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A Novel Approach to Estimation of Time-Variable Surface Sources and Sinks of Carbon Dioxide Using Empirical Orthogonal Functions and the Kalman Filter

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It is well known that greenhouse gases and, in particular, greenhouse gases of anthropogenic origin, influence the Earth climate to a great extend. Accurate estimates of strengths, and spatial and time variability of the surface sources and sinks of greenhouse gases are thus of great interest to both the scientific community and the policy makers. Carbon dioxide, (CO2), is the most important greenhouse gas of anthropogenic origin that affects radiative balance of the atmosphere and, eventually, the climate. Observations of CO2 concentrations in the atmosphere demonstrated short-time variability and spatial patterns reflecting influence of time-variable regional sources and sinks.

The objective of this study is to estimate absolute contributions of various geographical regions to the total carbon dioxide budget at relatively short time scales and in a computationally efficient manner. A traditional approach to this problem includes dividing the Earth's surface by a number of non-overlapping regions and estimating the sources and sinks for each one of them. One of the most well-known and successful experiments following this approach was Transcom 3 [1], which used 22 distinct regions. In subsequent work of P. Patra et al. [3], the number of the regions has been increased to 64.

In both cases, monthly mean CO2 surface emissions have been successfully estimated using ground based observations of carbon dioxide concentrations. Recently, (Feng et al, 2009 [3]), 144 distinct regions have been used and the time scale of carbon dioxide variability was reduced to 8 days using satellite observations of CO2. While very successful, the abovementioned approach relies on somewhat arbitrary division of the Earth surface to discrete regions. Refining the results would necessitate increasing the number of regions, and thus computational requirements, which in some cases might prove to be impractical.

We propose an approach based on representing the surface emissions of carbon dioxide as a linear combination of a number of pre-computed empirical orthogonal functions (EOFs). A Kalman filter is used to estimate coefficients of the EOF expansion and errors of the resulting emissions using observations of CO2 concentrations. The EOFs contain information about climatological spatial variability of the emissions and the final results thus are likely to be physically meaningful. Since a relatively small number of EOFs is needed to accurately represent CO2 surface emissions for a number of sources, the estimation problem becomes fairly inexpensive computationally. We present a method of calculation of the EOFs, results of the proposed approach, and comparisons with existing independent data.

Reference

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