Overall statements

The manuscript ”Air-water CO2 evasion from U.S. East Coast estuaries” by Goossens, N., Gildas, L.G., Arndt, S., Regnier, P. gives valuable estimates on the main biogeochemical fluxes of the estuaries along the US east coast. The authors model 43 tidal estuaries and subdivide the results into 3 different latitudinal zones showing distinct differences which appear reasonable. The problem is that the reader has to accept these “black box results” even though all the details of the different estuaries should be available. I will pinpoint the problems and possible ways to resolve them:

We are grateful for the reviewer’s evaluation and the constructive suggestions provided. We understand that the reviewer is mainly concerned about an apparent ‘lack of transparency’, as well as a seemingly weak validation of the model within the study area. Following the reviewer’s recommendations, we thus substantially modified the manuscript to respond to these concerns. More specifically, we added a comparison between model-predicted annual CO_2 outgassing fluxes and 13 published flux estimates, derived from direct measurements in local estuaries to section 2.6 (Model-data comparison). In addition, we also provide new validations of the hydrodynamic and biogeochemical model (section 2.6). Furthermore, we introduced a new section (section 3.4), which critically discusses the scope of applicability and model limitations.

Please find bellow a detailed answer to each comment. All our answers are written in blue and the modifications within the text are highlighted in bold and italic. In the revised manuscript, changes are tracked via Word’s track changes tool.

On behalf of all co-authors,

Goulven Laruelle

* The data preparation for the 43 estuaries is not transparent and reproducible. Please prepare a table in which all details for each estuary are inserted (like Volta et al., 2016a, Tab. 1). If this table appears too large, put it into the Appendix (supplemental data).

In the revised manuscript, we now provide 5 additional, extensive tables as supplementary information, which summarize all key parameters and boundary conditions required to perform the simulations. In addition to table SI1, which already provided the estuarine surface areas, as well as fresh water discharge fluxes for all systems and seasons, these new tables provide:

Table SI2: Geometric properties of the estuary (i.e. length, width at both boundaries, depth and convergence length)

Table SI3: Upstream boundary conditions for nutrients and chlorophyll concentrations

Table SI4: Downstream boundary conditions for nutrients and chlorophyll concentrations

Table SI5: Upstream boundary conditions for the organic carbon and carbonate system (i.e. TOC, DIC, pH…)

Table SI6: Downstream boundary conditions for the organic carbon and carbonate system (i.e. TOC, DIC, pH…)

Please use lat/lon positions of the mouth and estuary names if possible.

As requested, latitudes and longitudes, as well as the names of the largest rivers are provided for each estuary in all aforementioned tables. In addition, within the main text, we now make reference, whenever possible, to the name and coordinates of the estuaries that are being discussed.

* The validation chapter only refers to applications elsewhere. Please validate the model for at least one estuary in each latitudinal zone like Volta et al., 2016a did it for some North Sea estuaries.

The general performance of C-GEM in reproducing and predicting estuarine hydrodynamics and biogeochemical cycling has been extensively tested across a large range of different estuarine systems (e.g. Volta et al., 2014, 2016, see also Savenije 2001 for the estuarine physics). Here, we extended these tests by a number of local model-data comparisons. We added a new comparison between model-predicted annual CO_2 outgassing fluxes and 13 published flux estimates, derived from direct local measurements to section 2.6 (Table 1). In addition, we also evaluated the performance of the hydrodynamic model by comparing simulation results with seasonal, longitudinal salinity profiles in the Delaware Bay. Furthermore, the performance of the biogeochemical model is critically evaluated by comparing simulation results with longitudinal profiles of pCO_2 and pH, in the Delaware Bay and the Altamaha River estuary. These additional model-data comparisons reveal that C-GEM is able to reproduce local measurements of pCO_2 (Delaware Bay), as well as longitudinal pH and pCO_2 profiles (Altamaha). Following what was done in Volta et al. (2016) with the Scheldt and the Elbe in Europe, the choice of using the Delaware Bay and the Altamaha river estuary was motivated by their contrasting geometries: The Delaware Bay is a marine dominated system characterized by a pronounced funnel shape while the Altamaha River ends with a very prismatic estuary characteristic of river dominated systems (Jiang et al., 2008). Thus, selecting these two end-members estuaries reveals the ability of C-GEM to simulate widely differing estuarine dynamics. Although we agree that performing a simulation on a system located in the Northern region would be a valuable addition, we could not find suitable a suitable set of observed nutrient and carbon boundary conditions and their corresponding longitudinal profiles. Note, however, that several flux values reported in Table 1 refer to estuaries located in this region. Finally, within the new section 3.4 (Scope of applicability and model limitations), we critically discuss the difficulties associated with 'validating' regional/global model simulations with a limited set of local, instantaneous observations, as well as the uncertainties that arise from the proposed model approach.

See updated manuscript

* You used some arguable boundary conditions and forcing functions: The Alkalinity near the mouth, DIC and Alkalinity from GLORICH positions closest to the river boundary or older discharge estimates. I know that it is difficult to put this all together in a reasonable way. But the reader should get knowledge about the sensitivities of the model in relation to estimates of boundary or forcing data. Please show how the model reacts on changes in these data. In the detailed statements I will show in which context such studies should be done.

As pointed out by the reviewer, designing realistic and consistent boundary conditions is a critical step in model set-up. In the present study, this task is further complicated by the necessity to find complete sets of boundary conditions for 43 tidal systems located along the eastern coast of the US. C-GEM was specifically designed with this difficulty in mind. Some of the strengths of the model are its comparatively modest data requirement and its transferability from one estuarine system to another, which has already been demonstrated on the estuaries surrounding the North Sea (Volta et al., 2016). C-GEM is also well suited to be operated in conjunction with global databases such as GlobalNEWS (Mayorga et al., 2010) because they share in common the watershed as their fundamental unit , which is essentially what was done in this study. We agree with the reviewer that some of the assumptions and choices of data sources could be better justified and critically discussed in the manuscript. We thus carefully addressed all concerns raised in the answers to the detailed statements of the reviewer. In addition, we also added an entire new section to the manuscript ('Scope of applicability and model limitations') that summarizes the strengths and weaknesses of our regional model approach.

As different input parameters are means over several years, the time span of validity of the results should be defined.

In the present study, simulations are representative for the year 2000 because some the largest datasets we rely on to constrain boundary conditions or forcings (e.g. GlobalNEWS) are derived from models calibrated for that year. As a consequence, additional data used to constrain boundary conditions and forcing parameters was selected from the same time span. In the revised manuscript, we added a few sentences justifying our data choice and specifying the time period for which simulation results are representative. In addition, we also specify if boundary conditions/forcings are constrained on the basis of punctual measurements or averages of several years.

The introduction reads rather as an advertising text. Give, for example, details about the structure of the ms. A question, which could be tackled, is whether global models miss estuarine processes (Line 39).

In the previous version of our introduction, we tried to emphasize the originality and the potential of our modelling approach. We felt that it was important to stress the novelty of the approach developed here: an explicit simulation of seasonal carbon transformations and fluxes along the land-ocean continuum at a regional scale. This work builds on the study of Volta et al. (2016) which provided the first annually average estimates of estuarine carbon transformations and fluxes focusing on the estuaries surrounding the North Sea. However, we agree with the reviewer that the proportion of the introduction dedicated to the presentation of C-GEM was too long and sometime superfluous. Following the reviewer's advice, we shortened the introduction and emphasized the research questions that can be tackled with the presented model approach. We also provided a better overview of the structure of the manuscript and the studied area. Furthermore, we followed the reviewer's suggestion and shortly discuss the ability of global carbon cycle models to account for the influence of the estuarine modulator.

“Carbon fluxes along the land-ocean aquatic continuum are currently receiving increasing attention because of their recently recognized role in the global carbon cycle and anthropogenic CO_2 budget (Bauer et al., 2013; Regnier et al., 2013a; LeQuéré et al., 2014, 2015). Estuaries are important reactive conduits along this continuum, which links the terrestrial and marine global carbon cycles (Cai, 2011). Large amounts of terrestrial carbon transit through these systems, where they mix with carbon from autochthonous, as well as marine sources. During estuarine transit, heterotrophic processes degrade a fraction of the allochthonous and autochthonous organic carbon inputs, supporting a potentially significant, yet poorly quantified CO_2 evasion flux to the atmosphere. Recent estimates suggest that 0.15-0.25 PgC yr^{-1} is emitted from estuarine systems worldwide (Borges and Abril, 2012; Cai, 2011; Laruelle et al., 2010; Regnier et al., 2013a; Laruelle et al., 2013, Bauer et al., 2013). Thus, in absolute terms the global estuarine CO_2 evasion corresponds to about 15% of the open ocean CO_2 uptake despite the much smaller total surface area.

Currently, estimates of global estuarine CO_2 emissions are mainly derived on the basis of data-driven approaches that rely on the extrapolation of local measurements (Cai, 2011; Chen et al., 2013; Laruelle et al., 2013). While these approaches provide useful first-order estimates, they fail to capture the spatial and temporal heterogeneity of the estuarine environment (Bauer et al., 2013). In addition, these global estimates are biased towards anthropogenically influenced estuarine systems located in industrialized countries (Regnier et al., 2013a). ~~. Furthermore, observation-based approaches~~ ***and*** do not provide insights into the complex and dynamic interplay of biogeochemical and physical processes that controls estuarine CO_2 fluxes. ~~In this respect, integrated model-data approaches provide a suitable alternative.~~ ***However,*** reaction transport models (RTMs) allow, in conjunction with data, the investigation of the estuarine response over the entire spectrum of fluctuating forcing conditions, including the long-term effect of land-use and climate changes (Bauer et al., 2013; Paerl et al., 2006; Thieu et al., 2010). In addition, RTMs can fully resolve the dynamic interplay of transport and transformation processes that control CO_2 fluxes across the entire estuarine gradient and at a high temporal and spatial resolution (Arndt et al., 2009; Arndt et al., 2011; Vanderborght et al., 2002; Volta et al., 2014). ~~Integrated model-data approaches thus have the potential to significantly advance our mechanistic and quantitative understanding of global estuarine CO_2 fluxes, as well as their response to global change.~~ ~~RTMs~~ ***Such models*** have recently been successfully applied to quantify system-wide, integrated biogeochemical indicators, such as Net Ecosystem Metabolism (Volta et al., 2014), carbon and nutrients budgets (Soetaert and Herman, 1995; Vanderborght et al., 2002; Billen et al., 2009; Laruelle et al., 2009) or nutrient filtering capacities (Arndt et al., 2009). To our knowledge, however, published modeling studies dedicated to quantifying estuarine CO_2 dynamics remain limited to the Scheldt estuary in Belgium-The Netherlands (Hofmann et al., 2008; Vanderborght et al., 2002) and to the Elbe in Germany (Volta et al., 2016a). Recently, Regnier et al., (2013b) quantified the contribution of different biogeochemical processes for CO_2 air-water fluxes in an idealized, funnel-shaped estuary forced by typical summer conditions characterizing a temperate Western European climate. Volta et al. (2016b) further investigated the effect of estuarine geometry on the CO_2 outgassing using three idealized systems. ***The Carbon Generic Estuarine Model (C-GEM, Volta et al., 2014) used for these studies can be applied to any temperate tidal estuary with little data demand.*** Using ***C-GEM*** ~~a similar approach~~, Volta et al. (2016a) established the first regional carbon budget for estuaries surrounding the North Sea by explicitly simulating the six largest systems of the area. Yet, local and regional quantifications of estuarine CO_2 fluxes using such an integrated data-RTM approach remain extremely limited and a RTM-based global quantification of estuarine CO_2 fluxes is currently lacking. ***The global quantification of the estuarine filter thus remains ignored in modelling efforts because terrestrial models representing the river network typically do not account for the estuaries (i.e. GLOBALNEWS: Seitzinger et al., 2005; Mayorga et al., 2010; SPARROW: Schwarz et al., 2006) and the spatial resolution of most continental shelf models not do yet allow representing estuaries other than the largest ones (Hofmann et al., 2011).***

~~The lack of regional or global evaluations of the estuarine carbon dynamics can be partly explained by the high computational costs of RTM simulations. In addition, significant data requirements, such as comprehensive bathymetric and geometric information and boundary conditions may further limit the applicability of RTMs on a regional or global scale, while the need for benchmarking on a number of extensively surveyed, representative systems provides additional constraints. In attempt to overcome these constraints, the Carbon-Generic Estuary Model (C-GEM; Volta et al., 2014) has been developed with the aim of enabling the quantification of biogeochemical dynamics in estuaries on a regional and global scale. The focus is on tidal systems as defined by Dürr et al. (2011) and the approach is based on a one-dimensional, time-dependent representation of hydrodynamic, transport and reaction processes within an estuary. C-GEM is computationally efficient and reduces data requirements by using an idealized representation of the geometry to support the hydrodynamic calculations and, subsequently, transport and biogeochemical reaction processes. The C-GEM modeling platform thus enables hundreds to thousands of steady state or fully transient simulations spanning years to decades for a multitude of estuarine systems, using geometric information readily available through maps or remote sensing images. Despite the geometric simplification, C-GEM resolves the most important temporal and spatial scales characterizing the estuarine dynamics and provides an accurate description of the hydrodynamics, transport and biogeochemistry in tidal estuaries (Volta et al., 2014).~~

Here, an extended version of C-GEM (v1.0) is applied to quantify CO_2 exchange fluxes, as well as the overall organic and inorganic carbon budgets for the full suite of estuarine systems located along the entire East coast of the United States. The applied RTM approach allows to evaluate the relative significance of different physical and biogeochemical processes for the regional-scale CO_2 evasion within the ensemble of estuarine filters along the selected coastal segment, which is one of the most intensively monitored regions in the world. A unique set of regional data, including river and continental shelf sea partial pressure of CO_2 (pCO_2; Signorini et al., 2013; Laruelle et al., 2015), riverine biogeochemical properties (Lauerwald et al., 2013), estuarine eutrophication status (Bricker et al., 2007) and estuarine morphology (NOAA, 1985) are available. These comprehensive data sets are complemented by local observations of carbon cycling and CO_2 fluxes in selected, individual estuarine systems, making the East coast of the United States an ideal region for a first, fully explicit regional evaluation of CO_2 evasion resolving every major tidal estuary along the selected coastal segment. ***An extensive review of published local estimates of CO_2 fluxes in estuarine systems worldwide can be found in Laruelle et al. (2013).*** The scale addressed in the present study is unprecedented so far (> 3000 km of coastline) and covers a wide range of estuarine morphological features, climatic conditions, land-use and land cover types, as well as urbanization levels.

After a description of the model itself and of the dataset used to set up the simulations, a local validation is presented which includes salinity, pCO_2 and pH longitudinal profiles for two well monitored systems (the Delaware Bay and the Altamaha River Estuary). The yearly averaged rates of CO_2 exchange at the air-water interface simulated by the model for 13 individual estuaries are also compared with observed values reported in the literature. Next, regional scale simulations for 43 tidal estuaries of the eastern US coast provide seasonal and yearly integrated estimates of the Net Ecosystem Metabolism (NEM), CO_2 evasion and carbon filtering capacity, CFilt. Model results are then used to elucidate the estuarine biogeochemical behaviour along the latitudinal transect encompassed by the present study (30-45° N). Finally, our results are used to derive general relationships between carbon cycling and CO_2 evasion, and readily available estuarine geometrical parameters."

Detailed statements

L14/15 Write 697.000 km2

Done

L19 For which time period?

The sentence has been re-written to state that model simulations are representative of the year 2000.

"***Our simulations, performed using conditions representative of the year 2000, suggest that,*** together, US East coast estuaries emit 1.9 TgC yr^{-1} ***in the form of CO_2***, which correspond to about 40 % of the carbon inputs from rivers, marshes and mangrove"

L19 Only CO2, or also other gases including carbon?

Model simulations only account for CO_2 exchange at the air-water interface and the sentence has been modified to clarify this point.

"…, together, US East coast estuaries emit 1.9 TgC yr^{-1} ***in the form of CO_2***, which correspond to about 40 % of the carbon inputs from rivers, marshes and mangroves."

L25 the results

Done

"Finally, ***the*** results reveal that the ratio of estuarine surface area to the river discharge, S/Q…"

L100 Make a full sentence: For a review see Laruelle et al. (2013)

We added a sentence.

"These comprehensive data sets are complemented by local observations of carbon cycling and CO_2 fluxes in selected, individual estuarine systems, making the East coast of the United States an ideal region for a first, fully explicit regional evaluation of CO_2 evasion resolving every major tidal estuary along the selected coastal segment. ***An extensive review of published local estimates of CO_2 fluxes in estuarine systems worldwide can be found in Laruelle et al. (2013)."***

L107/109/124 unify "Fig. x" -> all over the text

On the website of Biogeosciences, the guidelines for authors states: 'The abbreviation "Fig." should be used when it appears in running text and should be followed by a number unless it comes at the beginning of a sentence, e.g.: "The results are depicted in Fig. 5. Figure 9 reveals that...".'

In the updated manuscript, we paid attention to strictly follow these rules.

L125 give lat/lon for these stations or enlarge Fig. 1 and indicate individual stations.

In the paragraph summarizing the published annual mean FCO_2 estimates based on measurements for Atlantic US estuaries, we replaced the reference to Figure 1 by a reference to Table 3, which provides a list of all the estuaries, as well as their respective coordinates mentioned in that section. Table 3 thus becomes Table 2 in the manuscript.

"A total of thirteen local, annual mean estuarine CO_2 flux estimates across the air-water interface based on measurements are also reported in the literature and are grouped along a latitudinal gradient ***(Tab. 2)***. "

L146ff 47 stationed were simulated. This contradicts the number of 43 (abstract).

Some watersheds flow into the same estuarine system and were merged to calculate boundary conditions for some of the systems (see section 2.4). The sentence the reviewer refers to mistakenly refers to the number of watersheds represented in our simulations rather than the number of estuaries actually represented. Only 43 tidal estuarine systems were simulated and the text was updated in sections 2.2, 2.3 and 3.4. The abstract, which refers to 43 estuaries, is thus still correct. We made the following corrections in the manuscript:

Line 147:

"The National Estuarine Eutrophication Assessment (NEAA) survey (Bricker et al., 2007), which uses geospatial data from the National Oceanic and Atmospheric Administration (NOAA) Coastal Assessment Framework (CAF) (NOAA, 1985), was used to identify and characterize ***58*** estuarine systems discharging along the Atlantic coast of the United States. From this set, ***43*** 'tidal' estuaries, defined as a river stretch of water that is tidally influenced (Dürr et al., 2011), were retained (fig.1) to be simulated by the C-GEM model, which is designed to represent such systems."

Line 171:

"The generic 1D Reactive-Transport Model (RTM) C-GEM (Volta et al., 2014) is used to quantify the estuarine carbon cycling in the ***43*** systems considered in this study."

Line 278:

"First, ***43*** coastal cells corresponding to tidal estuaries are identified in the studied area (Fig. 1)."

Line 568:

"The overall carbon filtering capacity of the region thus equals 41% of the total carbon entering the ***43*** estuarine systems (river + saltmarshes)."

15+47 is not 64 as I would expect from this sentence.
This is indeed a mistake, only 58 estuarine systems are presented (15+43, see comment above).

L151 Do you have a reference for this?

This figure was calculated using the GLOBALNEWS data (Mayorga et al., 2010) for POC and DOC combined with data from Hartmann et al. (2009) for DIC. We modified the sentence in a way that reflects the fact that we performed this calculation ourselves.

"***Using outputs from terrestrial models (Hartmann et al., 2009; Mayorga et al., 2010), the cumulated riverine carbon loads for all the*** non-tidal estuaries that are excluded from the present study ***amount to 0.9 Tg C yr^{-1} , which represents less than 15% of the total riverine carbon loads of the region. These 15 systems*** are located in the SAR (10) and in the MAR (5)."

L152 Tab. x not table x (all over the text)

We update the entire manuscript.

L169 2.9 m (use space)

Done

L207 "These parameters were determined through.."?

The geometric parameters we are referring to can be extracted using Geographic Information Systems (GIS). This widely used type of software allows the determination of, for example, a distance such as the width of an estuary at its mouth from a digitalized map. The manuscript has been modified to spell out GIS on its first occurrence and make clear that GIS is the tool that can be used to extract the data from local maps.

"These parameters can be easily determined ***from local maps or Google Earth using Geographic Information Systems (GIS)*** or obtained from databases (NASA/NGA, 2003)".

L210 are described

Corrected

L226 Use C only for concentration

C is the commonly used symbol for Chézy's coefficient but, to avoid any confusion with concentration, we followed the reviewer's advice and use Cz to denote the Chézy's coefficient. We updated equations (6) and the text.

L227 You mean eqs (5) and (6)?

Correct. The text was modified accordingly

L233 You mean eqs (5) and (6)?

Correct. The text was modified accordingly

L239 Use only English peer reviewed references

The original Dutch reference (Van der Burgh, 1972) was replaced by Savenije (1986), which is the oldest English peer reviewed publication using Van der Burgh's equations to calculate the dispersion coefficient in estuarine systems.

"The effective dispersion at the estuarine mouth can be quantified by the following relation ***(Savenije, 1986)***:"

L241 Define N by an equation

As stated in the text, the Canter Cremers' estuary number N corresponds to the ratio of the freshwater entering the estuary during a tidal cycle to the volume of salt water entering the estuary over a tidal cycle. We introduced a new equation (new equation 9) to define this parameter.

"…where h0 (m) is the tidally-averaged water depth at the estuarine mouth and N is the dimensionless Canter Cremers' estuary number defined as the ratio of the freshwater entering the estuary during a tidal cycle to the volume of salt water entering the estuary over a tidal cycle ***(Simmons, 1955)***:

$$N = \frac{Q_b \cdot T}{P}$$

In this equation, Q_b is the bankfull discharge ($m^3\ s^{-1}$), T is the tidal period (s) and P is the tidal prism (m^3). For each estuary, N can thus be calculated directly from the hydrodynamic model. "

Reference

Simmons, H. B.: Some effects of inland discharge on estuarine hydraulics, Proc. Am. Soc. Civ. Eng.-ASCE, 81, 792, 1955.

L260 Omit brackets

Done

L262 2000 m (use space)

Done

L272 273 please give a more detailed description here

The calculation of the gross primary production in the water column relies on a depth integration of the Platt equation (Platt et al., 1980), which assumes an exponential decrease of the light availability with depth. The article we are referring to (Vanderborght et al., 2007) described a cost efficient algebraic method to perform this integration using a gamma function. A sentence has been added to the text to provide more information about this procedure.

"The primary production dynamics, which requires vertical resolution of the photic depth, is calculated according to the method described in Vanderborght et al. (2007). ***This method assumes an exponential decrease of the light in the water column (Platt et al., 1980), which is solved using a Gamma function.***"

L276 For which year? Or are climatological or mean values used?

Boundary conditions for regional simulations that cover a large number of individual and sometimes underexplored systems are notoriously difficult to constrain. Comprehensive, temporally resolved observational data sets that would allow informing boundary conditions are rarely available. Global databases, such as GlobalNEWS, which provide model derived river loads of carbon and nutrients (Seitzinger et al., 2005; Mayorga et al., 2010) are a suitable alternative when direct observations are not available. Here, we used the GlobalNews database, the GloRich database and the World Ocean Atlas to constrain boundary conditions. GlobalNews model simulations have been calibrated for the year 2000. Boundary conditions for Alkalinity and pH are constrained on the basis of data extracted from the GloRiCh database. Most of the data compiled in this data base has been collected between 1990 and 2010. Finally, marine boundary conditions and water temperatures are derived the World Ocean Atlas. These values also correspond to climatological means centred on the year 2000. We explicitly paid attention to extracting coherent data sets from the respective databases that are representative of the same time period (around year 2000). We now clearly state in the main text which time period our boundary conditions are representative of:

"Boundary and forcing conditions are extracted from global databases and global model outputs that are available at 0.5° resolution. Therefore, C-GEM simulations are performed at the same resolution according to the following procedure. First, ***43*** coastal cells corresponding to tidal estuaries are identified in the studied area (***Fig.*** 1). If the mouth of an estuary is spread over several 0.5° grid cells, those cells are regrouped in order to represent a single estuary (e.g. Delaware estuary), and subsequently, a single idealized geometry is defined as described above. ***The model outputs (Hartmann et al. , 2009; Mayorga et al., 2010) and databases (Antonov et al., 2010; Garcia et al., 2010a; Garcia et al., 2010b) used to constrain our boundary conditions are representative of the year 2000.***"

L289 cloud coverage: Which is the origin of this data?

The data comes from ISCCP Cloud Data Products (Rossow and Schiffer, 1999) and the text was updated in order to include this reference:

"Mean daily solar radiation and photoperiods (corrected for cloud coverage ***using the ISCCP Cloud Data Products, Rossow and Schiffer, 1999***) are calculated depending on latitude and day of the year using a simple model (Brock, 1981).

Reference:

Rossow, W.B., and Schiffer, R.A., 1999: Advances in Understanding Clouds from ISCCP. Bull. Amer. Meteor. Soc., 80, 2261-2288."

L293 Are there no recent data available?

The UNH/GRDC runoff dataset of Fekete et al. (2002) is the dataset used in the GlobalNEWS simulations (Mayorga et al., 2010). Although these values are derived from long term averages over the 1960-1990 period, they have been adjusted to represent the year 2000 in the GlobalNEWS simulations. Here, we use the adjusted values to ensure that boundary conditions are representative of the same time period. In addition, while more recent databases exists such as the National Water Information System (NWIS), they do not provide water discharge for all US rivers and, thus, do not provide values for the totality of the systems used in our simulations.

L320 You mean 50 g C (g Chla)-1 ?

Correct. We meant 50 grams of carbon per gram of chlorophyll a and we updated the text with the notation suggested by the reviewer.

"The same source is used for phytoplankton concentrations, using a chlorophyll-a to phytoplankton carbon ratio of ***50 gC (gChla)$^{-1}$*** (Riemann et al., 1989) to convert the EPA values to carbon units used in the present study."

L332 339 W is not consistently defined. Is it percentage or surface area?

W corresponds to the fraction of the estuarine surface area represented by wetlands. The sentence introducing equation (11) has been updated to clarify this point:

"The DOC input of estuarine wetlands (Fig. 5b) scales to ***their fraction, W, of the total estuarine*** surface area and is calculated using the GlobalNEWS parameterization"

L341 give definition of "a"

The parameter 'a' is a calibration parameter used in the GlobalNEWS models and was first defined in Harrison et al. (2005) as: "unitless coefficient defining how non-point DOC export responds to runoff; for NEWS-DOC 'a' was set equal to 0.95."

In our calculations, we kept the same parametrization and rephrased the sentence as follows:

"W is the percentage of the land area within a watershed that is covered by wetlands, R is the runoff (m y-1) and a is a unit-less ***calibration*** coefficient defining how non-point source DOC export responds to runoff. ***The value of a is set to 0.95, consistent with the original GlobalNEWS -DOC model of Harrison et al. (2005)***."

L355 358 It seem that you use this argument twice. Here a sensitivity analysis would help.

The sentences pointed out by reviewer states that our models ignores DIC fluxes from tidal marshes because all the carbon exports from those systems come under the form of organic carbon and then justifies this assumption with the fact that very little degradation of organic matter takes place in the tidal marshes before it reaches the estuary. Considering the relatively small amounts of carbon that can be degraded within tidal marshes (and the lack of data to constrain such process) because of the short time scale of mixing processes, our assumption implicitly means that some biogeochemical processing taking place within tidal marshes may be accounted for by our estuarine model.

L364 I doubt that zero concentration for org C is appropriate at open sea boundary. Often org C is transported from the open sea into the estuaries were it is degradated.

Please substantiate this assumption.

We agree that the assumption that the open ocean is devoid of organic carbon is simplistic and that some organic carbon can enter the estuarine system from the seaward boundary. However, the focus of our study is to investigate and quantify the fate of the carbon delivered to estuaries by the riverine network. We introduced a sentence to section 2.4.4 to reflect on this limitation.

"This approach also reduces the influence of marine boundary conditions on the simulated estuarine dynamics, especially for all the organic carbon species whose concentrations are fixed at zero at the marine boundary. ***This assumption ignores the intrusion of marine organic carbon into the estuary during the tidal cycle but allows focusing on the fate of terrigenous material and its transit through the estuarine filter.***"

In addition, the implications of this assumption are also discussed in a paragraph of the new section 3.4:

"***C-GEM places the lower boundary condition 20 km from the estuarine mouth into the coastal ocean and the influence of this boundary condition on simulated biogeochemical dynamics is thus limited. At the lower boundary condition, direct observations for nutrients and oxygen are extracted from databases such as the World Ocean Atlas (Antonov et al., 2014). However, lower boundary conditions for OC and pCO_2 (zero concentration for OC and assumption of pCO_2 equilibrium at the sea side) are simplified. This approach does not allow addressing the additional complexity introduced by biogeochemical dynamics in the estuarine plume (see Arndt et al., 2011). Yet, these dynamics only play a secondary role in the presented study that focuses on the role of the estuarine transition zone in processing terrestrial-derived carbon."***

L374 domain -> boundary

Done

L377 Why longitudinal profiles? You mean at right angles with the river flow?

The term longitudinal profile is commonly used and refers to a concentration profile along the longitudinal (length) axis of the estuary, i.e. from the estuarine mouth to the river. Concentrations are thus representative of the cross-sectional average at the respective longitudinal position.

L383 How large do you estimate the error when neglecting degradation or burial in bottom sediments? A sensitivity test could help.

We agree that neglecting benthic processes is a potential limitation of our model. As the reviewer points out, organic matter degradation and burial may influence the biogeochemical of carbon in some estuaries and affect carbon retention within the system. However, because of the dynamic nature of estuarine sediments and the logistic challenges involved to sample them, direct observations and measurements of benthic processes are even more limited than those available for pelagic processes. Very little is known on the long term fate of organic carbon in estuarine sediments and its burial. Because of this lack of knowledge, benthic processes are not explicitly represented in the model. However, to a certain degree model parameters (such as organic matter degradation, denitrification rate constant) implicitly account for benthic dynamics. We acknowledge that, by ignoring benthic processes and burial in particular, our estimates for the estuarine carbon filtering may be underestimated. These considerations have been incorporated into a paragraph of the new section 3.4:

"***Although the reaction network of C-GEM accounts for all processes that control estuarine FCO_2 (Borges and Abril, 2012; Cai, 2011), several, potentially important processes, such as benthic-pelagic exchange processes, phosphorous sorption/desorption and mineral precipitation, a more complex representation of the local phytoplankton community, grazing by higher trophic levels, or multiple reactive organic carbon pools are not included. Although these processes are difficult to constrain and their importance for FCO_2 is uncertain, the lack of their explicit representations induces uncertainties in Cfilt. In particular, the exclusion of benthic processes such as organic matter degradation and burial in estuarine sediments could result in an underestimation of Cfilt. However, because very little is known on the long term fate of organic carbon in estuarine sediments, setting up and calibrating a benthic module proves a difficult task. Furthermore, to a certain degree model parameters (such as organic matter degradation and denitrification rate constant) implicitly account for benthic dynamics. We nonetheless acknowledge that, by ignoring benthic processes and burial in particular, our estimates for the estuarine carbon filtering may be underestimated, particularly in the shallow systems of the SAR.***"

In addition, although, the discussion is not centred around the role of benthic processes, a paragraph of the new section 3.4 is also dedicated the difficulty of quantifying the uncertainties of model simulations and an attempt is made using the sensitivity analysis performed by Volta et al. (2014, 2016b).

"***Biogeochemical model parameters for regional and global applications are notoriously difficult to constrain (Volta et al., 2016b). Model parameters implicitly account for processes that are not explicitly resolved and their transferability between systems is thus limited. In addition, published parameter values are generally biased towards temperate regions in industrialized countries (Volta et al., 2016b). A first order estimation of the parameter uncertainty associated to the estuarine carbon removal efficiency (CFilt) can be extrapolated from the extensive parameter sensitivity analyses carried out by Volta et al. (2014, 2016b). These comprehensive sensitivity studies on end-member systems have shown that the relative variation in Cfilt when a number of key biogeochemical parameters are varied by two orders of magnitude varies by is ±15 % in prismatic (short residence time on order of days) to ±25 % in funnel-shaped (long residence time) systems. Thus, assuming that uncertainty increases linearly between those bounds as a function of residence time, an uncertainty estimate can be obtained for each of our modelled estuary. With this simple method, the simulated regional Cfilt of 1.9 Tg C yr^{-1} would be associated with an uncertainty range comprised between 1.5 and 2.2 Tg C yr^{-1}. Our regional estuarine CO_2 evasion estimate is thus reported with moderate confidence. Furthermore, in the future, this uncertainty range could be further constrained using statistical methods such as Monte Carlo simulations (e.g. Lauerwald et al., 2015).”***

L408 Fluxes

Done

L430 Boundary conditions and forcings differ from European settings. Show validations for American estuaries.

We added validations for the American estuaries. Section 2.6 (Model-data comparison) now includes a comparison between model-predicted annual CO_2 outgassing fluxes and 13 published flux estimates, derived from direct measurements in local estuaries to section 2.6 (Model-data comparison). In addition, we provide a validation of our hydrodynamic model using several seasonal longitudinal salinity profiles in the Delaware Bay as well a validation of our biogeochemical model on the basis of pH and pCO_2 profiles from two estuaries (the Delaware Bay and the Altamaha estuary). These additional simulations reveal that C-GEM is able to reproduce observed pCO_2 (Delaware Bay) and both pH and pCO_2 longitudinal profiles along the estuarine gradient (Altamaha).

"***Although C-GEM has been specifically designed and tested for the type of regional application presented here, its transferability from North Sea to US East Coast estuaries was further evaluated by assessing its performance in two East Coast estuaries. First, the hydrodynamic and transport model was tested for the Delaware Bay (MAR). The model was forced with the monthly, minimal and maximal observed discharge at Trenton over the period between 1912 and 1985 (UNH/GRDC Database). Simulated salinity profiles are compared with salinity observations from January, February, May and June (the months with the highest number of data entries), which were extracted from the UNH/GRDC Database.*** ***Fig. 6 shows that the model*** ***captures both the salinity intrusion length and the overall shape of the salinity profile well. In addition, the performance of the biogeochemical model and specifically its ability to reproduce pH and*** pCO_2 ***profiles was evaluated by a model-data comparison for both the Delaware Bay (MAR) in July 2003 and the Altamaha river estuary (SAR) in October 1995. Similar to Volta et al., 2016a, the test systems were chosen due to their contrasting geometries. The Delaware Bay is a marine dominated system characterized by a pronounced funnel shape, while the Altamaha River has a prismatic estuary characteristic of river dominated systems (Jiang et al., 2008). Monthly upstream boundary conditions for nutrients, as well as observed pH data and calculated*** pCO_2 ***are extracted from datasets described in (Sharp, 2010) and (Sharp et al., 2009) for the Delaware and in (Cai and Wang, 1998; Jiang et al., 2008) and (Cai et al., 1998) for the Altamaha river estuary. The additional forcings and boundary conditions are set similarly to the simulation for 2000 (see table 2, 3, 4, 5, 6 in SI). Fig. 7 shows that measured and simulated pH values are in good agreement with observed pH and observation-derived calculations of*** pCO_2***. In the Delaware Bay, a pH minimum is located around km 140 and is mainly caused by intense nitrification sustained by large inputs of*** NH_4 ***from the Philadelphia urban area, coupled to an intense heterotrophic activity. Both processes lead to a well-developed*** pCO_2 ***increase in this area (Fig. 7b). Although no*** pCO_2 ***data were available for validation for the period from which boundary conditions were extracted, the simulated profile agree with*** pCO_2 ***measurement from July 2013 presented by Joesoef et al. (2015) with*** pCO_2 ***values close to equilibrium with the atmosphere in the widest section of the Delaware Bay (close to the estuarine mouth) and values above 1200 µatm at salinities below 5. For the Altamaha river estuary, pH steadily increases from typical river to typical coastal ocean values (Fig. 7b). In addition, both observations and model results reveal that outgassing is very intense in the low-salinity region with more than a 5 fold decrease in*** pCO_2 ***between salinity 0 and 5 (Fig 7d)."***

In addition, the new section 3.4 (Scope of applicability and model limitations) critically discusses the difficulties of validating regional/global simulations with local data:

"***The generic nature of the applied model approach and, in particular the application of seasonally/annually averaged or model-deduced boundary conditions renders a direct validation of model results on the basis of local and instantaneous observational data (e.g. longitudinal profiles), which is likely not representative of these long-term average conditions, difficult. Therefore, model performance is evaluated on the basis of spatially aggregated estimates (e.g. regional FCO_2 estimates based on local measurements) rather than system-to-system comparisons with longitudinal profile from specific days. However, note that the performance of C-GEM has been intensively tested by specific model-data comparisons for a number of different systems (e.g. Volta et al., 2014, 2016a) and we are thus confident of its predictive capabilities.***"

L443 a regional minimum

Done

L440-456 Give these numbers in a table and discuss the most relevant ones.

These results were compiled for all estuaries and seasons in supplementary table SI1 and discussed within the text of section 3.1.

L457-462 The percentages should sum up to 100%

When taking all decimals into account, the percentage values do sum up to 100%. We now provide the exact value in the new manuscript.

"In contrast, the 18 MAR estuaries, with their large relative contribution to the total regional estuarine surface area, account for ***as much as 70.1%*** of the total outgassing."

L466 What do you mean with "aspect ratio"?

Aspect ratio refers to the geometry of the estuary (which subsequently affect its biogeochemical behaviour) and more explicitly refers to the ratio between the estuarine width b0 and convergence length b. A wider, funnel shaped estuary whose dynamics are controlled by a strong marine influence while the dynamics in a narrower prismatic estuary is dominated by the river influence (Savenije, 2001).

In the text, the sentence has been modified and the meaning of the term aspect ratio has been clarified:

"The comparatively larger relative contribution of the NAR to the total NEM as compared to the total FCO_2 can be explained by the importance of the specific aspect ratio for NEM. ***A larger ratio of estuarine width b0 and convergence length b corresponds to a more funnel shaped estuary while a low ratio corresponds to a more prismatic geometry (Savenije, 2001; Volta et al., 2014)***"

L479ff Why do the small estuaries show higher mean values?

In large systems, the total outgassing of CO_2 extends over a much larger surface area. In small estuaries, the surface area acts as a limiting factor for the gas exchange with the atmosphere.

L485 Give more details about the assumptions made to calculate the partitioning for

In addition to the reference to Regnier et al. (2013), more details regarding the method used to calculate the respective contributions to the estuarine CO_2 outgasing (NEM, nitrification and riverine oversaturated CO_2) is now provided.

"***Following the approach used in Regnier et al. (2013),*** the contribution of biogeochemical process to *FCO_2* is assessed by evaluating their individual contribution to DIC and ALK changes ***taking into account the local buffering capacity of an ionic solution when TA and DIC are changing due to internal processes, but ignoring advection and mixing (Zeebe and Wolf-Gladrow 2001). In the present study, we quantify the effect of the NEM on the CO_2 balance, which is almost exclusively controlled by aerobic degradation rates because the contributions of denitrification and NPP to the net ecosystem balance are small. Nitrification, a process triggered by the transport and/or production of NH_4 in oxygenated waters, favors outgassing through its effect on pH, which shifts the acid-base equilibrium of carbonate species and increases the CO_2 concentration. The contribution of supersaturated riverine waters to the overall estuarine CO_2 dynamics is calculated as difference between all the other processes creating or consuming CO_2.***"

Fig. 8a. Were seasonal partitioning combined to overall partitioning?

Indeed, the partitioning presented in figure 8a (and figure 8b) are calculated on the basis of the 4 seasonal fluxes for each estuary. The manuscript was edited to clarify this point:

"Fig. 8a presents the contribution of the annually integrated NEM, nitrification and evasion of supersaturated, DIC enriched riverine waters to the total outgassing for each system, as well as for individual regions of the domain. ***The calculation of these annual values is based on the sum of the seasonal fluxes.***"

L489 Give more details about the different partitioning in the different zones here

An entire paragraph following L489 fully describes the partitioning of the 3 drivers of FCO_2 (NEM, nitrification and riverine CO_2) in the 3 different zones (i.e. NAR, MAR, SAR). This paragraph used to begin on L496 of the previous version of the manuscript. We now explain and discuss the regional breakdown earlier in the text and moved the description of the influence of nitrification and NEM on CO_2 outgassing to L 485. Now the discussion of the contributions of NEM, nitrification and riverine CO_2 to FCO2 in each of the 3 sub regions directly follows the sentence in L.489, pointed out by the reviewer.

"Model results reveal that, regionally, the NEM supports about 50% of the estuarine CO_2 outgassing, while nitrification and riverine DIC inputs sustain about 17% and 33% of the CO_2 emissions, respectively. ~~***Nitrification, a process triggered by the transport and/or production of NH_4 in oxygenated waters, favors outgassing through its effect on pH, which shifts the acid-base equilibrium of carbonate species and increases the CO_2 concentration. In addition, the NEM is almost exclusively controlled by aerobic degradation rates because the contribution of denitrification and NPP to the net ecosystem balance is small.***~~ The relative significance of the three processes described above shows important spatial variability..."

L508 Where is Table S1?

Table S1 was uploaded as a supplementary table and a link to download it was included on the page from which the manuscript could be downloaded (below the PDF symbol). Attached to this reply, we provide an archive containing the updated manuscript as well as all the supplementary information

L577 budgets

Done

L630 The normalization of NEM by a Q10 value appears reasonable. The normalization of FCO2 by a Q10 value must be justified. I'm not convinced of the latter normalization.

The rationale for the normalization of FCO_2 by a Q10 value, using the same approach as the one used for NEM, is the fact that, in many systems, NEM and FCO_2 are intimately linked. For instance, Mayer and Eyre (2012) proposed a linear relationship between NEM and FCO2. Applying the same normalization to both NEM and FCO_2 thus allows testing if a similar relationship can be observed along the entire climatic gradient of the US East Coast.

"In this section, we explore the relationships between such simple physical parameters and indicators of the estuarine carbon processing $\overline{NEM}$, $\overline{FCO_2}$ and *CFilt*. In order to account for the effect of temperature on C dynamics, -$\overline{NEM}$ and $\overline{FCO_2}$ are also normalized to the same temperature (arbitrarily chosen to be 0 degree). These normalized values are obtained by dividing -$\overline{NEM}$ and $\overline{FCO_2}$ by a Q_{10} function *f(T)* (see Volta et al., 2014). ***This procedure allows accounting for the exponential increase in the rate of several temperature dependent processes contributing to the NEM (i.e. photosynthesis, organic carbon degradation…). Applying the same normalization to -$\overline{NEM}$ and $\overline{FCO_2}$ is a way of testing how intimately linked NEM and FCO_2 are in estuarine systems. Indeed linear relationships relating one to the other have been reported (Mayer and Eyre, 2012).***"

L660 ff Here it becomes obvious that f(t) cannot be applied to FCO2.

Indeed, we agree with the reviewer that no clear relationship between Q10-normalized FCO_2 and S/Q can be observed over the entire spectrum of values of S/Q that can be found along the east coast of the US. In fact, our results clearly illustrate that a linear regression between FCO_2 / f(T) and S/Q only provides a good fit using estuaries located in the MAR and SAR regions. The small estuaries from the NAR region, characterized by values of S/Q < 3 d m^{-1} display a significantly different behaviour. We think that it is important to point out that small estuaries show a different biogeochemical response and establishing a range of values of S/Q within which Mayer and Eyre's relationship can be reproduced justifies the use of this normalization of FCO_2 by a Q10 . We modified the text to clarify our approach.

"Thus, the well-documented correlation between $\overline{NEM}$ and $\overline{FCO_2}$ (Maher and Eyre, 2012) does not seem to hold for systems with very short residence times. For systems with S/Q > 3 days m^{-1}, we obtain a regression FCO_2 = -0.64 x *NEM* + 5.96 with a r^2 of 0.46, which compares well with the relation FCO_2 = -0.42 x *NEM* + 12 proposed by Maher and Eyre (2012) who used 24 seasonal estimates from small Australian estuaries. ***However, our results suggest that this relationship cannot be extrapolated to small systems such as those located in the NAR.***"

"As a consequence of the distinct behavior of short residence time systems, the coefficient of determination of the best-fitted power law function relating $\overline{FCO_2}$ and S/Q is only significant if NAR systems are excluded (y = 31.64 $x^{-0.58}$ with a r^2 = 0.70). ***This thus suggest that such relationships (as well as that proposed by Maher and Eyre, 2012) cannot be applied to any system but only those for which S/Q>3 day m^{-1}.***"

L668 whom -> who

Done

L677 In this case the assumption of pCO2 in equilibrium with the atmosphere at the lower boundary contradicts the case "still oversaturated waters .."

In our simulations, the seaward boundary is located 20km away from the estuarine mouth and estuarine waters close to the mouths can thus be still oversaturated.

At the beginning of section 2.4.4, we state that '*For each estuary, the downstream boundary is located 20 km beyond the mouth to minimize the bias introduced by the choice of a fixed concentration boundary condition to characterize the ocean water masses (e.g. Regnier et al., 1998).*'

This assumption is also discussed in a paragraph of the new section 3.4:

"***C-GEM places the lower boundary condition 20 km from the estuarine mouth into the coastal ocean and the influence of this boundary condition on simulated biogeochemical dynamics is thus limited. At the lower boundary condition, direct observations for nutrients and oxygen are extracted from databases such as the World Ocean Atlas (Antonov et al., 2014). However, lower boundary conditions for OC and pCO_2 (zero concentration for OC and assumption of pCO_2 equilibrium at the sea side) are simplified. This approach does not allow addressing the additional complexity introduced by biogeochemical dynamics in the estuarine plume (see Arndt et al., 2011). Yet, these dynamics only play a secondary role in the presented study that focuses on the role of the estuarine transition zone in processing terrestrial-derived carbon."***

L682 No link to Fig. 10d ?

We added a reference to Fig. 10d (now Fig.12d), as well as a brief discussion of the non-normalized results to the text.

"***Figure 12d, which reports non-normalized FCO_2 reveals a monotonous increase of FCO_2 with S/Q. This suggests that, unlike the NEM for which the normalization by a temperature function allowed explaining most of the variability; FCO_2 is mostly controlled by the water residence time within the system.*** Discharge is the main FCO_2 driver in riverine dominated systems, while interactions with marshes are driving the outgassing in marine dominated systems surrounded by marshes."

L739 You really mean "prediction"? Not "projection"?

We agree that term projection is better suited and the text was updated accordingly.

"In regions with better data coverage, such as the one investigated here, our study highlights that the regional-scale quantification, attribution, and ***projection*** of estuarine biogeochemical cycling are now at reach."

L740 As your model is rather based on empirical relations than on first principles, I expect that changed systems due to climate shifts and consequences can change your basic relationship. Please include this aspect in a more careful outlook.

We agree with the remark of the reviewer stating that the domain of applicability of the relationship we found between NEM, temperature and the depth normalized estuarine residence is bound within the range of values observed within our study area. Some of these aspects are tackled in the new section 'Scope of applicability and model limitations'.

Additionally, following the reviewer's recommendation, a sentence was added in the outlook section to account for the limitations of the applicability of the relationships we designed. We would like however, to draw the attention of the reviewer on the mechanistic nature of our model. Thus, while the relationships presented in section 3.5 are indeed empirical, they stem from results produced by a model that is actually largely based on first principles.

"In the future, such simple relationships, relying on readily available geometric and hydraulic parameters could be used to quantify carbon processing in areas of the world devoid of direct measurements. ***However, it is important to note that such simple relationships are only valid over the range of boundary conditions and forcings explored and may not be applicable to conditions that fall outside of this range.*** In regions with better data coverage, such as the one investigated here, our study highlights that the regional-scale quantification, attribution, and ***projection*** of estuarine biogeochemical cycling are now at reach."

L1021 7(4), 1271-1295

The reference was updated:

"Volta, C., Arndt, S., Savenije, H. H. G., Laruelle, G. G., and Regnier, P.: C-GEM (v 1.0): a new, cost-efficient biogeochemical model for estuaries and its application to a funnel-shaped system, Geosci. Model Dev., ***7, 1271-1295, doi:10.5194/gmd-7-1271-2014***, 2014."

L1045 give units and if possible your own values.

Following the reviewer's advice, table 3 (now table 2) has been updated to include the unit of the values in the caption and the values calculated by our simulations for the selected estuaries.

“**Table 2**: Published local annually averaged estimates of $\overline{FCO_2}$ ***in mol C m^{-2} yr^{-1}*** for estuaries along the East coast of the US.”

Name	**Lon**	**Lat**	**$\overline{FCO_2}$ Observed.**	**Modeled**	**Reference**
Altamaha Sound	-81.3	31.3	32.4	72.7	Jiang et al. (2008)
Bellamy	-70.9	43.2	3.6	3.9	Hunt et al. (2010)
Cocheco	-70.9	43.2	3.1	3.9	Hunt et al. (2010)
Doboy Sound	-81.3	31.4	13.9	25.7	Jiang et al. (2008)
Great Bay	-70.9	43.1	3.6	3.9	Hunt et al. (2011)
Little Bay	-70.9	43.1	2.4	3.9	Hunt et al. (2011)
Oyster Bay	-70.9	43.1	4	3.9	Hunt et al. (2011)
Parker River estuary	-70.8	42.8	1.1	3.9	Raymond and Hopkinson (2003)
Sapelo Sound	-81.3	31.6	13.5	20.6	Jiang et al. (2008)
Satilla River	-81.5	31	42.5	25.7	Cai and Wang (1998)
York River	-76.4	37.2	6.2	8.1	Raymond et al. (2000)
Hudson River	-74	40.6	13.5	15.5	Raymond et al. (1997)
Florida Bay	-80.68	24.96	1.4	n.a.	Dufore (2012)

In addition, the text of the section 2.6 (Model-data comparison) has also been updated to compare observed and simulated FCO_2 in these 13 systems.

“***While such local validations allow assessing the performance of the model for a specific set of conditions, the purpose of this study is to capture the average biogeochemical behaviour of the estuaries of the eastern coast of the US. Therefore, in addition to the system-specific validation, published annually averaged FCO_2 estimates for 13 tidal systems located within the study area collected over the 1994-2006 period are compared to simulated FCO_2 for conditions representative of the year 2000. Overall, simulated FCO_2 are comparable to values reported in the literature (Tab. 2). Although discrepancies, which sometimes can significant, are observed at the level of individual systems, the model captures remarkably well the overall trend in CO_2 evasion rate across estuaries. The model simulates low CO_2 efflux (< 5 mol C m^{-2} yr^{-1}) for the 7 systems were such conditions have been observed, while the 6 systems for which the CO_2 evasion exceeds 10 mol C m^{-2} yr^{-1} are the same in the observations and in the model runs. The discrepancy at the individual system level likely result from a combination of factors, including the choice of model processes and there parametrization, the uncertainties in constraining boundary conditions and the limited representability of instantaneous and local observed.***”

L1052 definition of winter (DJF)?

We define winter in section 2.4 as January, February and March. The definitions of the seasons are now reiterated in the table caption of table 5 to avoid any confusion:

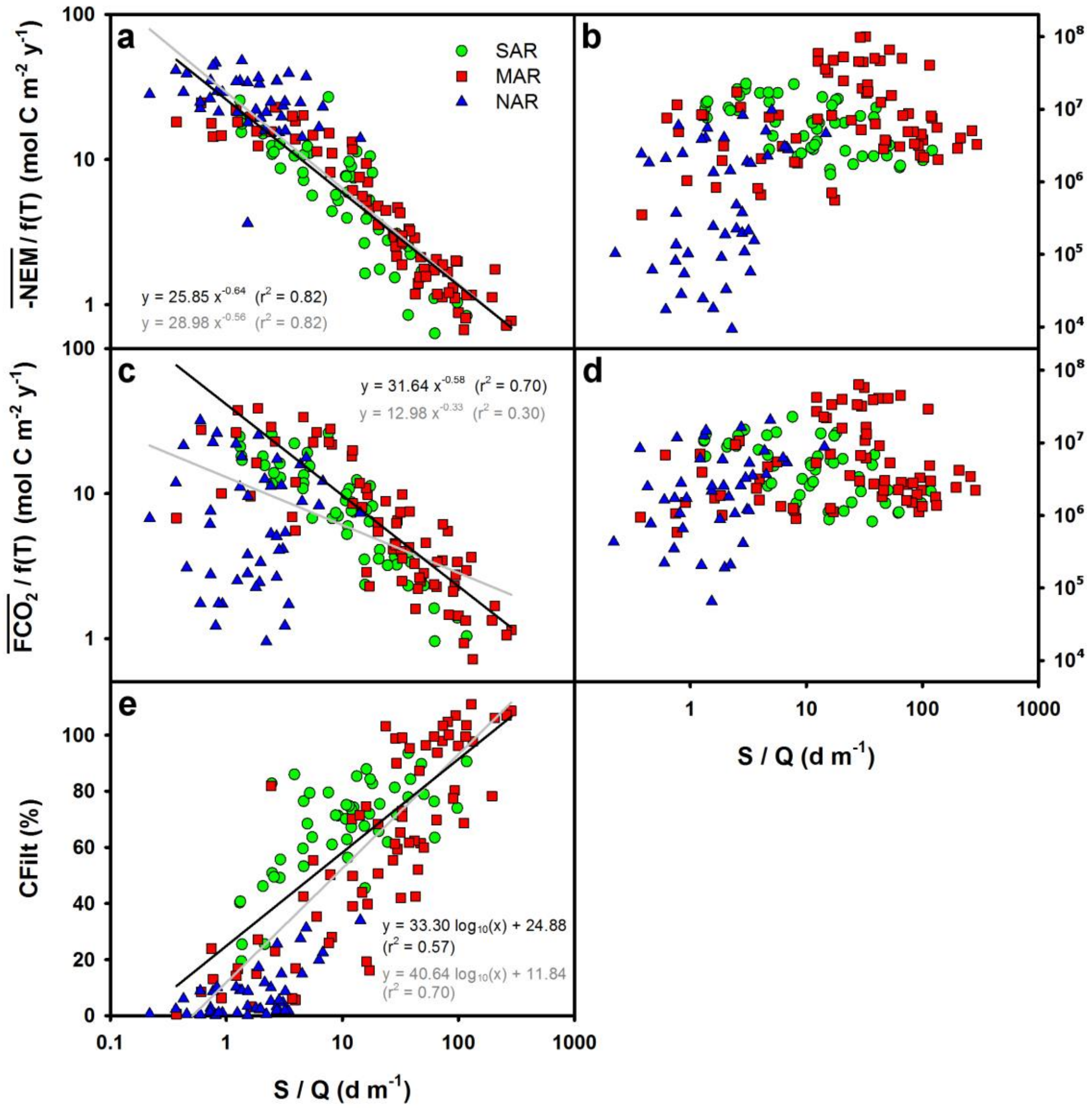
“Table 5: Seasonal contribution to FCO_2 and NEM in each the sub-region. The seasons displaying the highest percentages are indicated in bold. ***Winter is defined as January, February and March, Spring as April, May and June and so on…***”

L1103 The caption must be understandable alone. & L1105 Separate: “black lines .. using all points” “ grey lines are best fit only for ..”

The caption was rewritten taking into account the suggestion of the reviewer:

“Figure 10: ***System scale integrated biogeochemical indicators expressed*** as a function of the depth normalized residence time expressed as the ratio of the estuarine surface S and the river discharge Q ***for all seasons. Panels b, d and e represent NEM, -FCO_2 and CFilt, respectively.*** ***Panels a and c represent NEM, -FCO_2 normalized by a temperature Q_{10} function.*** Black lines are the best fitted ***linear*** regressions obtained using all the point. ***Grey lines are best fit using only*** the estuaries from the MAR and SAR regions.”

In addition, the y axis of panels b and d were updated.



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