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The long-term performance of the radiosonde observing system to be used in ERA-40

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ABSTRACT

The long-term performance of the radiosonde observing system over 50 years, from 1948 to present, has been investigated. The data will be used for ERA-40, the new ECMWF 40-year reanalysis. Temperature and humidity at some representative standard levels are investigated.

Consistent time series could be created, in fact, only for some limited stations. We needed to group stations into categories for statistical studies. From the time series, we could identify climatological changes and sudden jumps in the observed values, caused mainly by changes of instrument.

The quality of the observed values after the 1970s are significantly better and more consistent than those before the 1960s, which sometimes have very large biases. Careful treatment is needed in order to use radiosonde data from the 1950s and the 1960s in the data assimilation.

To show the effect of solar radiation on temperature, time series were produced separately for day-time and night-time observations at 100hPa.. When no radiation correction was made by the station operator, the differences between day and night were clear. In many cases we could detect whether a correction had been done and when the correction was begun.

Data assimilation experiments have been carried out for some years. The results are described in this report. Absolute biases, which cannot be found from the long-term time series, have been found. Therefore, we need to investigate both types of statistics in order to understand fully this component of the observing system for ERA-40.

1. INTRODUCTION

Radiosonde observations are the most consistent and important data describing the atmosphere. For a long term reanalysis project like ERA-40, the ECMWF project to reanalyse data from 1958 to present, radiosonde observations are important throughout the period, and dominant in the early years when there is no satellite data.

The first ECMWF reanalysis ERA-15, which covered from 1979 to 1993, has been described by *Gibson et al.* 1997. For ERA-40 there are many new developments and improvements, in the data assimilation scheme, resolution, dynamics, physics, land surface process, etc.

One difference between the two reanalyses is the observational data and how they will be used. In ERA-15, most of the observational data were taken from the ECMWF operational data archives. Some additional data were provided by a few national meteorological services but the amount was only a few percent of the entire dataset.

In ERA-40, all data before 1979 were provided by other organisations, mainly NCAR and NCEP. ECMWF has almost no experience of assimilation with data before 1979. The earlier satellite data to be used in ERA-40 are the radiances from VTPR, the pre-TOVS instrument, which are first available in 1972. From 1979, TOVS and SATOB data are available. In the 1990s, many kinds of advanced satellite data like ATOVS, scatterometer, SSM/I etc. can also be used. Data assimilation systems have been developed to exploit effectively these data over oceanic regions sparsely covered by conventional observations.

Before 1972, however, radiosonde observations were providing the main upper air soundings, although there were also some aircraft data, and SYNOP/SHIP data at the surface. Special and careful quality controls are required for the period.

There are many difficult problems. The instruments and sensors of radiosondes have been changed many times during the reanalysis years. The quality of radiosonde observations is known to vary in time. Furthermore, the locations and elevations of some stations have also changed quite often.

Here we can summarise the most important aspects of the use of radiosonde data in ERA-40 as follows.

a) How to determine the histories of the data and instruments as fully as possible

b) How to use problematic data in the assimilation

For the first item, there are two methods. One is to investigate and summarise the radiosonde history for each station. The other is to look at the actual observational data and make some changes when clearly indicated. No comprehensive study of this type has yet been completed, although the WMO/GCOS Upper Air Network (GUAN) project is ongoing. For our purpose, it is most important to use the radiosonde data correctly in ERA-40, although we also need to refer to the detailed instrument histories.

With regard to the second item, we need sufficient data assimilation experiments, using the problematic data, to investigate the observed departures from the background analyses carefully. For this purpose, we should ideally execute a data assimilation experiment for all the reanalysis years beforehand. This has not been possible to date.

We focus on the long-term performance of radiosonde observations in this report. Generally it is easy to reject problematic data, but since observational data are very valuable, we should make every effort to correct them and use them in the assimilation.

2. STATION LIBRARY

To use observations with large variations in quality, we should consider the history of each station. *Gaffen* (1993, 1996) has done considerable work on station histories and created station libraries. This is a difficult task, however. It is in fact quite impractical for us to detect the histories of all stations since the information often is incomplete. In some cases there are several meta-data sources for a station with different and inconsistent information.

We tried to make a simplified station history library by extracting the instrument history from Gaffen's library under some assumptions. For instance, radiosondes were classified only by their manufacturer and not by radiosonde type, and priority was given to a particular national data source when selecting data from that country.

Figure 1 shows the distribution of radiosonde instruments in January 1988. It seems to show a very well defined distribution although we should remember that the history library is incomplete. It gives us very useful information but it should only be used for reference.

3. LONG TERM TIME SERIES

Time series of observed values for long periods for each station and country have been investigated. They are quite useful for detecting significant changes in the observed values and they should reveal quality changes much more directly than the history files. We suggest that the best method is to investigate the observed values themselves and try to identify strange sudden jumps which can be distinguished from climatological changes.

The ideal would be to generate the time series for each individual station. In fact, however, long consistent time series could only be created for a limited number of stations. Stations have been moved and station identifiers (hereafter ID) have been changed very often during the years and it is difficult to detect when these changes happened. Especially in developing countries, observations have sometimes ceased for some years, or the observed data were not reported, or they were stored only in writing, or they were not released because of wars.

In order to make the time series significant, some stations were combined into groups depending on country, area or instrument type.

3.1 Data availability

The radiosonde data sets used in this research are shown in Table.1. They have been accumulated for use in ERA-40. For the FGGE period (1978.12 - 1979.11), most of the data are included in 'ECMWF'. Additional data provided by other meteorological organisations for ERA-15 are also included in 'ECMWF'.

All data sets except 'ECMWF', 'NCEP' and 'JMA' have been provided by NCAR.

3.2 Station Group

To make the time series, we have to overcome some difficult problems. The worst is the station ID number. Over these long periods, WMO-ID numbers may change several times. For example, the IDs of all the Canadian stations were changed in June 1977. And worse, in some data sources completely different IDs, probably local national IDs, were used. So we cannot use the IDs to trace the stations.

Another difficult problem is the location. Stations often move, and the location coordinates are sometimes slightly different for the same observation from different data sources.

In order to solve such problems, a 'Station group' idea was introduced. Firstly, the most recent position of each station is defined as the 'basic position'. Secondly, closely located observations, within a radius of 30km from the basic position, are searched throughout all data. The tolerance radius of 30km was defined empirically. Finally the data so identified are considered to belong to the unique station of each basic position. A representative ID number corresponding to the most recent WMO-ID is given to each station group.

Each group contains relevant information on the members, namely data source, position, original ID number, elevation and observation period. All such information from each observation can be recovered. Figure 2 shows distribution maps of all the station groups.

This idea is quite simple but very useful and makes it easier to make time series of the data. We are free from some difficult problems like tracing historical station IDs, station movements and so on.

3.3 Quality Control (QC)

Before making statistics, we have to check the quality of the data. There are many data with gross errors, especially in the early years. Simple quality controls were carried out to remove such data from each station group.

The preliminary QC is a climate-based QC in which each datum is compared with climatological criteria taken from the GDPS manual (*WMO*, 1993). It is executed to remove extremely strange data before deriving the statistics for each group.

In the first step, the mean value (m) and standard deviation (s) for the entire period are calculated. Data not within the range $m \pm 6s$ are removed. This procedure is repeated twice.

In the second step, a similar QC is performed for each year. Firstly m and s are calculated for a 2 year period spanning the target year. For example, if 1987 is the target year, data from July 1986 to June 1988 are used. Secondly the obtained m and s are applied to the target year. If a datum is outside of the range $m \pm 4s$, it is removed. The QC is applied for all years.

In the final step, if a sudden change of the observed value within 12 hours is found, the magnitude of the change is compared with a certain criterion of acceptable change.

3.4 Derivation of the statistics

Some parameters at some standard levels are selected to make the time series. They are temperature at 100hPa (T100), 500hPa (T500), 850hPa (T850) and specific humidity at 850hPa (Q850).

T500 is representative of mid-troposphere temperature and it is the best parameter to examine the performance there. T100 is the best parameter to find the effect of solar radiation. For T100, statistics are separately derived for day-time and night-time depending on solar elevation angle. If the solar angle of an observation is equal to or bigger than zero degrees, it is classified as a day-time observation. If the angle is smaller than zero degrees, it is a night-time observation.

For humidity, Q850 was selected because here the humidity is the largest of all the standard levels except 1000hPa. T850 is also selected because humidity is reported as the difference between temperature and dew-point temperature (T-Td) in a TEMP report. Q850 can be affected by the observed value of T850.

Geopotential height is a vertically integrated value of the temperature. To investigate the performance of geopotential height, we must investigate histories of elevations of all stations but that is more difficult than tracing ID-number and location.

The analysis variable of the ECMWF operational data assimilation was changed from geopotential height to temperature in July 1998, hence we do not need to check histories of geopotential height for ERA-40. We are free from tracing the history of the elevation of each radiosonde station as well as its ID-number and location.

For temperature observations, one of the most important issues is whether the observed values were corrected for effects of radiation. The effect of solar radiation is apparent from the upper troposphere upwards. We could have selected one more level in the stratosphere to check the temperature, but we did not because the number of data in the stratosphere is less than in the troposphere, especially during the earlier years. This is because there are two TEMP reports of standard levels, TEMP-A from the surface to 100hPa and TEMP-C above 100hPa. In the earlier years, the data amount decreased suddenly above 70hPa at many stations. Also, it is quite possible to confuse a sudden jump caused by some artificial reason with one caused by a natural sudden warming in the stratosphere.

After the QCs, annual moving averages were taken for all statistics in order to filter out seasonal features. For the day-time to night-time difference, hereafter simply called the DN-difference, there are some problems. For stations at high latitudes or at around 90E and 90W longitude, two observations (usually made at 00UTC and 12UTC) in a day can often be both in day-time (night-time) in summer (winter). For these periods, DN-differences cannot be calculated. If observations are made three or four times per day, separate averages of day-time and night-time observations were taken beforehand.

The DN-difference was calculated only when two day-time or night-time observations existed within 48 hours. If this condition is satisfied, the two day-time (night-time) observed values were interpolated to the time of night-time (day-time) observation between them and a DN-difference was calculated (see Figure 3). Otherwise observations had to be excluded to prevent confusing seasonal features from appearing.

This procedure was performed for each station group. Time series were then calculated for each country. In calculating a monthly value of a category, the weight of each station is selected to be proportional to the number of observations in the month.

There are two methods to classify the groups for deriving the statistics. One is to classify by country, the other is to classify by radiosonde type.

Generally the same instrument was used throughout a country at any one time, although there are some exceptions like the former USSR.

When a country changed instrument, all stations in that country generally changed their instruments gradually, usually within a year, and probably over a few years at the maximum.

We can also detect exactly when some countries became independent, and the countries that governed them as colonies before their independence.

But the radiosonde type can be known only from the station history. This information is NOT available in the data records. As mentioned in chapter 2, the reliability of station histories is relatively low and they do not provide us with sufficiently reliable information. Therefore, statistics were normally calculated for each country in this research.

Consistent time series could be generated for most countries in the extra-tropical region of the Northern Hemisphere. However, for most developing countries, especially African and Central and South American countries, we could not generate significant time series due to too few and too discontinuous observations.

We could make country groups by putting those countries together into larger regions. This has to be done carefully because each country might use different types of radiosondes. One possibility is to base the combination on the colonial history of the countries.

For large countries such as the USA and China, with large amounts of data, statistics were derived for several sub regions.

Hereafter the word 'category' means either country, country group or a region within a country.

3.5 Results

Time-series graphs are shown for all categories in Figure 4. Three kinds of statistics are shown for each category.

The first figure (left column) shows time series of T100 and T500. The monthly averaged T500 observation count is also shown. Monthly counts of T100 are almost the same as those of T500. One can clearly see many remarkable features in the temperature in the upper and middle troposphere.

The second figure (middle column) shows the time series of T100 only. The main purpose is to show the DN-difference. In the upper troposphere / lower stratosphere, DN-differences are clearly apparent when no radiation correction was done. Time series of all day-time, all night-time, limited day-time, limited night-time observations as well as the DN-differences with their counts are shown. Here 'limited observations' means observations limited for calculating DN-differences as explained in section 3.4 and Figure 3. If radiation corrections were made to the observed values, the DN-differences become almost zero. These graphs are also useful to find the times of instrument changes.

The third figure (right column) shows time series of Q850, T850 and the Q850 monthly counts. The monthly counts of T500 are almost the same as those of Q850. The main purpose of the figure is to show the performance of the humidity observations. In the TEMP reports, humidity is reported as the difference between temperature and dew point temperature, (T-Td). A humidity value can thus be affected by a temperature observation. Hence

T850 may give useful information on whether a humidity change depends on only the humidity sensor or is affected by changes of temperature.

The time series were generated only from data available to date at ECMWF for ERA-40. So if a time series is not shown, it does not always mean that observations were not performed at the time in the category. Data may exist but they may not have yet been received or may not be available in electronic form.

All the time series are annual moving averages. An annual moving average can be calculated only when there are data for 12 continuous months, from 6 months before to 5 months after the central month. Consequently if there is a monthly datum but the annual moving average cannot be calculated for the month because of discontinuity, no data is plotted for that month. The plotted monthly data counts are also annually moving averages. The vertical scales of temperature are every degree or every 2 degrees. In some left-column graphs the vertical scale is every 2 degrees for T100 but every degree for T500 and vice versa.

It should be noticed that absolute biases cannot be found from these time series. To determine them, it is essential to take statistics of the departures from first guess fields in data assimilations.

Features of each category with some comments are described in Table 3. Not all features are described in the table. Some features before the 1960s are not mentioned since they are often caused by few data or by large changes in the data counts.

Summaries of each continent or region follow.

[Europe] (WMO-ID : 01000-17999)

Europe is one of the best regions, with sufficient and good quality data. For most countries consistent time series can be drawn. We could detect most of the significant changes and jumps. In many countries, an obvious cooling of T100 in the 1990s can be seen. French data are continuously available since 1948. The jumps in the DN-difference in Norway, Finland and Denmark in 1983 may be related to the volcanic eruption of El Chichon.

[Former USSR] (WMO-ID : 20000-38999)

The former USSR had a huge domain, and it should be divided into several regions. The statistics of all USSR stations shows that T100 day-time observations have very large positive biases before the 1960s. Data counts in Russia have decreased substantially during the 1990s. We need to consider the decrease when we look at performance in the 1990s. The radiation correction is not sufficient in all the regions.

[Western Asia] (WMO-ID : 40000-41999)

Western Asia is a data sparse region. Wars have happened often in the area, for example, the Iran-Iraq war and the Gulf war. Radiosonde observations may have been suspended or the data were not released. It is difficult to draw consistent and reliable time series. The jump in 'Former British dependencies in Arabia' in 1984 is obviously related to the sudden increase in data count.

[South and East Asia] (WMO-ID : 42000-48999)

Data availability is better than in Western Asia. Consistent time series could be drawn for some countries, Japan for example. But the data counts are not large enough or too variable to draw reliable time series for some countries. The time series show relatively large variations. The sharp decrease of Q850 in Japan in 1981 is known to have been caused by a change of humidity sensor.

[China] (WMO-ID : 50000-59999)

In China, the same type of Chinese radiosonde (GZZ) has been used continuously. Between 1966 and 1976, the Cultural Revolution affected observation regularity. Since 1977, the situation has been normal and the time series are stable. However, Chinese observations are well known to suffer from consistent positive biases. So the quality of observations has to be investigated using a combination of the time series and departures from first guess fields.

[Africa] (WMO-ID : 60000-69999)

Africa is a most difficult region.

Most of the African countries have too few observations to make time series. Countries have to be gathered into groups based on their colonial history. Still there are some groups with too small samples to generate reasonable time series.

An alternative choice is that all African countries are divided into 3 regions, namely North, Middle and South.

[North America] (WMO-ID : 70000-76999)

North America is the best region for which to generate consistent and reliable time series. Holdings are likely to be relatively complete because most of data before FGGE (1979) was provided from NCAR and NCEP in the USA. Data counts are almost constant since the 1960s. Some significant long term trends in the data can be detected. There are increasing trends in T850, Q850 and T500 and a decreasing trend in T100.

[Central America] (WMO-ID : 78000-78999)

There are many small countries and there are few observations, so we need to make country groups. There are also a few countries for which time series could be created. In some categories there is a positive bias of T100 in the 1960s.

[South America] (WMO-ID : 80000-88959)

South America is also a difficult region due to low availability and high variability of data counts. Most countries except Brazil, Chile and Argentina are gathered into 'Former Spanish dependencies in South America'. Since

Chile has a very long north-south extent, the varying station locations are likely to affect the time series to quite some extent.

[Antarctica] (WMO-ID : (88960-89999)

Data counts are small but in many categories a decreasing tendency in T100 can be seen.

[Pacific Ocean and Oceania] (WMO-ID : 90000-98999)

Consistent and reliable time series could be drawn for US Pacific Islands since the data counts are sufficient and stable. Long term increasing trends can be seen in Q850, T850 and T500. They can be considered as climatological changes.

[T70 time series]

T70 time series for a few categories are shown in Figure 5 in order to show the effect of volcanic eruptions.

The T70 time series are quite similar to T100. However, data counts of T70 are less than for troposphere levels below 100hPa. Compared with the T100 time series, the effect of volcanic eruptions in 1983 and 1992 are much more apparent. They are caused by the eruptions of El Chichon and Pinatubo respectively.

[Summary]

Many kinds of changes were found in the time series. Most of them, such as jumps in the time series are presumed to be caused by artificial and non-climatological reasons. They should be corrected in the data assimilation if at all possible.

These non-climatological changes and jumps are mainly caused by changes of:

1) Observing method (i.e. radiation correction)
2) Instrument
3) Sensor
4) Frequency of observation at a station
5) Station

We must be careful when we find a jump. First we have to check whether there is a jump in the observation count at the same time. There are two reasons for jumps in the observation counts. One is a change of the number of observations per day at a station and the other is changes of stations. If data from a new station far from other stations in the group become available, it is quite possible it will lead to a jump in the time series. If there is no change of observation number, an alternative possibility is a change of instrument and sensor. And as seen in many categories, jumps in the DN-difference is a most apparent and effective way to detect changes of instruments or observing methods (e.g. in France in the early 1970s).

However, there are also some significant changes which can be related to climate change. The most significant is the cooling tendency in T100 from the late 1980s, and particularly in the 1990s. This tendency is found in many categories located in high and middle latitude. In some categories there are also slight warming tendencies in T500. In the tropics, Q850 is increasing in some categories. This is clearly seen in the USA Pacific islands. These also show a cooling in T100 in the 1990s.

Bell et al. (1998) reported that globally averaged temperature in the lower stratosphere observed by TOVS MSU Channel 4 has decreased significantly since 1992. *Newman* (1997) investigated the average total ozone in the Arctic area (north of 63°N) observed by some satellite data (TOMS etc.) since the 1970s. The amount did not decrease much until the 1980s, and has decreased significantly in the 1990s. WMO (1999) reported that the globally averaged cooling rate in the upper troposphere by 0.5 degree/10years observed for the years from 1979 to 1990 could be explained by ozone depletion. There may thus be a link between accelerated ozone depletion in the 1990s and the larger cooling in the 1990s than in the 1980s seen in the radiosonde time series. The ERA-40 analyses should enable the link to be investigated further.

The consistent increasing tendencies of T850 and Q850 shown in the time series for USA Pacific islands may be related to global warming.

There are several reports about global temperature rising at surface and in the lower troposphere. US's *NRC* (2000) and *Perker* (2000) summarised recent researches on temperature changes and pointed out the warming in the lower troposphere. *Santer et al. (*2000) reported that there was a statistically significant residual roughly 0.1degree per decade since 1979 in the lower troposphere. *Gaffen et al.* (2000) reported that radiosonde observation showed that greater warming at the surface than aloft in the tropics, which leaded to decrease stability of the atmosphere.

4. DATA ASSIMILATION EXPERIMENTS

The most effective method to detect biases of observation from individual radiosonde stations is to check departures between observations (OBS) and first guess fields (FG) in a data assimilation. In modern data assimilation system, observations typically make small corrections to a realistic model first guess. Hence the fields can be assumed to be largely physically consistent. Even in earlier years with no satellite data, relatively consistent fields may be created from rich surface observations over land.

We ran some data assimilation experiments with a prototype of the T159L60 ERA-40 production system for the late 1980s using only so-called conventional data and winds retrieved from cloud motions observed by geostationary satellites. In another experiment for 1976 no satellite were used at all. The versions of the ECMWF forecasting system used for the experiments are CY19R2 for 1988 and CY21R2 (with the physics from CY21R3) for 1976.

Statistics of temperature departures between observations and first guess fields were taken for each country. We defined the categories to be the same as those used for the time series. Some significant features resulted from the experiments. Some of those features are shown in the annual performance in 1988 (Figure 6(a)) and 1976 (Figure 6(b)).

From Figure 6(a) for 1988, certain types of the radiosondes show very good performance with small biases and small RMS differences. Vaisala radiosondes perform particularly well. In the Scandinavian countries Vaisala radiosondes have been used for many years. The soundings in Scandinavia show very small bias.

Some observed values do not correctly take the effects of radiation into account, so there are positive temperature biases in day-time and negative in night-time. The VIZ radiosonde used in the USA is typical. These departure features are consistent with the time series.

Some other radiosondes have systematically positive or negative biases. UK observations from the Kew radiosonde had negative biases throughout the year. Conversely, Chinese observations have significant positive biases.

In Figure 6(b) for 1976, the biases are larger than those of 1988. Also in Scandinavia, there are small positive biases. On the other hand, the UK radiosonde has no biases. It is quite possible that the first guess field has a slight negative bias in Europe. In 1976, there was no SATOB (cloud motion wind observed by geostationally satellites) data. The quality of forecast fields in 1976 could be significantly lower than those of 1988 particularly over the ocean.

Another feature detected from the profiles is that the first guess has systematic temperature biases in the tropics. There is positive bias at around 200hPa, and conversely there is negative bias at around 100hPa and 70hPa. We need to consider these model biases when we perform a bias correction based on departures. The effect of model biases can be reduced if we fit the profile vertically by a polynomial method as in the bias correction currently applied operationally at ECMWF (*Bouttier et al.*, 1999).

Figure 7 shows time series of temperature departures at three representative standard levels, 850, 500 and 100hPa. The biases and RMSs in 1976 are larger than those in 1988. The large positive biases at 100hPa in the tropics seen in Figure 6 can also be seen in Figure 7 for both years. The bias in 1988 is smaller than that in 1976.

5. BIAS CORRECTION FOR ERA-40

We are planning to apply bias corrections for radiosonde temperature observations. To select categories for which bias correction should be applied, we need to check both time series and departures from first guess field to decide to switch on/off the correction for each category.

For a practical method of radiosonde bias handling, we should take annual statistics of departures classified by solar elevation for every category and apply them to the next year. This is the method used in the current ECMWF operational bias correction (*Bouttier et al.*, 1999). Only radiation effects are corrected in the operational bias correction. In ERA-40, however, we have to correct systematic biases for some categories especially in the early years. In order to decide whether to correct both radiation and systematic biases or to correct only the radiation errors, the long-term time series must give us useful information.

It will not cause serious problems to apply the statistics from the previous year to the following year after the 1970s. However, before the 1960s, the behaviour of the time series is quite variable and it is quite dangerous to apply the previous year's statistics. A preliminary data assimilation to extract statistics should be done for the early years from the beginning of ERA-40 to at least 1972, and if possible 1979. For these years, statistics of the same year should be used for the bias correction. Otherwise lots of erroneous corrections might be made. We should remind ourselves that a problem of the method is that biased data could confuse the data assimilation. It is quite possible to damage the quality of assimilated fields.

From the result of the 1976 assimilation, we see that although it shows larger biases, they can be corrected. So far we have done no experiment for the 1960s. It is necessary to estimate forecast errors in early years to determine to what extent departures should be used in the actual bias correction. We need a further experiment to investigate performance in the 1960s before making a final decision on the bias correction method.

For the years with no satellite data, it might be possible to define relatively larger continental categories, i.e. to make statistics for regions like Central America, Tropical South America, Extra-Tropical South America, and so on.

It is a challenging task to develop a comprehensive bias correction method for over 40 years. We should pause the assimilation cycle at the end of every year to check the time series and the previous year's annual departures. If necessary, we have to reorganise the categories.

6. SUMMARY

We have made a comprehensive set of time series of radiosonde observations made over the last 50 years. Some reasonable climatological tendencies were found.

1. T100 in the 1990s are decreasing steeply in many countries.
2. T100 over the North American continent is decreasing continuously.
3. T500, T850 and Q850 over North America are increasing continuously.
4. Q850 over Pacific Islands is increasing continuously.
5. The effect of volcanic eruptions is obvious in T70.

These are very interesting features and merit further research. However, most of the changes we have found are likely to have been caused by changes of instruments, stations, and number and frequency of observations as mentioned in section 3.5.

We have seen that the quality of observational data varies considerably. There are many changes in performance during this long period. We are trying to reduce the impact of observational error on the reanalysis through the development of quality control and a bias correction method.

Finally, we should note that the set of radiosonde data used in this research, though comprehensive, is not complete, particularly, perhaps, for the early years. There must be more data sleeping in non-electronic volumes. If we had more data, the behaviour of some time series might be different. Although this is a difficult task, it is very important to make every effort to acquire as much data as possible for further reanalyses. For this purpose, a wide international co-operation is needed.

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Data source	Period	Parameter			
		Height	Temperature	Wind	Humidity
ECMWF	1978.12 - 1998.12	O	O	O	O
NCEP	1973-1980	O	O	O	O
JMA	1975-1978, 1993-1997	O	O	O	O
TD52	1945-1971	O	X	O	X
TD53	1948-1969	X	X	O	X
TD90	1943-1962	O	O	X	O
MIT	1958-1963	O	O	O	O
CCARDS	1952-1965	O	O	O	O
CHINA	1954-1962	O	O	X	O
FRANCE	1948-1979	O	O	O	O
B3	1962-1972	O	O	O	O
SCHERHAG	1954-1962	O	O	O	O
TOGA	1993	O	O	O	O
ALPEX	1982	O	O	O	O
GATE	1974	O	O	O	O

Table 1 Data sources used for the time series ‘ECMWF’ includes all the data used in ERA-15. O means an available parameter, X means an unavailable one.

Category Name	**Representative station group ID**
Norway	01000-01499
Sweden	02000-02699
Finland	02800-02999
UK, Gibraltar	03000-03949
Ireland	03950-03999
Iceland	04000-04099
Greenland(Denmark)	04100-04399
Denmark	06000-06199
Netherlands	06200-06399
Belgium	06400-06499
Luxembourg	06580-06599
Switzerland, Liechtenstein	06600-06999
France	07000-07999
Spain	08000-08494
Gibraltar	08495-08499
Portugal	08500-08599
Germany (Former Eastern)	09000-09999
Germany (Former Western)	10000-10999
Austria	11000-11399
Czech, Slovakia	11400-11999
Poland	12000-12699
Hungary	12700-12999
Former Yugoslavia	13000-13599
Albania	13600-13699
Romania	15000-15499
Bulgaria	15500-15999
Italy	16000-16595
Malta	16595-16599
Greece	16600-16799
Turkey	17000-17399
Cyprus	17600-17619

Category Name	Representative station group ID
Former USSR	20000-38999
Russia (70-80N)	20000-21999
Russia (60-70N)	22000-25999
Russia (50-60N)	26000-30999
Russia (Far East)	31000-32999
Ukraine, Belarus, Moldova, etc.	33000-34999,37000-37999
Kazakhstan, Middle Asia	35999-36999,38000-38999
Former French dependencies in Arabia (Syrian Arab Republic, Lebanon)	40000-40149
Israel	40150-40199
Former British dependencies in Arabia (Jordan, Qatar, UAE)	40250-40349,41150-41239
Saudi Arabia	40350-40549,41000-41149
Kuwait	40550-40599
Iraq	40600-40699
Iran	40700-40899
Afghanistan	40900-40999
Oman, Yemen	41240-41499
Pakistan, Bangladesh, Sri Lanka, Maldives	41500-41999,43400-43599
India	42000-43399
Mongolia	44200-44399
Hong Kong	45000-45010,45030-45040
North Korea	47000-47099
South Korea	47100-47199
Japan (Main lands)	47400-47899
Japan (South islands)	47900-47999
Myanmar	48000-48299
Thailand	48300-48599
Malaysia	48600-48679,96300-96499
Singapore	48680-48799
Former French dependencies in SE Asia (Vietnam, Laos, Cambodia)	48800-48999

Category Name	**Representative station group ID**
Northern Africa	60000-62999
Middle Africa	63000-65999
Southern Africa	66000-68999
Former Spanish dependencies in Africa (Canary Island, Western Sahara, Ceuta, Melilla)	60000-60096,60320-60338,64800-64849
Former French dependencies in Africa (Morocco, Algeria, Tunisia, Niger, Mali, Mauritania, Senegal, Guinea, Djibouti, Congo, Gabon, Central African Republic, Chad, Cameroon, Benin, Togo, Burkina Faso, Cote D'Ivoire Comoros, Madagascar)	60100-60349,60350-61699,61800-61849, 63100-63149,64400-64799,64850-64999, 65300-65399,65500-65599,67000-67199
Former British dependencies in Africa (Gambia, Sierra Leone, Mauritius, Kenya, Tanzania, Uganda, Seychelles, Nigeria, Ghana)	61700-61749,61850-61899,61900-61999, 63600-63999,65000-65299,65400-65499
Former Portuguese dependencies in Africa (Guinea-Bissau, Angola, Mozambique)	61750-61799,66100-66499,67200-67399
Egypt, Sudan	62300-62999
Former Italian dependencies in Africa (Libyan, Somalia)	62000-62299,63150-63299
Ethiopia, Eritrea	63000-63099,63300-63599
Former Belgium dependencies in Africa (Zaire,Rwanda,Burundi)	64000-64399
South Africa and surrounding countries (South Africa, Zambia, Malawi, Zimbabwe, Namibia, Botswana Swaziland, Lesotho Bouvet Island)	67400-68999
Alaska (USA)	70000-70999
Canada (All)	71000-71999
Canada(Southwest; 40-57N,100-145W)	71000-71999
Canada (Southeast; 40-57N,50-100W)	71000-71999
Canada (North; 57-90N,50-145W)	71000-71999
USA (All)	72000-74999
USA (Far south; 24-32N)	72000-74999
USA (South; 32-37N)	72000-74999
USA (Middle; 37-43N)	72000-74999
USA (North; 43-50N)	72000-74999
Mexico	76000-76999

Category Name	Representative station group ID
Middle America (all)	78000-78999
Countries (1) in Middle America (Bermuda, Bahamas, Turks and Caicos Island, Cayman, Jamaica, British Virgin Island, Belize, Antigua and Barbuda, St.Maarten St.Eustatius and Saba St Lucia, Barbados, Trinidad and Tobago, Guyana)	78000-78120,78383-78399,78550-78599, 78860-78874,78945-78949,78954-78955, 78960-78974,81000-81199
Cuba	78150-78379
Haiti Dominica	78400-78499
Countries (2) in Middle America (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica)	78501,78600-78774,
Puerto Rico (USA)	78502-78549
Panama	78775-78824
Countries (3) in Middle America (St.Martin, St.Bartholomew Guadeloupe and other French Islands., Martinique, French Guyana)	78890-78904,78915-78929,81400-81599
Curacao and Bonaire	78985-78994
Colombia, Venezuela, Ecuador, Peru, Bolivia, Paraguay	80000-80799,84000-85399,86000-86299
Brazil	82000-83999
Chile	85400-85999
Argentina	87000-87999
Falkland islands (UK)	88800-88959
Antarctica (All)	88960-89999
Antarctica (Argentina)	88960-88969,89034
Antarctica (South Africa)	89001
Antarctica (Germany)	89002
Antarctica (USA)	89009,89061,89083-89125,89175,89664,89674
Antarctica (UK)	89022,89042,89062-89063,89065
Antarctica (Former USSR)	89044-89050,89512,89542,89574,89592, 89606,89657
Antarctica (Japan)	89524-89532,89544
Antarctica (Australia)	89564-89571,89575,89600,89611
Antarctica (France)	89663,89665
USA Pacific islands	91000-91499
(Former) British dependencies in Pacific	91500-91549,91600-91719,91770-91799, 91900-

Category Name	Representative station group ID
islands (Solomon Islands, Nauru, Kiribati, Tuvalu, Fiji, Phoenix Islands, Tonga)	91902
(Former) French dependencies in Pacific islands (Vanuatu, New Caledonia, Southern line islands, French Polinesia)	91500-91599,91903-91959
New Zealand	93000-93999
Australia (North; 23S-0), Papua New Guinea	94000-95999
Australia (South; 50S-23S)	94100-95999
Indonesia	96000-96299,96500-96989,97000-97999
Philippine	98000-98999

Table 2 List of categories for time series. The table gives the list of countries or regions and their representative ID numbers of station groups for which time series are shown in Figure 4. There are some other countries not listed in the table because the amount of data from them are insufficient to make time series.

Category Name	T100	Radiation Correction (RC) DN-difference	T500	T850	Q850	Data availability	Other comments
Norway	D(90s)	RC-on(60sLH-) DN-P(82-83)*			SD(70sLH)		*volcanic eruption?
Sweden	D(90s)	RC-on(86-)					
Finland	D(90s)	RC-on DN-P(82)*					*volcanic eruption?
UK	SD(90s)	RC-on	I(a88)	I(a88)		Few(66-73)	
Ireland	SD(90s)	RC-on(84-)* DN-JD(84) DN-JI(88)				No(66-73)	*RC-correct (88-)
Iceland	D(90s)	RC-on(90-)	SI(86-) Var(86-)	I(80s)			
Greenland (Denmark)	D(90s)	RC-imp					
Denmark	D(90s)	RC-on(77-)* DN-JD(77,83**)			SD(70sLH)		*RC correct (90-) **volcanic eruption
Netherlands	D(90s)	RC-on(87-) DN-JD,V(72-73) DN-JD(87)	SI(80s-)				
Belgium	SD(80s) D(90s)	RC-on(84-)	SI(88)	I(87)	SD(75-85)		
Switzerland	SD(80s) P(92)*	RC-on(70-90) RC-off(90-)	SI(80s)	I(87)	SD(60s-)		*volcanic eruption?
France	D(70s-)	RC-on(90-) DN-JD(72) DN-P(57,71)		SI(80sLH)	JD(53) I(53-70) SD(70-)	Data avalable since 48	Daytime T100 has big positive bias before 72
Spain	D(90s) P(67)	RC-on(83-)*	SI(70-)	V(77),SI(80s)	SD(75-95)	Few(-73)	*RC correct (94-)
Gibraltar (UK)	JD(94)	RC-on(73-)	JI(94)	JI(94)	JD(90)		JJ(94)
Portugal	V(95)	RC-on(87-)	P(95)	P(95),I(75-)	I(80-)	No(66-73)	Big bias (50s,60s)
Germany (Former East)	SD(80s,90s), V(83)	RC-on (80sFH-)	I(80sLH)	P(90)	SD(90s)		DN slowly decreased (80-85).
Germany (Former West)	SD(80s) D(90s)	RC-on	SI(80sLH)	SI(80sLH)	SD(90s)	JI(95)	
Austria	SD(80s,90s)	RC-on(96-)	I(80s)	SI(80s)	SI(90sLH)		
Czech Slovakia	JD(83), P(62)	RC-on(69-)	P(62)	P(83,90)	D(93)		
Poland	D(90s) JD(82-83)	RC-on(71-)	SD(70-85) I(80sLH)		JD(93)		Daytime T100 has big positive bias before 71
Hungary	D(60s-) P(88,92)	RC-on(77)				D(90s)	
Former Yugoslavia		RC-off	I(80s)			Few(90s)*	*Wars in the 90s
Romania	JD(93)	RC-off				JD(91-) Few(91-)	Low reliability (90s)
Bulgaria	V(87)	RC-on(70?-)	I(80s)	SI(80s),SD(70s)	V(93) D(60-85)	JD(92)	
Italy	D(90s)	RC-on(86-)	I(79-83)	I(80-83)	JI(85)		
Malta		RC-on?					Only wind data (79-)
Greece	P(92-94)	RC-on(80?-)	P(66,68) V(73,76)		JD(77-80) SI(80-)		
Turkey	D(80sLH-)	RC-on(98-)	SI(60s-)	SI(60s-)	I(80sFH)	I(-87)	
Cyprus	P(83)	?				JD(76)	
Former USSR	D(-65)	RC-on(69-)				D(90s)	Daytime T100 positive bias (-65) RC partly done
Russia (70-80N)	D(90s) D(-65)	RC-imp	D(-65)	V(80)		D(90s) Few(96-)	
Russia (60-70N)	D(90s) D(-70)	RC-on(69-)	SI(80s) D(-70)	SI(80s)		D(90s)	RC partly done

Category Name	T100	Radiation Correction (RC) DN-difference	T500	T850	Q850	Data availability	Other comments
Russia (50-60N)	D(90s)	RC-on(69-)	SI(80s)			D(90s)	RC partly done
Russia (Far East)	D(-70)	RC-on(69-)	P(90-91) SI(90s) D(-70),V(70)	P(89,91)		D(90s)	RC partly done
Ukraine, Belarus, Moldova, etc.	D(-70)	RC-on(69-)	D(-75)	P(66) SD(60s-)	SD(60s-)	D(90s)	RC partly done
Kazakhstan, Middle Asia	JD(73) D(-73)	RC?	JI(76-77) JD(92)	I(70-85) JD(92)	I(70sLH)	D(90s) Few(95)	
Former French dependencies in Arabia	P(83)	RC-on?	V(83)	JI(76)		D(80s) Few(90s)	
Israel	D(-70)	RC-on(95)	SD(60s), P(91),V(93)		I(70s),P(69)		T100 positive bias (-60s)
Former British dependencies in Arabia	JD(84)*	RC-on?	JI(84)*	JI(84)*	JD(84)* I(94-)	JI(84)*	*JJ
Saudi Arabia		RC-on	SD(90s)			JI(79)	
Kuwait	JD(84)	RC-on(90s)			JD(84)	No (90-93)*	*Gulf war
Iraq		?				No (80-)*	*Iran-Iraq war,Gulf war
Iran	P(73)	?				No (80-88)*	*Iran-Iraq war
Afghanistan		?				Few	
Oman, Yemen		?			Var(80s)		
Pakistan, Bangladesh etc.	SD(80s-)	?	SI(90s)		V(87-90)		
India	I(80s) P(90)	RC-off?	I(80s) P(90)	SI(80s)	P(90-91) I(90s)		
Mongolia	I(80s) D(65-80)	?	I(80sLH) D(65-80)	P(89,91)		JD(92) Few(92-)	
Hong Kong	I(60s,70s) D(80sFH)	RC-on	SI(60s-80s)	SI(70s)	SI(70s)		
North Korea		RC-off?	JD(80)*	JD(80)*	JD(80)*	JI(80)*	*JJ
South Korea	V(79),D(80s) ,P(83,92)	RC-off	JI(90,98)		P(90) V(66)		
Japan (Main lands)	SD(-72)	RC-on(81-)			JD(81)* SI(86-)		*change of humidity sensor
Japan (South islands)	SD(90s) JD(64-67)	RC-on(81-)			I(65-80) JD(81)*		*change of humidity sensor
Myanmar		?				Too few	
Thailand	SI(90s)	RC-off			I(80s)		
Malaysia	V(85) SD(80s-)	RC-on(87-)	SI(70s)	SI(80s-)	I(75-88) P(88)		
Singapore	I(60s,70s) P(82-83)	?	I(75-85)	I(70s)	JD(71) I(75-85)		
French SE Asia	I(70s) D(90s)	?	SI(70s)	D(73-77)	I(60s-80s) D(90s)		
China (all)	V(65-66)	RC-on(67-) DN-P(75)			V(75)	Unstable during C.E.	66-76 Cultural Revolution
China (Northwest)	SD(90s)	RC-on	SI(77-) JI(90)		V(75)		66-76 Cultural Revolution
China (North, Northeast)		RC-on	SI(86-)		V(75)		66-76 Cultural Revolution
China (West, Tibet)		?		Impossible*	Impossible*		*because of high elevation 66-76 Cultural Revolution
China (Middle)	P(75)	RC-on(67-)		V(75-78)	V(75)		66-76 Cultural Revolution
China (Middle East)	V(66,72)	RC-on(67-)			V(75)		66-76 Cultural Revolution

Category Name	T100	Radiation Correction (RC) DN-difference	T500	T850	Q850	Data availability	Other comments
China (South)		RC-on(67-) DN-P(75)			V(75)		66-76 Cultural Revolution
Northern Africa	D(70s)	?	I(70s)	SI(70s,80s)			
Middle Africa	D,Var(-80sFH)	?			JI(79) SD(90s)		
Southern Africa	Var(-85)	?		SI(75-85)			
Former French dependencies in Africa	D(70-85) JD(95)	? DN-Var	I(93-)	I(70sLH-)	P(69,79)		
Former British dependencies in Africa	P(93,96)		V(93,96)	D(65-)	D(65-)		
Former Portuguese dependencies in Africa		?				Var,Few	
Egypt, Sudan	I(80s)	?			D(95-)	Var	
Former Italian dependencies in Africa		?	I(70sLH)	I(a75)		JD(71)	
Ethiopia, Eritrea		?				Too Few	
South Africa and surrounding countries	SD(80s-) P(73,75)	RC-on(92-)			V(80-83) I(84-87) SD(a90)		
Alaska (USA)	SD(80s-)	RC-on(95-)	SI(90s) P(90)	V(71) I(70s)	I(70s)	Constant	
Canada (All)	SD(60s-)	RC-on(95-) (some st.)	SI(60s-)	SI(70s-)	SI(65-)	Constant	
Canada (Southwest)	SD(70s-) P(83)	RC-on(95-) (some st.)	SI(70s-)	SI(70s-)	SI(65-)	Constant	
Canada (Southeast)	SD(60s-)	RC-on(95-) (some st.)	SI(60s-)	SI(70s-)	SI(65-)	Constant	
Canada (North)	SD(70s-)	RC-on(95-)	SI(70s-)	SI(70s-)	SI(65-)	Constant	
USA (All)	SD(85-) P(83)	RC-on(95?-) (some st.)	SI(70sLH-)	SI(80sLH-)	I(70sLH-)	Constant	
USA (Far south; 24-32N)	SD(90s)	RC-on(95?-) (some st.)	SI(80s-)	SI(90s)	I(70sLH-)	Constant	
USA (South; 32-37N)	SD(90s) P(83)	RC-on(95?-) (some st.)	SI(80s-)		I(80s-)	Constant	
USA (Middle; 37-43N)	SD(60s-) P(83)	RC-on(95?-) (some st.)	SI(80s-)	SI(80s-)	I(70sLH-)	Constant	
USA (North; 43-50N)	SD(60s-) P(83)	RC-on(96?-) (some st.)	SI(80s-) Var(80s-)	SI(80s-) Var(80s-)	I(70sLH-)	Constant	
Mexico	JI(65) JD(93) D(65-)	RC-on(93-)	JD(65) I(75-)	JI(93)	JD(65) I(70s-)		
Middle America (all)	D(a70) SD(70s)	RC-on(94?-)	SI(75-)	SI(75-)	I(70s-)		
Countries (1) in Middle America	D(70s)	RC-off	SI(70s)	I(70s-)	I(70s-)	D(90s)	Similar performance to all middle America
Cuba		?	JI(a76)	JI(a76)	JI(a76)	Few(80s) No(90s)	
Haiti Dominica		?	SI(70sLH)	SD(60s-a76) SI(70sLH)	SI(60sLH-70s)	Few(90s)	
Countries (2) in Middle America	D(70s) JD(80)* I(80s)	?	I(70sLH-)	SI(70sLH)	I(70s)	JI(74) JD(80)* Few(90s)	*JJ
Puerto Rico (USA)	SD(90s)	RC-off	I(76-) P(88)	I(a79)	I(a80)	constant	
Panama	P(92) SD(93-) D(60s)	RC-on?	SI(75-85)		JI(a80)	V(a88-92)	
Countries (3) in Middle America	JD(81) D(77-79,90s)	?	I(77-81)		P(80sFH)	JI(a95)	

Category Name		T100	Radiation Correction (RC) DN-difference	T500	T850	Q850	Data availability	Other comments
Curacao and Bonaire		P(83)	RC-off			JI(79) SI(80sLH-)		
Colombia, Venezuela, Ecuador, Peru, Bolivia, Paraguay		V(85) D(90s)	?		SI(-80)	V(86,90,96)		
Brazil		SD(80-)	RC-off		SI(80-)	SI(70s-80sFH)	Max (70s)	
Chile		I(70s-80s)	DN-JD(89)	D(70s-)	D(70s-)	D(70s) SI(80s-)		
Argentina		D(90s)	?	D(90s)	D(90s)	D(90s)		
Falkland islands (UK)			RC-on(88-)	Low(70s)		Low(70s)		Falklands war (82)
Antarctica	All	D(80s) SD(90s)	RC-imp	V(70sLH)	V(70sLH)	Constant		
Antarctica	Argentina		RC-imp					
Antarctica	South-Africa		RC-imp					
Antarctica	Germany	D(90s)	RC-imp					
Antarctica	USA	P(92) D(80sLH-)	RC-imp	P(92)				
Antarctica	UK	D(80s-)	RC-imp	SI(80s)				
Antarctica	Former USSR	D(70sLH-) P(89)	RC-imp	JI(80)*				*JJ
Antarctica	Japan	D(80s-) P(80)	RC-imp					
Antarctica	Australia	D(80s-) P(89)	RC-imp	I(80s-)				
Antarctica	France	P(89)	RC-imp	D(80s)	P(82,92)			
USA Pacific Islands		D(90s)	RC-on(95?-) (some st.)	SI(90s)	I(85-)	I(65-)		Obvious trend at 850hPa
(Former) British dependencies in Pacific islands		JD(84)	?	JD(84)		I(60s, 70s) SD(90s)		
(Former) French dependencies in Pacific islands		D(70s-)	?					T100(70s) big positive bias
New Zealand		V(87)	RC-on(89-)	P(87)	P(87)	P(73,87)	No(63-67)	JJ?(87,73)
Australia (North; 23S-O), Papua New Guinea		SD(70s) P(83)	RC-on(88-)	JI(87)	SI(70s-)	JI(83)		
Australia (South; 50S-23S)		D(80s-) (P(83,88,92)	RC-on(88-)		SI(70sLH-)	I(70-s-)		
Indonesia		D(80sLH)	RC-off		V(91-92)	V(91-92)	I(90s)	
Philippines		P(83),I(70s)	RC-off	I(70sLH)	SI(70sLH-)	SI(70s,80s) JD(91)	Var	

Table 3 Table describing detailed features of time series for each category shown in Figure 4. XX(YY):Basically event(XX) and year(YY) are described by this format. Year is expressed as 2 digit to save space. The acronyms are as follows; RC:radiation correction, DN:day-night difference, JD:decreasing jump, JI:increasing jump, I:increase, D:decrease, SI:increase slightly, SD:decrease slightly, P:peak, V:valley, Imp-HL;impossible to calculate because of high latitude, Var:big variability, aXX:about XX , X0sFH:first half of the X0s, X0sLH:latter half of the X0s, some st.: some stations, JJ:Jumps of profiles are caused by jumps of data number

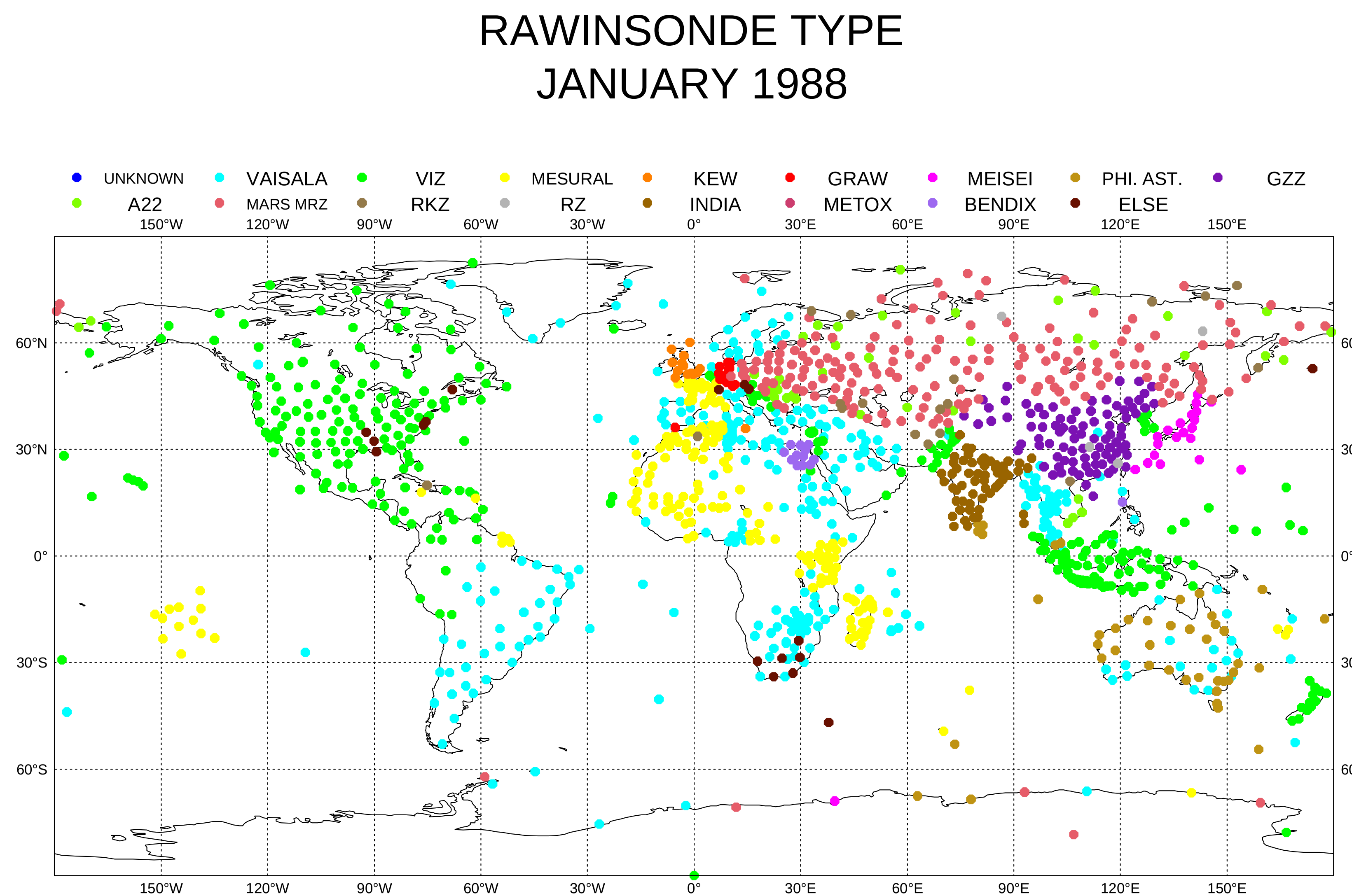


Figure 1 Radiosonde station distribution map for January 1988. Colour denotes radiosonde manufacturer. This map was drawn according to the simplified history file. It does not imply observations are available from all stations, and may be subject to some errors.

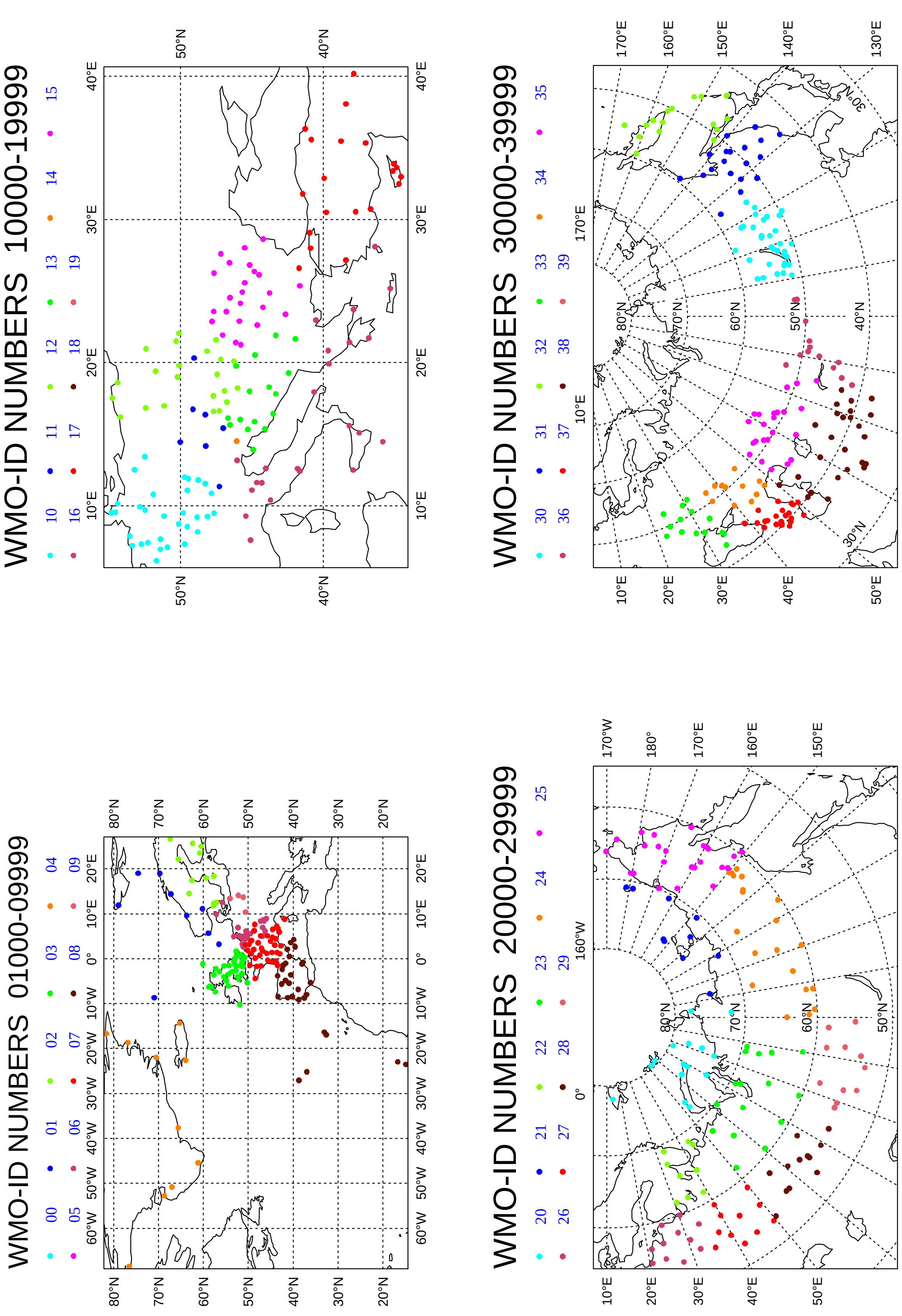
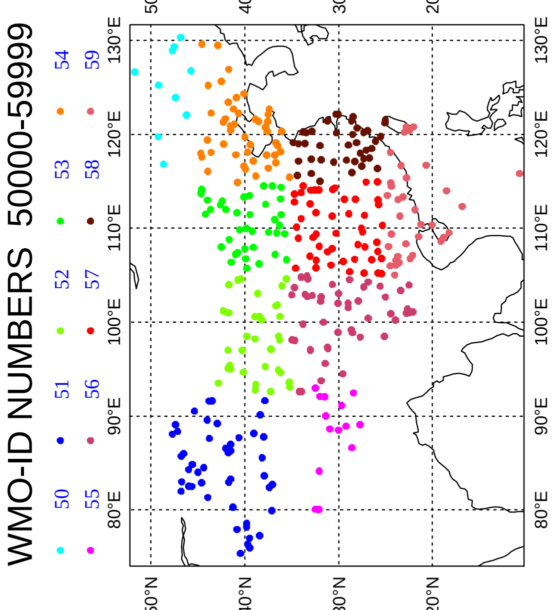
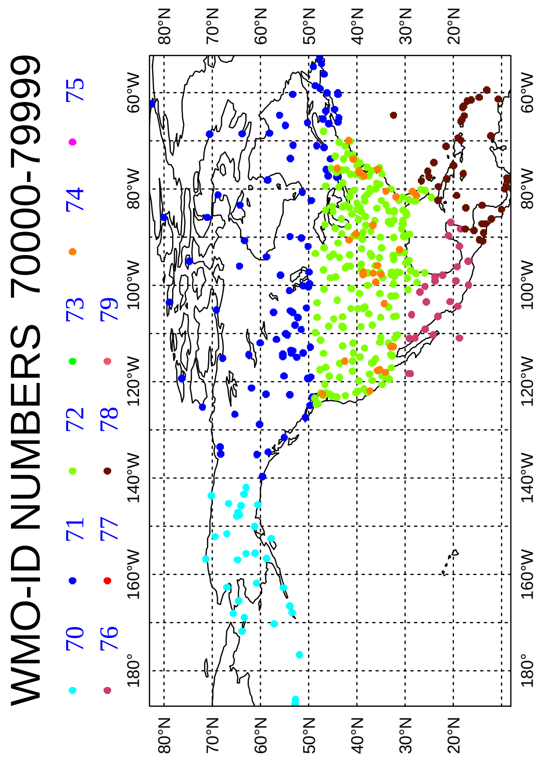
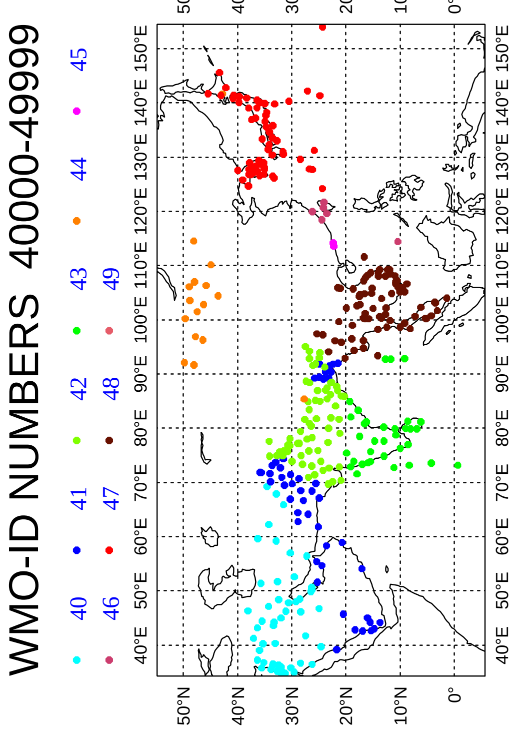


Figure 2 Maps showing distribution of representative ID numbers of the station groups.


WMO-ID NUMBERS 50000-59999


WMO-ID NUMBERS 70000-79999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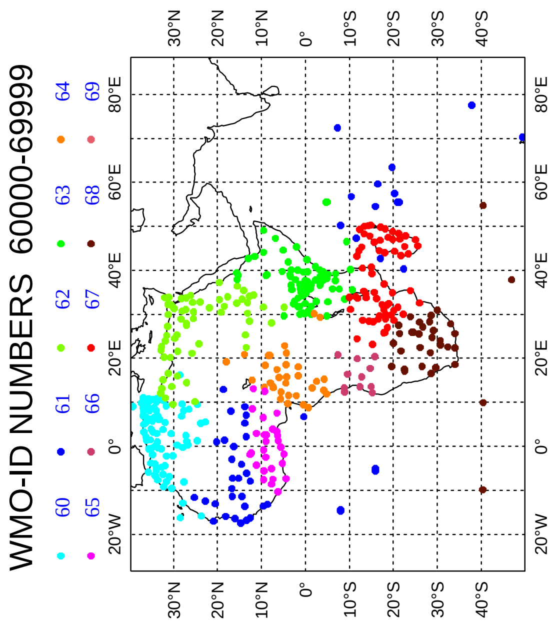
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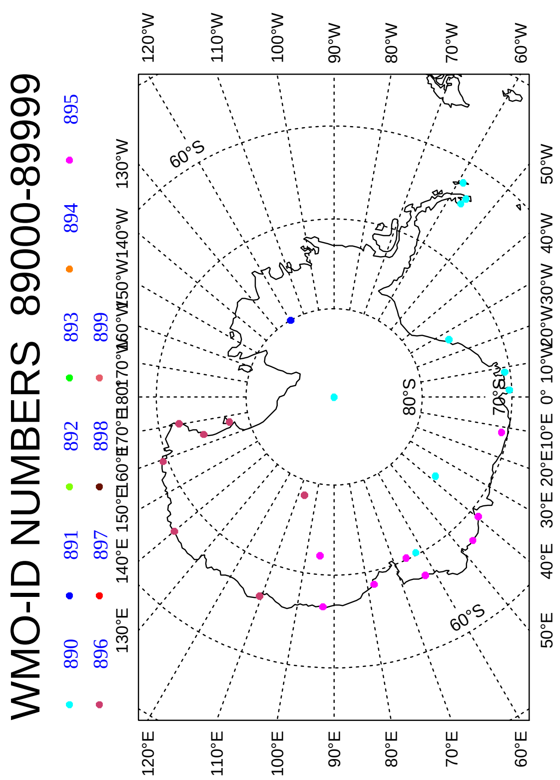
WMO-ID NUMBERS 89000-89999
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895
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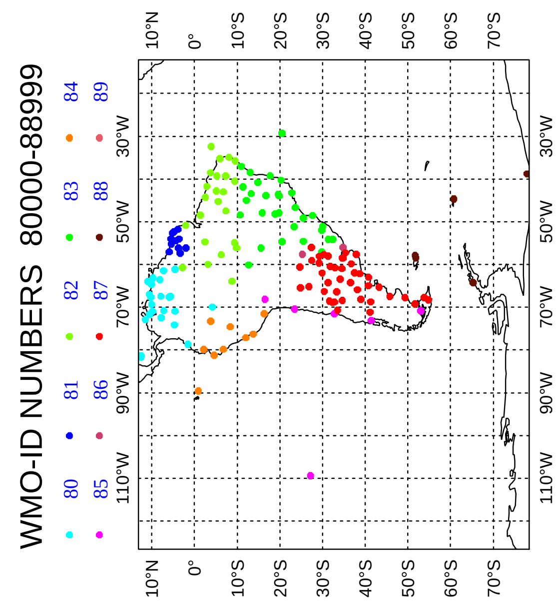
898
899


WMO-ID NUMBERS 80000-88999
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83
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85
86
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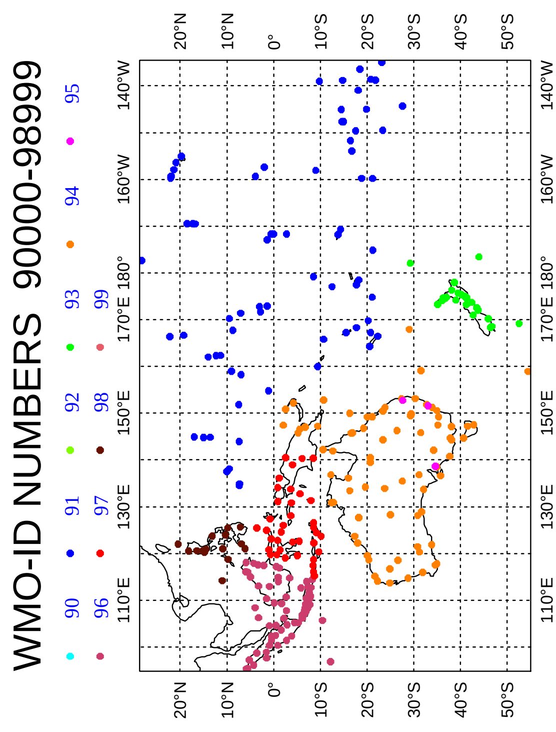
88
89


WMO-ID NUMBERS 90000-98999
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91
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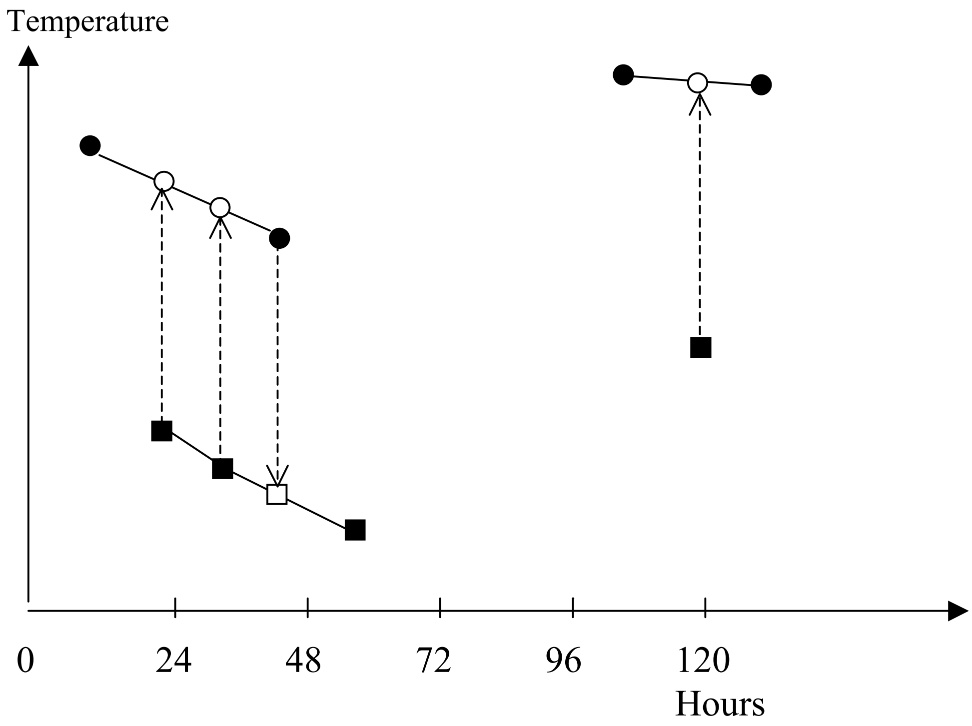
96
97
98
99

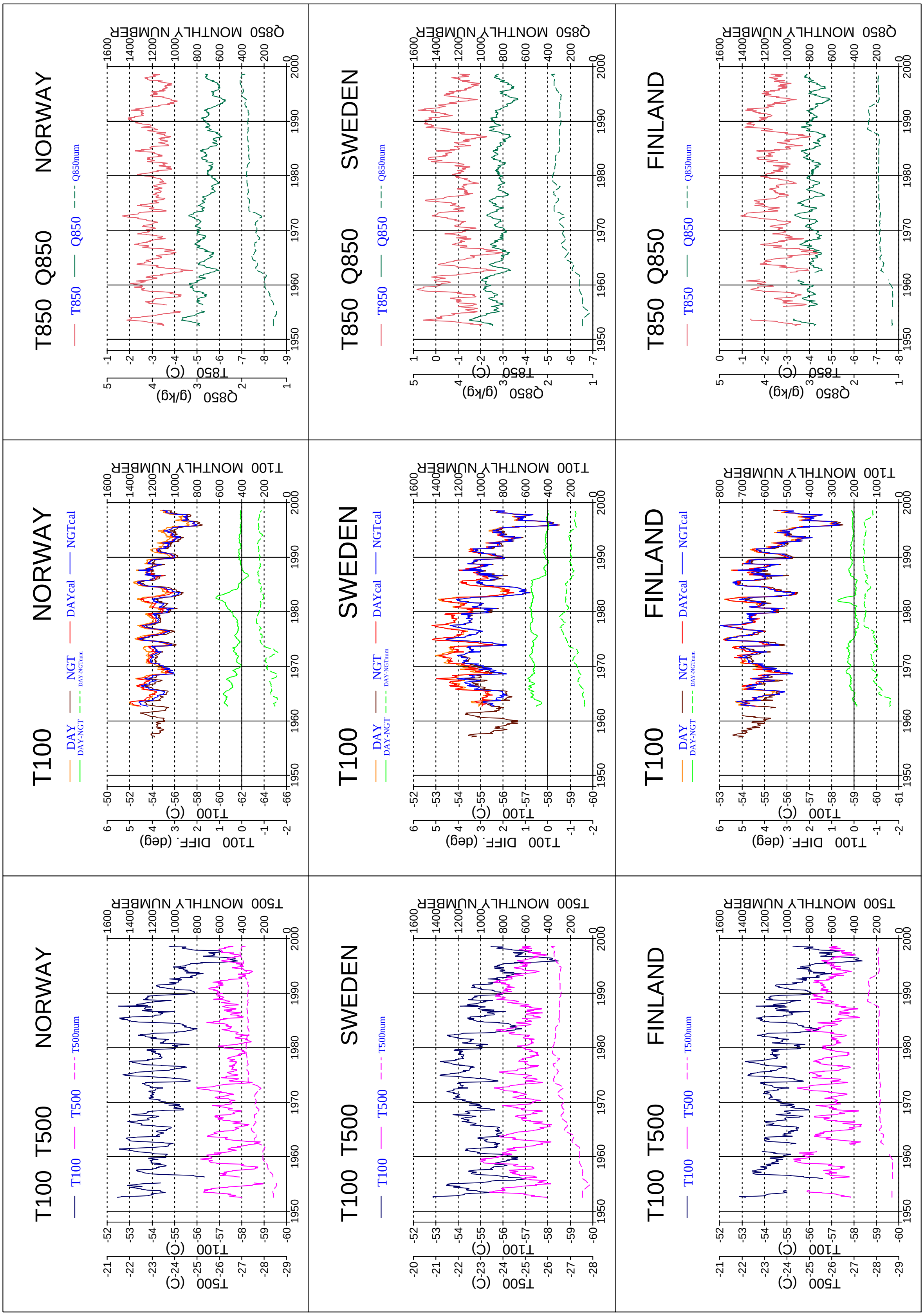


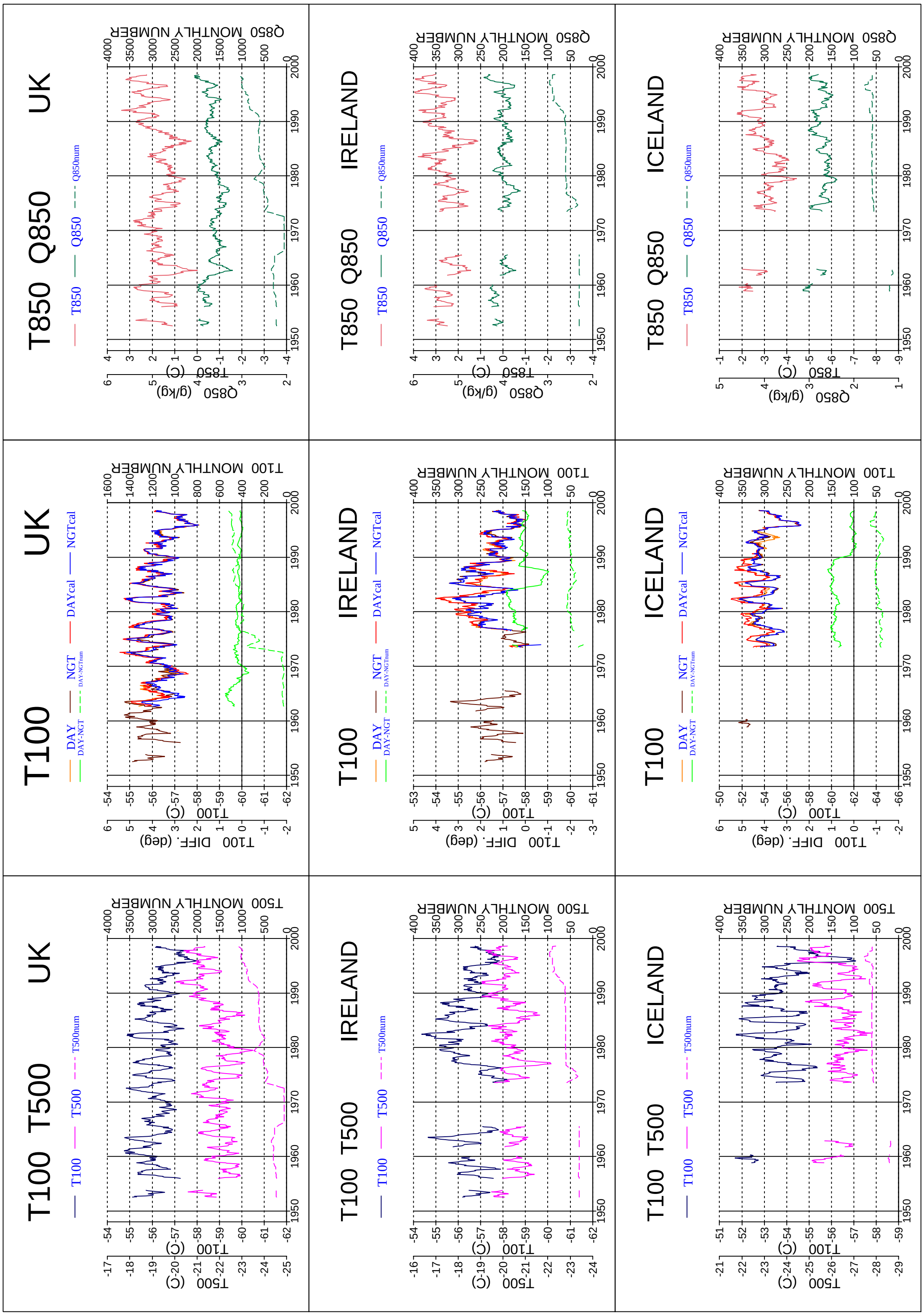
● : Actual Day-time observation
■ : Actual Night-time observation
○ : Interpolated Day-time observation
□ : Interpolated Night-time observation

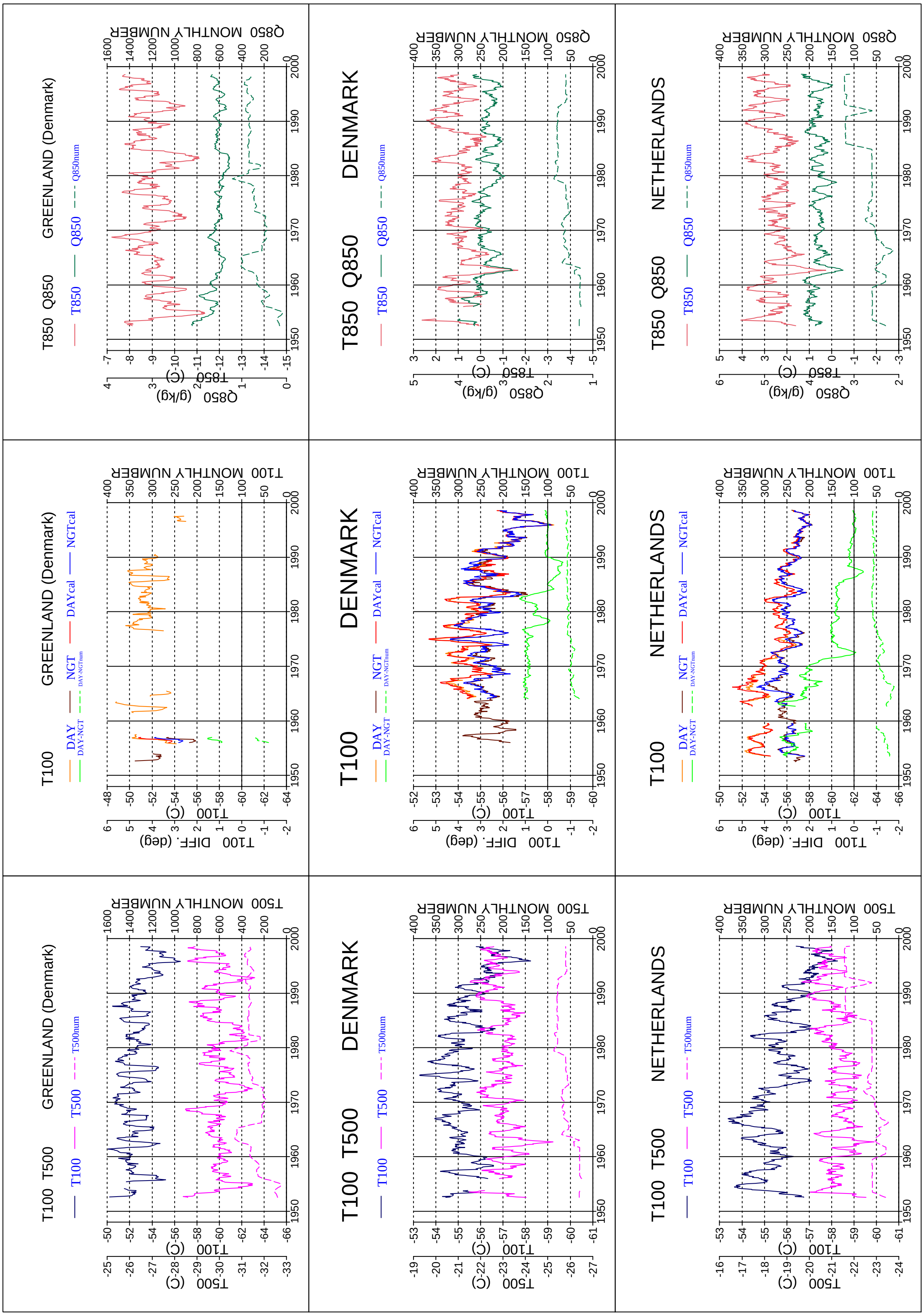
The DN-difference is calculated only when two day-time or night-time observations exist in 48 hours.

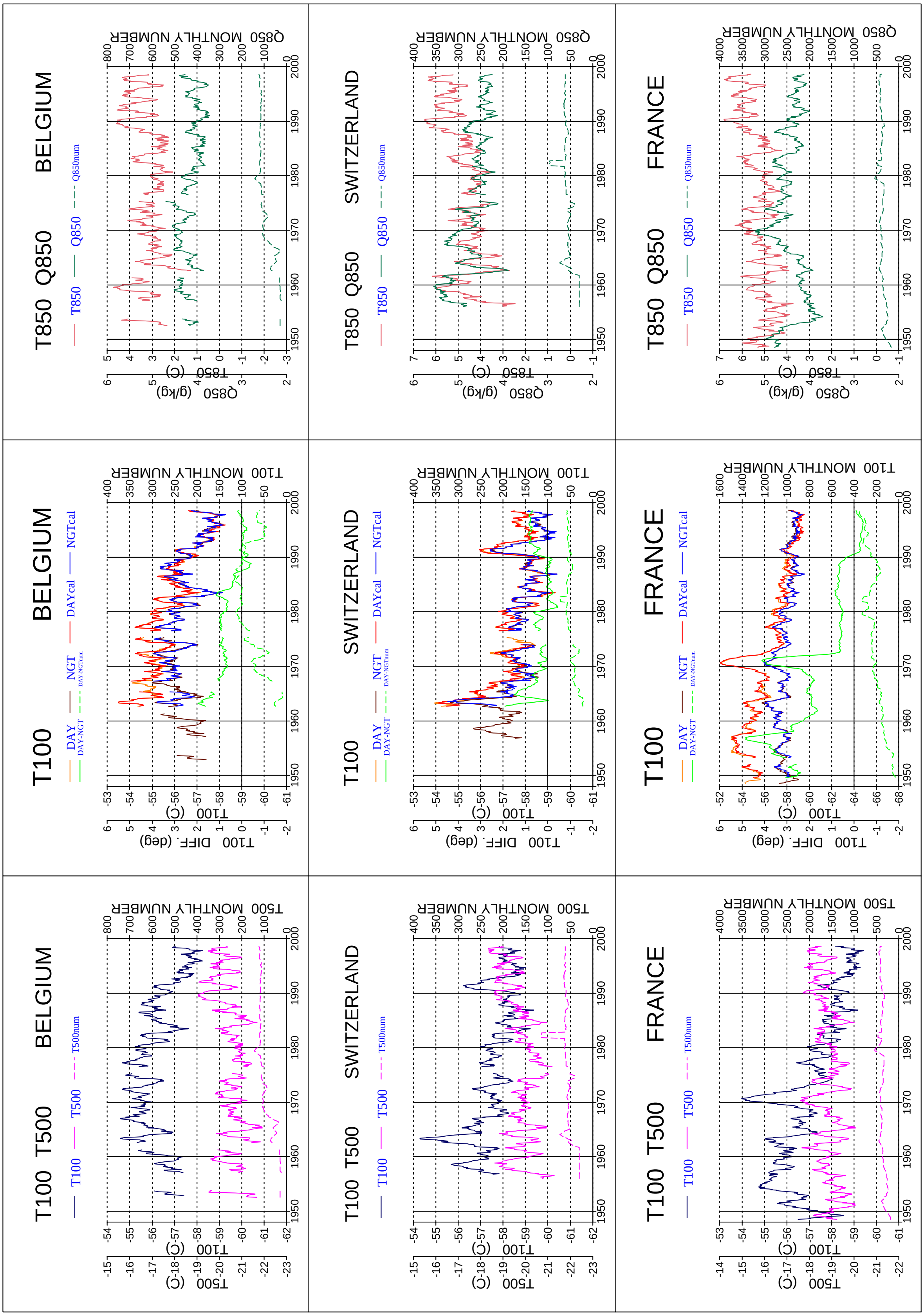
Figure 3 Day-Night difference chart. This chart explains how DN diffrences are calculated. A closed circle and square denote real day-time and night-time observations respectively. If two day-time (night-time) observations are less than 48 hours apart, the two day-time (night-time) values are interpolated to the time(s) of night-time (day-time) observation(s). Then the difference(s) is(are) calculated. An open circle and square denotes interpolated day-time and night-time observation respectively.

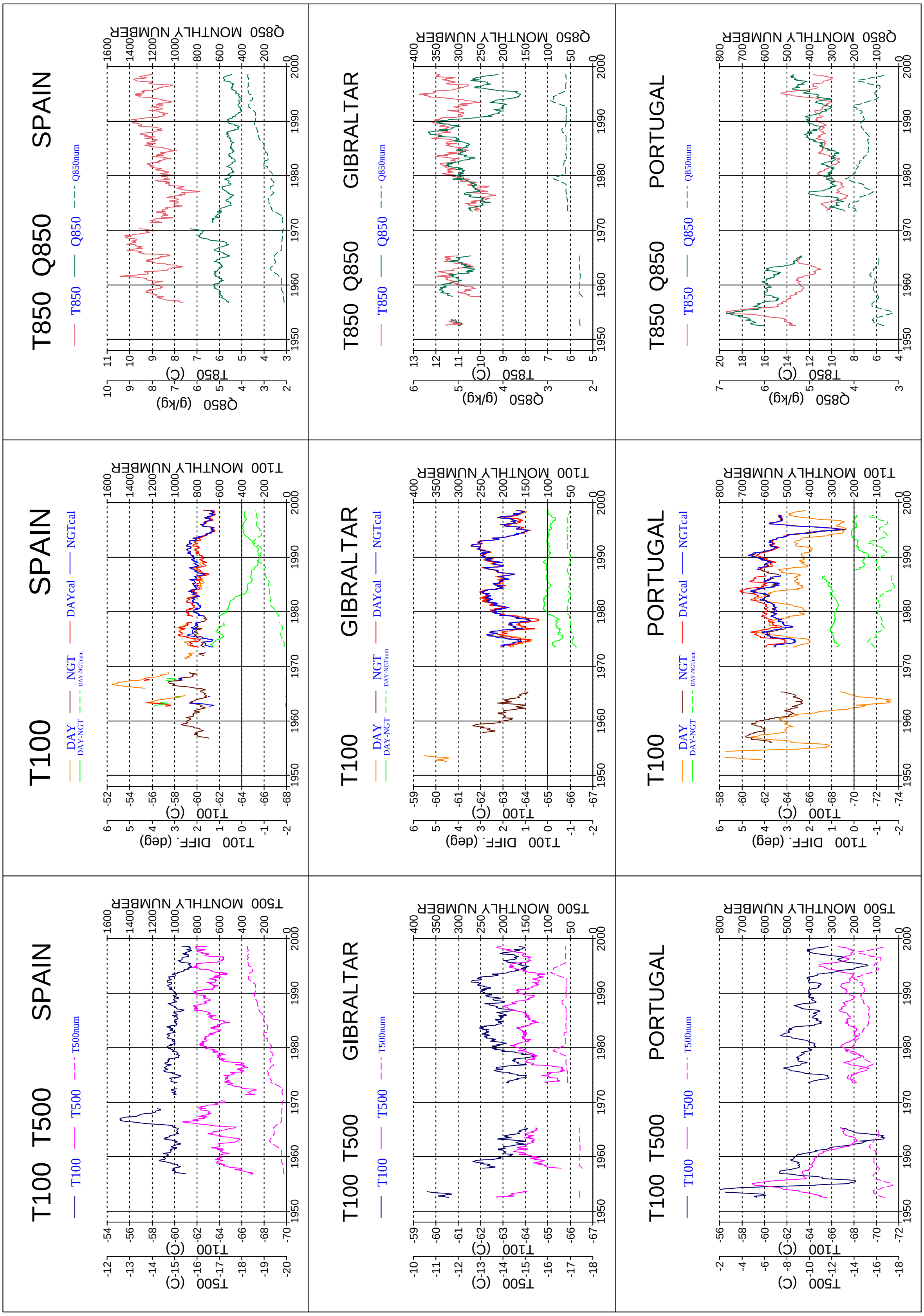
Figure 4 (Pages 31 – 70) Time series for each category for 51 years from 1948 to 1998. Three kinds of time series are shown for each category. The left figures show T100 (Navy), T500 and T500 counts (Magenta). The middle figures show T100 all day-time (Orange), all night-time (Brown), limited day-time (Red) and limited night-time (Navy) observations used to calculate DN-difference. They show also DN-differences and numbers (Green). The right figures show T850 (Pink), Q850 and Q850 numbers (Evergreen). For most Antarctic categories, the DN-differences are not shown because in the polar region the DN-difference could not be calculated. An annual moving average was applied to all time series including monthly data number.

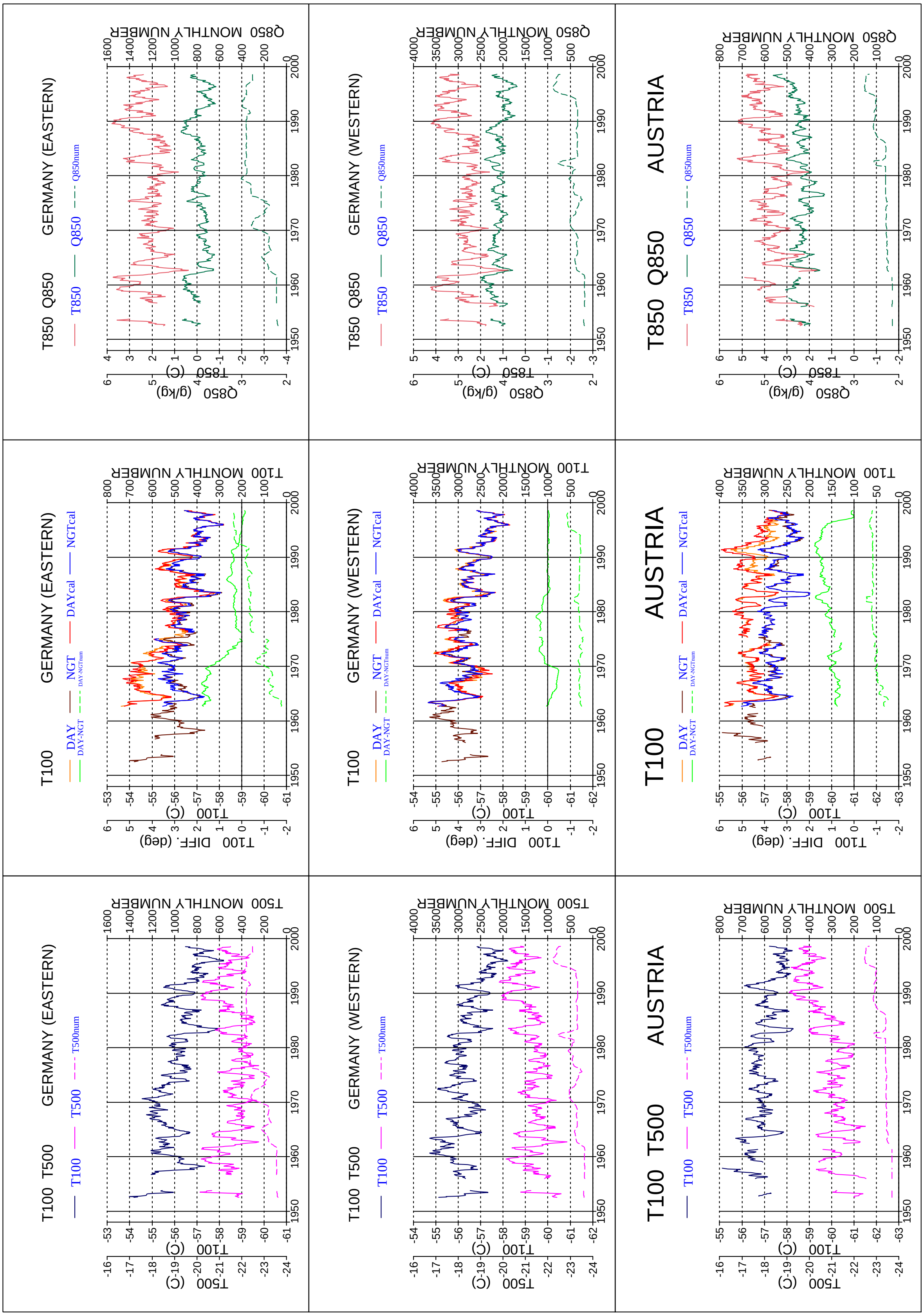

T850 Q850 NORWAY
T850 Q850 SWEDEN
T850 Q850 FINLAND
T100 NORWAY
T100 SWEDEN
T100 FINLAND
T100 T500 NORWAY
T100 T500 SWEDEN
T100 T500 FINLAND
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

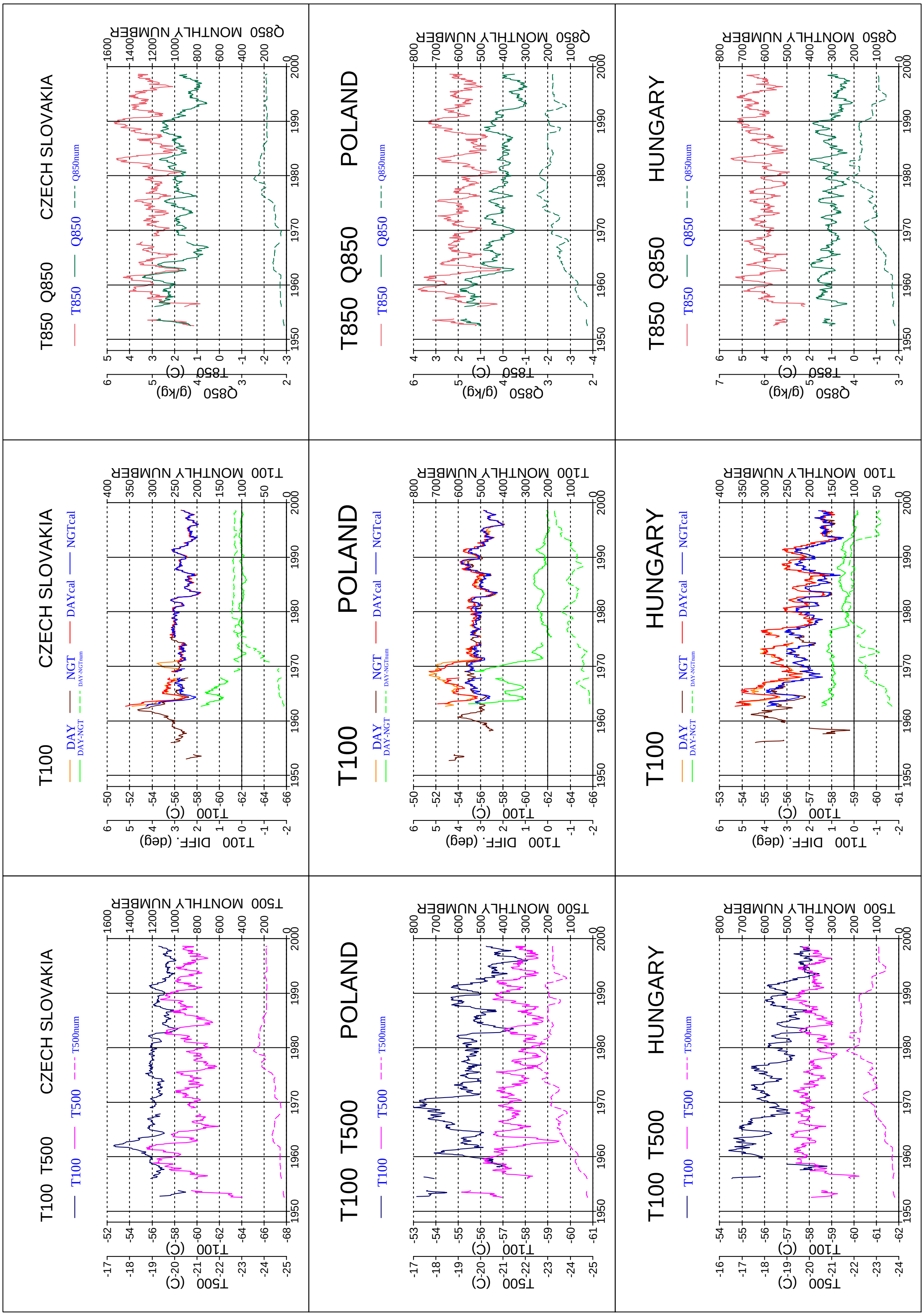

T100 T500 UK
T100 T500 IRELAND
T100 T500 ICELAND
T100 UK
T100 IRELAND
T100 ICELAND
T850 Q850 UK
T850 Q850 IRELAND
T850 Q850 ICELAND
T100
T500
T500num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T850
Q850
Q850num

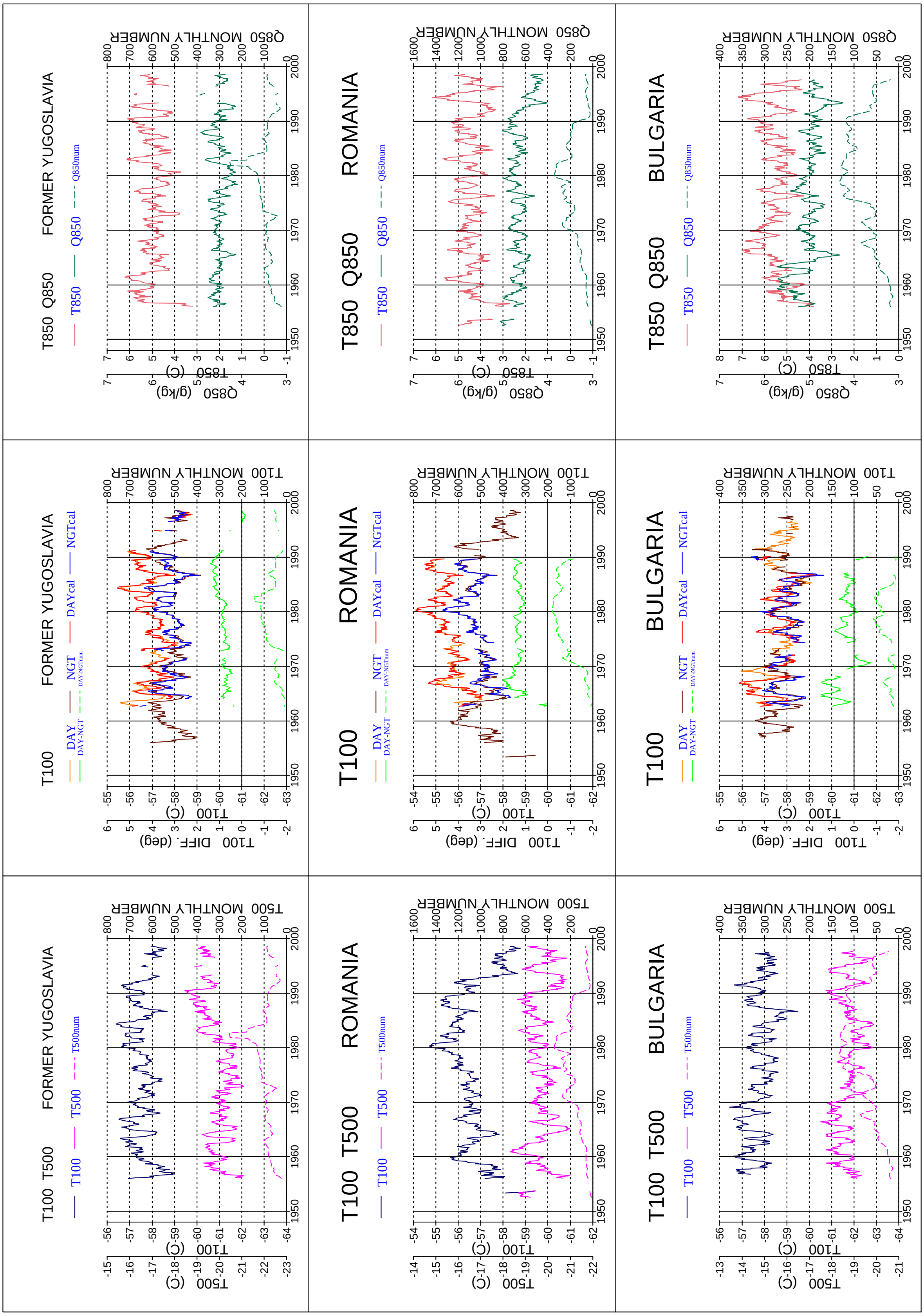

T850 Q850 GREENLAND (Denmark)
T100 GREENLAND (Denmark)
T100 T500 GREENLAND (Denmark)
T850 Q850 DENMARK
T100 DENMARK
T100 T500 DENMARK
T850 Q850 NETHERLANDS
T100 NETHERLANDS
T100 T500 NETHERLANDS

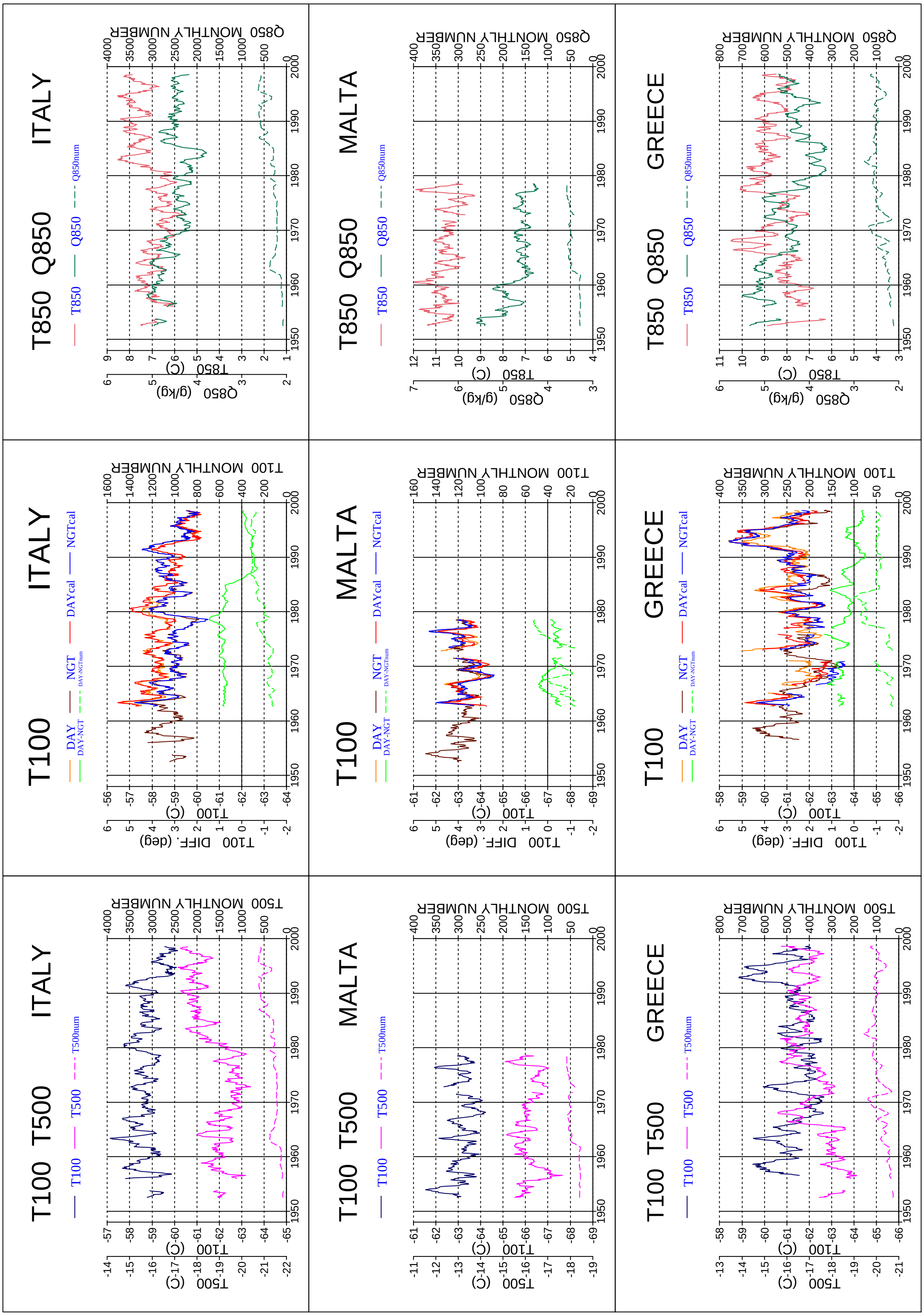

T850 Q850 BELGIUM
T100 BELGIUM
T100 T500 BELGIUM
T850 Q850 SWITZERLAND
T100 SWITZERLAND
T100 T500 SWITZERLAND
T850 Q850 FRANCE
T100 FRANCE
T100 T500 FRANCE

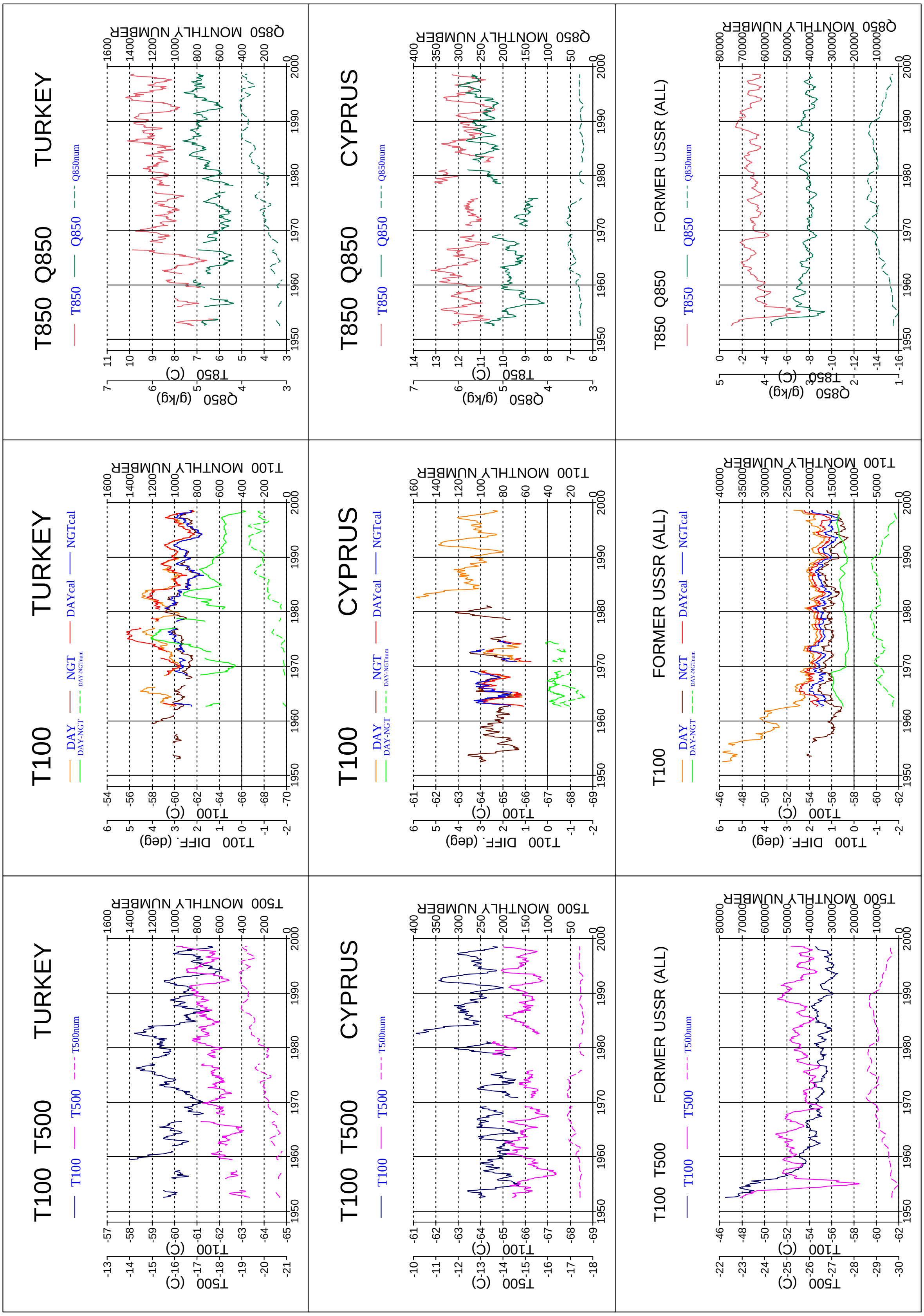

T100 T500 SPAIN
T100 SPAIN
T850 Q850 SPAIN
T100 T500 GIBRALTAR
T100 GIBRALTAR
T850 Q850 GIBRALTAR
T100 T500 PORTUGAL
T100 PORTUGAL
T850 Q850 PORTUGAL

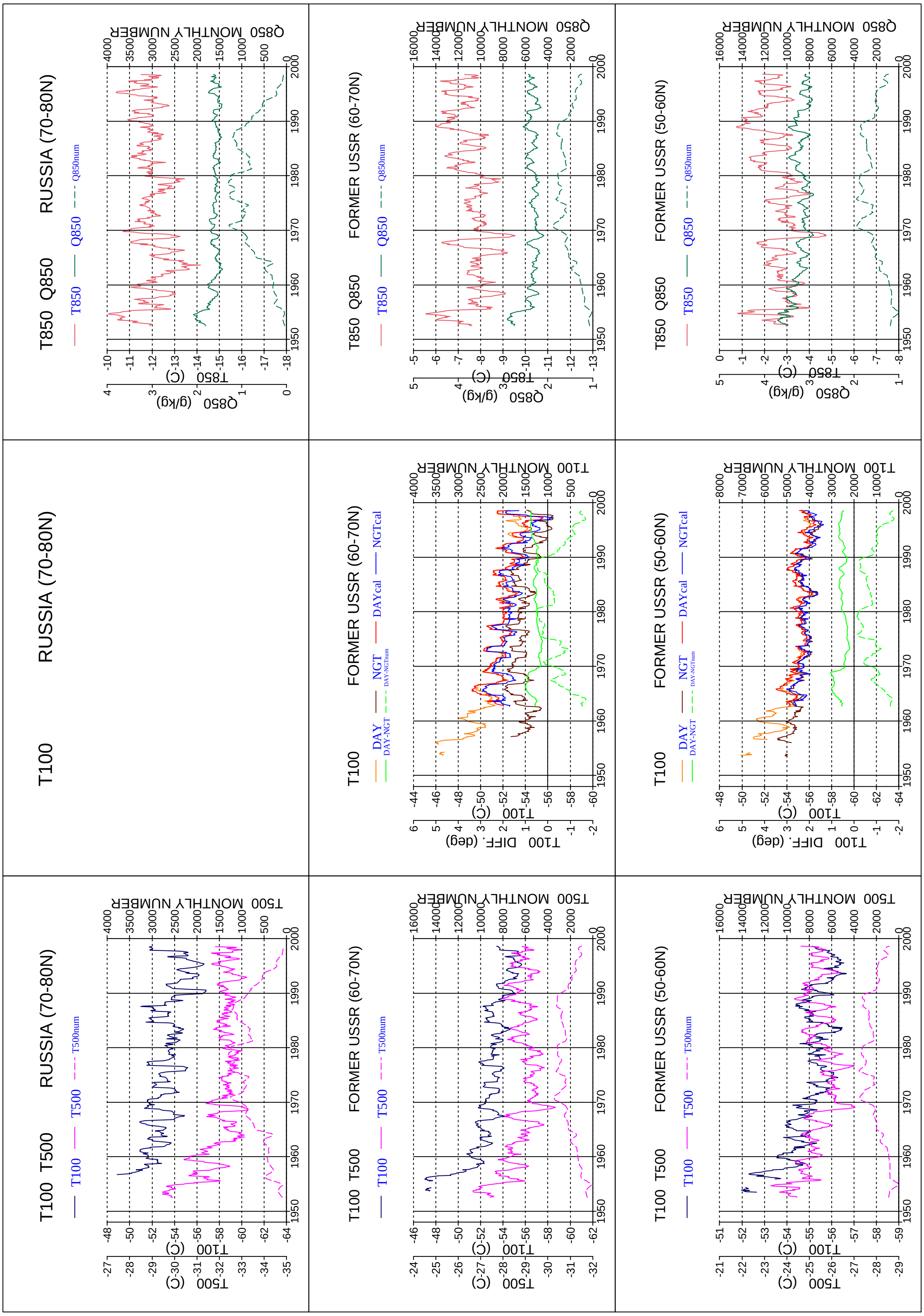

T100 T500 GERMANY (EASTERN)
T100 GERMANY (EASTERN)
T850 Q850 GERMANY (EASTERN)
T100 T500 GERMANY (WESTERN)
T100 GERMANY (WESTERN)
T850 Q850 GERMANY (WESTERN)
T100 T500 AUSTRIA
T100 AUSTRIA
T850 Q850 AUSTRIA
T100
T500
T500num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T850
Q850
Q850num
T500 (C)
T100 (C)
T100 DIFF. (deg)
T850 (C)
Q850 (g/kg)
T500 MONTHLY NUMBER
T100 MONTHLY NUMBER
Q850 MONTHLY NUMBER

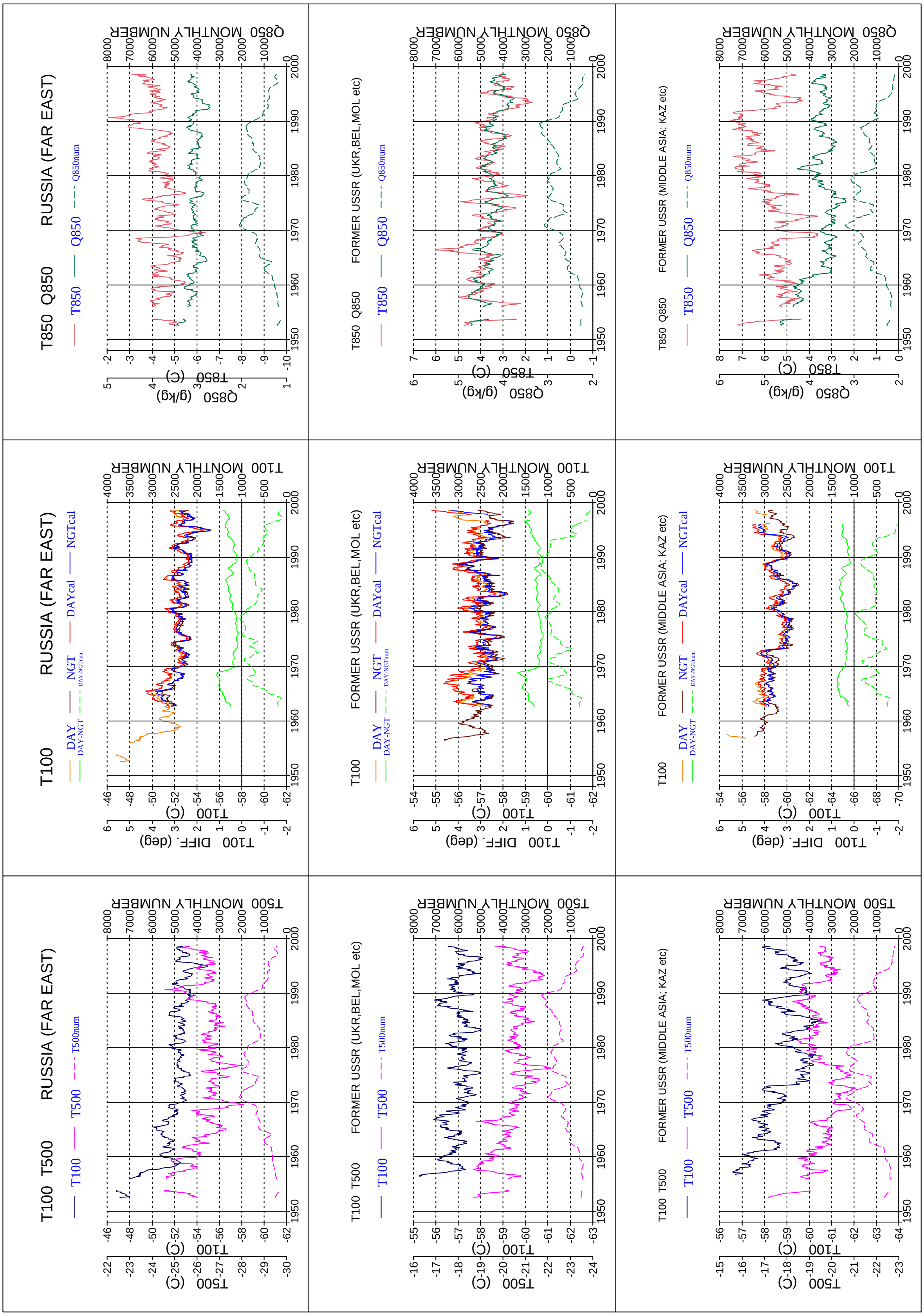

T850 Q850 CZECH SLOVAKIA
T850 Q850 Q850num
T100 CZECH SLOVAKIA
DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 T500 CZECH SLOVAKIA
T100 T500 T500num
T850 Q850 POLAND
T100 POLAND
T100 T500 POLAND
T850 Q850 HUNGARY
T100 HUNGARY
T100 T500 HUNGARY
Q850 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 MONTHLY NUMBER
T100 (C)
T100 DIFF. (deg)
T500 MONTHLY NUMBER
T500 (C)
1950
1960
1970
1980
1990
2000

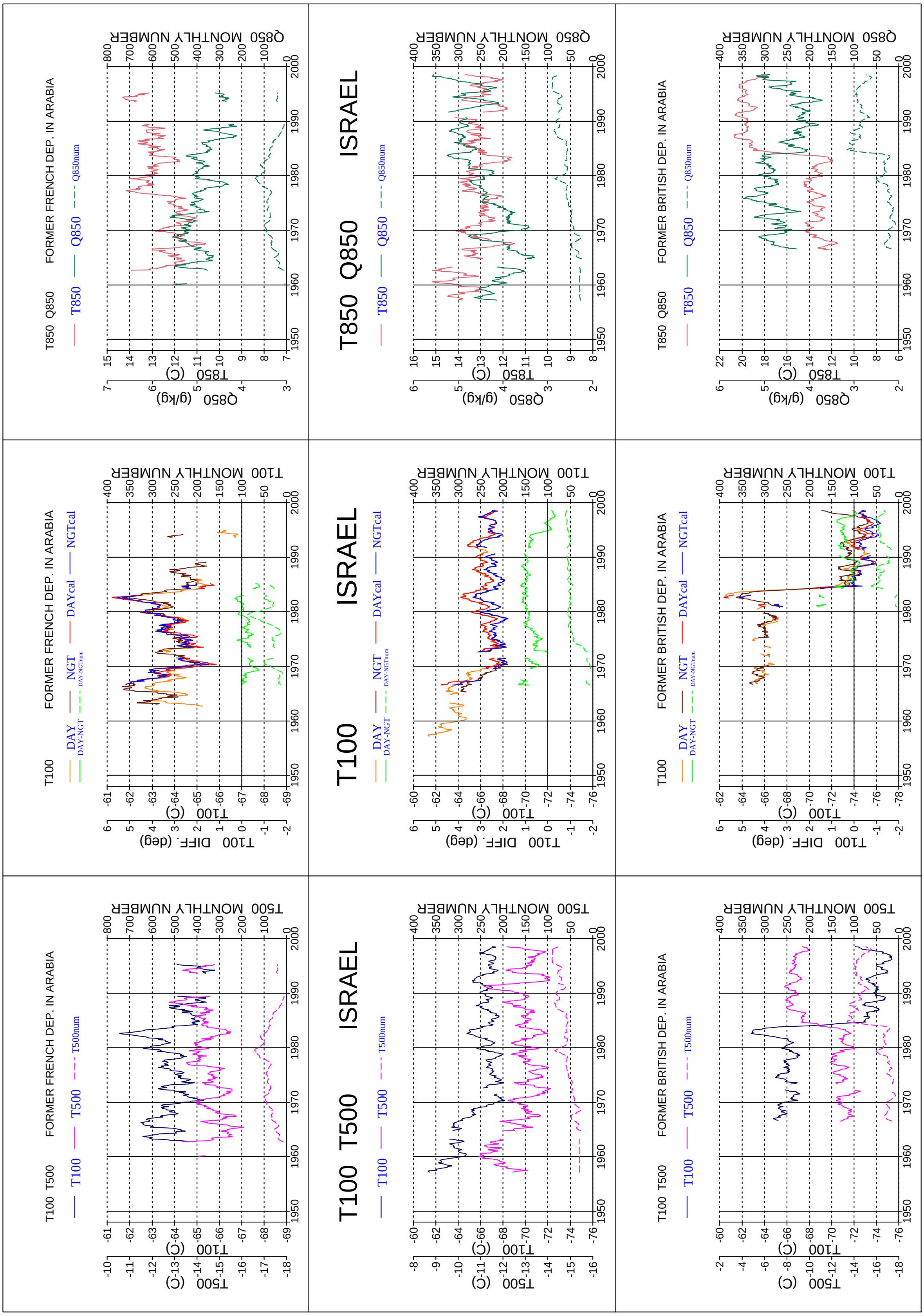

T850 Q850 FORMER YUGOSLAVIA
T850
Q850
Q850num
T100 FORMER YUGOSLAVIA
DAY
DAY-NGT
NGT
DAY-NGTnum
DAYcal
NGTcal
T100 T500 FORMER YUGOSLAVIA
T100
T500
T500num
T850 Q850 ROMANIA
T100 ROMANIA
T100 T500 ROMANIA
T850 Q850 BULGARIA
T100 BULGARIA
T100 T500 BULGARIA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

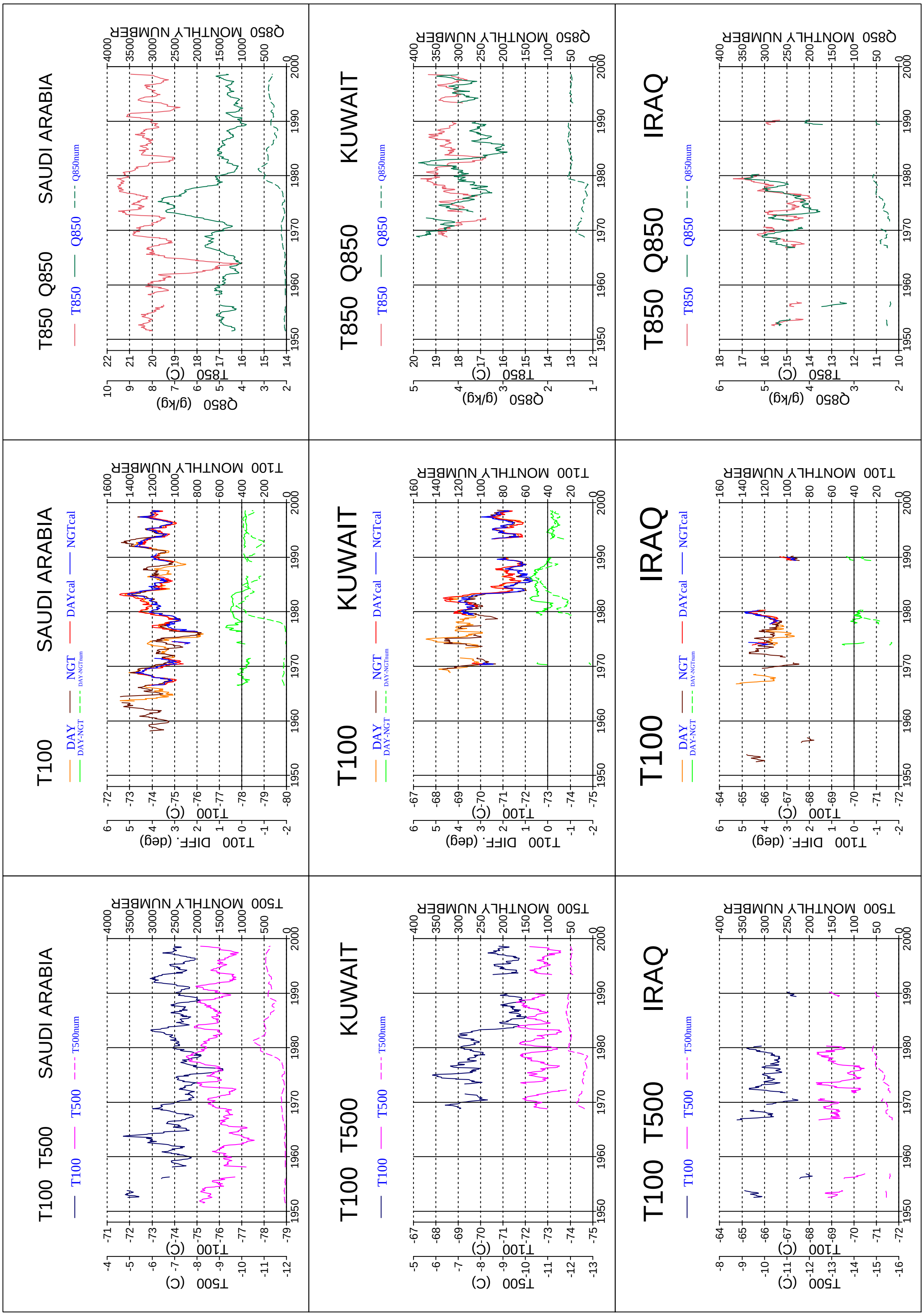

T100 T500 ITALY
T100 T500 MALTA
T100 T500 GREECE
T100 ITALY
T100 MALTA
T100 GREECE
T850 Q850 ITALY
T850 Q850 MALTA
T850 Q850 GREECE
T100
T500
T500num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T850
Q850
Q850num
T100 (C)
T500 (C)
T500 MONTHLY NUMBER
T100 DIFF. (deg)
T100 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
Q850 MONTHLY NUMBER

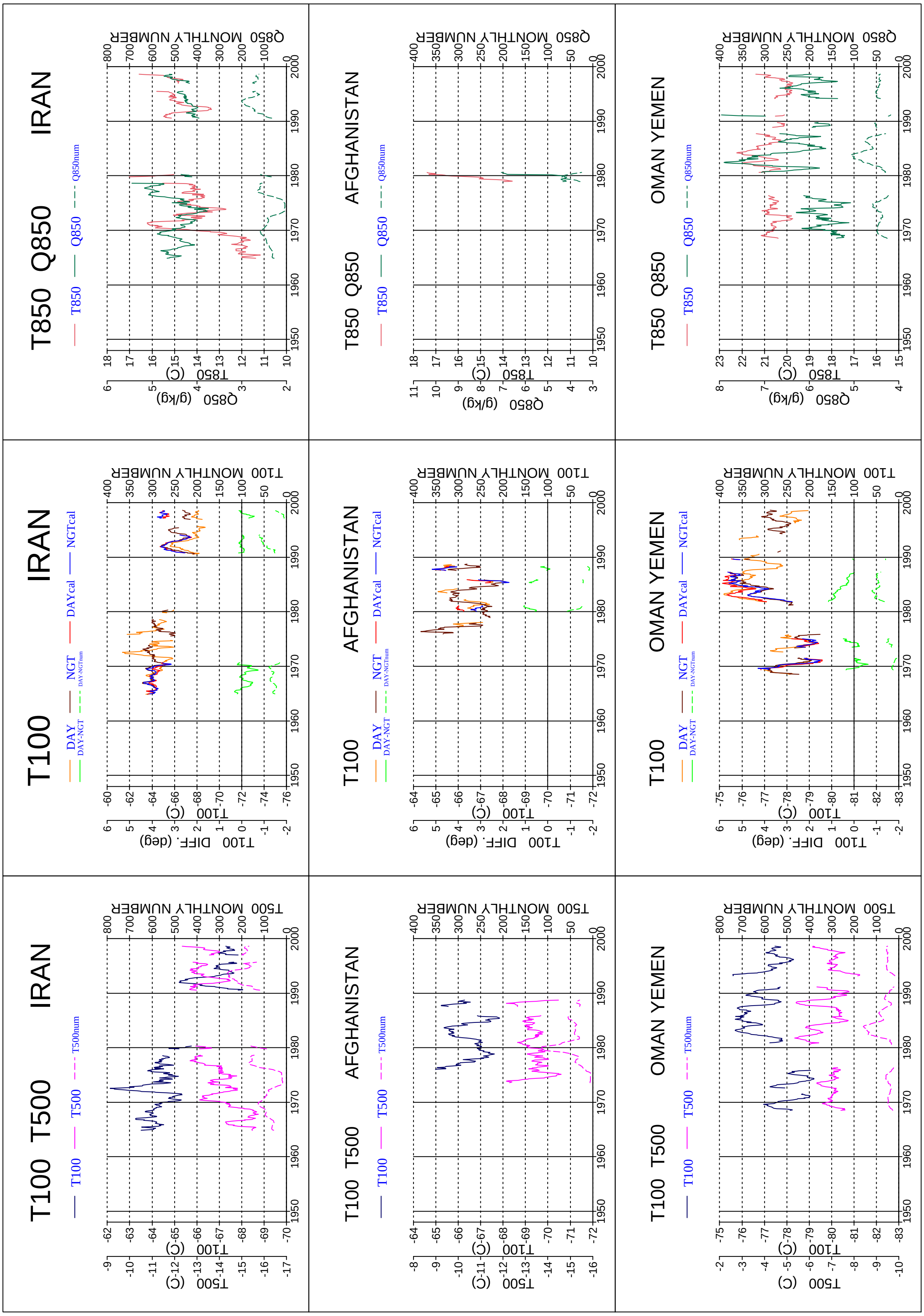

T850 Q850 TURKEY
T100 TURKEY
T100 T500 TURKEY
T850 Q850 CYPRUS
T100 CYPRUS
T100 T500 CYPRUS
T850 Q850 FORMER USSR (ALL)
T100 FORMER USSR (ALL)
T100 T500 FORMER USSR (ALL)


T850 Q850 RUSSIA (70-80N)
T850 Q850 FORMER USSR (60-70N)
T850 Q850 FORMER USSR (50-60N)
T100 RUSSIA (70-80N)
T100 FORMER USSR (60-70N)
T100 FORMER USSR (50-60N)
T100 T500 RUSSIA (70-80N)
T100 T500 FORMER USSR (60-70N)
T100 T500 FORMER USSR (50-60N)

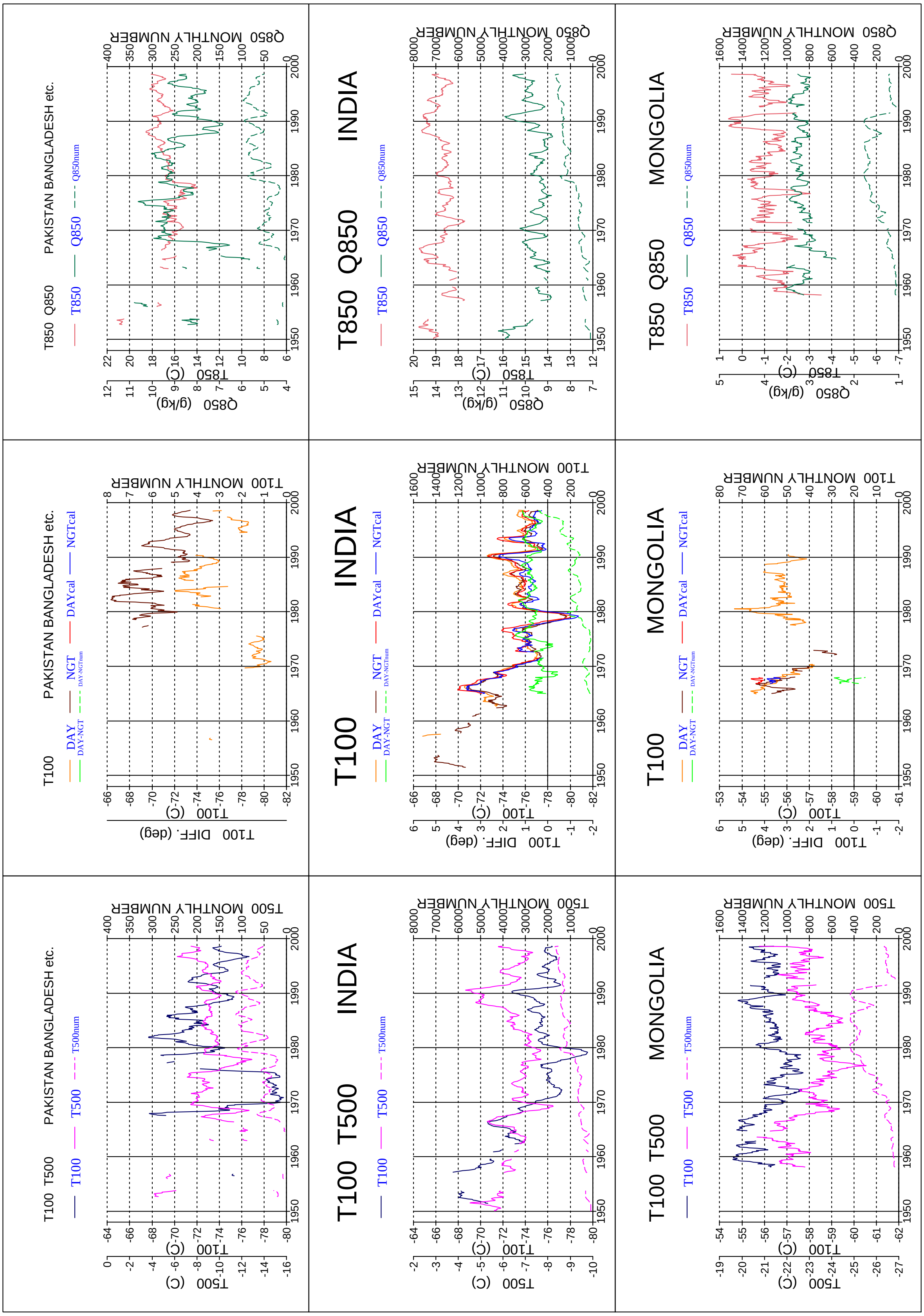

T100 T500 RUSSIA (FAR EAST)
T100 T500 T500num
T100 RUSSIA (FAR EAST)
DAY NGT DAYcal NGTcal
DAY-NGT DAY-NGTnum
T850 Q850 RUSSIA (FAR EAST)
T850 Q850 Q850num
T100 T500 FORMER USSR (UKR,BEL,MOL etc)
T100 FORMER USSR (UKR,BEL,MOL etc)
T850 Q850 FORMER USSR (UKR,BEL,MOL etc)
T100 T500 FORMER USSR (MIDDLE ASIA; KAZ etc)
T100 FORMER USSR (MIDDLE ASIA; KAZ etc)
T850 Q850 FORMER USSR (MIDDLE ASIA; KAZ etc)
T500 (C)
T100 (C)
T100 DIFF. (deg)
Q850 (g/kg)
T850 (C)
T500 MONTHLY NUMBER
T100 MONTHLY NUMBER
Q850 MONTHLY NUMBER
1950
1960
1970
1980
1990
2000

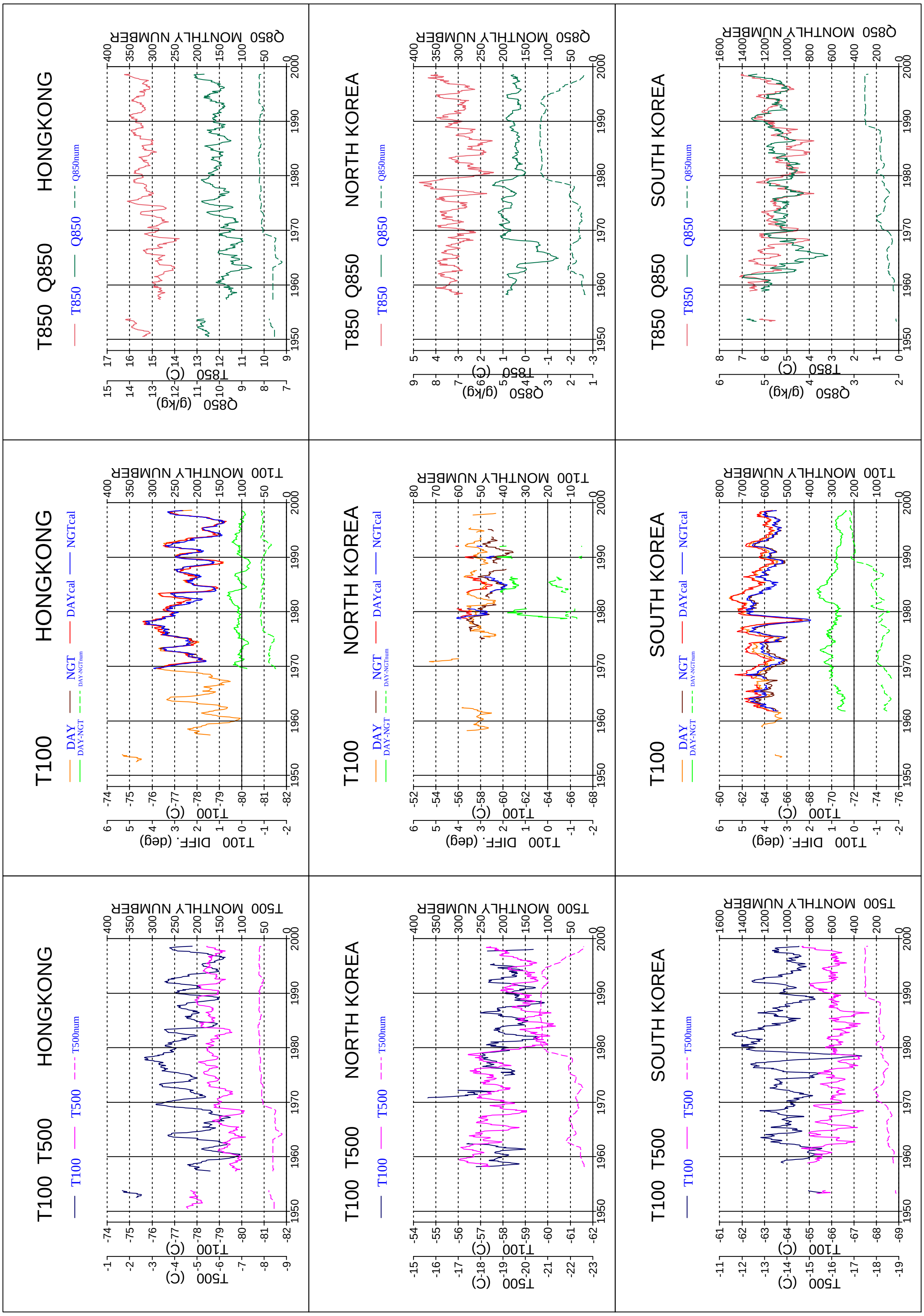

T850 Q850 FORMER FRENCH DEP. IN ARABIA
T850 Q850 Q850num
T100 FORMER FRENCH DEP. IN ARABIA
DAY NGT DAYcal NGTcal
T100 T500 FORMER FRENCH DEP. IN ARABIA
T100 T500 T500num
T850 Q850 ISRAEL
T100 ISRAEL
T100 T500 ISRAEL
T850 Q850 FORMER BRITISH DEP. IN ARABIA
T100 FORMER BRITISH DEP. IN ARABIA
T100 T500 FORMER BRITISH DEP. IN ARABIA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER

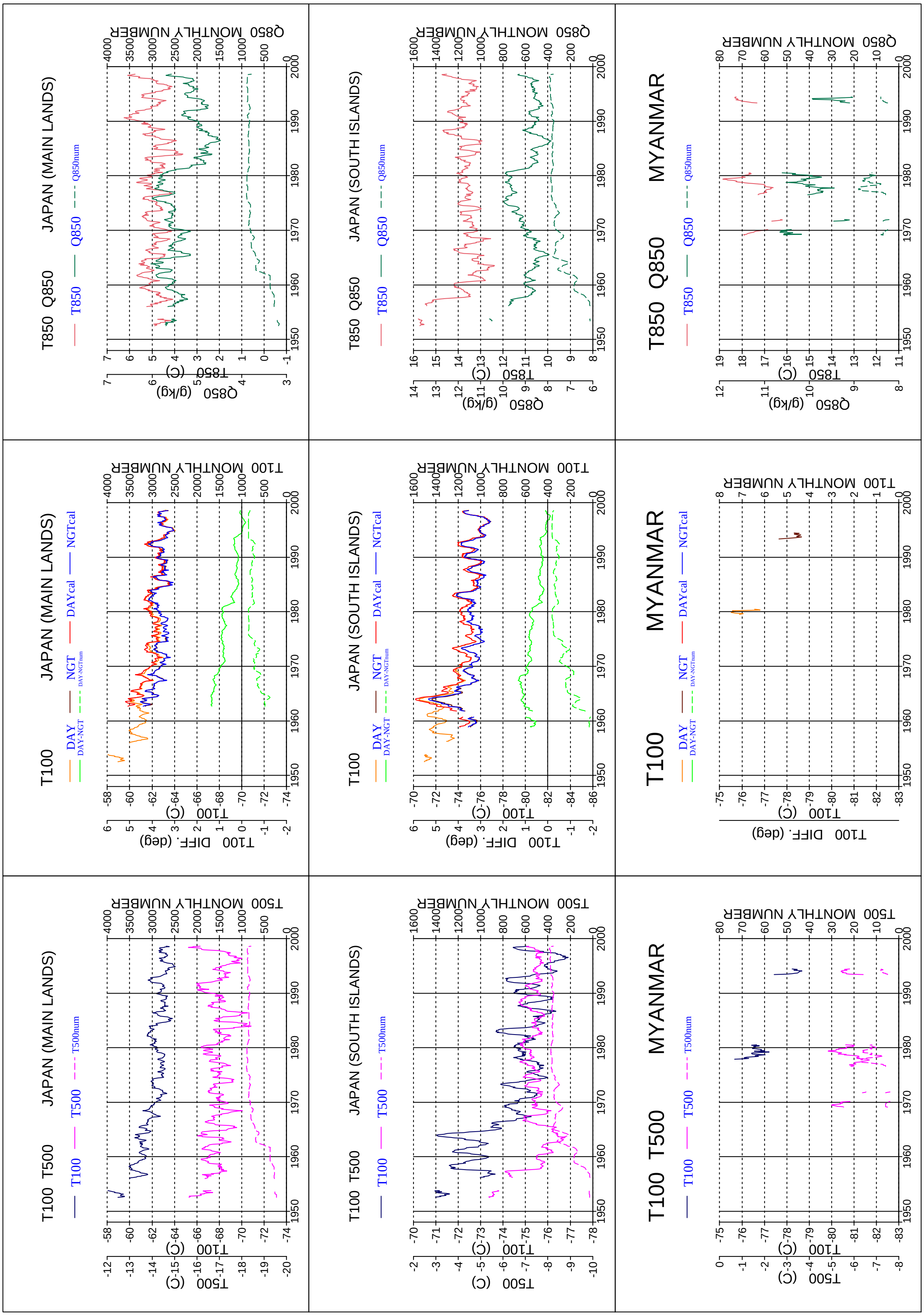

T850 Q850 SAUDI ARABIA
T850
Q850
Q850num
T100 SAUDI ARABIA
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T100 T500 SAUDI ARABIA
T100
T500
T500num
T850 Q850 KUWAIT
T100 KUWAIT
T100 T500 KUWAIT
T850 Q850 IRAQ
T100 IRAQ
T100 T500 IRAQ
T850 (C)
Q850 (g/kg)
Q850 MONTHLY NUMBER
T100 (C)
T100 DIFF. (deg)
T100 MONTHLY NUMBER
T500 (C)
T500 MONTHLY NUMBER

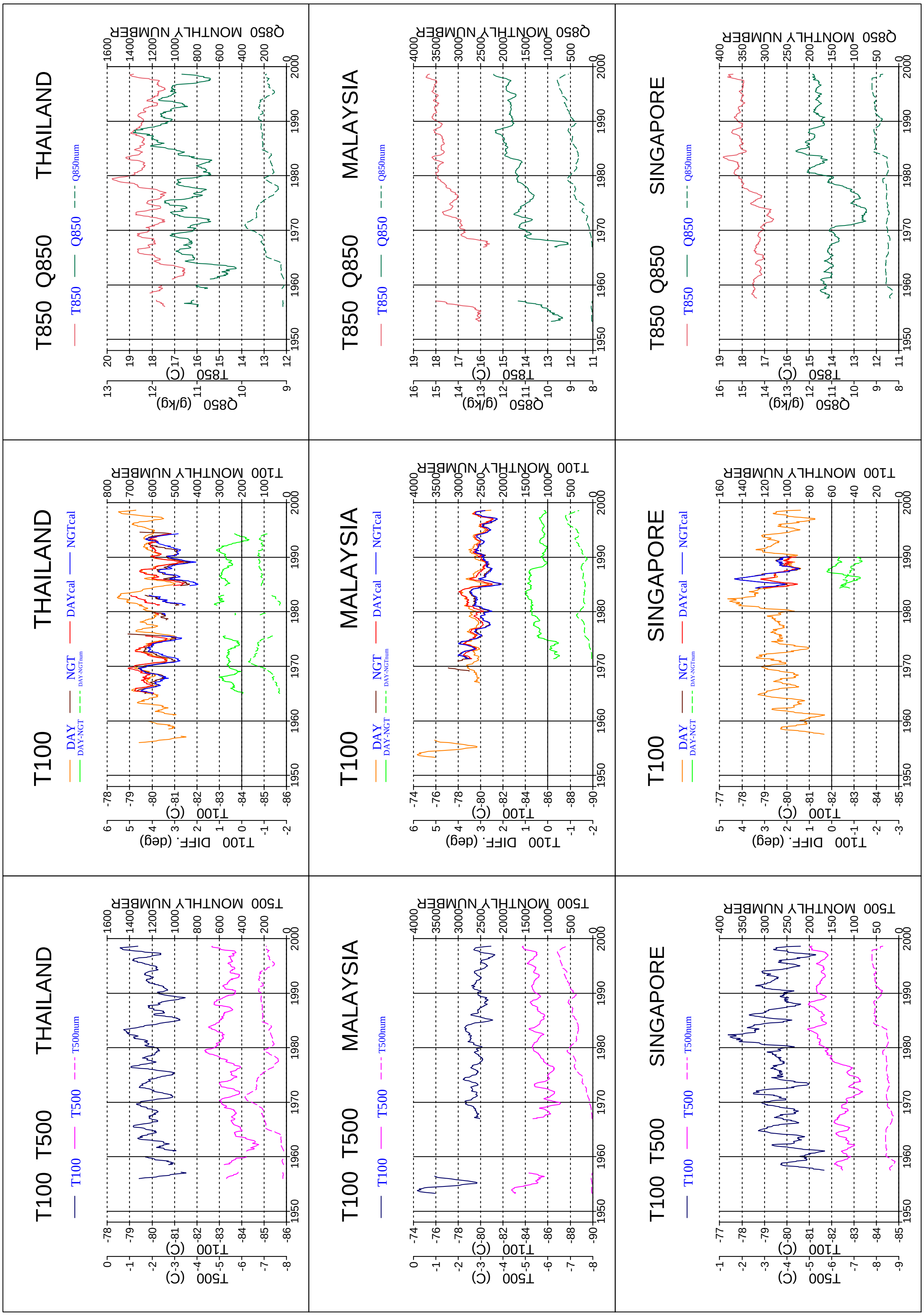


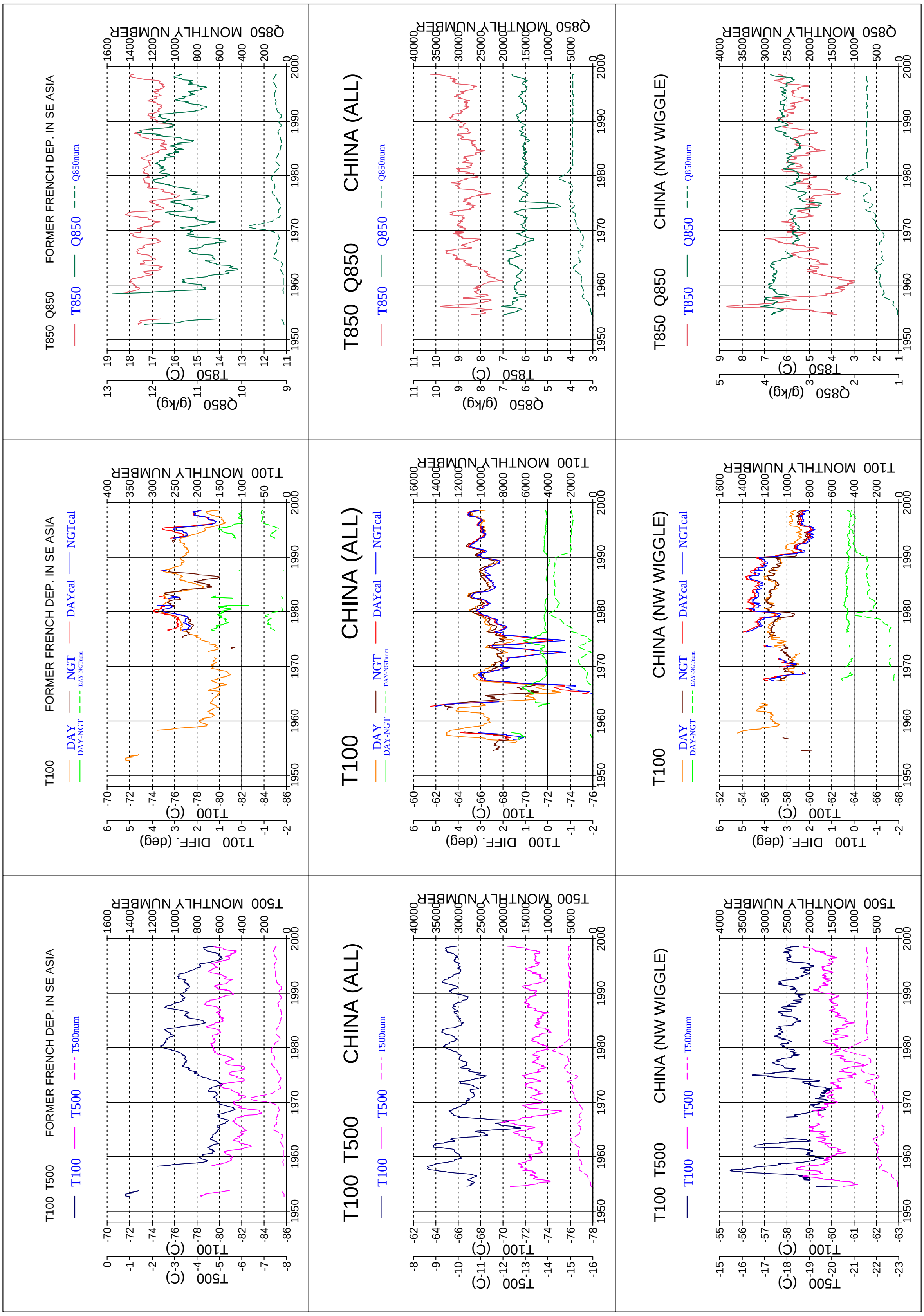
T850 Q850 IRAN
T100 IRAN
T100 T500 IRAN
T850 Q850 AFGHANISTAN
T100 AFGHANISTAN
T100 T500 AFGHANISTAN
T850 Q850 OMAN YEMEN
T100 OMAN YEMEN
T100 T500 OMAN YEMEN
T850
Q850
Q850num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T100
T500
T500num
T850 (C)
Q850 (g/kg)
Q850 MONTHLY NUMBER
T100 (C)
T100 DIFF. (deg)
T100 MONTHLY NUMBER
T500 (C)
T500 MONTHLY NUMBER

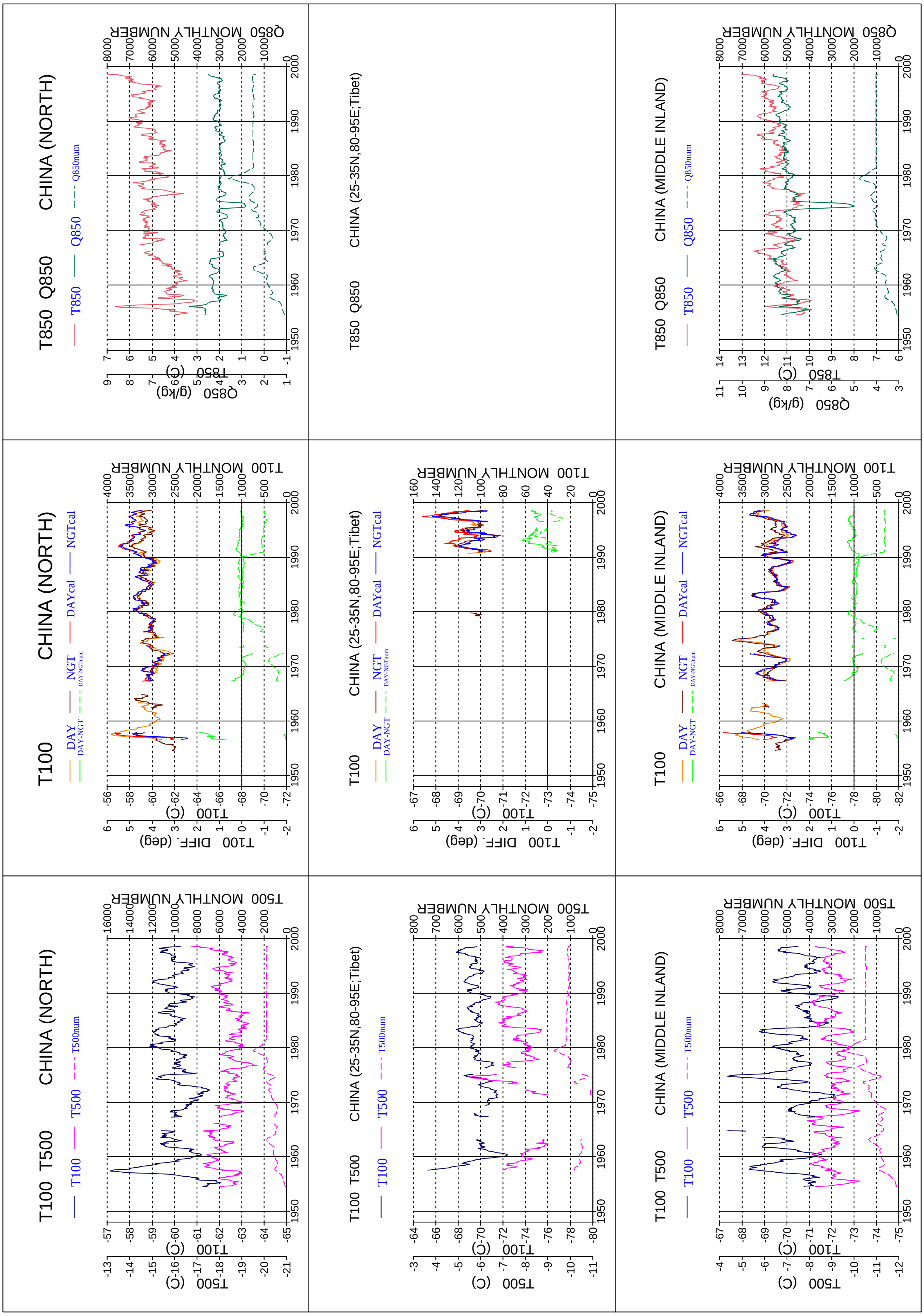

T850 Q850 PAKISTAN BANGLADESH etc.
T850 Q850 INDIA
T850 Q850 MONGOLIA
T100 PAKISTAN BANGLADESH etc.
T100 INDIA
T100 MONGOLIA
T100 T500 PAKISTAN BANGLADESH etc.
T100 T500 INDIA
T100 T500 MONGOLIA
T850
Q850
Q850num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T100
T500
T500num
Q850 (g/kg)
T850 (C)
Q850 MONTHLY NUMBER
T100 DIFF. (deg)
T100 (C)
T100 MONTHLY NUMBER
T500 (C)
T500 MONTHLY NUMBER

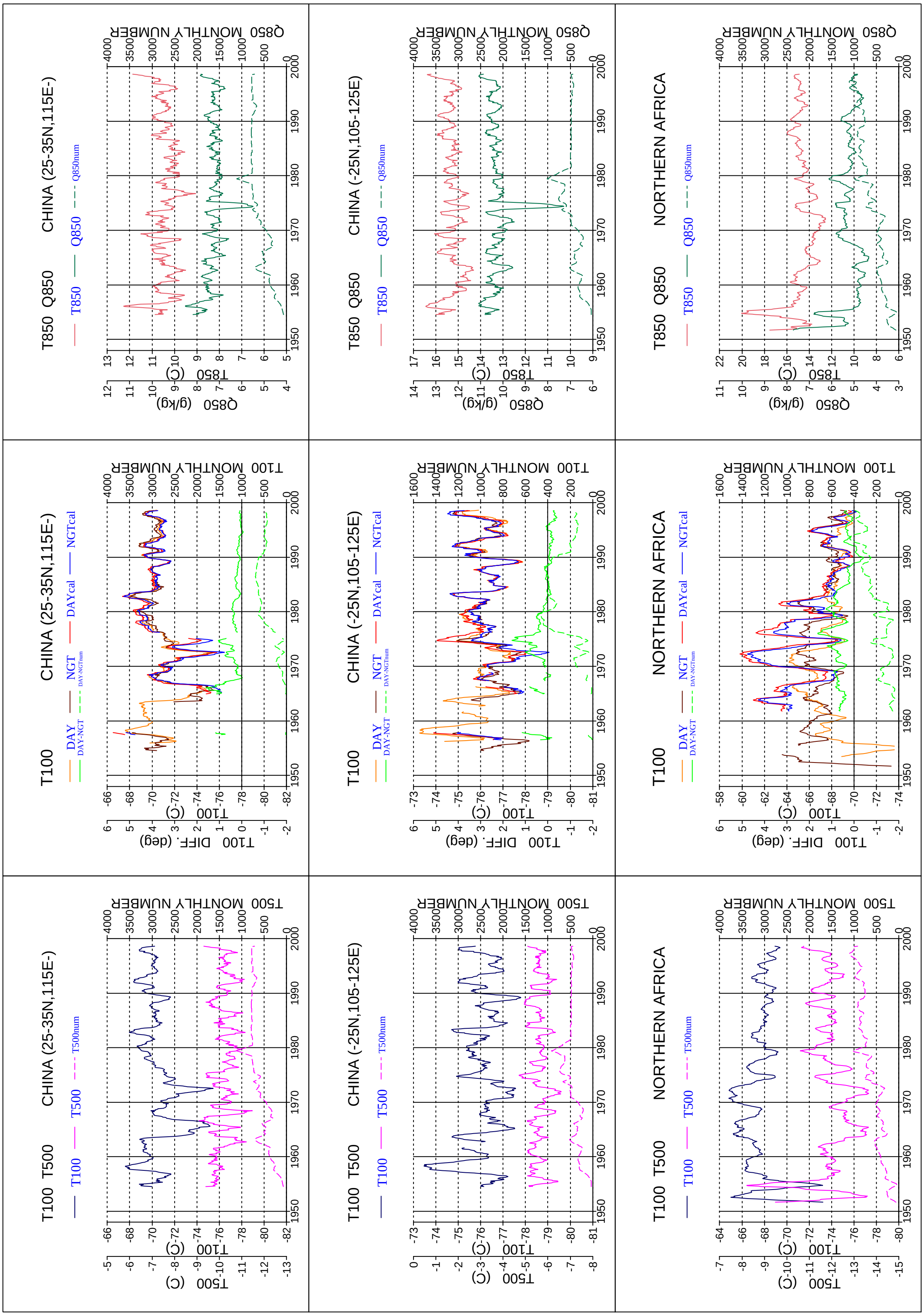

T850 Q850 HONGKONG
T100 HONGKONG
T100 T500 HONGKONG
T850 Q850 NORTH KOREA
T100 NORTH KOREA
T100 T500 NORTH KOREA
T850 Q850 SOUTH KOREA
T100 SOUTH KOREA
T100 T500 SOUTH KOREA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T100 DIFF. (deg)

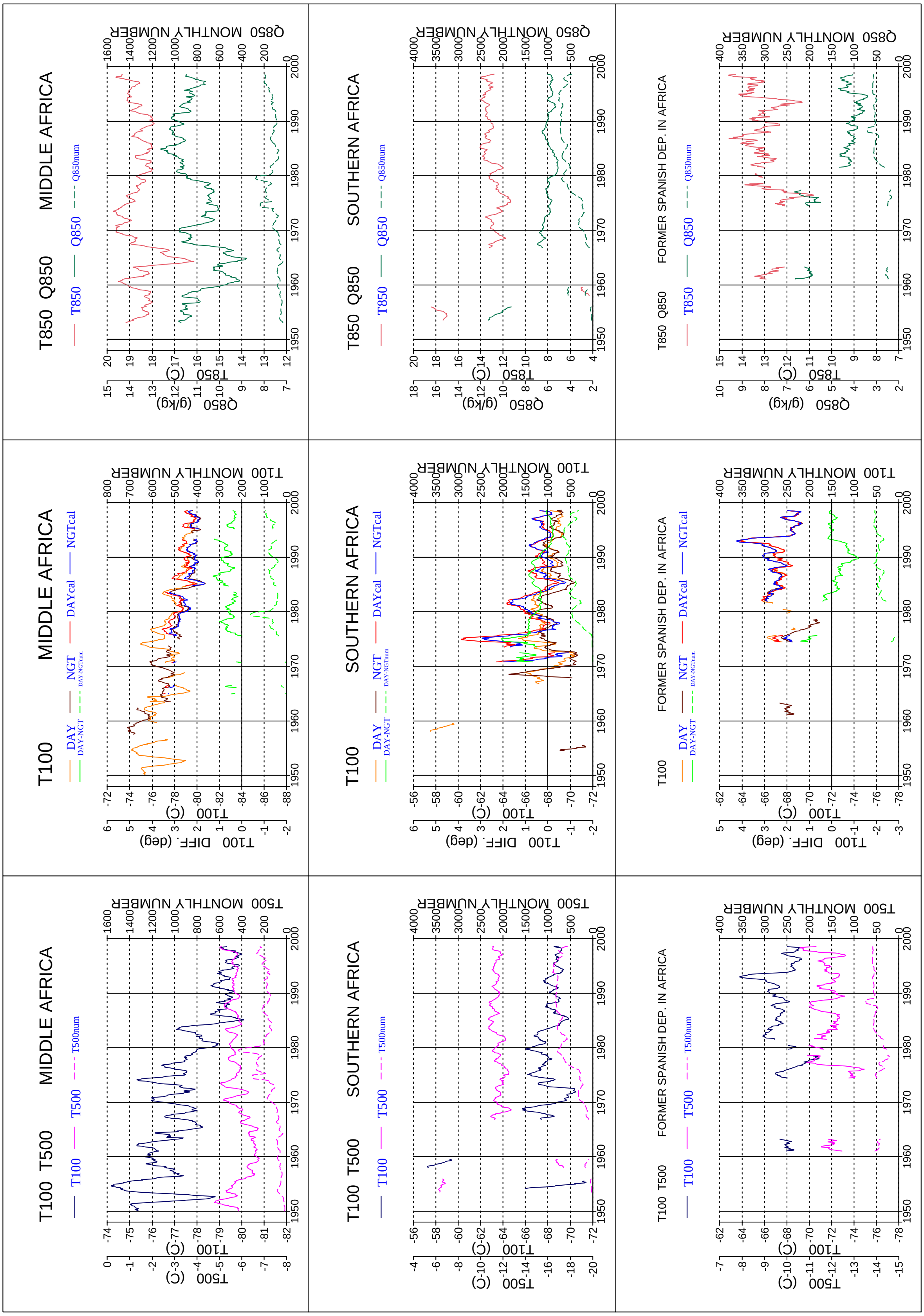

T850 Q850 JAPAN (MAIN LANDS)
T850 Q850 Q850num
T100 JAPAN (MAIN LANDS)
DAY NGT DAYcal NGTcal
DAY-NGT DAY-NGTnum
T100 T500 JAPAN (MAIN LANDS)
T100 T500 T500num
T850 Q850 JAPAN (SOUTH ISLANDS)
T100 JAPAN (SOUTH ISLANDS)
T100 T500 JAPAN (SOUTH ISLANDS)
T850 Q850 MYANMAR
T100 MYANMAR
T100 T500 MYANMAR
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

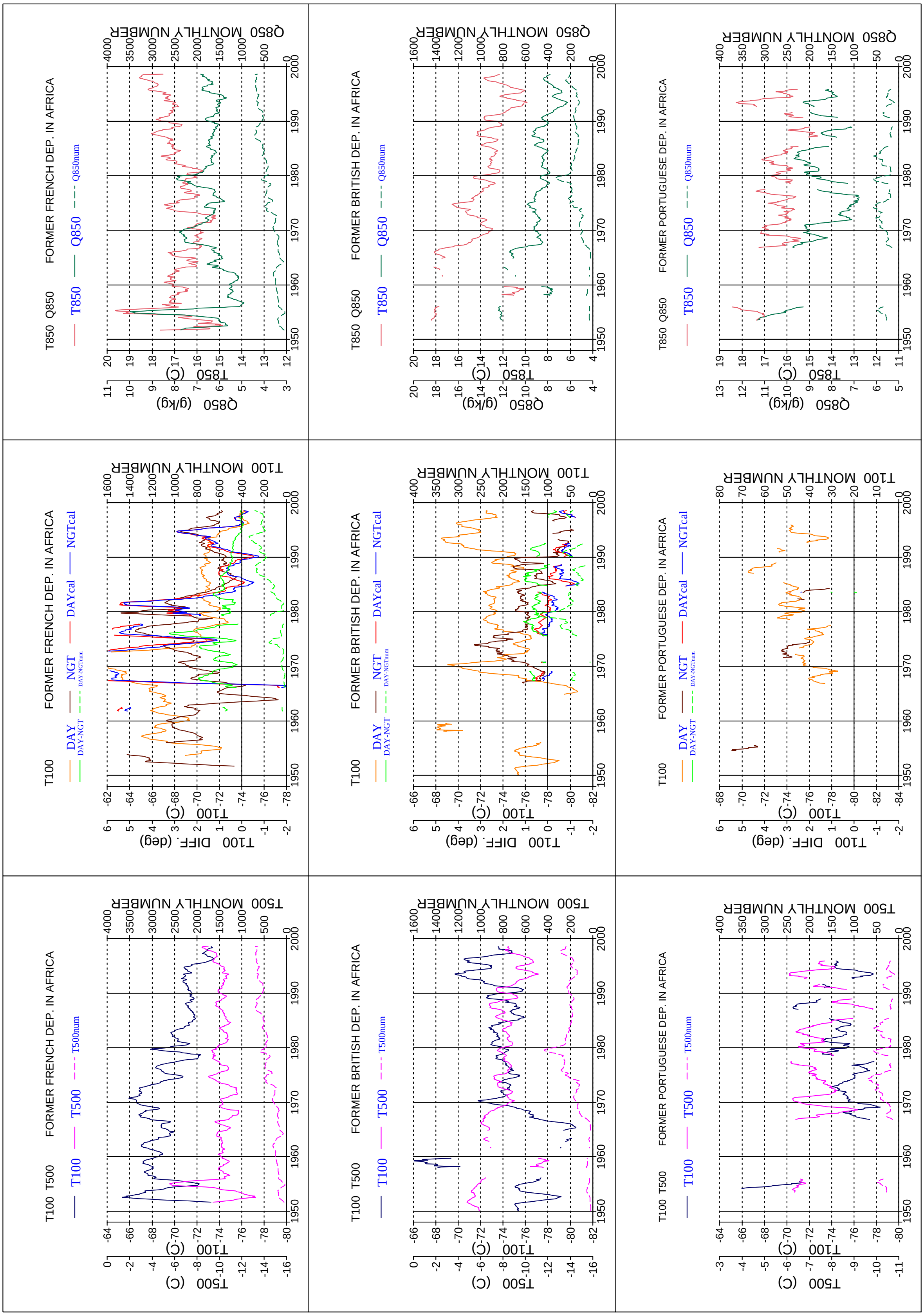

T850 Q850 THAILAND
T850 Q850 MALAYSIA
T850 Q850 SINGAPORE
T100 THAILAND
T100 MALAYSIA
T100 SINGAPORE
T100 T500 THAILAND
T100 T500 MALAYSIA
T100 T500 SINGAPORE

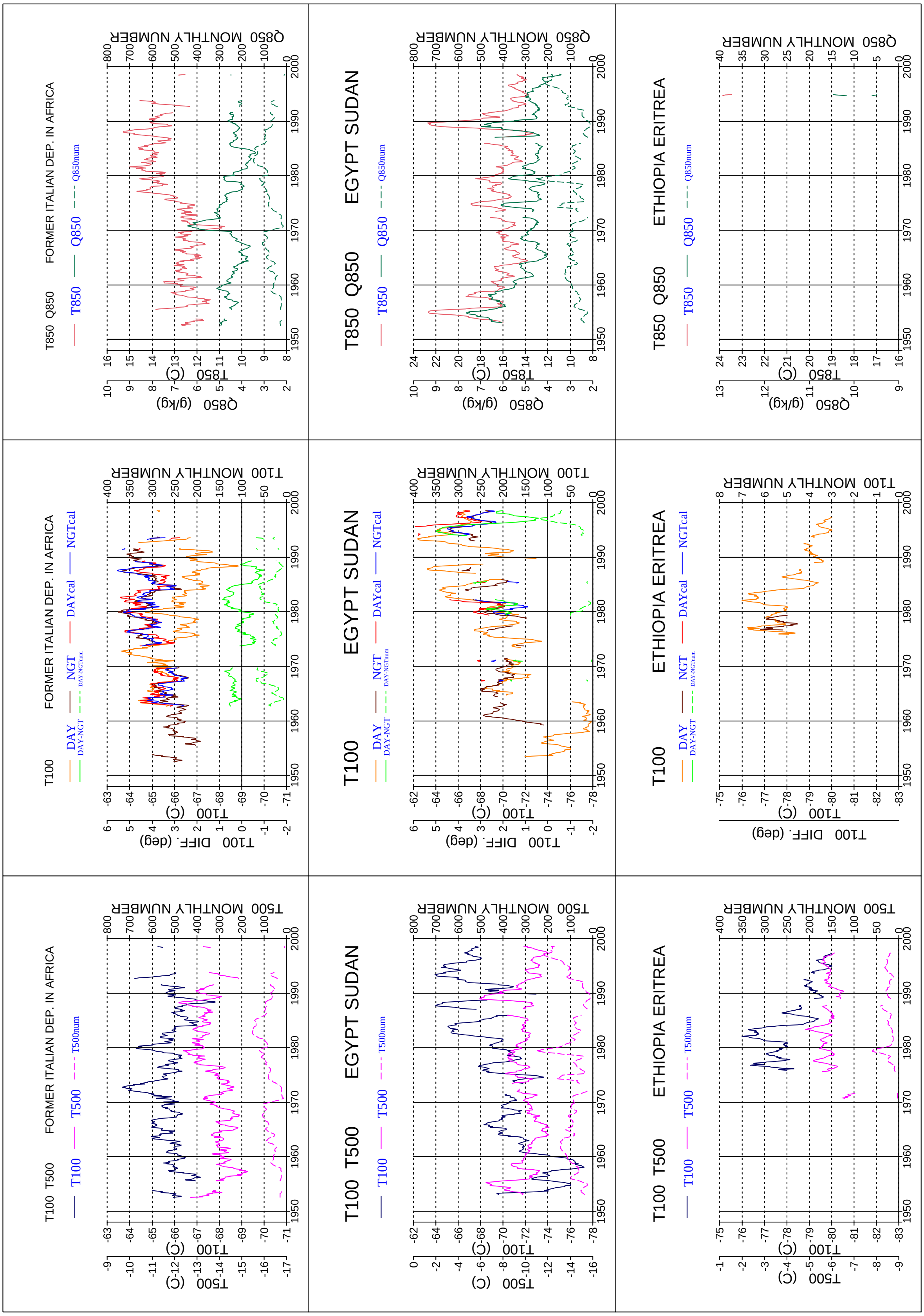

T850 Q850 FORMER FRENCH DEP. IN SE ASIA
T850 Q850 CHINA (ALL)
T850 Q850 CHINA (NW WIGGLE)
T100 FORMER FRENCH DEP. IN SE ASIA
T100 CHINA (ALL)
T100 CHINA (NW WIGGLE)
T100 T500 FORMER FRENCH DEP. IN SE ASIA
T100 T500 CHINA (ALL)
T100 T500 CHINA (NW WIGGLE)

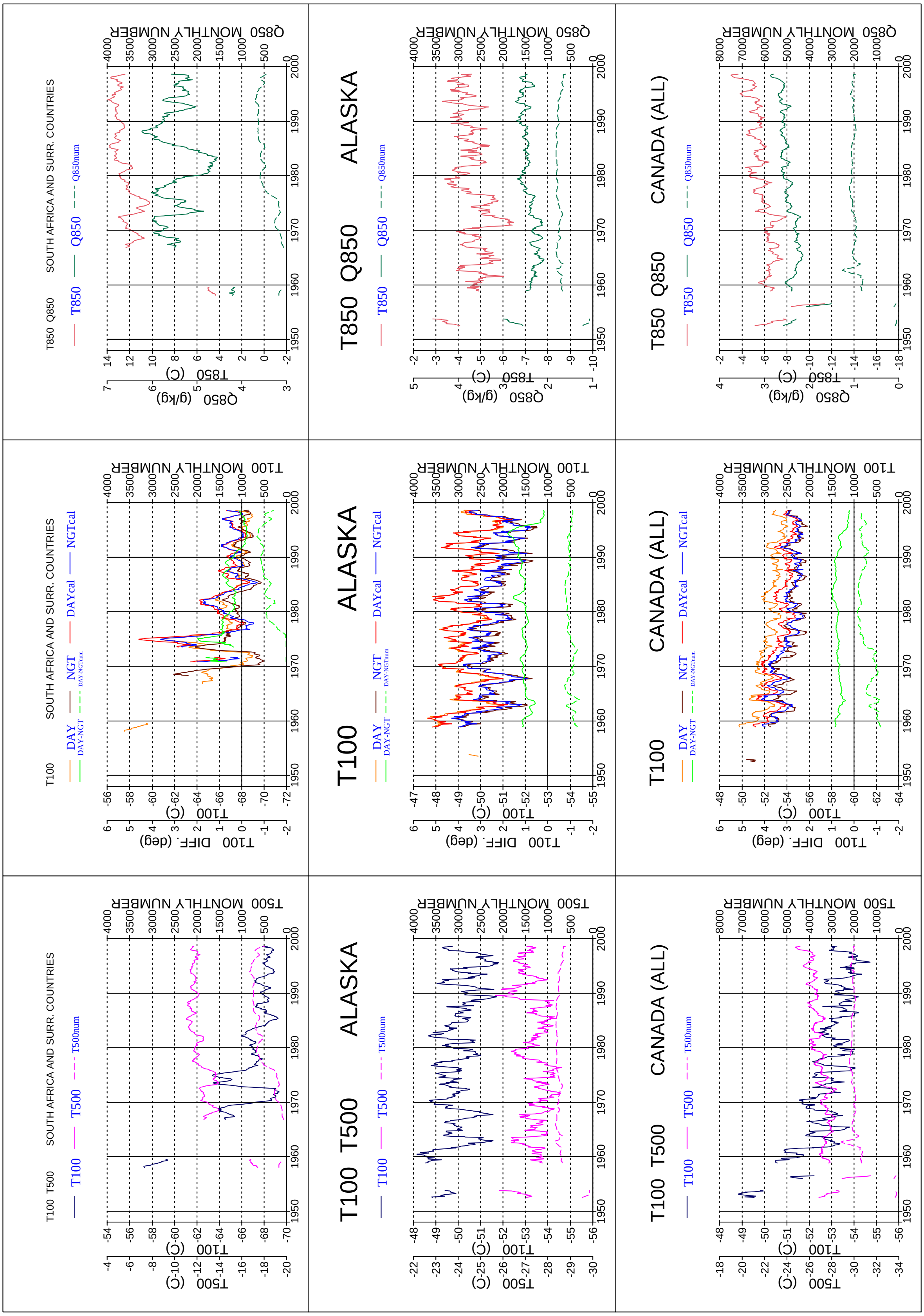

T850 Q850 CHINA (NORTH)
T100 CHINA (NORTH)
T100 T500 CHINA (NORTH)
T850 Q850 CHINA (25-35N,80-95E;Tibet)
T100 CHINA (25-35N,80-95E;Tibet)
T100 T500 CHINA (25-35N,80-95E;Tibet)
T850 Q850 CHINA (MIDDLE INLAND)
T100 CHINA (MIDDLE INLAND)
T100 T500 CHINA (MIDDLE INLAND)
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T100 DIFF. (deg)
Q850 (g/kg)
T850 (C)
T100 (C)
T500 (C)

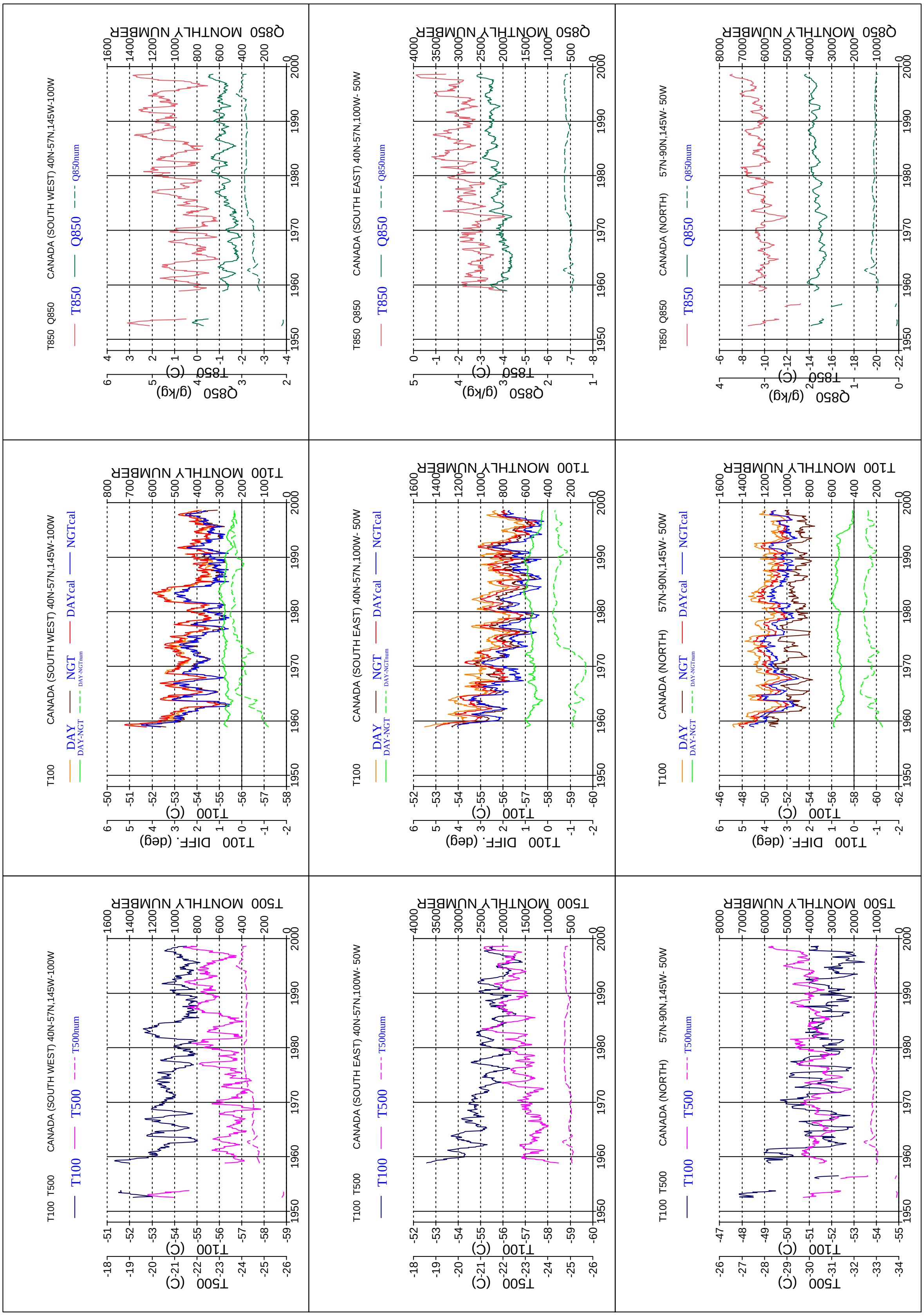

T850 Q850 CHINA (25-35N,115E-)
T850 — Q850 - - - Q850num
T100 CHINA (25-35N,115E-)
DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 T500 CHINA (25-35N,115E-)
T100 — T500 - - - T500num
T850 Q850 CHINA (-25N,105-125E)
T100 CHINA (-25N,105-125E)
T100 T500 CHINA (-25N,105-125E)
T850 Q850 NORTHERN AFRICA
T100 NORTHERN AFRICA
T100 T500 NORTHERN AFRICA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

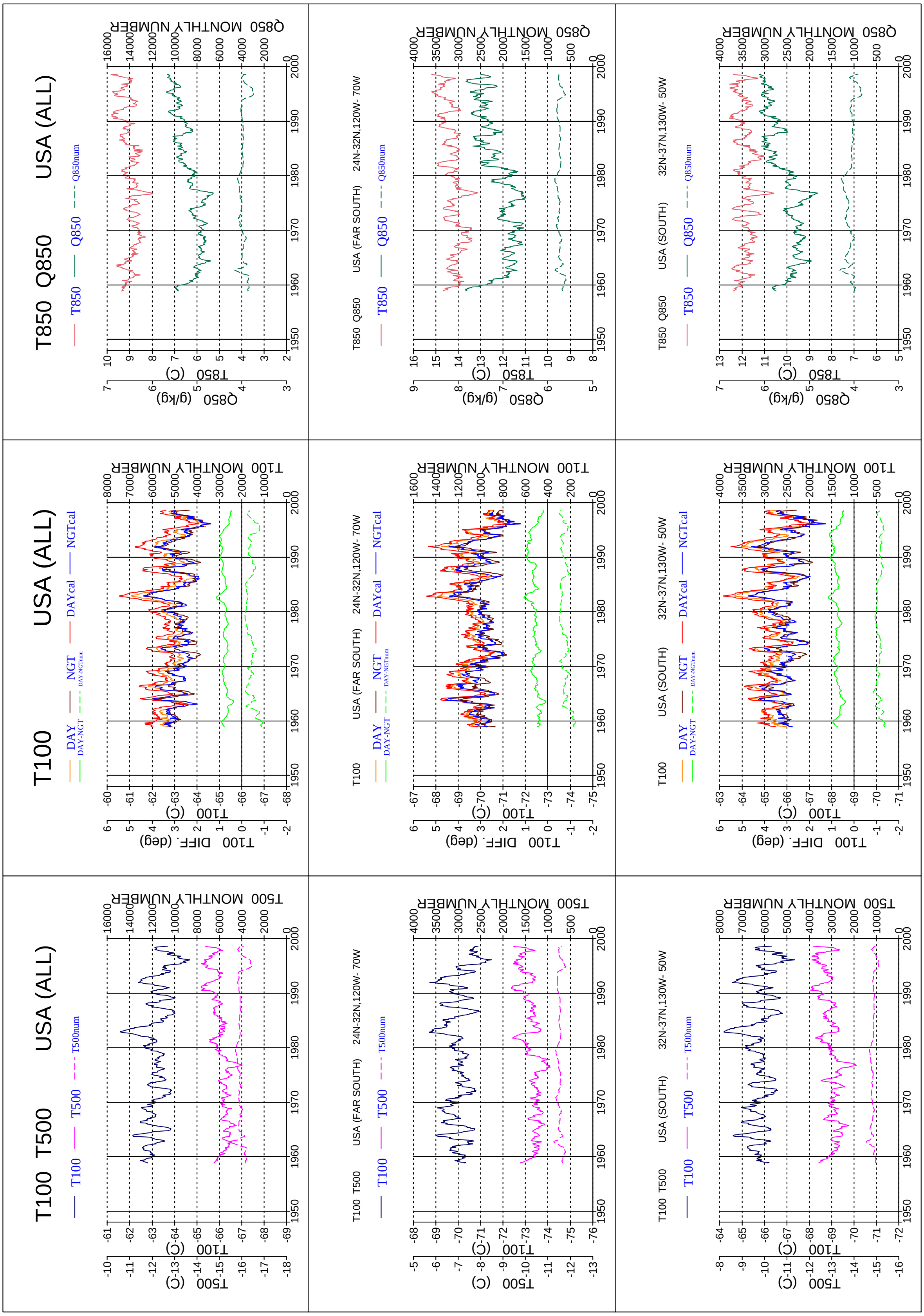

T850 Q850 MIDDLE AFRICA
T100 MIDDLE AFRICA
T100 T500 MIDDLE AFRICA
T850 Q850 SOUTHERN AFRICA
T100 SOUTHERN AFRICA
T100 T500 SOUTHERN AFRICA
T850 Q850 FORMER SPANISH DEP. IN AFRICA
T100 FORMER SPANISH DEP. IN AFRICA
T100 T500 FORMER SPANISH DEP. IN AFRICA
T850
Q850
Q850num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T100
T500
T500num
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

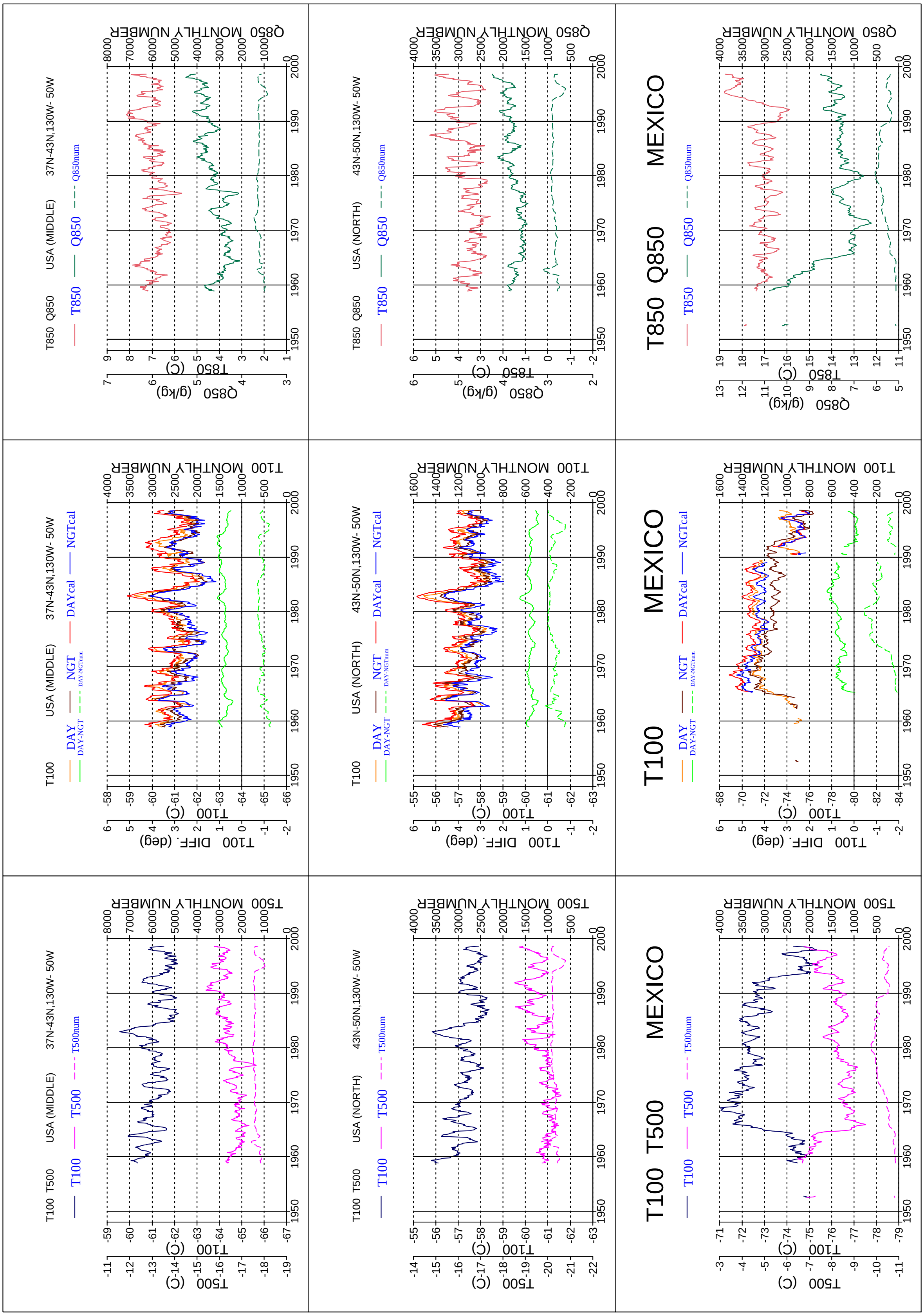

T850 Q850 FORMER FRENCH DEP. IN AFRICA
T850 Q850 Q850num
T100 FORMER FRENCH DEP. IN AFRICA
DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 T500 FORMER FRENCH DEP. IN AFRICA
T100 T500 T500num
T850 Q850 FORMER BRITISH DEP. IN AFRICA
T100 FORMER BRITISH DEP. IN AFRICA
T100 T500 FORMER BRITISH DEP. IN AFRICA
T850 Q850 FORMER PORTUGUESE DEP. IN AFRICA
T100 FORMER PORTUGUESE DEP. IN AFRICA
T100 T500 FORMER PORTUGUESE DEP. IN AFRICA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

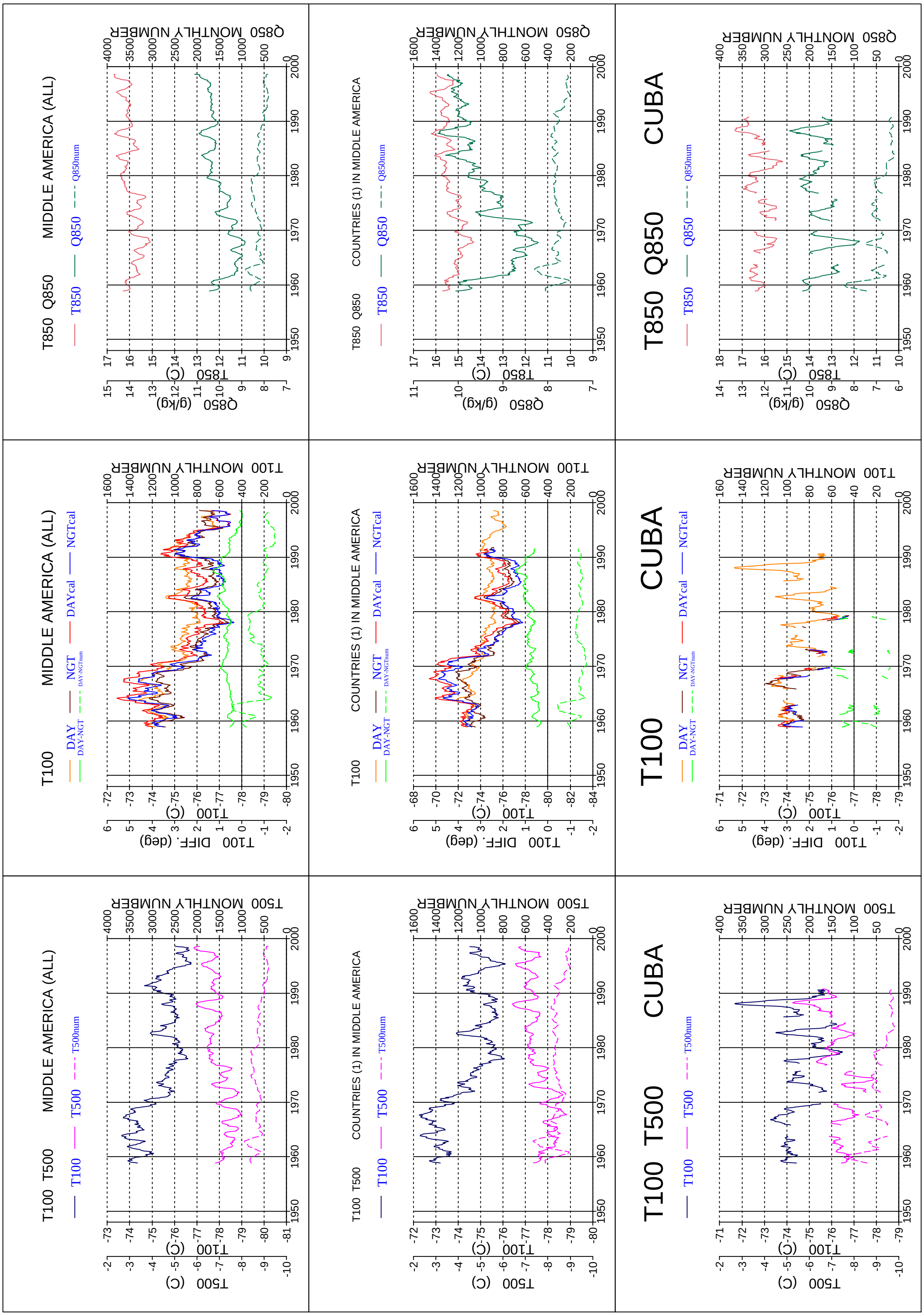

T850 Q850 FORMER ITALIAN DEP. IN AFRICA
T850 Q850 Q850num
T100 FORMER ITALIAN DEP. IN AFRICA
DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 T500 FORMER ITALIAN DEP. IN AFRICA
T100 T500 T500num
T850 Q850 EGYPT SUDAN
T100 EGYPT SUDAN
T100 T500 EGYPT SUDAN
T850 Q850 ETHIOPIA ERITREA
T100 ETHIOPIA ERITREA
T100 T500 ETHIOPIA ERITREA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

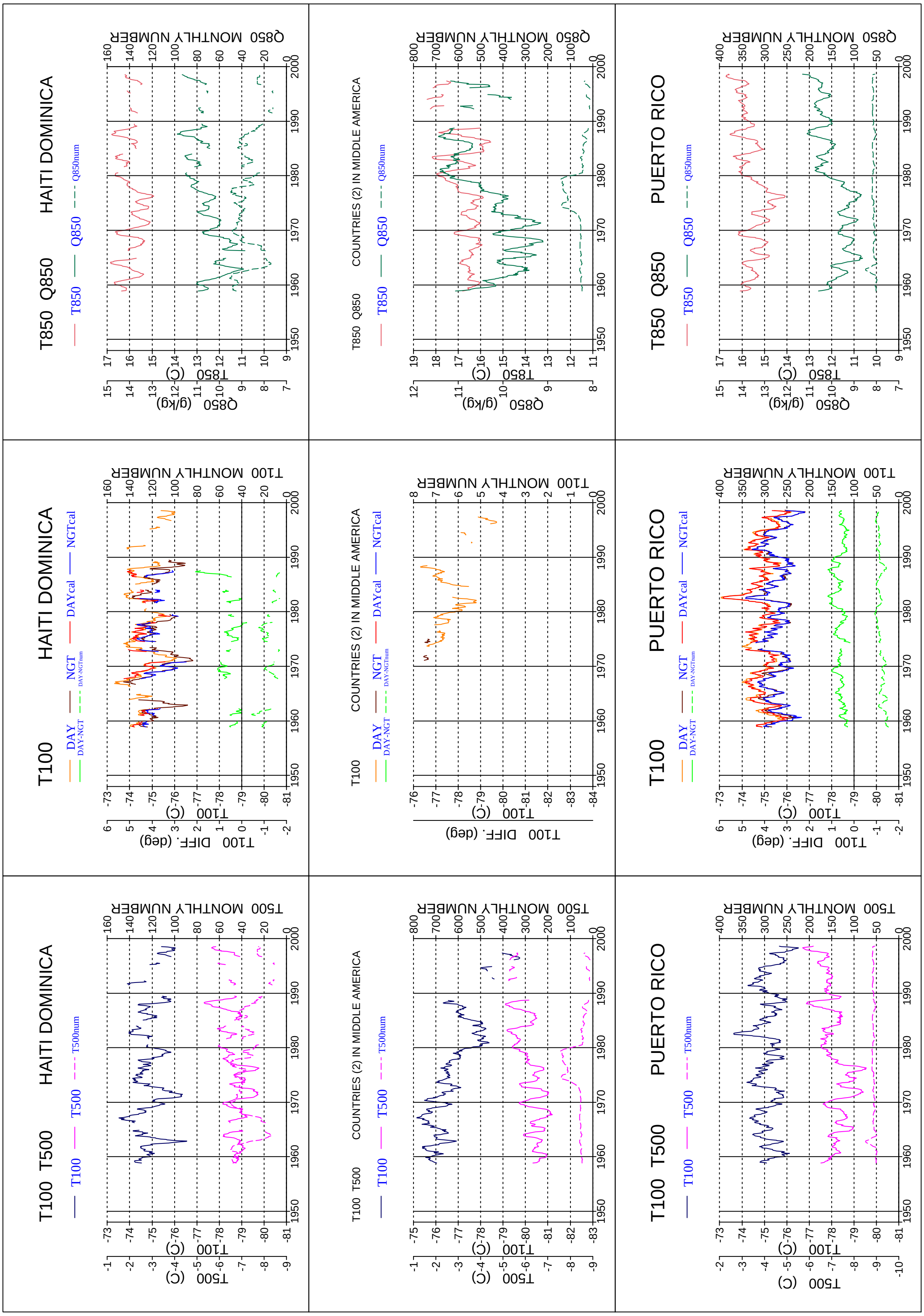

T850 Q850 SOUTH AFRICA AND SURR. COUNTRIES
T100 SOUTH AFRICA AND SURR. COUNTRIES
T100 T500 SOUTH AFRICA AND SURR. COUNTRIES
T850 Q850 ALASKA
T100 ALASKA
T100 T500 ALASKA
T850 Q850 CANADA (ALL)
T100 CANADA (ALL)
T100 T500 CANADA (ALL)
T850
Q850
Q850num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T100
T500
T500num
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

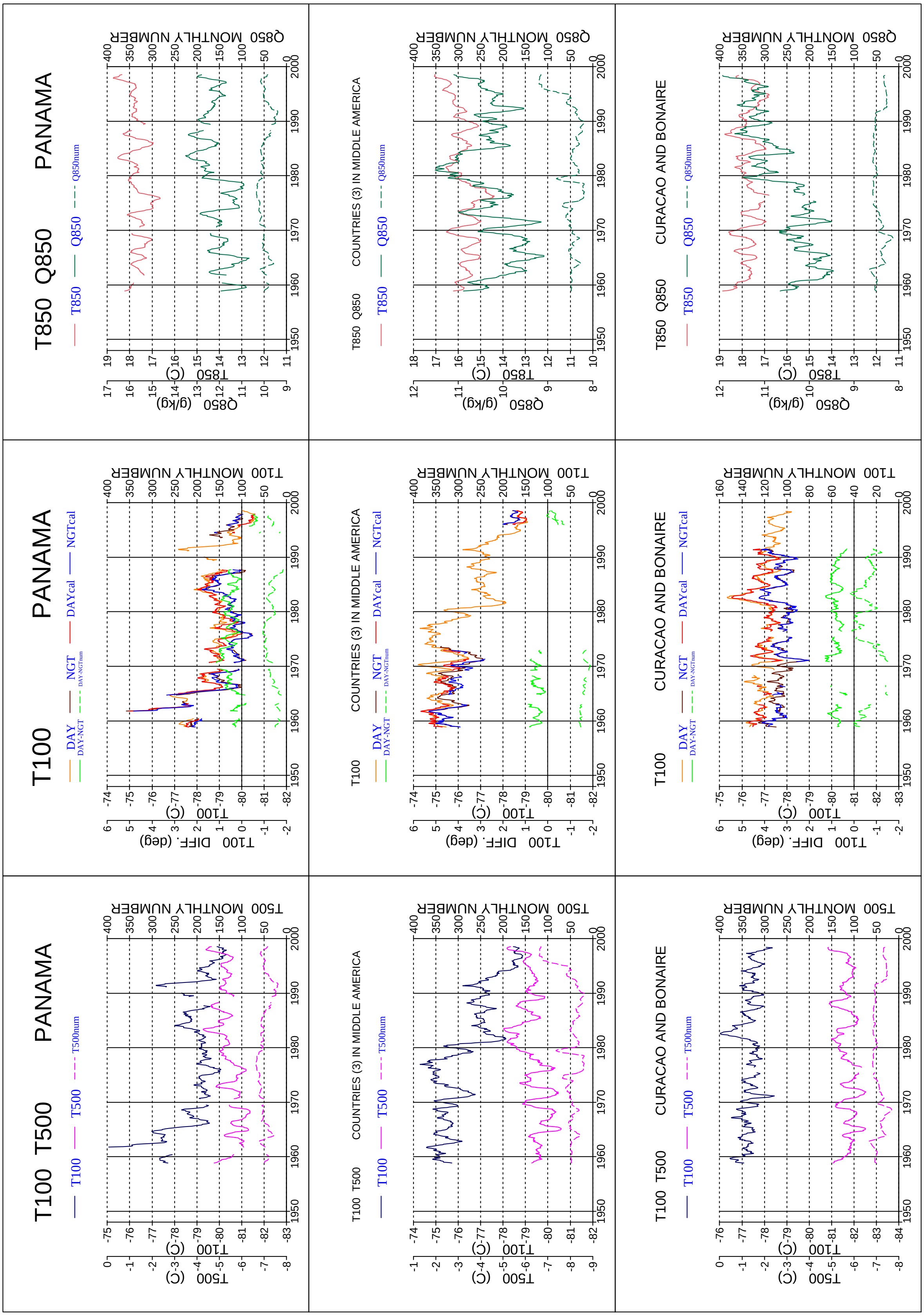

T850 Q850 CANADA (SOUTH WEST) 40N-57N,145W-100W
T850 Q850 Q850num
T850 Q850 CANADA (SOUTH EAST) 40N-57N,100W- 50W
T850 Q850 CANADA (NORTH) 57N-90N,145W- 50W
Q850 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 CANADA (SOUTH WEST) 40N-57N,145W-100W
T100 CANADA (SOUTH EAST) 40N-57N,100W- 50W
T100 CANADA (NORTH) 57N-90N,145W- 50W
DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 MONTHLY NUMBER
T100 (C)
T100 DIFF. (deg)
T100 T500 CANADA (SOUTH WEST) 40N-57N,145W-100W
T100 T500 CANADA (SOUTH EAST) 40N-57N,100W- 50W
T100 T500 CANADA (NORTH) 57N-90N,145W- 50W
T100 T500 T500num
T500 MONTHLY NUMBER
T500 (C)

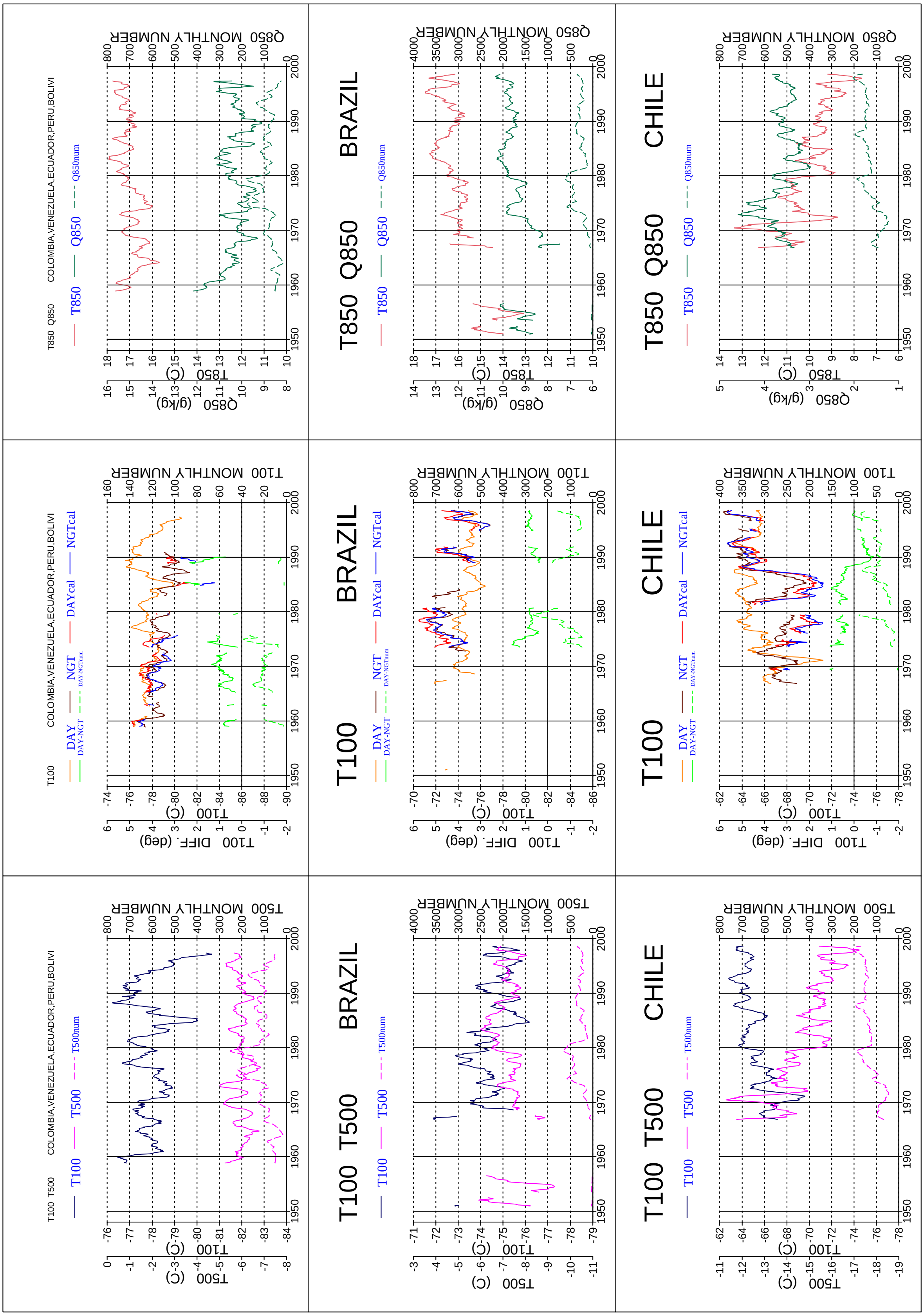

T100 T500 USA (ALL)
T100 USA (ALL)
T850 Q850 USA (ALL)
T100 T500 USA (FAR SOUTH) 24N-32N,120W- 70W
T100 USA (FAR SOUTH) 24N-32N,120W- 70W
T850 Q850 USA (FAR SOUTH) 24N-32N,120W- 70W
T100 T500 USA (SOUTH) 32N-37N,130W- 50W
T100 USA (SOUTH) 32N-37N,130W- 50W
T850 Q850 USA (SOUTH) 32N-37N,130W- 50W
T500 MONTHLY NUMBER
T100 MONTHLY NUMBER
Q850 MONTHLY NUMBER
T100 DIFF. (deg)
DAY
NGT
DAYcal
NGTcal
DAY-NGT
T500num
Q850num

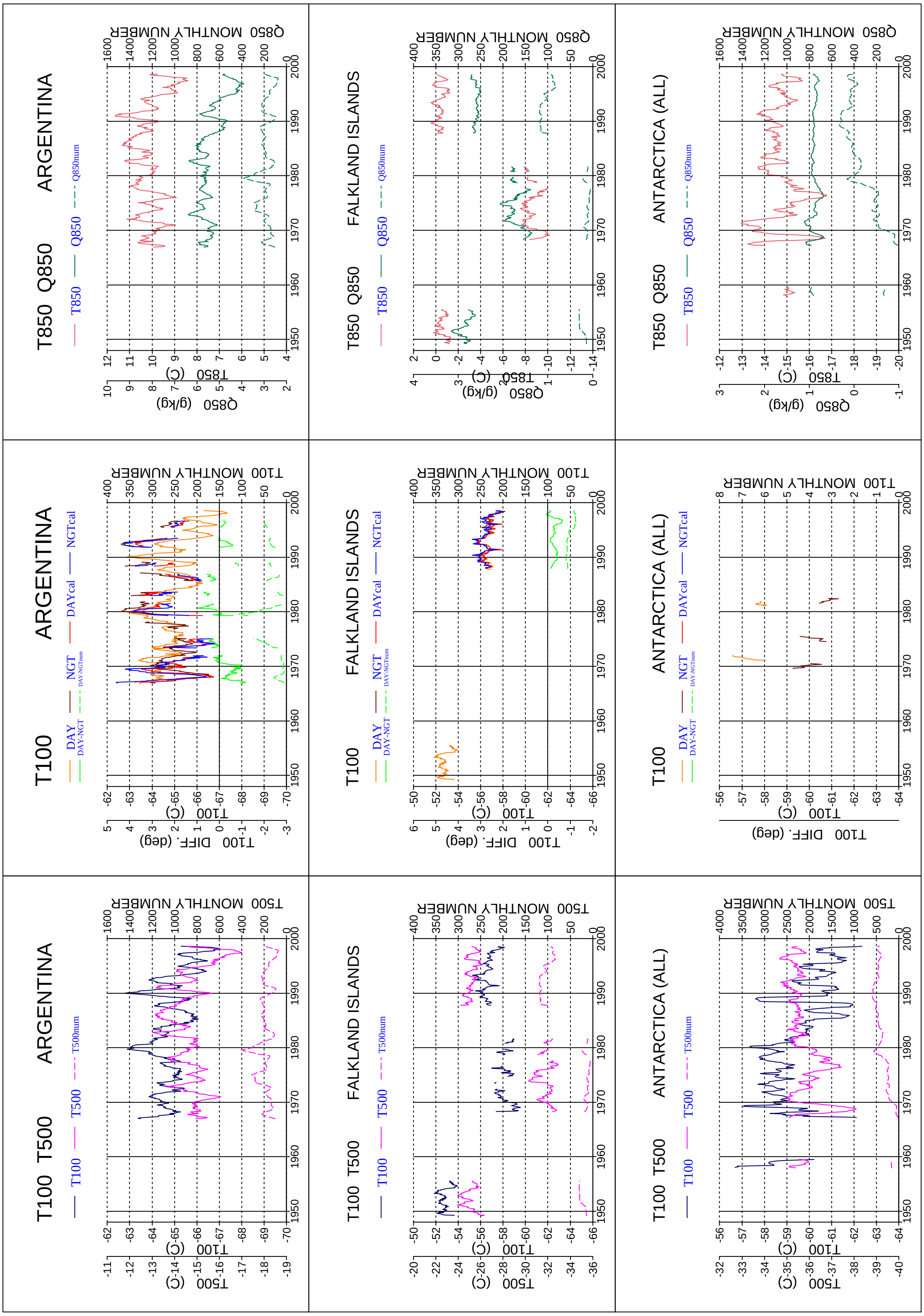


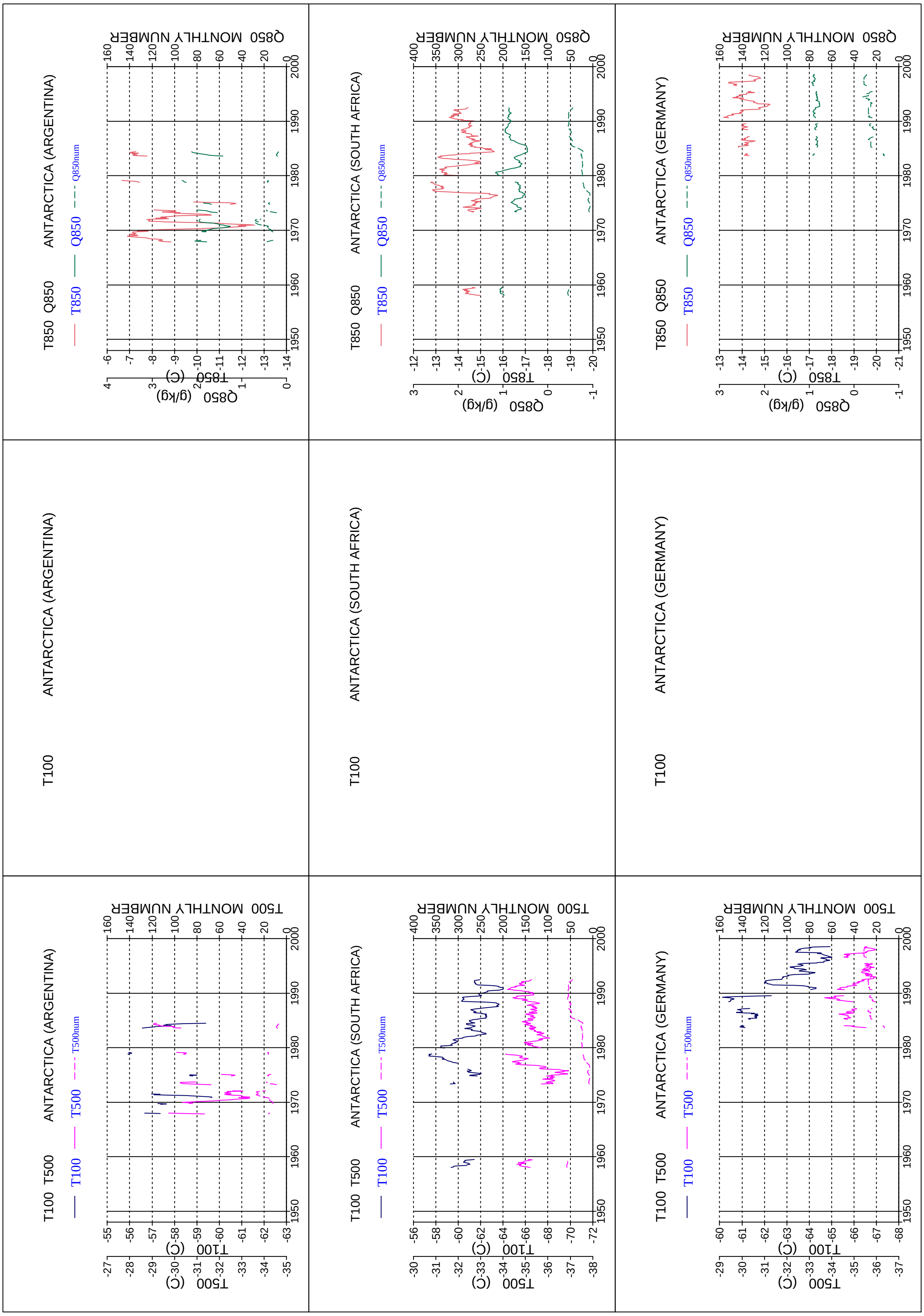

T850 Q850 MIDDLE AMERICA (ALL)
T850 Q850 T850 Q850num
T100 MIDDLE AMERICA (ALL)
DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 T500 MIDDLE AMERICA (ALL)
T100 T500 T500num
T850 Q850 COUNTRIES (1) IN MIDDLE AMERICA
T100 COUNTRIES (1) IN MIDDLE AMERICA
T100 T500 COUNTRIES (1) IN MIDDLE AMERICA
T850 Q850 CUBA
T100 CUBA
T100 T500 CUBA
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

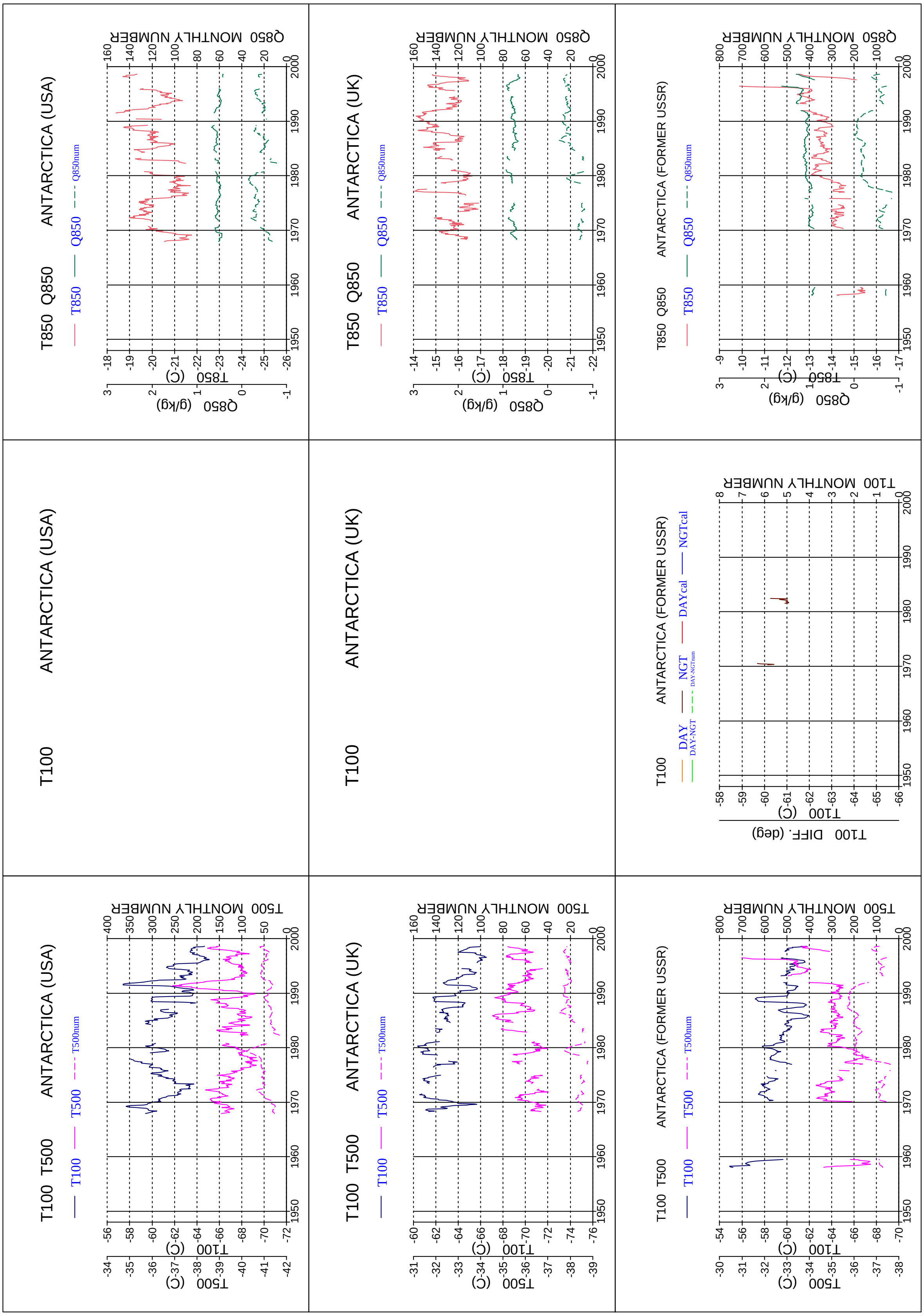

T100 T500 HAITI DOMINICA
T100 T500 T500num
T100 HAITI DOMINICA
DAY NGT DAYcal NGTcal
DAY-NGT DAY-NGTnum
T850 Q850 HAITI DOMINICA
T850 Q850 Q850num
T100 T500 COUNTRIES (2) IN MIDDLE AMERICA
T100 COUNTRIES (2) IN MIDDLE AMERICA
T850 Q850 COUNTRIES (2) IN MIDDLE AMERICA
T100 T500 PUERTO RICO
T100 PUERTO RICO
T850 Q850 PUERTO RICO
T100 (C)
T500 (C)
T100 DIFF. (deg)
T850 (C)
Q850 (g/kg)
T500 MONTHLY NUMBER
T100 MONTHLY NUMBER
Q850 MONTHLY NUMBER

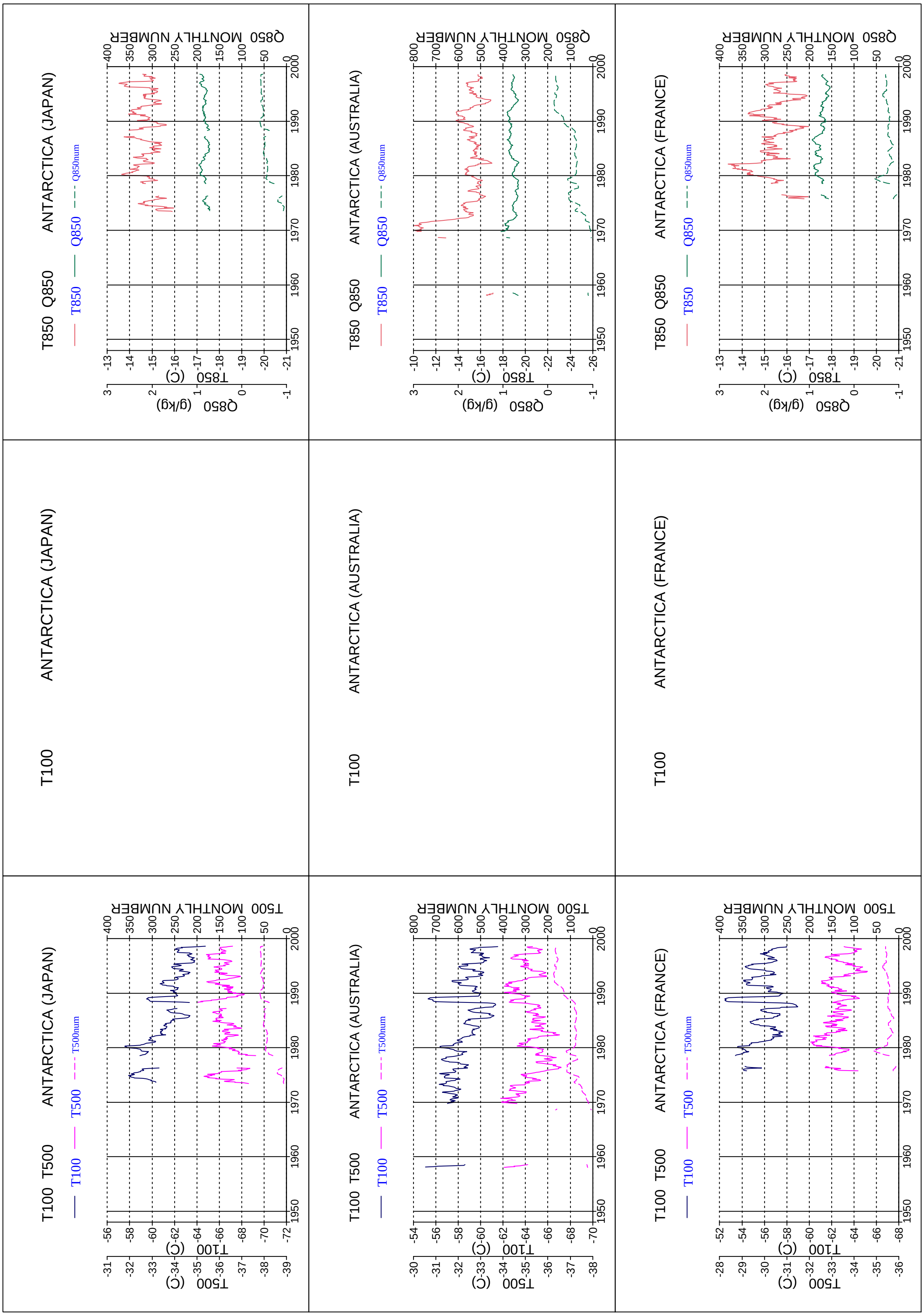

T100 T500 PANAMA
T100 PANAMA
T850 Q850 PANAMA
T100 T500 COUNTRIES (3) IN MIDDLE AMERICA
T100 COUNTRIES (3) IN MIDDLE AMERICA
T850 Q850 COUNTRIES (3) IN MIDDLE AMERICA
T100 T500 CURACAO AND BONAIRE
T100 CURACAO AND BONAIRE
T850 Q850 CURACAO AND BONAIRE
T100
T500
T500num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T850
Q850
Q850num
T500 (C)
T100 (C)
T100 DIFF. (deg)
T850 (C)
Q850 (g/kg)
T500 MONTHLY NUMBER
T100 MONTHLY NUMBER
Q850 MONTHLY NUMBER
1950
1960
1970
1980
1990
2000

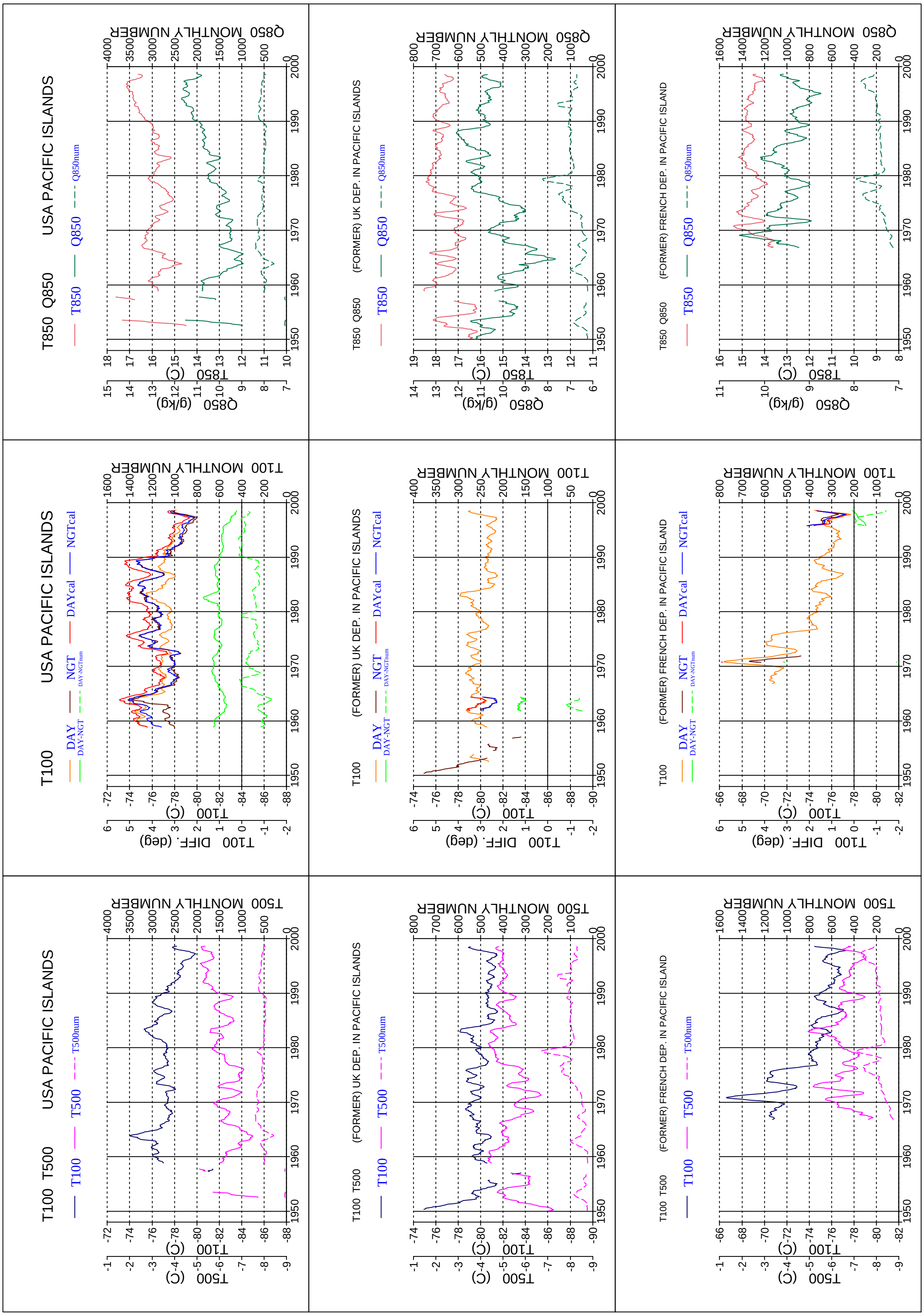

COLOMBIA,VENEZUELA,ECUADOR,PERU,BOLIVI
T100 T500
BRAZIL
CHILE
T100
T850 Q850
DAY
NGT
DAYcal
NGTcal
T500num
Q850num
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
Q850 MONTHLY NUMBER
T100 DIFF. (deg)

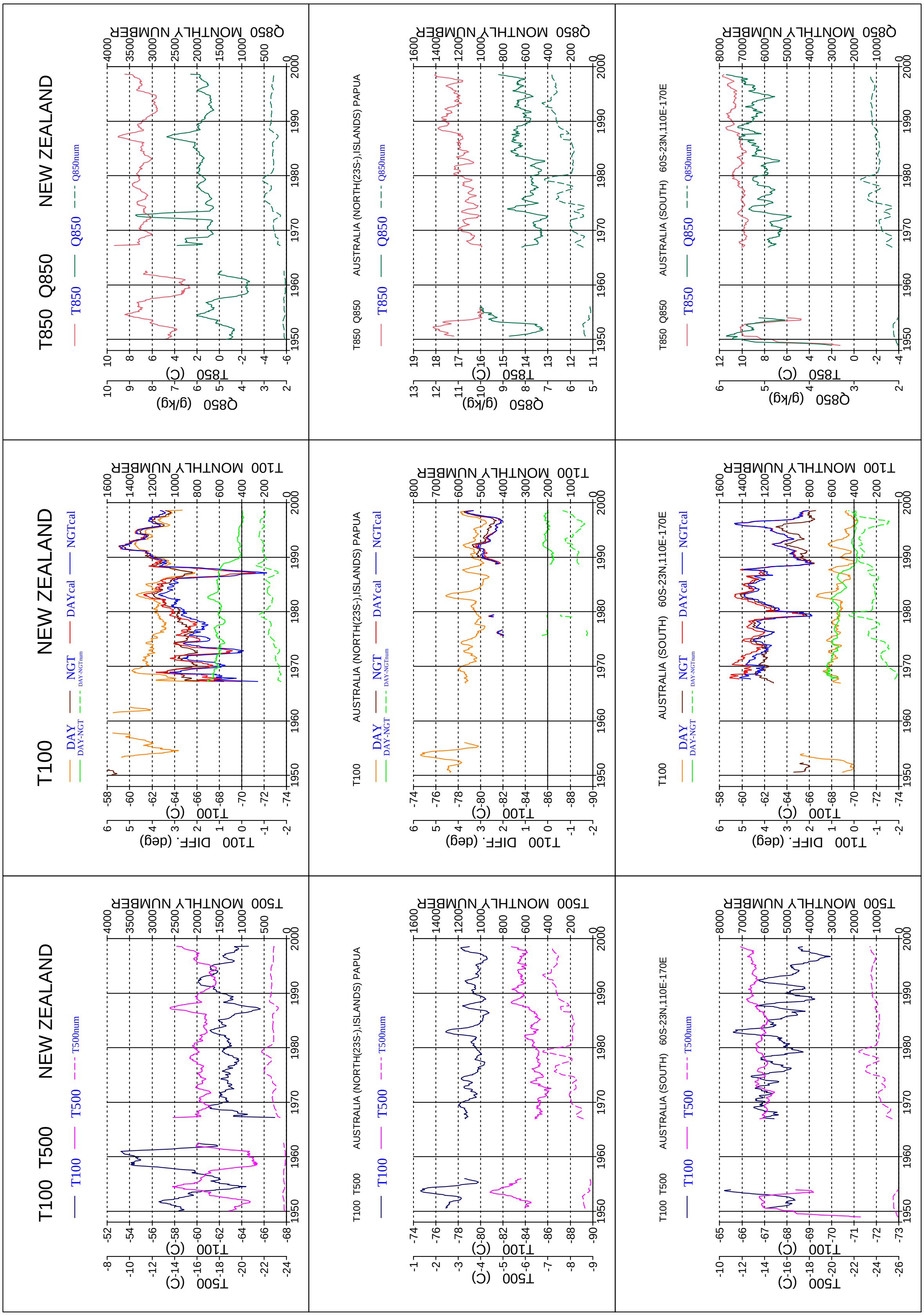

T100 T500 ARGENTINA
T100 ARGENTINA
T850 Q850 ARGENTINA
T100 T500 FALKLAND ISLANDS
T100 FALKLAND ISLANDS
T850 Q850 FALKLAND ISLANDS
T100 T500 ANTARCTICA (ALL)
T100 ANTARCTICA (ALL)
T850 Q850 ANTARCTICA (ALL)
T100
T500
T500num
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T850
Q850
Q850num
T100 (C)
T500 (C)
T100 DIFF. (deg)
T850 (C)
Q850 (g/kg)
T500 MONTHLY NUMBER
T100 MONTHLY NUMBER
Q850 MONTHLY NUMBER

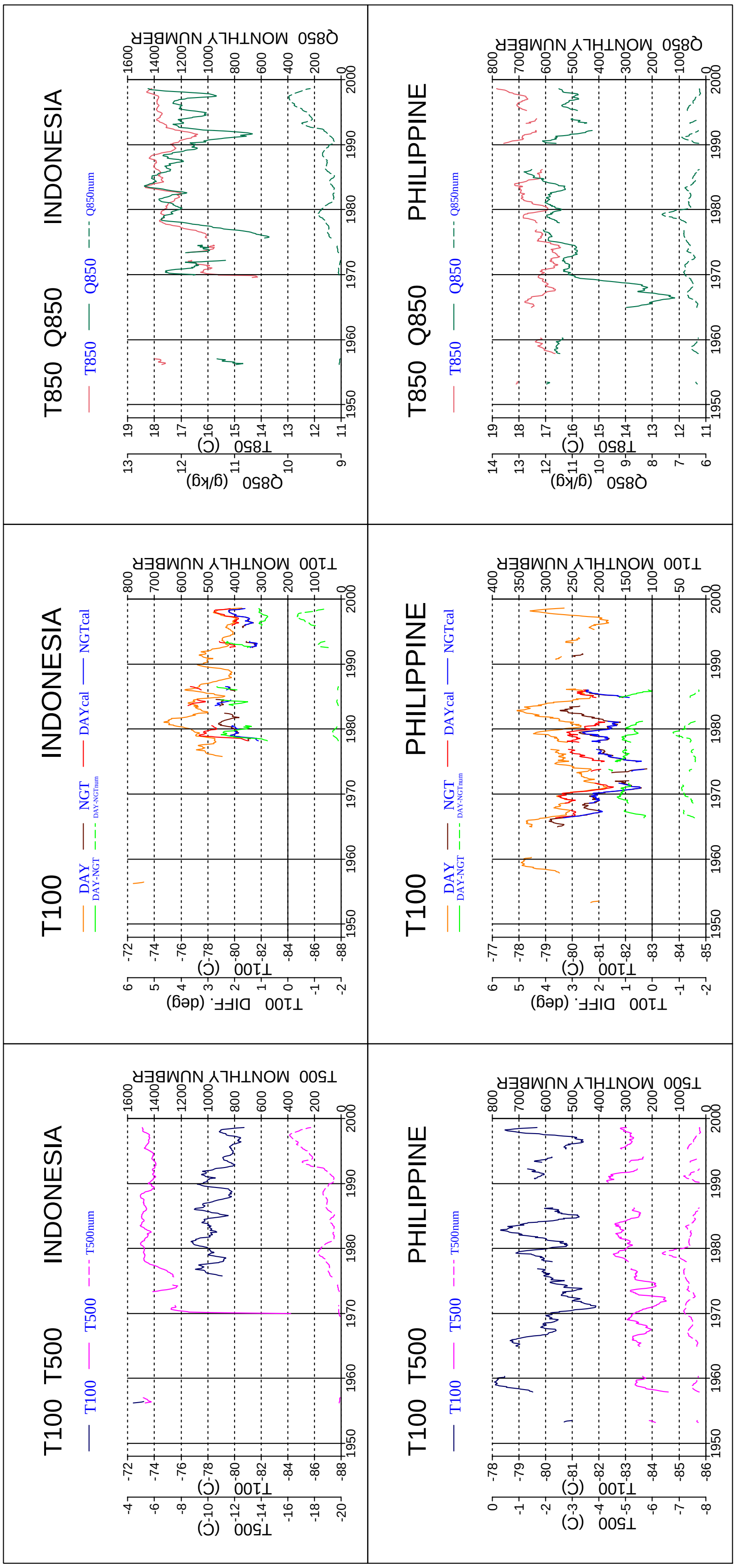

T850 Q850 ANTARCTICA (ARGENTINA)
T850 Q850 ANTARCTICA (SOUTH AFRICA)
T850 Q850 ANTARCTICA (GERMANY)
T850 Q850 Q850num
Q850 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 ANTARCTICA (ARGENTINA)
T100 ANTARCTICA (SOUTH AFRICA)
T100 ANTARCTICA (GERMANY)
T100 T500 ANTARCTICA (ARGENTINA)
T100 T500 ANTARCTICA (SOUTH AFRICA)
T100 T500 ANTARCTICA (GERMANY)
T100 T500 T500num
T500 MONTHLY NUMBER
T100 (C)
T500 (C)


T850 Q850 ANTARCTICA (USA)
T850 Q850 Q850num
T100 ANTARCTICA (USA)
T100 T500 ANTARCTICA (USA)
T100 T500 T500num
T850 Q850 ANTARCTICA (UK)
T100 ANTARCTICA (UK)
T100 T500 ANTARCTICA (UK)
T850 Q850 ANTARCTICA (FORMER USSR)
T100 ANTARCTICA (FORMER USSR)
DAY NGT DAYcal NGTcal
DAY-NGT DAY-NGTnum
T100 T500 ANTARCTICA (FORMER USSR)


T850 Q850 ANTARCTICA (JAPAN)
T850 Q850 Q850num
T850 Q850 ANTARCTICA (AUSTRALIA)
T850 Q850 ANTARCTICA (FRANCE)
Q850 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 ANTARCTICA (JAPAN)
T100 ANTARCTICA (AUSTRALIA)
T100 ANTARCTICA (FRANCE)
T100 T500 ANTARCTICA (JAPAN)
T100 T500 T500num
T100 T500 ANTARCTICA (AUSTRALIA)
T100 T500 ANTARCTICA (FRANCE)
T500 MONTHLY NUMBER
T100 (C)
T500 (C)


T850 Q850 USA PACIFIC ISLANDS
T850 Q850 Q850num
T100 USA PACIFIC ISLANDS
DAY NGT DAYcal NGTcal
T100 T500 USA PACIFIC ISLANDS
T100 T500 T500num
T850 Q850 (FORMER) UK DEP. IN PACIFIC ISLANDS
T100 (FORMER) UK DEP. IN PACIFIC ISLANDS
T100 T500 (FORMER) UK DEP. IN PACIFIC ISLANDS
T850 Q850 (FORMER) FRENCH DEP. IN PACIFIC ISLAND
T100 (FORMER) FRENCH DEP. IN PACIFIC ISLAND
T100 T500 (FORMER) FRENCH DEP. IN PACIFIC ISLAND


T850 Q850 NEW ZEALAND
T100 NEW ZEALAND
T100 T500 NEW ZEALAND
AUSTRALIA (NORTH(23S-),ISLANDS) PAPUA
AUSTRALIA (SOUTH) 60S-23N,110E-170E
T850 Q850 T850 Q850 Q850num
T100 DAY NGT DAYcal NGTcal DAY-NGT DAY-NGTnum
T100 T500 T100 T500 T500num
T850 (C)
Q850 (g/kg)
Q850 MONTHLY NUMBER
T100 (C)
T100 DIFF. (deg)
T100 MONTHLY NUMBER
T500 (C)
T500 MONTHLY NUMBER


T850 Q850 INDONESIA
T850
Q850
Q850num
T100 INDONESIA
DAY
NGT
DAYcal
NGTcal
DAY-NGT
DAY-NGTnum
T100 T500 INDONESIA
T100
T500
T500num
T850 Q850 PHILIPPINE
T100 PHILIPPINE
T100 T500 PHILIPPINE
Q850 MONTHLY NUMBER
T100 MONTHLY NUMBER
T500 MONTHLY NUMBER
T850 (C)
Q850 (g/kg)
T100 (C)
T100 DIFF. (deg)
T500 (C)

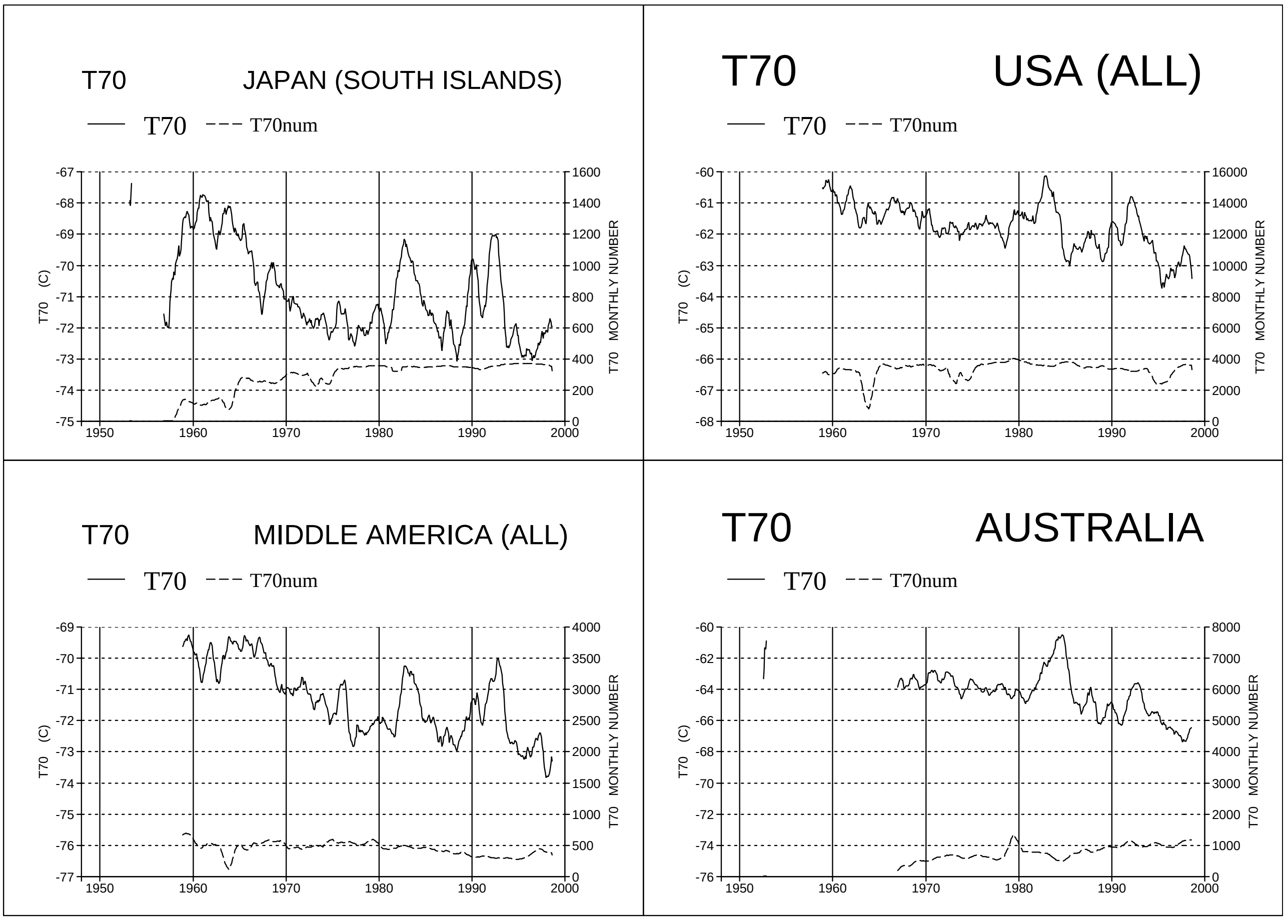


Figure 5 T70 time series for some categories. In 1983 and 1992, significant increases of T70 can be seen. They are presumed to be caused by the big volcanic eruptions of El Chichon in 1982 and Pinatubo in 1991.

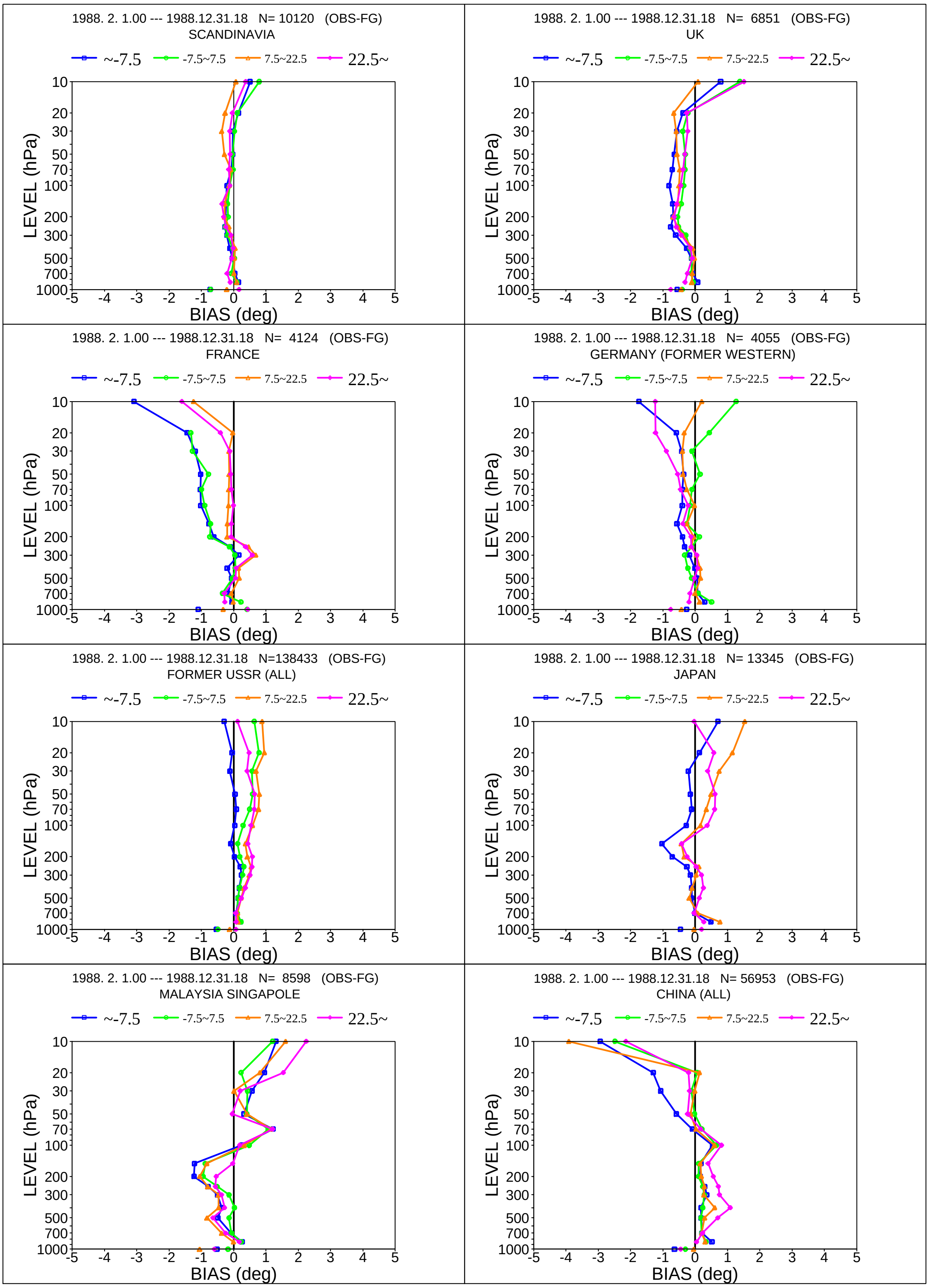


Figure 6a Vertical profiles for some categories. Vertical profiles of departures classified by solar elevations are shown for 1988(a) and 1976(b) for 16 categories. Statistics are taken for 11 months from February to December. January is excluded because data for 1976 are unreliable for the early part of this month due to the way the data assimilation had to be started. Profiles are clearly separated for observations for which no radiation correction has been applied.

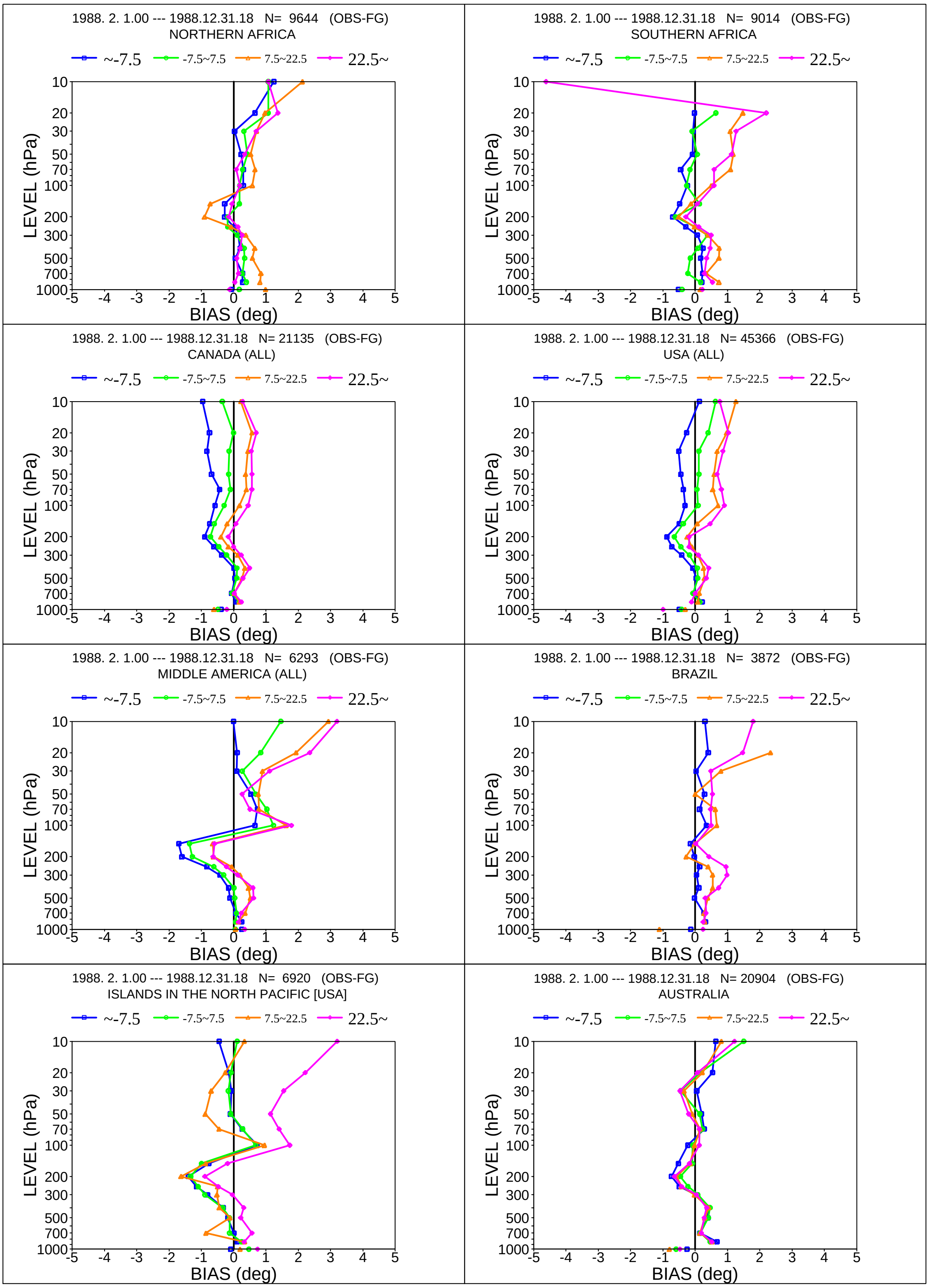


Figure 6a continued

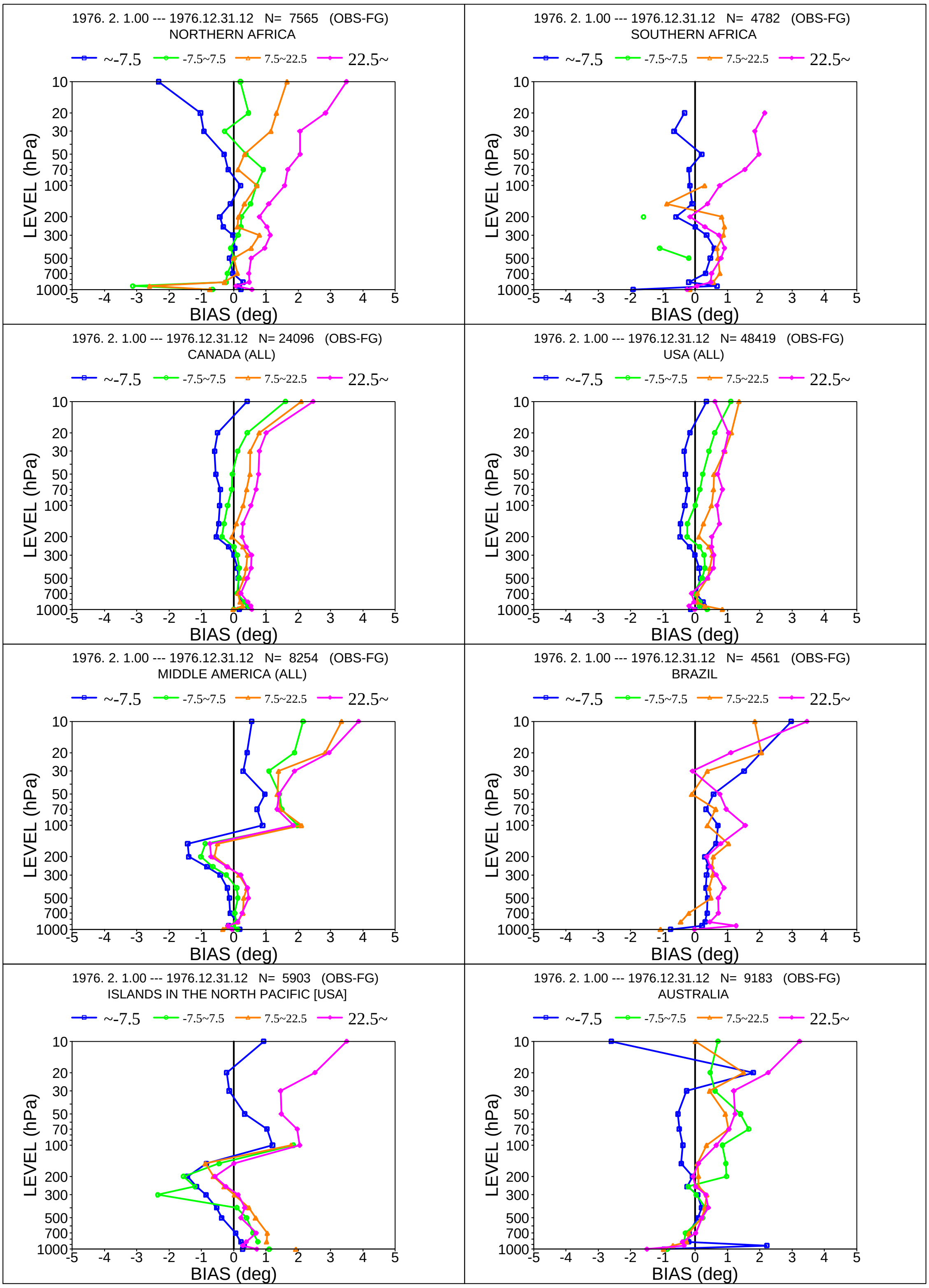

1976. 2. 1.00 --- 1976.12.31.12 N= 7565 (OBS-FG)
NORTHERN AFRICA
1976. 2. 1.00 --- 1976.12.31.12 N= 4782 (OBS-FG)
SOUTHERN AFRICA
1976. 2. 1.00 --- 1976.12.31.12 N= 24096 (OBS-FG)
CANADA (ALL)
1976. 2. 1.00 --- 1976.12.31.12 N= 48419 (OBS-FG)
USA (ALL)
1976. 2. 1.00 --- 1976.12.31.12 N= 8254 (OBS-FG)
MIDDLE AMERICA (ALL)
1976. 2. 1.00 --- 1976.12.31.12 N= 4561 (OBS-FG)
BRAZIL
1976. 2. 1.00 --- 1976.12.31.12 N= 5903 (OBS-FG)
ISLANDS IN THE NORTH PACIFIC [USA]
1976. 2. 1.00 --- 1976.12.31.12 N= 9183 (OBS-FG)
AUSTRALIA
~-7.5
-7.5~7.5
7.5~22.5
22.5~
LEVEL (hPa)
BIAS (deg)

Figure 6b

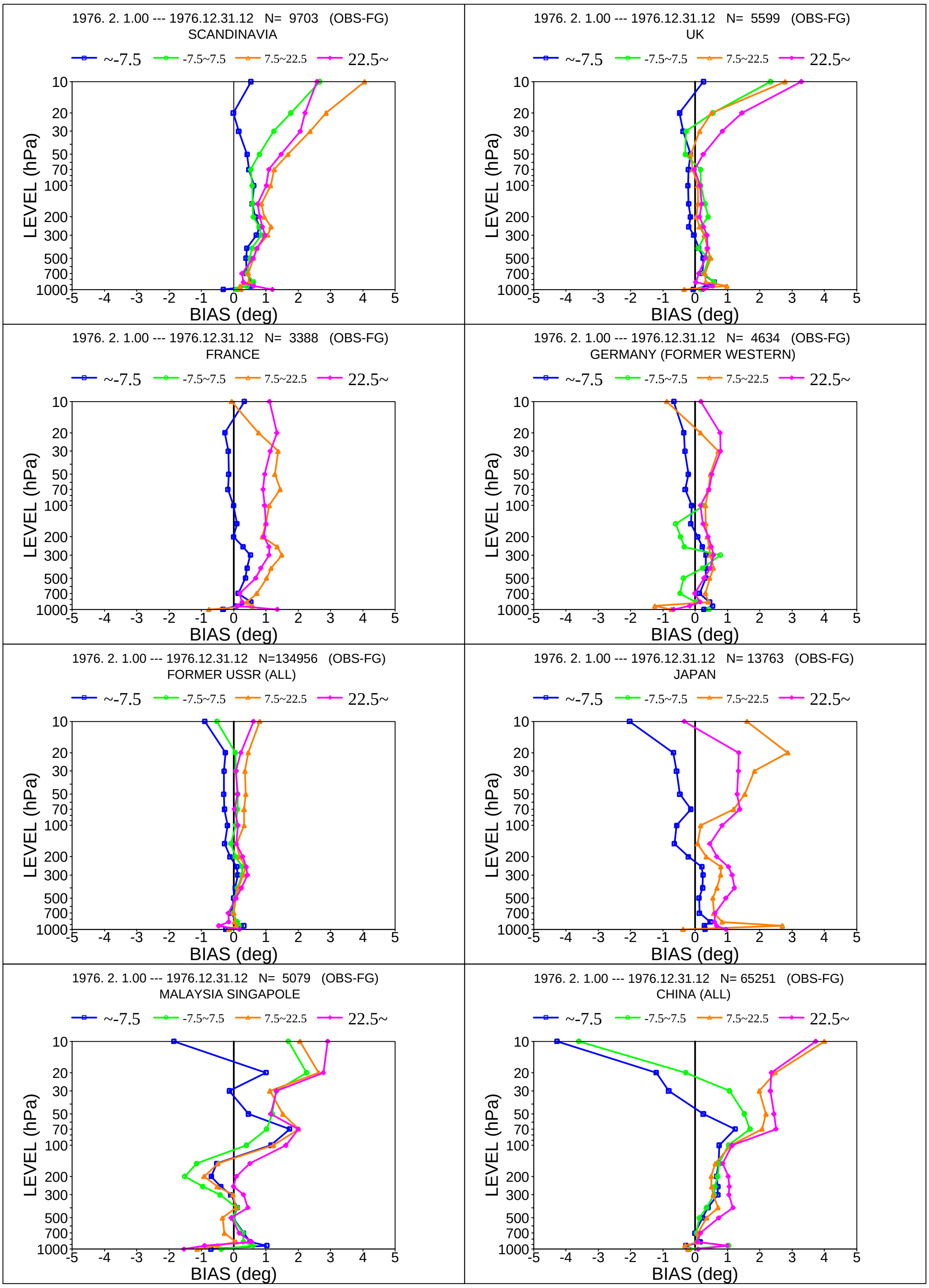


Figure 6b continued

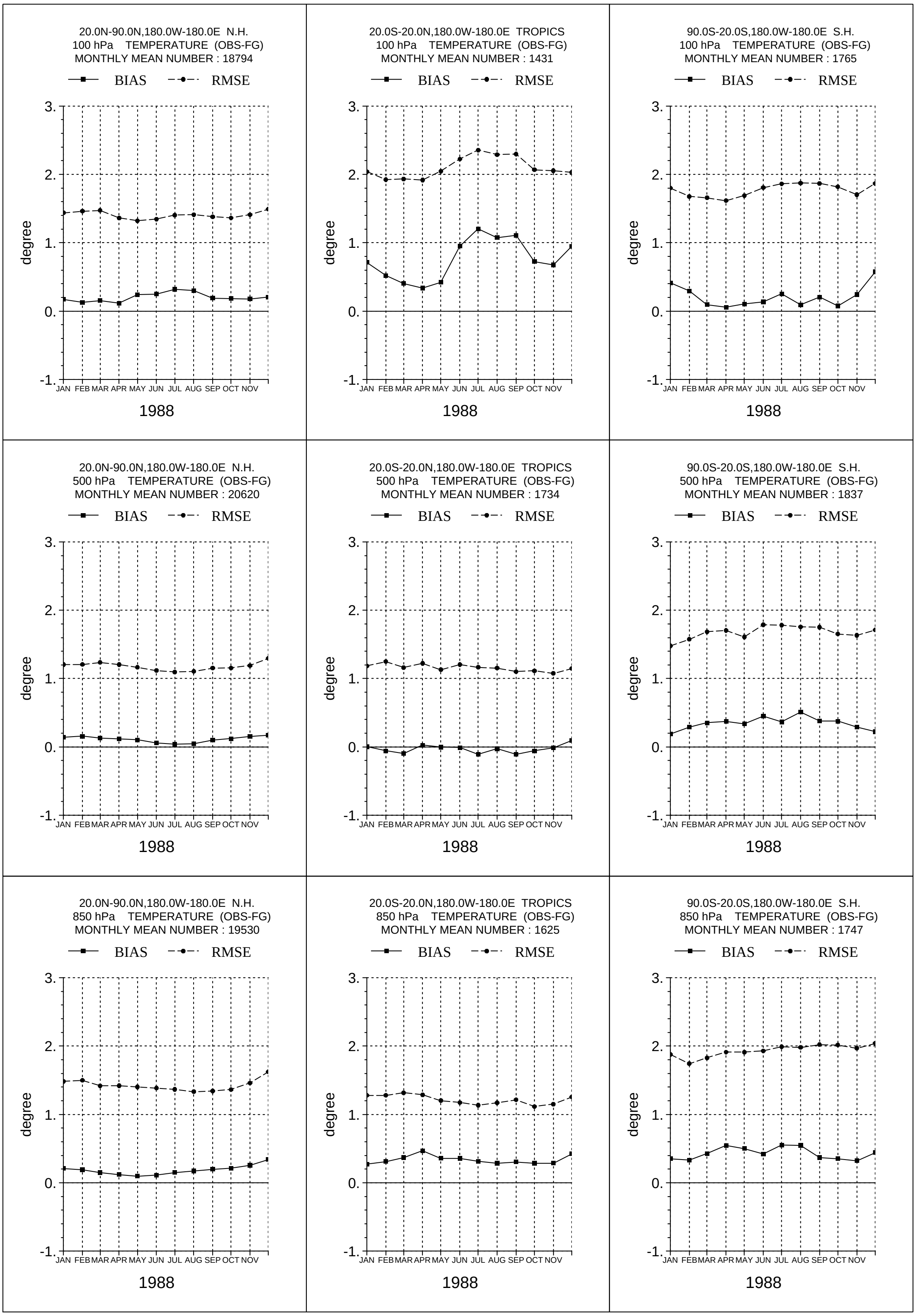


Figure 7 Time series of temperature departure at three levels for 1988 and 1976 in the northern hemisphere, the tropics and the southern hemisphere. Solid lines are biases, dashed lines are RMSs.

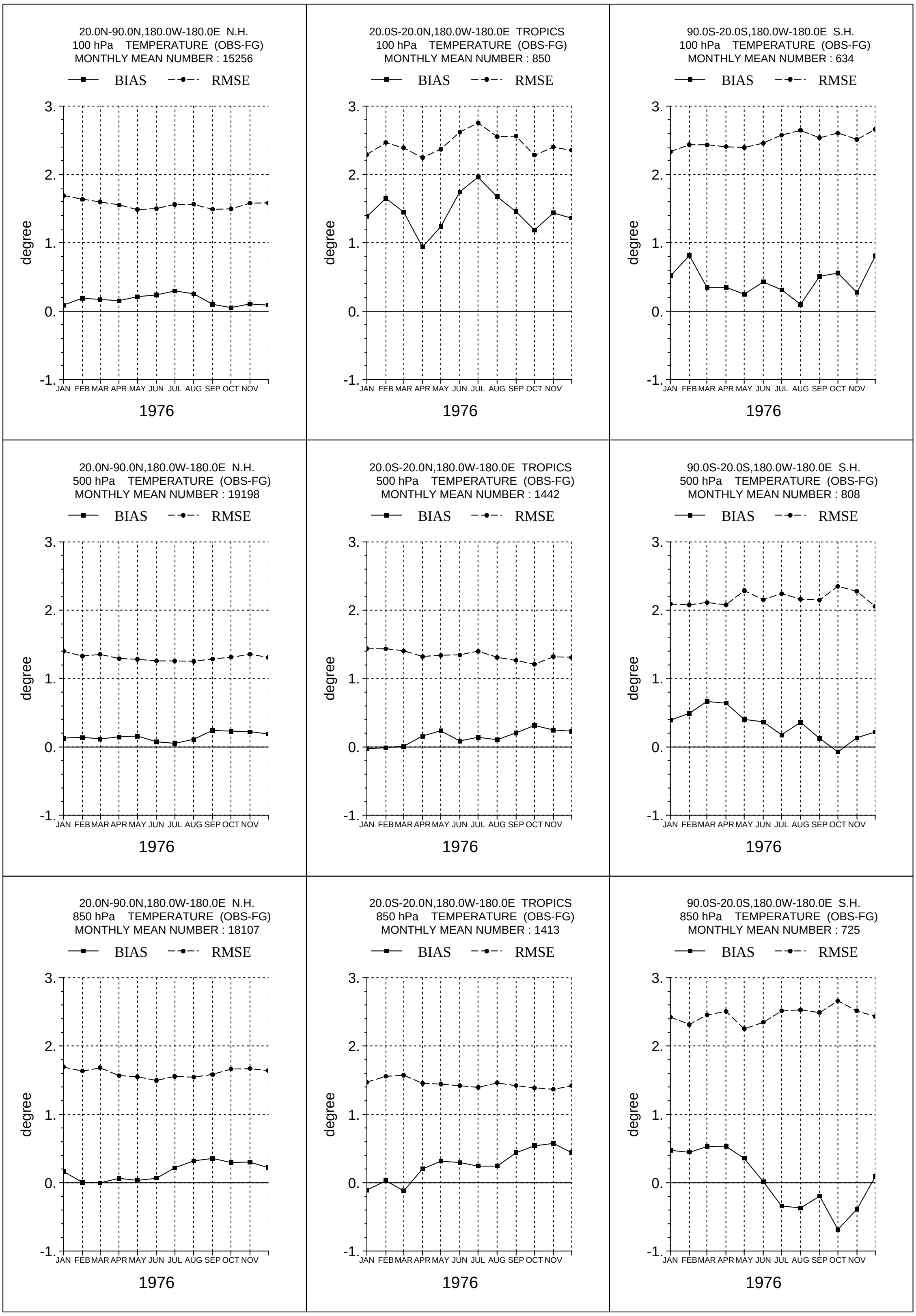


Figure 7 continued