



DOCUMENTOS CONGRESUALES

Climate Change Perspectives from the Atlantic:

Past, Present and Future

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Climate Change
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EDITED BY

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SERVICIO DE PUBLICACIONES
UNIVERSIDAD DE LA LAGUNA, 2013

CLIMATE change perspectives from the Atlantic : past, present and future / Edited by José María Fernández-Palacios ... [et al.]. – 1ª ed. – La Laguna : Servicio de Publicaciones, Universidad de La Laguna, 2013. – 727 p. : il. col. ; 24 cm. – (Documentos congresuales ; 33)

Bibliografía por cap.

D.L. TF 911-2013. – ISBN 978-84-15910-54-1

1. Climatología-Cambios-Atlántico(Región) 2. Climatología-Cambios-Aspectos ambientales I. Fernández-Palacios, José María (1958-), (ed.) II. Universidad de La Laguna. Servicio de Publicaciones III. Serie

551.583

Colección:

DOCUMENTOS CONGRESUALES/33

Edita:

Servicio de Publicaciones

UNIVERSIDAD DE LA LAGUNA

Campus Central

38200 La Laguna. Santa Cruz de Tenerife

Teléfono: 34922 31 91 98

Diseño Editorial:

Jaime H. Vera

Javier Torres. Cristóbal Ruiz

1ª Edición 2013

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Maquetación y preimpresión:

SERVICIO DE PUBLICACIONES

Impresión:

FABRICACIÓN CANARIA DEL DISCO, S.L.

I.S.B.N.: 978-84-15910-54-1

Depósito Legal: TF 911-2013

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FOREWORD

Two major challenges are faced by Mankind on the 21st century: human beings' health, in a broad sense —from disease to poverty—, and, the health of the planet —from the more specific problem, such as waste management, to the more general, such as global warming. Mankind attempts to manage them with a single tool: science.

The Tri-continental Atlantic Campus, Regional Campus of International Excellence «CEI Canarias» (Canary Islands CIE) has given us the opportunity to approach both challenges. This book records what is possibly most significant for future generations: the health of the planet. Approaching this problem from a region such as the Canary Islands —a paradigm of biodiversity— teaches us all what we will lose, what we must not neglect, and what we have to preserve.

Talking about the economic crisis —with the fall of the countries that we have witnessed during this decade—, talking about a humanitarian crisis —with the terrible tragedies that immigration or wars show us day after day—, and not getting all to talk at once about planetary crisis —with regards to what we are doing to our living environment— is a sign of selfishness that we cannot afford. Only relying on science can save us, because saving the future for our offspring will be our own salvation.

This book is a compendium of science. A present full of knowledge, generated by Mankind to help us; with a look at the present moment, back and forth in time, a look at what we were —and what we can become— if we don't pay attention to science. I highly value as an achievement being able to offer such a large and varied range of reflections —at a time when economy, social differences and politics seems to be the only thing that citizens are interested on.

The year 2012 was a hive of ideas for the Canary Islands CIE. The Canary Islands draw the attention of scientists between October and November. For a time, they met with the idea of looking at the sky, land and sea, and wonder what is happening, why happened and what will happen. In addition, what pleases scientists best: to share knowledge and experience.

Sitting all scientists who attended these three workshops in the same room meant, for the author of these lines, a pleasure that makes up for everything that's bad with academic administration. Having the opportunity to help science grow is a luxury available to few: from the land where one had the privilege to be born, where we want our offspring to live, and where future generations require us to

act with prudence and responsibility. This wonderful land does not deserve what we are doing to her.

I hope, and that's also my wish, that the result of these meetings—gathered in this volume— will provide the reader with enough satisfaction to meet their expectations, their thirst for knowledge and will open the door to find out more.

Finally, I cannot fail to mention the work of the editors. I greatly appreciate their effort to organize these workshops; to be able to combine interests of scientists from all continents; to concentrate in this Atlantic garden so much talent and passion for science—and make it accessible to the entire scientific community through this publication. It was an honour to support these projects from the beginning, to let me present them, to welcome all participants, and now, to author these forewords.

Rodrigo TRUJILLO GONZÁLEZ
Vice-chancellor of Internationalization and Excellence
Universidad de La Laguna
November, 2013

INTRODUCTION

Within the framework of the *Campus de Excelencia Internacional* (CEI), an award given by the Spanish Education Ministry to the University of La Laguna (Tenerife, Spain) for the period 2010–2012, the Atlantic Centre of Environmental and Climate Change Research [*Centro de Investigaciones Medio Ambientales y del Cambio Climático del Atlántico (CIMACCA)*] was launched. Among other activities, in autumn 2012, three different scientific workshops dealing, respectively, with the past, present and future impacts of climate change took place.

WORKSHOP I: PERSPECTIVES FROM THE PAST

This workshop, entitled «First Macaronesian Palaeoclimate Workshop», organized by the Island Ecology and Biogeography Group of the University of La Laguna took place between the 24th and 27th of October 2012. It was held in a charming venue; the historical building that houses the Vice-Rector's Office for Internationalization and Excellence of the University of La Laguna in *Poeta Viana* street, in the centre of this UNESCO World Heritage city. The main goal of this Workshop was to get together to facilitate contacts and promote discussion among scientists and researchers, who although involved in different lines of research, all have a common interest in the reconstruction of the ancient (i.e., the Last Glaciation Cycle, from 130 ka to the Holocene) climate of the Macaronesian Biogeographical Region *sensu lato*, including the oceanic archipelagos of Azores, Madeira, the Canary Islands and Cape Verde, as well as the Western Mediterranean Area (Iberian Peninsula and North Africa).

We managed to bring together some 30 researchers from different institutions and countries (Australia, Belgium, France, Germany, Portugal, Spain, Netherlands, and United Kingdom) with research profiles that included palaeoecologists, geomorphologists, palaeontologists, palaeoclimatologists, palaeobiogeographers, etc. This yielded a very multi- and trans-disciplinary workshop, specially designed for the discussion among specialists about the ancient climate of the North Eastern Atlantic Region.

The workshop was scheduled over three days (plus post-workshop excursion). Half the time was used for presentations of research works that we include in this book. The second half of the workshop was used for the discussion of

several questions regarding our current knowledge, certainties and uncertainties, and especially our lack of knowledge regarding the Macaronesian palaeoclimate. These topics were selected by all the participants following a participatory appraisal methodology (de Nascimento *et al.*, 2013).

The presentations dealt with either the whole Macaronesian realm (Hooghiemstra *et al.*, 2013; Rijdsdijk *et al.*, 2013) or with palaeoevidence extracted from different individual islands of specific archipelagos, such as Santa María (Ávila, 2013), and Pico and Flores (Connor *et al.*, 2013) in the Azores; La Palma (Rubiales *et al.*, 2013), La Gomera and Tenerife (Nogué *et al.*, 2013), Fuerteventura and Lanzarote (Criado *et al.*, 2013; von Suchodoletz *et al.*, 2013; Yanes *et al.*, 2013) in the Canary Islands, or finally Sal (Cabero *et al.*, 2013) in Cape Verde. In addition, other palaeoevidence from mainland territories off Macaronesia, such as the Atlas Chain in Morocco (Cheddadi, 2013) or the Western Mediterranean Alborán Sea Basin (Martínez-Ruiz *et al.*, 2013) were presented.

In these contributions, different proxies that may shed light on the reconstruction of the Last Glaciation Cycle's palaeoclimate in the Macaronesian realm were used, including fossil pollen assemblages (Cheddadi, 2013; Connor *et al.*, 2013; Hooghiemstra *et al.*, 2013; Nogué *et al.*, 2013), woody macrofossils (Rubiales *et al.*, 2013), palaeosoils and palaeodunes stratigraphy (Criado *et al.*, 2013; von Suchodoletz *et al.*, 2013), marine (Ávila, 2013; Cabero *et al.*, 2013) or terrestrial fossils (Yanes *et al.*, 2013) gastropods assemblages, archipelagos geographic configuration hindcasting models (Rijdsdijk *et al.*, 2013) or the geochemical composition of submarine sediments (Martínez-Ruiz *et al.*, 2013).

In relation to the temporal framework, several of the contributions focused on the entire Last Glaciation Cycle (Ávila, 2013; Cabero *et al.*, 2013; Martínez-Ruiz *et al.*, 2013; Rijdsdijk *et al.*, 2013; von Suchodoletz *et al.*, 2013; Yanes *et al.*, 2013); whereas others referred exclusively to the Holocene climatic variation (Cheddadi, 2013; Connor *et al.*, 2013; Hooghiemstra *et al.*, 2013; Nogué *et al.*, 2013; Rubiales *et al.*, 2013) or even to historical times (Criado *et al.*, 2013).

Finally, two additional and very interesting presentations were also part of the scientific content in this workshop, the first of them by Kathy J. Willis (University of Oxford) was the introductory presentation, entitled, «Biodiversity futures: Scenario setting for Africa using lessons from the past» and a further contribution by Francisco la Roche and Carolina Castillo (University of La Laguna) entitled, «Environmental meaning of the faunistic changes detected in the Quaternary of the Canary Islands».

One of the main goals of the organizers of this First Macaronesian Palaeoclimate Workshop was to launch a scientific initiative that would have continuity in the near future. We hope this will become a reality within the next few years!

WORKSHOP II: PERSPECTIVES IN THE PRESENT

This workshop focused on how climate change processes are currently affecting marine ecosystems and was entitled, «Responses of Key Sea Urchin Populations to Climate Change Processes: From Larvae to Ecosystems». This international meeting was organized by the Biodiversity, Marine Ecology and Conservation Research Group of the University of La Laguna and was held in the Canary Islands from 14th to 18th November 2012. The organizing committee came up with a dynamic venue consisting of a two-day meeting held at the University of La Laguna (conference rooms at the Faculty of Physics) on the island of Tenerife, followed by a two-day trip to El Hierro island (Restingolita Museum conference room, La Restinga). Activities included plenary conferences, short presentations, field trips and post-presentation discussions. In order to assess such a broad subject as the effects of climate change processes on marine ecosystems, we focused on recent knowledge about the influence of climate-related variables on the dynamics of habitat modifier species in coastal environments. Given that sea urchin-generated barren grounds are a global phenomenon of general concern for the conservation of marine ecosystems and their services worldwide, the main goal of the workshop was to bring together researchers working on different issues of the influence of environmental change on the biology and ecology of these key species.

Since the very first announcement of this workshop, it attracted the attention of both the national and international research communities in the field. The event brought together 34 researchers from 15 research institutions from all around the world (Australia, Canada, Japan, Mexico, Norway, Panama, Puerto Rico, Sweden, Spain and USA). These researchers had a wide area of expertise ranging from the impact of global changes on sea urchin larval ecophysiology (Dupont and Thorndyke, 2013) to ecosystem dynamics (Hernández *et al.*, 2013). It also included the assessment of baseline data of how populations change in response to natural and anthropogenic causes (Ebert, 2013) on the basis of both long-term data on population parameters and genetic diversity of populations (Lessios, 2013); causes and consequences of recurrent mass mortality events (Scheibling *et al.*, 2013); geographical range expansions (Ling, 2013); as well as forces acting on different temporal scales that drive changes in urchin populations in highly conserved marine protected areas (Hereu *et al.*, 2013). It is also worth highlighting the participation of about 20 undergraduate students from the University of La Laguna, who registered for the event and attended the conference.

The workshop was structured into six plenary talks from invited speakers plus one video-conference (thanks to the technical assistance of ULL-media department), all of them are included as full papers in this book, followed by eight short oral communications, which we are presenting as abstracts. The rest of the workshop was devoted to two field trips, where participants had the opportunity to dive both at an urchin barren off the coast of Tenerife and at an algae-dominated system at El Hierro island. Field trips provided a quick view of how marine

ecosystems work in the eastern Atlantic Islands (Canary Islands) and facilitated discussion about general patterns of the functioning of these alternative states in benthic ecosystems and common processes with other regions worldwide. The workshop in El Hierro ended with a general discussion on the main conclusions and with the commitment of writing an opinion paper about them. An early result of this workshop is the publication of some of the field data regarding catastrophic changes in temperate benthic communities (urchin barrens *vs.* macroalgae stands) as an invited paper that will be published in the journal *Philosophical Transaction of the Royal Society B: Biological Sciences* during this year (Ling *et al.*, 2014).

Plenary talks dealt with populations of several sea urchin species and the influence of climate change on several aspects of their dynamics: population fluctuations of *Strongylocentrotus droebachiensis* on the east coast of North America (Scheibling *et al.*, 2013); *Strongylocentrotus purpuratus* on the west coast of North America (Ebert, 2013); *Paracentrotus lividus* and *Arbacia lixula* in the Mediterranean (Hereu *et al.*, 2013); *Centrostephanus rodgersii* in Tasmania (Ling, 2013); *Diadema africanum* in the Canary Islands (Hernández *et al.*, 2013) and other sea urchin species (Lessios, 2013). Short presentations focused on several specific topics such as the effect of sea water warming on sea urchin recruitment in the north-eastern Atlantic Ocean (Fagerli *et al.*, 2013), the effect of different climatic events on population fluctuations of *Strongylocentrotus nudus* in Japan (Fujita, 2013), phylogeographic and past demographic patterns of *Arbacia lixula* in the Mediterranean Sea (Wangensteen *et al.*, 2013), recent sea urchin diseases in the eastern Atlantic Archipelagos (Lorenzo-Morales, 2013), as well as effects of ocean acidification and warming on *Paracentrotus lividus* fertilization and larvae development at its southernmost limit of distribution in the Canary Islands (García *et al.*, 2013). Finally, a special session of the workshop was devoted to the effects of the recent underwater volcanic eruption in El Hierro as examples of natural experiments to elucidate the effects of global change on benthic assemblages (Haroun *et al.*, 2013; Clemente *et al.*, 2013; Navarro *et al.*, 2013).

The general aim of all contributions was to collect existing data and evidence about the nature of fluctuations in sea urchin dynamics that drive alternative community states in marine systems, and to elucidate whether current knowledge permits any predictions regarding the future of echinoid populations under the current ocean global change scenario.

We hope everyone enjoyed the workshop «Responses of Key Sea Urchin Populations to Climate Change Processes: From Larvae to Ecosystems» as well as its compendium of proceedings, which included a fascinating foreword by Dr. J.M. Lawrence (Department of Integrative Biology, University of South Florida). We also hope this initiative provides a forum for critical reflection on the effects of climate change processes on benthic ecosystems for future actions.

WORKSHOP III: PERSPECTIVES FOR THE FUTURE

Finally, the third workshop, focusing on the regional modelling of the climate change and entitled «First CORDEX-WRF Workshop and CORWES/WRF4G hands-on tutorial», was organized by the Group of Observation of Earth and Atmosphere (GOTA, University of La Laguna), Santander Meteorological Group (University of Cantabria) and Group of Regional Modelling of Atmosphere (University of Murcia). The workshop and the tutorial took place in the School of Computer Science, University of La Laguna, from 1st to 5th October 2012. This meeting was organized in close collaboration with the research projects «Coordinated regional climate downscaling experiment using WRF: a contribution to the CORDEX initiative by the Spanish WRF community» and «High resolution climate regionalization and aerobiological analysis for the Canary Islands» (projects funded by the Spanish Ministry of Economy and Competitiveness, ref: CGL2010-21366-C04-01/CLI and CGL2010-22158-C02, respectively). The Insular Government of the Island of Tenerife also collaborated in the development of this event.

The conference consisted of two different parts. The first (1st-3rd October) was devoted to a review of the status and main issues of regional climate modelling using WRF. It included both invited and contributed papers, and aimed to foster open discussions in a friendly environment. The second segment (4th-5th October) consisted of hands-on laboratory sessions for training in WRF management frameworks, such as WRF for GRID (WRF4G), WRF code modifications for regional climate purposes like Climate WRF (CLWRF) and post-processing tools.

The main goal of the workshop was to bring together scientists using the WRF model in the CORDEX initiative or, more generally, using it as a dynamical downscaling tool in climate modelling. At all times, knowledge transfer and coordination among research groups using WRF was encouraged, both through presentations and a social program. The main task was to produce a rigorous state-of-the-knowledge framework to improve the coordination of the different efforts for every CORDEX region and engage in collaboration. The following aspects were highlighted:

- Current state of the simulations in the different regions
- Coordination needs
- State of database
- Common problems to be addressed and future plans
- Tools and data to be shared
- Synergies between different user communities: modelling, impacts, policymakers...

The program sessions were organized following the Coordinated Regional Climate Downscaling Experiment (CORDEX) regions. Keynote speakers presented either the main results of their own research or a review of recent results.

The efforts of coordination of the CORDEX-Africa community and the preliminary results were presented by Chris Lennard (Lennard *et al.*, 2013), with special emphasis on analysing CORDEX data for integration into community impacts. The use of WRF-ARW to simulate an extreme case that occurred in January 2002 on the Africa western coast, causing huge damage in Senegal and Mauritania, was presented by A. Sarr (Sarr, 2013). The discussion on current problems with modelling clouds was also a key point. Comparisons, in the Africa-CORDEX domain, between cloud cover data obtained from ISCCP and CRU databases, reanalysis of NCEP/DOE AMIP-II, ERA-40 and ERA-Interim data, and different simulation results from global climate models included in the Coupled Model Intercomparison Project Phase 5 (CMIP5) were presented by the Group of Observation of Atmospheres and Earth (GOTA) of the University of La Laguna (Pérez *et al.*, 2013).

Applications of dynamical downscaling to topographically complex archipelagos were discussed by Yuqing Wang, who talked about the configuration of the Weather Research and Forecasting model as a dynamical downscaling tool for the Hawaiian region and presented an evaluation of the model's performance based on a continuous ten-year simulation forced by observed boundary conditions with 3-km horizontal grid spacing (Wang *et al.*, 2013).

Lluis Fita presented the initiative, NSW/ACT Regional Climate Modelling project, which aims to provide a comprehensive dynamically downscaled climate dataset for the CORDEX-Austral Asia region at 50km, and South-East Australia at a resolution of 10km. These data will be used by governments to design their climate change adaptation plans (Fita *et al.*, 2013).

The situation in the CORDEX initiative in South America was presented by Silvina A. Solman, who summarized the progress achieved over the last decade on regional climate modelling activities over South America. The remaining challenges in modelling South American climate features were also discussed (Solman, 2013).

The situation for the Coordinated Downscaling Experiment in Europe (EURO-CORDEX) was presented by Kirsten Warrach-Sagi, who showed the results of an ensemble of regional climate model simulations at spatial resolutions of 0.11°, 0.22° and 0.44°, completed in 2012 (Kirsten *et al.*, 2013). The development of the project named EC-EARTH (see <http://eearth.knmi.nl>) and the applications over Ireland to provide dynamically downscaled RCM output data for use in other disciplines such as biodiversity mapping, forestry pest and disease control, water resource management, etc., was presented by R.F. Teck (Teck and Sweetney, 2013). Results from the hindcast simulation 1990–2008 performed with the WRF3.3.1 model within the framework of the EURO-CORDEX initiative and the comparison with the E-OBS observational dataset for two key climatic variables, 2m temperature and precipitation were discussed by E. Katragkou (Katragkou *et al.*, 2013). Dynamical downscaling simulations using the PRECIS (Providing Regional Climates for Impact Studies) regional climate model, based on the United

Kingdom (UK) Met Office Hadley Centre HadRM3P model for the 20th and 21st centuries, in the eastern Mediterranean and the Middle East regions were also discussed (Zittis *et al.*, 2013)

Other activities, connected with the above presentations, were the discussion sessions for the coordination of the different CORDEX domains and the definition of strategies to solve previously detected common problems as well as the definition of a matrix of configurations, access to the GCM data, validations datasets, post-processing tools, etc.

In conclusion, we wish to thank all those who attended this event and that the presentations and contacts you made will be of value to you. We hope you have fond memories of these workshops, and consider that they were fruitful both personally as well as professionally. Finally, for the readers of this book, we sincerely hope you find its contents interesting.

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