climate

MDPI

Editorial

Climate and Human Health: Relations, Projections, and Future Implementations

Alessandro Pezzoli [1,2,*], José Luis Santos Dávila [3] and Eleonora d'Elia [2]

1 Investigador Prometeo, Escuela Superior Politécnica del Litoral, EC090150 Guayaquil, Ecuador
2 Interuniversity Department of Regional and Urban Studies and Planning—Politecnico di Torino & Università di Torino, 10125 Turin, Italy; eleonora.delia23@gmail.com
3 FIMCBOR—Escuela Superior Politécnica del Litoral, ESPOL, EC090150 Guayaquil, Ecuador; jlsantos@espol.edu.ec
* Correspondence: alessandro.pezzoli@polito.it; Tel.: +39-011-0907-448

Academic Editor: Yang Zhang
Received: 13 March 2016; Accepted: 15 March 2016; Published: 25 March 2016

Abstract: It is widely accepted by the scientific community that the world has begun to warm as a result of human influence. The accumulation of greenhouse gases in the atmosphere, arising primarily from the combustion of carbon fossil fuels and agricultural activities, generates changes in the climate. Indeed various studies have assessed the potential impacts of climate change on human health (both negative and positive). The increased frequency and intensity of heat waves, the reduction in cold-related deaths, the increased floods and droughts, and the changes in the distribution of vector-borne diseases are among the most frequently studied effects. On the other hand, climate change differs from many other environmental health problems because of its gradual onset, widespread rather than localized effect, and the fact that the most important effects will probably be indirect. Some recent and important publications show that only the collaboration between the meteorological and the public health communities can help us to thoroughly study the link between climate and health, thus improving our ability to adapt to these future changes. The aim of this editorial is to give different perspectives on a widely discussed topic, which is still too complicated to be addressed to a satisfactory extent. Moreover, it is necessary to underline the importance of using new biometeorological indices (*i.e.* thermal indexes, *etc.*) for future projections, in order to reduce the impacts of negative outcomes, protecting the population through adaptation measures and public awareness.

Keywords: climate change; adaptation; biometeorology; human health

Climate has an essential role in human life. It affects human beings in many different ways, directly and indirectly [1]. With the rise of global temperatures, potential impacts of climate change on health have become a major concern worldwide and a widely discussed topic in the literature.

In fact, in 2012, with the publication of the "Atlas of Health and Climate" by the World Health Organization and the World Meteorological Organization, various areas of research started to be included in the studies regarding the link between climate and human health. The innovation of this publication is the multidisciplinary approach that includes biometeorology, health epidemiology, and other related disciplines [2].

Indeed great concern is growing around the connection between climate change and human health; for example, one of the Sustainable Development Goals is "[t]o take urgent action to combat climate change and its impacts" (Goal 13), which in turn is linked to Goal 3: "Ensure healthy lives and promote well-being for all at all ages" [3].

This editorial arises from the interest in these new approaches and aims to give an overview on the relations, projections, and possible future implementations by considering the papers selected for the special issue on "Climate Impacts on Health", which focuses not only on the effects but also on the different aspects that can be included in the subject.

There were 22 papers proposed, of which 11 were accepted for publication after the reviewing process. With a rejection rate of 50%, the call was closed 30 November 2015. The first paper was published on 26 June 2014 and the last one on 10 December 2015. Of the 11 papers accepted, 7 are articles, 3 are reviews, and there is 1 communication. It should be noticed that the paper presented by Zacharias *et al.* is the third most cited paper 2013–2015 from *Climate*, with a total of four citations. The papers handled are mainly from the European area (7 out of 11), but there are also studies from the USA and Africa, underling the worldwide importance and concern around the topic.

As a starting point, it is necessary to identify how to relate climate and health, in particular how the variation of climate that the world is witnessing today can impact human health.

Wolf *et al.* considered 53 countries, including the WHO European Region and 135 studies on the subject, identifying two pathways through which health can be affected by climate change, namely, directly or indirectly [1].

Direct effects imply those attributable to extreme events, which includes high/low temperatures, heat waves, and cold spells but also floods, wildfires, and UV radiation. Indirect effects are, on the other hand, the ones "*mediated through either natural or human systems*" [1], which are climate sensitive vector-borne infectious diseases, flood, and water related health effects (food security, water quality), and, finally, those related to air quality and allergic diseases [1].

Within the direct effects, extreme heat exposure is well established as one of the major threats to human health due to climate variations [4]. The link between heat waves and morbidity and/or mortality has been identified in many studies [3–11].

For instance, Zacharias *et al.* analyzed the effects of heat waves on Ischemic Heart Diseases (IHD) in Germany between the years 2001 and 2010. Defining heat waves as "*periods of at least three consecutive days with daily mean temperature above the 97.5th percentile of the temperature distribution*" [5], the results confirmed previous studies where heat waves were associated with an increase in IHD mortality in some European countries [5,7–10] and, moreover, with a short time gap between extreme events and mortality increase [5,8,11].

Different results were obtained about the link between morbidity and heat waves, since no effect could be found regarding the impact on morbidity nor about the connection between mortality and morbidity simultaneously [5,12–14].

The main concern about the relation between heat waves and mortality is that, with the exacerbation of the green house effects on climate, an increase in the frequency, duration, and intensity of these extreme events is expected [15–19]. Hence, it becomes necessary to understand how the phenomenon would vary in a certain amount of time and in a particular area. Two of the methods that authors most commonly use to provide a projection of the future perspective in a specific area are the regional climate models and the heat wave indexes [6,15].

An example is the use of the excess heat factor as a heat wave index, as defined by Nairn *et al.* [20]. An application can be found in the study of Keggenhoff *et al.* [15] regarding the Caucasian region, in which it is used to quantify both climatology and summer heat wave changes.

Hence, a dataset of daily maximum and minimum air temperatures series of 50 years (1961–2010) was analyzed for Georgia and Tbilisi stations, and eight heat wave aspects were studied: "*the yearly number of heat waves (HWN), length of the longest yearly event (HWD), the yearly sum of participating heat wave days (HWF), the hottest day of hottest yearly event (HWA), and the average magnitude of all yearly heat waves (HWM). Three new heat wave aspects have been applied to the study: the number of heat wave days (HWday), the number of severe heat wave days (HWsev) and extreme heat wave days (HWex) to allow a differentiated assessment of the spatial and temporal characteristics of low intensity, severe and extreme heat waves*" [15].

The results demonstrate an increase in number, duration, and intensity, but no change was found for the mean magnitude of the heat waves.

The heat wave trend magnitudes, however, differs from Tbilisi to Georgia averages, which can be explained by the urban heat island (UHI) effect [15]. Additionally, Olabode in his article identifies the effect of extreme weather events in urban areas (Akure, Ondo State, Nigeria [21]) and the relationship between monthly temperature and heat rush. Furthermore, the paper suggests the importance of increasing the awareness of this connection in order to have a proper adaptation plan to avoid the effects of extreme temperatures.

A second paper of Zacharias *et al.* is considered [6]. In the article, 19 regional model simulations considering the IPCC scenario A1B [22] are used to analyze how climate change can impact the frequency, intensity, duration of heat waves, and hence, how climate change can impact IHD mortality in Germany considering both no-acclimatization projection and a 50% acclimatization approach.

In their study, Zacharias *et al.* confirmed previous results [23–27] indicating an increase of the annual number of IHD excess deaths by a factor of 2.4, including a 50% acclimatization and a factor of 5.1 in the non-acclimatization perspective by the end of the century. The results obtained are strongly based on the model simulations applied, and the regional scale considered. In this case, the studies are based in Germany, where, in the North, the increase of annual days of heat wave is projected to be of a factor of 3.5, compared to the South, in which it is supposed to increase 5 times, underlying the spatial dependence of the phenomenon [6].

The high correlation between mortality and heat wave events is widely confirmed, although the highest importance should be given to which climatic variable is advocated in the analysis. In fact, Hart in its communication "Air Temperature and Death Rates in the Continental U.S., 1968–2013" analyzed the yearly "*temperature*" (mean daily maximum air temperature) for 45 years of 48 states of US plus the District of Columbia, compared to age-adjusted all-caused mortality ("*deaths*") [28]. The findings identified a decreasing death rate for warmer years, even considering the limitations of the study; the results were similar to the ones underlined by a Texas study [28,29]. Thus, with this editorial, a starting point for new possible studies is suggested.

However, weather extreme events are not only connected directly to mortality and morbidity, but capable of causing problems to human society indirectly, for example, through food security and famines.

An analysis of the two major Irish famines in the early 18th century demonstrated that the initiating driver in vulnerable societies is the weather and the occurrence of extreme events [30]. It is important to notice that weather/climate conditions are not the only factor; in fact, social, political, and economic variables, together with the weather extreme conditions, are all drivers equally involved in the spread and evolution of the problem [30].

Another important indirect effect of the impacts of climate change on human health is the issue of the infectious diseases [31–34].

Many studies assessed the influence of climate change on the expansion of several infectious diseases [31,35–37]. Climate and weather conditions changes have an impact on the pathogens, hosts, and transmission environments causing variation in the normal spread and evolution of some infectious diseases [31–37].

A review from Wu *et al.* gives an overview regarding this topic; temperature, precipitation, wind, and sunshine are considered as weather variables, and the alteration of these conditions have an impact on the life-cycle and distribution of the pathogens and the hosts, and on the disease transmission [31].

Although changes in the occurrence of infectious diseases are frequently associated to climate conditions variations, uncertainties about the non-climatic drivers is of interest. Specifically, Akin *et al.* [38] interviewed 56 Dutch experts, 29 of which yielded useful responses. In relation to the increase of infectious diseases risks, the respondents, divided in two groups "*policy*" (12 experts) and "*science*" (17 experts), gave more importance to the majority of non-climatic drivers considered, rather than the climate change ones [38].

Climatic drivers may not be the most influencing factors linked to an increase of infectious diseases outbreak risk, but they are particularly relevant for those vector-borne transmitted (*i.e.* by mosquitos, sand flies, and ticks) [1].

The gradualness of the temperature increase, and weather change, produces misconceptions about the magnitude of the influence it could have on everyday life. Stoutenborough *et al.* focus on this aspects, analyzing " . . . the contextual differences in public perceptions of the health risk posed by climate change" [39].

In fact, the potential butterfly effects of climate change events are not completely perceived by the public. Specifically, familiarity, self-interest, and the optimism bias influence the conception of the phenomenon attributing to health risks a high spatial dependency [39].

In particular, the study assessed that "*the more proximate the group evaluated, the less likely the individual is to perceive health risk*" [39] and, at the same time, if individuals do not really understand the problem, they generally perceive a greater level of risk [39].

All these perspectives and connections between human health and climate need to be explored in order to find ways to overcome and/or adapt to the increasing risk. For example, public authorities should be focusing on explaining local threats to guarantee a necessary comprehension of the health risk involved [39].

Moreover, to have a deeper comprehension of the impacts of climate change in everyday life, and to find appropriate ways to adapt, a new area of research should be implemented: "The Economics of Health Damage and Adaptation to Climate Change in Europe: A Review of the Conventional and Grey Literature" [40].

Martinez *et al.* [40] in their review analyzed the gray literature on the topic. They categorized the study in three main typologies:

- "*Studies on the cost of health damage of climate change tend to show significant costs due to mortality and morbidity attributable to climate change. Those costs, measured on a yearly basis, tend to increase with longer timeframes and under more severe climate change scenarios.*
- *Studies on the cost, cost-effectiveness and/or benefits of health adaptation tend to show moderate costs and substantial benefits of adaptation in the short term with a marked increase in the long term.*
- *The reviews of the literature commonly reflect the paucity of existing evidence, lack of comparability and gaps, but tend to confirm the general conclusions in the mentioned types of studies*" [40].

The level of uncertainty is very high, no study of the review discounted future values, and the choice of the mortality valuation method led to completely different results; moreover, the inconsistency of the data and the uncertainty of the projections is evident, as evident as the necessity to have more studies focusing on this new combined approach [40].

Finally, the connection between weather and human health also includes areas of social life, such as tourism or sports. It is possible to find a wide variety of literature concerning the issues related to tourism [41–43], but it is not that common to study the influence of climate, and climate change, on outdoor sports performers [44,45].

In fact, performances in outdoor sports, especially in case of high-level challenges, are strongly affected by climate conditions. As Brocherie *et al.* summarized in their review "Emerging Environmental and Weather Challenges in Outdoor Sports", there are many environmental-risk factors related to climate variations [45]. The direct effects, which were identified previously in this editorial, are exacerbated in case of an outdoor sports practitioner because of the stress to which the body is subjected. The current guidelines addressing situations of risk for the players are not fully implemented and are often too conservative to guide informed decisions [46].

Direct weather indices, such as air temperature or absolute humidity, are not accurate to evaluate the health risk in both a sportive and an everyday life situation. Usually, to assess the thermal stress level, two-parametric indexes are commonly used, based, for example, on the combination of temperature and humidity (to assess the perception of "*warm*") or on air temperature and wind speed (for the "*cold*" perception) [47,48]. Although these indicators are widely used, the lack of human heat budget, clothing behavior, or psychological well-being represents one of the main limitations of two-parameter indexes.

Using a multi-disciplinary approach, including thermo-physiology, occupational medicine, biophysics, meteorology, biometeorology, and environmental sciences, the Universal Thermal Climate Index (UTCI) has been developed. The UTCI "*corresponds to an equivalent temperature defined as a reference condition for subsequent comparison with all climatic conditions*" [45] and can be considered as one of the most complete multi-node model of human heat transfer and thermo-regulation [49].

Valid in all spatial, climatic, and seasonal scales, applicable to the entire body, used in human biometeorology (daily forecasting and warnings) as well as in environmental epidemiology and urban and regional planning, the UTCI is projected to enhance a more profound and comprehensive view on the main environmentally related risk factors [47–49].

Finally, it should be pointed out that applications of the UTCI on the Latin American Region are practically nonexistent; the authors of this editorial, together with other researchers, are currently investigating this subject in the tropical country of Ecuador, and some interesting results have already been obtained and will be published in the coming months.

What connects all these fields of research is the need to understand how the weather will change in time, to find measures to protect, and adapt to new conditions; it is necessary to raise public awareness about climate change by developing a new, more holistic research area which would include biometeorology, natural hazards, health, and all the fields related to the subject.

Acknowledgments: This research is funded by the PROMETEO project of the Secretaria de Educacion Superior, Ciencia, Tecnologia e Innovacion of the Ecuador Republic. The Academic Editor of the Special Issue "Climate Impacts on Health" wants to thank the Anonymous Reviewers that contributed to the success of the Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wolf, T.; Lyne, K.; Sanchez Martinez, G.; Kendrovski, V. The health effects of climate change in the WHO European Region. *Climate* **2015**. [CrossRef]
2. Sustainable Development Goals. Available online: https://sustainabledevelopment.un.org/sdgs (accessed on 4 March 2016).
3. World Health Organization; World Meteorological Organization. *Atlas of Health and Climate*; World Health Organization: Geneva, Switzerland, 2012; p. 64.
4. Luber, G.; McGeehin, M. Climate change and extreme heat events. *Am. J. Prev. Med.* **2008**, *35*, 429–435. [CrossRef] [PubMed]
5. Zacharias, S.; Koppe, C.; Mücke, H.-G. Influence of heat waves on ischemic heart diseases in Germany. *Climate* **2014**, *2*. [CrossRef]
6. Zacharias, S.; Koppe, C.; Mücke, H.-G. Climate change effects on heat waves and future heat wave-associated IHD mortality in Germany. *Climate* **2015**. [CrossRef]
7. Hutter, H.P.; Moshammer, H.; Wallner, P.; Leitner, B.; Kundi, M. Heatwaves in Vienna: Effects on mortality. *Wien. Klin. Wochenschr.* **2007**, *119*, 223–227. [CrossRef] [PubMed]
8. Kyselý, J.; Plavcová, E.; Davídkovová, H.; Kynčl, J. Comparison of hot and cold spell effects on cardiovascular mortality in individual population groups in the Czech Republic. *Clim. Res.* **2011**, *49*, 113–129. [CrossRef]
9. Huynen, M.M.; Martens, P.; Schram, D.; Weijenberg, M.P.; Kunst, A.E. The impact of heat waves and cold spells on mortality rates in the Dutch population. *Environ. Health Perspect.* **2001**, *109*, 463–470. [CrossRef] [PubMed]
10. Rocklov, J.; Barnett, A.G.; Woodward, A. On the estimation of heat-intensity and heat-duration effects in time series models of temperature-related mortality in Stockholm, Sweden. *Environ. Health* **2012**. [CrossRef] [PubMed]
11. Kyselý, J.; Plavcová, E. Declining impacts of hot spells on mortality in the Czech Republic, 1986–2009: Adaptation to climate change? *Clim. Chang.* **2012**, *113*, 437–453. [CrossRef]

12. Kovats, R.S.; Hajat, S.; Wilkinson, P. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. *Occup. Environ. Med.* **2004**, *61*, 893–898. [CrossRef] [PubMed]
13. Johnson, H.; Kovats, R.S.; McGregor, G.; Stedman, J.; Gibbs, M.; Walton, H.; Cook, L.; Black, E. The impact of the 2003 heat wave on mortality and hospital admissions in England. *Health Stat. Q.* **2005**, *25*, 6–11. [CrossRef] [PubMed]
14. Williams, S.; Nitschke, M.; Weinstein, P.; Pisaniello, D.L.; Parton, K.A.; Bi, P. The impact of summer temperatures and heatwaves on mortality and morbidity in Perth, Australia 1994–2008. *Environ. Int.* **2012**, *40*, 33–38. [CrossRef] [PubMed]
15. Keggenhoff, I.; Elizbarashvili, M.; King, L. Heat wave events over Georgia since 1961: Climatology, changes and severity. *Climate* **2015**. [CrossRef]
16. Kharin, V.; Zwiers, F.W.; Zhang, X.; Hegerl, G.C. Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. *J. Clim.* **2007**, *20*, 1419–1444. [CrossRef]
17. Perkins, S.E.; Alexander, L.A.; Nairn, J.R. Increasing frequency, intensity and duration of observed global heatwaves and warm spells. *Geophys. Res. Lett.* **2012**, *39*. [CrossRef]
18. IPCC. Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. In *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 709–754.
19. IPCC. Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. In *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 1133–1436.
20. Nairn, J.; Fawcett, R. *Defining Heatwaves: Heatwave Defined as a Heat-Impact Event Servicing all Community and Business Sectors in Australia*; CAWCR Technical Report No. 060; Centre for Australian Weather and Climate Research: Melbourne, Australia, 2013.
21. Olabode, A.D. Urban Extreme Weather: A challenge for a healthy Living environment in Akure, Ondo State, Nigeria. *Climate* **2015**. [CrossRef]
22. Nakicenovic, N.; Alcamo, J.; Davis, G.; de Vries, B.; Fenhann, J.; Gaffin, S.; Gregory, K.; Gruebler, A.; Jung, T.Y.; Kram, T.; *et al. Special Report on Emissions Scenarios, Working Group III, Intergovernmental Panel on Climate Change (IPCC)*; Cambridge University Press: Cambridge, UK, 2000.
23. Wu, J.; Zhou, Y.; Gao, Y.; Fu, J.S.; Johnson, B.A.; Huang, C.; Kim, Y.-M.; Liu, Y. Estimation and uncertainty analysis of impacts of future heat waves on mortality in the eastern United States. *Environ. Health Perspect.* **2014**, *122*, 10–16. [CrossRef] [PubMed]
24. Hales, S.; Kovats, S.; Lloyd, S.; Campbell-Lendrum, D. Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s. Available online: http://www.who.int/globalchange/publications/quantitative-risk-assessment/en/ (assessed on 5 November 2014).
25. Sheridan, S.C.; Allen, M.J.; Lee, C.C.; Kalkstein, L.S. Future heat vulnerability in California, Part II: Projecting future heat-related mortality. *Clim. Chang.* **2012**, *115*, 311–326. [CrossRef]
26. Morabito, M.; Crisci, A.; Moriondo, M.; Profili, F.; Francesconi, P.; Trombi, G.; Orlandini, S. Air temperature-related human health outcomes: Current impact and estimations of future risks in Central Italy. *Sci. Total Environ.* **2012**, *441*, 28–40. [CrossRef] [PubMed]
27. Petkova, E.P.; Bader, D.A.; Anderson, G.B.; Horton, R.M.; Knowlton, K.; Kinney, P.L. Heat-related mortality in a warming climate: Projections for 12 US cities. *Int. J. Environ. Res. Public Health* **2014**, *11*, 11371–11383. [CrossRef] [PubMed]
28. Hart, J. Air temperature and death rates in the Continental U.S., 1968–2013. *Climate* **2015**, *3*, 435–441. [CrossRef]
29. Hart, J. Air temperature and death rates in Texas, 1968–2013: A brief research note. *Epidemiol. Rep.* **2015**. accepted. [CrossRef]
30. Engler, S.; Werner, J.P. Processes prior and during the early 18th Century Irish famines—Weather extremes and migration. *Climate* **2015**, *3*, 1035–1056. [CrossRef]
31. Wu, X.; Lu, Y.; Zhou, S.; Chen, L.; Xu, B. Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environ. Int.* **2016**, *86*, 14–23. [CrossRef] [PubMed]
32. Altizer, S.; Ostfeld, R.S.; Johnson, P.T.J.; Kutz, S.; Harvell, C.D. Climate change and infectious diseases: From evidence to a predictive framework. *Science* **2013**, *341*, 514–519. [CrossRef] [PubMed]

33. Bouzid, M.; Colón-González, F.J.; Lung, T.; Lake, I.R.; Hunter, P.R. Climate change and the emergence of vector-borne diseases in Europe: Case study of dengue fever. *BMC Public Health* **2014**, *14*. [CrossRef] [PubMed]
34. Epstein, P.R. Climate change and emerging infectious diseases. *Microbes Infect.* **2001**, *3*, 747–754. [CrossRef]
35. Epstein, P.R.; Diaz, H.F.; Elias, S.; Grabherr, G.; Graham, N.E.; Martens, W.J.; Mosley-Thompson, E.; Susskind, J. Biological and physical signs of climate change: Focus on mosquito-borne diseases. *Bull. Am. Meteorol. Soc.* **1998**, *79*, 409–417. [CrossRef]
36. Ostfeld, R.S.; Brunner, J.L. Climate change and Ixodes tick-borne diseases of humans. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2015**, *370*. [CrossRef] [PubMed]
37. Rodó, X.; Pascual, M.; Doblas-Reyes, F.J.; Gershunov, A.; Stone, D.A.; Giorgi, F.; Hudson, P.J.; Kinter, J.; Rodríguez-Arias, M.-À.; Stenseth, N.C. Climate change and infectious diseases: Can we meet the needs for better prediction? *Clim. Chang.* **2013**, *118*, 625–640. [CrossRef]
38. Akin, S.-M.; Martens, P. A survey of Dutch expert opinion on climatic drivers of infectious disease risk in Western Europe. *Climate* **2014**. [CrossRef]
39. Stoutenborough, J.W.; Kirkpatrick, K.J.; Field, M.J.; Vedlitz, A. What butterfly effect? The contextual differences in public perceptions of the health risk posed by climate change. *Climate* **2015**, *3*, 668–688. [CrossRef]
40. Sanchez Martinez, G.; Williams, E.; Yu, S.S. The economics of health damage and adaptation to climate change in Europe: A review of the conventional and grey literature. *Climate* **2015**, *3*, 522–541. [CrossRef]
41. Fagence, M.; Kevan, S. Migration, recreation and tourism: Human responses to climate differences. In *Advances in Bioclimatology*; Auliciems, A., Ed.; Springer: Berlin, Germany, 1997; pp. 133–160.
42. Scott, D.; de Freitas, C.; Matzarakis, A. Adaptation in the tourism and recreation sector. In *Biometeorology for Adaptation to Climate Variability and Change*; Ebi, K., Burton, I., McGregor, G., Eds.; Springer: Dordrecht, The Netherlands, 2009; pp. 171–194.
43. Scott, D.; McBoyle, G.; Schwartzentruber, M. Climate change and the distribution of climatic resources for tourism in North America. *Clim. Res.* **2004**, *27*, 105–117. [CrossRef]
44. Pezzoli, A.; Bellasio, R. Analysis of wind data for sports performance design: A case study for sailing Sports. *Sports* **2014**, *2*. [CrossRef]
45. Brocherie, F.; Girard, O.; Millet, G.P. Emerging environmental and weather challenges in outdoor sports. *Climate* **2015**, *3*. [CrossRef]
46. Bahr, R.; Reeser, J.C. New guidelines are needed to manage heat stress in elite sports—The federation internationale de volleyball (FIVB) heat stress monitoring programme. *Br. J. Sports Med.* **2012**, *46*, 805–809. [CrossRef] [PubMed]
47. Pappenberger, F.; Jendritzky, G.; Staiger, H.; Dutra, E.; Di Giuseppe, F.; Richardson, D.S.; Cloke, H.L. Global forecasting of thermal health hazards: The skill of probabilistic predictions of the Universal Thermal Climate Index (UTCI). *Int. J. Biometeorol.* **2015**, *59*. [CrossRef] [PubMed]
48. Blazejczyk, K.; Epstein, Y.; Jendritzky, G.; Staiger, H.; Tinz, B. Comparison of UTCI to selected thermal indices. *Int. J. Biometeorol.* **2012**, *56*. [CrossRef] [PubMed]
49. Psikuta, A.; Fiala, D.; Laschewski, G.; Jendritzky, G.; Richards, M.; Blazejczyk, K.; Mekjavic, I.; Rintamaki, H.; de Dear, R.; Havenith, G. Validation of the Fiala multi-node thermophysiological model for UTCI application. *Int. J. Biometeorol.* **2012**, *56*. [CrossRef] [PubMed]