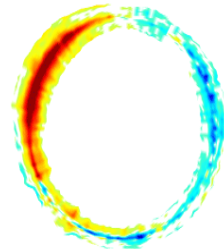# Verification Exercise

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The following anomaly thresholds can be used to define El Niño and La Niña events based on the NIÑO3 index:

Threshold	Value
El Niño event	index > 1.00
neutral event	$-1.00 \leq$ index ≤ 1.00
La Niña event	index < -1.00

Following is a set of forecasts of January NIÑO3 anomalies made in the previous August from five of the DEMETER models, together with observed anomalies for the 20 years, 1982-2001. The El Niño (E), neutral (N), and La Niña (L) years as defined from the table above are indicated in column 3.

Year	Observed		August forecasts of January NIÑO3 anomalies				
			ECMWF	LODYC	Météo-Fr	MPI	UKMO
1982	0.22	N	-0.29	-0.73	-0.47	-0.93	-0.77
1983	3.11	E	1.26	1.42	1.44	0.37	1.33
1984	-0.75	N	-0.81	-0.59	-0.35	-0.37	-0.43
1985	-1.11	L	-0.35	-0.46	-0.37	-1.41	-0.44
1986	-0.90	N	-0.04	0.17	-0.10	-0.27	-0.67
1987	0.97	N	0.87	0.62	0.52	-0.64	0.50
1988	0.50	N	0.11	0.88	0.60	0.84	1.83
1989	-1.55	L	-1.18	-0.88	-1.50	-0.98	-1.76
1990	-0.37	N	0.10	0.02	-0.67	0.59	0.16
1991	0.00	N	0.40	0.17	0.17	0.87	0.44
1992	1.30	E	1.14	0.85	1.04	0.61	0.89
1993	-0.12	N	0.07	-0.24	0.17	-0.52	0.23
1994	0.04	N	0.06	0.02	0.18	0.05	0.19
1995	0.70	N	0.26	0.24	0.10	-0.62	0.53
1996	-0.81	N	-0.62	-0.56	-0.44	-0.51	-1.18
1997	-0.90	N	-0.07	-0.41	-0.27	-0.65	-0.73
1998	3.18	E	2.03	2.22	2.29	5.88	3.52
1999	-1.14	L	-1.25	-1.27	-0.88	-1.06	-1.73
2000	-1.71	L	-1.30	-1.13	-1.14	-0.60	-1.46
2001	-0.66	N	-0.39	-0.32	-0.32	-0.66	-0.42

Year	Observed		August forecasts of January NIÑO3 anomalies									
			ECMWF		LODYC		Météo-Fr		MPI		UKMO	
1982	0.22	N	-0.29	N	-0.73	N	-0.47	N	-0.93	N	-0.77	N
1983	3.11	E	1.26	E	1.42	E	1.44	E	0.37	N	1.33	E
1984	-0.75	N	-0.81		-0.59		-0.35		-0.37		-0.43	
1985	-1.11	L	-0.35		-0.46		-0.37		-1.41		-0.44	
1986	-0.90	N	-0.04		0.17		-0.10		-0.27		-0.67	
1987	0.97	N	0.87		0.62		0.52		-0.64		0.50	
1988	0.50	N	0.11		0.88		0.60		0.84		1.83	
1989	-1.55	L	-1.18		-0.88		-1.50		-0.98		-1.76	
1990	-0.37	N	0.10		0.02		-0.67		0.59		0.16	
1991	0.00	N	0.40		0.17		0.17		0.87		0.44	
1992	1.30	E	1.14		0.85		1.04		0.61		0.89	
1993	-0.12	N	0.07		-0.24		0.17		-0.52		0.23	
1994	0.04	N	0.06		0.02		0.18		0.05		0.19	
1995	0.70	N	0.26		0.24		0.10		-0.62		0.53	
1996	-0.81	N	-0.62		-0.56		-0.44		-0.51		-1.18	
1997	-0.90	N	-0.07		-0.41		-0.27		-0.65		-0.73	
1998	3.18	E	2.03		2.22		2.29		5.88		3.52	
1999	-1.14	L	-1.25		-1.27		-0.88		-1.06		-1.73	
2000	-1.71	L	-1.30		-1.13		-1.14		-0.60		-1.46	
2001	-0.66	N	-0.39		-0.32		-0.32		-0.66		-0.42	

Year	Observed		August forecasts of January NıÑo3 anomalies									
			ECMWF		LODYC		Météo-Fr		MPI		UKMO	
1982	0.22	N	-0.29	N	-0.73	N	-0.47	N	-0.93	N	-0.77	N
1983	3.11	E	1.26	E	1.42	E	1.44	E	0.37	N	1.33	E
1984	-0.75	N	-0.81	N	-0.59	N	-0.35	N	-0.37	N	-0.43	N
1985	-1.11	L	-0.35	N	-0.46	N	-0.37	N	-1.41	L	-0.44	N
1986	-0.90	N	-0.04	N	0.17	N	-0.10	N	-0.27	N	-0.67	N
1987	0.97	N	0.87	N	0.62	N	0.52	N	-0.64	N	0.50	N
1988	0.50	N	0.11	N	0.88	N	0.60	N	0.84	N	1.83	E
1989	-1.55	L	-1.18	L	-0.88	N	-1.50	L	-0.98	N	-1.76	L
1990	-0.37	N	0.10	N	0.02	N	-0.67	N	0.59	N	0.16	N
1991	0.00	N	0.40	N	0.17	N	0.17	N	0.87	N	0.44	N
1992	1.30	E	1.14	E	0.85	N	1.04	E	0.61	N	0.89	N
1993	-0.12	N	0.07	N	-0.24	N	0.17	N	-0.52	N	0.23	N
1994	0.04	N	0.06	N	0.02	N	0.18	N	0.05	N	0.19	N
1995	0.70	N	0.26	N	0.24	N	0.10	N	-0.62	N	0.53	N
1996	-0.81	N	-0.62	N	-0.56	N	-0.44	N	-0.51	N	-1.18	L
1997	-0.90	N	-0.07	N	-0.41	N	-0.27	N	-0.65	N	-0.73	N
1998	3.18	E	2.03	E	2.22	E	2.29	E	5.88	E	3.52	E
1999	-1.14	L	-1.25	L	-1.27	L	-0.88	N	-1.06	L	-1.73	L
2000	-1.71	L	-1.30	L	-1.13	L	-1.14	L	-0.60	N	-1.46	L
2001	-0.66	N	-0.39	N	-0.32	N	-0.32	N	-0.66	N	-0.42	N

| Year	Observed		Probabilities of January Nıño3		
			El Niño	Neutral	La Niña
1981	0.22	N	0	100	0
1982	3.11	E	80	20	0
1983	-0.75	N	0	100	0
1984	-1.11	L	0	80	20
1985	-0.90	N	0	100	0
1986	0.97	N	0	100	0
1987	0.50	N	20	80	0
1988	-1.55	L	0	40	60
1989	-0.37	N	0	100	0
1990	0.00	N	0	100	0
1991	1.30	E	40	60	0
1992	-0.12	N	0	100	0
1993	0.04	N	0	100	0
1994	0.70	N	0	100	0
1995	-0.81	N	0	80	20
1996	-0.90	N	0	100	0
1997	3.18	E	100	0	0
1998	-1.14	L	0	20	80
1999	-1.71	L	0	20	80
2000	-0.66	N	0	100	0

$$\text{bias} = \frac{\text{average forecast probability}}{\text{observed relative frequency}}$$

Event	Bias
El Niño	12% / 15% = 80%
Neutral	75% / 65% = 115%
La Niña	13% / 20% = 65%

Forecast	El Niño	Neutral	La Niña
0%	0%	0%	0%
20%	0%	0%	50%
40%	100%	0%	
60%		0%	100%
80%	100%	67%	100%
100%	100%	100%	0%
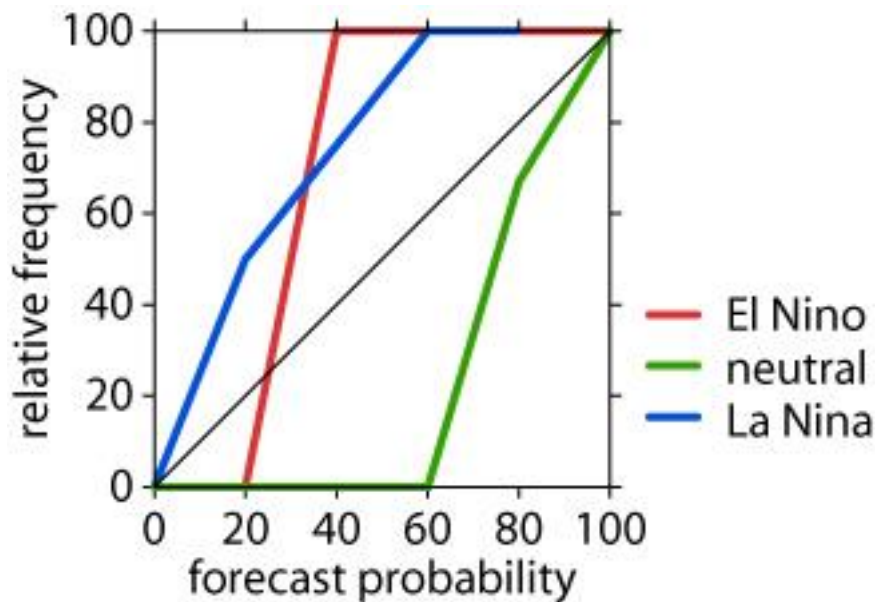
Calculate observed relative frequencies conditional upon the forecast probability for each category, and plot as a reliability diagram.

Warning	El Niño		Neutral		La Niña	
	H	**F**	**H**	**F**	**H**	**F**
≥ 100%	33%	0%	85%	0%	0%	0%
≥ 80%	67%	0%	100%	14%	50%	0%
≥ 60%	67%	0%	100%	29%	75%	0%
≥ 40%	100%	0%	100%	43%	75%	0%
≥ 20%	100%	6%	100%	86%	100%	6%
≥ 0%	100%	100%	100%	100%	100%	100%
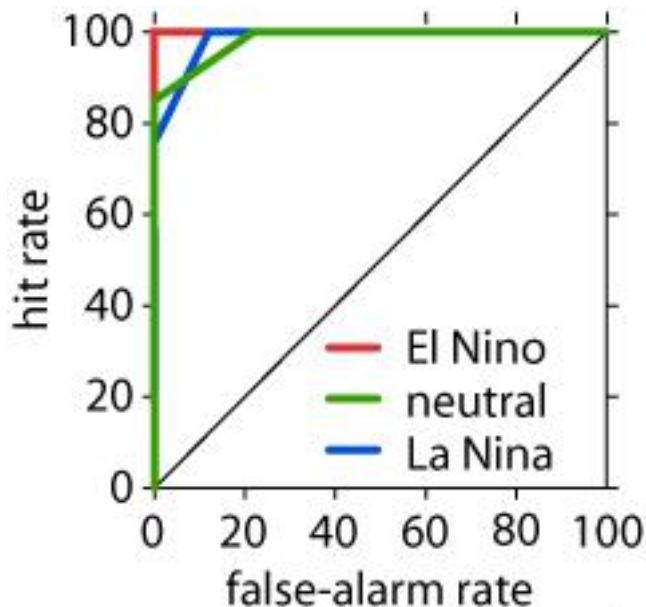
Calculate hit and false-alarm rates for each category, and plot as a ROC diagram. Calculate the areas beneath the curves.

	El Niño	Neutral	La Niña
Area	1.00	0.99	0.99

Relative Operating Characteristics

Year	Forecast
1984/85	661
1985/86	658
1986/87	573
1987/88	512
1988/89	707
1989/90	692
1990/91	621
1991/92	532
1992/93	584
1993/94	547
1994/95	496
1995/96	713
1996/97	623
1997/98	386
1998/99	728
1999/00	712
2000/01	682
2001/02	671
2002/03	571
2003/04	597

Retroactive forecasts of DJF rainfall for Lusaka.

In which years would we expect "droughts" (driest 25%) to occur?

Relative Operating Characteristics

Forecast	Year
386	1997/98
496	1994/95
512	1987/88
532	1991/92
547	1993/94
571	2002/03
573	1986/87
584	1992/93
597	2003/04
621	1990/91
623	1996/97
658	1985/86
661	1984/85
671	2001/02
682	2000/01
692	1989/90
707	1988/89
712	1999/00
713	1995/96
728	1998/99

The most sensible strategy would be to list the years in order of increasing forecast rainfall.

If the forecasts are good, the "drought" years should be at the top of the list.

Relative Operating Characteristics

Observed	Forecast	Year
563	386	1997/98
297	496	1994/95
537	512	1987/88
274	532	1991/92
269	547	1993/94
559	571	2002/03
538	573	1986/87
538	584	1992/93
749	597	2003/04
652	621	1990/91
615	623	1996/97
754	658	1985/86
588	661	1984/85
323	671	2001/02
813	682	2000/01
685	692	1989/90
929	707	1988/89
681	712	1999/00
401	713	1995/96
880	728	1998/99

For the first guess:

$$\text{Hit rate} = \frac{\text{number of hits}}{\text{number of events}}$$

$$= \frac{0}{5}$$

$$\text{FAR} = \frac{\text{number of false alarms}}{\text{number of non-events}}$$

$$= \frac{1}{15}$$

Repeat for all forecasts.

Relative Operating Characteristics

| Observed	Forecast	Year	Correct	Incorrect
563	386	1997/98	0 of 5	1 of 15
297	496	1994/95	1 of 5	1 of 15
537	512	1987/88	1 of 5	2 of 15
274	532	1991/92	2 of 5	2 of 15
269	547	1993/94	3 of 5	2 of 15
559	571	2002/03	3 of 5	3 of 15
538	573	1986/87	3 of 5	4 of 15
538	584	1992/93	3 of 5	5 of 15
749	597	2003/04	3 of 5	6 of 15
652	621	1990/91	3 of 5	7 of 15
615	623	1996/97	3 of 5	8 of 15
754	658	1985/86	3 of 5	9 of 15
588	661	1984/85	3 of 5	10 of 15
323	671	2001/02	4 of 5	10 of 15
813	682	2000/01	4 of 5	11 of 15
685	692	1989/90	4 of 5	12 of 15
929	707	1988/89	4 of 5	13 of 15
681	712	1999/00	4 of 5	14 of 15
401	713	1995/96	5 of 5	14 of 15
880	728	1998/99	5 of 5	15 of 15

Relative Operating Characteristics

We could do the same thing for the wet years …

Observed	Forecast	Year	Correct	Incorrect
880	728	1998/99	1 of 5	0 of 15
401	713	1995/96	1 of 5	1 of 15
681	712	1999/00	1 of 5	2 of 15
929	707	1988/89	2 of 5	2 of 15
685	692	1989/90	2 of 5	3 of 15
813	682	2000/01	3 of 5	3 of 15
323	671	2001/02	3 of 5	4 of 15
588	661	1984/85	3 of 5	5 of 15
754	658	1985/86	4 of 5	5 of 15
615	623	1996/97	4 of 5	6 of 15
652	621	1990/91	4 of 5	7 of 15
749	597	2003/04	5 of 5	7 of 15
538	584	1992/93	5 of 5	8 of 15
538	573	1986/87	5 of 5	9 of 15
559	571	2002/03	5 of 5	10 of 15
269	547	1993/94	5 of 5	11 of 15
274	532	1991/92	5 of 5	12 of 15
537	512	1987/88	5 of 5	13 of 15
297	496	1994/95	5 of 5	14 of 15
563	386	1997/98	5 of 5	15 of 15

Relative Operating Characteristics
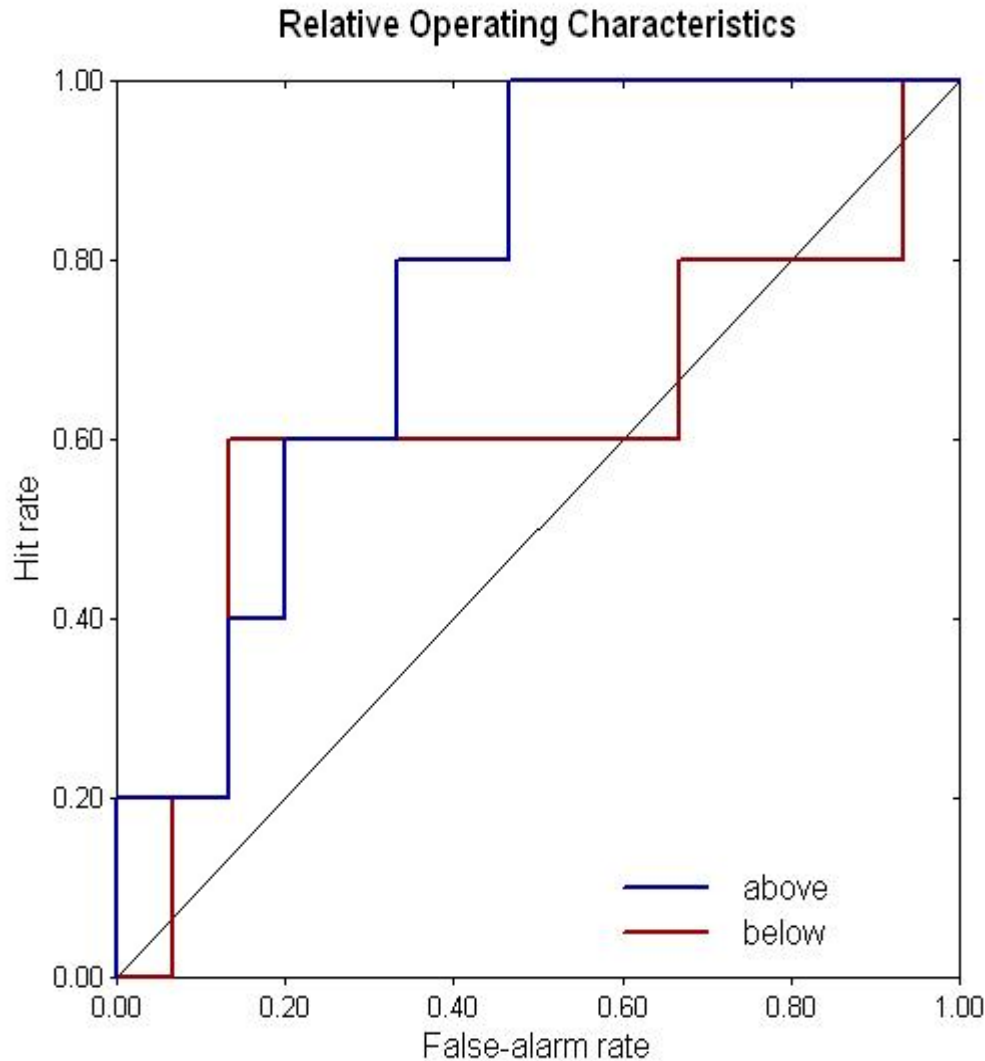
The area beneath the curve (0.61 and 0.77) gives us the probability that we will successfully discriminate a "drought" year from a non-drought year.