AeroCom

An Aerosol module inter-Comparison in global models

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Overview

Aerosol is one of the key properties in simulations of the Earth's climate. Model-derived estimates of anthropogenic influences (specifically from increases to greenhouses gases and aerosol) remain highly uncertain (IPCC, Houghton et al., 2001). A particular problem is the inadequate representation of (high variable) aerosol properties and of aerosol processes with chemistry and clouds (note that clouds are the major modulators of the energy balance). In recognition, improvements of the aerosol component in global (climate) models have become a major focus in climate research. At issue are concentration, composition, size and altitude of aerosol as function of region and season and methods capturing aerosol interactions with clouds and chemistry. In recent years worldwide parallel efforts have resulted in many new approaches to the aerosol representation and to aerosol processing (without overly compromising on computational efficiency). One of the most significant advances has been the recognition of different aerosol types (e.g. size and composition). The added complexity, however, required new assumptions. Many of those have remained untested. This is, because potentially useful measurements are either difficult to get (if available at all) and because a lack in communication. Modelers rarely make an effort to interact and learn from modeling competitors, yet community interactions are essential to evaluate (modeling), to identify outliers and to illustrate uncertainty. Particular important are interactions with measurements groups to communicate needs in terms of measurement and derived products. Eventually these interactions will give us more confidence in computations of the climatic impact attributed to aerosol.

Issues

In recognition of a more appropriate aerosol representation in climate models, aerosol modules distinguish now at least among five different aerosol types: sulfate, organic carbon, black carbon, sea-salt and dust. Despite the increased complexity, differences in the resulting direct forcing (the direct influence of aerosol on the energy balance) among different models have remained large. Inspections of intermediate results (e.g. simulated mass fields or derived aerosol optical depth fields) are evaluation-cornerstones but they provide only incomplete answers to deviations among models. Usually, explanations of model behavior are only possible, when all details on the treatment of individual aerosol types have been investigated and understood. However, this is only possible (1) with detailed model output (preferably of control experiments) and (2) if appropriate measurements are available.

For instance, global data-sets on the aerosol optical depth measurements are available from remote sensing. As example, by season, composites of aerosol optical depth retrievals from MODIS and MISR sensors on NASA's Terra platform of the year 2001 are provided in Figure 1.

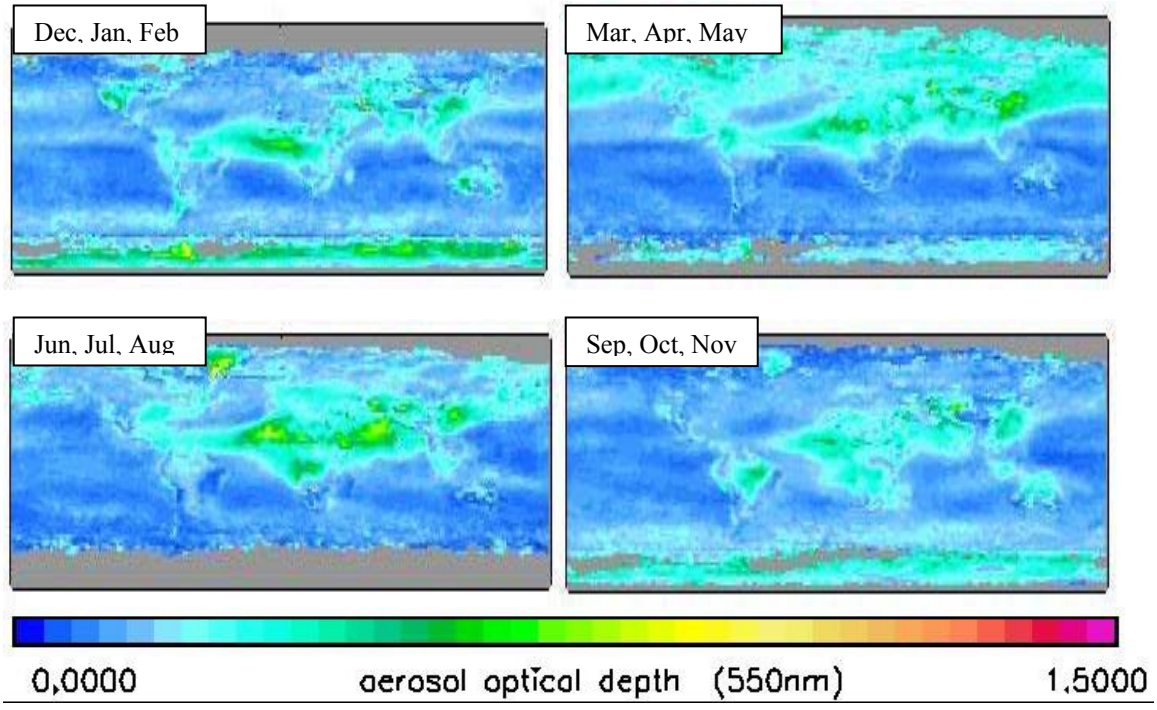

Figure 1 Attenuation of visible sunlight due to aerosol on a seasonal average basis. The data are based on retrievals of MODIS and MISR sensors of NASA"s Terra platform for the year 2001.

While the highly variable nature of aerosol creates a problem of its own, already yearly global averages suffice to demonstrate modeling issues. Figure 2 provides a comparison in total optical depth between several models and to a few data-sets from remote sensing. Yearly global averages for aerosol optical depth range between 0.17 and 0.20, if we ignore biased satellite datasets (AVHRR – no land data, TOMS – likely cloud-contamination). Compared to that value, all tested models tend to underestimate aerosol optical depth (on a global basis). The strongest underestimates come from older models. The agreement, though, seems encouraging (on the order of +/- 30%). That is until we notice that the fractional contribution from different aerosol types to the total optical depth varies among models (right column panels in Figure 3). Note that differences in composition mean differences in aerosol size and absorption. Thus, for the same optical depth we can expect significant differences in the associated aerosol radiative forcing at the top of the atmosphere (since IPCC the common measure to quantify Earth climatic impacts).

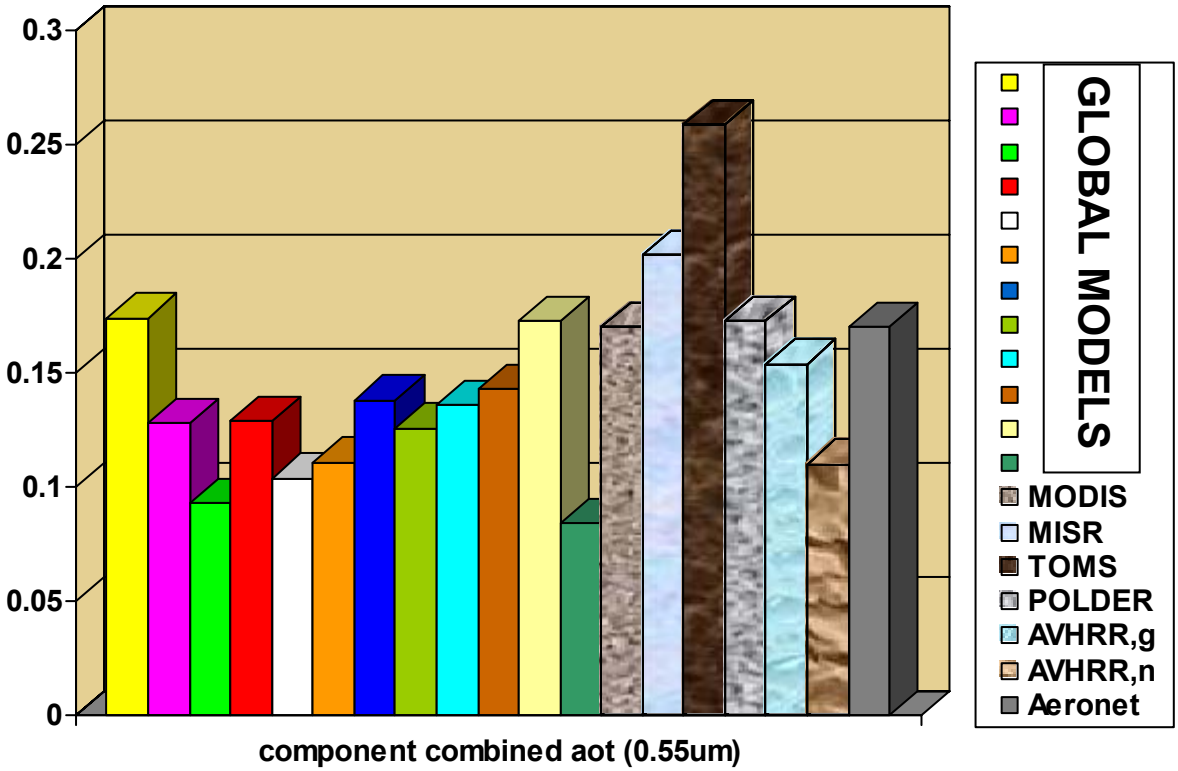

Figure 2: Global yearly averages for aerosol optical depth (aot) of *12 aerosol component models* (solid colors) in comparison to averages from *5 satellite data-sets* (textured) and *1 ground-based data-set* (grey). The general agreement belittles dramatic differences in modeling, not only on a seasonal or regional basis but also in terms of aerosol composition (see Figure 2). The major goal of AeroCom is to understand differences and to identify and eliminate weak components.

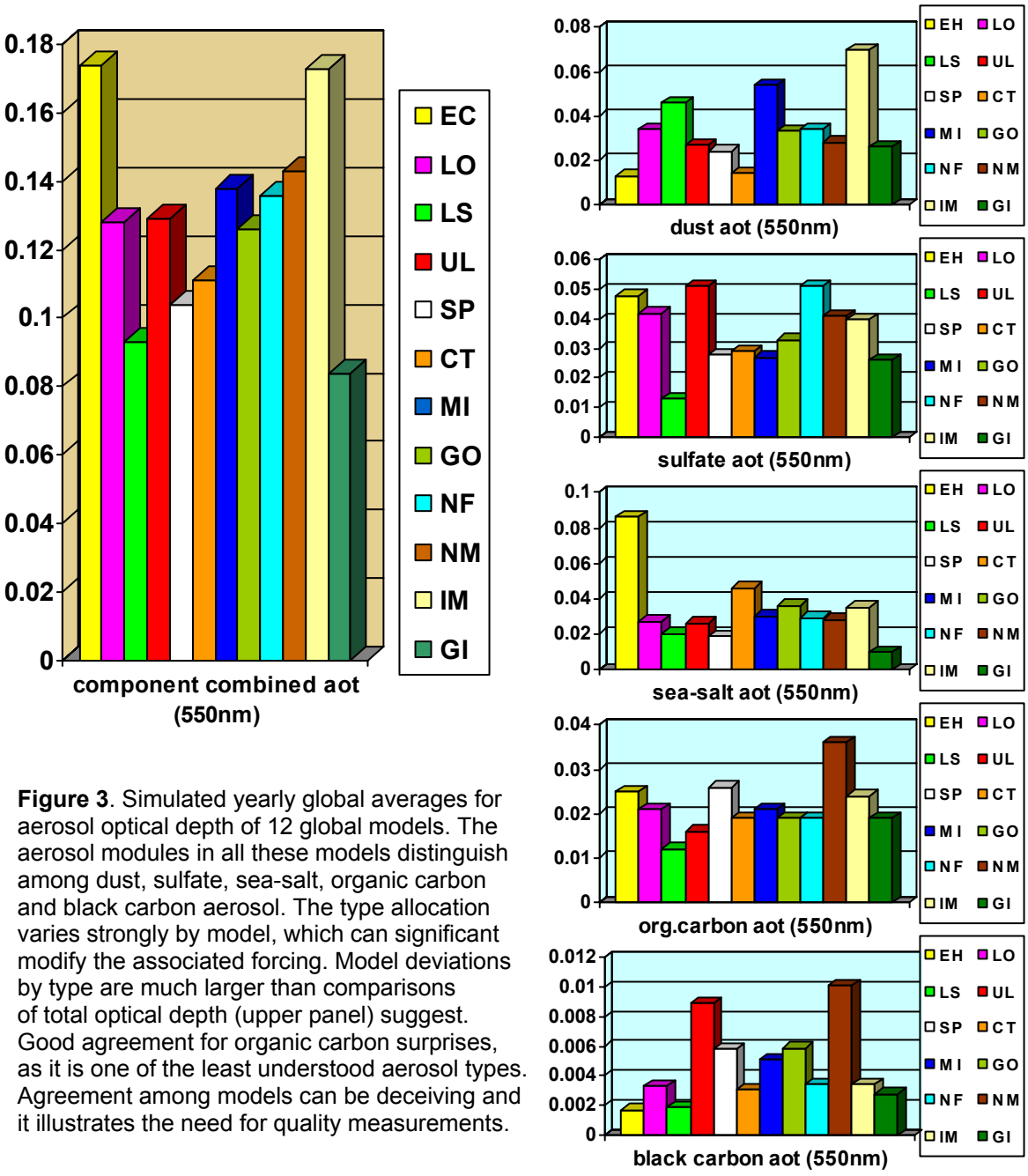

Figure 3. Simulated yearly global averages for aerosol optical depth of 12 global models. The aerosol modules in all these models distinguish among dust, sulfate, sea-salt, organic carbon and black carbon aerosol. The type allocation varies strongly by model, which can significant modify the associated forcing. Model deviations by type are much larger than comparisons of total optical depth (upper panel) suggest. Good agreement for organic carbon surprises, as it is one of the least understood aerosol types. Agreement among models can be deceiving and it illustrates the need for quality measurements.

All models derive their aerosol optical depth from assumed emissions. But, differences in component aerosol optical depth usually do not correspond to similar differences in emission. Since the results from the initial simulations were not constrained to specific emissions, it is more interesting to examine for each aerosol species the 'effective multiplication factors' on the road from emission to aerosol optical depth: the aerosol lifetime and the mass extinction efficiency.

The lifetime (the ratio between mass and emission) includes chemical- , transport- and removal-processes. The mass extinction efficiency (the ratio between optical depth and mass) mainly represents assumptions about aerosol size, including effects from permitted water uptake. Figure 4 illustrates large differences among models for both conversions.

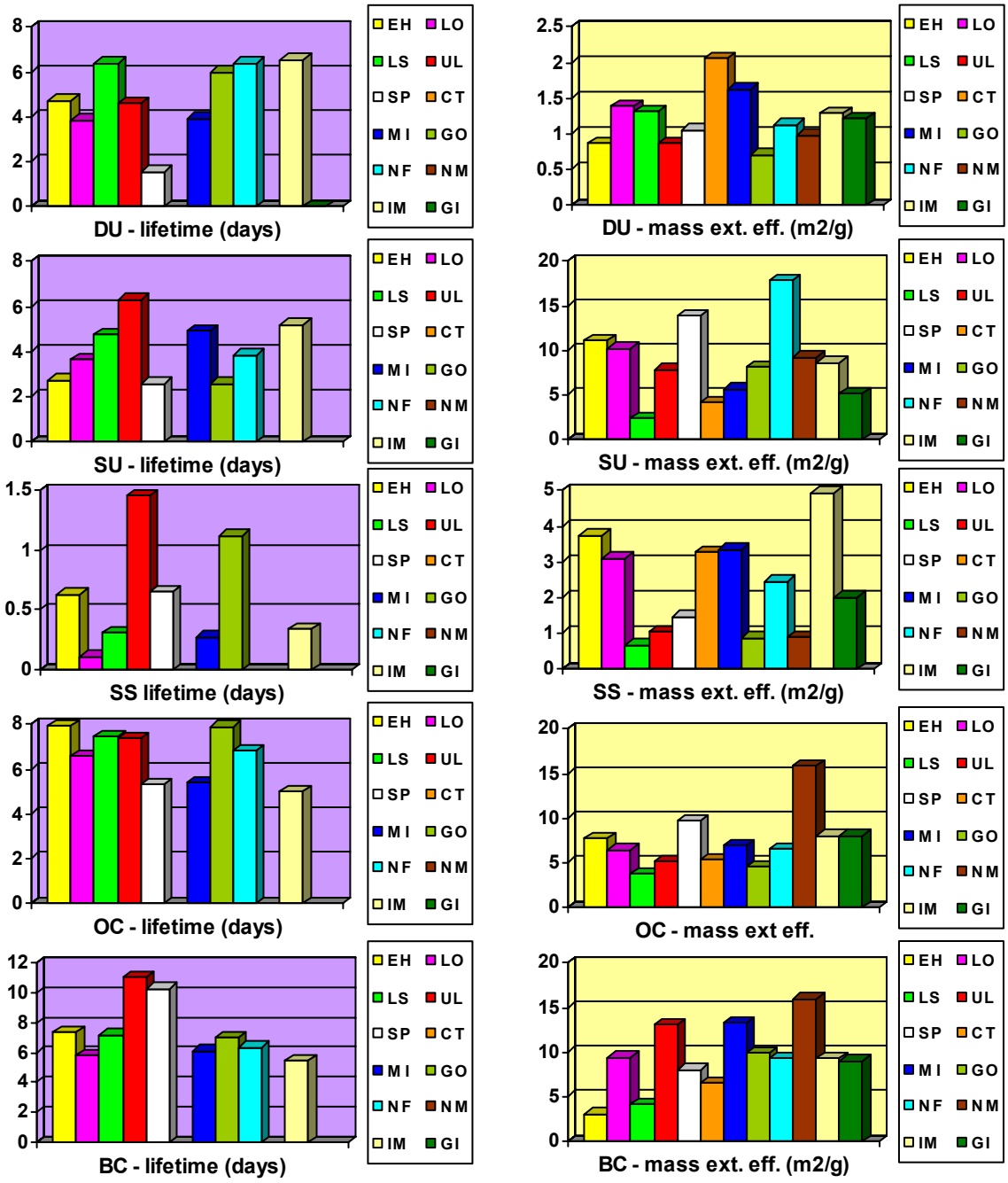

Figure 4: Global yearly averages of simulated lifetime and mass extinction efficiency for aerosol components of dust, sulfate, sea-salt, organic carbon and black carbon in different global models.

Initial attempts to look into modeling issues are sparse, in part because aerosol component modules in global modeling are fairly new and because necessary measurements are not available. In a pioneering effort the COSAM project (e.g. Barrie et al. 2001) addressed one aerosol component, sulfate aerosol, by comparing surface concentrations. However, similar comparisons for all aerosol types, on a global scale and as a function of altitude are necessary. Recent studies (Penner et al., 2002, Kinne et al., 2003) demonstrated the large differences among models on a component basis and they revived interest in the modeling community for coordinated model-intercomparisons – especially as global data from more capable satellite sensors (e.g. NASA's Terra and Aqua of ESA's Enivisat) provide now tighter constraints to the freedom in modeling

The AeroCom project (website: http://nansen.ipsl.jussieu.fr/AEROCOM) was created to provide a platform for detailed evaluations of aerosol modules. This includes definitions of even-footed test-beds for the model evaluations and simplified access to measurements. Initial results from participating modeling groups and from the evaluation staff were presented at the 2003 fall AGU in San Francisco and at the March 2004 AeroCom workshop at Ispra. The next AeroCom workshop is scheduled for November 2004 in New York City.

References

Barrie,L., Y.Yi, U.Lohmann, W.Leaitch, P.Kasibhatla, G.-J.Roelofs, J.Wilson, F.McGovern, C.Benkovitz, M Meliere, K.Law, J.Prospero, M.Kritz, D.Bergmann, C.Bridgeman, M.Chin, J.Christensen, R.Easter, J.Feichter, A.Jeuken, E.Kjellstrom, D.Koch, C.Land and P.Rasch: A comparison of large scale atmospheric sulphate aerosol models (COSAM): Overview and highlights, *Tellus 53B*, 615-645, 2001.

Houghton, J., Y.Ding, D.Giggs, M.Noguer, P.vanderLinden, X.Dai, K.Maskell, C.JohnsonL.Meira Filho, J.Bruce, H.Lee, B.Callander, E.Haites, N.Harris, K.Maskell, Climate Change 2001, The Scientific Basis, an evaluation of the IPCC (International Panel on Climate Change), *Cambridge University Press*, New York, 2001.

Kinne S, U. Lohmann, J.Feichter, C.Timmreck, M.Schulz, S.Ghan, R.Easter, M.Chin, P.Ginoux, T.Takemura, I.Tegen, D. Koch, M.Herzog, J.Penner, G.Pitari, B.Holben, T.Eck, A.Smirnov, O.Dubovik, I.Slutsker, D.Tanre, O.Torres, M.Mishchenko, I.Geogdzhayev, D.A.Chu and Y.Kaufman, Monthly Averages of Aerosol Properties: A Global comparison among models, satellite data and AERONET ground data, *J.Geophys.Res, 108*, 4634, 2003.

Penner, J., S.Zhang, M.Chin, C.Chuanh, J.Feichter, Y.Feng, I.Geogdzhayev, P.Ginoux, M.Herzog, A.Higurashi, D.Koch, C.Land, U.Lohamnn, M.Mishchenko, T.Nakajima, G.Pitari, B.Soden, I.Tegen, L.Stowe, A comparison of model- and satellite-derived aerosol optical depth and reflectivity, *J.Atmos.Sci. 59*, 441-460, 2002.

Appendix

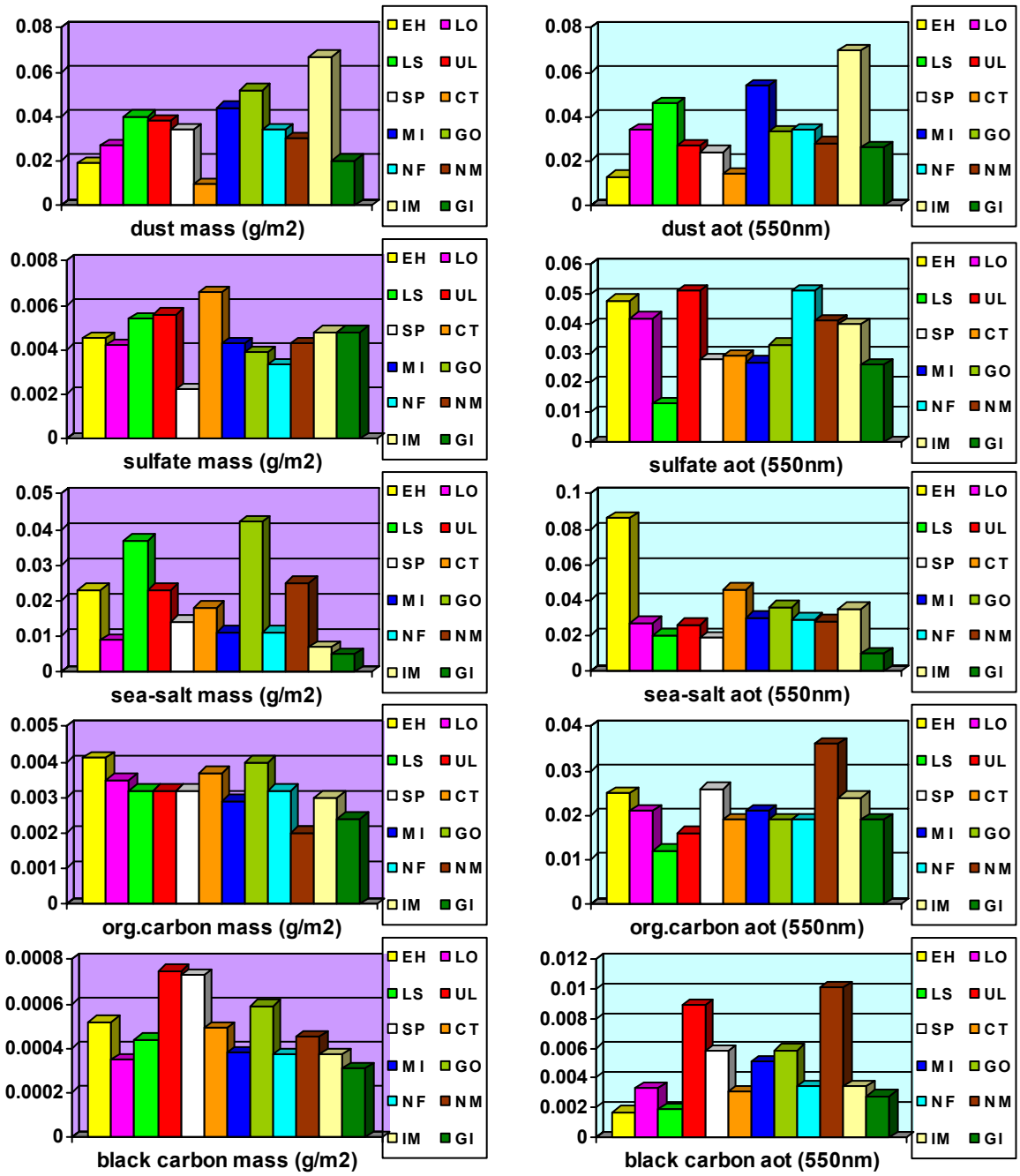

Figure A1: Global yearly averages of simulated mass and optical depth for aerosol components in twelve different global models. Aerosol modules in all models distinguish among dust, sulfate, sea-salt, organic carbon and black carbon. Strong differences in the partitioning of total mass and total optical depth exist. Relative model tendencies between mass and aot are largely due to differences in assumed aerosol properties (in particular size and water uptake). Also surprisingly, the models agree best on the least known aerosol component of carbon. Thus, good agreement among models can be misleading and quality measurements are a key to model improvement.

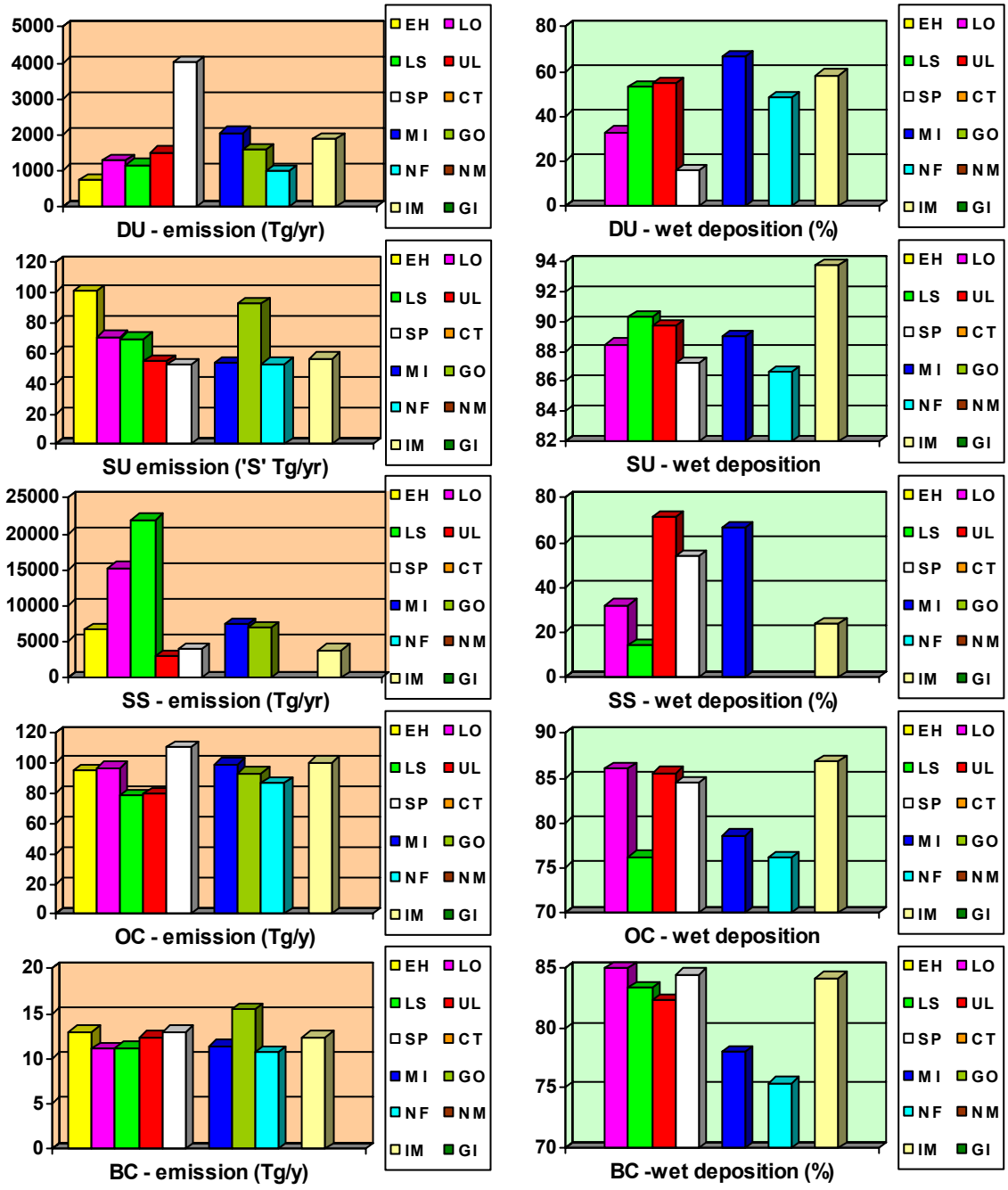

Figure A2: Global yearly averages of assumed emissions and wet deposition for aerosol component in twelve different global models. Aerosol modules in all models distinguish among dust, sulfate, sea-salt, organic carbon and black carbon.