Global Atmospheric Methane
12/03/2025

Atmospheric methane contributes to about 30% of short term global warming and is the second-most important greenhouse gas ranked only after carbon dioxide. Methane traps significantly more heat than carbon dioxide primarily because of its molecular structure (four C-H bonds in comparison to two C-O bonds in carbon dioxide) that allows it to absorb a greater amount of infrared radiation at a given gas concentration. It is estimated that over a 20-year period methane can trap 84 times more heat than carbon dioxide does even the latter at a much higher concentration in the air. In addition, methane contributes to the formation of tropospheric ozone that can harm human.

The global monthly average methane level is compiled by averaging the data for each measurement site across the world and then all the values are plotted as a function of site latitude for 48 equal time steps. The global monthly means are computed from the latitude plot at each time step by NOAA's Earth System Research Laboratory. The mole fraction of methane concentration is abbreviated as "ppb" for parts per billion. The original data resides at https://gml.noaa.gov/ccgg/trends_ch4/.

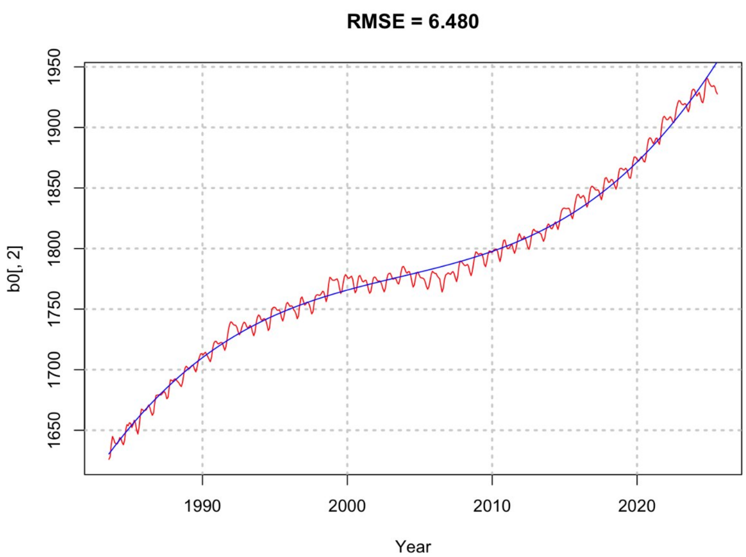

Figure 1, Global Methane Monthly Average Measurements (red) and the General Trend Line (blue) using a Cubic Linear Model.

Figure 1 shows cubic linear model fitting the data. A higher order linear model does not improve the root mean square error (RMSE). The seasonality of the data is modeled using the Fourier transformation. Figure 2 shows the spectrogram of the residual term from the trend model.

Several important frequency components are located at the frequency index of 44, 85 and 127, corresponding to seasonalities of 505/44 = 12 months, 505/85 = 6 months, and 505/127 = 4 months. The Fourier transformation includes all the frequency components whose index is below 150. Figure 3 shows the modeling results. The RMSE reduces from 6.48 for the general trend model to 0.495 after these seasonalities are accounted for.

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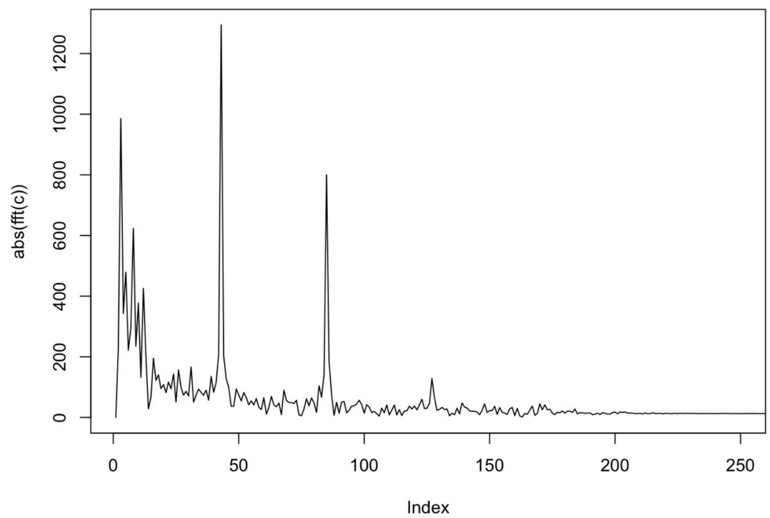

Figure 2, Fourier Transformation of the Residual Term from the Trend Model.

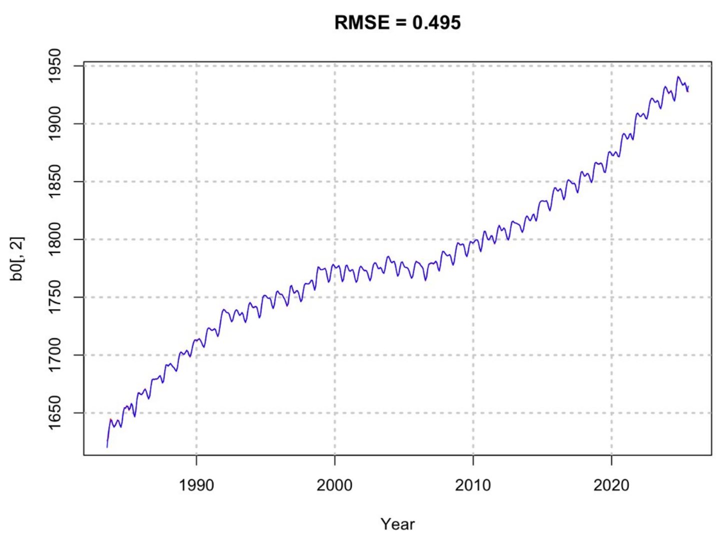

Figure 3, Global Monthly Average Measurements (red line, hidden) and Model of both the Trend and Seasonality (blue line).

The partial autocorrelation function (PACF) of the residual term from the seasonality model is shown in Figure 4. It suggests that the average value of one month is correlated to those values five months prior. These contributing monthly averages are then included into the autoregression model of the residual term.

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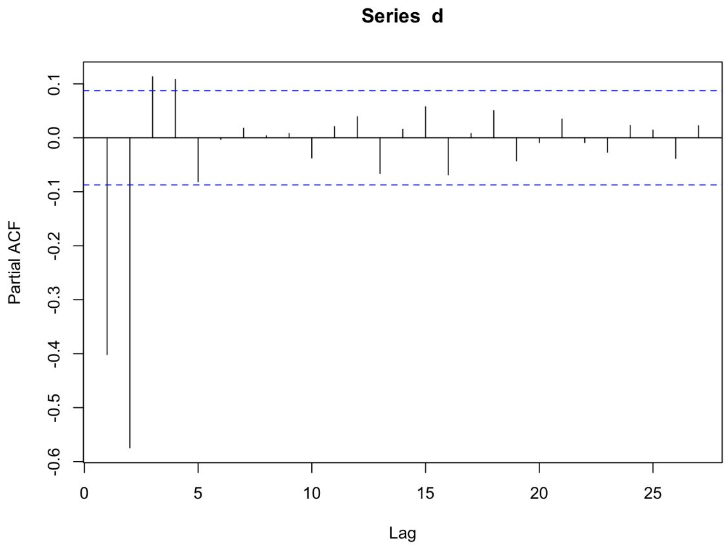

Figure 4, Partial Autocorrelation Function of the Residual Term (d) from the Seasonality Model.

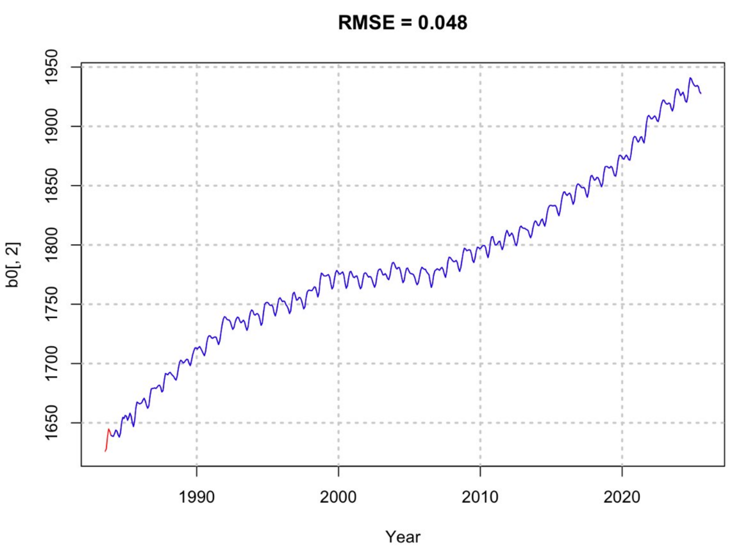

Figure 5, Combined Model with Trend, Seasonality, and Autoregression Components.

The combined model is shown in Figure 5. The RMSE of the combined model is further reduced to 0.048 from 0.495, a significant improvement in model accuracy. A closeup view of the model is also shown in Figure 6 where the model predictions are almost completely overlapping on top of the actual measurements from NOAA.

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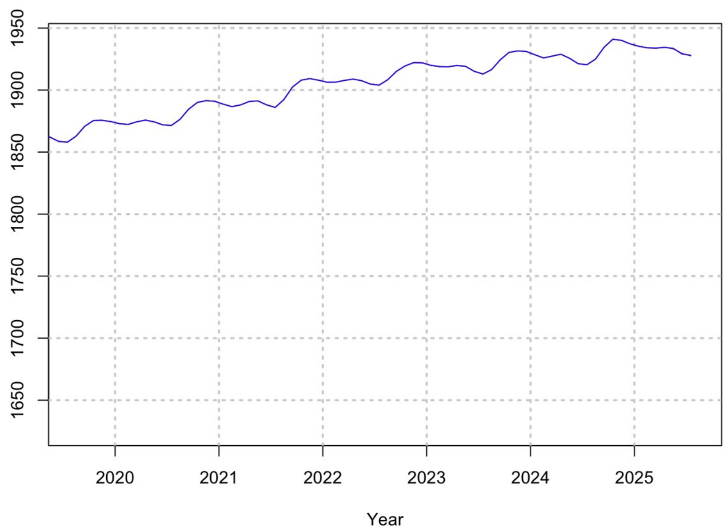

Figure 6, A Closeup View of Figure 5 of Actual Measurements (red line, hidden) and Model Prediction (blue line)

Concluding Remarks

Even though global methane concentration (approx. 1900 ppb) is still significantly less than that of carbon dioxide (approx. 430 ppm), its contribution to the global warming nonetheless cannot be underestimated due to methane's much higher infrared absorption coefficient. The global methane monthly average data show that the increase in concentration level slowed down between 1990 and 2000. The level even became stable briefly during 2000 to 2008. However, the stability was only short lived and the global monthly level quickly resumed an upward trend after 2008. In addition, the concentration level follows a quadrimester (every four months) cycle, semi-annual cycle (6 months), and an annual cycle (12 months), as demonstrated in Figure 2. These cycles are largely due to seasonal activities and show a reduction in methane level during the summer season but an increase in methane level during the fall season. Lately, the reduction during the summer appears to have been slowed down, but the increases in the fall accelerated.

The causes for the summer reduction and fall growth are not clear at this moment. Some researchers suggest that the water level and seasonal temperature change in the wetlands may play a role. In addition, the infamous Nord Stream II incident in September 2022 does not show as a particular significant impact to the global monthly methane concentration.

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