The second day was opened by A. Barrie Pittock who made a plea for including physical understanding of sources of variances and the physical processes in the atmosphere. Statistical models looking at the data set without knowing what is going on are likely to be misleading. He cited the classic example of water levels in Lake Victoria which showed two nice 11-year cycles prior to the early 1920s that correlated with sunspots, but then showed much shorter, small amplitude cycles until the early 1960s. A massive rise of more than a meter then took place and levels have dropped only slowly since then.

To illustrate his point that physical insights can make sense of climatic series and provide evidence of causal relationships, Pittock showed a time series of precipitation in Seattle with an apparent anomalous increase in rainfall in the Puget Sound area since 1940. He then showed how this apparent anomaly can be accounted for meteorologically with the location of high pressure. "Thus," Pittock concluded, "we can use one physical time series to account for another."

Pittock pointed out the high variability of atmospheric ozone content, the variance of which changes markedly with altitude (Fig. 42), and showed the results of a recent analysis which broke the total variance in ozone over Aspendale (38S) down into components having different time scales and possible causes (Fig. 43).

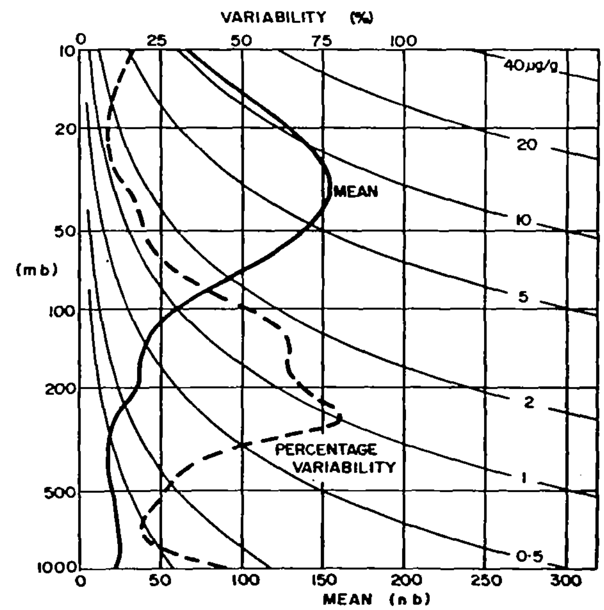


Figure 42. Variability of Atmospheric Ozone Content

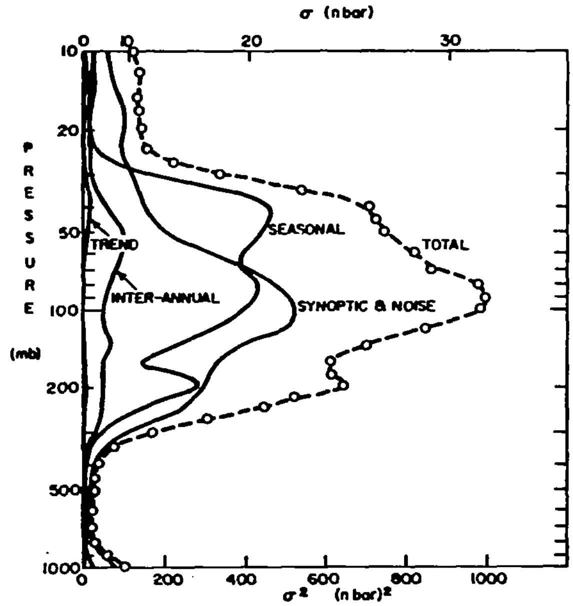


Figure 43. Components of Variance in Ozone over Aspendale

Noting that spatial patterns of variation give clues to the physics behind them, Pittock stressed the need to identify regions/stations which should be monitored to understand apparent trends.

In specific reference to Hill's methodology, Pittock said, "It is not just a matter of selecting equal area boxes but worrying about where the boxes are."

Spatial patterns of mean distributions or patterns of change, or eigenvector characteristic patterns, or patterns of correlations between stations or with circulation parameters can be used.

In eigenvector analysis, usually 80% to 90% of the total variance can be accounted for by the first eight or so patterns. So, Pittock suggested identifying patterns which account for the variances, then looking for what might cause them.

Pittock continued, "A few such patterns usually account for most of the variance, leading to physical hypotheses concerning causal relationships which can be tested." The dominant patterns in many climatic variations are standing waves, due to orographic effects and land-sea distribution, and patterns related to the strength of the Hadley circulation. These mechanisms, which operate on ozone, largely account for correlations between stations (Fig. 44) and suggest where monitoring stations should be located. Ozone in the southern hemisphere is highly correlated with the latitude of the high pressure belt (Fig. 45).

Correlations R, between Spring (ASO) mean total ozone amounts between various pairs of Southern Hemisphere stations. N is the number of data pairs, R^2 is the percentage of the variance accounted for by the correlation, and P is the percentage probability that the correlation has occurred by chance.

STATIONS	N	R	R^2	P
Hobart & Wellington v Aspendale	9	0.85	72	< 1
Macquarie Isle v Aspendale	10	0.81	66	< 1
Amundsen-Scott & Byrd v Aspendale	11	0.77	59	< 1
Brisbane v Aspendale	14	0.73	54	< 1
Darwin v Aspendale	5	0.20	4	large
Argentine Island v Aspendale	8	-0.33	11	large
Darwin v Brisbane	5	0.44	20	large

Figure 44. Correlations Between Stations

Time series of amplitudes of characteristic patterns should be monitored and compared with correlated circulation indices. A breakdown in well-established correlations between ozone variations and variations in other atmospheric parameters or indices would suggest the need to investigate anthropogenic causes.

Hypotheses as to anthropogenic causes should be tested by correlating indices of hypothesized causes, intermediate effects and corollaries, as well as effects on ozone. Pittock concluded, "If there is a change occurring and there is not a change occurring in the general circulation, then we'd get very suspicious."

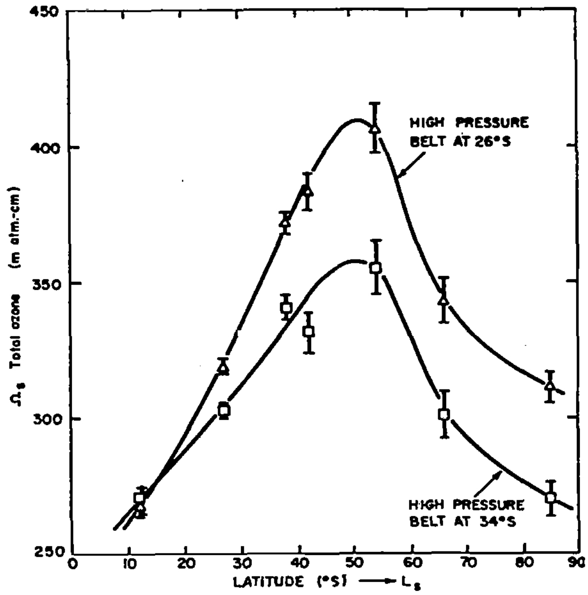


Figure 45. Total Ozone Versus Latitude

London presented information that the largest variance occurs with the largest ozone buildup (in winter), not at the largest total amount of ozone, to which Tukey added that "in a system with feedback, arguing with lags is hanging over an abyss because to say it occurs is also to say the reverse is true."

Lovill next discussed a paper, Temporal Variability of Total Ozone During 1957-75, written with his Lawrence Livermore Laboratory colleagues Thomas J. Sullivan and John A. Korver. The paper, as submitted to the proceedings, follows.

There are 152 stations that have taken total ozone observations. The length of record varies from 6,618 days (July 1957-December 1975) with observations taken at Aspendale, Australia to as few as six days at Woomera, Australia. This paper will use only the data from 15 of these 152 stations. The stations were selected on the basis of longevity of record and their individual standard deviation (σ). Each of these 15 stations has a minimum record data length of 18 years. The standard deviation of ozone values at a station is primarily a function of the instrument calibration and daily meteorological variability.

We have calculated the standard deviation of total ozone variations at a subset of 99 stations. These stations are located as shown in Figure 46 (a,b) and their σ's are indicated in Figure 47 (a,b) and Table 10. It is readily obvious that the σ's increase in value from lower to higher latitudes. The standard deviations range from as low as 9 m atm-cm at Huancayo, Peru to as high as 108 m atm-cm at Yakutsk, U.S.S.R.

It is worthwhile to compare the σ's at stations in similar latitude bands in order to obtain an estimation of individual station meteorological variability and instrumental accuracy. The σ's at stations in North America compare well with those in Western Europe at selected latitude bands. A comparison of the Western European and North American data with those of the Japanese stations also indicates similar values as a function of latitude. However σ's at many stations in the Soviet Union do not compare well with the data from North America, Japan, and Western Europe. In the southern hemisphere there are considerably fewer stations and the σ variability is large. Two stations do appear to deviate significantly from the average for their latitude band: these are Port aux Francais (σ = 83 m atm-cm) and Dumont d'Urville (σ = 85 m atm-cm).

Next we looked at regional total ozone variations during the 18-year period by combining the individual station records for selected regions (Figs. 48-51).

When this is done for the two Canadian stations ozone is observed to increase irregularly until 1966; thereafter it irregularly decreases. The combined record of the three Japanese stations indicates an irregular, slow increase of ozone that is continuing until the present. The two Australian stations indicate an irregular decrease of ozone continuing until the present. The Indian stations show a strong increase of ozone until 1964 and thereafter a slower increase and since $\sim$ 1970 a steady amount.

Next we have expanded our coverage using these 15 stations until it is global in extent. We will look at two different techniques for analyzing these 15 stations, which we think represent the best long-term data record available. In Figure 52 we have plotted the 18 years of data from the 15 stations such that each station contributes equally. These data in Figure 52, which are strongly biased toward the Northern Hemisphere (especially Europe) indicate an increase of total ozone until $\sim$ 1970 and thereafter a decrease. Figure 53 weights the station data in the Northern Hemisphere equally with those from the Southern Hemisphere. In this figure it is very difficult to determine a trend of any significance.

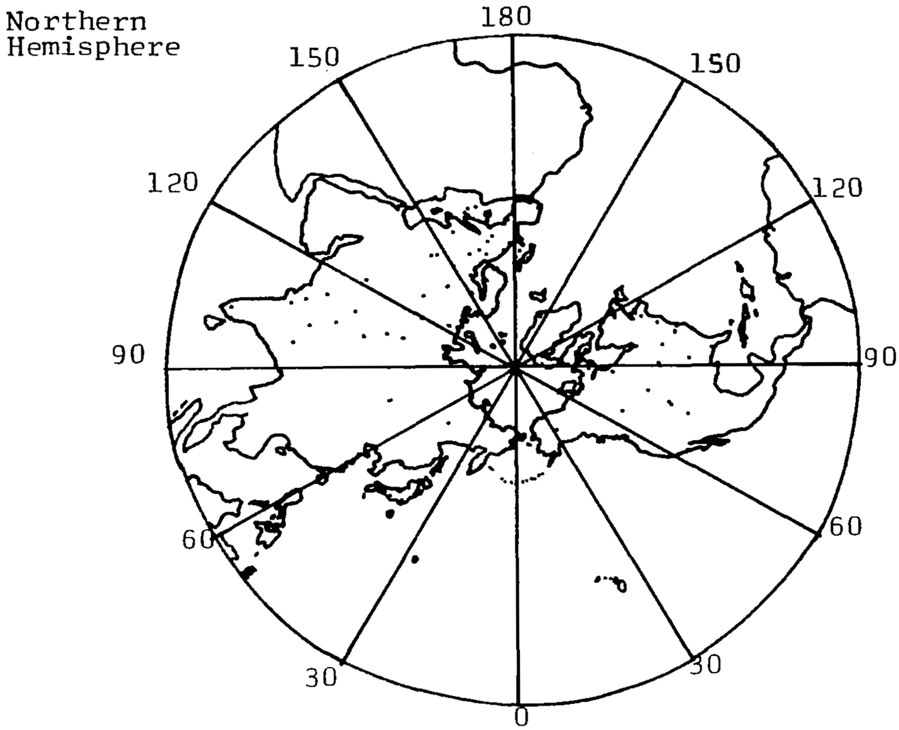


Figure 46a. Northern Hemisphere Station Locations

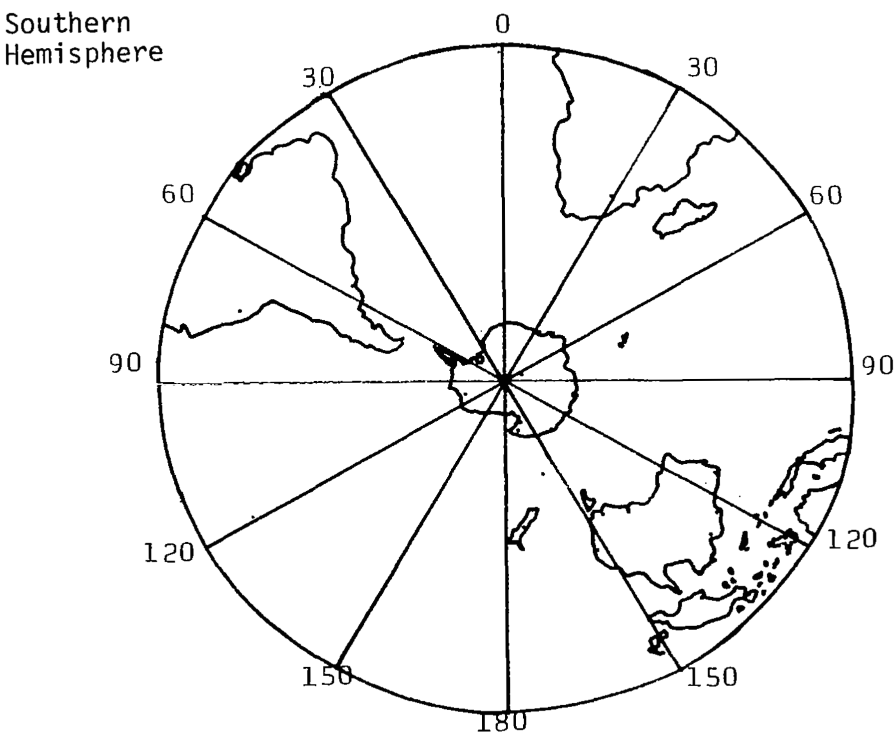


Figure 46b. Southern Hemisphere Station Locations

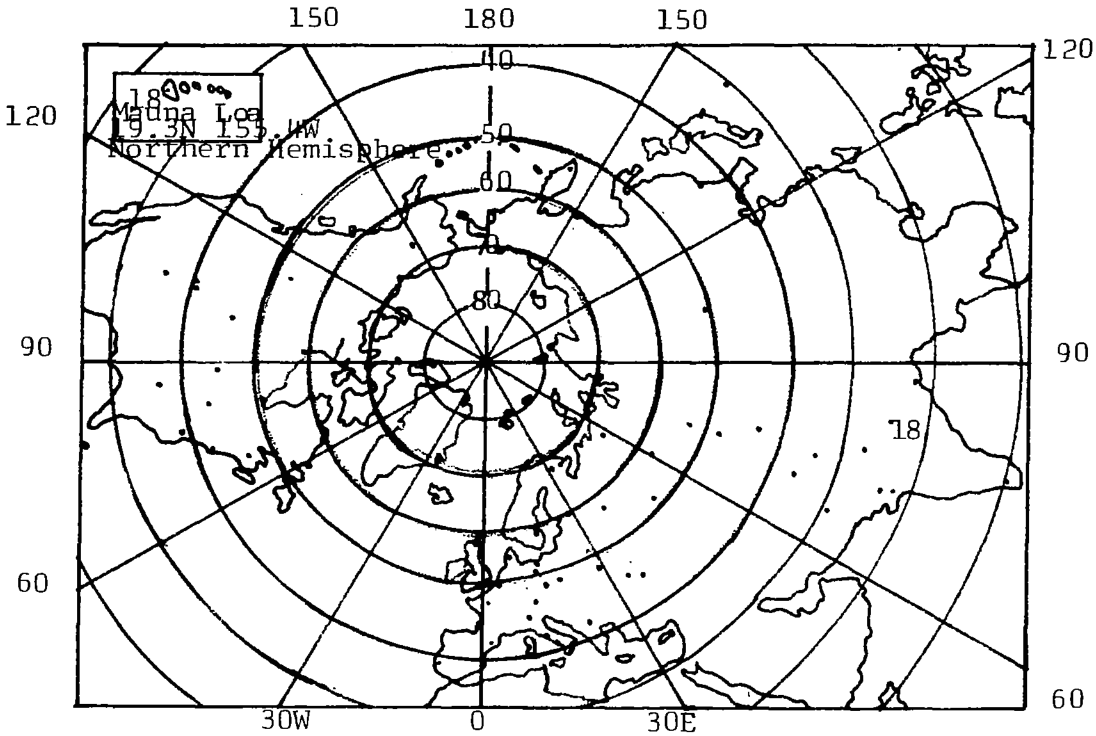


Figure 47a. Northern Hemisphere Total Ozone Observatory Stations Used to Calculate Standard Deviations

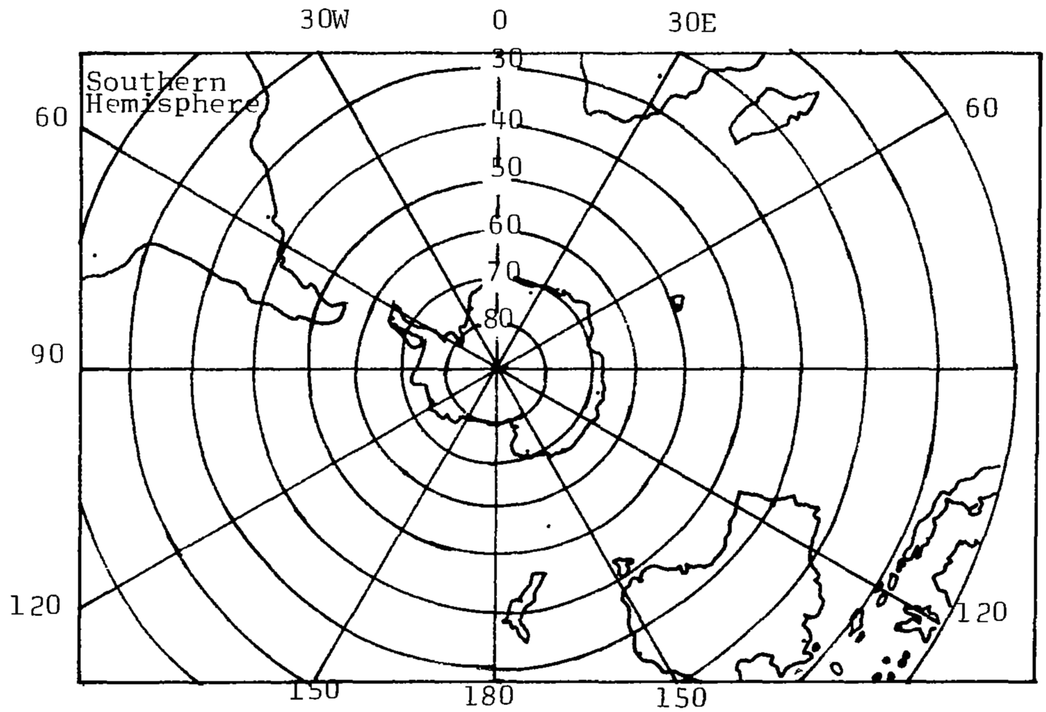


Figure 47b. Southern Hemisphere Total Ozone Observatory Stations Used to Calculate Standard Deviations

Table 10. Ninety-nine stations and their standard deviations

Station Number	Station Name	σ	$\overline{O}_3$	No. of Obser-vations	Latitude	Longitude
3	Alma Alta	67	321	4521	43.1N	76.5E
5	Dikson Island	103	364	1502	73.3N	80.1E
7*	Kagoshima	30	289	5804	31.4N	130.3E
8*	Kodaikanal	18	257	4457	10.1N	77.3E
9	Mount Abu	17	255	2678	24.4N	72.4E
10*	New Delhi	21	272	5974	28.4N	77.1E
11	Quetta	30	277	3325	30.1N	66.5E
12*	Sapporo	61	368	5918	43.0N	141.2E
13	Spinagar	26	292	4408	34.0N	74.5E
14*	Tateno	42	323	6515	36.0N	140.0E
15	Torishima	31	287	1404	30.3N	140.2E
16	Vladivostok	82	358	4577	43.1N	131.5E
17	Argentine Island	45	319	2310	65.2S	64.2W
19	Bismark	50	349	4946	46.5N	100.5W
20	Caribou	54	370	4098	46.5N	68.0W
21*	Edmonton	55	356	6278	53.3N	114.0W
22	Green Bay	49	358	4513	44.3N	88.1W
23	Moosonee	57	378	1356	51.2N	80.4W
24	Resolute	78	390	3878	74.4N	94.5W
26*	Aspendale	36	320	6618	38.0S	145.0E
27*	Brisbane	24	291	5280	27.3S	153.0E
28	Dumont d'Urville	85	317	333	66.4S	140.0E
29	Macquarie Isl.	50	342	4216	54.3S	158.5E
30	Marcus Island	28	270	1970	24.2N	153.5E
31	Mauna Loa	18	276	3372	19.3N	155.4W
32	Wellington	43	316	1622	41.2S	174.5E
34*	Arhus	63	351	5864	56.1N	10.1E
35*	Arosa	45	331	4879	46.5N	9.4E
36	Camborne	49	335	2577	50.1N	5.2W
38*	Elmas/Cagliari	40	331	6011	39.2N	9.0E
42	Leningrad	65	350	3997	59.5N	30.2E
43	Lerwick	60	354	4513	60.1N	1.1E
44	Spitzbergen	67	353	987	78.1N	15.4E
45*	Messina	40	343	6342	38.1N	15.3E
47	Naples	40	299	3139	40.5N	14.2E
48*	Oxford	53	356	5328	51.5N	1.1W
50	Potsdam	50	347	3024	52.2N	13.0E
51	Reykjavik	61	339	3179	64.1N	21.5W
52	Tromso	75	337	2474	69.4N	18.5E
53	Uccle	51	351	1411	50.5N	4.2E
54	Uppsala	64	329	439	59.5N	17.4E
55*	Vigna Di Valle	44	341	6458	42.1N	12.1E
57	Halley Bay	40	315	1999	75.3S	26.4W
58	Little America	83	318	152	78.0S	162.0W
62	Port Aux Francais	83	375	973	49.2S	70.2E
64	Sterling	42	340	1689	38.5N	77.3W
65*	Toronto	52	362	4298	43.4N	79.1W
66	Ft. Collins	39	310	1418	40.3N	105.0W
67	Boulder	40	332	2577	40.0N	105.2W
68	Belsk	50	341	3971	50.5N	20.5E
69	Hallett	41	339	400	72.2S	170.1E
70	Mont Louis	42	336	4450	42.3N	2.1E
71	Petoria	15	260	1799	25.5S	28.1E
72	Byrd	45	318	947	80.0S	119.3W
73*	Ahmedabad	16	253	3309	23.0N	72.4E
74	Varanasi	18	280	4071	25.3N	82.5E
75	Dumdum	17	268	2580	22.4N	88.3E
76	Goose	59	380	4752	53.2N	60.2W
77	Churchill	62	387	3572	58.5N	94.0W
79	Tallahassee	26	306	2432	30.3N	84.2W

Table 10 continued.

Station Number	Station Name	σ	$\overline{O}_3$	No. of Obser-vations	Latitude	Longitude
80	Gan	15	264	2215	0.4S	73.1E
81	King Bedouin	30	330	460	70.3S	24.2E
82	Lisbon	40	301	2235	38.5N	9.1W
84	Darwin	12	264	2706	12.3S	130.5E
85	Irkutsk	93	382	3003	52.2N	104.2E
86	Karadag	69	302	1927	45.0N	35.2E
87	Kiev	66	338	3880	50.2N	30.3E
88	Mirny	58	315	460	66.3S	93.0E
90	Ashkahabad	58	277	4188	37.5N	58.2E
91	Buenos Aires	28	287	1472	34.4S	58.3W
92	Hobart	40	327	2241	42.5S	147.2E
96	Hradec Kralove	51	335	3103	50.1N	15.5E
98	Val Joyeux	62	304	1801	48.5N	2.0E
99	Hohenpeissenberg	46	338	1770	47.5N	11.0E
101	Syowa	47	342	892	69.0S	39.4E
102	Bracknell	49	352	1512	51.3N	0.5W
103	Albuquerque	32	297	1493	35.1N	106.4W
104	Bedford	49	357	1569	42.3N	71.2W
105	Fairbanks	59	383	1288	64.5N	147.5W
106	Nashville	36	334	3836	36.2N	86.3W
107	Wallops Island	38	327	1779	37.5N	75.3W
110	Huancayo	9	263	3797	12.0S	75.2W
111	Amundsen-Scott	43	325	1377	90.0S	0.0W
112	Bolshaya Elan	89	364	3118	46.5N	142.4E
113	Dushanbe	64	278	3454	38.4N	68.5E
115	Kuibyshev	75	330	3328	53.2N	50.3E
116	Moscow	79	327	2874	55.5N	37.4E
117	Murmansk	87	354	2803	68.5N	33.0E
118	Nagaevo	102	386	2576	59.4N	150.5E
119	Odessa	71	329	3430	46.3N	30.4E
120	Omsk	77	369	3494	54.5N	73.2E
121	Riga	74	348	3411	56.5N	24.0E
122	Sverdlovsk	69	354	4103	56.5N	60.4E
123	Yakutsk	108	366	2668	62.1N	129.5E
128	Karaganda	62	269	1019	49.5N	73.1E
129	Pechora	85	303	955	65.1N	57.1E
130	Petropavlovsk	87	357	1277	52.5N	158.5E
132	Sofia	41	314	921	42.5N	23.2E
159	Perth	29	295	2314	31.5S	115.5E

*Key Stations

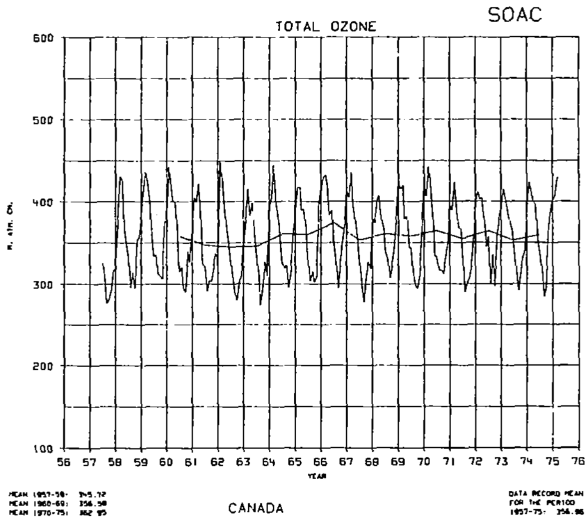


Figure 48. Ozone Variations at Canada

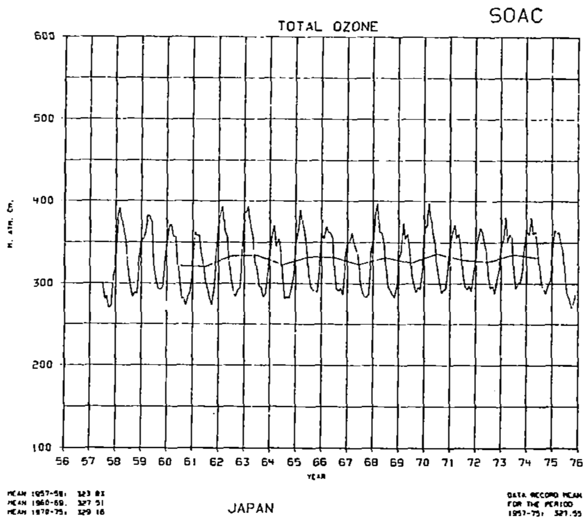


Figure 49. Ozone Variations at Japan

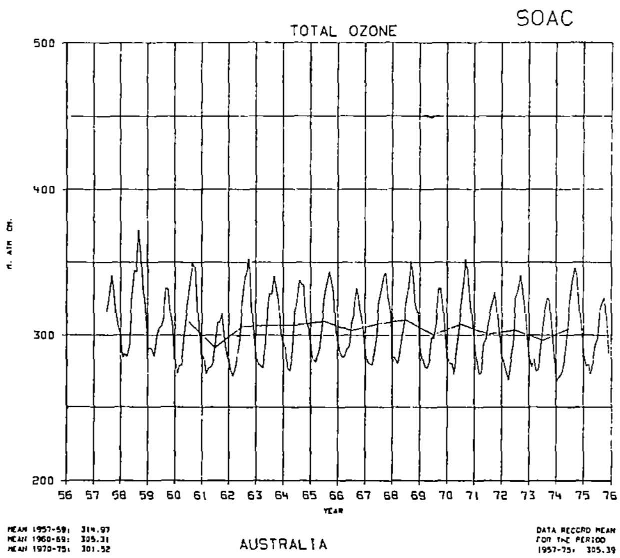


Figure 50. Ozone Variations at Australia

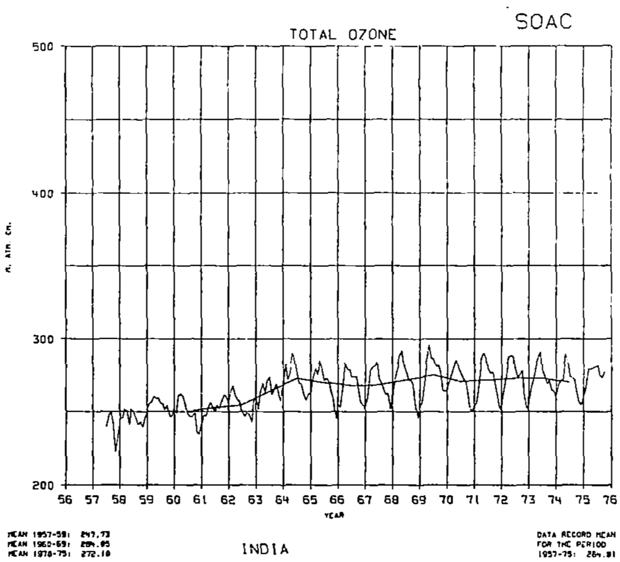


Figure 51. Ozone Variations at India

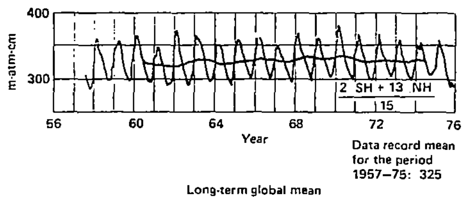


Figure 52. Ozone Content, Each Station Weighted Equally

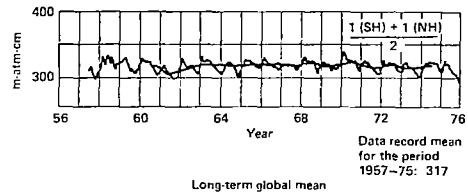


Figure 53. Ozone Content, Each Hemisphere Weighted Equally

Both data sets do show a decrease of ozone after ∿ 1970 and a distinct minimum in 1961.

It is our conclusion that a carefully selected data set of 15 stations indicates no obvious long-term trends in global total ozone. Because of the data sparsity over the oceanic regions and the strong bias toward the Northern Hemisphere (and especially Europe), we feel that analysts should utilize the total ozone data available with caution and careful inspection of parameters, such as the station σ's.

SATELLITE ANALYSIS

Figure 54 indicates ∿ 100 days of total ozone data as measured by the Nimbus 3 IRIS sensor. These data have been latitudinally weighted to remove areal bias. The data extend through a period starting with the Northern Hemisphere spring (Southern Hemisphere fall) and ending with the Northern Hemisphere summer (Southern Hemisphere winter). The standard deviation for the data set is 2.6 m atm-cm.

During this period there was approximately 5% more total ozone observed by satellite in the Northern Hemisphere (318 m atm-cm) than in the Southern Hemisphere (303 m atm-cm) (Table 11).

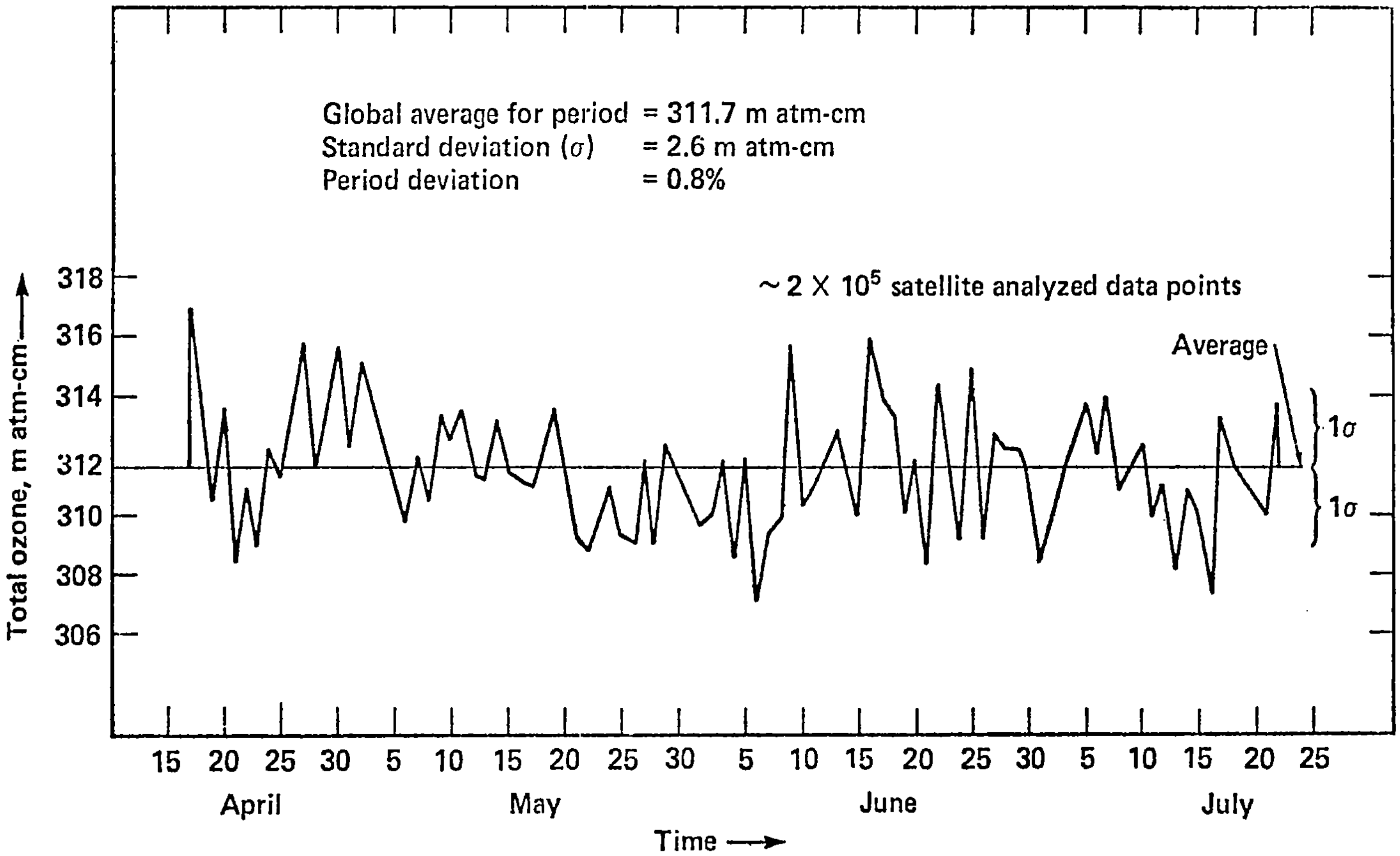


Figure 54. Total Ozone Data Measured by Nimbus 3 IRIS Sensor

Table 11. Land and Sea Distribution of Total Ozone (April 16-July 22, 1969; Nimbus 3; 1.85 × 10 data points; values in m atm-cm).

	Land	Sea	Total	Standard Deviation	Sea-Land (m atm-cm)	Sea-Land %
Global	310.3	312.1	311.7	2.6	1.8	0.58%
No. Hemis.	315.8	319.1	318.1	7.8	3.5	1.04%
So. Hemis.	302.9	303.1	303.1	8.9	0.2	0.07%
30^{o}N-60^{o}N	337.5	344.1	341.6	14.3	6.6	1.96%

Perry Gluckman presented his time series analysis which was done in the frequency domain rather than the time domain. His analysis tended to corroborate what other speakers had presented. Details of his presentation are not available for the proceedings.

John Tukey of Princeton University discussed the use of exogenous variables. "While I do not for a moment undervalue physical insight or physical explanation, it is important to keep in mind that purely statistical considerations call for making adjustments of empirical size for any internally reliable exogenous variable that could possibly make sense.

"We ought to do more to find and use exogenous variables." He concluded by suggesting some exogenous variables that might help:

- Pittock's general circulation quantities
- Reiter's energy sloshing and vacillation
- Gluckman's intermonth adjustment to fixed dates
- Gluckman's sector crossings - field reversal
- ??? geomagnetic character figures

Others suggested by conferees included:

- local winds aloft
- local barometer
- local height of tropopause

Tukey said, "Suppose we do adjust for the local barometer, then collect the global mean. Then we must think carefully about the interpretation if the mean barometric pattern is changing." London noted that this was already done, at least in part, in Pittock's general circulation.

Tukey summarized his suggestion to "use the things we can trust--such as local pressure--and see what happens when we use them and then look for explanations." London responded that the key problem is the use of extra information in terms of filtering. "You are bringing up the key to the filtering problem in getting the real information." Tukey agreed saying we should "use all available principles of witchcraft and if some are roughly orthogonal we should use both." He restated Hill's methodology as using persistence and shocks to see what they tell us, then focusing the analysis on the shocks. This methodology, Tukey said, "does get you out of certain technical problems; it saves trouble with the data Hill had. If we can provide better data, perhaps he can do better." But Tukey concluded, "We cannot bypass Basher."

James K. Angell, of NOAA, compared ozone trends with stratospheric water vapor, the temperature of the equatorial tropopause, and the north temperate latitude temperature (Fig. 55) to illustrate what he termed some "very interesting" results. Although the water vapor data record is short, beginning in 1964, and there are not many measurements (only one a month at the most), the total ozone is very well correlated with water vapor and distinctly out of phase with stratospheric temperatures. That

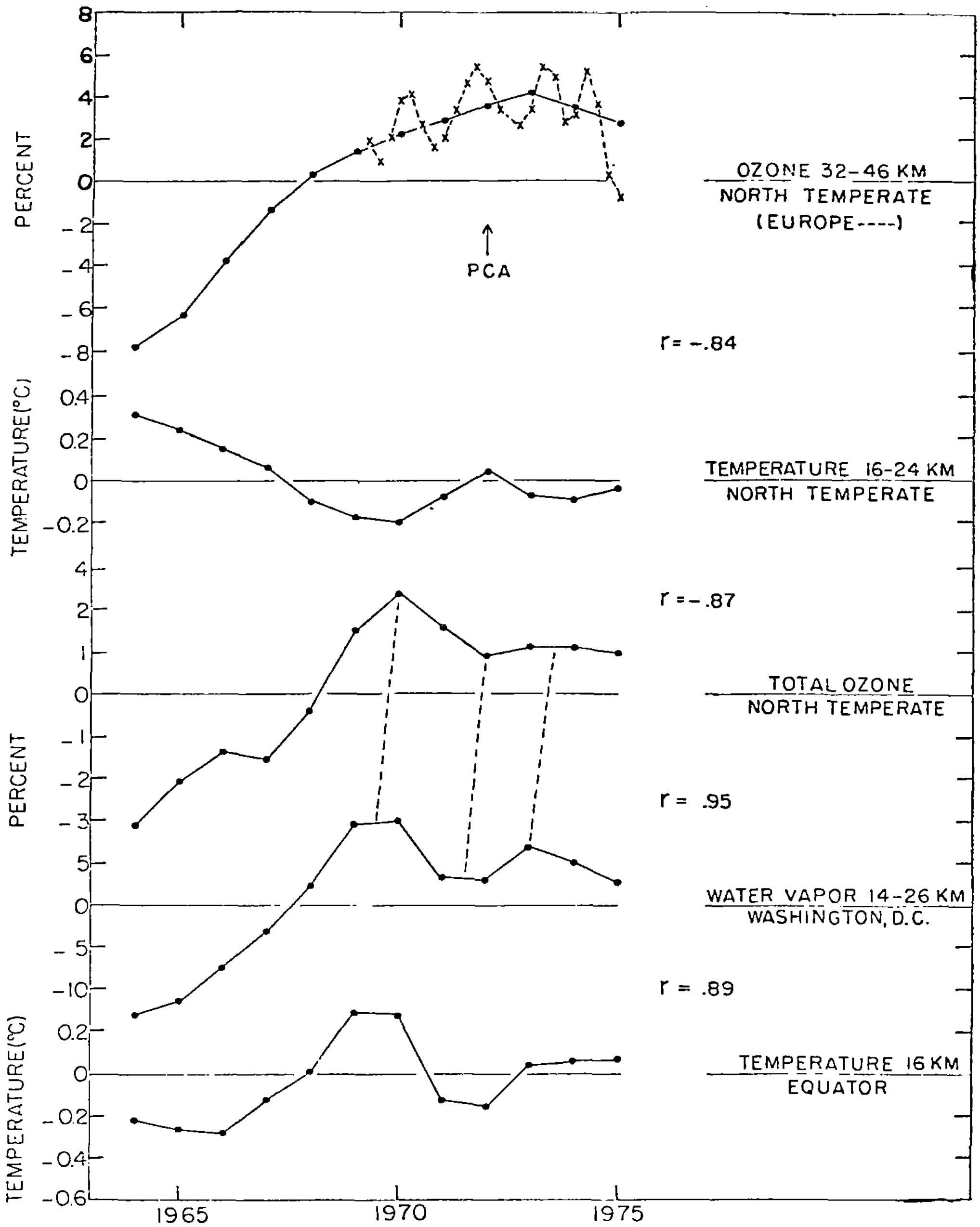


Figure 55. Comparison of Ozone Trends with Stratospheric Water Vapor, Temperature of Equatorial Tropopause, and North Temperate Latitude Temperature

is, the maximum ozone occurs when the stratospheric temperature is the lowest, an unexpected result for which Reiter offered a meteorological explanation: stratospheric water vapor comes mostly from summer monsoons whereas ozone is a winter characteristic. He further suggested that the anticorrelation of temperature may be due to pressure distributions as suggested earlier by Pittock.

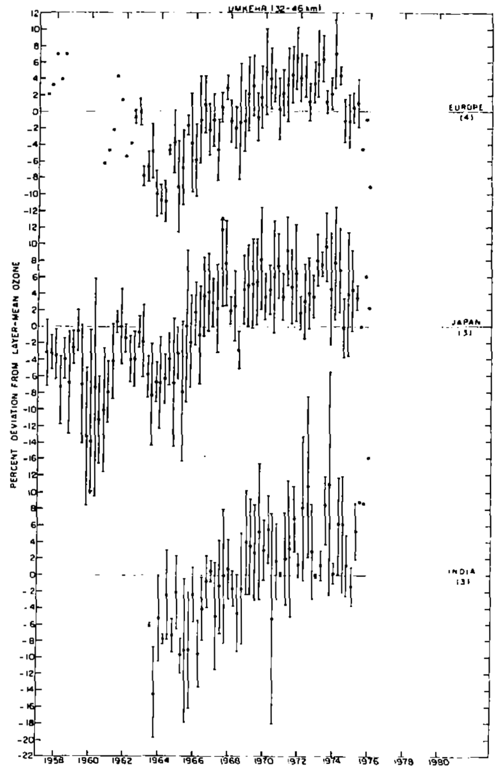


Figure 56. Umkehr Data

Angell expanded the puzzle with Umkehr data (Fig. 56) noting that, "If you accept Umkehr data, we see an increase instead of the expected decrease due to CFMs. This problem is not really resolved but, where we should see a 5% decrease and we see instead 12% the other way, it makes us wonder."

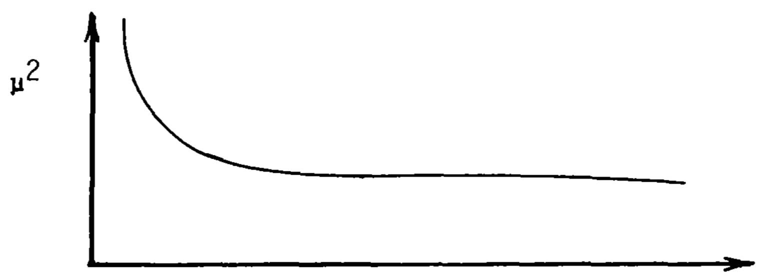
In subsequent discussion Angell pointed out that an anomaly in the data coincides with the eruption of Agung, leading him to question how Hill's analysis deals with such an anomaly. Hill said that he had misunderstood the previous question and that indeed the volcanic effect was in his analysis and that his techniques certainly try to quantify such interventions. Tukey elaborated that Hill's pre-whitening filter says nothing about mechanisms. "The effect of Agung is in there but it is not really significant --the whole question can be solved if Hill leaves out the quasi-biennial and uses only short analyses."

Pittock agreed that using only short analyses would avoid "the primary problem of building in a prediction that Agung will happen again."

Tukey, attempting again to summarize the issues at hand, said there are at least three parts to the problem--potential measurement troubles as described by Basher, the question of where you measure to gather global meaning, and the statistical factors--and each part "must be got at separately." One must allow for the real world because none of the other factors has yet included any natural trends.

Referring to a three-dimensional chemical-dynamical model developed by Jerry Mahlman of NOAA-GFDL, Campbell said this model showed poor agreement when used to compare the "true" global change in ozone to a global change estimated using Angell's best 53 stations placing equal weighting on each of the 53 stations. However, Tukey interjected, "a very different idea" could be achieved by "sensibly weighting the stations geographically." Tukey suggested 1) do a consistent (simplified) time-series analysis (short lags only) for say, 53 stations; and 2) study covariances and perhaps correlation coefficients between estimated shocks, and check the spectra, and some cross-spectra, of the estimated shocks. He recommended as further steps forward: "criticism" of empirical adjustment (regression) coefficients in terms of frequency bands (Fig. 57).

Breakdown of such analyses as



into at least a few frequency bands

Figure 57. Empirical Adjustment Coefficient in Terms of Frequency Bands

John DeLuisi asked if transformation can be made from historical ozone data to satellite data that, while global, will necessarily have some scatter. It would seem that a reasonable overlap would be at least one solar cycle. C. Desmond Walshaw noted that the Dobson instruments would be needed for some time. "Ozonesondes," he said, "were going to make the Dobsons obsolete and they did not." He continued, "Everyone who uses the total ozone network should be aware that there are all sorts of problems." (Fig. 58).

The Dobson measurements are not only extremely important for the next 10 years but they are equally important as historical records if they can be corrected by "measurement archaeology."

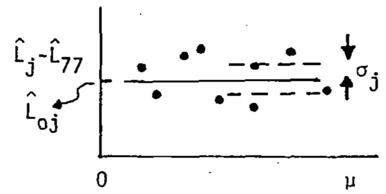
Komhyr noted that the basic problem in making Dobson spectrophotometer observations is the effect of pollution where it is estimated that errors of several percent can result. As far as NOAA's total O_3 data are concerned, we have the basic calibration information that can be used to improve the quality of existing data; however, we do not have the necessary resources to make these corrections.

$\Delta N = \mu \tilde{\alpha} \Delta x$

Take $\begin{cases} \Delta x = 300 \text{ m atm-cm} \\ \mu = 2 \end{cases}$ i.e. $\frac{\Delta x}{x} \approx 0.01 = 1\%$

	C	AD
$\tilde{\alpha}$	0.8	1.4
$10^3\ \Delta N$	4.8	8.4

BELSK INTERCOMPARISON 1974



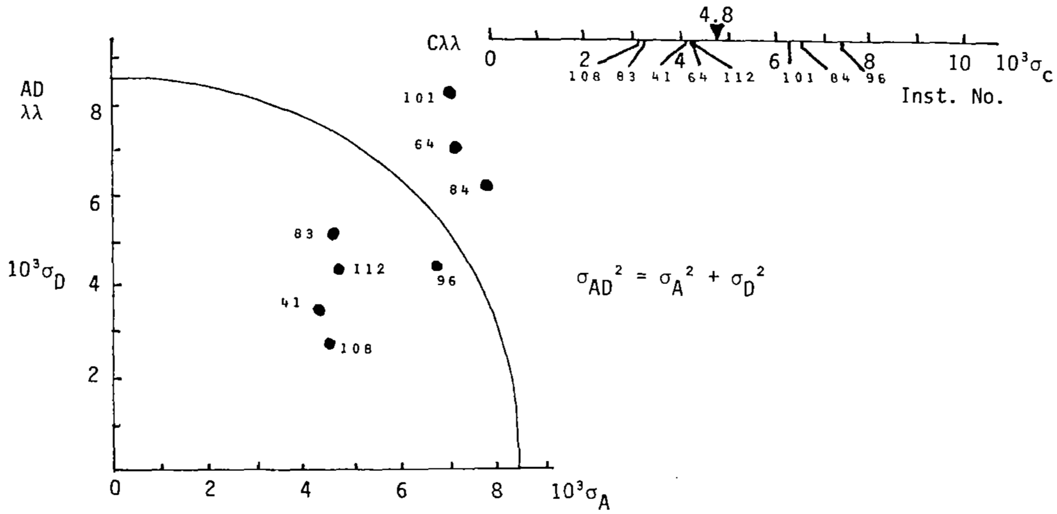


Figure 58. Accuracy of Total Ozone Network (Direct Sun)

THE FUTURE

PRIMARY REFERENCE INSTRUMENT 83	No. 83 (USA) USA	$\hat{L}_o$ Mauna Loa

SECONDARY REFERENCE INSTRUMENTS	41	64	77	112		108			
	UK	DDR	CANADA	INDIA	AFRICA	USSR	JAPAN	AUSTRALIA	
OTHER INSTS.	...	...	....	...	..	..	..	...	

- WORLD NETWORK
- CONTINUED RESEARCH — Stability, intercomparison by lamps
- NEW INSTRUMENTS
    - BREWER
        - Diffraction grating → small
        - Photon counting → no wedges
        - Built-in Hg & Stand. lamp
    - MATTHEWS — Filters (? stability)

Figure 59. Worldwide Network

But after the current intercomparisons Walshaw said, "We should have a satisfactory worldwide network for the first time." (Fig. 59)

Joseph Drewry explained that his primary interest was mission analysis. "What future satellite missions do we need to determine total ozone?" he asked.

"It is not obvious that time series analysis can address the ozone problem." Drewry proposed a possible solution of "letting the data develop a global spectral model of ozone in a natural coordinate system, and trying to minimize the variance of important model parameters with sampling analysis." Figure 60 shows the sampling capability of a simulated solar occultation mission over an ozone model based on weekly estimates over a $5^{\circ} \times 15^{\circ}$ global grid.

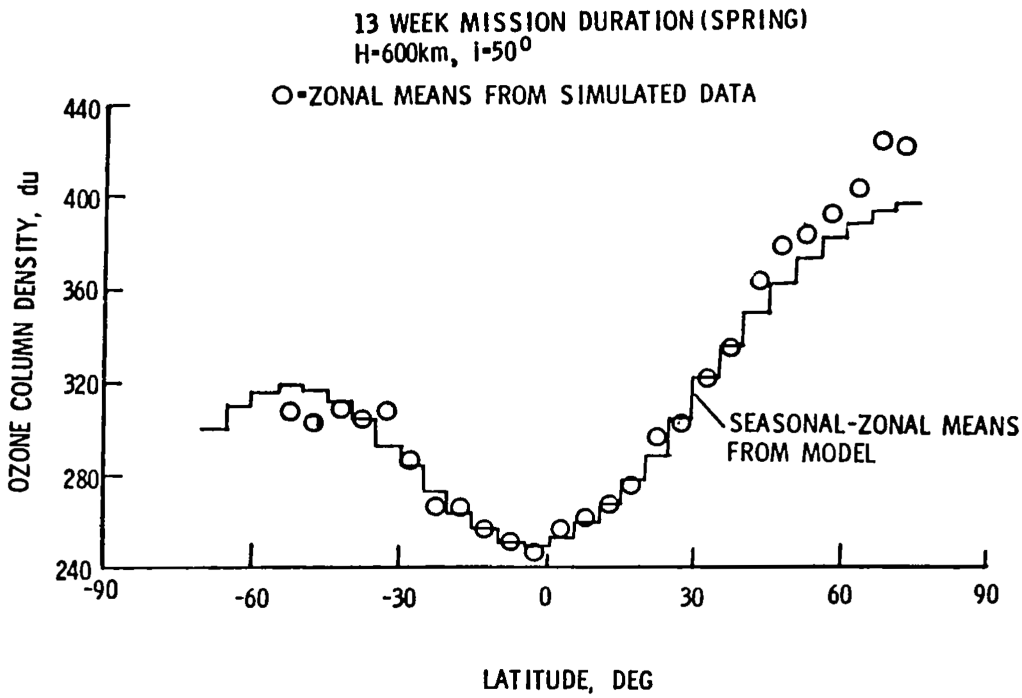


Figure 60. Sampling Capability of Solar Occultation Mission

He emphasized that the difference between the model estimates and estimates from the simulated mission reflects sampling distribution, not measurement errors. Drewry referenced Figure 61 when discussing empirical orthogonal functions as a technique for examining the information in a data set representative of global ozone data. He noted that "in the set of gridded data from which this example was taken, 98 percent of the variability about the monthly mean

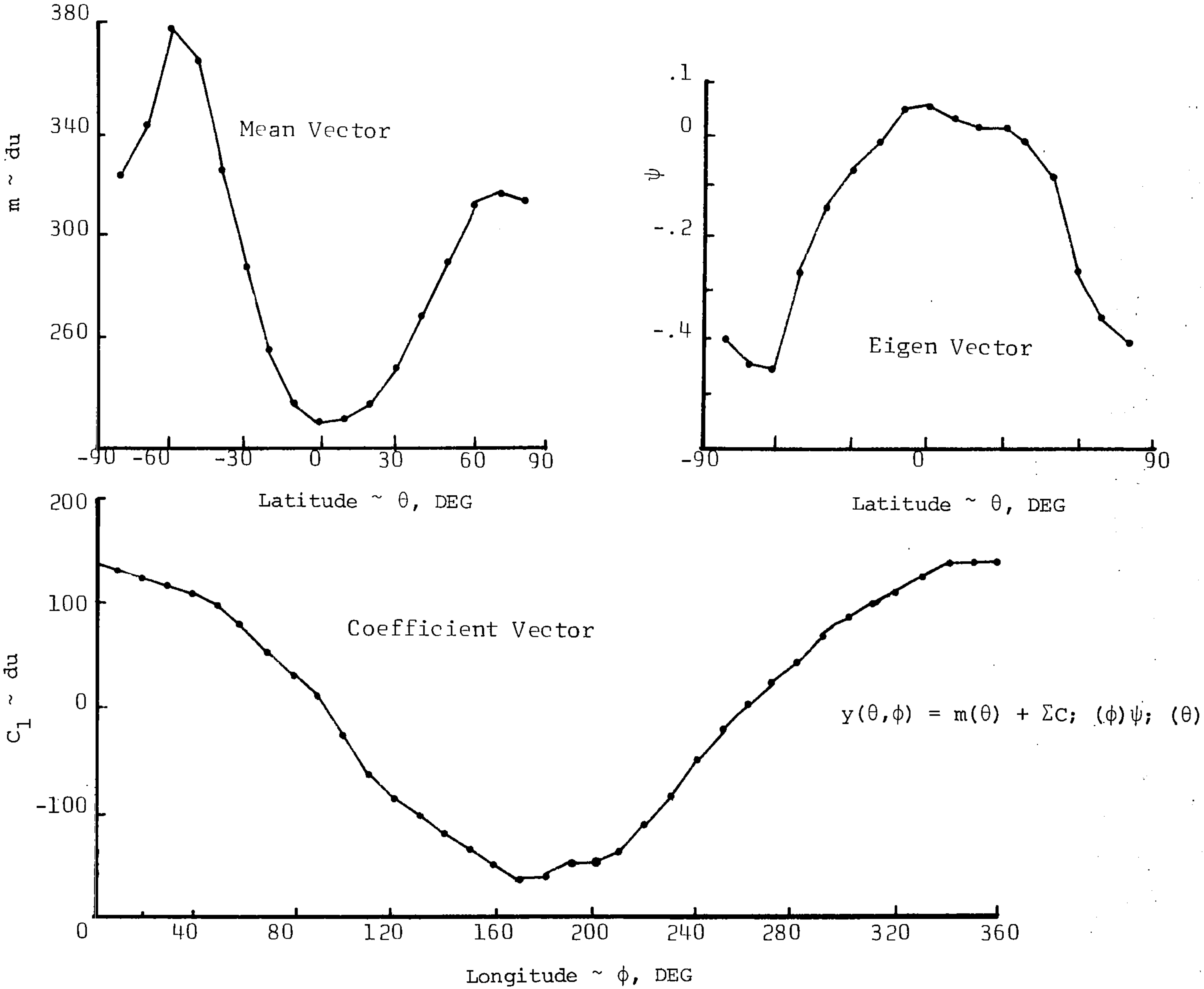


Figure 61. Principal Component of Data
Ozone Spatial Distribution -- October, 1970 Source: Nimbus IV

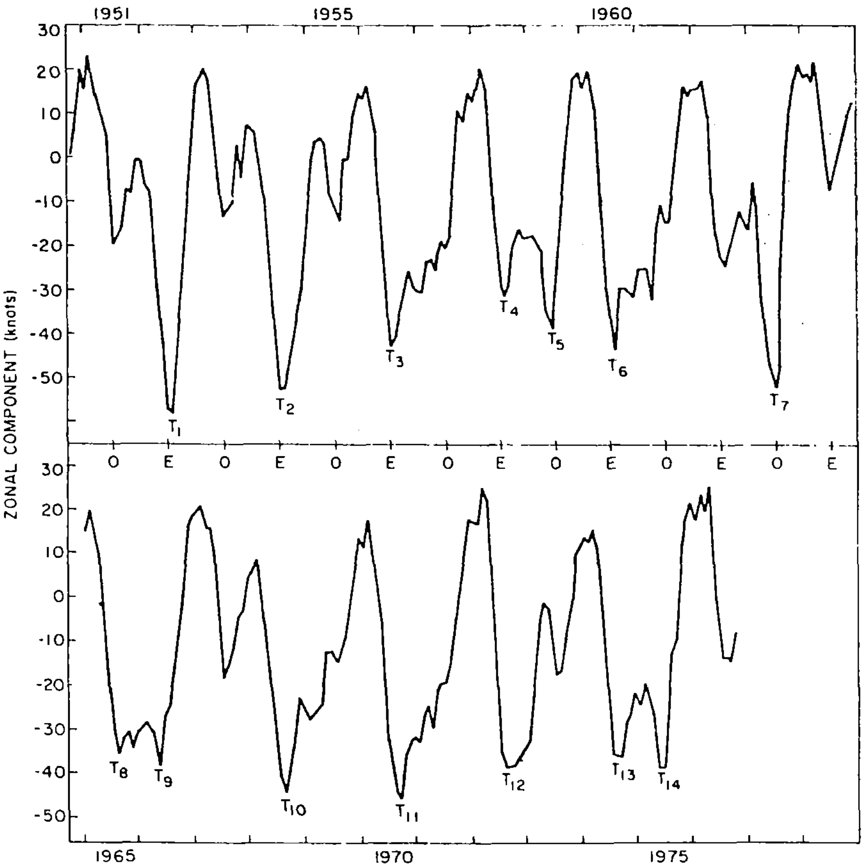


Figure 62. Balboa Data

can be explained by 6 eigenvectors; almost 85 percent is explained by the first principle component." He cautioned that data used in an analysis such as this could contain systematic errors which would be misinterpreted as ozone variability.

Tukey suggested contouring the next six eigenvalues to get the last 2% and then "looking for the physics behind them, assuming there is some physics behind them."

Glenn Brier presented a point of view as to how ozone helps understand the quasi-biennial oscillation using 26 years of data from Balboa (Fig. 62). He noted that, "If you look at a model with feedback you should expect trends and, in a two-season system, you should get a biennial result." The actual result (Fig. 63) is very asymmetrical with respect to the seasons, yielding a picture of interventions and shocks which are not randomly distributed. Narasimhan Sundararaman mentioned that the high altitude pollution problem led his agency to modify the original question, "Can we find a trend in the ozone?" into a new, more-to-the-point question, "What is the optimum Dobson network that would really give us the trends and how do we get that network?"

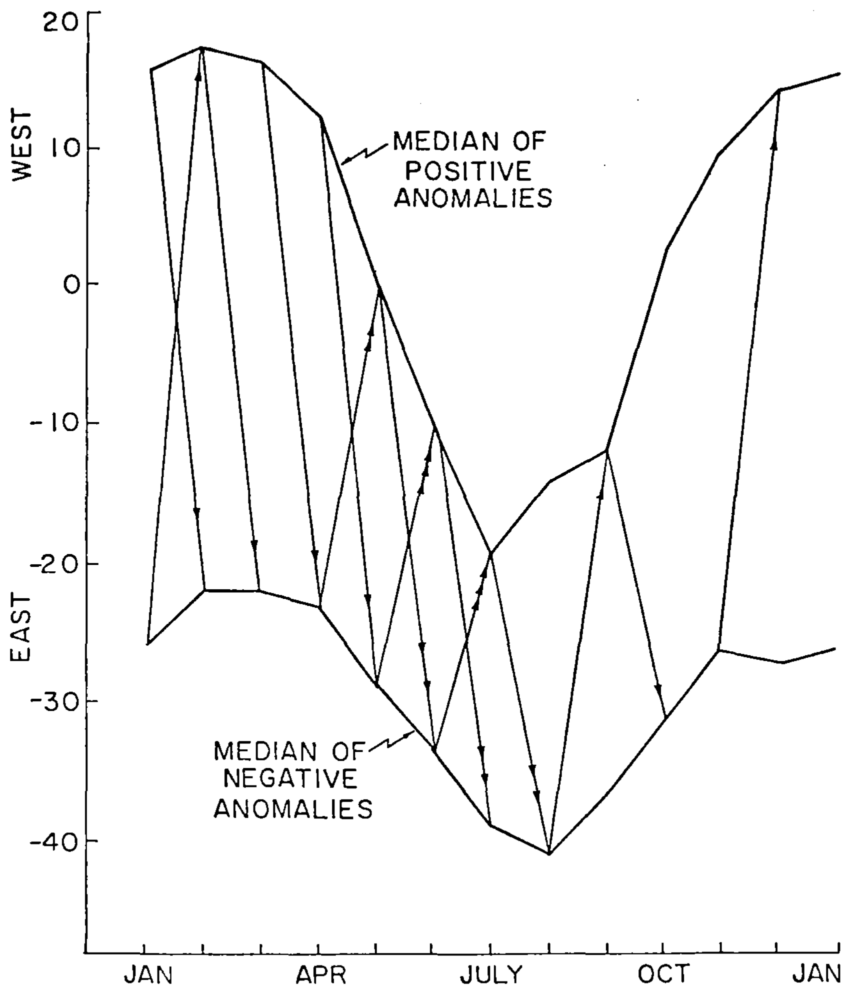


Figure 63. Results of Model with Feedback

To get a deeper understanding of the measurement error problems for ozonesondes and Dobson instruments, Heath suggested developing independent measurement checks, and comparing high quality Dobson data with satellite information. Rocket measurements, too, are possible. Although quite difficult, a standard rocket payload has now been developed. The rocket program, begun 10 years ago, should provide information on the total ozone trend by noting a trend in the 40-60 km altitude range.

SESSION IV: CONCLUDING REMARKS

At the conclusion of the Symposium, the chairmen from Sessions I and II were given an opportunity to make summary statements.

Dr. Hill began by thanking the conveners of the Symposium for the opportunity to present details of his time series analysis and the fruitful interchange that resulted. He reaffirmed his belief in empirical methods as "letting the data speak for themselves" rather than interjecting into models preconceived physical mechanisms that may not be supported by the empirical evidence. He conceded that empirical methods can lead to physically meaningless or unexplained results and, therefore, must be interpreted in light of plausible physical mechanisms. Dr. Hill concluded by expressing his hope that the dialogue begun at this symposium will continue.

In his summary remarks, Dr. London stated that there seem to be no serious objections to the statistical methods used. It is only the conclusions that are questioned, on the grounds that (1) the length of record was probably too short to eliminate low frequency effects of meteorological variabilities, (2) there may be systematic long-term trends affecting the observational system (giving incorrect data variations), and (3) stations chosen for the trend may not be representative of their geographic area and, therefore, would not give a correct global average.

Summarizing the suggestions offered during Session III, Dr. London underscored the recommendation that the same statistical methods be applied to meteorological data for which there are long, compatible series (e.g., temperature, precipitation, drought index, etc.) and where known trend changes have taken place (e.g., change from Northern Hemisphere warming to cooling around 1940). A second suggestion was that further research and data "washing" be done to make the various observational series homogeneous. The effects of optical wedge deterioration, atmospheric aerosol variation, solar irradiance variation, etc., need to be evaluated with more precision than has been done so far. "It should be emphasized that the importance of the problem dictates that reasonable sums of money must be expended to support this type of research." Finally, referring to the geographic representativeness of the data, Dr. London emphasized that a coupled satellite ground-based observational system is required to determine global long term trends. This requires maintenance and improvement of the Dobson network and long term planning for a satellite observing system.

Dr. London concluded by thanking the NASA sponsors, in particular Dr. Greenwood, for convening the Symposium, and the attendees who took time from their busy schedules to participate.

Dr. Greenwood also thanked the attendees and suggested that the participants send him their comments and/or recommendations after they have had time to reflect on the discussions. "A role that NASA can play is to encourage a continuing dialogue and we are open to suggestions on how best to do this."

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