

ROLE OF CLIMATE IN GLOBAL CHANGE

- From Milanković's time until end of 21st Century -

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Conclusions



- Global change
 - Climate change
 - Population growth and migrations
 - Land use (urbanization)
- Modeling global change
 - Challenges
 - High level of integration
 - High level of complexity
 - Common concerns
- Systems approach
 - Modeling of the whole system
 - System dynamics simulation)
- ANEMI model example

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Outline

- Global change modeling
 - Challenges of the old/new context
- Systems approach
- Role of climate
 - ANEMI model
 - Impacts of climate change
- Conclusions

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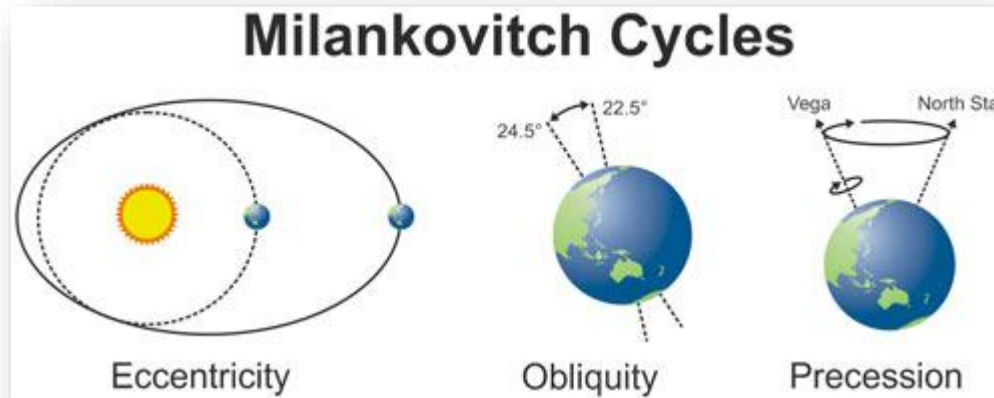
Challenges



- Global change
 - Climate change (mitigation – energy, adaptation – land and water)
 - Population (poverty, health)
 - Land use (urbanization)
- Sustainable management
 - Enormous opportunities for higher efficiency
 - Study of the whole complex system
 - Understanding interactions – it is all about feedbacks
- Scale
 - 1.4 billion people without access to electricity
 - 3 billion without access to modern fuels or technologies for cooking and heating
 - 900 million people without access to safe drinking water
 - 2.6 billion do not have sanitation
 - 900 million people are chronically hungry
 - 2 billion people lack food security

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Milanković



- Natural forcing
- A strong framework for understanding long-term changes in Earth's climate
 - Eccentricity – 100,000 year cycles
 - Obliquity – 41,000 year cycles
 - Precession – 26,000 year cycles
- Over last 150 years cycles did not change solar radiation very much
- Over last 40 years solar radiation decreased somewhat

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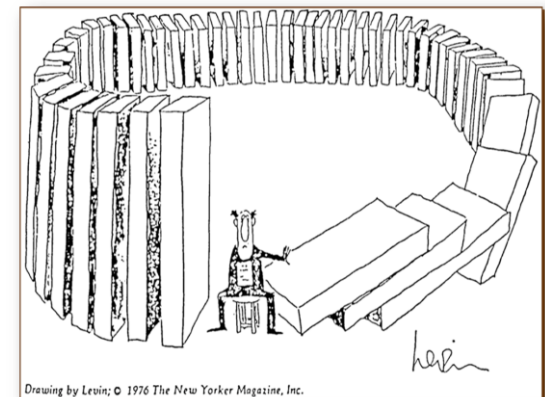
Systems approach

- Systems view
 - Complexity
 - Whole system approach
 - Difficult to translate into government policy making processes
- System structure
- Feedbacks
- System behavior
- System Dynamics simulation
 - A rigorous method of system description, which facilitates feedback analysis via a simulation model of the effects of alternative system structure and control policies on system behavior.

7 | Systems Modelling

System Dynamics (SD) simulation

- System Dynamics simulation
 - A rigorous method of system description, which facilitates feedback analysis via a simulation model of the effects of alternative system structure and control policies on system behavior.
 - System Dynamics simulation approach relies on understanding complex inter-relationships existing between different elements within a system.
 - This is achieved by developing a model that can simulate and quantify the behavior of the system.
 - Simulation of the model over time is considered essential to understand the dynamics of the system.



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ANEMI



- NSERC Discovery Grant (2005 – 2007) ANEMI ver 1
- NSERC Strategic Grant (2007 – 2011) ANEMI ver 2
- NSERC Discovery Grant (2016 – 2021) ANEMI ver 3

- Long-term project objectives
 - i. To develop system dynamics-based model of society-biosphere-climate system*
 - ii. To provide support for communication between the science and policy communities.*
 - iii. To examine the effects of climate change on socio-economic and environmental sustainability through the model outputs.*

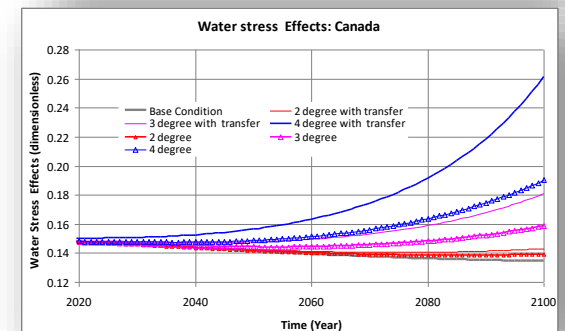
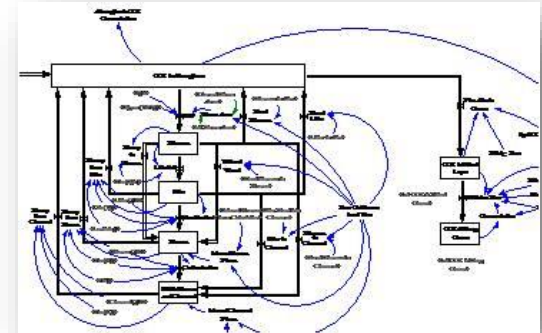
- Interdisciplinary team
 - Systems modelling – engineering
 - Climate policy – political science
 - Economics – economics

- Partners
 - Environment Canada
 - Natural Resources Canada
 - Department of Finance
 - Department of Fisheries and Oceans
 - Department of Agriculture

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ANEMI

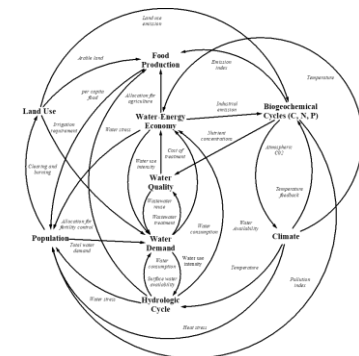
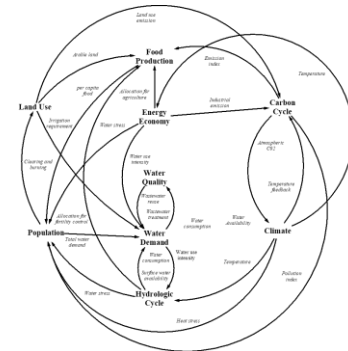
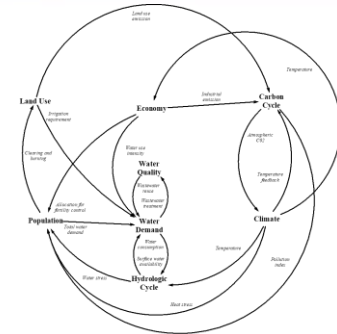
- Selection of the methodological approach
- *Initial communication*
- ANEMI model development
 - Structure
 - Sectors
 - Preliminary results
- Identification of key issues
 - Communication with the project collaborators
 - Selection of simulation scenarios
- *Model introduction*
- ANEMI model expansion
 - Economy-energy integration
 - Model regionalization
- Model use
 - Scenario analyses
 - Model limitations
- *Model transfer*
 - Model transfer
 - Future work



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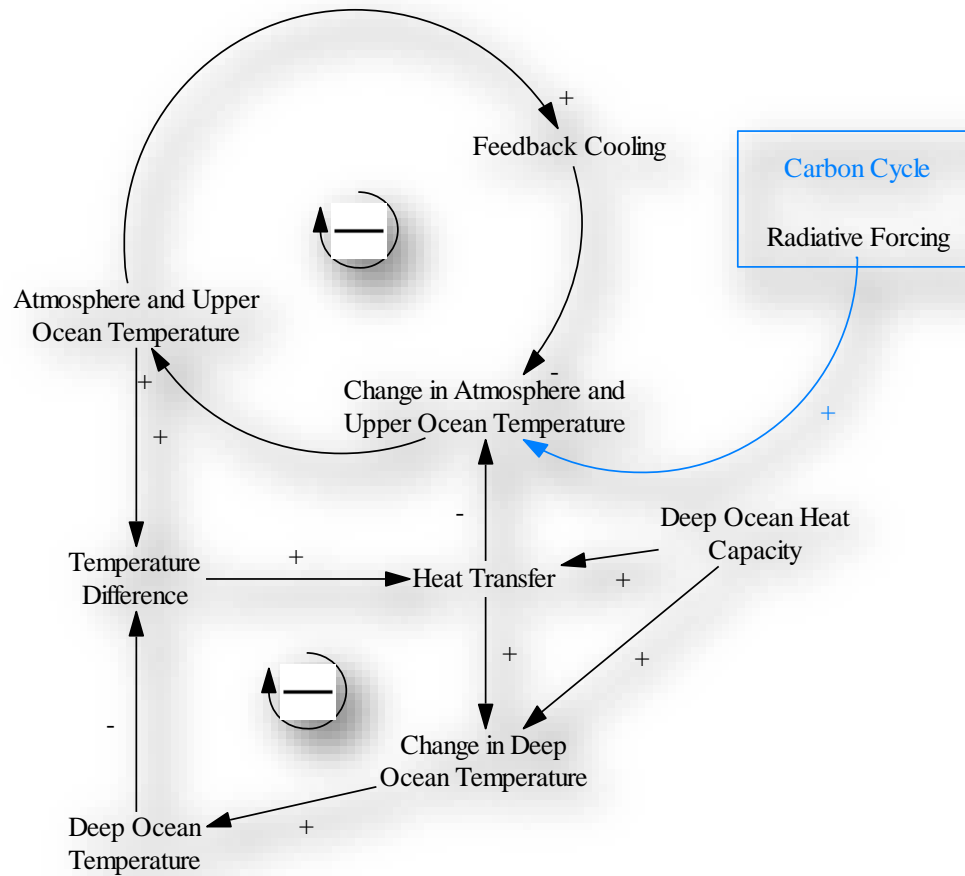
ANEMI

- *Version 1* – 8 sectors representing basic social and biophysical feedbacks
- *Version 2* – Food and energy sectors added and Population sector expanded
- *Version 3* – Carbon cycle expanded to include coupled nutrient cycles of Nitrogen and Phosphorus to allow better representation of water quality; Energy-economy sector expanded with water production



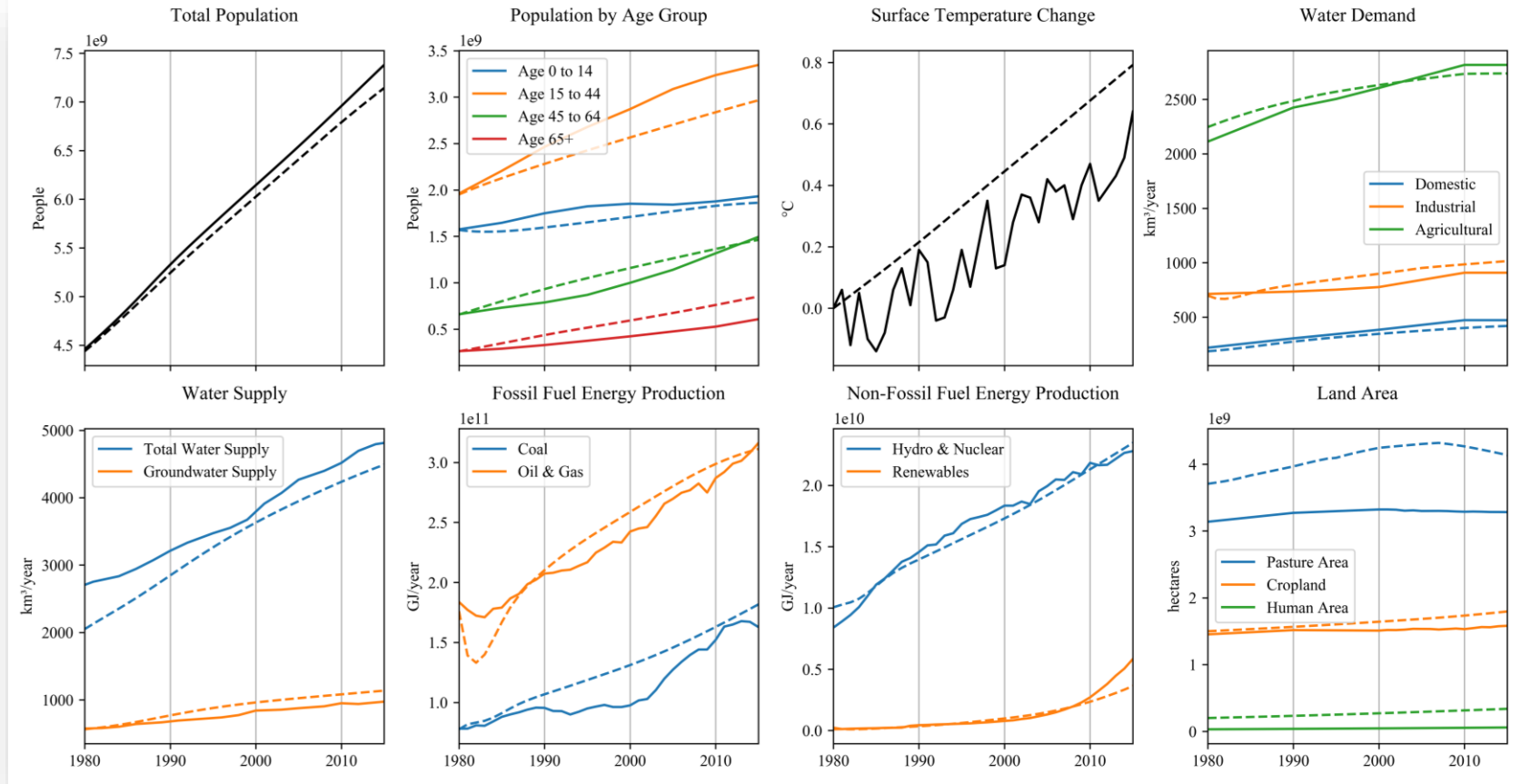
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ANEMI climate sector



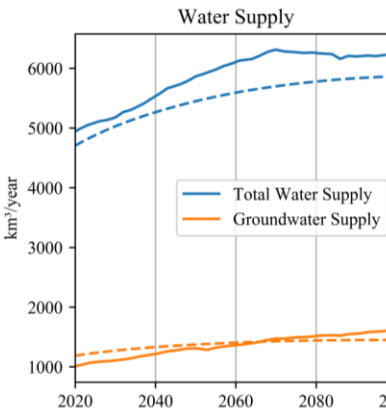
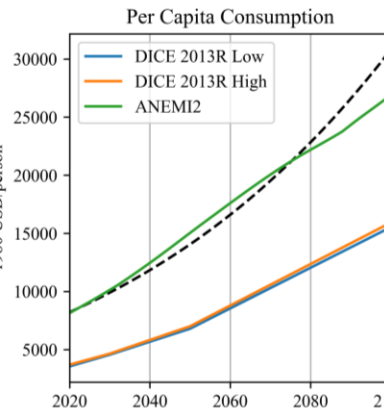
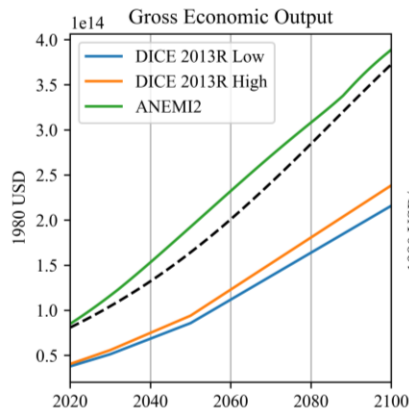
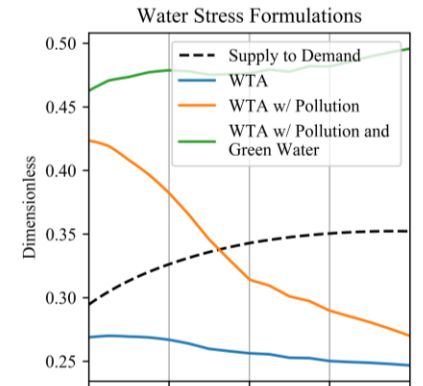
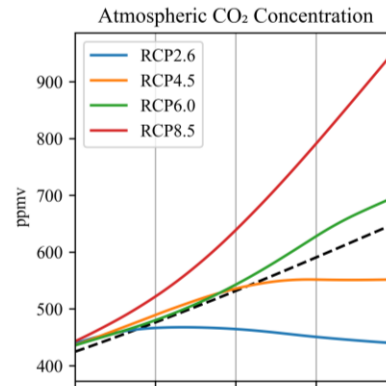
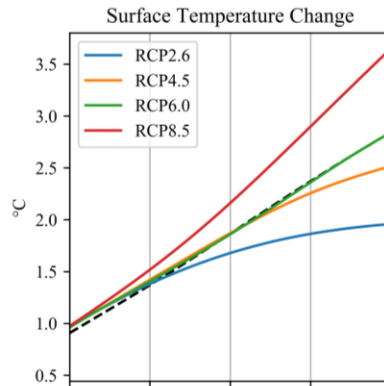
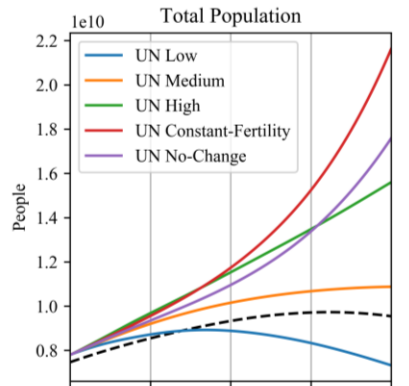
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ANEMI behavior reproduction



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ANEMI future predictions



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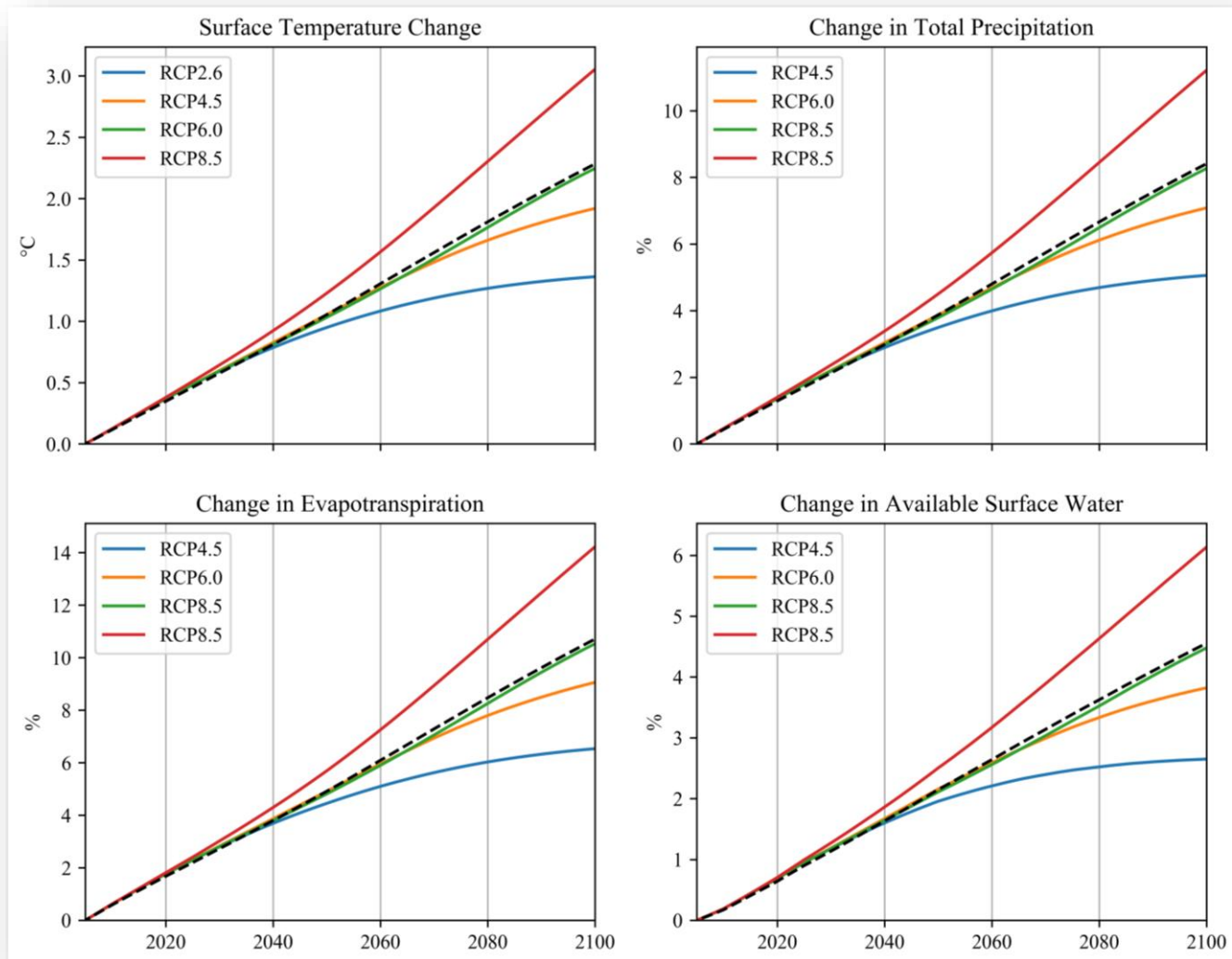
ANEMI – climate change impacts

- **Objective** - assessing climate change impacts on components of the Earth system
- **Alternatives** - Greenhouse gas emissions from the IPCC RCP scenarios are used to provide a range of temperature and precipitation projects from the ANEMI model
- **Impacts** - are assessed with respect to:
 - Water availability
 - Food production
 - Economic output



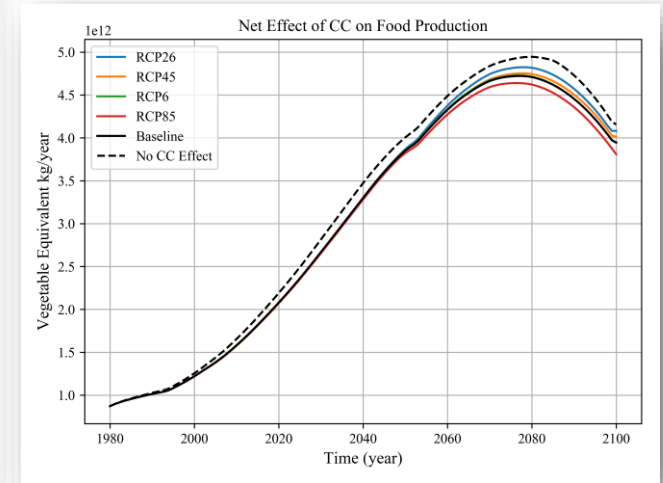
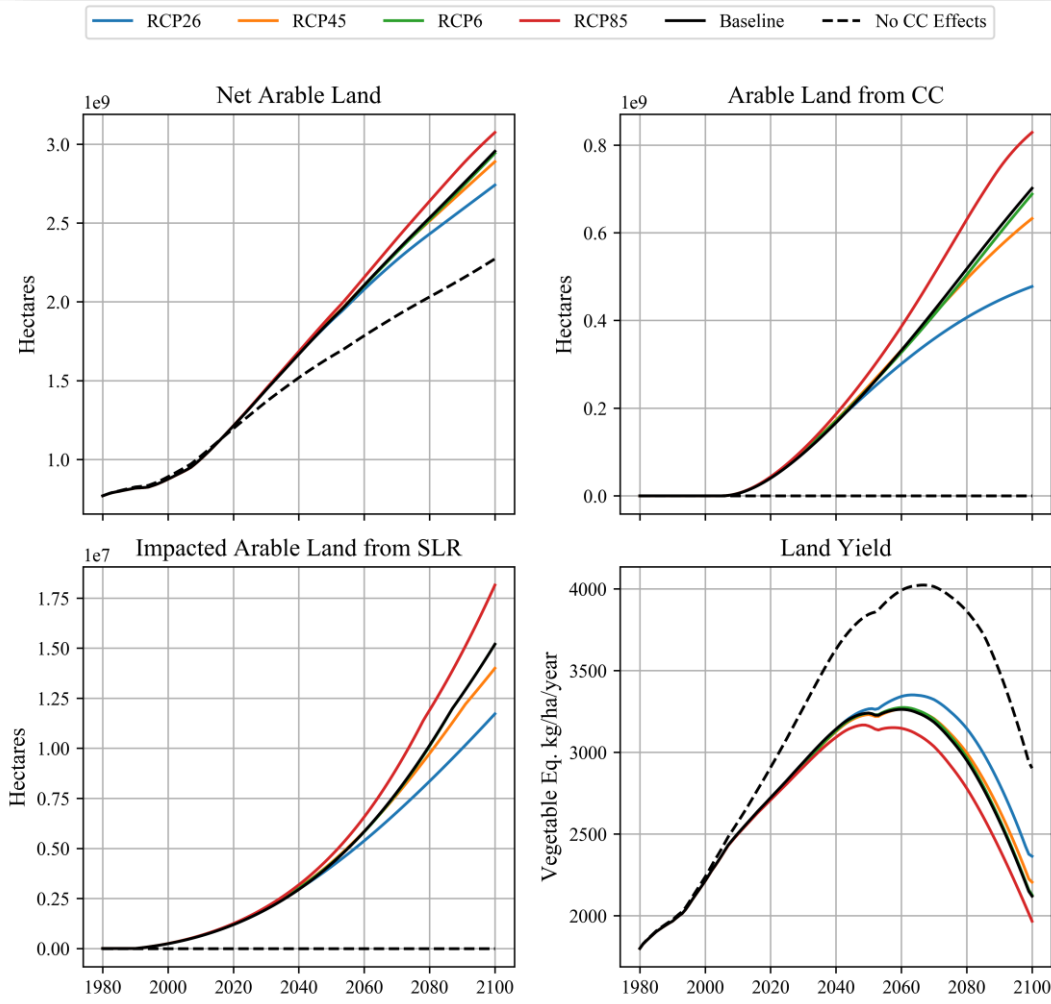
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ANEMI – climate change impacts on water



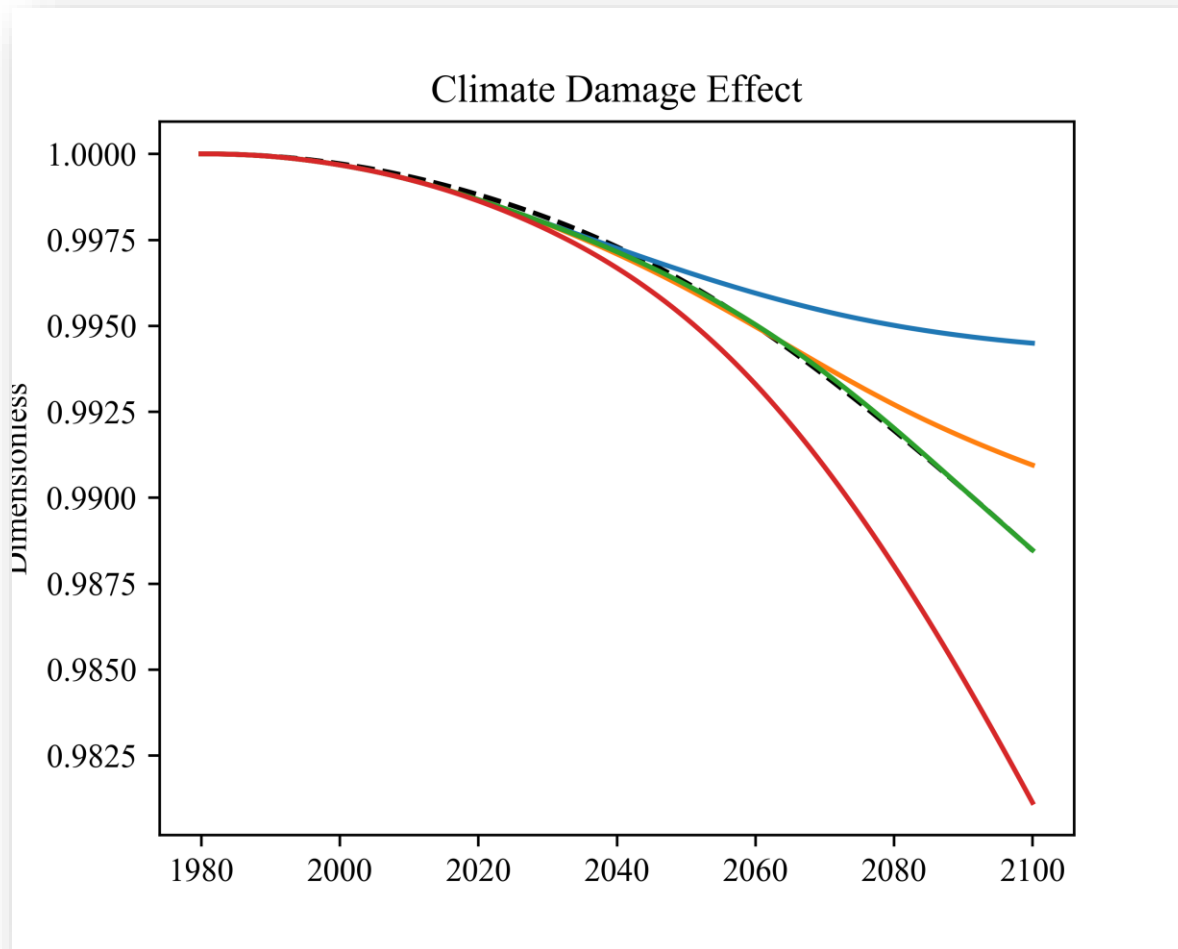
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ANEMI – climate change impacts on food



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ANEMI – climate change impacts on economy



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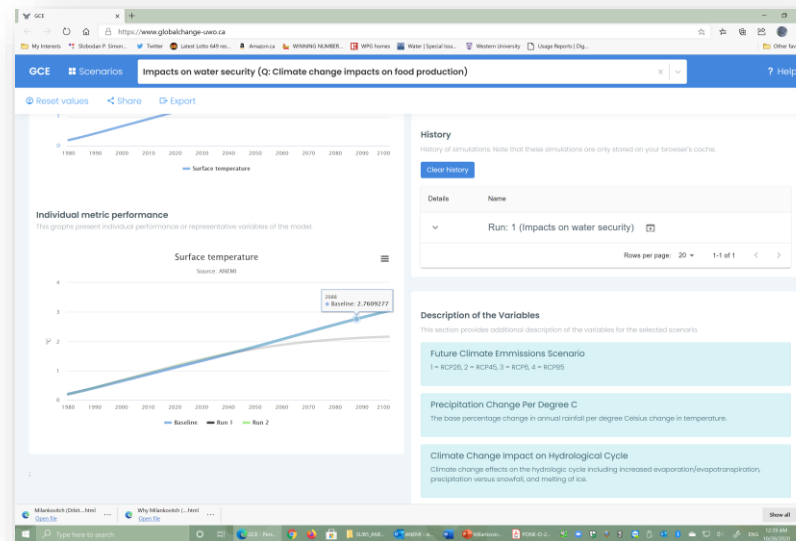
www.slobodansimonovic.com

ANEMI3 software available

Zenodo (<https://doi.org/10.5281/zenodo.4025424>)

Web-based ANEMI3 (beta testing)

GlobalChange-uwo.ca



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Resources

- **Papers**

- Davies, E.G.R, and S.P. Simonovic, (2010). “ANEMI: A New Model for Integrated Assessment of Global Change”, the *Interdisciplinary Environmental Review* special issue on Climate Change, 11(2/3):127-161.
- Davies, E.G.R. and S.P. Simonovic (2011). “Water Resources and Integrated Assessment Modeling – the ANEMI Model”, *Advances in Water Resources* (available online: 18 February 2011), 34:684-700.
- Akhtar, M.K., J., Wibe, S. P. Simonovic, and J., MacGee, (2013) “Integrated Assessment Model of Society-Biosphere-Climate-Economy-Energy System”, *Environmental Modelling & Software*, 49:1-21.
- Breach, P. A., and S.P. Simonovic, (2018) “Wastewater treatment energy recovery potential for adaptation to global change: an integrated assessment”, *Environmental Management*, 61:624-636.
- Akhtar, M.K., S.P. Simonovic, J. Wibe, and J. MacGee, (2018) “Future realities of climate change impacts: An integrated assessment study of Canada, *International Journal of Global Warming*, 17(1):59-88.
- Breach, P.A. and S.P. Simonovic “ANEMI: A Tool for Global Change Analysis”, under review, *PLOS ONE*.
- Simonovic, S.P. and P. A. Breach “The Role of Water Supply Development in the Earth System”, under review, *Water*, Special Issue - Feature Papers of Water Resources Management, Policy and Governance.

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Resources



- **Technical documents**
- Davies G. R. E., and S. P. Simonovic (2008). "[An integrated system dynamics model for analyzing behaviour of the social-economic-climatic system: Model description and model use guide.](#)" *Water Resources Research Report no. 059*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada, pp. 233.
- M. Khaled Akhtar, M.K., S. P. Simonovic, J. Wibe, J. MacGee and J. Davies (2011). [An Integrated System Dynamics Model for Analyzing Behaviour of the Social-Energy-Economy-Climate System: Model Description.](#) *Water Resources Research Report no. 075*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada, pp. 211.
- Akhtar, M.K., S.P. Simonovic, J.Wibe, J. MacGee and J. Davies (2011). [An Integrated System Dynamics Model for Analyzing Behaviour of the Social-Energy-Economy-Climate System: User's Manual.](#) *Water Resources Research Report no. 076*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada, pp. 161.
- Breach, P.A. and S. P. Simonovic (2020). [ANEMI 3: Tool for investigating impacts of global change.](#) *Water Resources Research Report no. 108*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, The University of Western Ontario, London, Ontario, Canada, pp. 134.



- Computer-based research laboratory
- Research:
 - *Subject Matter* - Systems modeling; Risk and reliability; Water resources and environmental systems analysis; Computer-based decision support systems development.
 - *Topical Area* - Reservoirs; Flood control; Hydropower energy; Operational hydrology; Climatic Change; Integrated water resources management.
- > 70 research projects
- Completed: 12 visiting fellows, 19 PosDoc, 24 PhD and 44 MEdSc
- Current: 3 PosDoc, 1 MEdSc



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Research results

- ~ 620 professional publications
- 247 in peer reviewed journals
- 3 major textbooks
- Water Resources Research Reports 110 volumes – <https://ir.lib.uwo.ca/wrrr/>
- > 99,500 downloads since 2011

