Modelling An Ozone Episode In The Greater Athens Area, Greece Using Both UAM-V And A Box Model

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Scope

- To study an ozone episode in the GAA.
- To examine the impact of the uncertainties in input data, required by the AQM.

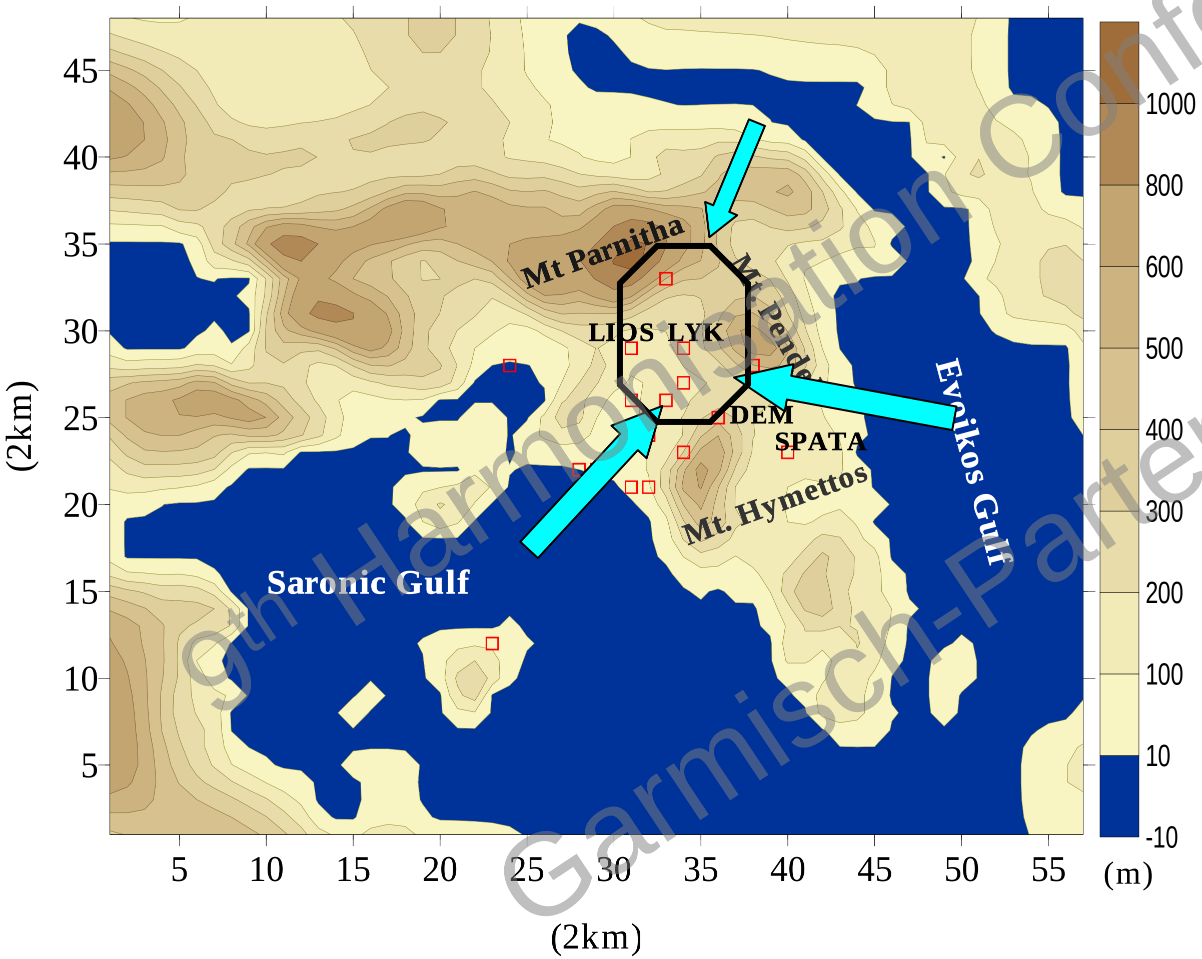
What We Know

- Critical factors contribute to the formation of high levels of photochemical pollutants in the GAA:
  - poor ventilation of the basin
  - frequent appearance of the sea breeze
  - intense solar irradiation
  - intense anthropogenic activities

- The long range transport of ozone precursors from the Western European continent over the Eastern Mediterranean, where the levels of solar irradiation and biogenic emissions are high, contributes significantly in high ozone concentrations.

- It is unclear yet which mechanism (LRT, downward mixing, in situ production) contributes the most *(Kalabokas, et al., 2000).*

GAA



- **Episodes** under SW winds or sea-breeze days
- **Suburban** stations on the SW-NE exhibit Max concentrations
- **Urban background/ suburban industrial** stations exhibit lower concentrations

What Is New

- An extended study on how the **Meteorology** affects the theoretical ozone concentrations in the GAA.
- A new and more detailed **Transport Emission Inventory**.
- Two **Speciation** profiles for the spatial distribution of the NMVOC emissions are considered. The profiles are reflecting the different characteristics of the air masses.
- Ozone simulations with a Box model using different chemical mechanisms.

Methodology

- The case selected is a severe pollution episode, **15th September 1994** (MEDCAPHOT-TRACE) (*Ziomas et al., 1998; Svensson et al., 1998*).

- A **base case** simulation constructed with the coupling of the photochemical UAM-V model with the meteorological MM5 model.

- **Numerical experiments** performed examining the:
  - *Biogenic emissions*
  - *VOC's speciation in urban areas and aged plumes*
  - *Background O_3 concentration levels*
  - *Meteorological data*

- The mean hourly ozone concentrations at selected sites were reproduced with the **Box SAPRC** model (*Carter, 1988*) coupled with MM5 model using CB-IV and SAPRC99 chemical mechanisms.

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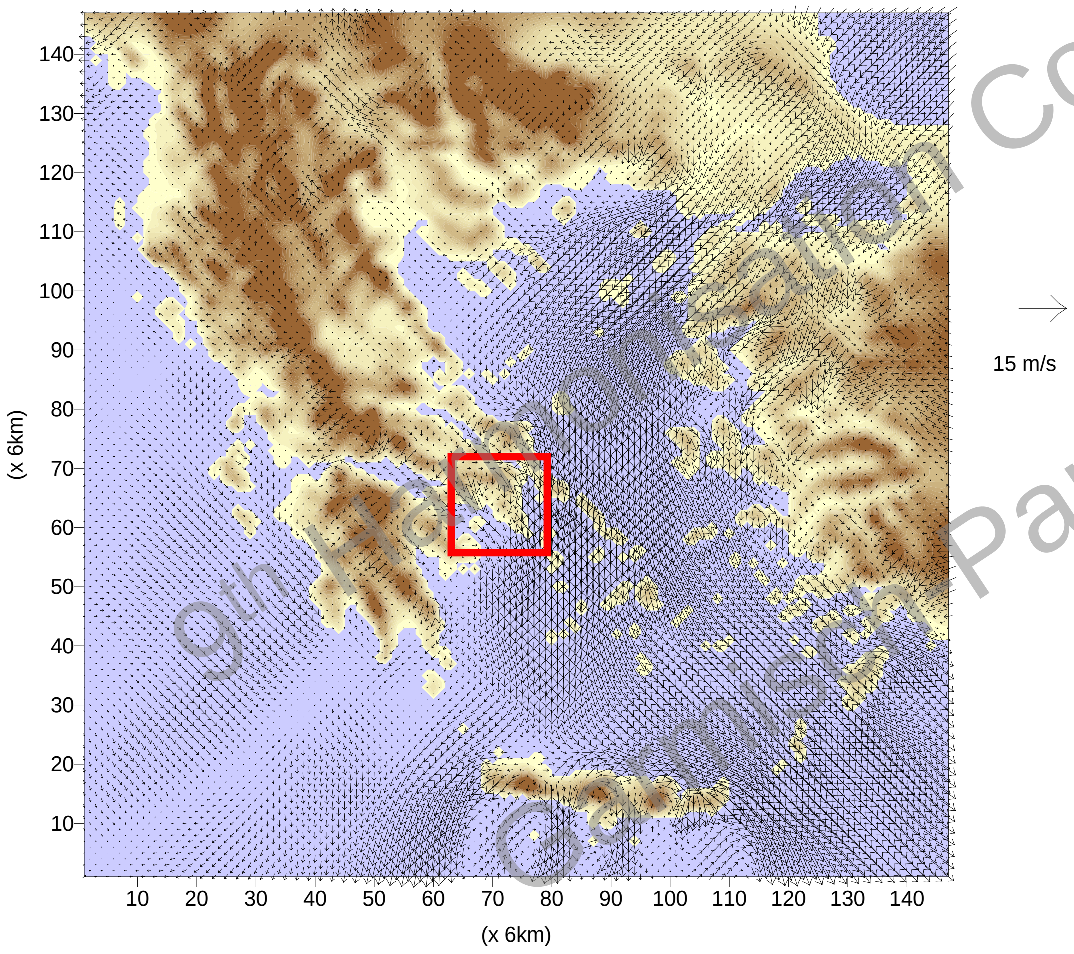
The Meteorological Model

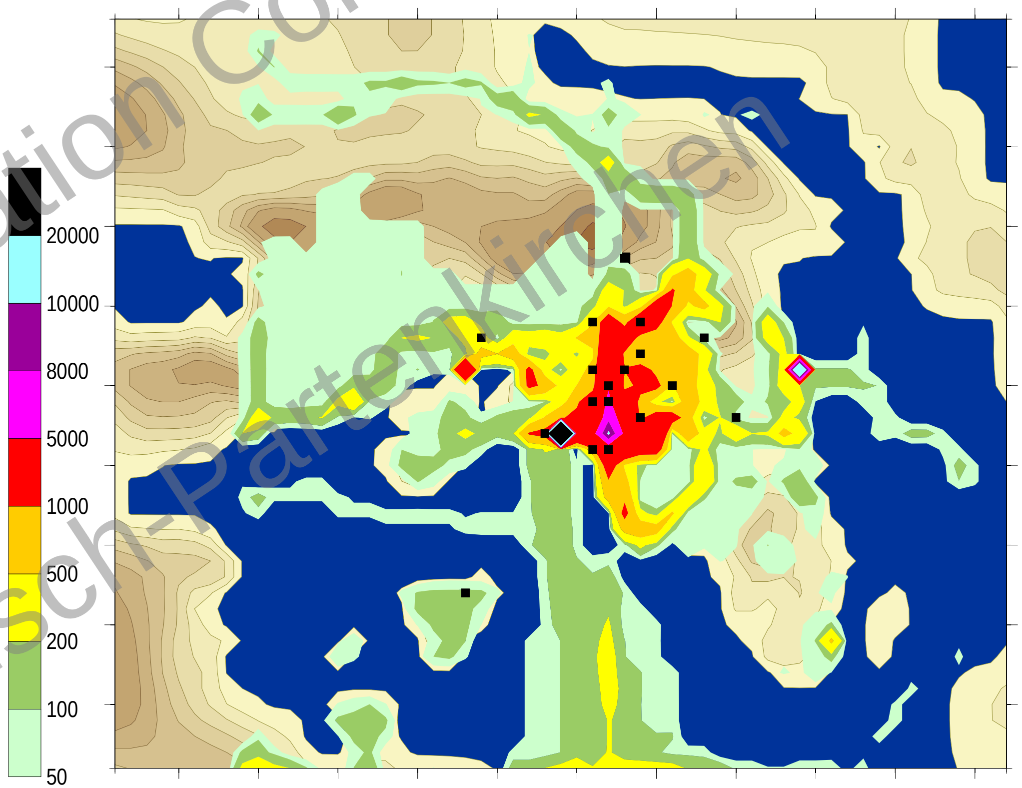


- The MM5 model run using double nesting:
  - **Coarse domain**: extended area of Greece, horizontal resolution 6kmx6km
  - **Nesting domain**: GAA, horizontal resolution 2kmx2km
- 23 vertical layers extended from the ground up to 12km
- 1st layer at 75m

Transport Emission Inventory

(*Symeonidis et al., 2003*)

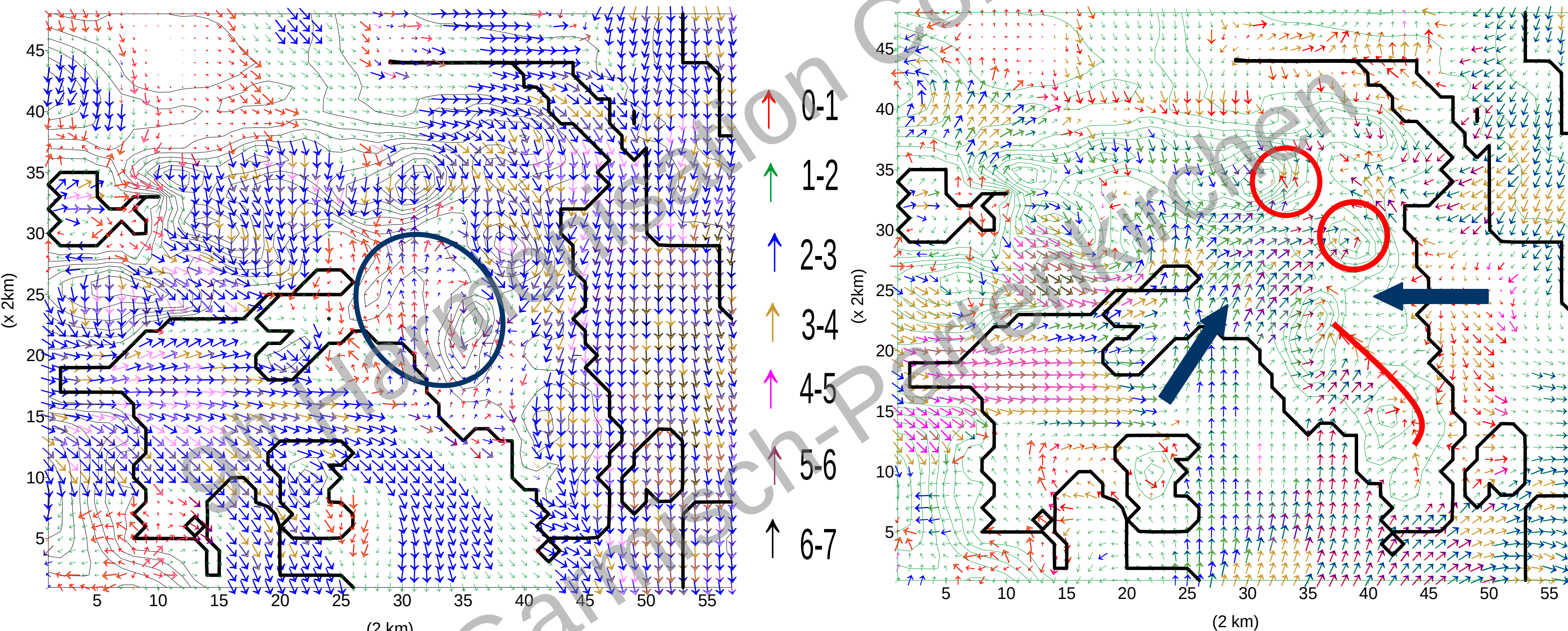
Sectors: On Road, Off Road, Railway, Ports, Air
Reference year: 1998
Species: NO_X, VOC, CO, PM
Horizontal resolution: 2kmx2km
Temporal resolution: 1h



NO_X emission rates (moles / h)

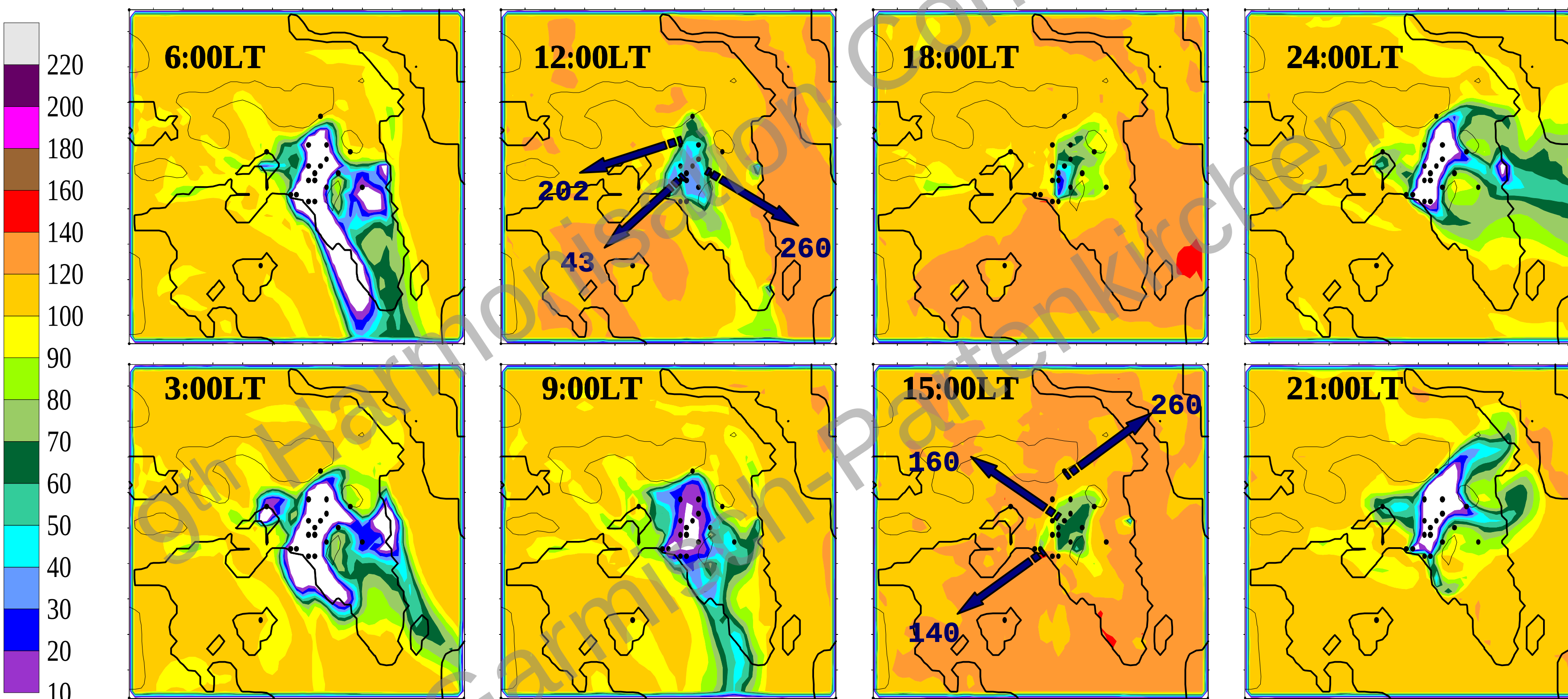
15th September 1994

High-pressure system over E. Mediterranean - NNW geos. wind



9:00LT Wind speed$_{10}$ (m/s) **15:00LT**

Base Case



Mean hourly ozone concentrations (ug / m^3)

Base case Results

- The UAM-V model predicts succesfully:
    - —The low concentrations in the center of the city
    - —The transport of the city plume towards the axis SW-NE.

- The UAM-V model didn't succeed to predict:
    - – The high ozone concentrations observed at the suburban stations of the northern basin (Thrakomakedones, Demokritos).

Emissions

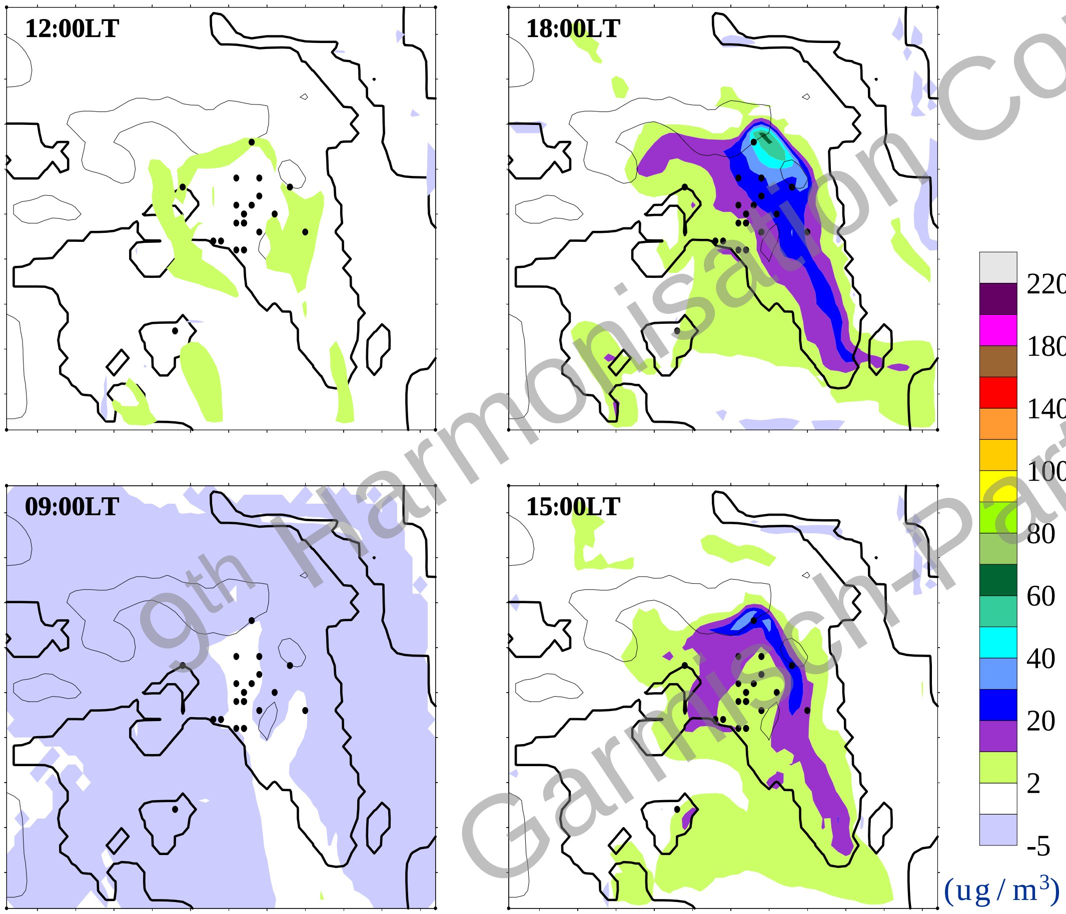
- The final Emission Inventory derived combining the emission inventory from the Ministry and the information received by processing a satellite image (1994).

- The spatial distribution of the **Land Use** was also revised according to the processed satellite image.

- The **Biogenic emissions** of the GAA have been encountered. Their spatial and hourly distribution (isoprene, a-pinene, other monoterpenes, unidentified) is based on:
  - emissions factors (*Roselle, S.J, et al.*, 1991; *Benjamin, M.T, et al.*, 1997) corrected for solar radiation and temperature
  - a vegetation index
  - a roughly assumption for the species composition

Contribution of Biogenic Emissions

Base case with BNMVOC - Base case



- **Morning** hours, the contribution of BNMVOC in ozone is insignificant

- **Noon/afternoon** hours, the reactivity of BNMHC emissions is much higher compared to that of anthropogenic NMVOC emissions, leading in ozone contribution up to 60ug / m^3

NMVOC Speciation

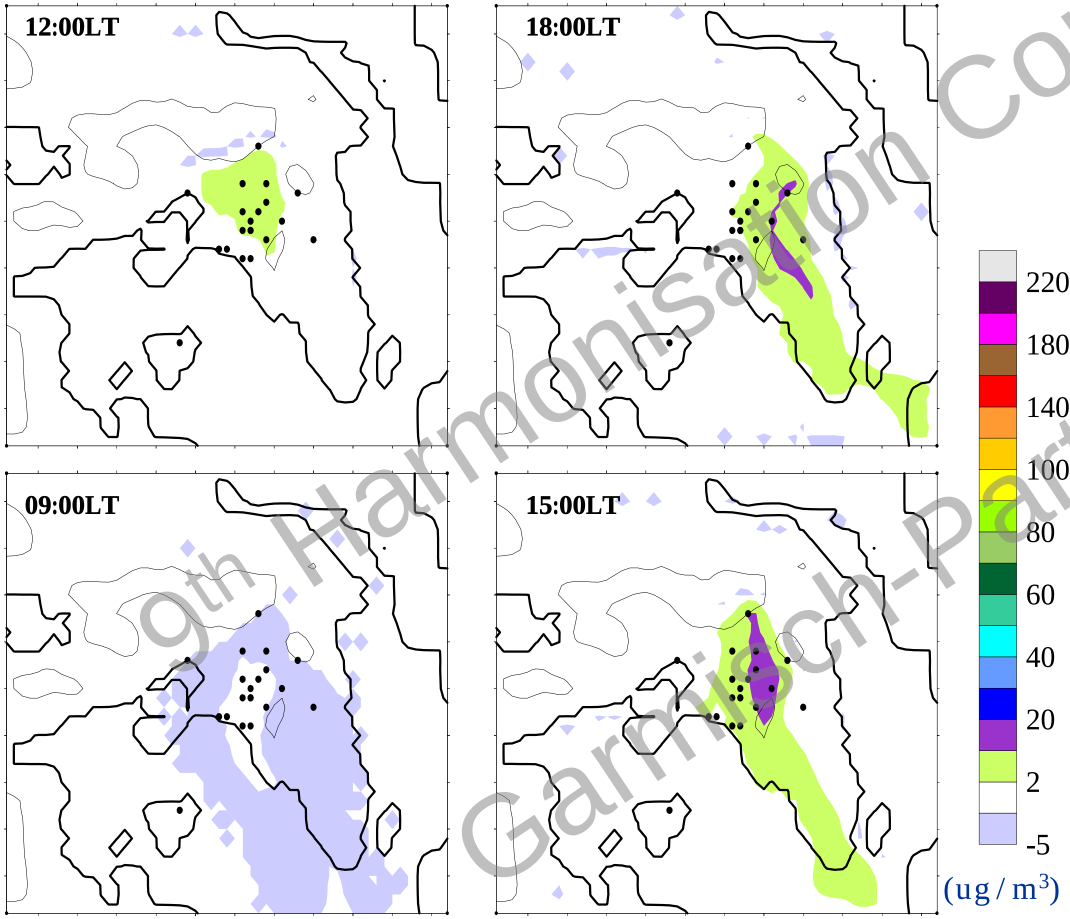
Two **NMVOC Speciation** profiles are based:

- on a limited number of HC species measured at a street canyon and in city plume of the GAA (*Klemm and Ziomas, 1998; Kourtidis et al., 1999*)
- emission rates of additional NMVOC species included in detailed emission profiles of LA (*Bossioli et al., 2002*)

- **Traffic** profile inside the urban area
- **City plume** profile in the periphery of the basin, reflecting the composition of the aged air masses.
  - In aged plumes some NMVOC (relatively low reaction rate with OH) are highly enhanced versus the background air masses.
  - The **city plume** profile brings additional NMVOC emissions (*Klemm, and Ziomas, 1998; Myeong Y. Chung et al., 2003*)

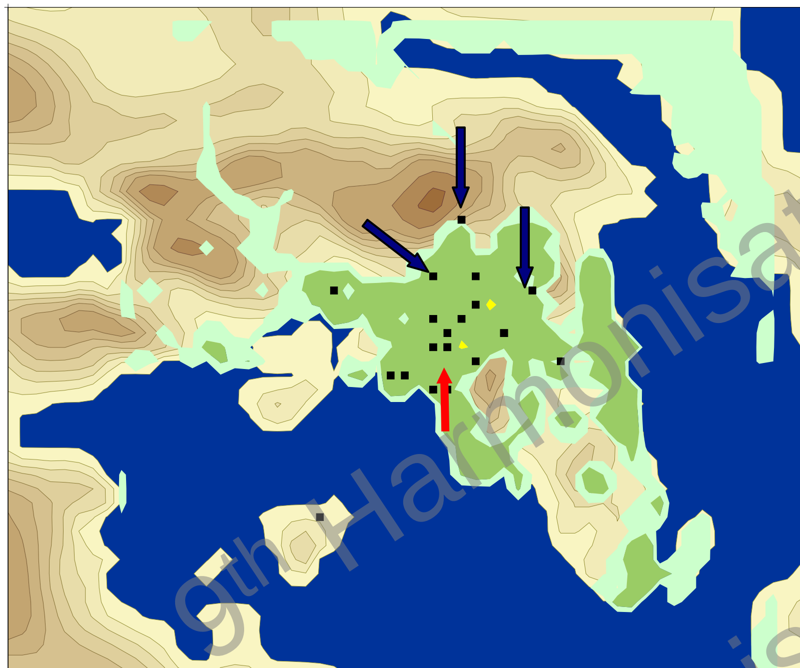
Contribution of NMVOC Speciation

Base case with NMVOC speciation - Base case

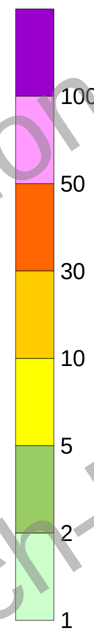


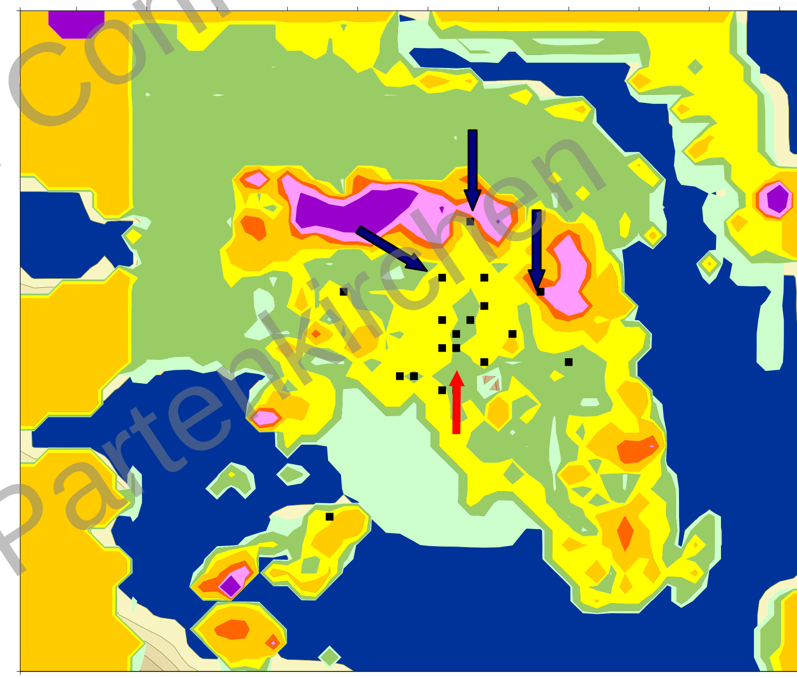
- **Suburban stations,** increase up to 15ug / m^3 is observed

NMVOC / NO$_X$



Base case





All emissions
(Corrections / Additions)

Boundary Inflow of O_3

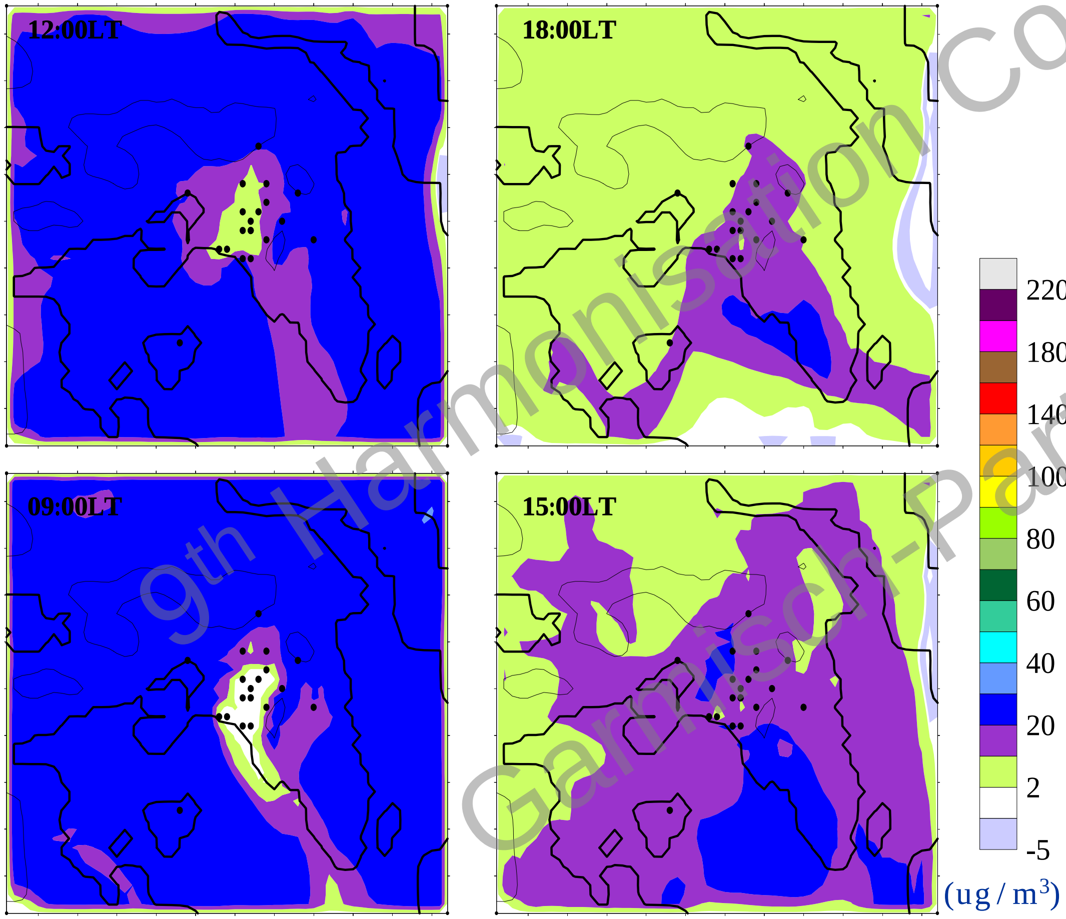
- Two approaches:
  - upwind air masses, not influenced by recent emissions within the last 24hours
  - 'rural' ozone received in the periphery of the basin under strong northern winds

- Background ozone in the GAA during summer period is about 60ppb (*Suppan, et al., 1998; Kalabokas, P.D, and J.G. Bartzis, 1998; Kalabokas, et al., 2000*).

- The critical contribution of the **Background** ozone was confirmed by using:
  - **Hourly concentrations of** O_3
  - **Background=0** (ozone forming potential of emissions)

Contribution of Hourly Background

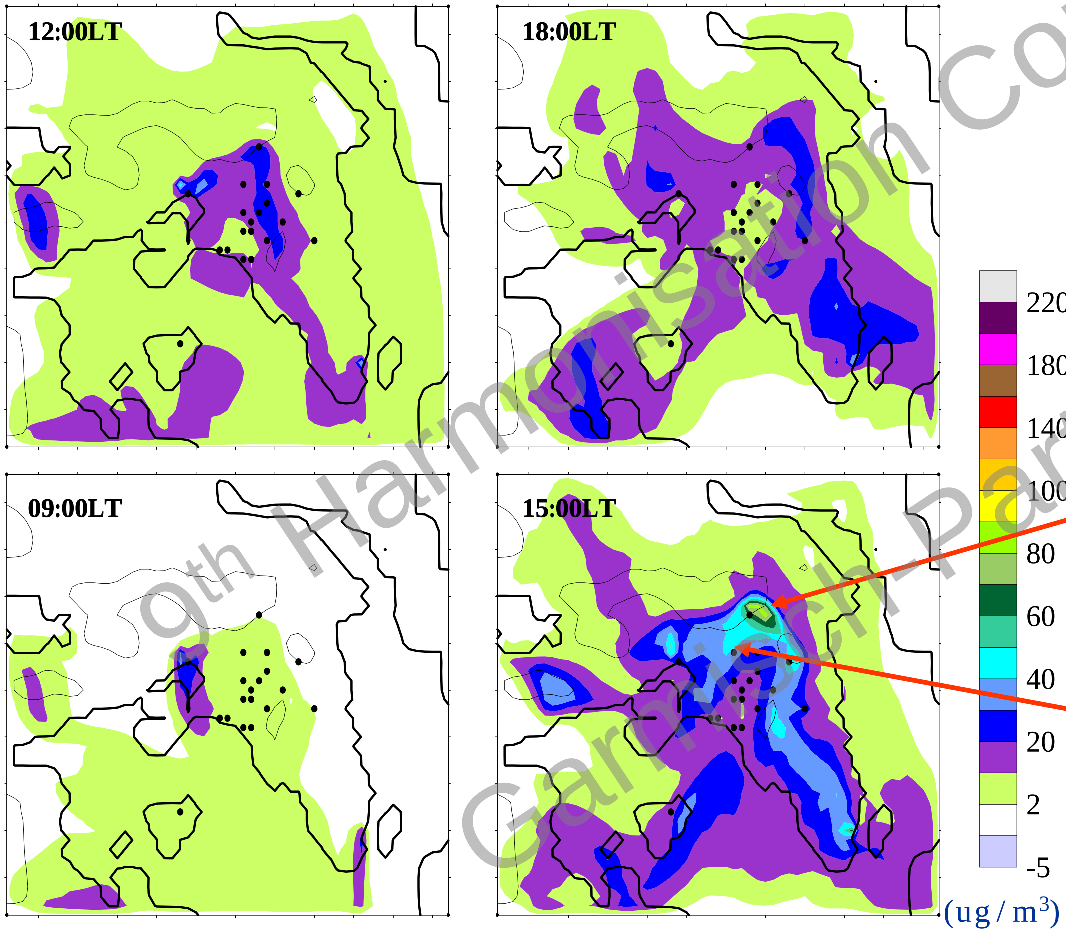
Base case Constant – Base case Hourly (GEOS-CHEM)



- **Morning** hours / **traffic stations**, the contribution is nearly zero.
- **Afternoon** hours, up to 12ug / m^3.
- The contribution is higher outside the basin

Contribution of Emissions (B+A)

Base case with Zero Ozone Background



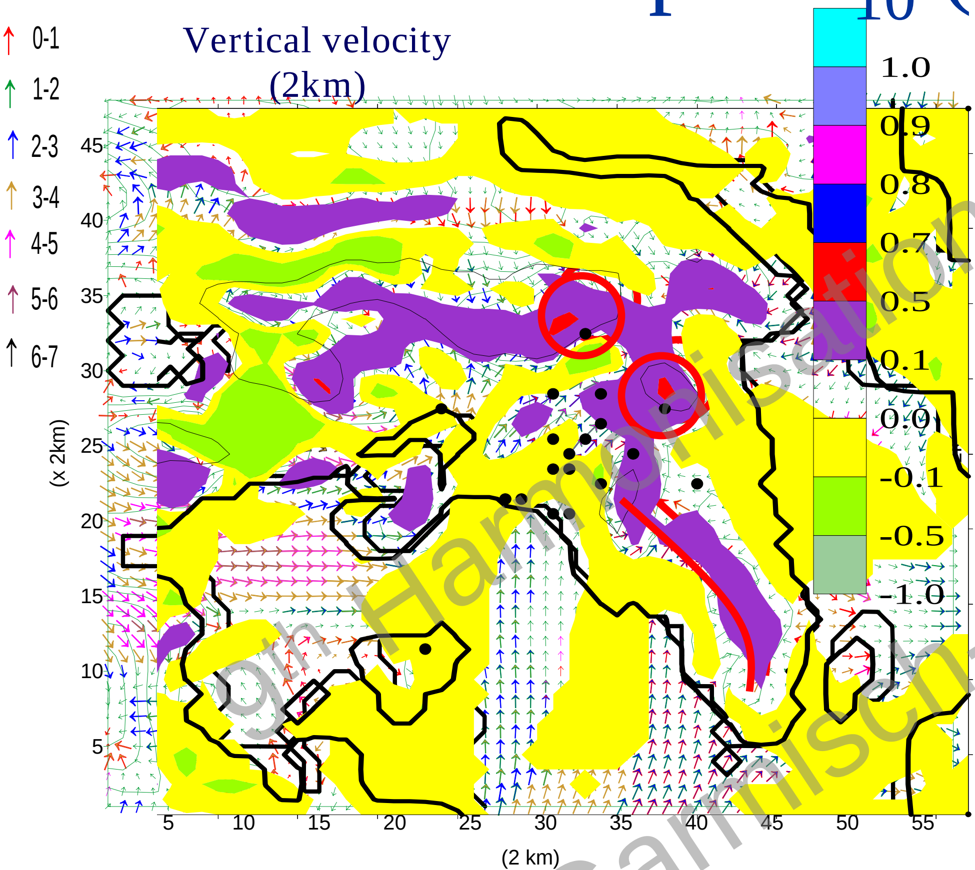
- **Traffic stations**
  - The city activity contributes much less than the rural background, 10% of the 98th percentile
- **Suburban stations**
  - Thrakomak. ozone forming potential is about 85ug / m^3, 55% of the 98th percentile
  - Liosia ozone forming potential is about 45ug / m^3, 30% of the 98th percentile (*Kalabokas, 2001*)

Meteorology

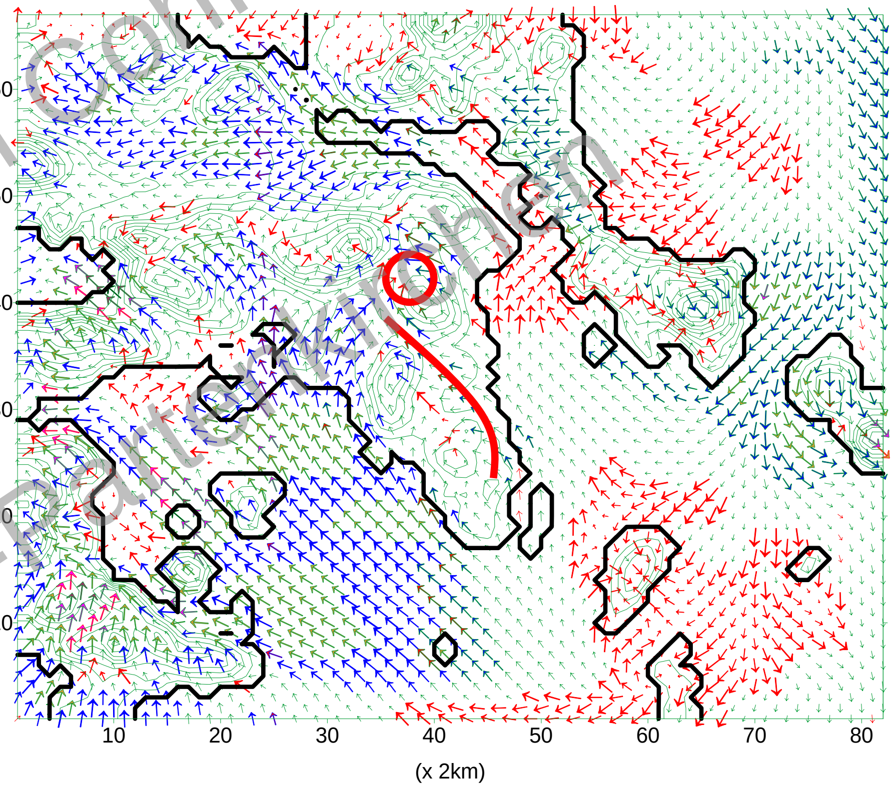
Various sets of meteorological fields, produced by the MM5 model:

- Different **Nesting** conditions.
- Incorporation of the **Effects of the Urban sector** on the wind speed and the diffusion coefficient *(Masson, 2000).*
- **1st vertical layer** at 130m (Base case at 75m).

Wind Speed$_{10}$ (m / s) at 15:00LT

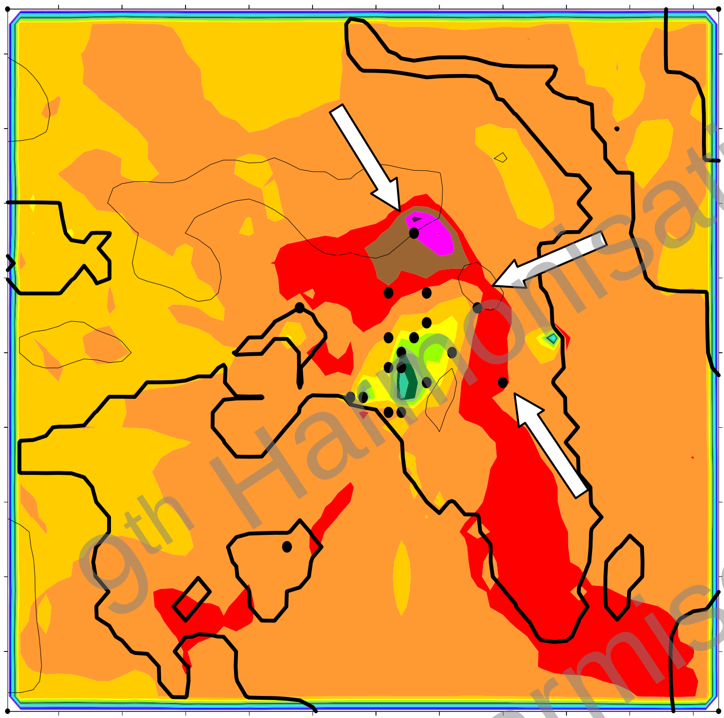


Nesting

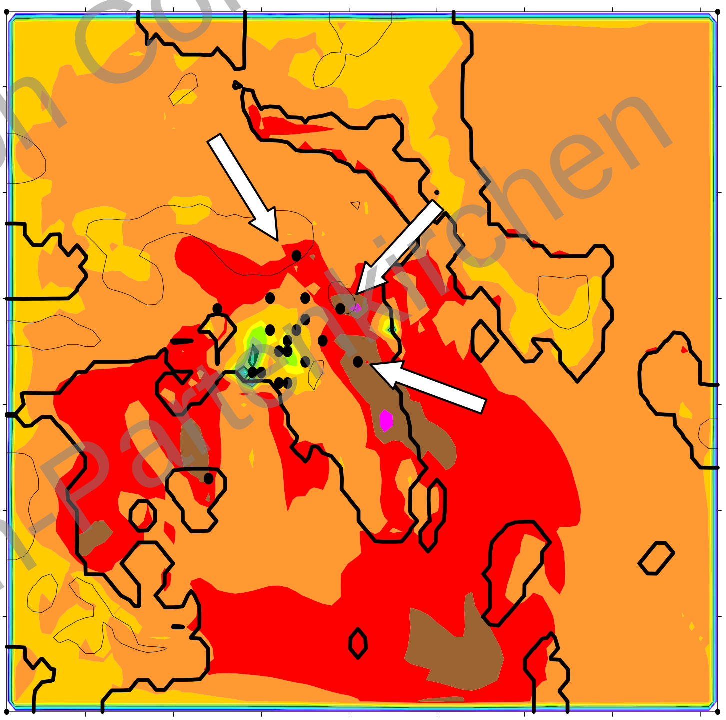


No Nesting

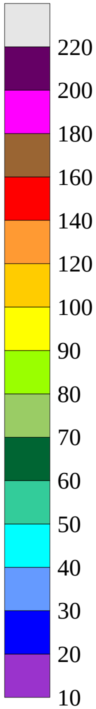
Concentrations of O_3 at 15:00LT



Nesting



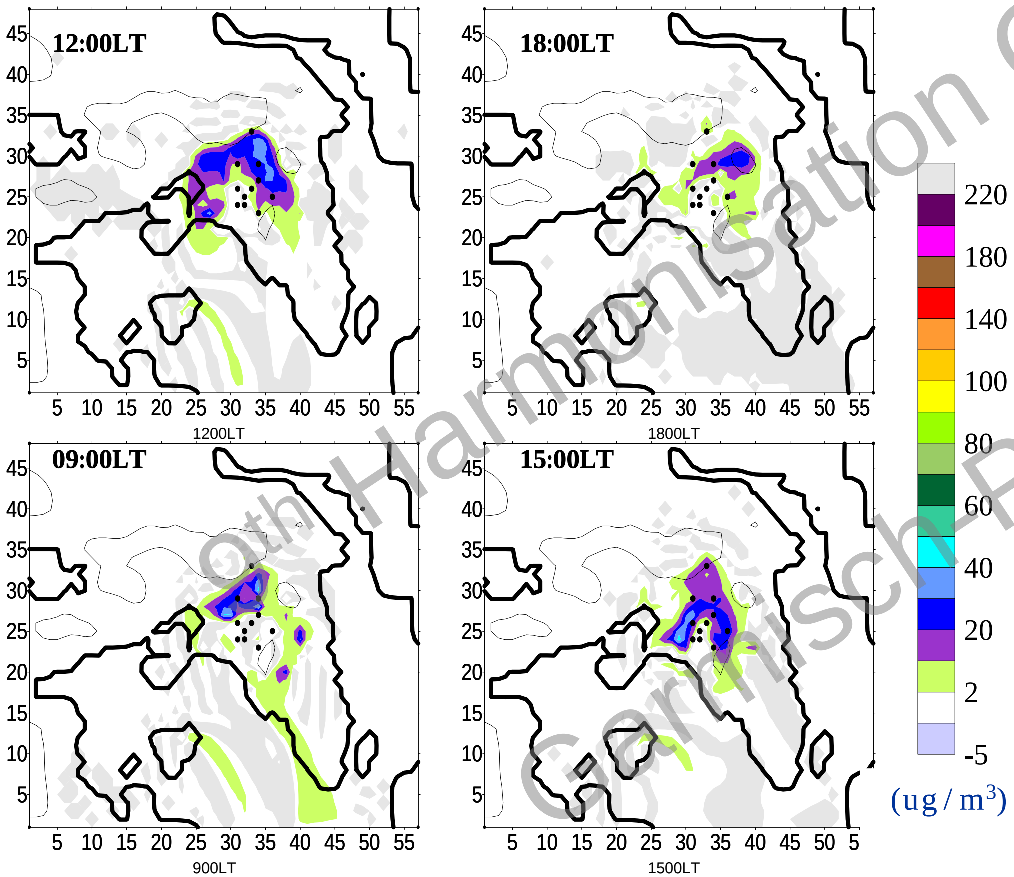
No Nesting



(ug/m^3)

Effect of the Urban sector *(Masson, 2000)*

Base case with Urban effects - Base case

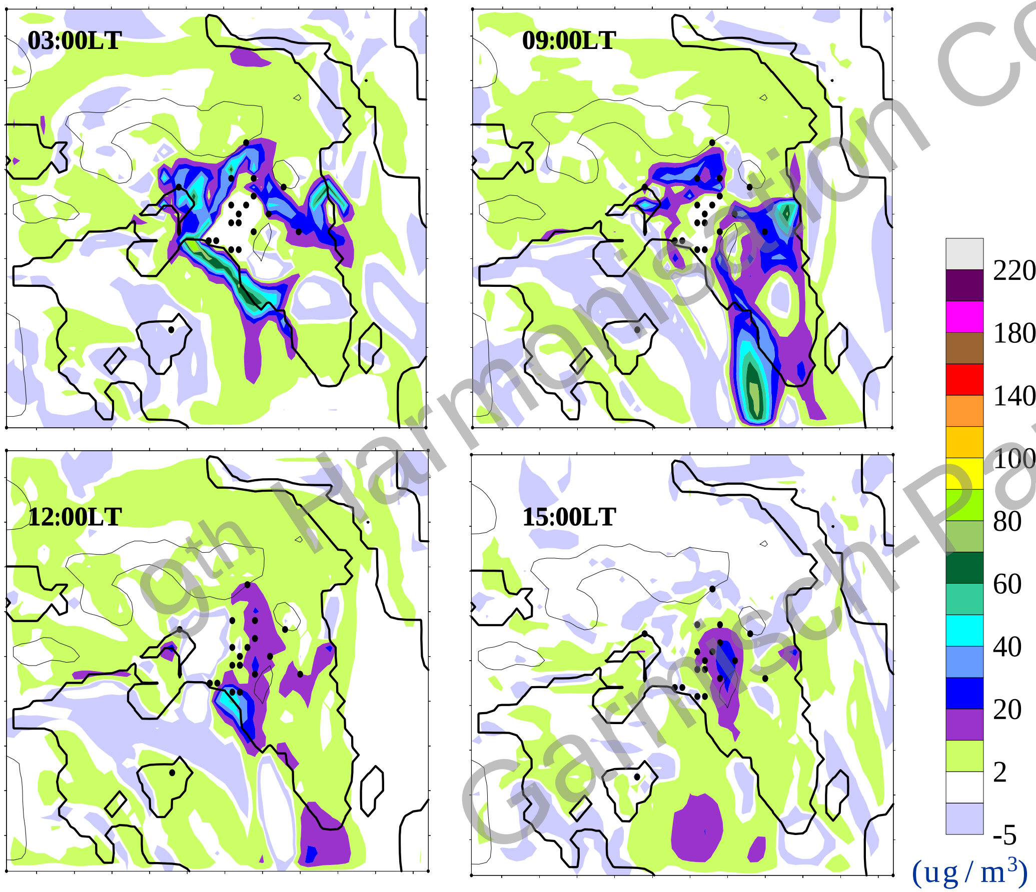


- **Traffic stations,** the decrease is 5ug / m^3 due to lower wind speeds.

- **Suburban stations,** the increase up to 30ug / m^3.

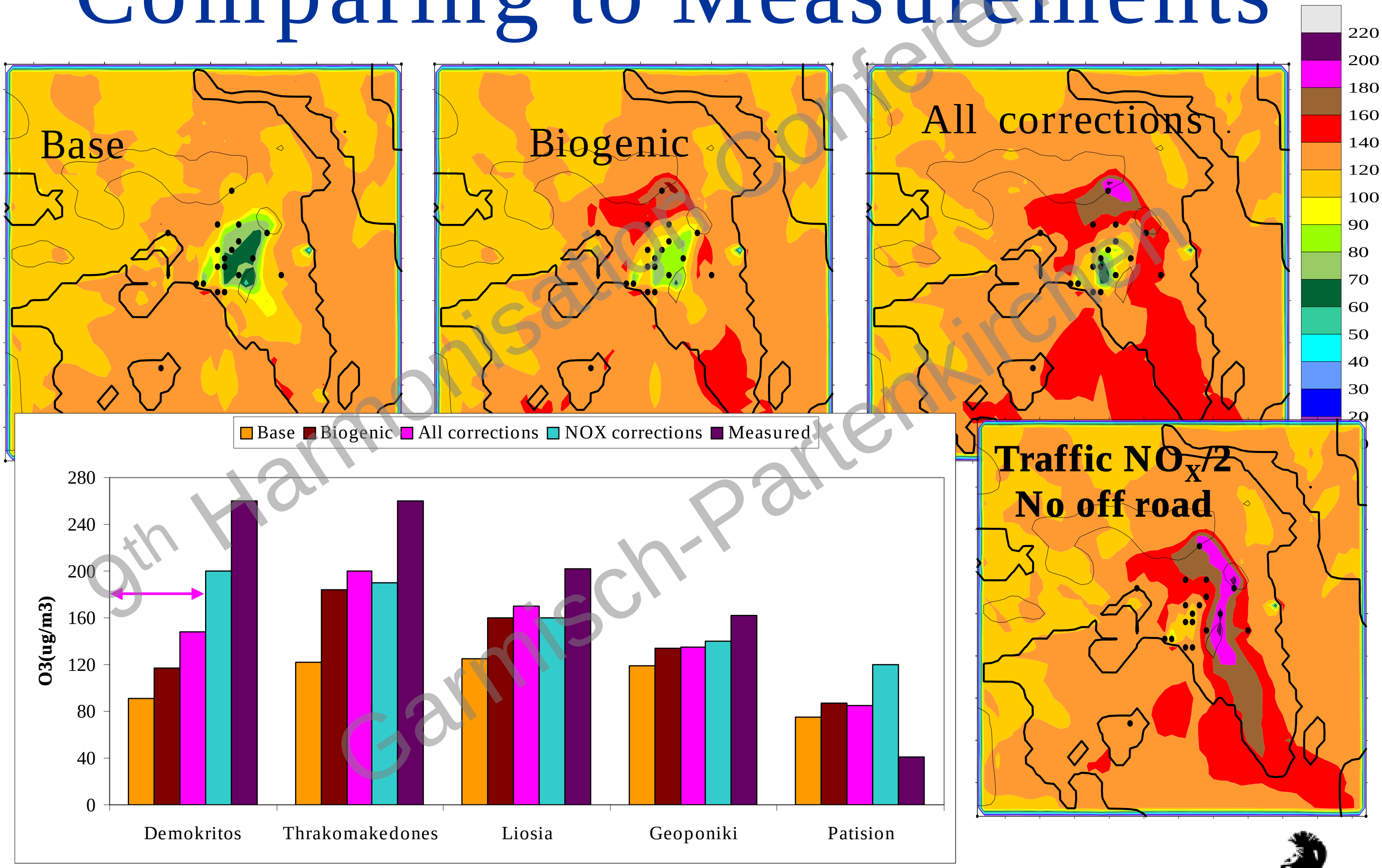
Vertical layer thickness

Base case (130m) - Base case (75m)



- **Night/morning** hours, prevent the O_3 titration in areas where the polluted air masses have been transported
- **Noon/afternoon** hours, the contribution is up to 25ug / m^3
- The **suburban** stations are mainly affected

Comparing to Measurements



Conclusions

- Most of the corrections/additions and modifications of the input data are necessary.
- Meteorology plays a significant role in the GAA.
- The results in the suburban stations were improved, with the meteorological parameters modification inside the urban sector and the NMVOC speciation.

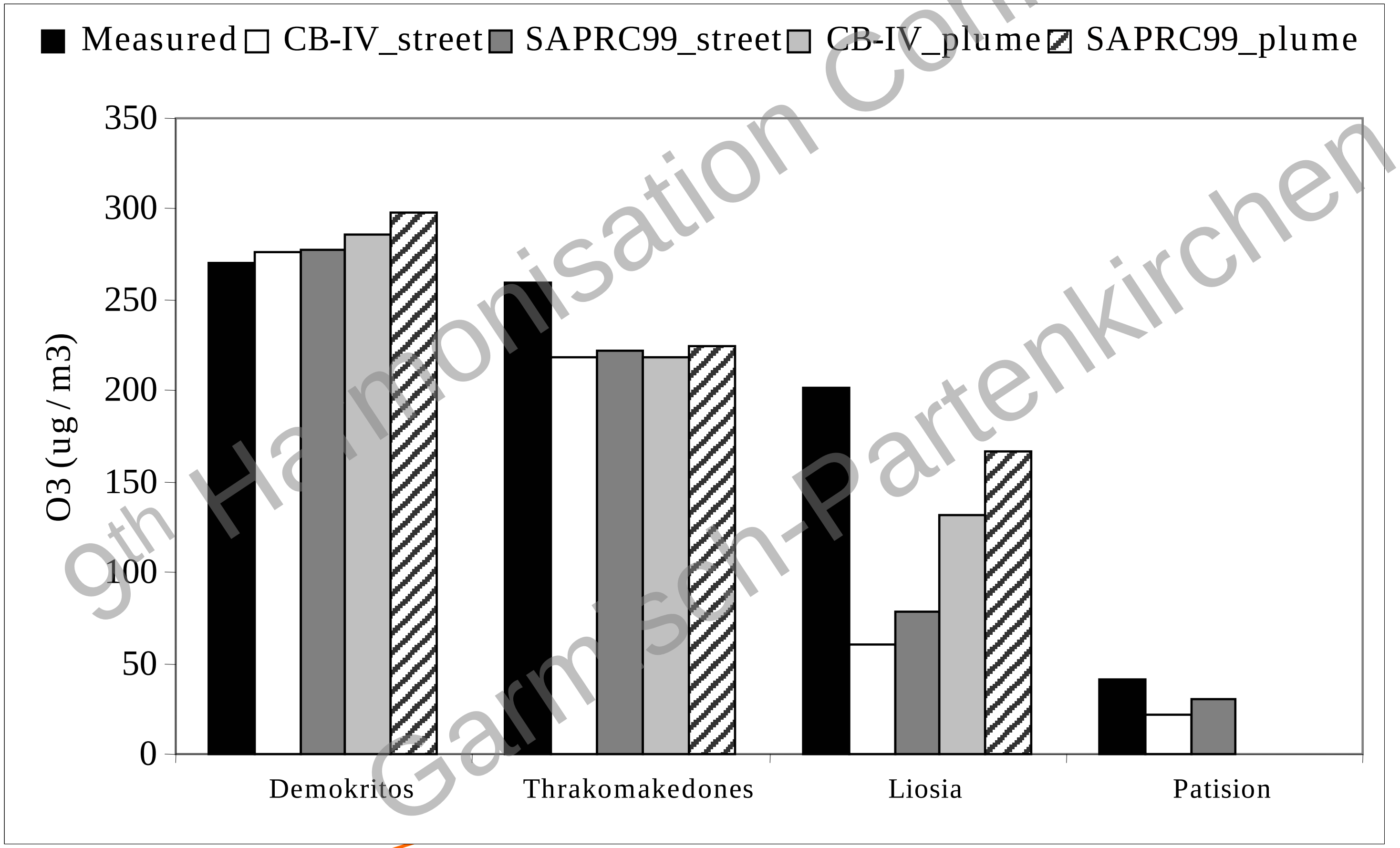
Box Model

- The mean hourly ozone concentrations at selected sites were further reproduced with the **Box SAPRC** model

- The **Box** model was applied either with CB-IV *(Gery, M.W, et al., 1989),* the approach considered by UAM-V or with SAPRC-99 *(Carter, W.P.L, 2000)* chemical mechanism.

- Two alternative scenarios for the anthropogenic emissions:
  - a common speciation profile with city center characteristics,‘street’
  - a ‘plume’ profile with increased VOC emissions, applied only over the suburban areas.

Calculated and Measured Maximum O_3 Concentrations



Suburban-Background

Box Results

- At the **suburban** stations (Demokritos and Thrakomakedones), the biogenic emissions have a major contribution, therefore, their high reactivity produces elevated concentrations.
- The **suburban** station (Liosia) seems to be very sensitive to the different VOC speciation profiles. The station is on the sea breeze axis, thus it feels the ‘plume’ speciation in the absence of biogenic emissions.
- The box model simulates more succesfully than the UAM-V, the limited values of ozone at the **traffic** station (Patision). The box model resolves more accurately the street canyon than the eulerian model (resolution of 4km2).
- SAPRC99 mechanism always gives higher concentrations.