

II Foro Tecnológico de Valencia (11-13 Junio 2019)

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

*Procesos meteorológicos relevantes en la acumulación y
venteo de ozono en el Sur de Europa: predicción e
identificación de orígenes*



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Objetivo

Mostrar con ejemplos algunos procesos (**meteorología/dispersión**) que contribuyen a la formación de **episodios de ozono** en la Península

- 1) **Método**
- 2) **El País Vasco. Cantábrico**
- 3) **El Mediterráneo: Valencia y Cataluña**
- 4) **Madrid**
- 5) **Conclusiones**

1) Método

¿Qué herramientas de diagnóstico?

- 1) Datos experimentales de meteorología y calidad de aire (estaciones de superficie, radares perfiladores de viento, radio-sondeos, aviones-satélites instrumentados)
- 2) Simulaciones mesoscalares RAMS/WRF
- 3) Trayectorias de alta resolución (HYPACT + CÓDIGO PROPIO)

$$X(t)=x(t-\Delta t)+u \Delta t$$

$$Y(t)=y(t-\Delta t)+v \Delta t$$

Modelo de trayectoria simple (backward/forward): si lanzamos un grupo de partículas desde O a la vez, todas llegan al mismo punto F, al mismo tiempo ...

Modelo de trayectorias múltiples-erráticas (de Monte Carlo)

Si introducimos el concepto de flujo turbulento ... $u = \bar{u} + u'$

Cada partícula presenta 2 movimientos superpuestos:

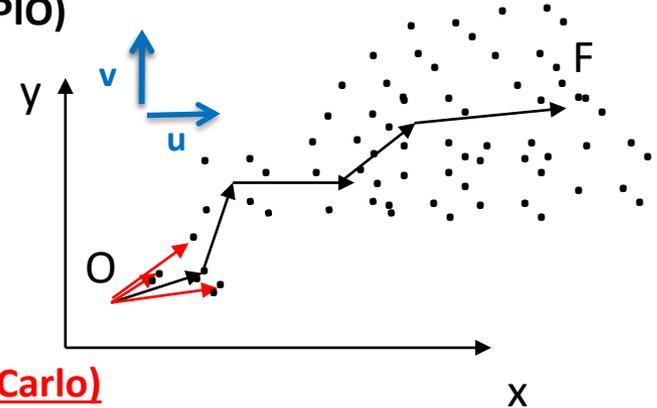
movimiento con el viento medio+ movimiento aleatorio

u' variable aleatoria, superpuesta a flujo medio \bar{u} .

$$u'(t) = u'(t-\Delta t) R(\Delta t) + u''$$

R función de correlación, que depende de estabilidad atmosférica

u'' variable aleatoria pura (números aleatorios con σ que depende de estabilidad atmosférica)

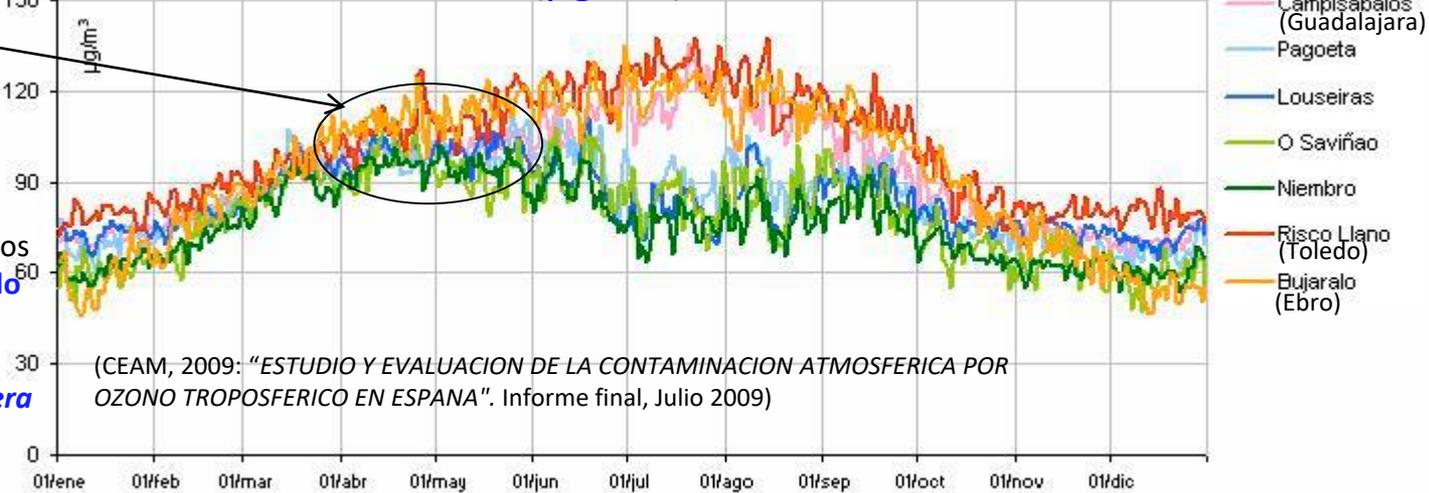


2) El Cantábrico es diferente al resto de España

Época de episodios característicos en el PV

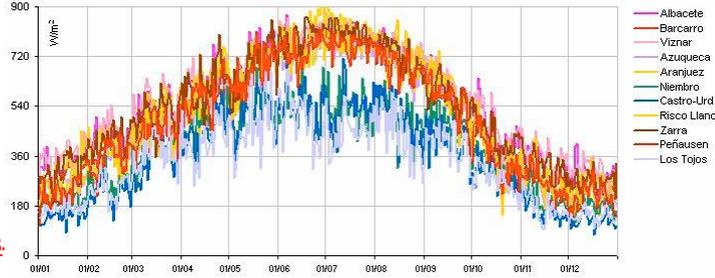
Ciclo anual promedio de algunas estaciones de fondo rural: máximos octo-horarios diarios en el periodo 1997- 2007: **“Menos concentraciones de O₃ y episodios desplazados a Primavera en lugar del verano”**

Concentración de ozono ($\mu\text{g}\cdot\text{m}^{-3}$)



(CEAM, 2009: “ESTUDIO Y EVALUACION DE LA CONTAMINACION ATMOSFERICA POR OZONO TROPOSFERICO EN ESPANA”. Informe final, Julio 2009)

Radiación ($\text{W}\cdot\text{m}^{-2}$)



Series anuales de radiación solar: máximos octo-horarios diarios en varios puntos de la península entre 1997-2007. (CEAM, 2009: ESTUDIO Y EVALUACION DE LA CONTAMINACION ATMOSFERICA POR OZONO TROPOSFERICO EN ESPANA”. Informe final, Julio 2009)

CAUSAS de las diferencias en O₃

- 1) Nubosidad (radiación)
- 2) Circulación atmosférica (recirculaciones térmicas peninsulares frente a advección continental en el Cantábrico)

EPISODIOS DE OZONO CARÁCTERÍSTICOS EN PAIS VASCO (TODO EL CANTÁBRICO):

Anticiclón continental europeo (vientos del Este, que rolan a S al final del episodio). **NO RECIRCULACION**

¿Cómo afectan? ¿Cuántas estaciones y qué frecuencia?

2) Episodios de ozono en País Vasco.

Estaciones con superación del valor objetivo de **120 $\mu\text{g m}^{-3}$**

“Situación actual del ozono en Euskadi “(2016). www.ingurumena.ejgv.euskadi.eus

SOLO 1 ESTACIÓN (DE UN TOTAL DE 50/30 ESTACIONES DE LA RED DE VIGILANCIA ENTRE 2009/2015) MUESTRA SUPERACIONES SISTEMATICAS DEL valor objetivo de 120 $\mu\text{g m}^{-3}$ para la protección de la salud humana

PARQUES NATURALES!

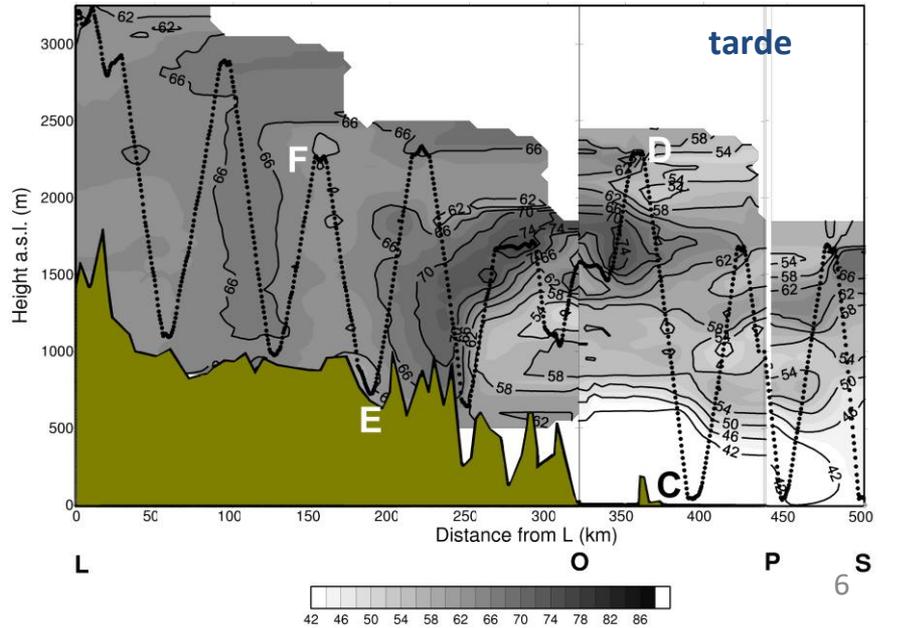
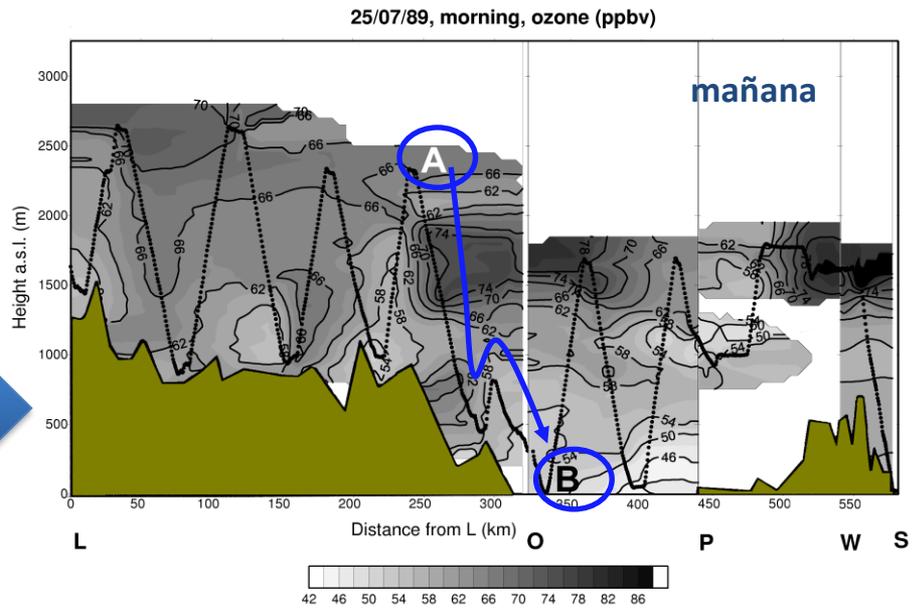
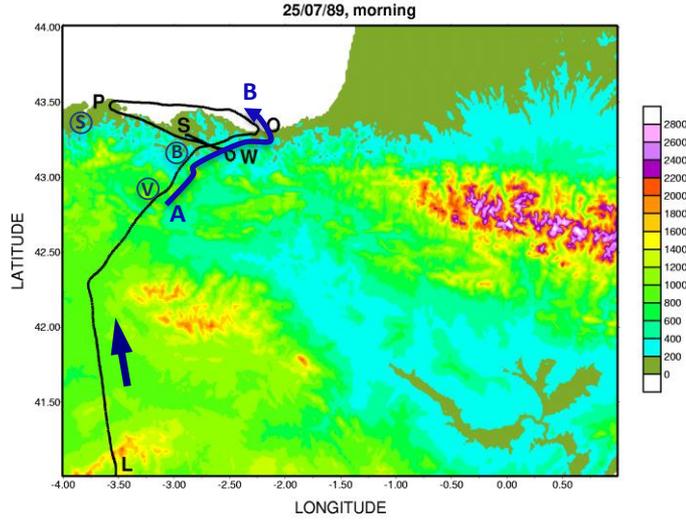
AÑO	ESTACION	Nº DE SUPERACIONES (Promedio de 3 años)
2009	Valderejo	27
2010	Elciego	28
2010	Izki	27
2010	Valderejo	26
2011	Urkiola	27
2011	Valderejo	34
2012	Jaizkibel	31
2012	Valderejo	35
2013	Jaizkibel	34
2013	Valderejo	33
2014	Jaizkibel	27
2014	Valderejo	32
2015	Valderejo	32

Hoy sabemos que parte de este ozono es de producción local (zona de Bilbao), pero una fracción es importada ¿DESDE DONDE?

Albizuri, A. (2004): Clasificación de patrones meteorológicos y su relación con los episodios de ozono en la CAPV, en: Proceedings of the IX Congress of Environmental Engineering, Published by the Bilbao Exhibition Centre and the University of the Basque Country, Bilbao, Spain, 441–451.
Albizuri, A. (2013) Environment & Systems S.A. (2013): Evolucion de la calidad del aire en la CAPV en el periodo 2001-2011. Ref: OF-15/12.

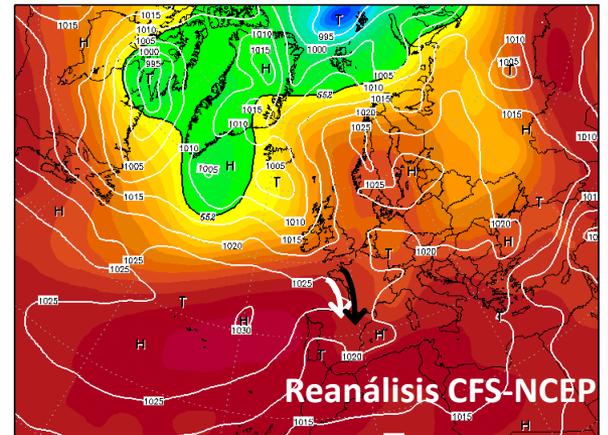
2) País Vasco Proyecto Europeo MECAPIP (vuelos instrumentados Julio 1989)

PRIMERAS EVIDENCIAS DE IMPORTACION DE OZONO



¿De dónde vienen el ozono que fumiga en Valderejo?

origen de los niveles de ozono detectados en altura (1400-1700 m) sobre la cuenca del Nervión por el avión instrumentado del proyecto europeo MECAPIP (1988-1991) método RAMS/retro-trayectoria (PROPIO)

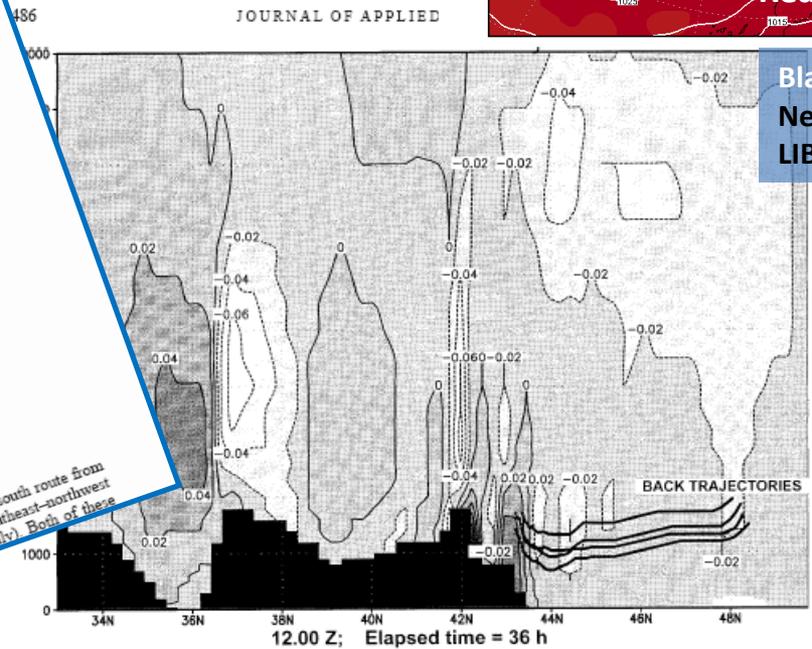


ALONSO ET AL.
J. Appl. Meteorol. Climatol.
 Transport of Tropospheric Ozone over the Bay of Biscay and the Eastern Cantabrian Coast of Spain
 LUCIO ALONSO, GOTZON GANGOTTI, AND MARIÑO NAVAZO
 Escuela Técnica Superior de Ingenieros Industriales de Bilbao, Universidad del País Vasco/Euzko Herriko Unibertsitatea, Bilbao, Spain
 MILLAN M. MILLAN AND ENRIQUE MANTILLA
 Centro de Estudios Ambientales del Mediterraneo, Valencia, Spain
 (Manuscript received 9 March 1998, in final form 20 August 1999)

ABSTRACT
 During the 1989 field campaigns of the European Commission's Mesometeorological Cycles of Air Pollution in the Iberian Peninsula (MECAPIP) project (1988-91), airborne data were obtained under typical summer synoptic weather conditions, that is, a ridge of the Azores high pressure system extending over the north coast of the Iberian Peninsula combined with a thermal low in the interior of the peninsula. This paper presents a detailed analysis of the flights over the coastal area of Bilbao and a high-resolution simulation of the trajectories of the polluted air masses to determine the mechanisms leading to the type of stratification observed. Over the Bay of Biscay, on the eastern Cantabrian coast, the data showed the presence of two distinct groups of atmospheric strata with high ozone concentrations. The higher layers contained older pollutants, trapped between an inversion at about 1200 m and a near-isothermal layer at about 2000 m, and were moving under persistent north to northeasterly winds. The lowest layers, close to the surface in the Bilbao area, contained recently emitted pollutants. Back trajectories computed by using the 3D wind field simulated by the Regional Atmospheric Modeling System (RAMS) have shown that the source of the pollutants in the upper layers, 36 h before, was within a region near the English Channel.

These flights followed a north-south route from Bilbao to Madrid (on 25 July) and a southeast-northwest route over the Ebro valley (on 28 July). Both of these

1. Introduction
 The field campaigns of the European Commission... corresponds to the low-resolution (27 km x 27 km) grid... meteorological simulation model, and the gray scale represents... topographic heights.



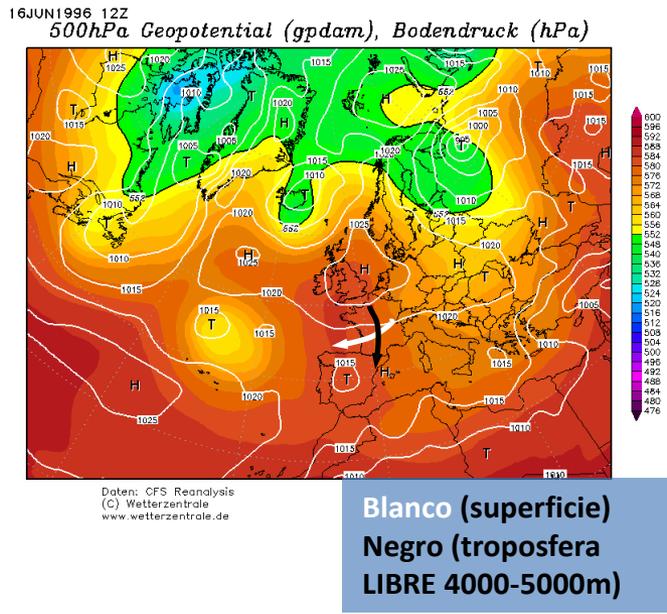
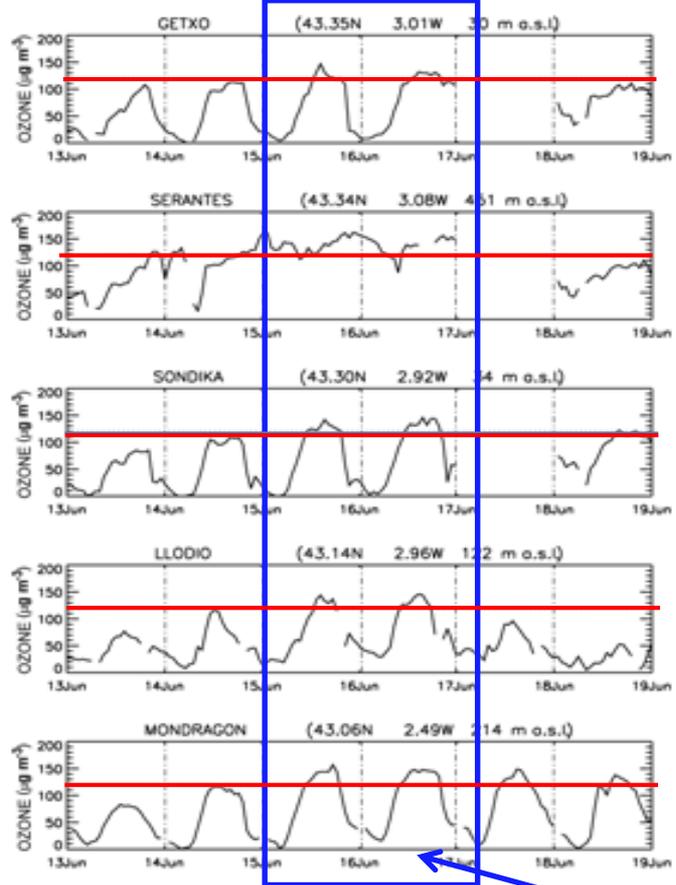
Blanco (superficie)
Negro (troposfera LIBRE, 4000-5000m)

FIG. 17. Vertical section along the 3°E meridian of the domain in Fig. 16. The back-trajectories have been drawn (in black) on a gray scale and contour line background, which represents the vertical wind speed field (m s⁻¹) at 1200 on 25 Jul—the arrival time for the simulated trajectories. The coordinates are in m MSL and latitude. Land sections of North Africa and the Iberian Peninsula can be seen (in black) at the bottom.

ESTE NO ES UN CASO CLÁSICO DE EXCEDENCIAS EN EL PAIS VASCO

2) País Vasco. CASO CLÁSICO DE EXCEDENCIAS CON ANTICICLÓN EUROPEO. EPISODIO DE JUNIO de 1996

Se sobrepasan los **120 $\mu\text{g m}^{-3}$** en todas las estaciones (costa, valles interiores y montañas) y dura varios días. **Nunca son días aislados** (dinámica anticiclónica)



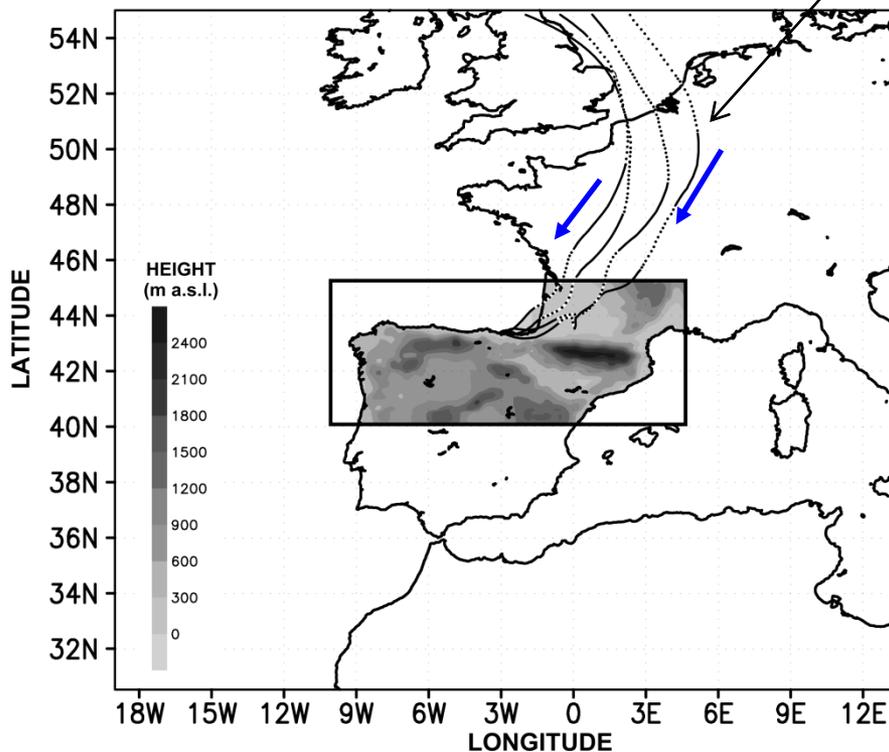
Días 15/16 mediodía (PICO del episodio)...

RETROTRAYECTORIAS DE ALTA RESOLUCIÓN...

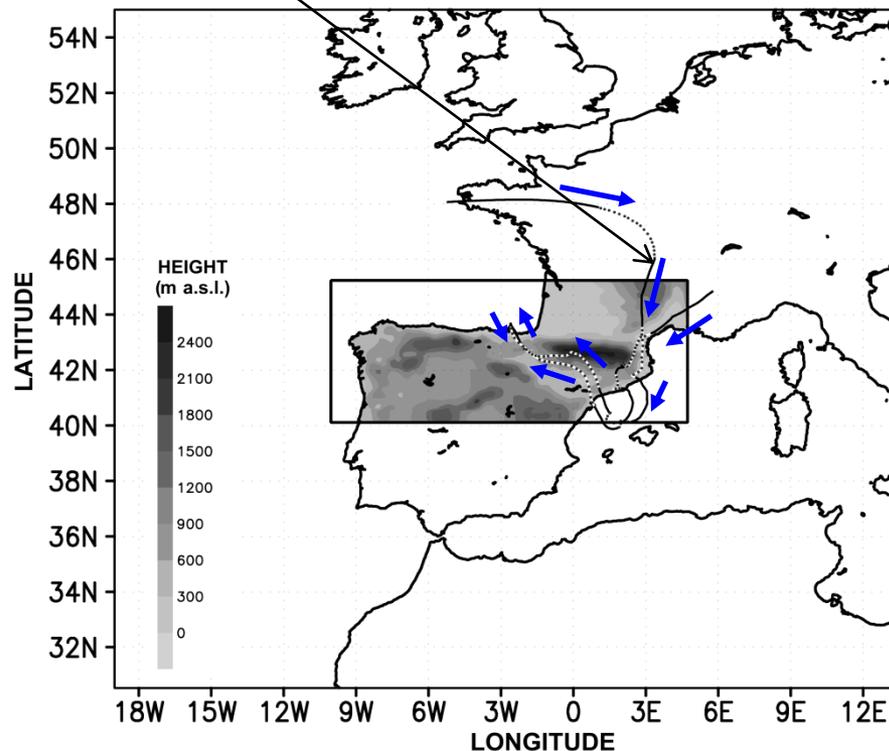
RETRO-TRAYECTORIAS SIMPLES CALCULADAS CON MODELO MESOSCALAR RAMS

línea discontinua (noche) línea continua (día)

BACK - TRAJECTORY (2500 - 2000 - 1500 - 1000 m a.s.l.)
1600 UTC 16 JUNE 1996 ELAPSED TIME = 111 h



BACK - TRAJECTORY (250 - 500 m a.s.l.)
1600 UTC 16 JUNE 1996 ELAPSED TIME = 111 h

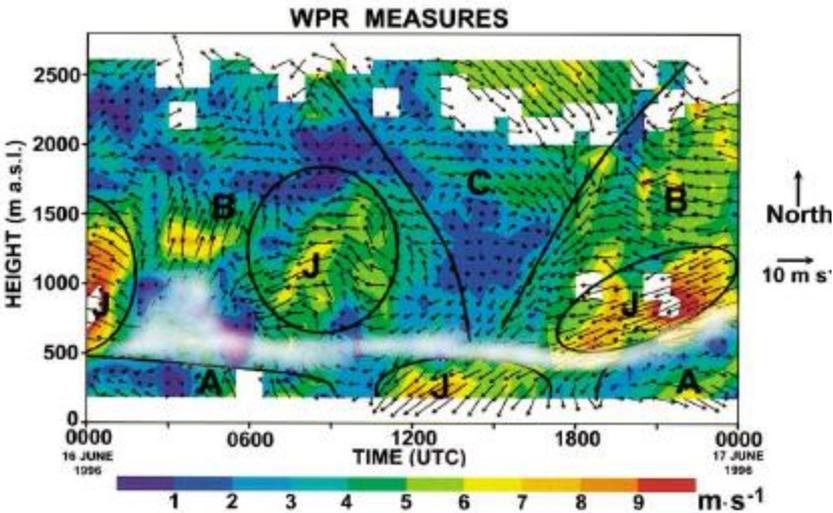
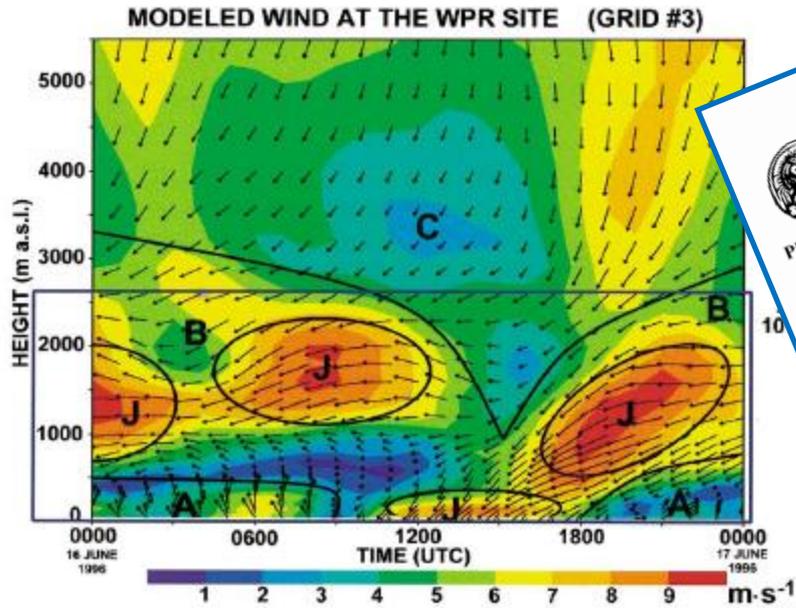


LAS TRAYECTORIAS BAJAS POR EL EBRO NO ERAN PREDECIBLES "A PRIORI" CON LOS MAPAS DE REANÁLISIS. ES UN PROCESO MESOSCALAR. NECESITAMOS VERIFICACIÓN PARA FLUJOS POR ENCIMA DE LA CAPA LIMITE SUPERFICIAL:

Por primera vez se utiliza el perfilador (WPR) del puerto de Bilbao para VERIFICACIÓN de simulaciones.

El perfilador (WPR) para verificación de simulaciones MET

G. Gangoiti et al / Atmospheric Environment 36 (2002) 1349–1361



Las simulaciones

Atmospheric Environment 36 (2002) 1349–1361

ATMOSPHERIC ENVIRONMENT
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Regional transport of pollutants over the Bay of Biscay: analysis of an ozone episode under a blocking anticyclone in west-central Europe

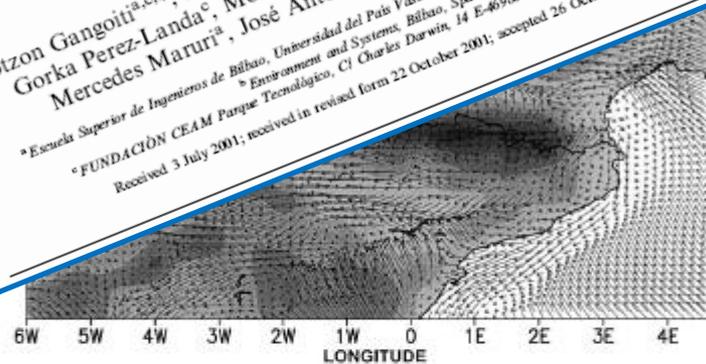
Gotzon Gangoiti^{a,c,*}, Lucio Alonso^a, Marino Navazo^a, Amaia Albizuri^b, Gorka Perez-Landa^c, Monica Matabuena^a, Veronica Valdenebro^a, Mercedes Maruri^a, José Antonio García^a, Millán M. Millán^c

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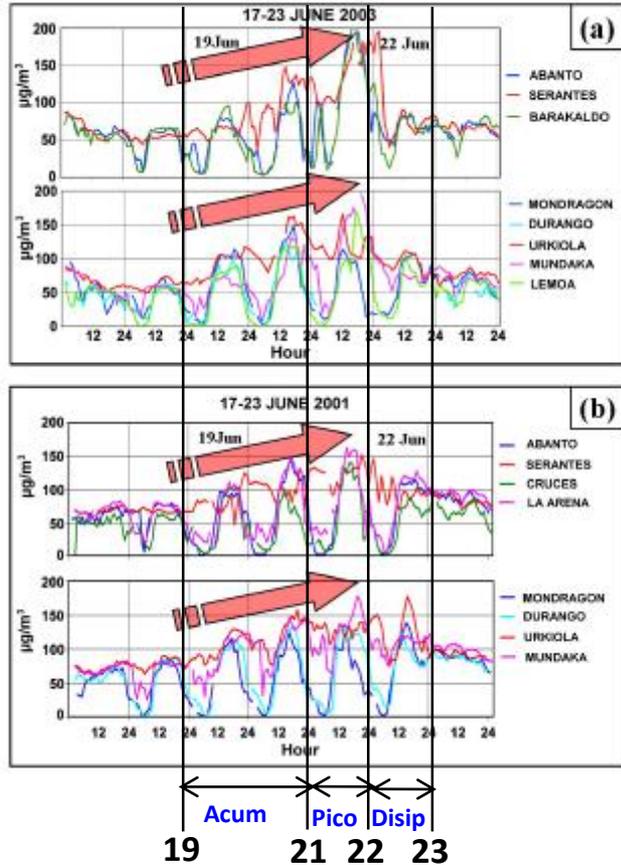
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Received 3 July 2001; received in revised form 22 October 2001; accepted 26 October 2001



EPISODIOS DE JUNIO de 2001 y JUNIO DE 2003. CASOS DE ANTICiclÓN EUROPEO



- 1) FASE DE ACUMULACION: FRANCIA + LOCAL
- 2) FASE PICO: SE AÑADEN DESDE EL EBRO+ OTRAS VIAS
- 3) ESTOS EPISODIOS AFECTAN A TODO EL CANTÁBRICO

Atmos. Chem. Phys., 6, 1469–1484, 2006
www.atmos-chem-phys.net/6/1469/2006/
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Sub-continental transport mechanisms and pathways during two ozone episodes in northern Spain

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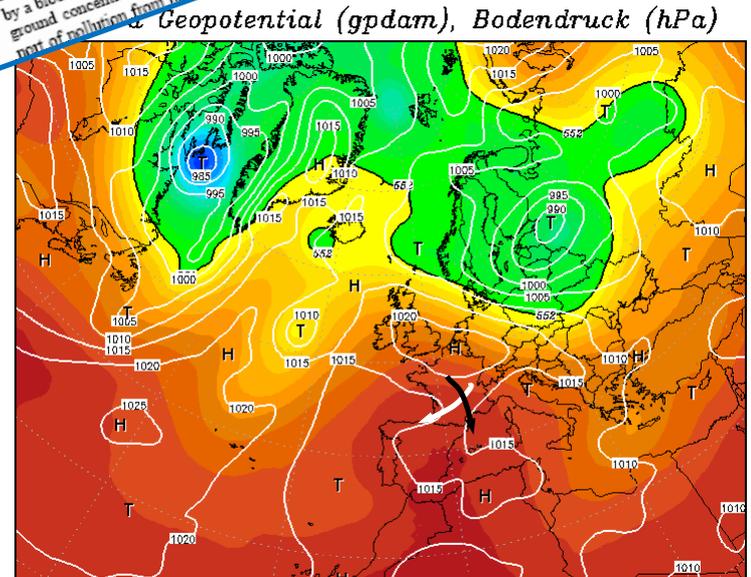
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Received: 27 July 2005 – Published in Atmos. Chem. Phys. Discuss.: 25 October 2005
Revised: 16 January 2006 – Accepted: 1 March 2006 – Published: 8 May 2006

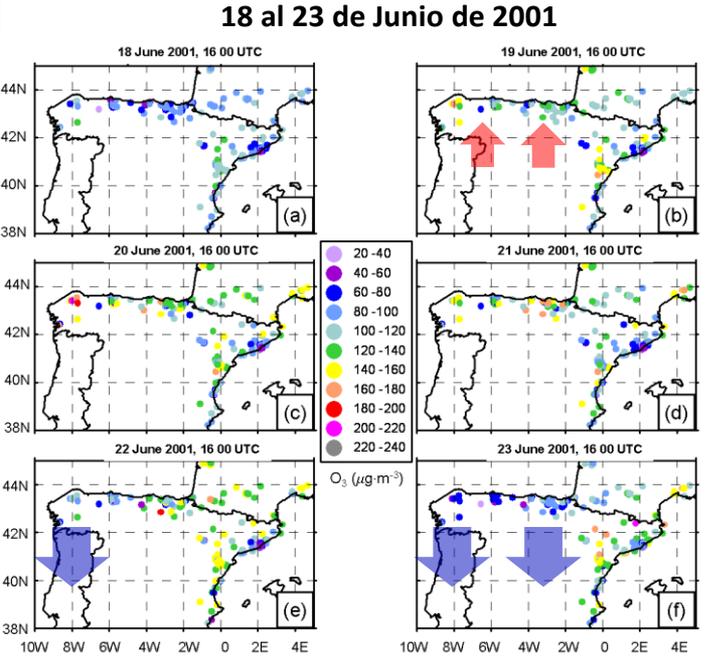
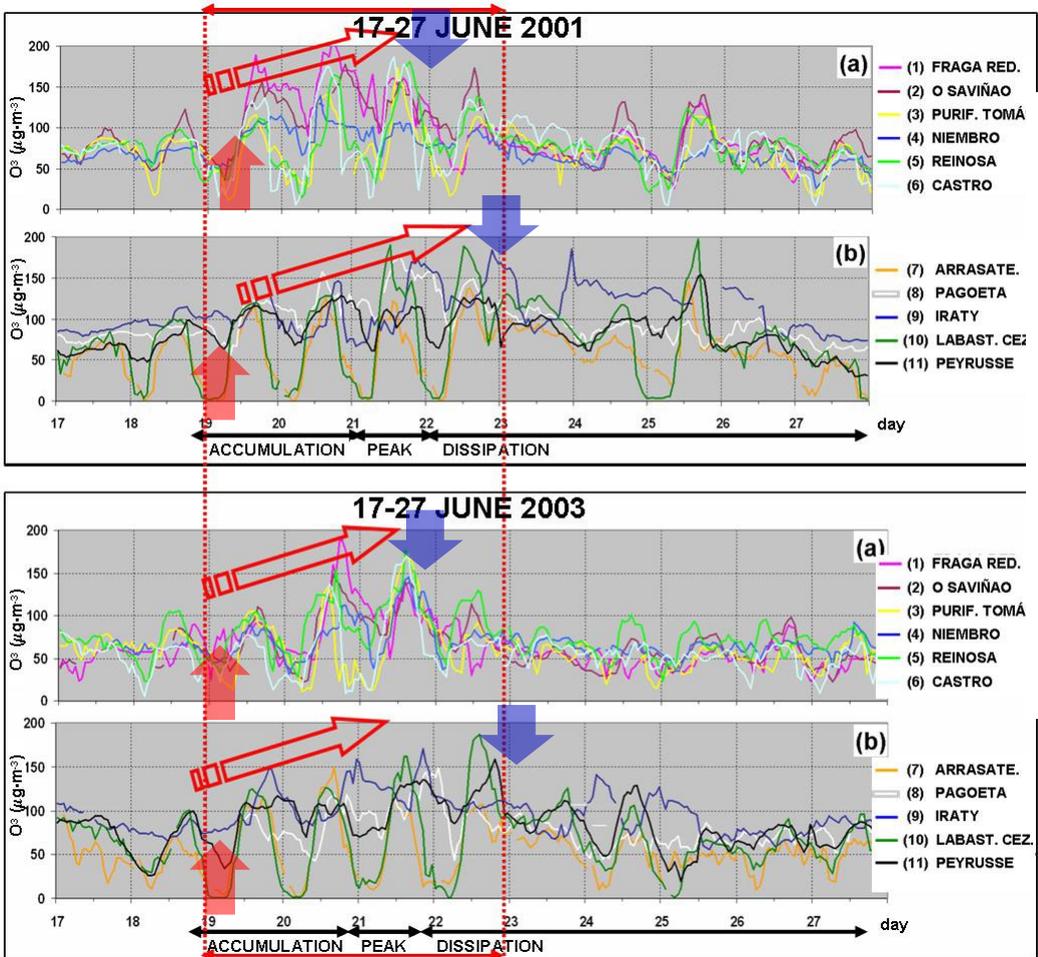
Abstract. Two ozone episodes (occurring in June 2001 and June 2003) in the air quality monitoring network of the Basque Country (BC) are analyzed. The population information threshold was exceeded in many stations (urban, urbanization and rural). During this type of episodes, ozone back-transport by a blocking anticyclone over the area increase after the import of pollution from both the continental Europe and the Western Mediterranean sea. The British Isles and the Iberian Peninsula are also affected.

1 Introduction



2) Estos episodios afectan a todo el Cantábrico.

Mismos Episodios de Junio 2001 y 2003: AFECTAN a toda la Cornisa Cantábrica: empiezan simultáneamente y terminan antes al W del Cantábrico.



Distribución espacial de concentraciones medias horarias de O₃ a las 16:00 UTC del 18 al 23 de Junio de 2001 en la región Cantabrico - Pirenaica y en la costa Mediterránea. Datos de todas las estaciones AirBase en el Cantábrico, estaciones adicionales en el Sur de Francia y la costa Mediterranea.

Series temporales de concentraciones de O₃ en estaciones seleccionadas del Norte de España y sur de Francia, en la costa y en el interior, de fondo rural o urbano: (a) al oeste de la País Vasco (1-6). (b) en la País Vasco y al este de la País Vasco (7-11). Se presenta un total de 11 días para mostrar el proceso de acumulación, pico y disipación del episodio. Los episodios se centraron entre el 19 y el 22 de junio en toda la costa cantabrica.

2) ESQUEMA CONCEPTUAL: exportaciones/importaciones de ozono entre CANTABRICO y SUR de FRANCIA

Atmospheric Environment 45 (2011) 1591–1603

Contents lists available at ScienceDirect

Atmospheric Environment

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Build-up and decay of two ozone episodes through northern Iberia and southern France – An inter-regional transport analysis

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V. Valdenebro et al. / Atmospheric Environment 45 (2011) 1591–1603

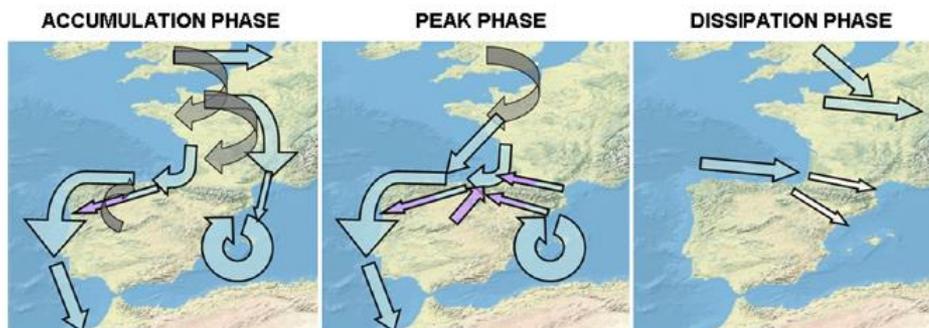


Fig. 13. Main pathways documented during the episodes (see Section 4).

C L E I N F O

97:
8 May 2010
in revised form
16 December 2010

er radar
transport

duction

ground

European Commission Decision of 19 March 2004, con-
guidance for implementation of ozone Directive 2002/3/
EC, recognizes that “the solution to ozone air pollution problems
requires a proper diagnosis of the processes in each region and
for each time of the year, as well as for the links between
regions”. It also states that “short-term actions may require
a regional-wide assessment and approach where layering and

A B S T R A C T

Further analysis of the previously-reported relationship between blocking anticyclones over the British Isles and severe ozone episodes in the Basque Country (BC) has shown that an even wider area is affected by these situations. Two episodes have been studied. The analysis of ozone data from approximately 60 AirBase stations throughout the area showed that they were among the most severe episodes of ozone exceedances in all northern Iberia and south-western France. Concentrations have been found to be related to inter-regional transport in southern Europe, and the temporal length of the whole process (development and decay) has been found to range from 7 to 10 days. A temporal delay in the recording of maximum concentrations within the region has been observed and explained for the first time. A new pathway for the export of European pollutants towards the Atlantic Ocean has also been documented, along with the export of pollutants from the eastern Cantabrian Coast (CC) to Africa at the beginning of the episodes. A huge eastward transport of pollutants across the CC towards southern France, and along the Ebro Valley towards the Mediterranean Sea, has been documented during the dissipation phase, but may not be definitive.

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transport account for a significant part of the observed ozone”. Vertical layering of both the lower atmosphere and the pollutants over the Bay of Biscay was previously documented during the summer flight campaigns of the European MECAPIP project (Millán et al., 1992, 1997). Further analysis of the data revealed long-range transport of photochemical pollutants from the English Channel into the BC (Alonso et al., 2000); this transport takes place under the typical summer synoptic scenario, with the Azores High extending a ridge of high pressures over the Bay of Biscay and pushing northerly winds over the CC. Recent studies by Gangoi et al. (2002, 2006a) have also shown the importance of vertical layering and transport in the generation of intense ozone episodes in the BC under a different synoptic situation, with persistent north-easterly winds associated with blocking anticyclones over the British Isles. The use of the hybrid Eulerian-Lagrangian concentration and transport HYPACT model (Tremback et al., 1993), together with the RAMS meteorological model (version 4.4.0, Pielke et al., 1992) – already validated with observations – allowed these authors to document the import of pollutants from several European source regions, including the Iberian peninsula itself, into the BC during the

Abbreviations: BC, Basque Country; CC, Cantabrian Coast; HYPACT, Hybrid Particle and Concentration Transport; RAMS, Regional Atmospheric Modelling System; WPR, Wind Profiler Radar; WEA, Western European Atlantic; WM, Western Mediterranean; MBL, Marine Boundary Layer

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doi:10.1016/j.atmosenv.2010.12.031

3) EL W-MEDITERRANEO: EPISODIOS DE OZONO Y MODO DE ACUMULACION

FORMACIÓN DE ESTRATOS DE ACUMULACIÓN/RECIRCULACIÓN EN LA VERTICAL

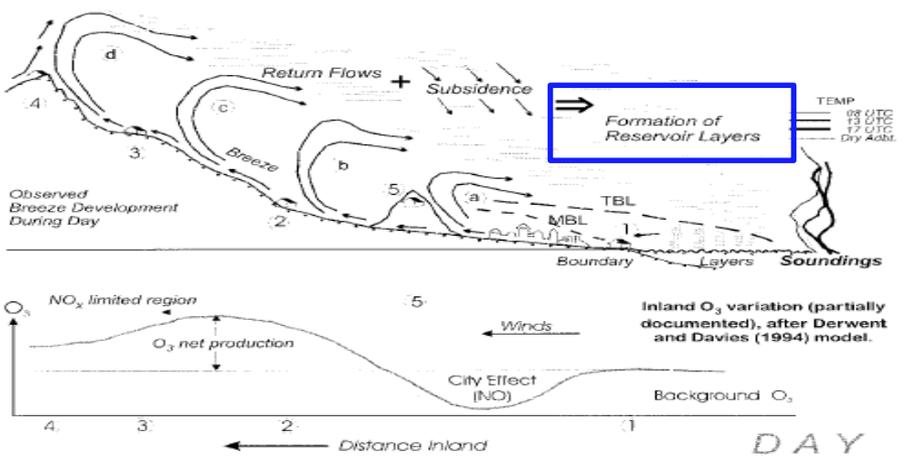
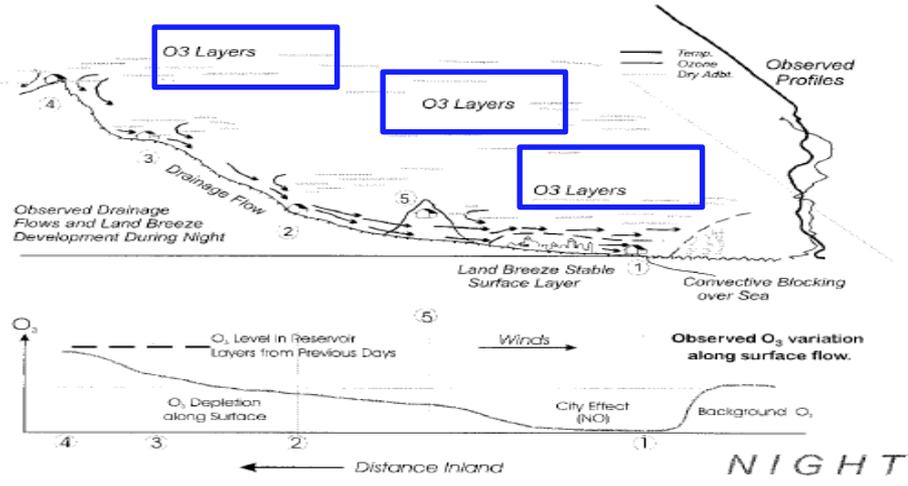


FIG. 11. Schematic of the circulations in the coastal regions of the western Mediterranean on a summer day. Letters a-d indicate successive stages in the entrance of the sea breeze and the formation of stratified reservoir layers aloft, and the numbers correspond to typical station sites (section 7). The lower graph, after Derwent and Davies (1994), represents the relationship between net ozone production and the amount of NO_x oxidized along the airmass trajectories. The soundings at right illustrate the sinking of the marine boundary layer on 23 Jul 1991 (Grao).



Atmospheric Environment 35 (2001) 6267–6276



Long-range transport and re-circulation of pollutants in the western Mediterranean during the project Regional Cycles of Air Pollution in the West-Central Mediterranean Area

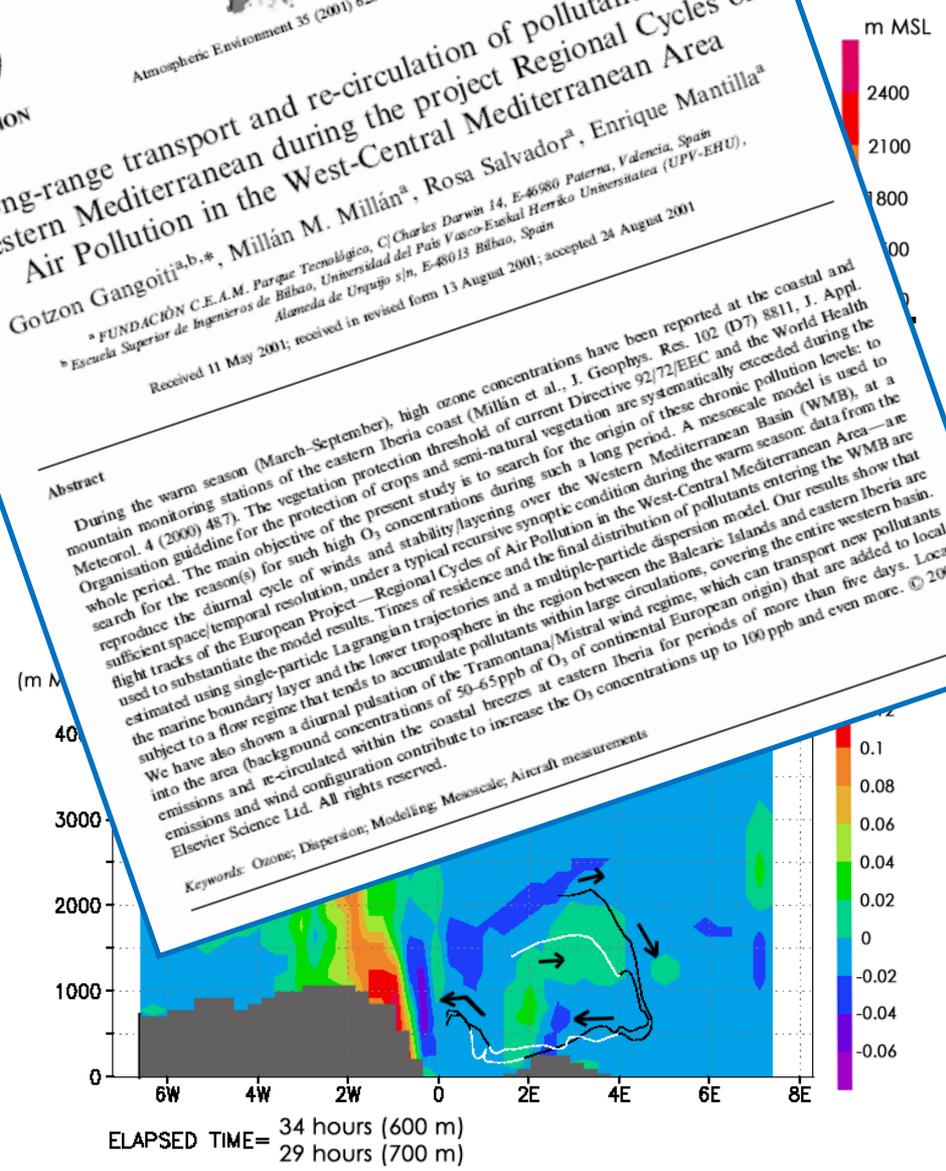
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Received 11 May 2001; received in revised form 13 August 2001; accepted 24 August 2001

Abstract

During the warm season (March–September), high ozone concentrations have been reported at the coastal and mountain monitoring stations of the eastern Iberia coast (Millán et al., J. Geophys. Res. 102 (D7) 8811, J. Appl. Meteorol. 4 (2000) 487). The vegetation protection threshold of current Directive 92/72/EEC and the World Health Organisation guideline for the protection of crops and semi-natural vegetation are systematically exceeded during the whole period. The main objective of the present study is to search for the origin of these chronic pollution levels: to search for the reason(s) for such high O₃ concentrations during such a long period. A mesoscale model is used to reproduce the diurnal cycle of winds and stability/layering over the Western Mediterranean Basin (WMB), at a sufficient space/temporal resolution, under a typical recursive synoptic condition during the warm season: data from the flight tracks of the European Project—Regional Cycles of Air Pollution in the West-Central Mediterranean Area—are used to substantiate the model results. Times of residence and the final distribution of pollutants entering the WMB are estimated using single-particle La grangian trajectories and a multiple-particle dispersion model. Our results show that the marine boundary layer and the lower troposphere in the region between the Balearic Islands and eastern Iberia are subject to a flow regime that tends to accumulate pollutants within large circulations, covering the entire western basin. We have also shown a diurnal pulsation of the Tramontana/Mistral wind regime, which can transport new pollutants into the area (background concentrations of 50–65 ppb of O₃ of continental European origin) that are added to local emissions and re-circulated within the coastal breezes at eastern Iberia for periods of more than five days. Local emissions and wind configuration contribute to increase the O₃ concentrations up to 100 ppb and even more. © 2001 Elsevier Science Ltd. All rights reserved.

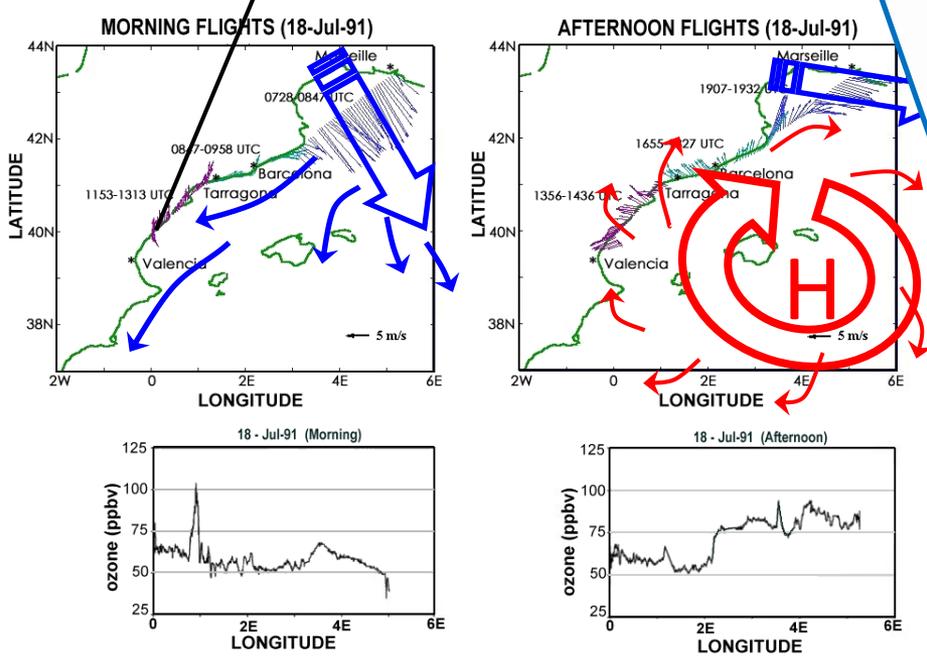
Keywords: Ozone; Dispersion; Modelling; Mesoscale; Aircraft measurements



3) EL W-MEDITERRANEO: MODO DE ACUMULACIÓN TRANSPORTE

Vuelo espiral hasta 3000 m de altura y máximos de ozono a 600-700m: ¿De dónde viene el ozono frente a SAGUNTO?.

Proyecto RECAPMA. VUELOS INSTRUMENTADOS 150-200 m altura constante sobre el mar



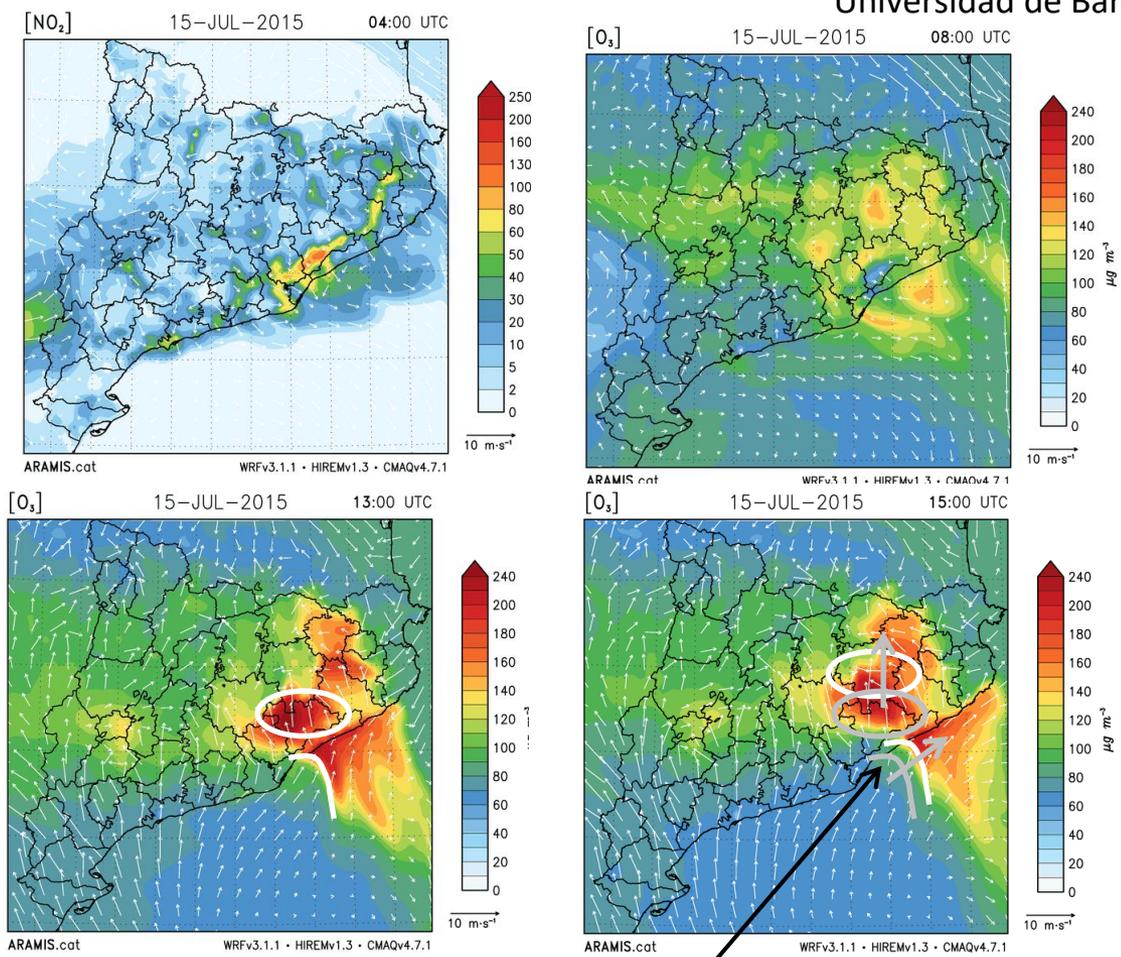
CADA 3-7 DÍAS SE ROMPE LA ACUMULACIÓN Y HAY UN PERIODO DE VENTEO

3) EL W-MEDITERRANEO: EPISODIO DE ACUMULACIÓN CATALUÑA TRANSPORTE HORIZONTAL

(CAMPAÑA INTENSIVA Y SIMULACIONES DE FOTOQUÍMICA DE JULIO 2015)

NO₂ y O₃ en superficie (15 Julio 2015) "ARAMIS": WRF/CMAQ/HIREM

Universidad de Barcelona



DIVERGENCIA/HUNDIMIENTO

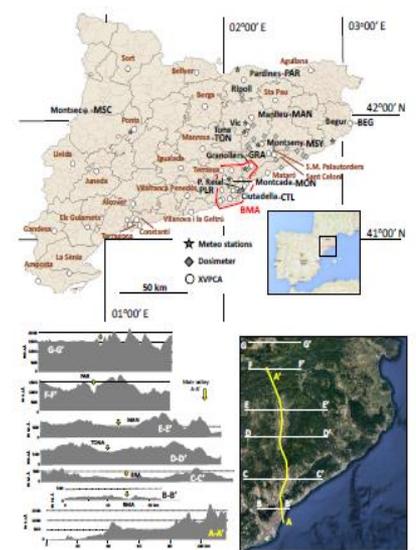
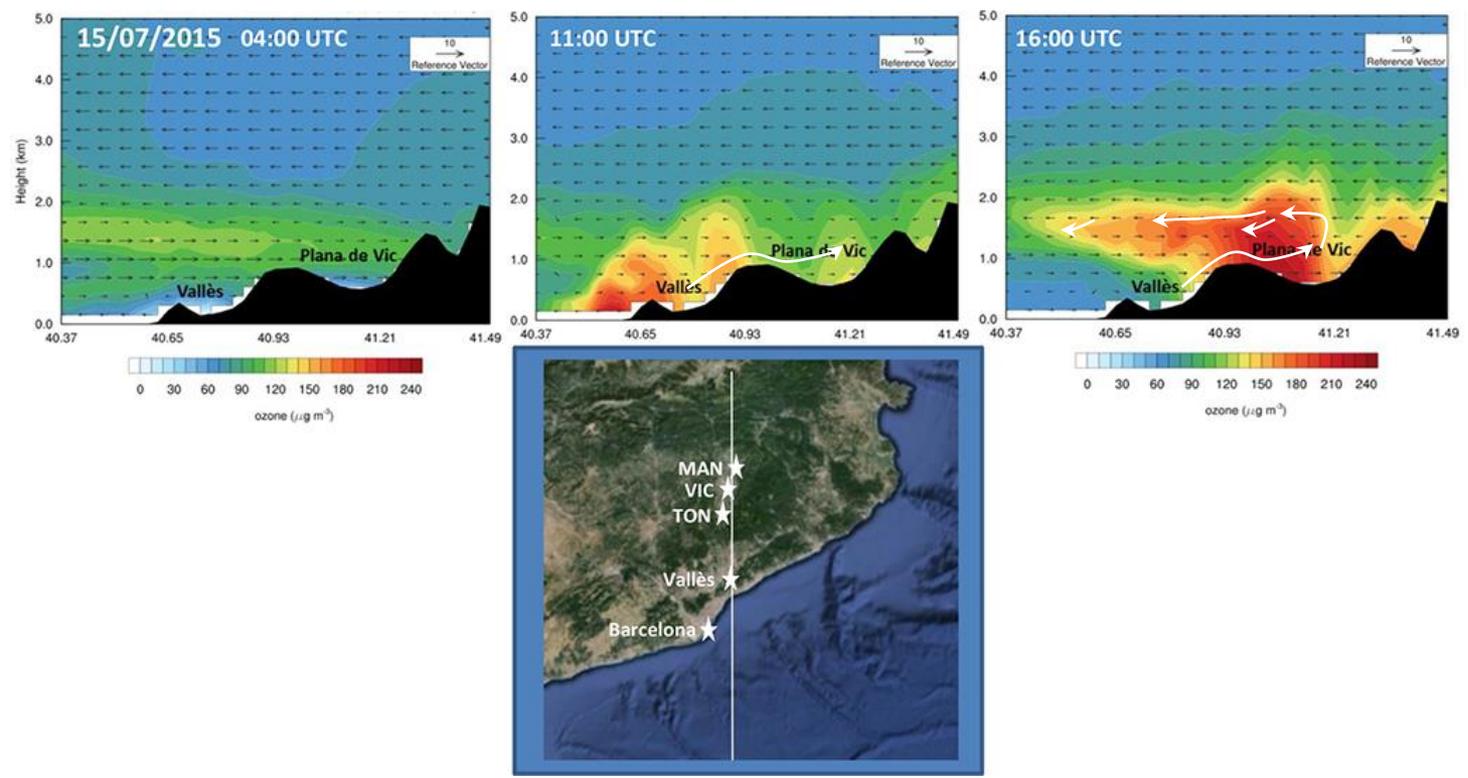


Figure 1. Top: study area and location of monitoring sites (regional air quality monitoring sites XVPCA, dosimeters, meteorological stations and vertical measurements). BMA: Barcelona metropolitan area. Bottom: topographic profiles across the study area, red arrows point to the valleys connecting BMA with the Vic Plain and the pre-Pyrenean regions.

X. Querol y cols., Atmos. Chem. Phys. (2017)

3) EL W-MEDITERRANEO: EPISODIO DE ACUMULACIÓN CATALUÑA TRANSPORTE VERTICAL

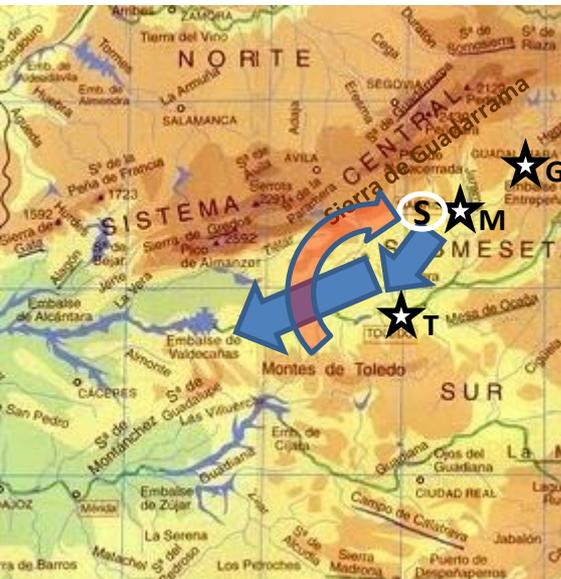


4) MADRID: EPISODIOS DE OZONO

CAMPAÑAS DECADA DE LOS 90

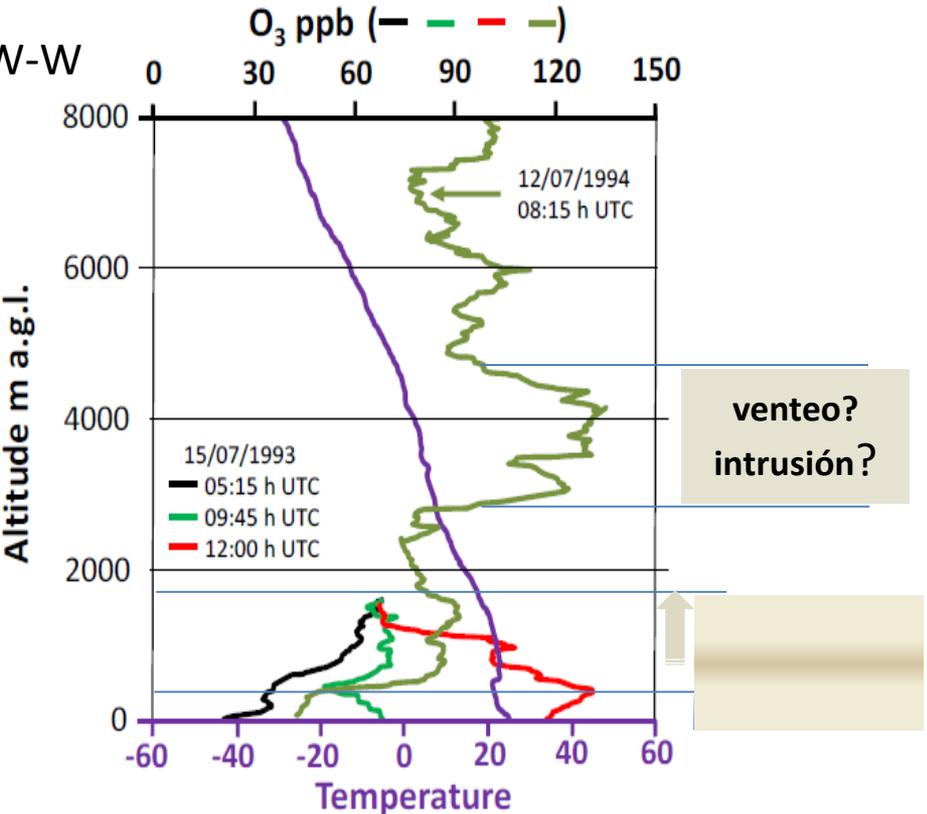
Cómo se forman los episodios y cómo se DISTRIBUYE EL OZONO EN ALTURA

CAMPAÑAS DECADA DE LOS 90



(T) Toledo (M) Madrid
(G) Guadalajara (S) sondeo

NE → S-SW-W



Plaza, J., Pujadas, M., and Artíñano, B. Formation and Transport of the Madrid Ozone Plume, JAPCA J. AirWaste Ma., 47, 766–774, 1997.

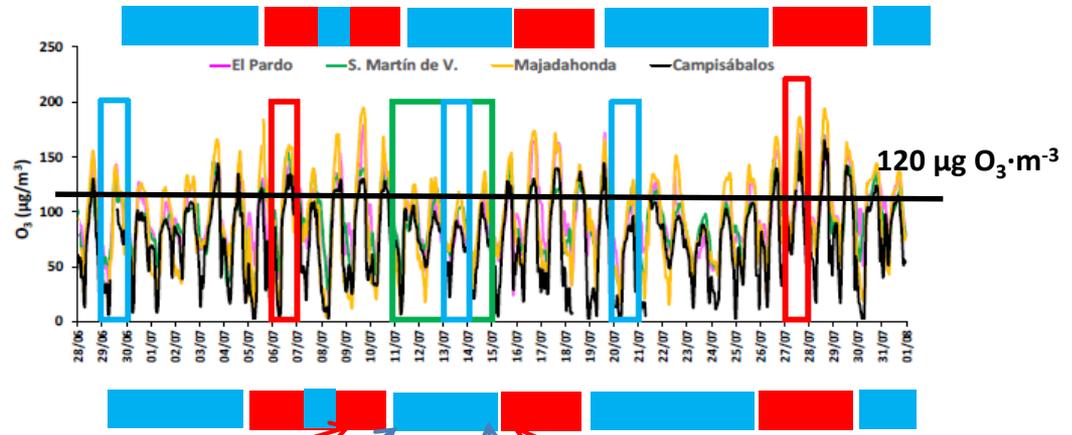
AMBOS DIAS SON EVENTOS DE **ACUMULACIÓN**.

El sondeo libre corresponde al último día de un periodo de acumulación

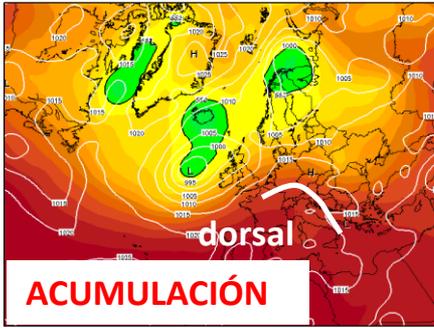
4) MADRID: EPISODIOS DE ACUMULACIÓN/VENTEO DE OZONO

CAMPAÑA INTENSIVA DE JULIO 2016

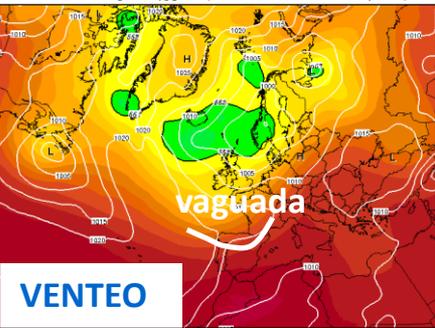
Querol et al., 2018; Phenomenology of summer ozone episodes over the Madrid Metropolitan Area, central Spain Atmos. Chem. Phys., 18, 6511–6533, 2018)



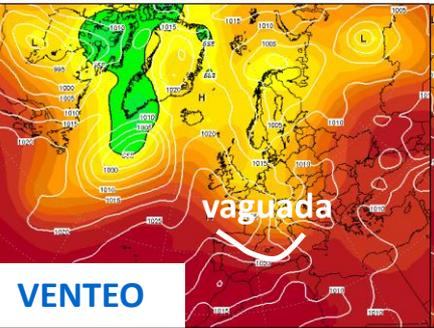
500 hPa Geopot. (gpdm) und Bodendruck (hPa) **Sat, 09 JUL 2016 18Z**



500 hPa Geopot. (gpdm) und Bodendruck (hPa) **Mon, 11 JUL 2016 18Z**



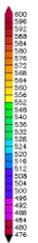
500 hPa Geopot. (gpdm) und Bodendruck (hPa) **Thu, 14 JUL 2016 00Z**



500 hPa Geopot. (gpdm) und Bodendruck (hPa) **Fri, 15 JUL 2016 18Z**



Data: GFS reanalysis 0.500°
(C) Wetterzentrale
www.wetterzentrale.de



Julio 2016: RELACION ENTRE CONCENTRACIONES DE OZONO ($\text{NO}_2 + \text{O}_3 = \text{O}_x$) Y ALTURA DE CAPA DE MEZCLA EN CAMPAÑA

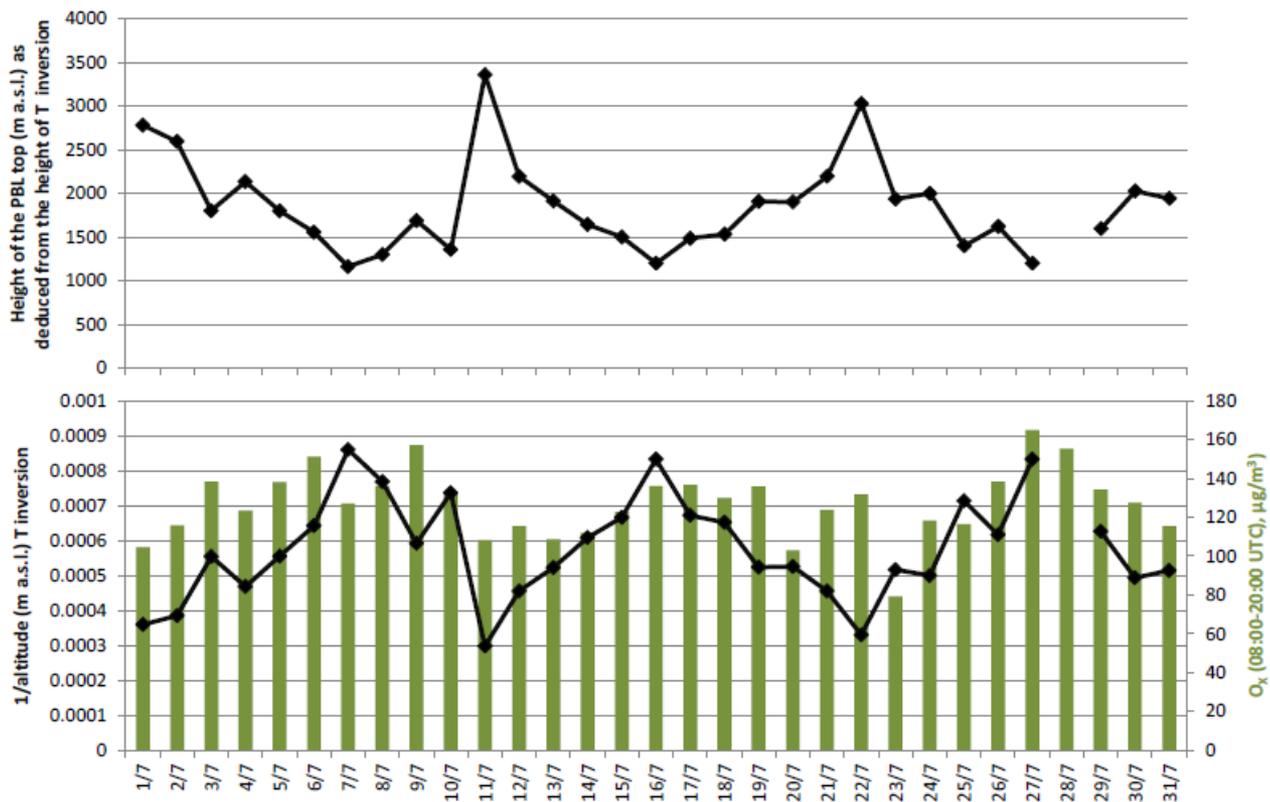
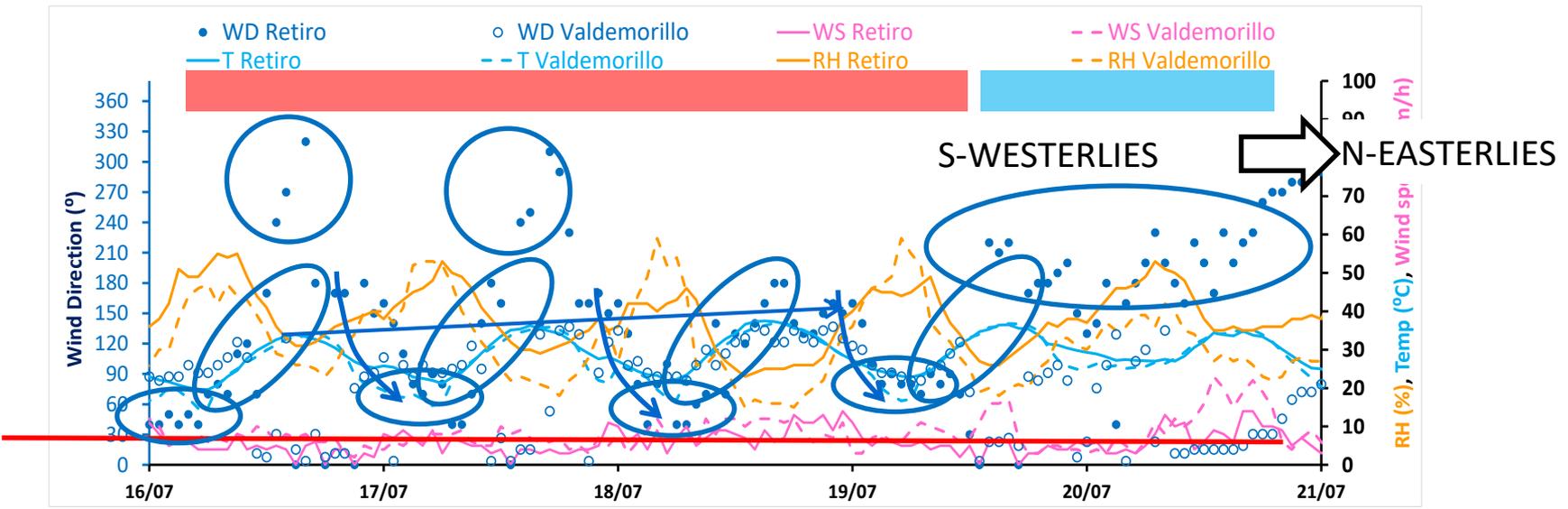
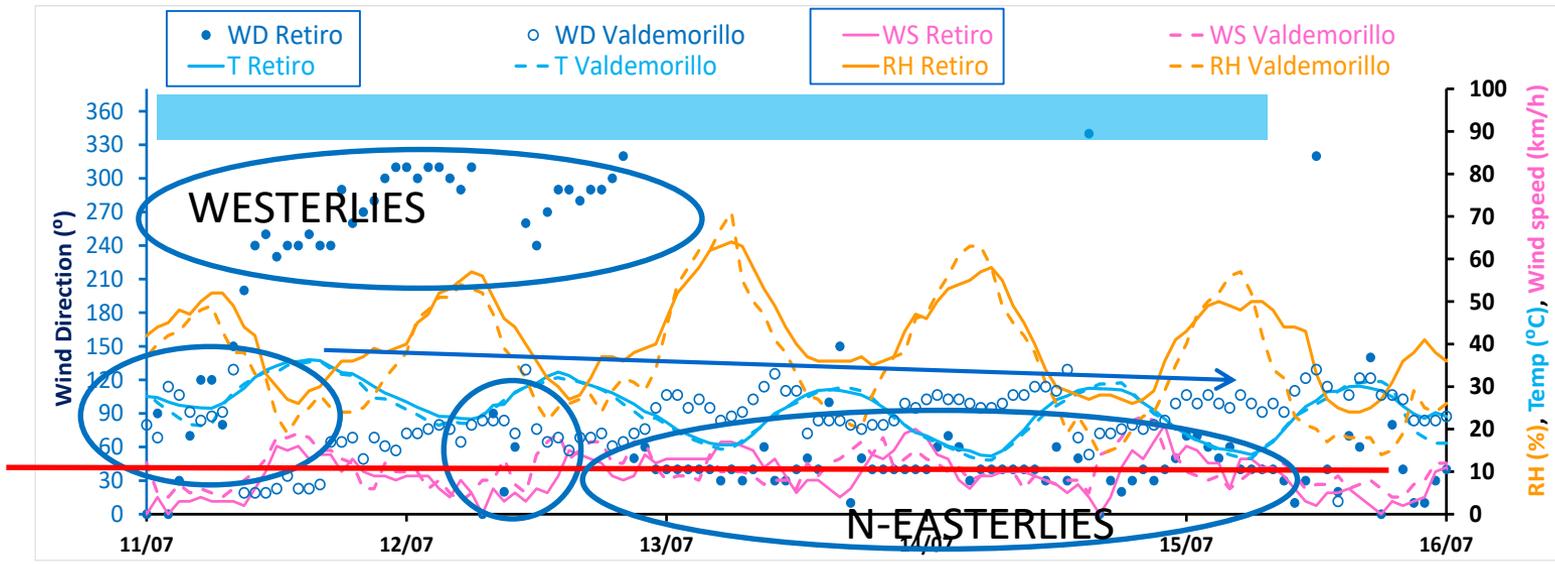


Figure S4. Top: Time series of the midday height of first thermal inversion (top of the PBL, HTPBL) obtained from the daily midday AEMET radio-soundings at Madrid airport for July 2016. Bottom: 1/HTPBL and average 08:00-20:00 UTC O_x concentrations at the MJDH air quality station.

¿Qué NOS DICEN LAS ESTACIONES DE METEO. SOBRE PROCESOS DE ACUMULACION/VENTEO? CAMPAÑA MADRID 2016

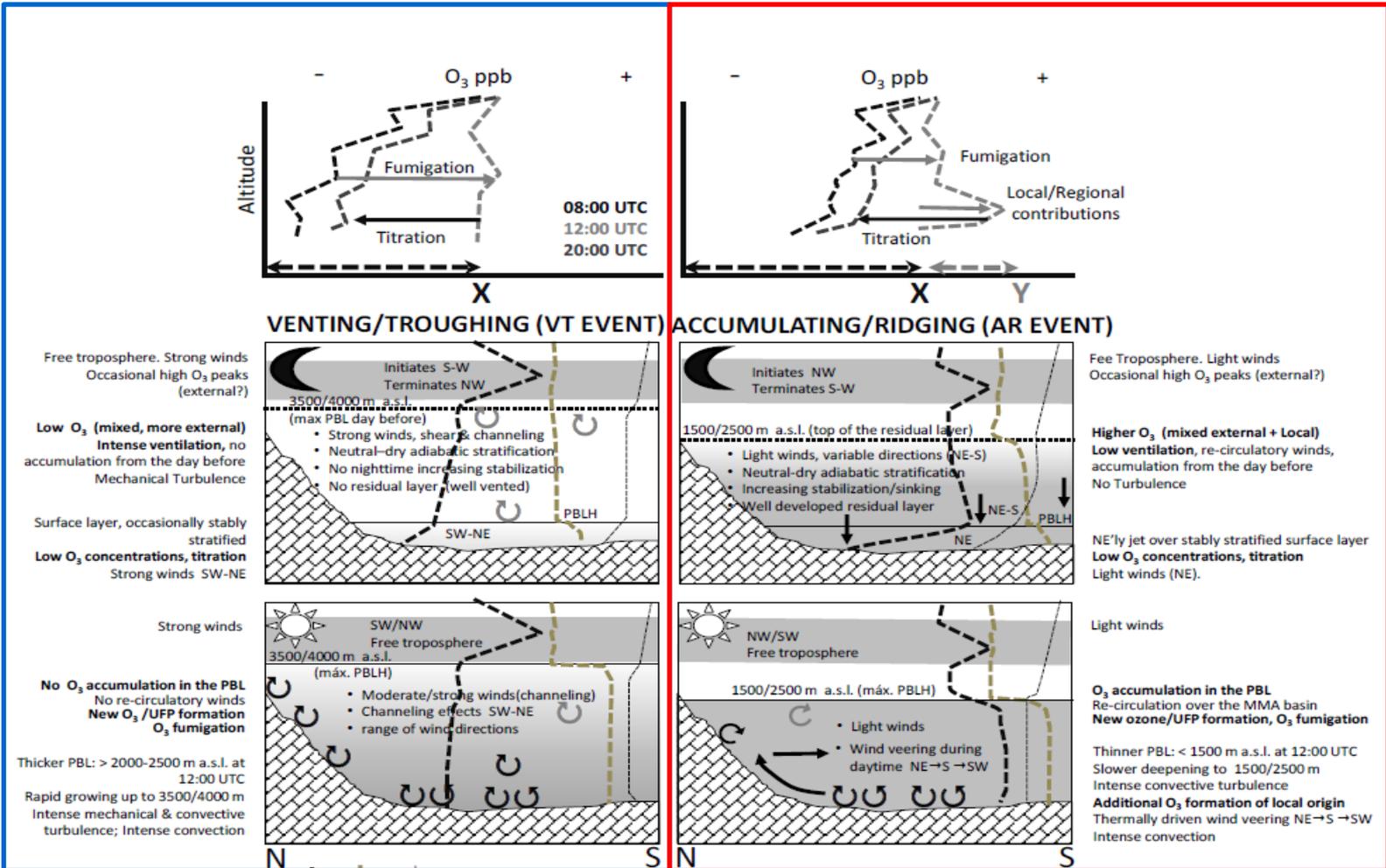


ACCUMULATION CYCLES

4) MADRID: ESQUEMA CONCEPTUAL DE LOS PROCESOS DE VENTEO/ ACUMULACION

VENTEO

ACUMULACIÓN



O₃ | UFP | Potential T | Height PBL | High altitude O₃ strata
 Convection Turbulence ↓ Sinking ↻ Thermally driven circulations

5) CONCLUSIONES

- CADA REGION DE LA PENISULA IBERICA GENERA SUS PROPIOS PROCESOS MESOSCALARES, QUE ESTAN DETRÁS DE LOS EPISODIOS DE ACUMULACION Y VENTEO CARACTERISTICOS DE OZONO. NO TODAS LAS REGIONES/PROCESOS ESTAN AUN DOCUMENTADOS
- NO SE CONOCEN LOS INTERCAMBIOS INTER-REGIONALES EN LA PENÍNSULA, NI CON EL NORTE DE AFRICA, PORTUGAL Y FRANCIA (TERRITORIOS LIMÍTROFES). LA EFECTIVIDAD DE LAS POLÍTICAS DE REDUCCIÓN DE PRECURSORES DEPENDE DE ELLO.