International workshop on

Asian Greenhouse Gases Budgets

Physical Research Laboratory, Ahmedabad, India
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Why Regional Carbon Budgets?

1. To provide higher spatial resolution of the global carbon balance with the aim to improve attribution to processes and hot-spots regions essential to understand the future evolution of the carbon-climate feedback.

Fate of Anthropogenic CO_2 Emissions 2010

9.1 ± 0.9 PgC y^{-1}

+

0.9 ± 0.6 PgC y^{-1}

5.0 ± 0.1 PgC y^{-1}

47%

2.6 PgC y^{-1}

27%

Calculated as the residual of all other flux components

26%

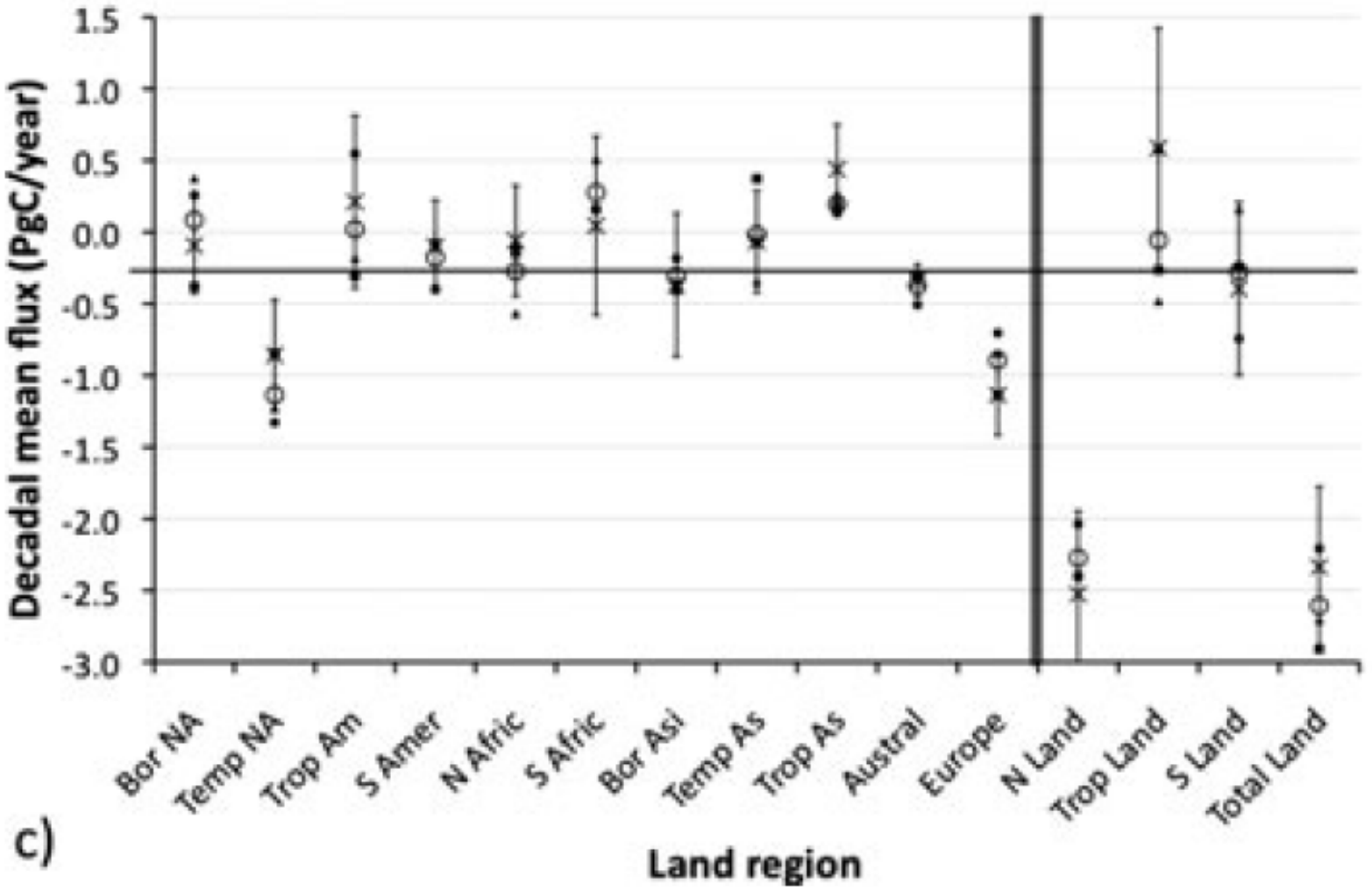
2.4 ± 0.5 PgC y^{-1}

Average of 5 models

Global Carbon Project 2011; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

Regional Net CO_2 and Sources

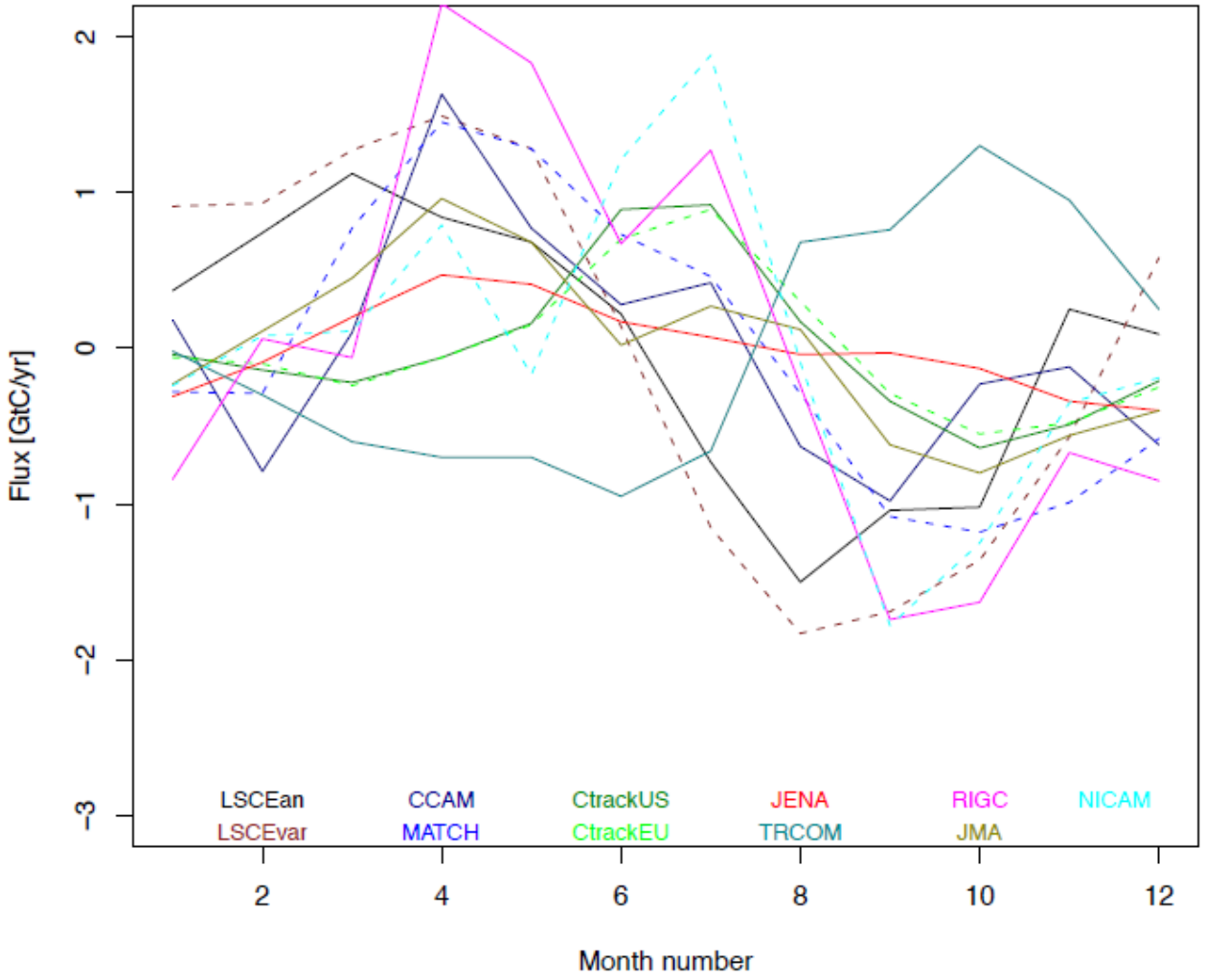
Atmospheric CO_2 Inversions - TransCom



Gurney et al. 2011, Tellus

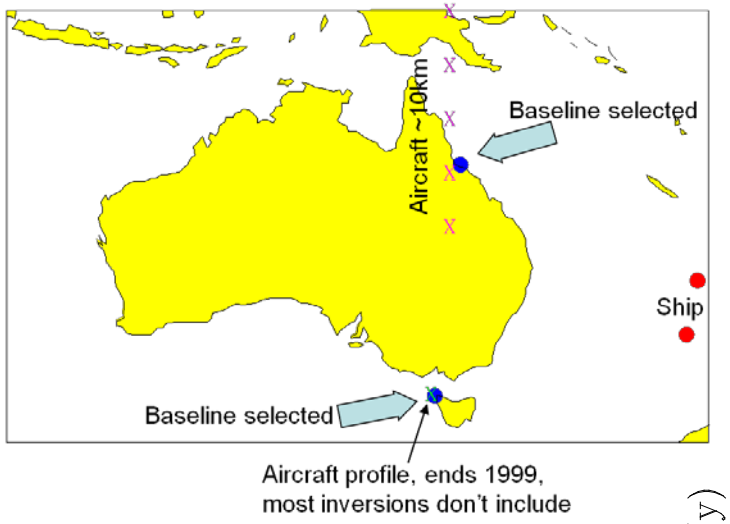
South Asia Seasonal Net CO_2 Flux

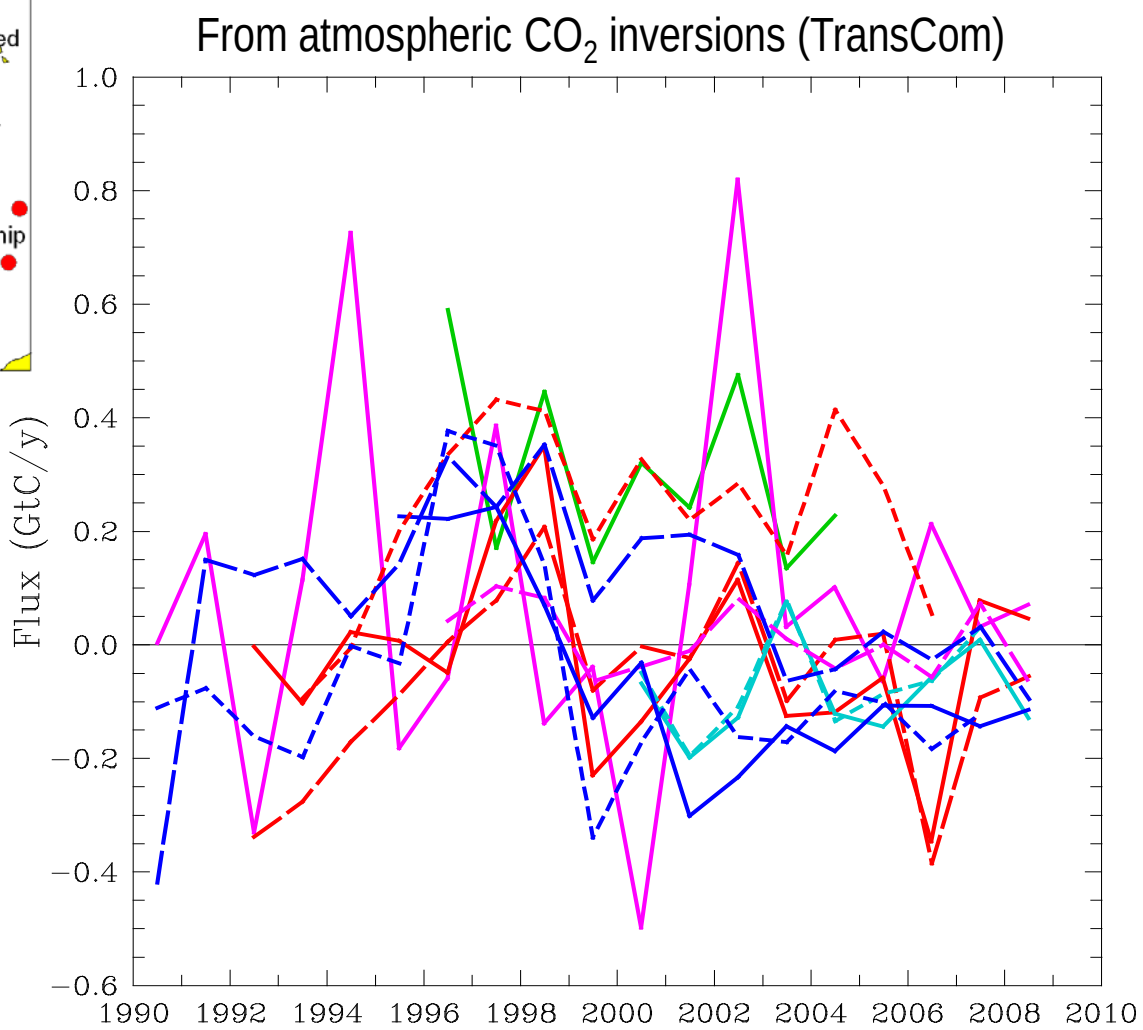
From atmospheric CO_2 inversions (TransCom)



Prabir Patra, TransCom, unpublished

Australian Annual Net CO_2 Flux





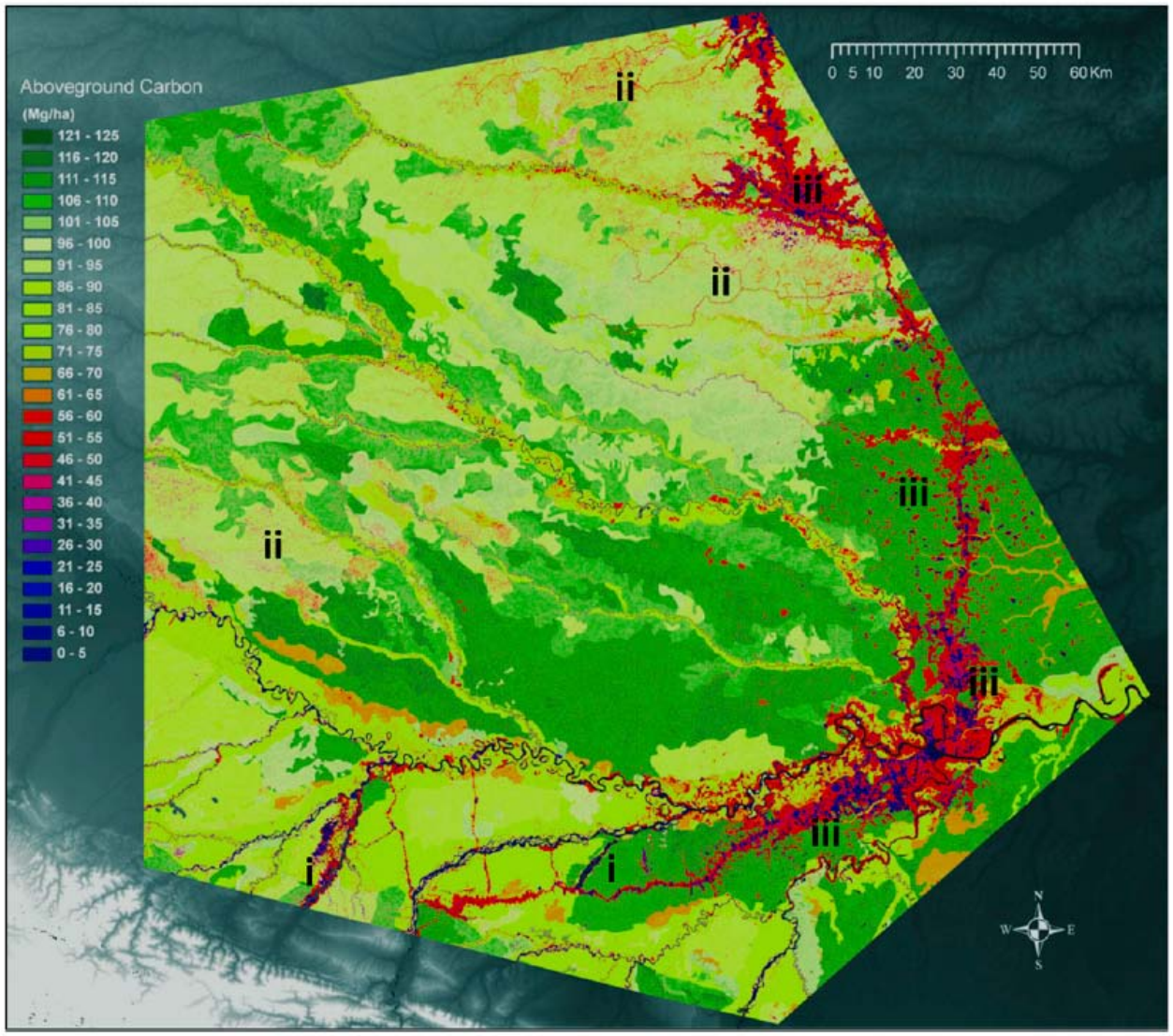
Rachel Law, TransCom, unpublished

Why Regional Carbon Budgets?

1. To provide higher spatial resolution of the global carbon balance with the aim to improve attribution to processes and hot-spots regions essential to understand the future evolution of the carbon-climate feedback.

2. To address a growing demand for a capacity to Measure, Report, and Verify (MRV) the evolution of regional fluxes and the outcomes of climate mitigation policies.

Monitoring and Reporting Carbon Reductions



e.g., REDD – Reduced Emissions from Deforestation and Degradation

Tracking Vegetation Carbon in the Amazon

Only 3% of tropical countries have the capacity to monitor and report changes in forest cover and C stocks (e.g., Panama)

Asner et al 2010, PNAS; Archer et al. 2011, ERL

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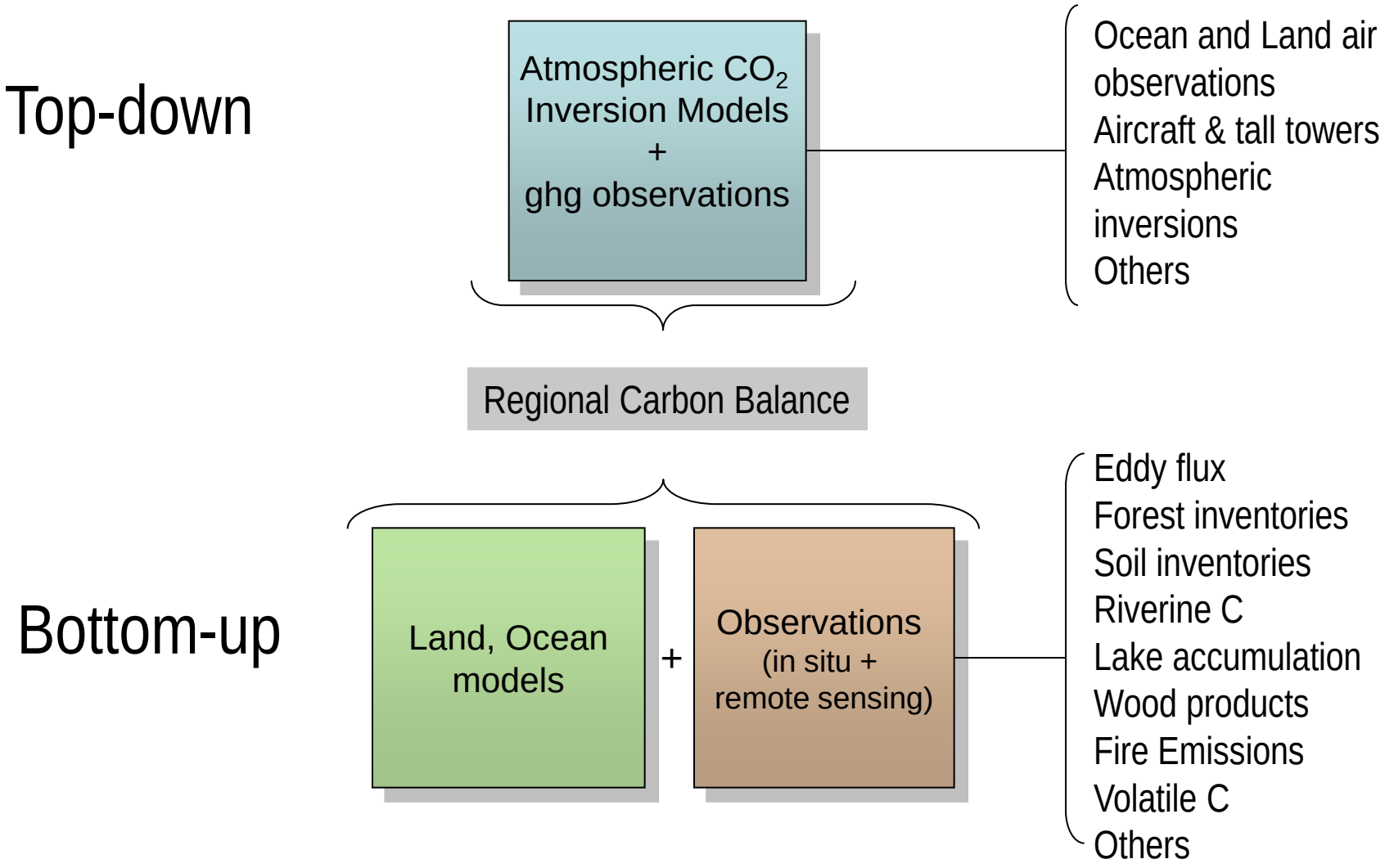
4. To respond to the Group on Earth Observations (EOS) in establishing a global carbon observatory to track the evolution of natural and anthropogenic carbon sources and sinks.

REgional Carbon Cycle Assessment and Processes (RECCAP)

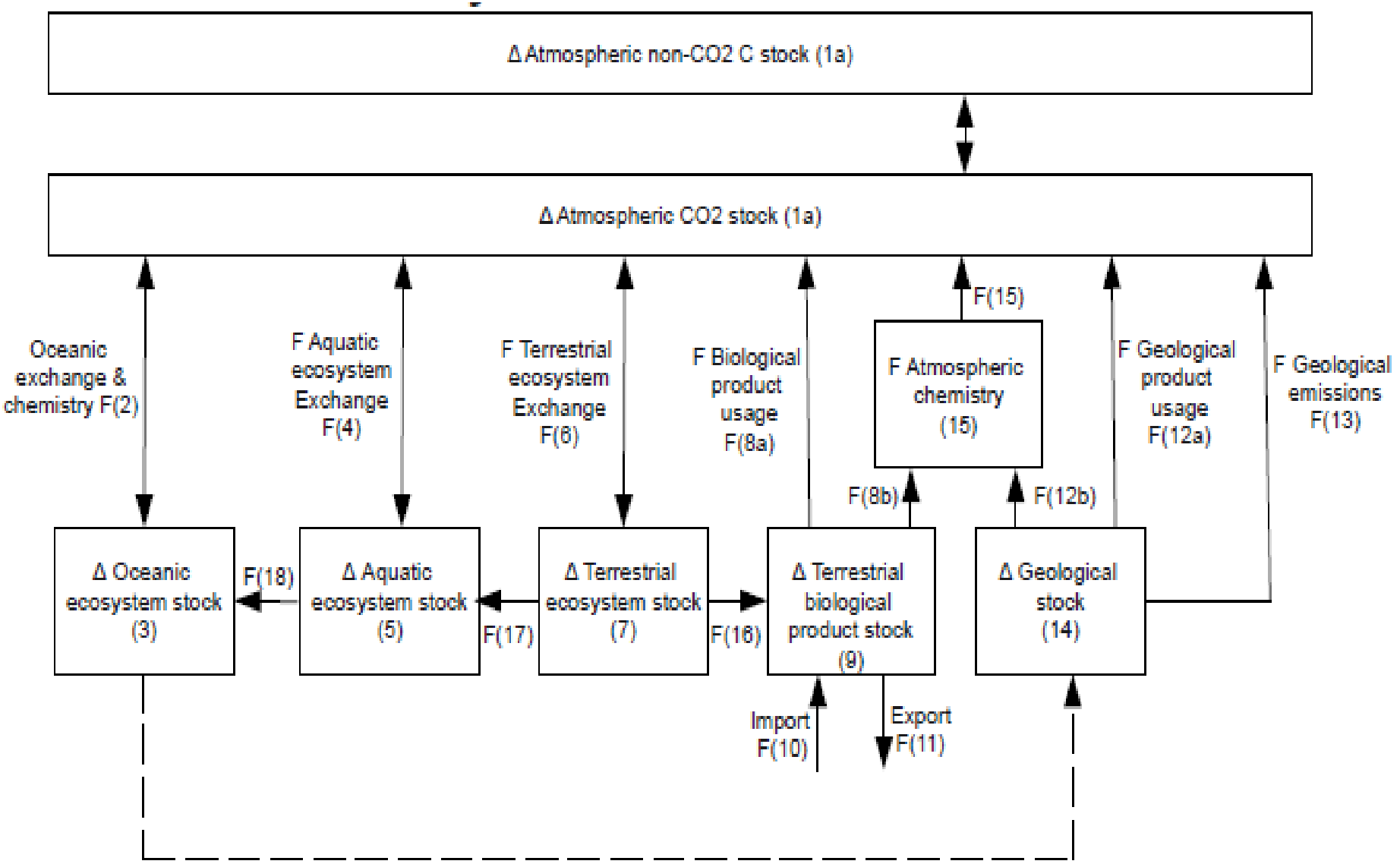
- To establish the mean carbon balance of large regions of the globe at the scale of continents and large ocean basins, including their component fluxes.
- To do it by comparing and reconciling multiple bottom-up estimates with the results of regional top-down atmospheric inversions, with attribution to main flux components.
- To evaluate the regional ‘hot-spots’ of interannual variability and possibly the trends and underlying processes over the past two (or more) decades by combining available long-term observations and modeling.

Principle of RECCAP

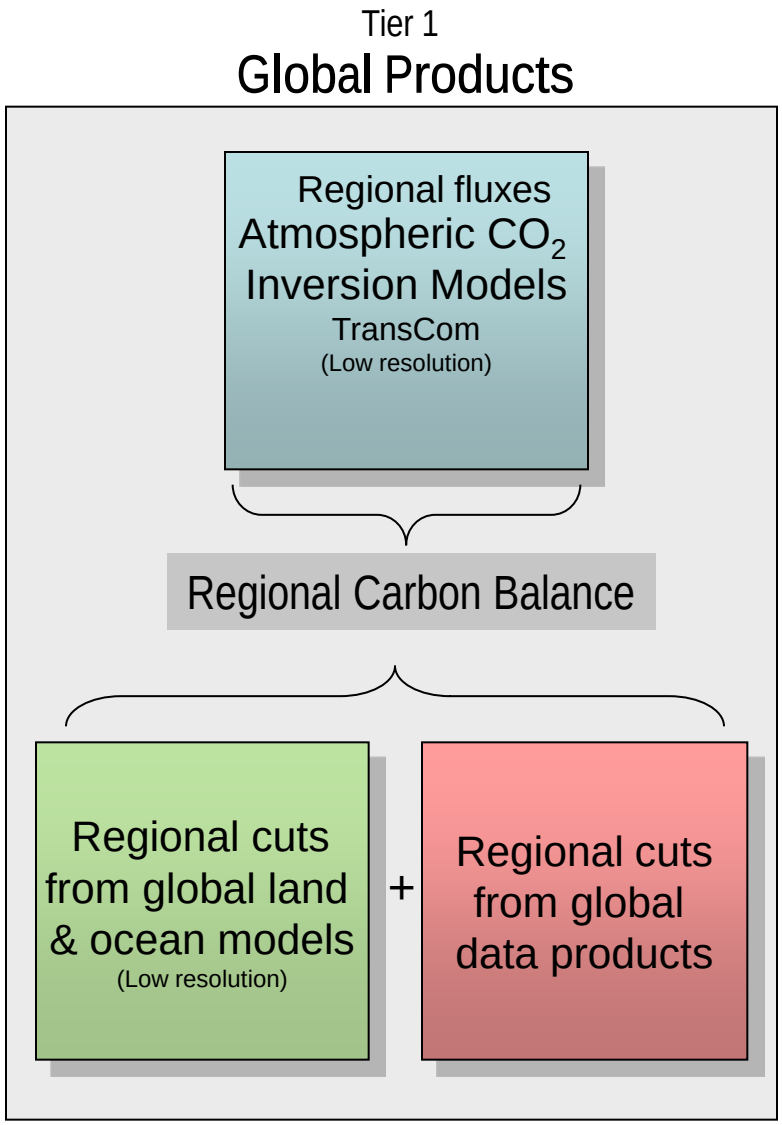
Multiple Constraints to Understand One Carbon Budget



The Carbon Cycle – Mass Balance Closure



Components of Regional Syntheses



Tier 1 model outputs are coordinated by RECCAP

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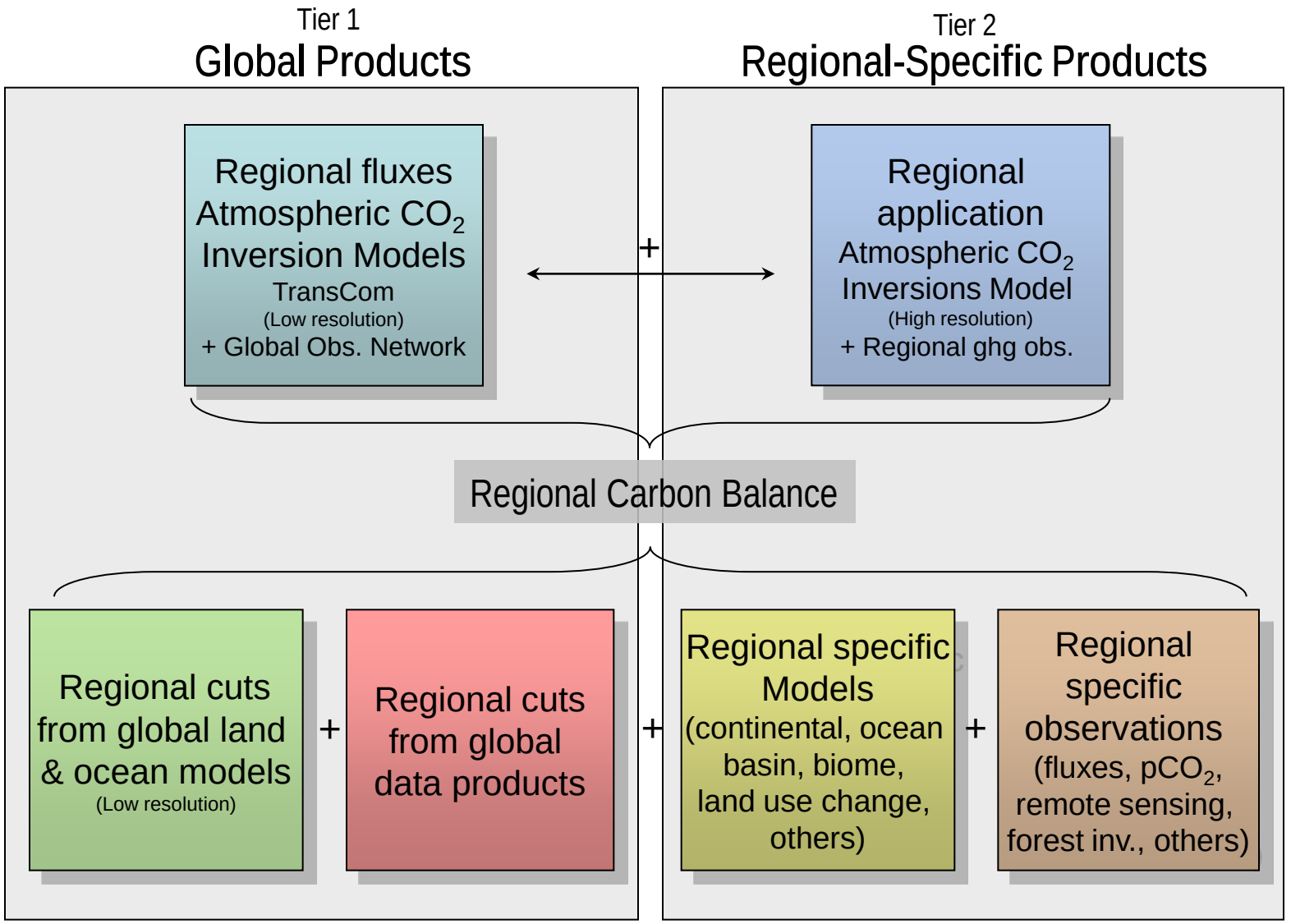

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Synthesis Approach

Top-down Bottom-up

- *Reconciliation of flux estimates* (independently assessed and often partially overlapping) as a means to build confidence in our understanding of the component fluxes, mean estimates, and inter-annual variability.

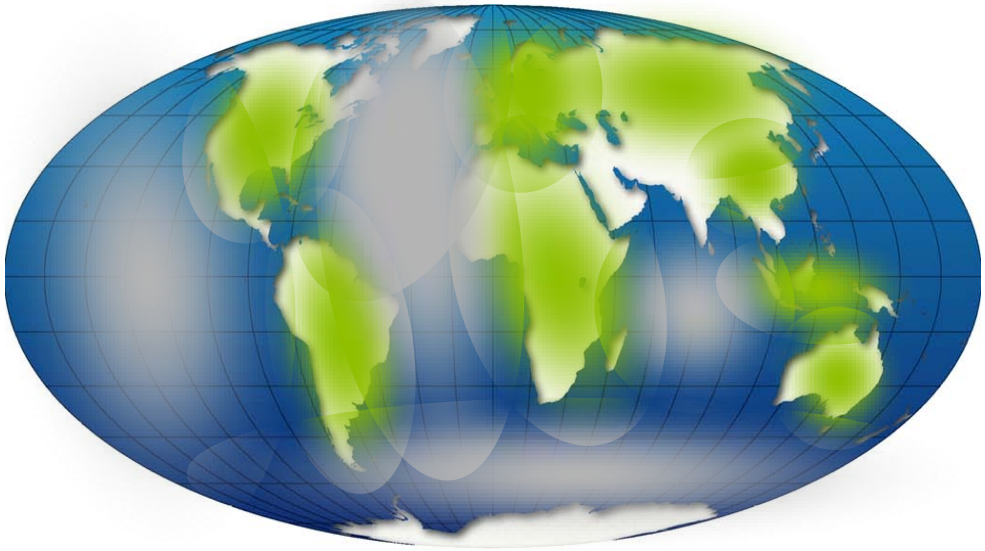
- Although we are ultimately interested in building a mathematically-formalized multiple constraint approach, model data fusion or data assimilation (eg, like in weather and hydrological forecast), we are not pursuing this approach in a first phase.

- Uncertainties need to be quantitatively estimated.

Global Tier 1 Products

- 10 Atmospheric CO_2 inversions
- 5 Ocean forward models
- 1 Ocean inversion
- 7 Terrestrial models (DGVMs)
- 1 NEP-flux empirical model
- 1 Fire emissions product
- 1 Land use change emissions
- 1 Rivers fluxes to oceans
- 1 Embedded fluxes in international trade

RECCAP (2007-2012)



Which GHGs?

Species:

- *Minimum requirement*: CO_2
- *Additiona*l: CH_4 (N_2O, others)

Spatially explicit:

- *Minimum requirement*: Biological fluxes of CO_2 (CH_4, N_2O, others)
- *Additional*: Fossil Fuel emissions

RECCAP Period

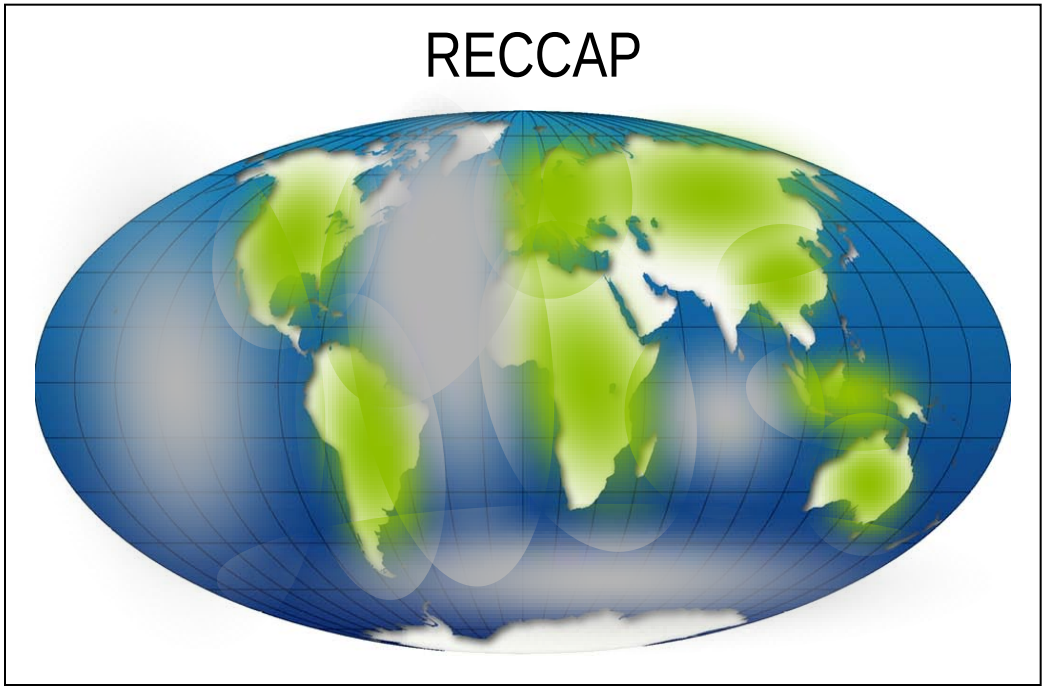
Variable but centered around:

- Budget period:
  - 1990-2009
- Trend analyses:
  - Land: 1958-2009
  - Ocean: 1983-2009

Land and Ocean Regional Syntheses

Land

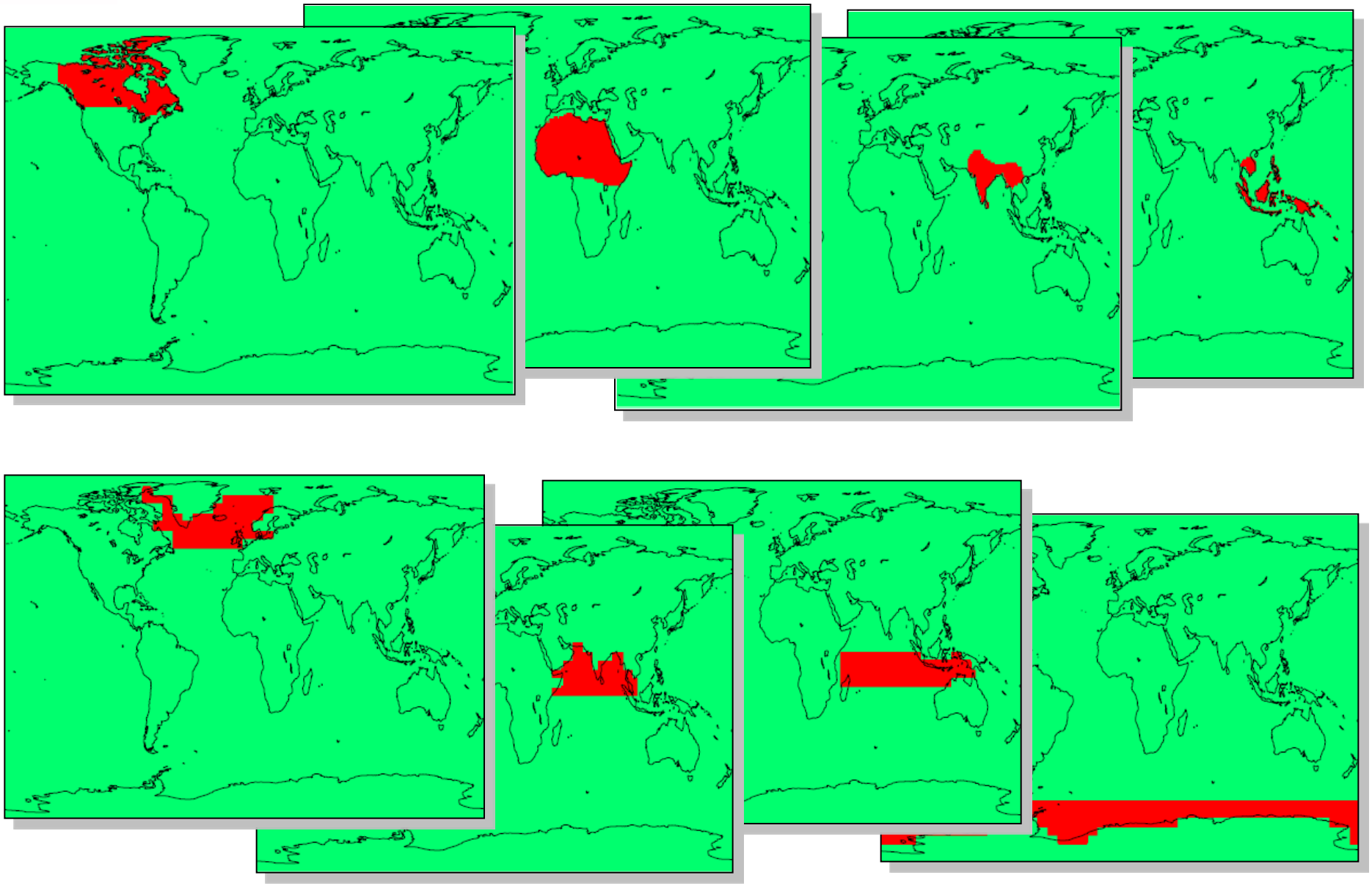
L1	Africa
L2	Arctic tundra
L3	Australia
L4	Europe
L5	North America
L6	Russia
L7	South America
L8	East Asia
L9	South Asia
L10	Southeast Asia



Oceans

O2	Pacific
O3	Atlantic and Arctic
O4	Southern Ocean
O5	Indian

Regional Masks

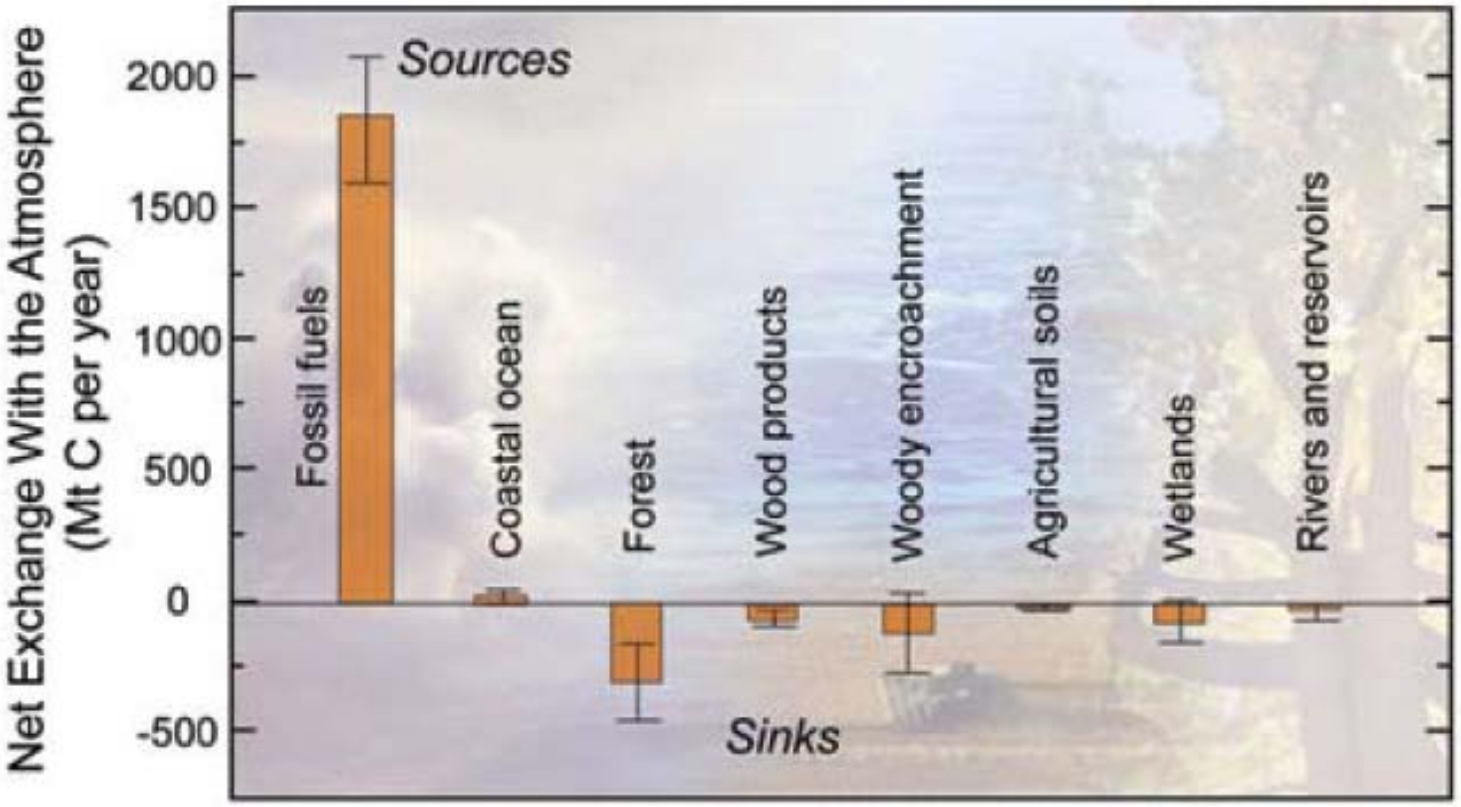


GHG Balance of Europe

b) Land-based fluxes		Continental Europe		
		Area (million km²)	Flux (Tg C yr⁻¹)	Uncertainty (Tg C yr⁻¹)
	Ecosystem CO_2 fluxes			
16.	Forest biomass	3.39	−157	27#
17.	Forest soil		−47	8#
18.	Other wooded land	0.50	−16	8
19.	Grassland	1.51	−85	12#
20.	Cropland ††	3.26	33	6#
21.	Peat undisturbed	0.39	−7	4
22.	Peat drained	0.16	24	12
23.	Subtotal	9.21	−255	35
	Additional CO_2 fluxes			
24.	Land-use change‡‡		−60	30
25.	Carbon trade balance		20	3
26.	Carbon export by rivers to ocean		−26	9
27.	Peat extracted		50	9
28.	Fossil fuel agriculture§§		36	18
29.	Subtotal		20	37
	Biological GHG fluxes			
30.	CH_4 agriculture*,‖		67	34
31.	CH_4 wetlands*		35	18
32.	CH_4 oxidation*		−7	3
33.	N_2O agriculture*,‖		97	49
34.	Subtotal		192	61

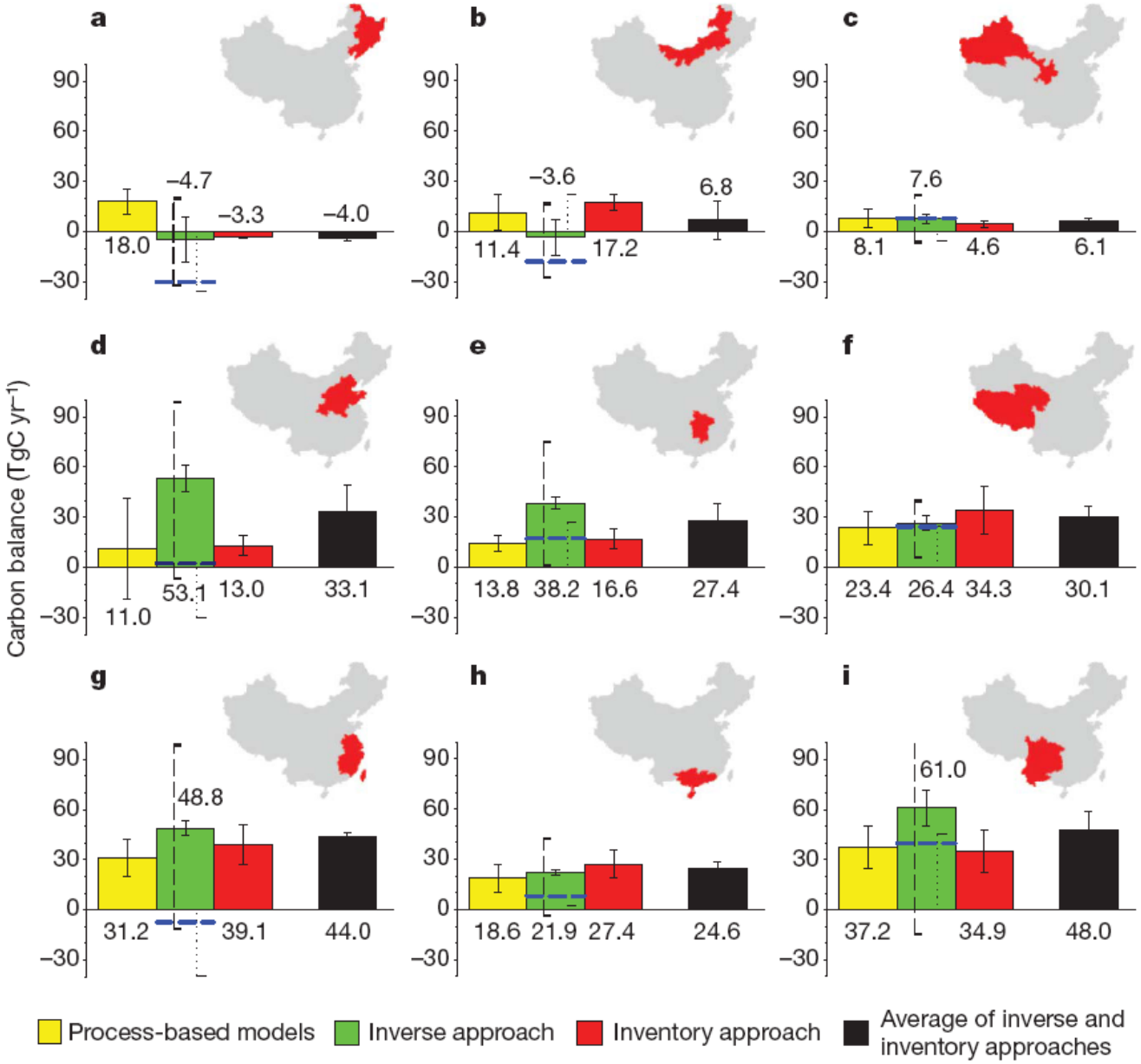
Schulze et al 2009, Nature Geosciences

Carbon Balance of North America



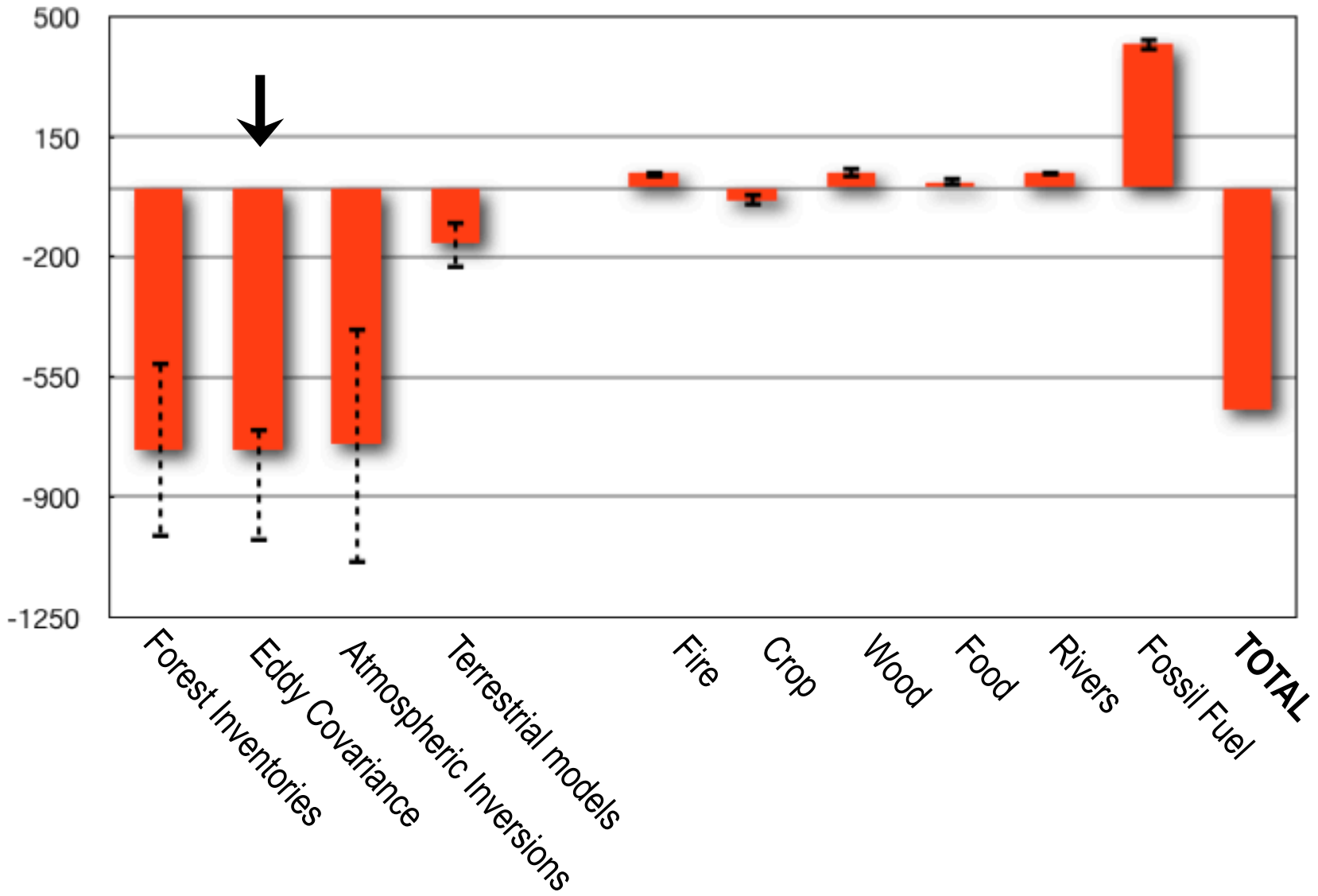
NACP 2008

Carbon Balance of China



Piao et al. 2009, Nature

Mean Carbon Budget of Russia (1990-2009)

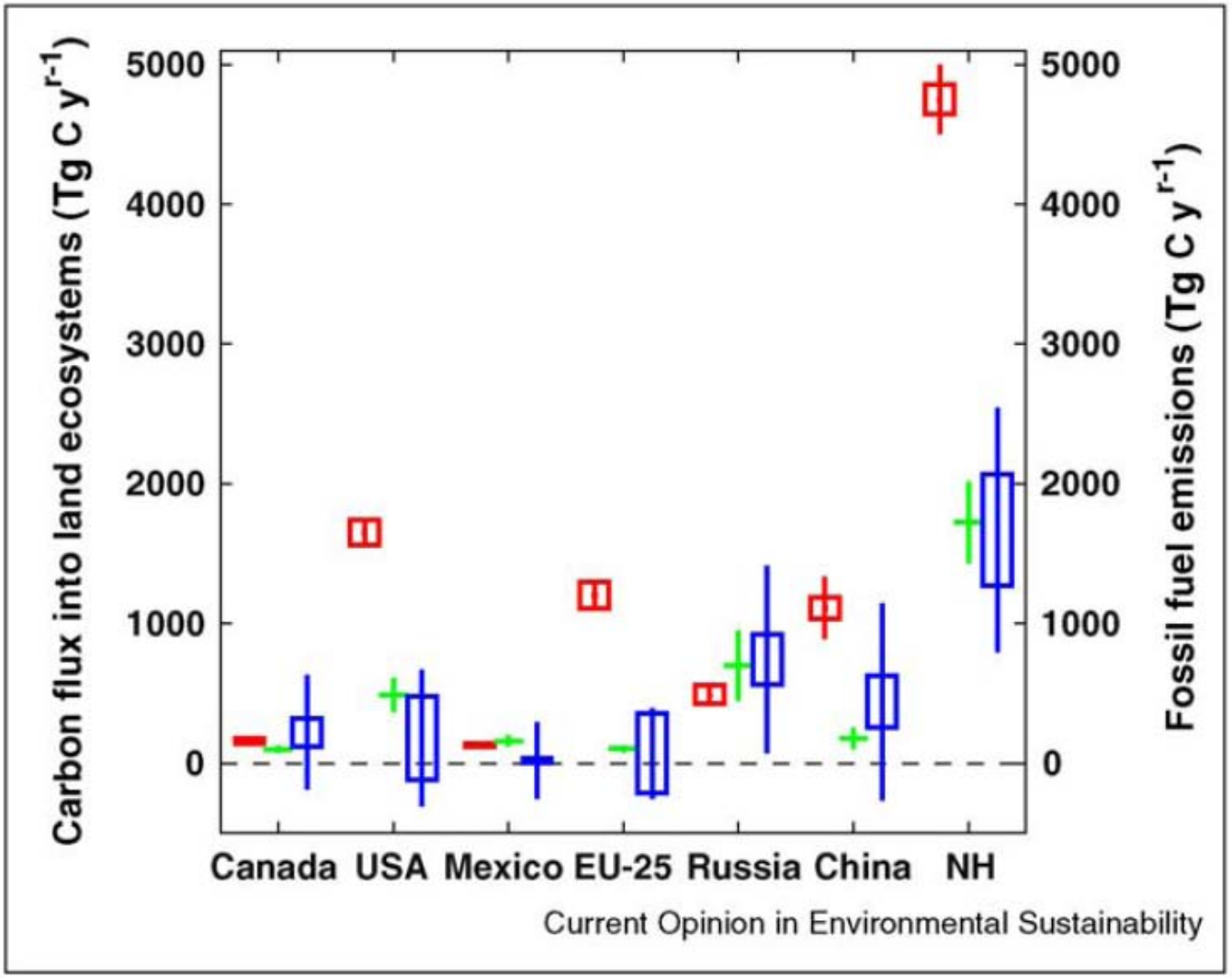


Han Dolman, unpublished, 2011

Northern Hemisphere Carbon Sink

Top down
1.7±0.9 PgC yr

Bottom up
1.7 0.3 PgC yr

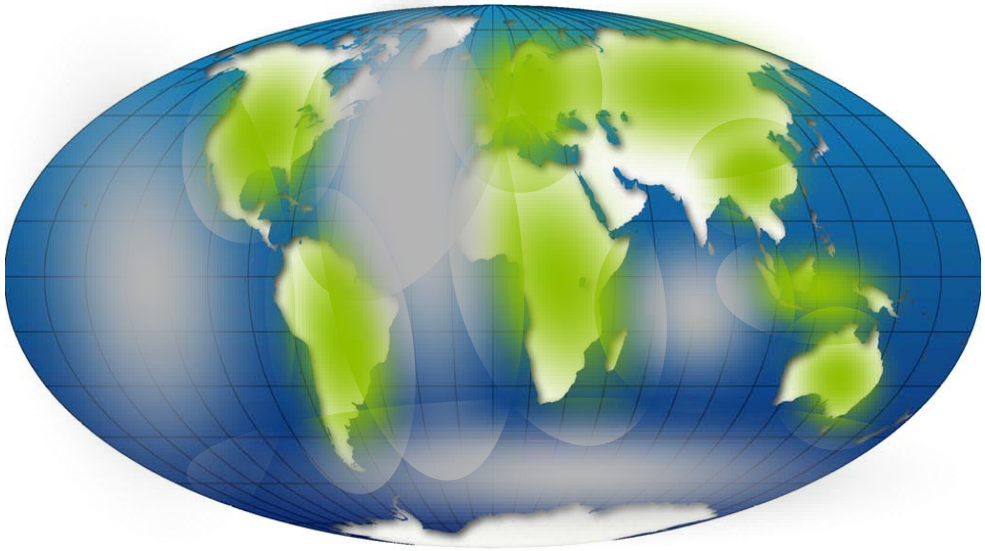


Ciais et al. 2011, COSUST

Global Assessments

- Fossil fuel emissions
- Land use change emissions
- Global atmospheric budget
- Global ocean surface CO_2
- Global ocean storage
- Coastal Ocean

RECCAP (2008-2011)



- Rivers fluxes
- Embedded fluxes in international trade

Global Syntheses of Syntheses

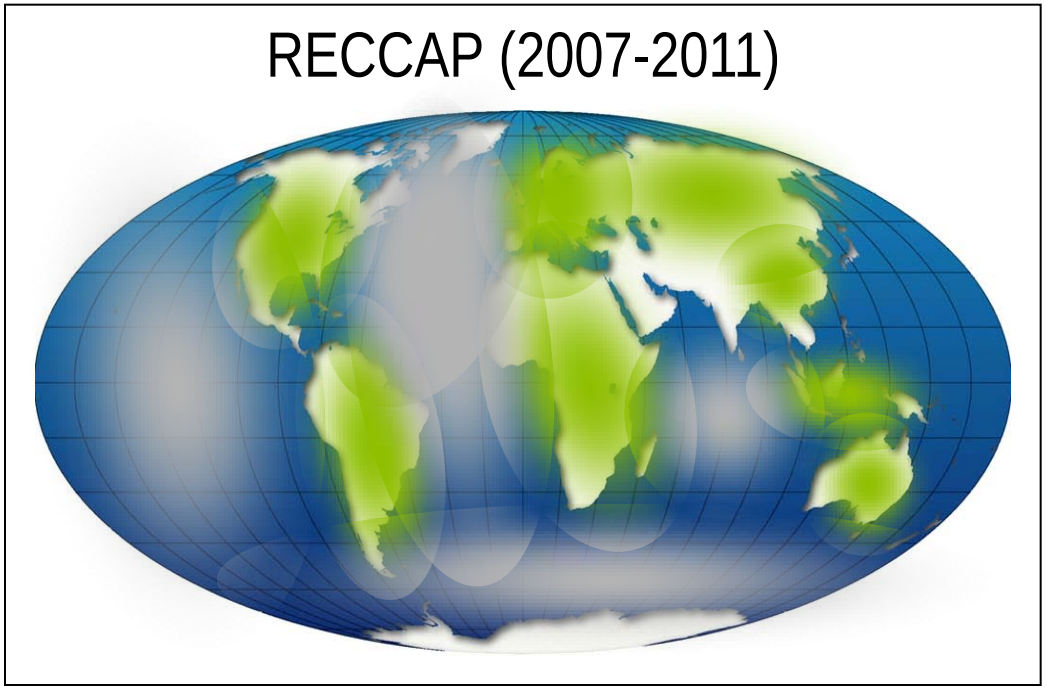
Ch-S1 Comparison of top & bottom up

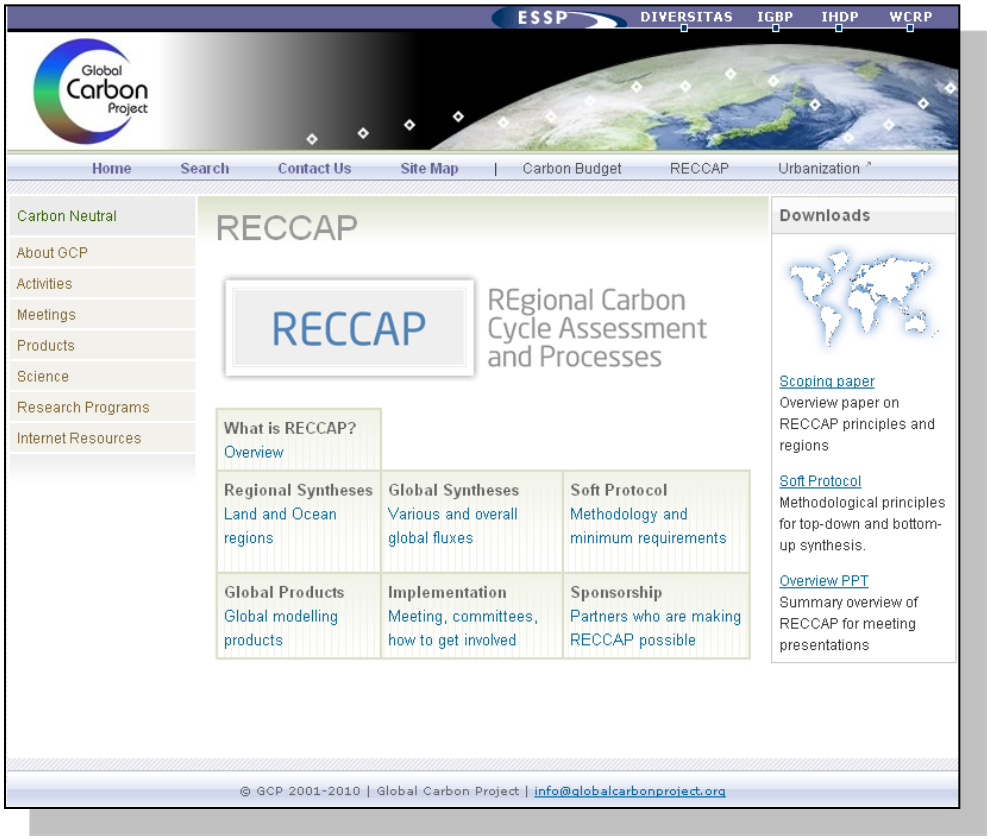
Ch-S2 Inter-annual var. region.

Ch-S3 Attribution to regional processes

Ch-S4 Past and future trends in regional C budgets

Ch-S5 Final recommendations





www.globalcarbonproject.org/RECCAP