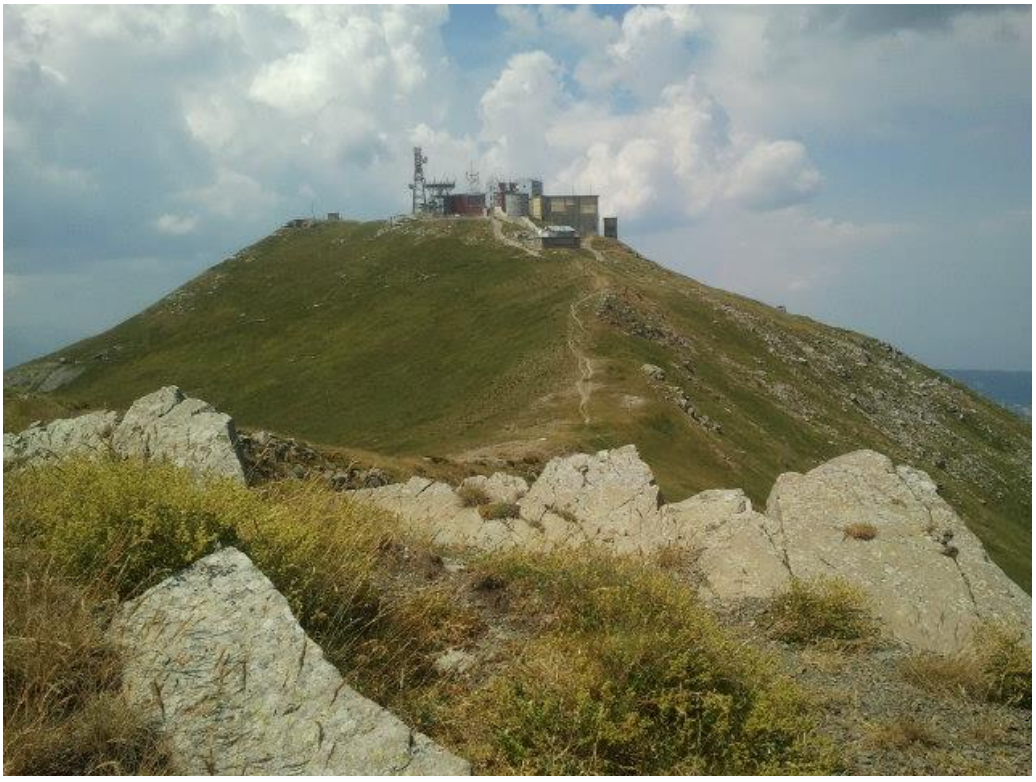
Consiglio Nazionale delle Ricerche
Istituto di Scienze dell'Atmosfera e del Clima

ITALIAN CLIMATE OBSERVATORY "O. VITTORI"
Mt. CIMONE
GAW-WMO Global Station

SUMMER 2015 REPORT



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The research activities and the measurement programmes carried out at the Italian Climate Observatory "O. Vittori" at Mt. Cimone are an Italian contribute to:

WDCGG
World Data Center for Greenhouse Gases
Centro Dati Mondiale per i Gas Serra
http://ds.data.jma.go.jp/gmd/wdcgg/

WDCA
World Data Center for Aerosol
Centro Dati Mondiale per gli Aerosol
http://www.gaw-wdca.org/

MACC-III
Monitoring Atmospheric Composition & Climate
http://gmes-atmosphere.eu/

SDS-WAS
WMO Sand and Dust Storm Warning Advisory and Assessment System
http://sds-was.aemet.es/

AGAGE
Advanced Global Atmospheric Gases Experiment
http://agage.eas.gatech.edu/

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List of contents

Foreword

This report summarizes the results concerning the atmospheric observations carried out during Summer 2015 at the Italian Climate Observatory "O. Vittori" (ICO-OV), managed by the Institute of Atmospheric Sciences and Climate (ISAC) of the National Research Council of Italy (CNR). This research infrastructure is part of the WMO/GAW global station of Monte Cimone together with the Meteorological Observatory of the Italian Air Force (GAW ID: CMN).

Firstly, we provide a brief description of the measurement site and running experimental programmes. Then, an overview of the atmospheric and weather conditions during summer 2015 is provided, by considering:

- **surface ozone**
- **carbon monoxide**
- **nitrogen oxides**
- **sulphur dioxide**
- **black carbon**
- **aerosol scattering coefficient**
- **fine and coarse particles**
- **meteorological data (temperature, relative humidity, pressure, wind speed and direction)**
- **solar radiation and UV-B**

For each atmospheric parameter, we provide basic statistical information (minimum, maximum and average values) together with a comparison with the climatological seasonal reference for Mt. Cimone.

Then, we present a list of special events, together with a description of the adopted selection methodologies:

- **pollution transport**
- **mineral dust transport**
- **transport of air-masses from the stratosphere**

For each observed parameter, a specific paragraph presents:

- **the time series of the daily mean values (calculated basing on 30-minute aggregated values, if the daily data coverage of 75% has been achieved)**
- **a table reporting the basic statistical parameters (on a 30-minute basis)**
- **a comparison with the seasonal historical mean values: for each year, the Summer mean values are calculated by averaging data from 2015, June 1st to 2015, August 31th.**

Premessa

Questo rapporto riassume i risultati relativi alle osservazioni atmosferiche effettuate durante l'estate 2015 presso l'Osservatorio Climatico "O. Vittori " (ICO-OV) dell'Istituto di Scienze dell'Atmosfera e del Clima (ISAC) del Consiglio Nazionale delle Ricerche Italia (CNR). Questa stazione di ricerca è parte, insieme all'Osservatorio Meteorologico dell'Aeronautica Militare, della stazione globale WMO/GAW di Monte Cimone (GAW ID: CMN).

In questo Report viene innanzitutto fornita una breve descrizione del sito di misura e dei programmi di ricerca in atto.

Viene quindi fornita una panoramica delle condizioni atmosferiche e meteorologiche che hanno caratterizzato la stagione estiva del 2015 considerando:

- **ozono superficiale**
- **monossido di carbonio**
- **ossidi di azoto**
- **anidride solforosa**
- **black carbon**
- **particolato fine e grossolano**
- **dati meteorologici (temperatura, umidità relativa, pressione, velocità e direzione del vento)**
- **radiazione solare e UV- B**

Per ogni parametro atmosferico sono fornite informazioni statistiche di base (valore minimo, massimo e medio) ed un confronto con il riferimento climatologico stagionale dell'Osservatorio "O. Vittori" per Monte Cimone.

Successivamente viene presentata una lista di eventi "speciali" identificati con procedure opportunamente messe a punto e descritte.

- **trasporto di masse d'aria inquinate**
- **trasporto di polvere minerale**
- **trasporto di masse d'aria dalla stratosfera**

Per ogni parametro osservato uno specifico paragrafo presenta:

- **Le serie storiche dei valori medi giornalieri (calcolati basandosi su valori mediati di 30 minuti, se la copertura dei dati giornaliera del 75% è stata raggiunta)**
- **Una tabella con i parametri statistici di base (su un base di 30 minuti)**
- **Il confronto con i valori medi storici stagionali per ogni anno, considerando che i valori invernali sono calcolati come media dal 1 giugno 2015 al 31 agosto 2015.**

Monte Cimone GAW/WMO Global Station

The **Global Atmosphere Watch (GAW)** programme of WMO is a partnership involving the Members of WMO, contributing networks and collaborating organizations and bodies which provides reliable scientific data and information on the chemical composition of the atmosphere, its natural and anthropogenic change, and helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere.

A network of measurement stations is the backbone of the GAW programme. This network consists of GAW Global and Regional measurement stations with additional measurements from Contributing stations. Both Global and Regional stations are operated by their host countries, either by their National Meteorological Services or by other national scientific organizations. More than 80 countries actively host GAW stations.

Currently GAW coordinates activities and data from 30 Global stations, more than 400 Regional stations, and around 100 Contributing stations operated by Contributing networks

Location of the 30 Global Stations of the WMO/GAW programme

Mt. Cimone is the only WMO/GAW Global Station in Italy

Global station name	Altitude (a.s.l.)	Country
Assekrem/Tamanrasset	2710 m	Algeria
Izaña	2372 m	Spain
Jungfraujoch	3580 m	Switzerland
Mauna Loa,	3397 m	United States
Monte Cimone*	2165 m	Italy
Mt. Kenya	3678 m	Kenya
Mt. Waliguan	3810 m	China
Nepal Climate Observatory – Pyramid*	5079 m	Nepal
Zugspitze/ Hohenpeissenberg	2962 m	Germany

*Managed by Italian Institutions

*List of GAW/WMO high altitude global station (*for more information: http://gaw.empa.ch/gawsis/)

La Stazione Globale GAW/WMO di Monte Cimone

Il programma **Global Atmosphere Watch (GAW**) dell'OMM coinvolge gli Stati Membri della OMM e diverse reti osservative, organizzazioni ed Istituzioni con lo scopo di fornire dati scientifici ed informazioni attendibili sulla composizione dell'atmosfera, sui cambiamenti naturali e dovuti alle attività umane, contribuendo a migliorare la conoscenza delle interazioni fra atmosfera, oceani e biosfera.

La spina dorsale del programma GAW è costituita dalla propria rete osservativa. Essa è formata da Stazioni Globali e Regionali, oltre che da Stazioni definite "Contributing" che forniscono informazioni addizionali. Le Stazioni Globali e Regionali sono gestite dai Paesi di appartenenza, sia attraverso i Servizi Meteorologici Nazionali che gli Enti Pubblici di Ricerca. Le Stazioni GAW sono ospitate in oltre 80 Paesi del mondo.

Allo stato attuale il programma coordina 30 Stazioni Globali e oltre 400 Stazioni Regionali, oltre a 100 Stazioni "Contributing".

Dislocazione delle 30 Stazioni Globali del programma WMO/GAW

Monte Cimone è l'unica Stazione Globale WMO/GAW in Italia

Nome	Quota (s.l.m.)	Paese
Assekrem/Tamanrasset	2710 m	Algeria
Izaña	2372 m	Spagna
Jungfraujoch	3580 m	Svizzera
Mauna Loa	3397 m	USA
Monte Cimone*	2165 m	Italia
Mt. Kenya	3678 m	Kenya
Mt. Waliguan	3810 m	Cina
Nepal Climate Observatory – Pyramid*	5079 m	Nepal
Zugspitze/ Hohenpeissenberg	2962 m	Germania

*Stazioni gestite da Istituzioni Italiane

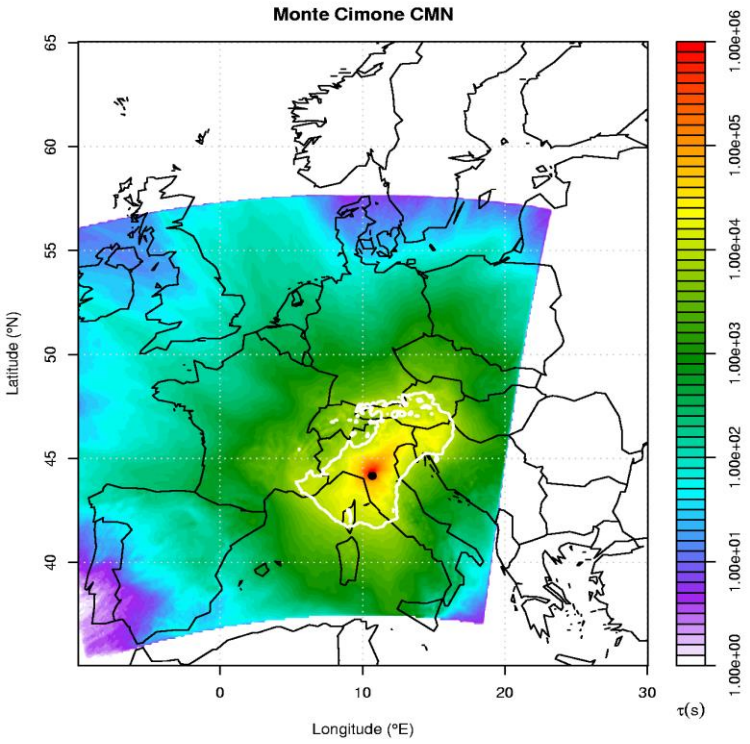
Lista delle stazioni globali GAW/WMO in aree di alta quota (for more information: http://gaw.empa.ch/gawsis/)

Geographical location

Mt. Cimone (44°12' N, 10°42' E, 2165 m a.s.l.) is the highest peak of the Northern Apennines, the border line of two different climatic regions: the continental Europe northwards and the Mediterranean Basin southwards.

The closest inhabited areas are small villages placed 15 km from and about 1100 m below the Observatory, whereas major towns (500000 inhabitants) are situated in the lowlands about 60 km away (Bologna, Firenze). The industrial areas are not closer than 40 km and 2 km lower. The closest roads with some traffic are 7 km far and 1 km lower. Forest of conifers and beech trees grow up to 1600 m, so that the Laboratory is above the timberline. Only some patches of vegetation are on the top of the mountain

Mt. Cimone is characterized by a completely free horizon for 360° and air masses originated in different areas can reach the station. In the following figure, the annual 48-hour catchment areas, (i.e. the areas from which the air masses come) is provided for ICO-OV (EU-Project GEOMON).



The catchment area of the site for the 48-hour integration time backwards in time is given by the intersection of the topography with the volume containing the largest residence time densities and comprises 50% of the total residence time.

Il "bacino di raccolta" delle masse d'aria a 48 ore è ottenuto considerando le aree geografiche sopra le quali si totalizza almeno il 50% del tempo di residenza totale delle masse d'aria durante il trasporto verso Monte Cimone.

For more information: http://geomon.empa.ch/.

The atmospheric observations carried out at Monte Cimone can be considered representative of the free tropospheric conditions of the Mediterranean Basin/South Europe. Only during the warm periods of the year, the measurement site can be affected by transport of air masses from PBL (planetary boundary layer).

Le osservazioni di composizione dell'atmosfera condotte a Monte Cimone possono essere considerate rappresentative delle condizioni di fondo della libera troposfera del bacino del Mediterraneo e del Sud Europa. Solo durante i mesi caldi, i processi convettivi possono favorire il trasporto di masse d'aria dallo strato limite planetario (PBL).

Posizione geografica

Monte Cimone (44°12' N, 10°42' E, 2165 m s.l.m.) è la cima più alta dell'Appennino Settentrionale, la linea di confine tra due diverse regioni climatiche: l'Europa continentale a Nord ed il bacino del Mediterraneo a Sud.

Le zone abitate più vicine sono piccoli paesi a circa 15 km di distanza e 1100 m di più in basso rispetto all'Osservatorio, mentre le città più grandi (Bologna, Firenze) sono situate in pianura a circa 60 km di distanza. Non vi sono importanti aree industriali nel raggio di circa 40 km. Le strade trafficate più vicine distano circa 7 km (1 km di quota più in basso). Boschi di conifere e faggi crescono fino a 1600 m. Nei pressi della cima si trovano prati e zone rocciose.

Monte Cimone è caratterizzato da un orizzonte completamente libero e quindi le masse d'aria possono raggiungere il sito di misura senza incontrare ostacoli orografici. Nella pagine precedente viene mostrata la media annuale del "bacino di raccolta" delle masse d'aria che nel giro di 48 ore sono arrivate a Mt. Cimone (EU-Project GEOMON).

NEWS

New publication: "Organic aerosol evolution and transport observed at Mt. Cimone (2165ma.s.l.), Italy, during the PEGASOS campaign "

High-resolution aerosol mass spectrometer measurements were performed, for the first time, at the Mt. Cimone Global Atmosphere Watch (GAW) station between June and July 2012, within the EU project PEGASOS (http://pegasos.iceht.forth.gr) and the ARPA–Emilia-Romagna project SUPERSITO.

***Submicron aerosol was dominated by organics (63 %),** with sulfate, ammonium and nitrate contributing the remaining 20%, 9% and 7 %, respectively. The observations suggest that **oxidation and secondary organic aerosol (SOA) formation** processes **occurred during aerosol transport** to high altitudes.*

*The measurements enable the separation of different contributions to the organic aerosol (OA) in relatively **fresh OA** originating from the PBL, more **aged OA** present at high altitudes during periods of atmospheric stagnation, and **very aged aerosols** transported over long distances in the free troposphere.*

Nuovo studio: *"Organic aerosol evolution and transport observed at Mt. Cimone (2165ma.s.l.), Italy, during the PEGASOS campaign "*

Nel periodo giugno – luglio 2012 sono state eseguite a Monte Cimone, per la prima volta in un sito montano Italiano, osservazioni di chimica dell'aerosol con un sistema AMS (spettrometro di massa), nell'ambito del progetto europeo PEGASOS e del progetto della regione Emilia-Romagna SUPERSITO.

I risultati mostrano che **l'aerosol sub-micronico è principalmente composto da aerosol organico (63%)**. Le osservazioni suggeriscono che i **processi ossidativi e di formazione dell'aerosol organico secondario (SOA) avvengono durante il trasporto** dell'aerosol a quote elevate.

I risultati conseguiti hanno evidenziato come il **trasporto di inquinanti** ed i **processi chimico fisici** che i medesimi subiscono durante il trasporto hanno un **impatto considerevole sulla composizione atmosferica anche in zone remote e lontane dalle principali sorgenti antropiche**, con **importanti conseguenze a livello climatico**.

***Reference**: Rinaldi M., Gilardoni S., Paglione M., Decesari S., Sandrini S., Fuzzi S., Massoli P., Bonasoni P., Cristofanelli P., Marinoni A., Poluzzi V., and Facchini. M. C., 2015. Organic aerosol evolution and transport observed at Mt. Cimone (2165 m a.s.l.), Italy, during the PEGASOS campaign. Atmospheric Chemistry and Physics, 15, 14403-14443.*

List of parameters

In the following table, we provide the list of the atmospheric parameters observed at ICO-OV, together with a brief description of their key roles in the atmospheric investigations and the experimental set-up.

Parameters	Key role	Instrumentation
Surface ozone	Short-lived climate forcer, greenhouse gas, secondary pollutant	UV-absorption analyser *(Thermo Tei 49i)*
Carbon monoxide	Primary pollutant, ozone precursor, combustion tracer	Non dispersive IR absorption *(Thermo Tei48c-TL)*
Nitrogen oxides	Primary (NO) and secondary (NO_2) pollutants, ozone precursors, combustion tracers.	Chemiluminescence analyser (*Thermo Tei42i-TL)*
Sulphur dioxide	Primary pollutant, secondary aerosol precursor, volcanic tracer.	UV-fluorescence analyser (*Thermo 43i-TLE*)
Black carbon	Short-lived climate forcer, primary pollutant, combustion tracer. It contributes to PM_1	Multi-Angle Absorption Photometer *(Thermo MAAP 5012)*
Aerosol light scattering coefficient	Investigation of the aerosol climate direct forcing	3 –wavelenghts Integrating nephelometer *(TSI 3563)*
Aerosol number concentration (fine)	Short-lived climate forcer, primary and secondary aerosol, pollution tracer. It contributes to PM_1.	Optical particle counter *(GRIMM 1108)*
Aerosol number concentration (coarse)	Short-lived climate forcer, primary aerosol, mineral dust and sea salt tracer. It contributes to PM_{10}.	Optical particle counter *(GRIMM 1108)*
Halogenated gases	Stratospheric ozone depleting substances and climate forcer	Gas chromatography-Mass spectrometry. *(Agilent 6850–5975)*
Volatile organic compounds	Ozone and PM precursors	Gas chromatography-Mass spectrometry *(Agilent 6850–5975)*
Stratospheric nitrogen dioxide	Ozone destroying substance and buffer against halogen catalysed ozone loss	GASCOD-MTC: UV-Vis spectrometer
Temperature and relative humidity	Meteorology and data interpretation	*Rotronic, IRDAM WS 7000*
Atmospheric pressure	Meteorology and data interpretation	*Technoel, IRDAM WS 7000*
Wind	Meteorology and data interpretation	*Vaisala WS425, IRDAM WST7000*
Solar radiation	Meteorology and data interpretation	Silicon cell pyranometer *(Skye SKS110)*
UV-B radiation	Meteorology and data interpretation	Silicon photodiode *(Skye SKU 430)*

Lista dei parametri

Nella tabella è presentata la lista dei parametri osservati, assieme ad una breve descrizione dei ruoli nelle ricerche condotte ed il set up sperimentale utilizzato presso l'ICO-OV.

Parametri	Ruolo chiave clima – qualità dell'aria	Strumentazione
Ozono superficiale	Forzante climatico a breve tempo di vita, gas serra, inquinante secondario.	Analizzatore ad assorbimento UV *(Thermo Tei 49i)*
Monossido di carbonio	Inquinante primario, precursore dell'ozono, tracciante della combustione	Analizzatore ad assorbimento infra-rosso *(Thermo Tei48c-TL)*
Ossidi d'azoto	Inquinanti primari (NO) e secondari (NO_2), precursori dell'ozono, traccianti della combustione. In stratosfera NO_2 influenza le concentrazioni di ozono.	Analizzatore a chemiluminescenza (*Thermo Tei42i-TL)*
Anidride solforosa	Inquinante primario, precursore dell'aerosol secondario, tracciante di eruzioni vulcaniche	Analizzatore a fluorescenza UV (*Thermo Tei43i-TLE)*
Black carbon	Forzante climatico a breve tempo di vita, inquinante primario, tracciante della combustione. Contribuisce al PM_1	Fotometro per l'assorbimento multi-angolare *(Thermo MAAP 5012)*
Coefficiente di scattering delle particelle	Studio della forzante climatica diretta degli aerosol	Nefelometro a 3 lunghezze d'onda *(TSI 3563)*
Numero delle particelle fini	Forzante climatico a breve tempo di vita, aerosol primario e secondario, tracciante dell'inquinamento. Contribuisce al PM_1	Contatore ottico *(GRIMM 1108)*
Numero delle particelle grossolane	Forzante climatico a breve tempo di vita, aerosol primario, tracciante delle polveri minerali e del sale marino. Contribuisce al PM_{10}	Contatore ottico *(GRIMM 1108)*
Gas alogenati	Distruggono l'ozono stratosferico, forzanti climatici	Gas cromatografia-Spettrometria di massa *(Agilent 6850–5975)*
Composti organici volatile	Precursori dell'ozono troposferico e del PM	Gas cromatografia-Spettrometria di massa *(Agilent 6850–5975)*
Biossido di azoto stratosferico	Distrugge l'ozono stratosferico e sostanza "tampone" per alogeni attivi nella deplezione dell'ozono stratosferico	Spettrometro UV/Vis GASCOD-MTC
Temperatura ed umidità relativa	Meteorologia ed interpretazione dei dati	*Rotronic, IRDAM WS 7000*
Pressione atmosferica	Meteorologia ed interpretazione dei dati	*Technoel, IRDAM WS 7000*
Vento	Meteorologia ed interpretazione dei dati	*Vaisala WS425, IRDAM WST7000*
Radiazione solare	Meteorologia ed interpretazione dei dati	Piranometro a celle di silicio *(Skye SKS110)*
Radiazione UV-B	Meteorologia ed interpretazione dei dati	Fotodiodo al silicio *(Skye SKU 430)*

Summary

OVERWIEV

Despite the occurrence of heatwave events, summer 2015 did not present high average levels of short-lived climate forcers (SLCF): a value lower than the climatological mean was observed for black carbon and surface ozone, while fine and coarse particles average concentrations were well comparable with the typical summer values. Only carbon monoxide was higher than the seasonal mean value.

The 42.3 % of the summer season was affected by pollution events, a large number of events on July (17/39) and August (16/39), when strong heatwaves affected the northern Italy.

12 days (13.0 %) were affected by mineral dust transport: the event occurring from July 5th to 8th showed the highest coarse particle average concentration.

The selection methodology allow the identification of 18 days (19.5 %) related with air-mass transport from the stratosphere. The periods from July 25th to 28th and from August 28th to 31st were continuously affected by the occurrence of SI events.

Daily **surface ozone** peak was recorded on 03-07 (80.0 ppb). 30-minute average values ranged from a minimum of 35.0 ppb (29-07) to 101.3 ppb (03-07), with an average seasonal value of 61.5 ppb. This value is slightly lower than the average climatological summer value obtained from the last 19 years (62.4 ppb).

Daily **carbon monoxide** peak was recorded on 12-08 (164.6 ppb). 30-minute average values ranged from a minimum of 59.4 ppb (04-06) to 187.9 ppb (03-07), with an average seasonal value of 123.0 ppb. This value is slightly higher than the average summer value obtained from the last 3 years (117.3 ppb).

Daily **nitric oxide** and **nitrogen dioxide** peaks were recorded on 31-07 (0.06 ppb) and 12-08 (0.31 ppb), respectively. 30-minute average values ranged from values below the detection limit to 0.23 ppb (for NO) and 2.06 ppb (for NO_2).

Daily **sulfur dioxide** peak was recorded on 12-08 (1.22 ppb). 30-minute average values ranged from values below the detection limit to 2.38 ppb (12-08), with an average seasonal value below the detection limit.

Daily **black carbon** peak was recorded on 02-07 (588.1 ng m^{-3}). 30-minute average values ranged from a minimum of 10.3 ng m^{-3} (16-08) to 1291.9 ng m^{-3} (02-07), with an average seasonal value of 266.6 ng m^{-3}. This value is slightly lower than the average climatological summer value obtained from the last 10 years (285.7 ng m^{-3}).

Sommario

VISIONE DI INSIEME

Seppur caratterizzata da eventi di ondate di calore, l'estate del 2015 non ha presentato valori medi elevati di *short-lived climate forcers* (SLCF): il black carbon e l'ozono hanno mostrato valori inferiori rispetto alle medie climatologiche, mentre i valori delle particelle fini e grossolane risultano essere in linea con i valori climatologici estivi. Solo il monossido di carbonio ha superato i valori medi climatologici estivi.

Tuttavia, il 42.3 % della stagione è stato influenzato da eventi di inquinamento, specialmente nel mese di luglio (agosto), quando sono stati osservati 17 (16) dei 39 eventi per lo più in concomitanza con le ondate di calore che hanno interessato il Nord Italia.

Eventi di trasporto di sabbia sahariana hanno interessato il sito di misura per 12 giorni (13.0% della stagione).

La metodologia di selezione ha permesso di identificare 18 eventi associabili a trasporto di masse d'aria provenienti dalla stratosfera: su base giornaliera, i periodi compresi fra il 25 ed il 28 luglio e tra il 28 ed il 31 Agosto sono stati interessati da tali eventi.

Il valore massimo giornaliero della concentrazione di **ozono superficiale** è stato registrato il 03-07 (80.0 ppb). Le medie semi-orarie variano da 35.0 ppb (29-07) a 101.3 ppb (03-07), con un valore medio stagionale di 61.5 ppb. Tale valore è leggermente inferiore a quello climatologico relativo agli ultimi 19 anni (62.4 ppb).

Il valore massimo giornaliero della concentrazione di **monossido di carbonio** è stato registrato il 12-08 (164.6 ppb). Le medie semi-orarie variano da 59.4 ppb (04-06) a 187.9 ppb (03-07), con un valore medio stagionale pari a 123.0 ppb. Tale valore è leggermente superiore a quello delle ultime tre stagioni estive (117.3 ppb).

I valori massimi giornalieri di **ossido d'azoto** e **biossido d'azoto** sono stati registrati rispettivamente il 31-07 (0.06 ppb) e il 12-08 (0.31 ppb). Le medie semi-orarie sono variate da valori inferiori al limite di rivelazione sino a 0.23 ppb (per NO) e 2.06 ppb (per NO_2).

Il valore massimo giornaliero di **biossido di zolfo** è stato registrato il 12-08 (1.22 ppb). Le medie semi-orarie sono variate da valori inferiori al limite di rilevabilità sino a 2.38 ppb (12-08), con un valore medio stagionale inferiore al limite di rilevabilità.

Il valore massimo giornaliero della concentrazione di **black carbon** è stato registrato il 02-07 (588.1 ng m^{-3}). Le medie semi-orarie variano da 10.3 ng m^{-3} (16-08) a 1291.9 ng m^{-3} (02-07), con un valore medio stagionale pari a 266.6 ng m^{-3}. Tale valore è leggermente inferiore a quello climatologico relativo agli ultimi 10 anni (285.7 ng m^{-3}).

Daily **fine aerosol particles** peak was recorded on 30-06 (137.4 cm^{-3}). 30-minute average values ranged from below the detection limit to 181.6 cm^{-3} (30-06), with an average seasonal value of 36.4 cm^{-3}. This value is on par with the average climatological summer value obtained from the last 13 years (36.4 cm^{-3}).

Daily **coarse aerosol particles** peak was recorded on 06-07 (1.3 cm^{-3}). 30-minute average values ranged from below the detection limit to 4.3 cm^{-3} (07-08), with an average seasonal value of 0.3 cm^{-3}. This value is on par with the average climatological summer value obtained from the last 13 years (0.3 cm^{-3}).

Daily **aerosol scattering coefficient at 550 nm** peak was recorded on 02-07 (59.9 Mm^{-1}). 30-minute average values ranged from below the detection limit to 232.1 Mm^{-1} (06-07), with an average seasonal value of 26.2 Mm^{-1}. This value is considerably lower than the average climatological summer value obtained from the last 8 years (38.0 Mm^{-1}).

Il valore massimo giornaliero della concentrazione di **particelle fini** è stato registrato il 30-06 (137.4 cm^{-3}). Le medie semi-orarie variano da valori inferiori al limite di rivelazione a 181.6 cm^{-3} (30-06), con un valore medio stagionale pari a 36.4 cm^{-3}. Tale valore è pari a quello climatologico degli ultimi 10 anni (36.4 cm^{-3}).

Il valore massimo giornaliero della concentrazione di **particelle grossolane** è stato registrato il 06-07 (1.3 cm^{-3}). Le medie semi-orarie variano da valori inferiori al limite di rivelazione a 4.3 cm^{-3} (07-08), con un valore medio stagionale pari a 0.3 cm^{-3}. Tale valore è in linea con quello climatologico relativo agli ultimi 13 anni (0.3 cm^{-3}).

Il picco giornaliero del **coefficiente di scattering dell'aerosol a 550 nm** è stato osservato il 02-07 (59.9 Mm^{-1}). Le medie sui 30-minuti oscillano tra valori inferiori al limite di rilevabilità e 232.1 Mm^{-1} (06-07), con un valore medio stagionale di 26.2 Mm^{-1} che risulta essere considerevolmente inferiore al valore medio climatologico relativo agli ultimi 8 anni (38.0 Mm^{-1}).

Daily **air temperature** peak was recorded on 07-07 (18.6 °C), minimum on 24-06 (5.3 °C). 30-minute average values ranged from a minimum of 3.7 °C (25-06) to 22.1 °C (04-07), with an average seasonal value of 12.1 °C, which is higher than the seasonal climatological value (10.5 °C).

Daily **relative humidity** minimum was recorded on 31-08 (45.1%). 30-minute average values ranged from a minimum of 8.8 % (11-07) to a maximum of 100.0 % (observed on 11 days), with an average seasonal value of 74.7 %. This value is comparable to the average climatological summer value obtained from the last 19 years (76.2 %).

Daily **atmospheric pressure** peak was recorded on 03-07 (803.0 hPa), the lowest value on 16-08 (787.1 hPa). 30-minute average values ranged from a minimum of 786.2 hPa (23-06) to 804.7 hPa (03-07), with an average seasonal value of 794.6 hPa, which is slightly higher than the average climatological summer value obtained from the last 19 years (792.7 hPa).

Daily **wind speed** peak was recorded on 11-08 (10.8 m s^{-1}). 30-minute average values ranged from a minimum of 0.3 m s^{-1} (01-07) to a maximum of 20.0 m s^{-1} (24-08), with an average seasonal value of 4.4 m s^{-1}. This value is lower than the climatological summer value (6.4 m s^{-1}).

Wind direction was prevalently SW (31.9 % of 30-minute data), in line with the climatological analysis over the last 19 years .

Daily **solar radiation** highest average daily value was recorded on 30-07 (413.9 W m^{-2}), with clear sky conditions observed throughout. The lowest average daily value (62.5 W m^{-2}) was observed on 10-08. This day, like two other with average values below 100 W m^{-2}, represents day characterized by the presence of cloud cover at the measurement site.

A similar trend was also observed for **UV-B radiation**, with the highest value observed on 20-07 (0.67 W m^{-2}).

Il valore massimo giornaliero della **temperatura** è stato registrato il 07-07 (18.6 °C), il valore minimo il 24-06 (5.3 °C). Le medie semi-orarie variano da 3.7 °C (25-06) a 22.1 °C (04-07), con un valore medio stagionale pari a 12.1 °C, superiore a quello medio climatologico estivo (10.5 °C).

Il valore minimo giornaliero dell'**umidità relativa** è stato registrato il 31-08 (45.1 %). Le medie semi-orarie variano da 8.8 % (11-07) a 100 % (osservato in 11 giornate), con un valore medio stagionale pari a 74.7 %. Tale valore è confrontabile con quello climatologico relativo agli ultimi 19 anni (76.2 %).

Il valore massimo giornaliero della **pressione atmosferica** è stato registrato il 03-07 (803.0 hPa), il valore minimo il 16-08 (787.1 hPa). Le medie semi-orarie variano da 786.2 hPa (23-06) a 804.7 hPa (03-07), con un valore medio stagionale pari a 794.6 hPa, leggermente superiore a quello climatologico relativo agli ultimi 19 anni (792.7 hPa).

Il valore massimo giornaliero della **velocità del vento** è stato registrato il 11-08 (10.8 m s^{-1}). Le medie semi-orarie variano da 0.3 m s^{-1} (01-07) a 20.0 m s^{-1} (24-08), con un valore medio stagionale pari a 4.4 m s^{-1}. Tale valore è inferiore rispetto a quello climatologico ottenuto dalle misure realizzate negli ultimi 19 anni (6.4 m s^{-1}).

La **direzione del vento** osservata nell' estate 2015 è stata prevalentemente da Sud-Ovest (31.9 % dei dati semi-orari), in linea con la climatologica prevalenza di venti sudoccidentali.

La **radiazione solare** mostra il valore giornaliero massimo il 30-07 (413.9 W m^{-2}), con valori elevati associati a condizioni di cielo libero da nubi osservate per quasi tutta la stagione. Il minimo giornaliero (62.5 W m^{-2}) è stato osservato il 10-08. Tale giornata, insieme ad altre due caratterizzate da valori medi inferiori a 100 W m^{-2}, rappresentano giornate caratterizzate dalla presenza di copertura nuvolosa.

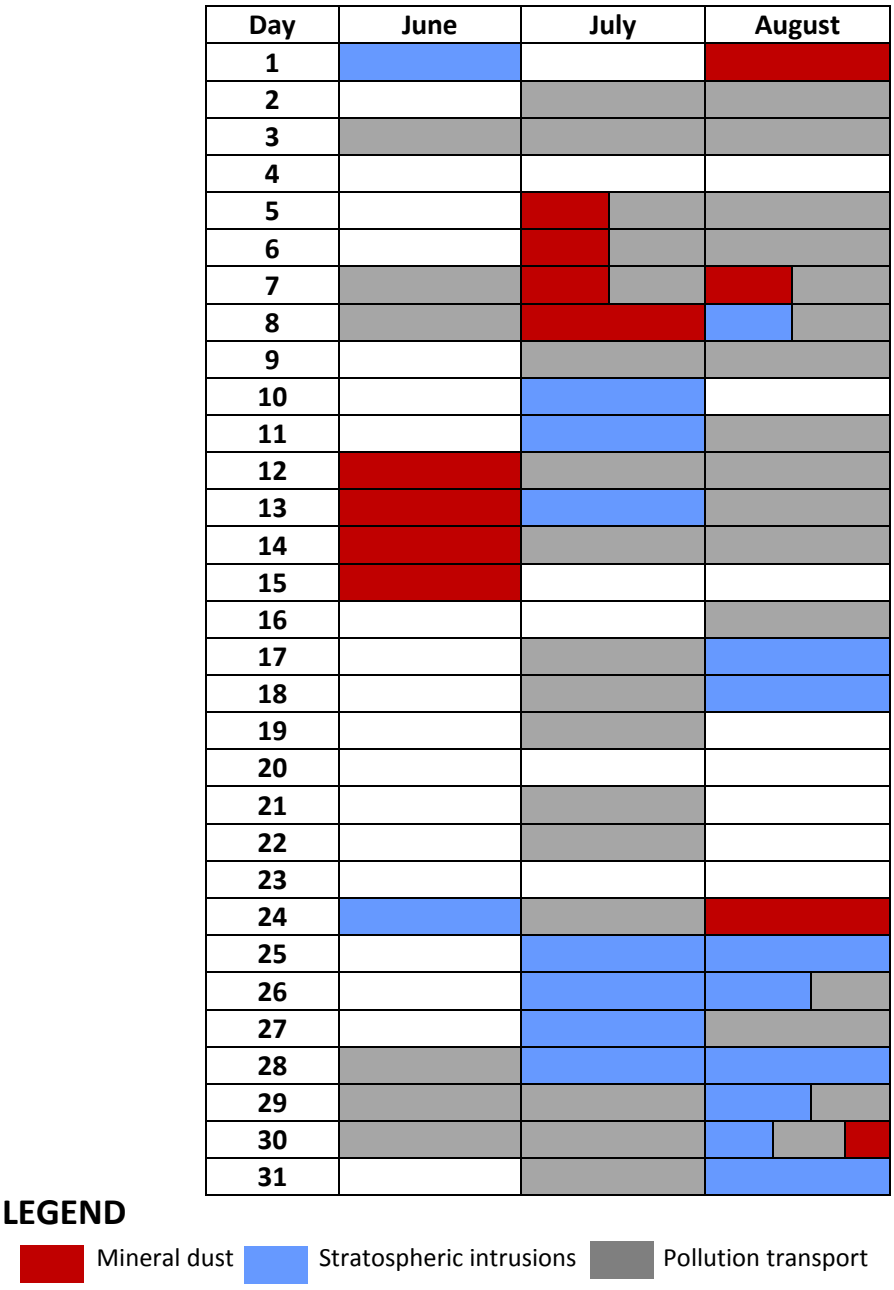
Analogo comportamento viene osservato per quanto riguarda la **radiazione UV**, con il massimo giornaliero, pari a 0.67 W m^{-2}, osservato il 20-07.

Special events

In this paragraph, we present a detailed overview of “special events” which have been detected at the ICO-OV during the reference period, namely:

- **Mineral Dust transport**
- **Stratospheric intrusions;**
- **Pollution transport;**

Please note that the event selection methodologies are executed on 30-minute basis, thus, for the same day, different classes of special events can be observed.

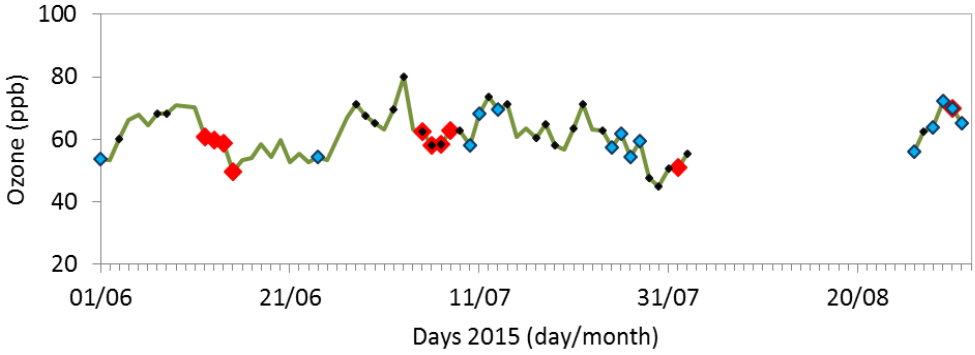


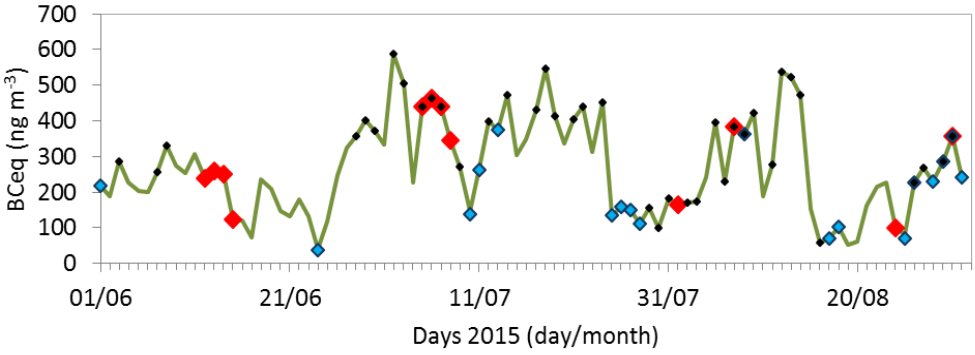
Eventi speciali

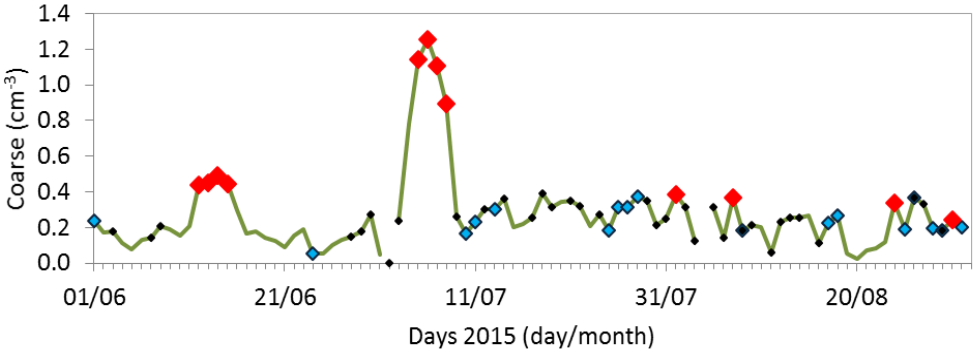
In questo paragrafo viene presentato l'elenco degli "eventi speciali" che sono stati registrati presso il sito di misura durante il periodo analizzato:

- **Trasporto di polveri minerali;**
- **Intrusioni stratosferiche;**
- **Trasporto di inquinanti**

Va notato che le metodologie di selezione degli eventi sono calcolate a partire dai dati a 30-minuti, quindi, per lo stesso giorno, possono essere osservate diverse tipologie di evento.







LEGENDA

Trasporto polveri minerali | Intrusioni stratosferiche | Trasporto di inquinanti

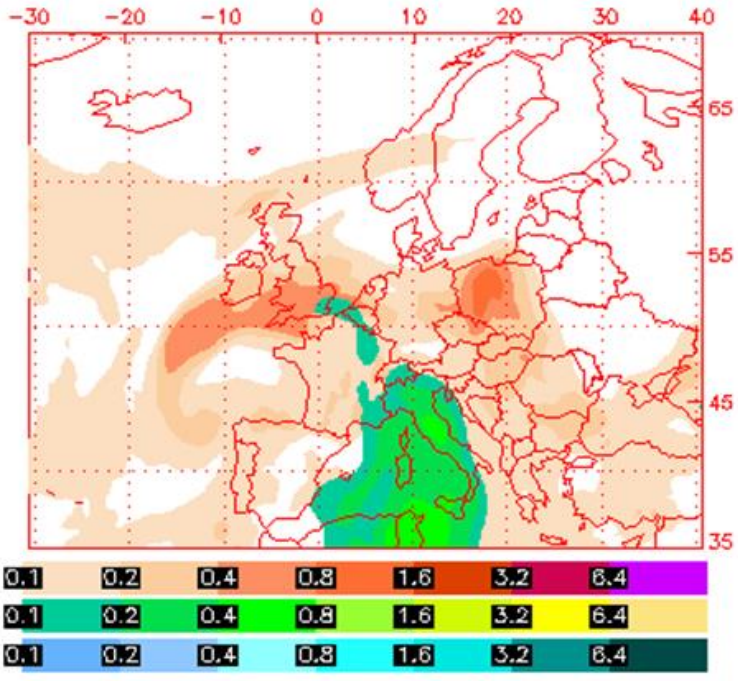
Mineral dust transport

The presence of mineral dust in the atmosphere plays direct and indirect role in affecting climate variations. Moreover, mineral dust can seriously affect air quality in regions downwind of desert areas, contributing to PM_{10} levels. Sahara desert exports more mineral dust than any other area of the world, injecting into the atmosphere millions of Tons of dust particles. Mt. Cimone represents one of the first mountain ridges that Saharan dust meet along their tracks towards Italy and Europe.

Selection methodology: we detected a Saharan dust event when the atmospheric concentration of coarse particles (particles with diameter 1 µm ≤ Dp≤ 20 µm) significantly increased with air-masses coming from North Africa, as deduced by three-dimensional air-mass back-trajectories and transport model outputs.

SUMMER 2015:

- **12 days were characterized by the transport of mineral dust from northern Africa (13.0 % of the period).**
- **The mineral dust transport event are evenly distribute throughout the season, with June and July characterized by the presence of a single event lasting for four days.**
- **The highest daily average coarse particle number concentration (1.3 cm^{-3}) was observed during the 5th – 8th July transport event, when the African anticyclone moved northward.**



Dust transport event simulation by NAAPS model (12th June 2015).

Simulazione dell'evento di trasporto di polveri minerali osservato il 12 Giugno2015 (modello NAAPS).

http://www.nrlmry.navy.mil/
Courtesy by NRL/Monterey Aerosol Modeling.

Trasporto di polveri minerali

La presenza di aerosol (polveri) minerali nell'atmosfera può influenzare il clima attraverso effetti diretti ed indiretti. Esse possono inoltre alterare in modo significativo la qualità dell'aria in regioni prossime alle aree di emissione o soggette a fenomeni di trasporto, influenzando le concentrazioni di PM_{10}. Masse d'aria ricche di polveri minerali possono essere trasportate dal deserto del Sahara, la più importante sorgente al mondo di polveri minerali, verso l'Italia e l'Europa. Mt. Cimone rappresenta uno dei primi rilievi montuosi che queste masse d'aria incontrano durante il loro movimento verso nord.

Metodologia di selezione: gli eventi di trasporto di polveri sahariane sono stati identificati quando la concentrazione delle particelle grossolane (1 µm ≤ Dp ≤ 20 µm) è aumentata in modo significativo con l'arrivo di masse d'aria provenienti dal nord Africa, come indicato da analisi di retro-traiettorie tri-dimensionali delle masse d'aria e da modelli di trasporto.

ESTATE 2015:

- **12 giorni sono stati caratterizzati dal trasporto di polveri minerali proveniente dal Nord Africa (13.0 % del periodo).**
- **Gli eventi di trasporto sono uniformemente distribuiti nei 3 mesi, con i mesi di giugno e luglio caratterizzati dalla presenza di singoli eventi della durata di 4 giorni.**
- **Il picco di concentrazione di particelle grossolane (1.3 cm^{-3}) è stato osservato durante il trasporto di aerosol minerale del 5 – 8 luglio.**

Dust transport observed by MODIS sensor on-board on AQUA and TERRA NASA satellite (14th June 2015). The brownish clouds represent mineral dust transported toward Monte Cimone.

Rappresentazione tramite immagine a colori dei satelliti Terra/Aqua dell'evento di trasporto di polveri minerali osservato il 14 Giugno 2015. Sono evidenti le masse d'aria ricche di aerosol minerale che vengono trasportate verso Monte Cimone.

https://earthdata.nasa.gov
Courtesy by NASA - Worldview

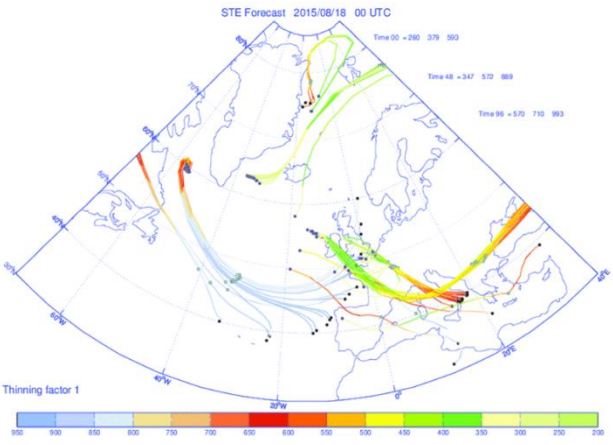
Stratospheric intrusions (SI)

Stratospheric intrusions (SI) can be considered as a specific aspect of stratosphere–troposphere exchange (STE): the irreversible downward transport of stratospheric air relatively deep into the troposphere. Such phenomena are highly episodic and can be favored by a number of different mechanisms, acting on different geographical and temporal scales: tropopause folding and cut-off lows at upper levels, and fronts or high-pressure systems at the surface.
Even though it has been assessed that nowadays the greatest contribution to tropospheric ozone concentrations comes from photochemical production, the contribution from STE is far from negligible, in particular in the free troposphere. For these reasons, at ICO-OV the frequency of SI and its contribution to ozone is assessed.

Selection methodology: at Mt. Cimone, we identified days probably affected by air-mass transport from the stratosphere or from the upper free troposphere by selecting the measurement periods characterized by at least 6 hours of relatively dry conditions (RH<60%) during which RH also reached a value below 30 %, together with analysis of air-mass three-dimensional back-trajectories corroborating the origin of the air masses (daily potential vorticity maximum at least 1.6 pvu).

SUMMER 2015:

- **During summer 2015, we detected 18 days affected by the transport of air masses from the stratosphere, representing the 19.6 % of the analysed period.**
- **The highest ozone concentration during a STE was observed on August 29th, with a daily average of 72.3 ppb.**
- **August 25th – 31th represents the longest seasonal period continuously interested (with the exception of August 27th) by the presence of Stratospheric Intrusions.**



Trajectories describing the path of stratospheric air-masses for the event of 18th August 2015. The color code represents the air-mass height (expressed as pressure level).
Courtesy by Michael Sprenger (ETH-Z, Switzerland)

Traiettorie che descrivono il moto in atmosfera di masse d'aria d'origine stratosferica per l'evento del 18 agosto 2015. Il colore rappresenta la quota (espressa come livello di pressione) delle masse d'aria.

Elaborazione: Michael Sprenger (ETH-Z, Switzerland)

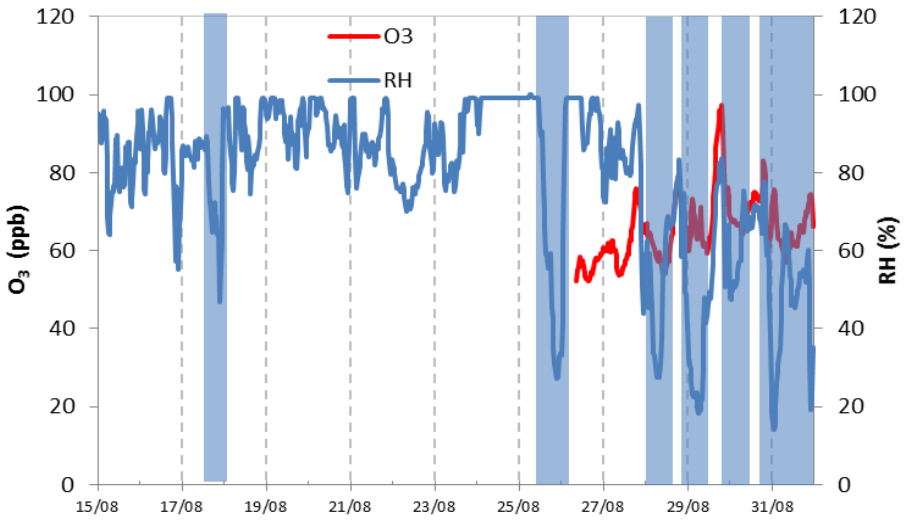
Intrusioni stratosferiche (SI)

Le intrusioni stratosferiche (SI) possono essere considerate un aspetto specifico degli scambi stratosfera-troposfera (STE). Tali fenomeni, che avvengono in maniera episodica, possono essere favoriti da processi dinamici e meteorologici caratteristici che agiscono su differenti scale spazio-temporali: ripiegamento della tropopausa, cut-off low, sistemi frontali o aree di alta pressione.
Sebbene il processo più importante che influenza la variabilità dell'ozono in troposfera sia oggi rappresentato dalla produzione fotochimica, il contributo dei processi STE è tutt'altro che trascurabile, in particolare nella libera troposfera. Per queste ragioni, presso l'ICO-OV viene effettuata l'identificazione e lo studio di questa classe di fenomeni.

Metodologia di selezione: a Mt. Cimone, sono stati identificati gli eventi di trasporto di masse d'aria dalla stratosfera o dalla parte superiore della libera troposfera come i periodi caratterizzati per almeno 6 ore dalla presenza di masse d'aria relativamente secche (RH<60%) e che abbiano presentato valori minimi di RH inferiori al 30%. Retro-traiettorie tridimensionali delle masse d'aria, sono state utilizzate per corroborare l'origine degli eventi (valore massimo giornaliero della vorticità potenziale superiore a 1.6 pvu).

ESTATE 2015:

- **Durante l'estate 2015 sono stati identificati 18 episodi di intrusione stratosferica, corrispondenti al 19.6 % del periodo analizzato.**
- **Il 29 Agosto è stata osservata la concentrazione stagionale di ozono più elevata durante un evento di intrusione stratosferica (valore medio giornaliero: 72.3 ppb).**
- **Il periodo compreso tra il 25 ed il 31 Agosto, con l'eccezione del 27 Agosto, è stato caratterizzato dalla continua presenza di intrusioni stratosferiche.**



Relative humidity (blue) and ozone (red) behaviors at CMN during the 15th – 31th August 2015. The blue bars indicates the days probably affected by SI.

Andamento dell'umidità relativa (azzurro) ed ozono (rosso) nel periodo 15 - 31 Agosto 2015. Le barre azzurre indica il periodo probabilmente influenzato dagli eventi di SI.

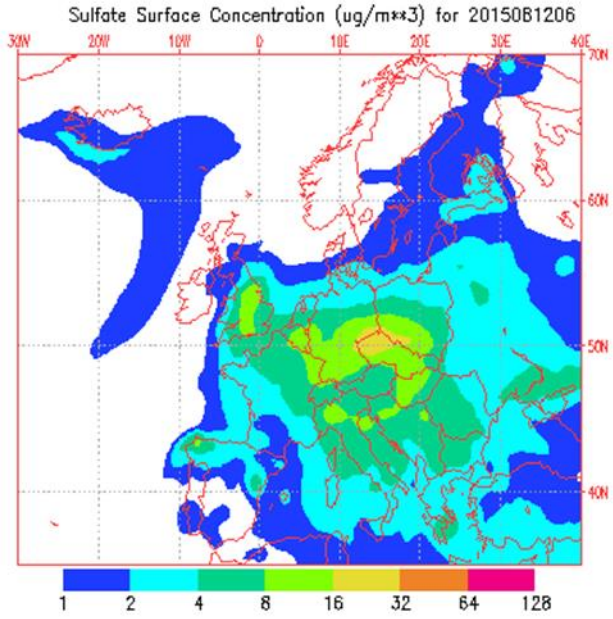
Pollution transport

The Mediterranean region represents a global hot-spot in terms of climate change and atmospheric composition variability while the Po Basin on which Mt. Cimone leans out, is considered one of the major polluted European regions. In particular during the summer seasons, when the high solar irradiance characterized these areas, many anthropogenic pollutants, including photochemically produced ozone can affect the lower troposphere. With the goal of better evaluating the influence of these processes on the atmospheric composition variability, polluted air-mass transport phenomena are systematically identified and investigated at ICO-OV.

Selection methodology: at Mt. Cimone, days possibly affected by polluted air-mass transport are identified by selecting the measurement periods for which at least two "primary" pollutants (CO, NO, BC, NO_2) showed average daily values higher than the monthly climatological mean value.

SUMMER 2015

- **39 days were characterized by significant transport of polluted air masses (42.3 % of the period).**
- **During the "heat wave" conditions registered at Mt. Cimone during July (August) 17 (16) of the identified pollution transport were observed. The enhanced temperature, associated with the "heat waves", could provoke an increase in the diurnal convective expansion of the local Planetary Boundary Layer (PBL). This in turn could favor the transport of polluted air masses to altitudes that would usually be in the free troposphere, thus explaining the associated increased frequency of episodes of pollution's transport.**



Sulfate transport simulation by NAAPS model (12th August 2015). The colored scale represents the sulfate mixing ratio expressed as μg m^{-3}.

Simulazione del trasporto di solfati (inquinamento antropico) del 12 agosto 2015 (modello NAAPS). La scala colorata rappresenta la concentrazione dei solfati, espressa in μg m^{-3}.

http://www.nrlmry.navy.mil/

Courtesy by NRL/Monterey Aerosol Modeling

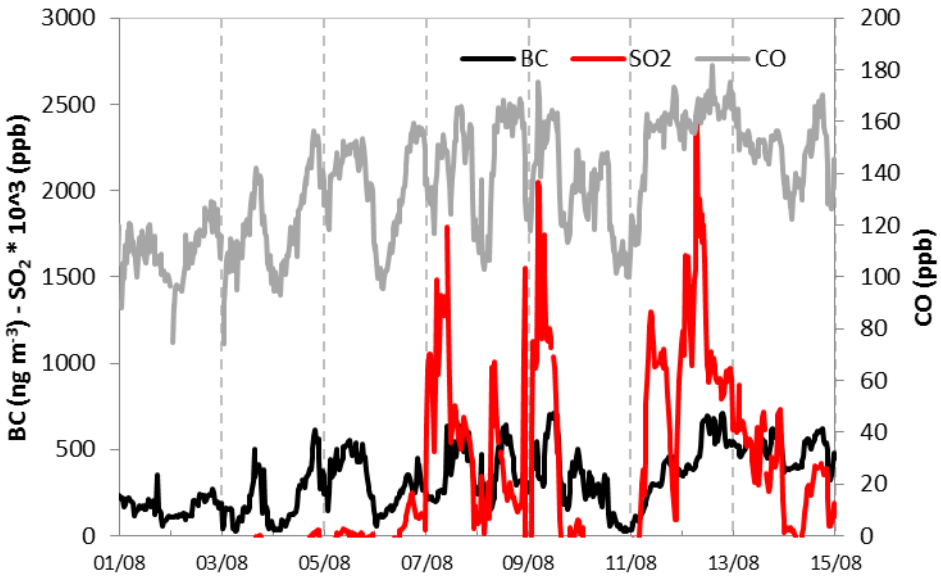
Trasporto di inquinanti

Il bacino del Mediterraneo rappresenta un "hot-spot" globale per quanto riguarda i cambiamenti del clima e della composizione dell'atmosfera, mentre la Pianura Padana rappresenta un'importante area sorgente di inquinamento antropico. In particolare durante l'estate, a causa dell'alto irraggiamento solare che caratterizza queste regioni, esse sono interessate da intensi eventi di produzione fotochimica e di ozono nella bassa troposfera. Con lo scopo di valutare l'influenza di tali eventi sulla composizione dell'atmosfera, i fenomeni di trasporto di masse d'aria inquinate sono sistematicamente identificati e studiati a Mt. Cimone

Metodologia di selezione: a Mt. Cimone, sono stati identificati i giorni possibilmente affetti da trasporto di masse d'aria inquinate selezionando i periodi di misura per i quali i valori medi giornalieri di almeno due inquinanti "primari" (CO, NO, BC, NO_2) siano superiori alle loro medie mensili climatologiche

ESTATE 2015

- **39 giorni (42.3% della stagione), sono stati caratterizzati da episodi significativi di trasporto di masse d'aria inquinate.**
- **Durante il mese di luglio (agosto) si sono verificati 17 (16) dei 39 episodi di trasporto di inquinanti individuati, in concomitanza con i valori più elevati di temperatura e pressione osservati a Monte Cimone. L'aumento delle temperature potrebbe aver provocato un maggiore innalzamento convettivo diurno del PBL, che potrebbe a sua volta favorire il trasporto di masse d'aria inquinate a quote solitamente facenti parte della libera troposfera, giustificando la maggiore frequenza di episodi di trasporto di inquinanti durante i mesi di Luglio ed Agosto.**



BC, SO_2, and CO behaviours at Mt. Cimone from 1st to 15th August 2015, during a major pollution event.

Andamento delle concentrazioni di BC, SO_2, e CO a Monte Cimone (1 – 15 agosto2015), durante il più lungo evento di inquinamento dell'estate 2015.

Surface ozone

Why is ozone so important?

Ozone (O_3) is one of the most important Short-Lived Climate Forcers and Pollutant (SLCF/P), being a powerful greenhouse gas at regional scale. Due to its chemical properties, O_3 is also a dangerous secondary pollutant in the lower troposphere. Its tropospheric mixing ratios are also affected by natural processes, e.g. stratospheric intrusions and lightning production. Being the precursor of oxidizing substances like OH radical and NO_3, O_3 is one of the key agents determining the oxidation capacity of the troposphere.

Instrumentation and calibration

Surface ozone is measured by using a UV-absorption analyser (Thermo Tei 49i). Intercomparisons with the laboratory standard (Thermo 49iPS, traced back to SRP#15 at the World Calibration Centre for surface ozone at WCC-EMPA of Zürich) are carried out every 3-months.

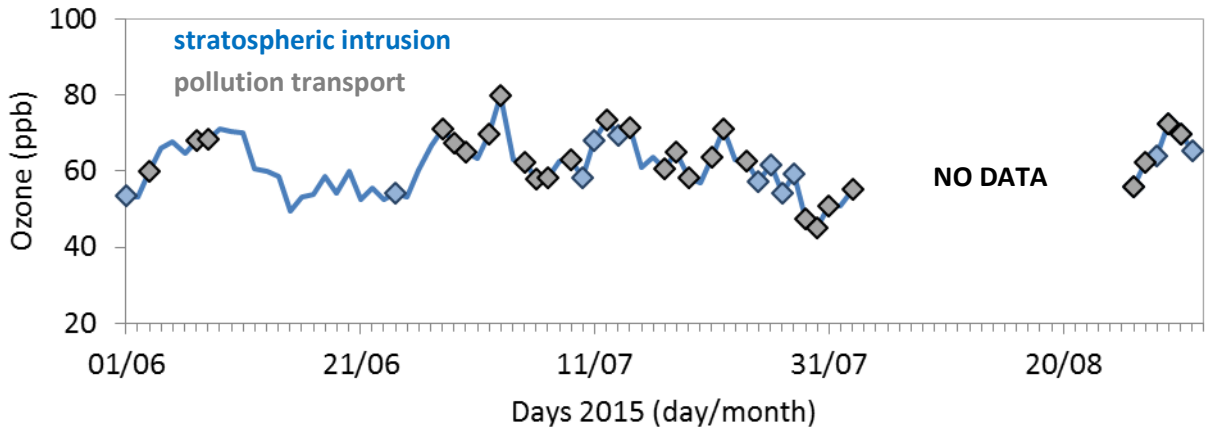
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (ppb)	25th Percentile (ppb)	50th Percentile (ppb)	Average mean value (ppb)	75th percentile (ppb)	Max value (ppb)
74.6	35.0	55.1	60.8	61.5	67.3	101.3

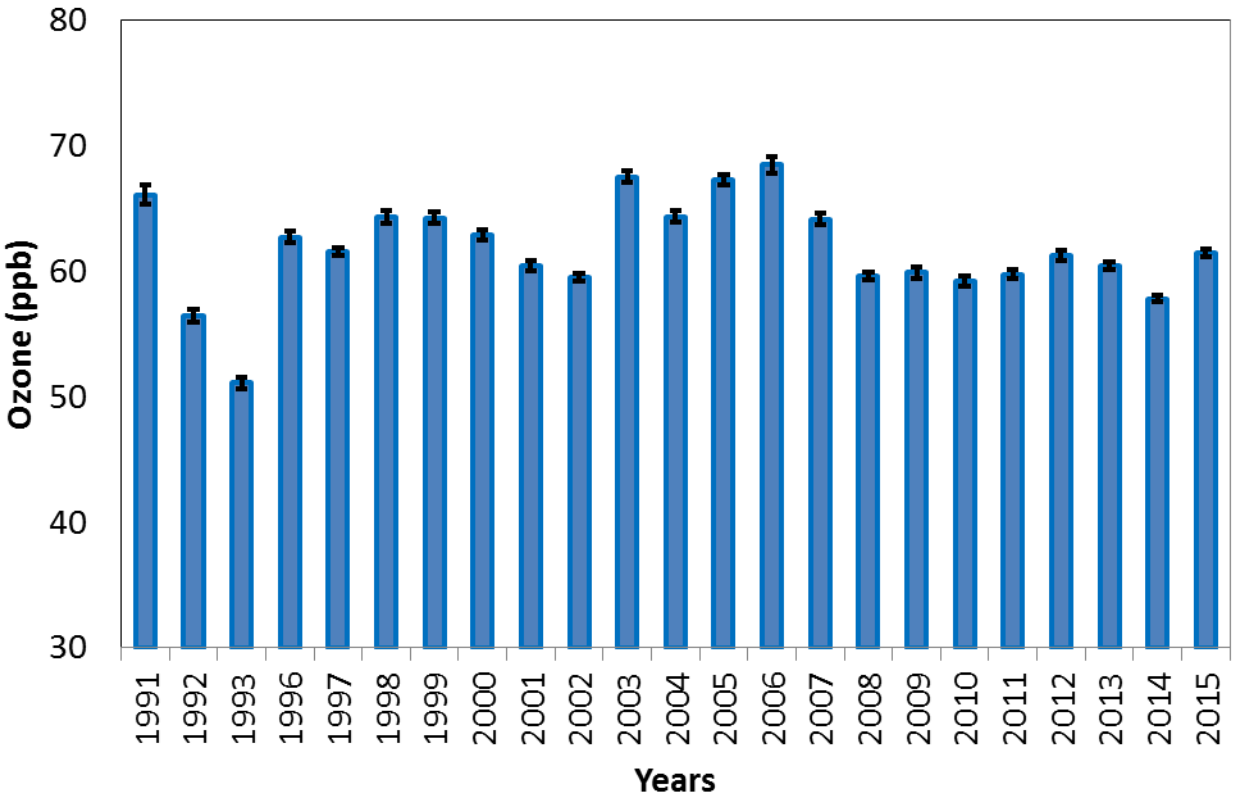
Time series of daily mean values

During this season, ozone mixing ratio was quite stable, representing the natural spring/summer maximum. Relatively high concentrations were observed in the first half of June and in the transition between June and July, tagged to the identified pollutions events.



Comparison with historical data-set

The O_3 seasonal mean value is 61.5 ppb, a value **slightly lower than the climatological one (62.4 ppb).** This is related to the lower than average concentrations during mid-June and the end of July. The absence of many data during August could also be responsible for this slight decrease in average mixing ratio. As it was observed for spring season, **in the last 8 years the inter-annual variability of summertime O_3 average concentration (standard deviation 1.2 ppb) is lower than for the previous 8-year period (standard deviation 3.3 ppb).**



Carbon monoxide (NDIR)

Why is carbon monoxide so important?

Carbon Monoxide (CO) plays an important role in the oxidation/reduction chemistry of the atmosphere and it participates in the reactions of photochemical O_3 production. CO has an indirect radiative forcing effect by influencing atmospheric mixing ratios of O_3 and methane. Through natural processes in the atmosphere, CO is eventually oxidized to CO_2. CO represents a tracer for combustion emissions (biomass burning, residential, traffic,...).

Instrumentation and calibration

Carbon monoxide is measured by using a non-Dispersive Infrared (NDIR) analyzer (Thermo Scientific TEI 48C-TL). A CO working standard (approx. 10 ppm, synthetic air, Messer Italia) is used to calibrate the instrument with a dilution system. On a monthly basis, these working standards were compared against secondary standards from NOAA-CMDL.

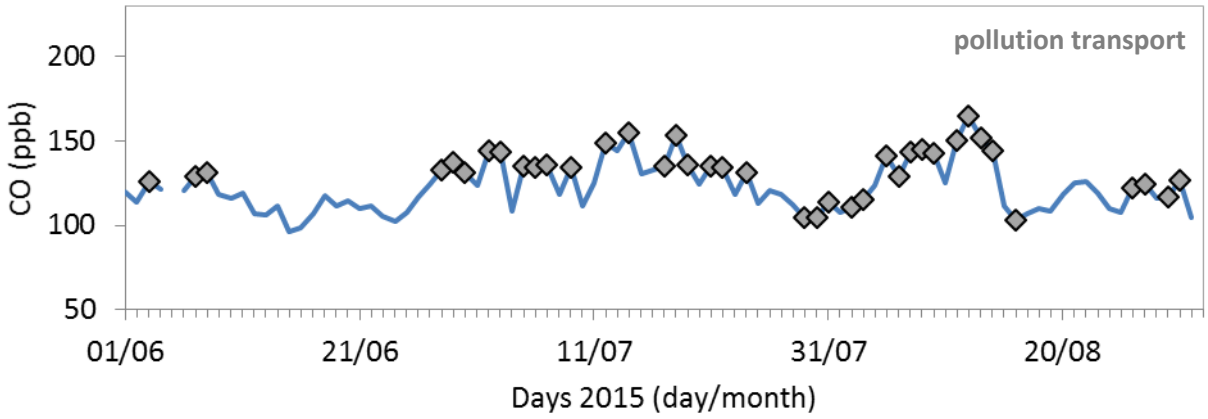
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (ppb)	25th Percentile (ppb)	50th Percentile (ppb)	Average mean value (ppb)	75th percentile (ppb)	Max value (ppb)
96.6	59.4	108.2	120.4	123.0	135.6	187.9

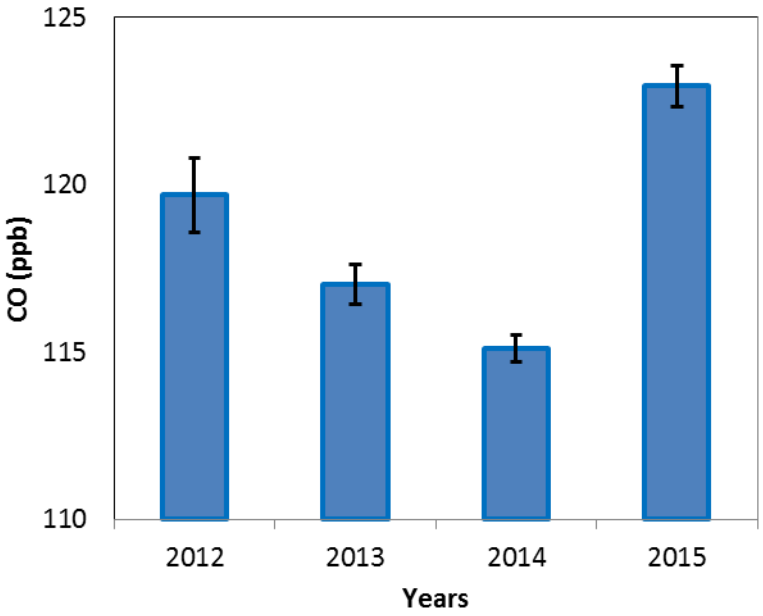
Time series of daily mean values

Like was observed for O_3, the CO mixing ratio was fairly stable throughout the season, with high values during mid-July and mid-August, when many pollution events were detected at the measurement site. The seasonal highest mixing ratio (164.6 ppb) was observed during one such event, on August 12th.



Comparison with historical data-set

The 2015 spring average mean value of CO was 123.0 ppb, which is **slightly higher than the average mean value of 117.3 ppb obtained from the last three years, and it is the highest average summer value observed.** It is fair to assume that the high concentrations observed during the 50 pollution events are responsible for this deviation from the climatological average.



Nitrogen oxides

Why are nitrogen oxides so important?

Nitrogen oxides (NO_x) encompasses nitric oxide (NO) and nitrogen dioxide (NO_2). NO is naturally produced by lightning. Anthropogenic contributions are related to combustion processes and agricultural fertilization. NO_x are key elements of atmosphere chemistry influencing a number of atmospheric compounds with roles on climate, air-quality and ecosystem threats, e.g. sulphur dioxide, halocarbons, methane, tropospheric ozone, secondary aerosols.

Instrumentation and calibration

Nitrogen oxides ($NOx=NO+NO_2$) are measured by using a Chemioluminescence analyser (Thermo 42i-TL), equipped with a photolityc converter (Blue Light Converter) for NO_2 determination. Every 48 hours, zero and span checks are carried out for NO by using an external zero air source (dry compressed air scrubbed with active charcoal and Purafill) and dilution of certified NO standard (5 ppm +/- 2%). GPT is used to determine the conversion efficiency of the NO_2 converter.

Basic statistical parameters

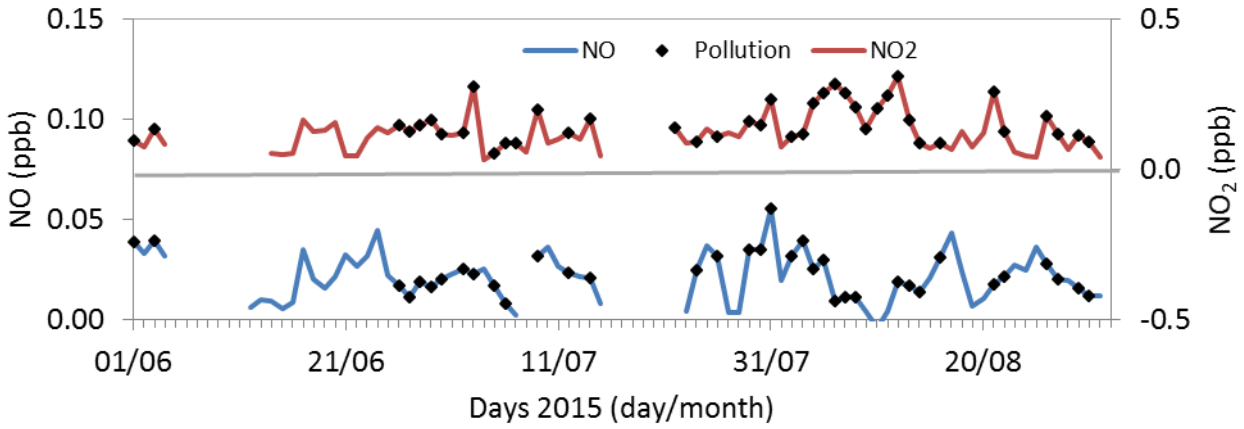
Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (ppb)	25th percentile (ppb)	50th percentile (ppb)	Average mean value (ppb)	75th percentile (ppb)	Max value (ppb)
NO 81.5	UDL	UDL	0.02	0.02	0.04	0.23
NO_2 81.5	UDL	0.06	0.10	0.1	0.15	2.1

UDL: under detection limit

Time series of daily mean values

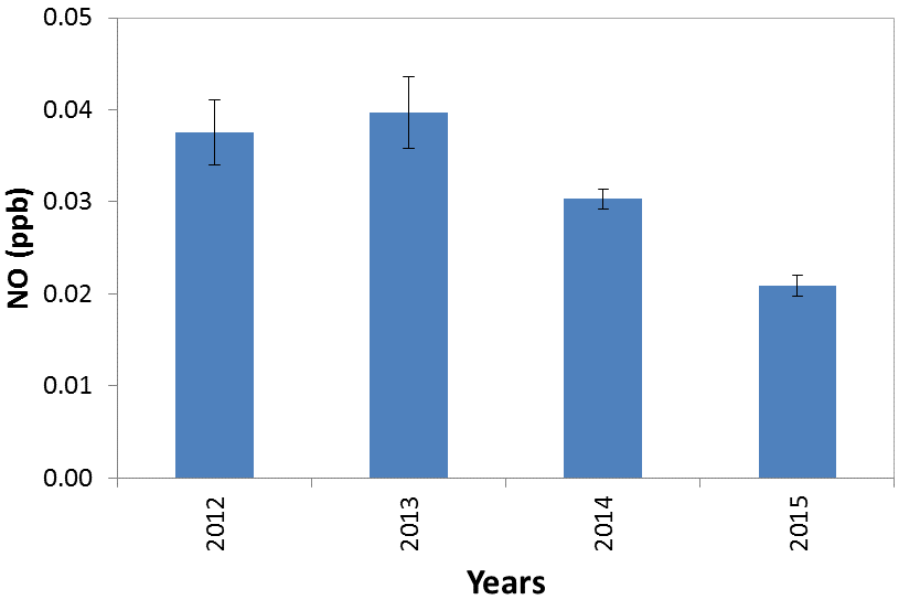
The highest NO value (blue line: 0.06 ppb) was observed on July 31th, while the highest NO_2 value (red line: 0.31 ppb) was observed on August 12th. The highest NO_x values were observed during the first half August, when the highest frequency of pollution events took place at CMN.

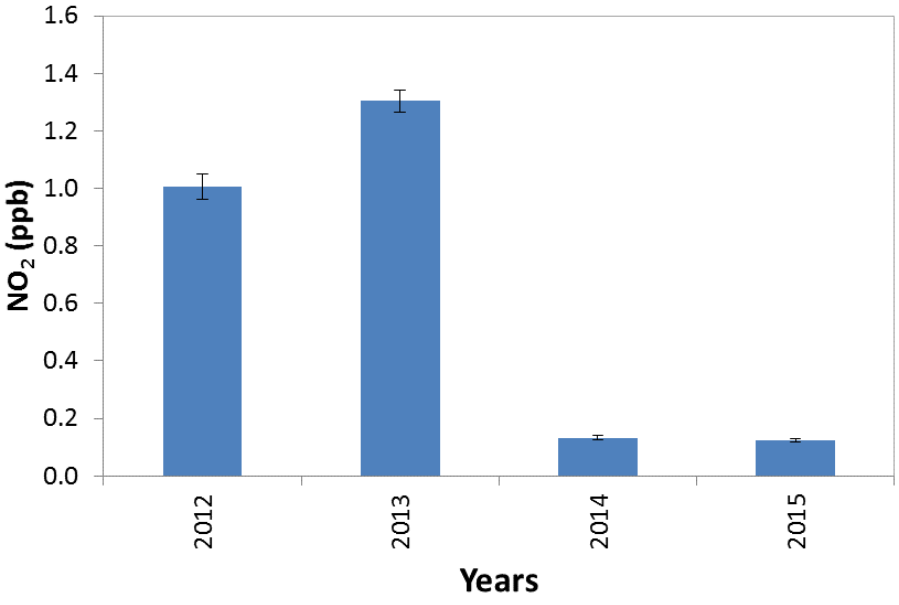


Comparison with historical data-set

The 2015 summer average mean value of NO (NO_2) was 0.02 ppb (0.1 ppb) which **is comparable (lower) to the average summer mean value of 0.03 ppb (0.54 ppb)**.

It should be noted that NO_2 data were obtained by analyzer equipped by Molybdenum during seasons 2012 - 2013. These data can be significantly overestimated in respect to the observations made by photolytic converter (year 2013) due to the interference of processed N-oxidised species (i.e. PAN) to the former data series.





Sulphur dioxide

Why is sulfur dioxide so important?

Sulfur dioxide (SO_2) is the main precursor to the sulphate aerosol which exerts a large influence on climate and air quality. It is a well know precursor for acid rains. SO_2 is also one of the main tracers for detecting the occurrence of ash plumes from volcanic eruption. In Europe, during the last years, SO_2 concentrations have been declining due to efficient restrictions on emissions.

Instrumentation and calibration

Sulphur dioxide is measured by using a UV-fluorescence analyser (Thermo 43i-TLE). Daily zero check are executed by using an external zero air source (scrubber with active charcoal), while daily span check are performed using a permeation tube with set point at 48 ppb. Detection limit for 1-minute average is estimated to be 0.11 ppb

Basic statistical parameters

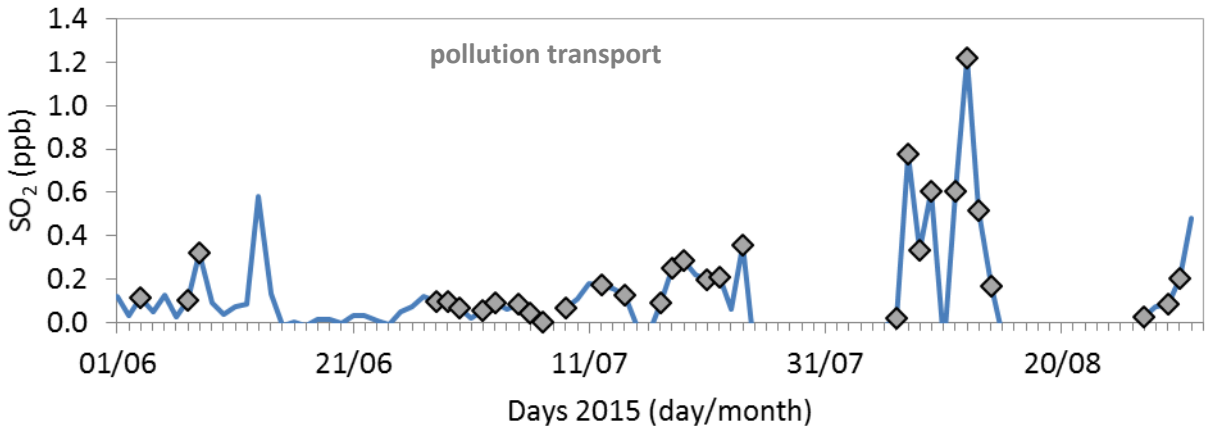
Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (ppb)	25th percentile (ppb)	50th percentile (ppb)	Average mean value (ppb)	75th percentile (ppb)	Max value (ppb)
97.8	UDL	UDL	UDL	UDL	0.13	2.4

UDL: under detection limit

Time series of daily mean values

During summer 2015 the average SO_2 mixing ratio was lower than the detection limit, even though several SO_2 peaks were observed throughout the season, especially on August, when many other pollution tracers exhibit higher concentration. The highest daily value (1.22 ppb) was observed on August 12th, during a pollution event.



NOTE: Negative values in the graph represent "under detection limit" conditions, common in a remote, high altitude, free troposphere measurement site.

Black carbon

Why is black carbon so important?

Black carbon (BC) is a primary aerosol resulting from incomplete combustion processes. Its main sources are fossil fuel combustion (anthropogenic) and biomass burning (natural and anthropogenic). BC, a Short Lived Climate Forcer and Pollutant, strongly absorbs solar radiation and it has been recognized as a driving factor of global warming: the magnitude of the direct radiative forcing due to BC can exceed that due to methane.

Instrumentation and calibration

Equivalent black carbon concentration is measured by a Multi Angle Absorption Photometer (MAAP, Model 5012 – Thermo Electron Corporation). Detection limit was measured as 3σ of 12 h measurement of free particle air. Calibration of sampling flow and internal temperature-pressure sensors are conducted every 6 months.

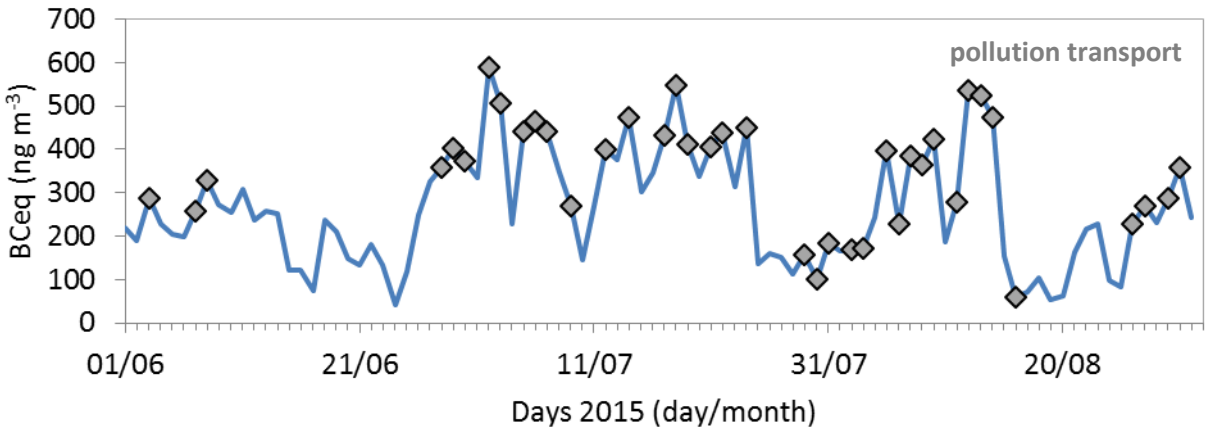
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (ng m^{-3})	25th percentile (ng m^{-3})	50th percentile (ng m^{-3})	Average mean value (ng m^{-3})	75th percentile (ng m^{-3})	Max value (ng m^{-3})
98.7	10.3	129.4	242.5	266.6	377.4	1291.9

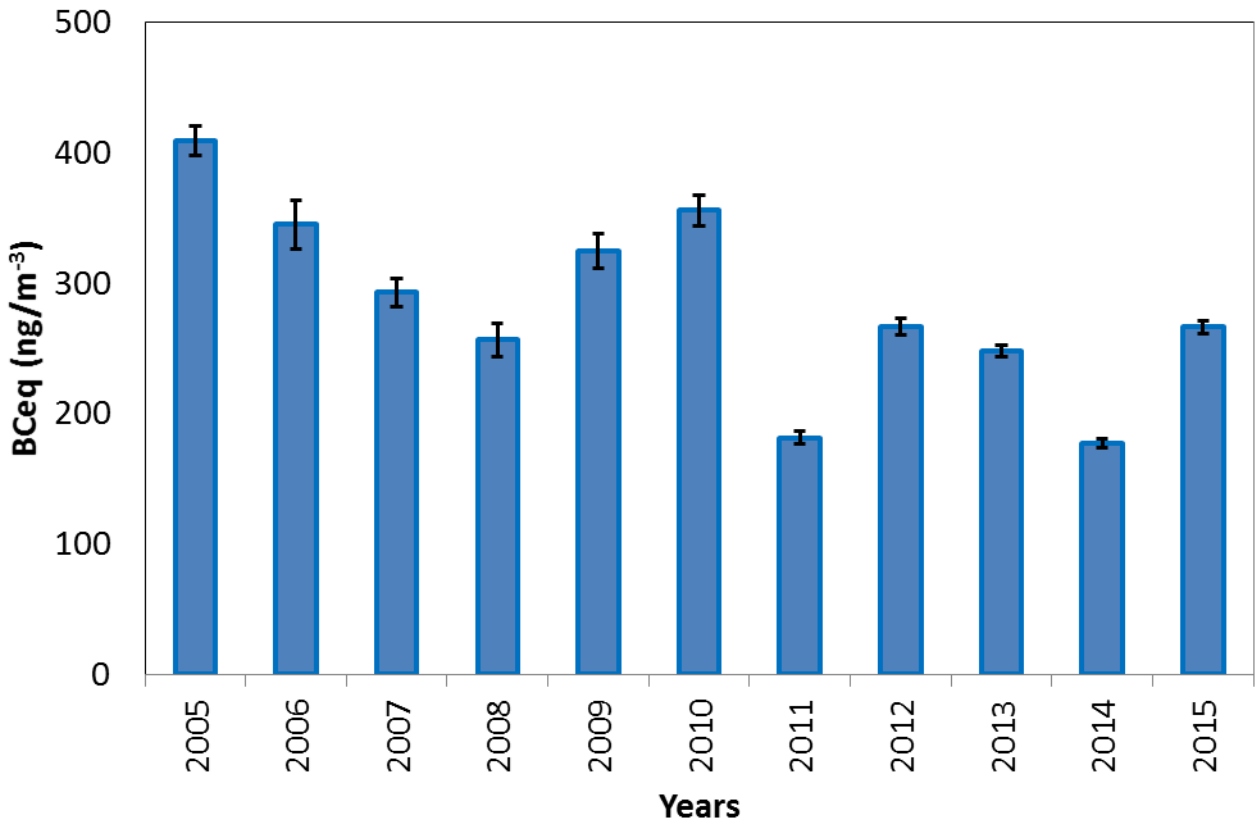
Time series of daily mean values

Similarly to what have been observed for other primary pollutants (CO, SO_2) the highest BC average concentrations were observed on August. Moreover also during July the BCeq concentration were higher than the usual summer mean value. The daily average maximum (588.1 ng m^{-3}) was observed on July 2nd.



Comparison with historical data-set

The 2015 summer average mean value of BC is 266.6 ng m^{-3}, **which is only slightly lower than the climatological mean value (266.6 ng m^{-3}).** Despite the high values observed throughout the season the low concentrations observed at the start and at the end of the season had a stronger impact on the seasonal average behavior. It is interesting to note a **general declining trend of BC concentration during the last decade.**



Aerosol light scattering coefficient

Why is aerosol light scattering coefficient so important?

Aerosol light scattering coefficient variability is an important parameter in deriving quantitative information on the optical properties of atmospheric aerosols, which are used to determine the direct effects of aerosols on the earth radiation balance (and therefore their impact on climate change). Moreover, information on the extinction coefficient, which is related to visibility in the atmosphere, is also an important parameter in many atmospheric applications.

Instrumentation and calibration

Starting from March 2014 a new three wavelength TSI Integrating nephelometer 3563 measures the aerosol light scattering coefficient at red (700 nm), green (550 nm), and blue (450 nm) wavelengths. A calibration on site with low span gas (filtered air) and high span gas (filtered carbon dioxide) is performed every 3 months.

Basic statistical parameters

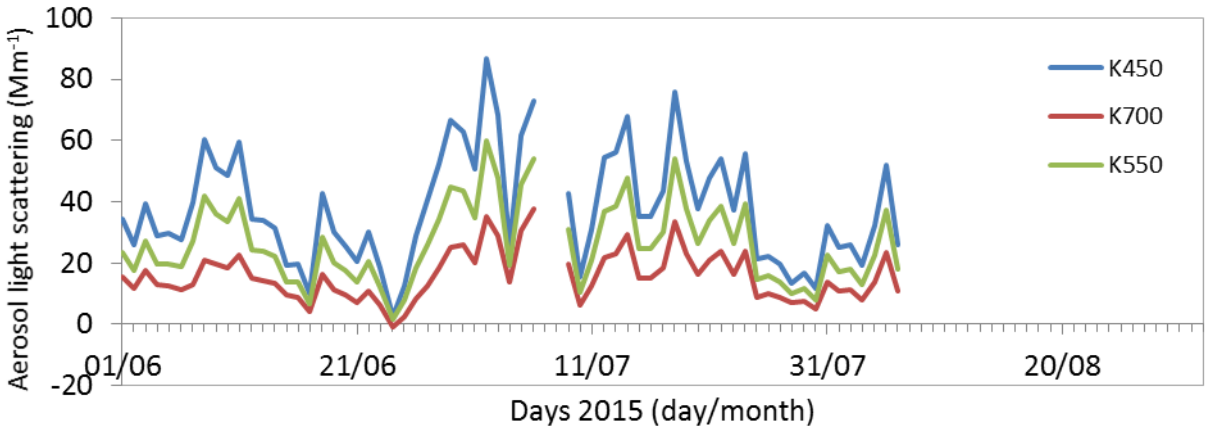
Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (Mm^{-1})	25th percentile (Mm^{-1})	50th percentile (Mm^{-1})	Average mean value (Mm^{-1})	75th percentile (Mm^{-1})	Max value (Mm^{-1})
700 nm 70.7	UDL	18.8	32.8	37.8	50.5	323.7
550 nm 70.7	UDL	13.1	22.5	26.2	35.0	232.1
450 nm 70.7	UDL	7.8	13.2	15.7	20.9	221.0

UDL: under detection limit

Time series of daily mean values

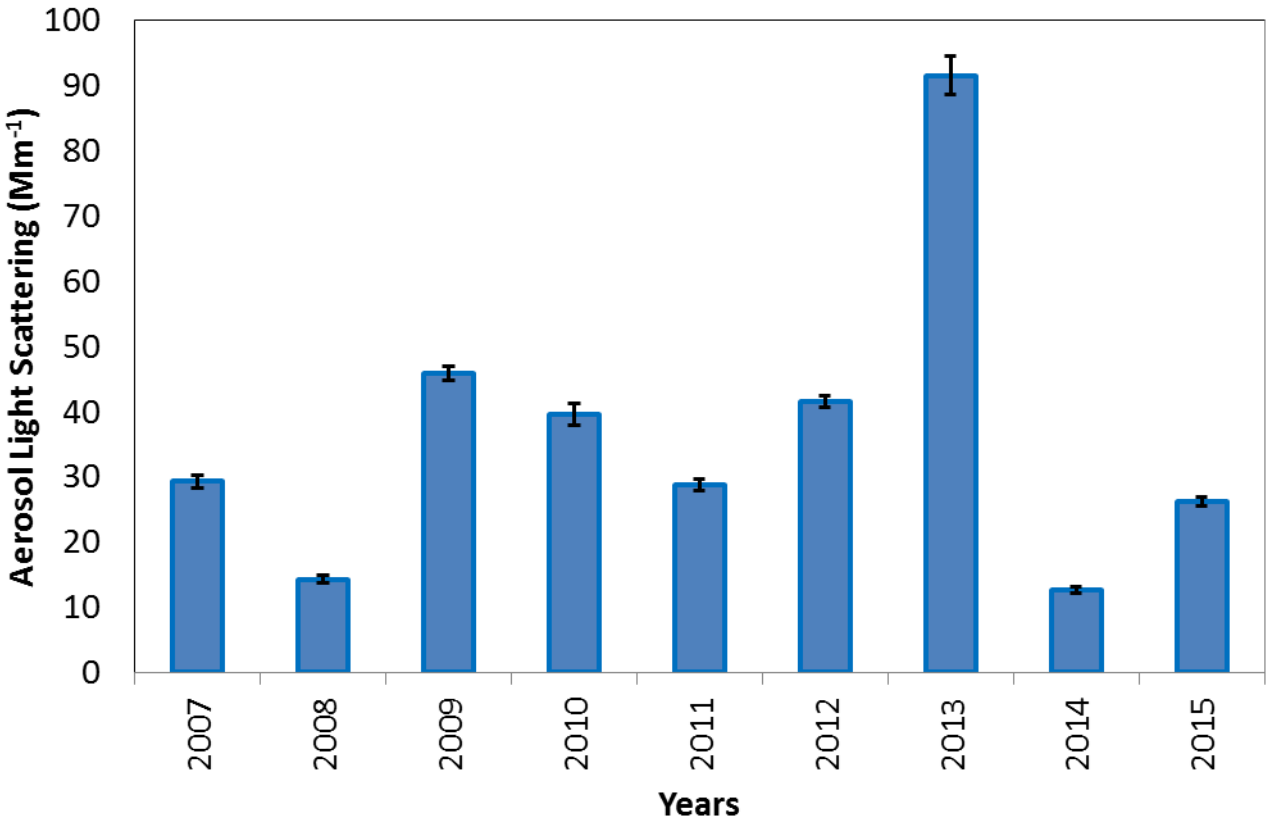
The highest daily mean value of the scattering coefficient at all three wavelength (450, 550, 700 nm) has been observed on July 2nd, during an identified pollution event that was also characterized by the highest BC content.



Comparison with historical data-set

The 2015 summer average mean value of scattering coefficient at 550 nm is 26.2 Mm^{-1}, which is **lower than the climatological mean value (38.0 Mm^{-1}).**

It should be noted that aerosol scattering data were obtained by a M9003 integrating nephelometer (ECOTECH) during autumn seasons 2007 - 2013.



Aerosol number concentration (fine)

Why are fine particle so important?

Fine particles are highly effective in modifying the radiation field by absorbing and scattering solar and thermal radiation, thus impacting radiative transfer through the atmosphere. Additionally, aerosols act as cloud condensation and ice nuclei, thus influencing cloud properties. Aerosols also help to control the concentrations, lifetime and the physical as well as the chemical behavior of many important trace gases by providing reaction sites and serving as carrier and/or sink for many atmospheric species. Moreover, fine particles strongly contribute to air pollution, representing a main fraction of PM_1.

Instrumentation and calibration

Aerosol concentration and size distribution of particles with optical diameter between 0.3 and 20 µm have been continuously recorded in 15-size channel by using an OPC Mod. GRIMM 1.108. These measurements allow the continuous measurement of the fine mode (0.3 µm ≤ Dp ≤ 1 µm) particle number. The instrument is based on the quantification of the 90° scattering of light by aerosol particles

Basic statistical parameters

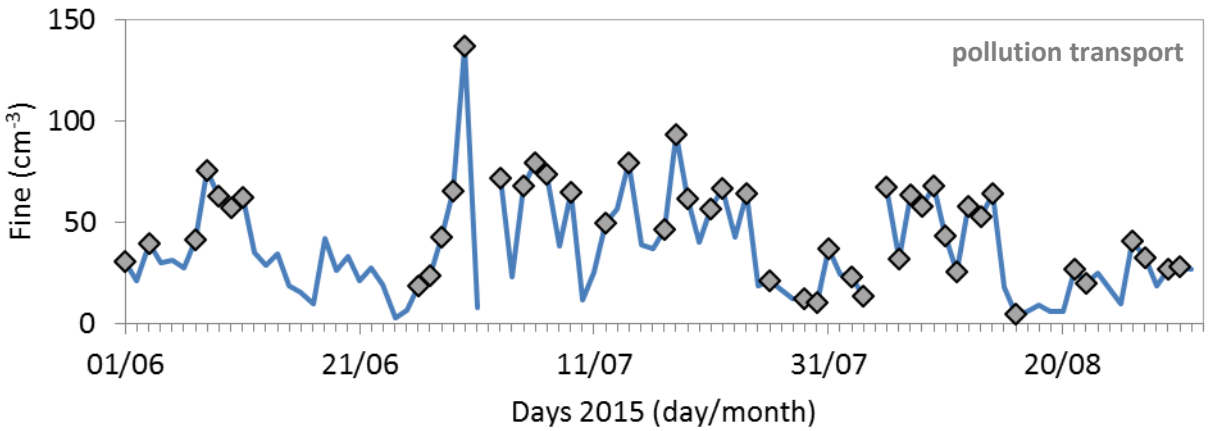
Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability %	Min value (cm^{-3})	25th percentile (cm^{-3})	50th percentile (cm^{-3})	Average mean value (cm^{-3})	75th percentile (cm^{-3})	Max value (cm^{-3})
95.0	0.3	14.1	28.5	36.4	49.5	181.6

UDL: under detection limit

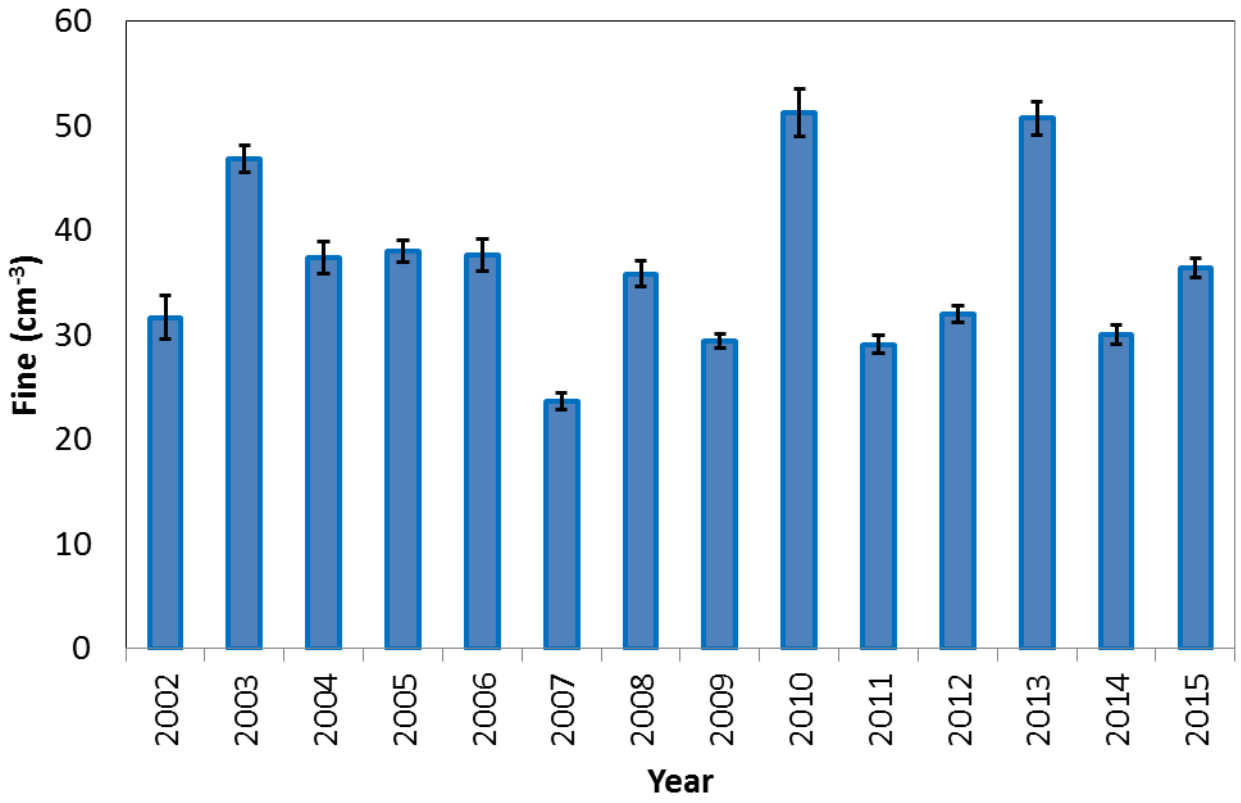
Time series of daily mean values

Like it was observed for BC, high fine particles number concentrations were observed especially during July and August, even though the highest daily average value was observed on June the 30th, when it reached a value of 137.4 cm^{-3}.



Comparison with historical data-set

Summer 2015 fine particle average number concentration was 36.4 cm^{-3}, **equal to the seasonal climatological value (36.4 cm^{-3})**.



Aerosol number concentration (coarse)

Why is this research so important?

Coarse particles measured in background conditions represent a good tracer for mineral dust or marine aerosol transport. They play a significant role in radiation budget by absorbing and especially scattering solar radiation and can act as condensation and ice nuclei. Coarse particles can represent one of the major contributors to the overall PM_{10} variability. Moreover, mineral dust contributes in determining the chemical behavior of many important trace gases (e.g. ozone) by way of heterogeneous-phase chemistry. Coarse particles strongly influence PM_{10} concentrations.

Instrumentation and calibration

Aerosol concentration and size distribution of particles with optical diameter between 0.3 and 20 µm have been continuously measured in 15-size channel by using an OPC Mod. GRIMM 1.108. These measurements permit the determination of the coarse (1 µm ≤ Dp≤ 20 µm) particle number. The instrument is based on the quantification of the 90° scattering of light by aerosol particles.

Basic statistical parameters

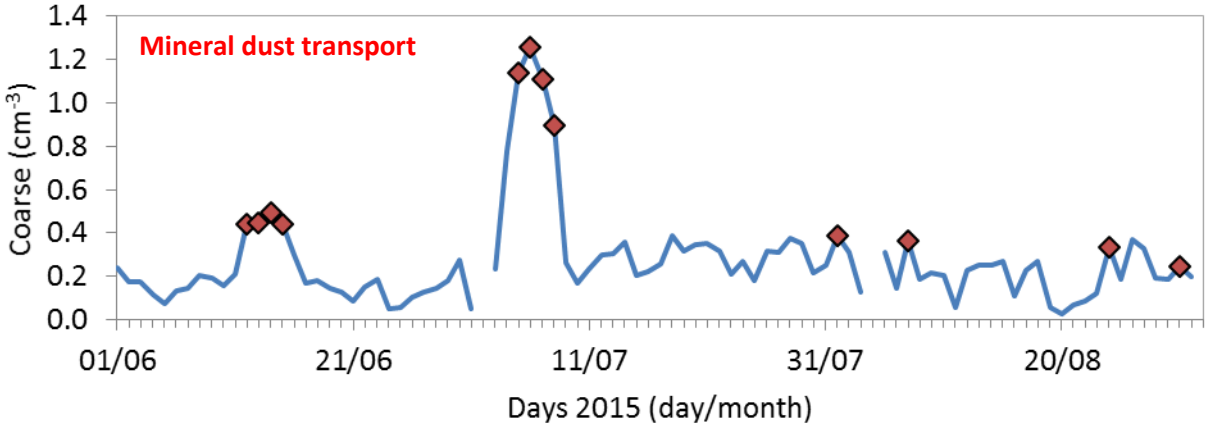
Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability %	Min value (cm^{-3})	25th percentile (cm^{-3})	50th percentile (cm^{-3})	Average mean value (cm^{-3})	75th percentile (cm^{-3})	Max value (cm^{-3})
94.0	UDL	0.12	0.21	0.3	0.33	4.3

UDL: Under Detection Limit

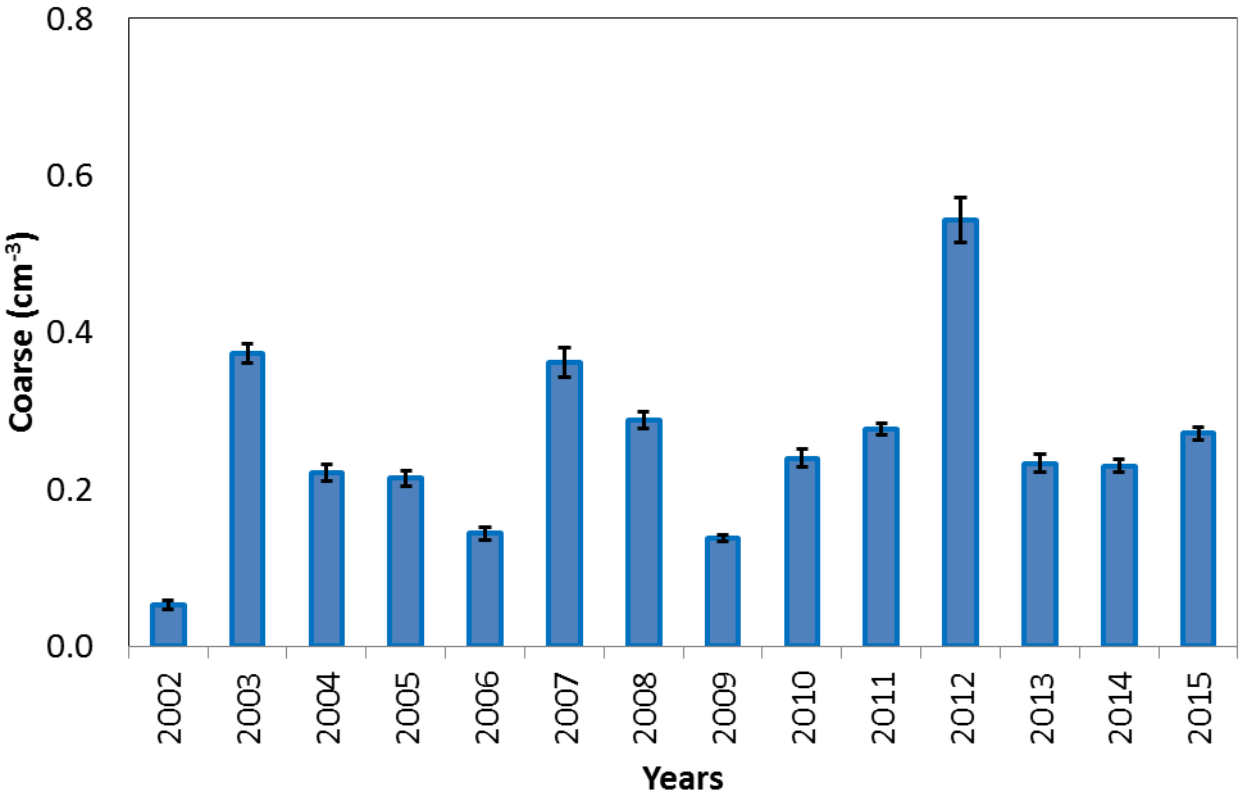
Time series of daily mean values

With the exception of the high values observed during June and July that were related to dust transport events (highest daily average concentration of 1.3 cm^{-3} was observed on July 6th), steady "background" coarse particles number concentrations were observed throughout the season.



Comparison with historical data-set

The summer 2015 average mean value of the coarse particles (0.3 cm^{-3}) is **equal to the climatological value (0.3 cm^{-3})**.



Air Temperature

Why is air-temperature so important?

Temperature data are useful to detect the occurrence of summer heat waves, during which photochemical smog episodes and transport of pollution from the boundary layer to the free troposphere can be favoured. The measurement of meteorological parameters at ICO-OV is a fundamental activity for the analysis of other measurements such as trace gases and aerosols.

Instrumentation and calibration

The basic meteorological data (temperature, relative humidity and atmospheric pressure) are measured above the ICO-OV terrace using instrumentation in compliance with WMO recommendations (IRDAM WST7000 and Rotronics thermo-hygrometer).

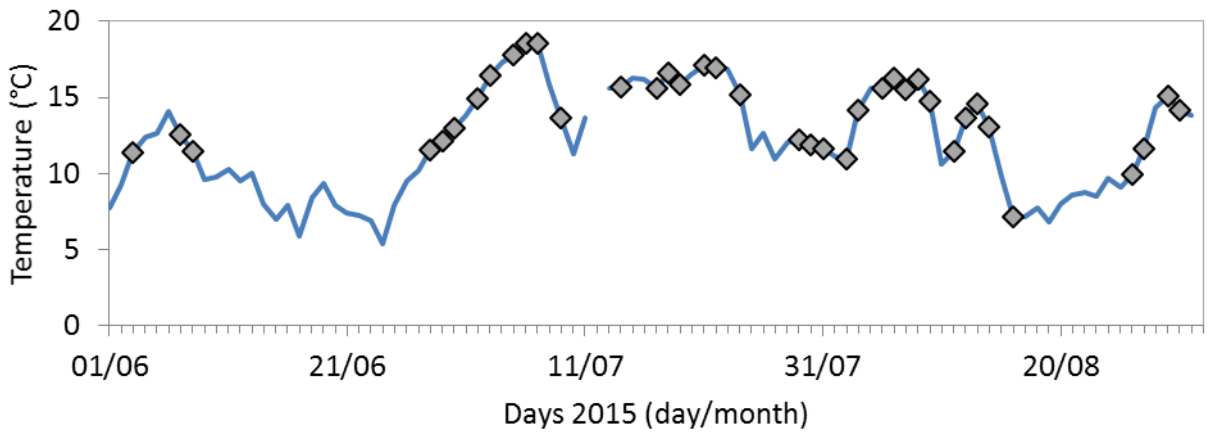
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability %	Min value (°C)	25th percentile (°C)	50th percentile (°C)	Average mean value (°C)	75th percentile (°C)	Max value (°C)
97.6	3.7	9.3	11.8	12.1	14.8	22.1

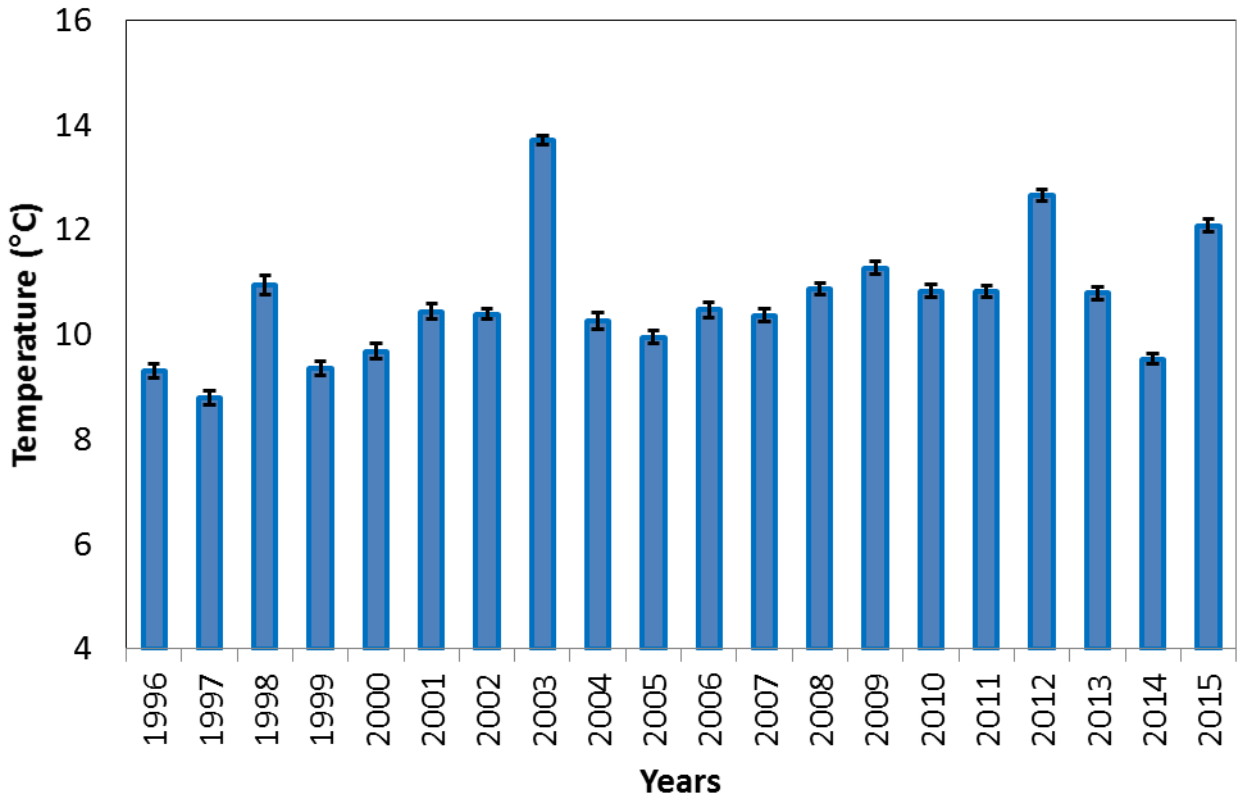
Time series of daily mean values

The air-temperature time series showed a clear increasing trend associated with the begin of the warm season, with higher values during July. The highest daily mean value (18.6 °C) has been observed on July 7th, along with the second seasonal highest coarse particle daily average number concentration, related to a dust event triggered by the northward expansion, over the western Mediterranean basin, of the African high-pressure. In general very high temperatures (above the climatological average) were observed during July and August.



Comparison with historical data-set

The summer 2015 average temperature (12.1 °C) is **higher than the seasonal climatological value (10.5 °C): it ranks as the third warmest summer from 1996 .** This is the result of a stable weather regime characterizing the majority of the season, especially during July and August, when high pressure values and low wind speed indicated the presence of a stagnant, anticyclonic regime characterized by warmer temperature and clear sky conditions.



Relative humidity

Why is relative humidity so important?

Relative humidity is a key parameter to identify the occurrence of dry meteorological conditions (RH<60%), usually associated with stratospheric intrusions or air-mass transport from the free troposphere. During summer, afternoon-evening RH increases can trace transport of air-masses from the boundary layer.

Instrumentation and calibration

The basic meteorological data (temperature, relative humidity and atmospheric pressure) are measured above the ICO-OV terrace using instrumentation in compliance with WMO recommendations (IRDAM WST7000 and Rotronics thermo-hygrometer).

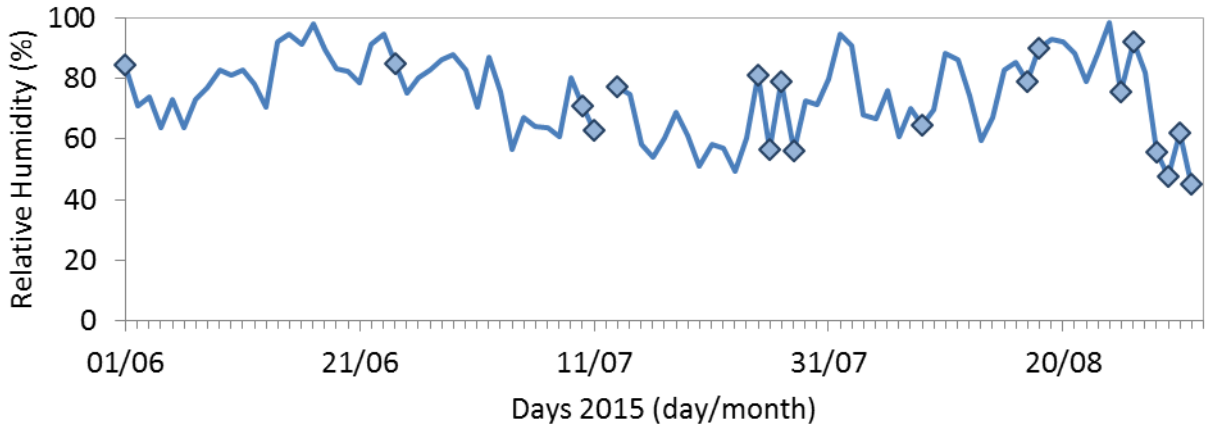
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (%)	25th percentile (%)	50th percentile (%)	Average mean value (%)	75th percentile (%)	Max value (%)
97.6	8.8	62.4	76.6	74.7	88.7	100.0

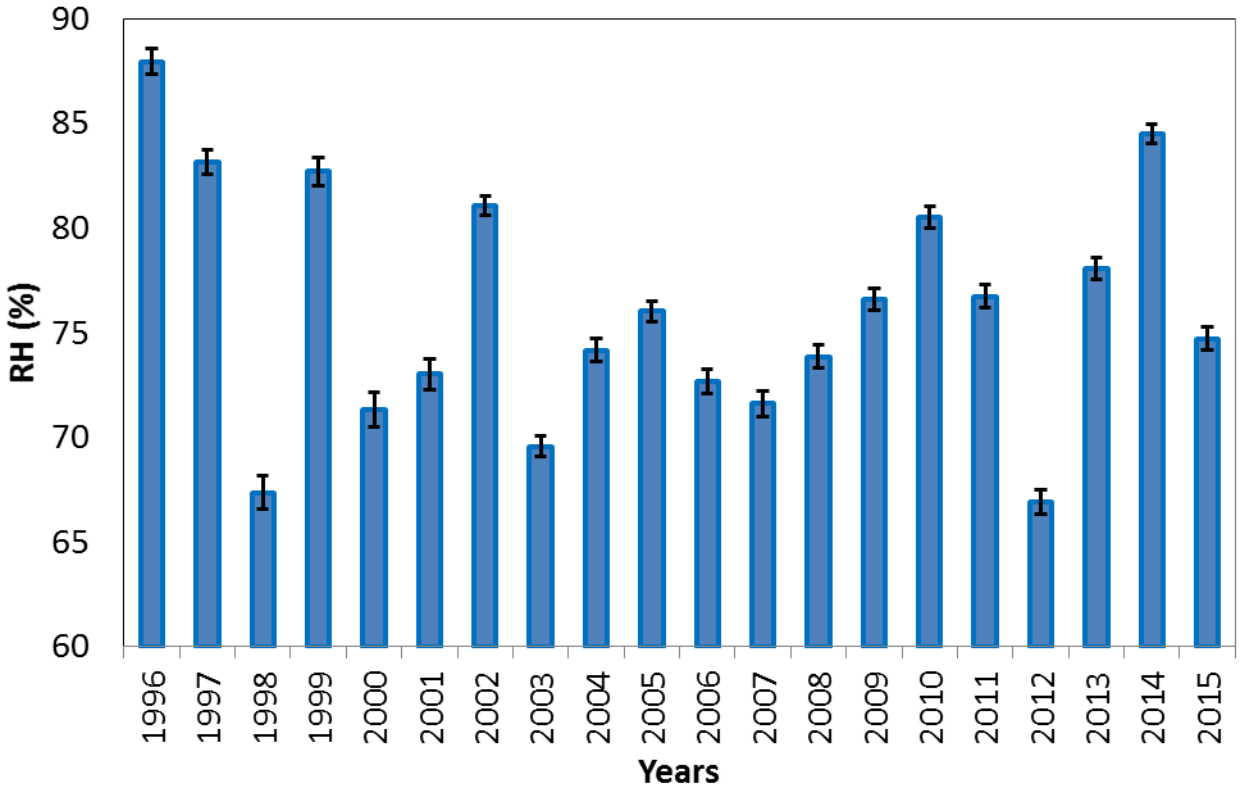
Time series of daily mean values

The daily mean RH values ranged from 100% to 8.8%, with 11.9% of days showing average value higher than 95%. Relatively dry conditions (mean daily values lower than 60%) characterized the central part of July, when also high temperature where observed at the measurement site.



Comparison with historical data-set

The summer 2015 average relative humidity (74.7%) was **comparable to the seasonal climatological value (76.2%).**



Atmospheric pressure

Why is atmospheric pressure so important?

Pressure is a key parameter to investigate the variability of weather conditions at the ICO-OV. As an example, heat waves periods are characterized by the occurrence of high pressure values, while sudden pressure variability can be used to identify the passage of synoptic-scale disturbances possibly related to stratospheric intrusions.

Instrumentation and calibration

The basic meteorological data (temperature, relative humidity and atmospheric pressure) are measured above the ICO-OV terrace using instrumentation in compliance with WMO recommendations (IRDAM WST7000 and Tecnoel barometer).

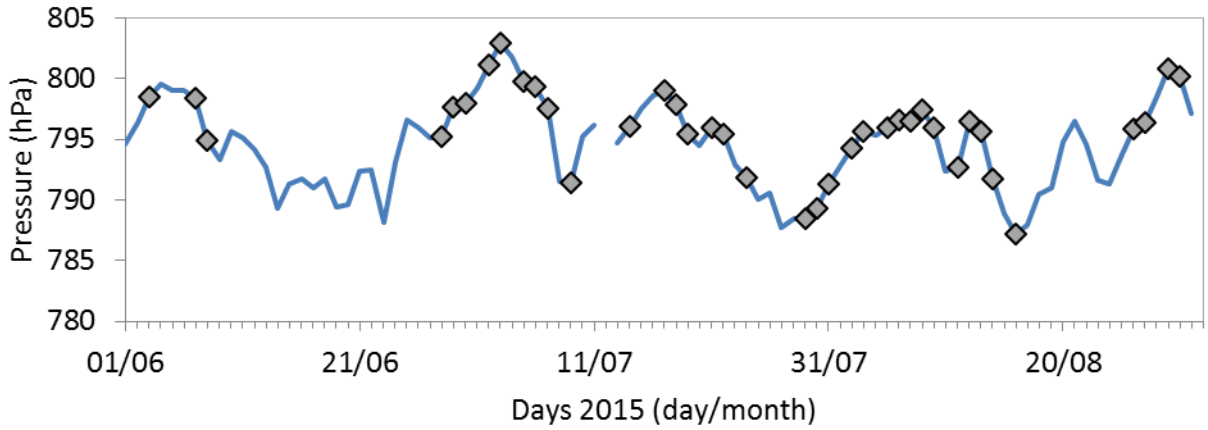
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (hPa)	Min value (hPa)	25th percentile (hPa)	50th percentile (hPa)	Average mean value (hPa)	75th percentile (hPa)	Max value (hPa)
97.6	786.2	791.8	795.1	794.6	797.1	804.7

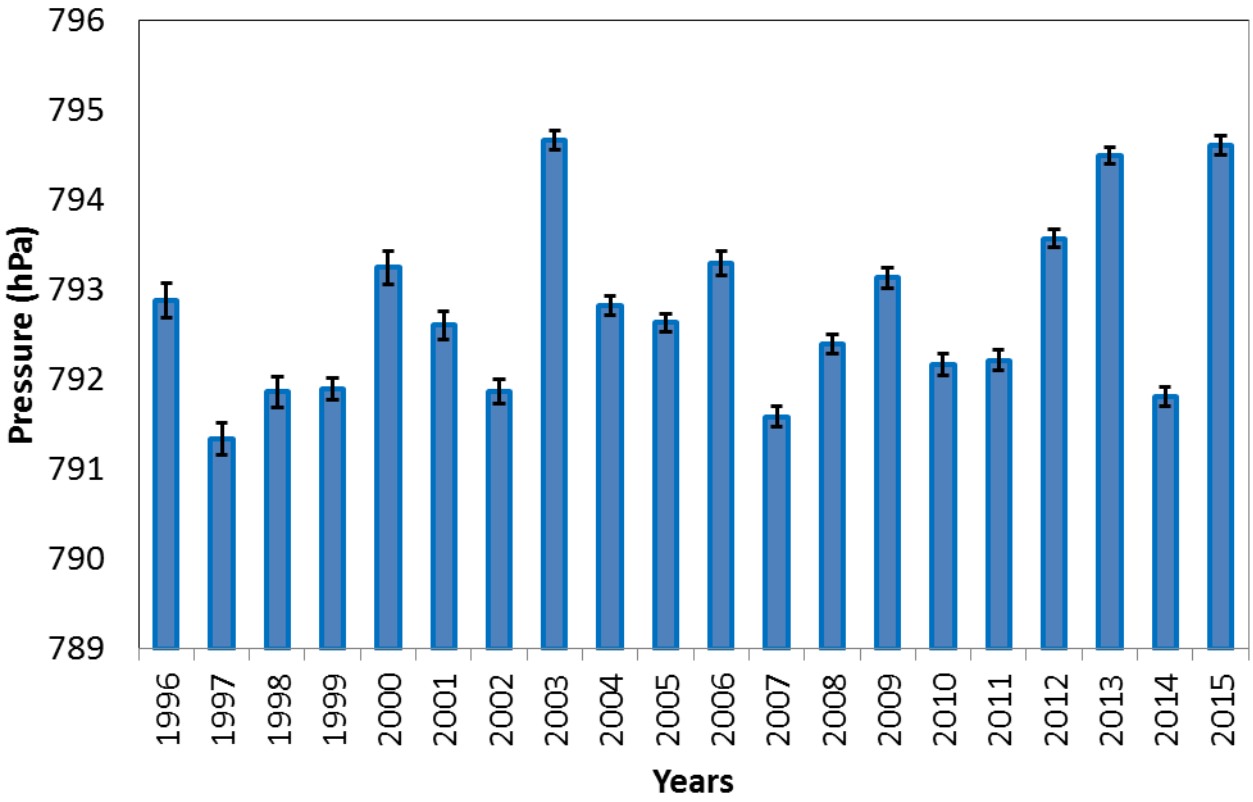
Time series of daily mean values

High pressure values were observed throughout the season, indicating the presence of stable conditions at the measurement site, as also confirmed by the clear sky condition and the high temperature observed. The highest daily average value (803.0 hPa) is observed on July 3rd.



Comparison with historical data-set

The summer 2015 averaged atmospheric pressure (794.6 hPa) was **higher than the climatological value (792.7 hPa): it ranks as the highest values observe data ICO-OV since 1996,** the result of a stable, anticyclonic regime dominating over the Mediterranean basin during July and August. The resulting "good" weather created conditions favorable for the high temperature observed during the same two months.



Wind speed and direction

Why is wind so important?

Wind speed and direction are used to identify the air mass circulation and therefore the transport of polluted air-masses from the near Po basin, as well as to identify the passage of surface fronts and the development of thermal wind circulation.

Instrumentation and calibration

Wind measurements are carried out at 5 m and 3 m high above the roof of the station, by using an integrated weather station IRDAM WST7000 and a sonic anemometer Vaisala WS425, respectively.

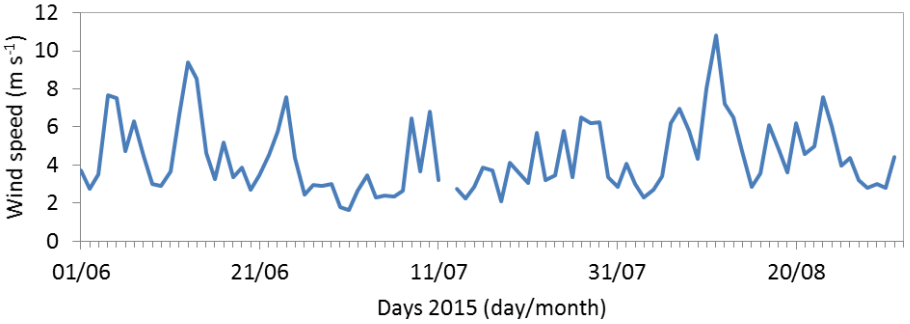
Basic statistical parameters of wind speed

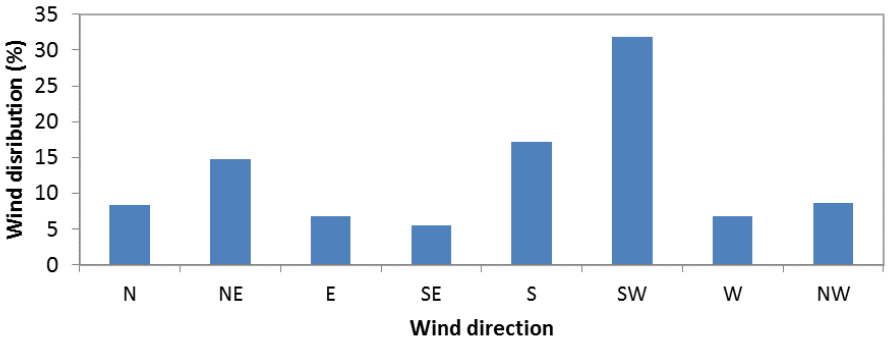
Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (m/s)	25th Percentile (m/s)	50th Percentile (m/s)	Average mean value (m/s)	75th percentile (m/s)	Max value (m/s)
97.6	0.3	2.2	3.7	4.4	5.9	20.0

Time series of daily mean values

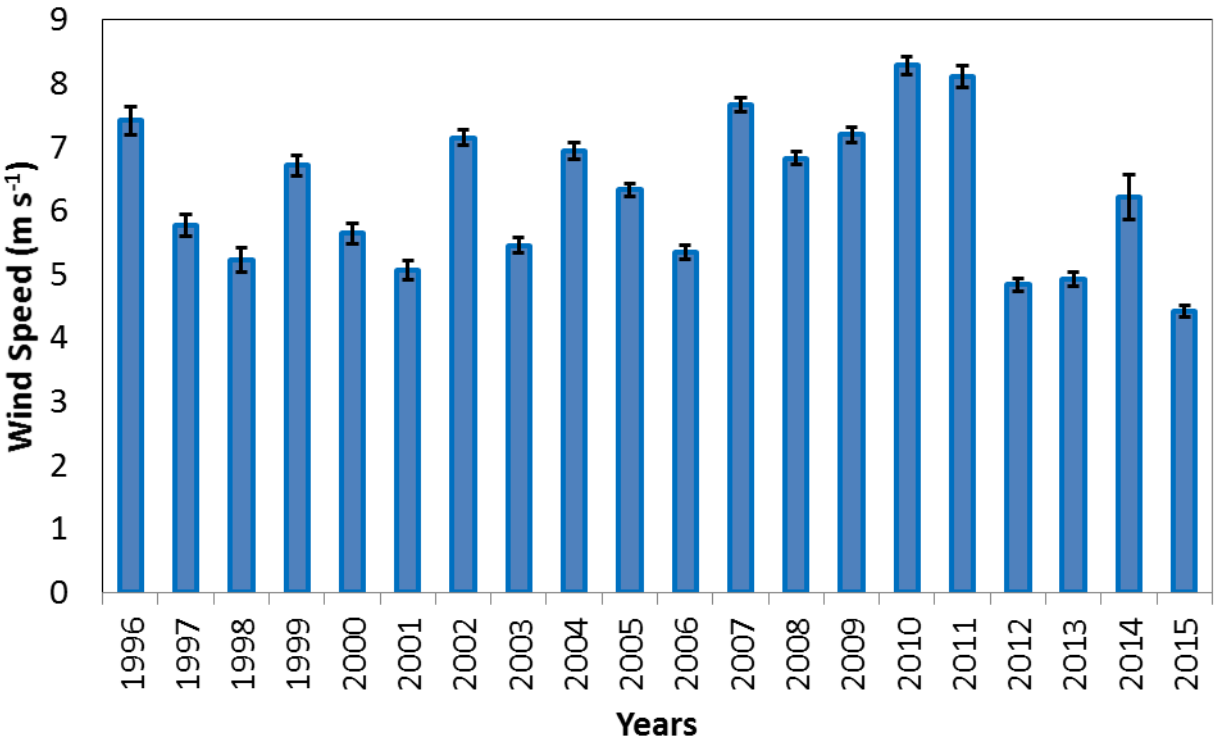
During the season, the observed prevailing wind direction is SW, with low wind speed characterizing the majority of the season, the result of the stagnant atmospheric circulation related to the presence of high pressure systems throughout the season.

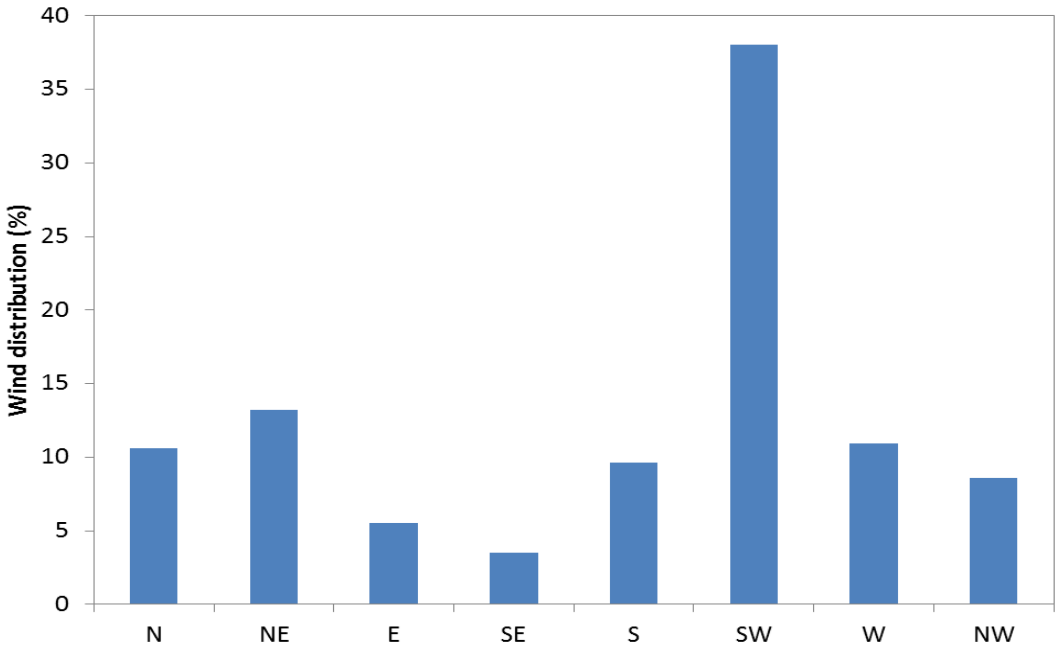




Comparison with historical data-set

The summer 2015 showed an average wind speed (4.4 m/s) **that is lower than the climatological value** (6.4 m/s): **it ranks as the lowest values observed since 1996**. The seasonal wind prevalent direction is SW (34.1 %), followed by S (17.2 %) and NE (14.8 %), in agreement with the prevailing wind direction observed at CMN. The observed low value of wind speed is related to the presence of high pressure systems over the Mediterranean basin, as also highlighted by the elevated temperature and pressure levels observed during July and August.





Solar radiation (short-wave and UV-B)

Why is solar radiation so important?

Solar radiation is a key parameter in studying climate change and also play a role in defining the chemical properties of the troposphere, triggering photochemical reactions of important compounds (like O_3). Moreover, UV-B radiation is fundamental in determining the oxidative properties of the troposphere by leading O_3 photo-dissociation and thus determining OH levels.

Instrumentation and calibration

Solar radiation (wavelength: 350 – 1100 nm) and UV-B (wavelengths: 280-315 nm) are respectively measured by a commercial silicon cell pyranometer (Skye SKS110) and a silicon photodiode (Skye SKU 430). Calibrations were performed by factory against a WMO secondary standard pyranometer (for Skye SKS110) and against the National Physical Laboratory UK reference standard lamp (for Skye SKU 430).

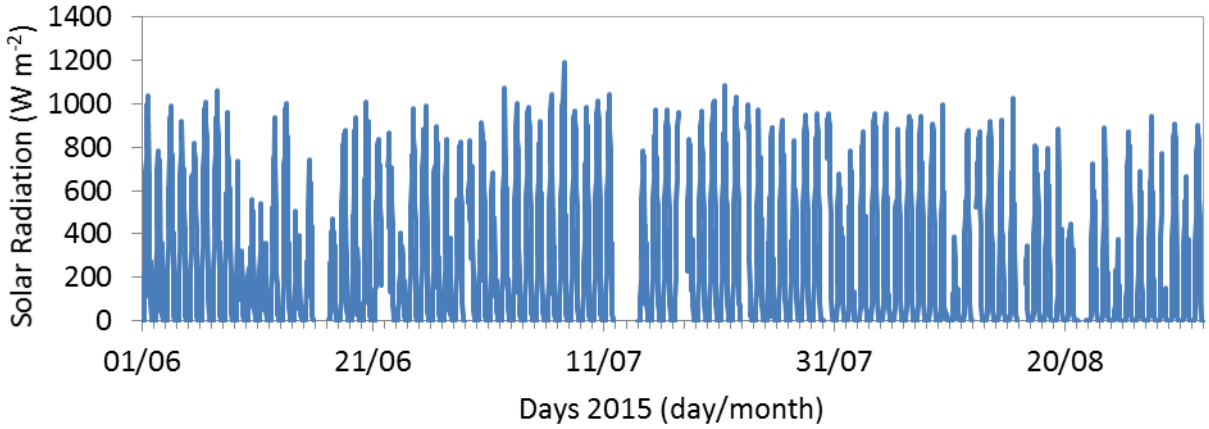
Basic statistical parameters (Solar radiation)

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (W/m^2)	25th Percentile (W/m^2)	50th Percentile (W/m^2)	Average mean value (W/m^2)	75th percentile (W/m^2)	Max value (W/m^2)
91.3	UDL	UDL	103.5	257.5	486.0	1192.4

UDL: under detection limit

Time series (Solar radiation)



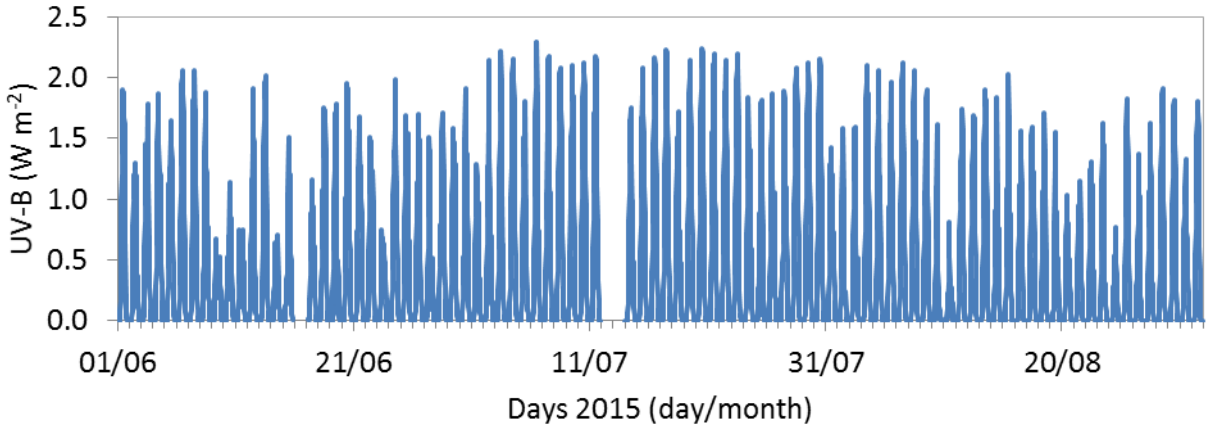
Basic statistical parameters (UV-B)

Statistical parameters are calculated basing on 30-minute aggregated values from June 2015 to August 2015.

Data availability (%)	Min value (W/m^2)	25th Percentile (W/m^2)	50th Percentile (W/m^2)	Average mean value (W/m^2)	75th percentile (W/m^2)	Max value (W/m^2)
96.3	UDL	UDL	0.10	0.4	0.77	2.3

UDL: under detection limit

Time series (UV-B)



Bibliography

Here we present a list of the main scientific articles, from the year 2000 onward, resulted from the research activity conducted at ICO-OV:

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Research Projects

GAW (Global Atmosphere Watch) The Global Atmosphere Watch (GAW) programme of WMO is a partnership involving 80 countries, which provides reliable scientific data and information on the chemical composition of the atmosphere, its natural and anthropogenic change, and helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere.

NextData The Project of Interest NextData will favour the implementation of measurement networks in remote mountain and marine areas and will develop efficient web portals to access meteoclimatic and atmospheric composition data, past climate information from ice and sediment cores, biodiversity and ecosystem data, measurements of the hydrological cycle, marine reanalyses and climate projections at global and regional scale.

SHARE (Station at High Altitude for Research on the Environment) Share is an integrated project funded by EV-K2-CNR Committe comprising an international climate and atmospheric monitoring network, researches in environmental and geophysical sciences and new technology development for monitoring activity in high mountain regions. Working in synergy with projects run by UNEP and WMO, data from the SHARE initiative benefit the international scientific community as well as decision makers.

ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) ACTRIS is a European Project aiming at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. ACTRIS will have the essential role to support building of new knowledge as well as policy issues on climate change, air quality, and long-range transport of pollutants. ACTRIS is building the next generation of the ground-based component of the EU observing system by integrating three existing research infrastructures EUSAAR, EARLINET, CLOUDNET, and a new trace gas network component into a single coordinated framework. ACTRIS is funded within the EC 7th Framework Programme under "Research Infrastructures for Atmospheric Research" and started on 1 April 2011 for a period of 4 years.

Monitoring atmospheric composition & climate MACC-2 (Monitoring Atmospheric Composition and Climate - Interim Implementation) is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. MACC-II combines state-of-the-art atmospheric modelling with Earth observation data to provide information services covering European Air Quality, Global Atmospheric Composition, Climate, and UV and Solar Energy.

EUSAAR (European Supersites for Atmospheric Aerosol Research) The objective of EUSAAR UE-funded project is the integration of measurements of atmospheric aerosol properties performed in a distributed network of 20 high quality European ground-based stations. This integration contributes to a sustainable reliable operational service in support of policy issues on air quality, long-range transport of pollutants and climate change.

EUROHYDROS The aim of EUROHYDROS has been the initialisation of a European Network for observations of molecular Hydrogen based on 12 continuous measurements sites which allow a wide range of observation, from clean air stations for measurements of atmospheric background to moderately polluted and urban. This in order to improve the understanding of hydrogen in the global background atmosphere and of the impact of European emissions on the present day atmosphere.

CIRCE (Climate Change and Impact Reserach: the Mediterranenan Environment) The general project objectives are to predict and to quantify physical impacts of climate changes in the Mediterranean area; to evaluate the consequences of climate changes for the society and the economy of the populations located in the Mediterranean area; to develop an integrated approach to understand combined effects of climate change; to identify adaptation and mitigation strategies in collaboration with regional stakeholders.

AGAGE-Advanced Global Atmospheric Gases Experiment AGAGE and its predecessors (the Atmospheric Life Experiment, ALE, and the Global Atmospheric Gases Experiment, GAGE) have been measuring the composition of the global atmosphere continuously since 1978. The AGAGE is distinguished by its capability to measure over the globe at high frequency almost all of the important gases species in the Montreal Protocol (e.g. CFCs and HCFCs) to protect the ozone layer and almost all of the significant non-CO2 gases in the Kyoto Protocol (e.g. HFCs, methane, and nitrous oxide) to mitigate climate change.

CEOP HE (Coordinated Energy and Water Cycle Observation Project - High Elevation) CEOP HE is a component of 'regional focus' within the Coordinated Energy and Water Cycle Observation Project (CEOP) of the Global Energy and Water Cycle Experiment (GEWEX), under the WCRP of WMO. CEOP HE aims to further knowledge on physical and dynamic processes in high elevation areas, contributing to global climate and water cycle studies by providing rare but crucial information from high elevations. This initiative was launched and is coordinated by the Ev-K2-CNR Committee.

ACCENT (Atmospheric Composition Change - The European Network of Excellence) The overall goals of the UE-network ACCENT are to promote a common European strategy for research on atmospheric composition sustainability, to develop and maintain durable means of communication and collaboration within the European scientific community, to facilitate this research and to optimise the interactions with policy-makers and the general public.

AEROCLOUDS (Climatic Effects of Aerosol and Clouds) AEROCLOUDS is a project funded by the Italian Ministry for University and Research to improve our knowledge of the role of aerosol and clouds in the climate system. Four research lines have been investigated: 1) Radiative properties of aerosols ("direct" climatic effects); 2) Aerosol-Cloud interactions ("indirect" climatic effects); 3) Climatic effects of clouds and precipitation; 4) Regional and global modelling of the aerosol effects on climate.

SOGE (System for Observations of Halogenated Greenhouse Gases in Europe) SOGE is an integrated system for observation of halogenated greenhouse gases in Europe. The project was funded by UE and builds on a combination of observations and modelling. The observations are partly surface in situ data collected continuously at four background stations as a part of national or international measurement programs. For some species(PFC, SF6), for which high-frequency measurements are not yet fully developed, such capacity will be developed as a part of SOGE.

POLPO (Pollution Hot Spot Monitoring from GOME Applied to the Po-basin) POLPO investigated the feasability of applying satellite data for monitoring large pollution plumes. The prototype service demonstrated the application of GOME data for case studies. Users as, e.g., environmental agencies, who have to rely on ground-based measurements, found the added value satellited data provide together with its limitations in the feasability study.

QUILT (Quantification and Interpretation of Long-Term UV-Vis Observations of the Stratosphere) The general aim was to use the existing ground-based, satellite and balloon borne UV-visible data as well as 3D atmospheric modelling tools for quantifying ozone loss in the past, to monitor its development in the present and to investigate its relation to active halogen and nitrogen species.

TOR-2 (Tropospheric Ozone Research - 2) The overall aim of TOR-2 was to quantify crucial processes in the atmosphere in order to improve the scientific background for the development of effect-based control strategies for photochemical oxidants over Europe.

STACCATO (Influence of Stratosphere-Troposphere Exchange in a Changing Climate on Atmospheric Transport and Oxidation Capacity) EU-project STACCATO is a comprehensive study of stratosphere-troposphere exchange (STE) processes and their effect on atmospheric chemistry. STE is a key factor controlling the budget of ozone, water vapour and other substances in both the troposphere and lower stratosphere.

MINATROC (Mineral Dust and Tropospheric Chemistry) Problems to be solved this EU-project focuses on the transformation of atmospheric pollutants from Europe in the presence of mineral dust over South Europe and Africa. Intensive field campaigns, experimental laboratory investigations and modeling studies were conducte dti evaluate the influence of mineral dust on troposphere oxidazing properties.

VOTALP-2 (Vertical Ozone Transport in the Alps - 2) The EU research project VOTALP II investigated the enhanced vertical exchange above the Alps as well as other processes which might be relevant for increased ozone concentrations. The role of stratospheric intrusions for mountain peaks and of horizontal advection of polluted air for the foothill area causing a high ozone abundance has been quantified for selected locations.

VOTALP (Vertical Ozone Transport in the Alps) The EU research project VOTALP investigated transport and formation of ozone in the Alps, focusing on processes which can cause increased ozone concentrations, namely stratospheric intrusions, horizontal advection of polluted air, and in-situ production of ozone due to emissions in Alpine valleys.

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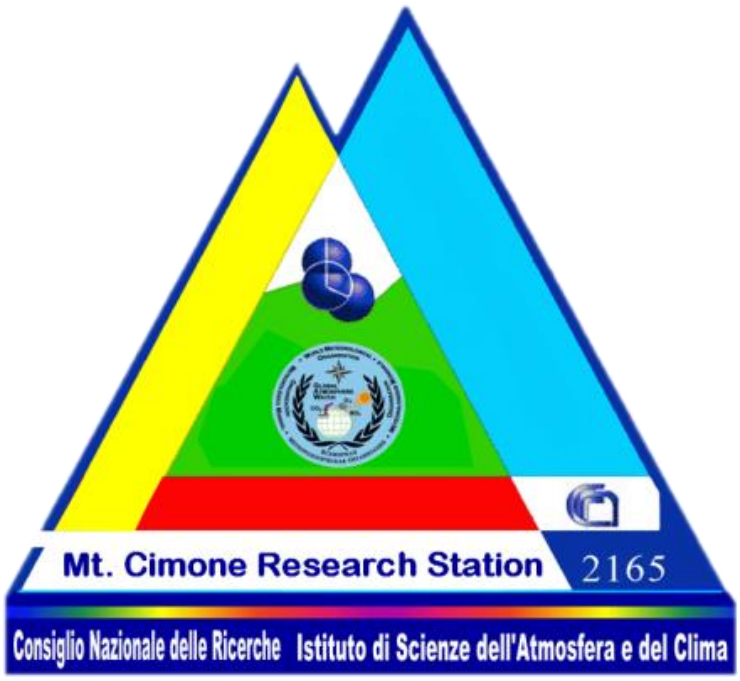

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