GOSAT RETRIEVED CO_2 AND CAUSAL INFERENCE BETWEEN IT AND SURFACE TEMPERATURE CHANGE

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Overview

Human activity, especially human-emitted CO_2, has been regarded as the dominant cause of the observed warming since the mid-20th century. But covariation between CO_2 and temperature is not equivalent to causality. The greatest impact of CO_2 on atmospheric temperature, the premise of many studied about Climate Change, should be made a further confirmation. Based on multivariate data of GOSAT Level 4B near surface CO_2 and CHCN CAMS surface temperature, we applied time-series analysis, quantitative analysis, and Granger-Causality, turning up that surface temperature presented an inter-annual variability but with no rising tendency same as near-surface CO_2, relative low Pearson Correlation Coefficients revealed a slighter significant correlations compared with other studies; none of CO_2 and temperature at the five chosen sites are useful in predicting each other and long-term equilibrium relationships between the both are non-existent, neither. Therefore, CO_2 variation doesn't happen prior to temperature variation and vice versa, and the hypotheses (1)(2) raised in this study are both false. Consequently, there is no evident causality between surface CO_2 and temperature, and a third affecting factor of the observed warming should be studied further.

Methods

Here we used correlation analysis (Pearson Correlation Coefficient) and regression analysis to verify this covariation, turning out an inconsistent result.

$$\rho_{x,y} = \frac{N\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{N\sum x_i^2 - \left(\sum x_i\right)^2}\sqrt{N\sum y_i^2 - \left(\sum y_i\right)^2}} \tag{1}$$

But covariation is not equal to causality. And the key is that the reason must happen before the result. Causal Inference plays a more important role on the topic of Green House Gases driving Climate Change. In this paper, we used Granger Causality Test, a statistical hypothesis test for determining whether one time series is useful in forecasting another, first proposed in 1969 (Granger 1969). Granger defined the causality relationship based on two principles (Granger 1980): (1)The cause happens prior to its effect. (2) The cause has unique information about the future values of its effect. Given these two assumptions about causality, Granger proposed to test the following hypothesis for identification of a causal effect of X on Y:

$$\mathrm{P}\left[Y(t+1) \in A \middle| \mathrm{T}(t)\right] \neq \mathrm{P}\left[Y(t+1) \in A \middle| \mathrm{T}_{-X}(t)\right] \tag{2}$$

Where P refers to probability, A is an arbitrary non-empty set, $\mathrm{T}(t)$ and $\mathrm{T}_{-X}(t)$ respectively denote the information available as of the time t in the entire universe, and that in the modified universe in which X is excluded. If the above hypothesis is accepted, we say that X Granger-Causes Y.

Here we didn't take the test conclusion as the criterion of true causality, because Granger causality is not the real causality. However, the predictive causality could draw a clear sequence between the near surface CO_2 and temperature, which is an important information to estimate if CO_2 is responsible for Global Warming.

Results

From the inter-annual variability and covariation of surface CO_2 and temperature at the five sites form TCCON, there is no rising tendency at all chosen sites not only in the Northern Hemisphere but also in in the Southern Hemisphere. The result of correlation between surface CO_2 and surface temperature is consistent with the study which drew the conclusion that there exist significant correlation (Wunch et al. 2013), but not so significant like that. Furthermore, even though proved a significant covariation, we still can't point to a large-scale dynamical effect, fires, fossil fuel use, or a biospheric reaction to the temperature changes, that is because covariation is not equal to causality, then we can't assume the driving factors of CO_2 as the causing factors of temperature too. From the Figure 1, we can bring forward three hypothesises: (1) seasonal changing of CO_2 results in temperature variation with a time lag; (2) seasonal changing of temperature results in CO_2 variation with a time lag; (3) a third factor results in this covariation of the both, without no causality between CO_2 and temperature. However, there is no rising tendency in temperature seasonal changing cycle along with CO_2 variation, this should be verified with a longer time-series data further.

Based on the two principles of Granger, and after Unit Root Test (Augmented Dickey-Fuller (ADF)) and Cointegration Test, we find that long-term equilibrium relationships between CO_2 and temperatures at the four sites are non-existent.

Conclusions

The annual cycle of CO_2 and surface temperature over the five sites were compared because long time-serial data are the precondition for covariation and causality. For the reason that covariation and causality do not equal each other, namely cause must happen ahead of its effect, we took a statistical hypothesis test, named Granger-Causality, to ascertain if there exists a sequence or predictability between near-surface CO_2 and temperature. We brought forward three hypothesizes. From the result of Granger-Cause and Cointegration Test, none of CO_2 and temperature at the five chosen sites are useful in forecasting each other and long-term equilibrium relationships between the both are non-existent, neither. CO_2 variation doesn't happen prior to temperature variation and vice versa, and the hypotheses (1)(2) are both false. Consequently, there is no evident causality between surface CO_2 and temperature, and a third affecting factor of the observed warming should be studied further.