FRACTAL

FUTURE RESILIENCE FOR AFRICAN CITIES AND LANDS

Climate Information Distillation: what is it and why do we need a framework?

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This briefing note has been developed as part of the Future Resilience of African CiTies and Lands (FRACTAL) project. The FRACTAL project aims to address the challenge of providing accessible, timely, applicable and defensible climate information that is needed by decision makers operating at the city-region scale in southern Africa. FRACTAL is part of the Future Climate for Africa (FCFA) multi-consortia programme. FCFA's major objective is to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent. FCFA is funded by the Department for International Development (DFID) and the Natural Environment Research Council (NERC). These knowledge products have been developed to share findings from the research in the hope of fostering dialogue and eliciting feedback to strengthen the research. The opinions expressed are therefore those of the author(s) and are not necessarily shared by DFID, NERC or other programme partners.

The Oxford Dictionary of English includes a definition of distillation that is particularly useful to us as we explore the concept of climate information distillation:

Distillation: The extraction of the essential meaning or most important aspects of something.

This definition should resonate with our personal experience of engaging with a world of opinions, perspectives, facts and figures. We are continually engaged in processes of distillation. What is the essential meaning of this article? What is the message in this movie? What is this presentation really saying? Distillation is clearly an essential part of our daily life as human beings.

The outcome of distillation depends on who is doing it. What I distill as the essential meaning of a film very often differs from what someone else distills. What conclusions I draw from reading a scientific paper often differ from what a colleague concludes. This is because distillation is part of a broader cognitive process that involves our existing beliefs[1], our knowledge and experience, our values (what is intrinsically important to us), and our interests (externalities that are important to us).

New information can inform and update our beliefs, but our beliefs also influence how we engage with new information. Beliefs are often represented by shared or private narratives that help us explain the world in which we live. If we hold the shared narrative that climate change is caused by humans and we read an article claiming otherwise, we may be tempted to dismiss the article, not on objective rationale grounds, but simply because it conflicts with our existing beliefs. This is called confirmation bias and has been widely studied and acknowledged as a significant factor in human engagement with new information.

Similarly, our values play an important role. If authority is a strong personal value, you may distil a different essential meaning from an article by a particular author than if creativity or curiosity were the stronger values. We are also influenced by our personal and professional interests. While less fundamental than our values, these are also measures of the importance we place on particular pieces of information. A statistician may identify a particular statistical result as the essential meaning within some information while an economist may focus more on potential costs or profits.

These are all different aspects of subjectivity. Subjectivity is not intrinsically good or bad. In fact the problem that emerges, and that the distillation concept aims to address, **is not subjectivity, but assumed objectivity**. Subjectivity is only a problem when it is denied or ignored. Embracing subjectivity, multiple views, values, interests, and perspectives allows for rich understanding to emerge within those involved. Furthermore, in complex problem-solving situations where, as we shall see, objectivity is impossible and no single person can provide the answers, acknowledging and even embracing subjectivity is essential to finding effective solutions. In many senses, Post-Normal Science (PNS) captures many of these elements[2].

Subjective science

Natural science is often viewed as a counter to subjectivity. At an even deeper level, science assumes the existence of objective reality, a basis for objective truth or knowledge. The natural sciences are the pursuit of this objective truth and so the norms and standards of the scientific process have developed in order to counter our innate subjectivity. We cannot simply hypothesise that the world is round, we must point to evidence and demonstrate how that evidence logically supports our hypothesis. We must do this in a way, which if replicated by someone else, will bring them to the same findings. We must embrace falsifiability. If evidence emerges that contradicts our hypothesis we cannot simply discard the new evidence. We must be willing to interrogate our hypothesis and beliefs as well as the evidence itself.

[1] For simplicity at this point I'm using the word "belief" to capture the spectrum of concepts ranging from "faith", through beliefs, and knowledge

[2] See Funtowicz, S.O. & Ravetz,J.R. 1993. Science for the post-normal age. Futures, 25(7): 739-755

At a structural level, the mechanisms and norms of science do indeed provide strong counters to the challenges that subjectivity bring to the pursuit of objective knowledge. Peer review is a key and critical component of this and counters subjectivity by ensuring that the research process, the choices made, and the conclusions drawn, are agreed to be defensible by the reviewers as well as the authors. Beyond peer review, others may counter or disagree with a published result by publishing their own work that attempts to correct or challenge prior work. And so the process continues towards establishing objective truths.

However, in many cases there is simply no known right decision or choice to be made and arguably subjective choices need to be made. Is one convective scheme better or worse than another? Is one statistical test better than another? Are these rainfall values from 40 years ago correct? We either simply cannot know, or we don't yet know, or we don't even know how to go about knowing. Similarly, assumptions must be made due to lack of knowledge, or for pragmatic reasons. Scientists are often forced to make opinion based decisions that are informed by knowledge and experience certainly, but ultimately remain subjective because they are subject to individuals experience, training, experience, beliefs, biases, and values. Peer review or commentary may debate these choices but often these debates are not resolvable, and a decision has to be made in the absence of resolution.

Some decisions are even more purely subjective and informed by beliefs, norms, values, and ethics. A climate scientist may hold particular beliefs about the injustice of climate change impacts. Even though many would argue that such beliefs should not influence the choices made by a scientist, it would be very difficult, given the role of expert opinion and judgement described above, to determine if such influences are at play. It may be valuable to assume that these influences are at play and rather make them explicit. This may be similar to the 'positionality statement' accompanying some social science research.

However, the inevitable subjectivity at play in the process of science does not necessarily invalidate the results. In drawing conclusions from an experiment, the potential impact of the assumptions and the methodological choices should be, and often are, critically considered, and assumptions and caveats explicitly communicated. Many scientific studies conclude with statements along the lines of: "The results provide evidence for the hypothesis, however assumptions A, B and C may impact the strength of this evidence in these ways, and an alternate study using a different method with different characteristics concluded differently". This provides a basis for inspiring and guiding further work.

Contradictions and uncertainty

We can of course question the depth of interrogation of assumptions, choices, and their potential consequences within the literature and within other articulations of scientific enquiry. More usefully we can argue that it is becoming increasingly difficult to interrogate these as science builds on previous results and the layers of complex interacting assumptions and choices increase significantly.

A numerical climate simulator (model) is a good example of this kind of intractability. Modern climate models, in particular those classed as earth systems models, involve so many components (algorithms, formulas, numerical methods, constants) that it is essentially impossible to know what the consequences of a particular assumption might be in every context in which that model is used to explore a question. For example, an assumption about the process of evaporation off a lake in central Africa may, under certain conditions, impact the models simulation of rainfall 500km away through a complex interplay of other non-linear dynamics. The result is that different implementations of climate models under identical boundary conditions, will produce different results.

In many cases we simply cannot comprehensively explain why the results differ. There may be some partial explanations. We may know that a particular convection scheme tends to produce more low intensity rainfall events than another scheme and this might explain some differences but the non-linear dynamics and feedbacks significantly challenges any definition explanation.

The fact that different models built on different sets of choices and assumptions produce different results creates uncertainty when the models are used to predict or project weather or climate under different boundary conditions (eg. increasing CO_2 emissions). Confronted with this challenge, we have several possible responses available. At one extreme we can decide that all models are wrong and therefore we should not use them at all. This is not a commonly chosen option though some climate scientists apply a nuance on this by ignoring the results of models at any scale finer than global. In other words, they only consider climate models to be useful simulators of global means and not regional or local climate. Another option is to attempt to decide what the best choices and assumptions should be and so construct the best possible model. An opposite extreme to this is to build as many models as we can that represent different sets of choices and assumptions and in turn assume that such an ensemble of models represents a "lower bound on the maximum range of uncertainty" in the result (Stainforth et al 2007). In between these options is the possibility of evaluating model quality or reliability and either remove poor models, or reduce their role in constructing climate messages (McSweeney et al papers).

The examples presented above illustrate not a failure of science in any way, but rather how science, and climate science in particular, robustly wrestles with methodological choices, assumptions, and the consequences for uncertainty. The same wrestle is at play when analysing historical climate trends for evidence of climate change, or estimating the economic impact of future climate change on the agricultural economy.

Climate information production

As the world attempts to respond to and plan for a changing climate, decision makers are under increasing pressure to include climate information into policies, strategic plans, and project implementation. The demand for climate information has grown significantly over the past decade and stimulated the emergence of climate information provision services, more commonly referred to as *climate services.*

The key role of climate services has been to mediate between the needs of decision makers, and the "disciplinary climate science", where "disciplinary climate science" is embodied in both data products, model outputs, reports, publications, etc. as well as climate scientists/experts themselves. Whether tailoring, translating, or even co-producing, climate services essentially still involves the distillation of messages from the body of climate data and knowledge available with the intent of informing decisions. These range from activities anchored deeply in disciplinary and academic science through to activities more akin to commercial consultancy services. Core to the process of distilling important messages from the body of available climate data, are the people involved (see example in Figure 1 below).

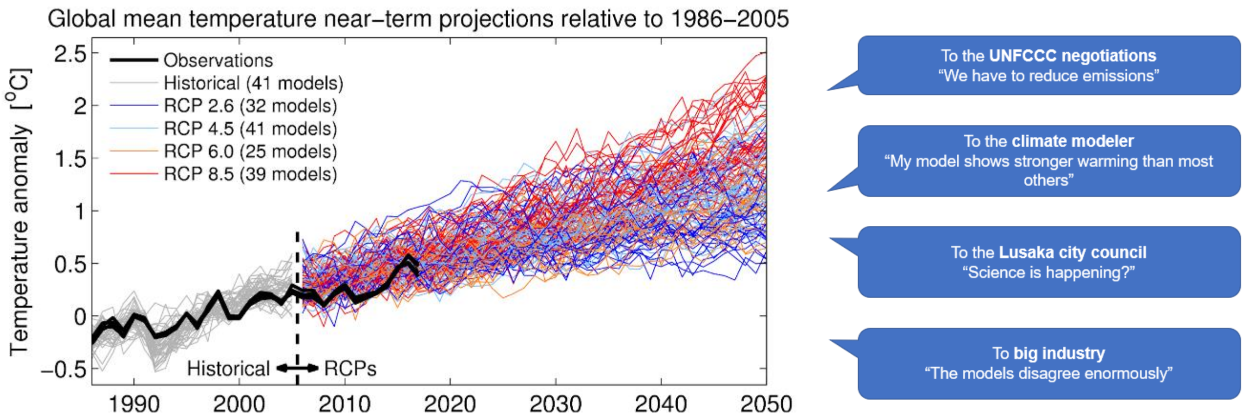

Figure 1. Examples of various interpretations of key messages from a graph showing observations and the CMIP5 model projections relative to 1986-2005 (adapted from IPCC AR5 Figure 11.25a)

Climate services products and processes, while drawing on and in some cases inspiring climate science, often sit outside of the formal disciplinary and academic science process. Climate services activities seldom starts with a hypothesis to prove or disprove (deductive), or with a set of observations/evidence from which to construct a hypothesis (inductive). Rather, climate services sets out to answer a perceived information need, a question. For example, we might be asked to answer the question: "How will climate change impact water supply in Lusaka?". While we could frame this as a hypothesis, eg: *Climate change will negatively impact water supply in Lusaka*, and then set out to prove or disprove this, I've yet to see this approach taken explicitly[3]. In practice, climate scientists tasked with this question tend to follow a common process:

1. If subscribed to the co-production/bottom up approach*:* engage with local expertise to identify the climate sensitivity (what is the climate sensitivity of Lusaka water supply?). Noting that often this step is challenging and ***many assumptions are made***. In the Lusaka case we learn that water is sourced from local groundwater as well as remote abstraction from the Kafue river. Local rainfall and temperatures, as well as Kafue catchment rainfall and temperatures would therefore be likely candidate climate variables reflective of the system sensitivity.
2. Historical trends and variations of these variables are often analysed. This is typically done in order to identify an climate change signal but can also be done in order to validate the climate sensitivity of the system or even extrapolate future changes. To do this, some observational data set must be selected. There are ***many and different datasets*** are known to have different characteristics. ***Norms*** (familiarity, trust, etc.), and pragmatics (availability, spatial resolution) most often determine the selection of a dataset.

[3] Though it does appear that often an existing hypothesis or assumption does exist (eg. climate change will produce negative impacts). This is evidenced by the introductions of many climate impacts studies that note all the potential negative impacts.

3. Future projected changes in the climate variables is typically the primary focus. Here climate scientists tend to follow **personal or institutional norms**. Some may choose to interrogate a global model ensemble such as CMIP5. Others may prefer to use downscaled products of which there are many to choose from. Some may decide to exclude certain models that are deemed to be of low performance, others will avoid this. Different approaches to uncertainty will be deployed; ensemble mean, ensemble statistics, decision scaling, ensemble sub-sampling, best model, etc.
4. Information will be presented in the form of maps of change or other visualisations and some necessarily partly ***subjective*** interpretation

Critically, these processes are seldom subjected to scientific review, that foundation stone of scientific integrity and rigour. Rather, they rest on the underlying tacit scientific authority of the experts involved and the science they draw on. However, the scientific authority is extrapolated. An observed rainfall product may indeed have passed through scientific review in the form of a publication describing its characteristics and performance. However, this generalised authority (the product generally performs well) is often extrapolated to the specific (and so we'll deploy it for our study of Lusaka) without further interrogation.

What is the consequence of the above? The consequence is that the messages that emerge, that are intended to inform decision making, very much depend on the choices and decisions made around the overall process and the various steps in the process. For example, if the approach to presenting a multi-model ensemble of projected changes is to calculate and present the ensemble average as the most likely or accurate future projection, that will form a starkly different message to an approach of presenting representative best- and worst-case scenarios. The first produces a simple/certain message, the second a wide range of possibilities.

Who makes the choices?

The question we wish to pose is not which choices are better or worse, but rather: *how are these choices made and are they informed by the decision?* Who decides that a single number from an ensemble average is "the essential meaning" of a collection of data rather than a range of options from best- to worst-case? Who decides that using a particular statistical downscaling approach, with associated assumptions and uncertainties, is the best choice? Who gets to consider the potential consequences of these choices in the context of real world decision making?

Do we push climate services back into a science modality with peer review and other mechanisms of objectivity and rigour? That is one option. But as noted above, many of these choices are not necessarily resolvable. They are open questions, or there are numerous opinions and views on the correct approaches and choices. So, while the need to continue pursuing resolution to many of these questions is important, reducing uncertainties, minimizing assumptions, and resolving debates takes time and it is increasingly clear that we don't have more time. We need a pragmatic approach to finding solutions to the emerging climate related problems that doesn't ignore the complexities of subjectivity, values, unknowns, and uncertainty, but rather allows a transparent and consequence aware negotiation of these elements in real world contexts.

Post-normality

The concept of Post-Normal Science (PNS), developed by Funtowicz and Ravetz in the 1990s, describes decision making conditions in which:

- facts are uncertain;
- values are in dispute;
- stakes are high; and
- decisions urgent.

It turns out that this is a very good description of many climate information production contexts, or to use the current framing, climate services. In particular, in "developing world" contexts these descriptors will resonate with many.

The classic or general scientific response to this post-normal context of facts, values, stakes, and urgency, is often as follows:

1. Make the facts more certain
2. Constrain the role of values (e.g. individual or societal)
3. Convert stakes into probabilities and risk frameworks
4. Do all of the above a fast as possible

Unfortunately, responses (1) and (4) are often at odds with each other in practice and given the irreducibility of much uncertainty, there are clear limits. Response (2) often defaults to a denial of the role of values, and response (3) is intellectually satisfying but often fails to address the complexity of decision making, i.e. technical, political, procedural, regulatory and institutional complexity.

The need for a framework

Recognising all of the above, FRACTAL has attempted to answer the question: "How do we then proceed?" The distillation framework (Figure 2) is an attempt to map out some guiding principles, concepts and processes as we necessarily proceed. I say "necessarily" because as much as it is clear that there are challenges and complexities involved, it is also clear that there is an ever increasing need for decisions to be made and actions taken, and that these decisions and actions are well informed.

The distillation framework is not an attempt to re-think science itself, far from it. Science is not broken, at least not fundamentally. The distillation framework is an attempt to re-think how we go about constructing information to inform decisions. The framework addresses collective distillation rather than individual distillation. In other words, it is not concerned as much with how an individual actor in the processes goes about identifying the essential meaning in some data, but rather how a group of diverse actors goes about doing the same.

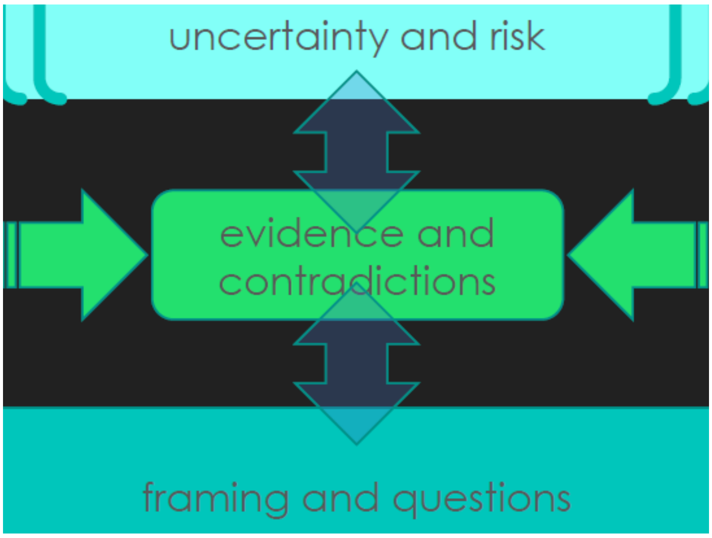

Figure 2. Graphic representation of the distillation framework

A distillation framework

The distillation framework is guided by some **core principles**:

Transparency and provenance: *Removing the foil of "trust me, science was done", and being as clear and transparent about what you are doing and it's and your limitations and strengths.*

1. **Humility:** *Being willing to acknowledge ignorance while not withholding expertise and to recognize knowledge and expertise in those outside of the science community*
2. **Dialectic:** *Conversations between equal partners are critical to counter the didactic norms*[4] *of science informed decision making*
3. ***Trust:*** Complex, contexts involving deep disciplinary expertise, experience and knowledge and many knowledge holders, rests strongly on building and maintaining trust. Collective distillation rests on being able to trust others roles in the process.

And by some **key concepts**:

Added value: *Not all facts, knowledge, understanding, expertise, adds value to a particular context. In particular, being a "scientific result" does not automatically add value*

1. **Assumptions and choices with consequences**: *Building on the principle of transparency and provenance, a rigorous interrogation of assumptions and choices made, and unpacking of the potential consequences*
2. **Good enough**: *In direct response to "decisions are urgent", a consideration of what amount of knowledge or information is sufficient to inform a decision is important. Related to added value in that more or "better" information may not substantively add value to a decision. This all challenges decision making that is delayed by insufficient information as it begs the question, what is sufficient information?*

Climate information distillation is facilitated by several elements:

Start conversations

[4] Didactic describes the teaching approach of knowledge transfer where the expert tells the subject new information

To instil the dialectic principle, distillation should start with conversations. There are many possible ways of doing this. One approach used in FRACTAL is through climate risk narratives, or stories of the future. We'll discuss these in detail below, but these stories should, at least initially, be as wide ranging, provocative, and exploratory as possible based on available evidence. Conversation starters raise questions and challenges but also break down barriers between disciplines and facilitate the sharing and integration of different knowledges.

Conversations should be started within appropriate processes designed to encourage honesty, trust, and questioning. This may be within the context of engaging with decision makers and other knowledge holders, or it maybe within a limited disciplinary context. Regardless, an initial broad reaching conversation is an invaluable starting point. From a climate information perspective, conversations can be started using the simplest of climate information which in most contexts would be that temperatures are expected to continue increasing, and rainfall may increase or decrease or stay the same.

Consensus, contradiction, and collective decisions

The objective of the conversations should be to distill the essential elements, the important aspects, of the information context. In the FRACTAL case, this took the form of identifying the burning issues within each city. While collective distillation processes often default to reaching consensus, or at least the appearance thereof, this may not always be the most valuable objective at every step in the process. Contradictions can be informative in their own right, forcing a consensus risks losing this information and risks disenfranchising important knowledge holders. Again, in the FRACTAL case, multiple climate narratives were developed for each city in order to capture the contradictions uncertainty in the climate projections, thus resisting the desire to develop a single consensus narrative.

Here is a key opportunity for distillation decisions and assumptions to be made collectively. For example, it may be desirable to reduce the uncertainty around rainfall change. That anything could happen to rainfall may be considered (a) too uncertain for decision making, and (b) not reflective of the available climate science evidence. Here the options can be placed on the table and the onus lies on the climate scientists involved to present different options along with the embedded assumptions, uncertainties, and potential consequences, including if the consequences are poorly understood or unknown… This is the most challenging aspect for the climate expert. It requires a diverse understanding of the available options and their embedded assumptions, as well as the direct consequences. The indirect consequences within the specific decision context must emerge through dialogue and deliberation.

For example, if the option of using the multi-model mean value is presented as an approach to reducing uncertainty, the direct consequence is that model projections far from the mean, such as a marked reduction in rainfall, will be hidden. The contextual consequence is that a reduction in rainfall will not be considered in the decision process. This may or may not be a significant risk. Whether it is should openly deliberated rather than opaquely decided by climate experts with little understanding of the context, or decided by decision makers without full understanding of the evidence. Such deliberations will, and in our experience do, reveal underlying values, beliefs, and even ethics. This is desirable and important as these are all at play regardless of whether they are acknowledged and deliberated. However, it does require a process that supports this, and a level of trust transparency and openness.

Write narratives

The importance of narratives as personal sense making tools was noted above. However, narratives are also shared. As much as narratives are informed by the evidence or information we engage with, narratives are often informed and modified through interaction with others as narratives are communicated. Narratives are also increasingly recognised as powerful mechanisms to communicate information. In fact narratives are so powerful that they are frequently used to influence popular opinion in ways that raise many ethical concerns.

Climate risk narratives are an example of the use of narratives. They emerged out of a recognition of the power and prevalence of narratives of climate risk and how difficult it is to influence existing narratives through presentations of complex scientific evidence. Climate risk narratives are an attempt to explicitly and openly construct evidence based narratives of climate risk in a particular context. These constructed narratives then form the basis of rich engagements with decision makers who can contribute other narratives or elements to the narratives.

Being forced to express information or knowledge in the form of an internally coherent story is extremely valuable. It encourages an integrated systemic thinking about a context and how elements relate to each other. Co-producing narratives encourages different disciplines, and experts representing those disciplines to wrestle with framings, language, and understandings. FRACTAL has demonstrated that the process of producing narratives seems to be of more value than the end product itself.

Adding value

Adding value is where the traditional climate science/services process intersects with the distillation framework. Noting that we started a conversation using the most basic of climate information assumptions, we can begin to ask how these assumptions might be usefully refined. How do we add climate information value to the process? Preceding this step by rich conversations, distilling the essential elements about the context including contradictions, and writing narratives, including contradictory narratives, means that we arrive at the question with a rich background to guide us. Perhaps it has become clear that it would be really valuable to know just how serious is the risk of a future reduction in rainfall. How do we go about adding value to move the answer from “we don’t know”, to something like “its more likely than an increase”, or even more ambitiously, “there is a 60% probability of rainfall reducing by more than 20%”? The question here is not what the climate analysis should be, but how we do that analysis following the principles of transparency, humility, dialogue, and trust.

One experiment in this space took place in a number of FRACTAL “Learning Labs”. Climate scientists and other disciplinary experts were challenged to allow the other participants to sit around them with their laptops and actually watch them “do science” and ask questions. The scientists were encouraged to be as transparent as possible and explain how they go about making decisions and what assumptions they make and why. While only a tentative experiment and clearly having many practical limitations, including that much analysis requires many days and weeks, the scientists involved and the other “observer” participants found it to be a paradigm shifting experience and definitely facilitated transparency, humility, dialogue and trust.

While there certainly are technical elements of climate analysis that would be challenging to explain succinctly, often these are nuances on top of an underlying process and set of decisions and assumptions that are fairly simple. We can imagine the process of refining the probability of decreasing rainfall in Lusaka in a dialogue form:

> *Scientist*: We will use the CORDEX Africa simulations to look at projected changes in rainfall over Lusaka in the 2040s.
> *Observer*: What are the CORDEX Africa simulations?
> *Scientist*: They are regional climate model simulations of African climate forced by CMIP5 global model simulations.
> *Observer*: Are they very accurate?
> *Scientist*: Some of them fix some of the errors the global models make, so they should be better than the global models.
> *Observer*: Should be, or are?
> *Scientist*: Well I guess they should be, but we can’t really be sure. You can’t actually validate a climate model projection of future climate because the future hasn’t happened yet.
> Observer: Okay, well if some of them fix the global models, then we use the good ones?
> *Scientist*: We could, some scientists do that. They remove models that don’t represent historical climate well. But other scientists feel that is unjustified.
> *Observer*: What kind of scientist are you?
> etc.

The point of this dialectic approach is that it strongly instills the core principles of transparency (the scientist has to be very clear about what they are doing and why), humility (it very rapidly identifies things that the scientist just doesn’t know), and trust (if the observer can understand and see what is being done, and it makes sense, then it builds trust in the resultant information).

In a broader context (ie. not a one on one discussion), it even creates opportunities for decision makers to play a role in analysis decisions. With enough understanding of the process, decision makers could contribute to deciding, for example, whether to draw on experimental high resolution downscaled data, or lower resolution but better interrogated and understood data.