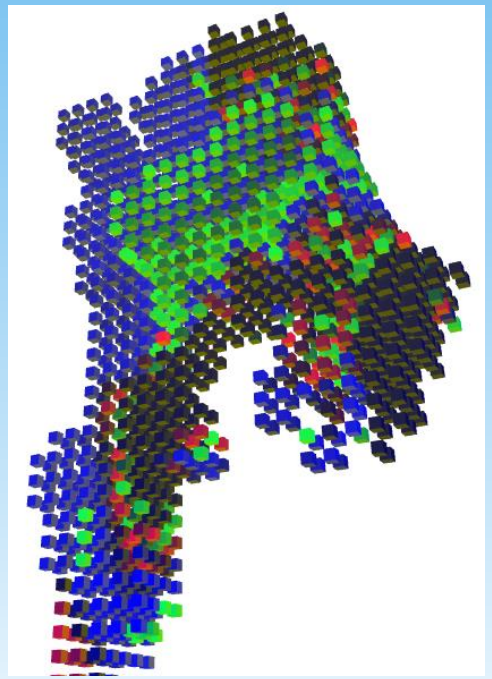
Understanding Lags, Thresholds and Cross Scale Dynamics in Social Ecological Systems: Cascading Impacts of Climatic and Land Use Changes on Missisiquoi Bay, 2000-2100



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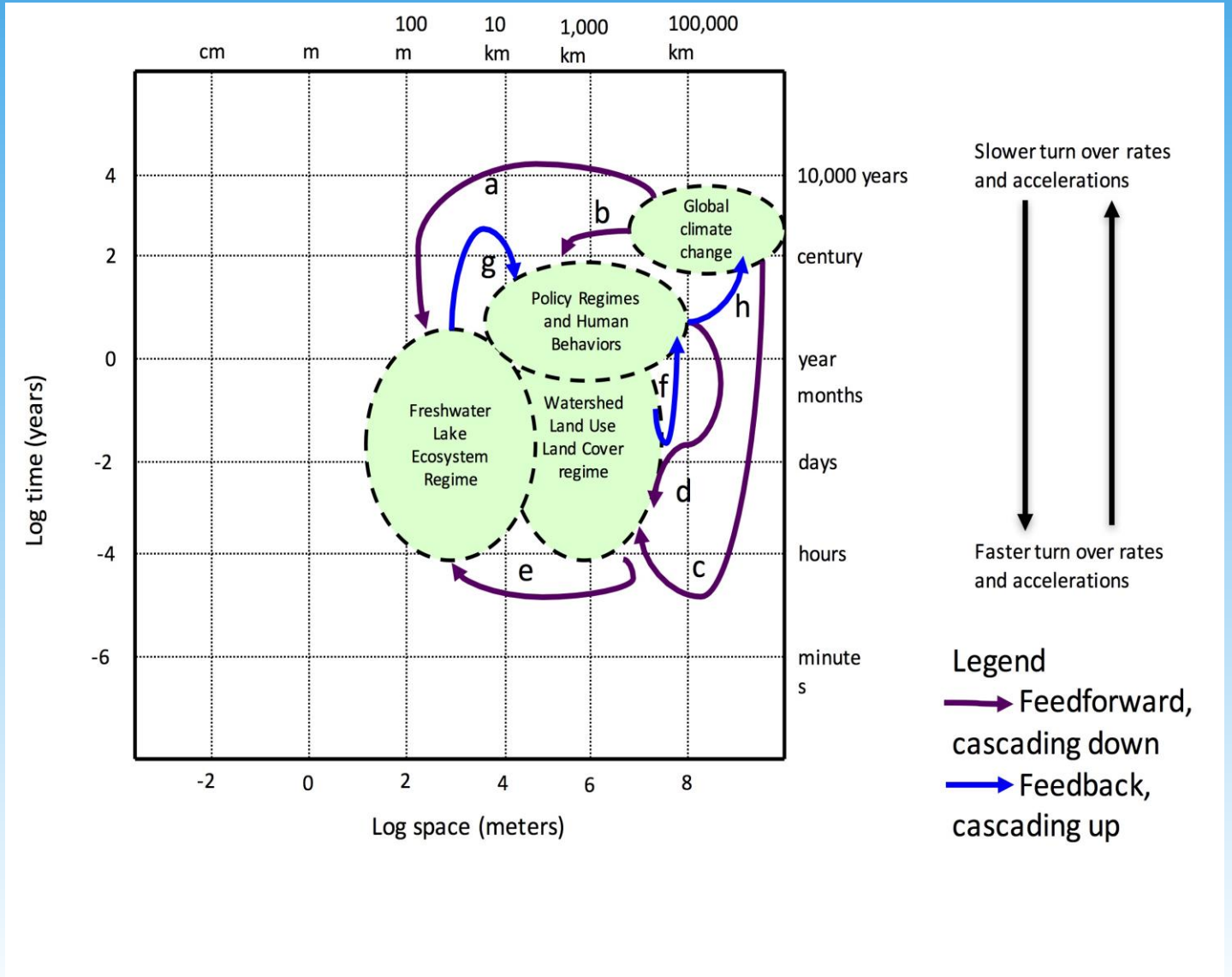
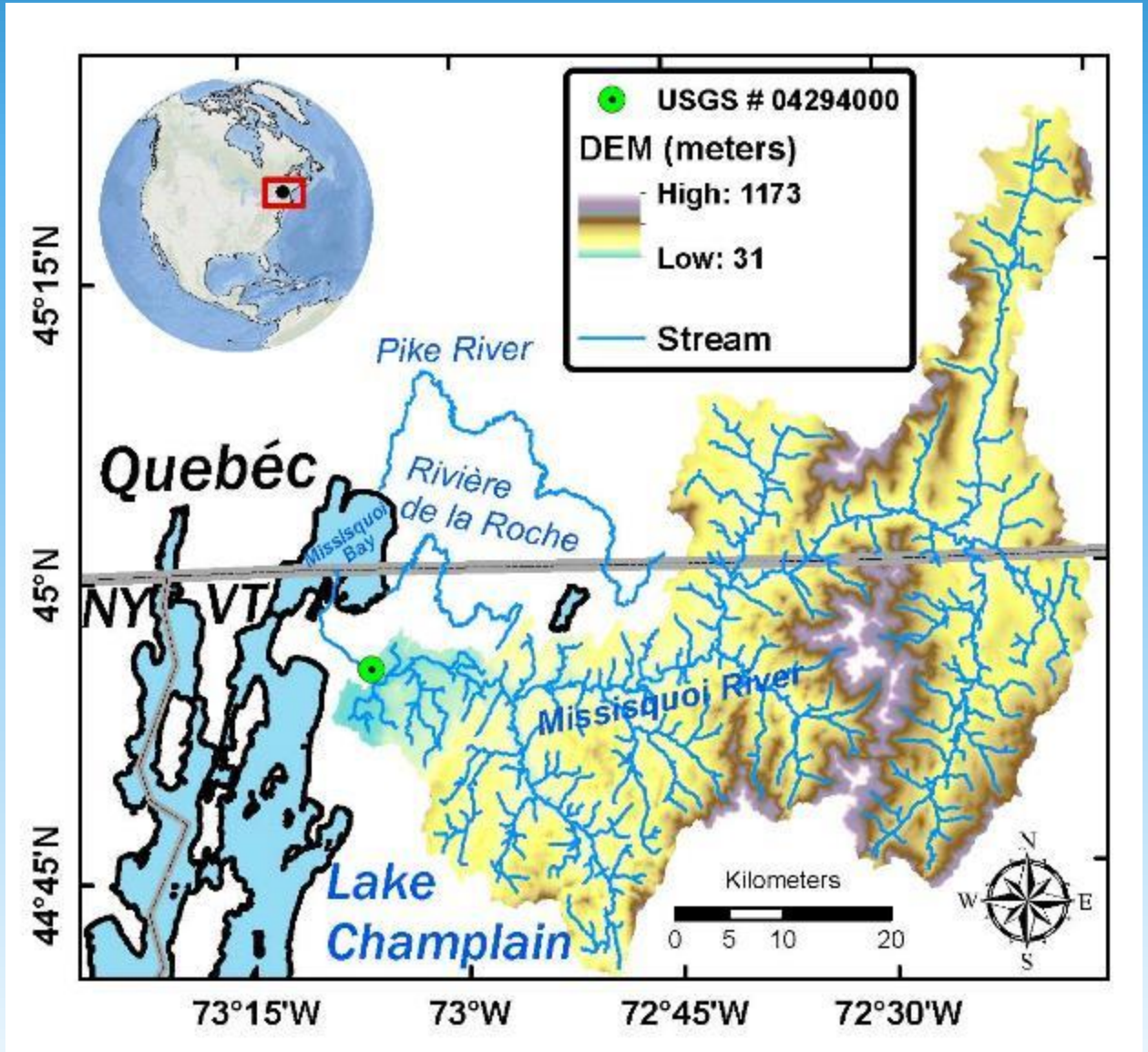
Acknowledgements: NSF-EPS-1556770 , members of Policy & Technical Advisory Committee for BREE project and engaged stakeholders

IAM framework to assess resilience of LCB Social Ecological System (SES)

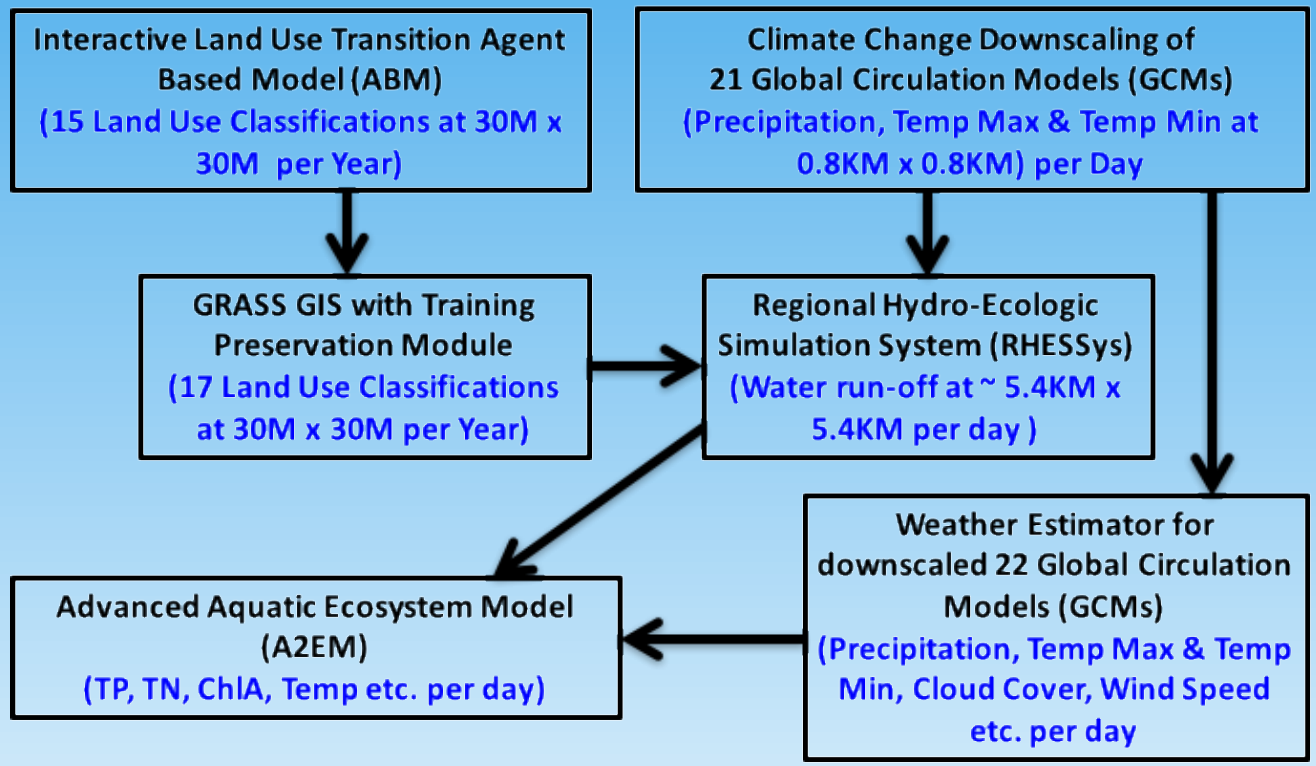
When exposed to exogenous shocks (e.g. extreme events) or endogenous surprises (e.g., ecological collapse), SES do not necessarily go through gradual change, but rather critical transitions (tipping points and thresholds) may cause abrupt "regime" shifts



Situated in Social Ecological Systems (SES) theoretical and empirical framework, this paper addresses the following question : **How do lags, inertia and thresholds (phase transitions) affect the evolution of state variables in Missisquoi Basin SES that interact across multiple scales of space and time ?**



High Resolution Projections of Global Climate Change Impacts on Watersheds and Lakes: Integrating Climate, Land-Use, Hydrological and Limnology Models



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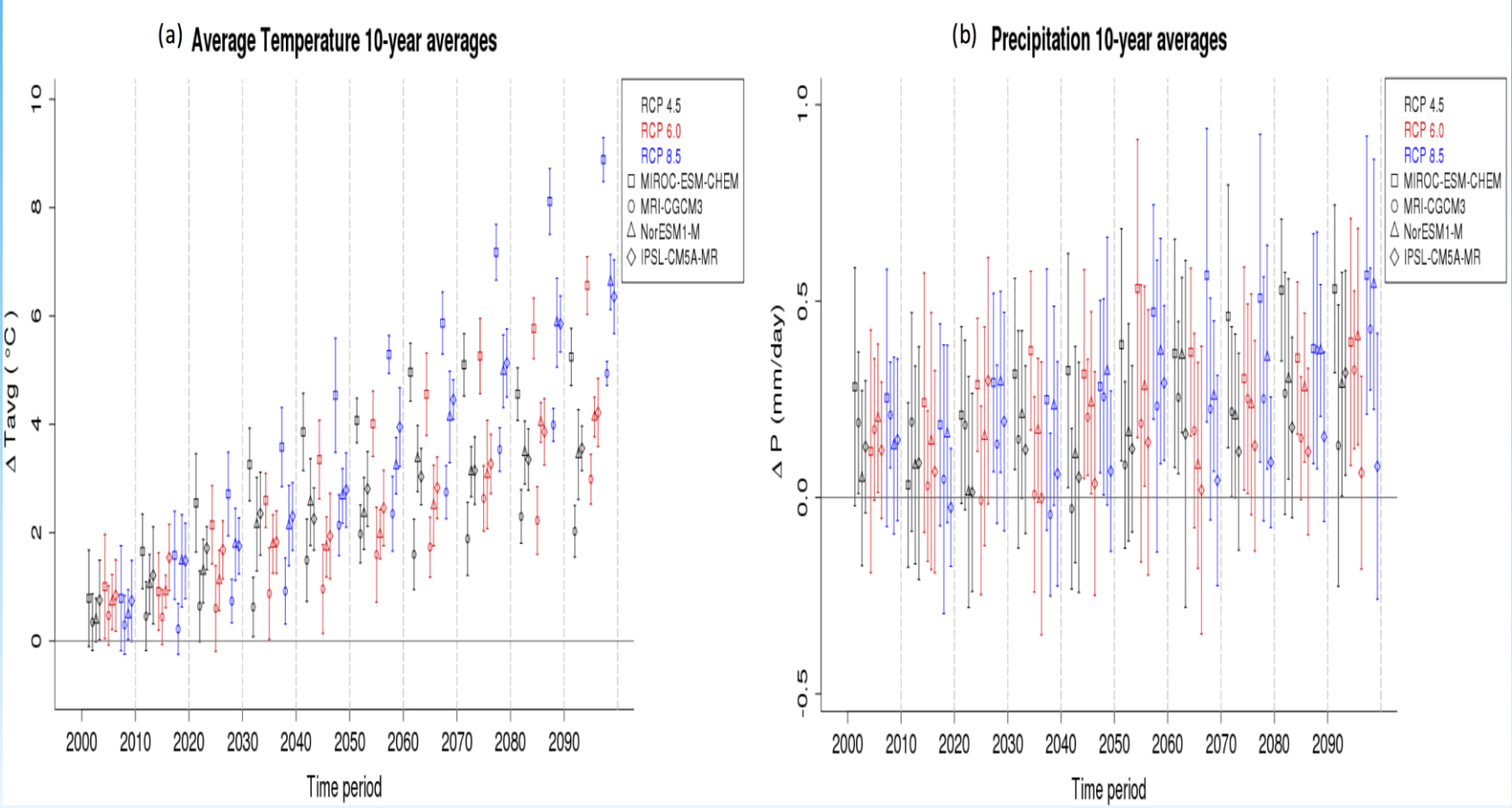
Coupled impacts of climate and land use change across a river–lake continuum: insights from an integrated assessment model of Lake Champlain's Missisquoi Basin, 2000–2040

Asim Zia[1,2,3,4], Arne Bomblies[4,5,6], Andrew W Schroth[7], Christopher Koliba[1,4], Peter D F Isles[8], Yushiou Tsai[6], Ibrahim N Mohammed[6], Gabriela Bucini[6], Patrick J Clemins[2,6], Scott Turnbull[6], Morgan Rodgers[6], Ahmed Hamed[6], Brian Beckage[9], Jonathan Winter[10], Carol Adair[8], Gillian L Galford[4,8], Donna Rizzo[4,5] and Judith Van Houten[6,10]

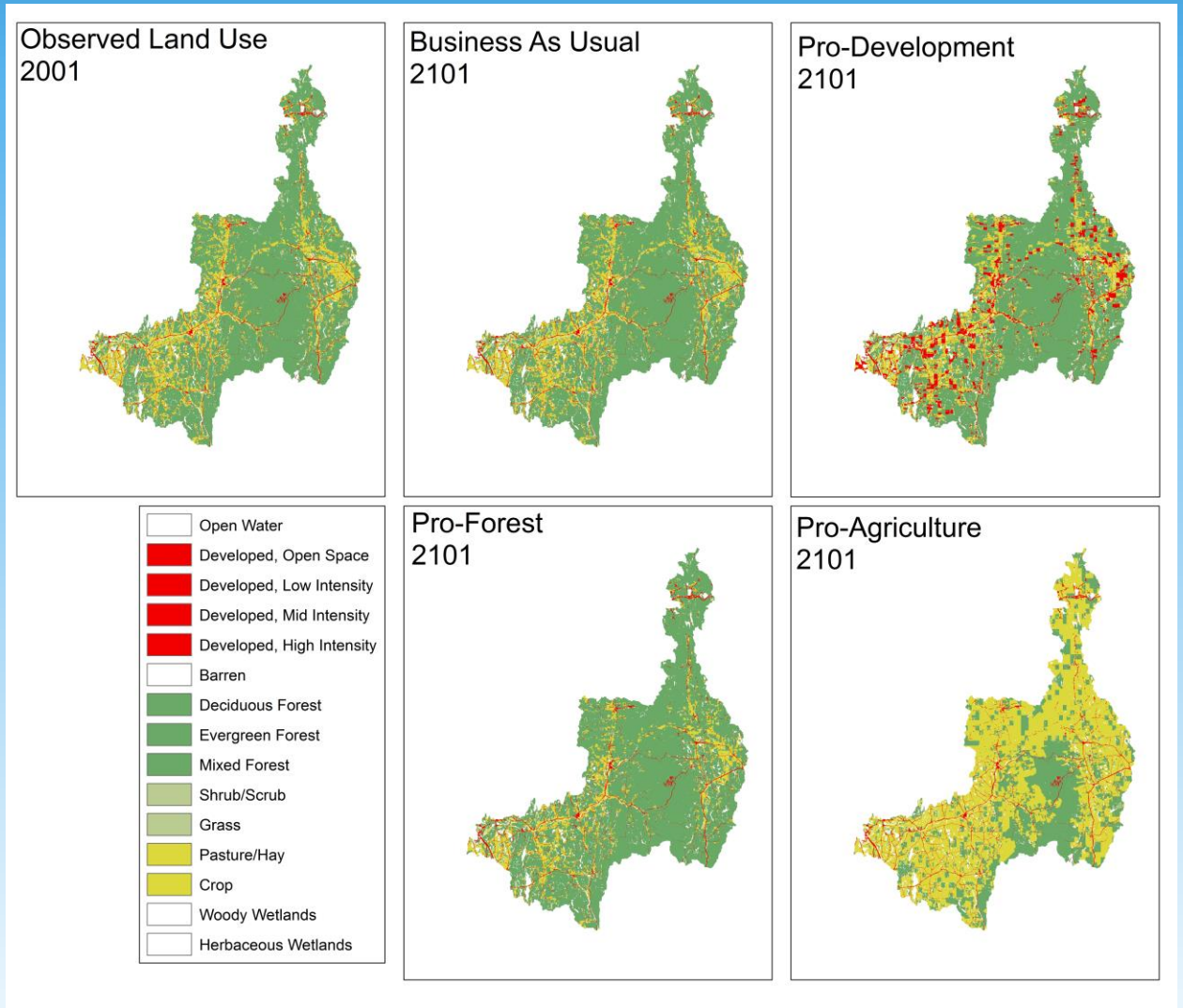
“EXTREME” SCENARIO SETTINGS

- **THREE “extreme” Climate Scenarios: RCP 4.5; RCP 6.0 and RCP 8.5**
- **Four extreme GCMs (Warm: miroc-esm-chem; Cool: mri-cgcm3.1; Wet: noresm1-m.1; Dry: ipsl-cm5a-mr.1) are used for three RCP scenarios.**

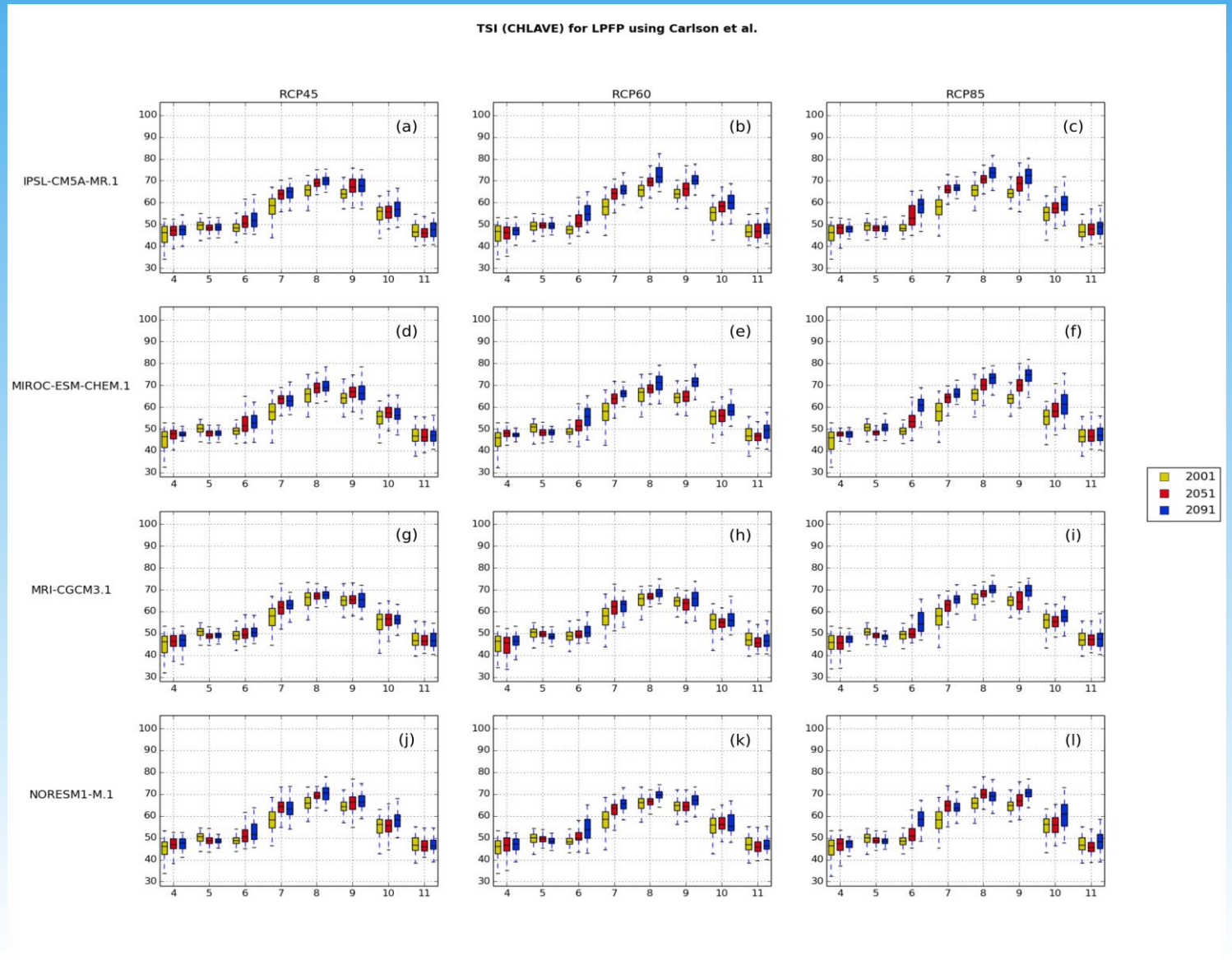


“EXTREME” SCENARIO SETTINGS

- **FOUR “extreme” LULCC ABM Scenarios**: BAU, Pro-forest, Pro-Ag, Urbanization

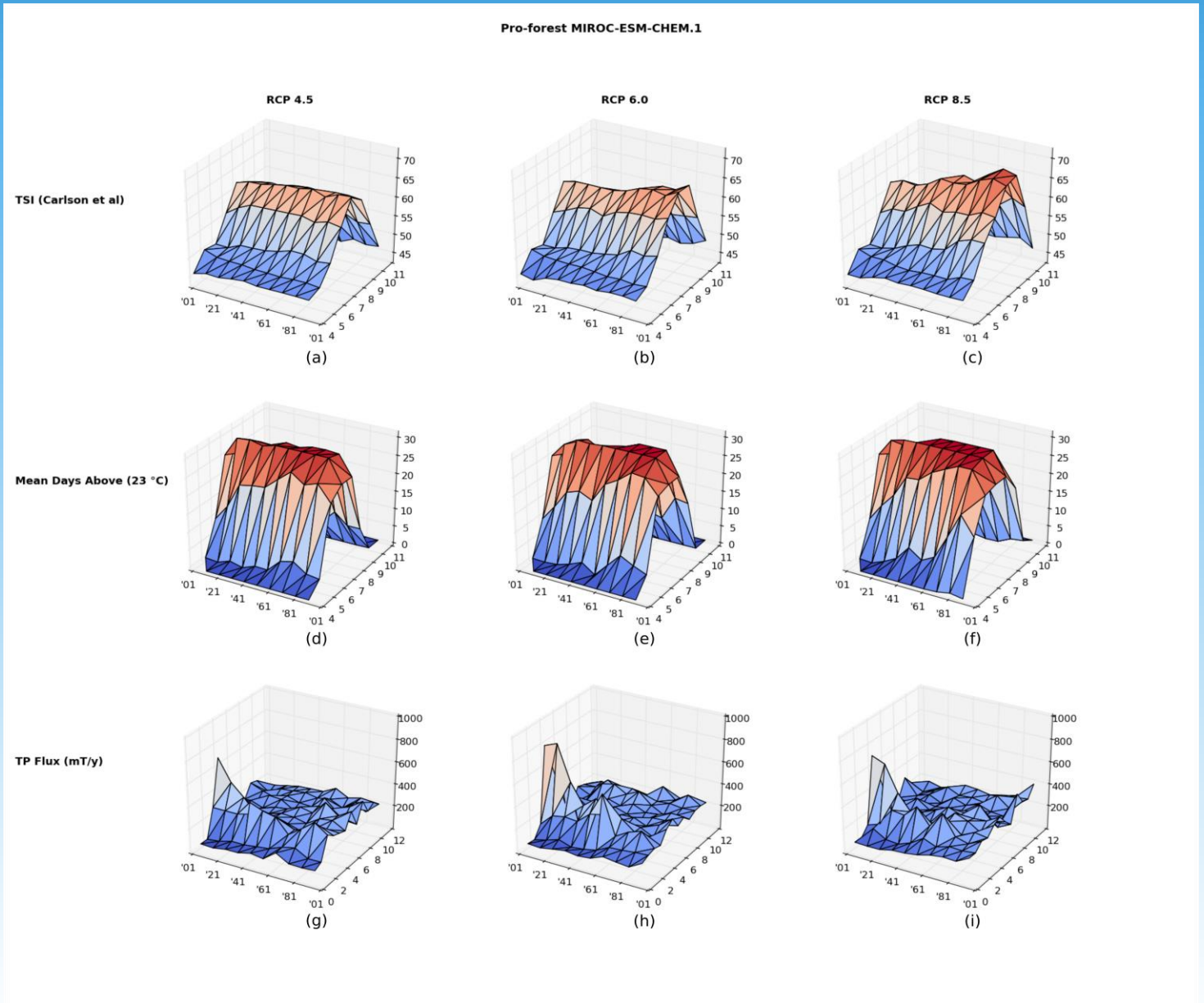


Projected Carlson's tropic state index for decadal averages (2001-11, 2051-61, 2091-2101) for the 'pro-forest scenario' under warm, wet, dry, and cool GCM. State transitions from mesotrophic to eutrophic occur at TSI 50, and from eutrophic to hypereutrophic conditions at TSI 70 with this metric.



At monthly scale, eutrophic regime will likely expand to June, July and October, while hyper-eutrophic regime will likely replace eutrophic regime in July and August

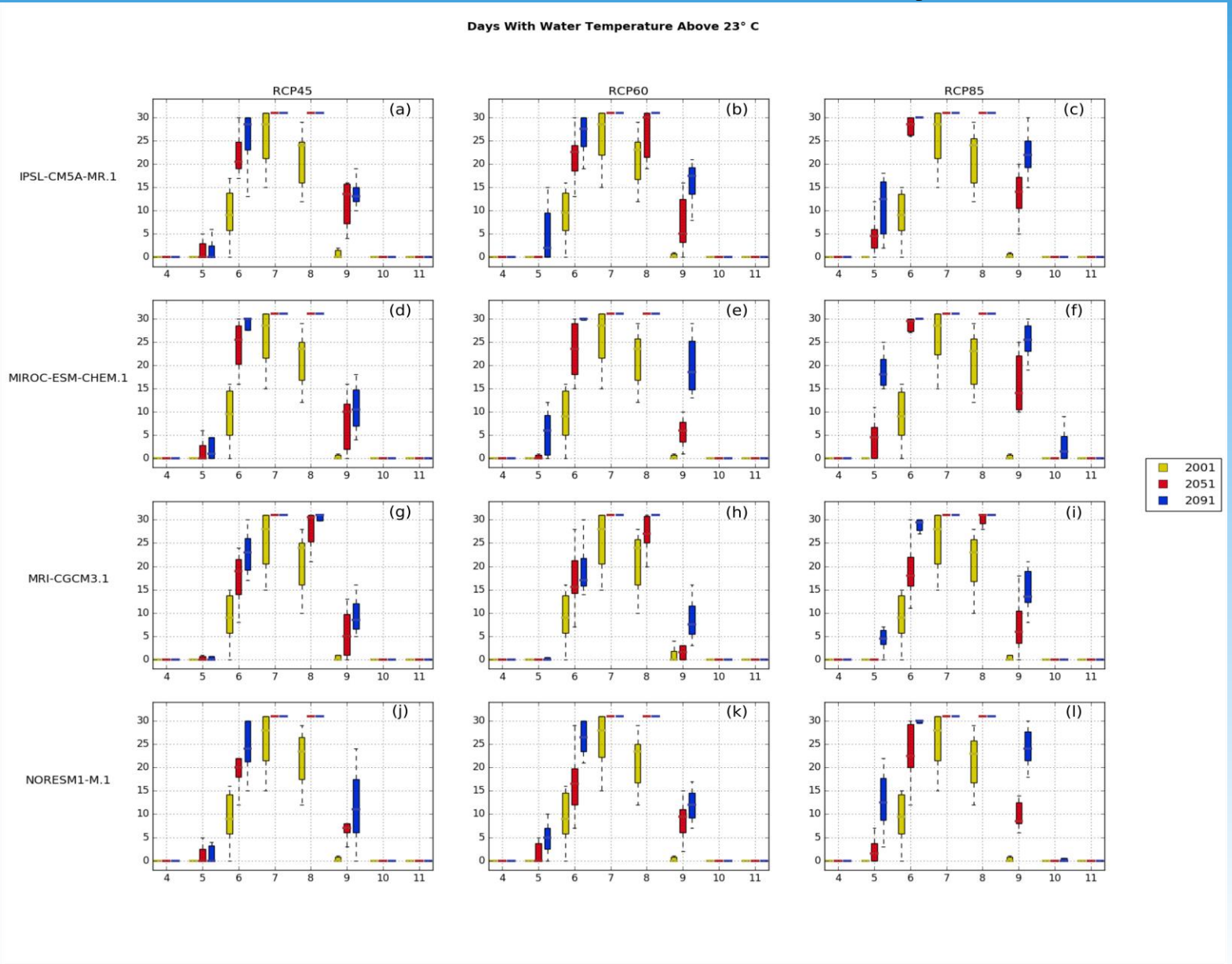
Projected change in TSI (Carlson et al. 1977) under high warming GCM for "pro-forest" land use scenario x 3 greenhouse gas emissions scenarios.



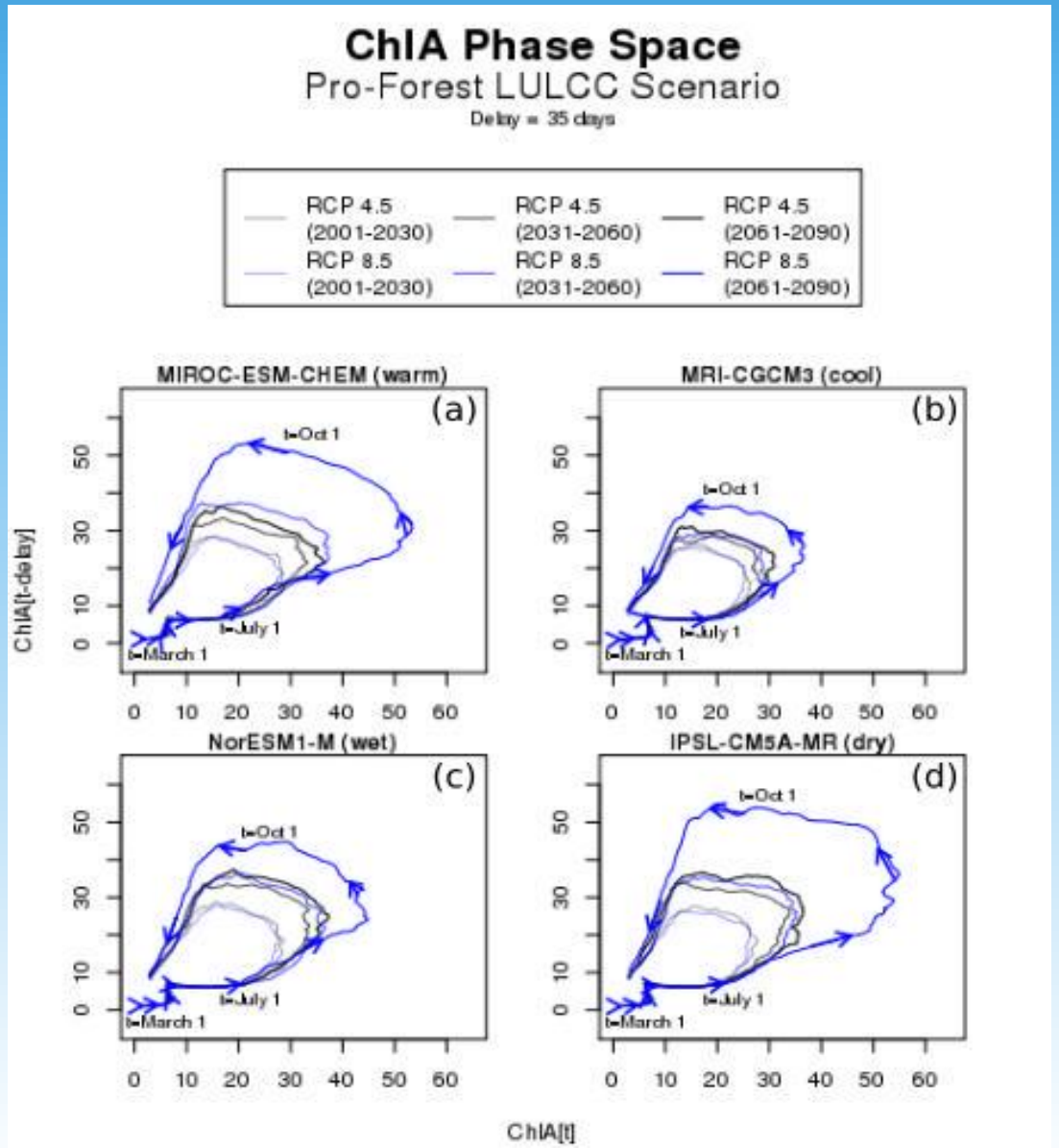
While riverine TP Flux (metric Tons per year) will likely decrease for this scenario, higher mean days above 23C (thresholds) in RCP8.5 will likely cause state shifts.

State transitions from mesotrophic to eutrophic occur at TSI 50, and from eutrophic to hypereutrophic conditions at TSI 70 with this metric.

Projected decadal mean days at or above 23ºC threshold for bay surface water for 12 climate scenarios. 23ºC threshold favors cyanobacteria dominance



Projected Phase Transitions in CHLA Concentrations under four GCMs x 2 RCPs for pro-forest land management scenario



The width of the "basin of the attraction" will likely expand under "worst-case climate scenario" (RCP 8.5), shifting the lake regimes from meso-trophic (CHLA<20) to eutrophic (CHLA 21-40) and hyper-eutrophic (CHLA>40) in summer and fall

Accelerating climate change will sustain eutrophication in shallow Missisquoi bay even if Clean Water Act targets were to be implemented

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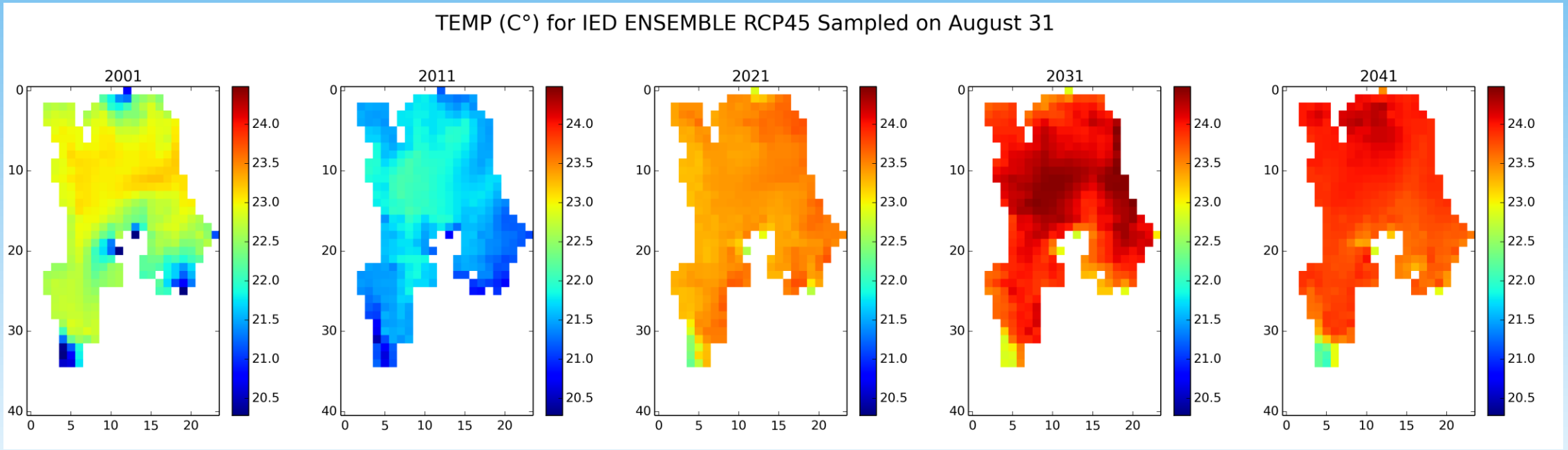


Acknowledgements: NSF-EPS-1556770 , members of Policy & Technical Advisory Committee for BREE project and engaged stakeholders

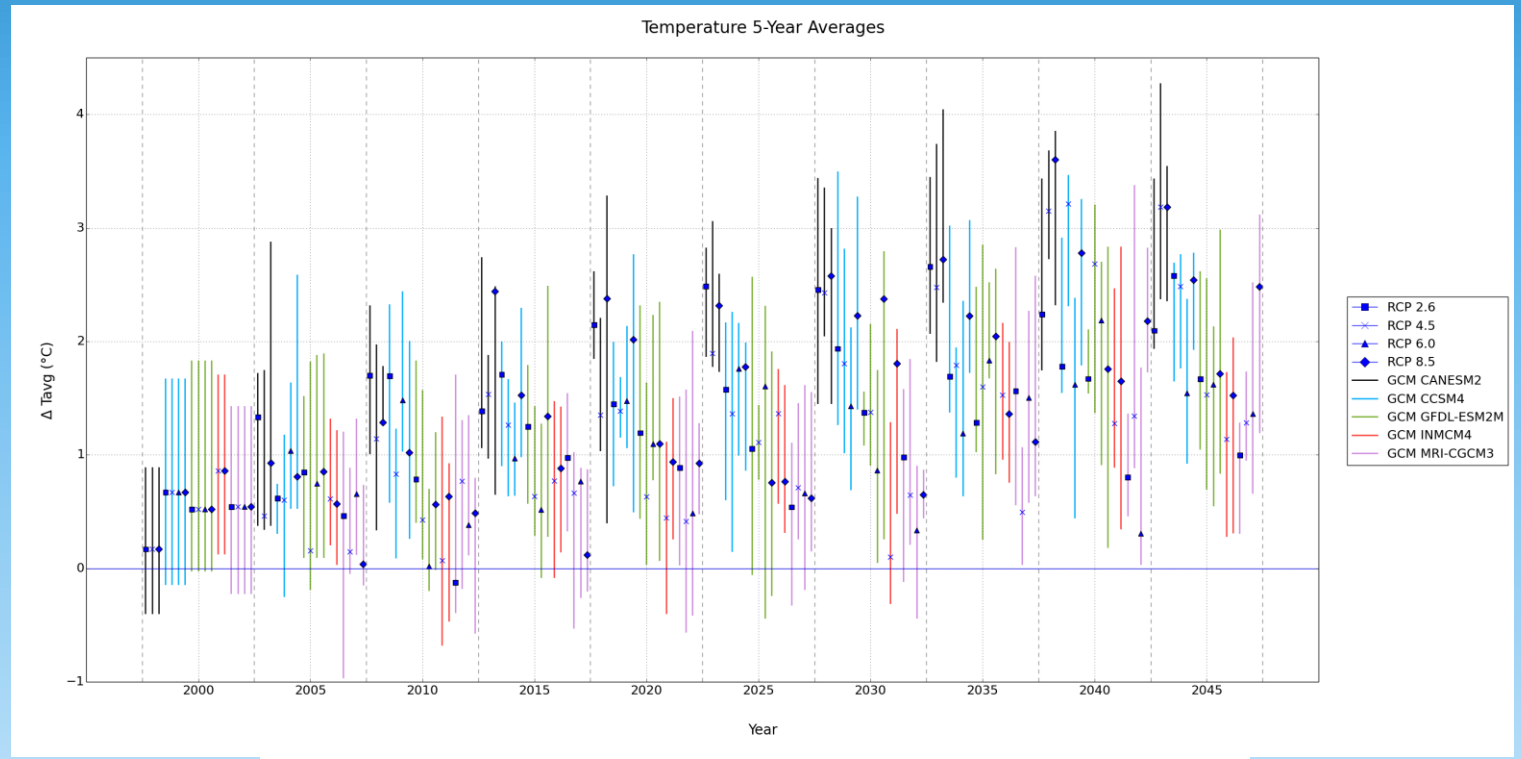
"Ensemble Method" of Scenario Settings Used for Cascading IAM Version 1.1 Missisquoi Runs, 2000-2050

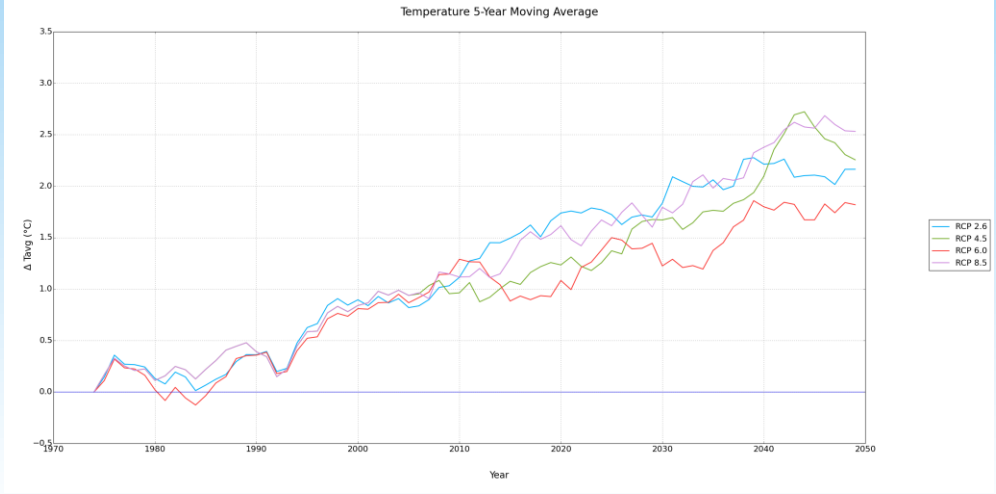
- **Four Climate Scenarios**: RCP 2.6, RCP 4.5; RCP 6.0 and RCP 8.5
  - Ensemble of five GCMs that are among the best to reproduce late 20th centruy North-Eastern US climatic conditions identified by Thibeault, J.M. and Seth, A., 2015. **Toward the credibility of Northeast United States summer precipitation projections in CMIP5 and NARCCAP simulations**. *Journal of Geophysical Research: Atmospheres*, *120*(19).

- **FOUR LULCC ABM Scenarios**: BAU, Pro-forest, Pro-Ag, Urbanization

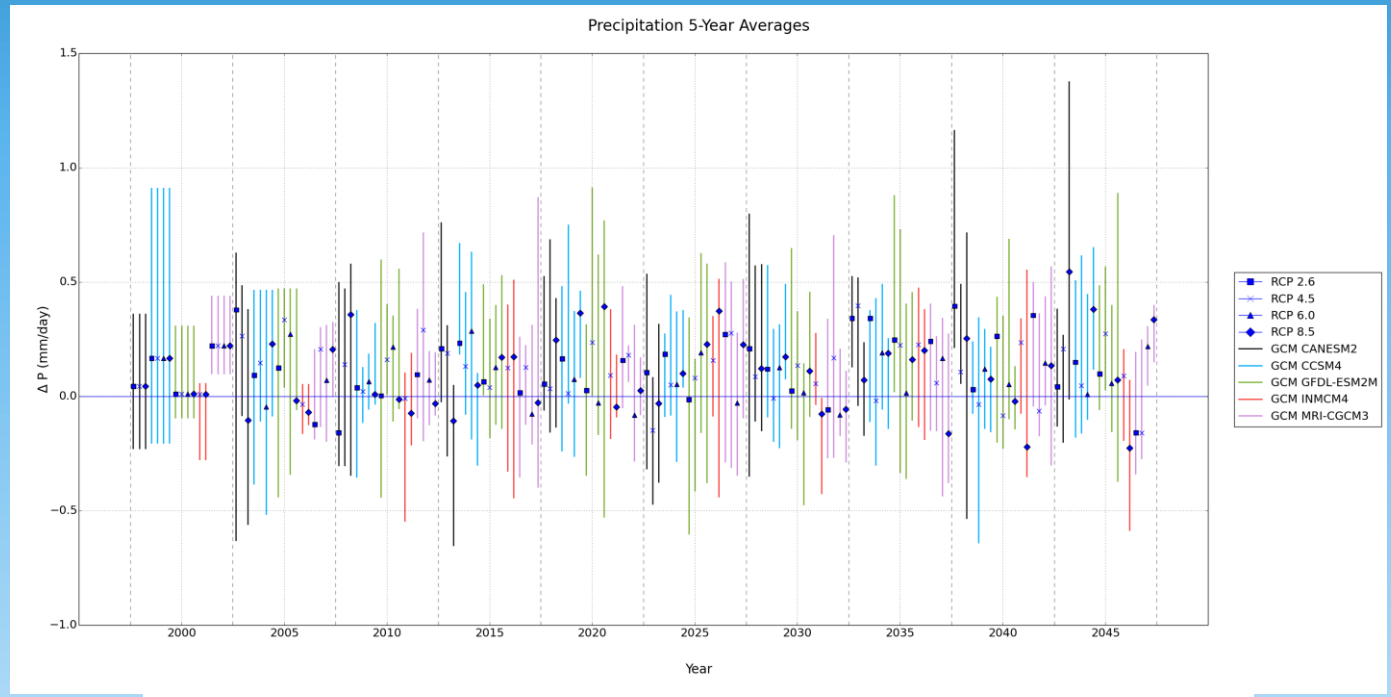
- **Hypothetical TP reduction scenarios for BAU LULCC ABM**
  - 100% TP reduction from 2016-2050 scenario (ex-Secretary Ag scenario)
  - 90%, 85%, 80%, **60%**...0% TP reduction scenario runs
- **Remaining settings are similar to IAM Version 1.0** (e.g. no additional changes in model settings and calibration)

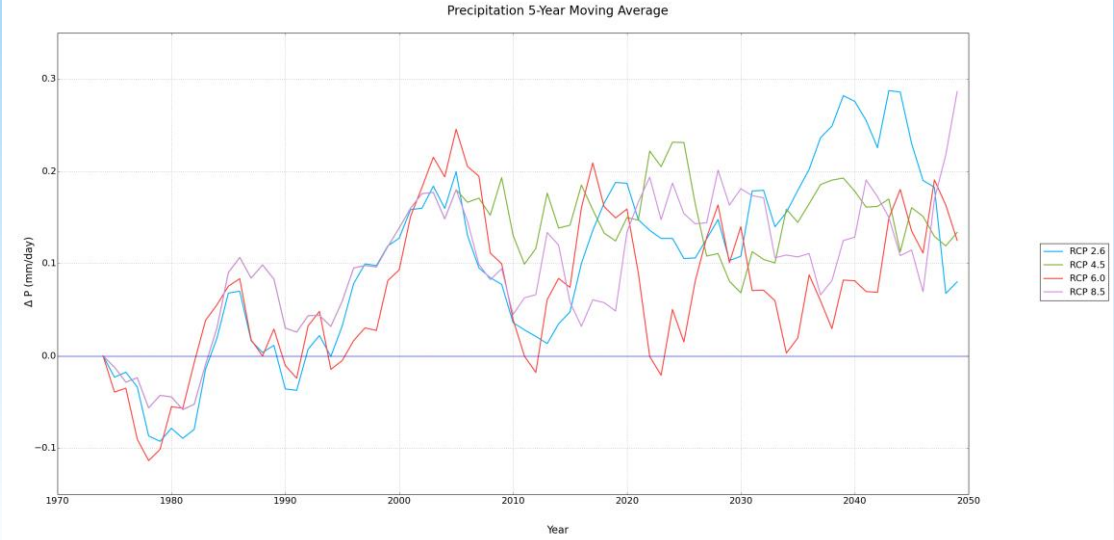
GCM Ensemble Projections, 2000-2050



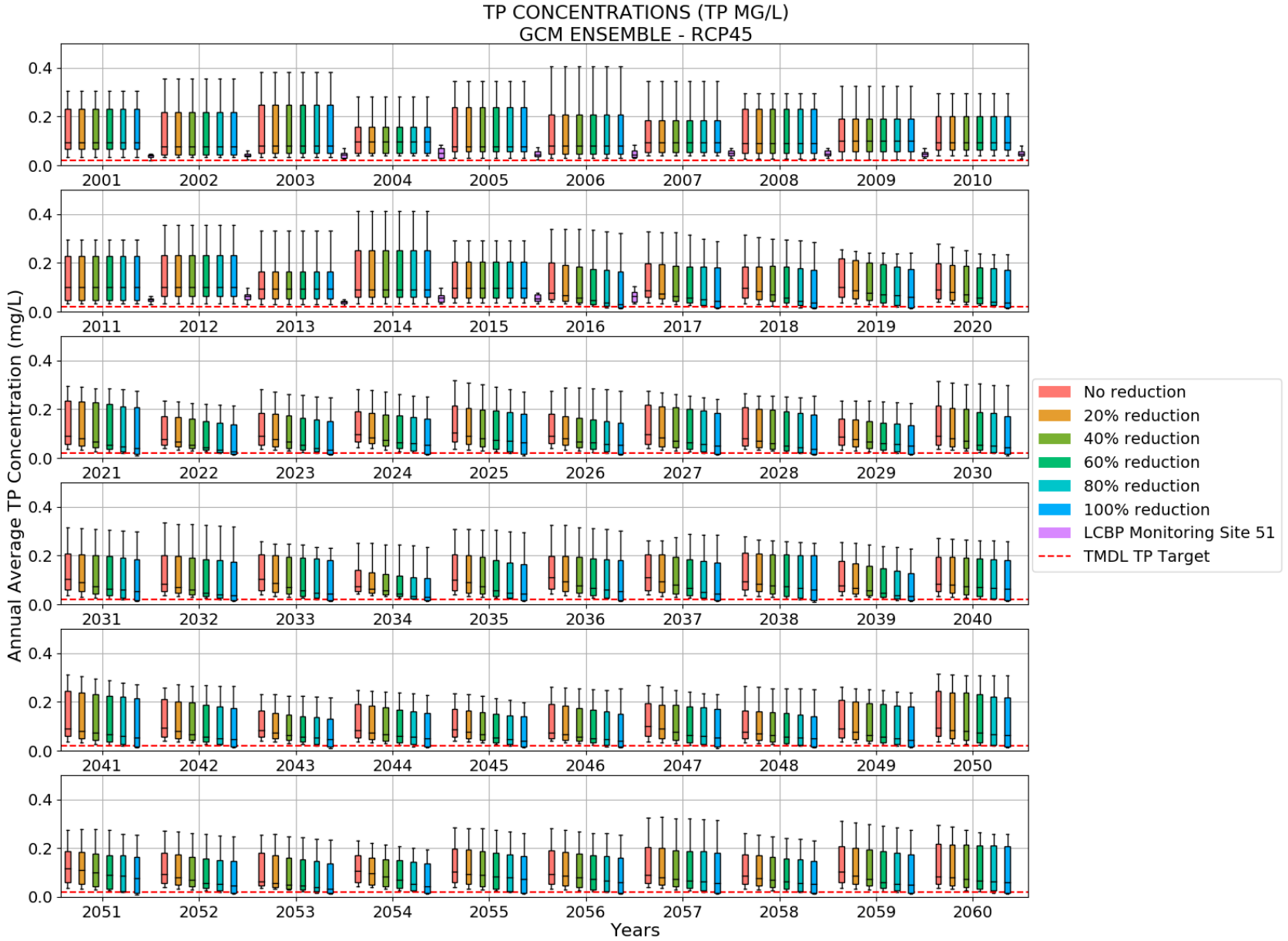


GCM Ensemble Projections, 2000-2050

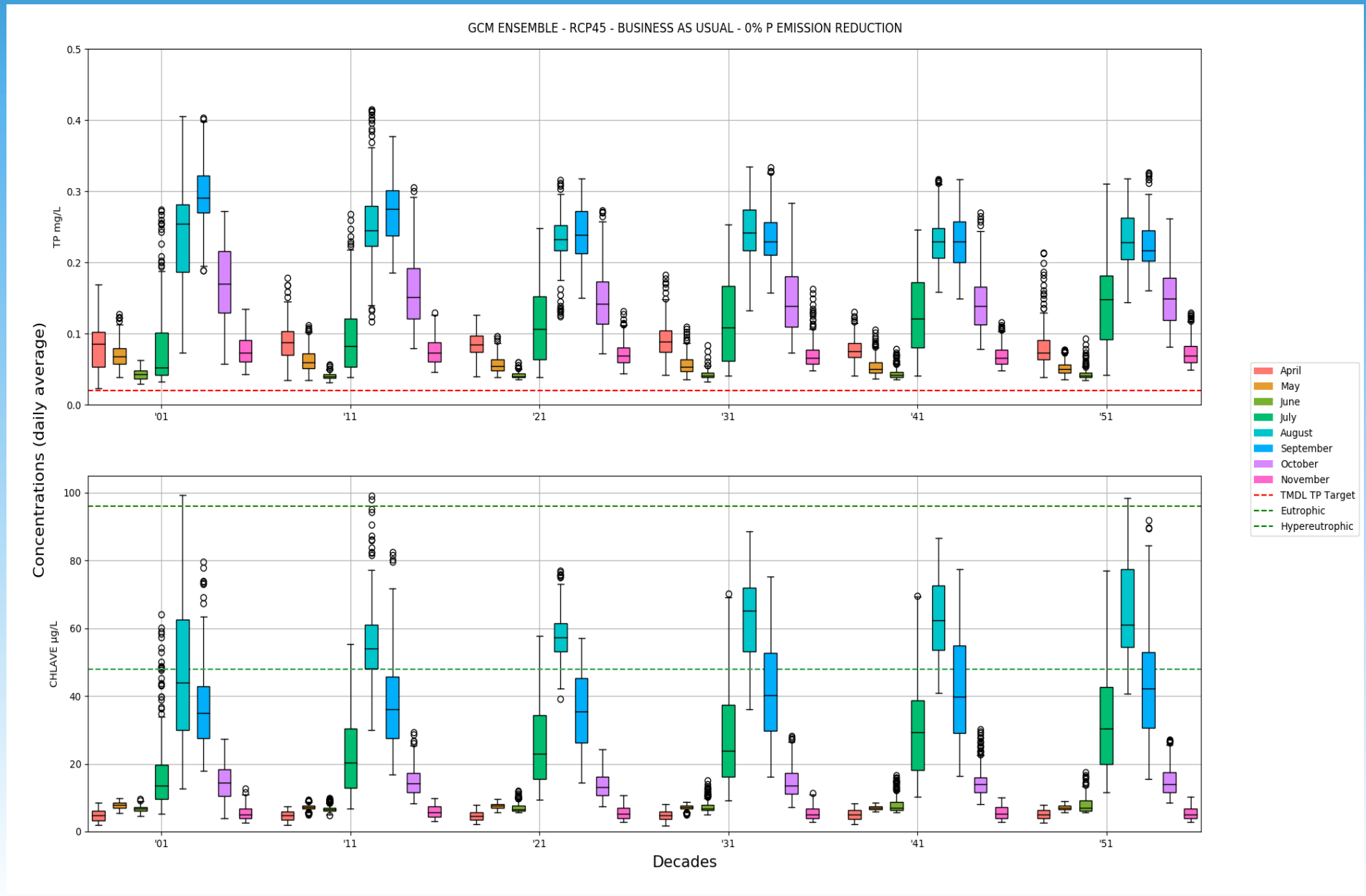




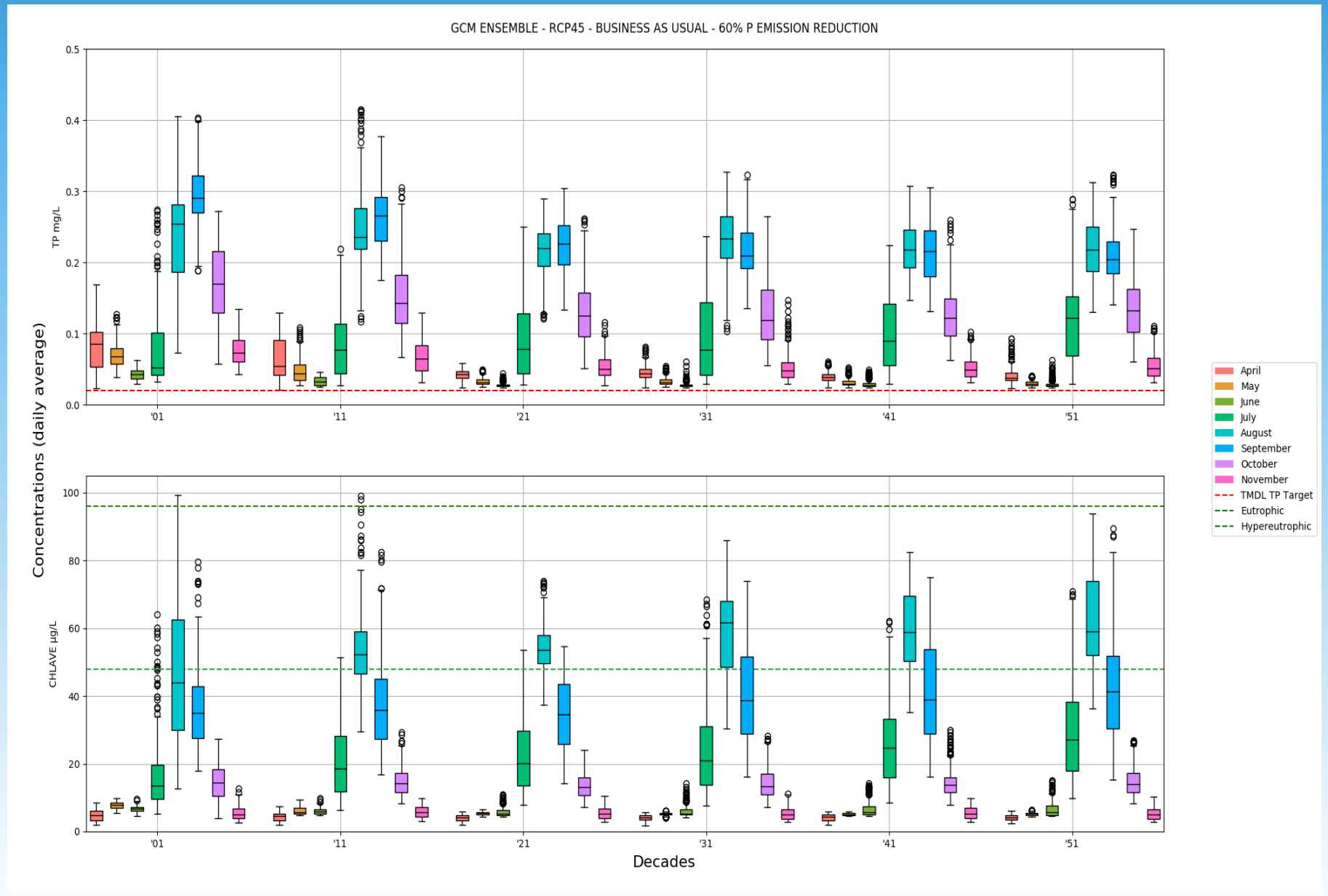
IAM projected TP concentrations for Missisquoi Bay under GCC stabilization RCP45 scenario for 0%, 20%, 40%, 60%, 80% and 100% TP loading reductions, compared with 2015 TMDL target of 0.025mg/L



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

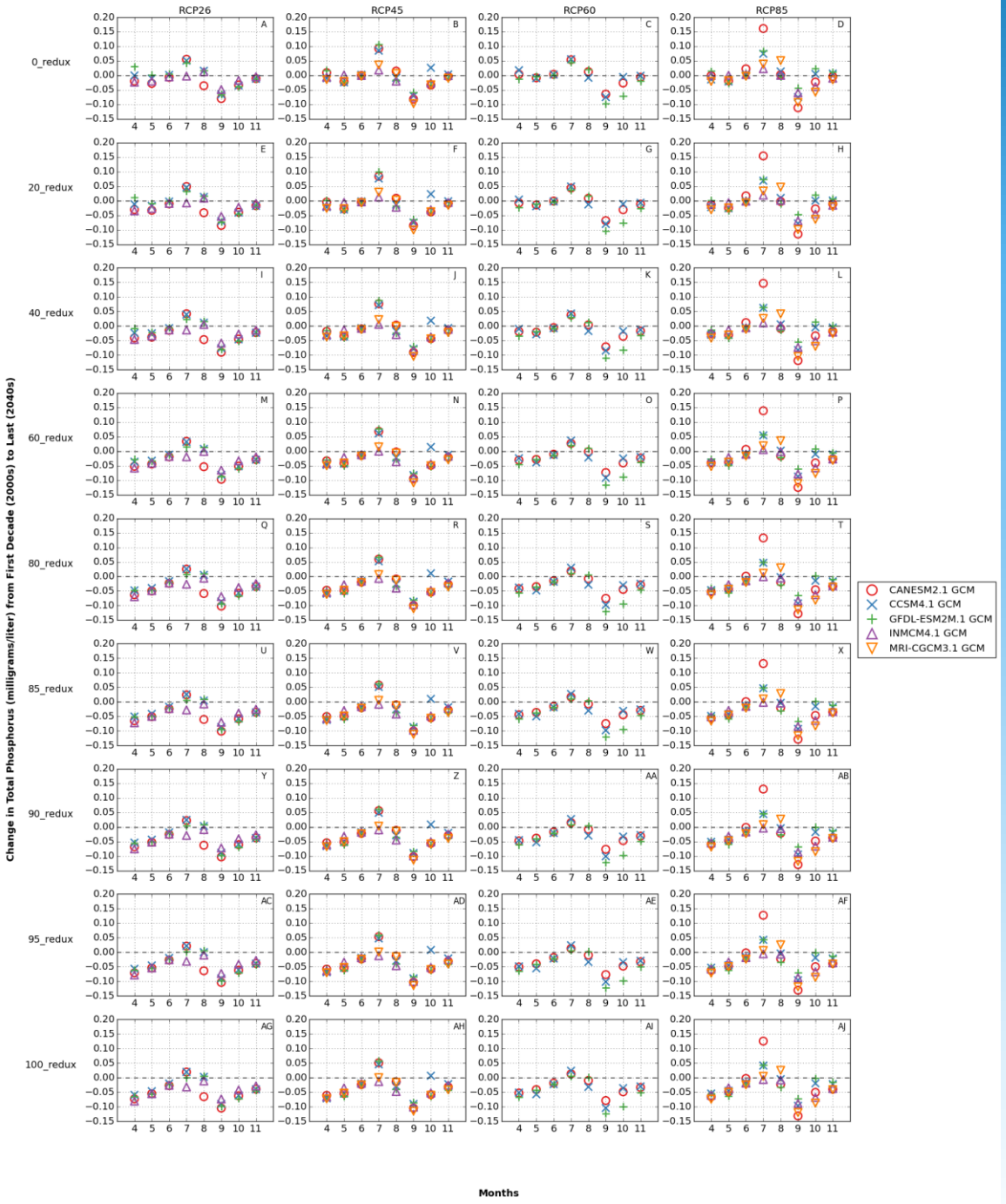


Projected TP and CHLA concentrations averaged for April through November for five decades (2000-2050) under GCC stabilization RCP4.5 scenario for **60% TP load** reductions



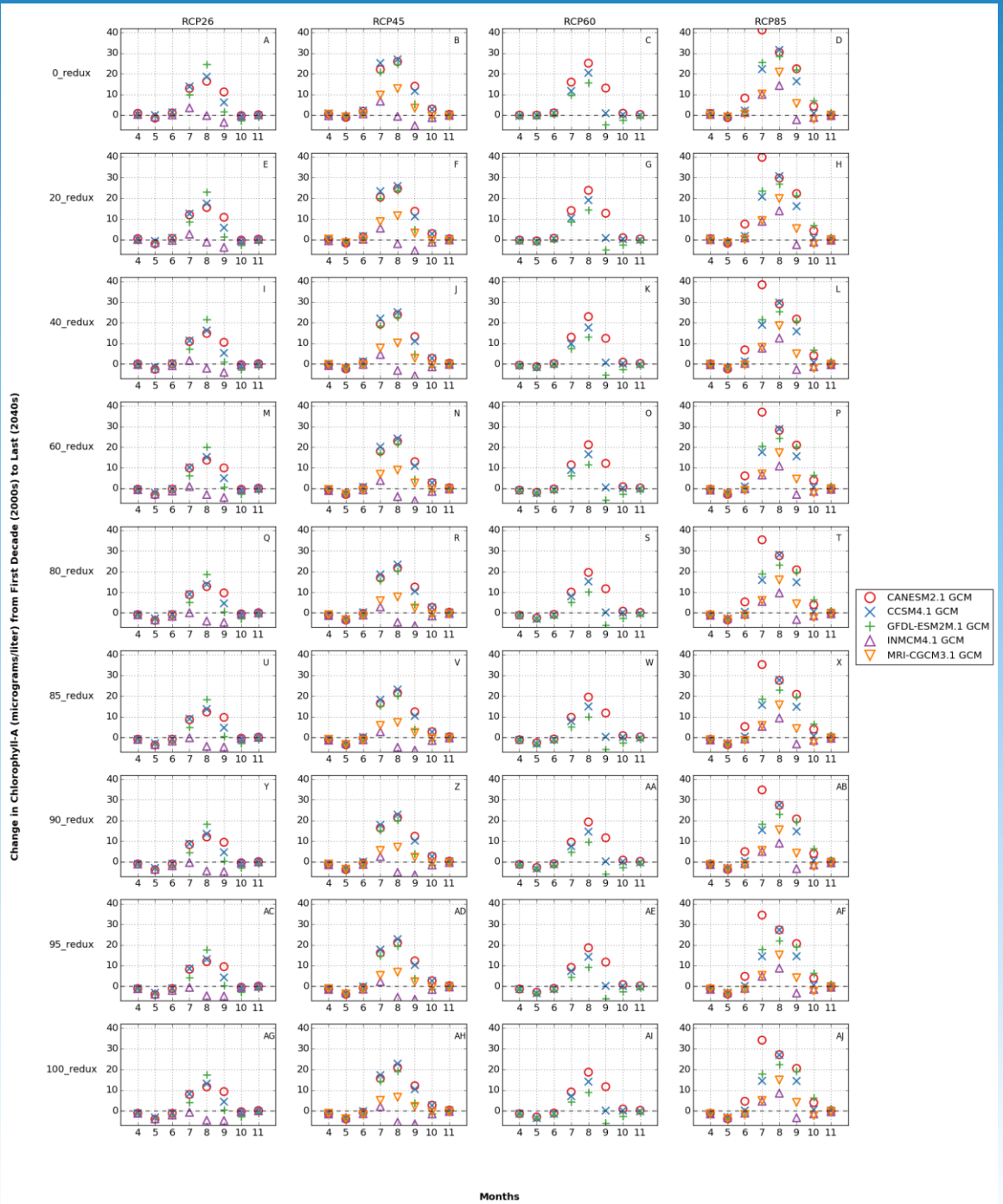
Projected changes in TP mg/L from the baseline first decade 2000s to mid-century 2040s under four GCC scenarios for 0% to 100% TP load reduction scenarios under BAU land use scenario

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



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



Thank you!

BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin