Numerical Weather Prediction

Evaluation of numerical model parameters used in the prediction of embedded cumulonimbus

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Contents

1 Introduction

1.1 Background

A major project within The Met. Office is concerned with automation of the production of Significant Weather (SIGWX) Charts. Decisions as to whether the production of a particular element can be automated must be based on objective verification of both the automated product and the manual alternative that it is replacing.

1.2 Objective Verification Methods

This report examines objective verification methods devised for embedded cumulonimbus clouds. It consists of two main parts, data collection and data analysis.

The data collected for this report consists of lightning observations from The Met. Office's database (sferics), satellite observations from The Met. Office's database (satob) and global model cloud information collected on a regular grid point system. The satob data used in this report consists mainly of observations taken from the Meteosat satellite. Collection of the data is restricted to an area which is 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. This is because coverage of satellite observations outside this area is less reliable.

The analysis presents methods and results of objective verification methods. It consists of statistical analyses and graphical displays of the collected data.

Section 2 briefly discusses the data collection and analysis methods. Details of these methods are discussed in various appendices.

Appendix A discusses a computer program that routinely collects sferics data on a daily basis from The Met. Office's database (MetDB). This data is stored daily in zipped files on the Unix system. Conway and Pamment (1990) discuss some aspects of the sferics system.

In Appendix B, a computer program is discussed which routinely collects satob data on a daily basis from MetDB. This data is also stored in zipped files on the Unix system.

Appendix C discusses the Cumulonimbus Cloud (Cb) Model Data Retrieval Program. This retrieves data on a twice-daily basis from the global model runs and stores it in zipped files on the Unix system.

Appendix D discusses a computer program that analyses, over a long time period, the fractional cloud cover for both the model and satob results. The output of the program is both a graphical display of the first order polynomial fit to the statistics and a statistics data file.

In Appendix E a further computer program is discussed which analyses, over a long time period, the number of lightning strikes and convective cloud depth. The output of the program is both a graphical display of the first order polynomial fit to the statistics and a statistics data file.

Appendix F discusses the Cloud Cover Analysis Program. The output of this program is a graphical display, associated with a model run, which shows information on cloud cover and cloud amount obtained from the model data and displays lightning strikes obtained for a time window around the same time.

The results of the three computer display and analysis programs are shown and discussed in section 3. Finally, conclusions and recommendations are made in section 4.

2 Method

Data has been collected for a period starting in October 1999 and continuing beyond the end of the project. Computer programs have been written which collect sferics data, satob data and Cb model data on a regular grid point system and for an area which covers 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. Details of these programs can be found in Appendices A to C. These results are used within analysis programs which have been used to produce output, some of which is shown in the figures in this technical report. Details of these analysis programs can be found in appendices D to F and results are shown in section 3.

3 Results

Output results for the cloud and lightning strikes graphics are shown in Figure 1. The aim is to present information on cloud amount and depth at a selected time on a chosen day and to show lightning strikes as they occurred during this time. Figure 1 shows six displays for the area 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E which correspond to the model data for forecast time T+018 at 1800Z on 17/12/1999 taken from 0000Z on 17/12/1999. The top left, top right and middle left show model data for high cloud amount, medium cloud amount and convective cloud amount as fractional cover in the range 0 to 1. The middle right, bottom left and bottom right show the convective cloud base in Kft, convective cloud top in Kft and the convective cloud depth in Kft. Superimposed on the three height displays are the lightning strike positions, shown as red triangles, which occurred during a three-hour time period on either side of the model forecast time (1500Z to 2100Z).
Output results from the Lightning Strikes and Convective Cloud Depth Analysis Program show the analysis of number of lightning strikes against weighted mean convective cloud depth, (wmccd), for six box sizes defined as squares consisting of M by M individual unified model (UM) grid boxes. Here M is considered to be one of 1, 2, 4, 8, 16 or 32. Figure 2 shows the analysis from 01-10-1999 till 31-01-2000. For low values of box size, M, there is little correlation between lightning strikes and wmccd. However, when M = 32, there is some correlation. The standard deviation normalised by the number M^2 decreases significantly from M = 1 to M = 32.
Output results from the Cloud Cover Analysis Program show the analysis of Meteosat Cloud cover against model cloud cover for the six box sizes. Figure 3 shows the analysis from 01-10-1999 till 31-01-2000. For low values of box size, M, there is little correlation between cloud cover. However, when M = 32, the fractional model cloud cover and fractional Meteosat cloud cover both increase together. The standard deviation decreases significantly from M = 1 to M = 32.

4 Conclusions and Recommendations

The model data display in Figure 1 shows that the lightning strikes correspond to an area where there is little or no cloud height information predicted by the model. Some of the lightning strikes occur in areas where there is a fairly significant high cloud amount and convective cloud amount, e.g. an area of the North Atlantic Ocean around 30 ^{O}N, 30 ^{O}W and also part of the South American continent near eastern Brazil. It is therefore reasonable to assume that lightning strikes are observed to occur in areas where both convective and high clouds are forecast by the model.

The analysis results over the time period examined in Figure 2 show that for box sizes comparable with the UM grid size (small M) there is little increase in the number of lightning strikes recorded as wmccd increases from 0 to 50 Kft. However, when the analysis areas become significantly larger than the UM grid size, the number of lightning strikes increases with an increase in wmccd. This is most pronounced in the case M = 32. The spread of points as measured by the normalised standard deviation also decreases significantly as the size of the analysis boxes increases.

The analysis results over the time period examined in Figure 3 show that as the fractional cloud cover predicted by the model increases, so does the fractional cloud cover observed from satob observations. This occurs for all box sizes, but there is a steeper increase in model fractional cloud cover as M increases. The results suggest that the fractional satob cloud cover, defined for a box of size M, reaches about 0.2 as the model fractional cloud cover tends to 1 for the case M = 32.

One of the drawbacks of the sferics data gathering of this report is that equal weight has been attached to sferics reports within the geographical area of interest i.e. 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. It has been observed in a private communication with Noelle Daly that in the sferics system the sensitivity decreases as the distance for the waveform to travel increases, because of propagation effects, echoes, etc.
As a rough idea, the location error is about 5.6km over the UK and 10km over Western Europe. In the near future, as part of The Met. Office’s Arrival Time Difference system (ATD) upgrade project, it is intended to improve the location accuracy by implementing a propagation model. This should provide better knowledge of the location error. It was also remarked that each sensor system is running independently and the gain of each is dynamically adjusted to give the best performance depending on the flow rate of data being sent to the central control system. Consequently, the gain is dependent on the amount of thunderstorm activity. The choice of selector station depends on the geometry of the outstations in relation to a flash, the energy received in the waveform, and the number of waveforms that the selector receives. Any subsequent investigation to this report should consider weighting on the sferics observations.

It has been found that as the number of observations grows, the amount of computer time needed to process the data has increased significantly. A possible change that could be made to the computer model is a rewrite of the statistical analysis routine in Fortran rather than PV-WAVE.

5 References

Conway B J and Pamment J A 1990. A comparison of the ATD and ECRC sferics systems for nowcasting applications in the UK. Met.O.24 Internal Report No. 11.

6 Glossary

ATD	The Met. Office's Arrival Time Difference system
Cb	Cumulonimbus Cloud
ECRC	Electricity Council Research Centre
K	Kelvin temperature scale
Kft	Thousand feet
M	Box size which is a multiple of UM grid boxes. There are M^2 UM grid boxes in a larger box.
MetDB	The Met. Office's database.
MKS Units	Metric units system (Metre, Kelvin, Second)
MSFC	Field Code
MSVC	Vertical Co-ordinate type Code
Pa	Pascal
satob	Satellite Observations in MetDB
sccd	Product of Convective Cloud Amount and Convective Cloud Depth in a larger box
sferics	Lightning Observations in MetDB
SIGWX	Significant Weather
tcca	Sum of Convective Cloud Depth in a larger box
UM	Unified Model
wmccd	Weighted mean of the convective cloud depth in a larger box

7 Acknowledgements

I would like to thank various colleagues who have given advice during this work. These range from e-mail answers to queries from Noelle Daly, John Nash, Dave Forrester, Steve Murray, and Chris Long to advice from Kirby James and to technical advice from colleagues and the Help Desk. I would also like to thank my manager Bob Lunnon, for his continual support and advice during this investigation.

Appendix A. Sferics Data Retrieval Program

A.1 Method

Sferics data is retrieved daily for the previous day from 0000Z till 2359Z using MetDB retrieval with subtype SFERICS for an area 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. The elements retrieved are shown in table 1.

Element name	Element Description	Units
HOUR	Hour	hour
MINT	Minute	minute
LTTD	Latitude	degrees
LNGD	Longitude	degrees

Table 1 Sferics Data Retrieval Elements from MetDB

A.2 Sferics Program

A crontab file runs the three Unix scripts, which control sferics data collection, daily at 0100Z, 0130Z and 0400Z. An input file /home/fr0900/fpap/sigwx/lightning/sferics.files is written daily by /home/fr0900/fpap/sigwx/lightning/start.script. This is used by the sferics data collection program /home/fr0900/fpap/sigwx/lightning/sferics.script. Finally, /home/fr0900/fpap/sigwx/lightning/stop.script produces a daily output file namely:
/data/fr0900/fpap/zipped/sferics/0023DdMmYyyy.dat
where Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year.

Appendix B. Satob Data Retrieval Program

B.1 Method

Satob data is retrieved daily for the previous day in four sets from 0000Z till 0559Z, from 0600Z till 1159Z, from 1200Z till 1759Z and from 1800Z till 2359Z using MetDB retrieval with subtype SATOB for an area 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. The elements retrieved are shown in table 2.

Element name	Element Description	Units
HOUR	Hour	hour
MINT	Minute	minute
LTTD	Latitude	degrees
LNGD	Longitude	degrees
TOTL_CLOD_COVR	Total cloud cover	%
LEVL_PESR	Cloud top pressure	Pa
LEVL_AIR_TMPR	Cloud top temperature	K

Table 2 Satob Data Retrieval Elements from MetDB

B.2 Satob Program

A crontab file runs the three Unix scripts, which control satob data collection, daily at 0100Z, 0130Z and 0400Z. An input file /home/fr0900/fpap/sigwx/meteosat/satob.files is written daily by /home/fr0900/fpap/sigwx/meteosat/start.script. This is used by the satob data collection program /home/fr0900/fpap/sigwx/meteosat/satob.script. Finally,

/home/fr0900/fpap/sigwx/meteosat/stop.script produces four daily output files namely:
/data/fr0900/fpap/zipped/meteosat/0005DdMmYyyy.dat
/data/fr0900/fpap/zipped/meteosat/0611DdMmYyyy.dat
/data/fr0900/fpap/zipped/meteosat/1217DdMmYyyy.dat
/data/fr0900/fpap/zipped/meteosat/1823DdMmYyyy.dat
where Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year. The final data files are stored with the time in hours only.

Appendix C. Cb Model Data Retrieval Program

C.1 Method

Cb data is retrieved twice daily for 00Z and 12Z for three forecast times T+000, T+018 and T+024 for an area 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. The elements retrieved are shown in table 3.

METEOROLOGICAL VARIABLE	FIELDSFILE			PP_PACKAGE		
	TYPE	LEVEL	UNITS	MSFC	MSVC	MKS Units
High Cloud Amount	80	8888		31	0	0.01
Medium Cloud Amount	81	8888		32	0	0.01
Convective Cloud Amount	82	8888		34	0	0.01
Convective Cloud Base	87	8888	Kft	34	136	304.8
Convective Cloud Top	88	8888	Kft	34	135	304.8

Table 3 Cb Model Data Retrieval Elements from the Standard Level Global Operational UM Fieldsfiles (COP.FFSTDA.QG00X12)

C.2 Cb Model Program

A crontab file runs the Unix script, which controls the 00Z Cb data collection, daily at 0459. This file is /home/fr0900/fpap/sigwx/read_ppp_files/cb.script and uses an input file /home/fr0900/fpap/sigwx/read_ppp_files/cb.files. A second data manipulation script is run daily from the crontab file at 0730. This file is /home/fr0900/fpap/sigwx/read_ppp_files/stop.script and produces three output files which are /data/fr0900/fpap/zipped/cbdata/00T+000DdMmYyyy.ppp
/data/fr0900/fpap/zipped/cbdata/00T+018DdMmYyyy.ppp
/data/fr0900/fpap/zipped/cbdata/00T+024DdMmYyyy.ppp
where Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year.
A crontab file runs the Unix script, which controls the 12Z Cb data collection, daily at 2259. This file is /home/fr0900/fpap/sigwx/read_ppp_files/cb2.script and uses an input file /home/fr0900/fpap/sigwx/read_ppp_files/cb.files. A second data manipulation script is run daily from the crontab file at 0330. This file is /home/fr0900/fpap/sigwx/read_ppp_files/stop.script and produces three output files which are /data/fr0900/fpap/zipped/cbdata/12T+000DdMmYyyy.ppp
/data/fr0900/fpap/zipped/cbdata/12T+018DdMmYyyy.ppp
/data/fr0900/fpap/zipped/cbdata/12T+024DdMmYyyy.ppp
where Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year.

Appendix D. Cloud Cover Analysis Program

D.1 Method

The Cb data files, which have been generated by the method of appendix C.2, are analysed together with the satob data files, which have been generated by the method of appendix B.2. The time at which a Cb data file is valid is determined by adding the forecast time to the hour e.g.
/data/fr0900/fpap/zipped/cbdata/12T+024DdMmYyyy.ppp
is valid at 1200Z on the following day (Dd + 1, Mm, Yyyy).
Satob data is normally generated one hour before the end time of a satob data file. As an example /data/fr0900/fpap/zipped/meteosat/0611DdMmYyyy.dat is generated at 1100Z on (Dd, Mm, Yyyy). Consequently, the satob data closest to the Cb data in the above example is /data/fr0900/fpap/zipped/meteosat/0611DDMmYyyy.dat where DD = Dd + 1.
A PV-WAVE program determines the satob file associated with the Cb data file, as the day manipulation routines are relatively easy in this language. A temporary file is generated which contains a list of the required Cb data files and the corresponding satob data files. When the model data does not have a corresponding satob data file, both the model data and satob are excluded from the subsequent analysis.
Once the required files have been determined, a Fortran program generates the temporary data files, which contain data needed by a PV-WAVE graphics routine.

D.1.1 Temporary Files List

This contains a number of lines, formatted so that the first entry is a Cb model data file name and the second entry on the same line contains the name of the satob data file. There are, in consequence, as many lines as Cb model data files. When there is no existing satob file, the default file name “missing_file” is written in its place.

D.1.2 Fortran Analysis Program

This suite of subroutines reads the stored Cb data from each of the Cb model files and stores the fractional high cloud amount as an internal array of latitude-longitude points. The meteosat cloud cover is read from the satob data files and the satob observations are converted from latitude and longitude to x,y positions in the range 1 to 65.
This internal array of size 65 by 65 of satob measurements is also stored subject to the following rules:

a) When two or more data sets are found at the same point, then the lower non zero cloud top pressure values are used.

b) Any values for which the pressure is above a threshold are ignored. This pressure corresponds to a height Threshold value set at 24.5 Kft. This value has been suggested in a communication from Dave Forrester.

c) Missing data values for the cloud cover are also ignored.

The satob cloud amount is converted into an array of Meteosat cloud amount in model co-ordinates, subject to the following rule:

d) Provided the product of COS (latitude) * COS (longitude) >= COS (50^O). Otherwise the array value is set to the missing data indicator.

The two sets of data corresponding to model and Meteosat results now exist in arrays of latitude-longitude points, which are UM grid boxes. Each type of data is averaged in a region consisting of M grid boxes squared. Here, M is taken to be each of 1, 2, 4, 8, 16, and 32 in turn. For all box sizes larger than 1, some of the area 50^ON, 50^OS, 50^OW and 50^OE represented by 181 latitude by 121 longitude UM grid boxes is not covered in an analysis. For the example of M = 16 shown in table 4, there are 11 latitude by 7 longitude boxes, corresponding to 77 data points calculated over each of the boxes.

The output of the Fortran suite of programs are temporary files in the directory /home/fr0900/fpap/sigwx/analysis/temporary. Six files are created for each Cb input file, which are:
/home/fr0900/fpap/sigwx/analysis/temporary/HhT+FffDdMmYyyy.anal_M.
Here Hh is 00 or 12 Hrs, Fff is one of 000, 018 or 024 Hrs and M is the grid box size which is one of 01, 02, 04, 08, 16, or 32. These files contain information similar to the example shown in table 4

00T+00001032000

array_size	box_size	missing data indicator
77	16	-32768.0

Meteosat Cloud Cover	Model Cloud Cover
-32768.0 0.0	0.6 0.1

Table 4 The format of the output file (with the first two of the 77 lines of cloud cover data shown) /home/fr0900/fpap/sigwx/analysis/temporary/00T+00001032000.anal_16

D.1.3 PV-WAVE Graphics Program

The graphics program reads each set of data files for the different grid box sizes. Initially it analyses the results for a box size of 1 and generates two large arrays, which consists of up to 21901 points (121 by 181 longitude-latitude grid) for each set of Meteosat-model data. When a missing data value occurs, as in table 4, both the Meteosat cloud cover and model cloud cover are omitted from the arrays. The program calls the PV-WAVE routine POLY_FIT, which returns the best first order polynomial fit to the points and statistical information on the run. A display is produced for a box size of 1, with the polynomial fit and standard deviation.
The graphics routine produces a display for each of the six box sizes. An example of which (described in the results section 3) is shown in figure 2.

D.2 Analysis Program

The Unix script which runs the fractional cloud cover analysis program is /home/fr0900/fpap/sigwx/analysis/run_meteosat_range.script. The method is to specify two dates (day1, month1, year1), (day2, month2, year2) and times which act as a marker for the start and finish for an analysis. The output of the program is a postscript file in a directory /home/fr0900/fpap/pv_wave_images of name: Dd1-Mm1-Yyyy1_Dd2-Mm2-Yyyy2_metsat.ps where Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year and 1 and 2 refer to the first and second dates. The postscript file shows the first order polynomial fit to the data points. Data is shown for box sizes of 1, 2, 4, 8, 16 and 32. Additionally, a file of statistical results is produced for the run in directory /home/fr0900/fpap/sigwx/analysis/stats of name: day1-month1-year1_day2-month2-year2_metsat.stats.

The analysis program produces a temporary file in directory /home/fr0900/fpap/sigwx/analysis/temporary which contains the names of each of the model data files and the corresponding Meteosat data file names in meteosat_files and uses it to analyse the data. When the model data does not have a corresponding Meteosat data file, the model data is excluded from the analysis.

Appendix E. Lightning Strikes and Convective Cloud Depth Analysis Program

E.1 Method

The Cb data files, which have been generated by the method of appendix C.2, are analysed together with the sferics data files, which have been generated by the method of appendix A.2. The time at which a Cb data file is valid is determined by adding the forecast time to the hour e.g.
/data/fr0900/fpap/zipped/cbdata/12T+024DdMmYyyy.ppp
is valid at 1200Z on the following day (Dd + 1, Mm, Yyyy).
Sferics data is normally generated during the whole of the sferics data file time duration. Consequently, a window of sferics observations that is 3 hours either side of the Cb file's time is used. The sferics data closest to the Cb data in the above example is /data/fr0900/fpap/zipped/sferics/0023DDMmYyyy.dat where DD = Dd + 1, for a time window from 0900 till 1500. Sferics observations are included for the starting time, 0900, but excluded for the finishing time, 1500. This avoids using data values on the boundary twice. When, the validity time for a Cb data file is 0000Z, sferics data is taken from two sferics files.
A PV-WAVE program determines the sferics files associated with the Cb data file, as the day manipulation routines are relatively easy in this language. A temporary file is generated which contains a list of the required Cb data files. This is used to generate two temporary data files in directory /home/fr0900/fpap/sigwx/analysis/temporary. These files are a pp_format Cb data file and a lightning results file. In the above example, the files are 12T+024DdMmYyyy.pp and 12T+024DdMmYyyy.light. The first entry in the lightning data file (.light) is the number of lightning strikes, which can include 0. When the Cb model data does not have a corresponding sferics data file, or when no lightning strikes occurred within the required period, the model data and sferics are still included in the subsequent analysis.
Once the required files have been determined, a Fortran program generates the temporary data files, which contain data needed by a PV-WAVE graphics routine.

E.1.1 Temporary Files List

This contains a number of lines, formatted so that all entries are Cb model data file names. These are written one per line and, in consequence, there are as many lines as Cb model data files.

E.1.2 Fortran Lightning and Convective Cloud Depth Analysis Program

This suite of subroutines reads the stored Cb data from each of the Cb pp_format files and stores the convective cloud depth in Kft and convective cloud amount as a fraction in internal arrays. It also reads the lightning information stored as a .light file for the number of lightning strikes and latitude and longitude in degrees.

The two sets of data corresponding to model and lightning results now exist in arrays of latitude-longitude points, which are UM grid boxes. Each type of data is analysed in a region consisting of M grid boxes squared. Here, M is taken to be each of 1, 2, 4, 8, 16, and 32 in turn. For all box sizes larger than 1, some of the area 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E represented by 181 latitude by 121 longitude UM grid boxes is not covered in an analysis. For the example of M = 16 shown in table 5, there are 11 latitude by 7 longitude boxes, corresponding to 77 data points calculated over each of the boxes.

The analysis consists of adding the number of lightning strikes which occur in a box of size M and determining the weighted mean of the convective cloud depth, wmccd. wmccd is obtained by summing the convective cloud amount in each UM grid box within each larger box, (tcca), and by summing the product of the convective cloud amount and the convective cloud depth in each UM grid box within each larger box, (sccd). The weighted mean of the convective cloud depth is now calculated from:

$$\text{wmccd} = \text{sccd}/\text{tcca} \qquad (1)$$

When tcca is zero within a larger box, wmccd is set to zero.

The output of the Fortran suite of programs are temporary files in the directory /home/fr0900/fpap/sigwx/analysis/temporary. Six files are created for each Cb input file, which are:

/home/fr0900/fpap/sigwx/analysis/temporary/HhT+FffDdMmYyyy.anal_M.

Here Hh is 00 or 12 Hrs, Fff is one of 000, 018 or 024 Hrs and M is the grid box size which is one of 01, 02, 04, 08, 16, or 32. These files contain information similar to the example shown in table 5

00T+00001032000

array_size	box_size	missing data indicator
77	16	-32768.0

Lightning strikes	Weighted Mean convective cloud depth Kft
10	12.9
0	2.1

Table 5 The format of the output file (with the first two of the 77 lines of lightning and weighted mean convective cloud depth data shown)
/home/fr0900/fpap/sigwx/analysis/temporary/00T+00001032000.anal_16

E.1.3 PV-WAVE Graphics Program

The graphics program reads each set of data files for the different grid box sizes. Initially it analyses the results for a box size of 1 and generates two large arrays, which consists of 21901 points (121 by 181 longitude-latitude grid) for each set of lightning strikes-model data. There are no missing data values in the arrays and zero lightning strikes and zero weighted mean convective cloud data are included in the analysis. The program calls the PV-WAVE routine POLY_FIT, which returns the best first order polynomial fit to the points and statistical information on the run. A display is produced for a box size of 1, with the polynomial fit and standard deviation normalised by the number of box sizes squared.
The graphics routine produces a display for each of the six box sizes. An example of which (described in the results section 3) is shown in figure 3.

E.2 Lightning Program

The Unix script which runs the lightning strikes against weighted mean convective cloud depth cover analysis program is /home/fr0900/fpap/sigwx/analysis/run_analyse_range.script. The method is to specify two dates (day1, month1, year1), (day2, month2, year2) and times which act as a marker for the start and finish for an analysis. The output of the program is a postscript file in a directory /home/fr0900/fpap/pv_wave_images of name: Dd1-Mm1-Yyyy1_Dd2-Mm2-Yyyy2_anal.ps where Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year and 1 and 2 refer to the first and second dates. The postscript file shows the first order polynomial fit to the data points. Data is shown for box sizes of 1, 2, 4, 8, 16 and 32. Additionally, a file of statistical results is produced for the run in directory /home/fr0900/fpap/sigwx/analysis/stats of name: day1-month1-year1_day2-month2-year2_light.stats.

The analysis program produces a temporary file in directory /home/fr0900/fpap/sigwx/analysis/temporary which contains the names of each of the model data files in cb_pp.files and uses it to analyse the data. On two occasions, the model data does not have a corresponding sferics data file. This is because sferics were not reported on those days and the model data is included in the analysis.

Appendix F. Cloud and Lightning Strikes Graphics Program

F.1 Method

One of the Cb data files, which has been generated by the method of appendix C.2, is analysed together with the appropriate sferics data files which have been generated by the method of appendix A.2. The time at which a Cb data file is valid is determined by adding the forecast time to the hour e.g.
/data/fr0900/fpap/zipped/cbdata/12T+024DdMmYyyy.ppp
is valid at 1200Z on the following day (Dd + 1, Mm, Yyyy).
Sferics data is normally generated during the whole of the sferics data file time duration. Consequently, a window of sferics observations that is 3 hours either side of the Cb file's time is used. The sferics data closest to the Cb data in the above example is /data/fr0900/fpap/zipped/sferics/0023DDMmYyyy.dat where DD = Dd + 1, for a time window from 0900 till 1500. Sferics observations are included for the starting time, 0900, but excluded for the finishing time, 1500. This is by analogy with the method of appendix E.1. When, the validity time for a Cb data file is 0000Z, sferics data is taken from two sferics files.

A PV-WAVE program determines the sferics files associated with the Cb data file, as the day manipulation routines are relatively easy in this language. A temporary file is generated which contains the name of the single required Cb data file. This is used to generate a temporary pp_format Cb data file in directory /home/fr0900/fpap/sigwx/analysis/temporary. In the above example, the file is 12T+024DdMmYyyy.pp.
A further PV-WAVE program generates graphics for high cloud amount, medium cloud amount, convective cloud amount, convective cloud base, convective cloud top, and convective cloud depth. The last three of these have lightning strikes shown as red triangles. An example of the output is described in section 3 and is shown in figure 1.

F.2 Model Graphics Program

The Unix script which runs the graphical output program is /home/fr0900/fpap/sigwx/analysis/run_cb.script. The method is to specify a date and forecast time (hour, forecast, day, month, year) which determines unique files for the graphics. The output of the program is a postscript file in a directory /home/fr0900/fpap/pv_wave_images of name:
HhT+FffDdMmYyyy_cb.ps where Hh is a two-digit hour, Ffff is a three-digit forecast time in hours, Dd is a two-digit day, Mm is a two-digit month and Yyyy is a four-digit year.

The graphics program produces a temporary file in directory /home/fr0900/fpap/sigwx/analysis/temporary which contains the name of the single model data file. This file is used to determine the corresponding sferics data files to be used.

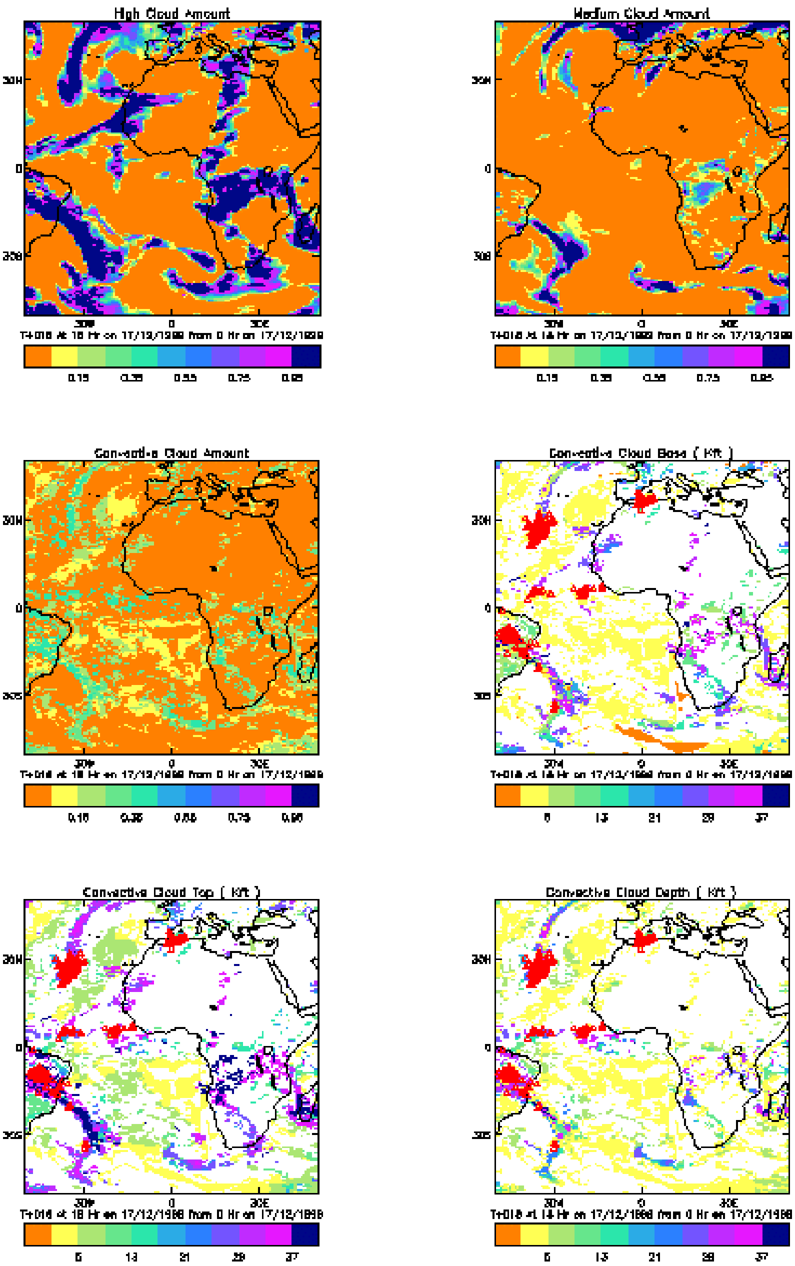

Figure 1 Model data for forecast time T+018 at 1800Z on 17/12/1999 taken from 0000Z on 17/12/1999 for the area 50^{O}N, 50^{O}S, 50^{O}W and 50^{O}E. The top left, top right and middle left show model data for high cloud amount, medium cloud amount and convective cloud amount as fractional cover in the range 0 to 1. The middle right, bottom left and bottom right show the convective cloud base, convective cloud top and the convective cloud depth all in Kft. Superimposed on the three height displays are the lightning strike positions, shown as red triangles, which occurred during a three-hour time period on either side of the model forecast time (1500Z to 2100Z).

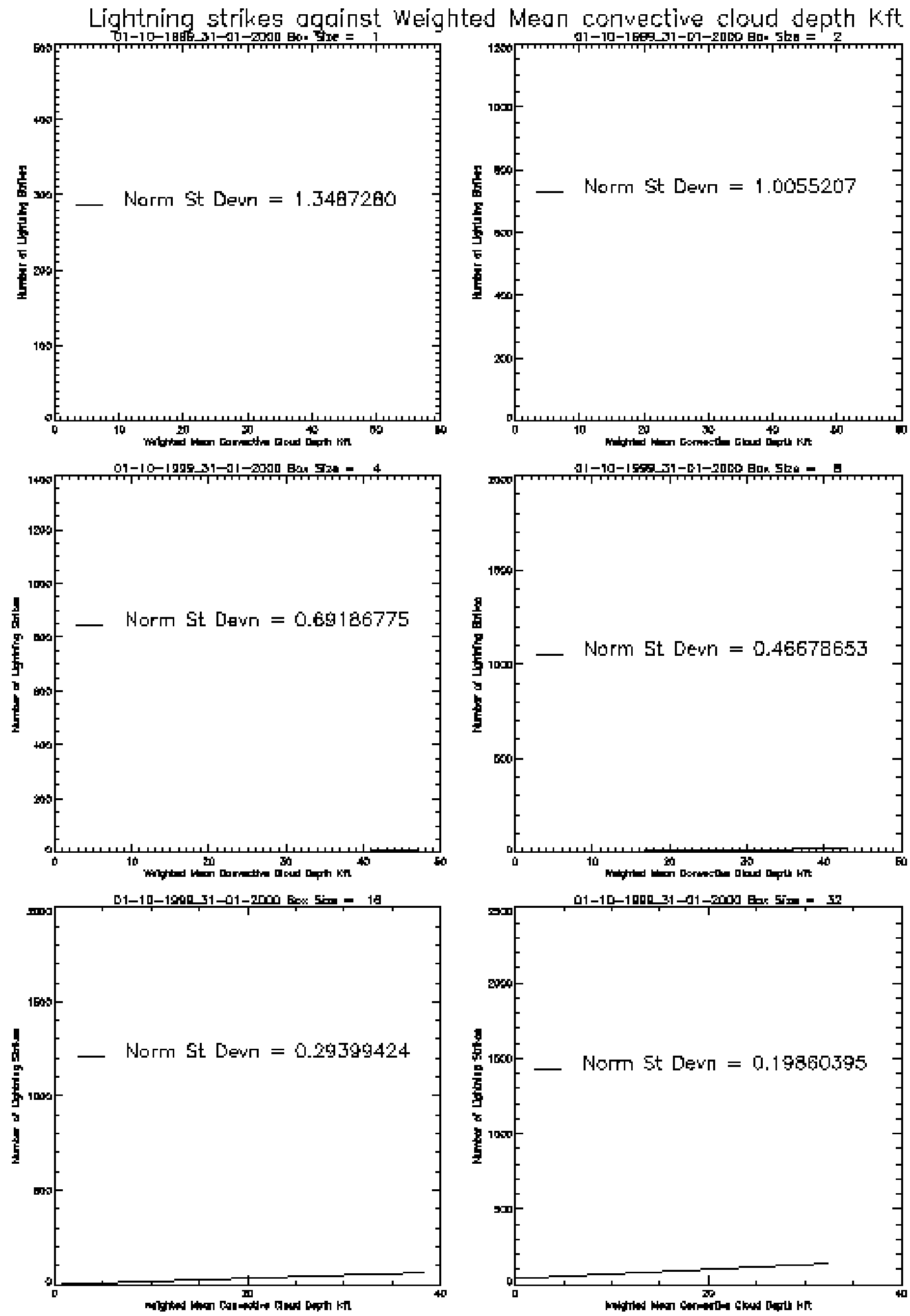

Figure 2 The analysis of lightning strikes against weighted mean convective cloud depth, wmccd, from 01-10-1999 till 31-01-2000. For low values of box size, M, there is little correlation between lightning strikes and wmccd. However, when M = 32, the number of lightning strikes increases with wmccd.

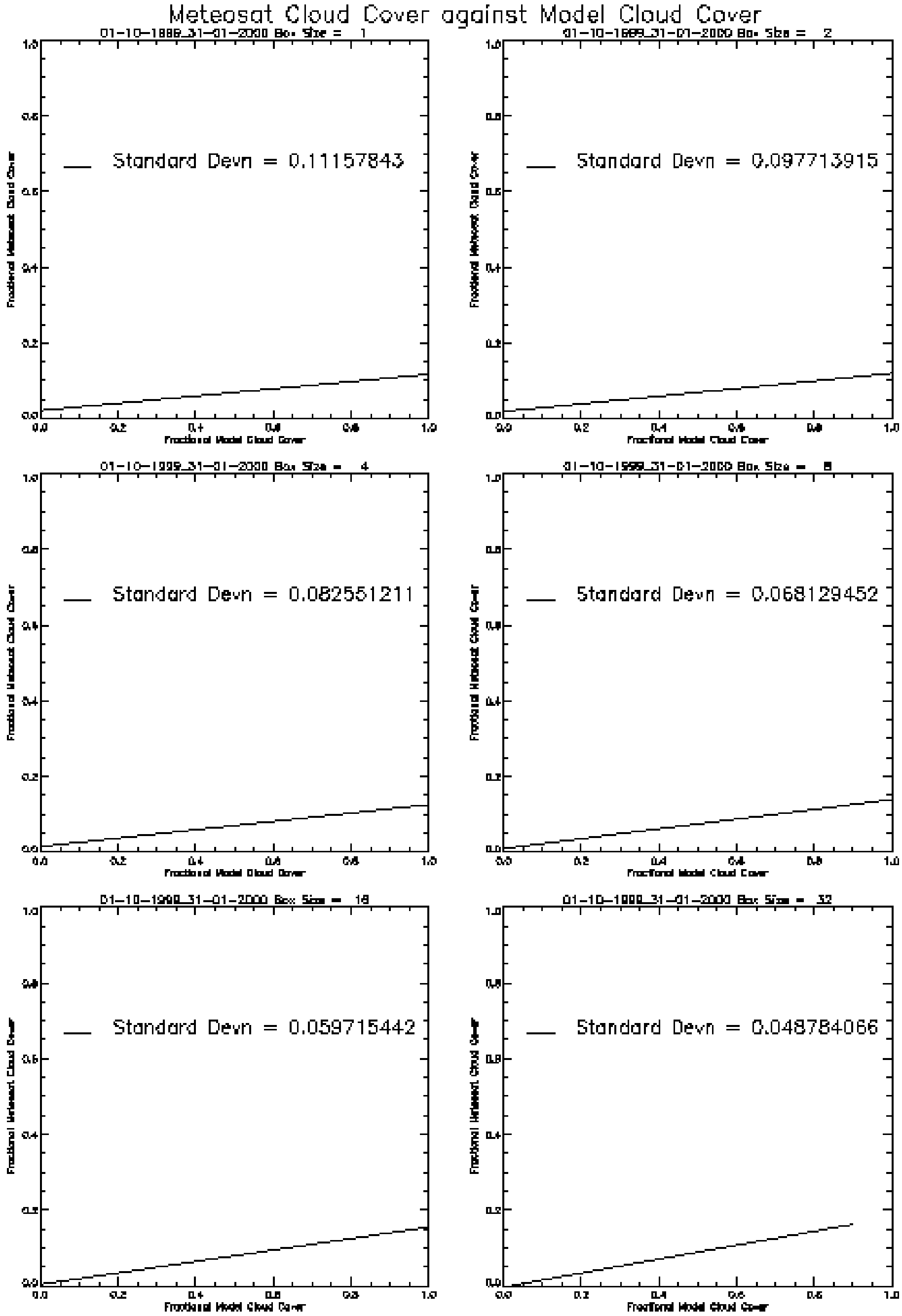

Figure 3 The analysis of Meteosat cloud cover against model cloud cover from 01-10-1999 till 31-01-2000. For low values of box size, M, there is little correlation between cloud cover. However, the value M = 32, shows that the fractional model cloud cover and fractional Meteosat cloud cover both increase together.