Institution: Imperial College London		
Unit of Assessment: 9 – Physics		
Title of case study: B9-8 Climate Change Risk Assessment for the Government of Cyprus		
Period when the underpinning research was undertaken: From July 2015 to April 2016		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr Apostolos Voulgarakis	**Role(s) (e.g. job title):** Reader in Atmospheric Physics	**Period(s) employed by submitting HEI:** July 2012-present
Period when the claimed impact occurred: 2017 - 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

As a result of Dr. Voulgarakis' extensive body of work on global and regional climate physics and science, he was invited to be the lead climate expert for the first ever Climate Change Risk Assessment for the Government of Cyprus. He provided information regarding atmospheric physics and regional climate change which was subsequently used by impact scientists (experts on agriculture, biodiversity, built environment, business, energy, forestry, natural disasters, health, fisheries, transport, and water resources) to provide a complete risk assessment on the effects of climate change in Cyprus.

Following on from the risk assessment, Dr Voulgarakis' research provided the evidence that directly informed the first National Strategy for Adaptation to Climate Change which was approved by the Parliament of Cyprus, and the Cypriot National Action Plan on climate. Beneficiaries include policy makers, sectors of green industry, and the wider population of Cyprus through primarily agriculture, forest, biodiversity, soils, public health and water. Broader impact includes influence on similar efforts in other Eastern Mediterranean countries with the formation of the Cyprus Government's Initiative for Coordinating Climate Change Action in the Eastern Mediterranean and Middle East.

2. Underpinning research (indicative maximum 500 words)

The impact reported here built on the extensive expertise developed on regional climate physics and change and its impacts conducted by Voulgarakis's team over the last decade, utilizing state-of-the-art ("IPCC (Intergovernmental Panel on Climate Change)-class") climate models for which Voulgarakis's team are acknowledged as the key specialists at Imperial, having established a dominant international reputation, as evidenced by their many international collaborations in this area.

Voulgarakis has been a key member and contributor **[1]** to the international ACCMIP (Atmospheric Chemistry and Climate Modelling Intercomparison Project), which has provided an invaluable resource for exploring issues of climate sensitivity, historical climate behaviour and importantly climate projections **[1-3]**. The associated comparison of different models together with observations related to atmospheric chemistry were used to evaluate the understanding of the interactions between atmospheric chemistry and climate. Particular emphasis was placed on simulations of tropospheric ozone and aerosols, both which exert substantial climate forcing which varies considerably in space and time. Methane, arising from human activity is the second most important greenhouse gas in the climate system and can be removed by oxidation. The oxidation reaction depends strongly on the levels of the hydroxyl radical present, which can also remove other trace pollutants such as nitrogen oxides, carbon monoxide and hydrofluorocarbon and Volulgarakis was the lead author on the key paper predicting future chemical lifetime for these key

components **[2]**. Fires, in particular biomass burning, are responsible for a range of gaseous and aerosol emissions. Voulgarakis and colleagues investigated biomass burning emissions as a driver of interannual variability of large-scale abundances of short-lived constituents such as carbon monoxide (CO), hydroxyl radicals (OH), ozone and aerosols, and demonstrated that there are strong implications of wildfire variability for air quality and climate **[4]**.

Such expertise and accumulated experience led to Voulgarakis being invited as the lead climate change expert in the Assessment, in order to provide estimates of future climate change over Cyprus to the wide range of impact scientists involved. The culmination of this were the Evidence Report **[5]** (which analysed and presented the climate change impacts on all economic sectors examined, and therefore was the central document produced) and the accompanying Climate Change Report **[6]** (which provided the information needed in order to analyse and estimate the climate change impacts in the various sectors). Overall, the aims of the reports were to provide the best information available on the vulnerability of Cyprus to climate change, identifying notable risks and opportunities and gaps in our current understanding. This was the first such study ever undertaken for Cyprus, while no similar study has ever been conducted for other countries in the Eastern Mediterranean area, including Greece. Thus, this study was an important pilot that can affect the future of climate change risk and impact assessments for the wider region.

The future climate change prediction data that mostly drove this analysis was based on unique regional climate models that participated in the leading regional climate model intercomparison project focusing on Europe, i.e. EURO-CORDEX, and its counterpart focusing specifically on the Mediterranean (MED-CORDEX). Members of our team (particularly Christos Giannakopoulos at Imperial) have been key participants in these intercomparisons. Our research was enriched with information gathered from the wider literature, to complement the main analysis of EURO-CORDEX and MED-CORDEX model data. The future climate change analysis was led by Voulgarakis who wrote the associated report [6] (working through Imperial Consultants, ICON) from July 2015 to April 2016.

The study addressed 12 “sectors” (or research areas) and drew evidence from literature reviews, expert elicitation and more detailed quantitative analysis conducted by our research team, where the data allowed. It incorporated feedback from stakeholders in these sectors, in order to identify potential impacts and to select risk sectors for more detailed analysis. A Sector Report was produced for each sector that included identification of risk metrics, development of response functions, an adaptive capacity assessment, mapping of competent authorities and quantification of the magnitude of the risks.

The overall project (“The Cyprus Climate Change Risk Assessment”) was led by Advanced Environmental Studies (Adens) SA, a high-profile environmental consulting company based in Athens that undertook the project, which was to start with supported by the Cypriot Government. The company approached me (Voulgarakis) to be the Lead Climate Scientist, and I worked on this role through Imperial Consultants. The direct project’s budget was 160,000 euros. The contract between Adens SA and myself was effective from July 2015 to April 2016 and was for ~£20,000. The work was also based on a large body of work pursued in preceding years, conducted both by our team and others and supported by a variety of sources (e.g. NERC studentships at Imperial that Voulgarakis supervised, an EU Marie Curie IRSES project in which Voulgarakis was the Imperial Co-I, a British Council UKIERI-UGC Grant in which Voulgarakis was the PI, collaborations with the Met Office that provided supercomputing resources to the group of Voulgarakis etc).

3. References to the research (indicative maximum of six references)

[1] Lamarque, J.-F., Shindell, D.T., Josse, B., et al. (2013) The Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP): overview and description of models, simulations and climate diagnostics. Geoscientific Model Development 6, 179-206, doi:10.5194/gmd-6-179-2013

[2] Voulgarakis, A., Naik, V., Lamarque, J.-F. et al. (2013) Analysis of present day and future OH and methane lifetime in the ACCMIP simulations. Atmospheric Chem and Phys. 13, 2563-2587, doi:10.5194/acp-13-2563-2013

[3] Naik, V., Voulgarakis, A., Fiore, A.M. et al. (2013) Preindustrial to present day changes in tropospheric hydroxyl radical and methane lifetime from the Atmospheric Chemistry and Climate Model Intercomparison Project. Atmospheric Chem and Phys. 13, 5277-5298, doi:10.5194/acp-13-5277-2013

[4] Voulgarakis, A., Marlier, M.E., Faluvegi, G., et al. (2015) Interannual variability of tropospheric trace gases and aerosols: The role of biomass burning emissions. J. Geophysical Res. Atmos., 120, 7157-7173, doi:10.1002/2014JD022926

[5] The main Evidence Report produced in 2016 ("The Cyprus Climate Change Risk Assessment Evidence Report") which was all based on the climate change information provided by our team to the different sectoral work packages can be found on this link of the Cypriot Government's website. All authors (including me) are listed on Page i.

[6] Also, the Climate Change Report (also produced in 2016) that was written by me based on my direct analysis can be found on the following link:
https://www.dropbox.com/s/eu8zb54rcsp6g9x/CCRA_Climate_Report_fin.pdf?dl=0

The following projects and papers (including by members of the team I formed for CCRA at Imperial, especially Dr. Christos Giannakopoulos) were crucial for providing the climate change data that was needed for informing the risk assessment for the different sectors:

- https://www.euro-cordex.net/
- https://www.medcordex.eu/
- Jacob D. et al. (2013), EURO-CORDEX: New high-resolution climate change projections for European impact research. Regional Environmental Change, 14(2), 563-578.
- Vaittinada Ayar et al. (2016), Intercomparison of statistical and dynamical downscaling models under the EURO and MED-CORDEX initiative framework: present climate evaluations Clim. Dyn. 46, 1301-1329.
- Hadjinicolaou, P. et al. (2011), Mid-21st century climate and weather extremes in Cyprus as projected by six regional climate models, Regional Environmental Change, 11, 3, 441-457, DOI: 10.1007/s10113-010-0153-1.

4. Details of the impact (indicative maximum 750 words)

The focus of the research was to provide the first ever Climate Change Risk Assessment for the Government of Cyprus. Dr Voulgarakis (representing Imperial) was the leading climate change expert in this work, based on his extensive experience in the area of regional climate change, and provided all the climate information that was then used by impact scientists in Greece and Cyprus (experts on agriculture, biodiversity, built environment, business, energy forestry, natural disasters, health, fisheries, transport, and water resources) in the different chapters of the Assessment Report **[A, B]**.

The Government-appointed reviewer of the Climate Change Risk Assessment report and Associate Professor (and climate expert) at the Cyprus Institute in Nicosia states that "*The climate change analysis carried out by Dr Voulgarakis and his team was critical in the success of the overall CY-CCRA Evidence Report. It provided the necessary data input for the impact sector studies that quantified the climate change driven risks in the environment society-economy spectrum of the country. The CY-CCRA outcome has importantly shaped the Cyprus Government's Climate Change National Adaptation Plan.*" **[C]**.

The major impact achieved is that our assessment was the main evidence that directly informed and shaped the first National Strategy for Adaptation to Climate Change that was successfully voted into legislation by the Parliament of Cyprus on the 18th May 2017 **[D]**. There were two workshops between Government representatives and the project's team which enabled the communication of information to the stakeholders. Our work provided the evidence for justifying and applying the National Strategy to Climate Change Adaptation (NSACC) (which involved a

National Action Plan (NAP)), which was finalised by the Department of Environment in April 2017 and approved by the Council of Ministers of the Republic of Cyprus on 18 May 2017 **[D]**. The Cyprus Climate Change Impacts and Adaptation Observatory (CYCLADAPT) project directly addresses adaptation measures covering most of the NAP sectors and primarily agriculture, forest, biodiversity, soils, public health and water (submitted September 2018, T. Mesimeris, personal communication). The implementation of the NAP is expected to bring substantial benefits to the environment and society in the long-term, as it foresees a total of 57 measures **[D]**. The NSACC and NAP can be found (in Greek) in **[E]** and **[F]**.

Beneficiaries include policy makers with Government of Cyprus, various sectors of industry, and the wider society of Cyprus. Specifically, the NAP addresses adaption in eleven key impact sectors: Water resources; Soils; Coastal areas; Biodiversity; Agriculture; Forest; Fisheries and aquaculture; Public health; Energy; Tourism; Infrastructure **[D]**. Example measures included in the NAP are the expansion of water use efficiency meters by the Agricultural Ministry, installation of new technologies in forests for the early detection of new climate-related diseases, the creation of new green spaces in cities, and many others. Broader implications of our work include influence on similar efforts that will be undertaken in the future in other countries and regions of the Eastern Mediterranean (e.g. Greece and countries of the Middle East). Our work also provided the evidence for follow-up international initiatives by the Government of Cyprus **[D]**.

This research impacted the whole population of Cyprus, 1.1 million people, as well as the many visitors and tourists to the country. The impact concerns the whole population, as climate change impacts are ubiquitous and affect all sectors of society, e.g. through changes in weather leading to increased flooding and to changes in energy demand for cooling, increase in pollution, and impacts on health and agriculture due to increased average temperatures, all of which are areas covered in our report.

Given the expected indirect influence of our work on similar efforts in other nations of the Eastern Mediterranean (we know that currently there are similar assessments planned for different peripheries of Greece, which will be influenced by our work), we expect our research to influence tens of millions of people.

Monetisation of the risks has been discussed in the final session of the report, though a total value from all sectors was not provided. However, indicative estimates have been provided for individual sectors; for example, for the 2050s and under the moderate RCP4.5 scenario, we identified potential annual costs exceeding €1M in three impact metrics (properties exposed to flooding and insurance premiums; temperature morbidity) and exceeding €10M in other three (energy demand for cooling; people exposed to flooding; temperature mortality).

The Head of the Climate Action and Energy Unit at the Department of Environment highlights the influence this report had on the wider region. He says that "*The Cyprus Climate Change Risk Assessment evidence report was one of the contributing factors to the development of the "The Cyprus Government Initiative for Coordinating Climate Change Actions in the Eastern Mediterranean and Middle East (EMME)" launched by H.E. President Anastasiades in March 2019. The initiative aims at the development of a Regional Action Plan to address the specific needs and challenges counties are facing in the mitigation actions in accordance with the Paris Agreement"* **[D]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[A] As mentioned in Sect. 3, the main Evidence Report produced in 2016 ("The Cyprus Climate Change Risk Assessment Evidence Report") which was all based on the climate change information provided by our team to the different sectoral work packages can be found on this link of the Cypriot Government's website. All authors (including me) are listed on Page i. (Archived here)

[B] The agenda of two workshops that were held in 2016 between us and the Cypriot Ministry of the Environment to discuss the outcomes of our work and exchange ideas can be found on this link and this link. (Archived here and here)

[C] Supporting letter from the Government-appointed reviewer of the Climate Change Risk Assessment report and Associate Professor (and climate expert) at the Cyprus Institute in Nicosia. is letter focuses on the scientific value of our work and its high quality. The Cyprus Institute is the leading institution for climate and environmental research in Cyprus, and one of the most important in the Eastern Mediterranean.

[D] The Head of the Climate Action and Energy Unit at the Department of Environment, Ministry of Agriculture, Rural Development and Environment of Cyprus has provided a letter explaining how our work has directly influenced their policy actions, and what specific aspects of our work were most valuable.

[E] National Strategy to Climate Change Adaptation (NSACC) in Greek
http://www.moa.gov.cy/moa/environment/environmentnew.nsf/All/C15CD89954708638C2257FF1003494BD/$file/%CE%95%CE%B8%CE%BD%CE%B9%CE%BA%CE%AE%20%CE%A3%CF%84%CF%81%CE%B1%CF%84%CE%B7%CE%B3%CE%B9%CE%BA%CE%AE%20%CE%B3%CE%B9%CE%B1%20%CF%84%CE%B7%CE%BD%20%CE%A0%CF%81%CE%BF%CF%83%CE%B1%CF%81%CE%BC%CE%BF%CE%B3%CE%AE%20%CF%83%CF%84%CE%B7%CE%BD%20%CE%9A%CE%BB%CE%B9%CE%BC%CE%B1%CF%84%CE%B9%CE%BA%CE%AE%20%CE%91%CE%BB%CE%BB%CE%B1%CE%B3%CE%AE.pdf (Archived here)

[F] National Action Plan (NAP) in Greek
http://www.moa.gov.cy/moa/environment/environmentnew.nsf/All/C15CD89954708638C2257FF1003494BD/$file/%CE%A3%CF%87%CE%AD%CE%B4%CE%B9%CE%BF%20%CE%94%CF%81%CE%AC%CF%83%CE%B7%CF%82%20%CE%B3%CE%B9%CE%B1%20%CF%84%CE%B7%CE%BD%20%CE%A0%CF%81%CE%BF%CF%83%CE%B1%CF%81%CE%BC%CE%BF%CE%B3%CE%AE%20%CF%83%CF%84%CE%B7%CE%BD%20%CE%9A%CE%BB%CE%B9%CE%BC%CE%B1%CF%84%CE%B9%CE%BA%CE%AE%20%CE%91%CE%BB%CE%BB%CE%B1%CE%B3%CE%AE.pdf (Archived here)