

Understanding unsaturated soil water dynamics of the Twente region using actual evapotranspiration and soil moisture data



Appendix report

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1. Appendices

1.1. Appendix A) Datasets

1.1.1. Appendix A.1: Overview of soil moisture state and hydrological conditions

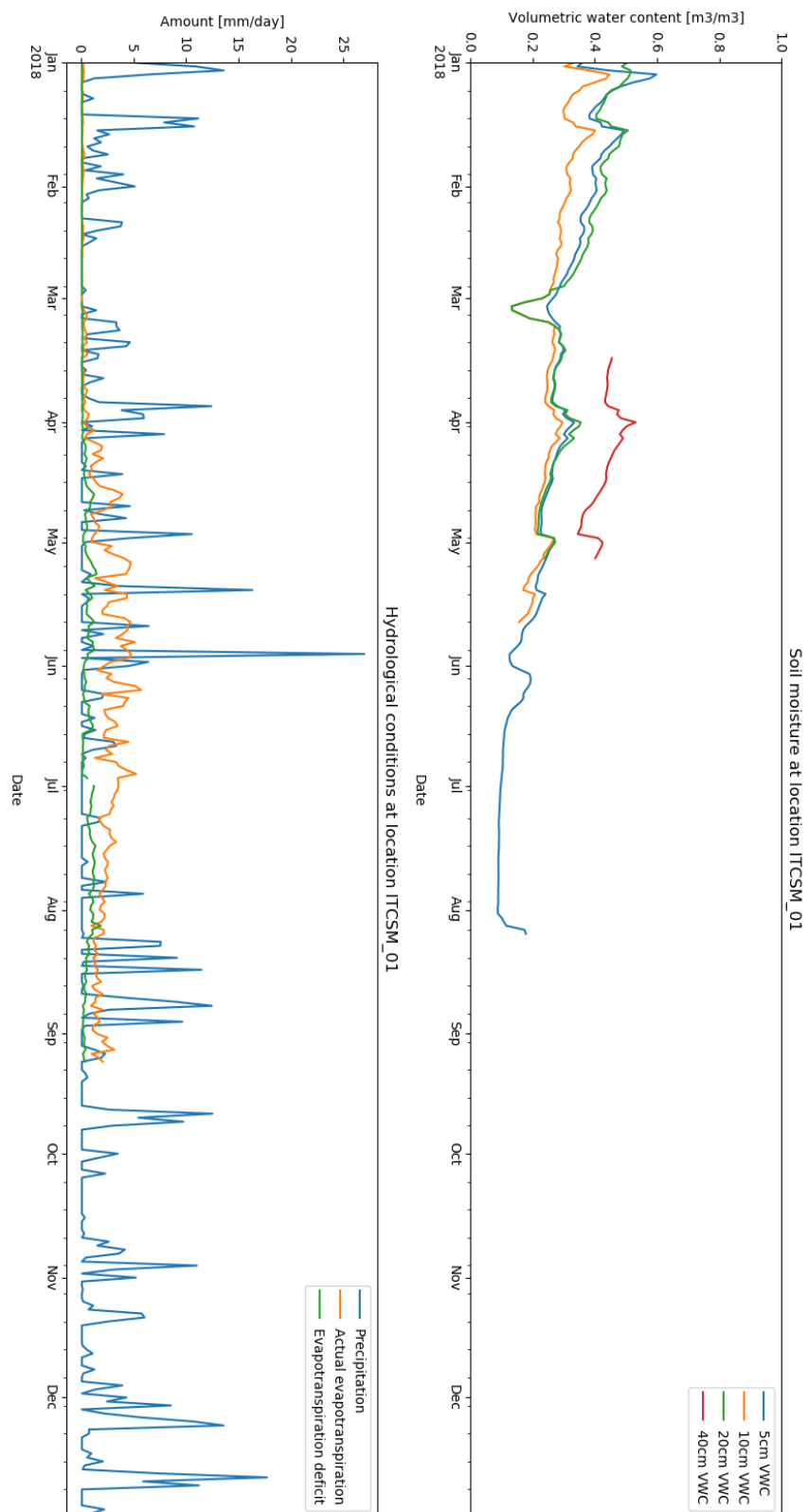


Figure 1: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_01.

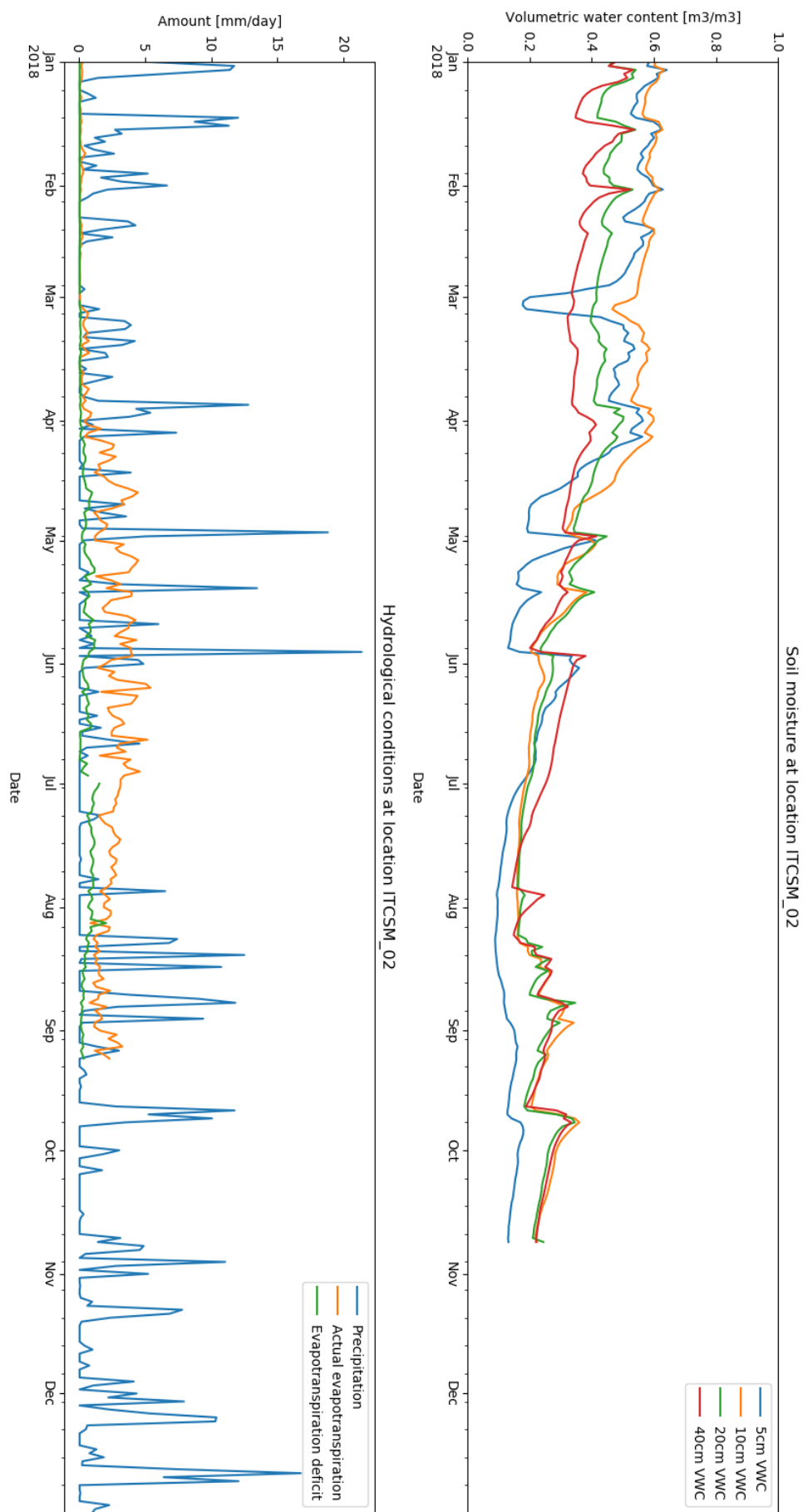


Figure 2: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_02.

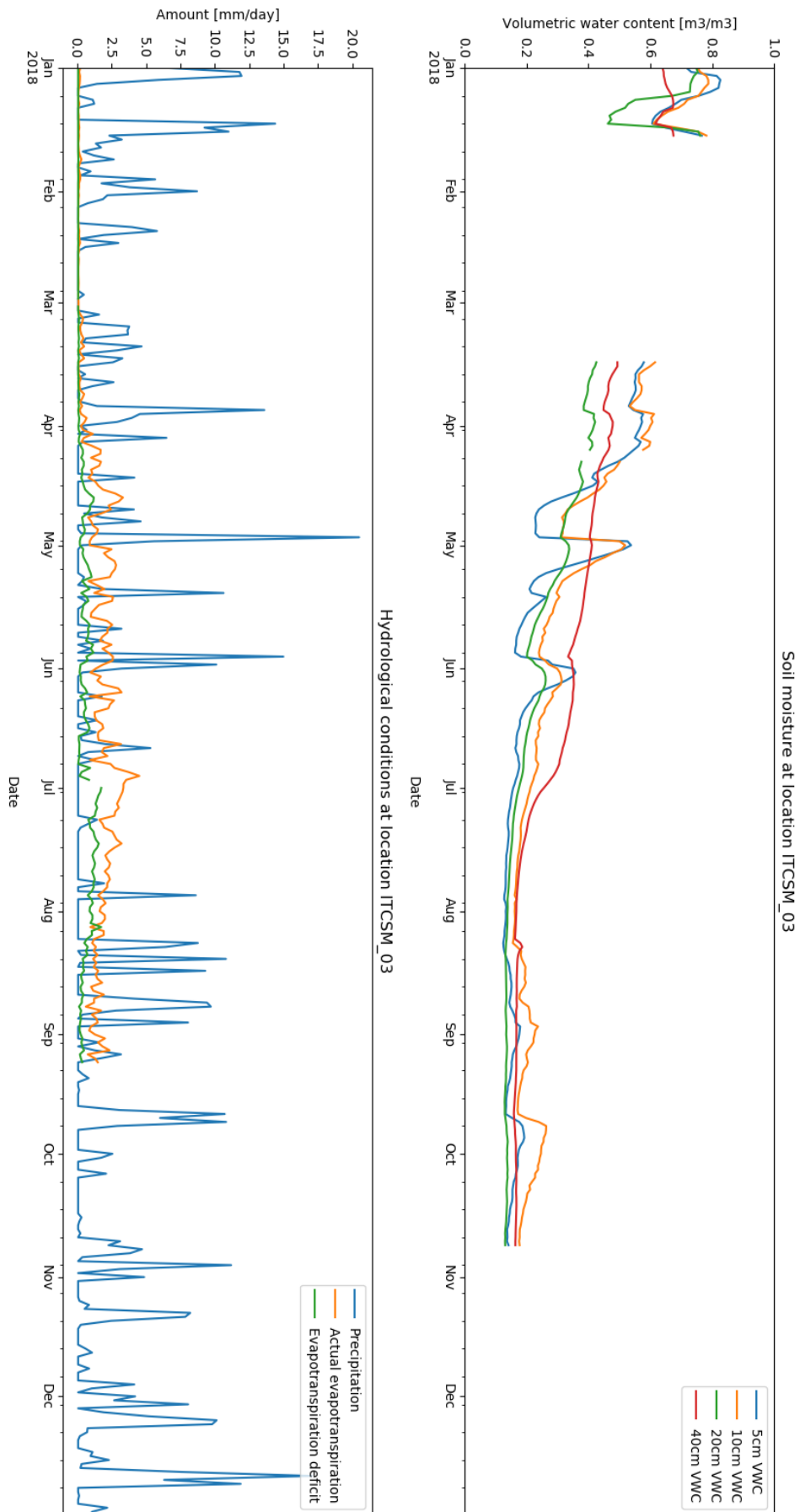


Figure 3: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_03.

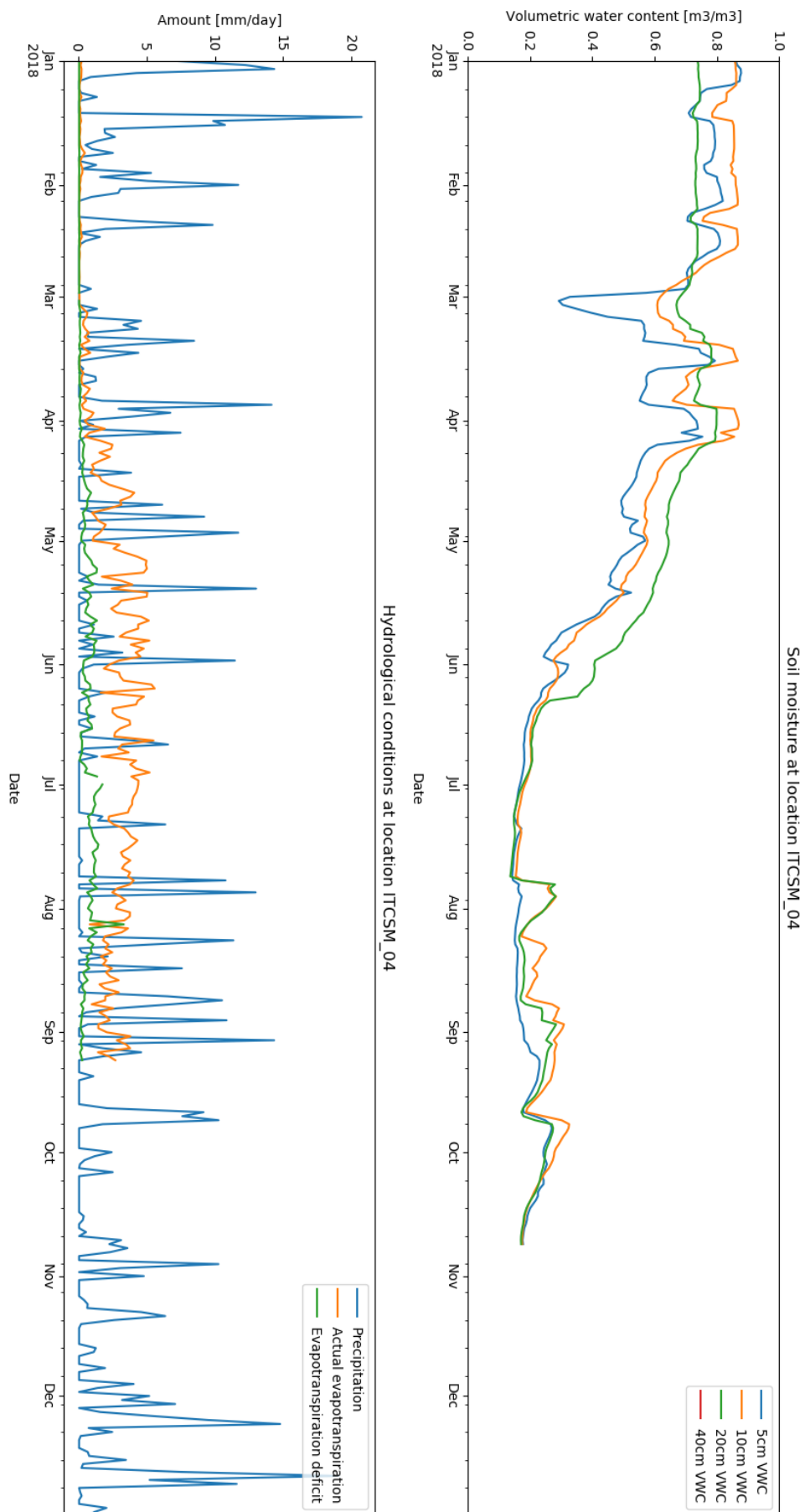


Figure 4: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_04.

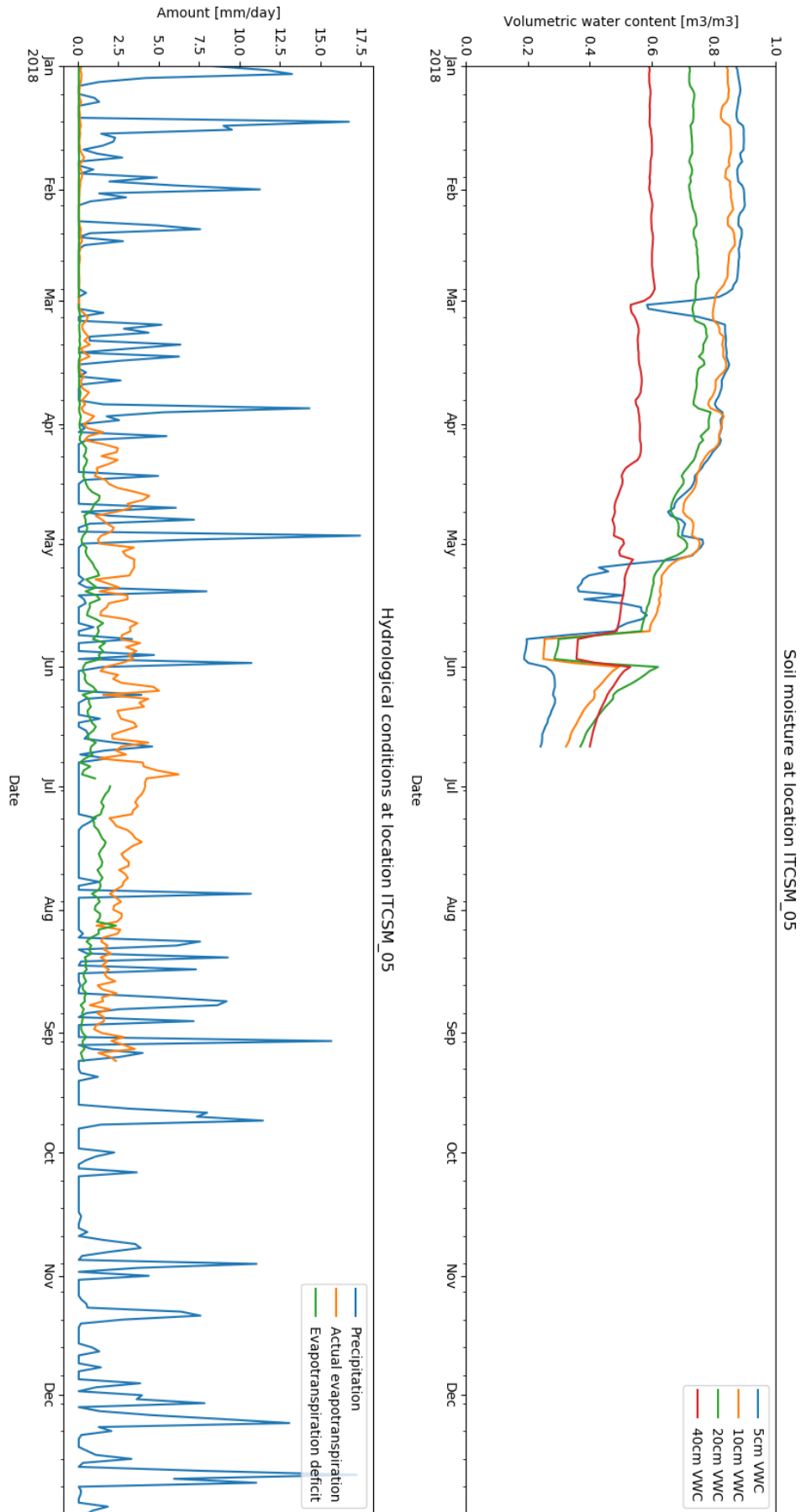


Figure 5: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_05.

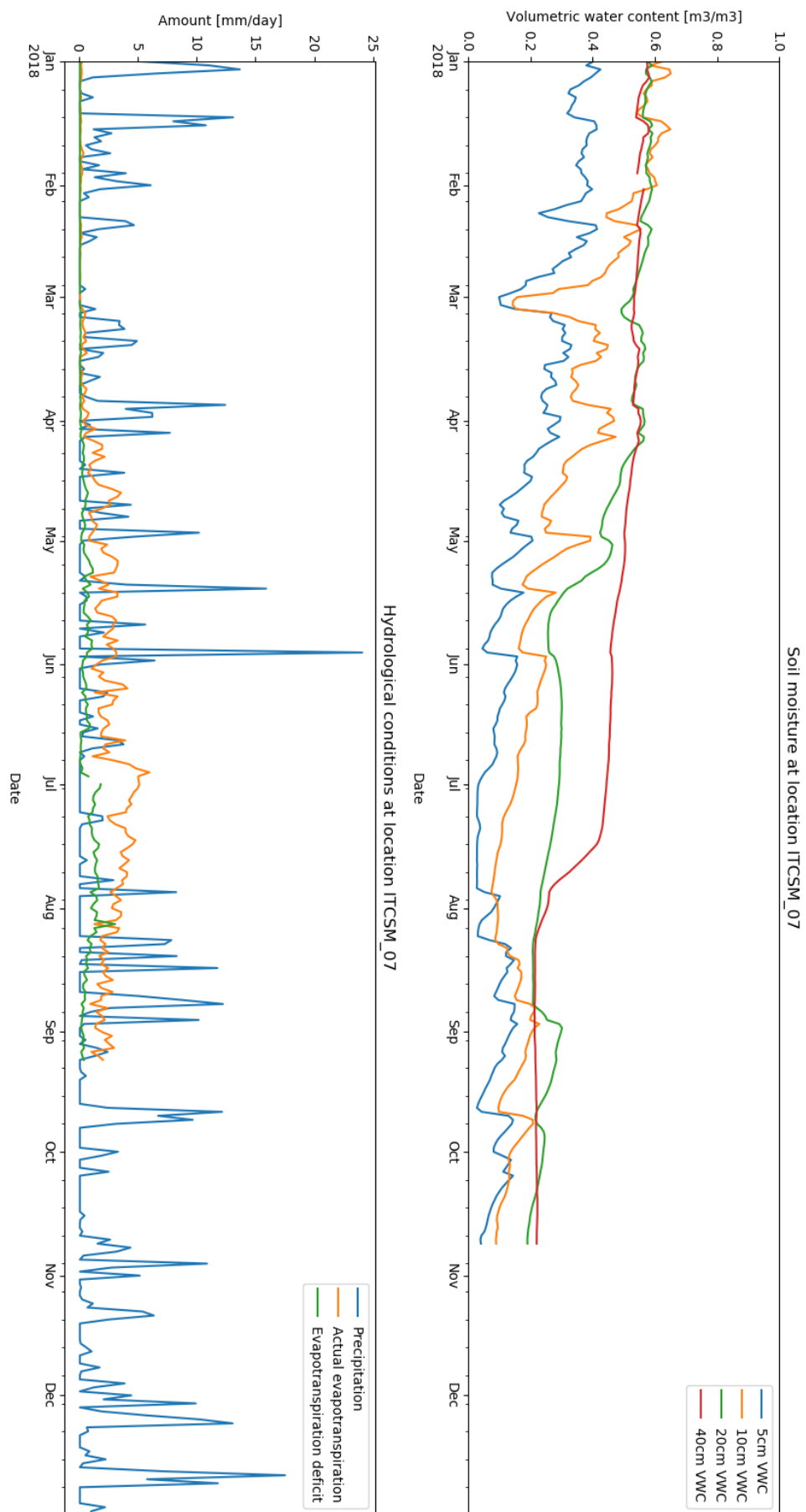


Figure 6: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_07.

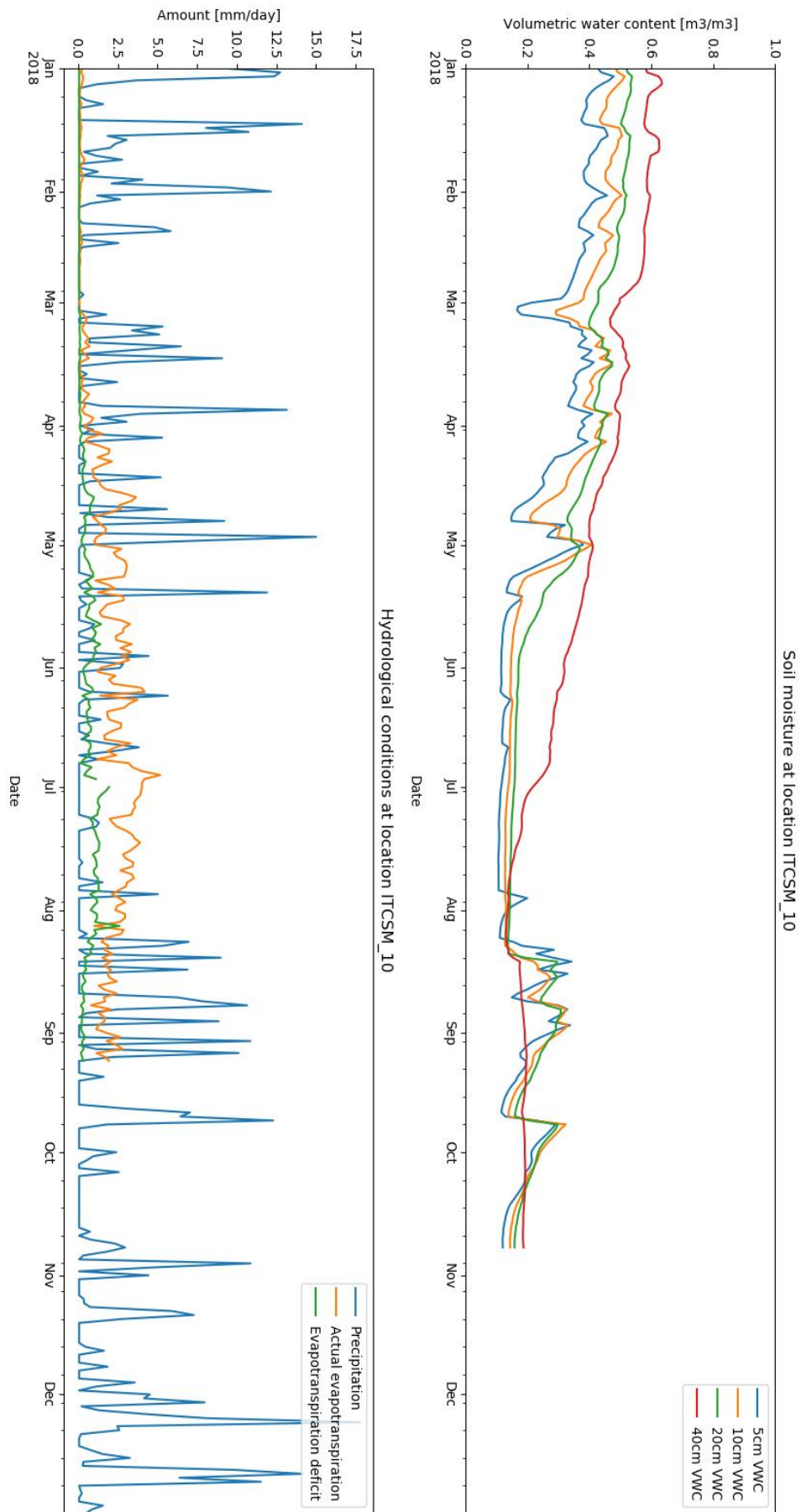


Figure 7: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_10.

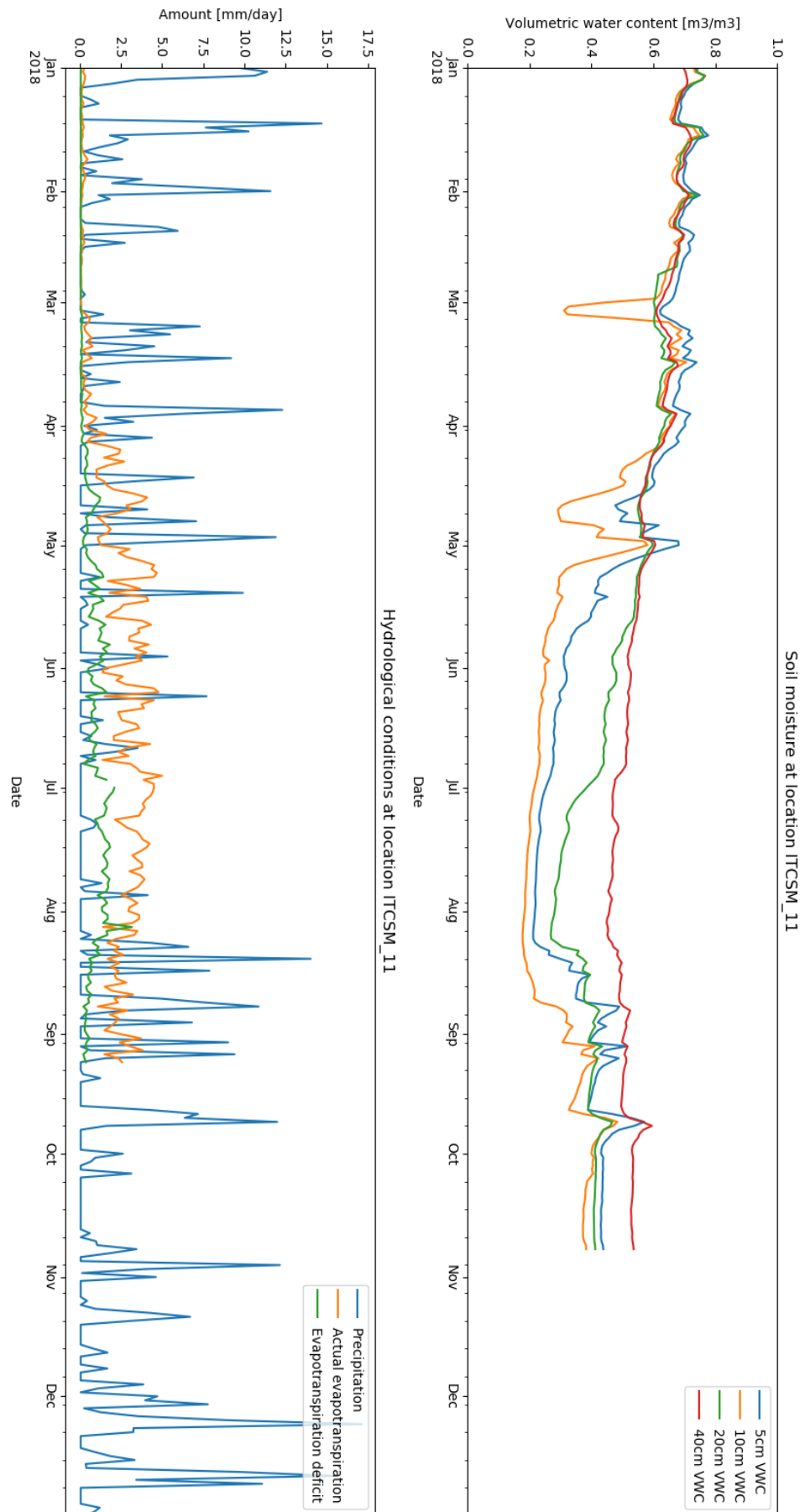


Figure 8: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_11.

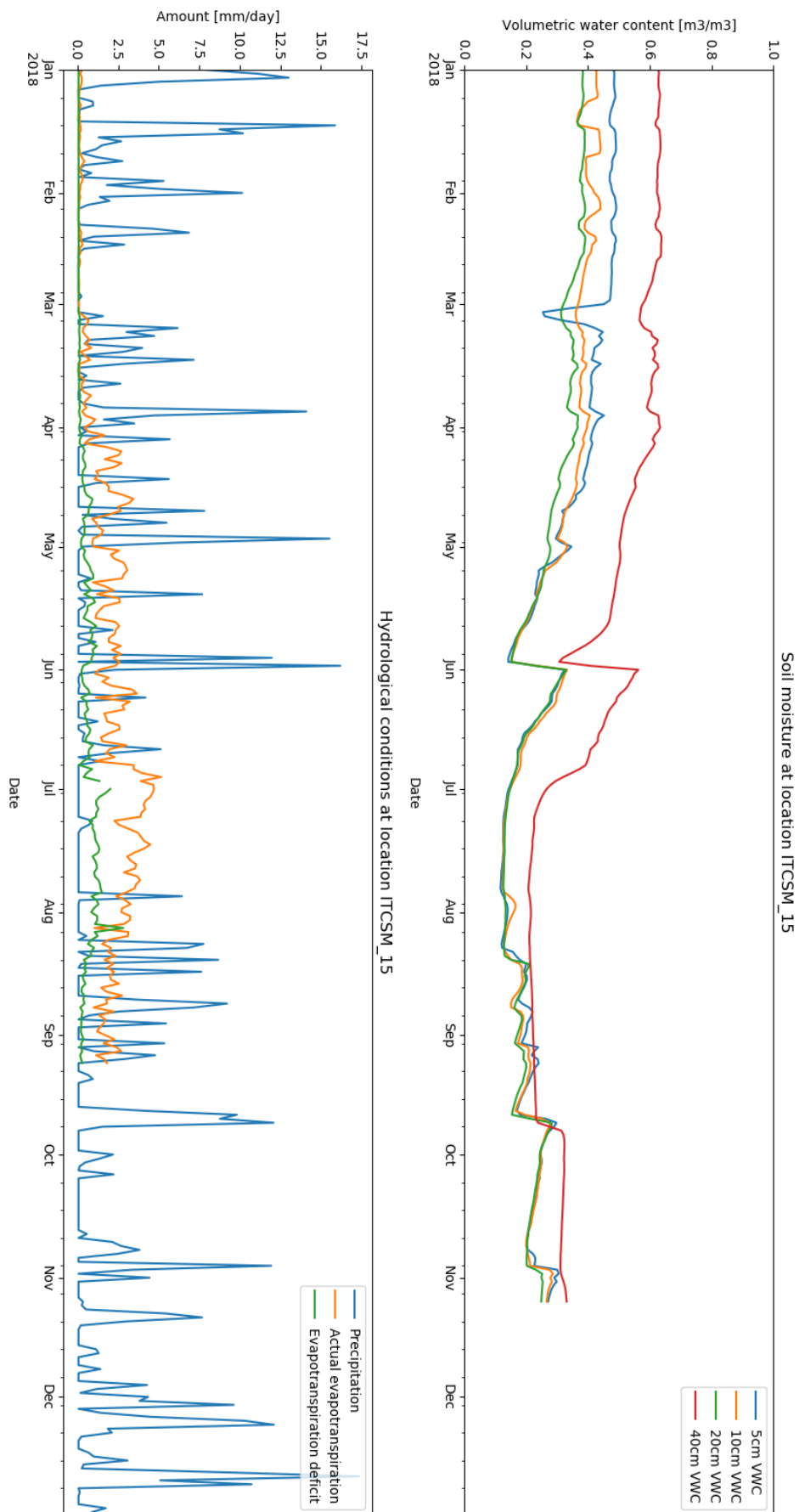


Figure 9: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_15.

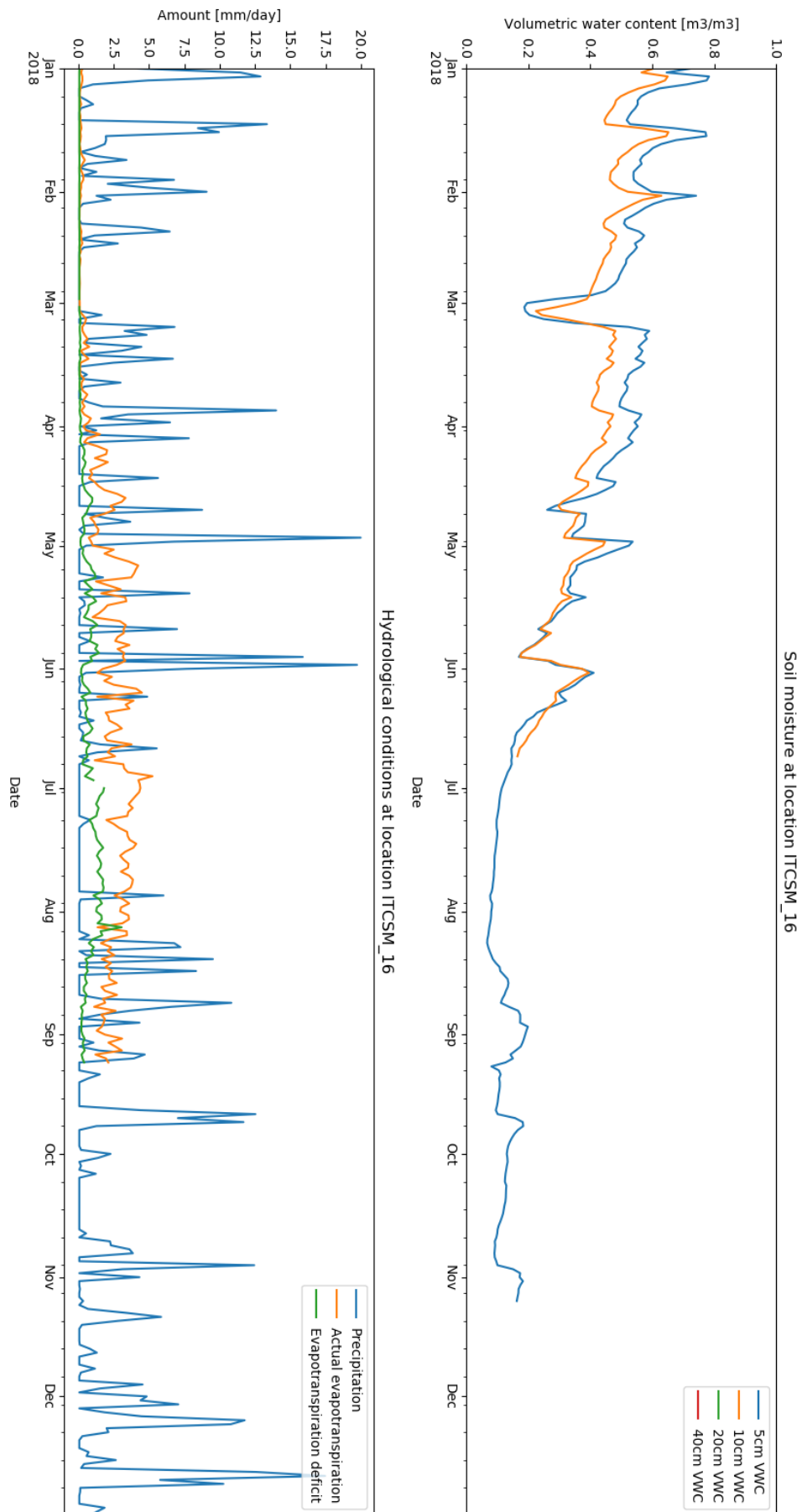


Figure 10: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_16.

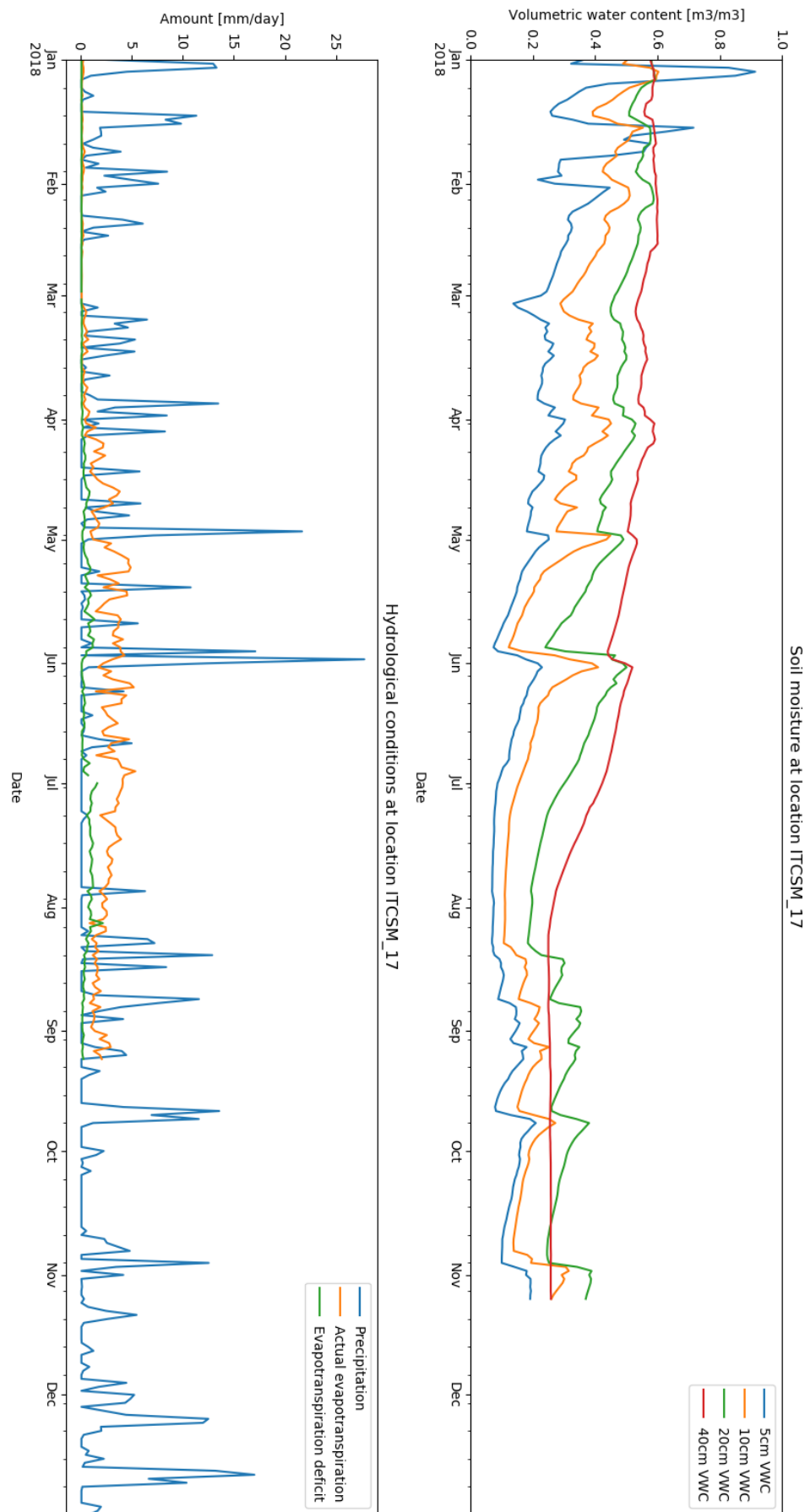


Figure 11: Overview of soil moisture, precipitation and evapotranspiration at location ITCSM_17.

1.1.2. Appendix A.2: Overview of groundwater data per soil moisture monitoring location

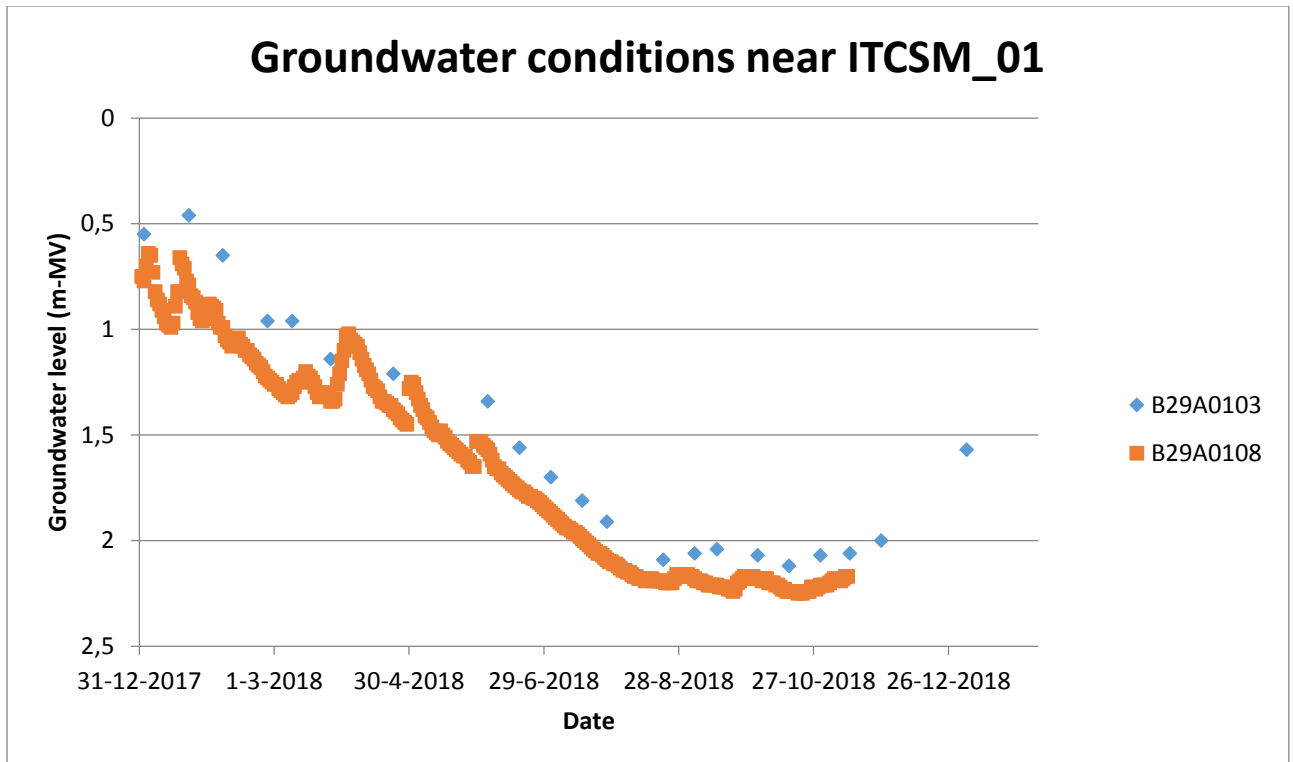


Figure 12: Groundwater conditions near ITCSM_01

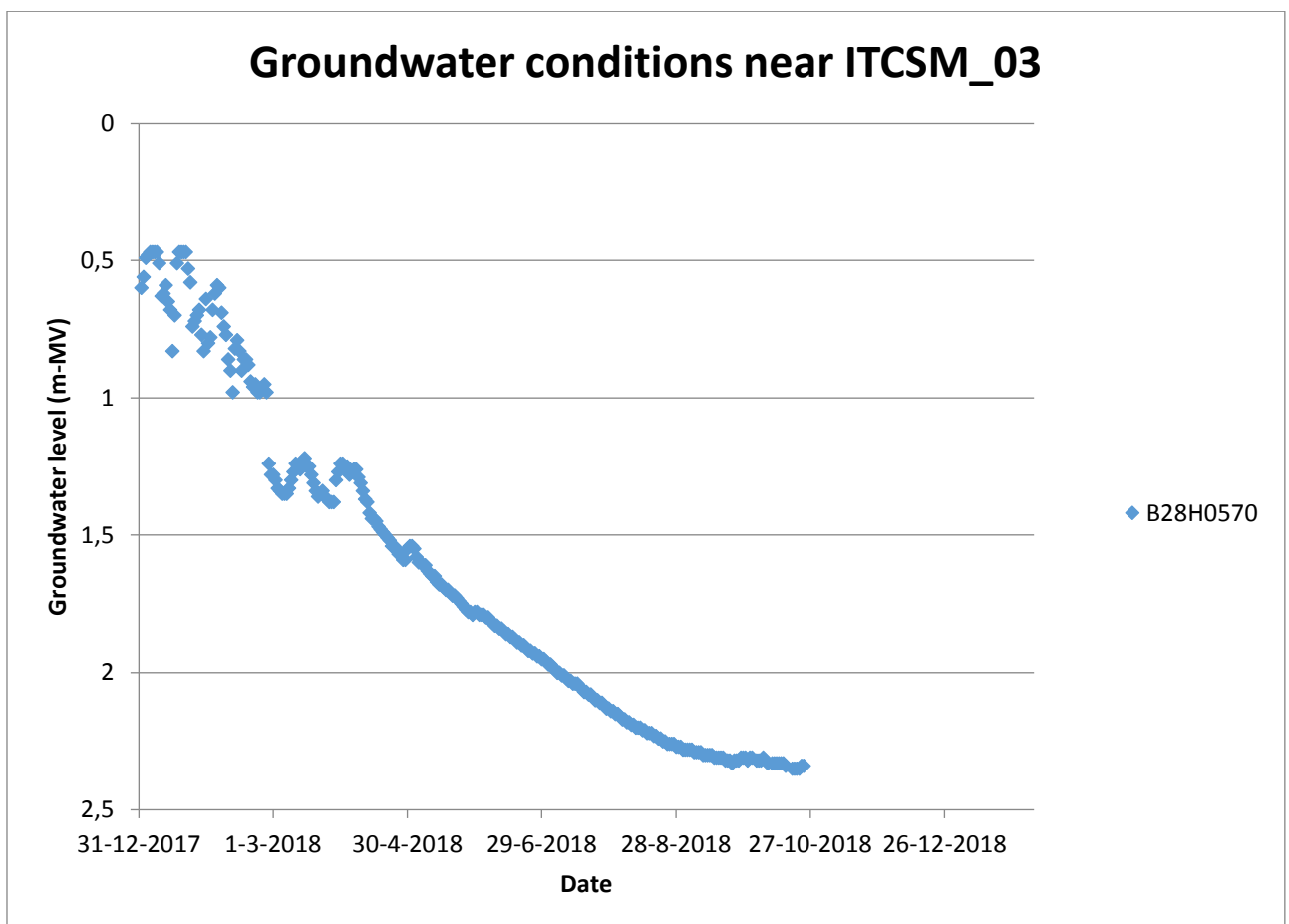


Figure 13: Groundwater conditions near ITCSM_03.

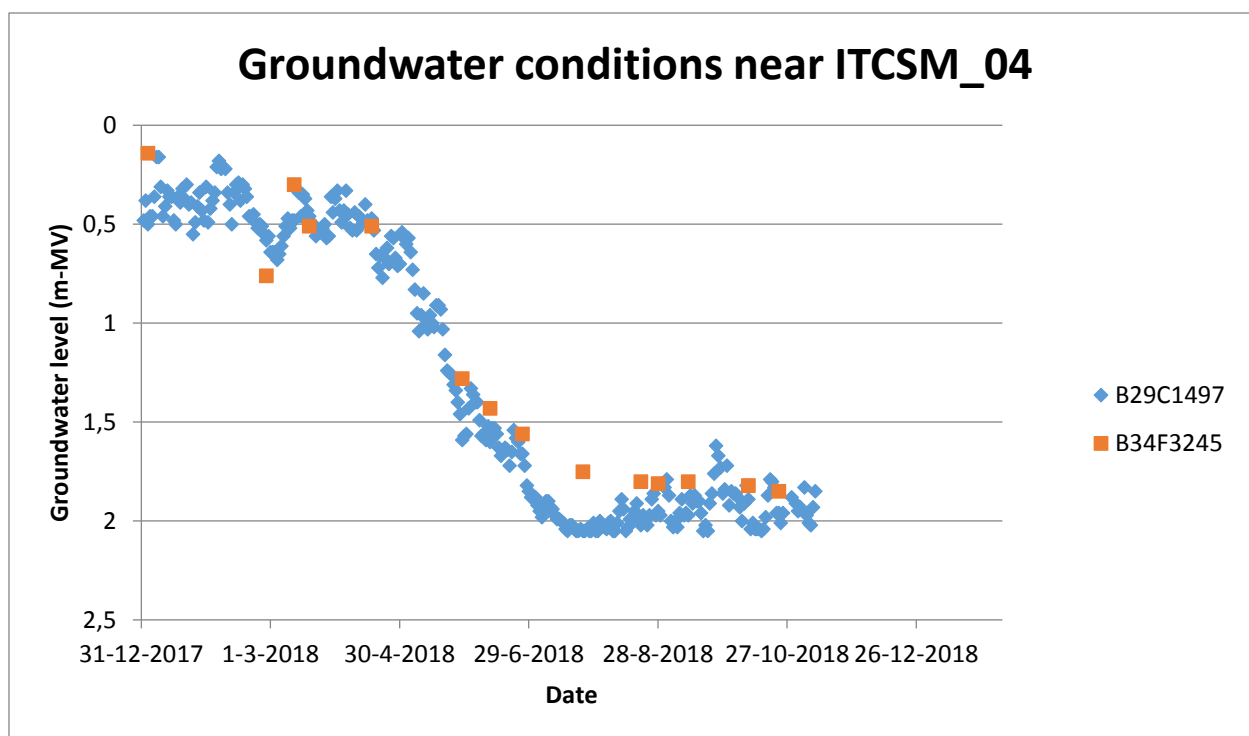


Figure 14: Groundwater conditions near ITCSM_04.

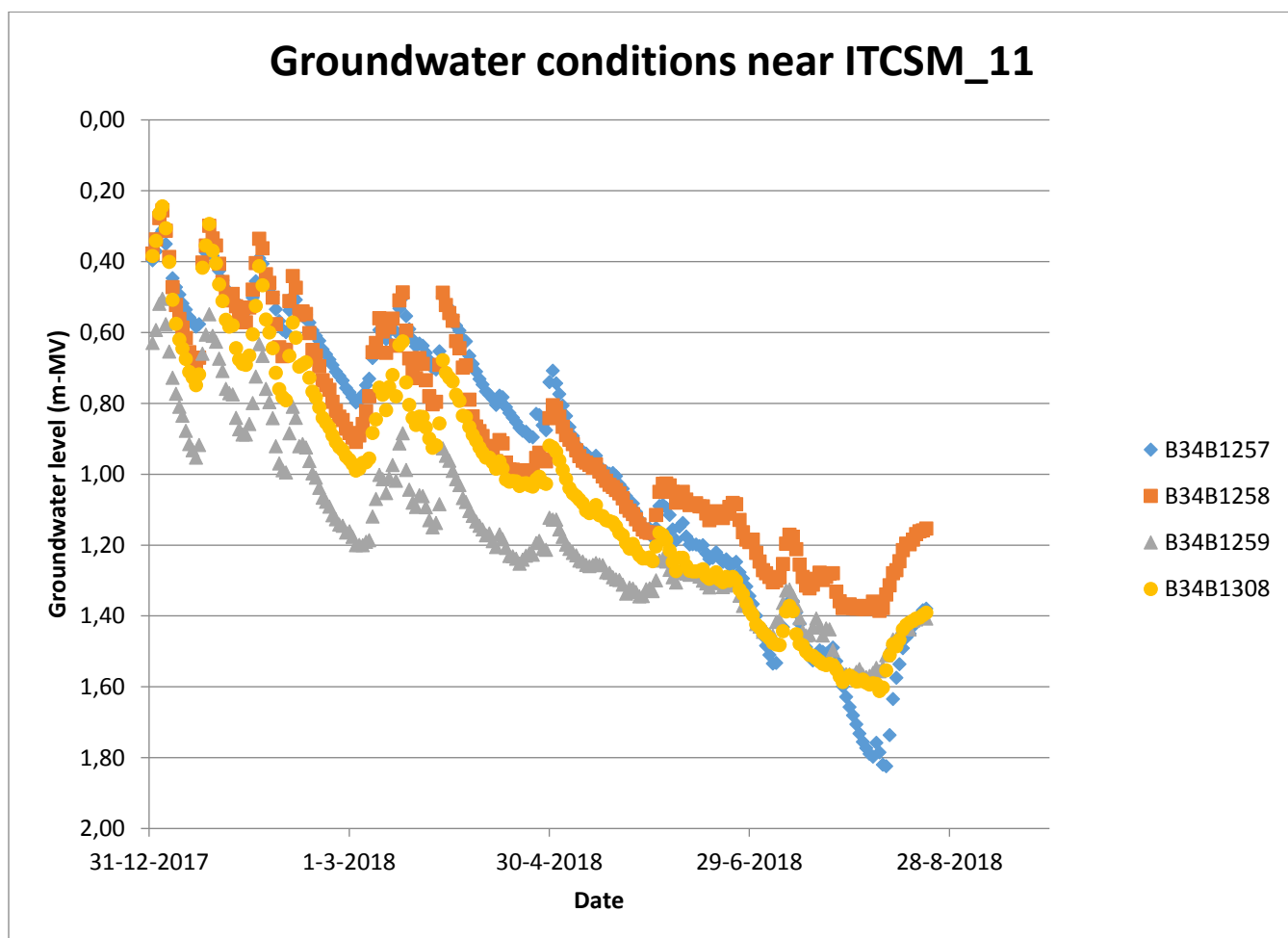


Figure 15: Groundwater conditions near ITCSM_11.

Groundwater conditions near ITCSM_16

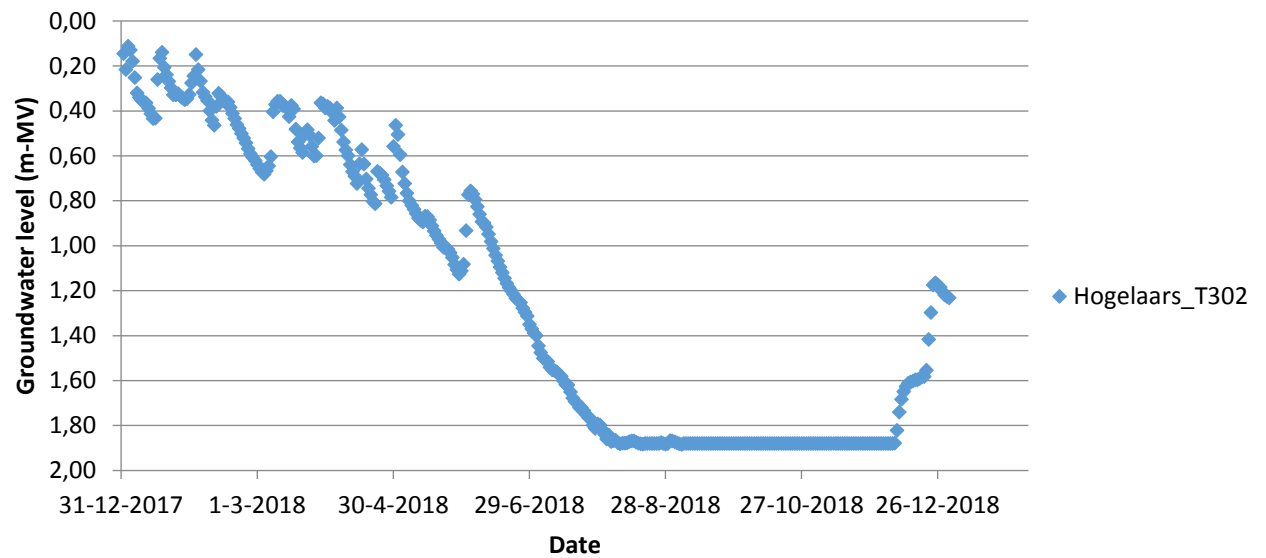


Figure 16: Groundwater conditions near ITCSM_16.

Groundwater conditions near ITCSM_17

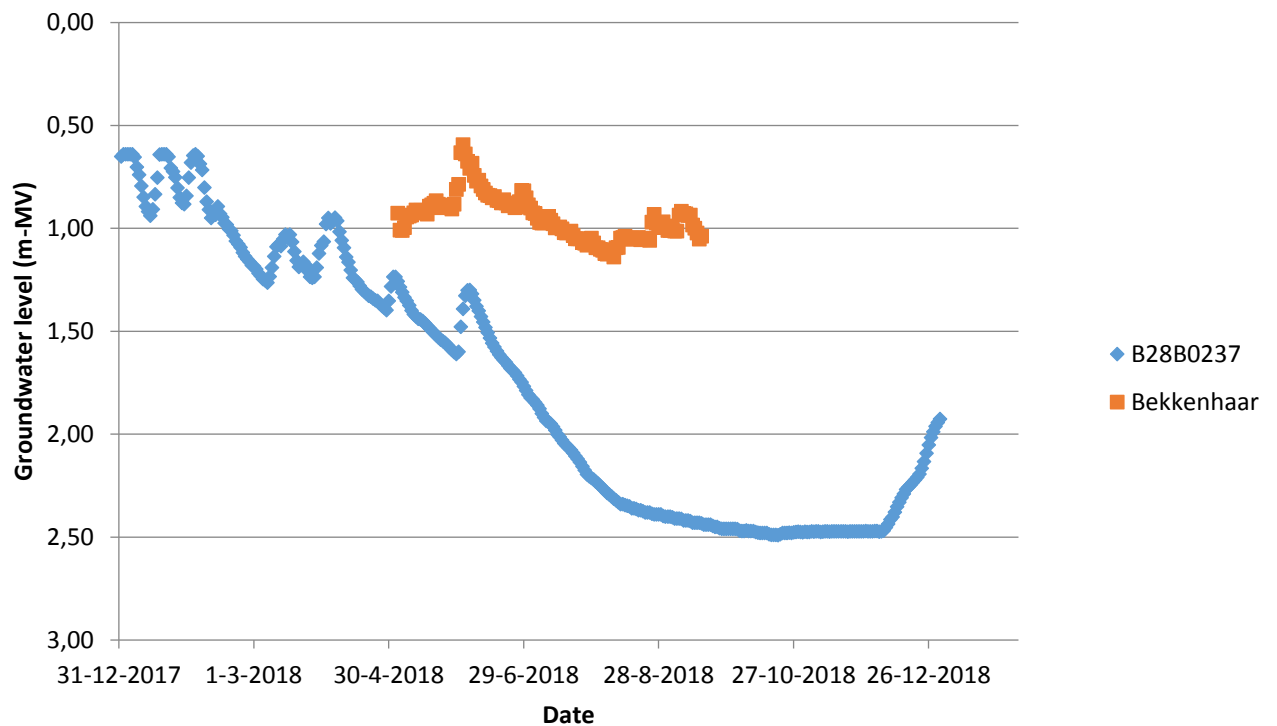


Figure 17 Groundwater conditions near ITCSM_17.

1.1.3. Appendix A.3: Comparison between different types of evapotranspiration

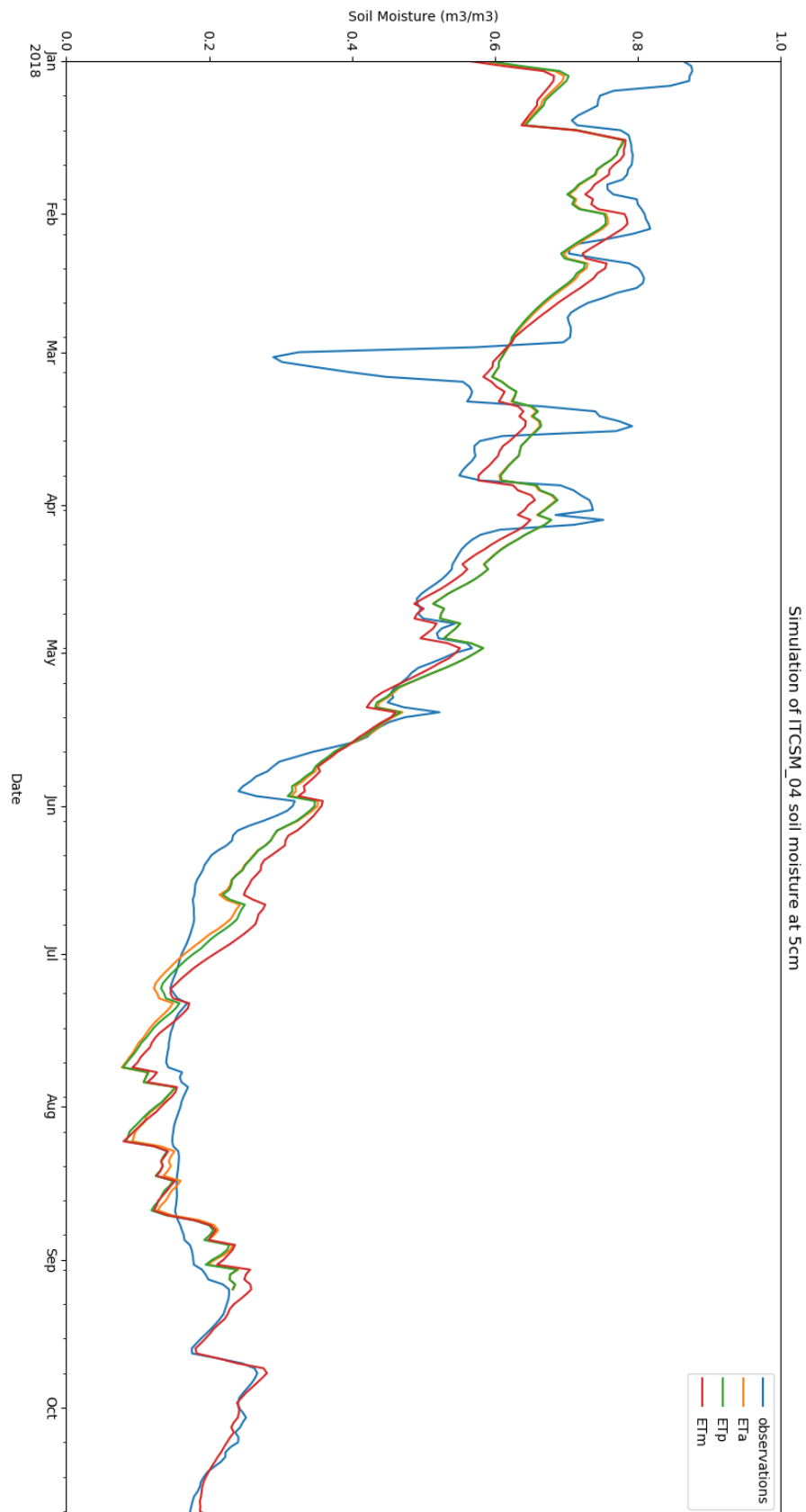


Figure 18: Analysis of soil moisture at location ITCSM_04 at 5 cm depth with different types of evapotranspiration.

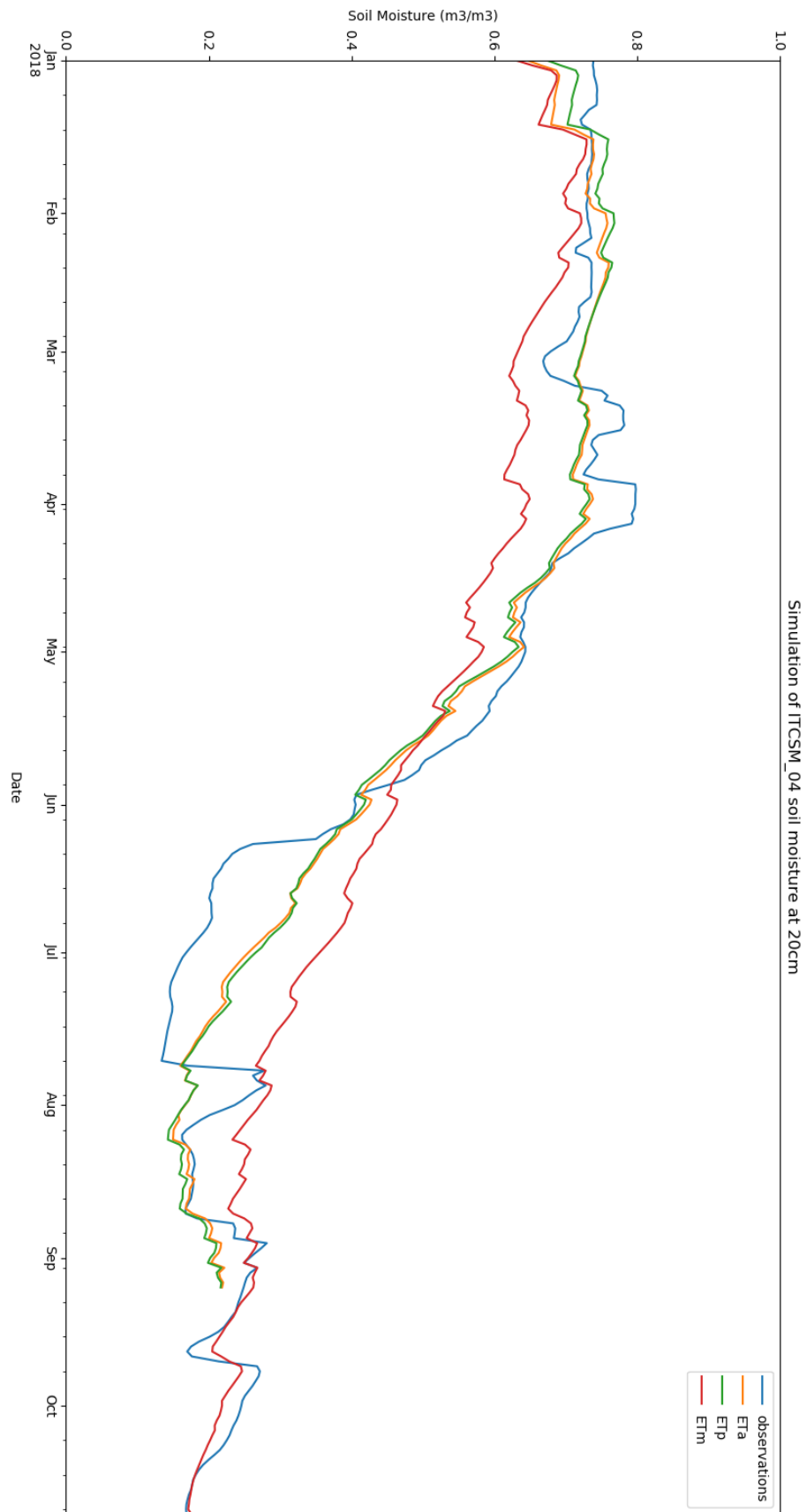


Figure 19: Analysis of soil moisture at location ITCSM_04 at 20 cm depth with different types of evapotranspiration.

1.1.4. Appendix A.4: Simulation of soil moisture with different data gaps

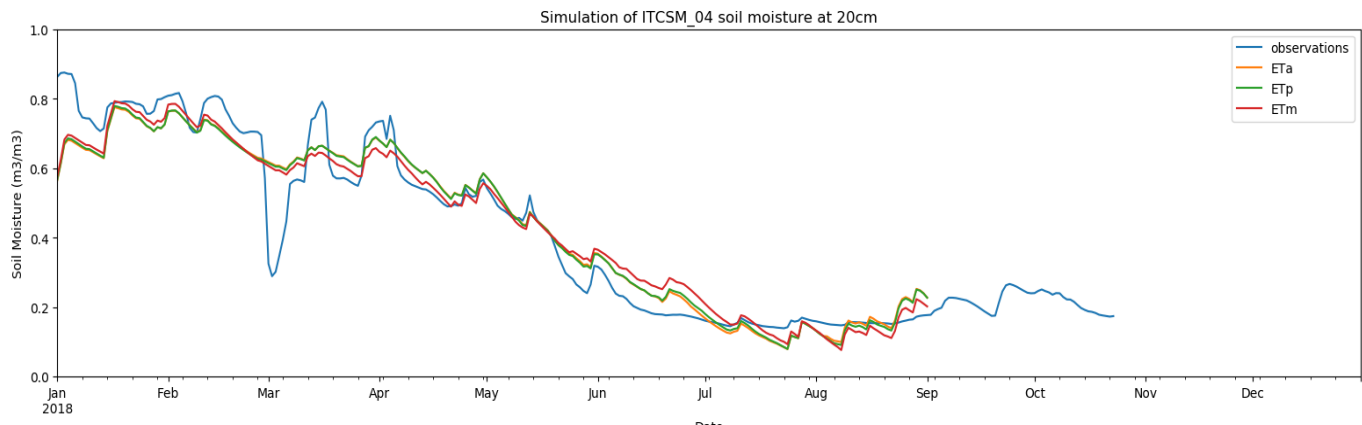


Figure 20: Analysis of soil moisture with precipitation and evapotranspiration without removing data.

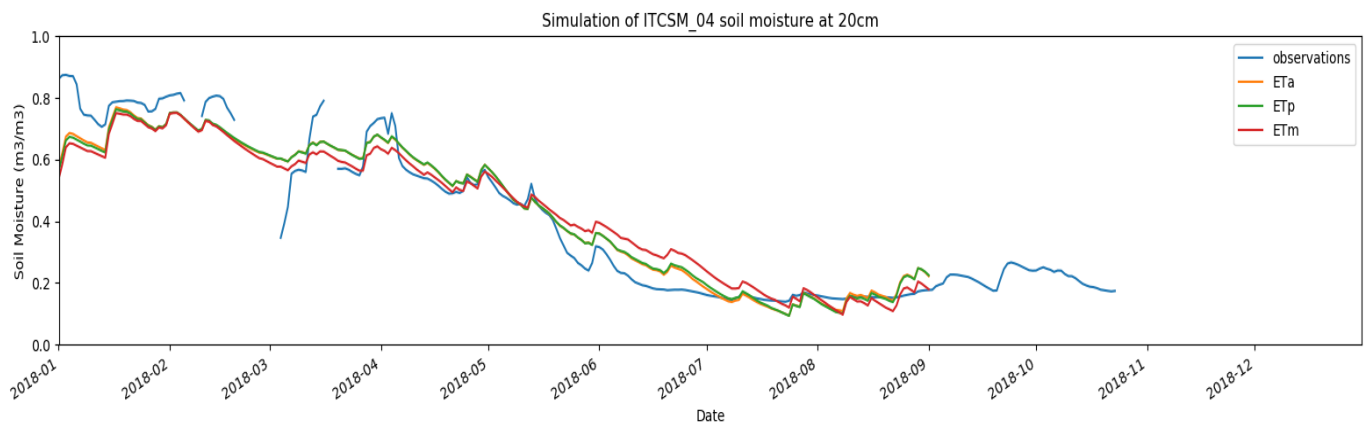


Figure 21: Analysis of soil moisture with precipitation evapotranspiration using days with an average temperature above 0°C.

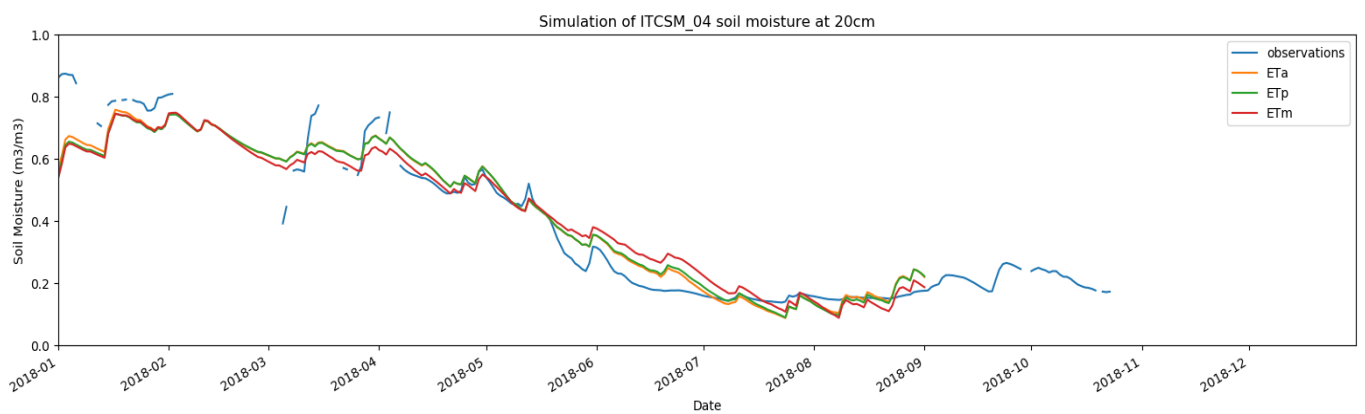


Figure 22: Analysis of soil moisture with precipitation evapotranspiration using days with a minimum temperature above 0°C.

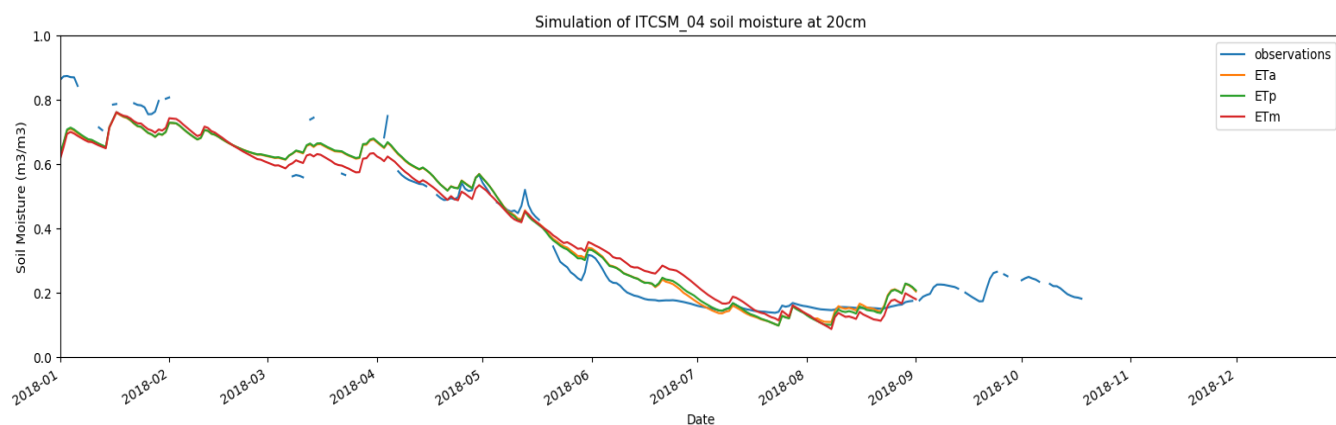


Figure 23: Analysis of soil moisture with precipitation evapotranspiration using days with a minimum temperature above 0°C, measured at 10 cm above ground level.

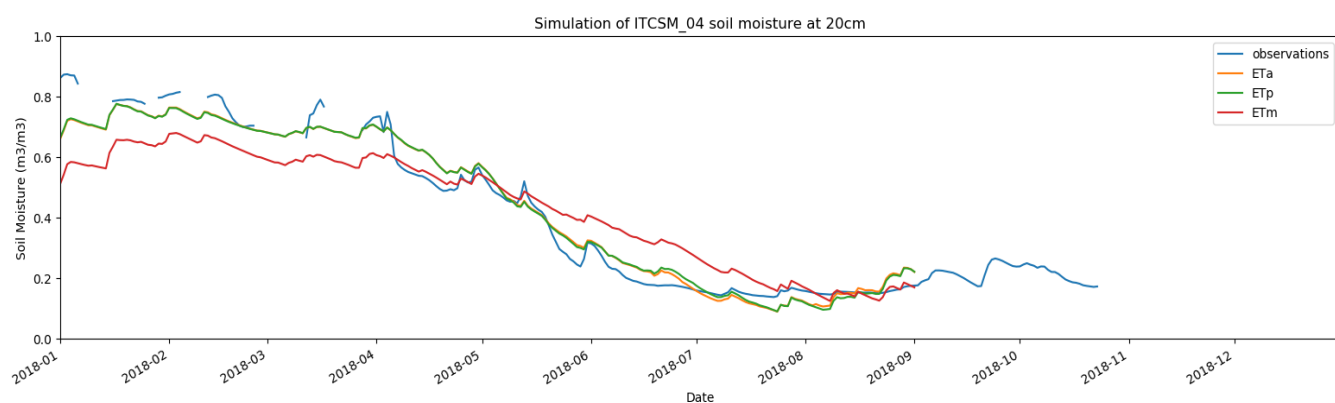


Figure 24: Analysis of soil moisture with precipitation evapotranspiration with manual removal of days that seem to have false measurements of soil moisture.

1.2. Appendix B) Output of the Pastas-package

1.2.1. Example analysis using different stresses for location ITCSM_01 at 5 cm depth.

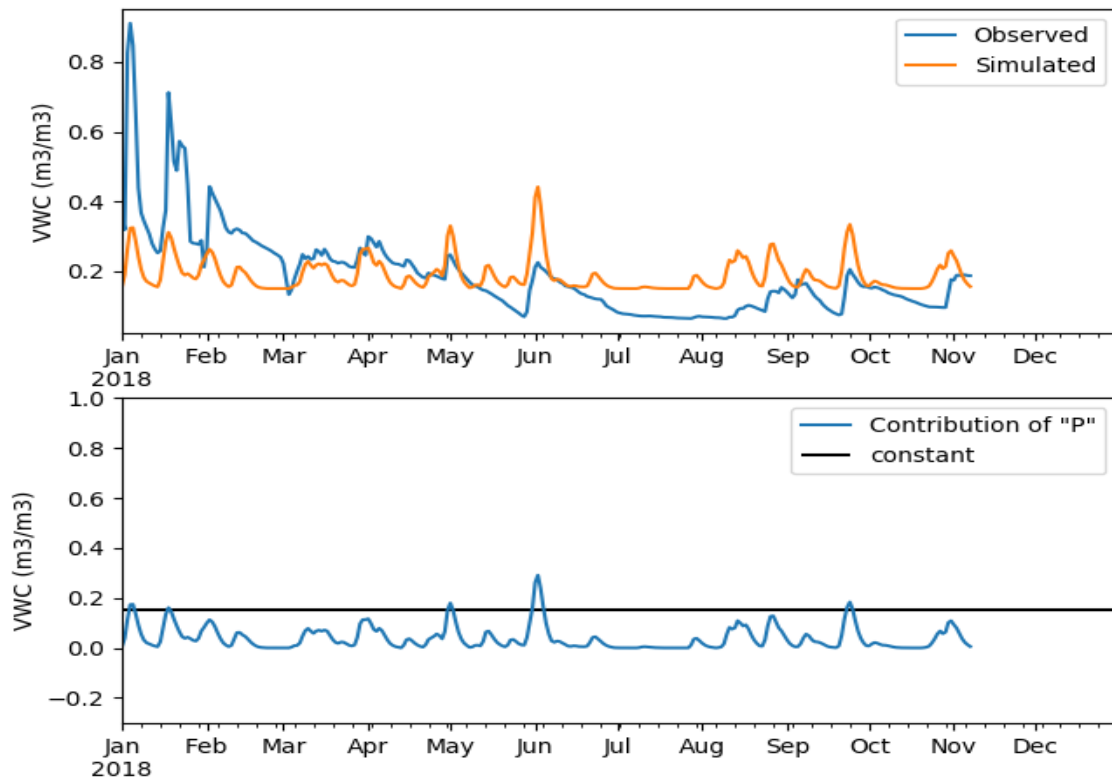


Figure 25: Simulation of soil moisture with precipitation as stress-model.

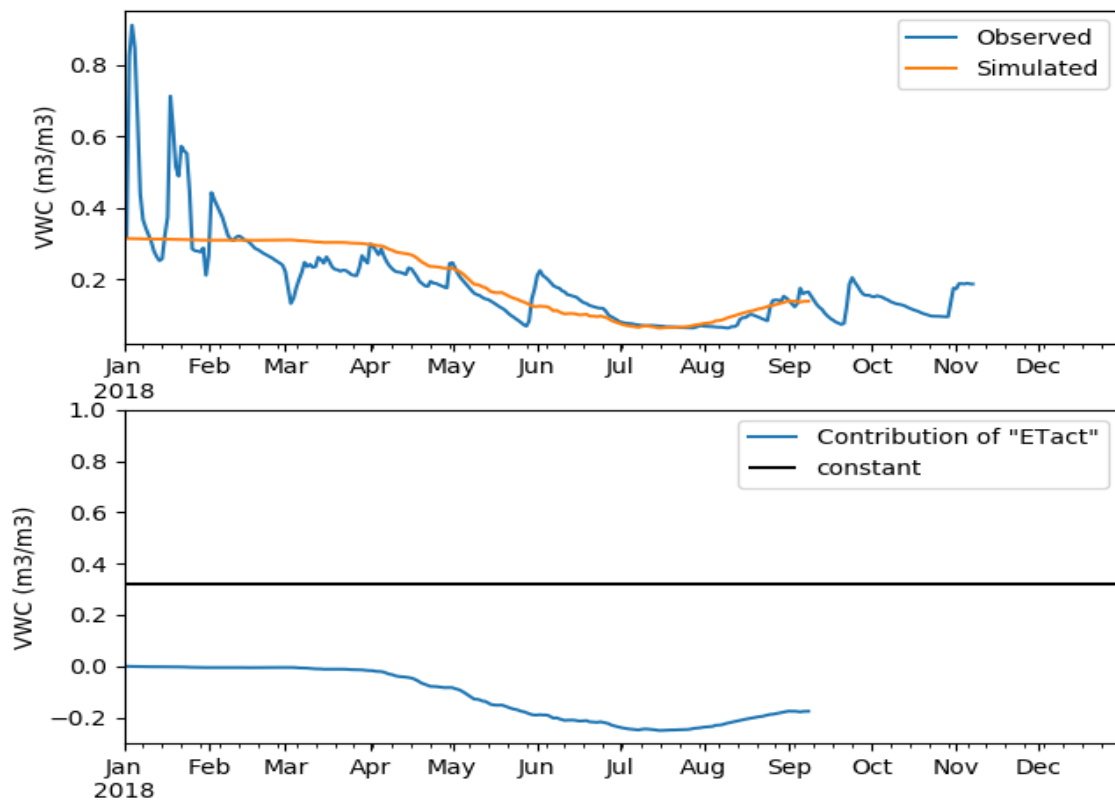


Figure 26: Simulation of soil moisture with actual evapotranspiration as stress-model.

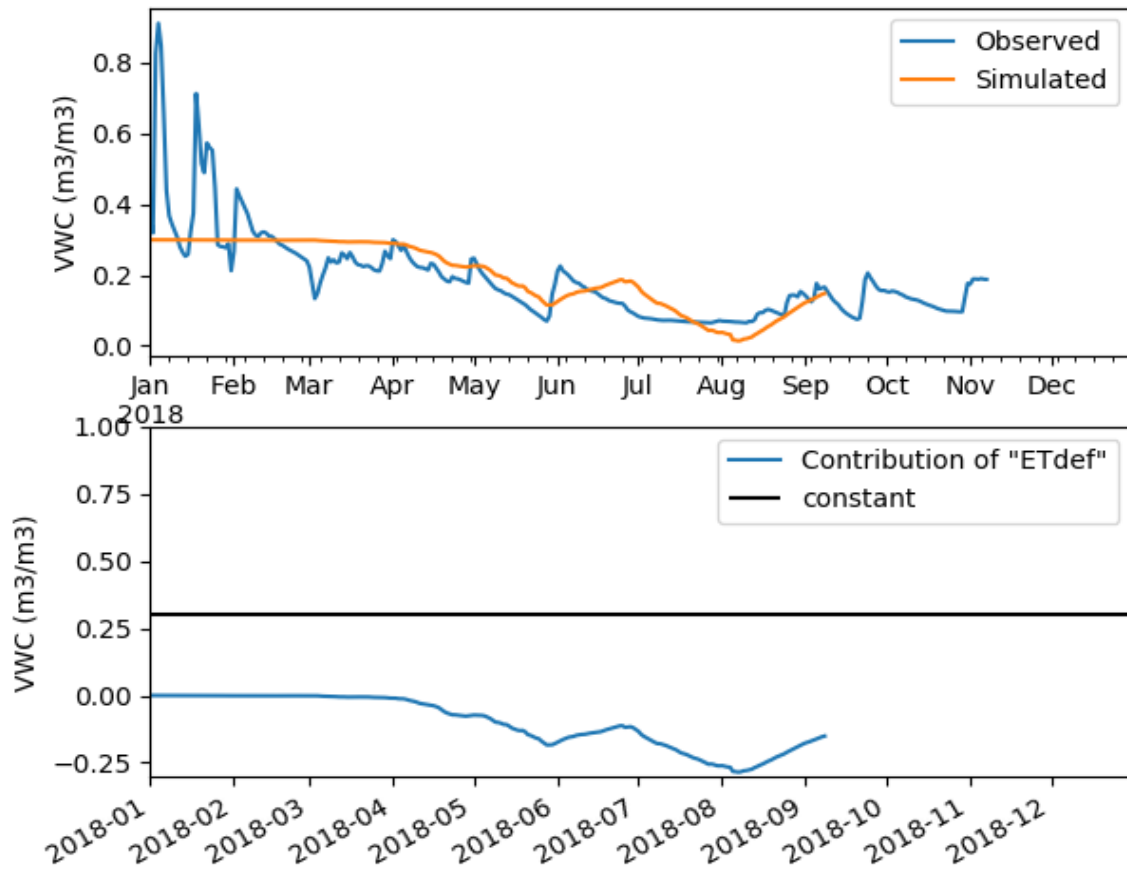


Figure 27: Simulation of soil moisture with evapotranspiration deficit as stress-model.

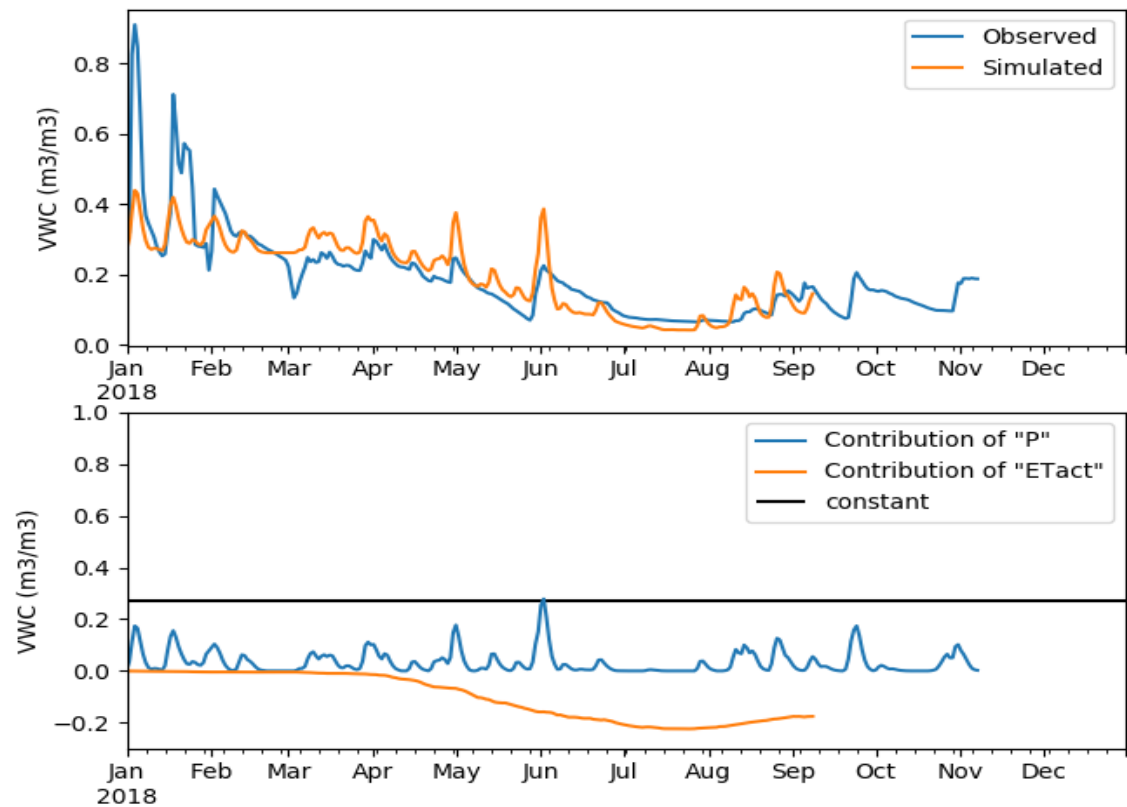


Figure 28: Simulation of soil moisture with precipitation and actual evapotranspiration as stress-models.

1.2.2. Appendix B.2: Impulse response parameters and percentage of explained variance for analysis using precipitation and actual evapotranspiration stresses.

Table 1:: Overall percentage variance explained and contribution per stress.

Station:	EVP total 5 cm (%)	EVP total 20 cm (%)	EVP 'P' 5 cm (%)	EVP 'P' 20 cm (%)	EVP 'ETa' 5cm (%)	EVP 'ETa' 20cm (%)
ITCSM_01	86.16	44.39	23.0	24.4	63.2	19.9
ITCSM_02	82.25	45.36	7.4	3.3	74.9	42.1
ITCSM_03	87.71	82.3	22.9	15.6	64.8	66.6
ITCSM_04	84.09	96.07	15.7	11.1	68.4	84.9
ITCSM_05	92.12	77.43	21.9	52.5	70.3	24.9
ITCSM_07	79.88	87.34	8.3	11.6	71.5	75.7
ITCSM_10	77.86	85.56	7.7	22.4	70.2	63.1
ITCSM_11	96.34	93.76	7.9	5.2	88.4	88.6
ITCSM_15	72.88	68.25	44.9	41.3	28.0	27.0
ITCSM_16	90.41	NaN	12.8	NaN	77.6	NaN
ITCSM_17	63.42	84.61	18.7	18.8	44.7	65.8
Average:	83.01	76.51	17.38	20.62	65.64	55.86

Table 1: Impulse response parameters precipitation.

Station:	A _p 5 cm	A _p 20 cm	n _p 5 cm	n _p 20 cm	a _p 5 cm	a _p 20 cm
ITCSM_01	0.02	0.01	2.21	2.57	2.27	1.47
ITCSM_02	0.01	0.01	5.06	6.31	0.44	0.29
ITCSM_03	0.04	0.02	2.32	2.57	2.08	1.67
ITCSM_04	0.02	0.02	2.37	2.08	1.78	3.41
ITCSM_05	0.03	0.17	2	1.3	4.07	41.57
ITCSM_07	0.01	0.01	5.67	2.24	0.33	3.53
ITCSM_10	0.01	0.02	10	2.14	0.19	3.96
ITCSM_11	0.01	0.01	4.22	6.71	0.48	0.29
ITCSM_15	0.05	0.03	1.63	1.8	7.93	5.1
ITCSM_16	0.02	NaN	4.93	NaN	0.45	NaN
ITCSM_17	0.02	0.01	3.48	2.7	0.79	1.46
Average:	0.022	0.031	3.99	3.042	1.891818	6.275

Table 2: Impulse response paramters for actual evapotranspiration

Station:	A _{ETa} 5 cm	A _{ETa} 20 cm	a _{ETa} 5 cm	a _{ETa} 20 cm
ITCSM_01	-0.07	-0.06	32.91	22.59
ITCSM_02	-0.16	-0.35	60.63	240.16
ITCSM_03	-0.22	-0.21	53.16	112.95
ITCSM_04	-0.31	-0.25	244.41	111.36
ITCSM_05	-0.3	-0.19	55.53	60.77
ITCSM_07	0.08	-0.12	17.99	73.71
ITCSM_10	-0.09	-0.12	13.9	67.71
ITCSM_11	-0.14	-0.1	19.98	38.87
ITCSM_15	-0.33	-0.26	672.98	937.21
ITCSM_16	-0.17	NaN	54.39	NaN
ITCSM_17	-0.08	-0.1	53.95	84.6
Average:	-0.163	-0.176	116.348	174.99

Table 4: Contant. noise parameter and number of observations.

Station:	Constant 5 cm	Constant 20 cm	Noise 5 cm	Noise 20 cm	N _{obs} 5 cm	N _{obs} 20 cm
ITCSM_01	0.3	0.33	17.36	25.71	219	125
ITCSM_02	0.48	0.51	25.59	359.87	297	297
ITCSM_03	0.47	0.4	14.75	15.18	241	239
ITCSM_04	0.58	0.72	125.23	36.14	297	297
ITCSM_05	0.81	0.55	7.83	8.95	172	172
ITCSM_07	0.27	0.49	15.13	99.98	297	297
ITCSM_10	0.35	0.39	14.31	37.56	298	298
ITCSM_11	0.7	0.66	8.65	25.62	298	298
ITCSM_15	0.29	0.25	26.91	251.41	311	311
ITCSM_16	0.5	NaN	9.06	NaN	311	0
ITCSM_17	0.27	0.47	6.41	18.68	311	311
Average:	0.46	0.48	24.66	87.91	277.45	240.45

- 1.3. Appendix C) Overview of explained variance percentage and impulse response parameters for each combination of stresses analysed
- 1.3.1. Comparison of EVP for all analysed combinations of stresses per location and per depth.

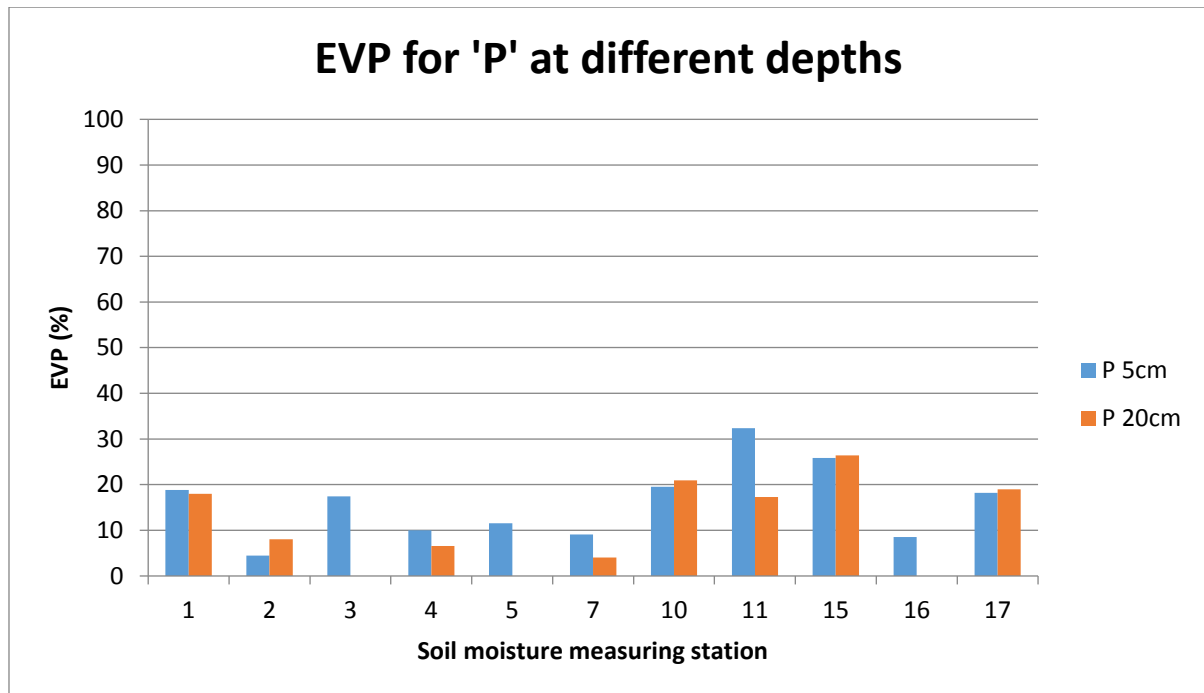


Figure 29: Comparison of EVP for precipitation.

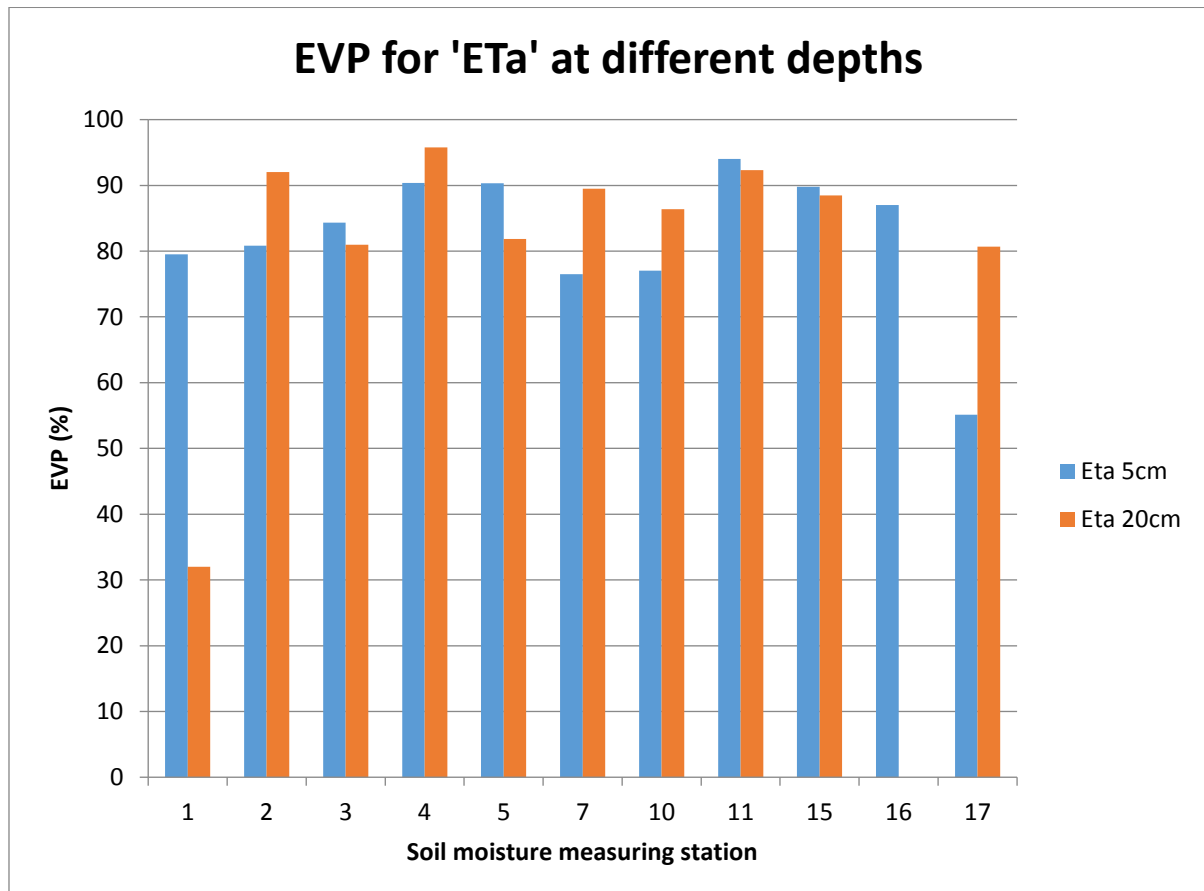


Figure 30: Comparison of EVP for actual evapotranspiration.

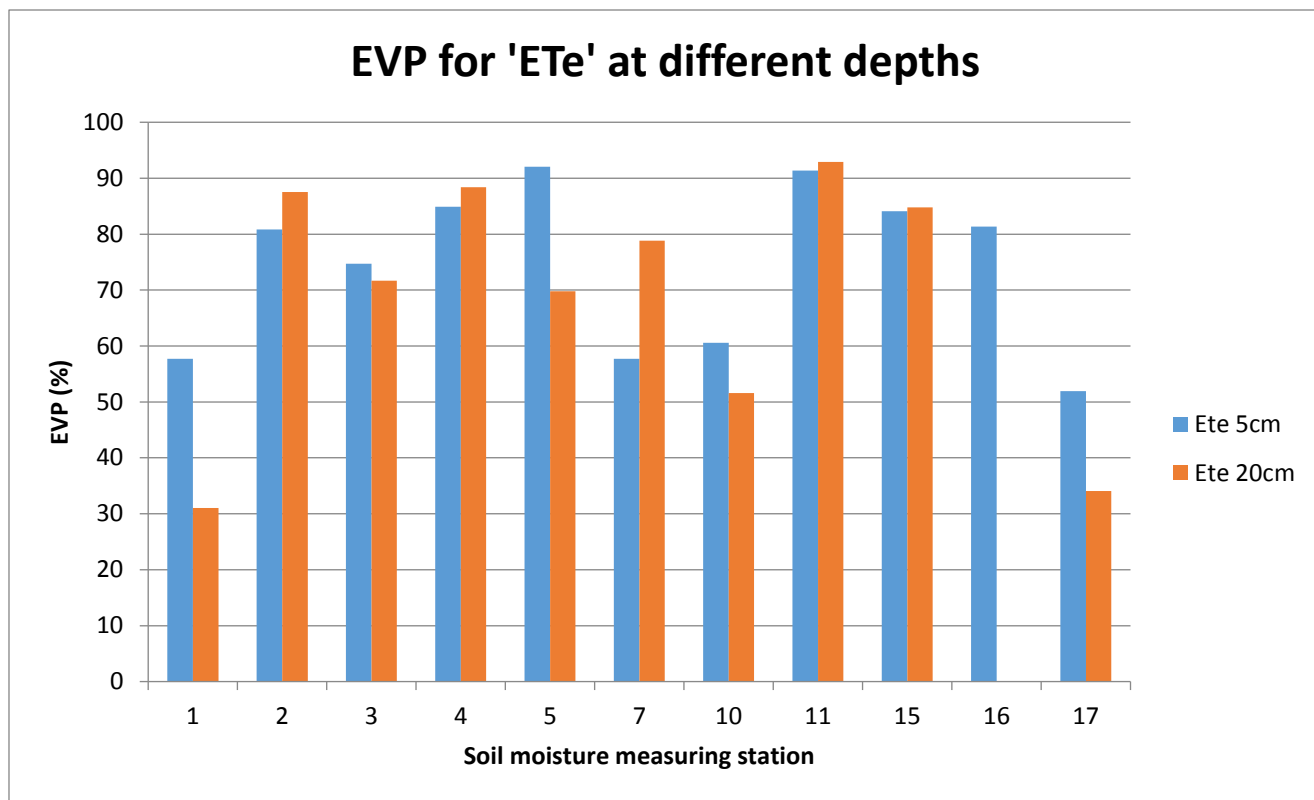


Figure 31: Comparison of EVP for evapotranspiration deficit.

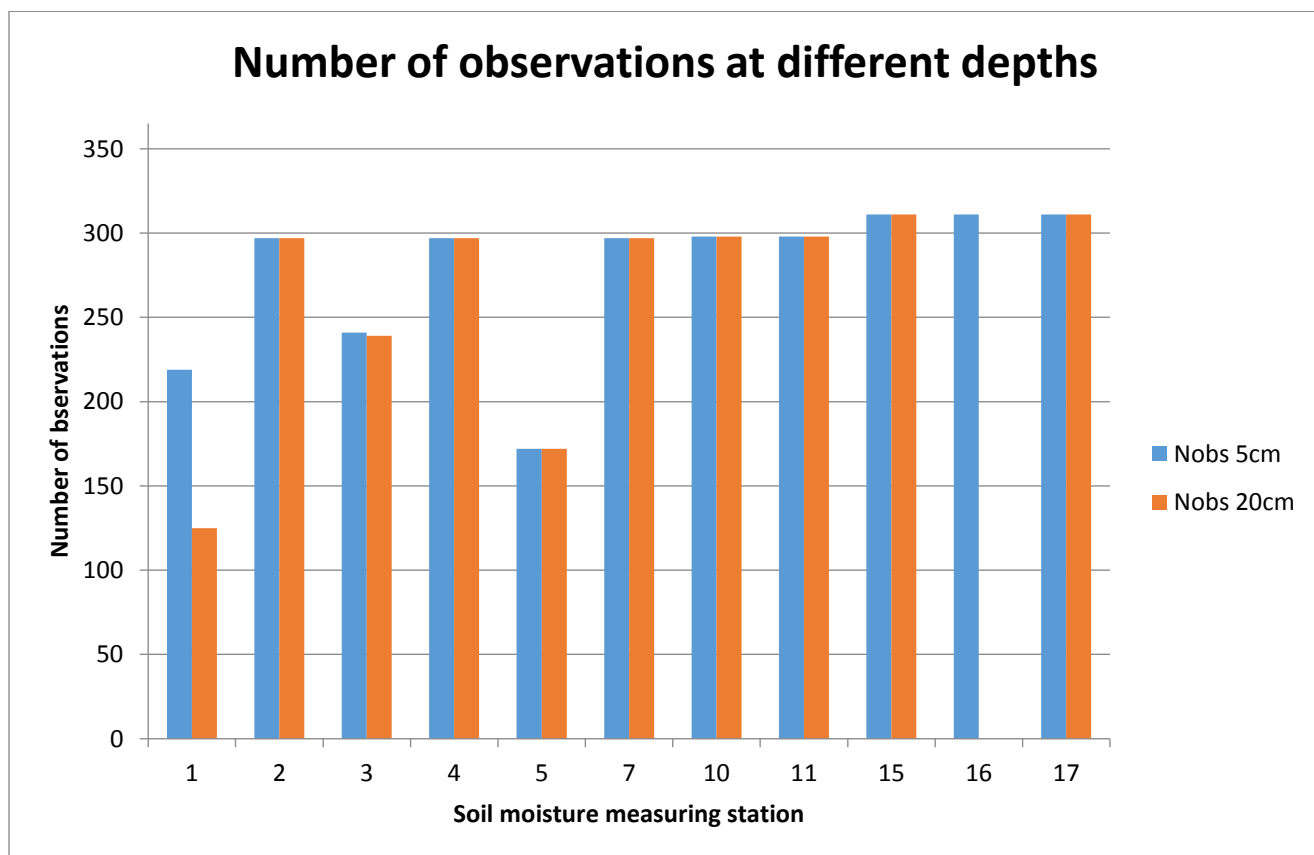


Figure 42: Comparison of number of observations.

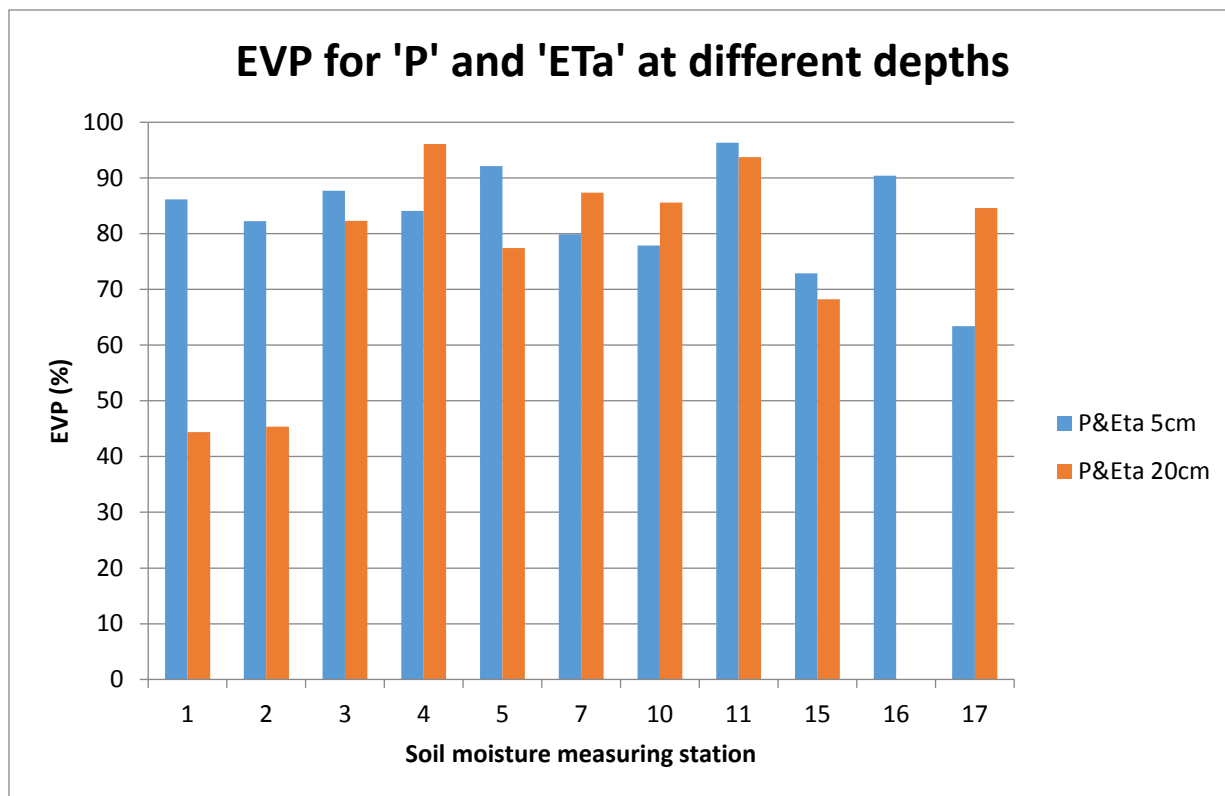


Figure 53: Comparison of EVP for precipitation and actual evapotranspiration

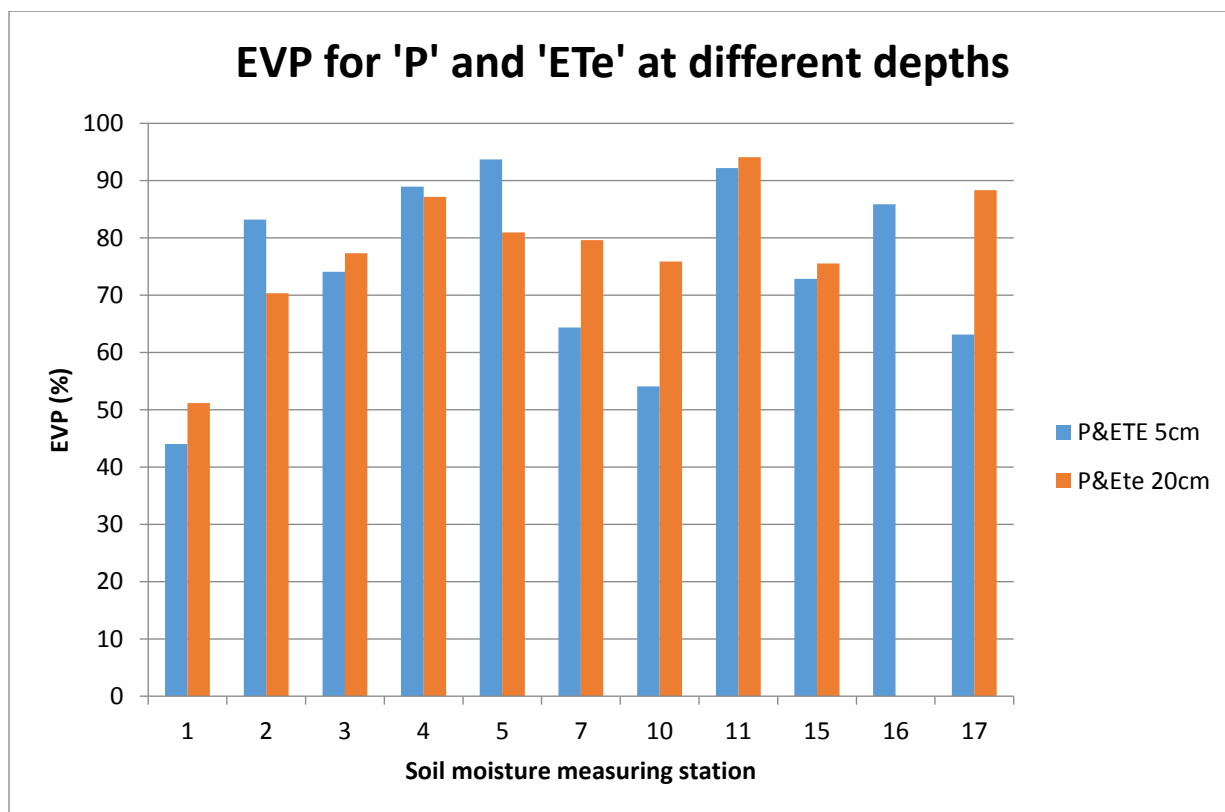


Figure 64: Comparison of EVP for precipitation and evapotranspiration deficit.

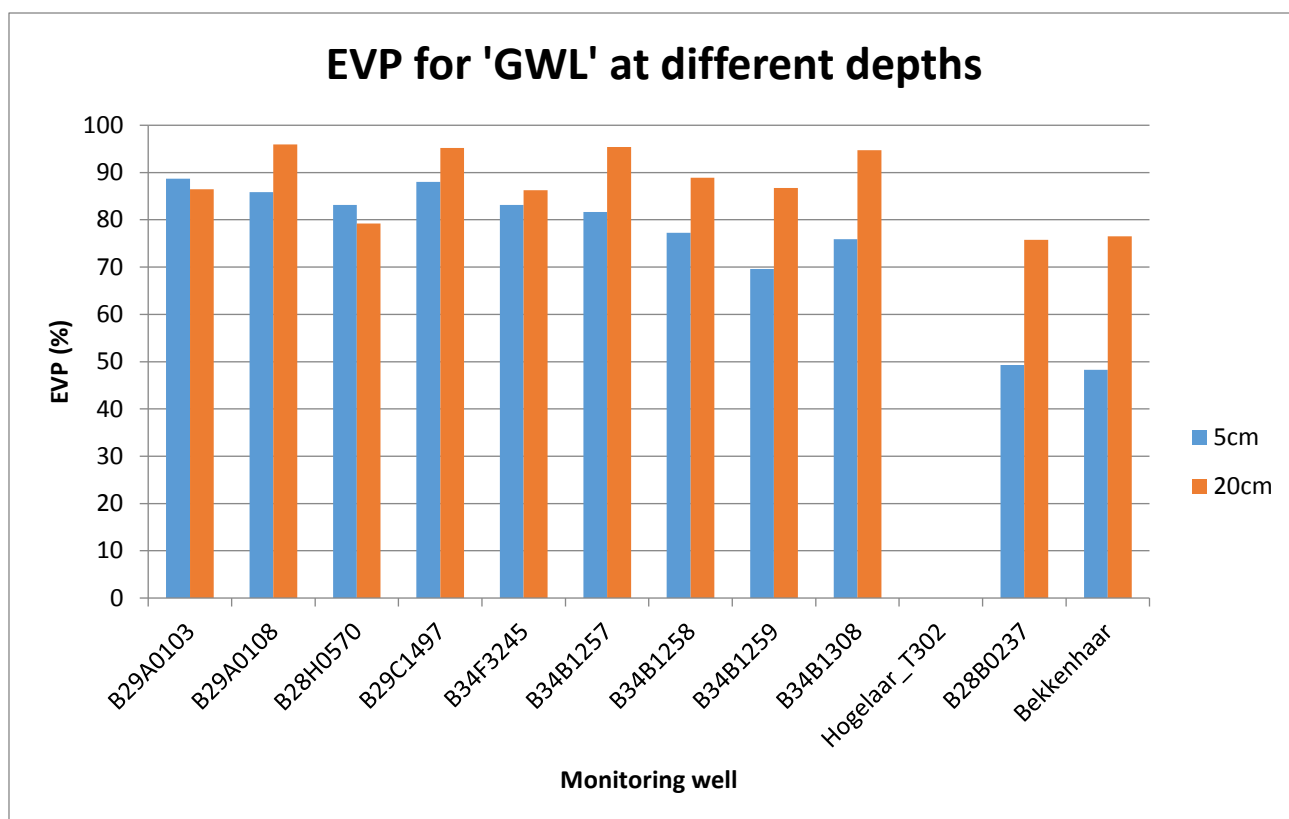


Figure 75: Comparison of EVP for groundwater levels.

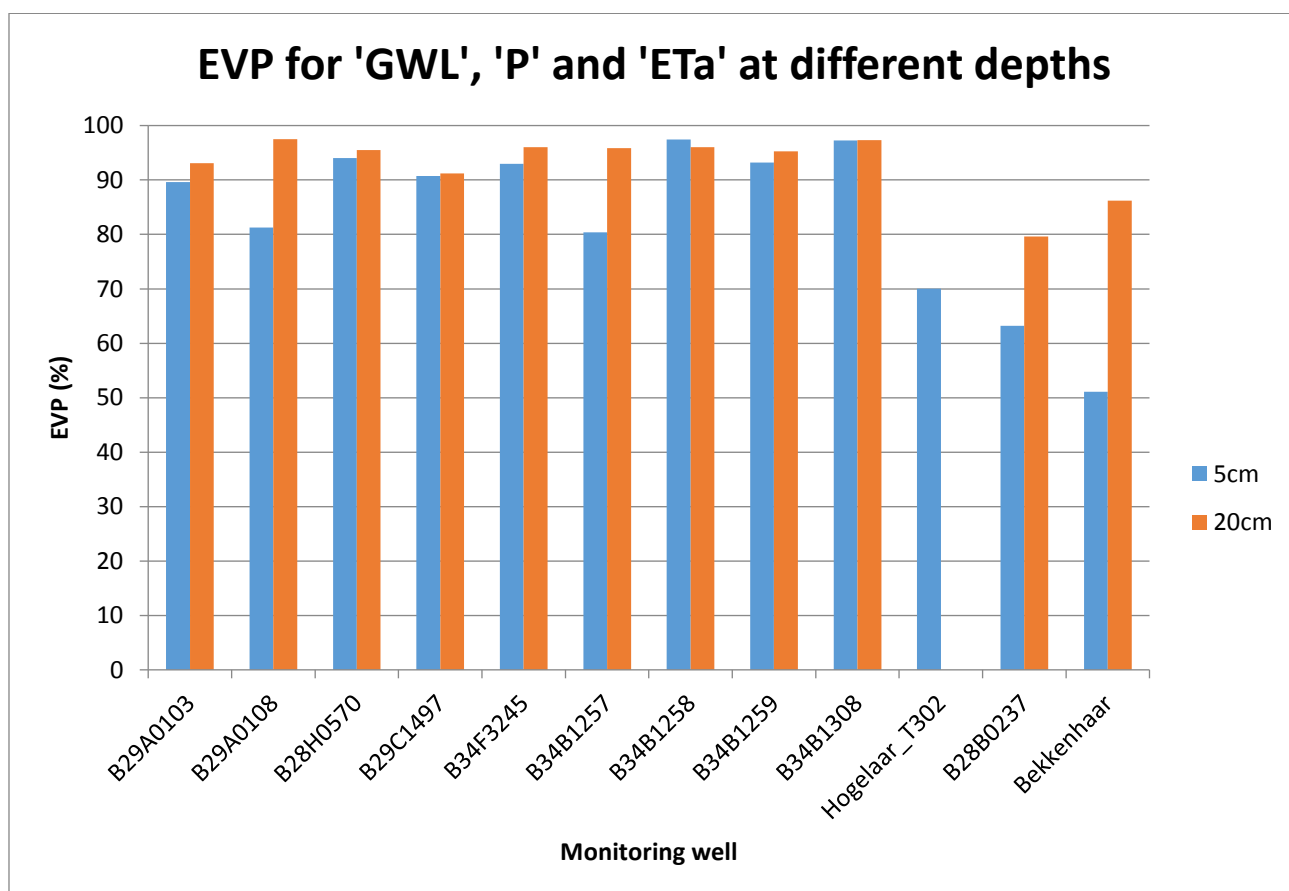


Figure 368: Comparison of EVP for groundwater levels, precipitation and actual evapotranspiration.

1.3.2. Overview of impulse-response parameters per stress-model per location

Table 5: Overview of impulse-response parameters for precipitation for 5cm depth.

Location	EVP (%)	RMSE	P _A	P _n	P _a	Constant	Noise
ITCSM_01	18,81	0,11	0,02	2,24	2,26	0,21	72,87
ITCSM_02	4,43	0,18	0,01	5,28	0,42	0,27	92,67
ITCSM_03	17,44	0,17	0,04	2,33	2,08	0,22	72,23
ITCSM_04	10,03	0,23	0,03	2,05	2,67	0,36	81,52
ITCSM_05	11,53	0,22	0,03	1,98	3,94	0,63	219,88
ITCSM_07	9,06	0,11	0,01	4,35	0,47	0,15	50,98
ITCSM_10	19,52	0,1	0,01	3,68	0,63	0,21	36,13
ITCSM_11	32,34	0,15	0,23	1,26	30,09	0,19	33,18
ITCSM_15	25,82	0,11	0,05	1,58	7,55	0,22	50,35
ITCSM_16	8,51	0,19	0,01	5,14	0,42	0,27	57,17
ITCSM_17	18,2	0,11	0,03	2,88	1,1	0,15	14,03

Table 6: Overview of impulse-response parameters for precipitation for 20cm depth.

Location	EVP (%)	RMSE	P _A	P _n	P _a	Constant	Noise
ITCSM_01	18,02	0,08	0,01	2,59	1,43	0,31	39,06
ITCSM_02	8,07	0,11	0,01	6,05	0,32	0,3	98
ITCSM_03	0	0,17	0,18	1,4	28,48	0,02	42,49
ITCSM_04	6,59	0,24	0,03	2	4,37	0,41	445,29
ITCSM_05	0	0,13	0,17	1,45	25,84	0,41	38,54
ITCSM_07	4,04	0,14	0,03	1,9	8,52	0,33	253,62
ITCSM_10	20,93	0,12	0,03	2,1	3,96	0,26	110,92
ITCSM_11	17,3	0,12	0,15	1,26	34,73	0,32	44,57
ITCSM_15	26,44	0,08	0,03	1,79	5,12	0,21	62,32
ITCSM_16	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ITCSM_17	19	0,11	0,02	2,2	2,57	0,34	58,85

Table 7: Overview of impulse-response parameters for actual evapotranspiration for 5cm depth.

Location	EVP (%)	RMSE	ETa _A	ETa _a	Constant	Noise
ITCSM_01	79,5	0,05	-0,08	36,16	0,34	19,54
ITCSM_02	80,82	0,08	-0,17	56,1	0,5	20,42
ITCSM_03	84,34	0,07	-0,26	32,47	0,61	18,38
ITCSM_04	90,39	0,08	-0,18	50,11	0,7	13,63
ITCSM_05	90,32	0,07	-0,29	43,45	0,88	9,29
ITCSM_07	76,48	0,06	-0,08	16,28	0,29	12,9
ITCSM_10	77,03	0,05	-0,09	10,42	0,38	9,04
ITCSM_11	94,01	0,04	-0,14	17,25	0,73	8,53
ITCSM_15	89,8	0,04	-0,11	24,34	0,45	12,1
ITCSM_16	86,99	0,07	-0,16	40,78	0,54	8,49
ITCSM_17	55,14	0,08	-0,08	39,88	0,32	6,41

Table 8: Overview of impulse-response parameters for actual evapotranspiration for 20cm depth.

Location	EVP (%)	RMSE	ETa _A	ETa _a	Constant	Noise
ITCSM_01	32	0,07	-0,06	10,2	0,36	30,95
ITCSM_02	92,04	0,03	-0,11	57,19	0,46	5,31
ITCSM_03	80,97	0,07	-0,21	83,25	0,45	22,95
ITCSM_04	95,77	0,05	-0,23	81,57	0,76	33,54
ITCSM_05	81,84	0,05	-0,35	154,3	0,76	8,59
ITCSM_07	89,5	0,05	-0,12	61,8	0,52	94,7
ITCSM_10	86,4	0,05	-0,11	39,52	0,45	38,8
ITCSM_11	92,3	0,04	-0,1	34,52	0,67	19,72
ITCSM_15	88,49	0,03	-0,07	25,84	0,36	15,25
ITCSM_16	NaN	NaN	NaN	NaN	NaN	NaN
ITCSM_17	80,66	0,05	-0,1	61,39	0,51	19,52

Table 9: Overview of impulse-response parameters for evapotranspiration deficit for 5cm depth.

Location	EVP (%)	RMSE	ETe _A	ETe _a	Constant	Noise
ITCSM_01	57,68	0,08	-0,21	33,02	0,29	38,69
ITCSM_02	80,82	0,08	-0,61	44,9	0,47	19,87
ITCSM_03	74,68	0,09	-0,61	41,02	0,52	30,52
ITCSM_04	84,89	0,1	-0,74	58,89	0,65	20,02
ITCSM_05	92,04	0,04	-0,87	32,05	0,87	7,76
ITCSM_07	57,72	0,07	-0,22	29,97	0,24	21,37
ITCSM_10	60,57	0,07	-0,24	17,81	0,33	15,41
ITCSM_11	91,37	0,05	-0,36	19,16	0,67	11,69
ITCSM_15	84,1	0,05	-0,33	27,33	0,42	18,25
ITCSM_16	81,35	0,09	-0,48	44,59	0,49	11,72
ITCSM_17	51,9	0,09	-0,37	31,38	0,3	6,88

Table 10: Overview of impulse-response parameters for evapotranspiration deficit for 20cm depth.

Location	EVP (%)	RMSE	ETe _A	ETe _a	Constant	Noise
ITCSM_01	31,02	0,07	-0,2	-0,2	0,35	31,5
ITCSM_02	87,52	0,04	-0,41	-0,41	0,44	8,55
ITCSM_03	71,66	0,08	-0,57	-0,57	0,4	31,59
ITCSM_04	88,41	0,08	-0,92	-0,92	0,68	90,99
ITCSM_05	69,81	0,07	-0,24	-0,24	0,74	24,25
ITCSM_07	78,82	0,07	-0,33	-0,33	0,48	167,15
ITCSM_10	51,58	0,1	-0,15	-0,15	0,36	133,43
ITCSM_11	92,9	0,04	-0,28	-0,28	0,65	16,51
ITCSM_15	84,8	0,03	-0,23	-0,23	0,34	19,66
ITCSM_16	NaN	NaN	NaN	NaN	NaN	NaN
ITCSM_17	34,09	0,1	-0,12	-0,12	0,42	51,24

Table 11: Overview of impulse-response parameters for precipitation and actual evapotranspiration for 5cm depth.

Location	EVP (%)	RMSE	P _A	P _n	P _a	ETa _A	ETa _a	Constant	Noise
ITCSM_01	86,16	0,04	0,02	2,21	2,27	-0,07	32,91	0,3	17,36
ITCSM_02	82,25	0,08	0,01	5,06	0,44	-0,16	60,63	0,48	25,59
ITCSM_03	87,71	0,07	0,04	2,32	2,08	-0,22	53,16	0,47	14,75
ITCSM_04	84,09	0,1	0,02	2,37	1,78	-0,31	244,41	0,58	125,23
ITCSM_05	92,12	0,07	0,03	2	4,07	-0,3	55,53	0,81	7,83
ITCSM_07	79,88	0,05	0,01	5,67	0,33	0,08	17,99	0,27	15,13
ITCSM_10	77,86	0,05	0,01	10	0,19	-0,09	13,9	0,35	14,31
ITCSM_11	96,34	0,03	0,01	4,22	0,48	-0,14	19,98	0,7	8,65
ITCSM_15	72,88	0,07	0,05	1,63	7,93	-0,33	672,98	0,29	26,91
ITCSM_16	90,41	0,06	0,02	4,93	0,45	-0,17	54,39	0,5	9,06
ITCSM_17	63,42	0,08	0,02	3,48	0,79	-0,08	53,95	0,27	6,41

Table 12: Overview of impulse-response parameters for precipitation and actual evapotranspiration for 20cm depth.

Location	EVP (%)	RMSE	P _A	P _n	P _a	ETa _A	ETa _a	Constant	Noise
ITCSM_01	44,39	0,06	0,01	2,57	1,47	-0,06	22,59	0,33	25,71
ITCSM_02	45,36	0,08	0,01	6,31	0,29	-0,35	240,16	0,51	359,87
ITCSM_03	82,3	0,06	0,02	2,57	1,67	-0,21	112,95	0,4	15,18
ITCSM_04	96,07	0,05	0,02	2,08	3,41	-0,25	111,36	0,72	36,14
ITCSM_05	77,43	0,06	0,17	1,3	41,57	-0,19	60,77	0,55	8,95
ITCSM_07	87,34	0,05	0,01	2,24	3,53	-0,12	73,71	0,49	99,98
ITCSM_10	85,56	0,05	0,02	2,14	3,96	-0,12	67,71	0,39	37,56
ITCSM_11	93,76	0,03	0,01	6,71	0,29	-0,1	38,87	0,66	25,62
ITCSM_15	68,25	0,05	0,03	1,8	5,1	-0,26	937,21	0,25	251,41
ITCSM_16	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ITCSM_17	84,61	0,05	0,01	2,7	1,46	-0,1	84,6	0,47	18,68

Table 13: Overview of impulse-response parameters for precipitation and evapotranspiration deficit for 5cm depth.

Location	EVP (%)	RMSE	P _A	P _n	P _a	ETe _A	ETe _a	Constant	Noise
ITCSM_01	44	0,09	0,02	2,51	1,72	-0,78	742,1	0,24	194,76
ITCSM_02	83,2	0,07	0,01	4,97	0,45	-0,6	45,35	0,45	23,59
ITCSM_03	74,09	0,09	0,04	2,32	2,08	-1,16	263,76	0,38	33,21
ITCSM_04	88,96	0,08	0,03	2,02	2,85	-0,85	86,13	0,58	14,81
ITCSM_05	93,7	0,06	0,03	1,85	4,56	-0,9	40,55	0,79	6,15
ITCSM_07	64,35	0,07	0,01	4,29	0,48	-0,23	38,26	0,23	23,47
ITCSM_10	54,1	0,08	0,02	3,59	0,64	-1,01	507,79	0,28	21,97
ITCSM_11	92,2	0,05	0,01	10	0,18	-0,34	21,36	0,65	18,21
ITCSM_15	72,87	0,07	0,05	1,62	7,78	-0,76	367,99	0,29	27,97
ITCSM_16	85,86	0,07	0,02	4,95	0,44	-0,5	54,35	0,46	12,71
ITCSM_17	63,16	0,08	0,02	3,42	0,81	-0,36	38,76	0,26	6,45

Table 14: Overview of impulse-response parameters for precipitation and evapotranspiration deficit for 20cm depth.

Location	EVP (%)	RMSE	P _A	P _n	P _a	ETe _A	ETe _a	Constant	Noise
ITCSM_01	51,17	0,06	0,09	1,5	10,92	-1,7	212,41	0,22	9,51
ITCSM_02	70,37	0,06	0,01	6,33	0,29	-1,82	457,6	0,44	192,36
ITCSM_03	77,35	0,07	0,02	2,58	1,66	-0,6	122,15	0,37	18,64
ITCSM_04	87,18	0,09	0,02	2,07	3,4	-1,18	186,02	0,63	98,39
ITCSM_05	80,97	0,05	0,15	1,27	46,88	-0,48	29,58	0,57	8,24
ITCSM_07	79,61	0,07	0,01	2,25	2,28	-0,36	72,36	0,46	135,57
ITCSM_10	75,88	0,07	0,02	2,13	3,93	-0,37	92,72	0,36	52,85
ITCSM_11	94,11	0,03	0,01	6,39	0,3	-0,28	38	0,63	20,86
ITCSM_15	75,52	0,04	0,06	1,45	15,6	-0,97	657,22	0,22	464,59
ITCSM_16	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
ITCSM_17	88,34	0,04	0,01	2,69	1,47	-0,41	39,1	0,48	14,06