RCPs and SSPs: What are they and where are they going?

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Outline

► Why do we need scenarios?

► The “Parallel Process”
  ■ Representative Concentration Pathways
  ■ Shared Socioeconomic Pathways
  ■ Shared Policy Assumptions

► SSPs: Current Status
  ■ Example: Forest cover

► Future SSP development
Scenarios

- Need for common scenarios
  - Earth System Model (ESM)
  - Integrated Assessment Models (IAM)
  - Impacts, Adaptation, and Vulnerability (IAV) models

- IPCC Scenario history
  - IS92 (1992)
  - SRES (2000)
  - Community-based, not IPCC-led scenario design (2007-present): RCPs and “parallel process”
The Parallel Process: Community-based scenario development

Goals of the parallel scenario process
- Shorten the time required to develop and apply new scenarios
- Improve integration between socio-economic drivers, climate system, and natural and human systems
- Develop consistent reference and policy scenarios

The Representative Concentration Pathways (RCPs) are alternative future global greenhouse gas and aerosol concentrations, developed to be used in parallel by:
- Earth System Models (ESMs): CMIP5 (climate model intercomparison, experiments using emissions, concentration, and land use outputs from RCPs, $\frac{1}{2} \times \frac{1}{2}$ degree resolution for LULUC and short-lived species)
- Integrated Assessment Models (Iams): Shared Socioeconomic Pathways (exploration of alternative socio-economic conditions consistent with future atmospheric composition changes)
- Climate projections from CMIP5 and socioeconomic drivers from RCPs used in Impacts, Adaptation, and Vulnerability (IAV) and IAM studies
Scenario Elements

- **Representative Concentration Pathways (RCPs)**
  - Four climate pathways defined by radiative forcing at the end of the century
  - CMIP5 database, $\frac{1}{2} \times \frac{1}{2}$ degree gridded climate projections

- **Shared Socioeconomic Pathways (SSPs)**

- **Shared Policy Assumptions (SPAs)**
Representative Concentration Pathways

Table 1. Types of representative concentration pathways.

<table>
<thead>
<tr>
<th>Name</th>
<th>Radiative Forcing$^1$</th>
<th>Concentration$^2$</th>
<th>Pathway shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP8.5</td>
<td>&gt;8.5 W/m² in 2100</td>
<td>&gt;~1370 CO₂-eq in 2100</td>
<td>Rising</td>
</tr>
<tr>
<td>RCP6</td>
<td>~6 W/m² at stabilization after 2100</td>
<td>~850 CO₂-eq (at stabilization after 2100)</td>
<td>Stabilization without overshoot</td>
</tr>
<tr>
<td>RCP4.5</td>
<td>~4.5 W/m² at stabilization after 2100</td>
<td>~650 CO₂-eq (at stabilization after 2100)</td>
<td>Stabilization without overshoot</td>
</tr>
<tr>
<td>RCP3-PD$^3$</td>
<td>peak at ~3W/m² before 2100 and then decline</td>
<td>peak at ~490 CO₂-eq before 2100 and then decline</td>
<td>Peak and decline</td>
</tr>
</tbody>
</table>

Each RCP is an independent pathway
RCP 8.5 is not a reference scenario for the other, lower RF scenarios

Scenario Elements

- **Representative Concentration Pathways (RCPs)**
  - Four climate pathways defined by radiative forcing at the end of the century
  - CMIP5 database, $1/2 \times 1/2$ degree gridded climate projections

- **Shared Socioeconomic Pathways (SSPs)**
  - Five socioeconomic development trajectories defined in terms of challenges to adaptation and mitigation
  - Not “matched” to reference RCPs

- **Shared Policy Assumptions (SPAs)**
Shared Socioeconomic Pathways (SSPs)

- SSPs are the basis of the new scenarios
  - Narrative storylines
  - Quantitative scenarios (demographics, economics, technology)
  - Other socioeconomic indicators

- Represent a range of future development pathways, defined around
  - Challenges to adaptation
  - Challenges to mitigation
Shared Socioeconomic Pathways (SSPs)

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**SSP1: Sustainability**

**SSP2: Middle of the Road**

**SSP3: Fragmentation**

**SSP4: Inequality**

**SSP5: Conventional Development**
SSP Narratives

SSP2: Middle of the Road
- Current trends continue
- Moderate population growth
- Slowly converging incomes between industrialized and developing countries
- Delayed MDG achievement
- Reductions in resource and energy intensity at historic rates
- Environmental degradation

SSP1: Sustainability
- Good progress towards sustainable development
- Stabilizing population
- Decreasing income inequality
- Early MDG achievement
- Low resource intensity and fossil fuel dependency
- Strong int’l governance and local institutions
- Well managed urbanization
- Environmentalism

SSP3: Fragmentation
- Rapid population growth
- Slow economic growth
- Failing to achieve MDG
- High resource intensity and fossil fuel dependency
- Low investments in technology development and education
- Unplanned settlements
- Weak int’l governance and local institutions

SSP4: Inequality
- Increasing inequality within and across countries
- Effective governance controlled by a small number of rich global elites
- Most of populations with limited access to higher education and basic services
- Energy tech R&D made by global energy corporations
- Low social cohesion

SSP5: Conventional Development
- Rapid economic development
- Stabilizing population
- Consumerism
- High fossil fuel dependency
- Eradication of extreme poverty and universal access to education and basic services
- Highly engineered infrastructure and ecosystems

Adapted from the meeting report of the Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research. https://www.isp.ucar.edu/sites/default/files/Boulder%20Workshop%20Report_0_0.pdf
SSPs are designed to provide a link between the RCPs and the CMIP5 climate ensembles.

<table>
<thead>
<tr>
<th>RCP Replication</th>
<th>SSP 1</th>
<th>SSP 2</th>
<th>SSP 3</th>
<th>SSP 4</th>
<th>SSP 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>8.5 Wm⁻²</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6.0 Wm⁻²</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4.5 Wm⁻²</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2.6 Wm⁻²</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
SSP Reference and RCP Radiative Forcings

Reference forcings, current results:
- SSP5: 8.9 - ... W/m²
- SSP2: 6.4 - 7.9 W/m²
- SSP3: 6.3 - 7.7 W/m²
- SSP4:
- SSP1: 5.3 - 7.1 W/m²

K. Riahi
Scenario Elements

- **Representative Concentration Pathways (RCPs)**
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- **Shared Socioeconomic Pathways (SSPs)**
  - Five socioeconomic development trajectories defined in terms of challenges to adaptation and mitigation
  - Not “matched” to reference RCPs

- **Shared Policy Assumptions (SPAs)**
  - Five (?) policy regimes used to meet policy targets
  - Not yet finalized
  - Potential attributes include:
    - Accession: immediate vs. delay
    - Carbon tax: universal vs. fossil fuel and industry
Current Status: SSP development

- First round: five IAMs ran multiple RCP-SSP combinations—no SPAs
- Currently analyzing results
  - Are the models’ implementations of SSPs consistent with the underlying land use storylines?
- Challenges in comparing LU results across models and SSPs?
  - SSP harmonization
  - Definitions: regions, variables
  - Data reporting
  - Many scenarios... Models x RCPs x SSPs x SPAs
    - 5 x 4 x 5 x 5(?) = 500* scenarios!
    (*Not all combinations may be appropriate or feasible)
    - How will IAV and ESMs deal with so many runs?

- Example: Forest cover
- Focus areas
  - Core set of scenarios?
  - Analytical topics?
(There are a LOT of scenarios!)

REFERENCE

RCP 4.5 – SPA0
Preliminary Results: Forest Cover
Global Forest Area

- Definition of forest varies by model
  - Harmonization in base year?
  - Particularly a problem for managed forest

- Patterns across SSPs vary by model
  - Is there a need for more guidance/harmonization in SSP storylines?

- Forest protection levels
  - SSP1 = Strong
  - SSP2 = Medium
  - SSP3 = Weak

  Strong - strong forest protection, limited non-agricultural land for conversion
  Weak - weak forest protection, high availability of non-agricultural land for conversion
Challenges: Base Year Data
Total Forest in 2005

Differences across models in calibration year data
Challenges: Variable Definition (& Data Reporting)
Managed Forest in 2005

- Various definitions of “managed forest”
Global Managed Forest

- **SSP1 – Ref**: Strong forest protection
- **SSP2 – Ref**: Medium forest protection
- **SSP3 – Ref**: Weak forest protection

- **Year**: 2025, 2050, 2075, 2100
- **Units**: Million Ha/yr

**Models**:
- AIM/CGE
- GCAM
- REMIND – MAGPIE

**Land Cover**:
- Strong: forest protection
- Medium: forest protection
- Weak: forest protection

**Global Managed Forest**
SSP Forest Protection Narratives

Forest protection levels
- Strong - strong forest protection, limited non-agricultural land for conversion
- Weak - weak forest protection, high availability of non-agricultural land for conversion

SSP1
- Low Income - Strong
- Medium Income - Strong
- High Income - Strong

SSP2
- Low Income - Medium
- Medium Income - Medium
- High Income - Medium

SSP3
- Low Income - Weak
- Medium Income - Weak
- High Income - Weak

SSP4
- Low Income - Weak
- Medium Income - Medium
- High Income - Strong

SSP5
- Low Income - Medium
- Medium Income - Medium
- High Income - Medium
SSP Future

► SSP near-term development

- Specific analytical focus areas, of particular importance to ESM community
  - Non-Kyoto forcing
  - Overshoots
  - Land use change

- Proposed time line
  - October 2013: Revise land use figures to include 5th model (data reporting issue)
  - November 2013
    - Five SSP teams update first round results
    - Improve data reporting, particularly for land use; additional reported variables; variable definition harmonization
  - March-April 2014
    - Final runs
    - Revisions to land use inputs and reporting outputs

- Special Issue of *Global Environmental Change* on SSPs

► Lessons learned

- Things always take longer than planned… publications had been planned for Spring 2013

- Too many scenarios?
  - Need to focus on specific SSP-Policy combinations
  - Marker scenarios?

- Continued coordination and collaboration across modeling communities
  - Some topics highly relevant to all communities (e.g. LUC)
Back-up Slides
Drivers
SSP Storylines: Land Productivity

- **SSP1** - faster catch-up of low-income countries; sustainability focus
  - Low Income - Rapid
  - Medium Income - Rapid
  - High Income - Medium

- **SSP2** - declining rates for high-income countries, converging rates for low-income countries
  - Low Income - Medium
  - Medium Income - Medium
  - High Income - Medium

- **SSP3** - lower rates everywhere
  - Low Income - Slow
  - Medium Income - Slow
  - High Income - Slow

- **SSP4** - no convergence between low-income and high-income regions
  - Low Income - Slow
  - Medium Income - Medium
  - High Income - Rapid

- **SSP5** - high yield growth
  - Low Income - Rapid
  - Medium Income - Rapid
  - High Income - Rapid
Cereal Yield Growth Rates

- **SSP1** - faster catch-up of low-income countries; sustainability focus
  - Low Income - Rapid
  - Medium Income - Rapid
  - High Income - Medium

- **SSP2** – declining rates for high-income countries, converging rates for low-income countries
  - Low Income - Medium
  - Medium Income - Medium
  - High Income - Medium

- **SSP3** - lower rates everywhere
  - Low Income - Slow
  - Medium Income - Slow
  - High Income - Slow

Reporting is sparse
Patterns vary by model, but not by SSPs

Is there a need for more guidance/harmonization in SSP storylines?
Yield growth in the SSPs
  - SSP1 = Rapid
  - SSP2 = Medium
  - SSP3 = Slow