Italian Report on IAMAS-IUGG activities 2012-2013

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Foreword

The aim of this report is to present the state of the art of the research activities that are performed by the Italian scientific community within the disciplines and topics that pertain to the various Commissions of the IAMAS-IUGG.
Collecting and reporting information on relevant projects, programs and publications has been a major undertaking which has been accomplished thanks to the dedication and competence of a group of Colleagues, members of the IAMAS Italian Team (Gruppo Nazionale IAMAS), who have served as Rapporteurs for the research activities that are conducted in the framework of the various IAMAS Commissions. We wish to express here our deep gratitude to them for their generous effort, as well as our thanks to all Colleagues who have provided the necessary information.
The Rapporteurs have worked with determination and competence and have always respectfully addressed and acknowledged the Italian scientific community. Nevertheless, it is still possible that due to the time and space constraints to which the making of this report has been subject, some imperfections, or even deficiencies may be found. We do apologize in advance for such an eventuality, and wish to assure all Colleagues that since for the time being this is an open report, the IAMAS Italian Team is willing to keep improving it, so as to present the national activities and findings in the most comprehensive way and to provide a useful means for their most successful dissemination. Thus, we strongly encourage all Colleagues to contact the IAMAS Italian Team for introducing any change they may deem necessary.

The national Representatives

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During 2010 -2012 the Italian research community has worked within different topics of IRC spanning from the development of modelling and atmospheric measurements for the study of the radiation properties of gas composition, aerosol and clouds to the participation to international networks devoted to radiation measurements. The research in this field is here below summarised divided in three main research topics.

Radiation balance in the atmosphere, direct radiative effects of aerosols and clouds, role of the surface

Aim of this research is to investigate the role that aerosols, clouds and surface reflectance characteristics have in modulating seasonal and inter-annual variability of radiation budget terms at the surface as well as at the top of the atmosphere in polar regions as well as at middle latitudes. Direct radiative effects are determined carrying out both experimental year-round and modelling activities, following as much as possible a closure approach (so to estimate uncertainties). Field activities are performed at Concordia and Mario Zucchelli stations in Antarctica, at Dirigibile Italia station (Svalbard) in the Arctic, at EV-K2-CNR Station in Nepal, in Italy at Bologna and surrounding Po Valley landscape (S. Pietro Capofiume, 30 km NE), at Climate Observatory "O. Vittori" - Mount Cimone, and at ENEA Station for Climate Observations on the island of Lampedusa. Activity is strongly anchored to the international context through cooperation with research groups of several Institutions (referring to radiation we can list AWI, NOAA/ERL-GMD, NIPR), through participation at international networks (BSRN, SKYNET) and also promoting networking aerosol activities (POLAR-AOD). In this way our perspective is enlarged to the regional as well as pan-Arctic/Antarctic scale. In the period 2010-2012 a lot of efforts have been devoted to develop and implement the CNR multidisciplinary project Climate Change Tower Integrated Project (CCT-IP) at Ny Alesund (www.isac.cnr.it/~radiclim/CCTower).
Italian research Groups involved in the development of this topic are: ISAC http://www.isac.cnr.it/~radiclim/, Atmospheric Research Group at IFAC and INO – CNR: http://ga.ifac.cnr.it/.
Main results achieved by the ISAC Group in the period 2010-2012 are:

- assessment of aerosol characteristics in polar regions and direct radiative effects at local and regional scale (through participation in the project CLIMSLIP and PAM-ARCMIP airborne campaigns, as well as pursuing funded PNRA projects POLAR-AOD, DECA-POL, BSRN)
- development of a procedure for modelling evaluation of aerosol direct radiative effects on a regional scale
- regular submission of data to the archive BSRN and development with other BSRN of a specific database for the Antarctic IPY 2007-2009 operational period
- assessment of cloud radiative effects in coastal and interior regions of Antarctica (similar evaluation for the Arctic are ongoing)
- upgrade of BSRN station at Concordia with upwelling measurements and cloud monitoring at 30 m height
- implementation at Ny Alesund of CCT radiation measurements.
- assessment of surface UV behaviour in early spring in the middle of ozone hole and deep analysis of effects at lower latitude of spring 2011 Arctic ozone depletion (paper submitted to Atmos. Environ.)

Infrared instrumentation for remote sensing and Earth observation

The activity performed within this topic concerns the development of infrared instrumentation for remote sensing and earth observation. Research groups operate prototypes and standard instrumentation in field campaigns and give scientific support to instrument development for space applications.
In this field one important result was the radiative characterisation of the properties of the water vapor rotational band and cirrus clouds in the under-explored region of the far IR from 100 to 600 cm^{-1}. Measurements from FTS spectrometer prototypes (REFIR-PAD and I-BEST) operated in field campaigns have been studied to address some basics issues in the spectroscopy of water vapour continuum and cirrus clouds, which are important for modelling atmospheric radiative balances. REFIR-PAD is currently operative from the Antarctic base of Concordia supplying wide-band spectra from 100 to 1400 cm^{-1} of the down-ward long-wave radiation with 24 h operation since December 2011 (http://refir.ifac.cnr.it/refir-pad-prana.html).
Italian research Groups involved in the development of this topic are: Atmospheric Research Group at IFAC and INO – CNR http://ga.ifac.cnr.it/; Applied Spectroscopy Group at the University of Basilicata, http://www2.unibas.it/gmasiello/assite/as/home.html (G.Masiello is Member of International Radiation Commission for the period 2009-2016) .

Line-by-line radiative transfer modelling

The activity is related to the development of line-by-line radiative transfer models for SW, IR, far IR and MW spectroscopy and atmospheric radiative transfer in presence of gaseous components and clouds.
Properties of atmospheric particulate components (clouds, aerosols) are studied with multiple scattering for the use in operational and future remote sounding instrumentation in meteorology and climatology applications. Analysis of optical, microphysical and vertical features of thin ice clouds in high troposphere is performed on a global scale by using measurements derived from satellite-borne instruments and integration of the acquired information in infrared codes for the inversion of cloud properties. Italian research Groups involved in the development of this topic are: Physics of Fluid Earth Group at the University of Bologna: http://www.physics-astronomy.unibo.it/en/research/areas/physics-of-fluid-earth/index.html; Applied Spectroscopy Group at the University of Basilicata, http://www2.unibas.it/gmasiello/assite/as/home.html; Atmospheric Research Group at IFAC – CNR: http://ga.ifac.cnr.it/.

Contribution to space missions

Research activity performed by Italian Groups within the IRC topics have contributed and continues to contribute to the development of different satellite missions:

- NASA: AIRS and CLARREO projects
- JAXA: IMG project
- EUMETSAT/ESA: IASI, GERB, MTG, Post-EPS projects
- ESA: ENVISAT, SWIFT, PREMIER projects

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International Ozone Commission

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The Italian contribution to the research on Ozone and its effects on dynamic, chemistry and surface biology covers many different areas. As stratospheric ozone is the main drivers of the stratospheric chemistry, radiative budget and dynamics, a lot of effort has been devoted to the study of its evolution, by means of dedicated chemistry-climate coupled model runs, in the framework of an intensive collaboration with the worldwide climate community. Coupled chemistry-climate model simulations covering the recent past and continuing throughout the 21st century have been compared (2), with emphasis on the simulations of the Antarctic ozone hole, using commonly used diagnostics. A distinct hemispheric asymmetry in the hemispheres (3) has been assessed. Results shows that stratospheric ozone is simulated to return to 1980 levels only 10 years ahead of chlorine. In the Antarctic, annually averaged ozone recovers at about the same rate as chlorine in high latitudes and hence does not return to 1960s values until the last decade of the century. The evolution of stratospheric ozone has been examined in simulations from a suite of chemistry-climate models (39,15), driven by prescribed levels of halogens and greenhouse gases, and with anthropogenic halogenated ozone depleting substances (ODSs) and greenhouse gases (GHGs) varying with time, to disaggregate the drivers of projected ozone changes. There is general agreement among the models that total column ozone reached a minimum around year 2000 at all latitudes, projected to be followed by an increase over the first half of the 21st century. The response of stratospheric climate and circulation to such ozone recovery and to increasing amounts of greenhouse gases (GHGs) in the twenty-first century has also been analyzed (6), and a pilot study (9), using an "ensemble of opportunity" of chemistry-climate model (CCM) simulations, has quantified the contribution of scenario uncertainty from different plausible emissions pathways for ODSs and GHGs to future ozone projections. Such contribution has been compared with is quantified relative to the contribution from model uncertainty and internal variability of the chemistry-climate system. These simulations were also used to assess the two distinct milestones of ozone returning to historical values (ozone return dates) and ozone no longer being influenced by ODSs (full ozone recovery). The impact of stratospheric ozone on the tropospheric general circulation of the Southern Hemisphere (SH) has examined with a set of chemistry-climate models participating in the Stratospheric Processes and their Role in Climate (SPARC)/Chemistry-Climate Model Validation project phase 2 (CCMVal-2) (56). Observation of N2O and mean age of air derived from many observational platforms have been used to identify realistic transport in models participating in the 2010 World Meteorological Organization Ozone assessment, and to evaluate the performance of chemistry-climate models (CCMs) in the extratropical upper troposphere/lower stratosphere (UTLS) (24) in order to explain their ozone predictions (57). Comparison reveals details of the model representation of tropical ascent and isolation. The tropics have been considered an area of particular interest. A global chemistry-climate model (5) has been used to investigate the contribution of African and Asian emissions to tropospheric ozone over Central and West Africa during the summer monsoon, showing that ozone in this region is most sensitive to lightning NOx and to Central African biomass burning emissions. The performance of a suite of coupled Chemistry Climate Models (CCMs) (19) have been evaluated in the Tropical Tropopause Layer (TTL) , analyzing trends in tropopause quantities in the tropics and the extratropical Upper Troposphere and Lower Stratosphere (UTLS).

A lively experimental and observational activity has resulted in the publication of several studies on atmospheric ozone, in the Arctic, Antarctica, in the Tropics, in the Mediterranean regions. Results from airborne campaigns in the tropics have been extensively published. Ozone measurements have been used to investigate the impact of convection on the composition of the tropical tropopause layer region (TTL) in West-Africa (17), the strength of UTLS subtropical barrier and changes on *the Brewer-Dobson circulation (25, 51), to analyze the chemistry going on in the deep convective outflow as a function of distance from the convective core (29) , to assess how different trace gas compositions in the boundary layer (BL) and ambient air may influence the O3 concentration in the outflow (2), to estimate the rate of lightning-produced nitrogen oxides per flash in selected thunderstorms and compare it to our previous results for the tropics(3). Airborne ozone observations have been used to constrain transport and photochemical processes in the tropical tropopause layer (TTL) (48, 49, 60, 35, 52). In situ airborne measurements have also been used to validate results from airborne (58) and satellite remote sensing instruments. A comparison of four Level 2 Processors for the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) onboard ENVISAT(MIPAS50retrieval) of MIPAS61mipas STR (34) has been carried on, a general quality assessment of MIPAS products has been issued (8) and comparison with in-situ temperature and O3 measurements (61) showed exceptional agreement.*

In the Arctic, the stratospheric ozone evolution has been related to the evolution of the polar vortex during the exceptional sudden stratospheric warming of 2009 (12). Diurnal variations in total ozone column were observed to exceed 40 DU during the QAARC campaign of late spring 2009 held at the Ny-Ålesund Arctic station in Svalbard. They were correlated to corresponding oscillations of surface UV-B irradiance (45). Solar UV irradiance measured at Antarctic Italian-French Plateau station Concordia during the austral springs of 2008 and 2009 have also been published (59) and discussed in term of possible variation of the ozone distribution. Ozone and nitric acid satellite observations of the 2010–2011 Arctic winter documented the largest ozone depletion ever observed in the Arctic (1). Studies on the influence of aerosols on the ozone photolysis have been carried out in the Mediterranean (7), showing that aerosol may largely affect photochemical processes. In particular, aerosol changes may compete with ozone variations in modulating the photolythic processes in the Mediterranean. A couple of studies were also dedicated to the assessment of quality of total ozone measurements carried out with the portable Microtops instrument (20, 21).

The long term record of ground-based Brewer spectrophotometer total ozone and surface UV irradiance measurements in Rome, dating back to 1992, has been continued (32) . Erythemal Dose Rates (EDRs) have been also determined by a broad-band radiometer (model YES UVB-1) operational since 2000. Ground-based measurements have been compared with satellite-derived total ozone and UV data from the Ozone Monitoring Instrument (OMI). Together with these measurements, the aerosol Single Scattering Albedo (SSA) and Absorbing Aerosol Optical Depth (AAOD) at 320.1 nm have been derived at Rome site by the comparison between Brewer and modelled spectra (33). The UVSPEC radiative transfer model has been used to calculate the UV irradiances for different SSA values, taking into account as input data total ozone and Aerosol Optical Depth (AOD) obtained from Brewer spectral measurements. A study to quantify the UV exposure of vineyard workers was carried out in Tuscany (Italy), covering three different stages of the vine's growth (54). Doses of erythemally weighted irradiances have been compared with measurements obtained using a reference spectroradiometer (55). Monthly averaged surface erythemal solar irradiance (UV-Ery) for local noon from 1960 to 2100 have finally been derived using radiative transfer calculations and projections of ozone, temperature and cloud change from a suite of chemistry climate models (CCM), as part of the CCMVal-2 activity of SPARC (4).

A novel approach, developed on the basis of the MSS (Measurement Space Solution) for optimal use of the information provided by indirect measurements of atmospheric vertical profiles, was successfully applied to data fusion of ozone from space-borne nadir (IASI/MetOp-A) and limb (MIPAS/ENVISAT) sounding (63,64), and from millimetre-wave and middle infrared limb measurements onboard the M-55/Geophysica aircraft in the Arctic UTLS (65).

For what concerns the effects of ozone and perturbed UV fluxes on the biota, the activity of monitoring, evaluation and analysis of the levels of ozone, harmonization of methods of measurement and observation of the effects of ozone on vegetation, has produced a wealth of published results.
The effects of environmental variables other than ozone on the supersensitive cultivar Nicotiana Tabacum Bel-W3 has been documented (10), and standards protocols have been validated (11) by testing biological responses vs. ambient data in the field. The actual responsiveness of native V. Lantana plants to ozone under field condition has been assessed (22). A sensitivity analysis of the effects of uncertainties in estimations of air temperature and atmospheric pressure on the ozone concentration conversion factor in mountain regions has been carried out (18), and Accumulated ozone concentrations Over a Threshold of 40 ppb (AOT40) retrieved from three years of passive ozone samplers at forest sites in Trentino (Northern Italy) were tested against an independent set of data from passive sampler sites across the country (16). In the same region, a study addressed the spatial variability of ozone concentrations (23). Ozone data from Italian, Slovenian and Croatian monitoring stations from the years 2000 onward, were used to calculate some recently introduced photochemical indicators during the growth season (30). Daily ozone deposition flux to a Norway spruce forest in Czech Republic was measured using the gradient method in July and August 2008. Results were in good agreement with a deposition flux model (62). The Urban Forest Effects (UFORE) model, designed to use tree allometric, air pollution and meteorological data to statistically estimate urban forest characteristics and various urban forest functions, was applied to the main park in the city of Florence, Italy (Cascine Park), in 1985 and 2004, in order to study how the natural and man-made evolution of the park affected its ability to control air quality (41).
To parameterize stomatal conductance or ozone uptake modeling in the Eastern Asian tree species Zelkova serrata, measurements of stomatal conductance were carried out in several Japanese sites across the growing season (26). Steady-state and dynamic gas exchange responses to ozone visible injury were investigated in field conditions. The results were translated into whole tree water loss and carbon assimilation by comparing trees exposed to ambient ozone and trees treated with the ozone-protectant ethylenediurea (EDU) (27). Gas exchange responses tos oil water stresses (28) and static and variable light (40) were also tested in various species and the effects of ozone were investigated. A delay in stomatal responses to variable light was found to be both an effect of O3 exposure and a reason for increased O3 sensitivity in some species.
A dose/response curve for EDU for protecting vegetation from ozone visible injury by means of EDU applications as soil drench has been studied (37, 43) . Finally, the conference "Ozone, climate change and forests" was organised by the COST Action FP0903 'Climate change and forest mitigation and adaptation in a polluted environment', and was attended by 90 participants from 25 countries (42). Ozone fluxes and effects, monitoring of O3 effects, O3 standards for forests, interaction of O3 effects with climate change, and O3 effects on the below-ground part of forest ecosystems (in collaboration with the COST FP0803 'Belowground carbon turnover in European forests') were the subjects of most interest.

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International Association of Meteorology and Atmospheric Sciences

International Commission on Clouds and Precipitation

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The clouds of Earth are fundamental to most aspects of human life. Through production of precipitation, they are essential for delivering and sustaining the supplies of freshwater upon which human life depends. Clouds further exert a principal influence on the planet’s energy balance. It is in clouds that latent heat is released through the process of condensation and the formation of precipitation. This form of heat is elementary to the development and evolution of the planet’s storm systems and, in turn, to the precipitation produced by these systems. Clouds further exert a profound influence on the solar and infrared radiation that enters and leaves the atmosphere. This influence is complex and not entirely understood, yet it has the potential to exert profound effects on climate and on forces that affect climate change.

Modern hydrology is rapidly turning towards remote sensing with an increasing use of radar and satellite data in flood forecasting models. Hydrologists are particularly interested in real time quantitative estimates of precipitation fields and the assessment of their uncertainty in particular for operational flood forecasting and warning purposes. Hydrological applications require (1) a detailed spatial and temporal statistical characterization of the rain rate estimation uncertainty, (2) the quantification of its non- linear propagation in the rainfall-runoff transformation and its statistical interaction with model uncertainties, and (3) a physically based distributed modeling approach for representing the rainfall-runoff process at different spatial scales. Multi-sensor approaches to improve precipitation estimation at spatio-temporal scales suitable for flood forecasting are needed. In particular, products derived at the very fine catchment scale from MW-calibrated satellite VIS/IR and ground-based long-range lightning observations are necessary. The quantification of orographic effects is crucial, especially in the Mediterranean area, where the catchments are relatively small and the cloud systems heavily interact with the complex orography, significantly limiting the quantitative use of operational weather radar observations.

It is for these reasons, among others, that the need to observe the distribution and variability of the properties of clouds and precipitation has emerged as a priority in earth observations. Moreover, it has become a priority to use numerical models to simulate the microphysical and dynamical processes leading to the formation of the different cloud systems and to study their effects on the Earth energy budget and the impact of the precipitation on the environment.

Italian research in Clouds and Precipitation demonstrates very large competence and covers all the necessary complementary components from observations to modeling: Satellite remote sensing using radiometers, cloud and precipitation radars, lidars, lightning detectors; Ground based remote sensing: polarimetric radars, lidars, MW radiometers, lightning detection networks; radiative transfer modeling (RTM) in a cloudy atmosphere; Retrieval techniques for cloud and precipitation parameter extraction; Calibration/validation activities using ground-based networks; Quantification of errors associated with rainfall products; High resolution cloud resolving modeling of different precipitating systems in the Mediterranean area; Quantitative precipitation estimates using numerical models; Assimilation strategies; Cloud parameterization schemes for NWP and climate models; cloud microphysics modeling and observations. The most recent research activity carried out in Italy in the field of Clouds and Precipitation can be grouped in five main areas, presented in the following sections.

a) Satellite observations of clouds and precipitation

Worldwide efforts are focused on the exploitation of new and future satellite data sources for clouds and rainfall products for meteorology, hydrology and climate. The synergy of multi-spectral, multi-angle and multi-instrument data from different platforms ensures that the satellite analysis of clouds and precipitation reaches the quality level necessary for quantitative applications, including assimilation into NWP models, climate analysis, hydrological applications, and Quantitative Precipitation Forecasts (QPF). Italy has a very active role in this context testified by fruitful research activities within numerous international programs and collaborations. Recently the activity has focused on: **1**) design and testing of passive microwave precipitation retrieval methods [i.e.,**1-7**] from cross-track (i.e., AMSU/MHS) and conically scanning (SSMIS, TMI) radiometers on board U.S and European LEO satellites (NOAA, Met-OP, DMSP, TRMM); 2) development of combined IR/MW techniques for the detection of convective clouds and the retrieval of precipitation [**8-10**]; 3) development of multispectral techniques (VIS/IR/MW) for the detection and classification of clouds, the study of cloud-aerosol interactions, the retrieval of water vapor and cloud liquid and ice water columnar content, and for temperature and humidity profiling [**11**]; 4) precipitating clouds detection using active (CloudSat) and passive (IR+MW) satellite sensors (and ground radar networks); 5) analysis of the information coming from MW-to-VIS spectral bands for the retrieval of the optical and microphysical characteristics of clouds and precipitations; 6) development of Nowcasting techniques using both LEO and GEO satellites observations [**8, 10**]; 7) observations (and modeling) of heavy precipitation events, such as Mediterranean cyclones [**12**]; 7) cloud climatology over Africa and Europe using geostationary satellites [**13, 14**]; 8) integration of satellite and ground-based observations in order to improve the retrieval accuracy of atmospheric parameters; 9) development of techniques for the dynamical retrieval of solar irradiance at Earth surface in clear and cloudy conditions [**15**].

All this activity is carried out within different international projects and collaborations. For over 20 years the Italian scientific community has played a very active role in the context of satellite missions dedicated to the passive microwave precipitation retrieval. After the launch of the NASA/JAXA TRMM mission in 1997 (and still ongoing) (*http://pmm.nasa.gov/TRMM)*, conceived in order to provide accurate precipitation and cloud structure retrieval in the tropical and equatorial region, precipitation retrieval from space has seen great advances. TRMM is equipped with the TRMM Microwave Imager, the first space-borne Precipitation Radar (PR), the TRMM Visible and Infrared Sounder (VIRS), and a Lightning Imaging Sensor (LIS). These set of instruments on board the same platform provide a unique set of measurements that have been extensively used for the analysis of convective cloud structure in the tropical region. In 2014 the launch of the Global Precipitation Mission (*http://pmm.nasa.gov/GPM*), equipped with the GPM Microwave Imager (GMI), with additional sounding capability with respect to TMI, and a Dual Frequency Radar (DPR) will sign a new era for global precipitation monitoring (including snowfall and light precipitation at high latitudes), and cloud microphysics measurements. In this perspective, in Italy the precipitation retrieval from space has recently seen great advances especially towards hydrological applications, and significant efforts have been made towards the detection and retrieval of snowfall and light rain from passive microwave radiometers [**4, 6**]. The participation to EUMETSAT's MTG and Post-EPS committees has been ensured in Italy to provide specifications for the future clouds and precipitation imagers and sounders.

Within the EUMETSAT H-SAF program (H-SAF: Satellite Application Facility on support to Operational Hydrology and Water Management, hosted at CNMCA-Italian Meteorological Service, *http://hsaf.meteoam.it*) ISAC/CNR is the leader for the development of operational passive microwave precipitation products over Europe/Mediterranean Basin (which will be soon extended to the MSG full disk) for radiometers flying on board current (DMSP, NOAA-18, NOAA-19, MetOp) and future (i.e., GPM, NPP, EPS-SG) LEO satellites. ISAC/CNR is also responsible for combined MW/IR precipitation products exploiting the higher spatial and temporal resolution of GEO observations. All the precipitation products in H-SAF are described by [**16**]. Within H-SAF, the Italian Department of Civil Protection (DPC) is leading the precipitation product validation, by coordinating the activity of 8 member European countries providing data from a highly dense network of rain gauges and radars. The Satellite Meteorology group at ISAC/CNR hosts the International Precipitation Working Group [**17, 18**] aimed at promoting the intercomparison of the main operational precipitation retrievals from satellites, and at establishing standard operational procedures and analysis techniques when ground data are used for this purpose (*http://www.isac.cnr.it/~ipwg/*).

A substantial part of ISAC/CNR within the FP7 project GLOWASIS (*http://glowasis.eu*) was devoted to the creation of global and regional satellite-derived precipitation datasets for use in water cycle and hydrological modeling [**19-20**].

b) Cloud microphysics modeling and observations

A key prerequisite to improved confidence in satellite-derived cloud characteristics is an improved representation of cloud structure, especially vertical structure and ice content. The standalone use of conventional or advanced satellite sensors limits the retrieval of cloud water and ice content, cloud particle size, and the radiative fluxes in a cloudy atmosphere. Only the synergetic combination of a series of satellite and ground-based passive and active instruments, as well as in situ measurements, can yield the data needed to assess model cloud representation.

Ground-based instruments are an important component and they include polarimetric weather radars, disdrometers, MW radiometers, lidars, and lightning detection networks. Disdrometers have been used to characterize rain events physically by deriving drop size distribution parameters, and, as in [**21-24**], rainfall rate and kinetic energy. Pludix, an X-band microwave disdrometer, measures the Doppler shift between transmitted and received radiation as backscattered by falling hydrometeors. It has been demonstrated by [**25**] that this sensor is capable of measuring the vertical speed of falling objects, and is able to retrieve the drop diameters at different altitudes. The precipitation cloud kinematics and microphysics observed from networks of Doppler and polarimetric radars when assimilated to cloud dynamic models can provide physically consistent estimation of all precipitating cloud variables, which is an invaluable information for the evaluation of cloud resolving model parameterizations, as shown by [**26**]. Several studies have been carried out to retrieve precipitation microphysics from disdrometers, Doppler and polarimetric X-band and C-band radars [**27,28**].

From the combined use of the TRMM Precipitation radar and the TRMM Microwave Imager the microphysical structure of precipitating cloud can be retrieved. This information has been used in [**29**] to verify the consistency of cloud microphysics structure of tropical cyclones simulated by cloud resolving WRF model using different microphysics parameterization schemes.

Lidars have been used to characterize clouds microphysical properties and variability of cloud fields and humidity profiles [**30-33**]. The CloudSat and Calipso missions hosting cloud radar and lidars provide the vertical profiles of clouds and aerosol on a global scale [**34**]. The upcoming ESA/JAXA Earth CARE mission will also host a backscatter lidar, a cloud profiling radar, a multi-spectral imager.

The use of sophisticated cloud microphysics and radiative transfer models is also a very important tool needed to interpret spaceborne and ground-based instrument data and to improve the retrieval algorithms of cloud properties. For example, [**35**] have developed a model for dry and partially melted snowflake morphology is performed by the development of a Snow Aggregation and Melting (SAM) model. The single-scattering properties of snowflakes are then computed by using a Discrete Dipole Approximation (DDA) technique. These properties are used to simulate synthetic radar and radiometer measurements in order to improve the performance of snow retrieval algorithms.

c) Aerosol-cloud interactions

Aerosol type and concentration have both direct and indirect effects on climate. The direct effects mainly involve scattering and absorption of solar and thermal infrared radiation by large numbers of atmospheric particles. Aerosol particles, however, also play an indirect role in modifying the climate system by entering the cloud hydrometeor formation mechanisms, thus modifying the radiative properties and extents of clouds.

Even though the indirect effects are still uncertain and not precisely quantified, aerosols are recognized as a factor of major importance in the determination of the properties of the cloud systems (through their microstructure, and subsequent effects on the radiative balance and precipitation) in the context of the climate system as a whole. The direct effects of aerosols on cloud properties include changes in cloud albedo and cloud cover, and precipitation amounts and intensity. In addition, aerosol-induced microphysical changes have major impacts on latent heat release and atmospheric dynamics, which can affect the general circulation, including storm tracks. Advanced observatories for atmospheric research in Italy, such as the CNR/ISAC Atmospheric Supersite (*http://www.artov.isac.cnr.it*, or the CNR/IMAA advanced observatory for atmospheric research [**36**] are used for in-situ measurements and remote sensing of atmospheric aerosol. Cloud microphysics and atmospheric chemistry models are used to resolve explicitly the aerosol-clouds-precipitation feedbacks. It is worth mentioning the WRF/Chem model applications over Europe [**37**] to simulate meteorological and chemical processes with online coupling.

Some international FP7 projects saw the participation of IMAA/CNR and they are:

1. In the frame of FP7 Research Infrastructure project ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network), study of cloud-aerosol interactions through the correlation of water vapor, aerosol extinction, vertical wind and the vertical (microphysical) structure of clouds measured by in situ and ground based remote sensing.
2. In the frame of GRUAN (GCOS Reference Upper-Air Network), high resolution observation of Essential Climate Variables including water vapor content, cloud base, cloud top, cloud fraction, cloud frequency, optical depth, liquid water path and liquid water content exploiting the synergy among radar, lidar, and microwave radiometer techniques: Study of droplet activation in thin cloud forming within aerosol layers.
3. In the frame of FP7 Marie Curie project ITaRS **(**Initial Training for Atmospheric Remote Sensing**),** study of aerosol-cloud interaction and the formation of supercooled liquid water in the twilight zone: Correlation between aerosol outbreaks from deserts and occurrence of rain events over the Mediterranean Basin.

d) Radar meteorology

Research in Italy on radar meteorology has been focused on dual polarization methodologies for quantitative precipitation estimation and cloud and precipitation microphysics. Italy has pioneered polarimetric methods even within operational weather services since 30 year. Remarkable efforts were focused on improving the precipitation products delivered by the national weather radar network recently wet up by the Department of Civil Protection of Italy (DPC). Recent studies by [**38-41**] have been specifically dedicated to the improvement of operational rainfall retrieval in Italy. These and other fundamental studies on the use of radar techniques to derive cloud and rainfall microphysics variables (described in Section **b**), have been conducted within the framework of international experimental programs such as HyMex [Hydrological Cycle in Mediterranean Experiment, *http://www.hymex.org*, see Section **e**)], and collaboration agreements between Italian research institutions (ISAC, IMAA, CETEMPS) and the DPC (i.e., IDRA project *http://cetemps.aquila.infn.it/idra*).

e) Monitoring and forecasting of rainfall regimes

Several Italian research groups in Italy (i.e., ISAC/CNR, CETEMPS) and regional agencies (ARPA) are dedicated to the simulation and forecasting of precipitation, in particular, heavy precipitation events, and orographic precipitation. Numerical simulations of conditionally unstable flows past an idealized mesoscale mountain ridge were performed [**42-43**]. These idealized simulations, which were performed with a three-dimensional, explicitly cloud resolving model, allowed the investigation of simulated precipitation characteristics as a function of the prescribed environment. The application of these theoretical results to observed cases of orographically forced convective rainfall has been analyzed [**44**]. The mechanisms responsible for the development of convection in several flash flood/heavy rain events in Italy have been analyzed using both numerical limited area model simulations and observations [**45-53**]. Studies have been also extended to deep convection over equatorial regions.

Dedicated studies have been carried out for specific regions characterized by the typical Mediterranean environment (such as Calabria), in order to study synoptic scale interactions with complex orography, precipitation climatology, and heavy precipitation forecast [**54-56**]. Numerical simulations of a tropical-like cyclone affecting southeastern Italy have been performed [**57-59**]. The role of different mechanisms (latent heat release, surface fluxes, sea surface temperature) has been analyzed in sensitivity experiments. Analysis of two Mesoscale Convective Systems in Central Mediterranean has been carried out through a combined model-satellite-lightning data analysis [**60**].

Several studies have been carried out on assimilation of precipitation data into mesoscale meteorological models, on the impact of satellite derived environmental parameters on the precipitation forecast [**61-64**], and on inter-comparison of precipitation forecasts and satellite retrieval. The coupling of meteorological and hydrological model for rainfall and river discharge forecasting has been recently a primary research topic in Italy [i.e., **65**].

Given the central position of Italy in the Mediterranean basin, particularly affected by severe weather phenomena and to the consequent hydro-geological effects, the interest in improving knowledge and forecasting of disastrous severe weather events is clearly evident, for both the scientific research and the operational activity. This interest has also been exploited through the participation of several Italian research institutions to international programs. Hymex (*http://www.hymex.org*) is an international experimental program that aims at advancing the scientific knowledge of the water cycle variability in the Mediterranean basin. In Italy special emphasis has been given to the forecast and monitoring of heavy precipitation and floods during the first HyMex Special Observing Period (SOP-1), on September-November 2012, which has seen an extraordinary monitoring activity as well as an outstanding number of implemented weather forecasting modeling (http://sop.hymex.org). During the SOP-1, three target areas were activated in Italy: Liguria-Tuscany, North-Eastern Italy and Central Italy, and a national operational center was organized at the University of L'Aquila, coordinated by the Centre of Excellence CETEMPS, with the aim of supporting the activity of the main Hymex Operational Centre (HOC) in Montpellier (France). Other two recent international projects promoting the integrated use of modeling and satellite and ground-based or in-situ observations, and have seen an active participation of Italian research institutions are: the Convective and Orographically Induced Precipitation Study (COPS) [**66**], aimed at investigating and understanding mechanisms and the characteristics of convective and orographically induced precipitation events in the Mediterranean areas (significant results from COPS are reported by [**67-74**]); and RiskMed (*http://www.riskmed.net*) described by [**75**].

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In the last years, studies on planetary atmospheres involving Italian researchers have been based on data returned by visible/near infrared and infrared spectrometers on board space missions. Their data sets represent a huge richness which analysis and study have allowed a great improvement of our understanding of Solar System bodies atmospheres.

Atmospheres of Saturn and Titan have been investigated through the observations performed by the image spectrometer VIMS (Visual and Infrared Mapping Spectrometer) on board of the NASA Cassini mission. Non-Local Thermal Equilibrium (Non-LTE) gas emission of the Titan thermosphere has been studied in the spectral range around 3 μm where the signatures from CH_4, C_2H_2 and HCN are present (Adriani et al., 2011, Garcıa-Comas et al., 2011). Non-LTE models have been developed to describe their emissions depending on the sun pumping under Titan atmosphere conditions and as a function of the sun illumination. Limb radiative transfer and retrieval models have been used to infer the concentration of those species in the range of altitudes 500-1200 km. An anomalous emission superimposed to the methane one has been discovered, likely due to the presence of polycyclic aromatic hydrocarbons (PAH) which would constitute the embryos of the Titan aerosol (Dinelli et al., *GRL in press,* Lopez-Puertas et al., *submitted to Astroph. J.).* A vortex in the mid-latitudes of the Saturn's northern hemisphere related to the storm begun on 2010 is under study by means of the observation performed by the VIMS visual channel operating in the visible and near infrared up to 1 μm. This study aims both to determine the morphology and the time evolution of the vortex by means of *ad hoc* tools for its size and shape best fitting, and to study the atmosphere vertical structure inside the vortex by means of the Bayesian inversion of the radiative transfer results coupled to the VIMS observations at different wavelengths.

Forthcoming missions to the Jovian system, such as the NASA Juno mission (launched in August 2011 and that will arrive at Jupiter on July 2016) and the ESA JUICE spacecraft (planned for launch in 2022), will host as a payload imaging spectrometers operating in the infrared and visible/infrared domains, respectively. In the Jupiter's atmosphere the so-called 'hot spots' represents limited regions of relatively thin cloud coverage, which allow thermal radiation by warmer, deeper atmospheric layers to be transmitted directly to space. Hot spots are thus suitable for probing physical conditions (namely chemical composition) below the main aerosol deck. Retrieval capabilities of the hot spot spectra that will be returned by the future IR spectro-imagers designed for studying the Jupiter's atmosphere have been evaluated, in particular for water vapor, ammonia and phosphine mixing ratios (Grassi et al. 2010a).

Martian atmosphere has been investigated thanks to the spectra collected by the PFS (Planetary Fourier Spectrometer) and OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) spectrometers, both on board the ESA Mars Express (MEx) mission. Water vapor represents one of the most important minor constituents of the Martian atmosphere, being involved in several processes characterizing the planetary atmosphere. The water vapor photolysis regulates the Martian atmosphere photochemistry, and so it is strictly related to carbon monoxide. The CO study is very important for the so-called "atmosphere stability problem", solved by the theoretical modeling involving photochemical reactions in which the H_2O and the CO gases are main characters. PFS spectra have allowed the seasonal monitoring of water vapor and carbon monoxide concentrations, showing strong variations at high latitudes. PFS seasonal water vapor maps reproduce very well the known seasonal water cycle, due to the carbon dioxide and water ices sublimation from the Martian polar ice caps. Seasonal variations of the carbon monoxide mixing ratio with the surface pressure has been also observed (Sindoni et al., 2011). PFS data have been used to map methane concentrations in the Martian atmosphere and investigate its behavior across the planet seasonally. A spatial variability of this non-condensable gas has been observed, demonstrating how the CH_4 transport in the atmosphere is linked to the carbon dioxide cycle. An increase of methane over the north polar cap during local summer, which cannot be explained by global circulation, strongly suggests that there could be methane reservoir associated with the polar cap (Geminale et al., 2011). By combining over more than 5 Martian years (corresponding to about 10 terrestrial years) the PFS data set with the one of a similar spectrometer, the Thermal Emission Spectrometer (TES) on board the NASA Mars Global Surveyor (MGS) mission, a high variability of atmospheric temperatures have been observed, while water vapor abundances retrieved by the two spectrometers have shown consistent seasonal and latitudinal variations (Wolkenberg et al., 2011). Moreover, PFS data have allowed the study of tidal variations in the Martian lower atmosphere, for altitudes <45 km (Sato et al., 2011). OMEGA maps of the O_2 dayglow emission at λ = 1.27 μm, arising from ozone photolysis, has revealed the occurrence of waves patterns on polar regions of Mars. The dayglow intensity fluctuations are of the order of ±3% at high incidence angle and can be explained by the propagation of gravity waves in the Martian atmosphere. The coupled mesoscale meteorological model has predicted gravity wave activity in the same range of latitudes as observed in the wave patterns traced by O_2 dayglow. Temperature oscillations are consistent with the measurements, thus confirming that airglow imagery is a powerful method to detect and study the bi-dimensional propagation of gravity waves (Altieri et al., 2012).

Venus’ atmosphere has been studied by means of the VIRTIS (Visible and Infrared Thermal Imaging Spectrometer) instrument on board the ESA Venus Express (VEx) spacecraft. Atmospheric temperature profiles in the 65-96 km altitude range have been retrieved thanks to its suitable spectral resolution. Average temperature fields have been studied as a function of latitude, subsolar longitude (i.e., local time, LT), and pressure (Grassi et al., 2010b). A further study has allowed to compare the thermal structure of the Venus' mesosphere in both hemispheres. The major thermal features reported in previous investigations (i.e. the cold collar at about 65-70°S latitude, 100 mbar pressure level, and the asymmetry between the evening and morning sides) have been confirmed. By comparing the temperatures retrieved by the VIRTIS spectrometer in the North and South, similarities have been found between the two hemispheres. Solar thermal tides have been detected in the average temperature fields, together with other tide-related feature clearly identified in the upper levels of the atmosphere (Migliorini et al., 2012). A comparative study between the Martian O_2 dayglow and the Venus’ O_2 nightglow has pointed out how imaging capabilities in both nadir and limb viewing observations combined with spectroscopy is crucial for investing the airglow intensity variations and mapping the occurrence of gravity waves (Migliorini et al., 2011). Recent observations with the VIRTIS instrument has allowed to re-examine the Herzberg II system of O_2 and study its vertical distribution. Three bands of the Chamberlain system, centered at 560 nm, 605 nm, and 657 nm have been identified as well. Their emission peak is located at about 100 km, 4 km higher than the Herzberg II bands. For the first time, the O_2 nightglow emissions were investigated simultaneously in the visible and in the IR spectral range (Migliorini et al., 2013). An airglow model, proposed by Gérard et al. (2013) starting from realistic O and CO_2 vertical distributions derived from Venus-Express observations, has allowed reproduction of the observed profiles for the three O_2 systems.

In order to perform gas identifications and infer species abundances, aerosol contents and temperature fields for constraining atmosphere compositions and dynamics, radiative transfer modelling and synthetic spectra comparison are used. Gaseous synthetic spectra are usually computed under certain assumptions and approximations validated for the study of the terrestrial atmosphere. For this reason, in the last years a laboratory dedicated to spectroscopy studies has been set up aiming to investigate the optical properties of gases under planetary conditions. Investigation of CO_2 at high pressures and high temperatures is the major activity, in order to simulate the physical and chemical conditions found in the deep atmosphere of Venus, in support to the Venus Express mission (Stefani et al. 2013). A further investigation deals volume mixing ratios typical of the Jupiter atmosphere, to interpret data coming from the NASA Juno mission and the future ESA one, JUICE.

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Lightning has charmed and provoked scientists for as long as they have watched the skies, but only recently, mainly due to the success of the Lightning Imaging Sensor (LIS) onboard the Tropical Rainfall Measuring Mission (TRMM - http://trmm.gsfc.nasa.gov), its study has been officially integrated with satellite-based remotely sensed atmospheric measurements and with cloud modeling research. LIS has provided (and is still providing) a unique amount of high quality optical lightning data over tropics (Adamo et al., 2007), while the establishment of new regional and global lightning networks, with improved location accuracy and detection efficiency, has further augmented the utilization of lightning data in many meteo-climatic studies, even at mid-latitudes.

In Italy, thanks to the collaboration with Prof. Betz from Munich University, CNR has made available its facilities all over the Italian peninsula to host sensors for the VLF/LF LINET network (http://www.pa.op.dlr.de/linet/). As a result, the Italian scientific community can finally make use of strokes data (http://www.artov.isac.cnr.it/cloud-electricity) having high quality in terms of location accuracy and detection efficiency.
ZEUS and LINET data have been used to develop strategies for precipitation nowcasting. Real time techniques aiming at the precipitation nowcasting infer the development (movement, morphology, and intensity) of convective rain cells from the spatial and temporal distribution of lightning strokes. One example is the Lightning-based Precipitation Evolving Technique (L-PET) algorithm (Dietrich et al., 2011). This is based on the cooperation between the satellite-based microwave multi-frequency brightness temperature data and lightning occurrences. Initially applied to study Mediterranean severe storms in the frame of EU FLASH project (Price et al., 2011 a-b), L-PET and other satellite based multisensor techniques are under evaluation by the Italian Civil Protection.

Using LINET data as validation, cloud electrification models, such as the 1D Explicit Microphysics Thunderstorm Model (Solomon et al., 2005), allow carrying out sensitivity studies of electrical activity and microphysics structure within the convective cloud. In these models explicit microphysics is required in order to include a charge transfer mechanism that is dependent on particle size (Formenton et al., 2013). Also Non-hydrostatic regional atmospheric modeling system used to make operational weather forecasts, such as the Calabria Regional Atmospheric Modeling System (CRAMS), have started to implement methodologies, calibrated and tested on LINET data, for providing lightning forecasting based on simulated microphysics (Federico et al., 2013).

A further boost to the Italian activity in the atmospheric electricity field has been the approval of Lightning Imager sensors concept for the next generation of European Geostationary Meteorological Satellites. The MTG Lightning Imager (LI) mission is planned in line with the recommendation of WMO 'Commission for Basic Systems' (11 July 2008) to add lightning imagers to the operational geostationary satellites to specifically measure cloud to cloud lightning for better locating areas of intensive convection within extended storm systems. The challenge of developing the lightning imager instrument now falls to Selex ES, an Italian company, which has recently signed an industrial contract for the provision of four novel lightning imagers.
The MTG LI (http://www.eumetsat.int/Home/Main/Satellites/MeteosatThirdGeneration/index.htm?l=en) will observe continuously and simultaneously the full visible disk, with high temporal resolution and it will have the highest timeliness among the MTG instruments, since it has no scanning cycle. Such

a lightning detection of IC and CG flashes from a geostationary orbit is regarded as a complementary source of lightning data to that provided by the ground-based lightning location systems. The high spatial homogeneity, that will be provided by the satellite perspective will allow the development of operational NWC applications on the European or hemispheric scale.

Also studies about the impact of lightning and transient luminous events (TLE) on NOx production (Arnone et al., 2008 and 2009) benefit from the improvement in lightning monitoring. In the field of TLEs, the Italian coordination and significant contribution to the observations in Europe have led to the first database, with climatological and case studies (Haldoupis et al., 2012, Neubert et al., 2011, Van der Velde et al., 2010). The activities were sponsored also by ESA through the CHIMTEA project (http://due.esrin.esa.int/stse/projects/stse_project.php?id=143), aiming at a better understanding of the chemical impact of these processes onto the atmosphere.

Finally, very interesting is the frontier research concerning the terrestrial gamma rays flashes (TGFs) and their connections with lightning and meteorology. An interesting workshop has been recently organized on this topic (http://www.asdc.asi.it/10thagilemeeting/). TGFs are very short bursts of gamma-rays associated to thunderstorm activity, currently observed by detectors onboard satellites or research airplanes. TGFs are likely produced by Bremsstrahlung of energetic electrons accelerated by a mechanism (e.g., the Relativistic Runaway Electron Avalanche mechanism, RREA) in close association with the lightning leader propagation. The AGILE satellite (Tavani et al., 2009) is one of the only three currently active space instruments capable of TGF detection, together with RHESSI, and *Fermi*-GBM. AGILE is especially tailored for the detection of high-energy photons in the tens of MeV regime (Marisaldi et al., 2010a). AGILE indicates that TGF high-energy spectral behavior deviates from the canonical RREA model, reporting photon energies as large as 100MeV (Marisaldi et al., 2010b; Tavani et al., 2011) that require electrons acceleration across a large fraction of the full available potential difference in a thundercloud.

Even if this overview is far from being exhaustive, the above results provide significant examples of the activity and growing interest of the Italian scientific community in cloud electricity and related fields.

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The scope of theICPM encompasses the meteorology and climatology of the Arctic and Antarctic. Polar regions are very sensitive indicators of climate change and are subjected to complex not linear interactions involving the snow-surface, atmospheric components, thermal stability conditions, sea-ice etc. Although both the Arctic and Antarctic are subject to a similar annual cycle of solar radiation and increasing greenhouse gas concentration, over the previous two decades the regions have experienced dramatically different changes in sea ice extent, temperature, and other climatic indicators. The main uncertainties in predicting these changes are due to uncertainties in parameters of known physical processes, which could be reduced through better observations and modeling, and uncertainties in our knowledge of physical processes themselves, reducible only through theoretical development and design of new, original observations/experiments. Several studies, field experiments, and modeling work were done from the Italian scientific community both in the Arctic and Antarctica to address and overcome this lack of knowledge.

In the Arctic, a significant share of research, driven not as episodic expeditions or field experiments but using permanent research stations, is done in the Svalbard. The Svalbard research is truly international, e.g. the international research station situated at NyÅlesund (78°55' N, 11°56' E) is operated by about 150 Norwegian, German, Japanese, Italian, French and the UK researchers and open for researchers of other nations. At Ny-Alesund Italy runs the Dirigibile Italia station. In the period 2010-2012 a lot of efforts have been devoted to develop and implement the CNR multidisciplinary project Climate Change Tower Integrated Project (CCT-IP) (www.isac.cnr.it/~radiclim/CCTower). In the Svalbard the temperature trends are clearly identified in observations but the attribution of specific climate change causes remains uncertain due to the large impact of non-local advective processes, teleconnections and long-term variability. This makes the attribution of the regional climate records distinct to the attribution on the larger continental and global scales. Novel projections focusing on the Svalbard region indicate a future warming rate for winter months up to year 2100, three times stronger than observed during the latest 100 years ([1]). The direct climatic effect of aerosols on radiative balance of the atmosphere, through absorption and scattering of incoming-short wave radiation, is particularly significant because of the high surface albedo due to show and ice, leading to atmospheric warming and reduction of the solar radiation reaching the surface. At present, global models have great difficulties in reproducing the annual aerosol quantities observed in the Arctic. In a recent work [2] have compared ground-based measurements of aerosol optical depth and Ångström parameter at six

Arctic stations in the period 2001–2006 with the results from two global aerosol dynamics and transport models, ECHAM-HAM and TM5. Assessment of aerosol characteristics and direct radiative effects at local and regional scale are investigated by [3], [4], [5]. Capability of standard passive remote sensing techniques to produce realistic Aerosol Optical Depth (AOD) data at very low concentration was also investigated promoting intercalibration campaign in the frame of POLAR-AOD initiative [6]. The Svalbard surface layer climate is significantly modified by the specific climate conditions of fjords and mountain valleys hence, interpretation of numerical simulation results where those specific conditions are not properly reproduced, such as in the state-of-the-art climate models, must be done with care ([1]). The atmospheric boundary layer (ABL) height is recognized as an important parameter which controls some features of the Earth's climate and the atmospheric chemical composition. Shallow, stably stratified ABLs in polar regions are especially sensitive to even weak impacts. [7] used a new lidar system (MULID) to estimate the ABL height from aerosol measurements. The Svalbard meteorology is also considerably affected by processes in the ocean surrounding the archipelago. A small meteorological mast, BEAR (Budget of Energy for Arctic Regions), was developed as part of a new autonomous system for monitoring the sea ice mass balance. The system was tested during a field experiment in 2010 using the CCT-IP measurements ([8], [9]). [10] used the CCT-IP meteorological measurements to quantify the transport processes and deposition fluxes of the nitrogen compunds on the snow surface in order to assess their impacts on the arctic ecosystems. The importance of the Svalbard meteorology on Arctic research motivated [1] to organize a special issue on "Svalbard Meteorology" on the journal Advances in Meteorology. A first evaluation of surface UV behavior in early spring in the middle of ozone hole as well as short-term variability of UV-B flux in an Arctic measurement site as Ny Alesund is carried out by [11] and [12], the UV measurements quality assurance was confirmed through intercomparison with the European reference spectrometer QUASUME ([13]).

In Antarctica two stations are runned by Italy: Mario Zucchelli at Terra Nova Bay (74°42'S,164°07'E), and the French-Italian Concordia at Dome C, Antarctic Plateau (75°06' S,123°20'E). In a manner similar to that observed for the Arctic, in Antarctica one of the most prominent uncertainty in the ongoing transient climate change is related to the poor understanding, and hence correct modeling of the thermal stratification, and dynamics processes occurring in the stable atmospheric boundary layer. The permanent station of Concordia over the Antarctic plateau at Dome C allows the study of the ABL processes during the whole year using ground based remote sensing systems ([14], [15]) and tower measurements ([16]). [17] and [18] compare the mixing height estimated by sodar measurements during the summer, at Dome C, with the results of a prognostic zero-order mixing layer model. The model performs well in the first part of the day, when the mixing layer is shallow, the sensible heat flux has a monotonic behavior, and the subsidence can be neglected. Dome C radiosoundings profiles are analysed by [19], [20] to improve radiative computations. A database using radiation measurements by a BSRN station at Concordia was realized by [21] during the Antarctic IPY 2007-2009. Typical emissivity characteristics of the atmosphere above the Antarctic Plateau were evaluated developing a parameterization for strong and persistent temperature inversion conditions [22]. Studies were done to understand the Surface Mass Balance processes and the source areas of Dust/ Precipitation. [23], [24], [25], [26] and [27] show the importance of complex atmospheric dynamics, over different spatial (from local to continental) and temporal scales, that allow to dust or chemical species (e.g. sulphate) to be lifted up into atmosphere from source areas and deposited in different part of the Antarctic continent. [28], [29] and [30] helped to better understand the atmospheric mechanisms ruling the moisture and precipitation paths from oceans poleward inside the continent. [31], [32] and [33] analyze and propose new methodologies to better understand the interaction between katabatic winds, blowing snow, and surface in different Antarctic areas. Several studies were carried out to understand the changes in sources intensity and transport efficiency of chemical markers of primary and secondary aerosol (sea spray, biogenic emissions, continental dust) in the marine and continental regions around Antarctica, as revealed by multi-annual continuous measurements of size-segregated atmospheric particulate collected at Dome C, East Antarctica ([34], [35], [36]). Seasonal and inter-annual changes of the chemical composition of the aerosol collected at Dome C are interpreted as the effect of changes of the main atmospheric circulation modes. The effect of the atmospheric emissions of mega-eruption events on climate and environment, such as that of the Toba volcano (occurred around 74 kyr ago), are evaluated by the spikes of sulphate along ice cores drilled in Antarctica and in Greenland ([37]). Common volcanic signatures identified in the Antarctic ice layers are used in synchronizing ice core drilled in different coastal and central areas of East and West Antarctica ([38], [39]). The scientific goal is to understand the propagation around Antarctica of the environmental answers to the climatic forcing occurred in the last millennia ([40], [41]) and along several tens thousand years ([42]). The study of the ice-core stratigraphies of chemical markers of atmospheric processes is also focused on gaining information about the changes in marine productivity, atmospheric and marine circulation modes, sea-ice extension and persistence, and hydrological cycles in the dust source areas around Antarctica for the last 800 kyr ([43], [44], [45]). Five-year analysis of background carbon dioxide and ozone variations during summer seasons at the Mario Zucchelli station are studied by [46].

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International Association of Meteorological and Atmospheric Sciences

Committee on Mathematical Geophysics

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Some relevant results of Italian research in Mathematical Geophysics(MG) are presented. The report is not meant to be exhaustive about the MG research in Italy. Instead, the emphasis is on papers where by means of theoretical approaches, and by means of state-of-the-art direct numerical simulations, evidences of new phenomena are given [1-4]. Meteorological or climate models call for an improvement in the description of atmosphere-ocean coupling: here the topic is reviewed in terms of the role of surface waves [5]. Two other review papers are also presented, concerning research fields of increasing interest in the atmospheric sciences, such as data assimilation techniques [6], and the modeling of dispersion processes in urban environment [7], i.e. in strongly non-homogeneous systems. These papers also reflect the fact that Italian researchers actively participate in international collaborations.

Two dimensional turbulence is a topic of interest for geophysics in many respects. Even tough, strictly speaking, it is never realized in nature because of the emergence of some degree of three-dimensionality, it is invoked to explain both large-scale atmospheric and oceanic circulations. However, many crucial features of two dimensional turbulence are to be explained, and new phenomena arise, despite the long history of theoretical and numerical research in the field. In particular a puzzling observation is the following: aircraft measurements (see G. Nastrom, K. Gage, W. Jasperson, Nature 310, 36 (1984)) of atmospheric winds indicate that horizontal kinetic energy spectra at the troposphere end (at 10 km altitude) display two power laws: one probably due to a 2D inverse cascade of energy, with energy spectrum $E(k) \sim k^{-5/3}$, at wave numbers in the mesoscales (~ 10–500 km), and one associated to a 2D direct cascade of enstrophy, with spectrum $E(k) \sim k^{-3}$, at synoptic scales (500–3000 km). Starting from this observation, in [1] authors perform direct numerical simulation (DNS) of two dimensional turbulence, injecting energy at both small and large scales (somehow mimicking the presence of injection mechanisms at the meso- and at the synoptic scales). Clearly these DNS are very far from the atmospheric flows that inspired the work, but they show that the coexistence of the two cascades is possible, resulting in a non-linear superposition of the two regimes.

Two turbulence is also interesting since it allows modeling of more complex situations: in [2], authors discuss the situation of stably stratified turbulence. In such case, the inverse cascade of energy towards large scales is stopped at the scale where the buoyancy force balances the inertial force. As a consequence, kinetic energy is converted into potential energy, which is transferred back towards small scales via a turbulent cascade of density fluctuations. The resulting *flux loop* is a novel mechanism which produces a non-trivial stationary state in two-dimensional, weakly stratified turbulence. These results show that numerical studies, and laboratory experiments, are still needed to gain a better understanding of the two dimensional upscale energy transfer. leading to the formation of condensed states populated by strong vortical structures.

Considering convective motion in stratified ocean systems, it can happen that two buoyancy-changing scalar fields with different diffusivities - such as salt and temperature-, develop a *fingering regime*: namely, a fluid parcel displaced from its equilibrium height exchanges the better diffusing and stabilizing scalar faster than it exchanges the destabilizing one, developing a buoyancy anomaly that further increases the displacement. In a regime of very low density ratio and very high Rayleigh number, in [4] authors give evidence of a new phenomenon of self-organization of fingers that cluster together to form larger-scale coherent structures. This is reminiscent of the clustering of plumes Rayleigh-Bénard convection.

Coupled atmosphere–ocean General Circulation Models (AOGCMs) combine modeling of atmospheric and oceanic dynamics, with the advantage of removing the need to specify fluxes across the interface of the ocean surface. They represent the future direction in the field and are currently still poorly developed. As discussed in [5], waves essentially affect the dynamics and thermodynamics both of the atmospheric boundary layer and of the upper ocean, which in turn define the air-sea interactions at scales larger than wave periods and storm duration. This paper discusses the fundamental problem of surface wave generation and wind-wave interaction, and it is a useful starting point for researchers willing to know current status and perspectives of the ocean surface wave research.

Back to the atmosphere, Lagrangian turbulent diffusion and dispersion has gained a renewed interest in the last ten years, thanks to the availability of new high-resolution, high-frequency data from laboratory experiments. Besides, a large number of numerical simulations have been performed. In [3], authors report the first study on turbulent pair dispersion of particles with inertia, i.e. small particles whose density is either much larger or much smaller than that of the ambient fluid. Cloud drops are a typical example of the former case. An interesting result is that inertia can slow down turbulent dispersion and mixing, since inertial particles form clusters, or can accelerate it, due to the so called *sling effect* (i.e., pair of particles with a very large relative velocity). Hence the turbulent pair dispersion of inertial particles is a highly non trivial phenomenon: in the cited paper, a mathematical model to reproduce inertial pairs relative separation is also presented.

Turbulence and dispersion mechanisms are also at the core of the review paper of [7], where the specific case of urban environment is discussed. Tough the paper mostly discusses experimental measurements, it also indicates which are the mathematical modeling challenges in the fluid dynamics of the urban atmospheric boundary layer and its prediction. In particular, theoretical modeling of non linear turbulent interaction at different scales in strongly non homogeneous system needs to go beyond dimensional analysis considerations.

Any atmospheric and ocean model has to deal with the fundamental problem of predictability: it is important to recognize that our limited capacity of forecasting is due to the chaotic nature of geophysical flows and not to computing capacities. In [6], the atmospheric predictability problem is reviewed and recently developed techniques of data assimilation are discussed. The topic is at the edge of modern research, since atmospheric and ocean numerical models do need clever assimilation, both of Eulerian and Lagrangian data.

To conclude, some relevant results of Italian research in Mathematical Geophysics (MG) have been reported. It is clear that numerical simulations are an emerging tool in geophysics. There are several reasons for this: i) increasing computing power is now widespread; ii) numerical simulations are *cheaper* than experiments and are often very useful to design experiments to be realized, and to gain a feeling with the physical phenomenon; iii) finally, tough in limited flow domains, numerical simulations give access to quantities that are often difficult to measure.

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International Association of Meteorological and Atmospheric Sciences
Union Commission on Geophysical Risk and Sustainability
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Catastrophic events that occurred in Italy have brought to the attention of public opinion and of the scientific community on the topic of the impact of climate change on the frequency and intensity of extreme events of hydrological and geomorphological nature. The evolution of hydrological phenomena in the last fifty years shows an increasing incidence of events, and a progressive increase in the risk to the population. The urban sprawl that has affected around the country significantly after the war led to the development of fragile territories, exposing to a high risk population. In addition, the change in the lifestyle of the population resulted in a progressive distancing from the rural interior to the urban centres, and the consequent abandonment of the maintenance function and territorial garrison contributed to maintain the balance of the territory.

The findings confirm some recent scientific research results nationally and internationally that pointed out the need for a study of the impact of climate change is conducted by analysing the environmental variations as a whole. It is necessary to combine the study of climate change analysis of land use of the slopes and river auctions, and urban planning. It should be analyzed the joint climate system-meteorology-hydrology-geology, including impact studies which analyze the hydrological change, or the change of the system that is the interface between climatic stresses and disasters. The analysis of the environmental system as a whole is therefore central to deciphering the impact of climate change, and for the proper planning of mitigation and adaptation measures.

Evaluation and analysis of the effects of the major catastrophic events require a cross-sectoral approach, in line with recent guidance of the international scientific community. The Italian scientific community owns the proper data, information, resources and skills to make a critical examination of hydro-geological phenomena that affect the Italian territory, in times that are compatible with environmental and social requirements. It is a difficult problem which evaluation can be of great support for the economic, social and cultural context of the country. At present, because of its geomorphological characteristics and urbanization, the Italian territory constitutes a high risk hydro-geologic area. For these peculiar characteristics, developed schools of researchers with specific skills on hydro-geological disasters that have examined this issue in a variety of situations.

In research aimed at identifying and developing mitigation strategies, adaptation and protection against natural hazards, which take into account the climatic and environmental changes, the Italian scientific community has enabled extensive research related to the field of atmospheric sciences. The main research themes may be schematized as follows:

1. creation and updating of archives and regional and national catalogues about phenomena of hydrogeological, essential to) the study of temporal and spatial distributions of hydrological disasters; ii) determination of risk reduction policies, and for the choice of actions to adapt to climate change;
2. development of methodologies for the study of the mechanisms of initiation and propagation of landslides;
3. evaluation of the role of the rainy regime on landslides, with particular reference to the following activities: s) time series analysis of precipitation heat for identifying trends and cycles for the triggering of landslides and possible ii) detection of rainfall thresholds for triggering of landslides at the national scale and/or regional level;
4. definition of procedures defining the susceptibility and landslide hazard depending on geological scenarios and diversified and typical evolution of the main Italian geological reality;

5. application of remote sensing technologies and use of remote sensing images from satellite platforms, terrestrial, aerial or for recognition, mapping, classification and monitoring of complex natural phenomena;
6. study of flood formation processes with particular reference to surface runoff, infiltration, full wave transfer;
7. implementing operational models to the prediction of flood-prone areas and for hazard assessment;
8. updating and improvement of existing estimates on levels of social and individual risk posed by geo-hydrological events.

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International Association of Meteorological and Atmospheric Sciences

Union Commission for Data and Information

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Main Activities

Most significant contributions of the Italian Community concerned the following National, European and International programmes and initiatives:

- The EU INSPIRE Directive;
- GEO-GEOSS;
- OGC standard specifications;
- NSF EarthCube initiative;
- GIIDA-EGIDA.

The EU INSPIRE Directive;

Subject: INSPIRE Data Specification for the spatial data theme Atmospheric Conditions and Meteorological Geographical Features

Description: This activity aimed to contribute to the INSPIRE Data Specification for the spatial data theme Atmospheric Conditions-Meteorological geographical features.

Outcome: A specification document submitted to the INSPIRE Committee [1].

Italian contribution: CNR was part of the INSPIRE Thematic Working Group Atmospheric Conditions-Meteorological geographical features.

GEO GEOSS

Subject: The Global Earth Observation System of Systems (GEOSS) aims to provide decision-support tools to a wide variety of users. As with the Internet, GEOSS will be a global and flexible network of content providers allowing decision makers to access an extraordinary range of information at their desk. GEOSS targets nine Societal Benefit Areas (SBAs) including one denominated "Weather". In GEOSS data and information are shared, combined, and used by means of a GEOSS Common Infrastructure (GCI).

Description: GCI realizes a real multi-disciplinary "system of systems" applying the GEOSS Data Sharing principles. A core element of GCI is the GEO Discovery and Access Brokering (GEO DAB) framework, implementing the necessary semantic mediation functionalities to interconnect the heterogeneous data and information resources. Through GEO DAB Atmospheric Sciences data model and protocols (e.g. THREDDS, CF-netCDF, etc.) are mediated and made accessible (in a transparent way) to others Disciplines.

Outcome: The GEO DAB software [2] [3] [4].

Italian contribution: CNR has been leading the design and development of the GEO DAB.

OGC standard specifications;

Subject: The OGC has developed a broad Standards Baseline. UCAR and the OGC believe that having netCDF included in that family will encourage broader use and greater interoperability among clients and servers interchanging data in binary form. Establishing CF-netCDF as a standard for binary encoding will make it possible to incorporate standard delivery of data in binary form via several OGC protocols, e.g., WCS, WFS, and SOS.

Description: This SWG has been focused on processing the CF-netCDF candidate standard submissions for the core standard and one extension for the CF conventions –processing any comments received during the public comment periods. Moreover, A WCS encoding specification for CF-netCDF has been drafted and submitted to the WCS SWG.
Outcome: The international standard: OGC "CF-netCDF3 Data Model Extension standard" [5]. This standard specifies the CF-netCDF data model extension that specifies the CF-netCDF data model mapping onto the ISO 19123 coverage schema. This standard deals with multi-dimensional gridded data and multi-dimensional multi-point data. In particular, this extension standard encoding profile is limited to multi-point, and regular and warped grids; however, irregular grids are important in the CF-netCDF community and work is underway to expand the CF-netCDF to encompass other coverages types, including irregular gridded datasets.
Italian contribution: CNR was among the proposing organizations; Stefano Nativi is one of the co-authors of the specification.

GIIDA-EGIDA

Subject: GIIDA is an initiative of the Italian National Research Council (CNR). It is an inter-departmental project aiming to design and develop a multidisciplinary e-infrastructure (cyber-infrastructure) for the management, processing, and evaluation of Earth and Environmental resources –i.e. data, services, model and sensors. This National experience was collected along with analogous developed by other European countries to form the baseline of a more general "methodology" to build multi-disciplinary interoperability and capacity building as to Earth Sciences. This was the objective of the FP7 project EGIDA coordinated by the CNR (DTA).
Description: The GIIDA activity has aimed to implement the CNR Spatial Information Infrastructure (SII) for Environmental and Earth Sciences resources –including atmospheric and climate sciences. GIIDA has established a collaboration with other National cyber-infrastructures, such as the SinaNet.
The EGIDA project prepared a sustainable process promoting coordination of activities carried out by: the GEO Science & Technology (S&T) Committee; S&T national and European initiatives; and other S&T Communities.
Outcome: The GIIDA forum and WG; the GIIDA architectural guidelines [6]. The EGIDA, a sustainable mechanism based on the GEO S&T approach at national and regional level, to coordinate national multi-disciplinary "System of Systems" [7] [8].
Italian contribution: The entire GIIDA programme. Coordination of the FP7 EGIDA project.

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International Association of Meteorological and Atmospheric Sciences
International Commission on Climate
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This document is organized reporting the main scientific achievements of the last years in the area of climate research, leaded or partecipated by italian scientists. Climate research is a broad and inter-disciplinary area that includes the study on the climate dynamic, the actual and past variability at various temporal and spatial scales, the coupling with the environment, the biosphere, and the society. ICCL reported a classification of the actual scientific scopes of the Association in climate related scientific fields (http://www.iccl-iamas.net/content/index.php/site/aboutus_extended/welcome_to_the_international_commission_on_climate_iccl_homepage/). This document follows as far as possible such classification to be homogeneous and harmonized with ICCL areas of interest, and reports scientific relevan results leaded or partecipated by italian teams and authors in the frame of each area, with a specific focus on the Mediterranean basin that is a highly sensible area for climate change and adaptation.

- The climates of the past, including the recent past, the industrial period, the period recorded in human records, and the paleoclimatic period covering the climatic history of the Earth, including interactions of climate with historical development.

Recently, by analyzing Antarctic ice cores to infer concentration of atmospheric CO2 and Antarctic temperature for the last deglacial warming [Science, 2013], the group of Parrenin (partecipated by Barbante) found no significant asynchrony between them, indicating that Antarctic temperature did not begin to rise hundreds of years before the concentration of atmospheric CO2, as suggested by previous studies.
Colleoni et al (2012) focused a Plio-Pleistocene analysis on the Mediterranean revealing such area detected the main global climate transitions over the last 5 Myr, being affected by the high-latitude climate dynamics more than the low-latitude one.

- The climate of the present, including its distribution around the world, trends in climatic conditions, and couplings to the environment and society.

Studying the effects of Global Climate Policies aimed at regulating GHG emissions requires interactions between physical, technological and economical frameworks. Direct and indirect costs of sea-level rise for Europe for a range of sea-level rise scenarios for the 2020s and 2080s have been estimtaed by Bosello et al (2012), revealing that impacts are quite significant with a large land loss and increase in the incidence of coastal flooding. By the end of the century Malta has the largest relative land loss at 12% of its total surface area, followed by Greece at 3.5% land loss. Economic losses are however larger in Poland and Germany ($483 and $391 million, respectively). While the direct economic impact of sea-level rise is always negative, the final impact on countries' economic performances estimated with the GTAP-EF model may be positive or negative. This is because factor substitution, international trade, and changes in investment patterns interact with possible positive implications.

- The climates of the future over periods of seasons, years, decades, centuries, and thousands of years into the future, including potential impacts of climate with the environment and society.

The Mediterranean region has been identified as one of the main climate change hotspots, among the most responsive areas to climate change. The area is populated by over 500 million people, distributed in about 30 countries in Africa, Asia, and Europe. Therefore, understanding climate variability here has also important social implications. A new study by CMCC (Gualdi et al 2012) illustrate an innovative multimodel system developed within the “Climate Change and Impact Research: The Mediterranean Environment (CIRCE)” EC project used to produce simulations of the Mediterranean Sea regional climate.
Carraro et al (2012) analyzed future energy and emissions scenarios in China, by assessing different scenarios in which greenhouse gases emissions are taxed, at different levels

- The factors contributing to climate variations and changes, including both natural and human-induced factors, in the past, the present, and projected for the future.

The topic of attribution of recent global warming is usually faced by studies performed through global climate models (GCMs), but also econometric models may be applied to this problem. Attanasio et al (2012) obtained a clear signal of linear Granger causality from greenhouse gases (GHGs) to the global temperature of the second half of the 20th century; while in contrast, Granger causality is not evident using time series of natural forcing.

- The observational systems used to gather information about the climate and document change as well as to reconstruct past climatic conditions.

Satellite data are today providing sufficiently long-term datasets to trigger climatological studies basd on such obersvational frameworks. Levizzani et al (2011) have used Meteosat IR channels to study a 10-year climatology of cloud patterns over Europe and Mediteranean.

- The empirical, theoretical, and numerical methods and analyses used to diagnose and interpret climatic behavior, including the processes and feedbacks (including those that are physical, chemical and biological) that determine the climate as well as its variations and change.

Climate extremes may strongly impact typical winter and summer Mediterranean crops inducing environmental and socio-economic feedbacks. Moriondo et al (2011) coupled atmospheric and crop models to investigate climate change effects on sunflower and winter wheat under the A2 and B2 scenarios of IPCC, including also the direct impact of extreme climate events. The authors found that the impact of climate change was different for winter and summer crops, with severe reductons for sunflower and increased yields for winter wheat, and stress the importance to include extreme events in crop-modelling approaches.

- Numerical models of the climate, including their construction, testing, and application, including the interpretation of their results.

The Centro Euro-Mediterraneo sui Cambiamenti Climatici Climate (CMCC) developed and implemented the CMCC-CM model, a coupled atmosphere–ocean general circulation model (Scoccimarro et al, 2011). The model is based on the atmospheric component ECHAM5 and oceanic component OASIS3 nad sevres as a basis for higher reso9lution nested regional domains.

- Interactions of the components of the Earth system, including the atmosphere, land surface, oceans, biosphere (terrestrial and marine), cryosphere, and lithosphere that together influence the climate.

Using data and models, the mechanisms controlling the interactions between different components may be elucidated and used in the future to improve predictive models. Manzini et al (2012) investigated the Stratosphere-troposphere coupling at inter-decadal time scales and the implications for the North Atlantic Ocean. They found that the long lasting stratospheric vortex anomalies are connected through the troposphere to mean sea level pressure, surface temperature and sea ice cover anomalies, providing evidence for a potential role of the stratosphere in decadal prediction.

- The cycling of chemical species, particularly those that are radiatively active, through the climate system and the interactions of these species on the climate.

In recent years the possibility to measure the exchange of passive and active scalars between the biosphere and the atmosphere has been widely improved thanks to a new generation of analyzers, based particularly on Cavity Ring Down Spectroscopy (CRDS). Zona et al (2013) used the eddy covariance micrometeorological tecnique to measure surface exchange of all relevant GHG (i.e CO_2, CH_4, N_2O) in a short-term biomass energy plantation, revealing that the sum of the CH_4 and N_2O losses was much higher than the net CO_2 uptake, thus stressing the importance of actually considering and contabilizing non-CO_2 gases that may greatly impact greenhouse effect.

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International Association of Meteorological and Atmospheric Sciences

International Commission on Middle Atmosphere

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The middle atmosphere is the region of the atmosphere between about 12 and 80 km and is composed by the stratosphere and the mesosphere. Due to the impact of anthropogenic factors on the stratospheric ozone layer and on coupling between stratosphere and surface climate, in recent years the processes taking place in the middle atmosphere have been widely investigated.
The Italian scientific community involved in the study of the middle atmosphere is composed of several research groups part of CNR, INGV, INAF, CMCC, Italian University and others National organizations. The scientific work consists on observational and modelling activities, data analysis and algorithm development. Climate Chemistry Models (CCM) are used for the investigations of dynamical and chemical processes. Observational data are collected from ground based sensors, and radiosonde. In addition, data from aircraft and satellites experiments are exploited for the the study of the stratosphere and of the mesosphere and new techniques and algorithms are developed for the analysis and exploitation of observational remote sensing data from satellite and aircraft.
Modelling of dynamical and chemical processes in the middle atmosphere is particularly important to understand the impact of stratospheric processes on climate.
The activity carried on at the CETEMPS/University of l'Aquila focus on the study of the interactions between ocean and middle atmosphere and, in particular, on the possible effects of the Pacific decadal oscillation (PDO) on the tropical belt width (Grassi et al., 2012) and the effects of sea surface temperature (SST) at tropical latitudes on the polar middle atmosphere (Grassi et al., 2009). These studies are performed through modelling approach (Grassi et al., 2012, 2008) and climatological data analysis (Grassi et al., 2009). In particular, the results obtained from a General Circulation Model (GCM) were used to highlight the role played by the tropical SST in the development of the characteristics of the Antarctic dynamics during the winter months and were used to investigate the anomalous weak Antarctic polar vortex conditions in 2002: the tropical SST anomalies during the winter of 2002 is thought to have influenced the preconditioning of the stratospheric vortex (Grassi et al., 2008). The influence of SST on polar winter atmosphere was previously investigated by E. Manzini (Manzini et al., 2006). In this case the influence of SST interannual variations on Northern Hemisphere winter polar atmospheric circulation was investigated using the MAECHAM5 GCM. The El Nino/Southern Oscillations (ENSO) influence on the stratosphere was also investigated in (Manzini, 2009) and by C. Cagnazzo (ISAC-CNR), (Cagnazzo et al., 2009, on Northern polar stratosphere). The CMCC-CMS Climate model was used to search for evidence of stratospheric-tropospheric coupling at interdecadal time scales by Manzini and C. Cagnazzo in (Manzini et al., 2012) using a a 260-year simulation. The importance of understanding the dynamical coupling between stratosphere and troposphere is one of the key points of the SPARC (Stratospheric Processes And their Role in Climate) activities.
SPARC contributed to the Ozone Assessment through the activity on chemistry-climate model validation (CCMVal). The activity of the group "Fisica dell'Atmosfera" of the Dipartimento di Scienze Fisiche e Chimiche at University of l'Aquila focus on stratospheric modelling. The ULAQ-CCM was used (together with others CCMs) for the investigation of the evolution of stratospheric ozone: in Eyring et al., 2010 to evaluate the ozone return data (ozone returning to historical values); in Butchart et al., 2010 to analyse with simulations of 11 CCMs the twenty-first century stratospheric climate and circulation changes and in Gettelman et al., 2010 to evaluate the CCM performances in UTLS (Upper Troposphere/Lower Stratosphere) and TTL. These activities were also part of the CCMVal project (e.g Son et al 2010). Activities related to the calculation of the life-time of ozone-depleting substances (ODS) also match the SPARC themes. All these studies are related to the WMO (World Meteorological Organization, UNEP/WMO, 2011) and SPARC assessment activities (CCMVal-1, CCMVal-2, lifetimes, GeoMIP). Part of the activity is also

related to the study of aerosols in the UTLS using numerical models. Furthermore, in the frame of the European project EC-REACT4C (European Commission-Reducing Emissions from Aviation by Changing Trajectories for the Benefit of Climate) the group was involved in the study of the impact of aircraft emissions on climate-chemistry of the atmosphere: impact of subsonic and supersonic aircraft emissions (both gas-phase species and particle emissions) on the chemical composition of the troposphere and on the stratosphere as well as the effects on radiative forcing were evaluated (Lee et al., 2010).

While GCM and CCM models can be used to predict stratospheric ozone recovery, ground-based measurements are a key element for the monitoring of the stratospheric ozone at polar latitudes.

In 2009 a ground-based millimetre-wave spectrometer (GBMS) for the measurements of O_3, N_2O, CO, and HNO_3, was installed at the Network for the Detection of Atmospheric Composition Change (NDACC) in Thule in Greenland. The GBMS measured vertical profiles of O_3 and HNO_3 during 2010-2011-2012 that were used to improve the understanding of the interannual variability of the winter Arctic stratosphere. GBMS profiles of O_3, N_2O and CO were used for the investigations of Sudden Stratospheric Warmings in 2009 (Di Biagio et al., 2010). In 2011 a new inversion technique, based on optimal estimation was developed for the retrieval of HNO_3 from GBMS measurements (Fiorucci et al., 2011). GBMS measurements were also used to characterize the O_3 vertical profiles between 35 and 80 km altitude and to perform comparison with Aura Microwave Limb Sounder (MLS) and Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instruments (Muscari et al., 2012). Polar winter stratospheric ozone (Total ozone column) was measured with a Brewer spectrophotometer in Norway in September 2007-March 2008 (Rafanelli et al., 2009).

In mid-latitude regions, observational activities from ground play an important role for both the validation of data from satellite and for the investigation of stratospheric processes.

Data from the "Ottavio Vittori" station at Monte Cimone were used to infer stratospheric NO2 trends from 1993 to 2009 (Kostadinov et al., 2011). Stratospheric-tropospheric exchange were investigated at the Nepal Climate Observatory–Pyramid (Bracci et al., 2011).

Balloon-based observations of temperature, pressure, humidity up to the stratosphere are part of the activities carried on at the CNR-IMAA Atmospheric Observatory (CIAO), Potenza, for the investigations of the stratosphere up to 35 km altitude (a description of the CIAO observatory can be found in Madonna et al, 2011). Radiosondes data collected at the atmospheric observatory were used for the validations of MIPAS (Michelson Interferometer for Passive Atmospheric Sounding)/ENVISAT instrument temperature profiles (Ridolfi et al., 2007).

The validation of MIPAS/ENVISAT temperature profiles was performed exploiting also radiosonde data from CETEMPS/ University of l'Aquila.

Moreover, At CETEMPS of the Department of Physics of the University of L'Aquila, the monitoring of vertical ozone profiles is performed using balloon-borne instruments in collaborations with Ministero dell'Ambiente e della Tutela del Territorio e del Mare (more than 10 years activity). The activities are also part of WMO Scientific Assessment Panels on stratospheric ozone. Data from the radiosonde were used also for the validation of MIPAS/ENVISAT ozone profiles (Cortesi et al., 2007). In the Antarctic region, at Dumont d'Urville, radiosondes were used to measure temperature profiles and to investigate the inter-annual stratospheric temperatures variability (David et al., 2010).

Balloon-based radiosonde data can be collected up to 30-35 km. Stratospheric aircraft has a maximum flight altitude of about 20-21 km. Measurements from stratospheric aircraft can therefore be used for the investigations of the processes in the lower stratosphere and in the UTLS (Upper Troposphere-Lower Stratosphere), a pivotal region for climate change investigations.

The russian M-55 Geophysica aircraft that has been exploited in several recent campaigns from tropical mid-latitude and polar regions. The data collected by the instruments were used to investigate the Arctic stratosphere as well as to investigate the Asian monsoon or the latitudinal exchange of air masses and the Tropical Tropopause Layer (TTL).

In particular the SCOUT-AMMA campaign, described by F.Cairo (ISAC-CNR) in (Cairo et al., 2010) and performed in 2006 from West Africa, aimed at the investigations of the impact of strong convective mesoscale systems on water, aerosol, dust and chemical species in the UTLS. Data from this campaign were used to investigate the impact of convection on TTL composition exploiting also mesoscale model simulations (Fierli et al., (2011)).
During the SCOUT-O3 campaign in 2005 (Darwin, Australia), the MARSCHALS (Millimetre-Wave Airborne Receivers for Spectroscopic Characterisation in Atmospheric Limb Sounding) collected its first measurements. These data were analysed by Dinelli et al., (2009) using the MARC retrieval code (Millimetre-wave Atmospheric Retrieval Code, Carli et al., 2007). This work highlighted the instrument capabilities of measuring the atmospheric composition in the UTLS region, even in presence of clouds that are optically thick at IR wavelengths.
The IFAC-CNR group and the ISAC-CNR Remote Sensing of the Stratosphere (RSS) group, were also involved in the ESA project "PREMIER Analysis of Campaign Data", aimed at inverse processing of limb measurements acquired during campaigns at mid-latitude (TC9 campaign, December 2009) and in the Arctic region (PREMIER-Ex campaign, March 2010 (Cortesi et al., 2011) and ESSENCE campaign in December 2011, Kiruna, Sweden) by MARSCHALS, as an airborne demonstrator of the mm-wave spectrometer of the PREMIER payload (ESA report), one of the three candidate core missions of Earth Explorer 7 in the frame of ESA's Living Planet programme.
While ground based, balloon and aircraft data can be used for the investigation of the stratosphere on a local scale, satellite measurements have the unique characteristic of providing wider data coverage.
In the mesosphere, analysis of OH zonal means, recorded at boreal high latitudes by Aura/MLS were be used to investigate mesospheric vortex dynamics (Damiani et al., 2010). Furthermore, data from Geostationary Operations Environmental Satellite (GOES) satellite were used to identify intense solar energetic particle (SEP) events. O_3, NO, NO_2, HNO_3, OH, HCl and OHCl profiles retrieved from different satellite sensors (solar occultation and limb emission) were investigated to analyse the mesospheric/stratospheric response to SEPs at high terrestrial latitudes by Damiani et al., (2009). In the stratosphere, satellite data were exploited to calculate the position and variability of stratospheric dynamical barriers (Palazzi et al., 2011) using PDF of long-lived tracers.
The MIPAS/ENVISAT instrument exploited the limb sounding technique to scan the atmosphere from 70 to 6 km from 2002 to 2012 (Fisher et al., 2008). The MIPAS/ENVISAT data are analysed to retrieve vertical profiles of atmospheric targets by ESA using a retrieval code that was developed and optimized under the scientific responsibility of the IFAC-CNR MIPAS group. The code is described in Raspollini et al., 2006. Retrieved MIPAS data were part of the validation exercises for the Atmospheric Chemistry Experiment (ACE) satellite (temperature, N_2O, NO_2, NO) (Sica et al., 2008, Strong et al., 2008, Kerzenmacher et al., 2008), were used for the validation of night time NO_2 from Global Ozone Monitoring by Occultation of Stars (GOMOS) (Verronen et al., 2009) and where assimilated into a system based on Numerical Weather Prediction and CTM models in the frame of the Assimilation of Envisat data (ASSET) project (Lahoz et al., 2007). Through the years, the code was updated with new characteristic like the self-adapting regularization (Ridolfi and Sgheri, 2011) and a new expression for the computation of covariance matrix and averaging kernels for the Levenberg-Marquartd regularization (Ceccherini and Ridolfi, 2010).
The MIPAS/ENVISAT data were also exploited for the application of an innovative algorithm for optimal exploitation of the information provided by indirect measurements of atmospheric vertical profiles (Ceccherini et al., 2009, 2010a, 2010b) as well as for the rigorous determination of stratospheric water vapour trends from MIPAS observations (Ceccherini et al., 2011) and the determination of quality quantifiers for indirect measurements (Ceccherini et al., 2012).
The ESA retrieval code approximates the atmosphere in 1-D, the GMTR code by Carlotti et al., (2006) was developed for the analysis of MIPAS/ENVISAT measurements exploiting the 2-D atmospheric approximation, therefore accounting for horizontal inhomogeneities effects (Kiefer et

al., 2010). The 2-D approach was exploited for several studies on the sensitivities and performances of MIPAS/ENVISAT (Carlotti and Magnani, 2009; Carlotti et al., 2011) and a modified version of the Forward model internal to the GMTR code was used for the 2-D retrieval of PSC extents (Polar Stratospheric clouds, involved in polar ozone depletion processes) (Castelli et al., 2011). The multi-target capability of the GMTR code (but not the 2-D approximation) was also exploited to retrieve for the first time the natural $H^{15}NO_3/H^{14}NO_3$ isotope ratio profile (Brizzi et al., 2009) from MIPAS. The GMTR was applied to the full MIPAS mission to produce the MIPAS2D database (Dinelli et al., 2010) that was used in (Tomasi et al., 2011) to calculate monthly mean vertical profiles of pressure, temperature and water vapour volume mixing ratio in the polar stratosphere and low mesosphere and to investigate the anomalous behaviour of the 2010-2011 Arctic winter with the detection of unprecedented Arctic ozone loss (Arnone et al., 2012).

MIPAS data analysed with the GMTR code were also used to investigate the impact of thunderstorms on middle atmosphere. E. Arnone et al. investigated the possible impact of sprites (discharges extending from 40 to 90km) on NO_x chemistry using NO_2 night time data from MIPAS/ENVISAT and lightning data as a proxy for sprite activity (Arnone et al., 2008, 2009). A local enhancement in NO_2 of about +10% at 52 km height and tens of per cent at 60 km height in coincidence with intense lightning activity were found. Data from GOMOS and MIPAS2D database were used to infer the impact of plasma processes on stratospheric NO_y (Arnone and Hauchecorne, 2012).

Thunderstorms can have an impact on the middle atmosphere also trough the production of Terrestrial Gamma Ray Flashes **(**TGF**).** TGFs are brief (<1 ms) bursts of gamma-rays and particles of energies up to several tens of MeV, produced during thunderstorms near cloud tops (15-21 km, in the lower part of the stratosphere) associated to the lightning process, which can travel through the atmosphere and be detected at satellite altitude**.** The AGILE (Astrorivelatore Gamma a Immagini Leggero) satellite was developed for the monitoring of TGFs. M. Marisaldi and F. Fuschino (INAF, IASF Bologna) are involved in the analysis of TGF detected by AGILE.

The main AGILE discoveries produced significative advance in TGF science during two and a half years of observations. The main points are the fact that TGF spectrum extends at least up to 40 MeV (Marisaldi et al., 2010); that the high energy tail of the TGF spectrum is harder than expected and cannot be easily explained by previous theoretical models (Tavani et al., 2011); TGFs can be localized from space using high-energy photons detected by the AGILE silicon tracker (Marisaldi et al., 2010b); TGFs are not a random sub-sample of global lightning activity as detected from space; moreover, significant regional differences exist, both in the degree of correlation and in the TGF/flash ratio (Fuschino et al., 2011).

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International Commission on Atmospheric Chemistry and Global Pollution

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Research activity of Italian research groups in the field of atmospheric chemistry and global pollution during the period 2010-2012 focused on the following subjects:

- Development of analytical techniques for characterization of air pollutants
- Pollution health impact,
- Model development and validation,
- Observations in urban, rural, remote, and marine areas.

Development of analytical techniques

Analytical methods have been developed in order to allow or facilitate quantification of trace species and markers in ambient particulate matter. Canepari et al (2010) developed a fast and reliable method to quantify Sb(III) and Sb(V) in particulate matter (PM) samples by ion chromatography – mass spectrometry (IC-MS). Cuccia et al. (2011) applied Fourier Transform Infrared (FTIR) spectrometry to the quantification of carbonate in Carrara area PM_{10} samples, while Piazzalunga et al. (2010) coupled ion chromatography with pulsed amperometric detection to quantify levoglucosan in PM_{10} samples from northern Italy during winter.

Piazzalunga et al. (2011a) discussed uncertainties and limitations of thermal-optical methods for quantification of elemental carbon and organic carbon on aerosol samples. In agreement with previous studies, large discrepancies were observed when different methodologies were employed. In particular, this study showed that the application of the EUASAAR method, developed as optimal methodology for the analysis of rural and remote site samples, might lead to underestimation of organic aerosol and overestimation of elemental carbon in urban areas.

Pollution health impact

Biological effects of ambient aerosol samples and primary combustion particles were tested by in-vitro analysis to investigate their cytotoxicity, oxidative potential, and mutagenicity. Gualtieri et al. (2011) reported miotic arrest and death of lung cells following exposure to $PM_{2.5}$, while limited effects were observed after exposure to PM_{10} samples. $PM_{2.5}$ exposure was also correlated with gene alteration, DNA damages, and oxidative potential (Gualtieri et al., 2012). Investigation of freshly emitted Diesel exhaust particles showed a correlation of PM_1 exposure with inflammatory response of human lung epithelial cells (Mazzarella et al., 2012). Lodovici et al. (2011) investigated the ability to induce oxidative stress of different gas pollutants and PM components.

Epidemiological studies performed by Italian research institutions highlighted a correlation between specific air pollution sources, like dust and traffic, and health outcome, including respiratory diseases, cardiac and respiratory mortality (Belleudi et al., 2010; Canova et al., 2010; Zauli et al., 2010; Mallone et al., 2011; Nuvolone et al., 2011; Tramuto et al., 2011)

Model development and validation

Large part of model research activity focused on development and validation of chemistry transport models. Validation of CAMx (Comprehensive Air Quality with extension) model in the Po valley showed an underestimation of organic mass and sulfate up to 60%, underlying the need of better emission inventories of carbonaceous aerosols and better description mechanisms for secondary aerosol formation (Lonati et al., 2010). In the framework of AQMEII intercomparison exercise, CAMx and CHIMERE performance were evaluated over the European and North American domains, showing again underestimation of $PM_{2.5}$ and PM_{10} concentration, likely due to underestimation of emission inventories and misrepresentation of deposition processes (Pirovano et al., 2012; Solazzo et al., 2012).

In the framework of MAP (Marine aerosol production) project, and in collaboration with European partners, a new function to simulate primary organic aerosol emission from ocean biogenic activity was formulated and implemented into the chemistry transport model TM5 (Vignati et al., 2010). Model simulations of primary organic mass were in agreement with observations performed at Mace Head and Amsterdam Island (Vignati et al., 2010).

An up-to-date global emission inventory of mercury was presented by Pirrone et al. (2010), while estimates of global and regional emissions of halocarbons were reported by Xiao et al., (2010) and Saikawa et al. (2012).

A regional air quality model was developed to forecast two days in advance PM_{10} concentration in urban areas, to support local policy decisions. The model used artificial neural networks and based predictions on PM_{10} monitoring network data and satellite images from MODIS (Carnevale et al., 2011).

In addition, research efforts were dedicated to develop statistical tools to identify specific PM sources (Contini et al., 2010; Cuccia et al., 2010; Masiol et al., 2010; Moroni et al., 2012), and to quantify the contribution of a specific PM source to ambient aerosol (Indarto et al., 2010). These studies highlighted the importance of wood burning for residential heating in northern Italy during the colder season (Piazzalunga et al., 2011b; Belis et al., 2011; Gilardoni et al., 2011a) and the relevance of Saharan dust transport during PM_{10} exceedance events in the Mediterranean basin (Pederzoli et al., 2010; Caggiano et al., 2011; Calastrini et al., 2012; Nava et al., 2012).

Observations

Several long-term and short-term studies were performed in urban areas to characterize aerosols physical and chemical properties, and to identify their sources (Amodio et al., 2010; Caggiano et al., 2010; Caselli et al., 2010; Perrino et al., 2010; Bernardoni et al., 2011; Bigi et al., 2011; Invernizzi et al., 2011; Lonati et al., 2011; Perrone et al., 2011; Bigi et al, 2012a; 2012b; Nava et al., 2012). Analysis of vertical profiles of particle number concentration and size distribution over urban areas of Milan and Terni showed an increase of fine particles diameter with height due to ageing, and a decrease of coarse particles concentration due to sedimentation (Ferrero et al., 2010; Sangiorgi et al., 2011; Ferrero et al., 2012). A few studies compared observation at urban, rural, and remote sites in order to distinguish local from regional PM sources (Carbone et al. 2010; Pavese et al., 2011; Perrone et al., 2012).

Italian research groups are responsible for gas and particulate phase measurements at a remote site part of the global atmospheric watch network, i.e. the Nepal Climate Observatory at Pyramid (NCO-P), in the Himalaya region. Long-term observations at the NCO-P of PM_1, PM_{10}, and black carbon (BC) showed higher pollutant concentrations in the pre-monsoon season and lower concentrations in the monsoon period (Bonasoni et al., 2010; Bonasoni et al., 2012). Chemical characterization of PM samples and BC time trend indicate that the site was influenced by long-range transport and by thermal winds that transported pollutants from the surrounding valleys (Decesari et al., 2010; Bracci et al., 2012; Marinoni et al, 2012). Long-term record of fully halogenated species, whose production and consumption is regulated under the Montreal Protocol, showed frequent “above baseline” events, indicating that chlorofluorocarbons are still used in the developing countries surrounding the region (Maione et al., 2011). In the framework of the EUCAARI project (European Integrated project on Aerosol Cloud Climate and Air Quality interactions) long-term observations of fine and coarse PM were performed at the remote site of

Manuas, in Brazil, where primary biogenic aerosol particles and secondary organic aerosol were identified as the main sources of carbonaceous aerosol (Gilardoni et al., 2011b). EUCAARI run also intensive filed experiments in Europe. Organic aerosol investigation in a boreal forest (Hyytiala - Finland) showed the presence of more oxidized particles from the European continental area (anthropogenic aged aerosol) and less oxidized particles that were classified as biogenic marine and terrestrial biogenic secondary organic aerosol (Finessi et al., 2012). Measurements at the remote site of Mace Head proved that atmospheric processing of particulate matter increases particle hygrocopicity, and thus their ability to act as cloud condensation nuclei (Dell'Osto et al., 2010).

In addition to continental remote locations, marine areas were investigated by several studies, mainly focused on the quantification of primary marine organic aerosol (Facchini et al., 2010; Becagli et al., 2012) and the characterization of gas phase ship emissions in coastal areas (Becagli et al., 2012; Schembari et al., 2012).

Air quality measurements are regularly performed at two EMEP (European monitoring and evaluation programme) stations in Italy, i.e. Rome and Ispra. PM chemical characterization performed during the EMEP intensive measurement period in 2006 were compared with EMEP model results and showed a good agreement with simulations, but revealed the need of better emission inventories for wood burning at the European level and reduction of nitrogen quantification uncertainties (Aas et al., 2012).

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International Association of Meteorological and Atmospheric Sciences

Committee on Nucleation and Atmospheric Aerosols

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The National Research Council (CNR), in collaboration with other Italian scientific institutions (e.g., the University of Florence), has a long tradition in excellence in research in cold climates. Observations of atmospheric aerosol properties over icy surfaces is of paramount importance because light-absorbing anthropogenic particles, such as black carbon (BC), can accelerate snow melting upon deposition or by altering the atmospheric radiative budget. The aerosol direct radiative forcing was measured in the Arctic during field campaigns, like PAM-ARCMIP (Stone et al., 2010). The indirect aerosol effects, i.e., those exerted by the aerosol through modifications of cloud properties, are more elusive and difficult to quantify. An important phenomenon controlling aerosol-cloud interactions is the increase of aerosol number densities and cloud condensation nuclei (CCN) concentrations caused by new-particle formation (NPF) events. In the recent years, our mechanistic understanding of the subtle physico-chemical processes which eventually lead to NPF has greatly improved, thanks to the rapid development of technologies looking at the nanoscale. The University of Milan was among the institutions which took part to the CLOUD experiment at CERN, which clarified the impact of cosmic rays on ionized molecular clusters acting as germs for nucleation (Kirkby et al., 2011). The role of NPF in the atmospheric lifecycle of the aerosol becomes critical especially at remote sites, where the concentrations of background particles is typically low ($\leq 10^3$ cm^{-3}). Unfortunately, newly formed particles are too small to be observed using remote sensing techniques, therefore, extending the coverage of in situ observations to new environments is critical for the assessment the actual impact of NPF on the global CCN budget. A very recent work, which was born from a collaboration between the University of Helsinki and CNR, showed that aerosol nucleation occurs even in the middle of Antarctica, at Dome C (Järvinen et al., 2013). Another frontier for NPF observation is the middle troposphere, where actually most clouds develop. Unfortunately, the intermittent nature of NPF hampers quantitative observations of event frequency using research aircrafts. For this reason, continuous measurements at high-altitude observatories provide unique datasets of aerosol number concentrations above the planetary boundary layer. A joint French-Italian atmospheric composition monitoring program started in 2006 at the station which has now become the "Nepal Climate Observatory – Pyramid" (NCP-P) site of the ABC network. The station is located at the foot of Mount Everest at 5048 m a.s.l., providing continuous measurements of aerosol physical properties, size distribution, BC and aerosol optical properties and optical depth (Bonasoni et al., 2010). Thanks to the satellite connection, everybody can follow the changes in aerosol concentrations and properties at the foot of Mount Everest virtually in real time on a friendly internet interface (http://evk2.isac.cnr.it/realtime.html). The French/Italian research team demonstrated that aerosol nucleation is a very common phenomenon also over the Himalayas, especially at the interface between the polluted boundary layer and the clean, dry air of free troposphere (Venzac et al., 2008). The impact of atmospheric aerosols on glacial melting and on the hydrological cycle in the Hindu Kush, Karakoram and Himalayan region is a "hot topic" of the current international climate research, because on the Asian "water tower" depend the lives of billions people. This is also the topic of the Italian project PAPRIKA, which has a counterpart in France, and involving both field campaigns in glaciated regions of Karakoram (Pakistan) and the use of state-of-the-art climate models (EC-Earth) and regional chemical transport models (Nair et al., 2012). Global CTMs were used to simulate the transport of anthropogenic light-absorbing aerosols over long distances, especially those produced in the mid- and upper troposphere from aviation (Sovde et al., 2007; Lee et al., 2010). Direct aerosol measurements in the upper troposphere and lower stratosphere were carried out during new missions with research aircrafts capable to fly at very high altitudes (Borrmann et al., 2010). Another compartment of the atmosphere targeted by Italian researchers dealing with aerosol climate impacts is the marine boundary layer. Specific research teams on marine aerosol were the effect of its chemical composition on the physical properties relevant for CCN activity (Ovadnevaite et al., 2011), and the direct radiative effect caused by sea spray (Balzarini et al., 2012) and by desert dust transport (Basart et al., 2009). Over (more anthropisized) terrestrial ecosystems, the aerosol measurements conducted by the Italian research organizations are now well integrated at the European scale (Putaud et al., 2010), thanks to infrastructure development programs such as EUSAAR, which provided high level quality assurance protocols for the determination of aerosol size-distribution, optical properties and CCN concentrations. The follow-up of EUSAAR, ACTRIS (http://www.actris.net/), coordinated by CNR, created a single framework for quality-controlled aerosol measurements involving both in-situ physical observations, the retrieval of vertical profiles of aerosol extinction by lidar, and aerosol-cloud interaction measurements. A scientific theme in which the Italian monitoring stations resulted strategic was again that of nucleation. In San Pietro Capofiume (SPC), located in an agricultural land in the eastern Po Valley, the concentrations of particles as small as three nm in diameter are routinely measured since 2002 thanks to the collaboration between CNR and the University of Eastern Finland (Hamed et al., 2007; Laaksonen et al., 2008). Ten-year -long records of observations of such small particles are rare and available in Europe only at other three locations, Hyytiälä (Finland), Melpitz and Hohenpeissenberg (Germany). The four stations allow to study MPF in contrasting environments in respect to climate, degree of anthropization and atmospheric composition. Examination of the seasonal and interannual variability of NPF in the last decade in the Po Valley is underway. Such retrospective analysis will provide unique diagnostics for the impact of climate and anthropogenic stressors on aerosol formation in Europe, because in this time lag not only climate extremes have been recorded, such as the summer 2003 heat wave, but also the strength and composition of anthropogenic emissions have varied significantly as a function of the progressive change of vehicle fleet composition and as a consequence of the application of more stringent air quality regulations. According to all bibliometric indicators, the research activities on atmospheric aerosols are rapidly expanding in Italy like in the other European countries, also thanks to successful coordination and support actions funded by the EC, in which Italian organizations played a key role. Specifically, CNR coordinated the Network of Excellence on atmospheric chemistry (ACCENT, FP6-Environment), the project that has paved the road for a cluster of projects improving knowledge on atmospheric chemistry and physics, with a focus on the multiple impacts of atmospheric aerosols on climate and air quality (e.g., EUCAARI, Kulmala et al., ACP, 2011; Manninen et al., 2010). The main results of ACCENT were recently published in a special issue of Atmospheric Environment (Monks et al., 2009), which represents a useful compendium of the current key research topics in aerosol science, while discussing the thorny problem of the dialogue between climate scientists and society and the policy makers.

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