Influence of 3D Model Grid Resolution on Tropospheric Ozone Levels

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Introduction

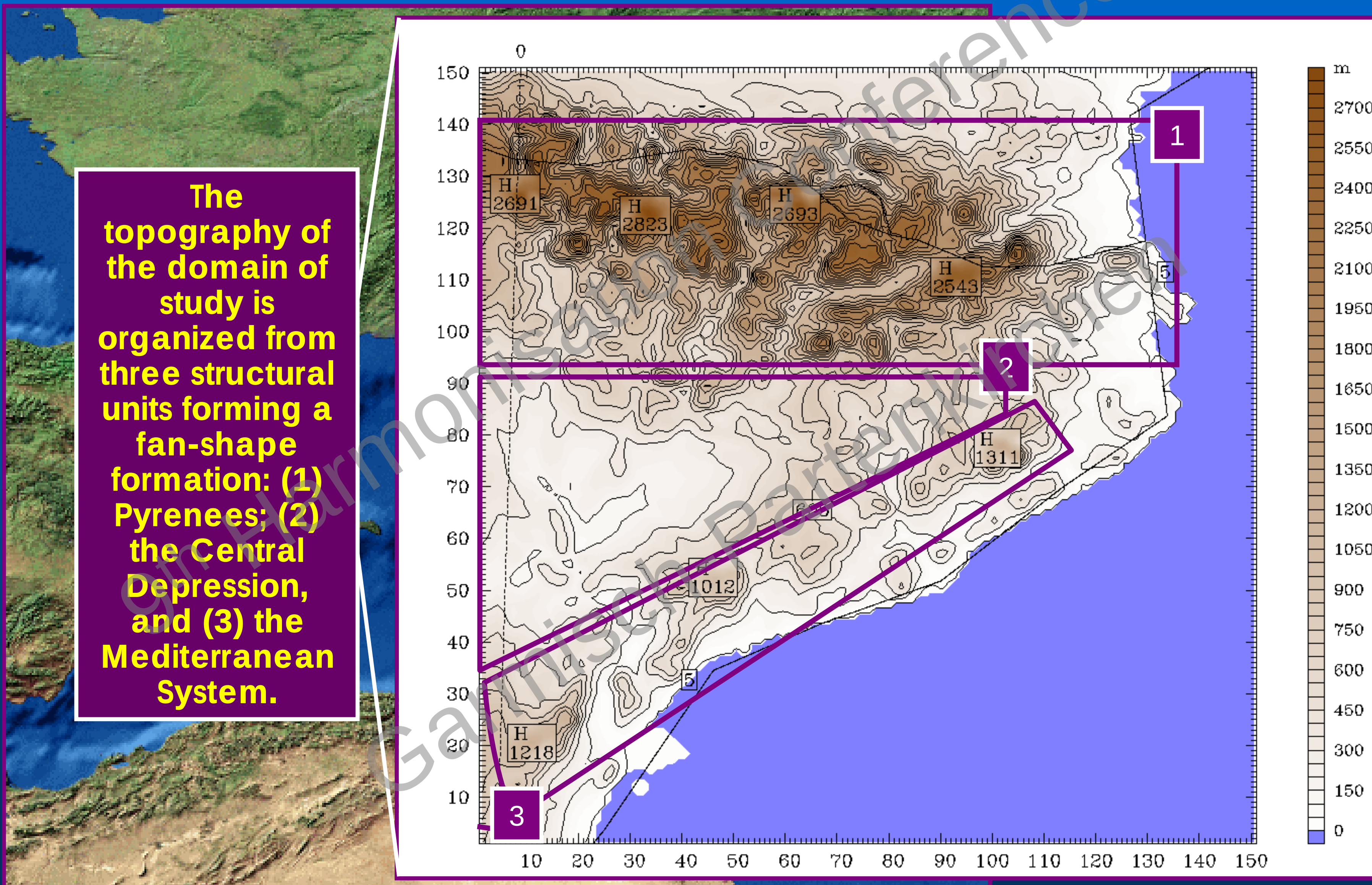
In order to illustrate the influence of grid size on tropospheric ozone levels, several simulations with a three-dimensional air quality model are carried out using different horizontal grid (*8 km, 4 km and 2 km*) and vertical (*6 and 16 layers*) resolutions.

This work encloses a detailed study of the observable differences in values, location and temporal behavior of tropospheric ozone in the northeastern Iberian Peninsula.

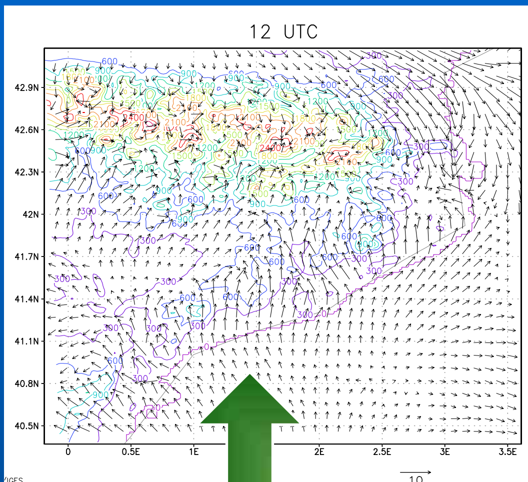
Role of the Geography in Very Complex Terrains

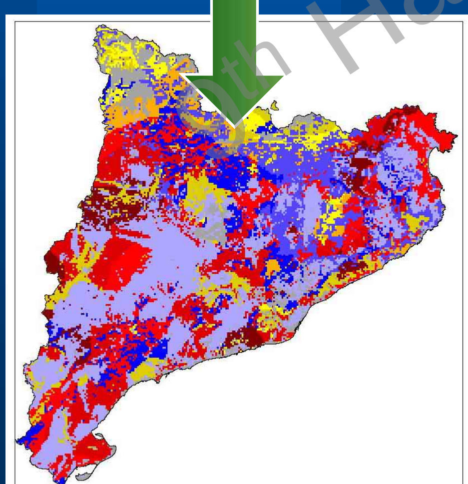
Scenario: Topography

The topography of the domain of study is organized from three structural units forming a fan-shape formation: (1) Pyrenees; (2) the Central Depression, and (3) the Mediterranean System.



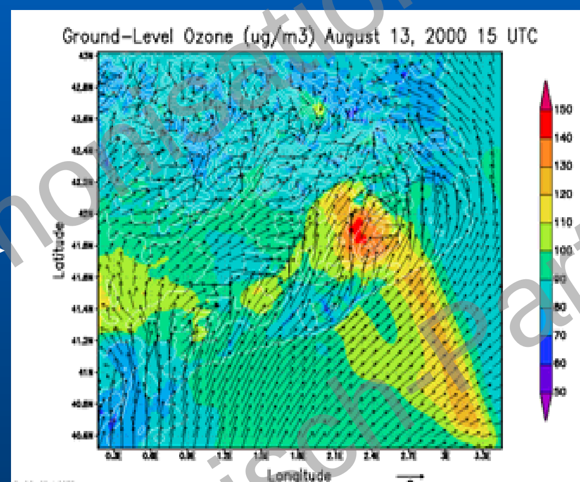
Air Quality Model





MM5-Models-3/CMAQ:

- Meteorological Model: **MM5**
- Emissions Model: **EMICAT2000**
- Chemical Transport Model: **CMAQ**



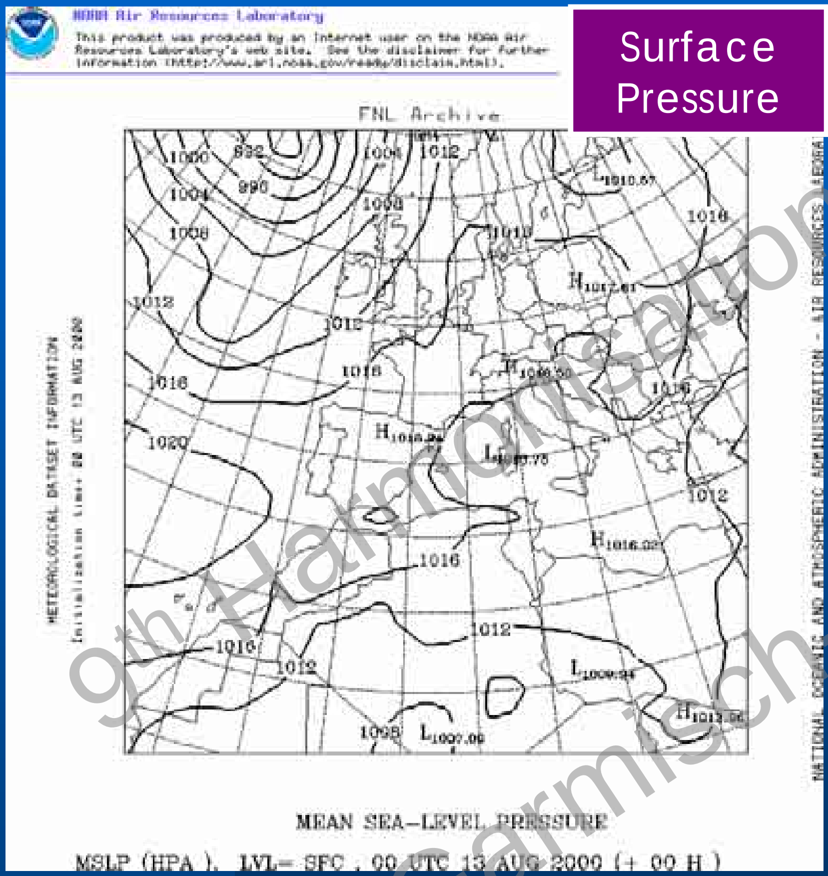
- Assessment of pollutants ground-level and dynamics through the application of high-temporal and spatial resolution numerica modelsl.

- Evaluation of the re-circulations of the Western Mediterranean Basin and the multilayer structures observed in this area.

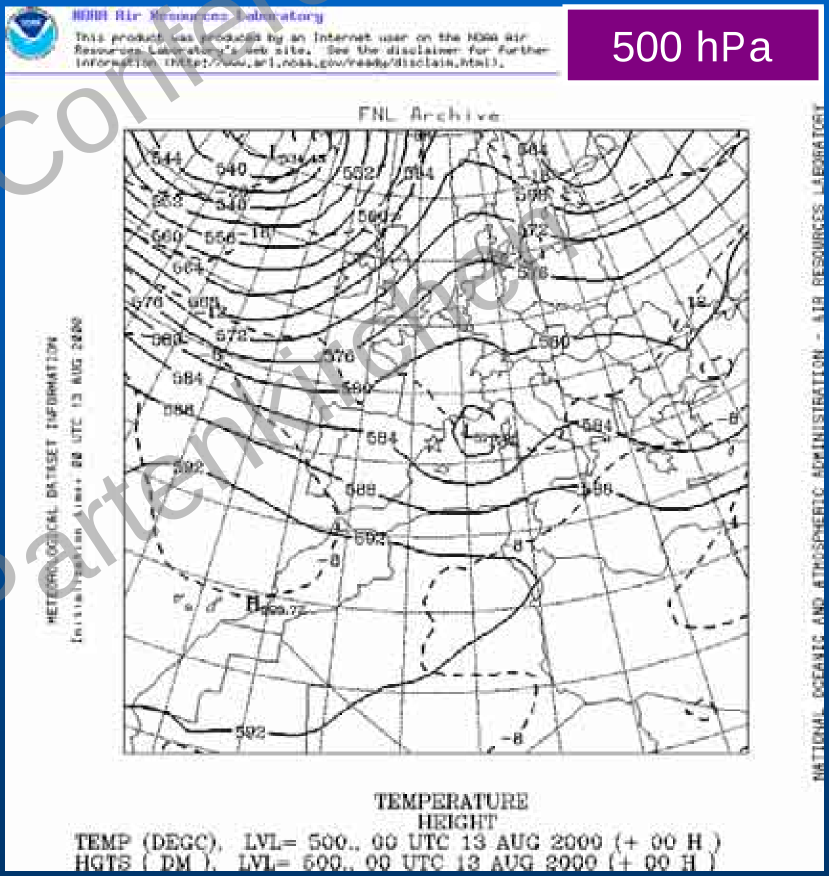
Study Case: August 13-16, 2000

Synoptic situation: low pressure gradient over the Iberian Peninsula

Surface Pressure



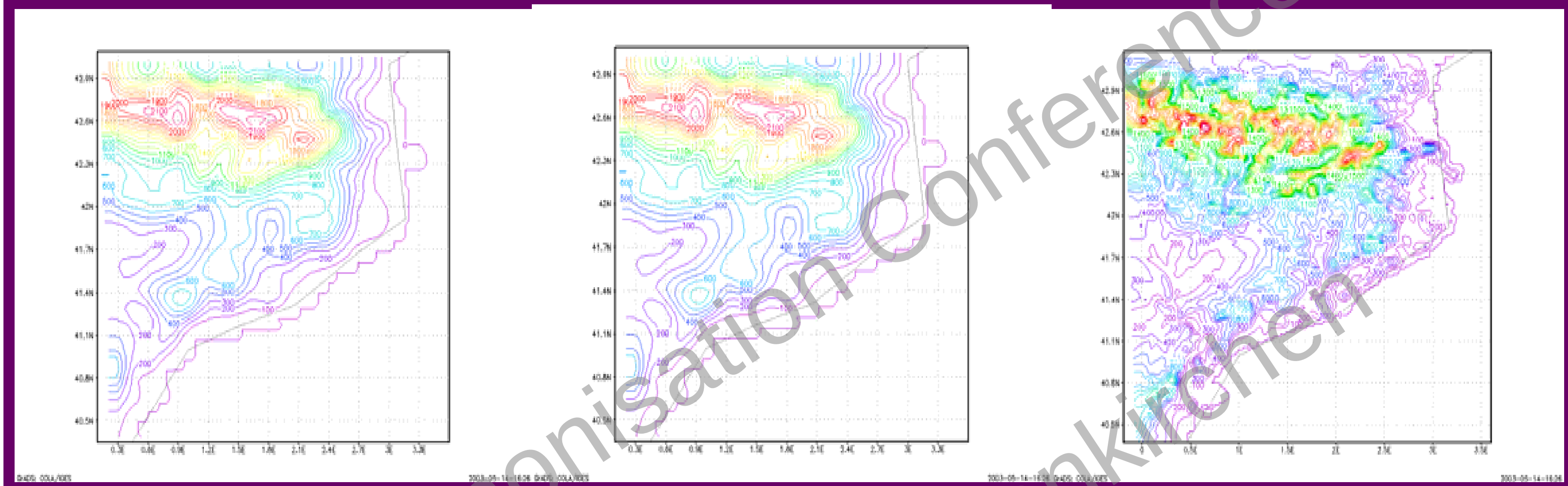
500 hPa



Photochemical pollution episode over the northeastern Iberian Peninsula

- August 13-16, 2000; Values over the European Information Threshold of 180 $\mu g/m^3$

Results: Topography

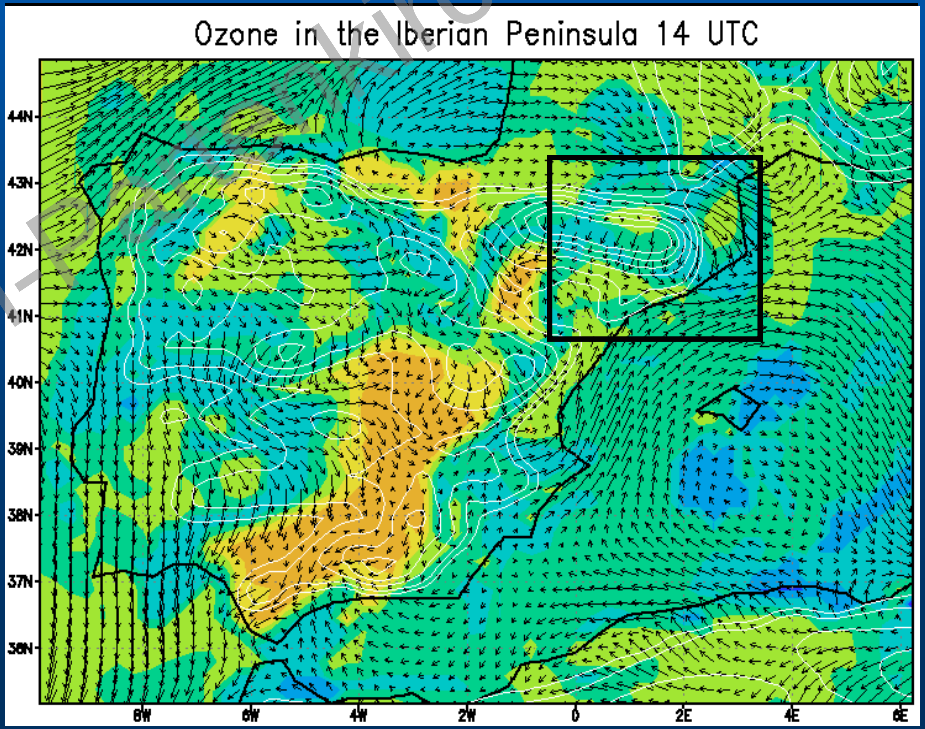


There are some significant differences between the coarse and fine topography. Despite the three main orographic units are captured by the model, the minor structural elements by the coast are not reproduced with a horizontal grid size of 8 km.

The complex terrain in the Barcelona Geographical Area (BGA) conditions the transport of pollutants from the BGA and the development of circulatory cells and should be captured with the finer simulations (2 km).

Methodology

- **Domain of study:**
  - 272 km x 272 km centered on 1.725 E – 41.715 N
  - Resolution: 2 – 4 – 8 km (horizontal) and 6 - 16 layers (vertical)
- **Meteorological initial and boundary data:**
  - ECMWF; NCEP: AVN, FNL
  - Data assimilation
- **CTM initial and boundary conditions:**
  - Nested simulation of the Iberian Peninsula with EMEP
  - 48-hr spin-up
- **EMICAT2000**
- **Parameterizations:**
  - Chemical mechanism: CBM-IV
  - Chemical algorithm: MEBI
  - Advection: PPM
  - Vertical diffusion: EDDY
  - Dry deposition: M3Dry
  - Wet deposition: RADM

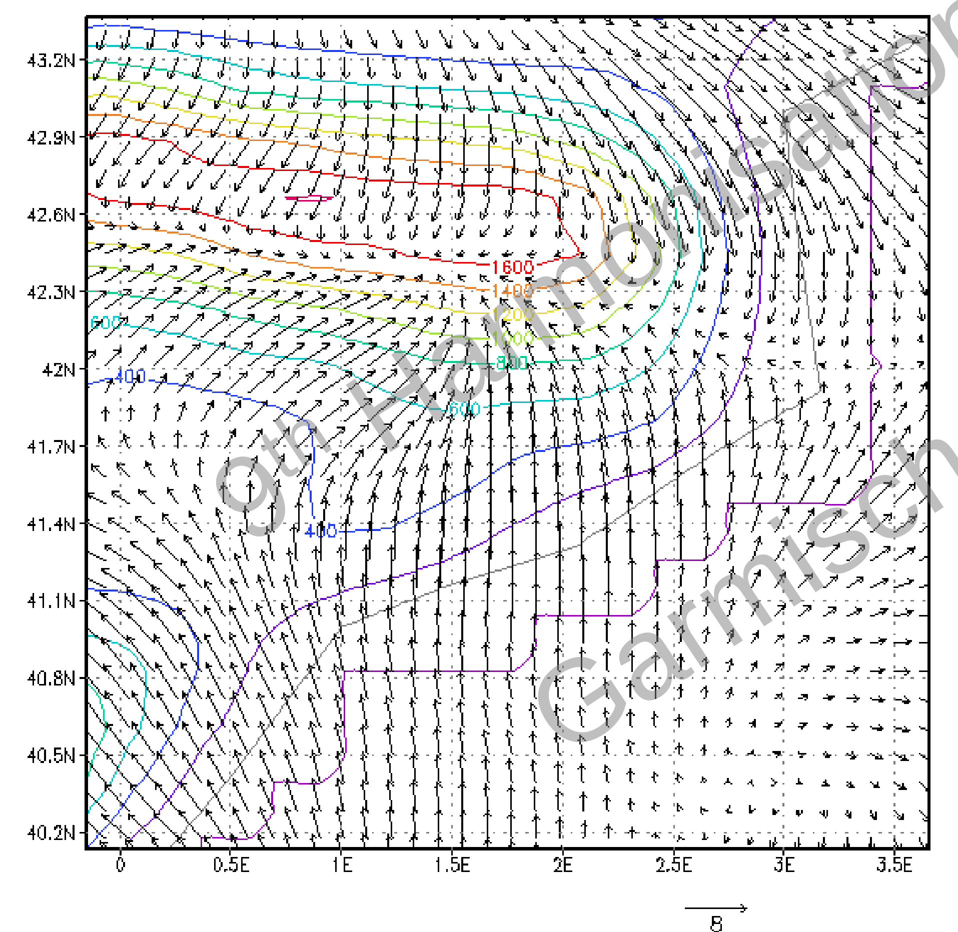


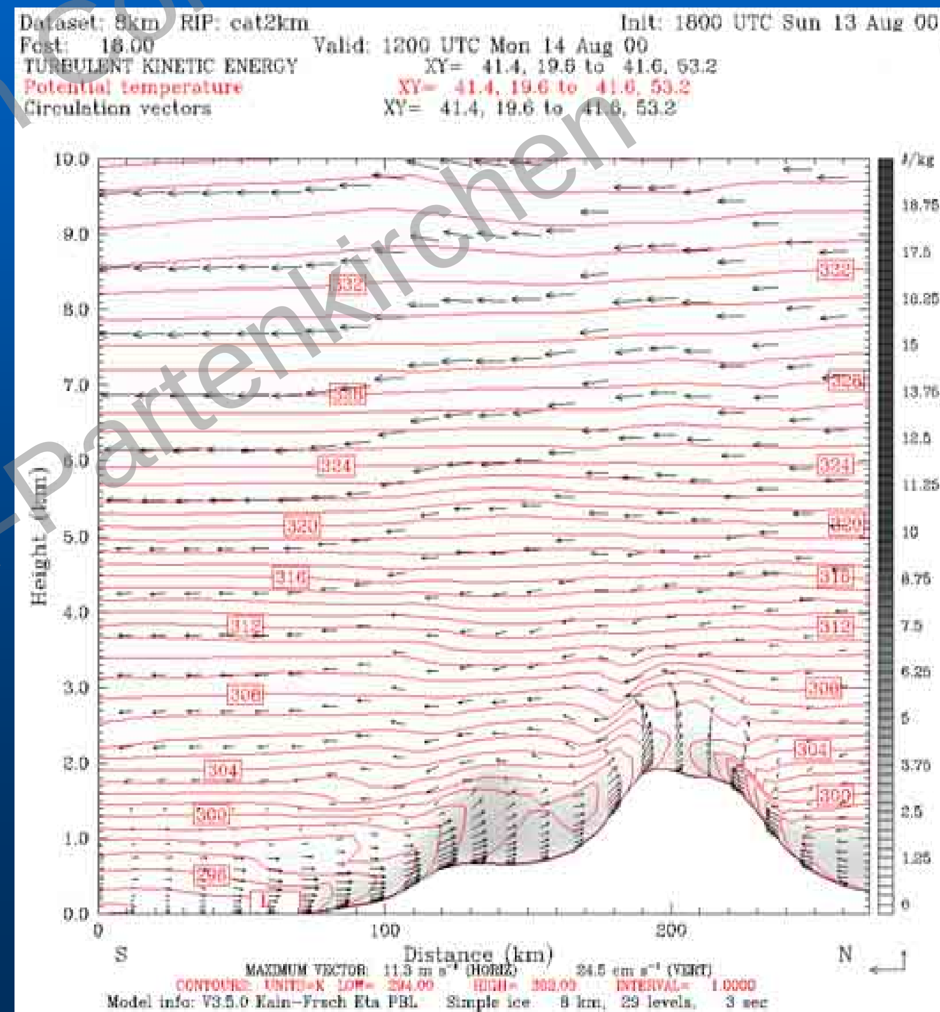
Topography

Horizontal Resolution:

8 km (14.8.2000, 12 UTC)

Grid size is influenced primarily by local topography. Topographical variations can have an important effect on mesoscale atmospheric flow and, therefore, they play a major role and should be well resolved in modeling exercises.





Topography

Horizontal Resolution:

4 km (14.8.2000, 12 UTC)

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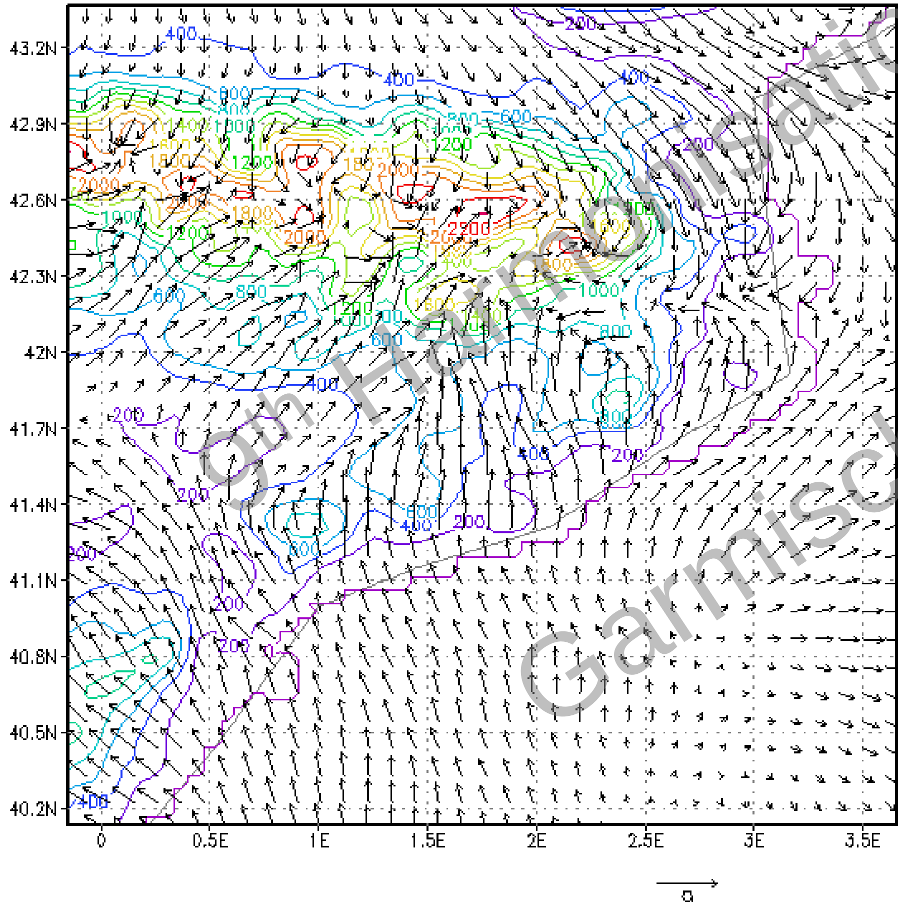

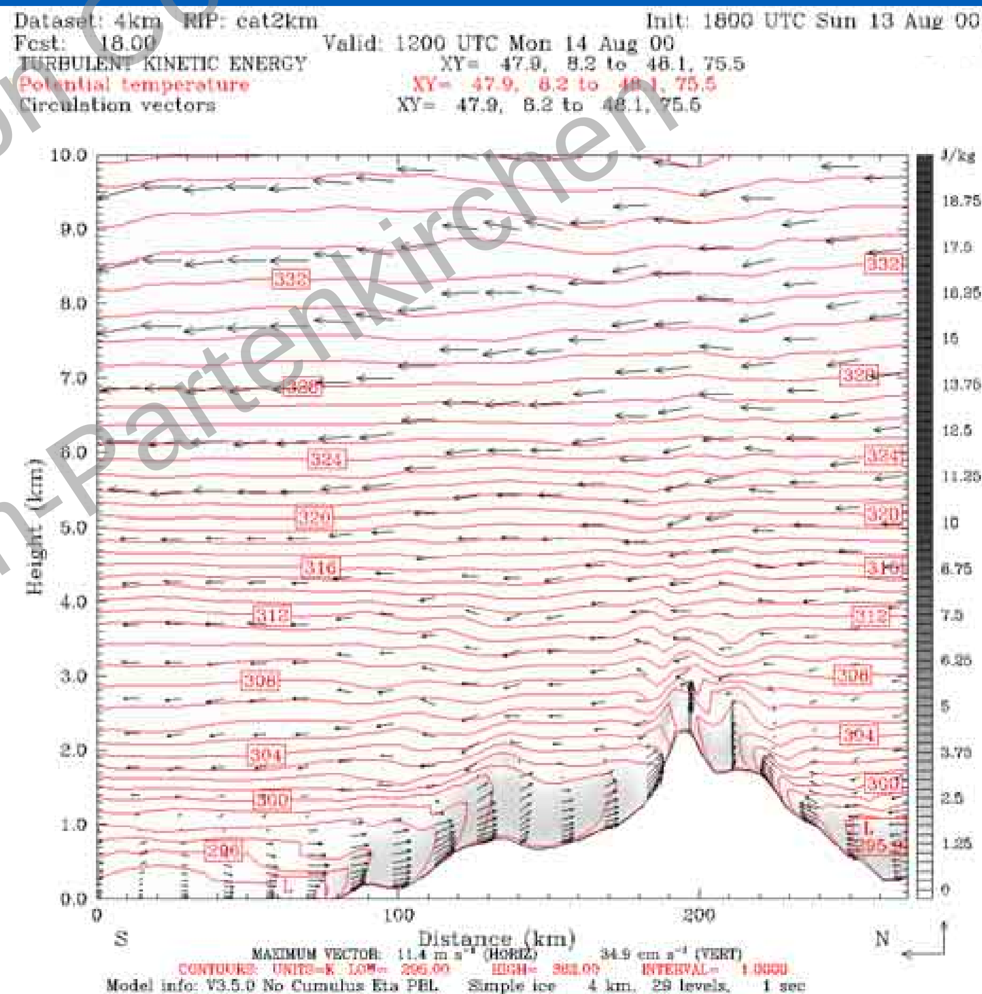

Topography

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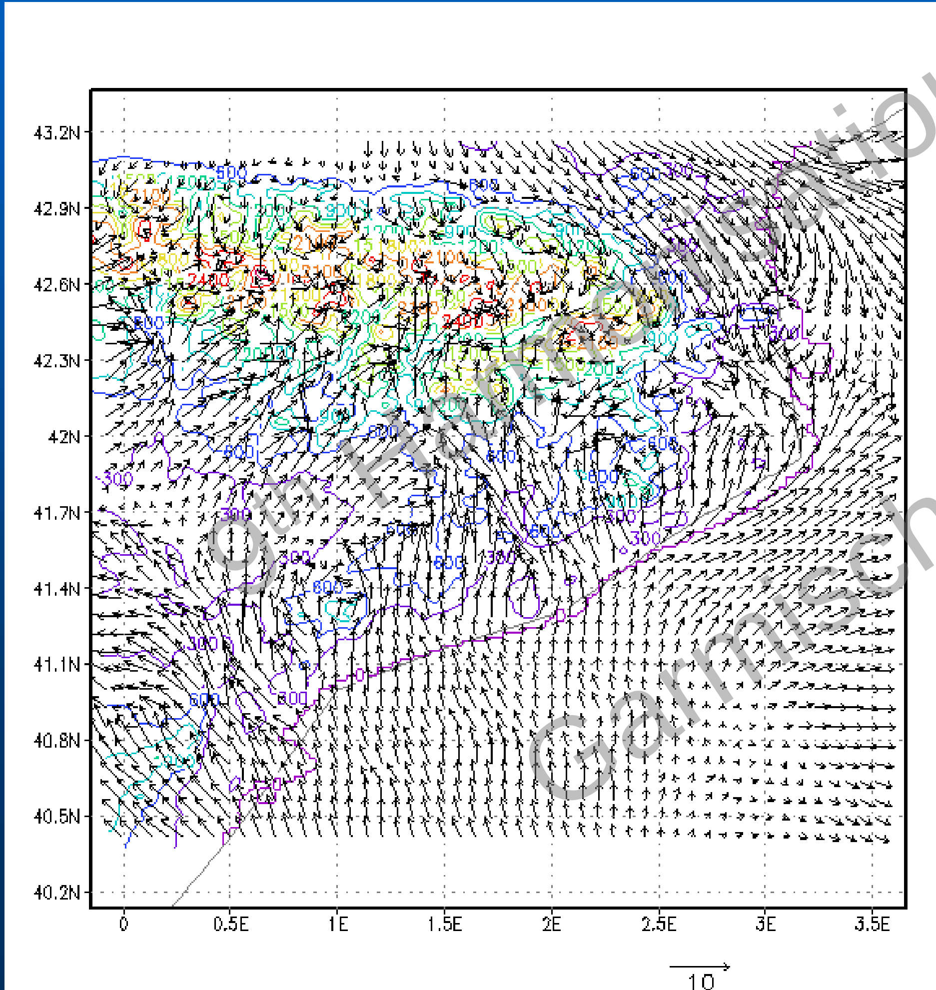
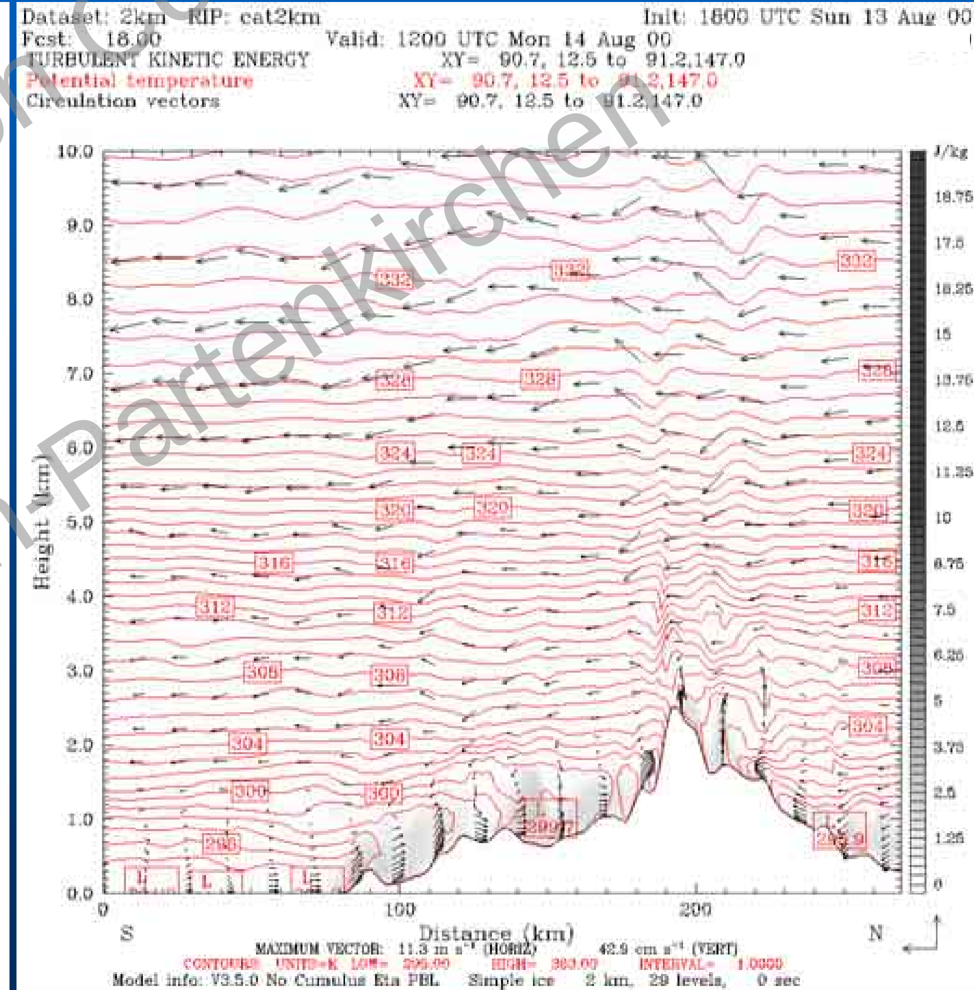
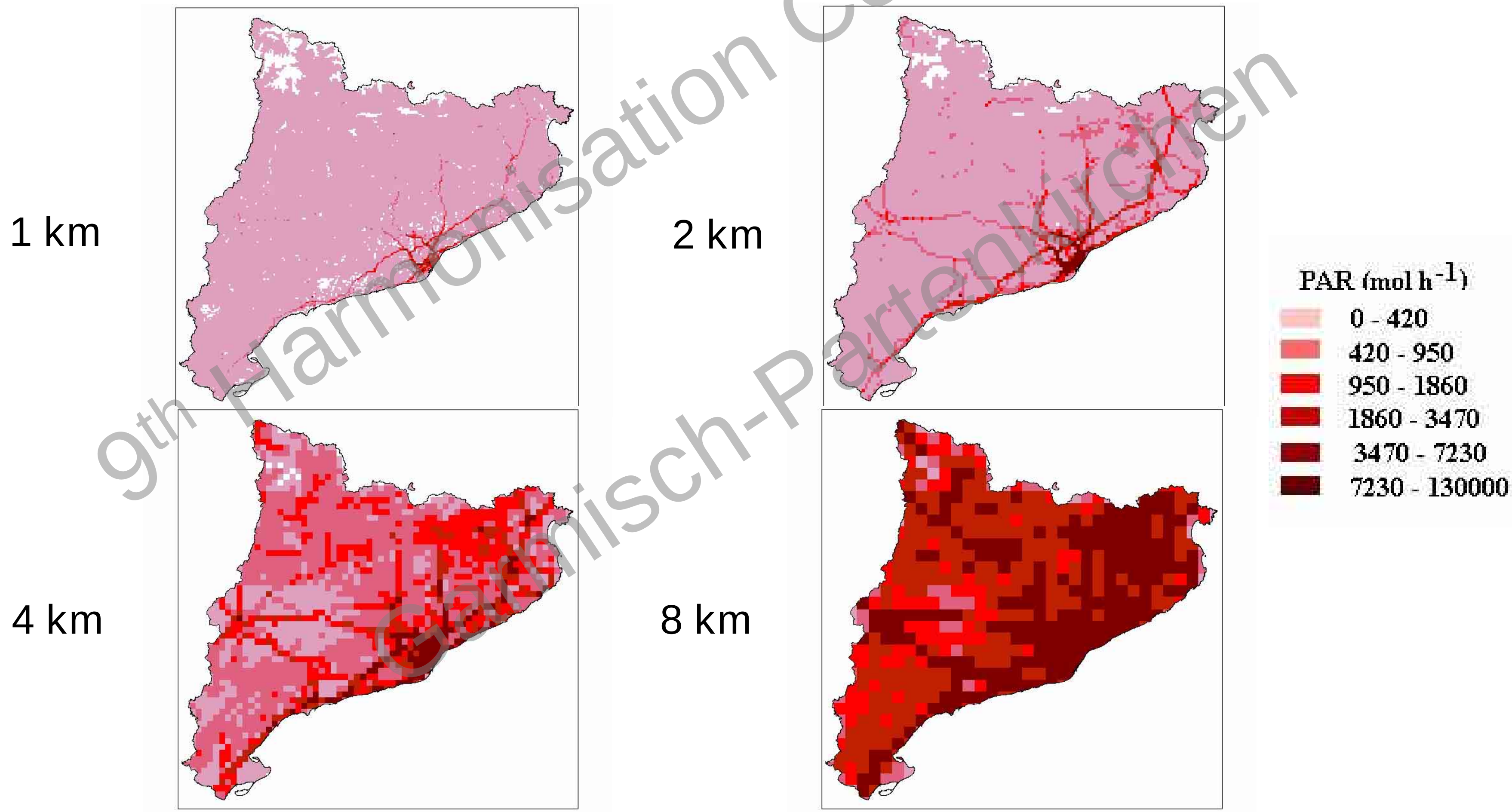




Influence of Resolution on Emissions (EMICAT2000)

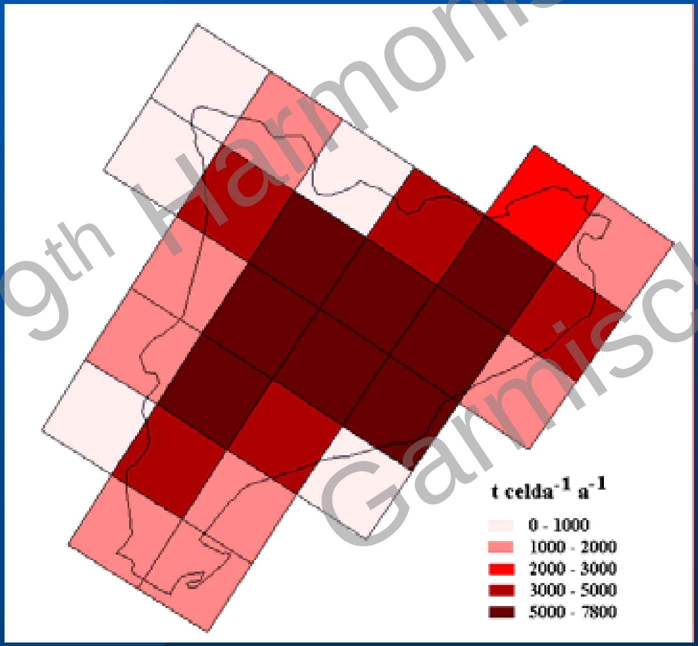
The 2-km map depicts in detail the emission configuration. The axis of the most important highways and roads are clearly defined and most of this species are emitted mainly from coastal areas (Metropolitan Area of Barcelona and Tarragona). With coarser spatial resolution, emission features get lost, and no clear definition of on-road emissions is observed with 8-km resolution, mainly in Barcelona.



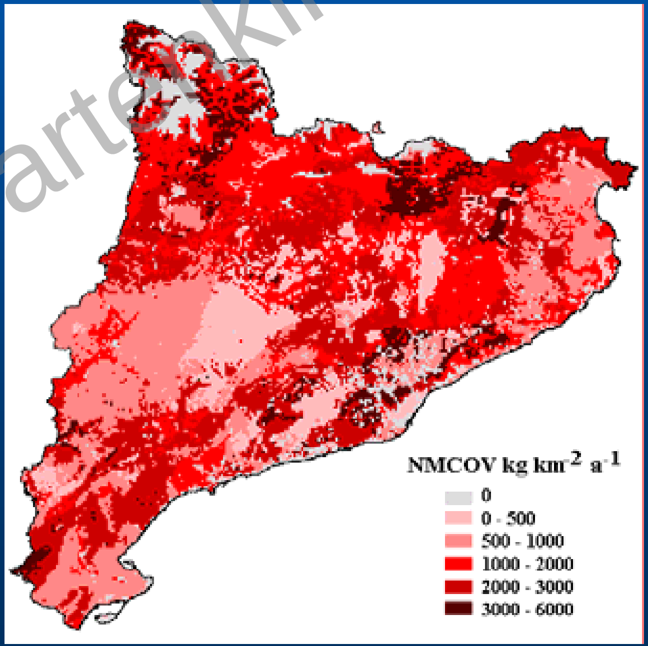
Comparison of annual emissions

Source	EMEP (kt y-1)			EMICAT2000 (kt y-1)		
	NO_x	**NMVOC**	**CO**	**NO_x**	**NMVOC**	**CO**
Biogenic		88.8			46.9	
Traffic	84.8	58.0	274.0	62.4	49.5	259.0
Industrial	42.3	24.8	22.2	41.0	22.8	7.5
Total	126.8	171.6	296.2	103.4	119.2	266.5

Different spatial resolution: EMEP vs. EMICAT2000

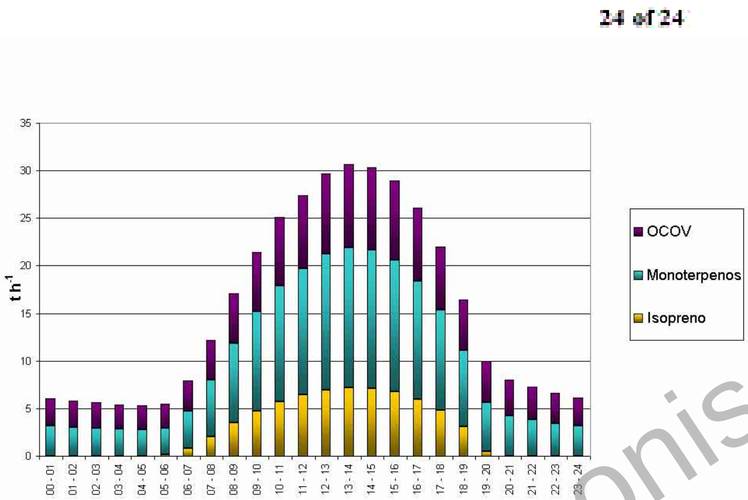


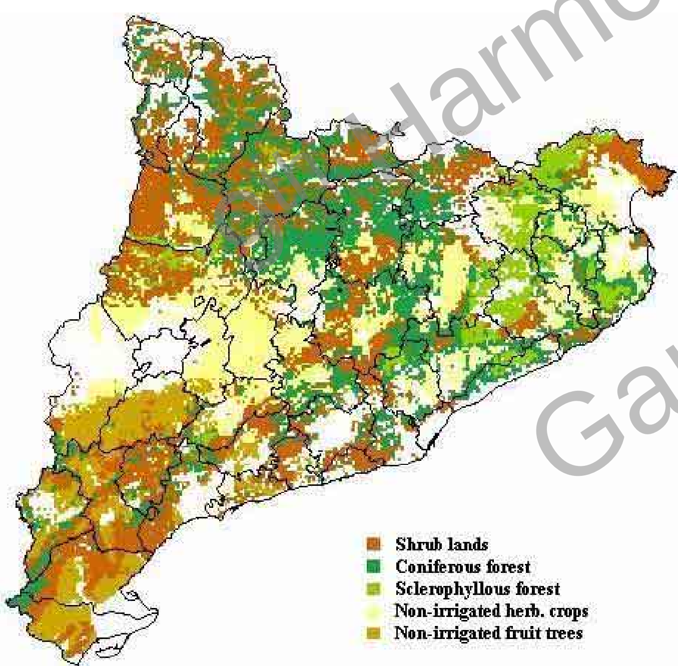
EMEP

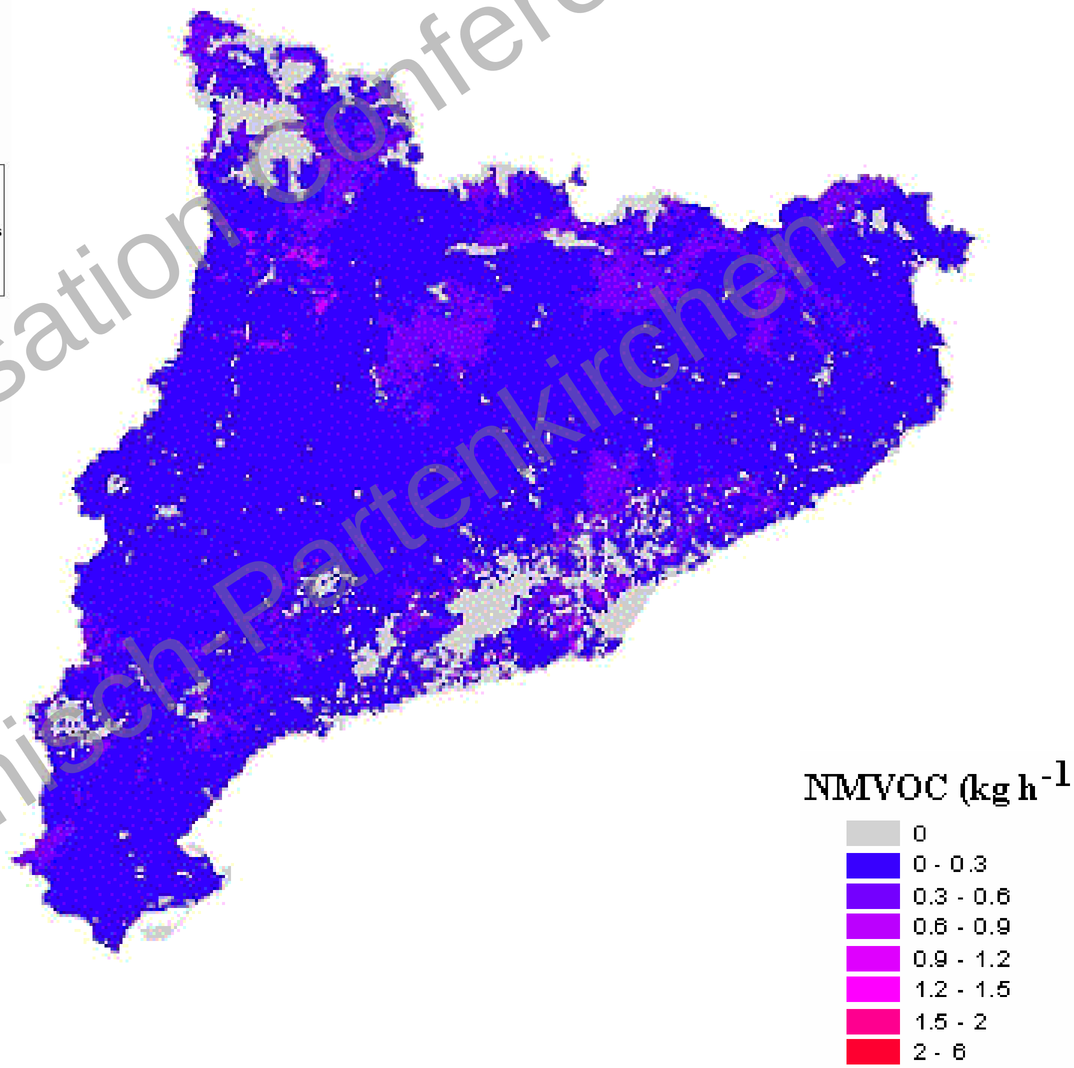


EMICAT2000

Biogenic emissions from Catalonia during August 15th 2000

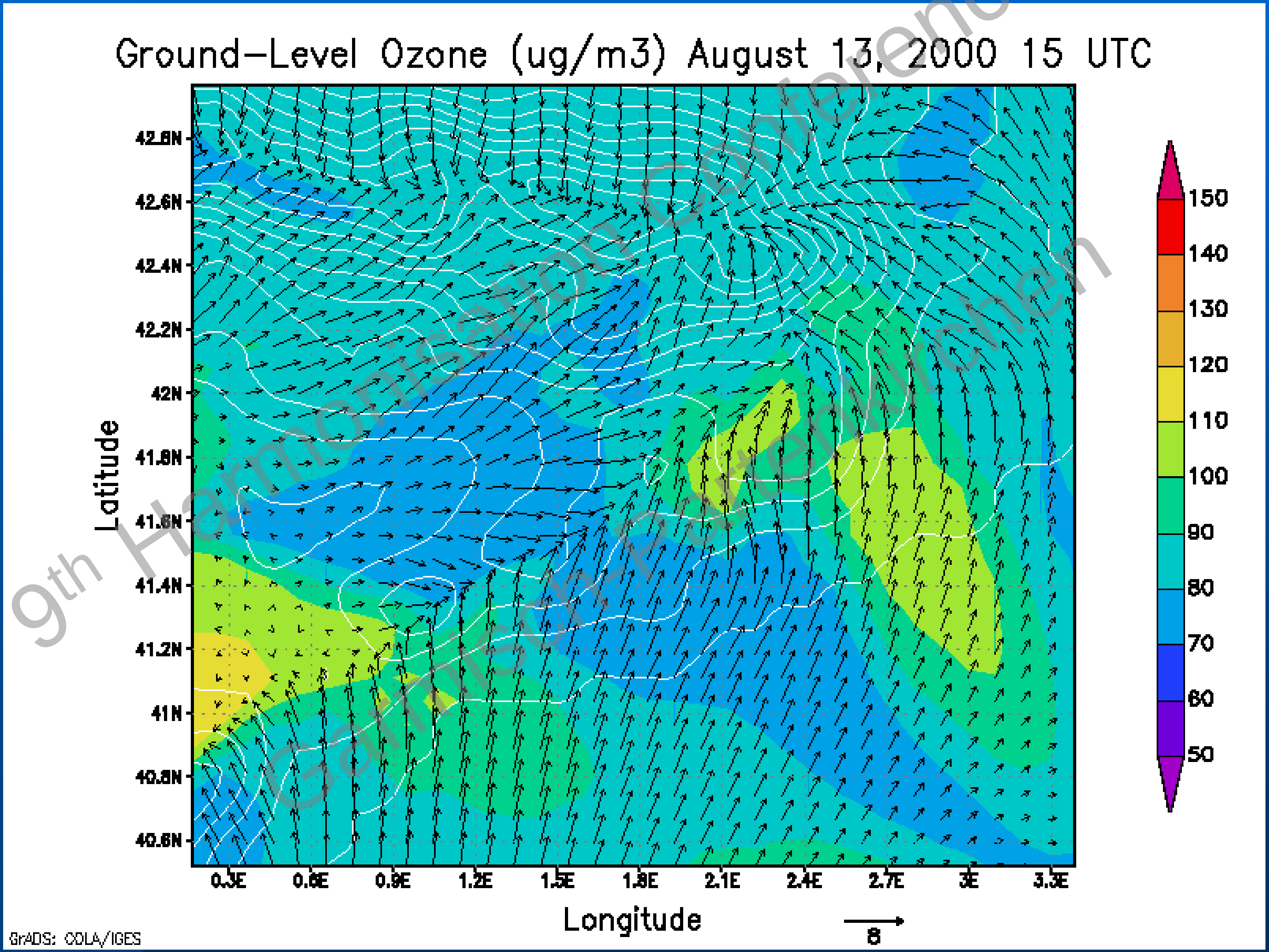






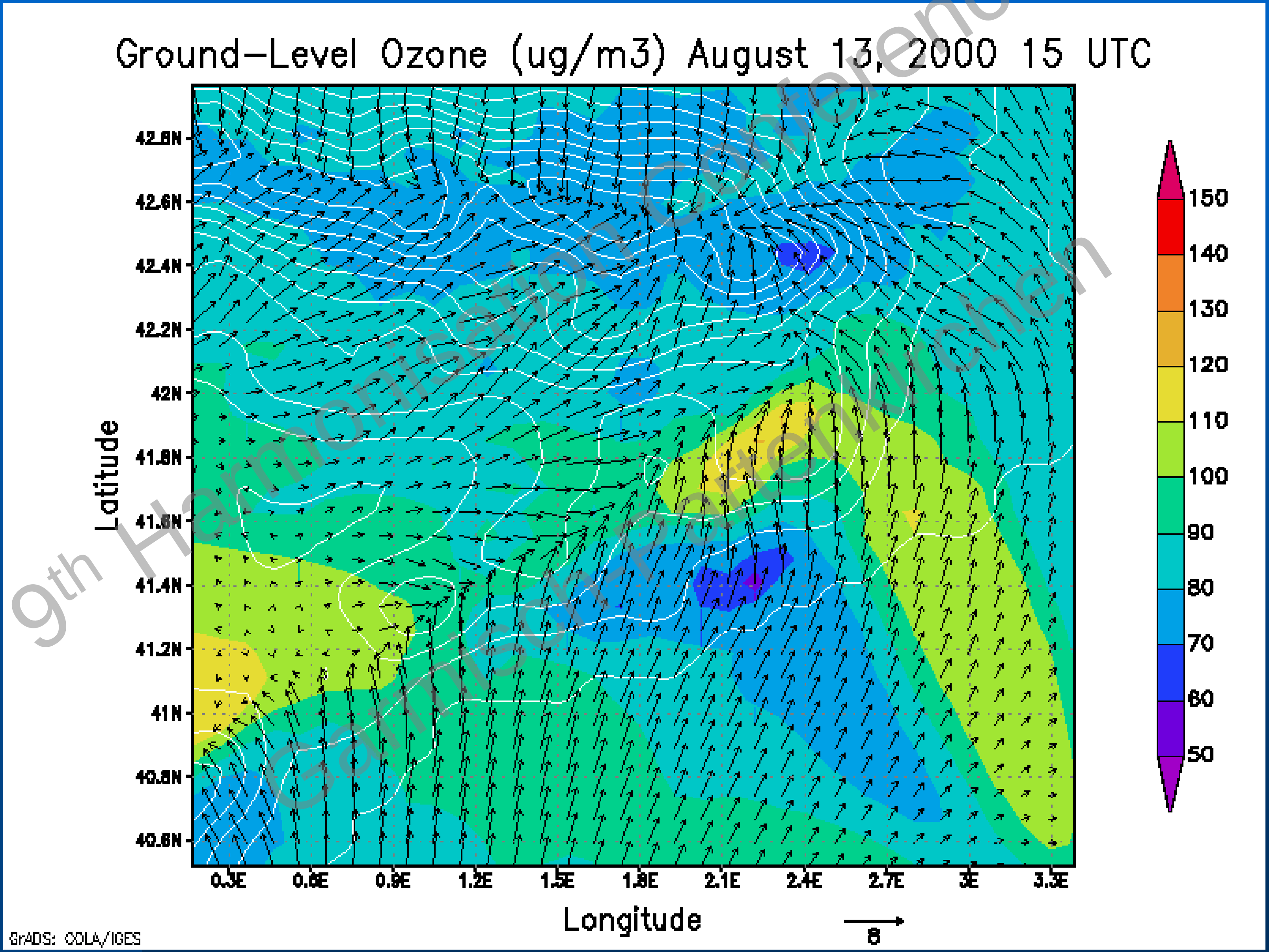
Necessity of High Resolution: August 13, 2000

8 km - 6 layers



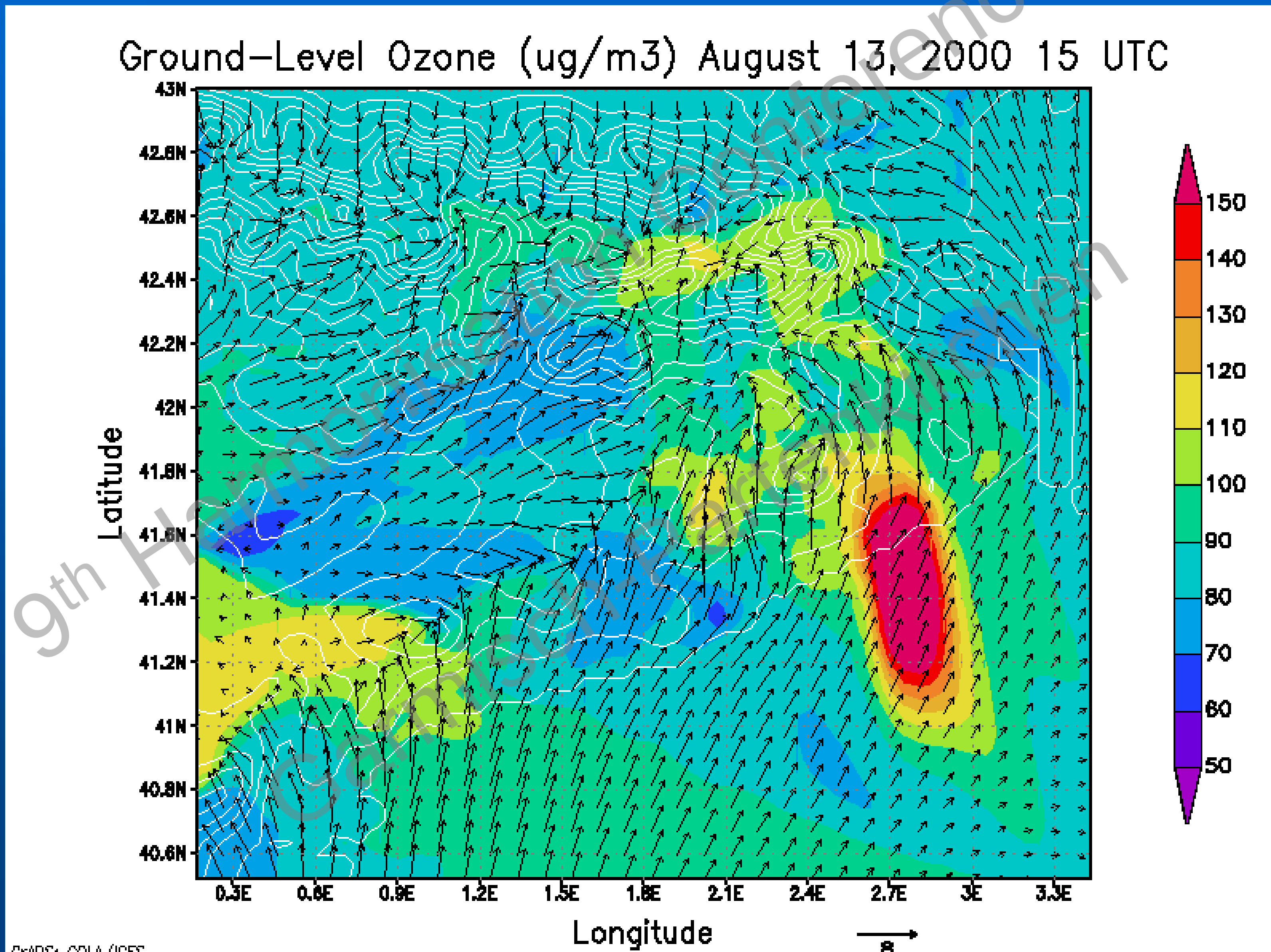
Necessity of High Resolution: August 13, 2000

8 km - 16 layers



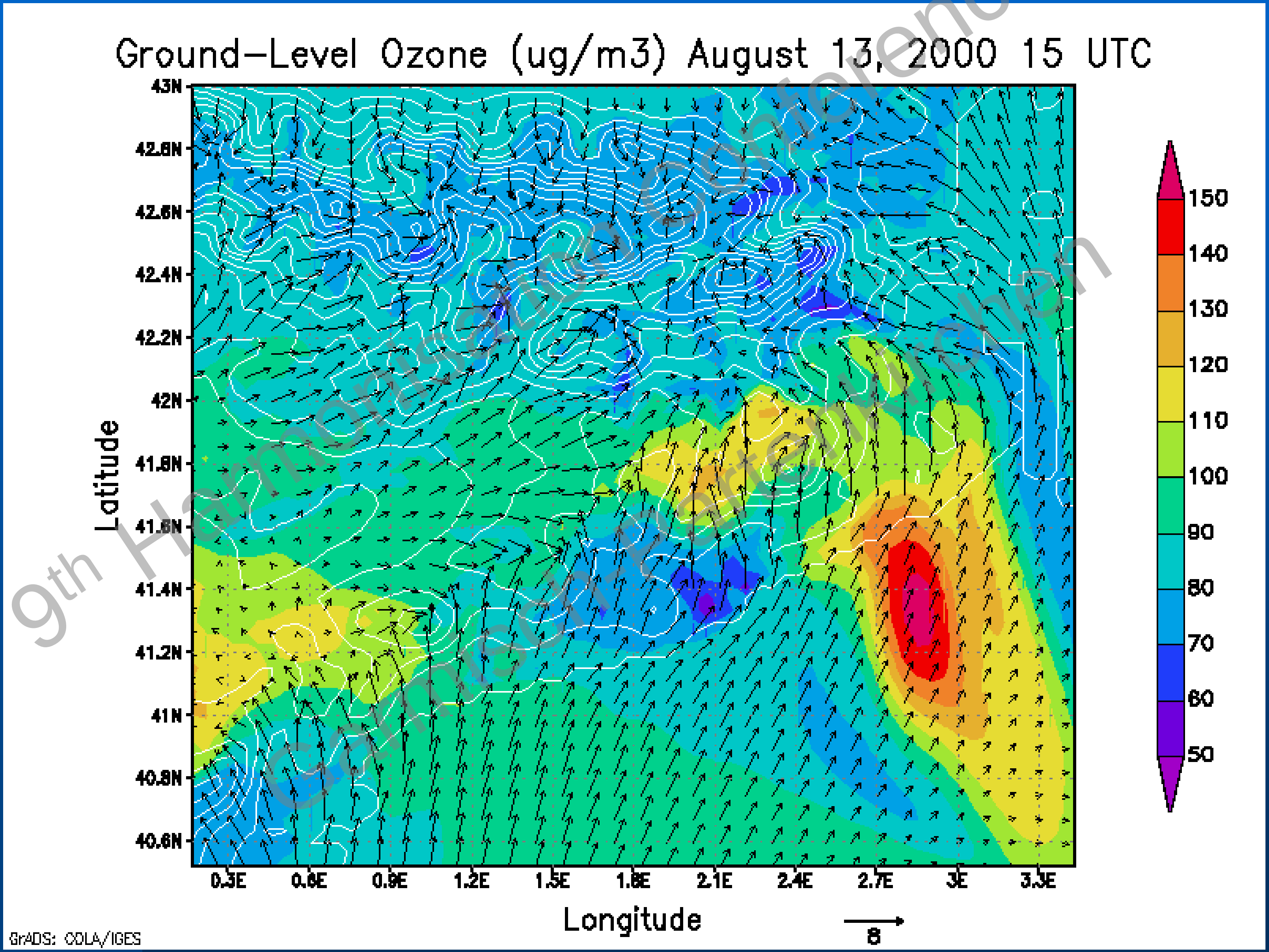
Necessity of High Resolution: August 13, 2000

4 km - 6 layers



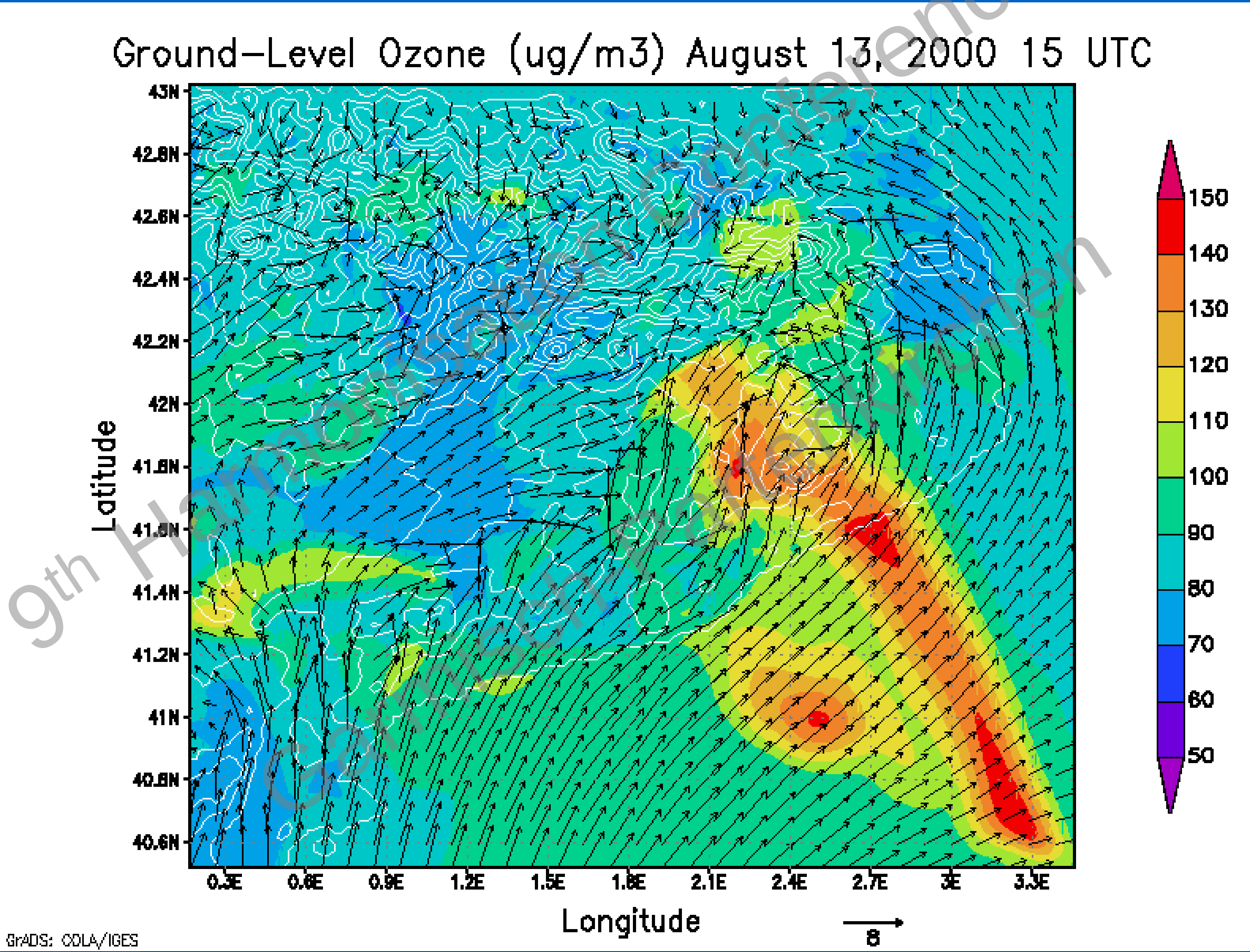
Necessity of High Resolution: August 13, 2000

4 km - 16 layers



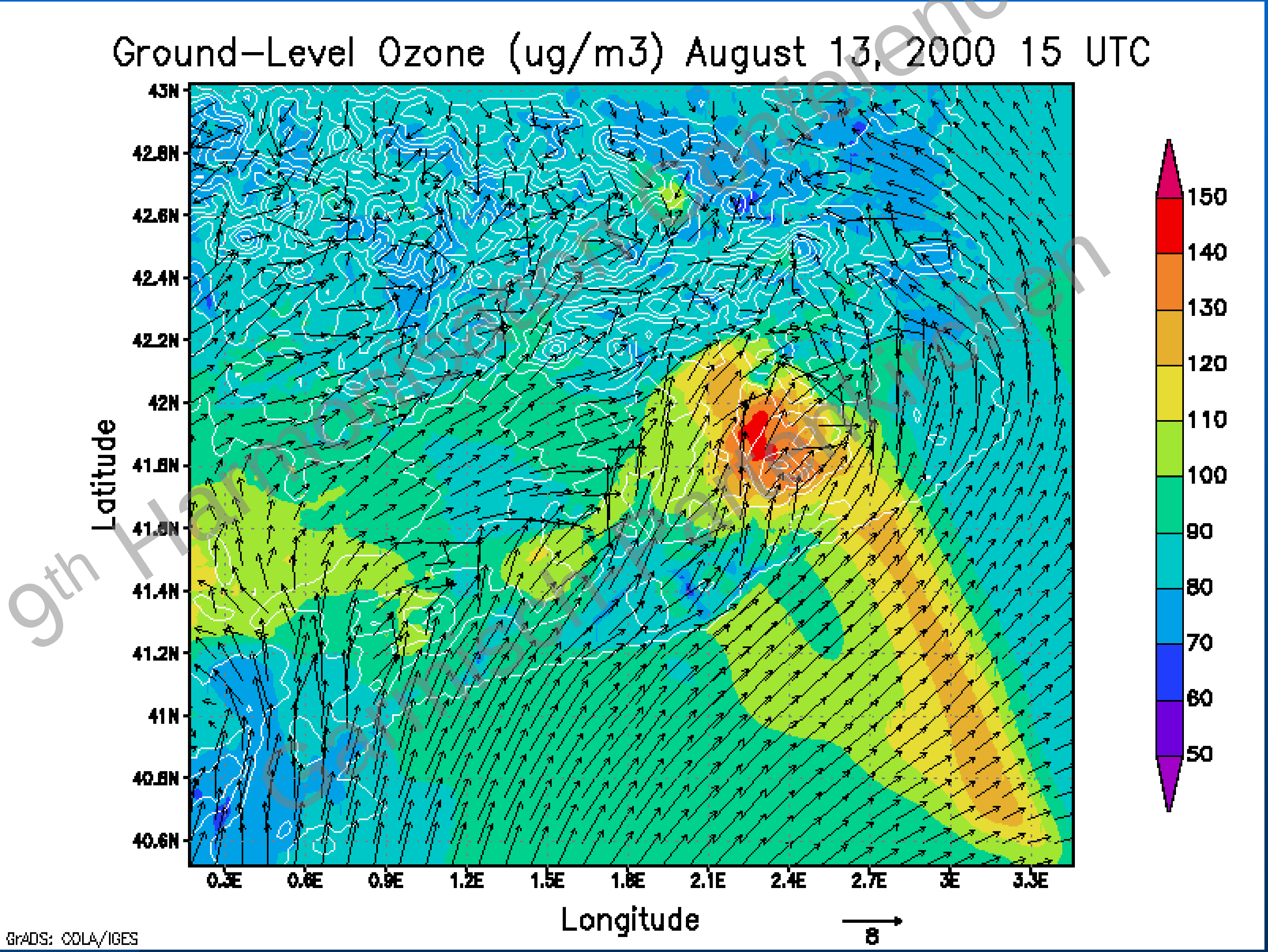
Necessity of High Resolution: August 13, 2000

2 km - 6 layers



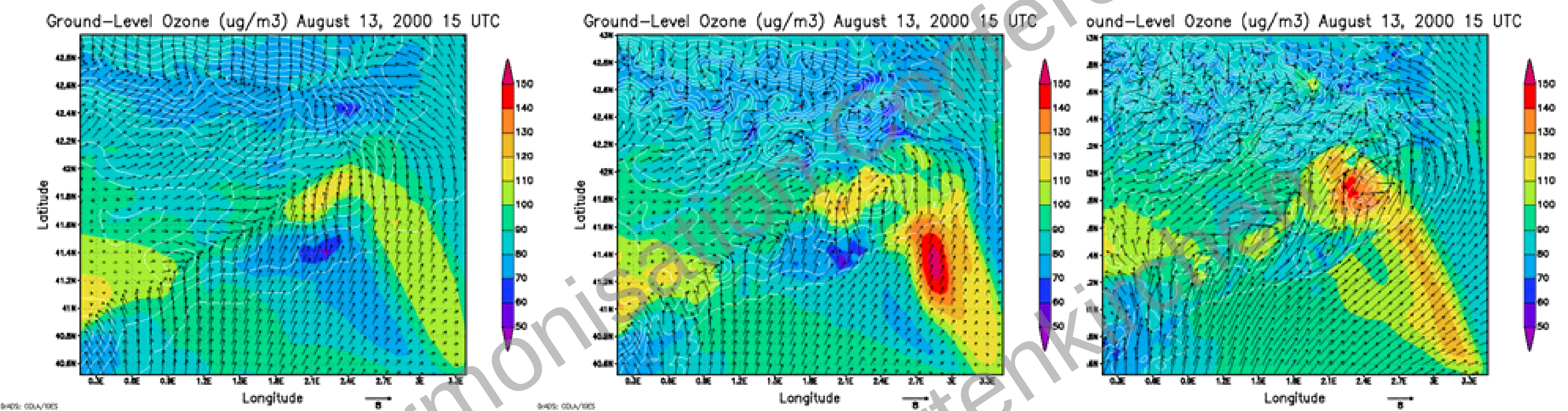
Necessity of High Resolution: August 13, 2000

2 km - 16 layers

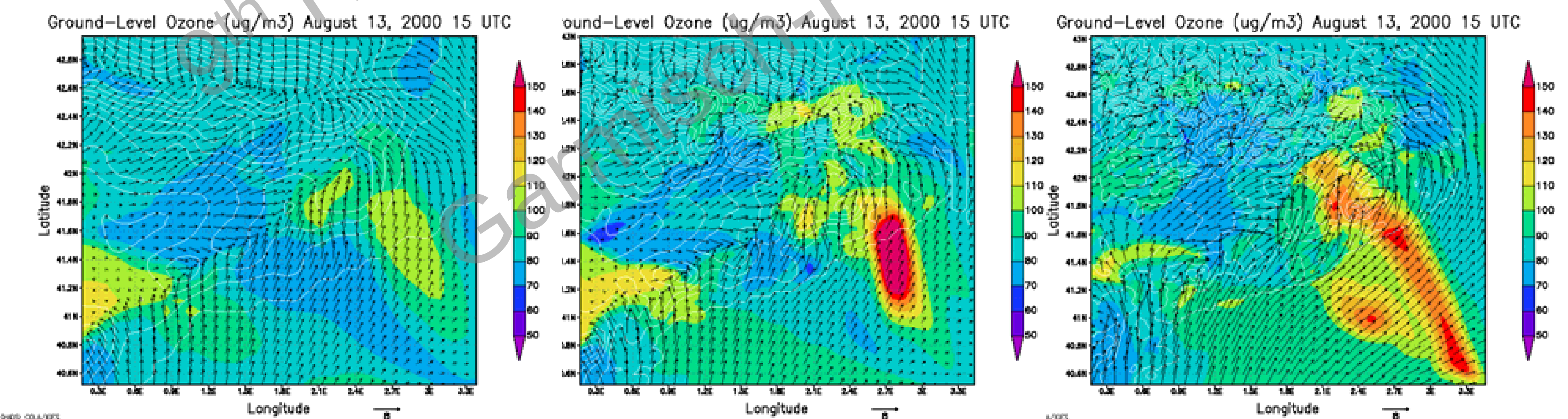


Influence of Vertical and Horizontal Resolution

16 vertical layers: 8 – 4 – 2 km

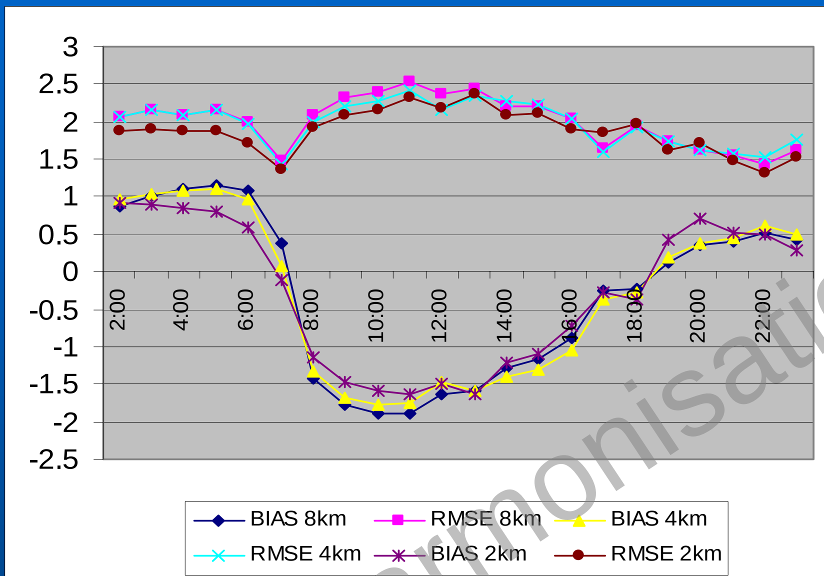


6 vertical layers: 8 – 4 – 2 km

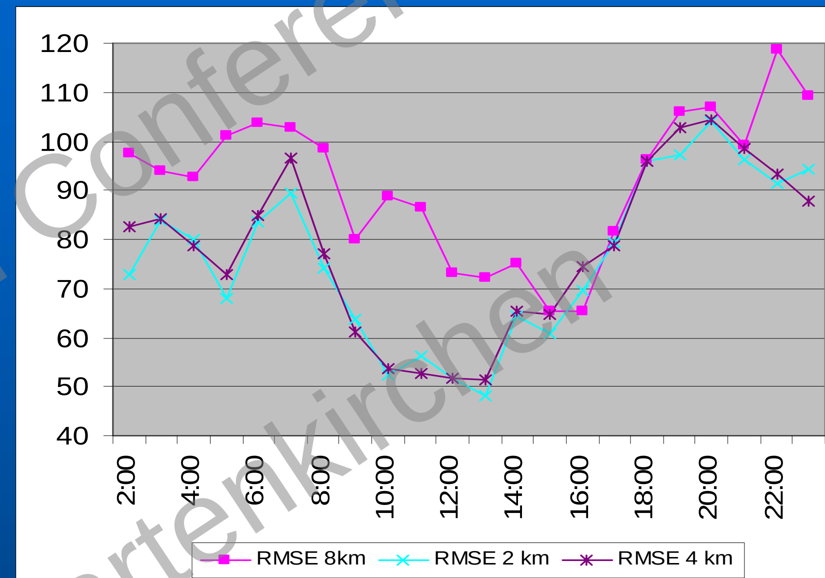


Evaluation of MM5 with stations and radiosondes

45 surface meterological stations (XMET).



Evolution of RMSE and BIAS of the horizontal wind speed at 10 m (m/s)



Evolution of RMSE of the horizontal direction at 10 m (m/s)

Radiosonde Barcelona: **RMSE horizontal wind speed**

	8 km			4 km			2 km		
	00 UTC	12 UTC	24 UTC	00 UTC	12 UTC	24 UTC	00 UTC	12 UTC	24 UTC
0-1000 m	1.23	0.83	1.04	0.88	1.23	1.02	0.88	1.06	0.94
1000-5000 m	1.74	2.84	3.66	1.67	3.07	3.95	1.62	3.02	3.18
>5000m	4.92	6.54	8.62	4.71	6.73	8.92	4.62	5.79	8.27

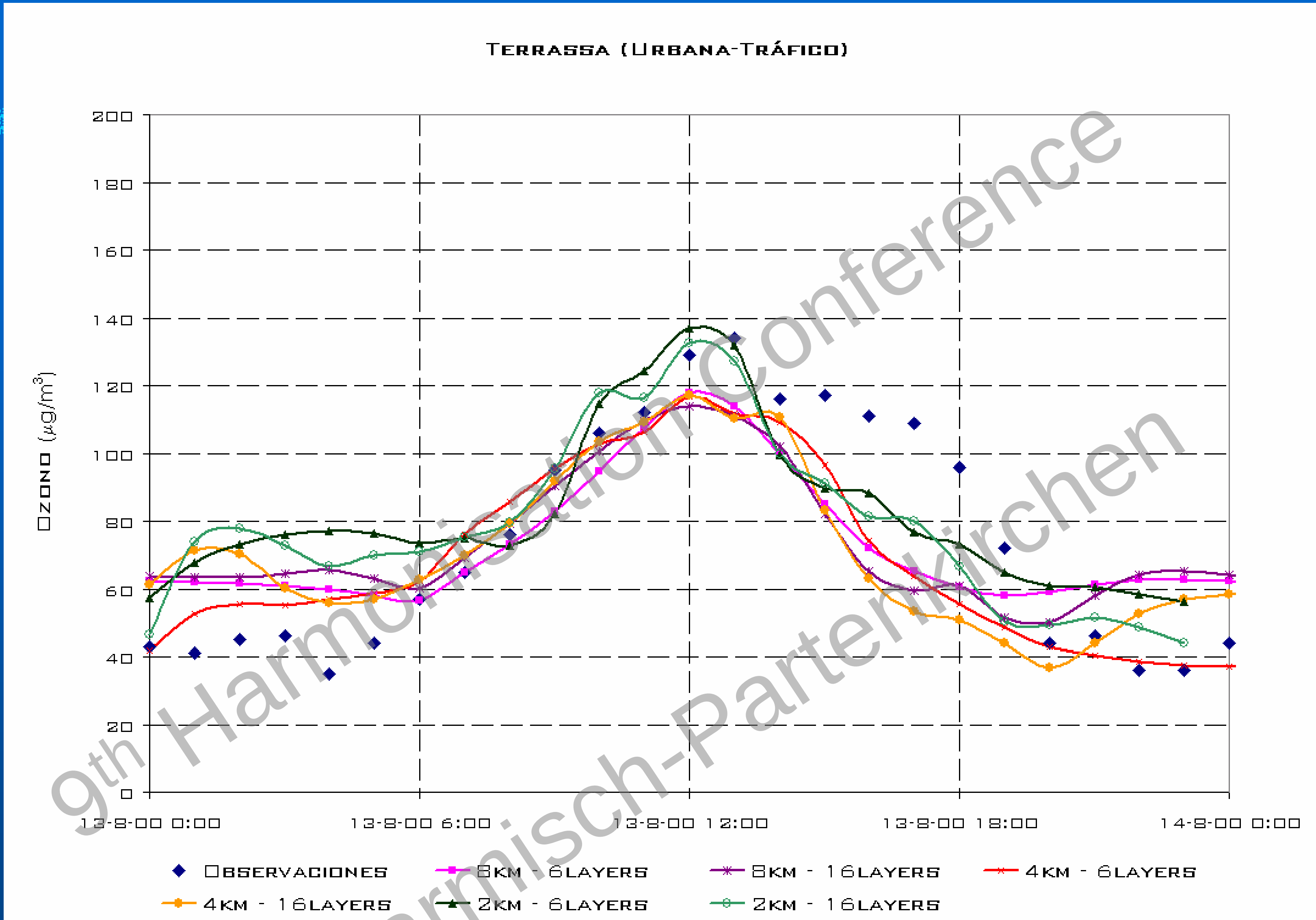
Evaluation of the air quality model

Discrete Evaluation						
	2km/6layers	*2km/16layers*	*4km/6layers*	*4km/16layers*	*8km/6layers*	*8km/16layers*
MNBE	-2.02	-11.38	-9.53	-16.92	-12.86	-13.12
MNGE	19.72	20.89	17.42	21.61	19.27	21.01
UPA	17.08	5.97	-26.07	-19.24	-22.53	-18.49
Categorical Evaluation						
	2km/6layers	*2km/16layers*	*4km/6layers*	*4km/16layers*	*8km/6layers*	*8km/16layers*
A	90.9	91.6	91.5	92.4	91.6	91.7
CSI	19.0	12.5	3.2	8.9	3.2	10.0
POD	26.4	14.9	3.4	9.2	3.4	11.5
B	0.7	0.3	0.1	0.1	0.1	0.3
FAR	59.6	56.7	72.7	27.3	70.0	56.5

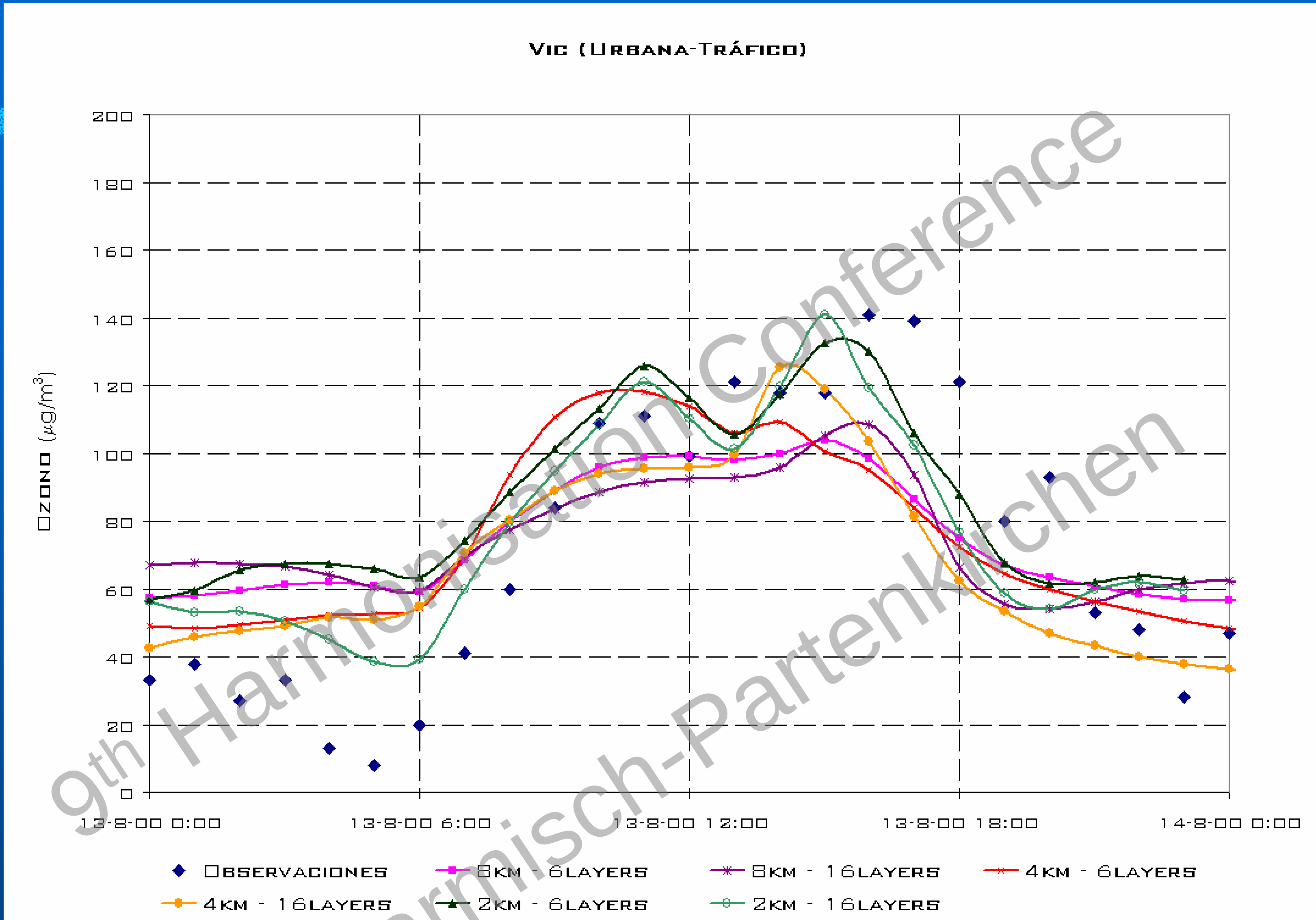
Discrete statistics: mean normalized bias error (MNBE), mean normalized gross error for concentrations above a 80 $\mu g/m^3$ threshold (MNGE), and unpaired peak prediction accuracy (UPA).

Categorical statistics: model accuracy (A), bias (B), probability of detection (POD), false alarm rates (FAR) and critical success index (CSI).

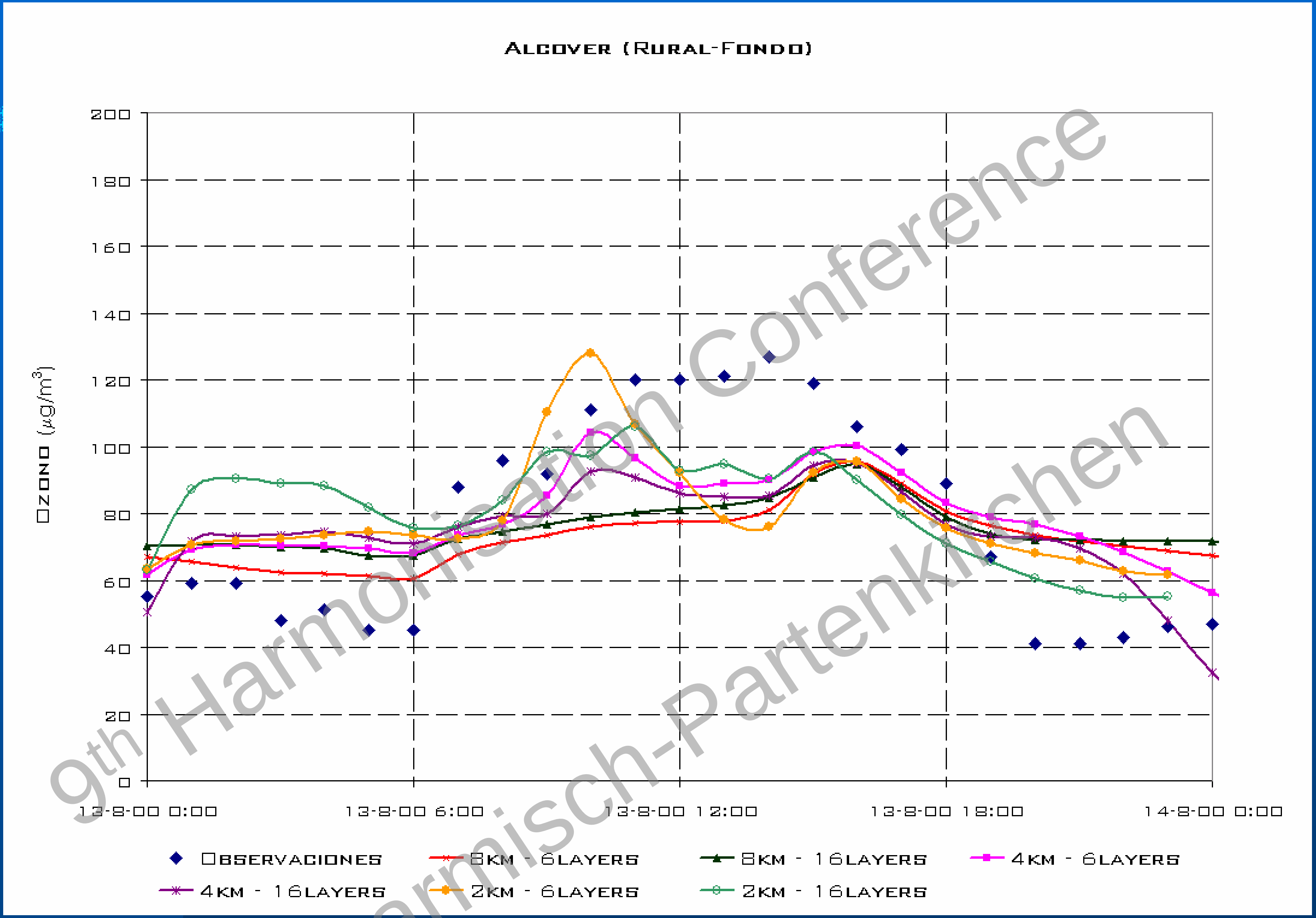
Air quality ambient data provided by the Environmental Department of the Catalonia Goverment (Spain)



	2 km 6 lay	2 km 16 lay	4 km 6 lay	4 km 16 lay	8 km 6 lay	8 km 16 lay	
NB (%)	-10.1	-10.7	-17.4	-21.0	-20.5	-20.6	±5-15%
NME (%)	15.2	14.3	17.5	21.0	20.5	20.6	±30-35%
A_u (%)	2.2	-1.2	-13.0	-12.6	-12.0	-14.9	±15-20%



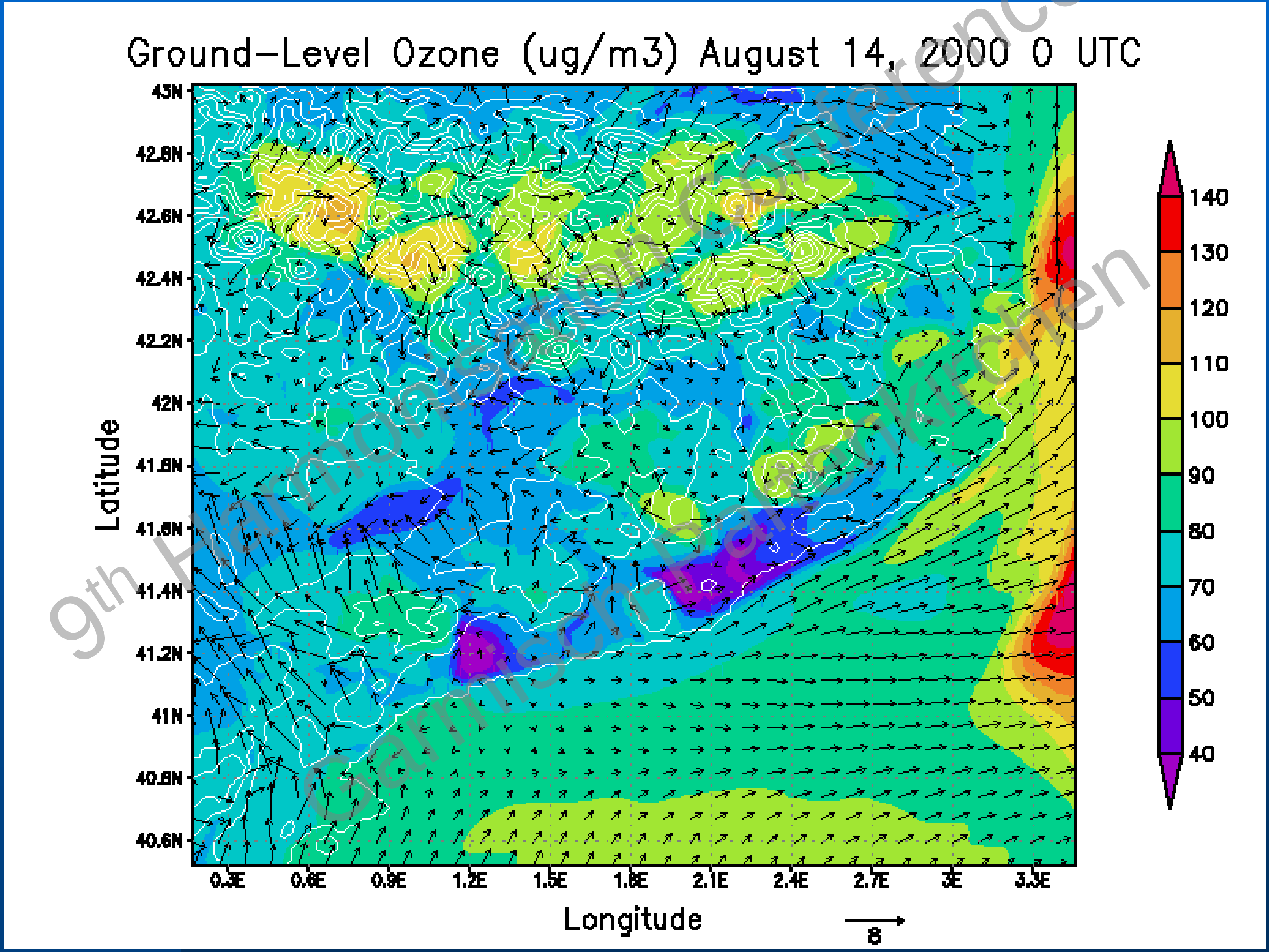
	2 KM 6 LAY	2 KM 16 LAY	4 KM 6 LAY	4 KM 16 LAY	8 KM 6 LAY	8 KM 16 LAY	
NB	-3.5	-7.6	-11.0	-18.3	-18.3	-21.7	±5-15%
NME	15.8	17.4	21.7	20.7	19.4	22.2	±30-35%
A_u (%)	-6.0	-0.2	-16.2	-10.9	-26.5	-23.0	±15-20%



	2 KM 6 LAY	2 KM 16 LAY	4 KM 6 LAY	4 KM 16 LAY	8 KM 6 LAY	8 KM 16 LAY	
NB	-14.4	-15.7	-15.7	-19.4	-24.7	-22.7	±5-15%
NME	20.3	15.7	16.8	19.4	24. 7	22.7	±30-35%
A_u (%)	0.8	-16.6	-18.1	-25.0	-24.9	-24.3	±15-20%

Daily Ozone Cycle (μg/m³), August 14 2000

(MM5-EMICAT2000-CMAQ, 2km, 16 layers, CBM-IV)



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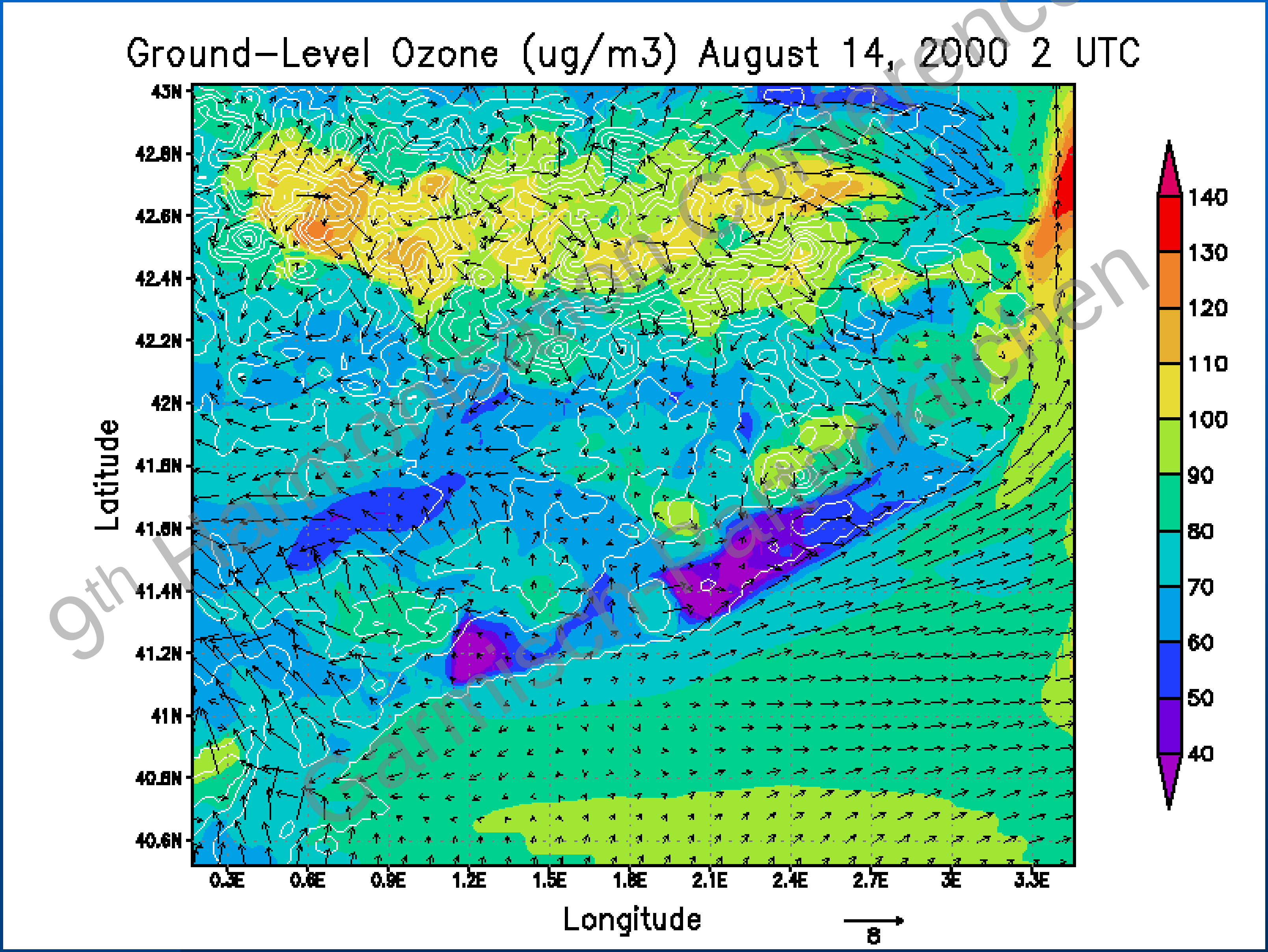

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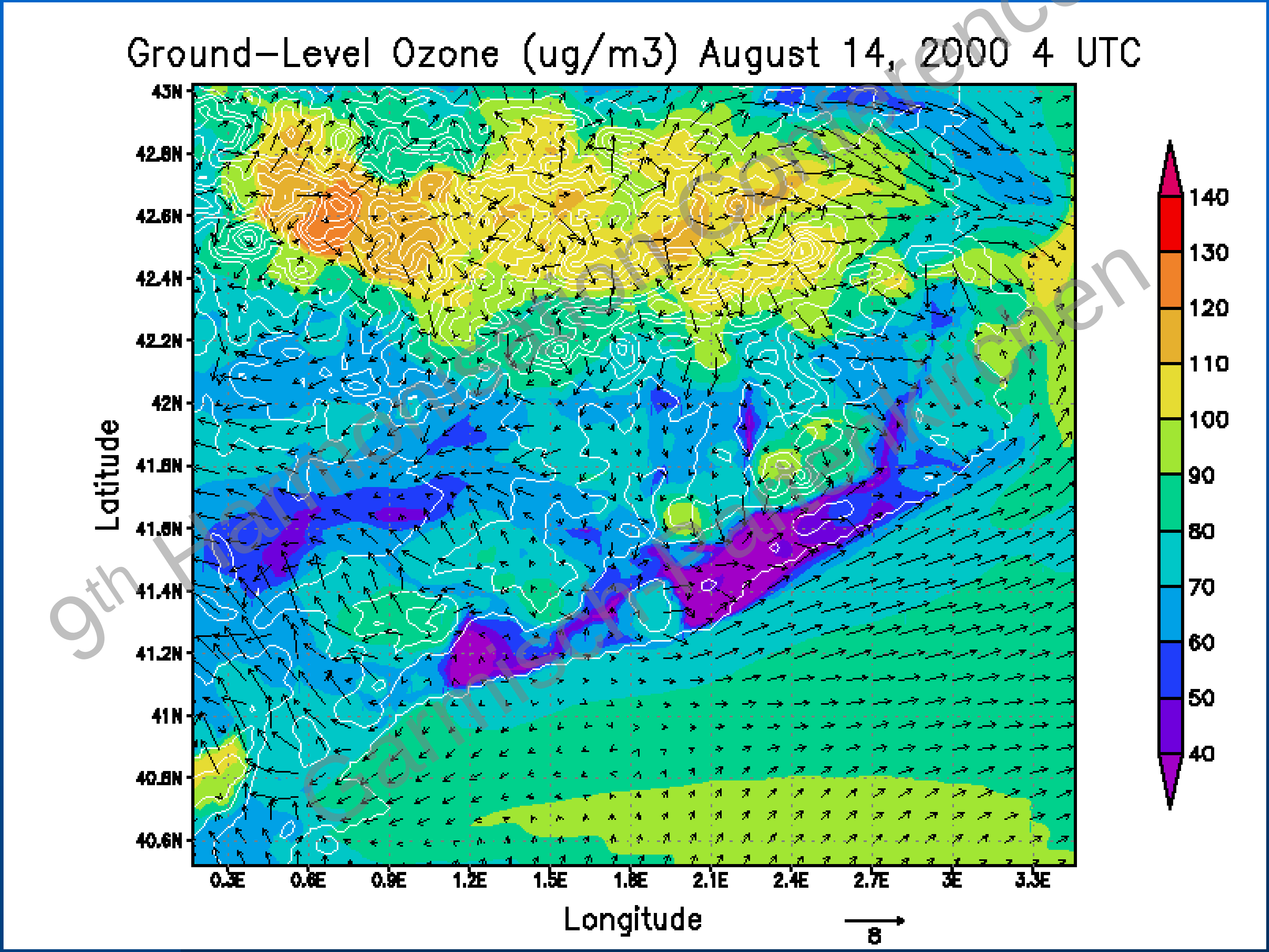

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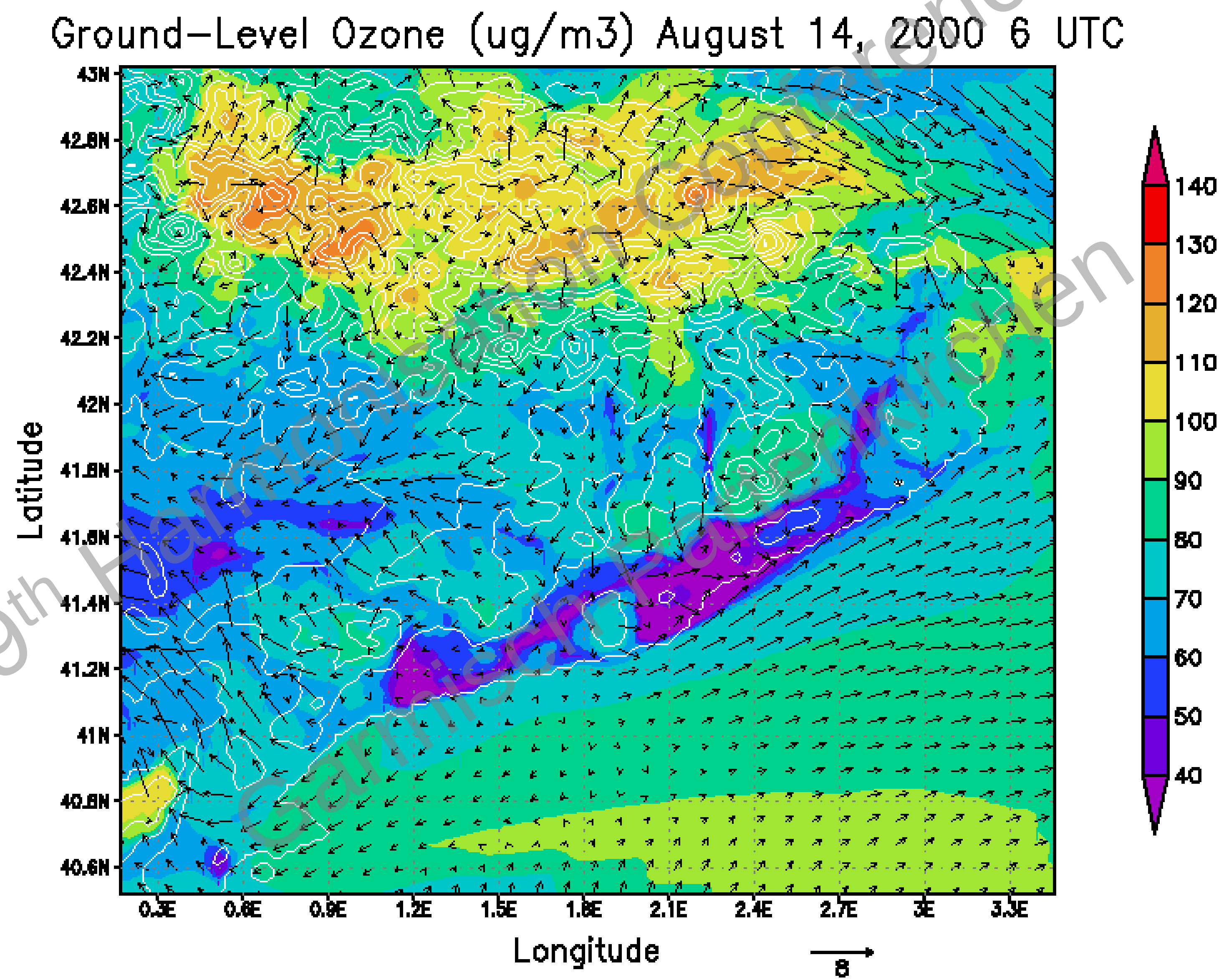

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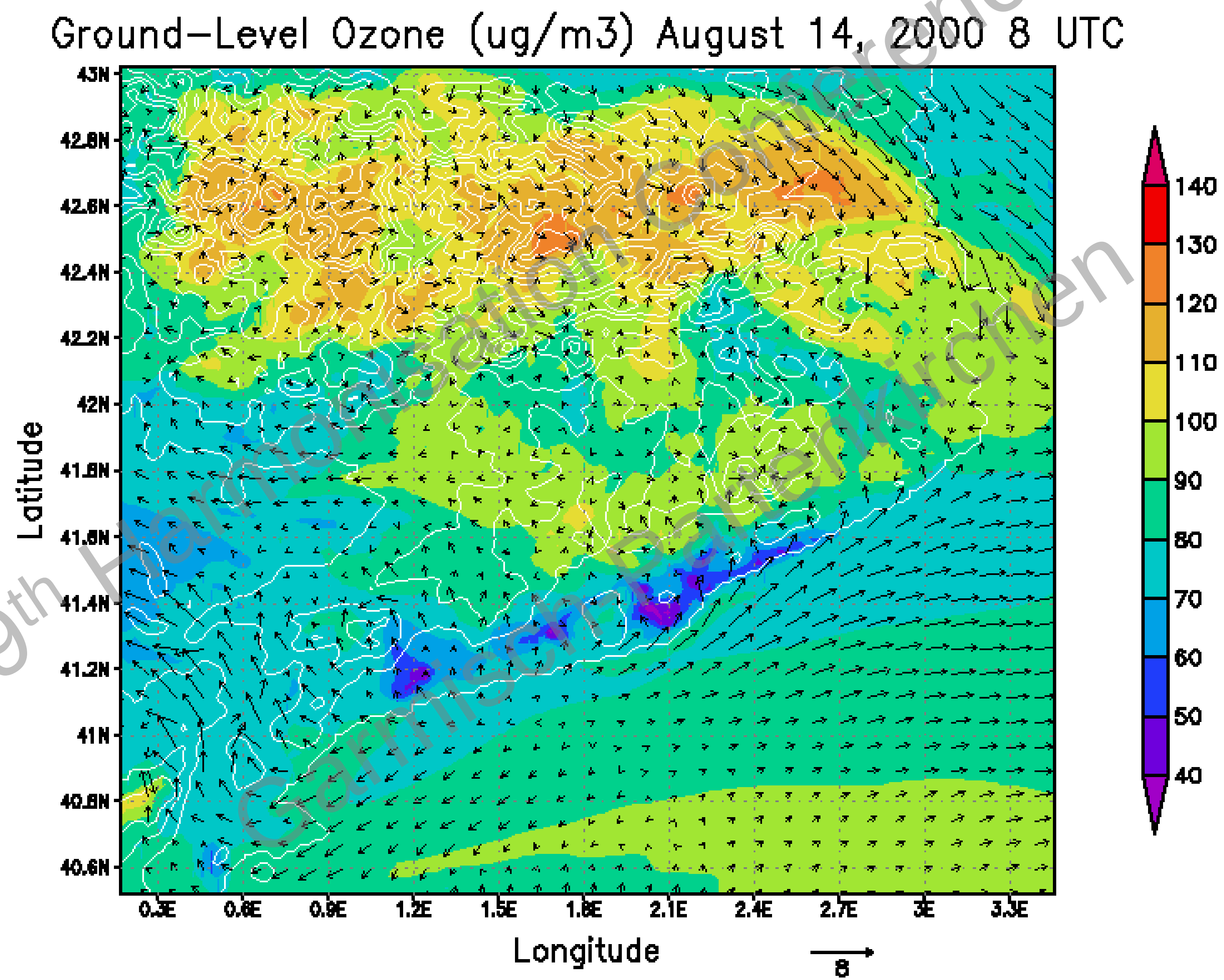

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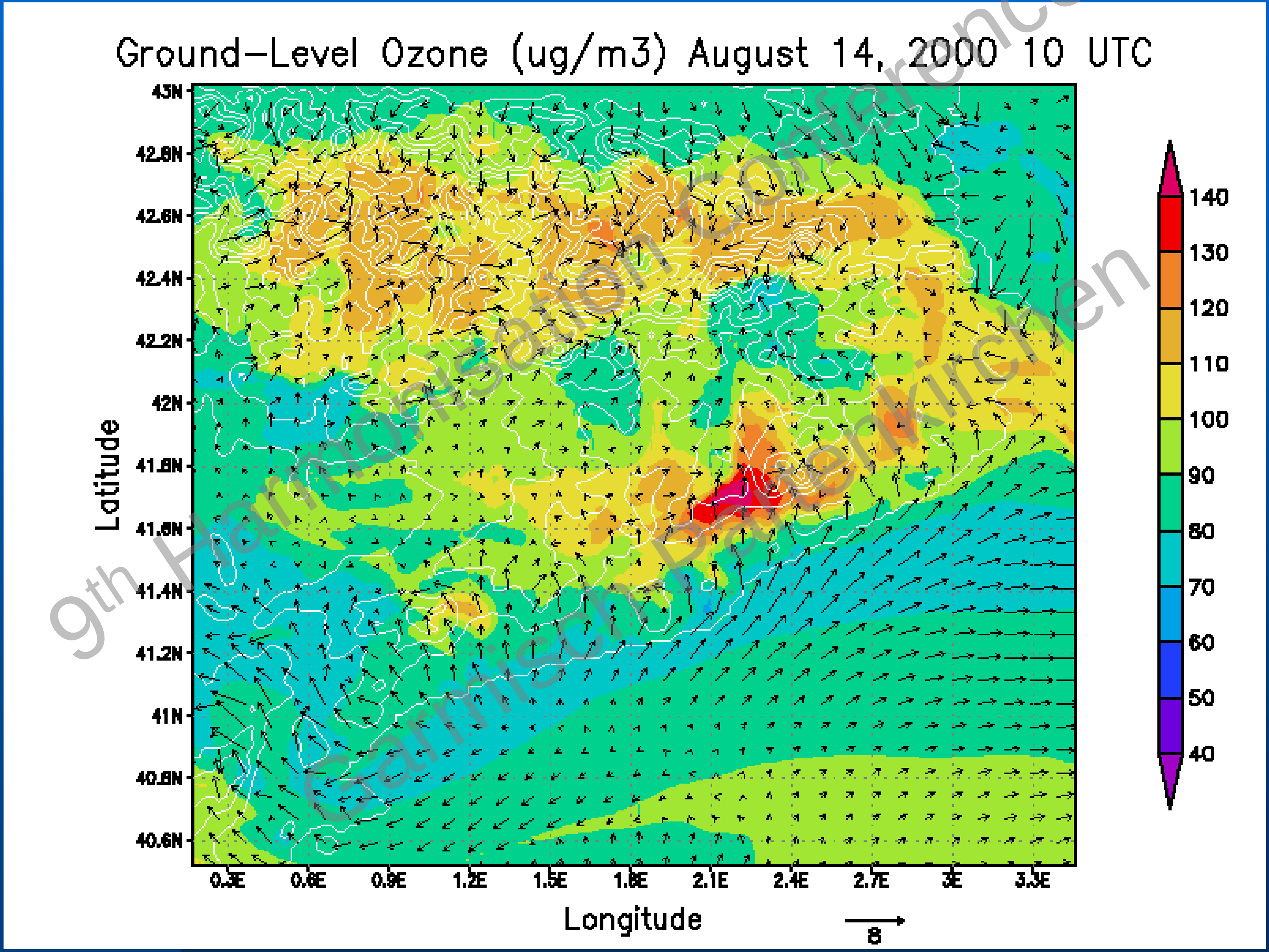

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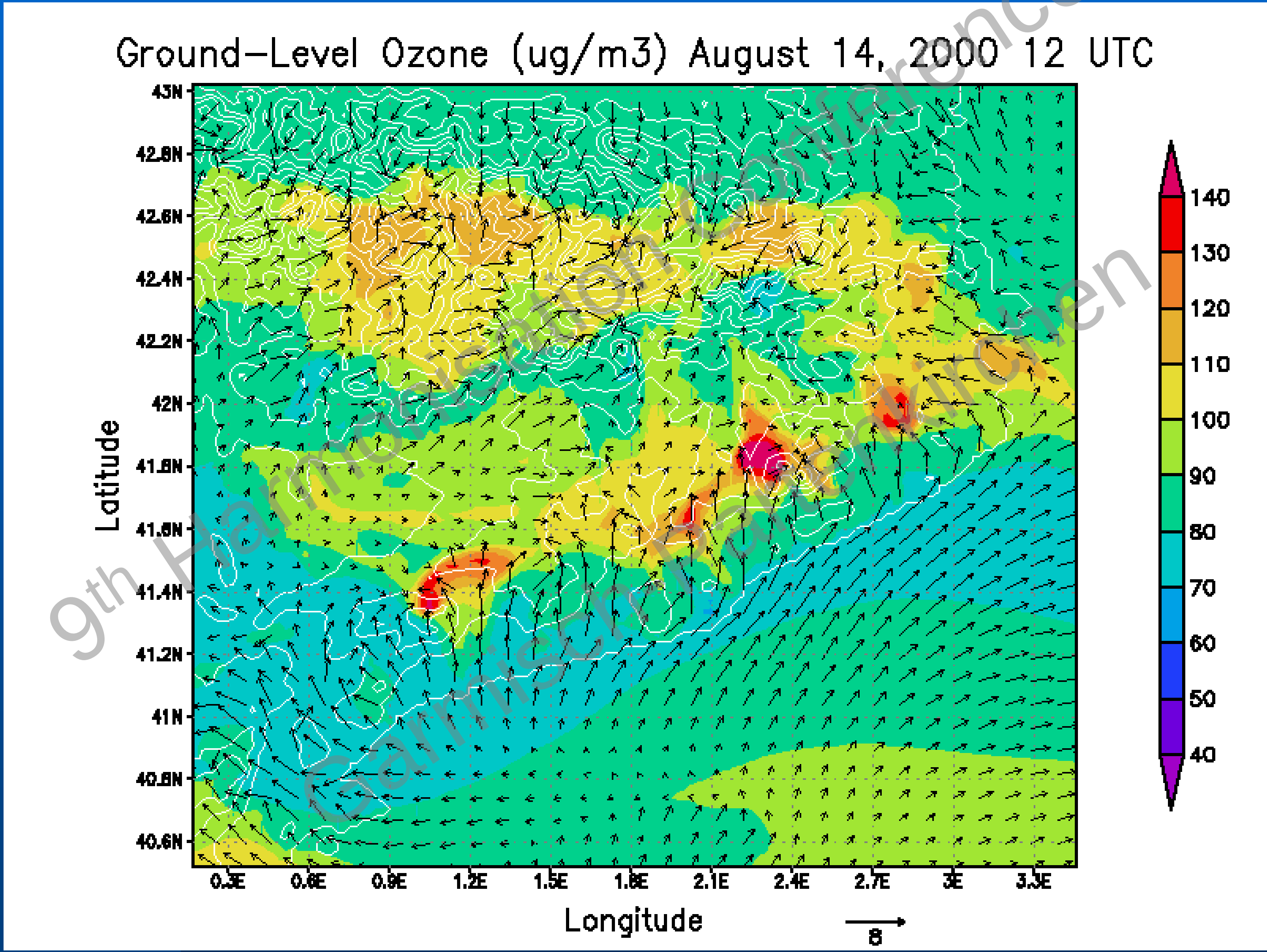

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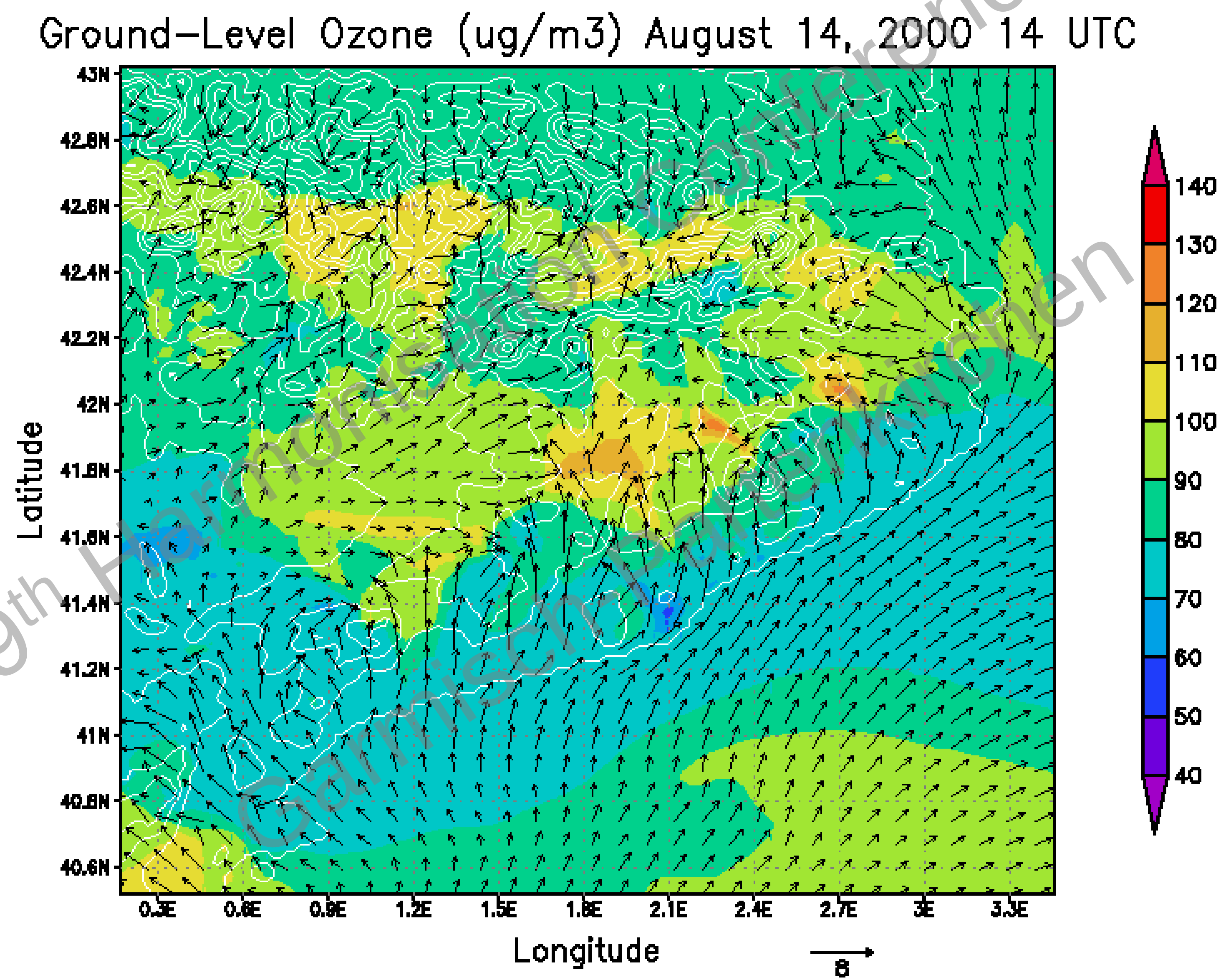

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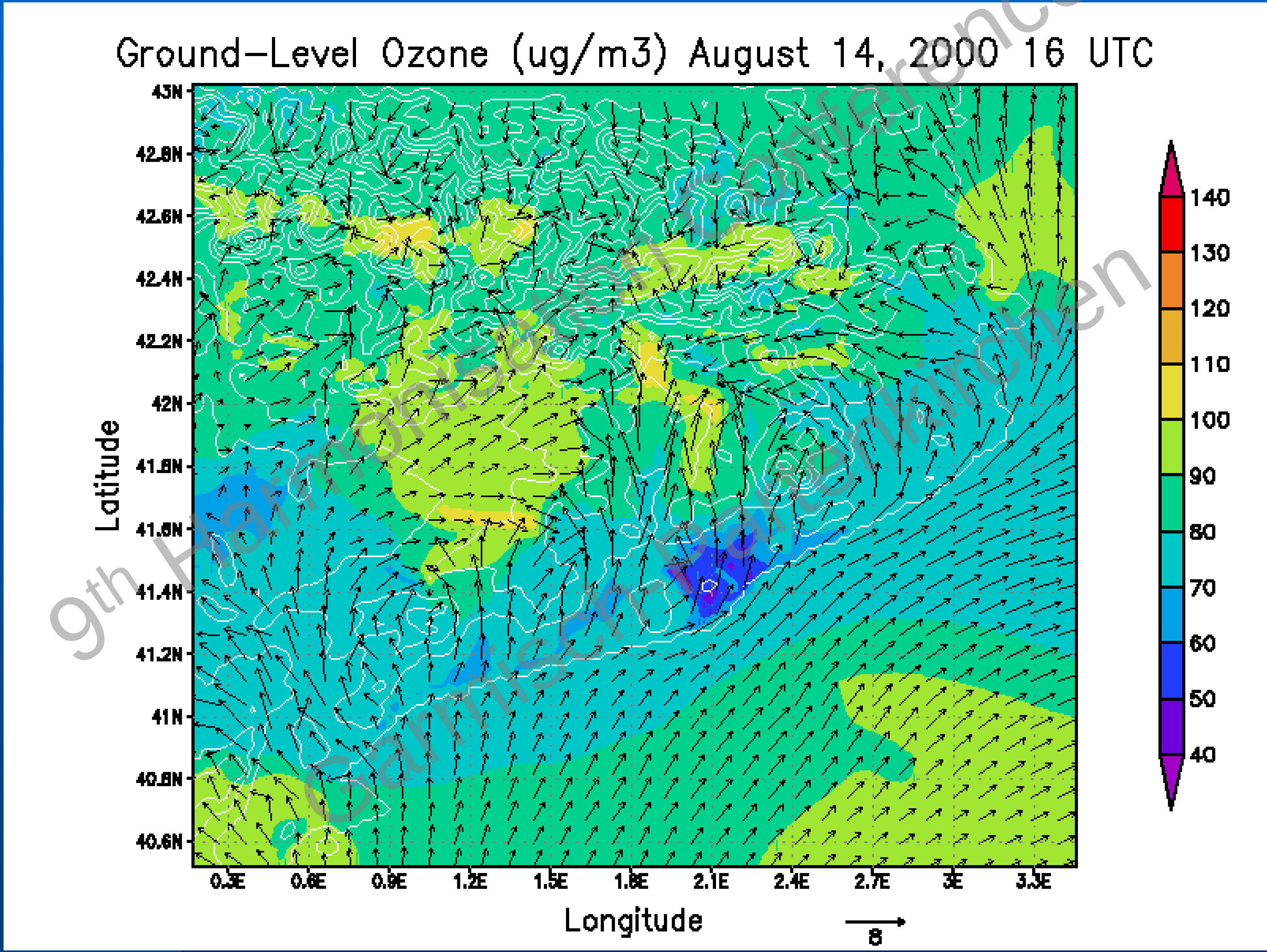

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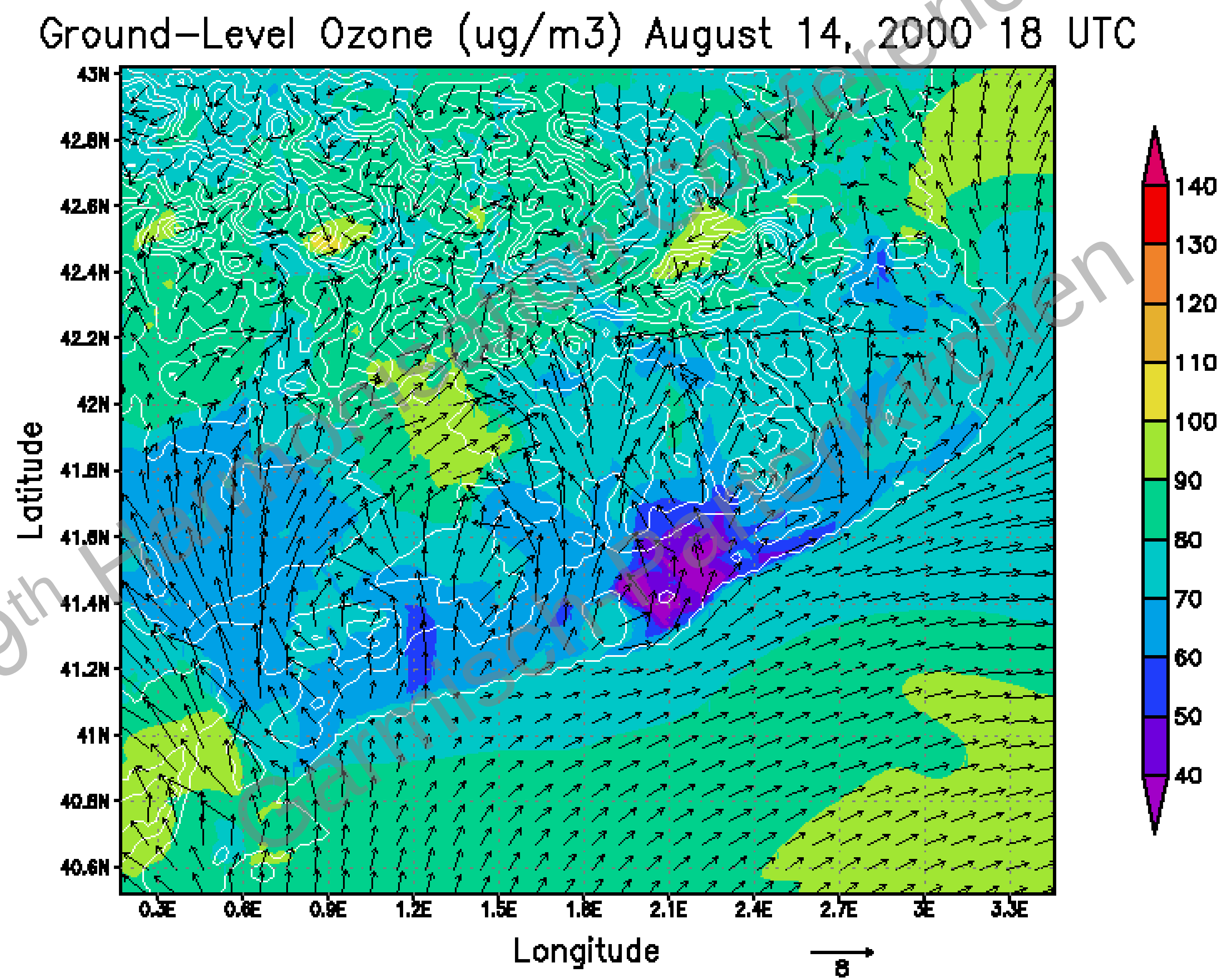

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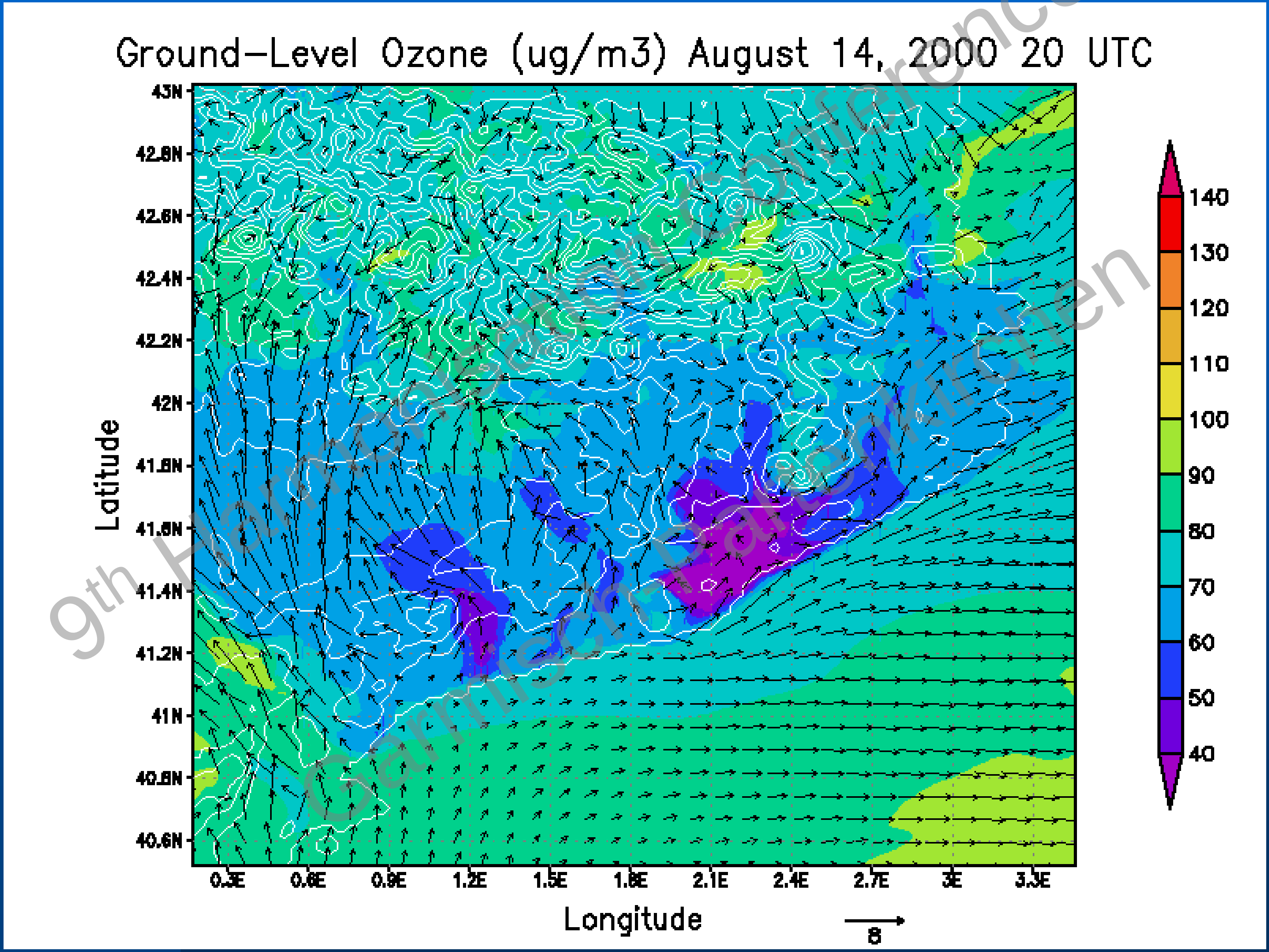

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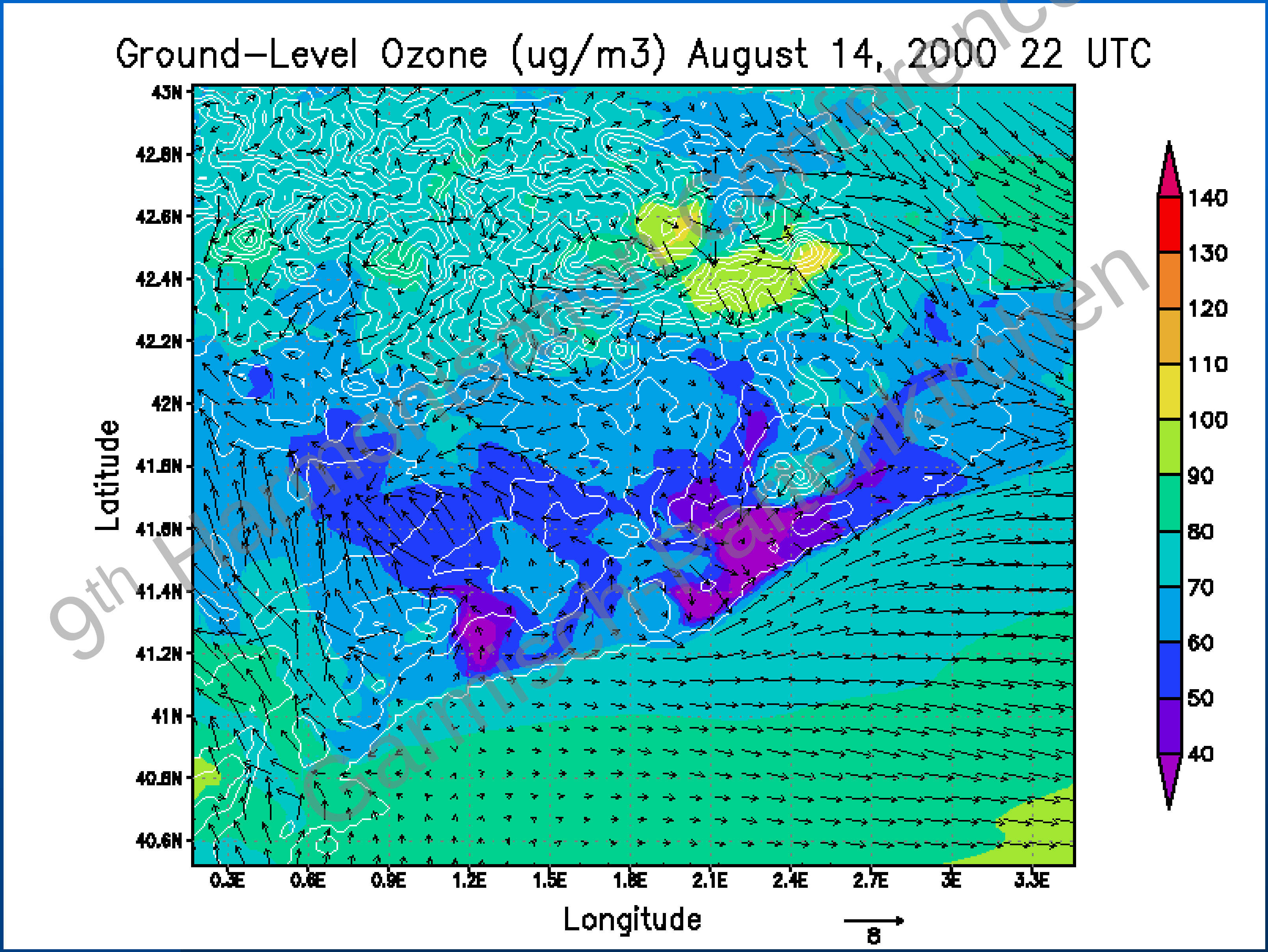
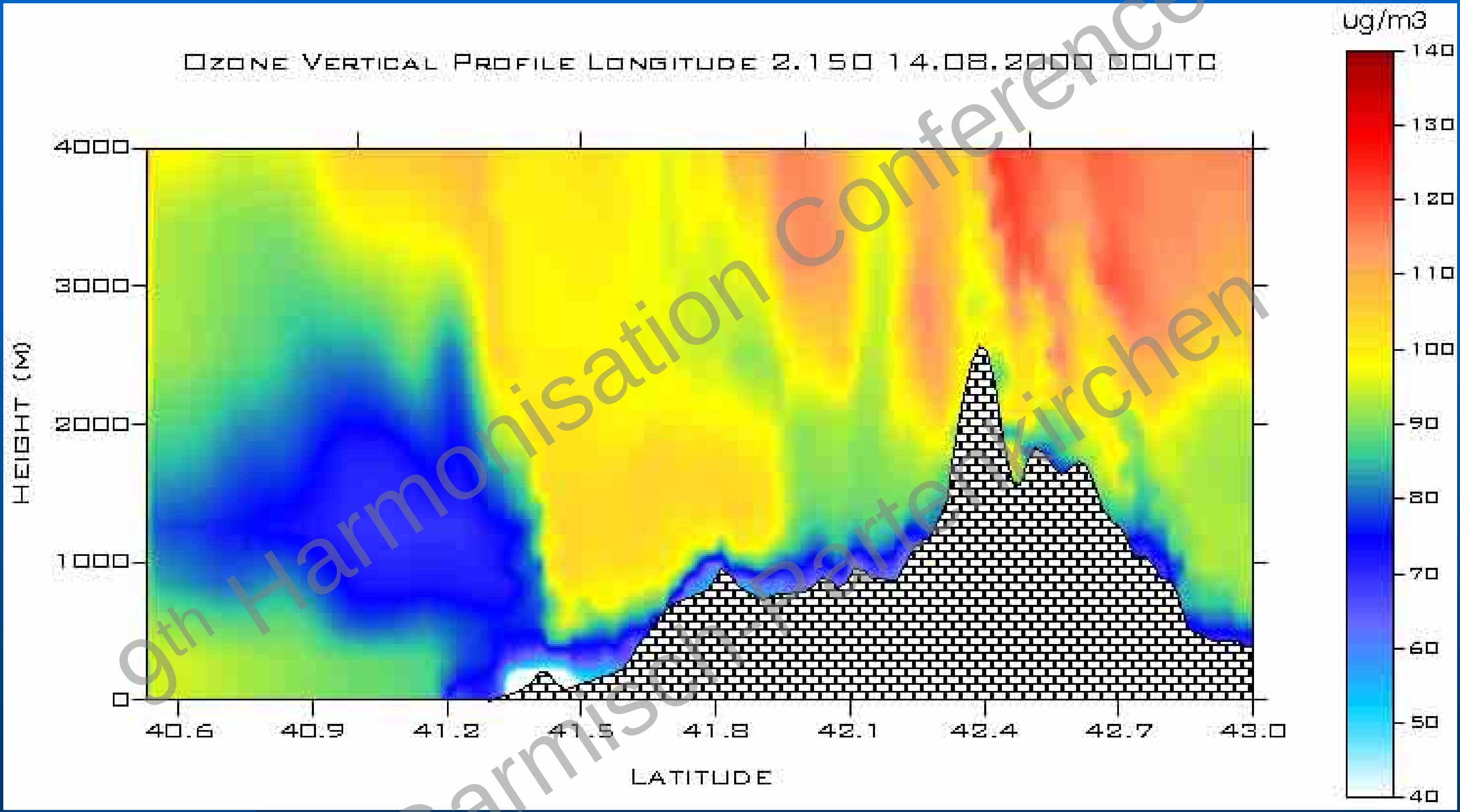


South-North O_3 Vertical Profile over BCN
(MM5-EMICAT2000-CMAQ, 2km, 16 layers, CBM-IV)



The vertical structure of the flows (specially in the Pyrenees valleys) is also influenced by the best representation of the topography when working with high horizontal and vertical resolution. The vertical structure of the see-breeze is improved, and several orographic injections appear when increasing the resolution.

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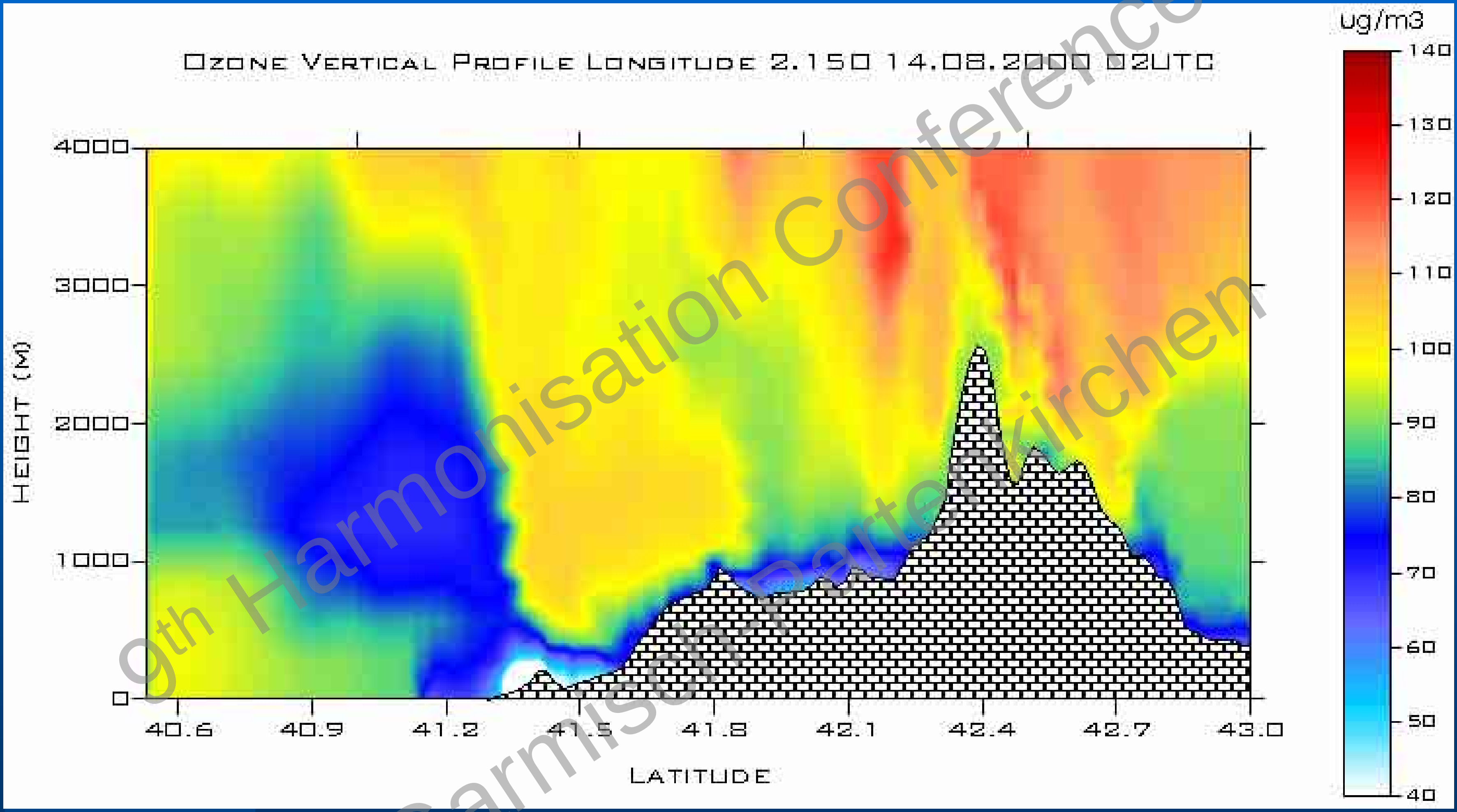

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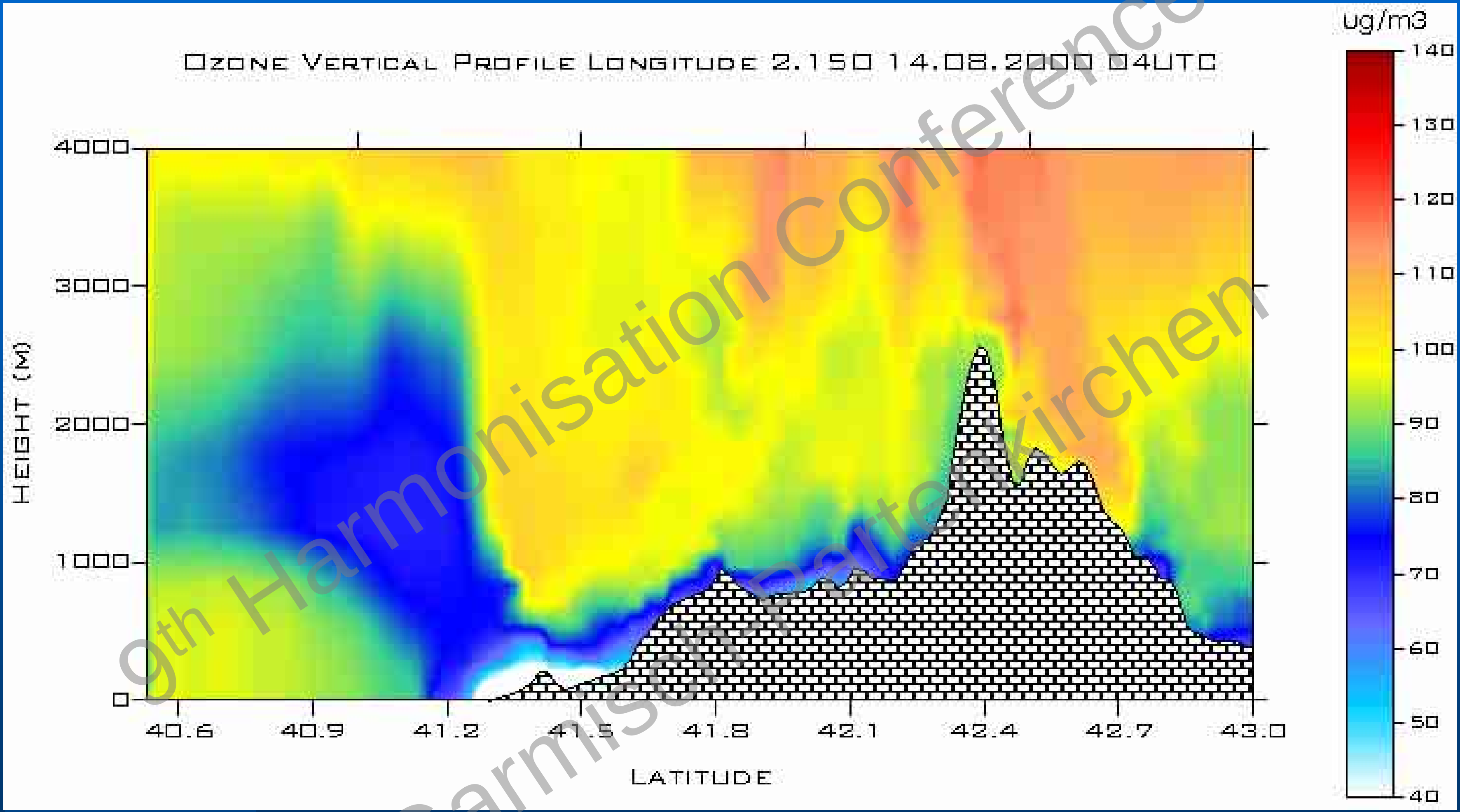

The vertical structure of the flows (specially in the Pyrenees valleys) is also influenced by the best representation of the topography when working with high horizontal and vertical resolution. The vertical structure of the see-breeze is improved, and several orographic injections appear when increasing the resolution.

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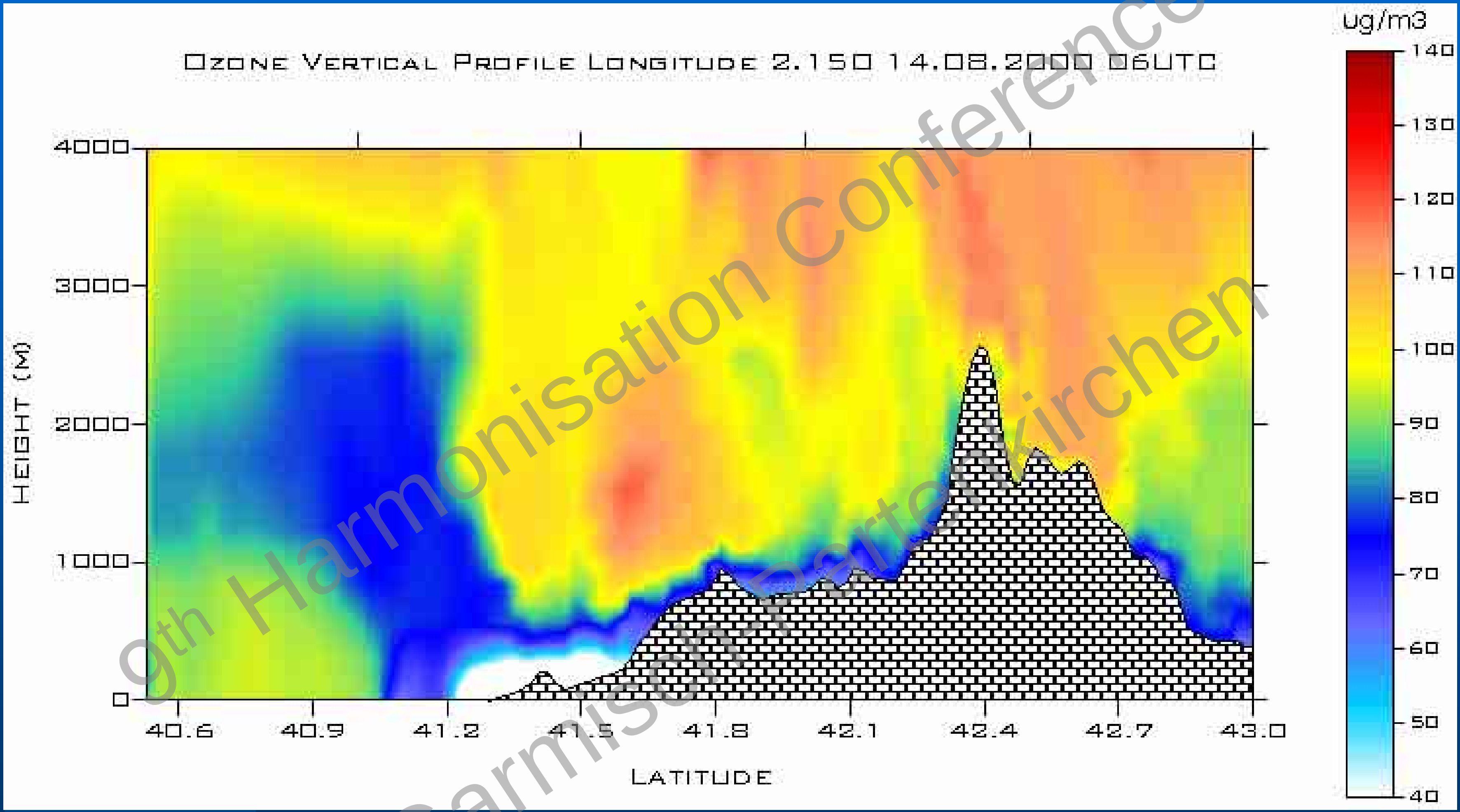

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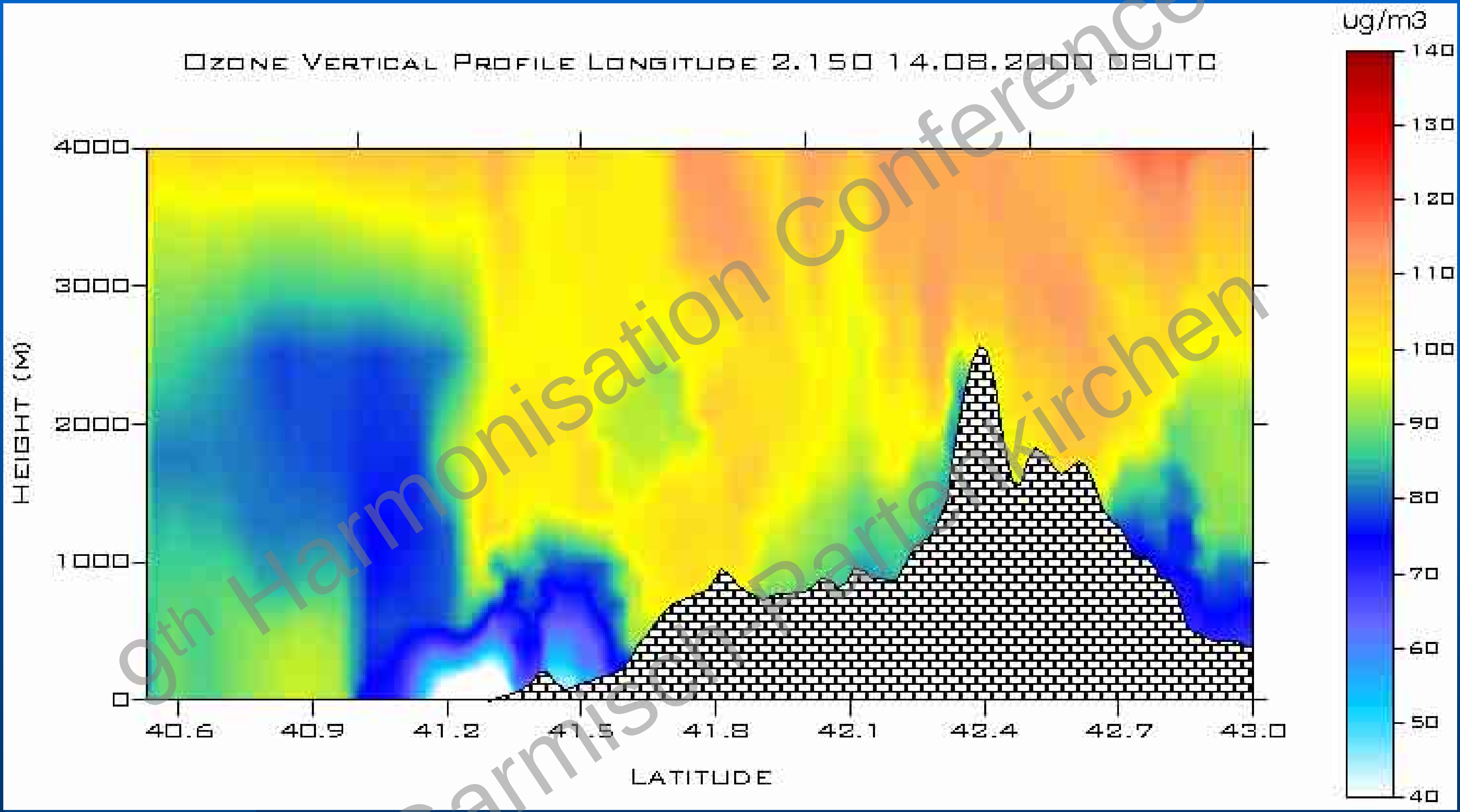

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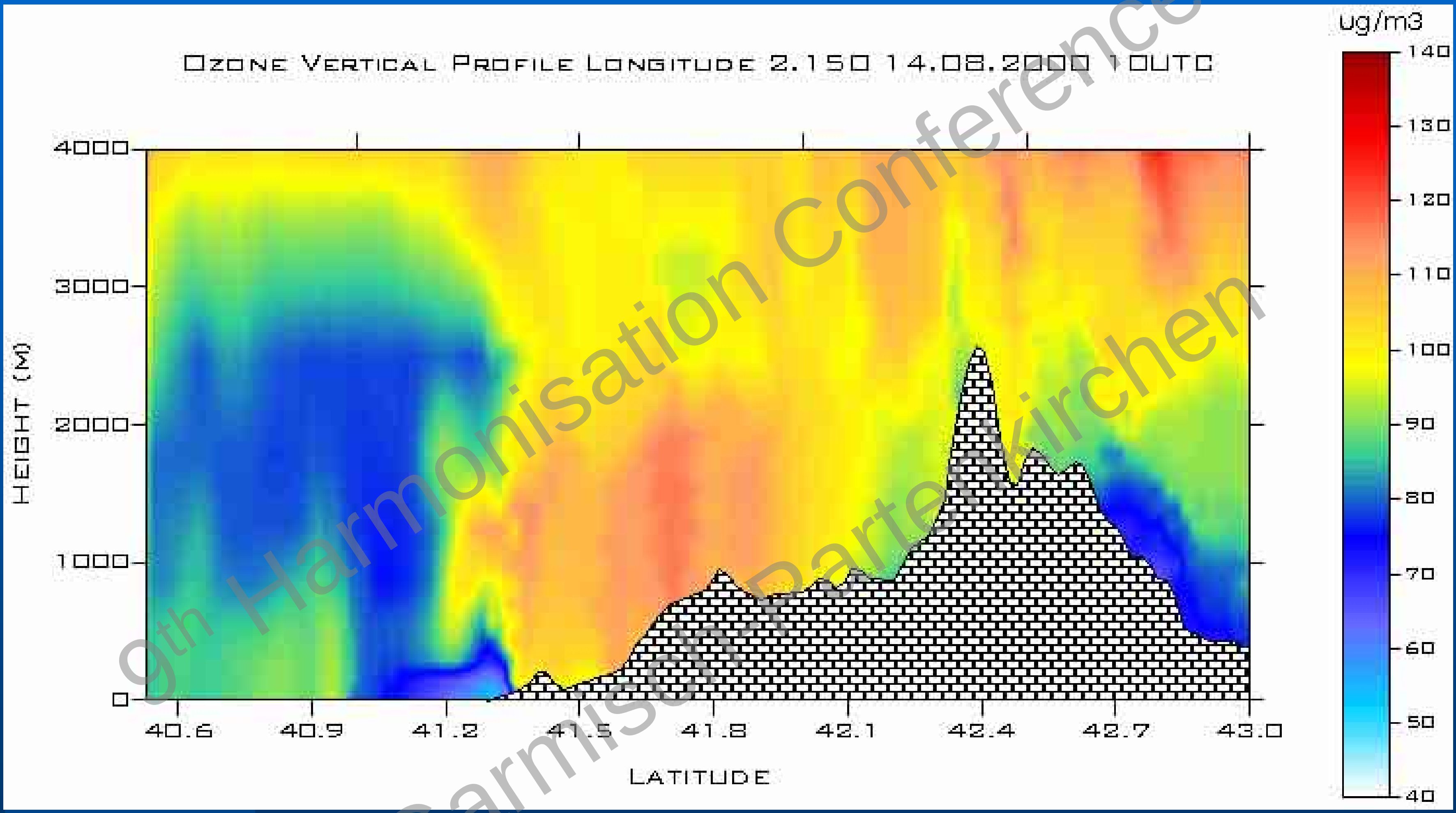

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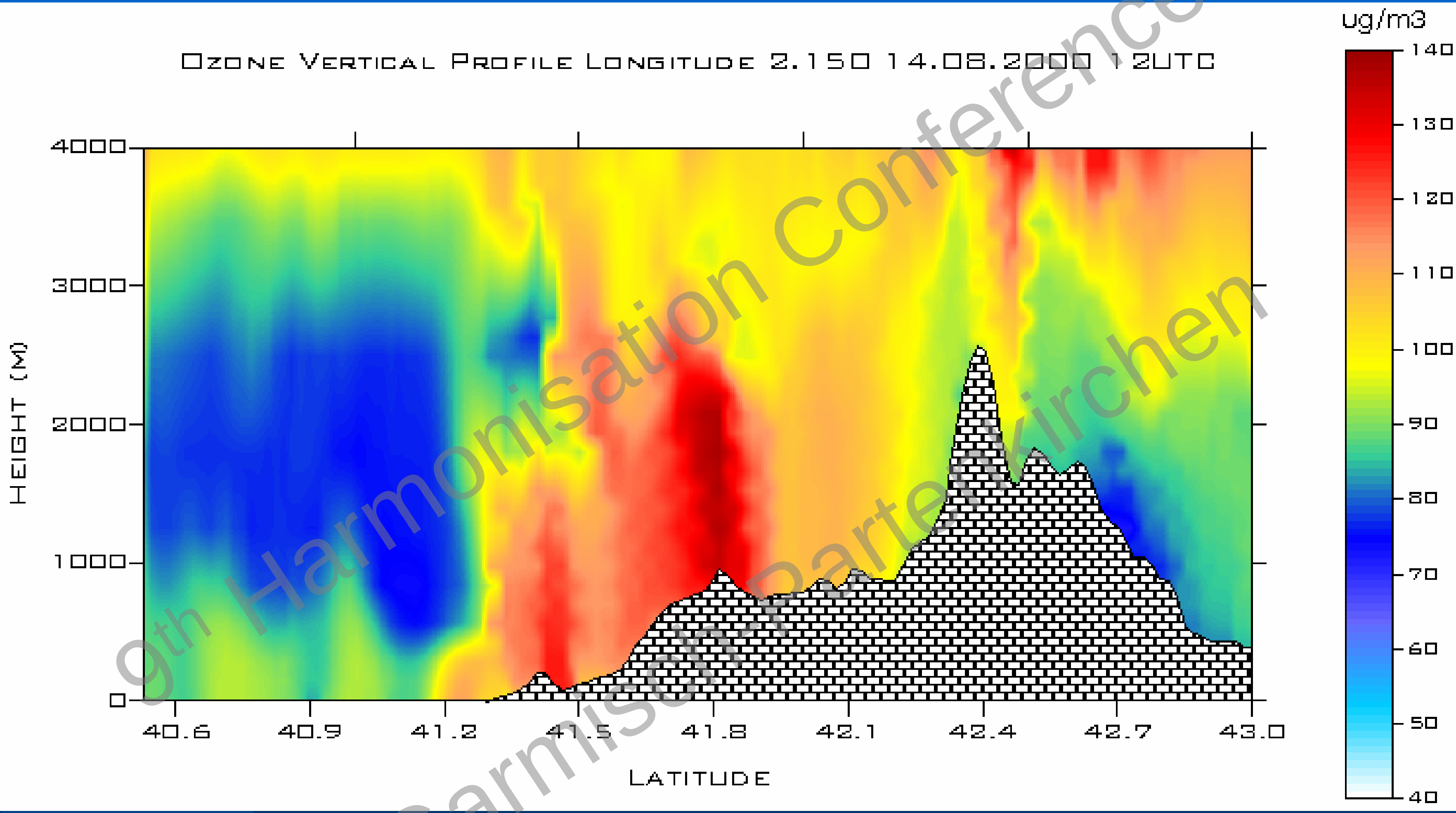

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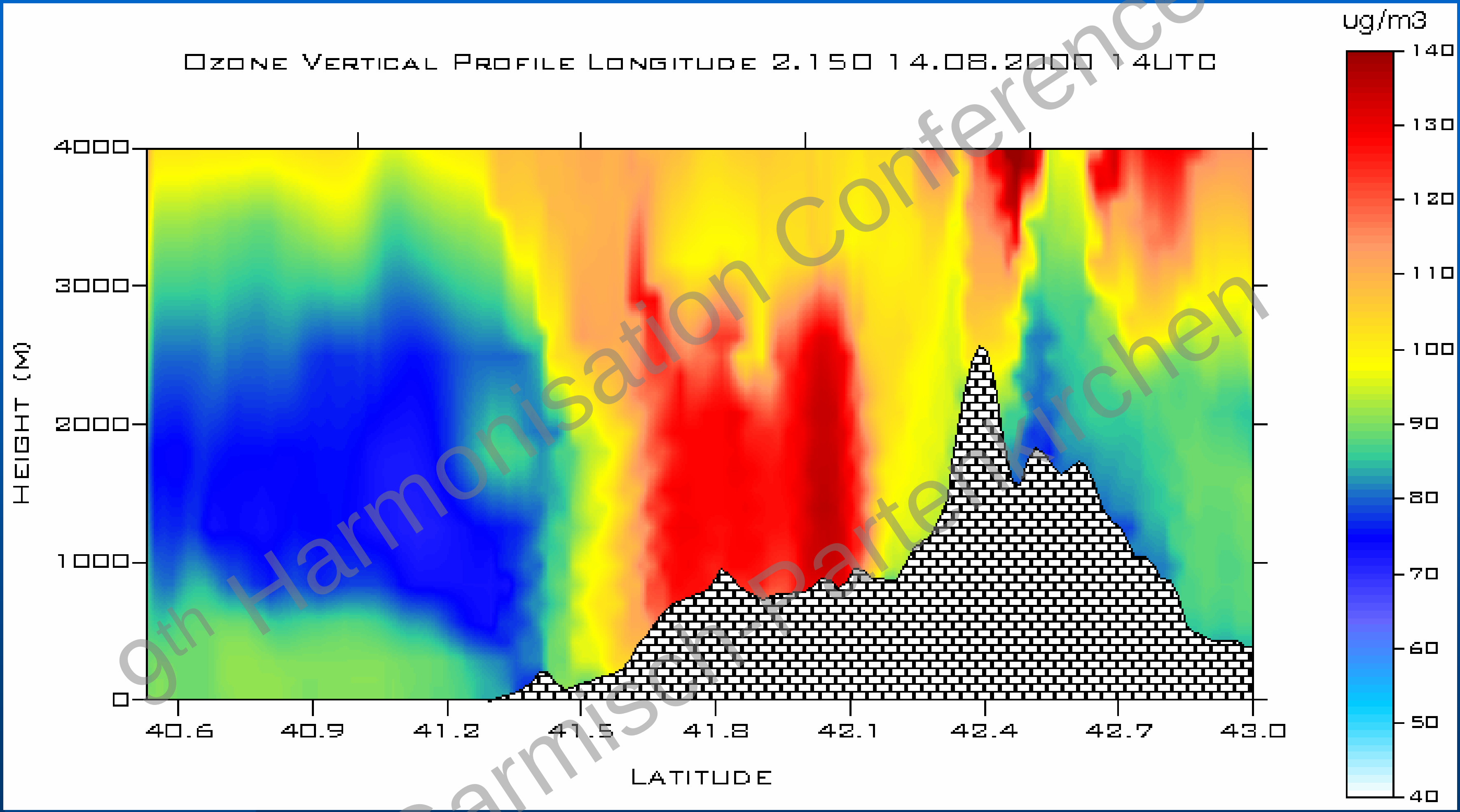

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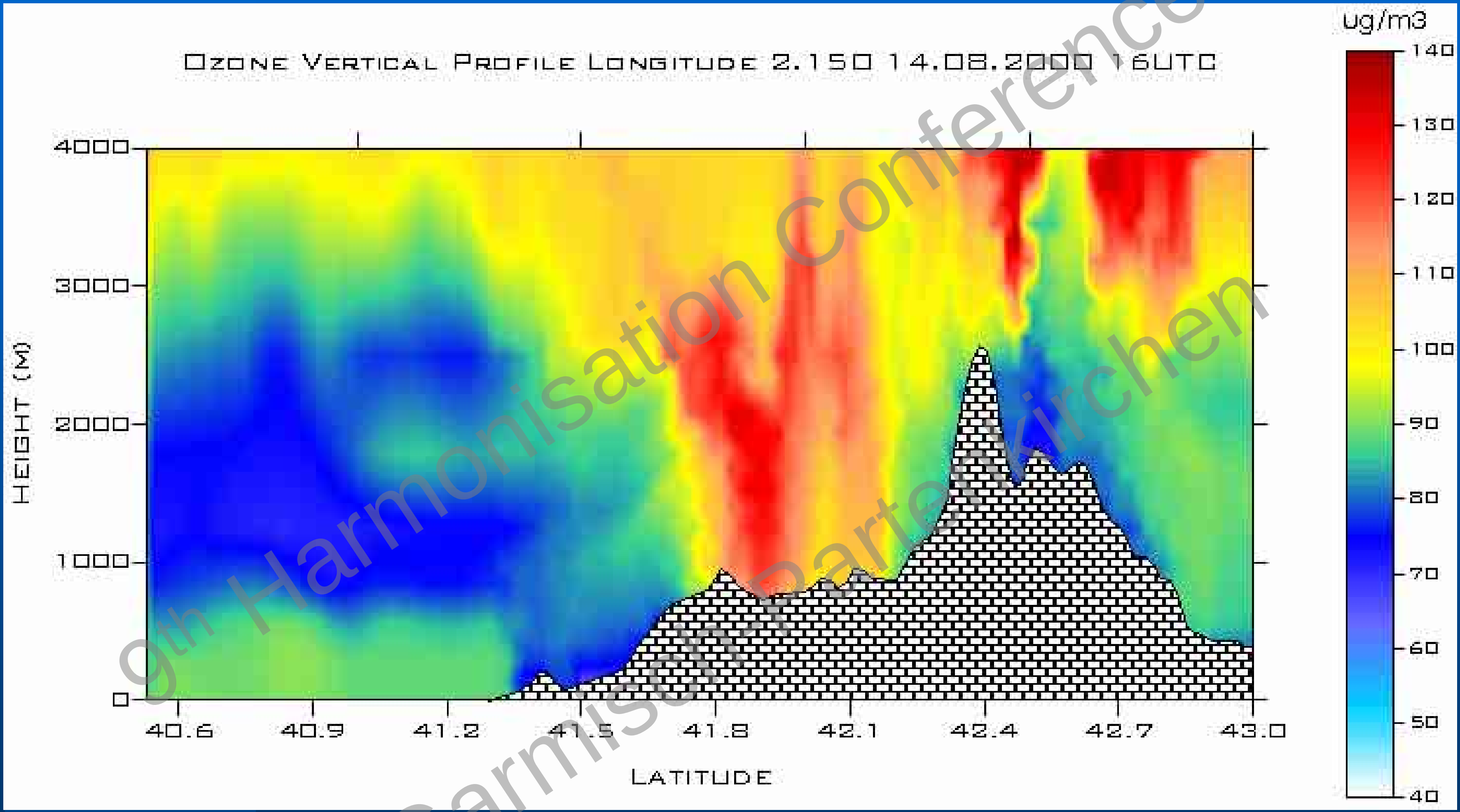

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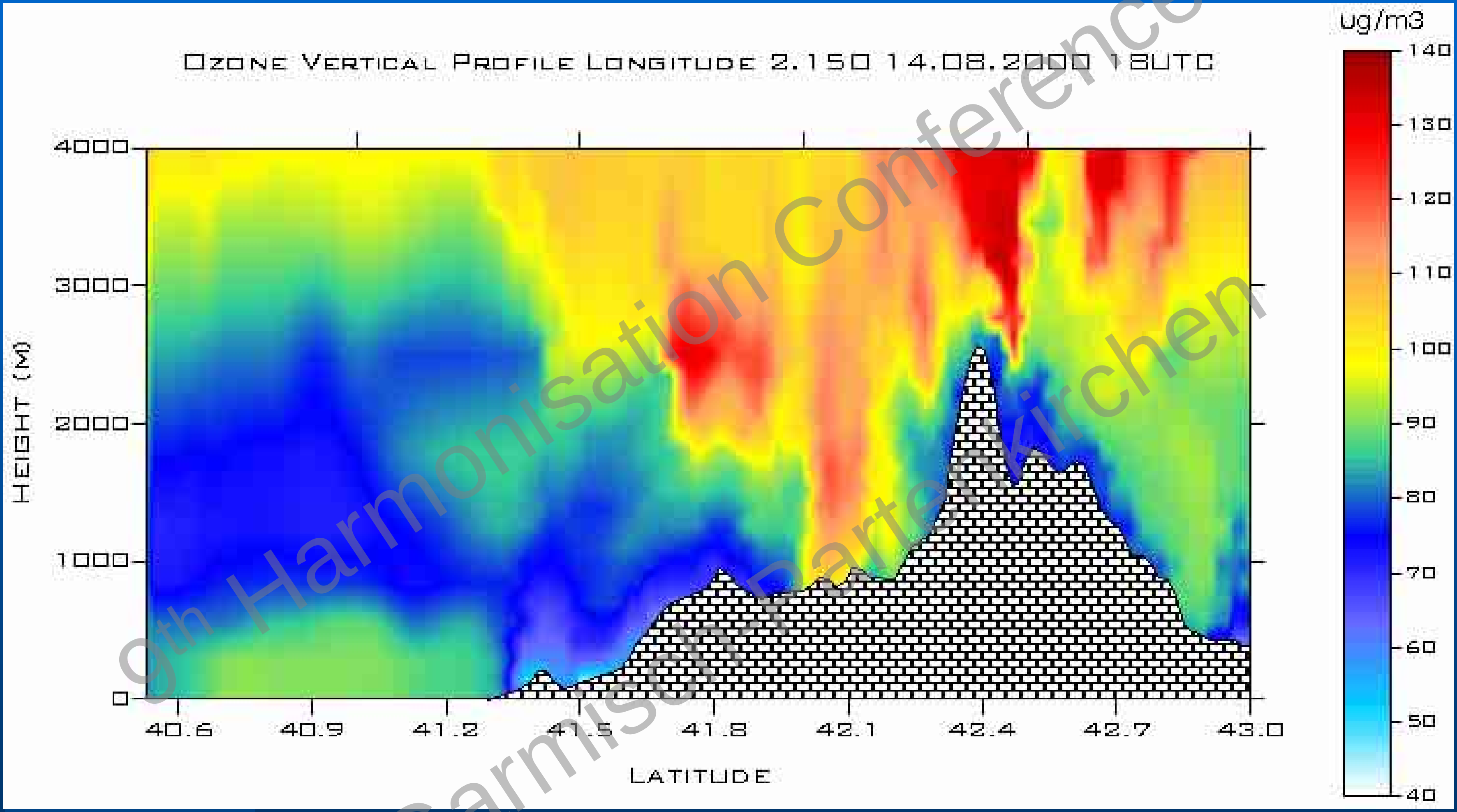

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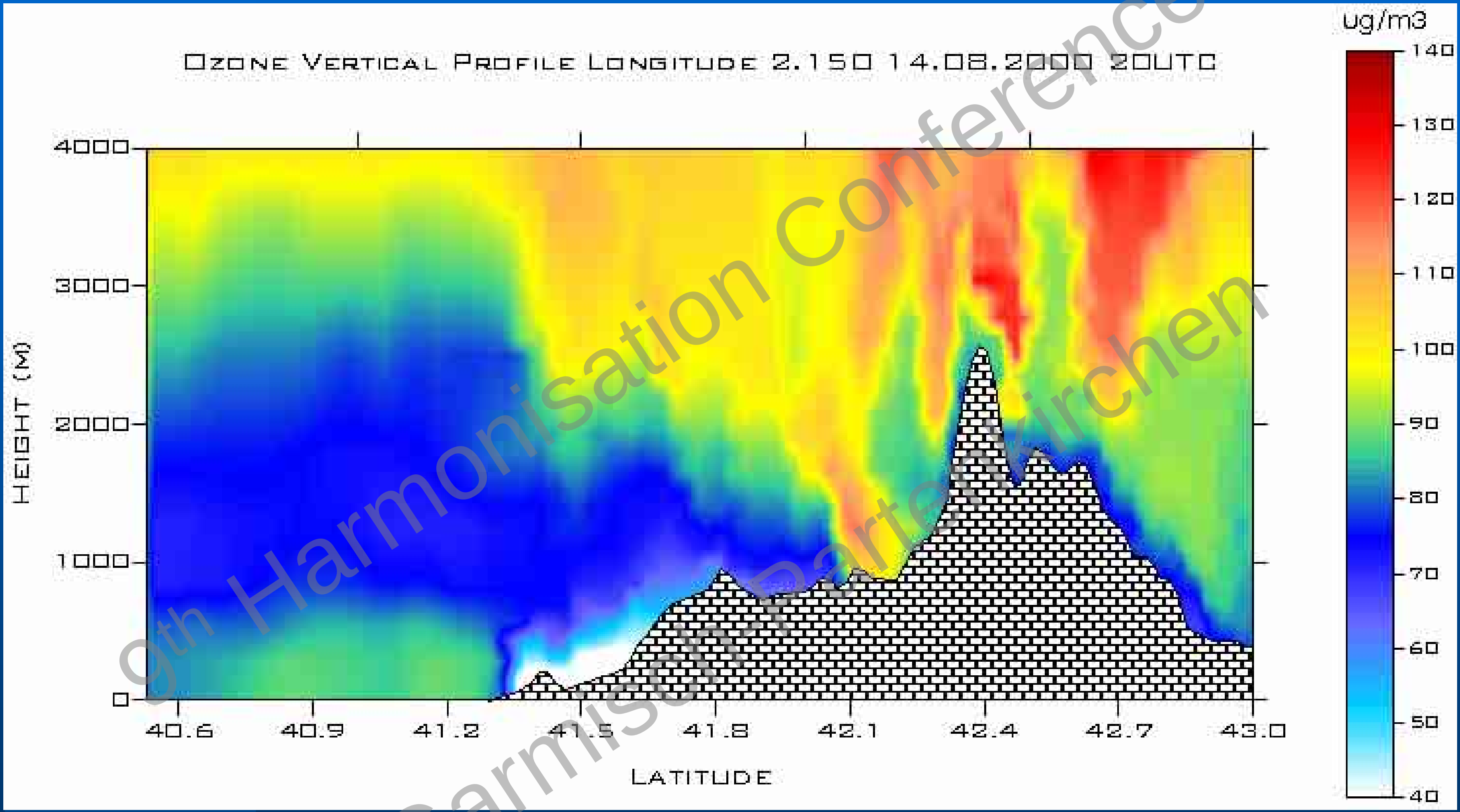

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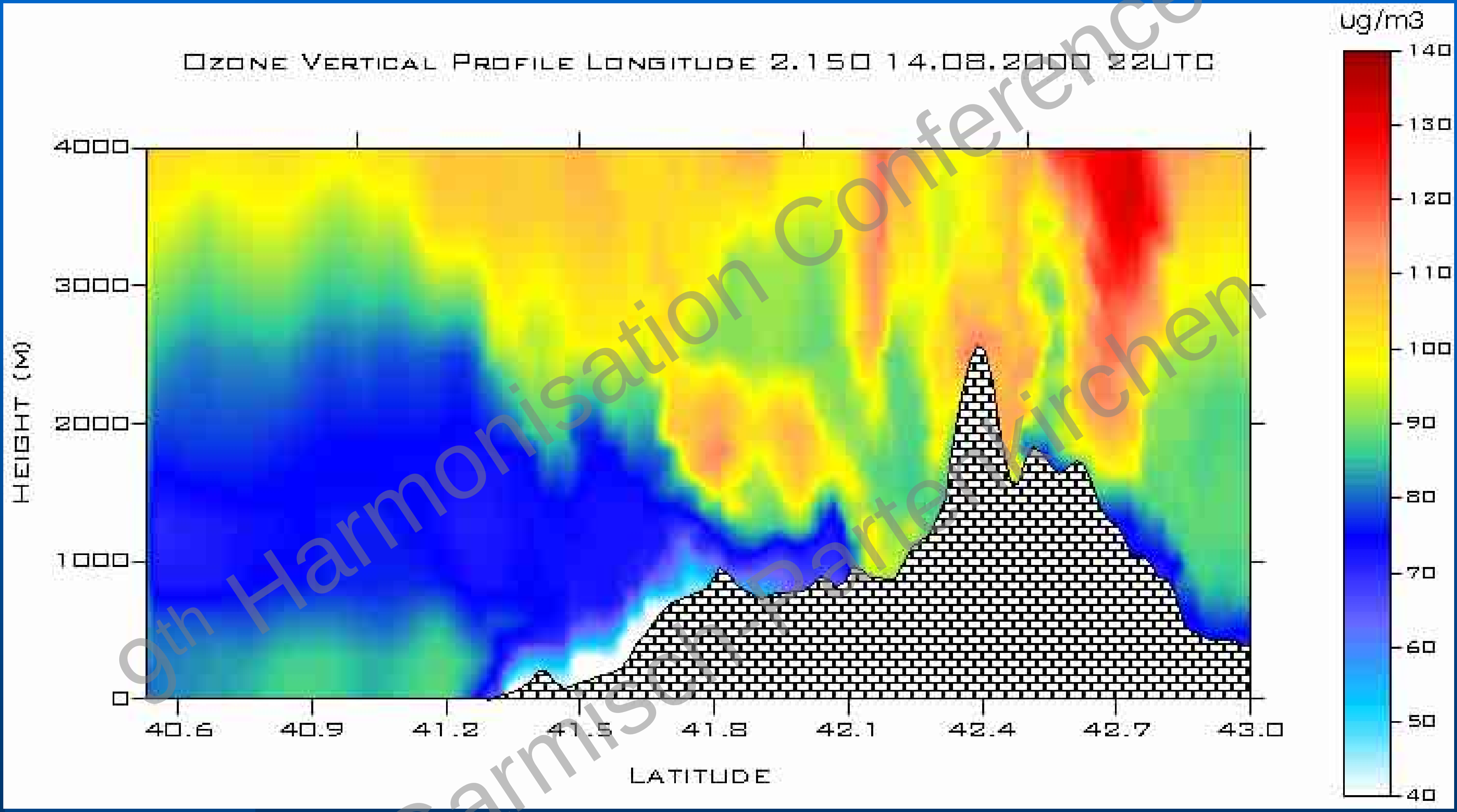

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Conclusions (1/2)

I. The effect of grid resolution on the results of a 3D air quality model applied to the northeastern Iberian Peninsula has been illustrated in this work. Simulations of the August 13-16, 2000 O_3 episode were used to depict the impact of grid resolution on photochemical pollution.

II. For the very complex domain studied, a clear improvement in the statistics of O_3 values has been observed when increasing model horizontal resolution from *8 km* to *2 km*, and the number of vertical layers.

III. MM5 simulations are very sensitive to the degree of topographical smoothing in this very complex terrain. The model is unable to reproduce the mountain-wind system with resolutions coarser than 4 km. Statistics of the 2 km simulation present the best behavior during the development of the sea breeze, but all three simulations overestimate surface flows during the nocturnal period. Model outputs were sensitive to the grid size employed in the simulations

Conclusions (2/2)

IV. Despite in outline the O_3 patterns do not change dramatically, some small-scale features appear when using a resolution of 2 km that cannot be captured with coarser horizontal resolutions.

V. If both discrete and categorical statistical parameters are compared with U.S. EPA's recommended values, a grid resolution of 2 km, both with 6 or 16 vertical layers, is needed in order to ensure that results are inside the range of error recommended. However, the model should have enough vertical resolution in order to represent correctly the low-troposphere processes throughout the day.

VI. Therefore, this work has shown the necessity of high-resolution modeling to accurately reproduce the ozone dynamics in the northeastern Iberian Peninsula due to local particularities.

Influence of 3D Model Grid Resolution on Tropospheric Ozone Levels

Thanks for your attention

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