Projecting Climate Change Impacts on Regional Hydrology and 21st Century Water Resources

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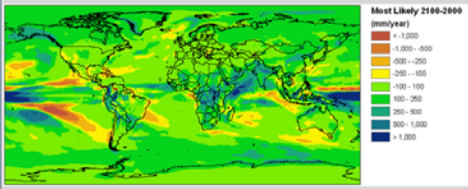
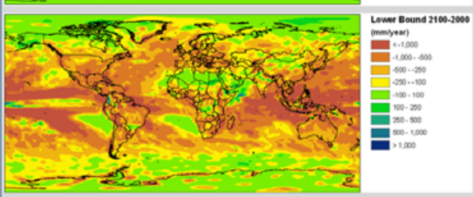
Background

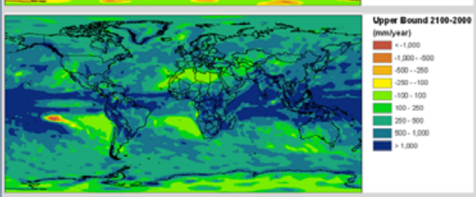
- **WHY? *Water is central issue for climate impacts***
  - Water resources and precipitation extremes critical
  - Considerable uncertainty in the global and regional precipitation and surface hydrology from GCMs
- **HOW? *Computational data sciences and GIS***
  - Model: CCSM3 / CLM3; Scenario: IPCC SRES A1FI, A1B
  - Compare global model precipitation with observations
  - Develop best- and worst-case regional assessments
  - Produce global and regional surface hydrology maps
  - Assess potential impacts by combining hydrology results with projected population and critical infrastructure

CCSM3 Precipitation Projections

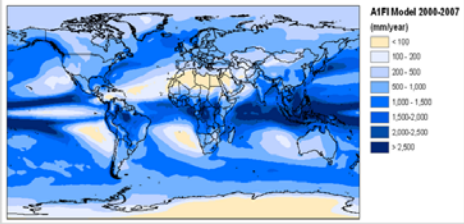
These three maps show different global precipitation projections for the for the end of the century (2090-2099). The "Most Likely" map (top) shows bias-corrected model outputs. The "Lower Bound" map (middle) and the "Upper Bound" map (bottom) have been calculated using "3 sigma" levels and show contrasting dry and wet worlds

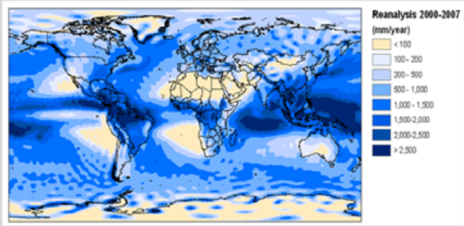


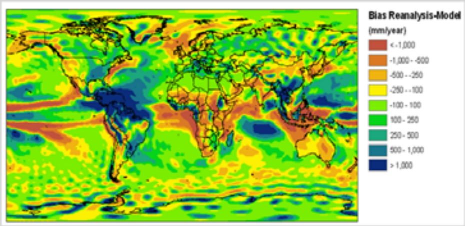




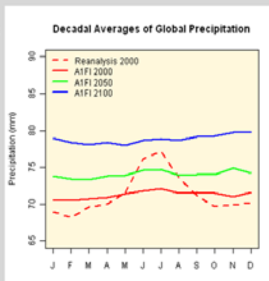
Confronting Model with Observations: 2000-2007







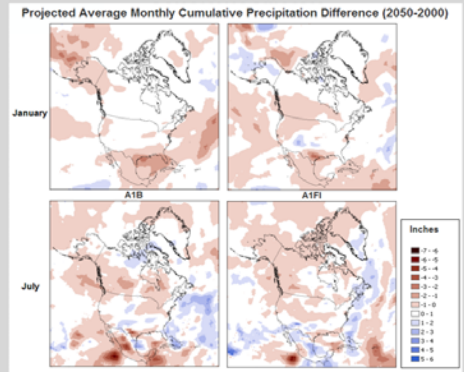
The CCSM3 precipitation projections from IPCC SRES A1FI (top) have been subtracted from the NCEP reanalysis results (middle) to get bias (bottom) and variance (not shown) at each T85 grid cell (equivalent to 1.40625 deg x 1.40625 deg, or approximately 125 km per cell edge).



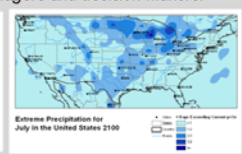
Global average seasonal trends in precipitation are not captured by the climate model

Projecting Changes in Precipitation and Surface Hydrology for the United States

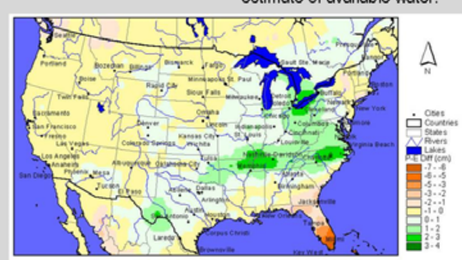
Breaking down the GCM results by region and by season is a first step toward making the climate projection outputs useful for decision-makers. In these maps of US precipitation differences created for a DOD exercise, the A1B results were considered to represent "business as usual" and the A1FI results were considered to be a "more severe" scenario.



The likelihood of extreme events (e.g., floods, droughts) is of great interest to resource managers and decision makers.



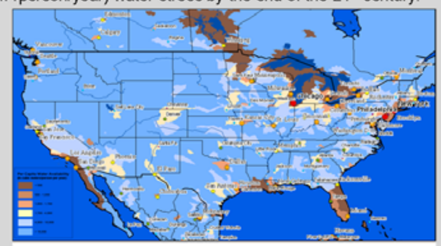
Since the coupled CCSM3 model incorporates land results into its climate outputs, precipitation minus evaporation (P-E) values may be used as an approximation of land surface runoff and a rough estimate of available water.



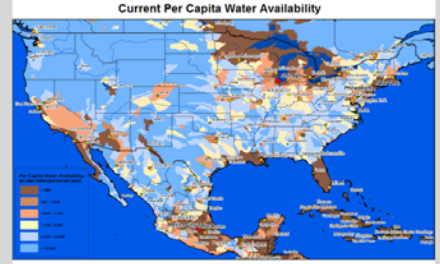
Projected Difference in July P-E for 2000 to 2050

Assessing Future Water Availability

By applying downscaled (global→regional→country) IPCC scenario population growth ratios to a grid of 2007 LandScan population and calculating the total predicted population and expected land runoff by Level 6 USGS HYDRO1K watershed, it was possible to get a rough estimate of future per capita water availability. These maps indicate that if emissions match the A1FI scenario trend and population grows to the extent predicted by the A2 scenario, then nearly every major city in the US may experience moderate (<1700 m^3/person/year) to severe (<1000 m^3/person/year) water stress by the end of the 21st century.



Current Per Capita Water Availability



Worst-Case Projected Per Capita Water Availability by 2100

Conclusions

- **Uncertainty in hydrologic projections**
  - Uncertainties are expected to be larger at regional and decadal scales, or when extreme stresses and extreme events are of interest; in addition decision makers will face cascading uncertainties from precipitation projections to surface hydrology and impacts on water resources
- **Future Research**
  - A comprehensive characterization of hydrologic uncertainty resulting from climate change is critical
  - Combining hydrological assessments with predictions of temperature, heat waves, population & critical infrastructure is also important for decision makers

References

Selected Bibliography

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- Elsner et al, Nature, 2008
- Milly et al, Science, 2008
- Alcamo et al, Hydro Sci, 2007
- Goswami et al, Science, 2006
- Meehl & Tebaldi, Science, 2004

Selected Prior Work

- Ganguly & Steinhaeuser, ICDM, 2008
- Khan et al., Water Resources, 2007
- Kuhn et al., Adv in Water Res, 2007
- Branstetter & Erickson, JGR, 2003

New Extension

Ganguly et al. (2009), Uncertainties in the Assessment of Climate Change Impacts on Regional Hydrology and Water Resources, invited submission, under double-blind review.

Relevant ORNL Websites

1. Climate Change War Game: http://www.ornl.gov/knowledgediscovery/WarGaming/
2. Climate Change & National Security: http://www.ornl.gov/knowledgediscovery/QDR/

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Note: Adapted by Esther Parish from a 2008 Fall AGU poster by the authors

¶ Presenter: Esther Parish

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