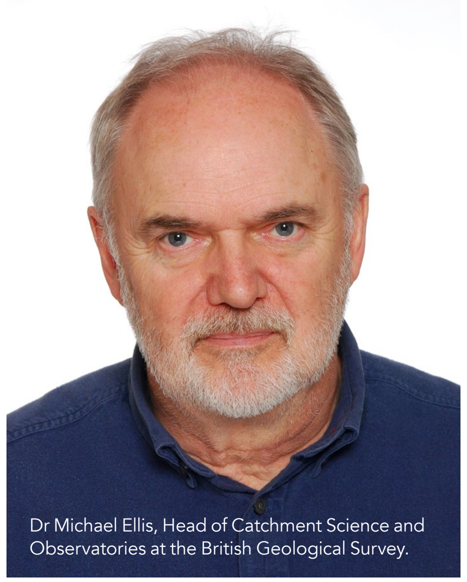
Engaging the human process in Earth science

Dr Michael Ellis is Head of Catchment Science and Observatories at the British Geological Survey. From this vantage point, he has developed a keen awareness of the intricate coupling of human and so-called natural processes. He is passionate that Earth scientists must make their work relevant at the human scale, whether that is in terms of time scale or seriously engaging with stakeholders; confronting the need to understand belief and value systems or by modelling human behaviour. At *Research Features*, we were delighted to discuss the importance of engaging the human process in Earth science with Dr Ellis.


Dr Michael Ellis, Head of Catchment Science and Observatories at the British Geological Survey.

What do you mean by "engaging the human process"?
To me, it means at least three things. The first is about the need to embrace prediction and to aim our work at human time-scales, to tackle problems that are genuinely important to society, to people. The second is about generating impact, making the research useful, which is more complicated than it might sound. The third is about incorporating the human process just as we engage the laws of physics, thermodynamics and biology.

How do you rationalise and cope with the need to work at human time-scales?
In principle, this is not a difficult sell. The combination of increasing population, rapidly increasing urbanisation, increasing inequality, continual demand for economic growth, globalisation, increasing demands for natural capital, and climate change... all of this provides a compelling driver for the need to tackle environmental problems (problems that ultimately involve earth science processes) at human time-scales. The real difficulty comes in the corollary, which is the need to predict the state of things into a human time-scale future, meaning anything from a few years to a century. Prediction in Earth science (which here includes uncertainties and is based on quantitative models), or at least in Earth-surface science, is notoriously challenging. The challenges are in effect a perfect storm of unrealistic expectations, the largely unknown role of antecedent conditions (and whether those conditions have a momentum or trajectory), the role of local contingencies, the role of emergent phenomena that in turn dictate the behaviour of the relevant system, which processes (and therefore, length-scales) we need to include and which we can safely neglect, and the role of external forcing (e.g. weather patterns). And this is just the physical part of the system; there are no humans in this predictive model yet! Inserting humans (or agents as we would call them) means that the model is essentially turned over to them, as they might change the policies and regulations that in part dictate how the environment will evolve! For the most part, we are still at the stage of isolating pieces of this system, and attempts to bring those pieces together struggle with the inevitable need to simplify several components.


Plastic washed up on the shore is a visible reminder of the impact humanity can have on the Earth.

If prediction in Earth science is so complicated and susceptible to large uncertainties, is it not better to rely on so-called expert opinion?
Expert opinion is in reality a predictive model, too. It's a combination of years of experience and a conceptual understanding (that is, a model) of how the system works. And deeply engrained in the conceptual model are biases and beliefs, whether explicit or not. That's not to say that quantitative models aren't vulnerable to similar biases, but they at least are easier to test and experiment with. And beyond the issue of biases and beliefs, there is great value in trying to develop quantitative predictive models. For one thing, they focus our attention on the important and necessary elements of our understanding. They allow us to prioritise which observations are needed to further develop and calibrate a model. Observations are very expensive, and there are so many potential observations or data to gather that we could waste a lot of resources chasing data that are secondary to the problem at hand. And so any ability to focus on which observations to chase is vital. I want to emphasise something here: a model that is not ultimately coupled to observations is more than useless, it's actually irresponsible. Models also allow us to experiment with internal parameters and external forcing conditions, essentially testing hypotheses and training our intuition, with the possibility of revealing dynamical behaviours that were completely unexpected or unnoticed. Models can be and should be pushed to a limit where they fail to reproduce reality. Models allow us to provide probabilistic estimates of outputs for particular future scenarios. You can't do all of that with an expert opinion.

Let's turn to the need to make impact. How do you think we should be approaching this?
The first step in this path is often assumed to be the need to effectively communicate our science to anyone who is willing to listen. The implicit rationale in this step often runs along these lines: if we could just learn how to communicate what we do with the same passion that we bring to the work itself, all would be well with the world. Funding agencies typically require an articulation of how the research results will be communicated and made impactful to stakeholders (stakeholders here means anything from individuals of the public to institutional organisations that may be within or without government). There is no doubt that clear communication is vital, this argument is well known and doesn't need repeating. The bigger problem, however, lies in the assumption that we know what those stakeholders need. Typically, we don't.


Major construction work changes the face of the Earth as surely as a natural disaster.

Stakeholders are dealing with an array of problems, and they generally need an outcome that is measured in terms of lives saved or bettered, an environment saved or bettered, or money saved or made, or preferably all of these. Notice that an *outcome* is not the same as an *output*, which is what the research will generate. Scientists should be engaging with stakeholders at the outset in order to work backwards from the required outcomes. Neither the stakeholders nor the researcher will know what is needed to get to the outcomes, that's where the research comes in, but the research cannot be mapped out until the outcome – the proverbial light at the end of the tunnel – is carefully articulated and acknowledged.

A lot of Earth scientists claim that it's difficult to get buy-in from policy "actors" (including regulatory agencies like the EA), leaving aside the even more difficult task of getting research into policy. Why is this?
I think that in many cases, by the time a research team comes along to the problem at hand, policy actors have already handed off the job of "ascertaining the facts" to a large and reputable consultancy. This consultancy has been paid, and there are contracts and terms-of-reference in place. At this stage in the process, researchers appear as late-stage interlopers with a questionable background (certainly not one that can be assessed adequately by the policy folks) and a short-term commitment. On top of this, researchers do not work in the mode of adhering to terms-of-reference. They are loose cannons in this respect, and their results are – by their own admission – always uncertain and in need of further research. This is not what policy makers/actors need. Researchers also approach the problem from the other end to the required outcome. In fact, the outcome is often part of the great unknown in front of the researcher. In contrast, policy actors know exactly what outcome they want. Research projects are typically designed from the bottom up, designed to answer curiosity questions. And that's a fine end-member model of research. What we need today, however, is more of the top-down or outcome-driven research programme.

It sounds like you're talking about the relatively new methodology, theory-of-change?
Yes I am, and it's being used increasingly in the context of research driven by international development programmes. It's a process that would do well to spill over to other Earth science research programmes that ostensibly aim to tackle problems at the human time-scale. One reason why we might not be very good at starting at the problem end of the research pipeline is that the problem itself is generally wicked.

How you feel about something is usually enough to trump the facts that science aims to deliver

NATURAL PROCESSES, HUMAN PROCESSES – WHY THE DIFFERENCE?

Traditionally and for all sorts of good reasons, we generally distinguish in Earth and environmental science between a natural and a human process, or more academically, between natural and anthropogenic processes. We do this largely because humans are a very late actor to the stage on which the evolution of the earth has played out. Natural processes in this context are anything that could have happened before the entry of humans, anything dictated by the so-called natural laws of physics and biology (writ large). Once a thing has been moved or transformed in some way by humans, the rules that govern that change are not codified by the likes of Newton or Darwin (at least, not simply). Of course, we've understood for a long time that the human process is as much natural as any traditional natural process. We are, after all, the stuff of the Earth, and we have evolved among similar environmental vicissitudes as most other life on the planet. Still, we retain the distinction for clarity (and less charitably, because we consider ourselves to be morally separate from other natural processes) but also for reasons of law. The distinction in law (mostly contractual) remains because legal outcomes often turn on whether an event was natural (e.g. an 'act of God' or *force majeure*) or man-made. But what does this say about the responsibility of future hurricane damage or sea-level flooding as anthropogenic climate change takes an ever-increasing hold? The distinction remains too, I suggest, because humans make things, like interstate highways, automobiles, and smartphones. None of this technology seems to be natural, nor for that matter do the symphonies of Beethoven or plays by the bard. Peter Haff argues eloquently that technology occupies a technosphere, similar to an atmosphere or a biosphere, and that technology is a natural outcome of a natural process (human evolution and human purpose). In this sense, technology is as natural as its source. And so the distinction between natural and human processes should not be based on the ill-conceived notion that the two things are mutually exclusive, but simply on the basis that the human process is a subset of all natural processes.

A typical UK landscape showing ridge and furrow and hedgerows – all strictly manmade features.

The English countryside and most of the US eastern seaboard landscape is completely man-made

And wicked in this context means what exactly?

Wicked here means a problem that appears to be intractable, that has multiple stakeholders with multiple goals, where both the problem and the solution(s) is dynamic, a moving target, and where there are inevitably trade-offs to be made, where standard optimisation approaches may not be appropriate. And most importantly, it's a problem that requires genuine buy-in from as many stakeholders as possible and as many diverse disciplines as possible. This can be a daunting process!

As you admit though, scientists are well aware that they need to communicate their science more effectively. But it seems that fewer and fewer people, our leaders included, are willing to listen to fact-based evidence. How do we cope with this?

This is where communicating our science gets hard, because the important next step is not only difficult to accomplish but difficult to even contemplate. It is the need to persuade (or less malevolently, to allow) people to *feel* comfortable with the conclusions that science comes to. How you feel about something is usually enough to trump the facts that science aims to deliver. A compelling illustration of this has occurred quite recently in the UK. In late 2017, the BBC aired the popular Blue Planet II programme[1]. This particular episode focused on the damage that plastics were doing to the marine environment and its biota. There was an enormous public outrage that quickly turned into Ministerial outrage and within a couple of months, the government announced new almost-policy to tackle the plastic problem. Now, we've known about the plastic problem for a long time, and many scientists and organisations have tried to persuade policy makers that something has to be done. The evidence has existed for years, but no action had been taken. What the Blue Planet II programme did was to put the problem in front of people's eyes and change the way they felt about it. The public's outrage was an emotional response.

The role played by personal beliefs and personal value systems in conflict with scientific information is well known, and importantly, scientists are not immune to its influence[2]. The role of belief systems in this context has emerged from the discipline of psychology, and its advocates are housed in departments that range from psychology to business and marketing. This is a difficult discipline for Earth scientists to engage with, for all sorts of reasons, but it will be worth the effort.

Let's turn to your third point then, the apparent need to engage the human process in the same way that we engage the laws of physics and so on. Can you unwrap this for us?

For me, this is the crux of the issue. The human process here means human behaviour at scales that range from individual to institutional. And we need to do this simply because the human process is now a geological agent as significant as any of the traditional geological agents. We move more mass around the terrestrial part of our planet per unit time than any traditional (or so-called natural) geological process. And we move that mass along transport paths that are governed by our ability to generate and control energy, paths that can be completely divorced from gravity. We also change the characteristics of many natural hazards either by a direct management intervention in one place that has unintended consequences elsewhere, or by indirect land-use management. An example of the former was demonstrated by Robert Criss and Everett Shock in their study of floods along the Mississippi-Missouri River system. They showed that numerous locations have had an increase of flood discharge by 2–4m, most likely as a result of flood control management schemes farther upstream.

We also generate compounds (synthetic rocks if you like) that are completely new to anything generated over the past 4.6 billion years, at least in our solar system. We have altered our landscape to an extent that less than a quarter of it is untouched by the human process, and that quarter is entirely in largely unpopulated northern latitudes and Antarctica. The English countryside and most of the US eastern seaboard landscape is completely man-made. This process is now well recognised to the extent that the geological community is defining a new geological epoch, the Anthropocene, the age of humans. Whether the Anthropocene is worthy of being a geological epoch or not, the importance of the human process, the likening of the human process as a geological agent, is not disputed. And so we need to engage that process in models that look to the future state of the Earth.

Engaging the human process in models that predict earth change is not easy, even if we pretend that humans behave rationally, which often we don't. Most attempts to do this, to my knowledge, have approached it from a complexity point of view. That is, group or institutional behaviour emerges from the interaction of many individuals (remember the agents from earlier) that are constrained in their behaviour by social norms, by economic processes, and by knowledge (usually tacit) of their environment. The importance of this sort of collective and emergent behaviour is well known in political and social science (beginning with the Schelling model in 1971 and the subsequent trail of agent-based models that tackle the emergence of cultural, political and economic patterns and events). And the discipline of behavioural economics has been tackling this process for decades (particularly the role of irrational behaviour), witness the recent Nobel prize award to Richard Thaler.

Are there examples of Earth scientists engaging the human process as you describe?

There are a few excellent attempts to model the human process as tantamount to geological processes, beginning (as far as I know) with the prescient work of Brad Werner at the Scripps Institute of Oceanography. Werner and his then PhD student, Dylan McNamara modelled the evolution of New Orleans as a coupled function of human and natural behaviours. They allowed seven types of agents (home buyers/labourers, home developers, hotel owners/employers, hotel developers, tourists, port services developers and port services owners/employers) to interact with an evolving natural system and within an economic and political system. The collective behaviour of these elements reproduced incredibly well the historical and basic elements of New Orleans (Werner and McNamara, 2007). Since then, Eli Lazarus (University of Southampton) and Dylan McNamara (University of North Carolina, Wilmington) and colleagues have shown that the evolution of partially urbanised sandy coastlines is a complex function of human decision making, property values and markets, resource costs, and physical (beach) processes. There are more examples in the fields of ecology and human geography, for obvious reasons perhaps, and slowly we are confronting this difficult process. But we should be doing a lot more, because in the end, it's our behaviour, whether as individuals or institutions, that will govern the future of our world.

A turtle swimming past ocean plastic - images like this captured the public's imagination when broadcast in the BBC documentary series Blue Planet II.

1 www.bbc.co.uk/newsbeat/article/42030979/blue-planet-2-how-plastic-is-slowly-killing-our-sea-creatures-fish-and-birds

2 For an interesting discussion of this concept, see http://theconversation.com/personal-beliefs-versus-scientific-innovation-getting-past-a-flat-earth-mentality-58842

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