Bases científico técnicas para la mejora de la calidad del aire en España

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Modelización de ozono troposférico para evaluar la eficacia de medidas sobre emisión de precursores

María Teresa Pay, Oriol Jorba, Marc Guevara, Miriam Olid, Carles Tena, Dene Bowdalo, Hervé Petetin, Vanessa Nogueira Dos Santos and Carlos Pérez García-Pando

Earth Sciences Department – Atmospheric Composition Group

Colaboradores externos:

X. Querol (CSIC), S. Napelenok (U.S. EPA), G. Gangoiti (Uni. Vasc Country)

Valencia
13 junio 2019

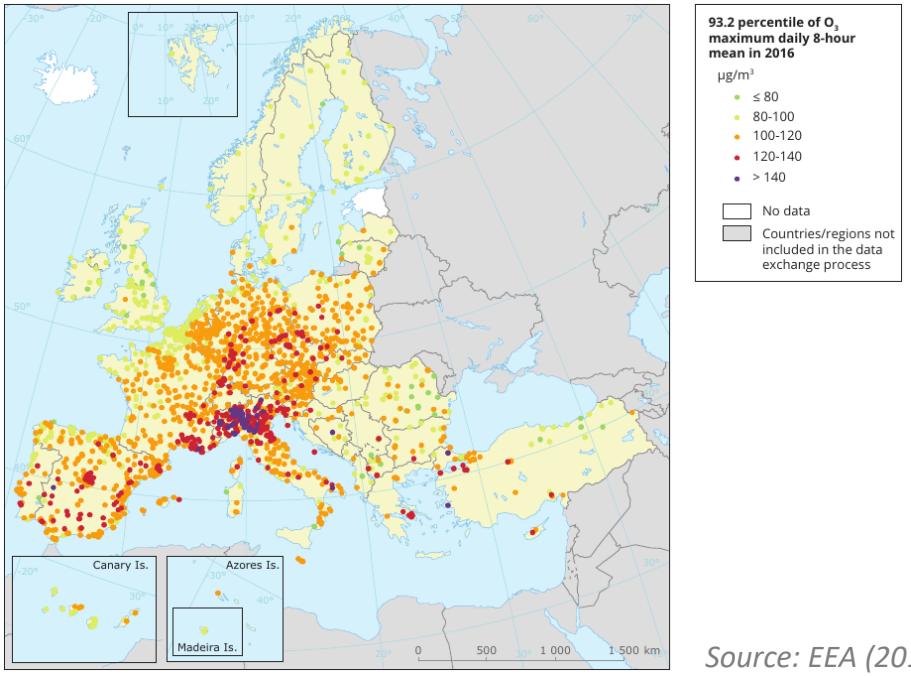
GENERALITAT VALENCIANA

GOBIERNO DE ESPAÑA MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

Fundación Naturgy

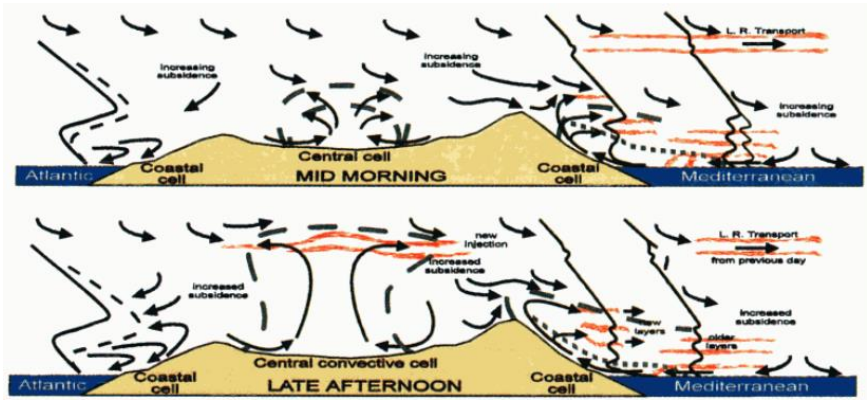
Background and motivation

O_3 concentration



Source: EEA (2018)

O_3 dynamic

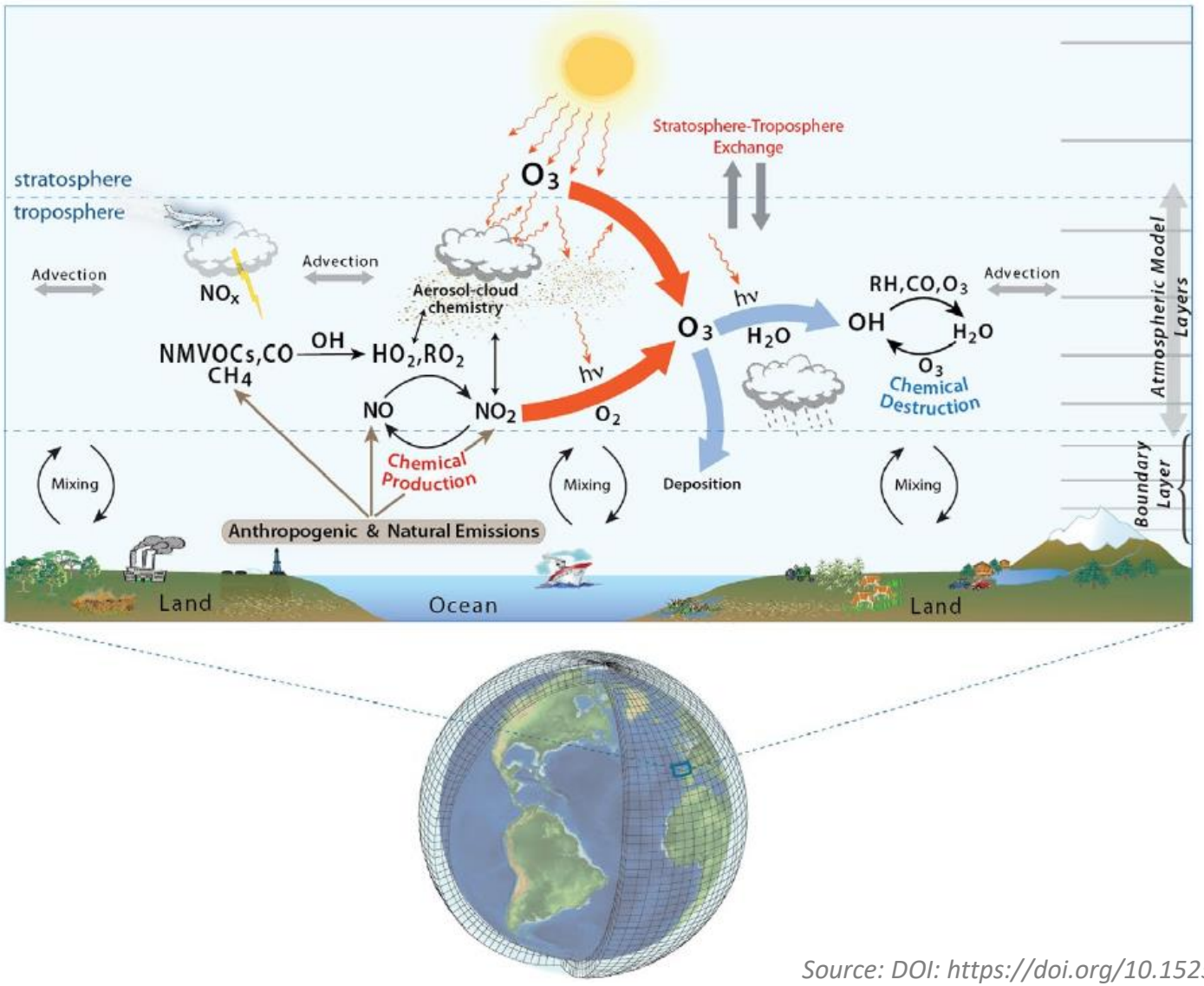


Sources: Millán et al., 1997, 2000, 2014; Gangoiti et al, 2001, 2002, 2006; Toll and Baldasano, 2000

Outline

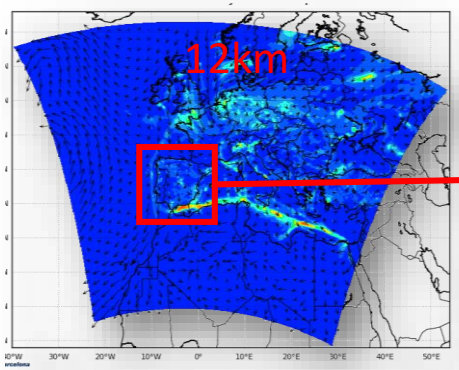
1. **How models forecast the O_3 episodes?** → BSC research work on AQ modelling.
2. **Who is responsible of the O_3 exceedances?** → First results on source apportionment.

1. How models forecast the O_3 episodes?

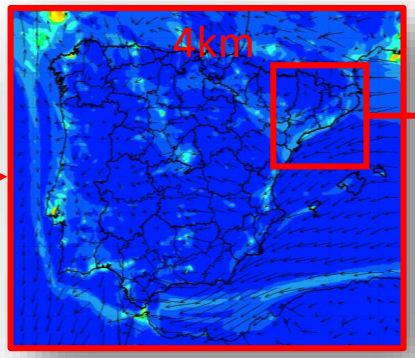


Source: DOI: https://doi.org/10.1525/elementa.265.f1

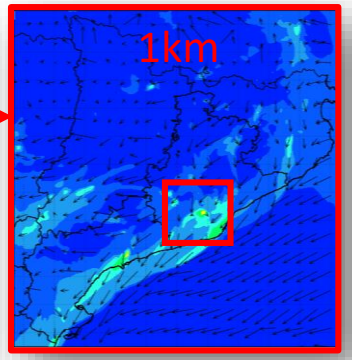
CALIdad del aire Operacional Para España (CALIOPE)



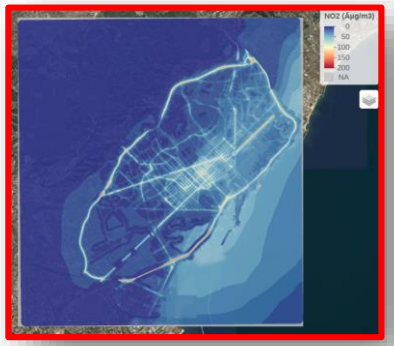
Pay et al. (2011; 2012 AE)



Baldasano et al. (2012 AE)

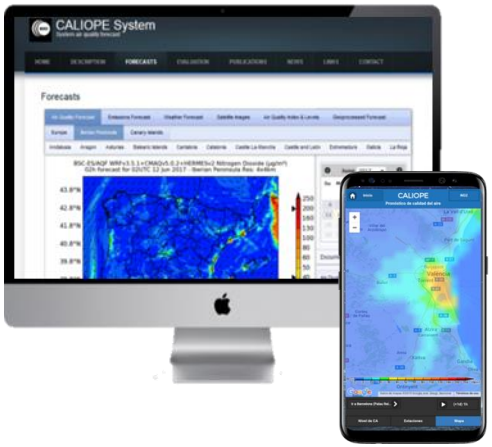


Pay et al. (2014 GMD)



Benavides et al. (2019 GMDD)

Citizen

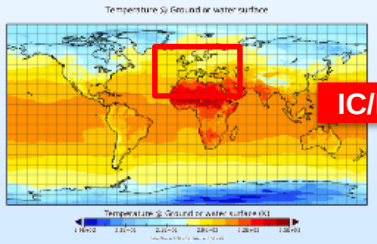


Administrations

The media

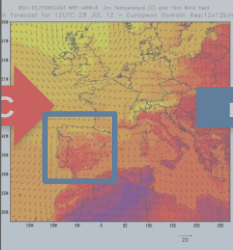
CALIOPE: main elements

METEOROLOGICAL FORECAST



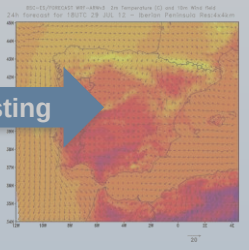
NCEP GLOBAL SIMULATIONS

IC/BC



WRF-ARWv3.5.2
12 km x 12 km

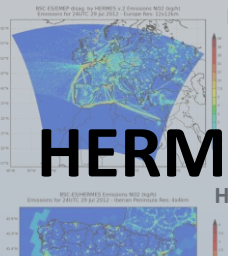
nesting



WRF-ARWv3.5.2
4 km x 4 km

Meteo. fields

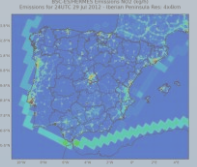
EMISSION FORECAST



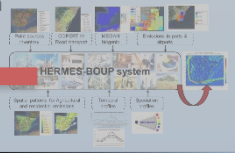
HERMESv2.0-DIS
12 km x 12 km

EMEP inventory

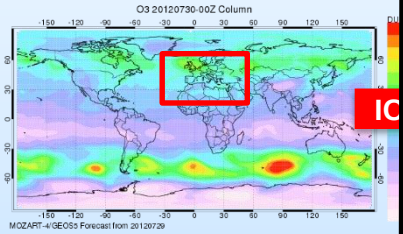
HERMESv3



HERMESv2.0-BOUP
4 km x 4 km



AIR QUALITY FORECAST

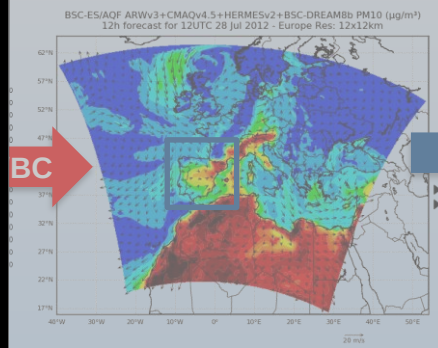


NCAR MOZART4
1.9 º x 2.5º

IC/BC

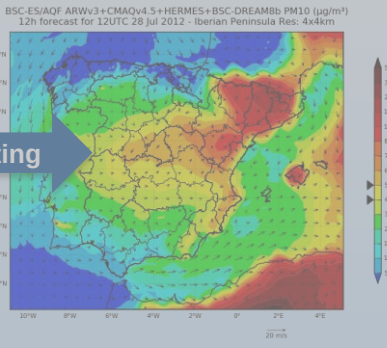
MONARCH

Meteo. fields



CMAQ v5.0.2
12 km x 12 km

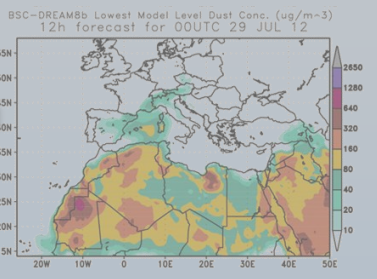
nesting



CMAQv5.0.2
4 km x 4 km

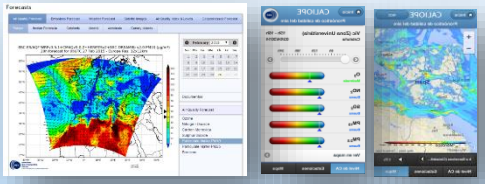
Emis. fields

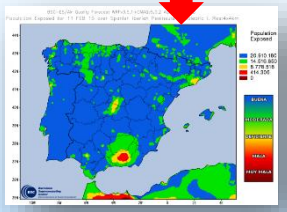
DESERT DUST FORECAST

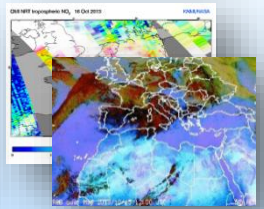


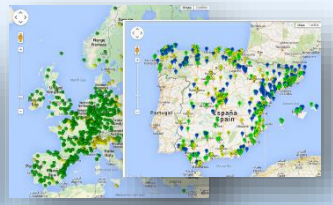
BSC-DREAM8b
50 km x 50 km

AIR QUALITY PRODUCTS



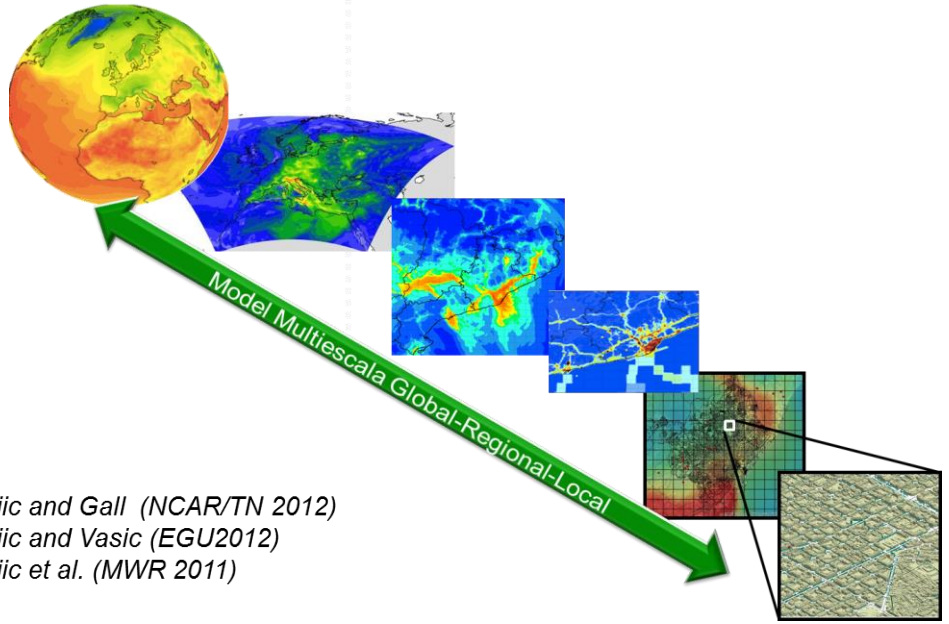


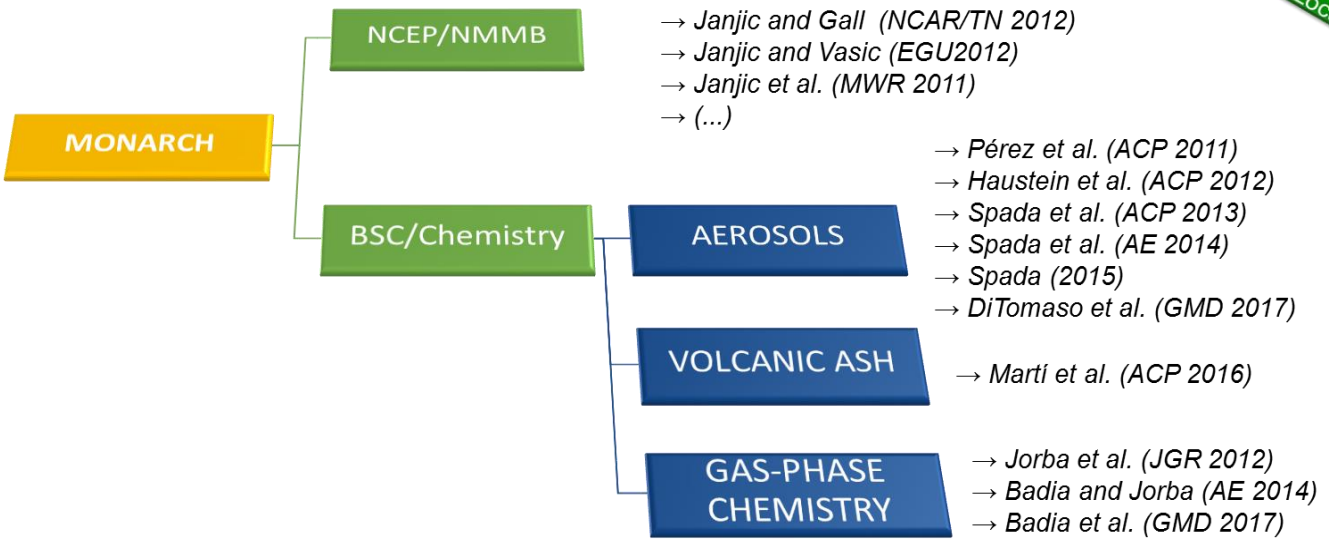




MONARCH: online weather-chemistry model

- Fully **on-line** coupling: weather-chemistry feedback processes
- In-house developed.
- **Multiscale**: global to regional (up to 1km) scales (nesting capabilities)
- **Data assimilation** system





Funding:

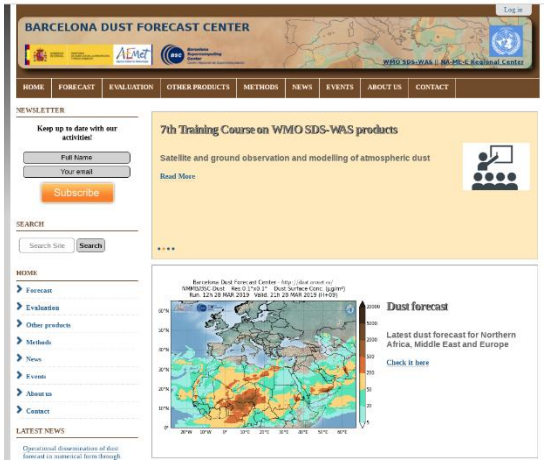
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

CGL2006-11879/CLI, CGL2008-02818/CLI, CGL2010-19652, CGL2013-46736-R1, CSD2007-0050, SEV-2011-00067, now with ERC-FRAGMENT

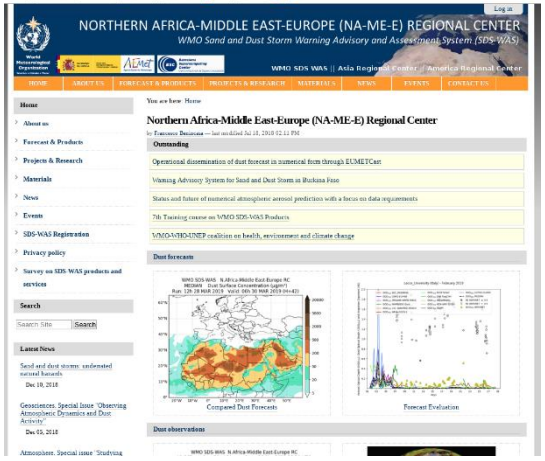
Mineral dust services

WMO Dust Centers

Barcelona Dust Forecast Center.
Unique specialized WMO Center for mineral dust prediction in Europe
http://dust.aemet.es
started in 2014 - **Operations**



SDS-WAS. North Africa, Middle East and Europe
Regional Center.
http://sds-was.aemet.es
started in 2010 – **Research**



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

World Meteorological Organization

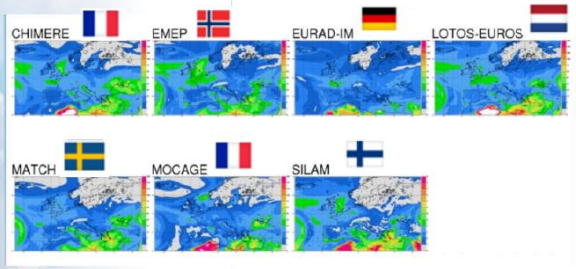
GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

AEMet
Agencia Estatal de Meteorología

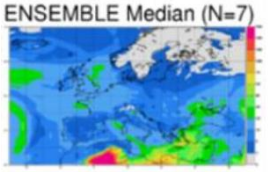
Copernicus Atmosphere Monitoring Service
Regional air quality (CAMS_50.II)

Inputs
Global products
Regional emissions
In situ observations

7 operational AQ models



1 ENSEMBLE model



How? Median of the individual results for each grid-cell
Why? Reliable, robust, performing

→ **to be used in priority**

Users

New operational AQ models

DEHM (AARHUS University)
GEM-AQ (IEP)

New candidates AQ models

MINNI (ENEA)
MONARCH (BSC)

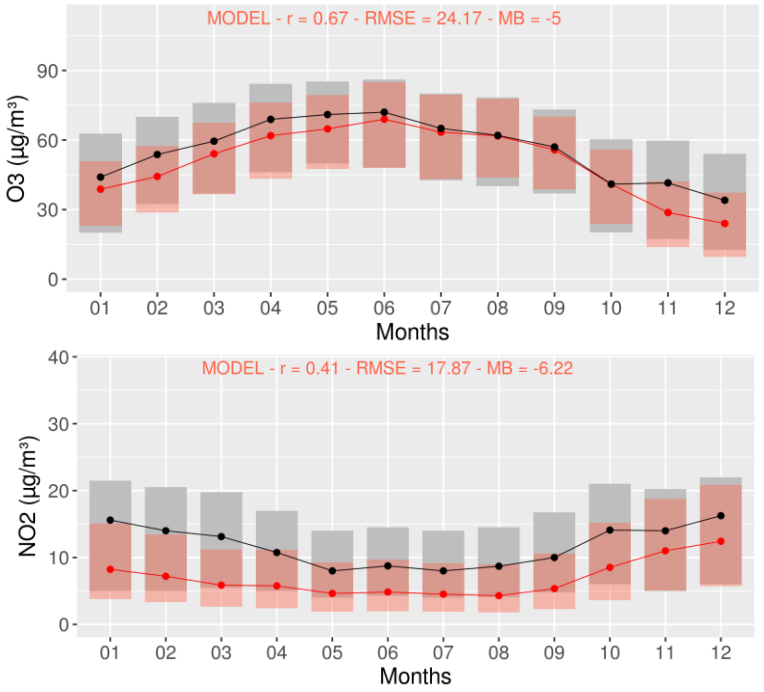
Products

- NRT Individual & Ensemble 4-Day Forecasts
- NRT Individual & Ensemble Analyses (DD-1)
- NRT Validation & Statistics products
- Reanalyses (2014-2017)

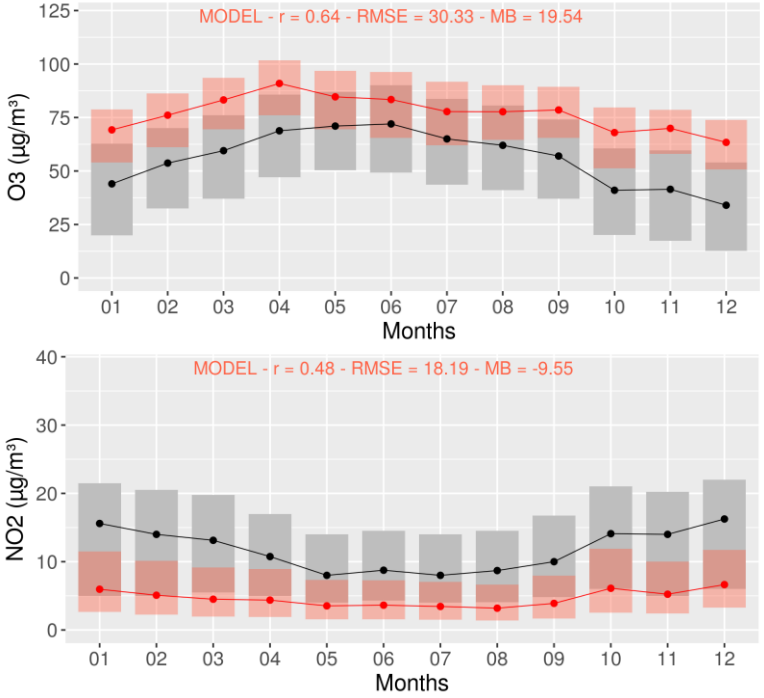
MONARCH vs CALIOPE: annual cycle

Period: full year 2015

MONARCH



CALIOPE (WRF-CMAQ)

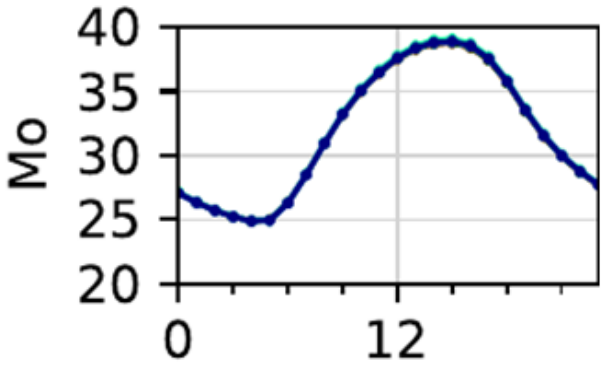


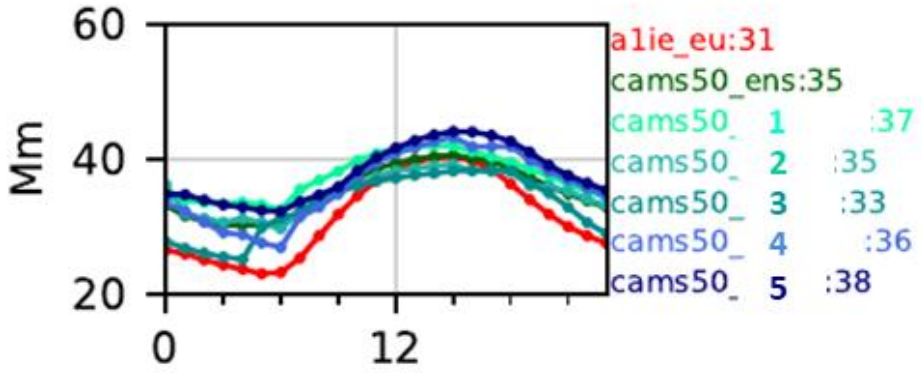
EIONET 2015 validated (rural, suburban, urban)

- 958 stations (O_3)
- 774 stations (NO_2)

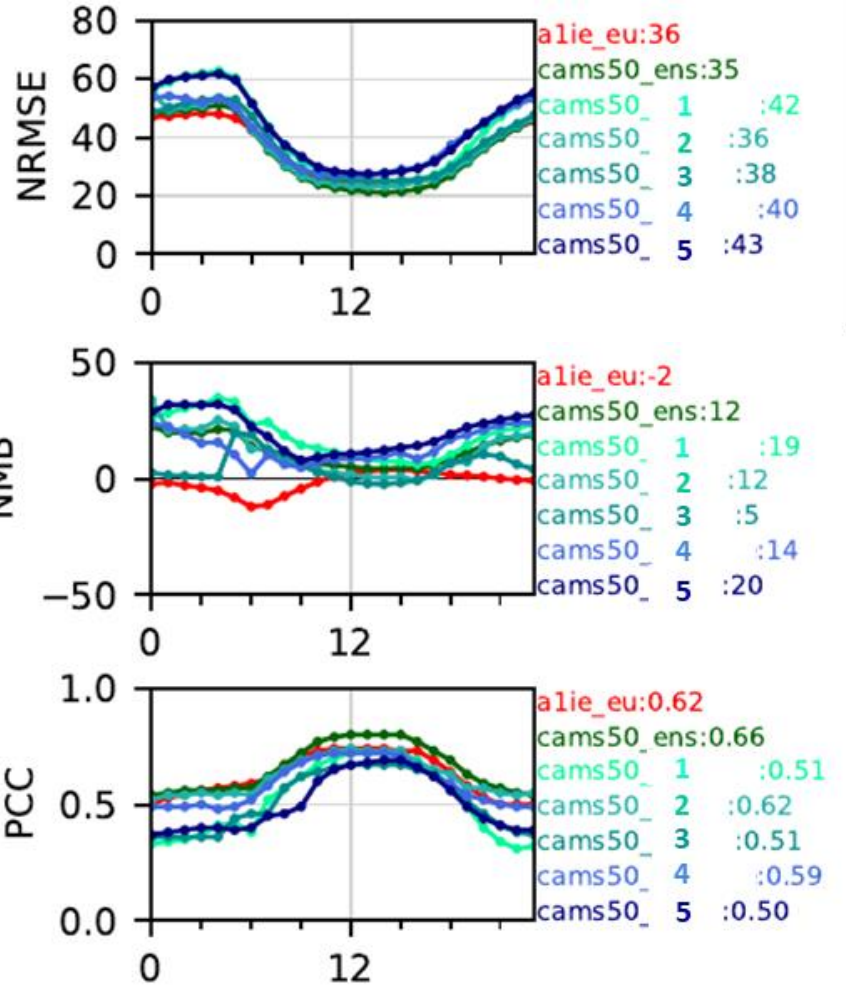
MONARCH vs CAMS: O_3

Period: 20160801-20160901



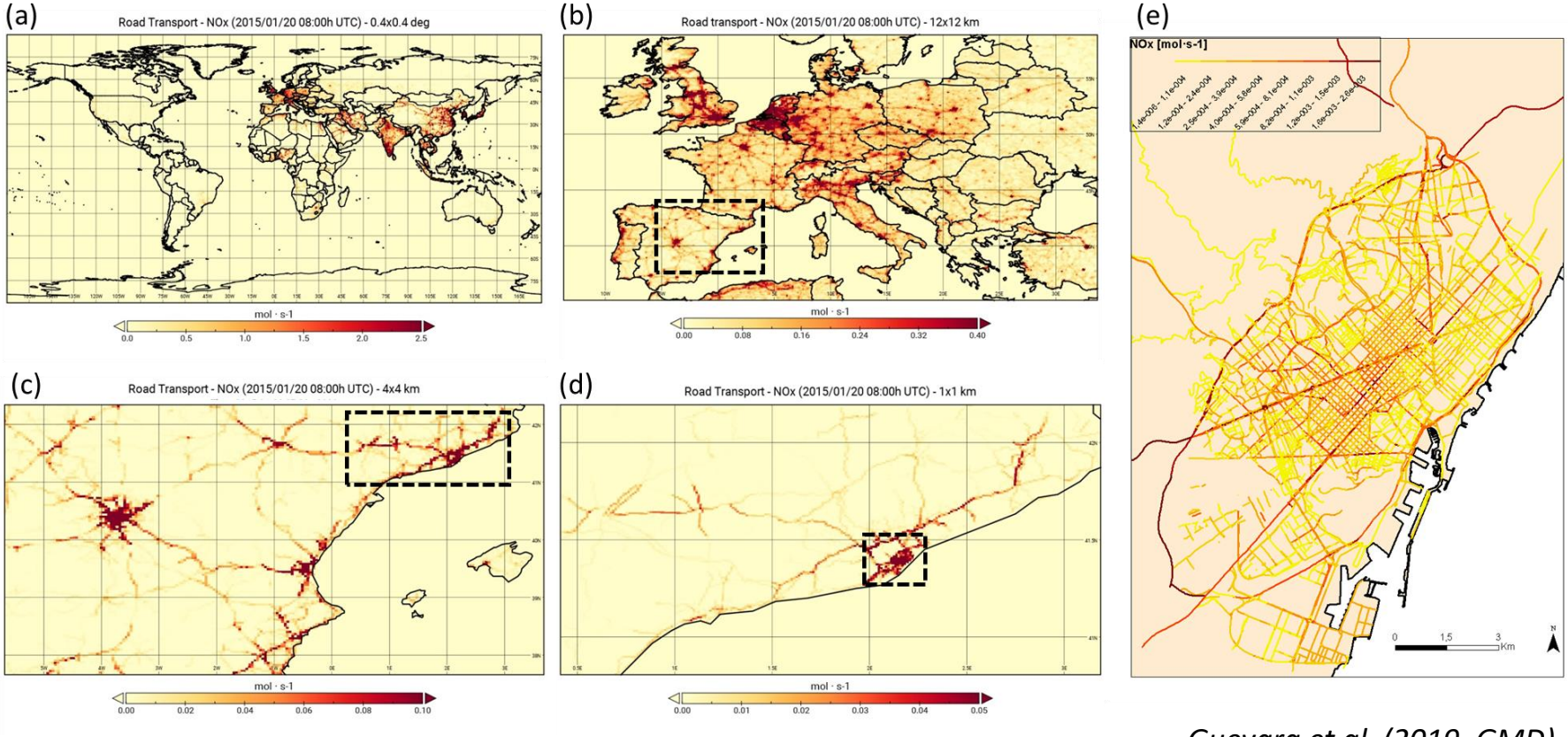


113 EBAS stations



HERMESv3

A **python-based, open source, parallel and multiscale** emission modelling framework that **processes and estimates gas and aerosol emissions** for use in atmospheric chemistry models.



Guevara et al. (2019, GMD)

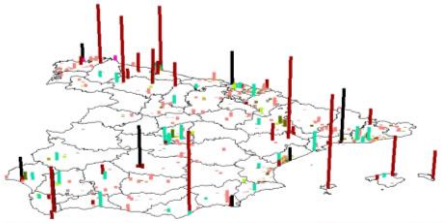
HERMESv3_BU: Bottom-up module

An **emission model** to estimate emissions at the source level (e.g. road link) combining state-of-the-art **bottom-up methods** with **local activity and emission factors**

Point Source

P

(x, y)

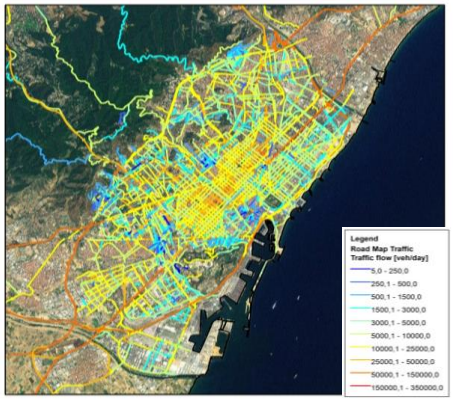


Line Source

S

a

$\{P_1, \ldots, P_n\}$

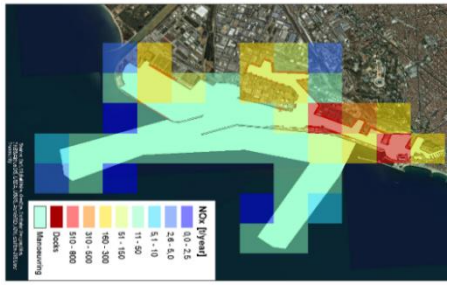


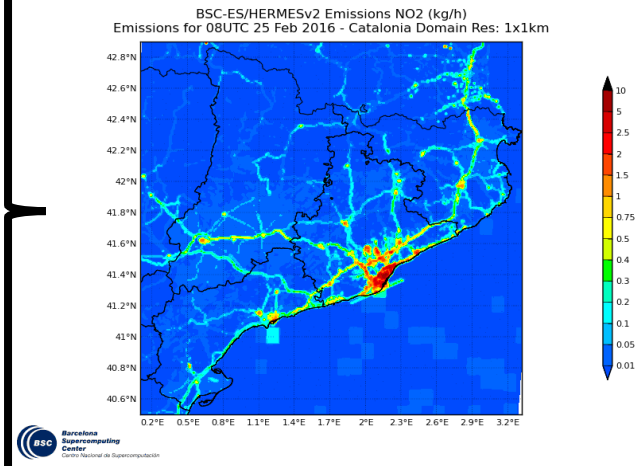
Area Source

F

A

$\{S_1, \ldots, S_n\}$





2. Who is responsible of the O_3 exceedances?

- Which are the economic activities responsible for high O_3? **(sectors)**
- Where do the precursors responsible for O_3 exceedances come from? **(regions)**

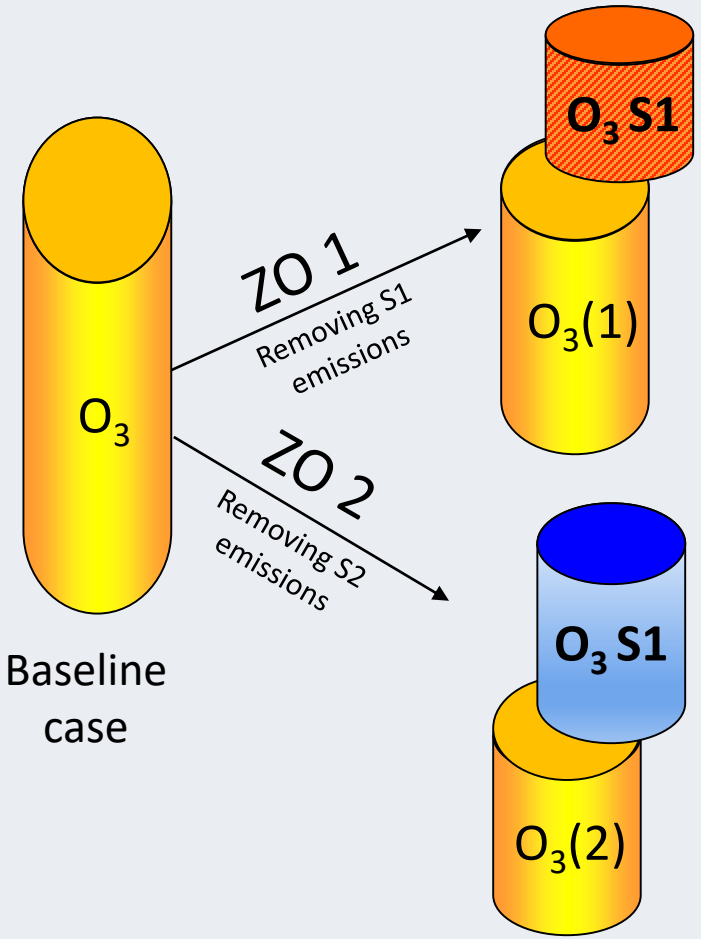
Unraveling the origin of the high surface O_3 concentrations in Spain is a previous step to design mitigation strategies:

- Quantifying the O_3 contribution from:
  - the **NO_x/VOC emission sectors within Spain.**
  - the **external contribution** (O_3 produced outside Spain).
- Using the **Integrated Source Apportionment Method** together with a **high detailed emission model**.

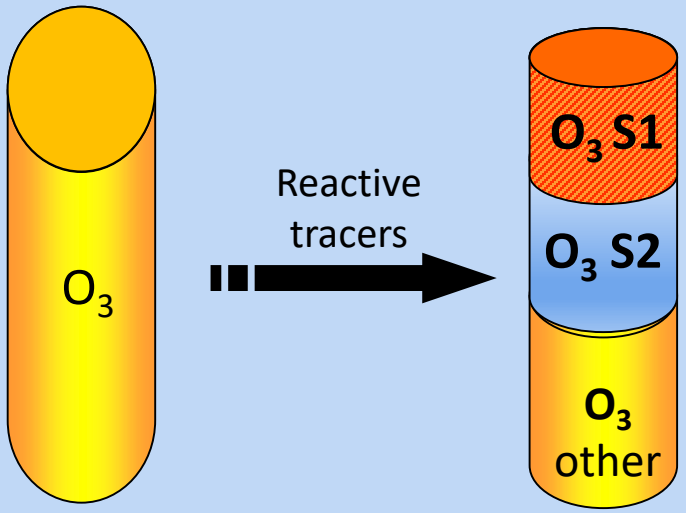
Source apportionment modelling

Emissions are critical

Zero-Out (ZO)



Tagging



Advantages

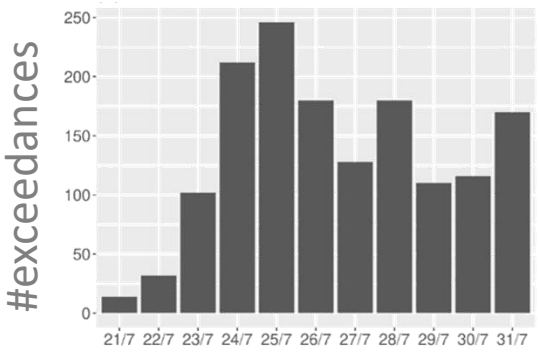
- Time saving (one simulation)
- Mass consistency
- Real atmospheric conditions
- Fully traceable

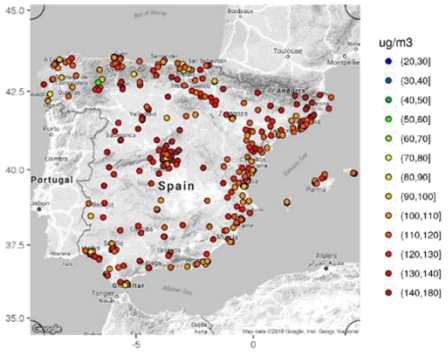
CALIOPE system (CMAQ-ISAM)

O_3 source apportionment in the Iberian Peninsula

Pay et al., 2019. Atmos. Chem. Phys. 19, 5467–5494

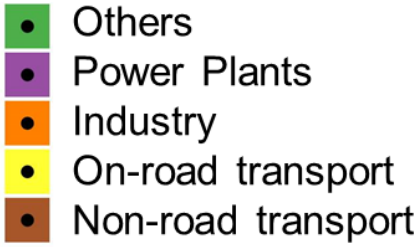
O_3 episode: 21-31 July 2012

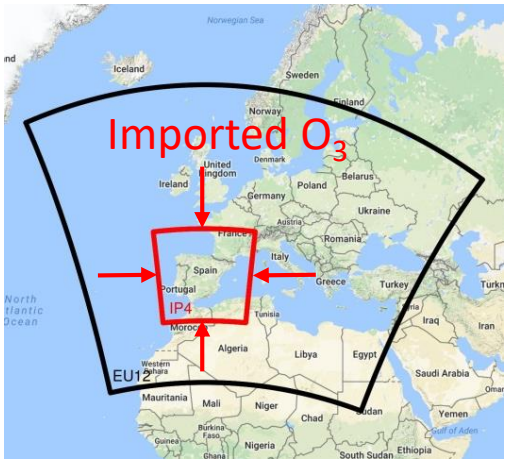




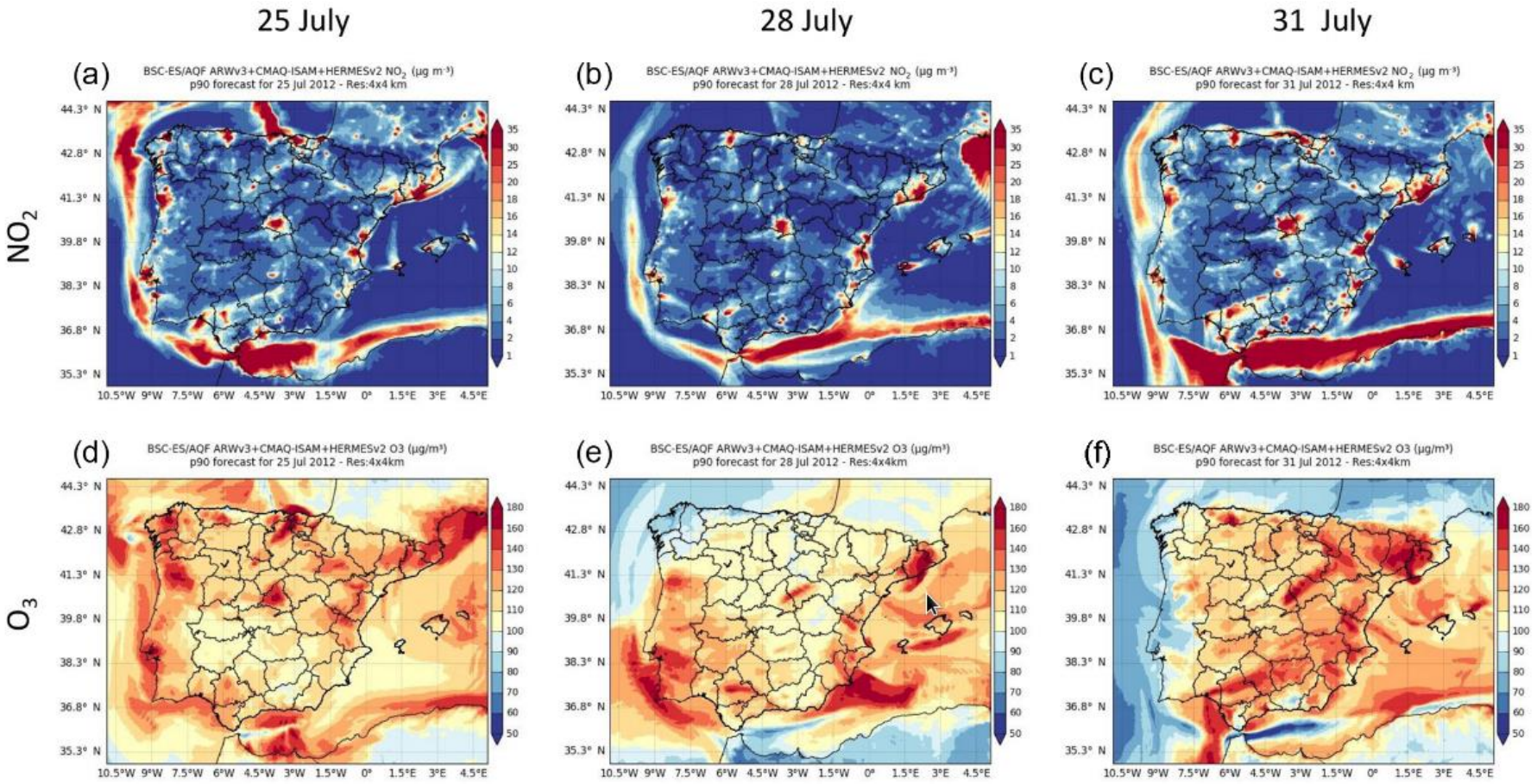
Contributions: anthropogenic emissions + imported O_3

Sectors accounting 92% of the total NO_x





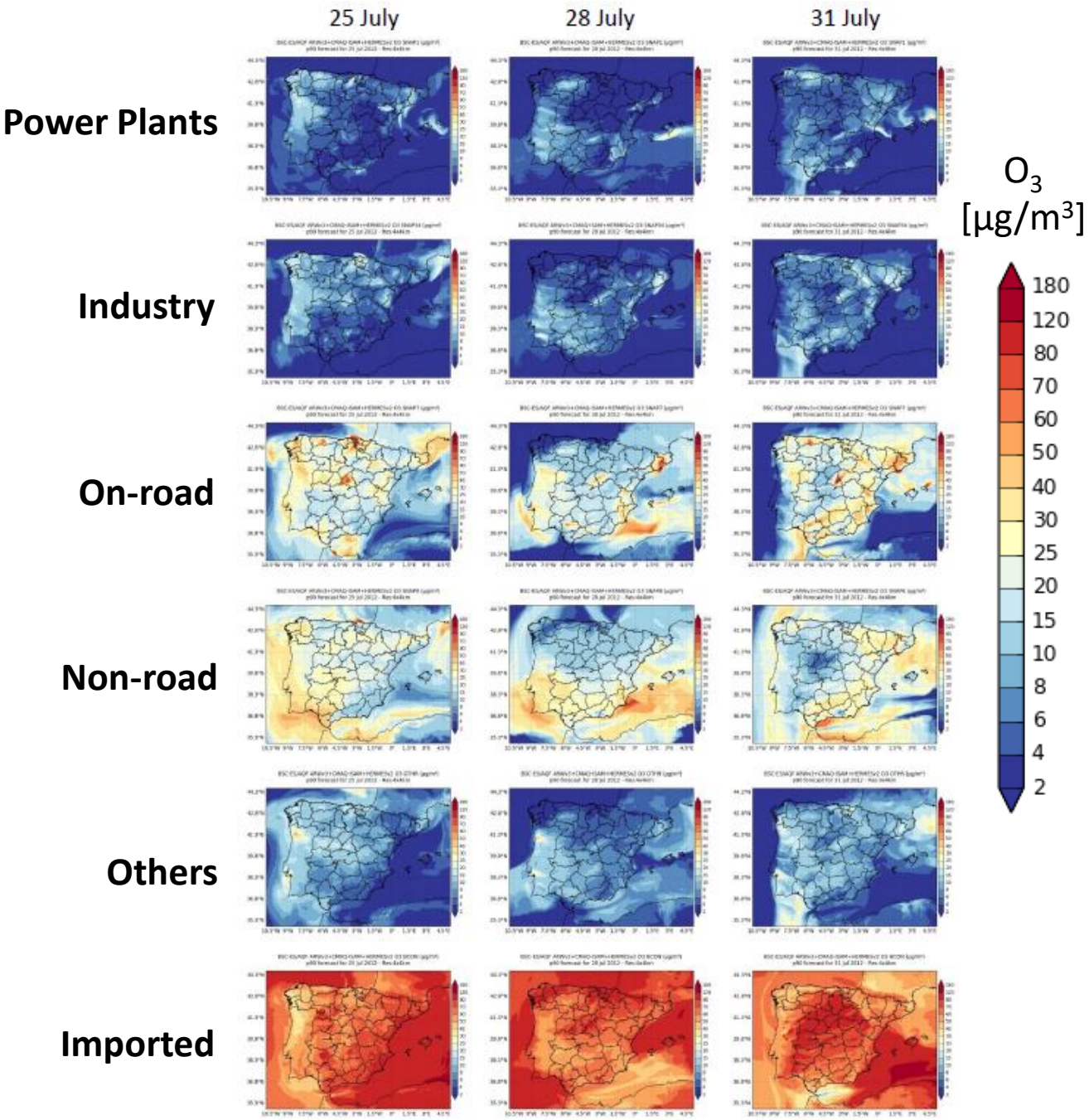
NO_2 and O_3 concentrations



ITL **NWadv** **ITL**

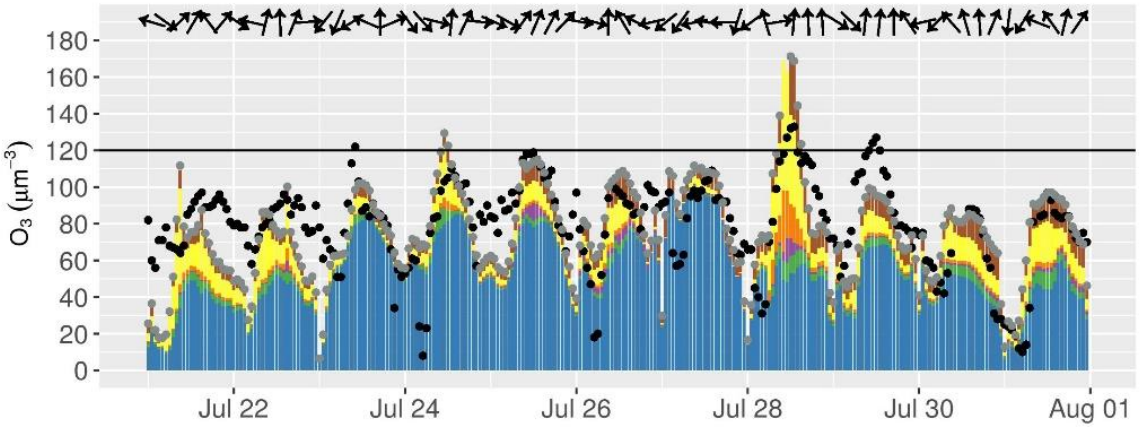
Iberian Thermal Low (ITL) and **NW advection (NWadv)** represent 44% of the days in the IP both taking place in summer (*Valverde et al., 2015*)

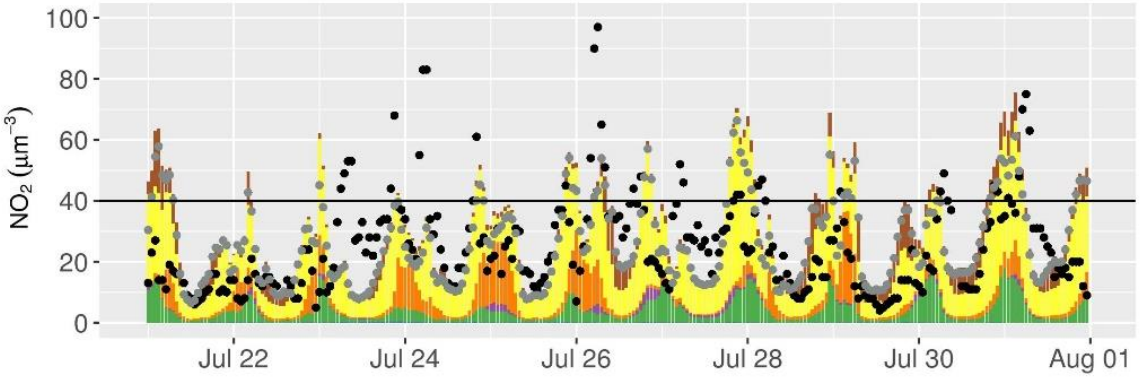
O_3 contributions
(p90 concentrations)



O_3 contribution in urban areas

(3) Urban station – Palau Reial (Barcelona)

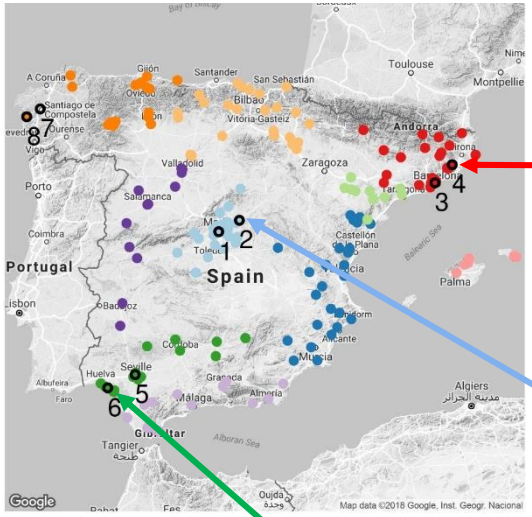




- obs
- cmaq

- Imported
- Others
- Power Plants
- Industry
- On-road transport
- Non-road transport

O_3 contribution in background areas



(4) Montseny

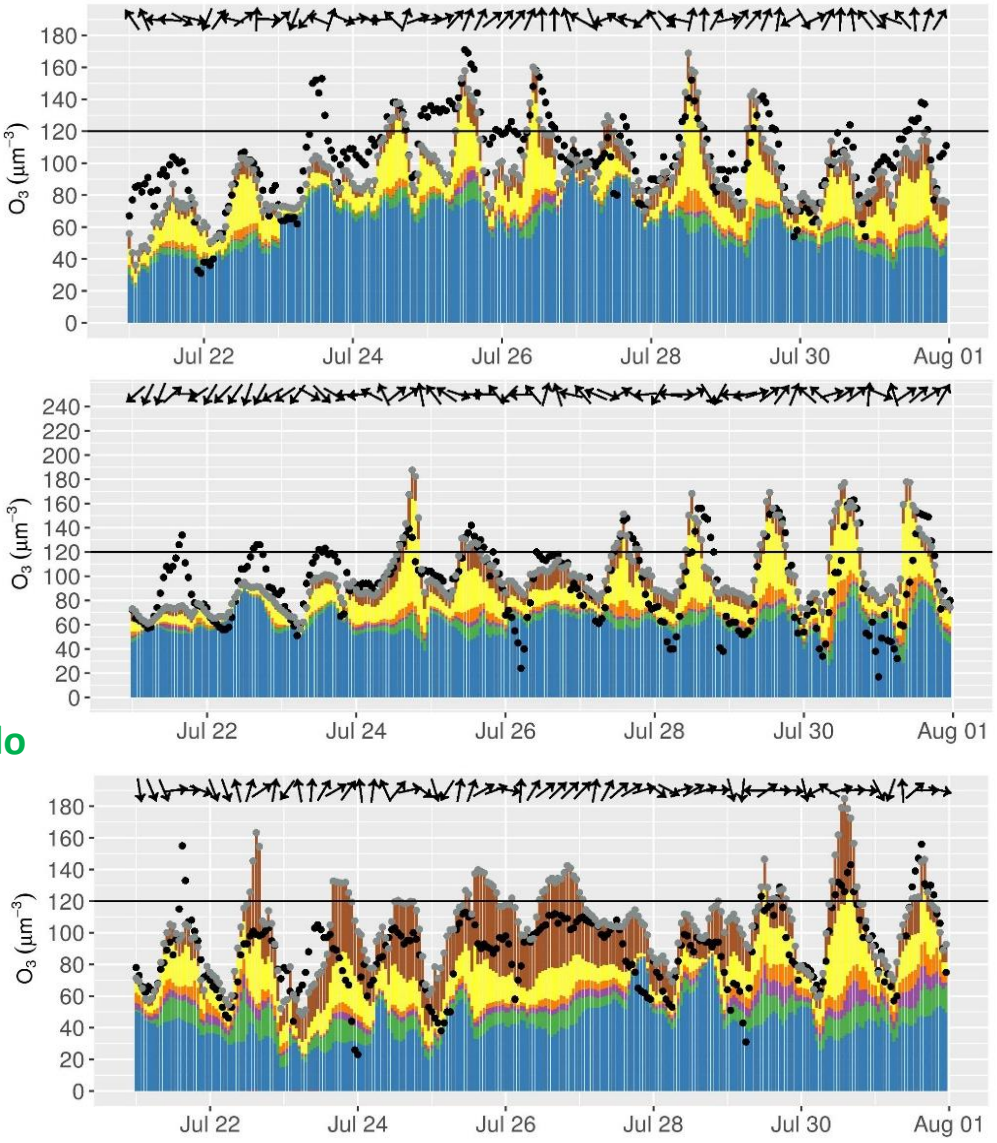
(2) Gadalajara

(6) El Arenosillo

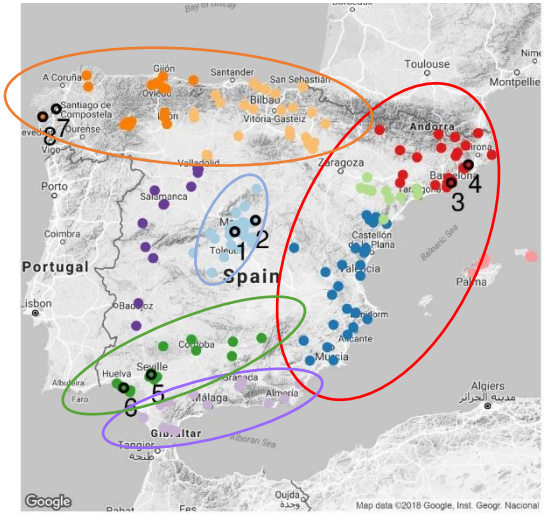
obs

cmaq

- Imported
- Others
- Power Plants
- Industry
- On-road transport
- Non-road transport



Regionalization of source-sector contribution

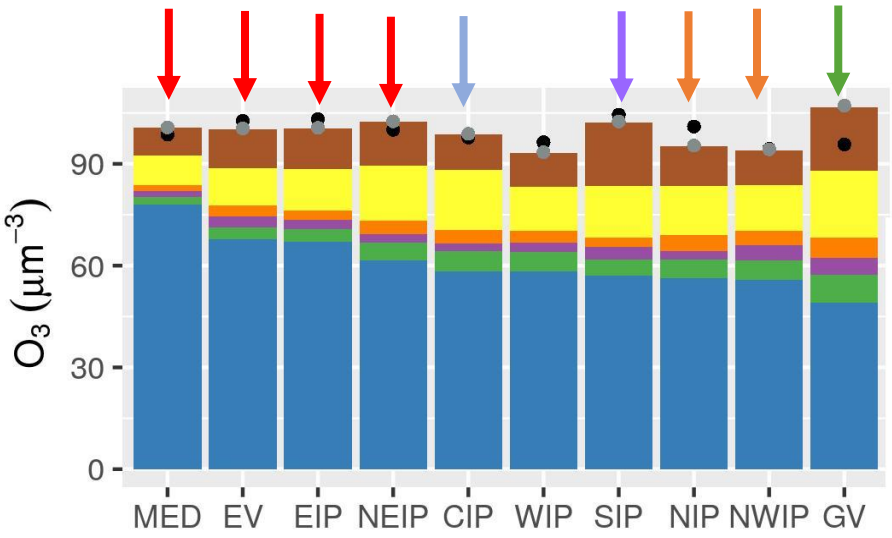


CIP
EIP
EV
GV
MED
NEIP
NIP
NWIP
SIP
WIP

obs
cmaq

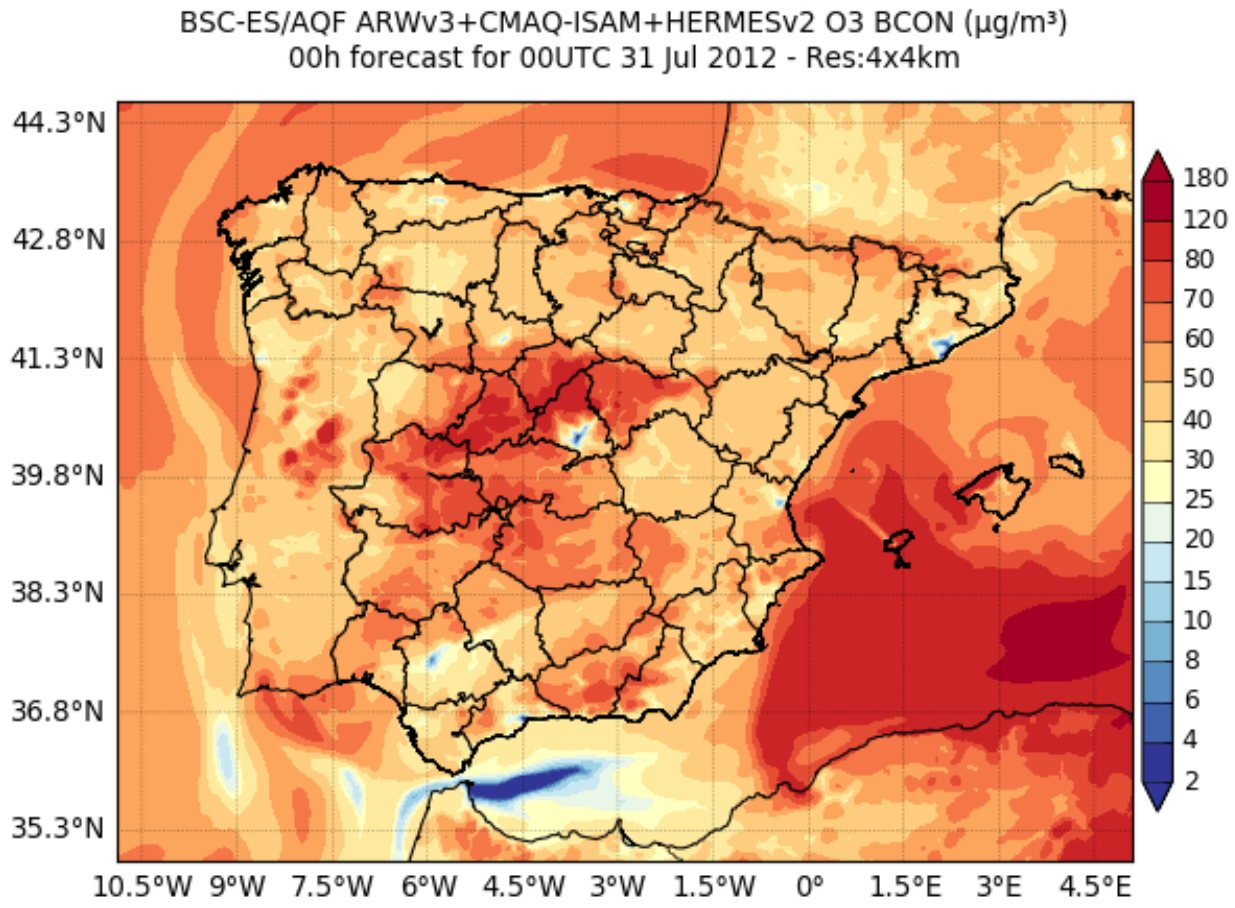
Imported
Others
Power Plants
Industry
On-road transport
Non-road transport

Daily mean contribution during DMA8 > 120 µ/m³

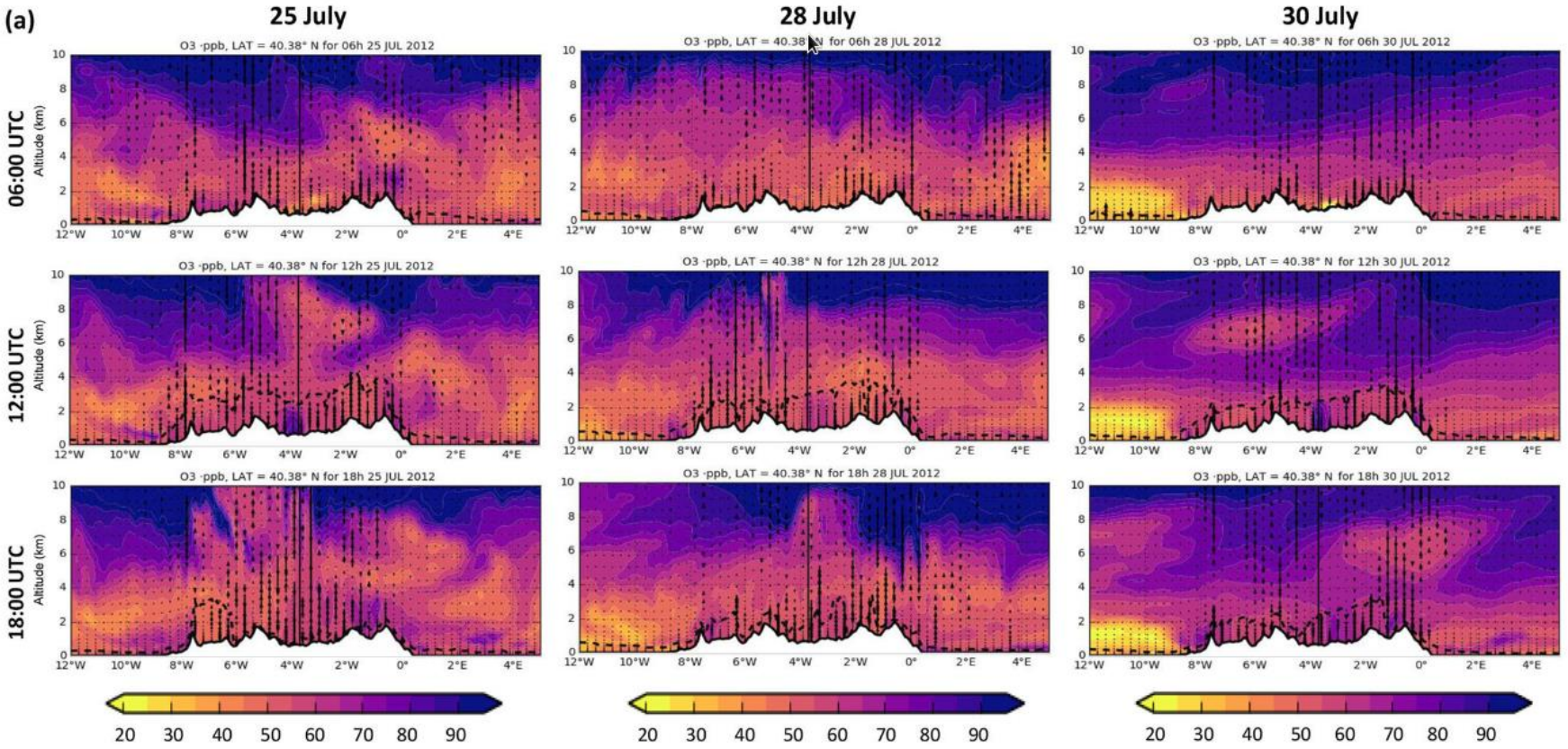


r =0.79 (without GV)

Imported O_3 concentration



O_3 vertical distribution



Conclusions

1. The improvement of models is necessary to improve the diagnosis of O_3

- emission + meteorology + chemistry + boundary conditions

2. The O_3 problem in Spain is local, regional and hemispheric.

- **Imported O_3** to the IP is a main contributor to ground-level O_3 concentration overall: 70-80% NW advections and 30-40% during stagnant conditions.
- **Regional/local source** contributions dominate O_3 during peaks:
  - Central and NE IP: the highest **road transport** contribution to O_3 (up to 40% in daily peak during events).
  - Industrial regions: **energy generation and industrial processes** contribute to O_3 up to 11%.
  - All sub-regions: the **non-road transport** is a contributor as significant as the road transport (10-19%).

3. Integrated source apportionment useful tool:

- Identification of potential errors in emission estimates
- Design more cost-efficient mitigation plans (together with source sensitivity).

Ongoing research work

1. Source apportionment for O_3

- Expand the quantification of the source contribution to O_3 in Spain including:

  (1) different O_3 episodes

  (2) multiyear O_3 seasons.

- Focus on main Spanish O_3 basin:

  (1) Quantify the contribution of key emission sectors.

  (2) Quantify the relative importance of imported vs regional/local O_3.

2. Source apportionment for PM2.5

- At the Spanish urban level:

  (1) Region (urban/national/transboundary) and sector contribution.

- At the European level focus on agriculture:

  (1) Health and economic cost of agricultural production and consumption.

Thank you!

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