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Year-long greenhouse gases measurements at the urban environment of Athens, Greece

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15th INTERNATIONAL CONFERENCE on Meteorology, Climatology and Atmospheric Physics
COMECAP 2021
Hybrid Congress
SEPTEMBER 26 - 29, 2021
Hotel Du Lac, Ioannina, Greece

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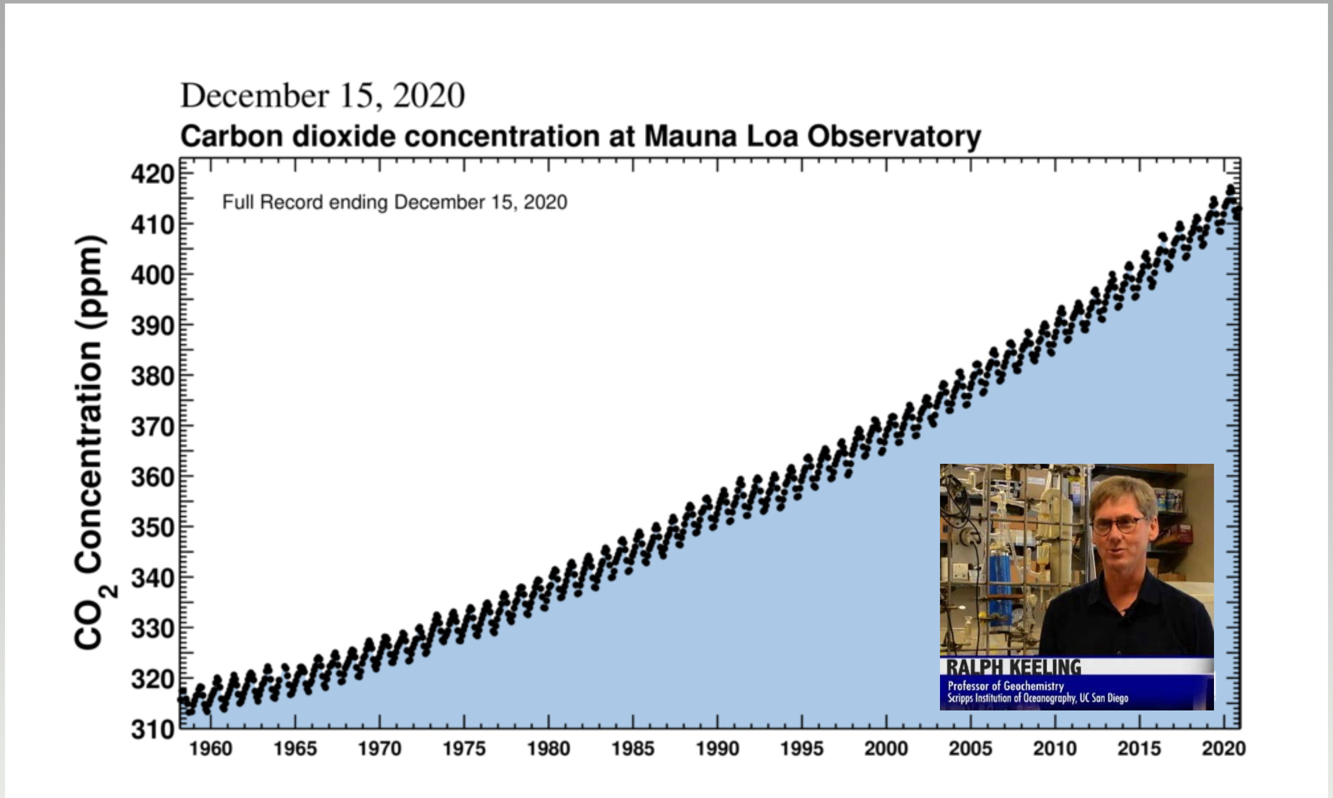
The role of Greenhouse Gases

The infrared radiation emitted by Earth is absorbed by the atmosphere for certain gaseous species, the Greenhouse Gases.

We now refer to the «greenhouse effect» as the **exacerbation of the aforementioned natural process due to air pollution originating from certain human activities - "greenhouse gases"** and the production of a positive climate forcing causing a warming effect.

The “Keeling curve”



- Atmospheric CO_2 concentrations measured at Mauna Loa since 1958
- Pre-industrial age levels below 300 ppm
- Since 1990 a 43% increase in total radiative forcing; CO_2 accounts for ~80% of this
- 2013 the first year where concentrations passed 400 ppm
- Since 2017 we are above 400 ppm
- Concentrations rise at about 2ppm per year
- In another 50 years CO_2 will likely exceed 500 ppm!

In a landmark study in 1996 Prof. Ralph Keeling proved that the excess emissions can no longer be removed by the earth and vegetation.

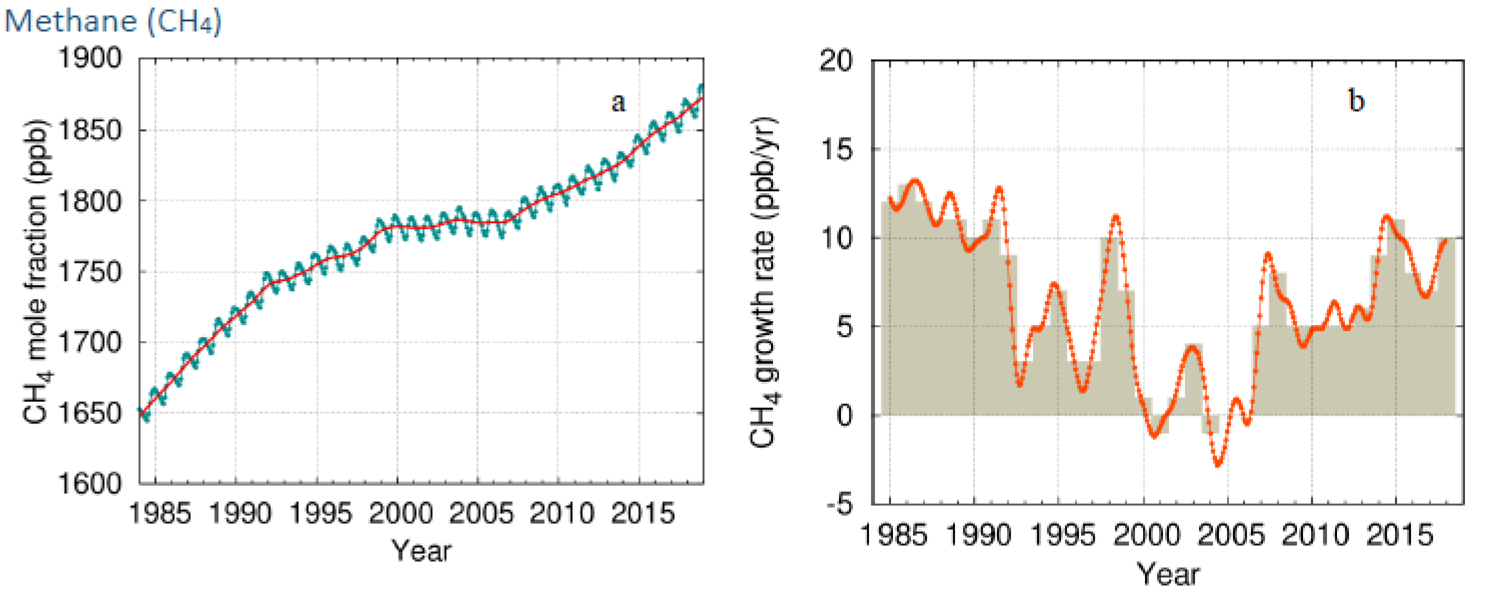


Figure 5. Globally averaged CH4 mole fraction (a) and its growth rate (b) from 1984 to 2018. Increases in successive annual means are shown as the shaded columns in (b). The red line in (a) is the monthly mean with the seasonal variation removed; the blue dots and line depict the monthly averages. Observations from 127 stations have been used for this analysis.

- Second most important long-lived greenhouse gas
- Contributes ~17% of radiative forcing
- 40% from natural sources (wetlands) and 60% from human activities (cattle breeding, rice agriculture, fossil fuel exploitation, landfills and biomass burning)
- Is now 259% of pre-industrial levels

Source: https://public.wmo.int

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Athens measurement site

- PICARRO G2401 cavity ring-down spectrometer measuring CO, CO_2, CH_4, H_20 with 1 s resolution
- Calibration according to WMO-X2007 and WMO-X2004A
- Target cylinders of known CO_2 and CH_4 concentrations twice a day
- Averaged to 1-h data
- 7-wavelength aethalometer AE33

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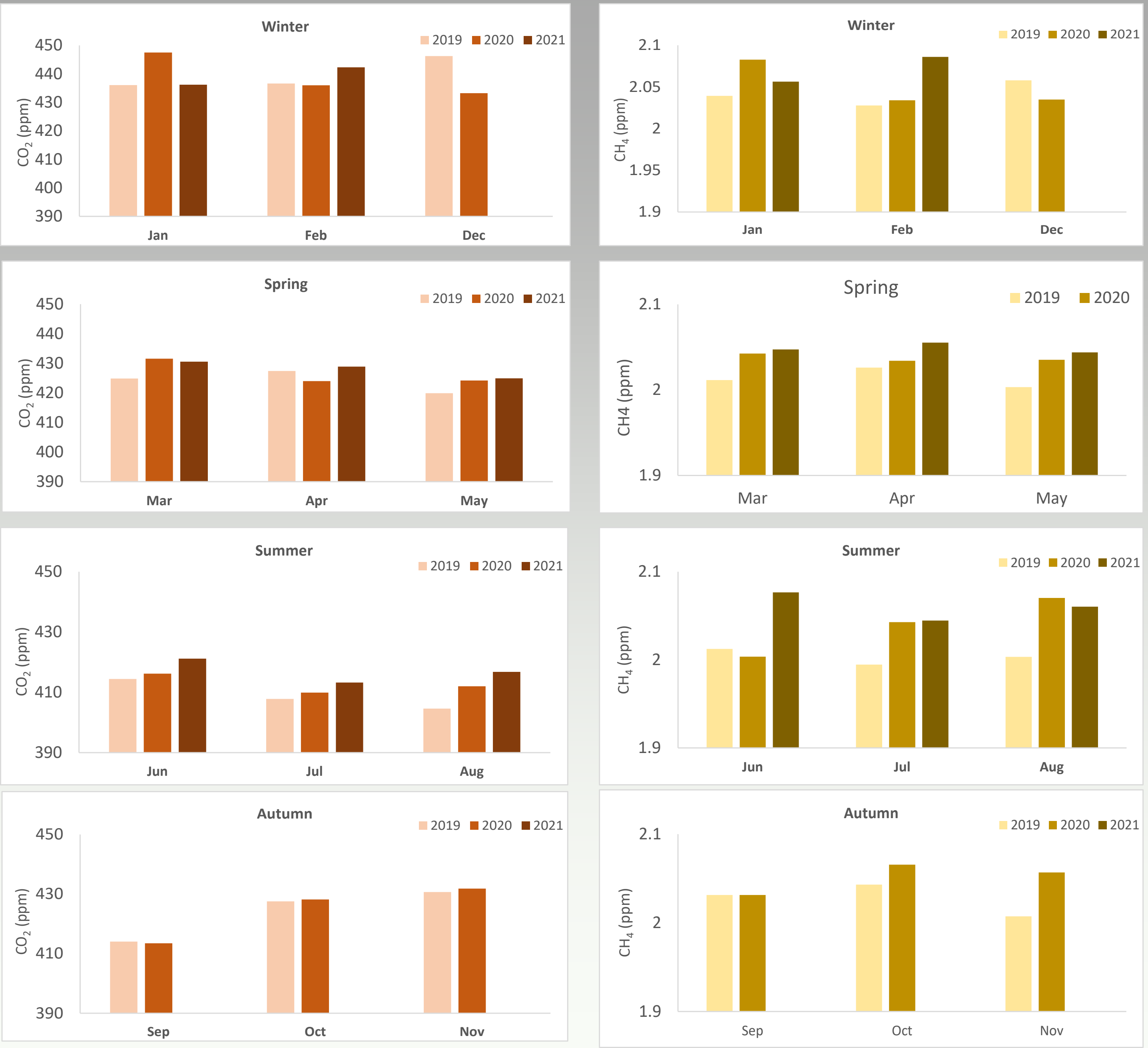
GHG time series



- Almost 3 years of continuous measurements
- Clear maximum concentrations for CO_2 during winter and minimum during summer
- For CH_4 similar concentrations throughout the year
- During summer when CO_2 concentrations are same as background clearly shows a yearly increase of ~3-4 ppm
- Larger increase observed for CH_4

ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ NATIONAL OBSERVATORY ATHENS

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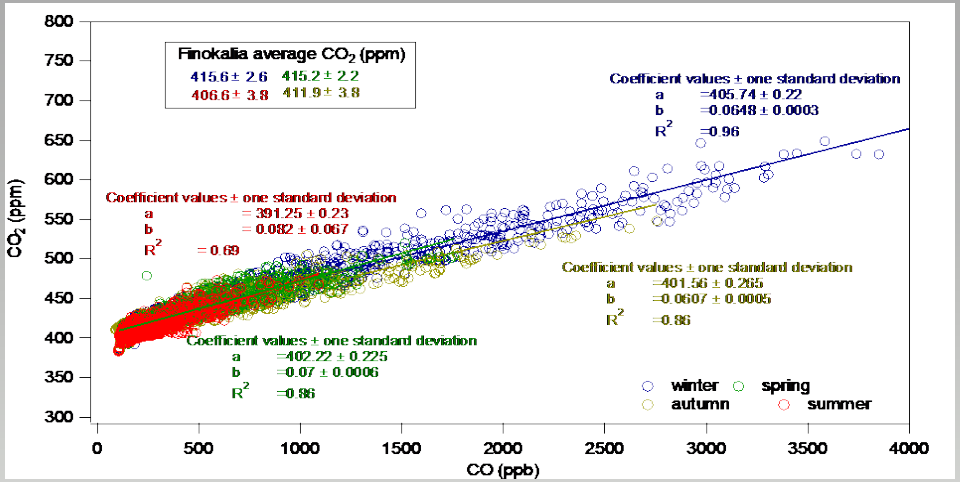
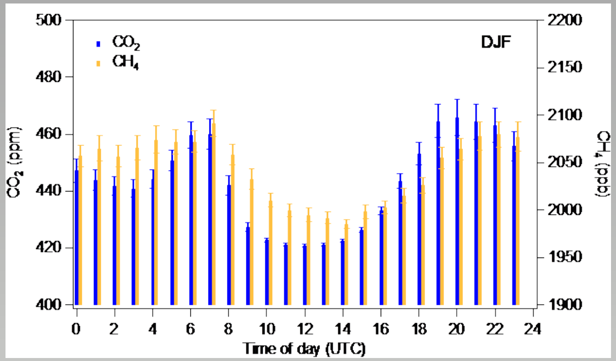
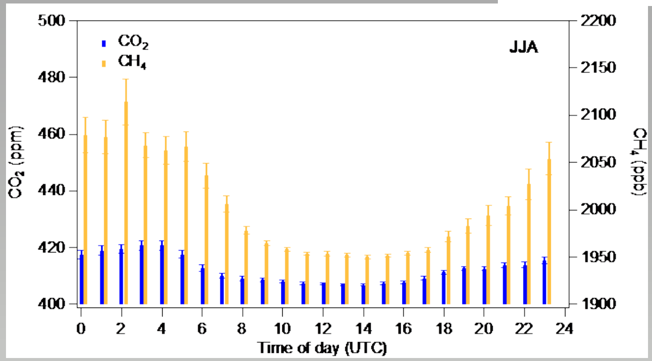
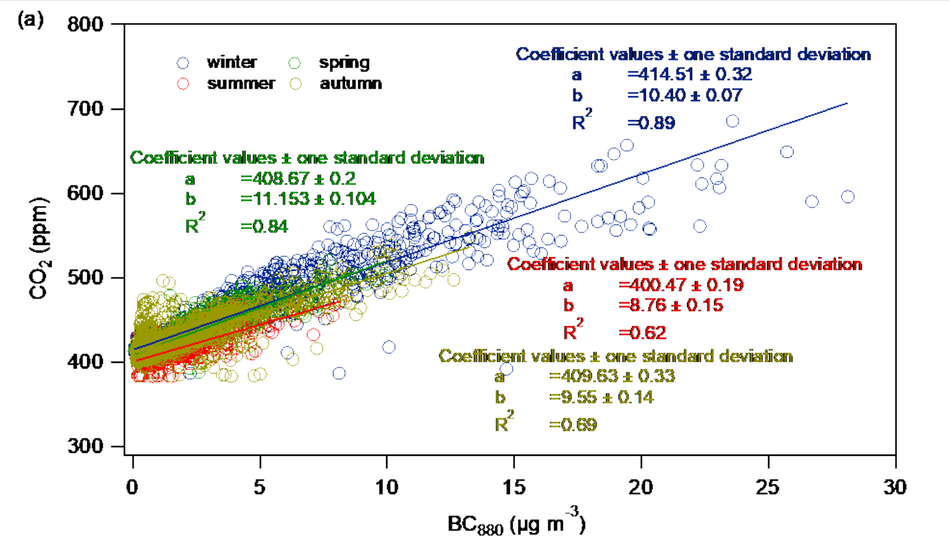




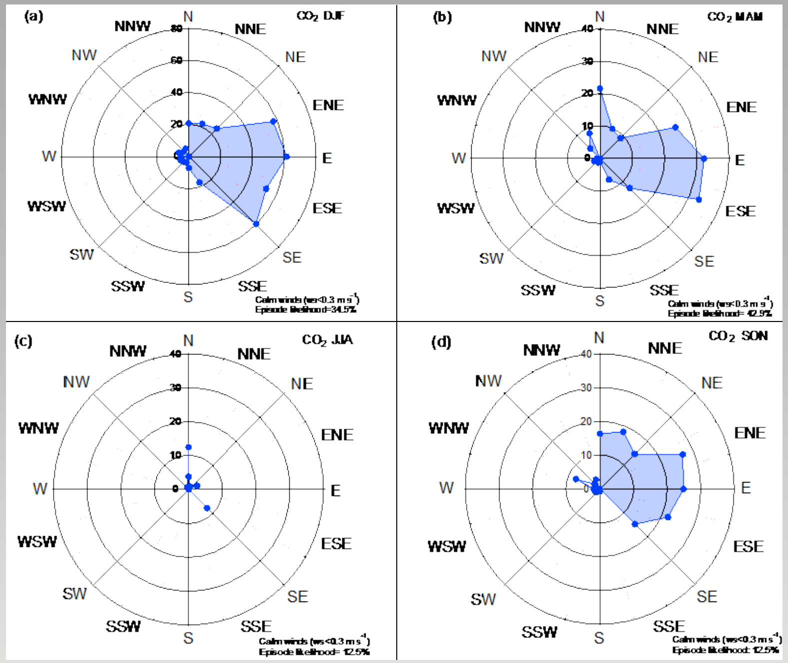


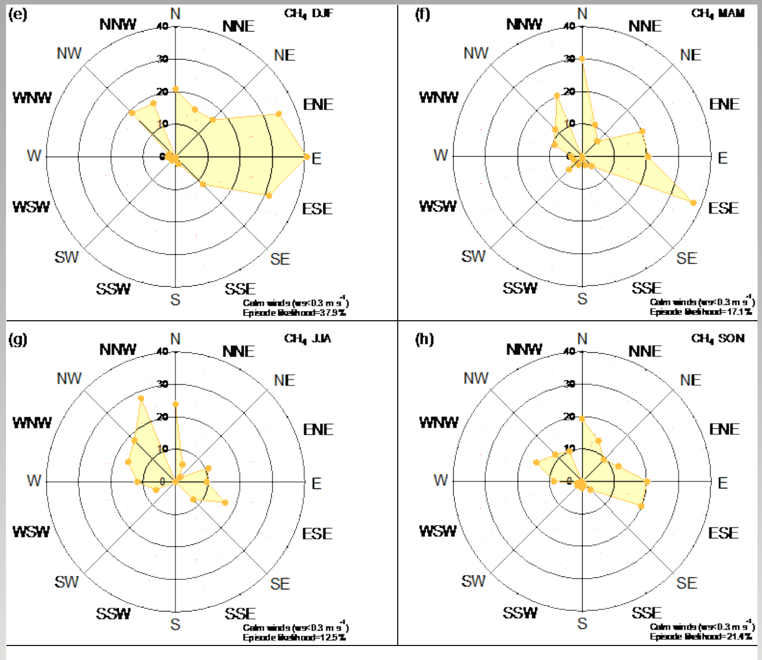


- Excellent correlation between CO and CO_2 denoting common sources
- Excellent correlation between CO_2 and BC during winter (combustion)
- Diurnal variability of CO_2 with maxima during night and morning traffic
- Levels drop considerably between winter and summer
- CH_4 levels same throughout the year, independent of season
- Maximum CH_4 concentrations during nighttime

Dimitriou et al., Atmos. Environ 253, 2021

Effect of wind direction





- Calm winds (<0.3 m s^{-1}) were associated with high episode probabilities primarily during winter (for CO_2 and CH_4) and spring (only for CO_2)
- Peak episode likelihood for CO_2 was related to winds originated from the eastern sector whereas winds from the northern sector had a stronger impact on CH_4 concentrations primarily during spring and summer

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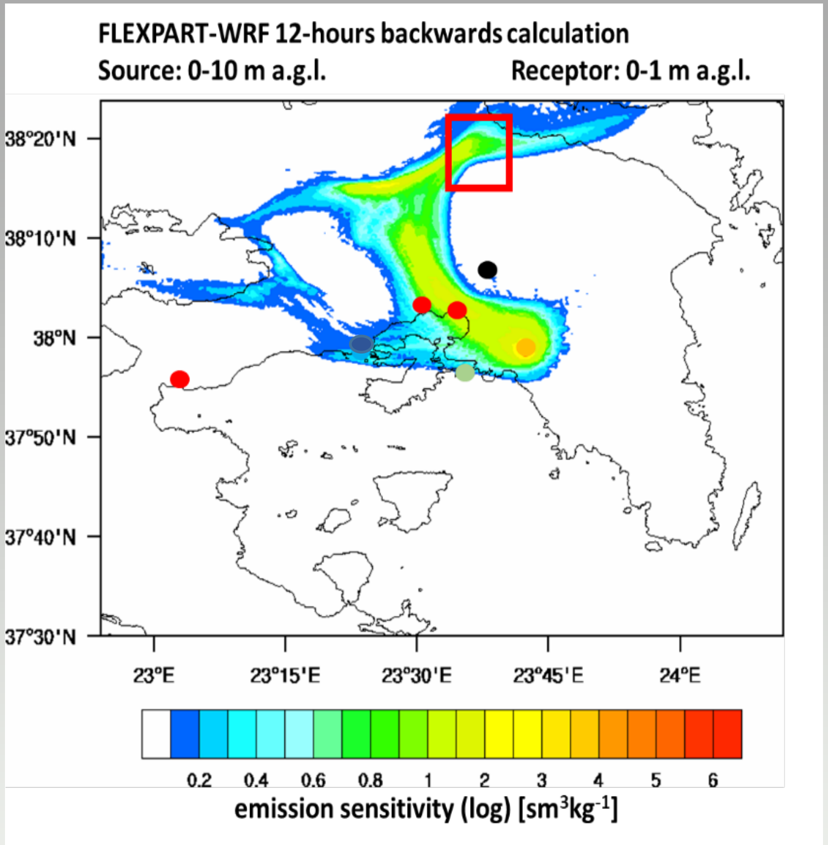
Case study: 15 March 2019



- oil refineries (red dots)
- Liquefied Natural Gas (LNG) transfer point
- industrial zone to the North of Athens
- waste water plant
- landfill

- Maximum measured CH_4 of 3355 ppb!
- High resolution WRF fields at 3×3 km grid space
- 12-h back trajectory analysis for air masses arriving directly at the measurement station (0-1 m height a.g.l.) while originating only from surface sources (0-10 m a.g.l.)
- Synergistic effect of multiple sources along the atmospheric path, all contributing to the extreme CH_4 levels

Dimitriou et al., Atmos. Environ 253, 2021

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Anthropogenic impact of Athens

Urban _Athens city center

Vs.

Remote background_Finokalia

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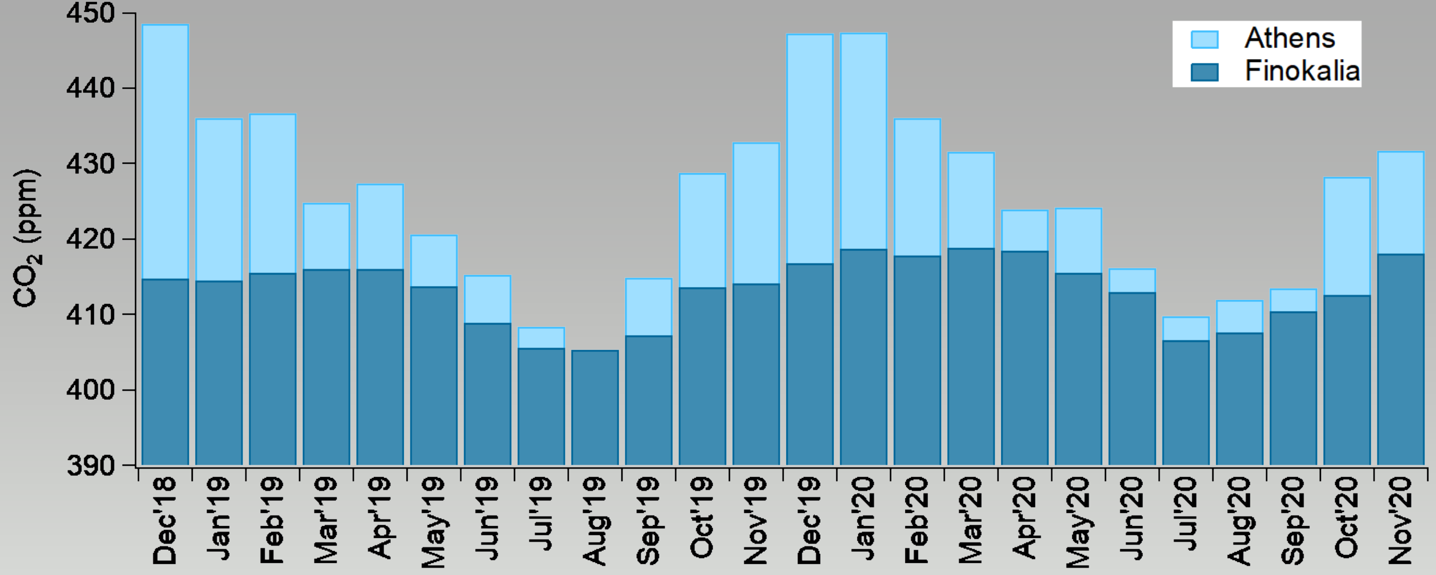
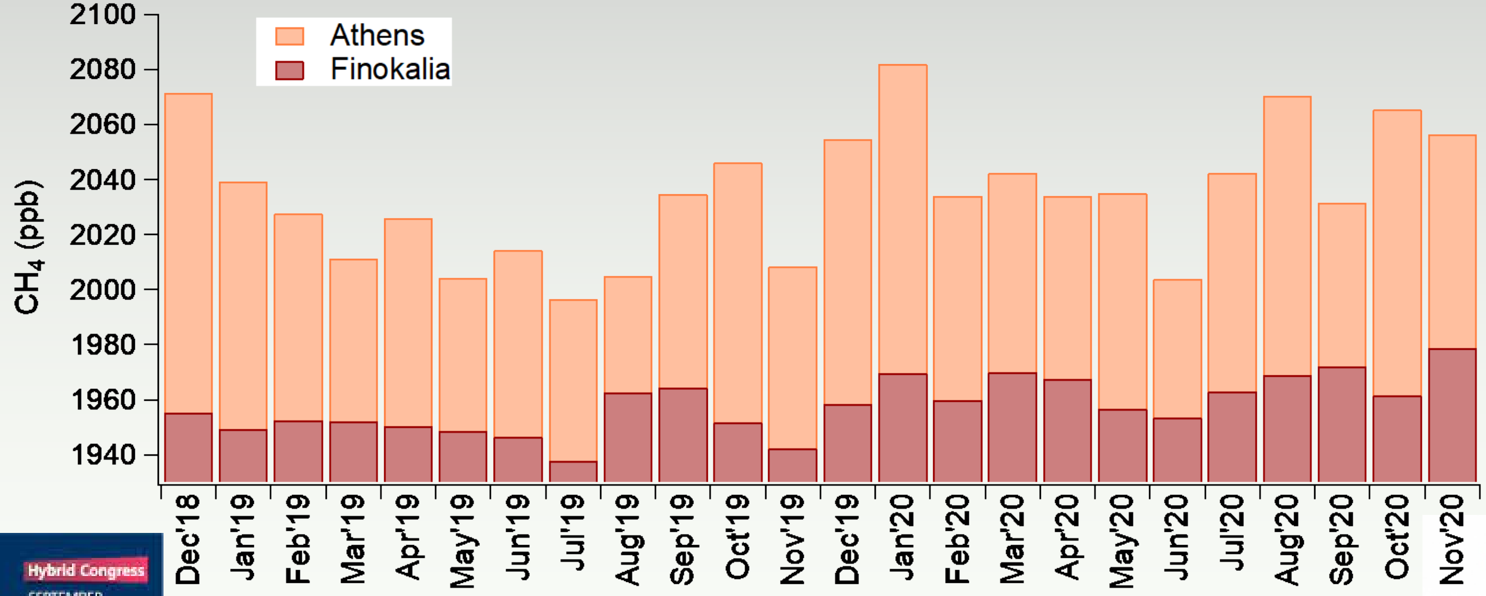
CO_2



CH_4



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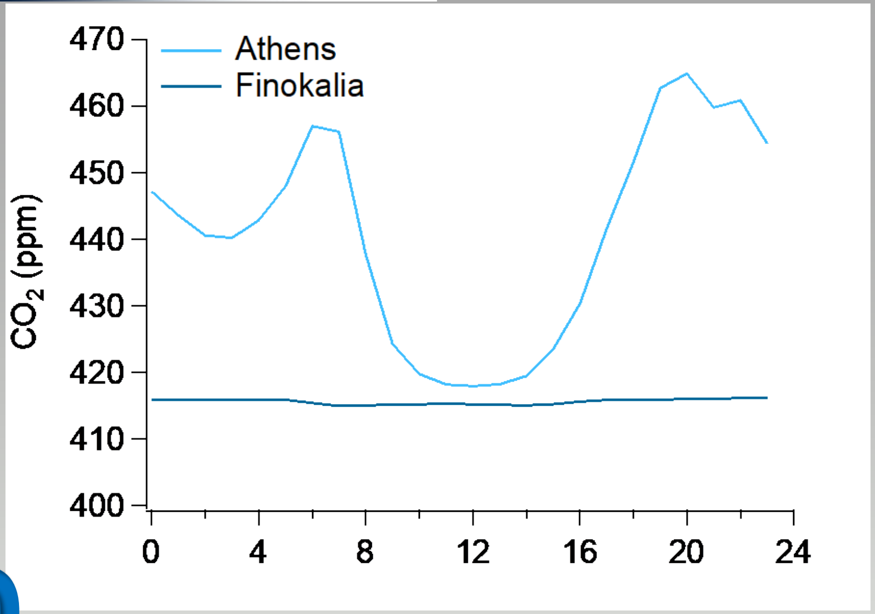
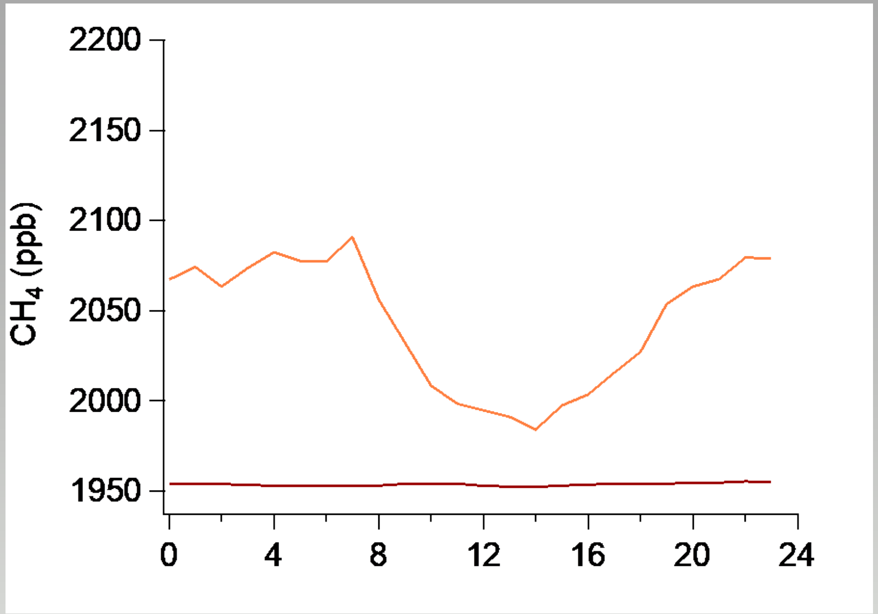
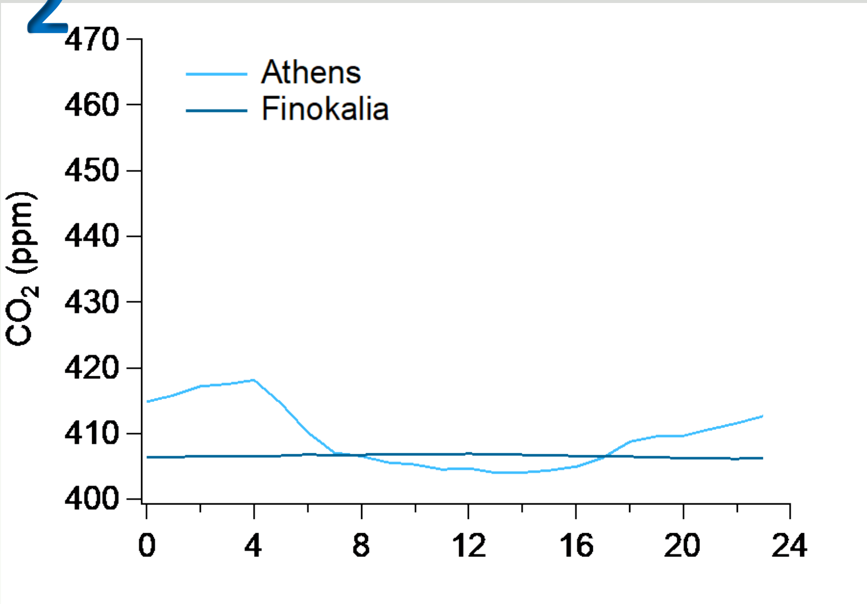
CO_2



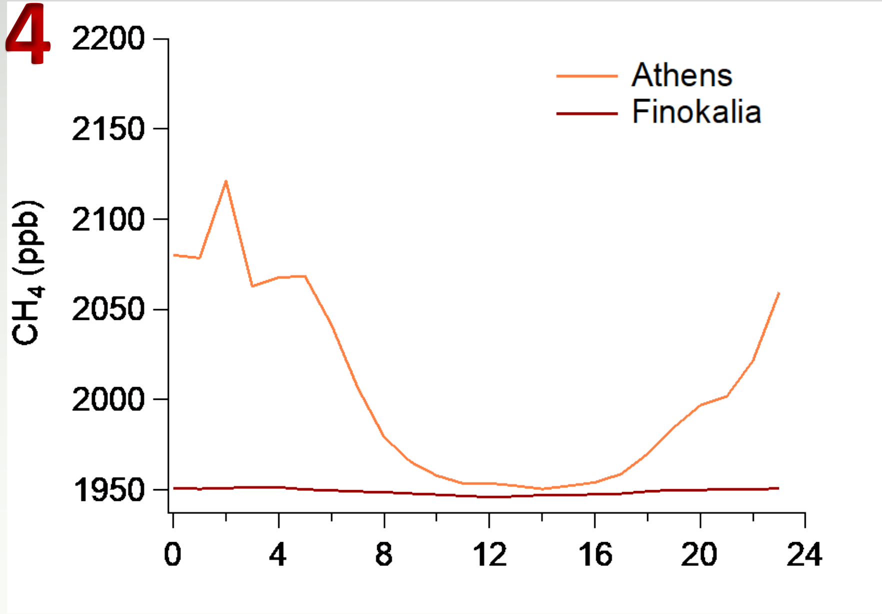
WINTER



CH_4



SUMMER



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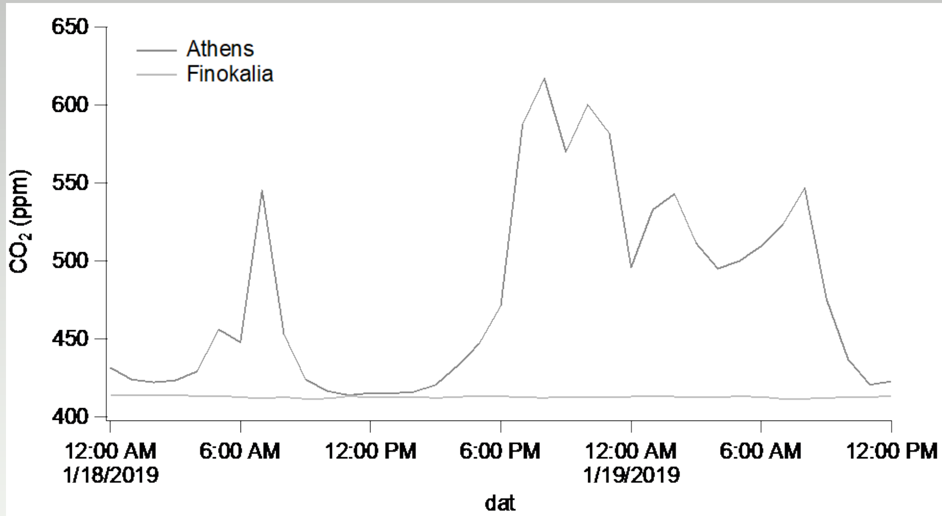
Anthropogenic fingerprint of Athens

- Levels at Finokalia are considered as background values
- Subtract Finokalia levels from Athens levels to find the urban burden
- Throughout the year urban fingerprint 3.6%
- During winter 6.1% on average (ranging from 5.5 to 7.7%) during nighttime sometimes values up to 20% higher!!
- During summer values merely 0.6 to 1.3% higher
- For CH_4 urban burden of 3.5% same throughout the year



Take-home messages

- The rule of “rise of CO_2 levels by 2 ppm per year” also applies in our area
- Athens levels during summer reach background (Finokalia)
- Additional burden from anthropogenic activities (combustion mostly) on average 3.6% throughout the year (5.5 to 7.7% during winter, 0.6 to 1.3% during summer)
- In Athens there is a source of methane that doesn’t change throughout the year adding an additional burden of 3.5%
- Calm winds (<0.3 m s^{-1}) associated with high episode probability during winter
- Increased hourly levels of both greenhouse gases mainly occurred in conjunction with winds blowing from northern and eastern directions in all seasons
- Regional sources of CH_4 isolated primarily to the north and to the west of the Athens basin (industrial & petrochemical zone, respectively)

Thank you for your attention!