A critique of the scientific content of Richard Lindzen's Seminar in London, 22 February 2012

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Introduction

The objective of this note is to produce a short critique of some of the major scientific arguments in the talk given by Richard Lindzen (RSL) in the House of Commons Committee Rooms. It is not intended to give a detailed slide-by-slide analysis of the talk.

We welcome the fact that RSL accepts that:

> There has been a large increase of atmospheric concentrations of carbon dioxide and other greenhouse gases due to emissions resulting from human activity over the past 150 years (although we do not agree that "equivalent CO_2" concentration has yet doubled, as claimed by RSL on Slide 4[6]),
>
> Global average surface temperature has very probably warmed by about 0.7°C in the same period (RSL Slide 10, or 0.8°C in Slide 4),
>
> Increasing carbon dioxide alone, and in the absence of climate feedbacks, should cause about 1°C warming for each doubling (RSL Slide 3).

We agree that scientific arguments should be based on physical reasoning and data, without exaggerating either the effects or our certainty (or uncertainty) about them. RSL is right to draw attention to uncertainties in climate change feedbacks e.g. associated with clouds. However, it is wrong to infer from this that we know nothing about these feedbacks. Contemporary science suggests unambiguously that there is a substantial risk that these feedbacks will lead to human-induced surface temperature change considerably larger than 1°C in global average this century and beyond.

Temperature and other data

We do agree with RSL that "obsessing" over the global-average temperature is not useful. However a global average is not exactly "an obscure statistical quantity". It is certainly true that on time-scales of a decade or less it is usually a residual of positive and negative anomalies in different regions and shows considerable year-to-year variability, associated with, for example, natural variations of sea-surface temperatures in the tropical Pacific Ocean. We also agree that "the quantity is easy to abuse". Unfortunately one of RSL's slides (Slide 12) on this contains a major error. The slide purports

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to show that one of the research institutes that performs an ongoing analysis of the global temperature record since 1880 revised its 2008 analysis of past data in 2012 so as to give an increased warming at a rate of 0.14^{o}C per decade. In fact RSL's figure was obtained by looking at the difference between data from land regions only in the later analysis and land *plus ocean* in the earlier analysis. Since the land is warming quicker than the ocean, a spurious impression of "manipulation" resulted. RSL has since admitted this error.

RSL is not consistent in his discussion of the accuracy of past temperature data. Having first agreed that there has been a century time-scale rise in global surface temperature of 0.7^{o}C or 0.8^{o}C, he then casts doubt on the accuracy of the global temperature record in the past 150 years. Following that he refers to "changes are small (order of several tenths of a degree)" and then remarks with great confidence that "changes of the order of several tenths of a degree are always present at virtually all time scales". The fact of the matter is that one would not expect the impact of a gradual increase in greenhouse gases to be a smooth year-on-year increase in temperature, but rather as a multi-decadal warming trend with periods of greater warmer and lesser warming (or even periods of cooling) on shorter timescales as seen in the observational record. Such a variation in temperature trends is also simulated in climate models; the recent decade with little trend, although unusual, is certainly not unprecedented in the recent record and is a feature of climate model projections for the future.

For Arctic sea-ice area, RSL shows the record since 1979 in a manner such that the dominant impression is the regular annual variation in sea-ice area between the late summer minimum and the late winter maximum. If each month is looked at individually (see for example http://nsidc.org/arcticseaicenews/) then it becomes apparent that the (March) maximum has decreased by about 10% in the period and the (September) minimum by about 30% over this period, with this longer-term trend superimposed on year-to-year variation. Since 1979, the availability of satellite data has allowed a much more complete coverage than hitherto possible. This contrasts with the very local and very variable data on sea-ice state that led to the earlier 20th century statements quoted by RSL.

In a recent paper, whose conclusions were referred to by RSL, Wunsch et al (2007) stated that it was difficult to close the budget for global sea level rise because of the complexity of some of the terms in it and the lack of detailed understanding of them. In consequence, according to Wunsch et al., it is not easy to predict future sea level rise. However, again RSL wrongly interprets uncertainty as to the magnitude of the expected rise in sea level with there being no reason for concern about it.

Palaeo data and climate

RSL comments on the correlation that is apparent between Antarctic temperature and climate over (in the full and most recent dataset) the last 800,000 years. He correctly points out that there is regional variability in the climate response, and that there is a small lead of Antarctic temperature with respect to CO_2 at the termination of the most recent glaciation. It is important to note that the observations show a small initial rise in southern and perhaps deep ocean temperature, followed by several thousand years in which these temperatures and CO_2 rose together.   This is entirely consistent with the role of CO_2 as an amplifier of an otherwise small external forcing. The current understanding is that it is the rise in CO_2, and the associated feedbacks, that amplifies a regional forcing (due to changes in the Earth's orbit and in ocean heat transport) into a strong (3-5°C) globalscale warming. RSL's claim (Slide 28) that the ice ages can be explained "simply" with orbital variations confuses the evidence – any correlations between orbital parameters and climate change are not evidence that they are the *sole* factor causing climate change.

There is an interesting dichotomy in RSL's line of argument between the implication in the rest of the presentation that the climate is rather insensitive to change, and the observation that, on glacial-interglacial scales, even very small changes in energy input led to massive change. The speculation with which RSL concludes his talk (Slide 58) that a new ice age may occur in the next several thousand years ignores the fact that the present orbital configuration is one of low orbital eccentricity. If the orbital changes are indeed the trigger for ice ages, it will likely be 50,000 years before the orbital configuration is favourable for ice ages (Berger and Loutre, 2002).

Models

RSL generally uses the term models to refer to coupled ocean-land-atmosphere general circulation models[7]. He contrasts these general circulation models with reasoning involving "physical processes that can be independently assessed by both observations and basic theory". We prefer to think of a hierarchy of models from the basic theory and those models designed to focus on a limited range of processes, to the most complex general circulation models which represent many components of the climate system (the atmosphere, the oceans, the land surface, and the cryosphere). At every stage models should be evaluated by exhaustive comparison with observations. The models encapsulate our understanding of the basic science of the climate system, including for example, Newton's laws of motion, the laws of thermodynamics and the quantum theory of radiation. When deficiencies are found at one level then improvements are sought and the lessons learnt should cascade to models at other levels. This is, of course, the ideal: the actual development of the science is rather more irregular but very definitely in this direction. Even the models at the more complete and complex end contain many uncertainties and deficiencies, which are widely recognised within the modelling community, but they are the best guide we have as to how the climate system may change in the future. Their results are not to be accepted in an unquestioning manner; they should be analysed in detail, with the dominant processes behind any climate variability and change thoroughly investigated using observations and simpler models in the hierarchy.

It is interesting that, given his general scepticism over models, RSL is able to "know that the models are correct", and hence "some of the recent temperature data must be wrong" – Slide 22, in giving a maximum in warming in the tropical upper troposphere – a hot spot. His view is based on the physical argument that the tropical atmosphere will have a temperature change with height consistent with it being neutral to tropical convection. Whatever the cause of surface warming in the tropics, our current understanding, in agreement with RSL's, is that this warming will amplify into the upper troposphere. Whether this is consistent with observational data from radiosondes and satellites has been a continuing source of debate, and has been used by those who question the

[7] Though on Slide 28 he confuses the issue by referring to "our present approach of dealing with climate as specified by a single number, globally averaged surface temperature, that is forced by another single number, atmospheric CO_2 levels, for example" – the most complex climate models resolve changes in temperature (and many other atmospheric and oceanic properties) at spatial resolutions of typically 100 km and at many levels in the atmosphere (and ocean) and include many more climate change influences (human and natural) than just CO_2.

validity of models as strong evidence for their rejection. The current understanding is that models and data are probably consistent within the model uncertainty and observational error, but there is still no firm observational confirmation of the “hot spot”. However, RSL uses the possible conflict between models and data to question the accuracy of the temperature data. Surprisingly his focus is not on the data for the middle and upper troposphere but on the surface data, with the suggestion that the warming there is actually less than analyses have given

Similarly in slides 34-38, RSL surprisingly invokes the lack of change in surface temperatures during summertime in the Arctic as evidence that “CO_2 in not a major player”. It has been well-established for decades, using the same models invoked by RSL for his “tropical upper troposphere hot spot” argument, that Arctic summer temperatures are not expected to increase significantlly, in response to increasing CO_2 levels, while sea-ice still exists in the Arctic. The physical reasoning is straightforward: once the Arctic sea-ice has been brought to melting point (as it is during summer), any additional energy goes into melting the ice, rather than raising its temperature.

Climate forcing and sensitivity

On Slide 3, RSL claims that the derived sensitivity of climate to a doubling of CO_2 is less than 1^oC, based on the assumption that all the observed warming is due to atmospheric greenhouse gases. This claim would be wrong even without this assumption, because it confuses the transient warming as CO_2 rises with the larger warming that would later be achieved as the oceans, with their large thermal capacity, come into equilibrium with the changed atmospheric state. The assumption itself is unjustifiable as it neglects other mechanisms that drive climate change. RSL notes that high sensitivities are possible only by “invoking unknown additional negative forcings from aerosols and solar variability as arbitrary adjustments”. It is indeed true, as is made clear in successive assessments of the Intergovernmental Panel on Climate Change, that there are considerable uncertainties in estimating the impact of aerosols on climate. However, to characterise these as “unknown” fails to recognise the considerable advances in understanding of the distribution and characteristics of aerosols over recent decades, from individual field campaigns, establishment of new observing networks, and observations of trends in solar radiation reaching the Earth’s surface. These present strong evidence that, in total, changes in aerosol concentrations will have cooled the climate system over recent decades. “Uncertain” does not imply “unknown” which in turn does not justify the assumption that their effects are, therefore, zero.

We are puzzled by RSL’s claim that unknown “solar variability” has been invoked by modellers to obtain a higher climate sensitivity – again, it is widely accepted that there are significant uncertainties in establishing solar variability, especially prior to the satellite era (i.e. before about 1980), but most models use reconstructions of solar variability that lead to a slight *warming* of the climate system over the past century, contrary to RSL’s assertion.

RSL claims to have estimated climate sensitivity from observations and to have shown that it is substantially smaller than that estimated from models. What he fails to note is that others have shown consistency between models and observations using the same observational data but a different methodology (e.g. Trenberth et al, 2010), using different data and the same technique (Dessler, 2011), or different longer-term data and different methods (e.g. Forster and Gregory, 2006). Even Lindzen and Choi (2011) show consistency between observations using their method with results from climate models which include a detailed representation of the oceans, as opposed to models in which with sea surface temperatures are prescribed from observations.

Several authors have criticised a number of aspects of RSL's approach, including the fact that he bases his main work on data confined to the tropics (20^{o}S to 20^{o}N) and the dependence on data and methodology used noted above. A more general criticism is that in this relatively short period the variability in the data is dominated by El Nino events. In these, the sea surface temperature changes are driven by changes tropical ocean currents, and this would seem likely to involve processes very different from those driven by a gradual increase in greenhouse gas concentrations. It should be noted that some of the difficulties in RSL's approach are common to other attempts to estimate climate sensitivity from observations – none of the studies to date can be said to be definitive.

On the other hand, RSL's assertion that the water vapour feedback may be negative goes against the body of observational, theoretical and modelling evidence which indicates that it is strong and positive. Modelling and observational studies do not rule out the possibility of a negative cloud feedback, though most models suggest a weak to moderate positive cloud feedback (there is not a strong positive feedback in models as RSL insinuates). In short, there is little credible evidence to support the low climate sensitivities that RSL proposes.

Concluding Comments

A pervasive aspect of RSL's presentation was the conflation of uncertainty with ignorance; in his view, because we are uncertain about some aspect, we therefore know nothing about it and any estimate of it is mere guesswork. In this way we believe RSL does a disservice to the scientific method, which seeks to develop understanding in the face of inevitable uncertainties in our knowledge of the world in which we live. The scientific method has served society well for many hundreds of years, and we see no reason to doubt its validity for trying to quantify the risk of climate change and its impacts on society this century. On this basis we reassert that there is a substantial risk of human-induced climate change considerably larger than 1^{o}C in global average this century and beyond. There is nothing in RSL's talk to cast doubt on the existence of this risk. It is up to policy makers, not scientists, to decide whether governments should take concerted mitigating action to try to reduce this risk. On this we do not comment.

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