PRAGMA Lake Expedition Workshop: GRAPLE team

(GLEON Research And PRAGMA Lake Expedition)

Harnessing the GRAPLEr to predict water quality and biogeochemical responses to climate change

What we accomplished at the lake workshop!

- 10:30-11:30:
  - Introductions (all)
  - Where we are (Cayelan & Arianna): updates & overview
  - Share visualizations (Visualization team)
  - Divide into teams and put together plan for the day
- 11:30-12:30: Work time: outline and figures
- 12:30-1:30: Lunch, walk, set priorities for afternoon
- 1:30-2:30: Work time
- 2:30-3:30: Authorship discussion, finalize outline & key figures, agree on tasks & timeline for post-workshop
- 3:30-4pm: Finalize presentation for larger PRAGMA debrief at 4:30pm
- 4pm: Return back to conference center
- 4:30-5pm: Presentation to PRAGMA

Overarching research questions:

- 1) How does increased air temperature affect the magnitude and variability of N and P export and retention from an oligotrophic vs. eutrophic lake?
- 2) What are the interacting physical, chemical, and biological drivers of nutrient responses?

Two approaches:

- Look at 10 year time series of observational data of Lakes Sunapee and Mendota (2005-2015)
- Use the GRAPLEr to run future air temperature scenarios based on statistically downscaled predictions

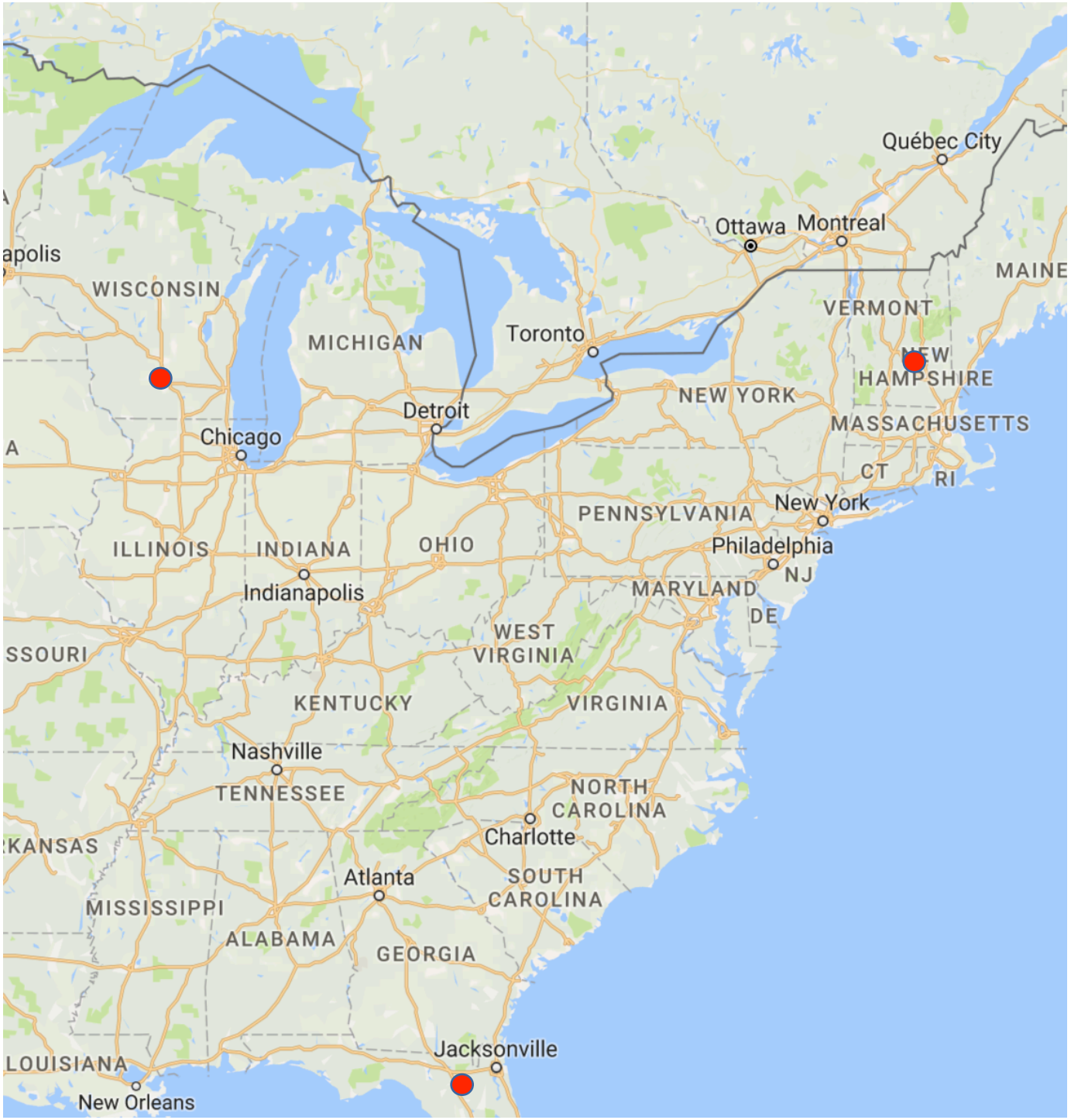
Two focal GLEON lakes: Mendota and Sunapee

<u>Lake Mendota, WI: eutrophic</u>

- Toxic cyanobacterial blooms
- Very high N and P loads from agricultural catchment
- Floods linked to blooms

<u>Lake Sunapee, NH: oligotrophic</u>

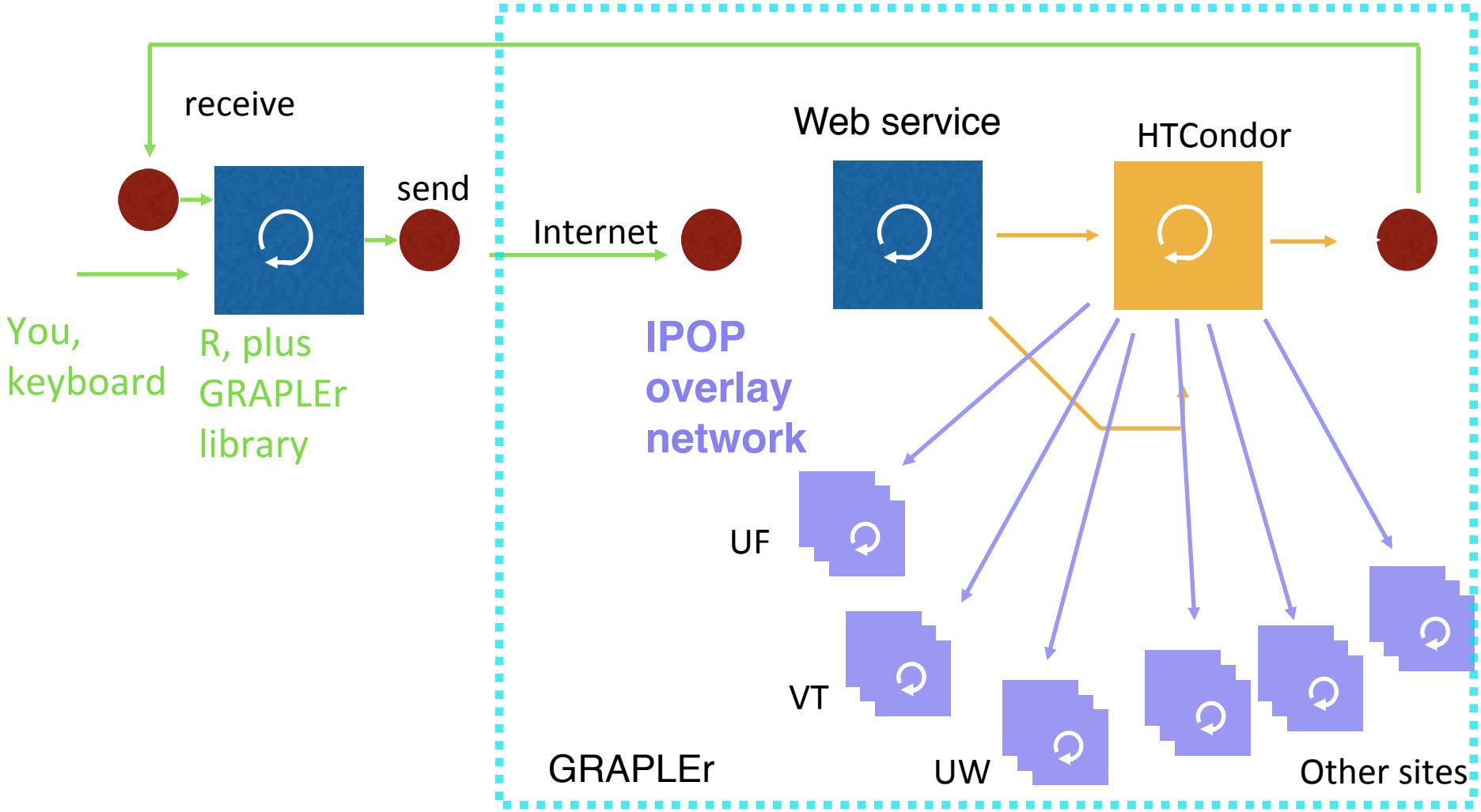
- Drinking water source
- Increasing impervious surface in catchment
- Experiencing increased extreme rain events


Québec City
Ottawa
Montreal
MAINE
VERMONT
WISCONSIN
MICHIGAN
Toronto
HAMPSHIRE
NEW YORK
Detroit
MASSACHUSETTS
Chicago
CT
RI
New York
PENNSYLVANIA
ILLINOIS
INDIANA
OHIO
Philadelphia
NJ
Indianapolis
MARYLAND
DE
WEST VIRGINIA
KENTUCKY
VIRGINIA
Nashville
TENNESSEE
NORTH CAROLINA
Charlotte
Atlanta
SOUTH CAROLINA
MISSISSIPPI
ALABAMA
GEORGIA
Jacksonville
New Orleans

GLM models are set up for Mendota and Sunapee

- Focusing on 2010 – 2014, expanding to 2005-2015
- Calibrated with observational data as part of NSF-CNH project
- Expected to experience increasing temps + increasing intense rain events in future scenarios
- Statistically downscaled GCM predictions for Mendota for 2099 in RCP 8.5: up to 7.2oC increase in air temp, and 0.08 m increase in precipitation
- Meeting biweekly between Jan-now to put together simulations

GRAPLEr: allows us to run *many* GLM model simulations



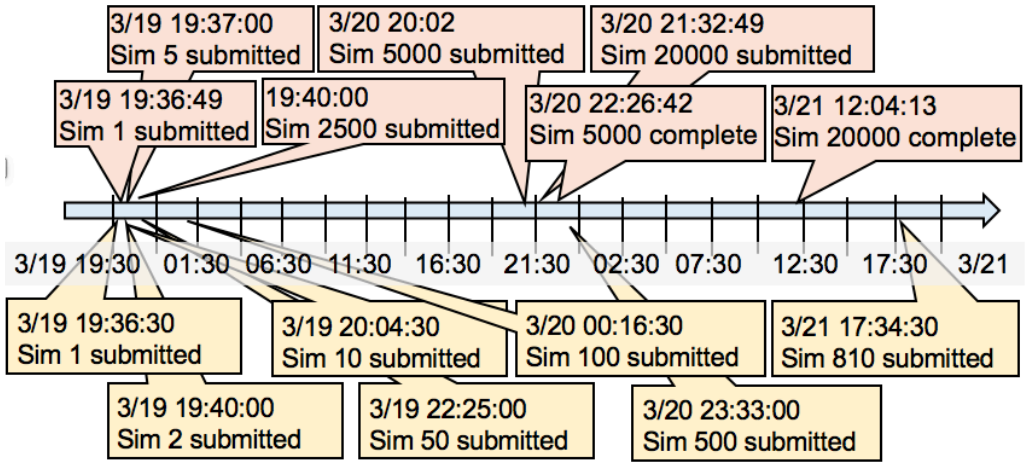
GRAPLEr is much faster than superhumans

Why do lake modelers need distributed computing?

GRAPLEr distributed computing platform

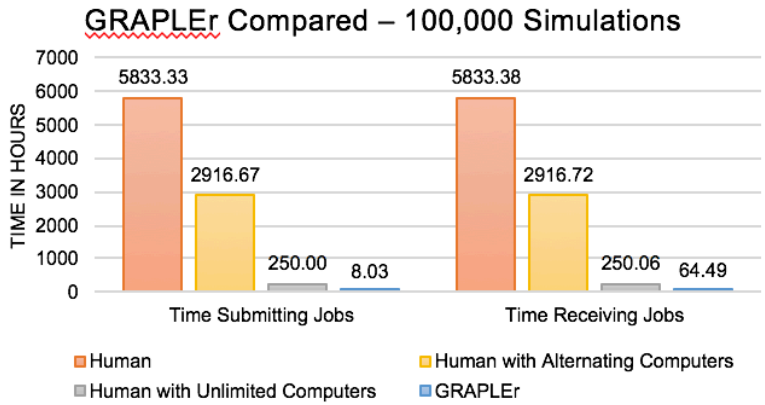
- Scenarios are set up via JSON file
- Results automatically collated
- Can continue to submit simulations past 5000

For the first 20k simulations…



Personal Computer, individual GLM runs

- Must assume scenarios have been set up manually
- ~9 seconds to enter commands to start model; avg. 3:16 mins/run
- Estimated 3.5 minutes per run at superhuman capacity
- Normally only one GLM run possible at a time (start time of sim = end time of previous sim)



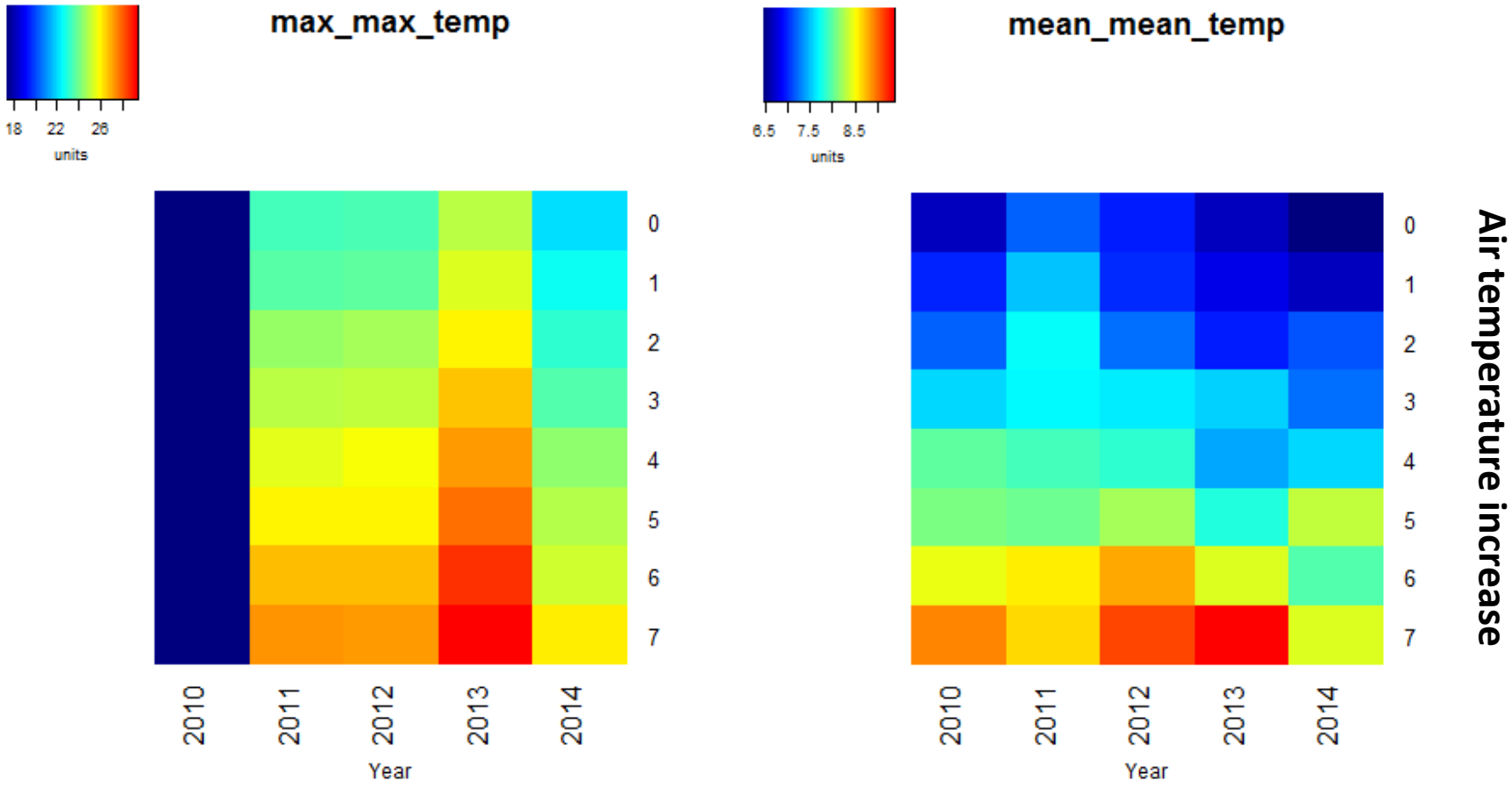
- GRAPLEr times include an allocation problem partway through the simulation
- The first 20,000 simulations were submitted and ran properly
- Simulations are submitted with increasing efficiency, but the more that are run, the longer the return time
- In practice, a superhuman could expect to submit <100 simulations in an 8-hr day

Schematic by Arianna Krinos: Come see her poster!

GRAPLEr scenarios: 5,000/lake

- Air Temp: 8 scenarios
  - +0, 1, 2, 3, 4, 5, 6, 7oC additive increase
- Rain: 5 scenarios
  - +0, 0.02, 0.04, 0.06, 0.08m additive increase
- Ammonium concentrations in inflow: 5 scenarios
  - x -0.2, -0.1, 0, 0.1, 0.2 multiplicative change
- Nitrate concentrations in inflow: 5 scenarios
  - x -0.2, -0.1, 0, 0.1, 0.2 multiplicative change
- Phosphate concentrations in inflow: 5 scenarios
  - x -0.2, -0.1, 0, 0.1, 0.2 multiplicative change

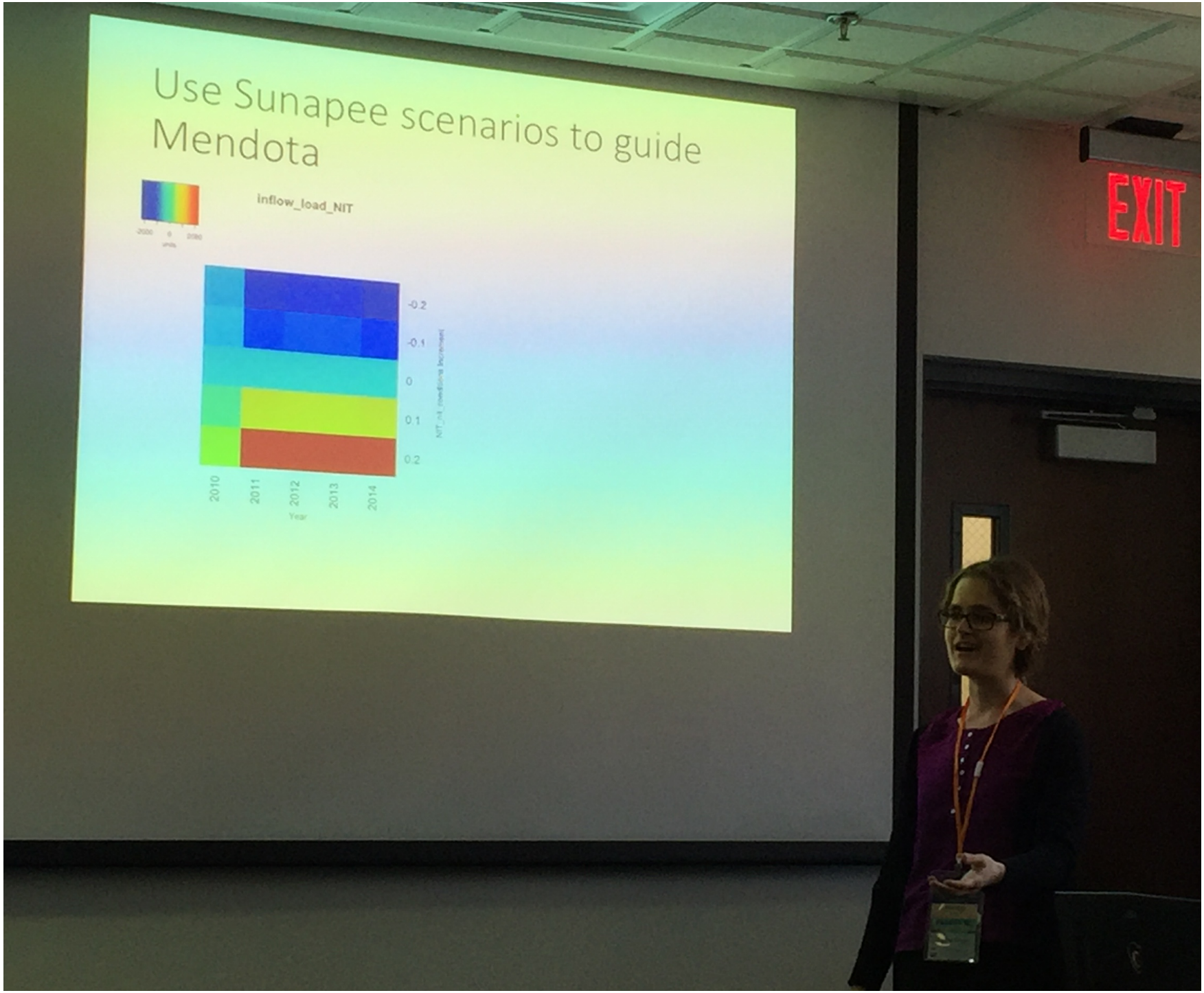
We looked at lots of plots that look like this…

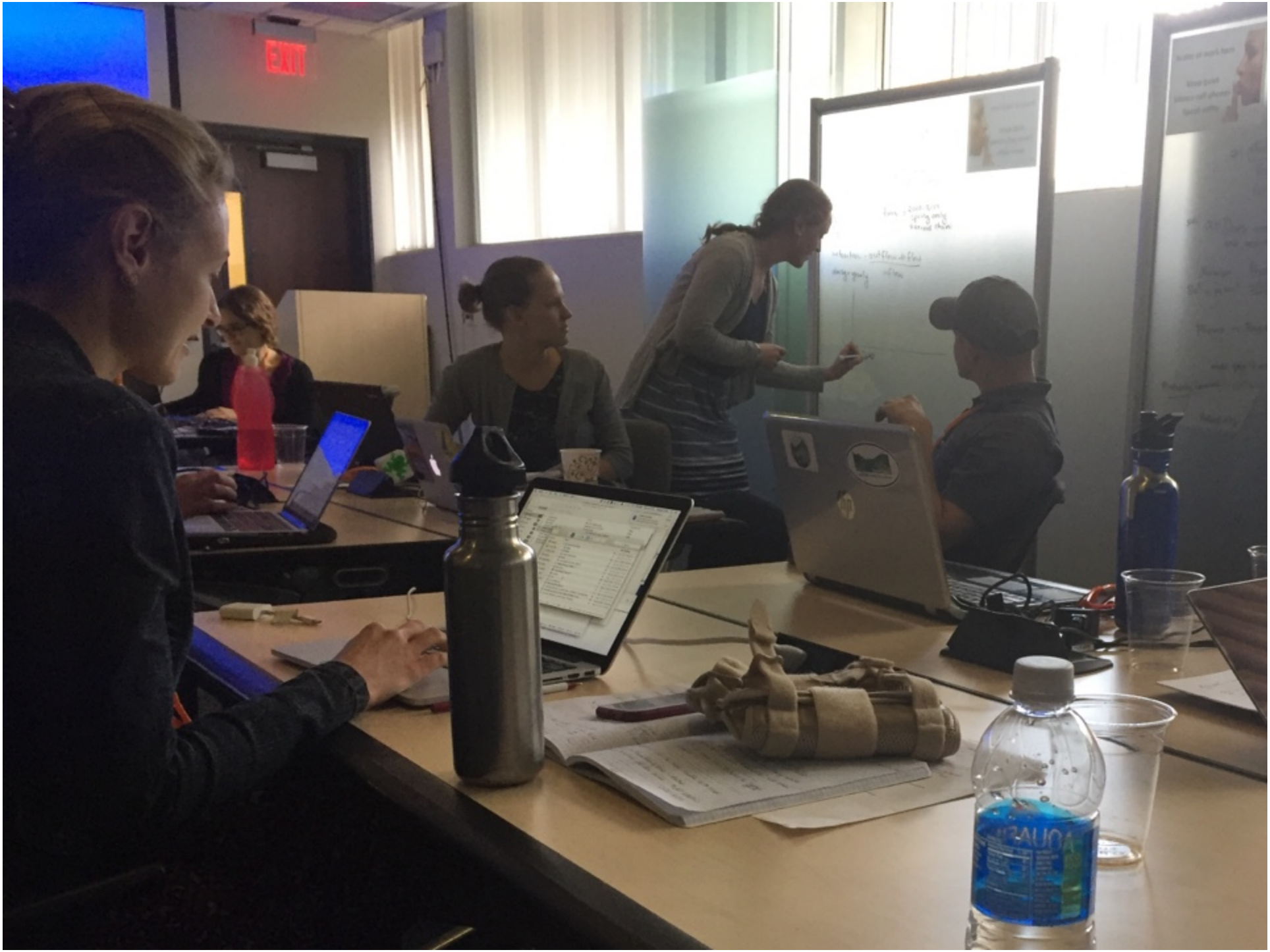


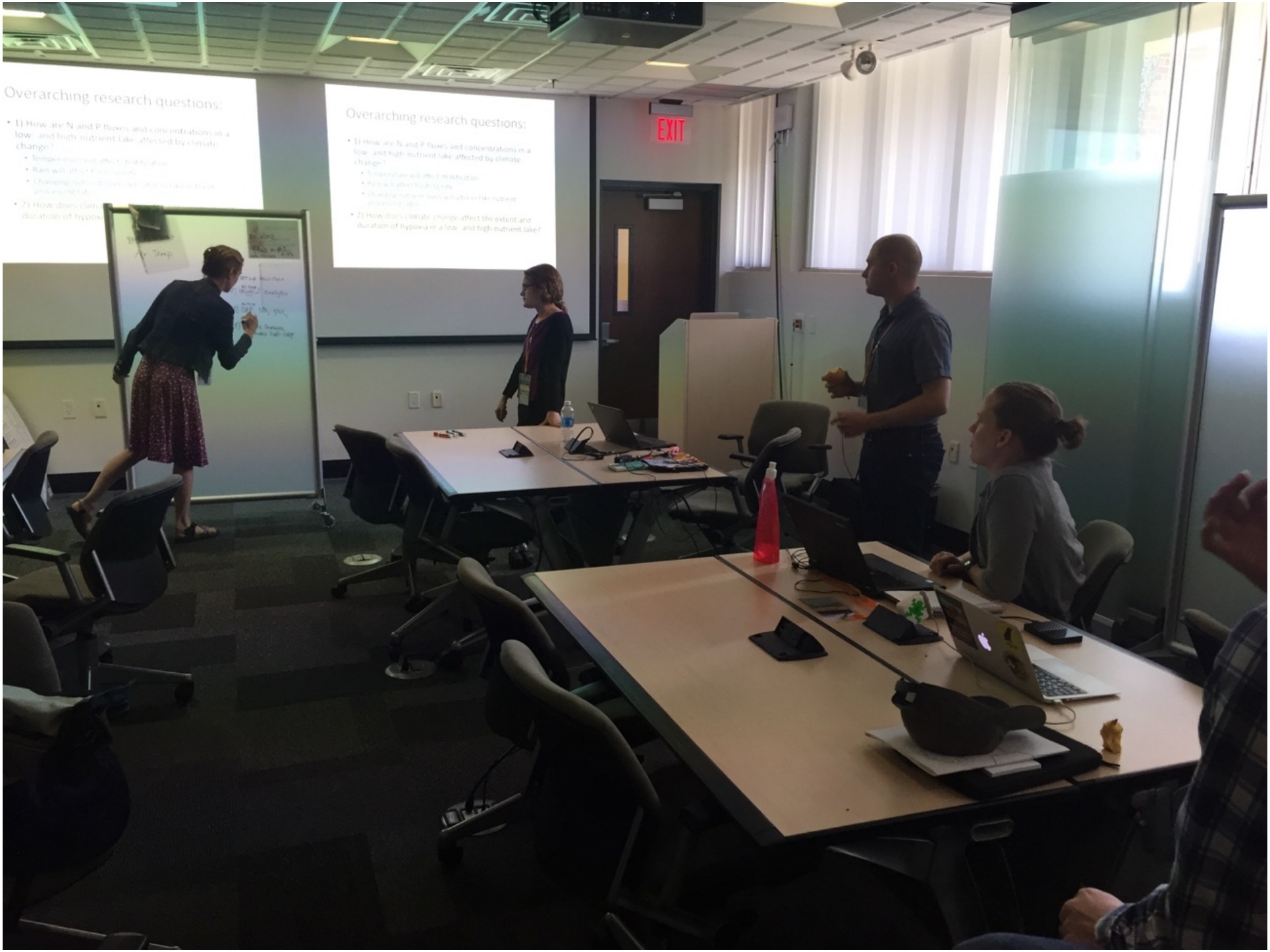
To-do's from the workshop!

- Arianna: Run 2010-2014 GRAPLEr sims for air temp x flow scenarios for Sunapee first (imminent)
  - Use nutrient retention x outflow data to inform question
- ALL: Lake expedition working group time this week: work through those sims and look at nutrient loads for 2010-2014 Mendota vs. Sunapee for relationships with temperature
- Paul: get "observational" Mendota nutrient input and output loads (before May 10)
- Nicole and Kait: look at observational data to see Sunapee output load and retention responses to temperature (early May)
- Kait: based off of observational data, explore nutrient load responses (May)
- Phil (May): gather the raw GLM simulation data into GRAPHITE for later post-processing and visualization

GRAPLEr allows us to model lakes in a sandbox, real-time environment


Use Sunapee scenarios to guide Mendota
inflow_load_NIT
-0.2
-0.1
0
0.1
0.2
2010
2011
2012
2013
2014
Year
EXIT


EXIT


Overarching research questions:
Overarching research questions:
EXIT

Synergistic outcomes of the lake expedition workshop

- Advancing fundamental science: Have identified a GRAPLEr project that will answer an important lake ecology research question and will lead to a research publication
- Capacity building: Cross-discipline knowledge transfer for the GRAPLEr team across career stages
- Developing GRAPLEr resources: New capacity for saving large model output files to access later
- Lessons learned from collaboration of ecologists & computer scientists: process publication

Questions?

- Check out our website: Graple.org
- Talk to Cayelan, Renato, and Paul this week!
- See our students' posters!

Things to keep in mind

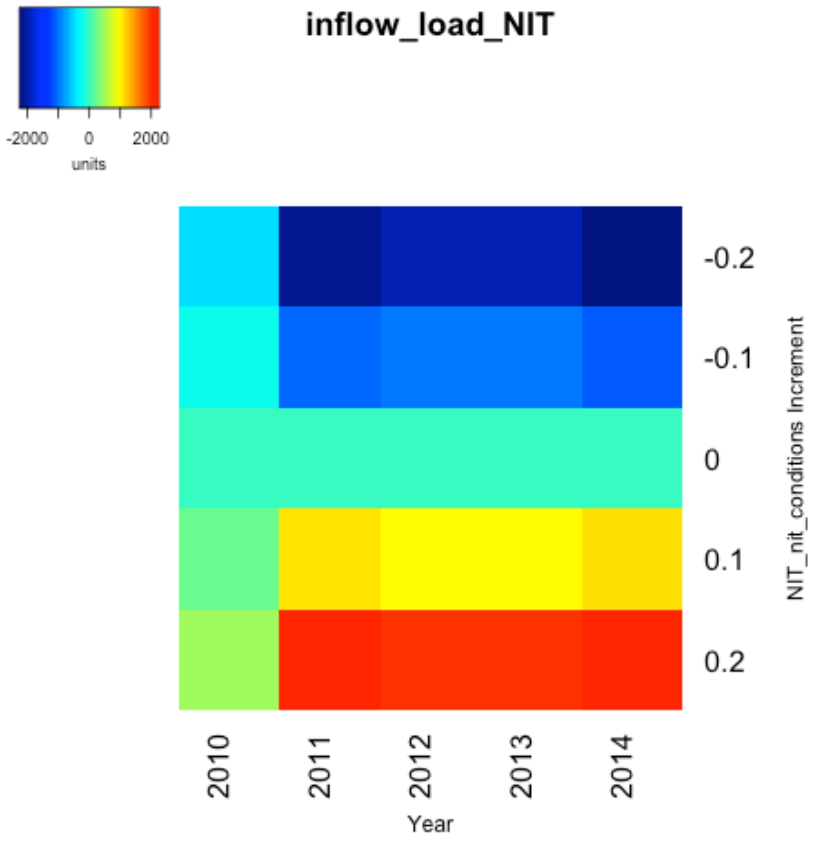
- These lake models are calibrated for O, N, P, not C or phytos
- Comparing two lakes
- Comparing multiple years within a lake
- Comparing multiple scenarios of changing air temp, rain, nutrient loads (simultaneously + independently)

What to focus on????

Goal from workshop: a GRAPLEr publication

- A developed outline + key results + figures
- Tasks & timeline for post-workshop submission
- Target journal + author list

Use Sunapee scenarios to guide Mendota



Sunapee Plots and Impressions: aka Arianna is a GRAPLEr rockstar

Important note

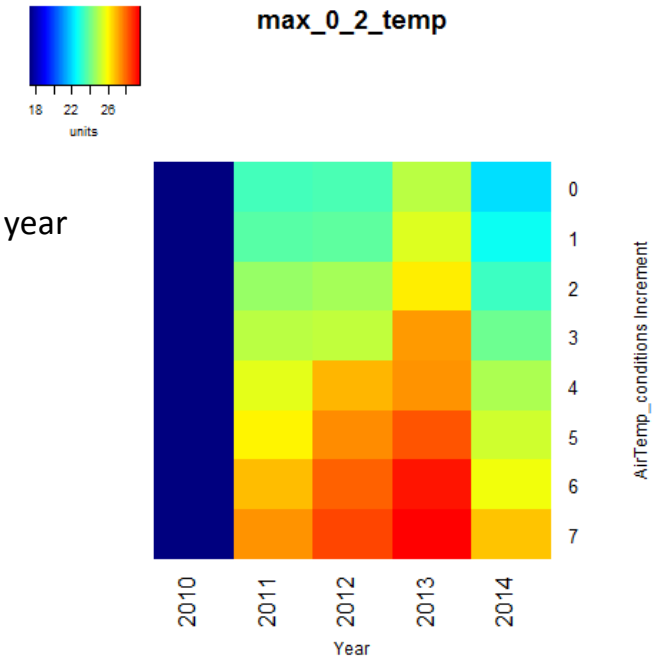
- mean_mean_oxy2, max_max_oxy2, mean_0_2_oxy2, max_0_2_oxy2, mean_sed_oxy2, max_sed_oxy2 all need to be **divided by 0.031** in the yearly data
- Inadvertently left a conversion to grams as P when adding this segment last minute & basing it on TP

Scripts & further analysis

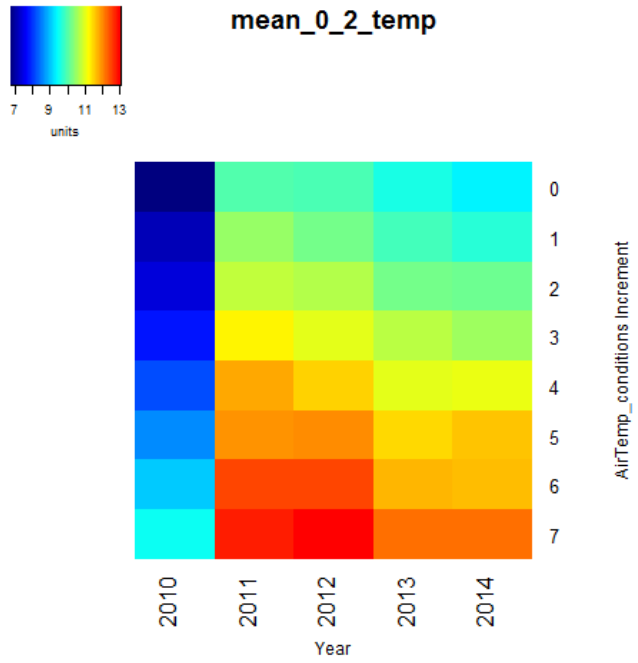
- Current visualization script
  - Grab data for two manipulated GRAPLE variables; plot changes as a heatmap
  - Can append and store comparison information for further work
  - Works in two dimensions across a single response variable
- Yearly analyses
  - One GRAPLE variable dimension
  - One for simulation year
  - Instrumental in gaining accurate insight from the output
- Time series analysis
  - In the works: automatic plot generation for full time series analysis for some sediment variables
- Phenology
  - Can be pulled meaningfully; use current yearly plots as a preliminary gauge although resolution low

Changes in surface temperature vary by year

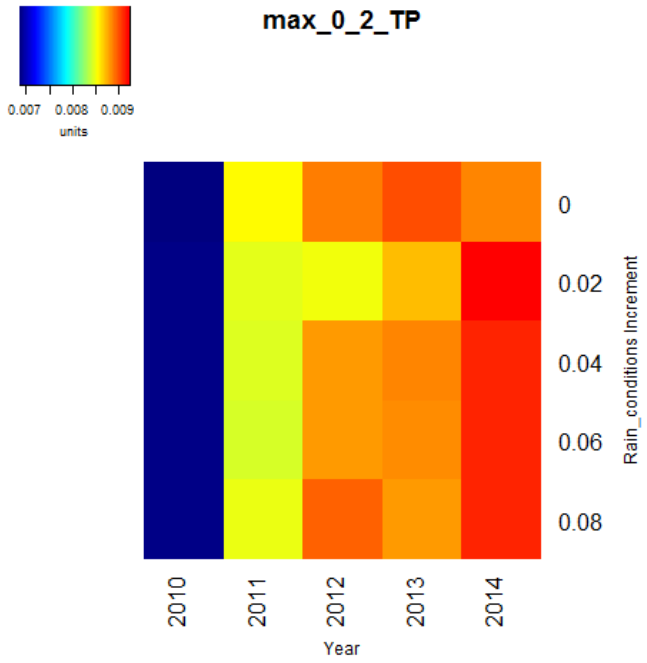
And may drive differences in response variables from year to year where air temp is concerned

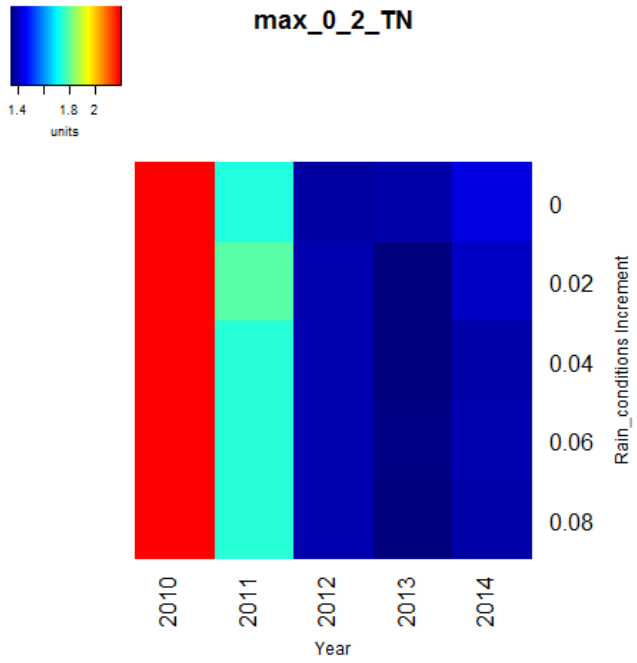


Mean surface temperatures have a different distribution

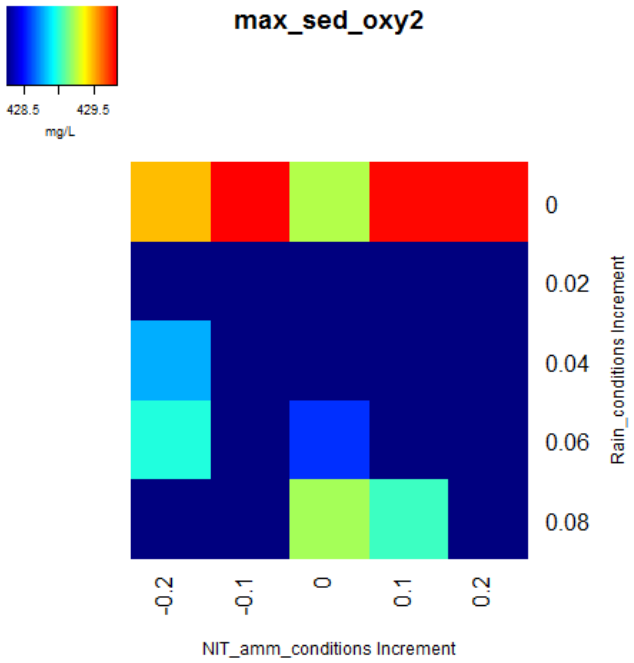


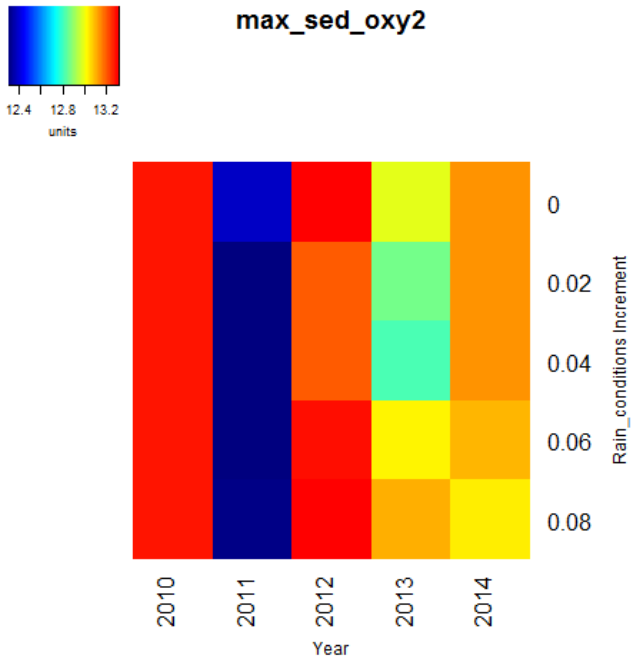
TNTP Succession



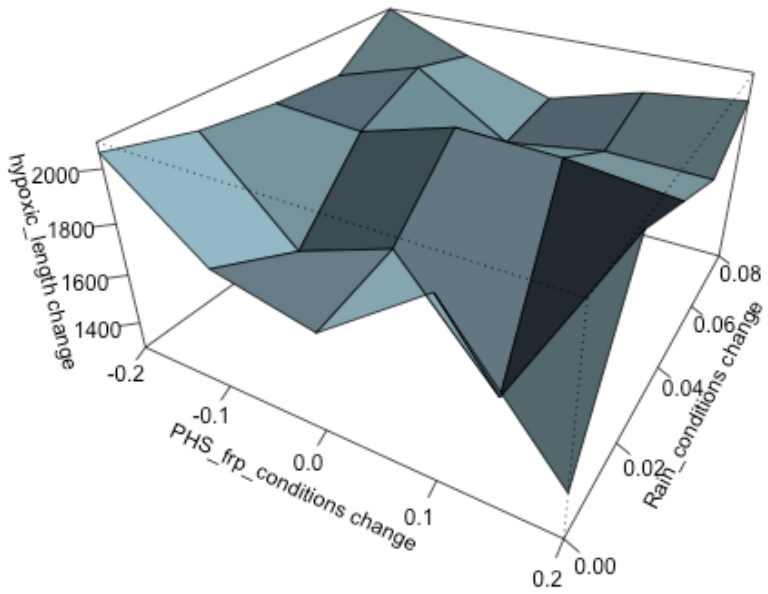


Something to keep in mind…false patterns!





FRP vs. Rain, Hypoxic Length

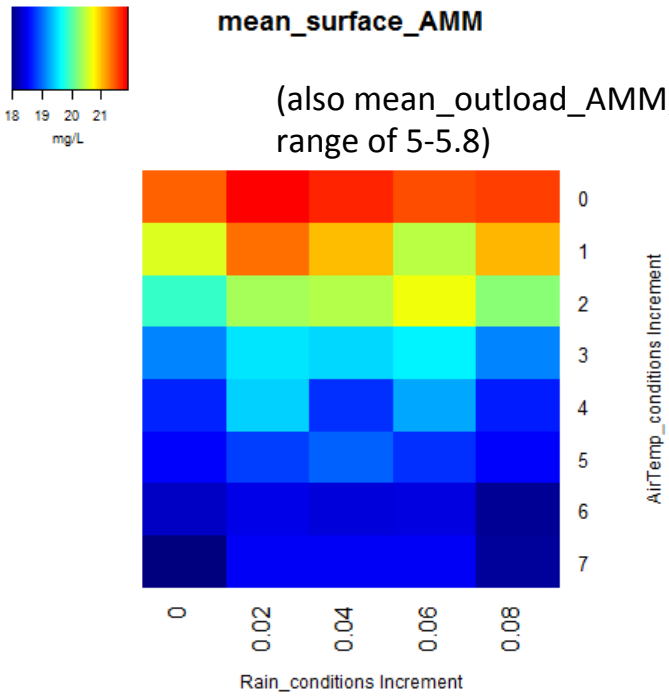


Proposed Focal Areas (teams)

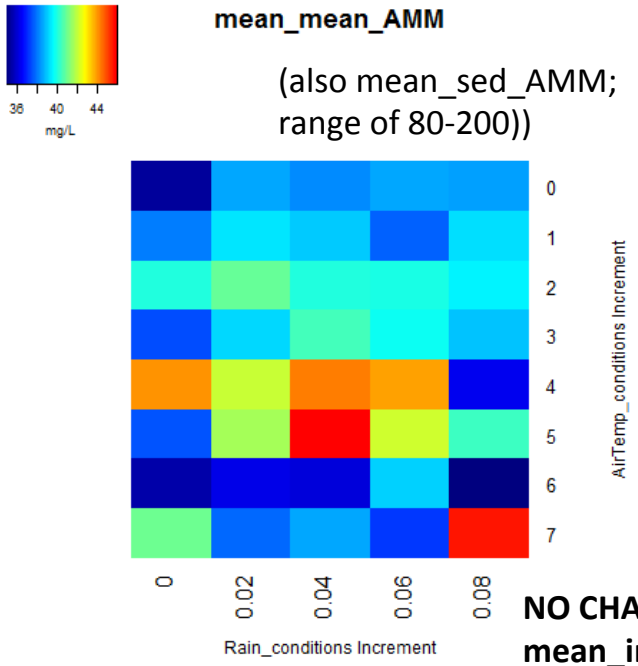
- Phosphorus: why do changes in P vary inversely with the intensity of temperature impact/how does this interact with hypoxia? What does this look like for Mendota?
- Degree of warming: potential threshold at 4 deg C? Study temperature equations in GLM and why strange patterns emerge at median temperature increase.
- Spin-up: what about the simulation makes 2010, 2011, 2014 more/less suitable for analysis? What drives changes in spin-up period among nutrients?
- Rain: compare magnitudes of nutrient increases among NIT/AMM/TN/TP with increases in precipitation...why are loads disproportionately impacted, and what secondary GRAPLE variables confound?

Mary’s Nitrogen Variables!

Sunapee: ammonia response variables (TR)



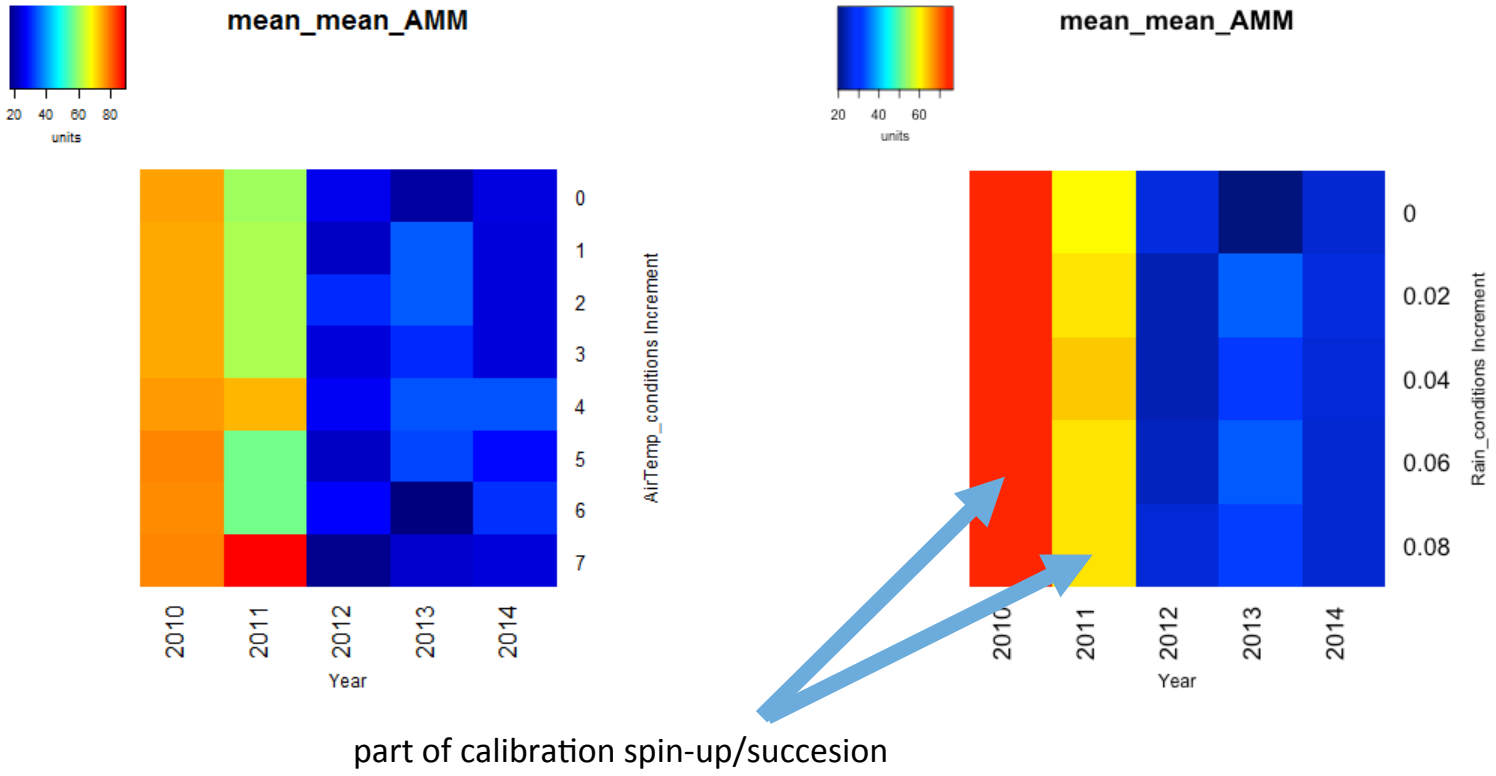
(also mean_outload_AMM; range of 5-5.8)



(also mean_sed_AMM; range of 80-200))

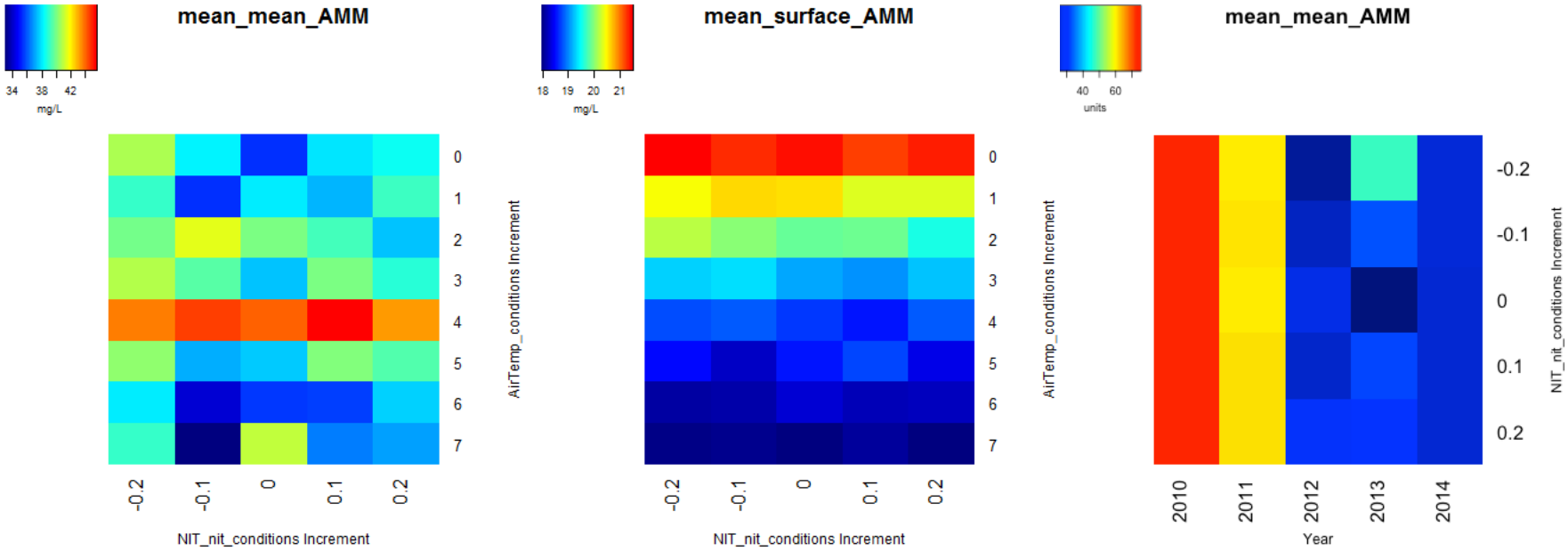
NO CHANGE IN:
mean_inload_AMM
total_inload_AMM
max_surface_AMM

Sunapee: yearly ammonia (TR)



part of calibration spin-up/succesion

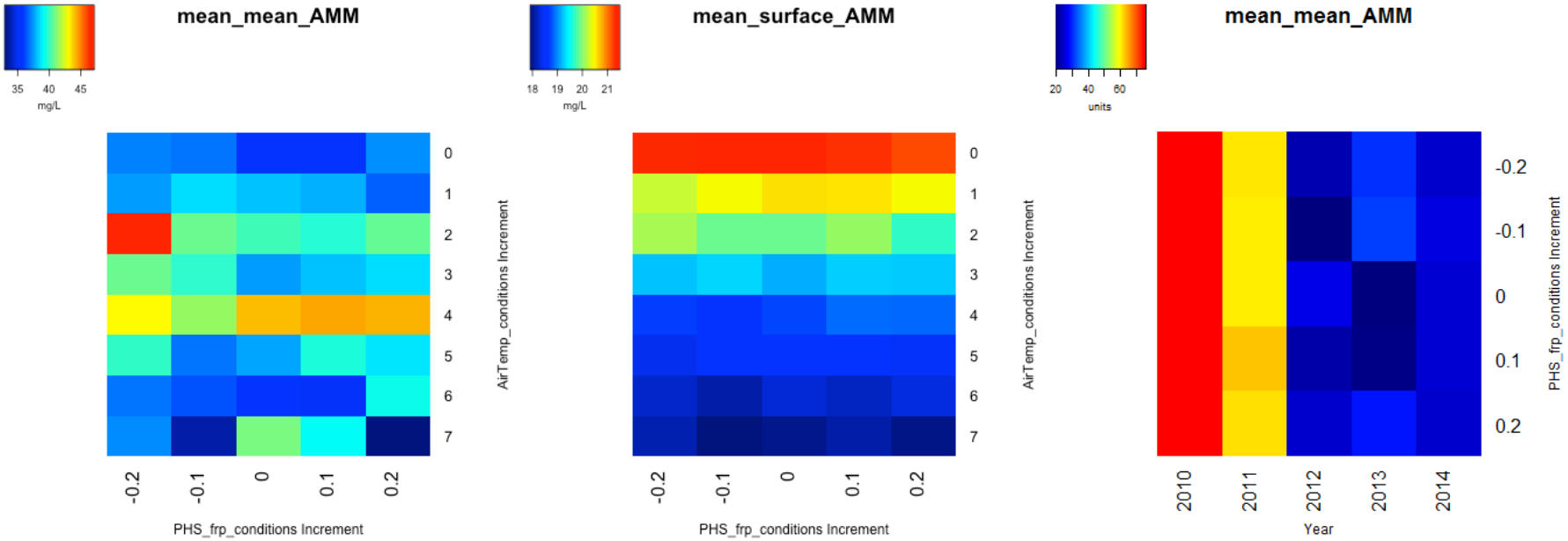
Sunapee: ammonia response variables (TN)



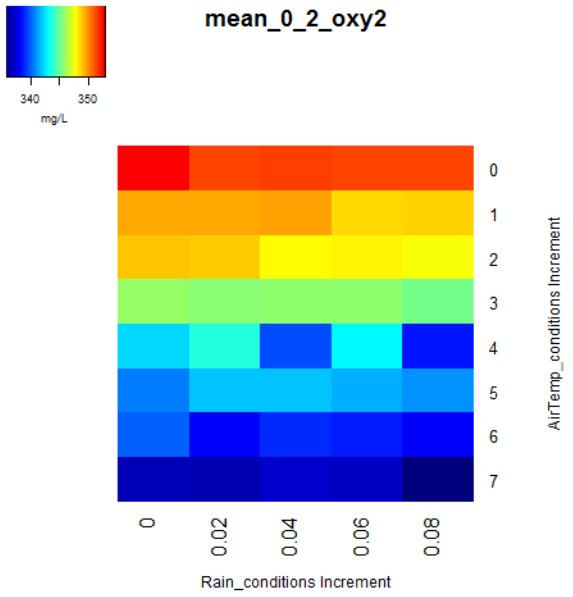
Is the “hot column” at 4 degrees real?

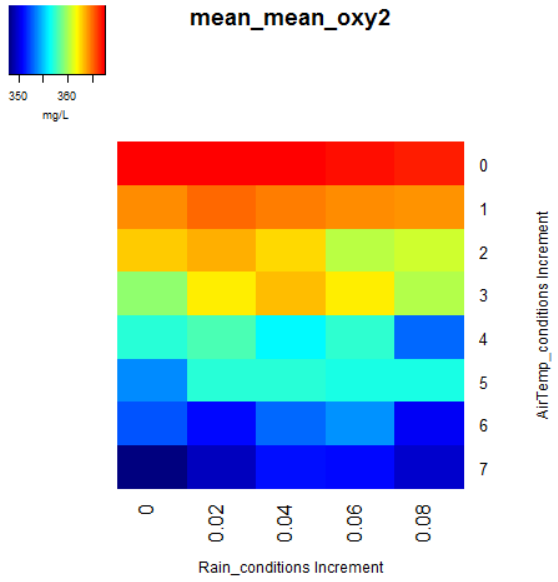
Is 18-21 mg/L really right? Units?

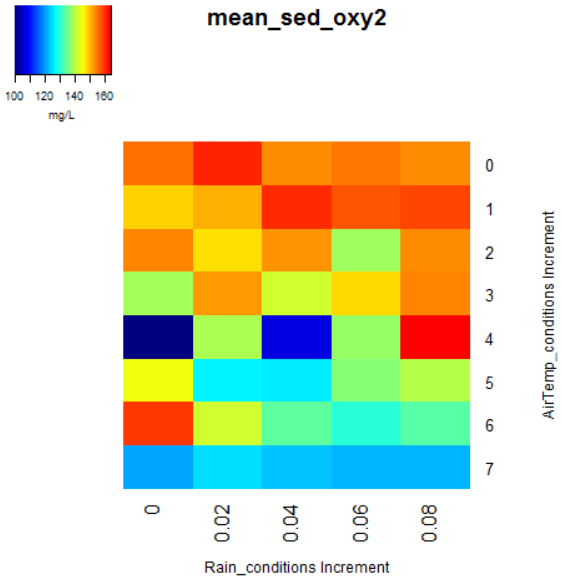
Sunapee: ammonia response variables (TP)



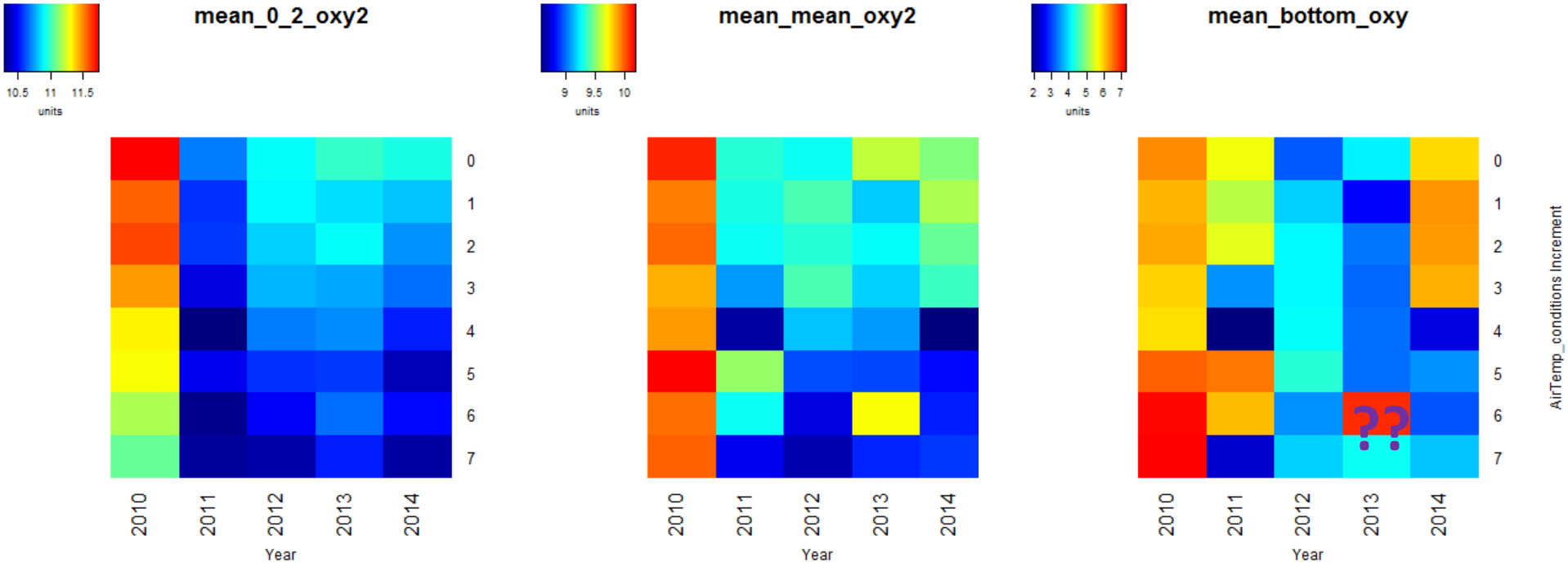
Sunapee: *some* oxygen response variables (TR)







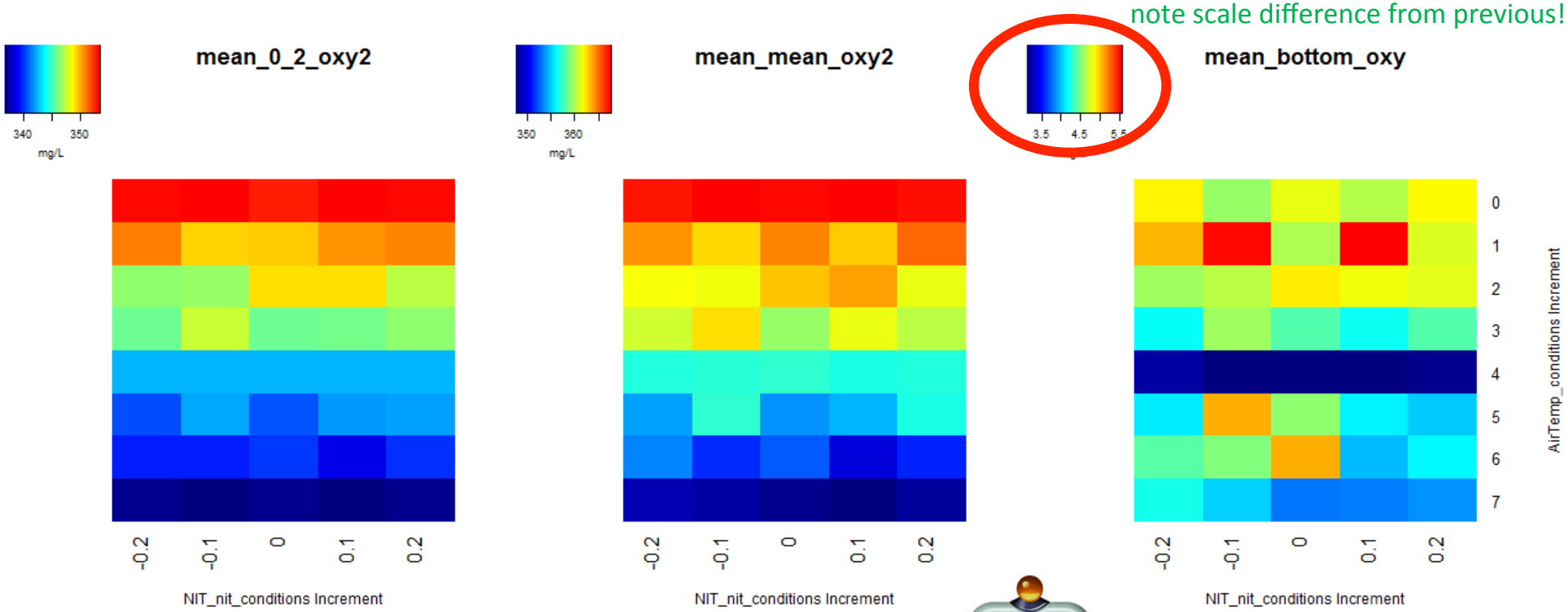
Sunapee: oxygen by year (TR)

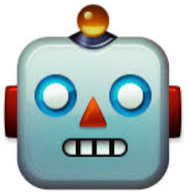


Maybe we should look at 2012-2014 averages?

Sunapee: *some* oxygen response variables (TN)

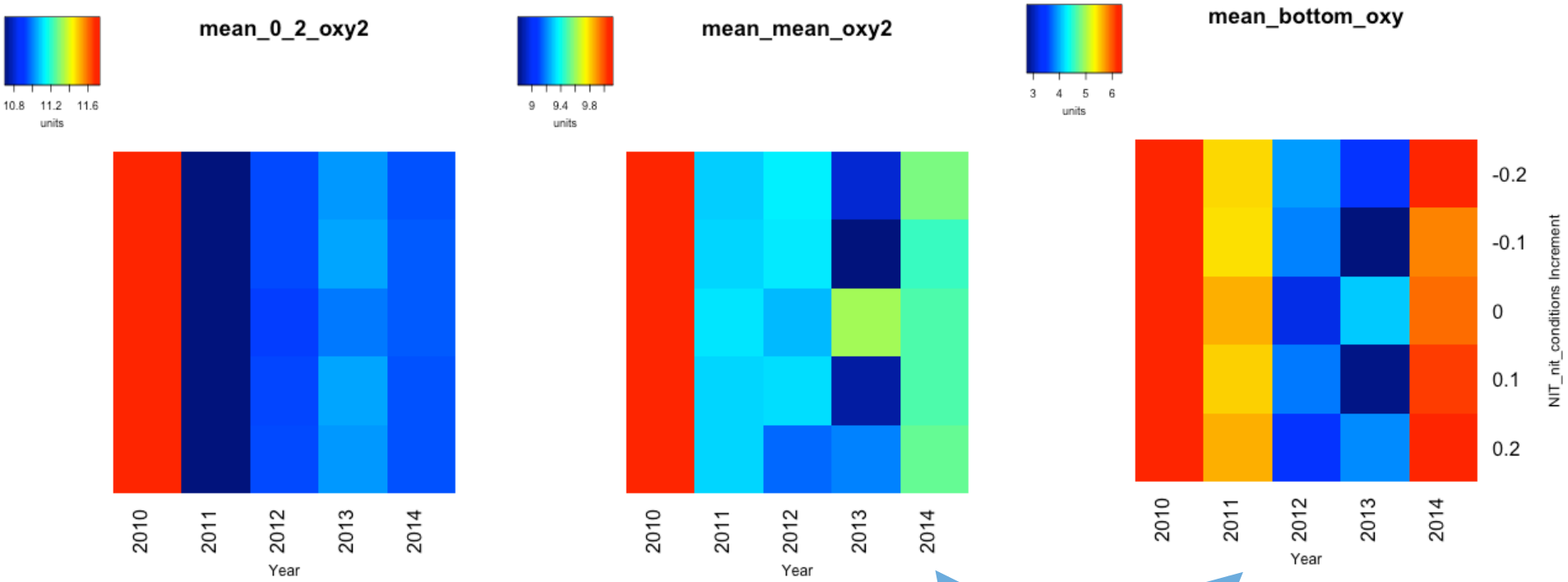
note scale difference from previous!





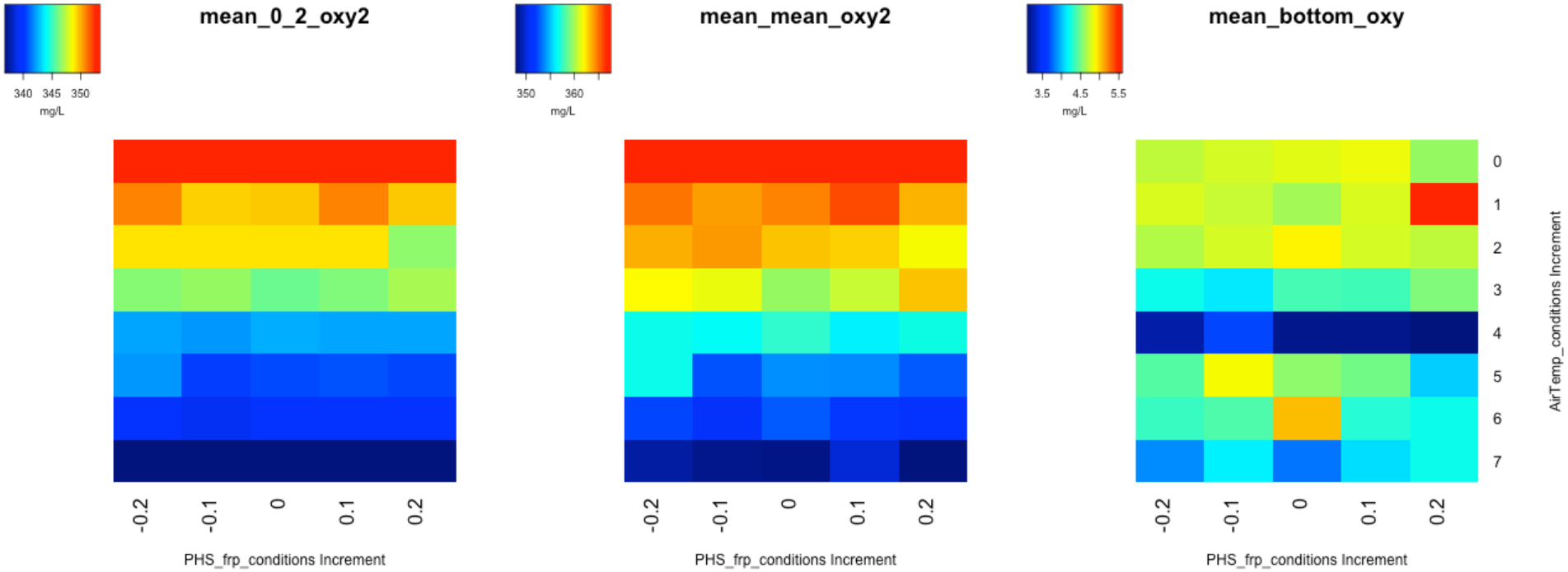
ha! looks like robot emoji…

Sunapee: oxygen by year (TN)



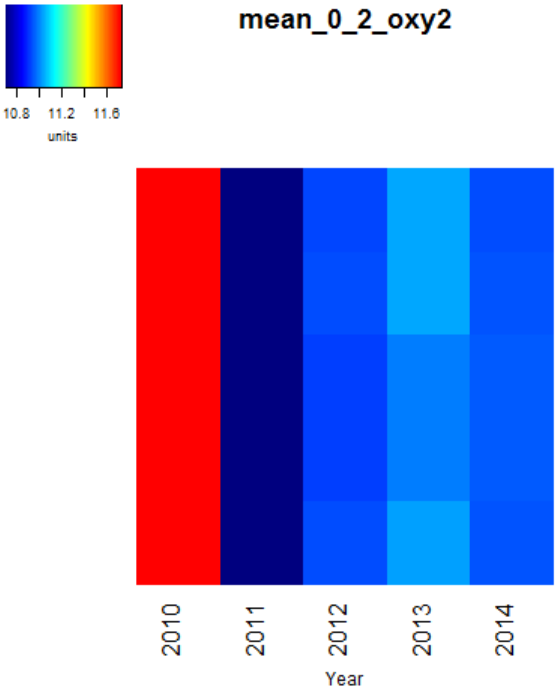
think there is potential here?
BUT…WHY is oxygen always higher in 2014??

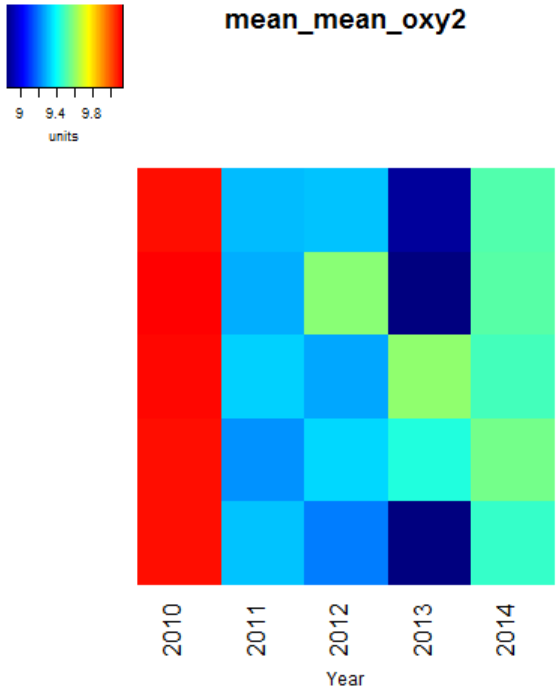
Sunapee: *some* oxygen response variables (TP)

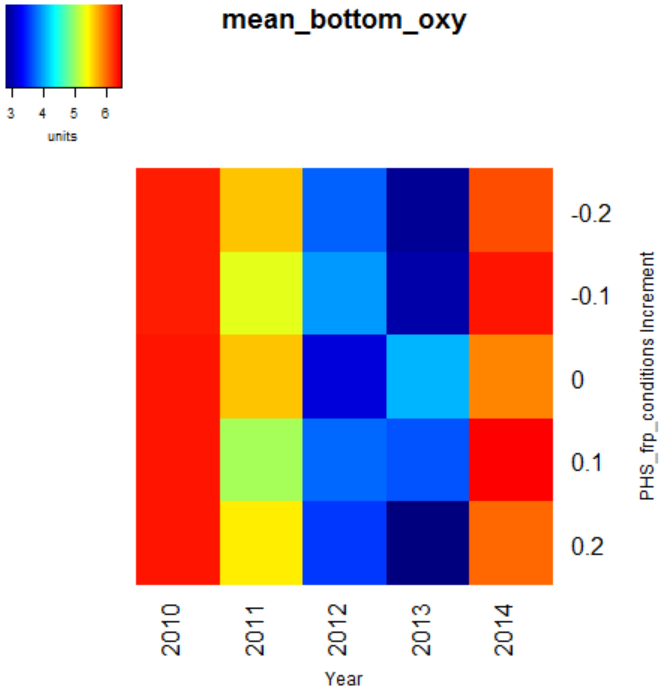


again, an interesting band at 4 degrees

Sunapee: oxygen by year (TP)







….what is special about 2014 weather?