**.
• Emitters responsability involves only emissions.	• Common thinking, respects the 'territorial claim' of nations.

Attribution experiments

Absirbers (E2)	Emitters (E3)
• Global ocean sink attributed to each region.	• Global ocean sink attributed to each region.
• Land sinks attributed to each **absorbing** region according to NR method	• Land sinks attributed to to each **emmitting** region

The land sink is treated as a national ressource

Which belongs to each absorber

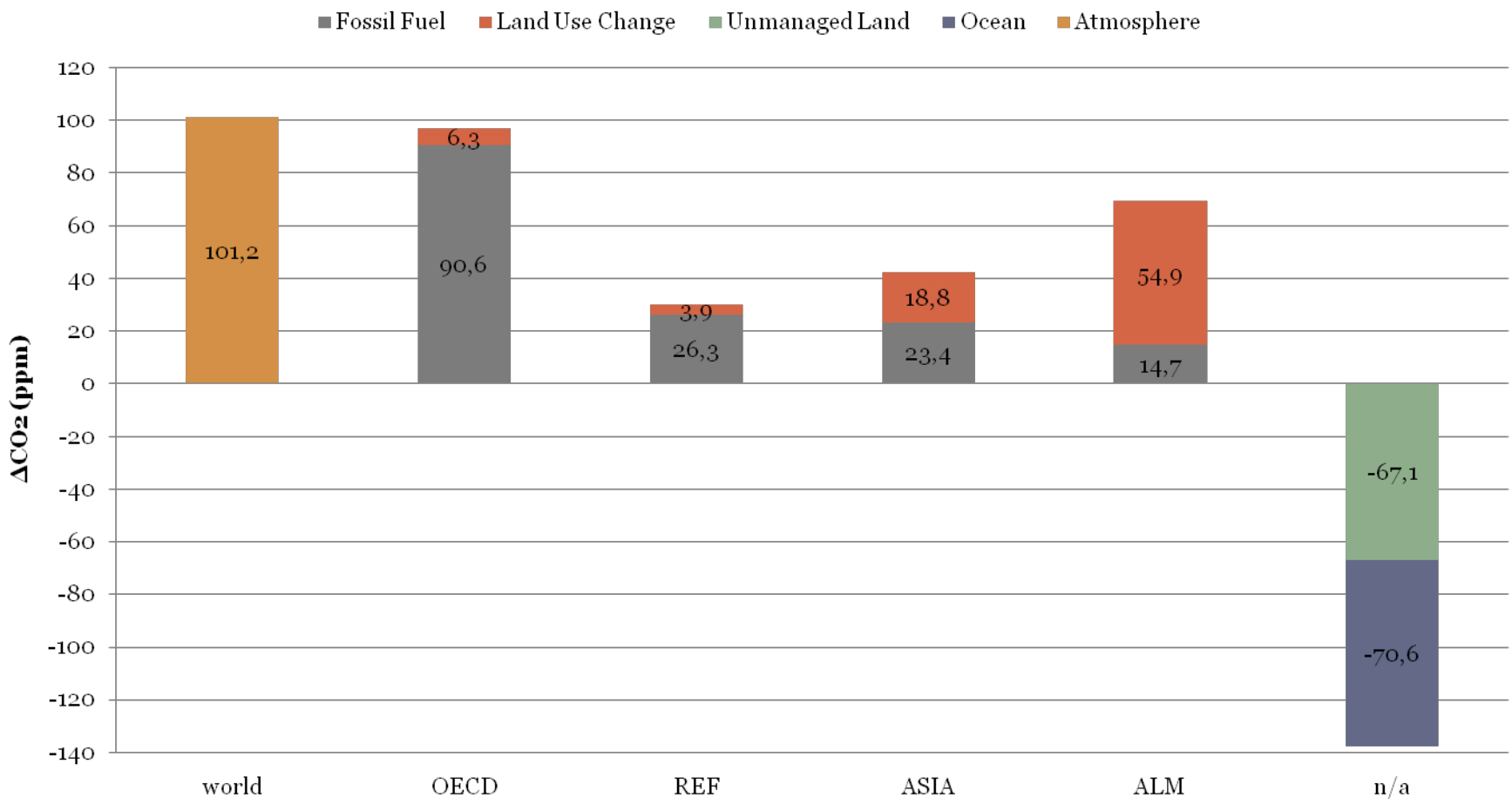
- $BS_i = \Sigma\ BS_{i\leftarrow}$

Reference = absorbers

Sink provided	to OECD	to REF	to ASIA	to ALM
by OECD	$BS_{1\leftarrow1}$	$BS_{1\leftarrow2}$	$BS_{1\leftarrow3}$	$BS_{1\leftarrow4}$
by REF	$BS_{2\leftarrow1}$	$BS_{2\leftarrow2}$	$BS_{2\leftarrow3}$	$BS_{2\leftarrow4}$
by ASIA	$BS_{3\leftarrow1}$	$BS_{3\leftarrow2}$	$BS_{3\leftarrow3}$	$BS_{3\leftarrow4}$
by ALM	$BS_{4\leftarrow1}$	$BS_{4\leftarrow2}$	$BS_{4\leftarrow3}$	$BS_{4\leftarrow4}$

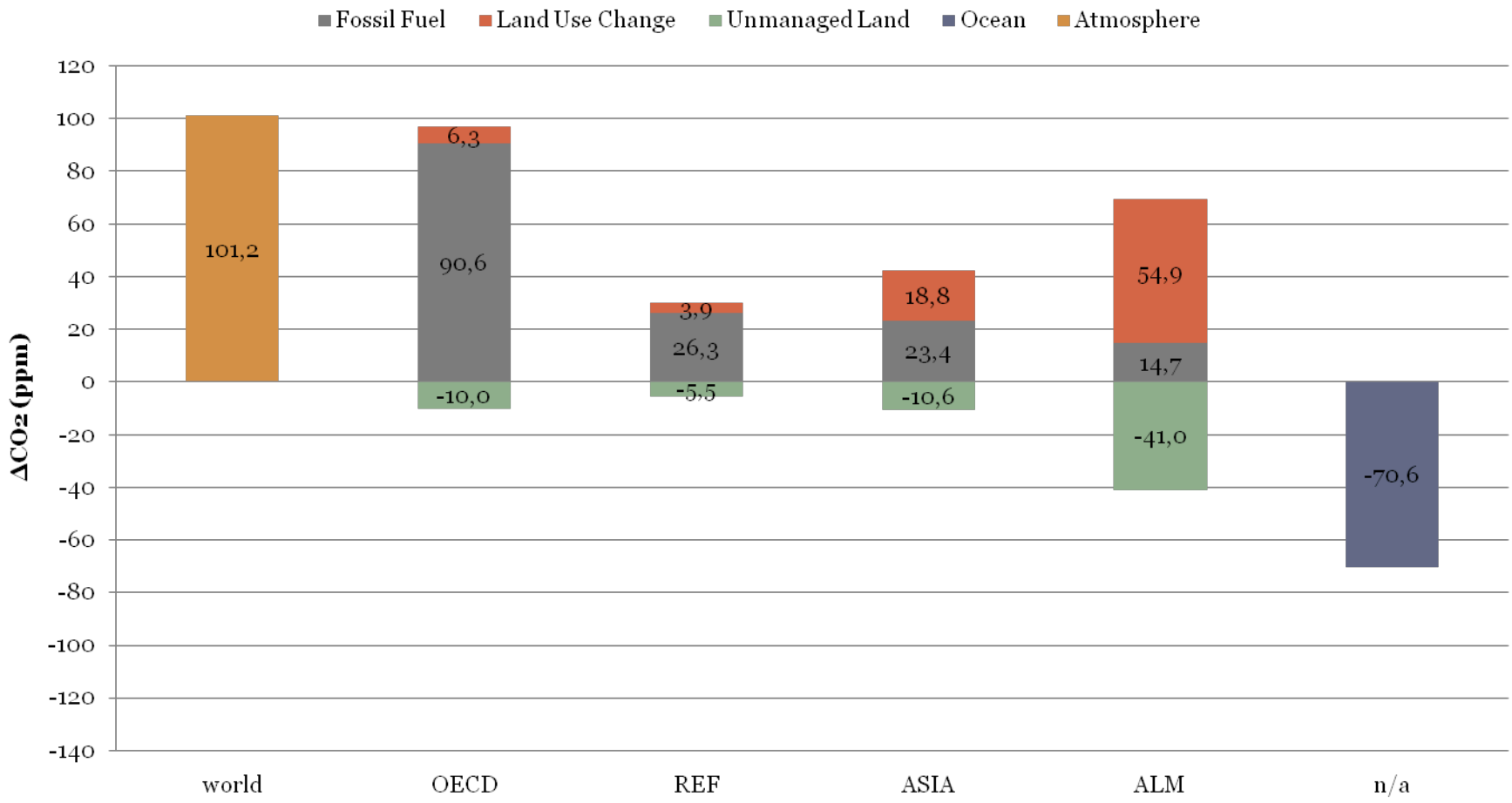
Experiment E0

Fossil and land use emissions only are attributed



Experiment E1

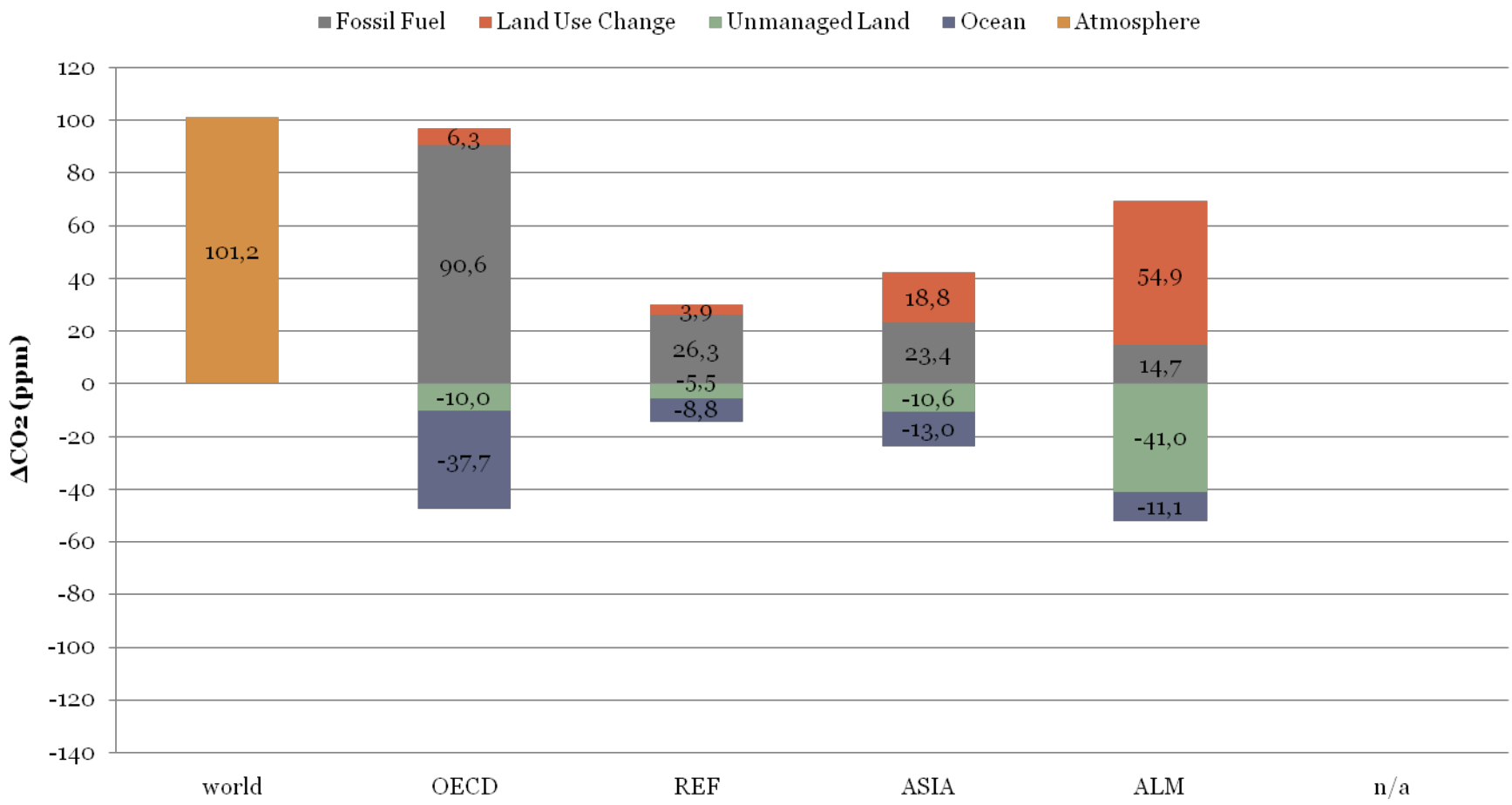
Absorbers responsibility. Ocean sink non-attributed



Claim : "What I absorb belongs to me"

Experiment E2

Absorbers responsibility. Ocean sink Attributed



Claim : What I absorb belongs to me and my ocean sink in proportion

Reference = emitters

The land sink is a 'common' belonging to emitting countries.

Each emitter is attributed a share of the global sink that has been caused by its own historical emissions

- $BS_i = \Sigma\ BS_{\beta i}$

Sink provided	to OECD	to REF	to ASIA	to ALM
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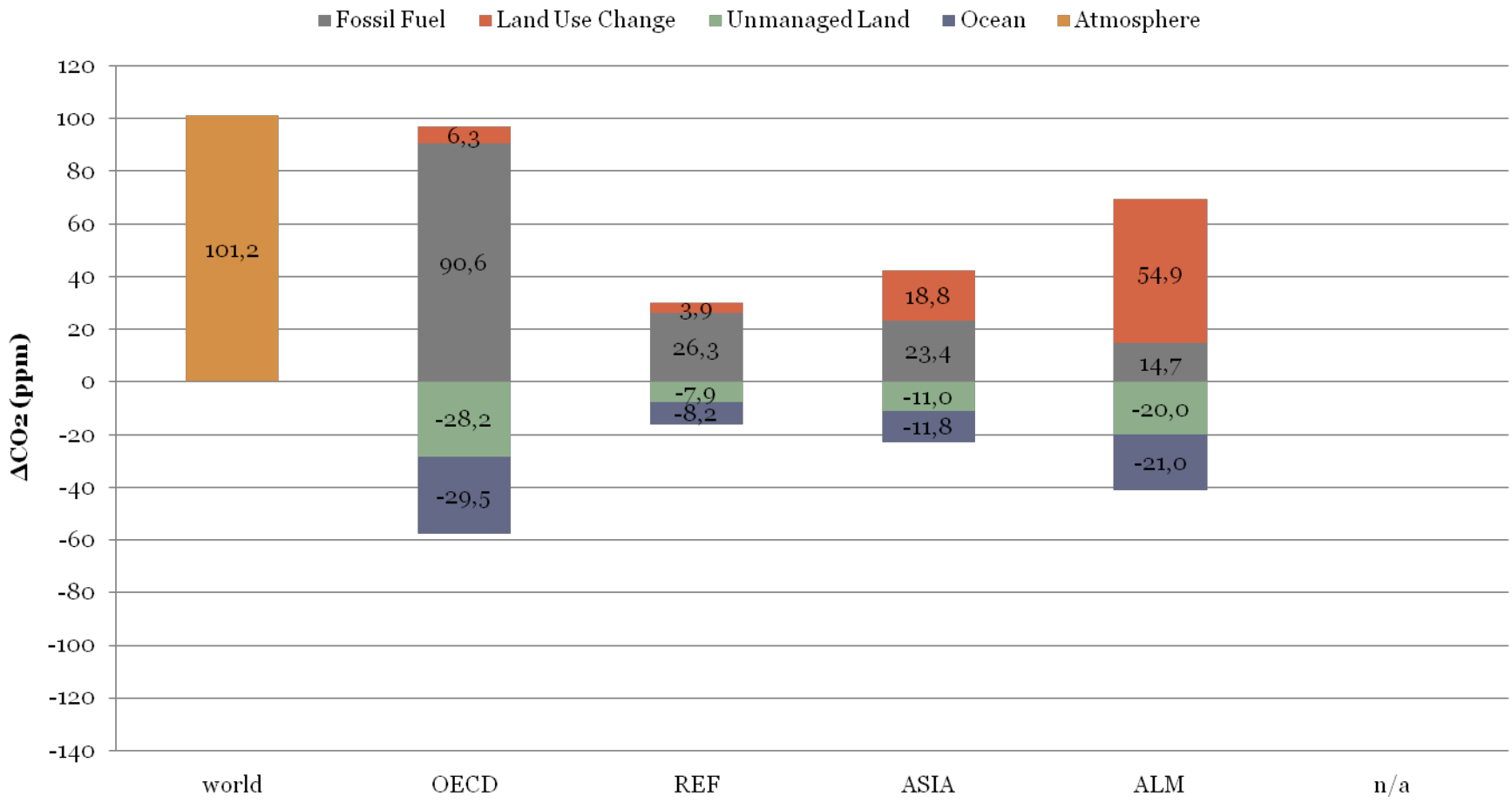
Experiment E3

Emitters responsibility

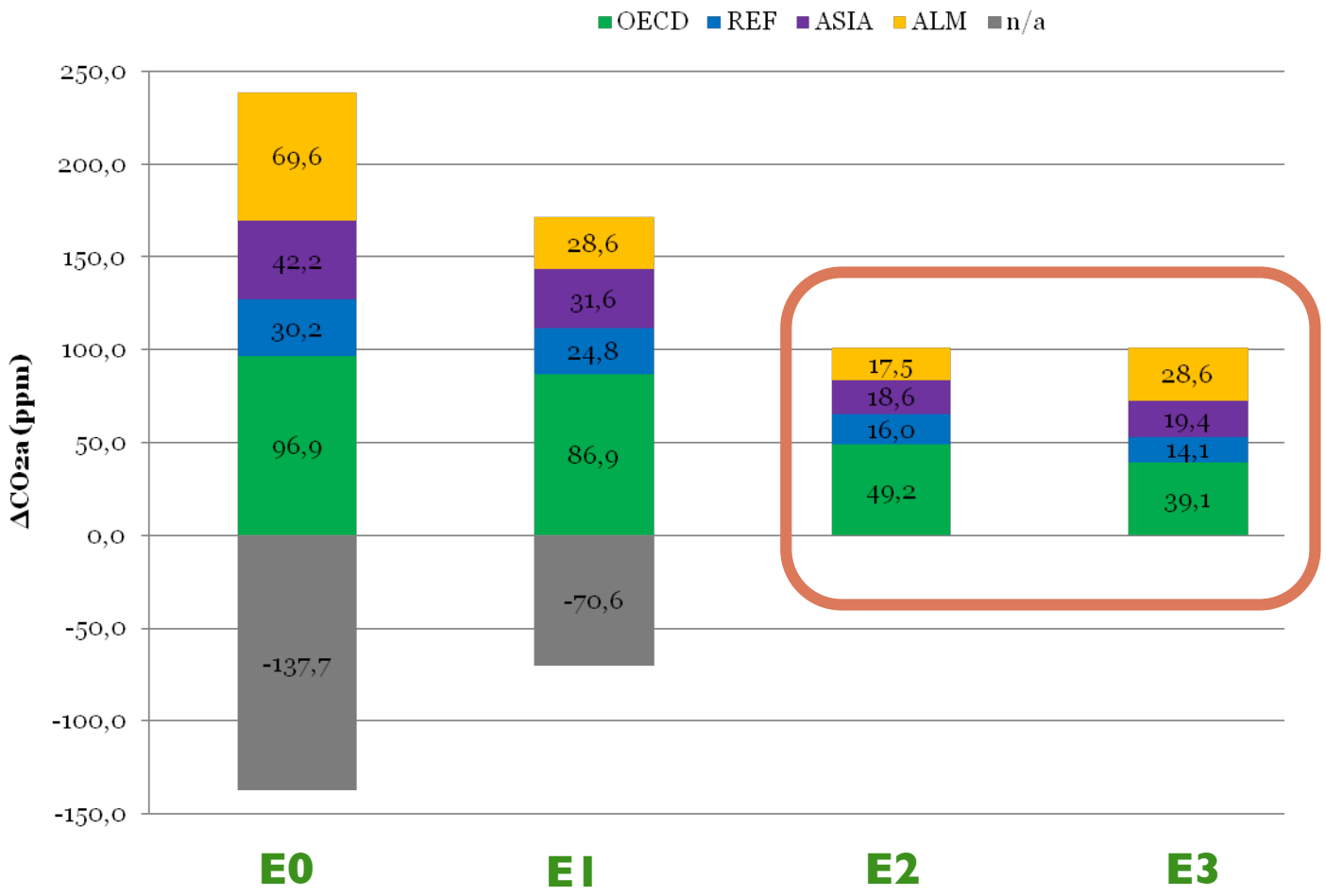


Claim : « Without my emissions, the carbon sink would be less »

Alternative Claim : « Without my forests, your carbon would not be in safety »

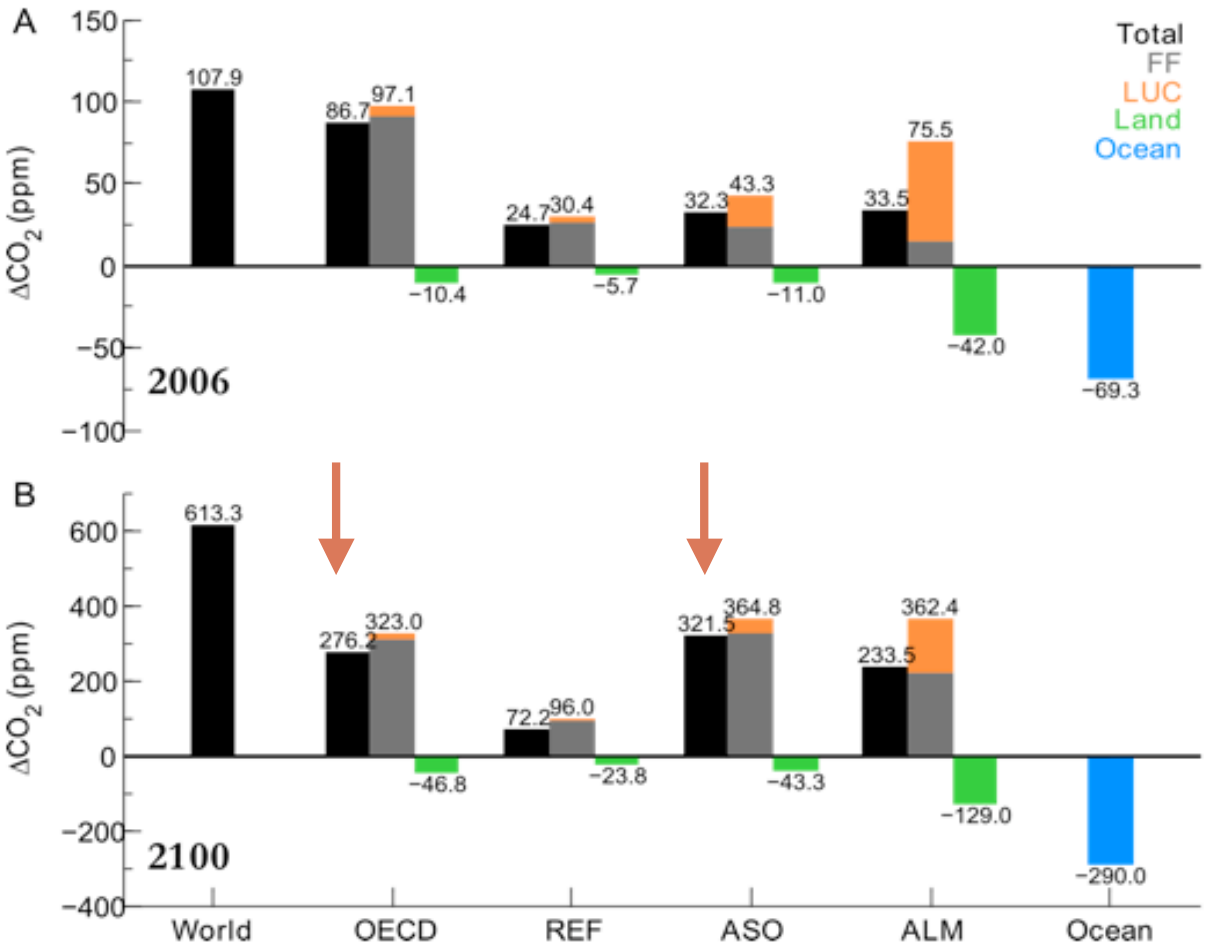
Absolute responsibilities in excess CO2 by 2006

Who did what in the observed 100ppm increase



Compare attribution to absorbers Past and Future

IPCC A2 scenario - Here ocean sink not attributed



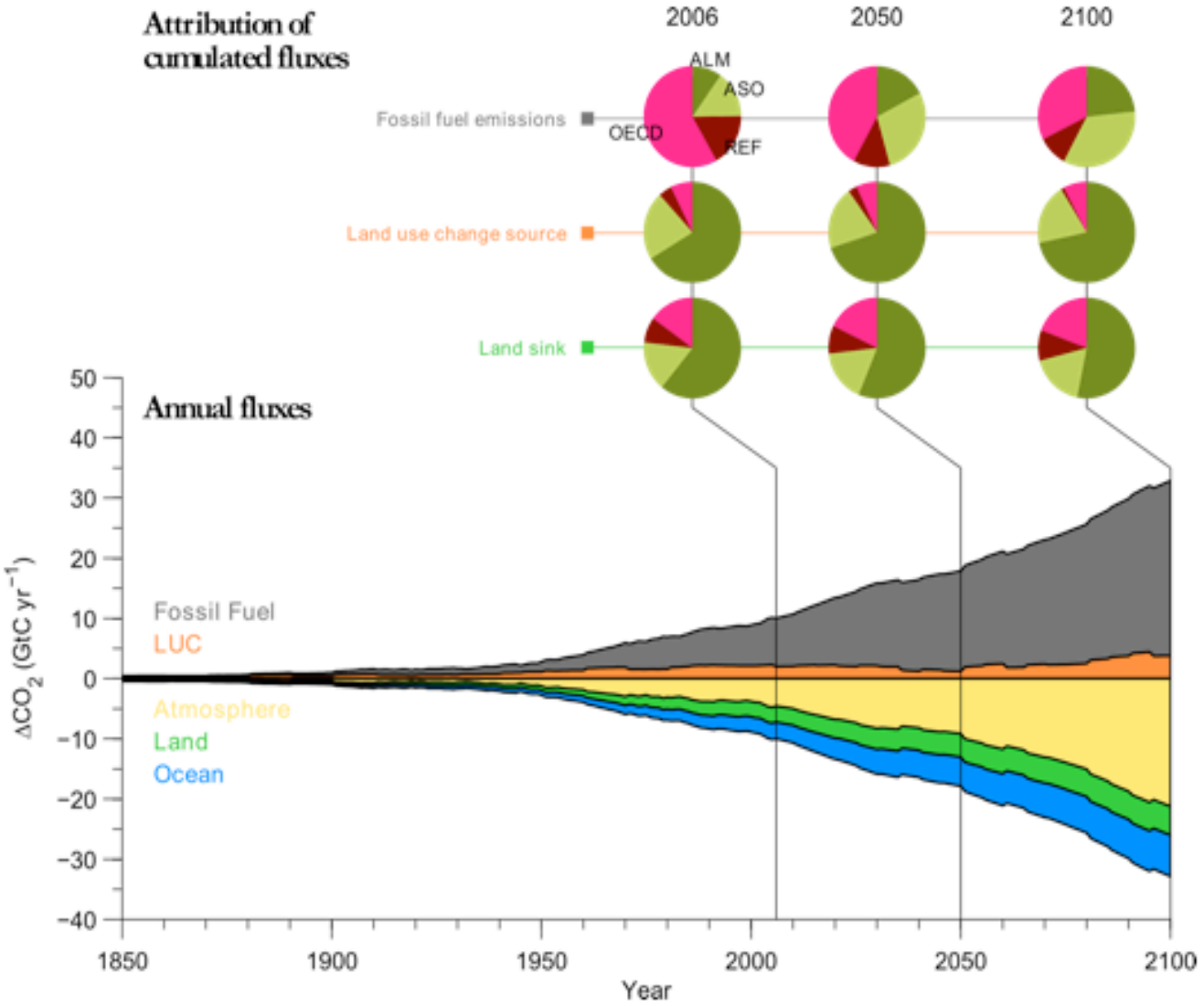
2006

2100

By the end of the 21st century, responsability from today's developped countries will be less than the one of today's developing countries

Attribution to absorbers

Setting the agenda to 2030 ?



Conclusions

- Sink attribution can be studied by carbon cycle models (and also by observations for today's attribution…)
- Responsibilities attribution implies a point of view
- In 2006, nearly all of the excess CO_2 is caused by developed countries
- In 2006, tropical land use has caused a significant 100 ppm excess CO_2, but two-third of this flux have been offset by tropical forest sinks.

Conclusions

- In 2100, developed countries will be responsible for less than 50% of the excess atmospheric CO_2
- Through their intense land use and fossil emissions, Latin America, Africa, South East Asia will contribute 2/5, and China will contribute 3/5 of the total developping countries responsibility
- In this study withno climate feedbacks, the tropical forest sink will be the only significant land discount on excess CO_2
- Keep in mind, this is **just** a model and a **simple** one

Perpectives

- Provide scientific elements to attribute responsibility and negociate emission reductions
- Observing regional C budgets should be more relevant to the attribution issue
- More complex models can be used, e.g. other processes and climate feedbacks included
- Land use biophysical radiative forcing (e.g. how much of the US XXth century deforestation has cooled Europe ?)

Thank you for your attention