Visual Analytics Tools
for the Global Change Assessment Model

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Result
What is the Global Change Assessment Model?

The Global Change Assessment Model (GCAM) is a global integrated assessment model with particular emphasis on the representation of human earth systems including interactions between the global economic, energy, agricultural, land use, and technology systems [1].

Challenges

- GCAM is complex.
- GCAM has limited abilities for exploring the outputs.
  - Existing tools are not enough for analysis purposes, such as Matlab and the Advanced Weather Interactive Processing System (AWIPS).
Research Goal

• Design and develop the first web-based visual analytics tool for the GCAM.
  – Scenario exploration
    • Geospatial perspective
    • Temporal perspective
  – Similarity analysis
    • Between scenarios
    • Between basins
GCAM Data

• Inputs:
  – Future precipitations
  – Greenhouse Gas control policies
  – Global population
  – China South-North Water Transportation Project

• Outputs:
  – Water demand
  – Water supply
  – Water scarcity

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>Demand for irrigation use</td>
</tr>
<tr>
<td>Livestock</td>
<td>Demand for livestock use</td>
</tr>
<tr>
<td>Electricity</td>
<td>Demand for electricity use</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Demand for manufacturing use</td>
</tr>
<tr>
<td>Domestic</td>
<td>Demand for domestic use</td>
</tr>
<tr>
<td>Total</td>
<td>Demand in total</td>
</tr>
<tr>
<td>Scarcity</td>
<td>Scarcity value</td>
</tr>
<tr>
<td>Supply</td>
<td>Supply value</td>
</tr>
</tbody>
</table>
GCAM Data

• Temporal info: From 2010 to 2095 at five year intervals, 18 year steps in total

• Spatial info:
  – Grid level: $0.5^\circ \times 0.5^\circ$, which is $720 \times 360$ in total
  – Basin level: 235 basins
  – Region level: 62 regions including 31 divisions in China
System Design

• Model-View-Controller (MVC)
GCAM Visual Analytics View
Similarity Analysis View
Dendrogram
- Model Level Similarity

- Parent Nodes are labeled with the parameters that have the smallest impact on the grouping procedure.

Dendrogram is one of the most frequent visualization approaches to illustrate the arrangement of the clusters in a hierarchical structure [2].

Node Labeling

Scenario Name and the Legend:
- Precipitation: term ‘g’
- Emissions: term ‘c’
- Population: term ‘p’
- Water Project: term ‘w’

For ‘g’: 6 ‘0’
For ‘c’: 6 ‘45’
For ‘p’: 2 ‘10’, 2 ‘95’, 2 ‘90’
For ‘w’: 3 ‘T’, 3 ‘F’

\[ \text{Diff}_p = \sum_{R \in P} \text{Absolute Value}(\text{Cluster1}_{p,R} - \text{Cluster2}_{p,R}) \]

Where R is the Rth record of parameter P.

value for water project

- Water Project
  - g: 12
  - c: 0
  - p: 0
  - w: 0

Scenario Values:
- Water Project:
  - 10WF, 10wT
  - 95wF, 95wT

Legend:
- Blue: Water Project
- Green: Population
- Orange: Emissions
- Red: Precipitation
Case Study - The impact of spatial variations and scales on scenario similarity

- World: 235 basins
- Continental: continents at the basin level
- Country, 31 divisions in China
World Scale

- World level: all 235 basins
  Future emissions will make the largest impact on the scenario dissimilarity, followed by precipitation, population, and the China S-N Water Transportation Project.
Continental Scale and Variations

- Africa
  Same as the world scale result
Continental Scale and Variations

- Asia
  Same as the world scale result
Continental Scale and Variations

- America
  Same as the world scale result
Continental Scale and Variations

- Europe
  The population makes bigger impacts
Continental Scale and Variations

- Australia
  The population makes bigger impacts
Country Scale

- China – Scenario Similarity Analysis
  Mixed sequences of precipitation, and population
Country Scale

• China – Basin Similarity Analysis

Average scarcity threshold: 0.4 (severe water scarcity)
Demo

- Similarity Analysis View
- GCAM Visual Analytics View
Thank You!

• **Contributions**
  – The first ever web-based geovisual analytics tool for the GCAM
  – Inter-comparison and similarity analysis of climate scenarios with the GCAM models across the globe

• **Future Work**
  – More clustering approaches
  – Methods that deal with a large number of sectors
  – More visualization features
  – UI improvement

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GCAM History

- GCAM was one of four models chosen to create the representative concentration pathways for the IPCC’s AR5.
- GCAM was one of three models used to create scenarios for the Climate Change Science Program’s scenario analysis.
- GCAM has been a prominent tool for analysis in the Climate Change Technology Program.
- GCAM has participated in virtually every major climate/energy/economics assessment over the last 20 years:
  - Every Energy Modeling Forum study on climate
  - Every IPCC assessment
- GCAM has been used for strategic planning by energy and other private companies.
- GCAM is now used by research institutions and governments internationally.
GCAM

- GCAM links economic, energy, land-use, and climate systems.
- Typically used to examine the effect of technology and policy on the economy, energy system, agriculture and land-use, and climate.
- Emissions of 16 greenhouse gases.
Overall structure of the general structure of the energy system of the GCAM.

Overview of energy production and transformation in GCAM.
Case Study - China South-North Water Project
• Spatial Exploration
  Dry future precipitation, low emissions, and 8 billion population in 2030
Temporal Exploration
The water scarcity situations in Ziya He Basin improves significantly when the water project carries on, whereas the water project does not dramatically worsen the water scarcity situations in Yangtze River Basin.
Labeled Time Line
- Yearly Average Water Scarcity
Parallel Coordinate Plot
-Basin Level Similarity
Parallel Coordinate Plot

- Brushing on axes