Climate Change Science Program Planning Workshop:

Session #11
Scenario Development
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Goal of CCRI Scenario Activity:

"develop, maintain, and enhance the capability to answer "If…,then" questions relevant to the full range of climate change decisionmaking…" (Page 45)

Two main questions:

• To what does "If…," apply?

• Do program resources create a one-legged or a three-legged stool?

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The charge to Panel #11 is to review and comment on the "scenario development" portions of Chapter 4 of the draft Climate Change Science Program Strategic Plan. As specified in this chapter, the goal of the Climate Change Research Initiative (CCRI) is to "develop, maintain, and enhance the capability to answer 'If…, then' questions relevant to the full range of climate change decision making…" (Page 45, draft Strategic Plan).

My remarks focus on two main questions and challenges to the scenario development and "If…, then" framework.

•First, to what does "If…," apply? This is a far more complex issue than apparent from the current draft of the Strategic Plan.

•Second, not withstanding that the SSCP is a science program, do the resources available to the CCRI effectively create a one-legged stool that will be unable to provide the critically needed decision-support basis for policymakers?

•Additionally, issues involved in two other CCRI proposals for testing climate model results (contained in Chapter 4) are raised. These involve testing climate model results more carefully against data for the last 25 years as well as against paleoclimate record.

To what does "If…," apply?

How do you keep the scenarios both manageable and meaningful with multiple possibilities for:

- Climate history ?
- Human activity & technology ?
- Climate models ?
- Climate change outcomes ?
- Impacts ?

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There is an extensive history of climate scenario development. The Intergovernmental Panel on Climate Change (IPCC) *Third Assessment Report* (TAR) and the IPCC's *Special Report on Emission Scenarios* (SRES) provide numerous examples of the difficulty facing the CCRI in scenario development to support "If…, then" analysis for policymakers.

A key aspect of an "If…, then" framework is keeping the scenarios internally consistent, manageable and meaningful while openly dealing with the difficulties that occur because of:

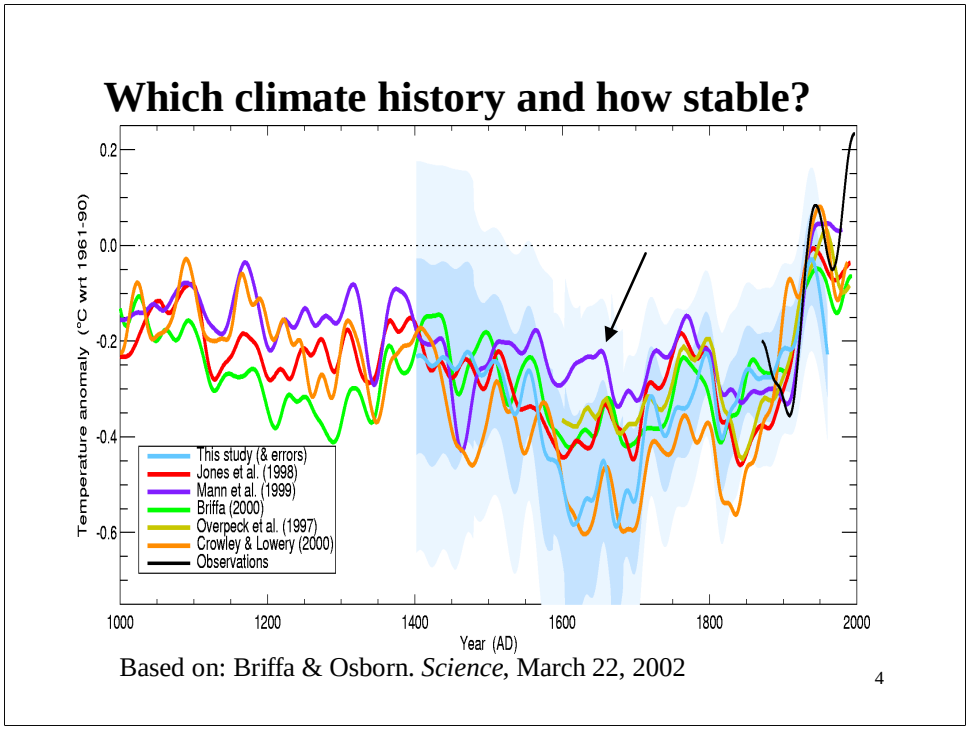
•Multiple climate histories;

•Multiple possibilities for human activity and technology development;

•Multiple climate formulations and multiple ways to model these formulations within multiple climate models;

•Multiple possible climate outcomes; and

•Multiple impacts.

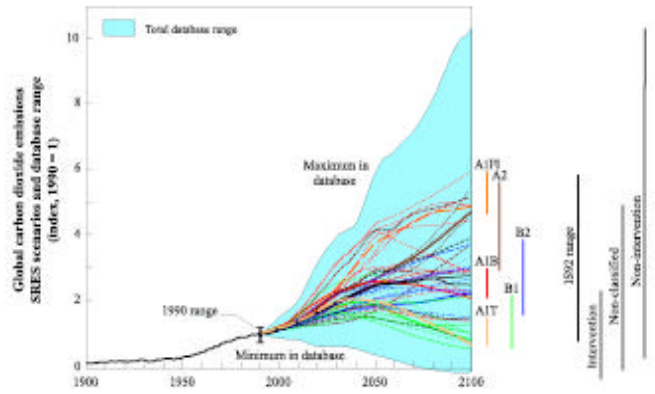


The first indication of "If…, then" scenario development difficulty is the fairly recent blossoming of multiple climate histories. The above figure is based on the March 22, 2002 issue of *Science* and illustrates temperature anomalies over the last 1,000 years as reported by six different major studies developed using paleoclimate data.

The temperature anomaly highlighted by the arrow is the anomaly history highlighted in the IPCC-TAR. This IPCC-highlighted climate history appears to have the smallest temperature anomaly and the least temperature oscillation over the last 1,000 years. This raises the important and broad question, was recent past climate quite stable or relatively volatile? From a climate modeling perspective, this figure is important because it illustrates the difficulty of separating anthropogenic impacts from natural variation when recent climate is neither quite stable nor known with much accuracy.

However, the implication of this figure for "If…, then" scenario development and policy support is different. The implication for the CCRI is that past climate history is not known. Until the differences between these various climate histories are resolved, there are multiple climate histories. No climate model, with a single set of parameters and assumptions, can accurately reproduce all of the above climate histories and the ability to reproduce "history" is critical for separating natural variation from anthropogenic impacts. So the very starting point of scenario development has multiple scenarios, even for climate history.

Human Activity – multiple carbon scenarios with observational equivalence issues



Source: IPCC, *SRES - Executive Summary*

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The problem of multiple scenarios carries over to the next stage of climate policy scenario development – what are greenhouse gas emissions from human activity?

The familiar figure above is from the Executive Summary of the IPCC *Special Report on Emission Scenarios*. This emission scenario effort developed several different "families" of scenarios, each hypothesizing different development paths for the developed and developing world. Sensitivities within each scenario family also were considered.

The issue here is not that there are many possible scenarios or that the range of future emission profiles is very large. The issue here is that many of the scenarios are "observationally equivalent but functionally different."

That is, there are many instances where the same emissions profile occurs under different scenario families – i.e., the scenarios are observationally equivalent. However, even if two scenarios are observationally equivalent, they may be functionally different. Because scenario families arrive at the same emissions trend for different reasons, each observationally equivalent scenario would respond differently to a policy "If…, then". The problem this causes for "If… , then" policy analysis is that for a single "If", there are multiple "thens" even before potential climate impacts are modeled.

What's in the climate models?

…. Natural = Solar & Volcanic

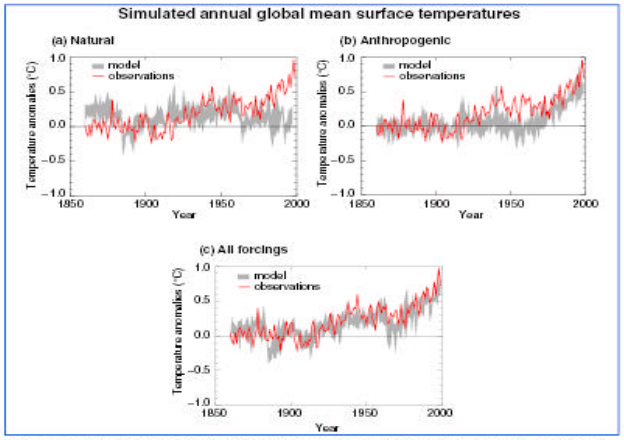

Figure 4: Simulating the Earth's temperature variations, and comparing the results to measured changes, can provide insight into the underlying causes of the major changes.

Source: IPCC, *TAR, WGI-SPM*

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This single "If…," multiple "then" issue carries over into the climate models but for somewhat different reasons. Some of the science issues are illustrated in the above figure from the IPCC Working Group I *Summary for Policymakers* from the *Third Assessment Report.*

Very briefly, the above figure was used to argue that: a) natural variation alone does not explain all temperature anomalies over the past 150 years; b) neither do anthropogenic impacts alone, but; c) natural variation and anthropogenic impacts combined do a "good" job of explaining 150 years of temperature anomalies.

However, the issue of multiple outcomes is present many reasons, two of which are: 1) what is included in natural variation, and; 2) how that natural variation is represented.

In the above IPCC example, natural variation was described as including solar and volcanic variations. Look only at solar and ask, what does the full IPCC report say is known about solar variation and how it impacts the earth's climate?

What's <u>really</u> in a climate model?

According to the full WGI report on <u>solar</u>:

• "However, because of the large uncertainty in the absolute value of TSI [total solar irradiance] and the reconstruction methods our assessment of the <u>'level of scientific understanding' is 'very low.'</u>"

• "We conclude that the mechanisms for the amplification of solar forcing <u>are not well established.</u>"

Source: IPCC, *TAR, WGI*-Full Working Group Report, pages 382 & 385. 7

If "solar" in the preceding figure is total solar irradiance forcing and the mechanisms for amplification of that forcing, then the full IPCC report says our "level of scientific understanding is "very low'" and that the mechanisms for amplifying this impact "are not well established." The implication here is disturbing – was a key IPCC finding based on a "very low" level of understanding and "not well established" mechanisms?

This is important, but the issue for "If…, then" scenario development is broader. This example simply illustrates that there are important uncertainties in developing the equations that make up climate models. Continuing the example of possible solar impacts on the earth's climate, three basic issues are obvious;

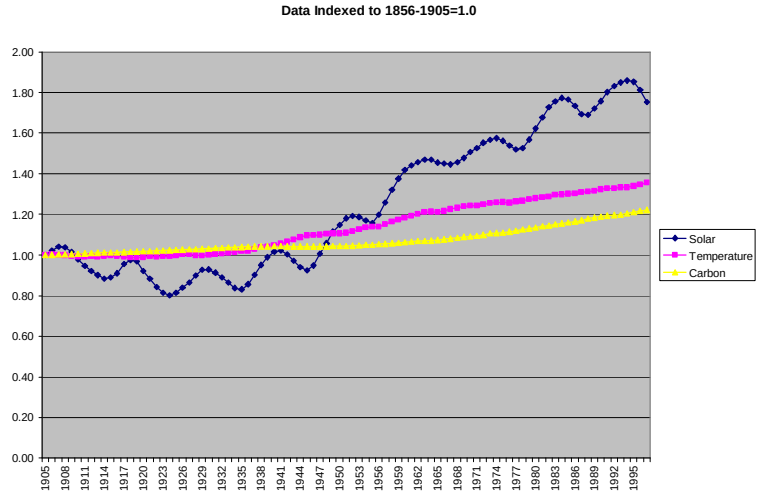
• What is/are the mechanism(s) by which the sun impacts the earth's climate?

• How are the(se) mechanism(s) implemented through equations in a climate model?

• What data is used as input data into the solar portion of a climate model?

In the current state of scientific uncertainty about how solar activity might impact our climate, it is likely that each of these questions has multiple possible answers. And out of that comes more multiple scenarios. And this is only for the question of solar impacts.

Carbon & Solar & Temperature – 50 Year Averages
Issue: Separating Multiple Influences



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The example of a multiple scenarios resulting from possible solar impacts on climate can be carried farther. An article in the 29 November 2002 issue of *Science* investigates the "intriguing possibility that a cosmic ray – cloud interaction may help explain how a relatively small change in solar output can produce much larger changes in Earth's climate." This article does not come to strong conclusions, instead focusing on possible physical processes and research possibilities.

But the article raises a number of significant issues for "If…, then" analysis.

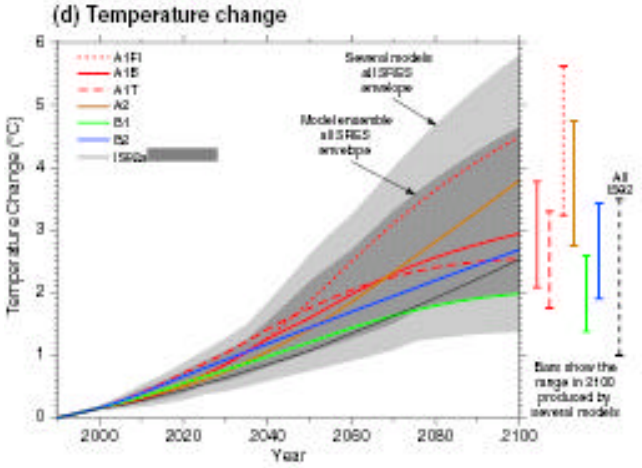
•The proposed mechanisms for solar impacts appear to be different than those discussed in the IPCC TAR, implying that multiple mechanisms are possible.

•The article clearly focuses on "one solar cycle" (the roughly 11-year cycle in sunspots).

•Even if there is a cosmic ray-cloud connection, there are multiple ways of modeling that connection. For example, the article does not address the issues raised by the above figure which illustrates that recent sunspot counts (see the top blue line with sunspot counts averaged over the preceding 50 years) are far greater than that 50 and 100 years ago. Focusing only on a single recent solar cycle could entirely miss this fact.

So even with a single element in climate modeling, in this case a solar cosmic ray – cloud interaction, there are multiple ways of modeling the interaction, and this yields multiple "then"s in "If…, then" analysis for policymakers.

Multiple measures of climate change for <u>one</u> measure of change



Source: IPCC, *TAR, WGI-SPM*

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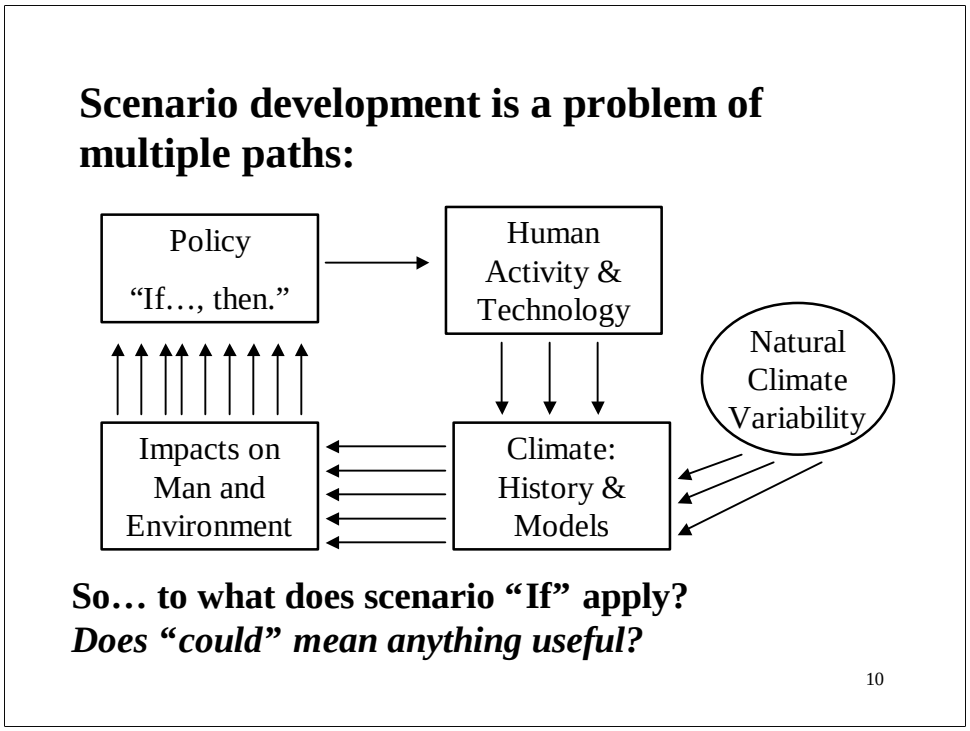
Very briefly, this figure from the TAR Working Group I *Summary for Policymakers* further illustrates the problem of observationally equivalent but functionally different scenarios.

There are multiple scenarios that yield effectively the same temperature change paths, and yet these scenarios come from different SRES scenario families which are functionally different. A single policy "If", when applied to the economic models (for the emission trends, etc) and climate models, will yield multiple "then"s.



This figure simply highlights the concerns raised in the preceding figures. A single "If" policy scenario will almost universally yield multiple possible results if logic chains are followed rigorously. But without rigorous logic chains, possibilities are being ignored.

Under these circumstances, there are so many "could happen" outcomes that any single "could happen" outcome is at best a highly selective representation of the many possible outcomes.

The real challenge facing the CCRI in developing meaningful "If…, then" analysis for policymakers is to address the "single IF, multiple THEN" problem.

Can you sort through multiple paths?

• **Probabilities:** A reasonable & widely acceptable basis for assigning probabilities?

• **Sensitivities:** Identify key but uncertain assumptions which determine outcomes?

• **Range of Results:** How select without biasing results?

Problems: avoiding arbitrary choices and infeasible demands on computing time

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A number of approaches have been used for dealing with multiple paths including observationally equivalent but functionally different paths. The severe complexities of the climate issue, however, cause serious difficulties for each of these approaches. For example:

•**Probabilities** could be assigned to each possible outcome, but what is the basis for these probabilities? Possible solar impacts indicate just one problem here. There are a number of competing theories and mechanisms for solar impacts. Weighting each theory equally is not only arbitrary, it also implies that the theories are mutually exclusive, which they may not be.

•**Sensitivity runs** could be made for all reasonable possibilities to identify which assumptions are key to different results. However, the number of options is enormous and the significant computing time for a comprehensive evaluation of each option multiplies the difficulty of this approach.

•Plausible **ranges of results** could be selected, but what is the selection basis? What is the basis for excluding outliers?

All these choices involve the possibility of arbitrary choices and/or infeasible demands for computing time. And this illustrates a key difficulty of meeting the "If…, then" goal of scenario development for policymakers.

2nd Question: CCSP focuses on science. Is that an adequate basis for "If…, then" ?

What is the value of early information?

• Cost of climate change	$31 billion	
• Mitigation cost	$16 billion	
• *Climate feedback*	*$7 billion*	←
• Population growth	$5 billion	
• GHG/Output ratio	$2 billion	
• *GHG retention rate*	*$1 billion*	←
• Productivity growth	<$1 billion	

Source: Nordhaus, "What is the Value of Scientific Knowledge", *Energy Journal, 1997,* Table 4.

"If… then" scenarios need:

• Climate – Impacts – Mitigation & Adaptation

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A second key issue for "If…, then" analysis as outlined in Chapter 4 is that "If…, then" issues are almost exclusively viewed as science oriented. Admittedly, the CCSP and the CCRI were created as part of the administration's climate science initiative. However, there are strong indications that issues involving economics of mitigation and adaptation as well as climate change impacts (as differentiated from climate change) are at least as important and perhaps as complex as fundamental issues in science.

For example, Dr. Nordhaus (Yale University) used an integrated assessment model to estimate the value of improved information. In one sensitivity case shown above, the value of improved information (knowing now what would otherwise be discovered at a date certain in the future) for seven key aspects of the integrated assessment model were tested. Climate science items (*italicized*) ranked a weak third and sixth out of seven sensitivities reported. In this example, the combined benefit of information on the "cost of climate change" and the "cost of mitigation" were more than seven times that of "climate feedback" sensitivity – a key climate science issue.

Since the "If…, then" approach in Chapter 4 of the draft strategic plan barely even acknowledges these non-climate science issues, is the proposed scenario development approach missing critical elements necessary for policy assessment?

Two other quick issues:

• *Carefully test climate model results against last 25 year record. (Page 49)*

  • Good, but sounds like testing an economic model against half of a business cycle.

• *Carefully test climate model results against the paleoclimate record. (Page 49)*

  • Good, but which paleoclimate record? Are we in a stable climate or a climate system with long-term variability? What is the future climate baseline?

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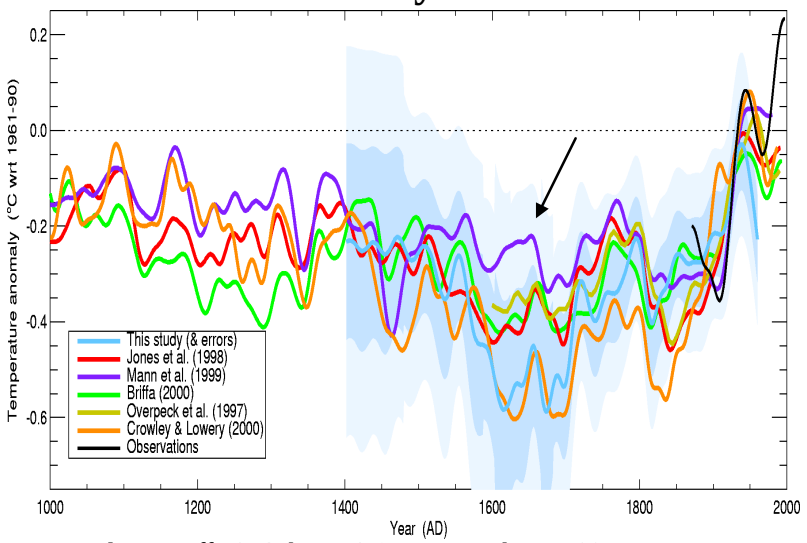
Very quickly, two other issues from Chapter 4 are noted.

First, the chapter proposes much more careful comparison of climate model results with the detailed climate record of the past 25 years. This, by itself, will be useful. But it sounds somewhat like building an economic model based on one-half of the business cycle – that model will not help you much during the other half of the business cycle. If there are important elements in climate (including natural variation or oscillation) that persist for significantly longer than 25 years, then the proposed analysis could well be misleading because the climate models will be evaluated for only a portion a climate "cycle."

Second, Chapter 4 proposes to carefully test climate model results against the paleoclimate record. As illustrated again on the next slide, the obvious question here is, tested against <u>which</u> paleoclimate record? A model that performs "well" against one record will not perform "well" against the others. Yet it currently is unclear which of the climate "histories" is more meaningful.

Which climate history and how stable?



Based on: Briffa & Osborn. *Science*, March 22, 2002

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