Biogeosciences Discuss., 8, C975–C987, 2011
www.biogeosciences-discuss.net/8/C975/2011/

Biogeosciences Discussions

Interactive comment on "Mega fire emissions in Siberia: potential supply of soluble iron from forests to the ocean" *by* A. Ito

A. Ito

akinorii@jamstec.go.jp

Received and published: 13 May 2011

The author is grateful to all reviewers for their constructive comments. Below is a detailed answer to the comments.

Comment 1: The title suggests that the manuscript primarily focuses on iron deposition. However, only a short chapter at the end of the manuscript discusses iron deposition. I understand that in order to get to iron deposition estimates many steps have to be made. The present study is clearly outstanding in the respect that all these steps are undertaken within one study, i.e. starting from the development of a biomass burning emission inventory for the high latitudes of the Northern Hemisphere. However, major conclusions of the manuscript are based on the simulated iron deposition, for which a more detailed analysis would be desirable. For example:

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Response: In the revised paper, the descriptions of the aerosol model and discussions on iron are added, while results of CO from previous Exp1, Exp2 and Exp4 are removed. The standard simulation was conducted on a horizontal resolution of 2.0° × 2.5° with daily emissions according to MISR plume heights for CO (Exp1) and iron aerosols (Exp3). The intense forest fire is often neglected in global chemistry-climate models to calculate radiative forcing due to biomass burning (Ito et al., 2007a; Naik et al., 2007). For the purpose of quantifying the effect of intense fires, sensitivity simulations were performed with 5-year averaged monthly emissions for CO (Exp2) and iron aerosols (Exp4). Below is a detailed answer to the comment 1.

Comment 1.1: - The deposition of iron onto the ocean surface depends besides the biomass burning emission source largely on the simulated aerosol transport. While the emission source if evaluated using MOPITT CO measurements, this does not allow any conclusions about the quality of the simulated iron deposition. The authors state that the comparison with observed AOD data is beyond the scope of this manuscript. However, this would highly contribute to an understanding of how well the aerosol processing is reproduced in the model.

Response: The aerosol model has been thoroughly evaluated in previous studies (Liu et al., 2005; Feng and Penner, 2007; Ito and Feng, 2010). The simulated AOD has been compared with observed AOD under the AEROCOM exercises (Kinne et al., 2006; Koch et al., 2009; Huneeus et al., 2010). The explanations and the references are added to the section 2.2.

Comment 1.2: - The simulations showed that iron from biomass burning significantly contributes to the iron deposition in the western North Pacific and conclude that fire play a role as a negative biosphere climate feedback, due to an increase of atmospheric CO2 uptake by the ocean. This only holds when primary production in the western north Pacific is limited by iron. The author should discuss more in detail (including references) the role of iron for the western north pacific at present and possible future changes.

BGD
8, C975–C987, 2011

Response: The description of the role of iron for the western north pacific is expanded to a paragraph in introduction, as follows:

The subarctic North Pacific Ocean is one of the major High Nitrate Low Chlorophyll (HNLC) regions of the world (Harrison et al., 1999). Sediment-trap experiments suggest that the biological pump in the western North Pacific works more efficiently to enhance the uptake of atmospheric CO2 by the ocean than other regions (Honda et al., 2002). Iron fertilization experiments suggest that the region is particularly sensitive to iron input (Tsuda et al., 2003; de Baar et al., 2005). Observation data indicates high correlations between Asian dust events and biological productivity (Yuan and Zhang, 2006). These results suggest that iron input from mineral aerosols stimulates biological productivity in the western North Pacific.

Comment 1.3:- The authors argue that the supply of soluble iron from dust could be reduced in the future, when SO2 emission are reduced. This is accounted for in the model by eliminating atmospheric processing of dust by acidic species. I was wondering how realistic this is. It is likely that SO2 emission will be reduced in the future to improve air quality. However, it is not likely that this will result in zero SO2 emissions. Do one needs a large amount of SO2 emissions to make dust iron soluble?

Response: A large amount of SO2 emissions are needed because of buffering ability of aerosols. The description of the acid mobilization of iron is added in introduction, as follows:

Global atmospheric observations have shown that iron in the aerosol has solubility ranging from 0.01% near the dust source regions to 80% over remote oceans (Mahowald et al., 2009). Atmospheric processing of mineral aerosols by anthropogenic pollutants may transform insoluble iron into soluble forms (Zhu et al. 1992; Meskhidze et al. 2003). The solution on the submicron particle surface may become highly acidic due to atmospheric processing of iron-rich mineral aerosols by sulfuric acid (Sullivan et al. 2007), while large dust particles (radius > 1 μm) do not generally acidify due

BGD

8, C975–C987, 2011

to the alkaline buffer ability of carbonate minerals (McNaughton et al. 2008; Fairlie et al. 2010). Global chemistry transport model implemented with an explicit iron dissolution scheme for dust aerosol (Meskhidze et al. 2005) suggests that the iron solubility strongly depends on ambient concentration of acidic trace gases (Solmon et al. 2009; Johnson et al. 2010). According to model calculations, iron dissolves significantly in the fine dust aerosols due to the acid mobilization of the iron-containing minerals, but does not dissolve in the coarse particles (Ito and Feng, 2010). In large portions of East Asia, emissions of alkaline gas (i.e., ammonia) exceed the amount that is needed to neutralize sulfate and nitrate (Tang et al., 2004). Consequently, a relatively high pH (> 3) over the ammonia source regions hinders the dissolution of iron-containing minerals (Ito and Feng, 2010).

Comment 2: The basis of this study is the development of a biomass burning emission inventory for the northern high latitudes. The modeling approach for the biomass burning emission model in partly difficult to follow:

Response: The descriptions of the biomass burning emission model are revised, as follows.

Comment 2.1: Page1490/Line 20: “The aboveground (ground-layer) fires are assumed to last 1 day (8days)”. Can you explain more how the length of the fire event enters your calculation and how this then relates to the daily fire count data?

Response: Surface fires of aboveground fuels usually last for several days, but MODIS may not capture all smoldering fires in part because of their low temperature. Thus the aboveground (ground-layer) fuels are assumed to burn for 1 day (1–8 days) from the initial date of the fire which is determined by the daily fire count data. The emission rates per hour for each fire are evenly entered to the atmosphere on a horizontal grid of the model.

Comment 2.2: Page 1491/Line 6: “For this study, the fire component embedded in the model is not used for standreplacement disturbance”. Do you apply the satellite

BGD

8, C975–C987, 2011

observed instead?

Response: For this study, the fire is not used as the stand-replacement disturbance. Thus, the process-based model simulates potential vegetation with no fire.

Comment 2.3: Page 1491/Line16: It is not clear to me how the scaling of the combustion factor is done in this study. Does this depend on the soil moisture index and the size of the fire?

Response: The combustion factor for the organic soil carbon is based on literature values (Soja et al., 2004; Kasischke et al., 2005), as a function of the fire severity and fuel condition, ranging from 8% to 100% (Table 1). Fire severity is widely used to describe the various impacts of a fire. In this paper, the fire severity is directly related to the type and size of the fires. The fractional fuel consumption was assumed to be higher for crown than for surface fires to reflect the higher energy state or intensity of crown fires (Kasischke et al., 2005). Additionally, all fire events larger than 100 km2 month–1 were assumed to be a large and severe fire (Soja et al., 2004). It was also assumed that the surface organic layer under drier condition results in deeper burning (Kasischke et al., 2005). Therefore, the function relates the spatial (x, y) and temporal (t) variability in combustion factor, CF (0–1), to soil moisture index, SMI (0–1), and fire size index, FSI (0.5–1) and empirical parameters (A and B), which depend on the type of fires, j.

$$[CF]xyt = Aj \times \exp(Bj \times (1 - [SMI]xyt) \times [FSIk]xyt \quad (2)$$

The soil moisture index of the top soil layer is taken from 3-hour time-averaged assimilated meteorological fields from the Goddard Earth Observation System (GEOS) of the NASA Global Modeling and Assimilation Office (GMAO) (Bloom et al., 2005). The fire size index for each land cover type, k, is derived from the areas affected by fires per month within a 0.5° grid cell. The empirical parameters are determined from the values in Table 1 (Kasischke et al., 2005).

BGD
8, C975–C987, 2011

Comment 2.4: Page 1492/Line3: How do you distinguish between flaming and smoldering burning?

Response: Because of the differences in combustion between aboveground and ground-layer biomass observed for boreal forests, we assumed: (1) 80% of the aboveground biomass was consumed by flaming combustion, and 20% by smoldering combustion; and (2) 20% of the soil organic layer was consumed by flaming combustion, and 80% by smoldering combustion (Kasischke and Bruhwiller, 2002).

Comment 2.5: Page 1494/Line1: The fuel consumption model for the surface fires considers ..." Is this not done with the SEIB-DGVM?

Response: This is done with our emission model. The fuel consumption model for the surface fires considers herbaceous vegetation in grasslands/shrubs, croplands, wetlands and forests (Ito and Penner, 2004, 2005, Ito et al., 2007b).

Comment 2.6: Page 1494/Line4: How do you derive EF and CF from NDVI?

Response: It would be more appropriate to cite the papers by Ward et al. (1996), Hoffa et al, (1999), Korontzi (2005), and Ito et al. (2007b), all of which gave detailed explanations on this matter. We used the relationship between the percentage of green grass out of the total grass (PGREEN) and NDVI. Then, we used the relationship between the combustion factors and the PGREEN. We also used the relationship between the modified combustion efficiency (MCE) and the PGREEN. Then, we used the regression model between MCE and EF. In short, the combustion factors and emission factors are modeled as functions of grass fuel moisture (Ward et al., 1996; Hoffa et al., 1999; Korontzi, 2005; Ito et al., 2007b). The fuel moisture is derived from 1-km satellite vegetation index time series (Huete et al., 2002).

Comment 3: Other remarks: Comment 3.1: Abstract: Page1484/Line24: "Without the atmospheric processing by acidic species" This needs more explanation even in the abstract. Why do you ignore atmospheric processing of dust particles by acidic

BGD

8, C975–C987, 2011

species?

Response: Bioavailable iron is derived from atmospheric processing of relatively insoluble iron from desert sources by anthropogenic pollutants (mainly sulfuric acid formed from oxidation of SO2) and from direct emissions of soluble iron from combustion sources. Emission scenarios for IPCC AR5 report (Intergovernmental Panel on Climate Change; Fifth Assessment Report) suggest that SO2 emissions are suppressed in the future to improve air quality.

Comment 3.2: Model approach: Page1489/Line 23: Point 4/5 are not an improvement of the Seiler and Crutzen approach.

Response: These are improvements of our emission model (Ito and Penner, 2004, 2005, Ito et al., 2007b).

Comment 3.3: Page1490/Line 20: "The aboveground (ground-layer) fires are assumed to last 1 day (8days)". Can you explain more how the length of the fire enters your calculation and how this then relates to the daily fire count data?

Response: Same as in response to Comment 2.1.

Comment 3.4: Page1495/Line19: "When a number of smoke plumes were observed at different altitudes within the same model grid and for the same date, the relative amounts of emissions were calculated by weighting the contribution from each plume by its digitized area" Do you mean relative heights?

Response: When a number of smoke plumes were observed at different altitudes within the same model grid and for the same date, the averaged injection heights and relative amounts of emissions more than 2 km above terrain to total emissions were calculated by weighting the contribution from each plume by its digitized area (Nelson et al., 2008).

Comment 3.5: Page1496/Line 14:" combusted-generated aerosols as described in Ito and Feng (2010)". Is this the same as the RETRO emissions mentioned earlier?

BGD
8, C975–C987, 2011

Response: The particulate emissions estimates are obtained from Ito and Penner (2005) and the emission factors are based on Luo et al. (2008). The conservative values for iron fractions in biomass burning aerosols are used here for fine particles (section 2.2.1).

Comment 3.6: Page 1502/Line23: “Compared to the delivery of soluble iron from dust sourced without the atmospheric processing by acidic species....” Did you perform another experiment were this is taken into account?

Response: The tracers of soluble iron from dust sources without the atmospheric processing by acidic species are carried in the aerosol simulation. This is expressed as “Exp5” for a comparison in the revised paper.

References

Bloom, S., da Silva, A., Dee, D., Bosilovich, M., Chern, J.-D., Pawson, S., Schubert, S., Sienkiewicz, M., Stajner, I., Tan, W.-W., and Wu, M.-L.; Documentation and validation of the Goddard Earth Observing System (GEOS) data assimilation systemâĂŤversion 4, Tech. Memo. 104606, in Technical Report Series on Global Modeling and Data Assimilation, vol. 26, NASA Goddard Space Flight Cent., Greenbelt, MD, 2005.

de Baar, H. J. W., Boyd, P. W., Coale, K. H. , Landry, M. R., Tsuda, A., Assmy, P., Bakker, D. C. E., Bozec, Y., Barber, R. T., Brzezinski, M. A., Buesseler, K. O., Boye, M., Croot, P. L., Gervais, F., Gorbunov, M. Y., Harrison, P. J., Hiscock, W. T., Laan, P., Lancelot, C., Law, C. S., Levasseur, M., Marchetti, A., Millero, F. J., Nishioka, J., Nojiri, Y., van Oijen, T., Riebesell, U., Rijkenberg, M. J. A., Saito, H., Takeda, S., Timmermans, K. R., Veldhuis, M. J. W., Waite, A. M., and Wong, C. S.: Synthesis of iron fertilization experiments: From the iron age in the age of enlightenment, J. Geophys. Res., 110, C09S16, doi:10.1029/2004JC002601, 2005.

Fairlie, T. D., Jacob, D. J., Dibb, J. E., Alexander, B., Avery, M. A., van Donkelaar, A., and Zhang, L.: Impact of mineral dust on nitrate, sulfate, and ozone in transpacific

BGD

8, C975–C987, 2011

Asian pollution plumes, Atmos. Chem. Phys., 10, 3999–4012, 2010.

Harrison, P. J., Boyd, P. W., Varela, D. E., Takeda, S., Shiomoto, A., and Odate, T.: Comparison of factors controlling phytoplankton productivity in the NE and NW subarctic Pacific gyres, Prog. Oceanogr., 43, 205–234, doi:10.1016/S0079-6611(99)00015-4, 1999.

Hoffa, E. A., Ward, D. E., Hao, W. M., Susott, R. A., and Wakimoto, R. H.: Seasonality of carbon emissions from biomass burning in a Zambian savanna, J. Geophys. Res., 104, 13841–13853, 1999.

Honda, M. C., Imai, K., Nojiri, Y., Hoshi, F., Sugawara, T., and Kusakabe, M.: The biological pump in the northwestern North Pacific based on fluxes and major components of particulate matter obtained by sediment-trap experiments (1997 – 2000), Deep Sea Res., Part II, 49, 5595–5625, 2002.

Huneeus, N., Schulz, M., Balkanski, Y., Griesfeller, J., Kinne, S., Prospero, J., Bauer, S., Boucher, O., Chin, M., Dentener, F., Diehl, T., Easter, R., Fillmore, D., Ghan, S., Ginoux, P., Grini, A., Horowitz, L., Koch, D., Krol, M. C., Landing, W., Liu, X., Mahowald, N., Miller, R., Morcrette, J.-J., Myhre, G., Penner, J. E., Perlwitz, J., Stier, P., Takemura, T., and Zender, C.: Global dust model intercomparison in AeroCom phase I, Atmos. Chem. Phys. Discuss., 10, 23781–23864, 2010.

Ito, A., Ito, A., and Akimoto, H.: Seasonal and interannual variations in CO and BC emissions from open biomass burning in Southern Africa during 1998–2005, Global Biogeochem. Cy., 21, GB2011, doi:10.1029/2006GB002848, 2007b.

Ito, A., and Penner, J. E.: Global estimates of biomass burning emissions based on satellite imagery for the year 2000, J. Geophys. Res., 109, D14S05, doi:10.1029/2003JD004423, 2004.

Ito, A., and Penner, J. E.: Estimates of CO emissions from open biomass burning in southern Africa for the year 2000, J. Geophys. Res., 110, D19306,

doi:10.1029/2004JD005347, 2005.

Ito, A., Sudo, K., Akimoto, H., Sillman, S., and Penner, J. E.: Global modeling analysis of tropospheric ozone and its radiative forcing from biomass burning emissions in the twentieth century, J. Geophys. Res., 112, D24307, doi:10.1029/2007JD008745, 2007a.

Johnson, M. S., Meskhidze, N., Solmon, F., Gasso, S., Chuang, P. Y., Gaiero, D. M., Yantosca, R. M., Wu, S. L., Wang, Y. X., and Carouge, C.: Modeling dust and soluble iron deposition to the South Atlantic Ocean, J. Geophys. Res., 115, D15202, doi:10.1029/2009JD013311, 2010.

Kasischke, E. S., and Bruhwiler, L. P.: Emissions of carbon dioxide, carbon monoxide, and methane from boreal forest fires in 1998, J. Geophys. Res., 108(D1), 8146, doi:10.1029/2001JD000461, 2002.

Kinne, S., Schulz, M., Textor, C., Guibert, S., Balkanski, Y., Bauer, S. E., Berntsen, T., Berglen, T. F., Boucher, O., Chin, M., Collins, W., Dentener, F., Diehl, T., Easter, R., Feichter, J., Fillmore, D., Ghan, S., Ginoux, P., Gong, S., Grini, A., Hendricks, J., Herzog, M., Horowitz, L., Isaksen, I., Iversen, T., Kirkevåg, A., Kloster, S., Koch, D., Kristjansson, J. E., Krol, M., Lauer, A., Lamarque, J. F., Lesins, G., Liu, X., Lohmann, U., Montanaro, V., Myhre, G., Penner, J., Pitari, G., Reddy, S., Seland, O., Stier, P., Takemura, T., and Tie, X.: An AeroCom initial assessment - optical properties in aerosol component modules of global models, Atmos. Chem. Phys., 6, 1815–1834, doi:10.5194/acp-6-1815-2006, 2006.

Koch, D., Schulz, M., Kinne, S., McNaughton, C., Spackman, J. R., Balkanski, Y., Bauer, S., Berntsen, T., Bond, T. C., Boucher, O., Chin, M., Clarke, A., De Luca, N., Dentener, F., Diehl, T., Dubovik, O., Easter, R., Fahey, D. W., Feichter, J., Fillmore, D., Freitag, S., Ghan, S., Ginoux, P., Gong, S., Horowitz, L., Iversen, T., Kirkevåg, A., Klimont, Z., Kondo, Y., Krol, M., Liu, X., Miller, R., Montanaro, V., Moteki, N., Myhre, G., Penner, J. E., Perlwitz, J., Pitari, G., Reddy, S., Sahu, L., Sakamoto, H., Schuster,

G., Schwarz, J. P., Seland, Ø., Stier, P., Takegawa, N., Takemura, T., Textor, C., van Aardenne, J. A., and Zhao, Y.: Evaluation of black carbon estimations in global aerosol models, Atmos. Chem. Phys., 9, 9001–9026, doi:10.5194/acp-9-9001-2009, 2009.

Korontzi, S.: Seasonal patterns in biomass burning emissions from southern African vegetation fires for the year 2000, Global Change Biol., 11, 1680– 1700, 2005.

Mahowald, N. M., Sebastian, E., Luo, C., Sealy, A., Artaxo, P., Benitez-Nelson, C., Bonnet, S., Chen, Y., Chuang, P. Y., Cohen, D. D., Dulac, F., Herut, B., Johansen, A. M., Kubilay, N., Losno, R., Maenhaut, W., Paytan, A., Prospero, J. M., Shank, L. M., and Siefert, R. L.: Atmospheric iron deposition: global distribution, variability, and human perturbations, Annu. Rev. Mar. Sci., 1, 245–278, 2009.

McNaughton, C. S., Clarke, A. D., Kapustin, V., Shinozuka, Y., Howell, S. G., Anderson, B. E., Winstead, E., Dibb, J., Scheuer, E., Cohen, R. C., Wooldridge, P., Perring, A., Huey, L. G., Kim, S., Jimenez, J. L., Dunlea, E. J., DeCarlo, P. F., Wennberg, P. O., Crounse, J. D., Weinheimer, A. J., and Flocke, F.: Observations of heterogeneous reactions between Asian pollution and mineral dust over the Eastern North Pacific during INTEX-B, Atmos. Chem. Phys., 9, 8283–8308, 2009.

Meskhidze, N., Chameides, W. L., Nenes, A. and Chen, G.: Iron mobilization in mineral dust: Can anthropogenic SO2 emissions affect ocean productivity?, Geophys. Res. Lett., 30(21), 2085, doi:10.1029/2003GL018035, 2003.

Meskhidze, N., Chameides, W. L., and Nenes, A.: Dust and pollution: A recipe for enhanced ocean fertilization?, J. Geophys. Res., 110, D03301, doi:10.1029/2004JD005082, 2005.

Naik, V., Mauzerall, D. L., Horowitz, L. W., Schwarzkopf, M. D., Ramaswamy, V., and Oppenheimer, M.: On the sensitivity of radiative forcing from biomass burning aerosols and ozone to emission location, Geophys. Res. Lett., 34, L03818, doi:10.1029/2006GL028149, 2007.

BGD

8, C975–C987, 2011

Soja, A. J., Cofer, W. R., Shugart, H. H., Sukhinin, A. I., Stackhouse, P. W., McRae, D. J., and Conard, S. G.: Estimating fire emissions and disparities in boreal Siberia (1998–2002), J. Geophys. Res., 109, D14S06, doi:10.1029/2004JD004570, 2004.

Solmon, F, Chuang, P. Y., Meskhidze, N., and Chen, Y.: Acidic processing of mineral dust iron by anthropogenic compounds over the North Pacific Ocean, J. Geophys. Res., 114, D02305, doi:10.1029/2008JD010417, 2009.

Sullivan, R. C., Guazzotti, S. A., Sodeman, D. A., and Prather, K. A.: Direct observations of the atmospheric processing of Asian mineral dust, Atmos. Chem. Phys., 7, 1213–1226, 2007.

Tang, Y. H., Carmichael, G. R., Seinfeld, J. H. Dabdub, D., Weber, R. J., Huebert, B., Clarke, A. D. , Guazzotti, S. A., Sodeman, D. A., Prather, K. A., Uno, I., Woo, J.-H., Yienger, J. J., Streets, D. G., Quinn, P. K., Johnson, J. E., Song, C.-H., Grassian, V. H., Sandu, A., Talbot, R. W., and Dibb, J. E.: Three-dimensional simulations of inorganic aerosol distributions in east Asia during spring 2001, J. Geophys. Res., 109, D19S23, doi:10.1029/2003JD004201, 2004.

Tsuda, A., Takeda, S., Saito, H., Nishioka, J., Nojiri, Y., Kudo, I., Kiyosawa, H., Shiomoto, A., Imai, K., Ono, T., Shimamoto, A., Tsumune, D., Yoshimura, T., Aono, T., Hinuma, A., Kinugasa, M., Suzuki, K., Sohrin, Y., Noiri, Y., Tani, H., Deguchi, Y., Tsurushima, N., Ogawa, H., Fukami, K., Kuma, K., and Saino, T.: A mesoscale iron enrichment in the western Subarctic Pacific induces a large centric diatom bloom, Science, 300, 958–961, 2003.

Ward, D. E., Hao, W. M., Susott, R. A., Babbitt, R. E., Shea, R. W., Kauffman, J. B., and Justice, C. O.: Effect of fuel composition on combustion efficiency and emission factors for African savanna ecosystems, J. Geophys. Res., 101, 23569–23576, 1996.

Yuan, W., and Zhang, J.: High correlations between Asian dust events and biological productivity in the western North Pacific, Geophys. Res. Lett., 33, L07603,

doi:10.1029/2005GL025174, 2006.

Zhu, X. R., Prospero, J. M., Millero, F. J., Savoie, D. L., and Brass, G. W.: The solubility of ferric ion in marine mineral aerosol solutions at ambient relative humidities, Mar. Chem., 38, 91–107, 1992.

Interactive comment on Biogeosciences Discuss., 8, 1483, 2011.