Atmos. Chem. Phys., 4, 523-538, 2004
www.atmos-chem-phys.net/4/523/2004/

Inverse modeling of CO_2 sources and sinks using satellite data: a synthetic inter-comparison of measurement techniques and their performance as a function of space and time

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Abstract. Currently two polar orbiting satellite instruments measure CO_2 concentrations in the Earth's atmosphere, while other missions are planned for the coming years. In the future such instruments might become powerful tools for monitoring changes in the atmospheric CO_2 abundance and to improve our quantitative understanding of the leading processes controlling this. At the moment, however, we are still in an exploratory phase where first experiences are collected and promising new space-based measurement concepts are investigated. This study assesses the potential of some of these concepts to improve CO_2 source and sink estimates obtained from inverse modelling. For this purpose the performance of existing and planned satellite instruments is quantified by synthetic simulations of their ability to reduce the uncertainty of the current source and sink estimates in comparison with the existing ground-based network of sampling sites. Our high resolution inversion of sources and sinks (at 8°x10°) allows us to investigate the variation of instrument performance in space and time and at various temporal and spatial scales. The results of our synthetic tests clearly indicate that the satellite performance increases with increasing sensitivity of the instrument to CO_2 near the Earth's surface, favoring the near infra-red technique. Thermal infrared instruments, on the contrary, reach a better global coverage, because the performance in the near infrared is reduced over the oceans owing to a low surface albedo. Near infra-red sounders can compensate for this by measuring in sun-glint, which will allow accurate measurements over the oceans, at the cost, however, of a lower measurement density. Overall, the sun-glint pointing near infrared instrument is the most promising concept of those tested. We show that the ability of satellite instruments to resolve fluxes at smaller temporal and spatial scales is also related to surface sensitivity. All the satellite instruments performed relatively well over the continents resulting mainly from the larger prior flux uncertainties over land than over the oceans. In addition, the surface networks are rather sparse over land increasing the additional benefit of satellite measurements there. Globally, challenging satellite instrument precisions are needed to compete with the current surface network (about 1ppm for weekly and 8°x10° averaged SCIAMACHY columns). Regionally,

however, these requirements relax considerably, increasing to 5ppm for SCIAMACHY over tropical continents. This points not only to an interesting research area using SCIAMACHY data, but also to the fact that satellite requirements should not be quantified by only a single number. The applicability of our synthetic results to real satellite instruments is limited by rather crude representations of instrument and data retrieval related uncertainties. This should receive high priority in future work.

Final Revised Paper (PDF, 1074 KB) Discussion Paper (ACPD)

Citation: Houweling, S., Breon, F.-M., Aben, I., Rödenbeck, C., Gloor, M., Heimann, M., and Ciais, P.: Inverse modeling of CO_2 sources and sinks using satellite data: a synthetic inter-comparison of measurement techniques and their performance as a function of space and time, Atmos. Chem. Phys., 4, 523-538, 2004. Bibtex EndNote Reference Manager