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Modelling the seasonal cycle of atmospheric $\delta^{13}C$-CH_4 using source specific $\delta^{13}C$-CH_4 values

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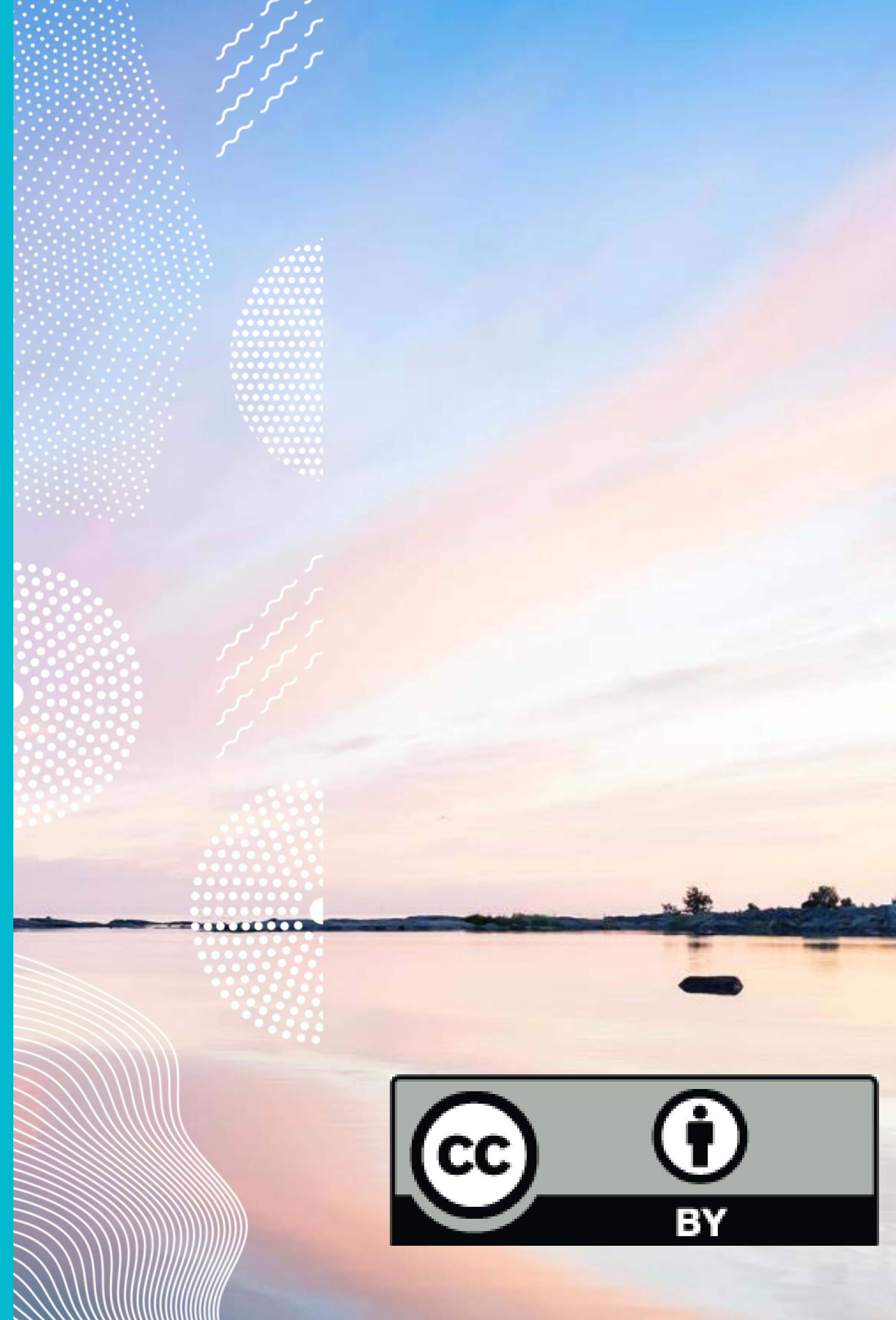
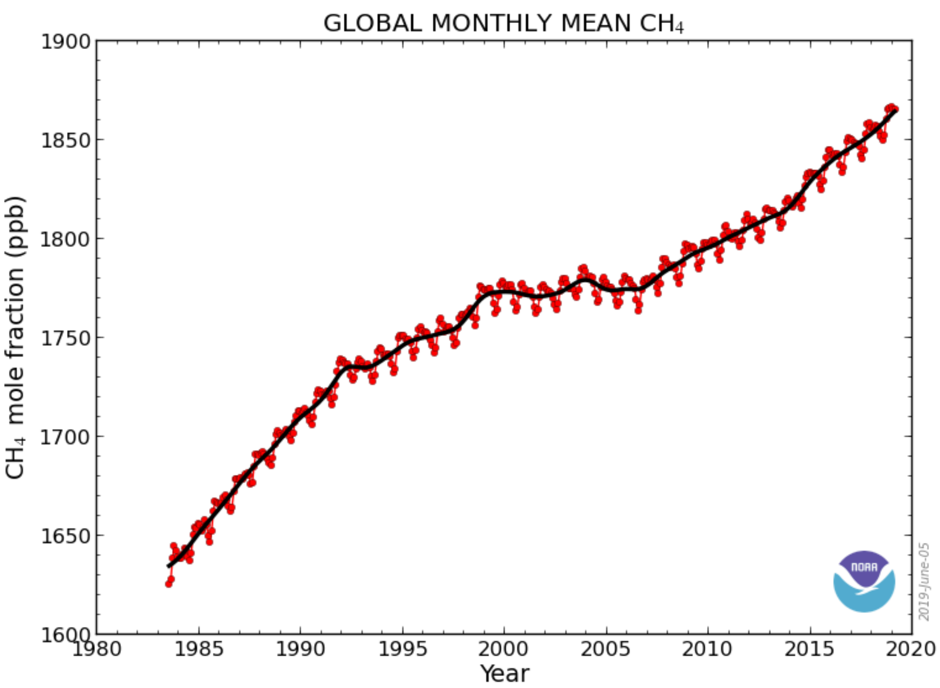
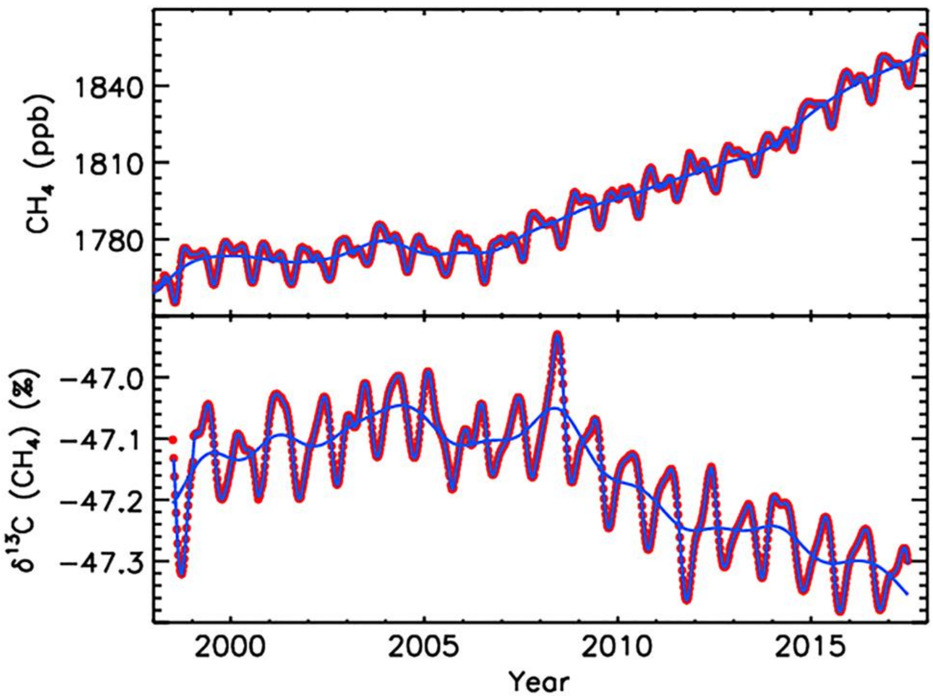


Background – CH_4

CH_4 increased until 2000, but during years 2000-2006 the atmospheric concentrations stayed constant after that the concentrations started to increase again (Figure in left) . In 2006 when the atmospheric CH_4 started to increase the $\delta^{13}CH_4$ became more negative i.e. atmosphere is less enriched with $^{13}CH_4$.



Ed Dlugokencky



Nisbet et al, 2019

Ed Dlugokencky
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Background – CH_4 carbon isotopes

- Stable isotopes $^{12}CH_4$ and $^{13}CH_4$
  - isotopic separation due to different masses
- Each CH_4 source have process specific isotopic signature
  - $\delta^{13}CH_4 = \left[\frac{(^{13}CH_4/^{12}CH_4)_{sample}}{(^{13}CH_4/^{12}CH_4)_{standard}} - 1\right] 1000‰$

- Research question of this study: How different CH_4 sources and sinks affect the CH_4 and $\delta^{13}CH_4$ seasonal cycle?

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Methods

- TM5 atmospheric chemistry model
  - Simulations starting from a well mixed initial 3D field
  - Includes atmospheric loss i.e. OH, $Cl+O^1D$ sinks
  - Resolution 1º x 1º over Europe, elsewhere 6ºx 4º
- TM5 spin-up: repeat year 2000 40 times
  - isotopic signatures (Table below) multiplied by 1.095
- Isotopic signature maps are used if available otherwise single value globally

Source (Database)	$\delta^{13}CH_4$(‰)	Source (Database)	$\delta^{13}CH_4$(‰)
Rice agriculture(EDGAR)	-63[1]	Landfills and waste water treatment (EDGAR)	-55[1]
Enteric Fermentation and Manure Management (EDGAR)	-62[1] [-67, -54][2]	Termites (Ito et al.)	-57[1]
Coal (EDGAR)	-35[1] [-64, -36][3]	Fire (GFED)	-21.8[1] [-25, -12][2]
Oil and gas (EDGAR)	-40[1] [-56, -29][2]	Ocean (FMI)	-59[1]
Residential (EDGAR)	-38[1]	Wetlands + soil sink (LPX-Bern DYPTOP)	-59[1] [-74.9, -50][5]
Geological (Etiope et al. 2019)	-68,-24.3 [4]	Wildanimals (FMI)	-62[1]

[1] Monteil et al. (2011) (Houweling et al. (2006), Bergamaschi (1997); Levin (1994); Bergamaschi et al. (1998); Gupta et al. (1996); Canttell et al. (1990); Brenninkmeijer et al. (1995); Tyler et al. (1994))
[2] Aryeh et al. 2017 [3] Sherwood et al. 2017 [4] Etiope et al. 2019 [5] Ganesan et al. (2018)

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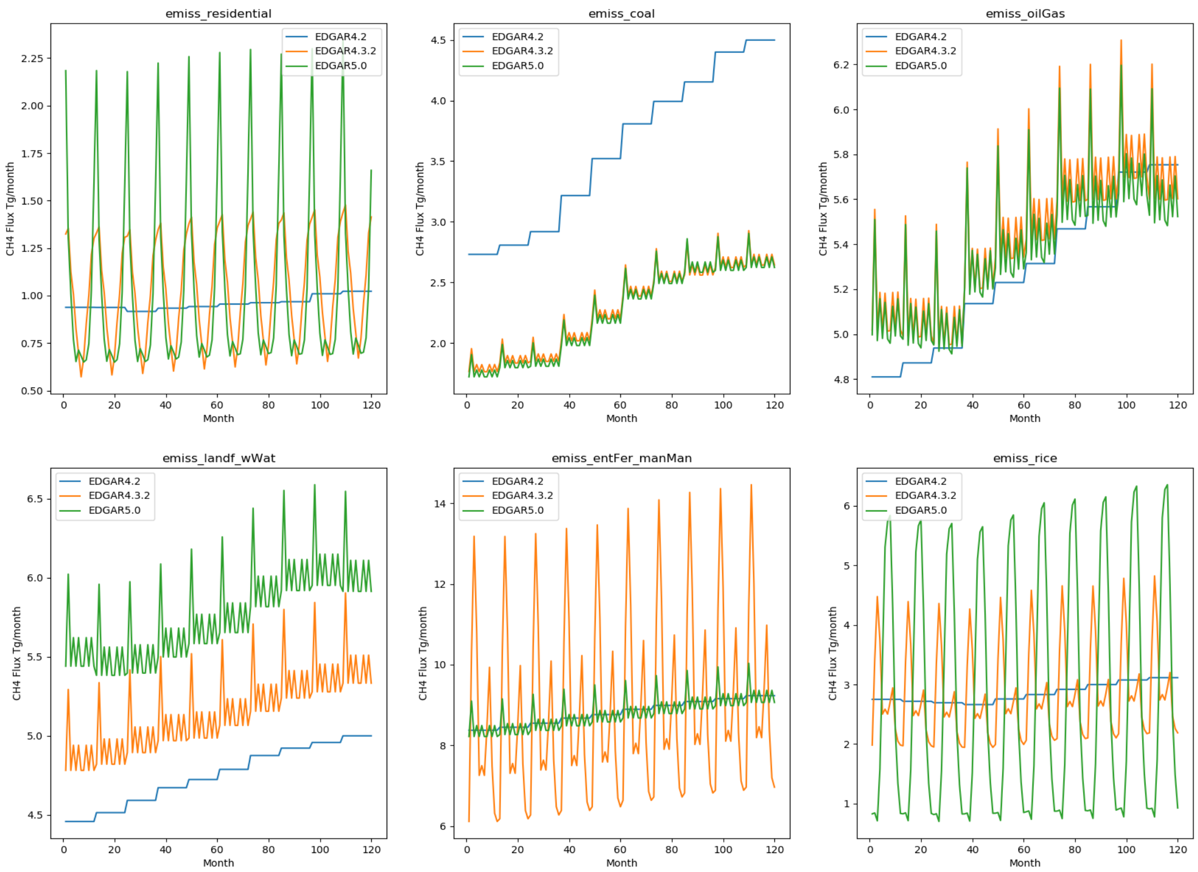
EDGAR FT2010 4.2/ 4.3.2 / 5.0

Differences in EDGAR versions (2000-2010)

- EDGAR v4.2 FT2010 has no seasonal cycle
- EDGAR v4.3.2 and v5.0 include seasonal cycle
- Enteric fermentation and Manure management has larger seasonal variation in v4.3.2 compared to v5.0
- Rice agriculture has larger seasonal variation in v5.0 vs v4.3.2
- Landfills and waste Water treatment emissions are higher in v5.0 compared to v4.2 and 4.3.2



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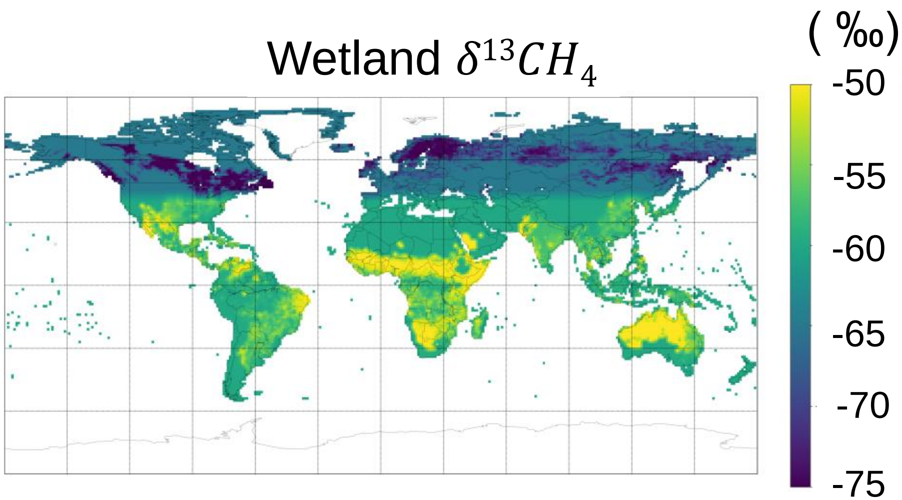
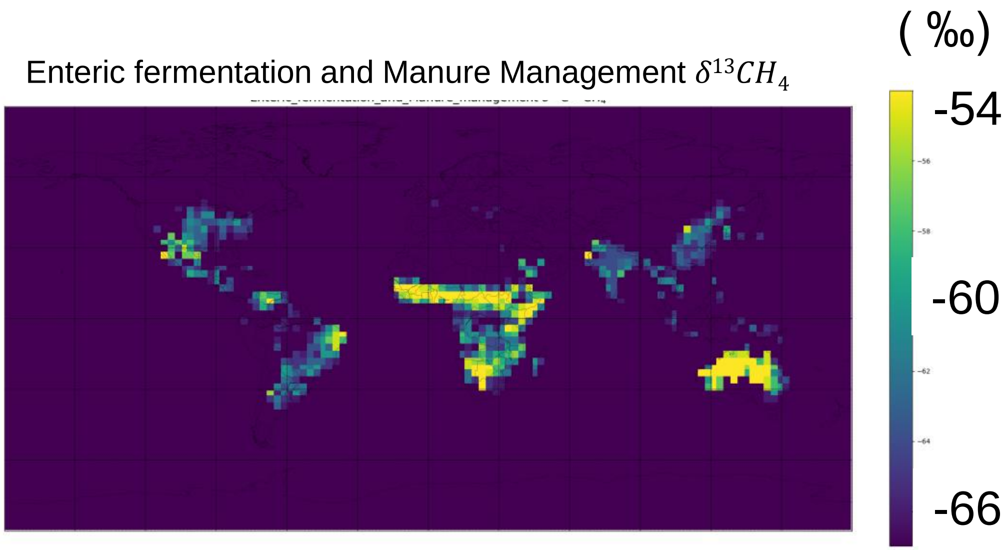
Biogenic isotopic sigantures globally





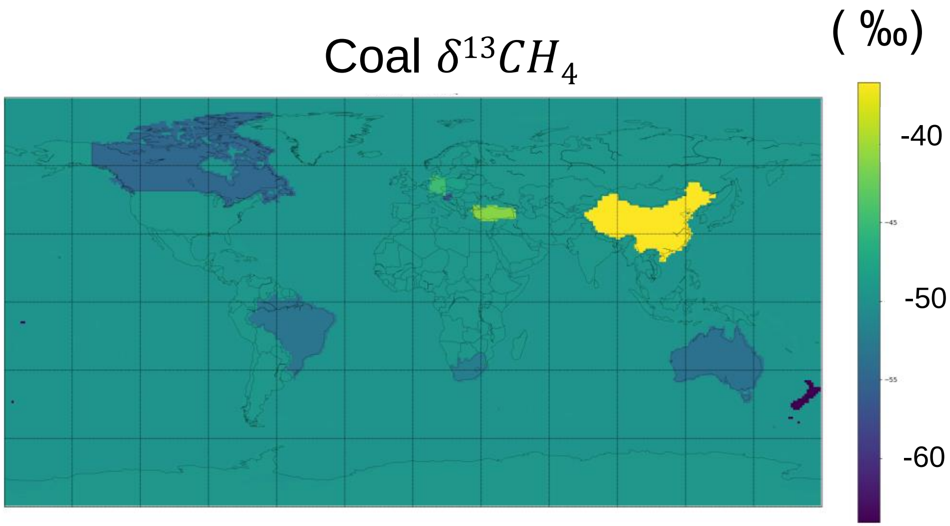
Methane emitted from northern Hemisphere is less enriched with $^{13}CH_4$ than in southern Hemisphere.

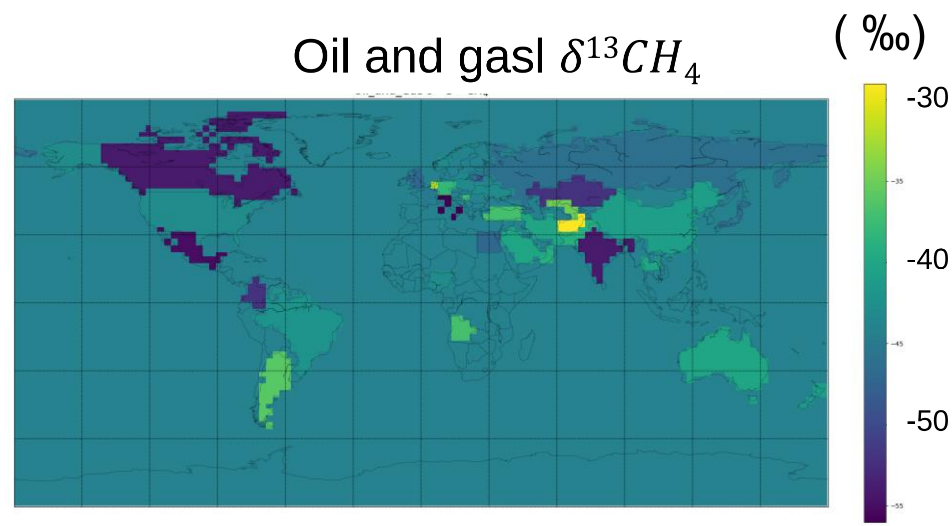
Ganesan et al. (2018) values combined with Monteil et al. (2011) values

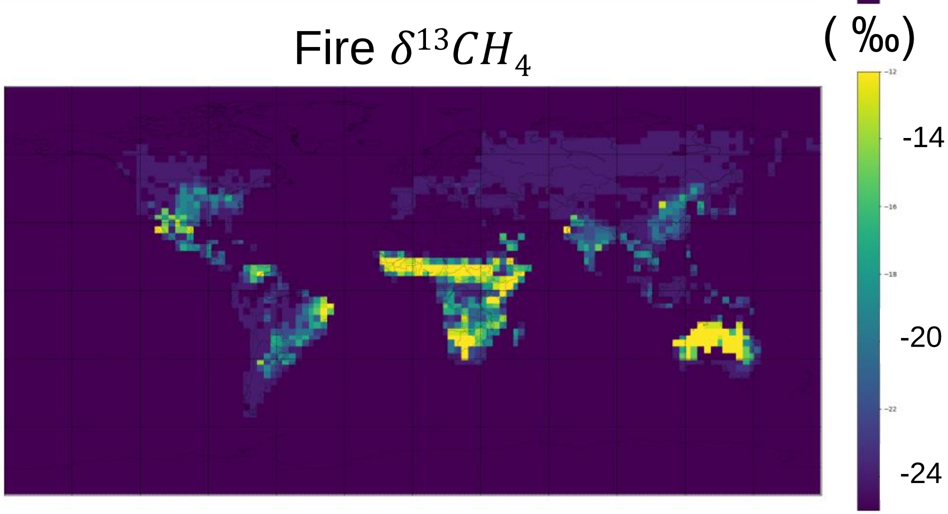
Methane emitted Sahara and Australia are more enriched with $^{13}CH_4$ than elsewhere.

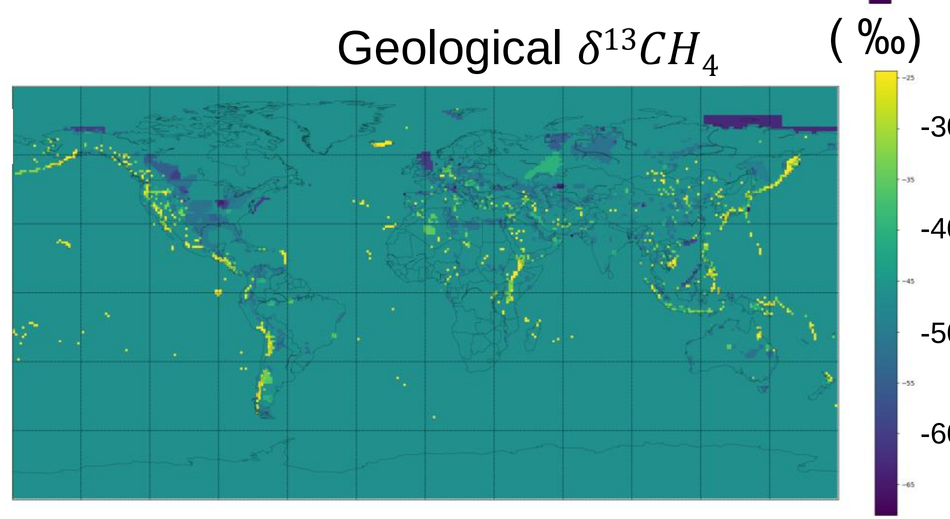
Aryeh et al. 2017

Other isotopic signatures globally









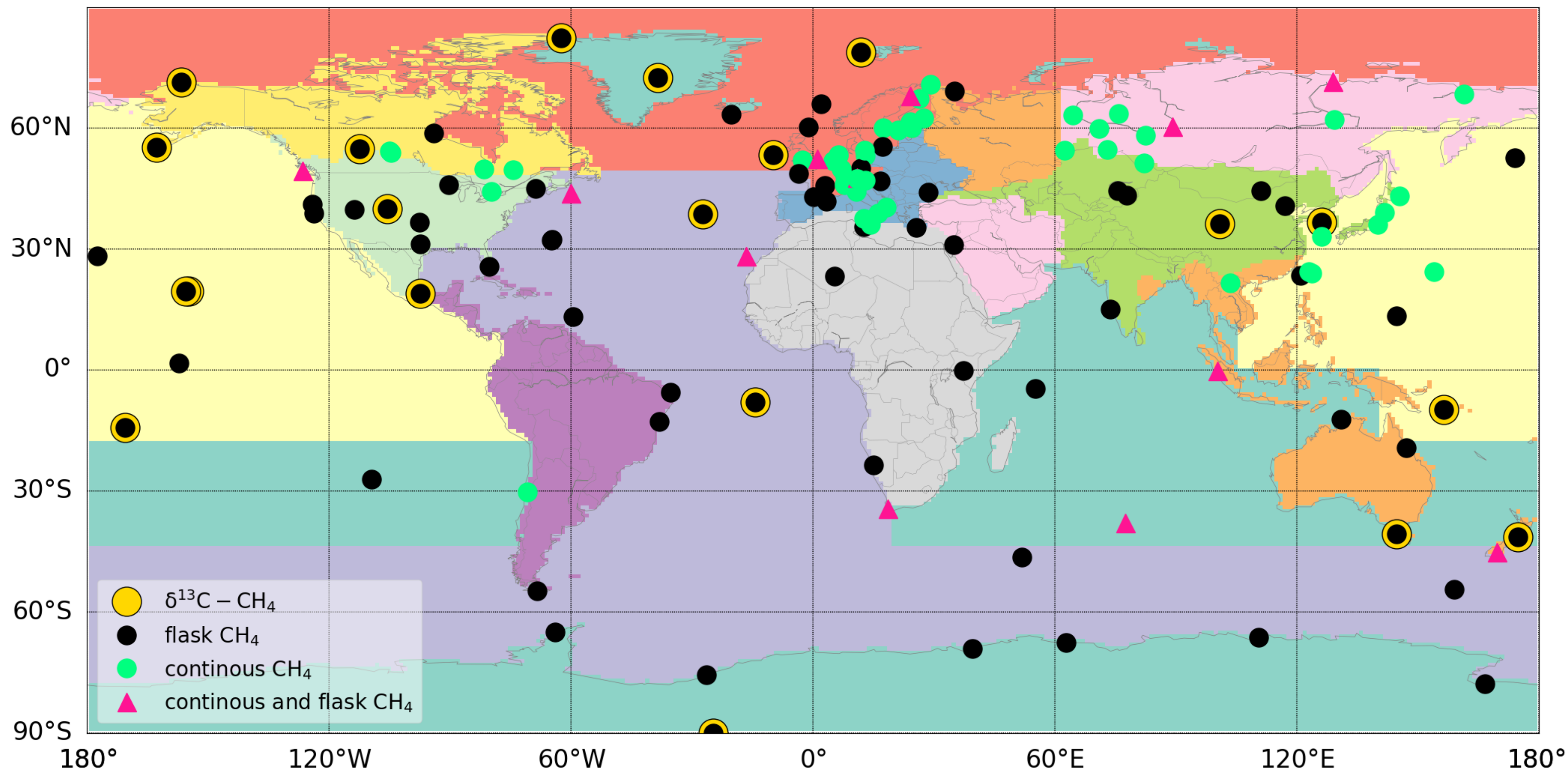
Sherwood et al. 2017, Aryeh et al. 2017, Etiope et al. 2019

Methods

- Different run set-ups to investigate the effect of each change
- Run set-ups
    1. **R1:** EDGAR 4.3.2
    2. **R2:** EDGAR 4.3.2 (no seasonal cycle for Enteric Fermentation and Manure management)
    3. **R3:** EDGAR 5.0
    4. **R4:** EDGAR 5.0 isotopic signature values scaled by a factor of 1.095

- Global in situ surface observations from NOAA and INSTAAR are used to evaluate the results

Observations of $\delta^{13}CH_4$ & CH_4 during 2000-2017



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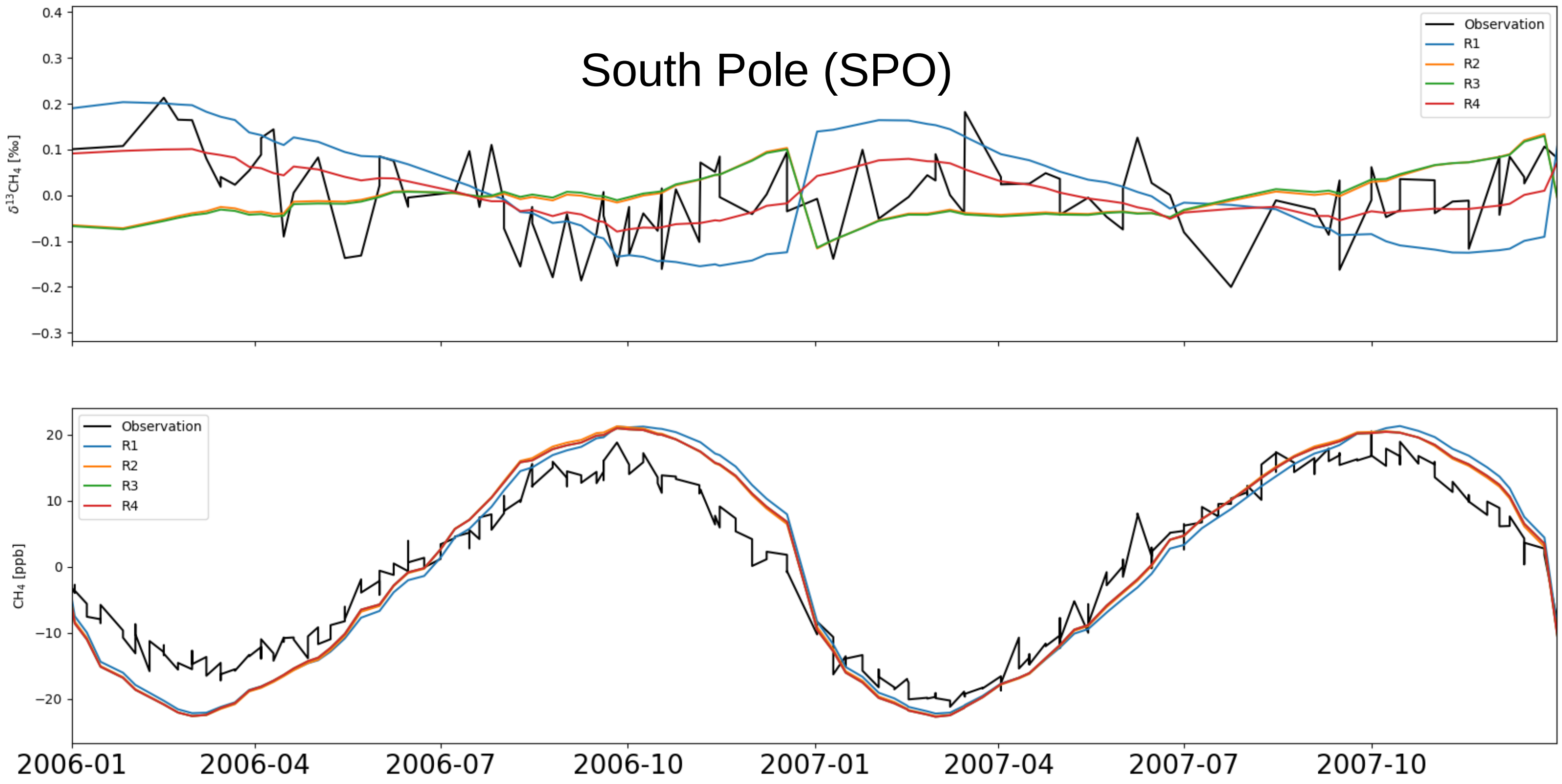
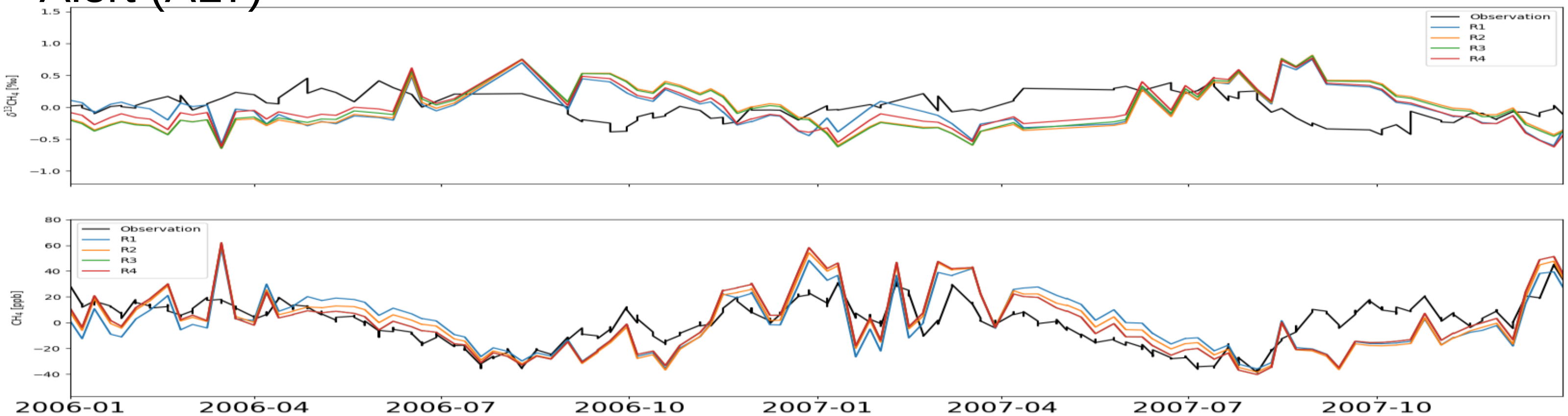
Results – yearly mean removed:

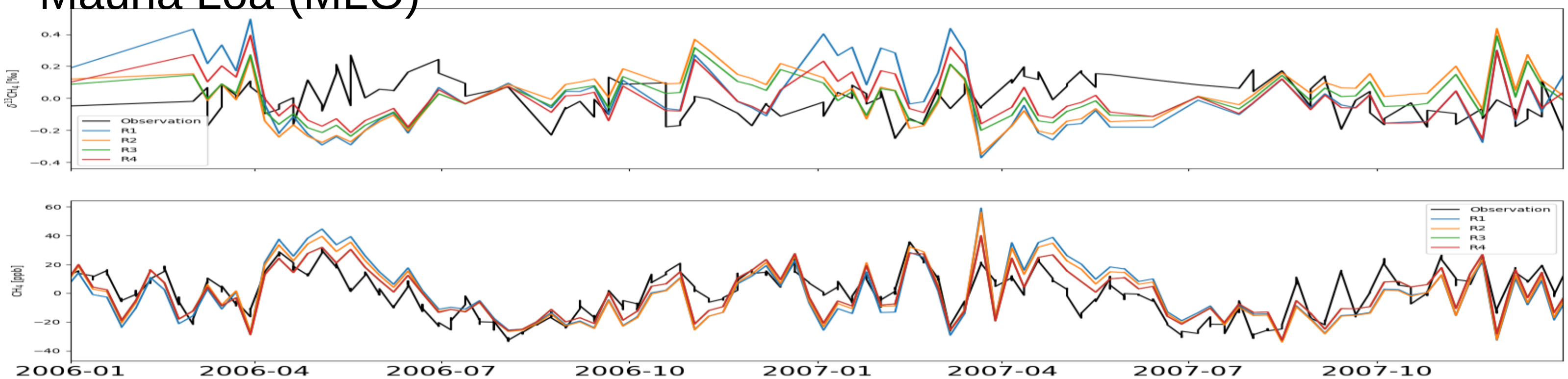
- CH_4 seasonal cycle at SPO is not affected much by changes in emission fields
- $\delta^{13}CH_4$ seasonal cycle is affected by
  - EDGAR versions (R1 and R3/R4)
  - Scaling of isotopic signature (R3 and R4)
  - Effect of seasonal cycle of enteric fermentation and manure management emissions to $\delta^{13}CH_4$ is small at SPO



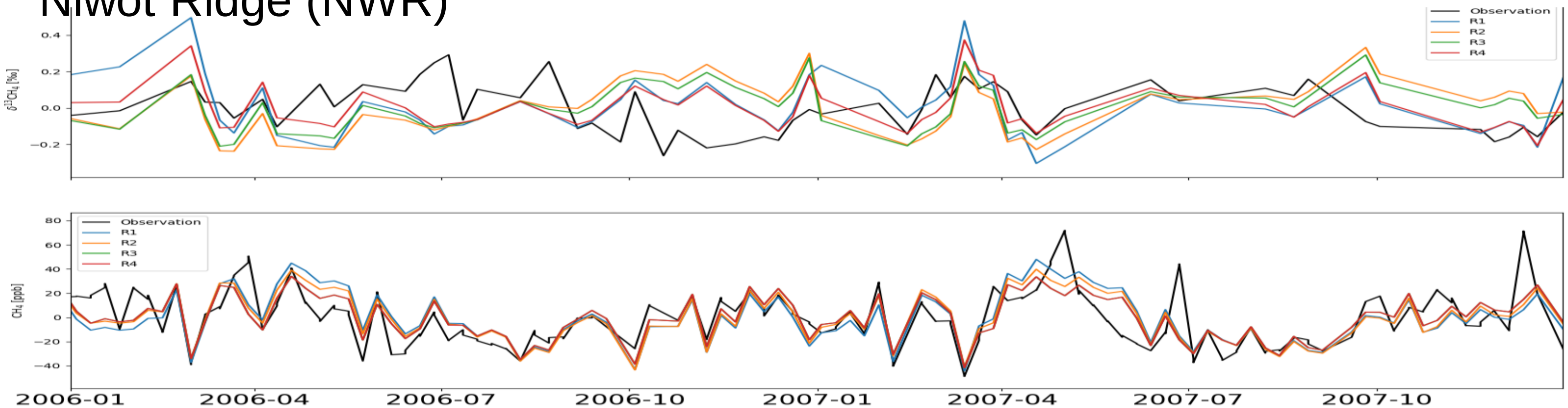
Alert (ALT)



Mauna Loa (MLO)



Niwot Ridge (NWR)



Effect of using different EDGAR versions at ALT is small - air signal sampled is mostly from biospheric (e.g. wetland) sources

MLO and NWR: the effect of seasonal cycle of entric fermentation and manure management emissions to $\delta^{13}CH_4$ is more visible than other sites - still hard to say which agrees better to the observations

Conclusions

- $\delta^{13}CH_4$ seasonal cycle is affected by
  - EDGAR versions (R1 and R3/R4)
  - Scaling of isotopic signature (R3 and R4)
- The effect of emission fields and isotopic signature is visible differently at each station depending on its location and sources near by
- It is important to use the same isotopic signatures as in the spin-up
  - Varying isotopic signature values affect more than varying the magnitude of sources and sink
- OH sink affect was also investigated, but the effect seemed small
- Next step:
  - Investigate other locations and effects on regional scale in more detail
  - Inversion run with CarbonTracker-Europe $^{13}CH_4$ with EDGAR v5.0 and isotopic signatures scaled with 1.095

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Thank you!

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