Resilience to Extreme Events in Social Ecological Systems of the Lake Champlain Basin

(Basin Resilience to Extreme Events, BREE)

BREE IAM Status and Development Plans

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BREE Overarching Research Question

What are properties within the Lake Champlain Basin that drive hydrologic and nutrient responses to extreme events, and what are strategies for increasing resilience to protect water quality in the social ecological system?

WORKING HYPOTHESIS

The structure and state of systems can either dampen or amplify the cascading impacts of extreme events as their effects flow through the Social Ecological System of the Basin

FOCAL EXTREME EVENTS

- We define “extreme events” as “meteorological phenomena such as high temperature and precipitation with consequent events that are system responses, such as floods or droughts (Field et al. 2012)”.

- Following specific extreme events are being investigated by the BREE team in the hydro-meteorological context of the Lake Champlain Basin:

  (1) heavy and persistent precipitation and resulting floods;

  (2) intra-annual and inter-annual droughts;

  (3) heat waves;

  (4) cold snaps; and

  (5) extreme changes in the distribution of precipitation form (snow to rain).

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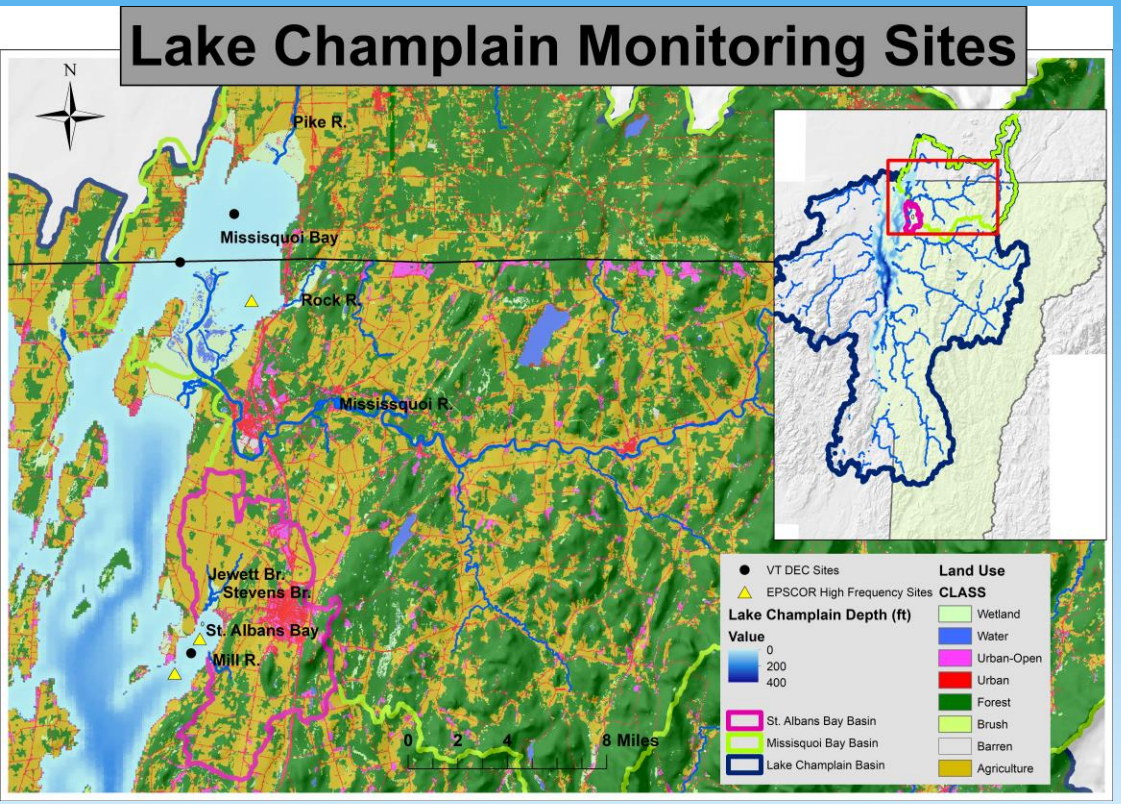
Basin Resilience to Extreme Events
in the Lake Champlain Basin

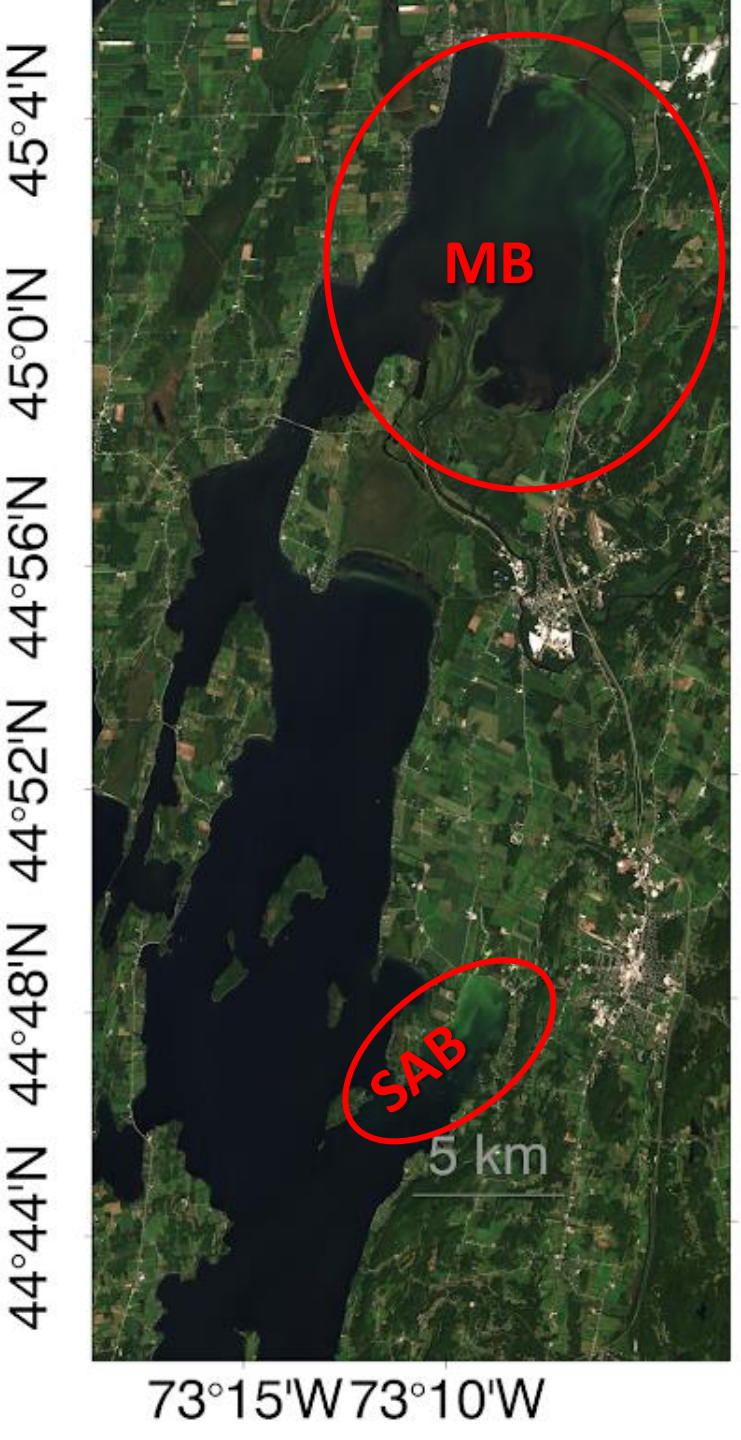
IAM Research Question: What strategies for resilience can be implemented to manage the risk from extreme events and what are the trade-offs for prioritizing public sector investments?

Extreme hydro-climatic event

Risk from change of state in the bay: mesotrophic to eutrophic

IAM Focal SES: Missisquoi & St. Albans





Shallow eutrophic systems that differ in terrestrial and open water connectivity

Adaptive Management Approach to Identify Resilient Strategies

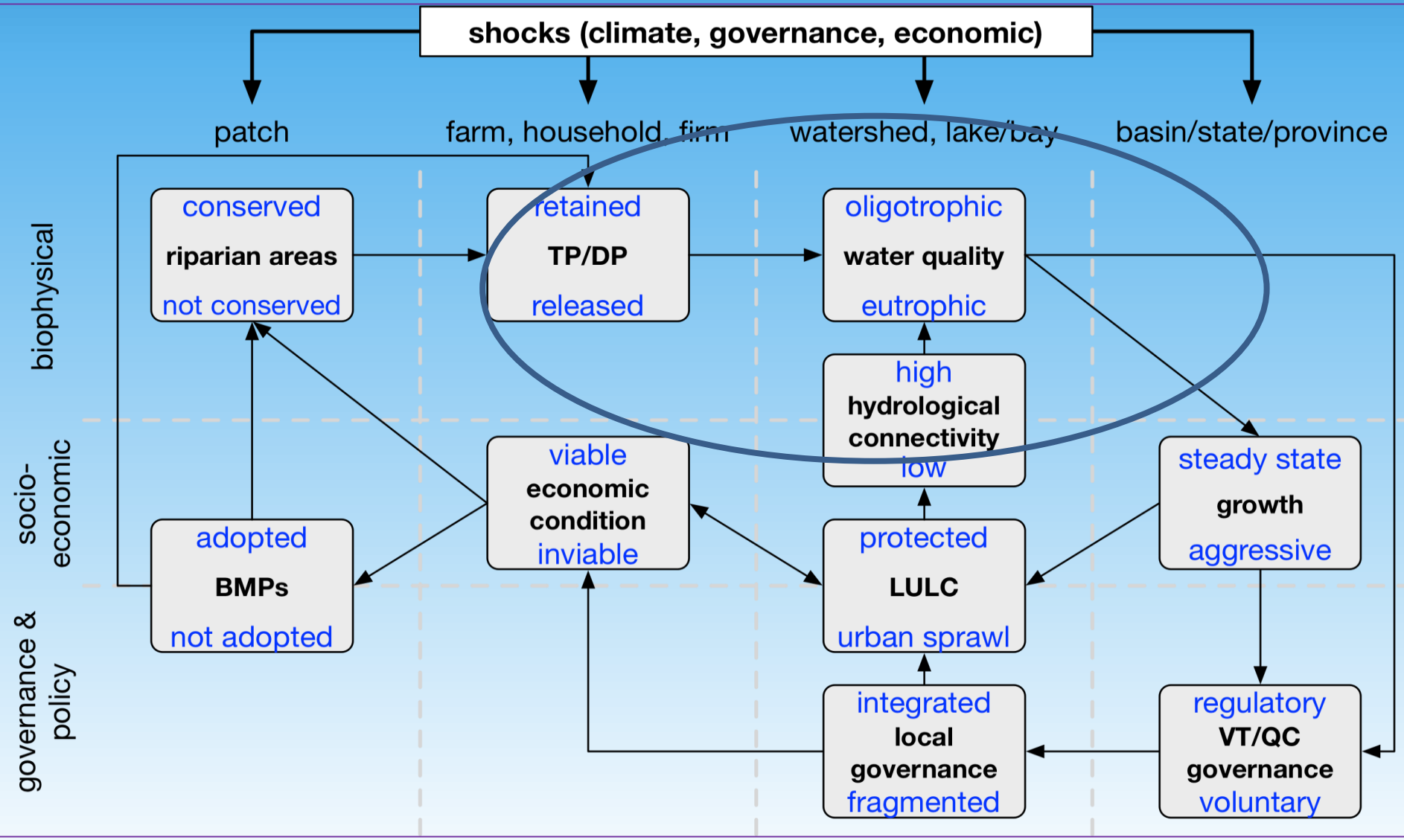
BREE IAM Policy & Technical Advisory Committee (PTAC) consensus on two definitions of resilience:

1: "The Lake Champlain Basin system should maintain critical functions after an event without significant post-event inputs" [Ex-Secretary, Agency of Agriculture]

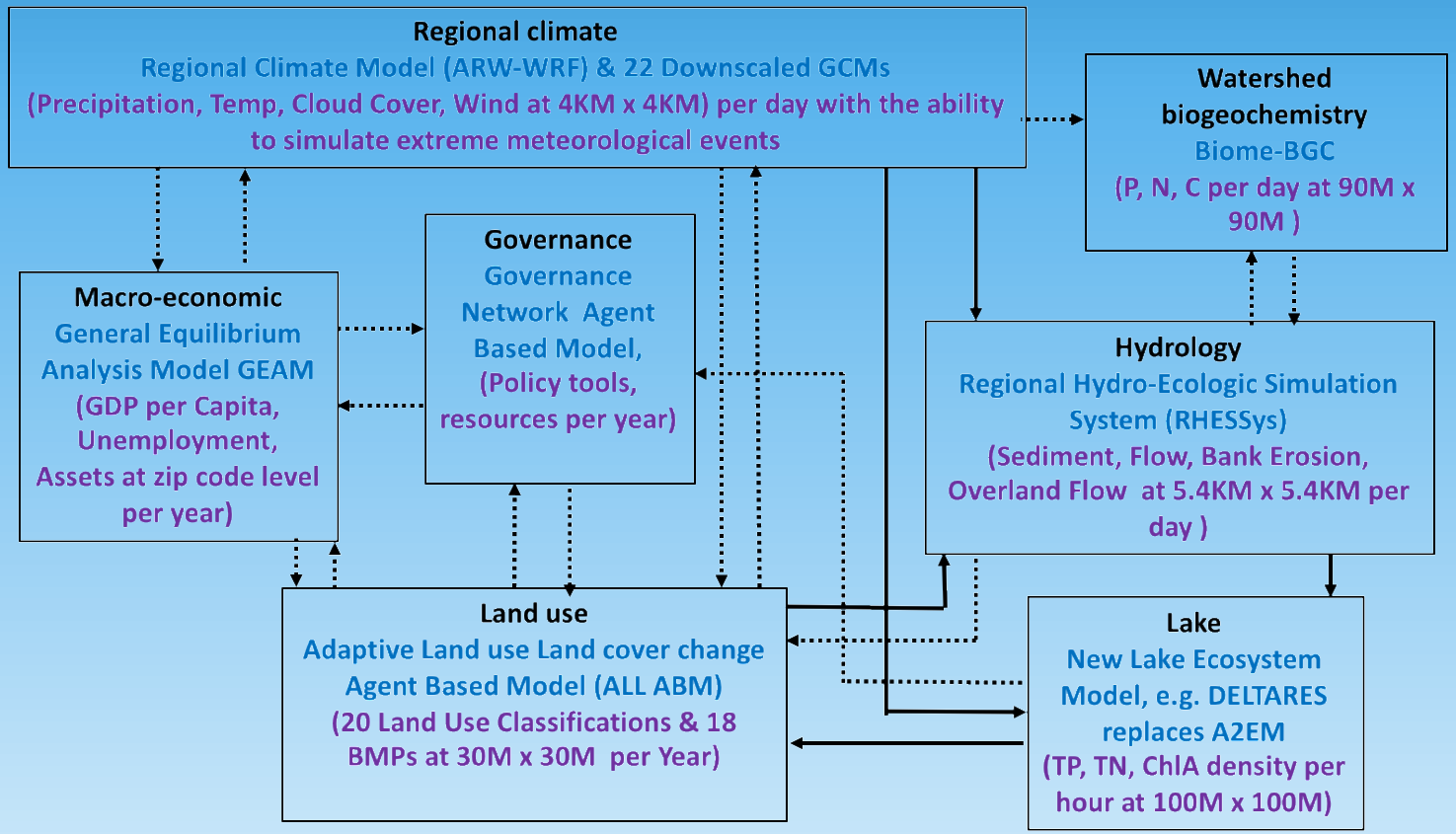
2: Ability to provide for public safety and property for as many people as possible affordably [Town Manager, St. Albans]

Identification of resilient strategies thus requires shared understanding BY ALL STAKEHHOLDERS of "desirable" alternate states in focal SES that maintain critical functions and maximize public interest

Hypothesized alternate states in the focal SES



BREE IAM V1.0: A modular, multi-scalar approach to test SES behavior in a computational IAM



Feedforward IAM can explore "baseline" SES behavior under various extreme event scenarios. Feedbacks and couplings will enable comparisons

→ Integration is enabled in BREE IAM

⇢ Integration is being tested/planned in BREE IAM

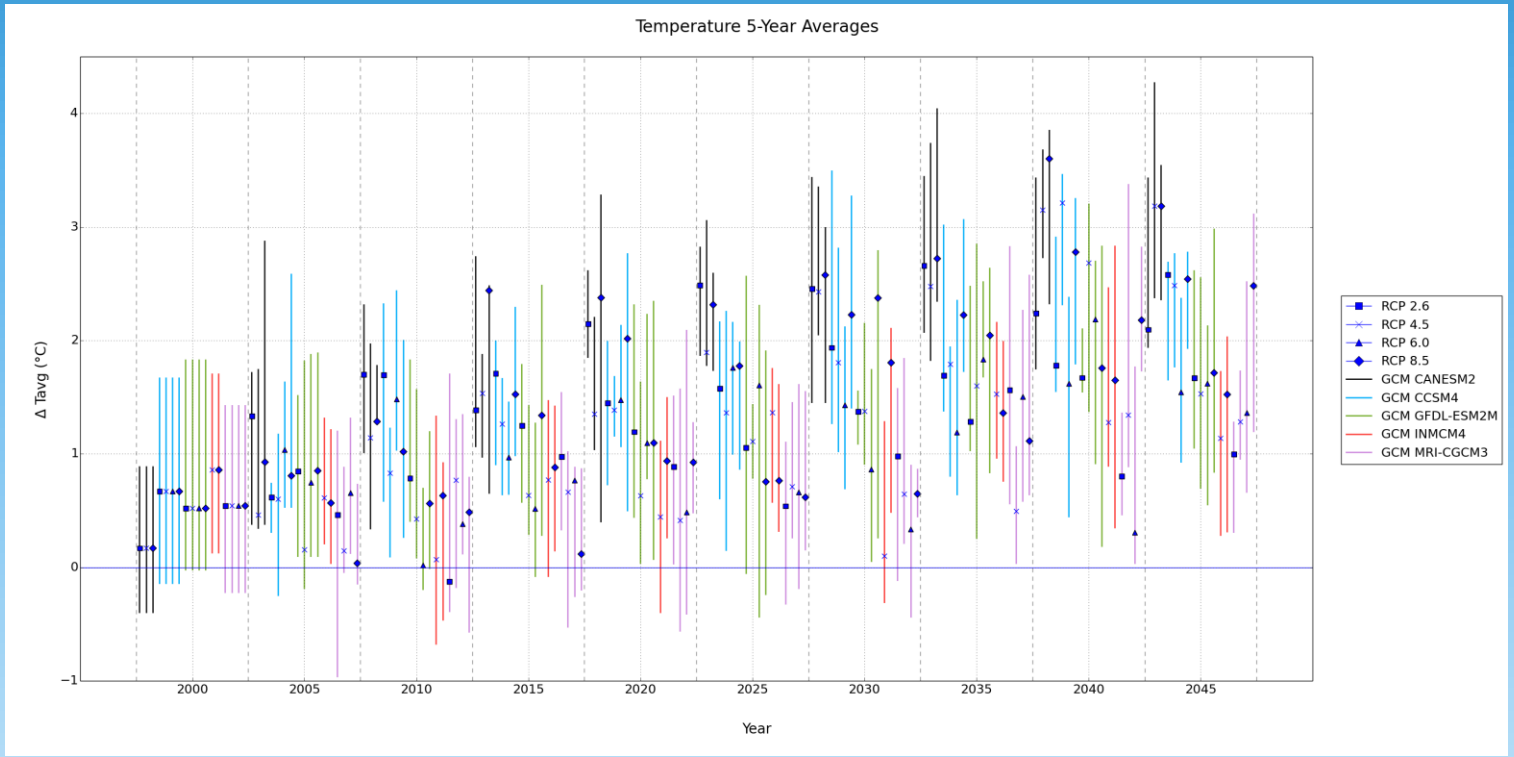
Papers in development from the current IAM configuration

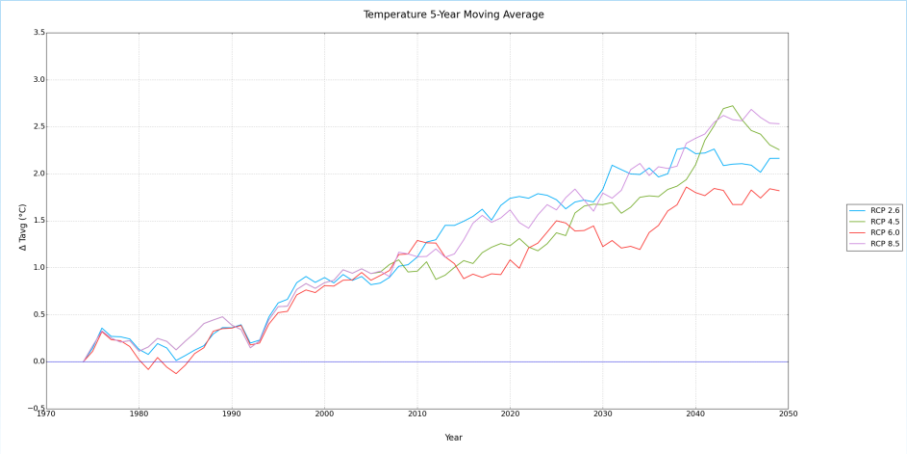
1. **Feedforward IAM mid-century projections under different climatic and P reduction scenarios**
2. Feedforward IAM end of century projections under different climatic and land use scenarios
3. Feedforward IAM P loading: quadratic vs weighted vs threshold based regressions
4. Feedforward IAM: Sensitivity of HABs to changing variance in temperature and precipitation
5. Feedforward IAM: Farmer BMP adoption and P load reductions
6. Feedback-enabled IAM scenarios

"Ensemble Method" of Scenario Settings Used for Cascading IAM Version 1.1 Missisquoi Runs, 2000-2050

- **Four Climate Scenarios**: RCP 2.6, RCP 4.5; RCP 6.0 and RCP 8.5
  - Ensemble of five GCMs that are among the best to reproduce late 20th centruy North-Eastern US climatic conditions identified by Thibeault, J.M. and Seth, A., 2015. **Toward the credibility of Northeast United States summer precipitation projections in CMIP5 and NARCCAP simulations**. *Journal of Geophysical Research: Atmospheres*, *120*(19).
- **LULCC ABM Scenario**: Business As Usual
- **Hypothetical TP reduction scenarios for BAU LULCC ABM**
  - 100% TP reduction from 2016-2050 scenario (ex-Secretary Ag scenario)
  - 90%, 85%, 80%, **60%**...0% TP reduction scenario runs
- **Remaining settings are similar to IAM Version 1.0** (e.g. no additional changes in model settings and calibration as reported in Zia et al. 2016)

GCM Ensemble Projections, 2000-2050





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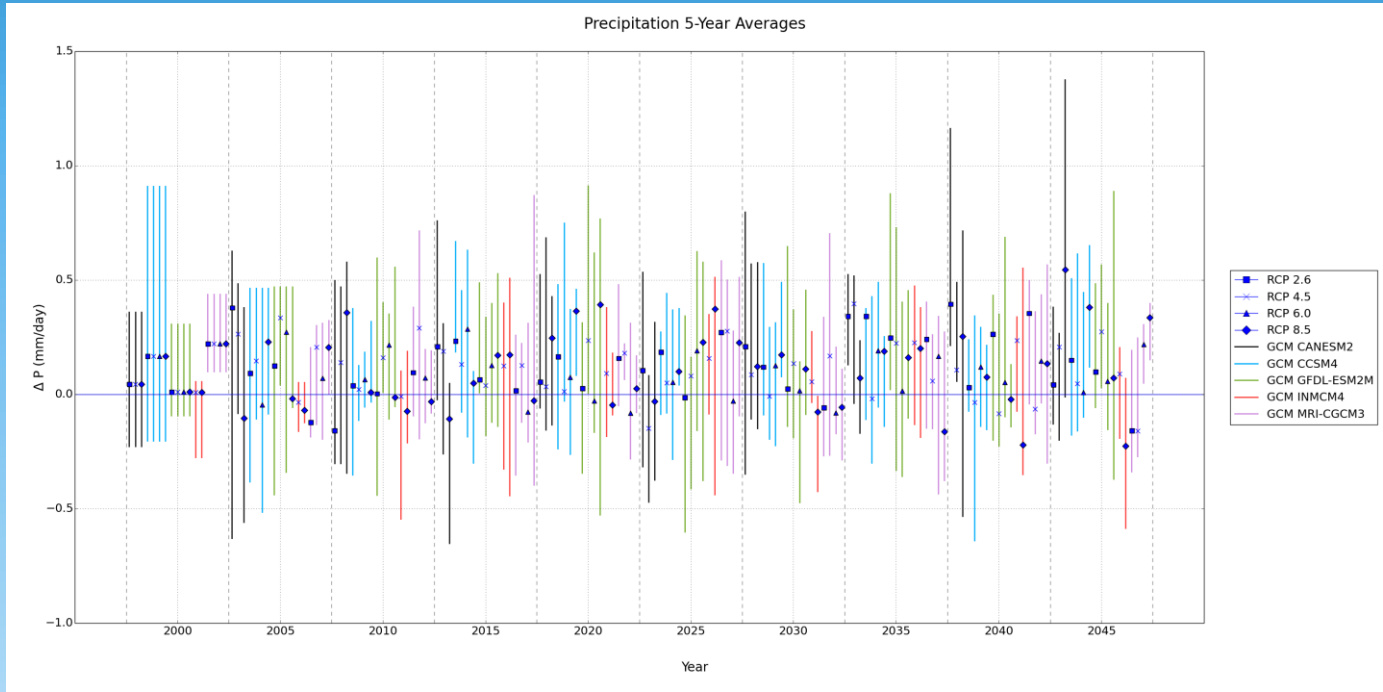
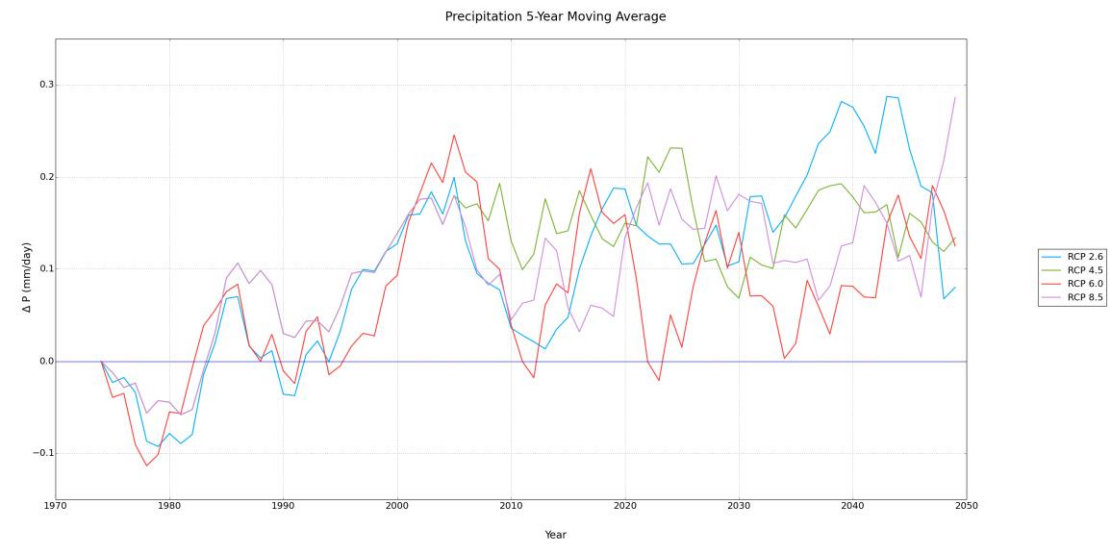
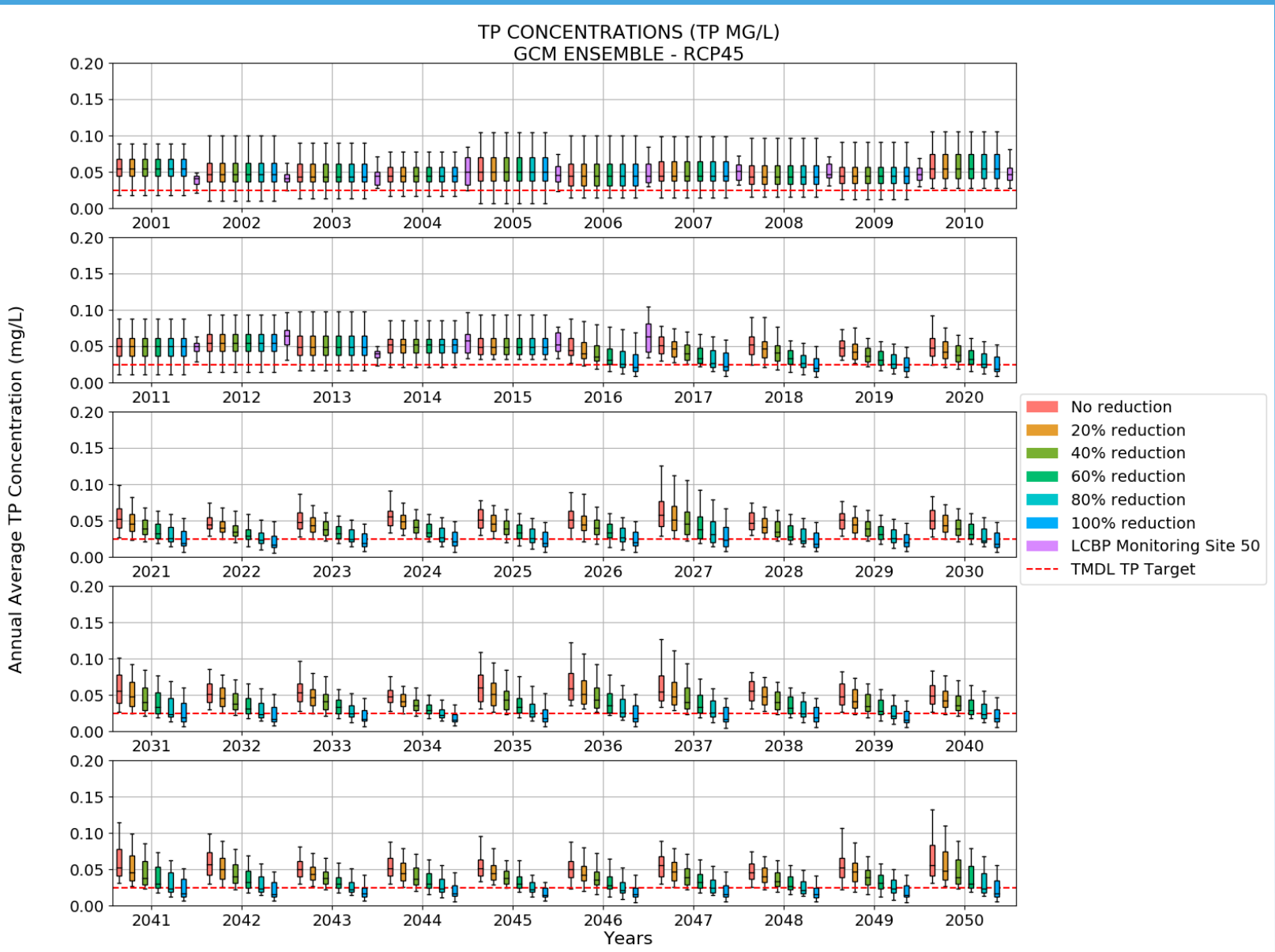
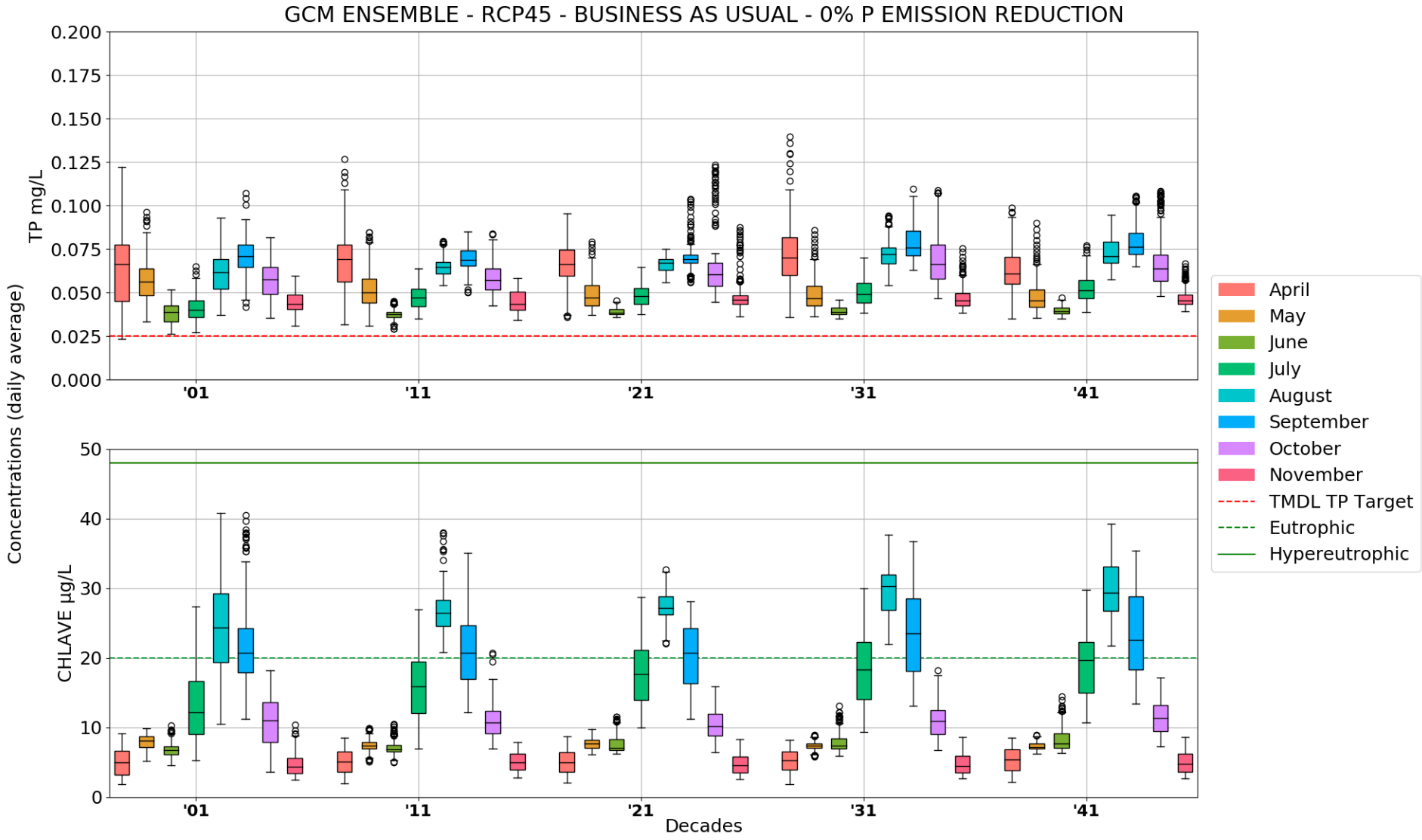




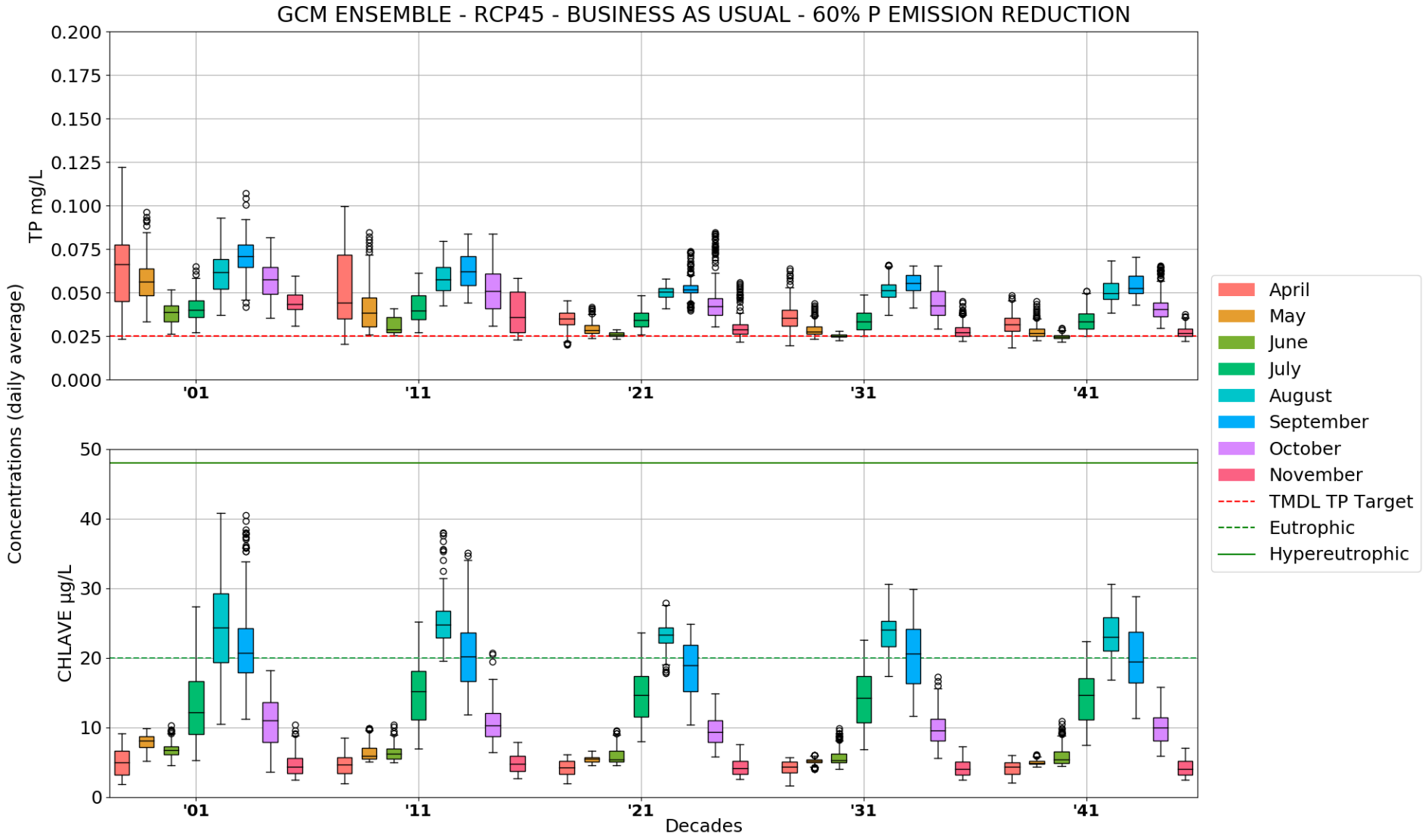
IAM projected TP concentrations for Missisquoi Bay site #50 under GCC stabilization RCP45 scenario for 0%, 20%, 40%, 60%, 80% and 100% TP loading reductions, compared with TMDL target of 0.025mg/L



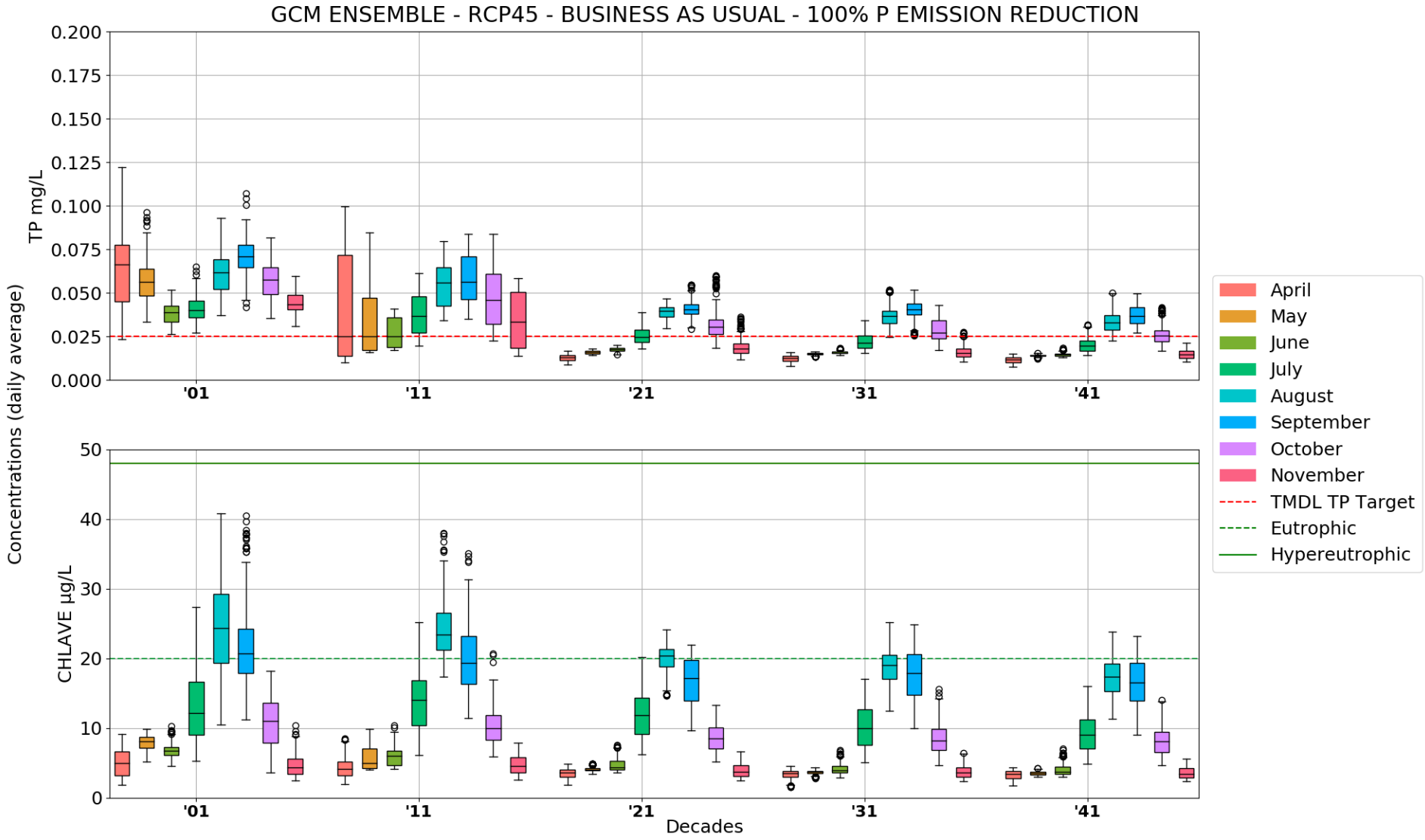
Projected TP and CHLA concentrations averaged for April through November for five decades (2000-2050) under GCC stabilization RCP4.5 scenario for **0% TP load** reductions



Projected TP and CHLA concentrations averaged for April through November for five decades (2000-2050) under GCC stabilization RCP4.5 scenario for **60% TP load** reductions

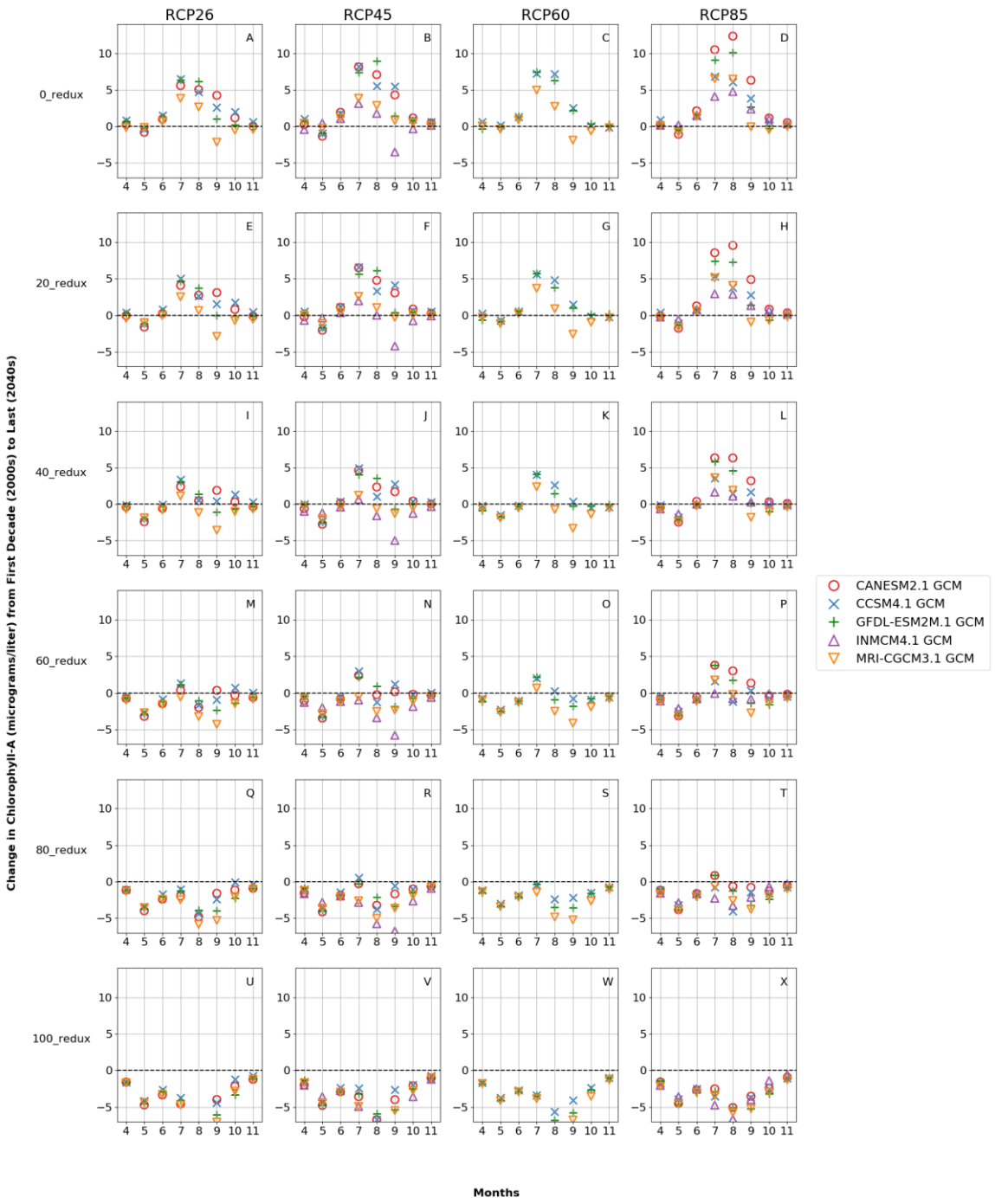


Projected TP and CHLA concentrations averaged for April through November for five decades (2000-2050) under GCC stabilization RCP4.5 scenario for **100% TP load** reductions

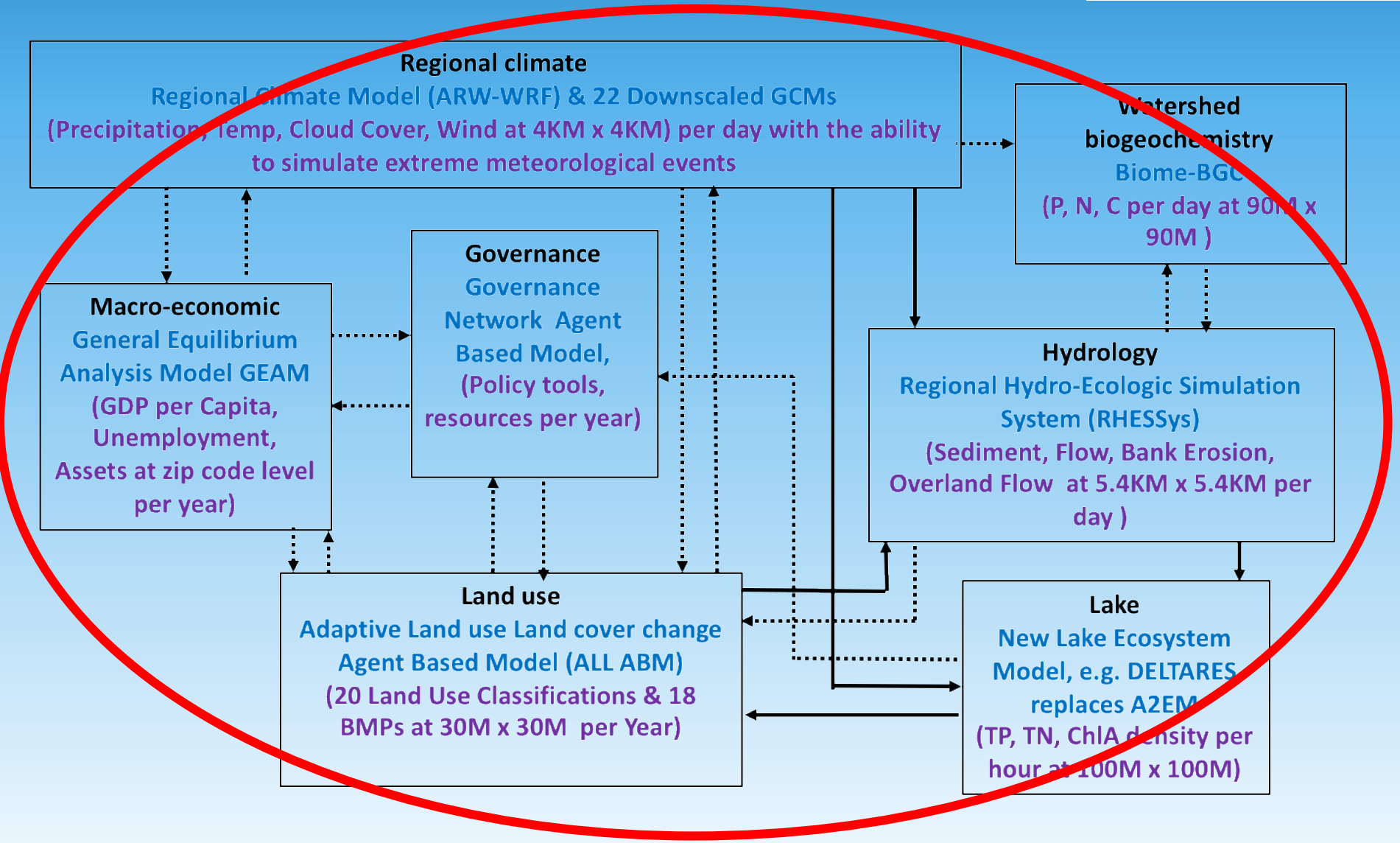


Projected changes in ChlA mg/L from the baseline first decade 2000s to mid-century 2040s under four GCC scenarios for 0% to 100% TP load reduction scenarios under BAU land use scenario

Relative sensitivity of ChlA to GCC vs TP loading reduction scenario is being estimated



BREE IAM DEVELOPMENT PLAN: SCENARIO DEVELOPMENT AND EVALUATION



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Multi-objective decision model for Identifying trade-offs among resilient strategies

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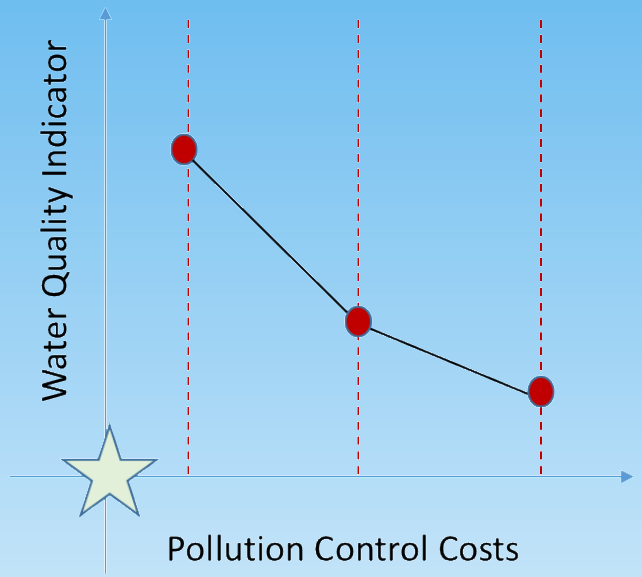
OBJECTIVES:
Min eutrophic days
Min bloom duration
Min cost
Max economic output

DECISIONS:
Investments
Regulations
Incentives
Programs
Treaties

CONSTRAINTS:
Budget
Regulations
Site characteristics
Stakeholder equity



HIERARCHICAL MODELING

Missisquoi basin regulators

Subwatershed and municipal decision makers

Landowners (farmers, residents, businesses)

Objectives, decisions and constraints will be iteratively refined with stakeholders as extreme event cascades and couplings are simulated

Thank you!