AYUDAS RAMÓN Y CAJAL

MEMORIA DE LA TRAYECTORIA INVESTIGADORA Y LA LÍNEA DE INVESTIGACIÓN PRINCIPAL QUE HA DESARROLLADO
(*SUMMARY OF THE RESEARCH CAREER OF THE CANDIDATE AND THE MAIN RESEARCH LINE THAT SHE/HE HAS CARRIED OUT)*

Esta memoria debe rellenarse preferiblemente en inglés - *Summary to be completed preferably in English*

INVESTIGADOR SOLICITANTE / *RESEARCHER APPLICANT*: Carlos Pérez García-Pando

PALABRAS CLAVE / *KEYWORDS:* Atmospheric aerosols, Mineral dust, Climate, Air Quality, Modeling, Health Impacts

RESUMEN (aprox. 300 palabras) / SUMMARY (approx. 300 words):

My research focuses on understanding the physical and chemical processes controlling atmospheric aerosols, and evaluating their effects upon climate, ocean biogeochemistry, air quality and health. My core area of expertise is atmospheric mineral dust. I am also a model developer with a large experience in supercomputers and operational forecasting. Since 2009 I work in the US where, currently, I am Associate Research Scientist at the NASA Goddard Institute for Space Studies and Columbia University, and I serve as PI and co-PI in competitive research projects funded by the Department of Energy, NASA and NOAA, with collaborators at NOAA/National Centers for Environmental Prediction, NOAA/Geophysical Fluid Dynamics Laboratory, Princeton University and Cornell University. Some of my achievements are:

1) I showed that the inclusion of dust aerosol as a radiatively active substance in numerical weather prediction models can significantly improve weather forecasts over dust affected regions, a seminal work inspiring a number of studies and initiatives thereafter.
2) I led an international multi-institutional initiative to develop a unique unified (regional and global) prediction model for weather, atmospheric aerosols and chemistry that today provides operational forecasts widely used by the international scientific community, weather services, companies and air quality managers.
3) I played a seminal role on the design, creation and successful implementation of the World Meteorological Organization (WMO) Regional Centers on Sand and Dust Storm Prediction in Spain, the only operational forecasting services for airborne dust fully recognized by WMO.
4) I proposed novel methods to constrain the mineral and chemical composition of dust in models in order to improve the currently uncertain estimates of dust aerosol effects upon climate.
5) I led an international cross-disciplinary research effort involving the World Health Organization to unravel the links between dust aerosols, climate and meningitis epidemics in Africa showing the current potential to forecast risk of meningitis epidemics based on climate and dust information.

My work has resulted in 46 peer-reviewed papers (67% in Q1, H-Index: 24, i10 Index: 38, number of citations: 2370, Google Scholar), 20 chapters in books, proceedings and reports, 150 contributions to conferences/workshops/seminars (26 as invited speaker) and the edition of a book of proceedings. I have organized an international conference and a workshop. I have participated in 27 international (US and EU) and national projects (in 6 of them as PD, PI or co-PI). I have co-advised 3 PhD students, 3 Master students, and 1 Postdoc. My work has been highlighted among others by NASA and the European Centre for Medium-Range Weather Forecasts, and covered by international media such as The Guardian.

Thanks to the international recognition of my contributions to basic, applied and cross-disciplinary aspects within my field, in October 2015 I was awarded with the highly selective AXA Chair to create my research group and program at the Barcelona Supercomputing Center, Spain, starting in October 2016. The obtained endowment amounts 1.8M Euro over 15 years that will allow me implementing an ambitious and stable long-term research program on mineral dust.

DESTACAR HASTA UN MÁXIMO DE LAS CINCO APORTACIONES MÁS RELEVANTES ENTRE LAS RECOGIDAS EN EL CURRÍCULUM VITAE

Highlights a maximum of 5 relevant achievements from the ones included in the cv

I am virtually interested in every aspect of atmospheric aerosols, from understanding the physical and chemical processes affecting them, to evaluating their effects upon weather, climate, ocean biogeochemistry, air quality and health. I am also a model developer with large experience in supercomputers and operational forecasting. My core area of expertise is airborne mineral dust, which is globally the most abundant of all aerosol species by mass, represents a serious hazard for life, health, property and economy in arid and semi-arid environments and adjacent regions, and its influence within the Earth System spans a wide range of spatial and temporal scales. I describe below five relevant achievements of my career:

1. Dust radiative effects, feedbacks upon dust emission, and improvement of numerical weather forecasts

Typically, aerosol-radiation-cloud interactions had been neglected in meteorological and air quality models, although their relevance in climate science was widely recognized. In *Pérez et al. (2006a JGR)* I demonstrated for the first time that the inclusion of mineral dust aerosols as radiatively active substances in numerical weather prediction models could significantly improve short-range weather forecasts over dust affected areas. I also related the decrease in dust emission to a reduction of eddy mixing within the boundary layer. I showed that negative dust radiative forcing at the surface can significantly reduce the flux of sensible heat from the ground that powers eddy mixing and therefore dust emission in arid regions. This seminal work has been significantly cited and more importantly, has inspired a number of studies and initiatives. For example, operational weather services have started to recognize the importance of representing dust in models to reduce systematic temperature biases and improve data assimilation in weather forecasting. The work has been identified as the first of its kind in a recent review on atmospheric chemical weather modelling *(Baklanov et al. 2014 ACP).* Together with my NASA colleagues I have also contributed to further understanding of the mechanisms by which dust affects global and regional climate *(e.g. Miller et al. 2014a, 2014b, 2014c JAMES).*

2. Aerosol-chemistry model developments from regional to global scales

In 2008 I launched the development of a new chemical weather prediction system (NMMB/BSC-CTM). The NMMB/BSC-CTM is a multi-scale non-hydrostatic atmospheric chemistry and weather prediction system comprised of an atmospheric model (the Non-Hydrostatic Multi-scale Model, NMMB) developed at the NOAA/National Centers for Environmental Prediction (NCEP) and a Chemical Transport Model (BSC-CTM) that I conceived, and which is further developed today by the Atmospheric Composition Group of the Barcelona Supercomputing Center (BSC-CNS) in close collaboration with NOAA/NCEP and other partners, including the NASA Goddard Institute for Space Studies (NASA GISS), the University of California, Irvine (UCI), and NOAA/Geophysical Fluid Dynamics Laboratory (GFDL). I initially developed the interactive aerosol component, including parameterizations for dust emission, source region identification, wet and dry deposition and radiative interaction (*Pérez et al., 2011 ACP; Haustein et al., 2012 ACP*), while designing the strategy towards the implementation of a fully interactive chemistry-aerosol model. Thereafter, during my period as research scientist in the US (2009-2016), I have contributed to the development of the gas-phase chemistry in the model (e.g. *Jorba et al, 2012 JGR*) and guided the development and study of other global aerosols (*Spada et al., 2013 ACP; 2015 AE)*. As for today, the NMMB/BSC-CTM includes seven types of tropospheric aerosols: sea salt, dust, black carbon, organic matter (both primary and secondary), sulfate, nitrate and volcanic ash. The model also includes detailed gas-phase chemistry with 51 chemical species and 156 reactions. It contains advanced physics, chemistry and aerosol packages, and has the unique ability to be configured as a global model or as a very high-resolution regional model, both with embedded 1- or 2-way static or moving nests, while allowing feedbacks between chemistry and meteorology. The system is currently operated at the BSC-CNS, participates in several international model intercomparison initiatives (e.g., AQMEII-Phase 2, ICAP, Charmex), and is used in research projects at NASA, NOAA/NCEP and NOAA/GFDL. The model is internationally recognized.

3. Operational dust forecasting and the WMO Sand and Dust Storm Warning Advisory and Assessment System

For countries in and downwind of arid regions, airborne dust presents serious risks to the environment, property and human health. Decision-makers have long desired the ability to forecast severe dust events in order to mitigate their impacts on transportation, energy and health. In some regions of the world, people's livelihoods are threatened by severe dust storms that can force the closing of roads and airports due to poor visibility. Health advisories to susceptible populations require dust information as input (see extensive book chapter by *Benedetti et al. (2014)* that I have co-authored). My work and leadership on mineral dust led to an internationally recognized dust modeling group at BSC-CNS that attracted the attention several research and operational communities. I played a key role on the design and launching of the World Meteorological Organization (WMO) Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) for Northern Africa, the Middle East and Europe. I was a Member of the writing team of the Implementation Plan. The mission of the SDS-WAS is to enhance the ability of countries to deliver timely and quality sand and dust storm forecasts, observations, information and

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knowledge to users through an international partnership of research and operational communities. To achieve this mission, WMO designated Regional Nodes consisting of a network of research and operational partners that are supported and coordinated by a Regional Center. My contribution was key for the BSC-CNS and the Spanish Meteorological Agency (AEMET) to be designated as hosts of the WMO Regional Center for Northern Africa, Middle East and Europe (http://sds-was.aemet.es/). The BSC-CNS is today uniquely positioned in the field, as it has managed to coordinate the efforts of multiple partners, allowing implementation of the only operational forecasting services for airborne dust fully recognized by WMO. The main European and international institutions involved in the observation and prediction of dust are among the partners of the Regional Center. Examples include EUMETSAT, ECMWF, NASA, NCEP and many National Meteorological Services. The dust component of the NMMB/BSC-CTM model that I developed produces forecasts at the Regional Center for a regional domain comprising Northern Africa, Middle East and Europe operational forecasts. These forecasts are widely used by the international scientific community, weather services, companies and air quality managers.

4. Dust mineralogy, anthropogenic dust sources, dust climate effects and the iron cycle

I was the director of a collaborative project between Columbia University, NASA and Cornell University whose goal is to improve our understanding of the atmospheric iron cycle and its impact upon the carbon cycle. Because the ocean currently absorbs about one-third of the CO_2 emitted by human activity, it is crucial to understand how ocean uptake of CO_2 will be modified during this century. The supply of soluble iron to the oceans is fundamental to oceanic primary production and CO_2 uptake. Iron deposition has the largest effect in high-nutrient low chlorophyll (HNLC) areas that comprise approximately 30% of the world's oceans. The vast majority of the global ocean, including the HNLC areas, is dependent on wind-transported atmospheric dust as a source of iron and the largest deposition of iron occurs downwind of the main deserts of the globe (including North Africa, Asia, the Middle East, Australia, and Patagonia). Because the iron content in dust particles depends upon mineral types, me and my team recently proposed novel approaches to represent the emission and global distribution of mineral aggregates, which were tested within the NASA GISS Earth System ModelE against a new global compilation of observations (*Perlwitz et al., 2015a ACP, 2015b ACP; Pérez García-Pando et al. 2014, 2015 AGU*). Constraining the size-resolved composition of dust aerosols is complicated. The composition of the emitted dust resembles to some degree that of the parent soil. Yet, soil mineral grains and aggregates fragment during emission through saltation and sandblasting on the soil bed, which generates differences in the size distribution and mineral fractions between the parent soil and the emitted dust aerosols. In addition, global atlases only provide coarse estimates of soil texture and mineral composition that are extrapolated from the analysis of a limited amount of soil samples after wet sieving, a technique that breaks the aggregates encountered in natural undisturbed soils. Our novel methods have remedied some important deficiencies of previous implementations in comparison to observations.

5. Impacts on health

I have combined my core research in aerosol modeling with a cross-disciplinary effort to unravel the effects of dust and climate conditions upon meningitis epidemics. Meningococcal meningitis is one of the most feared dry season infectious diseases in sub-Saharan Africa. I led a cross-disciplinary research community involving the World Health Organization (WHO) to create a meningitis incidence model based on climate, dust, population data, and proxies for immunological state or susceptibility. Given the lack of reliable and continuous dust data in the Sahel I also produced the first long-term regional dust model climatology in Northern Africa with the NMMB/BSC-CTM model that I had previously developed. Using a range of negative binomial generalized linear models fitted to meningitis data I showed the potential of climate and dust information in the early dry season to explain part of the variability of the disease at seasonal and district scales. A paper showing these achievements was published in a high-impact journal *(Pérez García-Pando et al., 2014a EHP*), which represents the first contribution of its kind. I also published a review paper on the subject *(Pérez García-Pando et al., 2014b EP)* where I critically review recent research and practice seeking to provide useful information for the epidemic response strategy of National Ministries of Health in the Meningitis Belt of Africa. The novelty of my research led to invitations as a speaker at the workshop "*Next Generation Modeling: Climate, Weather and Infectious Disease*" organized at Princeton University by the NIH Fogarty International Center Research and Policy for Infectious Disease Dynamics (RAPIDD) program, and the *"Conference on Human Health in the Face of Climate Change: Science, Medicine, and Adaptation"* organized by the "la Caixa" Foundation, BIOCAT, and the New York Academy of Sciences in Barcelona. My work on aerosol-infectious disease interactions has been highlighted by NASA, the Earth Institute, Columbia University and ECMWF, and has been covered by specialized media (e.g. *Astrobiology Magazine, Scidev.net, EarthZine, Phys.org*) and international mass media (e.g. *The Guardian, Voice of America)*.

DESARROLLAR LA TRAYECTORIA INVESTIGADORA ASÍ COMO LA LÍNEA DE INVESTIGACIÓN PRINCIPAL QUE HA DESARROLLADO.
Extended detail of the research career of the candidate and the main research line that he/she has carried out.
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I was born in Barcelona (Spain, 1977). *Industrial Engineer* from the Universitat Politècnica de Catalunya (UPC, Barcelona, Spain, 2001) and *Ingénieur des Arts et Manufactures* from the Ecole Centrale Paris (France, 2001), *Diploma of Advanced Studies* and *Ph.D. in Environmental Engineering* (Summa Cum Laude) from the UPC (Barcelona, Spain, 2006).

After the completion of my PhD, I began my scientific carrier at the Barcelona Supercomputing Center (BSC-CNS) where I held the position of Mineral Dust Group Leader between 2006 and 2009. Thereafter, I moved to the United States where I have worked at the National Oceanic and Atmospheric Administration (NOAA/NCEP), the International Research Institute for Climate and Society at Columbia University (IRI), and the NASA Goddard Institute for Space studies (NASA GISS).

Since 2011 I am Associate Research Scientist at NASA GISS and the Department of Applied Physics and Applied Mathematics at Columbia University in New York, where I lead research projects funded by the US Department of Energy, NASA, and NOAA.

My work has resulted in 46 peer-reviewed papers (67% in Q1, H-Index: 24, i10 Index: 38, number of citations: 2370, Google Scholar), 20 chapters in books, proceedings and reports, 150 contributions to conferences/workshops/seminars (26 as invited speaker) and the edition of a book of proceedings. I have organized an international conference and a workshop. I have participated in 27 international (US and EU) and national projects (in 6 of them as PD, PI or co-PI). I have co-advised 3 PhD students, 3 Master students, and 1 Postdoc.

Thanks to the international recognition of my contributions to basic, applied and cross-disciplinary aspects within my field, in October 2015 I was awarded with the highly selective AXA Chair to create my research group and program at the Barcelona Supercomputing Center, Spain, starting in October 2016. The obtained endowment amounts 1.8M Euro over 15 years that will allow me implementing an ambitious and stable long-term research program on mineral dust.

I detail below my journey as a scientist.

PhD period – 2002-2005

My formation in topics related to atmospheric chemistry, meteorology and climate started with a Ph.D. thesis in Environmental Engineering at the Laboratory of Environmental Modeling (UPC). The primary aim of my thesis was to understand a variety of atmospheric phenomena affecting the Mediterranean region using atmospheric modeling and aerosol LIDAR observations. This multidisciplinary thesis involved research in mesoscale dynamics, dispersion of pollutants in complex terrain, urban air quality, aerosol optical properties, and feedbacks between meteorology and aerosols. The most significant outcomes were:

- An improved understanding of regional the recirculation flows and layering in the Western Mediterranean Basin (*Pérez et al., 2004 AE*) and Saharan dust intrusions to the Mediterranean (*Pérez et al., 2006b JGR*).
- The determination of the mixing layer depth in a complex coastal area of the Western Mediterranean, its association to large mesoscale compensatory subsidence and thermal internal boundary-layer formation *(Sicard et al., 2005 BLM),* and its effects upon photochemical pollution *(Pérez et al., 2006 AE)* and aerosol levels *(Viana et al., 2005 AE).*
- The development of a dust-radiation interactive scheme within a regional atmosphere/dust model that allowed me to demonstrate for the first time that the inclusion of dust as a radiatively active substance in numerical weather prediction models could significantly improve short-term weather forecasts over dust affected areas (*Pérez et al., 2006a JGR*). **I highlighted this achievement in the previous section (achievement 1).**
- One of the practical applications of my Ph.D. results was the improvement of regional predictions of mineral dust in Northern Africa, Middle East and Europe with the DREAM model. I implemented and published daily online routine forecasts for the region (first time by a Spanish researcher) that started to be widely used by experimentalists to plan their experimental campaigns and understand their data, by air quality decision-makers to understand and quantify natural aerosol contributions in Southern Europe and by National Weather Services in North Africa and the Middle East.

During my PhD at the Laboratory of Environmental Modeling I participated in a number of European and National research projects (e.g., EARLINET, ACCENT, SAMUM I, IMMPACTE) and I performed a 4-month research visit at the Mediterranean Centre on Insular Coastal Dynamics in Malta, where I was mentored by Slobodan Nickovic, a pioneer in the numerical modeling of mineral dust. I also assisted as a lecturer in courses of Environmental Modeling and I acted as advisor of a Master thesis student at UPC.

Group Leader at the Barcelona Supercomputing Center (Spain) – 2006 - 2009

In 2006, the success and international visibility of my PhD results granted me a research position at the recently created Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS) in Spain. The BSC-CNS is today accredited with the Severo Ochoa Center of Excellence, an award given by the Spanish Ministry as recognition of leading research centers in Spain that are internationally known organizations in their respective areas. Although my intention was to apply for a postdoctoral position abroad, the offered research position provided an exciting research framework and the unique opportunity and means of creating my own research group on atmospheric mineral dust. During this period I obtained and successfully executed the DREAM project funded by the Ministry of Science and Technology as PI (130,000 Euro), and I participated in a number of national projects (e.g. CONSOLIDER, 5M Euro; CALIOPE, 1.2M Euro) and European projects funded by the 6th and 7th Framework Programme (e.g. MACC, EARLINET-ASOS). I acted as advisor of two PhD thesis (Sara Basart and Karsten Haustein), both of them covering topics related to atmospheric dust and obtaining the mark of Cum Laude. The chapters of these dissertations were published in different highly rated journals *(Basart et., 2009 ACP; Basart et al., 2012 ACP; Basart et al., 2012 Tellus B; Haustein et al., 2009 GRL; Haustein et al., 2012 ACP)*. I also supervised two technical assistants.

My work and leadership on mineral dust at the BSC-CNS led to an internationally recognized dust modeling group that attracted the attention several research and operational communities. In November 2007, I was the organizer of an International Workshop in Barcelona on sand and dust storm science, forecasting, observations and impacts, supported by the Group on Earth Observations (GEO) and the World Meteorological Organization (WMO). I was the editor of the proceedings derived from the workshop (*Pérez and Baldasano, 2009 IOP*). After that meeting I played a key role on the design and launching of the World Meteorological Organization (WMO) Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). I was a Member of the writing team of the Implementation Plan. The mission of the SDS-WAS is to enhance the ability of countries to deliver timely and quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership of research and operational communities. To achieve this mission, WMO designated Regional Nodes consisting of a network of research and operational partners that are supported and coordinated by a Regional Center. My contribution was key for the BSC-CNS and the Spanish Meteorological Agency (AEMET) to be designated as hosts of the WMO Regional Center for Northern Africa, Middle East and Europe (http://sds-was.aemet.es/). More recently, in view of the demand of many national meteorological services and the achievements of the SDS-WAS Regional Center, WMO designated the same consortium, formed by BSC-CNS and AEMET, to create in Barcelona the first Regional Specialized Meteorological Center with activity specialization on Atmospheric Sand and Dust Forecast, known as the Barcelona Dust Forecast Center (BDFC). The Center was created in February 2014 (http://dust.aemet.es/) and its mandate is to generate and distribute operational dust forecasts 365 days a year. The BSC-CNS is today uniquely positioned in the field, as it has managed to coordinate the efforts of multiple partners, allowing implementation of the only operational forecasting services for airborne dust fully recognized by WMO. The main European and international institutions involved in the observation and prediction of dust are among the partners of the Regional Center. Examples include EUMETSAT, ECMWF, NASA, NCEP and many National Meteorological Services. **I have highlighted this achievement in the previous section (achievement 3).**

During this period, I launched the development of a new chemical weather prediction system (NMMB/BSC-CTM). The NMMB/BSC-CTM is a multi-scale non-hydrostatic atmospheric chemistry and weather prediction system comprised of an atmospheric model (the Non-Hydrostatic Multi-scale Model, NMMB) developed at NOAA/NCEP and a Chemical Transport Model (BSC-CTM) that I conceived and that is further developed today by the Atmospheric Composition Group of the BSC-CNS in close collaboration with NOAA/NCEP and other partners, including the NASA Goddard Institute for Space Studies (NASA GISS), the University of California, Irvine (UCI), and NOAA/GFDL. I started with the development of the interactive aerosol component, including parameterizations for dust emission, source region identification, wet and dry deposition and radiative interaction (*Pérez et al., 2011 ACP; Haustein et al., 2012 ACP*), while designing the strategy towards the implementation of a fully interactive chemistry-aerosol model. Thereafter, during my period as research scientist in the US (2009-2015), I contributed to the development of the gas-phase chemistry in the model (e.g. *Jorba et al, 2012 JGR*) and guided the development and study of other global aerosols (*Spada et al., 2013 ACP; 2015 AE)*. As for today, the NMMB/BSC-CTM includes seven types of tropospheric aerosols: sea salt, dust, black carbon, organic matter (both primary and secondary, sulfate, nitrate and volcanic ash. The model also includes detailed gas-phase chemistry with 51 chemical species and 156 reactions. This state-of-the-art model is designed to be efficient, flexible, and extendible. It contains advanced physics, chemistry and aerosol packages, and has the unique ability to be configured as a global model or as a very high-resolution regional model, both with embedded 1- or 2-way static or moving nests, while allowing feedbacks between chemistry and meteorology. The system is currently operated at the BSC-CNS, participates in several international model intercomparison initiatives (e.g., AQMEII-Phase 2, ICAP, Charmex), and is used in research projects at NASA, NOAA/NCEP and NOAA/GFDL. The dust component produces forecasts at the SDS-WAS Regional Center for a regional domain comprising Northern Africa, Middle East and Europe, where it is combined with other dust model forecasts from top collaborating institutions (ECMWF, SEEVCC, Met Office, NASA, NCEP, EMA and CNR) and evaluated in near-real time. The model also runs operationally (7 days a week, 365 days a year) at the BDFC with a horizontal resolution of 10 km for the same region. These forecasts are widely used by the international scientific community, weather services, companies and air quality managers. At the global scale, the model contributes to the International Cooperative for Aerosol Prediction (ICAP) Multi Model Ensemble (*Sessions et al., 2014*), which is built from the following systems in addition to the NMMB/BSC-CTM: ECMWF MACC, JMA MASINGAR, NASA GSFC/GMAO, FNMOC/NRL NAAPS, NOAA NGAC, and Met Office Unified Model. **I have highlighted this achievement in the previous section (achievement 2).**

Other activities during this period include:

- My contributions to CALIOPE, the operational air quality forecasting system for Europe, Iberian Peninsula, Balearic Islands and Canary Islands at the BSC-CNS *(e.g. Jimérez-Guerrero et al. 2008 GRL, Baldasano et al., 2008 ASR),* and integrates the HERMES emission model, WRF-ARW meteorological model, BSC-DREAM8b model, and CMAQ chemical transport model.
- My collaboration with German experimentalists to investigate the impact of aged Saharan dust on heterogeneous ice formation *(Seifert et al., 2010 JGR),* which showed a significantly higher amount of ice-containing clouds (25%–30% more) for cloud top temperatures from −10°C to −20°C in air masses that contained mineral dust.

In 2007, I was invited as a dust expert by the World Meteorological Organization (WHO) to a workshop funded by the Group on Earth Observations (GEO) on Meningitis and Climate at John Knox Centre, Geneva. This was, in effect, the inaugural meeting of what has become the Meningitis Environmental Risk Information Technologies (MERIT) initiative. The MERIT initiative led by WHO was launched as a multi-sectoral partnership to provide a platform for enabling health specialists (public health specialists, epidemiologists, immunologists, microbiologists, demographers, etc.) and climate and environment specialists to work together to help solve a pressing health problem. The main objective was to address meningococcal meningitis epidemics in Africa in the context of perceived environmental, biological, economic and demographic influences. At the time, as a member of the SDS-WAS Steering committee I was seeking to identify opportunities for using new scientific and technical advances in aerosol early warning in the health sector. Since then I have developed an interest on epidemiology, and in particular, on understanding the complex interactions between environment/climate and infectious disease through mathematical modeling. This was one of the reasons I joined the Earth Institute at Columbia University in 2009 as I explain below.

Visiting Scientist at NOAA/National Centers for Environmental Prediction, Camp Springs (US) - 2009

In 2009 I obtained a mobility grant “José Castillejo” of the Spanish Ministry of Science and Innovation for a 4-month visit to NOAA/NCEP Environmental Modeling Center (EMC) in Camp Springs, Maryland. I was invited by Zavisa Janjic, who recently received the 57th IMO prize (one of the most prestigious international scientific awards in atmospheric physics) in recognition of his outstanding life-long contributions to the advancement of theory and practice of atmospheric modeling and numerical weather prediction, and, in particular, for the development of generations of atmospheric models based on his innovative numerical and parameterization schemes that have been used for research and weather forecasting all over the world inspiring the work of many scientists and producing forecasts reaching millions of users. My visit was related to our ongoing collaboration on the development of the NMMB/BSC-CTM model, particularly on the coupling between radiation, clouds and aerosols and their effect upon medium range global weather forecasts. Together, we developed a new type of convective aerosol mixing scheme based on the Betts-Miller-Janjic cloud parameterization scheme (included in *Pérez et al., 2011 ACP*) and I implemented a new radiation scheme (RRTM) into the NMMB model and its coupling with clouds and aerosols. This development increased the skills of medium range global weather forecasts of the NMMB. I also promoted an institutional Memorandum of Understanding between NOAA/NCEP/EMC and BSC-CNS for the development of the NMMB/BSC-CTM model that is on-going as of today. My developments at NCEP have been integrated in the operational weather forecasting model for North America. I also was an invited speaker at workshops and seminars at NOAA and NASA GSFC.

Fellow at the Earth Institute (Columbia University), NASA Goddard Institute for Space Studies and International Research Institute for Climate and Society, New York (US) – 2009 - 2011

In 2009 I was awarded with the highly competitive Earth Institute Fellowship. I moved to the US motivated by my growing interest on dust processes and effects at longer time scales and, more importantly, by my drive to break traditional research boundaries to understand and address the poorly studied dust impacts upon society. To tackle these objectives, I had the chance to join the NASA GISS, a major player in climate modelling and projections, and the International Research Institute for Climate and Society (IRI), a world-leader on enhancing society's capability to understand, anticipate and manage the impacts of climate and environment to improve human welfare, especially in developing countries.

(I note that from New York I kept a close collaboration with the BSC-CNS, advising my PhD students, co-developing the NMMB/BSC-CTM model and promoting scientific exchange between Spain and the US.)

As a fellow of the Earth Institute, I combined my core aerosol research with increased efforts to unravel the effects of dust and climate conditions upon meningitis epidemics in the Sahel, which is one of the most feared dry-season infectious diseases because of its rapid onset, high fatality rates and induced long-term disabilities. Vaccines for many strains of meningitis typically provide immunity for only two to three years. Given that meningitis public health measures in the Sahel, such as reactive vaccination, would benefit from prediction tools, I examined the potential of models of seasonal meningitis incidence based on climate and dust information. I became familiar with the main aspects of the epidemiology of infectious diseases and I led a cross-disciplinary community involving the World Health Organization (WHO) to create a meningitis incidence model based on climate, dust, population data, and proxies for immunological state or susceptibility. Given the lack of reliable and continuous dust data in the Sahel I also produced the first long-term regional dust model climatology in Northern Africa with the NMMB/BSC-CTM model that I had previously developed. Using a range of negative binomial generalized linear models fitted to meningitis data I showed the potential of climate and dust information in the early dry season to explain part of the variability of the disease at seasonal and district scales. A paper showing these achievements was published in a high-impact journal *(Pérez García-Pando et al., 2014a EHP*), which represents the first contribution of its kind. I also published a review paper on the subject *(Pérez García-Pando et al., 2014b EP)* where I critically review recent research and practice seeking to provide useful information for the epidemic response strategy of National Ministries of Health in the Meningitis Belt of Africa. The novelty of my research led to invitations as a speaker at the workshop "*Next Generation Modeling: Climate, Weather and Infectious Disease*" organized at Princeton University by the NIH Fogarty International Center Research and Policy for Infectious Disease Dynamics (RAPIDD) program, and the *"Conference on Human Health in the Face of Climate Change: Science, Medicine, and Adaptation"* organized by the "la Caixa" Foundation, BIOCAT, and the New York Academy of Sciences in Barcelona. My work on aerosol-infectious disease interactions has been highlighted by NASA, the Earth Institute, Columbia University and ECMWF, and has been covered by specialized media (e.g. *Astrobiology Magazine, Scidev.net, EarthZine, Phys.org*) and international mass media (e.g. *The Guardian, Voice of America)*. **I have highlighted this achievement in the previous section (achievement 5).**

Associate Research Scientist and PI at the NASA Goddard Institute for Space Studies and the Department of Applied Physics and Applied Mathematics, Columbia University, New York (US) – 2011 - present

In 2011 I became Associate Research Scientist at the Department of Applied Physics and Applied Math at Columbia University and the NASA Goddard Institute for Space Studies.

I obtained a multi-institutional collaborative project involving Columbia University, NASA GISS and Cornell University funded by the Department of Energy (DoE) for which I acted as Project Director and Institutional PI (700K Euro) (Co-Pi, Natalie Mahowald from Cornell University) and whose objective is to improve our understanding of the atmospheric iron cycle and its impact upon the carbon cycle. Because the ocean currently absorbs about one-third of the CO_2 emitted by human activity, it is crucial to understand how ocean uptake of CO_2 will be modified during this century. The supply of soluble iron to the oceans is fundamental to oceanic primary production and CO_2 uptake. Iron deposition has the largest effect in high-nutrient low chlorophyll (HNLC) areas that comprise approximately 30% of the world's oceans. The vast majority of the global ocean, including the HNLC areas, is dependent on wind-transported atmospheric dust as a source of iron and the largest deposition of iron occurs downwind of the main deserts of the globe (including North Africa, Asia, the Middle East, Australia, and Patagonia).

Because the iron content in dust particles depends upon mineral types, me and my team recently proposed novel approaches to represent the emission and global distribution of mineral aggregates, which were tested within the NASA GISS Earth System ModelE against a new global compilation of observations (*Perlwitz et al., 2015a ACP, 2015b ACP; Pérez García-Pando et al. 2014, 2015 AGU*). Constraining the size-resolved composition of dust aerosols is complicated. The composition of the emitted dust resembles to some degree that of the parent soil. Yet, soil mineral grains and aggregates fragment during emission through saltation and sandblasting on the soil bed, which generates differences in the size distribution and mineral fractions between the parent soil and the emitted dust aerosols. In addition, global atlases only provide coarse estimates of soil texture and mineral composition that are extrapolated from the analysis of a limited amount of soil samples after wet sieving, a technique that breaks the aggregates encountered in natural undisturbed soils. Our novel methods have remedied some important deficiencies of previous implementations in comparison to observations. Yet, substantial uncertainty remains in evaluating models and the soil databases due to the limited number of size-resolved measurements of mineral content that sparsely sample aerosols downwind of the major dust sources. For this work I gave invited talks at international conferences (e.g. AGU). Also my leadership in this area of knowledge led to my participation in a project proposal named "EMIT", recently submitted to the NASA Earth Venture Instrument-3 (EVI-3) program, whose team includes researchers from JPL, NASA GISS, NOAA GFDL and Cornell University. With a 30M Euro budget, the project would directly measure the surface mineral composition at very high resolution (~100m) by using imaging spectroscopy from the International Space Station, whose orbit provides ideal coverage for the dust source regions of the Earth. If the proposal is successful, the data provided by the new instrument would provide a more than a 10^5 improvement in resolution over the current mineral dust source composition estimates derived from global soil maps. **I have highlighted this achievement in the previous section (achievement 4).**

Together my NASA GISS colleagues I have contributed to further understanding of the mechanisms by which dust affects global and regional climate (*Miller et al., 2014a*). I am also a Co-PI (PI is Ron Miller from NASA/GISS) of a project funded by NASA MAP program ($950K Euro) entitled *"Contribution to Radiative Forcing and Climate By Anthropogenic Sources of Soil Dust Aerosol"* that intends to quantify the contribution to radiative forcing and climate by anthropogenic sources of dust aerosol. Calculations of radiative forcing since the pre-industrial era generally include the effect of anthropogenic aerosols except for the contribution by dust aerosols. This omission is partly because the changing dust burden due to anthropogenic trends in the circulation are estimated to be small, but also because little is known about historical changes in dust sources due to human activities like cultivation and grazing as well as natural source changes due to drought. Currently we are calculating rainfall responses to anthropogenic dust forcing for the present-day focusing in regions with extensive anthropogenic sources (like the Asian monsoon region or Australia) or societally important regions like the Sahel (*Miller et al., 2014b*).

I am also Co-PI (PI is Paul Ginoux from NOAA/GFDL) of the project entitled "*Implementation and testing of regional and global dust forecasting"* funded by the NOAA's R2O Initiative for the Next Generation Global Prediction System (NGGPS) (185K Euro). The project aims at developing NOAA NCEP dust prediction capabilities in North America using the NMMB/BSC-CTM. We are currently evaluating and refining a new global-scale high-resolution mapping of dust sources and parameters for dust emission based on high-resolution satellite retrievals based on MODIS satellite data. The new source map combines MODIS data with land use databases to distinguish between natural and anthropogenic (primarily agricultural) dust sources including ephemeral water bodies. Over most natural sources vegetation is sparse, the soil is dry, and the surface winds are strong, frequently exceeding the threshold velocity of wind erosion. However, this is not true in agricultural sources of dust, which are covered by crops (or litters after harvesting), and are located in moist areas or subject to irrigation. I am working to constrain the threshold wind speed using the new dust source frequency map and available information on global soil and surface characteristics, including vegetation cover, soil texture, soil moisture and aeolian roughness length. These novel approaches are expected to produce a major advance on the representation of present-day natural and anthropogenic dust sources and emission in the NMMB/BSC-CTM and other dust models.

Other activities and achievements during this period include:

- Co-mentoring of a Postdoctoral Research Scientist (Adrien Deroubaix at GFDL) and co-supervision of a PhD student (Michele Spada at the BSC-CNS) and a Master student (Yang Liu at Columbia University).
- I was invited as contributing author of the assessment report *"The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment"* in the US (http://www.globalchange.gov/health-assessment). This report was developed by USGCRP's Interagency Group on Climate Change and Human Health as part of the sustained National Climate Assessment and as called for under the President Obama Climate Action Plan. This assessment report is intended to present a comprehensive, evidence-based, and, where possible, quantitative estimation of observed and projected public health impacts related to climate change in the United States. The final version is expected to be released early 2006 and will provide needed context for understanding Americans' changing health risks.
- I co-authored the paper "CMIP5 historical simulations (1850-2012) with GISS ModelE2" by *Miller et al. (2014c JAMES)*. The paper reports on the NASA GISS modeling contribution to the Coupled Model Intercomparison Project Phase 5 (CMIP5) that was used to prepare the IPCC Fifth Assessment Report. The paper was selected "Best Publication of 2014" at the NASA Goddard Institute for Space Studies.
- My work on meningitis obtained the "Best Science Brief of 2014" at the NASA Goddard Institute for Space Studies for: "Climate Conditions Help Forecast Meningitis Outbreaks" (http://www.giss.nasa.gov/research/features/201403_perez/)

Future

In October 2015 I was awarded with the prestigious and highly competitive AXA Chair to develop my research at the BSC-CNS, starting in October 2016. The AXA Chair scheme is intended to support a significant step change in the development of a research area by supporting a world-class researcher coming from another Institution to the host Institution (in this case the BSC-CNS) to contribute in a distinctive way to the development of that research area in line with the Institution's long-term strategy. The AXA contribution is provided in the form of an endowment that amounts 1.8M Euro over 15 years. I will use the endowment to support a research group and implement an ambitious and long-term research program on mineral dust and sand and dust storms.

My research program reflects my unifying and cross-disciplinary vision of the field as well as my journey as a scientist over the last years. The BSC-CNS hosts two Regional Centers of the World Meteorological Organization (WMO) on Sand and Dust Storms and the Earth Sciences Department has recently merged the original atmospheric composition research group with one of the most important European research groups on climate prediction and services under the direction of Francisco Doblas-Reyes. This framework provides a unique potential to integrate innovative sand and dust storm research and prediction at multiple time scales with the much-needed implementation of dust risk assessment and mitigation strategies, particularly in some of the less developed countries in the world. The goals and focus areas, and their interactions within my research program are shown in Figure 1. The program will improve dust models by expanding our understanding of dust emission, transport and variability at multiple times scales (Goal 1). This will allow quantifying dust effects upon weather, climate, atmospheric chemistry and ocean biogeochemistry (Goal 2), and developing skillful short- and medium-range dust forecasts and long-range dust predictions and projections (Goal 3). The Chair program will also focus on assessing dust impacts upon key sectors of society and economy (health, agriculture, solar energy and transportation) (Goal 4), and promote capacity building, technology transfer, dissemination and public engagement (Goal 5).

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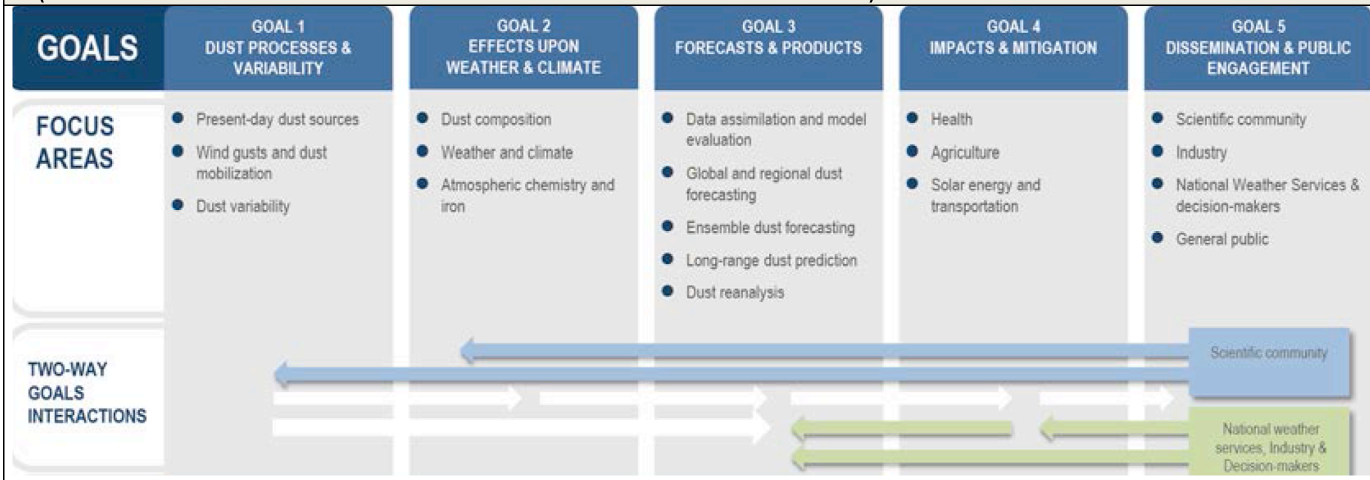

Figure 1: Goals and focus areas of my research program on atmospheric mineral dust.

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