Tall tower measurements of methane, carbon monoxide and carbon dioxide emissions in London, UK.

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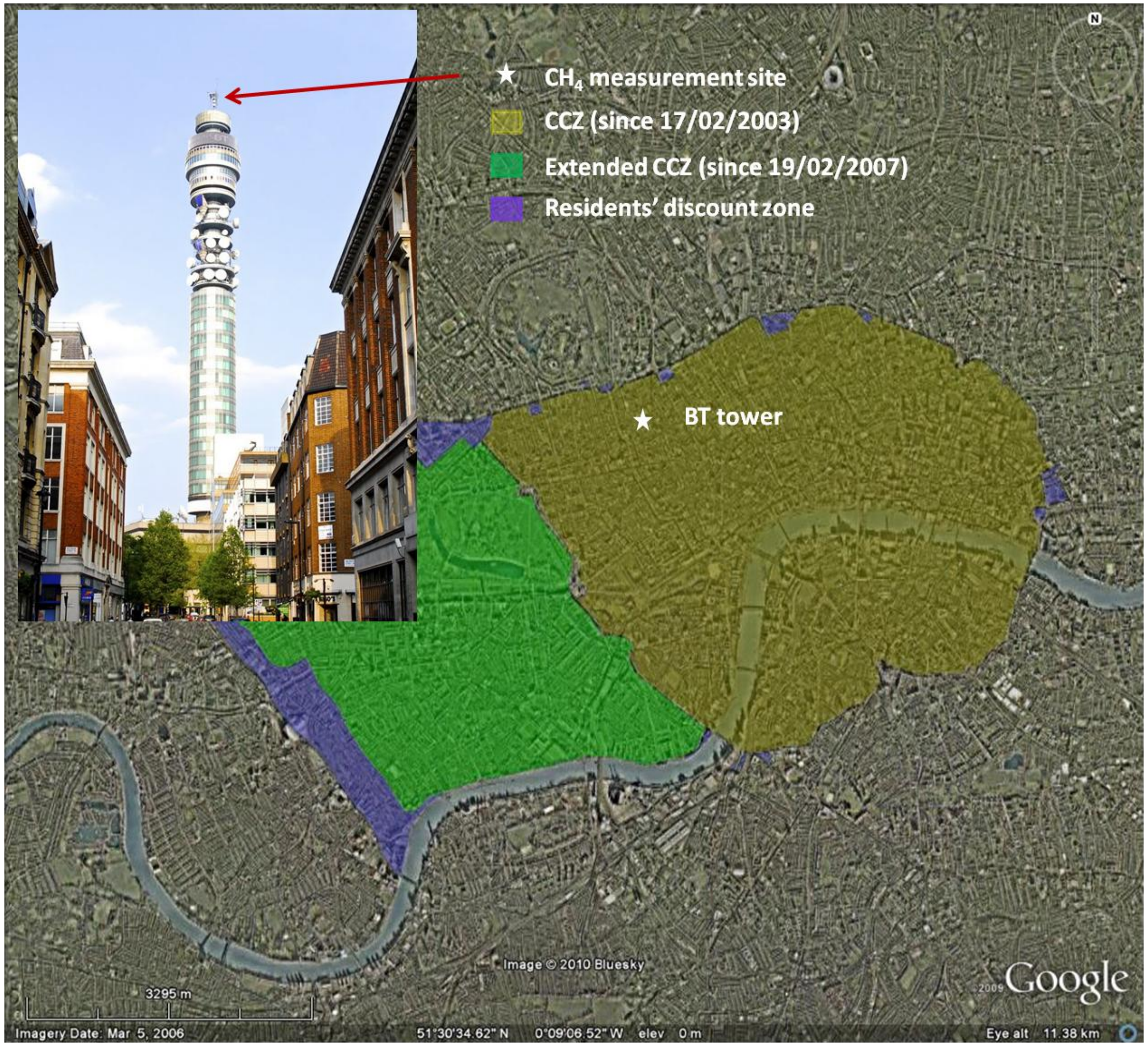
BT Tower – site description



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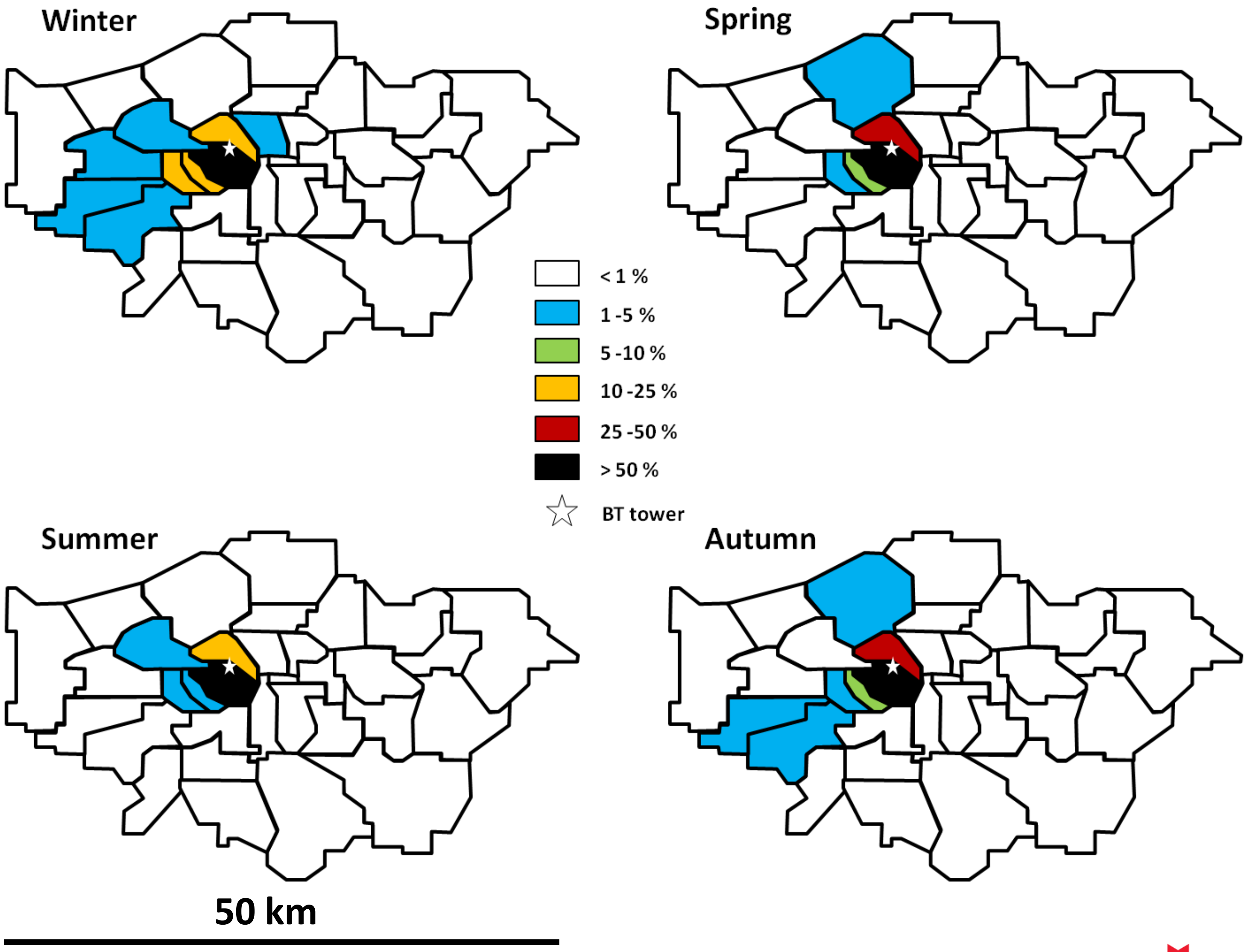
BT tower: flux footprint (2007)



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Footprint model: Kormann and Meixner , Bound.-Lay. Meteorol. (2001)
BT tower footprint: Helfter et al., Atm. Chem. & Phys. (2011)

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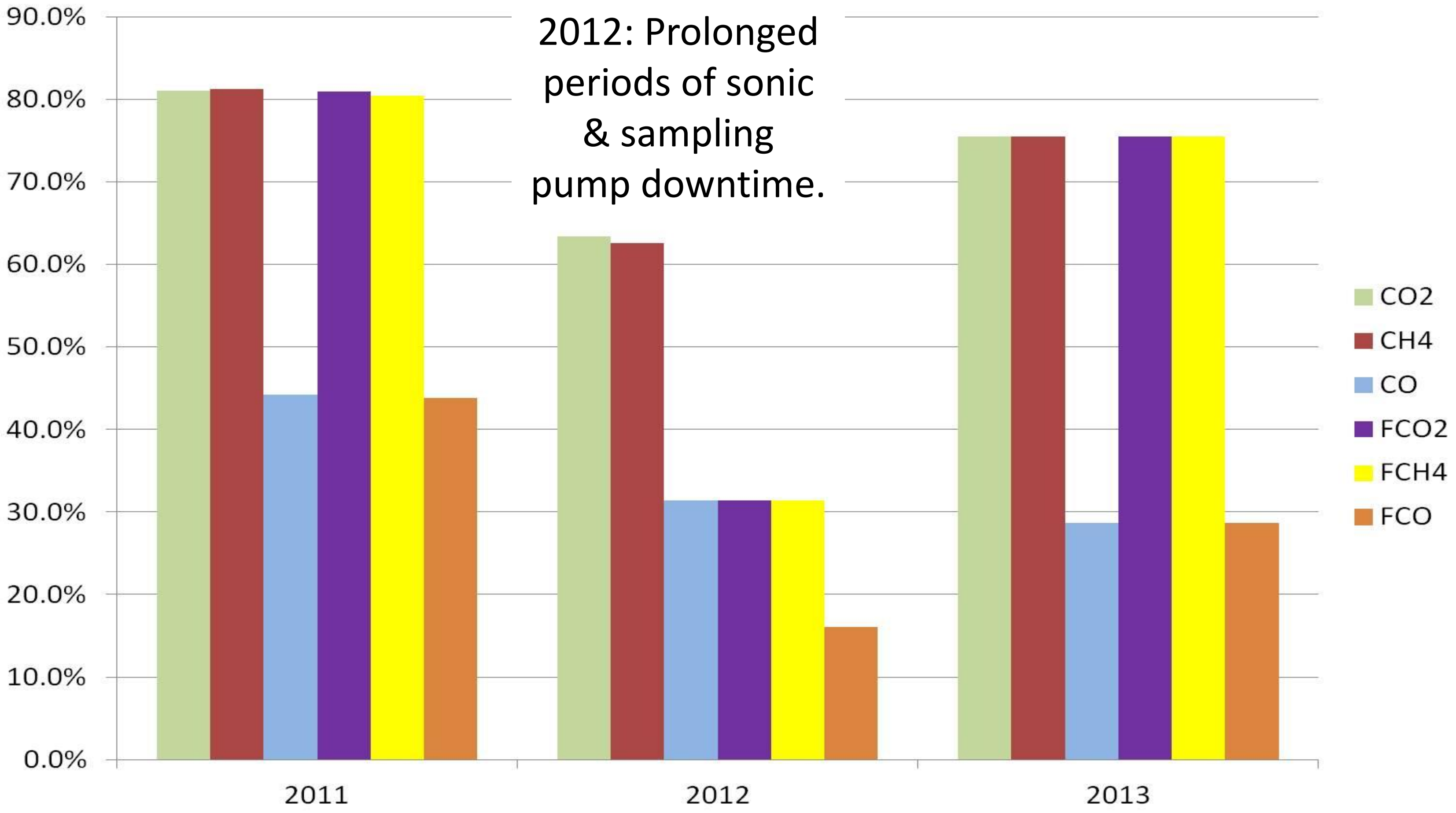
BT Tower – data coverage

Data coverage: 15/09/2011 – 30/06/2013



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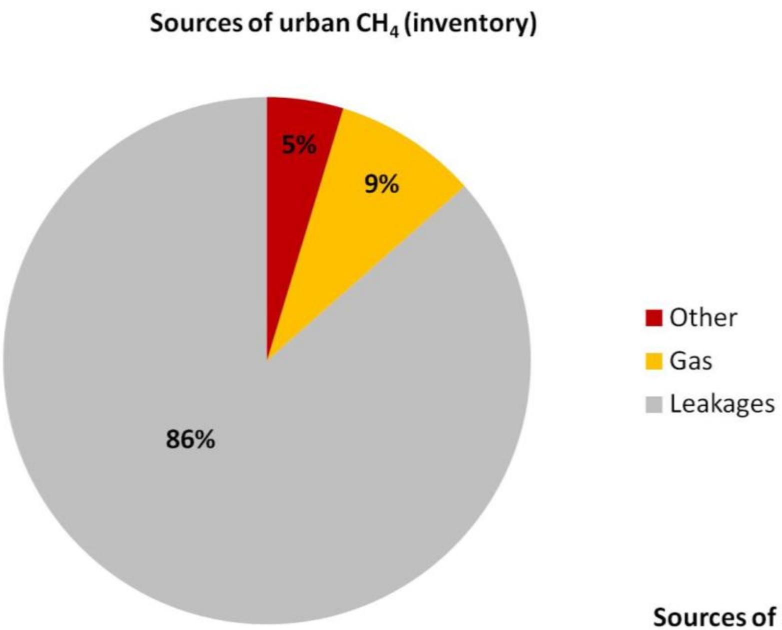
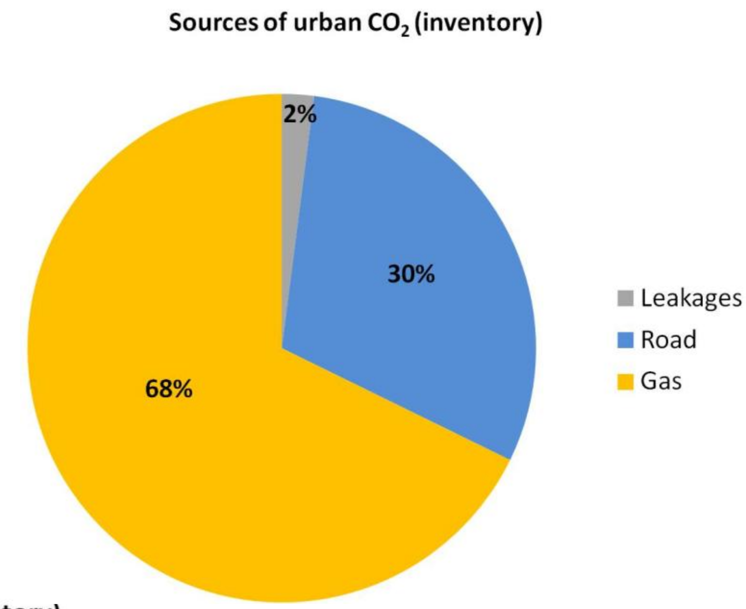
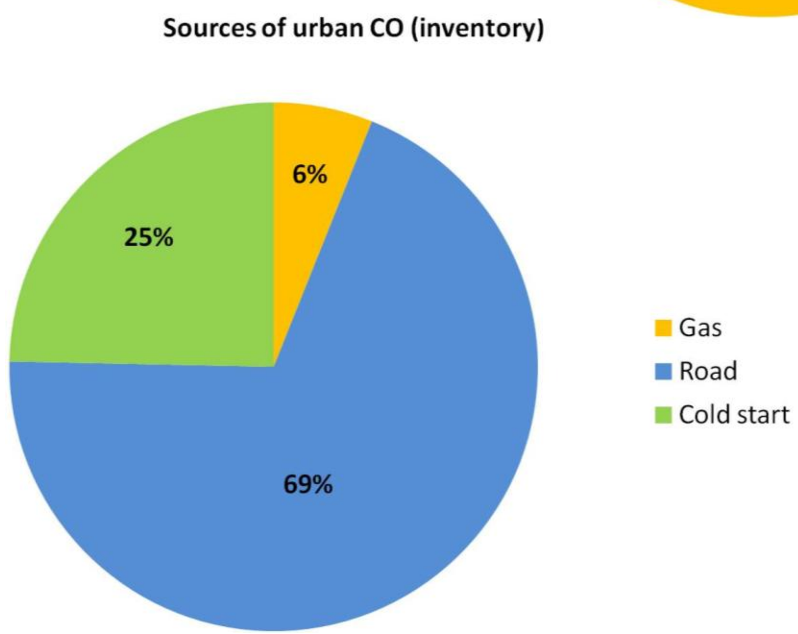
Urban sources (LAEI)







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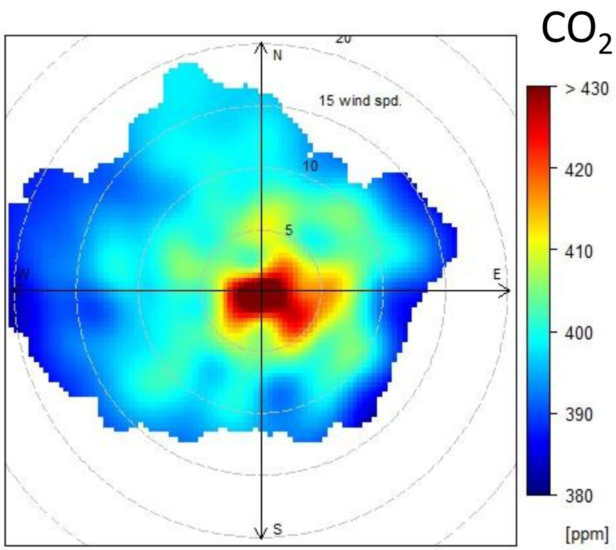
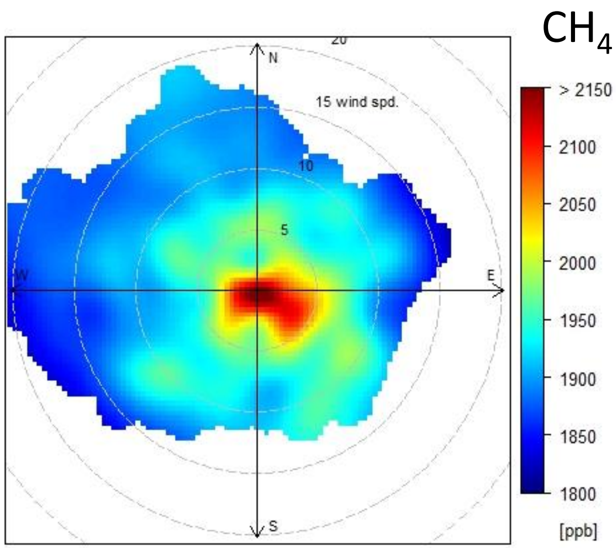
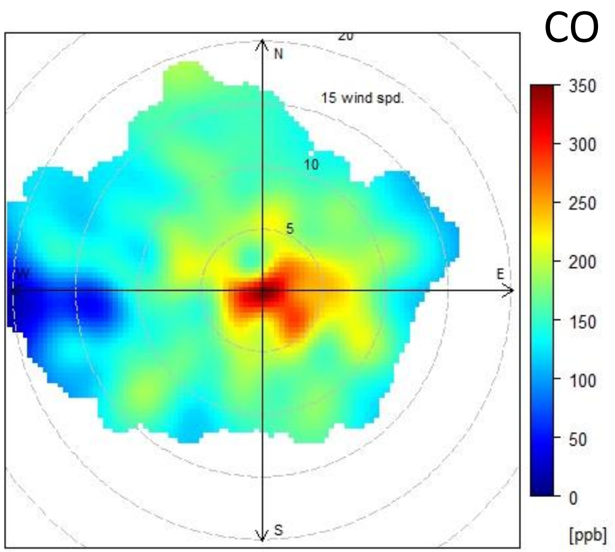
Concentration distribution



Range: 352 – 518 ppm
1st quartile: 391 ppm
3rd quartile: 404 ppm



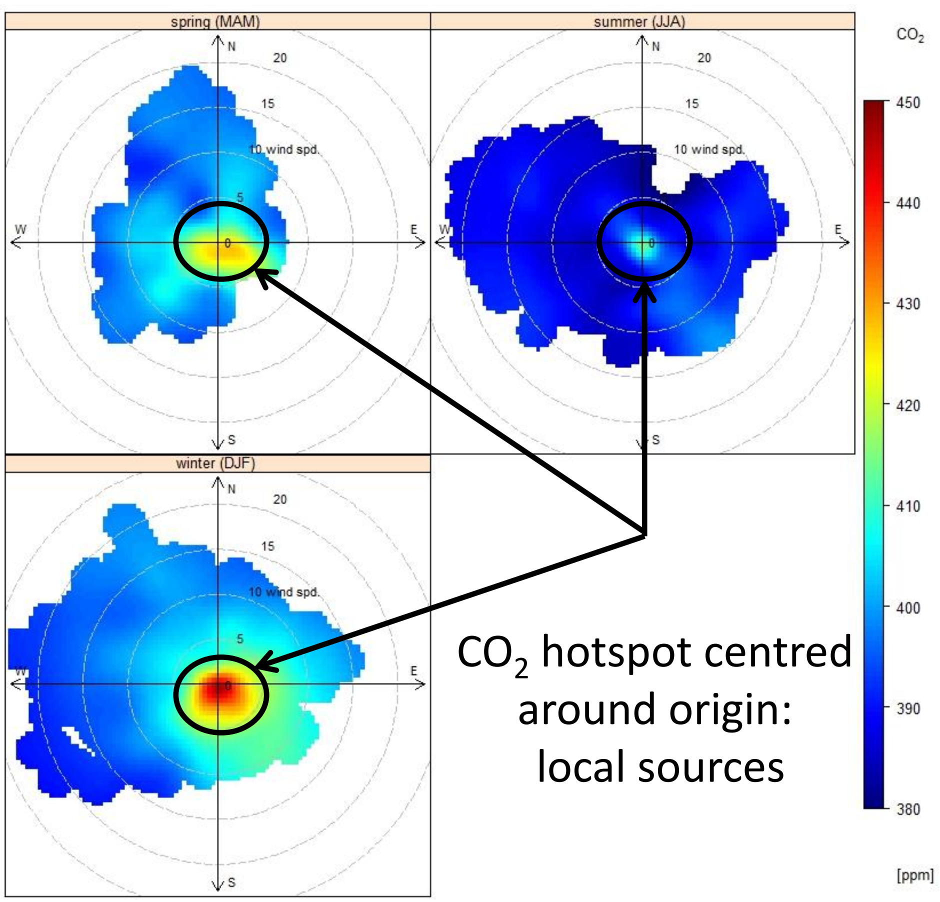
Range: 1811 – 2781 ppb
1st quartile: 1890 ppb
3rd quartile: 1958 ppb

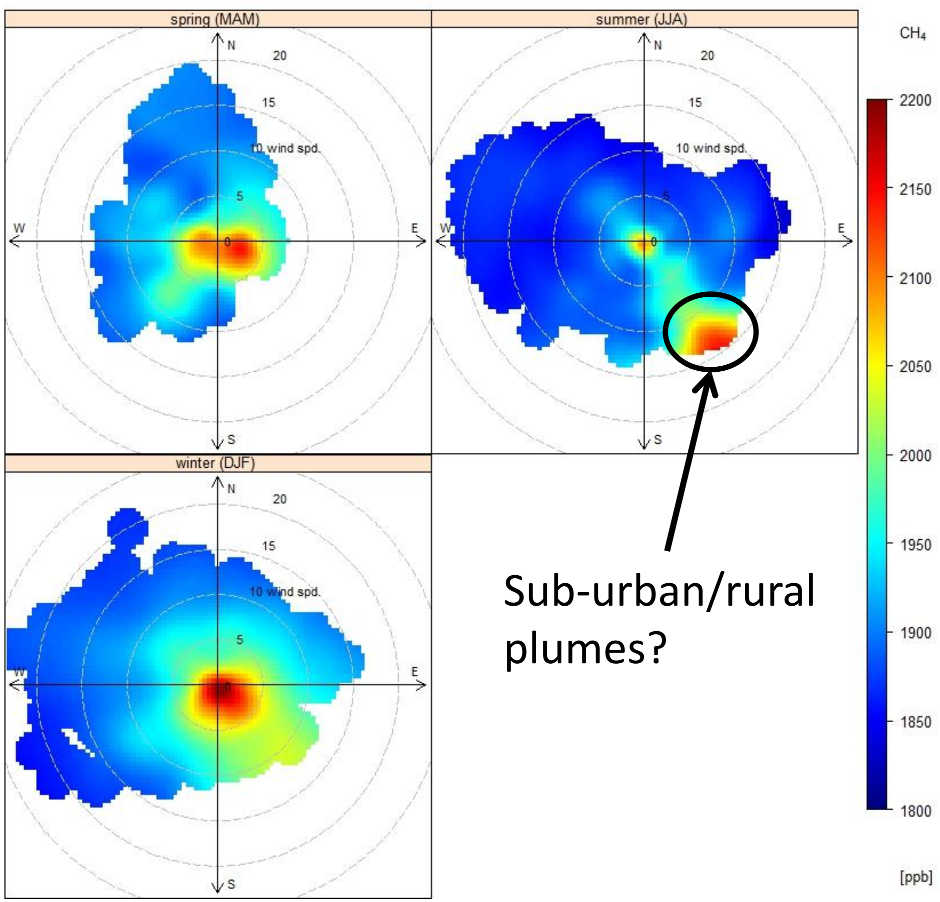


Range: 6 – 721 ppb
1st quartile: 140 ppb
3rd quartile: 205 ppb

- Spatially heterogeneous distributions of all 3 pollutants.
- Distribution of central hotspots consistent among the 3 species.

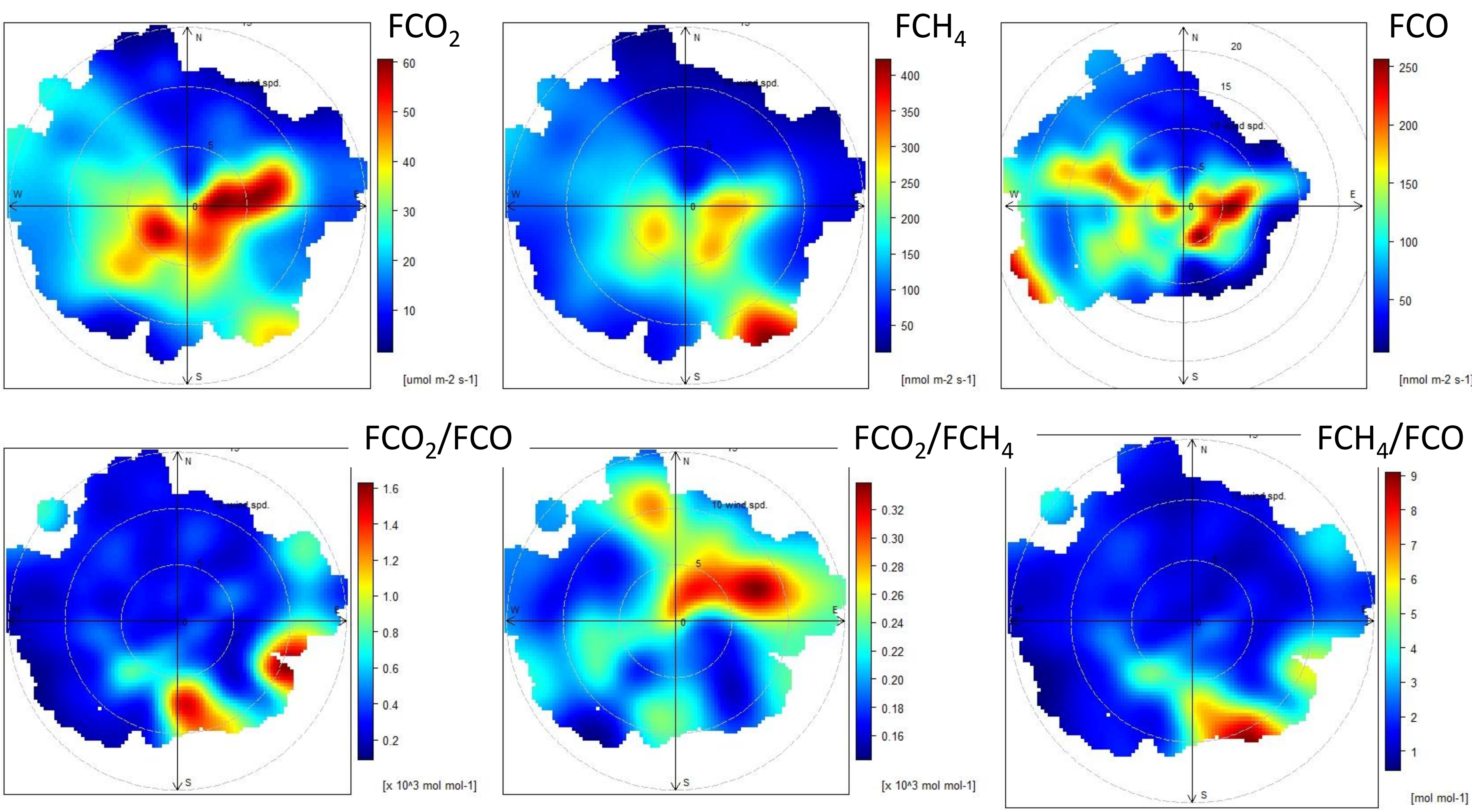
Seasonal distributions





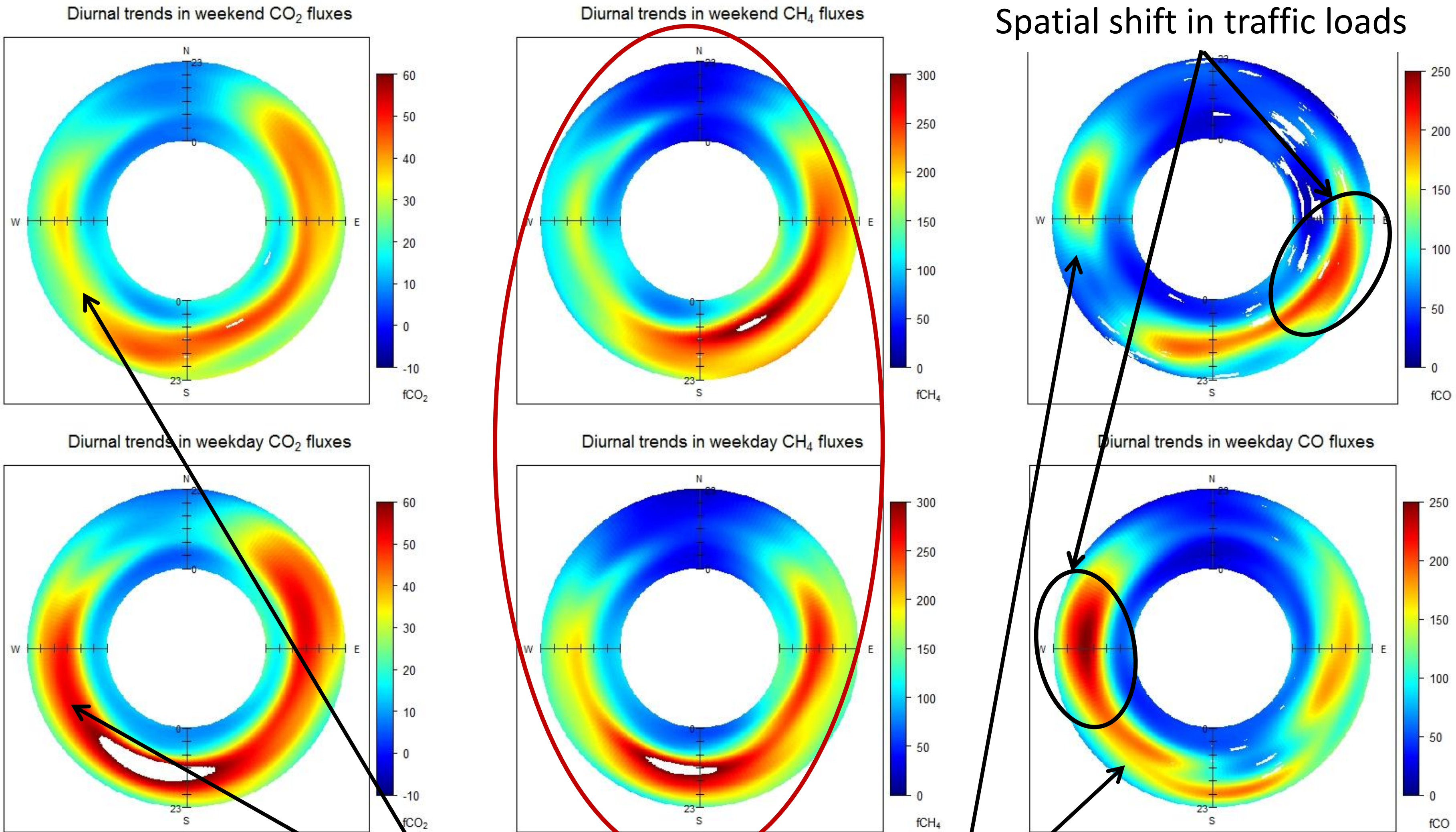
- Concentrations decrease in summer (reduction in traffic, heating, lower background...).
- CO_2 dominated by local sources all year.
- CH_4: possible transport from rural areas in summer.

Flux distributions



- Heterogeneous distributions of all 3 pollutants.
- Comparable range (ratio max/min ~ 6).
- “Excess” CH_4 from S-E (non-traffic source as local minimum for F_{CO} found in S-E).
- N-E: local maximum in FCO_2/FCH_4 due to traffic.

Diurnal trends (weekday & weekend flux)



Methane ~ unchanged

Decrease in magnitude and later start at weekends

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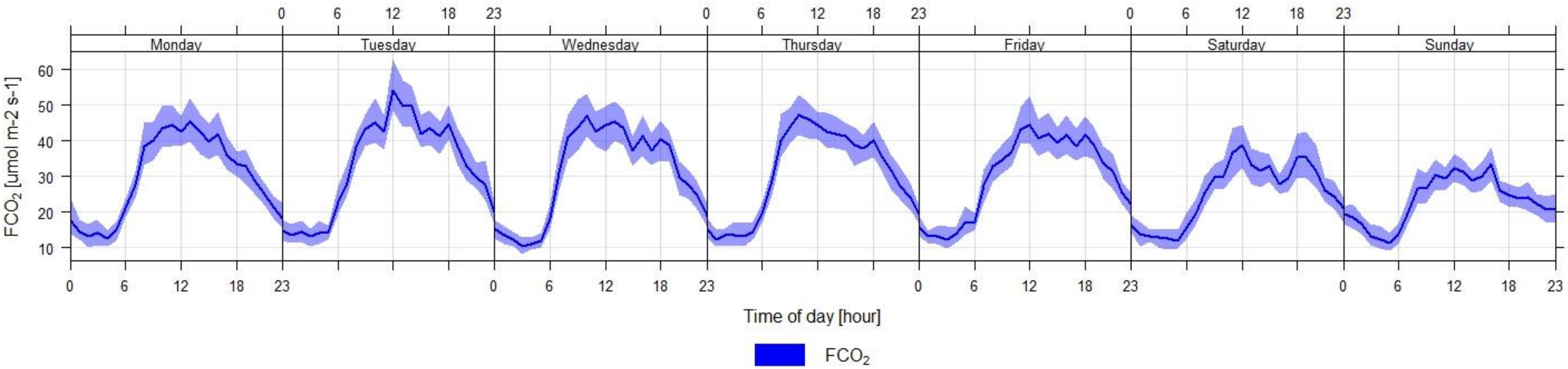
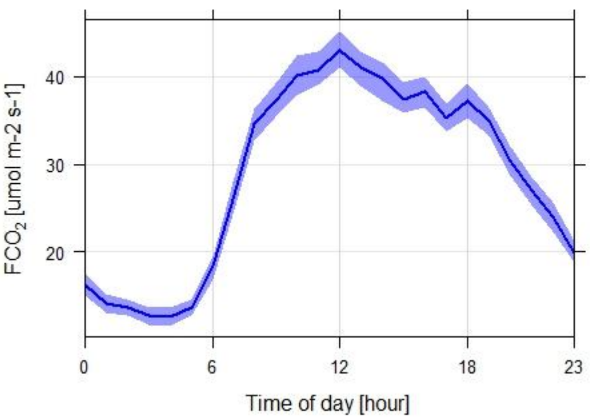
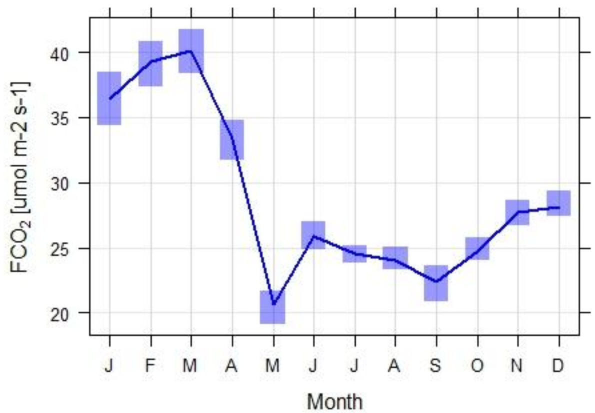
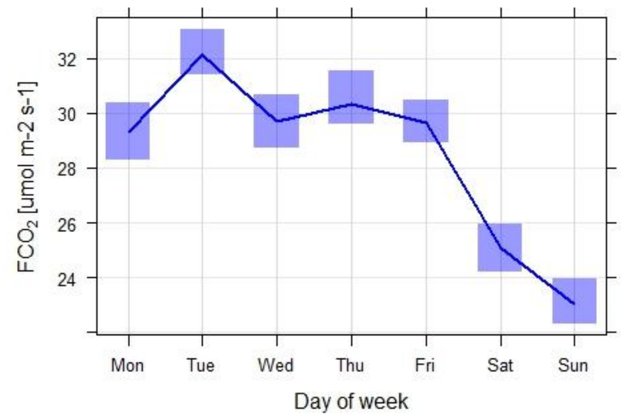
Diurnal & seasonal trends – F_{CO2}

Monday Tuesday Wednesday Thursday Friday Saturday Sunday









- **30% reduction between winter and summer**
- **20% reduction between weekdays and weekends**

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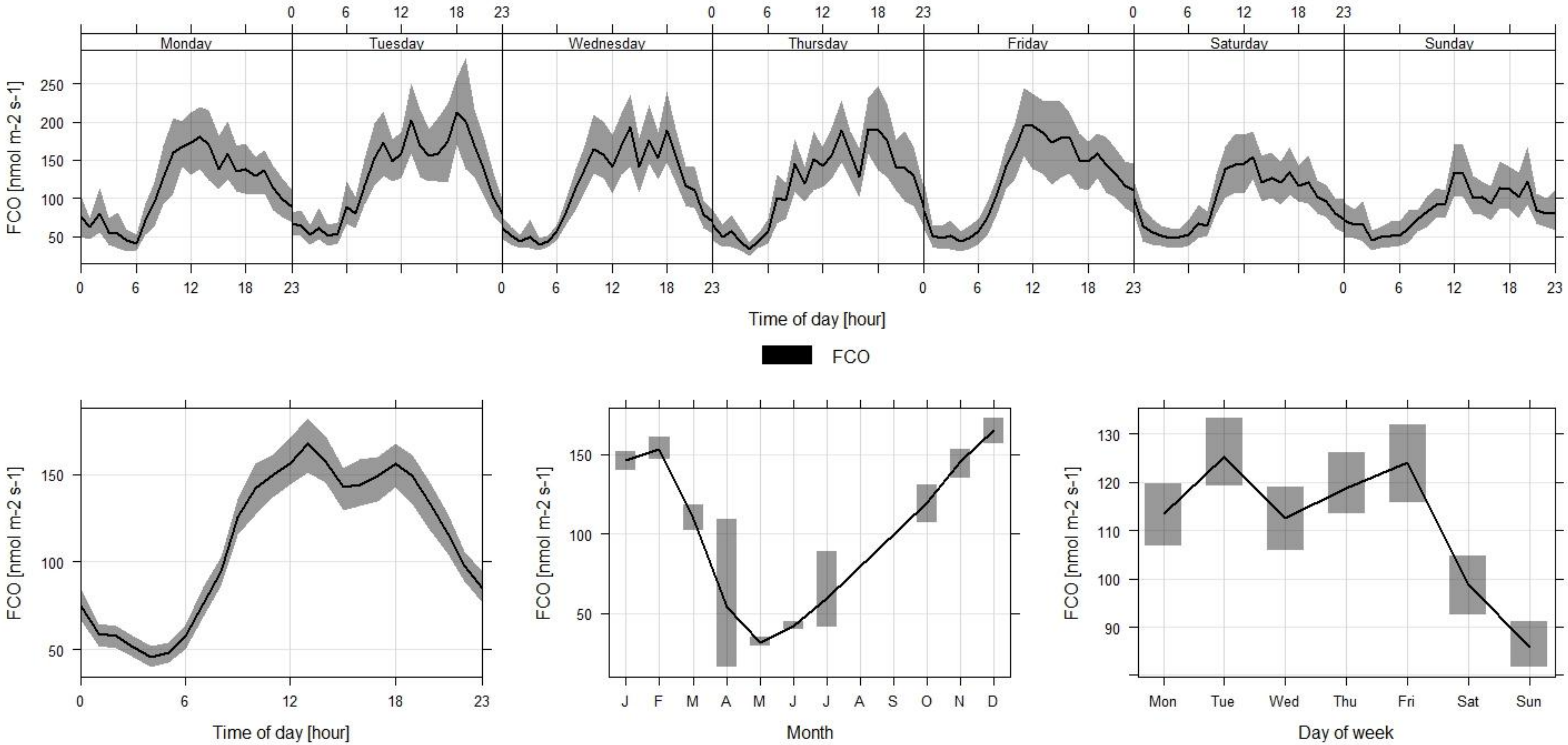
Diurnal & seasonal trends – F_{CO}

Monday Tuesday Wednesday Thursday Friday Saturday Sunday



- **65% reduction between winter and summer**
- **25% reduction between weekdays and weekends**

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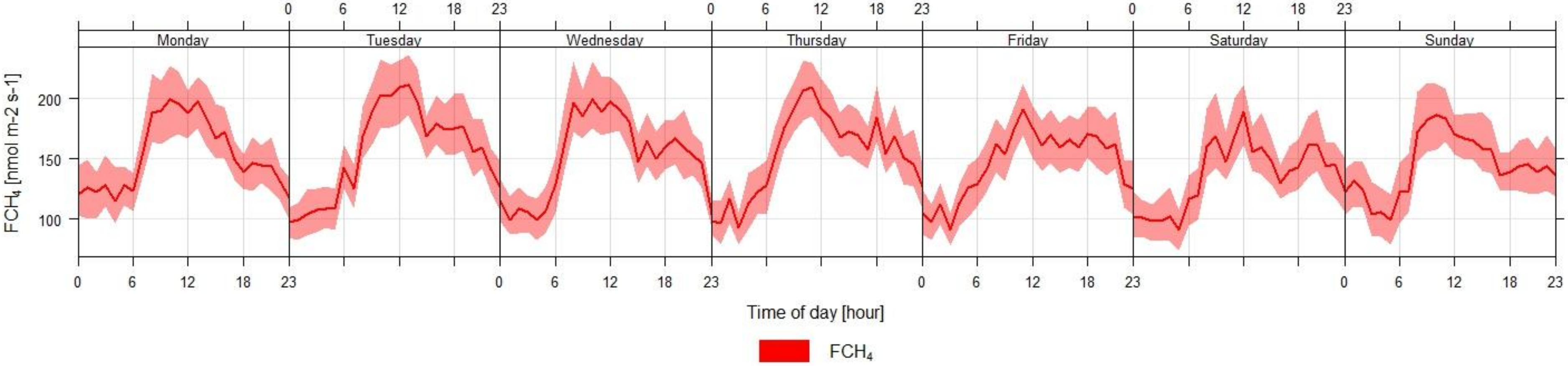
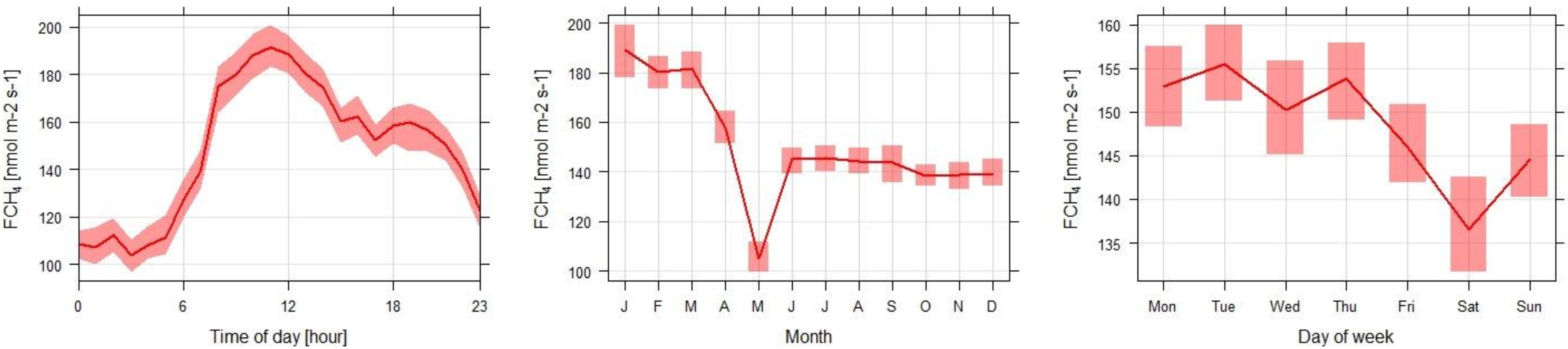
Diurnal & seasonal trends – F_{CH4}

Monday Tuesday Wednesday Thursday Friday Saturday Sunday





- **25% reduction between winter and summer**
- **10% reduction between weekdays and weekends**

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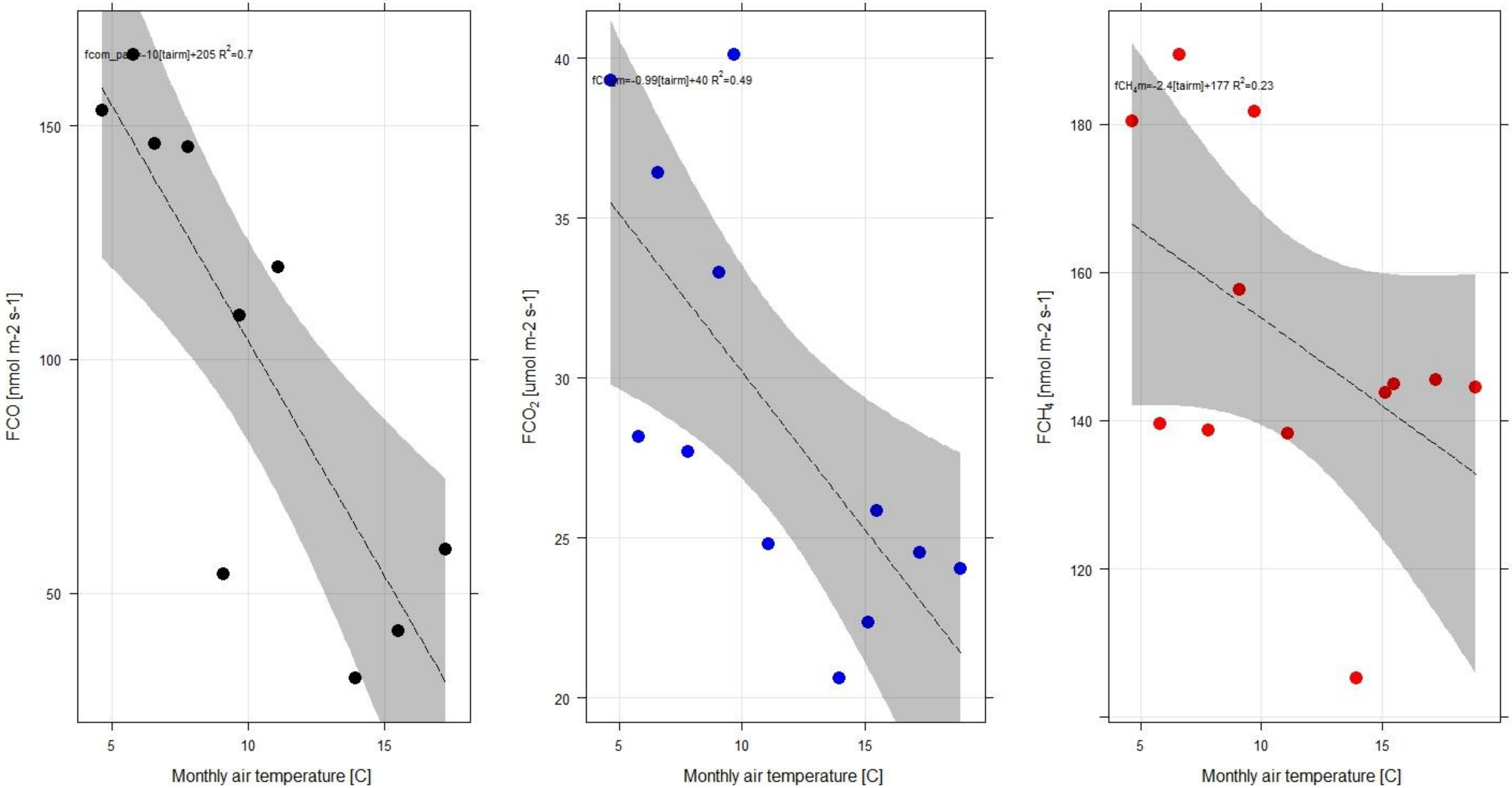
Seasonal trends



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Summary: diurnal and seasonal trends

- Fluxes of CO and CO_2 reduced by ca. 20% at weekends, -10% for FCH_4.
  - Lower traffic volumes at weekends.
  - Reduced commercial natural gas consumption at weekends.
- Winter-to-summer reduction of mean emissions (FCO: - 65%; FCO_2: -30%; FCH_4: < -25%).
  - Reduction in natural gas consumption (FCO, FCO_2, FCH_4).
  - Seasonal variations in traffic loads (FCO, FCO_2, FCH_4).
  - Air temperature: no cold starts in summer (FCO).

Inventories attribute 86% of FCH_4 to fugitive gas (constant leakage rate?), and 9% to gas consumption; 60% increase in FCH_4 measured during the day.

Question: Why do we see a diurnal trend in CH_4 emissions despite a constant pressure in the distribution network?

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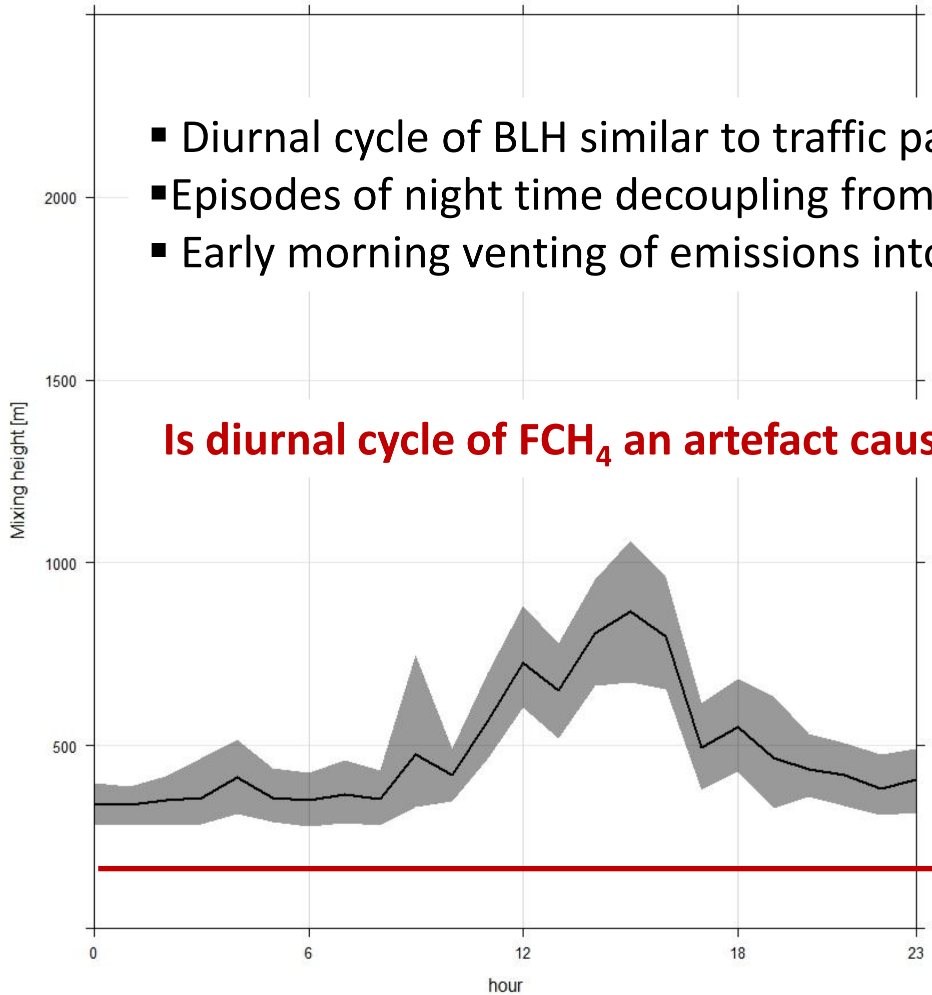
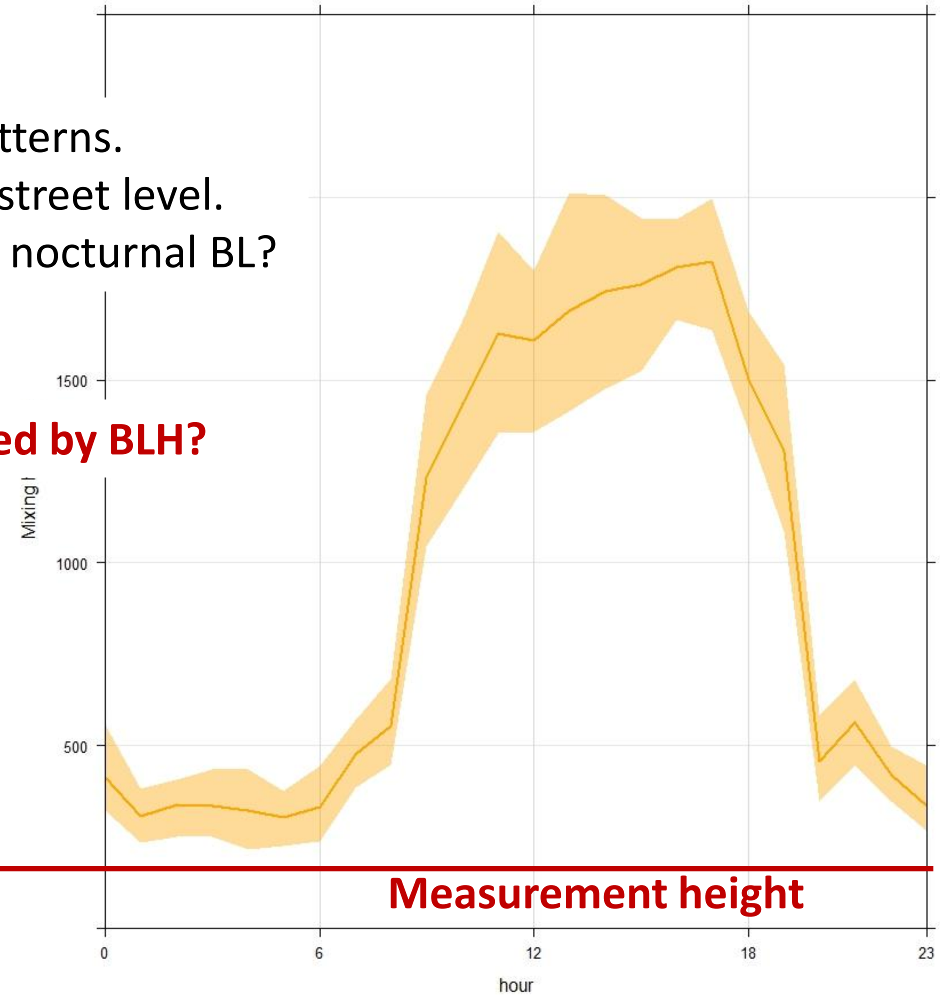
Boundary layer height

Winter 2012



Summer 2012



- Diurnal cycle of BLH similar to traffic patterns.
- Episodes of night time decoupling from street level.
- Early morning venting of emissions into nocturnal BL?

Is diurnal cycle of FCH_4 an artefact caused by BLH?

Measurement height

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LIDAR work: Barlow et al. (2014), Environ. Fluid Mech.

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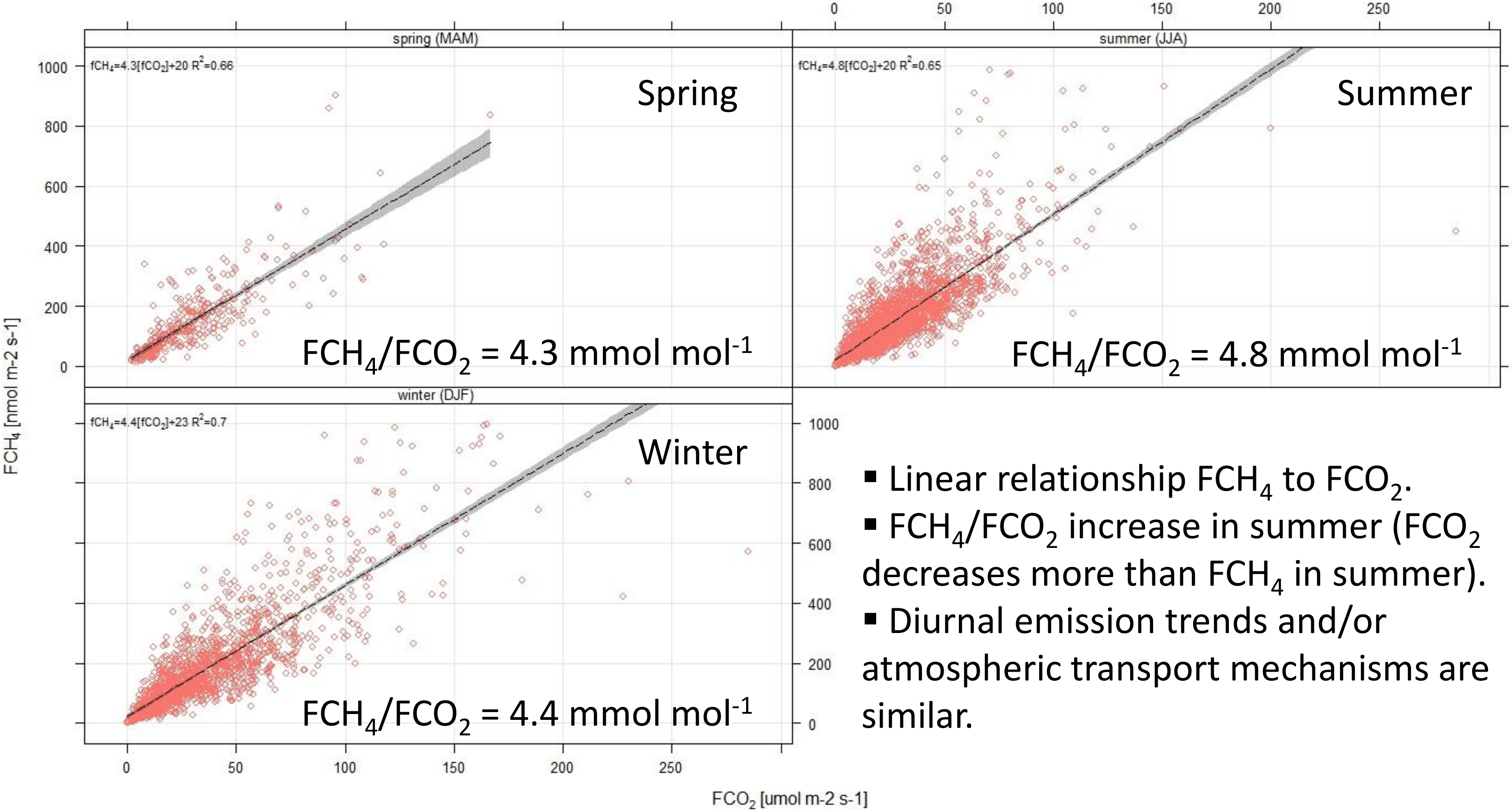
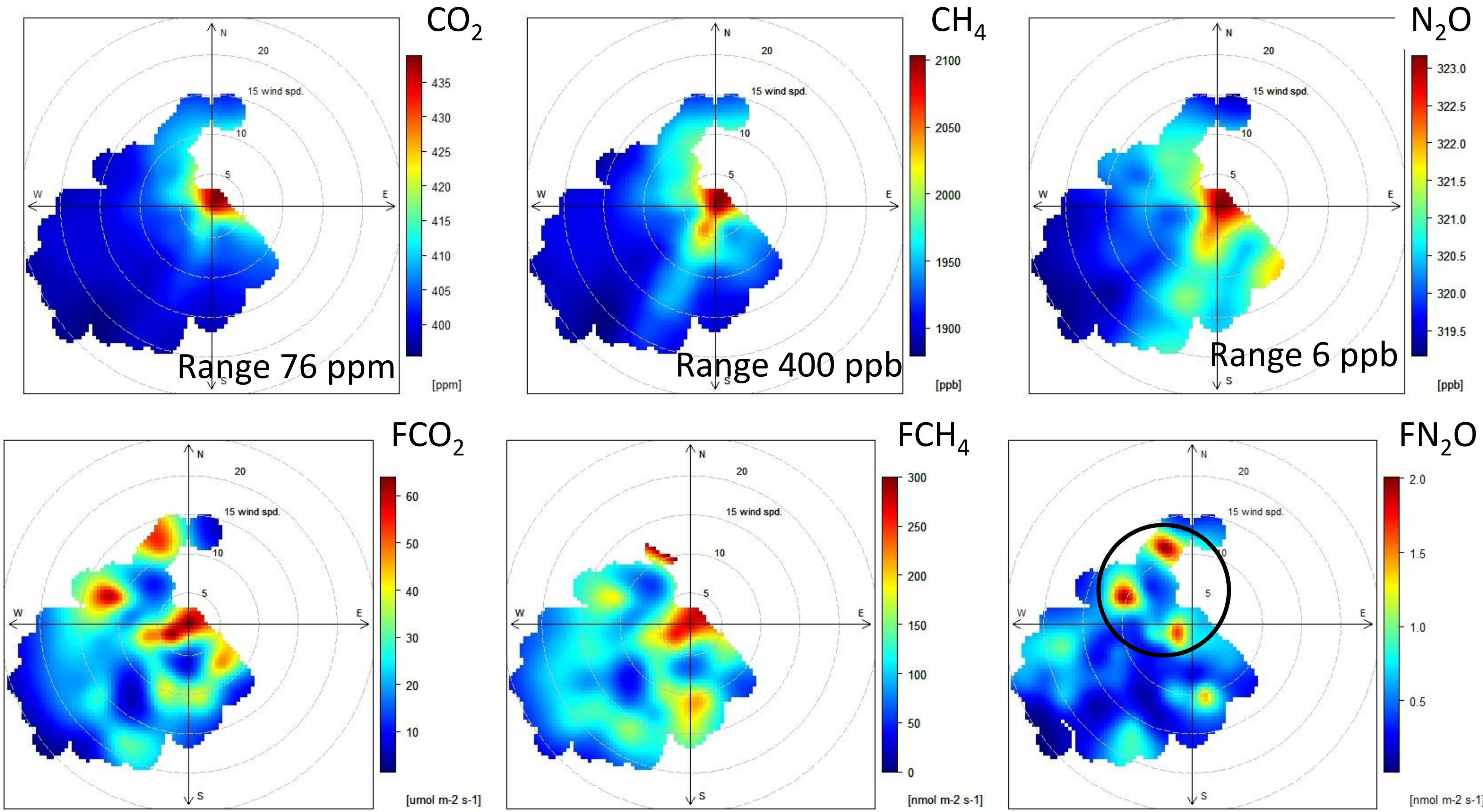
Diurnal & seasonal trends – Emission factors



- Linear relationship FCH_4 to FCO_2.
- FCH_4/FCO_2 increase in summer (FCO_2 decreases more than FCH_4 in summer).
- Diurnal emission trends and/or atmospheric transport mechanisms are similar.

CO_2, CH_4 and N_2O: winter 2014



FN_2O hotspots more localised but consistent with FCO_2 & FCH_4.

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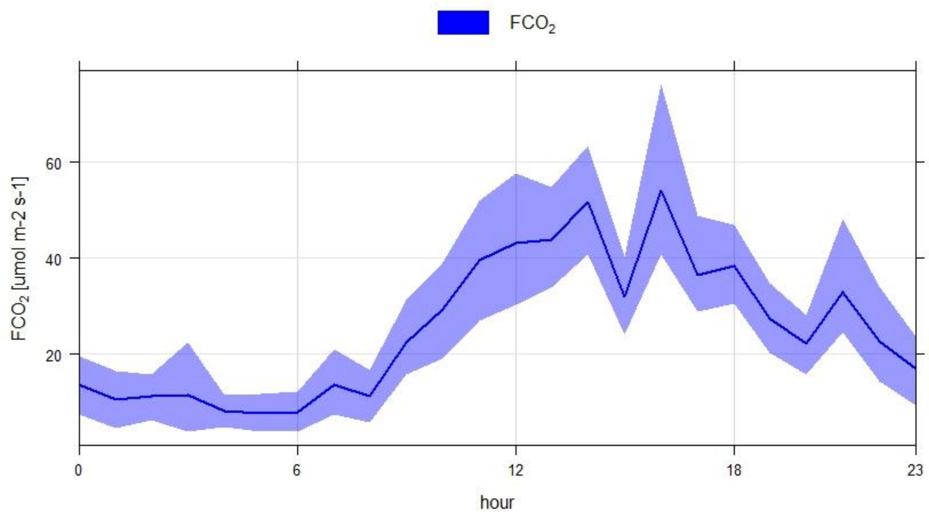
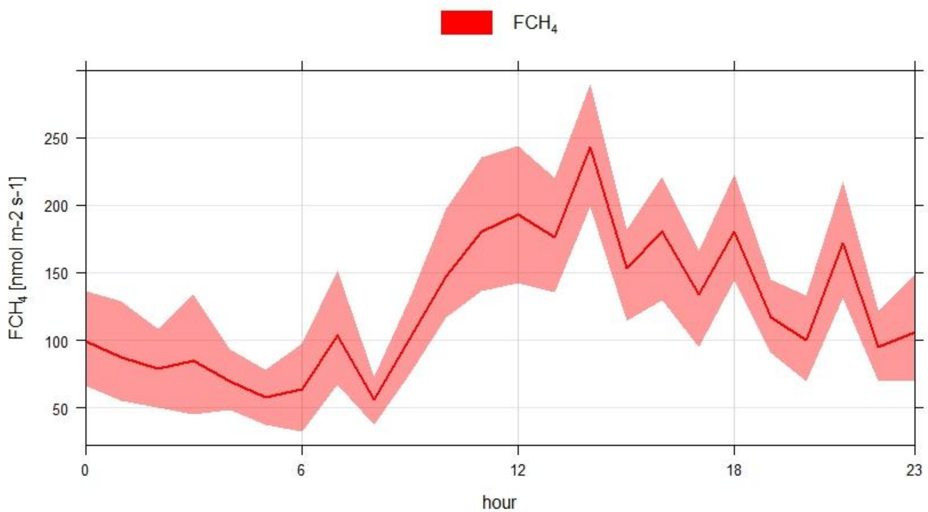
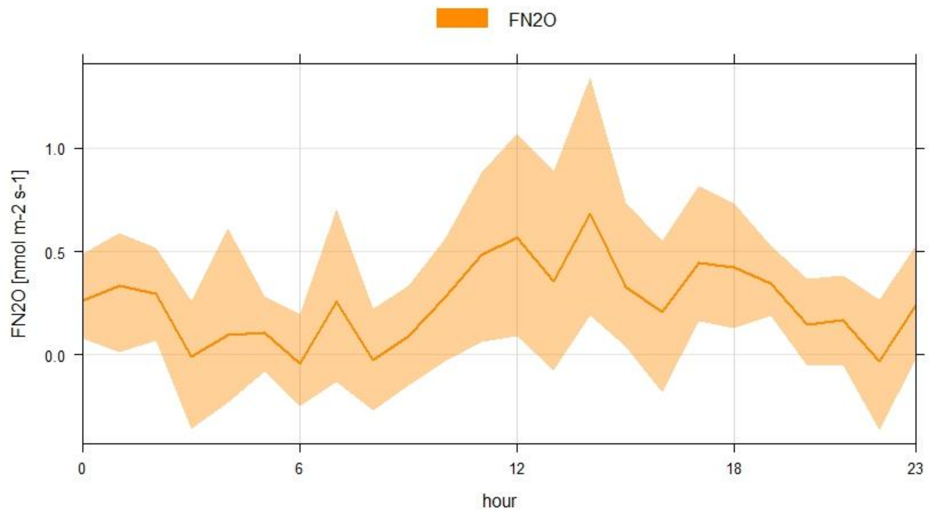
CO_2, CH_4 and N_2O: winter 2014







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CW-QCL detection limit ~ 10^{-2} nmol m^{-2} s^{-1}
Rannik et al., Biogeosciences Discussions (2014)

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BT tower – annual GHG budgets

	CO_2 [tons km^{-2}]	CH_4 [tons km^{-2}]	CO [tons km^{-2}]	N_2O [tons km^{-2}]
Measured at BT tower[1]	41000	75 (**CO_2e 1875**)	156	0.36 (**CO_2e 107**)
Westminster (LAEI) [2]	46000	34	145	0.42
London aircraft measurements (July 2012) [3]	29000	66	106	
London (Autumn 2007 & 2008) [4]			150 to 220	

mol mol^{-1}	CH_4/CO_2	N_2O/CO_2	N_2O/CH_4	CO/CO_2
BT tower measurements	$4.5\ 10^{-3}$	$1.1\ 10^{-5}$	$3.0\ 10^{-3}$	$2.0\ 10^{-3}$
LAEI	$2.1\ 10^{-3}$	$9.2\ 10^{-6}$	$4.3\ 10^{-3}$	$1.9\ 10^{-3}$

[1]Measured 2012 data (February 2014 for N_2O)
[2] London Atmospheric Emissions Inventory (LAEI), 2012 data
[3]O'Shea et al. (2014), Journal of Geophysical Research
[4]Harrison (2012), Atmospheric Chemistry and Physics

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Summary

- Dynamic system exhibiting temporal and spatial patterns.
- Annual budgets for the FCO_2, FCO & FN_2O gas in reasonable agreement with atmospheric inventory. Measured FCH_4 is 2x larger than inventory value.
- Atmospheric transport probably contributes to diurnal trends of all gas species. However, agreement between inventory and measured FCO_2, FCO & FN_2O suggests that there is no systematic loss of flux (advection, storage).
- Effects of (potentially spurious) diurnal trends minimised by integration over longer time periods (daily and beyond).
- Is atmospheric inventory underestimating a source of CH_4? Issue with spatial attribution of CH_4 sources?