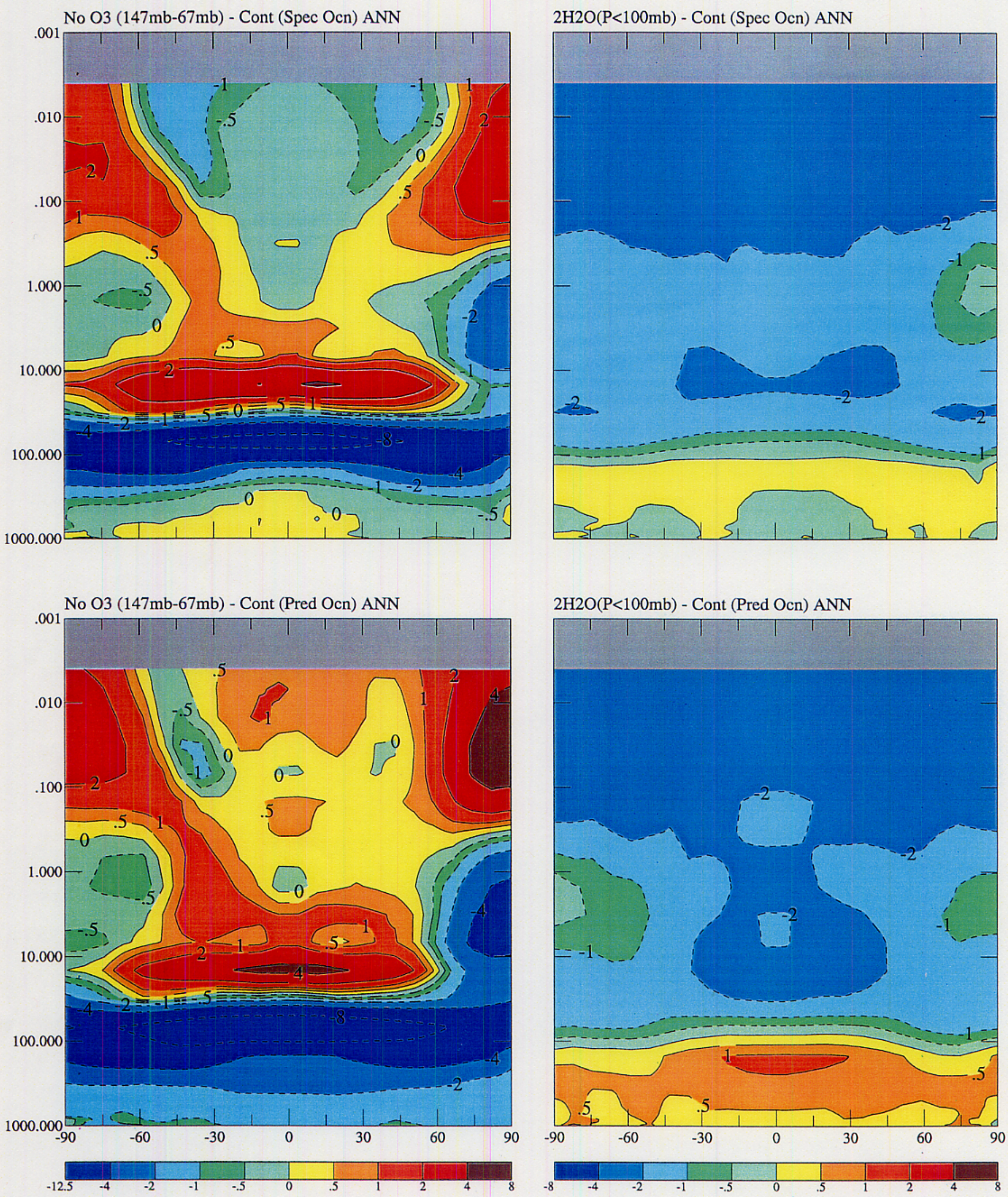
THE USE OF SAGE WATER VAPOR TO INVESTIGATE CLIMATE CHANGE ISSUES

D. Rind

- **SAGE II**
  - **DATA QUALITY**
  - **STRATOSPHERIC TRENDS**
  - **TROPOSHERIC TRENDS**
  - **TROPOSPHERIC PHYSICAL PROCESSES**
  - **CD**

- **SAGE III**
  - **DATA QUALITY**

ΔTemperature (°C)



ANNUAL GLOBAL TEMPERATURE CHANGES (°C)

EXPERIMENT	VARIABLE SSTS			CONSTANT SSTS		
	SURF	68MB	1.5 MB	SURF	68MB	1.5MB
$2CO_2$	5.15	1.35	-8.6	0.36	-1.5	-8.6
+2% SOLAR	4.73	1.5	1.4	0.16	0.5	1.1
$2CO_2$<100MB	0.54	0.5	-8.7	0.0	-0.4	-8.3
$2H_2O$<100MB	0.46	-0.6	-1.7	0	-0.8	-1.7
NO O_3 200-50MB	-1.15	-8.8	0.1	-0.03	-8.8	-0.1
-2% SOLAR	-4.09	-1.8	-1.4	-0.15	-0.4	-1.1
VOLC.AER. τ=0.15	-4.50	-0.17	-0.28	-0.09	1.4	0.14
+5% UV - -5% UV				0.03	0.2	3.7
+5% UV - -5%UV WQBO				-0.04	0.2	3.6
+5% UV - -5%UV EQBO				0.03	0.2	3.6
E-W QBO +5% UV				0.05	-0.6	0.1
E-W QBO –5% UV				0.03	-0.6	0.05
INTERANN. STD. DEV.	0.11	0.5	0.1	0.04	0.4	0.1

Table 1. Water vapor trends (ppbv/yr)

Pressure (mb)	Altitude (km)	MethOx 43N	Water 43N	MethOx 60S-60N	Water 60S-60N	Balloons 40N	HALOE 60S-60N
15	29	19	40	20	51	15	60 - 65
6.8	34	20	44	21	57	na	85 - 90
3.2	39	22	61	21	66	na	90 - 95
1.5	44	24	75	23	78	na	110 - 115
0.7	50	27	67	26	69	na	100 - 105

Model altitudes are approximate equivalent altitude for the GCM layers centered at the given pressure levels. Balloon data are those reported by *Oltmans and Hofmann* (1995) for Boulder, Colorado for 24–26 km altitude (the highest level reported). Uncertainty on that data is ± 15 ppbv/yr at the 95 percent confidence level. HALOE data are those reported by *Randel et al.* (1999), and are fits to 1993–1997 measurements. Uncertainty on the HALOE data is given as approximately ± 15 ppbv/yr at 32 mb, and ± 20 ppbv/yr at 1 mb.

Table 2. Temperature change, K/decade, 1979–1994

Pressure (mb)	Altitude (km)	Observations $\pm 1\sigma$	GHG run (G)	Ozone run (G+O)	MethOx run (G+O+M)	Water run (G+O+M+W)
15	29	-0.80 ± 0.29	-0.24	-0.29	-0.40	**-0.53**
6.8	34	-0.88 ± 0.30	-0.47	**-0.63**	**-0.73**	**-0.84**
3.2	39	-1.23 ± 0.33	-0.46	-0.70	-0.84	**-0.84**
1.5	44	-1.81 ± 0.37	-0.45	-0.74	-0.94	**-1.43**
0.7	50	-2.55 ± 0.40	-0.33	-0.63	-1.37	**-2.32**

Altitudes for the GCM runs are approximate, as in Table 1. The observations are from several, independent techniques, with an average latitude of 45 N, and altitudes at 5 km intervals beginning at 30 km [*WMO99*]. Modeled values lying within 1σ of the observations are shown in bold type. Latitudinal structure in the GCM does not alter the conclusion that water vapor increases are required to reproduce the observed trends. For comparison, the 60S-60N temperature trend averages for the GHG run are -0.33, -0.46, -0.55, -0.60, and -0.64 with increasing altitude, while for the Ozone run, they are -0.39, -0.60, -0.75, -0.85 and -0.92. See also Figure 3 for 60S-60N averages.

Shindell (2000)

Rosenlof et al. 2001

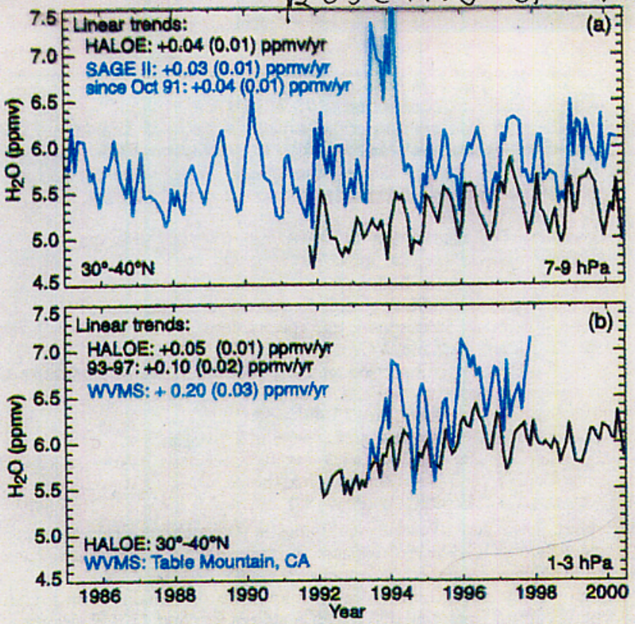


Figure 3. Monthly averaged NH midlatitude upper stratospheric water vapor. (a) HALOE (black) and SAGE II (turquoise) at 30°-40°N and 7-9 hPa. (b) HALOE (black) and WVMS (turquoise) at 1-3 hPa. HALOE and SAGE II data are averaged from 30°-40°N, WVMS data are from Table Mountain, CA. Linear trend (1σ uncertainty) results are annotated on the panels.

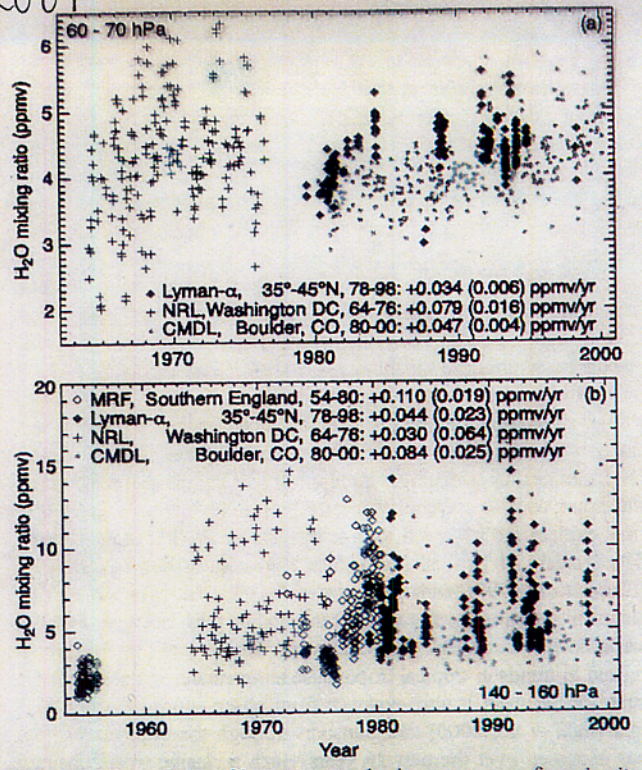


Figure 5. Time series of lower stratospheric water vapor from *in situ* measurements at NH midlatitudes for (a) 60-70 hPa (440-500K) and (b) 140-160 hPa (360-390K). Data were filtered by tropopause height. The linear trend (1σ uncertainty) results are annotated on the plot. For the CMDL and NRL data, the full regression analysis was done. Sparse temporal resolution permitted only a linear term in the MRF and AL Lyman-α regression analysis.

~1.1 ppmv, approximately half of that estimated here. Large changes are apparent in the lowermost NH midlatitude stratosphere below the 100 hPa level (Fig. 6a) where CH_4 oxidation is far from complete, indicating other mechanisms must also be important. There is vertical structure in the trends shown in Fig. 6a, with a relative minimum in the 50-100 hPa layer. Examination of HALOE trends (not shown) confirms this feature was present globally over the past decade. That this minimum exists indicates that the reason for trends in the midlatitude lowermost stratosphere (below 100 hPa) likely differs from that above 50 hPa.

Aircraft emissions in the lower stratosphere have increased over this period, but the effect at lower stratosphere midlatitudes is estimated to be only +0.018%/yr [*Danilin et al.*, 1998], much smaller than the observed 1%/yr increase. It has been suggested that changes in the tropical entry value of water vapor contribute to the observed increase [*Nedoluha et al.*, 1998; *Oltmans and Hofmann*, 1995]. However, decreasing tropical tropopause temperatures have been noted over the past 20 years [*Simmons et al.*, 1999]. This should have decreased stratospheric water if the tropical cold trap, which assumes air crosses

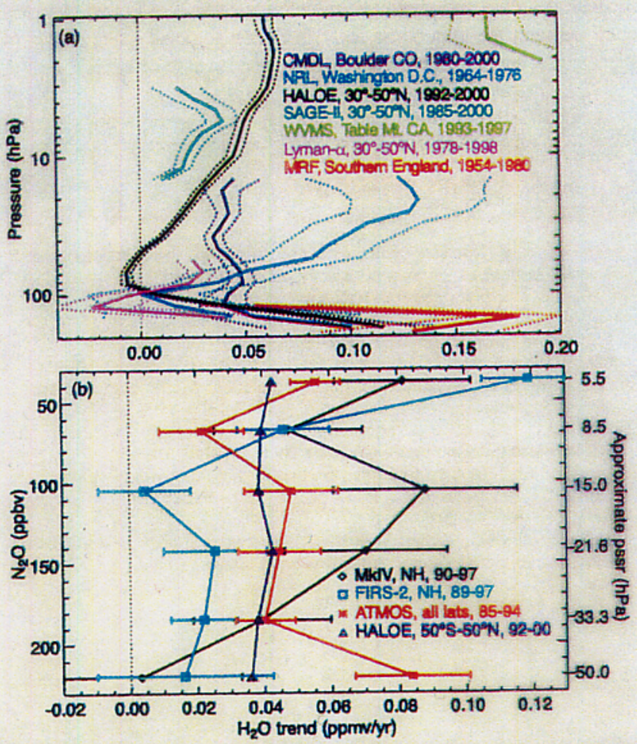


Figure 6. Vertical profiles of the estimated linear trends for all data sets. Colors and valid years are annotated on the panels. (a) Trends for 30°-50°N. (b) Trends from the balloon and shuttle instruments with variable latitude sampling. Data were binned by N_2O; approximate pressure is given on the right axis. A CH_4:N_2O relationship from the MkIV instrument was used to convert CH_4 binned HALOE trends to the N_2O axis. In both panels, trends are shown with a solid line; 1σ uncertainties are given by dashed lines in (a) and horizontal bars in (b).

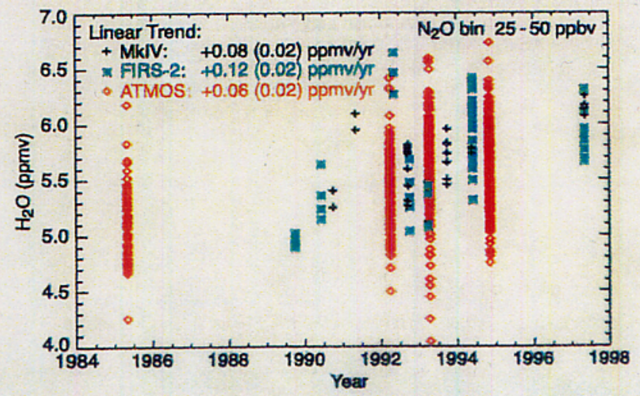
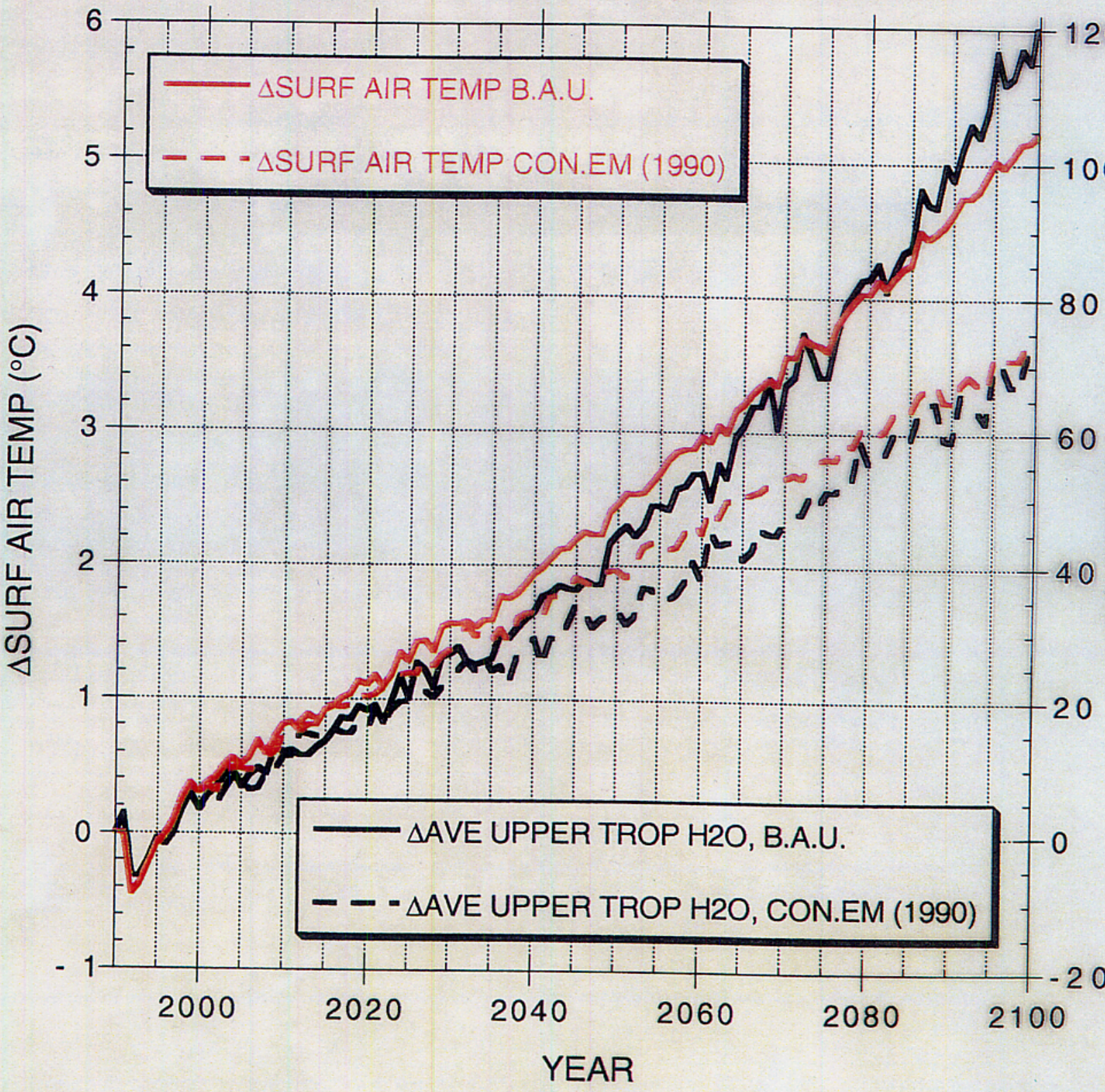


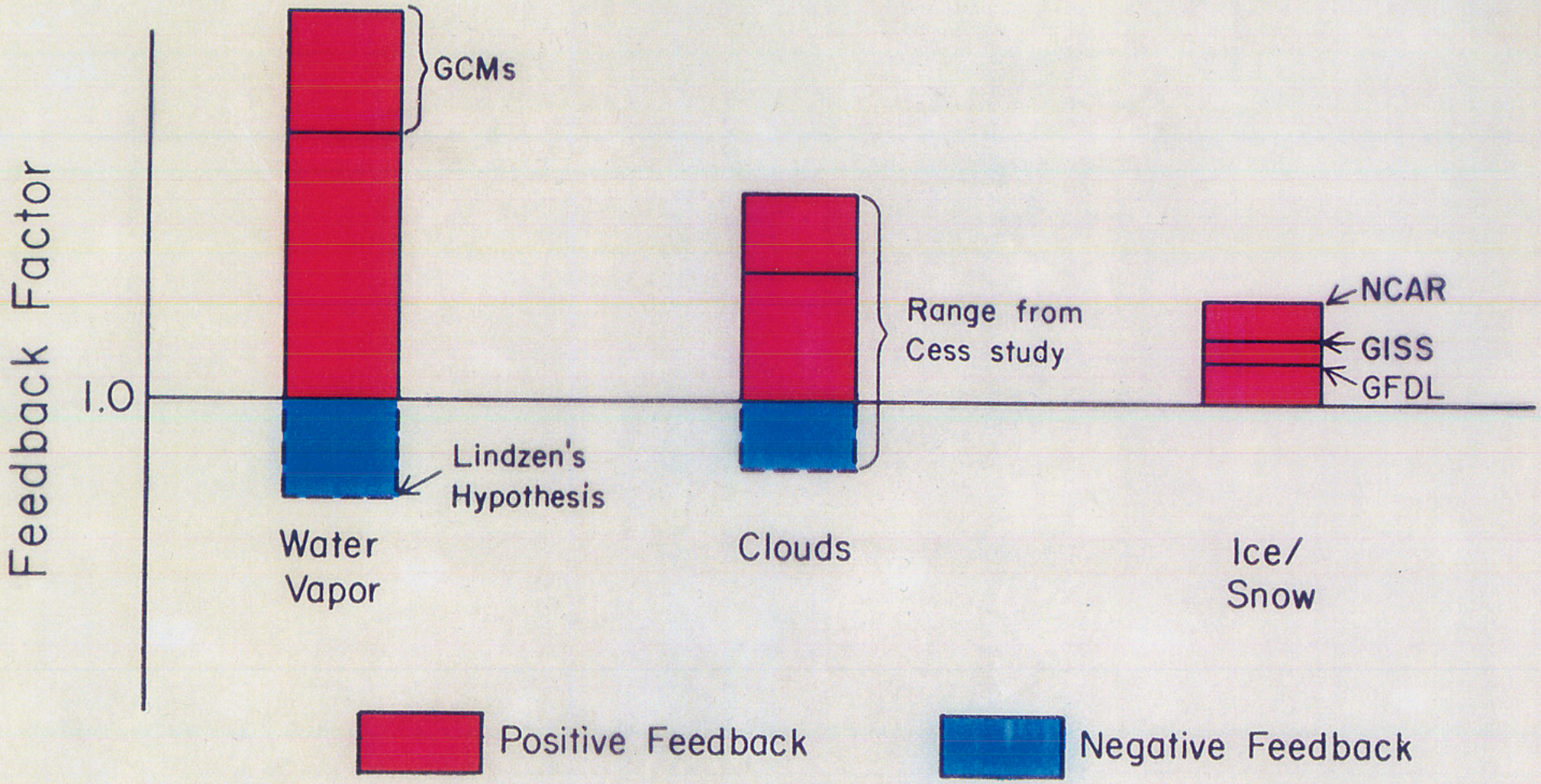
Figure 4. Water vapor time series from MkIV, FIRS-2, and ATMOS in the 25-50 ppbv N_2O bin, representative of the upper stratosphere at pressures from 5-10 hPa. Estimated linear trends (1σ uncertainties) are annotated on the plot.

CHANGE IN SURFACE AIR TEMPERATURE AND UPPER TROPOSPHERIC HUMIDITY



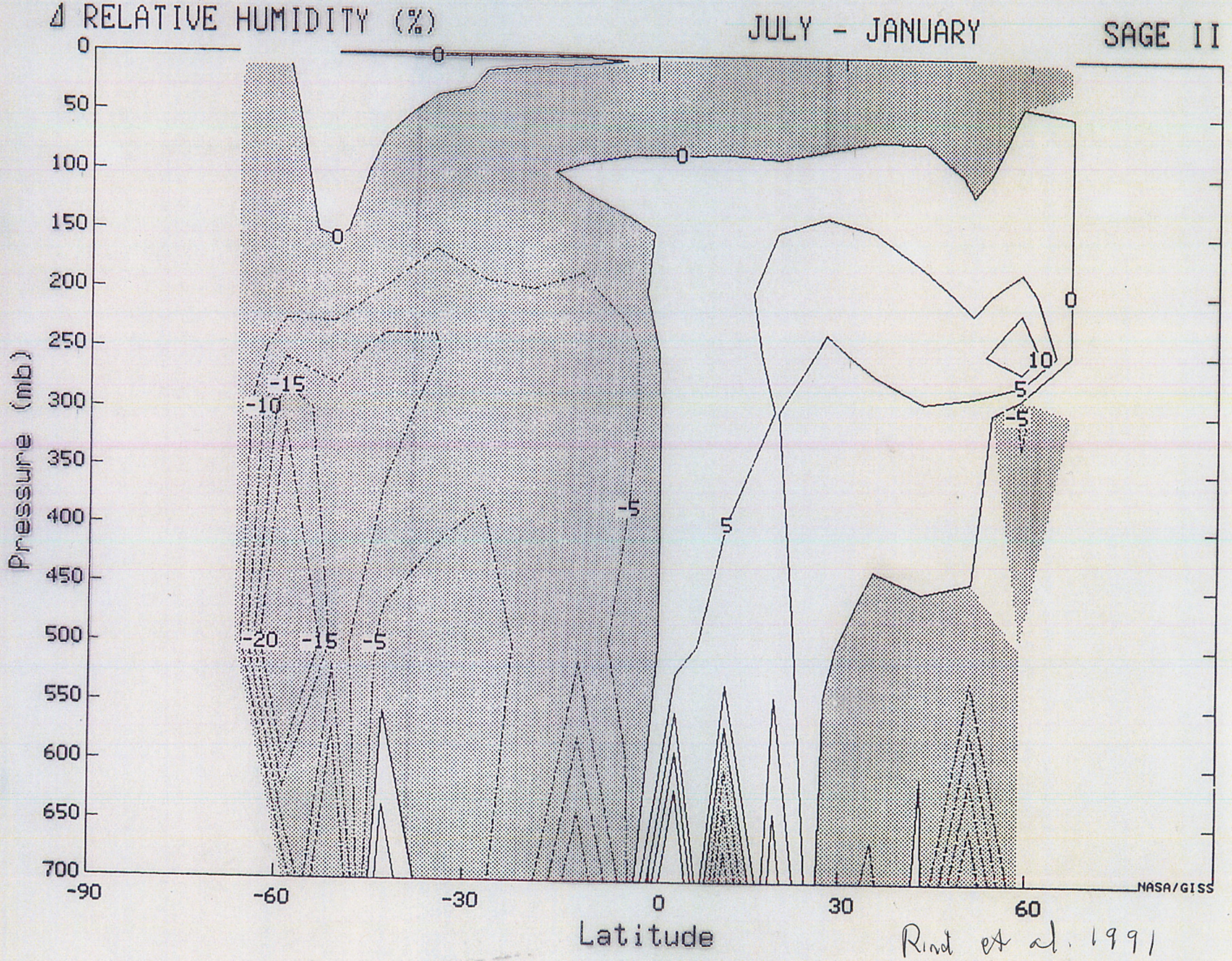
Rind (1998)

Estimated Climate Feedbacks
(each process acting independently)

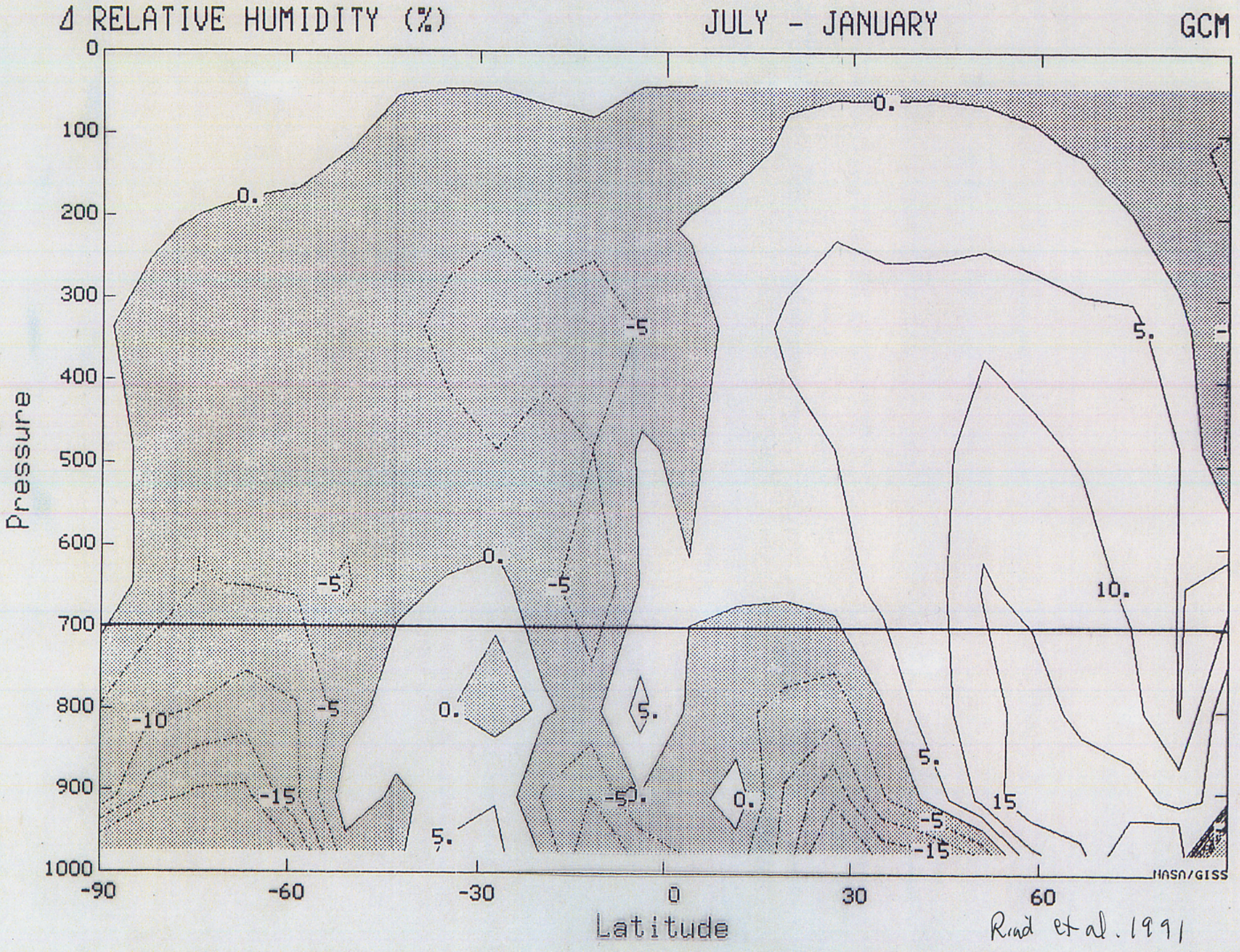


2×CO_2 4.0°C

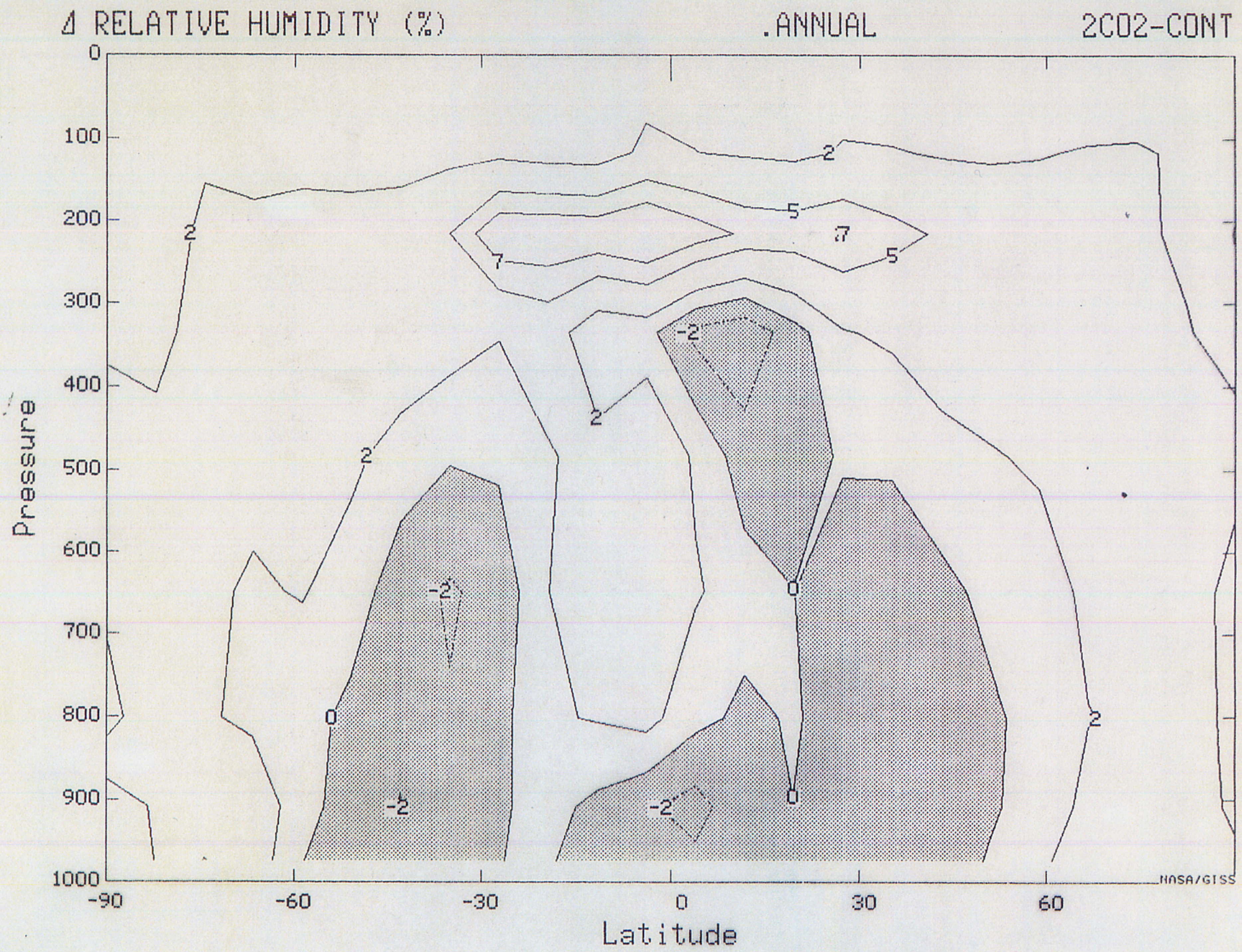
ΔCO_2 1.2°C
ΔH_2O 1.4°C
ΔClouds 1.0°C



Δ RELATIVE HUMIDITY (%)
JULY - JANUARY
SAGE II
Pressure (mb)
Latitude
NASA/GISS
Rind et al. 1991



Δ RELATIVE HUMIDITY (%)
JULY - JANUARY
GCM
Pressure
Latitude
0
100
200
300
400
500
600
700
800
900
1000
-90
-60
-30
0
30
60
0.
-5
5.
10.
15
-10
-15
NASA/GISS
Rind et al. 1991



Rind et al. 1991

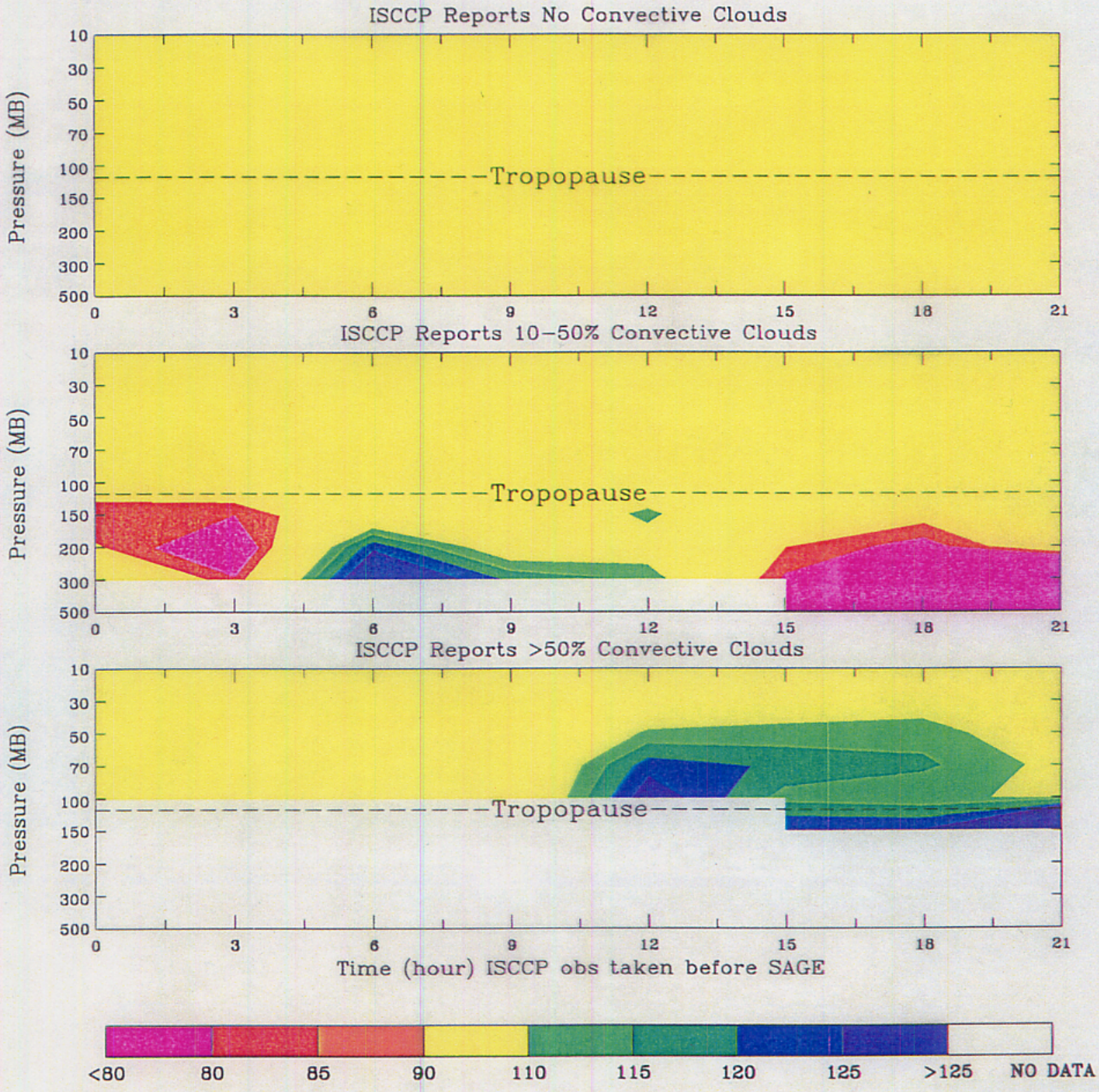


Figure 4: SAGE II mean water vapor change versus time after different convective situations as determined by ISCCP. The water vapor amount is % of its local climatology. 30S-30N July 1986-1990

Liao and Rind 1997

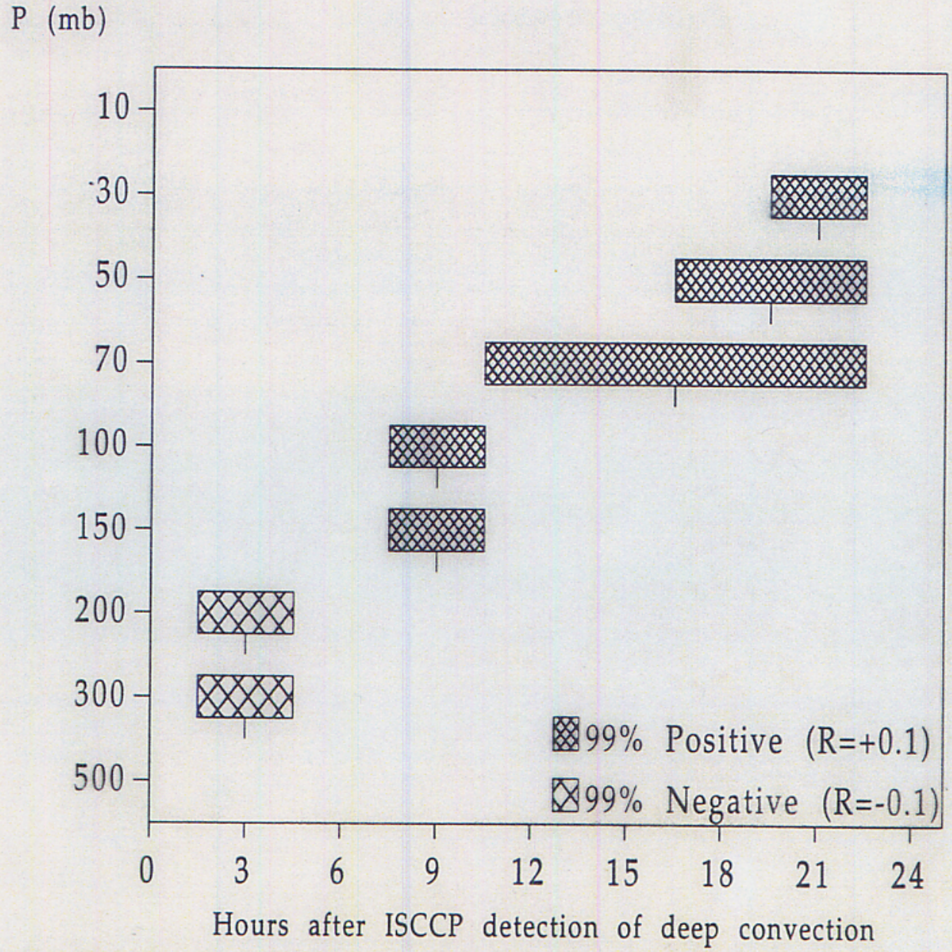
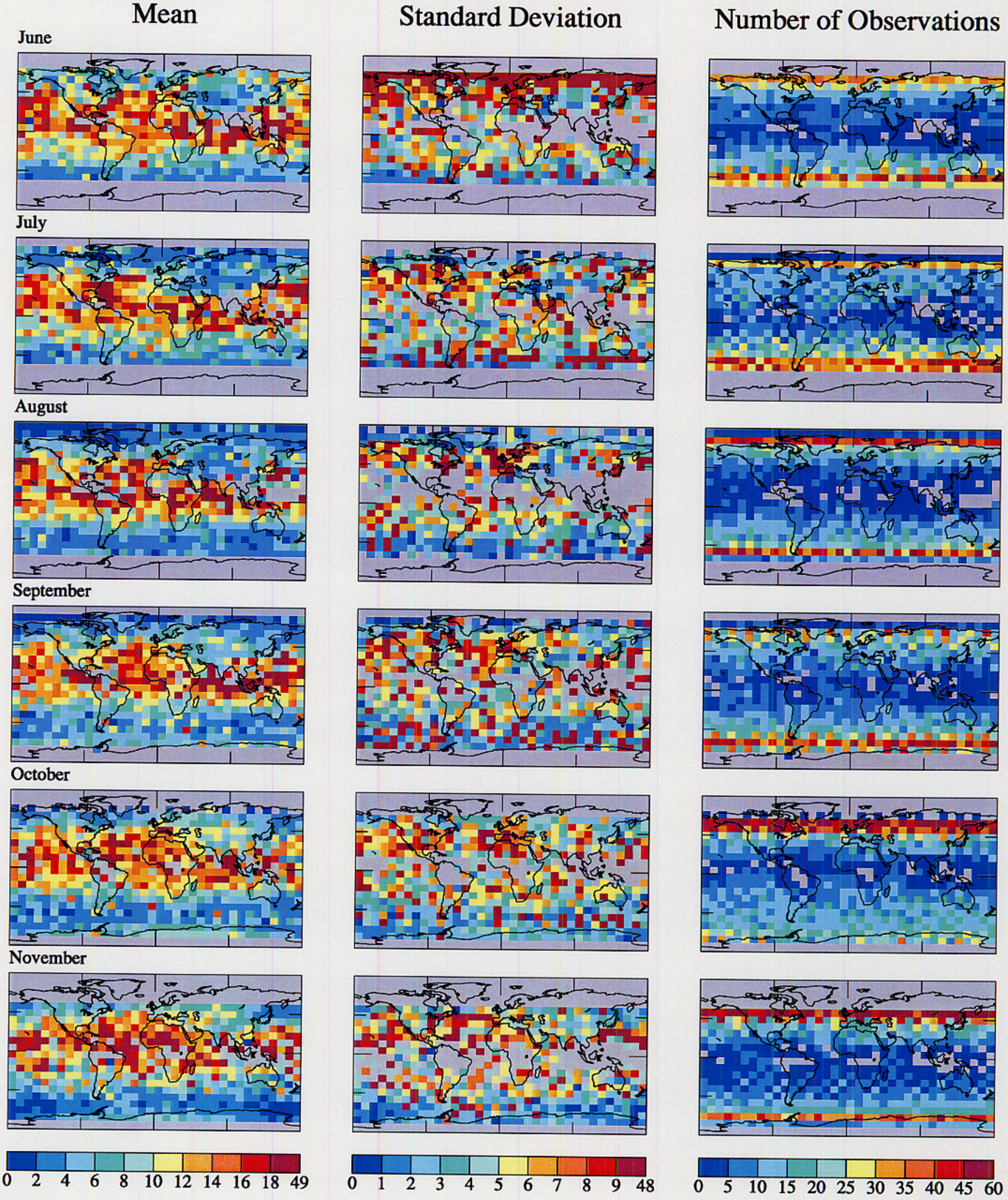
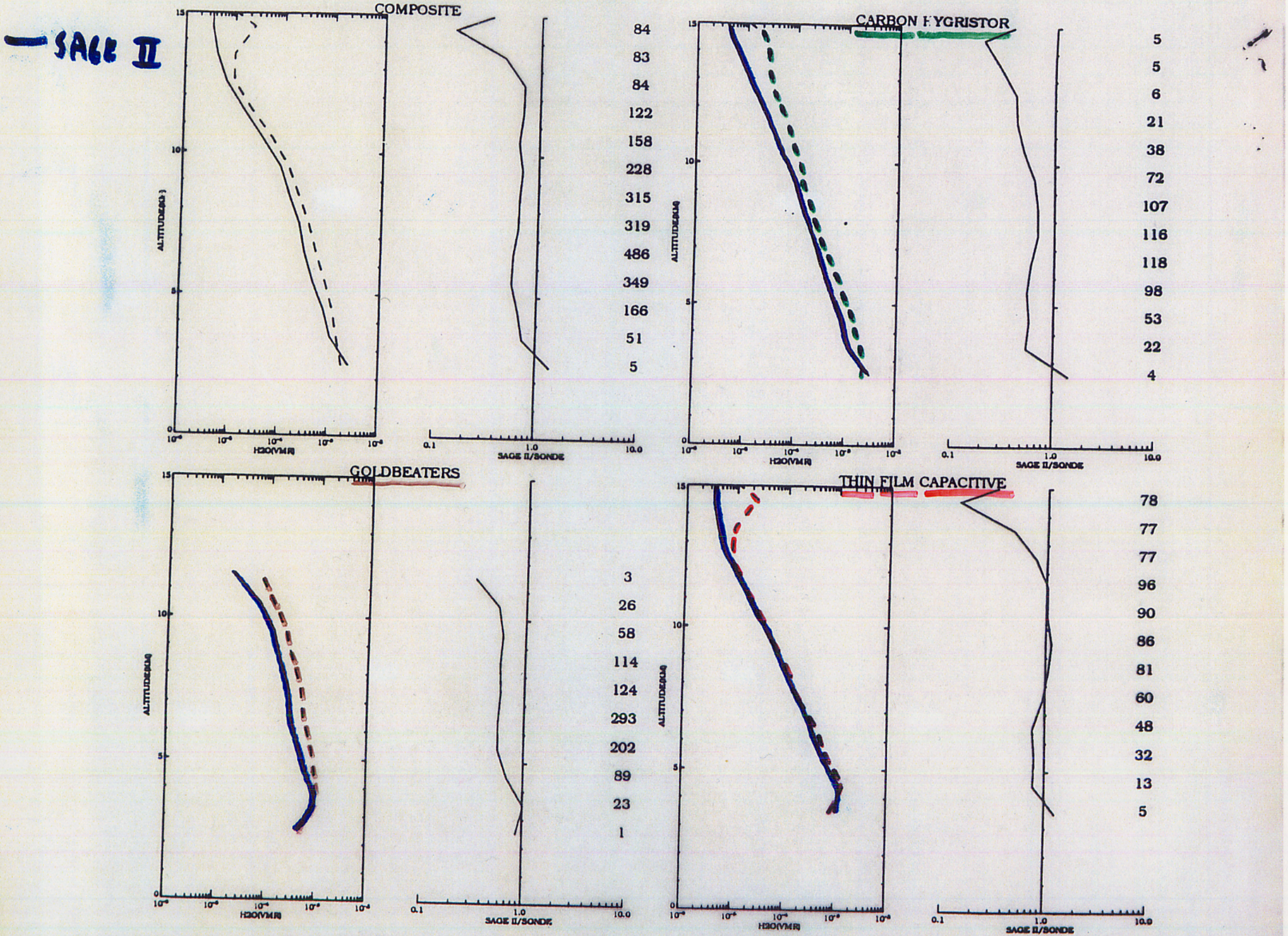


Figure 1: Areas with correlation between individual water vapor amount and matched convective fraction at the significance level of 99%. 60S-60N July 1986-1990

Liao and Rind 1997

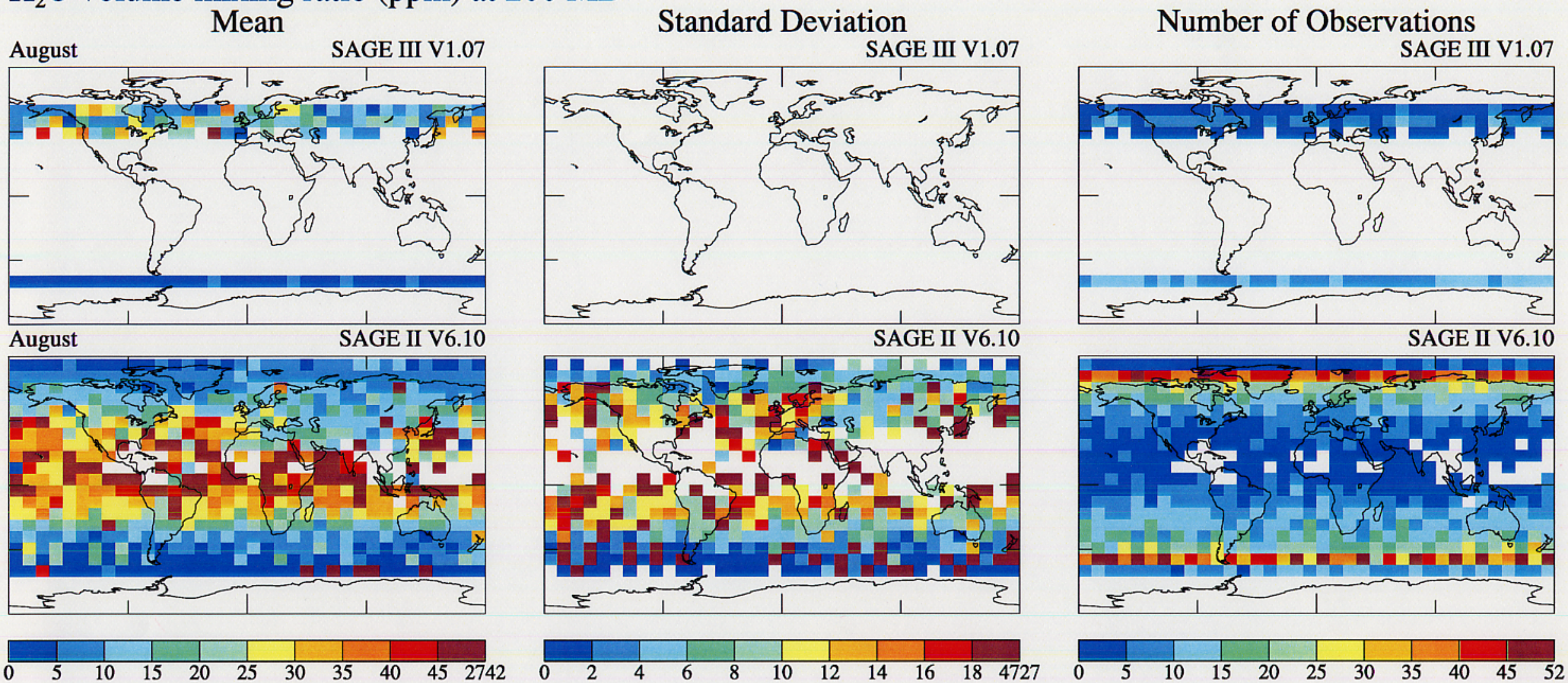
Relative Humidity (%) at 200 MB SAGE II V6.10





SAGE II - RADIOSONDE COMPARISON (Larson et al. 1992)

H_2O volume mixing ratio (ppm) at 200 MB



Stratospheric Aerosol and Gas Experiment II

Color Contour Maps of Monthly Mean Aerosols, Ozone, Water Vapor and Nitrogen Dioxide

January 1985 - December 1993

(*Version 1.0*)

Prepared by

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Goddard Institute for Space Studies
NASA Goddard Space Flight Center

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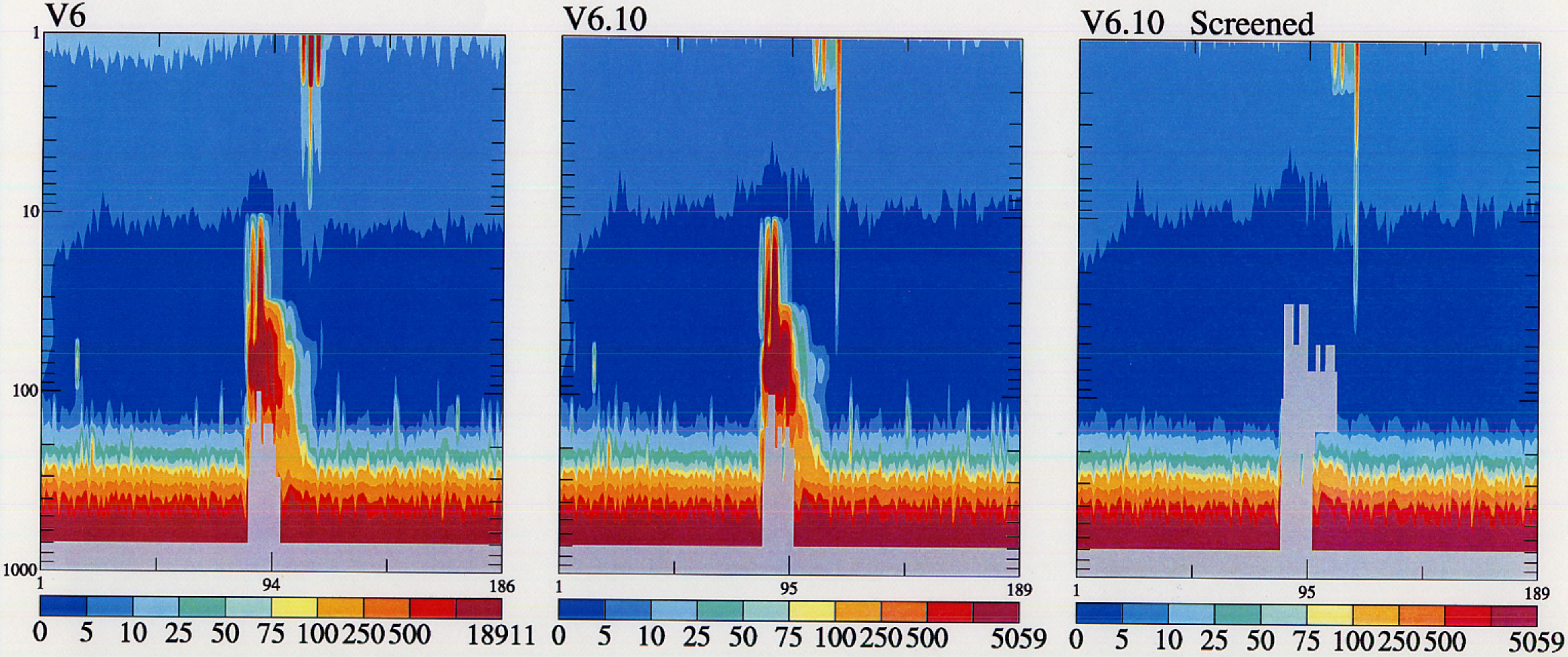
SAGE II CD CLIMATOLOGY VERSION 6.0

- 12 QUANTITIES
- 16 PRESSURE LEVELS
- MEAN, S.D., # OF OBS.
- LAT/ALT MEAN
- 12 MONTHS (AVE:11/84 - 4/00)
- FIGS (GIF, PS), DATA

H_2O volume mixing ratio (ppm); November 1984-July 2000



DATA QUALITY

- **ABSOLUTE MAGNITUDE**
- **ERROR ESTIMATE**
- **AEROSOL SCREENING**

2 CRITERIA:

- **1.02μ EXTINCTION$<5X10^{-4}$/km**
- **AEROSOL EXTINCTION$<$80% OF TOTAL AT 0.94μ**

H_2O volume mixing ratio (ppm) Apr1985 2000