

Review

King et al: North America's net terrestrial carbon exchange with the atmosphere 1990 – 2009

Biogeosciences – Discussions

I think it is great that this synthesis of the North American CO₂-exchange has been completed. It closes an important and final gap in the RECCAP-approach by presenting the ranges of estimates and discussing the causes for differences between estimates. I strongly recommend that this paper must be published, despite all uncertainties.

There are a few comments and questions to the authors, which may improve the paper

Title:

I think you may replace carbon by Carbon dioxide, because you do not include Methane

Abstract:

Line 9: North America: it would be nice to give the geographic boundaries, also in the text. Later you refer to TranCom3, but I bet, most potential readers not even know what TransCom is. I guess, Mexico includes the tropical southern part up to the boarder of Guatemala. Canada includes the arctic up to the Arctic Ocean? Is Greenland part of North America?

Also, the abstract should include a quantification of the total area, and its components of countries and land-use. Maybe you need a separate table in the methods.

Line 19: Presenting a ratio for source/sink is unfair. I think, at the least, you must present the numbers on which these ratios are based. I would request that instead of writing 4:1 you write 2000:500 or something like this.

The abstract should also make clear, that this is a CO₂ balance and not a carbon balance, because it does not include methane. Also, N₂O was not considered, and we know from Europe, that the GHG-balance changed the CO₂-sink into a GHG source.

The abstract should mention also, that trade, fire, and arid regions are included as variable fraction of each model (as far as I understand)

Introduction

I am missing some aspects in the introduction:

- it must be mentioned that CH₄ and N₂O (and other GHGs such as NO and CO) are not included. This balance refers to CO₂ only (including oxidation of methane in the atmospheric approach, which is important in view of fracking)

- The introduction should refer to the Global Carbon Project map (2013) which depicts North America and China as the main emitter world wide.

- The introduction should mention that the present analysis focuses on forests and croplands only, neglecting grazing lands, arid land and tundra for the land-based approaches. This is important in view of the recent publication by Poulter (Nature 2014), which shows that the arid lands (of the southern Hemisphere) cause the variability over time of the global terrestrial sink. Neglecting the arid lands in the land-based approaches, but including them in the atmosphere based approaches may lead to an important bias, because the effects of ElNino are clearly visible in North America.

Methods

I thank the authors that they try to clearly indicate the inclusions and exclusions of fluxes to the different methodologies, and maybe one could think of a cartoon to make this even clearer. Basically, not the length of the observation period (see discussion), but the differences in including or excluding different component fluxes, cause the numbers to be different.

Page 11031

Line 11 fossil fuel emission: I think you should include a paragraph on fossil fuel emissions, including methane burning (does methane include bio-generated methane, and diesel, and gasoline, which is 10% (?) of the energy burning?). CO₂ does include oxidation of Methane, even if it came from fossil sources (fracking), and this contribution has increased in the last decade.

You may have to discuss whether an annual budget (Table 3) or a more refined fossil fuel emission model is needed (Ciais, *Global Change Biology* 2010). Since the atmospheric model runs (I assume) on a 30-minute time scale, a bias may occur with respect subtracting fossil fuel emissions on an annual scale. I think the same bias is true for the TBMs.

I also think a consideration must be made to point sources of power plants as well as of large cities. There were several very important US-based publications since 1990 on this topic.

Line 11: Trade of grain, wood and fiber emerges in each of the models

All approaches are affected by trade of biomass (grain, fiber, wood), and it would be nice to know, which components are included, and the magnitude of these fluxes. I may refer to Ciais et al (2008) *Biogeosciences* 5, 1259ff. I mention this, because there are differences between countries. As far as I know, most state forests are not managed in the US, but the US imports most of its construction wood (as saw wood), Canada exports round wood to China.

Line 11: Sorry for another methods section: Fire and diseases

You basically exclude fire except for AIMs, but fire and insects changed Canadian forest from a sink into a source (Kurz et al). I think, you need to state the total area burnt in the TransCOM region. Also, it would be nice to know, how much area was affected by forest diseases in this period (Mountain Pine beetle, Gypsy Moth and others). These areas are now re-growths, and contribute to the land-based sink more than if these outbreaks would not happened?

Page 11032,

line 1: I think it would be fair to refer to *NatureGeoscience* Vol 2, 842ff (2009), where the top-down and bottom-up approach was used for the first time, and where the definition of fluxes were clearly depicted. Maybe, extending this flux scheme would help to clarify the differences in the approaches, which are discussed in the following.

Line 1: I think, you need to clearly say, that all numbers, also the atmospheric numbers, do NOT include fossil fuel emissions

Line 4: I bet, most readers do not even know of TransCom. I think you must give the borders of the region, and the areas and the land-use

Surely, I do not want to be prescriptive, but for clarity in the RECCAP environment, it could help, to include a cartoon, such as the flux bar of Figure 2 of the *NatureGeoscience* (2009) publication, to show, which fluxes are covered by AIMs (and by the other approaches).

Page 11032

Line 21: I think you have to add wood imports, and cop exports to your list

Page 11033

Line 7: It is not only fire but also Insect outbreaks

Line 8: Trade needs to be mentioned.

I also think, that it must be stated, that the TBMs ignore CH₄ from Range lands (Cattle) and N₂O from agriculture and Soy bean plantations.

Line 17: It would help the reader, if a cartoon would illustrate the fluxes which are included and which are neglected in the TBMs

Line 18: Inventory based approach: In Table 4, you are dealing with n=4 taking the two inventory-based approaches as independent estimates. I suggest that you separate these two approaches already in the methods. Right now, you have 13 lines to present AIMS, but you take 4 full pages to discuss the inventory based approach. To my knowledge, this is the first time, that these two approaches are discussed to this detail, and I think, it would make the paper even stronger if you would capture this in different titles.

Page 11034

Line 1 and 22: The inventory approach excludes trade. You need to say this.

Page 11036:

Line 6: I think you have to repeat in the brackets that exports are small for Canada only. I am not even sure about this. Canada is a big exporter of grain to the whole world, but also of round wood to China, and of wood pellets to Europe. (See IPCC special report on renewable energy).

Line 6: You may have to separate Canada from the US by a paragraph. The situation is different from Canada in the US. To my knowledge, you export grain and methanol and bio-diesel, and you import saw wood, because you do not manage your state forests. This is a big bias in the source-sink discussion. Your forests are sinks because of no harvest. I am not sure, if my generalization (based on IPCC) is true, but it needs clarification. E.g. how much of the US forest area is under forest management harvesting wood?

Page 11037

Line 6 and 16: I think you need to discuss the role of arid lands (and range land). How much area are they (including Mexico). These lands respond heavily to rain, which would be seen by AIMS but not by your inventory approach. Again a flux cartoon would help to make clear, what the limitations are.

Line 27: I thought that the Monte Carlo permutations were the state of the art for estimating the confidence limits (e.g. Global Change Biology 16, 1462, 2010).

Page 11038:

Line 10: I think you miss out on the inter-annual variability because you exclude range land and arid lands.

Page 11039:

Line 6: I guess the AIMS are corrected for fossil fuel?

Line 9 to 13: I think this is a bit too much “hand-waving”. First, you need to align the two approaches with respect to trade. AIMS includes trade, TBMs not? Second, The TBMS may be totally driven by arid lands, which you excluded, and by increasing irrigation in croplands (how much did irrigated land increase since 1990?). In fact, I think the area of crop-land

increased in the US since 1990? This points at the necessity to quantify the change in land-use since 1990 (crops, rangeland, forest, protection)

Line 29: The figure legend depicted inside the box of Fig 2 is not clear. “sum of all countries” means “global emissions”. At the first glance I thought that this is the sum of North America. What is the dashed line?

Page 11040

Line 3 and 10: I think it is unfair to hide behind China. This is a fairly recent event. The US was number 1 in the 1990ies. Maybe you refer to the Global Carbon Project map

Line 17: I do not agree with the statement that the uncertainties are due to the short record. The reasons, as stated in the methods, are clearly the differences in including some fluxes in AIMS and others in TBMs (trade, fire, insects, Methane conversion, arid regions, and others). I think it would be nice, if you could honestly state, that despite 20 yrs of work, the associated industrial fluxes remain obscure, and that more emphasis should be given to range lands (cattle) and arid lands (not only in North America!!!!).

Page 11041:

Line 4: But Canada changed to be a source due to fires and diseases (Kurz). I cannot believe this sentence.

Page 11042:

Line 21: I think the Canadian situation needs to be discussed. Kurz published an important paper that Canada changed from a sink to a source.

Also, the effects of ElNino on arid lands needs to be discussed in view of the recent Nature publication (Poulter et al).

Line 22 to page 11043 line 10: It is extremely reader-unfriendly and un-transparent to present these ratios, but hiding the quantitative numbers. I think, the information is needed, but not as a minimum fraction. You need to present real emission numbers.

Page 11043:

Line 16: see above. I think, there was enough time, but the anthropogenic fluxes remain unclear, and the models “see” different components of the anthropogenic part.

Line 29: Please add arid lands to grasslands, and maybe, the better term would be “rangelands” because an Artemisia steppe is not a grassland.

Page 11044, line 10: Again, you should mention the gap: Trade

Thanks to the authors for this stimulating paper. It could get a milestone in the discussion on what we are missing, rather on a plea for longer measuring sequences (which are also needed).

Detlef Schulze