# STUDY OF POLLUTANT TRANSPORT IN COMPLEX TERRAIN USING DIFFERENT METEOROLOGICAL AND PHOTOCHEMICAL MODELLING SYSTEMS


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# OBJECTIVE

To simulate the air quality of a rural topographic complex area as during later spring and summer can attain high values of ozone.

The simulation is conducted during an ozone episode (21-26 June 2001).

The first point is:

To evaluate the performance of the meteorological models used. In particular we will asses three meteorological models.

The second point, and still in relation with the performance analysis, is :

To couple two photochemical models to the meteorological models previously mentioned, evaluating the ability of the air quality models to forecast surface ozone concentrations



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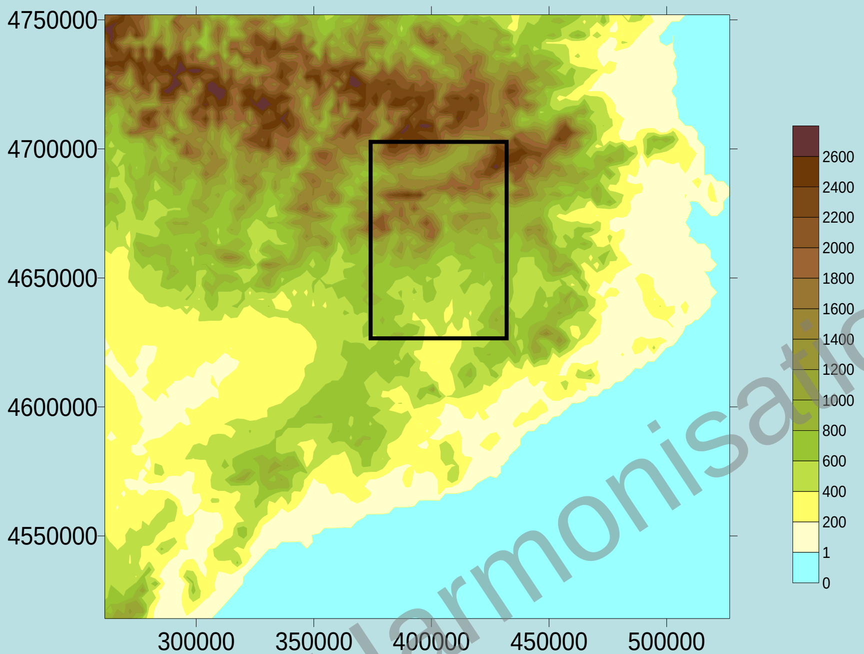
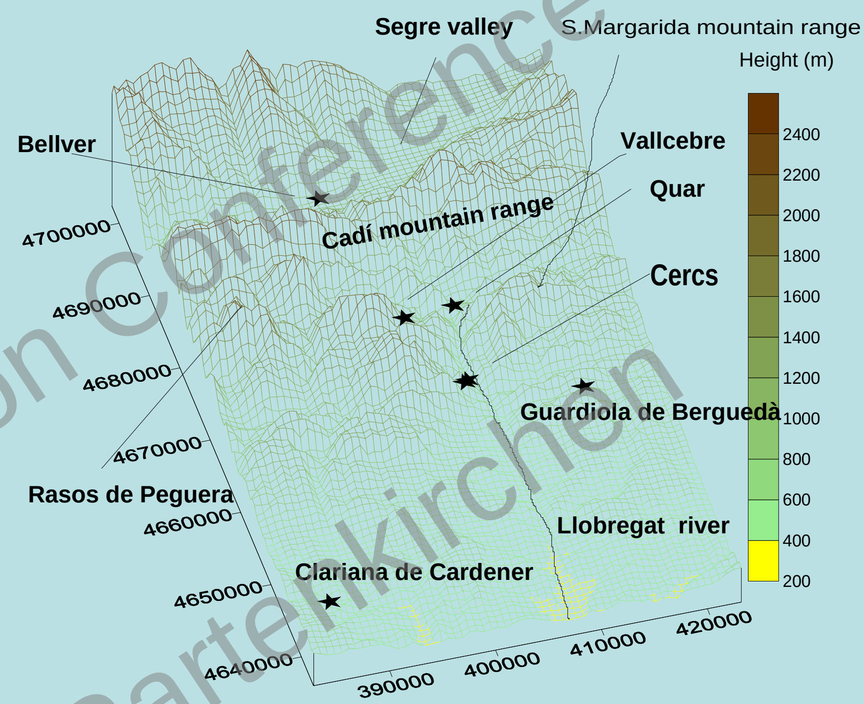
# REGION UNDER STUDY

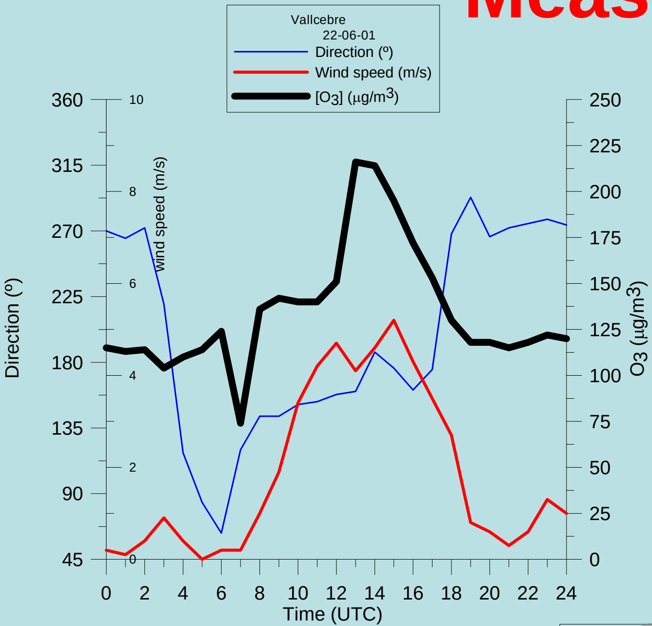


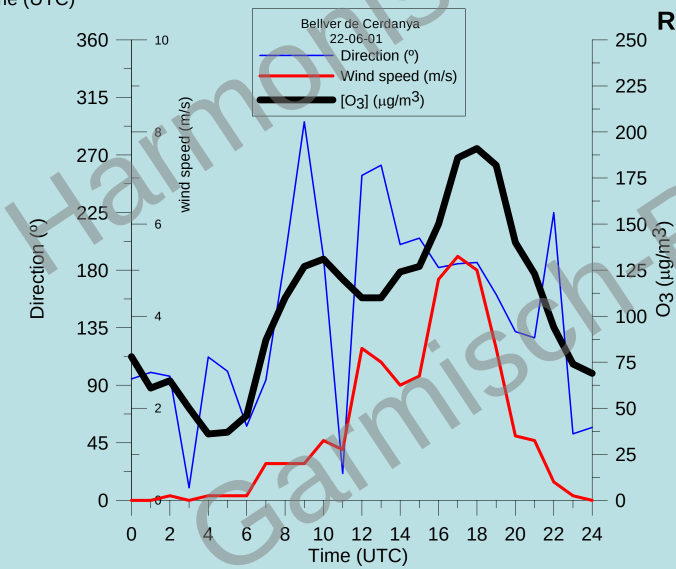


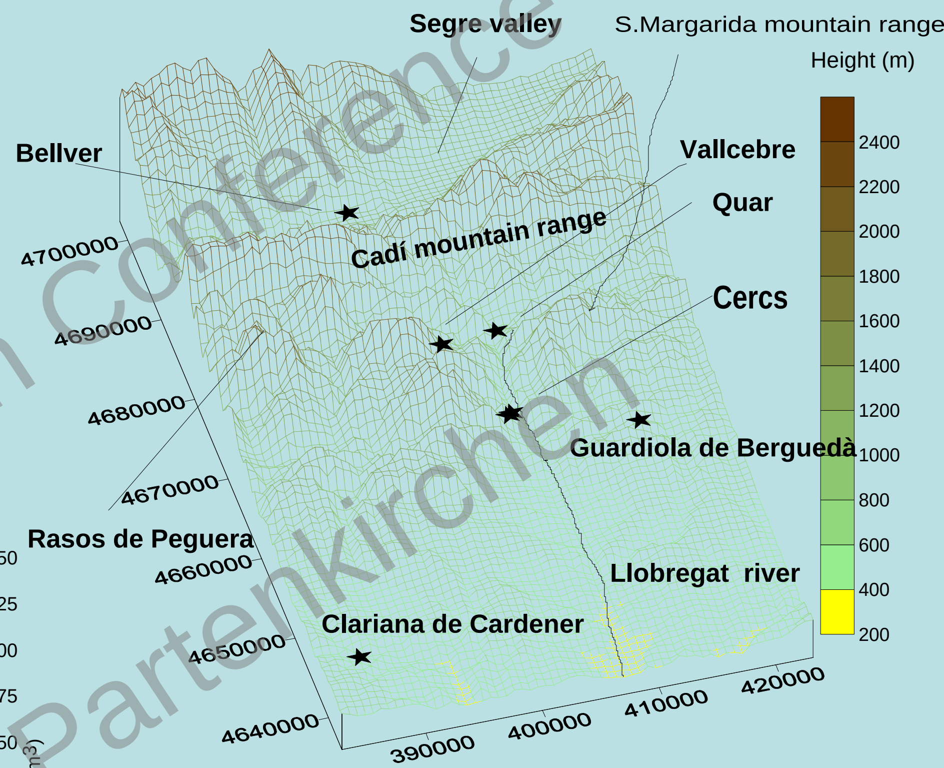

The studied area is located in the northeast part of Spain. It is characterized by complex terrain with mountain range rising over 2.500 m
The power plant is located on a small village named Cercs surrounded by two mountain ranges.
The valley links to the south with the Central Depression, where is located the industrial area, and to the north with the Serra del Cadí mountain range (2531 m height). In front of it there is the Segre valley.

# Measurements in the area




Vallcebre




Bellver

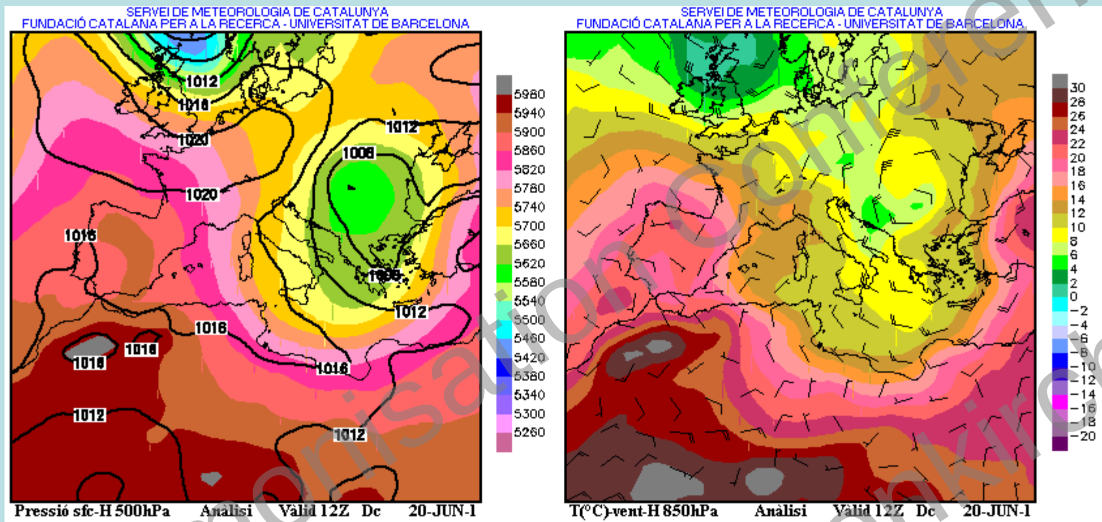
Indicate when the wind comes from the south direction, ozone concentration increases arriving to its maximum value. It seems that the South wind transports ozone and precursors from the power plant and industrial area to the different mountain ranges.

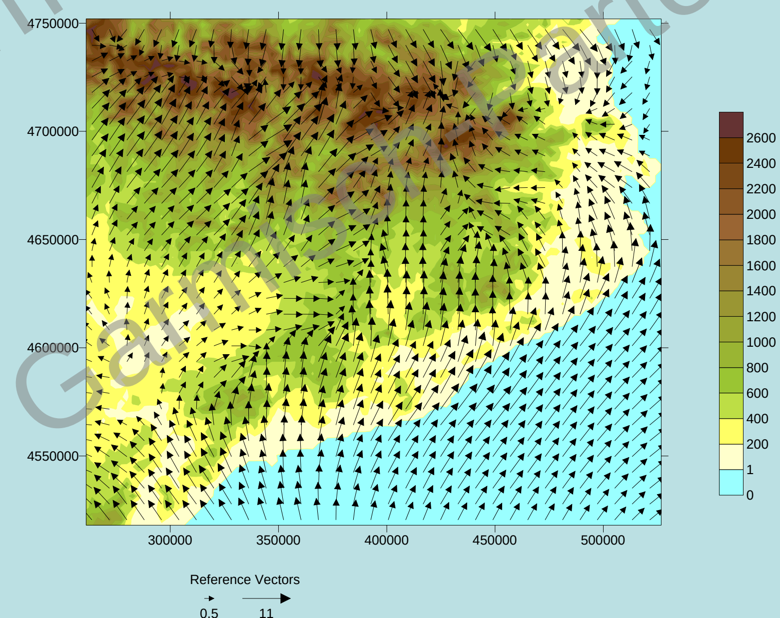
# LARGE SCALE SITUATION (21-26 June 2001)

The synoptic situation during the period studied is anticyclonic with high pressures and weak winds favouring the development of mesoscale circulations such as sea breeze

High pressures

Low winds




Sea breeze entrance simulated by MM5 model

# METEOROLOGICAL MODELS

**MM5** The Fifth-Generation Mesoscale Model Pennsylvania State University/ National Center for Atmospheric Research (PSU/NCAR)

**MASS** Upgrade version of The Mesoscale Atmospheric Simulation System, developed by Meso Inc.

**CLUSTER OF PC (Presently)**

**TAPM** The Air Pollution Model developed at the CSIRO Atmospheric Research Group, in Australia

**PC**

# PHOTOCHEMICAL and EMISSION MODELS



## UAM -V

Grid Urban Airshed Model (UAM-V),developed by Systems Applications International, (SAI), version 1.30 (fast chemistry solver).

## EMISSION MODEL

Considers biogenic and antropogenic emissions, developed in the UB, University of Barcelona (Ortega et al., 2003)

## PHOTOCHEMICAL MODEL OF TAPM

The air pollution component of TAPM developed at the CSIRO Atmospheric Research Group, in Australia.

I will do not speak about the characteristics of the meteorological, photochemical and emission models, you can find information in the bibliography, until two words about **PHOTOCHEMICAL MODEL OF TAPM**

In this study we present the version which only allows the inclusion of a point source.
A new version of TAPM photochemical model including 2D emission inventory will be executed soon.

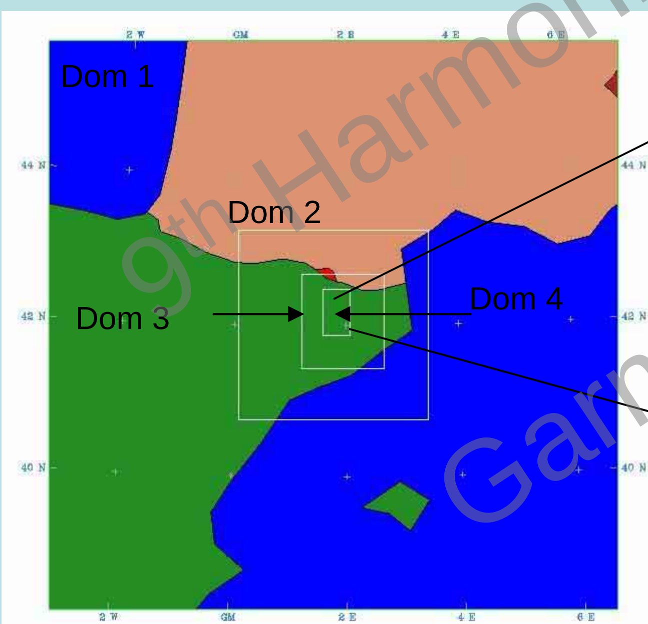
# MM5, MASS and UAM-V SIMULATION DOMAINS

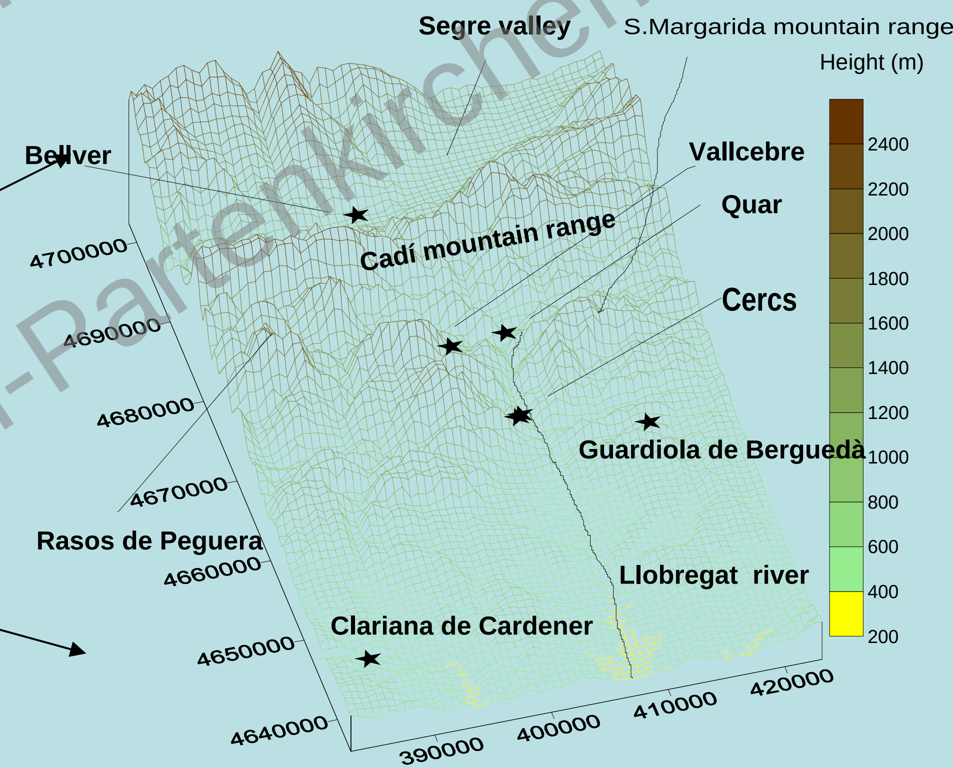
For meteorological models we have consider 4 nested domains.

For UAM-V we have considered two nested domains, which concord with the two inner domains of the meteorological models

For UAM-V model  boundary and initial conditions are provided on the basis of land use cover and have been derived from measurements and literature values.





# DETAILED INFORMATION

| MM5 - MASS | DOMAINS | RESOLUTION | GRID CELLS | VERT. LEVELS |
|---|---|---|---|---|
| | DOMAIN 1 | 27 km | 31x31 | 27 |
| | DOMAIN 2 | 9 km | 31x31 | |
| | DOMAIN 3 | 3 km | 46x40 | |
| | DOMAIN 4 | 1 km | 67x40 | |
| TAPM | DOMAIN 1 | 27 km | 67x40 | 30 |
| | DOMAIN 2 | 9 km | 67x40 | |
| | DOMAIN 3 | 3 km | 67x40 | |
| | DOMAIN 4 | 1 km | 67x40 | |
| UAM-V | DOMAIN 3 | 3 km | 46x40 | 8 |
| | DOMAIN 4 | 1 km | 67x40 | |

# METEOROLOGICAL SIMULATION

The meteorological simulation and later comparison have been conducted from 21 to 26 June 2001, during an ozone episode.

Basically all simulations are focused to evaluate how the models properly forecast the wind field (responsible for ozone transport)

We present :

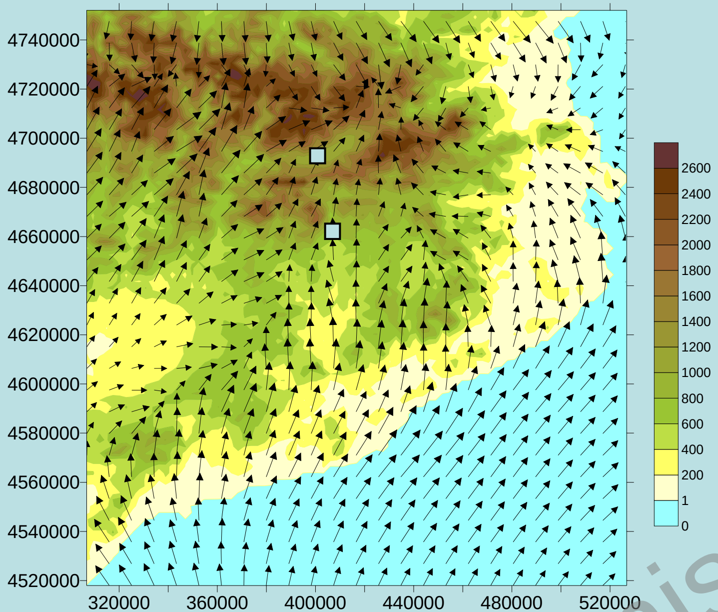
- The meteorological **circulatory patterns** given by the models in two domains: 9x9 $km^2$ (larger scale) and 1x1 $km^2$ (smallest scale).

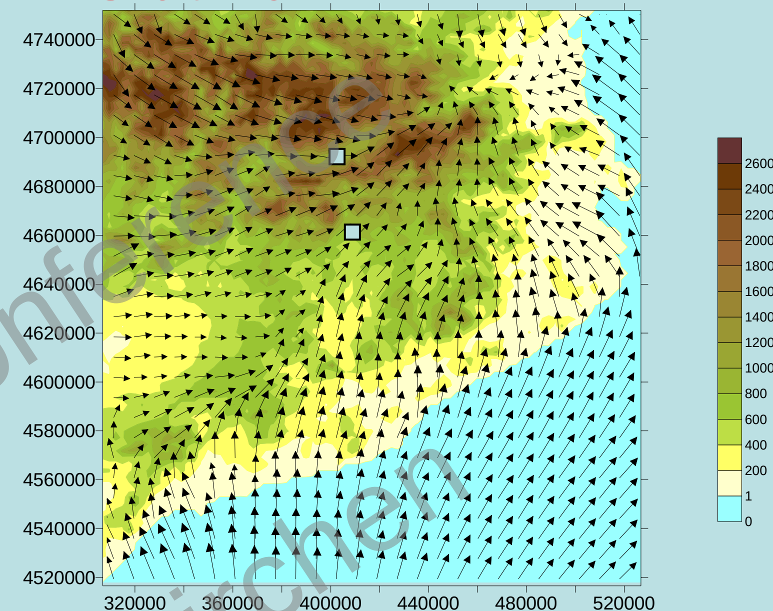
- Time evolution of wind measured in different stations and those simulated by the three models at the same grid. We attempt to have more detailed information.

- The values of some **statistical parameters** calculated for the inner domain.

# CIRCULATORY PATTERNS at 10 m

## (9x9) $km^2$ at 12 UTC 22 June

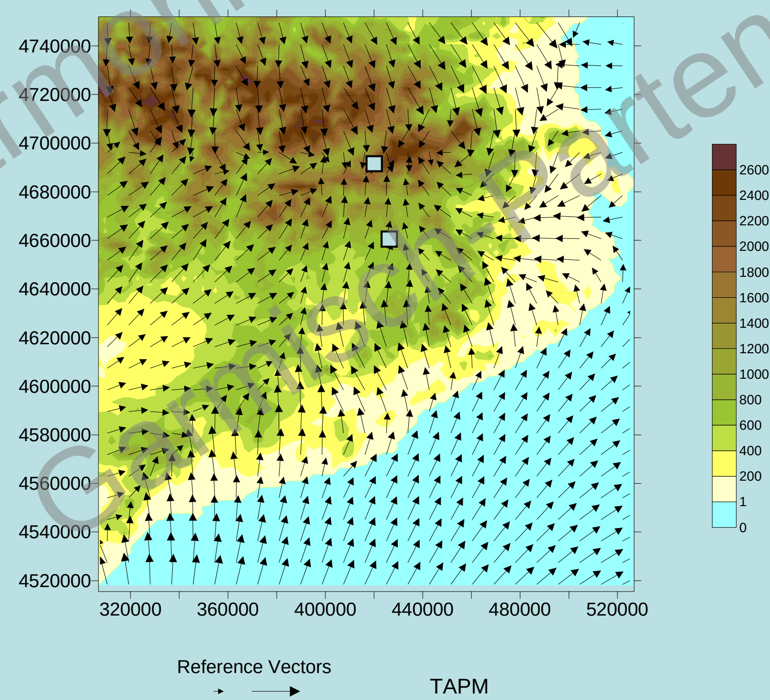


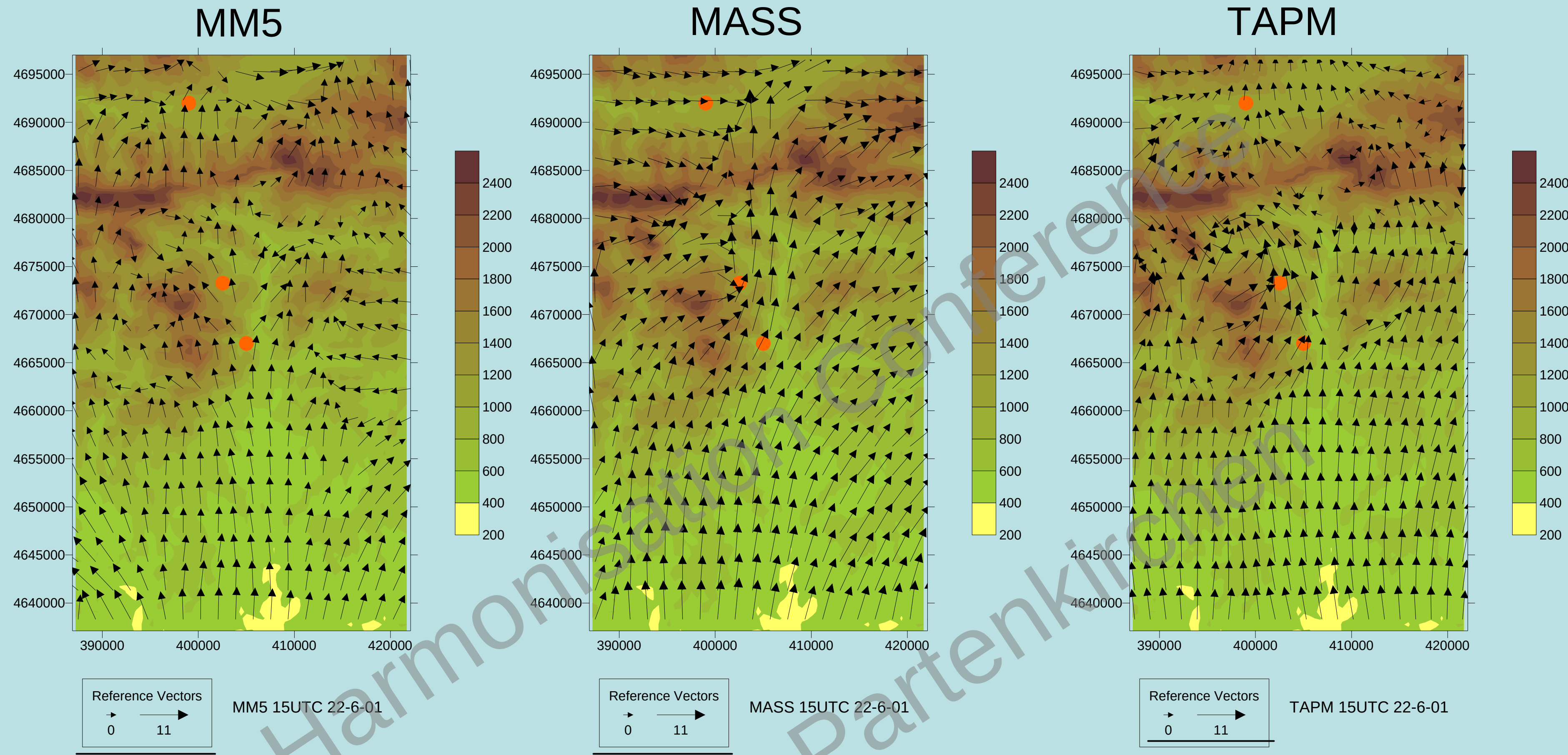

MM5

MASS

TAPM




Circulation patterns supplied by the three models. The results points out two prevailing directions in the area of interest, winds from the S-SW direction in the south part of the domain and winds from the W and SW at the Segre valley.



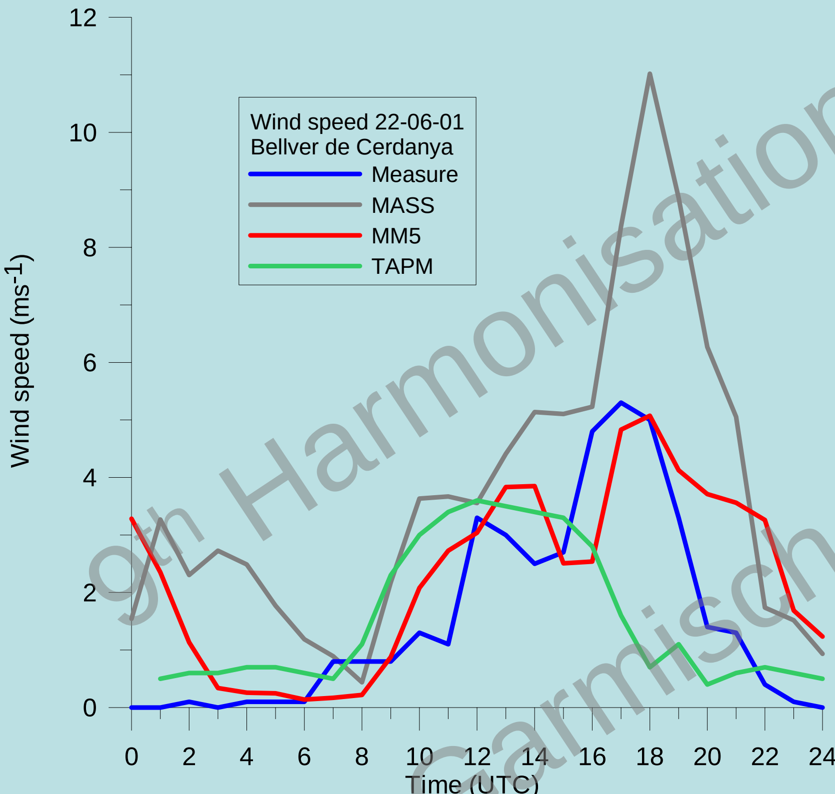



In a similar way this figure shows the circulation pattern for the inner domain **(1x1) km$^2$ at 15 hours.**

- At the bottom of the domain the three models successfully predicted the penetration of the sea-breeze front (characterized as a southerly wind).
- For MM5 and MASS models, this front will later overwhelm the mountain range and forced by the topography reaches the Segre Valley.
- For TAPM model the wind seems do not cross the mountain range, but the topography forces the wind to arrive to the Segre valley from the SW and S directions.

# Time evolution of winds measured in different stations and those simulated by the three models

## Comparison at Bellver station (example)

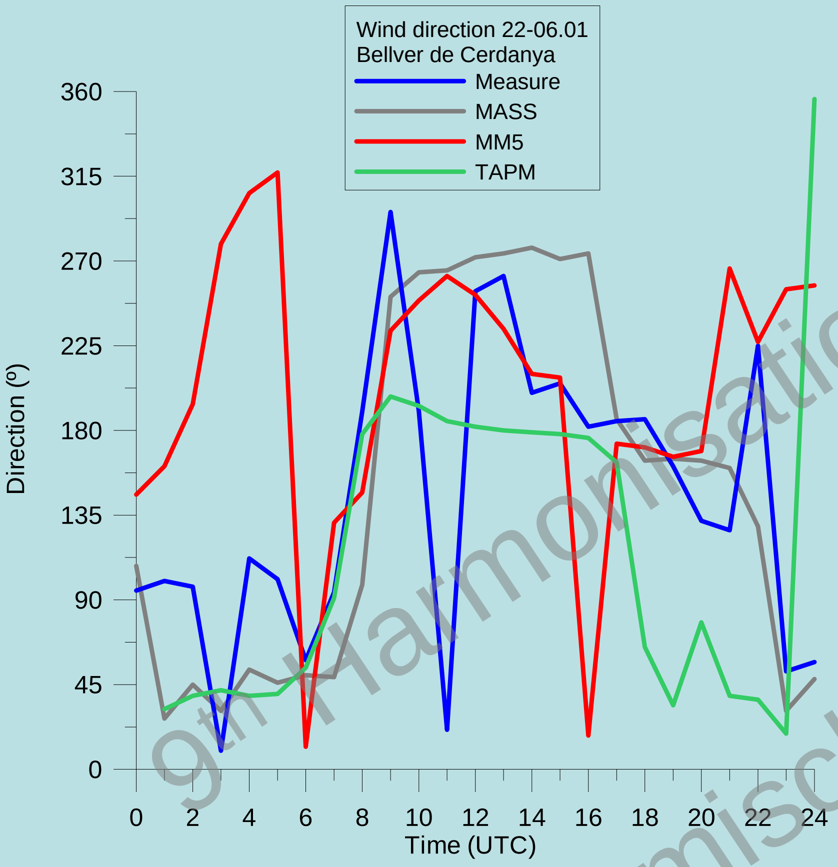



Results show:

Quite good agreement between MM5 simulated wind speeds and those measured.
MASS model tends to overestimate speeds mainly during the late afternoon.

The simulation results for TAPM indicate that, although the model forecasted increasing wind speeds during daytime, the winds predicted slow down during the late afternoon, in disagreement with measurements.

# WIND DIRECTION




Wind direction comparison should be done carefully during night-time and early morning due to the little confidence of this measurement in low winds conditions. This is the case in Bellver station until 10 UTC.

After this time, the models present several differences between measured and predicted values.

In general winds have westerly components turning towards the South as the late afternoon progresses. The bearing is more progressive in MM5, while MASS shifts suddenly around 17 UTC, and TAPM predicts the southerly winds too early.

In addition we have calculated from surface measurements the daily accuracy for meteorological models.

| Surface Stations | A (WS) m/s | | | A (DIR) º | | |
|---|---|---|---|---|---|---|
| | MM5 | TAPM | MASS | MM5 | TAPM | MASS |
| Bellver | 1.7 | 1.5 | 3 | 78 | 79 | 82 |
| Quar | 1.5 | 1.8 | 2.8 | 53 | 38 | 58 |
| Vallcebre | 1.1 | 3.8 | 3.8 | 50 | 47 | 48 |
| Cercs | 1.2 | 1.4 | 3.5 | 69 | 45 | 47 |
| Guardiola B. | 2.1 | 2.2 | 4.2 | 67 | 72 | 42 |
| Clariana C. | 2.1 | 2.0 | 3.1 | 70 | 41 | 57 |

All models over-predict wind velocity, specially MASS model while the accuracy values for wind direction are of the same order.

# STATISTICAL MODEL COMPARISON

We know the period of comparison is too short to be statistically representative, but even so, some parameters have been calculated as BIAS, RMSE and Direction accuracy.
They could be a guide

$$BIAS = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}(X_{model1,i,j} - X_{model2,i,j})}{m.n}$$

$$RMSE = \sqrt{\frac{\sum_{j=1}^{m}\sum_{i=1}^{n}(X_{model1,i,j} - X_{model2,i,j})^2}{m.n}}$$

Where the subscripts i and j represent de grid and the time, n is the number of grids and m the number of hours.

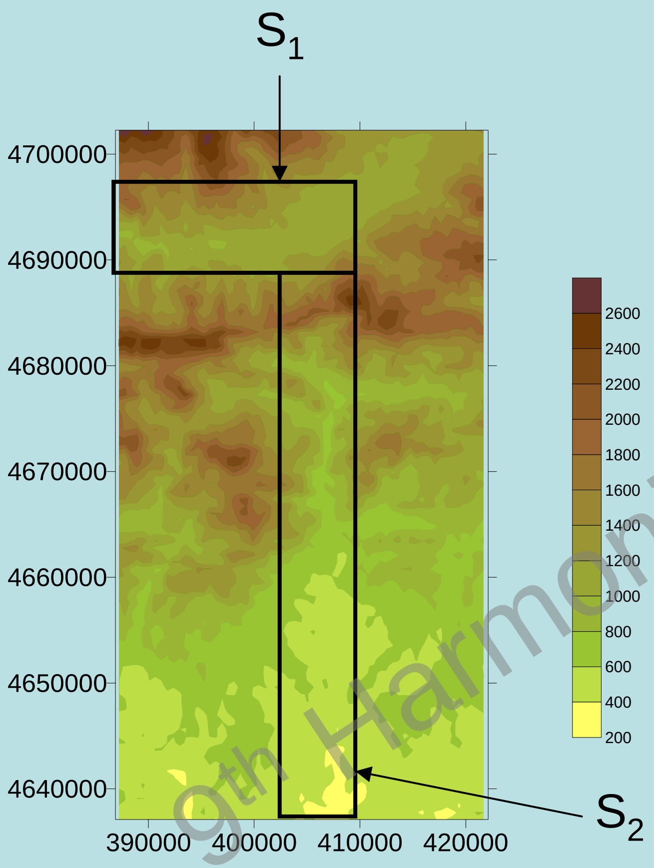
$$A = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n}| X_{model1,i,j} - X_{model2,i,j} |}{m.n}$$

$$\sum_{j=1}^{m}\sum_{i=1}^{n}| X_{model1,i,j} - X_{model2,i,j} | \quad < 180 \quad (1)$$

and |u| and |v| > 0.4 (2)

Model 2 =MM5 (The model presents better agreement with measures)

We present the statistics specially calculated in $S_1$ and $S_2$ domains




| DOMAIN $S_2$ | | RMSE ($ms^{-1}$) | BIAS ($ms^{-1}$) | Direction Accuracy (º) |
|---|---|---|---|---|
| MM5 vs. MASS | Global | 2.3 | 1.6 | 55 |
| | Daily 09-15 | 1.6 | 1.2 | 28 |
| MM5 vs. TAPM | Global | 2.5 | 1.5 | 76 |
| | Daily | 1.8 | 0.5 | 68 |

| DOMAIN $S_1$ | | RMSE ($ms^{-1}$) | BIAS ($ms^{-1}$) | Direction Accuracy (º) |
|---|---|---|---|---|
| MM5 vs. MASS | Global | 2.2 | 1.2 | 73 |
| | Daily | 1.4 | 1.1 | 34 |
| MM5 vs. TAPM | Global | 2.0 | 0.5 | 103 |
| | Daily | 1.7 | -0.1 | 100 |

Related to wind velocity, MASS and TAPM models tends to forecasts higher wind velocity in both domains, specially during later afternoon and night-time, The agreement between models is better within the S1 domain.

Related to wind direction, the agreement between model is worse, specially for TAPM model at S1 domain. For MASS model the agreement improves for daily hours in both domains.

# PHOTOCHEMICAL SIMULATIONS

The photochemical simulation is conducted, like the meteorological simulation from 21 to 26 June 2001.

The emission and the characteristics of the power plant are the following:

- 528.67 kg/h of CO; 996.21 kg/h of NOx; 5504.07 kg/h of $SO_2$ ;116 Kg/h of particles
- The stack has 120 m height and the emission temperature is 150 ºC, emission velocity= 21.1 $ms^{-1}$ and diameter 2.2 m.

We will present:

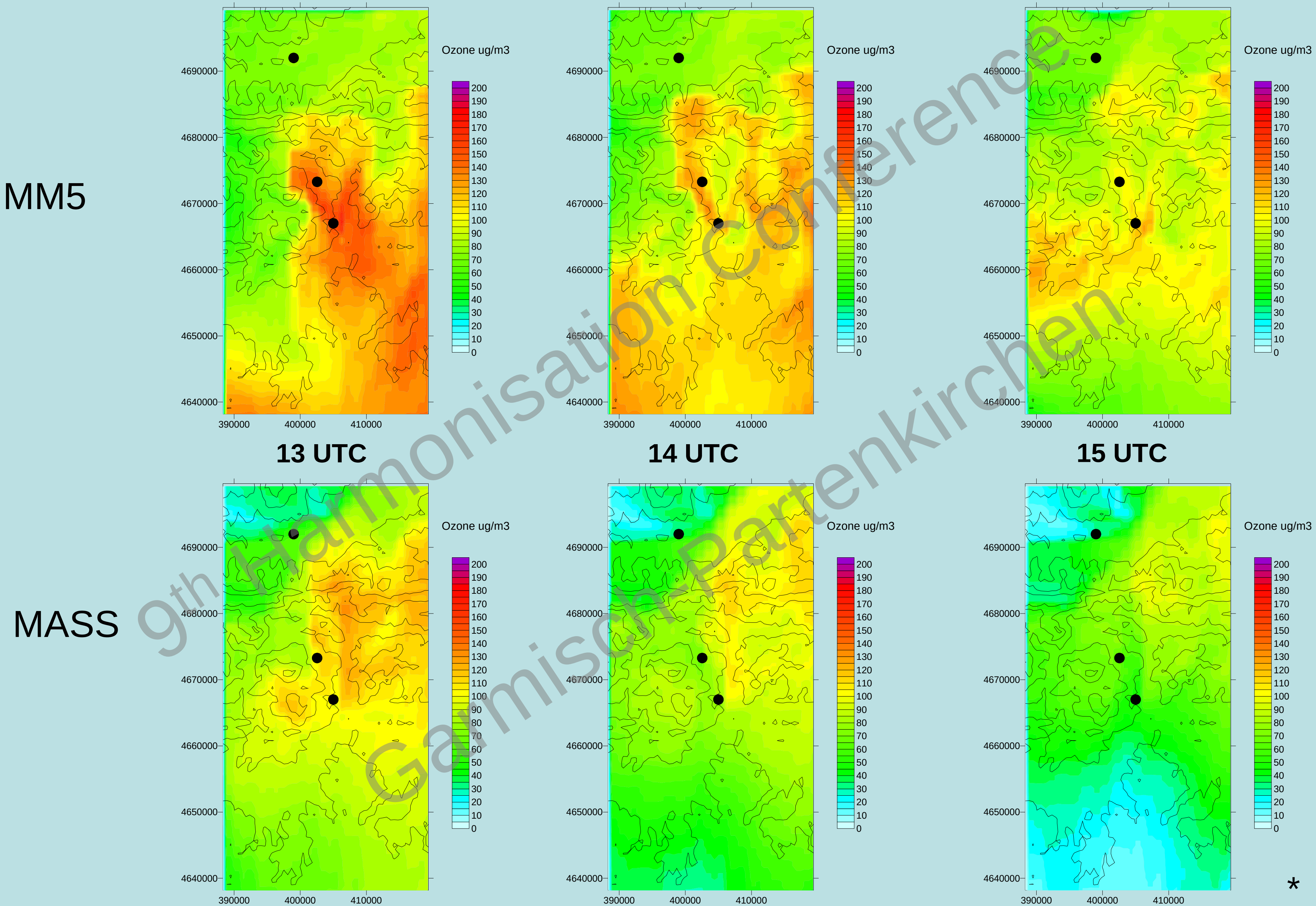
- The dispersion pattern of ozone concentration for the inner domains given by two air quality systems: UAM-V + MM5 and UAM -V + MASS. In this comparison we haven not taken into account TAPM model as the available version used for this work did not allow 2D emission inventory.

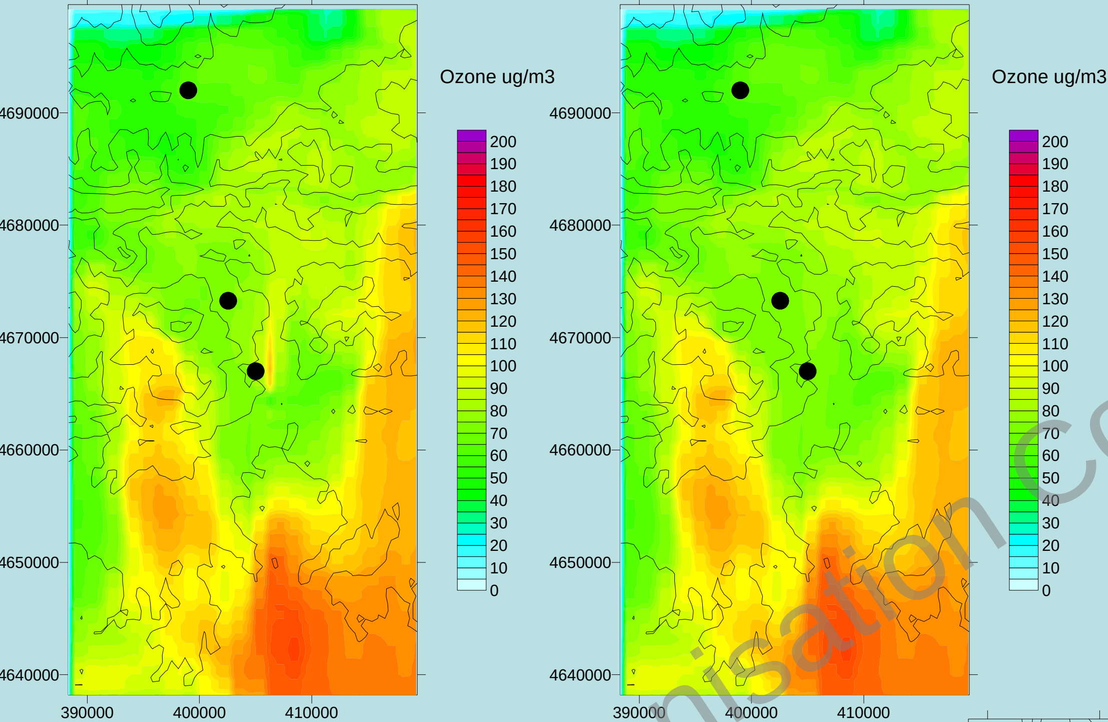
- The values of some statistical parameters calculated on the inner domain.

- The dispersion pattern of ozone concentration for the inner domain taking and not taking into account the emission from the power plant. Comparison of the two simulations allows us to evaluate its importance on surface ozone concentrations.

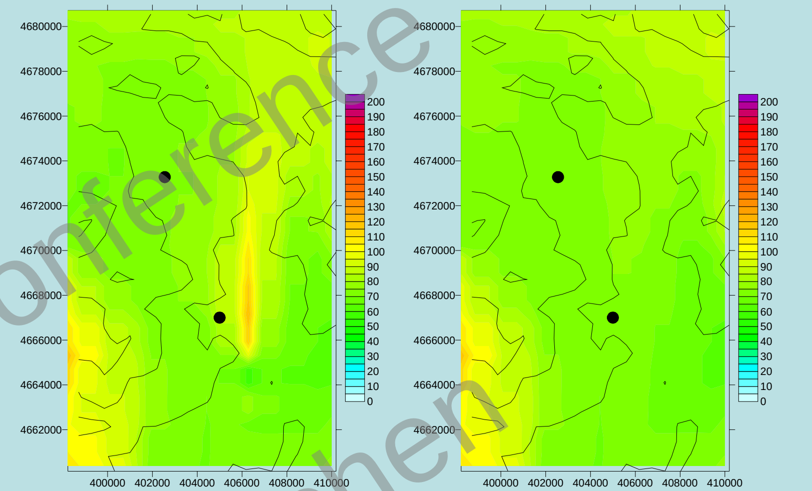
- The dispersion pattern of the plume, simulated by TAPM model. In this case we have used its capability to simulate non-reactive pollutants.

# OZONE DISPERSION PATTERN

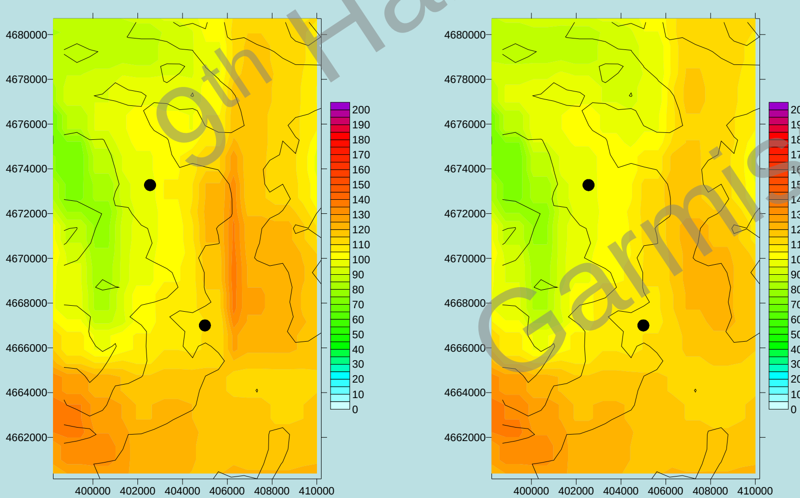


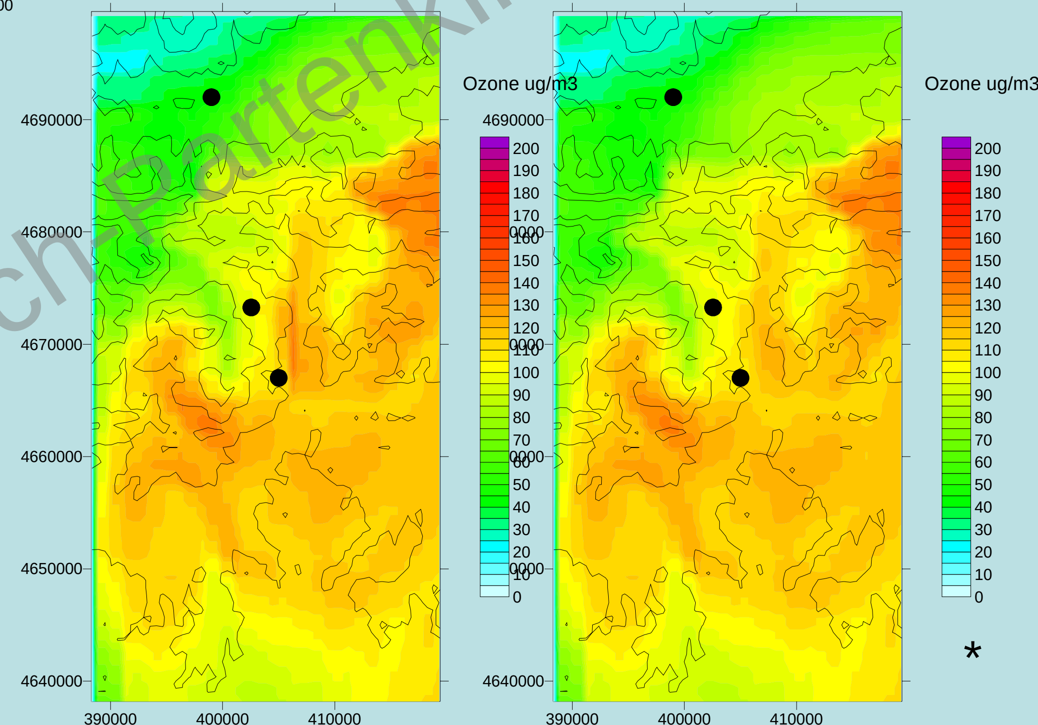



# MM5 (11 UTC)



# MASS(11 UTC)



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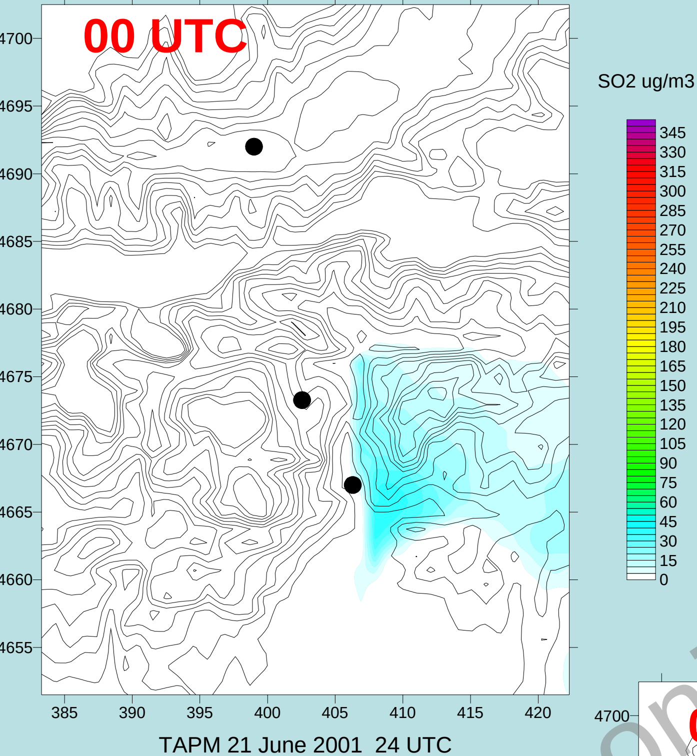
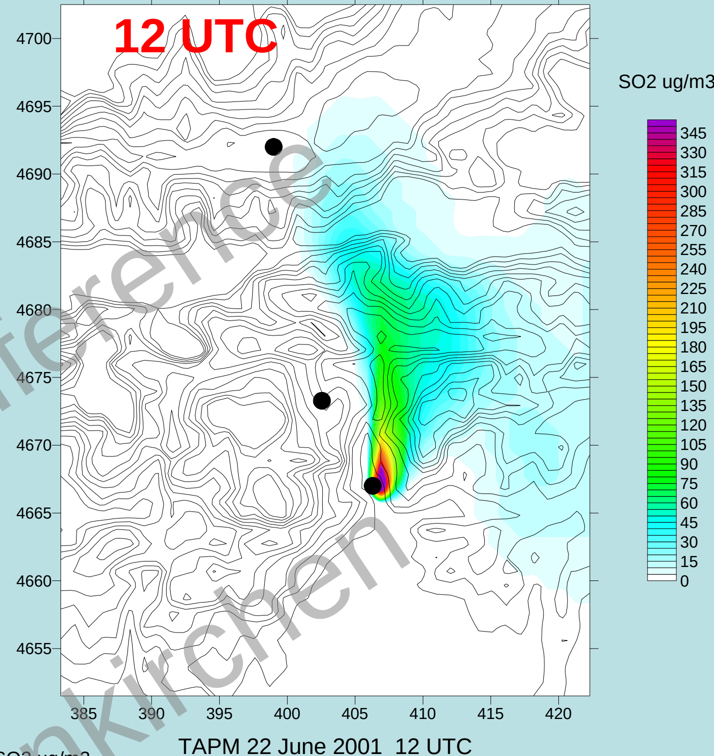
# STATISTICAL AIR QUALITY MODELS COMPARISON
# MM5+ UAM-V vs. MASS+UAM-V

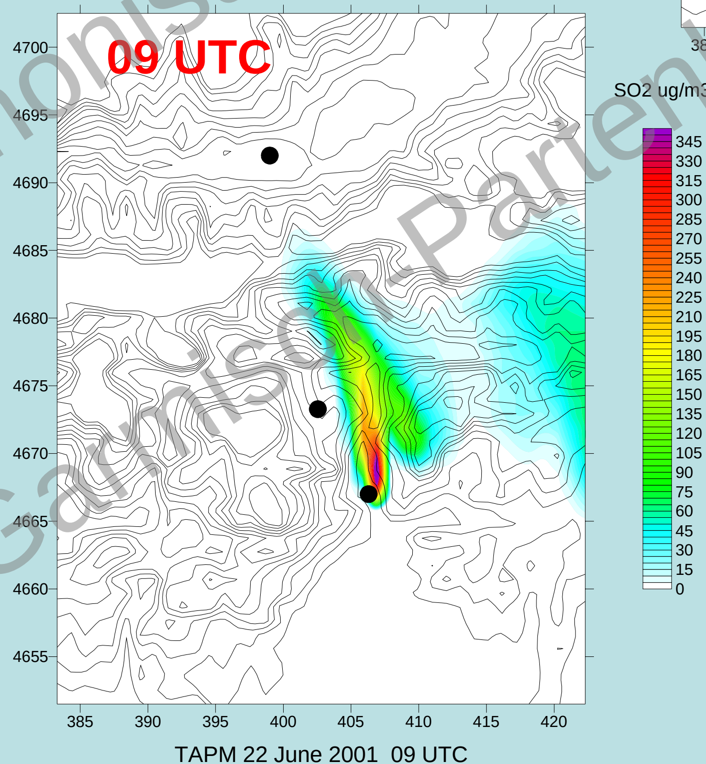
| SMALLEST DOMAIN | | Accuracy | BIAS |
|---|---|---|---|
| MM5 vs. MASS | Global | 20.2 | -9.8 |
| | Daily | 26.6 | -10.8 |

The BIAS is negative because MM5 concentration is higher than that forecasted by MASS model, as we commented before.

# BEHAVIOUR OF THE PLUME REPRESENTED BY THE $SO_2$ DISPERSION



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# CONCLUSIONS (Point out )

• 1.- Comparison between wind field observations and simulations seem to indicate that MM5 model gives better performances than MASS and TAPM models

• Comparison between models indicates that MASS and TAPM models overestimate the wind velocity and large difference in wind direction is obtained between MM5 and TAPM

• Dispersion patterns indicate that simulation given by UAM-V+ MASS shows a more efficient dispersion than UAM-V+ MM5, as the winds predicted by MASS model are higher than those simulated by MM5.

• 4.- Photochemical simulation tends to indicate that although the emission from the power plant contribute to ozone concentration, the main contribution is due to advection from industrial areas located outside of the inner domain.

• 5.- Neither of both air quality models is able to simulate high ozone concentrations in Segre Valley. We expected that the plume would arrive to this area, but the contribution of the plume to the final ozone levels seems to be minor. So we think that, either the plume contribution is underestimated, or there is another emission source or another effect that is not considered.

• We have presented here only the preliminary results given by the photochemical models, so we think that much more work must be done to arrive to a final conclusion.