

Supplement 2

Output S1: MARSS output from all six model classes for PD snails July using equations in Table S3 in Supplement 1. Note that Model 13.4c below is identical to "Process-error only" model 13.4c of Holmes EE, Scheuerell MD, Ward EJ (2023) Analysis of multivariate time-series using the MARSS package version 3.11.7. <https://atsa-es.github.io/MARSS/articles/index.html> (accessed 25/01/2025)

Tables 1 & 2 in main article contain Model 13.4 coefficients for PD snails in July shown below.

```
> writeLines(" smsc only PP and NP----Model 13.3.1 Multivariate
linear regression")
  smsc only PP and NP----Model 13.3.1 Multivariate linear regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -43.68102
AIC: 101.362   AICc: 103.9075
```

```
Estimate
R.diag      0.314
```

```
D. (PPsmcJL, SST_Feb)      0.482
D. (NPsmcJL, SST_Feb)     0.602
D. (PPsmcJL, SST_Aug)     0.502
D. (NPsmcJL, SST_Aug)     0.518
D. (PPsmcJL, PACHY_Jul)   -0.376
D. (NPsmcJL, PACHY_Jul)   -0.239
Initial states (x0) defined at t=0
```

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -43.68102
AIC: 101.362 AICc: 103.9075

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.314	0.0616	0.193	0.4349
D. (PPsmcJL, SST_Feb)	0.482	0.1099	0.266	0.6971
D. (NPsmcJL, SST_Feb)	0.602	0.1099	0.386	0.8173
D. (PPsmcJL, SST_Aug)	0.502	0.1179	0.271	0.7326
D. (NPsmcJL, SST_Aug)	0.518	0.1179	0.287	0.7488
D. (PPsmcJL, PACHY_Jul)	-0.376	0.1127	-0.597	-0.1550
D. (NPsmcJL, PACHY_Jul)	-0.239	0.1127	-0.460	-0.0183

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
>
> #residuals and values of model parameters and matrices
> #residuals.model.0 <- residuals(kem)
> #write.csv(residuals.model.0, "residuals.model.0.PPNP.smcJL.csv")
```

```

> #coef.model.0 <- coef(kem)
> #coef is a list so must redirect source to print it in a file.
> #sink(file = "coef.model.0.PPNP.smscJL.txt")
> #print(coef.model.0)
> #sink(NULL)
>
>
> ## ----Model 13.3.1b Multivariate linear regression-Q-equal-----
-----
>
> writeLines(" smsc only PP and NP----Model 13.3.1b Multivariate
linear regression-Q-equal----")
 smsc only PP and NP----Model 13.3.1b Multivariate linear
regression-Q-equal----
> R <- A <- U <- "zero"; B <- Z <- "identity"
> Q <- "equalvarcov"
> C <- "unconstrained"
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -50.41514
AIC: 120.8303   AICc: 126.1961

                                Estimate
Q.diag                          0.6400
Q.offdiag                        0.5073
x0.X.PPsmcJL                     1.4213
x0.X.NPsmcJL                     0.5976
C.(X.PPsmcJL,SST_Feb)            0.0645
C.(X.NPsmcJL,SST_Feb)            0.1886
C.(X.PPsmcJL,SST_Aug)            0.1381

```

```
C.(X.NPsmcJL,SST_Aug)      0.3846
C.(X.PPsmcJL,PACHY_Jul)   -0.2749
C.(X.NPsmcJL,PACHY_Jul)   -0.1702
Initial states (x0) defined at t=0
```

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -50.41514

AIC: 120.8303 AICc: 126.1961

	ML.Est	Std.Err	low.CI	up.CI
Q.diag	0.6400	0.160	0.32608	0.9539
Q.offdiag	0.5073	0.160	0.19336	0.8211
x0.X.PPsmcJL	1.4213	0.979	-0.49670	3.3393
x0.X.NPsmcJL	0.5976	0.979	-1.32035	2.5156
C.(X.PPsmcJL,SST_Feb)	0.0645	0.158	-0.24550	0.3745
C.(X.NPsmcJL,SST_Feb)	0.1886	0.158	-0.12138	0.4986
C.(X.PPsmcJL,SST_Aug)	0.1381	0.200	-0.25346	0.5296
C.(X.NPsmcJL,SST_Aug)	0.3846	0.200	-0.00688	0.7761
C.(X.PPsmcJL,PACHY_Jul)	-0.2749	0.167	-0.60218	0.0524
C.(X.NPsmcJL,PACHY_Jul)	-0.1702	0.167	-0.49746	0.1571

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
>
> ## -----
>
> writeLines(" smsc only PP and NP----Model 13.3.2----")
```

```
smsc only PP and NP----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -28.62608
AIC: 81.25217   AICc: 89.25217
```

	Estimate
B. (X.PPsmcJL,X.PPsmcJL)	0.321
B. (X.NPsmcJL,X.NPsmcJL)	0.216
Q.diag	0.247
Q.offdiag	0.173
x0.X.PPsmcJL	2.504
x0.X.NPsmcJL	1.490
C. (X.PPsmcJL,SST_Feb)	0.356
C. (X.NPsmcJL,SST_Feb)	0.518
C. (X.PPsmcJL,SST_Aug)	0.359
C. (X.NPsmcJL,SST_Aug)	0.481
C. (X.PPsmcJL,PACHY_Jul)	-0.332
C. (X.NPsmcJL,PACHY_Jul)	-0.219

Initial states (x0) defined at t=0

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
```

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -28.62608

AIC: 81.25217 AICc: 89.25217

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmcJL,X.PPsmcJL)	0.321	0.1059	0.1133	0.5284
B. (X.NPsmcJL,X.NPsmcJL)	0.216	0.0995	0.0214	0.4113
Q.diag	0.247	0.0591	0.1308	0.3624
Q.offdiag	0.173	0.0591	0.0573	0.2890
x0.X.PPsmcJL	2.504	2.0063	-1.4287	6.4360
x0.X.NPsmcJL	1.490	2.9209	-4.2350	7.2145
C. (X.PPsmcJL,SST_Feb)	0.356	0.1082	0.1437	0.5680
C. (X.NPsmcJL,SST_Feb)	0.518	0.1067	0.3088	0.7269
C. (X.PPsmcJL,SST_Aug)	0.359	0.1328	0.0988	0.6195
C. (X.NPsmcJL,SST_Aug)	0.481	0.1299	0.2261	0.7352
C. (X.PPsmcJL,PACHY_Jul)	-0.332	0.1024	-0.5325	-0.1309
C. (X.NPsmcJL,PACHY_Jul)	-0.219	0.1029	-0.4207	-0.0175

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

>

```
> ## ----Model 13.4c Process only equation-----
-----
```

>

```
> writeLines(" smsc only PP and NP----Model 13.4c Process only
equation")
```

```
smsc only PP and NP----Model 13.4c Process only equation
```

```
> x0 <- dat[,1,drop=FALSE]
```

```
> model.list$tinitx <- 1
```

```
> model.list$x0 <- x0
```

```
> kem <- MARSS(dat, model=model.list)
```

Success! algorithm run for 15 iterations. abstol and log-log tests passed.

Alert: conv.test.slope.tol is 0.5.

Test with smaller values (<0.1) to ensure convergence.

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -28.50881

AIC: 77.01761 AICc: 82.38347

	Estimate
B. (X.PPsmcJL,X.PPsmcJL)	0.321
B. (X.NPsmcJL,X.NPsmcJL)	0.216
Q.diag	0.256
Q.offdiag	0.180
C. (X.PPsmcJL,SST_Feb)	0.356
C. (X.NPsmcJL,SST_Feb)	0.518
C. (X.PPsmcJL,SST_Aug)	0.359
C. (X.NPsmcJL,SST_Aug)	0.481
C. (X.PPsmcJL,PACHY_Jul)	-0.332
C. (X.NPsmcJL,PACHY_Jul)	-0.219

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -28.50881

AIC: 77.01761 AICc: 82.38347

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmcJL,X.PPsmcJL)	0.321	0.1080	0.1089	0.5322
B. (X.NPsmcJL,X.NPsmcJL)	0.216	0.1014	0.0173	0.4150
Q.diag	0.256	0.0627	0.1336	0.3793

```

Q.offdiag                0.180  0.0627  0.0573  0.3030
C.(X.PPsmcJL,SST_Feb)   0.356  0.1104  0.1396  0.5722
C.(X.NPsmcJL,SST_Feb)   0.518  0.1088  0.3047  0.7311
C.(X.PPsmcJL,SST_Aug)   0.359  0.1355  0.0938  0.6247
C.(X.NPsmcJL,SST_Aug)   0.481  0.1325  0.2210  0.7403
C.(X.PPsmcJL,PACHY_Jul) -0.332  0.1045 -0.5365 -0.1269
C.(X.NPsmcJL,PACHY_Jul) -0.219  0.1049 -0.4247 -0.0135
Initial states (x0) defined at t=1

```

CIs calculated at alpha = 0.05 via method=hessian

```

> writeLines(" smsc only PP and NP----Model 13.5  both equations-
Cov-in-Process")
  smsc only PP and NP----Model 13.5  both equations-Cov-in-Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.218,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 118 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 118 iterations.

Log-likelihood: -33.46925

AIC: 90.93851 AICc: 98.93851

	Estimate
B.(X.PPsmcJL,X.PPsmcJL)	0.423
B.(X.NPsmcJL,X.NPsmcJL)	0.250


```

Q.diag                0.108
Q.offdiag             0.106
x0.X.PPsmcJL         1.811
x0.X.NPsmcJL         1.722
C.(X.PPsmcJL,SST_Feb) 0.337
C.(X.NPsmcJL,SST_Feb) 0.482
C.(X.PPsmcJL,SST_Aug) 0.417
C.(X.NPsmcJL,SST_Aug) 0.495
C.(X.PPsmcJL,PACHY_Jul) -0.381
C.(X.NPsmcJL,PACHY_Jul) -0.231
Initial states (x0) defined at t=1

```

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```

>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 118 iterations.

Log-likelihood: -33.46925

AIC: 90.93851 AICc: 98.93851

	ML.Est	Std.Err	low.CI	up.CI
B.(X.PPsmcJL,X.PPsmcJL)	0.423	0.1223	0.1830	0.66256
B.(X.NPsmcJL,X.NPsmcJL)	0.250	0.1339	-0.0126	0.51240
Q.diag	0.108	0.0654	-0.0202	0.23629
Q.offdiag	0.106	0.0658	-0.0233	0.23453
x0.X.PPsmcJL	1.811	0.4433	0.9419	2.67954
x0.X.NPsmcJL	1.722	0.4583	0.8233	2.61993
C.(X.PPsmcJL,SST_Feb)	0.337	0.1272	0.0880	0.58655
C.(X.NPsmcJL,SST_Feb)	0.482	0.1283	0.2307	0.73354
C.(X.PPsmcJL,SST_Aug)	0.417	0.1485	0.1256	0.70781
C.(X.NPsmcJL,SST_Aug)	0.495	0.1506	0.2001	0.79029
C.(X.PPsmcJL,PACHY_Jul)	-0.381	0.1190	-0.6145	-0.14789

C.(X.NPsmcJL,PACHY_Jul) -0.231 0.1203 -0.4665 0.00492

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

```
>
> ## ----Model 13.5b both equations-Cov-in-Observation-----
-----
>
> writeLines(" smsc only PP and NP----Model 13.5b both equations-
Cov-in-Observation")
  smsc only PP and NP----Model 13.5b both equations-Cov-in-
Observation
> C <- c <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> D <- "unconstrained"
> d <- covariates
> R <- diag(0.218,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 119 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 119 iterations.

Log-likelihood: -35.36011

AIC: 94.72021 AICc: 102.7202

	Estimate
B.(X.PPsmcJL,X.PPsmcJL)	0.688
B.(X.NPsmcJL,X.NPsmcJL)	0.472
Q.diag	0.114

```

Q.offdiag                0.112
x0.X.PPsmcJL             0.866
x0.X.NPsmcJL             0.464
D. (PPsmcJL, SST_Feb)    0.365
D. (NPsmcJL, SST_Feb)    0.554
D. (PPsmcJL, SST_Aug)    0.326
D. (NPsmcJL, SST_Aug)    0.423
D. (PPsmcJL, PACHY_Jul) -0.326
D. (NPsmcJL, PACHY_Jul) -0.183
Initial states (x0) defined at t=1
    
```

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```

>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
    
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 119 iterations.

Log-likelihood: -35.36011

AIC: 94.72021 AICc: 102.7202

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmcJL, X.PPsmcJL)	0.688	0.2059	0.2848	1.0920
B. (X.NPsmcJL, X.NPsmcJL)	0.472	0.3362	-0.1872	1.1306
Q.diag	0.114	0.0692	-0.0222	0.2492
Q.offdiag	0.112	0.0692	-0.0240	0.2473
x0.X.PPsmcJL	0.866	0.4808	-0.0761	1.8087
x0.X.NPsmcJL	0.464	0.5404	-0.5955	1.5229
D. (PPsmcJL, SST_Feb)	0.365	0.1236	0.1232	0.6076
D. (NPsmcJL, SST_Feb)	0.554	0.1211	0.3171	0.7918
D. (PPsmcJL, SST_Aug)	0.326	0.1379	0.0561	0.5966
D. (NPsmcJL, SST_Aug)	0.423	0.1394	0.1502	0.6967
D. (PPsmcJL, PACHY_Jul)	-0.326	0.1292	-0.5793	-0.0729
D. (NPsmcJL, PACHY_Jul)	-0.183	0.1214	-0.4213	0.0547

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

>

> ##### Stop here#####

Output S2: MARSS output from all six model classes for DD snails in July.

Table 1 in main article contains Model 13.4c Process only equation coefficients for DD snails in July shown below.

```
> writeLines(" smsub only PP and NP---Model 13.3.1 Multivariate
linear regression")
 smsub only PP and NP---Model 13.3.1 Multivariate linear
regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! abstol and log-log tests passed at 16 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 16 iterations.
Log-likelihood: -63.72345
AIC: 137.4469   AICc: 138.7513
```

	Estimate
R.diag	0.679
D. (PPsmsubJL, SSTbuoy_Feb)	-0.420
D. (NPsmsubJL, SSTbuoy_Feb)	-0.248
D. (PPsmsubJL, Salinity_Jul)	0.119
D. (NPsmsubJL, Salinity_Jul)	0.488

Initial states (x0) defined at t=0

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 16 iterations.

Log-likelihood: -63.72345

AIC: 137.4469 AICc: 138.7513

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.679	0.133	0.418	0.9401
D. (PPsmsubJL, SSTbuoy_Feb)	-0.420	0.170	-0.752	-0.0875
D. (NPsmsubJL, SSTbuoy_Feb)	-0.248	0.170	-0.581	0.0840
D. (PPsmsubJL, Salinity_Jul)	0.119	0.179	-0.232	0.4701
D. (NPsmsubJL, Salinity_Jul)	0.488	0.179	0.137	0.8390

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsub only PP and NP----Model 13.3.1b Multivariate
linear regression-Q-equal----")
```

```
 smsub only PP and NP----Model 13.3.1b Multivariate linear
regression-Q-equal----
```

```
> R <- A <- U <- "zero"; B <- Z <- "identity"
```

```
> Q <- "equalvarcov"
```

```
> C <- "unconstrained"
```

```
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
```

```
> kem <- MARSS(dat, model=model.list)
```

Success! algorithm run for 15 iterations. abstol and log-log tests passed.

Alert: conv.test.slope.tol is 0.5.

Test with smaller values (<0.1) to ensure convergence.

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -66.29195

AIC: 148.5839 AICc: 151.9327

	Estimate
Q.diag	0.8041
Q.offdiag	0.3607
x0.X.PPsmsubJL	-0.1408
x0.X.NPsmsubJL	0.0412
C.(X.PPsmsubJL,SSTbuoy_Feb)	-0.2726
C.(X.NPsmsubJL,SSTbuoy_Feb)	0.0862
C.(X.PPsmsubJL,Salinity_Jul)	-0.3067
C.(X.NPsmsubJL,Salinity_Jul)	0.2676

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -66.29195

AIC: 148.5839 AICc: 151.9327

	ML.Est	Std.Err	low.CI	up.CI
Q.diag	0.8041	0.173	0.465	1.1428
Q.offdiag	0.3607	0.173	0.022	0.6995
x0.X.PPsmsubJL	-0.1408	0.901	-1.908	1.6260
x0.X.NPsmsubJL	0.0412	0.901	-1.726	1.8081
C.(X.PPsmsubJL,SSTbuoy_Feb)	-0.2726	0.187	-0.639	0.0937

```
C. (X.NPsmsubJL, SSTbuoy_Feb)    0.0862    0.187 -0.280 0.4525
C. (X.PPsmsubJL, Salinity_Jul) -0.3067    0.188 -0.675 0.0613
C. (X.NPsmsubJL, Salinity_Jul)  0.2676    0.188 -0.100 0.6355
Initial states (x0) defined at t=0
```

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsub only PP and NP----Model 13.3.2----")
  smsub only PP and NP----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

```
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -53.86578
AIC: 127.7316   AICc: 133.0974
```

	Estimate
B. (X.PPsmsubJL, X.PPsmsubJL)	0.2366
B. (X.NPsmsubJL, X.NPsmsubJL)	0.3317
Q.diag	0.5736
Q.offdiag	0.3382
x0.X.PPsmsubJL	-1.3602
x0.X.NPsmsubJL	-0.1789
C. (X.PPsmsubJL, SSTbuoy_Feb)	-0.3865
C. (X.NPsmsubJL, SSTbuoy_Feb)	-0.1418
C. (X.PPsmsubJL, Salinity_Jul)	0.0106
C. (X.NPsmsubJL, Salinity_Jul)	0.4004

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.


```

>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -53.86578
AIC: 127.7316   AICc: 133.0974

      ML.Est Std.Err low.CI up.CI
B. (X.PPsmsubJL,X.PPsmsubJL)  0.2366  0.159 -0.0756  0.5488
B. (X.NPsmsubJL,X.NPsmsubJL)  0.3317  0.158  0.0211  0.6422
Q.diag                       0.5736  0.131  0.3176  0.8295
Q.offdiag                     0.3382  0.131  0.0822  0.5942
x0.X.PPsmsubJL                -1.3602  3.403 -8.0299  5.3096
x0.X.NPsmsubJL                -0.1789  2.303 -4.6929  4.3351
C. (X.PPsmsubJL,SSTbuoy_Feb) -0.3865  0.158 -0.6968 -0.0761
C. (X.NPsmsubJL,SSTbuoy_Feb) -0.1418  0.165 -0.4657  0.1822
C. (X.PPsmsubJL,Salinity_Jul)  0.0106  0.182 -0.3470  0.3681
C. (X.NPsmsubJL,Salinity_Jul)  0.4004  0.169  0.0684  0.7323
Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

> writeLines(" smsub only PP and NP----Model 13.4c Process only
equation")
 smsub only PP and NP----Model 13.4c Process only equation
> x0 <- dat[,1,drop=FALSE]
> model.list$tinitx <- 1
> model.list$x0 <- x0
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -52.77796

AIC: 121.5559 AICc: 124.9048

	Estimate
B. (X.PPsmsubJL,X.PPsmsubJL)	0.2362
B. (X.NPsmsubJL,X.NPsmsubJL)	0.3312
Q.diag	0.5966
Q.offdiag	0.3519
C. (X.PPsmsubJL,SSTbuoy_Feb)	-0.3865
C. (X.NPsmsubJL,SSTbuoy_Feb)	-0.1419
C. (X.PPsmsubJL,Salinity_Jul)	0.0108
C. (X.NPsmsubJL,Salinity_Jul)	0.4005

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -52.77796

AIC: 121.5559 AICc: 124.9048

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL,X.PPsmsubJL)	0.2362	0.162	-0.0821	0.555
B. (X.NPsmsubJL,X.NPsmsubJL)	0.3312	0.162	0.0145	0.648
Q.diag	0.5966	0.139	0.3251	0.868
Q.offdiag	0.3519	0.139	0.0803	0.623
C. (X.PPsmsubJL,SSTbuoy_Feb)	-0.3865	0.162	-0.7031	-0.070

```
C. (X.NPsmsubJL, SSTbuoy_Feb)  -0.1419    0.169 -0.4723    0.188
C. (X.PPsmsubJL, Salinity_Jul)  0.0108    0.186 -0.3539    0.375
C. (X.NPsmsubJL, Salinity_Jul)  0.4005    0.173  0.0620    0.739
Initial states (x0) defined at t=1
```

CIIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsub only PP and NP----Model 13.5  both equations-
Cov-in-Process")
 smsub only PP and NP----Model 13.5  both equations-Cov-in-Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.218,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 88 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 88 iterations.

Log-likelihood: -50.86332

AIC: 121.7266 AICc: 127.0925

	Estimate
B. (X.PPsmsubJL,X.PPsmsubJL)	0.46090
B. (X.NPsmsubJL,X.NPsmsubJL)	0.53752
Q.diag	0.32357
Q.offdiag	0.31584
x0.X.PPsmsubJL	-0.62177
x0.X.NPsmsubJL	0.33744

```
C. (X.PPsmsubJL, SSTbuoy_Feb) -0.32419
C. (X.NPsmsubJL, SSTbuoy_Feb) -0.17060
C. (X.PPsmsubJL, Salinity_Jul) 0.00131
C. (X.NPsmsubJL, Salinity_Jul) 0.25738
Initial states (x0) defined at t=1
```

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 88 iterations.

Log-likelihood: -50.86332

AIC: 121.7266 AICc: 127.0925

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL, X.PPsmsubJL)	0.46090	0.181	0.1063	0.81550
B. (X.NPsmsubJL, X.NPsmsubJL)	0.53752	0.166	0.2123	0.86275
Q.diag	0.32357	0.128	0.0737	0.57347
Q.offdiag	0.31584	0.127	0.0672	0.56451
x0.X.PPsmsubJL	-0.62177	0.440	-1.4837	0.24020
x0.X.NPsmsubJL	0.33744	0.428	-0.5022	1.17708
C. (X.PPsmsubJL, SSTbuoy_Feb)	-0.32419	0.160	-0.6385	-0.00992
C. (X.NPsmsubJL, SSTbuoy_Feb)	-0.17060	0.157	-0.4773	0.13614
C. (X.PPsmsubJL, Salinity_Jul)	0.00131	0.155	-0.3020	0.30461
C. (X.NPsmsubJL, Salinity_Jul)	0.25738	0.161	-0.0585	0.57325

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsub only PP and NP----Model 13.5b both equations-
Cov-in-Observation")
```

```
 smsub only PP and NP----Model 13.5b both equations-Cov-in-
Observation
```

```
> C <- c <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> D <- "unconstrained"
> d <- covariates
> R <- diag(0.218,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 88 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 88 iterations.

Log-likelihood: -51.6342

AIC: 123.2684 AICc: 128.6343

	Estimate
B. (X.PPsmsubJL,X.PPsmsubJL)	0.5353
B. (X.NPsmsubJL,X.NPsmsubJL)	0.6277
Q.diag	0.3455
Q.offdiag	0.3376
x0.X.PPsmsubJL	-0.6876
x0.X.NPsmsubJL	0.1141
D. (PPsmsubJL,SSTbuoy_Feb)	-0.2081
D. (NPsmsubJL,SSTbuoy_Feb)	-0.0084
D. (PPsmsubJL,Salinity_Jul)	0.0525
D. (NPsmsubJL,Salinity_Jul)	0.3946

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

>

```
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 88 iterations.

Log-likelihood: -51.6342

AIC: 123.2684 AICc: 128.6343

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL,X.PPsmsubJL)	0.5353	0.207	0.1304	0.940
B. (X.NPsmsubJL,X.NPsmsubJL)	0.6277	0.182	0.2713	0.984
Q.diag	0.3455	0.137	0.0767	0.614
Q.offdiag	0.3376	0.136	0.0702	0.605
x0.X.PPsmsubJL	-0.6876	0.446	-1.5610	0.186
x0.X.NPsmsubJL	0.1141	0.423	-0.7148	0.943
D. (PPsmsubJL,SSTbuoy_Feb)	-0.2081	0.163	-0.5267	0.111
D. (NPsmsubJL,SSTbuoy_Feb)	-0.0084	0.160	-0.3229	0.306
D. (PPsmsubJL,Salinity_Jul)	0.0525	0.180	-0.2996	0.405
D. (NPsmsubJL,Salinity_Jul)	0.3946	0.182	0.0378	0.751

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

>

> ##### Stop here#####

Table 2 in main article contains Model 13.4c Process only equation coefficients for DD snails in July shown below.

```
> writeLines(" smsc only PP and NP----Model 13.3.1 Multivariate
linear regression")
 smsc only PP and NP----Model 13.3.1 Multivariate linear regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -66.35458

AIC: 146.7092 AICc: 149.2546

	Estimate
R.diag	0.751
D. (PPsmsubJL, SST_Feb)	-0.338
D. (NPsmsubJL, SST_Feb)	-0.189
D. (PPsmsubJL, SST_Aug)	-0.121
D. (NPsmsubJL, SST_Aug)	-0.241
D. (PPsmsubJL, PACHY_Jul)	-0.252
D. (NPsmsubJL, PACHY_Jul)	-0.222

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -66.35458

AIC: 146.7092 AICc: 149.2546

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.751	0.147	0.463	1.0403
D. (PPsmsubJL, SST_Feb)	-0.338	0.170	-0.671	-0.0047
D. (NPsmsubJL, SST_Feb)	-0.189	0.170	-0.522	0.1445
D. (PPsmsubJL, SST_Aug)	-0.121	0.182	-0.478	0.2365
D. (NPsmsubJL, SST_Aug)	-0.241	0.182	-0.599	0.1159
D. (PPsmsubJL, PACHY_Jul)	-0.252	0.174	-0.593	0.0899
D. (NPsmsubJL, PACHY_Jul)	-0.222	0.174	-0.563	0.1199

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP----Model 13.3.1b Multivariate
linear regression-Q-equal----")
  smsc only PP and NP----Model 13.3.1b Multivariate linear
regression-Q-equal----
> R <- A <- U <- "zero"; B <- Z <- "identity"
> Q <- "equalvarcov"
> C <- "unconstrained"
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```



```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -67.98984
AIC: 155.9797   AICc: 161.3455
```

	Estimate
Q.diag	0.81765
Q.offdiag	0.28303
x0.X.PPsmsubJL	-0.87108
x0.X.NPsmsubJL	-0.31802
C.(X.PPsmsubJL,SST_Feb)	-0.26102
C.(X.NPsmsubJL,SST_Feb)	-0.00482
C.(X.PPsmsubJL,SST_Aug)	0.17591
C.(X.NPsmsubJL,SST_Aug)	0.18188
C.(X.PPsmsubJL,PACHY_Jul)	-0.25917
C.(X.NPsmsubJL,PACHY_Jul)	0.00952

Initial states (x0) defined at t=0

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -67.98984
AIC: 155.9797   AICc: 161.3455
```

	ML.Est	Std.Err	low.CI	up.CI
Q.diag	0.81765	0.170	0.4851	1.1502
Q.offdiag	0.28303	0.170	-0.0496	0.6156

```

x0.X.PPsmsubJL      -0.87108    1.106  -3.0390  1.2969
x0.X.NPsmsubJL     -0.31802    1.106  -2.4860  1.8499
C.(X.PPsmsubJL,SST_Feb) -0.26102    0.179  -0.6114  0.0894
C.(X.NPsmsubJL,SST_Feb) -0.00482    0.179  -0.3552  0.3456
C.(X.PPsmsubJL,SST_Aug)  0.17591    0.226  -0.2666  0.6184
C.(X.NPsmsubJL,SST_Aug)  0.18188    0.226  -0.2607  0.6244
C.(X.PPsmsubJL,PACHY_Jul) -0.25917    0.189  -0.6291  0.1108
C.(X.NPsmsubJL,PACHY_Jul)  0.00952    0.189  -0.3604  0.3794
Initial states (x0) defined at t=0

```

CI's calculated at alpha = 0.05 via method=hessian

```

> writeLines(" smsc only PP and NP----Model 13.3.2----")
 smsc only PP and NP----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 16 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 16 iterations.

Log-likelihood: -56.37693

AIC: 136.7539 AICc: 144.7539

	Estimate
B.(X.PPsmsubJL,X.PPsmsubJL)	0.2224
B.(X.NPsmsubJL,X.NPsmsubJL)	0.4047
Q.diag	0.6074
Q.offdiag	0.3305
x0.X.PPsmsubJL	-1.2812
x0.X.NPsmsubJL	1.1589
C.(X.PPsmsubJL,SST_Feb)	-0.3255
C.(X.NPsmsubJL,SST_Feb)	-0.1105
C.(X.PPsmsubJL,SST_Aug)	-0.0429
C.(X.NPsmsubJL,SST_Aug)	-0.1366
C.(X.PPsmsubJL,PACHY_Jul)	-0.2663

```
C. (X.NPsmsubJL, PACHY_Jul)    -0.1323
Initial states (x0) defined at t=0
```

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 16 iterations.
Log-likelihood: -56.37693
AIC: 136.7539   AICc: 144.7539
```

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL, X.PPsmsubJL)	0.2224	0.152	-0.07582	0.5206
B. (X.NPsmsubJL, X.NPsmsubJL)	0.4047	0.202	0.00828	0.8011
Q.diag	0.6074	0.136	0.34158	0.8732
Q.offdiag	0.3305	0.136	0.06456	0.5964
x0.X.PPsmsubJL	-1.2812	4.372	-9.85001	7.2877
x0.X.NPsmsubJL	1.1589	2.785	-4.30028	6.6181
C. (X.PPsmsubJL, SST_Feb)	-0.3255	0.154	-0.62804	-0.0230
C. (X.NPsmsubJL, SST_Feb)	-0.1105	0.158	-0.41928	0.1984
C. (X.PPsmsubJL, SST_Aug)	-0.0429	0.212	-0.45846	0.3726
C. (X.NPsmsubJL, SST_Aug)	-0.1366	0.242	-0.61092	0.3378
C. (X.PPsmsubJL, PACHY_Jul)	-0.2663	0.161	-0.58252	0.0498
C. (X.NPsmsubJL, PACHY_Jul)	-0.1323	0.163	-0.45226	0.1877

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP----Model 13.4c Process only
equation")
  smsc only PP and NP----Model 13.4c Process only equation
> x0 <- dat[,1,drop=FALSE]
```

```
> model.list$tinitx <- 1
> model.list$x0 <- x0
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -55.19368

AIC: 130.3874 AICc: 135.7532

	Estimate
B. (X.PPsmsubJL,X.PPsmsubJL)	0.2216
B. (X.NPsmsubJL,X.NPsmsubJL)	0.4030
Q.diag	0.6319
Q.offdiag	0.3442
C. (X.PPsmsubJL,SST_Feb)	-0.3256
C. (X.NPsmsubJL,SST_Feb)	-0.1107
C. (X.PPsmsubJL,SST_Aug)	-0.0433
C. (X.NPsmsubJL,SST_Aug)	-0.1381
C. (X.PPsmsubJL,PACHY_Jul)	-0.2663
C. (X.NPsmsubJL,PACHY_Jul)	-0.1325

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.
 Log-likelihood: -55.19368
 AIC: 130.3874 AICc: 135.7532

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL,X.PPsmsubJL)	0.2216	0.155	-0.08252	0.5257
B. (X.NPsmsubJL,X.NPsmsubJL)	0.4030	0.206	-0.00107	0.8071
Q.diag	0.6319	0.144	0.34986	0.9140
Q.offdiag	0.3442	0.144	0.06194	0.6264
C. (X.PPsmsubJL,SST_Feb)	-0.3256	0.157	-0.63415	-0.0170
C. (X.NPsmsubJL,SST_Feb)	-0.1107	0.161	-0.42572	0.2042
C. (X.PPsmsubJL,SST_Aug)	-0.0433	0.216	-0.46714	0.3806
C. (X.NPsmsubJL,SST_Aug)	-0.1381	0.247	-0.62196	0.3457
C. (X.PPsmsubJL,PACHY_Jul)	-0.2663	0.165	-0.58881	0.0562
C. (X.NPsmsubJL,PACHY_Jul)	-0.1325	0.166	-0.45880	0.1938

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP----Model 13.5  both equations-
Cov-in-Process")
  smsc only PP and NP----Model 13.5  both equations-Cov-in-Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.218,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 91 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is
 Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
 Estimation converged in 91 iterations.
 Log-likelihood: -52.1805
 AIC: 128.361 AICc: 136.361

	Estimate
B. (X.PPsmsubJL,X.PPsmsubJL)	0.4843
B. (X.NPsmsubJL,X.NPsmsubJL)	0.6444
Q.diag	0.3128
Q.offdiag	0.3053
x0.X.PPsmsubJL	-0.6012
x0.X.NPsmsubJL	0.3225
C. (X.PPsmsubJL,SST_Feb)	-0.2864
C. (X.NPsmsubJL,SST_Feb)	-0.1753
C. (X.PPsmsubJL,SST_Aug)	0.0646
C. (X.NPsmsubJL,SST_Aug)	-0.0482
C. (X.PPsmsubJL,PACHY_Jul)	-0.2749
C. (X.NPsmsubJL,PACHY_Jul)	-0.0951

Initial states (x0) defined at t=1

Standard errors have not been calculated.
 Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is
 Estimation method: kem
 Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
 Estimation converged in 91 iterations.
 Log-likelihood: -52.1805
 AIC: 128.361 AICc: 136.361

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL,X.PPsmsubJL)	0.4843	0.187	0.1177	0.8510
B. (X.NPsmsubJL,X.NPsmsubJL)	0.6444	0.206	0.2397	1.0491
Q.diag	0.3128	0.126	0.0662	0.5595

Q.offdiag	0.3053	0.126	0.0585	0.5522
x0.X.PPsmsubJL	-0.6012	0.442	-1.4671	0.2648
x0.X.NPsmsubJL	0.3225	0.419	-0.4984	1.1434
C.(X.PPsmsubJL,SST_Feb)	-0.2864	0.150	-0.5798	0.0070
C.(X.NPsmsubJL,SST_Feb)	-0.1753	0.150	-0.4694	0.1188
C.(X.PPsmsubJL,SST_Aug)	0.0646	0.208	-0.3422	0.4714
C.(X.NPsmsubJL,SST_Aug)	-0.0482	0.230	-0.4994	0.4030
C.(X.PPsmsubJL,PACHY_Jul)	-0.2749	0.153	-0.5742	0.0244
C.(X.NPsmsubJL,PACHY_Jul)	-0.0951	0.155	-0.3985	0.2082

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

```

>
> ## ----Model 13.5b both equations-Cov-in-Observation-----
-----
>
> writeLines(" smsc only PP and NP----Model 13.5b both equations-
Cov-in-Observation")
 smsc only PP and NP----Model 13.5b both equations-Cov-in-
Observation
> C <- c <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> D <- "unconstrained"
> d <- covariates
> R <- diag(0.218,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 79 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 79 iterations.

Log-likelihood: -53.07755

AIC: 130.1551 AICc: 138.1551

	Estimate
B. (X.PPsmsubJL,X.PPsmsubJL)	0.5237
B. (X.NPsmsubJL,X.NPsmsubJL)	0.6539
Q.diag	0.3722
Q.offdiag	0.3626
x0.X.PPsmsubJL	-1.0829
x0.X.NPsmsubJL	0.1682
D. (PPsmsubJL, SST_Feb)	-0.1108
D. (NPmsubJL, SST_Feb)	0.0697
D. (PPsmsubJL, SST_Aug)	0.1676
D. (NPmsubJL, SST_Aug)	-0.0132
D. (PPsmsubJL, PACHY_Jul)	-0.2792
D. (NPmsubJL, PACHY_Jul)	-0.1411

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 79 iterations.

Log-likelihood: -53.07755

AIC: 130.1551 AICc: 138.1551

	ML.Est	Std.Err	low.CI	up.CI
B. (X.PPsmsubJL,X.PPsmsubJL)	0.5237	0.174	0.1832	0.8643
B. (X.NPsmsubJL,X.NPsmsubJL)	0.6539	0.161	0.3390	0.9688
Q.diag	0.3722	0.143	0.0914	0.6531
Q.offdiag	0.3626	0.144	0.0813	0.6440


```
x0.X.PPsmsubJL      -1.0829    0.632  -2.3207  0.1550
x0.X.NPsmsubJL      0.1682    0.606  -1.0199  1.3562
D. (PPsmsubJL, SST_Feb) -0.1108    0.154  -0.4118  0.1902
D. (NPsmsubJL, SST_Feb) 0.0697    0.152  -0.2288  0.3681
D. (PPsmsubJL, SST_Aug) 0.1676    0.187  -0.1993  0.5345
D. (NPsmsubJL, SST_Aug) -0.0132    0.188  -0.3815  0.3550
D. (PPsmsubJL, PACHY_Jul) -0.2792    0.155  -0.5828  0.0244
D. (NPsmsubJL, PACHY_Jul) -0.1411    0.157  -0.4491  0.1668
Initial states (x0) defined at t=1
```

CIIs calculated at alpha = 0.05 via method=hessian

```
>
> ##### Stop here#####
```

Output S3: MARSS output from all six model classes for PD snails in December. Model 2 below is equivalent to Model 8.4c

Table 1 in main article contains Model 13.4c Process only equation coefficients for PD snails in December shown below.

```
> writeLines(" smsc only PP and NP Winter----Model 13.3.1
Multivariate linear regression")
  smsc only PP and NP Winter----Model 13.3.1 Multivariate linear
regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -54.20293
AIC: 118.4059   AICc: 119.6303

                Estimate
R.diag           0.420
D.(smc_PP_Dec,SST_Feb) 0.495
D.(smc_NP_Dec,SST_Feb) 0.496
D.(smc_PP_Dec,SST_Aug) 0.378
D.(smc_NP_Dec,SST_Aug) 0.566
Initial states (x0) defined at t=0
```

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -54.20293

AIC: 118.4059 AICc: 119.6303

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.420	0.0801	0.263	0.577
D.(smssc_PP_Dec,SST_Feb)	0.495	0.1275	0.245	0.744
D.(smssc_NP_Dec,SST_Feb)	0.496	0.1267	0.248	0.745
D.(smssc_PP_Dec,SST_Aug)	0.378	0.1341	0.115	0.640
D.(smssc_NP_Dec,SST_Aug)	0.566	0.1267	0.318	0.815

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smssc only PP and NP Winter----Model 13.3.1b
Multivariate linear regression-Q-equal----")
  smssc only PP and NP Winter----Model 13.3.1b Multivariate linear
regression-Q-equal----
> R <- A <- U <- "zero"; B <- Z <- "identity"
> Q <- "equalvarcov"
> C <- "unconstrained"
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -73.96102
AIC: 163.922   AICc: 167.0525
```

	Estimate
Q.diag	1.200
Q.offdiag	0.851
x0.X.smsc_PP_Dec	1.613
x0.X.smsc_NP_Dec	0.979
C.(X.smsc_PP_Dec,SST_Feb)	0.206
C.(X.smsc_NP_Dec,SST_Feb)	-0.047
C.(X.smsc_PP_Dec,SST_Aug)	0.075
C.(X.smsc_NP_Dec,SST_Aug)	0.447

Initial states (x0) defined at t=0

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -73.96102
AIC: 163.922   AICc: 167.0525
```

	ML.Est	Std.Err	low.CI	up.CI
Q.diag	1.200	0.280	0.6518	1.748
Q.offdiag	0.851	0.280	0.3012	1.400
x0.X.smsc_PP_Dec	1.613	1.298	-0.9319	4.158
x0.X.smsc_NP_Dec	0.979	1.290	-1.5506	3.508

```
C.(X.smsc_PP_Dec,SST_Feb)  0.206    0.217 -0.2188  0.630
C.(X.smsc_NP_Dec,SST_Feb) -0.047    0.215 -0.4690  0.375
C.(X.smsc_PP_Dec,SST_Aug)  0.075    0.258 -0.4300  0.580
C.(X.smsc_NP_Dec,SST_Aug)  0.447    0.252 -0.0467  0.942
Initial states (x0) defined at t=0
```

CI's calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP Winter----Model 13.3.2----")
 smsc only PP and NP Winter----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Warning! Abstol convergence only. Maxit (=500) reached before log-
log convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

WARNING: Abstol convergence only no log-log convergence.

maxit (=500) reached before log-log convergence.

The likelihood and params might not be at the ML values.

Try setting control\$maxit higher.

Log-likelihood: -46.99495

AIC: 113.9899 AICc: 118.9899

	Estimate
B.(X.smsc_PP_Dec,X.smsc_PP_Dec)	1.56e-03
B.(X.smsc_NP_Dec,X.smsc_NP_Dec)	3.60e-02
Q.diag	3.91e-01
Q.offdiag	2.21e-01
x0.X.smsc_PP_Dec	7.01e+02
x0.X.smsc_NP_Dec	2.59e+01
C.(X.smsc_PP_Dec,SST_Feb)	5.13e-01
C.(X.smsc_NP_Dec,SST_Feb)	4.93e-01
C.(X.smsc_PP_Dec,SST_Aug)	2.69e-01
C.(X.smsc_NP_Dec,SST_Aug)	4.69e-01

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

Convergence warnings

Warning: the x0.X.smsc_PP_Dec parameter value has not converged.
Type MARSSinfo("convergence") for more info on this warning.

>

```
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
```

Warning messages:

1: In MARSShessian(MLEobj, method = hessian.fun) :

MARSShessian: Hessian could not be inverted to compute the parameter var-cov matrix. parSigma set to NULL. See MARSSinfo("HessianNA").

2: In MARSSparamCIs(kem) :

MARSSparamCIs: No parSigma element returned by Hessian function. See marssMLE object errors (MLEobj\$errors)

```
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

WARNING: Abstol convergence only no log-log convergence.

maxit (=500) reached before log-log convergence.

The likelihood and params might not be at the ML values.

Try setting control\$maxit higher.

Log-likelihood: -46.99495

AIC: 113.9899 AICc: 118.9899

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	1.56e-03	NA	NA	NA
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	3.60e-02	NA	NA	NA
Q.diag	3.91e-01	NA	NA	NA
Q.offdiag	2.21e-01	NA	NA	NA
x0.X.smsc_PP_Dec	7.01e+02	NA	NA	NA
x0.X.smsc_NP_Dec	2.59e+01	NA	NA	NA
C. (X.smsc_PP_Dec, SST_Feb)	5.13e-01	NA	NA	NA
C. (X.smsc_NP_Dec, SST_Feb)	4.93e-01	NA	NA	NA

```
C.(X.smsc_PP_Dec,SST_Aug)      2.69e-01      NA      NA      NA
C.(X.smsc_NP_Dec,SST_Aug)      4.69e-01      NA      NA      NA
Initial states (x0) defined at t=0
```

CIs calculated at alpha = 0.05 via method=hessian

Convergence warnings

```
Warning: the x0.X.smsc_PP_Dec parameter value has not converged.
Type MARSSinfo("convergence") for more info on this warning.
MARSShessian: Hessian could not be inverted to compute the
parameter var-cov matrix. parSigma set to NULL. See
MARSSinfo("HessianNA").
```

```
> writeLines(" smsc only PP and NP Winter----Model 13.4c Process
only equation")
 smsc only PP and NP Winter----Model 13.4c Process only equation
> x0 <- dat[,1,drop=FALSE]
> model.list$tinitx <- 1
> model.list$x0 <- x0
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

```
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -45.83311
AIC: 107.6662   AICc: 110.7967
```

	Estimate
B.(X.smsc_PP_Dec,X.smsc_PP_Dec)	-0.1163
B.(X.smsc_NP_Dec,X.smsc_NP_Dec)	-0.0199
Q.diag	0.3975
Q.offdiag	0.2234
C.(X.smsc_PP_Dec,SST_Feb)	0.5498
C.(X.smsc_NP_Dec,SST_Feb)	0.5248

```
C.(X.smsc_PP_Dec,SST_Aug)          0.2898
C.(X.smsc_NP_Dec,SST_Aug)          0.4707
Initial states (x0) defined at t=1
```

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -45.83311
AIC: 107.6662   AICc: 110.7967
```

	ML.Est	Std.Err	low.CI	up.CI
B.(X.smsc_PP_Dec,X.smsc_PP_Dec)	-0.1163	0.1262	-0.3637	0.131
B.(X.smsc_NP_Dec,X.smsc_NP_Dec)	-0.0199	0.1380	-0.2904	0.251
Q.diag	0.3975	0.0883	0.2244	0.571
Q.offdiag	0.2234	0.0886	0.0497	0.397
C.(X.smsc_PP_Dec,SST_Feb)	0.5498	0.1305	0.2940	0.806
C.(X.smsc_NP_Dec,SST_Feb)	0.5248	0.1461	0.2384	0.811
C.(X.smsc_PP_Dec,SST_Aug)	0.2898	0.1558	-0.0155	0.595
C.(X.smsc_NP_Dec,SST_Aug)	0.4707	0.1452	0.1862	0.755

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP Winter----Model 13.5  both
equations-Cov-in-Process")
 smsc only PP and NP Winter----Model 13.5  both equations-Cov-in-
Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
```



```
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 19 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 19 iterations.
Log-likelihood: -45.77624
AIC: 111.5525   AICc: 116.5525
```

	Estimate
B.(X.smsc_PP_Dec,X.smsc_PP_Dec)	-0.1330
B.(X.smsc_NP_Dec,X.smsc_NP_Dec)	-0.0439
Q.diag	0.2704
Q.offdiag	0.2267
x0.X.smsc_PP_Dec	1.8615
x0.X.smsc_NP_Dec	2.1826
C.(X.smsc_PP_Dec,SST_Feb)	0.5543
C.(X.smsc_NP_Dec,SST_Feb)	0.5370
C.(X.smsc_PP_Dec,SST_Aug)	0.2737
C.(X.smsc_NP_Dec,SST_Aug)	0.4719

Initial states (x0) defined at t=1

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
```

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 19 iterations.

Log-likelihood: -45.77624

AIC: 111.5525 AICc: 116.5525

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	-0.1330	0.1598	-0.4463	0.180
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	-0.0439	0.1516	-0.3411	0.253
Q.diag	0.2704	0.0892	0.0957	0.445
Q.offdiag	0.2267	0.0895	0.0513	0.402
x0.X.smsc_PP_Dec	1.8615	0.3594	1.1570	2.566
x0.X.smsc_NP_Dec	2.1826	0.3604	1.4762	2.889
C. (X.smsc_PP_Dec, SST_Feb)	0.5543	0.1356	0.2885	0.820
C. (X.smsc_NP_Dec, SST_Feb)	0.5370	0.1431	0.2564	0.818
C. (X.smsc_PP_Dec, SST_Aug)	0.2737	0.1562	-0.0325	0.580
C. (X.smsc_NP_Dec, SST_Aug)	0.4719	0.1465	0.1849	0.759

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP Winter----Model 13.5b both
equations-Cov-in-Observation")
 smsc only PP and NP Winter----Model 13.5b both equations-Cov-in-
Observation
> C <- c <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> D <- "unconstrained"
> d <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 35 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 35 iterations.
Log-likelihood: -44.16259
AIC: 108.3252   AICc: 113.3252
```

	Estimate
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	-0.3841
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	0.0434
Q.diag	0.2370
Q.offdiag	0.2055
x0.X.smsc_PP_Dec	1.2671
x0.X.smsc_NP_Dec	0.9077
D. (smsc_PP_Dec, SST_Feb)	0.5773
D. (smsc_NP_Dec, SST_Feb)	0.5118
D. (smsc_PP_Dec, SST_Aug)	0.2496
D. (smsc_NP_Dec, SST_Aug)	0.4796

Initial states (x0) defined at t=1

Standard errors have not been calculated.
 Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 35 iterations.
Log-likelihood: -44.16259
AIC: 108.3252   AICc: 113.3252
```

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	-0.3841	0.2010	-0.7780	0.00977
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	0.0434	0.2801	-0.5057	0.59243

Q.diag	0.2370	0.0819	0.0765	0.39753
Q.offdiag	0.2055	0.0824	0.0441	0.36694
x0.X.smsc_PP_Dec	1.2671	0.5181	0.2516	2.28253
x0.X.smsc_NP_Dec	0.9077	0.5134	-0.0986	1.91391
D.(smsc_PP_Dec,SST_Feb)	0.5773	0.1177	0.3466	0.80806
D.(smsc_NP_Dec,SST_Feb)	0.5118	0.1238	0.2690	0.75447
D.(smsc_PP_Dec,SST_Aug)	0.2496	0.1436	-0.0318	0.53096
D.(smsc_NP_Dec,SST_Aug)	0.4796	0.1359	0.2132	0.74593

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

>
> ##### Stop here#####

Table 2 in main article contains Model 13.4c Process only equation coefficients for PD snails in December shown below.

```
> writeLines(" smsc only PP and NP Winter----Model 13.3.1
Multivariate linear regression")
  smsc only PP and NP Winter----Model 13.3.1 Multivariate linear
regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -53.28106
AIC: 120.5621   AICc: 122.9451
```

	Estimate
R.diag	0.4064
D.(smc_PP_Dec,SST_Feb)	0.4908
D.(smc_NP_Dec,SST_Feb)	0.4979
D.(smc_PP_Dec,SST_Aug)	0.3480
D.(smc_NP_Dec,SST_Aug)	0.5820
D.(smc_PP_Dec,PACHY_Jul)	0.1538
D.(smc_NP_Dec,PACHY_Jul)	-0.0767

Initial states (x0) defined at t=0

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -53.28106

AIC: 120.5621 AICc: 122.9451

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.4064	0.0775	0.2545	0.558
D.(smsc_PP_Dec,SST_Feb)	0.4908	0.1254	0.2450	0.737
D.(smsc_NP_Dec,SST_Feb)	0.4979	0.1246	0.2537	0.742
D.(smsc_PP_Dec,SST_Aug)	0.3480	0.1341	0.0852	0.611
D.(smsc_NP_Dec,SST_Aug)	0.5820	0.1271	0.3328	0.831
D.(smsc_PP_Dec,PACHY_Jul)	0.1538	0.1255	-0.0922	0.400
D.(smsc_NP_Dec,PACHY_Jul)	-0.0767	0.1254	-0.3226	0.169

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP Winter----Model 13.3.1b
Multivariate linear regression-Q-equal----")
 smsc only PP and NP Winter----Model 13.3.1b Multivariate linear
regression-Q-equal----
> R <- A <- U <- "zero"; B <- Z <- "identity"
> Q <- "equalvarcov"
> C <- "unconstrained"
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -72.22329

AIC: 164.4466 AICc: 169.4466

	Estimate
Q.diag	1.1702
Q.offdiag	0.8601
x0.X.smsc_PP_Dec	2.0045
x0.X.smsc_NP_Dec	0.9211
C.(X.smsc_PP_Dec,SST_Feb)	0.2109
C.(X.smsc_NP_Dec,SST_Feb)	-0.0472
C.(X.smsc_PP_Dec,SST_Aug)	-0.0238
C.(X.smsc_NP_Dec,SST_Aug)	0.4615
C.(X.smsc_PP_Dec,PACHY_Jul)	0.2556
C.(X.smsc_NP_Dec,PACHY_Jul)	-0.0399

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
```

```
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -72.22329

AIC: 164.4466 AICc: 169.4466

	ML.Est	Std.Err	low.CI	up.CI
Q.diag	1.1702	0.276	0.6294	1.711
Q.offdiag	0.8601	0.277	0.3179	1.402
x0.X.smsc_PP_Dec	2.0045	1.322	-0.5871	4.596
x0.X.smsc_NP_Dec	0.9211	1.313	-1.6523	3.495
C.(X.smsc_PP_Dec,SST_Feb)	0.2109	0.214	-0.2081	0.630

```

C.(X.smsc_NP_Dec,SST_Feb)   -0.0472   0.213  -0.4641  0.370
C.(X.smsc_PP_Dec,SST_Aug)   -0.0238   0.267  -0.5462  0.499
C.(X.smsc_NP_Dec,SST_Aug)    0.4615   0.261  -0.0495  0.973
C.(X.smsc_PP_Dec,PACHY_Jul)  0.2556   0.220  -0.1750  0.686
C.(X.smsc_NP_Dec,PACHY_Jul) -0.0399   0.219  -0.4697  0.390
Initial states (x0) defined at t=0

```

CI's calculated at alpha = 0.05 via method=hessian

```

> writeLines(" smsc only PP and NP Winter----Model 13.3.2----")
 smsc only PP and NP Winter----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Warning! Abstol convergence only. Maxit (=500) reached before log-
log convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

WARNING: Abstol convergence only no log-log convergence.

maxit (=500) reached before log-log convergence.

The likelihood and params might not be at the ML values.

Try setting control\$maxit higher.

Log-likelihood: -44.22962

AIC: 112.4592 AICc: 119.8878

	Estimate
B.(X.smsc_PP_Dec,X.smsc_PP_Dec)	0.00275
B.(X.smsc_NP_Dec,X.smsc_NP_Dec)	0.03550
Q.diag	0.37028
Q.offdiag	0.22877
x0.X.smsc_PP_Dec	508.16336
x0.X.smsc_NP_Dec	24.56650
C.(X.smsc_PP_Dec,SST_Feb)	0.51365
C.(X.smsc_NP_Dec,SST_Feb)	0.49350
C.(X.smsc_PP_Dec,SST_Aug)	0.19533
C.(X.smsc_NP_Dec,SST_Aug)	0.48411
C.(X.smsc_PP_Dec,PACHY_Jul)	0.21032
C.(X.smsc_NP_Dec,PACHY_Jul)	-0.04167

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

Convergence warnings

Warning: the x0.X.smsc_PP_Dec parameter value has not converged.
Type MARSSinfo("convergence") for more info on this warning.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

WARNING: Abstol convergence only no log-log convergence.

maxit (=500) reached before log-log convergence.

The likelihood and params might not be at the ML values.

Try setting control\$maxit higher.

Log-likelihood: -44.22962

AIC: 112.4592 AICc: 119.8878

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	0.00275	1.19e-01	-2.31e-01	2.37e-01
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	0.03550	1.30e-01	-2.20e-01	2.91e-01
Q.diag	0.37028	8.27e-02	2.08e-01	5.32e-01
Q.offdiag	0.22877	8.29e-02	6.62e-02	3.91e-01
x0.X.smsc_PP_Dec	508.16336	2.21e+04	-4.28e+04	4.38e+04
x0.X.smsc_NP_Dec	24.56650	9.24e+01	-1.57e+02	2.06e+02
C. (X.smsc_PP_Dec, SST_Feb)	0.51365	1.26e-01	2.67e-01	7.60e-01
C. (X.smsc_NP_Dec, SST_Feb)	0.49350	1.40e-01	2.19e-01	7.68e-01

```

C.(X.smsc_PP_Dec,SST_Aug)      0.19533 1.57e-01 -1.12e-01 5.02e-
01
C.(X.smsc_NP_Dec,SST_Aug)      0.48411 1.47e-01  1.97e-01 7.72e-
01
C.(X.smsc_PP_Dec,PACHY_Jul)    0.21032 1.23e-01 -3.17e-02 4.52e-
01
C.(X.smsc_NP_Dec,PACHY_Jul)    -0.04167 1.23e-01 -2.83e-01 2.00e-
01

```

Initial states (x0) defined at t=0

CI's calculated at alpha = 0.05 via method=hessian

Convergence warnings

Warning: the x0.X.smsc_PP_Dec parameter value has not converged.
Type MARSSinfo("convergence") for more info on this warning.

```

> writeLines(" smsc only PP and NP Winter----Model 13.4c Process
only equation")
 smsc only PP and NP Winter----Model 13.4c Process only equation
> x0 <- dat[,1,drop=FALSE]
> model.list$tinitx <- 1
> model.list$x0 <- x0
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -43.23045

AIC: 106.4609 AICc: 111.4609

	Estimate
B.(X.smsc_PP_Dec,X.smsc_PP_Dec)	-0.1015
B.(X.smsc_NP_Dec,X.smsc_NP_Dec)	-0.0190
Q.diag	0.3778
Q.offdiag	0.2325

```

C. (X.smsc_PP_Dec, SST_Feb)          0.5458
C. (X.smsc_NP_Dec, SST_Feb)         0.5241
C. (X.smsc_PP_Dec, SST_Aug)         0.2173
C. (X.smsc_NP_Dec, SST_Aug)         0.4854
C. (X.smsc_PP_Dec, PACHY_Jul)       0.2059
C. (X.smsc_NP_Dec, PACHY_Jul)      -0.0418
Initial states (x0) defined at t=1

```

Standard errors have not been calculated.
 Use MARSSparamCIs to compute CIs and bias estimates.

```

> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian

```

```

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -43.23045
AIC: 106.4609   AICc: 111.4609

```

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	-0.1015	0.1207	-0.3381	0.135
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	-0.0190	0.1321	-0.2779	0.240
Q.diag	0.3778	0.0859	0.2095	0.546
Q.offdiag	0.2325	0.0861	0.0637	0.401
C. (X.smsc_PP_Dec, SST_Feb)	0.5458	0.1269	0.2970	0.795
C. (X.smsc_NP_Dec, SST_Feb)	0.5241	0.1417	0.2463	0.802
C. (X.smsc_PP_Dec, SST_Aug)	0.2173	0.1579	-0.0922	0.527
C. (X.smsc_NP_Dec, SST_Aug)	0.4854	0.1482	0.1950	0.776
C. (X.smsc_PP_Dec, PACHY_Jul)	0.2059	0.1247	-0.0385	0.450
C. (X.smsc_NP_Dec, PACHY_Jul)	-0.0418	0.1246	-0.2860	0.202

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

```

> writeLines(" smsc only PP and NP Winter----Model 13.5  both
equations-Cov-in-Process")

```

```

smc only PP and NP Winter----Model 13.5  both equations-Cov-in-
Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 35 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 35 iterations.

Log-likelihood: -43.17149

AIC: 110.343 AICc: 117.7715

	Estimate
B. (X.smc_PP_Dec, X.smc_PP_Dec)	-0.1171
B. (X.smc_NP_Dec, X.smc_NP_Dec)	-0.0491
Q.diag	0.2554
Q.offdiag	0.2310
x0.X.smc_PP_Dec	1.8590
x0.X.smc_NP_Dec	2.1805
C. (X.smc_PP_Dec, SST_Feb)	0.5512
C. (X.smc_NP_Dec, SST_Feb)	0.5391
C. (X.smc_PP_Dec, SST_Aug)	0.1935
C. (X.smc_NP_Dec, SST_Aug)	0.4900
C. (X.smc_PP_Dec, PACHY_Jul)	0.2083
C. (X.smc_NP_Dec, PACHY_Jul)	-0.0439

Initial states (x0) defined at t=1

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 35 iterations.

Log-likelihood: -43.17149

AIC: 110.343 AICc: 117.7715

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec,X.smsc_PP_Dec)	-0.1171	0.1515	-0.4141	0.180
B. (X.smsc_NP_Dec,X.smsc_NP_Dec)	-0.0491	0.1457	-0.3347	0.236
Q.diag	0.2554	0.0870	0.0849	0.426
Q.offdiag	0.2310	0.0873	0.0599	0.402
x0.X.smsc_PP_Dec	1.8590	0.3596	1.1542	2.564
x0.X.smsc_NP_Dec	2.1805	0.3604	1.4742	2.887
C. (X.smsc_PP_Dec,SST_Feb)	0.5512	0.1326	0.2913	0.811
C. (X.smsc_NP_Dec,SST_Feb)	0.5391	0.1393	0.2660	0.812
C. (X.smsc_PP_Dec,SST_Aug)	0.1935	0.1595	-0.1190	0.506
C. (X.smsc_NP_Dec,SST_Aug)	0.4900	0.1510	0.1941	0.786
C. (X.smsc_PP_Dec,PACHY_Jul)	0.2083	0.1266	-0.0399	0.456
C. (X.smsc_NP_Dec,PACHY_Jul)	-0.0439	0.1264	-0.2916	0.204

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" smsc only PP and NP Winter----Model 13.5b both
equations-Cov-in-Observation")
```

```
 smsc only PP and NP Winter----Model 13.5b both equations-Cov-in-
Observation
```

```
> C <- c <- A <- U <- "zero"; Z <- "identity"
```

```
> B <- "diagonal and unequal"
```

```
> Q <- "equalvarcov"
```

```
> D <- "unconstrained"
```

```
> d <- covariates
```

```
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 87 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 87 iterations.

Log-likelihood: -40.65258

AIC: 105.3052 AICc: 112.7337

	Estimate
B. (X.smsc_PP_Dec,X.smsc_PP_Dec)	-0.4123
B. (X.smsc_NP_Dec,X.smsc_NP_Dec)	0.0399
Q.diag	0.2164
Q.offdiag	0.2084
x0.X.smsc_PP_Dec	1.5040
x0.X.smsc_NP_Dec	0.7792
D. (smsc_PP_Dec,SST_Feb)	0.5889
D. (smsc_NP_Dec,SST_Feb)	0.5159
D. (smsc_PP_Dec,SST_Aug)	0.1945
D. (smsc_NP_Dec,SST_Aug)	0.5172
D. (smsc_PP_Dec,PACHY_Jul)	0.2202
D. (smsc_NP_Dec,PACHY_Jul)	-0.0497

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 87 iterations.

Log-likelihood: -40.65258

AIC: 105.3052 AICc: 112.7337

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsc_PP_Dec, X.smsc_PP_Dec)	-0.4123	0.1823	-0.76964	-0.055
B. (X.smsc_NP_Dec, X.smsc_NP_Dec)	0.0399	0.2756	-0.50031	0.580
Q.diag	0.2164	0.0784	0.06286	0.370
Q.offdiag	0.2084	0.0791	0.05341	0.363
x0.X.smsc_PP_Dec	1.5040	0.5191	0.48656	2.521
x0.X.smsc_NP_Dec	0.7792	0.5308	-0.26125	1.820
D. (smsc_PP_Dec, SST_Feb)	0.5889	0.1131	0.36725	0.811
D. (smsc_NP_Dec, SST_Feb)	0.5159	0.1172	0.28622	0.746
D. (smsc_PP_Dec, SST_Aug)	0.1945	0.1415	-0.08285	0.472
D. (smsc_NP_Dec, SST_Aug)	0.5172	0.1369	0.24882	0.786
D. (smsc_PP_Dec, PACHY_Jul)	0.2202	0.1103	0.00402	0.436
D. (smsc_NP_Dec, PACHY_Jul)	-0.0497	0.1152	-0.27537	0.176

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

>

> ##### Stop here#####

Output S4: MARSS output from all six model classes for DD snails in December.

Table 1 in main article contains Model 13.4c Process only equation coefficients for DD snails in December shown below.

```
> writeLines(" sm only PP and NP Winter----Model 13.3.1
Multivariate linear regression")
  sm only PP and NP Winter----Model 13.3.1 Multivariate linear
regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -65.8722
AIC: 145.7444   AICc: 148.1274
```

	Estimate
R.diag	0.6424
D.(smsub_PP_Dec,SSTbuoy_Feb)	-0.4758
D.(smsub_NP_Dec,SSTbuoy_Feb)	-0.3780
D.(smsub_PP_Dec,Salinity_Jul)	0.0948
D.(smsub_NP_Dec,Salinity_Jul)	0.2215
D.(smsub_PP_Dec,CB_meanmax_air_Jul)	-0.2657
D.(smsub_NP_Dec,CB_meanmax_air_Jul)	0.0701

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -65.8722

AIC: 145.7444 AICc: 148.1274

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.6424	0.123	0.402	0.8825
D.(smsub_PP_Dec,SSTbuoy_Feb)	-0.4758	0.169	-0.807	-0.1448
D.(smsub_NP_Dec,SSTbuoy_Feb)	-0.3780	0.169	-0.709	-0.0471
D.(smsub_PP_Dec,Salinity_Jul)	0.0948	0.168	-0.234	0.4238
D.(smsub_NP_Dec,Salinity_Jul)	0.2215	0.166	-0.104	0.5470
D.(smsub_PP_Dec,CB_meanmax_air_Jul)	-0.2657	0.165	-0.588	0.0568
D.(smsub_NP_Dec,CB_meanmax_air_Jul)	0.0701	0.164	-0.252	0.3919

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.3.1b Multivariate
linear regression-Q-equal----")
  sm only PP and NP Winter----Model 13.3.1b Multivariate linear
regression-Q-equal----
> R <- A <- U <- "zero"; B <- Z <- "identity"
> Q <- "equalvarcov"
> C <- "unconstrained"
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
> kem <- MARSS(dat, model=model.list)
```

Success! algorithm run for 15 iterations. abstol and log-log tests passed.

Alert: conv.test.slope.tol is 0.5.

Test with smaller values (<0.1) to ensure convergence.

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -71.73144

AIC: 163.4629 AICc: 168.4629

	Estimate
Q.diag	0.8674
Q.offdiag	0.3720
x0.X.smsub_PP_Dec	-0.4234
x0.X.smsub_NP_Dec	-0.2444
C.(X.smsub_PP_Dec,SSTbuoy_Feb)	-0.5202
C.(X.smsub_NP_Dec,SSTbuoy_Feb)	-0.4107
C.(X.smsub_PP_Dec,Salinity_Jul)	-0.3194
C.(X.smsub_NP_Dec,Salinity_Jul)	0.0456
C.(X.smsub_PP_Dec,CB_meanmax_air_Jul)	-0.1503
C.(X.smsub_NP_Dec,CB_meanmax_air_Jul)	0.4056

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -71.73144

AIC: 163.4629 AICc: 168.4629

	ML.Est	Std.Err	low.CI
up.CI			
Q.diag 1.2197	0.8674	0.180	0.5151
Q.offdiag 0.7269	0.3720	0.181	0.0171
x0.X.smsub_PP_Dec 1.4115	-0.4234	0.936	-2.2584
x0.X.smsub_NP_Dec 1.5905	-0.2444	0.936	-2.0793
C.(X.smsub_PP_Dec,SSTbuoy_Feb) 0.1334	-0.5202	0.197	-0.9070 -
C.(X.smsub_NP_Dec,SSTbuoy_Feb) 0.0262	-0.4107	0.196	-0.7952 -
C.(X.smsub_PP_Dec,Salinity_Jul) 0.0605	-0.3194	0.194	-0.6994
C.(X.smsub_NP_Dec,Salinity_Jul) 0.4255	0.0456	0.194	-0.3342
C.(X.smsub_PP_Dec,CB_meanmax_air_Jul) 0.2307	-0.1503	0.194	-0.5312
C.(X.smsub_NP_Dec,CB_meanmax_air_Jul) 0.7797	0.4056	0.191	0.0316

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.3.2----")
  sm only PP and NP Winter----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -58.62461

AIC: 141.2492 AICc: 148.6778

	Estimate
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.1552
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.3715
Q.diag	0.5758
Q.offdiag	0.2991
x0.X.smsub_PP_Dec	-4.0206
x0.X.smsub_NP_Dec	-0.9258
C. (X.smsub_PP_Dec, SSTbuoy_Feb)	-0.4845
C. (X.smsub_NP_Dec, SSTbuoy_Feb)	-0.3895
C. (X.smsub_PP_Dec, Salinity_Jul)	0.0403
C. (X.smsub_NP_Dec, Salinity_Jul)	0.1611
C. (X.smsub_PP_Dec, CB_meanmax_air_Jul)	-0.2443
C. (X.smsub_NP_Dec, CB_meanmax_air_Jul)	0.1939

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -58.62461

AIC: 141.2492 AICc: 148.6778

	ML.Est	Std.Err	low.CI
up.CI			
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.1552	0.171	-0.1809
0.4912			
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.3715	0.155	0.0670
0.6759			

Q.diag 0.8177	0.5758	0.123	0.3338
Q.offdiag 0.5420	0.2991	0.124	0.0562
x0.X.smsub_PP_Dec 9.3067	-4.0206	6.800	-17.3480
x0.X.smsub_NP_Dec 3.1958	-0.9258	2.103	-5.0473
C.(X.smsub_PP_Dec,SSTbuoy_Feb) 0.1704	-0.4845	0.160	-0.7986 -
C.(X.smsub_NP_Dec,SSTbuoy_Feb) 0.0761	-0.3895	0.160	-0.7030 -
C.(X.smsub_PP_Dec,Salinity_Jul) 0.3790	0.0403	0.173	-0.2984
C.(X.smsub_NP_Dec,Salinity_Jul) 0.4756	0.1611	0.160	-0.1534
C.(X.smsub_PP_Dec,CB_meanmax_air_Jul) 0.0651	-0.2443	0.158	-0.5537
C.(X.smsub_NP_Dec,CB_meanmax_air_Jul) 0.5154	0.1939	0.164	-0.1276

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.4c Process only equation")
```

```
sm only PP and NP Winter----Model 13.4c Process only equation
```

```
> x0 <- dat[,1,drop=FALSE]
```

```
> model.list$tinitx <- 1
```

```
> model.list$x0 <- x0
```

```
> kem <- MARSS(dat, model=model.list)
```

Success! algorithm run for 15 iterations. abstol and log-log tests passed.

Alert: conv.test.slope.tol is 0.5.

Test with smaller values (<0.1) to ensure convergence.

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -57.47768

AIC: 134.9554 AICc: 139.9554

	Estimate
B. (X.smsub_PP_Dec,X.smsub_PP_Dec)	0.1545
B. (X.smsub_NP_Dec,X.smsub_NP_Dec)	0.3714
Q.diag	0.5974
Q.offdiag	0.3103
C. (X.smsub_PP_Dec,SSTbuoy_Feb)	-0.4844
C. (X.smsub_NP_Dec,SSTbuoy_Feb)	-0.3895
C. (X.smsub_PP_Dec,Salinity_Jul)	0.0407
C. (X.smsub_NP_Dec,Salinity_Jul)	0.1611
C. (X.smsub_PP_Dec,CB_meanmax_air_Jul)	-0.2445
C. (X.smsub_NP_Dec,CB_meanmax_air_Jul)	0.1939

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -57.47768

AIC: 134.9554 AICc: 139.9554

	ML.Est	Std.Err	low.CI
up.CI			
B. (X.smsub_PP_Dec,X.smsub_PP_Dec)	0.1545	0.175	-0.1879
0.4968			
B. (X.smsub_NP_Dec,X.smsub_NP_Dec)	0.3714	0.158	0.0612
0.6815			
Q.diag	0.5974	0.130	0.3418
0.8531			
Q.offdiag	0.3103	0.131	0.0536
0.5671			

C. (X.smsub_PP_Dec, SSTbuoy_Feb)	-0.4844	0.163	-0.8044	-
0.1645				
C. (X.smsub_NP_Dec, SSTbuoy_Feb)	-0.3895	0.163	-0.7088	-
0.0702				
C. (X.smsub_PP_Dec, Salinity_Jul)	0.0407	0.176	-0.3044	
0.3857				
C. (X.smsub_NP_Dec, Salinity_Jul)	0.1611	0.163	-0.1593	
0.4815				
C. (X.smsub_PP_Dec, CB_meanmax_air_Jul)	-0.2445	0.161	-0.5596	
0.0707				
C. (X.smsub_NP_Dec, CB_meanmax_air_Jul)	0.1939	0.167	-0.1337	
0.5214				

Initial states (x0) defined at t=1

CIs calculated at alpha = 0.05 via method=hessian

```

> residuals.model.2 <- residuals(kem)
>
write.csv(residuals.model.2, "residuals.model.2.smsubW.SSTbuoyFeb.Sa
linityJul.CB_maxairJul.csv")
> coef.model.2 <- coef(kem)
> sink(file =
"coef.model.2.smsubW.SSTbuoyFeb.SalinityJul.CB_maxairJul.txt")
> print(coef.model.2)
> sink(NULL)
> writeLines(" sm only PP and NP Winter----Model 13.5  both
equations-Cov-in-Process")
  sm only PP and NP Winter----Model 13.5  both equations-Cov-in-
Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 18 iterations.

```

Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 18 iterations.
Log-likelihood: -57.11144
AIC: 138.2229 AICc: 145.6514

	Estimate
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.1715
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.4335
Q.diag	0.4453
Q.offdiag	0.2978
x0.X.smsub_PP_Dec	-0.5614
x0.X.smsub_NP_Dec	-0.1573
C. (X.smsub_PP_Dec, SSTbuoy_Feb)	-0.4679
C. (X.smsub_NP_Dec, SSTbuoy_Feb)	-0.4145
C. (X.smsub_PP_Dec, Salinity_Jul)	0.0413
C. (X.smsub_NP_Dec, Salinity_Jul)	0.1666
C. (X.smsub_PP_Dec, CB_meanmax_air_Jul)	-0.2393
C. (X.smsub_NP_Dec, CB_meanmax_air_Jul)	0.1950

Initial states (x0) defined at t=1

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 18 iterations.
Log-likelihood: -57.11144
AIC: 138.2229 AICc: 145.6514

	ML.Est	Std.Err	low.CI
up.CI			
B. (X.smsub_PP_Dec, X.smsub_PP_Dec) 0.5490	0.1715	0.193	-0.2061
B. (X.smsub_NP_Dec, X.smsub_NP_Dec) 0.7895	0.4335	0.182	0.0775
Q.diag 0.6948	0.4453	0.127	0.1958
Q.offdiag 0.5471	0.2978	0.127	0.0486
x0.X.smsub_PP_Dec 0.1424	-0.5614	0.359	-1.2652
x0.X.smsub_NP_Dec 0.5304	-0.1573	0.351	-0.8451
C. (X.smsub_PP_Dec, SSTbuoy_Feb) 0.1548	-0.4679	0.160	-0.7811 -
C. (X.smsub_NP_Dec, SSTbuoy_Feb) 0.0989	-0.4145	0.161	-0.7301 -
C. (X.smsub_PP_Dec, Salinity_Jul) 0.3754	0.0413	0.170	-0.2929
C. (X.smsub_NP_Dec, Salinity_Jul) 0.4813	0.1666	0.161	-0.1480
C. (X.smsub_PP_Dec, CB_meanmax_air_Jul) 0.0742	-0.2393	0.160	-0.5529
C. (X.smsub_NP_Dec, CB_meanmax_air_Jul) 0.5196	0.1950	0.166	-0.1296

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.5b both
equations-Cov-in-Observation")
  sm only PP and NP Winter----Model 13.5b both equations-Cov-in-
Observation
> C <- c <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> D <- "unconstrained"
> d <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
```

```
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 31 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 31 iterations.

Log-likelihood: -58.40532

AIC: 140.8106 AICc: 148.2392

	Estimate
B.(X.smsub_PP_Dec,X.smsub_PP_Dec)	0.461764
B.(X.smsub_NP_Dec,X.smsub_NP_Dec)	0.509472
Q.diag	0.478579
Q.offdiag	0.314591
x0.X.smsub_PP_Dec	-0.696642
x0.X.smsub_NP_Dec	-0.172836
D.(smsub_PP_Dec,SSTbuoy_Feb)	-0.537188
D.(smsub_NP_Dec,SSTbuoy_Feb)	-0.314069
D.(smsub_PP_Dec,Salinity_Jul)	-0.081446
D.(smsub_NP_Dec,Salinity_Jul)	-0.000623
D.(smsub_PP_Dec,CB_meanmax_air_Jul)	-0.207988
D.(smsub_NP_Dec,CB_meanmax_air_Jul)	0.207944

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 31 iterations.

Log-likelihood: -58.40532

AIC: 140.8106 AICc: 148.2392

	ML.Est	Std.Err	low.CI
up.CI			
B. (X.smsub_PP_Dec, X.smsub_PP_Dec) 0.98851	0.461764	0.269	-0.0650
B. (X.smsub_NP_Dec, X.smsub_NP_Dec) 0.90771	0.509472	0.203	0.1112
Q.diag 0.74912	0.478579	0.138	0.2080
Q.offdiag 0.58056	0.314591	0.136	0.0486
x0.X.smsub_PP_Dec 0.02180	-0.696642	0.367	-1.4151
x0.X.smsub_NP_Dec 0.53281	-0.172836	0.360	-0.8785
D. (smsub_PP_Dec, SSTbuoy_Feb) 0.20817	-0.537188	0.168	-0.8662 -
D. (smsub_NP_Dec, SSTbuoy_Feb) 0.00274	-0.314069	0.162	-0.6309
D. (smsub_PP_Dec, Salinity_Jul) 0.28077	-0.081446	0.185	-0.4437
D. (smsub_NP_Dec, Salinity_Jul) 0.34486	-0.000623	0.176	-0.3461
D. (smsub_PP_Dec, CB_meanmax_air_Jul) 0.10181	-0.207988	0.158	-0.5178
D. (smsub_NP_Dec, CB_meanmax_air_Jul) 0.52625	0.207944	0.162	-0.1104

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

>

> ##### Stop here#####

Table 2 in main article contains Model 13.4c Process only equation coefficients for DD snails in December shown below.

```
> writeLines(" sm only PP and NP Winter----Model 13.3.1
Multivariate linear regression")
  sm only PP and NP Winter----Model 13.3.1 Multivariate linear
regression
> Q <- U <- x0 <- "zero"; B <- Z <- "identity"
> d <- covariates
> A <- "zero"
> D <- "unconstrained"
> y <- dat
>
> # to show relationship between dat & the equation
>
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,D=D,d=d,x0=x0)
> kem <- MARSS(y, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -72.97702
AIC: 159.954   AICc: 162.337
```

	Estimate
R.diag	0.8318
D.(smsub_PP_Dec,SST_Feb)	-0.3837
D.(smsub_NP_Dec,SST_Feb)	-0.1987
D.(smsub_PP_Dec,SST_Aug)	-0.2057
D.(smsub_NP_Dec,SST_Aug)	-0.1036
D.(smsub_PP_Dec,PACHY_Jul)	0.0795
D.(smsub_NP_Dec,PACHY_Jul)	0.0600

Initial states (x0) defined at t=0

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -72.97702

AIC: 159.954 AICc: 162.337

	ML.Est	Std.Err	low.CI	up.CI
R.diag	0.8318	0.159	0.521	1.143
D.(smsub_PP_Dec,SST_Feb)	-0.3837	0.179	-0.735	-0.032
D.(smsub_NP_Dec,SST_Feb)	-0.1987	0.178	-0.548	0.151
D.(smsub_PP_Dec,SST_Aug)	-0.2057	0.192	-0.582	0.170
D.(smsub_NP_Dec,SST_Aug)	-0.1036	0.182	-0.460	0.253
D.(smsub_PP_Dec,PACHY_Jul)	0.0795	0.180	-0.272	0.431
D.(smsub_NP_Dec,PACHY_Jul)	0.0600	0.179	-0.292	0.412

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.3.1b Multivariate
linear regression-Q-equal----")
```

```
  sm only PP and NP Winter----Model 13.3.1b Multivariate linear
regression-Q-equal----
```

```
> R <- A <- U <- "zero"; B <- Z <- "identity"
```

```
> Q <- "equalvarcov"
```

```
> C <- "unconstrained"
```

```
> model.list <- list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,C=C,c=covariates)
```

```
> kem <- MARSS(dat, model=model.list)
```

Success! algorithm run for 15 iterations. abstol and log-log tests passed.

Alert: conv.test.slope.tol is 0.5.

Test with smaller values (<0.1) to ensure convergence.

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -76.09329

AIC: 172.1866 AICc: 177.1866

	Estimate
Q.diag	0.9923
Q.offdiag	0.3751
x0.X.smsub_PP_Dec	-0.6442
x0.X.smsub_NP_Dec	-0.7817
C.(X.smsub_PP_Dec,SST_Feb)	-0.3753
C.(X.smsub_NP_Dec,SST_Feb)	-0.3269
C.(X.smsub_PP_Dec,SST_Aug)	0.0359
C.(X.smsub_NP_Dec,SST_Aug)	0.2195
C.(X.smsub_PP_Dec,PACHY_Jul)	-0.1019
C.(X.smsub_NP_Dec,PACHY_Jul)	0.1322

Initial states (x0) defined at t=0

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

>

> #request confidence limits on parameters

> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)

> kem.with.CIs.from.hessian

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Algorithm ran 15 (=minit) iterations and convergence was reached.

Log-likelihood: -76.09329

AIC: 172.1866 AICc: 177.1866

	ML.Est	Std.Err	low.CI	up.CI
Q.diag	0.9923	0.202	0.596	1.3886

```

Q.offdiag          0.3751    0.205 -0.026 0.7762
x0.X.smsub_PP_Dec -0.6442    1.225 -3.045 1.7566
x0.X.smsub_NP_Dec -0.7817    1.209 -3.151 1.5880
C.(X.smsub_PP_Dec,SST_Feb) -0.3753    0.198 -0.763 0.0122
C.(X.smsub_NP_Dec,SST_Feb) -0.3269    0.196 -0.711 0.0569
C.(X.smsub_PP_Dec,SST_Aug)  0.0359    0.250 -0.454 0.5257
C.(X.smsub_NP_Dec,SST_Aug)  0.2195    0.240 -0.251 0.6901
C.(X.smsub_PP_Dec,PACHY_Jul) -0.1019    0.203 -0.499 0.2952
C.(X.smsub_NP_Dec,PACHY_Jul) 0.1322    0.202 -0.264 0.5280
Initial states (x0) defined at t=0

```

CI's calculated at alpha = 0.05 via method=hessian

```

> writeLines(" sm only PP and NP Winter----Model 13.3.2----")
  sm only PP and NP Winter----Model 13.3.2----
> model.list$B <- "diagonal and unequal"
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 16 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 16 iterations.

Log-likelihood: -65.13764

AIC: 154.2753 AICc: 161.7039

```

                                     Estimate
B.(X.smsub_PP_Dec,X.smsub_PP_Dec)  0.23974
B.(X.smsub_NP_Dec,X.smsub_NP_Dec)  0.35716
Q.diag                               0.72397
Q.offdiag                             0.36854
x0.X.smsub_PP_Dec                    -0.09978
x0.X.smsub_NP_Dec                    -0.62460
C.(X.smsub_PP_Dec,SST_Feb)          -0.37793
C.(X.smsub_NP_Dec,SST_Feb)          -0.24352
C.(X.smsub_PP_Dec,SST_Aug)          -0.16819
C.(X.smsub_NP_Dec,SST_Aug)          0.00557

```

```
C.(X.smsub_PP_Dec,PACHY_Jul)      0.03961
C.(X.smsub_NP_Dec,PACHY_Jul)      0.08806
Initial states (x0) defined at t=0
```

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Estimation converged in 16 iterations.
Log-likelihood: -65.13764
AIC: 154.2753   AICc: 161.7039
```

	ML.Est	Std.Err	low.CI	up.CI
B.(X.smsub_PP_Dec,X.smsub_PP_Dec)	0.23974	0.172	-0.0982	0.5777
B.(X.smsub_NP_Dec,X.smsub_NP_Dec)	0.35716	0.169	0.0252	0.6891
Q.diag	0.72397	0.155	0.4210	1.0269
Q.offdiag	0.36854	0.155	0.0642	0.6728
x0.X.smsub_PP_Dec	-0.09978	4.402	-8.7278	8.5283
x0.X.smsub_NP_Dec	-0.62460	2.894	-6.2964	5.0472
C.(X.smsub_PP_Dec,SST_Feb)	-0.37793	0.169	-0.7089	-0.0470
C.(X.smsub_NP_Dec,SST_Feb)	-0.24352	0.169	-0.5742	0.0872
C.(X.smsub_PP_Dec,SST_Aug)	-0.16819	0.220	-0.5993	0.2629
C.(X.smsub_NP_Dec,SST_Aug)	0.00557	0.213	-0.4113	0.4224
C.(X.smsub_PP_Dec,PACHY_Jul)	0.03961	0.175	-0.3043	0.3835
C.(X.smsub_NP_Dec,PACHY_Jul)	0.08806	0.173	-0.2508	0.4269

Initial states (x0) defined at t=0

CIs calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.4c Process only
equation")
sm only PP and NP Winter----Model 13.4c Process only equation
```



```
> x0 <- dat[,1,drop=FALSE]
> model.list$tinitx <- 1
> model.list$x0 <- x0
> kem <- MARSS(dat, model=model.list)
Success! algorithm run for 15 iterations. abstol and log-log tests
passed.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

```
MARSS fit is
Estimation method: kem
Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
Algorithm ran 15 (=minit) iterations and convergence was reached.
Log-likelihood: -63.75433
AIC: 147.5087   AICc: 152.5087
```

	Estimate
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.23957
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.35713
Q.diag	0.75118
Q.offdiag	0.38223
C. (X.smsub_PP_Dec, SST_Feb)	-0.37794
C. (X.smsub_NP_Dec, SST_Feb)	-0.24352
C. (X.smsub_PP_Dec, SST_Aug)	-0.16824
C. (X.smsub_NP_Dec, SST_Aug)	0.00556
C. (X.smsub_PP_Dec, PACHY_Jul)	0.03964
C. (X.smsub_NP_Dec, PACHY_Jul)	0.08806

Initial states (x0) defined at t=1

Standard errors have not been calculated.
Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

```
MARSS fit is
Estimation method: kem
```

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001
 Algorithm ran 15 (=minit) iterations and convergence was reached.
 Log-likelihood: -63.75433
 AIC: 147.5087 AICc: 152.5087

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.23957	0.176	-0.1047	0.5838
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.35713	0.173	0.0190	0.6953
Q.diag	0.75118	0.163	0.4310	1.0713
Q.offdiag	0.38223	0.164	0.0606	0.7039
C. (X.smsub_PP_Dec, SST_Feb)	-0.37794	0.172	-0.7151	-0.0408
C. (X.smsub_NP_Dec, SST_Feb)	-0.24352	0.172	-0.5804	0.0933
C. (X.smsub_PP_Dec, SST_Aug)	-0.16824	0.224	-0.6074	0.2709
C. (X.smsub_NP_Dec, SST_Aug)	0.00556	0.217	-0.4190	0.4302
C. (X.smsub_PP_Dec, PACHY_Jul)	0.03964	0.179	-0.3107	0.3900
C. (X.smsub_NP_Dec, PACHY_Jul)	0.08806	0.176	-0.2571	0.4332

Initial states (x0) defined at t=1

CI's calculated at alpha = 0.05 via method=hessian

```
> writeLines(" sm only PP and NP Winter----Model 13.5  both
equations-Cov-in-Process")
  sm only PP and NP Winter----Model 13.5  both equations-Cov-in-
Process
> D <- d <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> C <- "unconstrained"
> c <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 17 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 17 iterations.

Log-likelihood: -63.43169

AIC: 150.8634 AICc: 158.2919

	Estimate
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.2851
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.4298
Q.diag	0.5991
Q.offdiag	0.3744
x0.X.smsub_PP_Dec	-0.5961
x0.X.smsub_NP_Dec	-0.1394
C. (X.smsub_PP_Dec, SST_Feb)	-0.3726
C. (X.smsub_NP_Dec, SST_Feb)	-0.2684
C. (X.smsub_PP_Dec, SST_Aug)	-0.1468
C. (X.smsub_NP_Dec, SST_Aug)	0.0210
C. (X.smsub_PP_Dec, PACHY_Jul)	0.0433
C. (X.smsub_NP_Dec, PACHY_Jul)	0.0720

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 17 iterations.

Log-likelihood: -63.43169

AIC: 150.8634 AICc: 158.2919

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.2851	0.197	-0.1001	0.6703

B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.4298	0.202	0.0340	0.8256
Q.diag	0.5991	0.162	0.2820	0.9161
Q.offdiag	0.3744	0.161	0.0587	0.6901
x0.X.smsub_PP_Dec	-0.5961	0.358	-1.2969	0.1047
x0.X.smsub_NP_Dec	-0.1394	0.354	-0.8324	0.5537
C. (X.smsub_PP_Dec, SST_Feb)	-0.3726	0.170	-0.7067	-0.0385
C. (X.smsub_NP_Dec, SST_Feb)	-0.2684	0.171	-0.6031	0.0662
C. (X.smsub_PP_Dec, SST_Aug)	-0.1468	0.222	-0.5822	0.2885
C. (X.smsub_NP_Dec, SST_Aug)	0.0210	0.218	-0.4060	0.4481
C. (X.smsub_PP_Dec, PACHY_Jul)	0.0433	0.175	-0.3002	0.3868
C. (X.smsub_NP_Dec, PACHY_Jul)	0.0720	0.174	-0.2689	0.4128

Initial states (x0) defined at t=1

CIIs calculated at alpha = 0.05 via method=hessian

```

>
>
> ## ----Model 13.5b both equations-Cov-in-Observation-----
-----
>
> writeLines(" sm only PP and NP Winter----Model 13.5b both
equations-Cov-in-Observation")
  sm only PP and NP Winter----Model 13.5b both equations-Cov-in-
Observation
> C <- c <- A <- U <- "zero"; Z <- "identity"
> B <- "diagonal and unequal"
> Q <- "equalvarcov"
> D <- "unconstrained"
> d <- covariates
> R <- diag(0.13,2)
> x0 <- "unequal"
> tinitx <- 1
> model.list <-
list(B=B,U=U,Q=Q,Z=Z,A=A,R=R,D=D,d=d,C=C,c=c,x0=x0,tinitx=tinitx)
> kem <- MARSS(dat, model=model.list)
Success! abstol and log-log tests passed at 55 iterations.
Alert: conv.test.slope.tol is 0.5.
Test with smaller values (<0.1) to ensure convergence.

```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 55 iterations.

Log-likelihood: -63.9738

AIC: 151.9476 AICc: 159.3762

	Estimate
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.3762
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)	0.4047
Q.diag	0.6325
Q.offdiag	0.4168
x0.X.smsub_PP_Dec	-0.4387
x0.X.smsub_NP_Dec	-0.1412
D. (smsub_PP_Dec, SST_Feb)	-0.3575
D. (smsub_NP_Dec, SST_Feb)	-0.1190
D. (smsub_PP_Dec, SST_Aug)	-0.0666
D. (smsub_NP_Dec, SST_Aug)	0.0143
D. (smsub_PP_Dec, PACHY_Jul)	0.0228
D. (smsub_NP_Dec, PACHY_Jul)	0.1216

Initial states (x0) defined at t=1

Standard errors have not been calculated.

Use MARSSparamCIs to compute CIs and bias estimates.

```
>
> #request confidence limits on parameters
> kem.with.CIs.from.hessian <- MARSSparamCIs(kem)
> kem.with.CIs.from.hessian
```

MARSS fit is

Estimation method: kem

Convergence test: conv.test.slope.tol = 0.5, abstol = 0.001

Estimation converged in 55 iterations.

Log-likelihood: -63.9738

AIC: 151.9476 AICc: 159.3762

	ML.Est	Std.Err	low.CI	up.CI
B. (X.smsub_PP_Dec, X.smsub_PP_Dec)	0.3762	0.229	-0.0718	0.8241

```
B. (X.smsub_NP_Dec, X.smsub_NP_Dec)  0.4047  0.201  0.0111  0.7982
Q.diag                               0.6325  0.172  0.2956  0.9695
Q.offdiag                             0.4168  0.171  0.0820  0.7516
x0.X.smsub_PP_Dec                     -0.4387  0.695 -1.8000  0.9225
x0.X.smsub_NP_Dec                      -0.1412  0.672 -1.4585  1.1762
D. (smsub_PP_Dec, SST_Feb)             -0.3575  0.171 -0.6918 -0.0232
D. (smsub_NP_Dec, SST_Feb)            -0.1190  0.170 -0.4525  0.2146
D. (smsub_PP_Dec, SST_Aug)            -0.0666  0.217 -0.4912  0.3580
D. (smsub_NP_Dec, SST_Aug)            0.0143  0.208 -0.3941  0.4226
D. (smsub_PP_Dec, PACHY_Jul)          0.0228  0.178 -0.3256  0.3712
D. (smsub_NP_Dec, PACHY_Jul)          0.1216  0.175 -0.2220  0.4652
Initial states (x0) defined at t=1
```

CIs calculated at alpha = 0.05 via method=hessian

```
>
> ##### Stop here#####
```