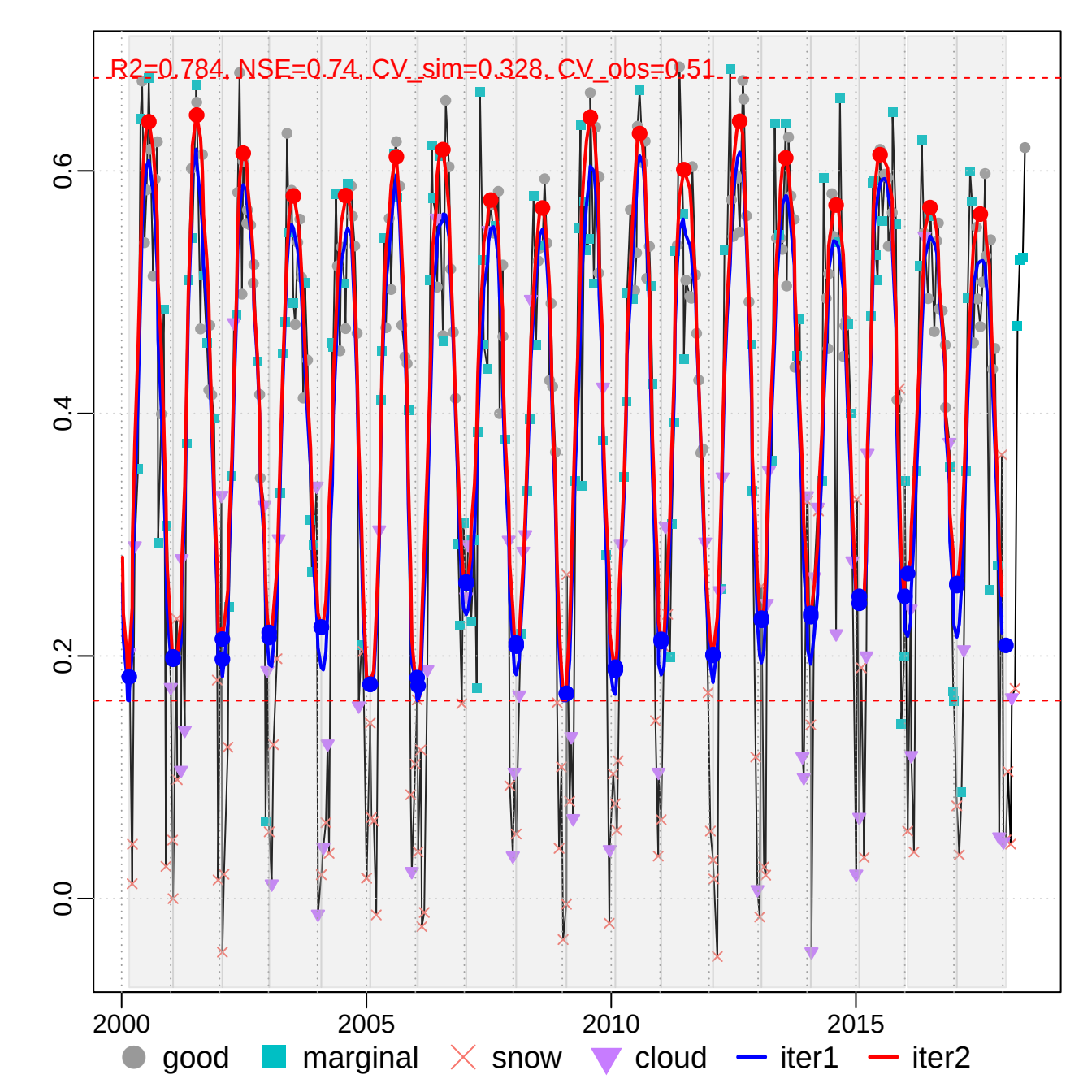
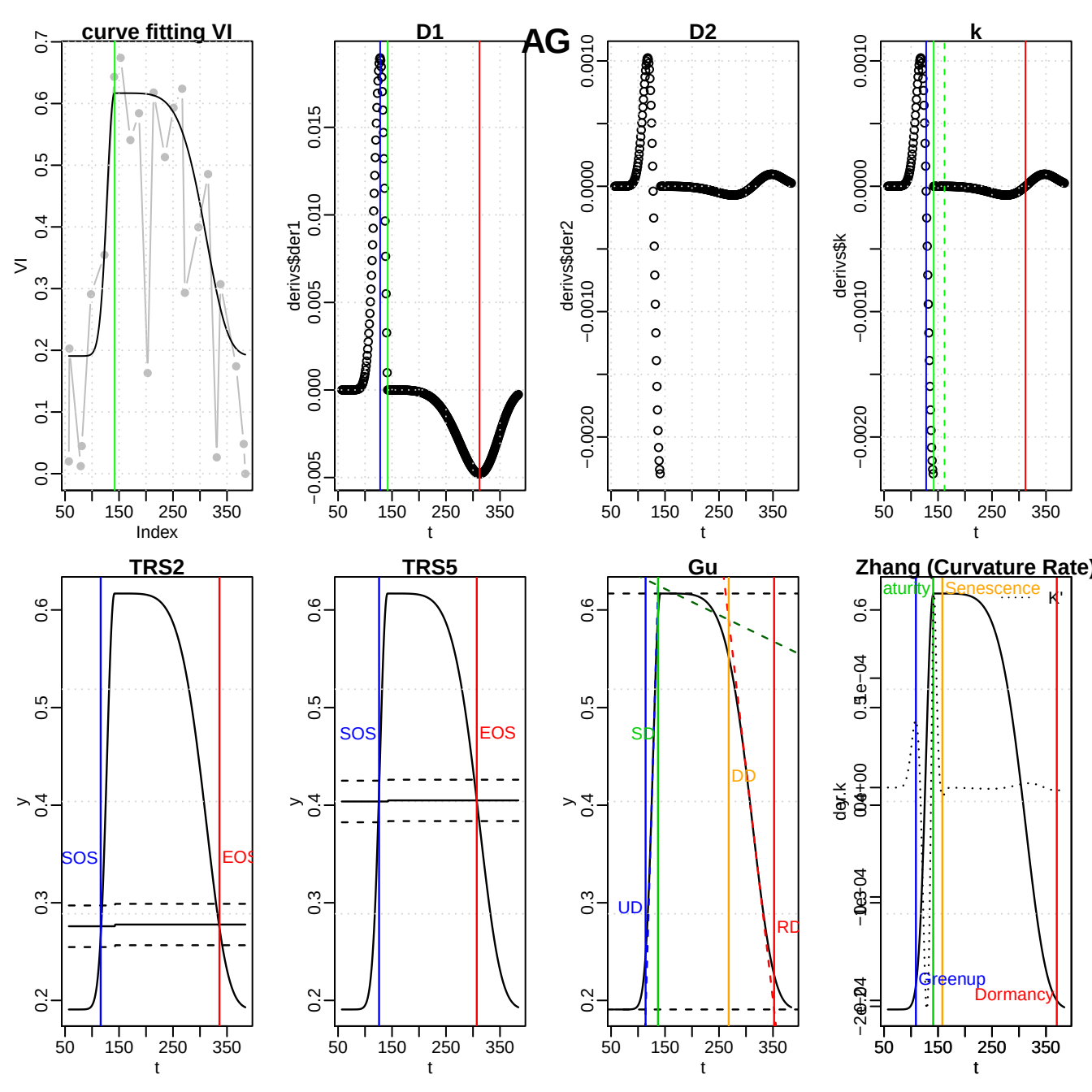
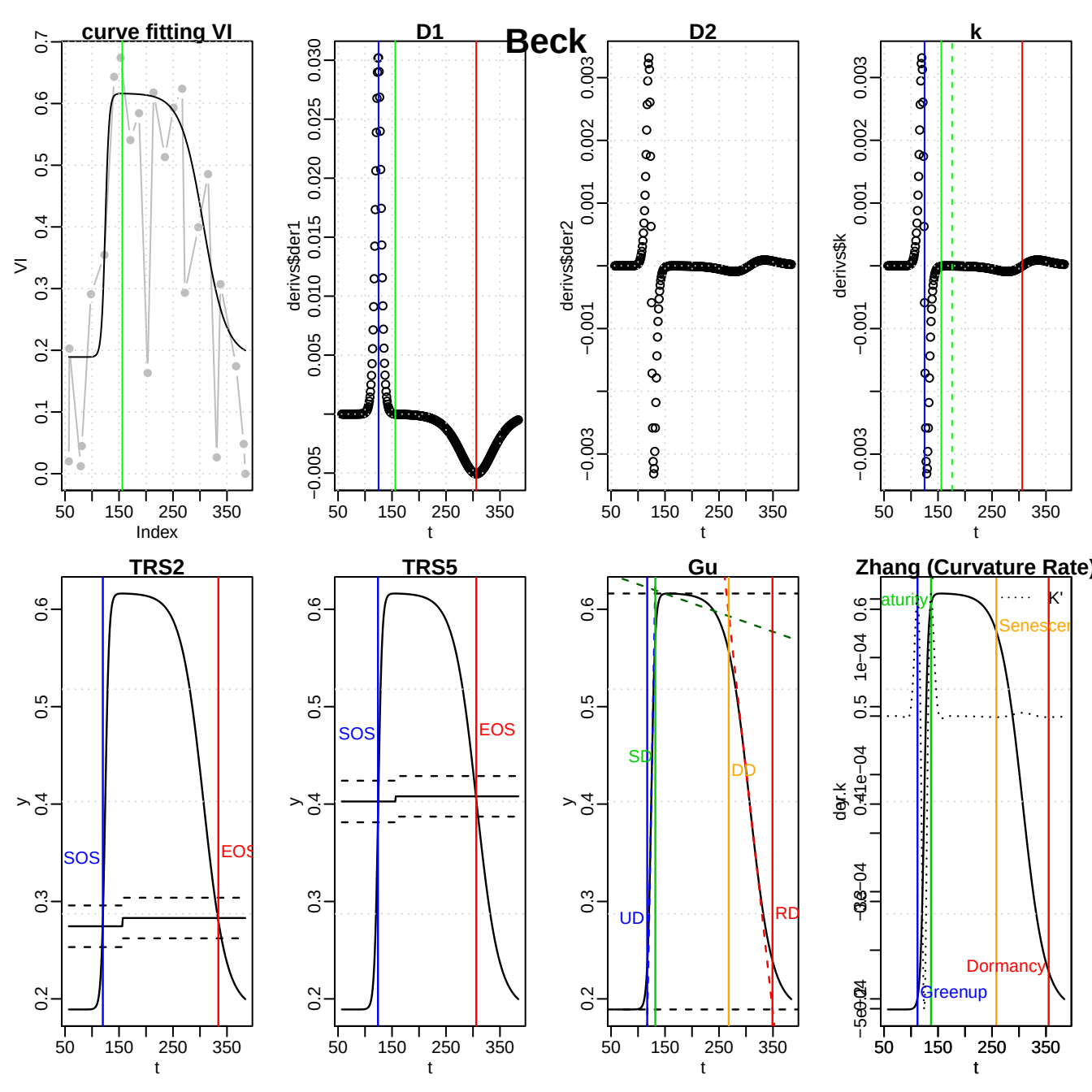
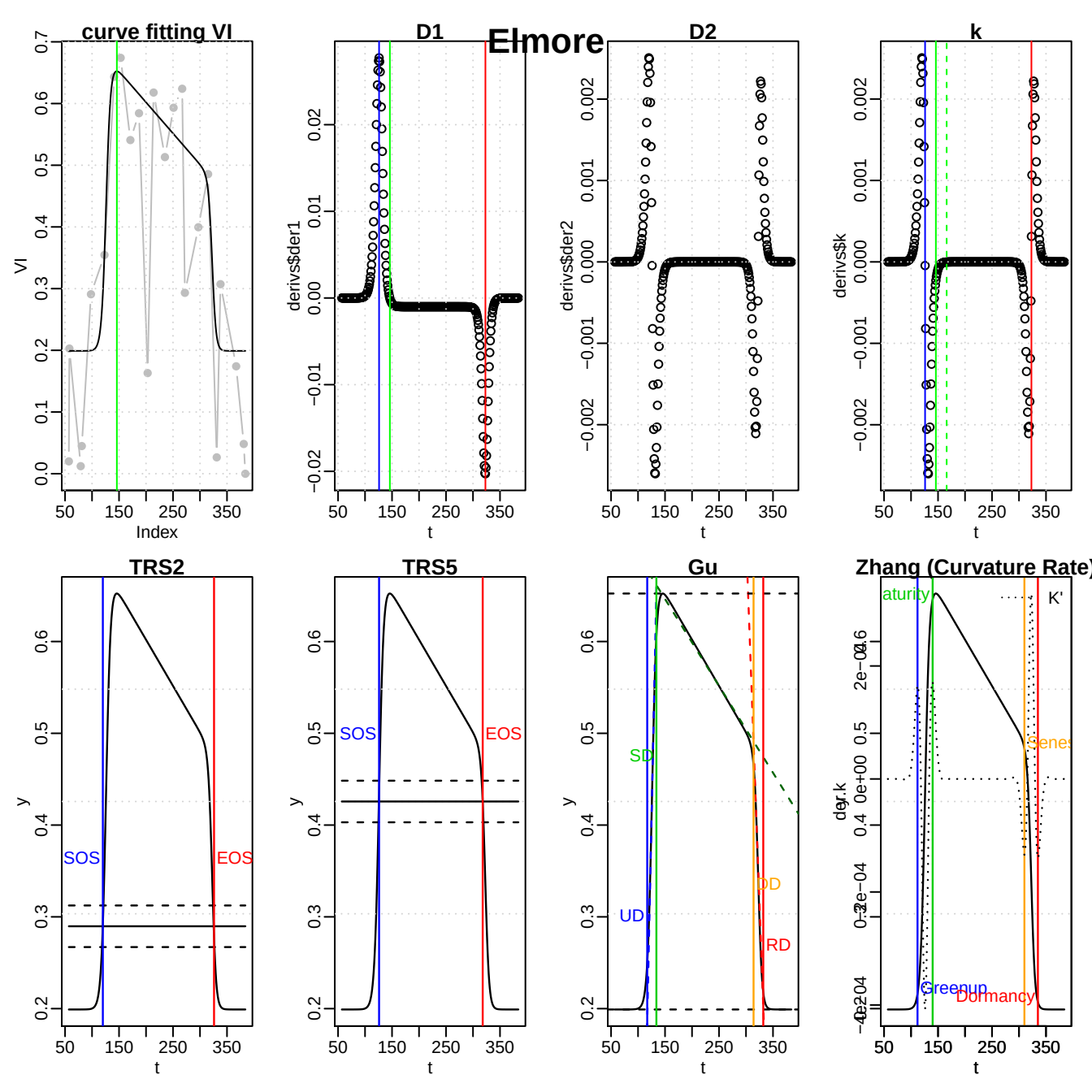
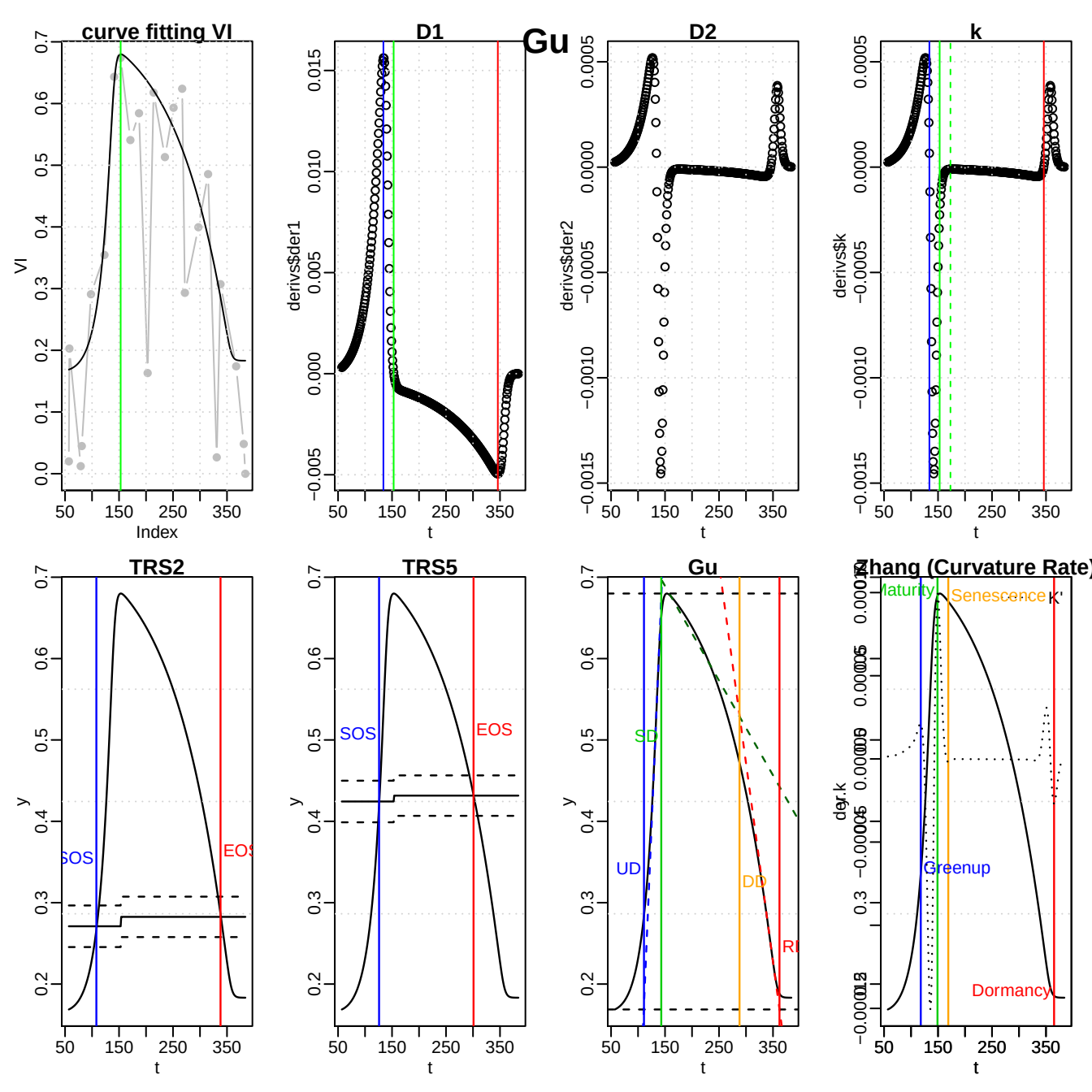
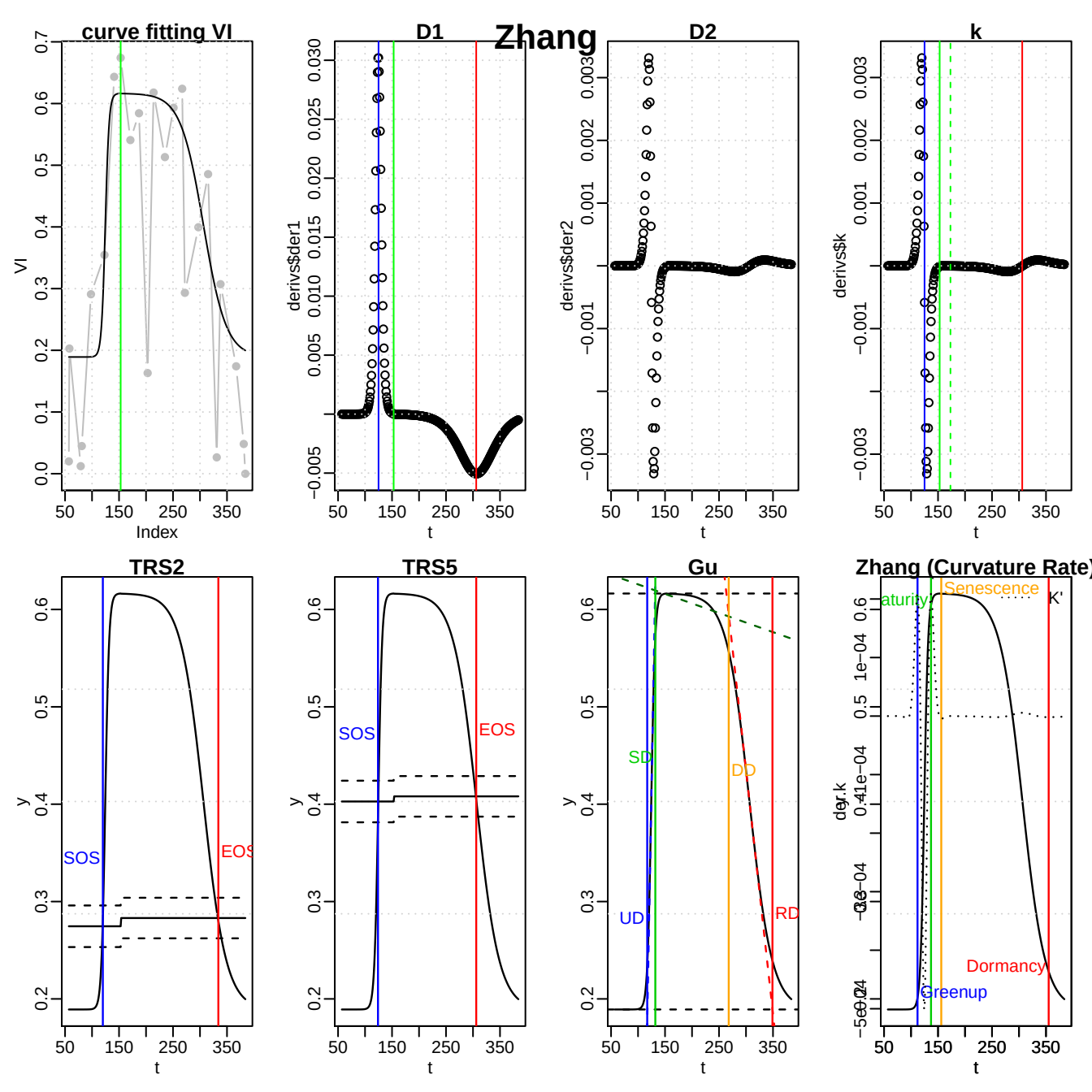

R2=0.784, NSE=0.74, CV_sim=0.328, CV_obs=0.51
0.0
0.2
0.4
0.6
2000
2005
2010
2015
good
marginal
snow
cloud
iter1
iter2

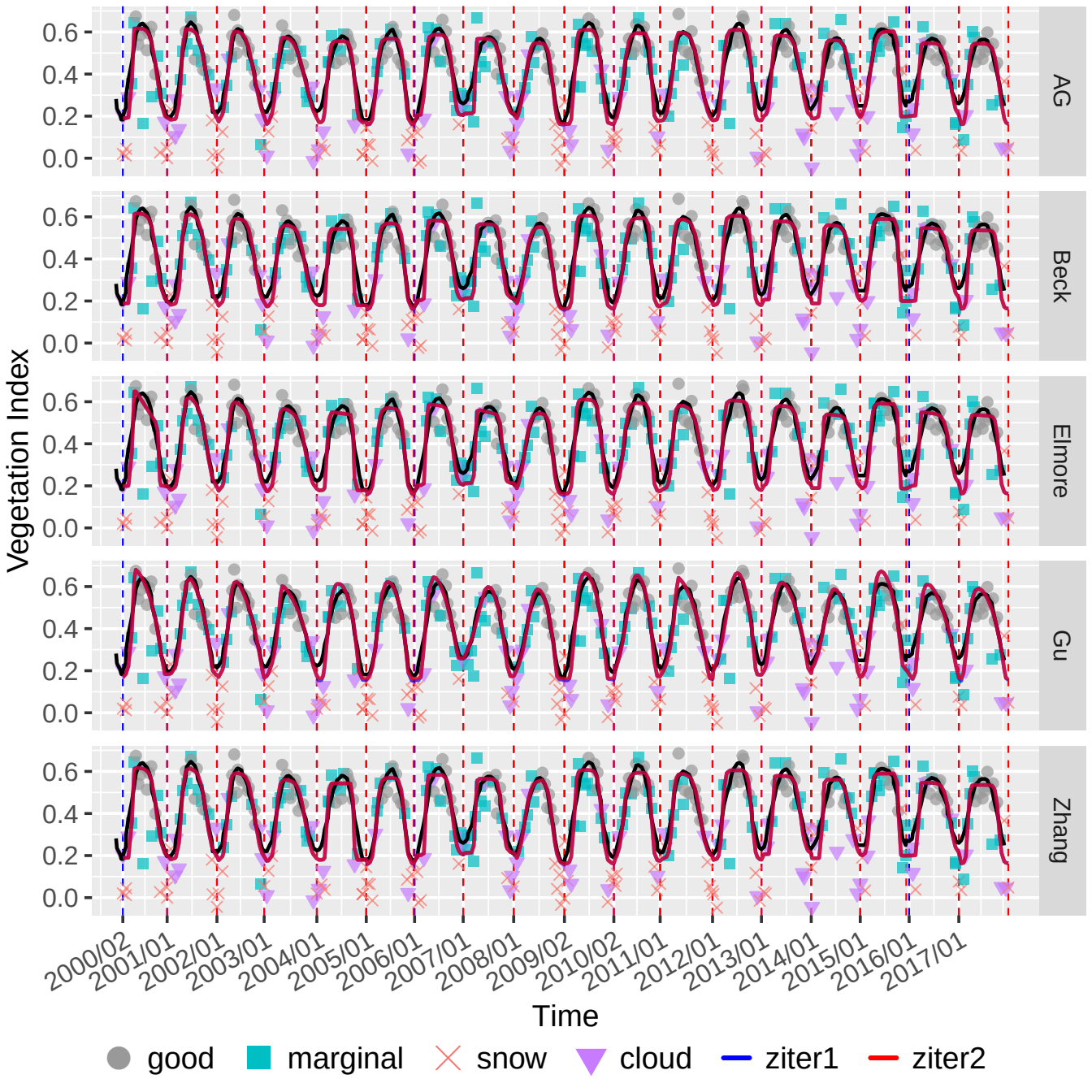

AG
curve fitting VI
VI
Index
D1
derivs$der1
t
D2
derivs$der2
t
k
derivs$k
t
TRS2
y
t
SOS
EOS
TRS5
y
t
SOS
EOS
Gu
y
t
SD
DD
UD
RD
Zhang (Curvature Rate)
aturity
Senescence
K'
der.k
t
Greenup
Dormancy

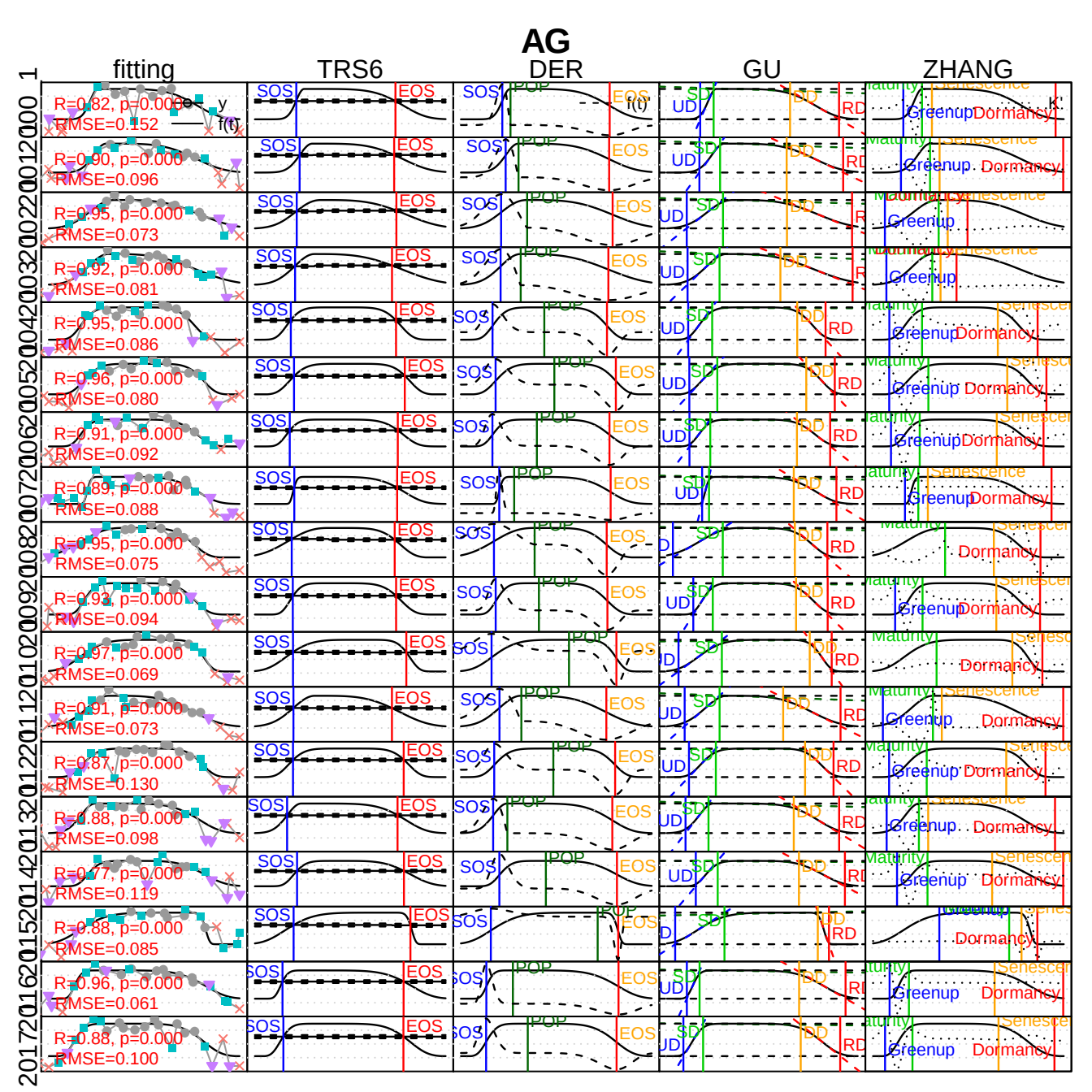

Beck
curve fitting VI
VI
Index
D1
derivs$der1
t
D2
derivs$der2
t
k
derivs$k
t
TRS2
y
t
SOS
EOS
TRS5
y
t
SOS
EOS
Gu
y
t
SD
DD
UD
RD
Zhang (Curvature Rate)
der.k
t
aturity
K'
Senescer
Dormancy
Greenup

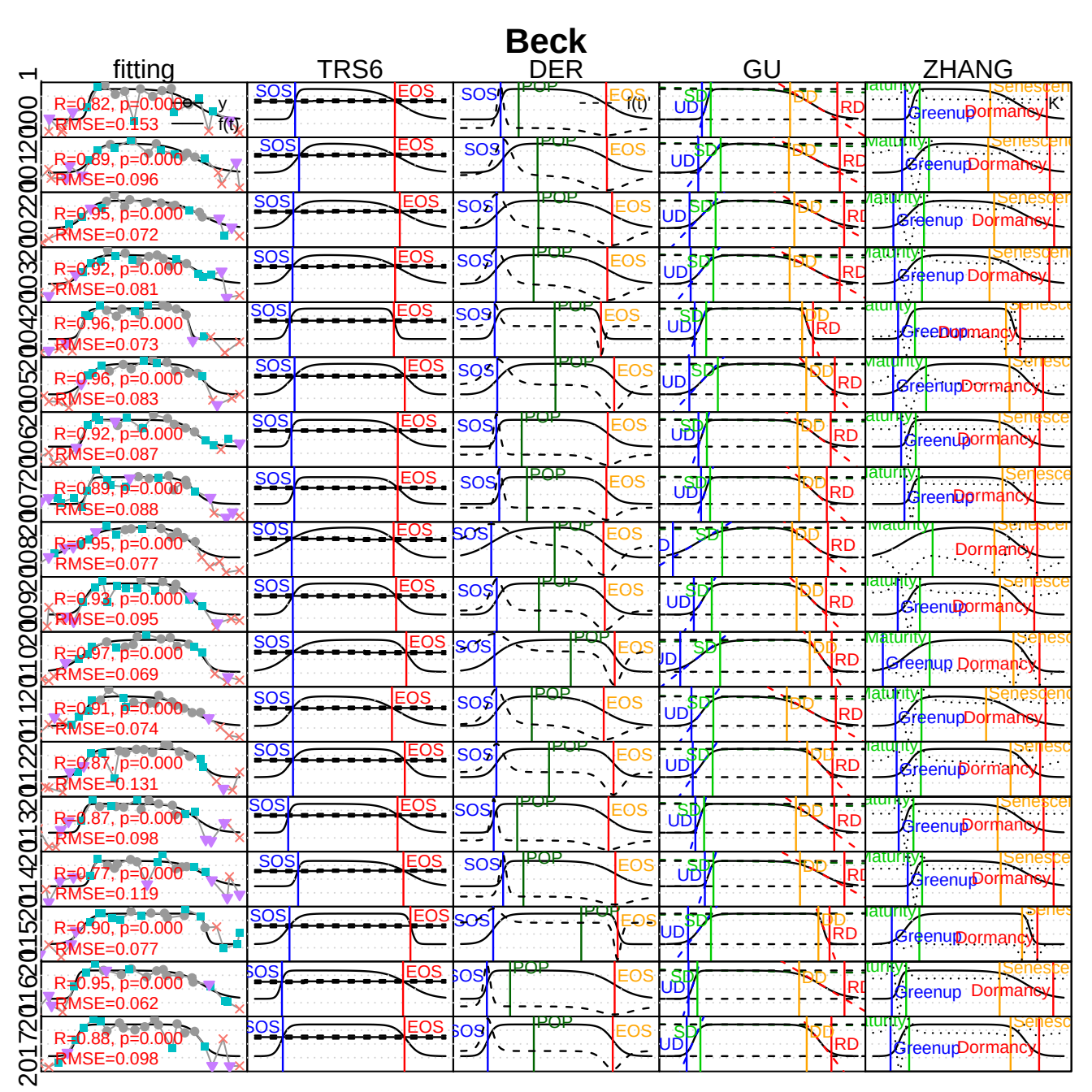

Elmore
curve fitting VI
VI
Index
D1
derivs$der1
t
D2
derivs$der2
t
k
derivs$k
t
TRS2
y
SOS
EOS
t
TRS5
y
SOS
EOS
t
Gu
y
SD
UD
OD
RD
t
Zhang (Curvature Rate)
aturity
K'
Senes
Greenup
Dormancy
t

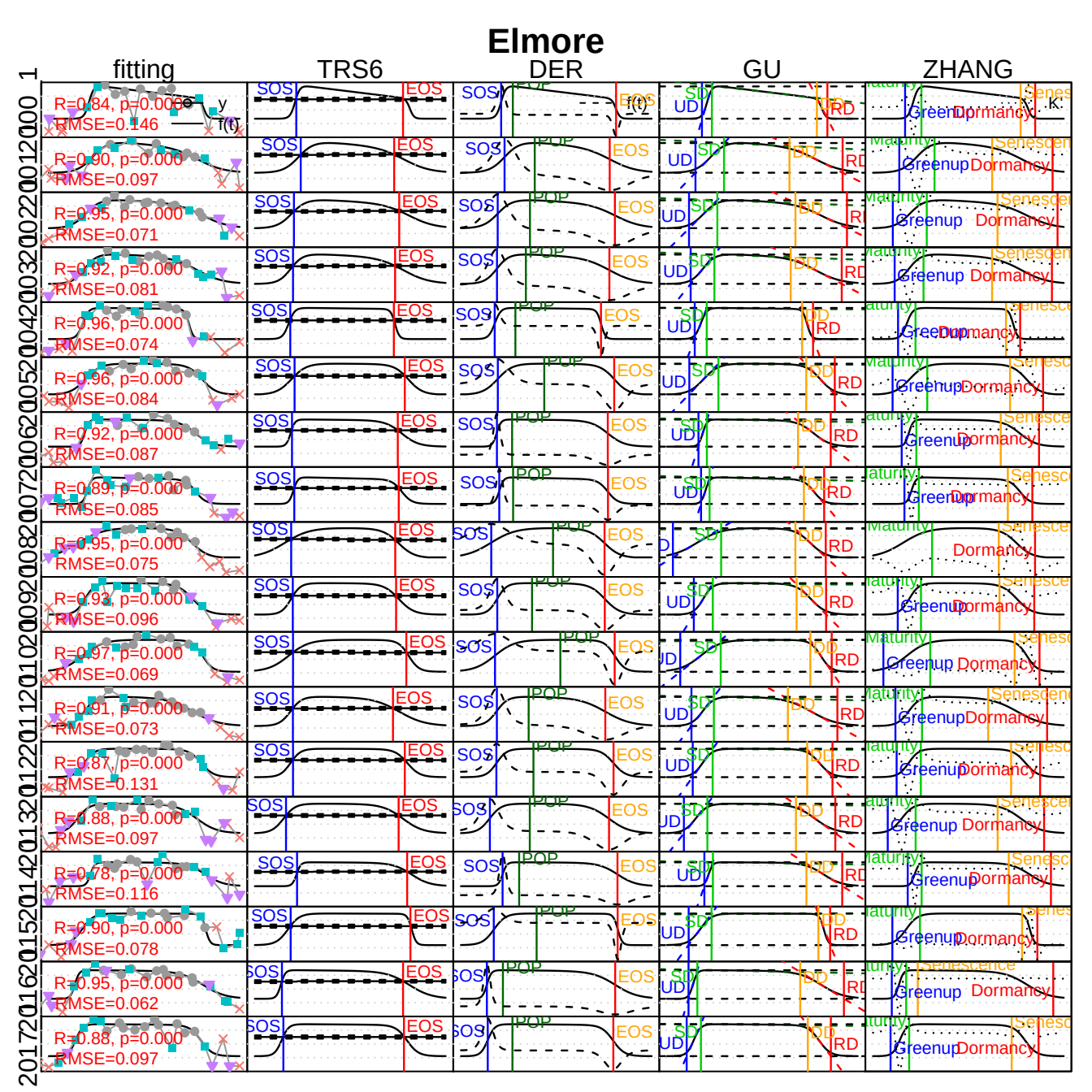

Gu
curve fitting VI
VI
Index
D1
derivs$der1
t
D2
derivs$der2
t
k
derivs$k
t
TRS2
SOS
EOS
y
t
TRS5
SOS
EOS
y
t
Gu
SD
UD
DD
RD
y
t
Zhang (Curvature Rate)
Maturity
Senescence
K'
Greenup
Dormancy
der.k
t

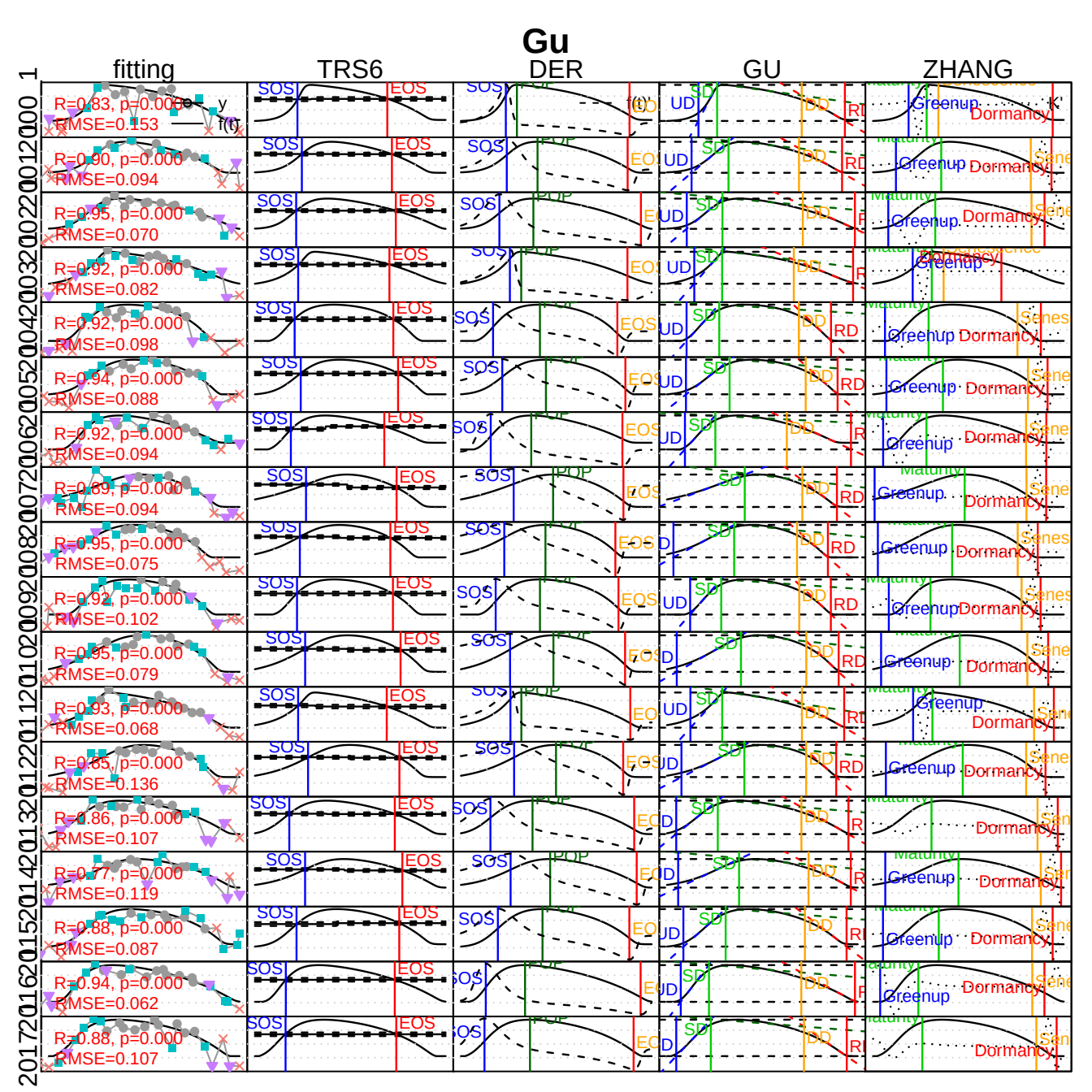

Zhang
curve fitting VI
VI
Index
D1
derivs$der1
t
D2
derivs$der2
t
k
derivs$k
t
TRS2
y
SOS
EOS
t
TRS5
y
SOS
EOS
t
Gu
y
SD
DD
UD
RD
t
Zhang (Curvature Rate)
der.k
Senescence
K'
Dormancy
Greenup
t

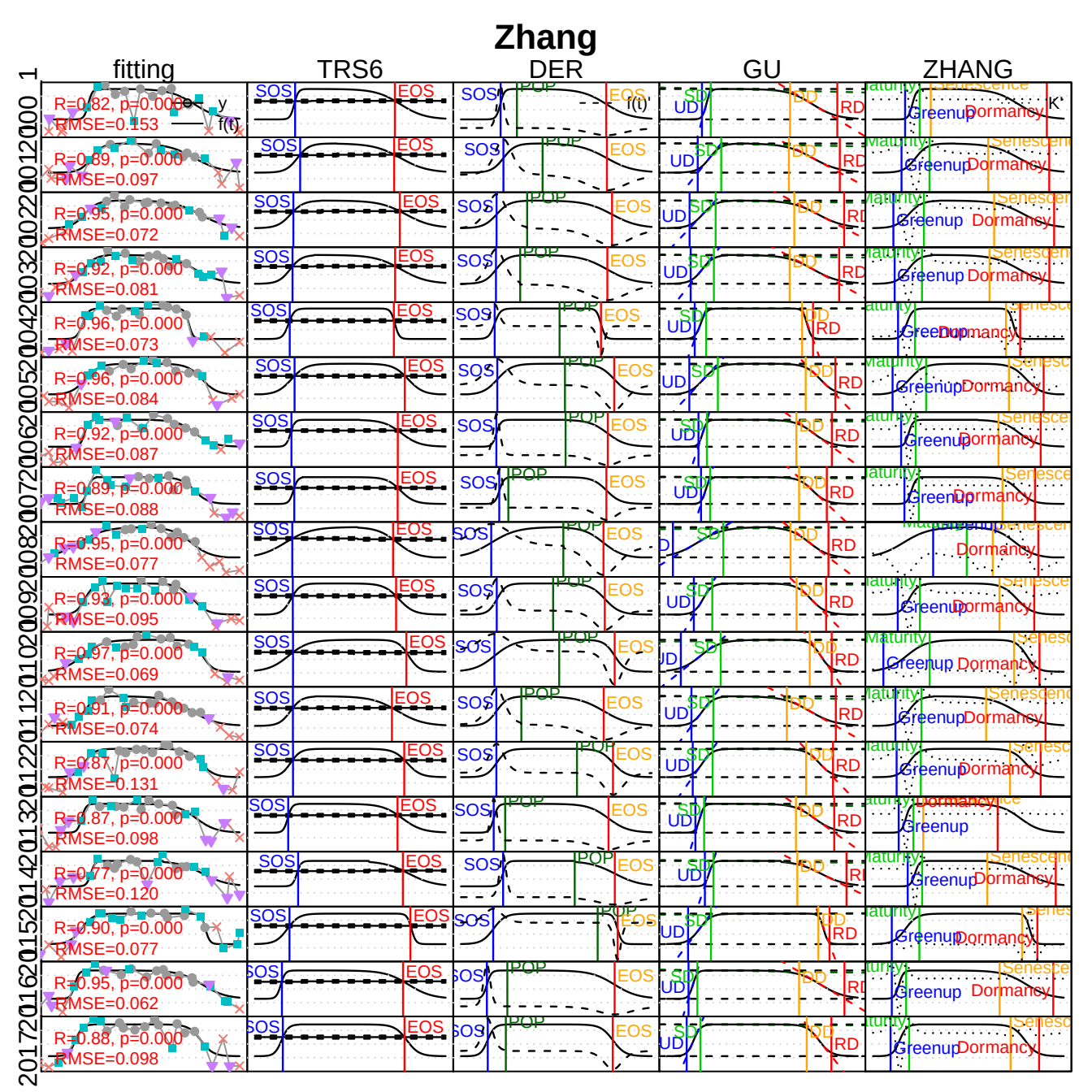

AG
Beck
Elmore
Gu
Zhang
Vegetation Index
0.0
0.2
0.4
0.6
2000/02
2001/01
2002/01
2003/01
2004/01
2005/01
2006/01
2007/01
2008/01
2009/02
2010/02
2011/01
2012/01
2013/01
2014/01
2015/01
2016/01
2017/01
Time
good
marginal
snow
cloud
ziter1
ziter2

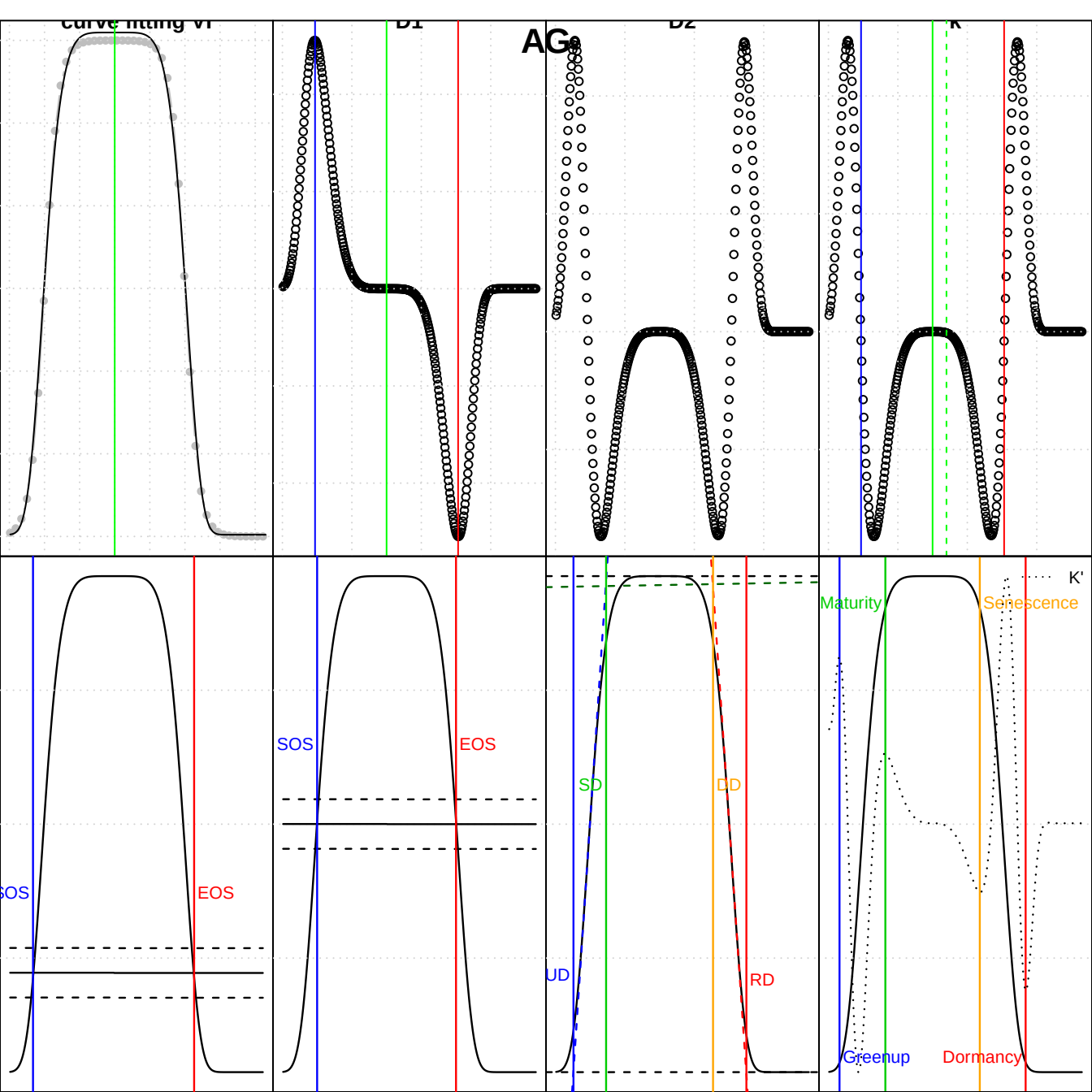

AG
fitting
TRS6
DER
GU
ZHANG
R=0.82, p=0.000
RMSE=0.152
R=0.90, p=0.000
RMSE=0.096
R=0.95, p=0.000
RMSE=0.073
R=0.92, p=0.000
RMSE=0.081
R=0.95, p=0.000
RMSE=0.086
R=0.96, p=0.000
RMSE=0.080
R=0.91, p=0.000
RMSE=0.092
R=0.89, p=0.000
RMSE=0.088
R=0.95, p=0.000
RMSE=0.075
R=0.93, p=0.000
RMSE=0.094
R=0.97, p=0.000
RMSE=0.069
R=0.91, p=0.000
RMSE=0.073
R=0.87, p=0.000
RMSE=0.130
R=0.88, p=0.000
RMSE=0.098
R=0.77, p=0.000
RMSE=0.119
R=0.88, p=0.000
RMSE=0.085
R=0.96, p=0.000
RMSE=0.061
R=0.88, p=0.000
RMSE=0.100
y
f(t)
SOS
EOS
IPOP
UD
SD
DD
RD
Greenup
Maturity
Senescence
Dormancy

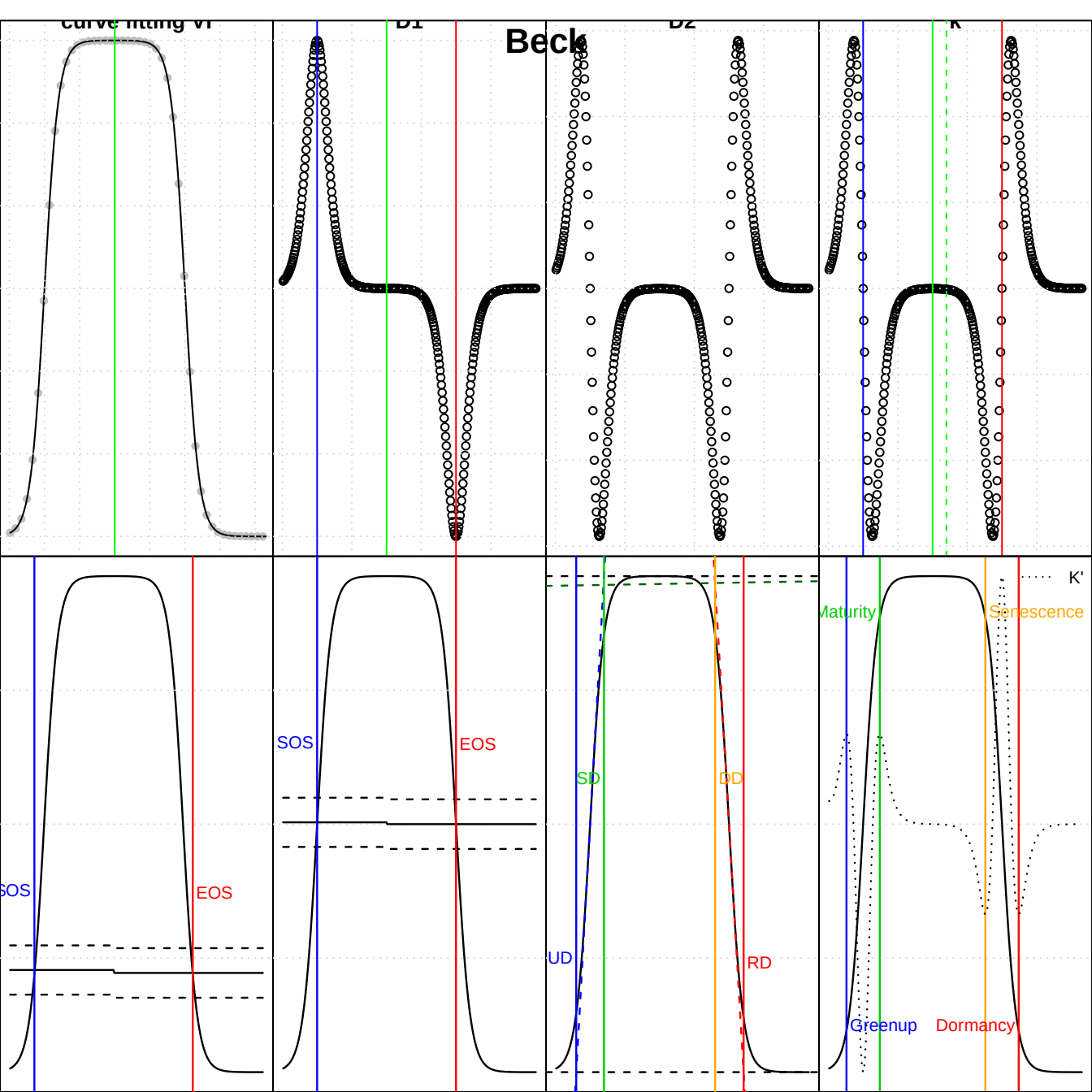

Beck
fitting
TRS6
DER
GU
ZHANG
R=0.82, p=0.000
RMSE=0.153
R=0.89, p=0.000
RMSE=0.096
R=0.95, p=0.000
RMSE=0.072
R=0.92, p=0.000
RMSE=0.081
R=0.96, p=0.000
RMSE=0.073
R=0.96, p=0.000
RMSE=0.083
R=0.92, p=0.000
RMSE=0.087
R=0.89, p=0.000
RMSE=0.088
R=0.95, p=0.000
RMSE=0.077
R=0.93, p=0.000
RMSE=0.095
R=0.97, p=0.000
RMSE=0.069
R=0.91, p=0.000
RMSE=0.074
R=0.87, p=0.000
RMSE=0.131
R=0.87, p=0.000
RMSE=0.098
R=0.77, p=0.000
RMSE=0.119
R=0.90, p=0.000
RMSE=0.077
R=0.95, p=0.000
RMSE=0.062
R=0.88, p=0.000
RMSE=0.098
y
f(t)
SOS
EOS
IPOP
UD
SD
DD
RD
Greenup
Maturity
Senescence
Dormancy

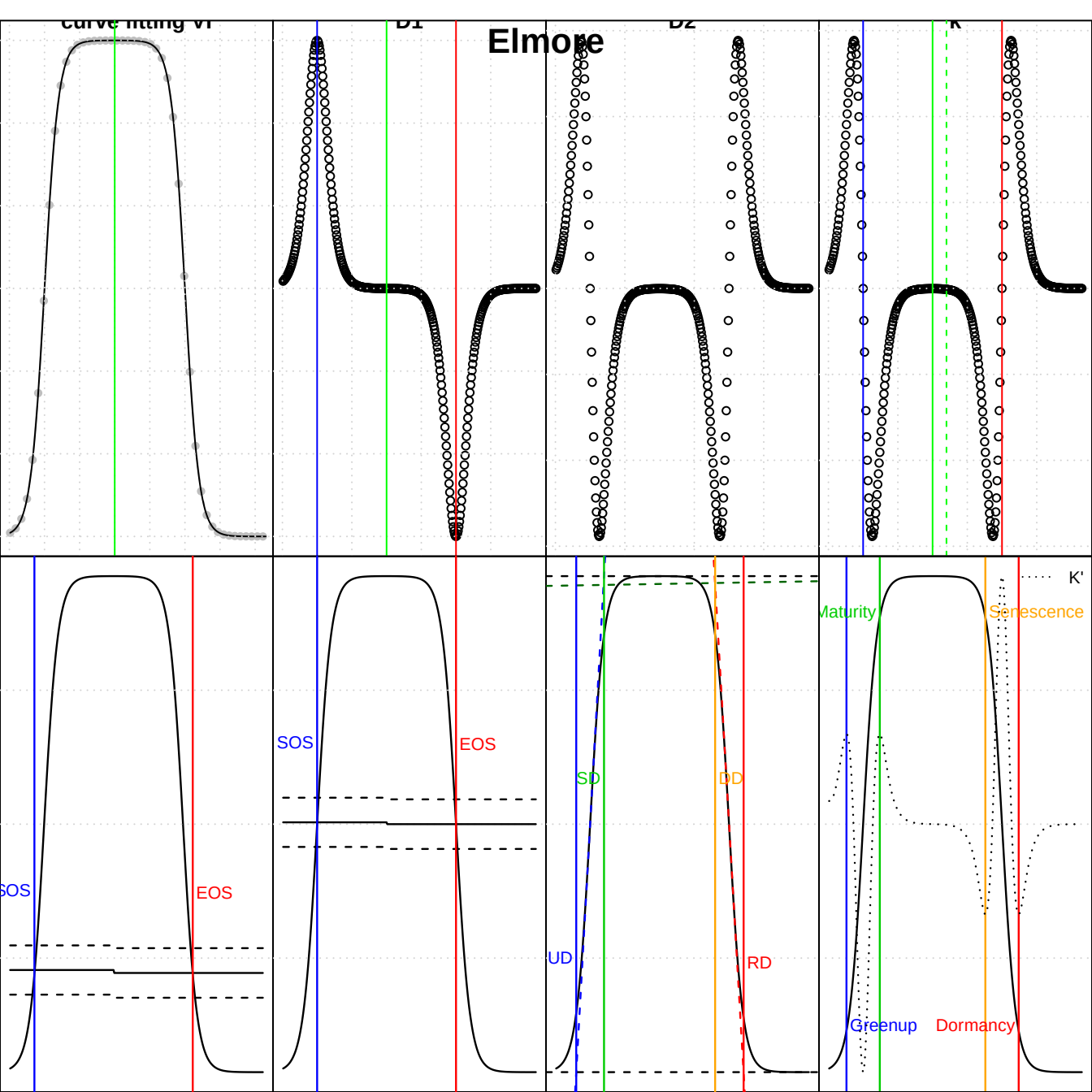

Elmore
fitting
TRS6
DER
GU
ZHANG
R=0.84, p=0.000
RMSE=0.146
R=0.90, p=0.000
RMSE=0.097
R=0.95, p=0.000
RMSE=0.071
R=0.92, p=0.000
RMSE=0.081
R=0.96, p=0.000
RMSE=0.074
R=0.96, p=0.000
RMSE=0.084
R=0.92, p=0.000
RMSE=0.087
R=0.89, p=0.000
RMSE=0.085
R=0.95, p=0.000
RMSE=0.075
R=0.93, p=0.000
RMSE=0.096
R=0.97, p=0.000
RMSE=0.069
R=0.91, p=0.000
RMSE=0.073
R=0.87, p=0.000
RMSE=0.131
R=0.88, p=0.000
RMSE=0.097
R=0.78, p=0.000
RMSE=0.116
R=0.90, p=0.000
RMSE=0.078
R=0.95, p=0.000
RMSE=0.062
R=0.88, p=0.000
RMSE=0.097
y
f(t)
SOS
EOS
POP
SD
UD
DD
RD
Greenup
Maturity
Senescence
Dormancy

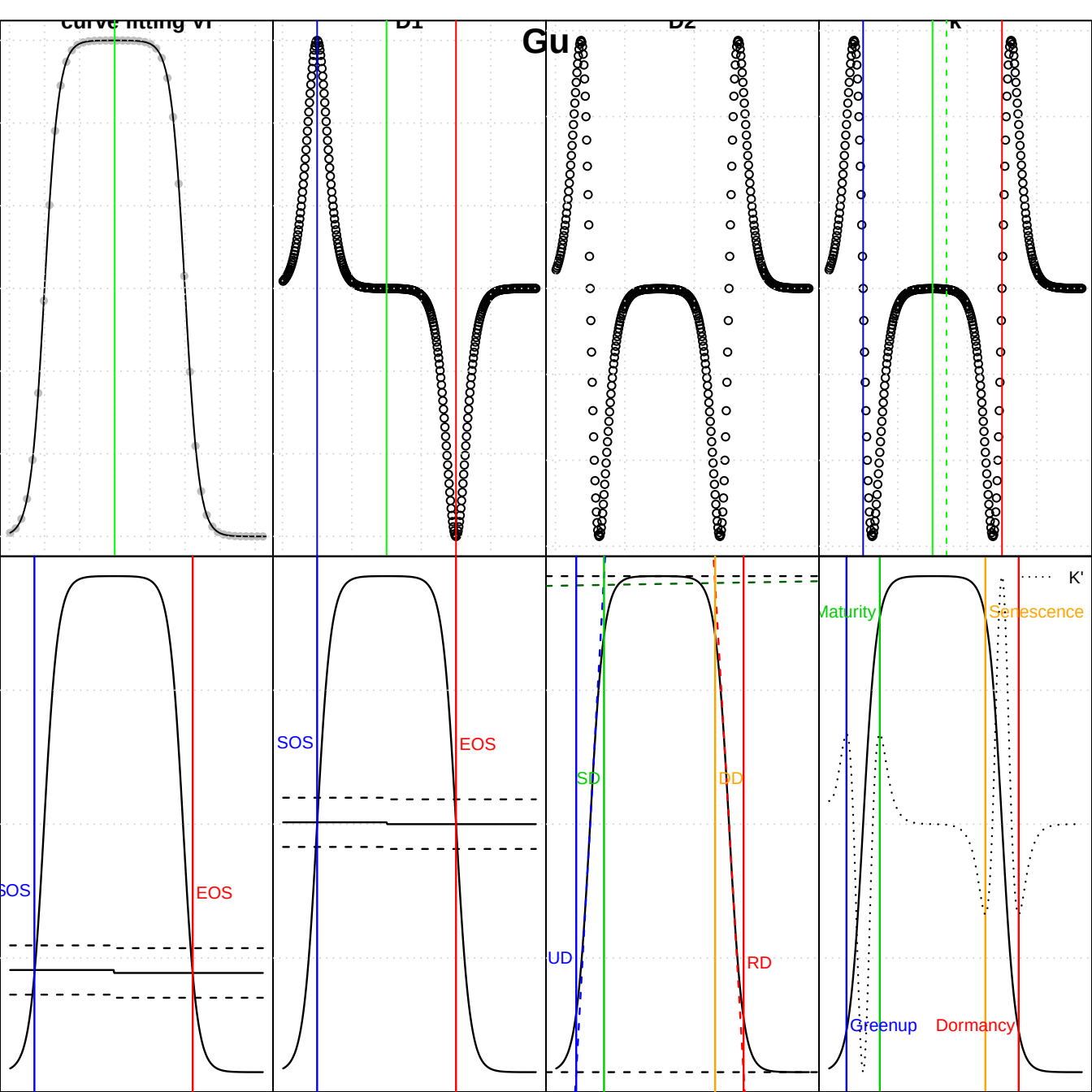

Gu
fitting
TRS6
DER
GU
ZHANG
y
f(t)
f'(t)
R=0.83, p=0.000
RMSE=0.153
R=0.90, p=0.000
RMSE=0.094
R=0.95, p=0.000
RMSE=0.070
R=0.92, p=0.000
RMSE=0.082
R=0.92, p=0.000
RMSE=0.098
R=0.94, p=0.000
RMSE=0.088
R=0.92, p=0.000
RMSE=0.094
R=0.89, p=0.000
RMSE=0.094
R=0.95, p=0.000
RMSE=0.075
R=0.92, p=0.000
RMSE=0.102
R=0.95, p=0.000
RMSE=0.079
R=0.93, p=0.000
RMSE=0.068
R=0.85, p=0.000
RMSE=0.136
R=0.86, p=0.000
RMSE=0.107
R=0.77, p=0.000
RMSE=0.119
R=0.88, p=0.000
RMSE=0.087
R=0.94, p=0.000
RMSE=0.062
R=0.88, p=0.000
RMSE=0.107
SOS
EOS
POP
EOD
UD
SD
DD
RD
Greenup
Maturity
Senescence
Dormancy
1
100
120
220
320
420
520
620
720
820
920
1020
1120
1220
1320
1420
1520
1620
1720

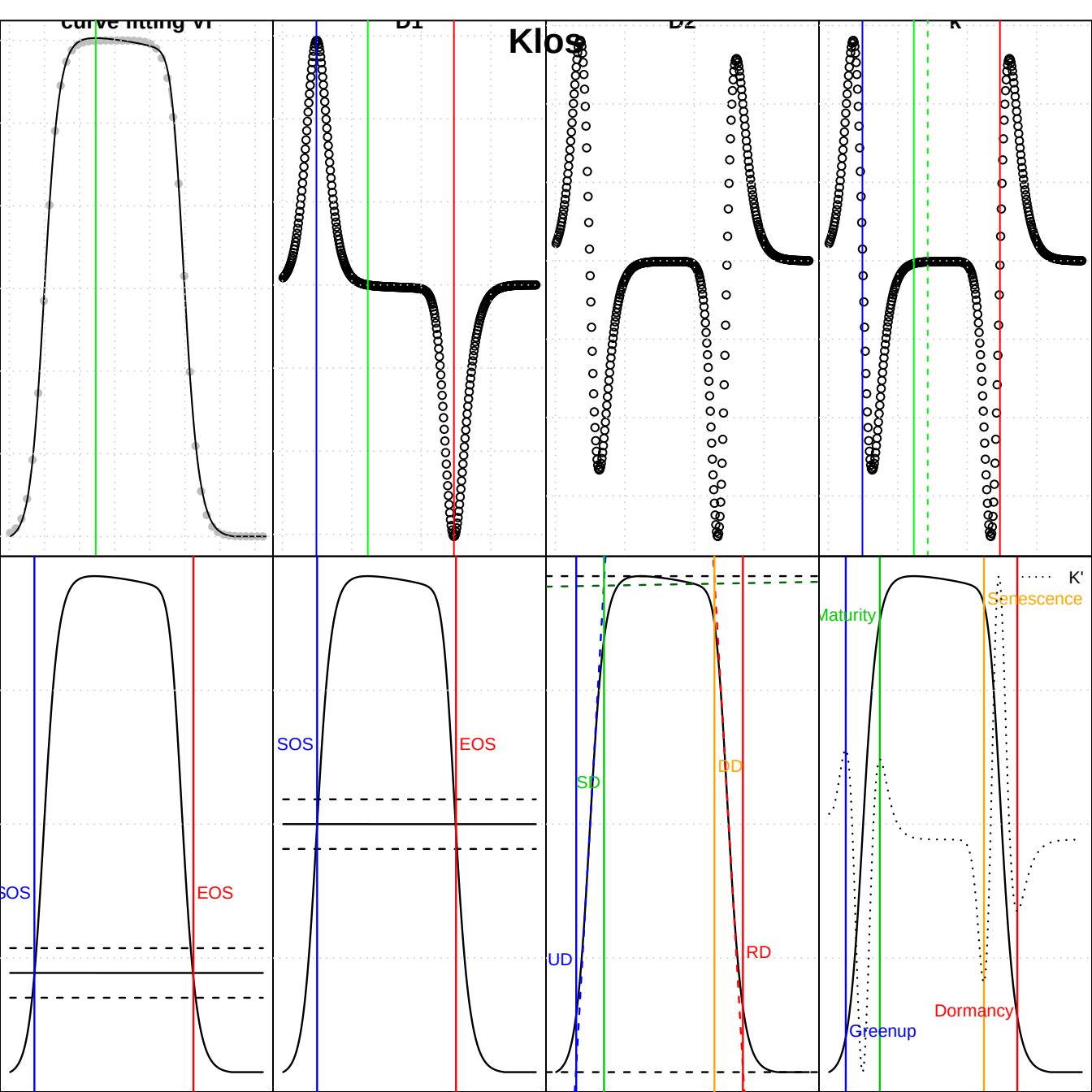

Zhang
fitting
TRS6
DER
GU
ZHANG
y
f(t)
R=0.82, p=0.000
RMSE=0.153
R=0.89, p=0.000
RMSE=0.097
R=0.95, p=0.000
RMSE=0.072
R=0.92, p=0.000
RMSE=0.081
R=0.96, p=0.000
RMSE=0.073
R=0.96, p=0.000
RMSE=0.084
R=0.92, p=0.000
RMSE=0.087
R=0.89, p=0.000
RMSE=0.088
R=0.95, p=0.000
RMSE=0.077
R=0.93, p=0.000
RMSE=0.095
R=0.97, p=0.000
RMSE=0.069
R=0.91, p=0.000
RMSE=0.074
R=0.87, p=0.000
RMSE=0.131
R=0.87, p=0.000
RMSE=0.098
R=0.77, p=0.000
RMSE=0.120
R=0.90, p=0.000
RMSE=0.077
R=0.95, p=0.000
RMSE=0.062
R=0.88, p=0.000
RMSE=0.098
SOS
EOS
POP
UD
SD
DD
RD
Greenup
Maturity
Senescence
Dormancy

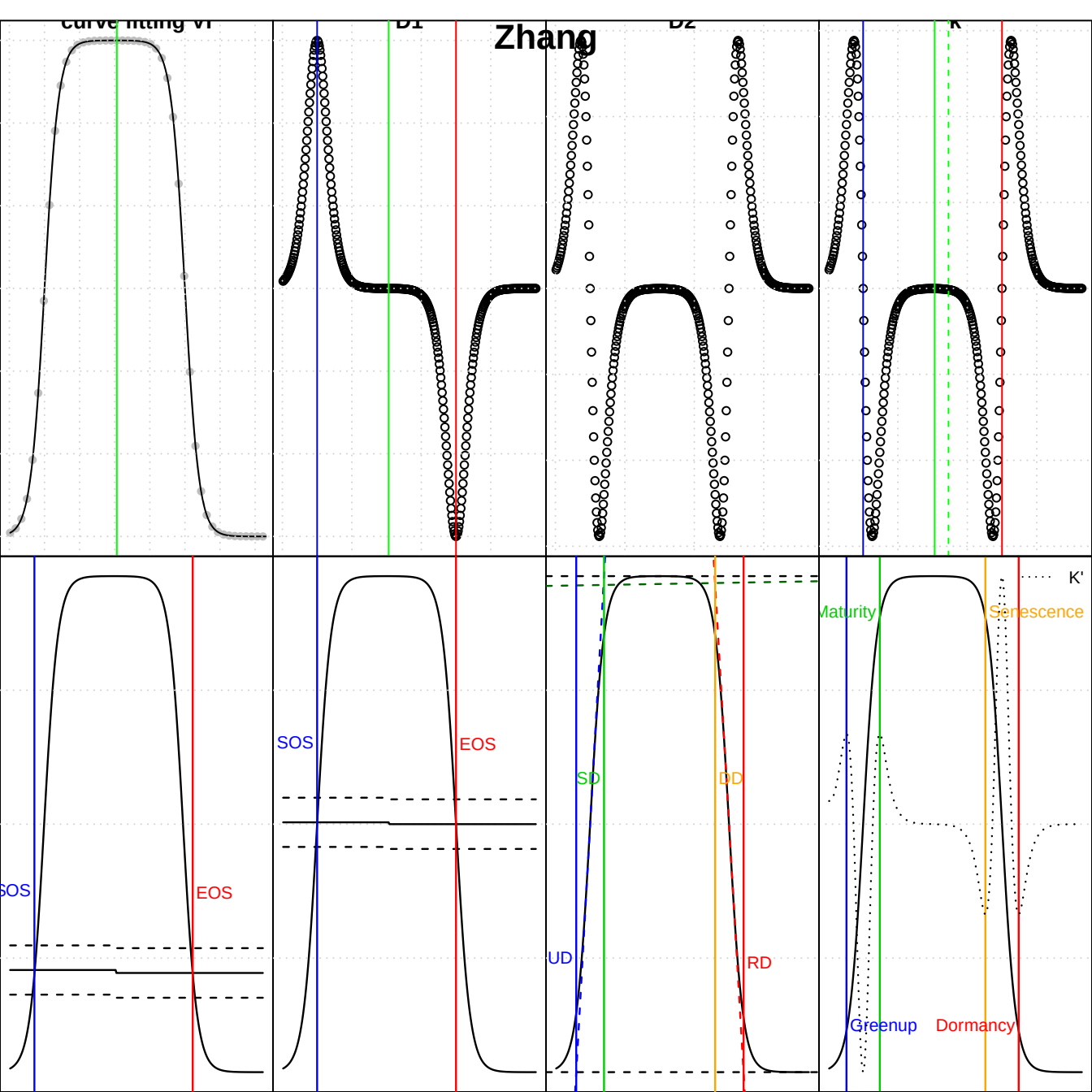

curve fitting VI
D1
AG
D2
K
SOS
EOS
SOS
EOS
SD
DD
UD
RD
K'
Maturity
Senescence
Greenup
Dormancy

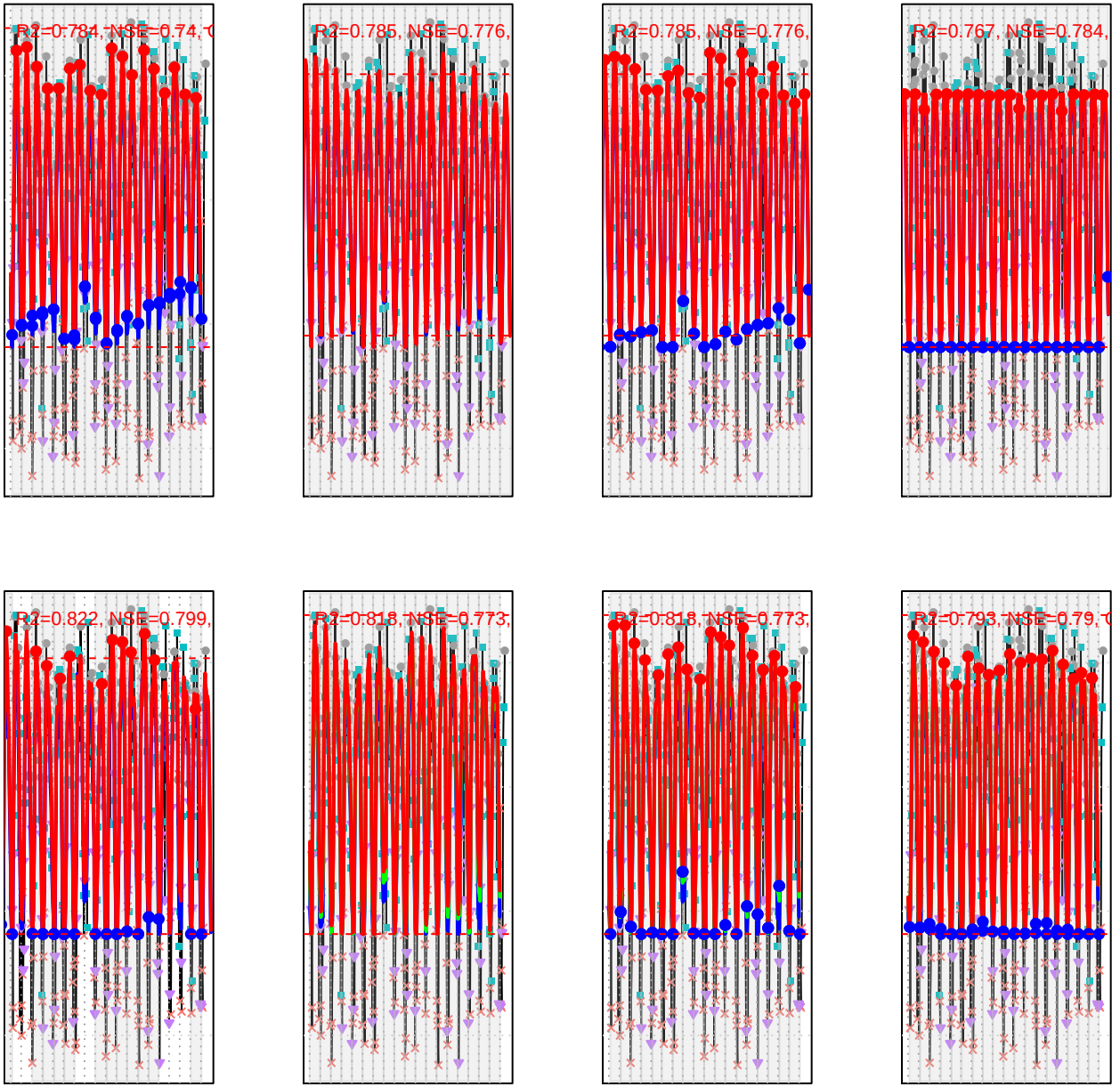

curve fitting VI
D1
D2
K
Beck
SOS
EOS
SOS
EOS
SD
DD
UD
RD
Maturity
Senescence
K'
Greenup
Dormancy


curve fitting VI
D1
D2
K
Elmore
SOS
EOS
SOS
EOS
SD
DD
UD
RD
K'
Maturity
Senescence
Greenup
Dormancy


curve fitting VI
D1
Gu
D2
K
SOS
EOS
SOS
EOS
SOS
EOS
SD
DD
UD
RD
Maturity
Senescence
K'
Greenup
Dormancy


curve fitting VI
D1
D2
K
Klos
SOS
EOS
SOS
EOS
SOS
EOS
SD
DD
UD
RD
Maturity
Senescence
K'
Greenup
Dormancy


curve fitting VI
D1
D2
K
Zhang
SOS
EOS
SOS
EOS
SD
DD
UD
RD
Maturity
Senescence
K'
Greenup
Dormancy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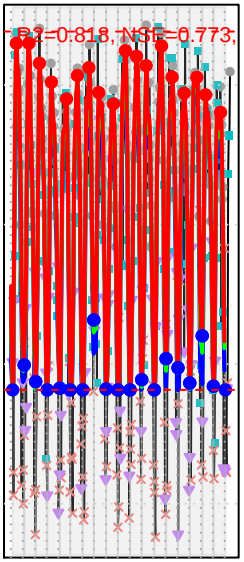
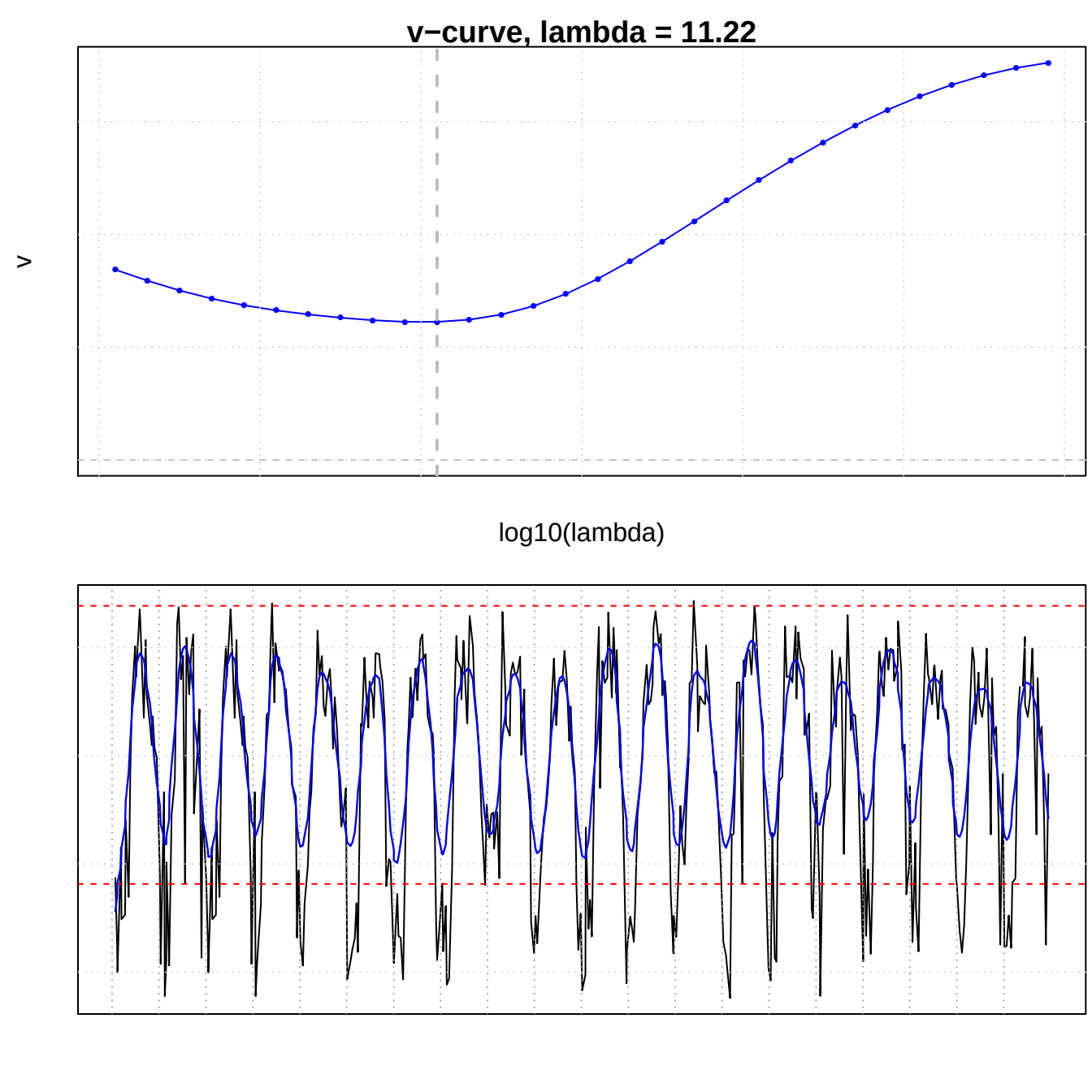
R2=0.785, NSE=0.776,
R2=0.785, NSE=0.776,
R2=0.767, NSE=0.784,
R2=0.822, NSE=0.799,
R2=0.818, NSE=0.773,
R2=0.818, NSE=0.773,
R2=0.793, NSE=0.79,
good
marginal
snow
cloud
iter1
iter2




good marginal snow cloud iter1 iter2 iter3


v−curve, lambda = 11.22
v
log10(lambda)