IAM Science Questions that Require Coupling and/or Inputs from IAV/ESM

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Integrated assessment model

Climate model

Impact model

Integrated assessment models

Energy
The economy
Health
Agriculture and forestry
Terrestrial carbon cycle
Climate models

Impacts, adaptation and vulnerability

Human settlement and infrastructure
Water
Ecosystems
Sea level rise
Cryosphere
Oceans
Atmospheric processes
What are IAMs and what does this imply for coupling

- Integrated assessment models
  - Interaction of human system – earth system (integration)
  - To support policy decisions (assessment)

Integrated models, preferably as simple as possible. Focussed on linkages and uncertainty

Costs-benefit IAMs

Damage curves — Yield-impacts

(Tol, Nordhaus)

Process IAMs

Agri
Consideration for best form of cooperation

IAV model
- Energy
- Food
- Ecosystems
- Health
- Water
- Coast

IA model
- Human systems
  - Population
  - Energy
  - Emissions
  - Natural earth systems
    - C,N,P cycle
    - Atm. chemistry
    - Water cycle
  - Land-cover
  - Climate
- Impact Emulator/metamodel

ES model
- Atmospheric Physics (climate)
- Ocean physics and biogeochemistry
- Land cover and plant ecology
- Atmospheric chemistry + C/N/P cycle
- Hydrology
- Climate Emulator/metamodel
How to organize cooperation?

A. Off-line

B. Improved IAM

C. Improved ESM

D. Full coupling
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Comparable to current set-up CMIP5/RCPs

- work with existing terminology and tools
- transparent information exchange
- High flexibility: easy exchange of ESMs and IAMs
- separate research strategies

• Feedbacks are only captured via (one-single) iterations.
• potential inconsistencies

How to organize cooperation?

A. Off-line

B. Improved IAM

C. Improved ESM

D. Full coupling

Further improve climate models in ESM (MAGICC emulation of CMIP4 models; pattern scaling; refined pattern scaling (sulphur, albedo etc)

- IAMs designed as integration platform
- allows for good representation of uncertainty
- Flexibility: different ESM might be represented
- model complexity tailored to question
- detail in treatment of socio-economic processes
- lack of detail in treatment of biophysical processes (often meta modeling)

How to organize cooperation?

Further include human system elements in ESMs (e.g. urban environment, land-use rules to better describe land-cover, water consumption rules)

- higher resolution analyses than in IAMs
- detail in treatment of biophysical processes
- lack of detail in treatment of socio-economic processes
- limitation of model runs limits representation of uncertainty

How to organize cooperation?

Include full IAMs in ESMs (e.g. iESM, IMAGE-CNRM).

- assessment of feedbacks
- highest degree of consistency
- technical difficulties
- complex cooperation
- lack of representation of uncertainty
- inflexibility (one IAM, one ESM)
- complexity/intransparency
- limitations in knowledge may hamper progress

How to organize cooperation?

A. Off-line
   IAM  
   Hum  
   Env  
   Emissions  
   Land use  
   Climate  
   ESM  
   Land  
   Atm.  
   Chem  
   Ocean

B. Improved IAM
   IAM  
   Hum  
   Env  
   ESM  
   Land  
   Atm.  
   Chem  
   Ocean

C. Improved ESM
   IAM  
   Hum  
   Env  
   ESM  
   Land  
   Atm.  
   Chem  
   Ocean

D. Full coupling
   IAM  
   Hum  
   Env  
   ESM  
   Land  
   Atm.  
   Chem  
   Ocean

No feedbacks on humans

Strong feedbacks on humans
Consideration for best form of cooperation

- One-way linkage dominant (feedbacks are weak, very slow, or non-existent) \( \rightarrow \) **category A**
- Interactions significant in both directions and simple formulation possible \( \rightarrow \) **category B** (e.g. radiative forcing by long-lived greenhouse gases)
- Main focus natural system; simple human system representation possible \( \rightarrow \) **category C** (e.g. land-use rules)
- Interactions (likely) significant and processes are complex (geographical, temporal) and/or cannot be adequately represented in simple models \( \rightarrow \) **category D**.
- Non-linear threshold behavior \( \rightarrow \) **category D**?
- Uncertainty very large? \( \rightarrow \) **category A or B**, at least to explore uncertainty range. Only if results indicate possible strong feedback \( \rightarrow \) **C or D analysis**.

In other words, it is only useful to consider complex coupling if potentially strong feedbacks are involved and the processes involved are rather well established.

Consideration for best form of cooperation

IAV model

- Energy
- Food
- Ecosystems
- Health
- Water
- Coast

Impacts on human activities or mitigation strategies

IA model

Human systems
- Population
- Energy
- Emissions
- Atm. chemistry
- Water cycle
- Economics
- Agriculture
- Land-use
- Climate

Natural earth systems (simplified)
- C,N,P-cycle
- Land-cover

Energy demand
- Thermal efficiency
- Hydropower
- Yields
- Ecosystems

Impact emulator

ES model

- Atmospheric Physics (climate)
- Ocean physics and biogeochemistry
- Land cover and plant ecology
- Atmospheric chemistry + C/N/P cycle
- Hydrology

Climate emulation

Planbureau voor de Leefomgeving
Key IAM questions that require coupling with ESMs

- *Interaction between climate change and land use*
  - *Carbon cycle responses (carbon intensity)*
  - Albedo, heat / water exchange processes.
    - Examples: Amazon forest deforestation; monsoon consequences in South Asia.
    - Use various methods: Method A for exploration; Method D for trying to find potential feedbacks.

- *Impact of climate change on energy use.*
  - Energy use
  - Cooling of thermal plants
  - Renewable energy
  - Relatively well-known, but mostly via aggregated processes. Small impacts (thus category B?).
Key IAM questions that require coupling with ESMs

- *Impacts via air pollution (and indirectly climate change)*
  - *Impacts of N, P, S, O3 on crops and vegetation*
  - Impacts of aerosols, O3, S on humans
- *Impact of climate change on transport and shipping routes*
- *Droughts, availability of water and impacts on societies*
- *Extreme and catastrophic events*
- *Avoiding particular (regional) climate change outcomes or impacts*
Key IAM questions that require coupling with IAV

- Impact of climate change on agricultural yields (temperature and precipitation change and CO2 fertilisation)
- Impact of climate change on water scarcity and thus agriculture and water choices
- Impacts on human health and thus economic growth and population
- Impacts on economic growth/infrastructure (also via adaptation investments)
- Natural vegetation/permafrost → C-cycle
- Sea level rise → Coastal infrastructure, cities
- [Fisheries]
Including climate in IAMs

Crop model

Land-use, Land cover

Energy demand

Energy production

GHG, air pollution

CO2 concentration

Overshoot 1.5°C

Different forcing

MAGICC

Climate model output

Type A, D

Type B

Pattern scaling

Climate models

Regional sulphur forcing

GMT
Optimal land-use land-based mitigation

- Land-based mitigation (bio-energy, reforestation, REDD) has impacts on carbon cycle, albedo, local climate.
- Global impacts (via carbon cycle possibly via simple tools) but local effects much harder.
- IAM could optimise deployment based on net impact.
- Could be extended to total land-use and also include water.

Bonan et al. 2008
SSP integration phase

- Comparison of the costs of mitigation against avoided impacts based on consistent scenarios

<table>
<thead>
<tr>
<th>Impacts/adaptation</th>
<th>SSP3</th>
<th>SSP2</th>
<th>SSP1</th>
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<tbody>
<tr>
<td>Climate signal</td>
<td>8.5</td>
<td>6.0</td>
<td>4.5</td>
</tr>
<tr>
<td>adaptation challenge</td>
<td>2.6</td>
<td>4.5</td>
<td>6.0</td>
</tr>
</tbody>
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Mitigation levels (NPV, 2010$)

- SSP1: 1.24 (0.43–1.24)
- SSP2: 0.38 (0.38–2.15)
- SSP3: 2.42 (0.97–2.42)
- SSP4: 3.70 (3.11–6.27)

This can be done by separate models (using SSPs as connecting element), but also in IAMs to couple possible interaction.
Work on damage curves

- Damage curves in CBA IAMs relatively old
- Would be nice if they can be based on more recent biophysical data (ISIMIP) and more regularly and transparently updated
- Possibly also interesting for process IAMs to build in.
Evaluation of SDGs (possibly with climate policy)

- SDG agreements: 17 goals that should be met at the same time

  - SDG1: No poverty
  - SDG2: Zero hunger
  - SDG3: Good health & wellbeing
  - SDG4: Quality education
  - SDG5: Gender equality
  - SDG6: Clean water & sanitation
  - SDG7: Affordable & clean energy
  - SDG8: Decent work & economic growth
  - SDG9: Industry, innovation & infrastructure
  - SDG10: Reduced inequalities
  - SDG11: Sustainable cities & communities
  - SDG12: Responsible consumption & production
  - SDG13: Climate action
  - SDG14: Life below water
  - SDG15: Life on land
  - SDG16: Peace, justice & strong institutions
  - SDG17: Partnerships for the goals

- What are trade-offs?
- Coupling or including more impacts in IAMs?
- Meta models or emulators?
Food – water – energy nexus
Conclusions

- Further cooperation between IAM/IAV/ESM needed; can answer more integrated questions.
- Often there are possibilities for more simpler coupling than full integration. Full integration could especially be useful in case of strong, local feedbacks that can be quantified.
- Development of more integration tools attractive from IAM perspective.
- Clear areas for more intense cooperation are mitigation strategies, integration phase SSPs, SDG evaluation, water-energy-land nexus.