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CO_2 - Just a big guess?

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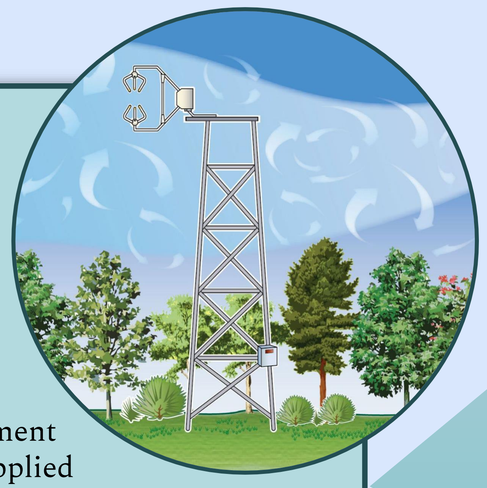
How is atmospheric CO_2 measured?

Devices

By determining the mole fraction of CO_2 in dry air with:

- Gas Chromatography Flame ionization detector (GC-FID)
- Infrared spectroscopy (IR abs)
- Cavity Ring-down Spectroscopy (CRDS)

Application



Eddy Covariance Flux Towers

Eddy covariance flux towers measure Vertical concentration gradients of gases to calculate energy and trace element fluxes of ecosystems. This method is applied to quantify the fluxes of scalars (e.g., CO_2, CH_4, water vapor) and energy between the biosphere and atmosphere. This can be used to evaluate and predict annual ecosystem responses.[3]

Location

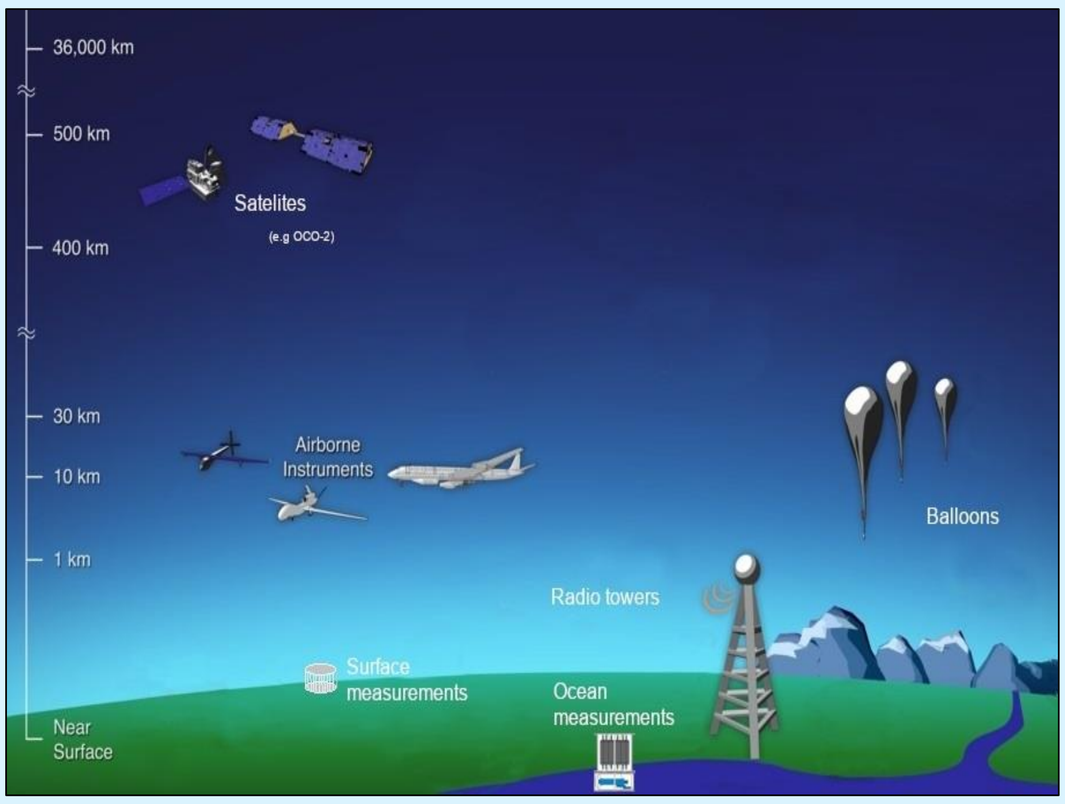
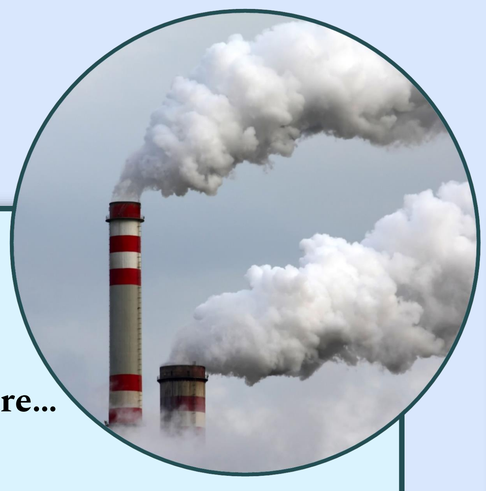


Figure 1: Different locations of global carbon measurements

How are global CO_2 emissions estimated?



Fossil CO_2 emissions are...

...based on:

- global and national emission estimates for coal, oil, natural gas, and peat fuel extractions
- greenhouse gas inventory reports in the United Nations Framework Convention on Climate Change (*UNFCCC*)
- the BP (*British Petroleum*) Statistical Review of World Energy[4]

... conceptually calculated as:

$$CO_2\ (\text{as C}) = P_i * FO_i * C_i$$

P_i produced amount of fuel
FO_i oxidized fraction
C_i carbon content

Land use change emissions are...

...based on:

- bookkeeping models (countries reporting to the Food and Agriculture Organisation of the UN (FAO))
- dynamic global vegetation models (DGVMs)[4]

Oceanic CO_2 sinks are...

...based on:

- global ocean biogeochemistry models (GOBM)
- maps from Surface Ocean CO_2 Atlas (SOCAT) generated by measurements of ships, moorings, drifting platforms
- observation-based estimates assessed by the Intergovernmental Panel on Climate Change (IPCC)[4]

Limitations

Differences between calculations and reported emissions, due to

- sum of countries' imports is not equal to exports because of reporting inconsistencies
- changes in stocks
- carbon which is not burned (e.g. used as solvents, lubricants)[4]

Limitations

- not all models do capture carbon emissions from peat fires directly, nor emissions from the organic layers of drained peat soils
- some bookkeeping models do not account for additional sink capacities due to CO_2 fertilization
- differences between bookkeeping models and DGVMs[4]

Limitations:

- observation-based estimates are mainly derived from models and one data product of the 1990s
- data for estimate adjustments are scarce[4]

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[2] Taylor, T. E.; O'Dell, C. W.; Frankenberg, C.; Partain, P. T.; Cronk, H. Q.; Savtchenko, A. et al. (2016): Orbiting Carbon Observatory-2 (OCO-2) cloud screening algorithms: validation against collocated MODIS and CALIOP data. In: Atmos. Meas. Tech. 9 (3), S. 973–989
[3]Kumar A, Bhatia A, Fagodiya RK, et al. Eddy covariance flux tower: a promising technique for greenhouse gases measurement. *Adv Plants Agric Res.* 2017;7(4):337-340.
[4]Friedlingstein, Pierre; O'Sullivan, Michael; Jones, Matthew W.; Andrew, Robbie M.; Hauck, Judith; Olsen, Are et al. (2020): Global Carbon Budget 2020. In: *Earth Syst. Sci. Data* 12 (4), S. 3269–3340. DOI: 10.5194/essd-12-3269-2020.
Figures: **1**: modified according to: https://svs.gsfc.nasa.gov/30892, **2**: https://www.youtube.com/watch?v=nrsYiVJ9WK4 , **3**: https://eesa.lbl.gov/wp-content/uploads/2015/02/EddyCovarianceDiagram_resizedforWeb.jpg, **4**: modified according to https://www.socat.info **4** (chimney): https://www.wienerzeitung.at/_em_daten/240968/_/1x6C6mNvhD5UXMunvHO6oDeQSX55GqOV3_S2lY81jYEh27P2-SK9sVNHLajJ5L_DmEq3F0jNu2SGMcCHdIuwIQ6yN-6eFklSx9/171113-0954-shutterstock-30072571-1mb.jpg, **5** (peat): https://www.worldatlas.com/r/w1200-h630-c1200x630/upload/81/da/7a/shutterstock-606018689.jpg, **6** (ocean): https://s3-eu-west-1.amazonaws.com/oceanographic/wp-content/uploads/2020/06/04110702/ocean-carbon-sink-1.jpg