North Dakota NSTEPS Progress Update

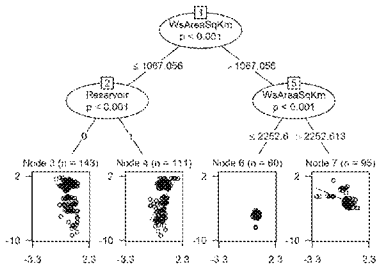
October 7, 2021

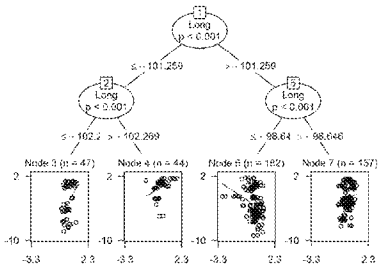
Agenda

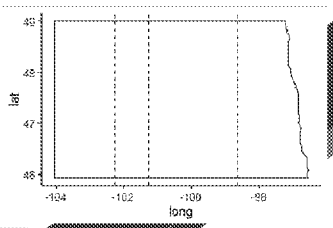
- Overview of planned approach & decisions
- Introduce NLA models and initial application for ND data

Classification Decisions

- Variables: watershed area, longitude (longitude good surrogate for lake vs. reservoir)
- Use values from chl~TN model (1,067 km2 and -101.26 degrees)
  - Lines up well with current rotating monitoring approach
  - Chl~TP model may be influenced by sample size in Missouri Coteau or Devil's Lake







Planning for stressor-response analysis

- Goal: ID nutrient and chlorophyll thresholds associated with adverse response conditions
- Use both individual observations (SiteDate) and temporal averaging (SiteYear)
- Consider spatial averaging for oversampled lakes (e.g., Devil's Lake)
- Filters on dataset: May-September, surface
- Variables
  - Predictor variables: TN, TP, Chlorophyll
  - Response variables: chlorophyll, pH, hypolimnetic DO?
  - Covariates: land use, non-algal turbidity, N:P

NLA Models

- Models with ND data:
  - Chlorophyll ~ TN
  - Chlorophyll ~ TP
  - Hypolimnetic DO ~ Chl
- Models w/o ND data:
  - Microcystin (9 data points)
  - Zooplankton (no data)
- https://nsteps.epa.gov/apps/tp-tn-chl/
- https://nsteps.epa.gov/apps/chl-hypoxia/

NLA Models

- Data requirements
  - **TN**
  - **TP**
  - **Chlorophyll**
  - DOC
  - Turbidity
- Imputing missing data
  - First cut: missing values imputed from log-normal fitted distribution of NLA ND data (parametric bootstrap)
  - Estimate from other measured parameters? e.g., TSS, Secchi for turbidity

Chlorophyll ~ TN Model

- Difference between total N and DIN predicted by algal N and DON
- DOC predicts DON
- Ecoregion-specific relationship

$$E[TN - DIN] = f_1 Chl^{k1} + DON = f_1 Chl^{k1} + f_2 DOC$$

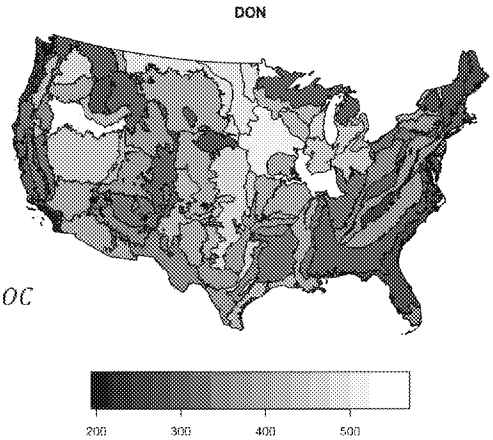
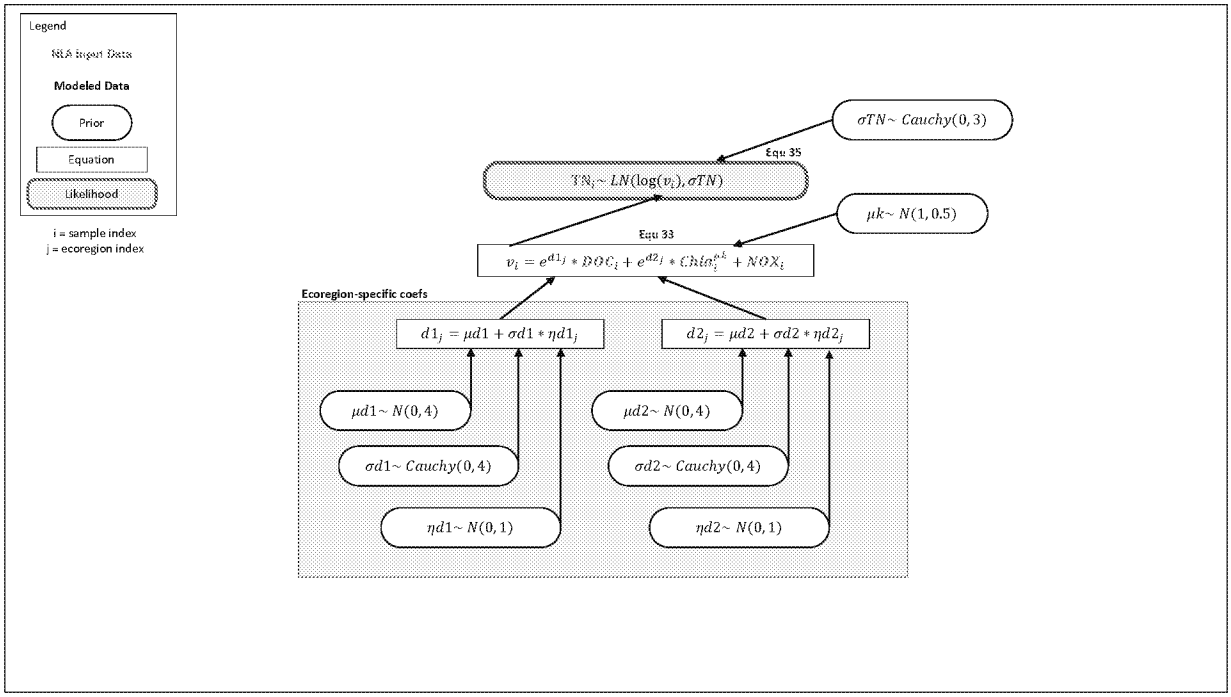
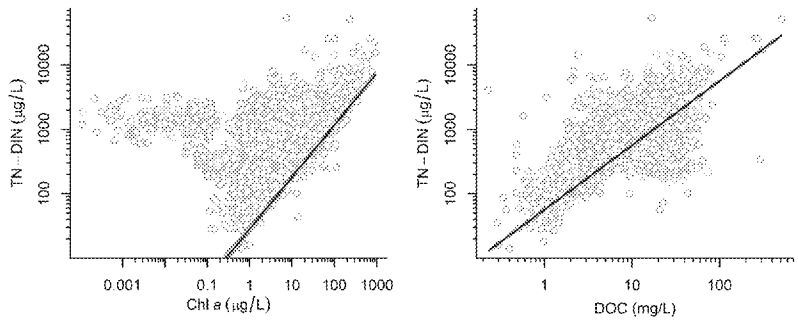


Figure 31. Variation in DON among Level III ecoregions at an overall mean DOC = 5.6 mg/L. Gray scale shows N concentrations in µg/L.


Legend
NLA Input Data
Modeled Data
Prior
Equation
Likelihood
i = sample index
j = ecoregion index
$\sigma TN \sim Cauchy(0,3)$
Equ 35
$TN_i \sim LN(\log(v_i), \sigma TN)$
$\mu k \sim N(1, 0.5)$
Equ 33
$v_i = e^{d1_j} * DOC_i + e^{d2_j} * Chla_i^{0.5} + NOX_i$
Ecoregion-specific coefs
$d1_j = \mu d1 + \sigma d1 * \eta d1_j$
$d2_j = \mu d2 + \sigma d2 * \eta d2_j$
$\mu d1 \sim N(0,4)$
$\sigma d1 \sim Cauchy(0,4)$
$\eta d1 \sim N(0,1)$
$\mu d2 \sim N(0,4)$
$\sigma d2 \sim Cauchy(0,4)$
$\eta d2 \sim N(0,1)$

Chlorophyll ~ TN Model

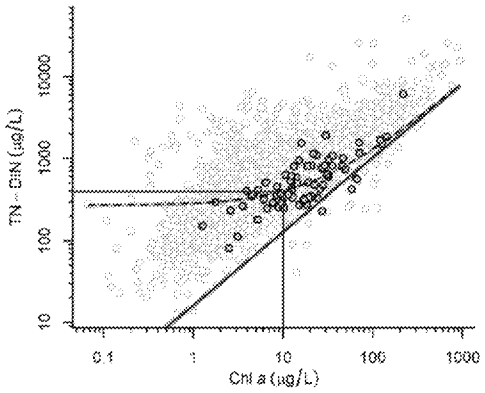
- Y axis: TN minus DIN
- Lines display limiting relationship (in theory all points should be above line)



Chlorophyll ~ TN Model

Applying the model:

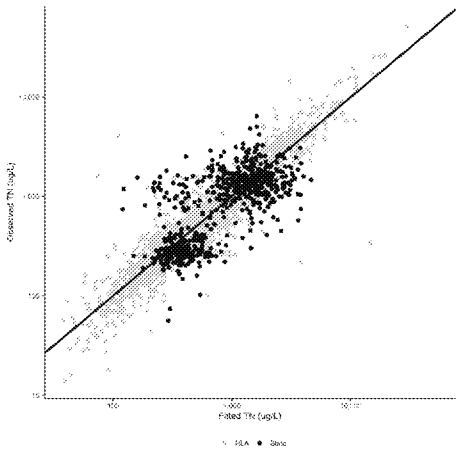
1. Select specific ecoregion
2. Apply limiting relationship (solid line)
3. Apply mean ambient relationship when ecoregion mean DOC is applied
4. Pick a chl target (vertical)
5. Trace line to find TN criterion (horizontal)



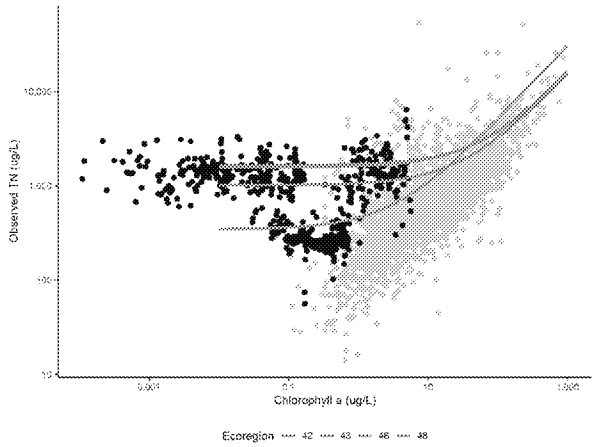
Chlorophyll ~ TN Model

Good fit for ND data

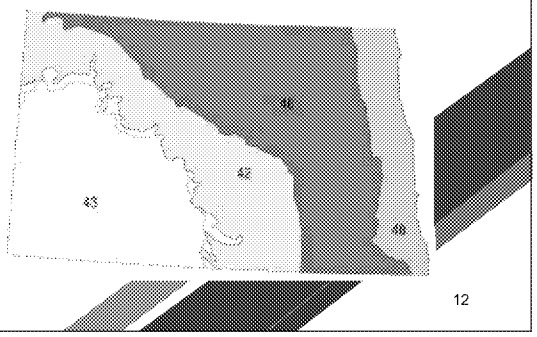
ND data occupy narrower range than national data



Chlorophyll ~ TN Model

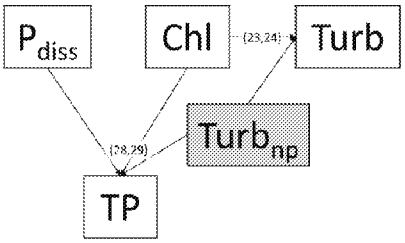


- Very low chl levels due to ROS imputation
- Highest chl concentration w/ paired TN: 6 ug/L (total range up to 292)
- Lake S currently included in ecoregion 43 output



Chlorophyll ~ TP Model

- TP is the sum of dissolved P, algal P, nonalgal P
- Turbidity can predict nonalgal P
- Max lake depth used to predict turbidity and dissolved P
- Ecoregion-specific relationship



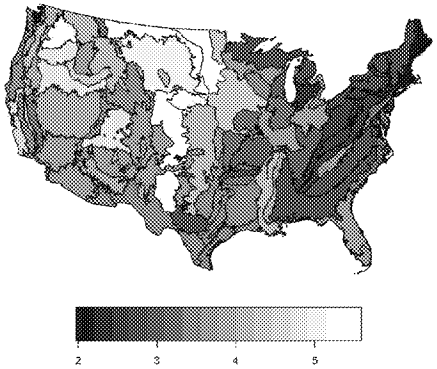
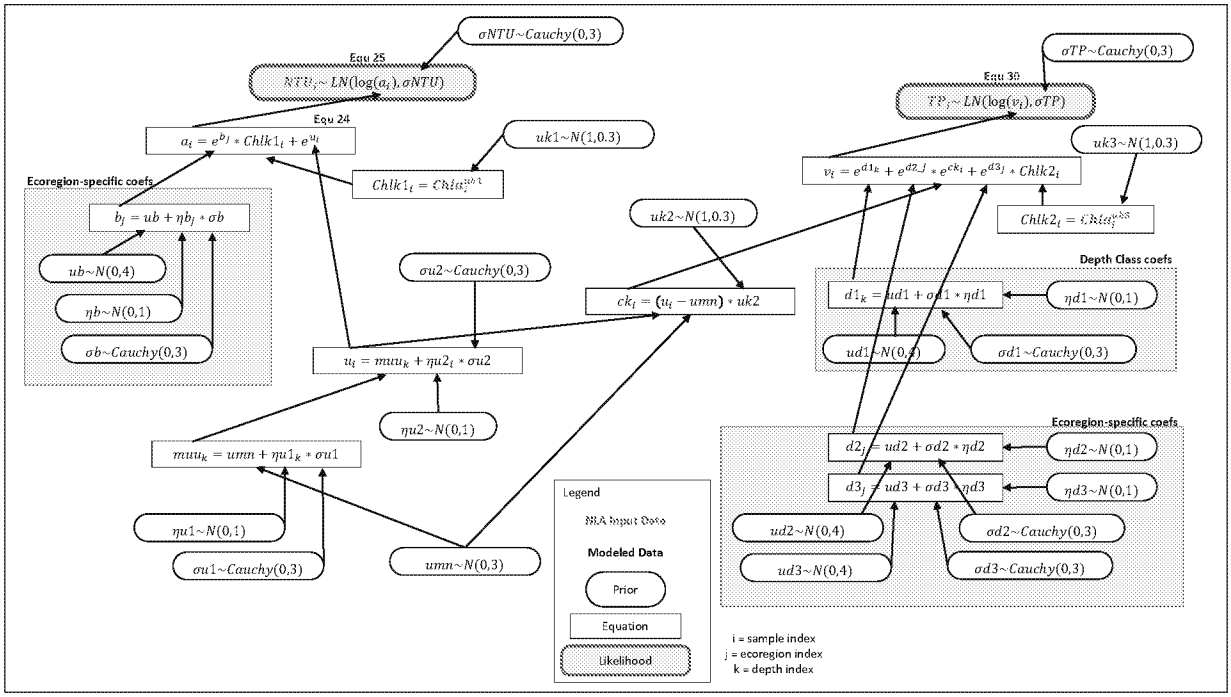
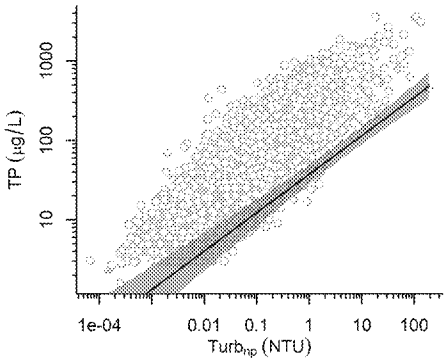


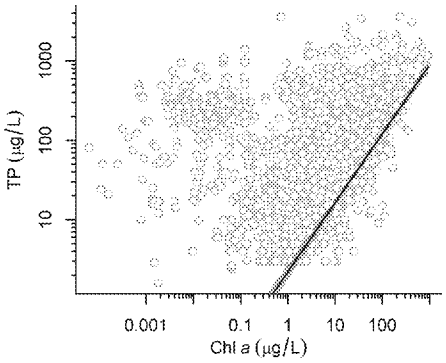
Figure 27. Ecoregion-specific values of $\log_e(\sigma_i)$, P bound to nonphytoplankton suspended sediment.


σNTU~Cauchy(0,3)
Equ 25
NTU_i ~ LN(log(a_i), σNTU)
Equ 24
a_i = e^{b_j} * Chlk1_i + e^{u_i}
uk1~N(1,0.3)
Chlk1_i = Chla_i^{w,1}
Ecoregion-specific coefs
b_j = ub + ηb_j * σb
ub~N(0,4)
ηb~N(0,1)
σb~Cauchy(0,3)
σu2~Cauchy(0,3)
uk2~N(1,0.3)
ck_i = (u_i − umn) * uk2
u_i = muu_k + ηu2_i * σu2
ηu2~N(0,1)
muu_k = umn + ηu1_k * σu1
ηu1~N(0,1)
σu1~Cauchy(0,3)
umn~N(0,3)
σTP~Cauchy(0,3)
Equ 30
TP_i ~ LN(log(v_i), σTP)
uk3~N(1,0.3)
v_i = e^{d1_k} + e^{d2_j} * e^{ck_i} + e^{d3_j} * Chlk2_i
Chlk2_i = Chla_i^{w,3}
Depth Class coefs
d1_k = ud1 + σd1 * ηd1
ηd1~N(0,1)
ud1~N(0,4)
σd1~Cauchy(0,3)
Ecoregion-specific coefs
d2_j = ud2 + σd2 * ηd2
ηd2~N(0,1)
d3_j = ud3 + σd3 * ηd3
ηd3~N(0,1)
ud2~N(0,4)
σd2~Cauchy(0,3)
ud3~N(0,4)
σd3~Cauchy(0,3)
Legend
NLA Input Data
Modeled Data
Prior
Equation
Likelihood
i = sample index
j = ecoregion index
k = depth index

Chlorophyll ~ TP Model

Lines display limiting relationship (in theory all points should be above line)

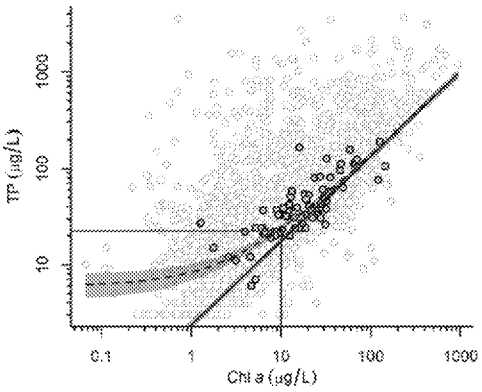




Chlorophyll ~ TP Model

Applying the model:

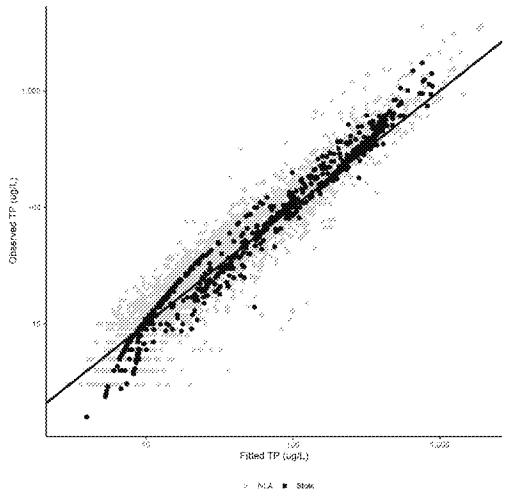
1. Select specific ecoregion
2. Apply limiting relationship (solid line)
3. Apply mean ambient relationship when nonalgal P for a given max depth is taken into account
4. Pick a chl target (vertical)
5. Trace line to find TP criterion (horizontal)



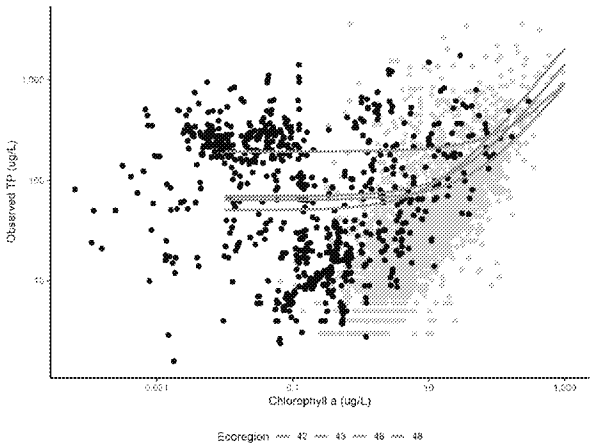
Chlorophyll ~ TP Model

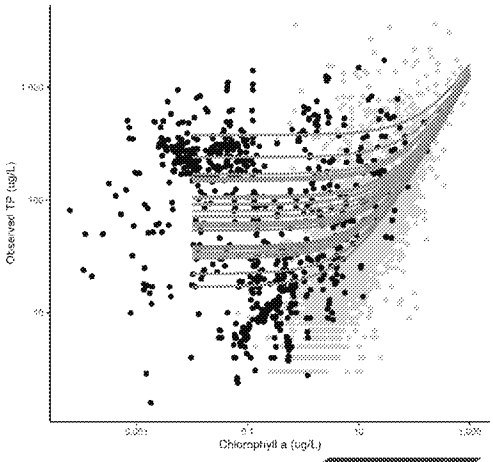
Good fit for ND data

ND data occupy similar range as national data



Chlorophyll ~ TP Model





Questions for DO models

Dissolved Oxygen (a)	5 mg/l as a daily minimum (up to 10% of representative samples collected during any 3-year period may be less than this value provided that lethal conditions are avoided)

(5) The numeric dissolved oxygen standard of five mg/l as a daily minimum does not apply to the hypolimnion of class III and IV lakes and reservoirs during periods of thermal stratification.

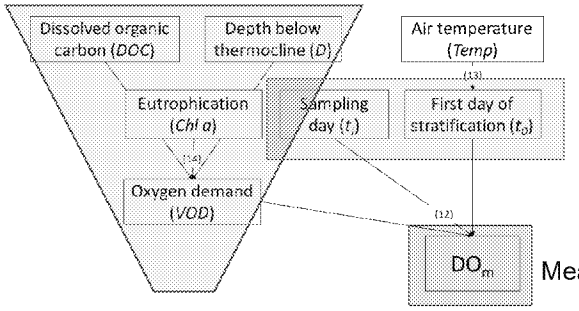
(6) The numeric dissolved oxygen standard of five mg/l as a daily minimum and the maximum temperature of eighty-five degrees Fahrenheit [29.44 degrees Celsius] shall not apply to wetlands and class 4 lakes.

Class	Characteristics
1	Cold water fishery. Waters capable of supporting growth of cold water fish species (e.g., salmonids) and associated aquatic biota.
2	Cool water fishery. Waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota.
3	Warm water fishery. Waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present.
4	Marginal fishery. Waters capable of supporting a fishery on a short-term or seasonal basis (generally a "put and take" fishery).
5	Not capable of supporting a fishery due to high salinity.

- How can we apply the DO criteria to ND lakes in the dataset?
- NLA model uses hypolimnetic DO and applies cold- and cool-water fishery assumptions
- Empirical model: unlikely to see exceedances for surface water
- Can we collect class info for the lakes in the dataset? Is this useful to inform models?

EPA hypolimnetic DO model

DRAFT AMBIENT WATER QUALITY CRITERIA RECOMMENDATIONS



Mean hypolimnetic DO

$$E[DO_{m,i}] = DO_{0,j[i]} + VOD_{j[i]}\left(t_i - t_{0,k[i]}\right)$$

$$E[VOD_j] = d_1 + d_2 \log\left(Chl_{mn,j}\right) + d_3 D_{mn,j} + d_4 \log\left(DOC_{mn,j}\right)$$

$$DO_m = DO_0 + [d_1 + d_2 \log(Chl_{mn}) + d_3 D + d_4 \log(DOC_{mn})](t - t_0)$$

Hypoxia Model Settings & Input

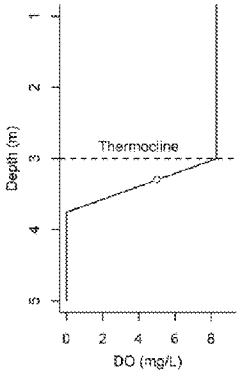
- Model created based on coarse filter for likely dimictic lakes

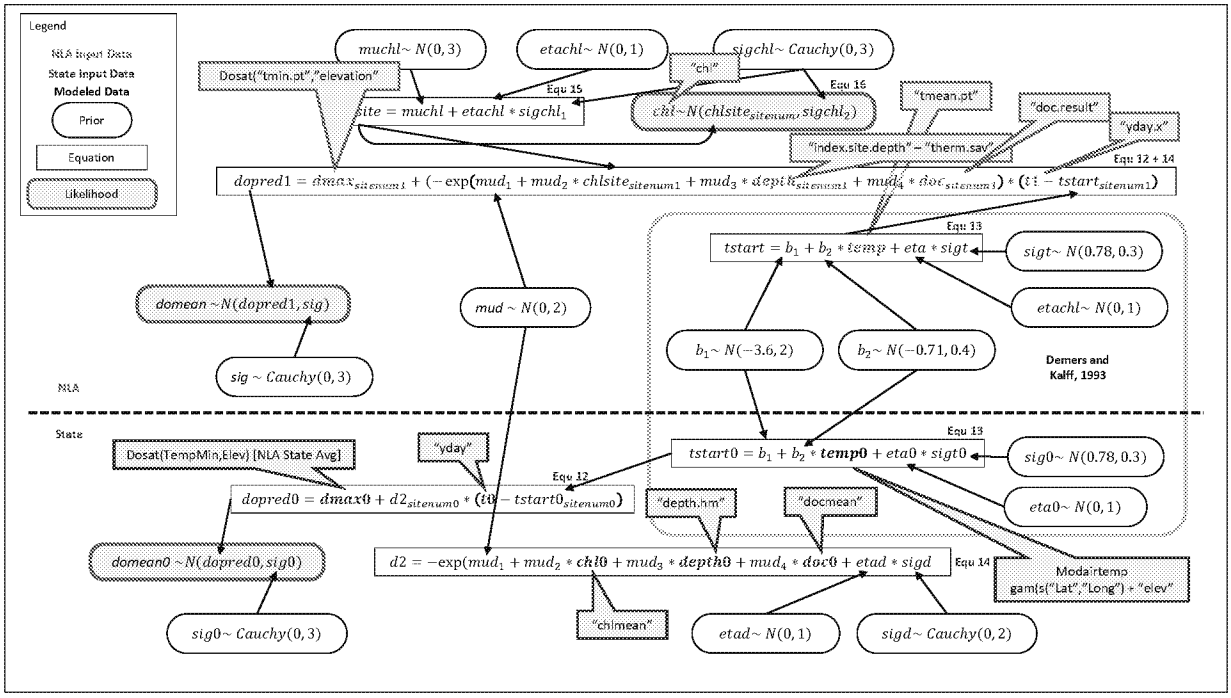
Settings

- Refuge depth: 1 m
- DO target: 4 mg/L
- Temperature threshold: 24 °C

Inputs

- DO + temp profile on a given DOY
- Chl seasonal average
- DOC long-term average




Legend
NLA Input Data
State Input Data
Modeled Data
Prior
Equation
Likelihood
muchl~ N(0,3)
etachl~ N(0,1)
sigchl~ Cauchy(0,3)
Dosat("tmin.pt","elevation")
"chi"
Equ 15
Equ 16
"tmean.pt"
"doc.result"
"yday.x"
"index.site.depth" – "therm.sav"
Equ 12 + 14
Equ 13
sigt~ N(0.78,0.3)
etachl~ N(0,1)
domean ~N(dopred1, sig)
mud ~ N(0,2)
b1~ N(−3.6,2)
b2~ N(−0.71,0.4)
Demers and Kalff, 1993
sig ~ Cauchy(0,3)
NLA
State
Dosat(TempMin,Elev) [NLA State Avg]
"yday"
Equ 13
sig0~ N(0.78,0.3)
Equ 12
"depth.hm"
"docmean"
eta0~ N(0,1)
domean0 ~N(dopred0, sig0)
Equ 14
Modairtemp
gam(s("Lat","Long") + "elev"
sig0~ Cauchy(0,3)
"chlmean"
etad~ N(0,1)
sigd~ Cauchy(0,2)

Next Steps

1. Empirical S-R analyses
2. Update NLA models based on conversation today