Kriging-based Mapping of Space-borne CO2 Measurements by Combining Emission Inventory and Atmospheric Transport Modeling

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Atmospheric CO2 measurement has proven its appositeness for different applications in carbon cycle science. Many satellites are currently measuring the atmospheric CO2 concentration worldwide, for example, NASA’s Orbiting Carbon Observatory-2 (OCO-2), Exploratory Satellite for Atmospheric CO2 (TanSat), Japanese Greenhouse gases Observing SATellite (GOSAT), and Environmental Satellite (ENVISAT). The OCO-2 measures the column-averaged CO2 dry air mole fractions (XCO2) in the atmosphere as contiguous parallelogram footprints, each having area up to about 3 km². The problem associated with this measurement is its narrow swath of approximately 10.6 km width which results in limited spatial coverage.

A number of research works have been reported to spatially map the available XCO2 samples on a regional scale or globally in different temporal scale and spatial resolution. Kriging, a family of geostatistical interpolation method, has been a popular choice for this mapping. In our recent research, we have shown that the univariate kriging methods are not able to produce a pragmatic surface of XCO2 and require the incorporation of more covariates. We have studied the OCO-2’s XCO2 observations and mapped them on a regional scale including multiple covariates, such as Open-source Data Inventory for Anthropogenic CO2 (ODIAC) and the Emissions Database for Global Atmospheric Research (EDGAR) emission estimates and land use and land cover (LULC) information. It is observed that the inclusion of these covariates is able to produce more accurate mapping compared to their baseline alternatives.

However, the CO2 concentration is usually highly influenced by the transportation of the emission particles through the wind. A larger temporal measurement window may ignore its effect by assuming that the wind direction is constantly changing. However, for regional mapping of space-borne XCO2 in a time instance, it is essential to model. This work has developed a novel multivariate kriging-based framework to map OCO-2’s XCO2 measurements including Stochastic Time-Inverted Lagrangian Transport-(STILT)-based atmospheric transport modeling. This model could be coupled with the biospheric flux models and emission estimates to map their local scale distributions.

In this framework, every unmeasured location that is required to be estimated is considered as
the receptor point in the STILT simulation. The emission particles are tracked backward in time from each of these receptor points to simulate possible routes from their upstream locations. A footprint map is then generated which is regarded as the influence of other points to the receptor point in the whole study region. The footprint map, being combined with the emission estimates, will produce a prior CO₂ concentration map. This STILT-generated prior concentration map is inserted into the multivariate kriging framework. The output map, i.e., the interpolated XCO₂ surface is more pragmatic to include the influence of atmospheric transport for the prediction of XCO₂. The accuracy of the framework is proven by comparing the estimated data with ground-based measurements. This work is one of the initial attempts to generate a Level-3 XCO₂ surface on a local scale by combining STILT with a multivariate kriging method.