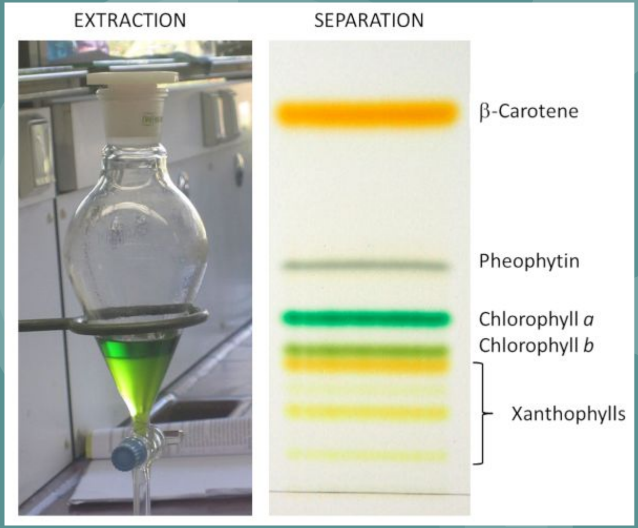
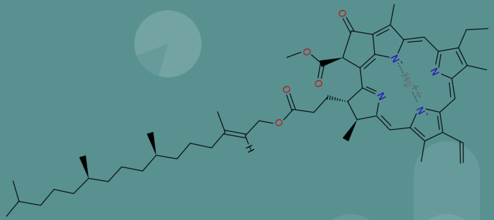
Chlorofun! Forecasting Chlorophyll-a in lakes!





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Background

Our System: Lake Barco in Florida

- Forecasting Chlorophyll a in this lake
- Originally examined Prairie Pothole in North Dakota
    - Switched to warmer climate to have relevant forecast

Lake Barco with a buoy–Wikipedia

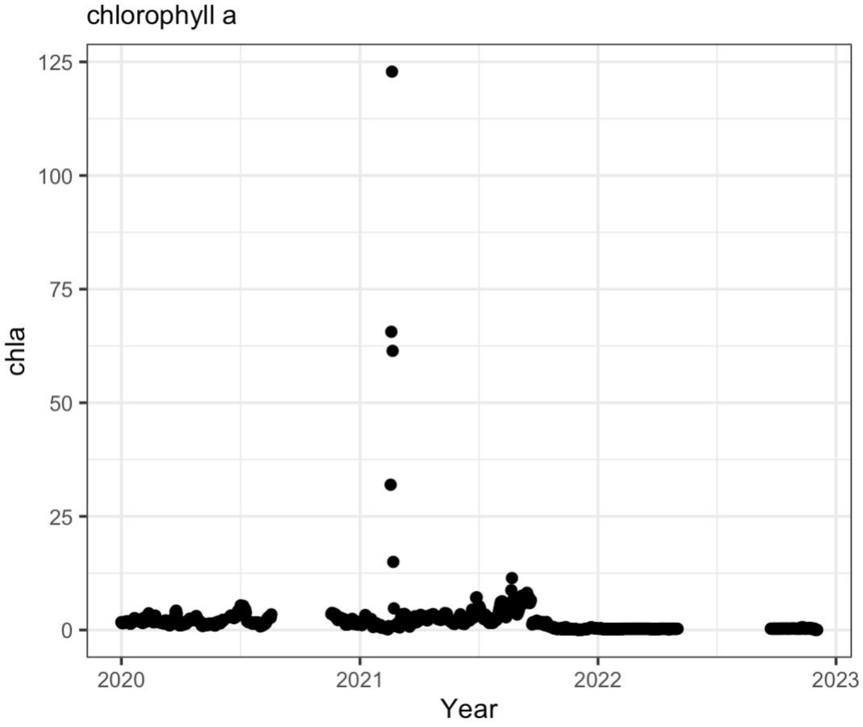
Why Chlorophyll a?

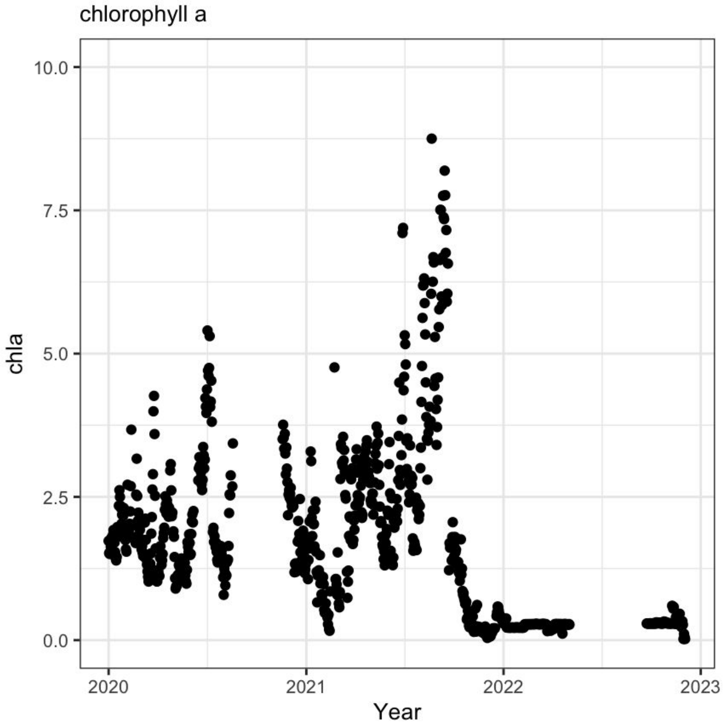
Measure of algal/phytoplankton abundance in lakes

- Key to photosynthesis
- Measure of nutrients (P, N) in lake
- Cost-effective, indirect measure of pollutants
- High levels can indicate algal bloom
    - Eutrophication
    - Fish die
    - Bad

Lake Barco (again)–NEON

Visualizing historic Chlorophyll a data





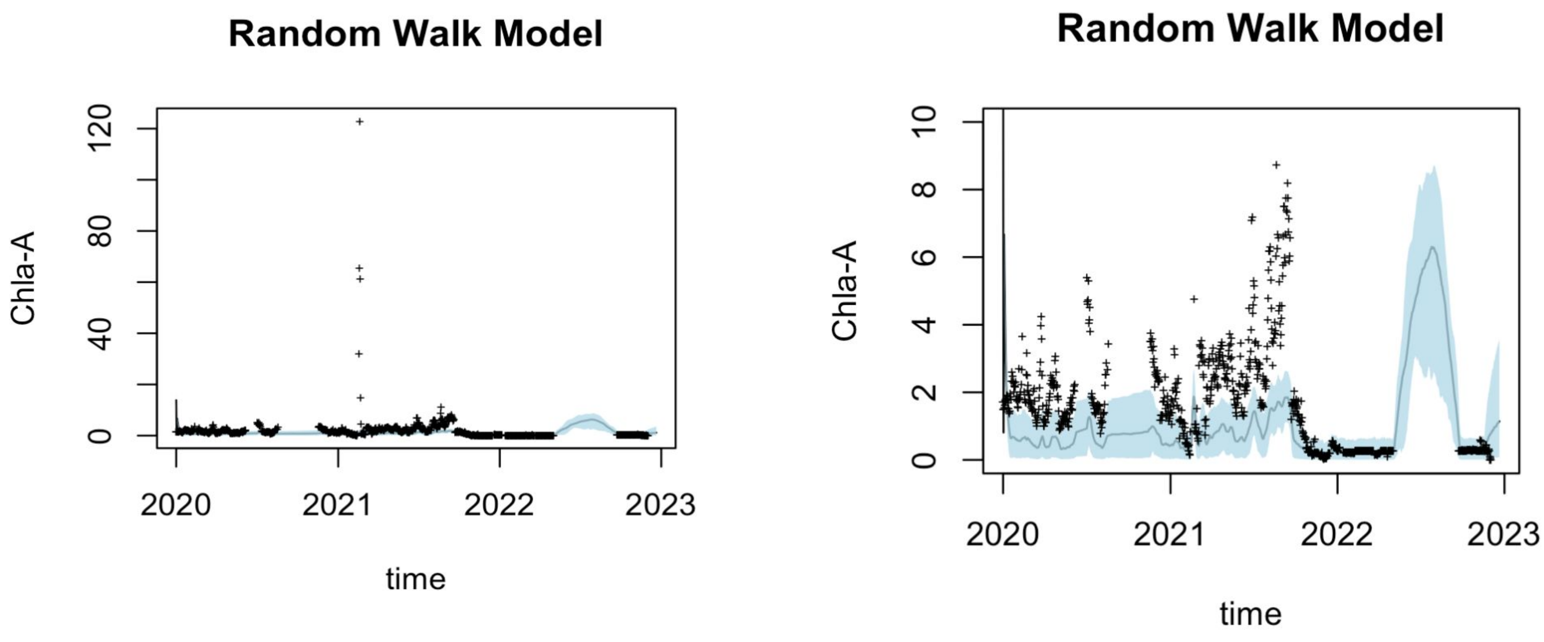
Null Model

```
#Random Walk JAGS
RandomWalk = "
model{
  #### Data Model
  for(t in 1:n){
    y[t] ~ dnorm(x[t],tau_obs)
  }
  #### Process Model
  for(t in 2:n){
    x[t]~dnorm(x[t-1],tau_add) T(0,200)
  }
  #### Priors
  x[1] ~ dnorm(x_ic,tau_ic)
  tau_obs ~ dgamma(a_obs,r_obs)
  tau_add ~ dgamma(a_add,r_add)
}
"
```

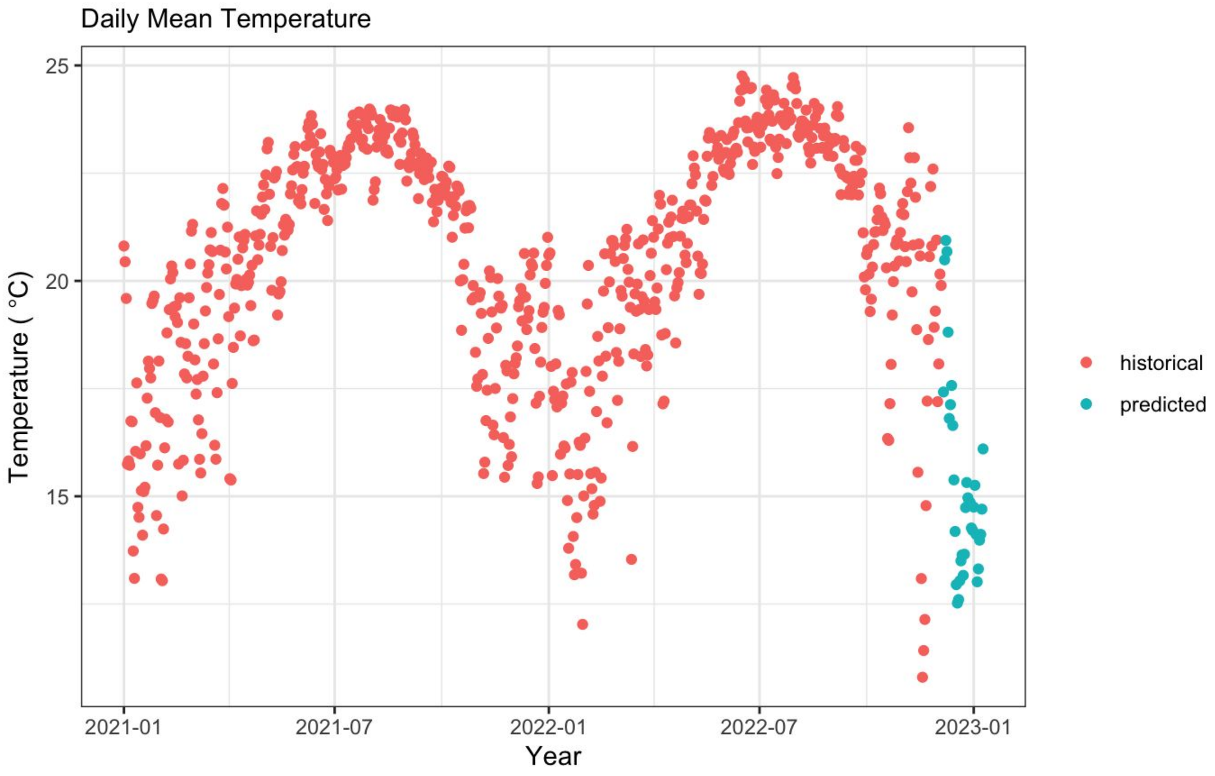
Random Walk

- Normal Prior on time
- Gamma (non-negative) Priors on variance
- Truncated normal on process model
- 1000 iterations for 3 chains

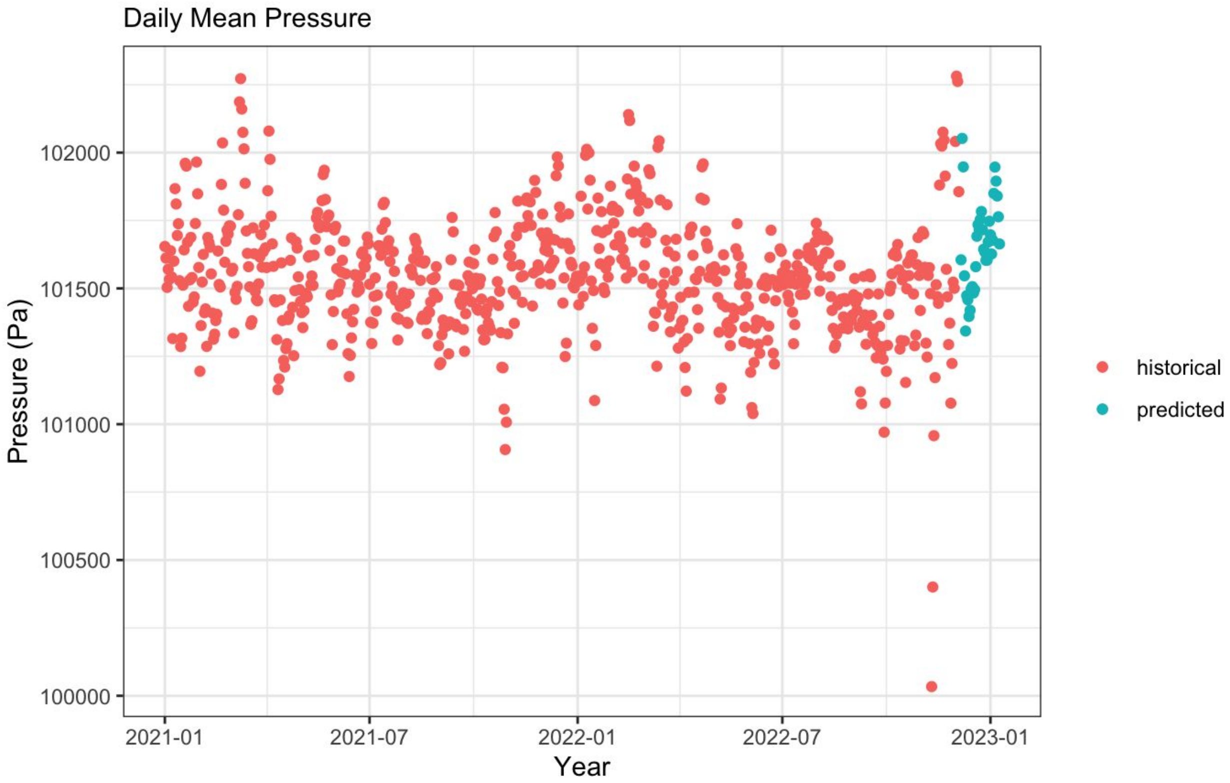
Forecast from null model



Visualizing air temperature



Visualizing air pressure



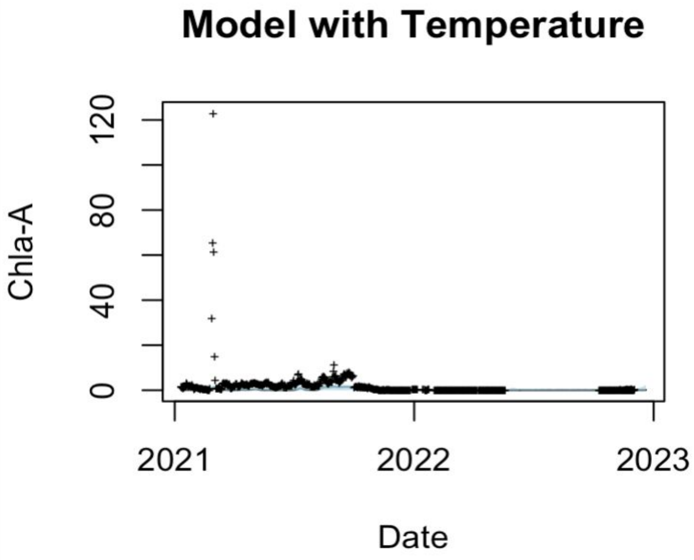
Model with Drivers

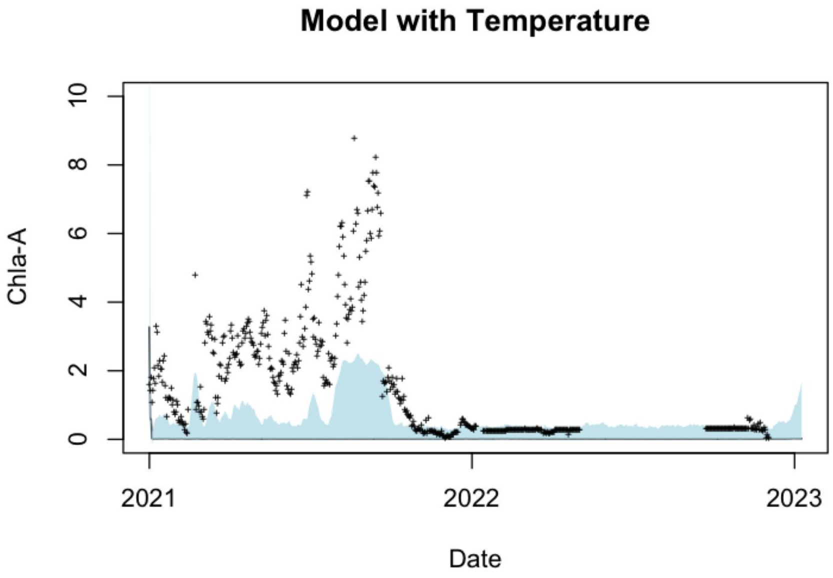
Added temperature to Random Walk Model

- Assumed linear relation between temperature, and past chla
- Normal Prior on temperature
- Truncated Normal process model eliminated negative chla values)
- Added uncertainties (Driver, Parameter, IC, Process)
- Same MCMC Conditions

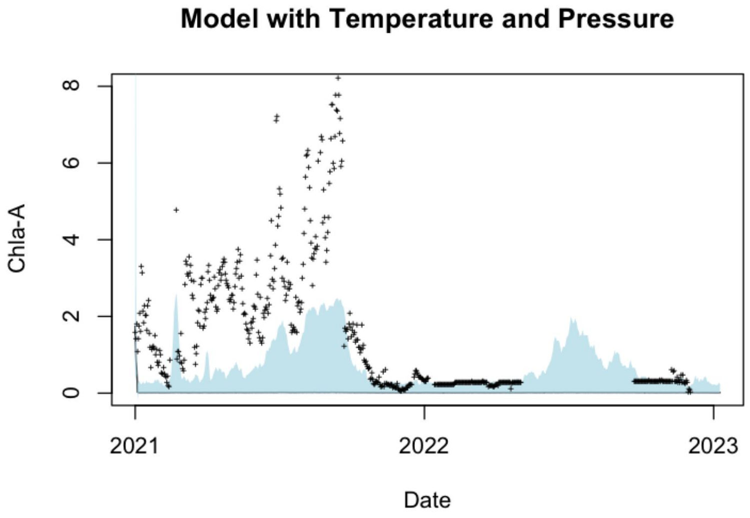
```
Temp_Covar = "
model{
  #### Data Model
  for(t in 1:n)
  {
    y[t] ~ dnorm(x[t],tau_obs) ##Observation uncertainty
  }
  #### Process Model
  for(t in 2:n)
  {
    mu[t] <- x[t-1]  + betaX*x[t-1] + betaTemp*Temp_a[t] #+ betaDriv*Driv_a[t]
    x[t]~dnorm(mu[t],tau_add) T(0,200) ##Process uncertainty
    Temp_a[t] ~ dnorm(Temp[t], tau_driv) ##Driver uncertainty
    #Driv_a[t] ~ dnorm(Driv[t],tau_driv2)
  }
  #### Priors
  x[1] ~ dnorm(x_ic,tau_ic) ##Initial condition uncertainty
  tau_obs ~ dgamma(a_obs,r_obs)
  tau_add ~ dgamma(a_add,r_add)
  tau_driv ~ dgamma(a_driv,r_driv)
  #tau_driv2 ~ dgamma(a_driv2,r_driv2)
  betaX ~ dnorm(0,0.1) ##Parameter uncertainty
  betaTemp ~ dnorm(0,0.1) ##Parameter uncertainty
  #betaDriv ~ dnorm(0,0.1) ##Parameter uncertainty
}
"
```

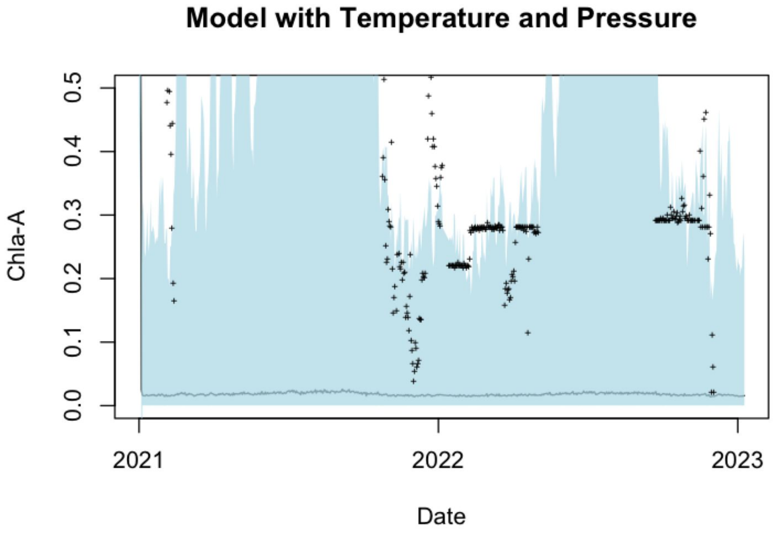
Forecast from model with air temp





Forecast from model with air temp and air pressure





Partitioning Uncertainty

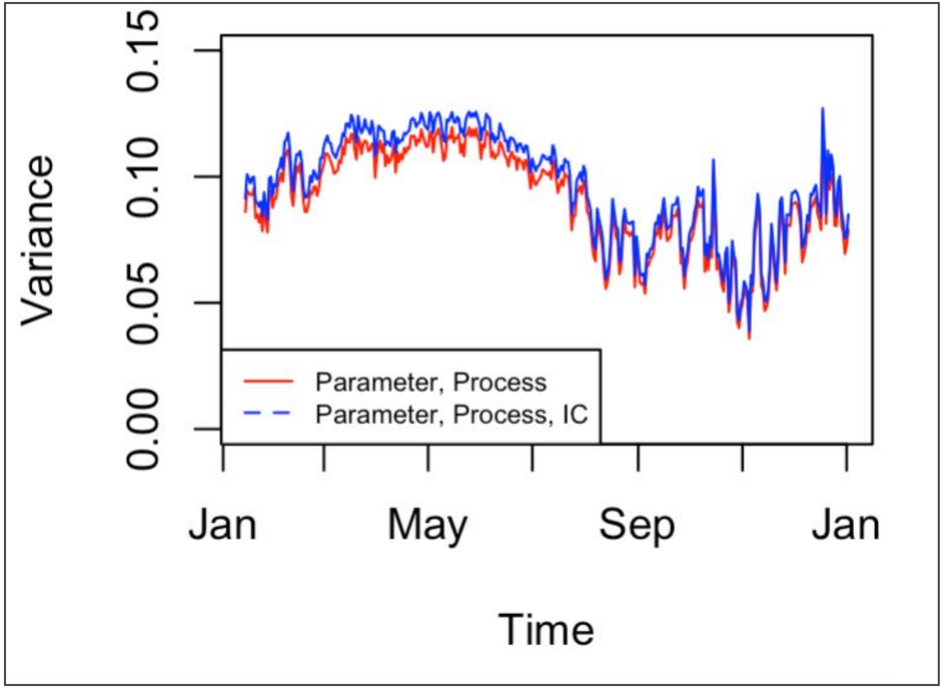
```
Rand_Par = "
model{
  #### Data Model
  for(t in 1:n)
  {
    y[t] ~ dnorm(x[t], tau_obs)
  }
  #### Process Model
  for(t in 2:n)
  {
    mu[t] <- x[t-1]  + betaX*x[t-1] + betaTemp*Temp_a[t]
    x[t]<-mu[t]
    Temp_a[t]<-Temp[t]
  }
  #### Priors
  x[1] <-x_ic
  tau_obs ~ dgamma(a_obs,r_obs)
  betaX ~ dnorm(0,0.1)
  betaTemp ~ dnorm(0,0.1)
}
"
```

```
Rand_Par_IC = "
model{
  #### Data Model
  for(t in 1:n)
  {
    y[t] ~ dnorm(x[t], tau_obs)
  }
  #### Process Model
  for(t in 2:n)
  {
    mu[t] <- x[t-1]  + betaX*x[t-1] + betaTemp*Temp_a[t]
    x[t]<-mu[t]
    Temp_a[t] = Temp[t]

  }
  #### Priors
  x[1] ~ dnorm(x_ic,tau_ic)
  tau_driv ~ dgamma(a_driv,r_driv)
  tau_obs ~ dgamma(a_obs,r_obs)
  betaX ~ dnorm(0,0.1)
  betaTemp ~ dnorm(0,0.1)
}
"
```

```
Rand_Par_IC_Process = "
model{
  #### Data Model
  for(t in 1:n)
  {
    y[t] ~ dnorm(x[t],tau_obs) ##Observation uncertainty
  }
  #### Process Model
  for(t in 2:n)
  {
    mu[t] <- x[t-1]  + betaX*x[t-1] + betaTemp*Temp_a[t]
    x[t]~dnorm(mu[t],tau_add) T(0,200) ##Process uncertainty
    Temp_a[t] <- Temp[t]
  }
  #### Priors
  x[1] ~ dnorm(x_ic,tau_ic) ##Initial condition uncertainty
  tau_obs ~ dgamma(a_obs,r_obs)
  tau_add ~ dgamma(a_add,r_add)
  betaX ~ dnorm(0,0.1) ##Parameter uncertainty
  betaTemp ~ dnorm(0,0.1) ##Parameter uncertainty
}
"
```

Partitioning Uncertainty



Future Steps & Ongoing Challenges

- Finish partitioning uncertainty
  - Determine why partitioning uncertainty is giving unexpected results
  - Visualize how proportions of uncertainty change over time

- Adding additional drivers
  - Dissolved oxygen
  - Water temperature

- Data Assimilation
  - ??

- Submit iterative Forecasts
  - Neon4cast::generate_metadata function?

Sources

[1] https://www.ysi.com/ysi-blog/water-blogged-blog/2014/06/the-basics-of-chlorophyll-measurement-in-surface-water