West Gooses Profiler Data Simulation Overview

Presentation to BORG

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Goals:

Test if the interpolation will mimic within day cycles and hour-to-hour correlation.

Test concepts for simultaneously predicting temporal and spatial correlation.

Test if a cloud of multiple interpolations covers the observed data.

Steps:

Daily Mean Interpolation and correlation:

1. Estimate smooth(doy,depth) for mid-day predictions.
2. Estimate day to day correlation for each depth
3. Simulate daily ar1 errors to add to daily predictions (ignoring depth covariance)

Small Scale Variability (within day by depth):

4. Estimate cyclic terms for diel and tide for each day and depth
5. Estimate hour-to-hour correlation for each day.
6. Estimate depth correlation for each day.
7. Simulate cyclic terms for each day and depth
8. Simulate hour by depth matrix of space-time correlated errors.

Combining Results:

9. Sum the following terms:
   s(doy,depth) +
   ar1.day(doy,depth) +
   cycles(diel,tidal /day, depth) +
   ST.err(depthXhour / day)

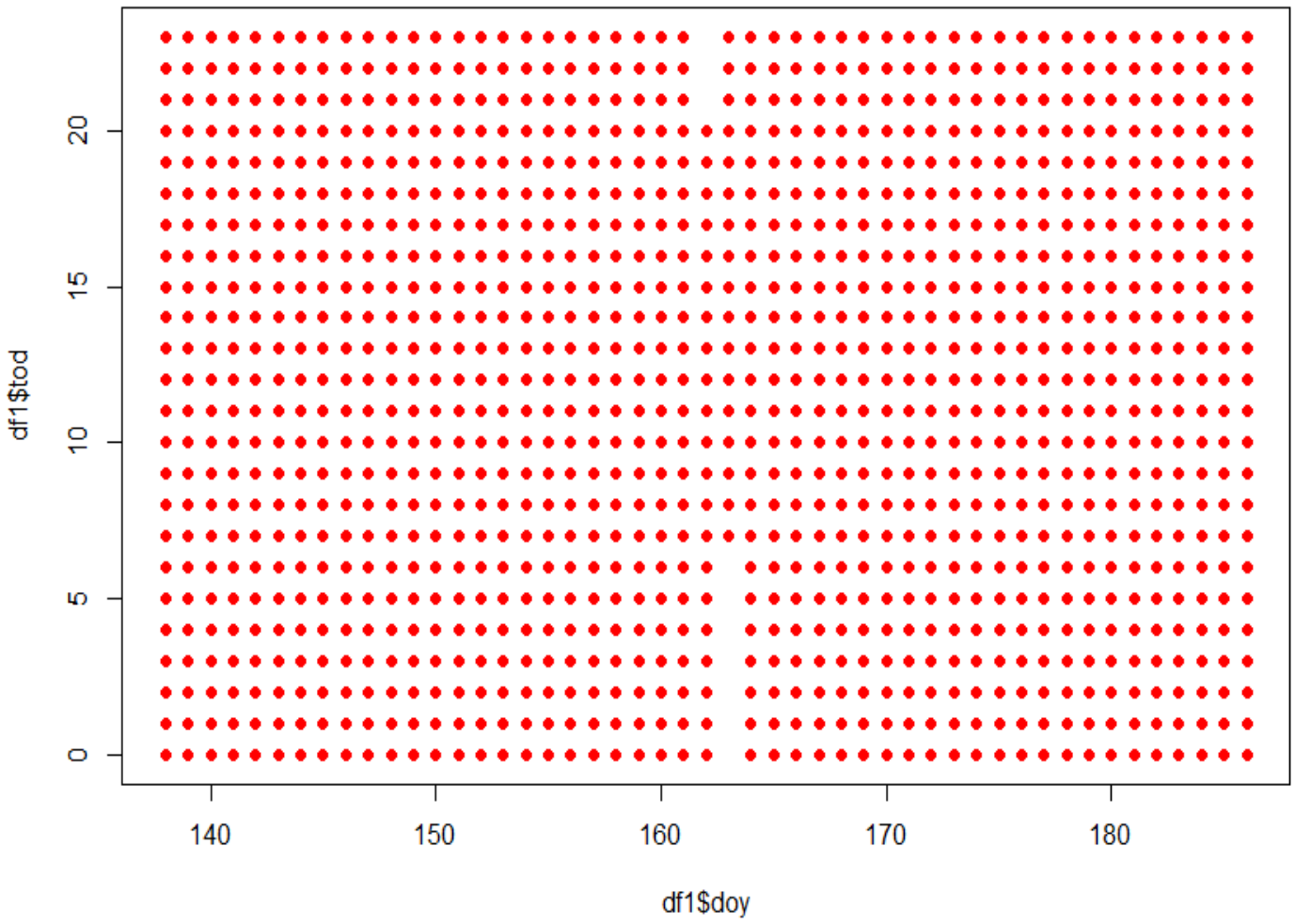
Overview of data:

East Gooses Reef Profiler Site:

Date range: 05/16 to 09/24 in 2022

Depths: 1 to 19 by 2-meter increments.

Observations reduced to 1 per hour.



1.Estimate s(doy,depth) for daily interpolation.

Transform DO by beta.logit transformation for normality, bl_do.

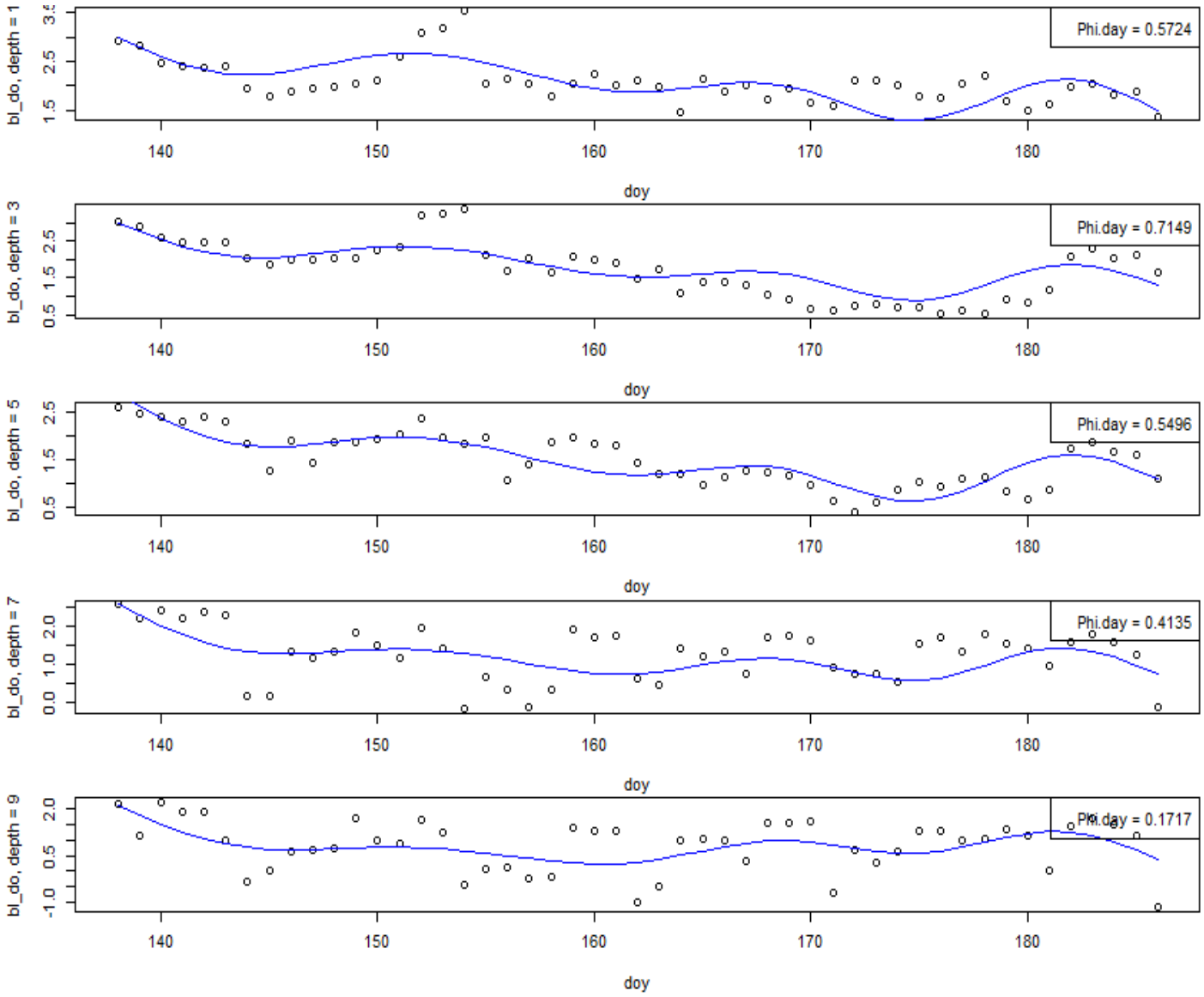
Select daily value close to 11:00 am.

Fit smooth bl_do(11) =s (depth) + s(doy) + ti(depth,doy)

Test run of space-time simulation for Gooses Reef East
Thu Aug 1 11:44:19 2024
gam results fitted to daily data

```
Formula:
bl_do ~ s(depth) + s(doy) + ti(depth, doy)


Approximate significance of smooth terms:
                  edf Ref.df       F p-value
s(depth)        2.570  3.195 465.101  <2e-16 ***
s(doy)          8.674  8.969  26.914  <2e-16 ***
ti(depth,doy) 11.548 14.004   5.848  <2e-16 ***
---

R-sq.(adj) =  0.787
```

2._Estimate day-to-day correlation for each depth



S(bl.do) vs observed by depths 1,3,5,7,9

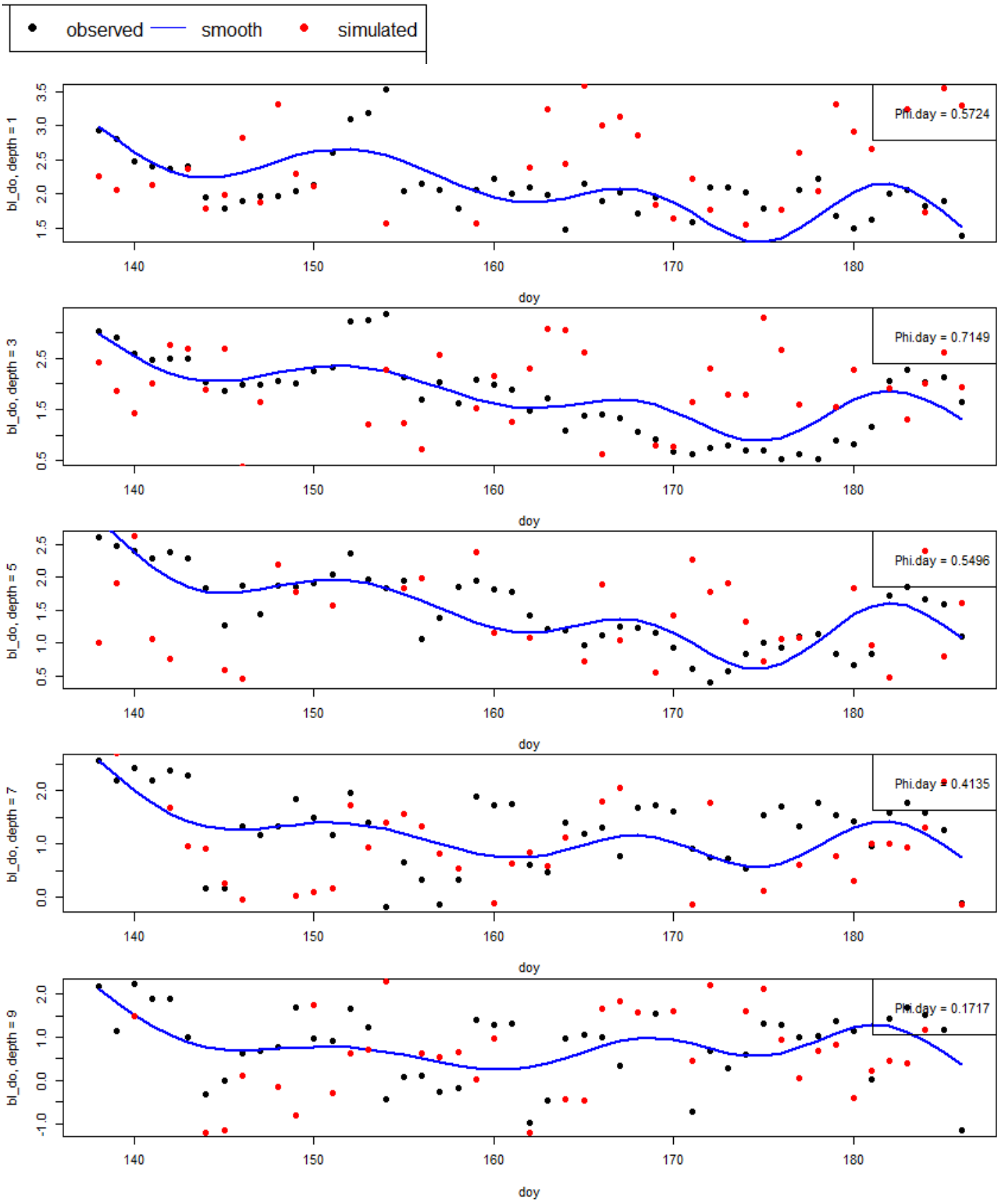
Simulating Daily Values:

Illustrate interpolation grid, day by depth.

		Days of Year				
depth		138	139	140	. . .	186
	1*					
	2					
	3*					
	4					
	. . .					
	19*					

*= observed

Daily Mean Interpolation with simulated error.



Small Scale cycles and correlation (within day by depth):

4._Estimate harmonic terms using hourly data for each day and depth

Subset to one day and one depth

Fit a curve with:

linear trend,

cycles at Diel Frequency,

cycles at Tidal Frequency,

```
bl_do ~ tod + sin_diel + cos_diel + sin_tide + cos_tide
```

5._Estimate hour-to-hour correlation for each day.

Combine across depths using Fisher's method.

6._ Estimate depth correlation for each day.

Combine across hours using Fisher's method.

Because data were collected at 2 meter intervals, the estimated depth correlation = $(\rho . depth)^2$ under exponential spatial dependence.

8.

Simulating Hourly Values:

Illustrate interpolation grid, hour by depth.

		Hours of Day				
		0	**1**	**2**	**. . .**	**24**
depth	**1***					
	2					
	3*					
	4					
	. . .					
	19*					

***= observed**

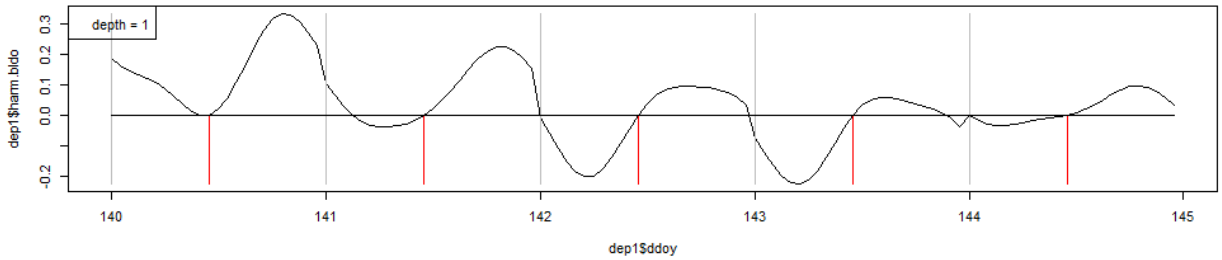
8._Simulate Small Scale (hour by depth) matrix of variation.

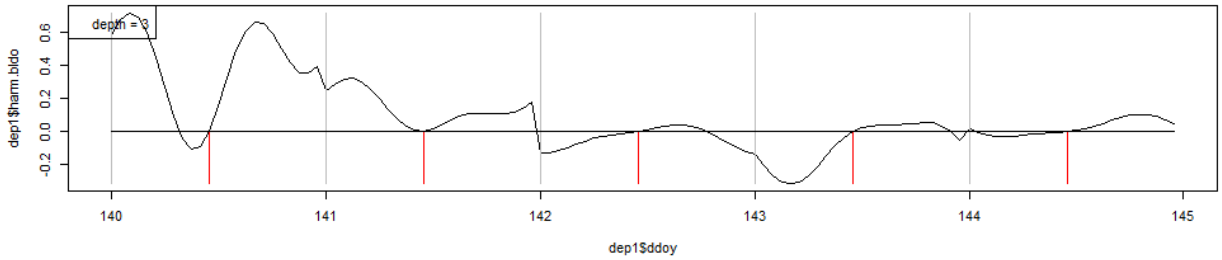
cyclic signal for each day and depth

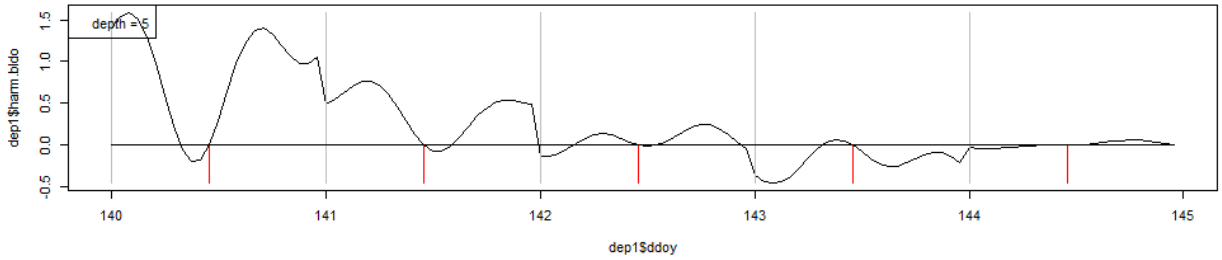
```
bl_do.hr ~ tod(hr) + Diel(hr)+ Tide(hr)

tod(hr) = {daily.mean(day+1)- daily.mean(day)}/24

# center signal on 11:00 am
harm.bldo <- harm.bldo - harm.bldo[12]
```

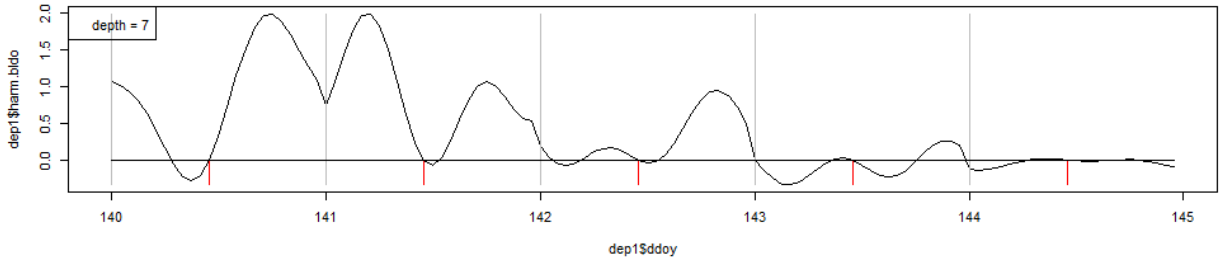
Simulate hour by depth matrix of space-time correlated errors using an AR(1) process over hours and an Exponential variogram of space.

(Explanation is lengthy, but details are available).


depth = 1
dep1$harm.bldo
-0.2
0.0
0.1
0.2
0.3
140
141
142
143
144
145
dep1$ddoy


depth = 3
dep1$harm.bldo
-0.2
0.0
0.2
0.4
0.6
140
141
142
143
144
145
dep1$ddoy


depth = 5
dep1$harm.bldo
-0.5
0.0
0.5
1.0
1.5
140
141
142
143
144
145
dep1$ddoy


depth = 7
dep1$harm.bldo
0.0
0.5
1.0
1.5
2.0
140
141
142
143
144
145
dep1$ddoy

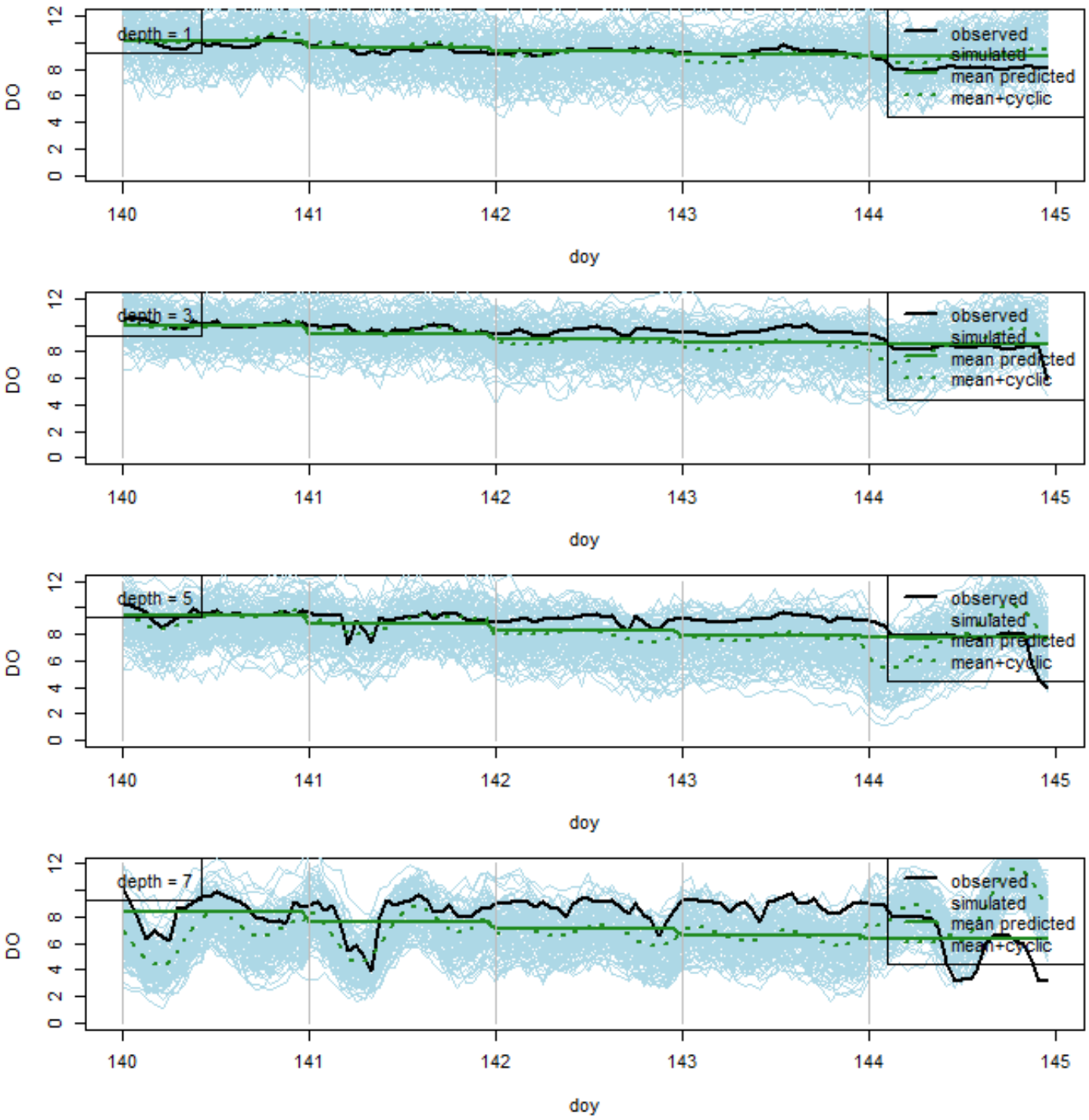
Combining Components:

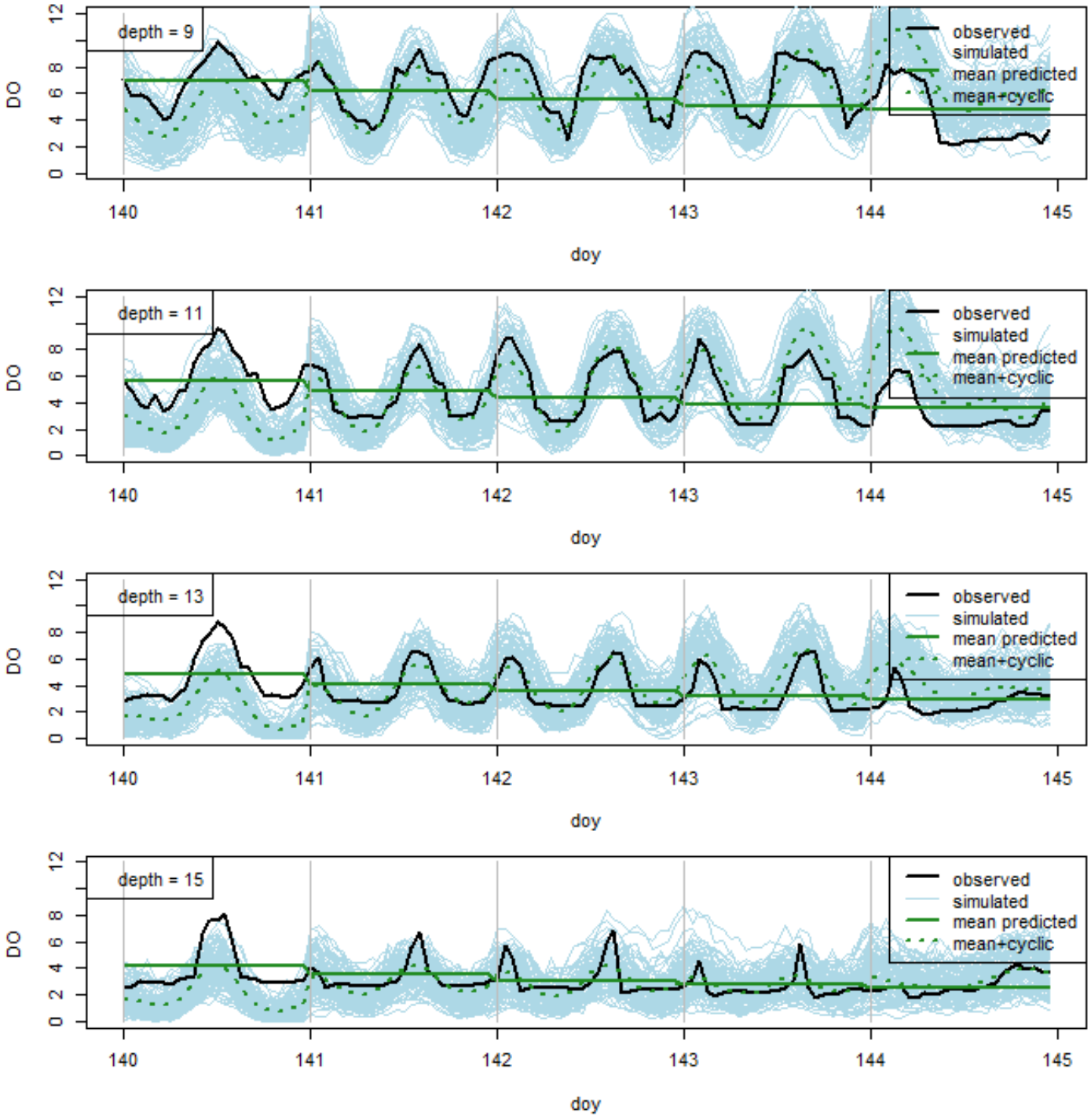
Beta.logit(Mid-day DO) = s(depth) + s(doy) + ti(depth, doy) + error(phi.day)

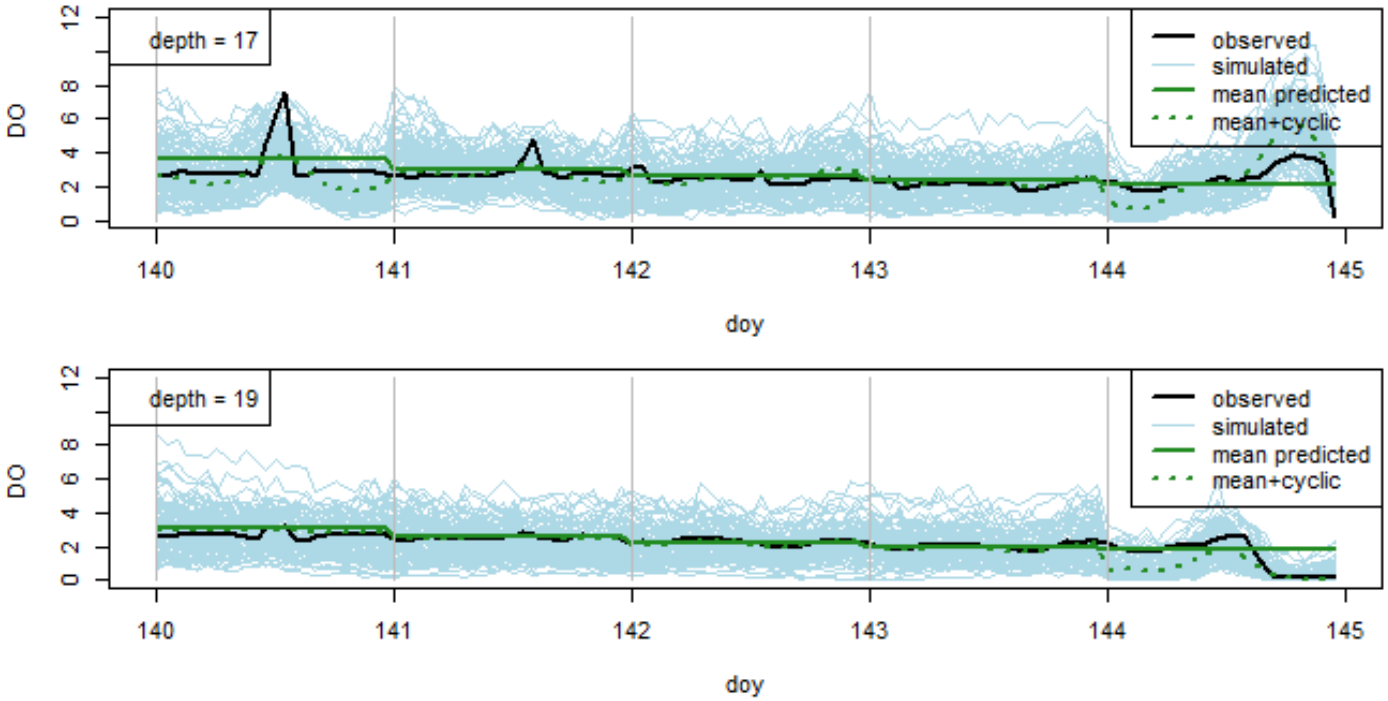
Beta.logit(hourly cyclic DO) = tod(hr) + Diel(hr)+ Tide(hr)+ error(phi.hr,rho.depth)

Simulated DO = Inverse.beta.logit(Mid-day DO + Hourly cyclic DO)

Time Series Plots of DO by depth (100 simulations)

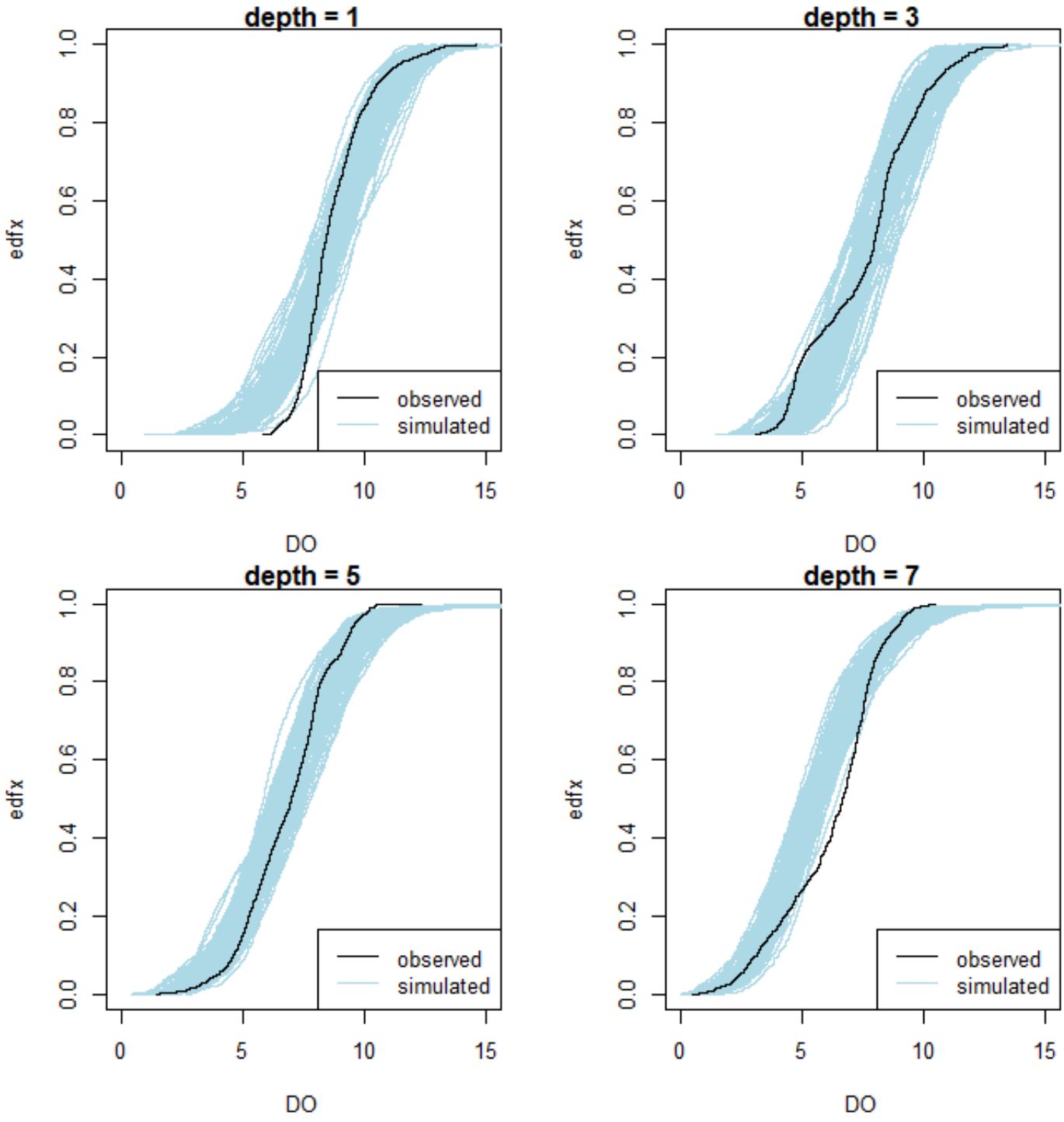


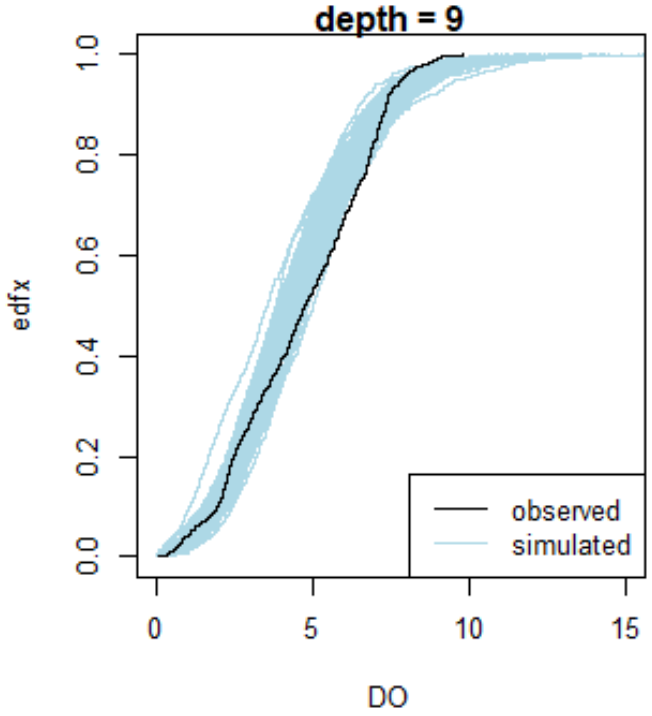

depth = 9
depth = 11
depth = 13
depth = 15
observed
simulated
mean predicted
mean+cyclic
DO
doy
0
2
4
6
8
10
12
140
141
142
143
144
145

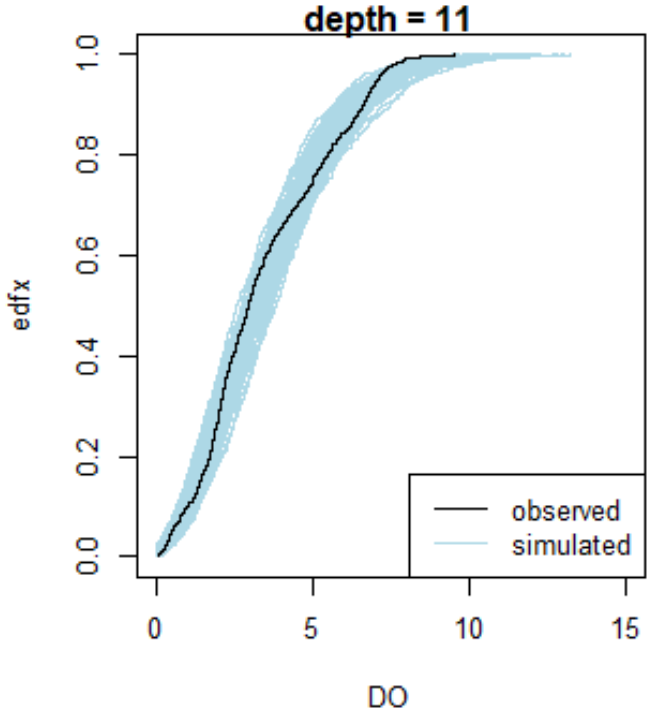

depth = 17
observed
simulated
mean predicted
mean+cyclic
DO
0
2
4
6
8
12
140
141
142
143
144
145
doy

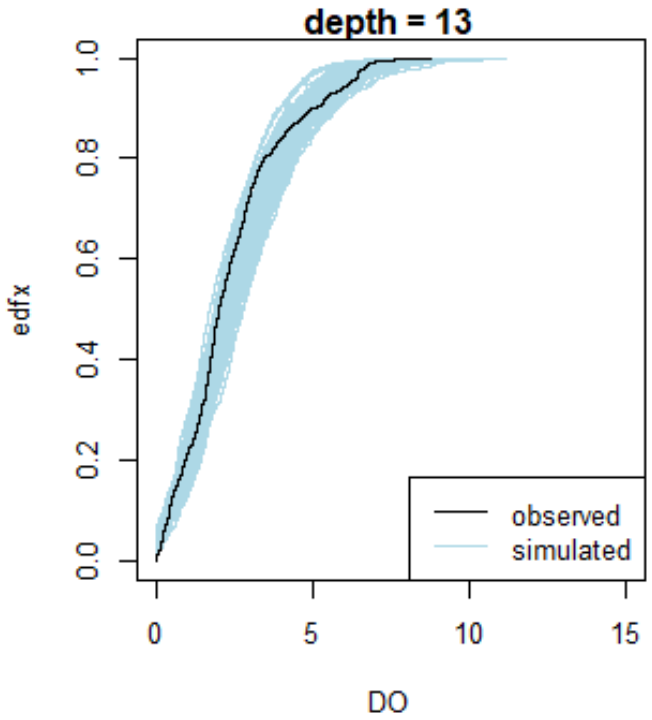
depth = 19
observed
simulated
mean predicted
mean+cyclic
DO
0
2
4
6
8
12
140
141
142
143
144
145
doy

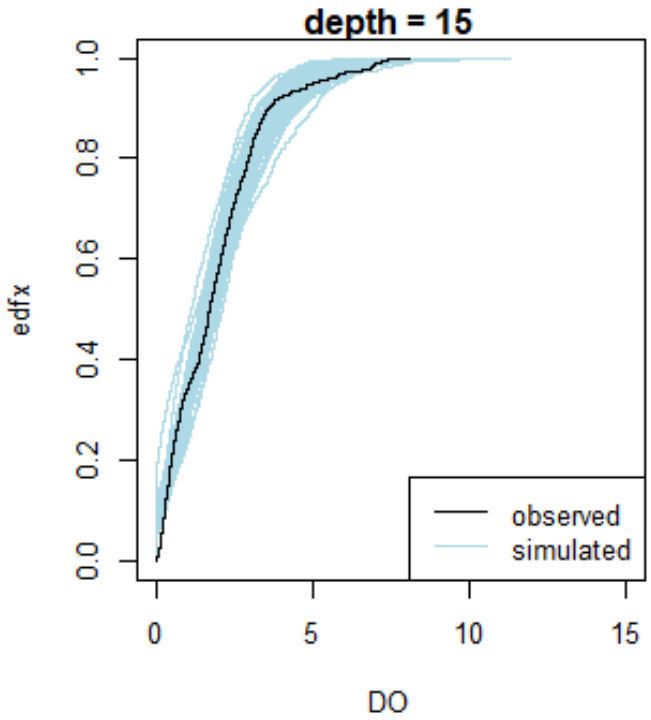
CDF plots of backtransformed DO for East Gooses reef.

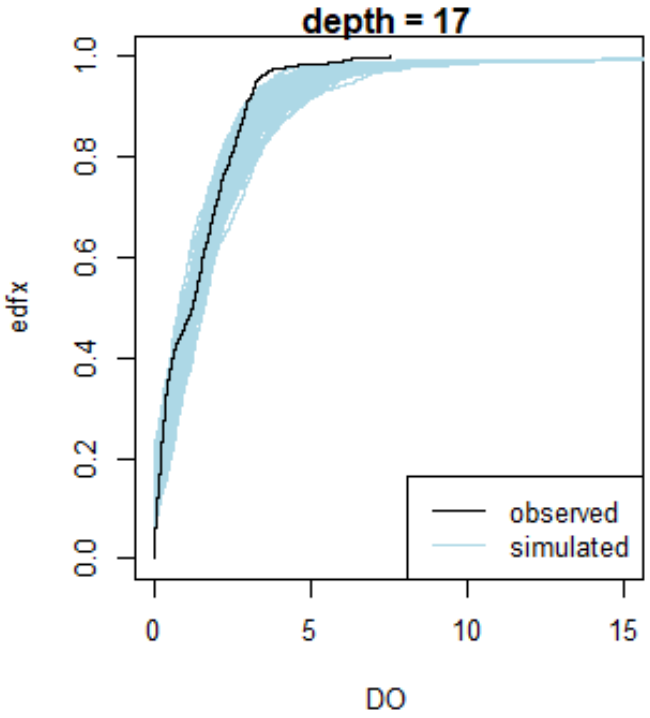


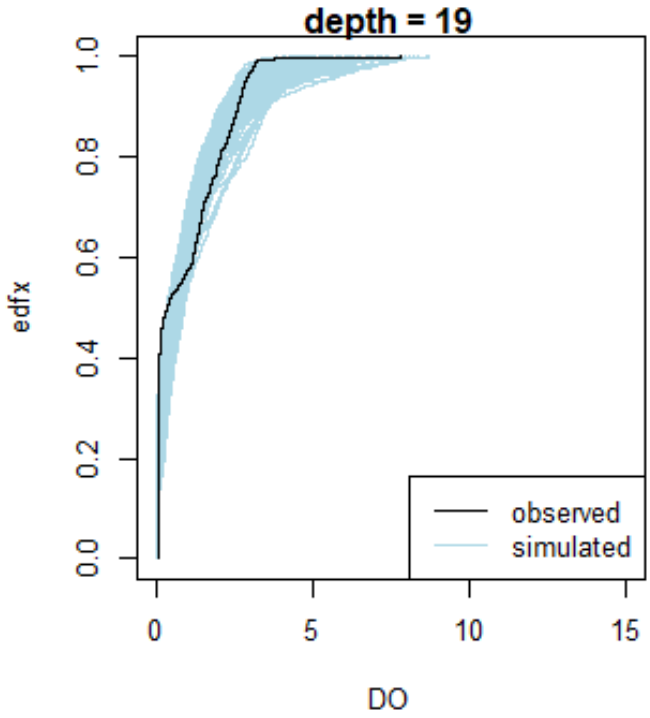

depth = 9
edfx
DO
observed
simulated
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15


depth = 11
edfx
DO
observed
simulated
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15


depth = 13
edfx
DO
observed
simulated
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15


depth = 15
edfx
DO
observed
simulated
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15


depth = 17
edfx
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
DO
observed
simulated


depth = 19
edfx
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
DO
observed
simulated