The Abdus Salam
International Centre
for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2444-26

College on Soil Physics - 30th Anniversary (1983-2013)

25 February - 1 March, 2013

ILLUSTRATION OF AN EXAMPLE OF THE STATE-SPACE APPROACH USING ASTSA (APPLIED STATISTICAL TIME SERIES ANALYSIS) SOFTWARE

TIMM Luis Carlos
Rural Engineering Department
Faculty of Agronomy Federal University of Pelotas
Campus Universitario s/n, CP 354, Bairro Jardim America, Capao do Leao, Pelotas
96001-970, RS
BRAZIL

ILLUSTRATION OF AN EXAMPLE OF THE STATE-SPACE APPROACH USING ASTSA (APPLIED STATISTICAL TIME SERIES ANALYSIS) SOFTWARE

TIMM, L.C.[1]*, REICHARDT, K.[2], WENDROTH, O.[3], NIELSEN, D.R.[4], DOURADO-NETO, D.[5], AQUINO, L.S.[6], BAMBERG, A.L.[7]

[1]Regular Associate of ICTP, Rural Engineering Department, FAEM/UFPel, CP 354, 96001-970, Capão do Leão, RS, Brazil; [2]Soil Physics Laboratory, CENA/USP, Piracicaba, SP, Brazil; [3]Department of Plant and Soil Sciences, University of Kentucky, Lexington, KY, USA; [4]Department of Land, Air and Water Resources, University of California, Davis, CA, USA; [5]Crop Production Department, ESALQ/USP, Piracicaba, SP, Brazil; [6]PhD student at Faculty of Agronomy/Federal University of Pelotas; [7]Researcher at Embrapa CPACT, Pelotas, RS, Brazil.
*email corresponding author: lctimm@ufpel.edu.br; lcartimm@yahoo.com.br

Introduction

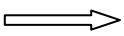
This text has the objective to illustrate a complete example the application of the software ASTSA. Here are some explanations on the "state" code that I have used and which was programmed by Shumway (1988):

Four columns of data (soil water content SWC, soil organic matter SOM, clay content CC, and aggregate stability AS) were normalized with respect to their mean and standard deviation using the equation:

xsc = (Xdat - (mean - 2 std)) / 4 std

The normalized data were saved as the file <trieste.prn>. Notice that the file must be saved space delimited. Tab delimited will not work!

Here follows the file <trieste.prn> with four variables data normalized.
Column
1: Soil water content SWC;
2: Soil organic matter SOM;
3: Clay content CC;
4: Aggregate stability AS.



-0.0817	1.1783	-0.0651	0.5111
-0.1539	1.0587	-0.0651	0.2936
-0.0396	1.0587	0.0967	-0.0330
-0.0034	0.7002	0.1507	0.4442
0.1109	0.6603	0.1507	0.1918

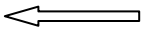
0.0748	0.7798	0.0428	0.2367
0.1410	0.9392	0.1507	0.8909
0.0989	0.7798	0.0428	0.6135
0.0267	0.7400	0.2586	0.7498
0.0989	0.5009	0.3664	0.5410
0.2554	0.6603	0.4204	0.5748
0.1049	0.5408	0.2586	0.0715
0.2614	0.5408	-0.0111	0.1582
0.5323	0.3814	0.1507	0.4226
0.3577	0.3017	0.2586	0.0277
0.4721	0.5408	0.4743	0.0735
0.2735	0.5408	0.3664	0.4618
0.3276	0.4213	0.3664	0.6484
0.4721	0.5806	0.2586	0.4675
0.3337	0.5806	0.2586	0.3581
0.3096	0.6205	0.2586	0.3658
0.3096	0.7002	0.2586	0.2168
0.3096	0.4213	0.3664	0.6131
0.5143	0.7002	0.2586	0.2267
0.4119	0.8595	0.2586	0.1310
0.4059	0.4611	0.2586	0.1796
0.5383	0.7798	0.3664	0.2447
0.4360	0.5806	0.5283	0.5690
0.4119	0.8197	0.2586	0.7771
0.5865	0.6205	0.2586	0.8517
0.3156	0.7798	0.2586	0.9207
0.5022	0.7002	0.2586	0.7734
0.2614	0.7798	0.5822	0.5531
0.8393	0.6603	0.5822	0.5864
0.6768	0.8197	0.5283	0.8059
0.5263	0.6603	0.3664	0.4886
0.4480	0.7400	0.3664	0.4963
0.9597	0.6603	0.5822	0.8014
0.6166	0.7002	0.4743	0.8946
0.7310	0.3814	0.4743	0.7546
0.6708	0.5009	0.5822	0.5214
0.5865	0.5408	0.6901	0.7599
0.6467	0.4611	0.5822	0.5013
0.7069	0.5408	0.5822	0.0820
0.7972	0.6205	0.6901	0.9715
0.7069	0.7798	0.7440	0.9135
0.8213	0.3814	0.8519	0.7024
0.9778	0.8197	0.7440	0.7722
1.0139	0.3814	0.9598	0.8831
0.8273	0.3814	0.7440	0.7423
0.8875	0.3416	0.6361	0.7337
0.7490	0.4611	0.6901	0.7010

0.5022	0.3017	0.6361	0.8282
0.4902	0.4611	0.7440	0.7394
0.3577	0.2619	0.6361	0.7193
0.6828	0.4611	0.7440	0.5703
0.3397	0.3416	0.8519	0.6928
0.5444	0.3017	1.0677	0.6860
0.7791	0.1025	0.8519	0.4432
0.5624	0.3017	0.7440	0.5005
0.5143	0.3416	0.7440	0.6512
0.6407	0.1424	0.6361	0.1482
0.5383	0.3017	0.6361	0.0685
0.5383	0.3416	0.5283	0.7079
0.7611	0.2619	0.7440	0.3923
0.6286	0.4611	0.5822	0.7513
0.6527	0.2619	0.6361	0.4966
0.5805	0.1822	0.6361	0.5096
0.7430	0.4213	0.6361	0.2894
0.5805	0.5408	0.8519	0.3124
0.5022	0.4611	0.6361	0.2658
0.5684	0.6603	0.6361	0.2837
0.5203	0.1822	0.7440	0.3282
0.4781	0.1822	0.7440	0.4282
0.5444	0.0228	0.5283	0.4342
0.5323	0.3017	0.7440	0.1223
0.7189	0.2619	0.5283	0.4290
0.6768	0.2619	0.7440	0.4600
0.7551	0.1424	0.4204	0.1213
0.7370	0.2619	0.7440	0.4851
0.6286	0.1822	0.6361	0.5698
0.6888	0.1822	0.7440	0.5451
0.6347	0.0228	0.6361	0.4054
0.4119	-0.0568	0.6361	0.3765

Next a parameter file is written, including file names, data information, and initial conditions for the estimation.
As an example, the file <trieste.txt> follows:

```
trieste.prn                    (name of input data file)
trieste.out                    (name of parameter output file)
strieste.out                   (name of output of the estimates)
84   4                         (number of data points, number of series in file)
4   4                          (dimension of matrices, usually the number of series in analysis)
1  2  3  4                     (column number of series that shall be used in the analysis, in this case: SWC,
SOM, CC, AS)
0  0  0  0                     (initial estimates of first data point of the series, will be optimized)
```

.1 0 0 0 0 .1 0 0 0 0 .1 0 0 0 0 .1 (initial estimate of state covariance, the higher, the more flexibility is given to the estimate of the first data point, this matrix is not optimized)
1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 (initial estimate of transition matrix)
.1 0 0 0 0 .1 0 0 0 0 .1 0 0 0 0 .1 (initial estimate of state covariance matrix)
.1 .1 .1 .1 (measurement variances)
1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 (measurement matrix)

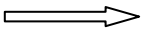


After starting the program <state>, you are asked for the name of the parameter input file, number of iterations, if you want detrending (y/n), forecasting. I usually set the number of iterations to 300, but the program is terminated when the transition matrix converges at 0.005, i.e., that the largest change of any transition coefficient from iteration k-1 to k is smaller than 0.5 %.

For this example, the solution converged after 161 iterations. Here follows the output parameter file <trieste.out> reporting the state after each iteration:

The state equation is written using the last transition matrix after the solution converged.

<trieste.out>



Iteration 1

Initial Mean
-3.372785E-02 .4251336 -1.491211E-02 .1541909
Initial Variances

.1
.1
.1
.1

Transition Matrix

.6407168 5.850731E-02 .1978915 9.451926E-02
2.977619E-02 .8061988 -1.255376E-02 .1179114
.1929867 2.282156E-02 .6598225 .1122457
.1279817 .1727082 8.834367E-02 .5957959
Relative Convergence= 1

State Covariance Matrix
4.777895E-02 1.366911E-03 5.808785E-03 3.253891E-03
1.366911E-03 5.562903E-02 9.048553E-05 5.53894E-03
5.808762E-03 9.050823E-05 4.784789E-02 3.197034E-03

3.253891E-03 5.538963E-03 3.197012E-03 5.055219E-02

Measurement Variances
4.988904E-02 .0523508 4.868516E-02 5.778823E-02

-2 log L= -407.335

Iteration 2

Initial Mean
-.1152796 .8478333 -.0891192 .2730116
Initial Variances

.1
.1
.1
.1

Transition Matrix
.5799738 5.477656E-02 .2739158 9.315998E-02
3.525546E-02 .8284709 -4.177506E-02 .1282054
.2566679 7.717549E-03 .6112735 .1205181
.1753394 .2233449 .1010427 .4968009
Relative Convergence= 1.9571

State Covariance Matrix
2.921547E-02 7.943426E-04 3.734861E-03 1.62908E-03
7.943426E-04 3.546944E-02 -.0005673 3.382047E-03
3.734884E-03 -.0005673 2.878791E-02 1.696836E-03
1.629103E-03 3.382047E-03 1.696859E-03 3.489592E-02

Measurement Variances
2.793513E-02 3.088344E-02 2.654431E-02 3.814406E-02

-2 log L= -642.3769

Iteration 3

Initial Mean
-.1888897 1.132355 -.1471604 .3444094
Initial Variances

.1
.1
.1
.1

Transition Matrix
.5706521 5.331521E-02 .3101322 7.383315E-02
5.457015E-02 .8532363 -6.407665E-02 .1108699
.2757021 2.724554E-03 .6165898 .1071838
.2118337 .2430152 9.438454E-02 .4527517
Relative Convergence= 1.832592

State Covariance Matrix
1.922601E-02 8.224078E-04 2.17633E-03 6.378492E-04
8.224078E-04 2.336454E-02 -5.859875E-04 1.785188E-03
2.17633E-03 -5.859875E-04 1.849109E-02 8.85532E-04
6.378038E-04 1.785165E-03 8.855093E-04 2.693985E-02

Measurement Variances
.0178521 2.028737E-02 1.635357E-02 2.908534E-02

-2 log L= -770.0905

Iteration 4

Initial Mean
-.2359613 1.258283 -.1520735 .3850268
Initial Variances

.1
.1
.1
.1

Transition Matrix
.5856861 5.681592E-02 .3175735 5.132887E-02
7.993343E-02 .8728788 -8.167616E-02 8.620524E-02
.2649067 5.444909E-03 .6468349 8.893599E-02
.2432656 .2476937 7.393993E-02 .4392868
Relative Convergence= .4996144

State Covariance Matrix
1.394771E-02 8.685475E-04 1.228469E-03 5.308787E-05
8.685702E-04 1.668367E-02 -5.432083E-04 9.033793E-04
1.228446E-03 -5.432765E-04 1.303037E-02 5.313101E-04
5.313328E-05 9.03402E-04 5.313101E-04 .0229566

Measurement Variances
1.295993E-02 1.497972E-02 1.134515E-02 2.473415E-02

-2 log L= -852.2478

Iteration 5

Initial Mean
-.2713971 1.294603 -.1255844 .4148268
Initial Variances

.1
.1
.1
.1

Transition Matrix
.6128565 6.132196E-02 .3069336 3.216751E-02
.1017085 .889752 -9.540257E-02 6.350477E-02
.2398663 9.150032E-03 .68624 7.315328E-02
.2705551 .2452787 4.671833E-02 .442321
Relative Convergence= .5956743

State Covariance Matrix
1.114759E-02 8.380073E-04 6.773812E-04 -3.20321E-04
8.379164E-04 1.298818E-02 -5.197071E-04 4.286085E-04
6.773812E-04 -5.19639E-04 1.012614E-02 4.429136E-04
-3.203437E-04 4.286539E-04 4.428909E-04 2.098011E-02

Measurement Variances
1.053895E-02 1.238334E-02 8.785712E-03 2.254251E-02

-2 log L= -898.1995

Iteration 6

Initial Mean
-.2982231 1.298585 -9.806863E-02 .4434789
Initial Variances

.1
.1
.1
.1

Transition Matrix
.6434181 6.530818E-02 .2877316 1.787391E-02
.1158994 .9033315 -.1032855 4.538414E-02
.2126692 .0121844 .7233818 6.149401E-02

.293426 .2399693 1.943856E-02 .452062
Relative Convergence= 1.403384

State Covariance Matrix
9.592919E-03 7.603509E-04 3.628958E-04 -5.867595E-04
7.603736E-04 1.081124E-02 -4.965464E-04 1.713889E-04
3.629185E-04 -4.965918E-04 8.533727E-03 5.015192E-04
-5.867822E-04 1.713889E-04 5.015192E-04 1.999492E-02

Measurement Variances
9.354251E-03 1.120008E-02 7.449064E-03 2.135839E-02

-2 log L= -920.9266

Iteration 7

Initial Mean
-.3119591 1.293073 -8.339319E-02 .4720712
Initial Variances

.1
.1
.1
.1

Transition Matrix
.6716315 6.827747E-02 .2673269 7.714958E-03
.1231695 .9136918 -.1057778 3.162174E-02
.1898088 .0147303 .7527502 5.327141E-02
.3123203 .2340732 -4.38959E-03 .4626388
Relative Convergence= 5.428331

State Covariance Matrix
8.645738E-03 6.629172E-04 1.937321E-04 -7.933208E-04
6.629172E-04 9.408428E-03 -4.74067E-04 3.880546E-05
1.937548E-04 -4.739534E-04 7.616383E-03 6.311734E-04
-7.933208E-04 3.880546E-05 6.311734E-04 1.949901E-02

Measurement Variances
8.815379E-03 1.076287E-02 6.754411E-03 2.065831E-02

-2 log L= -931.4516

Iteration 8

Initial Mean
-.3146417 1.28448 -7.963976E-02 .498886
Initial Variances

 .1
 .1
 .1
 .1

Transition Matrix
 .6952621 7.025459E-02 .249358 4.491503E-04
 .1261697 .9216494 -.1051944 2.119587E-02
 .1728642 1.694005E-02 .7738699 4.746347E-02
 .3282776 .2287506 -2.411999E-02 .4713792
Relative Convergence= 16.17678

State Covariance Matrix
 7.991564E-03 5.635534E-04 1.132148E-04 -9.59578E-04
 5.635761E-04 8.415063E-03 -4.570825E-04 -2.077648E-05
 1.132148E-04 -4.571279E-04 7.052512E-03 7.85646E-04
-9.596007E-04 -2.077648E-05 7.85646E-04 1.925162E-02

Measurement Variances
 8.627383E-03 1.071551E-02 6.410447E-03 2.020407E-02

-2 log L= -936.4449

Iteration 9

Initial Mean
-.3121418 1.275184 -8.062802E-02 .522824
Initial Variances

 .1
 .1
 .1
 .1

Transition Matrix
 .7144006 7.155549E-02 .2345748 -4.964057E-03
 .1271848 .9279749 -.1035091 1.311821E-02
 .1610143 .0187734 .7885057 4.325982E-02
 .3421948 .2244364 -4.034141E-02 .4776358
Relative Convergence= 1.09048

State Covariance Matrix
7.482847E-03 4.72364E-04 8.387792E-05 -1.094795E-03
4.723413E-04 7.652896E-03 -4.474549E-04 -3.919147E-05
8.387792E-05 -4.473868E-04 6.678036E-03 9.402321E-04
-1.09475E-03 -3.916877E-05 9.402321E-04 1.913738E-02

Measurement Variances
8.634467E-03 1.086087E-02 6.262126E-03 1.988349E-02

-2 log L= -939.1515

Iteration 10

Initial Mean
-.3086857 1.266443 -8.236866E-02 .5438919
Initial Variances

.1
.1
.1
.1

Transition Matrix
.7300029 7.248756E-02 .2224687 -9.201016E-03
.1275145 .9331605 -.1017367 6.661829E-03
.1528817 2.021222E-02 .7986832 4.008315E-02
.3546474 .2211608 -5.387045E-02 .4816693
Relative Convergence= .9691607

State Covariance Matrix
7.052263E-03 3.923688E-04 8.122126E-05 -1.205785E-03
3.923688E-04 7.034551E-03 -4.434132E-04 -3.64894E-05
8.124397E-05 -4.434586E-04 6.40742E-03 1.083079E-03
-1.205785E-03 -3.65121E-05 1.083056E-03 1.909853E-02

Measurement Variances
8.749408E-03 1.108919E-02 6.22345E-03 1.963984E-02

-2 log L= -940.9309

.....
.....
.....
.....
.....
.....

.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....

Iteration 151

Initial Mean
-.314539 1.266497 -1.937176E-02 1.17581
Initial Variances

 .1
 .1
 .1
 .1

Transition Matrix
 .9116966 7.074924E-02 6.094342E-02 -2.421624E-02
 .1793628 .9712795 -.12503 -5.170462E-02
 .0495155 3.390892E-02 .9456304 -1.238308E-02
 .7035516 .2574961 -.2942737 .3375235
Relative Convergence=   6.552606E-03

State Covariance Matrix
 1.203469E-03 -8.34624E-04 2.042453E-04 -2.68918E-03
-8.347148E-04 1.993111E-03 -6.522224E-04 -3.432319E-04
 2.04268E-04 -6.522224E-04 6.404831E-04 2.451034E-03
-2.689203E-03 -3.431411E-04 2.451011E-03 2.993527E-02

Measurement Variances
 1.401541E-02 1.456829E-02 1.131318E-02 7.612207E-03

-2 log L= -962.1385

Iteration 152

Initial Mean
-.314459 1.266535 -1.935858E-02 1.177021

Initial Variances

.1
.1
.1
.1

Transition Matrix
.9118998 7.070215E-02 6.072339E-02 -2.414808E-02
.1793132 .971301 -.1249462 -5.175339E-02
4.944421E-02 .0339409 .9457557 -1.246123E-02
.7040113 .2576459 -.2944752 .3371176
Relative Convergence= 6.271158E-03

State Covariance Matrix
1.199064E-03 -8.360545E-04 2.040636E-04 -2.690565E-03
-8.360545E-04 1.993157E-03 -6.540162E-04 -3.423918E-04
2.040409E-04 -6.540389E-04 6.37009E-04 2.453077E-03
-2.690588E-03 -3.424145E-04 2.453077E-03 2.998193E-02

Measurement Variances
1.402248E-02 1.456999E-02 1.131774E-02 7.567519E-03

-2 log L= -962.1896

Iteration 153

Initial Mean
-.3143882 1.266583 -.0193397 1.178224
Initial Variances

.1
.1
.1
.1

Transition Matrix
.9121155 7.065187E-02 6.048978E-02 -2.407492E-02
.1792565 .9713231 -.1248571 -5.180087E-02
.0493689 3.397367E-02 .9458869 -1.253962E-02
.7044846 .2578006 -.2946918 .336718
Relative Convergence= 6.251413E-03

State Covariance Matrix
1.194931E-03 -8.370536E-04 2.039728E-04 -2.691814E-03

-8.370536E-04 1.993066E-03 -6.556511E-04 -3.415743E-04
 2.039728E-04 -6.55583E-04 6.334441E-04 2.455325E-03
-2.691814E-03 -3.415516E-04 2.455348E-03 3.002805E-02

Measurement Variances
 1.402997E-02 1.457183E-02 1.132201E-02 7.523174E-03

-2 log L= -962.239

Iteration 154

Initial Mean
-.3143073 1.266628 -1.931766E-02 1.179412
Initial Variances

 .1
 .1
 .1
 .1

Transition Matrix
 .9123184 7.060064E-02 6.026707E-02 -2.400573E-02
 .1791884 .9713447 -.1247562 -5.184706E-02
 4.929478E-02 3.400236E-02 .9460136 -1.261372E-02
 .7049698 .2579525 -.2949183 .3363223
Relative Convergence=   5.874609E-03

State Covariance Matrix
 1.190753E-03 -8.378029E-04 2.040182E-04 -2.692926E-03
-8.377348E-04 1.993202E-03 -6.569453E-04 -3.406434E-04
 2.039274E-04 -6.569226E-04 6.302198E-04 2.45755E-03
-2.692926E-03 -3.406434E-04 2.457528E-03 3.007376E-02

Measurement Variances
 1.403706E-02 1.457363E-02 1.132631E-02 7.479152E-03

-2 log L= -962.2899

Iteration 155

Initial Mean
-.3142131 1.266672 -1.928869E-02 1.180585
Initial Variances

 .1
 .1

.1
.1

Transition Matrix
.9125299 7.055014E-02 6.003026E-02 -2.393388E-02
.1791274 .9713651 -.1246689 -5.189018E-02
4.927509E-02 3.402956E-02 .94608 -1.268555E-02
.7054525 .2580997 -.2951491 .3359331
Relative Convergence= 5.662137E-03

State Covariance Matrix
1.18653E-03 -8.385749E-04 2.034959E-04 -2.694244E-03
-8.385976E-04 1.993338E-03 -6.584894E-04 -3.397578E-04
2.034959E-04 -6.58444E-04 6.272452E-04 2.459526E-03
-2.69413E-03 -3.397351E-04 2.459526E-03 3.011928E-02

Measurement Variances
1.404384E-02 1.457504E-02 1.133027E-02 7.435463E-03

-2 log L= -962.3367

Iteration 156

Initial Mean
-.3141214 1.266722 -1.923562E-02 1.18175
Initial Variances

.1
.1
.1
.1

Transition Matrix
.9127292 7.049928E-02 5.981822E-02 -2.386548E-02
.1790894 .9713818 -.1246036 -.0519299
4.920281E-02 3.405834E-02 .9462044 -1.276023E-02
.7059179 .2582442 -.295366 .3355429
Relative Convergence= 5.852484E-03

State Covariance Matrix
1.182125E-03 -8.395513E-04 2.033824E-04 -2.69547E-03
-8.395286E-04 1.993475E-03 -6.598291E-04 -3.388723E-04
2.03337E-04 -6.598518E-04 6.242025E-04 2.461706E-03
-2.695447E-03 -3.389404E-04 2.461729E-03 3.016433E-02

Measurement Variances
1.405094E-02 1.457641E-02 1.133393E-02 7.392102E-03

-2 log L= -962.3804

Iteration 157

Initial Mean
-.3140348 1.266782 -1.920905E-02 1.182904
Initial Variances

.1
.1
.1
.1

Transition Matrix
.9129323 7.045013E-02 5.959442E-02 -2.379506E-02
.1790309 .9713993 -.1245198 -.0519688
4.915746E-02 .03409 .9463015 -1.283392E-02
.706398 .2583881 -.2955983 .3351618
Relative Convergence= 5.741958E-03

State Covariance Matrix
1.177969E-03 -8.40346E-04 2.031553E-04 -2.696673E-03
-8.40346E-04 1.993656E-03 -6.614866E-04 -3.381002E-04
2.031553E-04 -6.614639E-04 6.213869E-04 2.46384E-03
-2.696696E-03 -3.380775E-04 2.463818E-03 3.020895E-02

Measurement Variances
.0140583 1.457779E-02 1.133762E-02 7.34906E-03

-2 log L= -962.4266

Iteration 158

Initial Mean
-.313949 1.266825 -1.919103E-02 1.184049
Initial Variances

.1
.1
.1
.1

Transition Matrix

.9131084 7.040338E-02 5.939914E-02 -2.372814E-02
.1789733 .9714177 -.1244314 -5.200982E-02
4.908198E-02 .0341204 .9464264 -1.290746E-02
.7068518 .2585291 -.2958037 .3347822
Relative Convergence= 5.697411E-03

State Covariance Matrix
1.174223E-03 -8.41277E-04 2.030418E-04 -2.697672E-03
-8.411861E-04 1.993792E-03 -6.63008E-04 -3.372601E-04
2.030418E-04 -6.629853E-04 6.184124E-04 2.466134E-03
-2.697672E-03 -3.373055E-04 2.466134E-03 3.025357E-02

Measurement Variances
.0140654 1.457915E-02 1.134103E-02 7.306337E-03

-2 log L= -962.4721

Iteration 159

Initial Mean
-.3138728 1.266866 -1.918311E-02 1.185186
Initial Variances

.1
.1
.1
.1

Transition Matrix
.9132943 7.035724E-02 5.918963E-02 -.0236625
.1788968 .9714358 -.1243284 -5.205032E-02
4.901125E-02 3.414841E-02 .9465407 -1.297572E-02
.7073107 .2586669 -.296023 .3344114
Relative Convergence= 5.260693E-03

State Covariance Matrix
1.170408E-03 -8.417993E-04 2.032007E-04 -2.698717E-03
-8.418447E-04 1.993974E-03 -6.642115E-04 -3.3642E-04
2.031553E-04 -6.643023E-04 6.157557E-04 2.468586E-03
-2.698671E-03 -3.363973E-04 2.468563E-03 3.029778E-02

Measurement Variances
1.407188E-02 1.458052E-02 1.134457E-02 7.263911E-03

-2 log L= -962.5181

Iteration 160

Initial Mean
-.3137919 1.266902 -1.916699E-02 1.186313
Initial Variances

.1
.1
.1
.1

Transition Matrix
.9134971 7.031218E-02 5.897249E-02 -2.359585E-02
.1788591 .9714511 -.1242591 -.0520863
4.898128E-02 3.418268E-02 .9466231 -1.305107E-02
.7077752 .2587962 -.2962493 .3340505
Relative Convergence= 5.773157E-03

State Covariance Matrix
1.166389E-03 -8.42821E-04 2.026785E-04 -2.69992E-03
-8.429118E-04 1.994088E-03 -6.663913E-04 -3.357161E-04
2.027239E-04 -6.66255E-04 6.129628E-04 2.470584E-03
-2.699897E-03 -3.356252E-04 2.47063E-03 .0303416

Measurement Variances
1.407812E-02 1.458174E-02 1.134782E-02 7.221805E-03

-2 log L= -962.5623

Iteration 161

Initial Mean
-.3137077 1.266942 -1.916385E-02 1.187429
Initial Variances

.1
.1
.1
.1

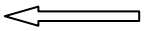
Transition Matrix
.9136859 7.026269E-02 5.876194E-02 -2.353143E-02
.1788296 .9714648 -.1242072 -5.212222E-02
4.891815E-02 .0342045 .9467272 -1.311319E-02
.7082351 .2589375 -.2964616 .3336791

Relative Convergence= 4.737651E-03

State Covariance Matrix
1.162234E-03 -8.438428E-04 2.028829E-04 -2.700987E-03
-8.436384E-04 1.99411E-03 -6.667546E-04 -3.347397E-04
2.026785E-04 -6.668681E-04 6.104424E-04 2.472968E-03
-2.700896E-03 -3.348759E-04 2.473059E-03 3.038497E-02

Measurement Variances
.0140851 1.458339E-02 1.135101E-02 7.179997E-03

-2 log L= -962.6094

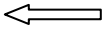


The respective estimates for the series are given in the output file of estimates <strieste.out>

Innovation residues					**Normalized estimated values**					**Standard deviations**			
SWC	**SOM**	**CC**	**AS**		**SWC**	**SOM**	**CC**	**AS**		**SWC**	**SOM**	**CC**	**AS**
0.1450	0.0631	-0.0594	0.0034		-0.2267	1.1152	-0.0056	0.5092		0.0530	0.0673	0.0464	0.0786
-0.1136	-0.0359	-0.0434	-0.1164		-0.1436	1.0152	0.0144	0.2879		0.0458	0.0572	0.0424	0.0768
-0.0170	0.0470	0.1119	-0.3583		-0.0417	0.9332	0.0262	0.0433		0.0422	0.0527	0.0395	0.0766
-0.0503	-0.2723	0.1114	0.1930		0.0221	0.8638	0.0778	0.3993		0.0404	0.0507	0.0372	0.0764
0.0217	-0.1695	0.0443	-0.1720		0.0888	0.8114	0.0883	0.2167		0.0395	0.0498	0.0354	0.0763
-0.0695	0.0428	-0.0963	-0.0698		0.1292	0.8072	0.0990	0.2736		0.0390	0.0494	0.0340	0.0762
-0.0272	0.2107	0.0147	0.5579		0.1197	0.7995	0.1510	0.8002		0.0388	0.0493	0.0330	0.0761
-0.0873	0.0284	-0.1285	0.0780		0.1360	0.7442	0.1701	0.6169		0.0386	0.0492	0.0321	0.0761
-0.1673	0.0115	0.0887	0.2836		0.1440	0.6853	0.2099	0.7130		0.0385	0.0491	0.0315	0.0760
-0.0923	-0.1797	0.1638	0.0600		0.1724	0.6091	0.2344	0.5446		0.0385	0.0491	0.0310	0.0760
0.0448	0.0860	0.1767	0.1770		0.1855	0.5634	0.2553	0.5335		0.0384	0.0490	0.0306	0.0760
-0.1462	-0.0110	-0.0240	-0.3439		0.2284	0.5256	0.2380	0.1271		0.0384	0.0490	0.0303	0.0760
0.0021	0.0121	-0.2776	-0.1151		0.2697	0.5086	0.2445	0.1742		0.0384	0.0490	0.0301	0.0760
0.2604	-0.1607	-0.0921	0.1173		0.3046	0.4718	0.2767	0.3768		0.0384	0.0490	0.0300	0.0760
0.0281	-0.1909	-0.0175	-0.3788		0.3516	0.4512	0.2693	0.0837		0.0384	0.0490	0.0299	0.0760
0.1137	0.1020	0.1943	-0.2344		0.3816	0.4754	0.2707	0.1289		0.0384	0.0490	0.0298	0.0760
-0.1365	0.0773	0.0613	0.1071		0.3724	0.5090	0.2887	0.4536		0.0384	0.0490	0.0297	0.0760
-0.0646	-0.0572	0.0463	0.1927		0.3583	0.5154	0.3071	0.6079		0.0384	0.0490	0.0297	0.0760
0.0892	0.1369	-0.0871	-0.0250		0.3520	0.5281	0.3006	0.4622		0.0384	0.0490	0.0297	0.0760
-0.0700	0.0994	-0.0844	-0.1071		0.3490	0.5503	0.2920	0.3717		0.0384	0.0490	0.0296	0.0760
-0.0898	0.1103	-0.0733	-0.0731		0.3498	0.5737	0.2892	0.3678		0.0384	0.0490	0.0296	0.0760
-0.0837	0.1590	-0.0650	-0.2280		0.3680	0.5908	0.2823	0.2682		0.0384	0.0490	0.0296	0.0760
-0.0878	-0.1679	0.0585	0.1921		0.3699	0.5940	0.3105	0.5597		0.0384	0.0490	0.0296	0.0760
0.1238	0.1788	-0.0853	-0.2766		0.3938	0.6087	0.2932	0.2573		0.0384	0.0490	0.0296	0.0760
-0.0204	0.2815	-0.0737	-0.3111		0.4230	0.6412	0.2828	0.1751		0.0384	0.0490	0.0296	0.0760
-0.0462	-0.2106	-0.0538	-0.2742		0.4682	0.6511	0.2902	0.2100		0.0384	0.0490	0.0296	0.0760
0.0744	0.1598	0.0430	-0.2158		0.5023	0.6863	0.2966	0.2848		0.0384	0.0490	0.0296	0.0760

-0.0660	-0.0922	0.1934	0.0499		0.5150	0.7123	0.3231	0.5638		0.0384	0.0490	0.0296	0.0760
-0.0977	0.1907	-0.1225	0.1770		0.5034	0.7468	0.3410	0.7434		0.0384	0.0490	0.0296	0.0760
0.0979	-0.0614	-0.1216	0.1919		0.5026	0.7454	0.3662	0.8144		0.0384	0.0490	0.0296	0.0760
-0.1883	0.1229	-0.1450	0.2392		0.4850	0.7544	0.3879	0.8743		0.0384	0.0490	0.0296	0.0760
0.0386	0.0214	-0.1410	0.0923		0.4980	0.7336	0.4074	0.7452		0.0384	0.0490	0.0296	0.0760
-0.2128	0.1067	0.1761	-0.0880		0.5278	0.7170	0.4215	0.5747		0.0384	0.0490	0.0296	0.0760
0.3740	-0.0090	0.1632	0.0180		0.5714	0.6918	0.4491	0.5875		0.0384	0.0490	0.0296	0.0760
0.1158	0.1748	0.0529	0.1887		0.5710	0.6973	0.4744	0.7601		0.0384	0.0490	0.0296	0.0760
-0.0645	-0.0199	-0.1382	-0.2172		0.5951	0.6871	0.4723	0.5150		0.0384	0.0490	0.0296	0.0760
-0.1406	0.0631	-0.1264	-0.1213		0.6240	0.6859	0.4857	0.5230		0.0384	0.0490	0.0296	0.0760
0.3878	-0.0378	0.1023	0.1900		0.6512	0.6546	0.5320	0.7738		0.0384	0.0490	0.0296	0.0760
-0.0384	0.0263	-0.0685	0.1581		0.6475	0.6303	0.5632	0.8667		0.0384	0.0490	0.0296	0.0760
0.0874	-0.2923	-0.0819	-0.0044		0.6662	0.5795	0.5875	0.7421		0.0384	0.0490	0.0296	0.0760
0.0130	-0.0830	0.0007	-0.1780		0.6859	0.5625	0.5944	0.5611		0.0384	0.0490	0.0296	0.0760
-0.0814	-0.0164	0.1004	0.1313		0.6845	0.5617	0.6202	0.7295		0.0384	0.0490	0.0296	0.0760
-0.0083	-0.0749	-0.0325	-0.1719		0.7100	0.5512	0.6202	0.5028		0.0384	0.0490	0.0296	0.0760
0.0484	0.0291	-0.0327	-0.5132		0.7650	0.5646	0.6042	0.1933		0.0384	0.0490	0.0296	0.0760
0.1107	0.0858	0.0927	0.4720		0.7559	0.5918	0.6602	0.8935		0.0384	0.0490	0.0296	0.0760
0.0097	0.2309	0.0982	0.1633		0.7537	0.5734	0.6861	0.8881		0.0384	0.0490	0.0296	0.0760
0.1211	-0.2128	0.1898	-0.0558		0.7830	0.5212	0.7073	0.7164		0.0384	0.0490	0.0296	0.0760
0.2424	0.3122	0.0379	0.0841		0.7863	0.5073	0.7265	0.7694		0.0384	0.0490	0.0296	0.0760
0.2334	-0.2121	0.2396	0.1312		0.7886	0.4546	0.7586	0.8619		0.0384	0.0490	0.0296	0.0760
-0.0015	-0.1265	-0.0419	-0.0420		0.7718	0.4324	0.7585	0.7479		0.0384	0.0490	0.0296	0.0760
0.0696	-0.1289	-0.1551	0.0092		0.7478	0.4248	0.7569	0.7269		0.0384	0.0490	0.0296	0.0760
-0.0624	0.0178	-0.0999	-0.0045		0.7130	0.4316	0.7502	0.7118		0.0384	0.0490	0.0296	0.0760
-0.2832	-0.1510	-0.1422	0.1449		0.6690	0.4315	0.7531	0.8061		0.0384	0.0490	0.0296	0.0760
-0.2209	0.0575	-0.0203	0.0827		0.6372	0.4236	0.7491	0.7361		0.0384	0.0490	0.0296	0.0760
-0.3057	-0.1388	-0.1135	0.1195		0.6183	0.4016	0.7507	0.6977		0.0384	0.0490	0.0296	0.0760
0.0878	0.1205	0.0136	0.0402		0.6205	0.3759	0.7500	0.5777		0.0384	0.0490	0.0296	0.0760
-0.2753	-0.0128	0.1238	0.1910		0.6102	0.3477	0.7637	0.6750		0.0384	0.0490	0.0296	0.0760
-0.0227	-0.0098	0.3362	0.1942		0.6145	0.2980	0.7768	0.6555		0.0384	0.0490	0.0296	0.0760
0.1994	-0.1490	0.0836	-0.0316		0.6289	0.2611	0.7648	0.4443		0.0384	0.0490	0.0296	0.0760
-0.0598	0.1186	-0.0403	0.0919		0.6092	0.2765	0.7492	0.4872		0.0384	0.0490	0.0296	0.0760
-0.0882	0.1372	-0.0208	0.2330		0.5843	0.2810	0.7429	0.5869		0.0384	0.0490	0.0296	0.0760
0.0652	-0.0802	-0.1162	-0.3032		0.6082	0.2687	0.7045	0.1770		0.0384	0.0490	0.0296	0.0760
-0.0524	0.1034	-0.0868	-0.2505		0.6253	0.3028	0.6748	0.1228		0.0384	0.0490	0.0296	0.0760
-0.0464	0.1064	-0.1583	0.4034		0.6032	0.3319	0.6927	0.6202		0.0384	0.0490	0.0296	0.0760
0.2089	-0.0012	0.0664	-0.0820		0.6180	0.3155	0.6833	0.4190		0.0384	0.0490	0.0296	0.0760
0.0315	0.2137	-0.1045	0.3294		0.5864	0.3307	0.6945	0.6898		0.0384	0.0490	0.0296	0.0760
0.0694	-0.0404	-0.0426	-0.0308		0.5844	0.3062	0.6885	0.5054		0.0384	0.0490	0.0296	0.0760
-0.0120	-0.0982	-0.0385	0.0467		0.5729	0.3009	0.6863	0.4948		0.0384	0.0490	0.0296	0.0760
0.1607	0.1783	-0.0372	-0.1575		0.5691	0.3137	0.6663	0.3218		0.0384	0.0490	0.0296	0.0760
-0.0333	0.2435	0.1941	-0.1104		0.5564	0.3355	0.6553	0.3448		0.0384	0.0490	0.0296	0.0760
-0.1209	0.1078	-0.0228	-0.1858		0.5515	0.3442	0.6408	0.3051		0.0384	0.0490	0.0296	0.0760
-0.0387	0.2752	-0.0007	-0.1553		0.5553	0.3388	0.6362	0.3241		0.0384	0.0491	0.0297	0.0760
-0.0908	-0.2831	0.1270	-0.1434		0.5761	0.2897	0.6482	0.3641		0.0385	0.0491	0.0297	0.0760
-0.1307	-0.1862	0.1056	-0.0276		0.5810	0.2574	0.6572	0.4373		0.0385	0.0491	0.0297	0.0760
-0.0454	-0.2752	-0.1235	-0.0157		0.5862	0.2300	0.6577	0.4149		0.0387	0.0492	0.0298	0.0760
-0.0367	0.0829	0.0971	-0.2931		0.6070	0.2258	0.6371	0.1829		0.0388	0.0493	0.0299	0.0760
0.1442	0.0255	-0.1040	0.0892		0.6110	0.2255	0.6470	0.4084		0.0391	0.0494	0.0300	0.0760

0.0886	0.0088	0.1130	0.0253		0.6146	0.2062	0.6535	0.4426		0.0395	0.0497	0.0301	0.0760
0.1509	-0.1026	-0.2266	-0.3369		0.6404	0.1882	0.6351	0.1810		0.0401	0.0501	0.0304	0.0760
0.1147	0.0185	0.1258	0.1073		0.6332	0.1865	0.6543	0.4785		0.0410	0.0508	0.0307	0.0760
-0.0092	-0.0642	-0.0073	0.0812		0.6157	0.1662	0.6650	0.5624		0.0424	0.0520	0.0312	0.0760
0.0685	-0.0449	0.0960	0.0450		0.6013	0.1339	0.6718	0.5414		0.0446	0.0542	0.0319	0.0761
0.0097	-0.1817	-0.0274	-0.0828		0.5912	0.1040	0.6660	0.4198		0.0478	0.0582	0.0332	0.0761
-0.2020	-0.2108	-0.0256	-0.0489		0.5745	0.0931	0.6581	0.3845		0.0528	0.0658	0.0355	0.0767



The number of columns of this file is 3 times the number of variables in the analysis, i.e. in this case 12 columns. The first block of four columns includes the innovation residuals for variables 1, 2, 3, 4. The second block of columns (6-9) includes the normalized estimates of soil water content SWC, soil organic matter SOM, clay content CC, and aggregate stability AS, and the third block (11-14) are the standard errors of estimation for the four variables.

I recommend Shumway's book (Shumway, 1988; Shumway & Stoffer, 2000; Shumway & Stoffer, 2011) as an important reference to study.

Acknowledgments

We wish to express thanks to the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy and to the Brazilian Research Council (CNPq) for the scholarships and funding.

References:

SHUMWAY, R.H. 1988. Applied statistical time series analyses. Prentice Halll, Englewood Cliffs, New York. 379p.

SHUMWAY, R.H., STOFFER, D.S. 2000. Time Series Analysis and Its Applications. New York: Springer, New York, USA. 549p.

SHUMWAY, R.H., STOFFER, D.S. 2011. Time Series Analysis and Its Applications: with R examples. 3. ed. New York: Springer, New York, USA. 608p.