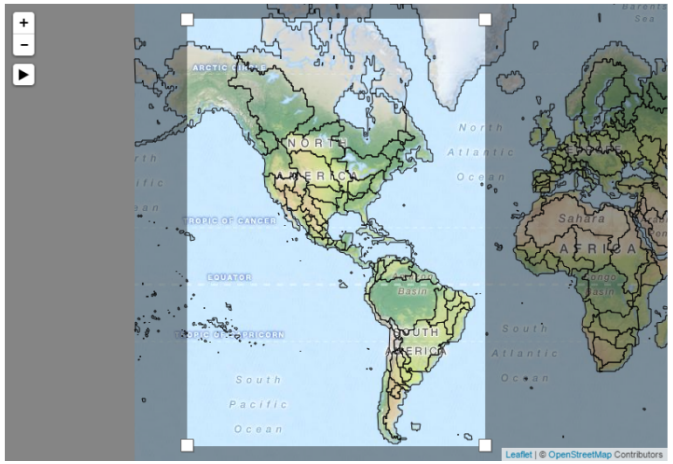
Computational Improvements

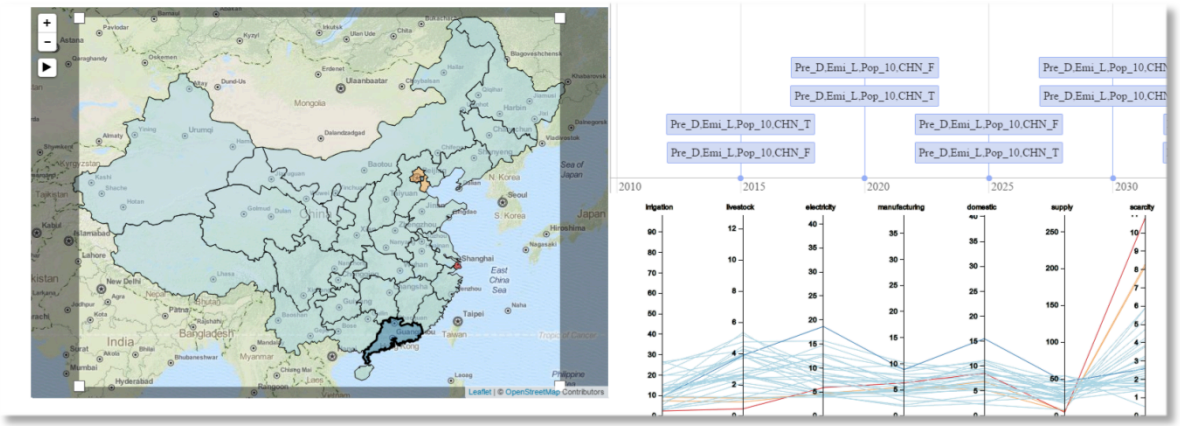
- Improvements to Performance
  - Reduce startup overhead
  - Improve multithreading performance
  - Massively-parallel GCAM
  - More efficient output
- Improvements to Usability
  - Diagnostic tools & test suite
  - Scenario configuration tools
  - GCAM automation suite

- Development Community
  - Better documentation for users
  - Community contributions
  - More frequent releases
- New Capabilities
  - Hindcasting and backtesting
  - API for updates to model parameters
  - Hooks for model coupling

Visualization

- Visualization development will be an area of emphasis
  - More efficient and user-friendly ways to visualize model output
  - Tools for putting results in a geographic context
- Visual Analytics tools will help extract insight from complex data sets
  - Ensembles of scenarios
  - Intra-scenario comparisons





AgLU Future Directions

- Near-Term:
  - Management Options (irrigation & fertilizer)
  - Albedo
  - Alternative Socioeconomic Pathways
- Longer-Term:
  - Updated historical land cover data
  - Ability to include agricultural impacts through the use of statistical climate-yield response functions
  - Sub-annual time steps
  - Inclusion of grain stockpiles
  - Improved demand representation
  - Improved trade representation

Energy System Model Developments: 1) Fossil Resource Supply and 2) Electricity Production

1) Fossil Resource Supply

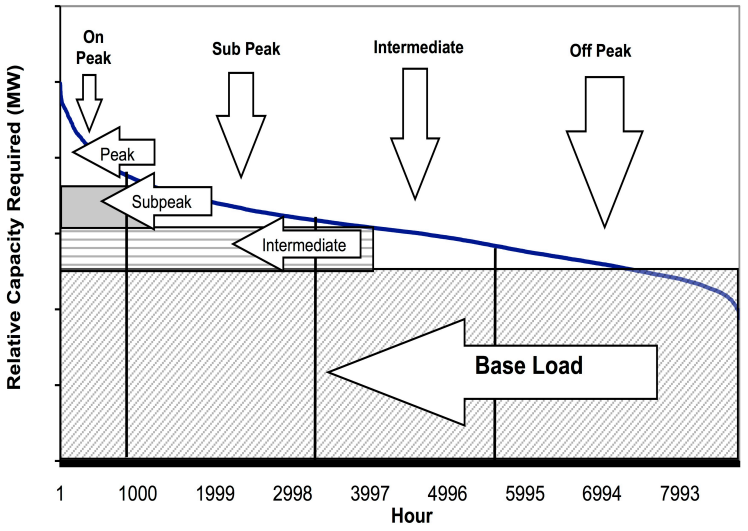
- Updated Resource and Reserves Data: New data on oil, gas, and coal reserves, resources, and graded costs (rely heavily on IIASA Global Energy Analysis).
  - Totals not drastically changed, but more grade granularity in unconv. oil and gas.

- Enhanced Regional and Global Trade Modeling: Incorporate parametric approach to integrating regional production and demand into global market.
  - Allows differentiation beyond a purely global market approach for oil, gas, coal.
  - Better control of modeled future regional oil, gas, and coal production.

2) Electricity Production (USA focus)

- Dynamically model separate long-term capacity investment decisions from short-term dispatch /operation.
- Foundational for modeling future responses to changes in demand profile and supply from drivers such as technology, policy, and climate.

Electric load duration curve (hourly electric demand in descending order of magnitude).



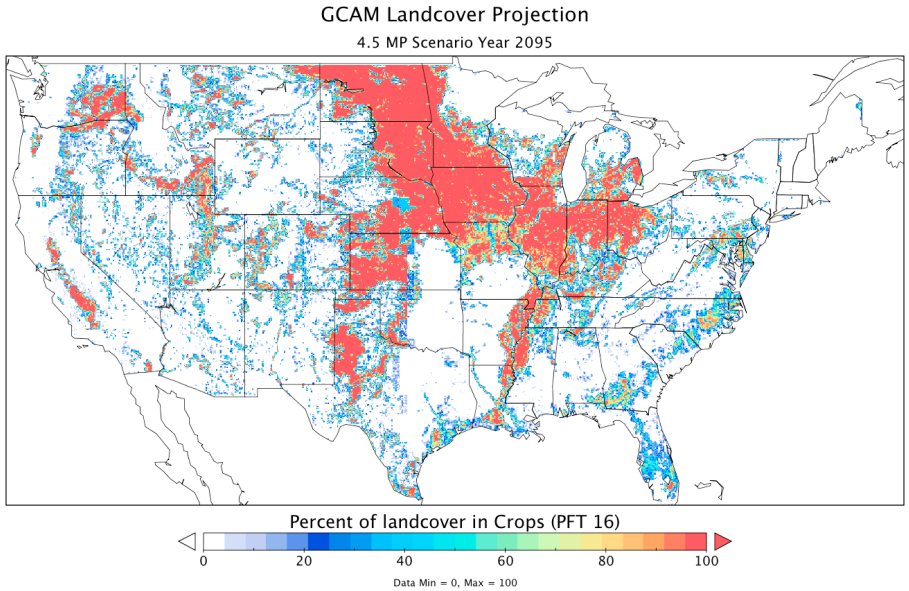
GCAM Data Products

As an integrated model that covers energy, land, water, emissions, and climate, GCAM requires a large number of global, consistent datasets.

As impacts-related research with GCAM increases, the amount of data work will also increase.

We will make datasets that are developed as a part of GCAM research available and usable for the wider community.

Figure: High resolution downscaled US crop cover area derived GCAM projections and satellite land-cover data



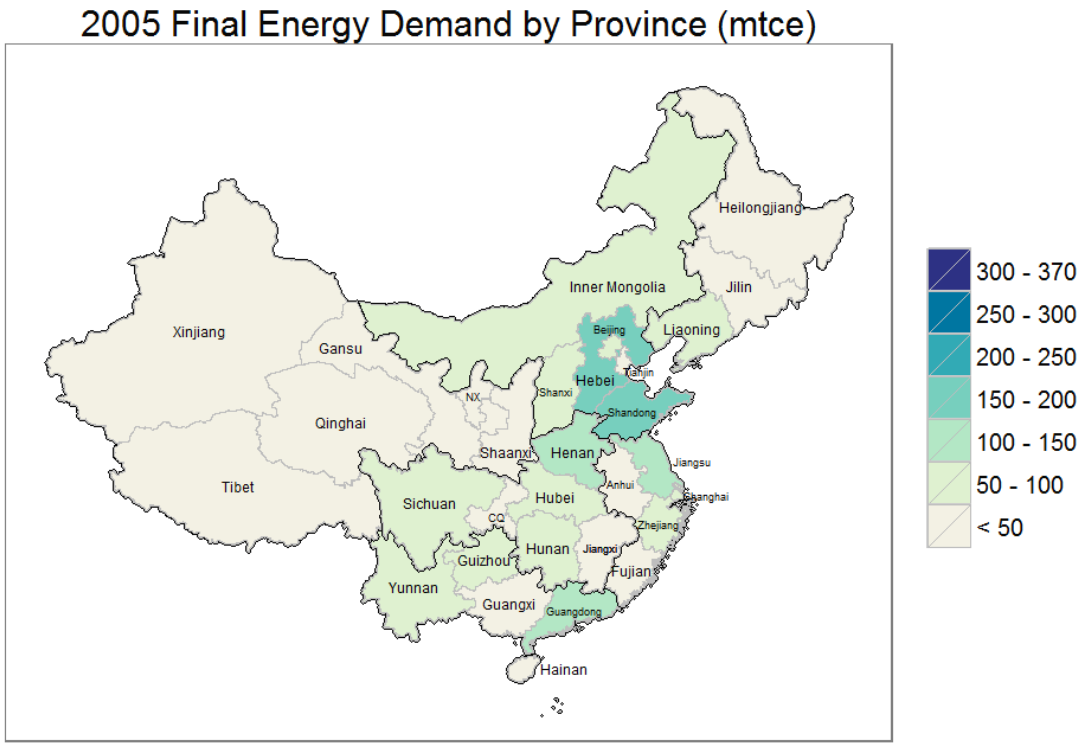
Potential Data Products

- Potential data products will be evaluated for: uniqueness, relevance, and effort required for documentation and release.
- Potential data include land-cover/land-use trends, bias-corrected climate data, emissions projections.

GCAM-China – A New Modeling Capability

- To explore regional activities in China, we have added <u>subnational</u> detail to GCAM:

  - 31-province energy and economic system
  - Agriculture and land use by AEZ
  - Water supply and demand at major watershed scale



GCAM-USA

We will be adding additional capabilities to the GCAM-USA model to address on-going research needs.

- Air pollutant emissions calibrated to US national emissions inventory (NEI) and current policies. *{See Talk D. Loughlin}*
- Detailed end-use industry representation (specific industrial sectors and end-use processes)
- Electricity load segments (base, intermediate, sub-peak, peak)
- State-level natural gas production (conventional, shale, tight, and coalbed methane) and trade
- Hindcast calibration experiments focused on electricity generation and agricultural production

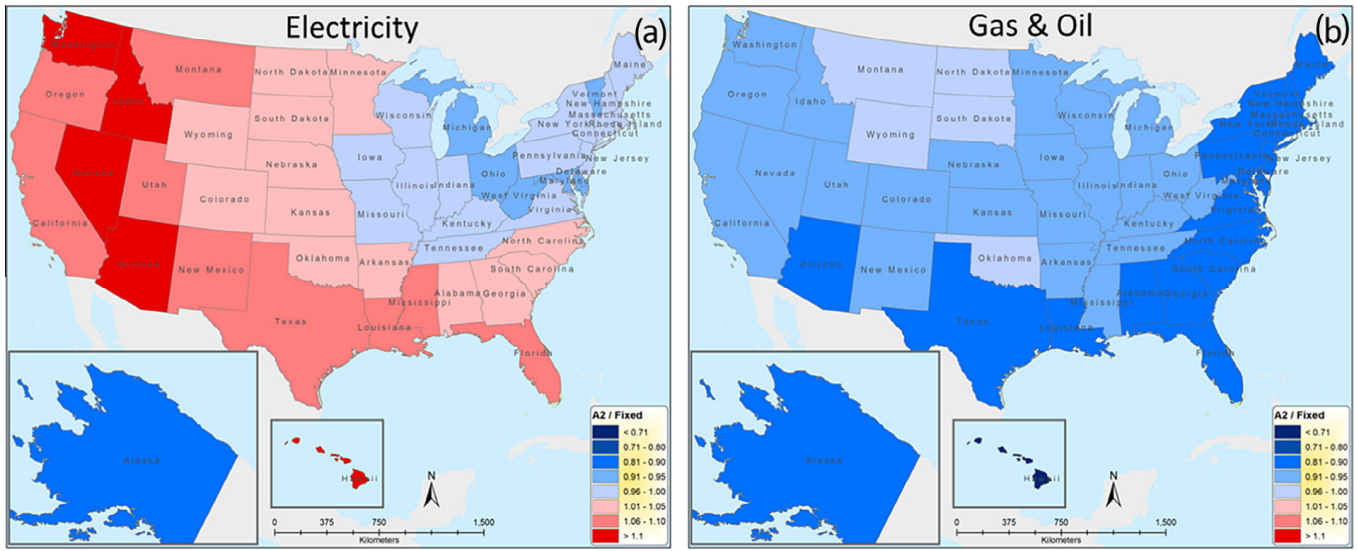


Figure: Change in cumulative building energy consumption due to climate feedbacks as compared to a scenario with a fixed climate over the century.

Development Areas in Economics

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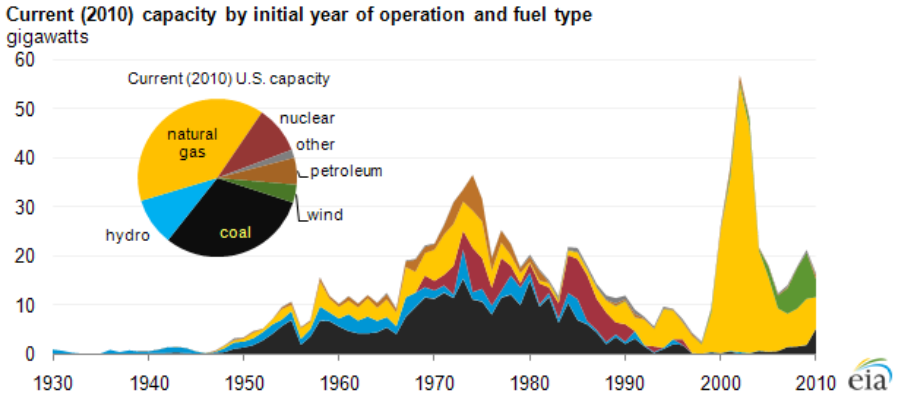
- Improving the representation of technology choice in GCAM
- Including agriculture and trade effects on aggregate economic activity
- Improved representation of consumer demands for agricultural commodities
- Improved representation of international trade in bioenergy and agriculture.

Technology Choice Highlight

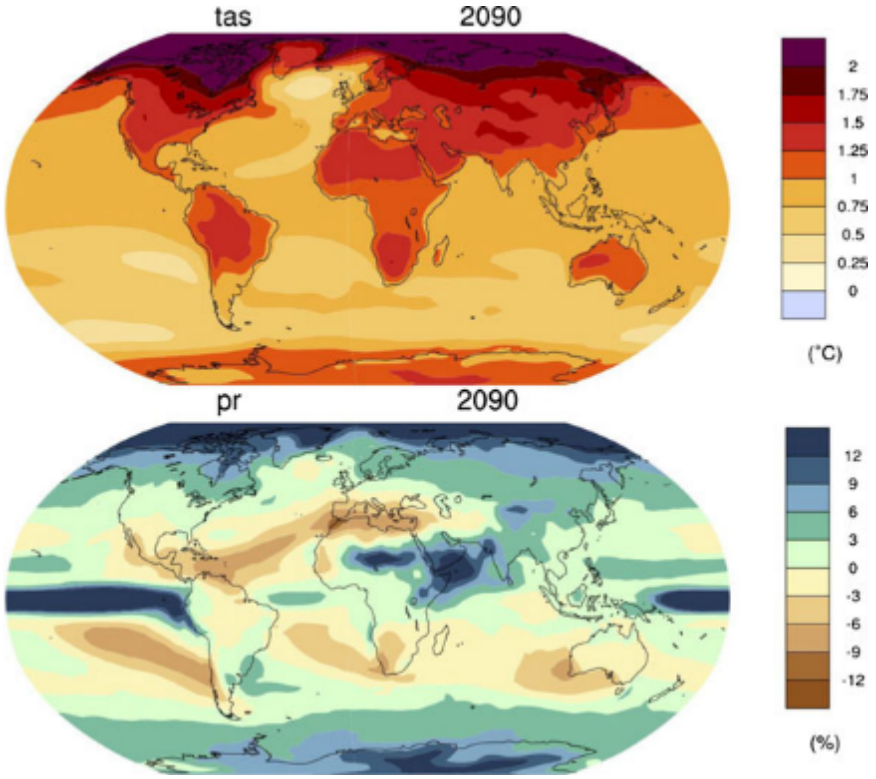


Source: EIA. http://www.eia.gov/todayinenergy/detail.cfm?id=1830

- **The problem:** IA models calibrate demand to reproduce a base year, but do not take full advantage of data, methods and models to accurately represent behavior.
- **Technology Choice Research Task** will explore the use of methods, models and data (e.g. hindcasting with pooled cross-section and time series data), to calibrate, test, and validate demands starting with the power sector.

The Climate System: Future Directions

- Continual model development in Hector
  - Emulate ESMs
  - Probabilistic outcomes
- Temporal and spatially resolved climate information from Hector's global mean temperature
  - Library of mean temperature and precipitation patterns
    - CMIP5 models
  - Endogenous impacts



Temperature and precipitation patterns at 2090 from Tebaldi and Arblaster, 2014.

Representing Water Processes at Finer Spatial and Temporal Scales in GCAM

- **Representing climate variability (Inter-annual & Intra-annual)**
  - Simulating water demands at monthly resolution and the ability to store water (reservoirs)
  - Improving fidelity of GCAM hydrologic modeling to generate reliable estimates of monthly water supply
  - Reconcile water demands and supplies at sub-annual scale (further down the road)
- **A range of model improvements:**
  - Closer mapping between land/ electricity and water basins
  - Distinguishing between renewable and non-renewable groundwater
  - Energy demands in the water sector (e.g., desalination and groundwater pumping)
- **Better formulating water technology scenarios**

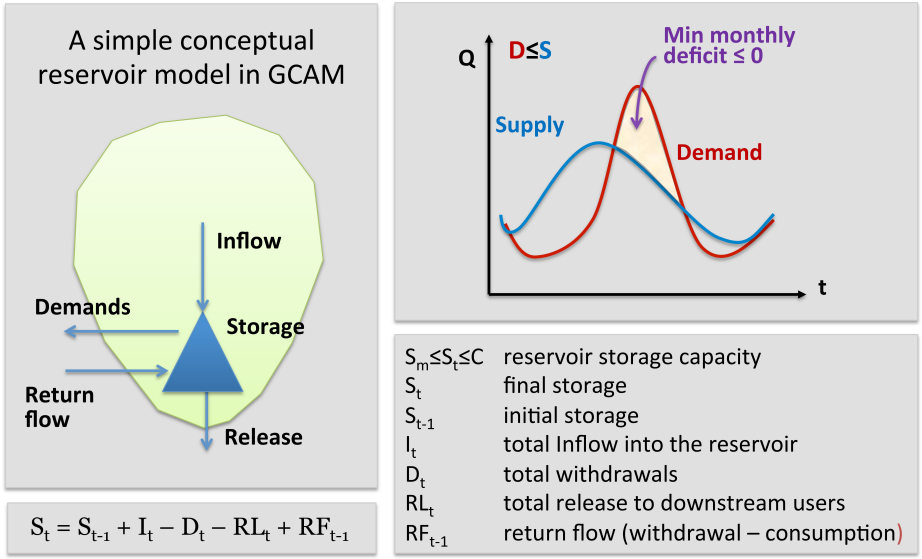


Figure. A schematic of the proposed framework to enable GCAM to account for climate variability in its water allocation framework. This approach will adapt a conceptual reservoir model (a single virtual reservoir in each basin), and a monthly water mass-balance accounting framework (monthly water allocation).

GCAM Modeling of Pollutant Emissions

Fossil fuel combustion is a primary source of many air pollutants as well as greenhouse gases. Aerosols and ozone also impact climate forcing. Due to these linkages, it is important for IAMs to consistently treat all emissions.

Over the coming year the representation of air pollutant emissions within GCAM will be enhanced.

- Base-year emissions will be calibrated to updated emission estimates from the Community Emissions Data System (CEDS). *{See Poster}*
- Regionally-specific changes in future emission factors will be incorporated.
- Emissions factors will be vintage-specific for electric generation and road transportation technologies.

Figure: Change in radiative forcing due to emissions reductions focused on Methane and black carbon (BC) in buildings and transportation. (Smith and Mizrahi 2013)