Modeling water, land, and energy interactions in GCAM - a water focus

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The 5th Annual IAMC Annual Meeting, Utrecht, Netherlands, Monday, November 12, 2012
Incorporating Water in GCAM - The links to land and energy

- Energy System
  - Energy Supply: Coal, Gas, Oil, Renewables, Electricity, Hydrogen
  - Energy Demand: Transportation, Buildings, Industry
  - Energy Markets: Fossil fuel prices, Electricity prices, Hydrogen prices, Bioenergy prices

- Climate System
  - Fossil and Industrial Emissions
  - Carbon Cycle: Atmosphere, Ocean, Land
  - Concentration, forcing calculations
  - Other things (aerosols, sea level, ...)

- Water System
  - Water Demand: Energy, Agriculture, Domestic
  - Water Supply: Surface, Ground, Natural Lakes
  - Water Markets: Water prices

- Regional GDP
  - Agricultural Demand: Crops, Livestock, Forest Products
  - Agricultural Markets: Crops prices, Livestock prices, Forest Product prices, Bioenergy prices

- Land Use & Land Cover

- Land Characteristics
  - Agricultural Technologies
  - Climate Inputs
  - Labor Force
  - Labor Productivity

- Resource Bases
- Energy Conversion Technologies
- Energy Demand Technologies
Water Supply – A Global Hydrologic Model

MODEL INPUTS:
- Potential Evapotranspiration (PET)
- Temperature
- Precipitation
- Maximum Soil Moisture Capacity

MODEL OUTPUTS:
- Storage
- Actual Evapotranspiration (AET)
- Runoff

Mean Annual Runoff in 2000 (mm/yr)

Change in Ensemble Mean Annual Runoff ($Q_{2006} - Q_{2009}$) (mm/yr)

Climatic Research Unit (CRU), University of East Anglia
Representation of all Components of the Water Demand Sectors in GCAM

Total Water Use
  Non-Agricultural Water Use
    Domestic
    Electricity Generation
      Hydro
      Wind
      PV
      CSP
      Geothermal
      Nuclear
      Biomass CCS
      Biomass
      Oil CCS
      Oil
      Gas CCS
      Gas
      Coal IGCC CCS
      Coal IGCC
      Coal
    Primary Energy
      Coal
      Natural gas
      Conventional oil
      Unconventional oil
      Uranium
    Manufacturing
    Agricultural Water Use
      Agriculture (irrigation)
        Corn
        Wheat
        Rice
        Oil crops
        Sugar crops
        Fiber crops
        Misc. crops
        Other grain
        Root Tuber
        Palm Fruits
        Fodder Herb
        Fodder Grass
        Biomass
      Livestock
        Buffaloes
        Cattle
        Sheep
        Goats
        Pigs
        Poultry
  Once-through
    Wet towers
    Cooling ponds
    Dry cooling
Estimates of Global Water Demands in 2005 & 2095

Global water demands by sector in years 2005 and 2095 (under three alternative scenarios with variations in technology, income, & population)
Socioeconomic Scenarios

SIX SCENARIOS:

1. Collapse (POP6/MDG-)
2. Sustainability and Equity (POP6/MDG+)
3. Muddling Through (POP9/MDG-)
4. Consumerism (POP9/MDG+)
5. Crowded Chaos (POP14/MDG-)
6. Social Conservatism (POP14/MDG+)


Comparison among the six scenarios with respect to socioeconomics (e.g.: population, GDP and per capita income), climatic variables (e.g.: ΔT, radiative forcings, & CO2 concentration), land (e.g.: cropland area, biomass area), & energy (e.g.: electricity generation, & primary energy consumption) assumptions
Global Water Withdrawals vs. Literature Estimates of Water Use

Preliminary Assessment of Water Scarcity

Water scarcity in years 2005, 2050, and 2095 at the 14-GCAM regions due to changing water demands; total water supply (renewable water + desalinated water) are assumed fixed to 2005 levels to capture the effect of demand projection alone on water scarcity; the error-bars represent the range of values based on the six SSP scenarios; WSI values above 0.4 are considered severely stressed regions.
Consistent World of Water
Demand & Supply in GCAM

Force GCAM to reproduce the above radiative forcing pathways using:

- UCT
- FFICT
- SOCIO
Future Global Water Demands

Global Accessible Water (10,150 km³/yr)
Postel et al. (1996)

- Assessments (from several studies)
- Forecasts (Published prior to 1980)
- Forecasts (Published between 1980 & 2000)
- Forecasts (Published after 2000)

Baseline (A1fi)
- UCT7.7 (A2)
- UCT5.5 (B2)
- UCT4.2 (B1)
- FFICT7.7 (A2)
- FFICT5.5 (B2)
- FFICT4.2 (B1)
- SOCI07.7 (A2)
- SOCI05.5 (B2)
- SOCI04.2 (B1)

Policy scenario range
Ref=8.8 W m⁻²
Policy 4.2 W m⁻²

Socioeconomic scenario range
Impact Assessment: Water Scarcity

For a given climate mitigation policy scenario & particular year:

Severe Stress:
0.4 ≤ WSI

Moderate Stress:
0.2 ≤ WSI < 0.4

Low Stress:
0.1 ≤ WSI < 0.2

No Stress:
WSI < 0.1

Global gridded-map of total water demands

Requirement: Downscale demands to grid scale

Water Supply
Change in Water Scarcity
The Effects of Socioeconomic Drivers on Water Scarcity in 2095

Shifts in the Cumulative Density Function of Global Population in 2095
## Experiments

### Baseline: current demands and current climate conditions in year 2005

<table>
<thead>
<tr>
<th>Variable</th>
<th>B1 (RF4.2)</th>
<th>B2 (RF5.5)</th>
<th>A2 (RF7.7)</th>
<th>A1Fi (RF8.8)</th>
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<tbody>
<tr>
<td><strong>Fixed</strong></td>
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### The effect of climate change alone

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### The effect of socioeconomic drivers alone

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### The effects of climate change and socioeconomic drivers together

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Climate Change Vs. Socioeconomic Drivers

Percent of Global Population Under Severe Stress Conditions ($WSI>0.4$) in Year 2095

- Socio. drivers alone
- Combined effect
- Climate change alone

Time:
- 2000
- 2020
- 2040
- 2060
- 2080
- 2100
Distribution of the range of the change (2005 to 2095) in average share of population living under water scarcity by water basin.
Future Research Directions

- Allocating water among competing water users and technology choices (two-way feedback)
- Climate change impacts on water demands
- Enhance the existing representations of the global hydrologic model and demand sectors in GCAM
- Accounting for non-renewable water sources, e.g., desalinated water and non-renewable (fossil) groundwater
QUESTIONS!
References


