SPRINGER BRIEFS IN METEOROLOGY

Paolo Cristofanelli · Erika Brattich
Stefano Decesari · Tony Christian Landi
Michela Maione · Davide Putero
Laura Tositti · Paolo Bonasoni

High-Mountain Atmospheric Research

The Italian Mt. Cimone WMO/GAW Global Station (2165 m a.s.l.)

Springer

SpringerBriefs in Meteorology

SpringerBriefs in Meteorology present concise summaries of cutting-edge research and practical applications. The series focuses on all aspects of meteorology including, but not exclusive to; tornadoes, thunderstorms, lightning, hail, rainfall, fog, extratropical and tropical cyclones, forecasting, snowfalls and blizzards, dust storms, clouds. The series also presents research and information on meteorological technologies, meteorological applications, meteorological forecasting and meteorological impacts (reports of notable worldwide weather events). Featuring compact volumes of 50 to 125 pages (approx. 20,000–70,000 words), the series covers a range of content from professional to academic such as: a timely reports of state-of-the art analytical techniques, literature reviews, in-depth case studies, bridges between new research results, snapshots of hot and/or emerging topics. Author Benefits: Books in this series will be published as part of Springer's eBook collection, with millions of users worldwide. In addition, Briefs will be available for individual print and electronic purchase. SpringerBriefs books are characterized by fast, global electronic dissemination and standard publishing contracts. Books in the program will benefit from easy-to-use manuscript preparation and formatting guidelines, and expedited production schedules. Both solicited and unsolicited manuscripts are considered for publication in this series. Projects will be submitted for editorial review by editorial advisory boards and/or publishing editors. If you are interested to submit a proposal, please contact your Publisher, Dr. Michael Leuchner.

More information about this series at http://www.springer.com/series/13553

Paolo Cristofanelli • Erika Brattich
Stefano Decesari • Tony Christian Landi
Michela Maione • Davide Putero
Laura Tositti • Paolo Bonasoni

High-Mountain Atmospheric Research

The Italian Mt. Cimone WMO/GAW Global Station (2165 m a.s.l.)

Springer

Paolo Cristofanelli
Institute for Atmospheric Sciences and Climate (ISAC)
National Research Council of Italy (CNR)
Bologna, Italy

Stefano Decesari
Institute for Atmospheric Sciences and Climate (ISAC)
National Research Council of Italy (CNR)
Bologna, Italy

Michela Maione
Institute for Atmospheric Sciences and Climate (ISAC)
National Research Council of Italy (CNR)
Bologna, Italy

Department of Pure and Applied Sciences
University of Urbino
Urbino, Italy

Laura Tositti
Department of Chemistry "G. Ciamician"
University of Bologna
Bologna, Italy

Erika Brattich
Department of Chemistry "G. Ciamician"
University of Bologna
Bologna, Italy

Tony Christian Landi
Institute for Atmospheric Sciences and Climate (ISAC)
National Research Council of Italy (CNR)
Bologna, Italy

Davide Putero
Institute for Atmospheric Sciences and Climate (ISAC)
National Research Council of Italy (CNR)
Bologna, Italy

Paolo Bonasoni
Institute for Atmospheric Sciences and Climate (ISAC)
National Research Council of Italy (CNR)
Bologna, Italy

ISSN 2199-9112 ISSN 2199-9120 (electronic)
SpringerBriefs in Meteorology
ISBN 978-3-319-61126-6 ISBN 978-3-319-61127-3 (eBook)
DOI 10.1007/978-3-319-61127-3

Library of Congress Control Number: 2017945270

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

The "O. Vittori" Observatory at Mt. Cimone: A "Lighthouse" for the Mediterranean Troposphere

Abstract The Mediterranean basin represents a global hotspot for climate change, air quality, and anthropogenic contributions to these issues. Since the early 1990s at Mt. Cimone, the highest peak of Italian northern Apennines, an observatory is performing continuous measurements of atmospheric composition. The Italian climate observatory "O. Vittori" is a research infrastructure managed by the Institute for Atmospheric Sciences and Climate (ISAC) of the National Research Council of Italy (CNR) and hosted by the Italian Air Force. It is part of the WMO/GAW global station "Mt. Cimone" (GAW id: CMN). Due to the completely free horizon, high altitude, and great distance from major pollution sources, CMN represents a strategic platform to study the chemical–physical characteristics and climatology of the free troposphere in the South Europe and Mediterranean basin. At this observatory, continuous monitoring of climate-altering compounds (trace gases and aerosol), solar radiation, as well as meteorological parameters is carried out. Besides providing a historical perspective of scientific research at CMN, we characterize the measurement site, and we describe the current observatory technical facilities, including the e-access to data and the services for near-real-time data delivery. Good practices for educational and outreach activities are also presented.

Keywords Mediterranean basin • Monte Cimone • Atmospheric composition • Aerosol particles • Trace gases • Meteorological parameters • Open data • Outreaching

1 Introduction

Southern Europe and Mediterranean basin are recognized as hotspot regions both in terms of climate change (e.g., Giorgi and Lionello 2008) and air quality (Monks et al. 2009). Meteorological conditions characterized by frequent clear sky and high solar radiation favor the occurrence of ozone (O_3) photochemical production also, thanks to the availability of natural and anthropogenic precursors. In particular, large amounts of anthropogenic pollutants emitted in continental Europe are transported toward the Mediterranean free troposphere and boundary layer (e.g., Safieddine et al. 2014). Saharan dust outbreaks from northern Africa (Querol et al.

P. Cristofanelli et al., *High-Mountain Atmospheric Research*, SpringerBriefs in Meteorology, DOI 10.1007/978-3-319-61127-3_1

Table 1 List observation programs running at the “O. Vittori” observatory at Mt. Cimone (Uniurb: Urbino University; Unibo: Bologna University)

Observations	Starting year	Lead institution
Surface O_3	1996	CNR-ISAC
NO, NO_2	2012	CNR-ISAC
SO_2	2014	CNR-ISAC
CO	2008	CNR-ISAC/Uniurb
CH_4	2008	Uniurb
N_2O	2008	Uniurb
SF_6	2008	Uniurb
CFCs, HCFCs	2002	Uniurb
HFCs	2002	Uniurb
Columnar NO_2	1993	CNR-ISAC
Aerosol size distribution (10 – 500 nm)	2005	CNR-ISAC
Aerosol size distribution (300 nm – 10 μm)	2000	CNR-ISAC
Aerosol scattering	2005	CNR-ISAC
Aerosol absorption	2005	CNR-ISAC
Equivalent BC	2005	CNR-ISAC
Aerosol chemistry (PM_1 – PM_{10})	2005	CNR-ISAC
Natural radionuclides (^{7}Be, ^{210}Pb, ^{222}Rn)	1998	Unibo
Solar photometry	2016	CNR-ISAC
Meteorological parameters and solar radiation	1996	CNR-ISAC

2009) and open biomass burning (Turquety et al. 2014) further exacerbate air quality and the influence of anthropogenic emissions on the regional climate (Mallet et al. 2013). Water scarcity, the concentration of economic activities in coastal areas, and reliance on climate-sensitive agriculture together with demographic, social, cultural, economic, and environmental changes are other critical factors which make this region particularly exposed to climate change and air quality worsening.

For these reasons, it is important to have long-term observations of essential climate variables with well-assessed quality. In particular, in situ or ground-based observations at mountain sites can provide key information about background atmospheric composition. They also provide the opportunity to investigate and assess the impact of natural and anthropogenic-related processes to atmospheric variables and then to regional climate and air quality.

Since the early 1990s of the last century, continuous observations of atmospheric composition have been carried out in Italy at Mt. Cimone (44°12’ N, 10°42′ E, 2165 m a.s.l.), by means of the “O. Vittori” atmospheric observatory managed by the National Research Council of Italy (CNR). Nowadays, at this locations, thanks to the collaboration with different research institutions (Italian Air Force - Centro Aeronautica Militare di Montagna, and Urbino University), several scientific programs covering research on reactive and greenhouse gases, chemical and physical aerosol particle properties, meteorological parameters, and solar radiation (Table 1) are carried out.

Fig. 1 Mt. Cimone peak, with the observatories of Italian Air Force and CNR

2 Presentation of the Measurement Site

The "O. Vittori" observatory is located at the top of Mt. Cimone (44°12′ N, 10°42′ E, 2165 m a.s.l., Fig. 1), the highest peak of the Northern Apennines, at the border line of two different climatic regions: the continental Europe northward and the Mediterranean basin southward.

The Mediterranean Sea is about 50 km to the SW of the measurement site (Fig. 2). The Po Valley, one of the most polluted region in Europe (Monks et al. 2009), lies immediately North of the site. The closest inhabited areas are small villages (1500 inhabitants) placed 15 km from and about 1100 m below the observatory, whereas major towns (500,000 inhabitants) are situated in the lowlands about 60 km away (Bologna, Firenze). Mt. Cimone is characterized by a 360° free horizon which allows the air masses to reach the measurement site without any topographic channeling. As assessed by the GEOMON EU Project (Henne et al. 2010), Mt. Cimone is characterized by a wide catchment area for air masses older than 48 h which experienced interaction with terrain surface, making this measurement site well representative of the atmospheric air masses originating within the central Mediterranean basin (Fig. 2). Within several kilometers from the site, there are no crops, and human activity is very limited. This makes the measurement site very suitable for investigating the background conditions of the Mediterranean troposphere as well as the direct impact of surface emissions to them.

The "O. Vittori" observatory is located above the timberline, and only some patches of grass can be found on the mountaintop, which is mostly rocky and covered with snow for 6–7 months a year. In spring, the last snowfall generally takes place in mid-April, while in autumn the early snowfall usually occurs in mid-November.

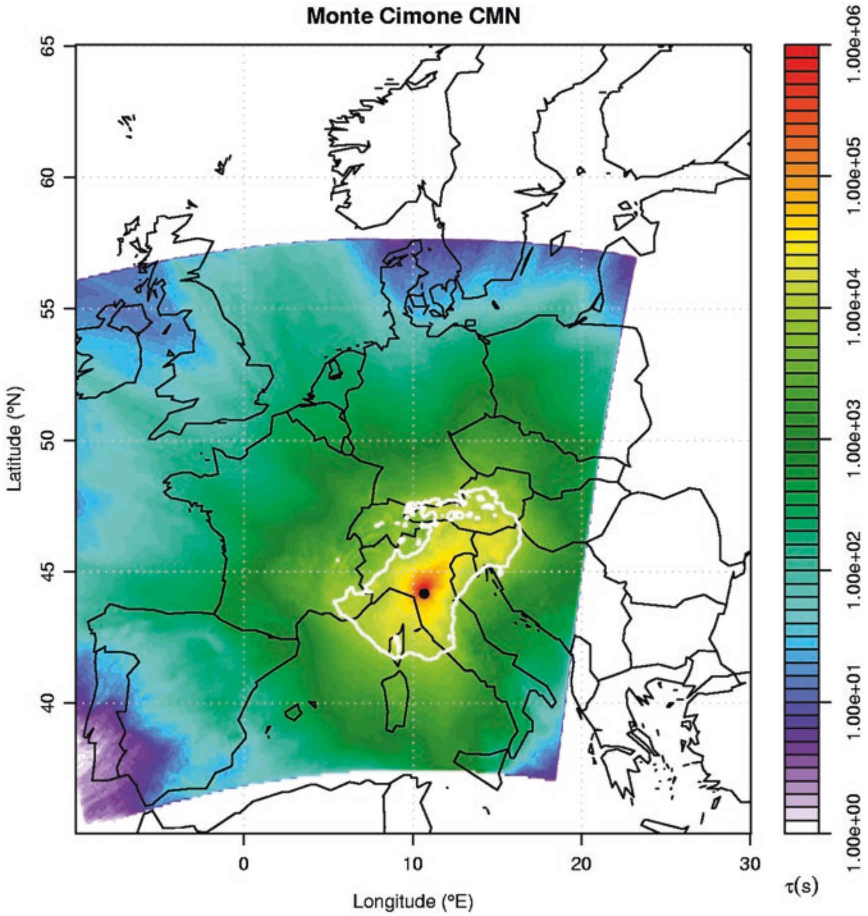

Fig. 2 Surface footprint 48 h catchment area for CMN (*white contour*). The catchment area is given by the intersection of the topography with the volume containing the largest residence time densities and comprises 50% of the total residence time. FLEXPART model (0.5° × 0.5° horizontal resolution) was used to derive catchment areas (From www.geomon.empa.ch)

Colombo et al. (2000) provided a meteorological description of Mt. Cimone weather regime from 1946 to 1999. They showed that Mt. Cimone is the windiest meteorological station in Italy (wind speed higher than 200 km/h is occasionally observed) and the prevailing winds blow from S–SW and N–NE. This was evident also by analyzing the wind observations carried out from 1996 to 2015 at the “O. Vittori” observatory (Fig. 3). In winter and fall, when temperate air masses flow from the Mediterranean Sea, the temperature only occasionally lies above 0 °C. On the other hand, when continental air comes from N and NE, the temperature is usually several degrees below 0 °C. As deduced by “O. Vittori” observatory measurements, the lowest monthly mean temperature was in February 2005 (−7.9 °C) and

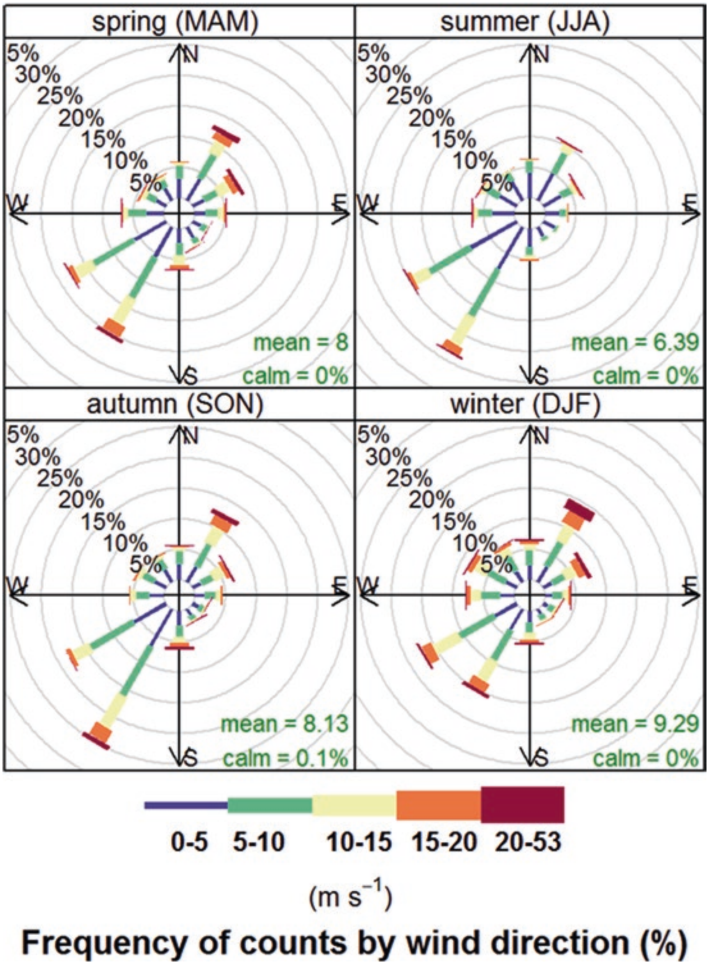

Fig. 3 Wind speed/direction frequencies by season at CMN (1996–2015). Wind speeds are split into the intervals shown by the scale in each panel. The *grey circles* show the 5% frequency intervals

the highest in July 2015 (14.9 °C). The annual mean (as deduced by averaging monthly mean values) is 2.1 °C. As reported by previous investigations, the atmospheric observations carried out at CMN can be considered representative of the free tropospheric conditions of the Mediterranean basin/South Europe during the cold months (see, e.g., Bonasoni et al. 2000; Henne et al., 2010) as well as during nighttime in the warm season. However, from April to September, the measurement site can be affected by “thermal” wind circulation and convective vertical transport of air masses. Indeed, during daytime, upslope and valley winds together with diurnal planetary boundary layer (PBL) growth and entrainment processes can favor the vertical transport of polluted PBL air to the measurement site (Colombo et al. 2000; Cristofanelli et al. 2009).

3 History

Across the last five centuries, Mt. Cimone represented a landmark for scientific researches.

In 1655, Fathers Riccioli and Grimaldi made the first measurement of the height of Mt. Cimone. In 1671, for the first time in Italy, the mathematician Geminiano Montanari went to Mt. Cimone to use a barometer for altitude measurement. In 1896, military engineers from Modena Duchy built a small pyramid on the top of the mountain for a survey to write the Duchy's new map. In 1817, Dr. Brioschi, director of the Naples observatory, performed geographical studies at Mt. Cimone to assess the level of Tyrrhenian and Adriatic Seas. In 1823, Father Inghirani used the small pyramid on the top of Mt. Cimone for triangulation studies of the Tuscan Grand Duchy. In 1888, a 14 m tower was built, dedicated to the memory of Geminiano Montanari and assigned to operate as scientific observatory and mountain cabin. It was used to perform earlier studies on electrical discharges, lightning rods, and solar radiation. Due to the harsh weather conditions affecting Mt. Cimone, the tower experienced strong damages across the years, and it was completely knocked down in the 1930s.

In 1936, the Air Force Ministry built small barracks on the top for meteorological observations and flight assistance: this represents the first presence of the Italian Air Force at Mt. Cimone. In 1937, the Italian Air Force inaugurated a Meteorological Station at the mountain top, and after the World War II (1948), the Osservatorio Scientifico Sperimentale di Meteorologia Aeronautica (OSSMA) "Air Force Experimental Scientific Meteorological Observatory" was built. This scientific observatory was used to perform atmospheric investigations about condensation nuclei by Dr. D. Fedele and Prof. O. Vittori. From 1950 to 1959, several research activities were carried out by the Italian Air Force at Mt. Cimone: studies about thunderstorms, hail, fog formation, and environmental radioactivity. In 1964, the first studies about atmospheric pollution were started, while in 1979 the monitoring program for atmospheric CO_2 measurement (still active at the Italian Air Force Meteorological Observatory, representing one of the longest time series of CO_2 observations in background conditions over the European continent; see Fig. 4) was implemented.

In 1981, Ottavio Vittori, who had already been the commanding officer of the Air Force Military Mountain Centre (CAMM) in Sestola and subsequently director of the CNR-FISBAT in Bologna, drew up a contract with the Italian Air Force to allow the CNR for using the "Romualdi" mountain cabin for scientific purposes. From this year, the CNR executed measurements of atmospheric physics and chemistry at Mt. Cimone.