Linking IA Models and ESMs

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### Types of IA-ESM Linkages

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| A Off-line information exchange, one-way | • Work with existing terminology and tools  
• Transparent information exchange  
• Flexibility  
• Separate research strategies | • Feedbacks are only captured via (one-single) iterations  
• Potential inconsistencies | • CMIP  
• AgMIP |
| B Improved IAMs               | • Allows for good representation of uncertainty  
• Model complexity tailored to question  
• Detail in treatment of socio-economic processes | • Lack of detail in treatment of biophysical processes | • MAGICC calibration to CMIP  
• GCAM-Albedo |
| C Improved ESMs               | • 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 | • Urban/crop component of CESM |
| D Full Coupling               | • Assessment of feedbacks  
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• Complexity/[opaqueness]  
• Limitations in knowledge may hamper progress | • iESM  
• IMAGE-CNRM |

**Source:** van Vuuren et al. (2012)
A. Offline One-Way Information Exchange: IAM to ESMs

IAMs Provide Scenarios for ESMs

**IS92 CO₂ Emissions (1994)**


- **RCP CO₂ Emissions (2011)**

- **SSP CO₂ Emissions (2016)**
A. Offline One-Way Information Exchange: IAM to ESMs via CMIP

The CMIP5 Process

- General characteristics
  - Broad range of forcing in 2100
  - Shape of radiative forcing over time
- Representative concentration pathways (RCPs) (four pathways from existing literature)
  - Greenhouse gases
  - Short-lived gases and aerosols
  - Land cover/use
- New socio-economic and emissions scenarios: vulnerability storylines
  - Adaptation
  - Mitigation
  - Stabilization
  - Overshoot
  - ...
- Consistent with RCPs of the RCPs
- Climate scenarios
  - Near-term (2035)
  - Long-term (2100+)
  - Regional climate modeling
  - Pattern scaling methods
- Integration of climate and socio-economic scenarios
  - Integrated scenarios
  - Pattern scaling (climate)
  - Downscaling of climate and socio-economic scenarios
  - ...

GMT Rise in CMIP5

IPCC AR5 Chapter 12
A. Offline One-Way Information Exchange: ESMs to IAMs

ESMs Provide Climate Information for IAMs

Zhou et al. (2014)

Hanasaki et al. (2014)

Nelson et al. (2014)
A. Offline One-Way Information Exchange: ESMs to IAMs via AgMIP

The AgMIP Process

- RCP exercise
  - Integrated Assessment Models
  - RCPs (Global Gridded Emissions Scenarios)
- CMIP5
  - General Circulation Models
  - Global Gridded Climate Change
- ISIMIP
  - Global Gridded Crop Models
  - Global Gridded Crop Yields
- AgMIP
  - Global Economic Models

Change in Cropland Area in 2050

Source: Redrawn from Nelson et al. (2014)
Results from the Agricultural Model Intercomparison Project
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Source: van Vuuren et al. (2012)
B. Improved IAMs

ESMs are used to develop parameterized components of IAMs

IAM Climate Modules

Van Vuuren et al. (2009)

Updating IAM Climate Modules

Meinshausen et al. (2011)
B. Improved IAMs

Used CLM to Parameterize GCAM

Radiative Forcing in 2100

Source: Jones et al. (2015)
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Source: van Vuuren et al. (2012)
C. Improved ESMs

Land Component of the CESM

Source: NCAR
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**Source:** van Vuuren et al. (2012)
D. Full Coupling

IAMs and ESMs can be Fully Coupled

**IMAGE + CNRM-CM3**

Voldoire et al. (2007)

Collins et al. (2015)
Jones et al. (2013) reported changes in carbon storage when two-way feedbacks are included. The figure shows the land carbon storage across ESMs for different RCP scenarios (RCP2.6, RCP4.5, RCP6.0, RCP8.5). The changes are indicated by the color scale on the right, which ranges from -0.3 to 0.3. The models include CanESM2, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-CC, HadGEM2-ES, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC-ESM-CHEM, MIROC-ESM, MPI-ESM-LR, NorESM1-ME, inmcm4, CESM1-BGC, and bcc-csm1-1.
Ongoing & Future Research Directions

A. Offline, one-way coupling
   - CMIP6
   - ISI-MIP

B. Improved IAMs
   - Emulators (including pattern scaling)
   - Natural emissions sources and other science insights

C. Improved ESMs
   - Improved crop modeling
   - Water management

D. Full Coupling
   - Continued experiments using iESM
   - Improved coupling
Ongoing & Future Research Directions

- Workshop on IA-ESM coupling
- Improved emulators
- Developing scenarios for improved climate science
THANK YOU!!!