INAUGURAL LECTURE

of

Prof Stuart Piketh

Understanding Atmospheric Processes through Transdiciplinary Research

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Discipline

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Inaugural address: April 2013

Introduction

The weather and its role in the fortunes and misfortunes of human beings has been the subject of scientific endeavor since humans started to think. Atmospheric science today continues to drive our curiosity about the natural system of the planet, and more recently the possibility that as people we are able and likely to be changing the natural equilibrium of the atmospheric system

As already stated atmospheric science is driven by our curiosity in the manner in which weather and climate work, the pattern in which they occur over time and very importantly the impact that they have on human lives, both positive and disastrous. On a global-scale atmospheric phenomena have all but dominated human tragedy over the past decade. These have included droughts in part of Africa, flooding around the world in both developed and developing countries; Europe, Pakistan, Southern Africa and severe storms in the form of hurricanes for example (United States of America). Of course the biggest climate related phenomena at the moment, that is at the forefront of atmospheric science, has been and will remain for the foreseeable future climate change.

Historically these phenomena would have been studied by considering only the physical aspects of their formation, development, decline and impact on the environment. It is important that these atmospheric phenomena are analyzed and understood in order to formulate strategies, which aim at reducing and/or minimizing the costs associated with these occurrences, both human and commercial.

An attempt will be made in this lecture to show how transdisciplinary research, that has evolved as a paradigm for my research over the past 20 years, provides a framework within which atmospheric science can understand the natural processes as well as give insight to mitigation strategies for risk and disaster management. Examples from my own research activities will be used to show how transdisciplinary research can and might in the future mold our understanding of the atmosphere.

Transdisciplinary research

Much of physical science over the centuries has been driven by positivism. The pursuit of physical "truth" has mostly been conducted through empirical methodologies. Still today, many physical scientists "truth" can only be measured through a mathematical relationship, beyond which one starts to move into the realm of psychology and spirituality. In a developing world context it is often difficult to justify research and funding without finding a societal relevance to the research. The South African National Research Foundation has indicated that it will favour research that applies a transdisciplinary philosophy. Important science questions are often couched within other complex difficulties in society. The challenge for scientists is developing the skills to conduct this pursuit of understanding within a framework that includes social scientists and the stakeholders that it affects.

Transdisciplinary research can be distinguished by four key characteristics. The first of these is the complexity of the problem. The questions are typically multi-dimensional and involve an interface between natural and human systems, in other words "real world problems" (Pohl, 2005 and Wickson *et al.*, 2006). Second, research that not only accounts for the scientific perceptions and methodologies but adapts these to reflect the problem and the context of the study. The net result of these interactions draws from a diverse set of methodologies that are combined into a unique and transformed methodology (Horlick-Jones and Sime, 2004; Hadorn etal., 2006 and Wickson *et al.*, 2006). Thirdly, research that sets out to produce applied knowledge that can be utilized by decision makers to improve processes, management structures or the day to day experiences of the citizenry and lastly research that is geared towards "the common interest" (Pohl, 2005, 1161). This process needs to include the stakeholders (communities and decision makers) in both the formulation of the problem statement and the evolution of the methodology (Wickson *et al.*, 2006).

This type of research paradigm is fraught with difficulties that are not related to the actual problems themselves but rather the interaction of the involved parties. My own experience of this was the development of a science program for the Southern African Fire-Atmosphere Experiment (SAFARI2000). The main objectives of the project, when it was conceived, were to use the nature of the atmospheric circulation as an integrating medium to understand the complex interactions between the atmosphere, hydrosphere, biosphere and the anthroposphere. The latter of these objectives remained in the project mostly as a good idea rather than a real focus point for two reasons; 1) the perception of the physical scientists that funding would be reduced if the "real science" was watered down by too much social science and 2) the inability of the social scientists to develop an integrated approach to linking social dimensions within the physical context. A transdisciplinary paradigm, in retrospect, would have provided a more structured framework within which to develop an integrated problem development and methodology. It was in fact necessary for the two science communities, natural and social, to try and develop new concepts that would enable them to address both the physical and social requirements of the original grand objectives (Pohl, 2005 and Stock and Burton, 2011).

It should be noted that historically scientists from diverse disciplines have had difficulty working across the very deeply entrenched boundaries that have been created in academic institutions (Lisowski, 2011). This situation has steadily improved since the 1970's and is at an advanced stage of being fully integrated in environmental and sustainability research (Goebel *et al.*, 2010).

Atmospheric research in South Africa

Over the past two decades I have been involved in atmospheric research that has by its nature been inter-disciplinary. The research has had three focus areas; air pollution, cloud microphysics and climate change. The fields of air pollution and climate change lend themselves well to multidisciplinary research and in fact also to the transdisciplinary paradigm. The reasons being that both require a fundamental understanding of the physical science as well as impacting directly on the daily lives of people. Successful management of air quality and climate change requires decision makers to understand the processes that are most likely to have detrimental impacts and to implement management strategies that counteract negative outcomes or put in place structures to help make communities resilient.

Air pollution studies

South Africa has passed very progressive legislation for the management of poor air quality: National Air Quality Act, 2004, (DEA, 2005). Studies that I have been involved in include the use of ground base monitoring stations as well as airborne campaigns. The majority of these campaigns have been positivist in their approach. The primary objectives of most of these research activities have been a) the characterization of the extent of air quality at remote sites and in urban townships and b) the causes of the problems. Ground based measurements have confirmed the long-range transport of pollutants from the major source region of South Africa, the Highveld, to remote sites. The atmospheric transport pathways have been determined from large-scale trajectory models and confirmed by source apportionment studies of aerosol samples collected in Mpumalanga and the Eastern Cape (Piketh et al., 1999a and 199b; Freiman and Piketh, 2004). Airborne measurements further confirmed the transport of atmospheric constituents over South and southern Africa and provided the nature of the atmospheric boundary layer and pollution plumes (Ross *et al.*, 2003; Elias *et al.,* 2003; Campbell *et al.*, 2003 and Stein *et al.,* 2003).

Many of these projects have included both an understanding of the physical environment as well as an understanding of real world problems in communities where air quality and the consequences of air pollution have had to be taken into account. These studies are a mixture of both inter- and multi-disciplinary research.

Air quality research in townships of South Africa and the implications for the local communities have been an ongoing activity (Mduli, Piketh and Igbafe, 2005). The most recent project sets out to understand air quality in a South African township in which coal is used as a major source of domestic energy. The initiation of the project included discussions between physical and social scientists as well as stakeholders such as affected communities, air quality authorities and industries (Piketh, Burger and Pauw, 2013). The project has been used in this paper to provide the framework for TR in atmospheric science (see section below).

Climate studies.

My research group and I have approached Climate studies in two distinct ways. The first is to focus on atmospheric processes that are uncertain in the debate of climate science. These include the transport and nature of atmospheric aerosols as well as the direct and indirect impacts that aerosols have on radiative forcing.

Ground based studies of the radiative properties of aerosols in the atmosphere have included measurements of the optical properties of aerosols using CIMEL Sun Photometers that have been distributed throughout southern Africa and the Middle East (Queface *et al.*, 2003; Eck *et al.*, 2003; Queface *et al.*, 2011 and Eck *et al.*, 2013). In addition, in order to characterise these properties in remote regions of the world measurements have been taken on the SA Aghulas (Wilson *et al.*, 2008). This work has been completely empirical although it can best be described as multidisciplinary.

Most recently we have made an attempt to use Global Climate Models to understand the likely future climate scenarios and devise management focused activities that might make South African cities more resilient to coupe with the predicted changes. This study has come closest to representing a TR approach to conducting a research project. Decision makers, stakeholders and scientists from both the physical and social sciences worked on solving this complex problem and results were communicated to the community through an accessible report and in a peer reviewed scientific article (Piketh *et al.*, 2014).

A Transcdiciplinary framework for atmospheric science research

A framework for TR in the atmospheric science is outlined in this section. The framework is built around the notion of a complex set of questions that require both physical and social scientists to engage with communities and decision makers to arrive at the most plausible solutions. The framework is depicted diagrammatically in Figure 1.

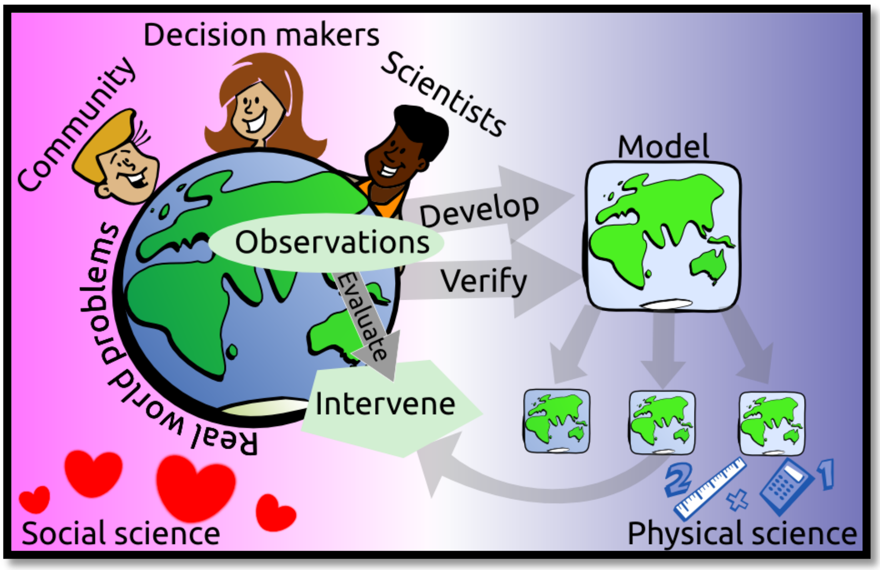

Figure 1. Schematic diagram depicting the proposed TR framework for atmospheric science.

The framework is tested using the case study of developing appropriate emissions offsets for scheduled industries that primarily address the single biggest air quality problem in South Africa which is domestic coal burning.

The problem statement and research objectives have been identified and constructed through the interaction of physical scientists, social scientists, community members, air quality authorities and industry stakeholders. The methodology is a mix of empirical investigation and community based interviews. The outcome will be a model of reality (combination of numerical and social models) with the primary objective of reducing air quality for individuals living in townships in which emissions from domestic coal burning is a major problem. The improvement in air quality will be brought about through a series of interventions that reduce coal combustion and, as a result, domestic burning emissions. The model will be tested by implementing an offset plan and evaluated through the measurement of air quality and conducting interviews to assess the social acceptability of the interventions. Findings will drive changes to the theoretical model and adaptations applied. Results will be shared with the various stakeholders, highlighting the successes and failures of the research and outlining the implications for a national offset program in South Africa.

Obstacles to transdisciplinary research in Science

Fry (2001), outlined a number of obstacles to undertaking successful TR. Over the past decade some of these challenges have been resolved but in my opinion, most of them remain.

Science discipline silos

Deeply entrenched silos of scientific disciplines remain a major obstacle to conducting inter and multi-disciplinary research in South Africa let alone TR. Scientists often cannot see the value of exploring the interconnectivity of processes to gain fundamental step changes in understanding. I have two examples where I recently experienced this obstacle. The first involved a project looking into African Horse Sickness in Southern Africa. It seemed viable to researchers in my group that environmental and climatic conditions held some clues to the intensity of the outbreak of the disease on a seasonal and annual basis. This belief is linked to the knowledge that the midges that carry the disease thrive under specific climatic conditions. It took a fair amount of discussion and arguing to convince some of the more traditional entomologists that exploring the link of the life cycle of the midge to larger scale climatic fluctuations could yield any valuable insights. The second example was the inability of a group of agricultural scientists to see that understanding the influence that the spatial variation of rainfall on a very small scale might have on crop yield and production was an important consideration.

Language and meaning

One of the things that I try to teach students in my Climatology I course is that at the initial stages of learning a subject the most important thing is to learn how to speak the language of the subject; in other words how to speak climatology. This is of course not only a problem for first year students but is a challenge for effective TR. Not only is it important for the physical and social scientists to learn to speak to each others "language" or jargon but in TR it is important for stakeholders and policy makers to speak a common language also. I believe that a great deal of time spent in joint workshops is required in all TR projects to remove this obstacle. The outputs of the TR should be written in plain and simple language that is understandable to large segments of society.

Qualitative vs. Quantitative research

In general, a significant contrast between physical and social science is the focus of the former on quantitative research and the latter on qualitative research. Both groups of scientists need to engage with alternative methodologies in order to devise a unique approach that accounts for the problems context and social needs.

Publishing multidisciplinary research

A challenge that researchers engaged in TR have had is that publishing the outcomes of the research has not always been easy. It is essential that research is published and exposed to peer review for the paradigm to grow and become more mainstream (Fry, 2001 and Kueffer *et al.*, 2007). At the same time, however, communication of results to the stakeholders and communities within which the research has been conducted is a key measure of the success of the outcomes. In particular physical scientists typically do not communicate their results in an accessible manner. This should be made a key outcome and measure of the success of the research.

Conclusions

TR is an emerging paradigm within which real world problems can be studied by combining physical and social sciences as well as community-based knowledge. TR has evolved largely out of the need to understand how the natural and human environments interact and if it is possible to ensure long-term sustainability.

My own research over the past two decades has been a mix of inter- and multi-disciplinary research. Recently it has become necessary to move towards a transdisciplinary approach for both studies that involve the understanding of climate change on human systems as well as the complex interactions of air pollution and mitigation strategies that benefit society, economic development and environmental sustainability.

Barriers to TR include the interactions between the scientists themselves, language barriers between disciplines and methodological differences in the manner in which research is conducted and reported. These challenges can best be addressed by developing strong TR framework that promote dynamic methodological approaches and account for societal needs identified by the various role players.

The interaction between scientists, decision makers and stakeholders is a challenge that requires careful attention. The use of common language with common meaning is an essential part of this interaction. One of the calls in the literature is for all involved to use plain and direct language avoiding jargon and euphemisms (Fry, 2001). The effective communication of the results and recommendations is a key performance and success indicator for any TR research project.

Agencies that control academia and academic funding do not currently have structures in place that promote and support transdisciplinary research. This needs to be addressed if society relevant research is to survive.

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