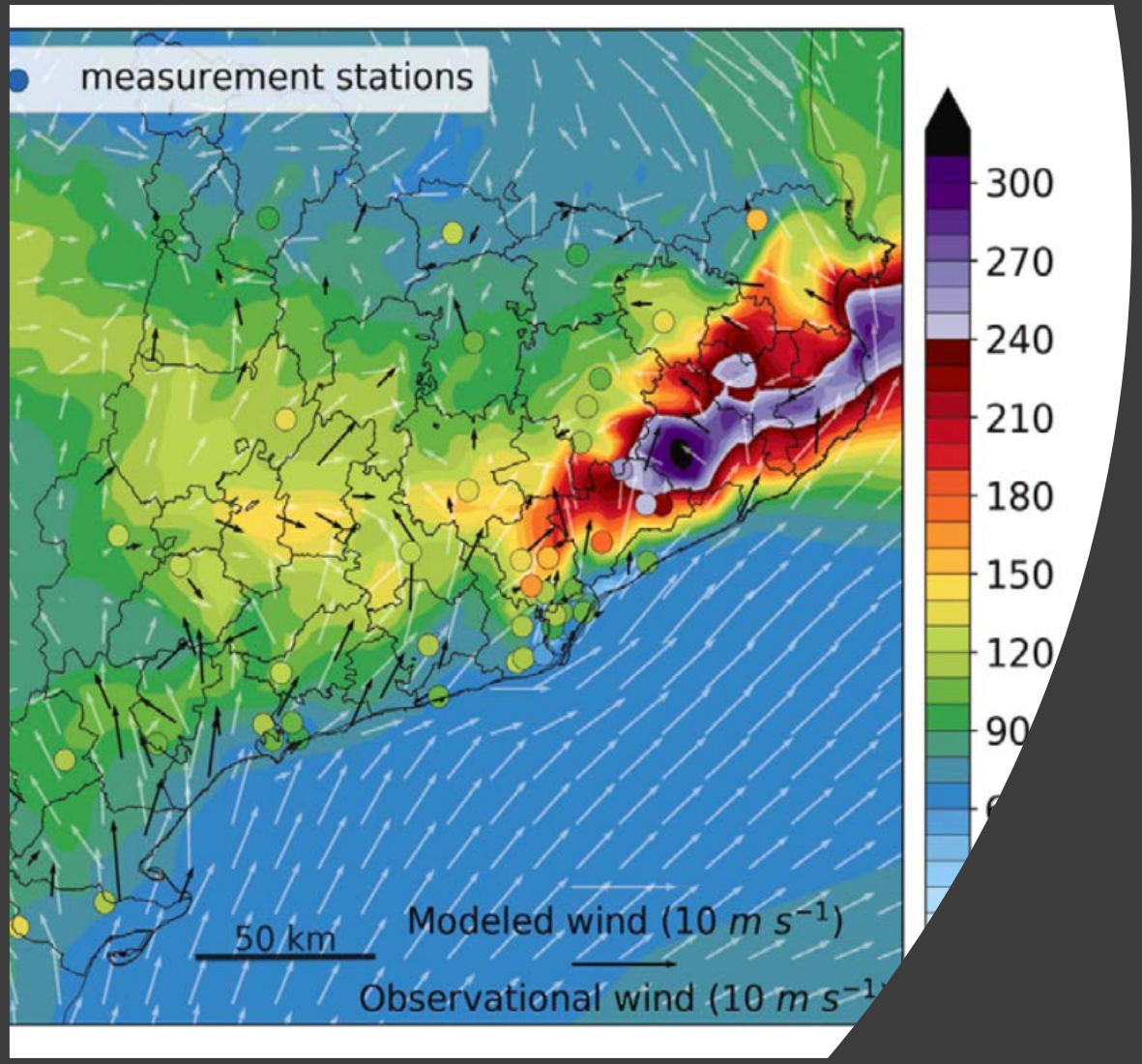

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14-15 d'octubre 2021

Meteorological and photochemical modeling analysis of extreme ozone episodes in Barcelona and surrounding region during summer 2019

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Introduction

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- Tropospheric ozone: secondary pollutant formed from the interaction between solar radiation (λ>424 nm), NOx and VOCs. Temperature increases the reactivity of hydrocarbon radicals (VOCs and CH_4).

- Heat waves: high temperatures, low ventilation -> ozone accumulation
  Several O_3 episodes around the world related with heat waves -> (Pyrgou et al., 2018; Zhao et al., 2019; Gu et al., 2020)

- In Catalonia: ozone exceedances in summer, in areas downwind the urban and metropolitan influence. Barcelona metropolitan area (AMB): Besòs-Congost valley and Llobregat valley.

Objective

To describe the extreme ozone episodes occurred during a heat wave in summer 2019:
- Analyze the registered concentrations and the air quality model forecasts
- Investigate the meteorological factors that influenced on ozone transport, recirculation and accumulation

Methodology: Data and modeling configuration

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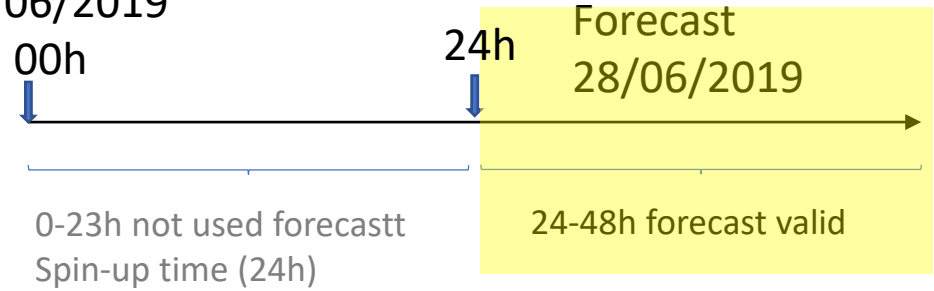
I. Observational data from 49 measurement stations (XVPCA=Xarxa Vigilància i Previsió de la Contaminació Atmosfèrica)

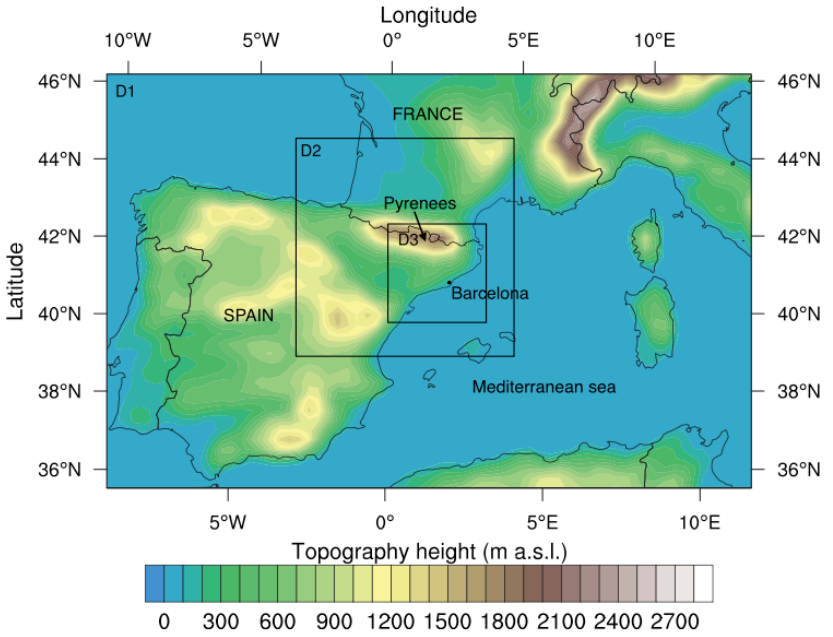
II. Air quality model data from ARAMIS forecasts (Soler et al. 2015), see www.ub.edu/mair.

ARAMIS (A Regional Air-Quality Modelling Integrated System) is an air quality modeling system that integrates 3 eulerian models: **WRF** (meteorological model), HIREM (emissions model) and **CMAQ** (photochemical model).

Inner domain D3 (Catalunya): 3x3 km grid size
Forecasts 28, 29 June; 23 July 2019
- 32 vertical levels (20 levels < 1500 m)
- Initial and boundary conditions (every 6h) from ECMWF model

Simulation start
27/06/2019
00h





Integrated process analysis (IPR) of CMAQ: quantifies the contribution of each physical process to the total pollutant concentration change (horitzontal and vertical diffusion, advection, dry deposition, chemical transformation)

III. Model HYSPLIT: Hybrid Single- Particle Lagrangian Integrated Trajectory -> Trajectories backward and forward (10 h).

Ozone episodes during summer 2019

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2019: Exceptional summer with many ozone threshold exceedances

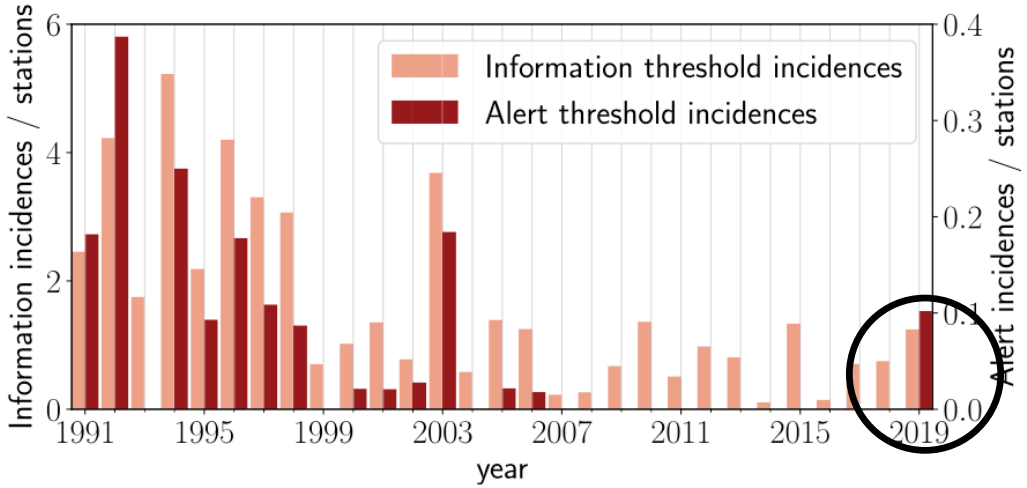
- Alert threshold (AT) -> hourly values > 240 µg/m^3:
  - 28/06: 4h stations of Montseny (2h), Santa M. Palautordera, St Celoni
  - 29/06: 1h Gavà
  - 23/07: 1h Vic

- Information threshold (IT) -> hourly values > 180 µg/m^3:
  - 28/06: 20h in 8 stations
  - 29/06: 49h in 17 stations
  - 23/07: 10h in 7 stations

Heat wave declared between 25-30 June 2019
Maximum temperatures in Catalonia:
- 28/06: 43,6°C
- 29/06: 43,8°C

Heat wave declared between 22-25 July 2019

In Catalonia:



Ozone episodes during summer 2019

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28 June and 23 July: precursors advection from AMB through Besòs-Congost valley

ZQA6: Plana de Vic

ZQA8: Comarques de Girona

ZQA9: Empordà

28 June 2019 + 23 July 2019

Ozone episodes during summer 2019

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28 June and 23 July: precursors advection from AMB through Besòs-Congost valley
ZQA6: Plana de Vic
ZQA8: Comarques de Girona
ZQA9: Empordà

29 June: Barcelona, Llobregat valley up to Bellver de Cerdanya
ZQA1, ZQA2, ZQA3, ZQA5, ZQA10, ZQA11

28 June 2019 + 23 July 2019

29 June 2019

Temporal analysis: observations

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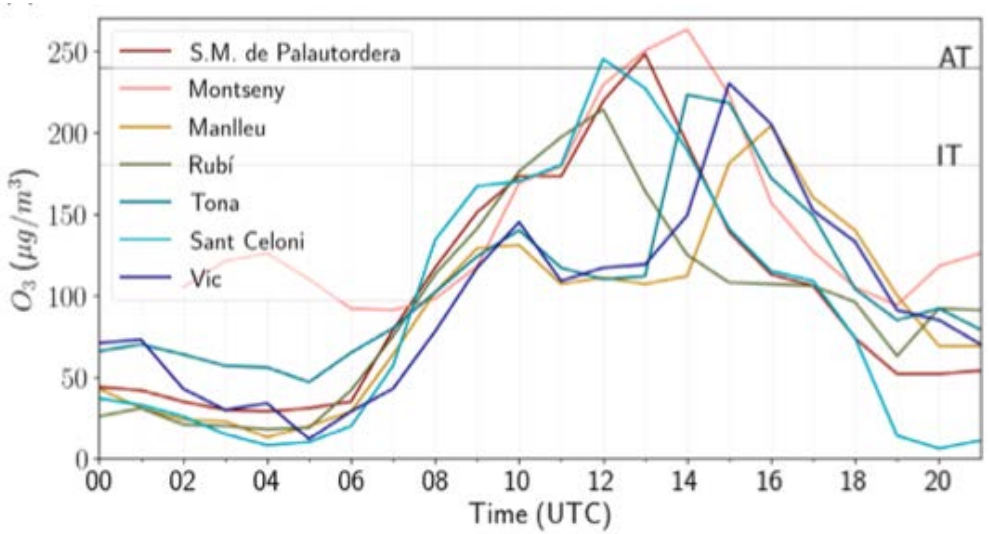
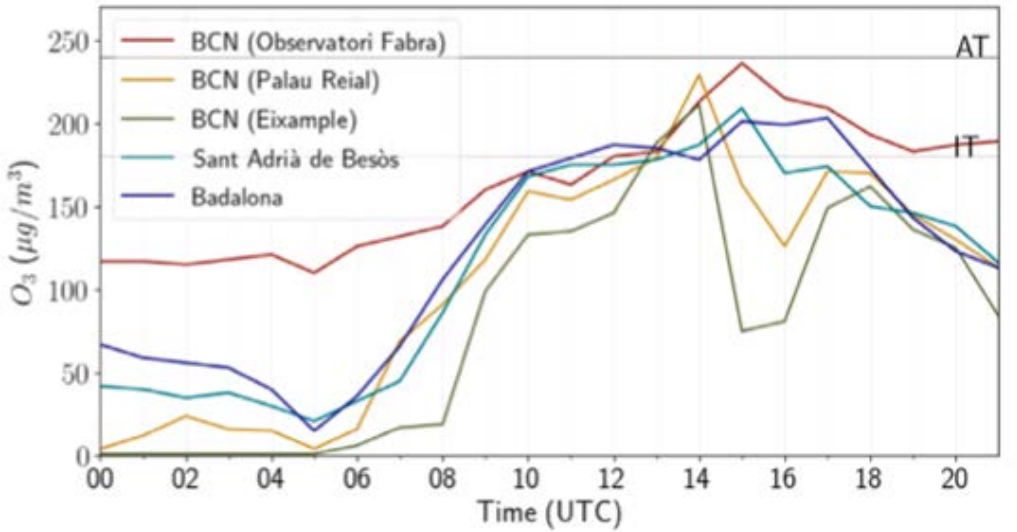
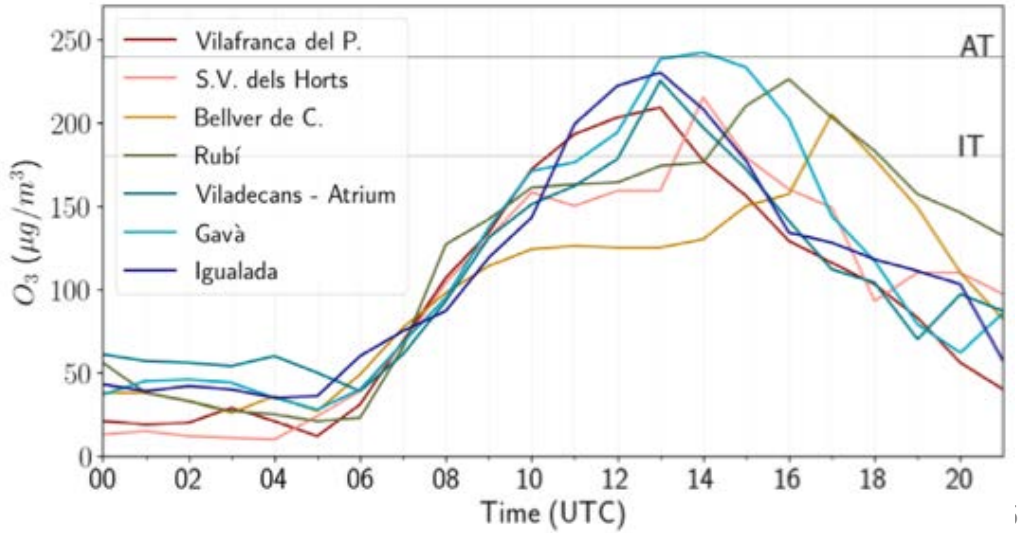
28 June 2019

29 June 2019

Stations that exceeded ozone concentrations of 200 $\mu g/m^3$







Temporal analysis: observations vs model

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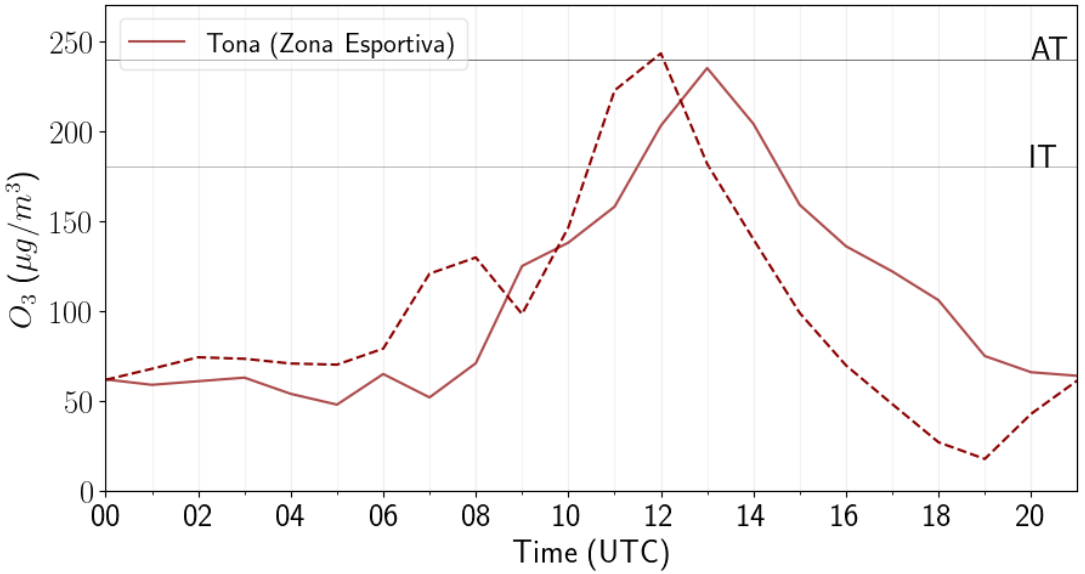
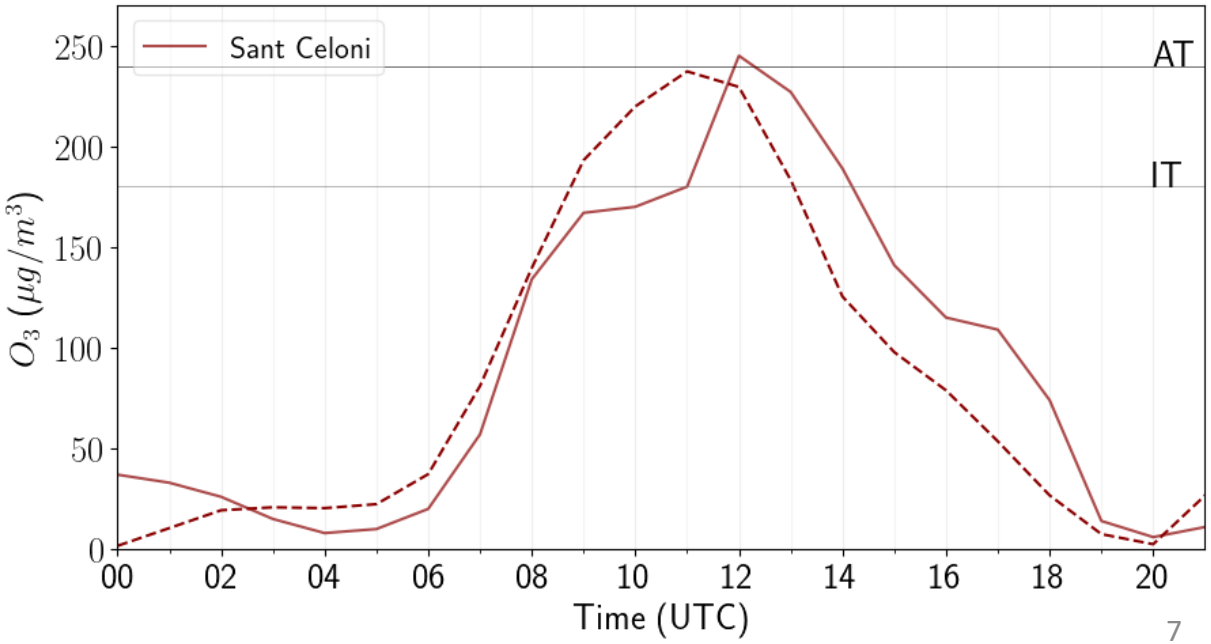
28 June 2019



Observation
Model



Model performance:

- Anticipates the ozone concentration peak around 2 hours
- Approximates well the concentration values (~240 μg/m³)
- Reproduces the diürnal cycle

Temporal analysis: observations vs model

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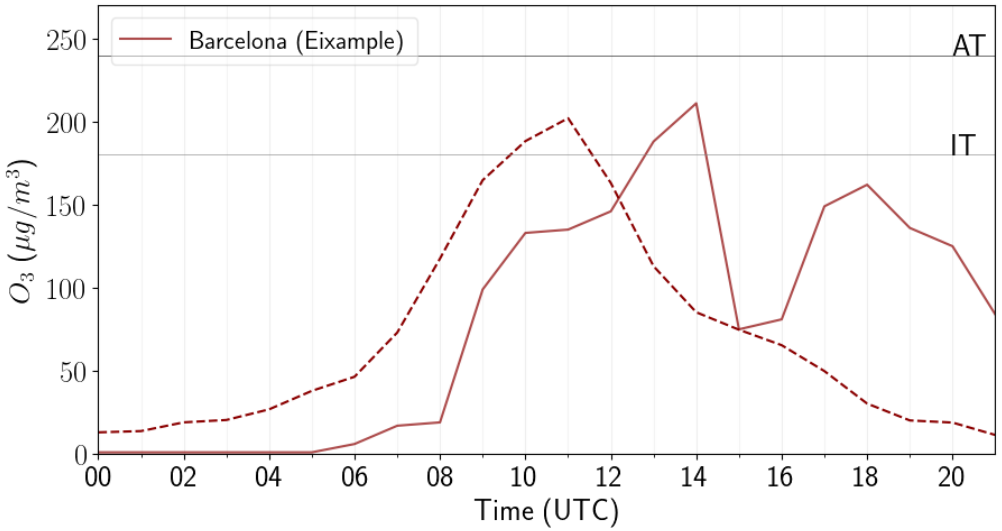
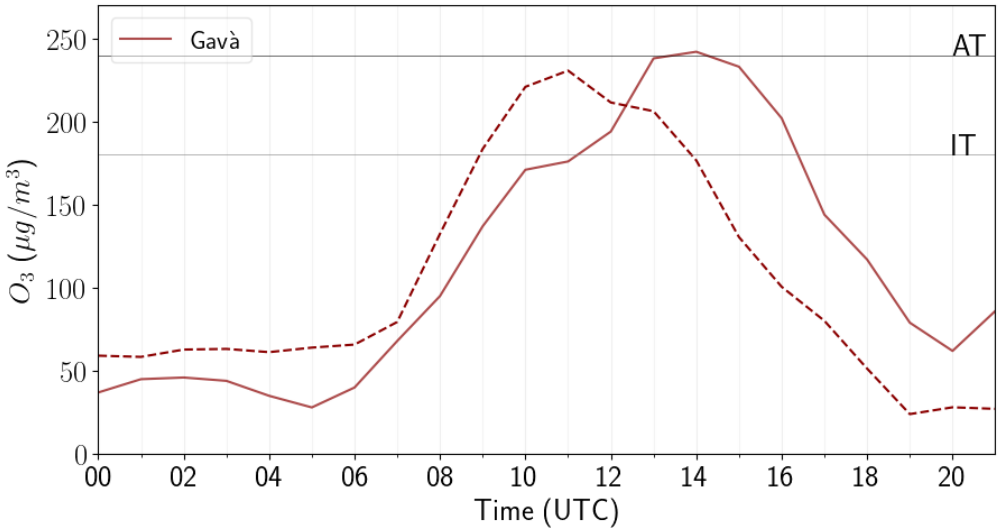
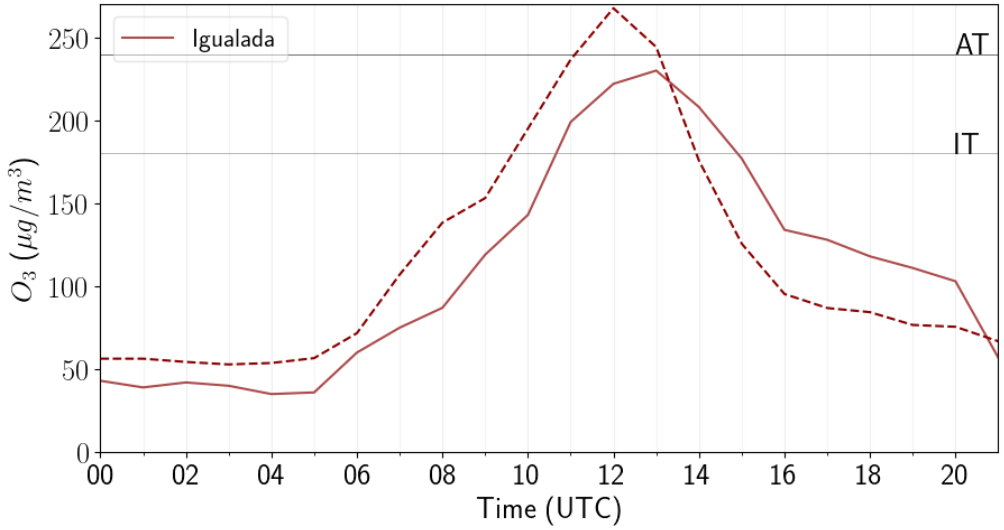
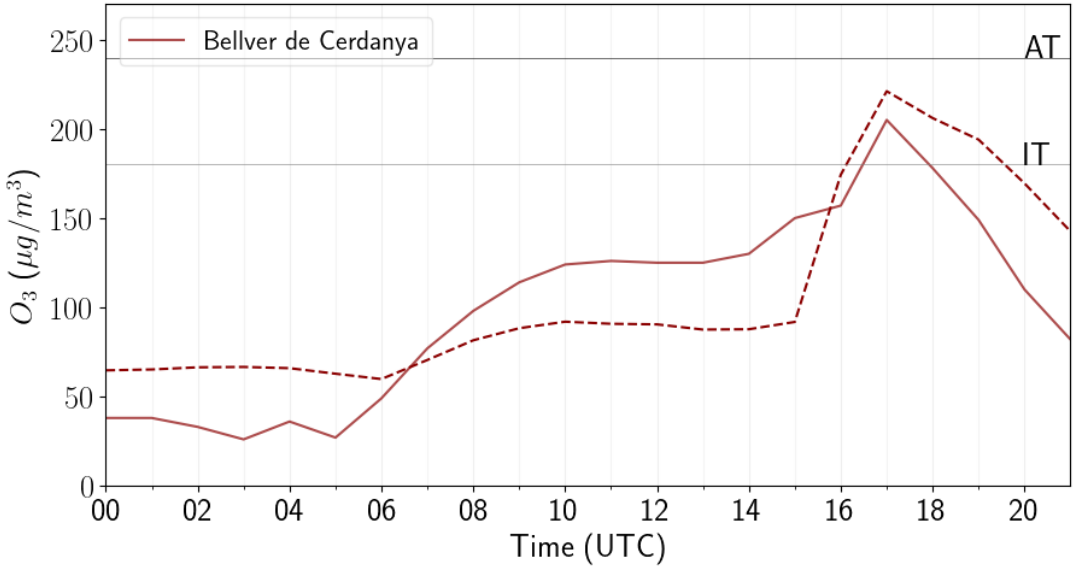
29 June 2019

Observation
Model









Spatial analysis: observations vs model

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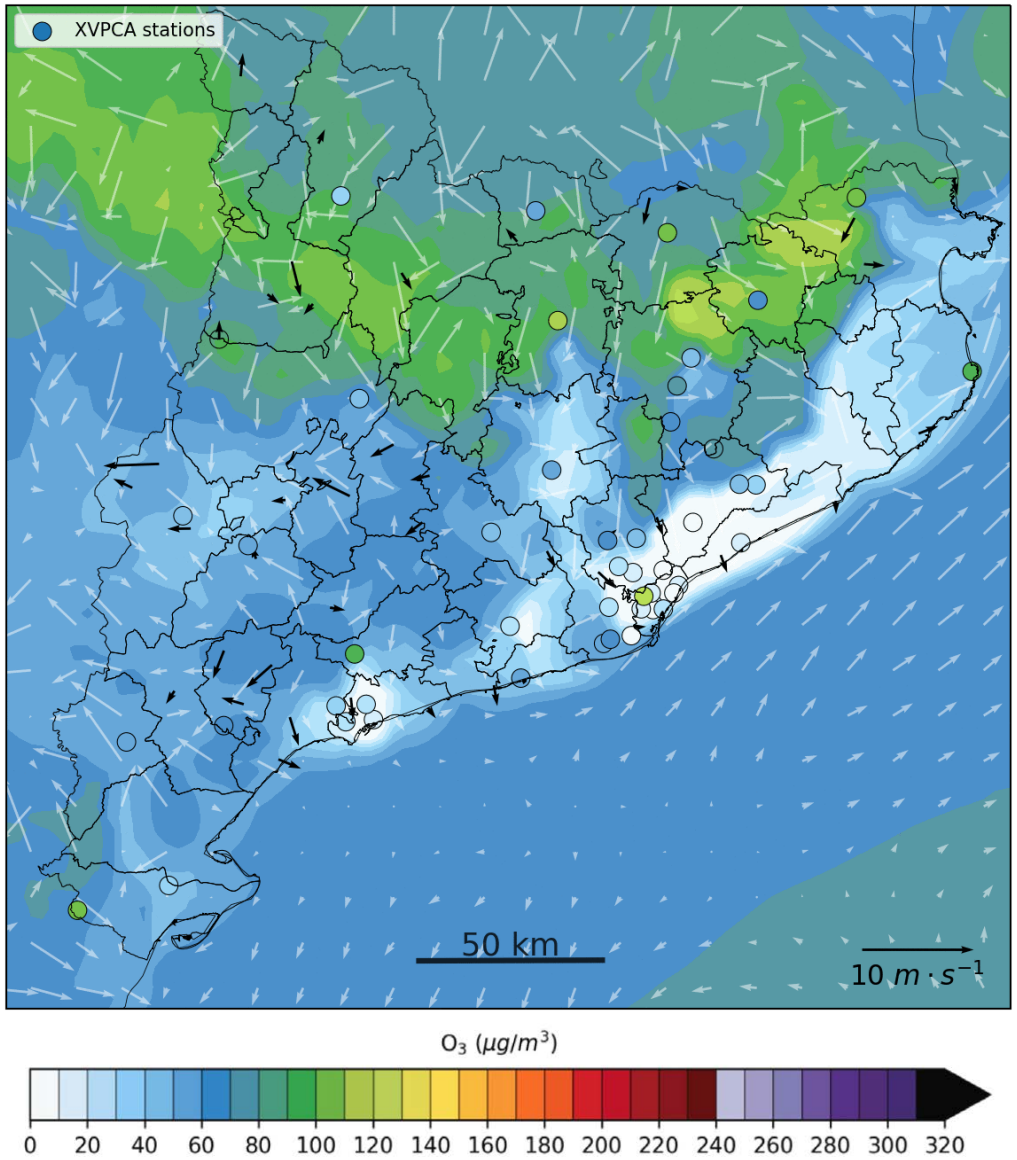
28 June 2019

Animation



Shaded colors: ozone concentration forecasts
Colored circles: ozone concentration stations
White arrows: 10-m wind forecasts
Black arrows: 10-m wind stations

Spatial analysis: observations vs model

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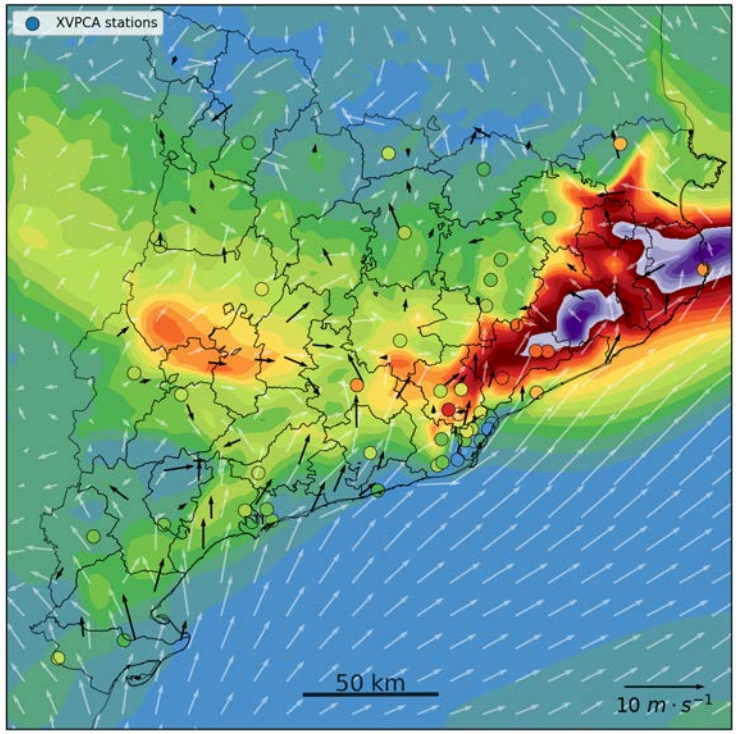
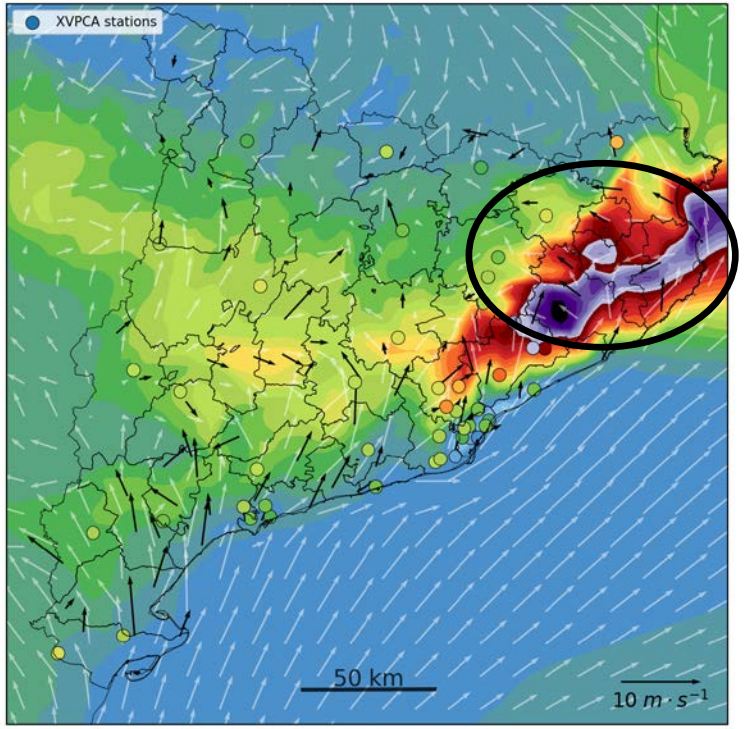
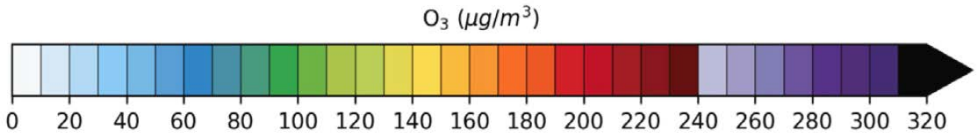
28 June 2019

11 UTC



13 UTC





- Altert threshold exceedance forecasted by the model in Montseny, Santa M. Palautordera, St Celoni
- The model establishes concentrations **> 300 μg/m³** in the north-east of Comarques de Girona (ZQA8) and l'Empordà (ZQA9), where there are no stations to compare

Spatial analysis: observations vs model

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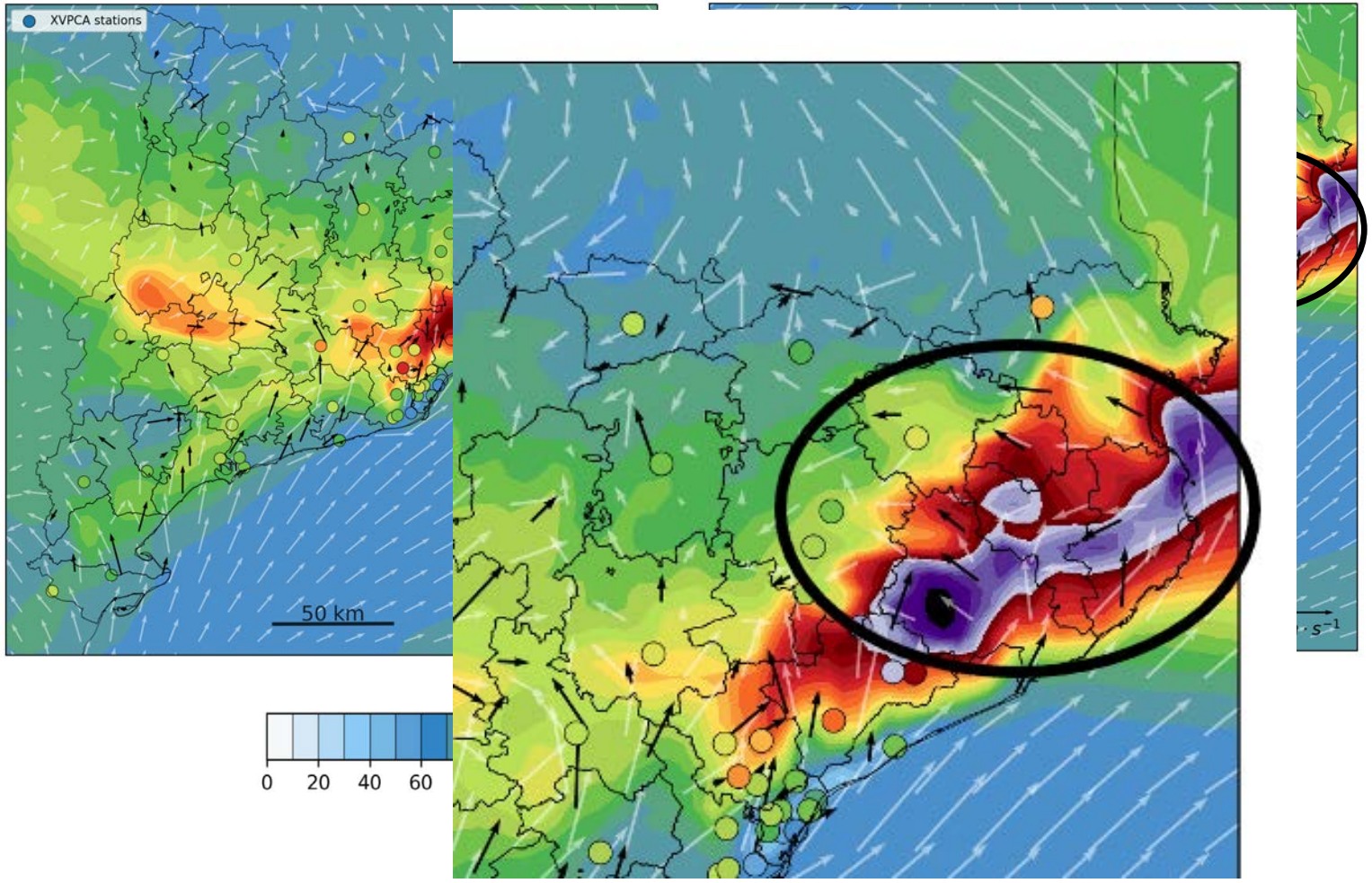
28 June 2019

11 UTC

13 UTC



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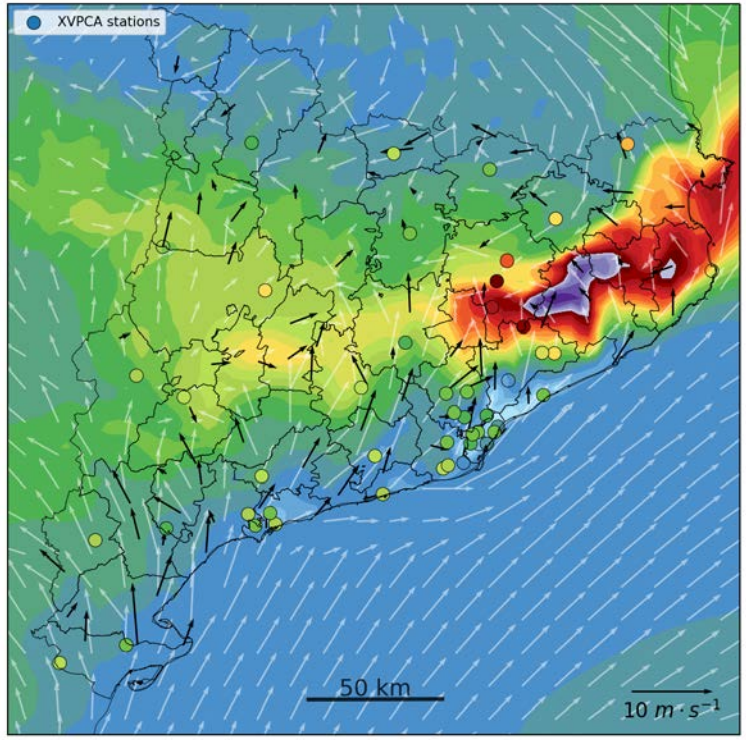
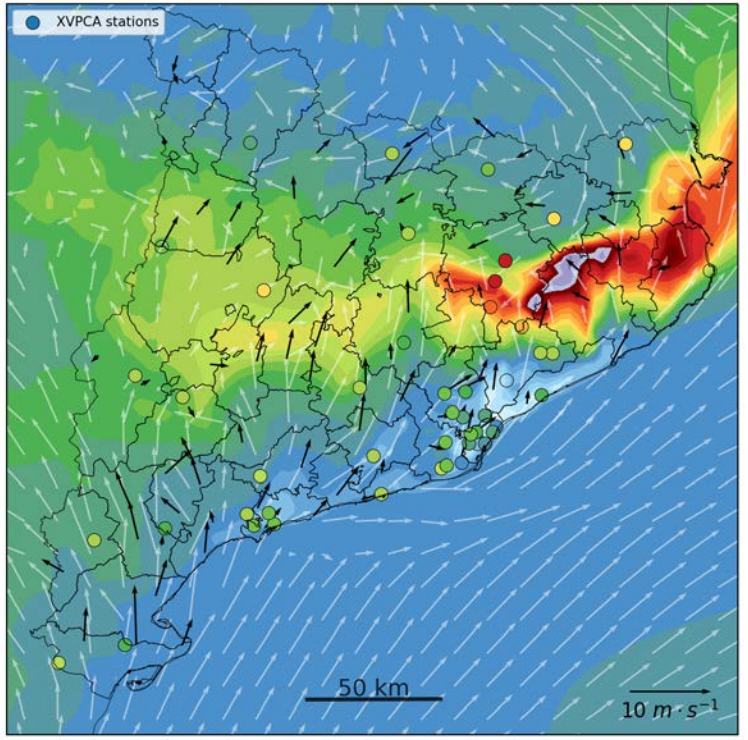
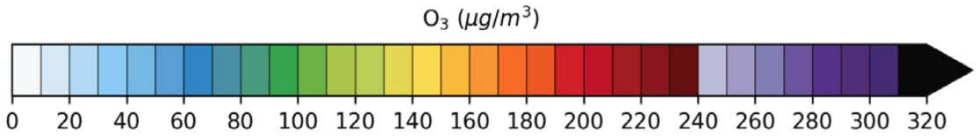
28 June 2019

15 UTC



16 UTC





- Altert threshold exceedance forecasted by the model in Montseny, Santa M. Palautordera, St Celoni
- The model establishes concentrations **> 300 μg/m³** in the north-east of Comarques de Girona (ZQA8) and l'Empordà (ZQA9), where there are no stations to compare
- High concentrations around ZQA8 and ZQA9 are maintained during 3-4 hours
- Around ZQA6 (Plana de Vic) -> information threshold exceedance

Spatial analysis: observations vs model

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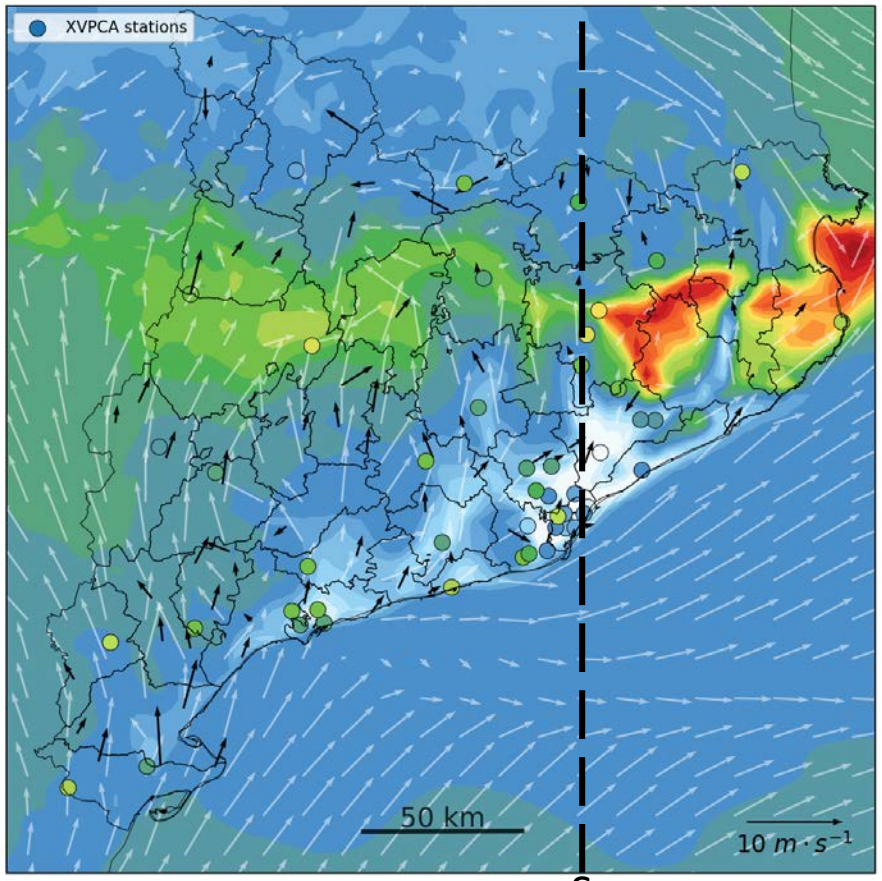
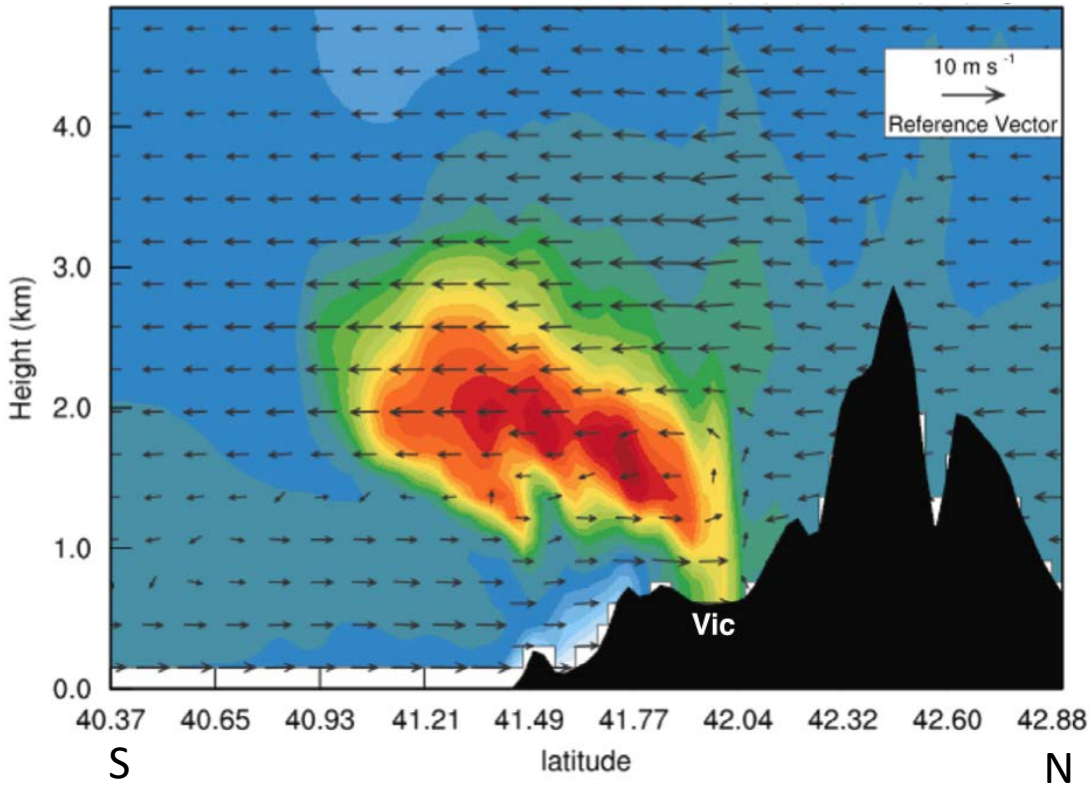
28 Juny 2019

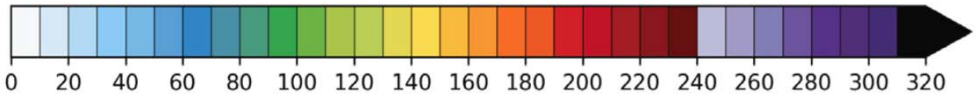
- Recirculation returning ozone to the coast at elevated layers -> contribution to episode of 29 June
- Convergence between sea breeze and northern wind contribution to the upward motion

18 UTC



N-S transect 18 UTC





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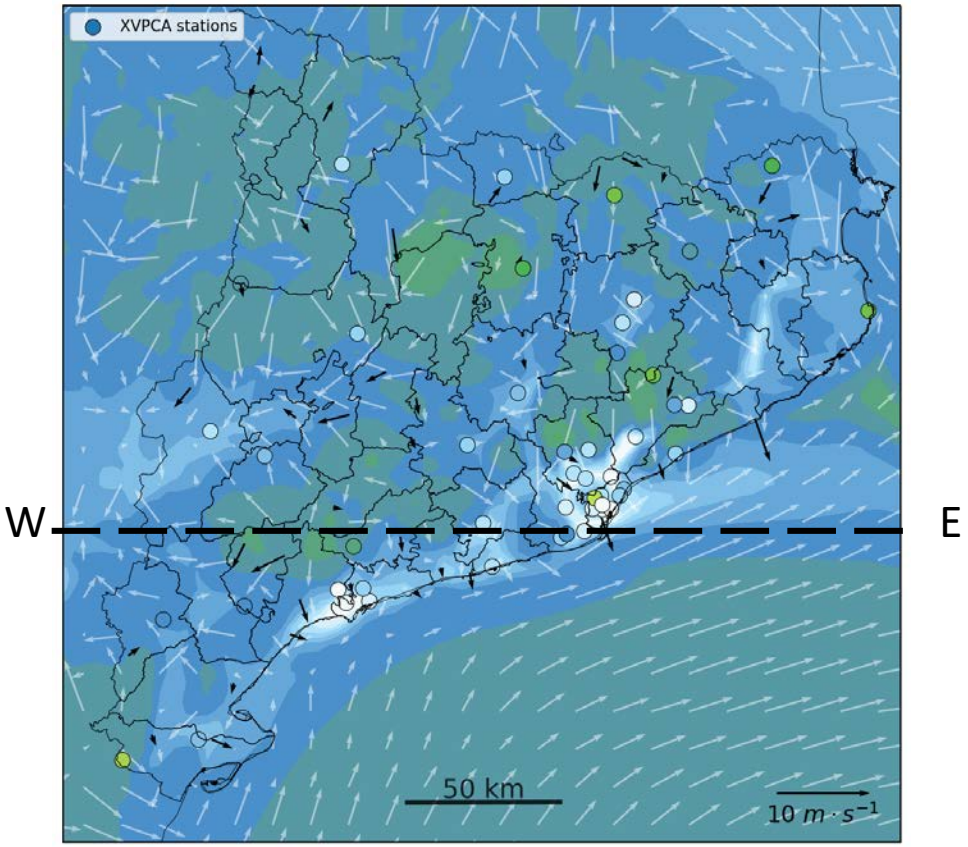
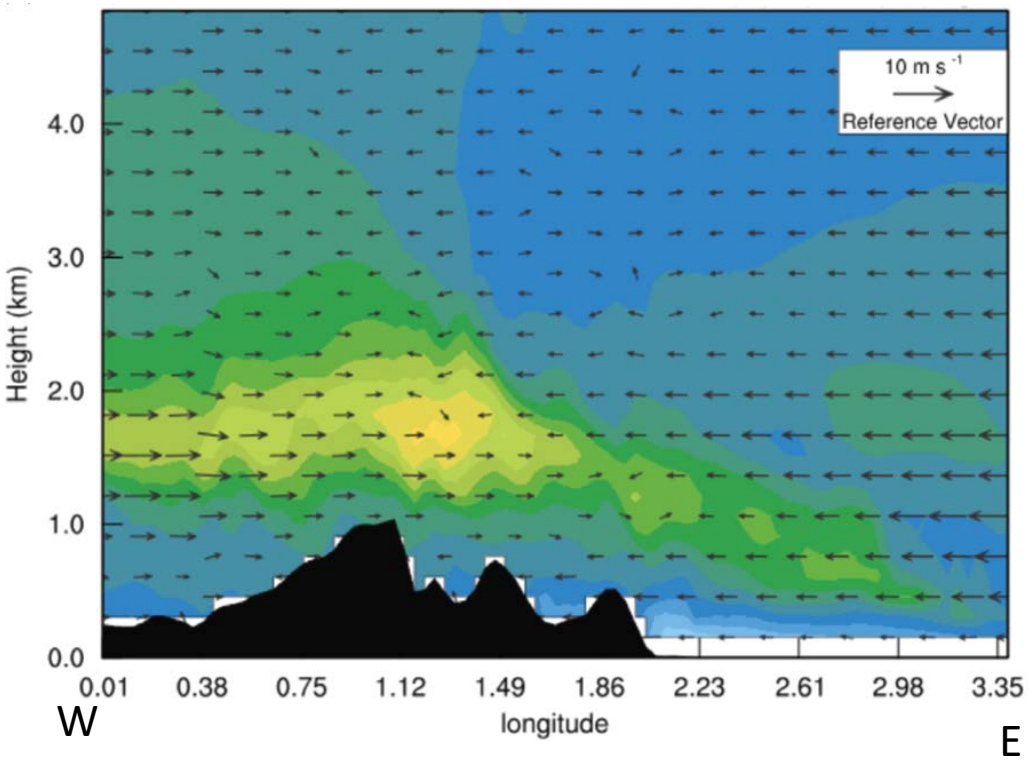
29 June 2019

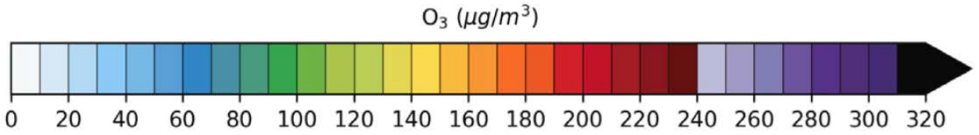
04 UTC



- Early morning 28-29 June: **accumulated** ozone at elevated layers above the sea
- **Ozone fumigation** when the mixed layer begins to grow

W-E transect 04 UTC





Spatial analysis: observations vs model

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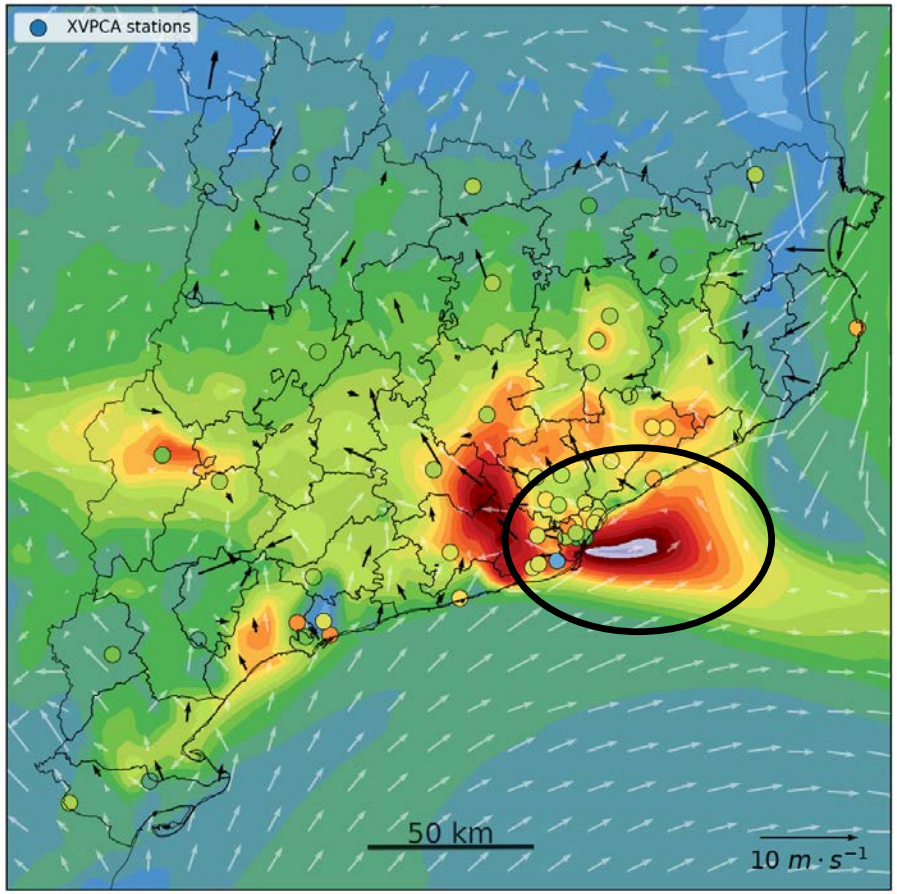
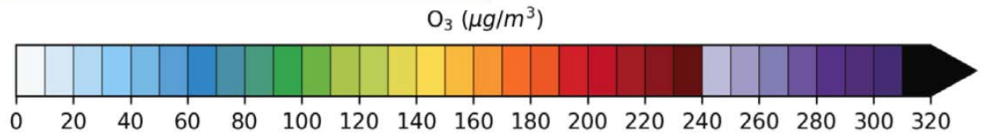
29 June 2019

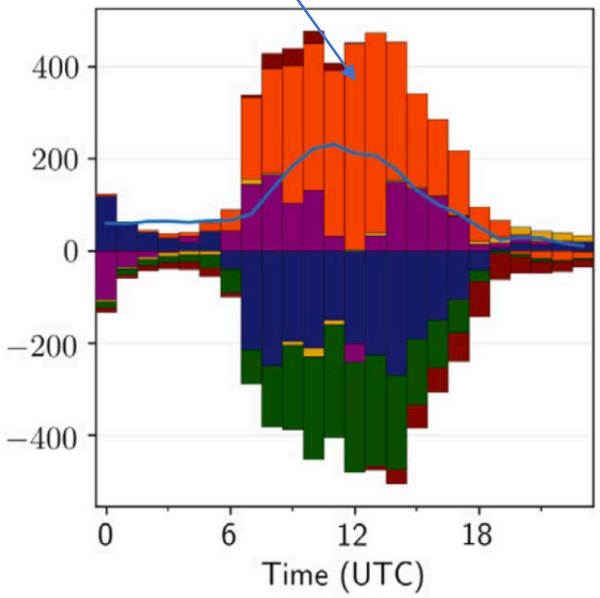
09 UTC





- Early morning 28-29 June: **accumulated** ozone at elevated layers above the sea
- **Ozone fumigation** when the mixed layer begins to grow

Gavà IPR analysis



Process analysis shows vertical difusion in a coastal station -> ozone fumigation (Jaén et al 2021)

Spatial analysis: observations vs model

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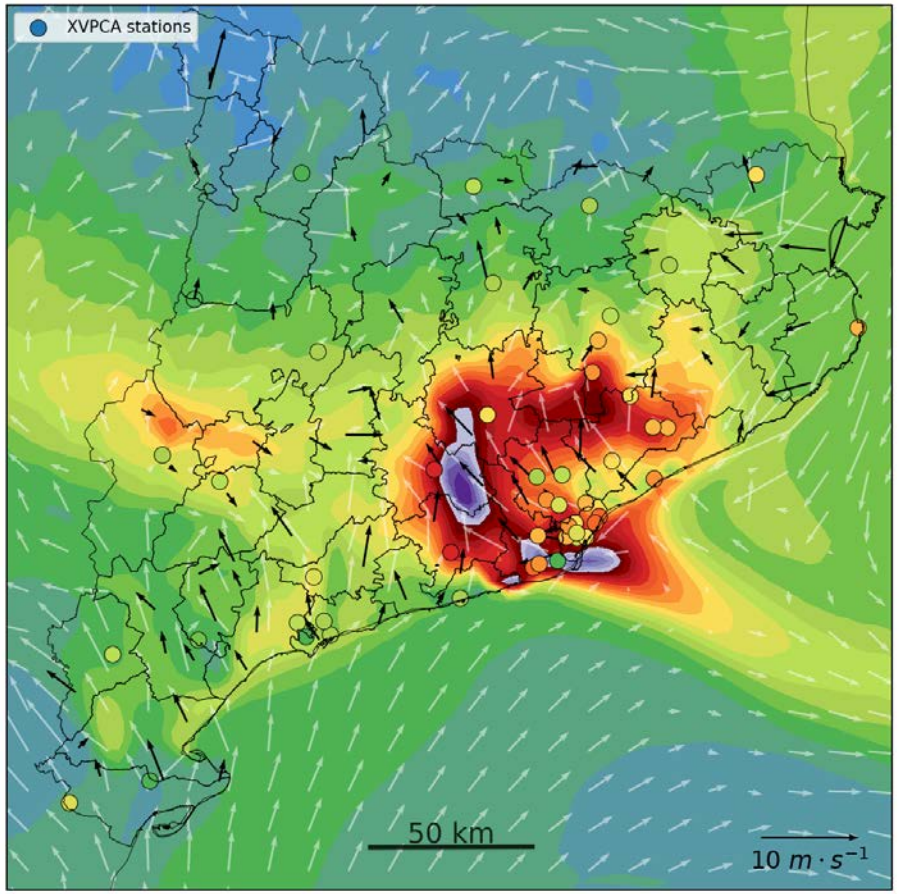
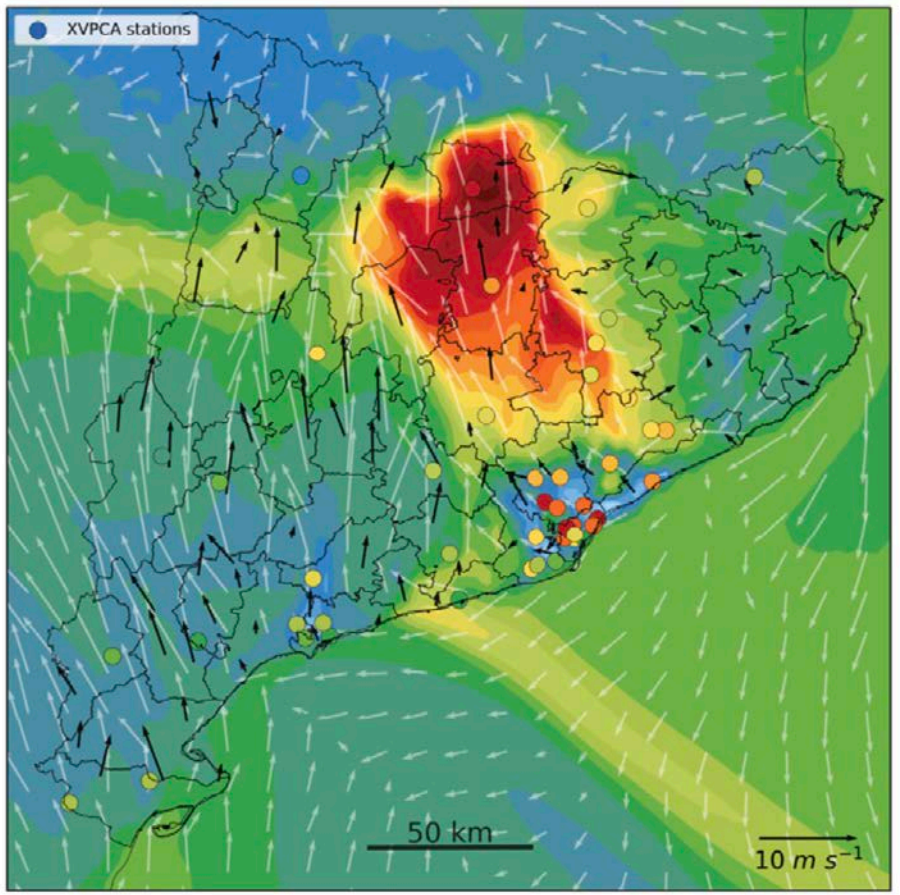
29 June 2019

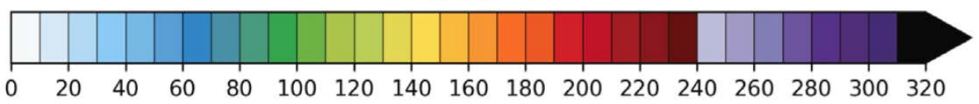
- High ozone concentrations in **Barcelona** and over the sea
- Ozone advection through the **Llobregat valley**

11 UTC



17 UTC





Trajectories analysis

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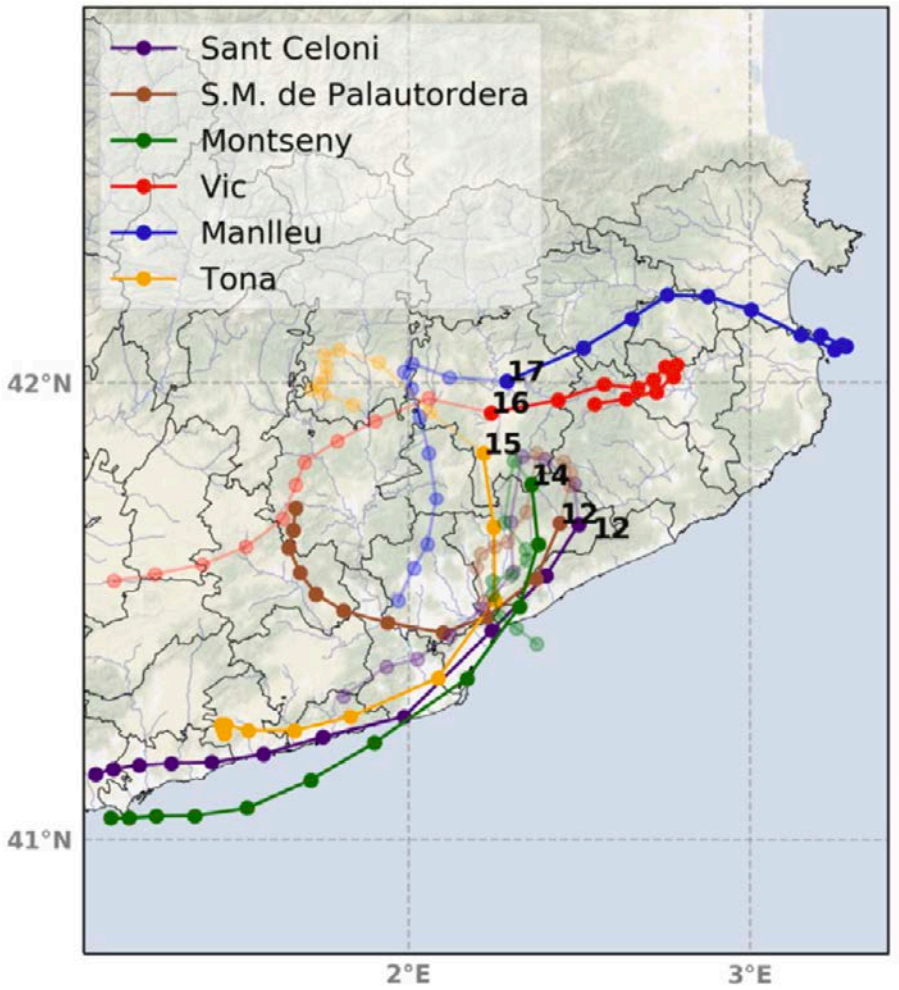
28 June 2019

HYSPLIT model using WRF data



- Backward trajectories 10h (solid color):

  Montseny, St Celoni, S.M. Palautordera and Tona: air mass coming from AMB and Tarragona

  Vic and Manlleu, parcels coming from east, recirculation and regional ozone transport

- Forward trajectories 10h (transparent color):

  Ozone return to the coast and AMB

Trajectories analysis

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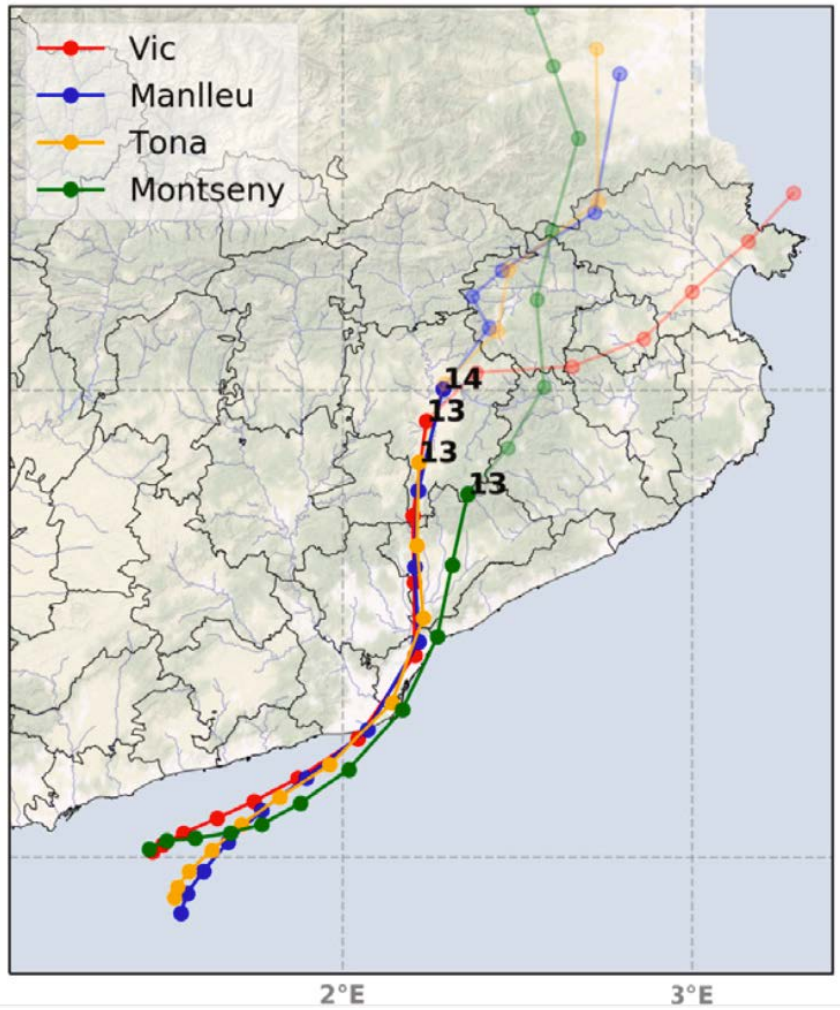
23 July 2019

HYSPLIT model using WRF data



- Backward trajectories 10h (solid color):

  Air mass coming from AMB and sea coast in front of Tarragona

- Forward trajectories 10h (transparent color):

  To the north →no ozone return to the coast

Conclusions

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- 2019: Exceptional ozone exceedances:
  28/06: 4h Alert threshold, 20h Information threshold
  29/06: 1h Alert threshold, 49h Information threshold
  23/07: 1h Alert threshold, 10h Information threshold

- Heat wave: high temperatures and strong solar radiation -> increase ozone concentrations

- Sea breeze circulation: 28 June: advection through Besòs-Congost valleys and Comarques de Girona
  Night 28-29: recirculation through the coast -> ozone accumulation
  29 June: advection through vall del Llobregat
  23 July: no recirculation

- The model tends to overestimate ozone peaks and underestimate in the rest of hours.

- The model estimates very high ozone concentrations > 300 $\mu g/m^3$ in the north-east of Catalonia (Comarques de Girona) where no measurements are available.

- There is a strong relationship between ozone levels and NOx levels, following the sensitivity regimes (28 June high NO_x concentrations in AMB, 29 June low NO_x concentrations)

- The analysis gives tools and clues to mitigate future episodes