Supplemental Information

Section S1. Model Comparison of Independent Sites

Here we show the comparison between the model and surface observations at the independent observation sites that have not been used in the assimilation. The model captures the SCA amplitude well when compared with surface observations (Fig. S1). The Siberia sites (DEM, BRZ and KRS) have a very short observation record of 6 years and the SCA is quite variable within this time period, leading to large error bars.
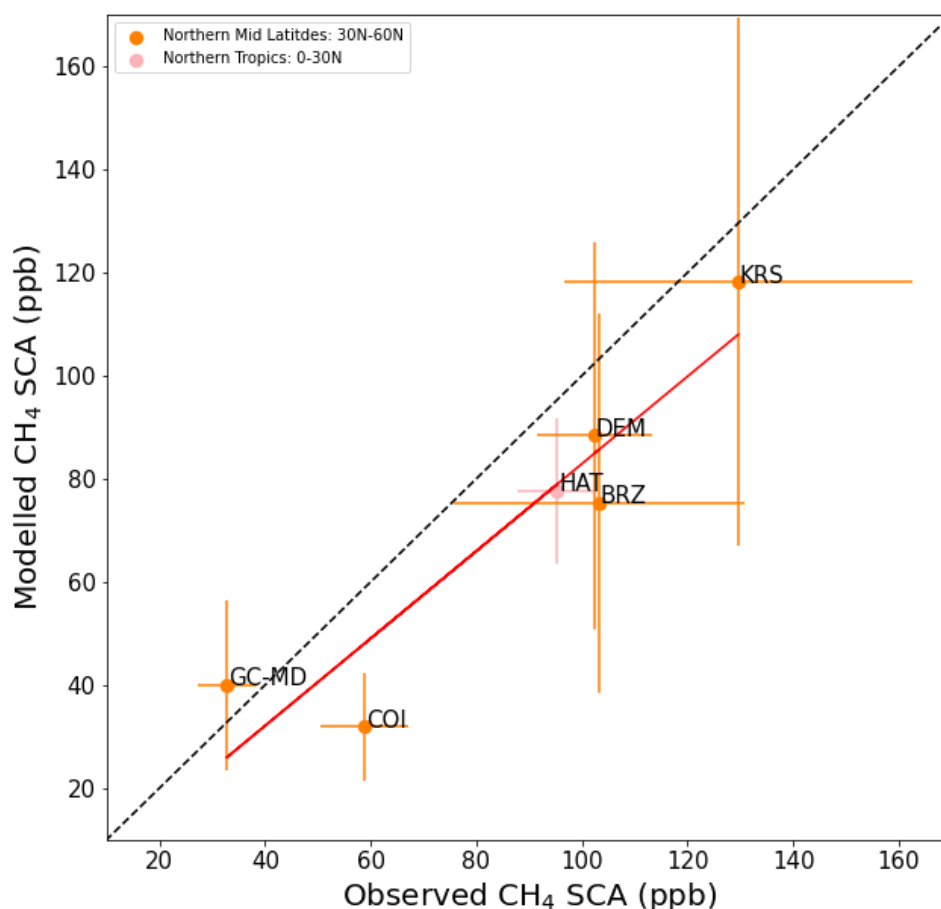
Figure S1: The comparisons between simulated and observed CH₄ at the independent surface observation sites. The solid line represents the unit lie and the red line represents the least squares regression line. The error bars denote ±1σ.

Section S2. SCA Time Series

This section contains the time series of the modelled and observed SCA and the trend at the NOAA observation sites (Fig. S2)
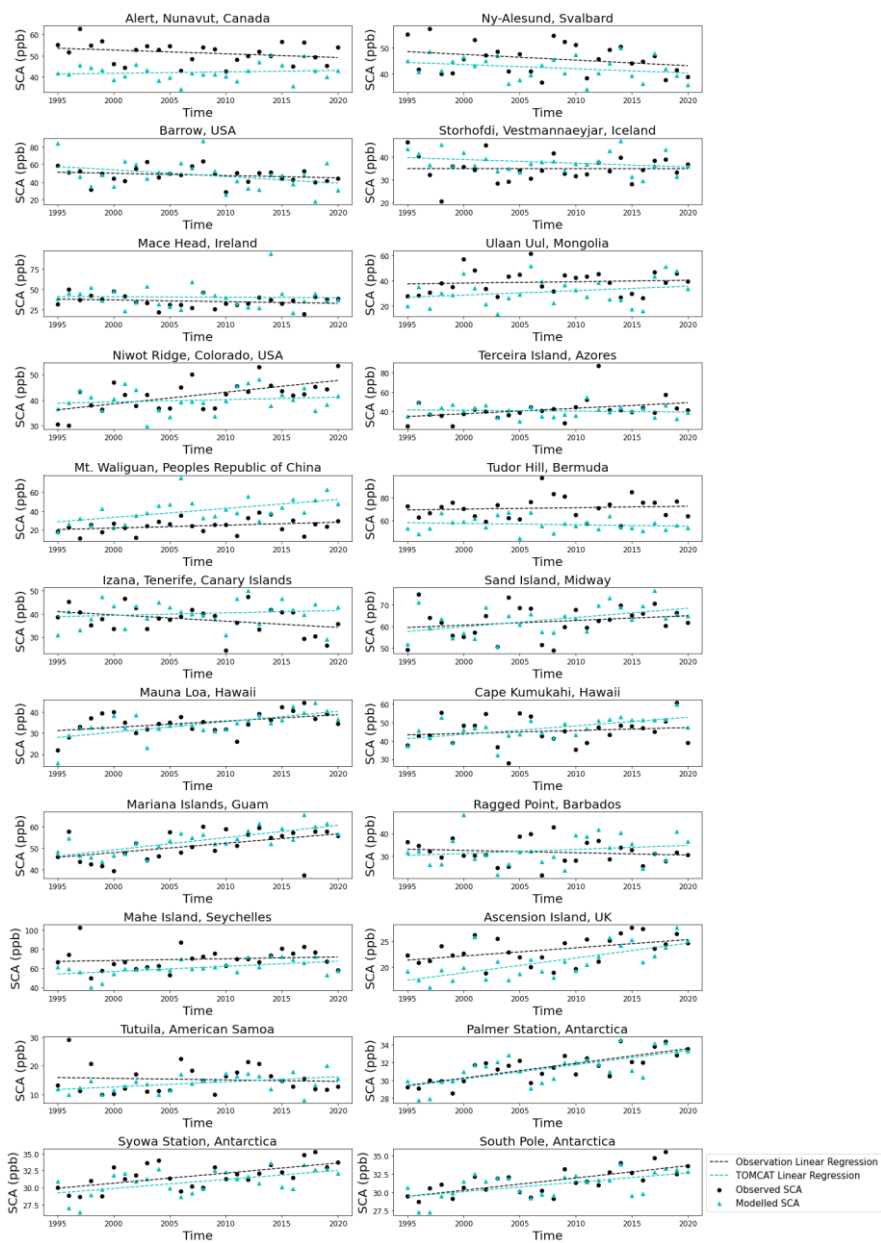
Figure S2: The time series comparison of modelled and observed SCA and the trend at the NOAA observation sites. The sites are ordered north to south.

Section S3. Mean Emission Maps & Trends

This section contains the seasonal mean emissions for the regions which contribute the most to the ΔSCA in the NHL. It also contains the seasonal trends of emissions in each of these regions.
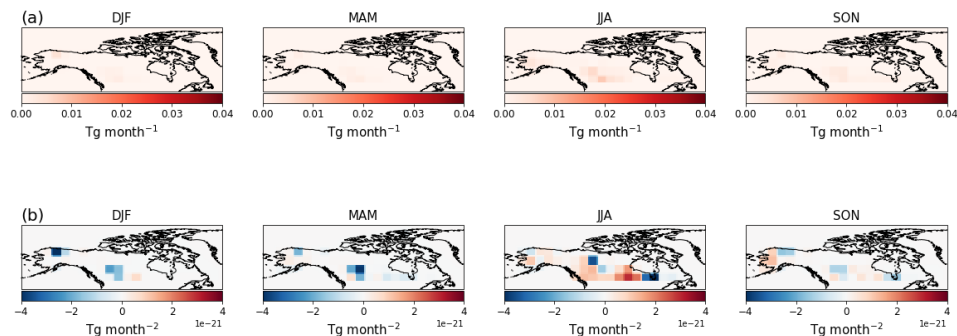
Figure S3: (a) Seasonal mean emissions (Tg month^{-1}) and (b) seasonal trend in emissions (Tg month^{-2}) over Canada between 1995-2020.
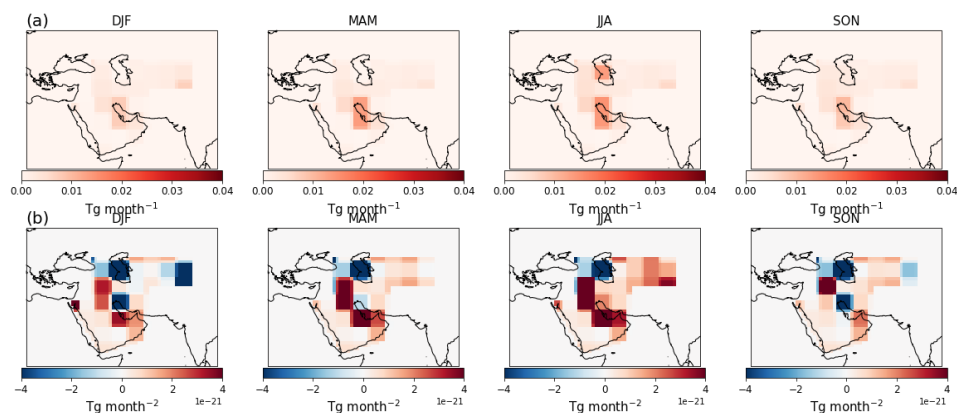
Figure S4: (a) Seasonal mean emissions (Tg month^{-1}) and (b) seasonal trend in emissions (Tg month^{-2}) over Middle East between 1995-2020.
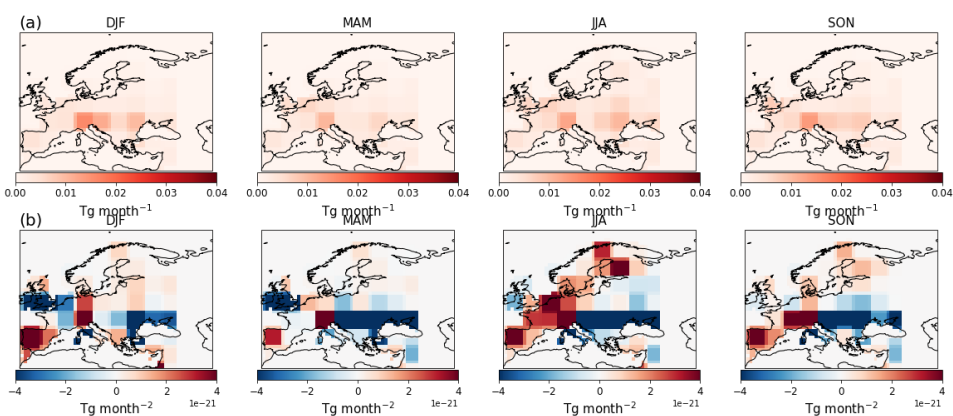
Figure S5: (a) Seasonal mean emissions (Tg month^{-1}) and (b) seasonal trend in emissions (Tg month^{-2}) over Europe between 1995-2020.
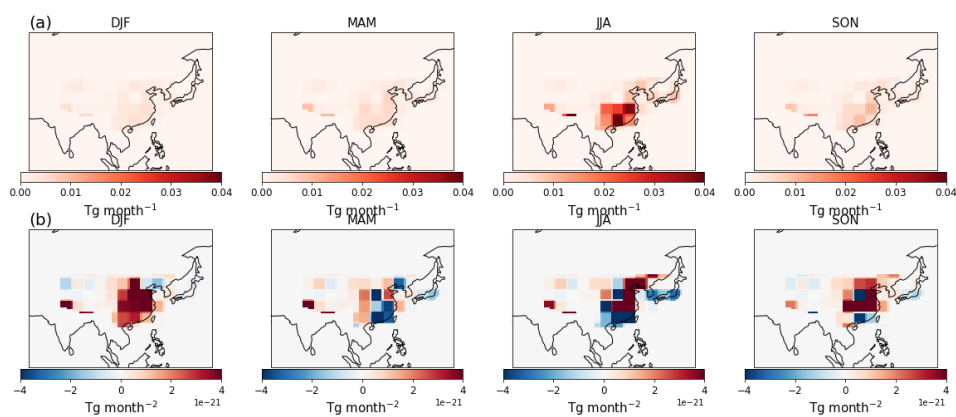
Figure S6: (a) Seasonal mean emissions (Tg month^{-1}) and (b) seasonal trend in emissions (Tg month^{-2}) over China & Japan between 1995-2020.

Section S4. GFED Fire Emissions
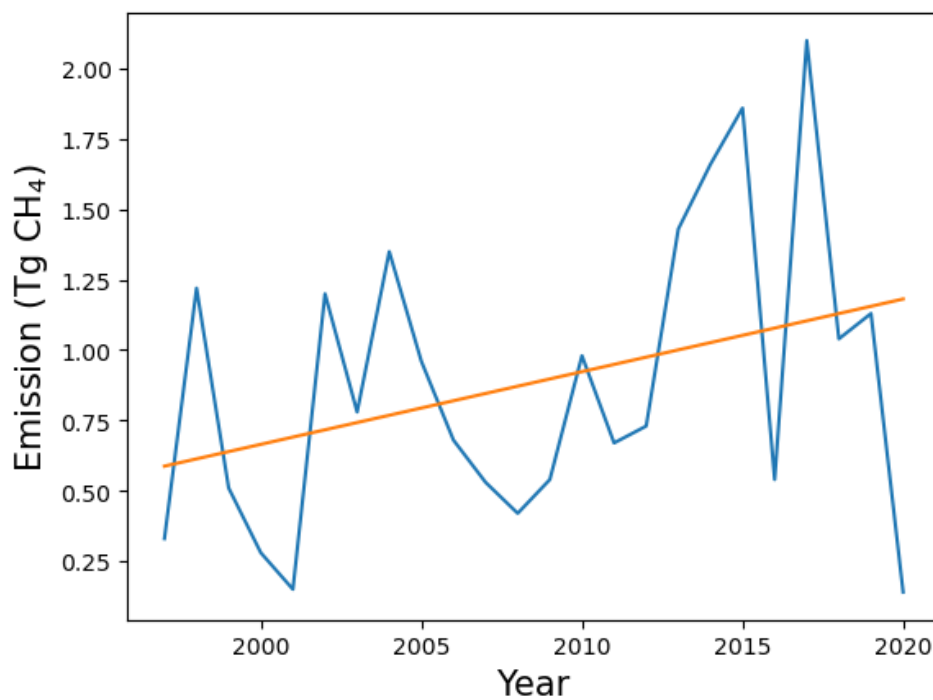
Figure S7: Emissions of CH$_4$ (Tg CH$_4$) from fires over Canada between 1997-2020 (blue) and its trend (orange).

Section S5. Regional Concentration Contributions to Northern High Latitudes
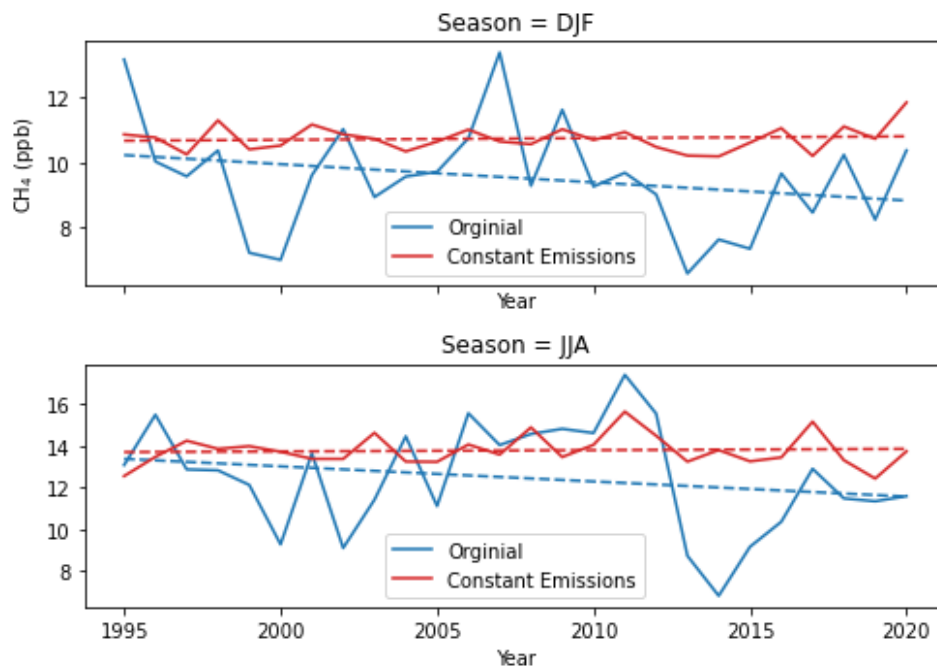
Figure S8: Mean CH$_4$ (pbb) contribution across the NHL at the surface (60N-90N) for the TOM_regional simulation (blue) and the TOM_transport simulation (red) from Canada.
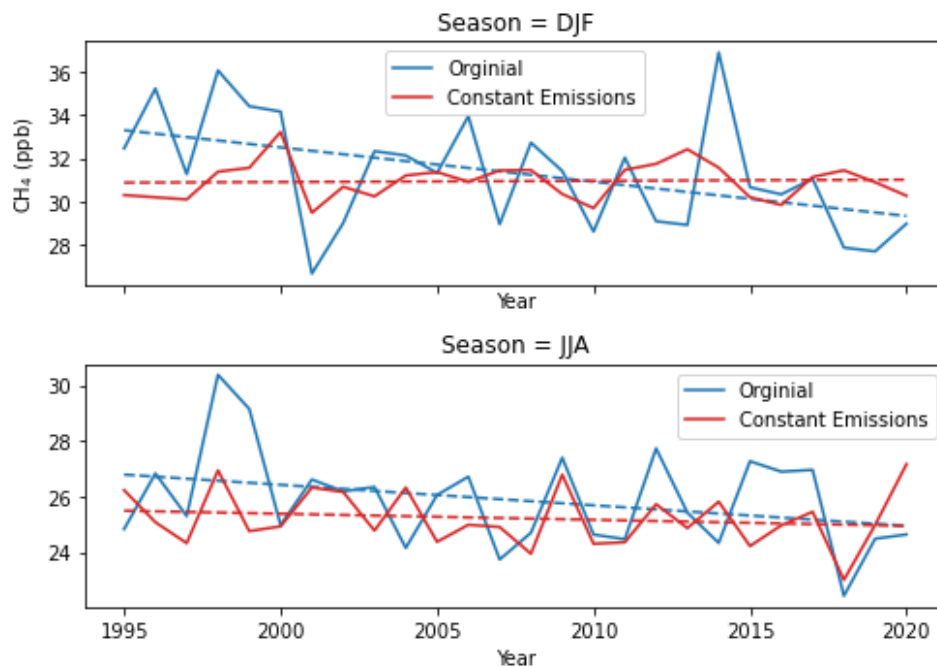
Figure S9: Mean CH$_4$ (pbb) contribution across the NHL at the surface (60N-90N) for the TOM_regional simulation (blue) and the TOM_transport simulation (red) from Europe.
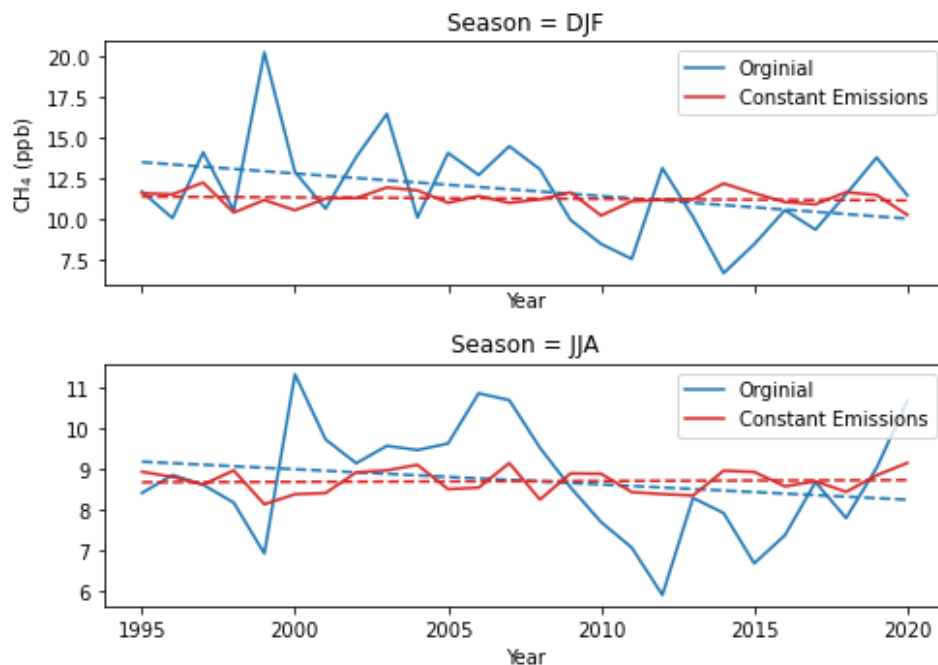
Figure S10: Mean CH₄ (pbb) contribution across the NHL at the surface (60N-90N) for the TOM_regional simulation (blue) and the TOM_transport simulation (red) from the Middle East.
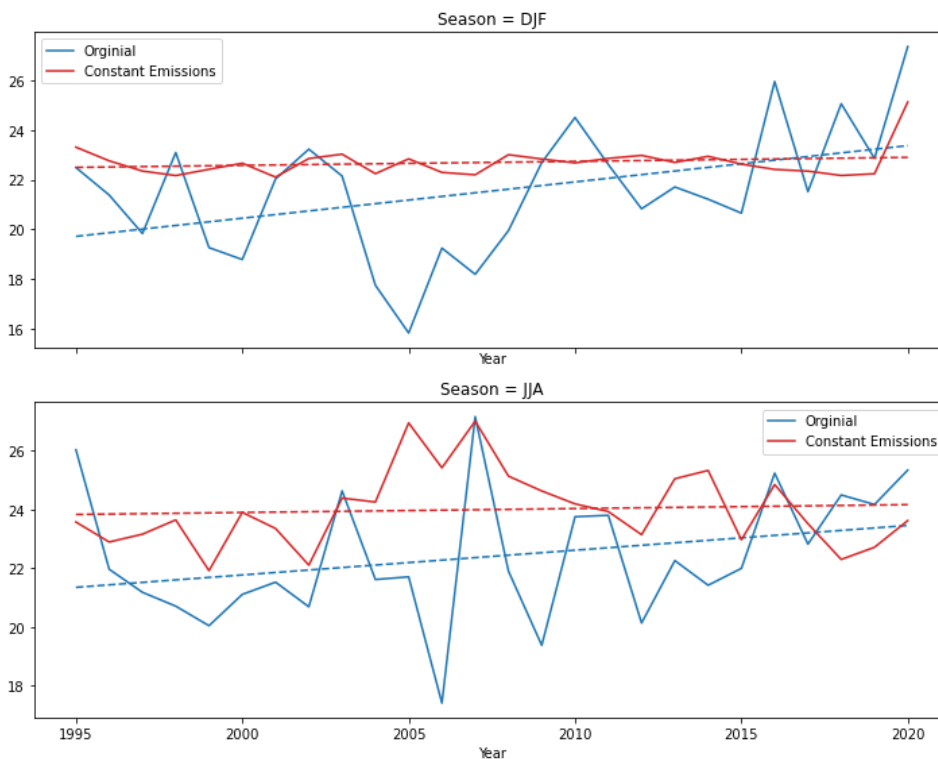
Figure S11: Mean CH₄ (pbb) contribution across the NHL at the surface (60N-90N) for the TOM_regional simulation (blue) and the TOM_transport simulation (red) from China & Japan.