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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 425

MONITORING OF RADIOSONDE HIEGHTS AND TEMPERATURES BY THE COMPLEX QUALITY CONTROL FOR THE NCEP/NCAR REANALYSIS

William G. Collins
Mesoscale Modeling Branch

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THIS IS AN INTERNALLY REVIEWED MANUSCRIPT, PRIMARILY INTENDED FOR INFORMAL EXCHANGE OF INFORMATION AMONG NCEP STAFF

Abstract

The NCEP/NCAR Reanalysis provides information not only on the state of the atmosphere for the 1958 to 1997, but also on the state of the observing system. One step in performing the Reanalysis is to quality control the radiosonde heights and temperatures, using the Complex Quality Control for Heights and Temperatures (CQCHT) program. CQCHT reads all the upper-air data, determines which data are in error, and makes corrections to "rough" errors associated with hydrostatic inconsistencies. Information is gathered on the stations reporting and on all errors detected. This information is customarily processed at one month intervals. This note describes the results obtained from those monthly summaries.

This note is divided into two main sections. The first describes the major changes to the number of radiosonde reports available through the 40-year period. The second describes the nature of the errors detected. In some cases there was a change at NCEP that led to an increase in errors for all regions; in other cases, the errors were isolated to a single geographical region. In only a limited number of cases is the reason for a change in the number of errors known. The reader of this note may be able to provide additional reasons.

Introduction

The CQCHT program has undergone continuous improvement since its introduction. The version used by the Reanalysis is documented in detail in Collins (1992). The basic philosophy for complex quality control (cqc) is given by Gandin (1988). The CQCHT contains several checks of the radiosonde heights and temperatures that are computed independently and prior to any decisions regarding data quality. These checks include: hydrostatic, incremental (observed value – 6 hr forecast value), vertical statistical check of increments, horizontal statistical check of increments, and temporal check of full values. When there are hydrostatic inconsistencies of sufficient magnitude, then, due to the redundancy of reported heights and temperatures, a correction to the data may be possible. When there are no hydrostatic inconsistencies, as for observation errors, then no correction is possible, but when appropriate the data may be identified as questionable or bad. These matters are discussed in somewhat more detail later in this note.

Each execution of the CQCHT program writes its decisions to files for later analysis. A subsequent summary program reads the collected decisions at monthly intervals and produces tables of summarized information. These tables include counts of data receipt and counts of errors, stratified in different ways. This information provides the basis for this note.

The emphasis in this note is not upon the correction of the data, but upon the numbers of reports available to the Reanalysis and upon the numbers of errors of various kinds detected. Nevertheless, some background on how the CQCHT detects errors, and just what those errors are, would be helpful. With this in mind, section 1 gives results on the overall counts of radiosondes and counts by large WMO region. Section 2 gives enough background of CQCHT to understand what the different error types are and how they are detected, and section 3 describes the overall numbers of the errors during the 40-year period and also describes any significant anomalies in the error counts for particular regions. There is some discussion of the reasons for some changes to error counts, but generally the reasons are obscure. If the reader knows of the reason for any of the unexplained anomalies he/she is encouraged to contact the author (William.Collins@noaa.gov). A final section discusses persistent baseline errors and some possible causes.

Numbers of reports available to Reanalysis

During the period covered by this note, August 1958 through December 1997, the main upper-air observation times were 00 and 12 UTC. There were only relatively small numbers of reports at 06 and 18 UTC, and these were dominated by particular geographical regions. Figs. 1-4 show the monthly radiosonde totals for the four observation times 00, 06, 12 and 18 UTC. There was a general swell in number to a maximum of about 23,000 in 1990. At 00 UTC there is an early increase, followed by a sharp decrease in May 1963. This decrease is not shared by all regions, but is dominated by decreases in (F)USSR, China and other regions. For some reason, this change is much less evident at 12 UTC. At these two times, note that there is a sharp negative spike at January 1973. This is associated with the introduction of O.N. 29 data format at NCEP (formerly NMC). At this time, the format of the data changed and (likely) a new upper-air decoder was introduced. Note also in the later years that the *daily* count is apparently regular enough so that the *monthly* count shows a dip each February.

At 06 and 18 UTC the global monthly counts of upper-air reports reach a maximum for the 40-year period of barely 5000. There are rapid and wild changes, usually determined by changes to one or a few regions. For instance, the rapid increase at 18 UTC for November 1969 was mostly due to the USSR, as was the rapid decrease in February 1990. These same changes are also evident at 06 UTC. The almost complete lack of reports at both 06 and 18 UTC for about two year after January 1973 is likely associated with the changes made at NCEP with the introduction of O.N. 29 data format.

Some of the regional data count changes in time are of interest. When the changes are shared by most regions then it may be safely assumed that the reason is to be found in alteration to the data receipt, handling, decoding or other process at NCEP. When the changes are found only at one or several regions, then the reason may be otherwise. As an example, Fig. 5 shows the 00 UTC monthly report counts for China (WMO blocks 50-59). The counts mirror closely the global changes. In particular, there is a sharp decrease from about 3500 to 600 in May 1963, with the numbers not recovering for 10 years. Another large region, USSR, as shown in Fig. 6 for 00 UTC, had a decrease from about 7000 to 5000, with rapid recovery to about 5800 or more. At the same time, the U.S. (Fig. 7) showed an increase over a one-year period from about 500 to over 2000, and Northern and Central Africa (WMO block 60-65,67) (Fig. 8) showed a sharp increase from less than 200 to about 350. Other regions show no significant change at that time. The reason for these changes is unknown, but they seem to be orchestrated in some way beyond individual regions. They may be associated with modification to the methods of data collection by the U.S.

The report counts for the combined region of Taiwan, Korea and Japan (WMO blocks 45-47) (Fig. 9) show a curious annual variation at 06 and 18 UTC. For much of the 1970s and into the 1980s there is a monthly maximum of about 70 in October, with a minimum near zero. One year only, 1990, this fall maximum reached 275. Annual variations may also be found for other regions, but the time of maximum varies. The reason for such annual cycles is not known. However, for one region with an annual variation, the time of maximum report count might be associated with the ease of taking observations. For the Antarctic, there is an annual variation, particularly evident at 12 UTC, with maximum in December. The same is true for Australia and New Zealand. By contrast, western Asia (WMO blocks 40, 41) shows an annual cycle at 06 UTC for the 1990s which peaks in March.

Table 1 lists briefly the notable characteristics of several large regions, identified by WMO blocks.

Table 1. Characteristics of Monthly Report Counts by Region

Region	WMO blocks	Comments
All	all	The total for all regions, 00, 12 UTC shows a general increase until about 1990 and then a decrease. 06 and 18 UTC counts are erratic. High count periods were 1969-1973, 1975-1982 and up to 1990. There was a dramatic drop in 1990. (Figs. 1-4)
W Europe E Europe	1-8,10,16 9,11-15,17	Both western Europe and Eastern Europe have times with significant jumps. Western Europe had fairly constant numbers, while eastern Europe has decreased from about 2500 in 1958 to about 500 in 1997, at both 00 and 12 UTC. Dramatic drops in eastern Europe counts were in late 1967 and early 1979. Western Europe has shown an increase in counts at 06 and 18 UTC to about 1000.

Former USSR	20-38	The counts were fairly stable from 1958 until a rapid decline, beginning in 1990. The decline may have abated, with counts less than half of what they were previously (> 6000 to ~2500). At 06 and 18 UTC the counts fluctuate wildly from 0 to 4400. (Fig. 6)
W Asia	40,41	Counts were variable, increasing to over 600 at 00 UTC, but were at a more level number around 400 at 12 UTC.
India	42,43	The numbers have steadily increased from about 500 to 900 at 00 and 12 UTC; small counts at other times.
Mongolia	44	The counts built up to about 200 at 00 and 12 UTC by 1991, when they dropped to almost 0. Since then they have increased back up to about 75.
Taiwan/ Korea/ Japan	45-47	Counts were very stable at 00 and 12 UTC (~900). But 06 and 18 UTC show an annual variation with sharp peak and minimum for many years near 0. (Fig. 9)
Indochina/ Malaysia	48	Counts are stable at about 400 at 00 UTC and 300 at 12 UTC, with small numbers at other times.
China	50-59	China has a big drop in count from 3200 in 1963, taking 10 years to get back up to the same level. Since 1980, the count has been quite stable at 3500 to 4000. 06 and 12 UTC counts are small. (Fig. 5)
North and Central Africa	60-65,67	Somewhat erratic counts, near 300 at 00 UTC and near 600 at 12 UTC. The 06 UTC counts dropped from about 300 to near 0 in January 1963, while the South Africa counts for most times showed a sharp up-turn at the same time. (Fig. 8)
South Africa	68	The numbers have built up to almost 400 from very small counts, beginning in 1963.
U.S.	70,72,74	After increases in the 1960s, the counts have been stable at about 2600 at 00 and 12 UTC and near 0 at other times. For some reason, Canadian stations were given block 72 numbers for 1973-1977 and counted with U.S. (Fig. 7)
Canada	71	After increases in the 1960s, the counts have been very stable at about 1000 for 00 and 12 UTC and near 0 at other times.
Central America	76,78	Central America had a quantum leap in 1979, increasing from about 100 to 700. The numbers have declined somewhat since at 12 UTC while increasing and showing an annual variation, peaking in September, at 00 UTC.
South America	80-88	South America is curious since 00 UTC and 12 UTC have different character. There were more data at 12 UTC, with general increase until 1973. 00 UTC showed the same increase, but then a large decrease in 1975. These lower numbers have persisted. Off-times have small, variable counts.
Australia/ New Zealand	93,94	An annual variation in count is especially noticeable for these regions in the mid-1970s at 12 UTC. The variation is up to 100/month, out of 300. Counts are somewhat variable, but average about 1100 at 00 UTC and 350 at 12 UTC.
Antarctica	89	An annual variation in count is especially noticeable for these regions in the mid-1970s at 12 UTC. The variation is up to 100/month, out of

		150. Counts at main observation times were up to 300-400 in the 1990s.
Pacific	91,96-98	The counts for the Pacific region have been generally increasing from about 100 in 1957 to about 1400 in 1997, at 00 UTC. The 12 UTC increase is more moderate, to about 800.

Description of CQCHT

Data error types

Observational data are subject to two major types of errors: instrument errors and rough errors. By instrument error is meant a (usually) small random error that all instruments have, even when operating as designed. Usually the characteristics of this error are well-known and its magnitude is taken into account during the analysis of the data. Rough errors come in two main varieties: observation errors and hydrostatic errors. By observation error is meant an error made by the observing sensor that is not operating as designed, e.g. a temperature sensor behaving badly at low temperatures. By this definition, observation errors are not random, and may be small or large. A rough hydrostatic error is evident when the reported heights and temperatures are not in hydrostatic balance. This is evidence that one or more of the heights or temperatures used to compute the hydrostatic imbalance is in error. These errors are special in that almost all of them are caused by direct human error, e.g. incorrect calculation or transcription of data. The rough hydrostatic errors also are not random and may be small or large.

There is in fact a third kind of rough error whose existence is implicit but not measurable by CQCHT. The radiosonde data are encoded in four parts, divided by pressure at 100 hPa and divided into mandatory and significant levels. Within each part, the data is encoded in groups of five-digit integers. In this form the data are transmitted over the Global Telecommunications Service for world-wide distribution. The WMO has established rules, which sometimes change, for encoding of data into this format. One task of a decoder is to assemble the parts into a whole. When there is an error in the encoding, or in the transmission of this data, then there may be, nevertheless, the possibility for a decoder to recover from the error. Different decoders will have different levels of skill in this error recovery. The fact is that the data used by the Reanalysis is not the original messages but radiosonde data that has been decoded and then put into another form for data storage and archival. Thus, the characteristics of the decoding stage in the handling of the data can only be inferred.

Basic philosophy of CQCHT design

The CQCHT is designed to detect rough errors of the observation type and hydrostatic type. It is also designed to correct the rough hydrostatic errors. In order to do this, it must accurately identify the erroneous data, determine the cause of the error, and determine the magnitude of the error for hydrostatic errors. With these objectives in mind, Lev Gandin formulated the principles of complex quality control. First is that the data are to be subjected to several checks, each as independent from the others as possible. The results of these checks are to be in quantitative terms, called residuals. No decision is to be made regarding data quality until all the check residuals are available. A final decision is made using all the available checks.

The decision involves identifying which data are in error, the type of error, and any correction that might be appropriate. No correction is made unless the resulting value leads to reduced residual values. In addition, since almost all rough hydrostatic errors are due to human error, corrections are sought that would return data to values before simple human errors, e.g. sign change for temperature, or single digit change, or interchange of two digits.

The checks

Each of the checks computes a residual, which, when taken together, form the complex of values used by the Decision Making Algorithm (DMA) to provide decisions on data quality. The most important of the checks is the hydrostatic check. The hydrostatic residual is the difference between the thickness of a layer between mandatory levels as given by the reported geopotential heights and that computed, using mandatory (and significant level) temperatures. In the Reanalysis version of CQCHT, the moisture influence upon the thickness is not calculated since its value is small and the moisture data has lower quality than the other mass data. There is a special form of the hydrostatic residual between the surface and the first mandatory level, called the baseline check.

Other checks are based on the difference between the observed value (of temperature or height) and the 6-hour forecast of the value. This difference is call the increment. The increment, by itself, is valuable in determining data quality, but is limited in use for small errors and in locations where the forecast error may be significant. There is also a horizontal statistical check, where the value of the increment is horizontally interpolated to the observation location, not using the datum in question. The difference between the increment and the horizontally interpolated increment is the horizontal residual. And there is similarly a vertical statistical check, leading to the vertical residual.

In addition, for the Reanalysis, it is possible to compute a temporal residual, which is the difference between an observed (full) value and the value interpolated from values for the same station and elevation at 12 or 24 hours before and after the observation time. This check is particularly useful at isolated locations where the horizontal check cannot be computed.

Detection of errors

Consider the information given by each check regarding the *location* of possible errors. Table 2 summarizes what each check tells.

Table 2. Location of error information for each check

Check	**Location information**
Increment	Error at same horizontal, vertical location and time as large increment
Vertical	Error at same horizontal location and time as large residual
Horizontal	Error at same pressure level and time as large residual
Temporal	Error at same horizontal and vertical location as large residual
Hydrostatic	Error at same horizontal location and time as large residuals. Further diagnosis of the complex of hydrostatic residuals, sometimes in concert with other residuals, is used to determine the pressure level(s) of the error(s).
Baseline	Error at same horizontal location and time as large residual.

Note, somewhat ironically, that the horizontal check cannot tell the horizontal location of an error, the vertical check cannot tell the pressure of an error, and the temporal check cannot tell the time of an error. And the situation with the hydrostatic check is even more complicated. If there is a pair of large hydrostatic residuals, for consecutive vertical layers, then their values must be used to determine whether the intermediate height or temperature, or both are in error. This is discussed fully in Collins and Gandin (1990). Only the increment, by itself, may be used to determine the location of an error, but all checks must be used to avoid identifying data as bad when it is really the 6-hour forecast that is in error.

When there are large hydrostatic residuals, a correction of data may be possible. As stated above, an attempt is made to recover the original value of the data. For this to be successful, there must be an accurate measure of the error. Because of the redundancy of reported heights and temperatures, the hydrostatic residuals provide such an accurate measure, particularly for heights. Therefore, the hydrostatic residuals are relied upon heavily to provide a provisional error correction. A 'simple' correction is looked for numerically close to the provisional correction—one that would lead to a single digit correction, interchange of digits, or sign correction by itself or in combination with single digit or interchange of digits correction.

Error types

There are specific error types that are identified, and some corrected. For the purposes of this note, it is not necessary to discuss them in detail, but they are listed in Table 3.

Table 3. Error types detected by CQCHT

Type	**Variable**
Observation	Temperature or height
1	Communication error to single height
2	Communication error to single temperature
3	Communication error to height and temperature at same level
4	Communication error to height and/or temperature at the lowest reported level
5	Communication error to height and/or temperature at the highest reported level
6	Computation error between two levels
7	Communication errors to heights at adjacent vertical levels
8	Communication errors to temperatures at adjacent vertical levels
9	Communication errors to height and temperature at next adjacent vertical levels
10	Communication errors to temperature and height at next adjacent vertical levels
11	Small type 1 error
12	Hydrostatically proposed correction would lead to significant super-adiabatic lapse rate
13	Data hole including 100 hPa surface
14	Data hole not including 100 hPa surface
22	Small type 2 error
99	Hydrostatically proposed corrections of type 8, 9 or 10 would lead to significant super-adiabatic lapse rate

Not all these errors occur in substantial numbers and will not be discussed in later sections. The most important error types are observation errors and hydrostatically detected error types 1-6. Not considered at all by this note are errors to significant level temperatures. Such errors were diagnosed by the CQCHT used by the Reanalysis, but have not been summarized.

History of errors detected by the Reanalysis

Error counts for the sum of all regions

The largest number of errors are to a single, isolated height or temperature (error types 1 and 2). The monthly count of errors of these types is displayed in Fig. 10. The numbers of these errors is comparable to each other, with a sharp increase in January 1973 to about 2500, followed by a general decrease and then another rise in March 1997. This figure should be compared to Figs. 1 and 3. The jump in errors in January 1973 is accompanied by only a one month dip in the report count, and the general *decline* in errors from 1975 onward is associated by a general *increase* in the count of reports. Therefore, the changes to error counts are not due to parallel changes in data counts. Rather, it is changes to the operations at NCEP that are responsible. In January 1973, NCEP (then NMC) changed data format from so-called O.N. 20 to O.N. 29 format. This was coincident with a major change to the WMO upper-air code. Associated with this was the introduction of a new upper-air decoder at NCEP. Other unknown changes may have also taken place. In any event, the changes either caused errors in the decoded data or did not correct for errors as effectively as previous procedures and codes. It took 20 years for the error level to return to the pre-1973 level. And then in 1997 an operational change was adopted by the Reanalysis that set back error levels by 10 years. In March 1997 the Reanalysis began using the new NCEP data 'tanks' set up for operational use of the BUFR data format. Along with this data format change went the introduction of a new upper-air decoder. This new decoder is not known to introduce any data errors, but it is not designed to handle complicated data error problems, thereby not recovering as much of the intended data as the previous decoder.

There is a drop in the numbers of type 1 and 2 errors in January 1960, due mostly to a drop of over 50% in these errors in the FUSSR. This happened at a time when the count of reports remained stable. One source for possible reasons for either data count changes or error count changes is the WMO report by D. Gaffen (1993) on "Historical Changes in Radiosonde Instruments and Practices." Unfortunately, no associated change to Soviet instrumentation or practices is found in this case. In fact, the search for any correspondence between instrument changes for any region and rough error count changes was fruitless, indicating that other factors overwhelmingly dominate.

Fig. 11 shows the monthly counts of errors of type 3—communication errors in both height and temperature at the same level. These errors share the decrease in January 1960 with errors of type 1 and 2. There is also an increase in counts in January 1973 with the introduction of O.N. 29. In addition, there is a unique feature for this error type. In July 1987 there is a sharp peak in type 3 errors of over 5500, with neighboring months of only about 1200. It is found that many regions share this peak, and that it occurs mostly at 20 hPa. For these cases, the temperature, before correction, often has one of the values 10.1, -10.1 or –88.8. Circumstantially, the evidence is that this error could be caused by an international change to encoding practice, not embodied in NCEP's decoding practice until a month or so later. The actual cause in unknown.

There is a sharp peak in error counts for types 1,3,5,7 in January 1965. Several regions individually have peaks, but they are the strongest for China. For the sum of all regions, the count jumps from about 20 to nearly 500 for type 7. No possible cause is known.

Error counts for individual regions

Naturally, the individual regions share in many of the characteristics already described for error counts for the sum of all regions. This section will concentrate on errors unique to a single or few regions. For western Europe (WMO blocks 1-8,10,16) there was a significant step decrease in errors of type 13 in September 1973. Errors of this type are usually caused by corruption to the lower mandatory level part of a report (Part A), with the upper mandatory level part (Part C) normal. This leads to a "hole" in the report between the level of the error and 100 hPa. Since this decrease in error count is not shared by other regions, the cause is likely due to a local improvement in encoding practice.

The error counts for India and Ceylon (WMO blocks 42,43) show a number of curious features. In January 1965, the counts for most error types, but particularly types 1 and 2, jump from very small numbers to significant numbers. Type 1 error counts increase to about 40, decreasing again to about 10 by just before March 1997, jumping again to over 150 with the use of the new NCEP decoder. The count for type 2 error before March 1997 is about 75, jumping to about 240. This relative increase in errors is greater than for most other regions. For error type 13 there is a peak of error count of about 200 in July 1978 from a base of about 20. This increase is not shared by other error types or regions. It must be due to a change to procedures internal to India. During none of these times when there were jumps to error counts was there a change to the data counts.

Suspicions of small temperature errors at mandatory levels are called type 22. These error suspicions are not corrected but are a sensitive indicator of potential problems. The number of type 22 errors shows a general increase for India, FUSSR, Taiwan/Korea/Japan, Indochina/Malaysia, China, Pacific and U.S. after 1990. In addition, the diurnal component of the variation greatly increases at the same time. This is disturbing, but no reason is known.

The Taiwan/Korea/Japan region (WMO blocks 45-47) exhibits three unexplained bursts of error. Type 1 errors increase briefly in late 1991; type 3 errors spike to over 1100 in August 1980; and type 5 errors increase to over 200 in about August 1987. For neighboring months, all these errors have small numbers.

China (WMO blocks 50-59) shows some periods with excessive error counts. The most distinctive is the short-term increase for January-February 1965. This increase is shared by most error types. This spike increase for several error types is also shared by South Africa (WMO block 68). It is also probably no accident that this happens at the same time that several error types for India show a step increase. There are other spikes for individual error types that are of less interest. The count of "holes" detected for China is very high for some periods of time: late 1950's to 1963 and early 1970's. During these times the counts of error types 13 or 14 are as high as 1800.

The only notable error characteristic for North and Central Africa (WMO blocks 60-65,67) and for Antarctica (WMO block 89) is that the increase of some error types was relatively great in March 1997, associated with the upper-air decoder change at NCEP. The inference is that these regions have a rather large number of irregularities in their encoded data, many of which could be corrected with the previous decoder.

The United States (WMO blocks 70,72,74) shows a unique spike for errors of type 3 and 5 in July 1983, with about 600 type 3 errors and 2500 type 5 errors. Usual numbers of each is less than 100. No explanation is known.

Canada (WMO block 71) shows low error counts in general. However, in September 1984, the monthly counts of error types 1, 2, 3, 5 and 7-10 increased dramatically and remained high. Routine monitoring at NCEP with CQCHT, beginning in 1988 noticed the unusually large number of type 5 errors (up to over 500/month). This problem was discussed with the personnel at CMC and it was determined by them that the problem was in the software to their automated stations—software that was introduced in late 1984. Any temperature observation within one hPa of mandatory levels was assigned to the mandatory level, thereby leading to increasingly large height errors at lower pressures. The error was detected by CQCHT as a hydrostatic inconsistency most often at the highest level, i.e. error type 5. By January 1989 the error was largely eliminated.

Australia/New Zealand (WMO blocks 93,94) shows error count spikes in late 1992 and early 1993, peaking in September 1992 for types 3 and 13 and in January 1993 for type 4. No reason in known.

Baseline errors

The baseline residual is the difference between the station elevation, as given by the NCEP station dictionary, and the station elevation that would be hydrostatically consistent with the reported heights and temperatures just above the ground level. In most cases, a large baseline residual signifies that one or more of the temperatures or heights that are used in this computation is in error. However, a persistent baseline error at a station, with magnitude that changes only within small limits, is due to a station elevation that does not match the rest of the report. This can be due to: 1) the station consistently using the incorrect station elevation in working up its reports, or 2) the NCEP station dictionary having the wrong station elevation. What is important to the Reanalysis is that the magnitude of this error, from whatever cause, can be estimated and removed in a subsequent reanalysis from the same data source.

There are three kinds of baseline errors that must be considered in identifying persistent large baseline errors. They are: 1) small random errors (with magnitude that generally increases with station elevation), 2) large rough errors, and 3) persistent errors. From this mix, it is desired to determine the magnitude and time span of any persistent errors. The bi-weight mean and standard deviation of the baseline residual for every month at each station were calculated, as suggested by Lanzante (1996). These measures are insensitive to outliers, thus giving a good estimate of any consistent error. Statistics were used only when a station had 5 or more large baseline residuals in a single month.

The most common cause for persistent large baseline errors is an error in NCEP's station dictionary elevation for a station. One way that this can happen is for a station to change its location without the necessary change being made to the dictionary. From time to time, comparisons have been made with other weather centers' dictionaries, with the goal of reconciling differences. This has led to several station elevations being changed in the dictionary at the same time. The results of the processing of baseline residuals for the Reanalysis shows that this likely happened in May 1963, in mid-1989 and likely at other times.

The correction to several station elevations in NCEP's dictionary in mid-1989 was directly due to the operational introduction of CQCHT and the monitoring of baseline residuals. Some of the stations whose dictionary elevations were corrected at that time and the magnitude of the errors are: 16144 (40m), 21358 (100m), 22820 (-65m), 23418 (-50m), 27707 (-37m), 29838 (34m), 30309 (-82m), 36003 (35m), 37260 (-100m, 41661 (170m), 51463 (-270m), 51886 (185m), 54337 (37m), 57516 (95m), 58666 (115m), 59134 (-80m), 60571 (-45m), 60760 (-41m), 62053 (87m), 71043 (-32m), 71926 (-37m), and 89512 (-40m). Most of these errors had persisted for a number of years. But 8 station errors began in mid-1986, at the same time that another 4 station elevations were corrected.

Since the introduction of CQCHT and its precursor in the late 1980's, the large persistent baseline errors have been routinely monitored. Cross-checks were made to all available sources and dictionary station elevation errors corrected as possible on an intermittent basis. Much of the final checking and actual change to the station elevations was done by Central Operations personnel. At this writing, there are a few stations that may need to have their elevations corrected and study is underway.

It is impossible in this note to give complete results for all the stations with baseline inconsistencies. About 450 stations show an inconsistency for some period of time. However, Appendix A shows a condensed summary of all the errors that are judged by inspection to be truly persistent. This list contains 218 stations.

There are certain dates that appear with unusual regularity, e.g. errors beginning in January 1976 and ending in December 1978. There is also strong evidence that 2 values were used interchangeably for some stations, beginning in January 1990 (and ending in 1993?). Interviews with then Automation Division personnel at NMC gives a likely explanation that two different upper-air decoders were in use, each with its own station elevation dictionary. Some data was processed by the Office of Systems Operations decoder and some by the NMC decoder. The stations that were likely affected are: 36870, 37789?, 41661, 51628, 51886, 57816? and 58666.

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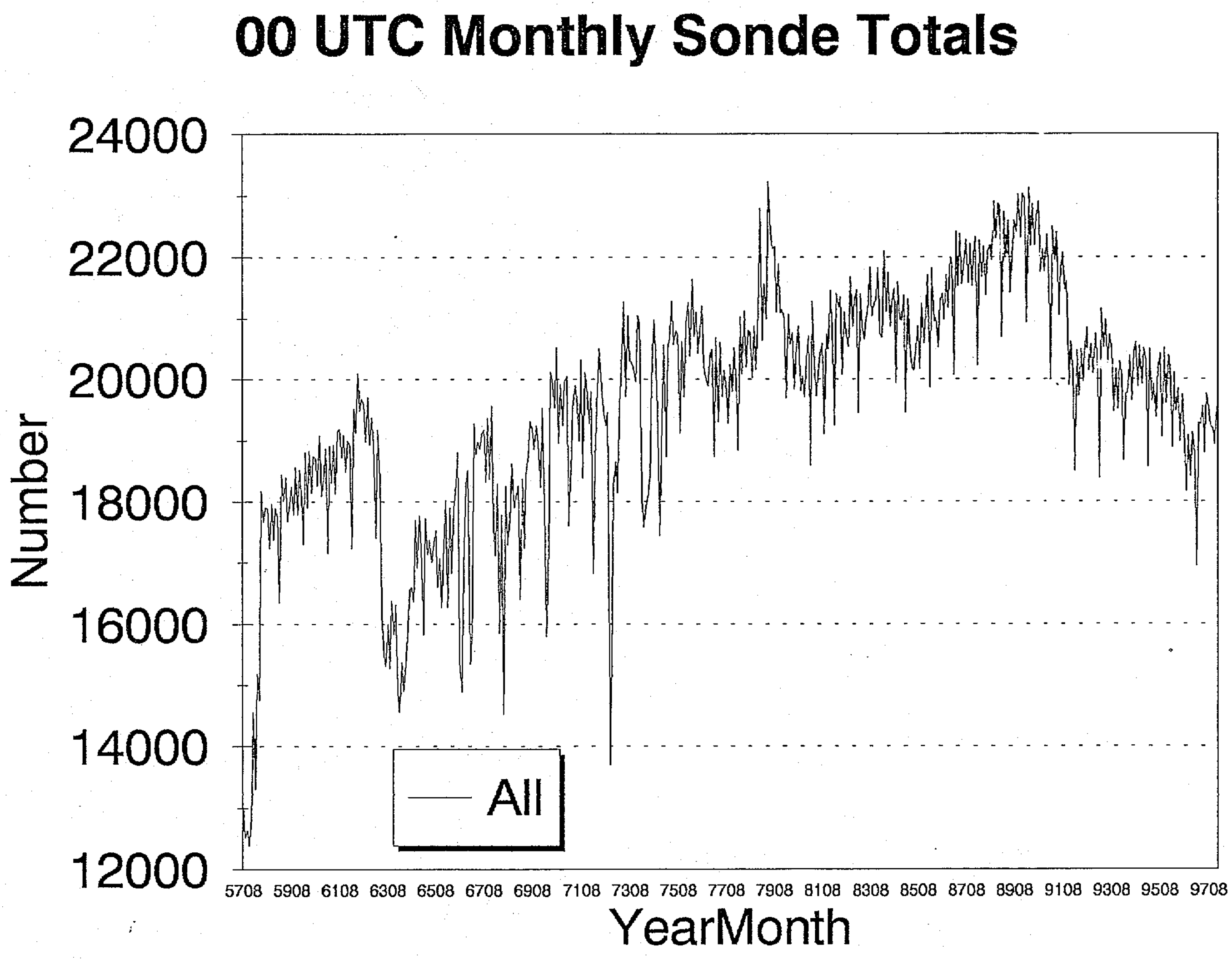
LIST OF FIGURES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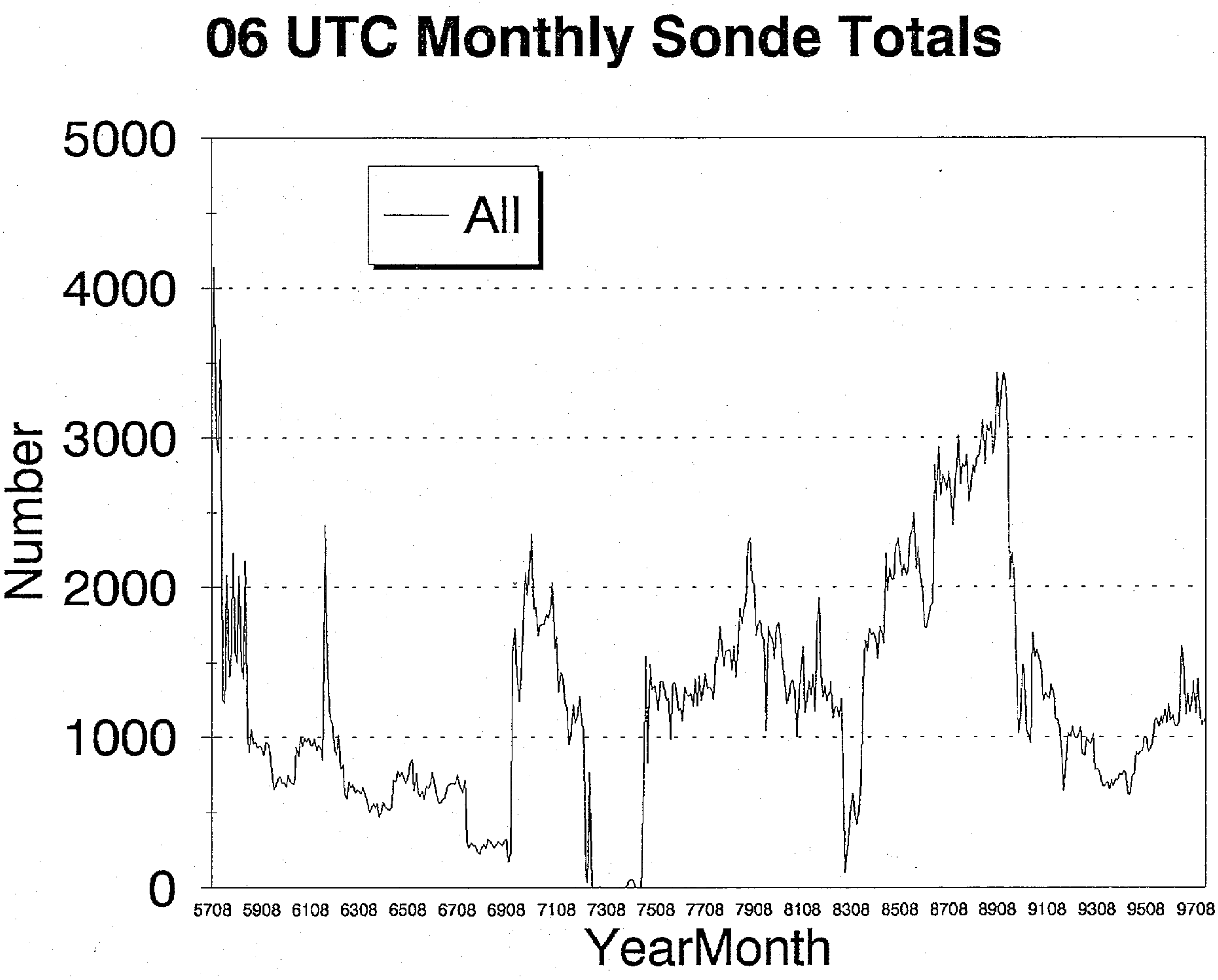
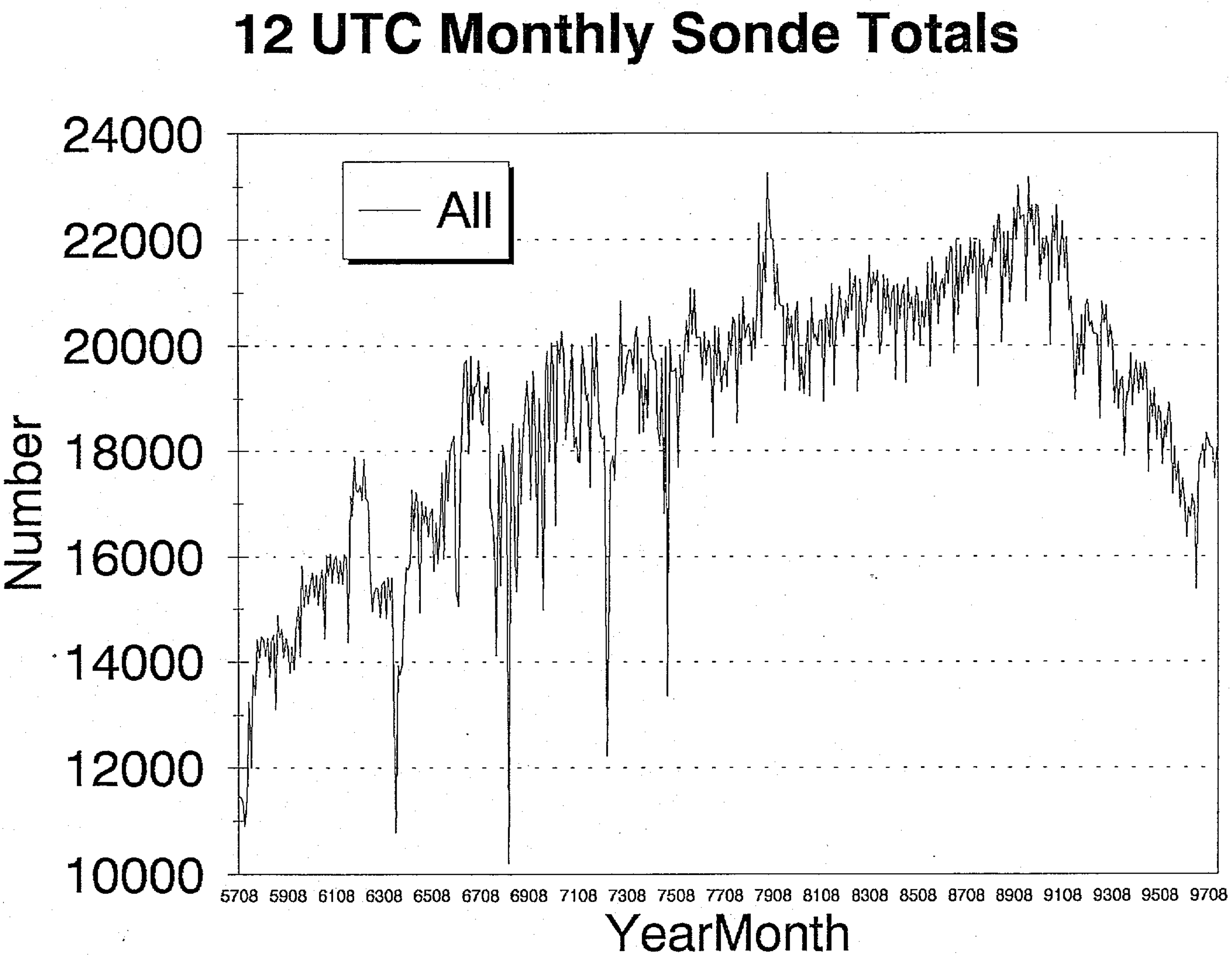
YearMonth

Fig. 1



06 UTC Monthly Sonde Totals
All
Number
5000
4000
3000
2000
1000
0
5708
5908
6108
6308
6508
6708
6908
7108
7308
7508
7708
7908
8108
8308
8508
8708
8908
9108
9308
9508
9708
YearMonth

Fig. 2



12 UTC Monthly Sonde Totals

Fig. 3

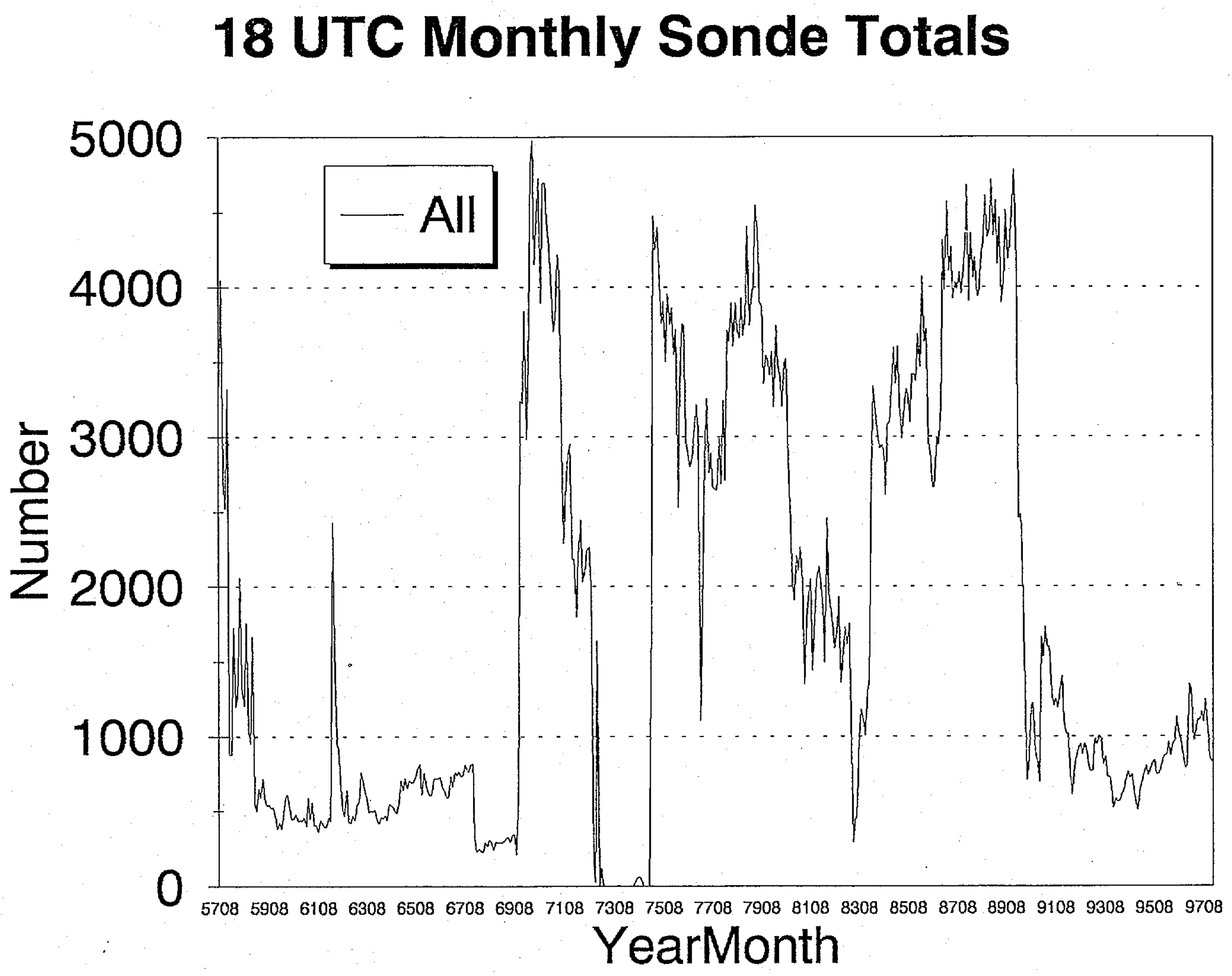

18 UTC Monthly Sonde Totals
All
Number
5000
4000
3000
2000
1000
0
5708
5908
6108
6308
6508
6708
6908
7108
7308
7508
7708
7908
8108
8308
8508
8708
8908
9108
9308
9508
9708
YearMonth

Fig. 4

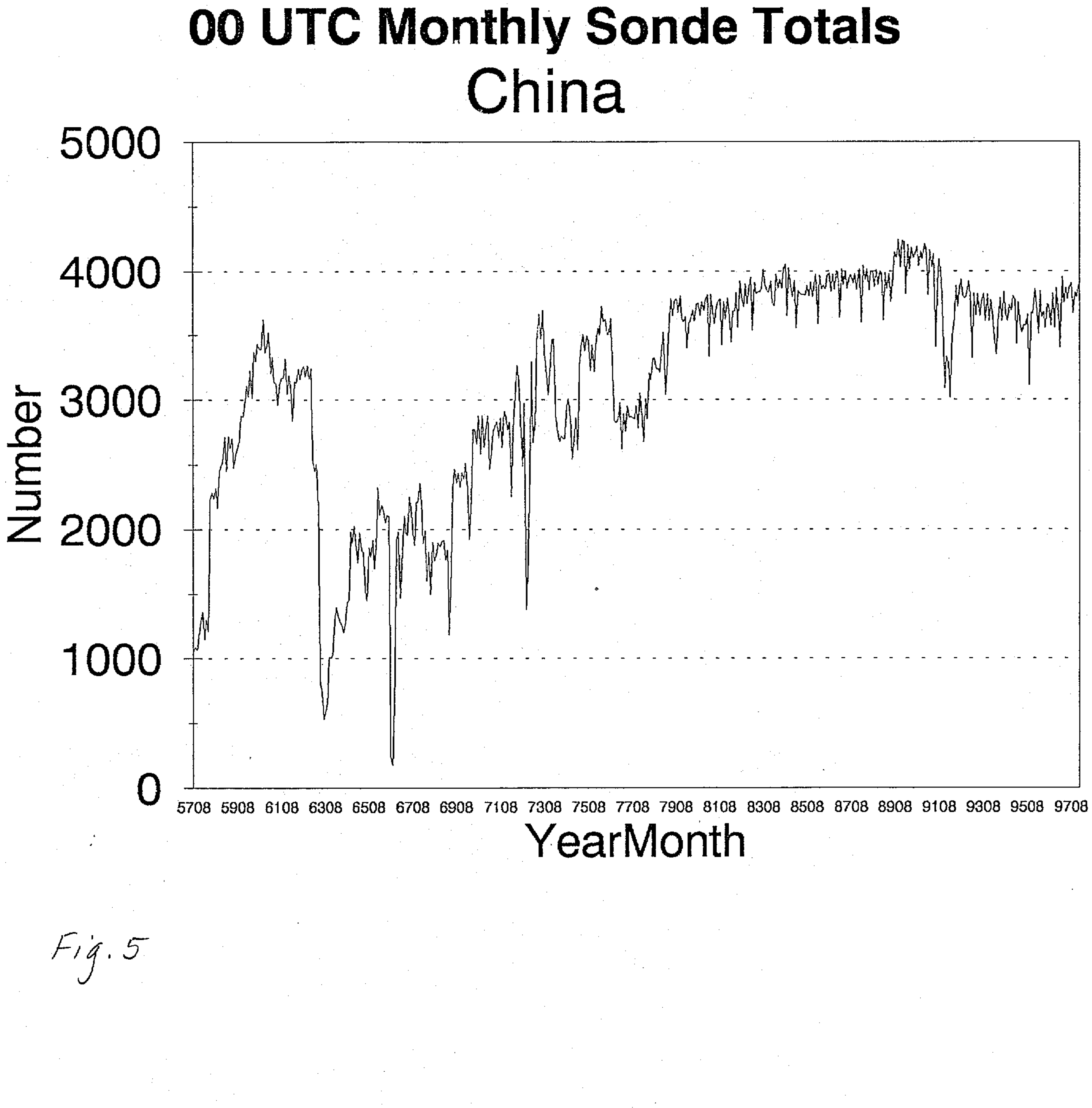
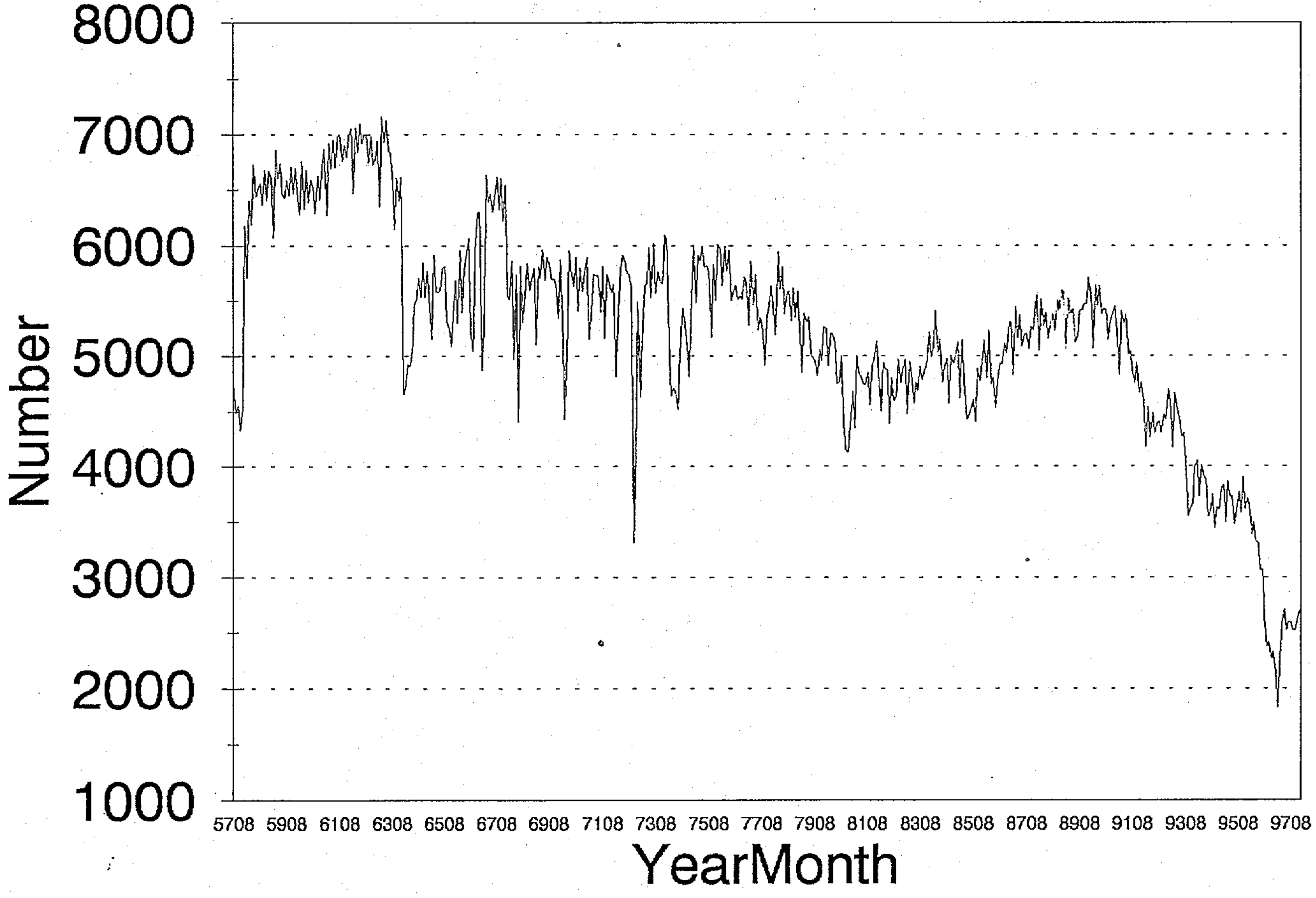

00 UTC Monthly Sonde Totals
China
Number
5000
4000
3000
2000
1000
0
5708
5908
6108
6308
6508
6708
6908
7108
7308
7508
7708
7908
8108
8308
8508
8708
8908
9108
9308
9508
9708
YearMonth

Fig. 5



00 UTC Monthly Sonde Totals
Former USSR

Fig. 6

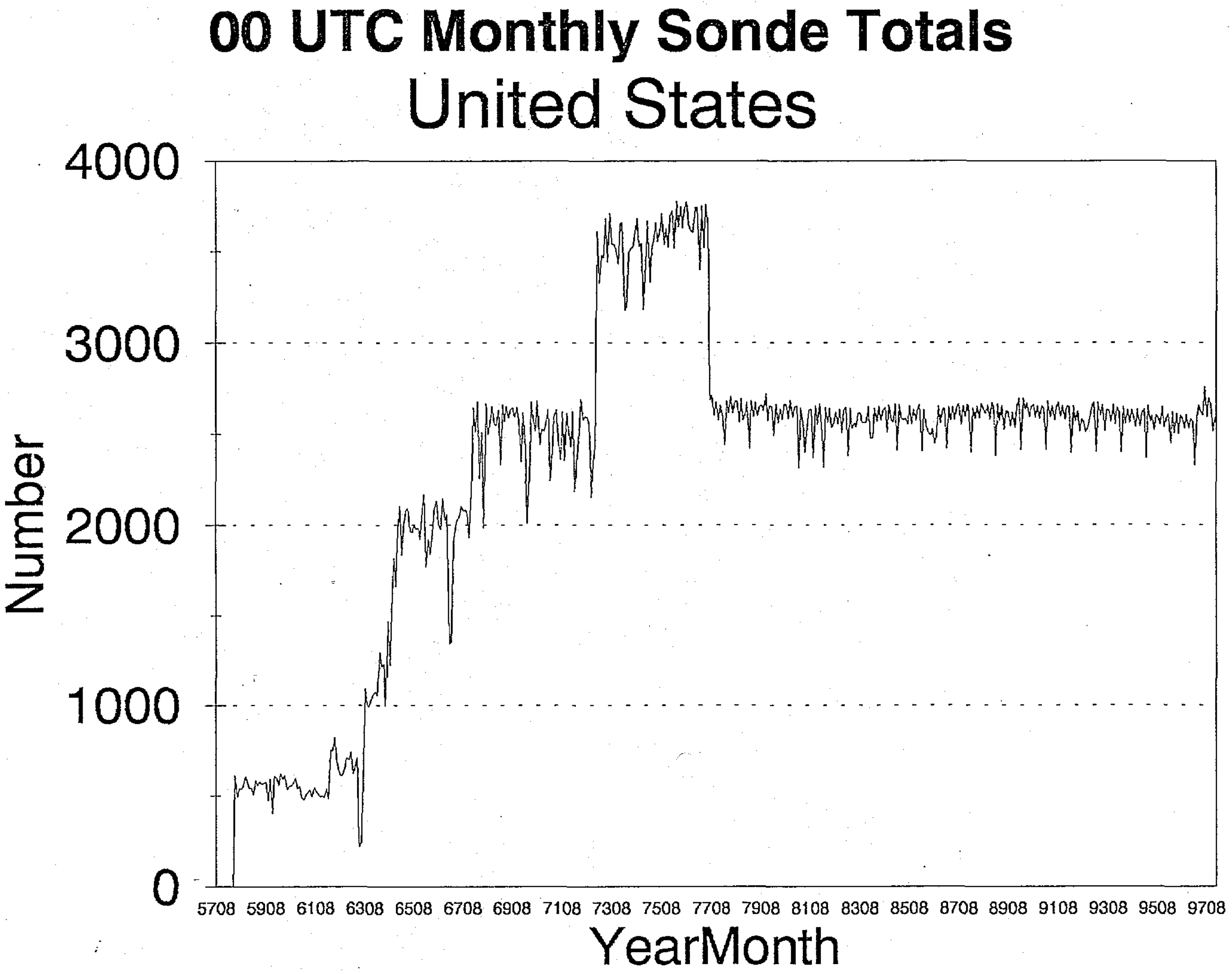

00 UTC Monthly Sonde Totals
United States
4000
3000
2000
1000
0
Number
5708
5908
6108
6308
6508
6708
6908
7108
7308
7508
7708
7908
8108
8308
8508
8708
8908
9108
9308
9508
9708
YearMonth

Fig. 7

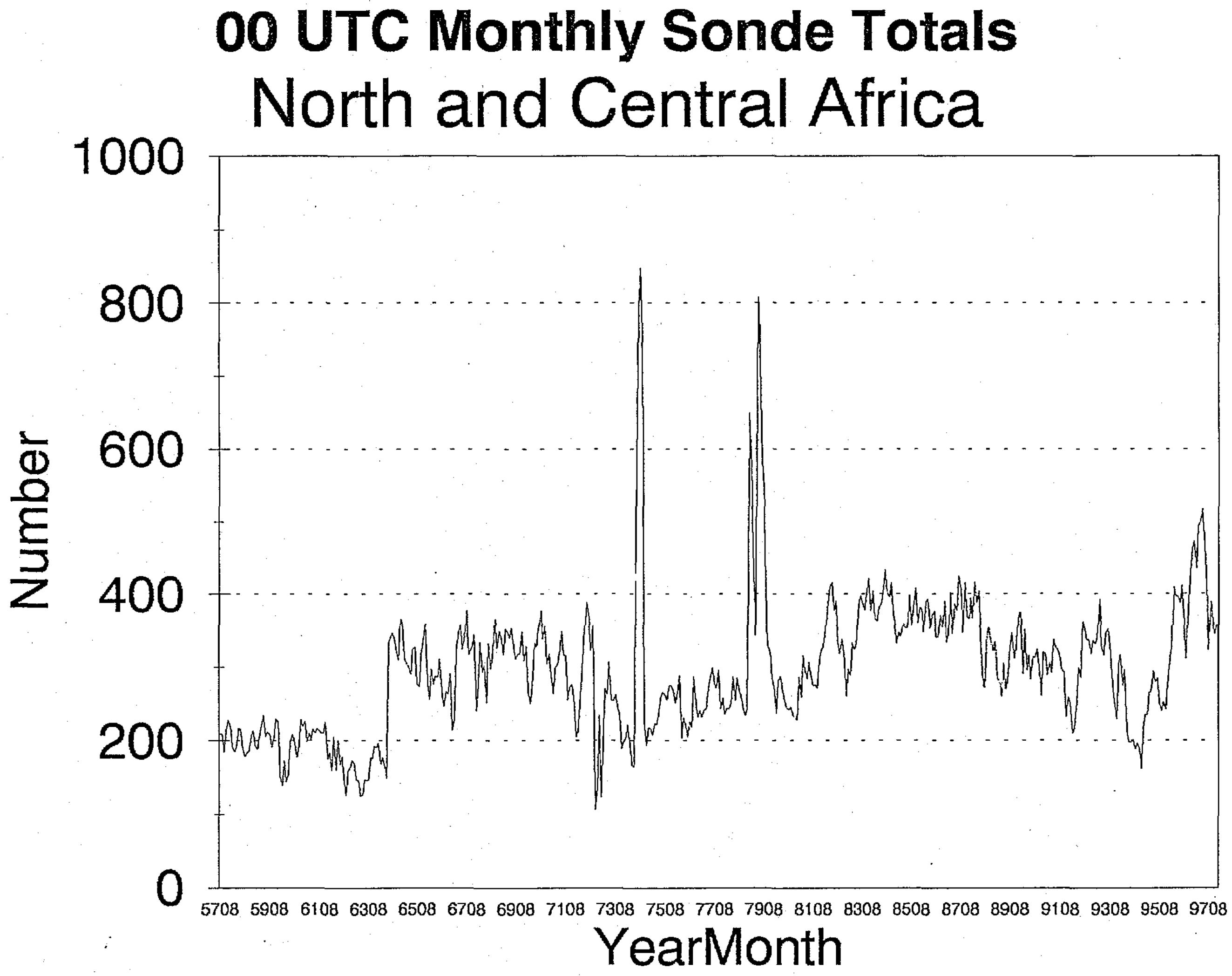

00 UTC Monthly Sonde Totals
North and Central Africa
1000
800
600
400
200
0
Number
5708
5908
6108
6308
6508
6708
6908
7108
7308
7508
7708
7908
8108
8308
8508
8708
8908
9108
9308
9508
9708
YearMonth

Fig. 8

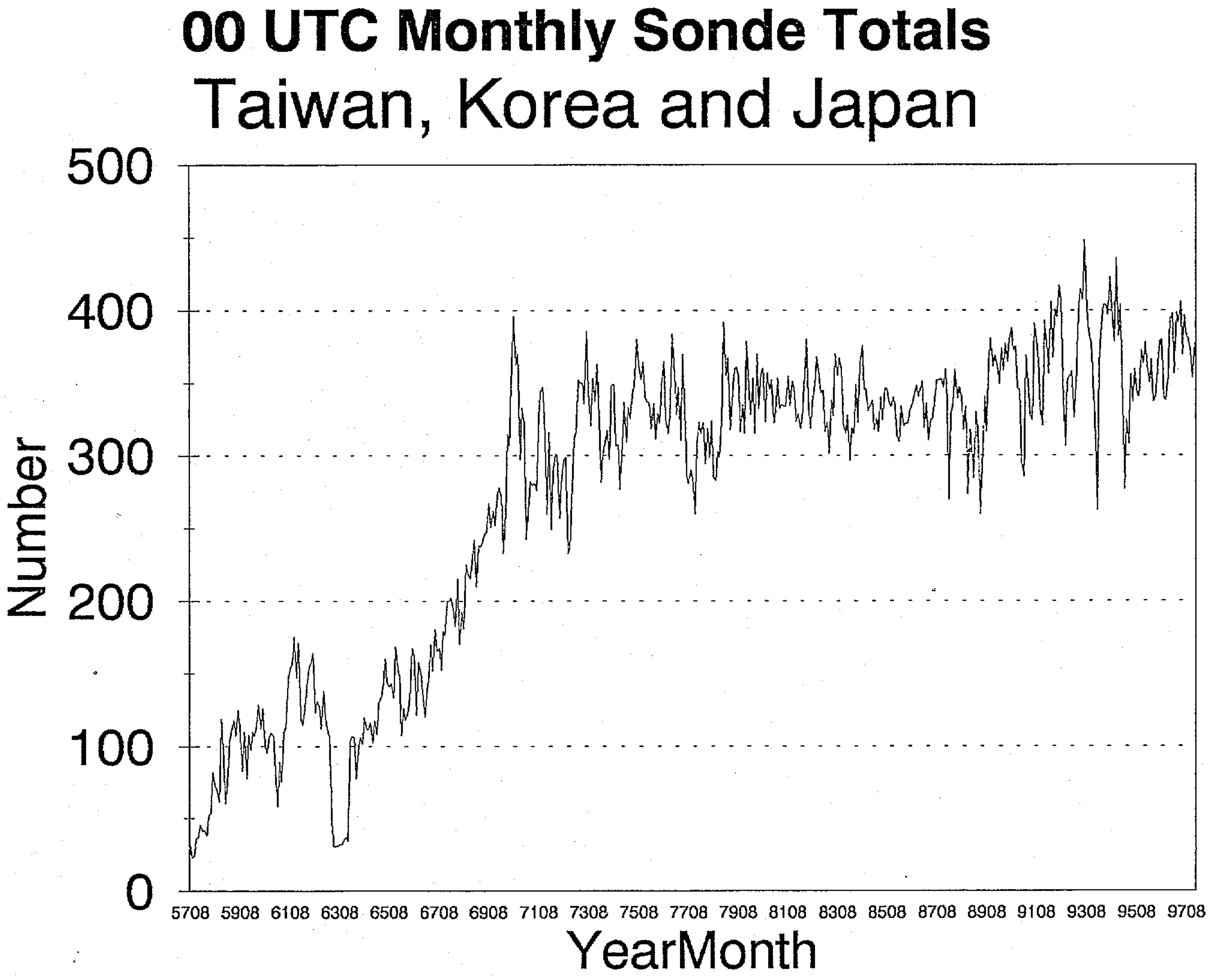

00 UTC Monthly Sonde Totals
Taiwan, Korea and Japan
500
400
300
200
100
0
Number
5708
5908
6108
6308
6508
6708
6908
7108
7308
7508
7708
7908
8108
8308
8508
8708
8908
9108
9308
9508
9708
YearMonth

Fig. 9

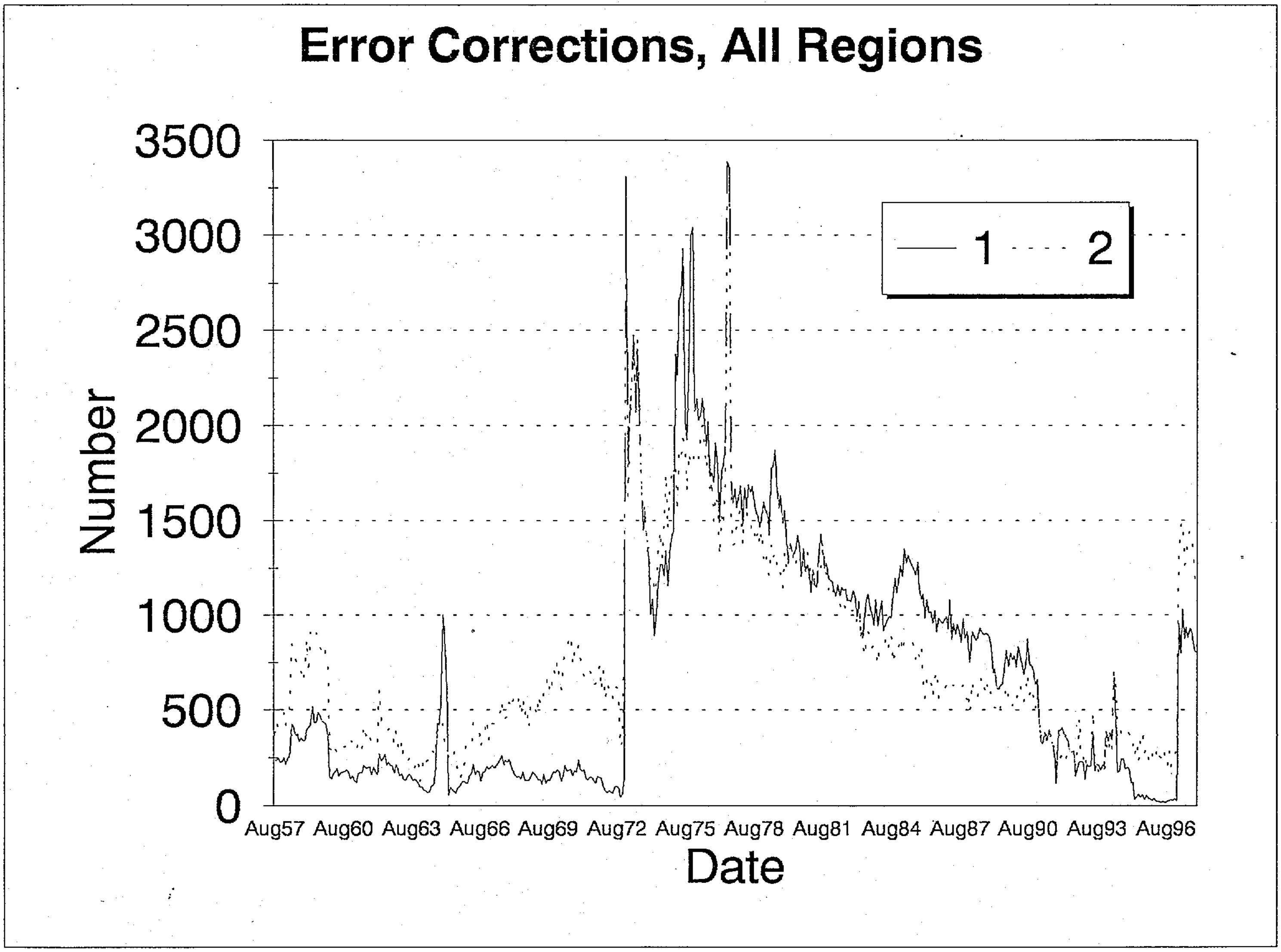

Error Corrections, All Regions
Number
3500
3000
2500
2000
1500
1000
500
0
Aug57
Aug60
Aug63
Aug66
Aug69
Aug72
Aug75
Aug78
Aug81
Aug84
Aug87
Aug90
Aug93
Aug96
Date
1
2

Fig. 10

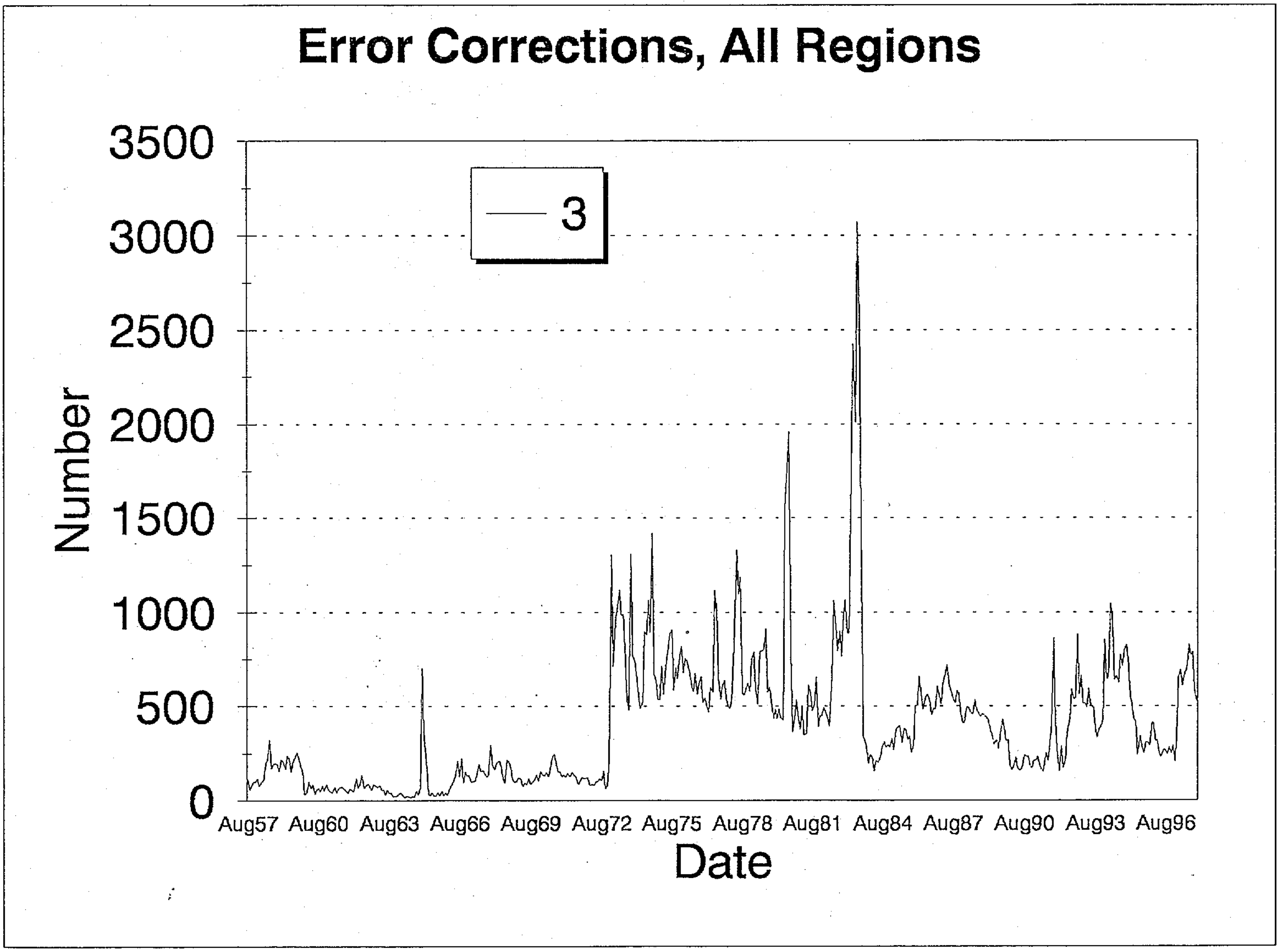

Error Corrections, All Regions
3500
3000
2500
2000
1500
1000
500
0
Number
3
Aug57
Aug60
Aug63
Aug66
Aug69
Aug72
Aug75
Aug78
Aug81
Aug84
Aug87
Aug90
Aug93
Aug96
Date

Fig. 11

APPENDIX A: List of persistent baseline errors from Reanalysis

The information in the following table has the form:
Station: (initial month/year , final month/year , magnitude)

Note: all years are in 1900's.
Month/years are inclusive.
Only reasonably definite errors are included.
Magnitudes of errors are approximate.
A '?' after a date indicates uncertainty, usually because one or more intermediate months appear to have no error.
A '?' after a value indicates large standard deviation.

00005: (774,974,-50) Is this a station?
01020: (957,458,670)
02062: (857,1257,55) (262,665,56)
03005: (461,463,83)
03146: (362,1267,72)
03322: (461,463,57)
03774: (461,463,145)
03808: (461,463,88)
03917: (461,563,66)
03920: (462,463,42)
04202: (975,1178,47)
06476: (792,892,145)
08221: (379,1179,49)
08508: (1091,192,56) (392,892,-56)
08589: (774,974,-42)
10659: (384,584,-98)
13275: (887,789?,42) (690,1091,42)
13334: (857,958,85) (1058,1259,80) (362,1062,80)
15120: (160,160,77) (364,766,76)
15730: (1077,180,-85)
16144: (1287,689,41)
17030: (873,689,40)
17220: (160,560,-535?) others?
17280: (276,180?,45) (583,983,-55)
17606: (871,1171,121)
20107: (857,1057,-53) (1087,689,-50)
21358: (176,1278,105) (1279,280,110) (686,889,103)
21965: (158,463?,43) (676,1188?,-40)
22113: (688,689,-55) (789,989,-75) (1089,591,-57) (691,691,-81)
22820: (176,180,-70) (686,889,-70)
23418: (686,889,-55)
23804: (690,891?,-79)

23921: (1089,790?,-110)
23955: (690,791?,-150)
24125: (857,1061,80) (176,1278,-78) (1279,280,-77)
24507: (176,1278,-47) (1279,180,-47)
24793: (857,659,9360) !!!
24944: (857,858?,-85) (173,1278,90) (1279,280,85)
25428: (186,1289?,-15)
25563: (176,1278,62) (1279,280,65)
25677: (176,1278,-83)
26083: (957,1160?,44) (1266,467?,45)
26063: (176,1278,-67) (1279,280,-67)
27101: (1065,1267?,-40)
27553: (176,1278,-75) (1279,280,-74)
27595: (176,1278,-55) (1279,680,-55)
27707: (168,671,-43) (376,180?,-43) (686,789,-41)
28440: (176,1278,-50) (1279,280,-50)
28722: (168,1272,92) (176,1278,92) (1279,280,95)
29572: (894,195,92)
29574: (857,361,42)
29634: (1268?,572?,42)
29838: (176,280?,42) (986,989?,36) cold season only
30309: (176,280,-85) (686,1089,-85)
30372: (186,1289?,-10) cold season only
30554: (857,1263,-318) (965,169,-318) (176,1278,-87) (1279,280,-88)
30710: (168,1272,55) (176,1278,55) (1279,280,55)
31329: (787,987,-191)
31510: (472,472,-43) (995,396,-42)
31538: (579,180?,-42) (686,989?,-42)
31735: (989?,891?,-130)
31909: (1275,1278,-57) (1279,280,-58)
31960: (176,1278,59) (1279,280,59)
32540: (176,1278,-71) (1279,280,-71)
33008: (590,791?,-60)
33041: (1087,1087,-49) (1089,891?,-68)
33631: (490,791?,-78)
33815: (175,1278,-79) (1279,280,-79)
33946: (168,1272,-75) (176,1278,-76) (1279,280,-76)
34009: (176,1279,-79) (1279,280,-80)
34122: (176,1278,63) (1279,182,65)
34560: (889,891?,-55)
34858: (889,791?,-108)
34880: (173,1073,105) (176,1278?,42) (1279,180,43)
35700: (273,1073,373) (176,1278,42) (1279,180,43)
35746: (675,775,47) (889?,791?,-130)
36003: (280,586?,-100) (187,1289,28?)
36870: (984,389,175) (489,1091,185)

37018: (176,1278,-95) (1279,280,-94)
37260: (176,478,-103) (686,1089,-103)
37472: (173,1073,138)
37484: (168,772,-193) (173,176,209)
37549: (186,786?,-65)
37789: (1176,1278,-232) (1279,686,-232)
37985: (173,1073,924)
38341: (1197,?,-100)
38353: (176,280,66)
38457: (176,1278,-66) (1279,280,-65)
38750: (173,1073,213) (176,1278,48) (1279,280,44)
38880: (176?,1278,-74) (1278,280,-76)
38954: (168,568?,-45) (776?,885?,-42)
40007: (676,180?,-41)
40462: (1082,1282,124)
40754: (361,962,-3100?) !!
40800: (1294,1297?,42)
40809: (890,895?,-43)
41256: (893,686,124)
41661: (186,1295?,172)
42071: (857,759?,-60?)
42182: (857,1267,71) (176,1278,-62) (179,1179,-57) (1279,280,-61)
42410: (758,860?,-55?)
42809: (857,762?,-54) summer only
43149: (658,861?,-51) summer only (778,1279,-42)
44212: (176,1285,-15) (190,397,-15) winter only
44292: (857,1060?,63) (179,1285?,20)
47122: (176,1078,-42) (579,180?,-41)
47827: (857,1157,275) (579,879,-277) (294,494,253)
48565: (796,197?,-45)
50953: (186,1288?,30) winter only
51133: (1187,1290?,44) winter only
51243: (186,289,50?) winter only
51463: (857,1060,-195?) (1160,161,46) (1266,1275,45?) winter only (176,889,-272)
51628: (1159,1061,187) (288,1291,179)
51644: (158,961?,26)
51709: (558,558,-672) (760,760,-656) (461?,463?,-720?)
51777: (857,1259,-55)
51828: (260,260,-668?) (761,463?,-600?)
51848: (579,879?,-226)
51886: (1087,390,193)
51895: (857,1258,170) (159,260?,111)
52391: (1060,1061,515) (1161,463,-550?)
52533: (558,558,-511) (1260,463?,-540?)
52652: (361,463?,-540?)
52681: (1060?,463?,-650?)

52866: (1058,1061,50?)
52889: (359,359,-483) (1161,363?,-510?) winter only
53845: (674,1283,-182)
53915: (260,260,-667?) (1161,463?,-680?)
54337: (875,176?,274) (276,989?,40) (696,996,728)
54401: (474,176?,110)
54511: (785,788?,-41) summers only (186,289?,-22) winters only (note overlap!)
54662: (857,463?,80)
56080: (176,1176,52)
56096: (1057,1061,100)
56137: (186,1289,-110?)
56247: (1075,176,1035)
56964: (958,958,-697?) (1161,463,-680)
57178: (1175,176,-41)
57245: (1286,1287?,45)
57447: (882,788??,-41)
57461: (957,1061?,60) (567,767,60)
57516: (887,1289,100?)
57749: (483,585,-270) (685,785,151) (1185,687,-270)
57810: (857,1258,-177) (176,280,-73) (190,1091,-73) (1191,493,78)
58666: (1174,176?,-194) winter only (1082,689,121)
58725: (159,960,-54)
58847: (558,1259,83)
58912: (660,361,-102)
59096: (1175,1275,-110)
59134: (558,958?,50) (1180,689,-80)
59211: (1057,1061?,58) winter only
59431: (1057,1061?,-48) winter only
60571: (665,567,66) (176,278?,43) (1178,1278,42) (182,789?,-48) (790,790,-47)
60630: (176,177,-51)
60760: (180,989?,-43)
61052: (374,1274?,185)
61901: (877,1278,194) (1279,180,194)
62001: (666,1066,-249)
62053: (857,658,-84) (176,989,91)
62414: (1158,362?,87) winter only
62721: (774,874,-620)
62760: (674,774,-275?)
63450: (674,1175??,-45) (383,992?,-55?) erratic
63478: (1286,288?,90)
65418: (274,1077?,188) 779,879,174)
67085: (857,1259,135)
67402: (1063,265?,-60?) winter only
68424: (179,1179,-50)
68442: (179,1179,48)
68512: (188,1188?,-87)

68906: (857,1259,47) (161,463,49)
70266: (883,384,75) 586,287,78)
71043: (286,289?,-34) winter only
71072: (777,180?,-41)
71926: (1180,389,-41)
71957: (777,1278,-43) (1279,180,-43)
72225: (679,1169?,-68)
72280: (176,676,-65)
72291: (1175,978?,145) (185,691?,142)
72340: (1275,478?,-90)
72414: (173,575,116)
72455: (781,493??,-77) spotty
72662: (558,1260,380??)
72681: (558,1259,300??)
72764: (179,379,48)
72768: (558,1260,150??)
72793: (662,463,71) (1272,1272,123) (976,282?,123) summer only
72826: (558,1260,100??)
72957: (373,674,-42) (176,677,-42)
74004: (892,493,95)
74072: (276,677,-41)
74732: (893,1194?,50)
78783: (1270,671?,-50)
78806: (178,1278,-59)
78988: 1279,280,-43)
80447: (583,287?,43)
80462: (176,579?,56)
82824: (994,1094,-42)
83208: (780,1084?,53) (586,591?,42)
83378: (992,694,-80?) (597,1297,-80?)
83827: (1192,393,-56)
83840: (1092,594?,-50?)
85801: (168,869,-400???) bad
87418: (173,1273,-120)
89512: (570,1070,-60?) (1281,789?,-30?)
89601: (857,1158,261)
89606: (889,1289,-200??)
90001: (169,1169?,250?)
91030: (168,668,140)
91487: (1177,1177,44) (179,679,42)
91517: (178,1278,-50) (1279,1281?,-48)
91610: (192,993?,43)
91948: (173,176,125) (397,1297,-78)
94326: (170,571?,400??) (574,674,48)
94750: (857,1160,-78)
94986: (857,1196?,-???) large, erratic

94995:	(1188,192,42)
97072:	(486,1280?,-80)