

Climate System: Integrating human and modeling uncertainty, impacts and extreme projections, missing processes, and ensemble limitations

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No solutions, just some thoughts and questions.

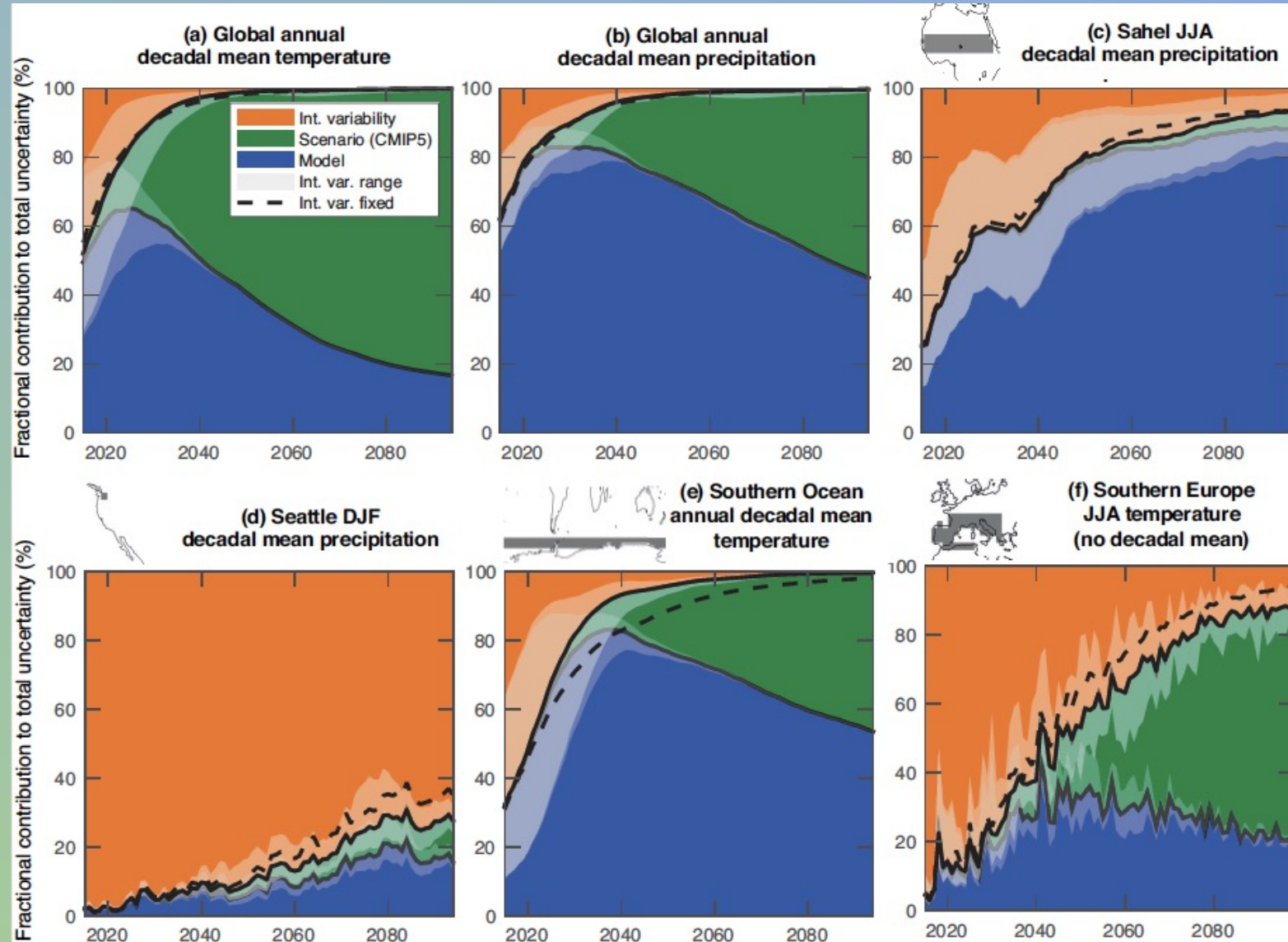
Uncertainty sources in Earth System Modeling

Model Internal Variability -- The noise of the system

Model Structural Uncertainty – The choice of what to represent and how

Scenarios of Future External Forcings – Anything that is not endogenously generated and is expected to change: anthropogenic (emissions, land use) and natural (solar cycle, volcanoes)

Uncertainty sources in Earth System Modeling



Lehner et al., 2020, ESD

Does the difference in the relative importance of the various sources of uncertainty over time and across scales apply to human-earth system processes and dynamics too?

Model Internal Variability

(conditional on model and scenario – in fact used to be characterized through “control experiments”, i.e. not externally forced)

Makes sense to explore with fully coupled ESMs (simple models do not represent internal variability) through **large Initial Condition ensembles**.

The community standard right now is ~50 ensemble members generated by adding noise to the atmosphere state

Does that explore internal variability exhaustively? What about ocean states?

But given the necessary computational resources we know how to do it, and work is ongoing to determine the ensemble size requirements for various applications.

Through this exploration we **separate forced signal from the system noise**, and we better characterize **rare/extreme events**.

What is the equivalent of internal variability for human processes?

What are “control” experiments when human systems are involved?

Model Structural Uncertainty

(e.g., what makes the NCAR model different from the MPI model)

Characterizing the one with the **big S** relies on **MIPs**. Intelligently designing MIP experiments is necessary (but probably not sufficient) condition for success.

What are the modeling/input/experimental “standards” that would define a MIP in the case of coupled human-earth system modeling? (Remember C&B-L 2018)

There is one with a **small S**, i.e. parameter uncertainty, which has been explored with **perturbed parameters ensembles**, whose paradigm can apply to analyzing coupled human-earth system modeling experiments (as well as IAMs alone):

- choose **alternative values of parameters** within a plausible range,
- maybe **fill-in gaps** in the sampling by using **emulators**.
- **filter** the hundreds of alternative realizations according to observational constraints

What are observational constraints for coupled earth-human systems, what does validation mean?

Scenario uncertainty (without impacts)

We run a **handful of them with ESMs**, possibly **hundreds of them with EMICS and simple models**.

We use their time evolution as a **boundary condition**.

We compare and contrast, look at **benefits of mitigation, time until separation, time until crossing of thresholds**.

The closest to **human system uncertainty exploration**, but still it's a very **idealized humanity** that does not feel the effects of climate change if not through assumed mitigation policies.

Human-Earth system interaction types

Feedbacks on and from policy choices:

It gets so bad that people start doing something about mitigation.

What does this buy us that mitigation scenarios don't already?

Traversing scenarios in mid-course?

RCP8.5 becoming really impossible?

Feedbacks on and from human physical and economic activities:

It gets so bad that

a) Forests burn and dry up, changing **albedo**;

b) Crops fail, have to be moved somewhere else, or irrigated, changing albedo and

land-atmosphere fluxes, and changing **GDP**;

c) Labor productivity changes – changing **GDP**;

d) People die or migrate – changing **population dynamics**.

LULCC and its effects on physical processes (and their possible feedback on human decisions) are being incorporated in ESMs and can be subject to all the uncertainty exploration tools we have in the ESM arsenal;

Everything else:

IAM scenarios incorporating impacts : uncertainty tools like **PPEs** applicable if implementation relies on econometric models or computationally efficient process models; we can represent **impacts in IAM through global temperature scaling**;

BUT

- large uncertainty in the relation of impacts to global temperature, especially if the climate drivers are extremes;
- consistency requirements with ESM global temperature change, once the scenario is used as boundary condition)

coupling of IAMs and ESMs: uncertainty tools like PPEs applicable if implementation relies on econometric models or computationally efficient process models; no need to approximate the effects of climate change;

BUT

- hurdles to uncertainty exploration from computational time and cost (How many ensemble members would the additional dimension require? path dependency of uncertainty?)