The Hidden Diurnal Cycles of Atmospheric Methane at the Top of Mt. Fuji

Chang-Feng Ou-Yang[1], Shungo Kato[2], Kojiro Shimada[3], Hiroshi Okochi[3], Ting-Hung Yu[4], Neng-Huei Lin[1]
1. National Central University, Taiwan, 2. Tokyo Metropolitan University, Japan,
3. Waseda University, Japan, 4. Academia Sinica, Taiwan

1. Introduction

Methane (CH_4) is the second most abundant anthropogenic greenhouse gas next to CO_2, accounting for approximately 16.5% of the global radiative forcing as reported by NOAA/GMD in 2018. According to the AR5 published by IPCC, a CH_4 has a 28 times greater global warming potential than a CO_2 over a 100-year period (GWP_{100})[1)]. This study presents the temporal variation of atmospheric CH_4 measured at the Mt. Fuji Research Station (FRS, 35.37°N, 138.73°E, 3776 m a.m.s.l.) in the summer of 2019. The observation period of the campaign was July 12 to August 20, 2019.

2. Methods

Ambient CH_4 was measured continuously using a cavity ring-down spectrometer (G1301, Picarro, USA). The instantaneous data points were taken at a frequency of approximately 2 s and further calculated into hourly averages. A series of NOAA/GMD tertiary standards ranging from 1599 to 2024 ppb using the NOAA04 scale was served for the calibration of CH_4 prior to the campaign. Meteorological data such as wind speed (WS) are provided by the FRS.

Three-day (72 h) backward trajectories at a frequency of 1 synoptic time per day (15:00 UTC) are computed using the NOAA/ARL HYSPLIT4 model. Four groups are identified accordingly as China, Japan, Pacific, and Korea (sort in chronological order).

Table 1 Statics of CH_4 and WS for individual trajectory groups

	Number of Days	CH_4 (ppb)	WS (m/s)
China	3	1850.2±46.0	4.77±2.35
Japan	16	1811.4±30.3	4.03±4.11
Pacific	18	1766.4±21.7	1.55±0.21
Korea	3	1812.6±3.0	3.35±3.70
All	39	1791.5±36.0	3.34±3.21

3. Results and Discussion

The observational results are illustrated in Fig. 1. Mean concentration of CH_4 during the campaign is 1791.5±36.0 ppb, with a maximum and a minimum value of 1903.3 ppb and 1733.5 ppb, respectively. The mean values of CH_4 and WS for each trajectory group are calculated as shown in Table 1. Group China has the highest level of CH_4 (1850.2±46.0 ppb) and WS (4.77±2.35 m/s) on average, whereas group Pacific has the lowest level of CH_4 (1766.4±21.7 ppb) and WS (1.55±0.21 m/s).

As suggested in the literature[2)], mountain-valley breezes are suppressed at Mt. Fuji due to the minimal radiation from the small surface area of the isolated mountaintop. However, a veiled diurnal cycle of CH_4 was found during a clam period (July 29 – August 8) of the campaign with lower wind speed. Reduced CH_4 in association with elevated H_2O was observed around noontime, which was likely driven by uplifting winds. The mean diurnal variation of CH_4 during the clam period is thus treated as a model for calculating the similarity for each day except the first (July 12) and the last (August 20) one. The similarity is evaluated based on Minkowski distance metric (D_{Mink}) as given as follows[3)]:

$$D_{Mink} = \left(\sum_{t=1}^{N} \left| f_t^p - f_t^q \right|^r \right)^{\frac{1}{r}}$$

where f_t^p and f_t^q are the two individual time series at time t and N is the number of samples in the time series. A Chebyshev distance is defined ($r = \infty$), which is more sensitive to outlier values due to the non-linear character of the dataset. Regardless of the discrepancies between different originations of air masses, the similarity increases against daily mean wind speed with a regression coefficient (R^2) of 0.5 as illustrated in Fig. 2, meaning that the diurnal cycle of CH_4 could be more distinct when the wind speed is low.

4. Conclusion

The results of continuous measurement of atmospheric CH_4 conducted at the FRS during July 12 – August 20, 2019, was presented. A minor diurnal feature of CH_4 hidden in the time series was observed during the calm period of low wind speed, which has been analyzed by the similarity test in this study.

References

1) IPCC (2013). Climate Change 2013: The Physical Science Basis, *Cambridge University Press*, Cambridge and New York.
2) Igarashi, Y., Sawa, Y., Yoshioka, K., Takahashi, H., Matsueda,

連絡先：Chang-Feng OU-YANG　cfouyang@cc.ncu.edu.tw

H., Dokiya, Y. (2006). Seasonal variations in SO_2 plume transport over Japan: Observations at the summit of Mt. Fuji from winter to summer. *Atmos. Environ.*, **40**, 7018-7033.

3) Jain, A.K., Murty, M.N., Flynn, P.J. (1999). Data clustering: A review. *ACM Comput. Surv.*, **31**, 264-323.

a) b)

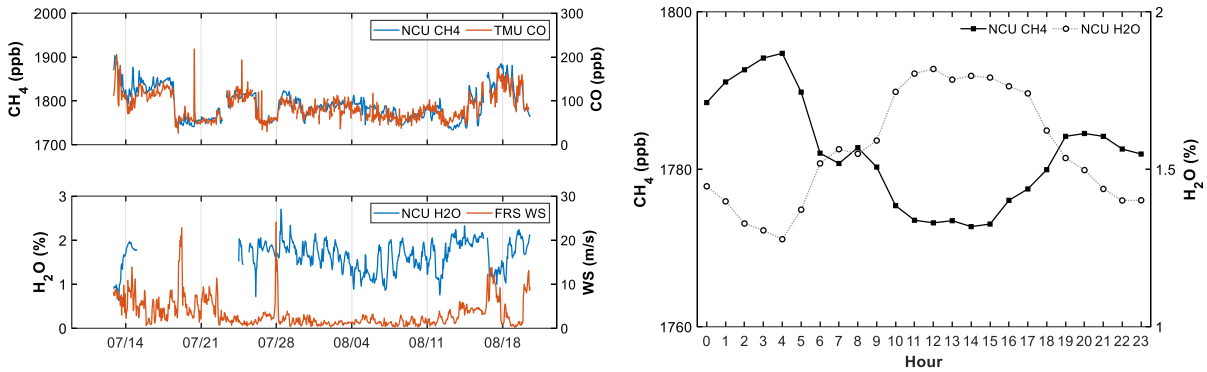

Fig. 1 a) Results of the continuous measurements during the 2019 campaign. b) Mean diurnal cycles of CH_4 and H_2O during the calm period July 29 – August 8.

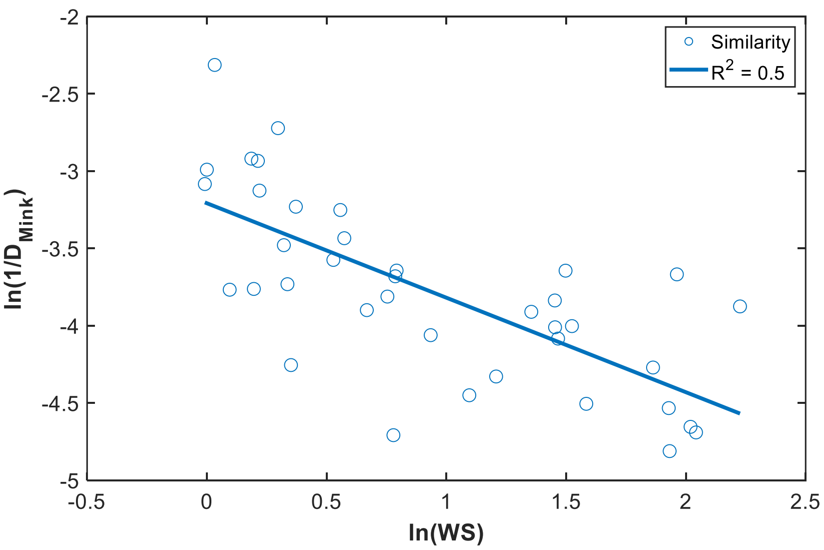

Fig. 2 Relationship between natural logarithms of similarity ($1/D_{Mink}$) and mean WS (m/s) for each day during the 2019 campaign