Model Skills and Uncertainties

An evaluation of model prediction performance against observations at eight LBA-MIP sites

- Latent Heat Flux -

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Acknowledgements

- *LBA-DMIP team*
- *Modeling teams*
- *Michel Muza*
- *Grayson Badgley*
- *Biosphere 2*

Data

- Hourly observations for multiple years of key meteorological/biophysical variables, with corresponding model predictions
- We average all data to the monthly scale

The challenge

- Identify which models perform well against the observations (assumption: perfect observations)
- Identify potentially problematic sites & models

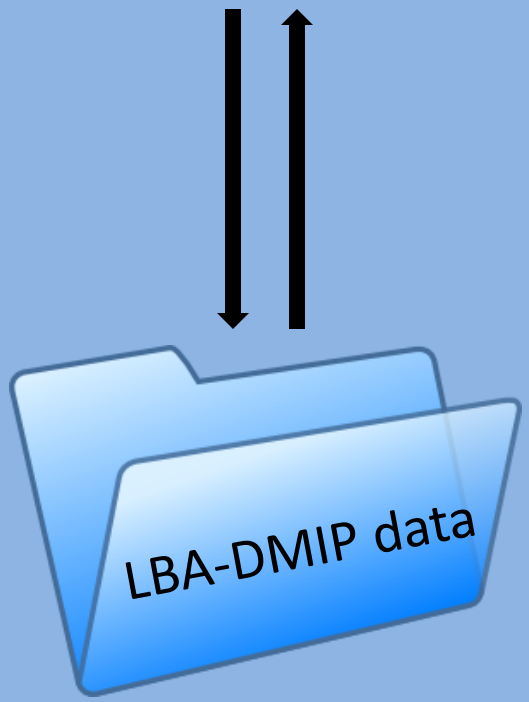
Method

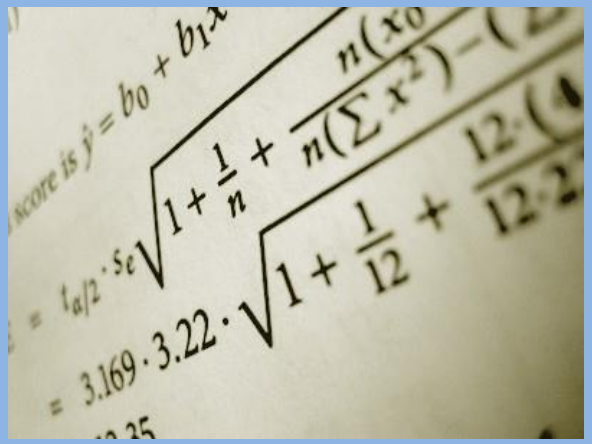
- Plot time series
- Bias (MBE), spread (RMSE), and agreement (R^2) on a per-site/per-model basis

Broad objective: a protocol for automated analysis

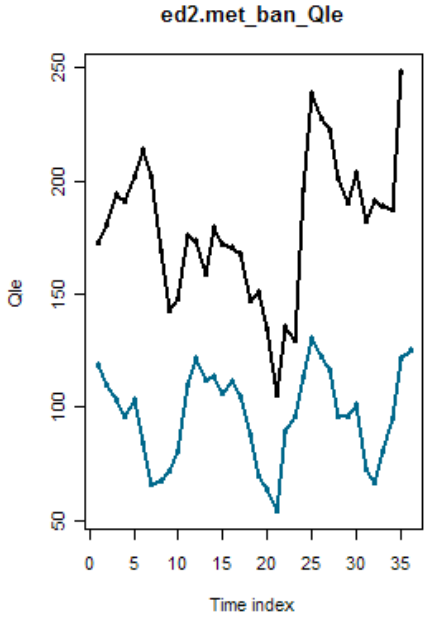
Select:

- Variables of interest and corresponding model output
- Whether daily or monthly averages of hourly data are desire
- Daytime or daily averages





Monthly time series plots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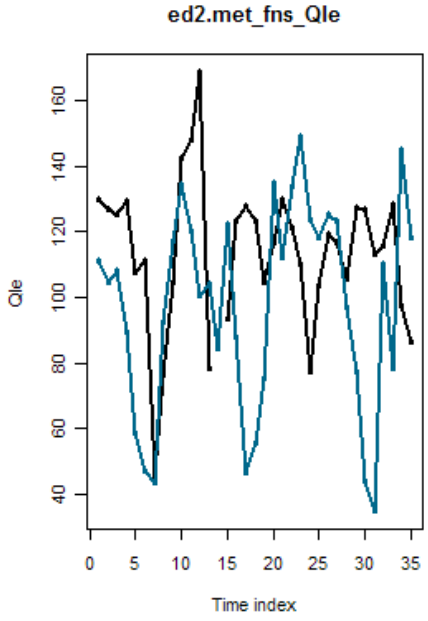
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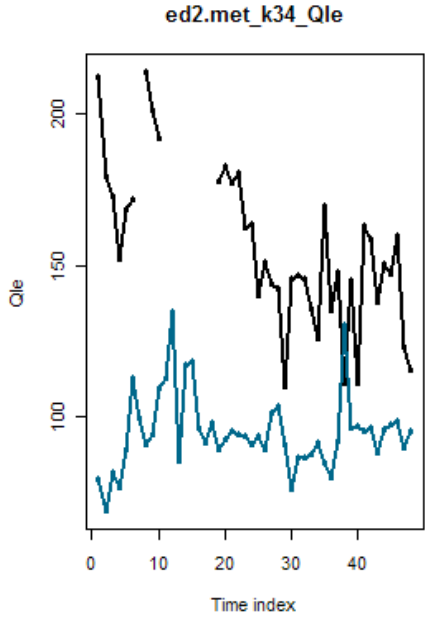
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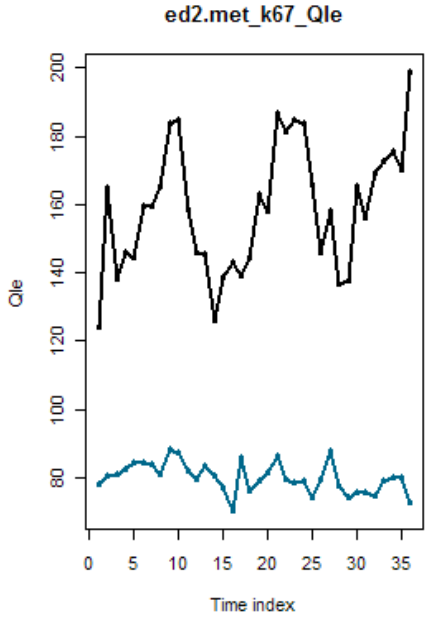
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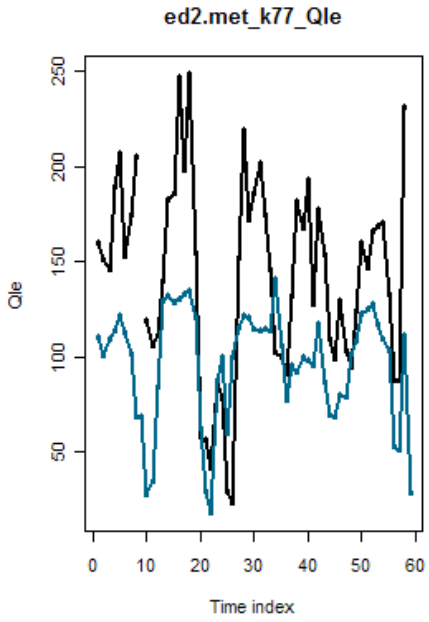
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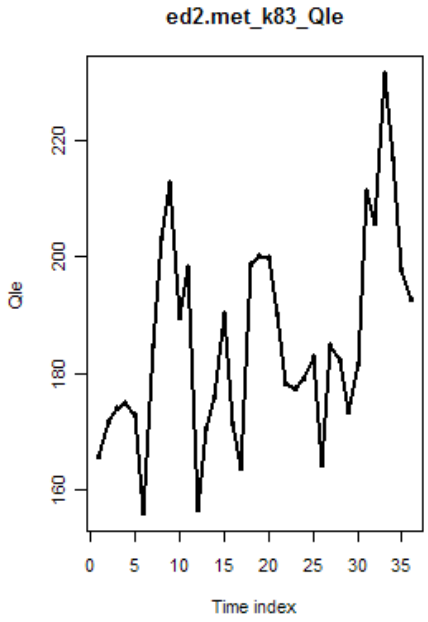
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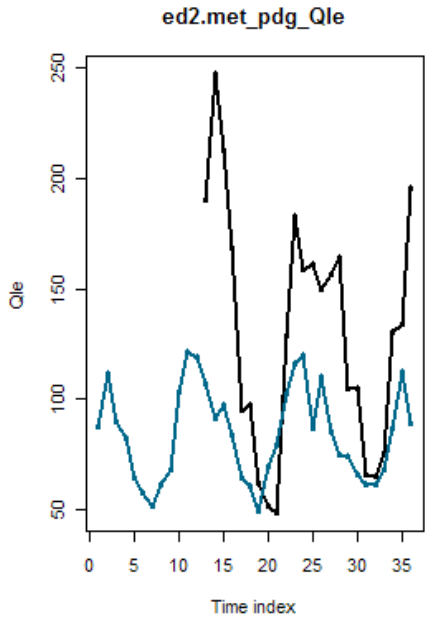
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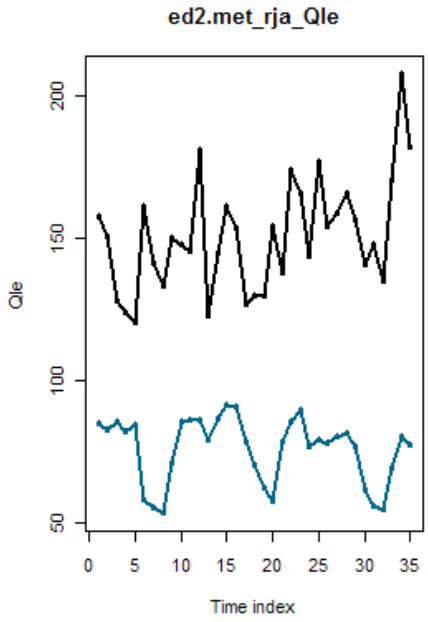
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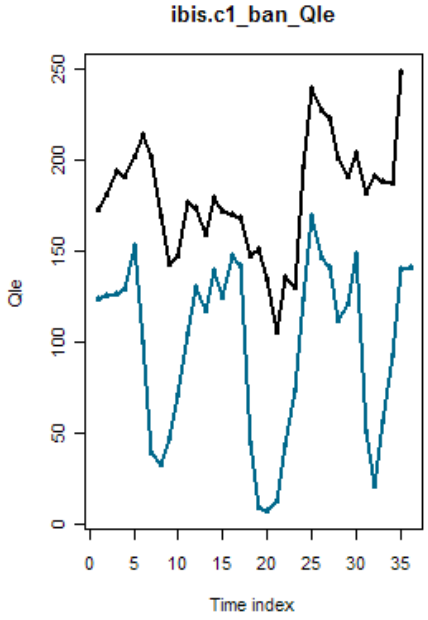
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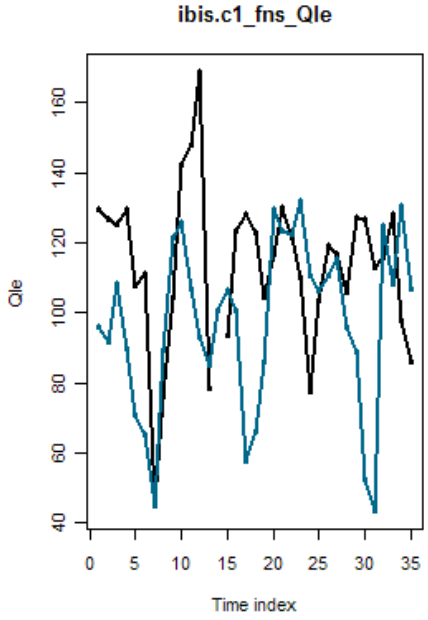
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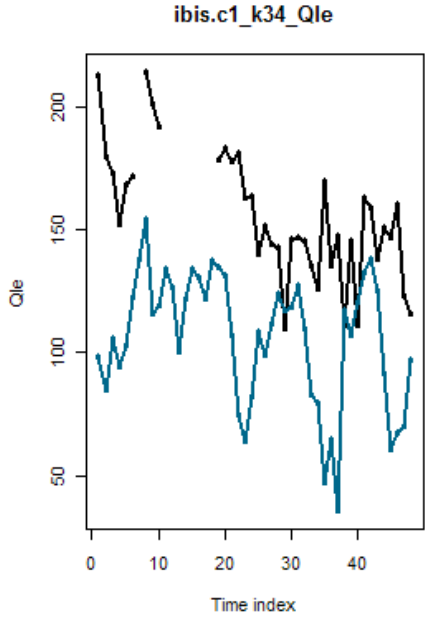
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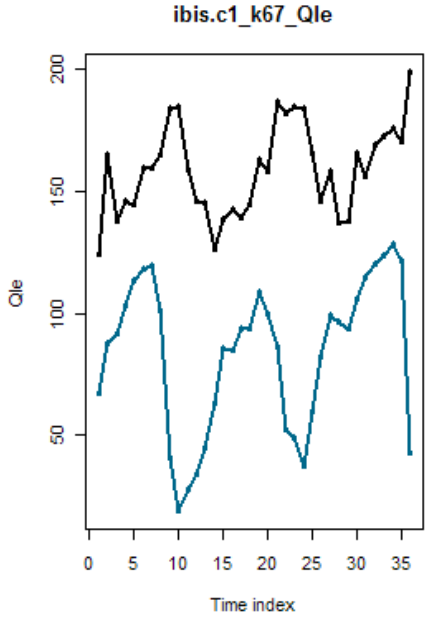
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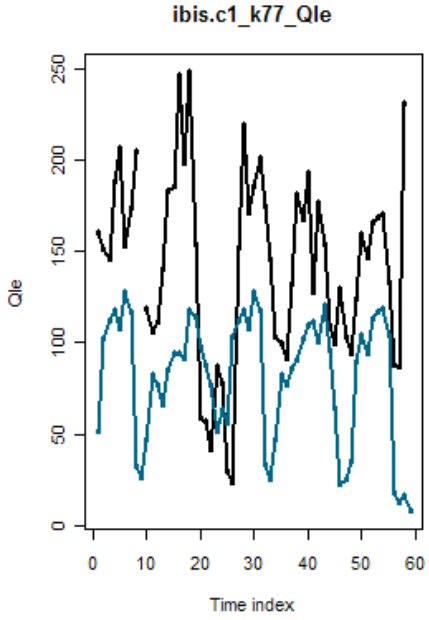
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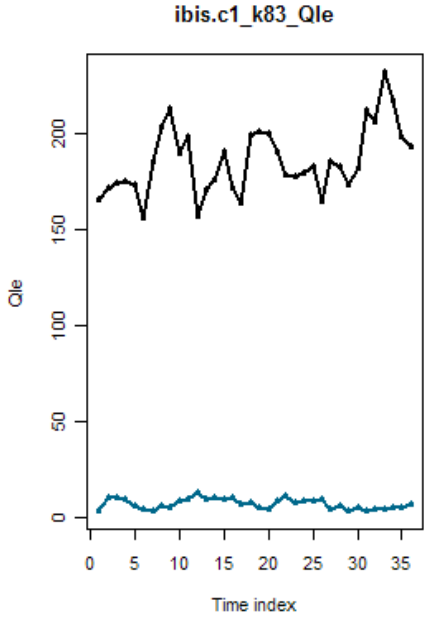
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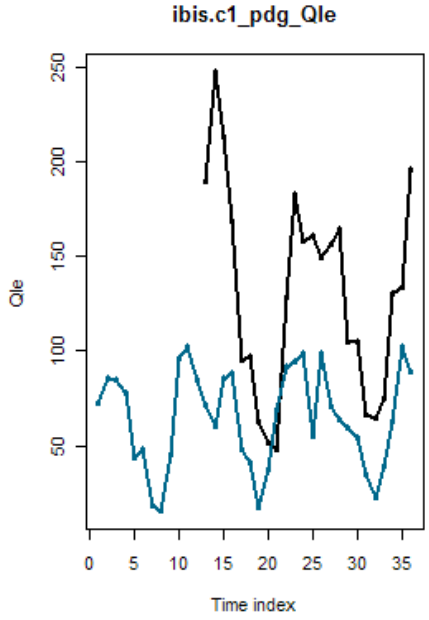
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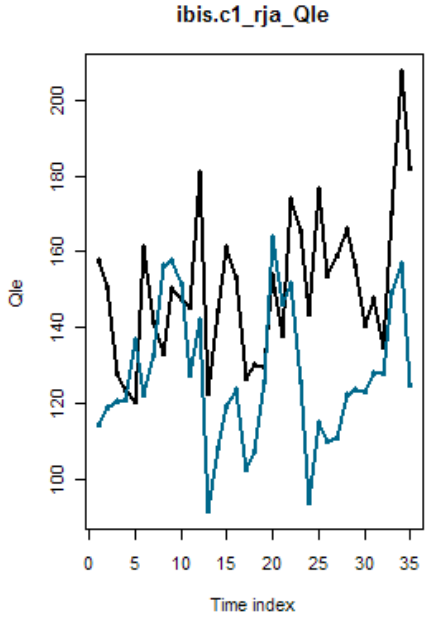
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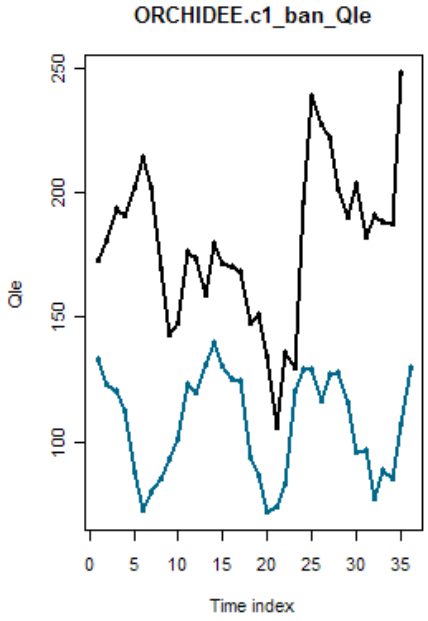
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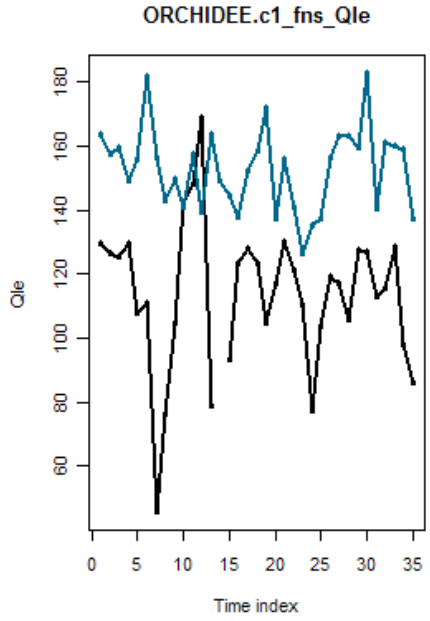
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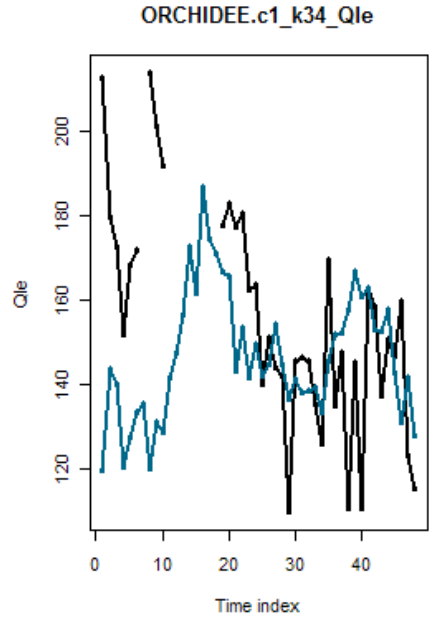
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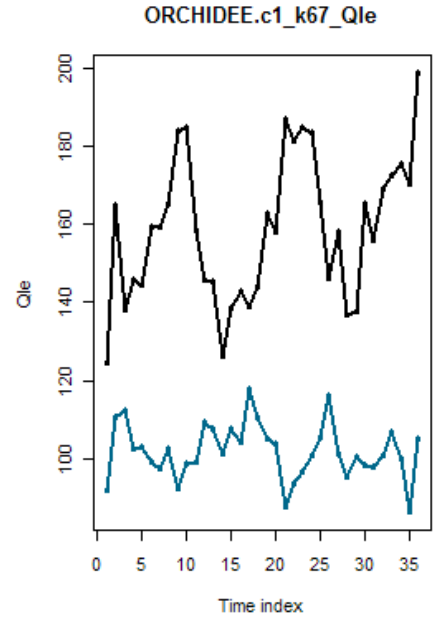
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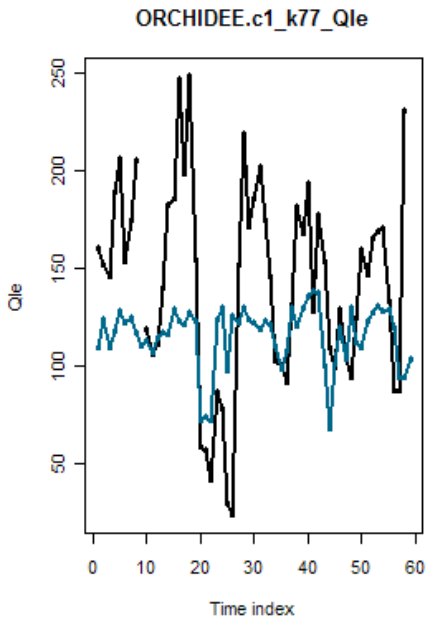
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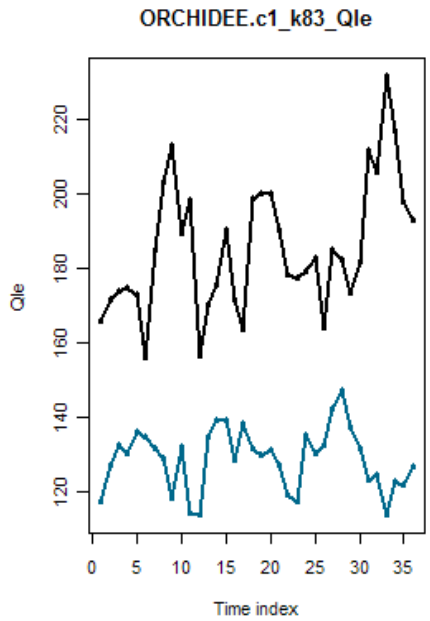
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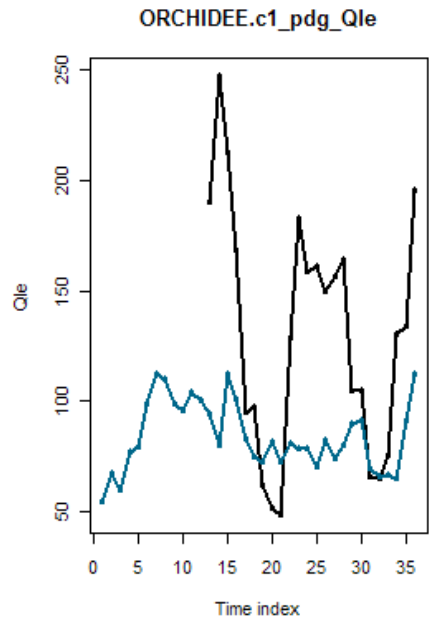
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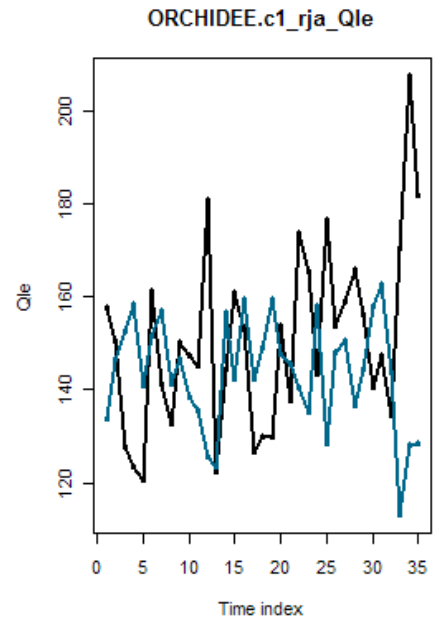
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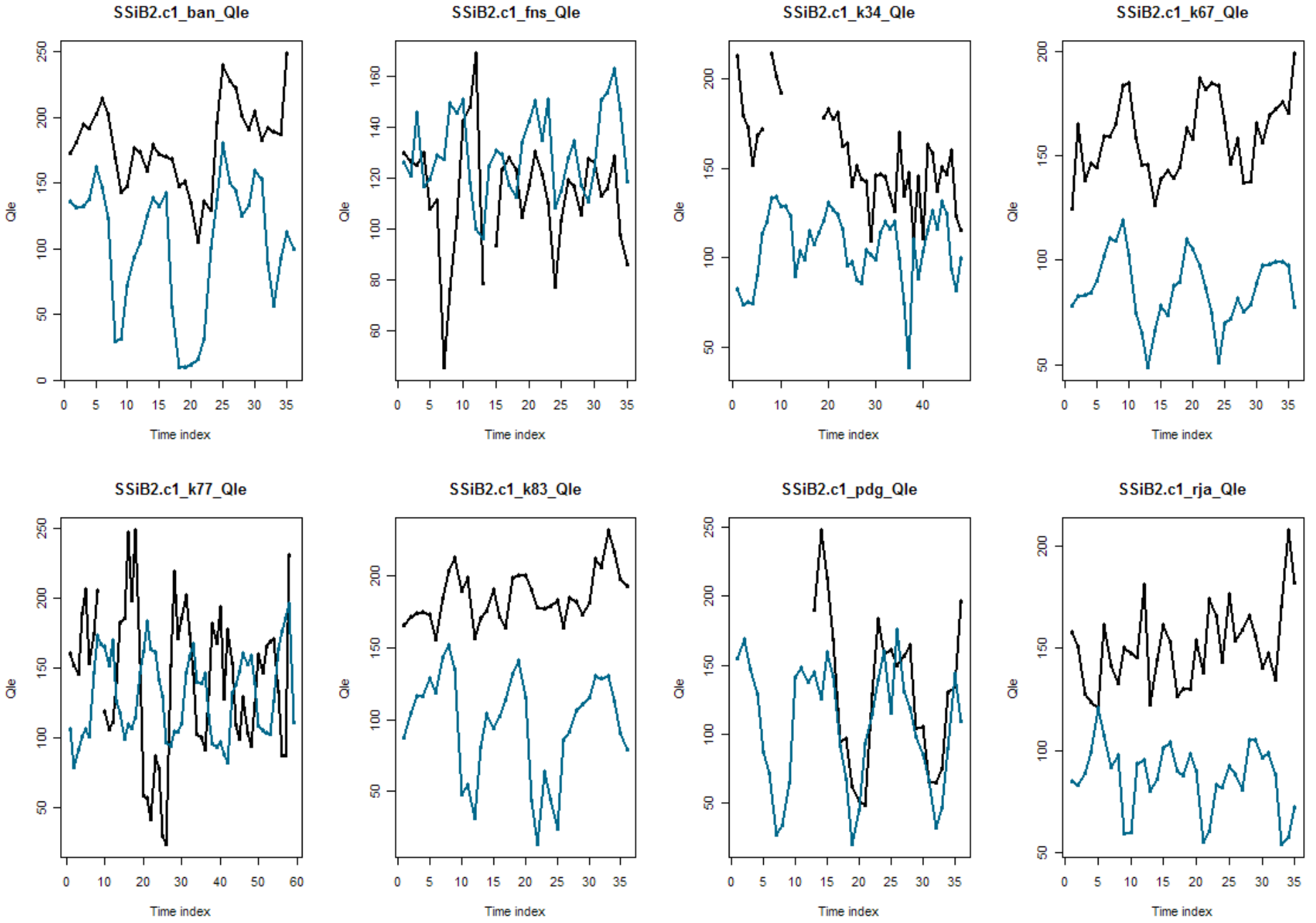
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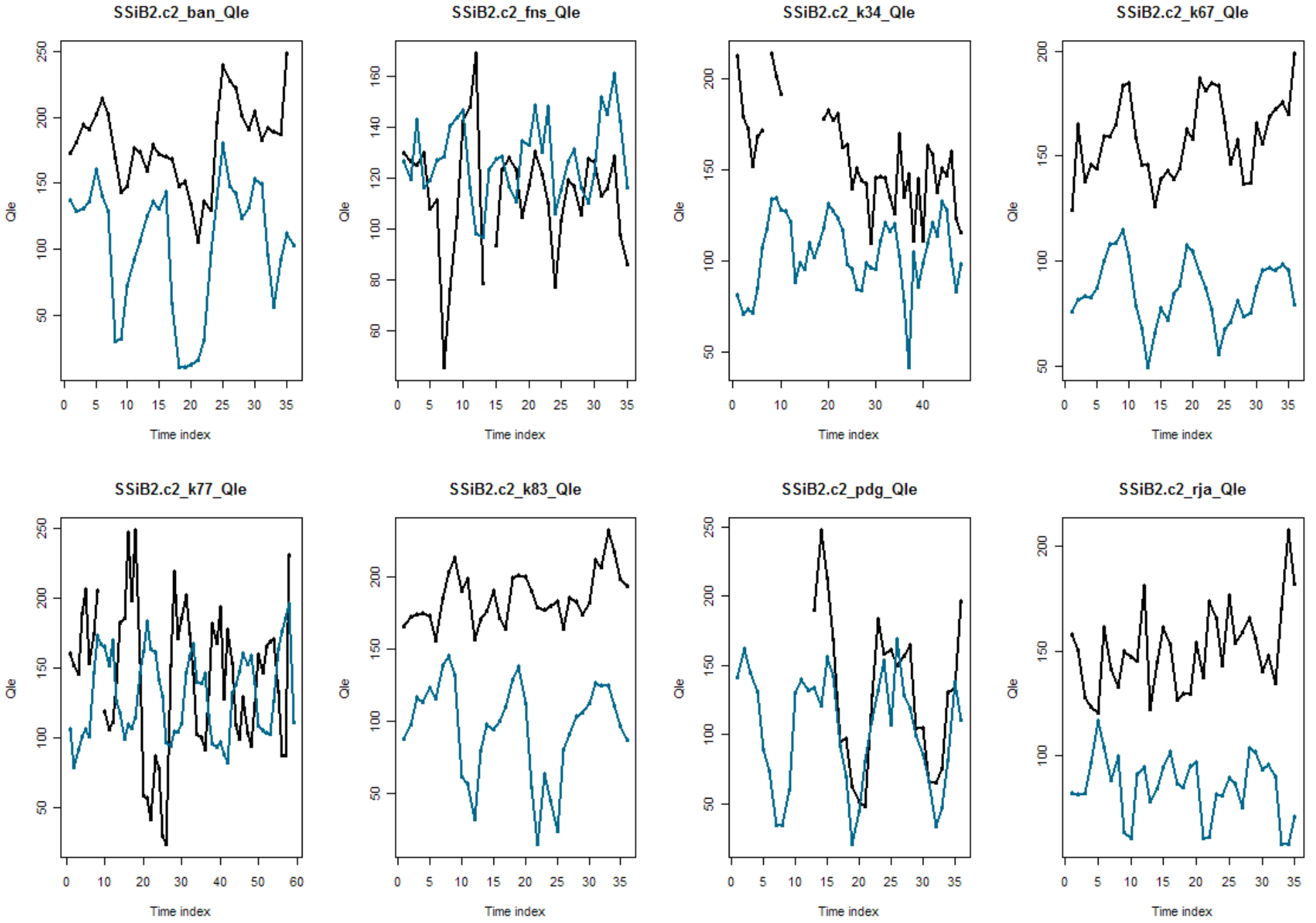
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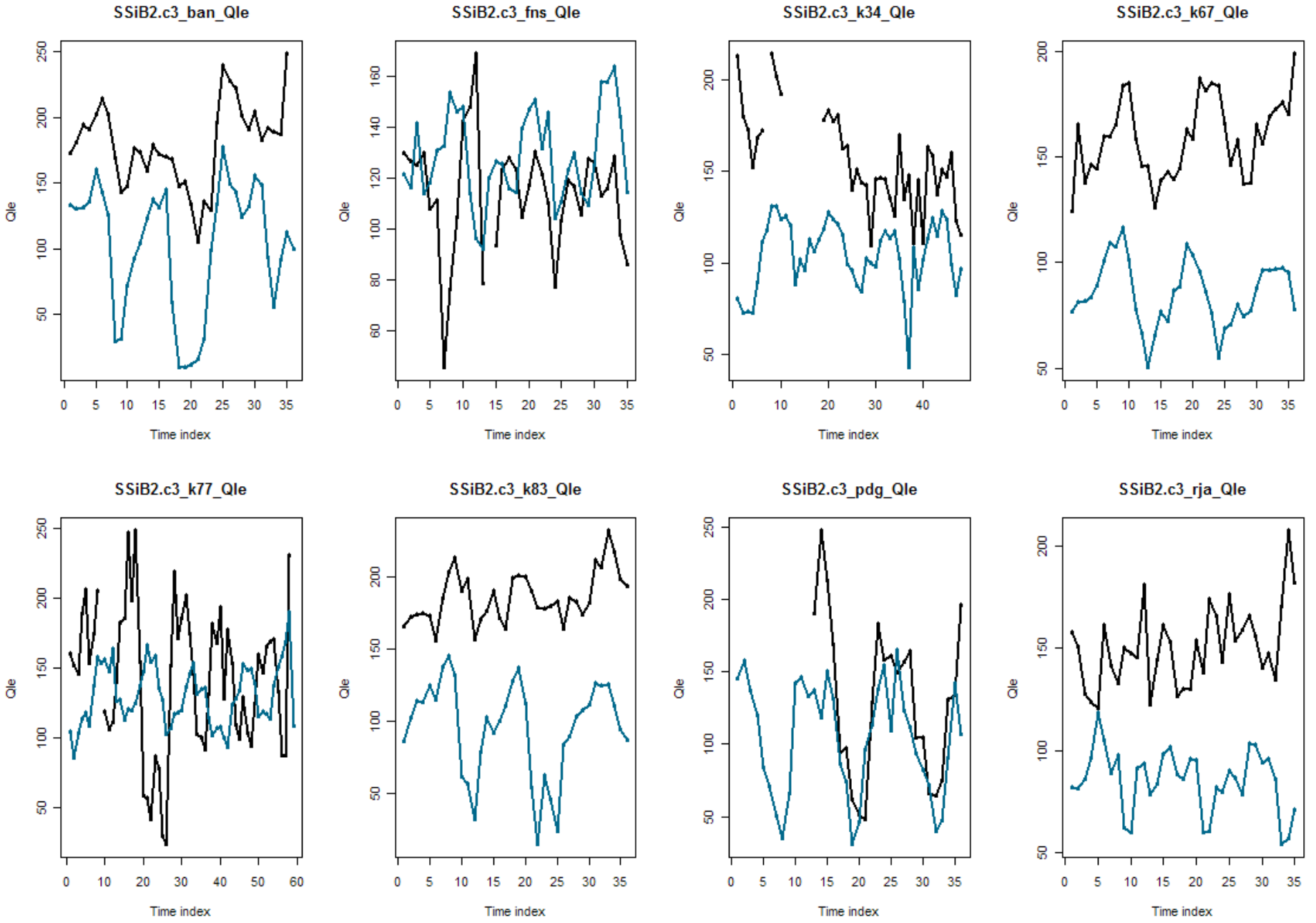
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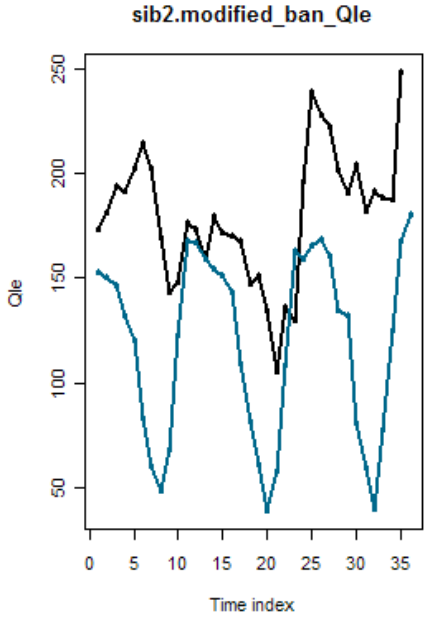
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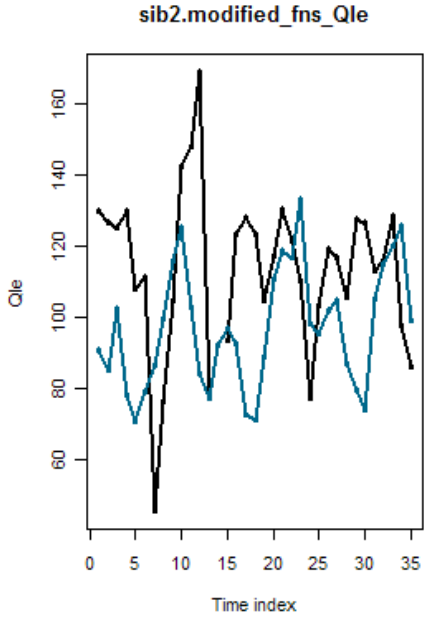
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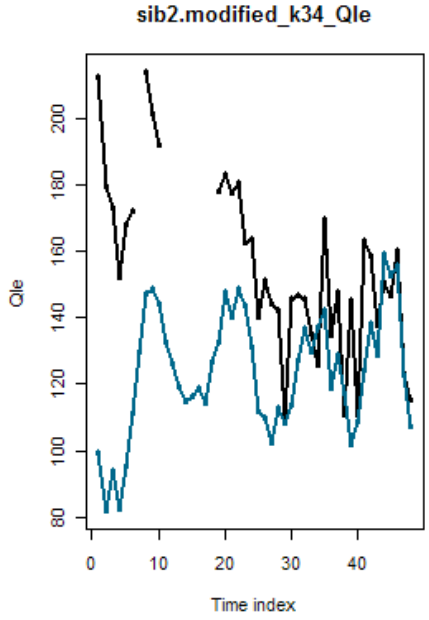
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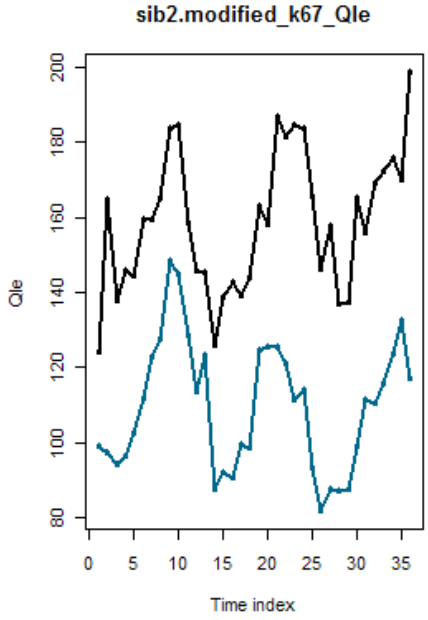
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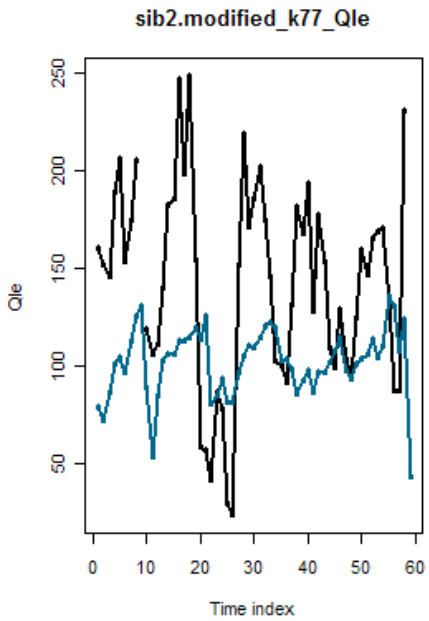
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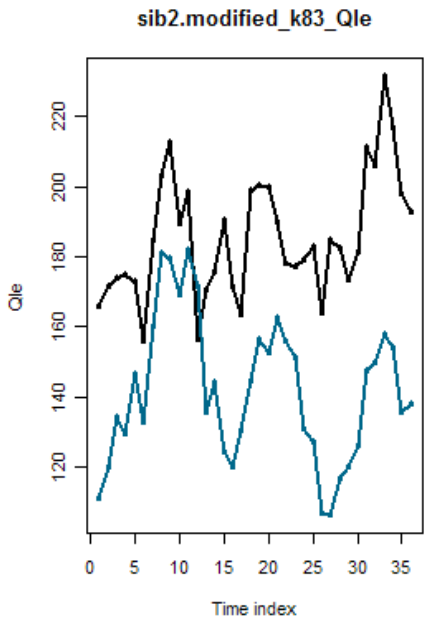
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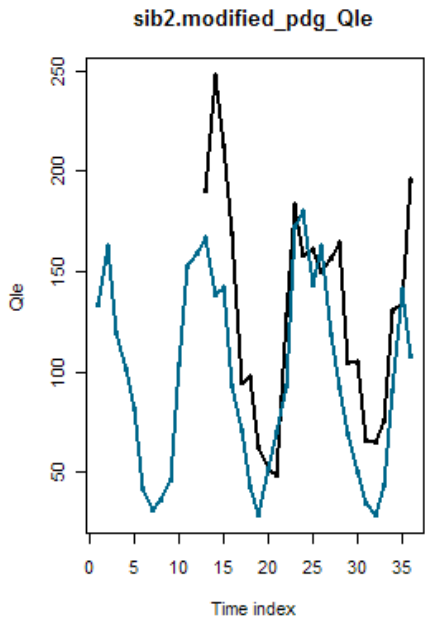
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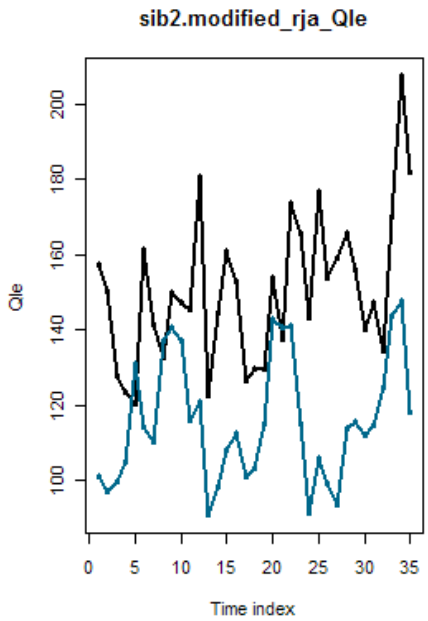
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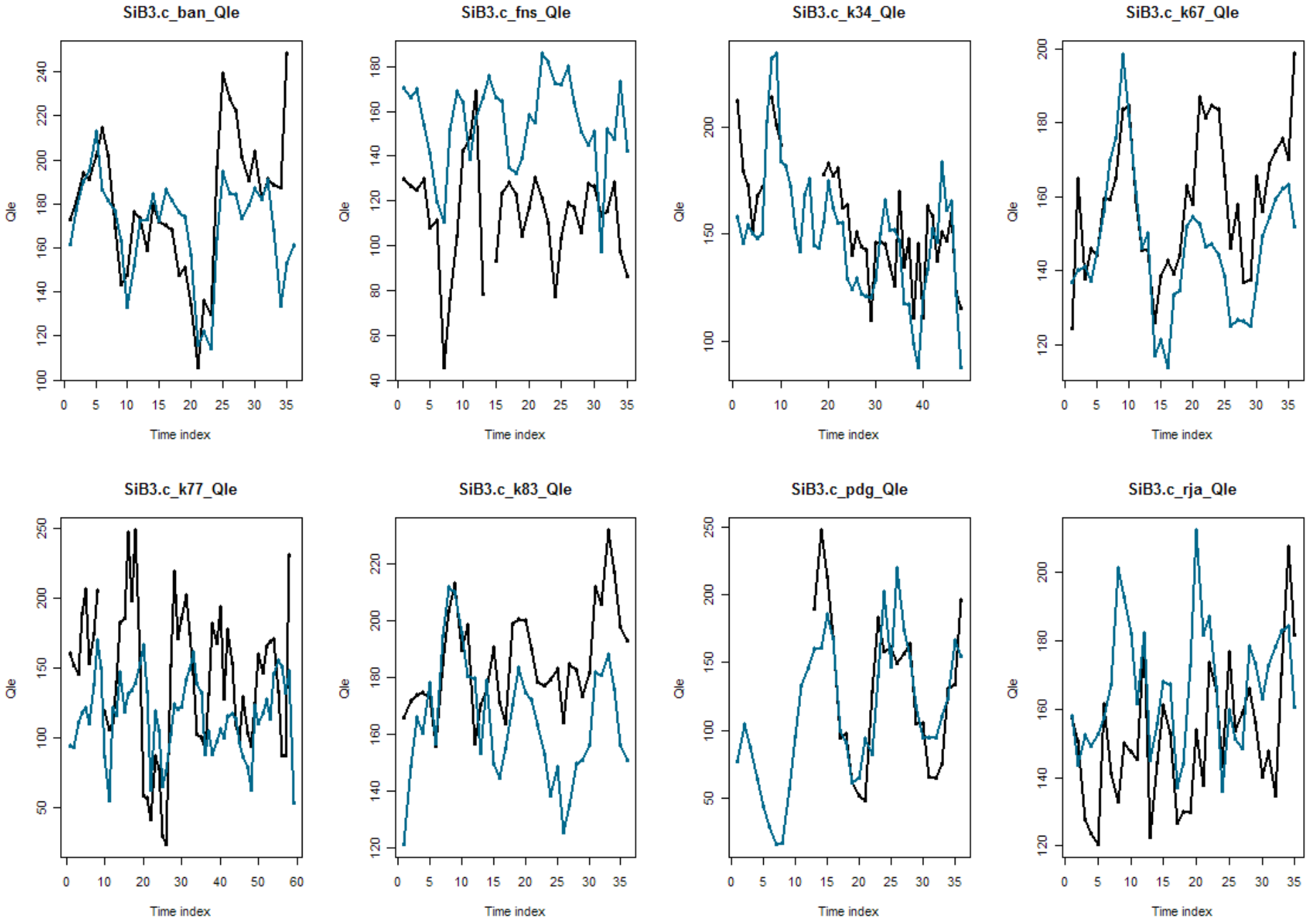
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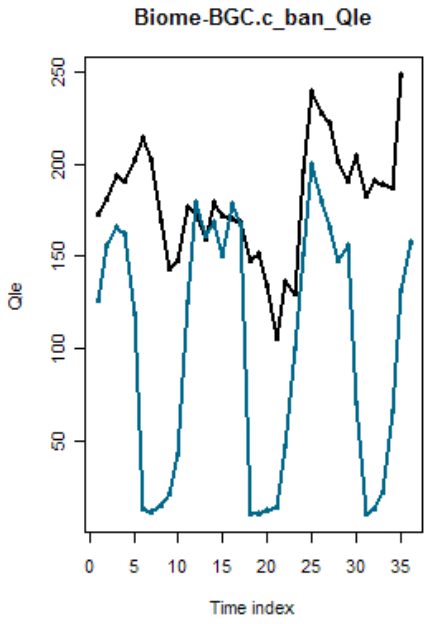
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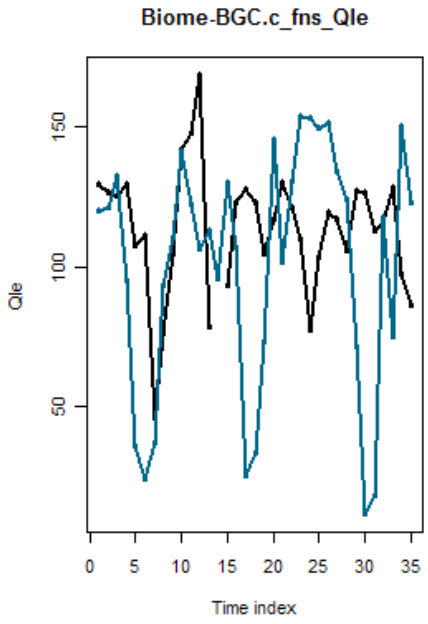
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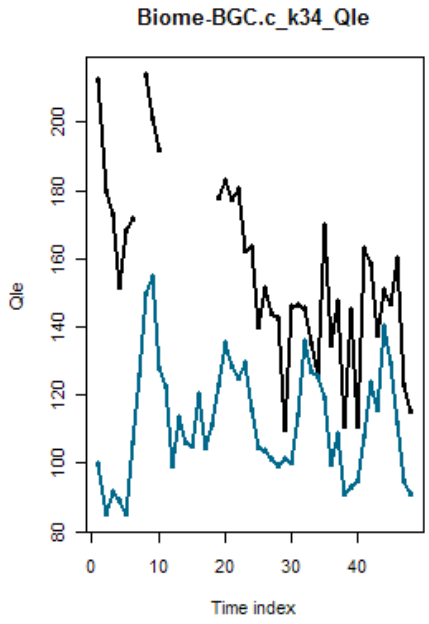
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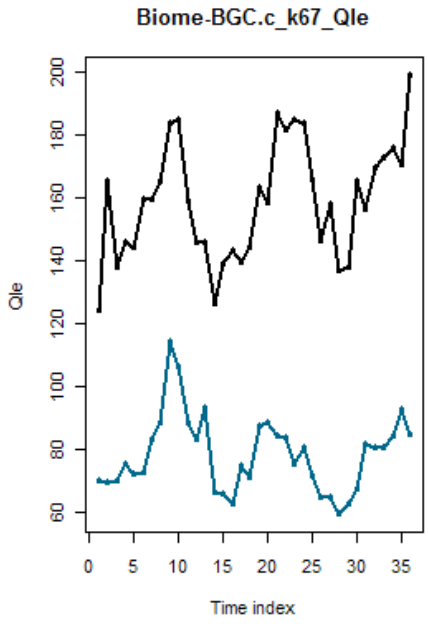
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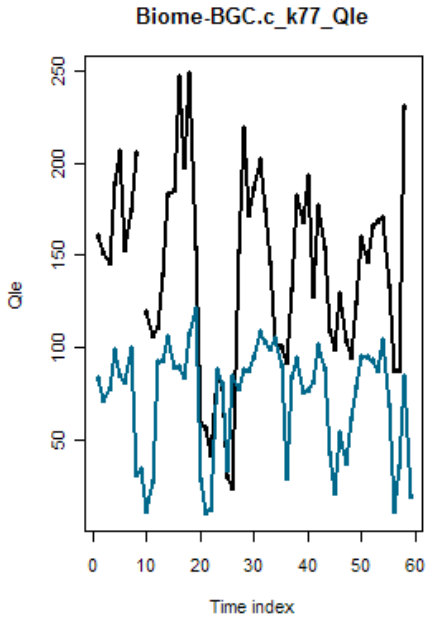
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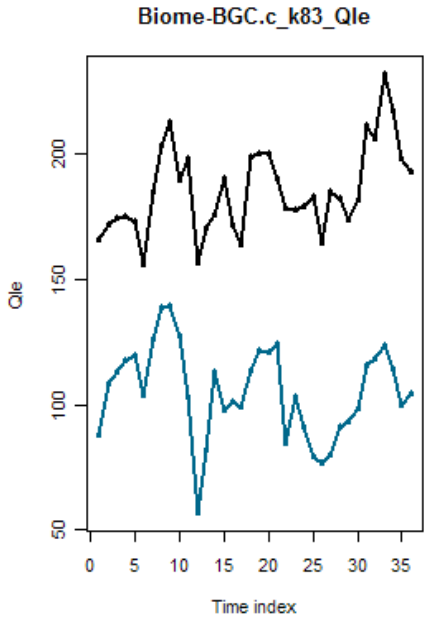
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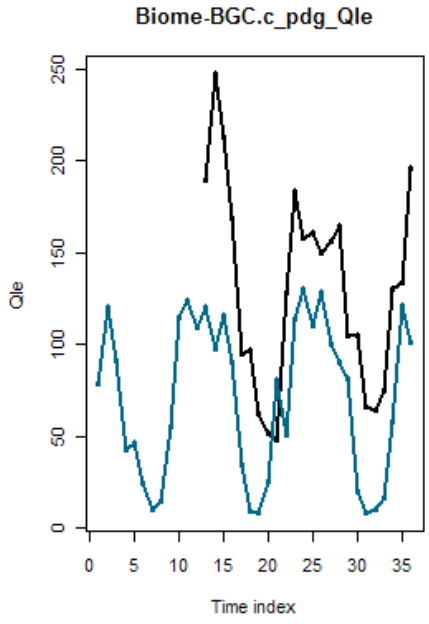
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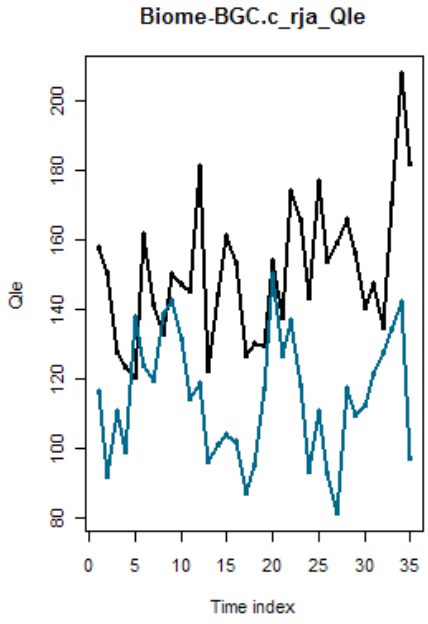
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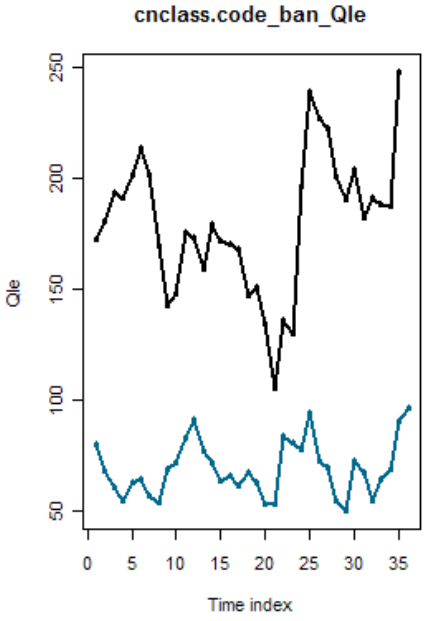
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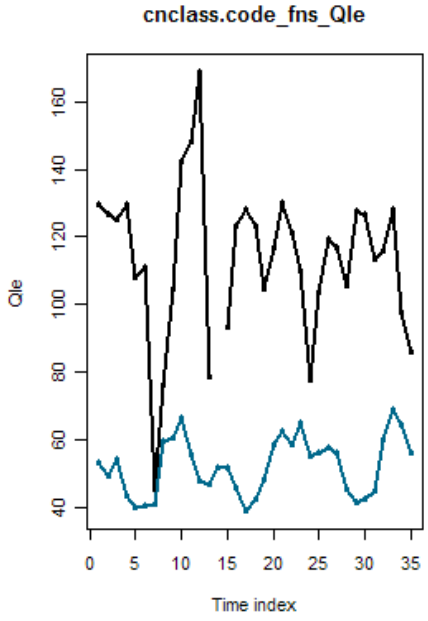
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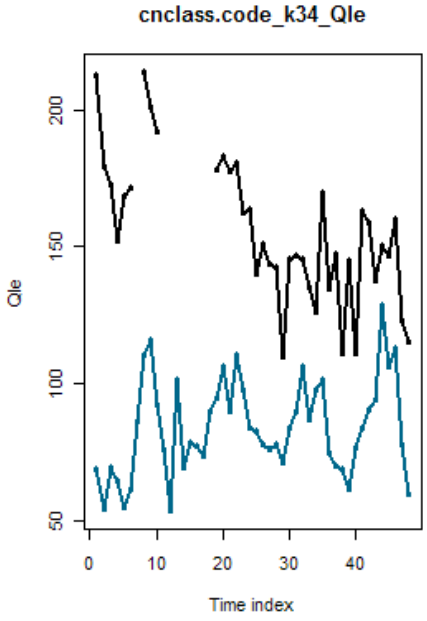
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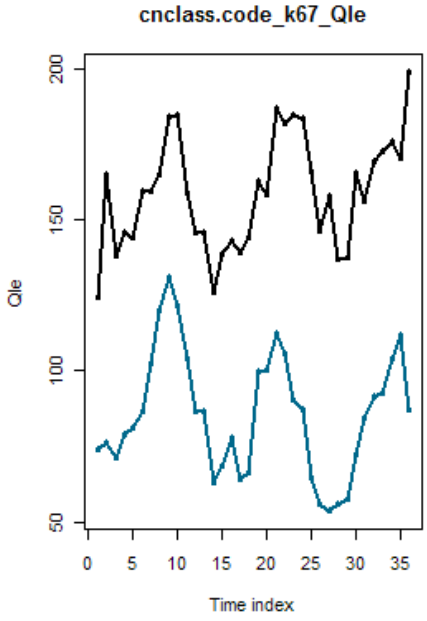
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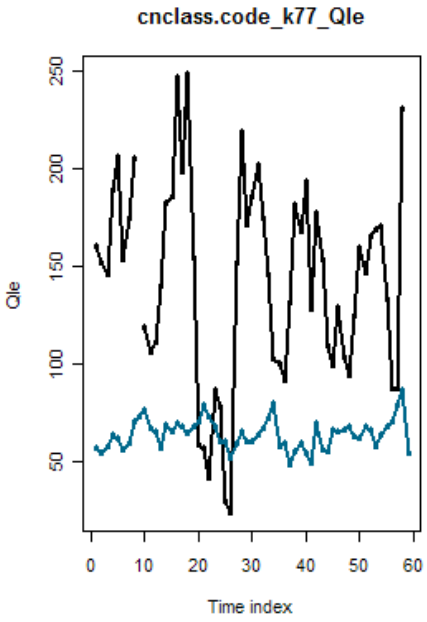
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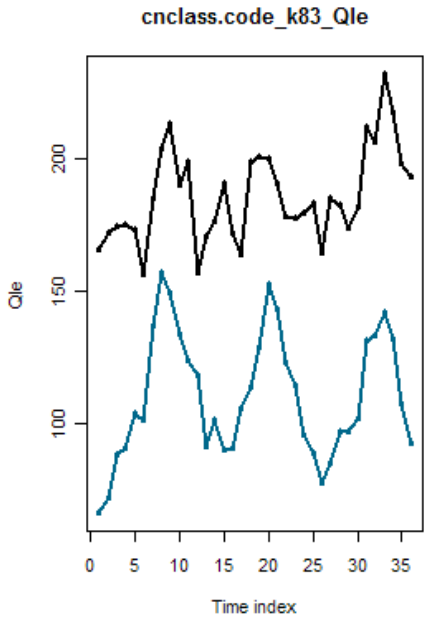
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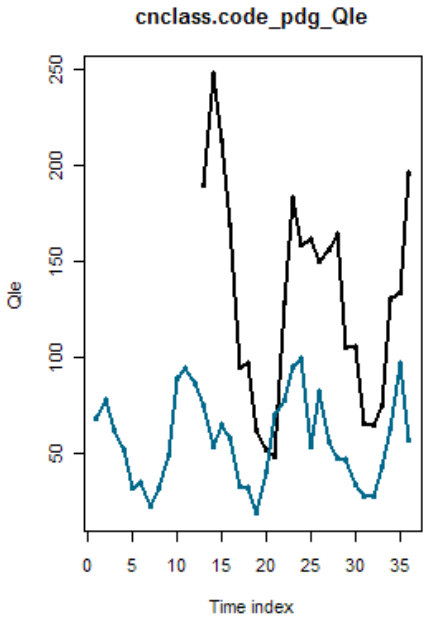
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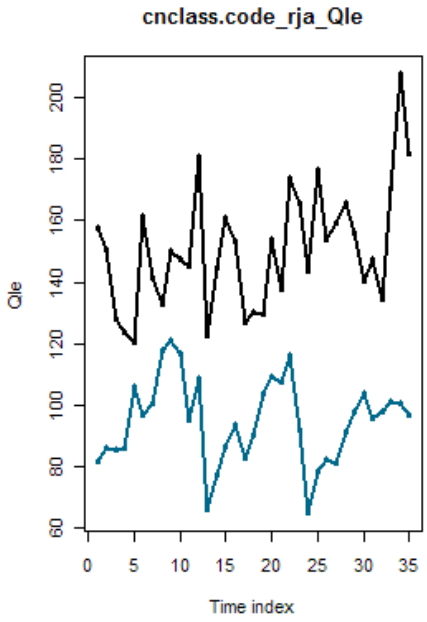
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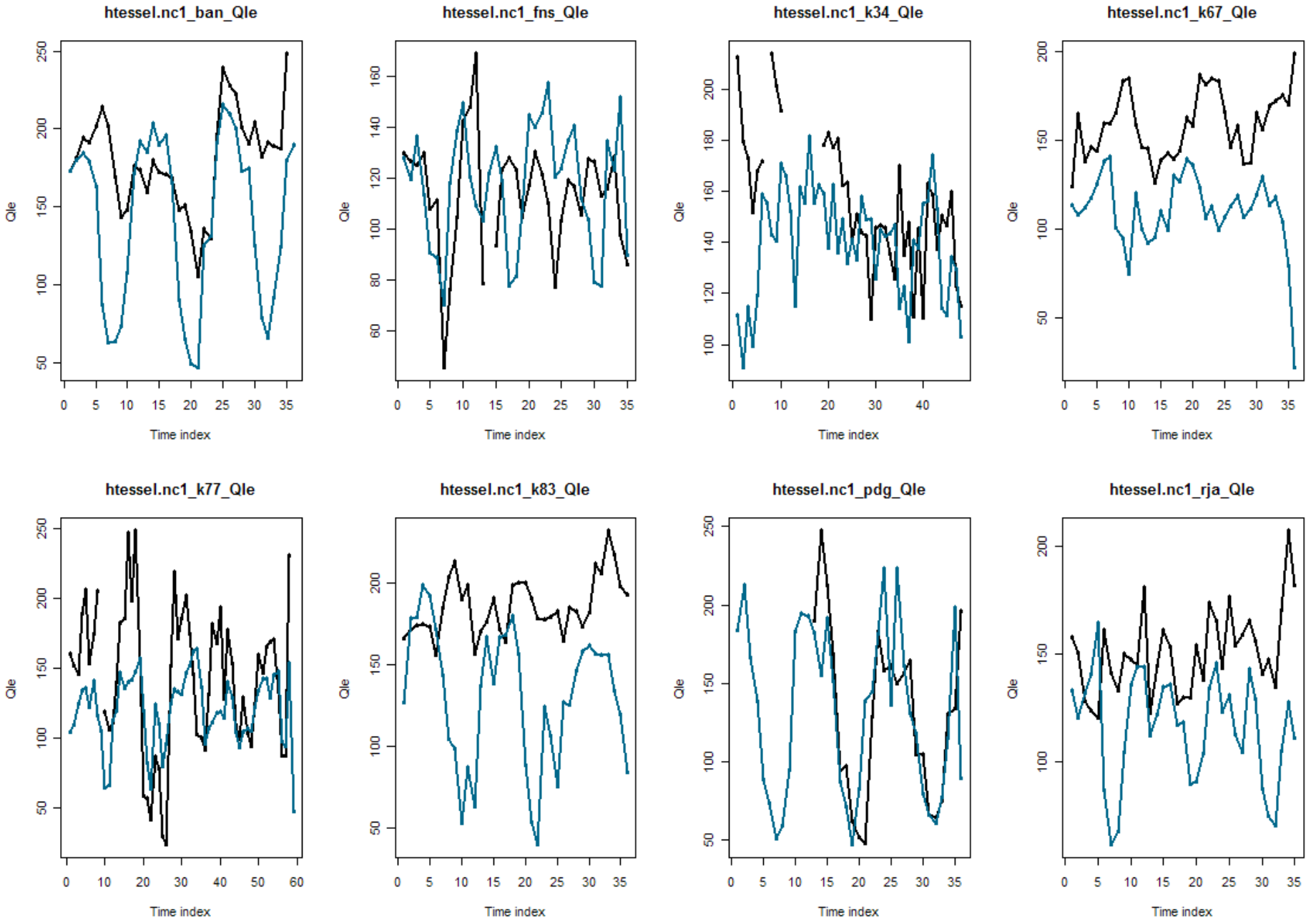
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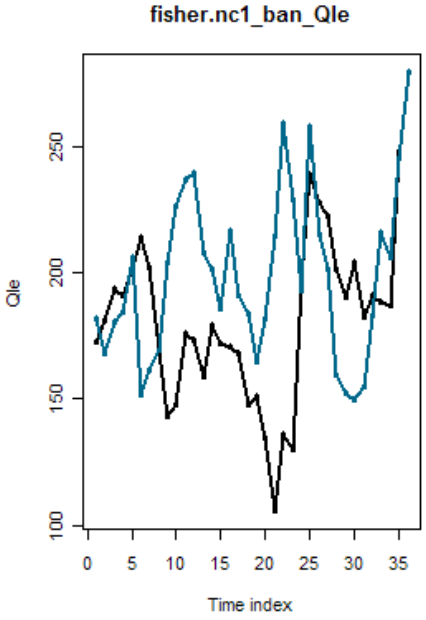
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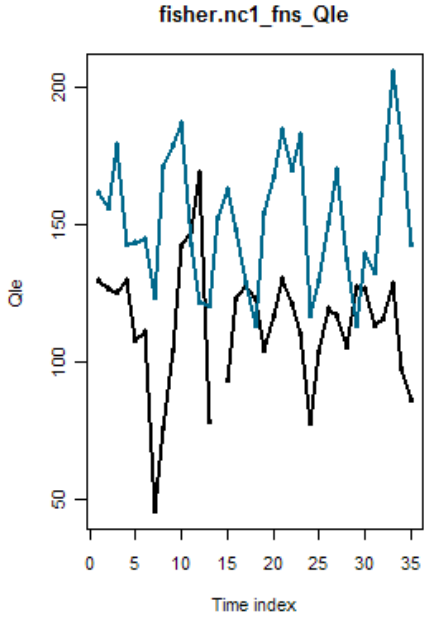
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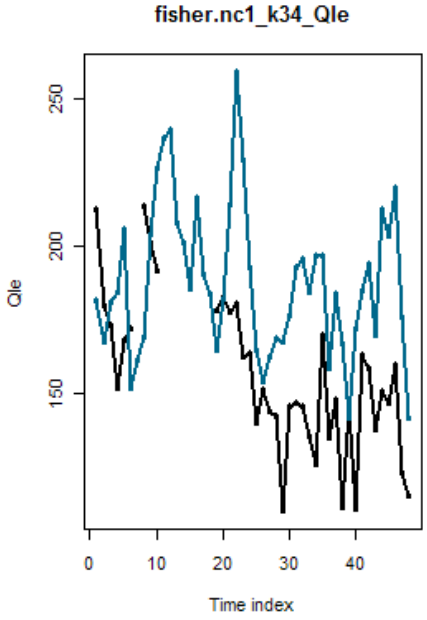
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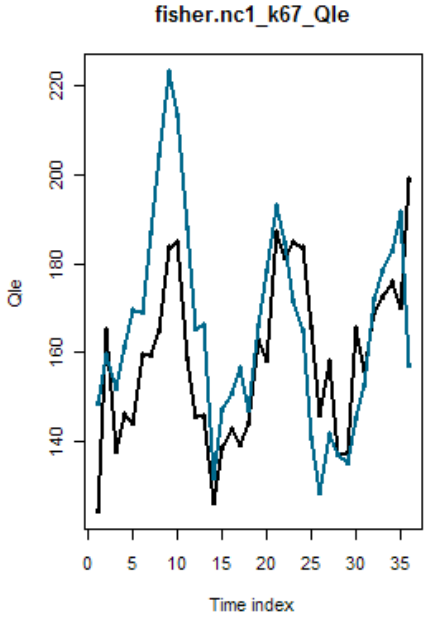
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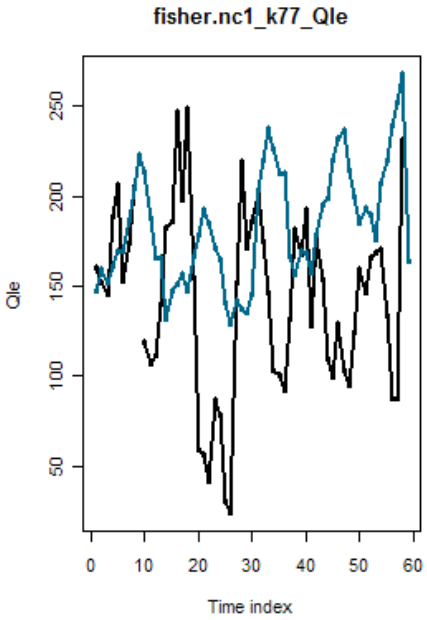
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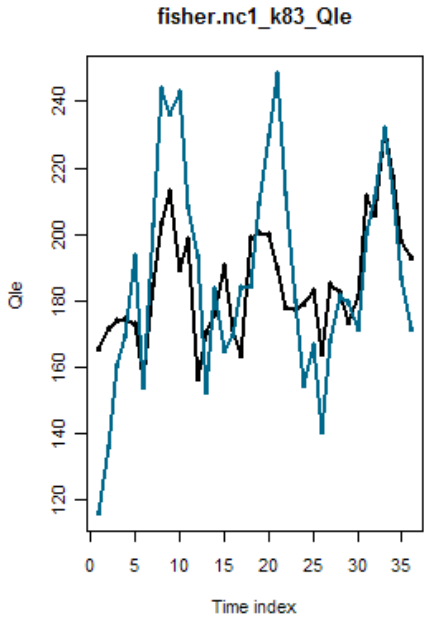
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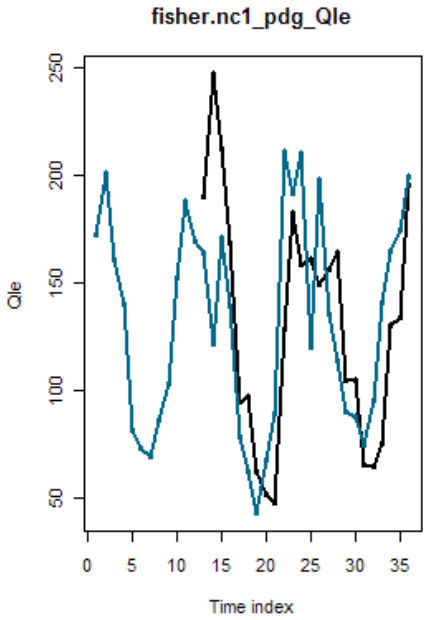
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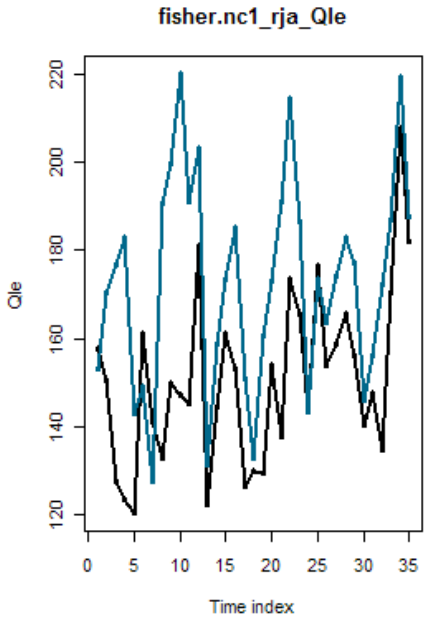
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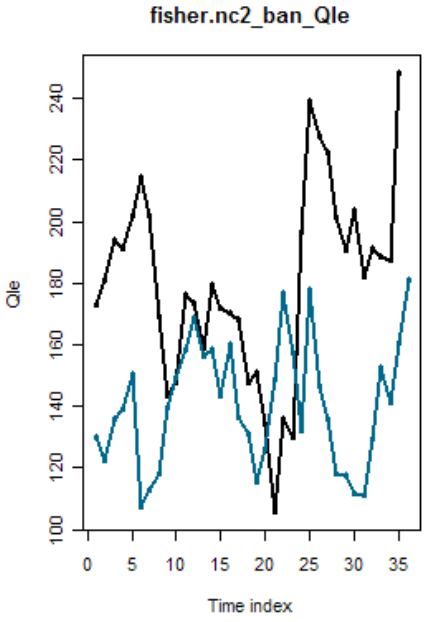
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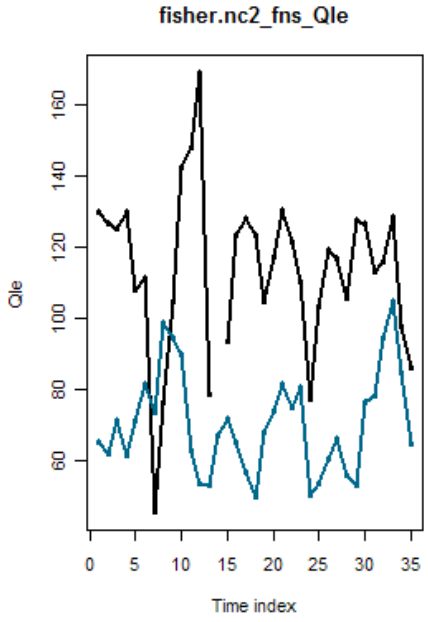
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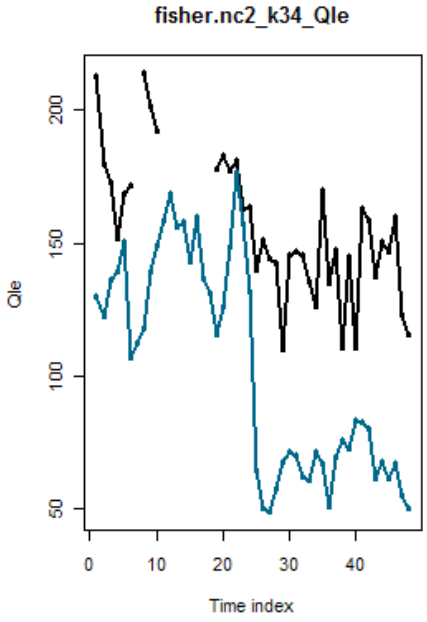
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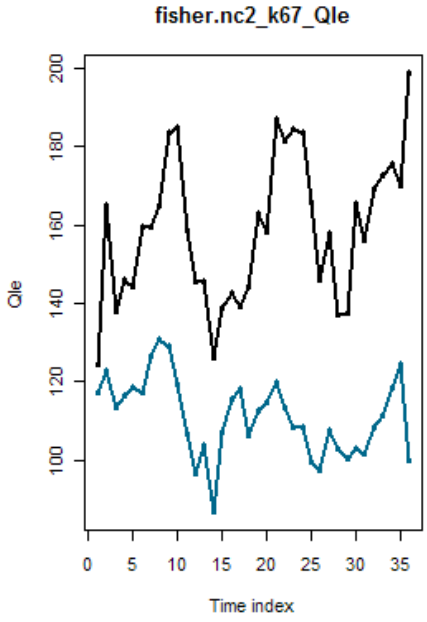
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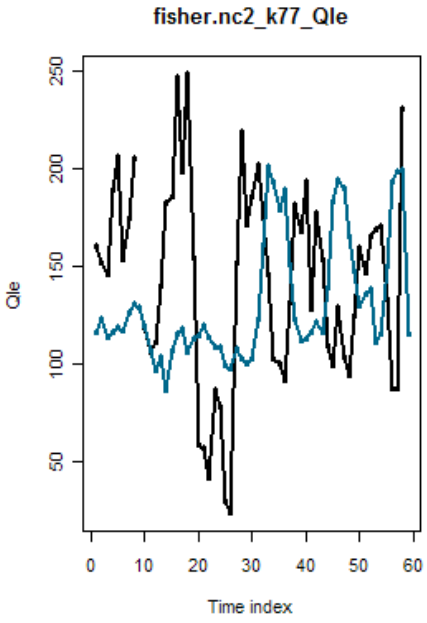
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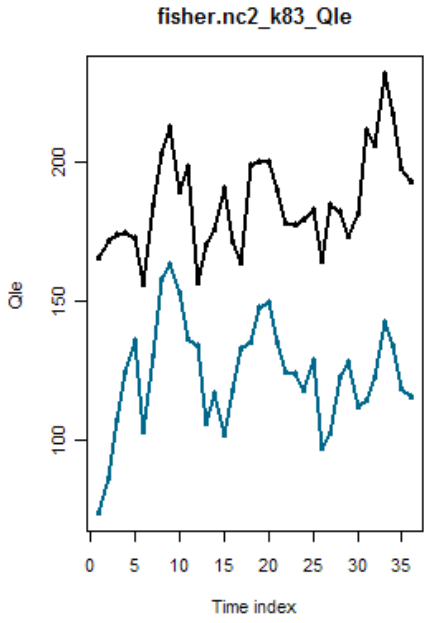
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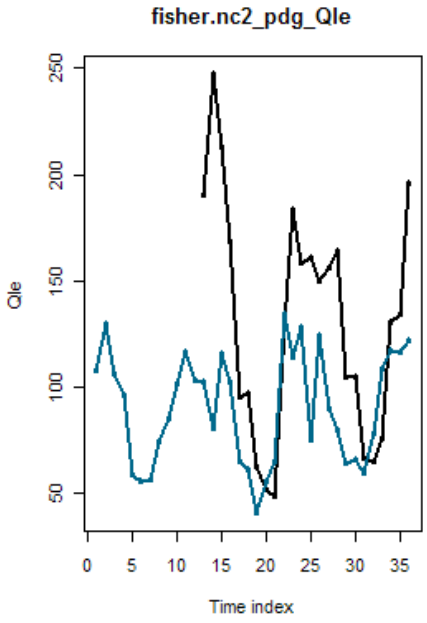
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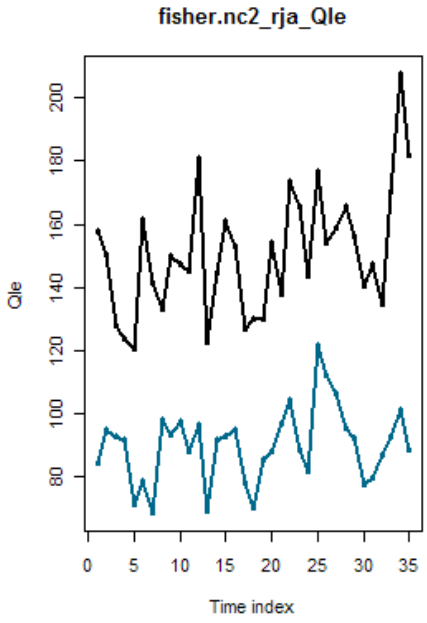
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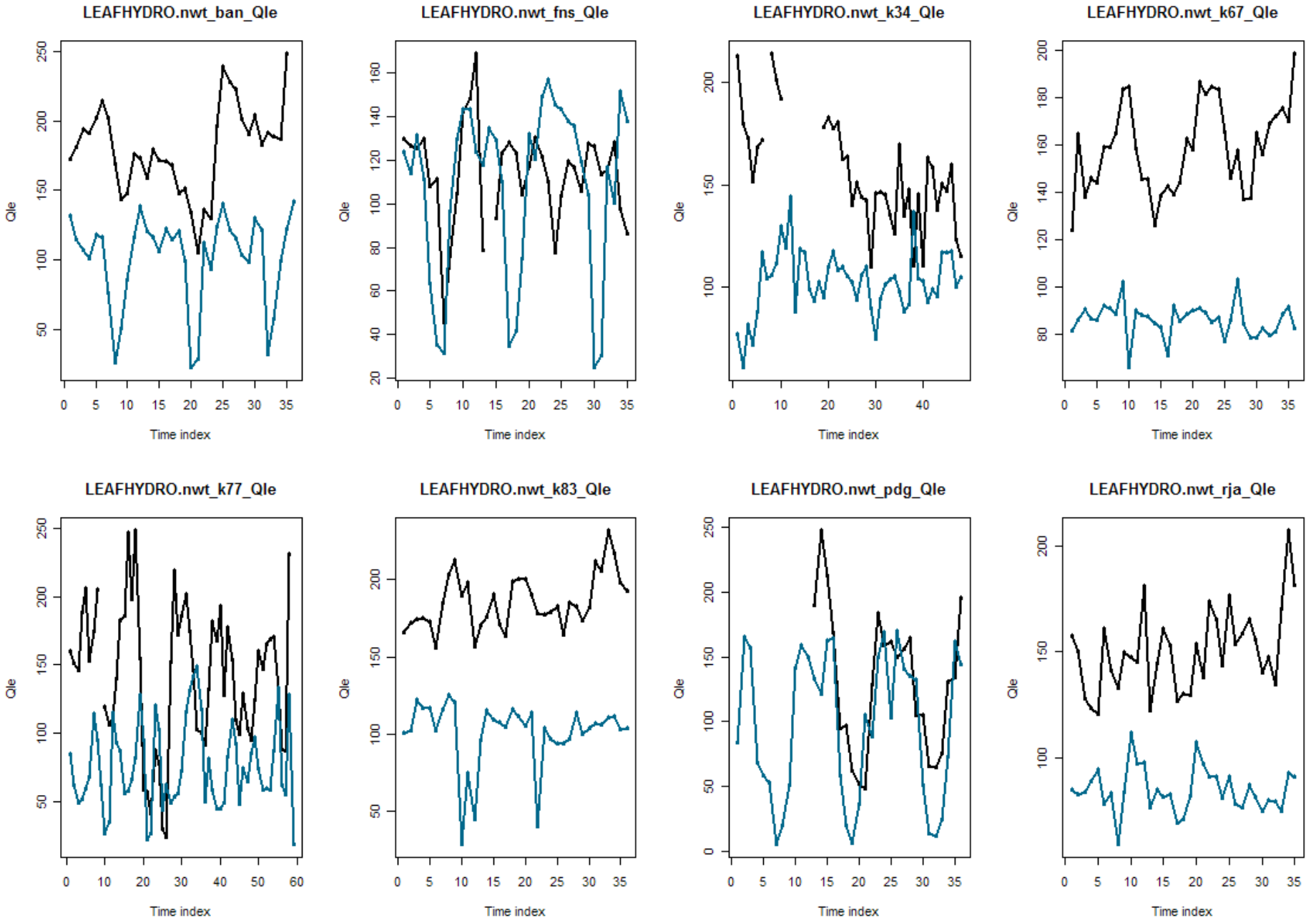
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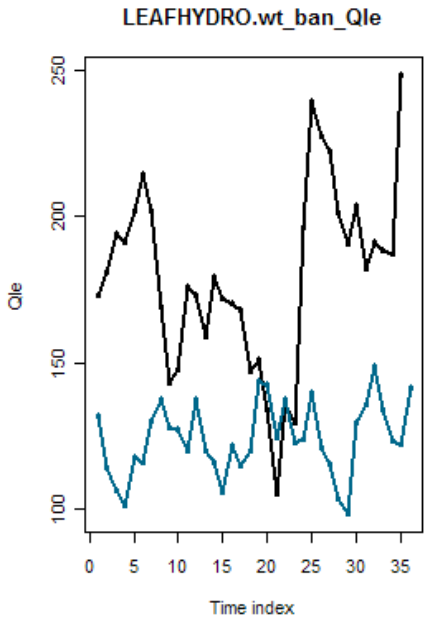
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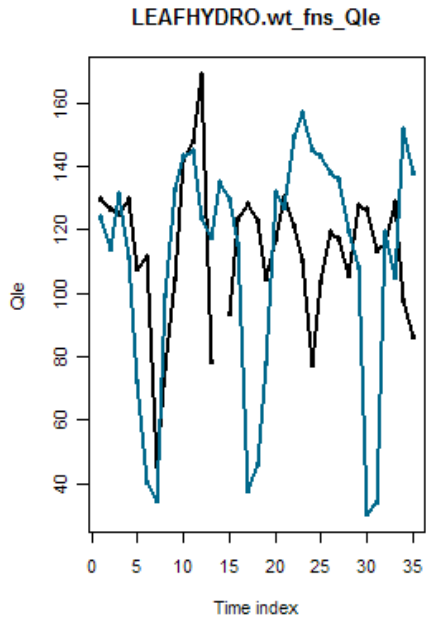
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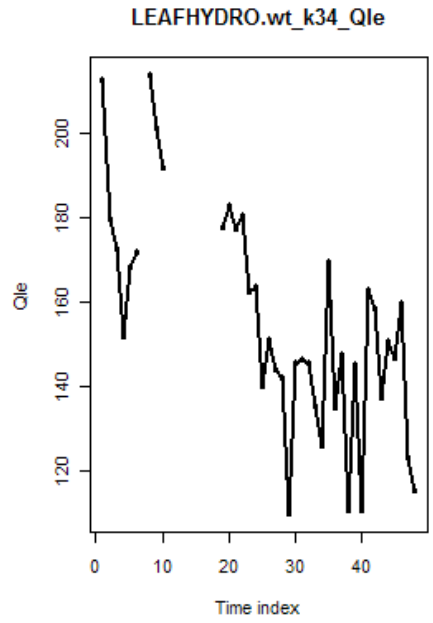
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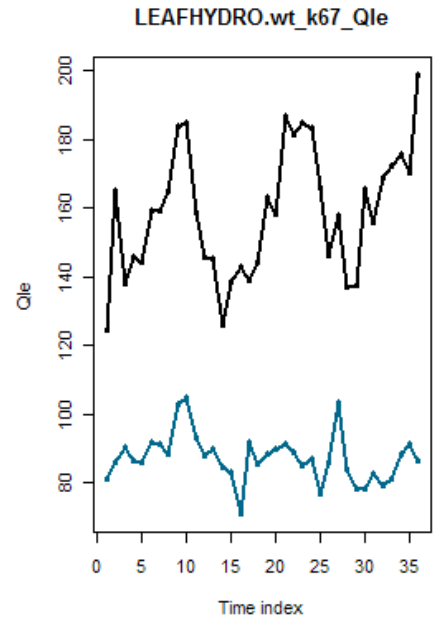
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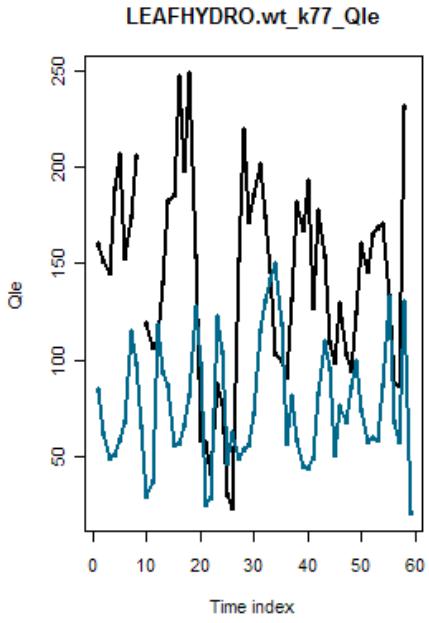
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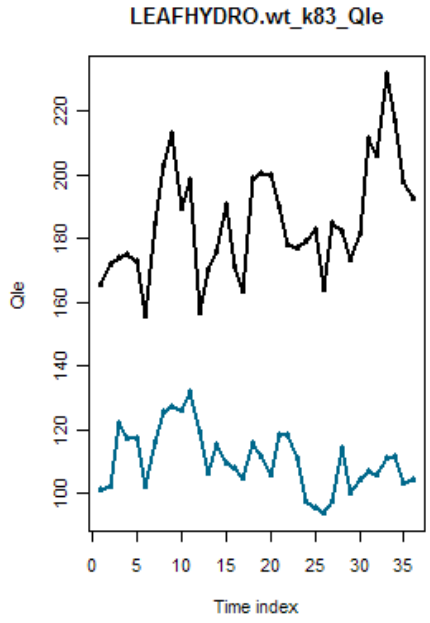
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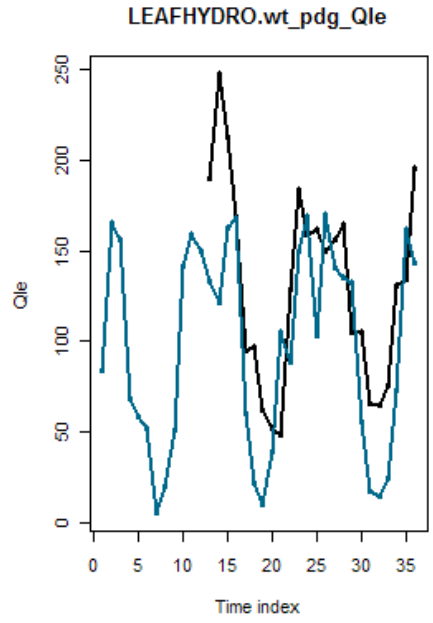
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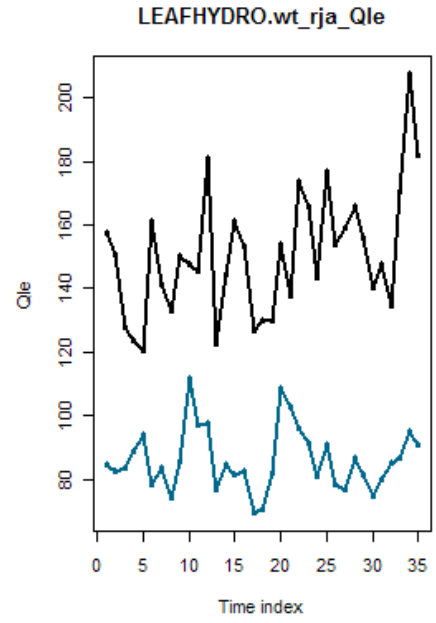
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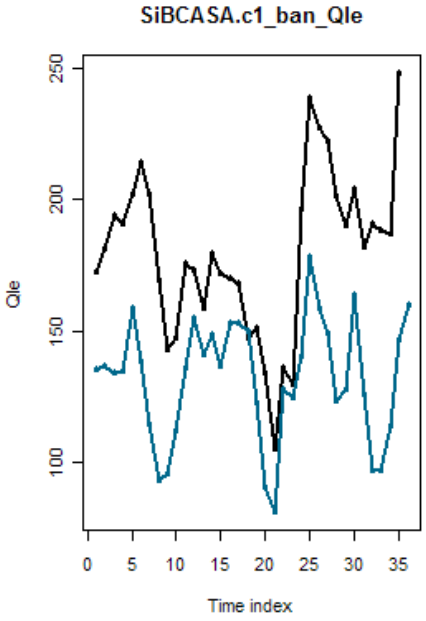
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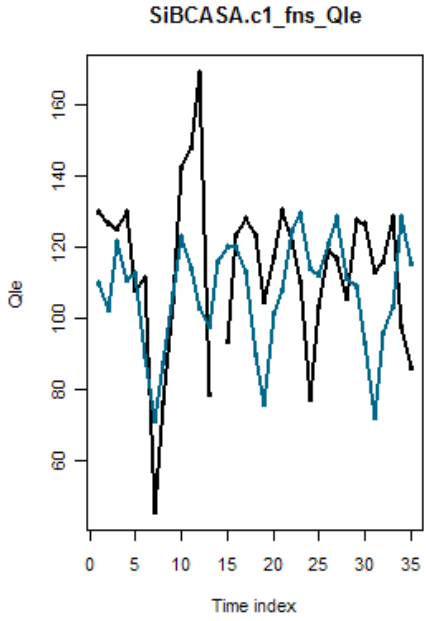
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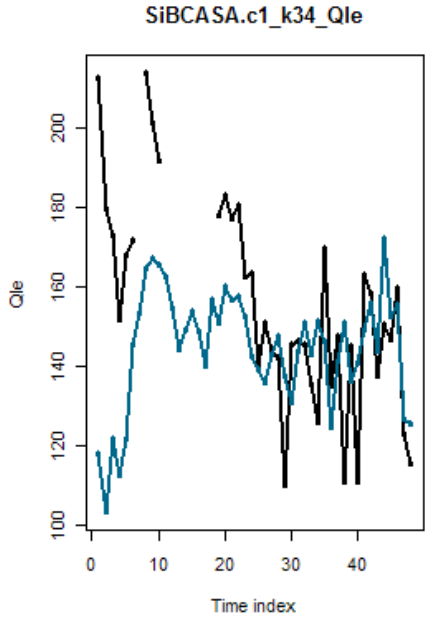
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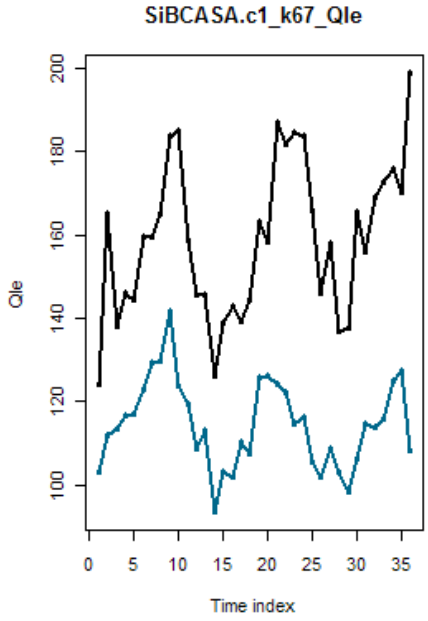
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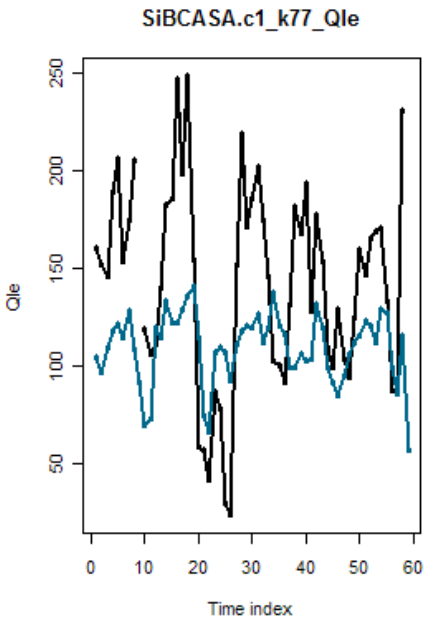
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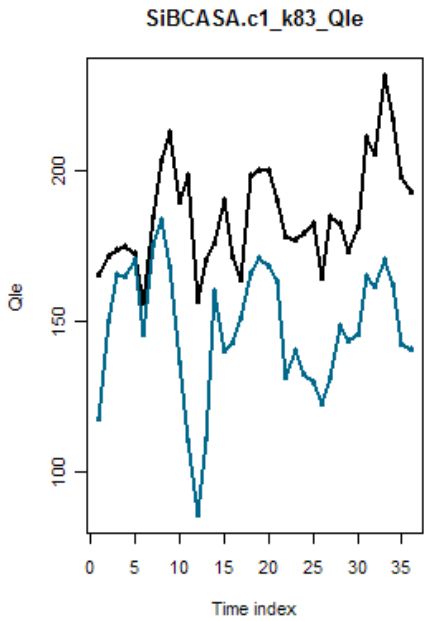
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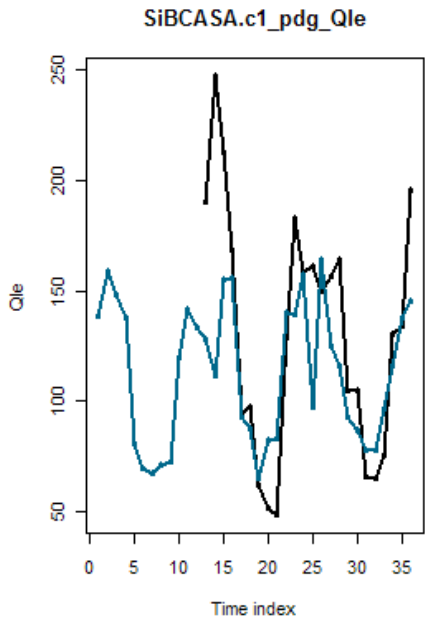
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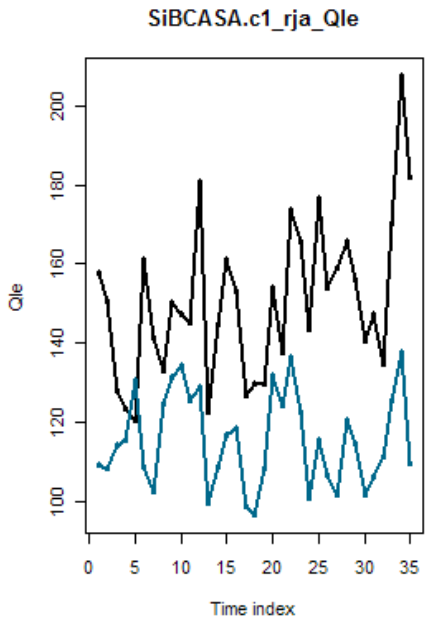
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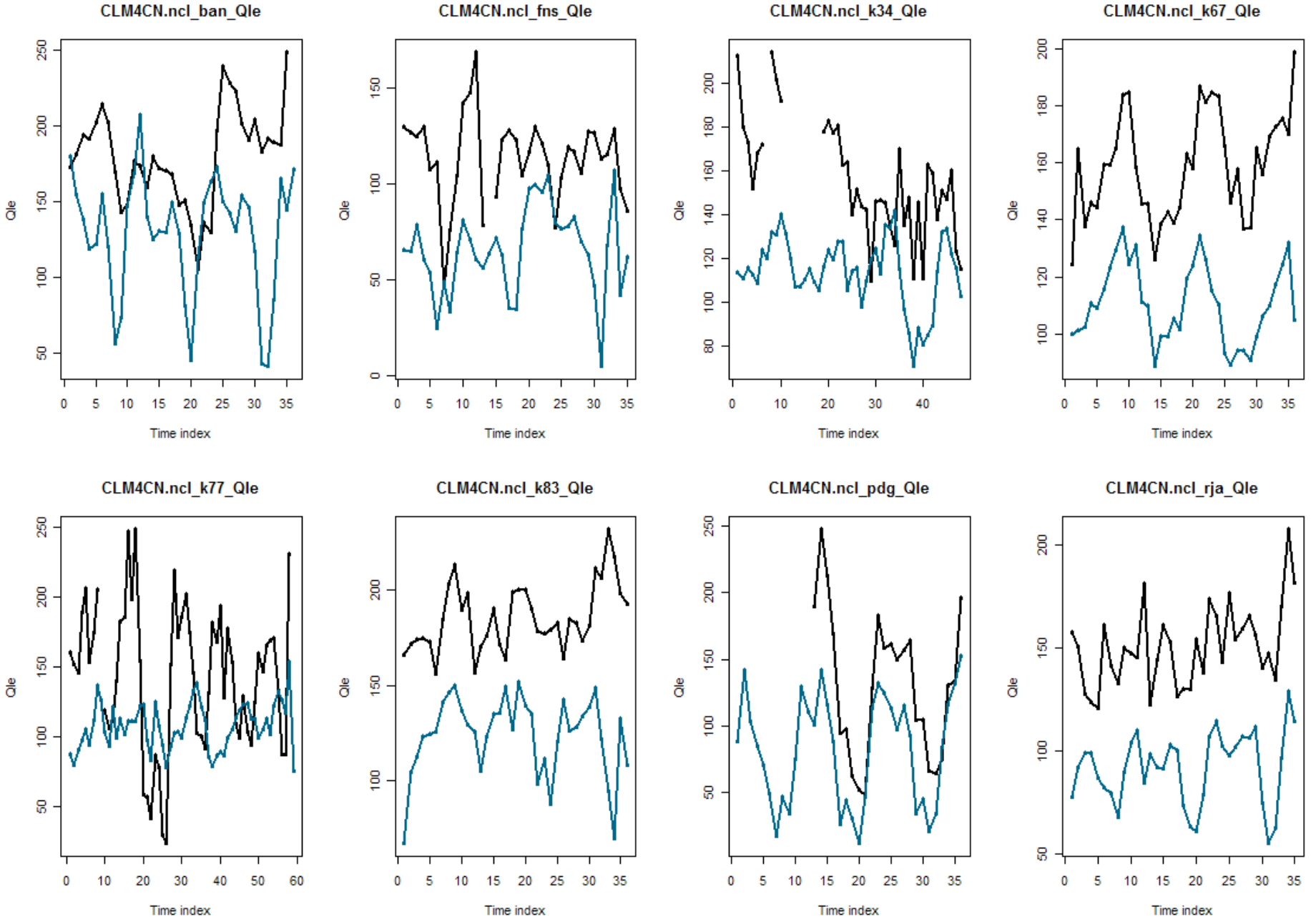
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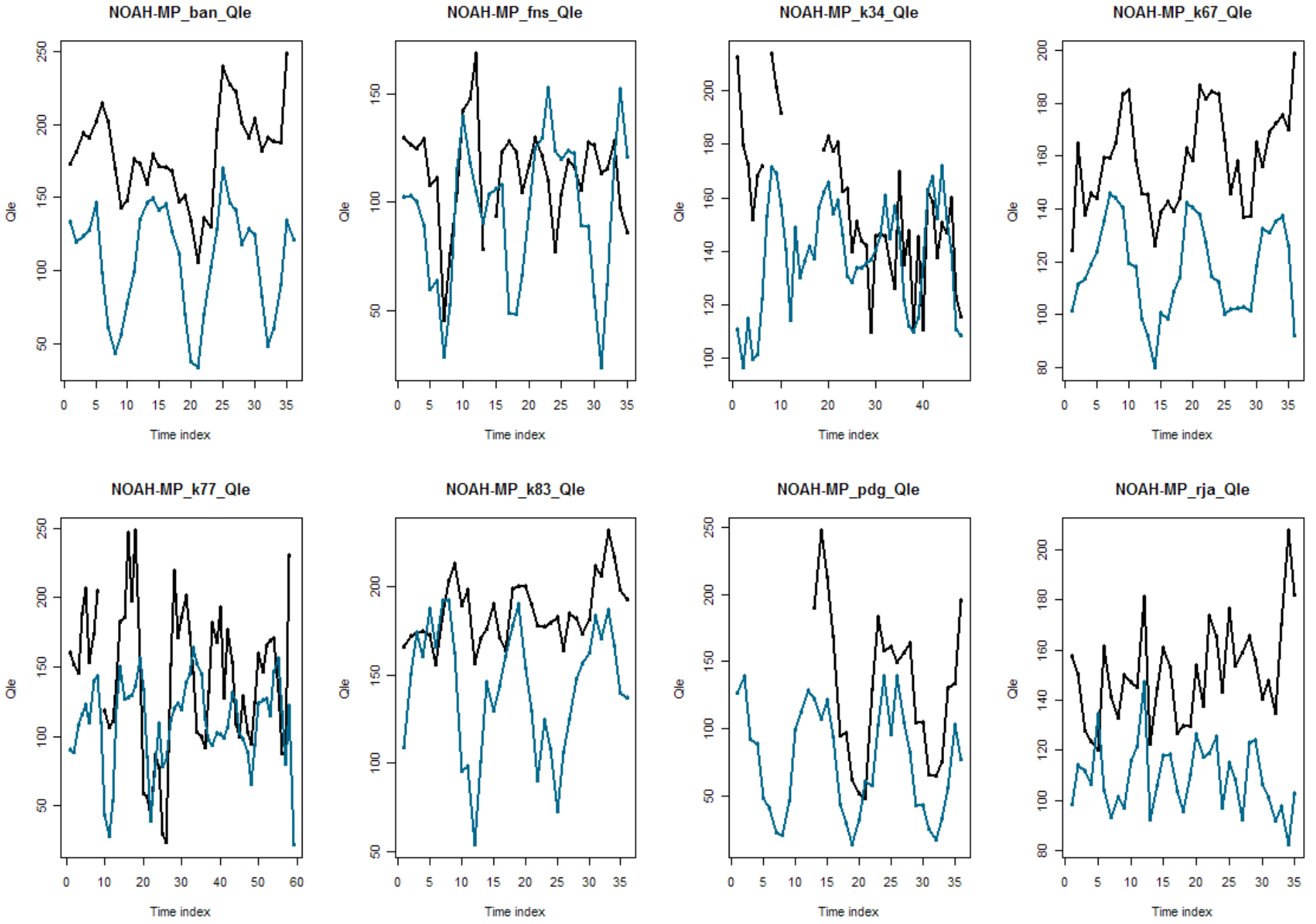
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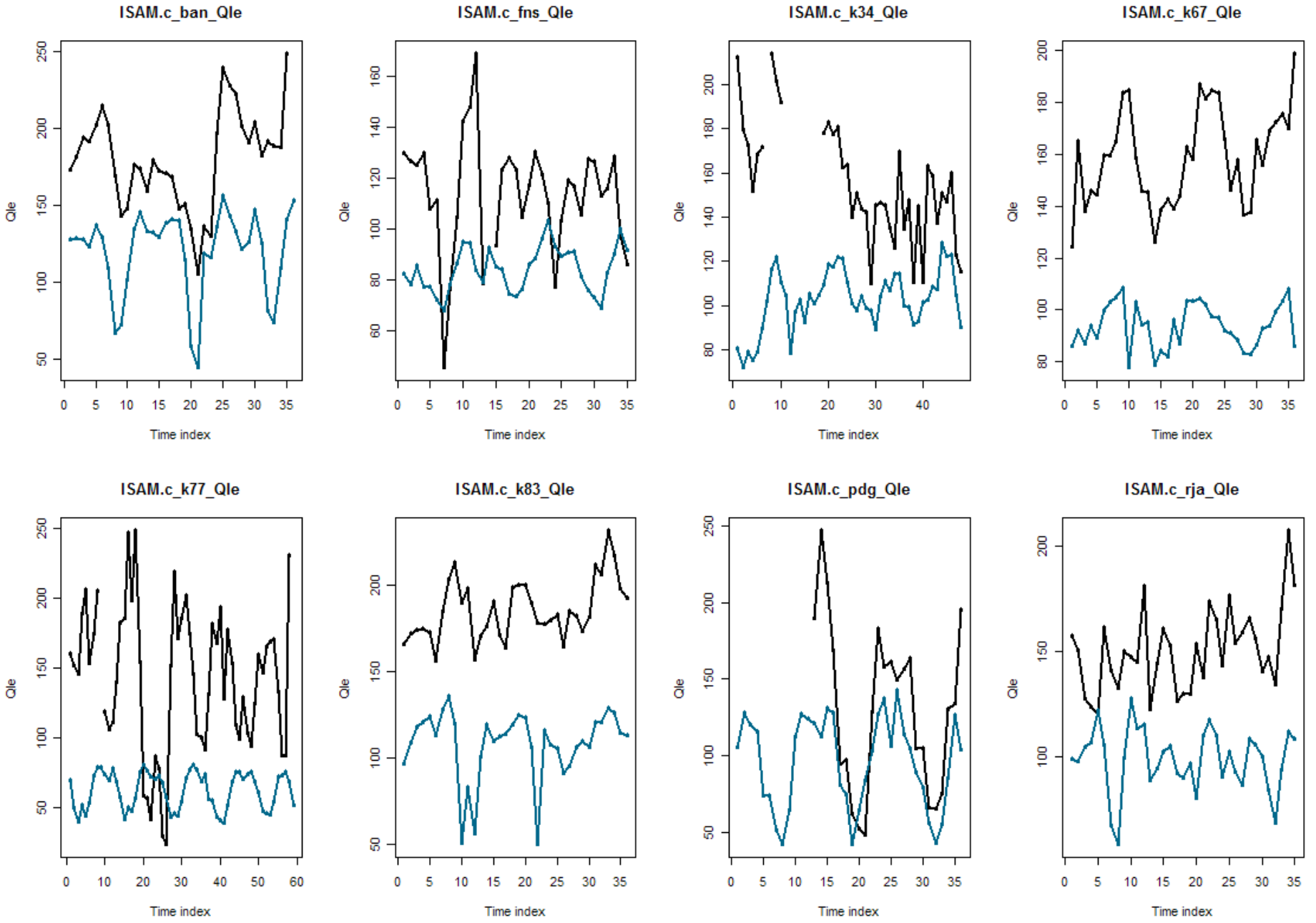
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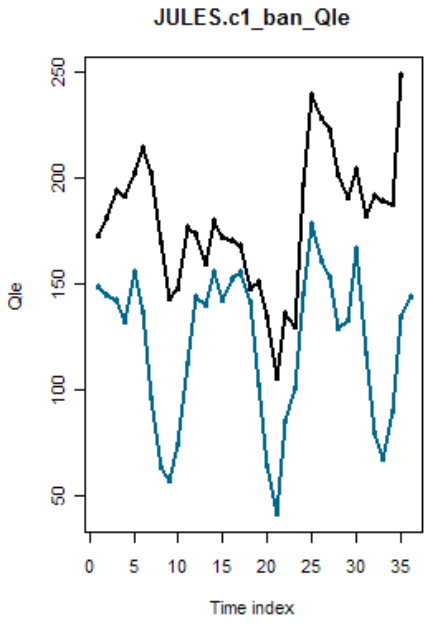
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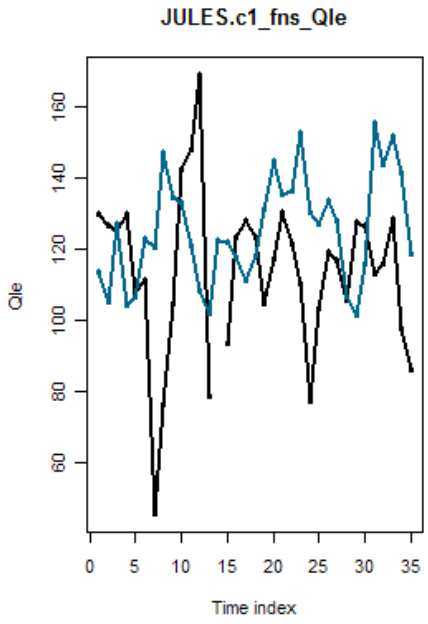
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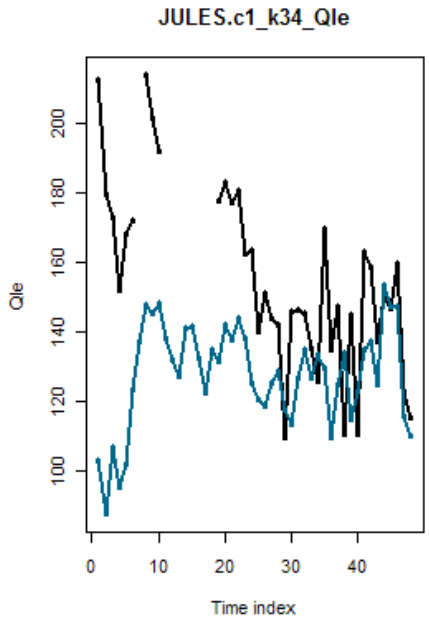
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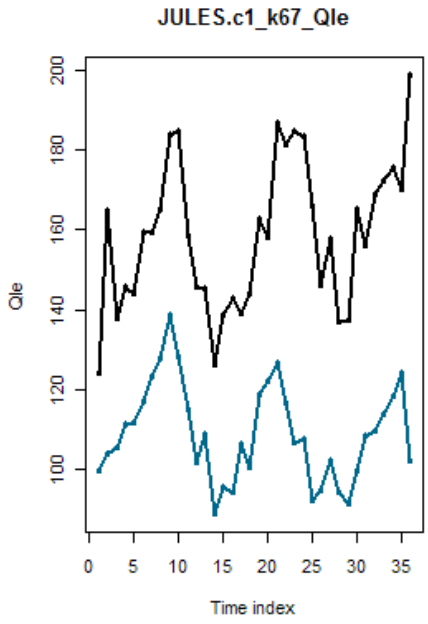
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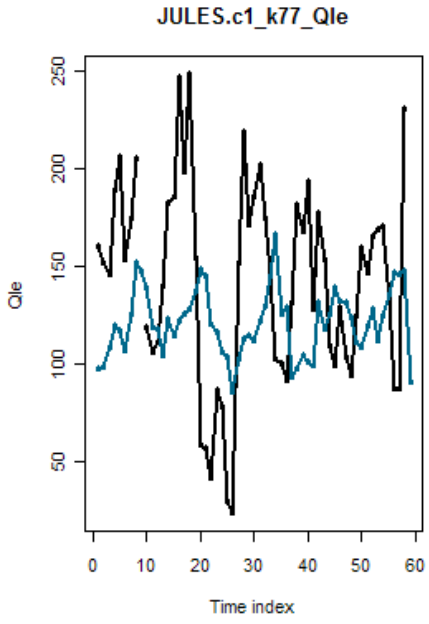
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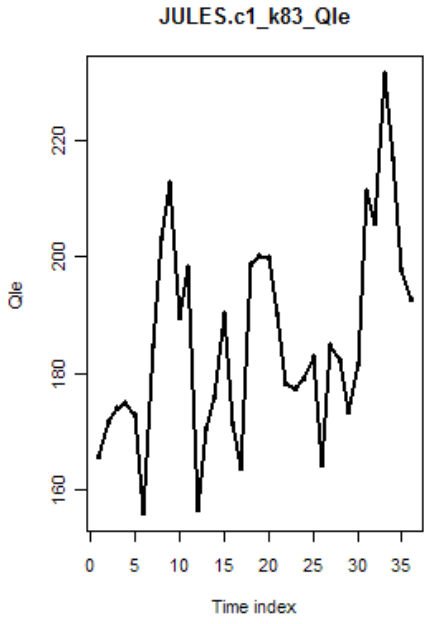
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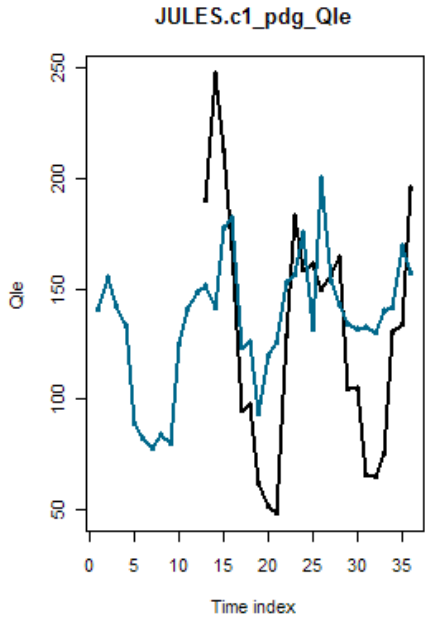
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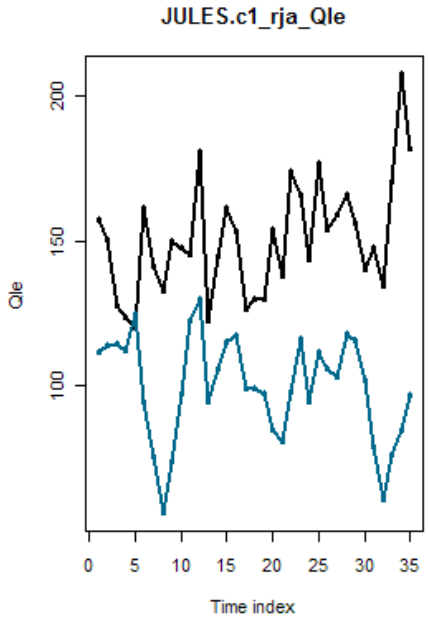
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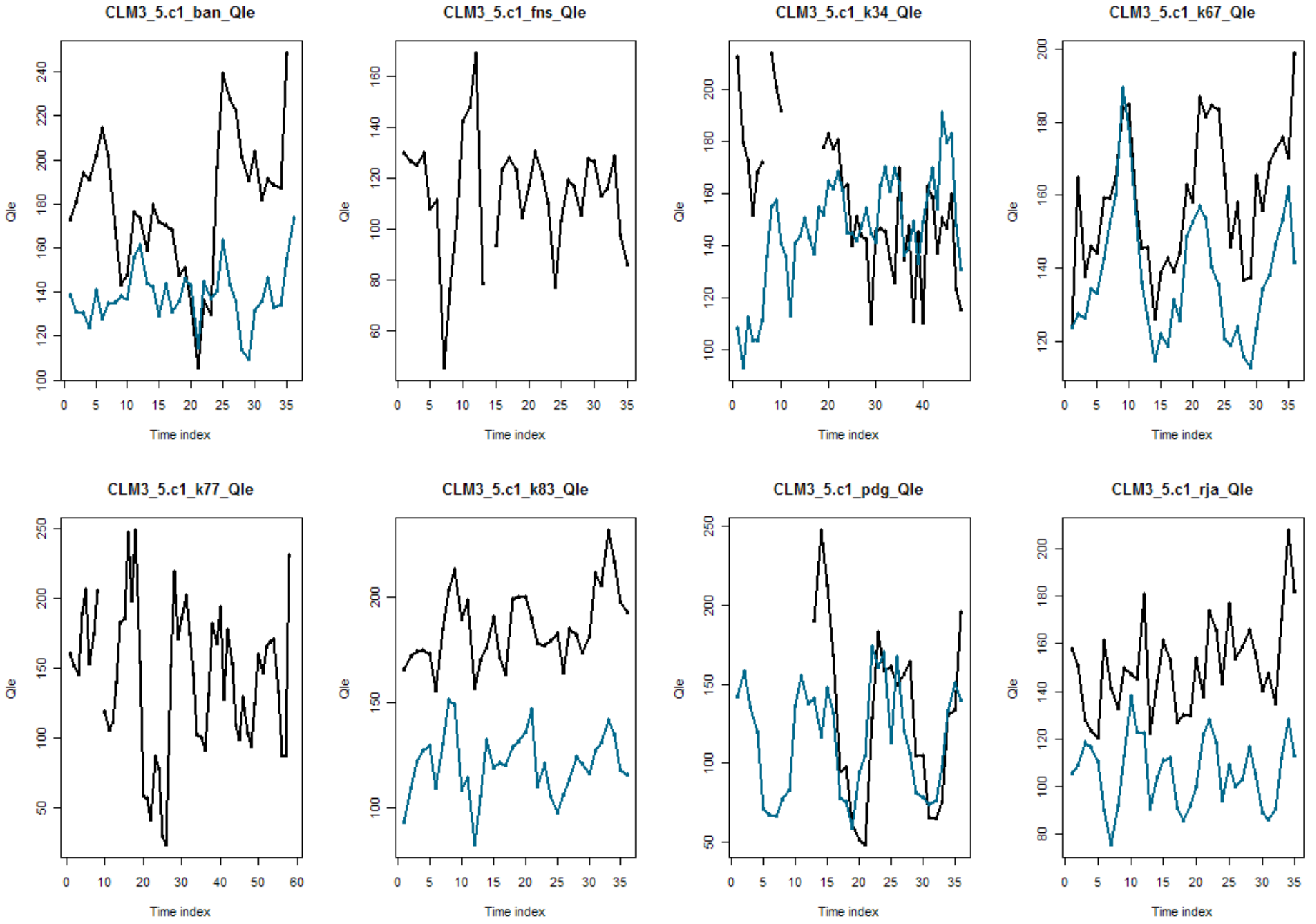
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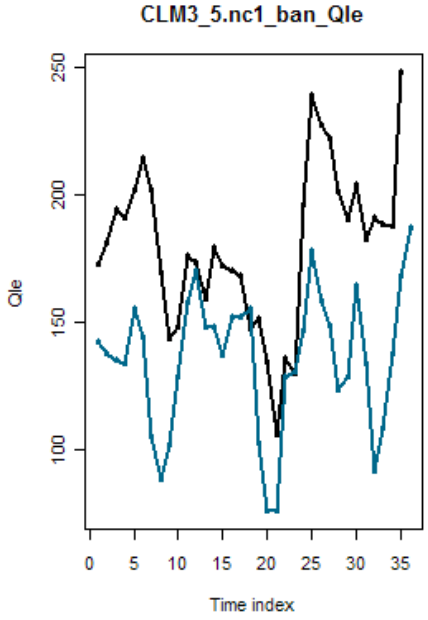
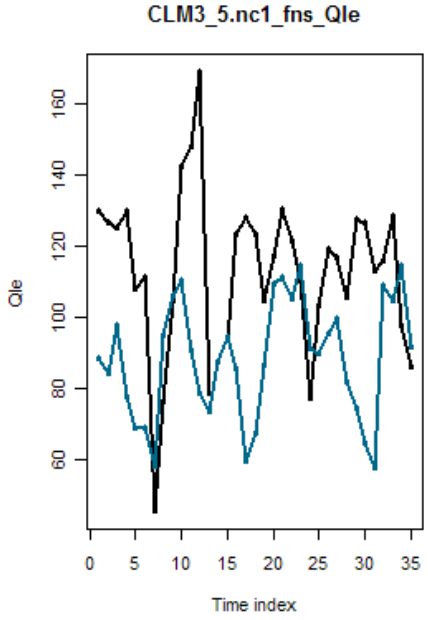
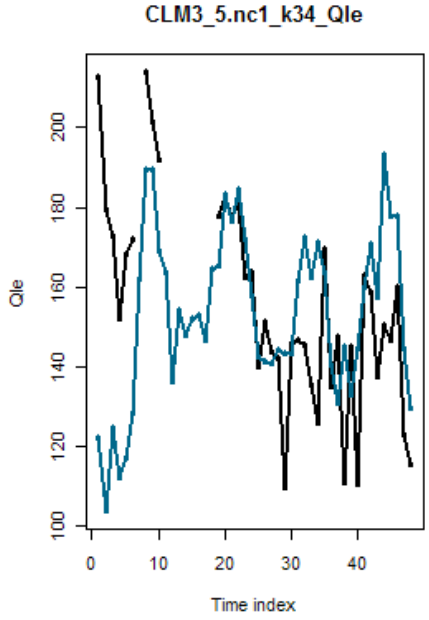
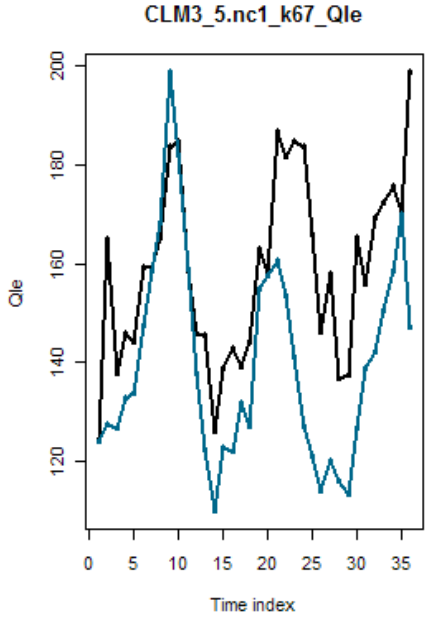
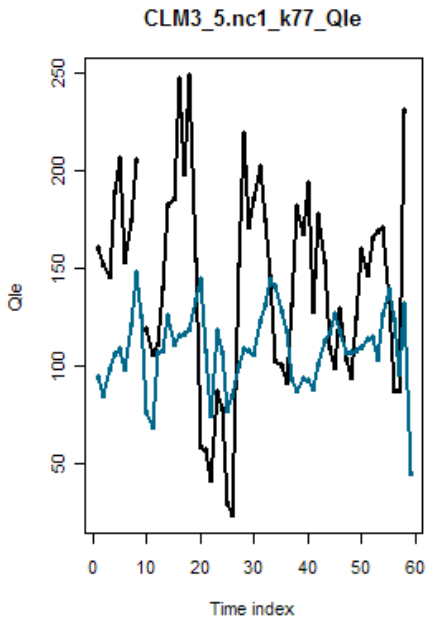
Qle
Time index

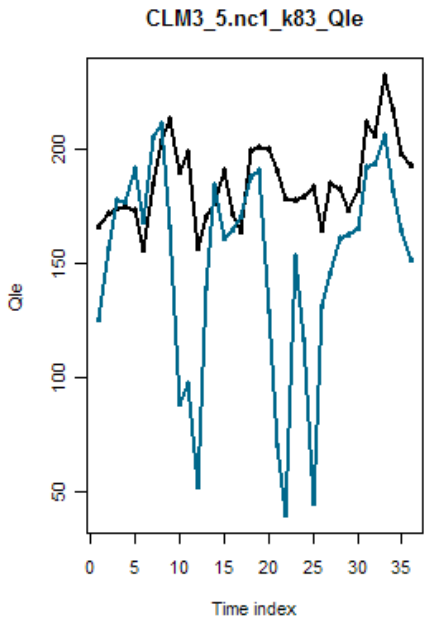

CLM3_5.nc1_ban_Qle
Qle
Time index

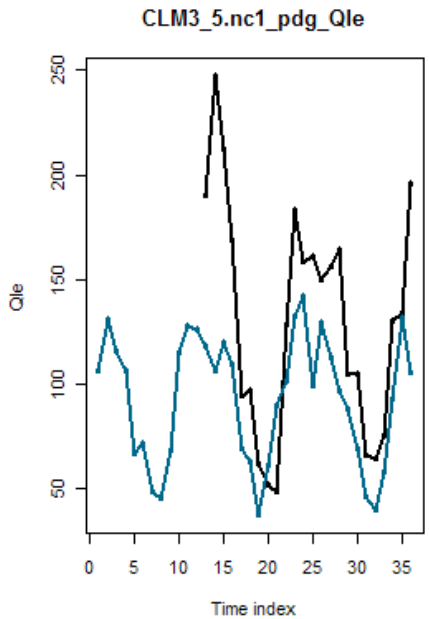

CLM3_5.nc1_fns_Qle
Qle
Time index

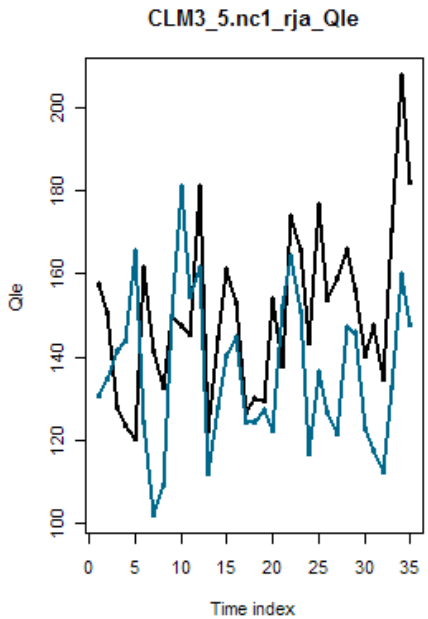

CLM3_5.nc1_k34_Qle
Qle
Time index

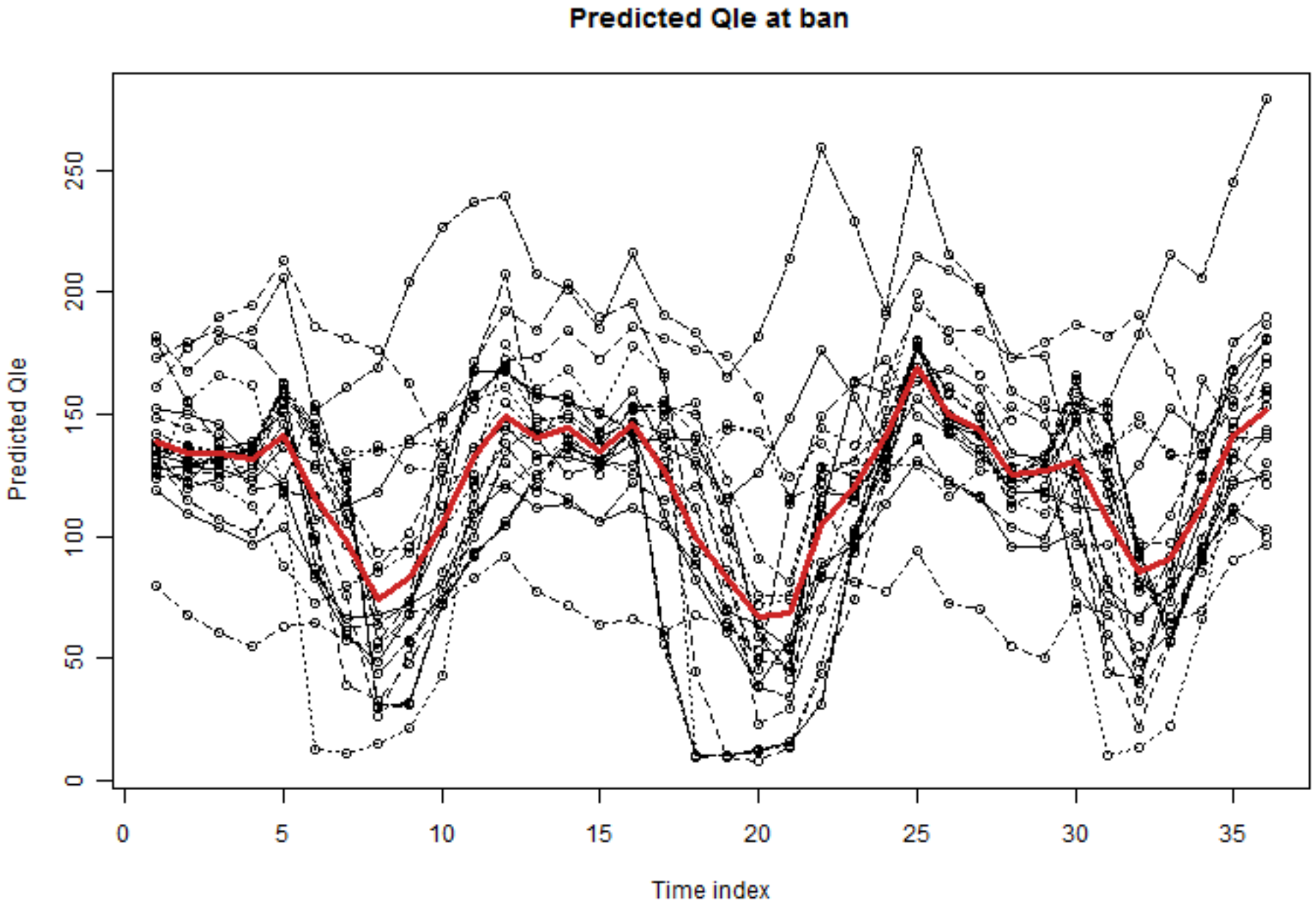

CLM3_5.nc1_k67_Qle
Qle
Time index

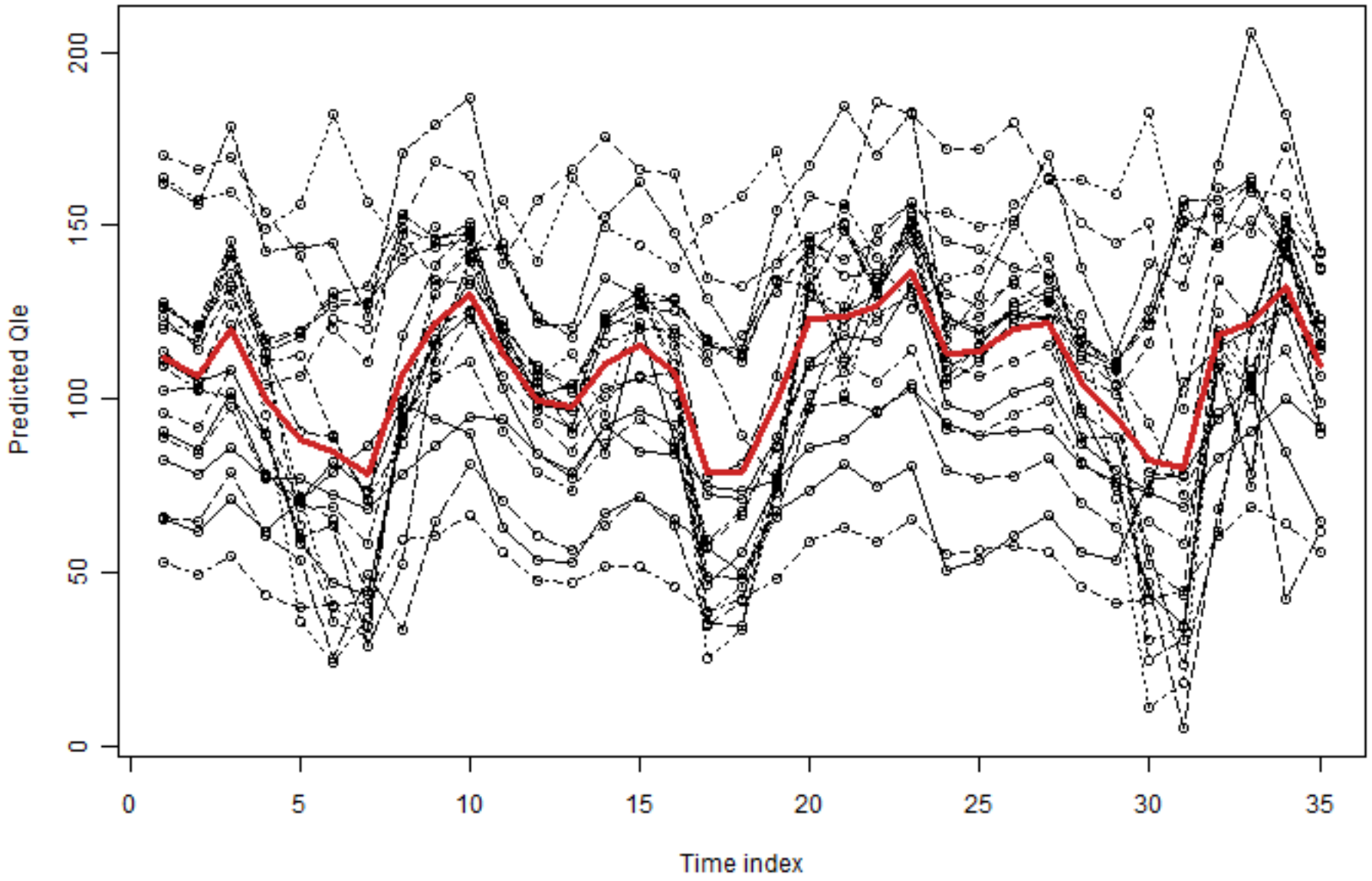

CLM3_5.nc1_k77_Qle
Qle
Time index

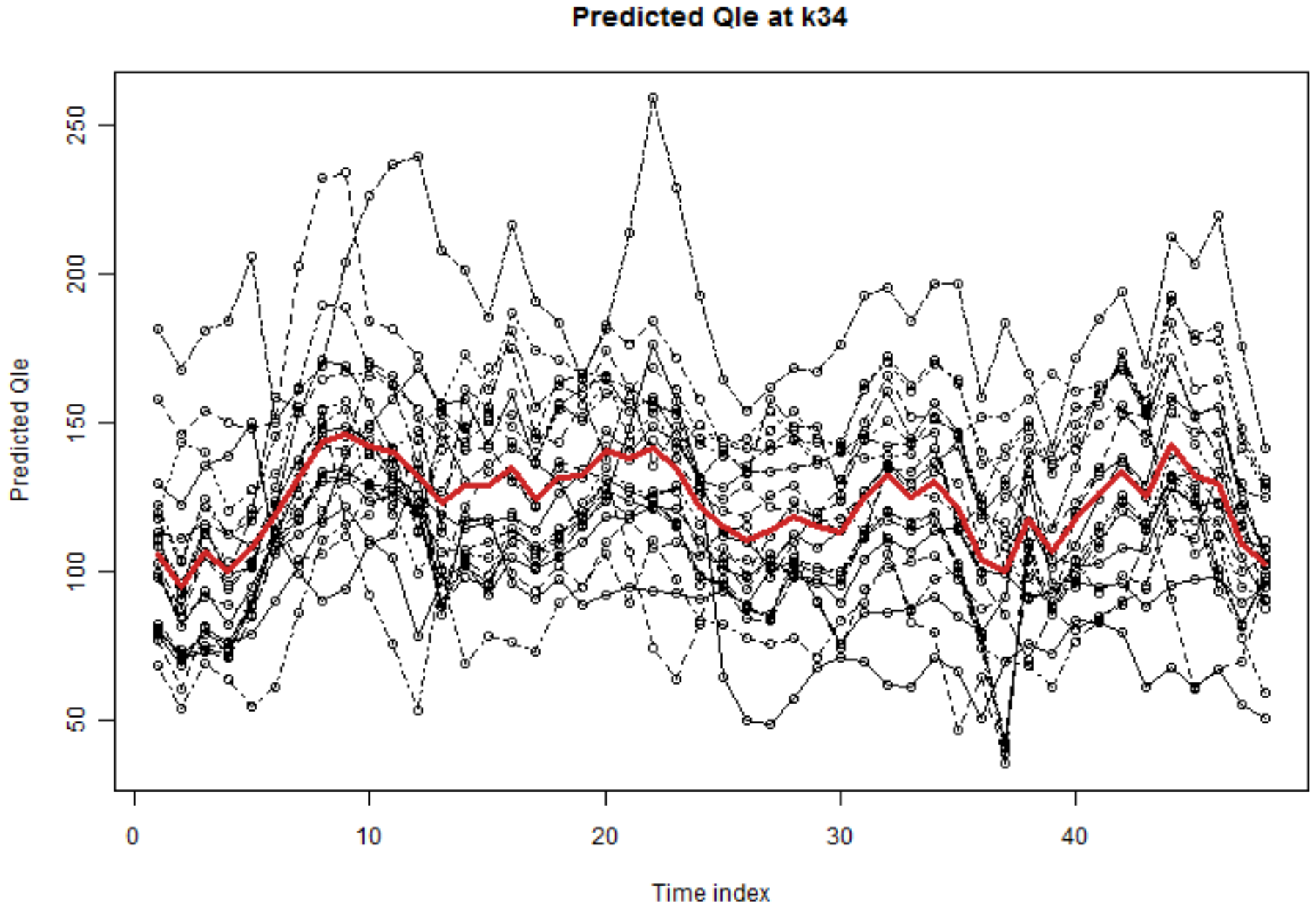

CLM3_5.nc1_k83_Qle
Qle
Time index

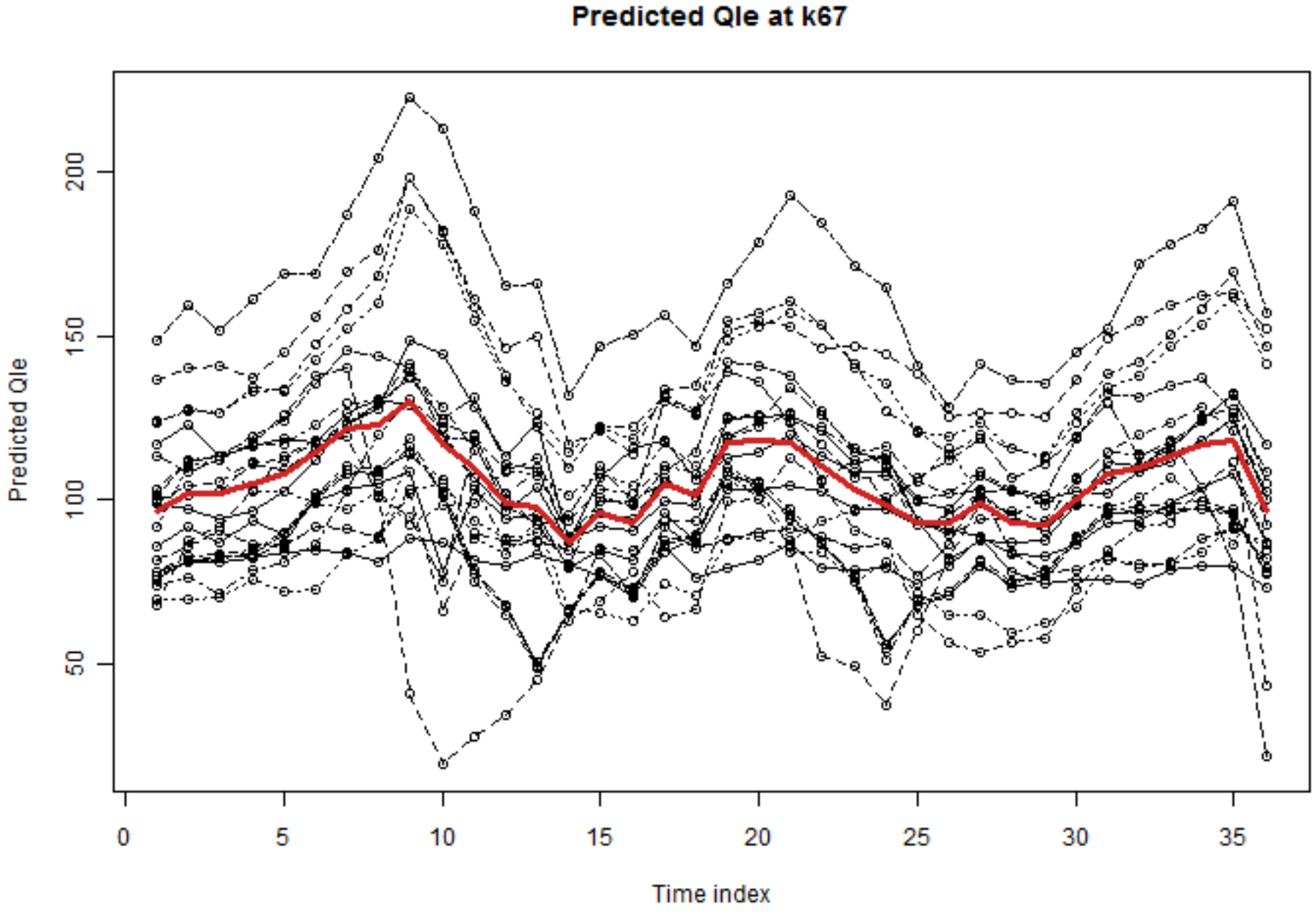

CLM3_5.nc1_pdg_Qle
Qle
Time index

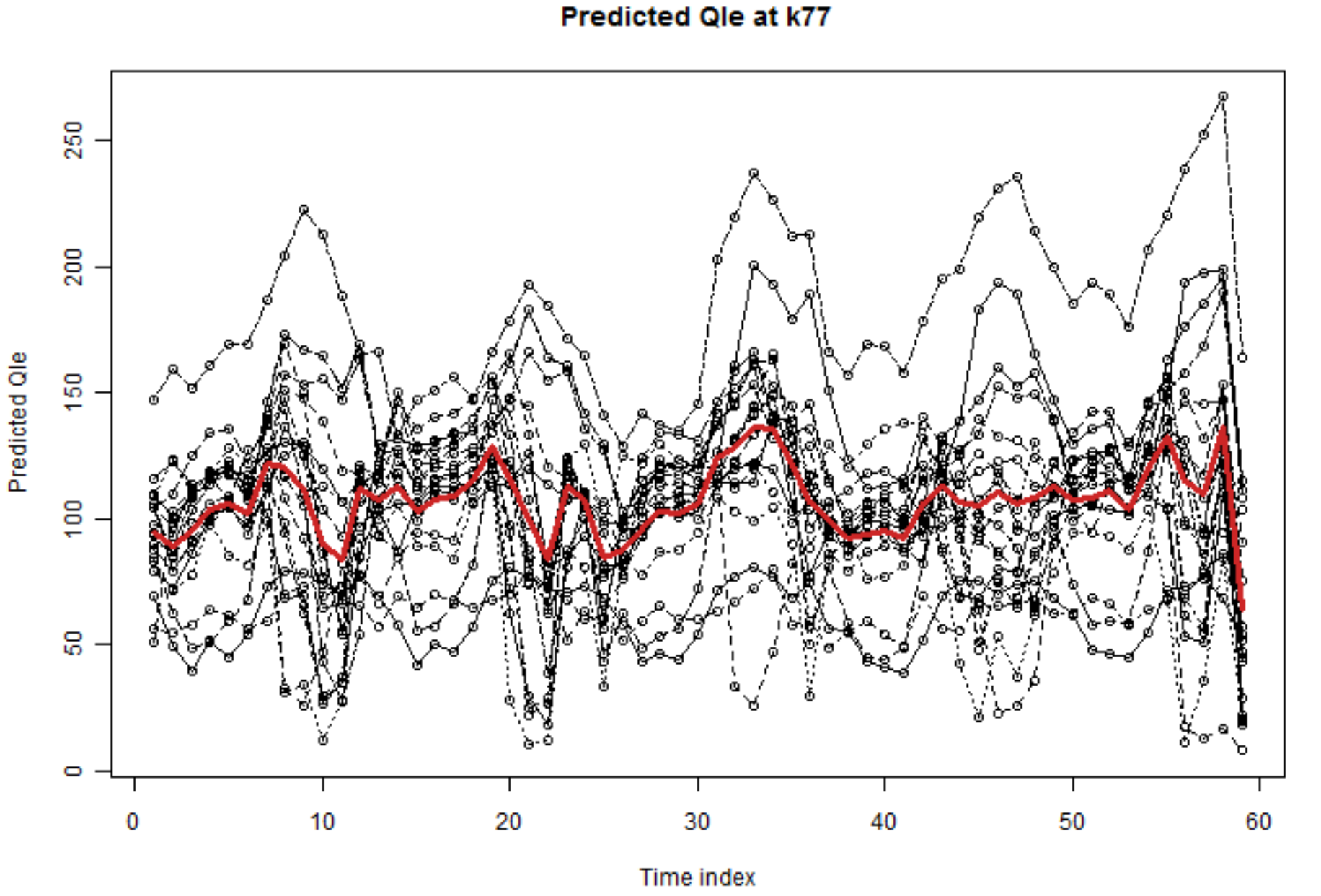

CLM3_5.nc1_rja_Qle
Qle
Time index

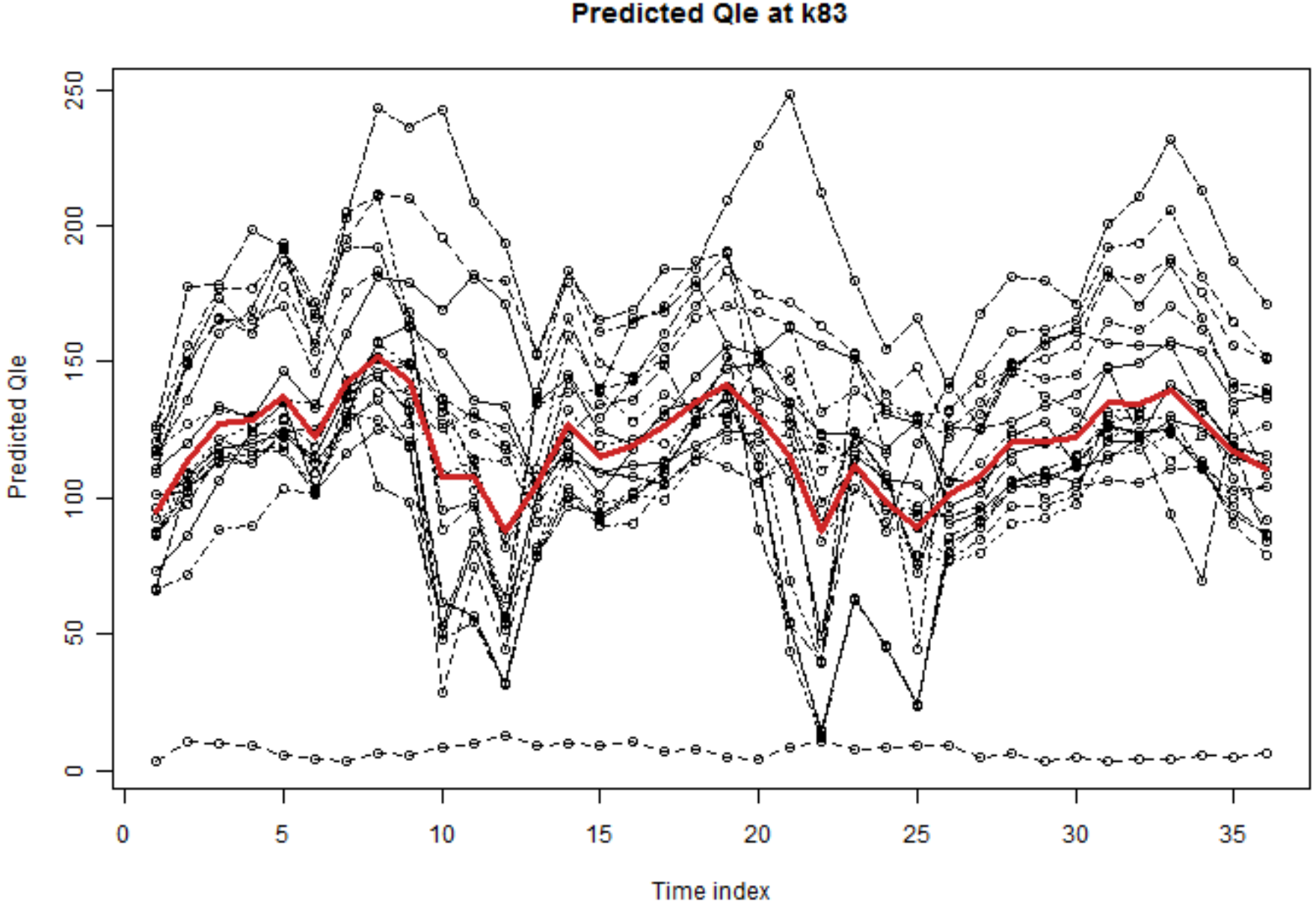

Predicted Qle at ban
Predicted Qle
0
50
100
150
200
250
0
5
10
15
20
25
30
35
Time index

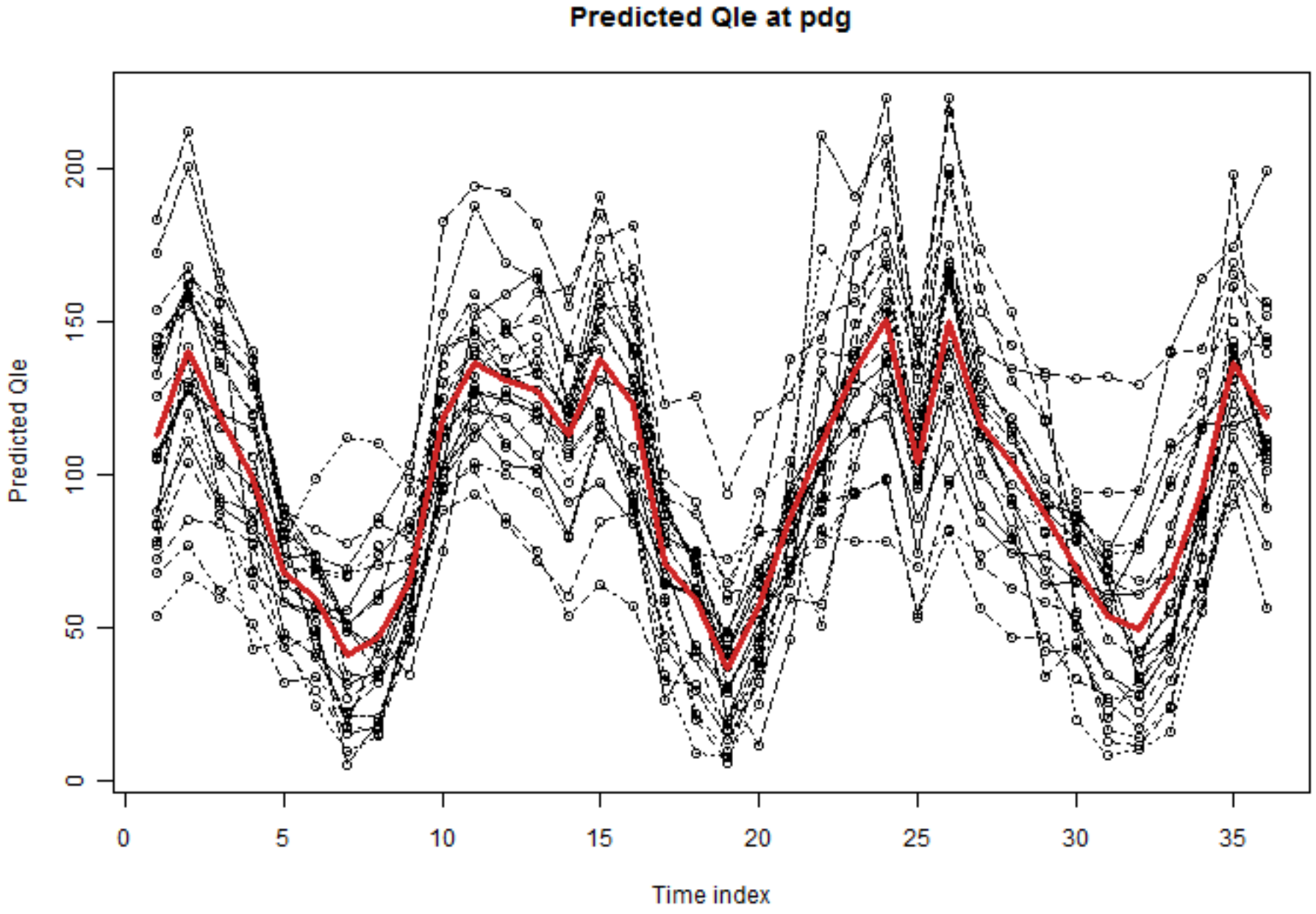

Predicted Qle at fns
Predicted Qle
0
50
100
150
200
0
5
10
15
20
25
30
35
Time index

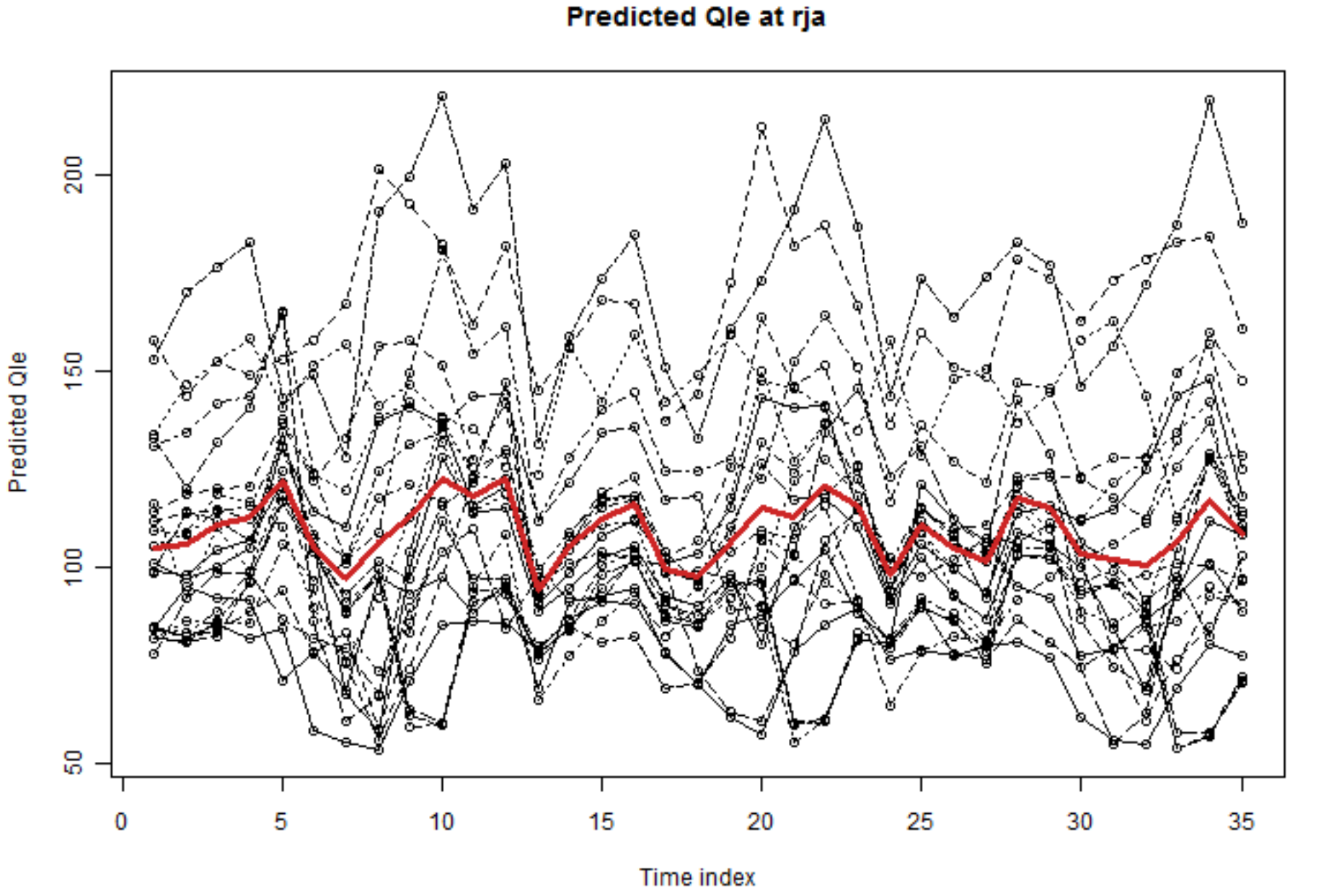

Predicted Qle at k34
Predicted Qle
50
100
150
200
250
0
10
20
30
40
Time index


Predicted Qle at k67
Predicted Qle
50
100
150
200
0
5
10
15
20
25
30
35
Time index


Predicted Qle at k77
Predicted Qle
0
50
100
150
200
250
0
10
20
30
40
50
60
Time index


Predicted Qle at k83
Predicted Qle
Time index
0
50
100
150
200
250
0
5
10
15
20
25
30
35


Predicted Qle at pdg
Predicted Qle
0
50
100
150
200
0
5
10
15
20
25
30
35
Time index


Predicted Qle at rja
Predicted Qle
50
100
150
200
0
5
10
15
20
25
30
35
Time index

Statistical output

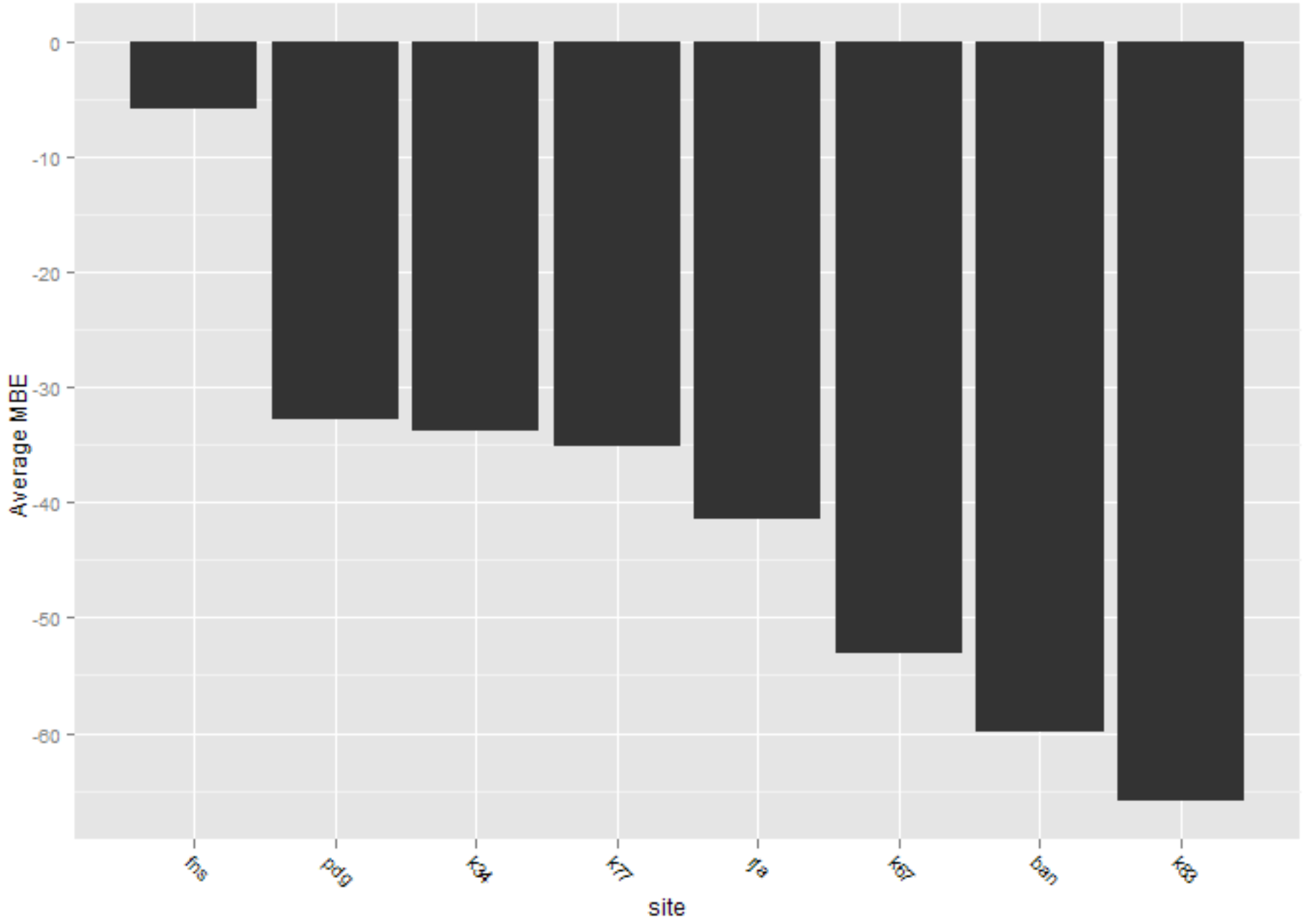
$$MBE = \frac{\sum_{i=1}^{n}(P_i - O_i)}{N}$$

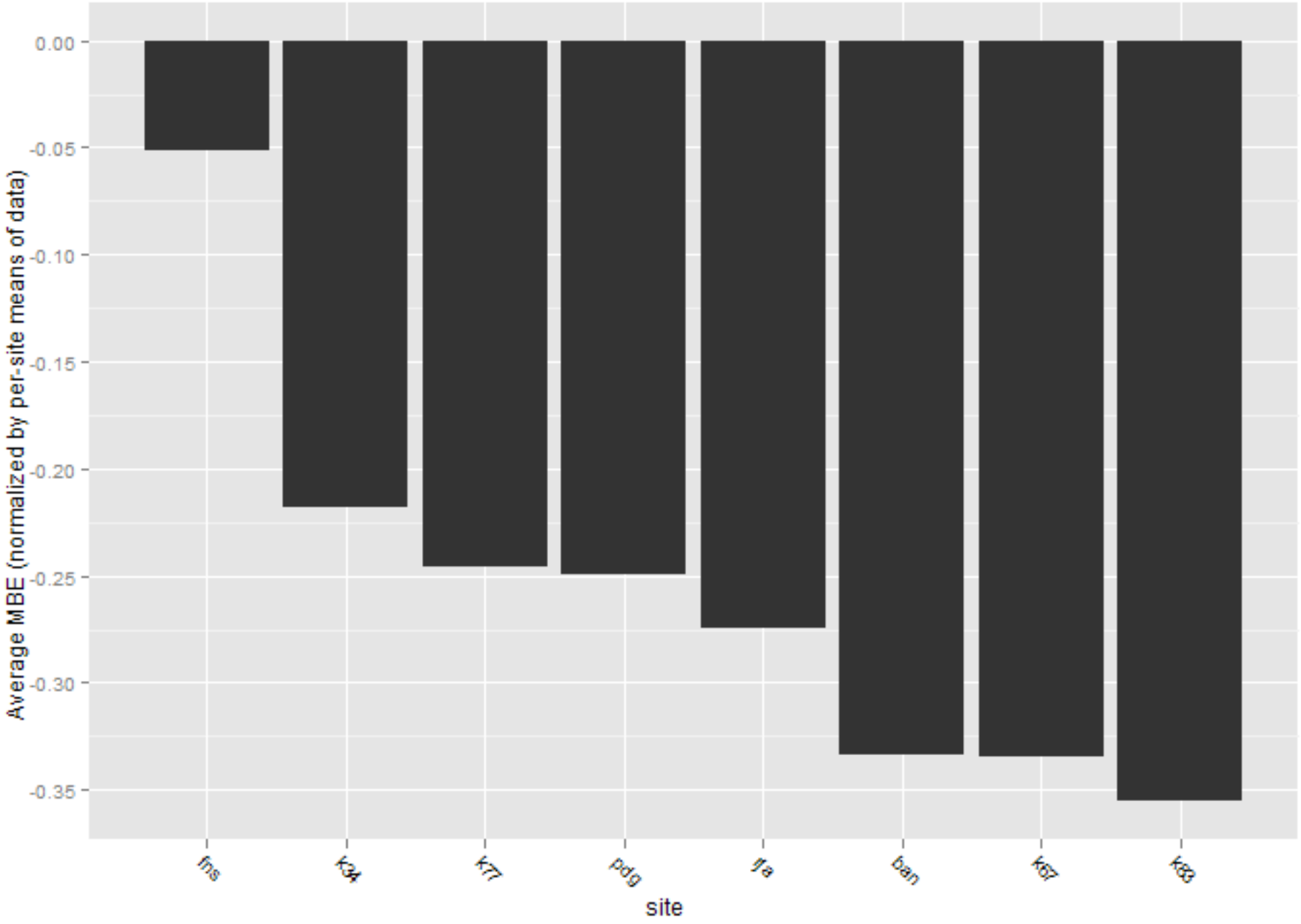
$$MBE_{norm} = \frac{\left(\frac{\sum_{i=1}^{n}(P_i - O_i)}{N}\right)}{\overline{O}}$$

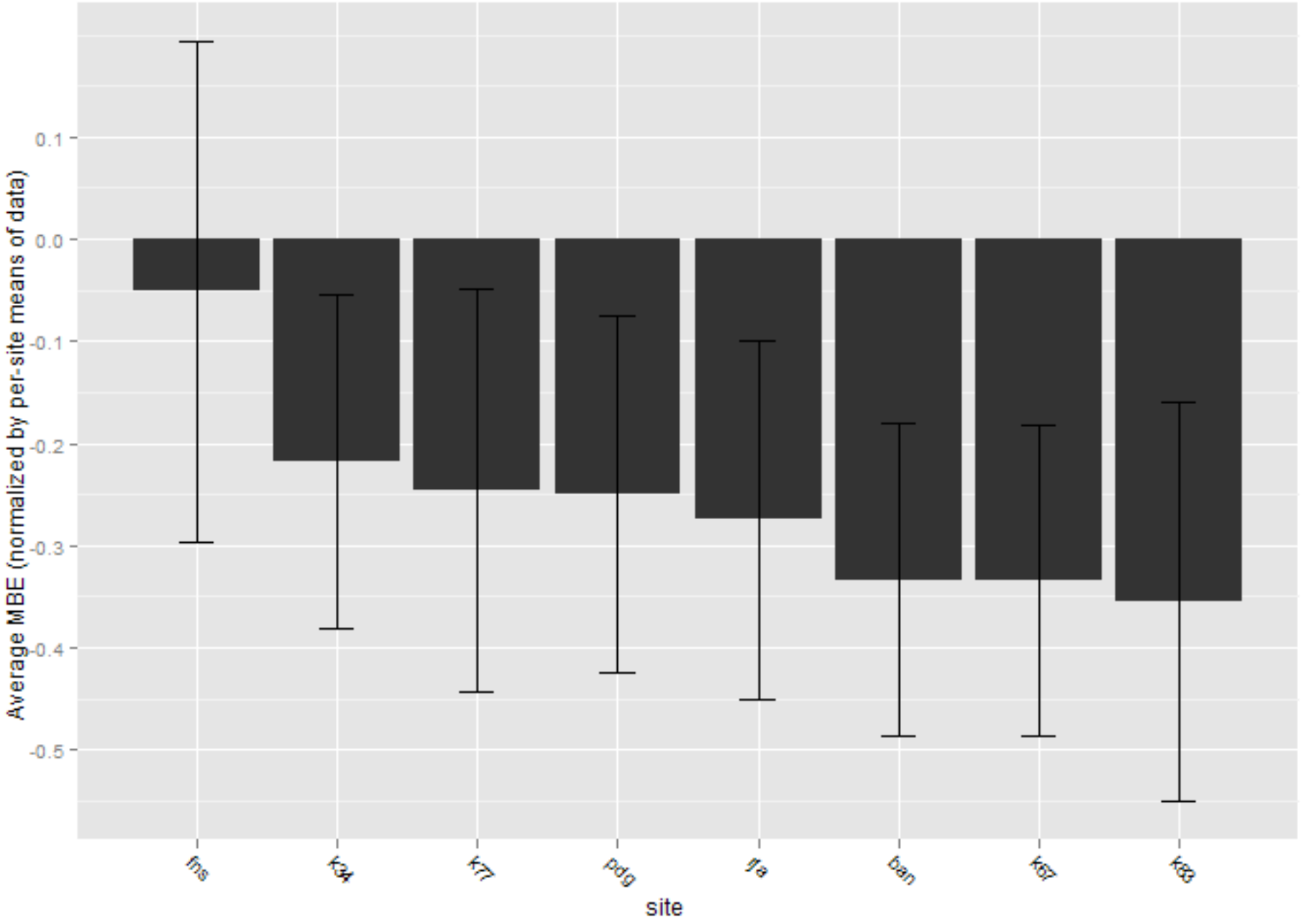
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{N}}$$

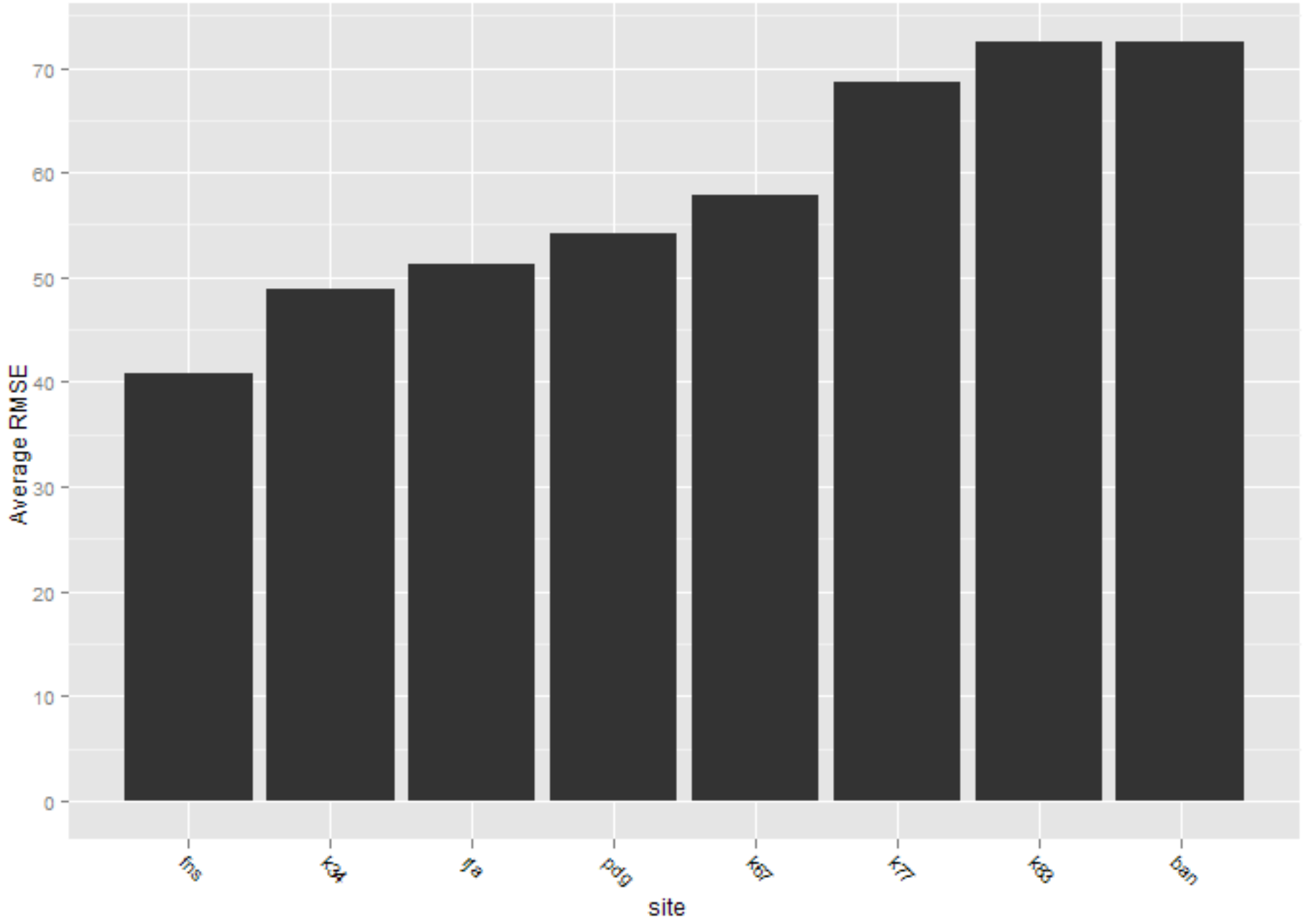
$$RMSE_{norm} = \frac{\left(\sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{N}}\right)}{SE_{Obs}}$$

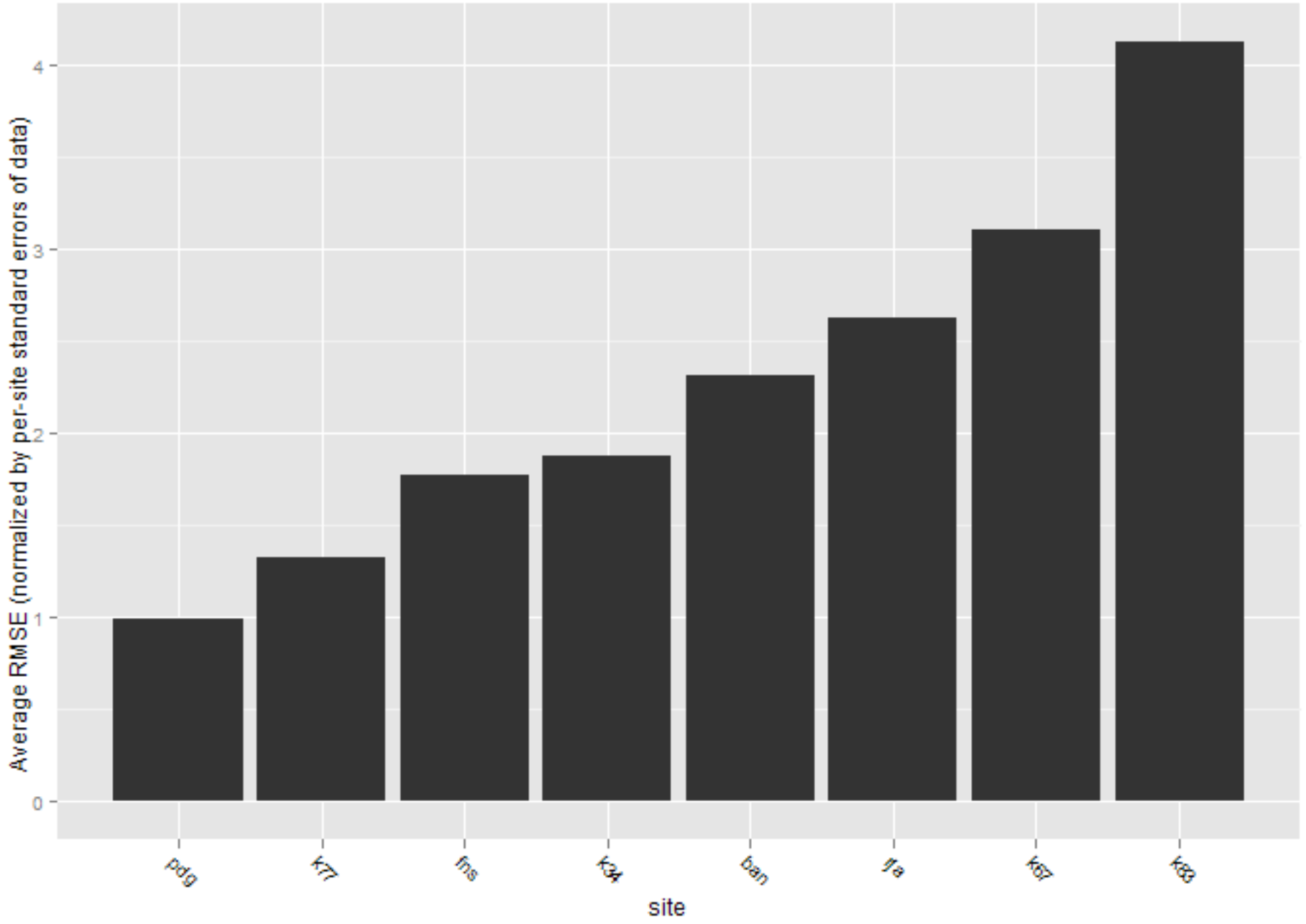
$$R^2 = \frac{SS_{err}}{SS_{tot}}$$

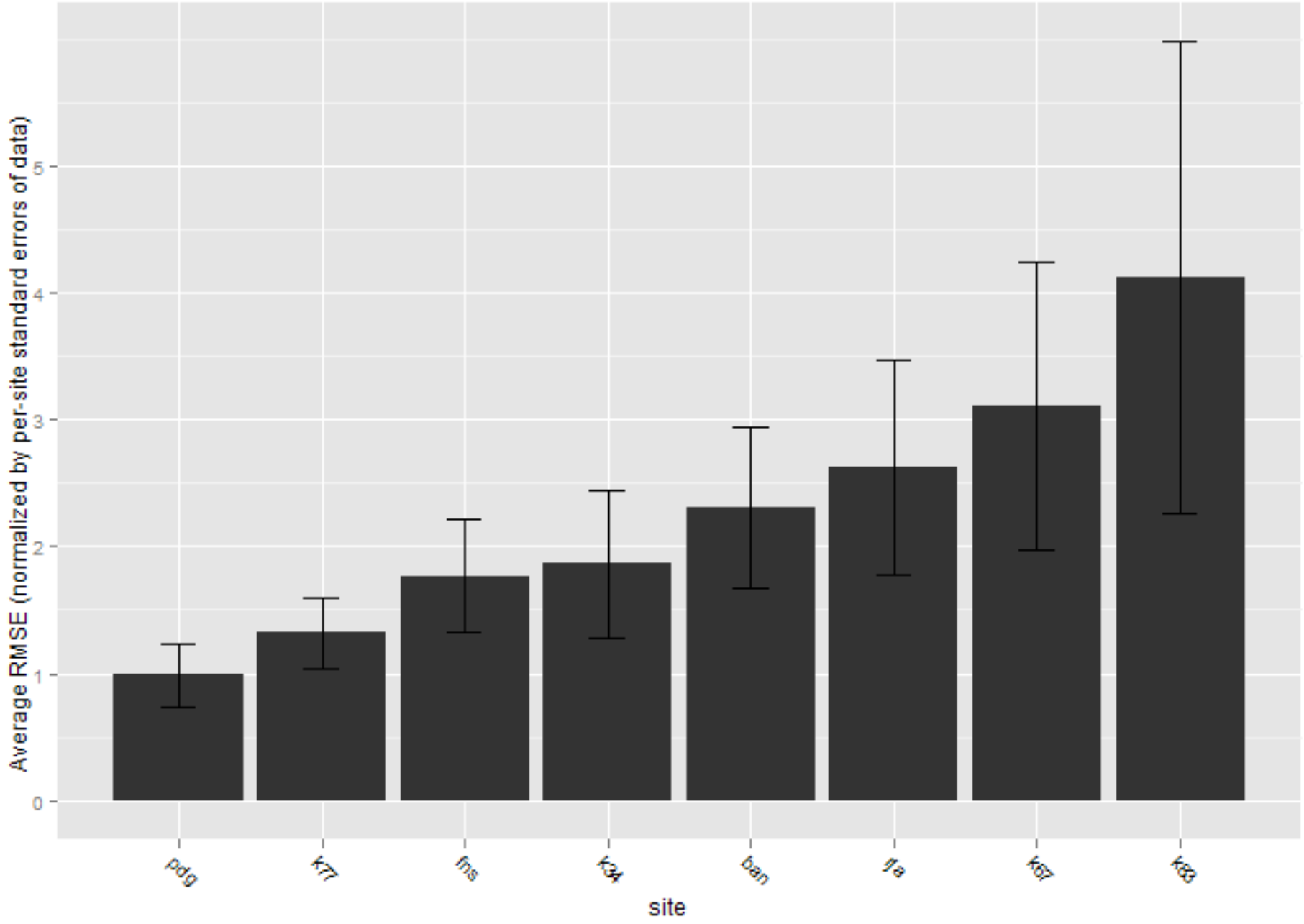

0
-10
-20
-30
-40
-50
-60
Average MBE
fns
pdg
k34
k77
fja
k67
ban
k83
site

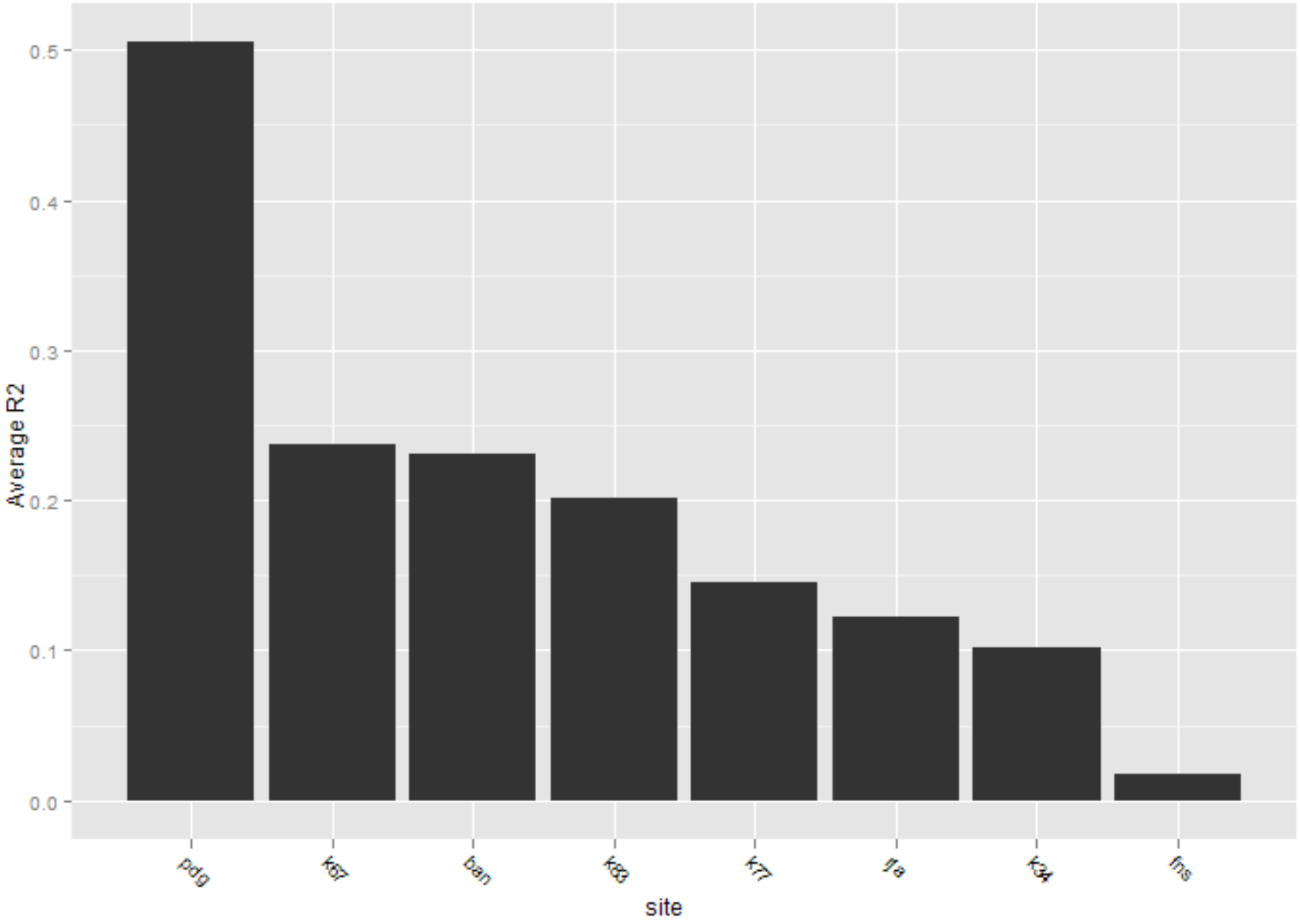

0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
Average MBE (normalized by per-site means of data)
fns
k34
k77
pdg
ffa
ban
k67
k83
site

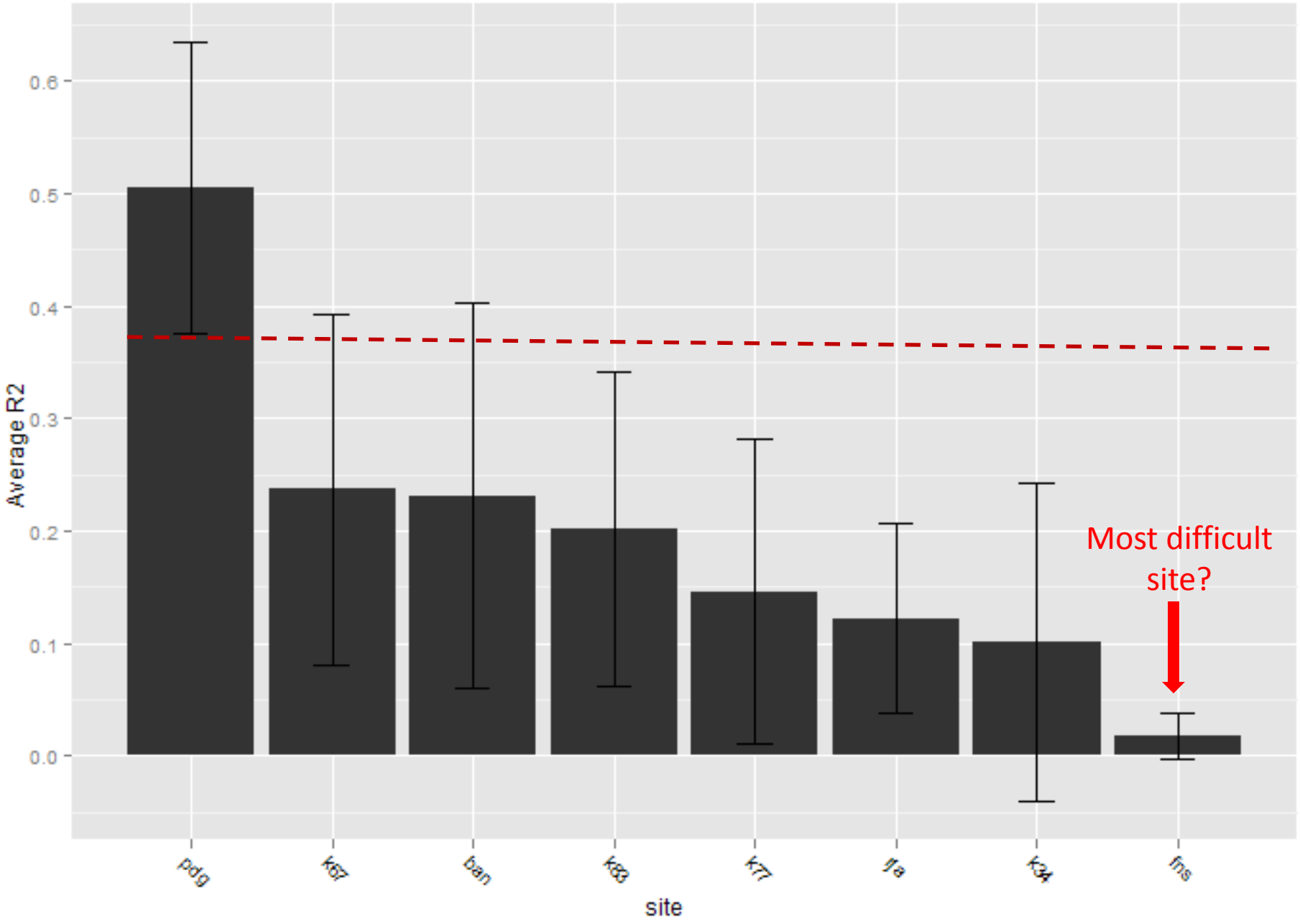

Average MBE (normalized by per-site means of data)
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
fns
k34
k77
pdg
fja
ban
k67
k83
site

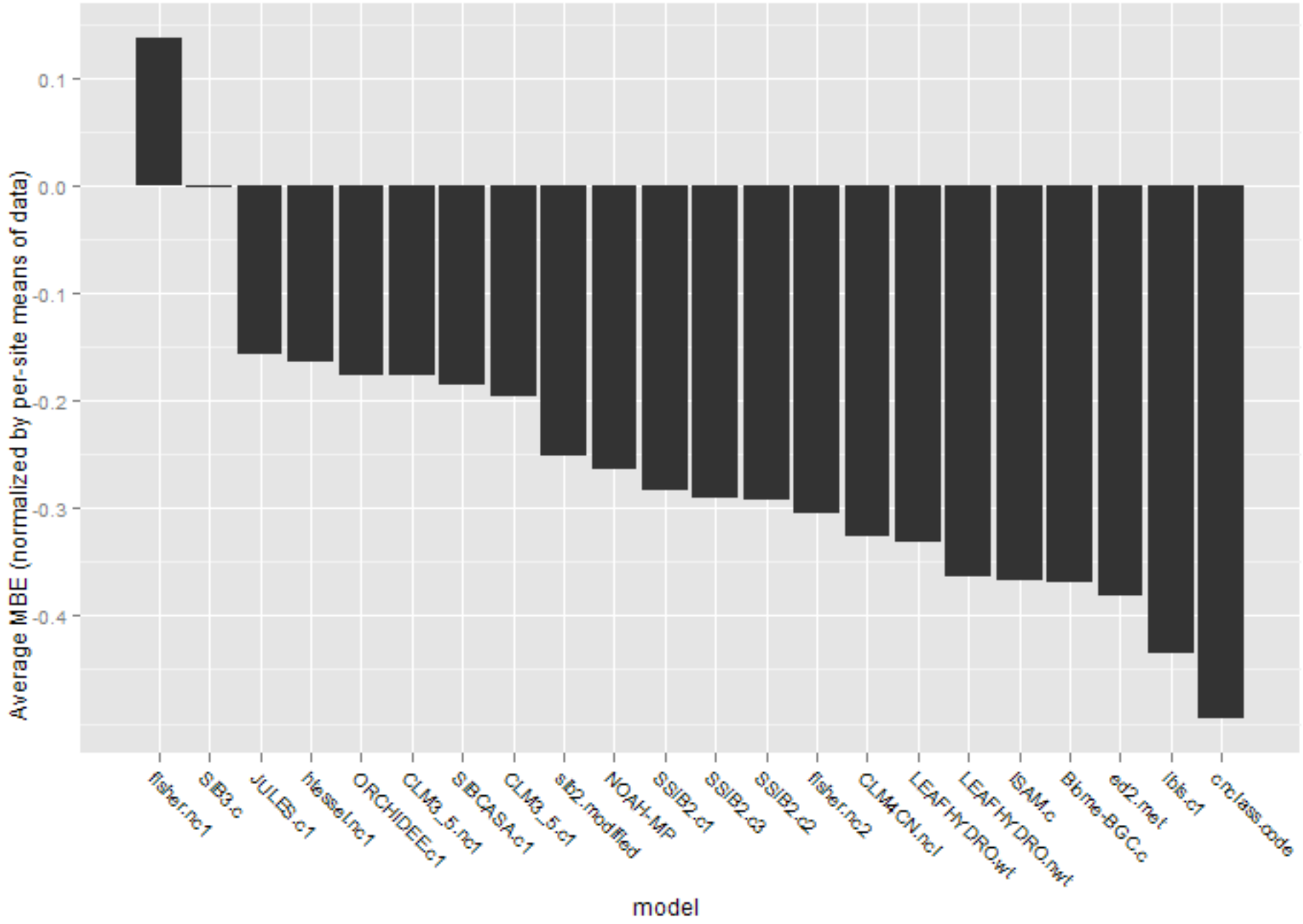

Average RMSE
0
10
20
30
40
50
60
70
fns
k34
ifa
pdg
k67
k77
k83
ban
site

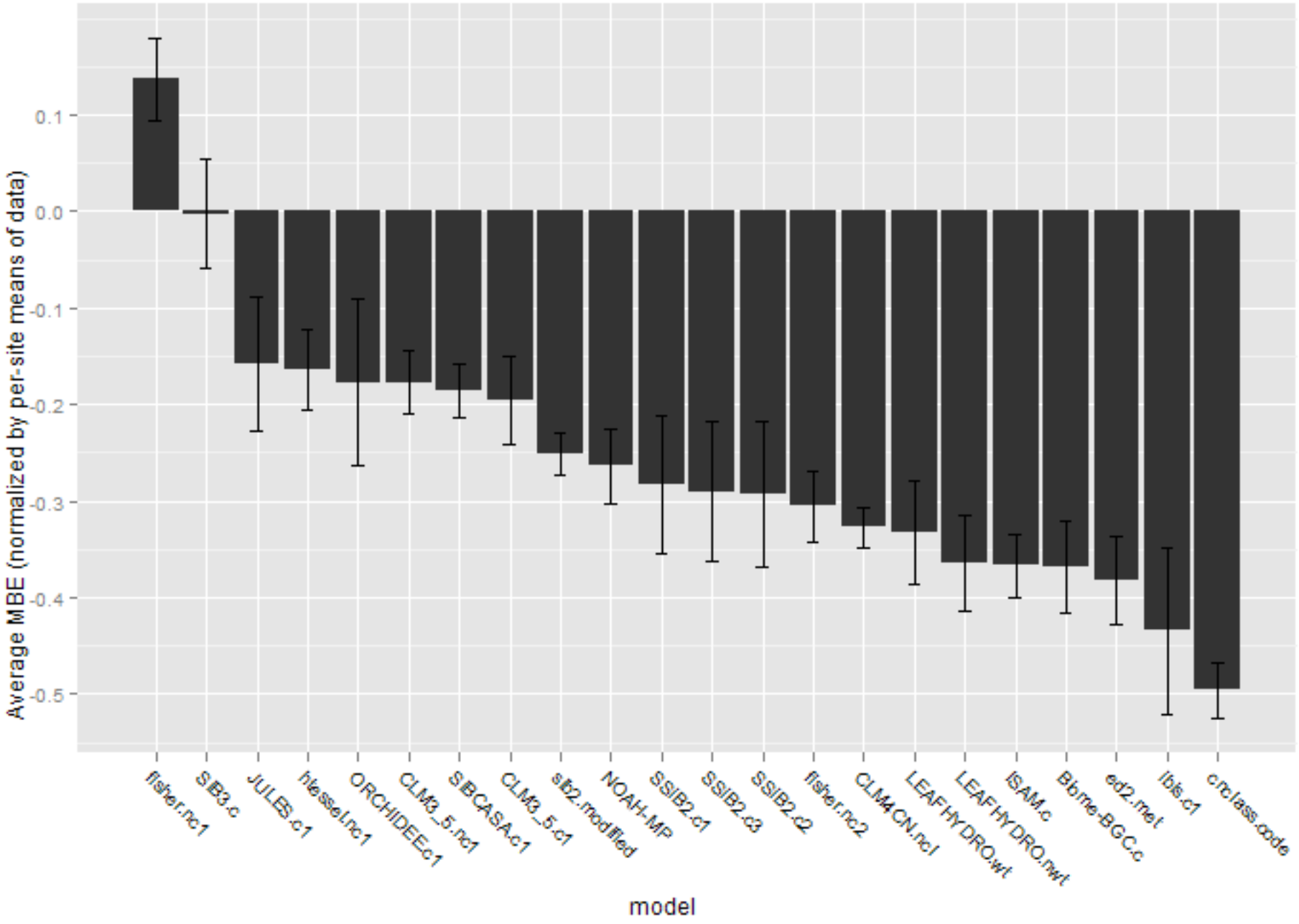

Average RMSE (normalized by per-site standard errors of data)
0
1
2
3
4
pdg
k77
fns
k34
ban
fla
k67
k83
site

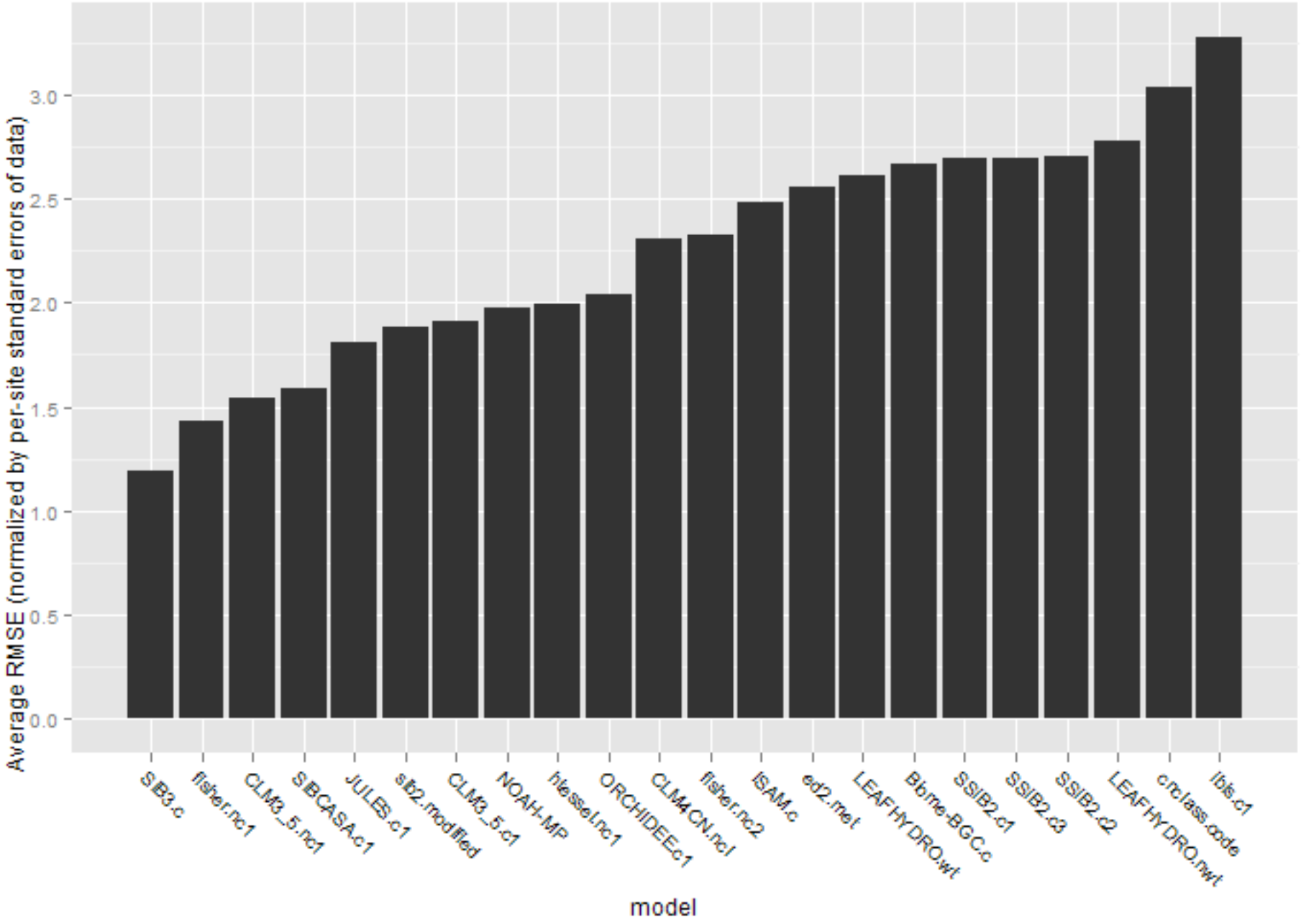

Average RMSE (normalized by per-site standard errors of data)
0
1
2
3
4
5
pdg
k77
fns
k34
ban
fla
k67
k83
site

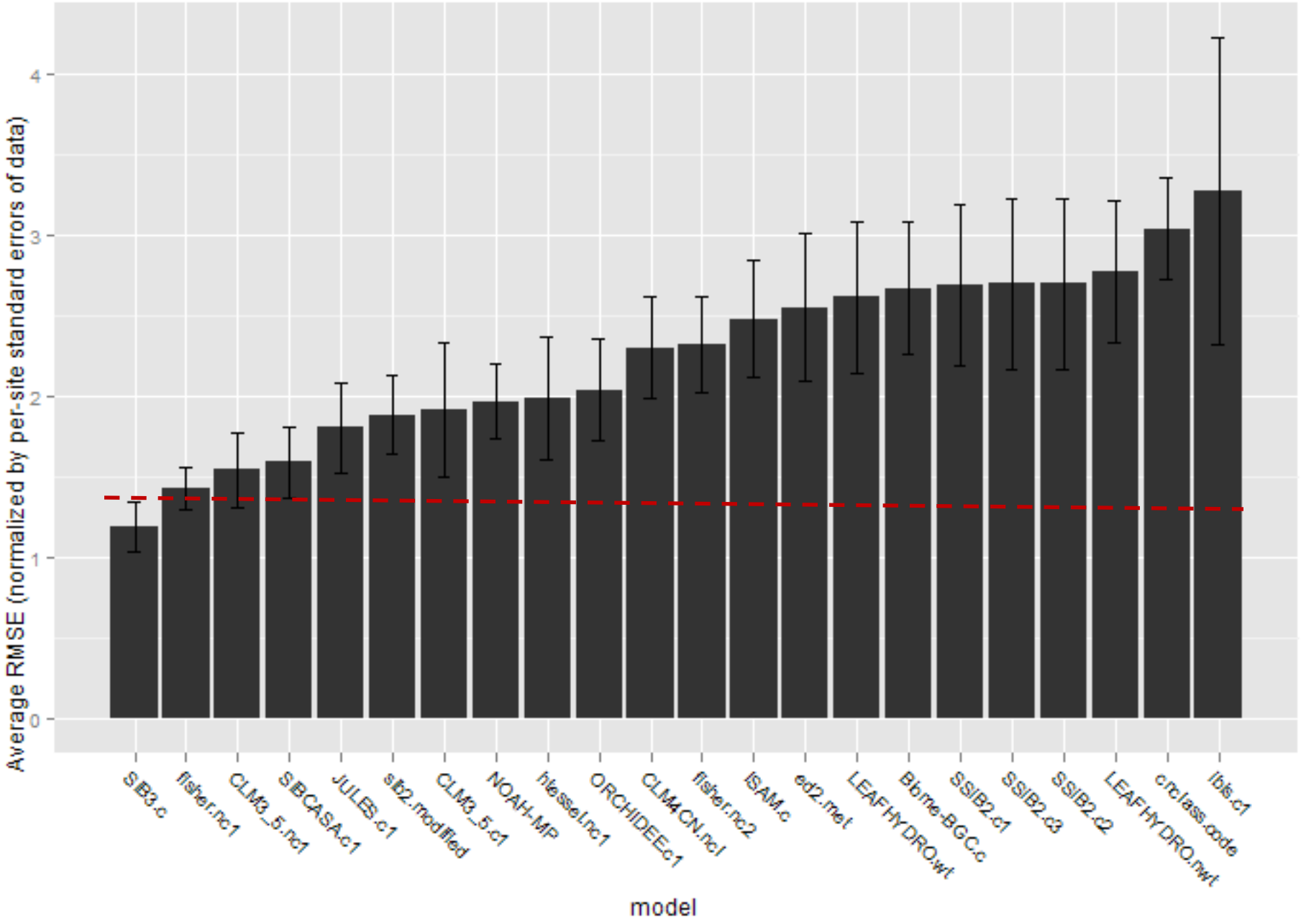

0.5
0.4
0.3
0.2
0.1
0.0
Average R2
pdg
k67
ban
k68
k77
fja
k34
fns
site

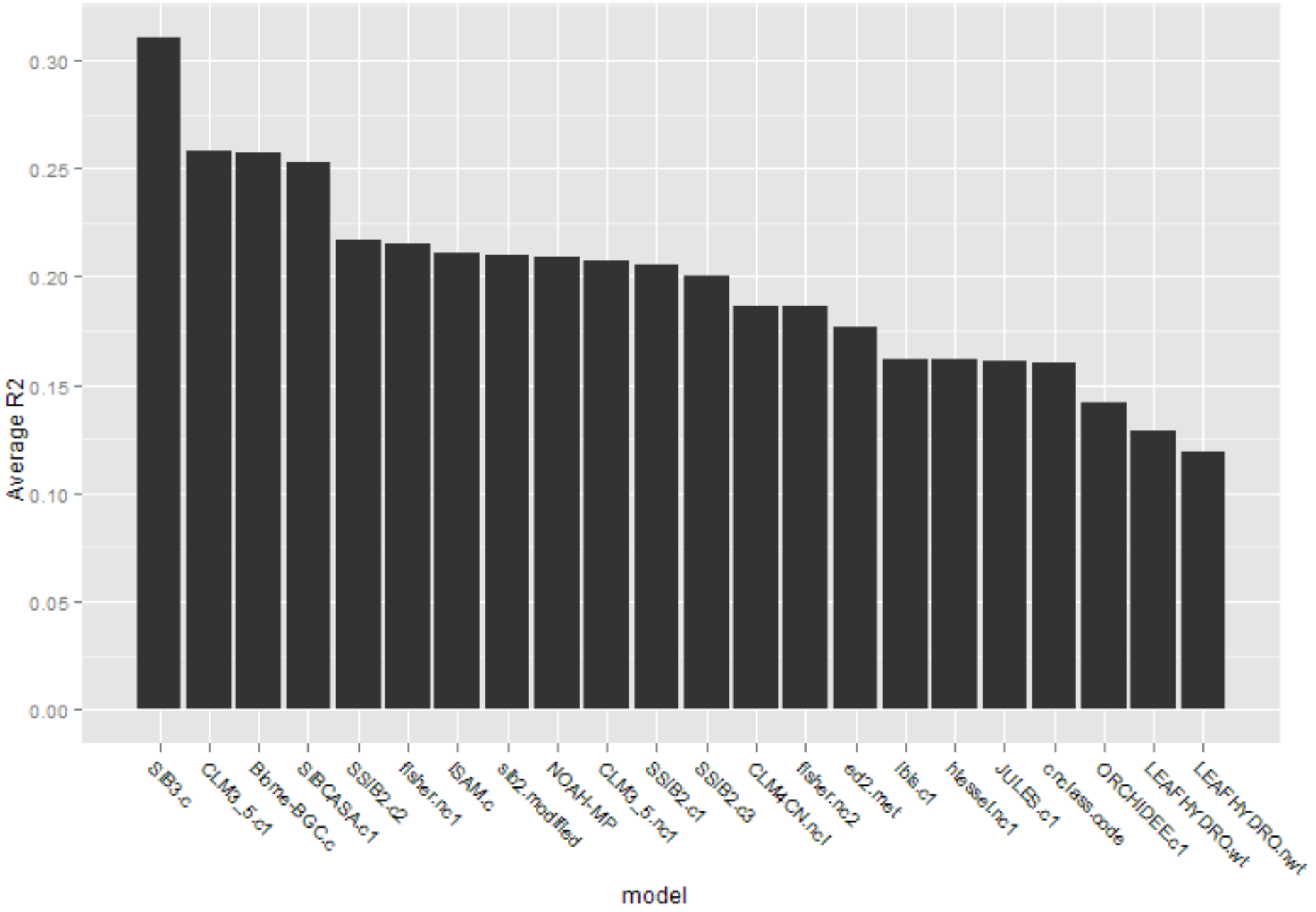

0.6
0.5
0.4
0.3
0.2
0.1
0.0
Average R2
pdg
k67
ban
k83
k77
fja
k34
fns
site
Most difficult site?

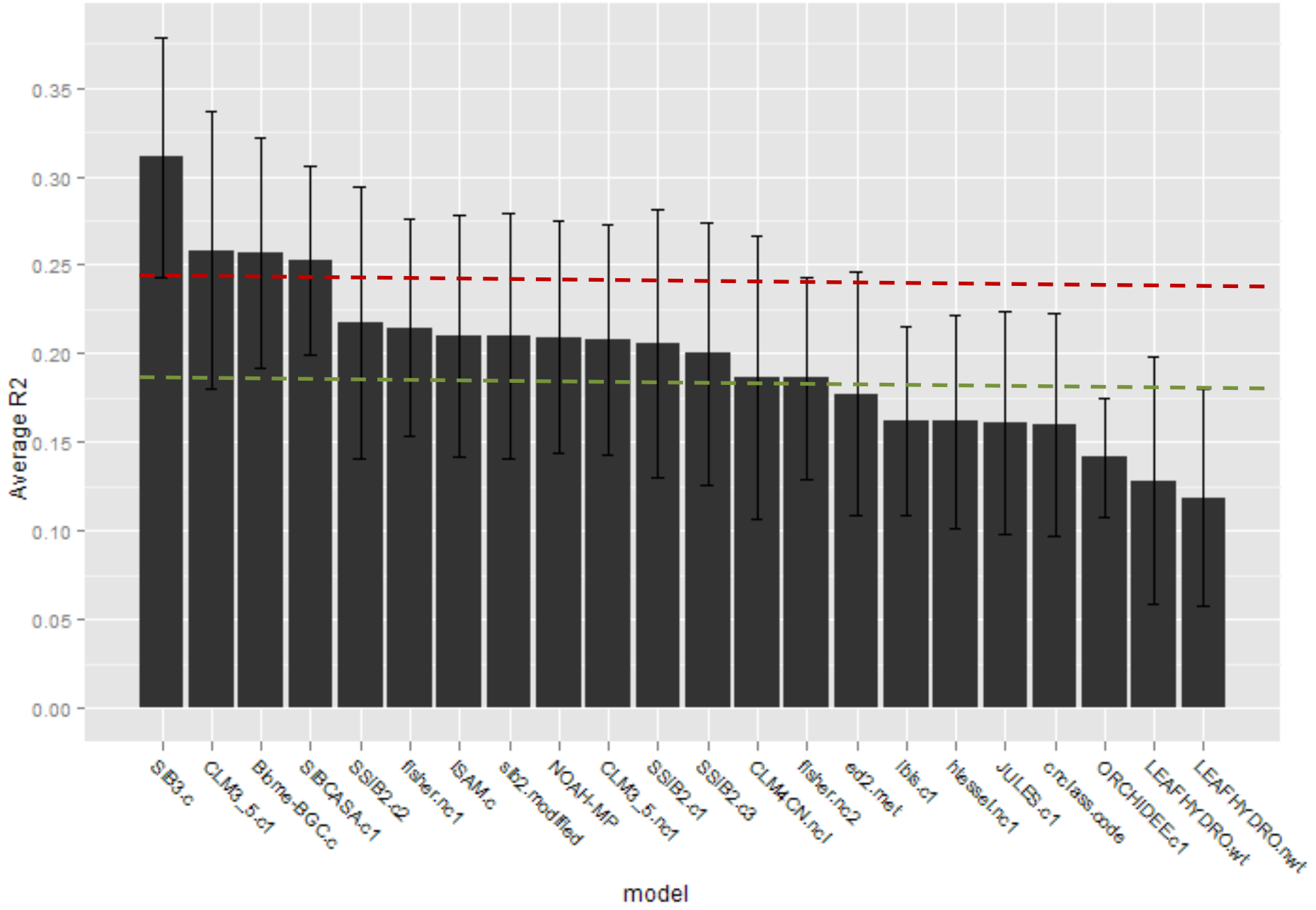

Average MBE (normalized by per-site means of data)
0.1
0.0
-0.1
-0.2
-0.3
-0.4
fisher.rc1
SIB3.c
JULES.c1
hlessel.nc1
ORCHIDEE.c1
CLM3_5.nc1
SIBCASA.c1
CLM3_5.c1
s62.modified
NOAH-MP
SSIB2.c1
SSIB2.c3
SSIB2.c2
fisher.rc2
CLM4CN.nc1
LEAFHYDRO.wt
LEAFHYDRO.nwt
ISAM.c
Biome-BGC.c
ed2.met
lbls.c1
crc.lass.code
model


Average MBE (normalized by per-site means of data)
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
fisher.rc1
SiB3.c
JULES.c1
hlesselnc1
ORCHIDEE.c1
CLM3_5.nc1
SiBCASA.c1
CLM3_5.c1
sib2.modified
NOAH-MP
SSiB2.c1
SSiB2.c3
SSiB2.c2
fisher.rc2
CLM4CN.nc1
LEAFHYDRO.wt
LEAFHYDRO.nwt
ISAM.c
Biome-BGC.c
ed2.met
lbls.c1
crc.lass.code
model


Average RMSE (normalized by per-site standard errors of data)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
SiB3.c
fisher.nc1
CLM3_5.nc1
SiBCASA.c1
JULES.c1
sib2.modified
CLM3_5.c1
NOAH-MP
hlesselnc1
ORCHIDEE.c1
CLM4CN.nc1
fisher.nc2
ISAM.c
ed2.met
LEAFHYDRO.wt
Biome-BGC.c
SSiB2.c1
SSiB2.c3
SSiB2.c2
LEAFHYDRO.nwt
crtclass.code
lbls.c1
model


Average RMSE (normalized by per-site standard errors of data)
0
1
2
3
4
SiB3.c
fisher.nc1
CLM3_5.nc1
SiBCASA.c1
JULES.c1
sib2.modified
CLM3_5.c1
NOAH-MP
htessel.nc1
ORCHIDEE.c1
CLM4CN.nc1
fisher.nc2
ISAM.c
ed2.met
LEAFHYDRO.wt
Biome-BGC.c
SSiB2.c1
SSiB2.c3
SSiB2.c2
LEAFHYDRO.nwt
crtclass.code
ibis.c1
model


Average R2
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SiB3.c
CLM3_5.c1
Biome-BGC.c
SiBCASA.c1
SSiB2.c2
fisher.nc1
ISAM.c
sib2.modified
NOAH-MP
CLM3_5.nc1
SSiB2.c1
SSiB2.c3
CLM4CN.nc1
fisher.nc2
ed2.met
lpjs.c1
hesse.nc1
JULES.c1
crc.lass.code
ORCHIDEE.c1
LEAFHYDRO.wt
LEAFHYDRO.nwt
model


Average R2
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SiB3.c
CLM3_5.c1
Biome-BGC.c
SiBCASA.c1
SSiB2.c2
fisher.nc1
ISAM.c
sib2.modified
NOAH-MP
CLM3_5.nc1
SSiB2.c1
SSiB2.c3
CLM4CN.nc1
fisher.nc2
ed2.met
lbls.c1
hesse1.nc1
JULES.c1
crc1ass.code
ORCHIDEE.c1
LEAFHYDRO.wt
LEAFHYDRO.nwt
model

Discussion

- SiB3 emerges as overall ‘strongest performer,’ though with a large degree of variation.
- Models were in the right range at the FNS site, but lacked agreement with the observed data as measured by R^2.
- PDG emerges at the best overall site, but with a tendency toward model under—prediction.
- Seasonality dominates performance metrics much more at some sites than others.
- Observed data is very stochastic for some sites—how confident are we that these values are ‘true’ as opposed to noisy?
- No model or site is the clear `winner’—at this point standard errors are too large.
- What is observed data uncertainty? May need to think about whether predictions fall within error range of observations.

Next steps…

- Protocol for error attribution—a mix of summary stats, OLS, and machine learning algorithms

Thanks!
Questions?
Suggestions?