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Was auch noch zu Buche schlägt - Wetter, Zusatzverbraucher, Fahrverhalten,_…

Jean-Yves Favez

Abteilung Verbrennungsmotoren
Eidg. Materialprüfungs- und Forschungsanstalt Empa
8600 Dübendorf (CH)

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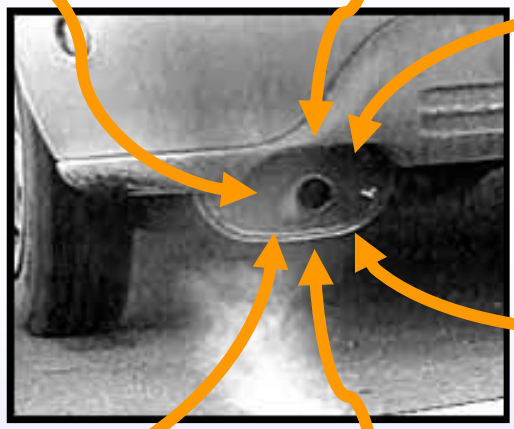
Emissions are a function of:

Vehicle
model
state *engine, cat., tyre,...*
payload *outside/inside*
add. load *air condition*

Street type
slope - winding
urban – rural - highway

Fuel



Traffic situation
Traffic jam
column
clear

Driving behaviour

Driving style
aggressive
normal
slow

Using behaviour
who many times
trip length
stop time

Climate
Temperature
Humidity

Contents of the presentation

Street type
slope - winding
urban – rural - highway

Vehicle
model
state *engine, cat.,* *tyre,...*
payload *outside/inside*
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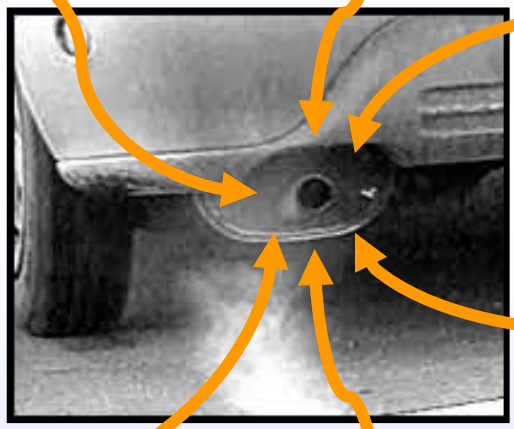
Fuel



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Contents

1. Cold start emission at low ambient temperature
   - Catalyst and engine (model and state)
   - Climate (ambient temperature)
   - Using behaviour (trip length)
2. Cold start emission as a function of stop time
   - Catalyst and engine (model and state)
   - Using behaviour (stop time)
3. Fuel consumption and emissions linked to air condition activity
   - Climate (ambient temperature and humidity)

Cold start extra emissions

Illustration by means of a repetitive cycle: IUFC15

IUFC cycle:

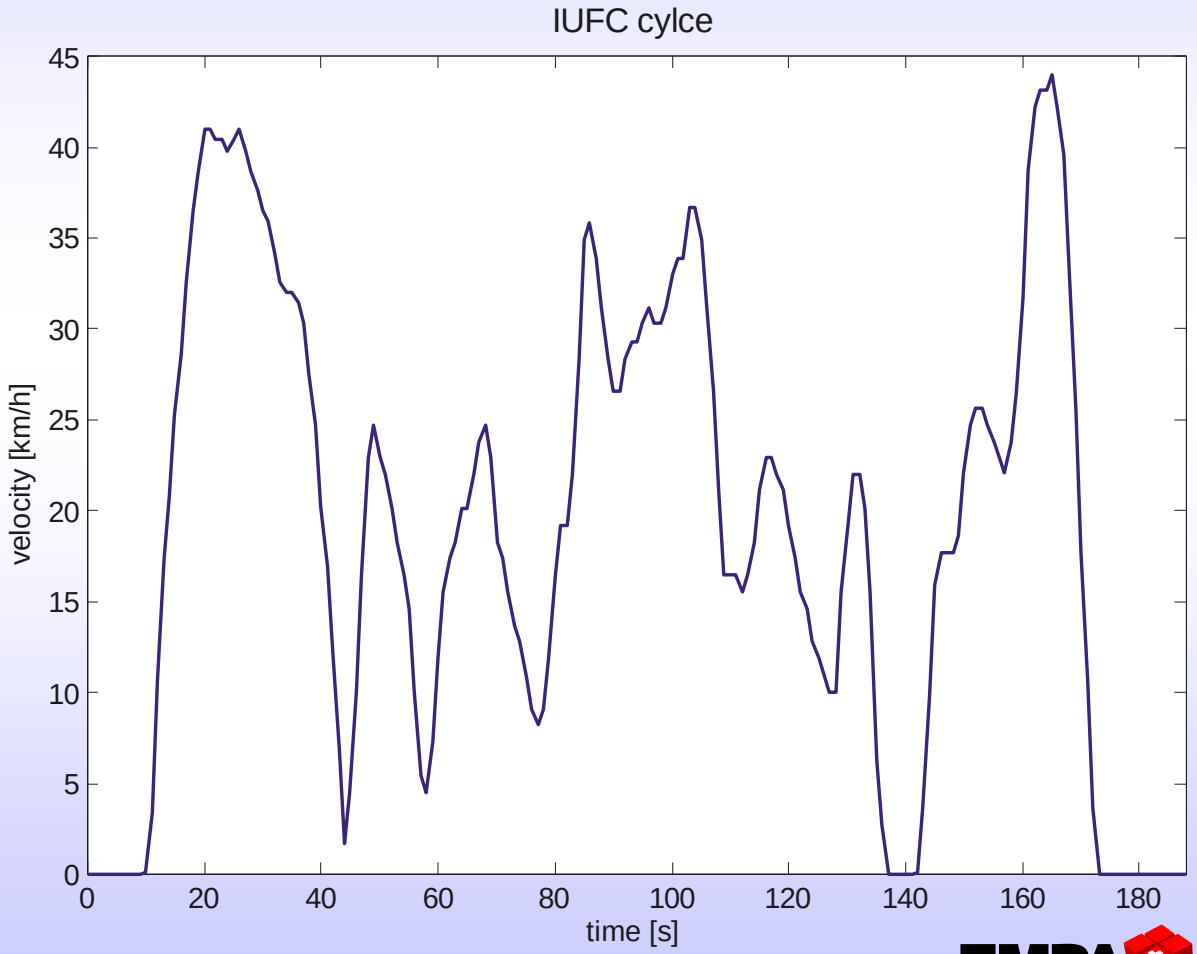
Duration: 189 [s]

Length: 1 [km]

IUFC15 cycle:

Repetition of

15 IUFC subcycles



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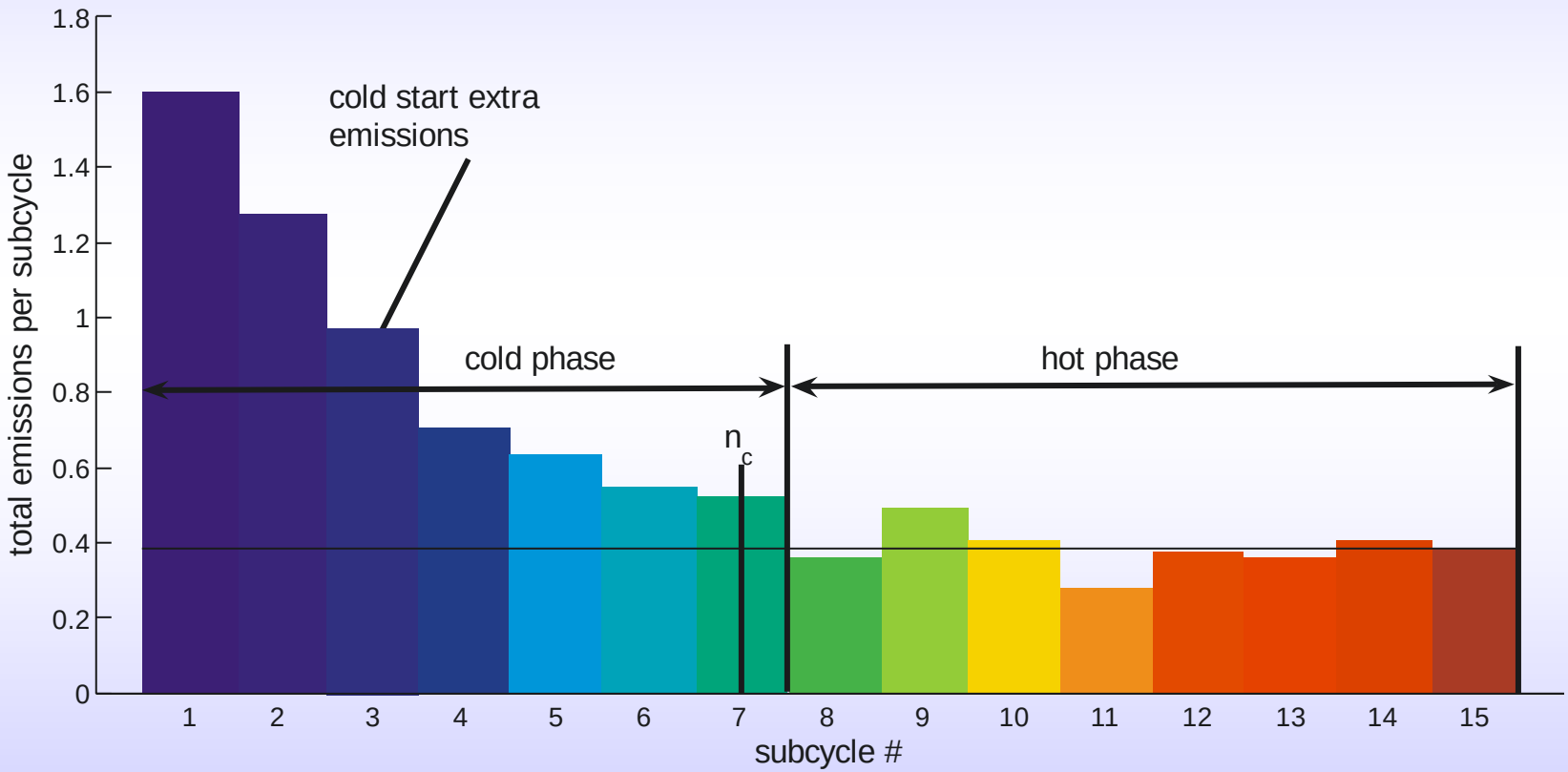
Subcycle emissions



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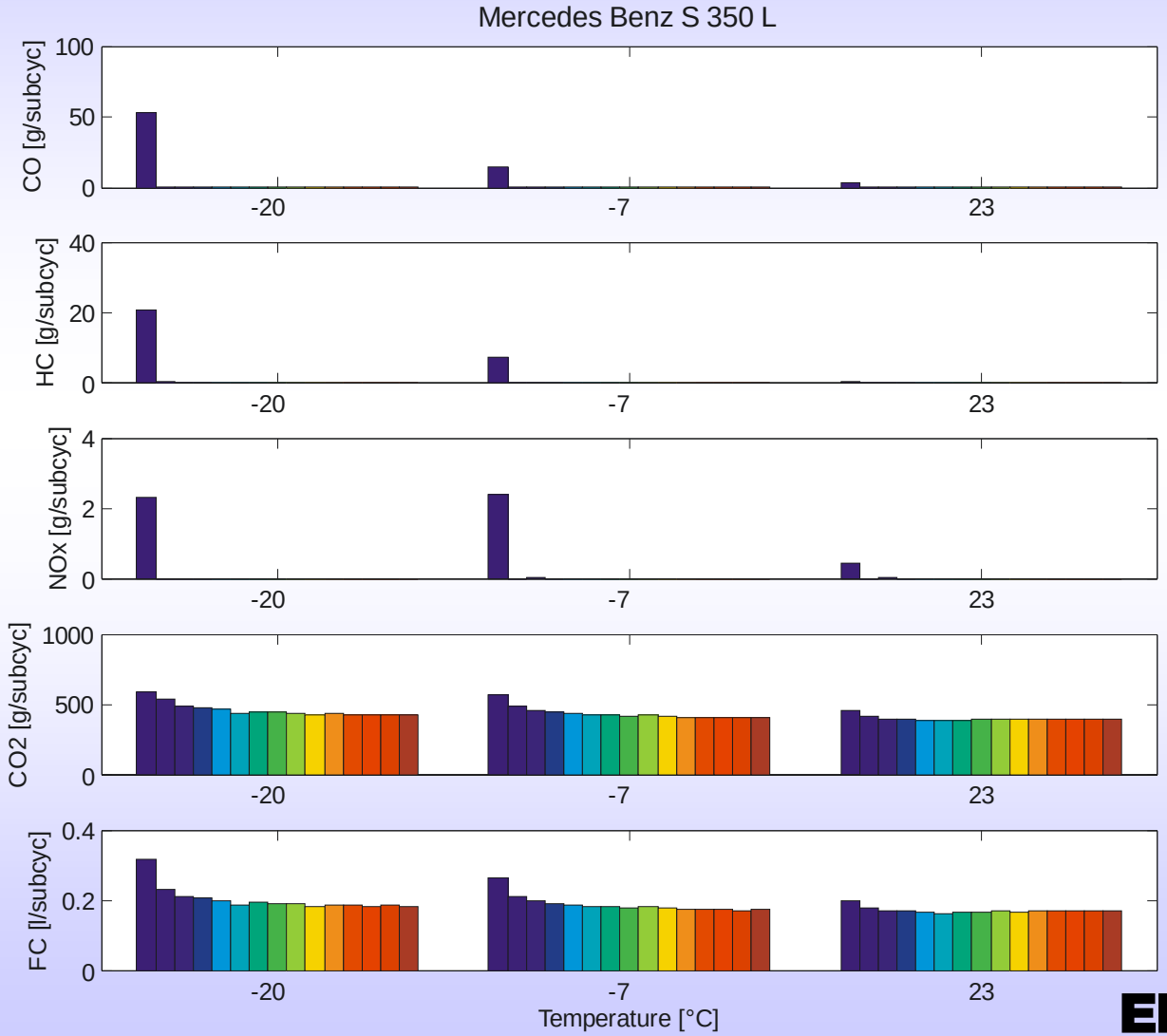
Emissions as a function of **ambient temperature** (Euro-4, IUFC15)



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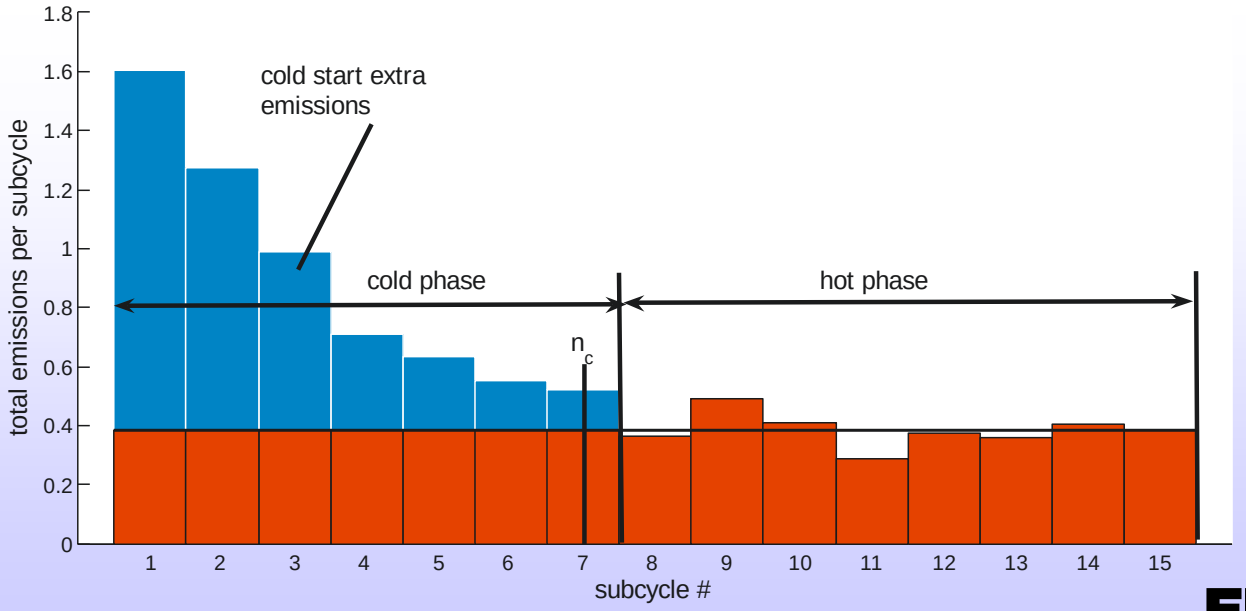
Cold start extra emission estimation method

Subcycle analysis method

- For repetitive cycles, e.g. IUFC15 →15 x IUFC (subcycles)
- When online (continuous) acquisition is available
- $$EE_{cold} = E_{cyc} - E_{hot} = \sum_{i=1}^{15} E(i) - 15 \cdot \frac{1}{15 - n_c} \sum_{i=n_c+1}^{15} E(i)$$



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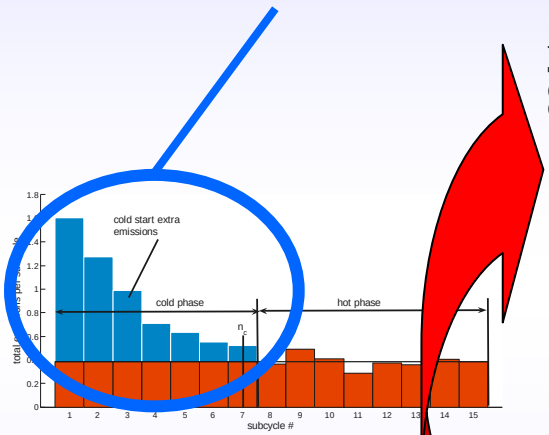
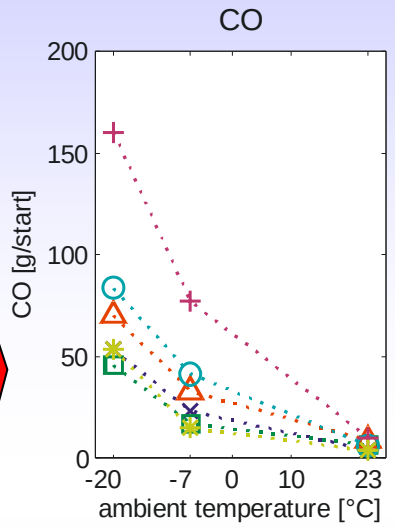
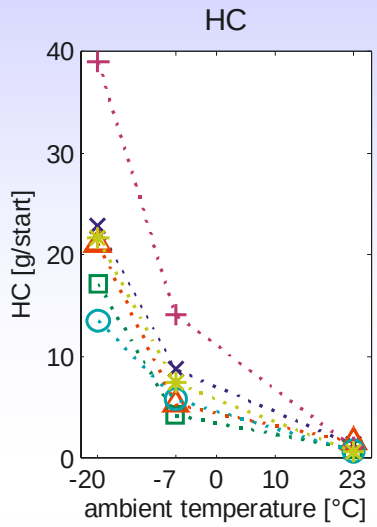
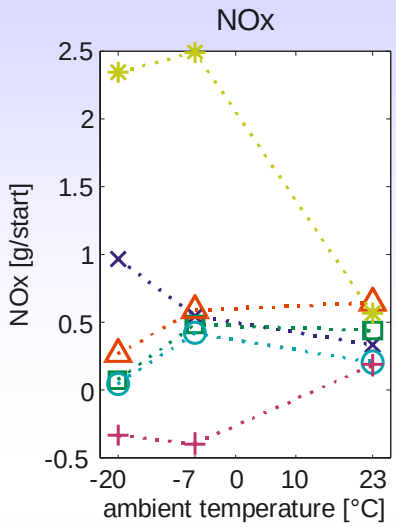
Cold start extra emission

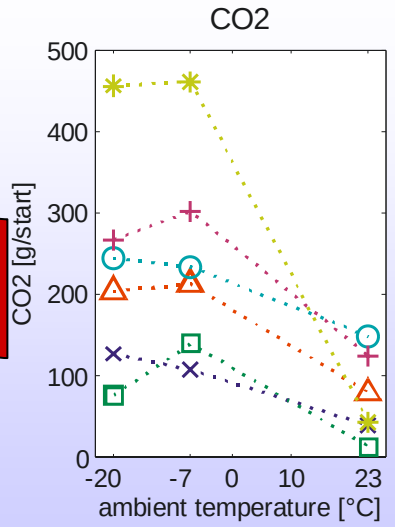
Cold start extra emission in [g/start]

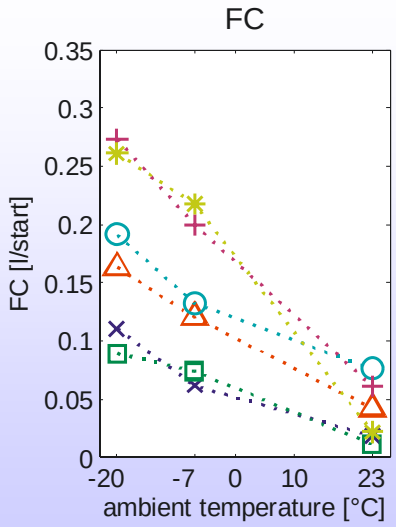












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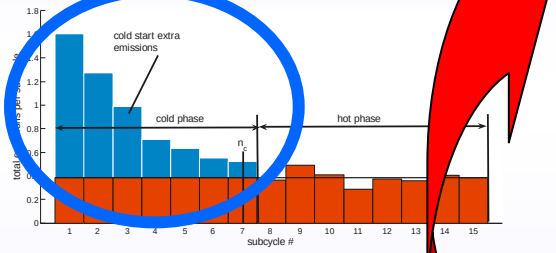
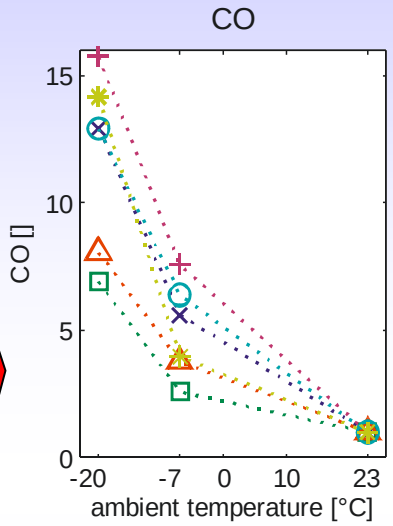
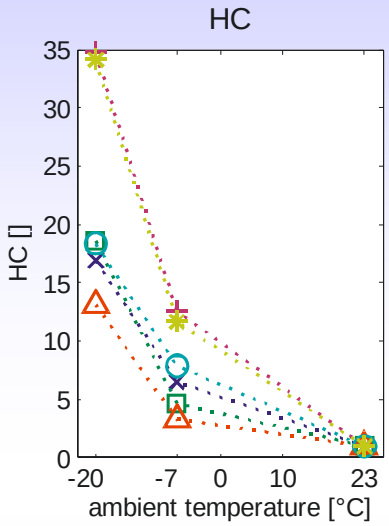
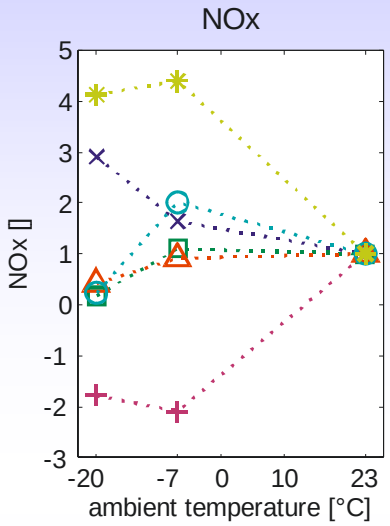
Cold start extra emission (normalised @ 23°C)

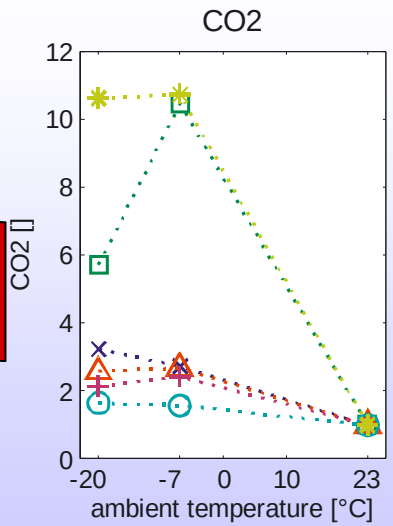
Cold start extra emission in [g/start]

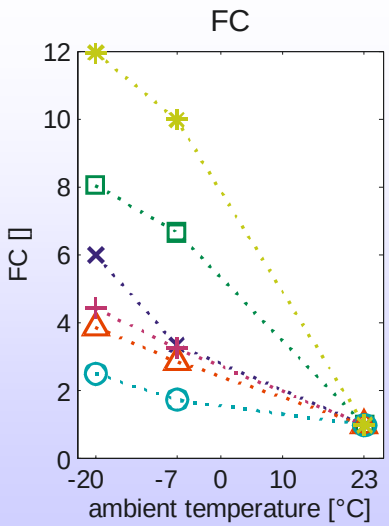












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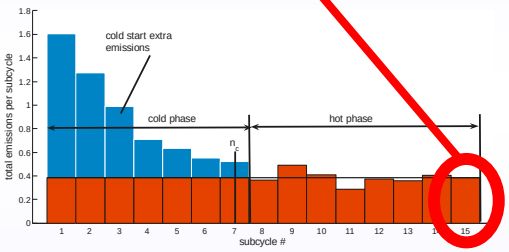
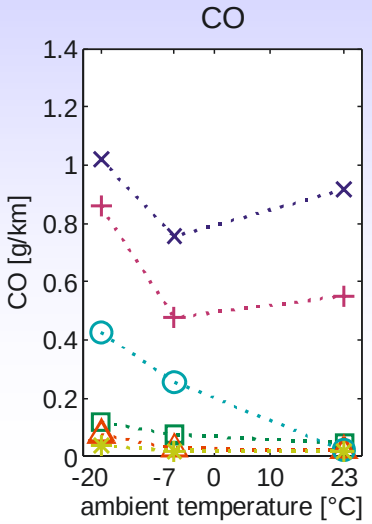
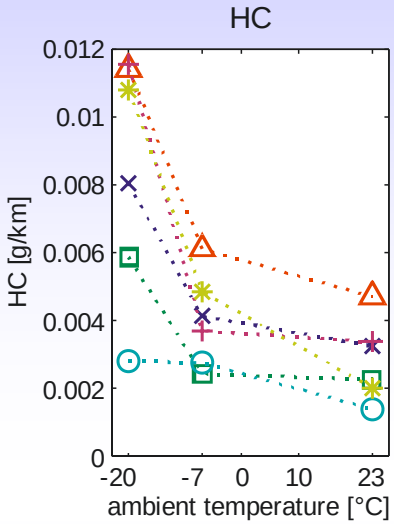
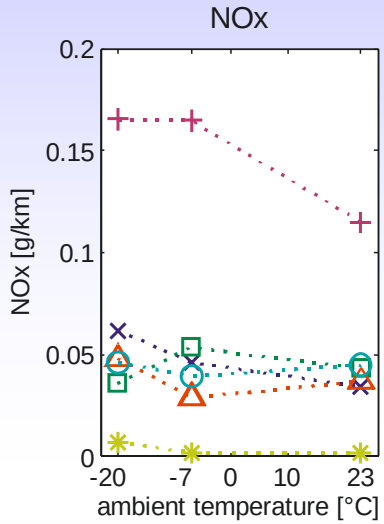
Hot phase emission

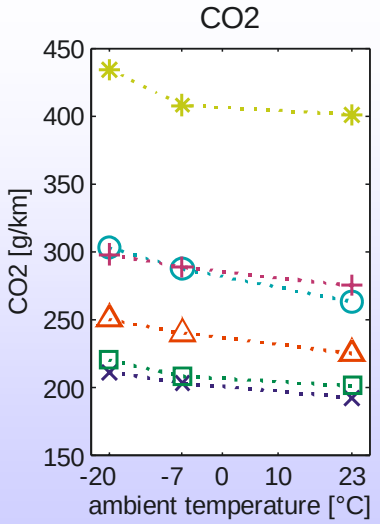
Hot phase emission in [g/km]

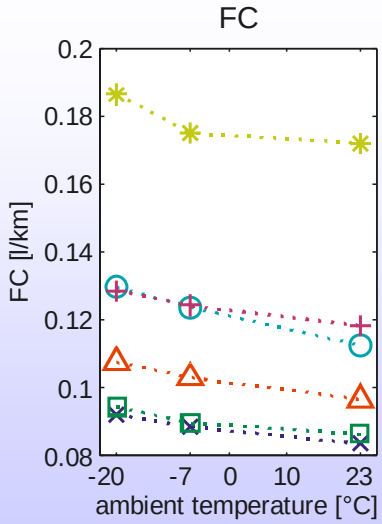












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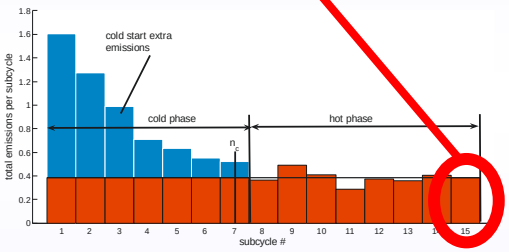
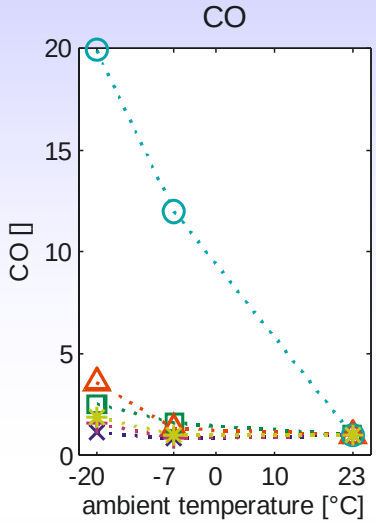
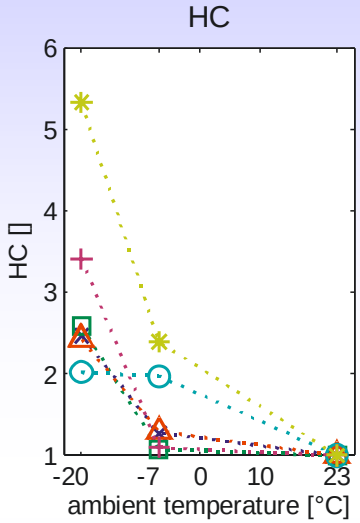
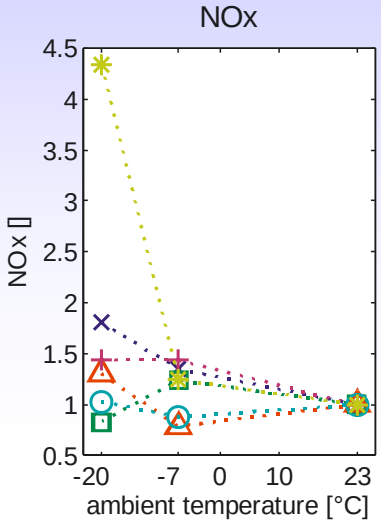
Hot phase emission (normalised @ 23°C)

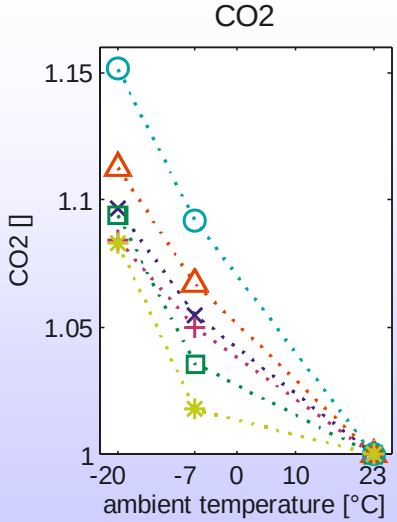
Hot phase emission in [g/km]

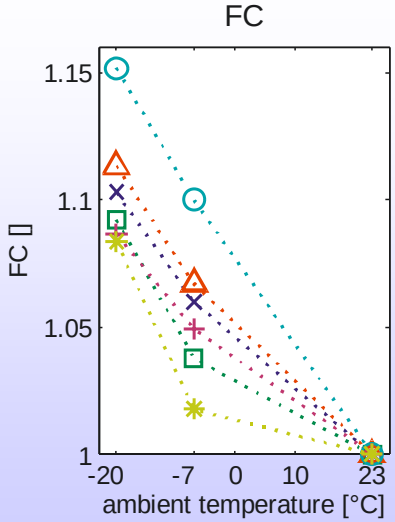












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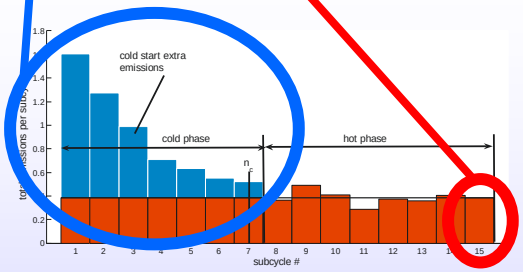
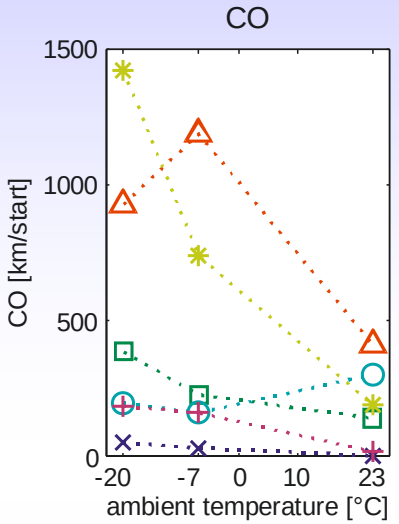
Cold start equivalent driving distance

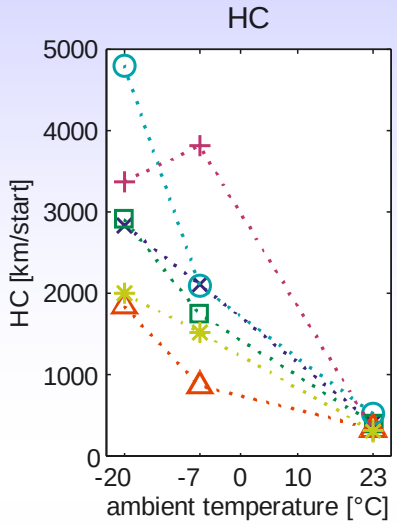
Cold start [g/start]

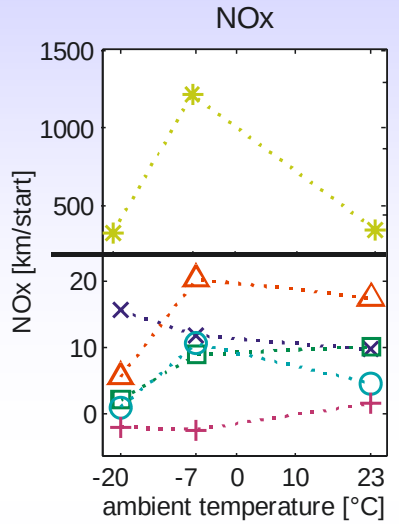
Hot phase [g/km]

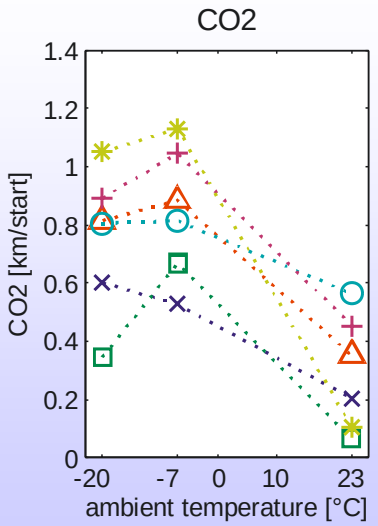
[km / start]

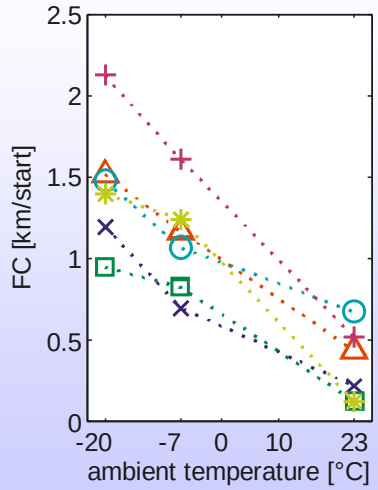


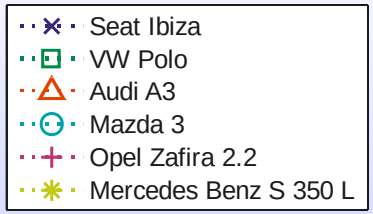












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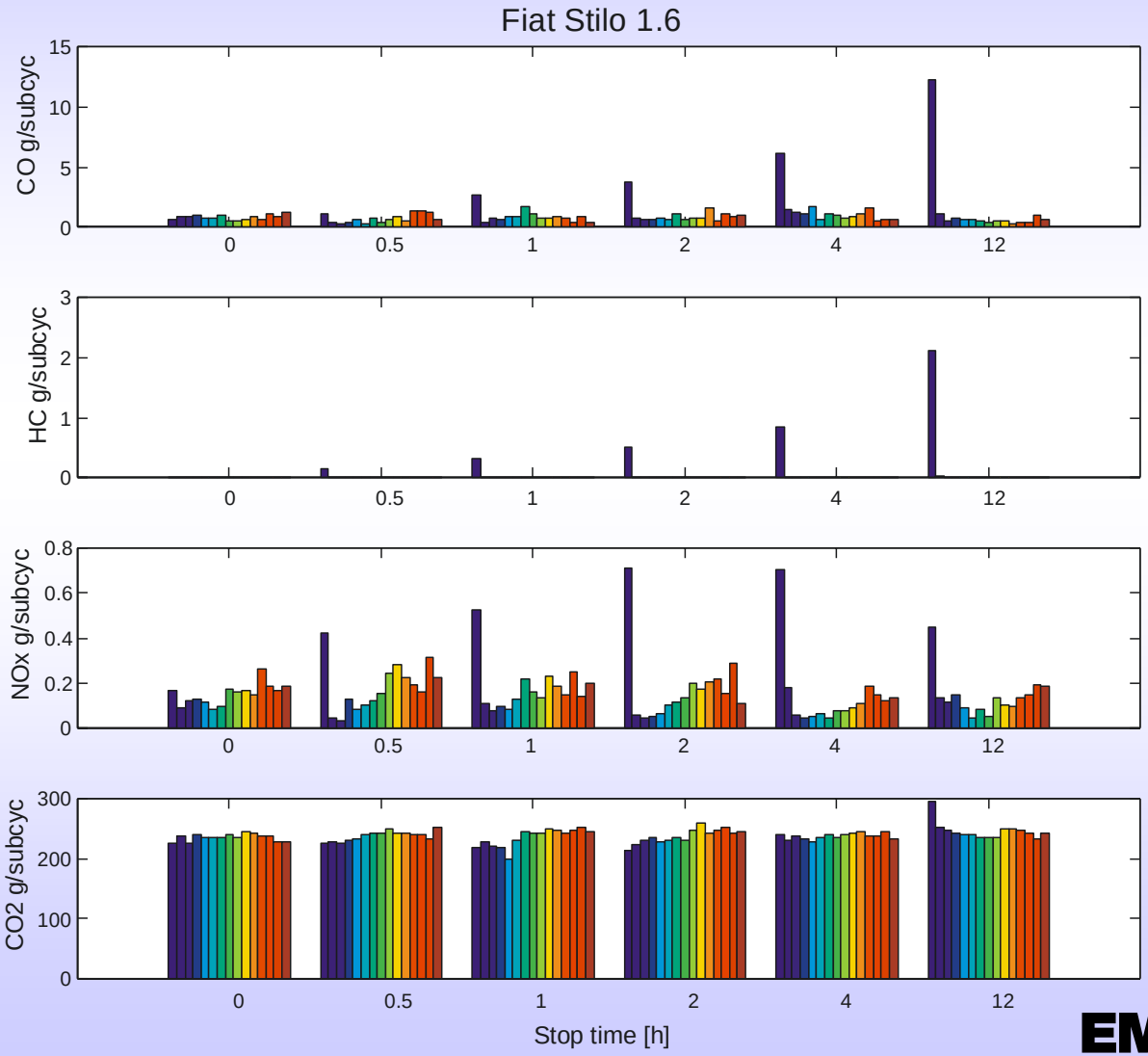
Conclusions: Emissions at low ambient temperature

- Cold start emissions:
  - CO and HC: exponential increase as temperature decreases, up to 15 times and 35 times higher emissions @ -20°C
  - Fuel consumption: linear increase as temperature decreases
  - No increase of CO_2 emissions form -7°C to -20°C → a significant part of CO_2 emissions is substituted by CO and HC emissions
  - No clear trends for NO_x

- Hot phase emissions:
  - Up to 5 times higher emissions for CO and HC @ -20°C
  - Fuel consumption increase of 10% @ -20°C and 5% @ -7°C

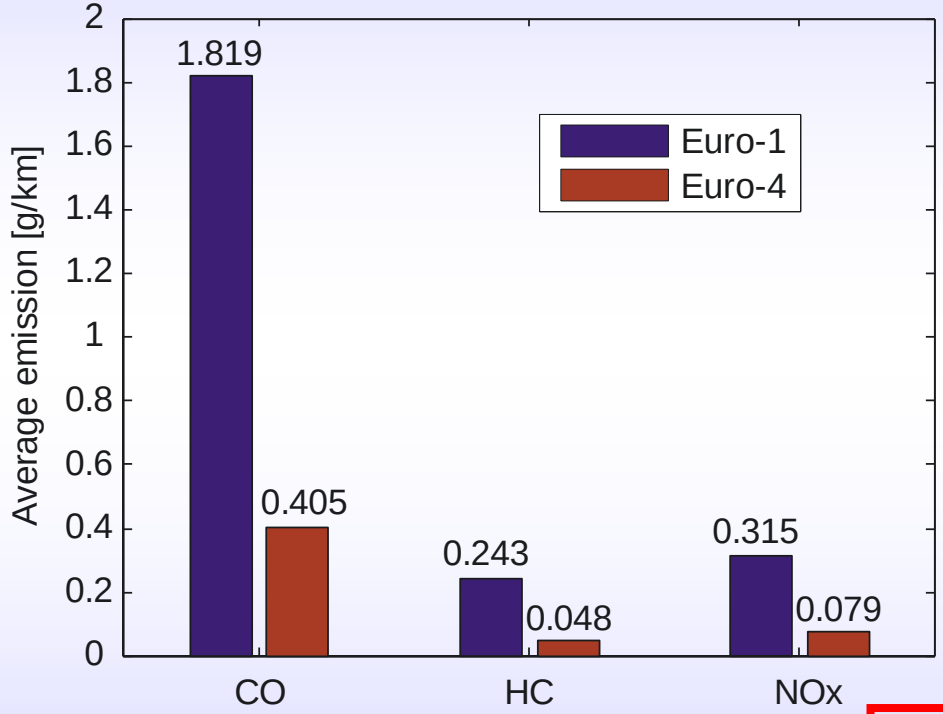
Stop time

Emissions as a function of stop time



Comparison of relative cold start extra emissions

Absolute total emissions of Euro-1 and Euro-4 cars (NEDC)

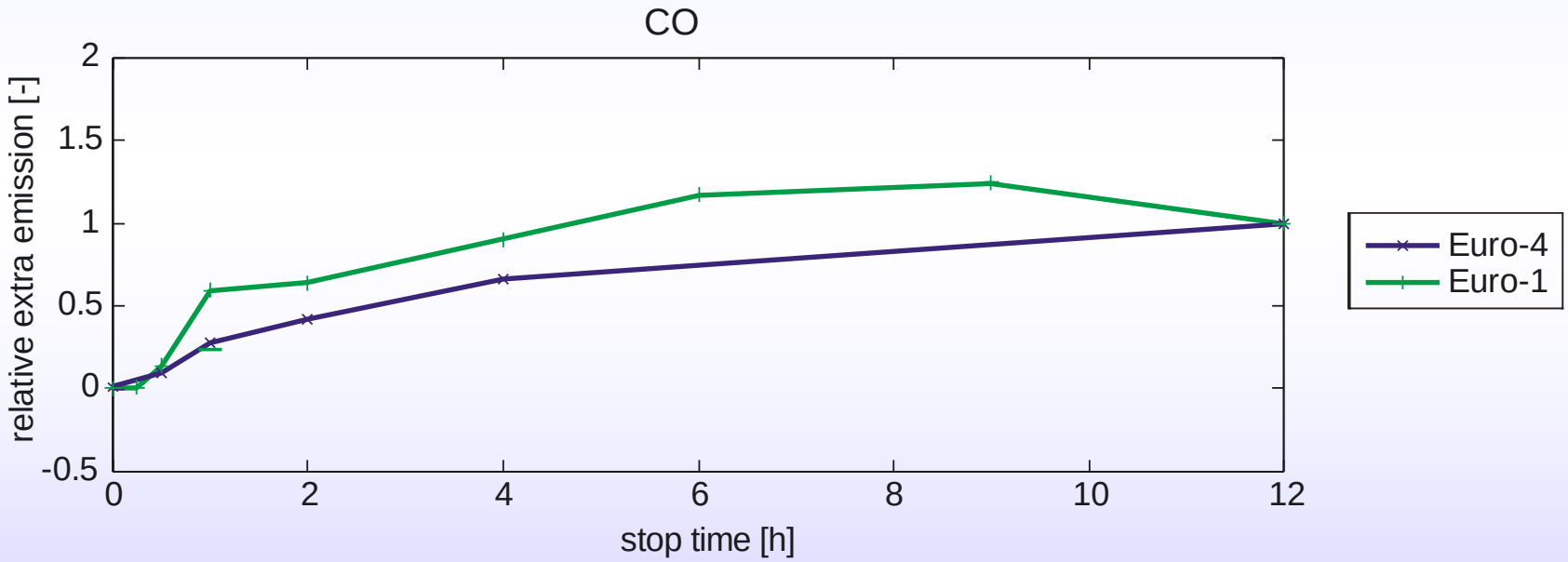


We consider relative extra emissions:

$$EE_{rel}(t) = \frac{EE(t)}{EE(12)}$$

Comparison of relative cold start extra emissions: CO

$$EE_{rel}(t) = \frac{EE(t)}{EE(12)}$$



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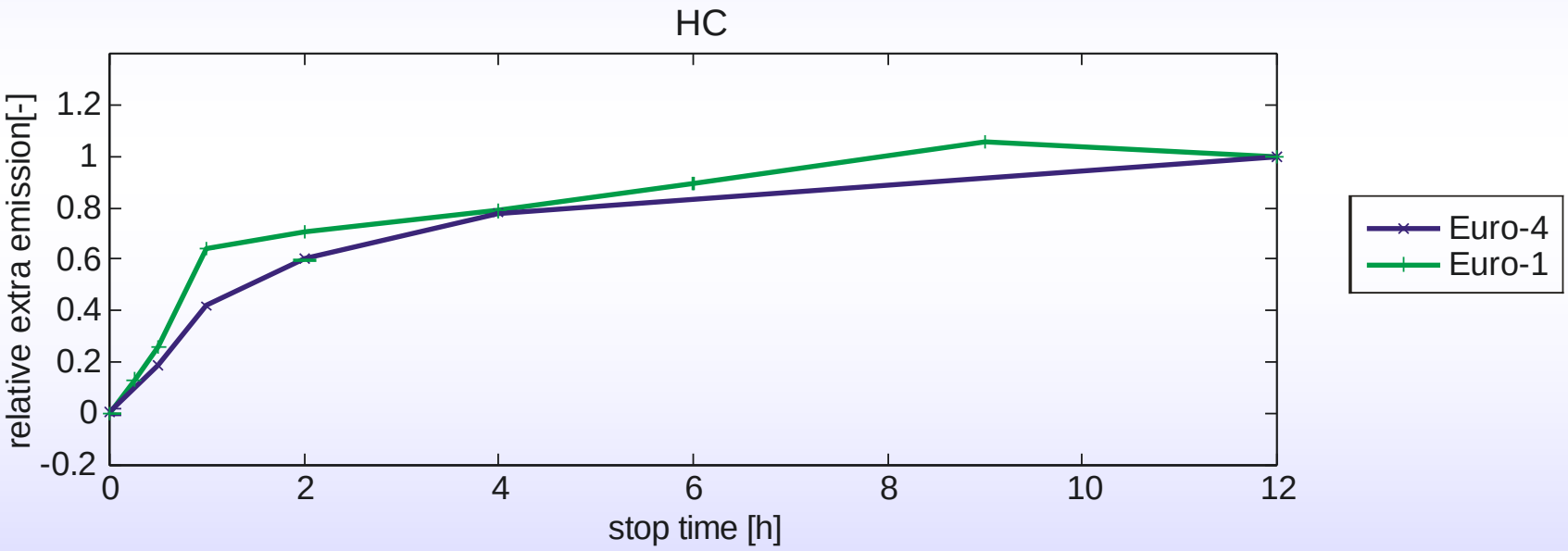
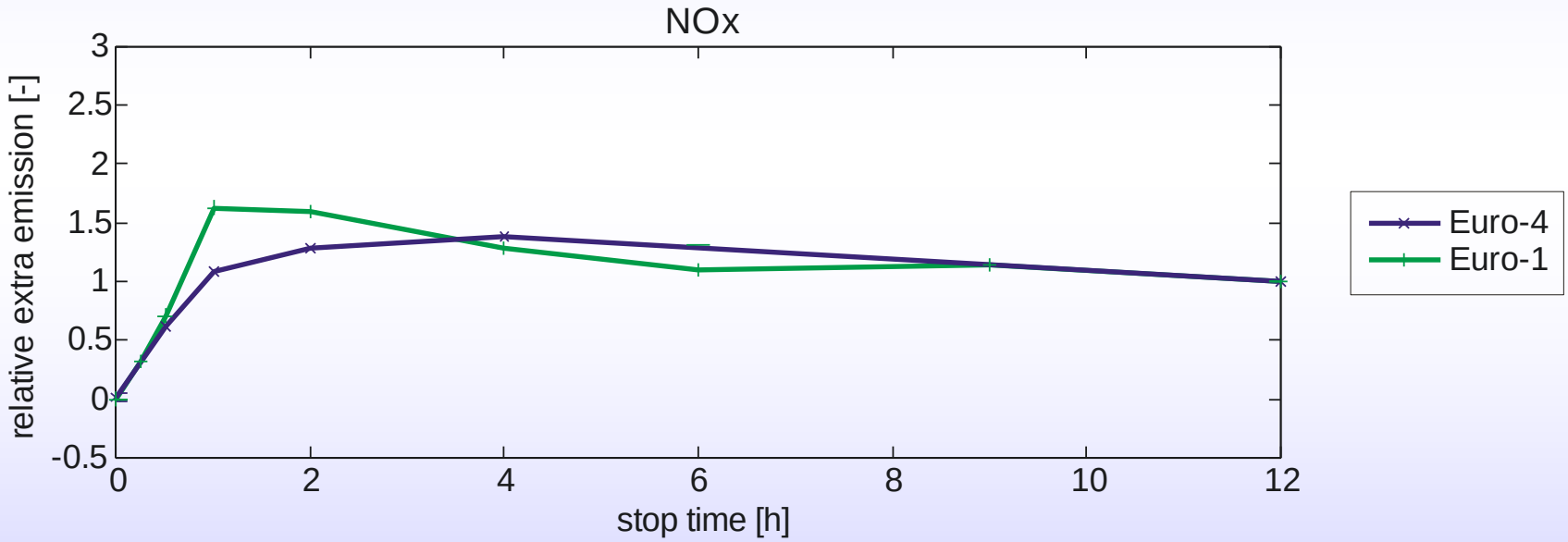
Comparison of relative cold start extra emissions: HC

$$EE_{rel}(t) = \frac{EE(t)}{EE(12)}$$



Comparison of relative cold start extra emissions: NOx

$$EE_{rel}(t) = \frac{EE(t)}{EE(12)}$$



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Conclusions: Cold start emissions as a function of stop time

- 50 % of full cold start (stop time of 12 hours) emissions reached after (Euro 4 vehicles):
  - 3 hours for CO
  - 1.5 hours for HC
  - 0.5 hour for NOx
- NOx:
  - 100 % are already reached after a stop time of 1 hour.
  - Up to 30 % more emissions at mid stop times
- No distinguishable trends for CO2

Air Conditioning systems

- What is the impact of A/C on emissions and fuel consumption in real world?
- What studies are available?
  - Mobile 6
    - Suitable for European cars?
      - Vehicle/engine size
      - System technology
    - Suitable for European weather?
      - Temperatures below 25 °C
  - Other studies?
    - Some full load data
      - How to apply?
      - Where is full load?

Extra emisson = function of weather?

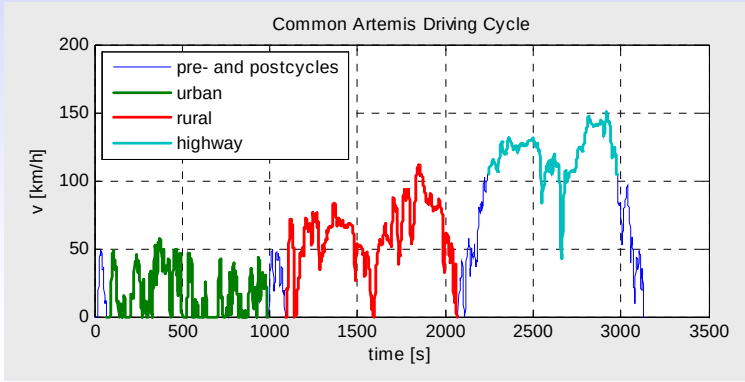
What technologies?

- For the driver /manipulation?
  - Manual
    - Set ventilator speed
    - Set cooling intensity/duct air temperature
  - Semi automatic
    - Set ventilator speed
    - Set desired internal temperature
  - Automatic
    - Set desired internal temperature

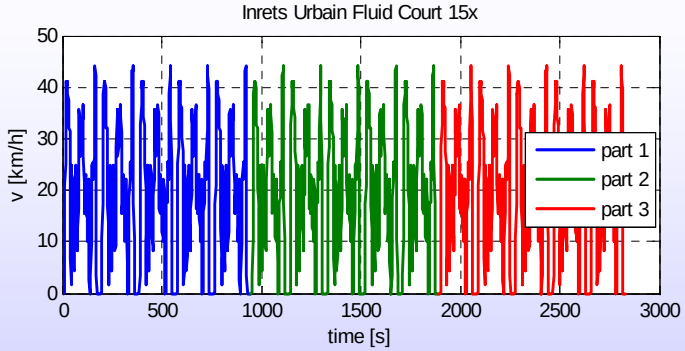
Test setup (1)

- Basic idea:
  - Simulate meteorological conditions in the lab
    - Four temperatures: 13°, 23°, 30° and 37° C
    - Shadow and sun (1.7 m^2, frontal, 45°)
  - Choose cars with different technologies
    - 2 clutching, manual A/C‘s
    - 2 clutching, automatic A/C‘s
    - 2 modulating, automatic A/C‘s
    - (all Euro-3 gasoline vehicles from private owners)

Test setup (2)



- Test Series
  - „keep cool“
    - Engine stabilized warm
    - Interior stabilized on 23°
    - Test cycle CADC (representative urban, rural, highway)
    - 13°, 23°, 30°, 37° C
    - A/C off, A/C on shadow, A/C on sun
  - „initial cool down“
    - Engine cold
    - Interior +20° overheated
    - 23°, 30°, sun
    - IUFC15 (real world repetitive cold start test)



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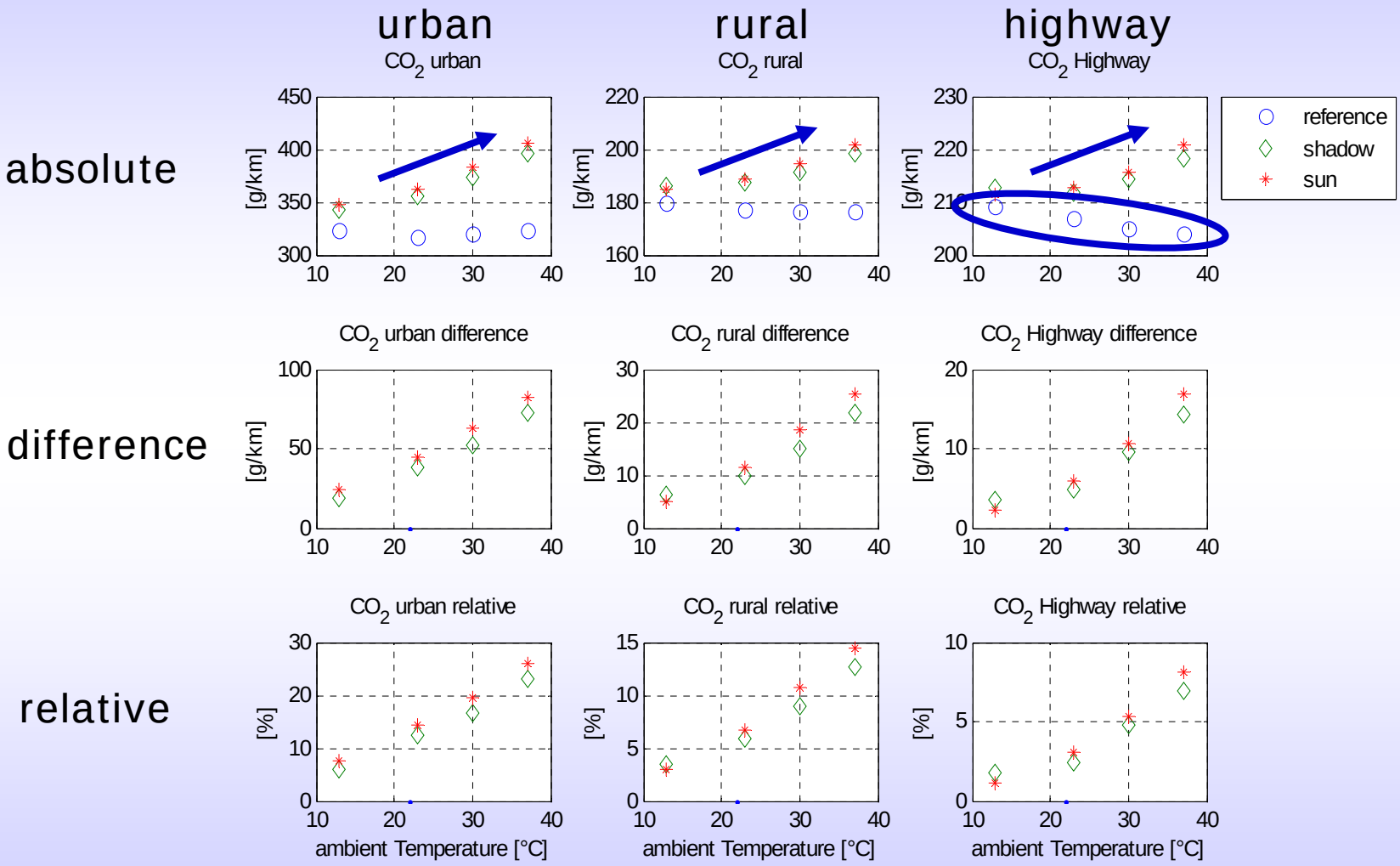
Test setup (3)

- More sensors for technical information

Results „keep cool“: CO_2



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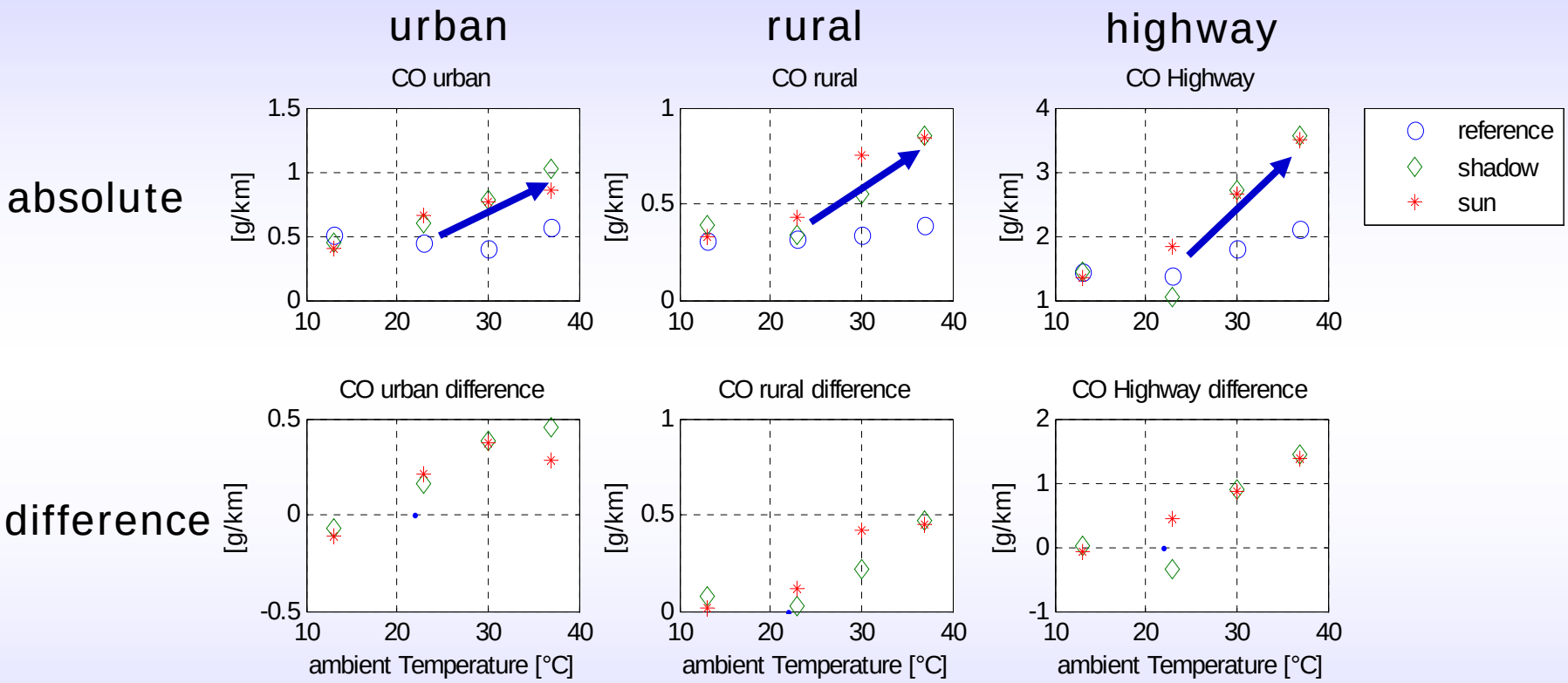
Results „keep cool“: CO



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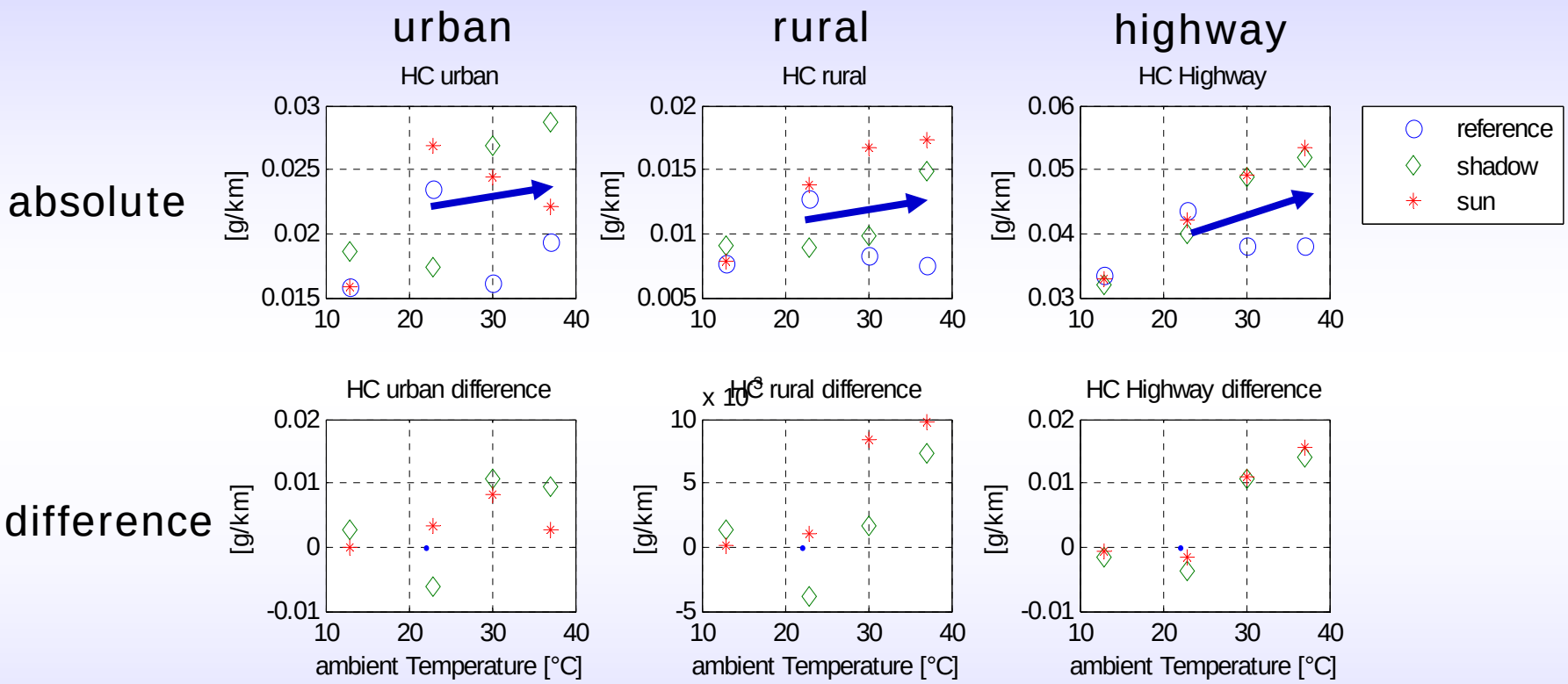
Results „keep cool“: HC



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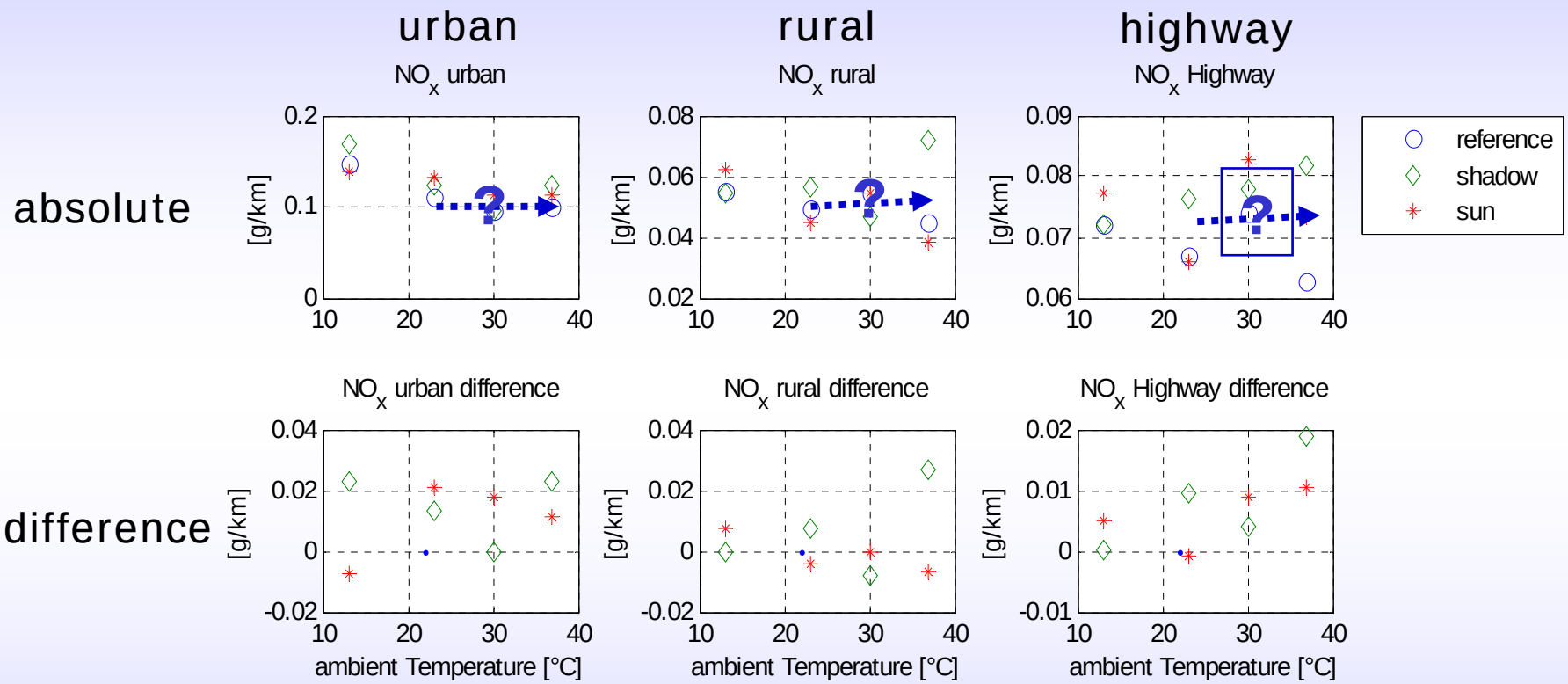
Results „keep cool“: NO_x



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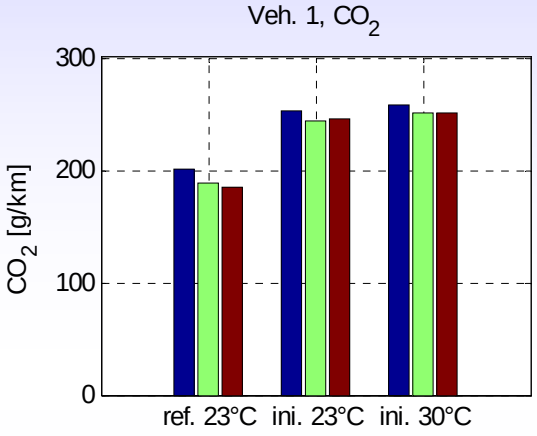
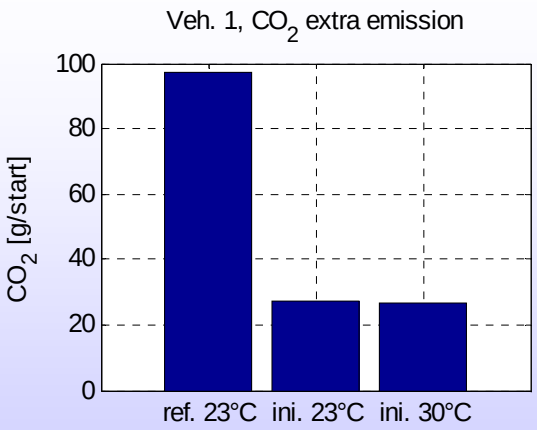
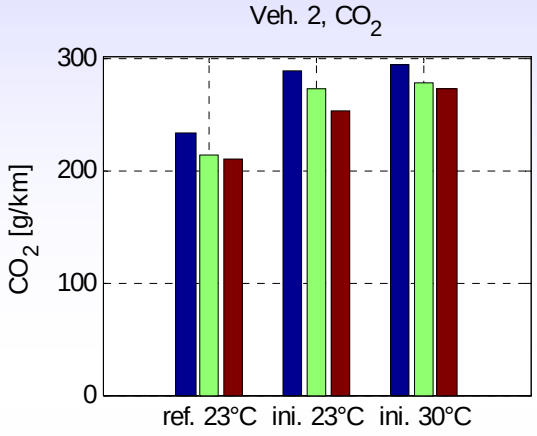
Results “initial cool down“: CO_2

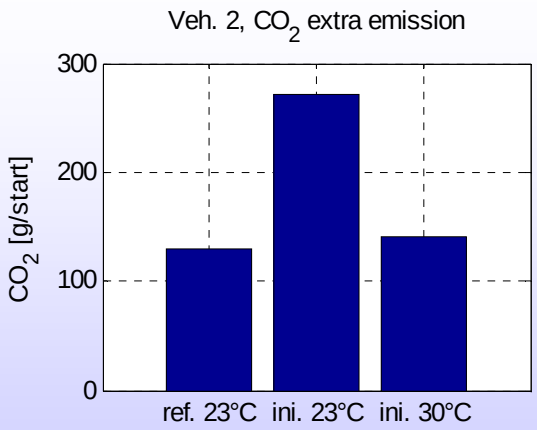
vehicle 1



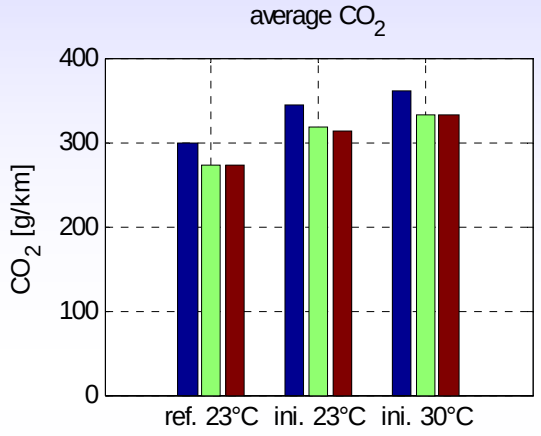


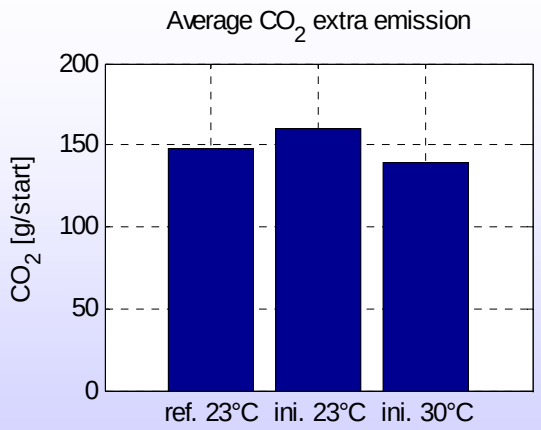
vehicle 2





average





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Summary of test results

- Keep cool:
  - Clear trends for CO_2 and CO
  - Some trend for HC, no trend for NO_x
- Initial cool down:
  - No trend of emissions

What about humidity?

- How does the human experience humidity?

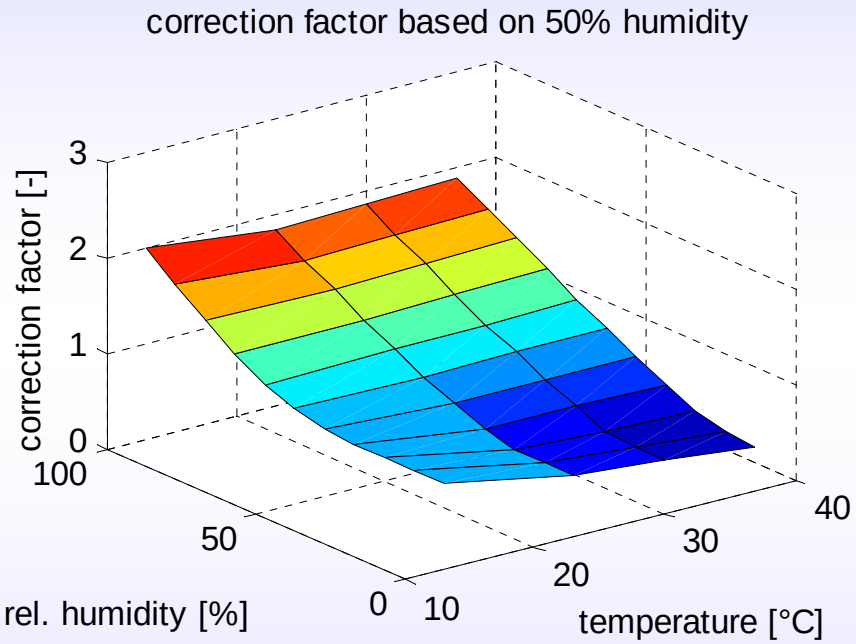
  Assumption: the A/C dries the incoming air

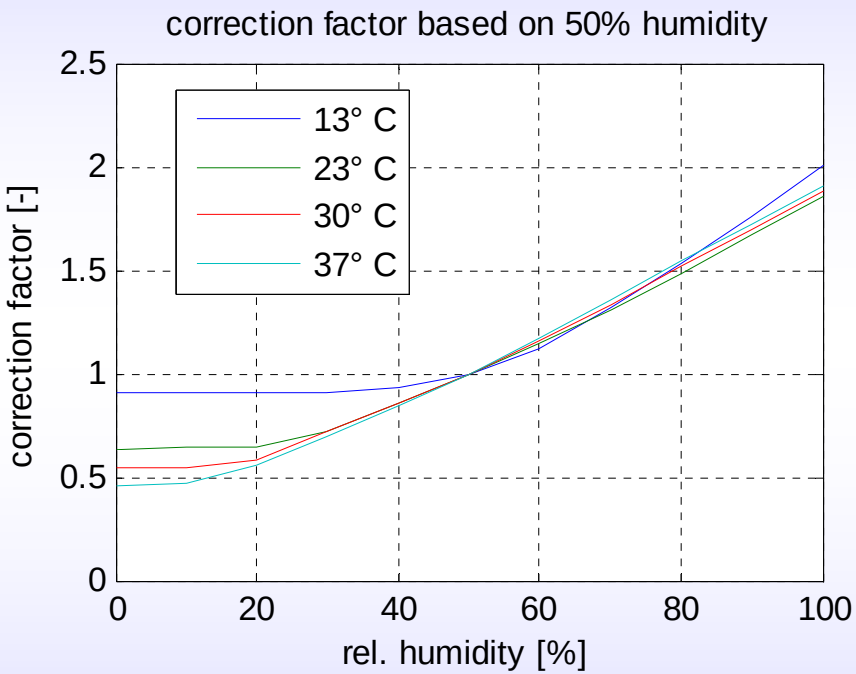
  → same inside air quality if dry or humid.

  → no different setting of the A/C if dry or humid.

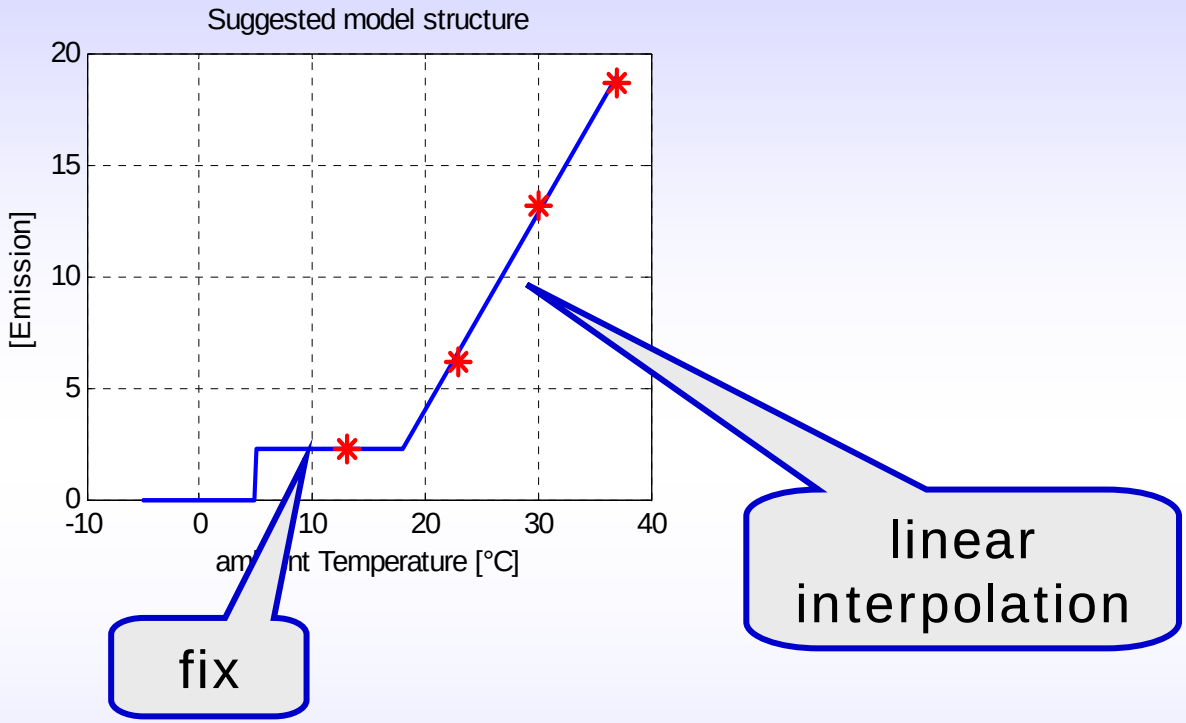
- How does the system experience humidity?
  - possibly cooling and drying humid air needs more power.

Humidity correction function



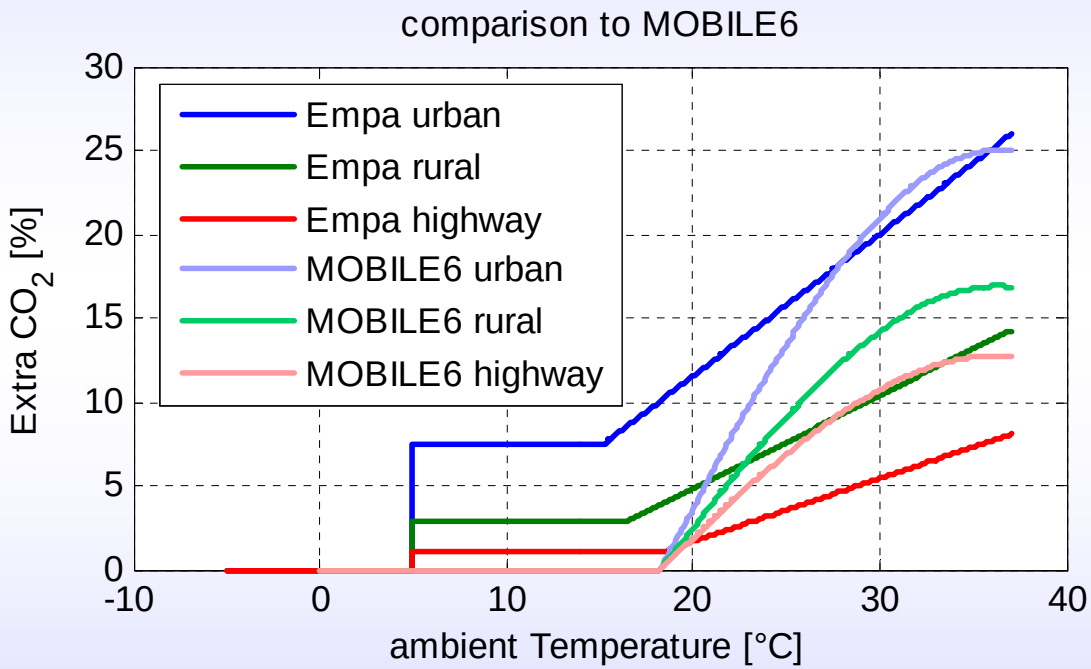


Model design



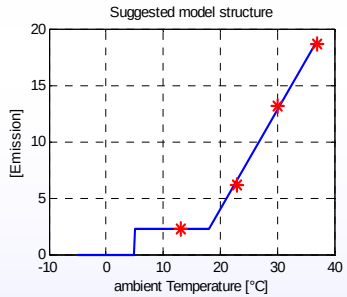
- Apply this to emission difference

Model comparison



Conclusions: A/C

- Extra emissions from A/C‘s are remarkable
  - Maximal rise: CO_2 25%, CO 150%, HC ~50%
- No model for “initial cool down” needed
- Constant + linear approach for model
- Remarkable load at lower temperatures
  - Important for fleet modeling
  - Switch off below 20° C!



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Conclusions

- Estimation of total emissions is complex since it is a function of a multitude of parameters:

  temperature, humidity, travel distance, stop time, A/C on/off

- Due to the efforts in optimizing catalysts the cold start emissions are contributing to a major part of the total emissions (CO, HC and NOx).

  Modeling of cold start emissions as a function of temperature and stop time becomes very important

- A major contingent of new vehicles have a A/C system
  - Modeling, especially for a lower temperature range, becomes important
  - Additional fuel consumption of +1.5 % has been underestimated
  - Expectation with new model: +2-5 %