Seasonal and inter-annual variation of CO_2 flux and concentration in Basel

10 years of CO_2 measurements in an urban environment

1) measurements and methods

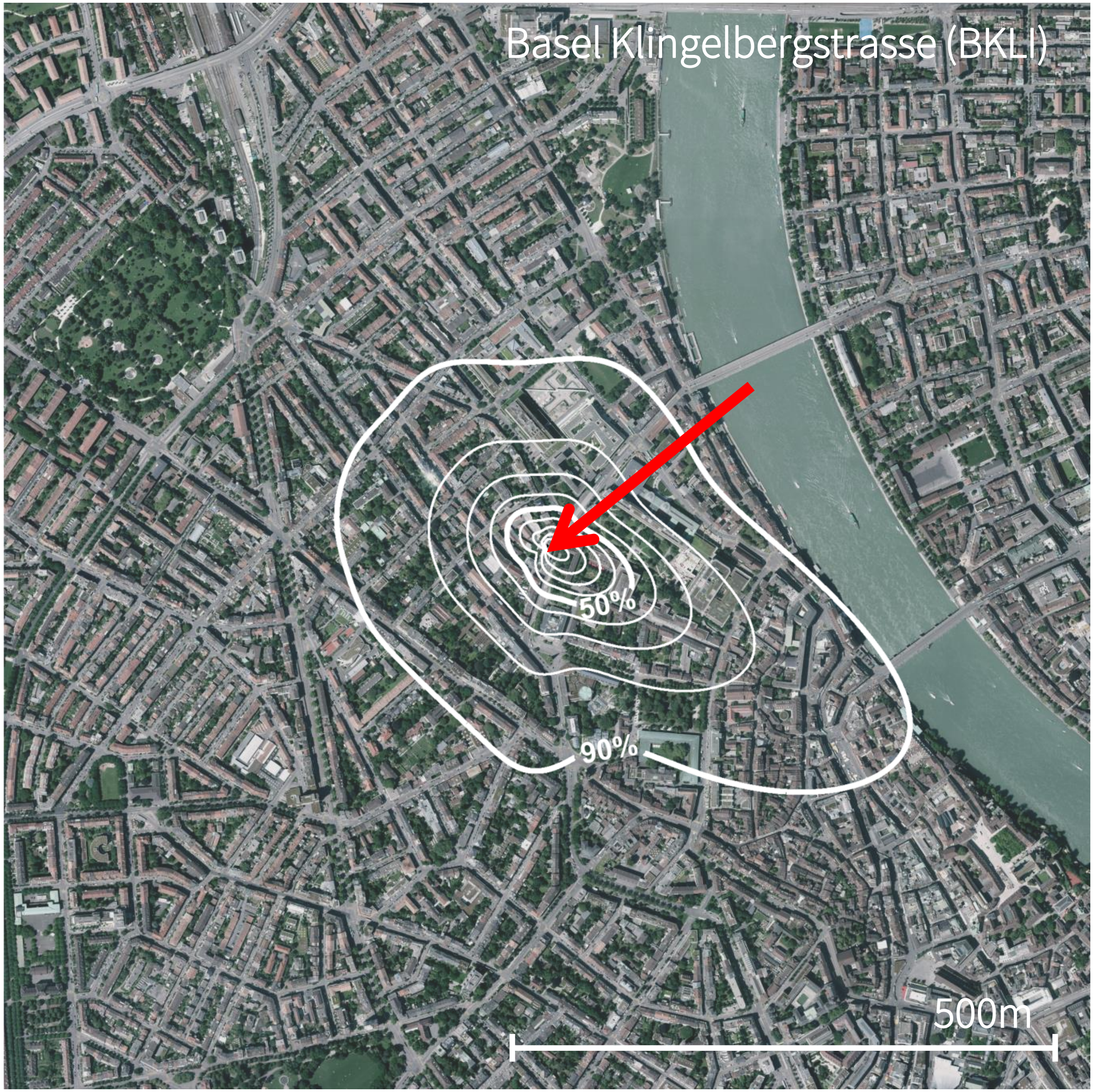
2) typical cycles - seasonal and inter-annual variability

University of Basel

Michael Schmutz - University of Basel, mcr

mcr meteorology climatology remote sensing

mcr meteorology climatology remote sensing



Eddy-Covariance (EC) method

For determination of the turbulent fluxes of energy and mass:

F_H	sensible heat	[$W\ m^{-2}$]
F_L	latent heat	[$mmol\ H_2O\ m^{-2}\ s^{-1}$]
F_C	flux of carbon dioxide	[$\mu mol\ CO_2\ m^{-2}\ s^{-1}$]
ρ_{CO2}	concentration of CO_2	[ppm]
NEE	net ecosystem exchange	[$kgC\ m^{-2}\ y^{-1}$]

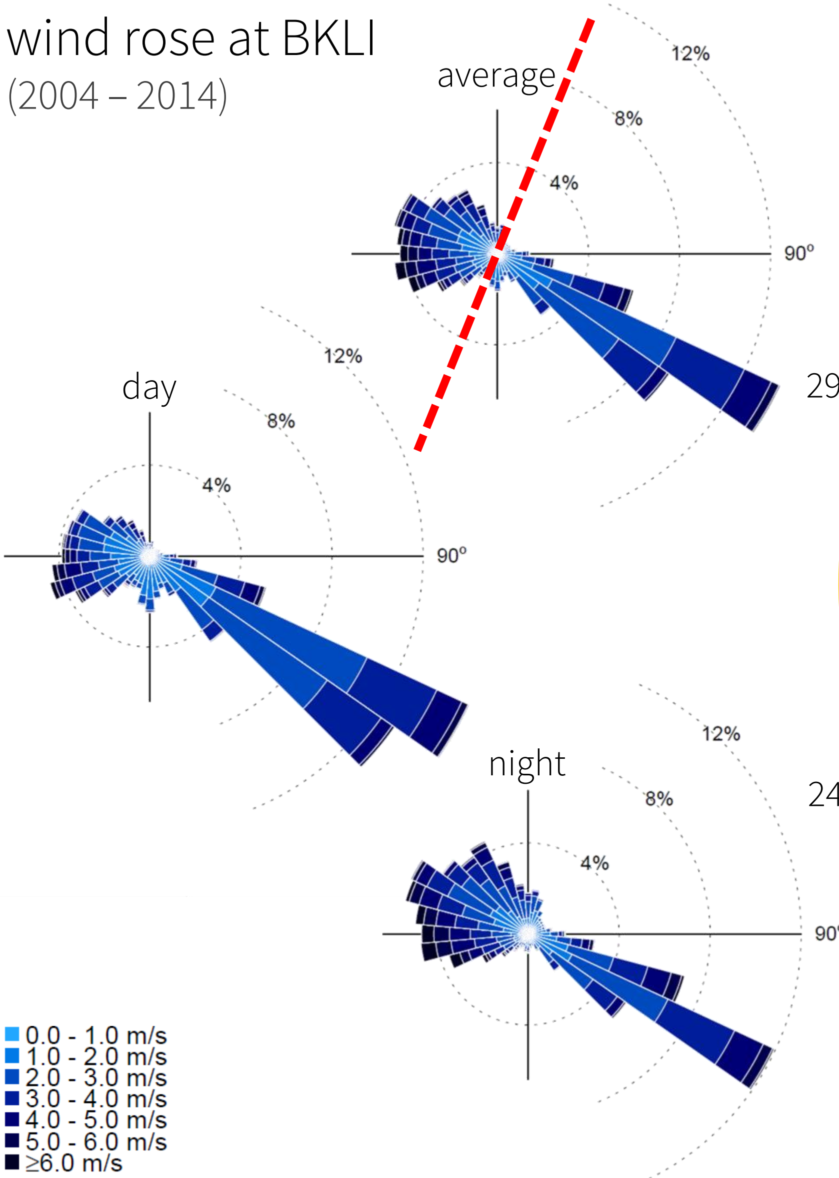
CO_2 flux composition

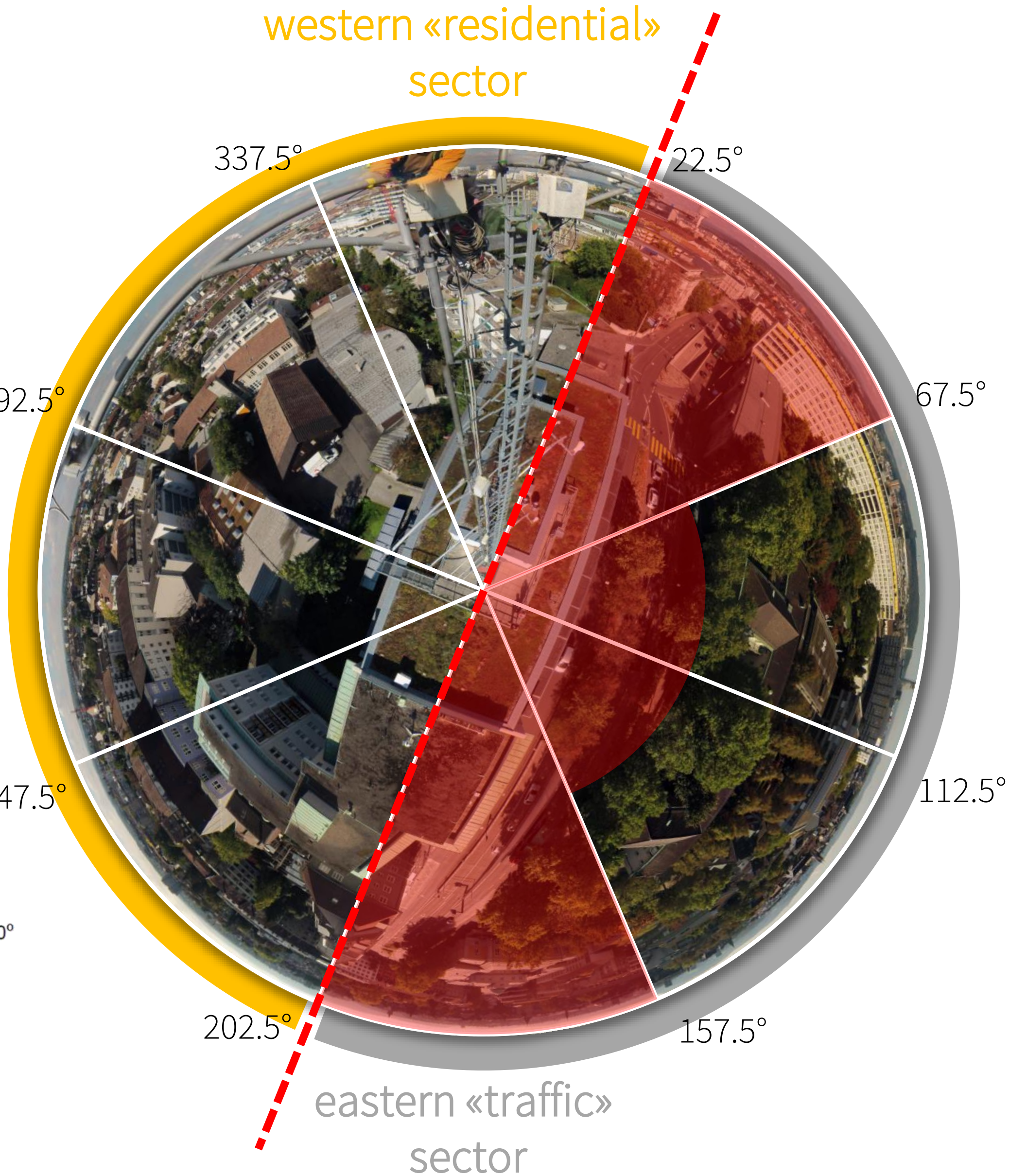
- Industry (source)
- Heating (source)
- Traffic (source)
- Waste management (source)
- Human respiration (source)
- Vegetation (source/sink)

Carbon fluxes measured by eddy covariance are the net result of these controlling factors.

$<F_C>$ and <NEE> represent horizontal averages meteorology climatology remote sensing

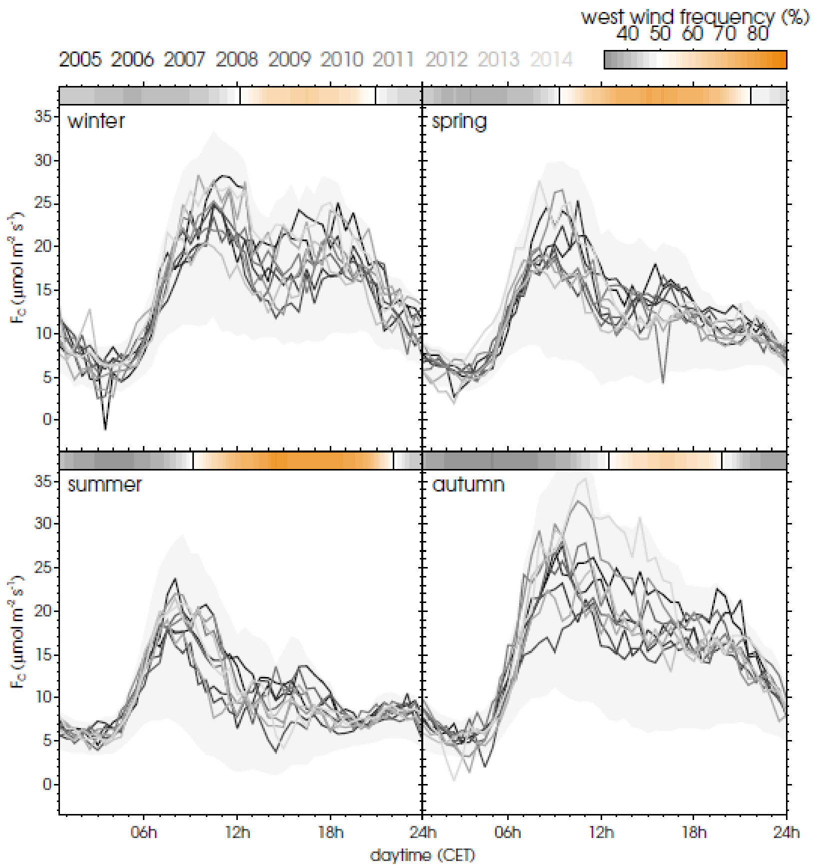
wind rose at BKLI
(2004 – 2014)

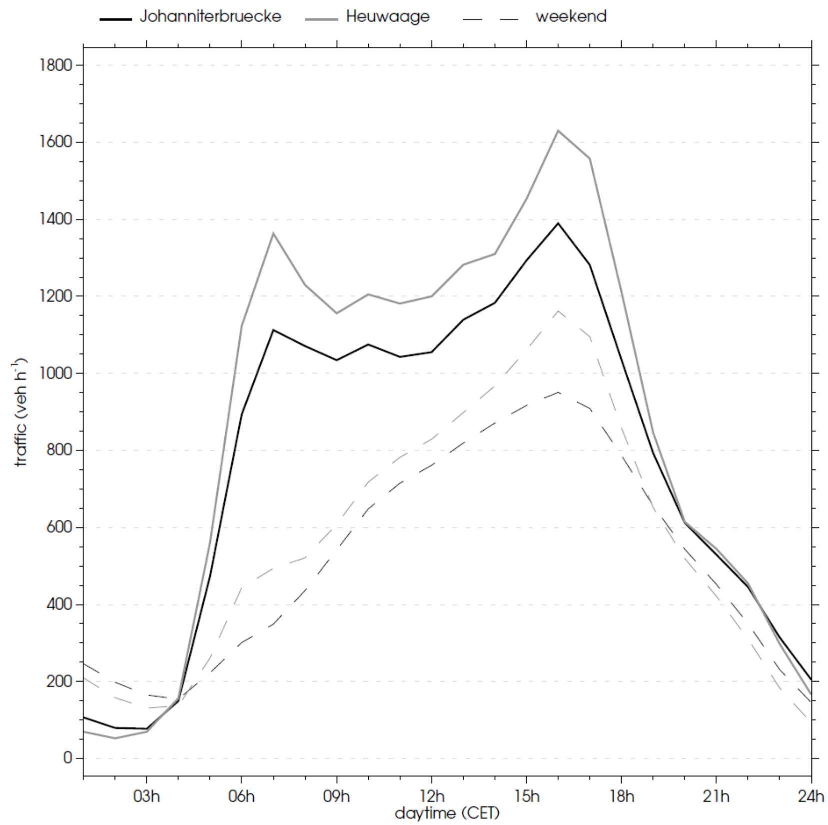




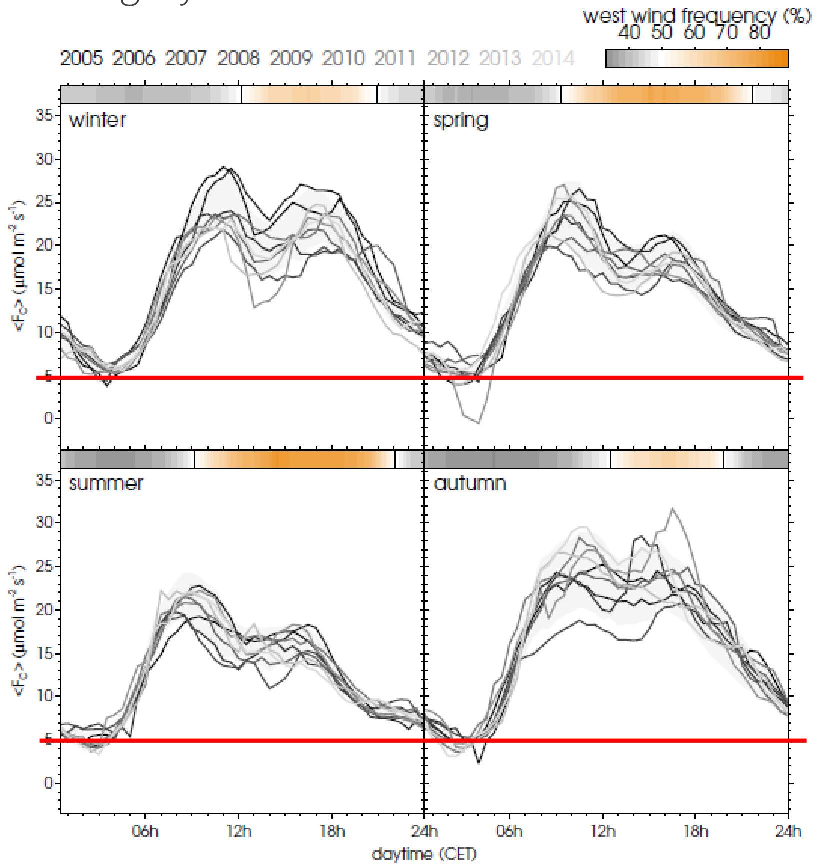
diurnal course of F_C is coupled to the traffic volume

→ east winds: high emissions from the Klingelbergstrasse
→ west winds: lower emissions from the residential area





mean diurnal course of <F_C> for single years and different seasons:



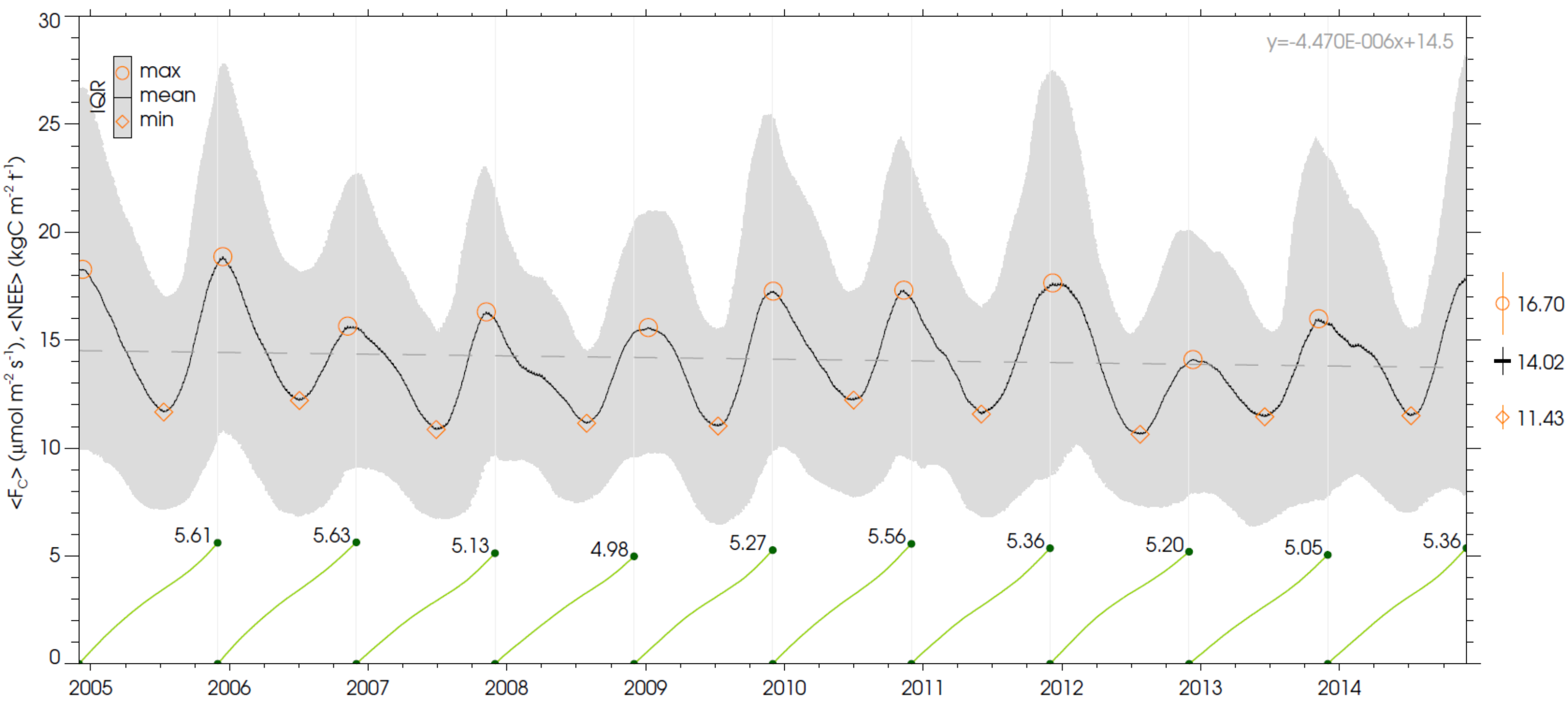
variability is largest during the day, but diurnal course is very similar for each season/year

early morning: lowest activity of sources → minimal emissions and nearly same values during all seasons/years

«urban metabolism» shows a background flux of approx. 5 µmol m^{-2} s^{-1}

mcr meteorology climatology remote sensing

time series of <F_C> and yearly cumulative <NEE>

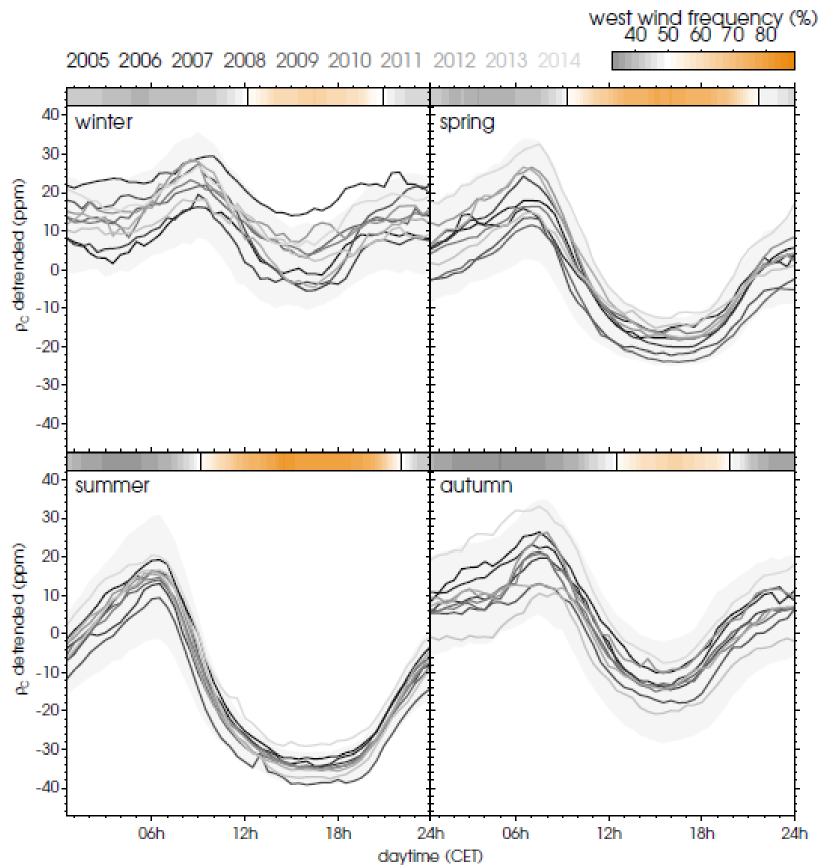


average seasonal amplitude of <F_C>: 5.27 µmol m^{-2} s^{-1} ± 1.30 sdev

average yearly <F_C>: 14.02 µmol m^{-2} s^{-1} ± 0.62 sdev

annual mean <F_C> and <NEE> vary by approximately 10%

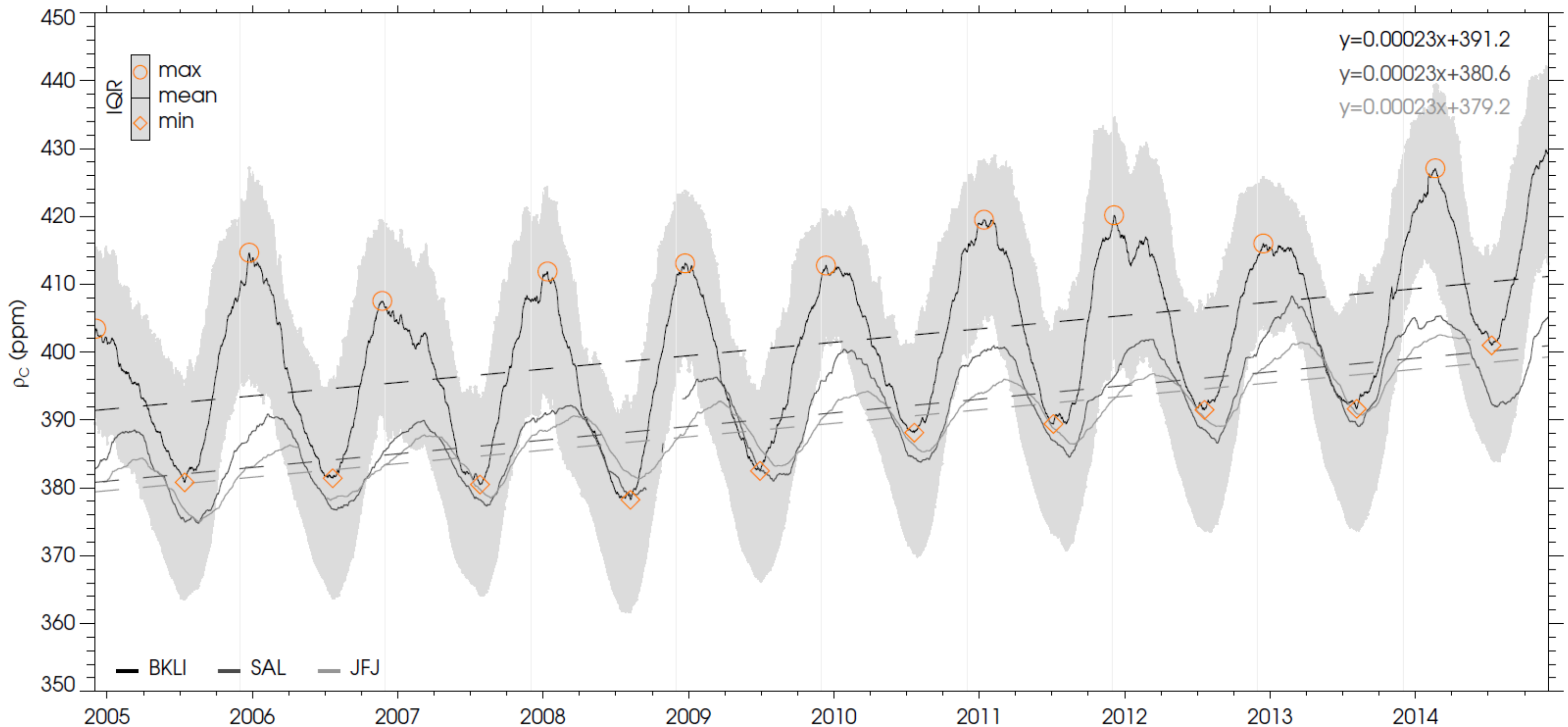
de-trended mean diurnal course of ρ_{CO2} for single years and different seasons:



the seasonal and diurnal course of ρ_{CO2} is controlled by the boundary layer height

variability is larger in winter than in summer → variability of atmospheric stability

same night-time peak values during all seasons time series of CO_2 concentration at BKLI (260 m), Schauinsland (DE, 1284m) and Jungfraujoch (CH, 3471m)



BKLI: 1.97 ppm y^{-1}

SAL: 2.01 ppm y^{-1}

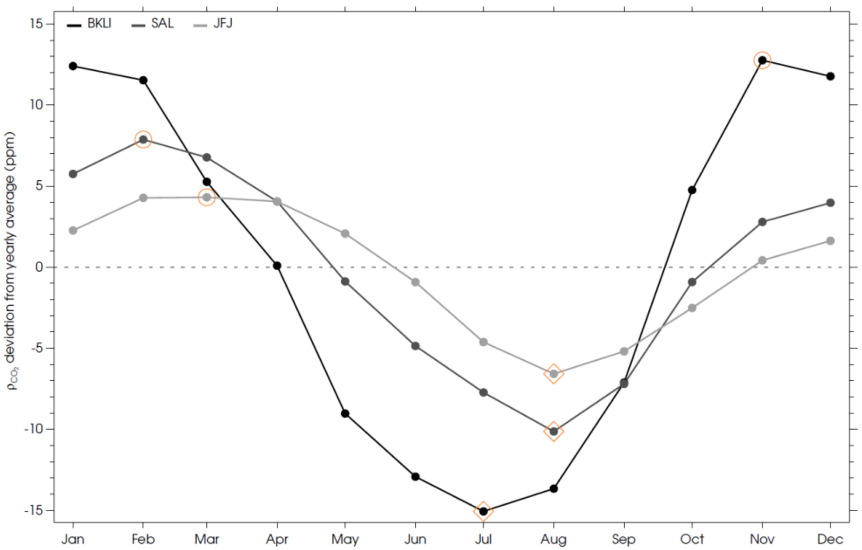
JFJ: 1.99 ppm y^{-1}

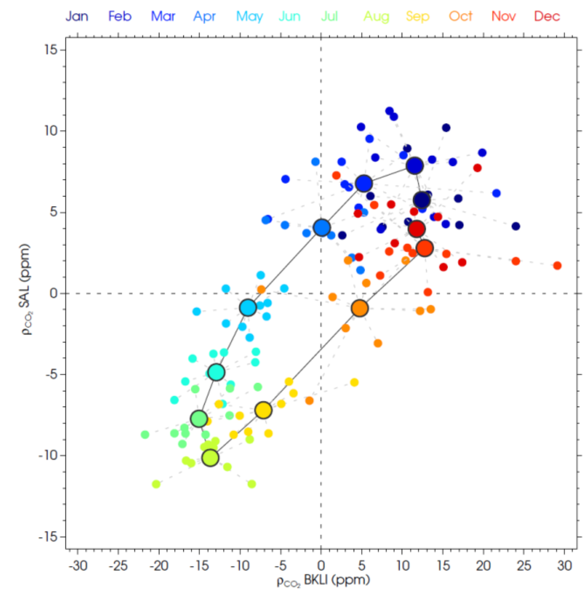
IPCC 2013: 2.0 ppm y^{-1} (between 2001 and 2013 from Mauna Loa and South Pole)

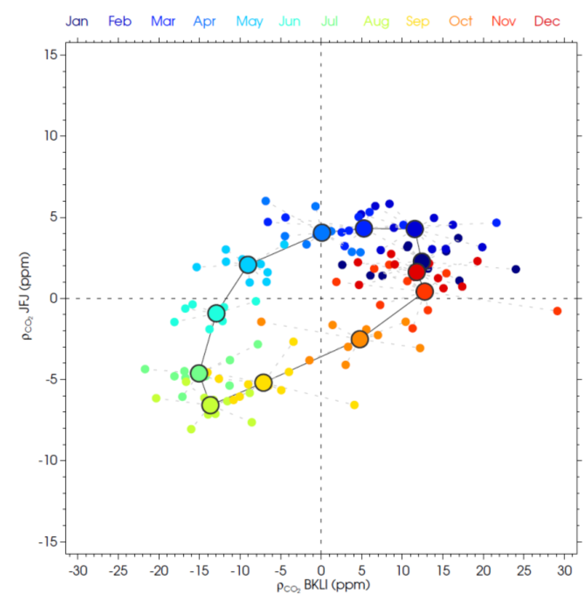
→ trends of local ρ_{CO2} and background ρ_{CO2} compare well

CO_2 concentration

seasonal amplitude and coupling to background concentration

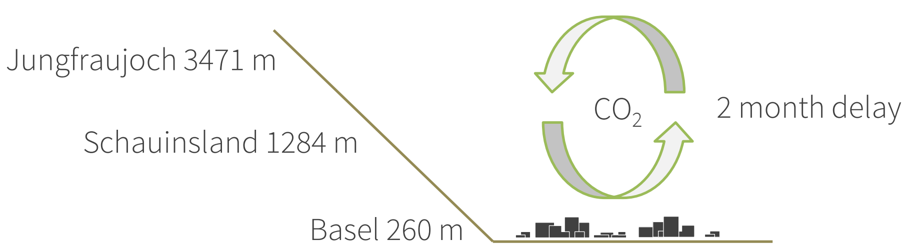






with increasing distance (horizontally and vertically) to sources of CO_2 the yearly amplitude becomes smaller and the seasonal peaks occur later

→ coupling between local concentration and background concentration follows a hysteresis.



summary

- local wind system and heterogeneity of the surrounding area influence the measurements
  → need to consider horizontal averages to achieve representative values

- variability of $\langle F_C \rangle$ is largest during winter and during the day due to the activity of sources

- lowest values of $\langle F_C \rangle$ around 5 $\mu mol\ m^{-2}\ s^{-1}$ occur in the early morning
  → background flux of "urban metabolism"

- CO_2 concentration is coupled to background concentration by a hysteresis

- long term trend of 2 $ppm\ y^{-1}$ compares well to e.g. IPCC 2013

reliable long term time series offer the opportunity, to learn more about the interplay between controlling factors and measured fluxes:

- correlation between trends in controlling factors and trends in $\langle F_C \rangle$?

- reliability of results from “short-term” case studies?

- how to track changes in urban structure or controlling factors in general?

- …

?