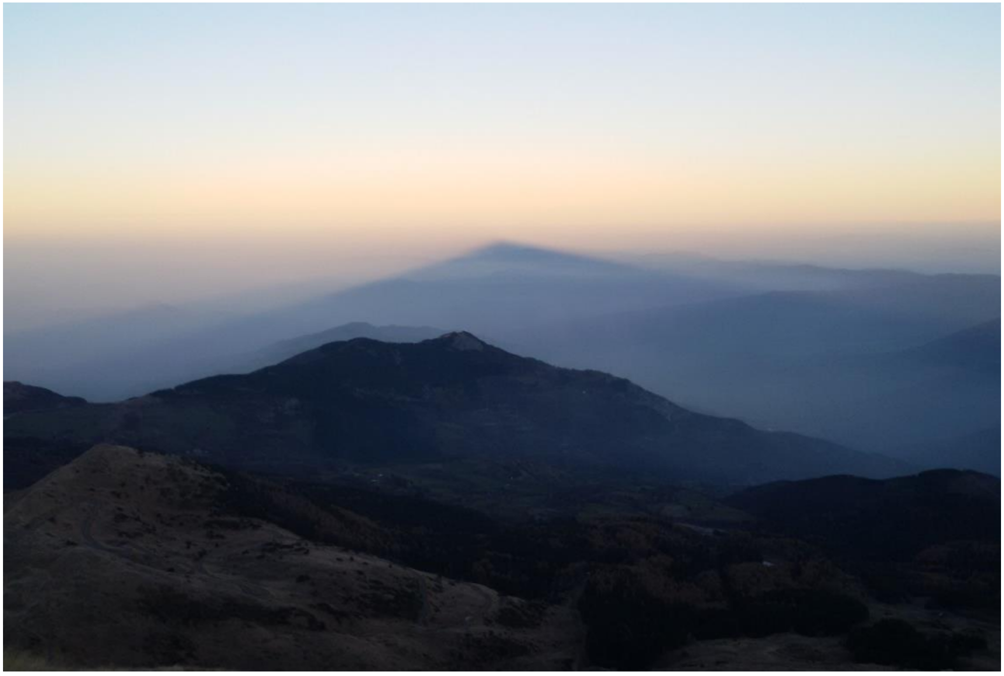
Consiglio Nazionale delle Ricerche
Istituto di Scienze dell'Atmosfera e del Clima

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

AUTUMN 2015 REPORT



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ITALY

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CNR
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DTA
Earth and Environment Department
Dipartimento di Scienze del Sistema Terra e Tecnologie per l'Ambiente

ACTRIS
Aerosol, clouds and trace gases research infrastructure network
Rete di infrastrutture per la ricerca su aerosol, nubi e gas in tracce

NEXTDATA
A national system for the retrieval, storage, access and diffusion of environmental and climate data from mountain and marine areas.
Un sistema nazionale per la raccolta, conservazione, accessibilità e diffusione dei dati ambientali e climatici in aree montane e marine.

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-3
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 Autumn 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 autumn 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 Autumn mean values are calculated by averaging data from 2015, September 1st to 2015, November 30th.**

Even if quality control procedures have been applied, the data series presented in this report must be considered as preliminary: adjustments can occur during the final validation processes.

Premessa

Questo rapporto riassume i risultati relativi alle osservazioni atmosferiche effettuate durante l'autunno 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 autunnale del 2015 considerando:

- **ozono superficiale**
- **monossido di carbonio**
- **ossidi di azoto**
- **anidride solforosa**
- **black carbon**
- **aerosol scattering coefficient**
- **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 autunnali sono calcolati come media dal 1 settembre 2015 al 30 novembre 2015.**

Benché sottoposti a processi di controllo di qualità, i dati presentati in questo report sono da considerare preliminari e suscettibili di aggiustamenti in fase di validazione finale

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.

GLOBAL ATMOSPHERE WATCH

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

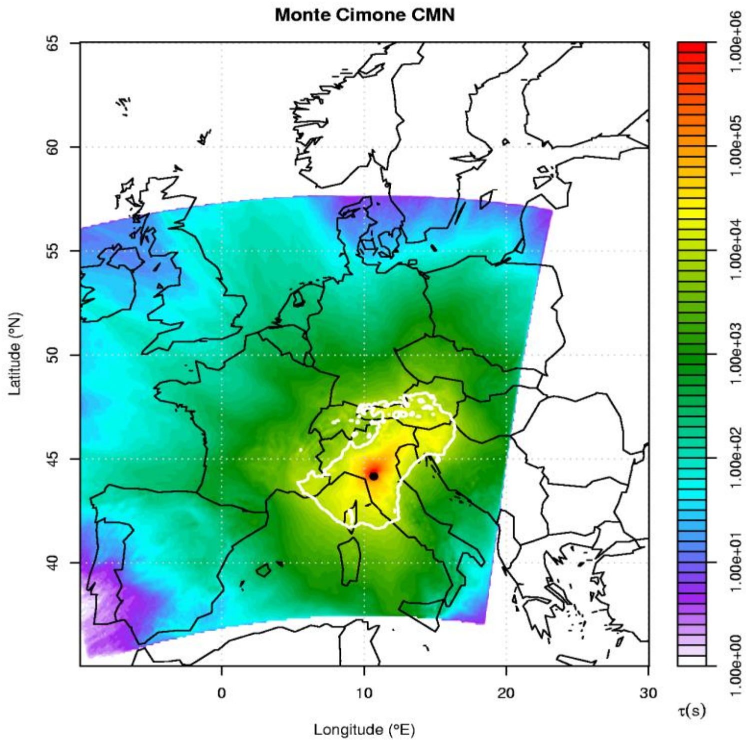
Lista delle stazioni globali GAW/WMO in aree di alta quota (for more information: http://gaw.empa.ch/gawsis/)

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 originated) 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

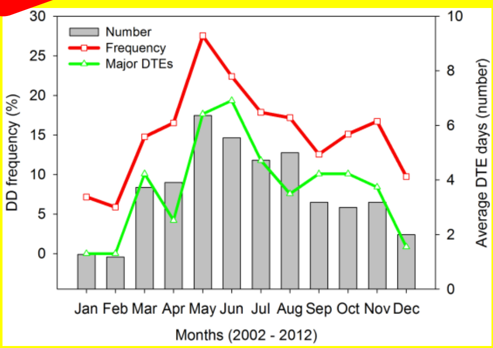
Monte Cimone (44°12' N, 10°42' E, 2165 m s.l.m.) è la cima più alta dell'Appennino Settentrionale, la linea di confine tra due diverse regioni climatiche: l'Europa continentale a Nord ed il Mediterraneo a Sud.

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.

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

NEWS

New publication: "Long-term (2002–2012) investigation of Saharan dust transport events at Mt. Cimone GAW global station, Italy "



A new paper published on "Elementa – Science of the Anthropocene" analyzed the long-term dataset (2002 – 2012) of mineral dust outbreaks observed at Mt. Cimone.

More than 400 episodes of dust outbreaks have been identified, *which means that 15.7% of the measurement period was affected by dust transport events (DTE). The monthly frequency showed a marked seasonal cycle: a minimum in winter and a maximum during the warm season.*

The DTEs observed at CMN are mostly tagged to a macro-region encompassing the Djouf (19°N, 9°W) and Chotts (34°N, 9°E) basins, in Africa.

Finally, ***we found that the O_3 observed at CMN significantly decreased in the presence of high mineral dust loading in the atmosphere****. This can be explained considering the impact of heterogeneous chemistry occurring at the dust particle surface and the ability of dust particles to modify the actinic flux .*

Nuovo studio: *"Long-term (2002–2012) investigation of Saharan dust transport events at Mt. Cimone GAW global station"*

Un articolo appena pubblicato sulla rivista "*Elementa – Science of the Anthropocene*", analizza la serie storica di eventi di trasporto di aerosol minerale (2002 – 2012) a Monte Cimone.

Sono stati identificati oltre 400 episodi di trasporto di sabbia dal Nord Africa (il 15.7% del periodo di misura): la frequenza degli eventi identificati mostra un chiaro ciclo stagionale con un minimo in inverno ed un massimo in primavera-estate.

Sono state identificate le principali aree sorgenti dell'aerosol minerale a Monte Cimone: una macro-regione Africana che include i bacini del Djouf (19°N, 9°W) e del Chotts (34°N, 9°E),oltre alla Libia centrale (25°–30° N; 15°–20°E, 14.4% dei casi).

Infine, **è stata messa in evidenza un diminuzione significativa della concentrazione di ozono al crescere della quantità delle particelle grossolane dell'aerosol** (ossia del quantitativo di sabbia in atmosfera). Tale fenomeno può essere spiegato considerando processi di chimica eterogenea che avvengono sulla superficie dell'aerosol minerale o alla capacità di modificare i flussi di radiazione solare in atmosfera e quindi di interagire con i processi fotochimici che regolano le concentrazioni di ozono

Reference: *Duchi et al., 2016. Long-term (2002–2012) investigation of Saharan dust transport events at Mt. Cimone GAW global station, Italy (2165 m a.s.l.). Elementa. doi 10.12952/journal.elementa.000085*

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 studies and the experimental set-up at ICO-OV (shaded rows indicate the parameters considered by this Report).

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 (le righe colorate indicano i parametri considerati in questo Report).

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

Autumn 2015 was characterized by low average levels of short-lived climate forcers (SLCF): values lower than the climatological mean were observed for black carbon and surface ozone and fine particles, while the coarse particle average concentration was well comparable with the typical autumn values.

No major pollution events affected this season, a result corroborated by the lowest seasonal average concentrations of black carbon and fine particles ever observed at CMN.

15 days (16.5 %) were affected by mineral dust transport: the event occurring from September 12th to 18th showed the highest daily coarse particle average concentration.

The selection methodology allows the identification of 9 days (9.9 %) related with air-mass transport from the stratosphere, with the SI events equally distributed during the three months.

Daily **surface ozone** peak was recorded on 12-09 (60.1 ppb). 30-minute average values ranged from a minimum of 11.0 ppb (27-11) to 75.8 ppb (02-09), with an average seasonal value of 46.9 ppb. This value is lower than the average climatological autumn value obtained from the last 19 years (48.2 ppb).

Daily **carbon monoxide** peak was recorded on 21-10 (177.2 ppb). 30-minute average values ranged from a minimum of 59.0 ppb (27-11) to 207.2 ppb (21-10), with an average seasonal value of 111.9 ppb. This value is higher than the average autumn value obtained from the last 3 years (109.2 ppb).

Daily **nitric oxide** and **nitrogen dioxide** peaks were recorded on 23-11 (0.25 ppb and 1.12 ppb respectively). 30-minute average values ranged from values below the detection limit to 2.40 ppb (for NO) and 5.95 ppb (for NO_2).

Daily **sulfur dioxide** peak was recorded on 31-10 (0.96 ppb). 30-minute average values ranged from values below the detection limit to 1.99 ppb (01-11), with an average seasonal value of 0.10 ppb.

Daily **black carbon** peak was recorded on 11-09 (262.9 ng m^{-3}). 30-minute average values ranged from a minimum of 10.0 ng m^{-3} (07-11) to 503.1 ng m^{-3} (30-09), with an average seasonal value of 79.9 ng m^{-3}. This value is lower than the average climatological seasonal value obtained from the last 10 years (179.9 ng m^{-3}).

Sommario

VISIONE DI INSIEME

L'autunno 2015 si caratterizza per la presenza di bassi valori medi di *short-lived climate forcers* (SLCF): il black carbon, l'ozono e le particelle fini mostrano concentrazioni inferiori rispetto alle medie climatologiche, mentre i valori delle particelle grossolane risultano essere in linea con i valori tipici della stagione autunnale.

Di particolare rilevanza è l'assenza, durante questa stagione, di eventi significativi di inquinamento, risultato ulteriormente sottolineato dal fatto che le concentrazioni medie stagionali di black carbon e particelle fini sono le più basse mai osservate nei periodi autunnali.

Eventi di trasporto di sabbia sahariana hanno interessato il sito di misura per 15 giorni (16.5% della stagione). Le concentrazioni più elevate di particelle grossolane sono state osservate nel corso dell'evento registrato dal 12 al 18 settembre.

La metodologia di selezione ha permesso di identificare 9 eventi (9.9 %) associabili a trasporto di masse d'aria provenienti dalla stratosfera.

Il valore massimo giornaliero della concentrazione di **ozono superficiale** è stato registrato il 12-09 (60.1 ppb). Le medie semi-orarie variano da 11.0 ppb (27-11) a 75.8 ppb (02-09), con un valore medio stagionale di 46.9 ppb. Tale valore è inferiore a quello climatologico relativo agli ultimi 19 anni (48.2 ppb).

Il valore massimo giornaliero della concentrazione di **monossido di carbonio** è stato registrato il 21-10 (177.2 ppb). Le medie semi-orarie variano da 59.0 ppb (27-11) a 207.2 ppb (21-10), con un valore medio stagionale pari a 111.9 ppb. Tale valore è superiore a quello delle ultime tre stagioni autunnali (109.2 ppb).

I valori massimi giornalieri di **ossido d'azoto** e **biossido d'azoto** sono stati registrati il 23-11 (0.25 ppb e 1.12 ppb rispettivamente). Le medie semi-orarie sono variate da valori inferiori al limite di rivelazione sino a 2.40 ppb (per NO) e 5.95 ppb (per NO_2).

Il valore massimo giornaliero di **biossido di zolfo** è stato registrato il 31-10 (0.96 ppb). Le medie semi-orarie sono variate da valori inferiori al limite di rilevabilità sino a 1.99 ppb (01-11), con un valore medio stagionale pari a 0.10 ppb.

Il valore massimo giornaliero della concentrazione di **black carbon** è stato registrato il 11-09 (262.9 ng m^{-3}). Le medie semi-orarie variano da 10.0 ng m^{-3} (07-11) a 503.1 ng m^{-3} (30-09), con un valore medio stagionale pari a 79.9 ng m^{-3}. Tale valore è inferiore a quello climatologico relativo agli ultimi 10 anni (179.9 ng m^{-3}).

Daily **fine aerosol particles** peak was recorded on 01-09 (23.0 cm^{-3}). 30-minute average values ranged from below the detection limit to 44.9 cm^{-3} (11-09), with an average seasonal value of 5.6 cm^{-3}. This value is lower than the average climatological autumn value obtained from the last 13 years (16.2 cm^{-3}).

Daily **coarse aerosol particles** peak was recorded on 14-09 (1.6 cm^{-3}). 30-minute average values ranged from below the detection limit to 9.7 cm^{-3} (16-09), with an average seasonal value of 0.2 cm^{-3}. This value is on par with the average climatological autumn value obtained from the last 13 years (0.2 cm^{-3}).

Daily **aerosol scattering coefficient at 550 nm** peak was recorded on 05-10 (12.2 Mm^{-1}). 30-minute average values ranged from below the detection limit to 45.6 Mm^{-1} (06-11), with an average seasonal value of 2.6 Mm^{-1}. This value is lower than the average climatological autumn value obtained from the last 8 years (18.3 Mm^{-1}).

Il valore massimo giornaliero della concentrazione di **particelle fini** è stato registrato il 01-09 (23.0 cm^{-3}). Le medie semi-orarie variano da valori inferiori al limite di rivelazione a 44.9 cm^{-3} (11-09), con un valore medio stagionale pari a 5.6 cm^{-3}. Tale valore è inferiore a quello climatologico degli ultimi 13 anni (16.2 cm^{-3}).

Il valore massimo giornaliero della concentrazione di **particelle grossolane** è stato registrato il 14-09 (1.6 cm^{-3}). Le medie semi-orarie variano da valori inferiori al limite di rivelazione a 9.7 cm^{-3} (16-09), con un valore medio stagionale pari a 0.2 cm^{-3}. Tale valore è in linea con quello climatologico relativo agli ultimi 13 anni (0.2 cm^{-3}).

Il picco giornaliero del **coefficiente di scattering dell'aerosol a 550 nm** è stato osservato il 05-10 (12.2 Mm^{-1}). Le medie sui 30-minuti oscillano tra valori inferiori al limite di rilevabilità e 45.6 Mm^{-1} (06-11), con un valore medio stagionale di 2.6 Mm^{-1} che risulta essere inferiore al valore medio climatologico relativo agli ultimi 8 anni (18.3 Mm^{-1}).

Daily **air temperature** peak was recorded on 12-11 (12.9 °C), minimum on 26-11 (-8.0 °C). 30-minute average values ranged from a minimum of -9.6 °C (26-11) to 17.6 °C (12-11), with an average seasonal value of 4.3 °C, which is higher than the seasonal climatological value (3.8 °C).

Daily **relative humidity** minimum was recorded on 13-11 (18.1%). 30-minute average values ranged from a minimum of 6.3 % (24-10) to a maximum of 100.0 % (observed on 44 days), with an average seasonal value of 76.3 %. This value is lower than the average climatological autumn value obtained from the last 19 years (81.6 %).

Daily **atmospheric pressure** peak was recorded on 08-11 (803.5 hPa), the lowest value on 22-11 (767.6 hPa). 30-minute average values ranged from a minimum of 761.6 hPa (22-11) to 804.2 hPa (08-11), with an average seasonal value of 791.1 hPa, which is higher than the average climatological autumn value obtained from the last 19 years (789.7 hPa).

Daily **wind speed** peak was recorded on 22-10 (23.4 m s^{-1}). 30-minute average values ranged from a minimum of 0.4 m s^{-1} (11-11) to a maximum of 28.1 m s^{-1} (22-10), with an average seasonal value of 7.2 m s^{-1}. This value is lower than the climatological autumn value (8.0 m s^{-1}).

Wind direction was prevalently SW (37.5 % 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 08-09 (258.4 W m^{-2}). The lowest average daily value (8.2 W m^{-2}) was observed on 14-10. The week starting on 10-10, with average values below 100 W m^{-2}, is representative of a period 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 01-09 (0.43 W m^{-2}).

Il valore massimo giornaliero della **temperatura** è stato registrato il 12-11 (12.9 °C), il valore minimo il 26-11 (-8.0 °C). Le medie semi-orarie variano da -9.6 °C (26-11) a 17.6 °C (12-11), con un valore medio stagionale pari a 4.3 °C, superiore a quello medio climatologico autunnale (3.8 °C).

Il valore minimo giornaliero dell'**umidità relativa** è stato registrato il 13-11 (18.1 %). Le medie semi-orarie variano da 6.3 % (24-10) a 100 % (osservato in 44 giornate), con un valore medio stagionale pari a 76.3 %. Tale valore è inferiore a quello climatologico relativo agli ultimi 19 anni (81.6 %).

Il valore massimo giornaliero della **pressione atmosferica** è stato registrato il 08-11 (803.5 hPa), il valore minimo il 22-11 (767.6 hPa). Le medie semi-orarie variano da 761.6 hPa (26-11) a 804.2 hPa (08-11), con un valore medio stagionale pari a 791.1 hPa, superiore a quello climatologico relativo agli ultimi 19 anni (789.7 hPa).

Il valore massimo giornaliero della **velocità del vento** è stato registrato il 22-10 (23.4 m s^{-1}). Le medie semi-orarie variano da 0.4 m s^{-1} (11-11) a 28.1 m s^{-1} (22-10), con un valore medio stagionale pari a 7.2 m s^{-1}. Tale valore è inferiore rispetto a quello climatologico ottenuto dalle misure realizzate negli ultimi 19 anni (8.0 m s^{-1}).

La **direzione del vento** osservata nell' autunno 2015 è stata prevalentemente da Sud-Ovest (37.5 % dei dati semi-orari), in linea con la climatologica prevalenza di venti sudoccidentali.

La **radiazione solare** mostra il valore giornaliero massimo il 08-09 (258.4 W m^{-2}), con valori elevati associati a condizioni di cielo libero. Il minimo giornaliero (8.2 W m^{-2}) è stato osservato il 14-10, con la settimana iniziata il 10-10 caratterizzata da valori medi inferiori a 100 W m^{-2}, rappresentativo di un periodo caratterizzato dalla presenza di copertura nuvolosa.

Analogo comportamento viene osservato per quanto riguarda la **radiazione UV**, con il massimo giornaliero, pari a 0.43 W m^{-2}, osservato il 01-09.

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.

Day	September	October	November
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			

LEGEND

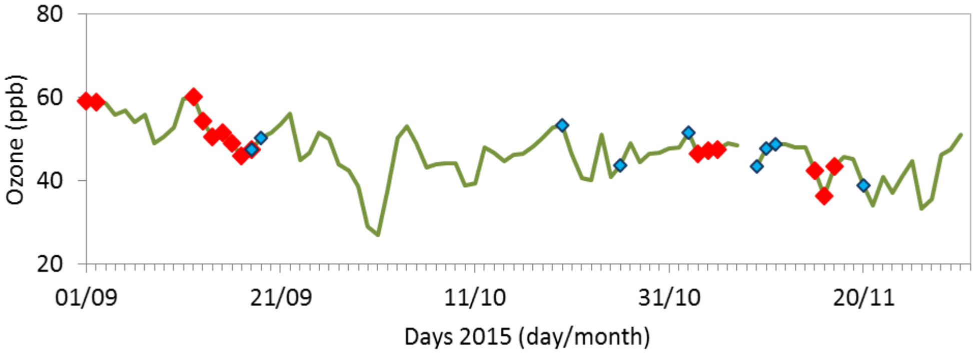
Mineral dust   Stratospheric intrusions   Pollution transport

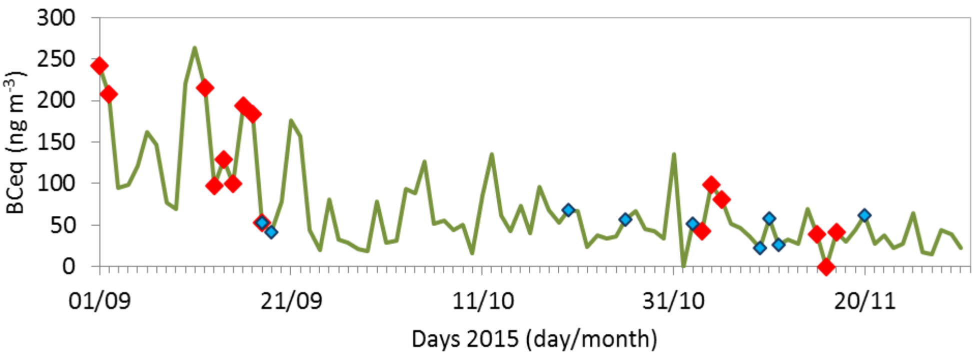
Eventi speciali

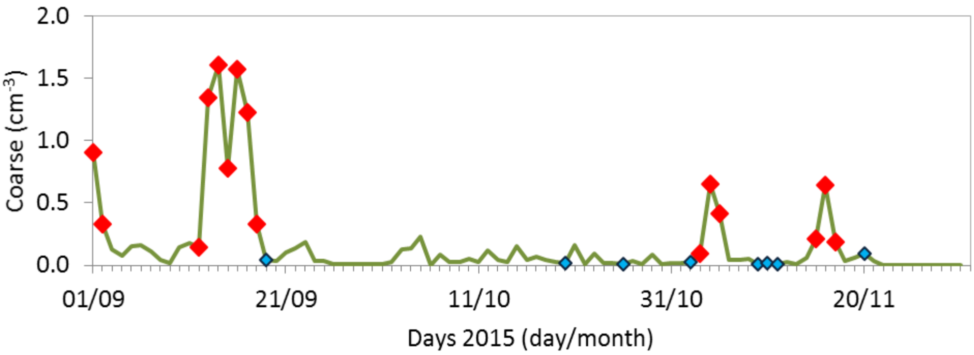
In questo paragrafo viene presentato l'elenco degli "eventi speciali" che sono stati registrati presso il sito di misura durante il periodo analizzato:

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

<u>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.</u>







LEGENDA

Trasporto polveri minerali | Intrusioni stratosferiche | Trasporto di inquinanti

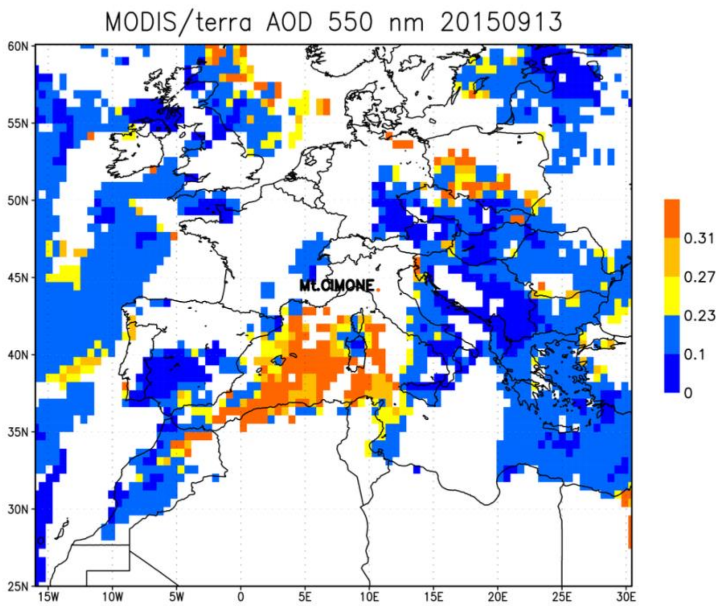
Mineral dust transport

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.

AUTUMN 2015:

- **15 days were characterized by the transport of mineral dust from northern Africa (16.5 % of the period).**
- **No mineral dust transport event were detected during October, with September characterized by the presence of a single event lasting 7 days.**
- **The highest daily average coarse particle number concentration (1.6 cm^{-3}) was observed during the 12th – 18th September transport event.**



Aerosol Optical Depth at 500 nm from MODIS sensor on board of *Terra* satellite by NASA. Elaboration by ISAC-CNR (13th September 2015).

Misura dello spessore ottico dell'aerosol (AOD) a 550 nm dal sensore MODIS a bordo del satellite *Terra* della NASA. Elaborazioni ISAC-CNR (13 settembre 2015).

http://www.isac.cnr.it/cimone/SMA/

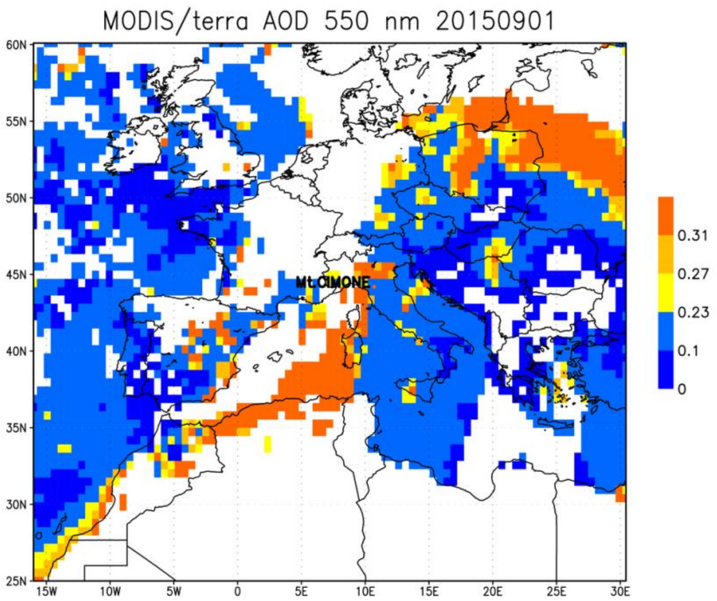
Trasporto di polveri minerali

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.

AUTUNNO 2015:

- **15 giorni sono stati caratterizzati dal trasporto di polveri minerali proveniente dal Nord Africa (16.5 % del periodo).**
- **Non sono stati osservati eventi di trasporto nel mese di Ottobre. Settembre è stato caratterizzato dalla presenza di un singolo eventi della durata di 7 giorni.**
- **Il picco di concentrazione di particelle grossolane (1.6 cm^{-3}) è stato osservato durante il trasporto di aerosol minerale osservato dal 12 al 18 settembre.**



Aerosol Optical Depth at 500 nm from MODIS sensor on board of *Terra* satellite by NASA. Elaboration by ISAC-CNR (1st September 2015).

Misura dello spessore ottico dell'aerosol (AOD) a 550 nm dal sensore MODIS a bordo del satellite *Terra* della NASA. Elaborazioni ISAC-CNR (1 settembre 2015).

http://www.isac.cnr.it/cimone/SMA/

Stratospheric intrusions (SI)

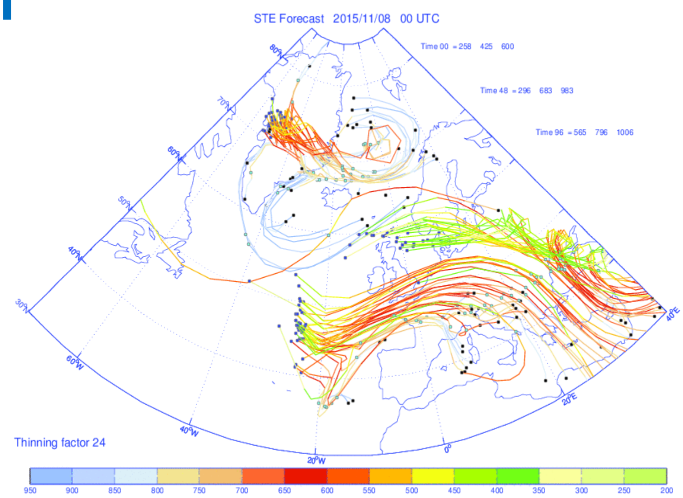
Stratospheric intrusions (SI) can be considered as a specific aspect of stratosphere–troposphere exchange (STE): the irreversible downward transport of stratospheric air relatively deep into the troposphere. Such phenomena are highly episodic and can be favored by a number of different mechanisms, acting 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).

AUTUMN 2015:

- **During autumn 2015, we detected 9 days affected by the transport of air masses from the stratosphere, representing the 9.9 % of the analysed period.**
- **The highest ozone concentration during a STE was observed on October 20th, with a daily average of 53.5 ppb.**
- **November 9th – 11th represents the longest seasonal period continuously affected by this kind of phenomena.**



Trajectories describing the path of stratospheric air-masses for the event of 11th November 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 dell' 11 novembre 2015. Il colore rappresenta la quota (espressa come livello di pressione) delle masse d'aria.

Elaborazione: Michael Sprenger (ETH-Z, Switzerland)
http://www.isac.cnr.it/cimone/ste

Intrusioni stratosferiche (SI)

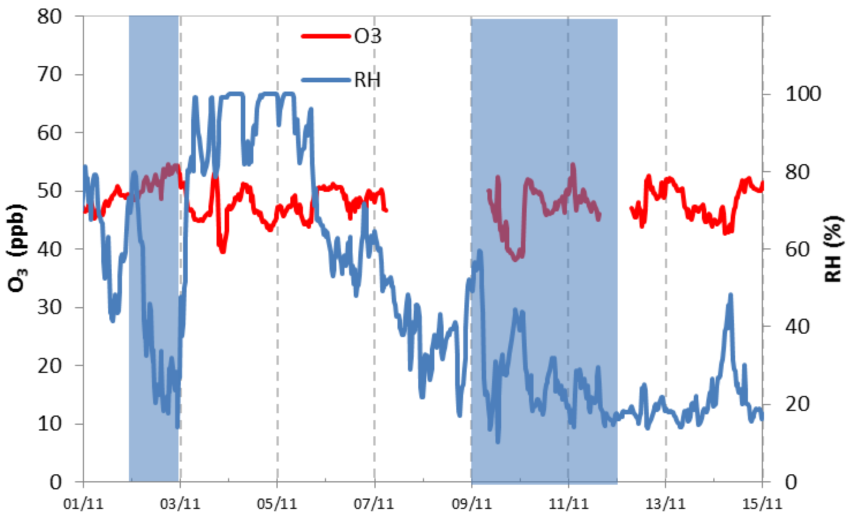
Le intrusioni stratosferiche (SI) possono essere considerate un aspetto specifico degli scambi stratosfera-troposfera (STE). Tali fenomeni, che avvengono in maniera episodica, possono essere favoriti da processi dinamici e meteorologici caratteristici che agiscono su differenti scale spazio-temporali: 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).

AUTUNNO 2015:

- **Durante l'autunno 2015 sono stati identificati 9 episodi di intrusione stratosferica, corrispondenti al 9.9 % del periodo analizzato.**
- **La concentrazione media giornaliera più elevata di ozono durante gli eventi di intrusione stratosferica è stata osservata il 20 ottobre (53.5 ppb).**
- **Il periodo compreso tra il 9 e l'11 Novembre è stato caratterizzato dalla continua presenza di intrusioni stratosferiche.**



Relative humidity (blue) and ozone (red) at CMN during the 1st – 15th November 2015. *The blue bars indicates the days probably affected by SI.*

Andamento dell'umidità relativa (azzurro) ed ozono (rosso) nel periodo 1 - 15 Novembre 2015. *Le barre azzurre indicano il periodo probabilmente influenzato dagli eventi di SI.*

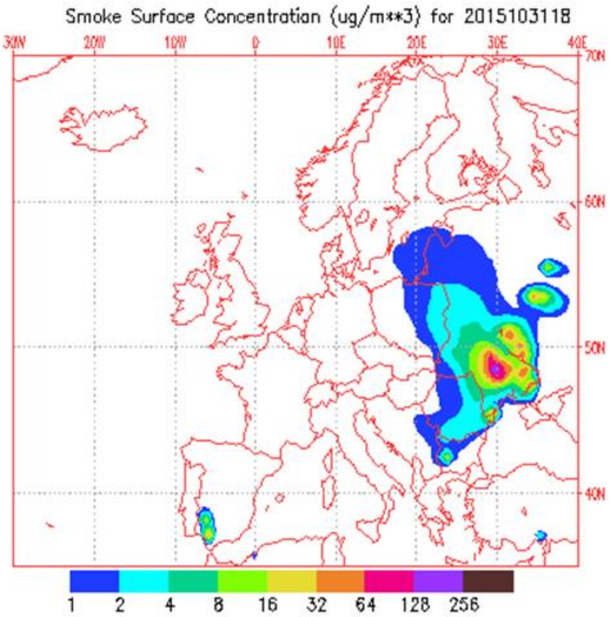
Pollution transport

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.

AUTUMN 2015

- **Basing on the selection methodology and data interpretation, during this season no major pollution events were observed at CMN.**
- **This result is further stressed by the low values of seasonal average concentrations of black carbon and fine aerosol.**
- **However, during the period from October 30th till November 2nd, high daily average concentrations of SO_2 were observed, when air-masses from East Europe affected CMN. A possible role of widespread open fires occurring in East Europe as further source of SO_2 cannot be neglected (see below).**



Smoke Surface concentration simulation by NAAPS model (31th Ocotber 2015). The colored scale represents the smoke mixing ratio expressed as μg m^{-3}.

Simulazione della concentrazione di prodotti di combustione da fuochi del 31 Ottobre 2015 (modello NAAPS). La scala colorata rappresenta la concentrazione del fumo, espressa in μg m^{-3}.

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

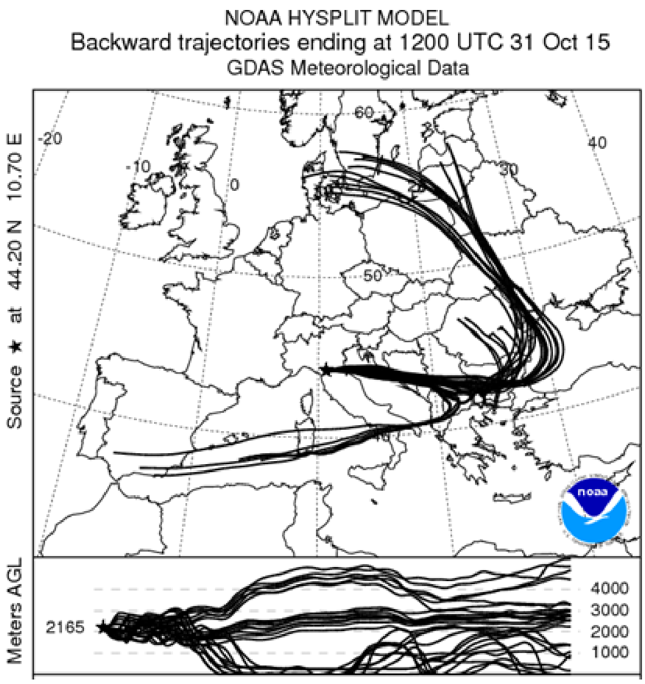
Trasporto di inquinanti

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

AUTUNNO 2015

- **Sulla base della metodologia di selezione e sull'analisi dei dati osservati, durante questa stagione non sono stati registrati eventi significativi di inquinamento.**
- **Le concentrazione medie di black carbon e della frazione fine dell'aerosol atmosferico hanno fatto registrare le concentrazioni stagionali più basse di sempre.**
- **Tuttavia, è stato registrato un evento di elevate concentrazioni di SO_2 tra il 30 Ottobre ed il 2 Novembre, associato al trasporto di masse d'aria dall'Europa dell'Est. Per tale evento non può essere esclusa anche l'influenza di emissioni legate all'occorrenza di incendi nella regione a Nord del Mar Nero.**



120-h back-trajectories (HYSPLIT model) ending at Mt.Cimone on October 31th, for the major SO_2 concentration peak.

Retrotraiettorie a 5 giorni ottenute tramite il modello HYSPLIT della NOAA calcolate per l'evento di incremento della SO_2.

http://ready.arl.noaa.gov/HYSPLIT_traj.php

Courtesy by NOAA Air Resources Laboratory.

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.

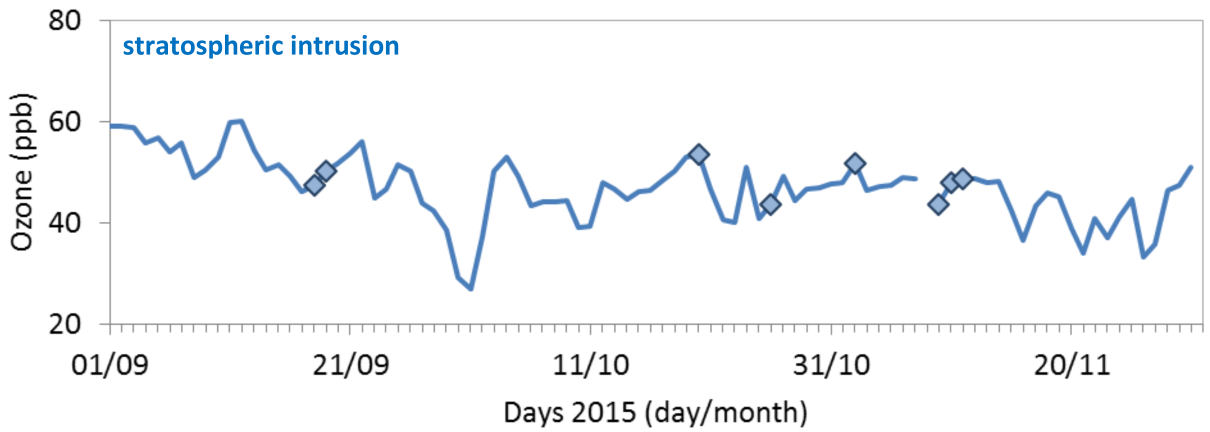
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

Data availability (%)	Min value (ppb)	25^{th} Percentile (ppb)	50^{th} Percentile (ppb)	Average mean value (ppb)	75^{th} percentile (ppb)	Max value (ppb)
97.0	11.0	43.1	47.4	46.9	51.1	75.8

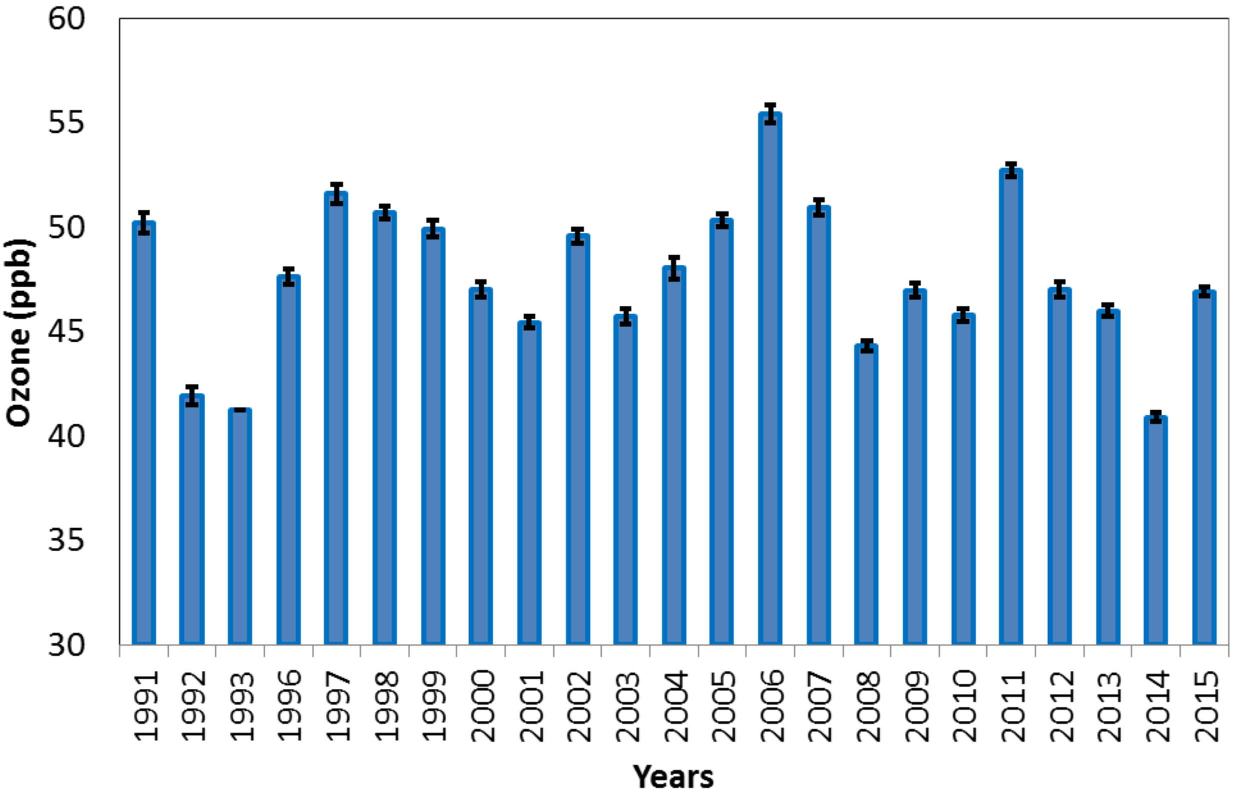
Time series of daily mean values

Relatively high concentrations were observed in the first half of September, while very low values were observed at the end of September, together with high NO and NO_2 mixing ratios, a likely indication of tritation processes.



Comparison with historical data-set

The O_3 seasonal mean value is 46.9 ppb, a value **lower than the climatological one (48.2 ppb).** This is related to the lower than average concentrations observed throughout the season with the exception of the first half of September.



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.

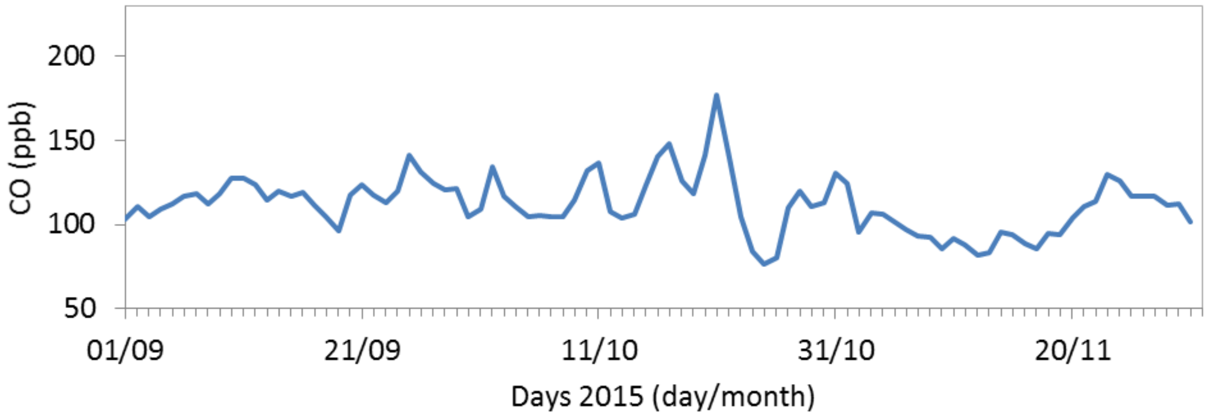
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

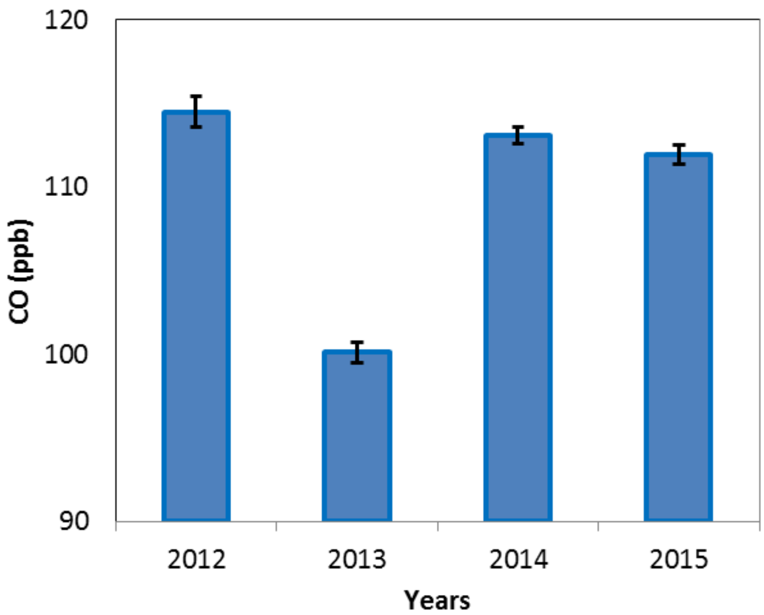
Data availability (%)	Min value (ppb)	25th Percentile (ppb)	50th Percentile (ppb)	Average mean value (ppb)	75th percentile (ppb)	Max value (ppb)
96.5	59.0	99.3	111.8	111.9	122.2	207.2

Time series of daily mean values

The CO mixing ratio showed a steady decrease in the observed mixing ratio, with 6 days below the average seasonal climatological value during September, 12 days during October and 20 out of 30 during November. Extremely low values were observed in the central part of November, when clean, warm air coming from North Africa reached the measurement site.



Comparison with historical data-set
The 2015 autumn average mean value of CO was 111.9 ppb, which is **higher than the average mean value of 109.2 ppb obtained from the last 3 years.** However, it should be noted that this result is skewed by the presence of the extremely low values on autumn 2013.



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

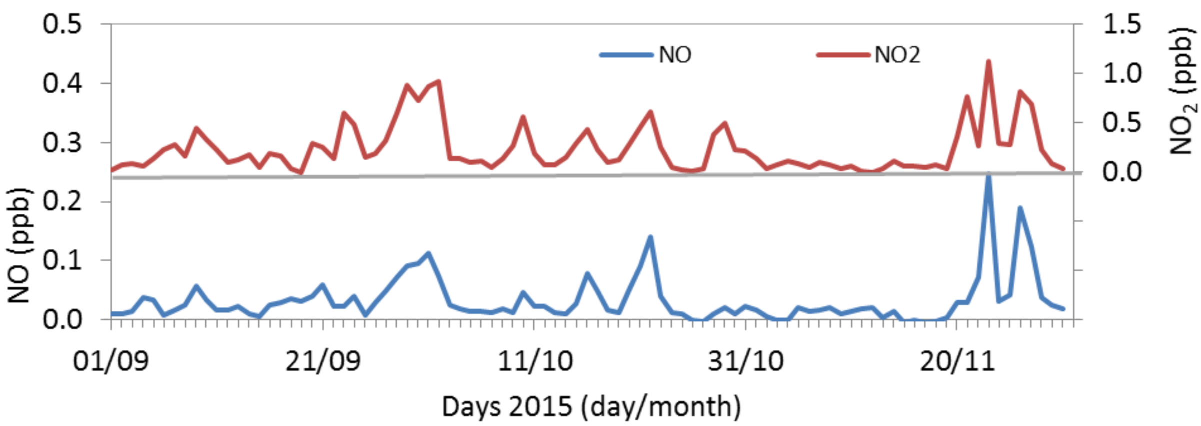
Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

Data availability (%)	Min value (ppb)	25^{th} percentile (ppb)	50^{th} percentile (ppb)	Average mean value (ppb)	75^{th} percentile (ppb)	Max value (ppb)
NO 98.4	UDL	UDL	0.01	0.03	0.03	2.40
NO_2 98.4	UDL	0.05	0.12	0.2	0.26	5.9

UDL: under detection limit

Time series of daily mean values

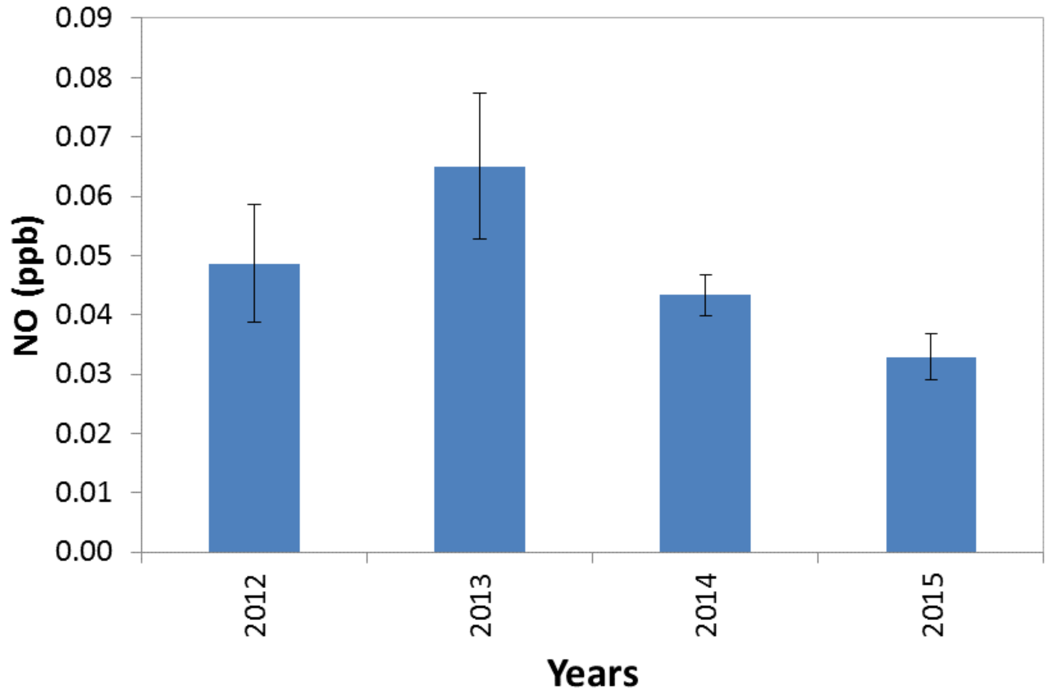
The highest daily average NO value (blue line: 0.25 ppb) was observed on November 23^{th}, together with the highest NO_2 value (red line: 1.12 ppb), after a "clean" period from 1^{st} to 20^{th} November.

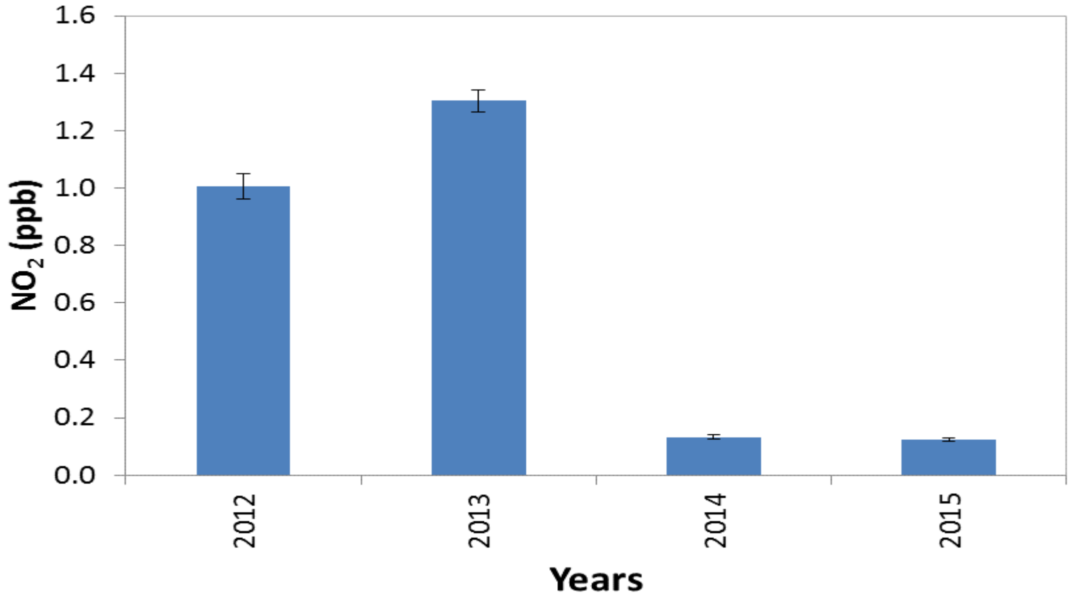


Comparison with historical data-set

The 2015 autumn average mean value of NO (NO_2) was 0.03 ppb (0.2 ppb) which **is comparable (lower) to the average autumn mean value of 0.05 ppb (0.7 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

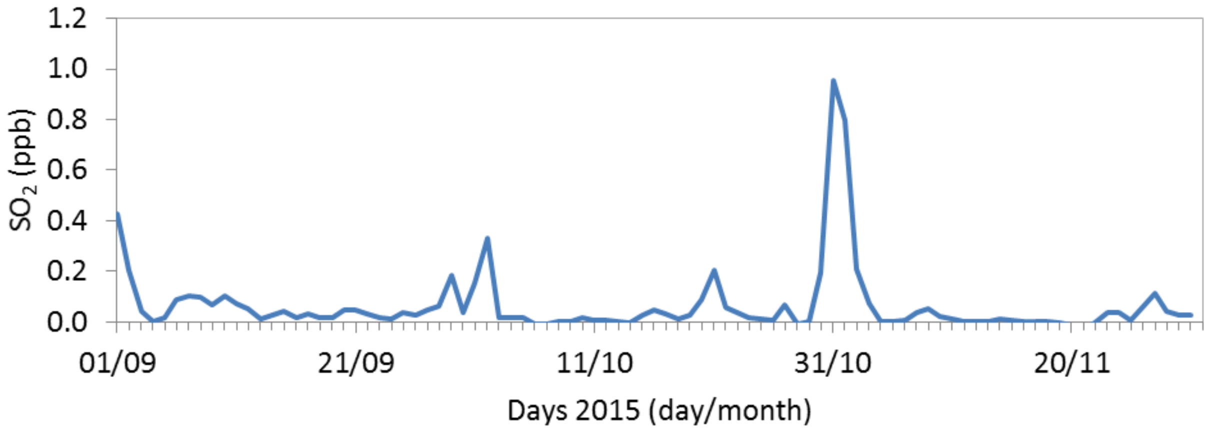
Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

Data availability (%)	Min value (ppb)	25th percentile (ppb)	50th percentile (ppb)	Average mean value (ppb)	75th percentile (ppb)	Max value (ppb)
98.1	UDL	UDL	0.02	0.10	0.15	2.0

UDL: under detection limit

Time series of daily mean values

During autumn 2015, the average SO_2 mixing ratio was lower than the detection limit for the most part of the period. However, even though several SO_2 peaks were observed, with the highest daily mixing ratio (0.9 ppb) observed between October 30th and November 02nd, when easterly air masses reached the measurement site after passing over the Black Sea region.



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.

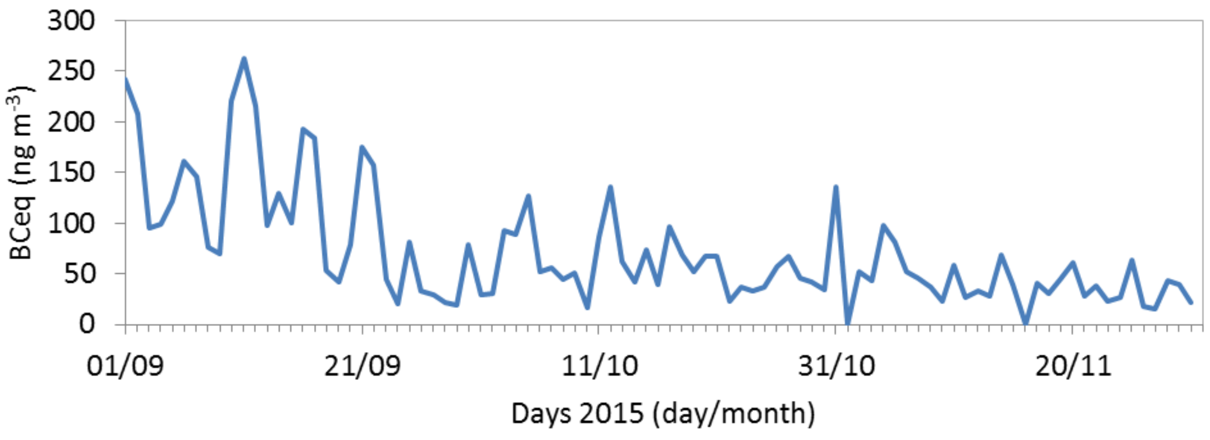
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 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})
81.0	10.0	26.6	53.8	79.9	105.9	503.1

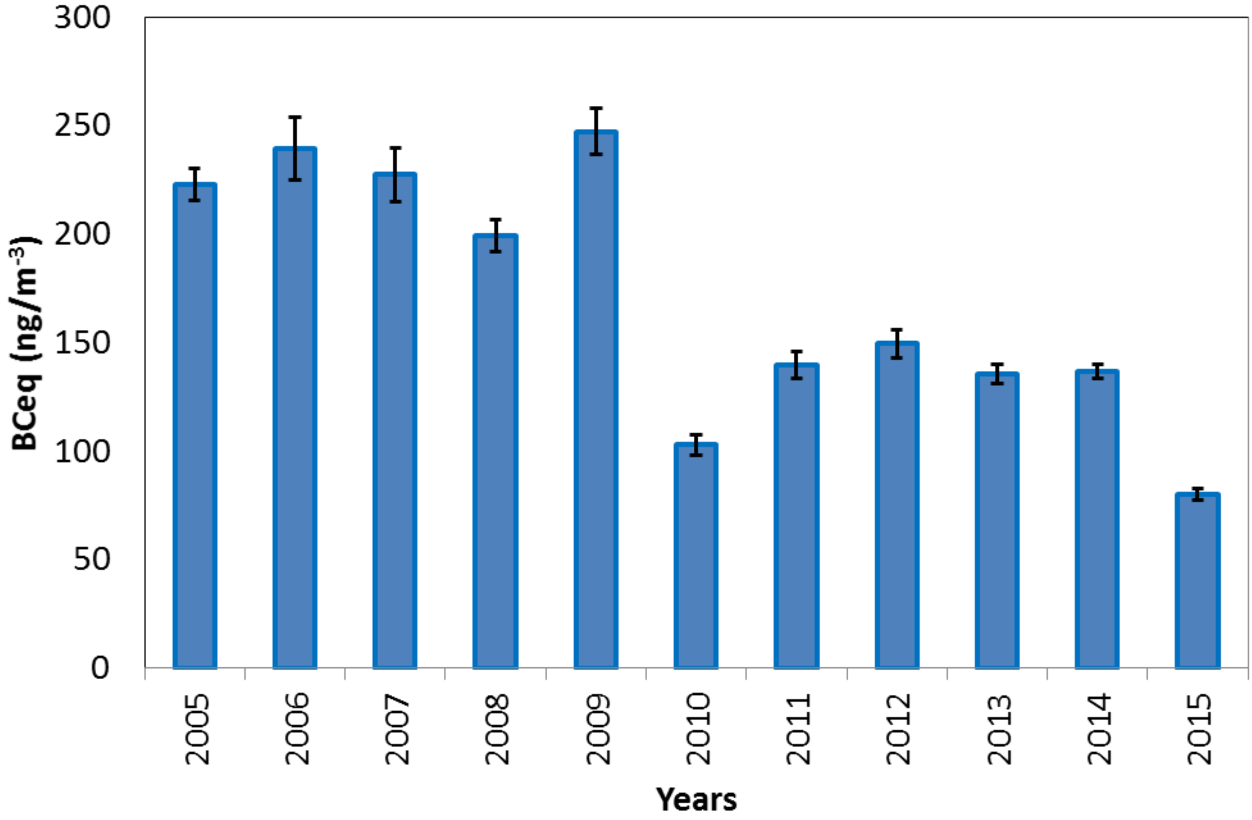
Time series of daily mean values

During autumn 2015, the absorbing aerosols concentration was characterized by a steady decrease. This behavior is in agreement with the typical seasonal cycle, which is characterized by the highest concentration during summer declining towards winter. Moderate black carbon daily value peaks (higher than 150 ng m^{-3}) were observed on September.



Comparison with historical data-set

The 2015 autumn average mean value of BC is 79.9 ng m^{-3}, **which is lower than the climatological mean value (179.9 ng m^{-3}).** This represents **the lowest seasonal concentration ever observed during autumn** at Mt.Cimone.



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

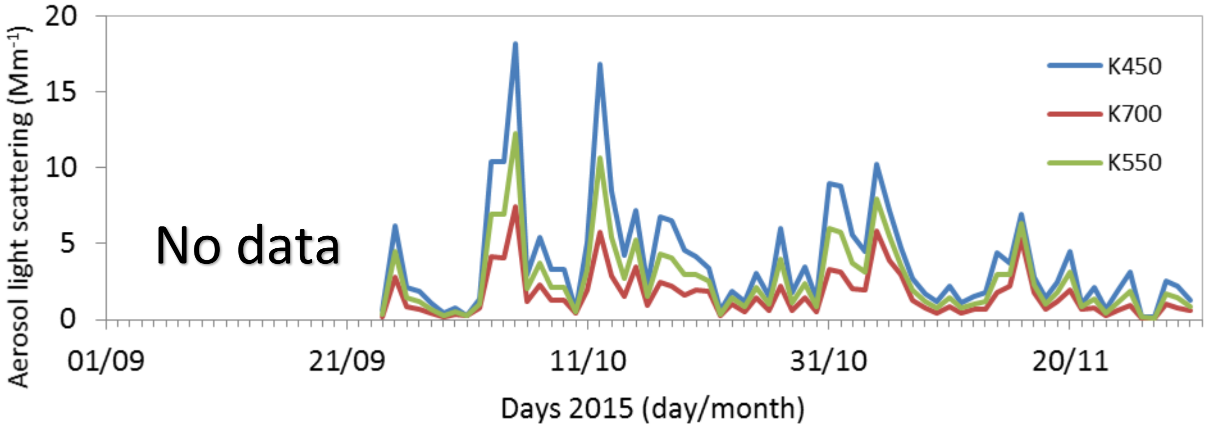
Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

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 73.3	UDL	0.8	1.9	3.8	5.2	53.9
550 nm 73.3	UDL	0.5	1.2	2.6	3.5	45.6
450 nm 73.3	UDL	0.3	0.7	1.6	2.1	53.1

UDL: under detection limit

Time series of daily mean values

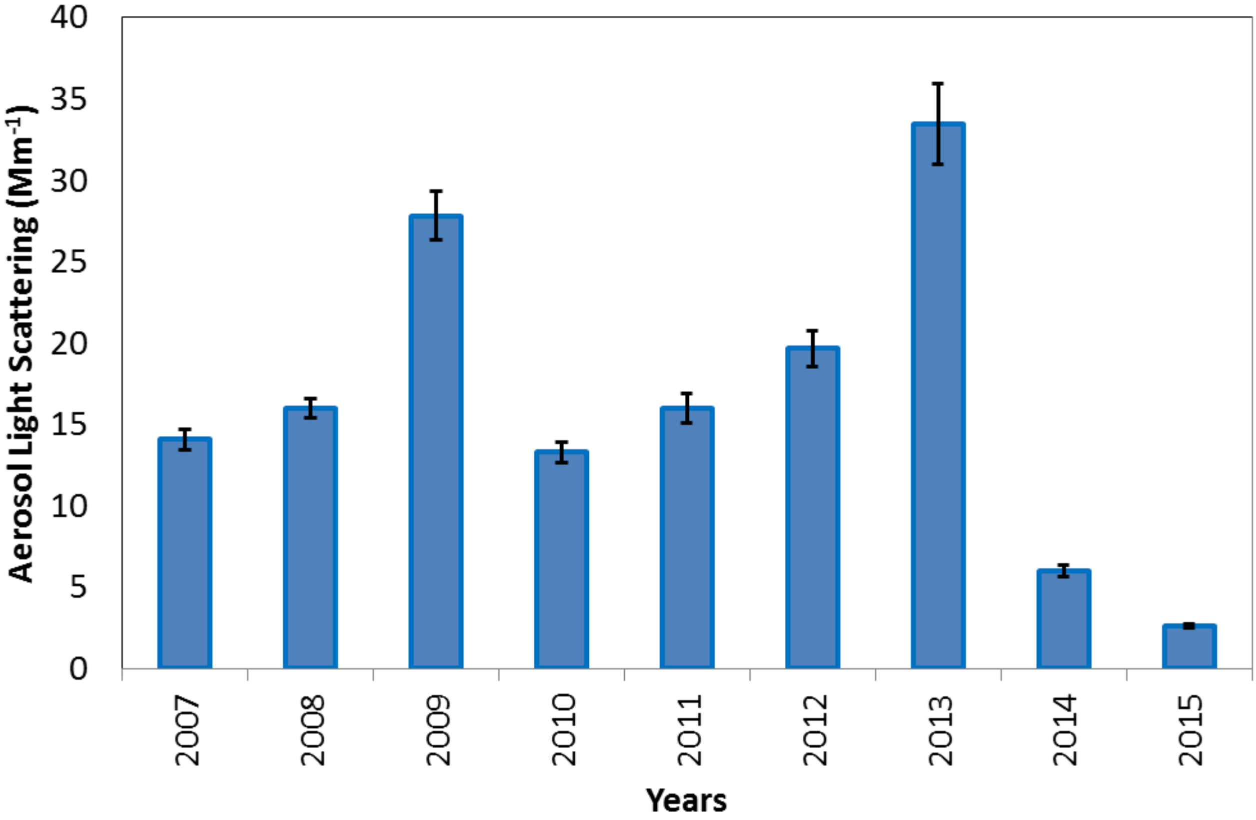
The highest daily mean value of the scattering coefficient at all three wavelength (450, 550, 700 nm) has been observed on October 05th, with the time series well matching the black carbon ones.



Comparison with historical data-set

The 2015 autumn average mean value of scattering coefficient at 550 nm is 2.6 Mm^{-1}, which is **lower than the climatological mean value (18.3 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

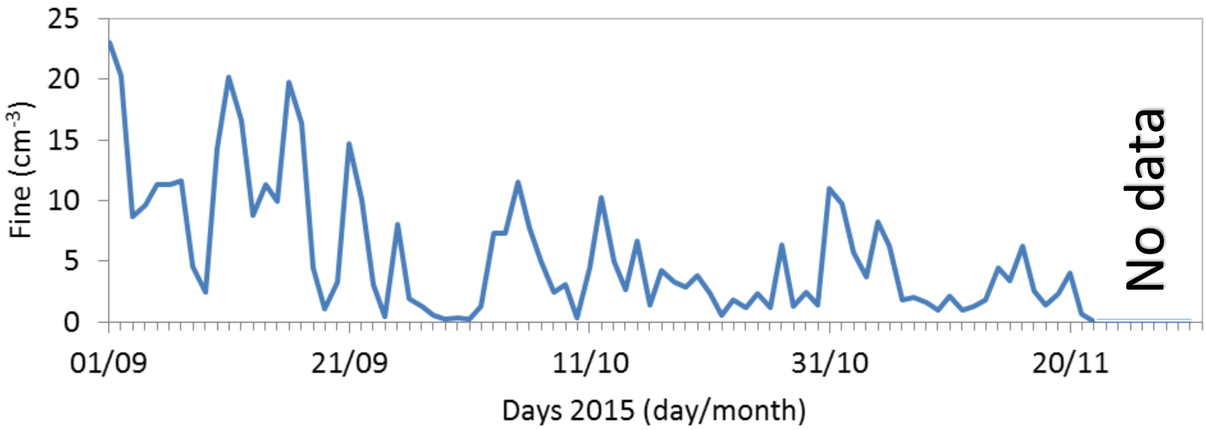
Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

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})
89.0	UDL	0.8	2.7	5.6	8.0	44.9

UDL: under detection limit

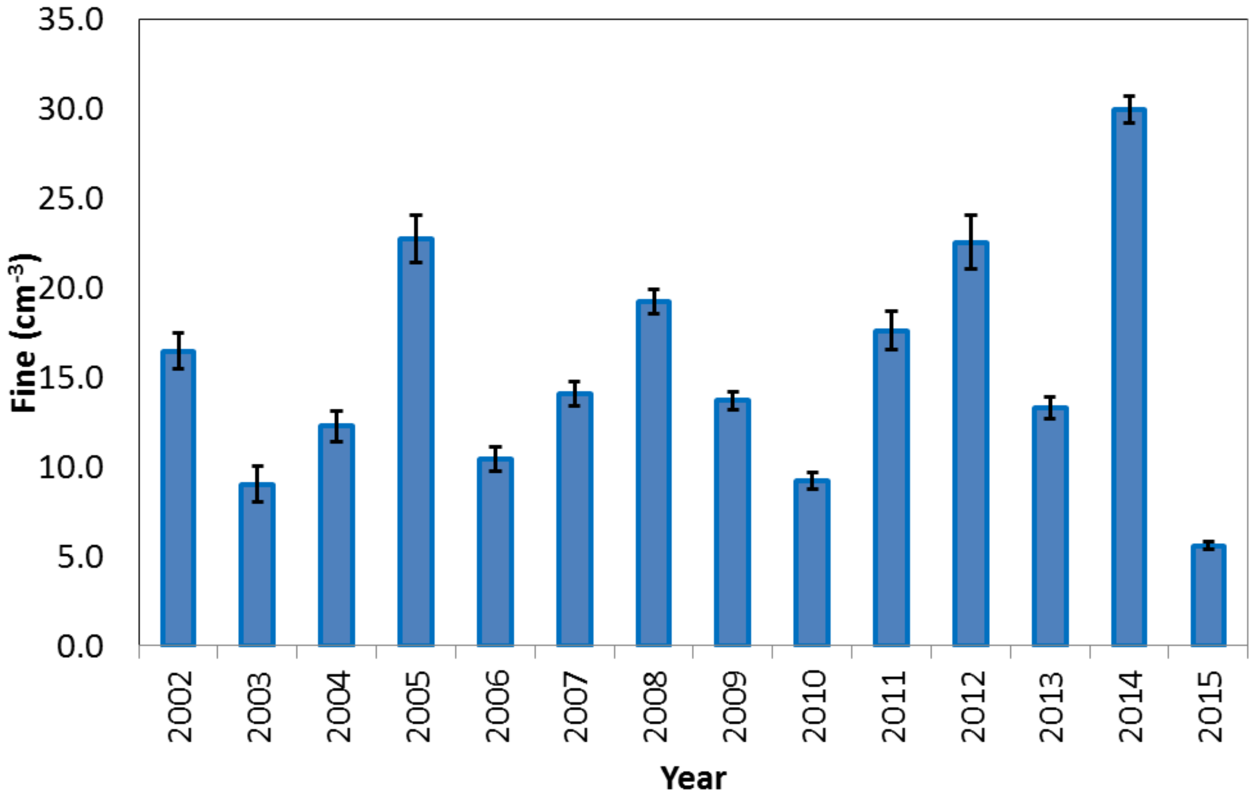
Time series of daily mean values

As observed for BC, the highest fine particles number concentrations were on September, with a decreasing trend representing the seasonal transition from summer to winter regimes.



Comparison with historical data-set

Autumn 2015 fine particle average number concentration was 5.6 cm^{-3}, **lower to the seasonal climatological value (16.2 cm^{-3}).** This value ranked as the lowest ever observed at Mt.Cimone.



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

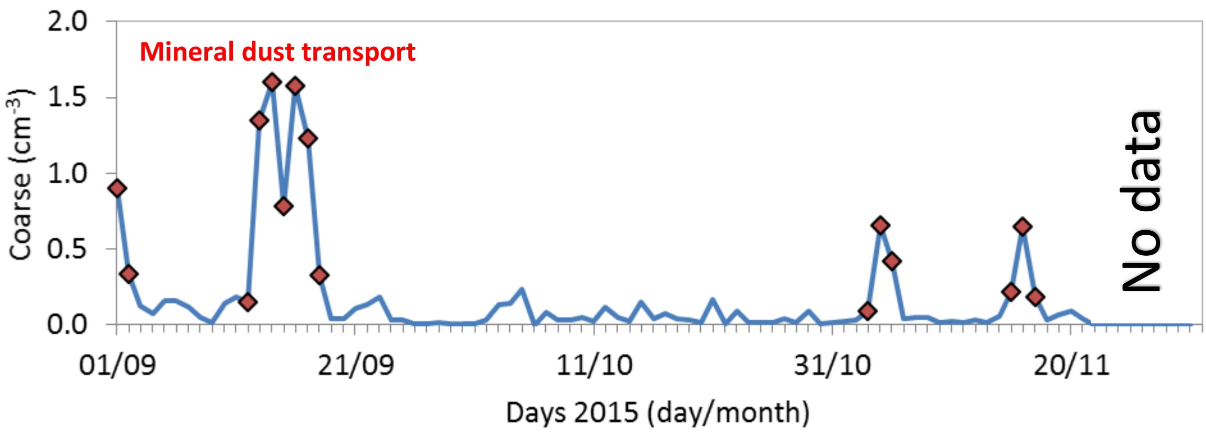
Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

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})
86.6	UDL	UDL	UDL	0.2	0.14	9.7

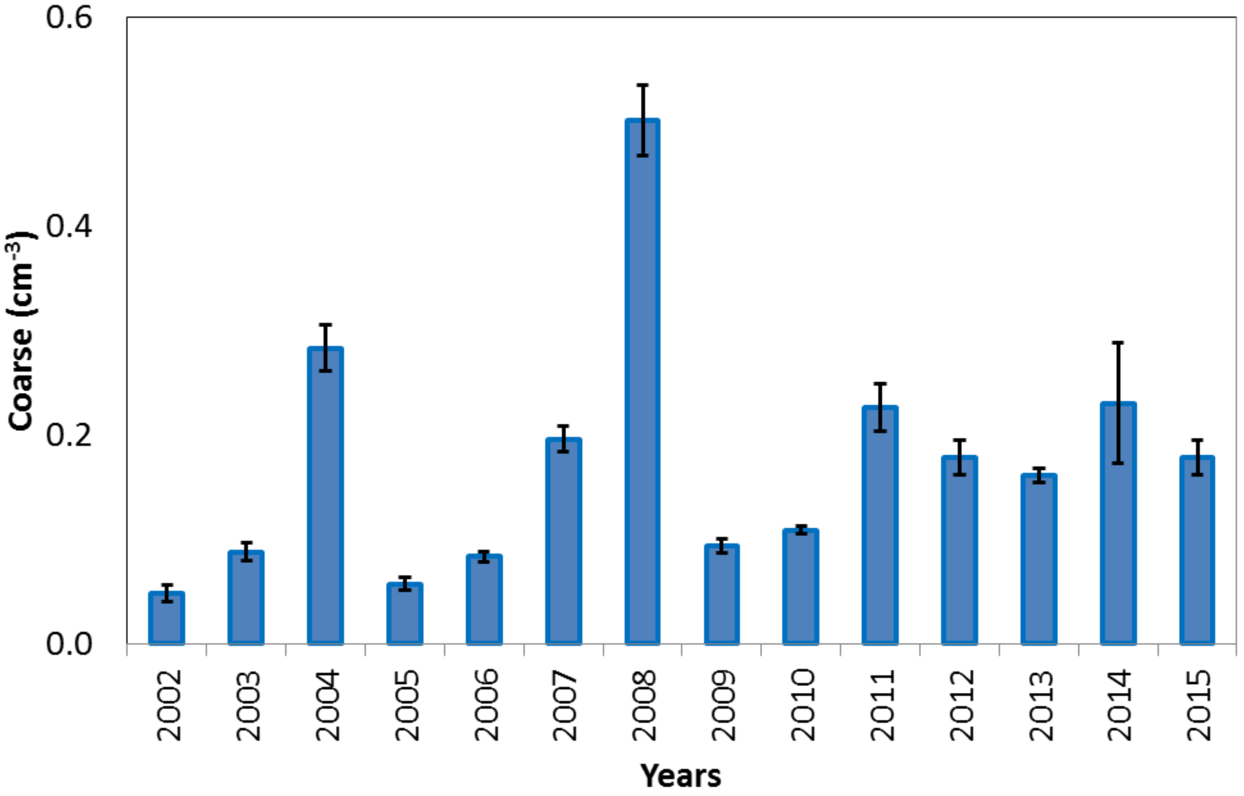
UDL: Under Detection Limit

Time series of daily mean values

With the exception of the high values observed during the identified dust transport event (highest daily average concentration of 1.6 cm^{-3} was observed on September 16th), steady "background" coarse particles number concentrations were observed throughout the season.



Comparison with historical data-set
The autumn 2015 average mean value of the coarse particles (0.18 cm^{-3}) is **similar to the climatological value (0.20 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).

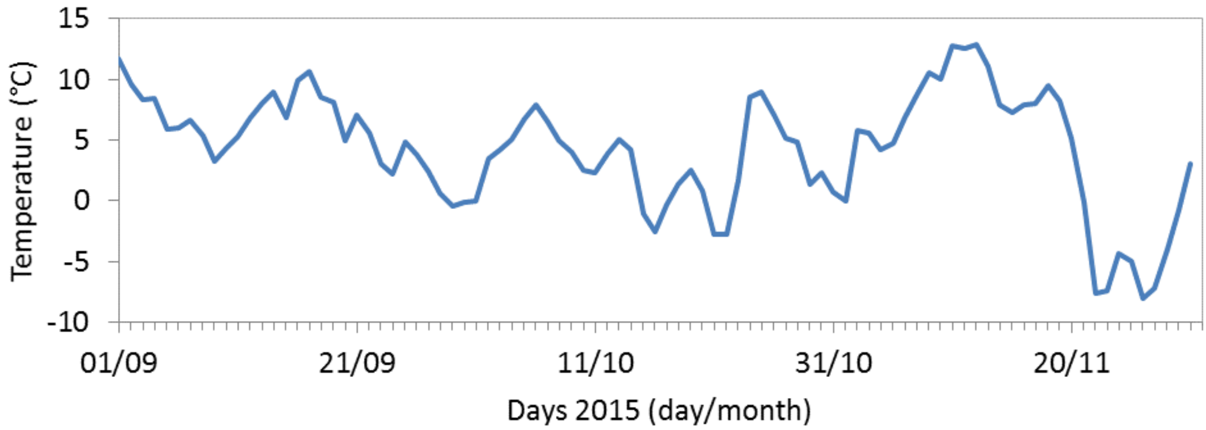
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

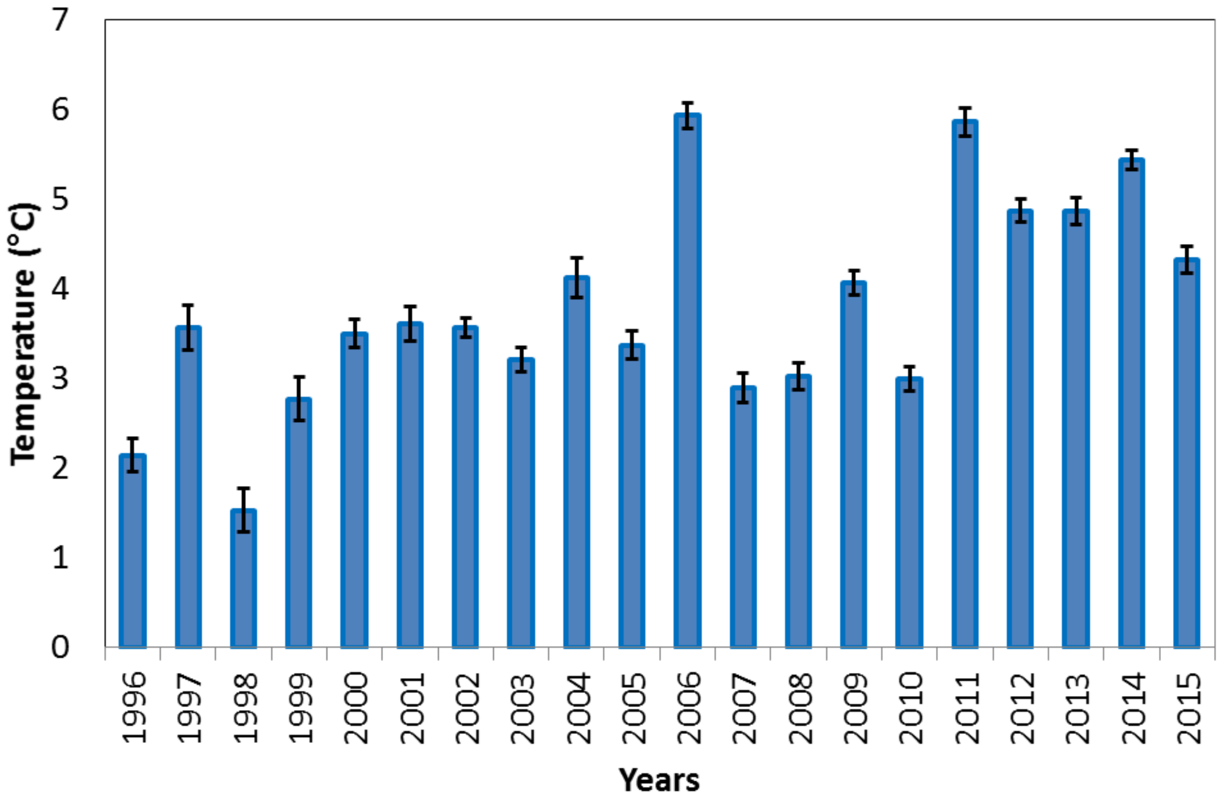
Data availability %	Min value (°C)	25^{th} percentile (°C)	50^{th} percentile (°C)	Average mean value (°C)	75^{th} percentile (°C)	Max value (°C)
99.3	-9.6	1.3	4.9	4.3	7.8	17.6

Time series of daily mean values

The air-temperature time series showed a significant fraction of day with positive mean average value (81 %). The highest daily mean value has been observed on November, 11^{th} -12^{th} (12.9 °C), while the lowest mean daily values was observed on November, 26^{th} (-8.0 °C).



Comparison with historical data-set
The autumn 2015 average temperature (4.3 °C) was **higher than the seasonal climatological value (3.8 °C):** it ranks as the sixth warmest autumn from 1996.



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).

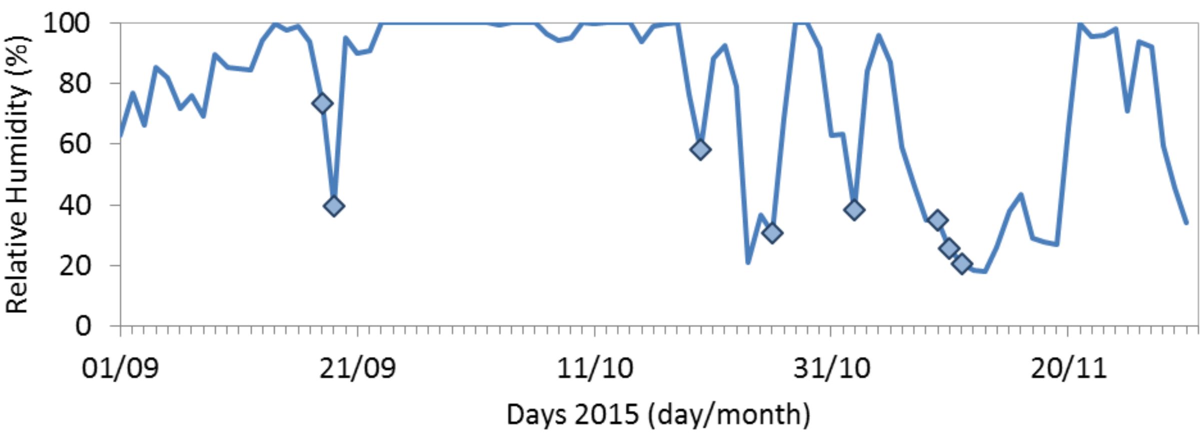
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

Data availability (%)	Min value (%)	25th percentile (%)	50th percentile (%)	Average mean value (%)	75th percentile (%)	Max value (%)
99.3	6.3	53.1	93.9	76.3	100.0	100.0

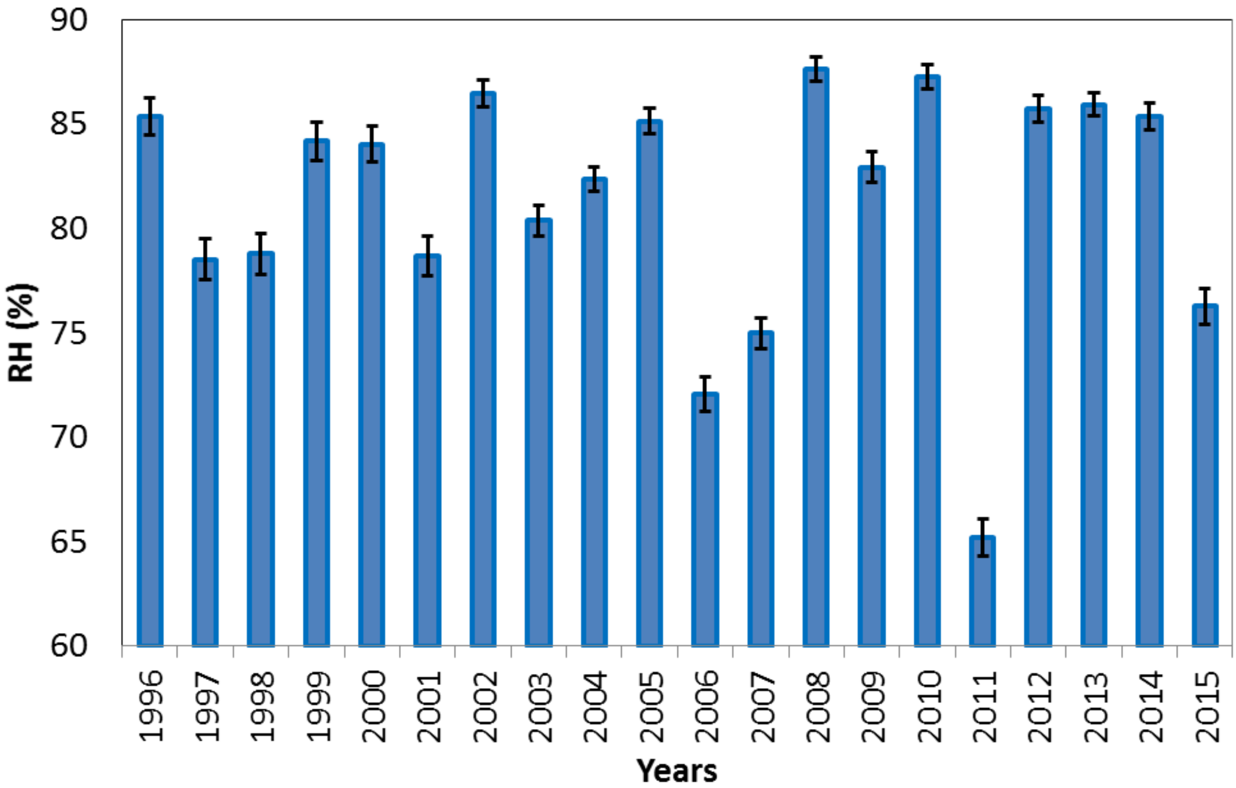
Time series of daily mean values

The daily mean RH values ranged from 100% to 18.1%, with 38.5% of days showing average value higher than 95%. Relatively dry conditions (mean daily values lower than 60%) characterized the end of October and the begin of November.



Comparison with historical data-set

The autumn 2015 average relative humidity (76.3%) was **lower than the seasonal climatological value (81.6%):** it ranks as the fourth driest autumn since 1996.



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).

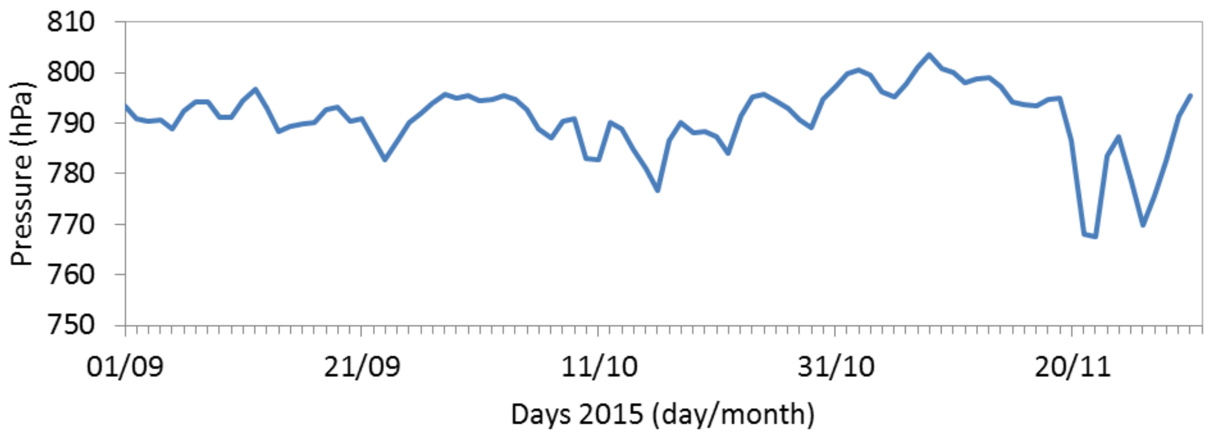
Basic statistical parameters

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

Data availability (hPa)	Min value (hPa)	25th percentile (hPa)	50th percentile (hPa)	Average mean value (hPa)	75th percentile (hPa)	Max value (hPa)
98.6	761.6	788.5	792.1	791.1	795.1	804.2

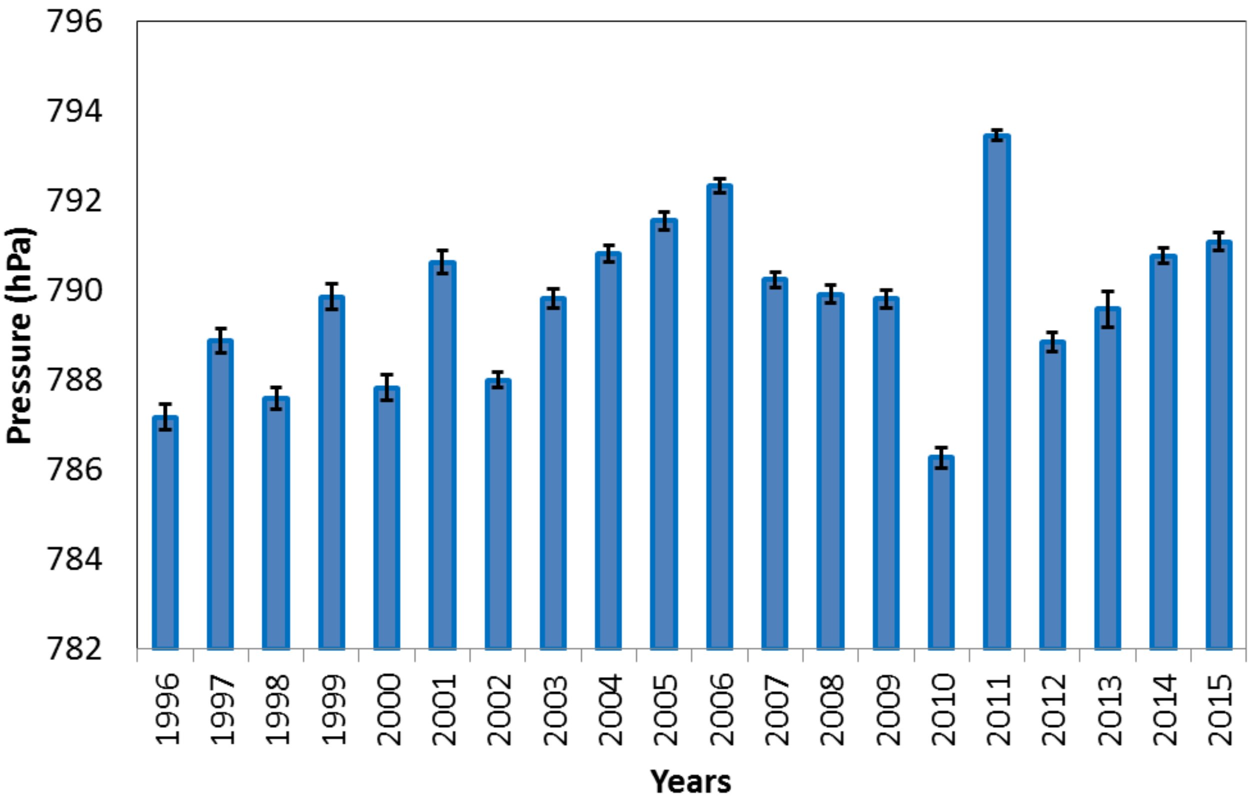
Time series of daily mean values

69% of days were characterized by daily mean values higher than the climatological value. Prolonged period of high-pressure conditions were observed from September, 25th to October, 3rd and from October,30th to November 18th, when an abrupt pressure decreased was observed.



Comparison with historical data-set

The autumn 2015 averaged atmospheric pressure (791.1 hPa) **was slightly higher than the average climatological autumn value** obtained from the last 19 years (789.7 hPa).



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.

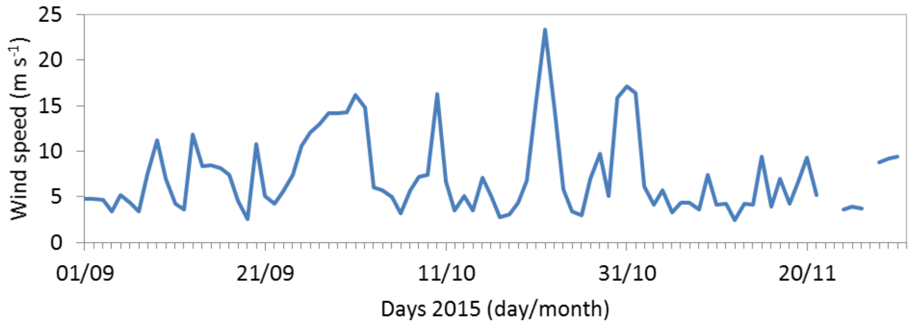
Basic statistical parameters of wind speed

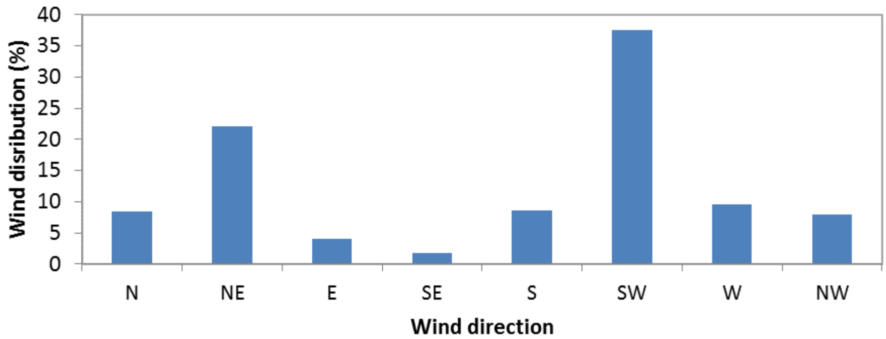
Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 2015.

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)
92.3	0.4	3.4	5.7	7.2	10.1	28.1

Time series of daily mean values

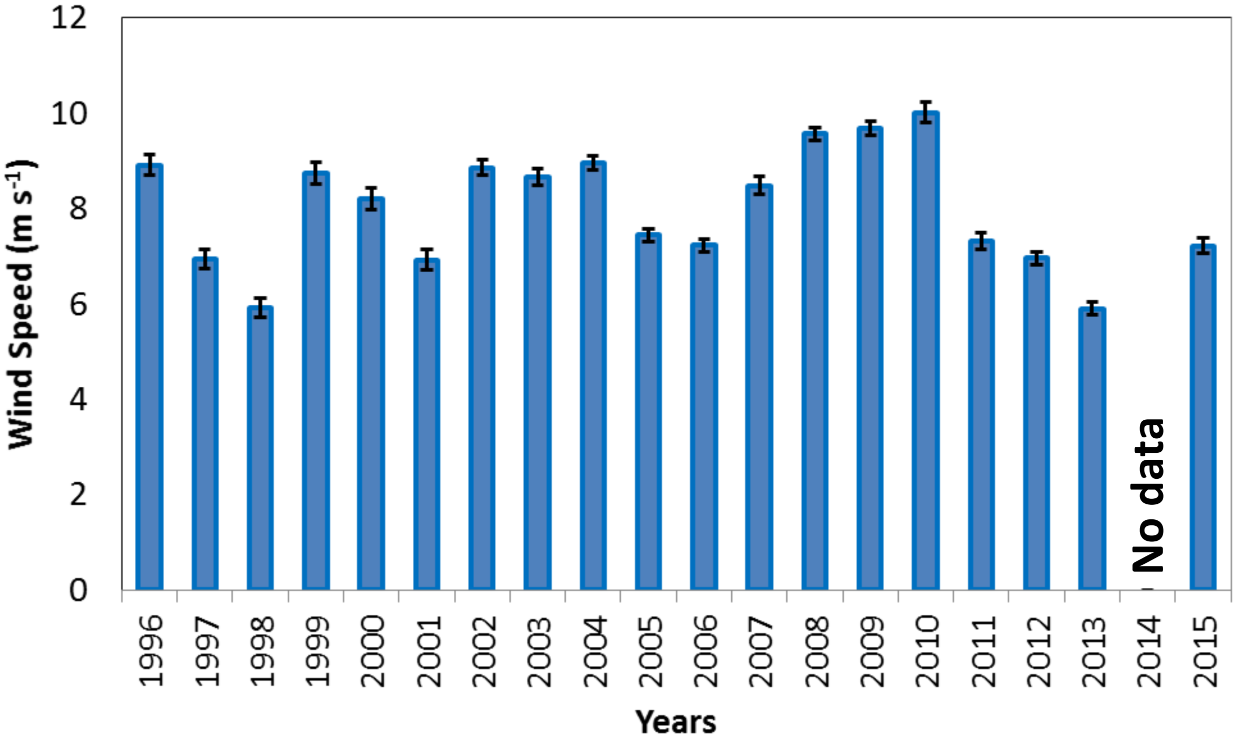
Usually, gentle to fresh breezes affected the measurement site. A few periods with enhanced wind speed (higher than 12 m/s) were observed during autumn 2016: 26th September – 2nd October; 21st -23rd October, 30th October – 1st November.

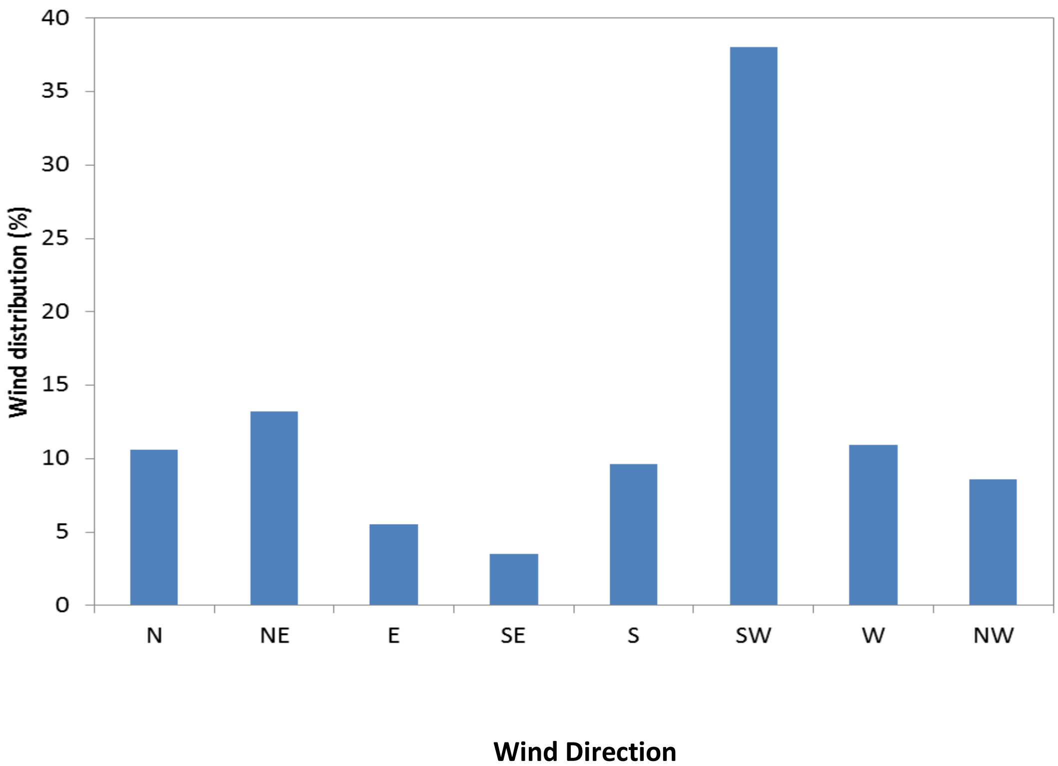




Comparison with historical data-set

Autumn 2016 average wind speed (7.2 m s^{-1}) was **lower than the climatological autumn value (8.0 m s^{-1}).** The prevailing wind direction is from SW, in agreement with the climatological wind regime.





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).

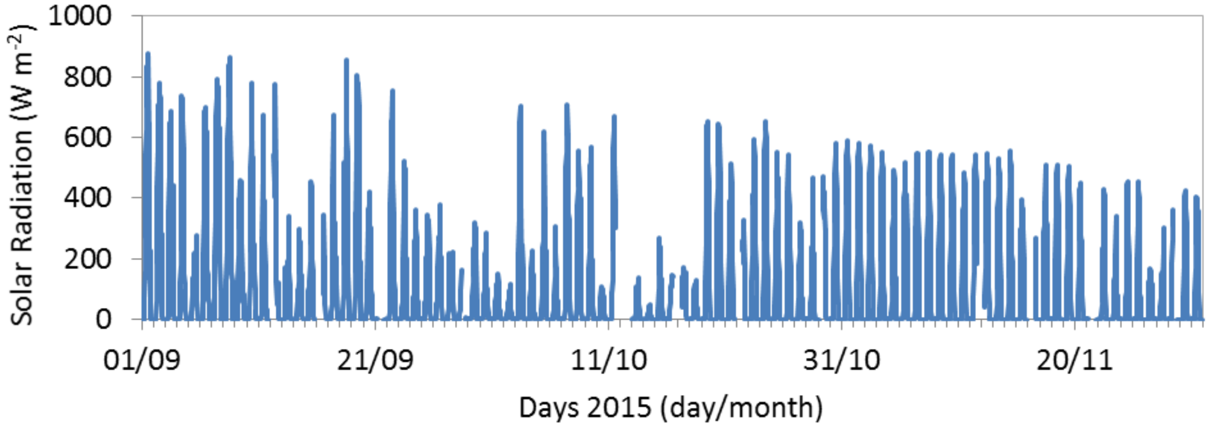
Basic statistical parameters (Solar radiation)

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 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)
92.0	UDL	UDL	UDL	112.6	167.1	875.6

UDL: under detection limit

Time series (Solar radiation)



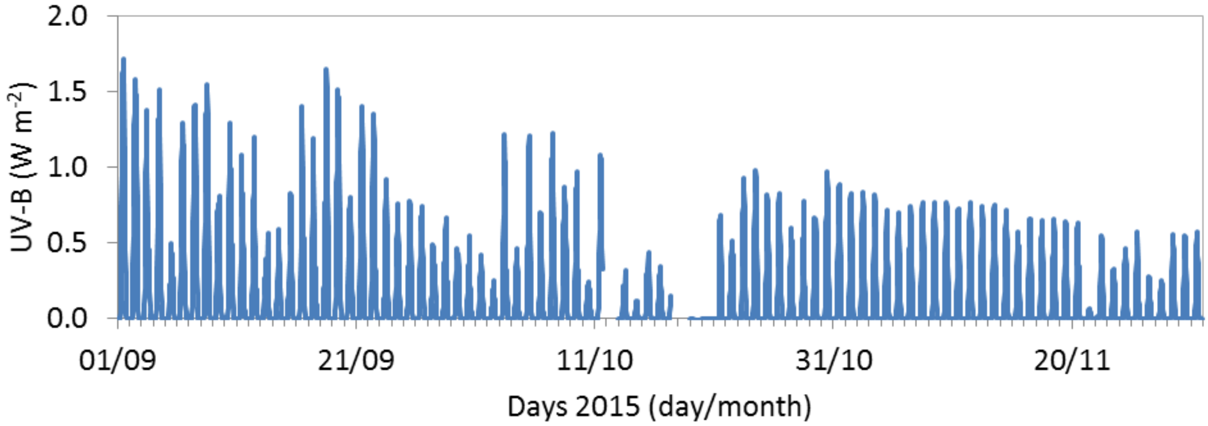
Basic statistical parameters (UV-B)

Statistical parameters are calculated basing on 30-minute aggregated values from September 2015 to November 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)
96.7	UDL	UDL	UDL	0.2	0.22	1.7

UDL: under detection limit

Time series (UV-B)



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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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   http://www.sciencedirect.com/science/article/pii/S1352231099003635
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