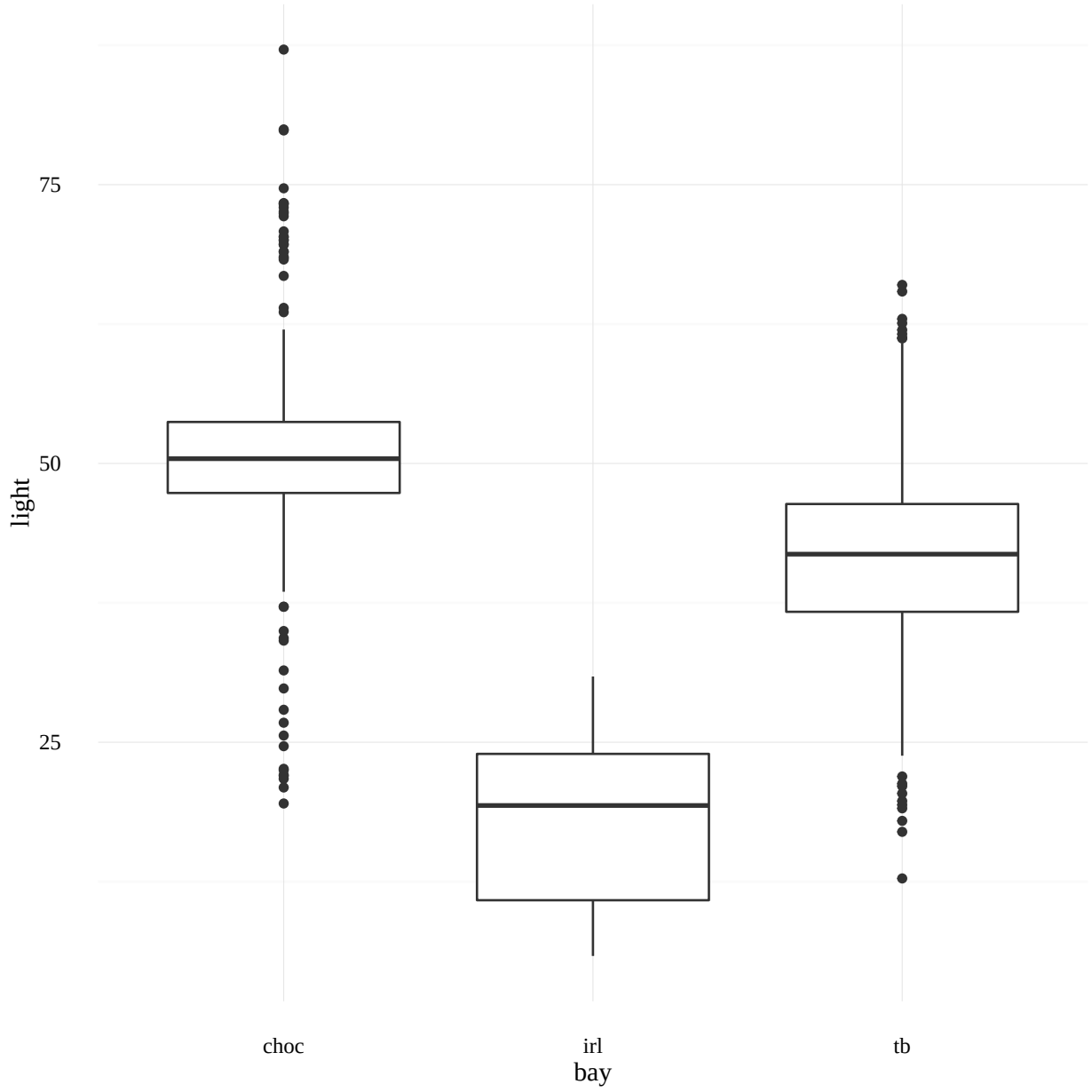
```r
library(nlme)
library(stargazer)

data(ests_out)
tmp <- filter(ests_out, seg == '303') %>%
  select(z_cmax, long, lat)

modnl <- gls(z_cmax ~ 1, data = tmp)
mod1 <- gls(z_cmax ~ 1, correlation = corSpher(form = ~ long + lat, nugget = TRUE),
  data = tmp)
mod2 <- gls(z_cmax ~ 1, correlation = corLin(form = ~ long + lat, nugget = TRUE),
  data = tmp)
mod3 <- gls(z_cmax ~ 1, correlation = corRatio(form = ~ long + lat, nugget = TRUE),
  data = tmp)
mod4 <- gls(z_cmax ~ 1, correlation = corGaus(form = ~ long + lat, nugget = TRUE),
  data = tmp)
mod5 <- gls(z_cmax ~ 1, correlation = corExp(form = ~ long + lat, nugget = TRUE),
  data = tmp)

# AIC(modnl, mod1, mod2, mod3, mod4, mod5)

stargazer(modnl, mod1, mod2, mod3, mod4, mod5,
  title = 'Comparison of regression models with different correlation structures for gri
  column.labels = c('null', 'Spher', 'Lin', 'Ratio', 'Gaus', 'Exp'),
  model.numbers = F
  )
```

Table 1: Comparison of regression models with different correlation structures for grid locations.

	Dependent variable:					
	z_cmax					
	null	Spher	Lin	Ratio	Gaus	Exp
Constant	2.382***	2.355***	2.271***	2.356***	2.364***	2.349***
	(0.070)	(0.136)	(0.506)	(0.219)	(0.144)	(0.177)
Observations	31	31	31	31	31	31
Log Likelihood	−16.082	−7.722	−9.699	−8.044	−7.326	−8.639
Akaike Inf. Crit.	36.165	23.445	27.399	24.088	22.652	25.279
Bayesian Inf. Crit.	38.967	29.050	33.003	29.693	28.256	30.883
Note:						*p<0.1; **p<0.05; ***p<0.01

```r
data(choc_light)
data(irl_light)
data(tb_light)

choc_light <- select(choc_light, z_c_all, light, seg, Longitude, Latitude) %>%
  mutate(bay = 'choc')
irl_light <- select(irl_light, z_c_all, light, seg, Longitude, Latitude) %>%
  mutate(bay = 'irl')
tb_light <- select(tb_light, z_c_all, light, seg, Longitude, Latitude) %>%
  mutate(bay = 'tb')

all_light <- rbind(choc_light, irl_light, tb_light) %>%
  mutate(bay = factor(bay))

znl <- lme(z_c_all ~ 0 + bay, random = ~ 1 | bay, data = all_light)
zm1 <- lme(z_c_all ~ 0 + bay, random = ~ 1 | bay,
  correlation = corGaus(form = ~ Latitude + Longitude | bay, nugget = FALSE),
  data = all_light)
zm2 <- lme(z_c_all ~ 0 + bay, random = ~ 1 | bay,
  correlation = corGaus(form = ~ Latitude + Longitude | bay, nugget = TRUE),
  data = all_light)


lnl <- lme(light ~ 0 + bay, random = ~ 1 | bay, data = all_light)
lm1 <- lme(light ~ 0 + bay, random = ~ 1 | bay,
  correlation = corGaus(form = ~ Latitude + Longitude | bay, nugget = FALSE),
  data = all_light)
lm2 <- lme(light ~ 0 + bay, random = ~ 1 | bay,
  correlation = corGaus(form = ~ Latitude + Longitude | bay, nugget = TRUE),
  data = all_light)
```

```r
# boxplots
ggplot(all_light, aes(x = bay, y = light)) +
  geom_boxplot() +
  theme_minimal()
```




```
summary(zm1)
```

```
## Linear mixed-effects model fit by REML
##  Data: all_light
##         AIC       BIC   logLik
##   -87.99629 -59.64608 49.99814
##
## Random effects:
##  Formula: ~1 | bay
##         (Intercept)  Residual
```

```
## StdDev:  0.04474165 0.2800867
##
## Correlation Structure: Gaussian spatial correlation
##  Formula: ~Latitude + Longitude | bay
##  Parameter estimate(s):
##       range
## 0.007992795
## Fixed effects: z_c_all ~ 0 + bay
##            Value  Std.Error DF  t-value p-value
## baychoc 2.124354 0.05637388  0 37.68330     NaN
## bayirl  1.073833 0.06374245  0 16.84643     NaN
## baytb   1.199982 0.04764828  0 25.18416     NaN
##  Correlation:
##        baychc bayirl
## bayirl 0
## baytb  0      0
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -5.6196257 -0.5367480  0.2614813  0.9666520  7.3331159
##
## Number of Observations: 836
## Number of Groups: 3
```

```
summary(lm1)
```

```
## Linear mixed-effects model fit by REML
##  Data: all_light
##        AIC      BIC    logLik
##   5680.798 5709.149 -2834.399
##
## Random effects:
##  Formula: ~1 | bay
##         (Intercept) Residual
## StdDev:    1.335232  8.35838
##
## Correlation Structure: Gaussian spatial correlation
##  Formula: ~Latitude + Longitude | bay
##  Parameter estimate(s):
##       range
## 0.007154898
## Fixed effects: light ~ 0 + bay
##            Value Std.Error DF  t-value p-value
```

```
## baychoc 51.19770  1.640932  0 31.20037     NaN
## bayirl  17.83239  1.889493  0  9.43766     NaN
## baytb   41.65458  1.408418  0 29.57544     NaN
##  Correlation:
##        baychc bayirl
## bayirl 0
## baytb  0      0
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -3.791201263 -0.554951340 -0.005255754  0.506392145  4.296715152
##
## Number of Observations: 836
## Number of Groups: 3
```

```
stargazer(znl, zm1, zm2, lnl, lm1, lm2,
  title = 'Inter-bay differences for median depth of colonization and light requirements
  column.labels = c('null', 'Gaus', 'Gaus, nug', 'null', 'Gaus', 'Gaus, nug'),
  model.numbers = F
  )
```

```
library(multcomp)
summary(glht(zm1, linfct = mcp(bay = 'Tukey')))
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = z_c_all ~ 0 + bay, data = all_light, random = ~1 |
##     bay, correlation = corGaus(form = ~Latitude + Longitude |
##     bay, nugget = FALSE))
##
## Linear Hypotheses:
##                 Estimate Std. Error z value Pr(>|z|)
## irl - choc == 0 -1.05052    0.08509 -12.345   <1e-04 ***
## tb - choc == 0  -0.92437    0.07381 -12.523   <1e-04 ***
## tb - irl == 0    0.12615    0.07958   1.585    0.251
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

Table 2: Inter-bay differences for median depth of colonization and light requirements. Null models do not include a grouped correlation structure. Gaussian models with and without nuggets for the spatial correlation structures are also shown.

	Dependent variable:					
	z_c_all			light		
	null	Gaus	Gaus, nug	null	Gaus	Gaus, nug
baychoc	2.242	2.124	2.021	50.758	51.198	48.077
	(0.059)	(0.056)	(0.110)	(1.528)	(1.641)	(3.012)
bayirl	1.054	1.074	1.101	17.932	17.832	17.664
	(0.075)	(0.064)	(0.096)	(1.946)	(1.889)	(2.591)
baytb	1.210	1.200	1.163	41.577	41.655	42.062
	(0.057)	(0.048)	(0.081)	(1.474)	(1.408)	(2.202)
Observations	836	836	836	836	836	836
Log Likelihood	−303.580	49.998	537.481	−3,011.239	−2,834.399	−2,542.856
Akaike Inf. Crit.	617.160	−87.996	−1,060.961	6,032.477	5,680.798	5,099.712
Bayesian Inf. Crit.	640.785	−59.646	−1,027.886	6,056.103	5,709.149	5,132.787
Note:						*p<0.1; **p<0.05; ***p<0.01

```r
summary(glht(zm2, linfct = mcp(bay = 'Tukey')))
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = z_c_all ~ 0 + bay, data = all_light, random = ~1 |
##     bay, correlation = corGaus(form = ~Latitude + Longitude |
##     bay, nugget = TRUE))
##
## Linear Hypotheses:
##                 Estimate Std. Error z value Pr(>|z|)
## irl - choc == 0 -0.91965    0.14626  -6.288   <1e-05 ***
## tb - choc == 0  -0.85789    0.13672  -6.275   <1e-05 ***
## tb - irl == 0    0.06176    0.12606   0.490    0.876
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```r
summary(glht(lm1, linfct = mcp(bay = 'Tukey')))
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = light ~ 0 + bay, data = all_light, random = ~1 |
##     bay, correlation = corGaus(form = ~Latitude + Longitude |
##     bay, nugget = FALSE))
##
## Linear Hypotheses:
##                 Estimate Std. Error z value Pr(>|z|)
## irl - choc == 0  -33.365      2.503 -13.332   <1e-04 ***
## tb - choc == 0    -9.543      2.162  -4.413   <1e-04 ***
## tb - irl == 0     23.822      2.357  10.108   <1e-04 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```r
summary(glht(lm2, linfct = mcp(bay = 'Tukey')))
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = light ~ 0 + bay, data = all_light, random = ~1 |
##     bay, correlation = corGaus(form = ~Latitude + Longitude |
##     bay, nugget = TRUE))
##
## Linear Hypotheses:
##                 Estimate Std. Error z value Pr(>|z|)
## irl - choc == 0  -30.412      3.973  -7.654   <1e-04 ***
## tb - choc == 0    -6.014      3.731  -1.612    0.239
## tb - irl == 0     24.398      3.400   7.175   <1e-04 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```