U.S. Climate Change Impacts and Risk Analysis Research

James McFarland, Jeremy Martinich, Marcus Sarofim
*Climate Change Division, US EPA*
Stephanie Waldhoff, *PNNL*

IAMC 5th Annual Meeting
*Utrecht, Netherlands*
13 November 2012
Overview

• Goal and Scope
• Methodology
• Illustrative results
• Next steps
Goal and Scope of Impacts Research

• Our goal is to quantify (where possible) and communicate the benefits (i.e., avoided or reduced impacts) of mitigation & adaptation actions.

• The research explores how impacts and damages may change under a consistent set of scenarios, data, and assumptions.
  – Existing impacts literature is largely based on inconsistent assumptions along the causal chain from socio-economics to emissions to climatic effects and impacts.

• Initial focus is on:
  – Risks and impacts within the U.S., without ignoring key global linkages or key regional components.
    • Impacts and benefits across a range of sectors, e.g., water resources, human health, ecosystems, energy.
  – Potential benefits of mitigation scenarios (adaptation later).
  – Analyzing key sources of uncertainty, including emissions pathway, climate sensitivity, climate models, etc.
Our ideal tools and results

- Integrated model(s) with internally consistent emissions drivers, impact sectors, and economic valuation
  - Climate impacts feed back into the economy and climate
- Identify, quantify, and be transparent about key uncertainties along the causal chain
- Multiple future scenarios, BAU and policies
- Outputs that communicate effectively to multiple audiences about how impacts and risks change from one scenario to another.
Methodology
Analytical Approach

• Develop estimates of climate change impacts and damages in multiple sectors that can be synthesized
  – *Begin with integrated assessment (IA) models to develop three internally consistent socio-economic, emissions, and climate scenarios (BAU, RF 4.5, RF 3.7)*
  – *All sectoral models use consistent population, GDP, and emissions data*
  – *Climate inputs consistent with all socio-economic and emissions scenarios*

• Explore uncertainties around impacts estimates
  – *Scientific: Multiple climate sensitivities (2.0, 3.0, 4.5, and 6.0)*
  – *Model: Use of multiple IA and sectoral models where possible*
  – *Variability: Analysis of changing temperature and precipitation patterns*

• Understand what drives differences in model results
  – *Comparison of data inputs and outputs*
  – *Discussions about model structures, methods, etc.,*
Methodology

- Begin with IA models (MIT IGSM and GCAM) to develop three internally consistent socio-economic, emissions, and climate scenarios
  - Reference: Business as usual
    - GDP and population harmonized with US (EIA) data through 2035, EPPA projections through 2100
  - Policy scenarios:
    - 4.5 W/m² and 3.7 W/m², stabilization in 2100
- Multiple climate sensitivities (2.0, 3.0, 4.5, and 6.0)
- Climate data from MIT’s 3D CAM component of IGSM
- Sectoral models develop estimates with these consistent socio-economic and climate data
Impacts Research Operational Schematic

**Scenarios:**
- BAU (MIT)
  - Target 3.7
  - Target 4.5

**Timeframes:**
- Generally 1980-2115 (1980-2009 historic per.)
- 2025, 2050, 2075, 2100

**Sensitivities:**
- 2.0, 3.0, 4.5, and 6.0 W/m²

**Sectoral Models**
- SLR NCPM
- Vegetation (MC1)
- Forest fires (MC1)
- COMBO
- Road infrastructure
- FASOM
- Inland flooding
- Bridge vulnerability
- Heat health
- IPM
- NREL elect. supply (REEDS)
- Freshwater fish
- Water supply/demand
- Drought risk

**Yield Changes (Crops, forests)**

**Core runs**

**Rahmstorf high ice-melt SLR model**

**SIMCLIM**

**CLIRUN**
- (runoff model)

**AEO**
- GDP, Pop to 2035

**MIT IGSM (3D)**
- Future climate, pop, GDP, LU

**Harmonization**
- BAU GDP/Pop

**PNNL GCAM Hector**

**Impacts/Benefits Estimates**

Alternate Sources of Sectoral Model Data: PNNL GCAM Hector or AR5 GCM RCP 4.5 input, possibly through SIMCLIM.
Data Flow

• **Inputs**
  - Reference GDP and population (EIA through 2035)
  - Policy scenario, RF targets

• **IA Model Outputs**
  - Global GHG concentrations
  - Global and domestic emissions
    - CO₂, non-CO₂ GHG, criteria pollutants
  - Sea Level Rise
  - Temperature change
    - Global annual average
    - Gridded monthly, daily, hourly
  - Precipitation
    - Gridded monthly, daily, hourly

• **Changes in impact sectors** (use IA outputs as inputs)

  - Temperature-related mortality
  - SLR property damages and adaptation response costs
  - Road and bridge infrastructure adaptation
  - Inland flooding damages
  - Water supply and demand
  - Drought risk (not monetized)
  - Electricity supply
  - Energy demand
  - Population
  - Crop yields projections
  - Vegetative carbon sequestration and provisioning of grazing lands
  - Forest fire frequency/magnitude and suppression costs
  - Coral reef cover and recreational/existence values
  - Freshwater fish habitat and recreational fishing impacts
  - Air quality
Examples of Data Needs for Sectoral Modeling

<table>
<thead>
<tr>
<th>Sector/Model</th>
<th>Socio-economic</th>
<th>Climate</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMBO</td>
<td></td>
<td>Global avg $\Delta T$</td>
<td></td>
</tr>
<tr>
<td>SLR/Coastal Property Model</td>
<td>GDP growth</td>
<td>Global avg SLR</td>
<td></td>
</tr>
<tr>
<td>Ecoservices/forest fires</td>
<td>$\Delta LU$ (Developed Land)</td>
<td>Monthly avg $T$, daily max $T$, CO2 Concentrations, monthly mean precip elevation</td>
<td></td>
</tr>
<tr>
<td>Inland flooding</td>
<td>Population growth</td>
<td>Monthly $\Delta Precip$</td>
<td></td>
</tr>
<tr>
<td>Heat health</td>
<td>Pop growth, demographic changes, VSL = f(GDP/cap)</td>
<td>Max and min daily $T$</td>
<td></td>
</tr>
<tr>
<td>Bridge vulnerability</td>
<td></td>
<td>Daily precip to calculate 2 y and 100 y 24 hour max precip</td>
<td>Land cover type</td>
</tr>
<tr>
<td>Drought risk</td>
<td></td>
<td>Monthly avg temp and precip</td>
<td></td>
</tr>
<tr>
<td>Freshwater fisheries</td>
<td>Value of fishing day, Population growth</td>
<td>Monthly avg max $T$ and avg precip</td>
<td></td>
</tr>
<tr>
<td>Water supply-demand</td>
<td>Population growth</td>
<td>Monthly avg, max, and min $T$, total monthly precip, cloud cover, wind, relative humidity</td>
<td>Yield changes due to climate changes (EPIC)</td>
</tr>
<tr>
<td>FASOM</td>
<td>Demand (population, GDP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPM</td>
<td>Population, GDP</td>
<td>$\Delta T$ (daily/hourly)</td>
<td></td>
</tr>
</tbody>
</table>

**Inputs**
Coverage of Impacts in CIRA vs. North American Impacts Listed in AR4

- **Human health**
  - Thermal stress (mortality)
  - Waterborne illness
  - Vector- and rodent-borne disease
  - Extreme event morbidity, mortality

- **Agriculture**
  - Crop yield
  - Livestock production
  - Carbon storage

- **Fishery productivity**

- **Forests**
  - Change in production
  - Change in CO$_2$ storage

- **Freshwater Resources**
  - Water quality
  - Water supply
  - Water demand

- **Energy**
  - Temperature effects on energy (electricity) supply and demand
  - Precipitation and system effects on hydro power
  - Climate and system effects on wind and solar generation

- **Infrastructure**
  - Roads and bridges
  - Waterways
  - Coastal property
  - Inland property

- **Tourism**
  - Coral reefs
  - Other recreation

- **Ecosystems**
  - Biodiversity
  - Services (coral reef existence)
Change in US Climate
CO₂ Emissions

U.S. Annual CO₂ Emissions

Global Annual CO₂ Emissions

GCAM Global Fossil fuel and LU CO₂ Emissions (Mt-CO₂)
CO$_2$ Concentrations

Reference

3.7 Policy

U.S. Environmental Protection Agency
Forcing

Reference

3.7 Policy

U.S. Environmental Protection Agency
Temperature

Reference

3.7 Policy

U.S. Environmental Protection Agency
Presentation of Results
(Global Average ΔT from 1990, IGSM)
Changes in Temperature Extremes
Without mitigating GHGs, today’s hottest days become more frequent, and the number of frosts will decrease.

**Daily Max Temperature**
- **Business As Usual**
- **Less Stringent Policy (RF4.5)**
- **More Stringent Policy (RF3.7)**

**Frost Frequency**
- Change in # of days above present day 95th percentile
- # of future frost days per year
Changes in Extreme Precipitation

Without mitigating GHGs, extreme precipitation will become more common.

**Winter**

**Business As Usual**

**Less Stringent Policy (RF4.5)**

**More Stringent Policy (RF3.7)**

Change in # of days above present day 95th percentile

- Without mitigating GHGs, extreme precipitation will become more common.
Impacts
Changes in Drought Risk Through 2100

- More stringent (RF 3.7)
- Less stringent (RF 4.5)
- BAU

Change in number of drought months within a 30yr window (difference between 1980-2009 and 2085-2115)
Road Incremental Maintenance Costs by Scenario 2025-2100

Note: Values are expressed in undiscounted year 2005$.
Temperature sensitive demand is 37% greater in the Ref scenario and 13% higher in the Pol3.7 scenario than the BC by 2050.

The change in temperature sensitive demand increases total electricity demand by over 6%.
Estimated Decline in U.S. Coral Reefs

- GHG mitigation delays Hawaiian coral reef loss compared to BAU.
  - The more stringent policy scenario (RF3.7) avoids ~$9B in lost recreational value for Hawaiian reefs, compared to the BAU.
- GHG mitigation provides only minor benefit 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.
Next Steps
Peer Review of Impacts Research

• Peer review of methods and results
  – Special issue
    • Overview of methodology and goals
    • Individual papers on each component of the project
  – Individual papers for each topic/impacts sector
    • Overall approach and scenario development
    • Extreme events and assessing uncertainty of regional climate change
    • Coastal development, infrastructure, and heat health
    • Energy supply/demand and water resources (drought, flooding damages, water supply/demand)
    • Ag/forestry and ecosystems (coral reefs, freshwater fish, vegetation/wildfire)
  – Key methods and results assembled in a single paper
    • Will require a significant amount of supplementary material.
Communication of Results

- Estimating impacts and economic damages in an analytically rigorous and consistent way will enable clear communication of climate change impacts and risks to a variety of audiences
  - Researchers
    - Distribute findings through peer reviewed publication and conference presentations
  - Policy makers
    - Schedule briefings with interested committees
    - Incorporate results into legislative analyses
  - Public
    - Share results through EPA's updated climate change website
    - Summary report
Other Potential/Future Impact Analyses

• Incorporate impacts into CGE framework
• Population
  – Leverage EPA-ORD’s ICLUS model to examine climate change impacts on regional population growth
  – Disaggregated data may be used in future iterations as inputs to other sectoral models (e.g. land use, energy)
• Energy Supply
  – NREL’s ReEDS model to look at climate change impacts on energy transmission, including extreme events
• State-level impacts
  – Penn State, Boston University developing a state-level impacts model using sectoral damage functions to examine impacts with interstate trade
Thank you.

Contact information: mcfarland.james@epa.gov