Air Pollution and Traffic in the Alpine Transit Corridors of Gotthard and Brenner 2004 - 2010

Study in the Frame of iMonitraf!

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NOx:	Nitrogen monoxide
NO_2:	Nitrogen dioxide
"CV":	Central Valley
"UPV":	Upper part Valley
AADT:	Annual Average Daily Traffic.

1. Introduction

This study carried out in the frame of iMonitraf! project, takes into consideration the effect of traffic on air pollution in the alpine transit corridors of Gotthard and Brenner. In this direction, data of air pollution and traffic counting are analyzed from 2004 to 2010 and put together with a meteorological parameter of the temperature inversion.

The study is based on detailed analysis of five categories of vehicles and their emissions of NOx, NO_2 and particulate matter (PM). It differs from other iMonitraf! studies with a more general traffic and air pollution overview but done for all the corridors in the iMonitraf! project.

In fact, this work analyses each pass and compares the corridors by three main components:

- Concentrations of NOx, NO_2, PM10 and PM2.5
- Road traffic
- Road emissions of NOx, NO_2, PM (particulate matter)

To reach this aim, many investigations have been conducted in this study for both corridors and for each component, as following:

- Comparing annual averages of 2010.
- Exposing the development of components and their trend for the period of 2004-2010.
- Exposing the ratio between emissions and air concentrations.

Furthermore, this study proposes to define the effect of temperature inversions on air pollution, in particularly on the NOx concentrations.

At last, some regional studies from the Gotthard and Brenner corridors with general interest for all the regions of the iMonitraf! project are summarized.

2. Framework

2.1. Geographical Context and Studied Area

The corridor of Gotthard, with a tunnel, is connecting Central Switzerland and Ticino, both regions in Switzerland. The Brenner corridor is connecting Austria (Tyrol) to Italy (South Tyrol) (Figure 2.1).

The aim of this study is to look at the following questions:

- Are there similarities or difference in pollution level between corridors or between the sides of the same corridor?
- How is the relationship between corridors in terms of road traffic and emissions, main source of air pollution?
- Which indicators characterize both corridors and allow comparison?
- What is the influence of temperature inversions on air pollution?

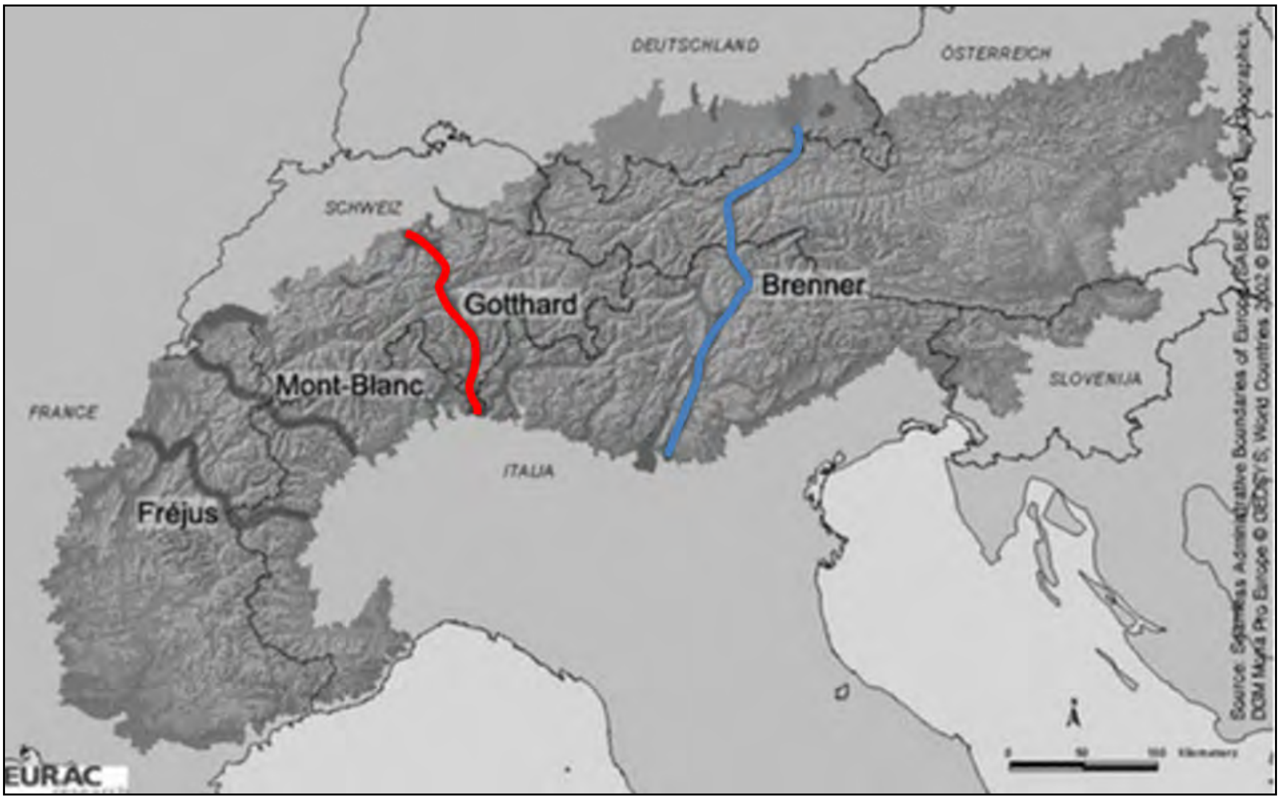


Figure 2.1: Studied corridors in the iMonitraf! project area.

!!! For a quick comprehension of the graphics, the colors for each corridor follow with in all this study!!!

Many air monitoring stations data are analyzed for 2004-2010 as yearly development, but in this advanced analysis, the focus is made on two stations from each side of the passes (roadside stations). For each, a parallel road traffic counting station is investigated and one temperature profile.

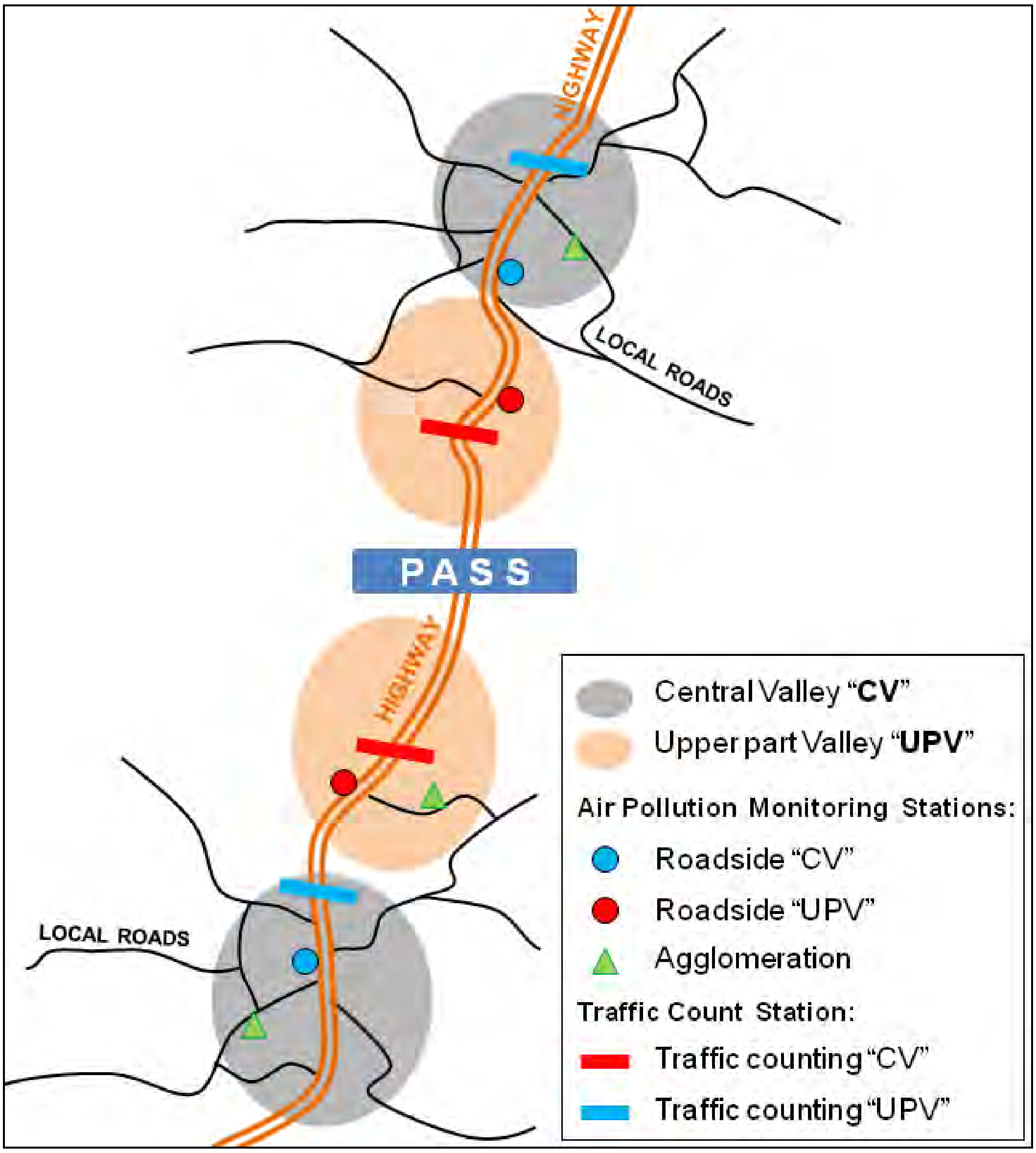


Figure 2.2: Schematic illustration of the geographical situation of air pollution monitoring stations and road traffic counts.

Criteria have been considered in the selection of the studied stations helping for further comparison, as:

- The station type: roadside, situated in proximity of the highway.
- The geographical situation of the station with regard to the pass as following:
  - The Central Valley "**CV**" characterized by high human density and activities.
  - The Upper part Valley "**UPV**" characterized by less human activities and more dominating transit flow near the pass (Figure 2.2).

!!! For a quick comprehension of the graphics, the colors of the geographical situation of each station follow with in all this study!!!

2.2. Classification of studied Air Pollution Monitoring Stations

The stations presented in the following table and map are divided in two classes (Table 2.1):

- The specific studied stations are the roadside stations from which the characterization of corridors can be conducted: for these stations, the distance of the highway is 5 m (with the exception of Auer, 25m), several components are measured for many years and a traffic counting station in the near proximity is available (for the case of Moleno, the recordings are taken from Biasca, situated in the same section of the highway).
- Some additional stations in urban or agglomeration background are presented with only a general overview that characterize the air pollution level in the surrounding regions of the highways.

Table 2.1: Classification of studied stations.

Name	Country	Pass	Geographic situation	Classifica-tion	Distance of highway	Monitored Pollutant	Related Traffic counting station
Specific studied stations:							
Erstfeld**	CH	Gotthard	UPV	Roadside	5 m of A2	NOx, NO_2, PM10, PM2.5*	Erstfeld
Reiden	CH	Gotthard	CV	Roadside	5 m of A2	NOx, NO_2, PM10, PM2.5*	Reiden
Moleno	CH	Gotthard	UPV	Roadside	5 m of A2	NOx, NO_2, PM10, PM2.5*	**Biasca**
Camignolo	CH	Gotthard	CV	Roadside	5 m of A2	NOx, NO_2, PM10, PM2.5*	
Mutters	AT	Brenner	UPV	Roadside	5 m of A12	NOx, NO_2, PM10	Mutters
Vomp	AT	Brenner	CV	Roadside	5 m of A12	NOx, NO_2, PM10	Vomp
Klausen (Chiusa)	IT	Brenner	UPV	Roadside	5 m of A22	NOx, NO_2, PM10*, PM2.5*	Klausen
Auer (Ora)	IT	Brenner	CV	Roadside	25 m of A22	NOx*, NO_2, PM10*, PM2.5*	Auer
Stations studied in a general overview:							
Altdorf	CH	Gotthard	UPV	Agglomera-tion		NOx, NO_2, PM10	
Chiasso	CH	Gotthard	CV	Urban		NOx, NO_2, PM10	
Bioggio	CH	Gotthard	CV	Agglomera-tion		NOx, NO_2, PM10	
Hall	AT	Brenner	CV	Agglomera-tion		NOx*, NO_2, PM10	
Brixen	IT	Brenner	UPV	Urban		NOx, NO_2, PM10*	

* Data are not available continuously from 2004 till 2010.

** Erstfeld station has been relocated end of 2007.

The yearly average of each component is calculated on a basis of more than 70% of data availability. If necessary, the number exposed in the graphic is noted by an asterisk (*) and explained in a subsequent text.

For the PM10, the data are continuously measured for some years, but mostly, the measurement method is gravimetric. For some stations, the presented data combine both measurements technique.

The following map shows the localization of the investigated stations:

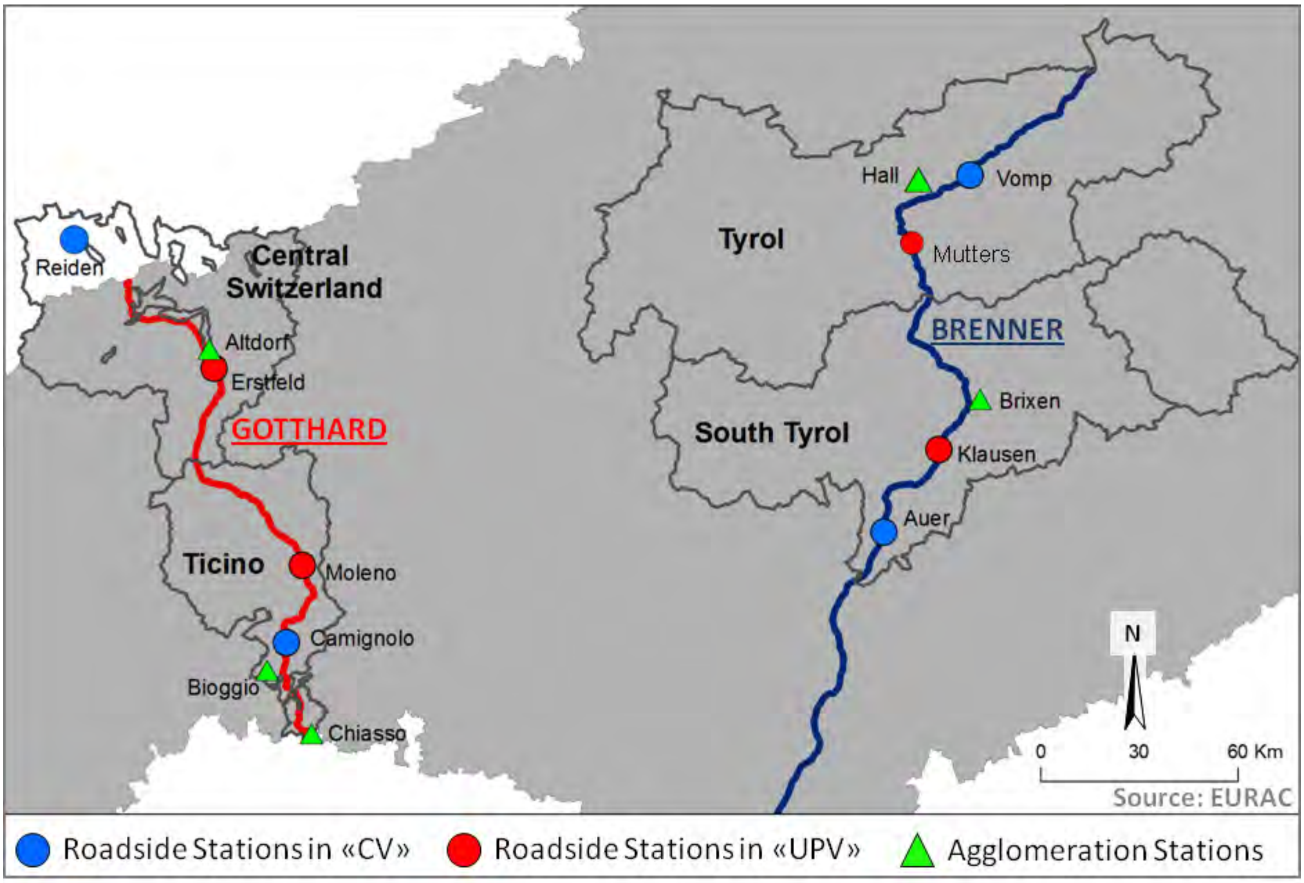


Figure 2.3: Localization of the investigated monitoring stations

3. Air Pollution Data and Trends 2004-2010

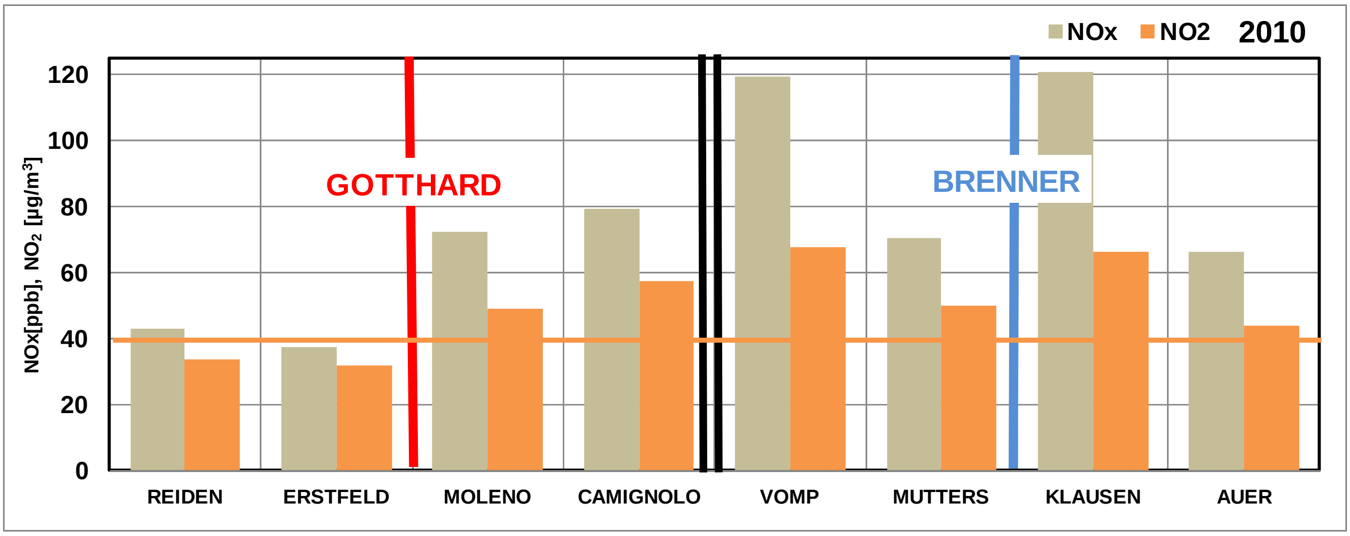
This chapter exposes the yearly mean and the trend which is calculated in percentage per year from 2004-2010 for the NOx, NO_2, PM10 and PM2.5 and a seasonal analysis between winter and summer.

3.1. Concentrations of NOx, NO_2, PM10 and PM2.5 in 2010

In 2010, for NOx and NO_2, the annual averages of all stations show that Vomp ("CV") and Klausen ("UPV") at different side of the Brenner register the highest level of pollution, with 120 ppb for NOx and more than 60 µg/m^3 for NO_2. The lower level is recorded in Central Switzerland at Reiden and Erstfeld (Figure 3.1). Only for these two stations, the NO_2 level is less than the threshold of 40 µg/m^3 (RL 1999/30/EG) (Figure 3.2).

In fact, regarding to the geographical situation of the station (in the Central or Upper part Valley), the levels of NOx and NO_2 are for:

- **Gotthard**: less in the "UPV" and higher in the "CV"
- **Brenner**: the Austrian side shows the same result as Gotthard, less in the "UPV" and higher in the "CV", but the Italian side shows an opposite effect, which is in large part caused by the fact of a distance of 25 m from highway of the "CV"-station Auer (Figure 3.1).



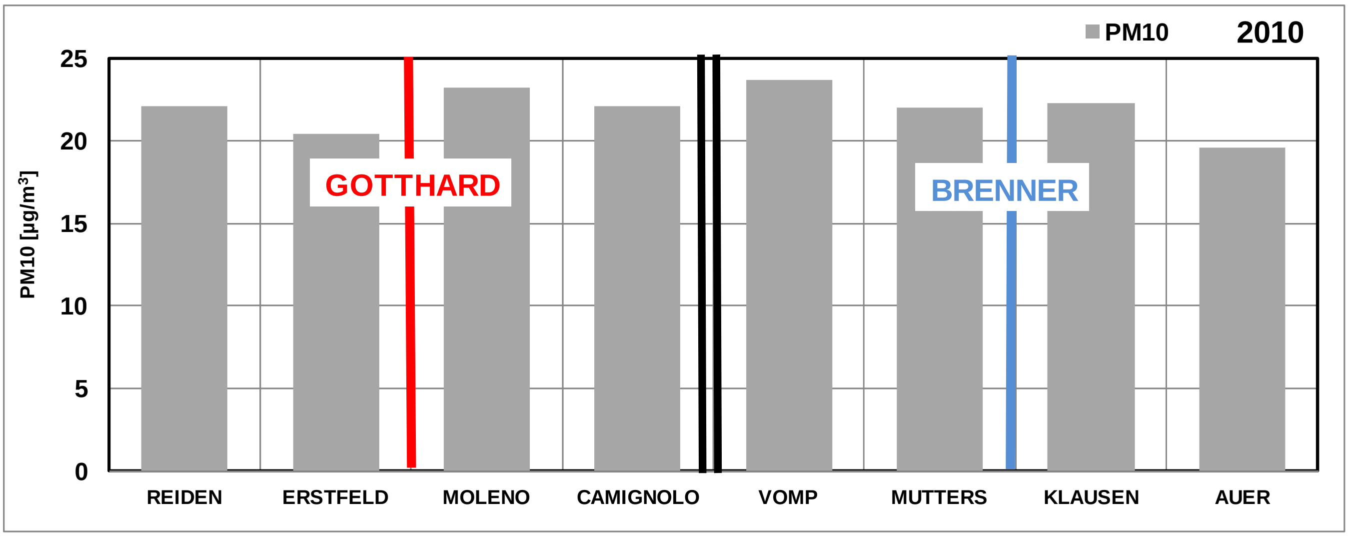


Figure 3.1: Yearly average of NOx, NO_2 and PM10 concentrations at Gotthard and Brenner in 2010.

For the PM10 concentrations, all stations show similarity as the level varies between 19 and 25µg/m^3. These results are far from the European annual limit value of 40µg/m^3 in 2010 but exceeding over annual threshold is registered at the Swiss stations where the limit value is 20µg/m^3.

3.2. Development of Annual Concentrations and Trends 2004-2010

The annual limit values of NO_2 and PM10 vary with years and countries (Figure 3.2):

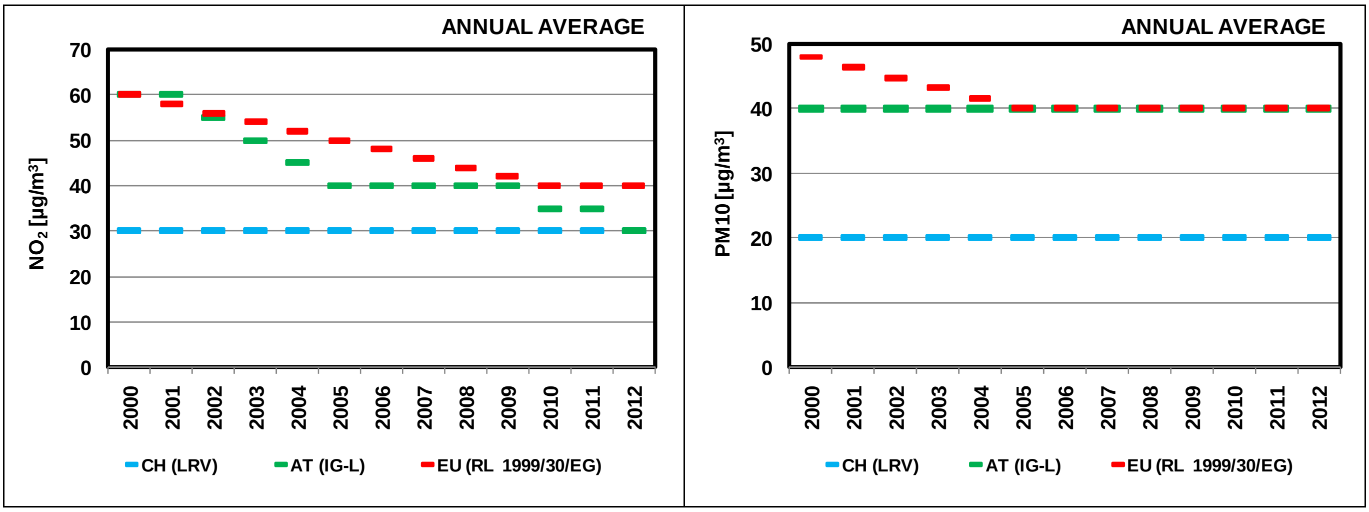
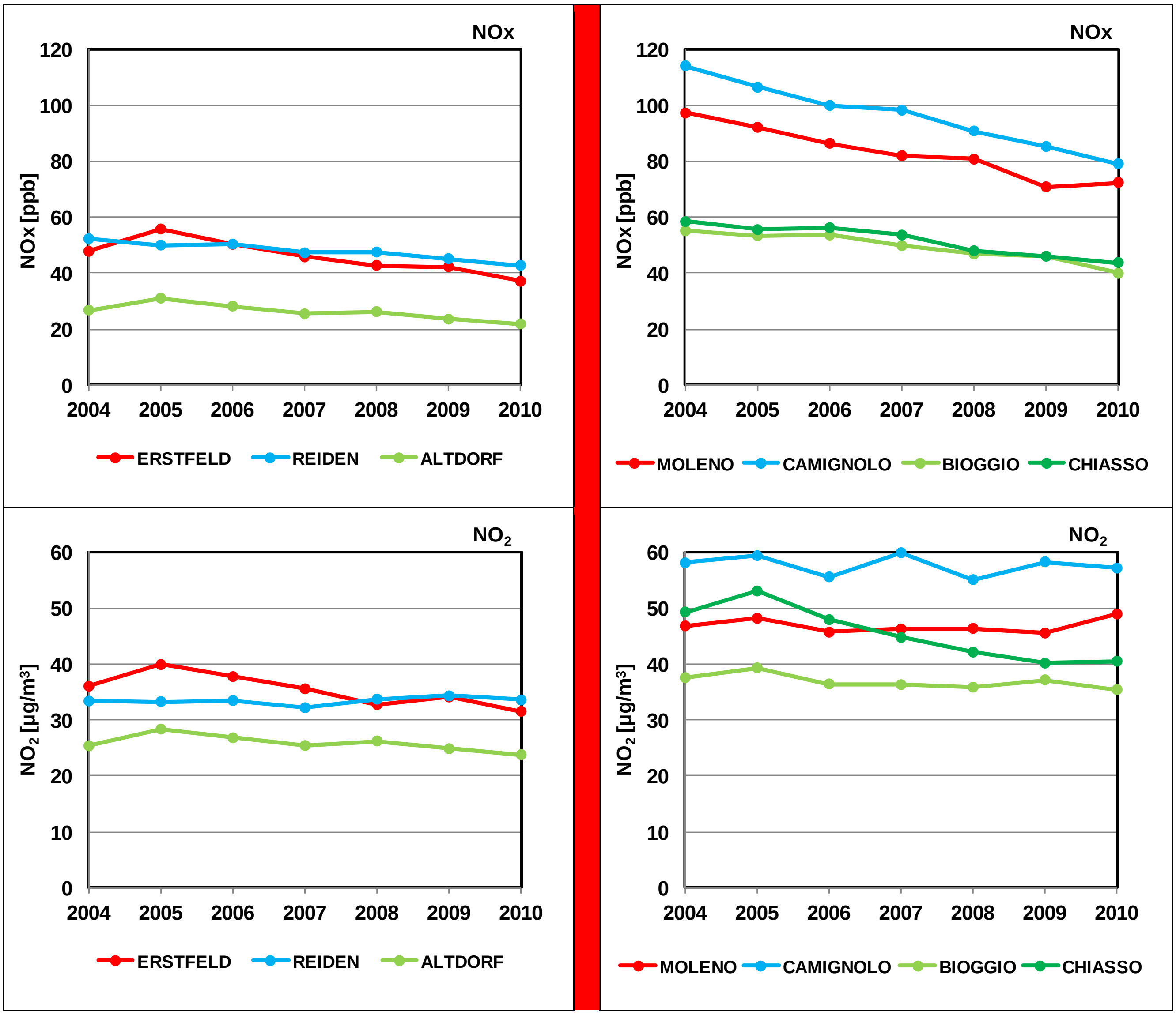


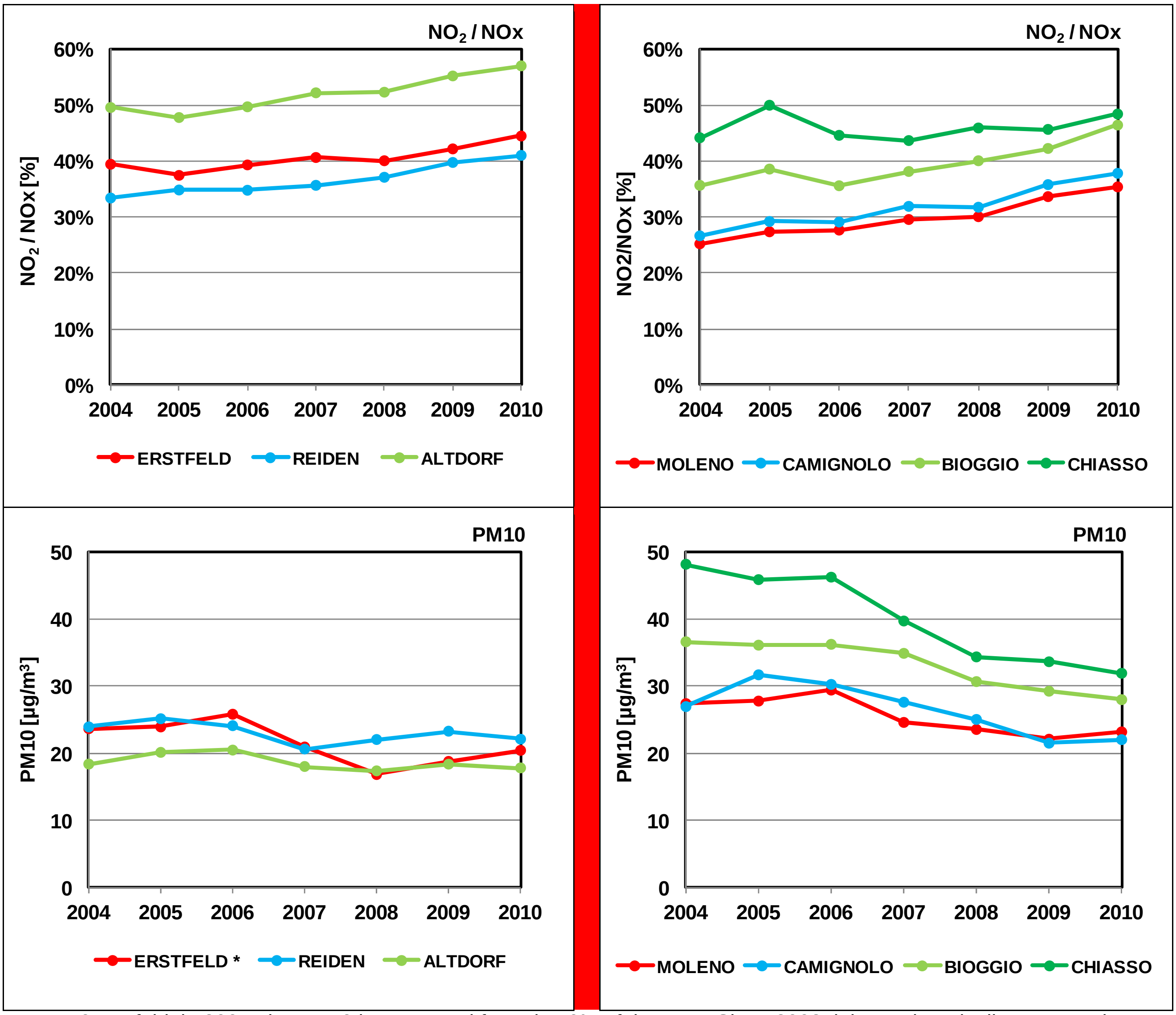
Figure 3.2: Annual limit values for NO_2 and PM10 concentrations for Switzerland (LRV), Austria (IG-L) and Europe (RL 1999/30/EG), 2000-2012.

The evolution of pollution at both corridors can be resumed as follows:

- The **NOx** shows a decreasing through the years for all type of stations. The analyses of this pollutant must be considered from three different sides: both part of the pass, the geographic situation and the classification of the stations.
    - The level of pollution is different for each side of the Gotthard, but is generally the same for both sides of the Brenner.
    - The “CV” stations present a higher level of NOx than the “UPV” stations for Gotthard and the Austrian part of Brenner.
    - The Agglomeration and Urban stations observe less concentrations of NOx.
    - At Vomp, road works took place near the station for two months in 2010 which led to more emissions and less distance of traffic to the station, therefore to enhanced air pollution.
- The **NO_2** is more stable throughout the years. The variation between the passes and the stations is the same as for the NOx.
- The **NO_2/NOx** ratio illustrates the part of NOx being NO_2. When the NOx decreases, the ratio increases. With the modernization of the fleet, the direct emitted NO_2 is higher. Consequently, this ratio is increasing from 2004 to 2010. Note that for the Agglomeration and Urban stations, this ratio is higher because of the greater conversion of NO into NO_2 with the distance of the road.

- The **PM10** present a stable level at the Central Switzerland but a decreasing for Ticino and Brenner to reach the levels of the Central Switzerland. On the opposite of the NOx, the Roadside stations are less polluted than the Agglomeration and urban stations because the PM10 results also of the human activities in the urban zones (diffuse sources of particles). The PM10 level at Hall station in 2010 present a good example for this case: roadwork took place near the station therefore the PM10 raises from 22µg/m^3 in 2009 to 29 µg/m^3 in 2010. In fact, the inventory of any change of activities in the surroundings of the air pollution monitoring stations is a guide to validate the measurements.

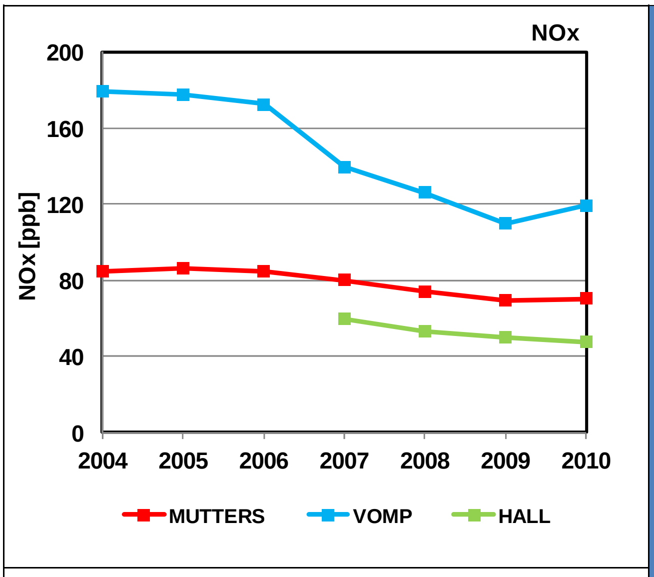


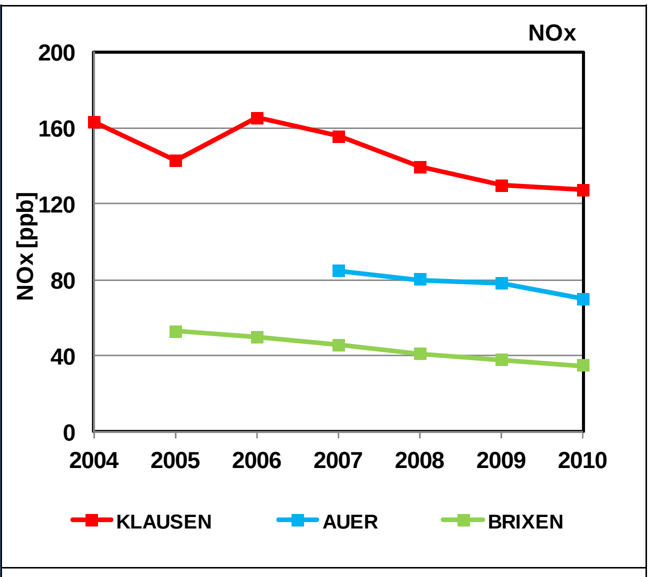


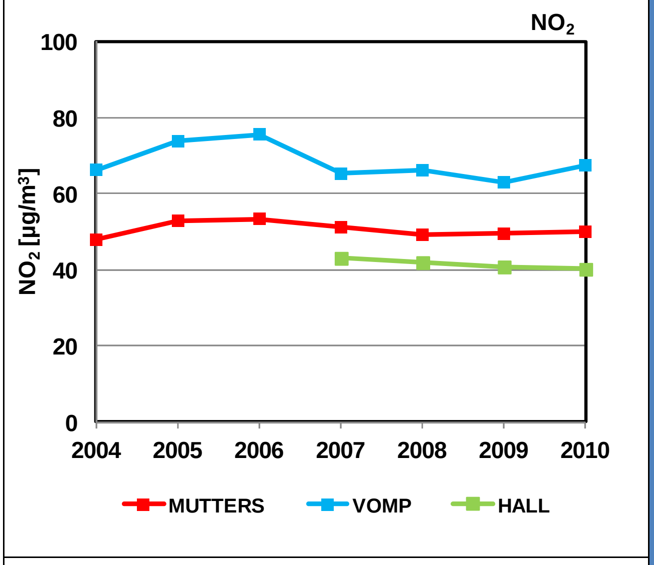
* PM10 Erstfeld: in 2007, the PM10 is measured for only 76% of the year. Since 2008, it is gravimetrically measured.

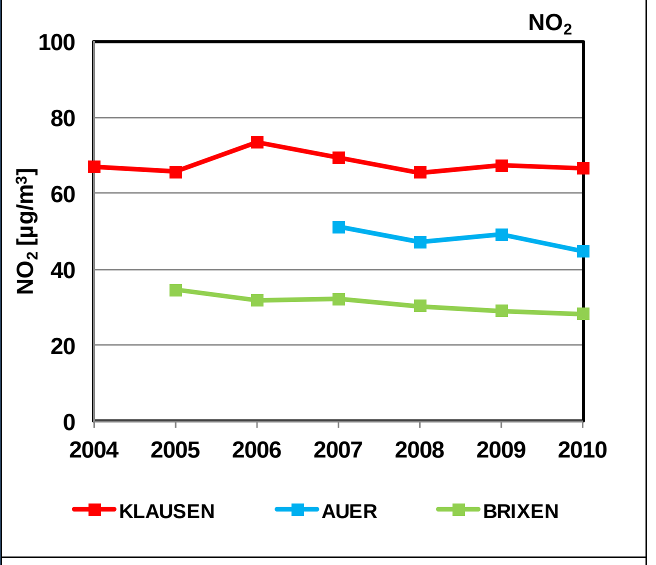
Figure 3.3: Yearly average of NOx, NO_2 and PM10 concentrations at Gotthard, 2004-2010.

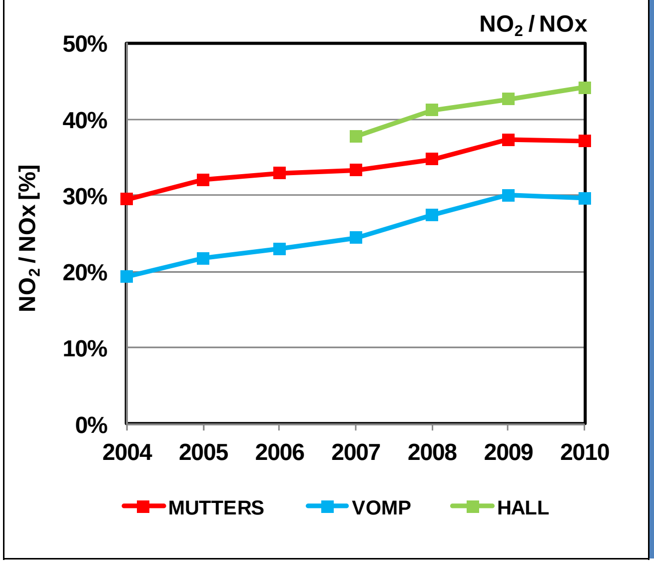
For the Brenner corridor it has to be considered that Auer has a distance of 25 m from highway, whereas all other stations have ca. 5 m as mentioned above.

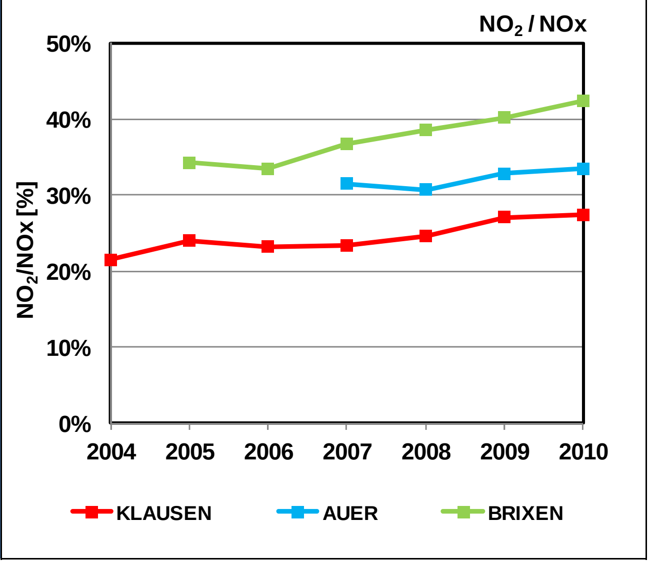

NOx
NOx [ppb]
0 40 80 120 160 200
2004 2005 2006 2007 2008 2009 2010
MUTTERS VOMP HALL

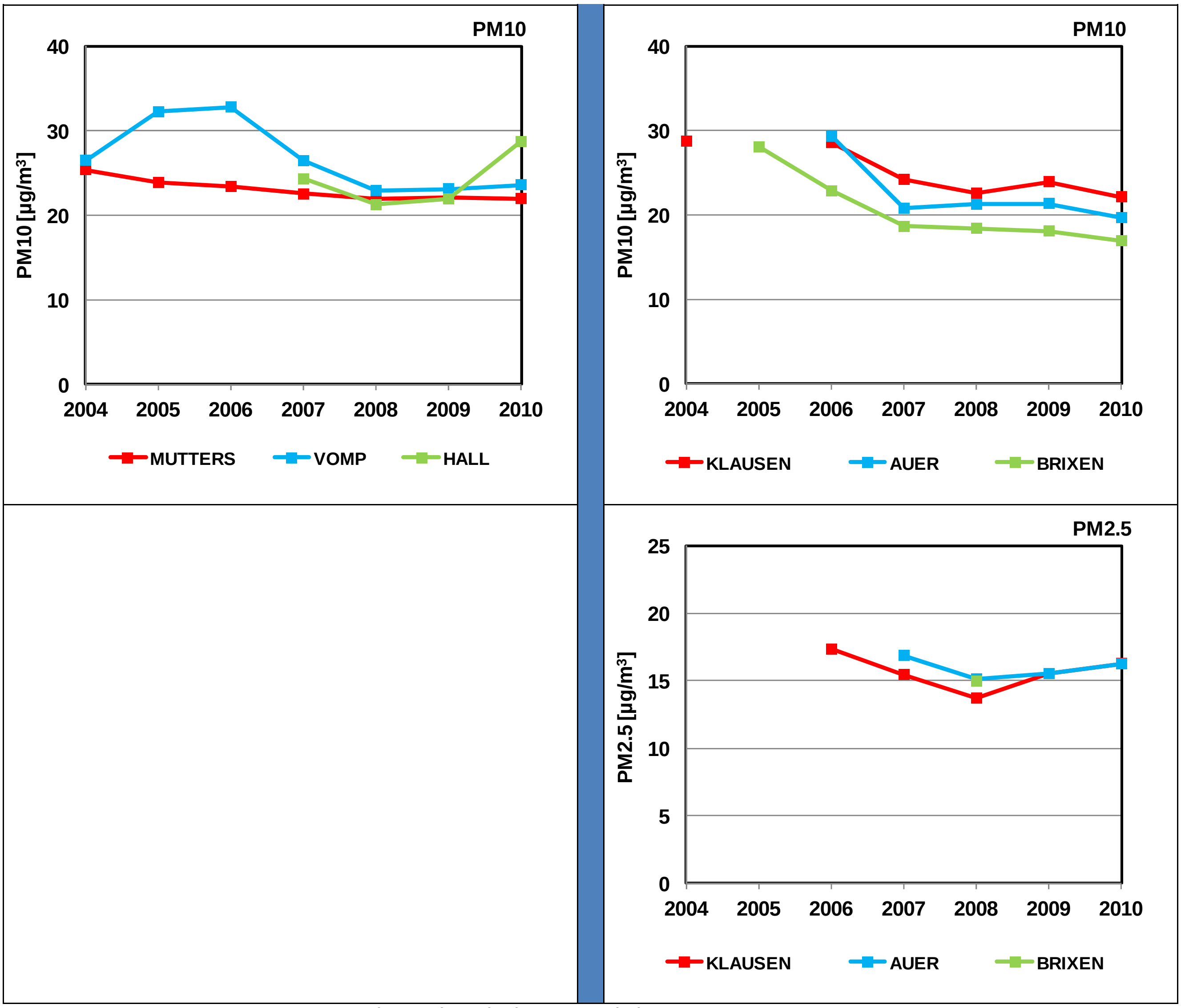

NOx
NOx [ppb]
0 40 80 120 160 200
2004 2005 2006 2007 2008 2009 2010
KLAUSEN AUER BRIXEN


NO_2
NO_2 [µg/m³]
0 20 40 60 80 100
2004 2005 2006 2007 2008 2009 2010
MUTTERS VOMP HALL


NO_2
NO_2 [µg/m³]
0 20 40 60 80 100
2004 2005 2006 2007 2008 2009 2010
KLAUSEN AUER BRIXEN


NO_2 / NOx
NO_2 / NOx [%]
0% 10% 20% 30% 40% 50%
2004 2005 2006 2007 2008 2009 2010
MUTTERS VOMP HALL


NO_2 / NOx
NO_2/NOx [%]
0% 10% 20% 30% 40% 50%
2004 2005 2006 2007 2008 2009 2010
KLAUSEN AUER BRIXEN



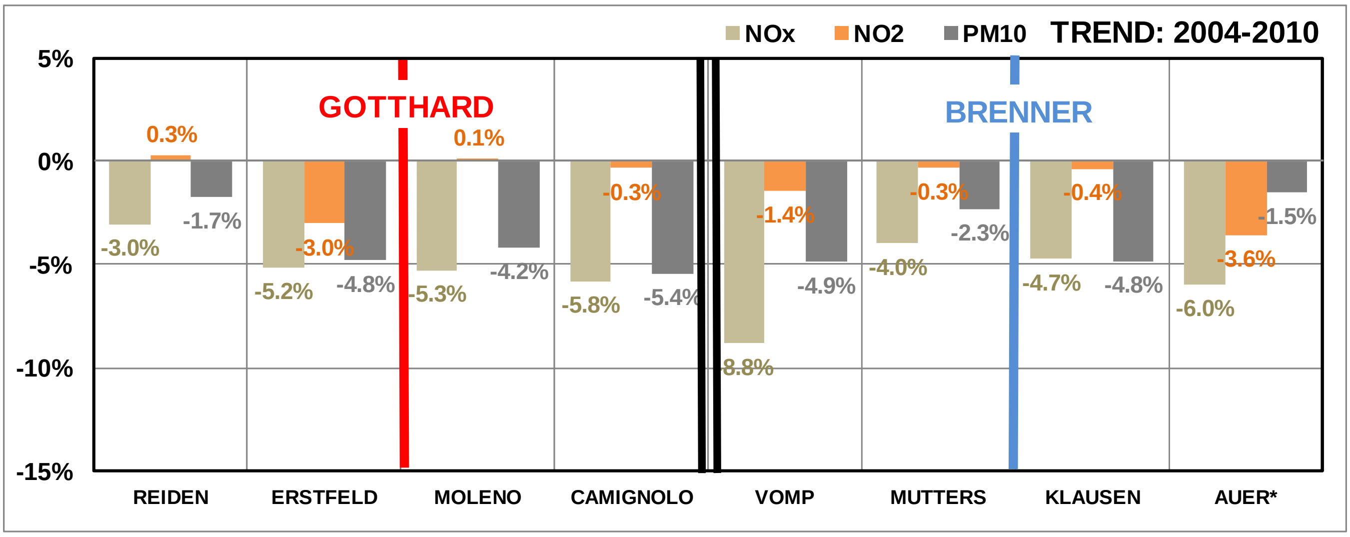
* PM10 at Vomp is gravimetrical measured since 2005.

Figure 3.4: Yearly average of NOx, NO_2, PM10 and PM2.5 concentrations at Brenner, 2004-2010.

→ The trend of NOx, NO_2 and PM10 concentrations for 2004-2010 is negative for all the studied stations. The results are comparable between both passes. However, the relationship between the geographical situations of the stations is not homogenous for both passes.

In fact, for the NOx, at northern Gotthard, “UPV”-Erstfeld decreases more than at “CV”-Reiden. At the southern part, the decreasing is mostly the same at the “CV” and “UPV” stations. At Brenner, the “CV” stations show a higher decrease than the “UPV” with about -9%/y and -7%/y at Vomp and Auer (Figure 3.4).

The PM10 presents a different behavior with regard to the geographical situation of the stations.



* For Auer, the trend is calculated from 2007 till 2010, for NOx, NO_2 and PM10.

Figure 3.5: Trend (in %) per year for NOx, NO_2 and PM10 at Gotthard and Brenner, 2004 – 2010.

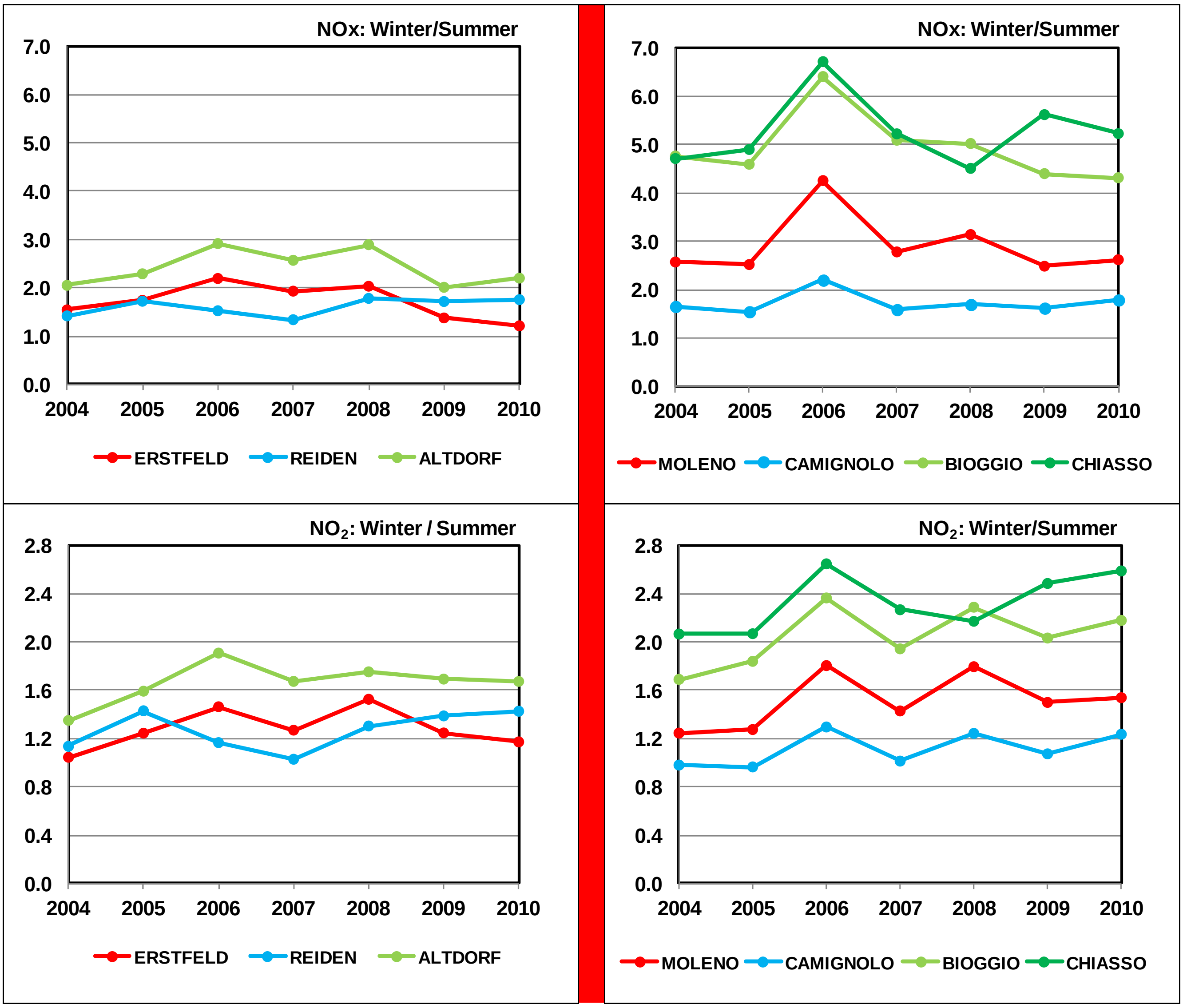
3.3. Seasonal development 2004-2010

The seasonal development of pollutants is exposed in this part by investigating the relationship between winter and summer averages: the more the ratio is high between the two seasons, the bigger the difference is in term of pollution level. For example, for NOx in 2006, the ratio is elevated between winter and summer due to the high levels of Ozone on European level which makes generally less NOx in summer. In winter, on the other hand, persistent inversion situations over Europe led to enhanced pollution levels. At Bioggio and Chiasso in 2006, NOx level in winter was multiplied by 7 with regard to the summer (Figure 3.5).

The main results of this research are:

- All stations and pollutants present a higher level of pollution in winter than in summer time. This is due to the stagnation in winter opposing to the elevated turbulence in summer.
- The NOx presents the higher concentration variation between winter and summer.
- The Agglomeration and Urban stations present a higher ratio for Winter/Summer because the larger distance from the highway, main source of pollution, which increase the role of the dispersion in summer.

- The shape of curves presents similarities for the same side of the passes and for many stations, i.e. case of NO_2 for Moleno, Camignolo and Bioggio. This explains that the meteorological effects may influence a large region.
- Chiasso knows the higher difference between winter and summer for the PM10 because this pollution is due mainly to domestic heating in winter [5].



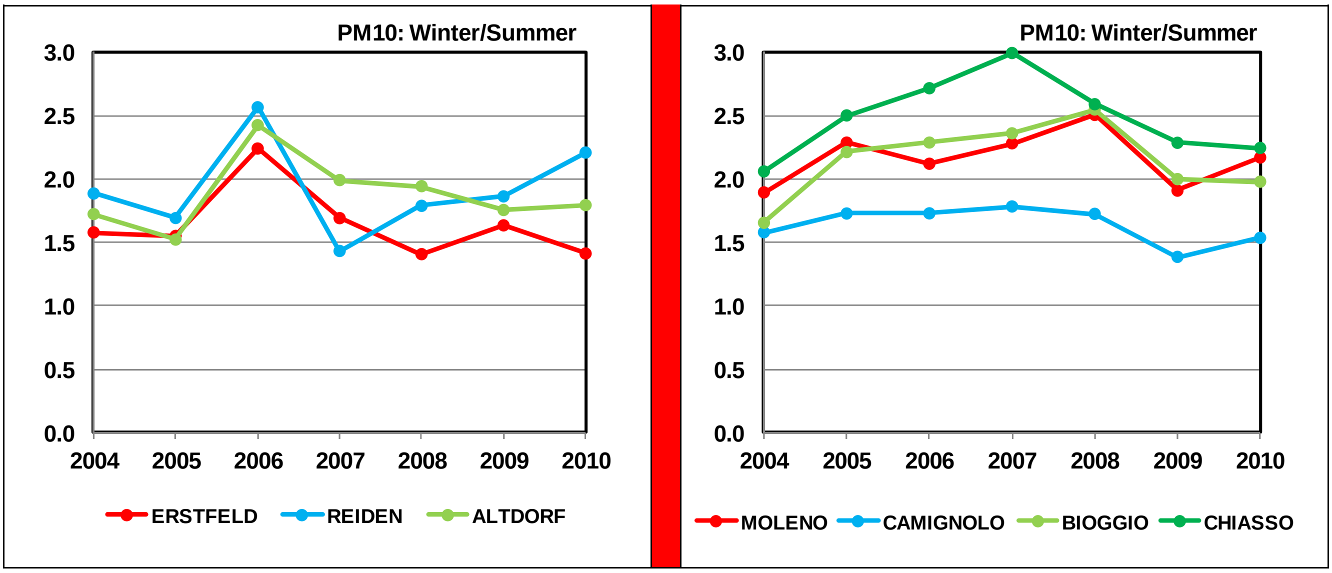
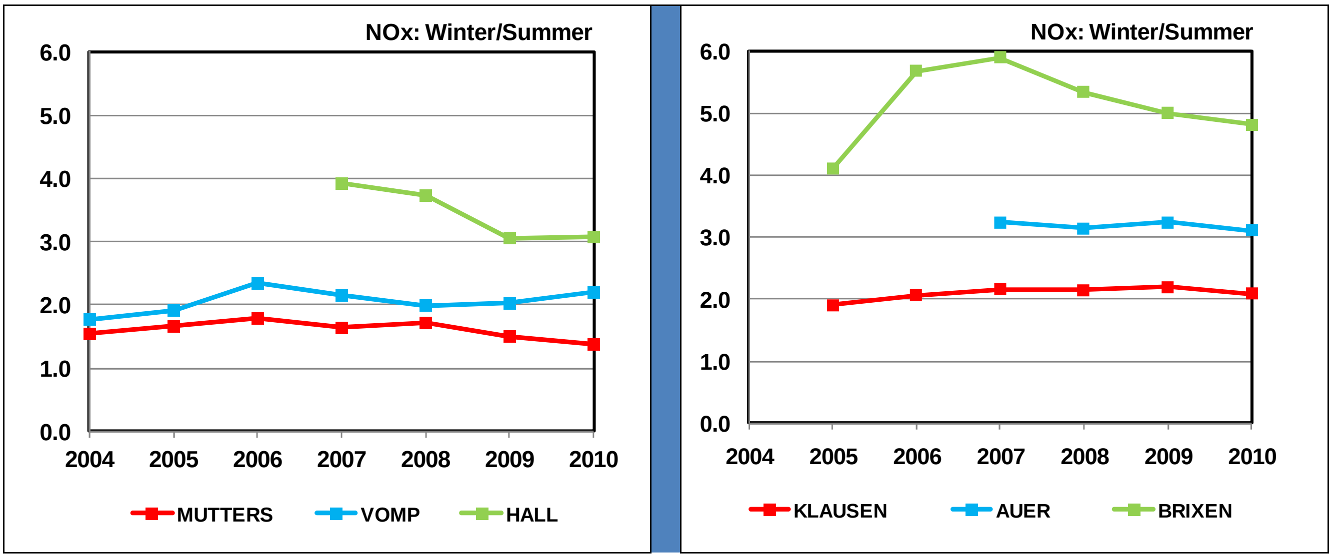


Figure 3.6: Seasonal variation of NOx, NO_2 and PM10 between winter and summer at Gotthard, 2004-2010.



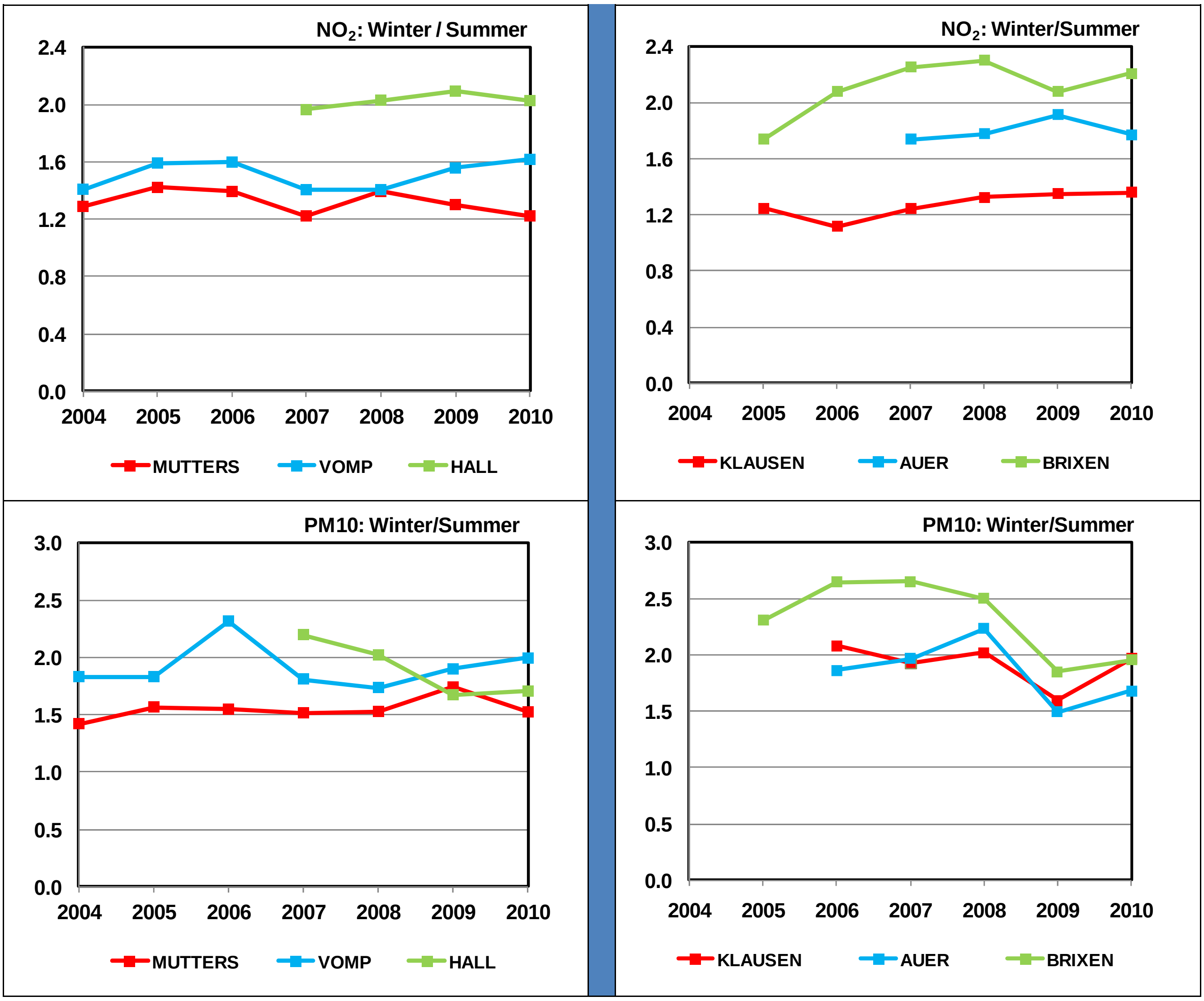


Figure 3.7: Seasonal variation of NOx, NO_2 and PM10 between winter and summer at Brenner, 2004-2010.

3.4. Number of Days over Threshold for PM10 2004-2010

The calculation of the days exceeding the threshold for the PM10 can be used as an indicator for describing the human exposure and the influence on the environment. The number of permitted days exceeding over threshold of 50 $\mu g/m^3$ for PM10 is fixed for 35 days/y since 2005 by EU-Directive. The limit in Switzerland is for one day of this exceeding per year and 25 in Austria since 2010 (Figure 3.8).

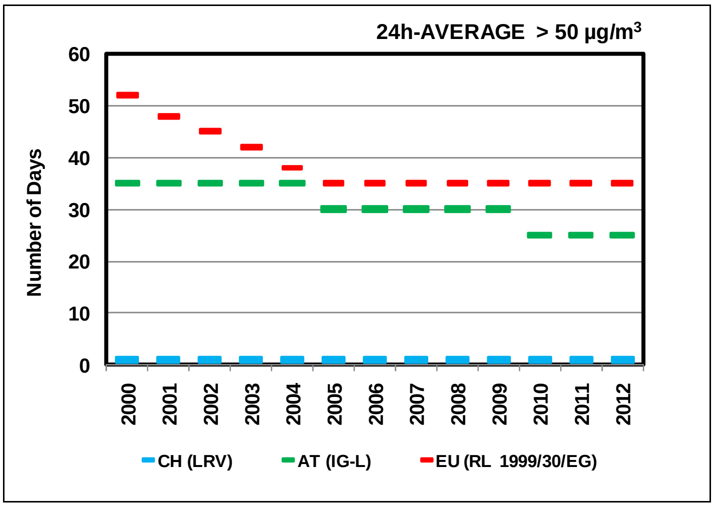
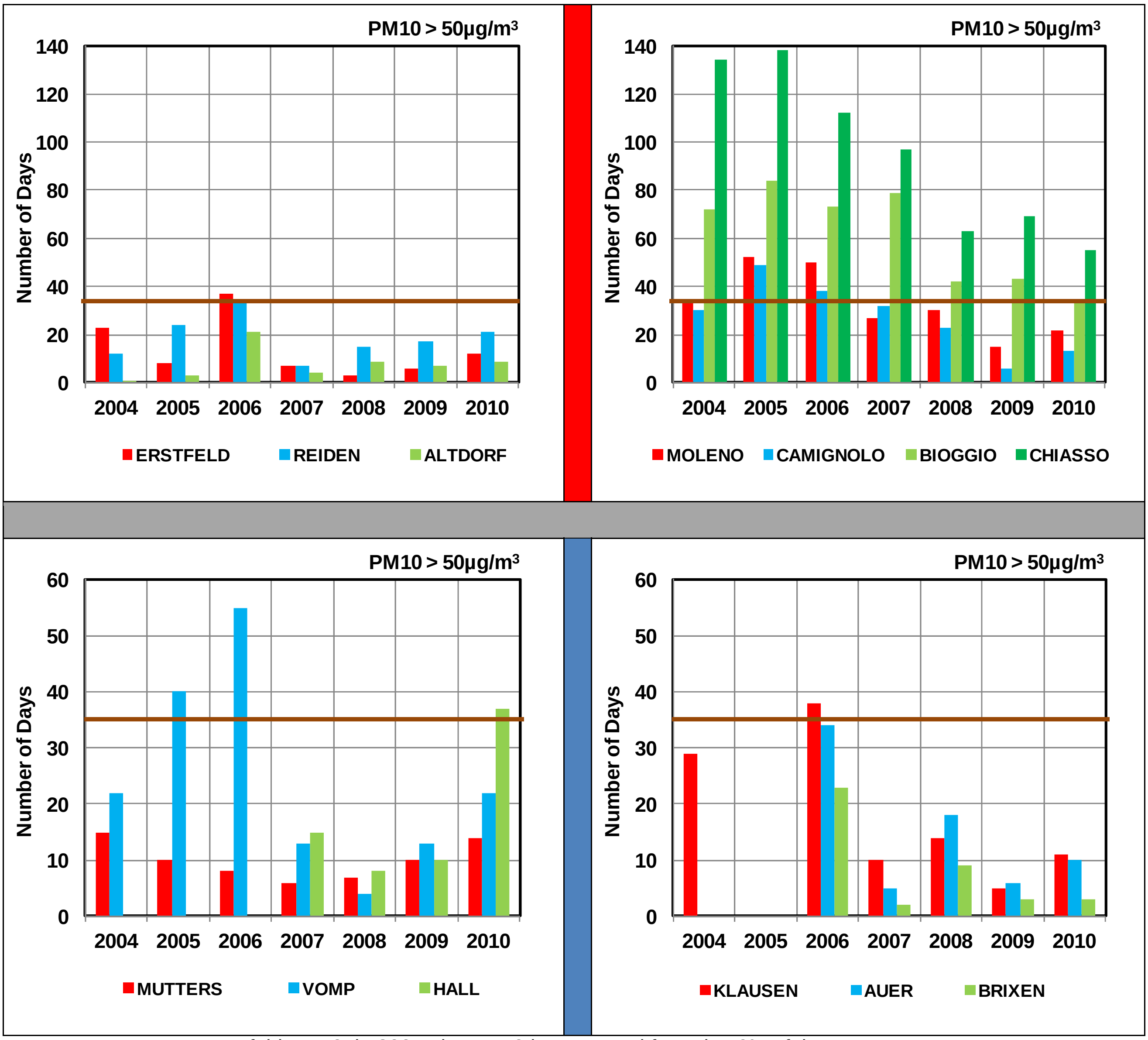


Figure 3.8: Daily limit value for PM10 concentrations for Switzerland (LRV), Austria (IG-L) and Europe (RL 1999/30/EG), 2000-2012.

For this calculation, daily data are required which was not available for all stations or years. The main results of this investigation show that:

- The highest exceeding is recorded in Ticino in spite of the remarkable decreasing since 2008. However, if the 35 days/year of the European Directive are considered (brown line in graphs), all stations in Central Switzerland and Brenner are under the exceeding, with exception for 2005 at Vomp and the year 2006 at most stations because of the bad meteorological parameters on a European level. The exceeding at Hall 2010 occurred because of the roadwork in the near area, as mentioned above.
- A classification with regard to the geographical situation of the station cannot be done: number of days of exceeding can differ for each year and part of the passes. At Central Switzerland, the station in “CV” register the higher exceeding, but at Ticino, the “UPV” station is higher and particularly the Agglomeration and Urban stations are at most exceeding the limits, including influence of the human activities.



* Erstfeld PM10: in 2007, the PM10 is measured for only 76% of the year.

Figure 3.9: Number of days per year over the daily threshold of 50 µg/m³ for PM10 at Gotthard and Brenner, 2004-2010.

4. Road Traffic 2004-2010

Road transport, main source of pollution in transit corridors, is considered in this study based on local records taken from a real traffic counting on highways. Therefore, a homogenization of 5 categories of vehicles is strived for both corridors.

4.1. Traffic Data Collection

Traffic data are presented in five different categories, which can be derived as estimations from three different counting systems (Italy, Austria and Switzerland). These five categories are:

Table 4.1: Road traffic categories and acronyms used in graphics:

Type of vehicle	**Acronym**
Passenger cars & Motorcycles	PC + MC
Light Duty Vehicles	LDV
Busses	BUS
Lorries	LORRIES
Trailer-Trucks	T-T

The "**Heavy Duty"** category is the sum of **Lorries + Trailer-Trucks**. The differentiation between LORRIES and T-T depends also on the counting system and therefore, their sum, in Heavy Duties, is the important category for this study.

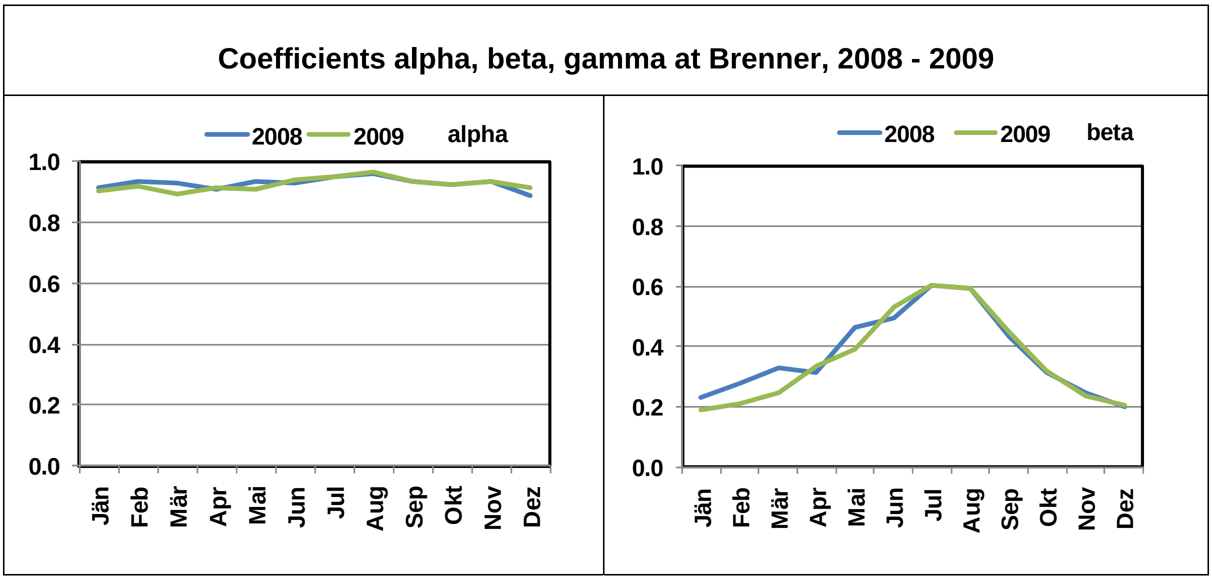
The traffic data were derived from the regional counting systems as follows:

Table 4.2: Estimation of traffic fluxes at Gotthard and Brenner:

Country	Traffic classifications	PC + MC	LDV	Busses	Lorries	Trailer-Trucks
		Passenger cars + Motorcycles	Light Duty Vehicles		Single trucks	inclusive articulated lorries
Switzerland (Gotthard)	Swiss 7	PW, MR	LW	Busse	LKW	Lastenzug, Sattelzug
Austria (Brenner north)	'8+1'	Pkw, Krad, Pkw mA, NkKfz	Lfw	Busse	SoloLkw	SZ, LZ
South Tyrol (Brenner south)	Classe di pedaggio A,B,'3','4','5'	A + β * '3'	α * B	(1-α)*B + (1 -β-γ)*'3'	γ* '3'	'5' + '4'

The 5 categories are derived for Swiss and Austrian counting stations by simple addition. The system for South Tyrol was derived from the Italian toll fee classifications (A,B,3,4,5) and traffic counting in '8+1' categories at Matrei (Brenner north).

The coefficients α, β, γ, derived with the help of the counting at Matrei, are dependent on season, but were well repeated for 2008 and 2009:



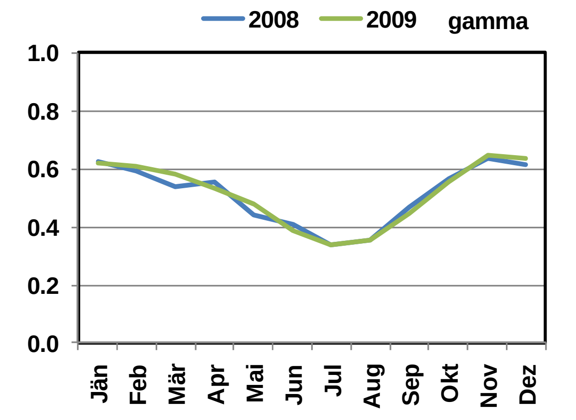


Figure 4.1: Seasonal variation of traffic categories coefficients α, β, γ for A22 (South Tyrol).

The used values for South Tyrol (Highway A22) are as follows:

Table 4.3: Values of α, β, γ for A22 (South Tyrol):

	Alpha	Beta	Gamma
Jan	0.91	0.21	0.62
Feb	0.93	0.24	0.60
Mar	0.91	0.29	0.56
Apr	0.91	0.32	0.54
May	0.92	0.43	0.46
Jun	0.93	0.51	0.40
Jul	0.95	0.60	0.34
Aug	0.96	0.59	0.36
Sep	0.93	0.44	0.46
Oct	0.92	0.32	0.56
Nov	0.93	0.24	0.64
Dec	0.90	0.20	0.62

The hourly values of vehicle's length classification showed a similar temporal behavior as the toll fees classes’ data. But in absolute values, the compatibility was not given to use these data for calculating the traffic in the five categories. Also, the amounts of vehicles with 4 or 5 axis were rather larger (ca. +10%) than those for vehicles with lengths >12.5 m (we would expect the contrary because of long busses, and in any case only small differences).

For Vomp traffic counting data are available from April 2004.

For Mutters, for 2004-2006 and 2009-2010, the traffic data are estimated from the data of Matrei, traffic counting station located in the south of Mutters.

In following graphics, data are presented as the Annual Average Daily Traffic (AADT).

4.2. Road Traffic in 2010

Data analysis shows that the traffic is higher in the “CV” as in “UPV” (Figure 4.3). In the latter, the local traffic is more significant.
To apprehend the existing difference between the two parts of the valley, a short examination of the hourly data of PC+MC is carried out. In fact, the curves shape of the hourly variation of the AADT for this vehicle category shows the effect of the local traffic in the “CV”: two commuter peaks are taking place, in the morning at 7:00 - 8:00h and in the afternoon at 17:00 – 18:00h (see example of Reiden in the “CV” for 2004 and 2010, Figure 4.2).
However, this is not the case in the “UPV”: in this part of the valley, the rush hours are reduced because the traffic is more influenced by the transit and regional tourism. The morning peak takes place at 10:00 - 11:00h and the afternoon peak at 17:00 - 18:00h and a high amount of vehicles continues to flow between the two peaks (see example of Erstfeld in 2004 and 2010, Figure 4.2).

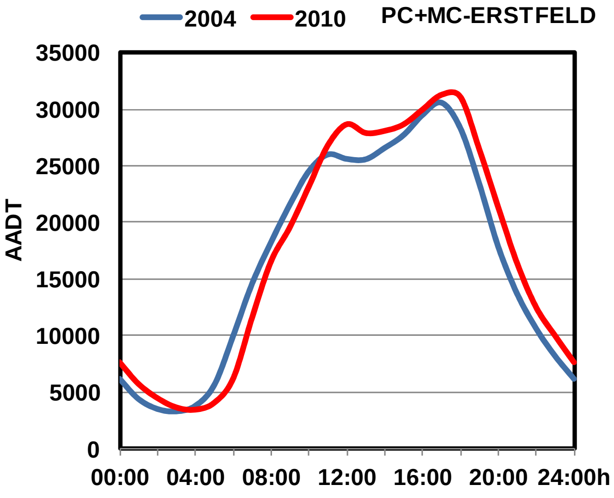
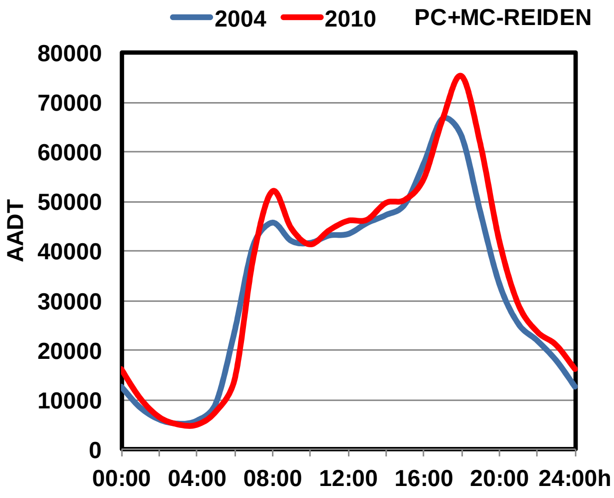
“UPV”	“CV”
	

Figure 4.2: Hourly variation of the AADT for PC+MC at Erstfeld (“UPV”) and Reiden (“CV”) for 2004 and 2010.

For 2010, data analysis shows that:

- The Brenner records higher amounts of heavy duties than the Gotthard. The PC+MC are in the north higher at Brenner, in the south higher at Gotthard (Figure 4.3).
- At “UPV” stations, the mean number of PC+MC varies from 15000 vehicles/day at Erstfeld to 33500 vehicles/day at Mutters. The maximum of PC+MC number is registered by the “CV” stations: Camignolo and Vomp with more than 40000 veh./d.
- This situation is also found for the Heavy Duty vehicles: In the proximity of the pass (“UPV”), the number of vehicles decreases.

Annex 1 includes the results of the five vehicles categories as well as the total vehicles per station and per year from 2004 to 2010.

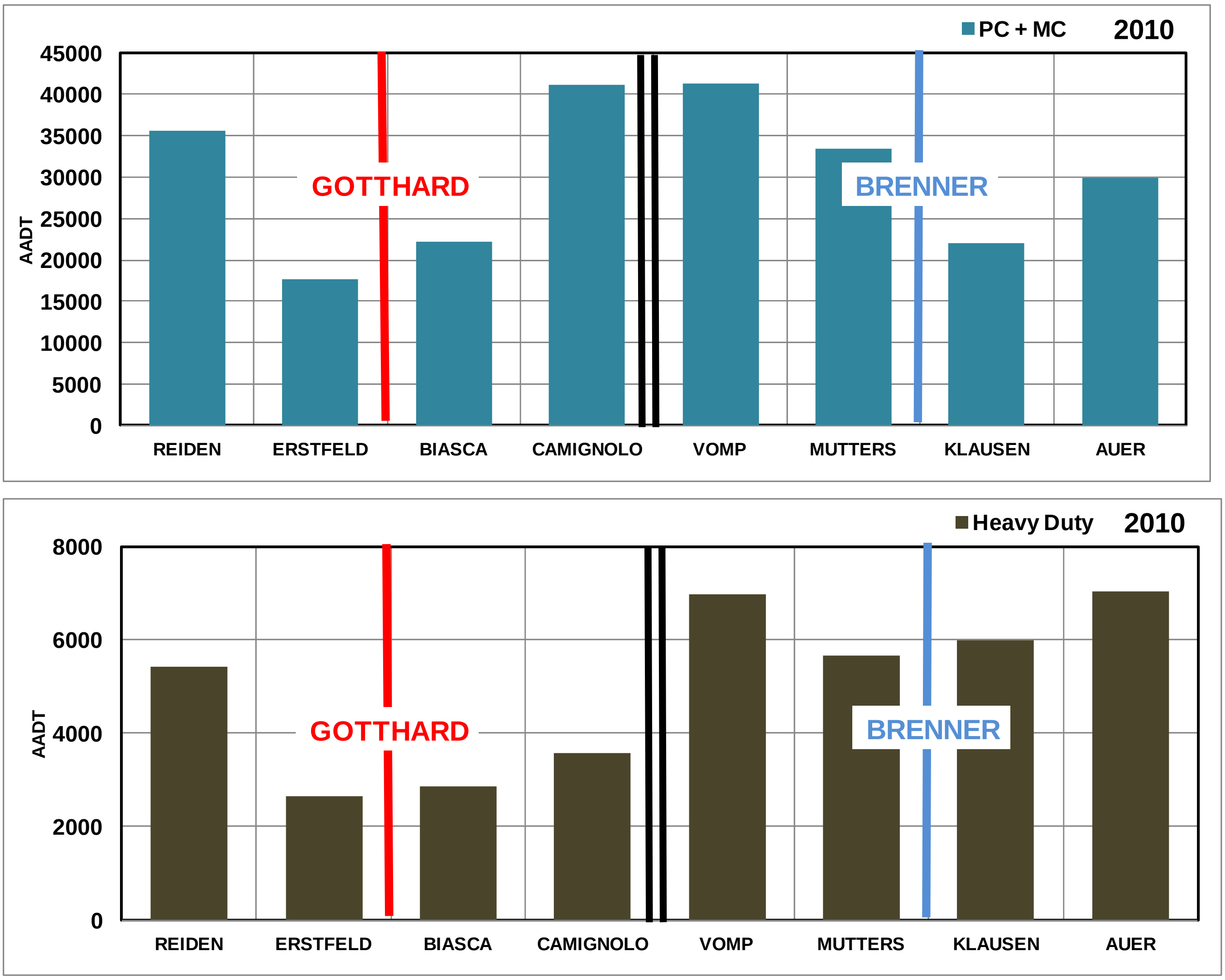


Figure 4.3: AADT of PC+MC and Heavy Duty categories at Gotthard and Brenner in 2010.

→ The next Figure 4.4 compares the traffic directly recorded at both Passes Gotthard and Brenner for 2010. The Brenner-pass registers about a quarter of PC+MC more than Gotthard and more than the double of Heavy duties.

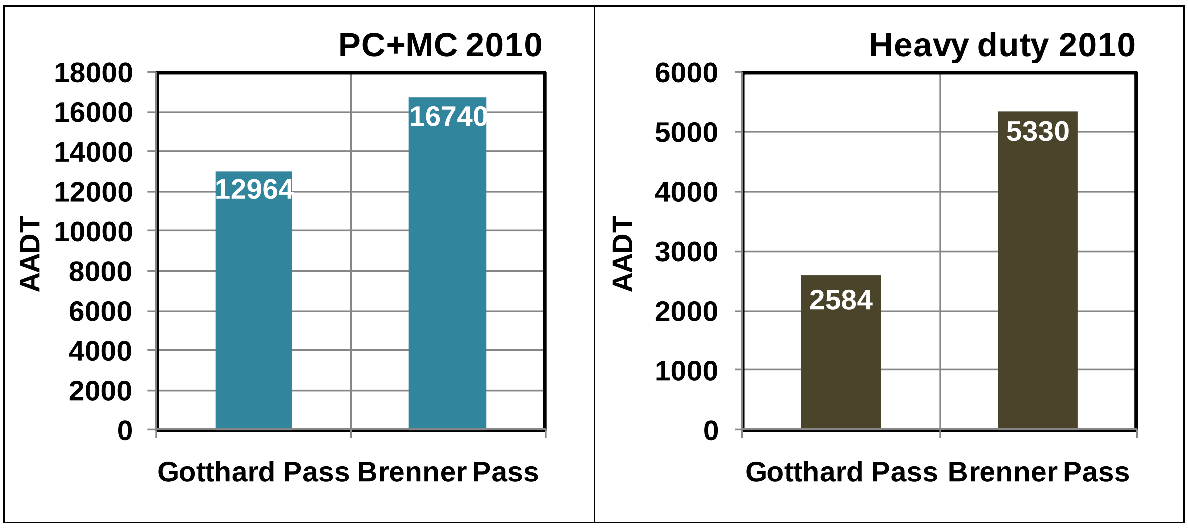


Figure 4.4: AADT of PC+MC and Heavy Duty at Gotthard and Brenner-Passes in 2010.

→ The relationship between the AADT of vehicles recorded at the Pass and those recorded in different part of the valley is the portion of transalpine traffic in that part.

The main results of this indicator in 2010 are:

- The difference between "**CV**" and "**UPV**"-region are evident concerning the portion of transalpine traffic: all "UPV" have a greater percentage of transalpine PC+MC and Heavy Duty. Therefore the "CV" has more local traffic.
- The percentage of transalpine traffic is higher for the Heavy Duty category than the PC+MC, reaching more than 95% in the "CV"-regions.
- For the **PC+MC** category:
  - Gotthard: Central Switzerland knows higher percentage of transalpine vehicles with Erstfeld 73%, against 58% at Biasca, Ticino. The "CV"-regions register less than 40% of transalpine traffic.
  - Brenner: Italian part knows higher transalpine part: example of Klausen which 76% of its PC+MC are transalpine. The difference between the two parts of the Brenner is the presence of high amount of local traffic and commuter in the surroundings of Innsbruck and its agglomeration.
- For the **Heavy Duty** category, all the stations in the "UPV"-regions register 89 - 97 % of transalpine portion, and the "CV"- station register 70 - 80 %, with the exception of Reiden (less than 50%) which is located in the Swiss Plateau with other than the transalpine highways in the surrounding as well.

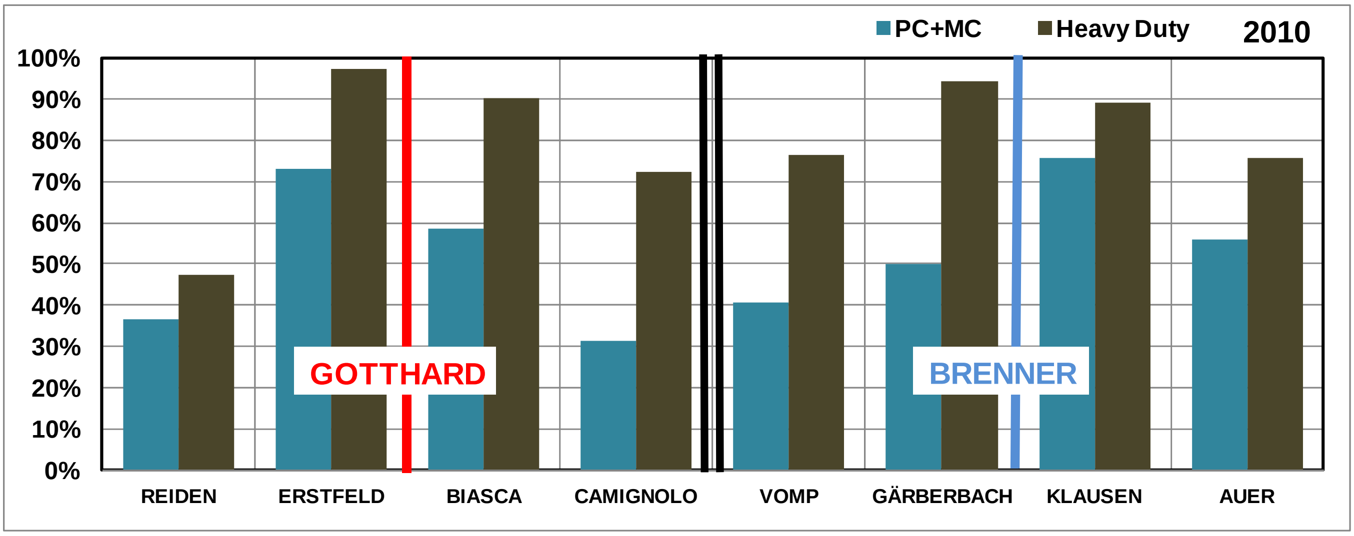


Figure 4.5: Relationship between AADT of PC+MC and Heavy Duty recorded at each station and the AADT recorded at the Passes (Gotthard and Brenner) in 2010.

→ The proportion of Heavy Duty on the total vehicles numbers indicates the weight of the freight transport about the rest of the traffic (passenger transport, public transport, light freight transportation) through the corridors.
This indicator is calculated for 2010 for the stations in the “UPV”, so that it includes nearly only the transalpine freight.

The Brenner register a higher percentage of Heavy Duty of the Total vehicles: Mutters counts 13% of Heavy Duty in the total vehicles and Klausen 19%.
At Gotthard, the stations count nearly 12% for Erstfeld and 10% for Biasca. The Central Switzerland counts a higher percentage of freight transit.

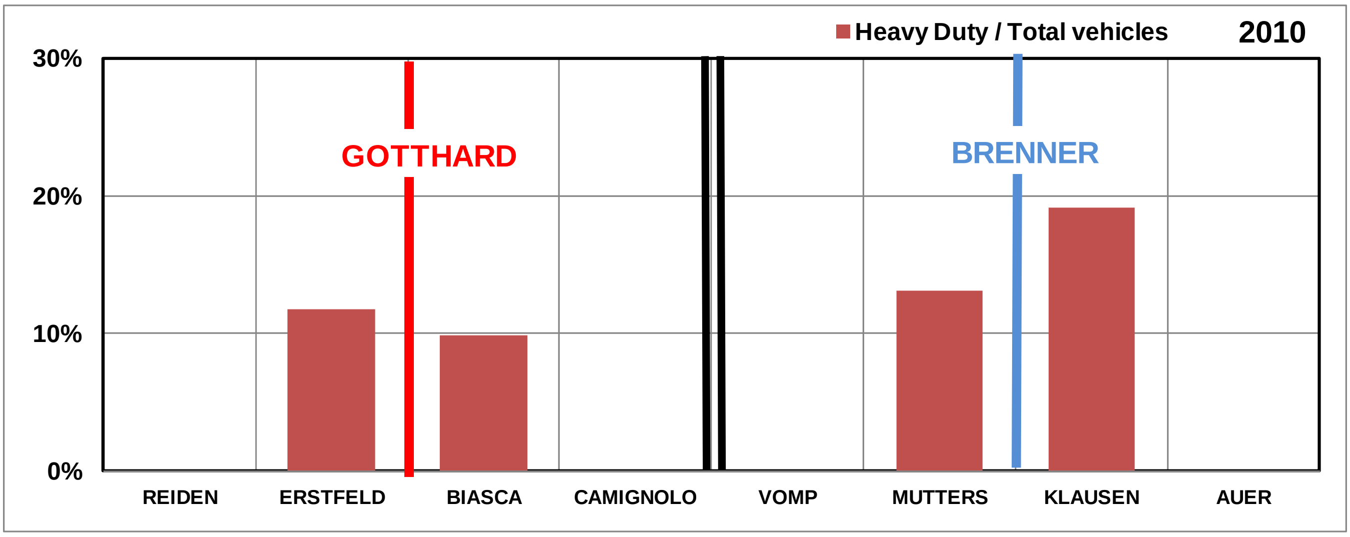


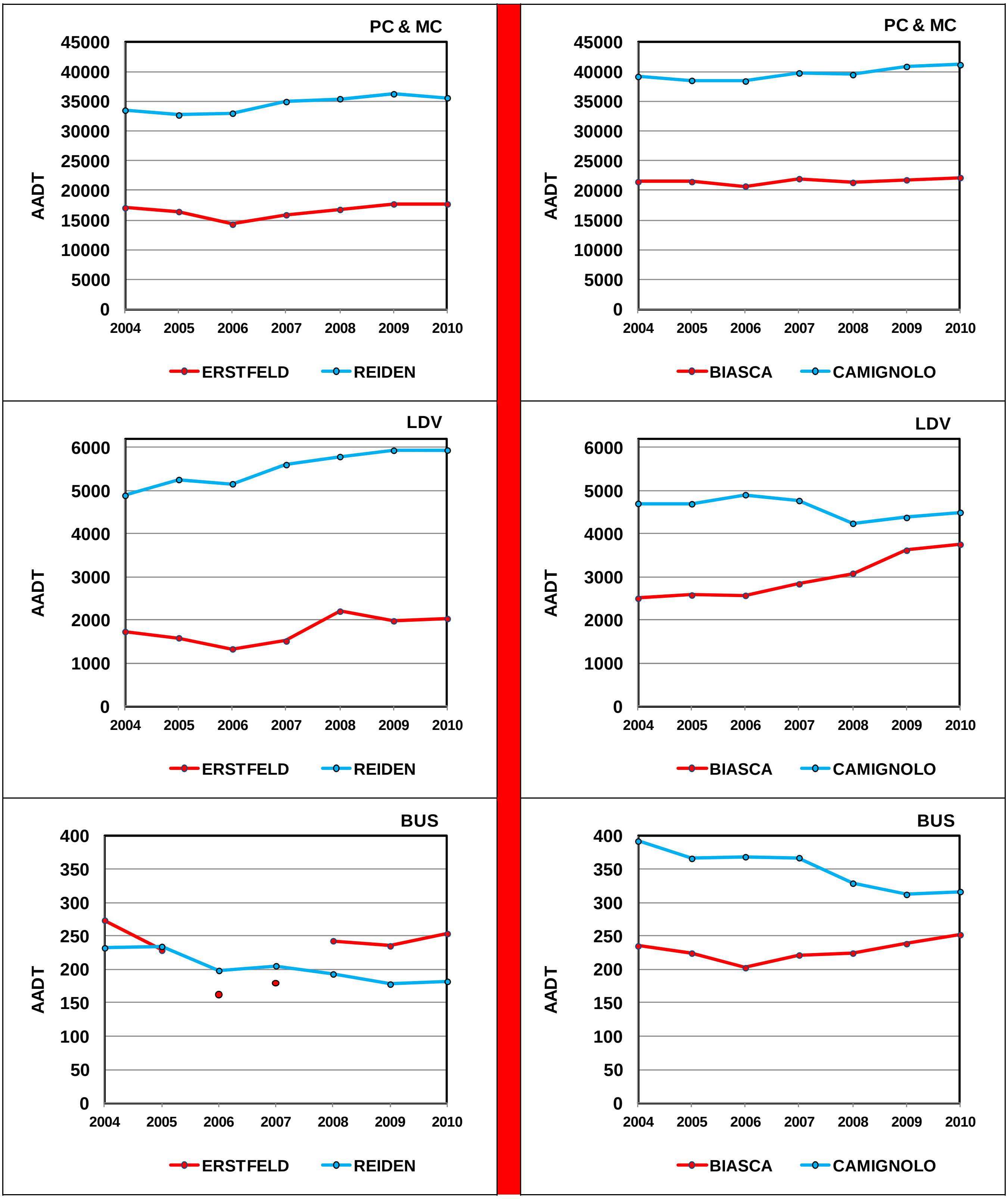
Figure 4.6: Relationship between the Heavy Duty and the Total vehicles in the Upper part Valley at Gotthard and Brenner in 2010.

4.3. Annual Road Traffic Development and Trends 2004-2010

The Annual Average Daily Traffic (AADT) is presented for the five vehicles categories and the Heavy Duty at Gotthard and Brenner stations from 2004 till 2010.

The main results of the traffic development are:

- All stations in the “CV” have higher amounts of all vehicles categories than at the “UPV”, with exception for BUS at Tyrol and at Erstfeld (where approaches were necessary for 2006-2007).
- The shape of the curves between the stations at the same side of the pass has good similarity for the four categories of PC+MC, LDV, LORRIES and T-T. The BUS has different behavior depending on stations.
- Heavy Duty shows respite in 2009 due to the world economic crisis at Gotthard and an accentuated one at Brenner and then both corridors show an increase in 2010.


PC & MC
AADT
45000 40000 35000 30000 25000 20000 15000 10000 5000 0
2004 2005 2006 2007 2008 2009 2010
ERSTFELD
REIDEN
PC & MC
AADT
45000 40000 35000 30000 25000 20000 15000 10000 5000 0
2004 2005 2006 2007 2008 2009 2010
BIASCA
CAMIGNOLO
LDV
AADT
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2004 2005 2006 2007 2008 2009 2010
ERSTFELD
REIDEN
LDV
AADT
6000 5000 4000 3000 2000 1000 0
2004 2005 2006 2007 2008 2009 2010
BIASCA
CAMIGNOLO
BUS
AADT
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BIASCA
CAMIGNOLO

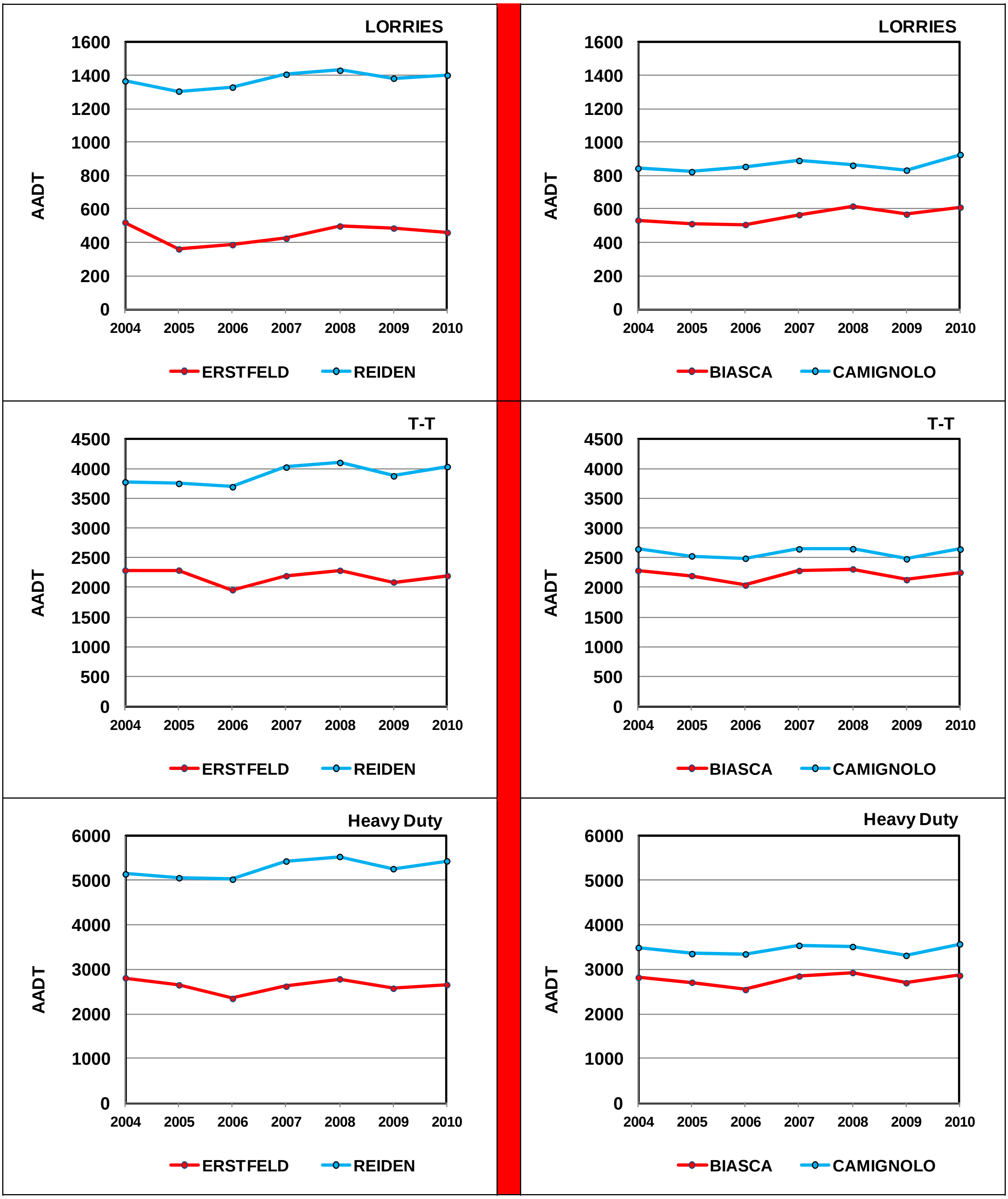
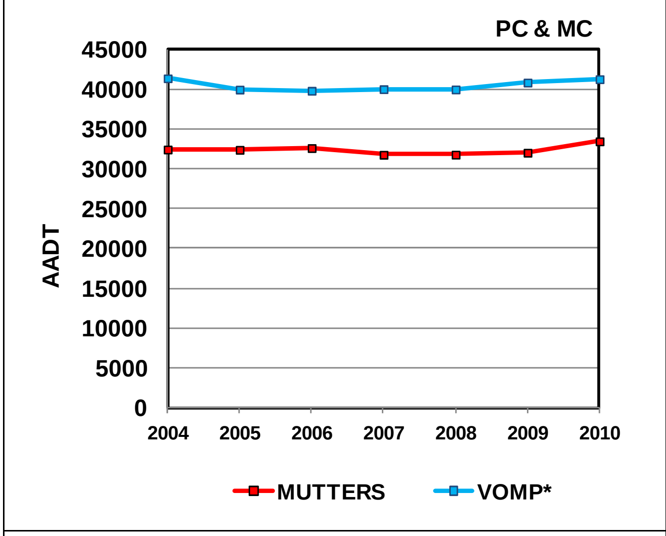


Figure 4.7: Annual Average Daily Traffic (AADT) of Passenger Cars & Motorcycles, Light Duty Vehicles, Busses, Lorries and Trailers-Trucks and the Heavy Duty at Gotthard, 2004-2010.


PC & MC
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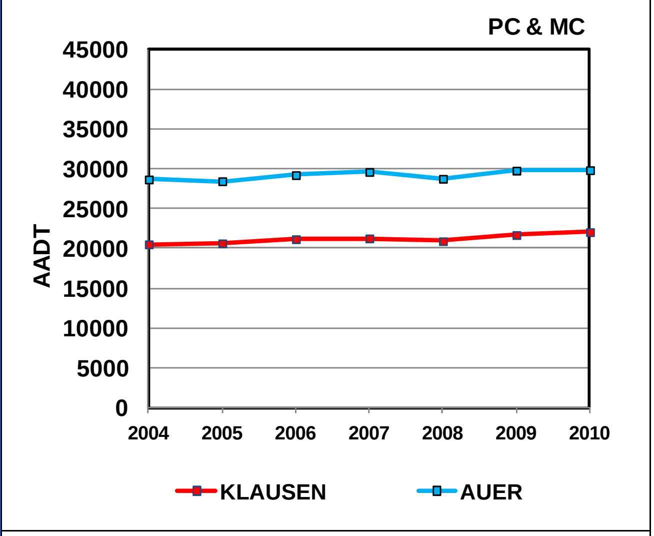
2009
2010
MUTTERS
VOMP*


PC & MC
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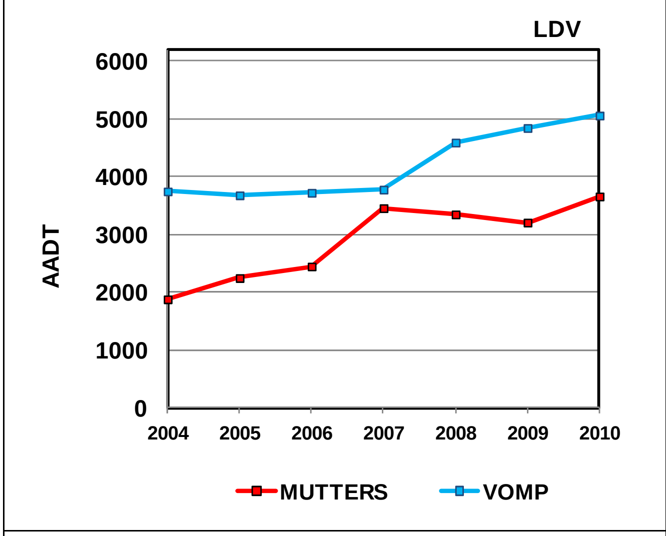
AUER


LDV
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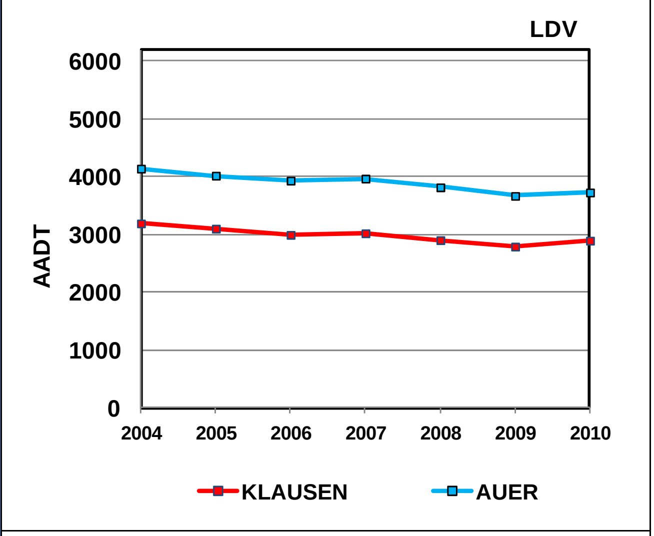
LDV
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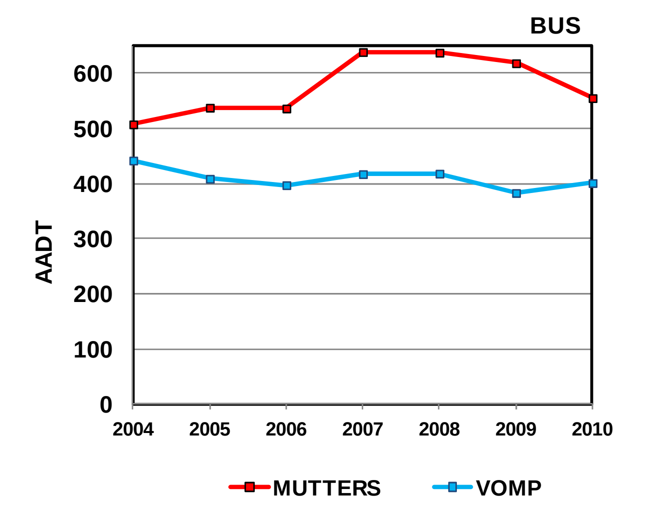
BUS
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MUTTERS
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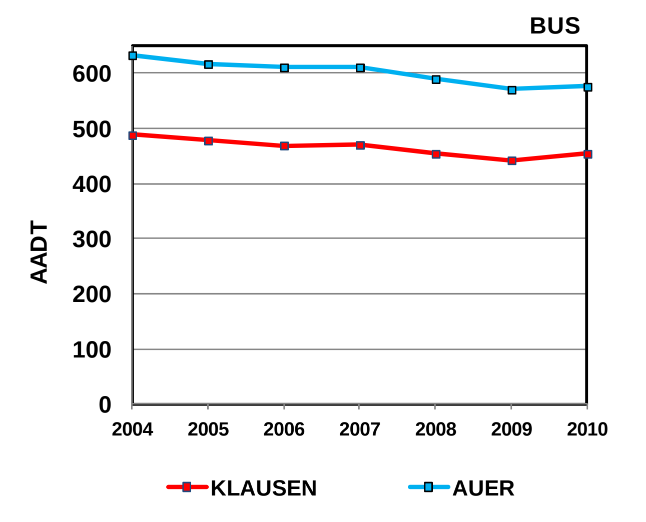
BUS
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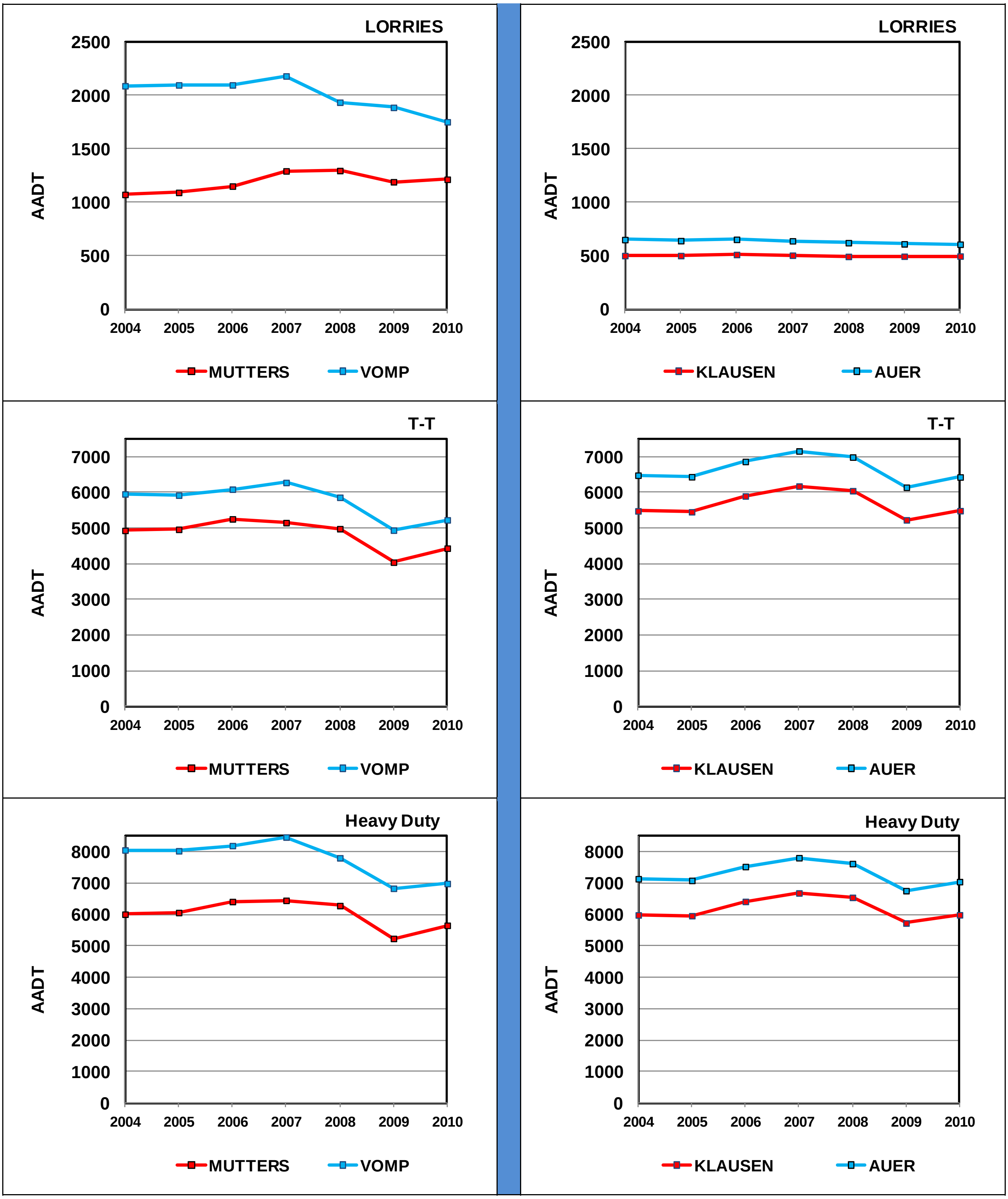
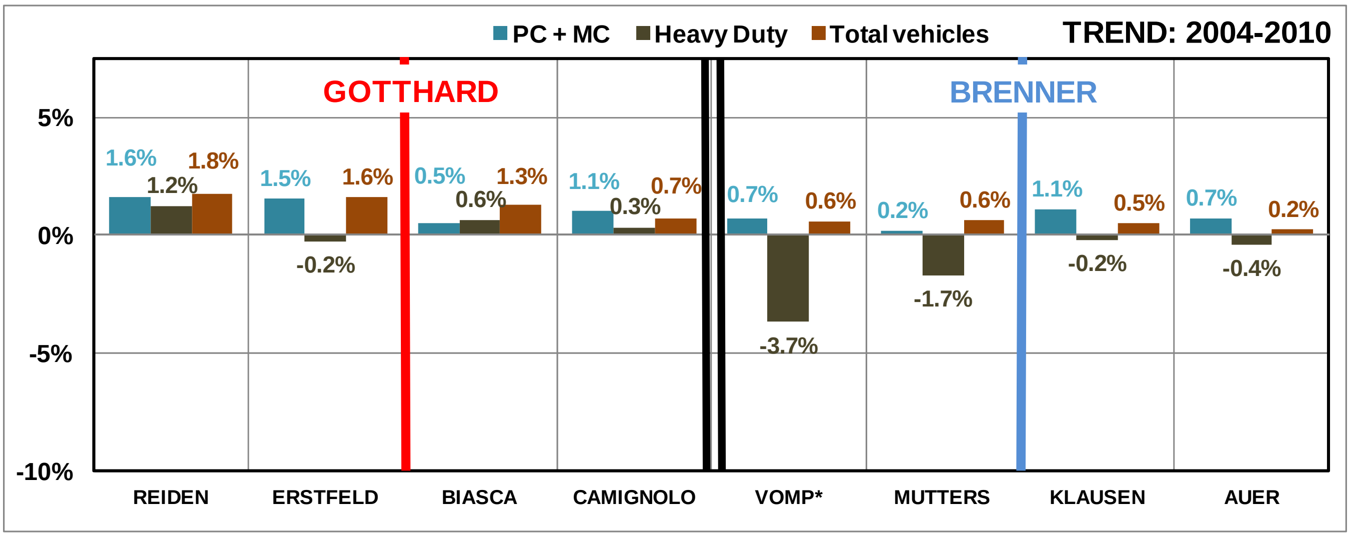


Figure 4.8: Annual Average Daily Traffic (AADT) of Passenger Cars & Motorcycles, Light Duty Vehicles, Busses, Lorries and Trailers-Trucks and the Heavy Duty at Brenner, 2004-2010 *(*For Vomp, the traffic counting started in April 2004).*

→ The trend calculated for the Total vehicles, PC+MC and the Heavy Duty between 2004 and 2010 shows the following results:

- The annual trend of the **Total vehicles** is positive for all stations. For both corridors, the increases are higher for the stations in the “UPV” in southern side of the pass. The other side knows equal increase for “CV” and “UPV”. The Central Switzerland part records an increase for +1.6%/y at Erstfeld and +1.8%/y at Reiden. Less increase at Ticino part with +1.3%/y and +0.7%/y respectively at Biasca and Camignolo.
  Brenner have a slight increase of the Total vehicles, particularly at Auer where the traffic is stable between 2004 and 2010.
- The annual trend of the **PC+MC** is also positive for all stations for 2004-2010. North of Gotthard and Italian Brenner register the higher increases with more than +1%/y, reaching +1.6%/y at Reiden and +1.1%/y at Klausen.
- As for the **Heavy Duty**, the trend from 2004 to 2010 is positive at Gotthard with exception of Erstfeld and negative at Brenner with -3.7%/y at Vomp (for 2005-2010), -1.7%/y for Mutters. The freight transit is directly influenced by the world economic crisis at Brenner, and in Tyrol, the effect of measures concerning heavy duties can also be seen (Figure 4.9).



* For Vomp, the trend is calculated from 2005 to 2010.

Figure 4.9: Trend (in %) per year of PC+MC, Heavy Duty (Lorries + Trailer-Trucks) and the Total vehicles at Gotthard and Brenner, 2004 – 2010.

5. Road Traffic Emissions and their Trend 2004-2010

The emissions of NOx, NO_2 and Particulate Matter (PM) are calculated from the fleet data previously presented in chapter 4, based on the emission factors of the Handbook HBEFA 3.1 as follows.

All vehicle categories except Heavy Duty:

Gotthard: HBEFA 3.1 for Switzerland, corresponding to year and to light vehicles speed.

Brenner: HBEFA 3.1 for Austria, corresponding to year and to light vehicles speed.

Heavy Duty:

Emission factors per euro class from HBEFA 3.1.

Distribution of euro classes:

Gotthard: Mixing of transit fleet and mean Swiss fleet (as postulated by HBEFA 3.1); at Erstfeld, only transit fleet. Transit fleet: Corresponding to ALPIFRET (2009) [1] and Bundesamt für Verkehr (2011) [6] and [7].

Brenner: Corresponding to CAFT (2009) [2]. Temporary development following the fleet modernization model from TU Graz [3]. Transalpine fleet is more modern than average fleet (by one year), in Tyrol fleet is essentially more modern than in Austrian average because of the Tyrolean measures, thus affecting also the situation in South Tyrol, where Klausen is equal to Vomp and Mutters, Auer one year older in the average.

The following distributions of euro classes for Heavy Duty (example of 2009) were used:

Table 5.1: Euro classes of Heavy Duty vehicles at Gotthard, 2009:

	EURO 0	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6	TOTAL
Erstfeld	1.3%	1.7%	5.9%	37.7%	15.6%	37.9%	0.0%	100.0%
Moleno	1.3%	1.8%	6.1%	37.6%	15.5%	37.7%	0.0%	100.0%
Reiden	1.9%	2.7%	8.0%	36.7%	14.9%	35.9%	0.0%	100.0%
Camignolo	1.6%	2.1%	6.9%	37.2%	15.2%	37.0%	0.0%	100.0%

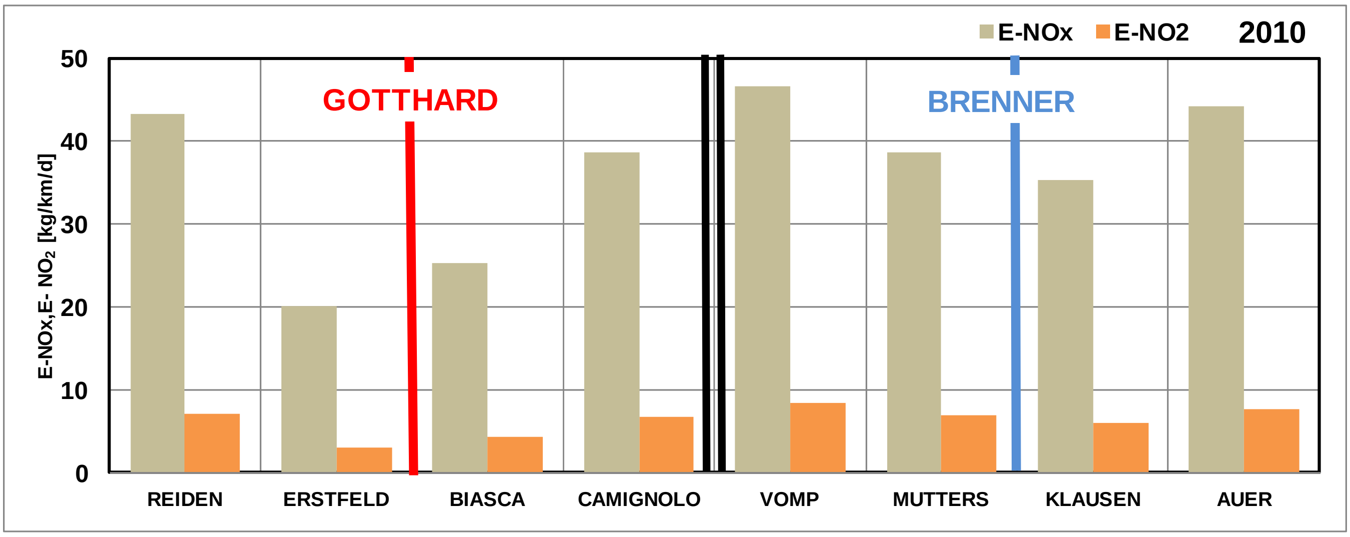
Table 5.2: Euro classes of Lorries and Truck-Trailers at Brenner, 2009:

Lorries 2009	Euro 0-1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	TOTAL
Vomp, Gärberbach, Klausen	4.6%	12.6%	36.1%	18.2%	28.5%	0.0%	100.0%
Auer	5.9%	15.3%	41.1%	19.4%	18.3%	0.0%	100.0%
Truck-Trailers 2009	Euro 0-1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	TOTAL
Vomp, Gärberbach, Klausen	0.1%	1.0%	34.9%	13.4%	50.6%	0.0%	100.0%
Auer	0.4%	2.6%	40.0%	15.2%	41.8%	0.0%	100.0%

5.1. Emissions of NOx, NO_2 and PM in 2010

As a direct consequence of the traffic data, the emissions of pollutant are higher in the “CV” for all pollution in 2010 (Figure 5.1). At Reiden, Camignolo, Vomp and Auer, NOx-emissions are close to or more than 40 kg/km/d for 2010. On the other hand, at Erstfeld and Biasca, less than 25 kg/km/d are emitted.

PM-emissions are higher at Brenner than at Gotthard. However, for both corridors, the emissions are higher in the “CV”.



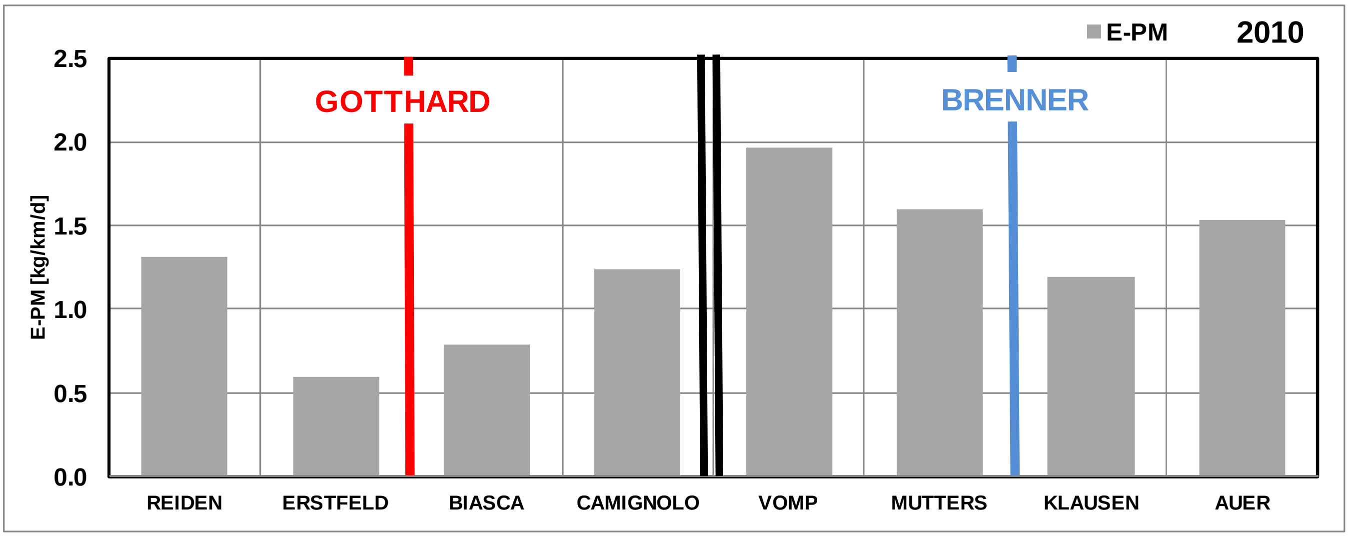


Figure 5.1: Emissions of NOx, NO_2 and PM at Gotthard and Brenner in 2010.

The next Figure 5.2 compares the emissions calculated for the traffic registered directly at both Passes Gotthard and Brenner for 2010 (see Figure 4.4). The Brenner-pass knows about 50% more emissions of NOx and NO_2 than Gotthard and nearly the double of PM.

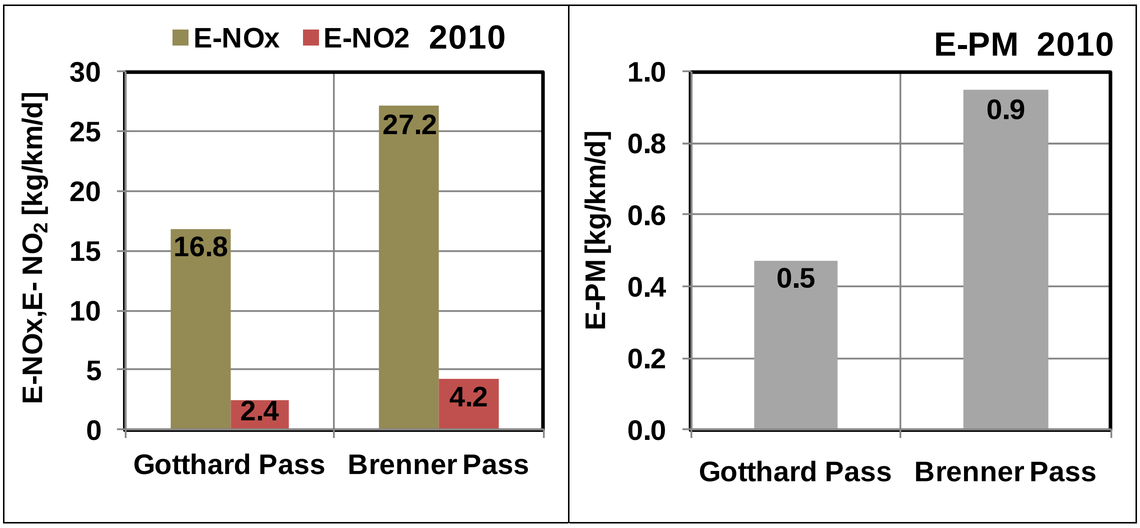


Figure 5.2: Emissions of NOx, NO_2 and PM at Gotthard and Brenner-Passes in 2010.

→ Emission emanating of the transalpine portion: this calculation refers to the chapter 4.2, (see Figure 5.2 and Figure 5.3).

- The transalpine portions are similar for all emissions (NOx, NO_2 and PM) per station.

- The portions are higher in the "UPV" with 60 – 80 % than in the "CV"-regions with 40 – 60 % of the total emissions.
- Klausen and Erstfeld in the "UPV" and Auer in the "CV"-region show the largest transalpine portions of the emissions, corresponding to the transalpine traffic portions.

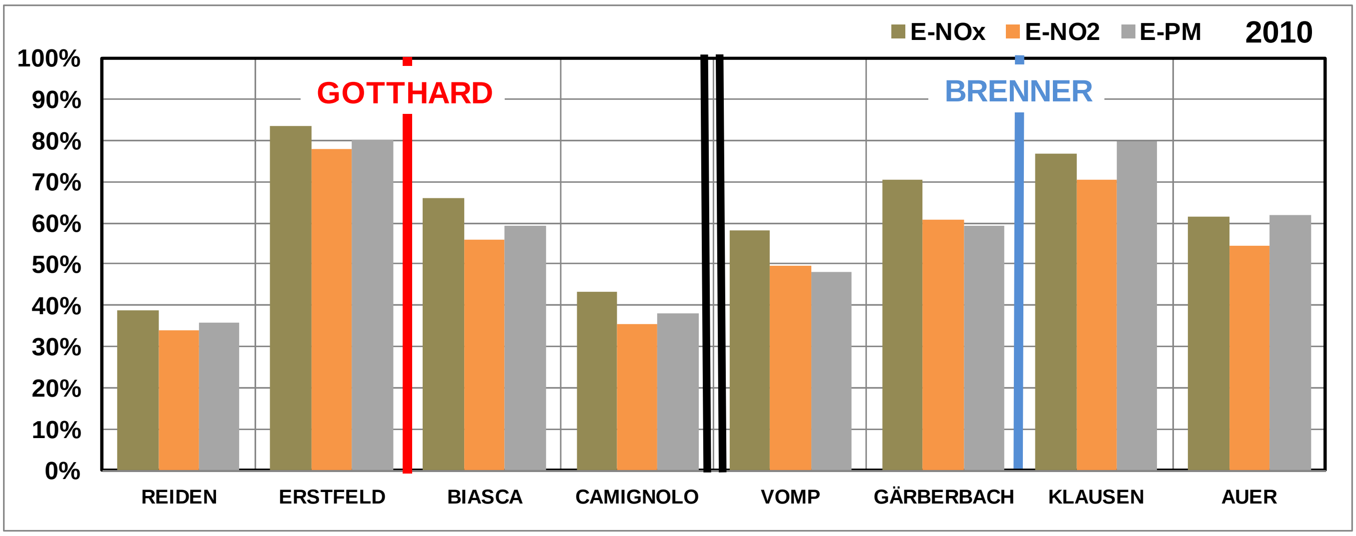


Figure 5.3: Transalpine portion: ratio of emissions (NOx, NO_2 and PM) for the Passes (Gotthard and Brenner) on emissions for each station in 2010.

5.2. Annual Emissions Development and Trends 2004-2010

The emission factors (NOx and Particles) of vehicles and particularly of the Heavy Duty are decreasing through years because of the progress in the vehicles construction. Consequently, the modernization of the vehicles fleet on European roads follows this progress.
As for the NO_2 emissions, the newer emissions factors are increasing because of the direct emitted NO_2.

In spite of the slight increase of the fleet at Gotthard and Brenner, the emissions of NOx and PM are considerably decreasing for all stations.
The NO_2 emissions increases at Reiden and Camignolo, it passes from 6 to 7 kg/km/d from 2004 to 2010. Vomp and Auer know a stability going around 9 and 8 kg/km/d correspondingly.

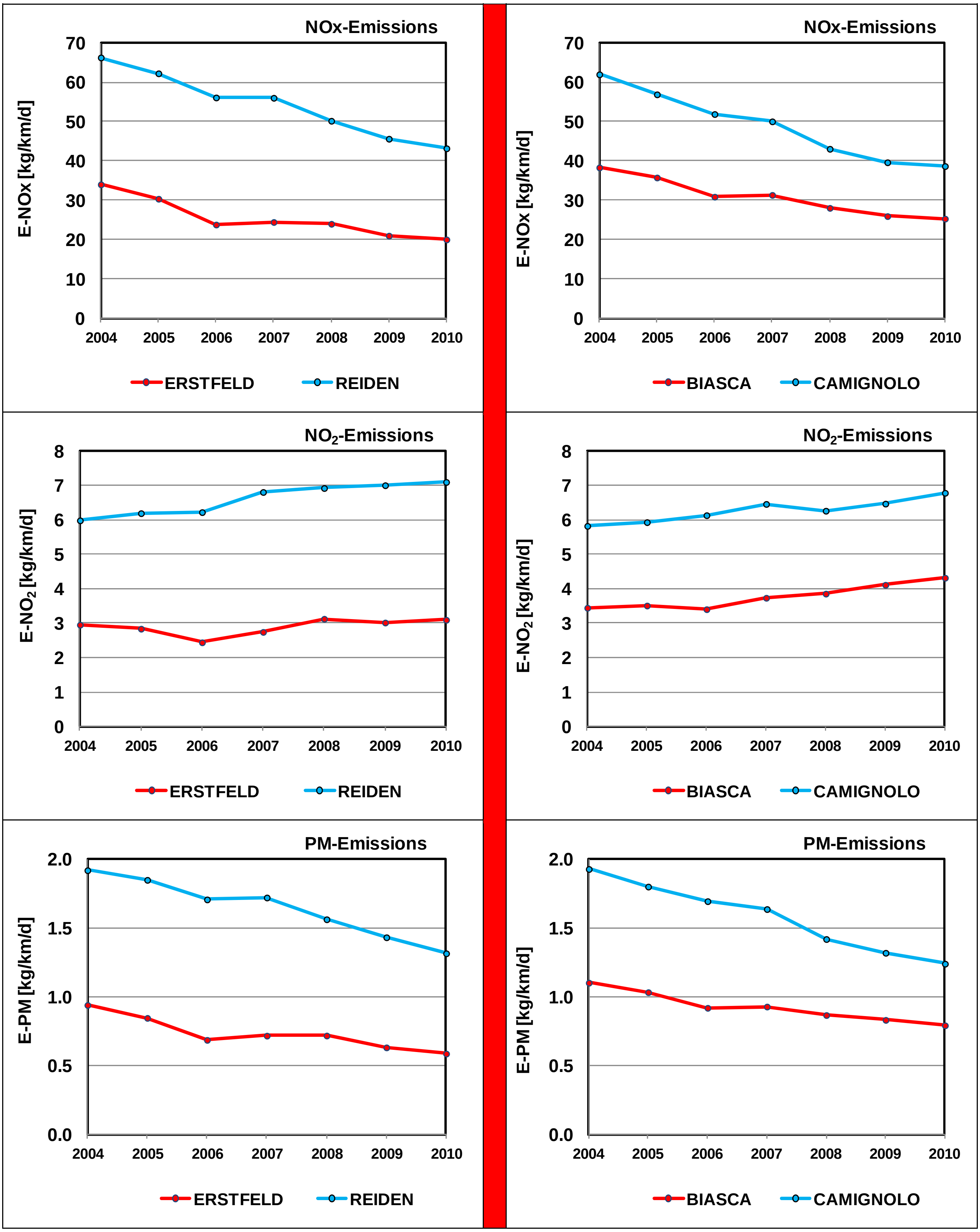


Figure 5.4: Emissions of NOx, NO_2 and PM at Gotthard, 2004-2010.

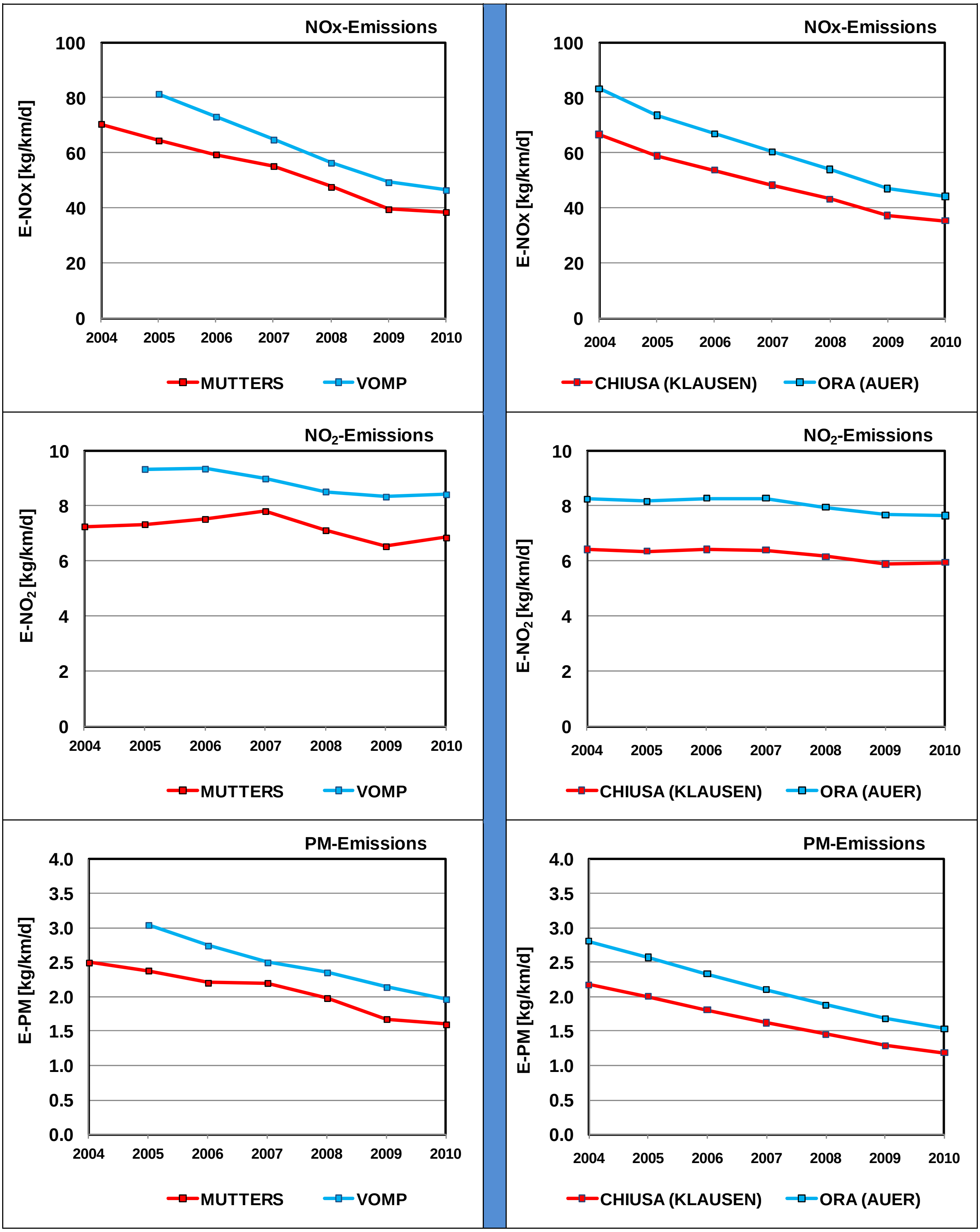
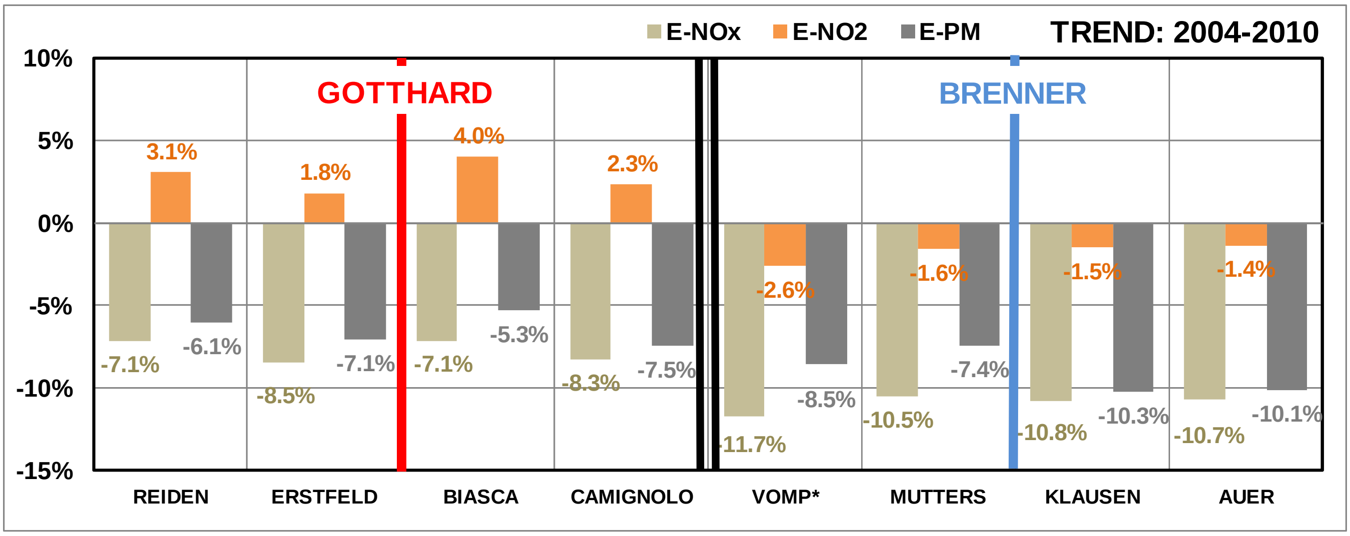


Figure 5.5: Emissions of NOx, NO_2 and PM at Brenner, 2004-2010.

→ Therefore, the trends of the NOx and PM emissions are negative at all stations between 2004 and 2010.

- At Gotthard, the NOx emissions are decreasing the most at Erstfeld with -8%/y. At Brenner, for all the stations, the decrease is approximately -11%/y (Figure 5.6). The larger reduction at Brenner is also an effect of the measures taken in Tyrol.
- The NO_2 emissions are positive at Gotthard and negative at Brenner. In fact, in Switzerland, the portion of Diesel PC is still increasing (in opposite to Austria and probably also Italy), so that the NO_2 emissions have also increased from 2004-2010.



* For Vomp, the trend is calculated from 2005 to 2010.

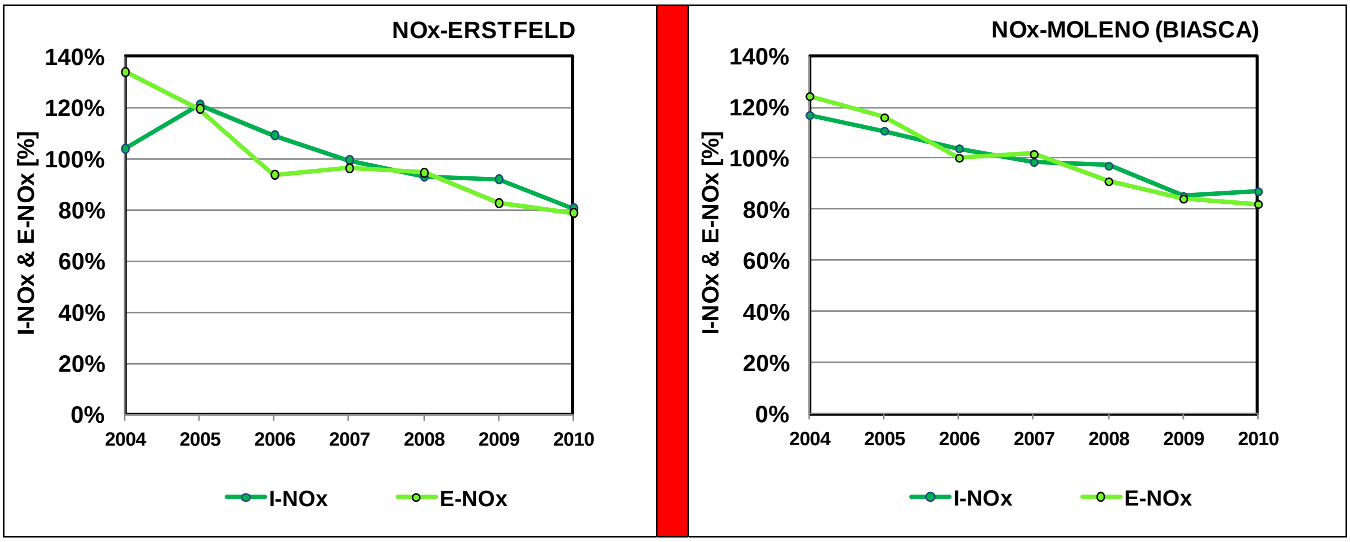
Figure 5.6: Trend (in %) per year of the emissions of NOx, NO_2 and PM at Gotthard and Brenner, 2004 – 2010.

6. Air pollution of NOx related to Road Emissions 2004-2010

The relation between emissions and corresponding air concentrations is an indicator to the comprehension of the temporary development of air pollution, to modelling, to measures etc. The next two sections treat with this relation.

6.1. Relative Behavior of Air Concentration and Emission of NOx

This section presents the annual averages of air concentrations and emissions of NOx in percentage of the whole episode 2004-2010 (2005-2010 for emissions at Vomp and Klausen and 2007-2010 for emission at Auer).
For all the stations, a decrease is shown according to the period average. The both curves correspond quite well, with a tendency that the decreases of air concentrations are smaller than the ones of emissions. At Mutters and Klausen, both in the “UPV”-regions of Brenner, this difference is obvious. This is discussed later in this study.



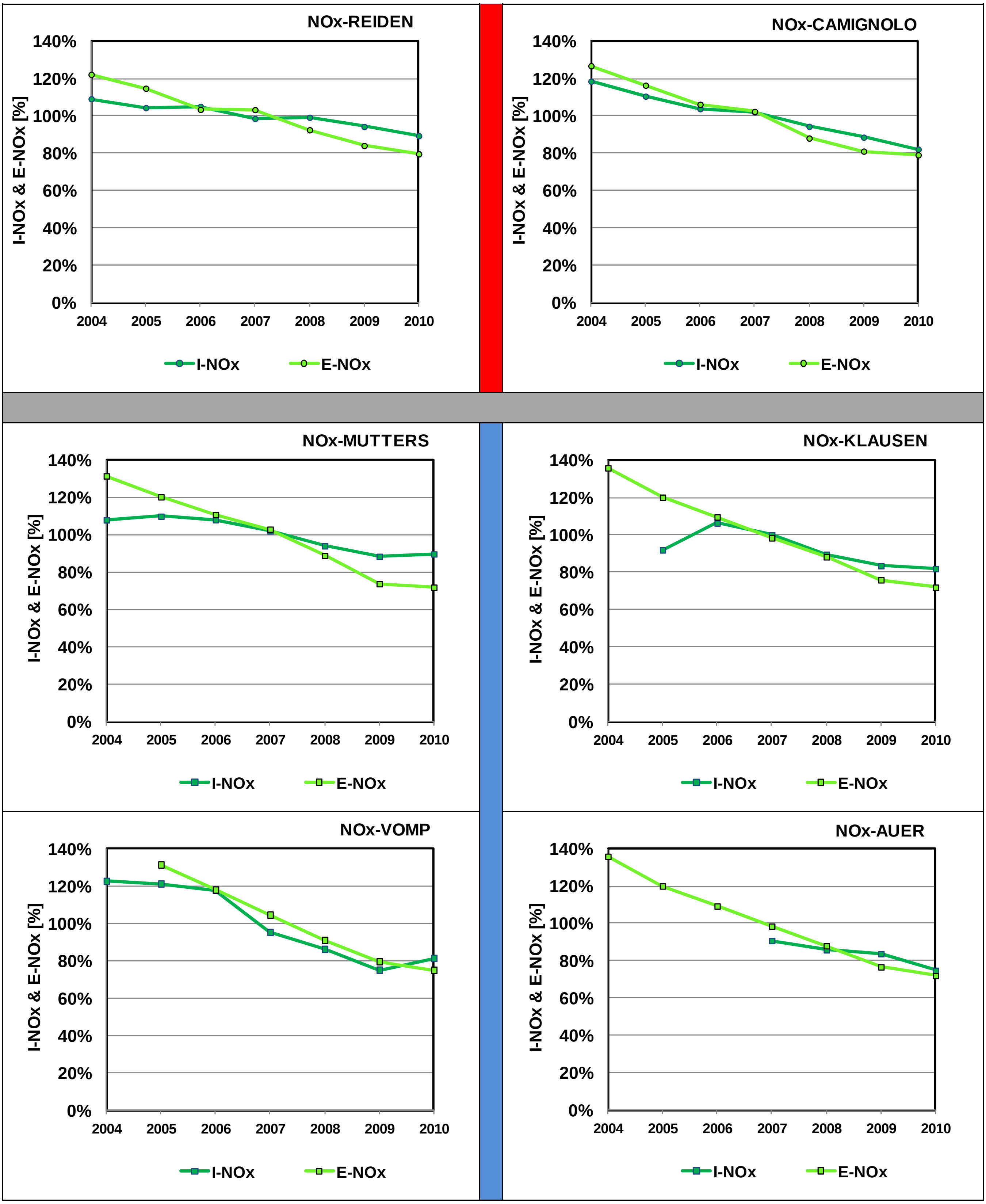


Figure 6.1: Relationship of the air concentrations (I) and the emissions (E) of NOx between 2004 and 2010 at Gotthard and Brenner.

The NO_2 analysis shows at Gotthard larger differences between the two curves, because of increase of directly emitted NO_2, as mentioned above.

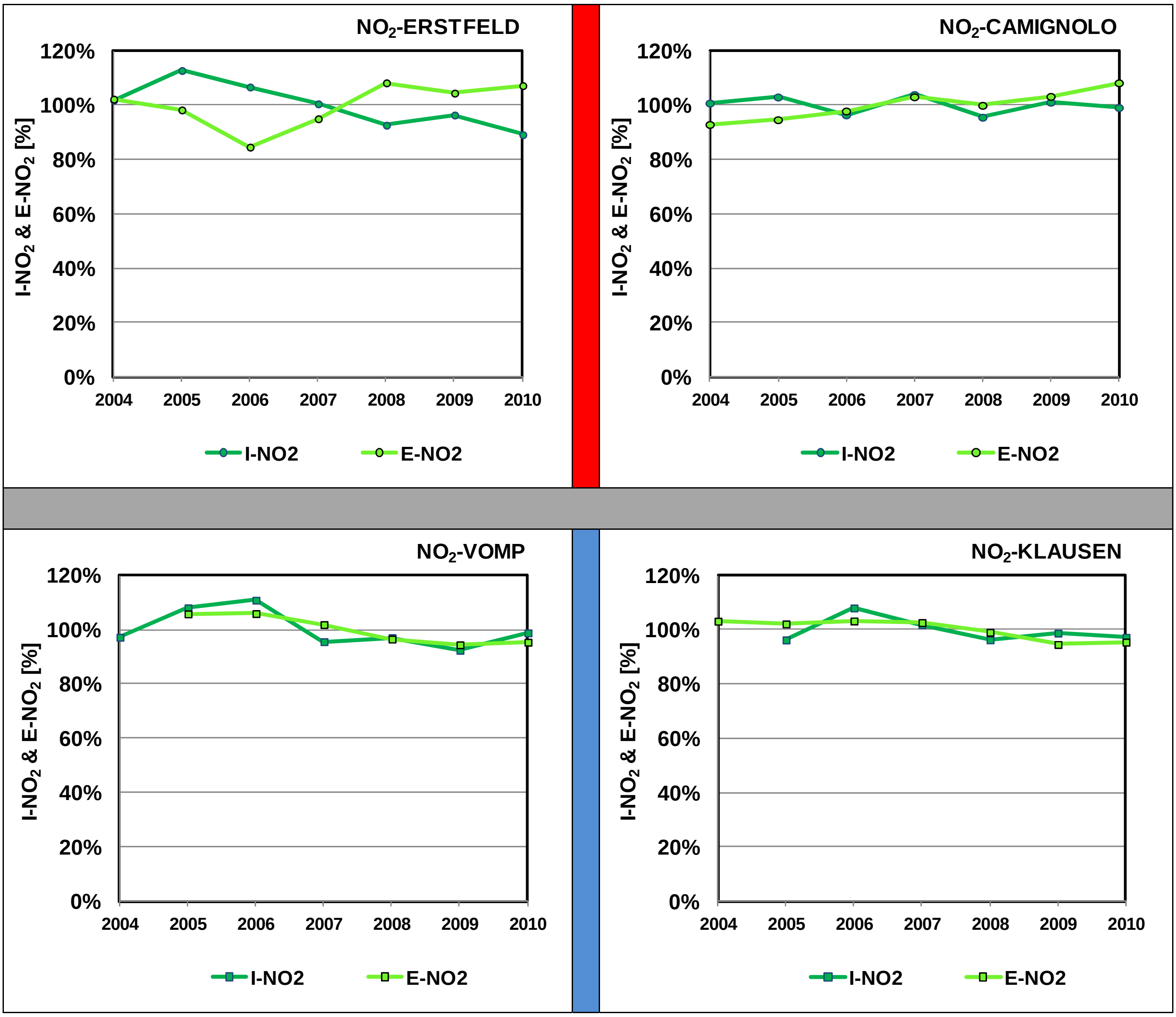


Figure 6.2: Relationship of the air concentrations (I) and the Emissions (E) of NO_2 between 2004 and 2010 at Erstfeld and Camignolo (Gotthard) and at Vomp and Klausen (Brenner).

6.2. Tau: Air Concentration / Emission of NOx 2004-2010

The concept of the model Tau is to estimate air concentrations in the proximity of roads related to source emissions.

The ratio between air pollutant concentration and initial emission is determined by the topography and the meteorological dispersion conditions. The starting-point of this model is that empirical ratio, which is determined for each hour from measurements (traffic, air pollution). Therefore, the real dispersion conditions are empirically known and need not to be estimated from other parameters. A dynamic backdrop of air pollutants, variable with time, has to be considered, originating in earlier emissions and those from other sources.

Once the dispersion and conversion conditions of each hour for a certain period (e.g. one year) are known, less or more hypothetically emissions can be assumed or the chronological distribution can be changed and the impacts on air pollution can be calculated.

For this study, a simple approach has been made: the ratio of the annual averages of air concentration and emission was accomplished, considering a certain background concentration level derived from other studies in the Brenner and Gotthard corridors.

The main results of Tau calculation for 2010 are:

- The Tau is highest at “UPV” at Biasca (Moleno) and Klausen with more than 2.5 ppb*km*d/kg: in other words, an annual mean emission of 1 kg/km/d leads to an annual concentration of more than 2.5 ppb.
- This result is about 3 times more than at Reiden in the Swiss midlands, representing a more or less “flat” terrain: The same emission quantity causes an about 3 times higher air concentration in alpine valleys compared with European average. European regulations to reduce air pollution may therefore not be sufficient for alpine valleys and additional measures could be necessary. The factor Tau is a good indicator to demonstrate air pollution sensitivity of the specific region.
- At Auer the values of Tau are considerably lower because of the distance of 25 m of the highway, whereas the other stations have distances of about 5 m.

So Tau of Auer is not comparable to the other stations (highlighted in red, Figure 6.3).

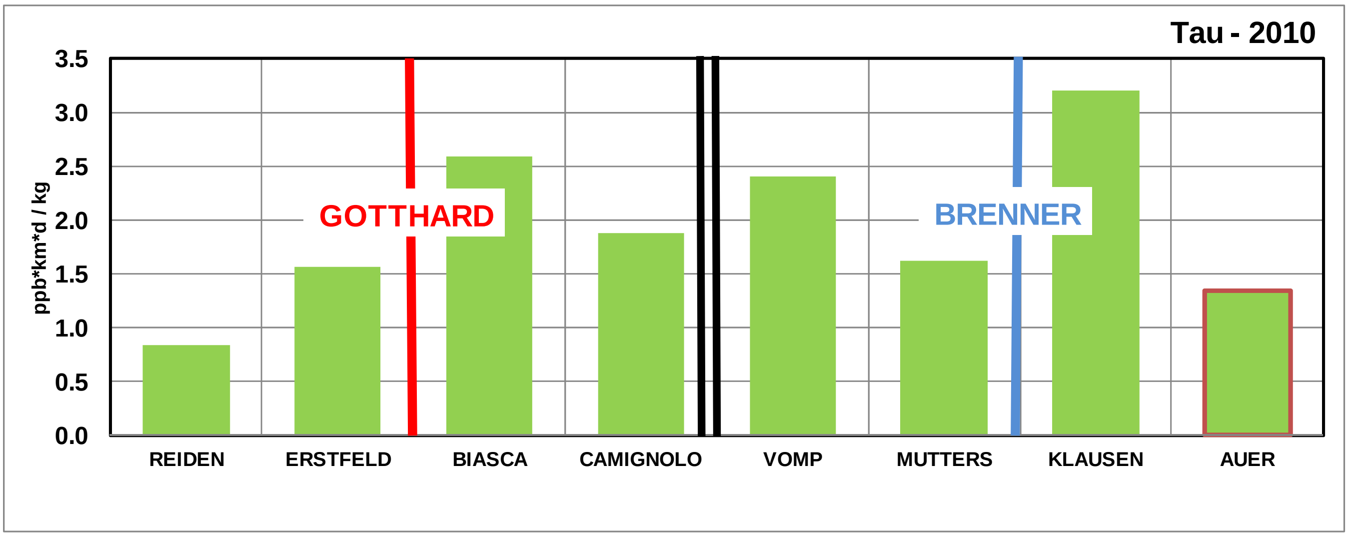


Figure 6.3: Tau: Ration of NOx air concentration / NOx-Emission at Gotthard and Brenner in 2010.

→ The ratio Tau is slightly increasing through the years at all stations, more pronounced at Mutters and Klausen (Vomp 2010 influenced by road works, s. above) (Figure 6.4). The hypothesis is that the decrease of emission factors from 2004 to 2010 is overestimated by the HBEFA 3.1, since the emissions of modern Diesel-PC (Euro4 and Euro5) are higher than predicted [4]. With a smaller decrease of emission factors, the values of Tau would remain more stable for each station. Variations from year to year are due to meteorological variations, affecting the resulting air concentrations. For Mutters and Klausen, further reasons are obviously influencing the resulting Tau values.

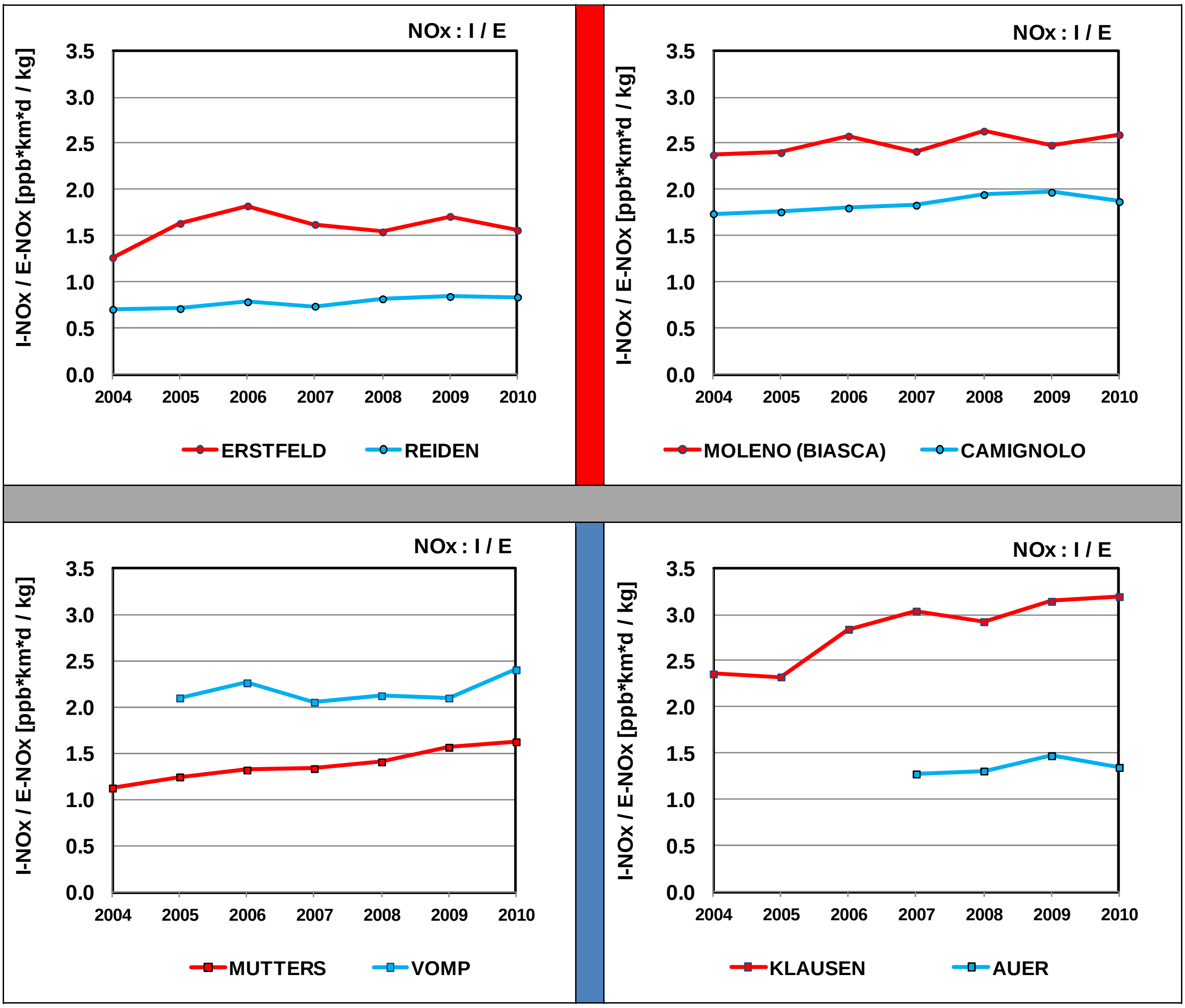


Figure 6.4: Tau: Ratio of NOx air concentration / NOx-Emission at Gotthard and Brenner, 2004-2010.

7. Temperature Inversion

Temperature inversions are affecting the pollution level by stagnation of pollution at lower height atmosphere layers and preventing its vertical dispersion. The inversion is characteristic of alpine regions causing more pollution level for the same amount of emissions.
The higher frequencies of inversion are observed in wintertime before noon and in the evening where the ground is colder than the higher layers of the atmosphere.

For this study, four temperature profiles are taken into consideration at Erstfeld (120 m) and Moleno (120 m) for Gotthard and at Schwaz (300 m) and Bozen (1445 m*, the only available couple of temperature measurements in this region*) for Brenner.

7.1. Frequencies of Temperature Inversions 2002-2010

From 2002 to 2010, the tendency of the frequency of temperature inversion is to decrease. These time series are too small to explain if this trend is a result of a climate change or only a fluctuation. Longer times series analysis should be achieved to comprehend this phenomenon.

The comparison between profiles shows that (Figure 7.1):

- The shape of the curves has similarity: the frequency of temperature inversion was low in 2004 for all temperature profiles. 2006 it was higher for all profiles except for Erstfeld. At Erstfeld, many inversion layers at wintertime have a thickness of several hundred meters, being part of the cold air pool over the Swiss midlands. They are neutral on the lower approximately 200 m and are not detected within 120 m above ground. In this study, local inversions are considered, which are nevertheless influenced by large scale weather situation.
- Erstfeld is the only gradient that does not show a large seasonal difference between winter and summer. In 2003, 2004, 2006 and 2010, the inversion

frequency was even higher in summer than in winter. This for the same reasons as mentioned above.

- Both sides of Brenner have few inversions in summer, particularly at Bozen.

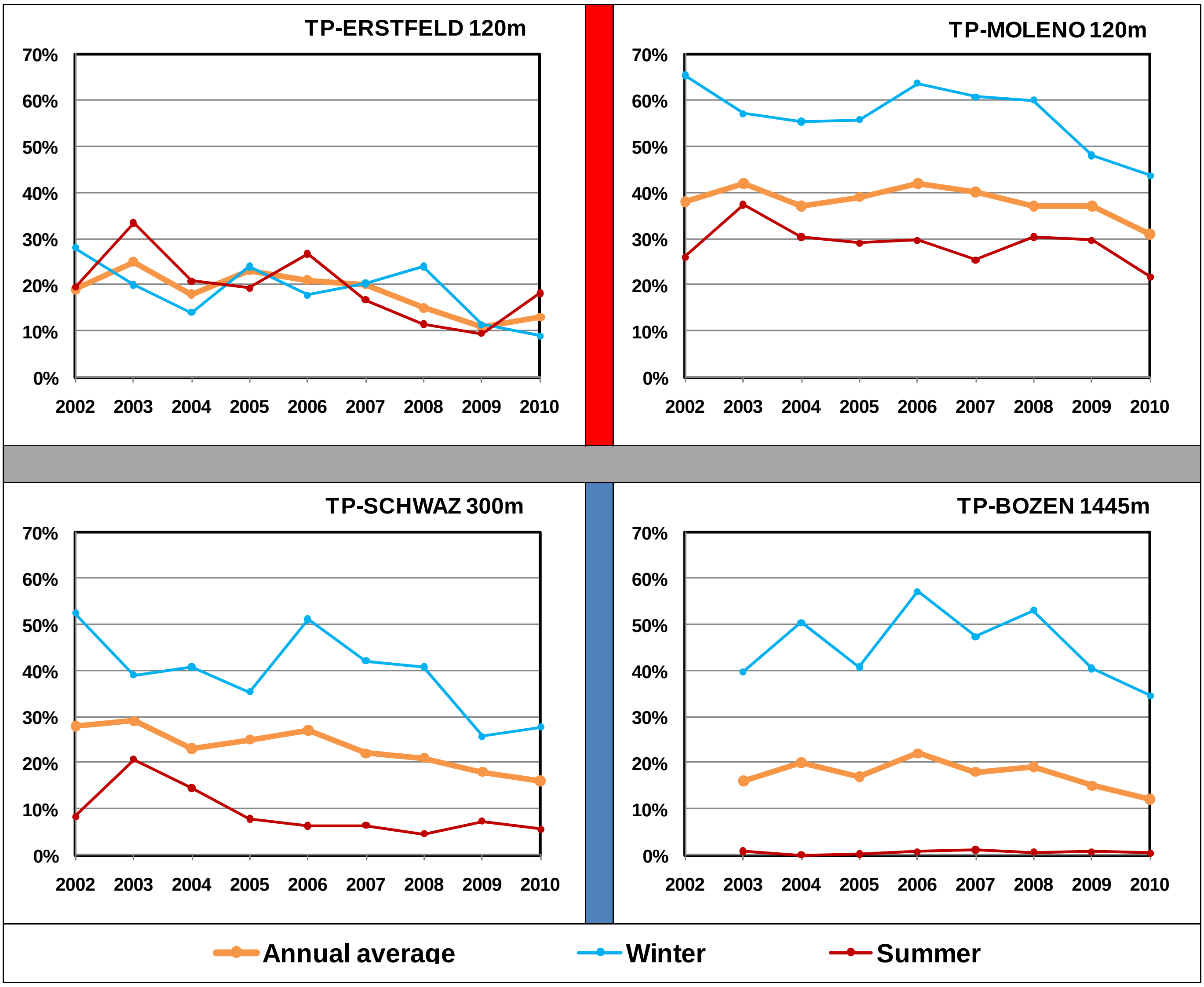
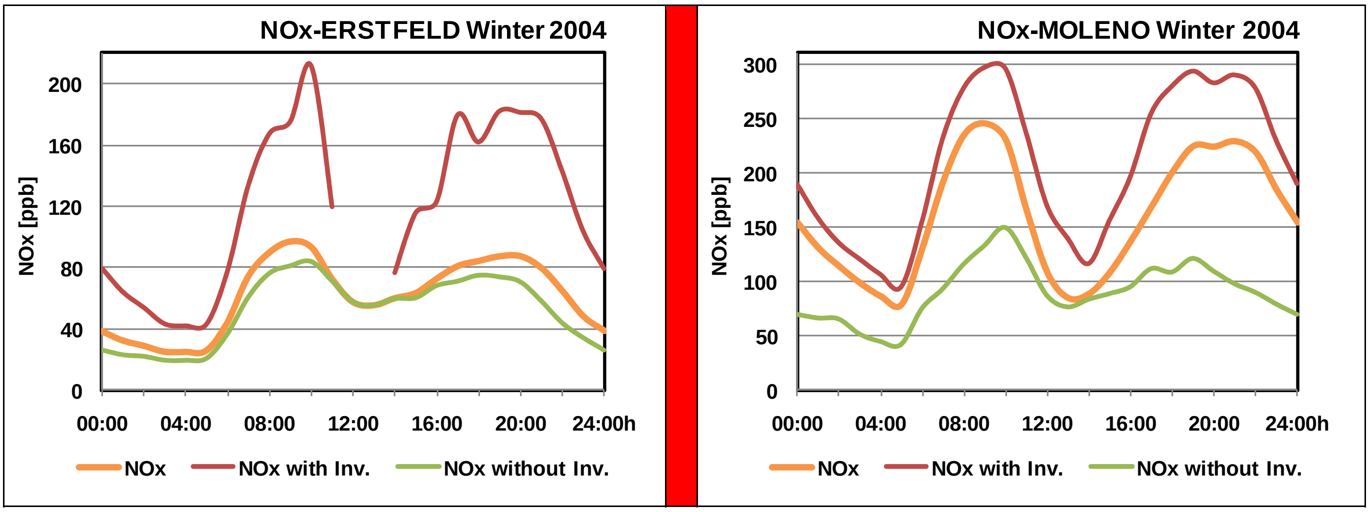


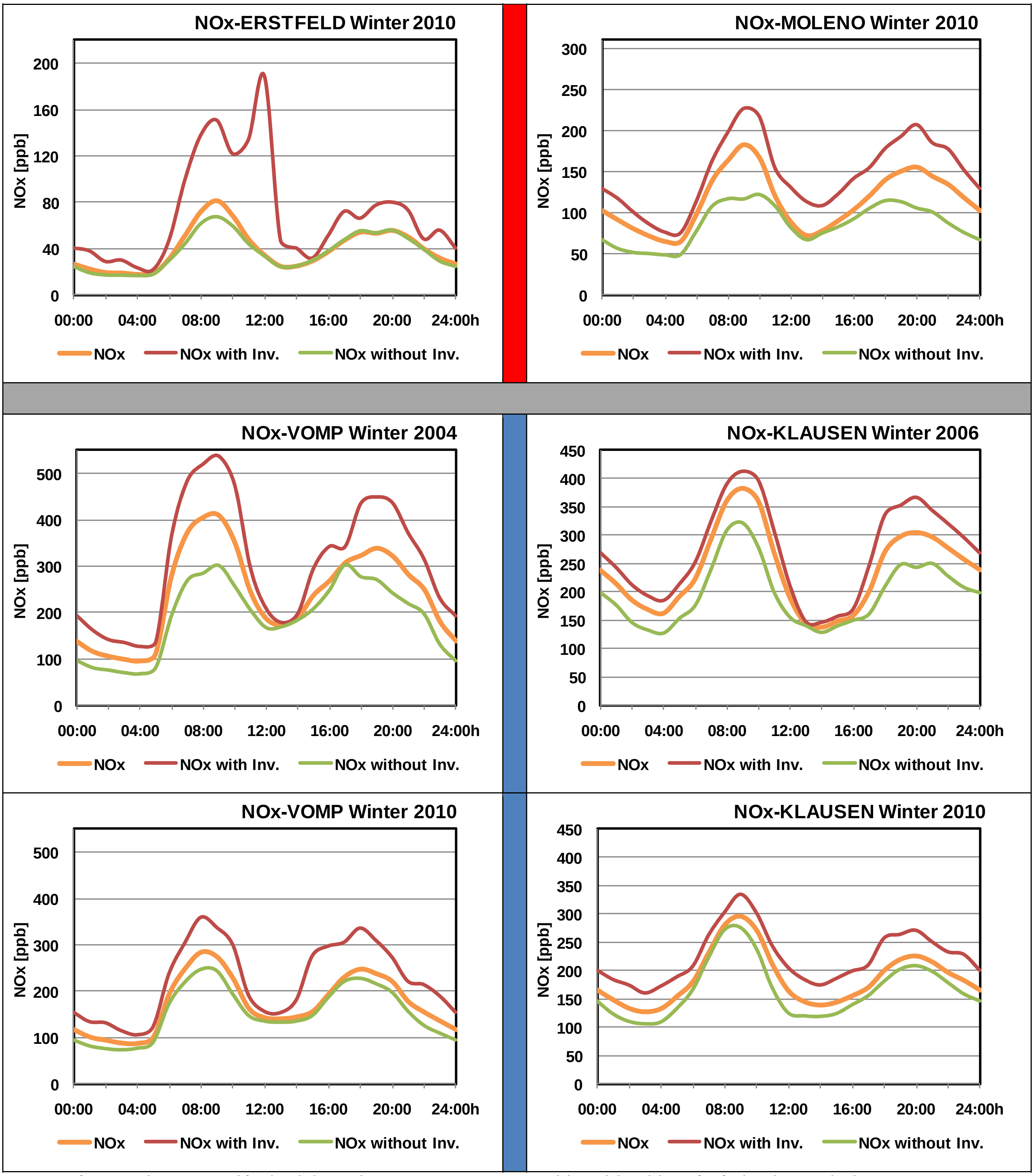
Figure 7.1: Annual and seasonal (winter: Jan.-Feb.-Dec. and summer: May-Aug.) averages of temperature inversion at Gotthard and Brenner, 2002-2010.

7.2. Coefficients of Impact of Temperature Inversions on Pollution Level

The effect of inversion on air pollution can change for many parameters as the geographic situation of the air monitoring station, the time (yearly and seasonally) and the emitted pollutant.

A coefficient is calculated to illustrate the weight of the temperature inversion on air pollution stagnation. Hourly variation of NOx is calculated in winter 2004 and 2010 for Erstfeld (TP Erstfeld), Moleno (TP Moleno), Vomp (TP Schwaz) and Klausen (TP Bozen). This consideration combines the presence of inversion or not and the NOx level.
The results show a disparity in the hourly variation curves: higher peaks of NOx in the before and afternoon-evening when an inversion occurs in relation to the hourly winter average (Figure 7.2).





* For Klausen, because of lack of data, the year 2006 was considered for this calculation instead of 2004.

Figure 7.2: Examples of dependency of NOx to temperature inversion in winter (January, February and December), 2004 and 2010.

→ The coefficient of inversion sensitivity (concentrations of "NOx with Inversion" divided by "NOx without Inversion") is a good indicator of the sensitivity of air pollution to inversion in winter (Table 7.1):

- Some sites are more influenced by inversions as Erstfeld 2004 and 2010 and Moleno 2004 with an effect of double pollution in case of inversion occurrence.
- The influence of inversion can vary by year, example of Moleno where the influence of inversion is for 2.3 times in winter 2004 against 1.7 in 2010.

Table 7.1: Coefficient of inversion sensitivity: Concentrations of "NOx with Inversion" / "NOx without Inversion" in winter 2004 and 2010 for Erstfeld, Moleno, Vomp and Klausen.

	Erstfeld	**Moleno**	**Vomp**	**Klausen**
Winter 2004	**2.0**	**2.3**	**1.6**	**1.4 ***
Winter 2010	**2.2**	**1.7**	**1.4**	**1.4**

* For Klausen, because of lack of data, the year 2006 was considered for this calculation instead of 2004.

For evaluation of real effect of the measures to reduce pollution, it is important to know that varying inversion frequencies may have played a role in the concentration levels; so a simple "before - after" difference is not adequate to judge the effect of undertaken measures.

8. Summary of Regional Studies

In this section some regional studies from the Gotthard and Brenner corridors are summarized; their results are of general interest for all the regions of the iMonitraf! project.

Four studies have been selected:
Tyrol: Calculation of Air Concentration of NOx and NO_2 near Highway from Road Emissions, Ozone and Meteorological Parameters.
Central Switzerland: Lateral Gradients of NOx and NO_2 Air Concentrations near Highway.
Ticino: Enhanced PM10 Concentrations 2003-2006 at Chiasso.
South Tyrol: Typical Wind Conditions in Alpine Valleys.

8.1. Tyrol: Calculation of Air Concentration of NOx and NO_2 near Highway from Road Emissions, Ozone and Meteorological Parameters

For the measuring site of Vomp in the Inn valley in Tyrol, monthly averages of NOx and NO_2 air concentrations were calculated from road emissions, ozone and meteorological parameters by linear regression.

→ In the case of NOx, the independent variables for this calculation are the road emission of NOx, the occurrence of thermal atmospheric inversions and the temperature.

The results show that 91% of temporary variability of NOx in a monthly scale can be explained only by these three parameters. All other influencing parameters (as the uncertainties in traffic counting and in the emission factors or the local meteorological factors) are together within 9% of variability.

Figure 8.1 shows the results of monthly concentrations of measured NOx and NOx calculated by this regression. A good parallelism is observed. The green circles in indicate phases with construction works, changing traffic speed and sometimes also traffic lanes.

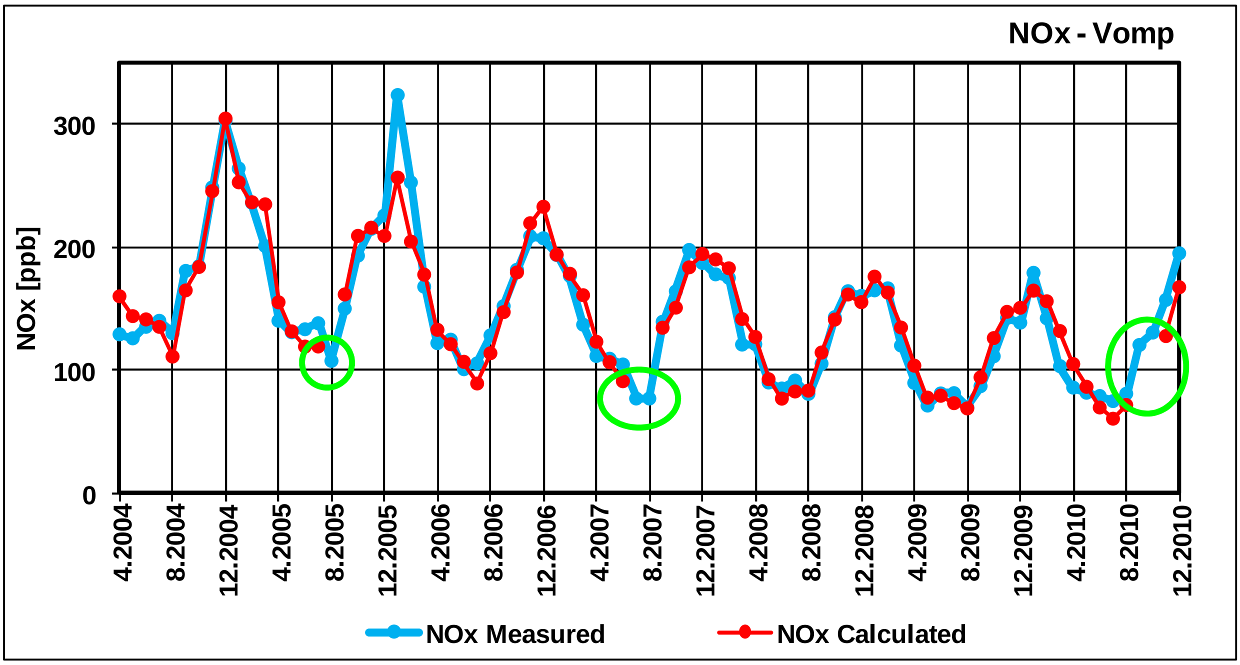


Figure 8.1: Monthly average of NOx for Vomp (Tyrol), April 2004 - Dec 2010.

→ In the case of NO_2, the independent variables for the linear regression are the NOx concentration, the ozone concentration about 100 m above the valley floor and the portion of NO_2-emission at total NOx-emission.

As result, 88% of temporary variability of NO_2 in a monthly scale can be explained only by these three parameters. Also in this case, a good parallelism is observed (Figure 8.2). It should be emphasized that NO_2 air concentration originates only partly in NO_2 emission; the other part is formed in the atmosphere from NO and ozone.

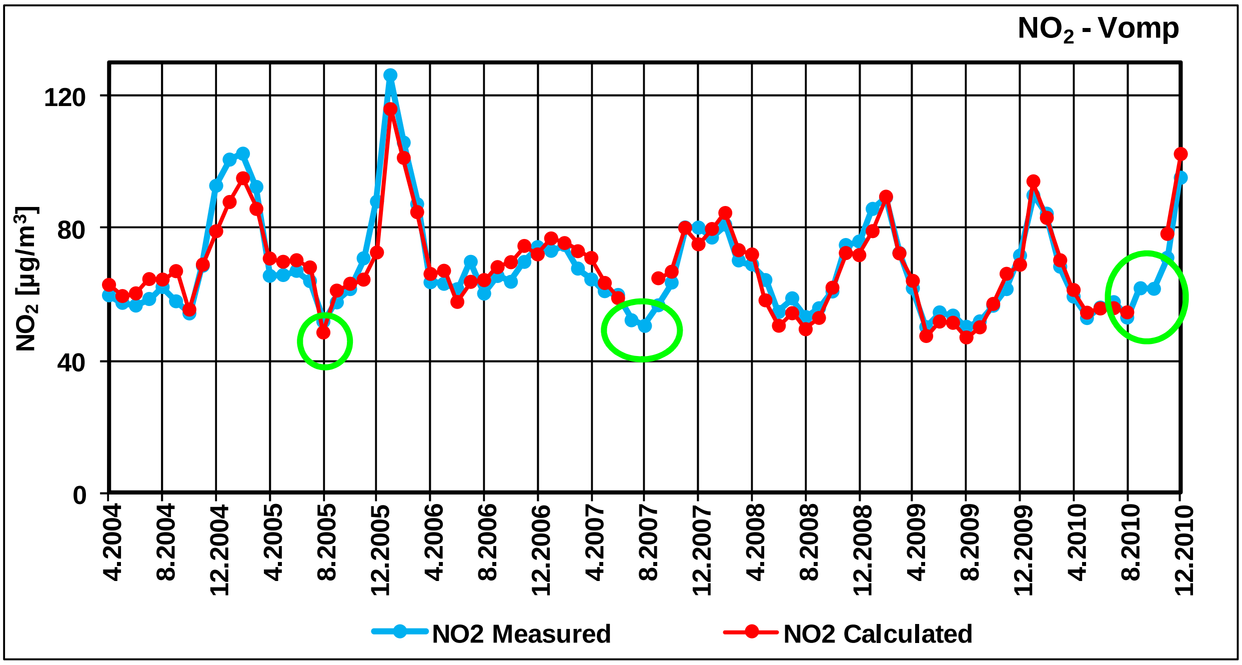


Figure 8.2: Monthly average of NO_2 for Vomp (Tyrol), April 2004 - Dec 2010.

Literature:

Entwicklung von Verkehr und Emissionen auf der A12 und der Immissionen im Unterinntal 2004 – 2010, Oekoscience, 2011.

8.2. Central Switzerland: Lateral Gradients of NOx and NO_2 Air Concentrations near Highway

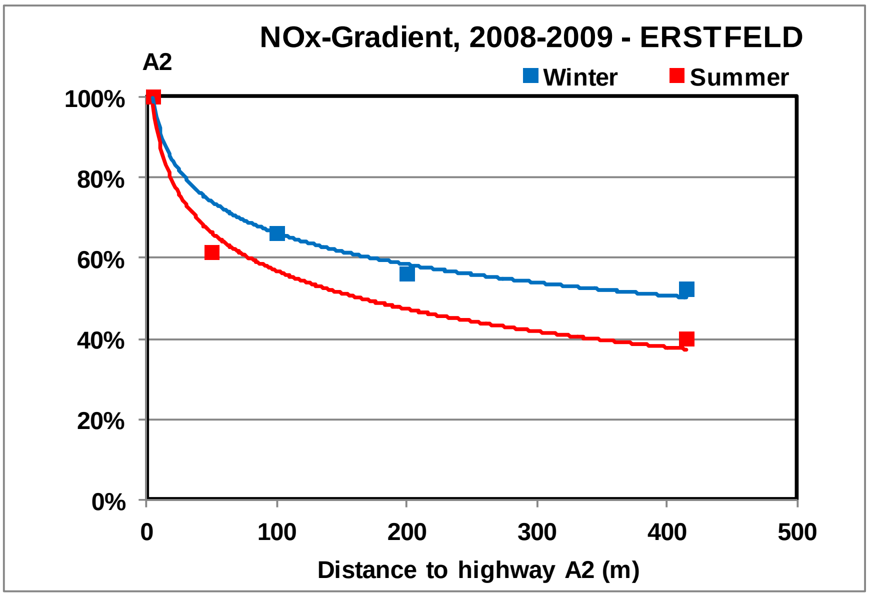
In 2008 and 2009, gradients of NOx and NO_2 air concentrations were measured with several measuring stations in the region of Erstfeld at the Gotthard highway (A2) in Central Switzerland.

NOx was only measured in summer and winter time, whereas NO_2 was measured the whole period of time by passive samplers.

→ In a distance of 200 m to the road, the NOx level is about 50% compared with near the border of the road at a distance of 5 m (=100%), the NO_2 level is about

70%. The decrease of NO_2 is lower than that of NOx because of the formation of NO_2 in the atmosphere from NO and ozone.

→ The lateral decrease of air pollution depends on atmospheric conditions: It is more effective with stronger winds and convective dilution, so generally more effective in summer than in winter, and more effective during day time than during night time. Especially for NO_2, the difference between winter and summer conditions is rather large (s. Figure 8.3).



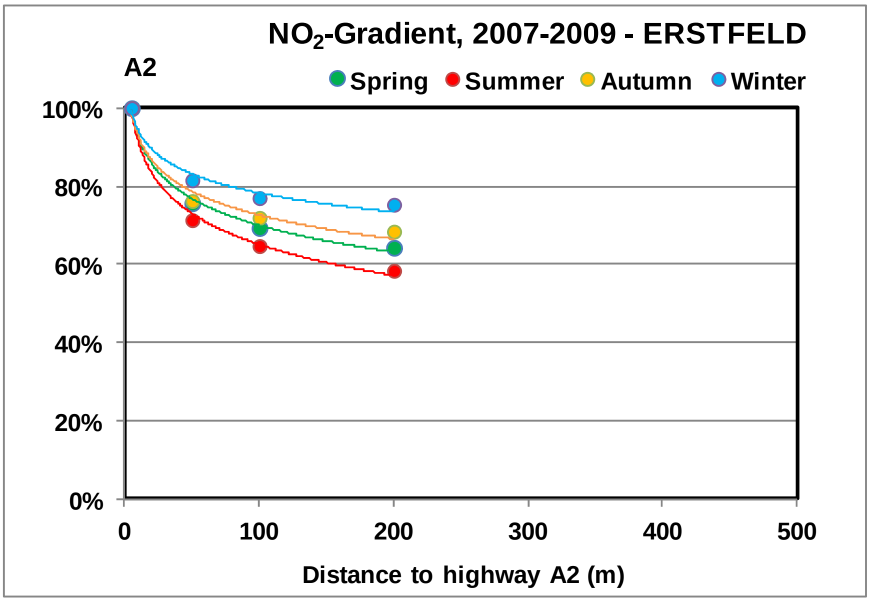


Figure 8.3: Gradients of NOx and NO_2 air concentration at Gotthard highway A2, Central Switzerland.

Literature:

Immissionsgradienten an der Autobahn A2 im Urner Reusstal bei Erstfeld, Oekoscience, 2009.

8.3. Ticino: Enhanced PM10 Concentrations 2003-2006 at Chiasso

Chiasso is situated in a basin with an only rather narrow exit long the river of Breggia to the Lake of Como. Thus, this region is rather sensitive to meteorological dispersion conditions and shows elevated air pollution, especially in winter. The basin is also crossed by the Gotthard highway. The urban measuring site of Chiasso is not directly exposed to traffic.

From 2003-2006, PM10 concentrations and number of days over threshold were essentially elevated at Chiasso (Figure 8.4); this fact could not be seen at the stations in the neighborhood in Ticino and Lombardy.

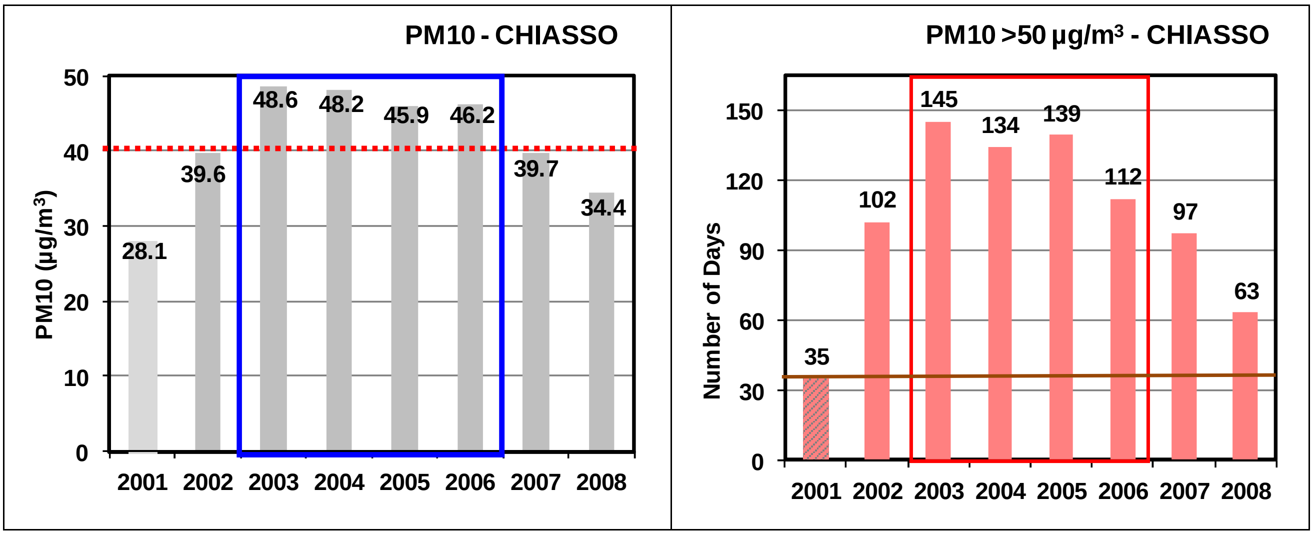


Figure 8.4: PM10 at Chiasso, Ticino, 2001 – 2008 (in winter 2001, there was 33 days with missing data).

→ At the same time, in the four winter half-years 2003-2006, the mean temperature was lower than the years before and after. Also in the surrounding regions it was colder, but not as distinctly as in the basin of Chiasso. As consequence, the index “heating degree”, a measure for heating activity, was enhanced, and the formation of secondary particles from the gaseous phase increased also.

→ Furthermore, the frequencies of atmospheric inversions were increased in these four winter half-years. Therefore enhanced heating emissions together with worse atmospheric dispersion conditions led to increased PM10 concentrations. Investigation showed that there was no specific source of particulate matter only for these four years at Chiasso.

Literature:

Erhöhte PM10-Immissionen in Chiasso von 2003 – 2006, Oekoscience, 2009.

8.4. South Tyrol: Typical Wind Conditions in Alpine Valleys

The measuring station at Salurn is representative for typical wind conditions in alpine transit valleys. At this site, the valley axis is from east to west, valley downwind is an easterly wind, valley upwind a westerly. The situation is rather different in summer and winter (Figure 8.5).

→ In summer, the wind field is dominated by regional valley upwind from late morning till midnight, caused by thermal processes. During night, the most frequent wind is valley downwind. Lateral winds play a role especially in morning, when downwind is replaced with upwind. In summer time, regional and over regional exchange of air masses takes place during daytime, what is important for dilution of air pollution.

→ In winter, the wind field is dominated by valley downwind all of the day. Only in afternoon there is some lateral wind, caused by solar radiation on slopes with southerly exposition, also a local wind. That means that in winter time (October – March) with enhanced air pollution, an import of air pollution is practically inexistent. Most of present air pollution is locally produced and should be abated by measures with also local effectiveness.

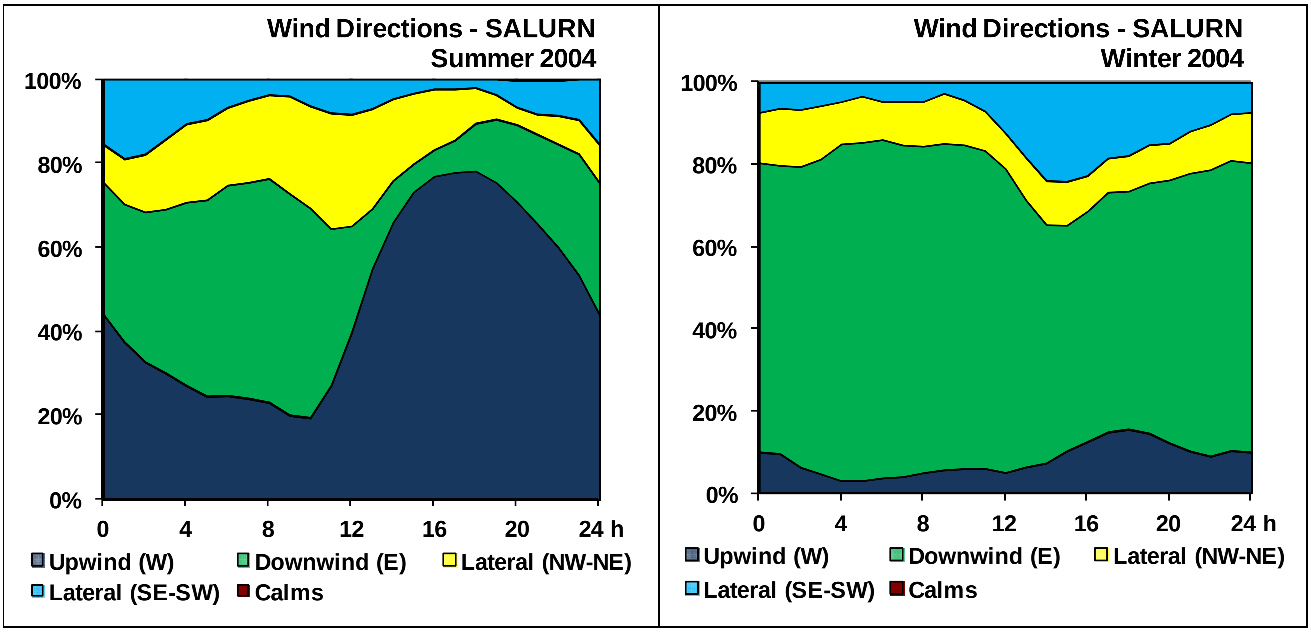


Figure 8.5: Wind directions at Salurn, South Tyrol, summer and winter 2004.

Literature:

Verkehr, Emissionen und Immissionen an der Brennerautobahn in Südtirol, Oekoscience, 2005.

9. Conclusions

Systematic comparison of emission and air pollution conditions at Gotthard and Brenner have led to a better comprehension of road traffic induced air pollution in transalpine corridors.
The main results are summarized as follow:

- The central parts of the transalpine corridors are more polluted than the upper parts. Vomp and Klausen at the Brenner corridor are the most polluted sites.
- NOx air concentration has essentially decreased in the last 7 years at all stations. Also PM10 concentrations have decreased in some extent in all corridors except Central Switzerland. However, a slight decrease in NO_2 is seen.
- The numbers of vehicles have increased in both corridors in the last 7 years; but the number of Heavy Duty vehicles at Brenner, above all on the north side, has decreased. This may also be an effect of measures taken by Tyrol.
- For the Heavy Duty category, all the stations in the upper part valleys register 89 - 97 % of transalpine portion and in the central valleys 70 – 80 %, with the exception of Reiden (less than 50%).
- At Brenner, a larger part (13-19%) of all vehicles is Heavy Duty than at Gotthard (10-12%).
- The Brenner-pass registers about a quarter of passenger cars more than Gotthard and more than the double of Heavy Duty vehicles. Therefore, the Brenner-pass knows about 50% more emissions of NOx and NO_2 than Gotthard and nearly the double of particulate matter.
- The road emissions of NOx and particulate matter have essentially decreased in the last 7 years, caused by reduced emission factors due to fleet modernization. The NO_2 emissions have increased due to larger portion of directly emitted NO_2 in modern Diesel vehicles.
- The decrease of emissions is larger at Brenner than at Gotthard, which may also be an effect of measures taken by Tyrol.
- The transalpine portions in the emissions are similar for all components (NOx, NO_2 and PM) per station. The portions are higher in the upper part

of the valleys with 60 – 80 % than in the central parts with 40 – 60 % of the total emissions.

- The factor Tau (ratio between air pollutant concentration and initial emission) is a good indicator to demonstrate air pollution sensitivity of a specific region. In alpine valleys, this factor is essentially larger than in the European average. European regulations to reduce air pollution may therefore not be sufficient for alpine valleys and additional measures could be necessary.
- The factor Tau in the Gotthard and Brenner corridors is slightly increasing through the years at all stations. The hypothesis is that the decrease of emission factors from 2004 to 2010 is overestimated by the HBEFA 3.1, since the emissions of modern Diesel-PC (Euro4 and Euro5) are higher than predicted.
- Inversions enhance air pollution levels in the Gotthard corridors by about 100%, in the Brenner corridors by about 50%. It is important to reflect that fact for the evaluation of developments and measures.

10. Literature

[1] ALPIFRET: Observatoire des trafics marchandises transalpins, Rapport annuel 2009, Commission Européenne – DG MOVE, Département Fédéral de l'Environnement, des Transports, de l'Energie et de la Communication et al., 2010.

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[6] Bundesamt für Verkehr (BAV): Güterverkehr auf Strasse und Schiene durch die Schweizer Alpen 2009, May 2011.

[7] Bundesamt für Verkehr (BAV): Private communication to ALPIFRET 2001-2010, September 2011.

11. Acknowledgements

We would like to thank Mr. Gerhard Wagner from Eurac for his help to collect data from South Tyrol.

12. ANNEX 1: Traffic and Emissions at Gotthard and Brenner 2004-2010

Reiden A2	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pw+MR	Lw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	66.3	5.99	1.92	33511	4892	232	1367	3777	43780
2005	62.3	6.19	1.85	32708	5259	234	1306	3752	43259
2006	56.1	6.22	1.71	33002	5160	198	1330	3696	43386
2007	56.0	6.81	1.72	34959	5605	205	1407	4026	46202
2008	50.2	6.92	1.56	35440	5792	193	1430	4104	46960
2009	45.6	7.01	1.43	36217	5938	178	1383	3878	47594
2010	43.2	7.10	1.32	35597	5943	182	1402	4035	47158

Erstfeld A2	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pw+MR	Lw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	34.0	2.96	0.94	17084	1734	274	521	2292	21904
2005	30.4	2.84	0.85	16448	1588	229	361	2292	20917
2006	23.8	2.45	0.69	14313	1331	162	387	1962	18155
2007	24.5	2.75	0.72	15901	1515	179	425	2197	20218
2008	24.0	3.13	0.72	16800	2207	243	498	2289	22037
2009	21.0	3.02	0.63	17720	1982	235	486	2091	22514
2010	20.0	3.10	0.59	17726	2035	254	460	2199	22674

GOTTHARD-PASS

Biasca A2	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pw+MR	Lw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	38.3	3.45	1.10	21475	2504	235	534	2288	27036
2005	35.8	3.51	1.03	21484	2580	224	512	2199	27000
2006	30.9	3.41	0.92	20724	2573	203	507	2040	26047
2007	31.4	3.74	0.93	21979	2840	222	566	2285	27892
2008	28.1	3.86	0.87	21508	3084	224	617	2312	27746
2009	26.0	4.11	0.83	21758	3619	239	569	2132	28317
2010	25.3	4.32	0.79	22156	3756	252	611	2255	29030

Camignolo A2	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pw+MR	Lw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	62.0	5.82	1.93	39193	4705	392	845	2649	47783
2005	56.9	5.93	1.80	38528	4696	366	824	2532	46945
2006	51.9	6.13	1.69	38424	4908	369	855	2492	47047
2007	50.1	6.46	1.64	39785	4772	367	891	2650	48464
2008	43.1	6.27	1.42	39503	4243	329	862	2652	47589
2009	39.7	6.47	1.32	40882	4379	312	833	2482	48888
2010	38.7	6.79	1.24	41173	4498	317	926	2646	49560

Vomp A12	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pkw+MR	Lfw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	92.2	9.62	3.35	41375	3749	442	2090	5958	53614
2005	81.5	9.35	3.04	39981	3682	409	2098	5923	52093
2006	73.2	9.36	2.74	39810	3726	397	2098	6090	52121
2007	64.9	9.00	2.50	40011	3781	417	2182	6279	52670
2008	56.5	8.53	2.35	39983	4595	418	1937	5863	52796
2009	49.4	8.34	2.14	40384	4847	383	1888	4942	52444
2010	46.6	8.43	1.97	41520	5062	401	1753	5229	53965

Mutters A13	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pkw+MR	Lfw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	70.6	7.26	2.50	32433	1882	508	1074	4933	40830
2005	64.6	7.34	2.38	32402	2250	538	1092	4966	41248
2006	59.5	7.53	2.20	32621	2450	537	1152	5258	42017
2007	54.9	7.76	2.18	31781	3460	639	1294	5153	42327
2008	47.7	7.12	1.98	31815	3355	639	1299	4995	42104
2009	39.6	6.54	1.68	32035	3211	619	1193	4042	41099
2010	38.6	6.86	1.60	33461	3662	555	1216	4436	43331

BRENNER-PASS

Klausen (Chiusa) A22	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pkw+MR	Lfw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	66.7	6.42	2.17	20536	3195	488	502	5481	30202
2005	59.0	6.36	2.00	20663	3104	478	502	5456	30204
2006	53.8	6.43	1.81	21173	2998	469	512	5900	31052
2007	48.3	6.39	1.62	21279	3024	470	505	6176	31455
2008	43.3	6.17	1.45	20927	2906	454	494	6049	30830
2009	37.3	5.89	1.29	21702	2793	443	496	5230	30664
2010	35.4	5.94	1.19	22068	2898	454	497	5489	31406

Auer (Ora) A22	E_NOx	E_NO2	E_PM	PC + MC	LDV	Busses	Lorries	Trailer-Trucks	TOTAL
				Passenger cars + Motorcycles	Light Duty Vehicles	Busses	Single trucks	inclusive articulated lorries	
German:	E_NOx	E_NO2	E_PM	Pkw+MR	Lfw	Busse	SoloLkw	SLZ	TOTAL
Unit:	kg/km/d	kg/km/d	kg/km/d	AADT	AADT	AADT	AADT	AADT	AADT
2004	83.4	8.25	2.81	28683	4143	633	652	6483	40594
2005	73.6	8.16	2.57	28457	4022	617	641	6439	40177
2006	67.0	8.27	2.33	29223	3936	611	653	6868	41291
2007	60.4	8.27	2.10	29616	3970	611	640	7161	41999
2008	54.0	7.96	1.88	28768	3820	590	623	6993	40793
2009	47.1	7.68	1.68	29793	3671	571	612	6144	40790
2010	44.2	7.66	1.53	29850	3730	576	608	6433	41197