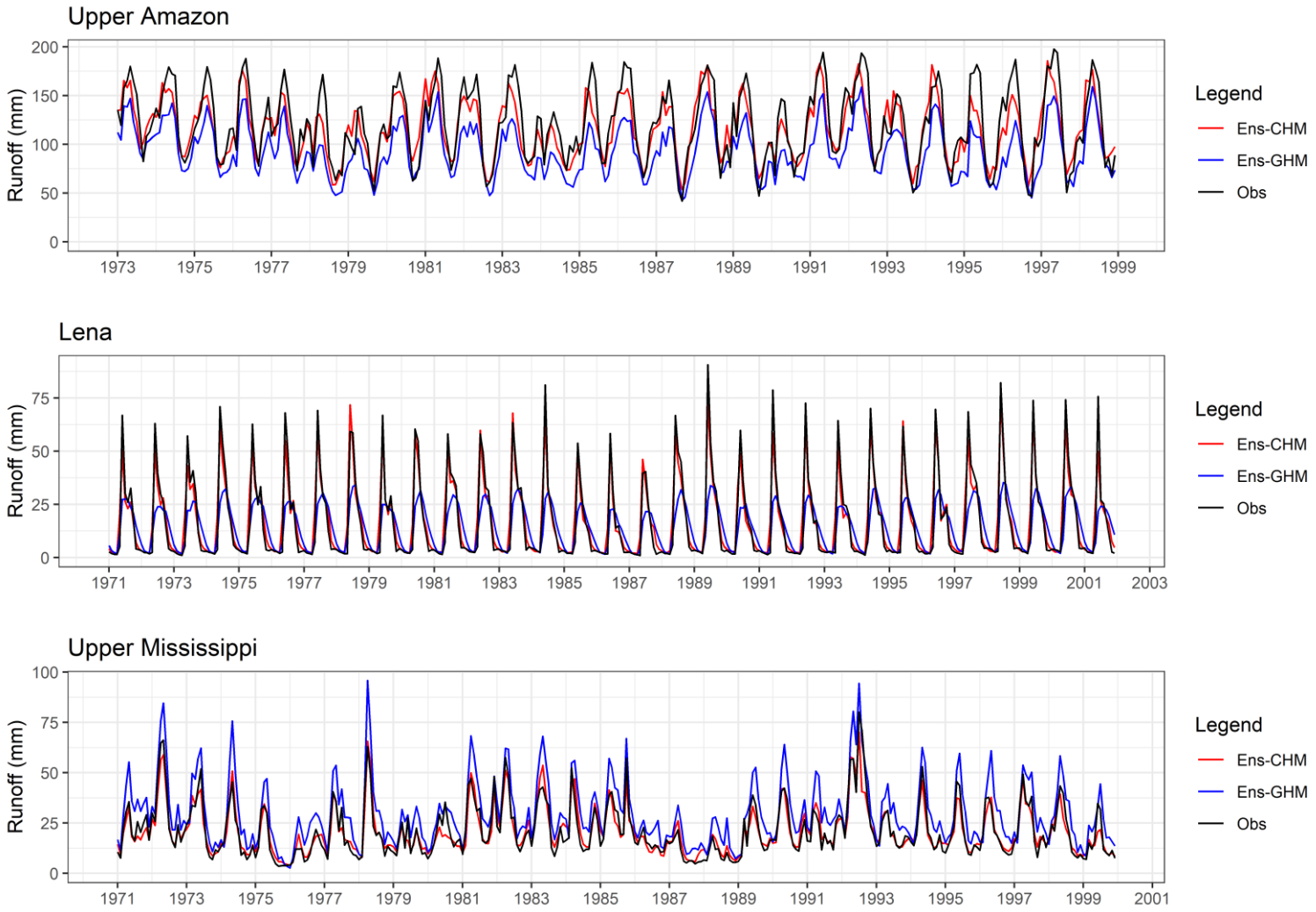
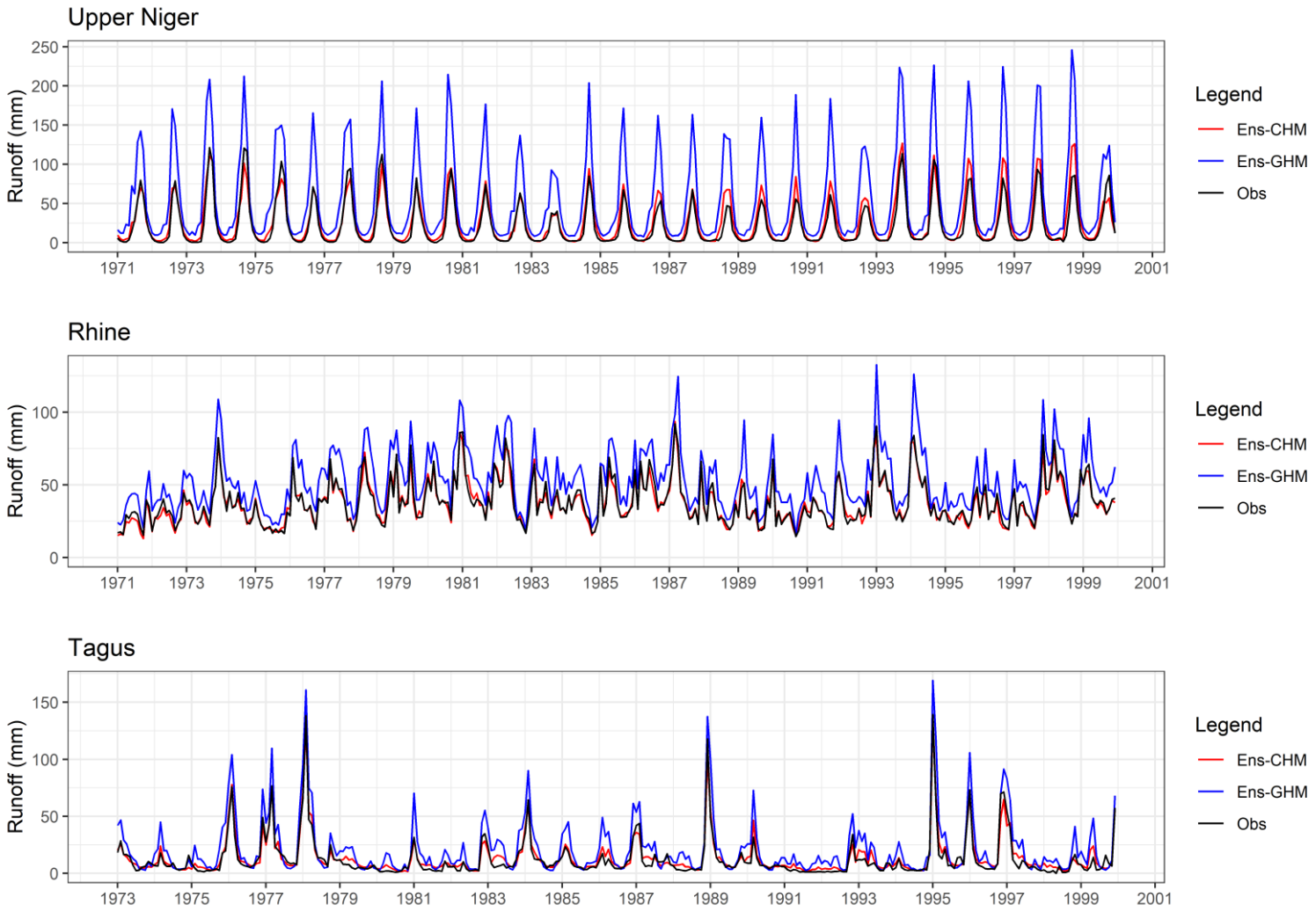
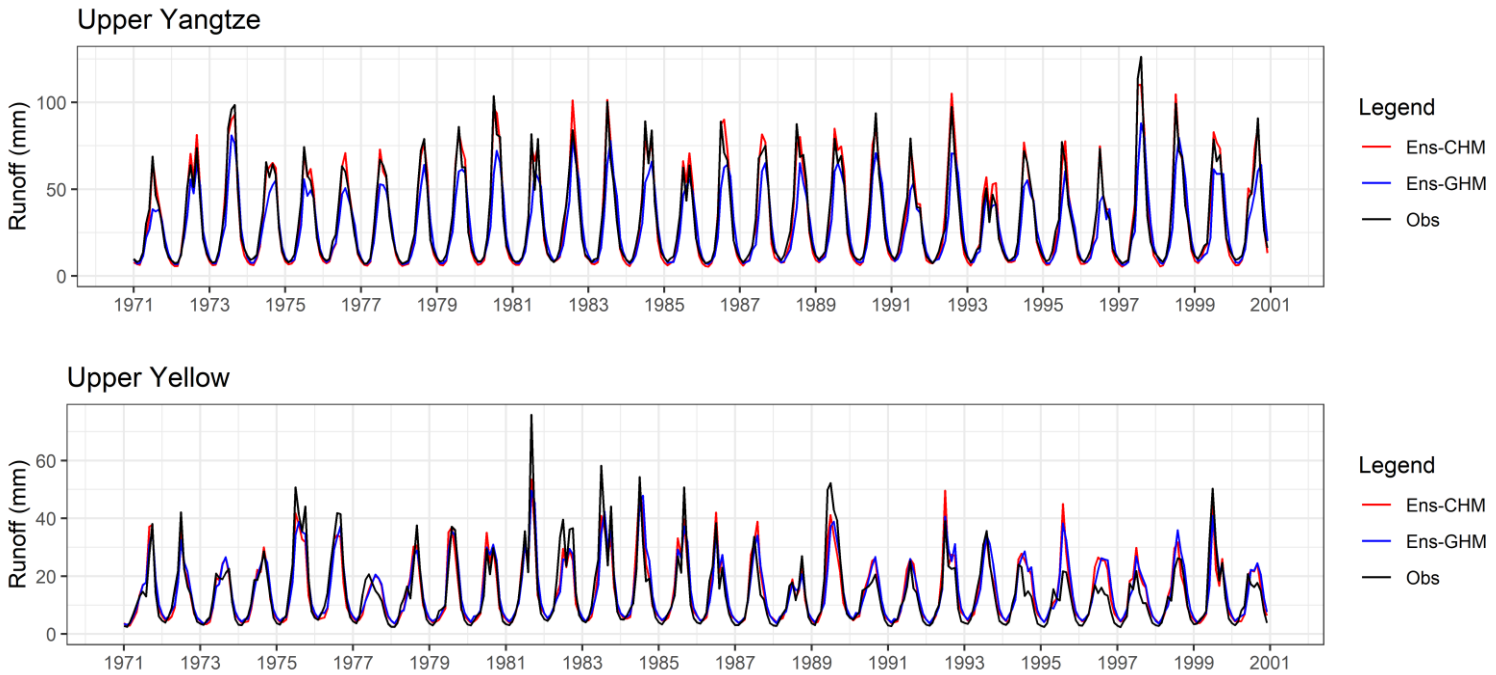
Supplementary Materials

SM 1 Observed and simulated Runoff from catchments Upper Amazon, Lena, Upper Mississippi, Upper Niger, Rhine, Tagus, Upper Yangtze, and Upper Yellow respectively




Upper Niger
Runoff (mm)
250
200
150
100
50
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
Legend
Ens-CHM
Ens-GHM
Obs
Rhine
Runoff (mm)
100
50
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
Legend
Ens-CHM
Ens-GHM
Obs
Tagus
Runoff (mm)
150
100
50
0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
Legend
Ens-CHM
Ens-GHM
Obs



SM 2 Akaike's Information Criteria (AIC) values of the observed runoff when fitted to 1) Gamma, 2) Normal, and 3) Weibull distributions, lower AIC as a measure of goodness of fit

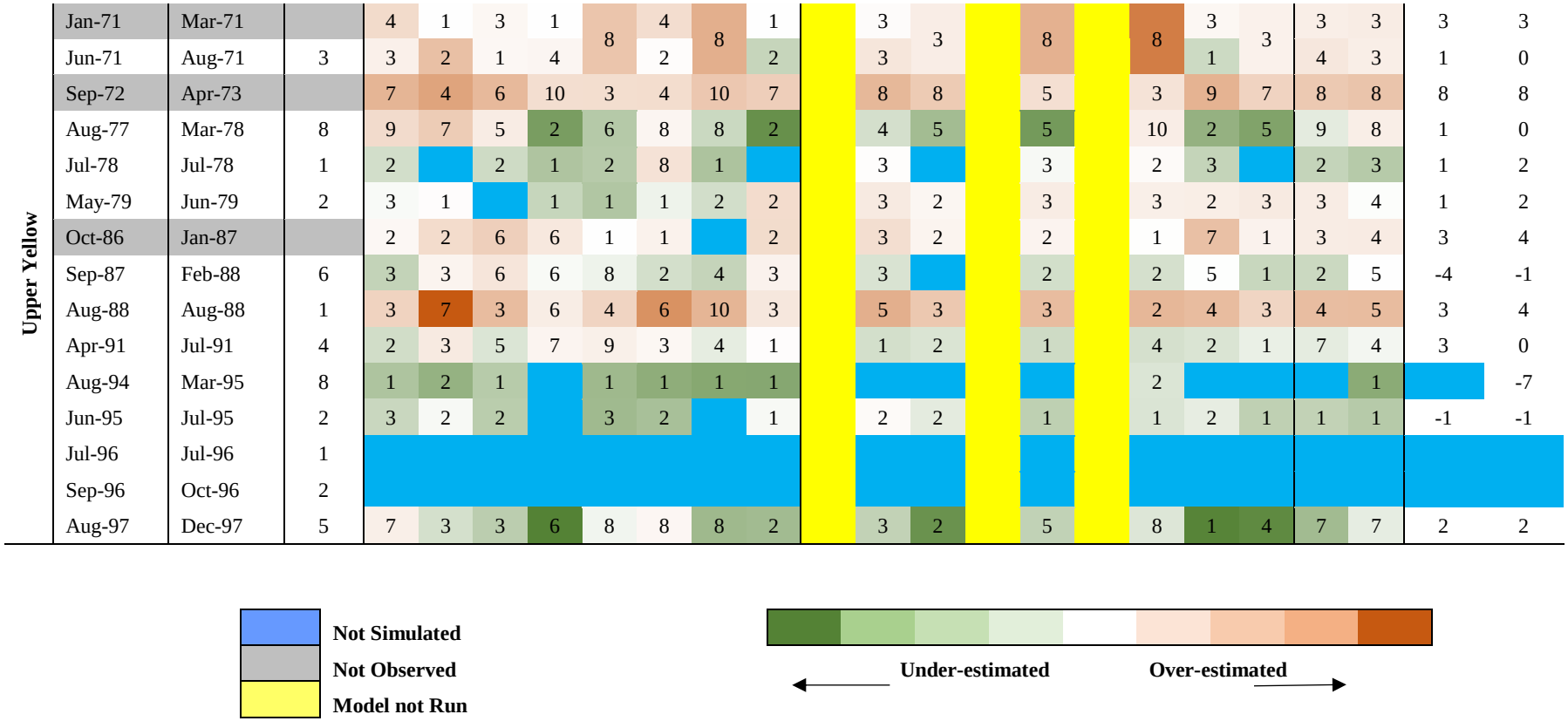
Catchments	Gamma	Normal	Weibull
Upper Amazon	3147.168	3154.803	3158.09
Lena	2823.417	3295.07	2832.797
Upper Mississippi	2662.094	2787.256	2685.137
Upper Niger	2825.069	3316.613	2835.352
Rhine	2818.866	2894.941	2869.276
Tagus	2288.573	2792.935	2285.24
Upper Yangtze	3174.814	3354.76	3186.509
Upper Yellow	2583.06	2800.161	2596.997

SM 3 Observed and simulated *severe* runoff-deficit drought events (drought events with *severity* greater than mean *severity* in each catchment). Displayed is each observed drought's start and end date, with the numbers indicating the observed and simulated drought duration in months. Drought events are colour coded based on the difference in simulated and observed drought *severity* (separately for each catchment), marked from shades of green to brown as under-estimated to over-estimated, respectively. Blue cells are observed droughts not present in simulated records. Grey cells are simulated droughts (either by Ens-GHM or Ens-CHM or both) not present in the observed record. Yellow cells denote that the particular model was not run for the specific catchment

	Observed			Simulated																		Duration Difference (months)	
				GHMs								CHMs									Ens-CHM	Ens-GHM		
Catchments	Start Date	End Date	Duration (months)	CLM	DBH	H08	MATSIRO	MPI	PCR	WaterGAP2	LPJML	ECOMAG	HBV	HYMOD	HYPE	mHM	SWAT	SWIM	VIC	WaterGAP3			Ens-CHM	Ens-GHM
Upper Amazon	Feb-78	May-78	4	13	5	11	19	11	7	10	7		10	10		10	10	12	11	5	10	12	6	8
	Jan-79	Jun-79	6		7			8	3	2	2		5	8		7	7	8	6	2	7	7	1	1
	Jul-82	Aug-82	2	3	1	3	4	5	2	3	2		4	2		4	4	5	4	2	4	4	2	2
	Feb-84	Jun-84	5	6	5	5	7	8	2	6	6		7	7		6	7	8	7	3	7	6	2	1
	Oct-84	Feb-85		4	4	5	5	6	2	4	2		2	4		3	4	5	4		5	4	5	4
	Apr-87	Sep-87	6	2	4	2	5	5	4	3	3		2	3		3	4	4	4	4	3	3	-3	-3
	Dec-89	Aug-90	9	6	6	6	8	7	8	6	6		7	7		10	10	7	8	4	7	7	-2	-2
	Mar-93	Jun-93	4			1			2	1			2	4		1	1	7	2	1	1	1	-3	-3
	Aug-96	Oct-96	3		2	3	4	4	2	2	2		1	2		2	2	3	3	1	2	2	-1	-1
	Nov-98	Dec-98	2			1				2	2		1			1	1	2	2	1	1	1	-1	-1
Lena	Jul-71	Jul-71	1								1	1			1			7			2		1	
	Jun-73	Jun-73		2		2	1	2	3	1	1	1			2			2	1	1	1	1	1	1
	Jul-79	Aug-79	2				1		2	2	2	2			2			2		2	2	1	0	-1
	Sep-84	Mar-85			2	8	7	6	7	7	2	8			3			3	8	7	7	6	7	6
	Jun-85	Nov-85	6	8	5	6	2	5	34	3	2	3			2			7	3	8	11	10	5	4
	May-86	Jun-87	14	23	7	10	15	12		11	7	12			12			12	12	11	12	21	-2	7

	Sep-87	Jan-88	5		2	3		5		1	1				4			8	7	5	5		0	16
	Aug-90	Sep-90	2	1		6	3	1	2	3	1	12			2			4	7	8	5	9	3	7
	Sep-91	Apr-92		8	2	1	7	6	7			5			3			7	6	7	5	8	5	8
	Aug-96	Aug-96	1						1			1			2			1	1	1	1		0	
	Jul-01	Jul-01	1	2	3	4		2	1			2			1			1	3	2	2	3	1	2
Upper Mississippi	Jun-75	Aug-76	15	14	9	10	22	15	14	14	6		10	9		15	14	16	12	10	15	14	0	-1
	May-79	May-79	1	5	4		1	4	1	4	1		1	3		1	1		1	3	3	1	2	0
	Mar-86	Jul-86		4	4	5		5	3	6	3		5	5		6	6	3		5	5	5	5	5
	Apr-87	Aug-88	17	15	5	6	26	9	16	8	5		6	5		8	8	23	16	7	8	7	-9	-10
	Oct-88	Jan-89	4	5	3	4		4	5	5	3		5	2		5	7		5	4	5	5	1	1
	Nov-98	May-99	7	3	2	4	2	3	2	3	1		3	8		3	6	4	1	3	3	4	-4	-3
Upper Niger	Apr-79	Jul-79	4	1		1				1			2	2				1	2					
	Oct-81	Dec-81			4	2	14		1	1	1		8				8			1		3		3
	Jul-82	Apr-83		5	6	1	14	10		6			9	9		10	6	9	9	8	10	6	10	6
	Sep-83	Jan-84	5	3	4	3	8		3	12	3		11	12		12	11	7	11	7	12	10	7	5
	Jul-85	Aug-85	2		1	1	1	1		1	1		1	2		1	2	1	1		1	1	-1	-1
	Jul-86	Sep-86	3	1	1	1	2	1	1	2	2		1	1		1	1	3	1	1	1	2	-2	-1
	Oct-87	Jan-88	4	3	1	2	5	7	2	7	1		4	7		7	7	4	4	4	6	3	2	-1
	Jun-88	Sep-88	4		1		1		1	1	1							1				1		-3
	Sep-89	Nov-89	3										1				1	2	1		1		-2	
	Aug-90	Sep-90	2	1				1	3	1	1			1				1	1	1	1	1	-1	-1
	Aug-92	Oct-92	3	2	1	1	1	2	1	1	1		2	2		2	1	1	2	1	1	1	-2	-2
Rhine	Jan-71	Mar-71	3	4	3	4	11	4	3	7	3		7	10	5	7	3	7	3	3	7	4	4	1
	Sep-71	Oct-71			2	1		1	2	1	2		2		2	2	2	2	2	2	2	1	2	1
	Jan-72	Jan-72	1		1	2	7	4	1	4	1		1	4	2	3	4	1	3	2	4	3	3	2
	Apr-73	Jun-73	3	2	3	2	3	2	2	2	2		1	3	3	3	2	1	3	3	2	2	-1	-1
	Mar-75	Jan-76	11	7	7	4	12	7	6	7	5		10	10	6	11	9	7	7	8	9	7	-2	-4
	Nov-77	Dec-77	2	1	2	2		2	2	2	2		2	2	2	2	2	2	2	2	2	2	0	0
	Nov-82	Dec-82	2	6	2	2	2	1	2	1	2		1		1	2	1	2	2	2	1	1	-1	-1

	Oct-84	Dec-84	3	4	3	3	1	3	3	3	3		3	3	3	3	3	3	3	3	3	3	0	0
	Apr-90	Oct-90	7	4	2	2	8	3	3	3	3		2	3	2	3	2	3	3	3	3	3	-4	-4
	Mar-92	Jun-92	4	2	4	2		5	2	1	4		2	1	1	1	2	1	1	2	2	5	-2	1
	Feb-95	Apr-95	3	4	3	2	4	2	5	5	4		2	4	2	3	2	6	3	2	2	4	-1	1
	Jun-97	Aug-97	3	2	3	3	1	3	1	2	2		2	1	3	2	3	2	2	3	2	2	-1	-1
Tagus	Oct-74	Jan-75		1	2	3	2	3	2	4	2		3		4				2	9	4	2	4	2
	May-75	Jun-75		4	1	1	4	7	4	6	2		7		6				4		4	2	4	2
	Jan-80	Sep-80	9	5	4	4	7	7	4	6	4		11		4				4	12	12	4	3	-5
	Nov-80	Nov-80		1	1	1	1		1	6	1				4				1			1	12	1
	Jan-82	Apr-82		1	4	1		1	1	4	3		4		1				3		2	4	0	2
	Jan-88	Feb-88		1	2	2	1	1	2	2	2				5				3		2	2	2	2
	Jan-91	Mar-91		5	3	2	3	2	5	3	3		4		2				3	1	3	3	-1	-1
	Jun-91	Sep-92	16	4	4	4	4	7	4	7	2		17		5				4	17	17	4	1	-12
	Dec-93	Jan-94	2	2	1	1	1		1	1	1		1		1				1			1		-1
	Apr-94	Aug-94		5	5	3	3	9	7	7			8		8				3		8	5	8	5
	Nov-97	May-98	7	3	3	2	3	7	4	8	3		3		10				2	6	6	3	-1	-4
	Jul-98	Sep-98	3	2	1		2	7	4	8					10					6	6	2	3	-1
Upper Yangtze	Aug-71	Mar-72	8	8	8	5	6	10	8	8	5		8				8	2	4		8	9	0	1
	Jan-78	Jul-78	7	9	5	12	8	12	4	3	4		10				4	4	4		4	10	-3	3
	Oct-83	Dec-83	3	3	2	5	1	2	2	5	1		5				4	2	5		5	4	2	1
	Jul-85	Aug-85	2						1				1				4	1	1		1		-1	
	Feb-86	Jun-86	5	3	1	4	4	2	3	4	5		3				4	3	6		5	4	0	-1
	Jun-87	Jul-87		2	1	2	2	2	2	1	2		2				1	1	2		1	2	1	2
	Sep-91	Sep-91	1		2	3	4	5	1	2	2		2				1	5	1		1	4	0	3
	Jun-92	Jun-92	1	2	1	2	2	2	3	2	1		1									2		1
	Jul-93	Sep-93	3	4	1	3	2	3	2	1	2		3				2	2	2		2	2	-1	-1
	Sep-95	Oct-95	2	2	2	1	2	2	1	2	2		2				2	2	1		2	2	0	0
	Aug-96	Dec-96	5	10	9	2	9	10	9	6	4		9				6	2	2		7	9	2	4
	Jul-00	Jul-00	1		1				1	2	2		1				1	1	1		1		0	


Upper Yellow
Jan-71 Mar-71 4 1 3 1 8 4 8 1 3 3 8 8 3 3 3 3 3 3
Jun-71 Aug-71 3 3 2 1 4 8 2 8 2 3 3 8 8 1 3 4 3 1 0
Sep-72 Apr-73 7 4 6 10 3 4 10 7 8 8 5 3 9 7 8 8 8 8
Aug-77 Mar-78 8 9 7 5 2 6 8 8 2 4 5 5 10 2 5 9 8 1 0
Jul-78 Jul-78 1 2 2 1 2 8 1 3 3 2 3 2 3 3 1 2
May-79 Jun-79 2 3 1 1 1 1 2 2 3 2 3 3 2 3 3 4 1 2
Oct-86 Jan-87 2 2 6 6 1 1 2 3 2 2 1 7 1 3 4 3 4
Sep-87 Feb-88 6 3 3 6 6 8 2 4 3 3 2 2 5 1 2 5 -4 -1
Aug-88 Aug-88 1 3 7 3 6 4 6 10 3 5 3 3 2 4 3 4 5 3 4
Apr-91 Jul-91 4 2 3 5 7 9 3 4 1 1 2 1 4 2 1 7 4 3 0
Aug-94 Mar-95 8 1 2 1 1 1 1 1 2 1 -7
Jun-95 Jul-95 2 3 2 2 3 2 1 2 2 1 1 2 1 1 1 -1 -1
Jul-96 Jul-96 1
Sep-96 Oct-96 2
Aug-97 Dec-97 5 7 3 3 6 8 8 8 2 3 2 5 8 1 4 7 7 2 2
Not Simulated
Not Observed
Model not Run
Under-estimated
Over-estimated

SM 4 MAE (across all catchments) in simulating drought *duration* by ensemble and individual models for each drought category

	Models	Drought events based on SRI Values			Drought events based on Runoff Deficit
		Moderate (-1 to -1.49)	Severe (-1.5 to 1.99)	Extreme (-2 or Below)	
GHMs	**CLM**	3.69	4.53	2.83	1.89
	DBH	2.3	3.5	5.29	1.6
	H08	2.53	3.21	6.13	1.76
	MATSIRO	5.62	5.78	7.47	2.60
	MPI-HM	3.78	5.15	3.58	2.17
	PCR-GLOBWB	3.01	4.27	3.64	1.78
	WaterGAP2	2.69	3.91	2.77	1.88
	LPJML	2.77	2.65	6.09	1.42
CHMs	**ECOMAG**	3.63	2	5.33	2.06
	HBV	3.89	4.78	3.16	2.07
	HYMOD	3	4.35	5.85	2.14
	HYPE	3.29	2.47	2.11	1.61
	mHM	3.5	6.15	2.36	1.85
	SWAT	3.11	3.51	3.78	1.67
	SWIM	2.8	4.28	2.38	1.69
	VIC	2.92	4.26	2.66	1.76
	WaterGAP3	2.92	3.05	4.61	1.75
	Ens-GHM	3.24	3.9	3	1.83
	Ens-CHM	2.94	4.18	2.45	1.72