Global Atmospheric Methane
12/03/2025

Atmospheric methane contributes to about 30% of short term global warming and is the second-most impactful 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 concentration. It is estimated that over a 20-year period methane can trap 84 to 86 times more heat than carbon dioxide.   In addition, methane contributes to the formation of tropospheric ozone that can damage crops and harm human.

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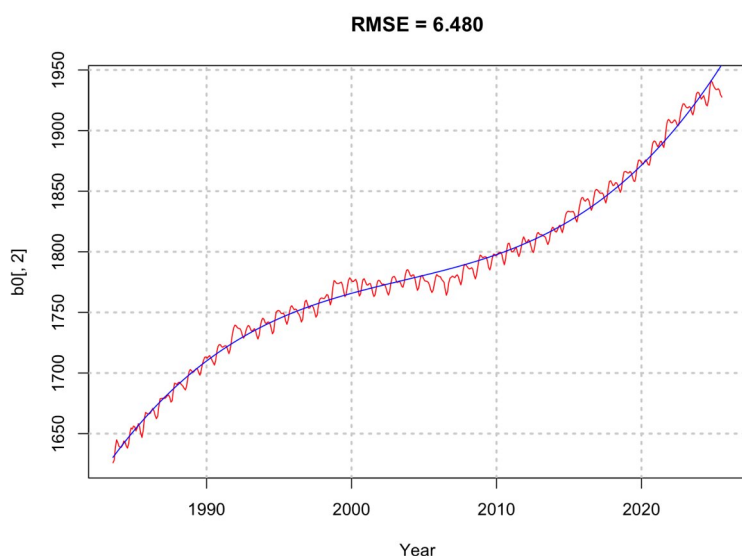

Figure 1, Global Methane Monthly Average Measurements (red) and the General Trend Line (blue) using a Cubic Linear Model.

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 include all the frequency components below 150. Figure 3 shows the modeling results. The root mean square error (RMSE) reduces from 6.48 for the general trend model to 0.495 when these seasonalities are accounted for.
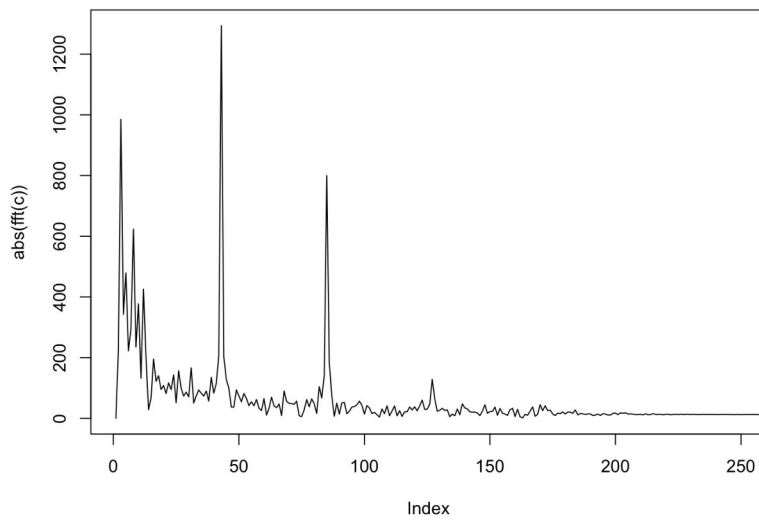
Figure 2, Fourier Transformation of the Residual Term from the Trend Model.
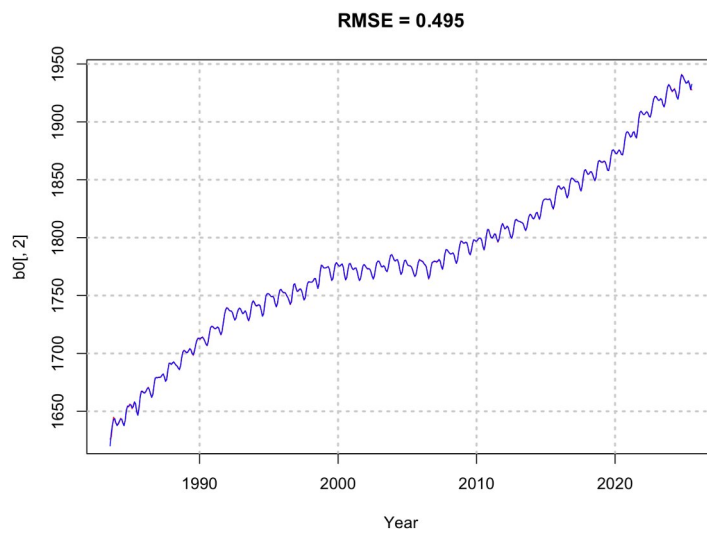
RMSE = 0.495

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

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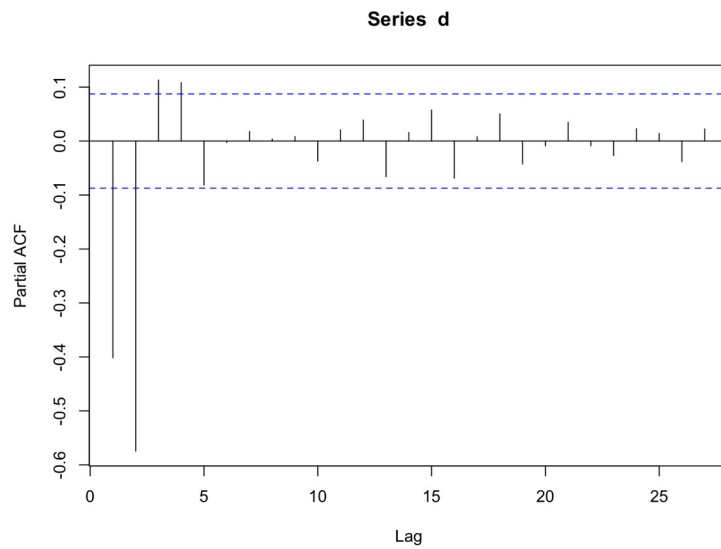
Series d

Figure 4, Partial Autocorrelation Function of the Residual Term (d) from the Seasonality Model.
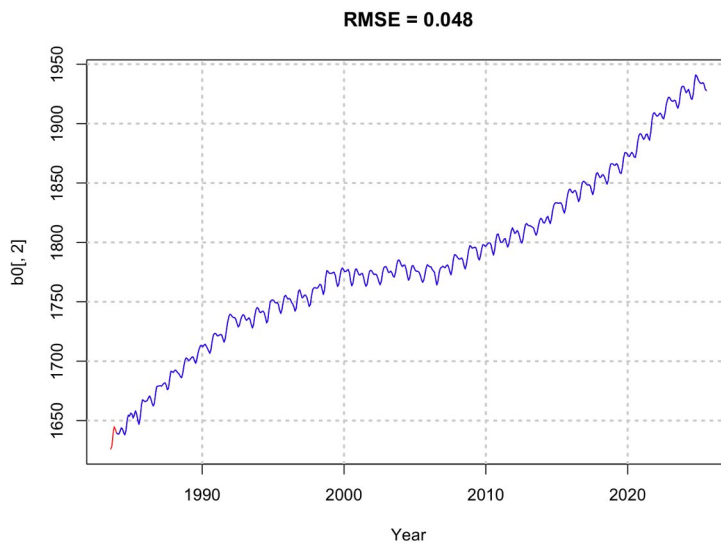
RMSE = 0.048

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 reduced to 0.048 from 0.495, a significant reduction. A closeup view of the model is also in Figure 6 where the model data is almost overlapping on top of the actual measurements from NOAA.
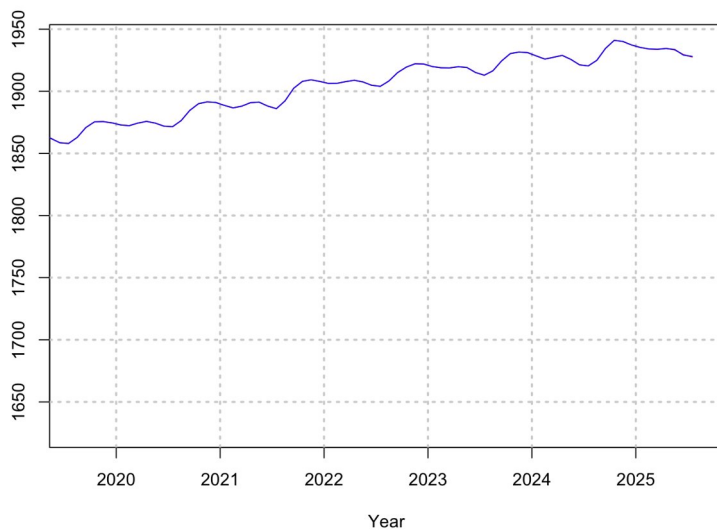
Figure 6, A Closeup View of Figure 5 of Actual Measurements (red line, hidden) and Model Prediction (blue line)

Concluding Remarks

Even though global methane concentration (1900 ppb) is still significantly less than that of carbon dioxide (430 ppm), its contribution to the global warming nonetheless cannot be underestimated due to methane's higher optical absorption coefficient. The global methane monthly average data show that the concentration level increase 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 level quickly resumed an uptrend after 2008 at an accelerated rate. In addition, the concentration level follows a quadrimester (every four months) cycle, semi-annual cycle (6 months), plus 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.