

Supplementary material for

Evidence for an earlier greenhouse cooling effect in the stratosphere before the 1980s over the Northern Hemisphere

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Supplementary Table 1 (SMT1): Trend calculations in northern hemisphere summer (JJA) based on the monthly normalised time series of temperature ($^{\circ}\text{C}/\text{decade}$) at various levels calculated from RICH dataset and filtered from natural variations at the latitudinal belts a) 5 N-30 N, b) 30 N - 60 N and c) 60 N - 90 N. The trends calculations refer to the periods 1958-1979, 1980-2001 and 1980-2005.

Period 1958-1979

Level (hPa)	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
850	.00 \pm .11	.00	-.06 \pm .05	-1.15	-.16 \pm .03	-5.12
500	-.18 \pm .09	-1.96	-.25 \pm .04	-6.33	-.06 \pm .04	-1.24
300	-.22 \pm .13	-1.74	-.31 \pm .04	-6.90	-.17 \pm .05	-3.54
100	-.22 \pm .29	-.77	-.34 \pm .05	-6.90	-.13 \pm .06	-2.39
50	.06 \pm .33	.19	-.54 \pm .08	-6.47	-.39 \pm .12	-3.34
30	.00 \pm .31	.01	-.66 \pm .10	-6.86	-.46 \pm .11	-4.34

Period 1980-2001

Level (hPa)	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
850	.30 \pm .10	2.95	.37 \pm .06	6.37	.13 \pm .03	4.77
500	.08 \pm .08	1.00	.31 \pm .05	6.43	-.01 \pm .04	-.34
300	.00 \pm .14	-.01	.24 \pm .05	4.75	.09 \pm .05	2.00
100	-.62 \pm .32	-1.92	-.53 \pm .06	-8.96	.01 \pm .05	.18
50	-.79 \pm .34	-2.37	-.89 \pm .09	-9.88	-.53 \pm .11	-4.73
30	-.81 \pm .30	-2.67	-.93 \pm .09	-10.22	-.82 \pm .09	-8.85

Period 1980-2005

Level (hPa)	90-60N		60-30N		30-05N	
	Trend	t-test	trend	t-test	trend	t-test
850	.44 \pm .08	5.52	.39 \pm .05	8.58	.11 \pm .02	5.83
500	.21 \pm .07	3.17	.29 \pm .04	8.20	.03 \pm .03	1.08
300	.06 \pm .11	.51	.24 \pm .04	6.66	.13 \pm .03	3.89
100	-.42 \pm .25	-1.66	-.34 \pm .05	-6.91	.00 \pm .04	-.07
50	-.62 \pm .26	-2.37	-.67 \pm .08	-8.91	-.37 \pm .09	-4.06
30	-.66 \pm .24	-2.81	-.73 \pm .07	-10.02	-.62 \pm .08	-7.80

Supplementary Table 2 (SMT2): Trend calculations in northern hemisphere summer (JJA) based on the monthly normalised time series of the layer mean temperature ($^{\circ}\text{C}/\text{decade}$) calculated from FU-Berlin and filtered from natural variations at the latitudinal belts a) 5 N-30 N, b) 30 N - 60 N and c) 60 N - 90 N. The layers are: L4: 100-50 hPa and L5: 50-30 hPa. The trend calculations refer to the periods 1958-1979 and 1980-2001.

Period 1958-1979

layer	90-60N		60-30N		30-05N	
	Trend	t-test	trend	t-test	trend	t-test
L4	.13 \pm .40	.33	-.28 \pm .10	-2.89	-.90 \pm .13	-7.05
L5	-.14 \pm .35	-.40	-.85 \pm .09	-9.17	-.86 \pm .14	-6.23

Period 1980-2001

layer	90-60N		60-30N		30-05N	
	Trend	t-test	trend	t-test	trend	t-test
L4	-.64 \pm .37	-1.74	-.76 \pm .07	-10.44	-.52 \pm .11	-4.91
L5	-.96 \pm .38	-2.56	-1.11 \pm .091	-12.17	-.95 \pm .14	-6.98

Supplementary Table 3 (SMT3): Trend calculations based on the monthly normalised time series of the layer mean temperature ($^{\circ}\text{C}/\text{decade}$) and tropopause pressure TP (hPa/decade) calculated from NCEP reanalysis and filtered from natural variations at the latitudinal belts a) 5 N-30 N, b) 30 N - 60 N and c) 60 N - 90 N. The layers are: L1: 1000-925 hPa, L2: 925-500 hPa, L3: 500-300 hPa, L4: 100-50 hPa, and L 5: 50-30 hPa. The trends calculations refer to the periods 1958-1979, 1980-2001, 1980-2005 and 1980-2011.

Period 1958-1979

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
L1	.07 \pm .05	1.28	-.03 \pm .02	-1.28	.13 \pm .01	10.03
L2	.02 \pm .04	.44	-.10 \pm .02	-5.72	-.02 \pm .02	-.87
L3	-.38 \pm .04	-10.23	-.25 \pm .02	-13.83	-.14 \pm .03	-5.73
L4	-.56 \pm .15	-3.61	-.69 \pm .03	-24.49	-.31 \pm .06	-5.44
L5	-.63 \pm .17	-3.62	-.74 \pm .04	-16.84	-.56 \pm .05	-11.47
TP	2.35\pm.62	3.78	1.99\pm.14	14.19	-.29\pm.12	-2.45

Period 1980-2001

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
L1	.47 \pm .06	8.27	.23 \pm .02	10.79	.03 \pm .01	2.30
L2	.08 \pm .04	1.91	.19 \pm .02	9.49	.05 \pm .02	2.52
L3	.10 \pm .04	2.69	.07 \pm .02	2.98	-.06 \pm .02	-2.63
L4	-.70 \pm .17	-4.09	-.80 \pm .03	-24.47	-.78 \pm .05	-14.49
L5	-.76 \pm .18	-4.25	-.84 \pm .04	-20.42	-.68 \pm .04	-15.61
TP	-3.09\pm.84	-3.70	-1.05\pm.17	-6.08	-.42\pm.12	-3.54

Period 1980-2005

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
L1	.78 \pm .05	17.41	.29 \pm .02	17.17	.09 \pm .01	9.12
L2	.23 \pm .03	6.94	.25 \pm .02	16.37	.13 \pm .01	9.33
L3	.26 \pm .03	8.77	.11 \pm .02	6.84	.04 \pm .02	2.37
L4	-.38 \pm .13	-2.88	-.61 \pm .03	-21.14	-.76 \pm .04	-18.40
L5	-.50 \pm .14	-3.67	-.66 \pm .03	-19.56	-.55 \pm .04	-13.88
TP	-2.25\pm.64	-3.50	-.49\pm.13	-3.70	-.52\pm.09	-5.84

Period 1980-2011

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
L1	.84 \pm .04	23.96	.28 \pm .01	21.09	.12 \pm .01	13.76
L2	.29 \pm .03	11.03	.26 \pm .01	20.60	.17 \pm .01	14.32
L3	.25 \pm .02	10.58	.15 \pm .01	10.96	.10 \pm .01	7.00
L4	-.29 \pm .11	-2.72	-.46 \pm .03	-17.68	-.64 \pm .03	-19.56
L5	-.43 \pm .11	-3.93	-.50 \pm .03	-16.84	-.42 \pm .03	-13.16
TP	-1.23\pm.53	-2.32	-.72\pm.12	-5.77	-.76\pm.08	-10.00

Supplementary Table 4 (SMT4): Trend calculations based on the monthly normalised time series of temperature (°C/decade) at various levels calculated from RICH dataset and filtered from natural variations at the latitudinal belts a) 5 N-30 N, b) 30 N - 60 N and c) 60 N - 90 N. The trend calculations refer to the periods 1958-1979, 1980-2001 and 1980-2005.

Period 1958-1979

Level (hPa)	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
850	-.06± .05	-1.03	-.10± .03	-3.51	-.13± .02	-8.05
500	-.19± .05	-4.16	-.26± .02	-12.98	-.04± .02	-1.80
300	-.11± .06	-1.69	-.34± .02	-15.24	-.14± .02	-5.83
100	-.07± .14	-.52	-.42± .02	-17.06	-.26± .03	-9.39
50	-.09± .17	-.52	-.69± .04	-16.63	-.44± .06	-7.66
30	-.02± .16	-.15	-.67± .05	-14.10	-.32± .05	-6.10

Period 1980-2001

Level (hPa)	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
850	.28± .05	5.67	.36± .03	12.61	.15± .01	11.17
500	.10± .04	2.49	.29± .02	12.20	.04± .02	2.03
300	.09± .07	1.22	.21± .02	8.38	.15± .02	6.51
100	-.40± .16	-2.52	-.43± .03	-14.65	.00± .02	.03
50	-.75± .17	-4.49	-.86± .04	-19.37	-.61± .06	-10.86
30	-.89± .15	-5.91	-.97± .04	-21.61	-.83± .05	-18.23

Period 1980-2005

Level (hPa)	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	trend	t-test
850	.47± .04	11.98	.37± .02	16.61	.14± .01	14.75
500	.27± .03	8.08	.28± .02	15.99	.09± .01	6.71
300	.18± .05	3.36	.21± .02	11.81	.18± .02	11.13
100	-.17± .13	-1.33	-.27± .02	-11.13	.02± .02	1.08
50	-.56± .13	-4.32	-.66± .04	-17.81	-.48± .05	-10.54
30	-.80± .12	-6.78	-.78± .04	-21.50	-.62± .04	-15.75

Supplementary Table 5 (SMT5): Trend calculations based on the monthly normalised time series of the layer mean temperature (°C/decade) calculated from FU-Berlin and filtered from natural variations at the latitudinal belts a) 5 N-30 N, b) 30 N - 60 N and c) 60 N - 90 N. The layers are: L4: 100-50 hPa and L5: 50-30 hPa. The trend calculations refer to the periods 1958-1979 and 1980-2001.

Period 1958-1979

layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	Trend	t-test
L4	.26± .20	1.31	-.24± .05	-4.89	-.94 ± .06	-14.59
L5	.01± .18	.038	-.84 ± .05	-18.26	-.86 ± .07	-12.47

Period 1980-2001

layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	Trend	t-test
L4	-.54 ± .18	-3.01	-.63 ± .04	-17.37	-.53 ± .053	-9.90
L5	-.72 ± .19	-3.88	-.90 ± .05	-19.88	-.94 ± .07	-13.96

Supplementary Table 6 (SMT6): Trend calculations based on the monthly normalised time series of the layer mean temperature ($^{\circ}\text{C}/\text{decade}$) and tropopause pressure TP (hPa/decade) calculated from WACCM and filtered from natural variations at the latitudinal belts a) 5 N-30 N, b) 30 N - 60 N and c) 60 N - 90 N. The layers are: L1: 1000-925 hPa, L2: 925-500 hPa, L3: 500-300 hPa, L4: 100-50 hPa and L 5: 50-30 hPa. The trends calculations refer to the periods 1958-1979, 1980-2001 and 1980-2005.

Period 1958-1979

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	Trend	t-test
L1	.80±.23	3.53	-.13±.16	-.80	.11±.05	2.34
L2	.36±.04	8.32	.05±.02	2.35	.17±.01	15.77
L3	.12±.03	4.14	.05±.02	2.24	.22±.02	14.30
L4	-.52±.16	-3.26	-.25±.05	-5.12	-.31±.05	-6.74
L5	-.50±.17	-2.90	-.30±.07	-4.46	-.53±.05	-11.03
TP	.87±.56	1.56	-1.47±.22	-6.55	-.49±.26	-1.88

Period 1980-2001

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	Trend	t-test
L1	.16±.21	.78	.32±.18	1.82	.36±.05	7.12
L2	.37±.05	7.34	.27±.02	12.36	.22±.02	10.55
L3	.30±.04	8.48	.26±.02	10.36	.30±.03	9.03
L4	-.19±.14	-1.36	-.10±.07	-1.51	-.22±.07	-2.99
L5	-.14±.16	-.90	-.39±.08	-4.73	-.39±.08	-4.88
TP	-1.98±.50	-3.93	-.45±.21	-2.12	-.31±.26	-1.17

Period 1980-2005

Layer	90-60N		60-30N		30-05N	
	Trend	t-test	Trend	t-test	Trend	t-test
L1	.30±.16	1.85	.10±.14	.68	.36±.04	9.15
L2	.39±.04	10.24	.27±.02	14.71	.24±.02	15.27
L3	.30±.03	10.90	.27±.02	13.61	.33±.02	13.47
L4	-.33±.11	-2.98	-.06±.05	-1.11	-.20±.05	-3.90
L5	-.32±.12	-2.55	-.32±.06	-5.20	-.32±.06	-5.66
TP	-3.60±.43	-8.47	-.38±.17	-2.23	-.56±.20	-2.81