High altitude CO_2 measurements at the Jungfraujoch (Switzerland): Comparison between the Sphinx (3570 m a.s.l.) and East Ridge (3690 m a.s.l.)

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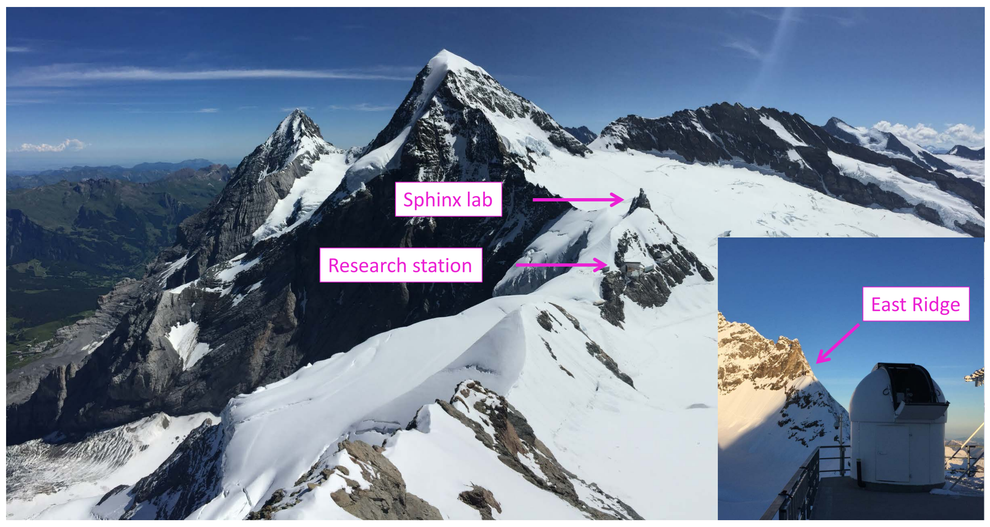
The Sphinx high altitude research station located at the Jungfraujoch has been hosting for decades several experiments of various research institutes worldwide and constitutes a lead location for atmospheric measurements in Europe. A key feature of the site is the remote setting and its exposure to pristine air masses with only sporadic pollution events originating from the surrounding lowlands. Since December 2014, we have had an additional location available for research (not accessible to tourists) at the Jungfrau East Ridge building, where we installed a Picarro G2301-i laser based instrument which is continuously measuring the atmospheric CO_2 mixing ratio that allows a comparison with the Sphinx data (Maihak instrument). It is used to evaluate the suitability of the new site and to investigate the potential pollution inherent to the touristic exploitation of the Jungfraujoch.

LOCATION



(Left) View from the East Ridge building located 120 m higher up and 1 km westward from the Sphinx laboratory and the Jungfraujoch tourism area. (Right) View from the Sphinx

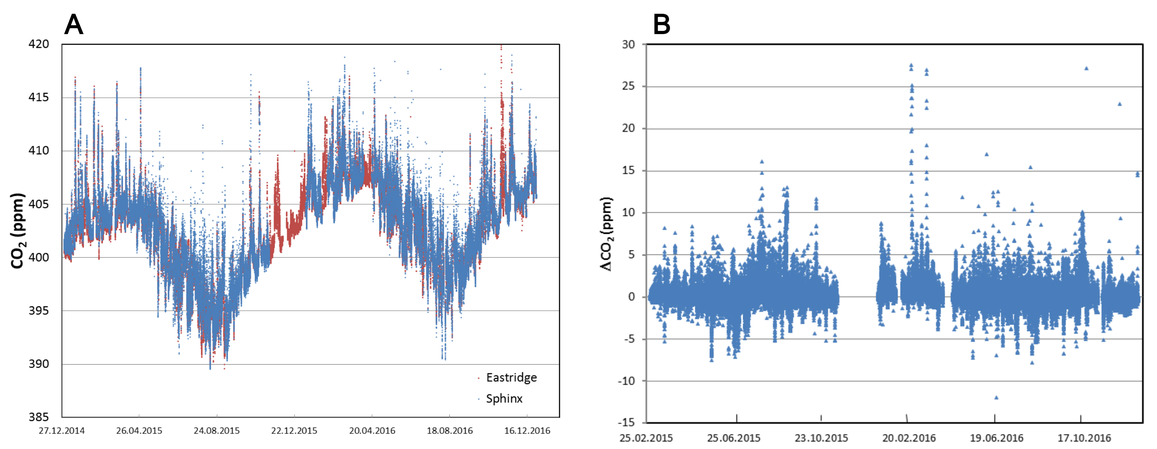


Fig. 1: (**A**) Comparison between the East Ridge (red) and Sphinx CO_2 time series (blue) (**B**) Differences between the two datasets.

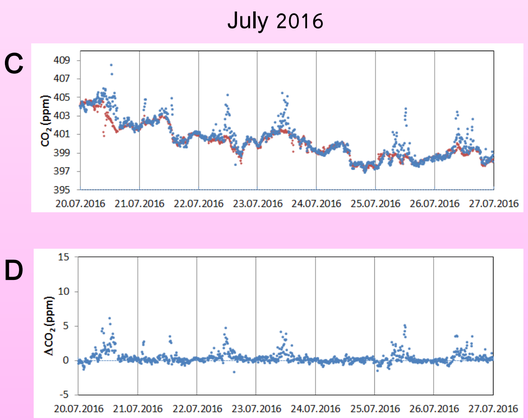


Fig. 2: Example of July 2016 summer (**C**) CO_2 mixing ratios for the East Ridge (red) and the Sphinx observatory (blue) and; (**D**) diurnal positive CO_2 excursions at the Sphinx location.

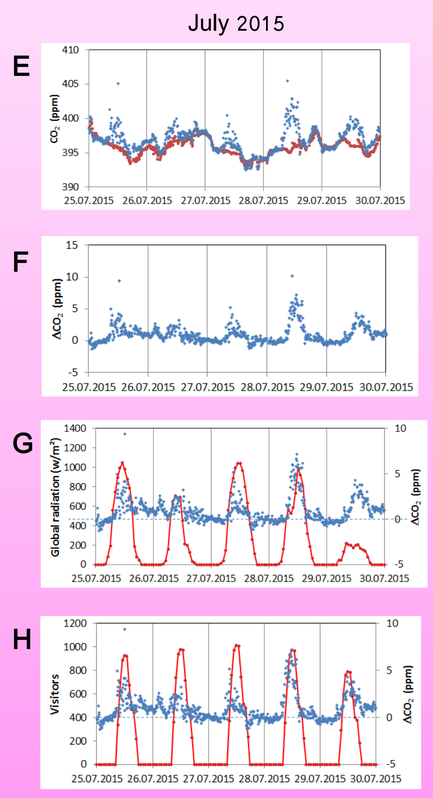


Fig. 3: Example of July 2015 summer (**E**) CO_2 mixing ratios for the East Rifge (red) and the Sphinx observatory (blue); (**F**) CO_2 excursions at the Sphinx location; (**G**) CO_2 difference compared with global radiation and; (**H**) CO_2 difference compared with number of visitors.

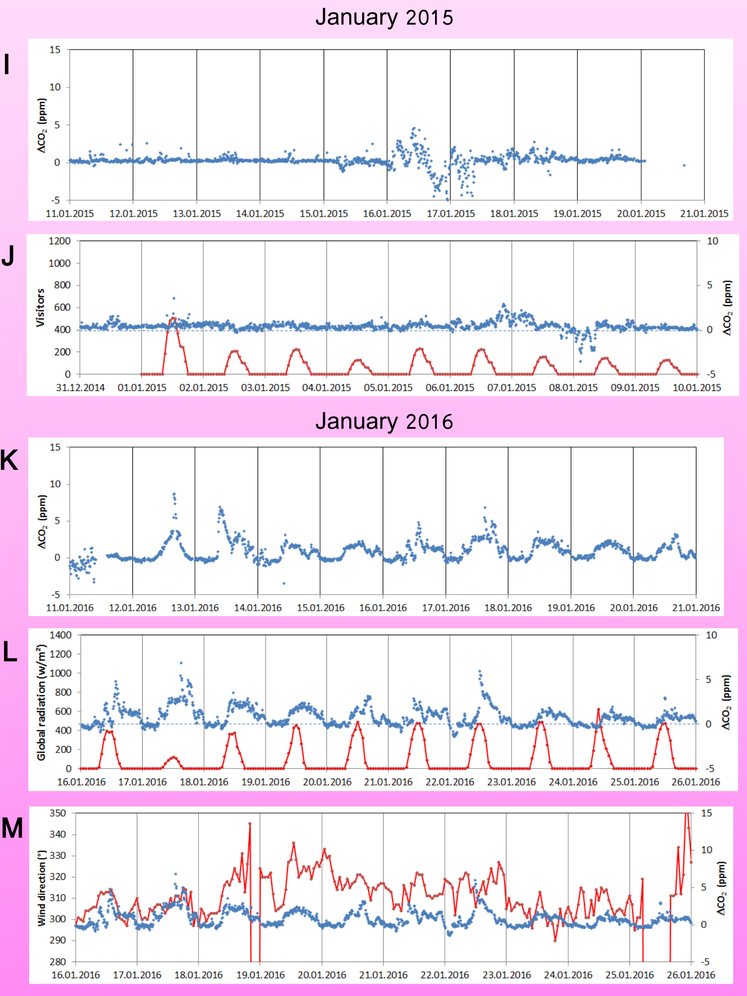


Fig. 4: Winter examples: (**I**) Rare period without CO_2 diurnal excursions in January 2015 and; (**J**) CO_2 difference compared with number of visitors; (**K**) CO_2 diurnal excursions in January 2016; (**L**) CO_2 difference compared with global radiation and; (**M**) CO_2 difference compared with wind direction.

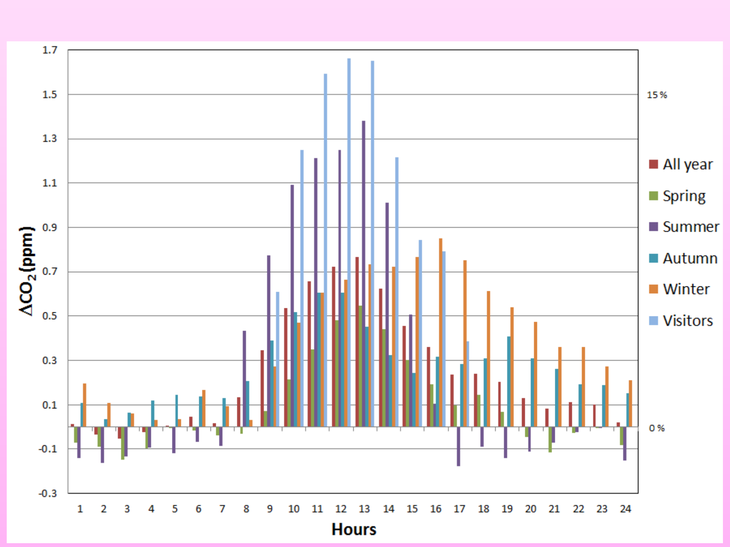


Fig. 5: CO_2 differences versus daily hours sub-divided into seasons. The mean percentage of visitors is also shown (secondary axis, light blue). Differences during the night are stable inside the measurements uncertainy of ±0.1 ppm.

RESULTS

- The two years long comparison of CO_2 records shows a good agreement between both sites (**Fig. 1A**) but exhibits annual mean daily differences of less than 1 ppm whereas the corresponding nighttime values are indistinguishable within the measurement precision (**Fig. 5**). Night measurements are considered to be robust atmospheric background values.
- Diurnal CO_2 cycles are not seen at the East Ridge whereas cycles (with maximum values up to ~5 ppm) are seen at the Sphinx on most days of the year (**Figs. 2, 3 and 4**).
- There is a distinct seasonal pattern with highest CO_2 excess values for mean summer midday values of maximal 1.5 ppm (**Fig. 5**).
- Possible influence of visitors on the Sphinx CO_2 measurements. Other potential influencing parameters are: global radiation, wind direction and velocity leading to variable planetary boundary layer heights and therefore to different dilution behaviours (**Figs. 3 and 5**).
- Further study may help to disentangle this issue such as (i) the use of PBL height estimation (ongoing) to check if possible contamination from convective air masses with polluted air from the valley, (ii) ^{14}C measurements could highlight contamination by fossil fuel emission or (iii) ^{13}C and O_2 measurements as indicator of biosphere origin may help identify the contamination source.
- The CO_2 measurements are promising for assessing the suitability of the East Ridge building as an additional spot to perform high quality atmospheric measurements.
- Based on these and additional aerosol observations not shown here, visitors have been asked not to smoke on the terrace close to the laboratory.

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