Issues in Modeling Cascading Uncertainties

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As a Gap-filler for This Session, I Offered to Talk a Bit About One Uncertainty Issue in IAM Modeling:

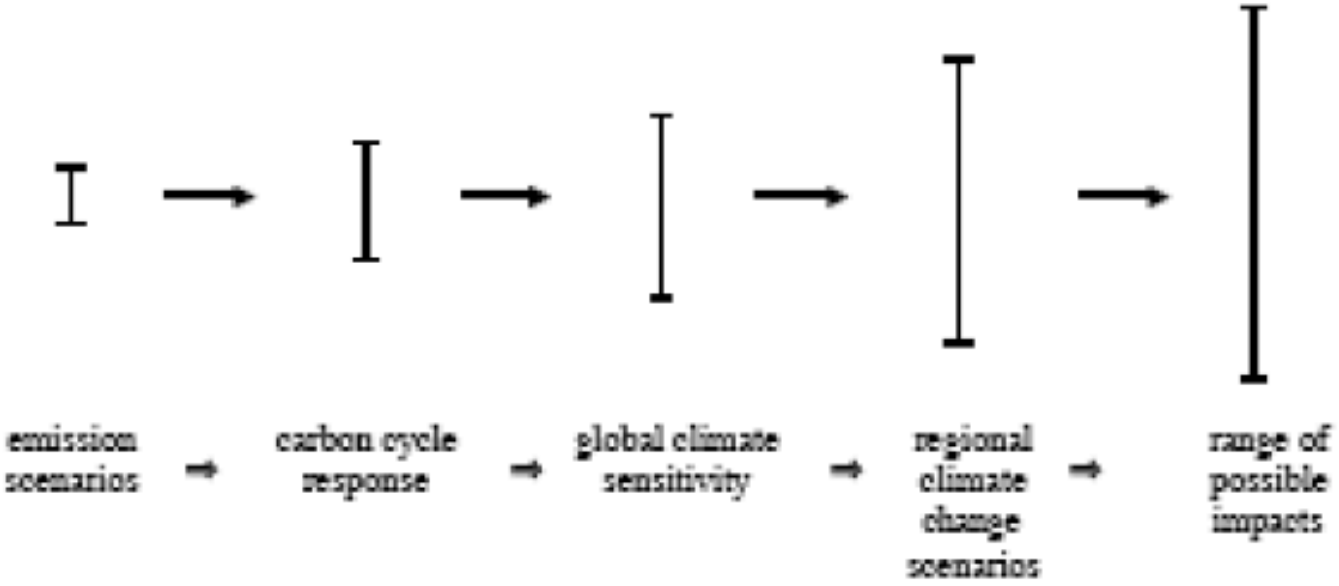
- The issue is that often, as steps in many IAM analytical processes unfold, uncertainties in preceding steps are preserved, and each succeeding step adds further uncertainties: in a sense, "cascading uncertainties"
- If a user of the analysis looks carefully, this can raise questions about whether any impact conclusions can be associated with a high level of confidence (Pat Reed…)
- I will am going to very briefly review two examples of this issue, summarize a current case study of cascading uncertainties related to projecting Greenland ice sheet melting, and consider possible lessons for IAM modeling

Just a Part of the Challenge of "Reducing Uncertainties about Uncertainties", e.g.:

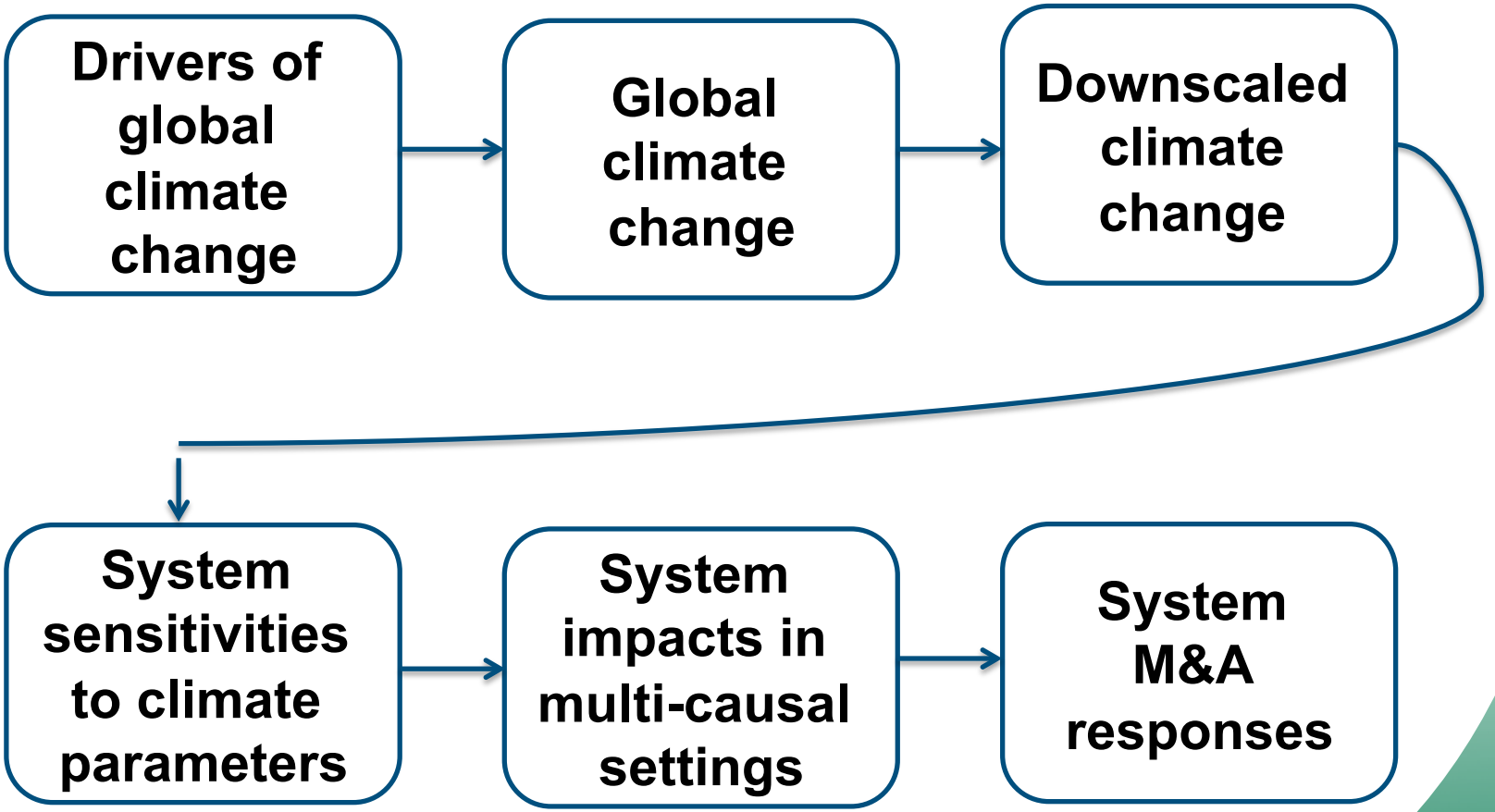
- Ambiguously defined concepts
- Complications in projecting human behavior
- Limitations in available data: gaps, biases, etc.
- Limitations in modeling: structure, functional relationships, imported parameters, approximations, incorporating non-stationarity, etc.
- Coupling models and stages of analysis (what's endogenous vs. what's exogenous): different uncertainties, different metrics, scales, logics…

The Classic Depiction of Cascading Uncertainties from One Modeling Focus to Another (Roger Jones, 2000):

Figure 2.



Accounting for Uncertainties in Integrated Assessments of Climate Change IAV:



But There Is Also Another Familiar Instance of Cascading Uncertainties As Well – Within One Modeling Focus as the Scope Enlarges:

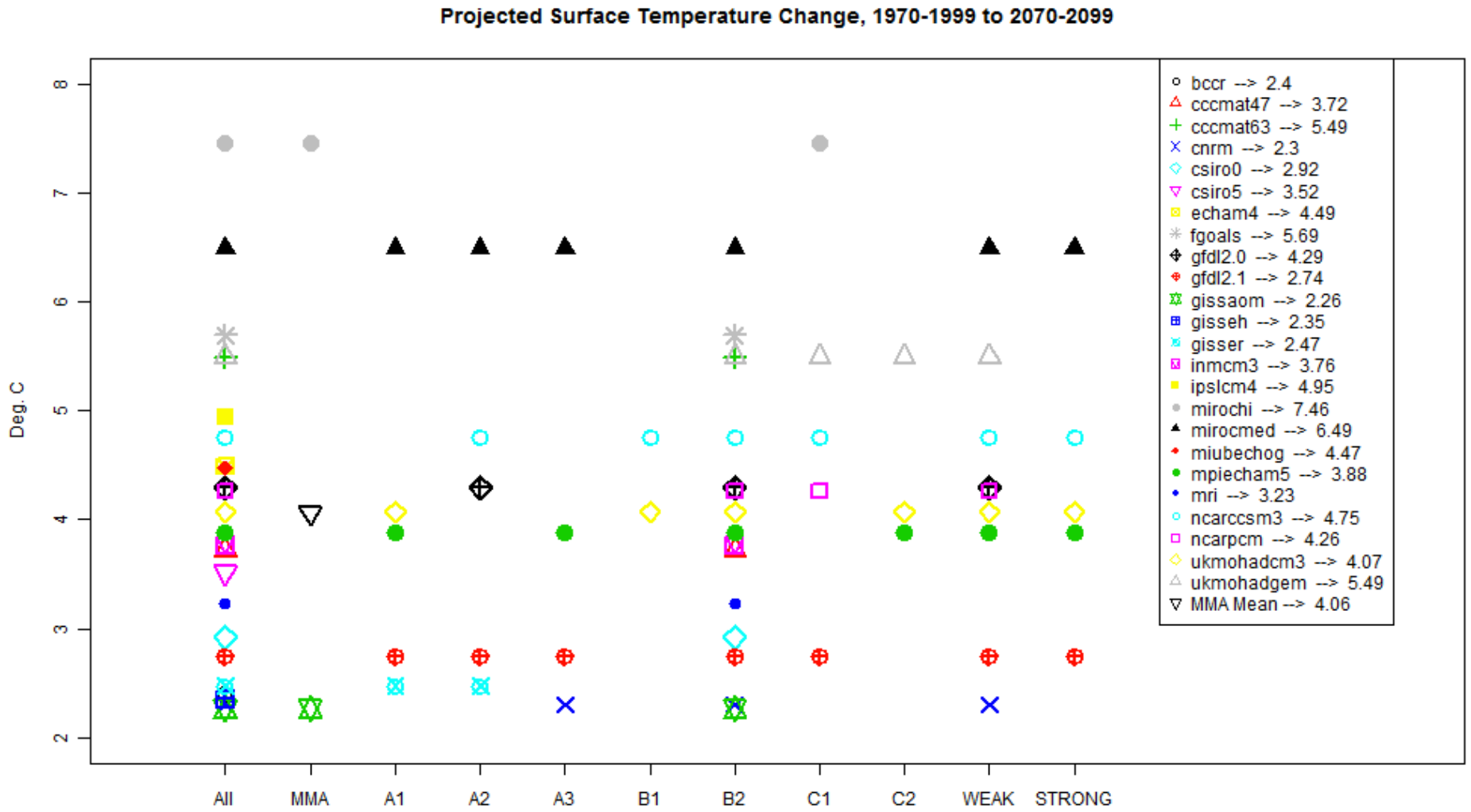
- In climate science, for instance, researchers frequently start with uncertainties associated with relatively conservative mainline GCMs, along with the tails of their ensemble PDFs
- If they then also consider other climate change projections not incorporated in the current expert consensus, the uncertainty bounds usually expand, because other possibilities arise
- If they step back and add uncertainties regarding the emission projections that the GCMs take as input assumptions, the bounds expand further
- And there is still one more possible step: considering plausible qualitative arguments for still wider bounds, based on apparently valid research -- difficult to dismiss if sometimes difficult to quantify

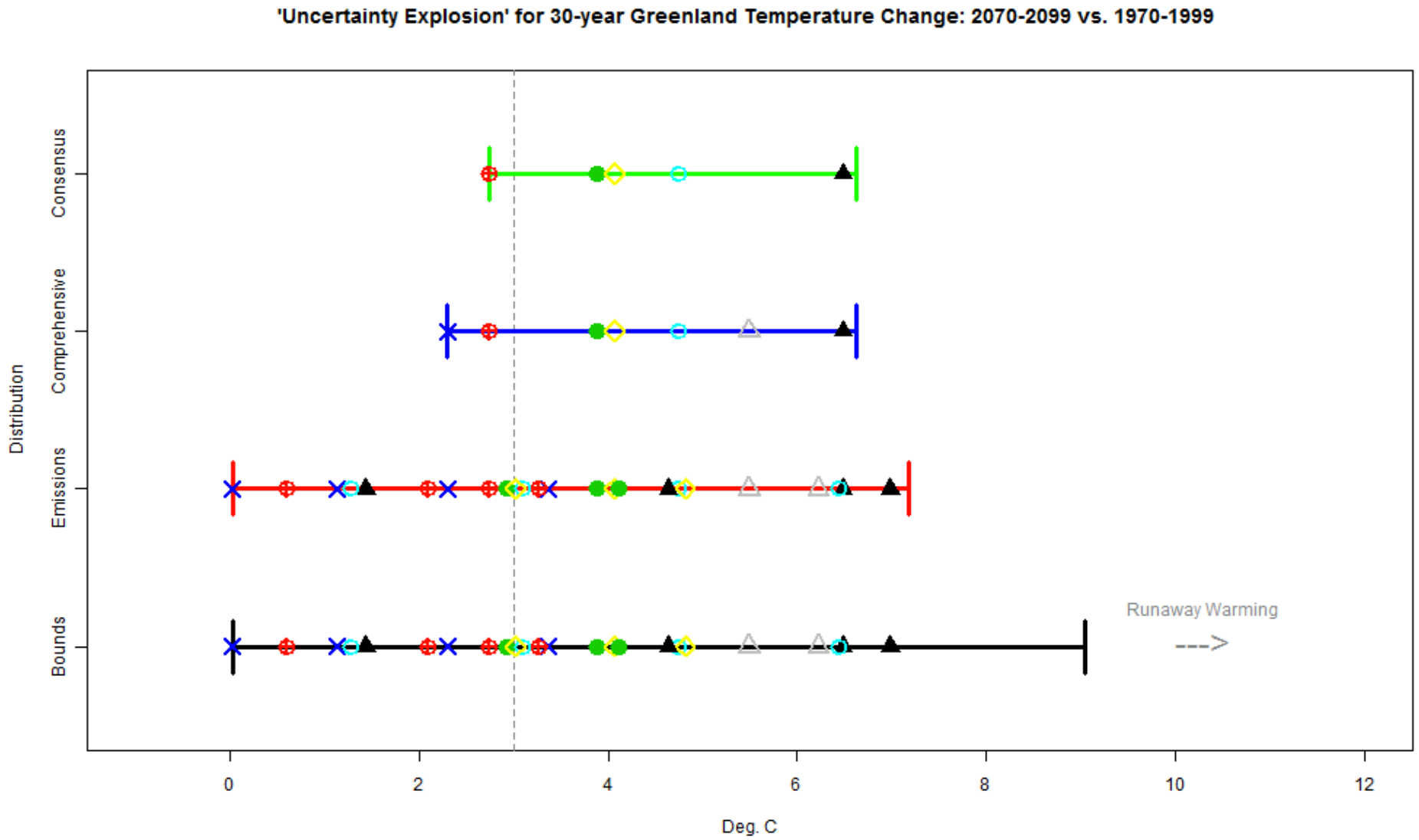
The ORNL Climate Change Science Institute (CCSI) Has Identified as One of Its Research Thrusts "Climate Change Variance and Extremes:"

- One expression of this thrust has been to examine some particular cases where possible extreme impacts might be of global concern
- One such case is possible effects of warming on the rate of melting of land-surface ice sheets as a driving force for sea-level rise
- A current ORNL research project is examining the possibility that estimates of these effects could under-represent the envelope of possibilities in the case of the Greenland ice sheet because they do not consider the second kind of "cascading uncertainties"
- Focused on uncertainties in estimating surface temperatures in Greenland in the 2070-2100 period

The Analysis Considers Four Steps that Progressively Expand Bounds of Uncertainty Estimates regarding Surface Temperatures in Greenland:

- GCM projections as summarized by "expert consensus": 24 GCMs in CMIP3, three multi-model studies – one scenario at a time
- A wider range of possible implications of the entire range of available models
- Uncertainties regarding GHG emissions associated with multiple scnearios: e.g., SRES B1, A1b, and A2
- Other plausible factors not treated in archived GCM runs that could affect surface temperatures:
  - Conceptual upper limits of climate sensitivity, as derived from paleo-data
  - Polar amplification of global warming


Projected Surface Temperature Change, 1970-1999 to 2070-2099
Deg.C
2
3
4
5
6
7
8
All
MMA
A1
A2
A3
B1
B2
C1
C2
WEAK
STRONG
bccr --> 2.4
cccmat47 --> 3.72
cccmat63 --> 5.49
cnrm --> 2.3
csiro0 --> 2.92
csiro5 --> 3.52
echam4 --> 4.49
fgoals --> 5.69
gfdl2.0 --> 4.29
gfdl2.1 --> 2.74
gissaom --> 2.26
gisseh --> 2.35
gisser --> 2.47
inmcm3 --> 3.76
ipslcm4 --> 4.95
mirochi --> 7.46
mirocmed --> 6.49
miubechog --> 4.47
mpiecham5 --> 3.88
mri --> 3.23
ncarccsm3 --> 4.75
ncarpcm --> 4.26
ukmohadcm3 --> 4.07
ukmohadgem --> 5.49
MMA Mean --> 4.06


'Uncertainty Explosion' for 30-year Greenland Temperature Change: 2070-2099 vs. 1970-1999
Distribution
Consensus
Comprehensive
Emissions
Bounds
Runaway Warming
--->
0
2
4
6
8
10
12
Deg. C

Are There Lessons in This Line of Research for Uncertainty Analysis in IAMs (I)?

- **Sequential expansions of uncertainty bounds are issues where IAMs are being utilized to analyze IAV issues – a serious problem, although *not all combinations of uncertainties are plausible* (as the ongoing IAMC and IPCC socio-economic pathway processes are showing)**
- **Otherwise, the cascading issue may be less clear-cut for many IAMs:**
  - **Most of the different categories of IAM uncertainties would appear (to me) to be interactive, not sequential: e.g., technology mixes, prices, policies**
  - **And, if IAM results are being used to inform broad, robust, qualitative perspectives, it is not entirely clear how quantifying uncertainties associated with precise quantitative results might make a big difference**
- **But the socio-economic pathway processes are opening up discussions of other sources of uncertainties for IAM as well, often related to qualitative differences in pathways rather than quantitative model-based scenarios, that could introduce potentials for cascading uncertainties: e.g., different economic development pathways, governance pathways, technological change, the rate of market penetration by new technologies, climate policy assumptions, energy/water/land interactions…**

Are There Lessons in This Line of Research for Uncertainty Analysis in IAMs (II)?

- In other words, conventional techniques and methods could (are likely to?) underestimate uncertainties because they do not capture some of these factors
- A question is how to address these kinds of "external" uncertainties in terms of shared protocols, comparability, metrics, etc.
- Possible strategies could include:
  - Multiple projections representing implications of a range of different kinds of uncertainties
  - Making use of matrices as the socio-economic pathways are suggesting (especially helpful in indicating permutations that are too improbable to take seriously)
  - Imbedding quantitative "mainstream" estimates of uncertainties in wider bounds of possibilities, which could be "notional" (qualitatively-derived?) depictions of possible bounds