VLBA TEST MEMO NO. 46

VLBA SYSTEM TEMPERATURES AND EFFICIENCIES

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1 Introduction

This memo summarizes our knowledge of the sensitivities of the VLBA antennas as of early December, 1993. The values for the noise cal temperature, the gain, the system temperatures, the efficiencies (gain divided by 0.178), and the System Equivalent Flux Densities (SEFD) for all antennas at all bands at that time are given in the tables. Plots of the system temperature and efficiency as a function of time are also given. A new file that is available to users, giving the best values we have for the calibration parameters, is introduced.

2 Data Analysis

Most of the information on the sensitivities of the VLBA antennas that is available is a byproduct of pointing observations. Many of these observations are done as part of the weekly STARTUP systems checks. The rest are usually the result of special tests or attempts to check the pointing equations. The pointing observations involve making total power measurements at off-source, half-power, and on-source points on a number of strong radio sources. The program that fits for the pointing offsets also determines a peak antenna temperature for the source. Since a full pointing pattern is used, this antenna temperature is reasonably independent of pointing errors, assuming those errors are not larger than about half the beam size. A file for each experiment is created that contains the pointing offsets, the antenna temperatures and off-source system temperatures and much other information. Those files for data from the last few years are available on disk.

The sensitivity measurements are made using previously determined positions for the subreflector. No attempt is made during normal pointing observations to peak up the FRM position. If changes in the FRM position used are made that are large enough to affect the gain, the periods before and after the change are treated separately in the same way that they would have been if the receiver had been changed. Recently, several FRM's were moved laterally in an effort to improve the gain curves at 7mm. This caused noticable changes at 2cm, 1cm, and 7mm. Those changes are reflected in the gains file discussed below.

The gain measurements at the 7mm band are mostly made in separate experiments, usually using Jupiter. Vivek Dhawan has made most of these observations. Maser sources, and recently DR21, are used in regular pointing to make sure the systems are working and to determine gain curves.

At wavelengths longer than 2cm, the gain curves are assumed to be flat. At 2cm and 1cm, some of the antennas show a change in gain with elevation that is essentially linear. Eyeball estimates of the magnitude of this linear slope have been made using the 1cm data. The normalized gain curve is then a constant plus this slope. The 2cm gain curve is assumed to have 1/2 the slope of the 1cm curve, an approximation that appears to be in reasonable agreement with the data. The gain

curves are for data that have been corrected for opacity. The sharp drop in gain at low elevations in the gain curves typically provided by Network VLBI stations are actually the result of opacity, not antenna deformations. The opacity can vary with time (weather) so it is better to deal with it separately. This must be done when using the VLBA gain curves.

The gains values are determined from the antenna temperatures on calibrators. For frequency bands other than 7mm, the calibrators are mostly from Baars et al. (Baars, Genzel, Pauliny-Toth, and Witzel, 1977, A&A, 61, 99). Corrections are made for resolution by a 25 m antenna for 3C274 (Virgo A) and for variability for 3C48. The calibrator fluxes for each observation are corrected for opacity and for the gain curve. The opacity is determined by fitting the system temperatures minus an assumed spillover to a sec(Z) curve to get a receiver temperature. Then the system temperature minus spillover minus receiver temperature is divided by an atmospheric temperature (the temperature from the weather station minus 15K) to give an opacity. For this step, it is important that the cal temperature, and hence the measured system temperatures, be correct since the atmospheric temperature in the above ratio is dependent on a real thermometer, not the cal. These are essentially the methods described by Kari Leppanen in VLBA Scientific Memo 1 (1993).

The system temperatures reported here are zenith values (receiver plus one atmosphere) determined from the fit described above.

A large command file that can be used to rerun the pointing and gain analysis on old data are being maintained. For each new experiment, the necessary commands are added to run the analysis on those stations and receivers for which reasonable data were obtained. This ability to rerun the analysis has proven valuable when either the analysis software is upgraded or when parameters such as gain curves or cal temperature corrections, that can affect the results, are changed. The results here are from a recent complete run of all data taken since mid 1992.

Software is available to find and gather the results of the analysis of each of the individual experiments and derive best fit values. It is also possible to plot the history of many parameters. A list of the programs involved is in the appendix.

3 The `vlba_gains.key` file.

The best fit values for the gains and system temperatures along with other information such as gain curves, observing frequencies, cal temperatures, and scaling factors, are available in a file called `vlba_gains.key`. There are separate entries for each station, band, and polarization and for each period of time for which the values should be reasonably constant. Each entry is tagged with a time range. Separate entries are created whenever there is a receiver change, telescope geometry change, or other change which is likely to cause a change in the values. The old entries are kept, and updated if the full analysis is redone, in order to allow old data to be calibrated. The data should be complete from about mid 1992 to the present.

The `vlba_gains.key` file is available in the anonymous ftp area on `ftp.aoc.nrao.edu` in subdirectory pub. The file is in the Caltech package keyin format. Some of the lines can be extracted and used directly in ANCAL (AIPS) or CAL (Caltech) input files. There are comments at the beginning of the file that explain the meaning of the various parameters. This is the file to which users wishing to calibrate data should refer.

In the long run, the information in `vlba_gains.key` should be integrated into the data bases associated with the correlator. The archive tape for each observation should then contain the information appropriate for calibration of that experiment and that information should be passed to the FITS file and eventually to AIPS or whatever analysis package is used.

Note that the cal temperatures given are those assumed for the receivers. They come from files maintained by the operations group that are based on laboratory measurements made before

the receivers were installed. In a few cases, there are clearly significant errors in these values and corrections must be made if reasonable opacity corrections are to be made. If so, the correction factor is given by the FT value in `vlba_gains.key`. Where a non-unity FT value is given, the system temperature and gain shown are assuming that all system and antenna temperatures are scaled by that value. When users are given system temperature data for their observations, they will be based on the assumed cal values. In order to use the gain value given in `vlba_gains.key` correctly, the system temperatures must be scaled by the FT value, a capability built into ANCAL and CAL.

4 The Data

The attached tables give the cal temperatures, gains, system temperatures, efficiencies, and SEFD's for the current data for all antennas and all bands. The attached plots show the system temperatures and efficiencies for all antennas and bands for the period from mid 1992 to the present. The fit values, as given in the `vlba_gains.key` file are shown as lines, with separate lines for each time range. All of the plots on a page have the same scale to facilitate comparison.

Note that the quantity of data contributing to each of the averages varies considerably. It is clear that averages of values such as any of the 4cm numbers are likely to be rather better than, say, the 90 cm Tsys at PT (in fact that receiver has been essentially broken for a while). These plots should help users guage the quality of the calibration data they are using. They should also help spot systematic problems with the data such as tcal variations that show up as otherwise unexplained variations in the system temperature and efficiency that leave the SEFD constant.

What follows are detailed comments on the data for individual frequencies. They are based both on the tables and the plots.

90 and 50 cm: During 1993, many of the 50/90 cm feeds were replaced giving significant performance improvements.

PT: There is a new low frequency receiver and it was not yet working properly at the time these data were collected. It is working now and data should be available soon. The efficiency is for the old receiver.

90 cm: OV and HN are best with SEFDs (System Equivalent Flux Density) of about 2000 Jy. Other than PT, MK is the worst by a significant margin.

The cal values used for the old receiver at PT clearly were too high since the derived efficiency was close to 1.0.

50 cm: OV is best with SEFD about 1900. Other than PT, the worst are SC (LCP) and MK.

20 cm: FD, PT, and BR are best with SEFD about 280-290. The worst is NL at 348. The range is small which is good.

SC, HN, NL, FD, and possibly others show changes in system temperature and efficiency in which both change in the same sense. These events do not correspond to receiver changes. In all cases, there was no significant change in the SEFD (System Equivalent Flux Density). This suggests that what has changed is the temperature of the cal.

13 cm and 13 cm S/X: The dichroic plate that is permanently mounted over the 13cm feed introduces anomalous spillover at all but the very highest elevations. An effort has been made to subtract this effect and the values here are for the zenith. Because of this, the

achieved performance at most normal observing elevations will be below that implied here by something like 20%.

The performance of these two systems is quite similar which is expected since they only differ in the focus setting. For 13cm, the focus is optimized for 13cm. For 13cmsx, the focus is optimized for 4cm. The performance loss is fairly large. The possibility of a joint optimization should be investigated.

The best systems are at OV (SEFD=280), FD and MK (SEFD 300). The worst is KP at 430. The range is a bit large — it would be good to improve the worst ones.

PT: There are large and unexplained variations of Tsys.

Note the contrast between stations in the scatter of the measurements. For example, compare LA and FD. The cause is not clear. One possibility is RFI.

KP: What caused the big change at 1993.25?

6 cm: The best system is LCP at MK with SEFD=235 (the efficiency of 0.8 suggests that there is an error in the assumed cal value but that does not change the SEFD). All other systems are below 330 Jy except RCP at SC and both polarizations at NL (SEFD about 400). NL is quite poor by comparison and should be worked on.

Generally, the 6 cm results look very stable. This may be the best calibrated frequency.

BR and OV: The changes at about 1993.25 correspond to much smaller SEFD changes. These are probably cal changes.

4 cm: The best system is MK RCP with SEFD=236. FD and KP are also well below 300. The worst systems are NL (SEFD about 420) and OV (SEFD over 500). These systems need help, especially OV.

4 cm sx: This is 4cm but with the dichroic and ellipsoid in use. The following table gives the SEFD for 4cm and for 4cmsx, the difference, and the percentage increase for 4cmsx. The range of differences, both in Jy and in percentage, seems excessively large. The cause should be investigated. Values of the percentage change in the vicinity of 20 percent are what are expected. The smaller percentage changes are on less sensitive systems (OV, NL) where a fixed system temperature change would not be as significant. However in those cases, the absolute difference is also a bit low. (Note that, if this table does not quite agree with the main tables later, it is because I have updated the other tables more recently.)

COMPARISON OF 4CM AND 4CMSX SEFDs

	RCP				LCP			
Sta.	4cm	4cmsx	diff	%chg.	4cm	4cmsx	diff	%chg.
SC	315	417	102	32	376	485	109	30
HN	340	459	119	35	350	482	132	38
NL	417	485	68	16	423	501	78	18
FD	261	322	59	23	273	336	63	23
LA	340	420	80	23	301	374	73	24
PT	307	403	96	31	299	415	116	39
KP	267	383	116	43	274	365	91	33
OV	553	621	68	12	505	556	51	10
BR	351	430	79	22	345	421	76	22
MK	236	318	88	35	289	379	90	31

3 cm: Only PT has this receiver and it has not been used in several years to my knowledge other than to get the sensitivity point shown here. In fact, the pointing may not have been updated since the FRM move recently. Is there a good reason to keep this receiver going? Perhaps some other observatory would have a better use for it.

2 cm: The best systems are at MK, FD (RCP) and KP (RCP) with SEFDs of about 420 Jy. The worst is HN at 650 with several others around 550.

Simultaneous changes in Tsys and efficiency that indicate tcal changes have been seen at BR and perhaps in the most recent data at LA.

This system has been plagued with moisture in the feeds. This accounts for many of the cases of high Tsys and low efficiency.

1 cm: The best system is at PT with an SEFD of 780 Jy. Most of the systems are better than about 1000 Jy. BR is about 1220 Jy, at least partially because of problems with the surface. SC is the worst with SEFDs of about 1700 Jy. The problem is partly atmosphere, but also the receiver seems poor. At this frequency, a significant seasonal effect is clear in the system temperature data.

For amusement, the following table gives the minimum and typical zenith atmosphere temperatures for each VLBA site for 1cm and 7mm for the observations used to derive the gain histories. The high end of the range for each site is rather arbitrary since the opacity can be very high during bad weather. Values up to about twice the "typical" value are seen in decent observations. The numbers are eyeball values taken from plots of the history. Single, highly discrepant values have been ignored. It would appear from these data that the continental sites are rather similar while the island sites provide the extremes in both directions. Beware that the 7mm data are based on only about 6 to 10 experiments. Note that, while the best 1cm days seem to be a bit better than the best 7mm days, the scatter and the typical values are worse at 1cm then at 7mm because of the influence of water vapor.

Zenith Atmosphere Temperatures

	1cm		7mm	
Site	Min.	Typ.	Min.	Typ.
SC	30	50	30	35
HN	10	22	15	20
NL	10	22	15	20
FD	10	18	15	20
LA	8	18	12	18
PT	8	20	12	16
KP	7	18	11	16
OV	10	18	12	14
BR	10	24	16	20
MK	6	10	5	7

7mm: Most of the efficiency data are taken from Jupiter measurements by Vivek and others. The stand out best system is at MK with an SEFD of about 750 Jy. This is better than the best 1 cm system! However the next best is KP at over 1000 Jy and others lag even more. The worst is BR, most likely because of the surface. The Tsys is similar to other sites. The

overall system would be much better if all sites performed at least as well as LA and KP and it would be great if a few more could match MK.

APPENDIX

A Robust Averaging and Fitting.

At several stages of the process of deriving the various sensitivity related values reported here, averages are taken. First averges over individual observations in an experiment are made. Then averages are made over the various experiments. In all cases, robust averaging schemes that try to ignore seriously deviant points are used. Conceptually similar methods are used in the fitting for receiver temperature (and also for pointing parameters, but that is not the subject of this memo). These methods seem to work well. The details of the algorithms used are of my own devising and are based mainly on what seems to work empirically rather than on anything with a solid theoretical basis. I thank Kari Leppanen for the basic idea behind them.

B Software

The programs and major files currently used for pointing and gain analysis are listed below.

mkpoint: Make sched input files for specific UT time ranges from LST templates.

sched: Make telescope control files.

tsm: Read monitor data and derive pointing offsets, antenna temperatures etc.

ptanal: Derive gains, pointing equations etc from tsm data.

Best_ptanal.com: Command file to rerun ptanal on all good experiments.

getsummary: Gather results from many observations from the ptanal outputs.

newgain: Reads the old gains file and the getsummary output and creates a new gains file. The latest value of TCAL and average values for TS and DPFU are substituted for the values in the input gains file.

gaintable: Create tables like those in this memo for a specific time using information in the gains file.

plotts: Make Tsys and efficiency plots like those in this memo using the gains file and the getsummary output file.

plotsum: Interactively plot a page of 8 plots of various gain related parameters for a requested band and station using the getsummary output and gains files.

pointing: This memo is concerned with sensitivity, not pointing, so the pointing related programs will just be mentioned. They are `plotptg` which plots pointing histories from getsummary output, `plottilt` which does just the tilt terms, `rotpat` which helps set up schedule for measurements of focus and rotation, and `rotanal` which analyzes focus/rotation observations.

CAL TEMPERATURES

St	P	90cm	50cm	20cm	13cm	13cmsx	6cm	4cm	4cmsx	3cm	2cm	1cm	7mm
SC	RCP:	7.70	4.00	0.80	1.26	1.26	2.39	3.48	3.48	----	2.71	14.21	5.46
	LCP:	6.90	4.00	0.94	1.34	1.34	2.39	3.44	3.44	----	2.78	13.96	5.37
HN	RCP:	8.00	4.69	2.28	1.20	1.20	1.40	2.59	2.59	----	3.20	11.42	6.90
	LCP:	9.00	4.60	2.27	1.48	1.48	1.30	2.77	2.77	----	2.91	11.44	6.90
NL	RCP:	6.00	5.10	1.74	1.02	1.02	3.47	4.03	4.03	----	3.16	10.27	8.81
	LCP:	6.00	4.60	1.84	1.12	1.12	3.79	4.08	4.08	----	2.71	9.43	5.85
FD	RCP:	11.75	5.86	3.34	2.82	2.82	3.34	3.89	3.89	----	3.85	3.71	12.48
	LCP:	11.07	6.06	3.43	2.00	2.00	3.26	3.81	3.81	----	3.92	3.63	13.33
LA	RCP:	8.90	5.70	3.60	0.92	0.92	3.43	3.56	3.56	----	3.03	3.08	7.36
	LCP:	9.30	5.70	3.69	1.28	1.28	3.40	3.71	3.71	----	2.93	3.38	6.56
PT	RCP:	0.00	0.00	2.70	2.42	2.42	2.89	3.52	3.52	4.12	1.90	7.82	8.48
	LCP:	0.00	0.00	2.59	2.62	2.62	3.07	3.96	3.96	3.86	1.66	10.03	16.63
KP	RCP:	10.20	6.90	3.07	1.42	1.42	2.63	3.71	3.71	----	2.95	23.38	7.01
	LCP:	10.00	6.70	3.06	1.52	1.52	2.37	3.48	3.48	----	2.70	23.97	10.14
OV	RCP:	7.00	4.00	2.81	1.52	1.52	1.09	3.42	3.42	----	4.30	1.00	14.60
	LCP:	6.50	4.00	2.81	1.32	1.32	1.20	3.69	3.69	----	3.98	1.06	11.45
BR	RCP:	7.20	4.00	2.87	1.04	1.04	1.86	2.21	2.21	----	3.61	3.53	5.54
	LCP:	7.10	4.00	2.64	1.02	1.02	1.79	2.94	2.94	----	3.79	3.72	8.37
MK	RCP:	5.30	4.20	3.39	1.24	1.24	1.40	4.13	4.13	----	3.92	3.43	1.99
	LCP:	5.30	4.20	3.56	1.62	1.62	1.30	3.79	3.79	----	3.49	3.09	2.62

GAIN (K/Jy)

St	P	90cm	50cm	20cm	13cm	13cmsx	6cm	4cm	4cmsx	3cm	2cm	1cm	7mm
SC	RCP:	0.111	0.088	0.081	0.075	0.064	0.133	0.112	0.107	----	0.104	0.107	0.085
	LCP:	0.111	0.092	0.101	0.076	0.063	0.131	0.120	0.116	----	0.106	0.107	0.085
HN	RCP:	0.088	0.075	0.119	0.096	0.079	0.129	0.095	0.092	----	0.113	0.094	0.063
	LCP:	0.105	0.081	0.099	0.112	0.091	0.131	0.097	0.094	----	0.114	0.095	0.063
NL	RCP:	0.103	0.093	0.070	0.082	0.066	0.126	0.108	0.106	----	0.113	0.099	0.079
	LCP:	0.111	0.088	0.074	0.092	0.075	0.101	0.111	0.109	----	0.108	0.099	0.079
FD	RCP:	0.100	0.089	0.099	0.109	0.091	0.120	0.125	0.120	----	0.122	0.131	0.098
	LCP:	0.096	0.094	0.101	0.105	0.086	0.126	0.117	0.112	----	0.123	0.114	0.098
LA	RCP:	0.096	0.090	0.092	0.081	0.068	0.146	0.125	0.118	----	0.133	0.100	0.097
	LCP:	0.099	0.090	0.126	0.095	0.082	0.136	0.119	0.114	----	0.128	0.108	0.097
PT	RCP:	0.151	0.064	0.116	0.087	0.076	0.137	0.129	0.117	0.130	0.102	0.125	0.098
	LCP:	0.189	0.071	0.109	0.101	0.091	0.139	0.123	0.107	0.165	0.114	0.128	0.098
KP	RCP:	0.091	0.098	0.096	0.079	0.065	0.146	0.124	0.111	----	0.124	0.104	0.096
	LCP:	0.094	0.097	0.101	0.079	0.066	0.138	0.125	0.118	----	0.115	0.112	0.096
OV	RCP:	0.116	0.087	0.086	0.102	0.083	0.143	0.092	0.090	----	0.106	0.063	0.086
	LCP:	0.110	0.094	0.108	0.113	0.092	0.149	0.098	0.097	----	0.103	0.067	0.086
BR	RCP:	0.102	0.087	0.098	0.086	0.072	0.115	0.113	0.112	----	0.114	0.088	0.053
	LCP:	0.113	0.089	0.097	0.102	0.086	0.109	0.123	0.121	----	0.107	0.086	0.053
MK	RCP:	0.077	0.102	0.098	0.088	0.073	0.144	0.128	0.124	----	0.121	0.095	0.086
	LCP:	0.078	0.094	0.101	0.122	0.101	0.142	0.125	0.118	----	0.120	0.088	0.086

SYSTEM TEMPERATURES

St	P	90cm	50cm	20cm	13cm	13cmsx	6cm	4cm	4cmsx	3cm	2cm	1cm	7mm
SC	RCP:	256.	201.	25.	27.	29.	46.	35.	44.	----	60.	174.	129.
	LCP:	252.	284.	36.	28.	28.	42.	46.	56.	----	64.	192.	134.
HN	RCP:	180.	168.	38.	39.	40.	37.	32.	41.	----	68.	97.	100.
	LCP:	210.	176.	35.	46.	47.	42.	34.	43.	----	73.	97.	111.
NL	RCP:	227.	203.	24.	32.	33.	47.	45.	52.	----	63.	98.	118.
	LCP:	246.	212.	26.	36.	37.	41.	48.	55.	----	59.	102.	107.
FD	RCP:	238.	201.	27.	32.	35.	37.	33.	39.	----	51.	103.	99.
	LCP:	216.	205.	27.	31.	33.	42.	31.	38.	----	54.	89.	117.
LA	RCP:	210.	197.	28.	30.	31.	43.	42.	50.	----	67.	71.	107.
	LCP:	221.	190.	37.	35.	35.	40.	36.	43.	----	64.	94.	106.
PT	RCP:	0.	0.	32.	35.	35.	44.	39.	47.	93.	45.	97.	141.
	LCP:	0.	0.	31.	40.	41.	46.	36.	45.	93.	47.	102.	111.
KP	RCP:	194.	185.	31.	34.	36.	44.	33.	42.	----	51.	101.	102.
	LCP:	199.	191.	32.	33.	36.	44.	34.	43.	----	62.	104.	97.
OV	RCP:	242.	165.	33.	27.	28.	36.	50.	56.	----	47.	72.	104.
	LCP:	220.	175.	35.	33.	33.	41.	49.	54.	----	51.	73.	90.
BR	RCP:	219.	185.	29.	31.	32.	31.	39.	48.	----	70.	110.	103.
	LCP:	237.	182.	28.	39.	40.	31.	42.	51.	----	61.	107.	111.
MK	RCP:	201.	268.	31.	26.	27.	34.	31.	39.	----	50.	87.	70.
	LCP:	201.	240.	34.	38.	39.	38.	36.	45.	----	50.	88.	72.

EFFICIENCIES (Percent)

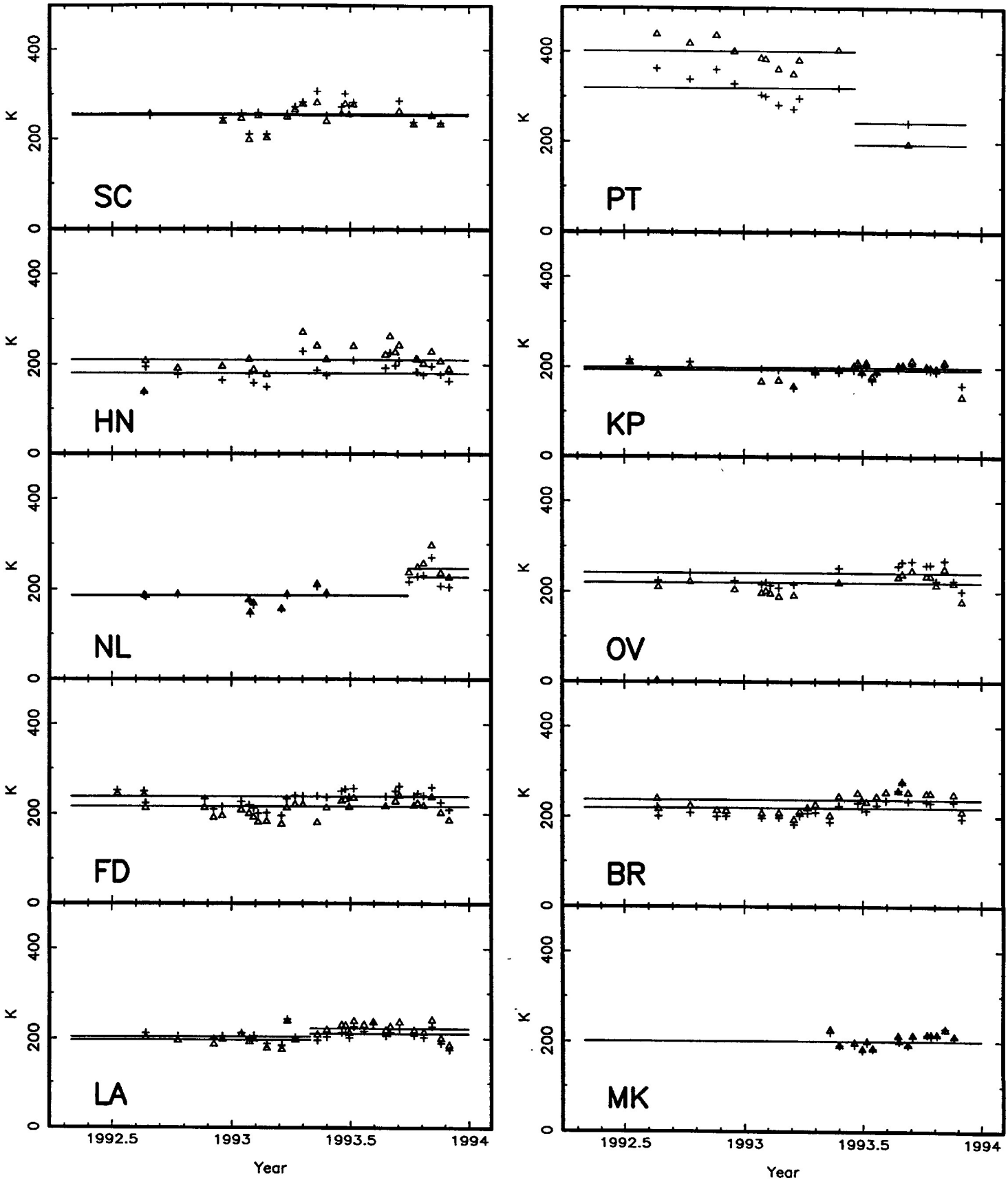
St	P	90cm	50cm	20cm	13cm	13cmsx	6cm	4cm	4cmsx	3cm	2cm	1cm	7mm
SC	RCP:	62	49	46	42	36	75	63	60	----	58	60	48
	LCP:	62	52	57	43	35	74	67	65	----	60	60	48
HN	RCP:	49	42	67	54	44	72	53	52	----	63	53	35
	LCP:	59	46	56	63	51	74	54	53	----	64	53	35
NL	RCP:	58	52	39	46	37	71	61	60	----	63	56	44
	LCP:	62	49	42	52	42	57	62	61	----	61	56	44
FD	RCP:	56	50	56	61	51	67	70	67	----	69	74	55
	LCP:	54	53	57	59	48	71	66	63	----	69	64	55
LA	RCP:	54	51	52	46	38	82	70	66	----	75	56	54
	LCP:	56	51	71	53	46	76	67	64	----	72	61	54
PT	RCP:	85	36	65	49	43	77	72	66	73	57	70	55
	LCP:	106	40	61	57	51	78	69	60	93	64	72	55
KP	RCP:	51	55	54	44	37	82	70	62	----	70	58	54
	LCP:	53	54	57	44	37	78	70	66	----	65	63	54
OV	RCP:	65	49	48	57	47	80	52	51	----	60	35	48
	LCP:	62	53	61	63	52	84	55	54	----	58	38	48
BR	RCP:	57	49	55	48	40	65	63	63	----	64	49	30
	LCP:	63	50	54	57	48	61	69	68	----	60	48	30
MK	RCP:	43	57	55	49	41	81	72	70	----	68	53	48
	LCP:	44	53	57	69	57	80	70	66	----	67	49	48

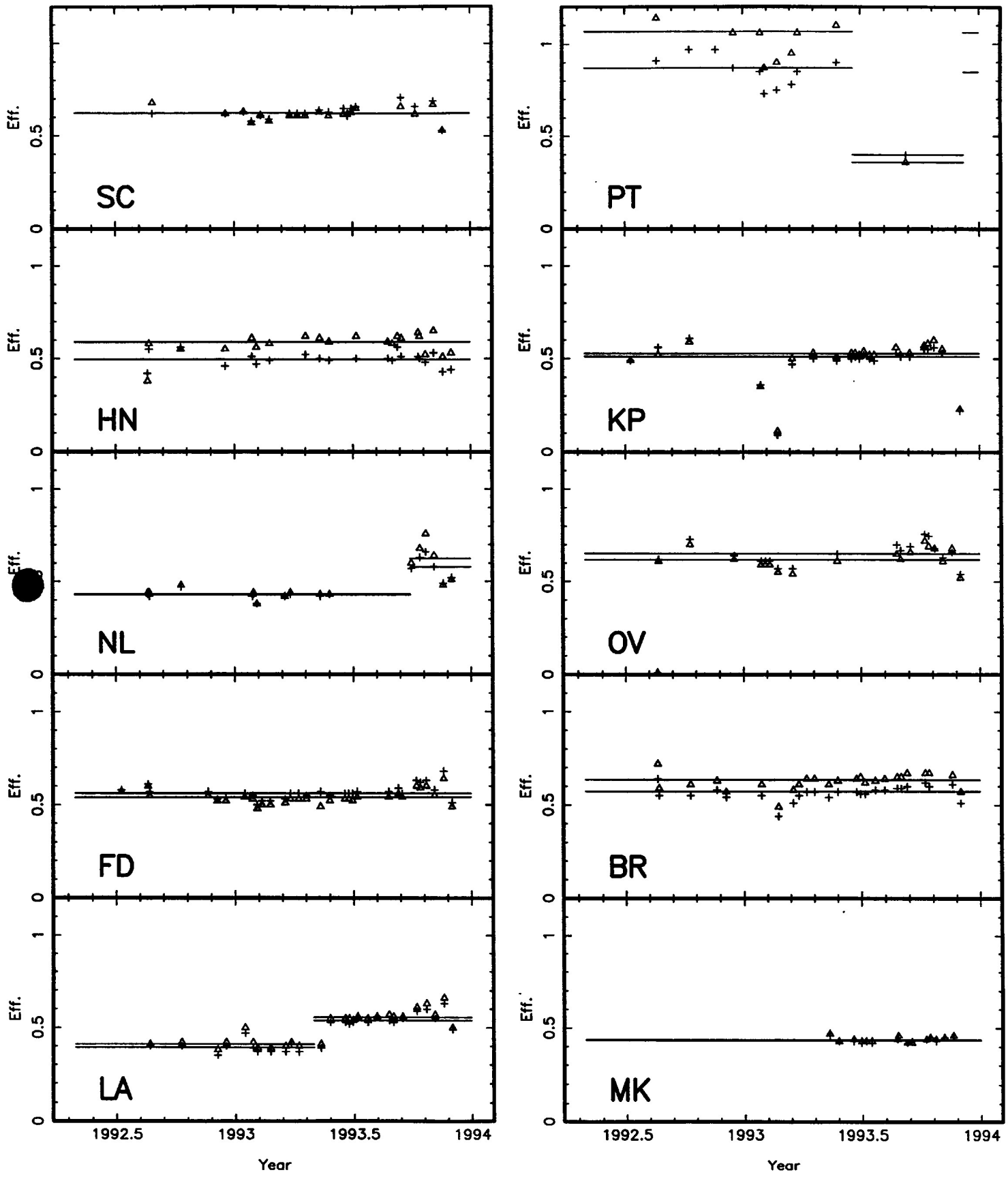
SEFD (System Equivalent Flux Density)

SEFD (System Equivalent Flux Density)

St	P	90cm	50cm	20cm	13cm	13cmsx	6cm	4cm	4cmsx	3cm	2cm	1cm	7mm
SC	RCP:	2306	2284	309	360	453	346	313	411	----	577	1626	1518
	LCP:	2270	3087	356	368	444	321	383	483	----	604	1794	1576
HN	RCP:	2045	2240	319	406	506	287	337	446	----	602	1032	1587
	LCP:	2000	2173	354	411	516	321	351	457	----	640	1021	1762
NL	RCP:	2204	2183	343	390	500	373	417	491	----	558	990	1494
	LCP:	2216	2409	351	391	493	406	432	505	----	546	1030	1354
FD	RCP:	2380	2258	273	294	385	308	264	325	----	418	786	1010
	LCP:	2250	2181	267	295	384	333	265	339	----	439	781	1194
LA	RCP:	2188	2189	304	370	456	295	336	424	----	504	710	1103
	LCP:	2232	2111	294	368	427	294	303	377	----	500	870	1093
PT	RCP:	0	0	276	402	461	321	302	402	715	441	776	1439
	LCP:	0	0	284	396	451	331	293	421	564	412	797	1133
KP	RCP:	2132	1888	323	430	554	301	266	378	----	411	971	1063
	LCP:	2117	1969	317	418	545	319	272	364	----	539	929	1010
OV	RCP:	2086	1897	384	265	337	252	543	622	----	443	1143	1209
	LCP:	2000	1862	324	292	359	275	500	557	----	495	1090	1047
BR	RCP:	2147	2126	296	360	444	270	345	429	----	614	1250	1943
	LCP:	2097	2045	289	382	465	284	341	421	----	570	1244	2094
MK	RCP:	2610	2627	316	295	370	236	242	315	----	413	916	814
	LCP:	2577	2553	337	311	386	268	288	381	----	417	1000	837

SYSTEM TEMPERATURES 90cm + RCP △ LCP




EFFICIENCY 90cm + RCP △ LCP
SC
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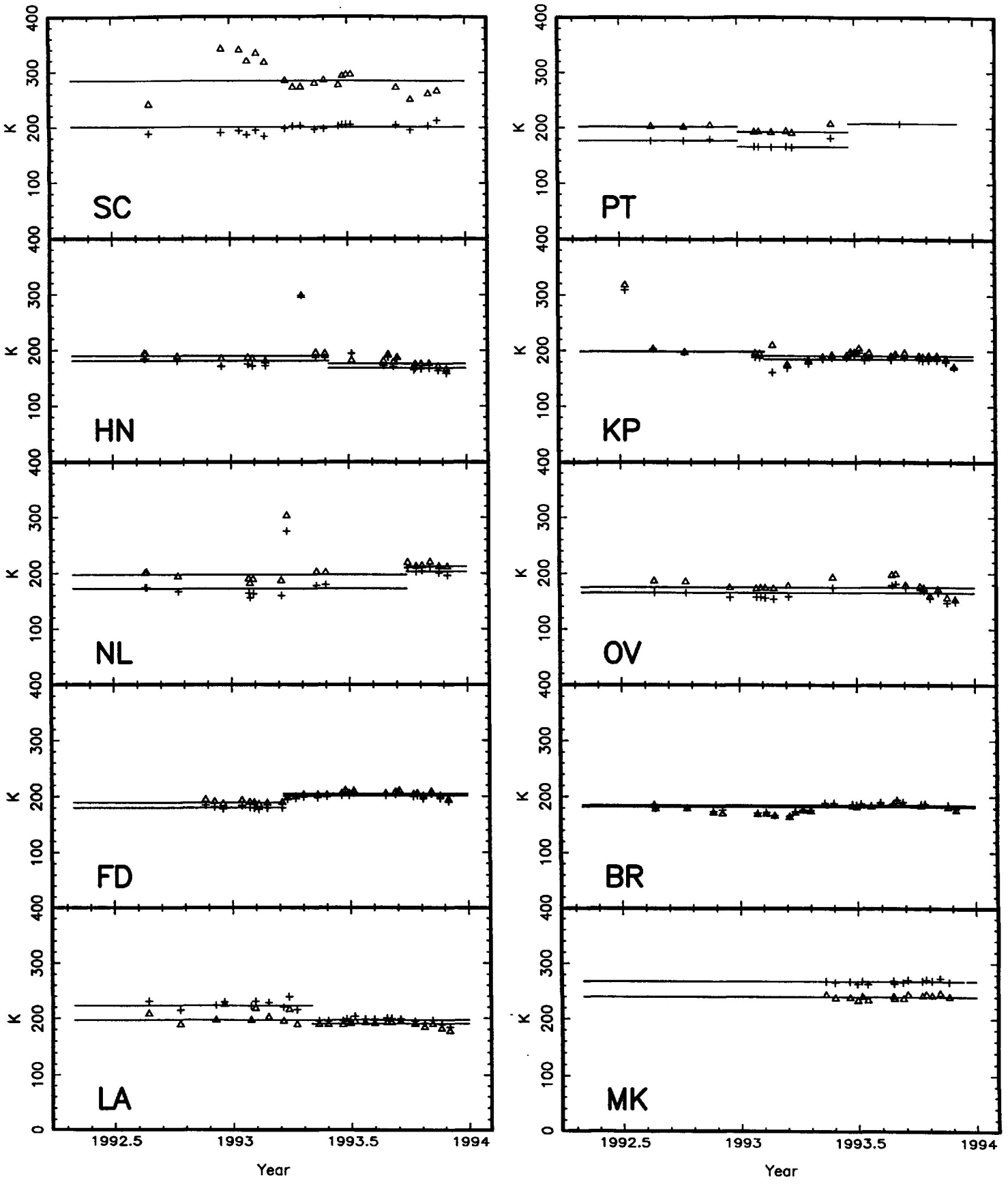
1994
Year


SYSTEM TEMPERATURES 50cm + RCP △ LCP
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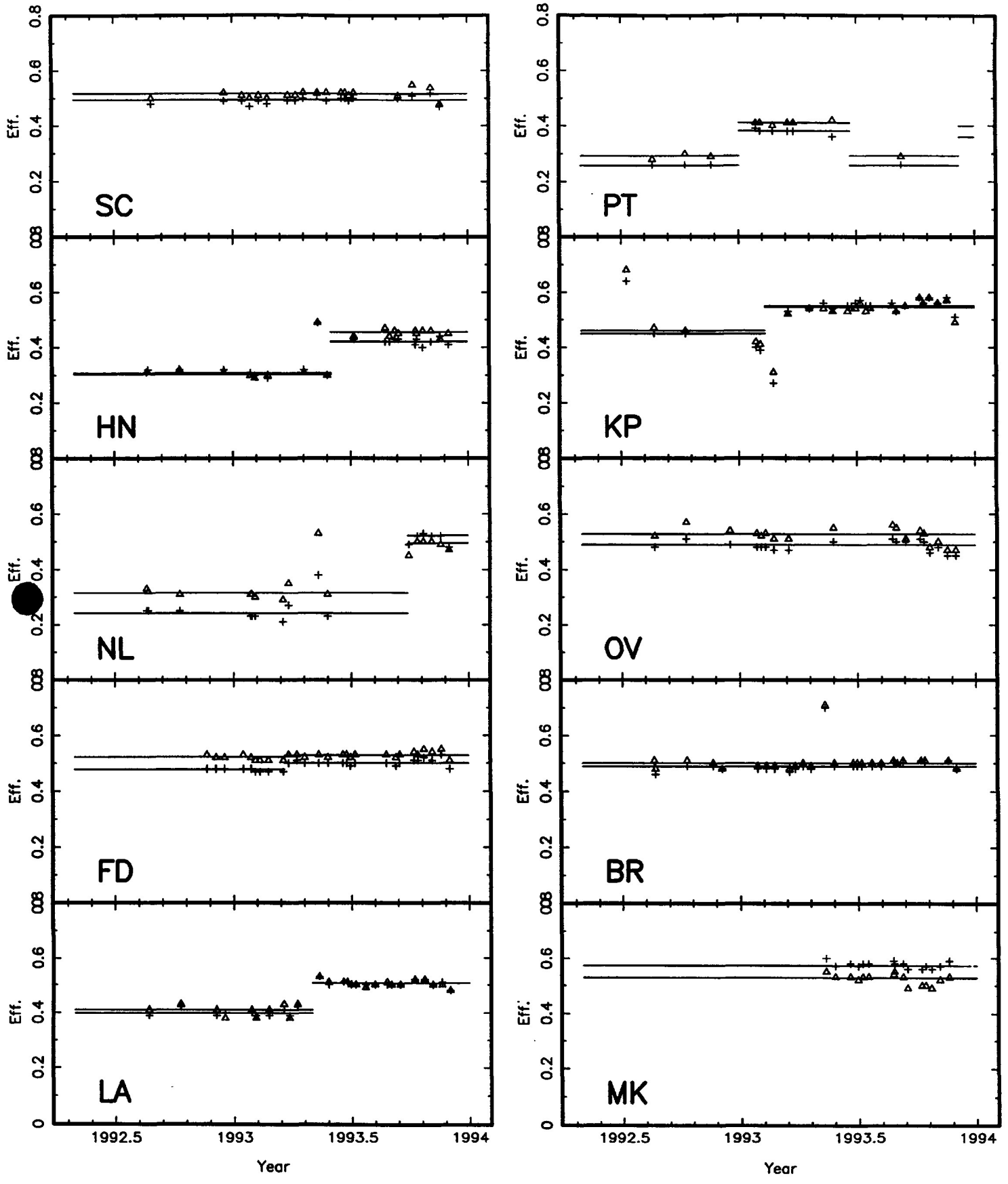
1994
Year


EFFICIENCY 50cm + RCP △ LCP
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LA
PT
KP
OV
BR
MK
Eff.
Year
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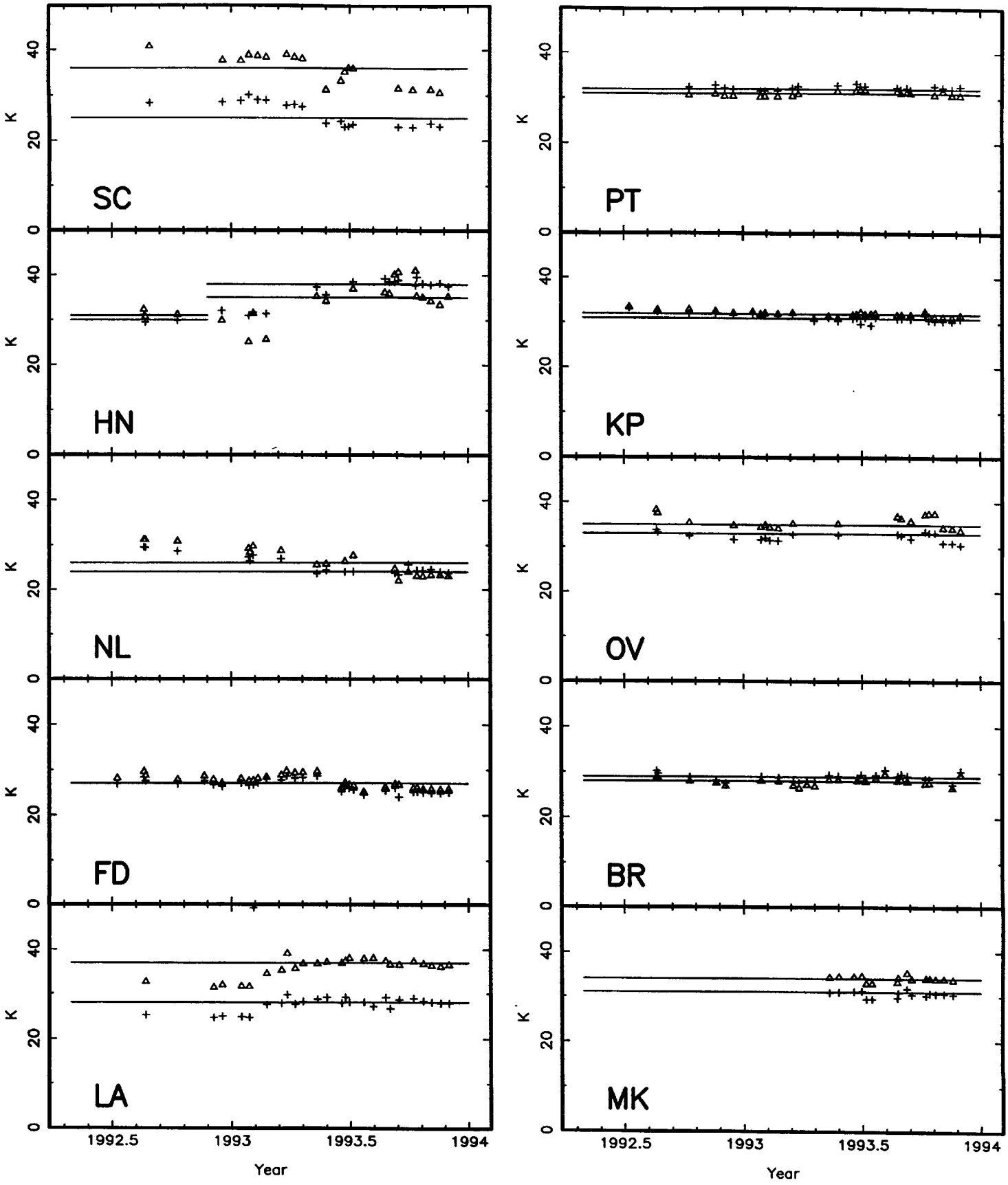
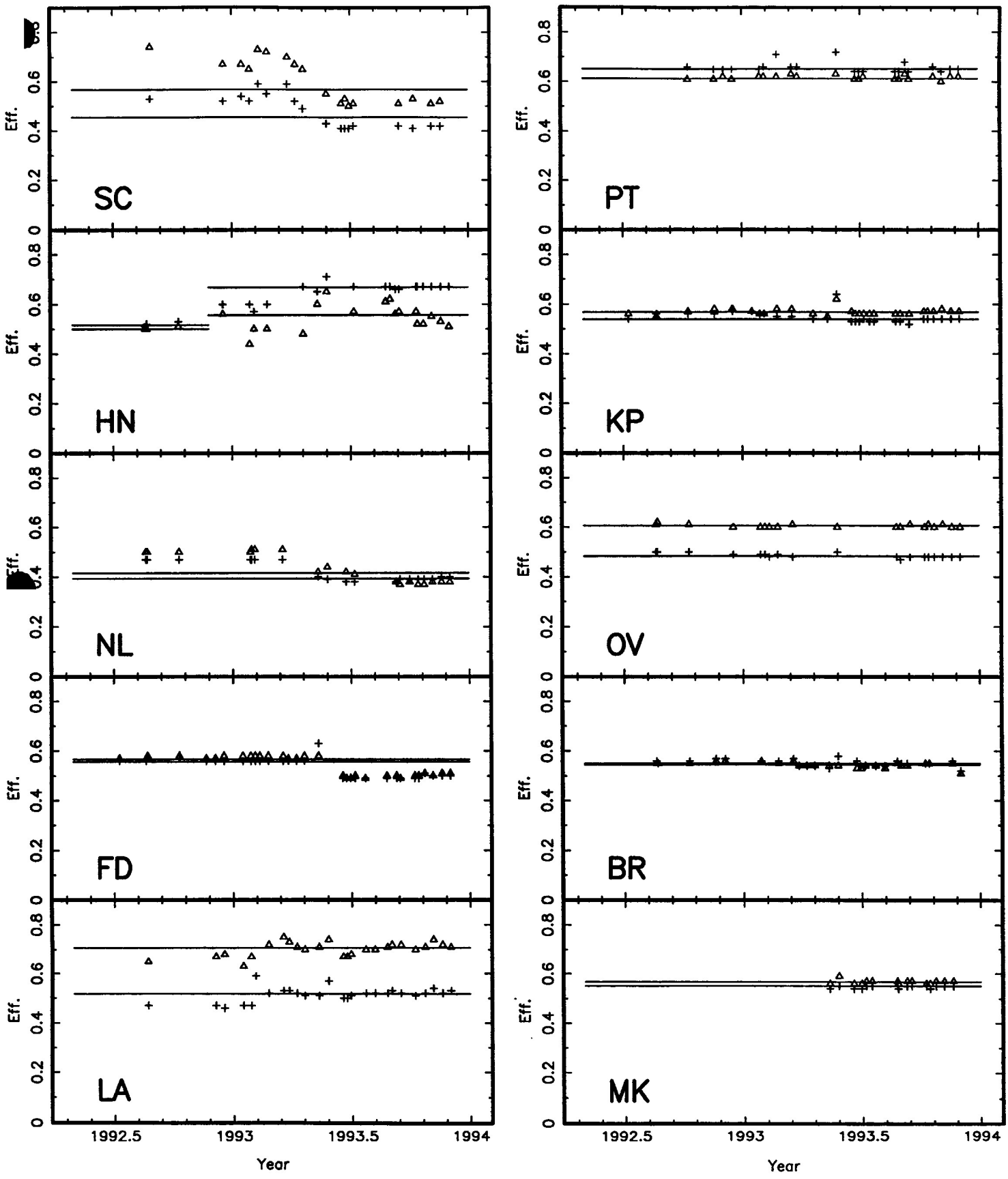
0.4
0.6
0.8
1992.5
1993
1993.5
1994

SYSTEM TEMPERATURES 20cm + RCP △ LCP




EFFICIENCY 20cm + RCP △ LCP
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HN
NL
FD
LA
PT
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MK
Eff.
Year
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1992.5
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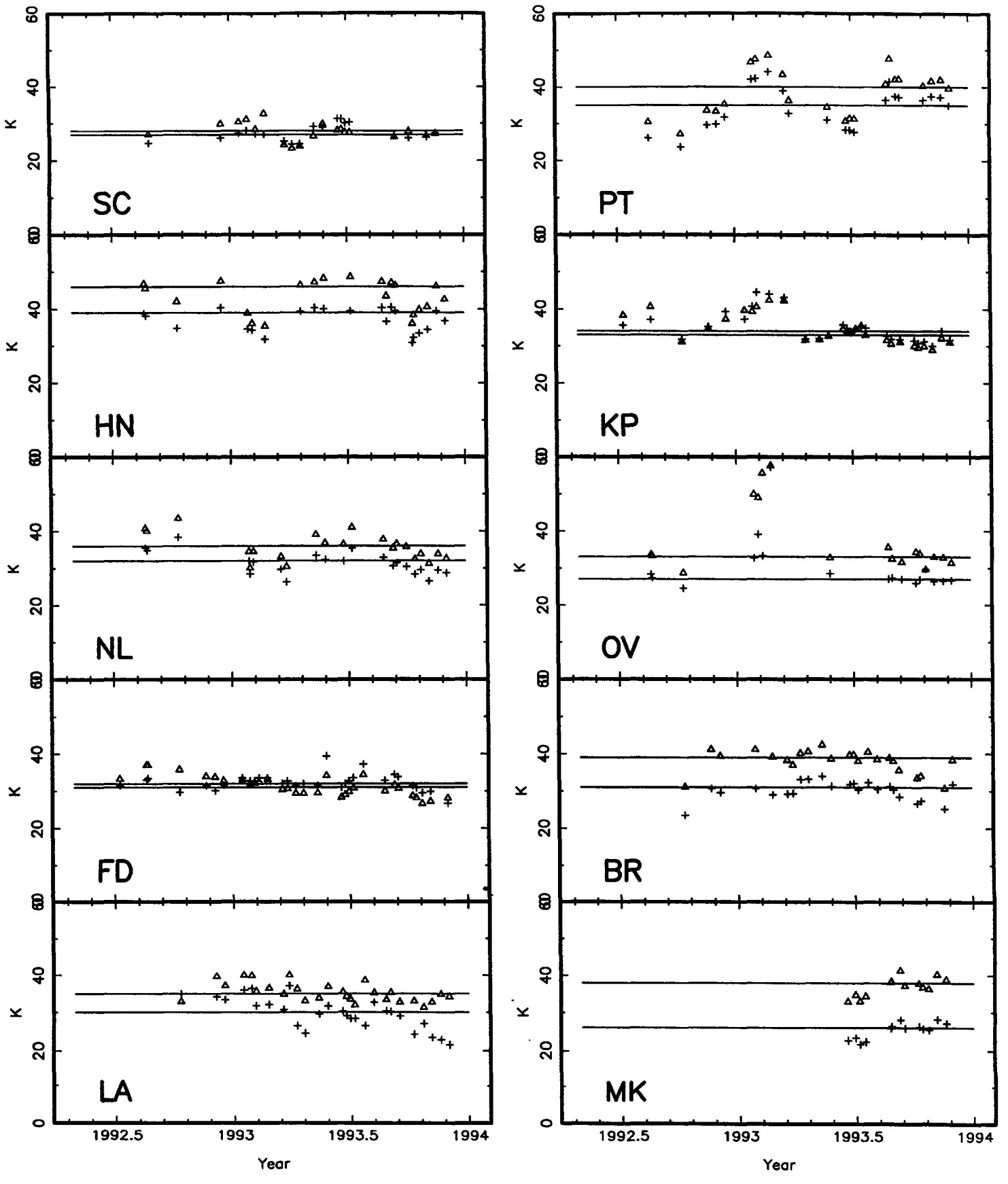
1993.5
1994


SYSTEM TEMPERATURES 13cm + RCP △ LCP
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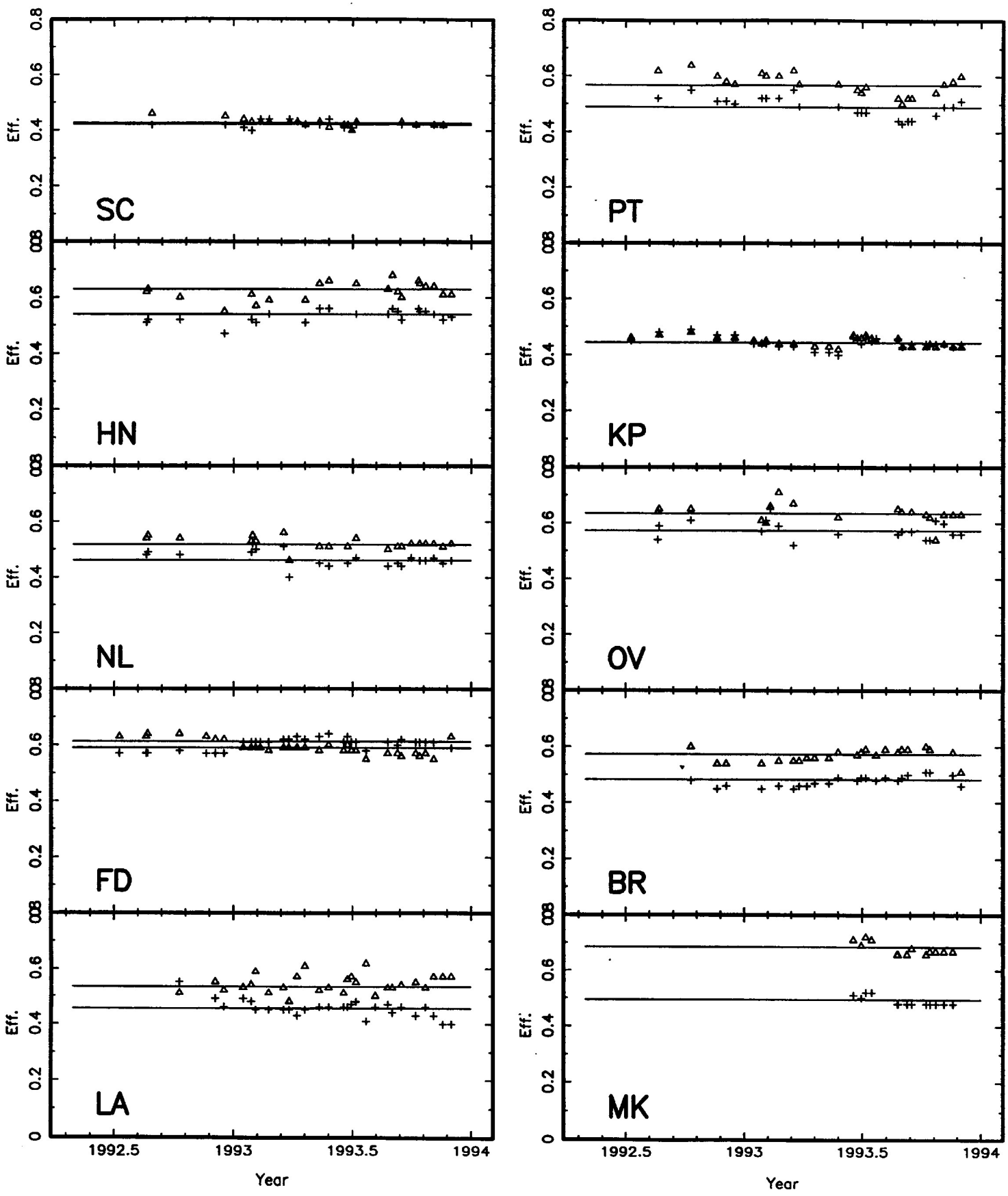
1993
1993.5
1994
Year


EFFICIENCY 13cm + RCP △ LCP
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HN
NL
FD
LA
PT
KP
OV
BR
MK
Eff.
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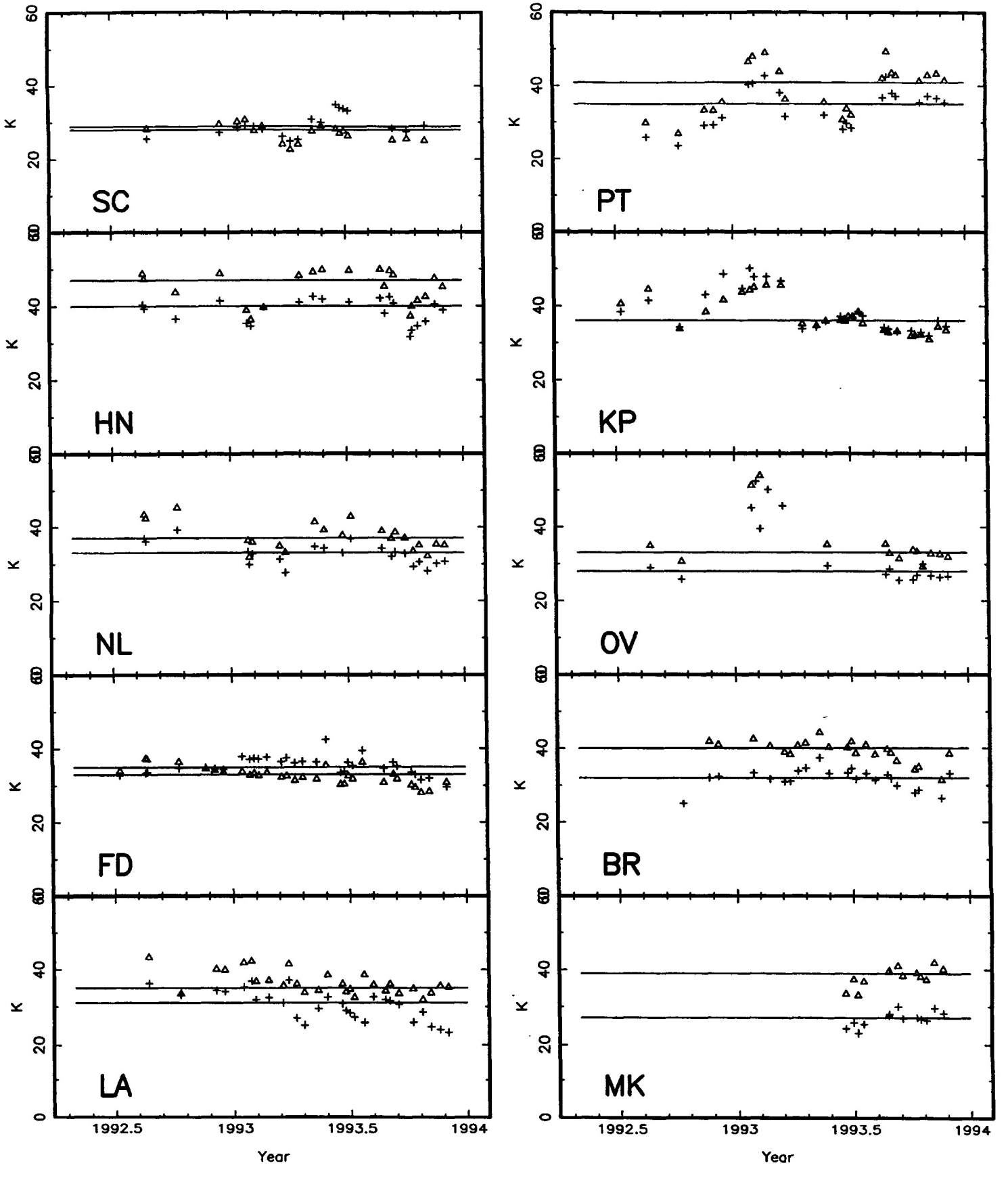
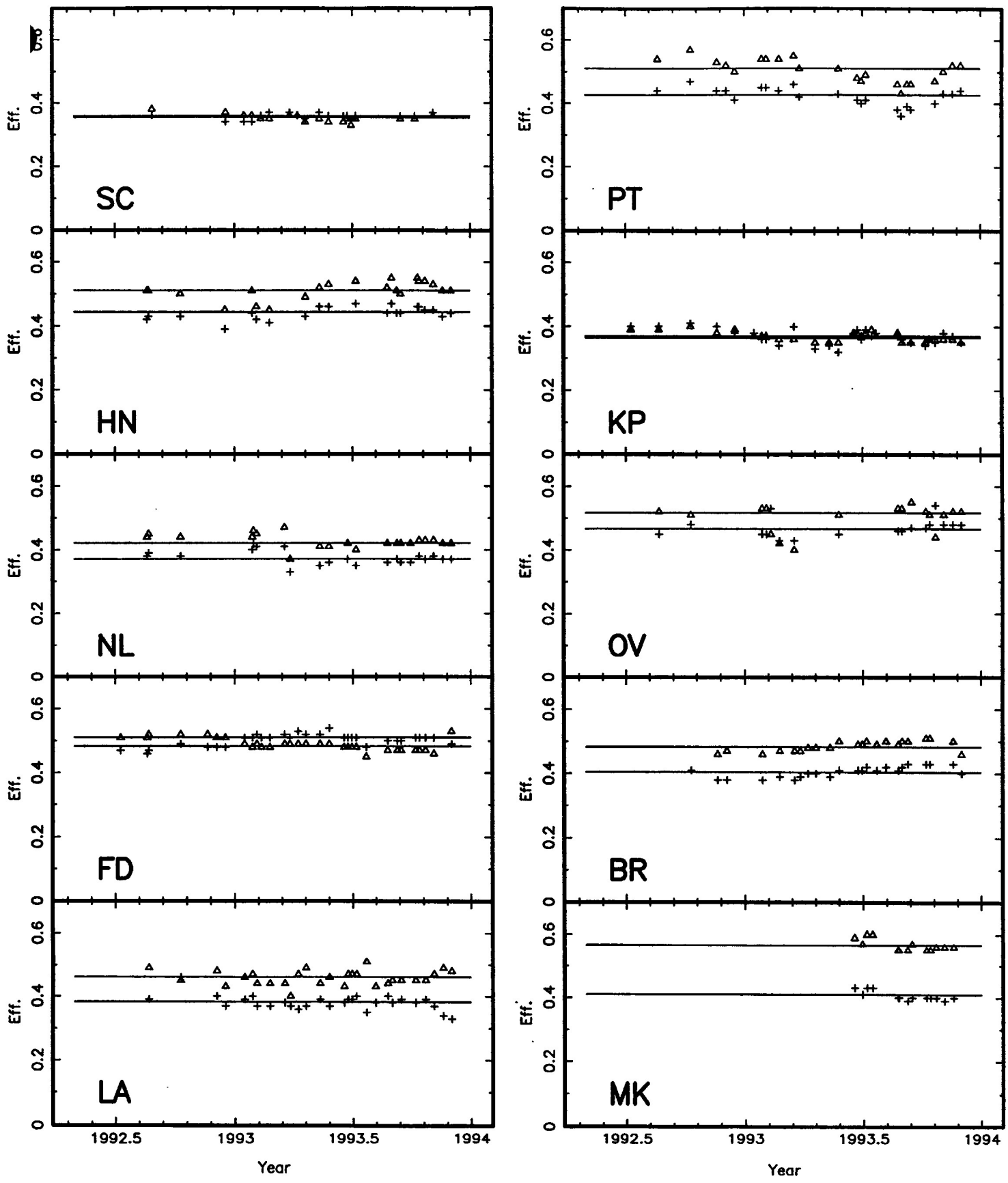
0.6
0.8
1992.5
1993
1993.5
1994
Year

SYSTEM TEMPERATURES 13cmsx + RCP △ LCP




EFFICIENCY 13cmsx + RCP △ LCP
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LA
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KP
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BR
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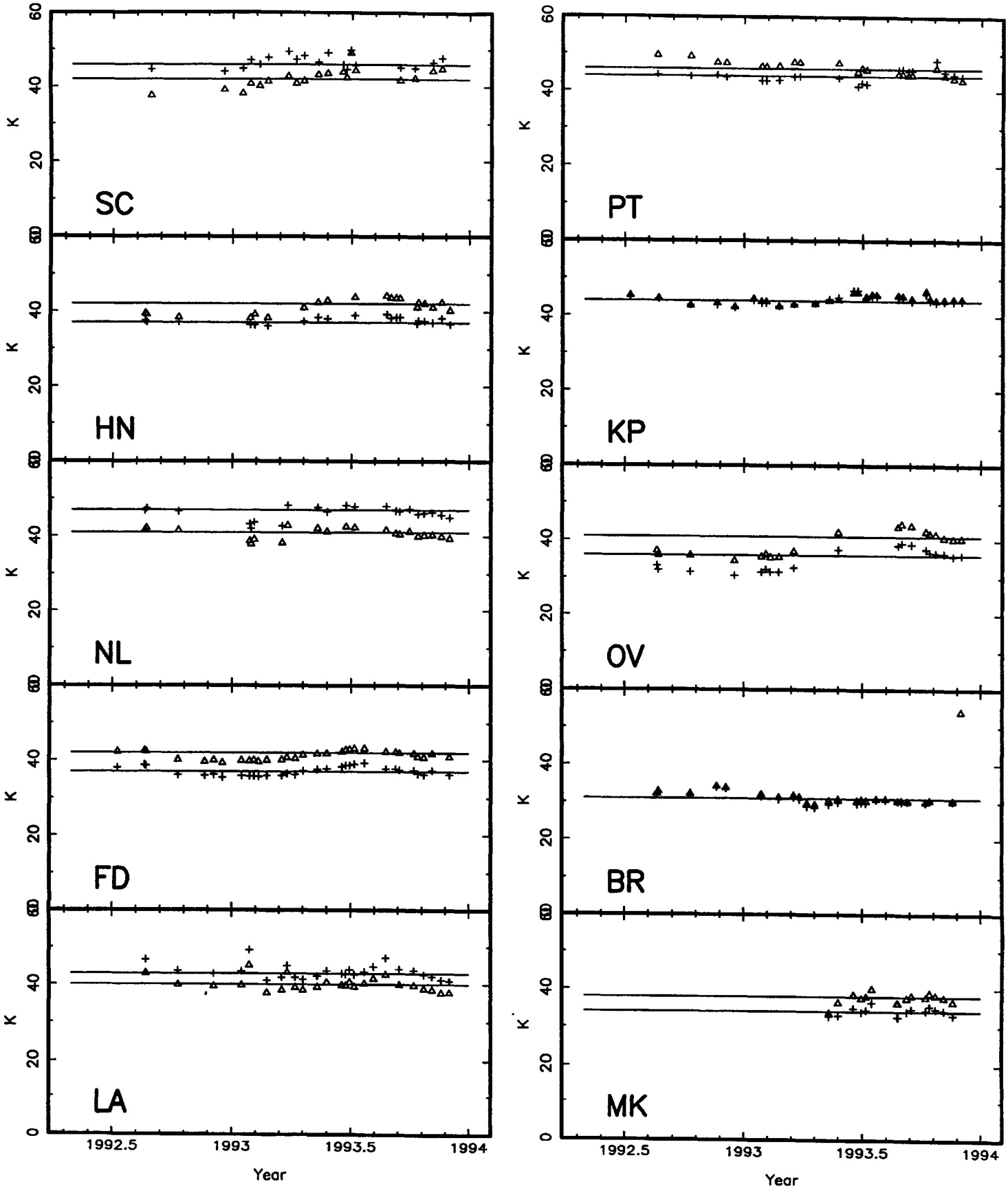
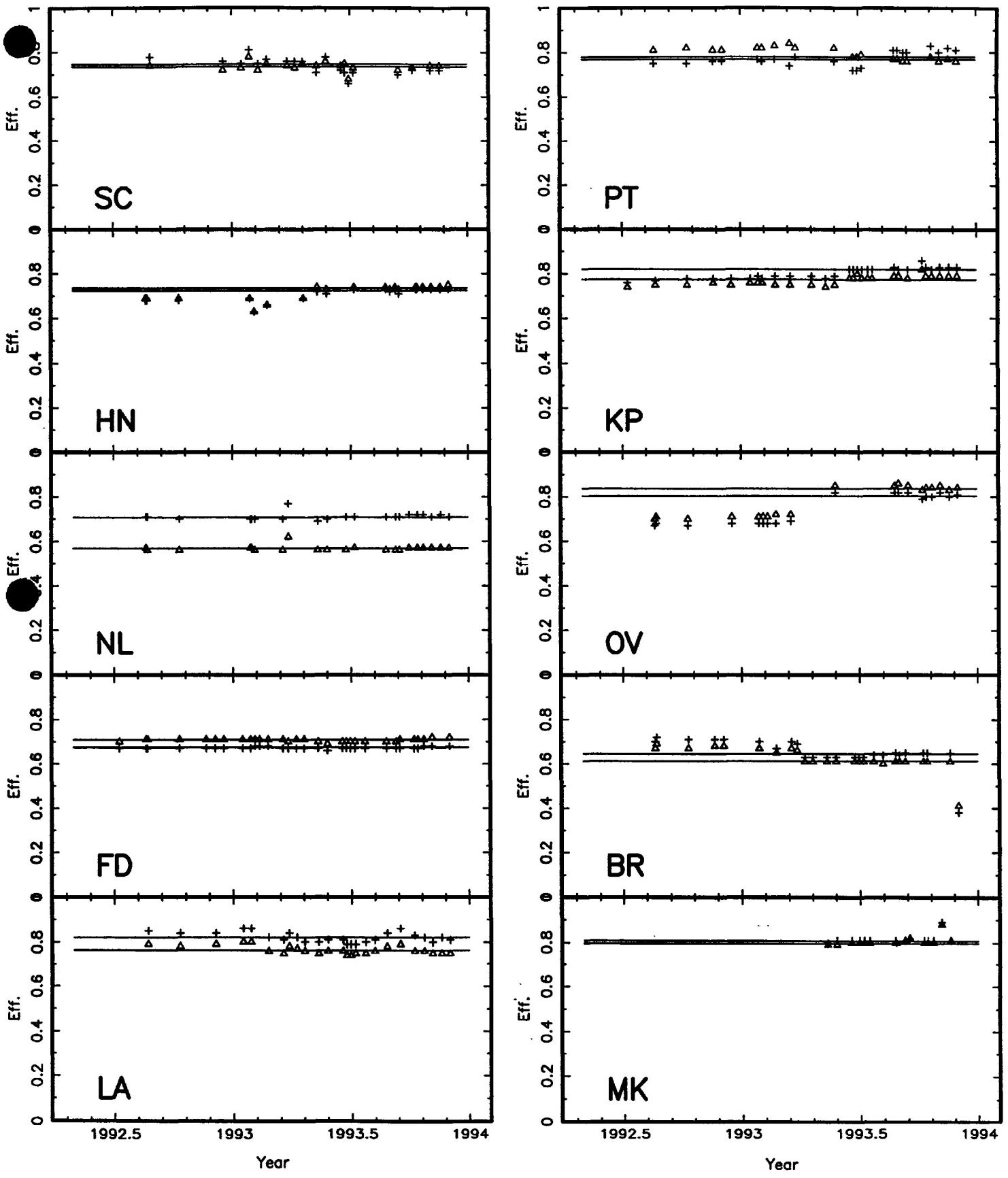
0.4
0.6
1992.5
1993
1993.5
1994
Year

SYSTEM TEMPERATURES 6cm + RCP △ LCP




EFFICIENCY 6cm + RCP △ LCP
SC
HN
NL
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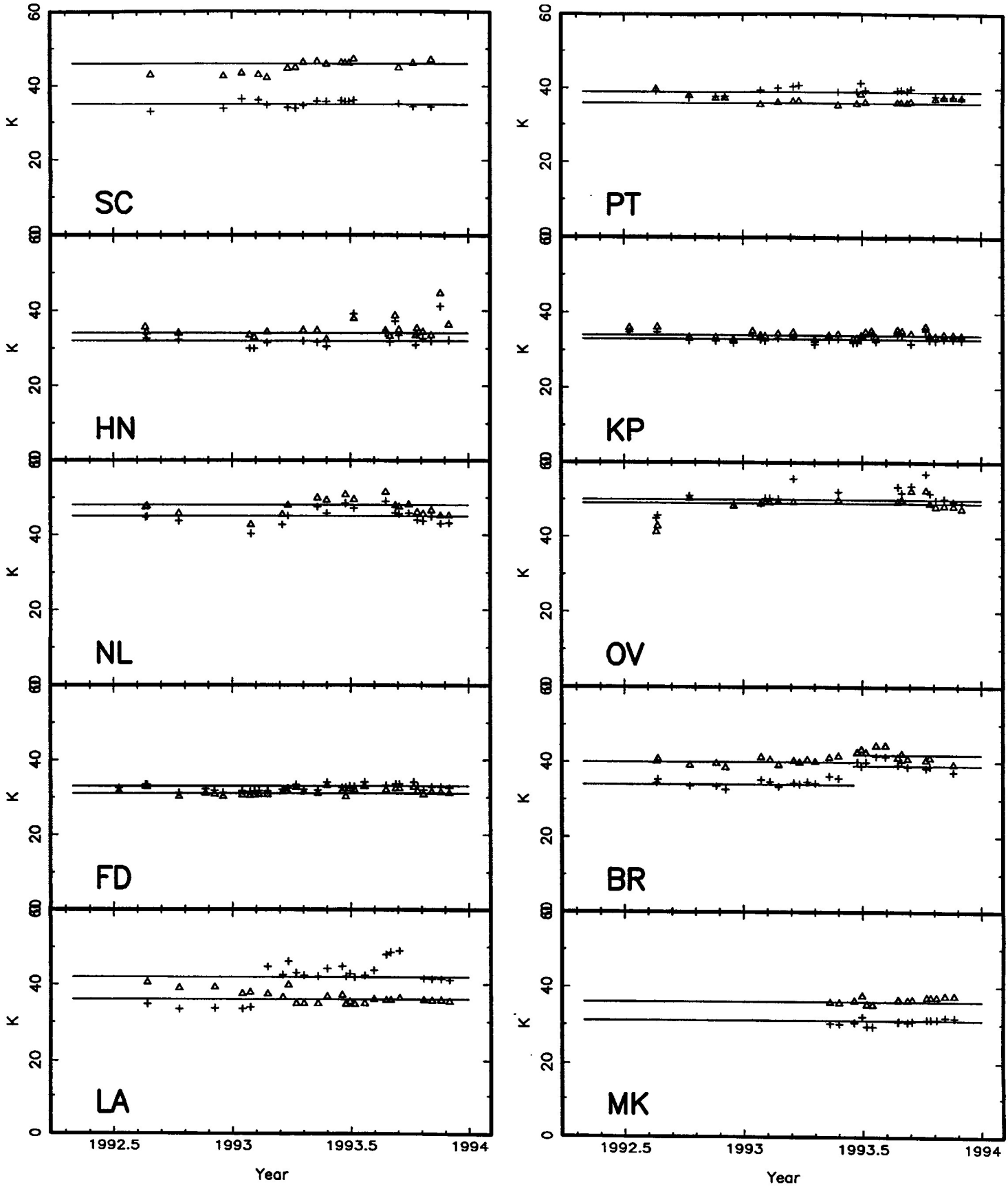
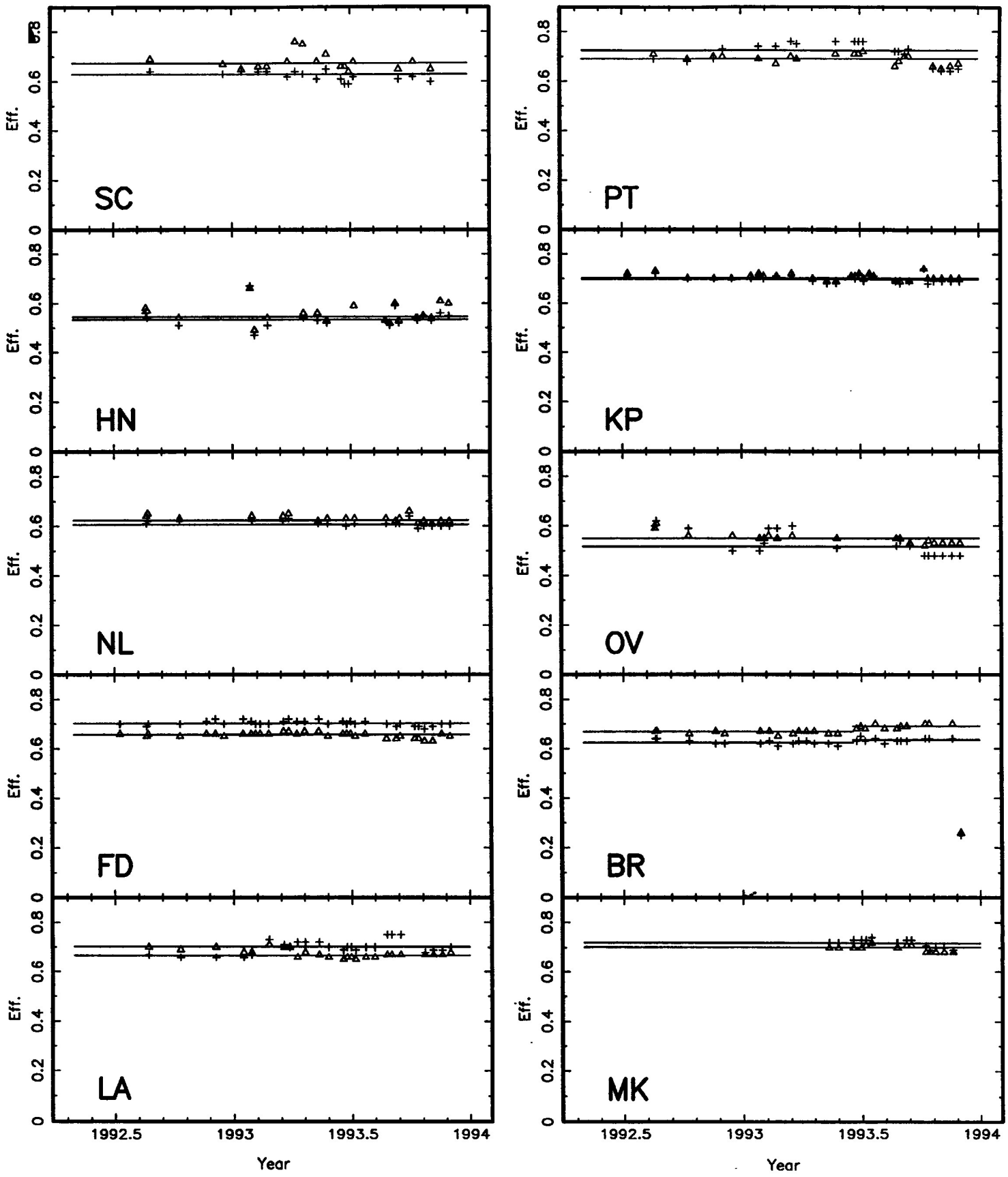
BR
MK
Eff.
Year
1992.5
1993
1993.5
1994

SYSTEM TEMPERATURES 4cm + RCP △ LCP




EFFICIENCY 4cm + RCP △ LCP
SC
PT
HN
KP
NL
OV
FD
BR
LA
MK
Eff.
Year
1992.5
1993
1993.5
1994
0
0.2
0.4
0.6
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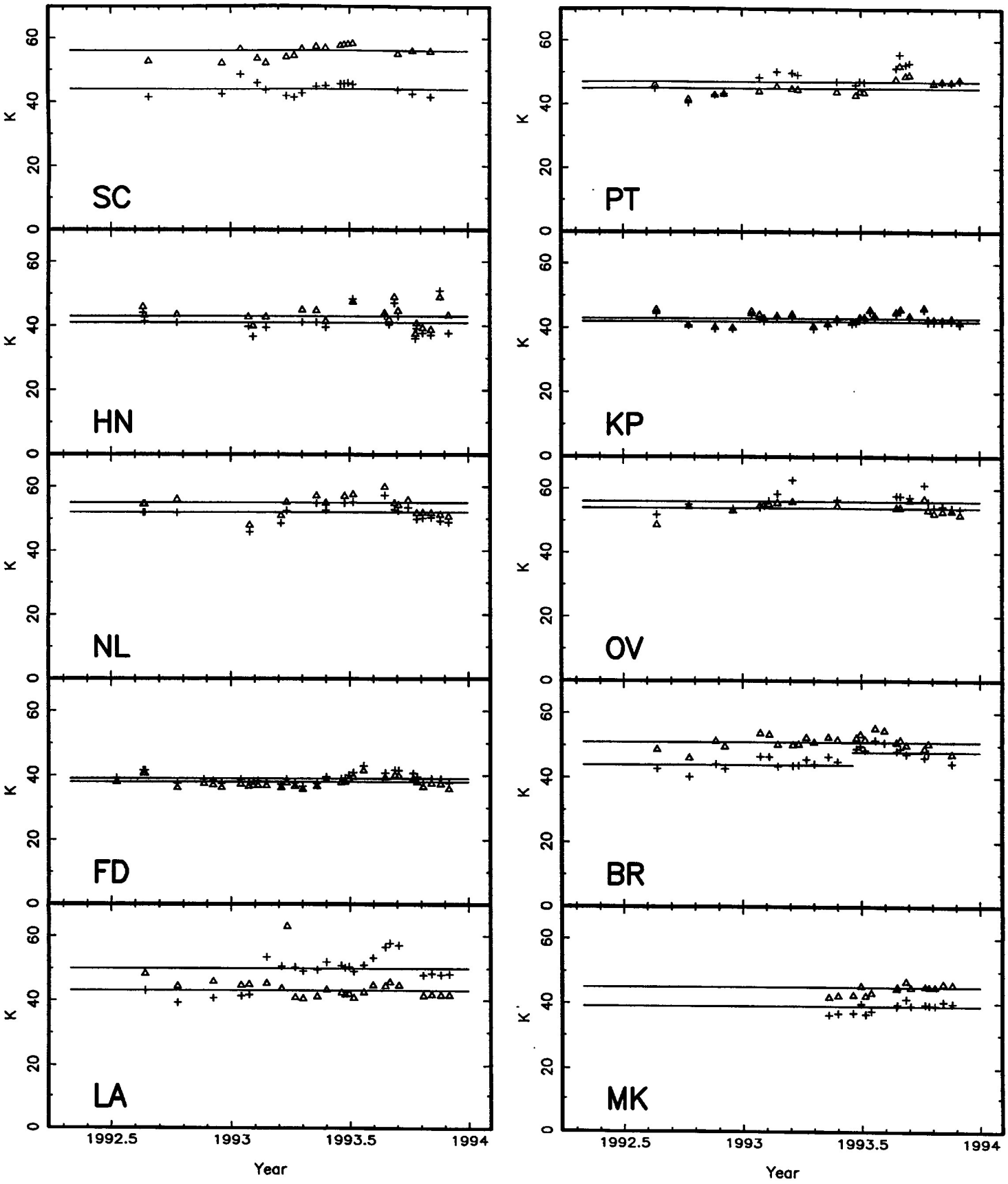
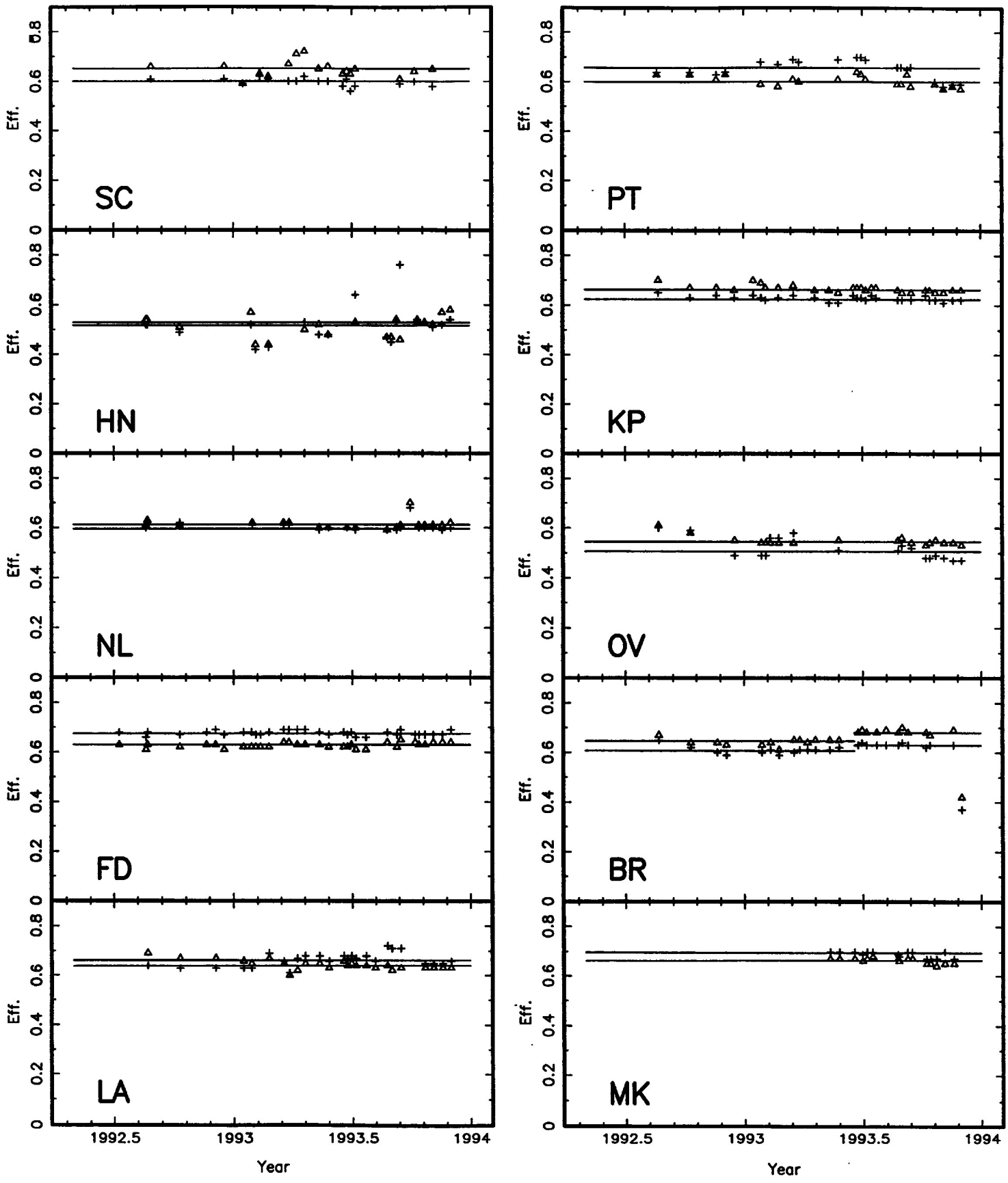
SYSTEM TEMPERATURES 4cmsx + RCP △ LCP




EFFICIENCY 4cmsx + RCP △ LCP
SC
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NL
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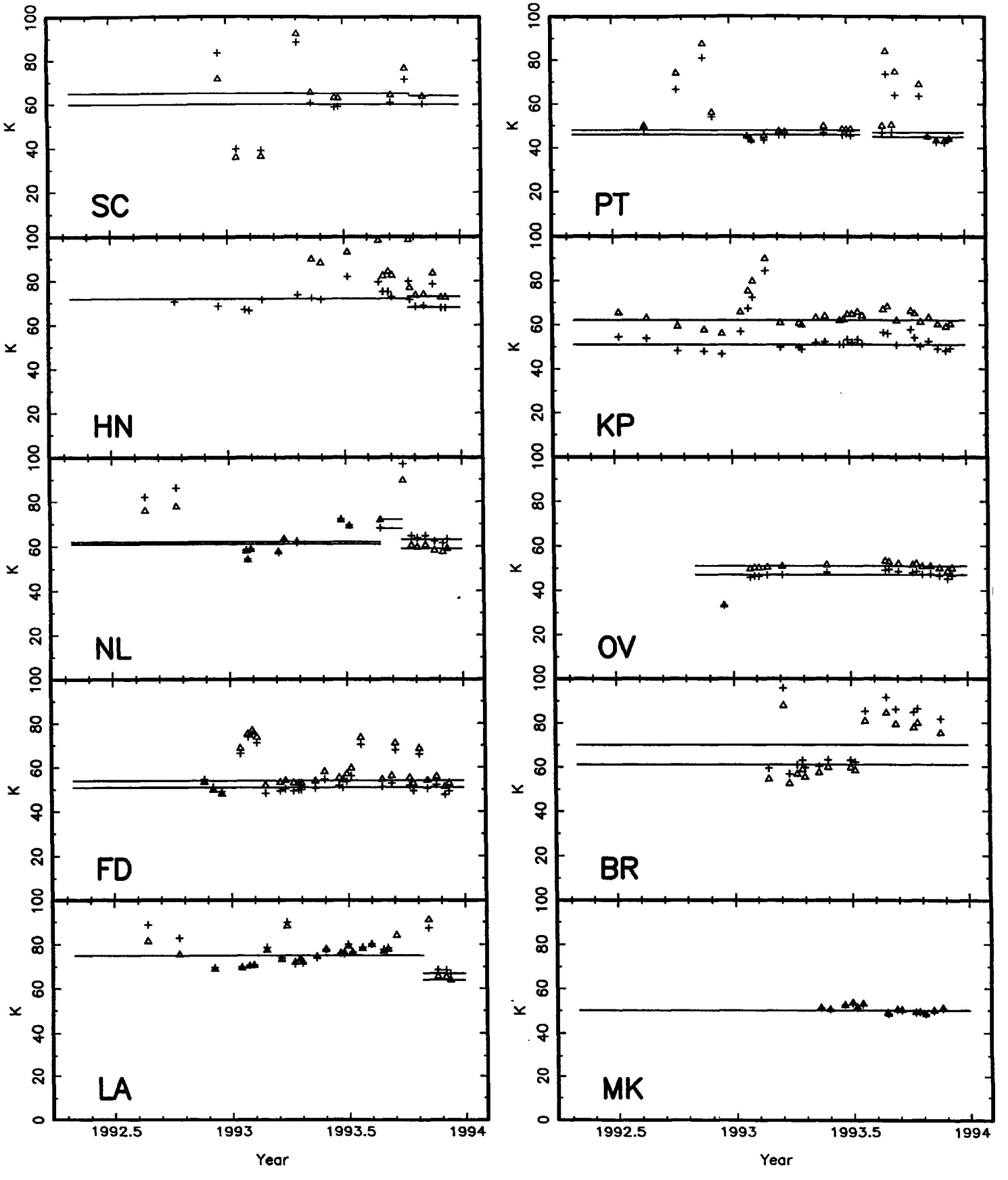
SYSTEM TEMPERATURES 2cm + RCP △ LCP
SC
HN
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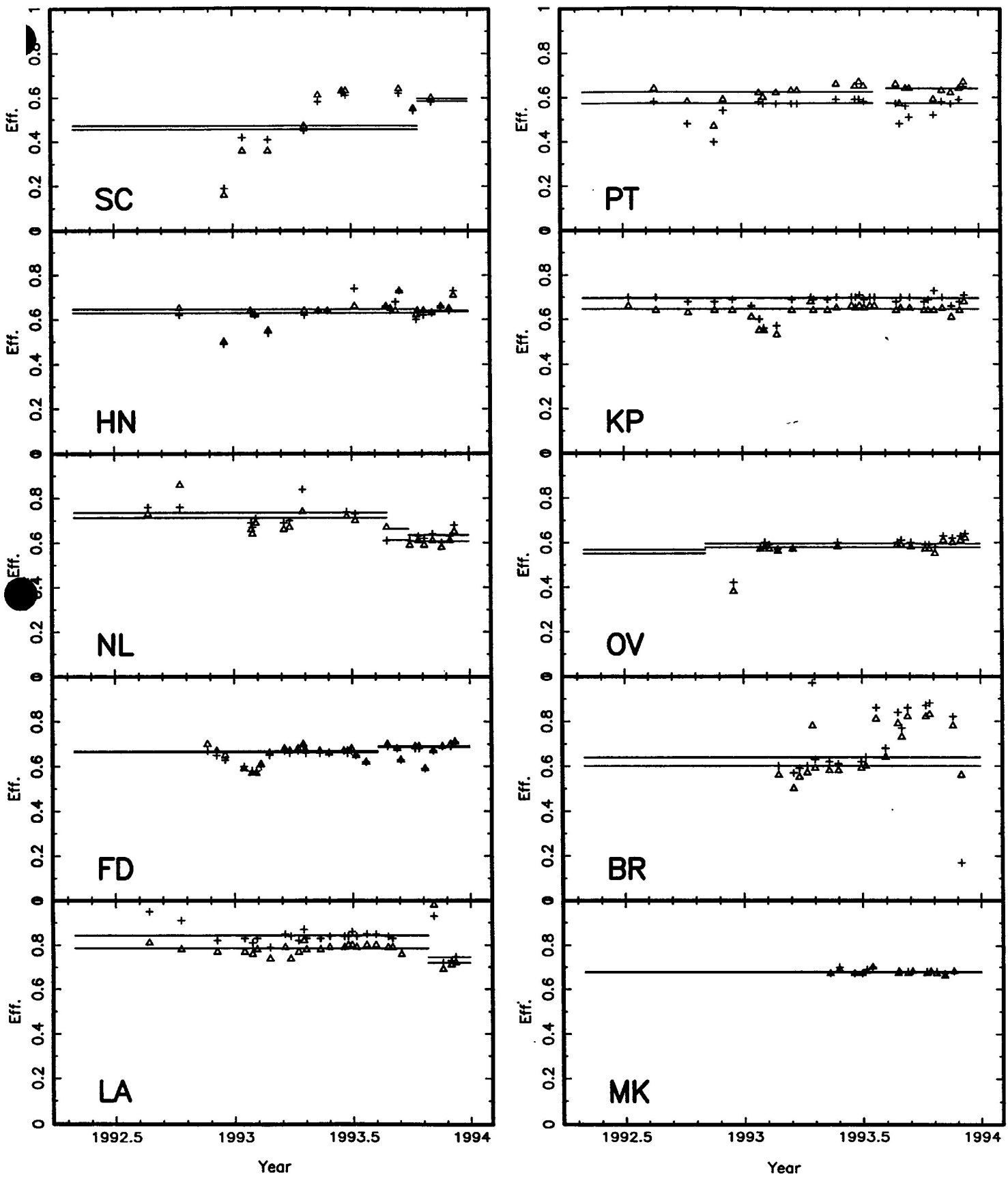
1993.5
1994
Year


EFFICIENCY 2cm + RCP △ LCP
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PT
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Year
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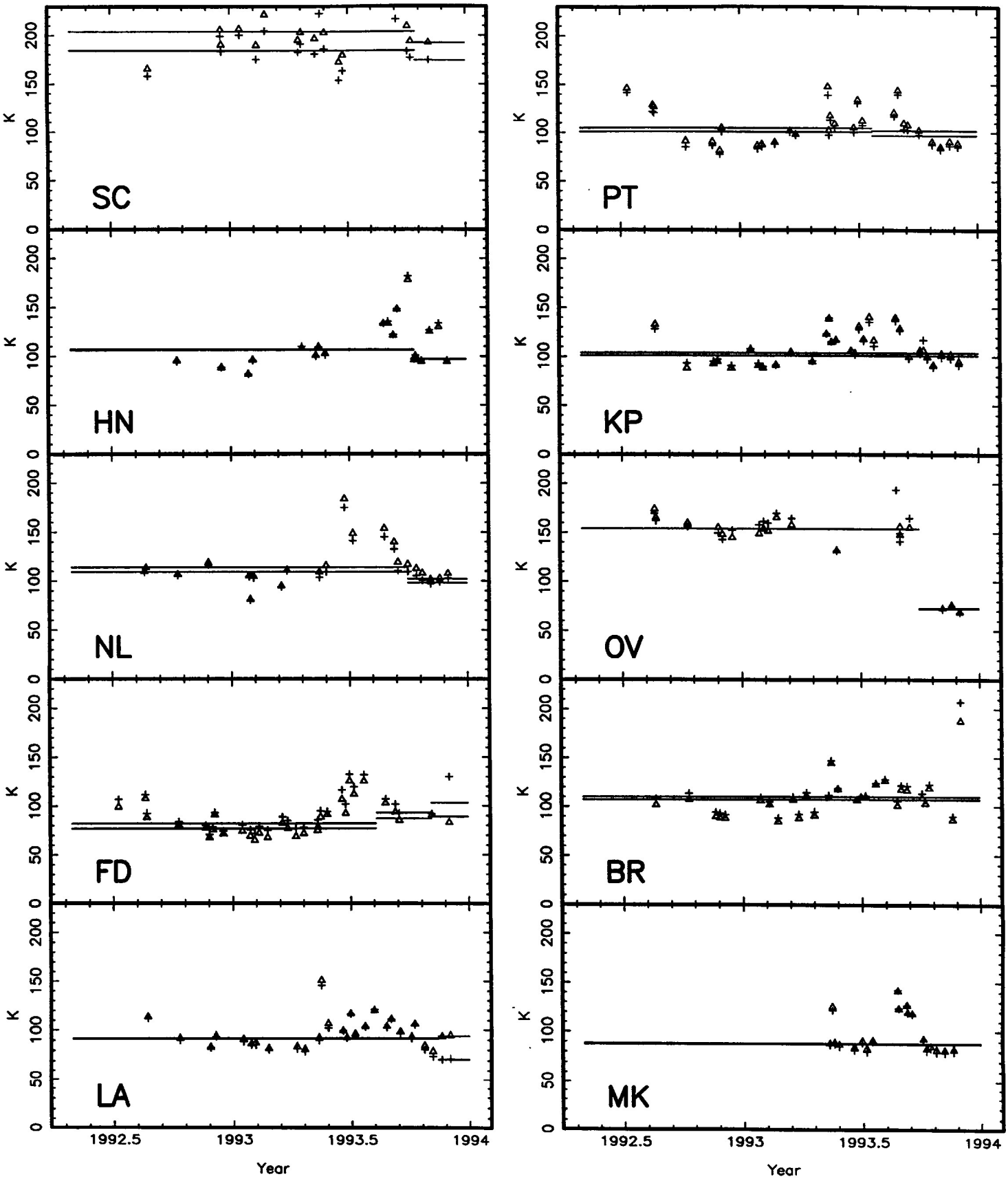
SYSTEM TEMPERATURES 1cm + RCP △ LCP
SC
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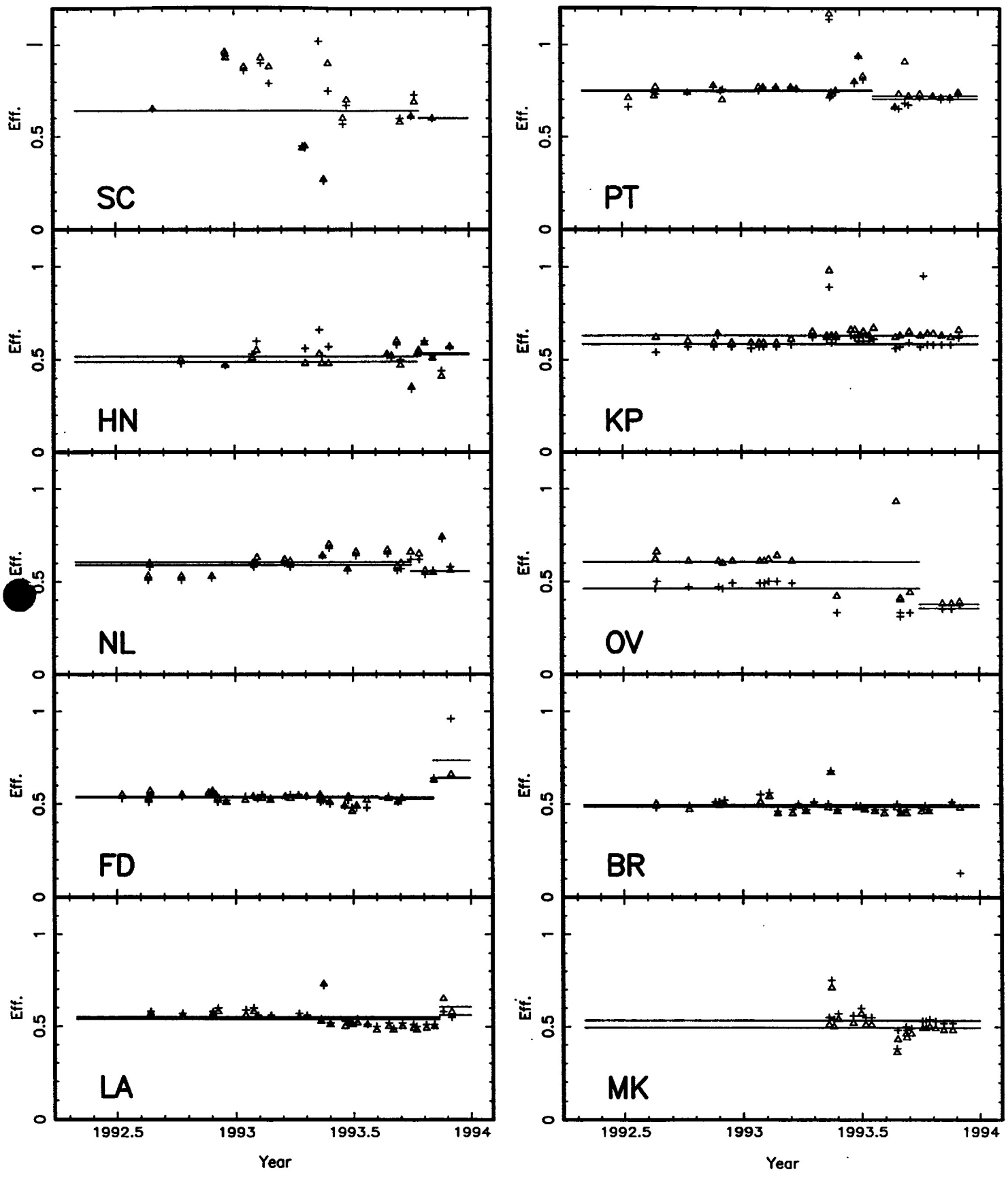
Year


EFFICIENCY 1cm + RCP △ LCP
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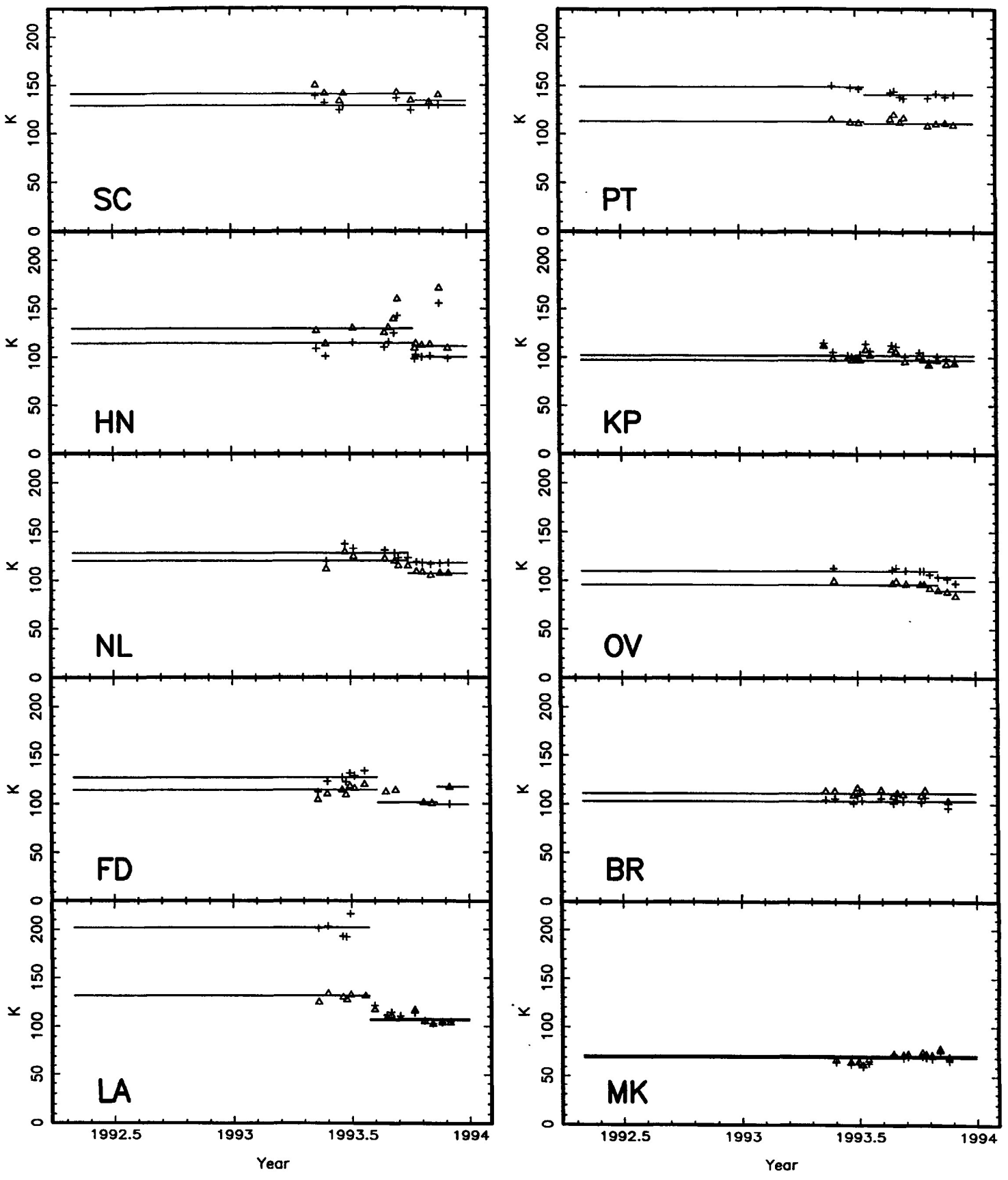
SYSTEM TEMPERATURES 7mm + RCP △ LCP
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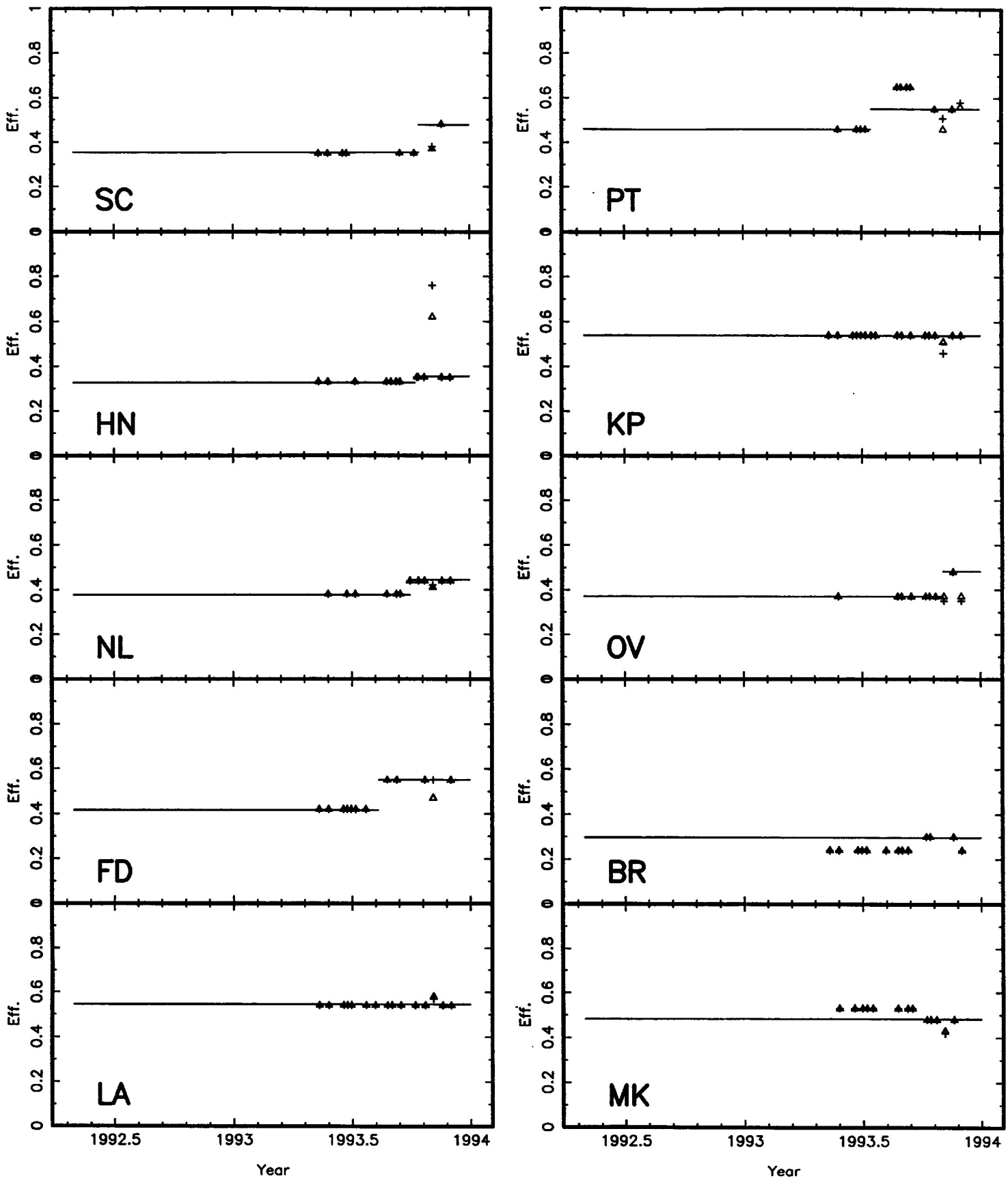
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1993.5
1994
Year