Options for exploring the range of climatic change

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Outline

1. Climate assumptions embedded in IAMs
2. ‘Pattern scaling’ (or scenario dependence of climate change patterns)
3. Can we choose a small number of ‘representative’ climate scenarios?
   1. Better performance of models?
   2. Better coverage of uncertainty?
4. Summary
Climate assumptions embedded in IAMs

Relationship between *emission* and *radiative forcing* calculated in IAMs is dependent on

- Carbon cycle
- Radiative forcing intensity (per unit abundance of forcing agent)

If temperature dependence of carbon cycle is implemented, result is also dependent on *climate sensitivity*. 
Sensitivity of IAM results to climate assumptions

Cumulative CO₂ Em. (GtC)

Stabilization level (ppmCO₂eq)

T-dep  CO₂ Fert

- CO₂ Fert

+ RF high
- RF low

Num. infeasible

(Model=AIM, CS=3K)

(Strassmann, in preparation)
Sensitivity of IAM results to climate assumptions

T-dep $\mathrm{CO}_2$-Fert

- RF high
- RF low

Num. infeasible

(Model=AIM, CS=3K)

(Strassmann, in preparation)
Pattern scaling

• Way to produce additional climate scenarios by scaling (or interpolating) available AOGCM runs.

\[ \Delta V = \left( \frac{\Delta V}{\Delta T} \right)_{\text{from AOGCM}} \times \left( \Delta T \right)_{\text{from simple climate model}} \]

• Assumption is that the spatial pattern of climate change per unit global mean temperature rise (scaling pattern) is independent of underlying scenarios.
Do you need pattern scaling?

• If you try to explore scenarios between RCP levels (e.g., 3.5W/m² stabilization), yes.
• If you need a RCP6 run and that doesn’t happen to be available for a certain AOGCM, yes. (Note that RCP6 run is given a lower priority in CMIP5 experiment request)

Even if you don’t need pattern scaling, you might still need to know about the scenario dependence of climate change patterns ... Why?
Scenario dependence of climate change patterns

• Scenarios for the same RCP level but based on different SSPs might be associated with different aerosols emissions and different land use.

• These might cause different spatial patterns of climate change, though global mean temperature changes should be almost the same.

• RCP runs of AOGCMs are based on particular aerosols and land use scenarios given by the particular RCP scenarios, which are generally different from those implied by each SSP.
Temperature change patterns for different RCP runs

- **RCP2.6**
- **RCP8.5**

\[ \text{RCP8.5} - \text{RCP2.6} \approx 15\% \] (diff. ~ 15%)  

AOGCM = MIROC5

(Ishizaki, in preparation)
Temperature change patterns for different RCP runs

Temperature change pattern difference

Aerosols radiative forcing pattern difference

due to aerosols

due to non-linearity

(Effect of land use seems insignificant.)

RCP8.5 - RCP2.6
AOGCM = MIROC5

(Ishizaki, in preparation)
Precipitation change sensitivity for different SRES runs

14 AOGCMs of CMIP3

(a) $\Delta P/P/\Delta T$ [%/K]

Less precipitation increase in scenarios with relatively more aerosols.

(Shiogama et al., 2010)
Potential biases from pattern scaling in runoff changes

Biases (‘A2 scaled from B1’ minus A2) of runoff changes

14 AOGCMs of CMIP3

(Shiogama et al., 2010)
Can we choose a small number of ‘representative’ climate scenarios?

- CM community might not like the idea very much. (Would most AOGCM runs not be used in scenario exercise?)
- On the other hand, mandating the use of all AOGCM runs is not practical.
- It might be agreeable to decide a (small) set of ‘high-priority’ climate scenarios for better comparability.
Better performance of models?

• It is not obvious how to measure the performance of models.
• Better performance of reproducing past/current climate does not ensure better credibility of projecting future climate.
• Recent studies have shown that the performance-credibility relationship is generally weak for ‘overall metrics’ (e.g., RMS of temperature, precipitation etc.).
• Performance/credibility might be region/variable dependent.
Better coverage of uncertainty?

• It seems reasonable to choose models with high/medium/low temperature rise. (Note that ocean heat uptake as well as climate sensitivity affects transient climate response)

• How about the coverage of uncertainty in precipitation change or other variables?

• Coverage of uncertainty might be region/variable dependent.
Better coverage of uncertainty?

(Ruosteenoja et al., 2003)
Summary

• There are climate assumptions embedded in IAMs (carbon cycle, radiative forcing, climate sensitivity). Sensitivity studies of IAM results to them would be valuable, perhaps with updated uncertainty range.

• It should be recognized that scenario dependence of climate change pattern (e.g., same RCP run mapped on different SSPs) might cause error of ~15% or larger in regional climate scenarios. This is mainly due to different aerosols distributions (effect of land-use change seems insignificant at this scale).
Summary (2)

• It might be agreeable to decide a set of ‘high-priority’ climate scenarios for better comparability across scenario studies.

• To pick up models with better performance might be desirable, but how to measure the performance is not at all obvious.

• To pick up models to cover a wide range of climate uncertainty might also be desirable. For variables other than temperature, the coverage of uncertainty range might be region/variable dependent.
Runoff Changes from Various Models

(Shiogama et al., 2011)
Two principal modes of model diversity

The 1st mode of $\Delta R$

-1

0

+1

The 2nd mode of $\Delta R$

-1

0

+1

Ensemble Mean

‘Best Estimate’ based on an observational constraint

(Shiogama et al., 2011)