Interannual variability of atmospheric CH_4 and its driver over South Korea captured by integrated data in 2019

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Introduction

- Understanding of the regional and/or local CH4 growth rate is essential in improving the large scale carbon budget constraint.
- CH4 sources: wetland, livestock, waste, rice paddy, oil/gas, fossil fuel burning, fire, … whereas,
- sinks: tropospheric OH oxidation, soil uptake
- Geographical distribution, sectorial attribution of CH4 emissions, and the interannual variations of the sources are uncertain
- This gap hampers the effective formulation of the emission mitigation strategies
- Complying with the Paris Agreement, South Korea declared a roadmap for attaining net zero carbon emission by 2050
- Large growth rate of CH4 was registered in 2019 without strong ENSO in Korea region. What are the specific sources and triggering factors?

National Institute of Meteorological Sciences

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Data

- **In-situ**
- Cavity Ring Down Spectroscopy (CRDS 2401, Picarro, USA)
- calibrated against WMO-X2004A scale with 4 reference tanks every 2 weeks
- Station: **AMY** (36.54˚N, 126.33˚, 46 m amsl)
- CH4 measured from 40 m tower
- A part of WMO/GAW regional stations

Satellite

S5P TROPOMI

- Spatial resolution: 7×7 km^2 since its launch in October 2017 and upgraded to 5.5×7 km^2 in August 2019
- Daily, near-full surface coverage
- CH_4 is derived from the SWIR band
- Data analysis period: April 2018-2020

GOSAT

- Spatial resolution ~ 10 km radius
- Global spatial coverage, relatively sparse
- Revisit time 3-day
- CH_4 is derived from the SWIR band
- Data analysis period: 2014-2019

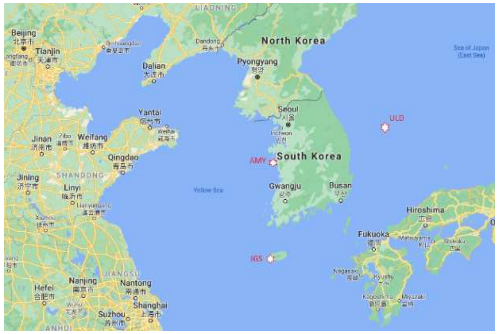
Flask sampling

- 13C-CH4 isotope
- Weekly
- Period: 2014-2019
- Location: AMY

Ancillary data

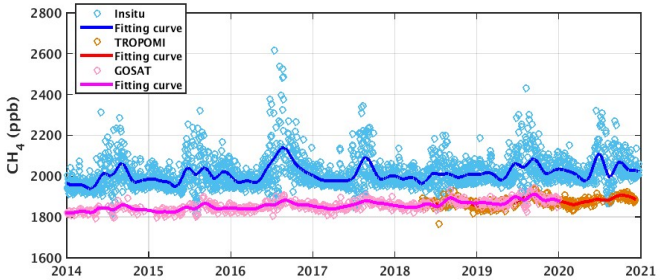
- Soil temperature, soil moisture from FLDAS Noah Land Surface Model L4 Global Monthly 0.1 x 0.1 degree
- **ENSO index** https://psl.noaa.gov/data/climateindices/

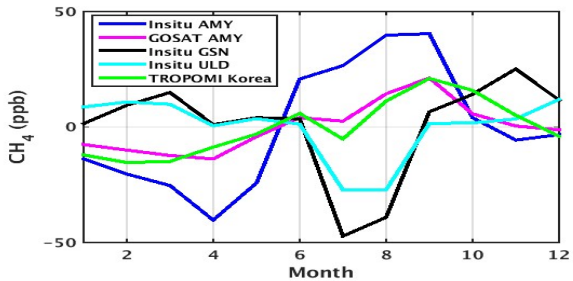
Map of South Korea in-situ stations



Taken from the Google map.

- **Seasonal variability of CH_4 in Korea**

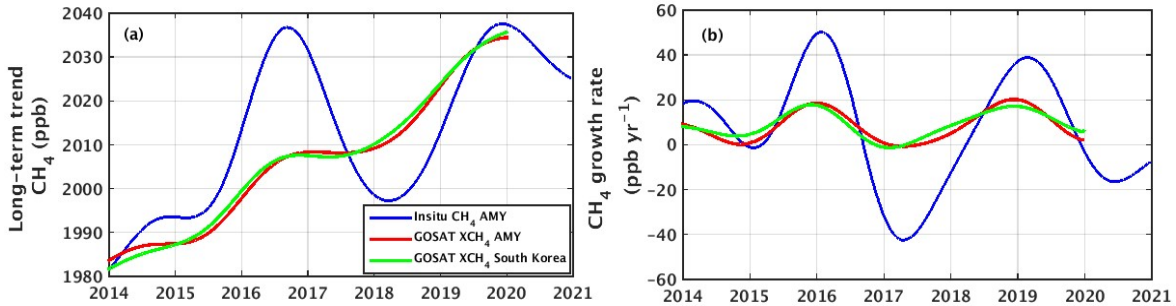




AMY from in-situ (Jan. 2014-Dec. 2020), Jeju-Gosan (JGS, 33.3˚N,126.16˚E, 71.47 m) Jan. 2014-Feb. 2020, and Ulleungdo (ULD, 37.48˚N,130.9˚E, 220.9 m) Jan. 2014-March 2021 XCH_4 from TROPOMI (April 2018-Dec. 2020), and GOSAT (Jan. 2014-March 2021).

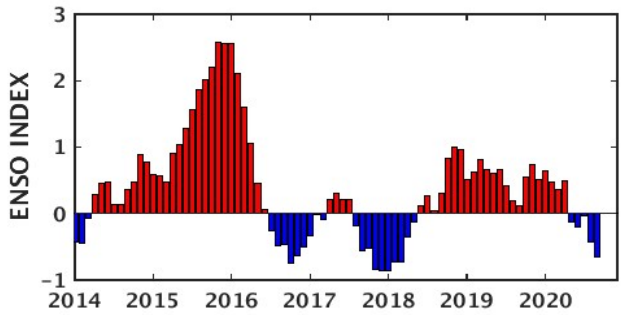
Seasonal maximum and minimum are summer and spring at AMY, which is contrasting to JGS and ULD

- **Interannual variability of CH_4 growth rate**



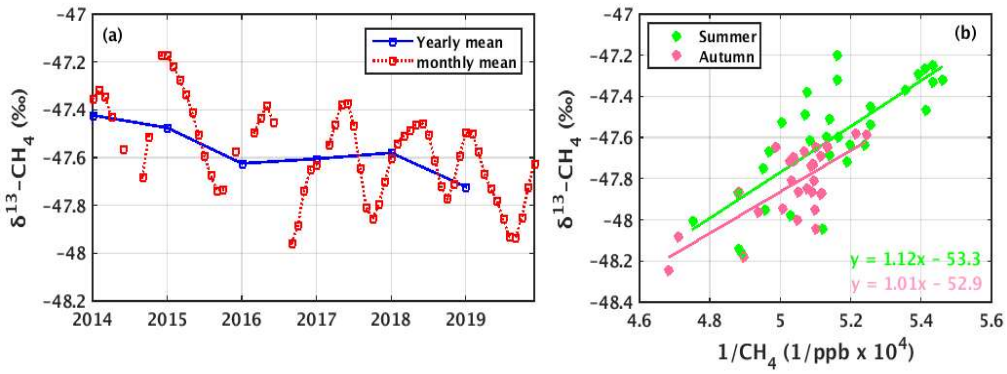
De-seasonalized long-term trend (a) and instantaneous growth rates (b) of in-situ CH_4 , GOSAT XCH_4 AMY, and GOSAT XCH_4 Korea, 2014-2020. Noted that GOSAT XCH_4 in panel (a) is scaled by adding 150 ppb (GOSAT XCH_4 +150 ppb)

- The high growth rates at AMY were found in 2016 and 2019, resulting 31.3 ppb yr^{-1} and 27.4 ppb yr^{-1} from in-situ, respectively. The large growth in 2016 is most likely associated with strong El Niño events occurred in 2016, whereas observed growth rate in 2019 was not related to ENSO signal



Time series of ENSO index during 2014-2020.

- **CH_4 growth rate related to isotopic ratios**



Left panel shows the time series of monthly and yearly means of atmospheric observations of $\delta^{13}C$-CH_4 (‰) collected by flask sampling at AMY during 2014-2019. Right panel depicts $\delta^{13}C$-CH_4 (‰) versus inverse CH_4 mole fractions at AMY for summer (green) and autumn (pink) seasons.

- The isotopic composition of CH_4 (δ^{13}-CH_4) reflected that the enhanced depletions were also appeared in 2016 and 2019 that matched with the large growth of CH_4
- Elevated depletions shown in 2016 and 2019 were driven by summer and autumn seasons.
- The intercept of the Keeling plot reflected isotopic signature of the source responsible for enhancements in CH_4, and the intercept values for summer and autumn were found to be -53.3‰ and -52.9‰, respectively, which is consistent with biogenic emissions

Spatial distribution of annual mean XCH4 and observed anomaly

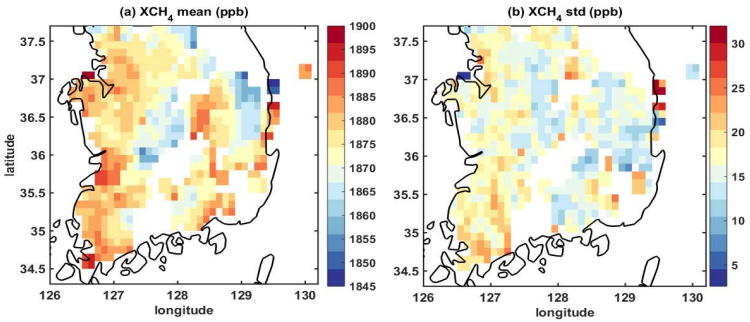


Figure 1. Spatial distribution of XCH_4 annual mean (a), its standard deviation (b), derived from the monthly means with spatial gridded of 0.1 by 0.1 degrees of TROPOMI data during April 2018 to December 2020.

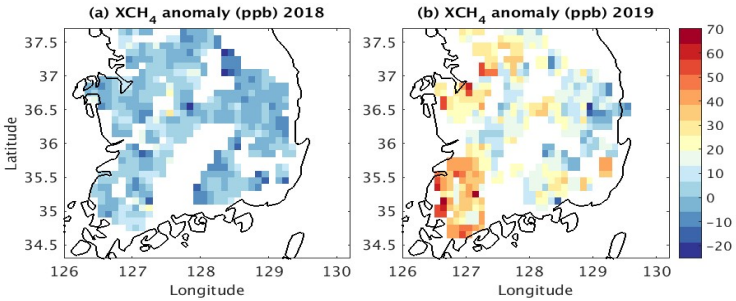


Figure 2. XCH_4 anomaly, calculated as XCH_4 anomaly in Oct. 2018 (ppb) = monthly mean of XCH_4 in Oct. 2018 - annual mean, and similarly for XCH_4 anomaly in Oct. 2019.

- Anomalous events of XCH4 detected in Oct. 2019 that can contribute for the large annual growth

Soil-associated drivers

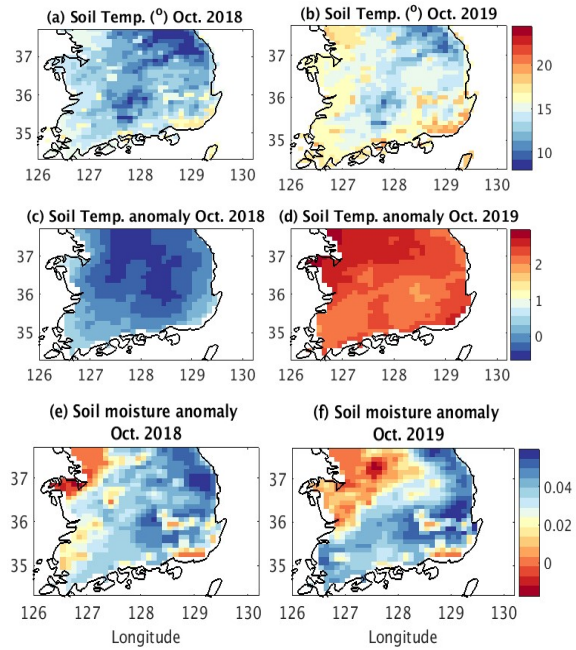


Figure 3. soil temperatures and moisture at 10 cm depth in Oct. 2018 and 2019

- A higher soil temperature was evident in October 2019, which is almost 2-3 ˚C higher than the same month in 2018

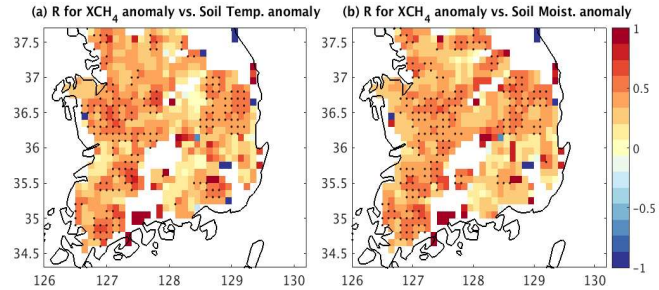


Figure 4. The correlation of TROPOMI XCH_4 anomaly versus soil temperature and soil moisture

- Soil-associated drivers (soil temp. and moisture) are able to exert large-scale influence on regional distribution of CH4 in Korea