Nocturnal surface fluxes of N_2O and CH_4 determined from atmospheric measurements at the Cabauw tall tower

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1. Introduction

- N_2O and CH_4 are potent greenhouse gases, with the global warming potential of 298 and 25 times that of CO_2 for a 100-year timescale .
- The implementation of mitigation needs accurate quantifications.
- The compiled inventories: large uncertainties

- *The fluxes determined from atmospheric measurements on larger scale can help to constrain the inventories.*

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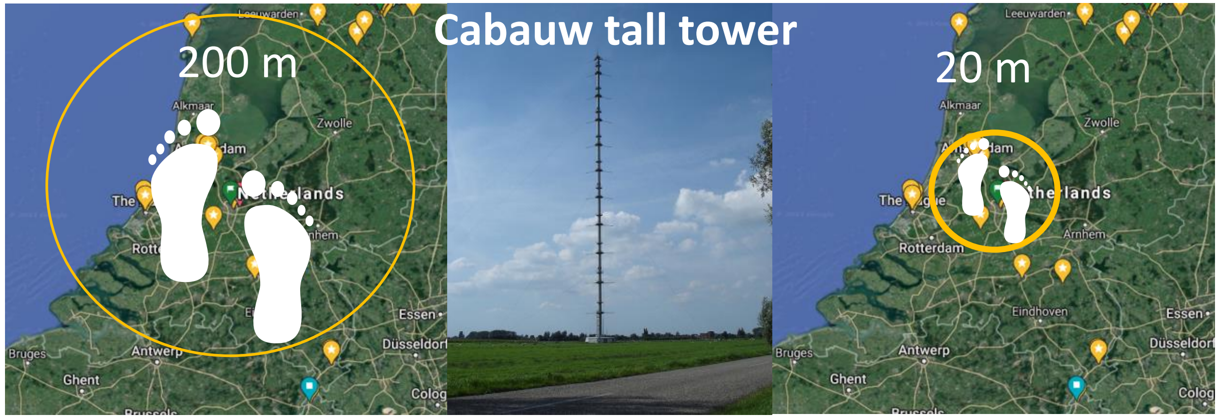
1. Introduction

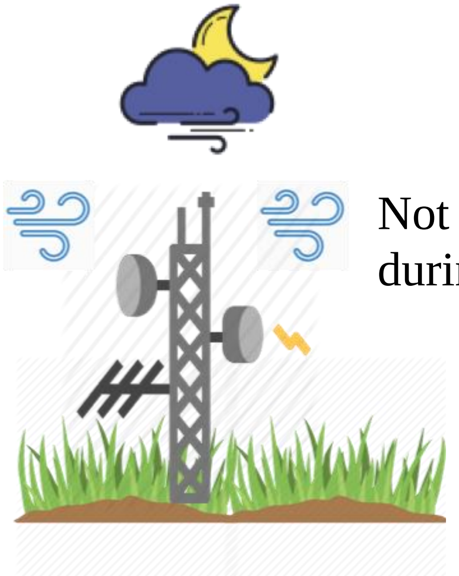
➢ Tall tower measurements:

higher height level for larger footprints



➢ How to make use of the tall tower measurements to derive the fluxes?

Eddy covariance techniques:



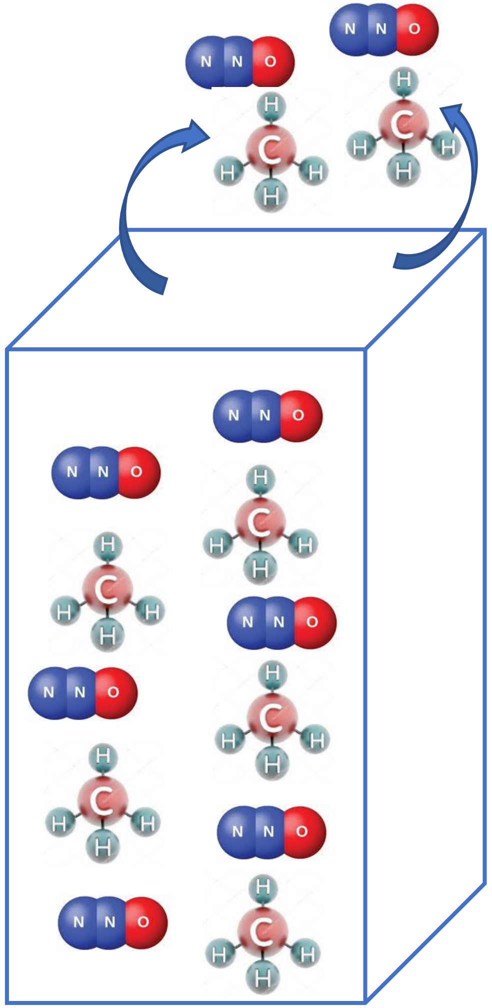
Not very accurate during calm nights

➢ *Exploit the concentration profiles measured at the Cabauw tall tower*

2. Methods and materials

2.1 The vertical gradient method (VGM)

Surface flux = Storage flux +Turbulent flux + ~~advective flux~~[1,2]

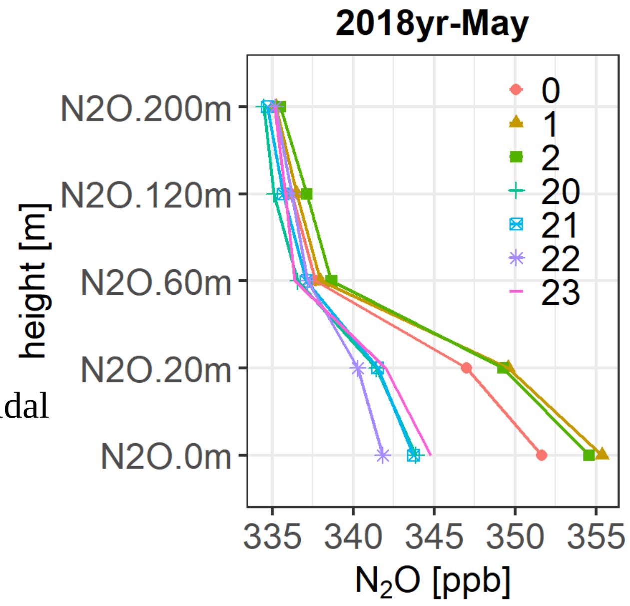


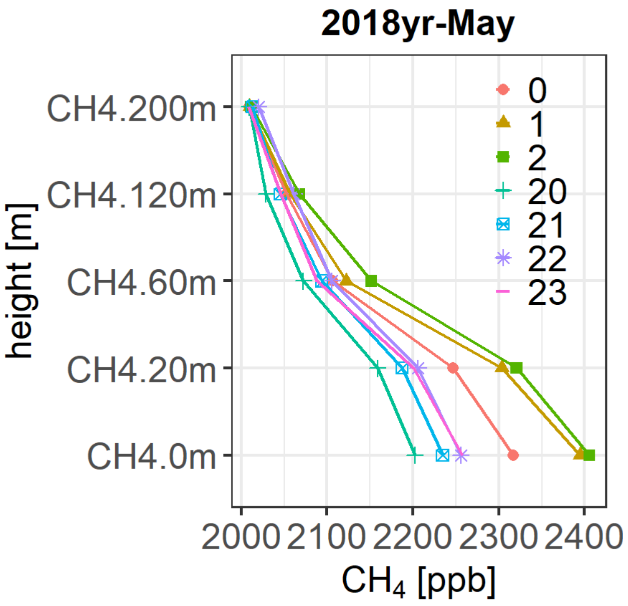
turbulent

❖ The modified Bowen ratio similarity method [3] $= \frac{H}{C_p M_{Air}} \cdot \frac{\partial c}{\partial T_{pot}}$

storage

❖ The sum of the trapezoidal areas constructed between hour steps and the heights

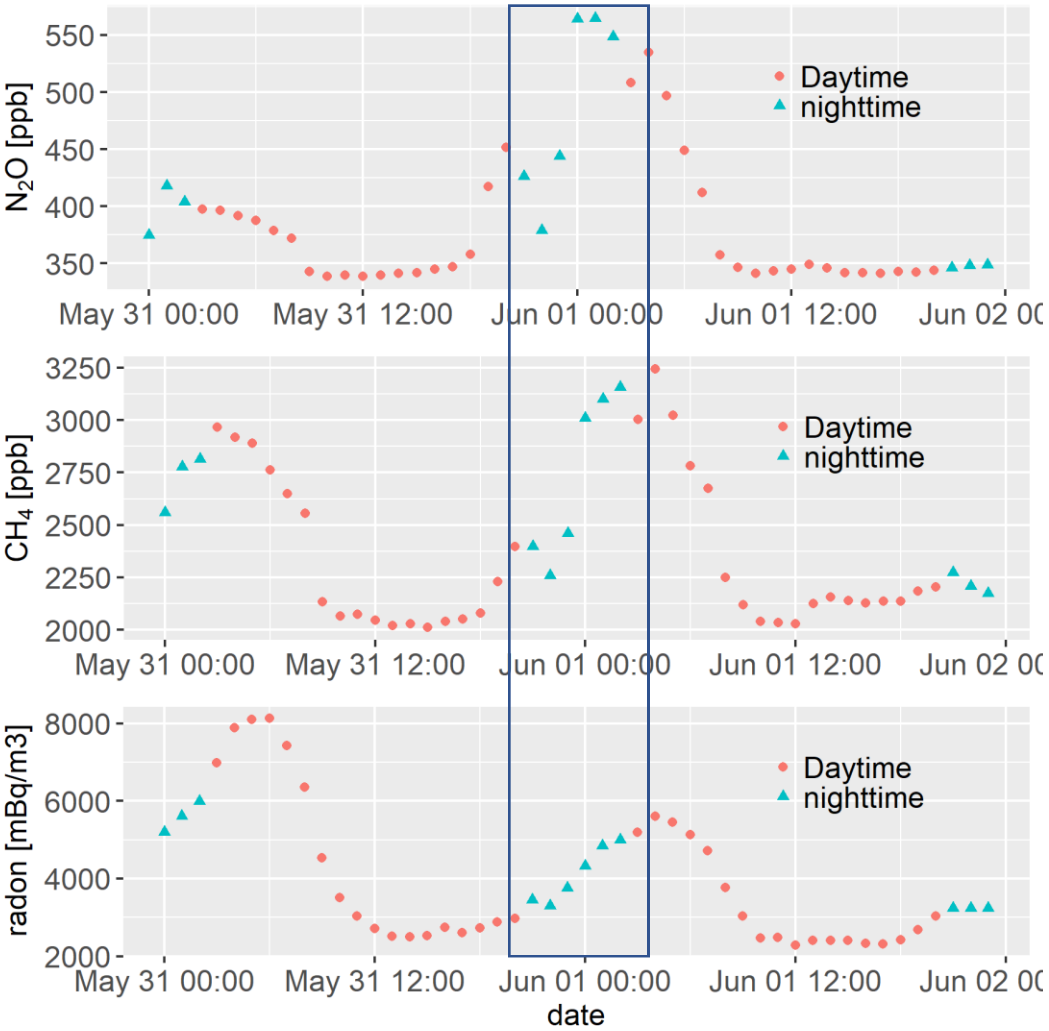




References: 1. Winderlich et al., 2014; 2. Yi et al., 2000; 3. Businger, 1986

2. Methods and materials

2.2 ^{222}Rn tracer method (RTM)



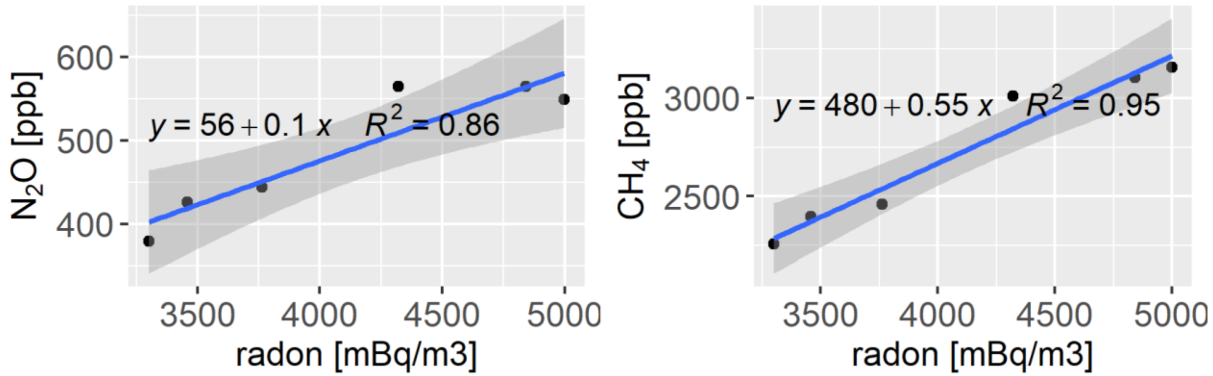


Figure. The example of the concentrations from 2018 May 31 to June 1. The bottom figures show the linear regression between ^{222}Rn and N_2O (left) and CH_4 concentrations (right).

$$F_{N_2O\,(CH_4)} = F_{^{222}Rn} \cdot \frac{\Delta N_2O\,(CH_4)}{\Delta_{222Rn}}$$

❖ **The criteria for choosing the events:**

- The slope > 0
- $R^2 \geq 0.7$

❖ **Concentrations of Rn, N_2O and CH_4:** 20m

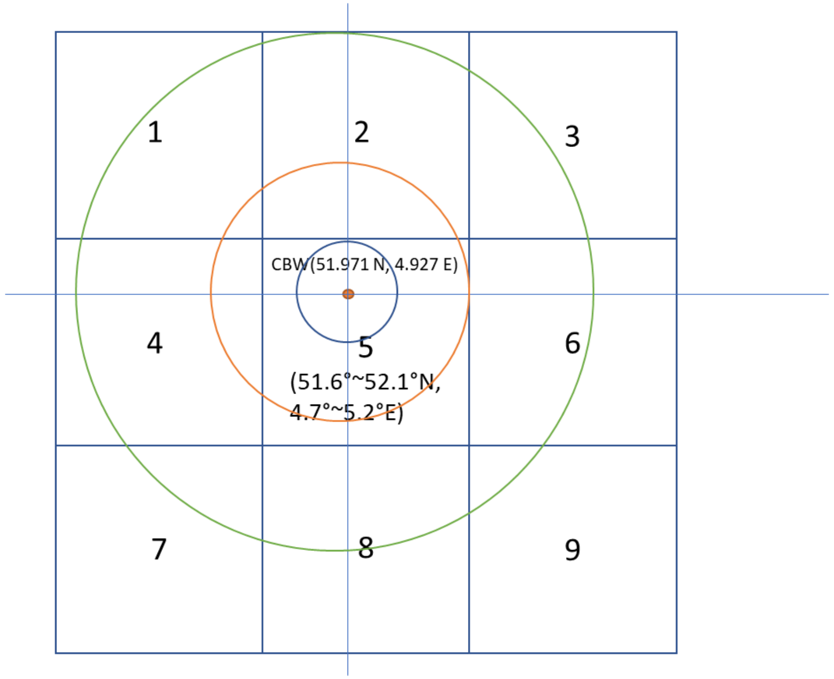
❖ **Rn flux:**

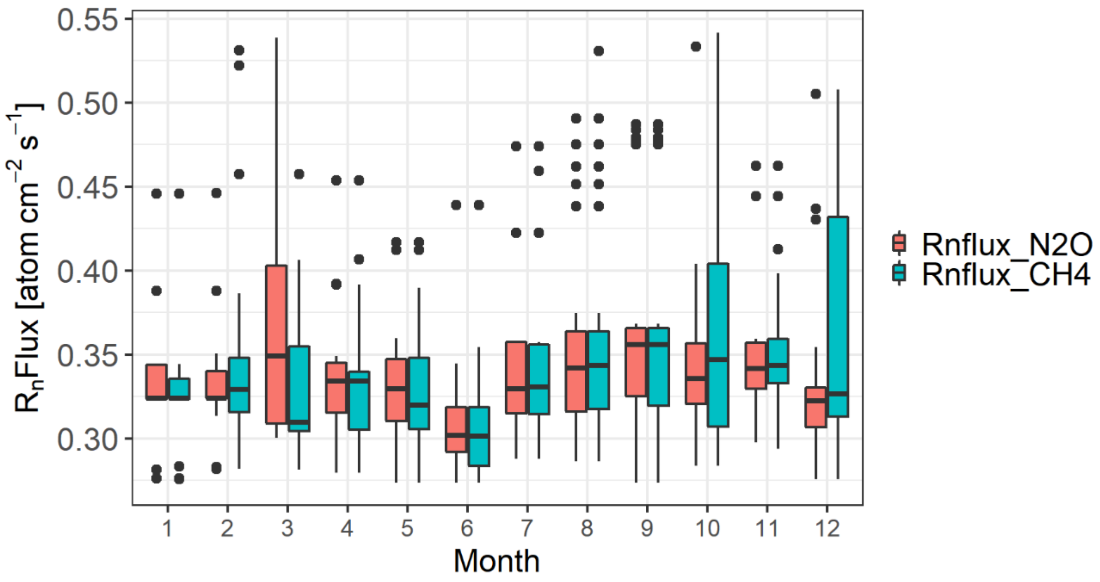
- Daily variable Rn flux from the estimated ^{222}Rn flux in Europe with 0.5°×0.5° grid [1] (data available at: http://radon.unibas.ch).

References: 1. Szegvary et al., 2007;

2. Methods and materials

2.2 ^{222}Rn tracer method (RTM) - variable Rn flux

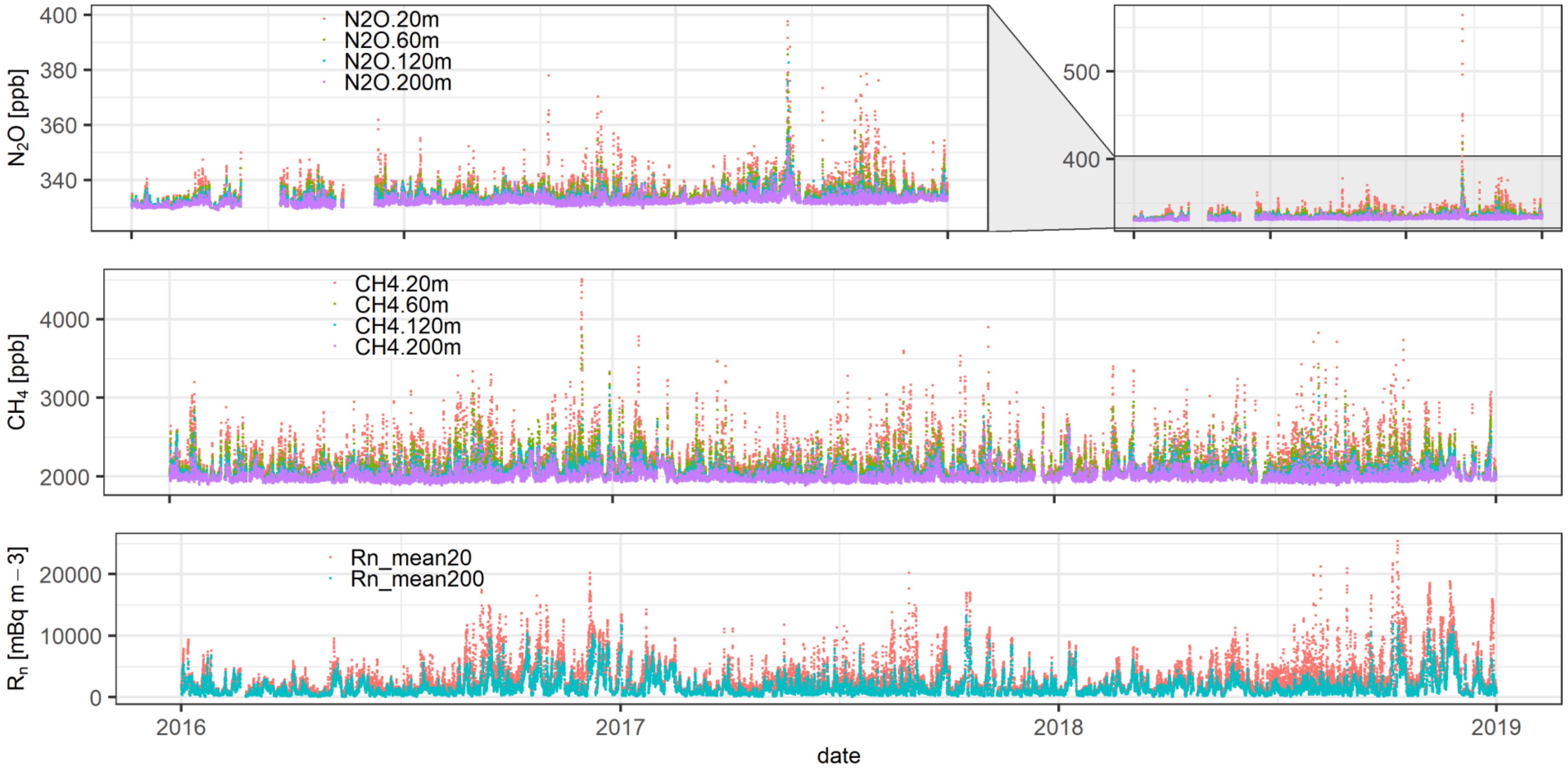




- Roughly estimate which grids should be averaged as the variable Rn flux per night
- Not clear seasonal pattern

2. Methods and materials

2.3 measured concentrations



- ➢ N_2O: Clear seasonal cycle
- ➢ CH_4: Weak seasonal pattern

3. Results and discussion

3.1 Diurnal and seasonal variability for the concentrations

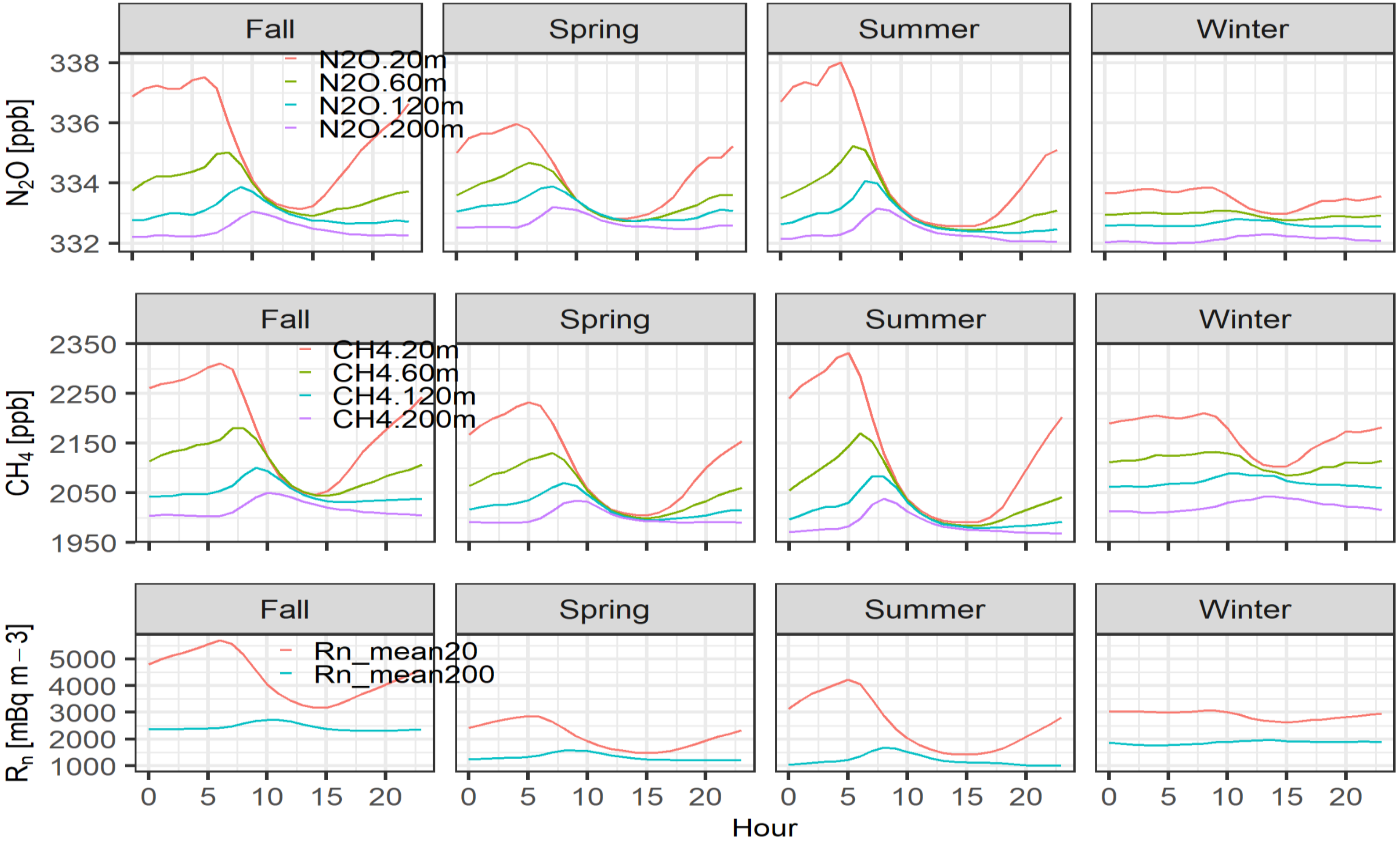


Figure. The diurnal cycle for the concentrations of N_2O, CH_4 and Rn; ‘Spring’ indicates March-May, ‘Summer’ indicates June-August, ‘Fall’ indicates September-November and ‘Winter’ indicates December-February.

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3. Results and discussion

3.2 The surface flux – N_2O

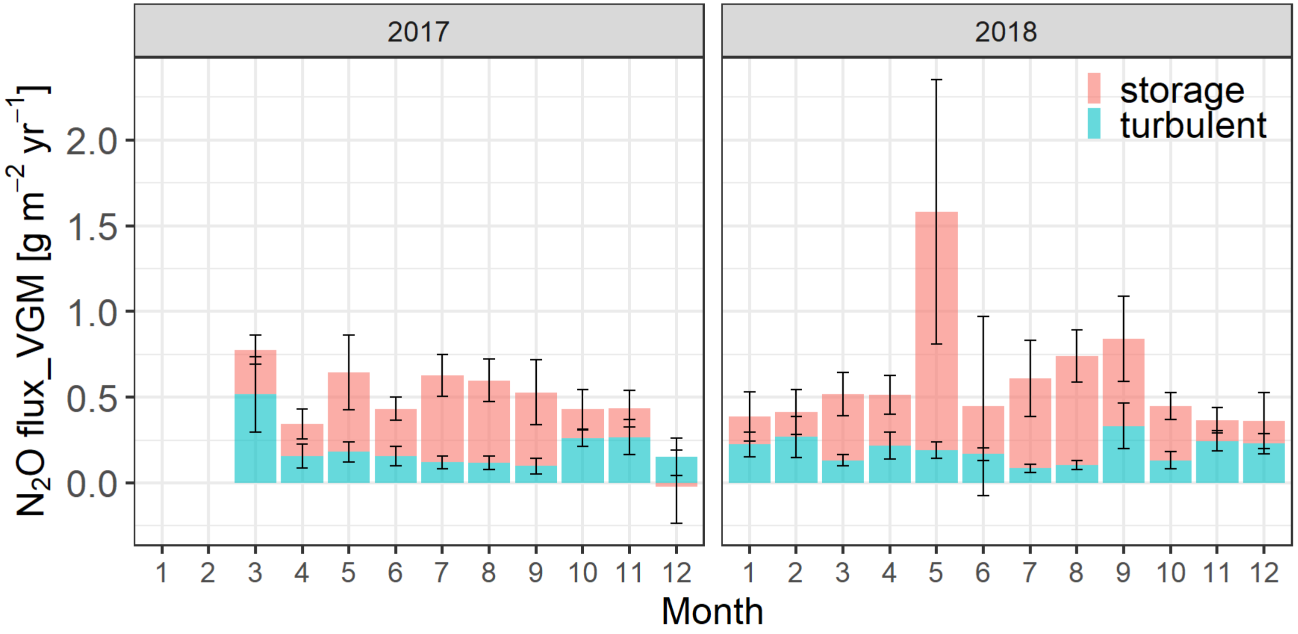
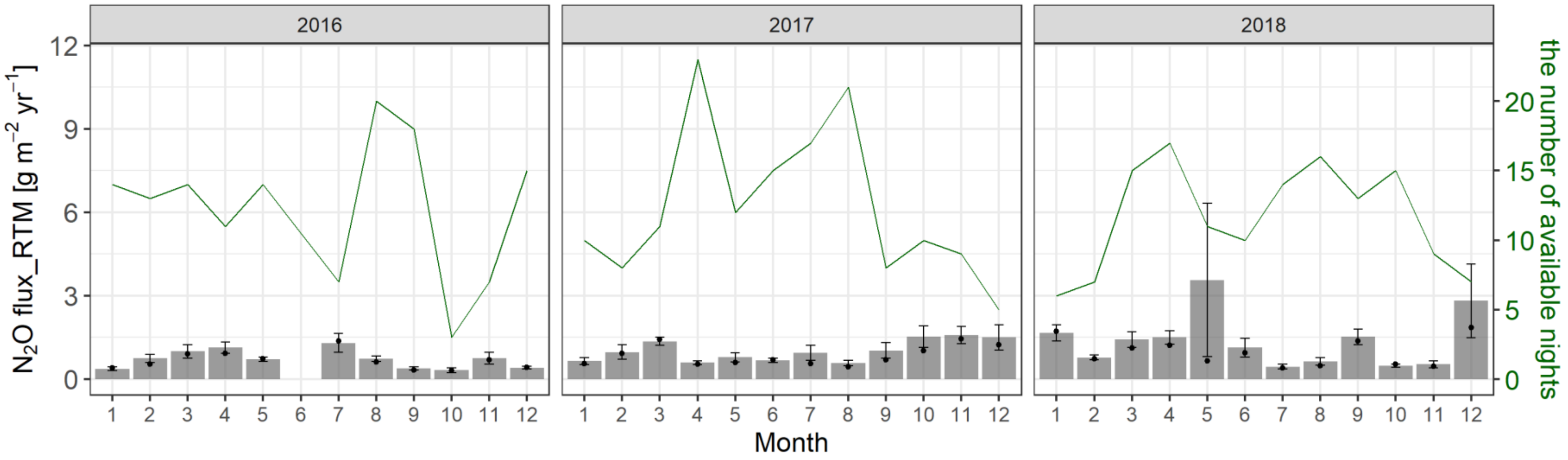


Figure. The nocturnal surface fluxes of N_2O by vertical gradient method (left) and Rn-tracer method (right). The bar and error bars indicate the month mean and standard errors.

- Another long-term EC observations at Cabauw also reported the high peak in summer (Kroon et al., 2007).
- The annual mean of 2017 and 2018 is 0.5 g m^{-2} yr^{-1} and 0.61 g m^{-2} yr^{-1}

3. Results and discussion

3.2 The surface flux – N_2O



Unit: g m^{-2} yr^{-1}	2016	2017	2018
Mean	0.94	1.1	1.5
Median	0.62	0.71	0.72

- no clear seasonal cycle.
- The median of annual fluxes by RTM is close to the fluxes by VGM.

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3. Results and discussion

3.2 The surface flux – CH_4

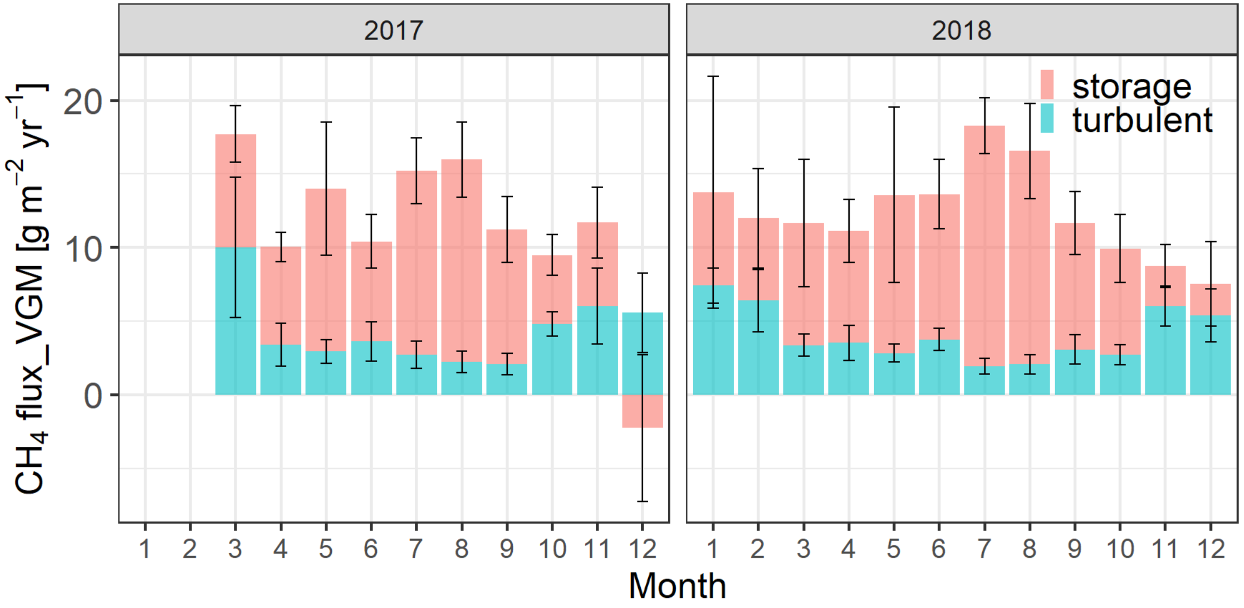

Figure. The nocturnal surface fluxes of CH_4 by vertical gradient method (left) and Rn-tracer method (right). The bar and error bars indicate the month mean and standard errors.

- Most monthly mean hourly flux estimates in winter seasons were considerably close to zero with big uncertainties as large as the signals (Satar et al., 2016).
- The annual mean of 2017 and 2018 is 12.9 g m^{-2} yr^{-1} and 12.5 g m^{-2} yr^{-1}
- The flux in June: 12 g m^{-2} yr^{-1} ; EC: 6.1 g m^{-2} yr^{-1} (Peltola et al., 2014)

3. Results and discussion

3.2 The surface flux – CH_4

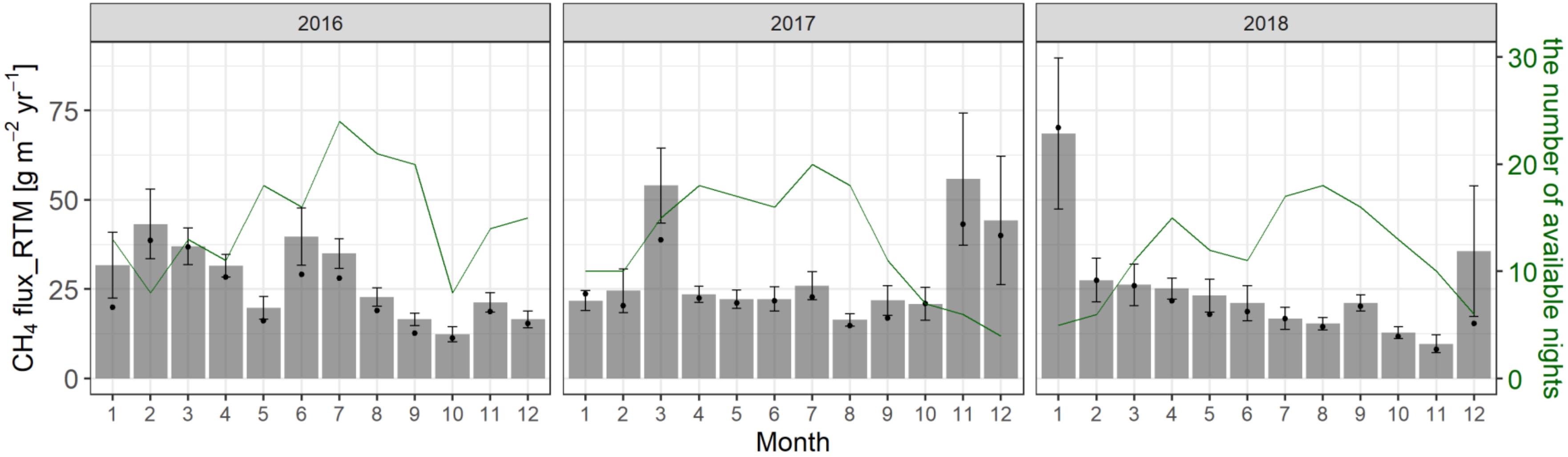

Figure. The nocturnal surface fluxes of CH_4 by vertical gradient method (left) and Rn-tracer method (right). The bar and error bars indicate the month mean and standard errors.

Unit: g m^{-2} yr^{-1}	2016	2017	2018
Mean	30	34	22
Median	21	23	17

- no clear seasonal cycle.
- The fluxes estimated by two methods especially in winter show the discrepancy.

3. Results and discussion

3.3 The comparison between two methods-windrose

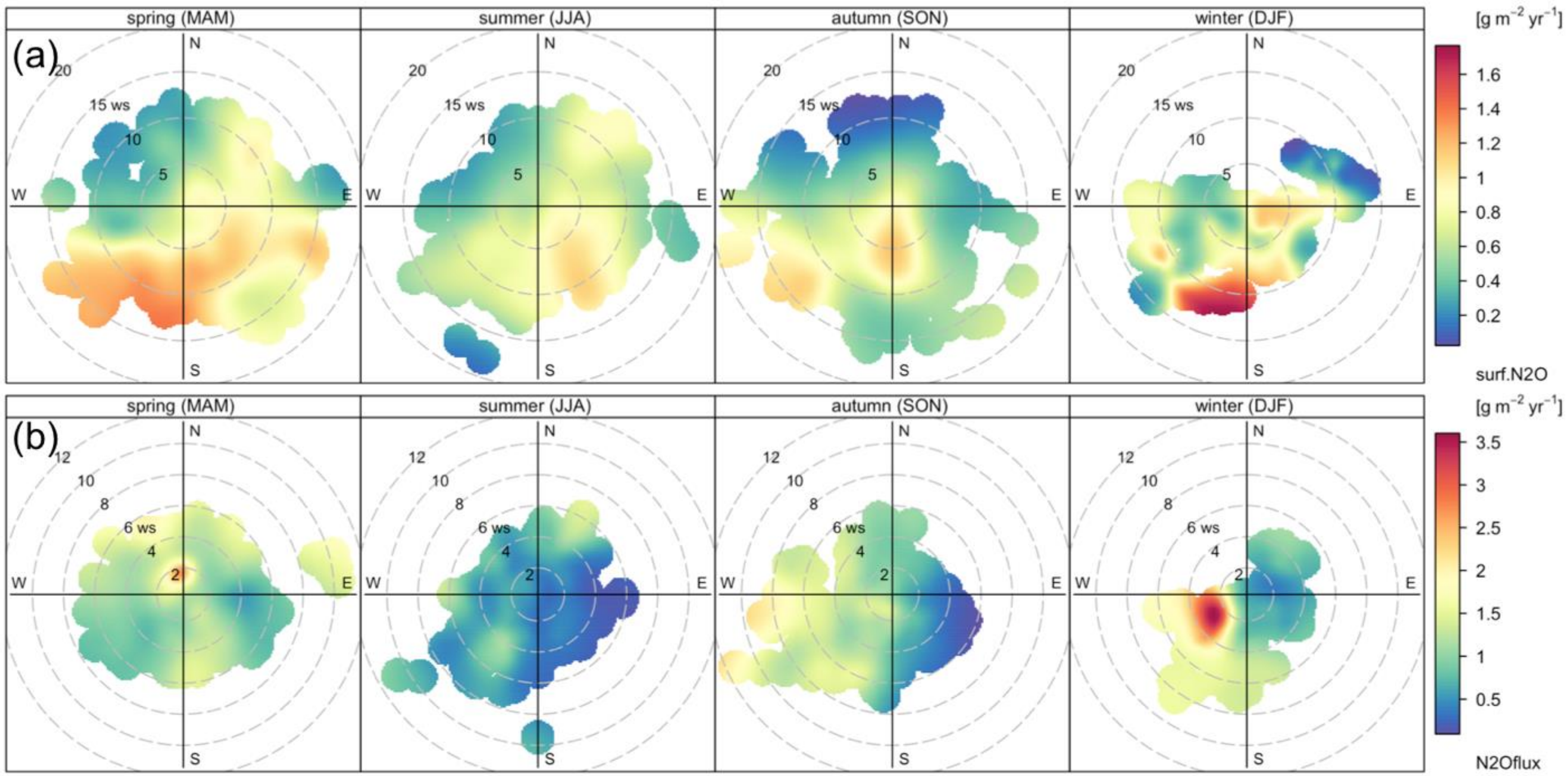

Figure. The windrose plots for the fluxes of N_2O and CH_4 with the nights by (a) VGM and (b) RTM sectored by each season. The colour bar shows the value of the fluxes and the number around the circle drawn by the dashed line.

- The main source at lower level is near the real field and the hot spot at the highest level covers relatively large areas.
- CH_4 emissions by EC measurements at 6m, 20m and 60m at the Cabauw tower show the spatial variability (Peltola et al., 2015).

3. Results and discussion

3.3 The comparison between two methods-different nights

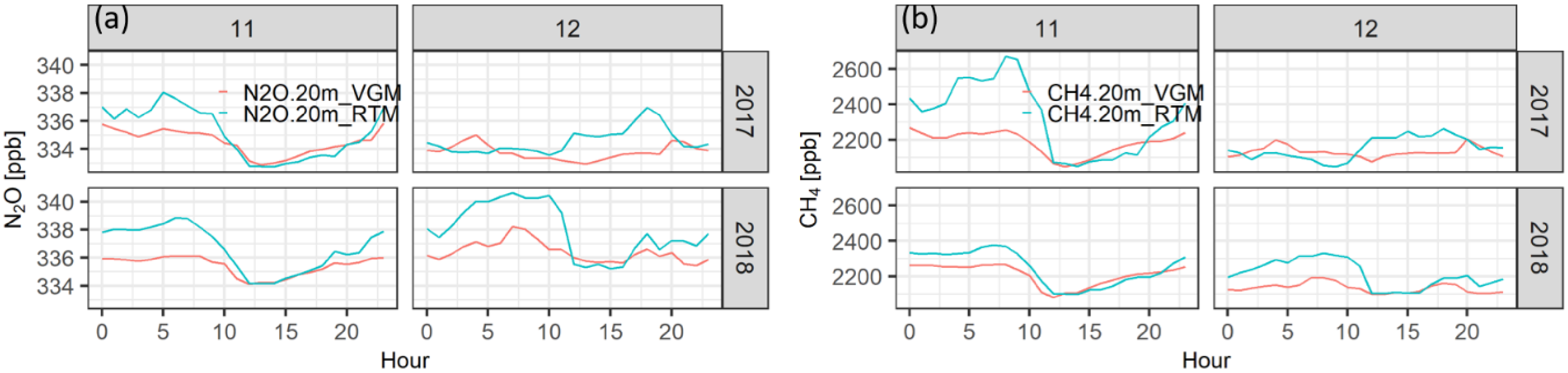

Figure. The diurnal cycle of the concentrations of (a) N_2O and (b) CH_4 averaged from different nights for the two methods in November and December.

- The peaks could have been smoothed by more available nights by VGM, while it can be preserved much for RTM due to the limited available nights.

3. Results and discussion

3.4 Seasonal variation

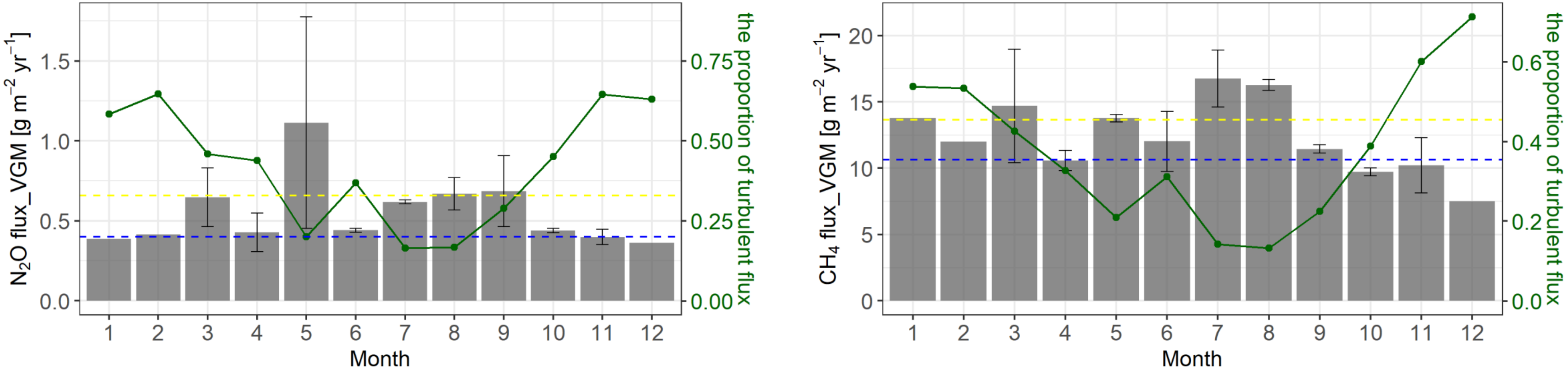

Figure. The nocturnal surface fluxes of N2O (left) and CH4 (right). The bar and error bars indicate the mean and standard errors for each month. The light green line indicates the proportion of the turbulent flux in the total surface flux. The yellow dashed line displays the mean surface flux from March to September, and the blue dashed line displays the means of non-grazing months of October-February. For CH4, the storage flux in 2017 December is negative apparently, so it is not included.

- N_2O: a seasonal amplitude of around 0.83 g/m^2/yr
- $CH_{4:}$ a seasonal amplitude of around 7.85 g/m^2/yr
- Summer months: more storage fluxes; winter months: more turbulent fluxes

4. Conclusions

- VGM and RTM are both useful to estimate the fluxes.

- The fluxes by VGM show a clear seasonal pattern for N_2O and weak seasonal pattern for CH_4.

- The fluxes by RTM do not show a seasonal pattern:
  - Different footprints
  - The peak is preserved due to the limited nights

- The fluxes by RTM is larger than those by VGM.

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Thanks!