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Earth System Dynamics Discussions

Interactive comment on "The ocean carbon sink – impacts, vulnerabilities, and challenges" *by* C. Heinze et al.

Anonymous Referee #2

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This review summarizes the current view on the marine carbon cycle and its perturbation by humans. Research challenges and knowledge gaps are discussed.

The review is useful and I suggest publication.

I miss a discussion on useful carbon isotopes and non-carbon tracer variables, including 13C, 14C and CFCs,SF6, Ar-39 (new interest as low water volume samples may be in reach with atomic trap technology) that provide information on the time scales of water mass movements relevant for the mixing of excess carbon to the deep ocean

Section 2. I miss a clear organization and structure of the presentation. Personally, I would have preferred if the authors would have organized this section by clearly distinguishing between

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a) main physico-chemical processes responsible for the uptake of excess CO2, (b) processes regulating the natural distribution of carbon within the ocean and the inventory split between ocean and atmosphere (c) feedbacks from climate and environmental changes on a) and b)

and by clearly separating different time scales, e.g. sesonal, interannual, decadal, century-scale, glacial-interglacial

The relevant text in the carbon cycle chapter in the IPCC Third Assessment Report provides a good example.

Section 3 on Variability What I miss here is a proper discussion of internal modes of variability (ENSO; SAM, NAO, NPD, etc) and of external drivers of variability and their imprints, e.g. volcanic forcing. As well as on detection of signals (signal-to-noise, time of emergence) and the attribution of signals to underlying processes

Detailed comments ————————

line 15, abstr: Would argue for the entire hierarchy of models, including EMICS, and not just so-called state-of-the-art ESMs.

abstract: what about inverse methods/models and probabilistic approaches?

page 1610: the first paragraph in the introduction needs to be revised.

page 1610, line 6: I am not so familiar with the history. As far as I know, Tyndall was the first to prove experimentally that CO2 is a greenhouse gas in the 1860ies or so. Not sure that the structure of the molecule was know back then as this requires knowledge on quantum mechanics.

1610, line 7: What about rotational modes?

p 1610, line 8: "discrete wavelength intervals" I find the use of 'discrete' together with 'intervall' perhaps a bit confusing in this context. Perhaps distinct intervalls?

ESDD

5, C705–C709, 2015

p 1610, line 9-11: Again a somewhat inaccurate sentence mixing different concepts. Solar radiation is electromagnetic as well and most of the energy radiated by the sun and from Earth's surface is thermal. Would also say that the vast majority of the energy from the sun is in the short-wave range and similar that most of the radiation from Earth's surface and the atmosphere is in the long-wave range. Perhaps you wish to give relevant wavelengths

p 1610, line 21 ff: If you wish to be so precise with the dates you need to give the location of measurements for direct atmospheric samples. The date derived from the Law Dome ice core data should come with an uncertainty estimate. Note that individual air samples from the ice have an age distribution about the mean age. In addition individual samples have a measurement error.

p1612, l 13,14: indicate that the percentages for the different species of DIC are only approximations, in particular for dissolved CO2.

p1612, line 18: I find 70 times more DIC than in the atmosphere a high estimate for preindustrial,e.g. 278 ppm*2.12 Pg/ppm/37500 PgC = 1/64

1616 top: I miss here a discussion on the controversy whether calcite and aragonite can dissolve above the saturation horizon or not

1616, l. 13: 'biological pump' should be 'biological productivity' as strong upwelling leads often to high surface nutrient concentrations and thus a low degree of surface nutrient utilization and comparably small surface-to-deep nutrient gradients.

1617, line 23: 'biological uptake' should be 'marine uptake'

1618: the discussion on the comparison with DIC misses the point. Uptake of anthropogenic carbon is by large a physico-chemical process, with the uptake capacity given by carbonate chemistry and the rate limiting step of surface-to-deep transport. A proper representation of ocean uptake of excess CO2 does require (i) a correct representation of carbonate chemistry, and (ii) a correct representation of surface-to-deep transport of

ESDD
5, C705–C709, 2015

excess carbon. The first process is well known from field and lab studies, the second can be gauged by comparing with, e.g., radiocarbon and CFCs. The comparison with DIC is blurred by the less well understood marine biogechemical cycle.

1621, line 10, next to ocean only and ESM, there are also EMICs that were used to quantify the different processes and feedbacks discussed in this manuscript

section: 3 I miss here a proper discussion of modes of variability, e.g. the work by Lovenduski, Gruber et al for SAM, Keller et al, Tellus, 2012 for NAO, and very recently Keller et al, GRL,2015 for ENSO, and of signal-to-noise and time of emergence of a signal as discussed e.g. by Ilyina for Alkalinity, McKinley et al for pCO2, or Keller et al, BG, 2014 for various variables and reference to detection and attribution (Seferian et al, GRL, 2014).

1623 top: I think it is not so clear that SO upakte of excess CO2 really slowed and there is a controversial discussion in the literature which should be referenced here.

1625 top: "Scenarios with Earth system models (advanced climate models, for a more detailed explanation see Sect. 3.2) reveal that the ocean sink may become less efficient in the future as higher cumulative CO2 emissions counteract the general tendency for oceanic CO2 uptake." Why not simply state that the fraction of fossil fuel emissions absorbed by the ocean over the 21st century is projected to be lower for high emission BaU scenarios than stringent emission mitigation scenarios (Jones et al., J. Clim, 2013).

1625, top: This is an incorrect statement and it should be deleted from the MS: "It, thus, remains to be explored what the ocean's ultimate uptake capacity for atmospheric CO2 is, when it may be reached, and how until then the ocean may regulate the environmental effects of anthropogenic CO2." There is no ultimate uptake capacity for atm. CO2. Perhaps you refer here to excess CO2. A certain fraction of emission will always end up in the ocean on multi-century time scales and then excess atm. CO2 will be further removed by CaCO3 compensation and removed from the ocean-atm system by

ESDD
5, C705–C709, 2015

weathering-sediment (imbalances). See e.g. Archer et al, GBC, 1999.

1626 ,11: delete: “such as Integrated Assessment Models” IAMs are not reservoir models

1627, l18 delete “future”

1630, line 7 replace “in designing correct future scenarios for” by “in”

1631, 23: miss d13C here (e.g. Heimann and Maier Reimer, GBC, 199x, and refs therein, Resplandy et al., ..)

1641, bottom: give a time frame, e.g. within the last 850,000 years

Figure 4: Is this mid-depth pH change the result of anthropogenic invasion or of water mass changes in this area?

Figure 5: I am confused here and do not understand this figure. The title talks about modelled trend, but my impression is that the bars refer to the state of the system? What is the relation between the bars and the y-axis labels (atm CO2) and the x-axis label? What is a seasonal trend? ... The figure caption definitely needs much more work.

Interactive comment on Earth Syst. Dynam. Discuss., 5, 1607, 2014.