Climate Change Impacts and Risk Analysis Project (CIRA)

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Outline

• Objectives of the CIRA project
• CIRA overview
  – Caveats and limitations
  – Status and next steps
• Results
Objectives and Drivers

• The goals of CIRA
  – Analyze multiple climate change impacts and damages in the U.S. under consistent socio-economic and climate scenarios
  – Estimate the avoided damages (benefits) from climate policies
  – Explore aspects of uncertainty and articulate changes in risks
  – Develop and communicate credible, robust, and meaningful climate impact and benefit estimates to inform policy

• This method is used routinely by EPA in other settings, such as estimating the benefits of air pollution reductions (e.g., avoided premature deaths, respiratory illness, economic loss)
  – Unique challenges compared to traditional EPA analyses (e.g., global nature, wide-reaching impacts, long time scales).
  – To date, limited ability to estimate avoided impacts under GHG mitigation scenarios
    • The design of CIRA and resulting analyses differ from the Social Cost of Carbon in both purpose and approach
Overview of CIRA

- EPA-led, collaborative modeling effort, focus on regional impacts in the U.S.
  - Multiple impacts sectors: water resources, human health, ecosystems, energy
  - Reliance on established models
  - Designed to analyze how climate change impacts and risks in the U.S. change between BAU and global policy scenarios
  - Estimates the costs of inaction (and benefits of mitigation and adaptation) in terms of physical effects, economic damages, and changes in risk

- Designed to use consistent socio-economic, emissions, and climate data to estimate damages under BAU and policy scenarios
  - Differences in damages between policy and BAU legitimately interpreted as the benefits of mitigation policy
  - Enables comparison of damages across multiple, diverse impacts sectors
  - Examines key sources of uncertainty:
    - Emissions pathways
    - Climate sensitivity
    - Model uncertainty
  - Other comprehensive impact analysis efforts have not emphasized consistency and the exploration of uncertainty to the same extent as CIRA
Overview of the CIRA Process

**Socioeconomics & Emissions**

- **CIRA emission scenarios**
  - Reference (no mitigation) scenario: 2100 global emissions ~2.5 x 2005 levels 1650 ppm CO₂ eq (IPCC gases)
  - Global mitigation scenario: 2100 global emissions ~57% < 2005 levels 600 ppm CO₂ eq (IPCC gases)
  - Stronger global mitigation scenario: 2100 global emissions ~70% < 2005 levels 500 ppm CO₂ eq (IPCC gases)

**Climate Data Generation**

- **Project future climate data**
  - Temperature
  - Precipitation
  - Sea level rise
  - Cloud cover
  - Wind speed
  - Relative humidity

**Impacts Estimation & Valuation**

- **Run sectoral impacts models**
  - Coastal property damages
  - Road infrastructure
  - Bridge vulnerability
  - Electricity supply/demand
  - Extreme temp. health
  - Ag & forestry yields
  - Terrestrial carbon storage
  - Forest fires
  - Coral reefs
  - Freshwater fish
  - Inland flooding damages
  - Water supply/demand
  - Drought risk

**Impact/benefit estimates**

- Physical impacts
- Economic damages
- Changes in risk

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**Analyzing Key Sources of Uncertainty**

- GHG emissions
- Climate sensitivity
- Climate model selection
- Initial climate model condition
- Structural uncertainty in sectoral models
Caveats and Limitations

• CIRA is a policy analysis tool, not a comprehensive climate science assessment such as those conducted by IPCC and USGCRP

• Results are not intended for local scale vulnerability assessments
  – Designed to examine national-scale impacts and benefits questions

• Not intended to estimate the benefits of marginal levels of mitigation

• Likely underestimates of the benefits of GHG mitigation policies
  – Not all known impacts that are not currently included

• Climate projections are based on one climate model
  – The sectoral analyses do not incorporate climate model uncertainty

• CIRA is designed to examine climate change *impacts and damages*, though some of the sectoral models do include *adaptation* costs
CIRA Project Status and Next Steps

• Sectoral model runs complete
  – In some cases conducting follow-up sensitivity analyses prior to publication

• Special issue of Climatic Change
  – Submitted 12 papers, anticipate publication starting fall 2013

• Communication of results to broader audiences, e.g.
  – Summary for policy makers report
  – Presentations for external groups, academic conferences, stakeholders

• A next phase of CIRA analysis?
  – Complete initial agriculture and forestry sector analyses
  – Develop impacts/damages modeling capacity in new sectors (e.g. air quality)
  – Assessment of additional sources of uncertainty (e.g. climate model)

• Further research and questions
  – Potential to use results to develop reduced form relationships
  – Identify highest priority gaps in sectoral impacts modeling

• Continued development of integration of climate impacts into IAMs
CIRA Scenarios and Results
CIRA Climate Scenarios

In 2100:

- **Reference (~10 W/m²) scenario**
  - Global emissions ~ 2.5 x 2005 levels
  - U.S. emissions ~ 1.8x 2005 levels
  - GHG concentrations (IPCC gases) ~1750 ppm

- **Policy 4.5 W/m² mitigation scenario**
  - Global emissions ~ 57% below 2005 levels
  - U.S. emissions ~ 67% below (38% in 2050)
  - GHG concentrations (IPCC gases) ~ 600 ppm

- **Policy 3.7 W/m² mitigation scenario**
  - Global emissions ~ 73% below 2005 levels
  - U.S. emissions ~ 73% below (60% in 2050)
  - GHG concentrations (IPCC gases) ~ 500 ppm
Scenario Comparisons

Temperature increase relative to 1980-1999 (°C)

*Likely ranges for CIRA scenarios represent year 2100 values for climate sensitivity 2 and 4.5°C

[Source: Rogelj et al. 2012]
Analyzing Key Sources of Uncertainty in Projecting Temperature Changes in temperature (°C) in 2100 relative to present day

**Emission scenario**
Both GHG mitigation scenarios show a marked decrease in warming compared to the reference

**Climate sensitivity**
Climate sensitivity analysis shows a wide range in the magnitude of future warming

**Initial condition of climate model**
Varying the initial conditions of the climate model results in temperature differences less than 1.0°C

**Climate model pattern**
Similar magnitude of temperature change across models, but with different spatial patterns

* Preliminary - Do Not Cite *
Analyzing Key Sources of Uncertainty in Projecting Precipitation Changes in precipitation (mm/day) in 2100 relative to present day

**Emission scenario**
Both policies lead to decreases in the magnitude of precipitation change across U.S.

**Climate sensitivity**
The effects of climate sensitivity appear to be highly localized

**Initial condition of climate model**
Changes in the initial conditions of the model have a larger impact on regional precipitation than temperature

**Climate model pattern**
Climate model pattern shows largest spatial heterogeneity across the U.S.

* Preliminary - Do Not Cite *
Changes in Temperature in 2100

- With no mitigation, average and extreme temps increase substantially.
- These changes are substantially reduced under both mitigation scenarios.

*Preliminary - Do Not Cite*
Summary Results

• Electricity supply and demand (GCAM, ReEDS, and IPM)
  – Change in power system costs due to the temperature effects from climate change are greater than the change in power system costs from the Policy 3.7 scenario (-0.8%–3.5%)

• Extreme temperature mortality (BenMAP)
  – Considerable annual risk reduction for ETM; reduction grows over time and with stringency of GHG mitigation scenario

• Drought risk
  – Largest increases in drought frequency in the Southwest; this regional also has the largest benefits from mitigation scenarios

• Wildfire risk (MC1)
  – Relative to the Reference, the Policy 3.7 scenario reduces cumulative acreage burned in the continental U.S. (2011 – 2100) by roughly 303 million acres; This results in a reduction in wildfire response costs (i.e., labor, equipment) of (2005)$9.24 billion (r = 3%)

• Coral reef die off
  – GHG mitigation provides minor benefits to coral cover in South Florida and Puerto Rico, but significantly delays reef loss in Hawaii; Policy 3.7 avoids ~$18B (r = 3%) by 2100 in lost recreational value for all 3 regions

• Costal property damages and adaptation
  – In the Reference scenario, cumulative economic impacts of sea level rise through 2100 (140cm) are $85B (r = 3%); Policy 4.5 and 3.7 avoid $6.4B and $7.5B, respectively

• Freshwater fisheries
  – Reference scenario, by 2100 coldwater fish habitat declines by ~62%; Policy 4.5 and Policy 3.7 decline by only 12% and 11%, respectively
Climate Impacts on Electricity Demand and Supply using multiple models—GCAM, ReEDS, & IPM

• Projected temperature changes increase electricity demand for air conditioning and lower the demand for heating.

• Power sector models show electricity demand increases 1.5%–6.5% nationally in 2050 with Reference air temperature (left figure)

• Supplying this additional electricity raises power system costs by 1.5%–6.8% across the models (discounted at 5%, cumulative costs from 2012–2050, right figure)

• Change in power system costs due to the temperature effects from climate change are greater than the change in power system costs from the Policy 3.7 scenario (-0.8%–3.5%, right figure)

% Change in Elec Demand vs. Control

% Change in System Costs

* Preliminary - Do Not Cite *
Extreme Temperature Mortality

- Increases in projected heat mortality through 2100; cold mortality diminishes
- Considerable annual risk reduction for ETM; grows over time with GHG mitigation
- Does not incorporate the effects of adaptation on reducing mortality
Changes in Drought Risk Through 2100

- Drought risk is measured by changes in both precipitation and temperature (Palmer Drought Severity Index, PDSI)
- Green represents reductions in drought risk associated with the GHG mitigation policies compared to the reference scenario
- Largest increases in drought frequency (reference) in southwestern U.S.
  - This region also has the largest benefits from mitigation
- These are likely to be underestimates of impacts/benefits, given the comparative ‘wetness’ of the climate model used for this analysis

![Map of change in number of PDSI drought months in a 30-yr period due to mitigation (policy-reference)]

*Preliminary - Do Not Cite*
Relative to the Reference, the Policy 3.7 scenario reduces cumulative acreage burned in the continental U.S. (2011 – 2100) by roughly 303 million acres.

This results in a reduction in wildfire response costs (i.e., labor, equipment) of (2005)$9.24 billion (discounted at 3%).

Aggregated national-level results are driven by wildfire incidence in a limited number of regions (e.g., Rocky Mountains).

* Preliminary - Do Not Cite *
Estimated Decline in U.S. Coral Reefs

- GHG mitigation delays Hawaiian coral reef loss compared to the reference.
- Policy 3.7 avoids ~$18B (r = 3%) by 2100 in lost recreational value for all 3 regions, compared to the reference.
- GHG mitigation provides minor benefits to coral cover in South Florida and Puerto Rico (*not shown*), as these reefs are already being affected by climate change, acidification, and other stressors.
Coastal Property Damages and Adaptation Response Costs

- In the Reference scenario, cumulative economic impacts of sea level rise through 2100 (140cm) are $85B (r = 3%)
  - Policy 4.5 scenario avoids $6.4B of these damages
  - Policy 3.7 scenario reduces damages by $7.5B
- Inundation risks and economic damages increase as storm surge is incorporated
- Projected abandonment areas have higher fraction of socially vulnerable populations than projected protection areas
Freshwater Recreational Fishing

• Significant changes to the spatial distribution of fish habitats

• In the Reference scenario, by 2100 coldwater fish habitat declines by ~62%
  – Policy 4.5 and Policy 3.7 decline by only 12% and 11%, respectively
  – Mitigation preserves coldwater habitat in most of Appalachia & the Mountain West

• Policy 3.7 avoids $324M (r = 3%) in total recreational fishing damages by 2100 compared to the Reference scenario
Back-up Slides
CIRA Impact Sector Coverage

- **Human health**
  - Thermal stress (mortality)
  - Air quality
  - Vector-borne disease
  - Extreme event morbidity, mortality
  - Environmental justice / vulnerable populations
  - Thermal stress (labor productivity)

- **Agriculture**
  - Crop yield (U.S.)
  - Crop yield (global)
  - Livestock production
  - Carbon storage

- **Forests**
  - Change in production
  - Change in CO₂ storage
  - Wildfire

- **Freshwater Resources**
  - Drought
  - Flooding damages
  - Water supply and demand
  - Water quality

- **Ecosystems**
  - Species (coral, freshwater fish, others)
  - Biodiversity
  - Other acidification effects

- **Energy**
  - Temperature effects on energy (electricity) supply and demand
  - Precipitation and system effects on hydro power
  - Change in water flow effects on cooling capacity
  - Climate and system effects on wind and solar generation

- **Infrastructure**
  - Roads and bridges
  - Coastal property and infrastructure
  - Urban drainage
  - Inland property damages from floods
  - Waterways
  - Telecommunication infrastructure

- **Tourism**
  - Coral reef recreation
  - Recreational fishing
  - Other recreation (e.g., winter, boating, birding)

- **Other extreme events**
  - Residual damages post extreme events (e.g., hurricanes)
  - Catastrophic climate change (e.g., ocean circulation shutdown)
  - National security risks (e.g., mass migration)
Relative Importance of Uncertainty Sources Analyzed

**Mean Spread* of Temperature Change for Each Source of Uncertainty**

- The mean spread (1991-2010 mean vs. 2091-2110 mean) displays little spatial heterogeneity. The largest source of uncertainty is the policy (mean spread between 2.0 and 3.0˚C), with the spread from climate sensitivity selection also being substantial (values between 1.0 and 1.7˚C).

**Mean Spread of Precipitation Change for Each Source of Uncertainty**

- The mean spread of each source is more heterogeneous. The choice of policy and of models are the largest contributors of uncertainty in precipitation changes, with a mean spread >0.2mm/day in most of U.S.
- A particular feature is the small spread in the Southwest, indicating that this region shows the least amount of uncertainty in precipitation changes.
Both efforts use model-based approaches to estimate mitigation benefits and address climate and model uncertainty, however the approaches differ in important ways:

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<th>CIRA</th>
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<td>Geographic scope</td>
<td>U.S. regional + global</td>
<td>Global</td>
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| Applicability and usage | • Significant global action.  
                           • Informs analysis and helps tell story of benefits of mitigation. | • Assess marginal changes in GHG trajectories.  
                           • Meant to provide a comprehensive metric for benefit-cost analysis.  
                           • Limited communication tool. |
| Characterization of impacts | • Highly specific for U.S.  
                              • Meaningful physical impacts (e.g., heat mortality, drought, habitat loss).  
                              • Physical + monetized estimates. | • Too aggregated for U.S. specific impacts.  
                              • Only monetized estimates.  
                              • Often difficult to see underlying physical impacts. |
| Coverage of impacted sectors | Detailed U.S.- and sector-specific coverage. A number of known impacts not included (e.g., vector-borne disease, catastrophic events). | Aims to measure economic damages from all impact sectors; in practice models do not capture all important damages. |
| Approach to impact estimates | Bottom-up modeling: directly modeled at sector level using consistent data, assumptions, and scenarios. | Aggregated damage functions developed from available literature (with inconsistent inputs, data, etc.). |

In the future, results from CIRA’s impact analyses may help inform aggregate damage functions used in the SCC models’ estimates.
Both MIT (IGSM) and PNNL (GCAM) are developing fully integrated impacts modeling capacity.