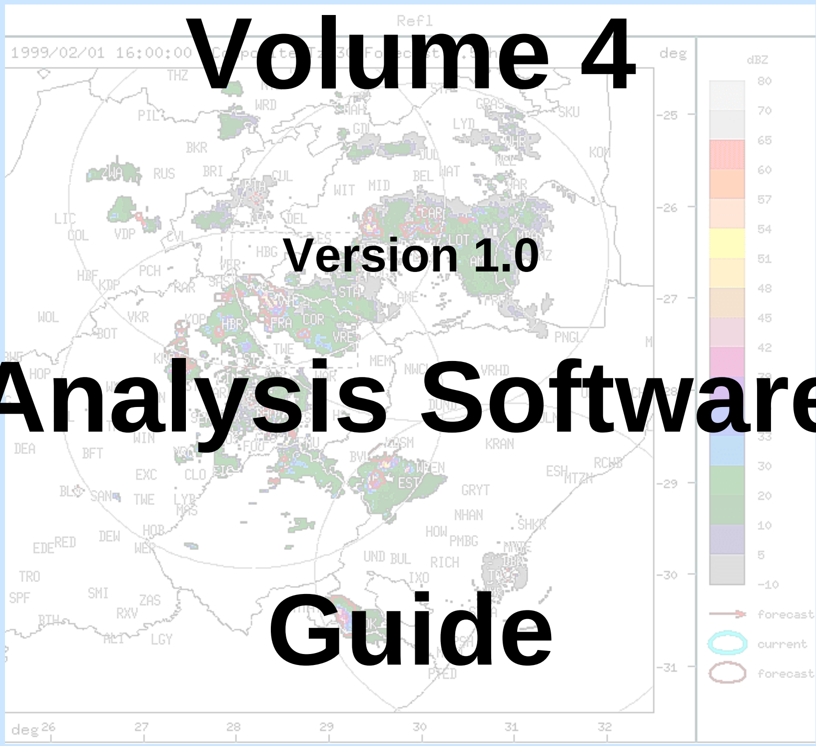
TITAN

DOCUMENTATION



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Guide

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1. INTRODUCTION

1.1 Background

This analysis software has its roots in the randomized hygroscopic seeding experiments conducted in South Africa between 1991 and 1995 as reported in Mather et al 1999). The original software was revamped by Dr. M. Dixon for the randomized hygroscopic seeding experiments in Mexico. When the South African research effort was transformed from a purely scientific one to a semi-operational project in late 1997 a means of evaluating the seeding effects was needed to be and the software was further expanded.

The Thunderstorm Identification Tracking Analysis and Nowcasting software or TITAN for short was developed by Dixon and Wiener (1993). The software saw its first use in a weather modification framework in South Africa in 1995. It was found to be an invaluable tool during operations for the directing of aircraft to suitable storms, based on the observed three-dimensional radar characteristics. It was therefore a logical extension that TITAN and its underlying software would form the backbone of any future seeded storms analyses.

1.2 The reasoning

The most pressing dilemma with semi-operational and operational seeding work is to obtain a set of control storms (that do not have mock decision times) in an objective manner without introducing bias into the analysis. A novel way of achieving this was to use the tracking algorithms time-of-track origin as the point of reference instead of the decision time. Storms are then matched based on their behaviour from time-of-origin to time t. Of course the longer this interval is made the more complicated the storm dynamics become. Small discrete storm units early in their lifetimes can become large messy storm complexes. That is why this method of analysis is only effective and suitable for storms that were seeded early on in their lifetimes where the origin storm has retained a strong sense of its own identity. Therefore type "A" storms are defined as those that were seeded within the first 30 minutes from time-of-origin. From this it can be appreciated that many storms cannot be analysed using this method. This is however the subset of storms where it is most likely for a seeding response (if there is one) to be detected.

1.3 What is needed for the analysis

For analysis a complete log of each seeded case including the :
- seeding aircraft
- seeded storm location (from the TITAN tracking)
- aircraft tracks
- seeding agent
- seeding times
- atmospheric parameters (optional)

is required.

1.4 Data partitioning

Data will be partitioned in at least one way, based on whether a case was a type "A" storm or not. Remember that this analysis package can only analyse type "A" storms. However, the type "A" storms subset can be partitioned further by differentiating between different seeding agents and/or methods and/or atmospheric conditions.

1.5 Generating parameter files for TITAN utilities

Each TITAN utility is accompanied by a parameter file. The parameter files for this analysis process are not part of a standard TITAN installation and have to be generated at a site. Fortunately they have to be generated only once using the "-print_params" command line option, e.g. type in under the params directory

```
TrackMatch -print_params > TrackMatch.test
```

to generate the parameter file for the TrackMatch utility. This params file is produced to contain the DEFAULT settings for the utility. For most applications very little editing (except for paths) is usually required. The default variable values are typically the best for a given application and should only be changed with the utmost caution. Be especially aware of punctuation conventions. Stray or missing semi-colons may result in programs dumping core.

The file can now be edited further to tune it for local use. More on this subject as we go through the analysis steps in section 2.

2. THE ANALYSIS PROCESS

NOTE : All programs are run from the params directory, i.e. that is the way in which the command lines are referenced.

2.1 Definition of a case

For each case there exists a corresponding experimental unit.

The experimental unit is defined as the storm as measured by the radar and tracked by TITAN, using a set threshold (e.g. 30 dBZ) for the time 'x' minutes prior to decision time to 'y' minutes after decision time. If the storm does not exist 'x' minutes before decision time (i.e. there may be no echo as yet or the maximum echo intensity is less than the set tracking threshold) the case starts at the first detection by TITAN. Similarly if the storms die before 'y' minutes after decision time the case ends when TITAN no longer detects it above the tracking threshold.

Any mergers and splits which occur during the specified time period will be included in the analysis, but any mergers and splits that occur outside that time window are ignored.

2.2 Visual analysis in rview

The rview and time_hist displays are the main tools for identifying cases. It is assumed that the radar data, TITAN tracks and aircraft tracks are available for each case.

Use rview to find the case at decision time, using the TITAN tracks and the aircraft position. Set the annotation to 'track numbers'. Note the complex and simple track number. The track number appears either as a single number or as a pair, such as 129/277. If there is a pair, the complex number is the first of the pair and the simple number is the second.

Middle double-clicking on the case at decision time will give an idea of what the case looks like. Edit the time-hist parameter file to ensure that it includes the following TWO lines :

```
time_hist.partial_track_past_period: 20.0
time_hist.partial_track_future_period: 60.0
```

If not, add them in and save.

If set as above, middle-clicking on the case will highlight the case from 20 minutes prior to and 60 minutes after decision time. Middle-clicking on the track menu button will turn OFF all other tracks, leaving only the case.

2.3 Creating the case_tracks file

Create an ASCII file with the following headers, that contains the details of all the cases. The headers are self-explanatory. Comments start with a "#".

For each case analysed as in par. 2.1 the columns of the case_tracks file need to be filled in.

```
#Case  Seed?  N.   Seed track ref time      Ref-  End- Compl Simpl
#num   Y/N    of   Dur  YYYY MM DD HH MM SS start ref  track track Base  Ratio   Temp  500mb
#             Flrs (min)                    (min) min) num   num   (km)  (g/kg)  (C)    (C)
#----  ----- ---- ---- ------------------- ----- ----- ---- ----- ----- ------ ------ ------
 01     Y      8    23  1997 12 05 14 47 00    0    100    9    9 -999.0 -999.0 -999.0 -999.0
```

Note that "track ref time" and "decision time" are synonymous.

"Ref-start" is the time (in minutes) from the desired start of the case to decision time. "End-ref" is the time from decision time to the desired end of the case.

Only include cases for which a TITAN track was found, i.e. those cases for which no TITAN tracks existed, must be commented out.

The environmental data (cloud base, mixing rations, CCL temperature or lifted index) are included for partitioning purposes (see also par. 1.4). If any of the environmental data are not available use -999.0 to indicate a missing value.

All seeded cases need to be recorded in the case_tracks file. Once this has been done, the type "A" cases can then be identified by determining whether seeding commenced within 30 minutes from time-of-track-origin. Those cases that do not qualify must be commented out using the "#".

2.4 Verifying the case_tracks file in rview

Before continuing it is necessary to check that the correct portions of the case track have been included for analysis by viewing the case again in rview. Both rview and time_hist have been updated to identify cases from the case_tracks file. It is once again necessary to check that the following parameters are included in the time_hist parameter file :

```
time_hist.use_case_tracks : true
time_hist.case_tracks_file_path : $(TITAN_HOME)/params/case_tracks.??
```

With these parameters set, then, in rview, when clicking on a case using the middle button, the case number will be displayed on both the rview and time_hist, instead of the track number. For example case 15 will appear as C15. To see the track number as before, use the left button (complex track) or right button (simple track).

Check ALL the cases using rview and time_hist. The storm time-history window (upper right) can show all the storm properties to be viewed at once. The storm time-height window (middle right) can optionally display the maximum reflectivity plotted against the vertical centroid.

2.5 How to deal with bad mergers

It may be upon inspection that the track includes a part of a storm that is not relevant to the case. This may occur occur early or late in a storm's lifetime, some time before seeding started or after seeding ended. Such merges can then be excluded by limiting the duration of the case by setting the "Ref-start" and "End-ref" values accordingly.

2.6 Extracting track properties using Tracks2Ascii

This program is used to extract scan-by-scan information on all tracks for a given day or period. The output from Tracks2Ascii is required as input to the TrackMatch utility (par. 2.8). The command line options are as given below.

```
Usage: Tracks2Ascii [options as below]
options:
       [ --, -h, -help, -man ] produce this list.
       [ -check_params ] check parameter usage
       [ -count ] only count storms - no other output
       [ -debug ] print debug messages
       [ -entity ?] target_entity
         COMPLETE_TRACK, TRACK_ENTRY, TRENDS, INITIAL_PROPS
       [ -f file_paths] track file paths list (*.th5)
       [ -mdebug level ] set malloc debug level
       [ -params ?] params file path
       [ -print_params ] print parameters with comments
       [ -print_short ] print parameters - short version
       [ -verbose ] print verbosedebug messages
```

If no parameter file exists for Tracks2Ascii, generate one using the "-print_params" command line option (see also par. 1.5).

The most important parameter to check in a newly generated Tracks2Ascii parameter file (see Appendix A.1) is that the "target_entity" is set to INITIAL_PROPS.

Typically the command line would be as follows :
Tracks2Ascii -f ../storms/19971205.th5 -params Tracks2Ascii.test > outfile
Batch processing is also possible, e.g. if a whole month's or season's data is to be processed -f ../storms/2000*.th5 can also be used.

Note : For use by TrackMatch (as described in par. 2.8) it is vital that all possible storms are included, i.e. the pool for matching needs to be as big as possible. If Tracks2Ascii is run in a fragmented manner (this is recommended) all the files need to be concatenated to produce one all-inclusive file for use by TrackMatch.

WARNING : This program is prone to dump core. If this happens there may either be a problem with the parameter file or with one of the storm track (th5) files. To test whether the parameter file is at fault run the program with the -print_params command and drop the re-direct output "> outfile" option. If the core dump persists then the problem is in the params file. Generate a new parameter as discussed in par. 1.5. Beware of the pitfalls of punctuation such as quotes, semi-colons and commas.

Occasionally a storm track file may also be corrupt causing the program to dump core. It is then necessary to re-generate the storm tracks for that day. This will be discussed in par. 2.7.

2.7 StormIdent and StormTrack

StormIdent has the capability of tracking storms at multiple thresholds, i.e. addressing the problem of large cumbersome tracks that result under widespread or more general rain conditions.

For completeness sake both the old (storm_ident) and the new (StormIdent) and their usages are included below.

```
Usage: storm_ident
 [ --, -h, -help, -man ] produce this list
 [ -debug ] print debug messages
 [ -endtime yyyy/mm/dd_hh:mm:ss ] end time (archive mode)
 [ -mdebug ?] set malloc debug level
 [ -mode ?] 'archive' or 'realtime'
 [ -params name ] set parameters file name
 [ -reftime yyyy/mm/dd_hh:mm:ss ] ref time (archive mode)
                (will be phased out - should not be used)
 [ -starttime yyyy/mm/dd_hh:mm:ss ] start time (archive mode)
 [ -track ] perform tracking?
 [ -verbose ] print verbose messages

Usage: StormIdent [options as below]
options:
       [ --, -h, -help, -man ] produce this list.
       [ -debug ] print debug messages
       [ -end "yyyy mm dd hh mm ss"] end time
                              ARCHIVE mode only
       [ -mdebug level ] set malloc debug level
       [ -mode ?] ARCHIVE or REALTIME
       [ -start "yyyy mm dd hh mm ss"] start time
                                  ARCHIVE mode only
       [ -track ] perform tracking?
       [ -verbose ] print verbose debug messages

NOTE: for ARCHIVE mode, you must specify the times using start
and end. Then ARCHIVE mode will be automatically invoked.
```

In archive mode the command line for StormIdent would be as follows :

StormIdent -params StormIdent.ops -mode ARCHIVE
        -start "2000 03 01 06 00 00" -end "2000 03 02 06 00 00" -track

StormIdent will start the storm_track program with the "-track" option.

In this manner tracks can be regenerated. It is important to go back to par. 2.4 and verify that the track numbers have not changed, i.e.

influencing the outcome of all the output up to this point.

Alternatively : it may be desirable to perform the analysis for a different tracking threshold. In that case the tracking would need to be re-run for all the data prior to commencing the analysis.

2.8 The TrackMatch utility

This routine forms the heart of the analysis procedure. Given a case as specified in the case_tracks file and a complete Tracks2Ascii output file, the program will proceed to identify the "x" best storm track matches from the "data base" based on one of the following variables - the maximum rate of increase of VOLUME, AREA, MASS or PRECIP_FLUX with the first 20 minutes from the track time-of-origin.

Be wary of the fact that sometimes one of the "x" storms may be another seeded storm. It is VERY IMPORTANT not to contaminate the control storm sample with a seeded case !!

The program usage is as follows :

```
Usage: TrackMatch [options as below]
options:
       [ --, -h, -help, -man ] produce this list.
       [ -check_params ] check parameter usage
       [ -case ? ] case number
       [ -debug ] print debug messages
       [ -prop ?] match_property
         VOLUME, AREA, MASS or PRECIP_FLUX
       [ -f file_paths] input file path list
       [ -mdebug level ] set malloc debug level
       [ -params ?] params file path
       [ -print_params ] print parameters with comments
       [ -print_short ] print parameters - short version
       [ -verbose ] print verbosedebug messages
```

If no parameter file exists create one using the "-print_params" option.

There are a number of parameters in the default parameter file that need to be changed (see Appendix A.2). The "case_file_path" needs to be input, the "time_margin" and "range_margin" may also be set. A -1 value for both disables time and range constraints.

TrackMatch -case 2 -params TrackMatch.test -f outfile > match02.out

You can add the -props to override the specified parameter in the params file. Experience has taught that the -case option may not work off the command line. You will then need to change the case number in the parameter file for each case. TrackMatch needs to be run on a case-by-case basis.

TrackMatch output looks as follows :

```
#  Run time: 2000/05/02 08:51:13
#  case_num: 19
#  case_file_path: /hd/titan5/titan_home/params/case_tracks.tzaneen
#  n_candidates: 20
#  match_property: PRECIP_FLUX
#  time_margin: -1
#  range_margin: -1

#  File name(s):
#    tzaneen_tracks_all

CASE TRACK DATA
  num: 19
  seed_flag: 1
  num_flares: 10
  seed_duration: 1320
  ref_time: 1998/01/21 12:22:00
  ref_minus_start: 0
  end_minus_ref: 6000
  start_time: 1998/01/21 12:22:00
  end_time: 1998/01/21 14:02:00
  complex_track_num: 34
  simple_track_num: 34
  cloud_base: -999
  mixing_ratio: -999
  temp_ccl: -999
  deltat_500mb: -999


Case properties:

    1    34    34 1998  1 21 12 22 44    61.7   -59.3   -26.5    19.2    62.0    25.1    50.1    11.6    17.7     1.7     8.8

Track match array:

    1    34    34 1998  1 21 12 22 44    61.7   -59.3   -26.5    19.2    62.0    25.1    50.1    11.6    17.7     1.7     8.8
    1    16    16 1999 11 27  8 33 49    58.0   -42.6    38.6    13.2    32.6    11.1    24.6     4.7     1.6    -1.4     8.8
    1    32    32 1998  1 29  8 42 28    40.7   -39.9    -4.6    12.8    22.8     5.8    17.1     6.4    22.9     5.4     8.6
```

All the relevant variables are shown in the header. It is useful to print out these files for reference. The first line in the track_match array is always the case itself. The second line is then the best match (i.e. control, make sure it isn't a seeded storm in its own right) that was found.

2.9 Updating the case_tracks file and match verification

Before updating the case_tracks file the matched storm needs to be viewed in rview and time_hist and compared to the case it was matched to. Make sure that the match appears to be a genuine one.

Then for each seeded storm case a corresponding control storm must be entered in the case_tracks file. Typically seeded cases matched using the PRECIP_FLUX are numbered from 500 onwards, i.e the control storm corresponding to case 19 is 519. Now complete enter all the information as required in the case_tracks file based on the TrackMatch output.

Repeat the steps outlined in par. 2.8 and 2.9 for all the type "A" cases.

2.10 The PartialProps utility

The track propeties are computed for the cases by running the program PartialProps. See the parameter file (Appendix A.3) for more details. The most important parameter is the "altitude_threshold". This the altitude cut off for computing the volume_above_alt and mass_above_alt properties.

If no parameter file exists in the params directory create one using the instructions described in par. 1.5.

Under TITAN_HOME a directory called "props_files" needs to be created.

```
Usage: PartialProps [options as below]
options:
       [ --, -h, -help, -man ] produce this list.
       [ -check_params ] check parameter usage
       [ -debug ] print debug messages
       [ -mdebug level ] set malloc debug level
       [ -params ?] params file path
       [ -print_params ] print parameter usage
       [ -print_short ] print short parameter usage
       [ -verbose ] print verbose debug messages
```

For example : PartialProps -params PartialProps.test

For each case PartialProps will create a global properties and a time series properties file. For example, for case 19 the files `global.019` and `tseries.019` will be created.

These files are ASCII, and are needed for the next step in the analysis process. The time series files have one data line per volume scan in the case. The delta times are relative to decision time. These are the actual time series.

Listed below are examples of global and tseries files.

```
*********************************global.019**************************************
num: 19
seed_flag: 1
num_flares: 10
ref_time: 1998 1 21 12 22 0 885385320
seed_duration: 1320
complex_track_num: 34
simple_track_num: 34
cloud_base: -999
mixing_ratio: -999
temp_ccl: -999
deltat_500mb: -999
altitude_threshold: 6
start_time: 1998 1 21 12 22 44 885385364
end_time: 1998 1 21 12 54 15 885387255
start_scan: 18
end_scan: 23
nscans: 6
duration_before_decision: 113
duration_after_decision: 2093
dbz_max_mean: 43.0833
dbz_max_max: 47.5
dbz_max_max_roi: 131.847
precip_flux_mean: 43.183
precip_flux_max: 81.5188
precip_flux_max_roi: 846.186
volume_mean: 54.5
volume_max: 93
volume_max_roi: 859.873
volume_above_alt_mean: 10.6667
volume_above_alt_max: 26.5
volume_above_alt_max_roi: 217.834
mass_mean: 21.7337
mass_max: 41.5942
mass_max_roi: 434.391
mass_above_alt_mean: 3.43503
mass_above_alt_max: 8.80756
mass_above_alt_max_roi: 78.8014
area_mean: 17
area_max: 27
area_max_roi: 217.834
ht_of_dbz_max_mean: 5.33333
ht_of_dbz_max_max: 7
ht_of_dbz_max_max_roi: 0
refl_centroid_z_mean: 4.74077
refl_centroid_z_max: 6.08719
refl_centroid_z_max_roi: -0.0994357
ht_max_minus_centroid_z_mean: 0.592567
ht_max_minus_centroid_z_max: 0.912814
ht_max_minus_centroid_z_max_roi: 2.87965
top_mean: 7.5
top_max: 9.5
top_max_roi: 22.9299
base_max_roi: 0
ATI: 10.8336
precip_mass: 99.8774
VCDI: 0.320041
```

The list of variables in the global file is self-explanatory, except for "roi" meaning "rate of increase", "ht_max_minus_centroid_z" which is the "ht_of_dbz_max" minus "refl_centroid_z" and VCDI is the Vertical Centroid Difference Integral, which is the "ht_max_minus_centroid_z" integrated over time.

```
************************************************************tseries.019************************************************************

nscans: 6
delta_time n_parts dbz_max precip_flux volume mass area ht_of_dbz_max refl_centroid_z ht_max_minus_centroid_z base top volume_above_alt
mass_above_alt ATI precip_mass VCDI
    44   1  36.0   7.7126  15.0000   3.7056   6.0000  7.000  6.087   0.9128  4.500  7.500   7.5000   1.9343     0.33     1.55   0.0510
   358   1  47.5  81.5188  90.0000  41.5942  25.0000  5.000  4.731   0.2692  2.500  9.500  26.5000   8.8076     2.52    27.15   0.0744
   672   1  47.0  75.4545  93.0000  38.4183  27.0000  5.000  4.580   0.4199  2.500  7.500  16.5000   5.8892     6.06    62.76   0.1295
  1303   1  42.5  46.3794  65.0000  23.9072  21.0000  5.000  4.563   0.4373  2.500  7.500  10.0000   3.1691     8.81    84.70   0.1870
  1619   1  47.0  39.2659  47.0000  18.0269  17.0000  5.000  4.310   0.6901  2.500  6.500   3.0000   0.7086    10.31    97.11   0.2475
  1935   1  38.5   8.7666  17.0000   4.7500   6.0000  5.000  4.174   0.8261  2.500  6.500   0.5000   0.1014    10.83    99.88   0.3200
```

2.9 Calculating the statistics using CaseStats

CaseStats uses the property files generated by PartialProps. It produces statistics on the differences between the seed and control cases. Optionally you can run the re-randomization option to produce p-factors. The program also used the case_tracks file.

If no parameter file exists in the params directory create one using the instructions described in par. 1.5. See also Appendix A.4 for an example file.

```
Usage: CaseStats [options as below]
options:
       [ --, -h, -help, -man ] produce this list.
       [ -arith ] arithmetic means
       [ -check_params ] check parameter usage
       [ -debug ] print debug messages
       [ -geom ] geometric means
       [ -interp ] write interp tseries files
       [ -mdebug level ] set malloc debug level
       [ -params ?] params file path
       [ -print_params ] print parameter usage
       [ -print_short ] print short parameter usage
       [ -quart1 ] first quartile
       [ -quart2 ] second quartile
       [ -quart3 ] third quartile
       [ -verbose ] print verbose debug messages
       [ -zeros ] use 0 instead of missing value when
                  no storm exists at the interp time

NOTE: -arith, -geom, -quart1, -quart2, -quart3 are
      mutually exclusive
```

For example :
CaseStats -quart1 -interp -params CaseStats.new -zeros > quart1.out

The case tracks file contains the list of cases that are to be analysed. The case tracks file also contains the time window of the time series that is to be analysed.

When the "-interp" command is invoked the interpolated time series is written to a file in the props_files directory, e.g. interp.019, in the same format as the raw time series. These interpolated time series may be useful for other analysis purposes or to plot and compare different storms (i.e. the time scale is comparable).

Here is an example interp file.

```
****************************************************************interp.019*********************************************************************

ntimes: 23
dbz_max precip_flux volume mass area ht_of_dbz_max refl_centroid_z ht_max_minus_centroid_z volume_above_alt mass_above_alt ATI VCDI precip_mass
 -600    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 -300    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
  300   45.3758   67.8858   76.1465   34.5957   21.4904    5.3694    4.9815    0.3881   22.9904    7.5380    2.1155    0.0701   22.4213
  600   47.1146   76.8450   92.3121   39.1465   26.5414    5.0000    4.6146    0.3853   18.7930    6.5584    5.2483    0.1169   54.5946
  900   45.3740   64.9488   82.8827   33.1750   24.8320    5.0000    4.5739    0.4262   14.1513    4.9063    7.0537    0.1503   70.6876
 1200   43.2345   51.1254   69.5705   26.2759   21.9794    5.0000    4.5658    0.4345   11.0610    3.6131    8.3611    0.1776   81.1187
 1500   45.3054   41.9447   53.7785   20.2413   18.5063    5.0000    4.4053    0.5949    5.6361    1.6352    9.7451    0.2247   92.4366
 1800   42.1313   21.7964   29.8165   10.4221   10.6994    5.0000    4.2321    0.7680    1.5680    0.3608   10.6078    0.2890   98.6966
 2100    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 2400    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 2700    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 3000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 3300    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 3600    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 3900    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 4200    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 4500    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 4800    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5100    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5400    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 5700    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
 6000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
```

Other constraining conditions may be placed on the analysis. These are specified as follows :

```
conditions = {
       {
         "volume@0, /* prop_name:string */
         0.0        /* min_val:double */
         750.0      /* max_val:double */
       }
};
```

This statement would only include those cases with volumes at time 0 (decision time) between 0 and 750 km3. The "@" in the property name indicates a time series property at a number of minutes relative to decision time. If no "@" exists in the property name it is assumed to be a global property.

The analysis can be based on the following statistics :
- arithmetic means
- geometric means
- first, second (median) or third quartiles

These can be entered at the command line or specified in the parameter file.

If the rerandomization option is chosen, then the case number and the worst split are also specified.

Below is an example of a CaseStats output file without rerandomization.

```
Program CaseStats, run at Tue May  2 09:01:08 2000
==================================================


STAT TYPE: THIRD_QUARTILE

Using ZERO when no storm exists at interp time

Performing rerandomization:

    n_rerand:       1000
    n_random_list:   200
    max_split:         7

Conditional properties:

                 Property name    Min-val    Max-val
                 seed_duration      0.000   3600.000


Using cases:   2  10  12  14  16  17  19  20  23  24  30  34  38  39  43
              44  45  46  47  48  49  51  53  54 502 510 512 514 516 517
             519 520 523 524 530 534 538 539 543 544 545 546 547 548 549
             551 553 554

                   Property name n_seed n_no_seed  stat_seed stat_no_seed diff_in_stats     % diff    Pfactor
                                 ====== =========  ========= ============ =============      =====    =======

Global properties
=================

                      cloud_base     0        0     -999.000     -999.000      -999.000     -999.0
                    mixing_ratio     0        0     -999.000     -999.000      -999.000     -999.0
                        temp_ccl     0        0     -999.000     -999.000      -999.000     -999.0
                    deltat_500mb     0        0     -999.000     -999.000      -999.000     -999.0
                          nscans    24       24       18.250       12.250         6.000       49.0       96.7
                   seed_duration    24       24     1935.000        0.000      1935.000        0.0      100.0
        duration_before_decision    24       24      145.750      164.750       -19.000      -11.5        2.3
         duration_after_decision    24         24   4964.750     3354.000      1610.750       48.0       91.2
                    dbz_max_mean    24         24     51.155       49.650         1.505        3.0       80.2
                     dbz_max_max    24         24     58.250       57.125         1.125        2.0       65.1
                 dbz_max_max_roi    24         24    137.903      111.073        26.830       24.2       84.0
               precip_flux_mean    24         24    348.443      197.877       150.566       76.1       95.7
                precip_flux_max    24         24    691.111      440.771       250.340       56.8       83.9
            precip_flux_max_roi    24         24   4028.033     2703.050      1324.983       49.0       81.1
                     volume_mean    24         24    252.938      210.896        42.043       19.9       65.9
                      volume_max    24         24    426.250      338.500        87.750       25.9       69.7
                  volume_max_roi    24         24   2155.625     1621.365       534.260       33.0       71.2
           volume_above_alt_mean    24         24    103.617       90.755        12.862       14.2       58.3
            volume_above_alt_max    24         24    202.375      195.375         7.000        3.6       53.1
        volume_above_alt_max_roi    24         24    973.820      892.682        81.138        9.1       56.1
                       mass_mean    24         24    142.394      100.104        42.290       42.2       82.5
                        mass_max    24         24    294.574      174.033       120.541       69.3       87.1
                    mass_max_roi    24         24   1486.773     1173.643       313.130       26.7       76.6
             mass_above_alt_mean    24         24     43.166       39.305         3.861        9.8       55.9
              mass_above_alt_max    24         24    106.948       77.899        29.048       37.3       64.9
          mass_above_alt_max_roi    24         24    733.619      418.275       315.344       75.4       69.7
                       area_mean    24         24     59.570       60.798        -1.228       -2.0       49.7
                        area_max    24         24     96.500      124.000       -27.500      -22.2       35.7
                    area_max_roi    24         24    428.051      535.100      -107.049      -20.0       32.8
              ht_of_dbz_max_mean    24         24      4.424        5.132        -0.708      -13.8        0.9
               ht_of_dbz_max_max    24         24      7.000        8.000        -1.000      -12.5        3.1
           ht_of_dbz_max_max_roi    24         24     31.441       22.240         9.201       41.4       73.6
             refl_centroid_z_mean    24         24      4.899        5.567        -0.668      -12.0        5.8
              refl_centroid_z_max    24         24      6.056        7.380        -1.324      -17.9        4.1
          refl_centroid_z_max_roi    24         24      7.767        9.436        -1.669      -17.7       35.1
    ht_max_minus_centroid_z_mean    24         24      0.077        0.351        -0.274      -78.0       14.8
     ht_max_minus_centroid_z_max    24         24      1.187        1.337        -0.150      -11.2       32.6
 ht_max_minus_centroid_z_max_roi    24         24     28.383       22.026         6.357       28.9       79.1
                        top_mean    24         24     10.182       10.050         0.132        1.3       53.6
                         top_max    24         24     12.500       12.500         0.000        0.0       50.1
                     top_max_roi    24         24     31.304       23.753         7.551       31.8       80.3
                    base_max_roi    24         24      0.000       11.009       -11.009     -100.0        6.8
                             ATI    24         24     95.131       63.352        31.778       50.2       83.4
                     precip_mass    24         24   1985.492      640.086      1345.406      210.2       96.7
                            VCDI    24         24      0.004        0.210        -0.206      -98.3       16.3

Time series property: dbz_max
=============================

                     dbz_max@-10    24         24      0.000        0.000         0.000        0.0
                     dbz_max@ -5    24         24      0.000        0.000         0.000        0.0
```

```
                dbz_max@  0     24        24     42.000      43.375       -1.375       -3.2       11.1
                dbz_max@  5     24        24     48.798      49.788       -0.990       -2.0       30.6
                dbz_max@ 10     24        24     52.716      51.962        0.754        1.5       59.0
                dbz_max@ 15     24        24     53.478      52.841        0.636        1.2       59.1
                dbz_max@ 20     24        24     53.558      52.418        1.140        2.2       67.3
                dbz_max@ 25     24        24     53.172      52.736        0.435        0.8       54.5
                dbz_max@ 30     24        24     51.607      50.738        0.869        1.7       74.2
                dbz_max@ 35     24        24     50.382      47.184        3.198        6.8       96.2
                dbz_max@ 40     24        24     49.731      46.019        3.713        8.1       96.8
                dbz_max@ 45     24        24     50.209      47.207        3.002        6.4       86.7
                dbz_max@ 50     24        24     50.145      38.585       11.560       30.0       95.7
                dbz_max@ 55     24        24     48.791       0.000       48.791        0.0       94.2
                dbz_max@ 60     24        24     48.121       0.000       48.121        0.0       91.8
                dbz_max@ 65     24        24     47.262       0.000       47.262        0.0       90.9
                dbz_max@ 70     24        24     41.554       0.000       41.554        0.0       81.9
                dbz_max@ 75     24        24      9.109       0.000        9.109        0.0       76.0
                dbz_max@ 80     24        24      0.000       0.000        0.000        0.0       49.3
                dbz_max@ 85     24        24      0.000       0.000        0.000        0.0       49.3
                dbz_max@ 90     24        24      0.000       0.000        0.000        0.0       55.7
                dbz_max@ 95     24        24      0.000       0.000        0.000        0.0
                dbz_max@100     24        24      0.000       0.000        0.000        0.0

Time series property: precip_flux
=================================

            precip_flux@-10     24        24      0.000       0.000        0.000        0.0
            precip_flux@ -5     24        24      0.000       0.000        0.000        0.0
            precip_flux@  0     24        24     26.866      51.880      -25.014      -48.2        9.3
            precip_flux@  5     24        24    127.651     156.620      -28.969      -18.5       21.5
            precip_flux@ 10     24        24    253.002     263.839      -10.837       -4.1       45.1
            precip_flux@ 15     24        24    307.594     288.175       19.419        6.7       60.8
            precip_flux@ 20     24        24    367.626     319.128       48.497       15.2       67.1
            precip_flux@ 25     24        24    534.294     316.837      217.457       68.6       87.2
            precip_flux@ 30     24        24    473.563     219.178      254.385      116.1       90.6
            precip_flux@ 35     24        24    421.881     198.425      223.456      112.6       95.8
            precip_flux@ 40     24        24    381.091     195.547      185.545       94.9       90.8
            precip_flux@ 45     24        24    425.488     182.018      243.470      133.8       90.9
            precip_flux@ 50     24        24    250.713      60.480      190.232      314.5       90.9
            precip_flux@ 55     24        24    178.710       0.000      178.710        0.0       84.1
            precip_flux@ 60     24        24    182.483       0.000      182.483        0.0       84.6
            precip_flux@ 65     24        24    147.547       0.000      147.547        0.0       84.4
            precip_flux@ 70     24        24     74.939       0.000       74.939        0.0       79.1
            precip_flux@ 75     24        24      4.355       0.000        4.355        0.0       76.0
            precip_flux@ 80     24        24      0.000       0.000        0.000        0.0       49.3
            precip_flux@ 85     24        24      0.000       0.000        0.000        0.0       49.3
            precip_flux@ 90     24        24      0.000       0.000        0.000        0.0       55.7
            precip_flux@ 95     24        24      0.000       0.000        0.000        0.0
            precip_flux@100     24        24      0.000       0.000        0.000        0.0

Time series property: volume
============================

                 volume@-10     24        24      0.000       0.000        0.000        0.0
                 volume@ -5     24        24      0.000       0.000        0.000        0.0
                 volume@  0     24        24     45.250      72.000      -26.750      -37.2        7.4
                 volume@  5     24        24    130.413     132.338       -1.926       -1.5       48.0
                 volume@ 10     24        24    171.929     177.281       -5.352       -3.0       43.5
                 volume@ 15     24        24    204.634     206.713       -2.079       -1.0       48.9
                 volume@ 20     24        24    219.032     200.418       18.614        9.3       61.5
                 volume@ 25     24        24    354.215     177.518      176.697       99.5       87.8
                 volume@ 30     24        24    357.034     180.770      176.264       97.5       90.4
                 volume@ 35     24        24    346.941     208.100      138.841       66.7       76.1
                 volume@ 40     24        24    306.725     213.341       93.384       43.8       76.3
                 volume@ 45     24        24    236.476     198.584       37.893       19.1       71.2
                 volume@ 50     24        24    230.691      66.642      164.049      246.2       92.2
                 volume@ 55     24        24    214.730       0.000      214.730        0.0       94.2
                 volume@ 60     24        24    217.861       0.000      217.861        0.0       96.6
                 volume@ 65     24        24    137.912       0.000      137.912        0.0       87.8
                 volume@ 70     24        24    116.292       0.000      116.292        0.0       90.1
                 volume@ 75     24        24     10.721       0.000       10.721        0.0       76.0
                 volume@ 80     24        24      0.000       0.000        0.000        0.0       49.3
                 volume@ 85     24        24      0.000       0.000        0.000        0.0       49.3
                 volume@ 90     24        24      0.000       0.000        0.000        0.0       55.7
                 volume@ 95     24        24      0.000       0.000        0.000        0.0
                 volume@100     24        24      0.000       0.000        0.000        0.0

Time series property: mass
==========================

                   mass@-10     24        24      0.000       0.000        0.000        0.0
                   mass@ -5     24        24      0.000       0.000        0.000        0.0
                   mass@  0     24        24     14.021      23.649       -9.628      -40.7        9.5
                   mass@  5     24        24     68.776      76.059       -7.283       -9.6       42.5
                   mass@ 10     24        24    133.537     109.293       24.244       22.2       76.4
                   mass@ 15     24        24    161.727     107.155       54.572       50.9       82.4
                   mass@ 20     24        24    166.552     118.455       48.097       40.6       79.6
                   mass@ 25     24        24    182.729     131.892       50.837       38.5       82.7
                   mass@ 30     24        24    196.877     102.280       94.597       92.5       92.0
                   mass@ 35     24        24    184.015     103.596       80.418       77.6       90.8
                   mass@ 40     24        24    166.205     111.079       55.126       49.6       80.4
                   mass@ 45     24        24    156.252      77.420       78.833      101.8       89.6
                   mass@ 50     24        24    129.888      30.077       99.811      331.9       92.7
```

```
                 mass@ 55     24         24      94.902        0.000       94.902       0.0       88.2
                 mass@ 60     24         24     108.199        0.000      108.199       0.0       96.4
                 mass@ 65     24         24      71.656        0.000       71.656       0.0       87.6
                 mass@ 70     24         24      36.045        0.000       36.045       0.0       80.9
                 mass@ 75     24         24       2.470        0.000        2.470       0.0       76.0
                 mass@ 80     24         24       0.000        0.000        0.000       0.0       49.3
                 mass@ 85     24         24       0.000        0.000        0.000       0.0       49.3
                 mass@ 90     24         24       0.000        0.000        0.000       0.0       55.7
                 mass@ 95     24         24       0.000        0.000        0.000       0.0
                 mass@100     24         24       0.000        0.000        0.000       0.0

Time series property: area
==========================

                 area@-10     24         24       0.000        0.000        0.000       0.0
                 area@ -5     24         24       0.000        0.000        0.000       0.0
                 area@  0     24         24      13.500       22.250       -8.750     -39.3        6.8
                 area@  5     24         24      40.401       47.005       -6.604     -14.1       38.3
                 area@ 10     24         24      54.456       53.281        1.175       2.2       53.0
                 area@ 15     24         24      60.846       57.629        3.217       5.6       60.7
                 area@ 20     24         24      66.426       69.190       -2.764      -4.0       45.8
                 area@ 25     24         24      78.270       68.325        9.946      14.6       70.6
                 area@ 30     24         24      76.770       66.057       10.713      16.2       77.3
                 area@ 35     24         24      75.577       59.854       15.723      26.3       74.6
                 area@ 40     24         24      77.828       69.225        8.603      12.4       67.1
                 area@ 45     24         24      73.997       64.966        9.031      13.9       65.6
                 area@ 50     24         24      56.891       24.329       32.562     133.8       89.6
                 area@ 55     24         24      48.672        0.000       48.672       0.0       86.8
                 area@ 60     24         24      53.325        0.000       53.325       0.0       90.7
                 area@ 65     24         24      42.804        0.000       42.804       0.0       80.5
                 area@ 70     24         24      42.569        0.000       42.569       0.0       82.7
                 area@ 75     24         24       3.597        0.000        3.597       0.0       76.0
                 area@ 80     24         24       0.000        0.000        0.000       0.0       49.3
                 area@ 85     24         24       0.000        0.000        0.000       0.0       49.3
                 area@ 90     24         24       0.000        0.000        0.000       0.0       55.7
                 area@ 95     24         24       0.000        0.000        0.000       0.0
                 area@100     24         24       0.000        0.000        0.000       0.0

Time series property: ht_of_dbz_max
===================================

        ht_of_dbz_max@-10     24         24       0.000        0.000        0.000       0.0
        ht_of_dbz_max@ -5     24         24       0.000        0.000        0.000       0.0
        ht_of_dbz_max@  0     24         24       5.250        7.250       -2.000     -27.6        0.7
        ht_of_dbz_max@  5     24         24       5.000        6.030       -1.030     -17.1        2.4
        ht_of_dbz_max@ 10     24         24       4.831        5.000       -0.169      -3.4       22.8
        ht_of_dbz_max@ 15     24         24       4.925        5.000       -0.075      -1.5       28.8
        ht_of_dbz_max@ 20     24         24       4.608        5.000       -0.392      -7.8       14.4
        ht_of_dbz_max@ 25     24         24       5.000        5.000        0.000       0.0       52.1
        ht_of_dbz_max@ 30     24         24       4.634        5.000       -0.366      -7.3       31.2
        ht_of_dbz_max@ 35     24         24       4.034        5.041       -1.007     -20.0        8.2
        ht_of_dbz_max@ 40     24         24       4.000        5.000       -1.000     -20.0        6.4
        ht_of_dbz_max@ 45     24         24       3.497        4.039       -0.542     -13.4       35.1
        ht_of_dbz_max@ 50     24         24       3.971        3.000        0.971      32.4       74.2
        ht_of_dbz_max@ 55     24         24       3.974        0.000        3.974       0.0       96.2
        ht_of_dbz_max@ 60     24         24       3.864        0.000        3.864       0.0       94.3
        ht_of_dbz_max@ 65     24         24       3.505        0.000        3.505       0.0       90.1
        ht_of_dbz_max@ 70     24         24       3.223        0.000        3.223       0.0       89.3
        ht_of_dbz_max@ 75     24         24       0.750        0.000        0.750       0.0       75.8
        ht_of_dbz_max@ 80     24         24       0.000        0.000        0.000       0.0       49.3
        ht_of_dbz_max@ 85     24         24       0.000        0.000        0.000       0.0       49.3
        ht_of_dbz_max@ 90     24         24       0.000        0.000        0.000       0.0       55.7
        ht_of_dbz_max@ 95     24         24       0.000        0.000        0.000       0.0
        ht_of_dbz_max@100     24         24       0.000        0.000        0.000       0.0

Time series property: refl_centroid_z
=====================================

      refl_centroid_z@-10     24         24       0.000        0.000        0.000       0.0
      refl_centroid_z@ -5     24         24       0.000        0.000        0.000       0.0
      refl_centroid_z@  0     24         24       5.304        7.057       -1.753     -24.8        1.3
      refl_centroid_z@  5     24         24       4.944        5.402       -0.458      -8.5        3.9
      refl_centroid_z@ 10     24         24       4.926        5.374       -0.448      -8.3       15.3
      refl_centroid_z@ 15     24         24       4.853        5.047       -0.195      -3.9       31.2
      refl_centroid_z@ 20     24         24       5.007        5.246       -0.239      -4.5       28.5
      refl_centroid_z@ 25     24         24       4.959        4.732        0.227       4.8       65.8
      refl_centroid_z@ 30     24         24       4.790        4.694        0.096       2.0       58.3
      refl_centroid_z@ 35     24         24       4.656        4.665       -0.009      -0.2       48.1
      refl_centroid_z@ 40     24         24       4.753        4.573        0.180       3.9       57.6
      refl_centroid_z@ 45     24         24       4.693        4.441        0.252       5.7       71.9
      refl_centroid_z@ 50     24         24       4.234        3.787        0.447      11.8       78.7
      refl_centroid_z@ 55     24         24       4.399        0.000        4.399       0.0       95.9
      refl_centroid_z@ 60     24         24       4.730        0.000        4.730       0.0       97.7
      refl_centroid_z@ 65     24         24       4.815        0.000        4.815       0.0       96.6
      refl_centroid_z@ 70     24         24       4.127        0.000        4.127       0.0       92.7
      refl_centroid_z@ 75     24         24       1.088        0.000        1.088       0.0       79.1
      refl_centroid_z@ 80     24         24       0.000        0.000        0.000       0.0       49.3
      refl_centroid_z@ 85     24         24       0.000        0.000        0.000       0.0       49.3
      refl_centroid_z@ 90     24         24       0.000        0.000        0.000       0.0       55.7
      refl_centroid_z@ 95     24         24       0.000        0.000        0.000       0.0
      refl_centroid_z@100     24         24       0.000        0.000        0.000       0.0
```

```
Time series property: ht_max_minus_centroid_z
=============================================

     ht_max_minus_centroid_z@-10     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@ -5     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@  0     24        24      0.000        0.685        -0.685    -100.0        0.3
     ht_max_minus_centroid_z@  5     24        24      0.080        0.380        -0.300     -79.1       18.8
     ht_max_minus_centroid_z@ 10     24        24      0.020        0.139        -0.119     -85.9       32.6
     ht_max_minus_centroid_z@ 15     24        24      0.237        0.053         0.184     347.4       77.0
     ht_max_minus_centroid_z@ 20     24        24      0.089        0.298        -0.209     -70.0       36.0
     ht_max_minus_centroid_z@ 25     24        24      0.107        0.391        -0.285     -72.7       29.6
     ht_max_minus_centroid_z@ 30     24        24      0.387        0.270         0.117      43.5       73.3
     ht_max_minus_centroid_z@ 35     24        24      0.107        0.502        -0.395     -78.7       11.3
     ht_max_minus_centroid_z@ 40     24        24      0.000        0.255        -0.255    -100.0        9.7
     ht_max_minus_centroid_z@ 45     24        24      0.000        0.000         0.000       0.0       66.7
     ht_max_minus_centroid_z@ 50     24        24      0.000        0.000         0.000       0.0       56.9
     ht_max_minus_centroid_z@ 55     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@ 60     24        24      0.000        0.000         0.000       0.0       41.7
     ht_max_minus_centroid_z@ 65     24        24      0.000        0.000         0.000       0.0       52.4
     ht_max_minus_centroid_z@ 70     24        24      0.000        0.000         0.000       0.0      100.0
     ht_max_minus_centroid_z@ 75     24        24      0.000        0.000         0.000       0.0      100.0
     ht_max_minus_centroid_z@ 80     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@ 85     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@ 90     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@ 95     24        24      0.000        0.000         0.000       0.0
     ht_max_minus_centroid_z@100     24        24      0.000        0.000         0.000       0.0

Time series property: volume_above_alt
======================================

            volume_above_alt@-10     24        24      0.000        0.000         0.000       0.0
            volume_above_alt@ -5     24        24      0.000        0.000         0.000       0.0
            volume_above_alt@  0     24        24     11.625       32.250       -20.625     -64.0        7.5
            volume_above_alt@  5     24        24     38.895       55.441       -16.546     -29.8       29.5
            volume_above_alt@ 10     24        24     38.725       61.789       -23.064     -37.3       25.1
            volume_above_alt@ 15     24        24     75.734       50.039        25.696      51.4       72.5
            volume_above_alt@ 20     24        24     87.279       43.463        43.815     100.8       78.7
            volume_above_alt@ 25     24        24    155.139       58.808        96.330     163.8       76.8
            volume_above_alt@ 30     24        24    159.615       50.643       108.972     215.2       75.2
            volume_above_alt@ 35     24        24    144.054       49.216        94.838     192.7       80.7
            volume_above_alt@ 40     24        24     95.334       47.612        47.723     100.2       73.0
            volume_above_alt@ 45     24        24     72.852       37.692        35.161      93.3       70.3
            volume_above_alt@ 50     24        24     72.237        5.304        66.933    1261.8       90.1
            volume_above_alt@ 55     24        24     69.195        0.000        69.195       0.0       93.0
            volume_above_alt@ 60     24        24     70.700        0.000        70.700       0.0       91.5
            volume_above_alt@ 65     24        24     40.583        0.000        40.583       0.0       89.7
            volume_above_alt@ 70     24        24     18.193        0.000        18.193       0.0       89.4
            volume_above_alt@ 75     24        24      0.999        0.000         0.999       0.0       87.2
            volume_above_alt@ 80     24        24      0.000        0.000         0.000       0.0       51.7
            volume_above_alt@ 85     24        24      0.000        0.000         0.000       0.0       51.7
            volume_above_alt@ 90     24        24      0.000        0.000         0.000       0.0       55.7
            volume_above_alt@ 95     24        24      0.000        0.000         0.000       0.0
            volume_above_alt@100     24        24      0.000        0.000         0.000       0.0

Time series property: mass_above_alt
====================================

              mass_above_alt@-10     24        24      0.000        0.000         0.000       0.0
              mass_above_alt@ -5     24        24      0.000        0.000         0.000       0.0
              mass_above_alt@  0     24        24      3.156        7.720        -4.565     -59.1       18.5
              mass_above_alt@  5     24        24     14.860       29.177       -14.317     -49.1       25.3
              mass_above_alt@ 10     24        24     15.704       32.613       -16.909     -51.8       24.6
              mass_above_alt@ 15     24        24     26.539       16.553         9.985      60.3       79.9
              mass_above_alt@ 20     24        24     33.449       19.162        14.287      74.6       72.2
              mass_above_alt@ 25     24        24     50.487       17.619        32.868     186.6       73.4
              mass_above_alt@ 30     24        24     51.196       16.951        34.245     202.0       74.0
              mass_above_alt@ 35     24        24     51.066       20.889        30.177     144.5       78.8
              mass_above_alt@ 40     24        24     28.321       17.737        10.584      59.7       64.2
              mass_above_alt@ 45     24        24     31.647       17.414        14.233      81.7       63.3
              mass_above_alt@ 50     24        24     31.258        1.386        29.872    2155.7       92.3
              mass_above_alt@ 55     24        24     21.884        0.000        21.884       0.0       91.0
              mass_above_alt@ 60     24        24     24.789        0.000        24.789       0.0       91.5
              mass_above_alt@ 65     24        24     12.620        0.000        12.620       0.0       89.3
              mass_above_alt@ 70     24        24      4.293        0.000         4.293       0.0       88.6
              mass_above_alt@ 75     24        24      0.218        0.000         0.218       0.0       87.2
              mass_above_alt@ 80     24        24      0.000        0.000         0.000       0.0       51.7
              mass_above_alt@ 85     24        24      0.000        0.000         0.000       0.0       51.7
              mass_above_alt@ 90     24        24      0.000        0.000         0.000       0.0       55.7
              mass_above_alt@ 95     24        24      0.000        0.000         0.000       0.0
              mass_above_alt@100     24        24      0.000        0.000         0.000       0.0

Time series property: ATI
=========================

                         ATI@-10     24        24      0.000        0.000         0.000       0.0
                         ATI@ -5     24        24      0.000        0.000         0.000       0.0
                         ATI@  0     24        24      0.438        0.990        -0.552     -55.8        1.8
                         ATI@  5     24        24      4.923        4.309         0.615      14.3       58.5
                         ATI@ 10     24        24      9.150        9.159        -0.010      -0.1       49.7
                         ATI@ 15     24        24     14.351       13.584         0.767       5.6       64.8
                         ATI@ 20     24        24     19.987       19.191         0.796       4.1       61.4
                         ATI@ 25     24        24     25.132       26.265        -1.133      -4.3       43.6
```

ATI@ 30	24	24	31.133	31.195	-0.062	-0.2	51.7
ATI@ 35	24	24	37.105	39.225	-2.120	-5.4	43.7
ATI@ 40	24	24	44.580	43.970	0.610	1.4	54.9
ATI@ 45	24	24	52.051	42.401	9.650	22.8	72.4
ATI@ 50	24	24	58.276	28.100	30.176	107.4	94.9
ATI@ 55	24	24	56.536	0.000	56.536	0.0	96.4
ATI@ 60	24	24	58.983	0.000	58.983	0.0	93.6
ATI@ 65	24	24	64.564	0.000	64.564	0.0	95.4
ATI@ 70	24	24	49.987	0.000	49.987	0.0	81.8
ATI@ 75	24	24	11.131	0.000	11.131	0.0	76.0
ATI@ 80	24	24	0.000	0.000	0.000	0.0	49.3
ATI@ 85	24	24	0.000	0.000	0.000	0.0	49.3
ATI@ 90	24	24	0.000	0.000	0.000	0.0	55.7
ATI@ 95	24	24	0.000	0.000	0.000	0.0	
ATI@100	24	24	0.000	0.000	0.000	0.0	

Time series property: VCDI
==========================

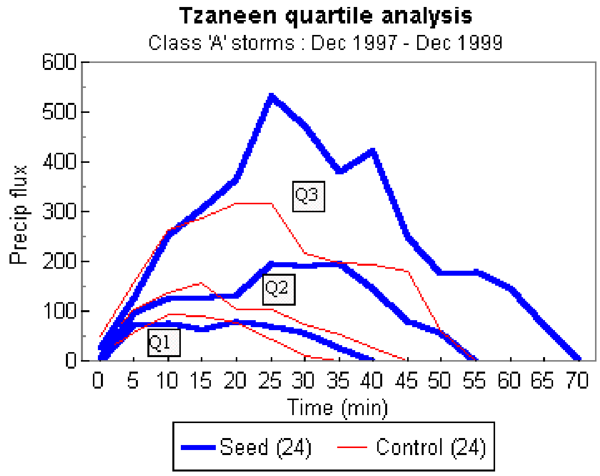
VCDI@-10	24	24	0.000	0.000	0.000	0.0	
VCDI@ -5	24	24	0.000	0.000	0.000	0.0	
VCDI@ 0	24	24	0.000	0.031	-0.031	-100.0	0.1
VCDI@ 5	24	24	0.011	0.053	-0.043	-80.2	10.6
VCDI@ 10	24	24	0.008	0.048	-0.041	-84.4	12.3
VCDI@ 15	24	24	0.004	0.050	-0.046	-92.6	15.8
VCDI@ 20	24	24	0.007	0.075	-0.069	-91.2	22.1
VCDI@ 25	24	24	0.004	0.094	-0.089	-95.2	17.6
VCDI@ 30	24	24	0.038	0.045	-0.007	-15.7	47.6
VCDI@ 35	24	24	0.000	0.035	-0.035	-100.0	20.9
VCDI@ 40	24	24	0.000	0.032	-0.032	-100.0	15.5
VCDI@ 45	24	24	0.000	0.000	0.000	0.0	20.0
VCDI@ 50	24	24	0.000	0.000	0.000	0.0	
VCDI@ 55	24	24	0.000	0.000	0.000	0.0	
VCDI@ 60	24	24	0.000	0.000	0.000	0.0	
VCDI@ 65	24	24	0.000	0.000	0.000	0.0	
VCDI@ 70	24	24	0.000	0.000	0.000	0.0	
VCDI@ 75	24	24	0.000	0.000	0.000	0.0	
VCDI@ 80	24	24	0.000	0.000	0.000	0.0	
VCDI@ 85	24	24	0.000	0.000	0.000	0.0	
VCDI@ 90	24	24	0.000	0.000	0.000	0.0	
VCDI@ 95	24	24	0.000	0.000	0.000	0.0	
VCDI@100	24	24	0.000	0.000	0.000	0.0	

Time series property: precip_mass
==================================

precip_mass@-10	24	24	0.000	0.000	0.000	0.0	
precip_mass@ -5	24	24	0.000	0.000	0.000	0.0	
precip_mass@ 0	24	24	3.117	9.210	-6.093	-66.2	10.8
precip_mass@ 5	24	24	59.094	56.458	2.635	4.7	55.8
precip_mass@ 10	24	24	139.904	142.723	-2.819	-2.0	42.8
precip_mass@ 15	24	24	218.301	238.236	-19.935	-8.4	43.5
precip_mass@ 20	24	24	336.521	306.460	30.061	9.8	59.9
precip_mass@ 25	24	24	533.242	375.265	157.977	42.1	82.5
precip_mass@ 30	24	24	690.913	434.725	256.188	58.9	88.0
precip_mass@ 35	24	24	855.191	507.352	347.839	68.6	90.2
precip_mass@ 40	24	24	880.307	511.022	369.285	72.3	91.1
precip_mass@ 45	24	24	792.048	412.024	380.024	92.2	87.7
precip_mass@ 50	24	24	979.362	393.286	586.077	149.0	86.9
precip_mass@ 55	24	24	903.607	0.000	903.607	0.0	93.7
precip_mass@ 60	24	24	1021.139	0.000	1021.139	0.0	91.3
precip_mass@ 65	24	24	924.202	0.000	924.202	0.0	83.8
precip_mass@ 70	24	24	526.089	0.000	526.089	0.0	79.7
precip_mass@ 75	24	24	83.240	0.000	83.240	0.0	76.0
precip_mass@ 80	24	24	0.000	0.000	0.000	0.0	49.3
precip_mass@ 85	24	24	0.000	0.000	0.000	0.0	49.3
precip_mass@ 90	24	24	0.000	0.000	0.000	0.0	55.7
precip_mass@ 95	24	24	0.000	0.000	0.000	0.0	
precip_mass@100	24	24	0.000	0.000	0.000	0.0	

2.11 Evaluating the results

The ASCII output from all these programs can be imported into a spread sheet program and manipulated further for graphing purposes etc. As has been mentioned previously the results obtained from this analysis can not be considered to be statistically creditable. However the do allow an objective means of determining the differences between so-called natural and seeded storms and in some cases differences in response to different seeding agents.



The figure above is an example of the type of graph that can be produced from the analysis.

2.12 The TrackGridStats utility

Another very handy tool is the TrackGridStats utility. It allows for the compilation of a local storm climatology over various time scales that can be displayed in rview. It provides insight into storm motion on a monthly and seasonal scale. This facilitates climatological differences between different seasons and is handy for planning purposes as well.

The usage is as follows :

```
Usage: TrackGridStats [options as below]
options:
       [ --, -h, -help, -man ] produce this list.
       [ -check_params ] check parameter usage
       [ -debug ] print debug messages
       [ -f file_paths] set file paths for analysis
       [ -mdebug level ] set malloc debug level
       [ -model ] use model track data files (overrides -titan)
       [ -params ?] params file path
       [ -print_params ] print parameter usage
       [ -print_short ] print short parameter usage
       [ -titan ] use TITAN track data files (default)
       [ -verbose ] print verbose debug messages
```

If no parameter file exists create one using the "-print_params" option as described in par. 1.5. A grid_stats directory needs to be created under $TITAN_HOME. In the parameter file the latitude-longitude position of the radar installation as well as the TITAN domain particulars need to be entered.

Typically :
 TrackGridStats -params TrackGridStats.test -f ../storms/200001*.th5

This will process all the January 2000 tracks.

To display these fields a separate rview parameter file and MDV_server parameter file need to be created. It is easiest to copy some existing files, giving them a ".grid_stats" extension. In Appendices A.6 and A.7 these files are shown.

3. Final Remarks

I hope that this manual has been helpful and that the results are all you had hoped they would be. This is quite a complex process but it succeeds or fails depending on the input data provided. It stands to reason that the better the input data the better the results are likely to be.

My thanks to Mike Dixon for his valuable assistance and training through the years. This is for you Mike.

References

Dixon M. J. and G. Wiener (1993). Thunderstorm Identification Tracking Analysis and Nowcasting A radar-based methodology.
J. Atmos. Ocean. Tech., **10(6)**, 785-797.

Terblanche D.E., F.E. Steffens, L. Fletcher, M.P. Mittermaier and R.C. Parsons, 1999: Towards the operational application of hygroscopic flares for rainfall enhancement in South Africa.
Accepted for publication in *J. Appl. Meteor*.

APPENDIX A

Appendix A.1

```
/**********************************************************************
 * TDRP params for Tracks2Ascii
 **********************************************************************/

///////////// debug //////////////////////////////////
//
// Debug option.
// If set, debug messages will be printed with the appropriate level of
//   detail.
//
// Type: enum
// Options:
//   DEBUG_OFF, DEBUG_WARNINGS, DEBUG_NORM, DEBUG_VERBOSE
//
//

debug = DEBUG_OFF;

///////////// malloc_debug_level //////////////////////
//
// Malloc debug level.
// 0 - none, 1 - corruption checking, 2 - records all malloc blocks and
//   checks, 3 - printout of all mallocs etc.
// Minimum val: 0
// Maximum val: 3
// Type: long
//

malloc_debug_level = 0;

///////////// instance ////////////////////////////////
//
// Process instance.
// Used for registration with procmap.
// Type: string
//
```

```
instance = "Test";

///////////// target_entity //////////////////////////
//
// Entity for which data is sought.
// COMPLETE_TRACK - properties for the whole track. Where more than one
//   part exists at a time the properties are aggregated from the parts.
//   TRACK_ENTRY - instantaneous properties for each part of the tracks at
//   regular intervals. INITIAL_PROPS - properties at the start of the
//   track, used for selecting storms similar to seeded cases in weather
//   mod activities.
//
// Type: enum
// Options:
//   COMPLETE_TRACK, TRACK_ENTRY, INITIAL_PROPS
//
//

target_entity = INITIAL_PROPS;

///////////// use_complex_tracks /////////////////////
//
// Option to process complex tracks.
// If set, tracks with mergers and splits will be processed.
// Type: boolean
//

use_complex_tracks = TRUE;

///////////// use_simple_tracks //////////////////////
//
// Option to process simple tracks.
// If set, tracks without mergers and splits will be processed.
// Type: boolean
//

use_simple_tracks = TRUE;

///////////// count_only /////////////////////////////
//
// Option to only count storms to get total number.
```

```
// Suppresses normal print output.
// Type: boolean
//

count_only = FALSE;

///////////// sample_interval /////////////////////////
//
// Sampling interval (secs).
// TRACK_ENTRY entity only. The track entry properties are printed out
//   at this interval. If set to -1, all entries are printed.
// Type: long
//

sample_interval = 1800;

///////////// scan_interval ///////////////////////////
//
// Volume scan interval (secs).
// Used in conjunction with sample_interval to determine whether to
//   print the entry for a given scan. It is a temporal search region. If
//   no entries lie within this interval on either side of the search
//   time, no analysis is done for this time.
// Type: long
//

scan_interval = 360;

///////////// min_duration ////////////////////////////
//
// Minimum track duration (secs).
// Only tracks which exceed this duration are processed.
// Type: long
//

min_duration = 900;

///////////// use_box_limits //////////////////////////
//
// Option to limit analysis to a bounding box.
// If set, only tracks which pass through the box will be processed.
```

```
// Type: boolean
//

use_box_limits = FALSE;

///////////// box //////////////////////////////////////
//
// Box parameters.
// The parameters of the bounding box - see 'use_box_limits'. The size
//   limits are in km relative to the grid origin. min_percent is the
//   minimum percentage of the tracks which must lie in the box.
//   min_nstorms is the minimum number of scans for which storms must lie
//   in the box.
//
// Type: struct
//   typedef struct {
//      double min_x;
//      double min_y;
//      double max_x;
//      double max_y;
//      double min_percent;
//      long min_nscans;
//   }
//
//

box = { 0, 0, 0, 0, 0, 0 };

///////////// check_too_close /////////////////////////
//
// Option to reject tracks too close to radar.
// This allows rejection of tracks with tops missing because it is too
//   close to the radar.
// Type: boolean
//

check_too_close = FALSE;

///////////// max_nscans_too_close ////////////////////
//
// Max nscans too close to radar - tops missing.
```

```
// Max number of scans per track allowed with missing tops.
// Type: long
//

max_nscans_too_close = 5;

///////////// check_too_far ///////////////////////////
//
// Option to reject tracks at max range.
// This allows rejection of tracks too far from the radar - data missing
//   because part of the storm is out of range.
// Type: boolean
//

check_too_far = FALSE;

///////////// max_nscans_too_far //////////////////////
//
// Max nscans too far.
// Max number of scans per track allowed at max range.
// Type: long
//

max_nscans_too_far = 5;

///////////// check_vol_at_start //////////////////////
//
// Option to check vol at start of track.
// This allows rejection of tracks which existed at radar startup.
// Type: boolean
//

check_vol_at_start = FALSE;

///////////// max_vol_at_start ////////////////////////
//
// Max vol at start of sampling (km2).
// Tracks with starting vol in excess of this value are rejected.
// Type: double
//
```

```
max_vol_at_start = 5;

///////////// check_vol_at_end ////////////////////////
//
// Option to check vol at end of track.
// This allows rejection of tracks which existed at radar shutdown.
// Type: boolean
//

check_vol_at_end = FALSE;

///////////// max_vol_at_end //////////////////////////
//
// Max vol at end of sampling (km2).
// Tracks with ending vol in excess of this value are rejected.
// Type: double
//

max_vol_at_end = 5;

///////////// print_polygons //////////////////////////
//
// Option to print storm polygons.
// TRACK_ENTRY only. If set the storm polygons are printed out for each
//   track entry.
// Type: boolean
//

print_polygons = FALSE;

///////////// initial_props_nscans ////////////////////
//
// Number of scans used to compute initial props.
// Type: long
//

initial_props_nscans = 5;
```

A.2 TrackMatch params file

```
/**************************************************
 * TDRP params for TrackMatch
 **************************************************/

/*
 * Debug option.
 * If set, debug messages will be printed with the appropriate
 *   level of detail.
 *
 * Type: enum
 * Default: DEBUG_OFF
 * Legal values: DEBUG_OFF, DEBUG_WARNINGS, DEBUG_NORM,
 *   DEBUG_VERBOSE.
 */
debug = DEBUG_OFF;

/*
 * Malloc debug level.
 * 0 - none, 1 - corruption checking, 2 - records all malloc blocks
 *   and checks, 3 - printout of all mallocs etc.
 *
 * Type: long
 * Default: 0
 * Min value: 0
 * Max value: 3
 */
malloc_debug_level = 0;

/*
 * Process instance.
 * Used for registration with procmap.
 *
 * Type: string
 * Default: "Test"
 */
instance = "Test";

/*
 * Case number for the match.
```

```
 * This is the case for which the match is sought.
 *
 * Type: long
 * Default: 1
 */
case_num = 19;

/*
 * File path of seed cases.
 * This file indicates the time and track numbers for each seeded
 *   case. In addition the environmental conditions, such as cloud
 *   base and CAPE are input from this file.
 *
 * Type: string
 * Default: "null"
 */
case_file_path = "$(TITAN_HOME)/params/case_tracks.tzaneen";

/*
 * Number of track candidates in list.
 * This program finds tracks which match the given case as closely
 *   as possible. A list of candidate tracks is found and sorted.
 *   The list is n_candidates long.
 *
 * Type: long
 * Default: 20
 */
n_candidates = 20;

/*
 * Property for matching tracks.
 * This is the property used for matching up the tracks.
 *
 * Type: enum
 * Default: PRECIP_FLUX
 * Legal values: VOLUME, AREA, MASS, PRECIP_FLUX.
 */
match_property = PRECIP_FLUX;

/*
 * Option to use rate for matching.
```

```
 * If set, the rate of change will be used for matching. If not, the
 *   absolute value will be used for the match.
 *
 * Type: boolean
 * Default: TRUE
 */
use_rate_for_match = TRUE;

/*
 * Margin between time of case track and candidate track (hr).
 * Only tracks with a start time difference within this margin
 *   are considered. Use -1.0 for no checking.
 *
 * Type: double
 * Default: 2
 */
time_margin = -1.0;

/*
 * Margin between range of case track and candidate track (km).
 * Only tracks with a start range difference within this margin
 *   are considered. Use -1.0 for no checking.
 *
 * Type: double
 * Default: 25
 */
range_margin = -1.0;
```

A.3 PartialProps params file

```
/****************************************************
 * TDRP params for PartialProps
 ****************************************************/

/*
 * Debug option.
 * If set, debug messages will be printed appropriately.
 *
 * Type: enum
 * Default: DEBUG_OFF
 * Legal values: DEBUG_OFF, DEBUG_NORM, DEBUG_VERBOSE.
 */
debug = DEBUG_NORM;

/*
 * Malloc debug level.
 * 0 - none, 1 - corruption checking, 2 - records all malloc blocks
 *   and checks, 3 - printout of all mallocs etc.
 *
 * Type: long
 * Default: 0
 * Min value: 0
 * Max value: 3
 */
malloc_debug_level = 0;

/*
 * Process instance.
 * Used for registration with procmap.
 *
 * Type: string
 * Default: "Test"
 */
instance = "Test";

/*
 * Storm and track file data directory.
 * The directory in which to find the storm and track data files
 *   for use in this analysis.
```

```
 *
 * Type: string
 * Default: "null"
 */
storm_data_dir = "$(TITAN_HOME)/storms";

/*
 * File path for seed/no-seed cases.
 * This file indicates the time and track numbers for each seeded
 *   case. In addition the environmental conditions, such as cloud
 *   base and CAPE are input from this file.
 *
 * Type: string
 * Default: "null"
 */
case_file_path = "$(TITAN_HOME)/params/case_tracks.tzaneen";

/*
 * Path for output directory.
 * Case data is written to files in this directory.
 *
 * Type: string
 * Default: "null"
 */
output_dir = "$(TITAN_HOME)/props_files";

/*
 * Altitude threshold for computing altitude-thresholded properties.
 * There are a number of properties, e.g. volume, which are computed
 *   for the whole storm and for the region above an altitude threshold.
 *   This threshold is used for those computations.
 *
 * Type: double
 * Default: 6
 * Min value: 0
 * Max value: 30
 */
altitude_threshold = 6;
```

A.4 CaseStats params file

```
/**************************************************
 * TDRP params for CaseStats
 **************************************************/

/*
 * Debug option.
 * If set, debug messages will be printed appropriately.
 *
 * Type: enum
 * Default: DEBUG_OFF
 * Legal values: DEBUG_OFF, DEBUG_NORM, DEBUG_VERBOSE.
 */
debug = DEBUG_OFF;

/*
 * Malloc debug level.
 * 0 - none, 1 - corruption checking, 2 - records all malloc blocks
 *   and checks, 3 - printout of all mallocs etc.
 *
 * Type: long
 * Default: 0
 * Min value: 0
 * Max value: 3
 */
malloc_debug_level = 0;

/*
 * Process instance.
 * Used for registration with procmap.
 *
 * Type: string
 * Default: "Test"
 */
instance = "Test";

/*
 * File path for seed/no-seed cases.
 * This file indicates the time and track numbers for each seeded
 *   case. In addition the environmental conditions, such as cloud
```

```
 *   base and CAPE are input from this file.
 *
 * Type: string
 * Default: "null"
 */
case_file_path = "$(TITAN_HOME)/params/case_tracks.tzaneen";

/*
 * Directory for properties files.
 * This directory holds the files produced by PartialProps.
 *
 * Type: string
 * Default: "null"
 */
props_files_dir = "$(TITAN_HOME)/props_files";

/*
 * Global property list.
 * The is the list of global properties used in the analysis. Global
 *   properties apply to the entire case, for example mean_volume.
 *
 * Type: string
 * Array elem size: 4 bytes
 * Array has no max number of elements
 */
global_propsglobal_props = {"cloud_base", "mixing_ratio", "temp_ccl", "deltat_500mb", global_prop
"seed_duration","seed_duration",   "dura"seed_duration",   "duration_before_d"seed_dura
"dbz_max_"dbz_max_mean","dbz_max_mean",   "dbz_max_max",   "dbz_max_max_roi",   "pr"dbz_
"precip_flux_max","precip_flux_max",   "precip_flux_max_roi",   "volume_mean",   "vol"pre
"volume_max_roi""volume_max_roi","volume_max_roi",   "volume_max_roi",   "volume_a
"volume_above_"volume_above_alt_max_roi","volume_above_alt_max_roi",   "mass_mean",   "m
"mass_abo"mass_above"mass_above_alt_mean","mass_above_alt_mean", "mass_above_alt_max", "mass_abov
"area_max","area_max",   "ar"area_max",   "area_max_roi",   "ht_of_dbz_max_mean",   "ht_
"ht_o"ht_of_dbz_max_max_roi","ht_of_dbz_max_max_roi",   "refl_centroid_z_mean",   "refl_
"refl_centro"refl_centroid_z_max_roi","refl_centroid_z_max_roi",   "ht
"ht_max_minus_c"ht_max_minus_centroid_z_max","ht_max_minus_centroid_z_max",   "ht_max_minus_cent
"top_max", "top_max_roi", "base_max_roi", "ATI", "precip_mass", "VCDI"};

/*
 * Time series property list.
 * The is the list of time series properties used in the analysis.
```

```
 *   Time series properties are instanteous values, for example
 *   the volume at a given time.
 *
 * Type: string
 * Array elem size: 4 bytes
 * Array has no max number of elements
 */
tseries_propstseries_props = {"dbz_max",tseries_props = {"dbz_max", "precip_flux", "volume", "mass'
"refl_centroid_z","refl_centroid_z", "ht_max_minus_centroid_z", "volume_above_alt","refl_centroic
"ATI", "VCDI", "precip_mass"};

/*
 * Time series delta time list (secs).
 * The is the list of time series delta time values used in the analysis.
 *   Delta_times are relative to decision time. Each of the tseries
 *   properties will be computed at each of these times.
 *
 * Type: long
 * Array elem size: 4 bytes
 * Array has no max number of elements
 */
tseries_dtimestseries_dtimes = {-600, -300, 0, 300, 600, 900, 1200, 1500, 18tseries_dtimes = {-6C
3000, 3300, 3600, 3900, 4200, 4500, 4800, 5100, 5400, 5700, 6000};

/*
 * Conditions on variables for analysis.
 * If you wish you may impose conditions on the analysis by using
 *   this parameter array. For global props, just insert the prop_name
 *   and the max and min vals (e.g. precip_flux_max). Only cases
 *   in which the global val falls with the range will be included.
 *   For time_series props, designate the prop_name as prop_name@time,
 *   where time is the number of seconds from decision time in the
 *   time series (e.g. precip_flux@300 for precip_flux 5 mins after
 *   decision time).
 *
 * Type: struct
 * Array elem size: 20 bytes
 * Array has no max number of elements
 */
conditions = {{
  "seed_duration", /* prop_name:string */
```

```
  0, /* min_val:double */
  3600  /* max_val:double */
}};

/*
 * Statistic type for analysis.
 * One of the following stats may be utilized in any single analysis:
 *   arithmetic mean, geometric mean (better for log-normal data),
 *   first quartile, second quartile and third quartile.
 *
 * Type: enum
 * Default: ARITH_MEAN
 * Legal values: ARITH_MEAN, GEOM_MEAN, FIRST_QUARTILE,
 *   SECOND_QUARTILE, THIRD_QUARTILE.
 */
stat_type = ARITH_MEAN;

/*
 * Option to set the interpolated value to missing if the storm
 *   did not exist at the interp time.
 * If false, 0 will be used instead of missing data.
 *
 * Type: boolean
 * Default: TRUE
 */
set_missing_val_in_interp = FALSE;

/*
 * Option to perform re-randomization.
 * If set, the re-randomization technique will be used to compute
 *   the significance of any changes between the seed and no-seed
 *   data. The results will be included in the printout.
 *
 * Type: boolean
 * Default: TRUE
 */
use_rerandomization = TRUE;

/*
 * Number of re-randomization sequences.
 * If rerandomization is used, this is the number of re-randomized
```

```
 *   sequences which are used in the analysis.
 *
 * Type: long
 * Default: 1000
 * Min value: 10
 */
n_rerand = 1000;

/*
 * Number of entries in randomized list.
 * Each time a random list is created, it will be n_random_list
 *   long. The entries in the list will be used from the start of the
 *   list, one per case. If there are more cases than n_random_list
 *   an error will be reported.
 *
 * Type: long
 * Default: 200
 * Min value: 10
 */
n_random_list = 200;

/*
 * Maximum seed-no_seed split.
 * This is the max allowable split between the seed and no-seed
 *   pools in the re-randomization. If the split in a list exceeds
 *   this value, a new list will be generated.
 *
 * Type: long
 * Default: 7
 */
max_split = 7;

/*
 * Option to write interpolated time-series files.
 * If set, interpolated time-series files are written to props_files_dir.
 *   The file names are interp.nnn, where nnn is the case number.
 *
 * Type: boolean
 * Default: FALSE
 */
write_interp_files = FALSE;
```

A.5 TrackGridStats params file

```
/**********************************************************
 * TDRP params for TrackGridStats
 **********************************************************/

/*
 * Debug option.
 * If set, debug messages will be printed appropriately.
 *
 * Type: enum
 * Default: DEBUG_OFF
 * Legal values: DEBUG_OFF, DEBUG_WARNINGS, DEBUG_NORM,
 *   DEBUG_VERBOSE.
 */
debug = DEBUG_OFF;

/*
 * Malloc debug level.
 * 0 - none, 1 - corruption checking, 2 - records all malloc blocks
 *   and checks, 3 - printout of all mallocs etc.
 *
 * Type: long
 * Default: 0
 * Min value: 0
 * Max value: 3
 */
malloc_debug_level = 0;

/*
 * Process instance.
 * Used for registration with procmap.
 *
 * Type: string
 * Default: "Test"
 */
instance = "Test";

/*
 * Note for stats file.
 * Note to go in track stats grid file.
```

```
 *
 * Type: string
 * Default: "Track grid statistics"
 */
note = "Track grid statistics";

/*
 * Type of input track data.
 * Two track data types are permissable: (a) TITAN track files,
 *   (b) track files generated from the stochastic model StormModel.
 *
 * Type: enum
 * Default: TITAN_TRACKS
 * Legal values: TITAN_TRACKS, MODEL_TRACKS.
 */
track_data_type = TITAN_TRACKS;

/*
 * Track grid stats directory.
 * Upper level directory for output grid stats files.
 *
 * Type: string
 * Default: "none"
 */
grid_stats_dir = "$(TITAN_HOME)/grid_stats";

/*
 * Output file extension.
 * File name extension for output cartesian files.
 *
 * Type: string
 * Default: "mdv"
 */
output_file_ext = "mdv";

/*
 * Number of seasons for stats.
 * The number of seasons for computing the seasonal means, such
 *   as precip.
 *
 * Type: long
```

```
 * Default: 1
 */
n_seasons = 1;

/*
 * Radar vol scan interval (secs).
 * Interval between radar volume scans (secs).
 *
 * Type: double
 * Default: 360
 * Min value: 0
 * Max value: 1800
 */
scan_interval = 300;

/*
 * Min track duration (secs).
 * The minimum duration for including a track in the analysis (secs).
 *
 * Type: double
 * Default: 900
 * Min value: 0
 * Max value: 10000
 */
min_duration = 900;

/*
 * Grid parameters.
 * The grid params for the track stats.
 *
 * Type: struct
 */
grid = {
  -23.8648, /* origin_lat:double */
   30.3095, /* origin_lon:double */
  240, /* nx:long */
  240, /* ny:long */
  -119.5, /* minx:double */
  -119.5, /* miny:double */
  1.0, /* dx:double */
  1.0  /* dy:double */
```

```
};

/*
 * Z-R coefficient.
 * The coefficient in the Z-R relationship.
 *
 * Type: double
 * Default: 200
 * Min value: 1
 * Max value: 2000
 */
z_r_coeff = 200;

/*
 * Z-R exponent.
 * The exponent in the Z-R relationship.
 *
 * Type: double
 * Default: 1.6
 * Min value: 0.1
 * Max value: 10
 */
z_r_exponent = 1.6;

/*
 * Hail dBZ threshold.
 * The reflectivity threshold above which hail is assumed.
 *
 * Type: double
 * Default: 55
 * Min value: 40
 * Max value: 80
 */
hail_dbz_threshold = 70;

/*
 * Dbz histogram interval.
 * Reflectivity interval for histogram computations related
 *   to the reflectivity distribution. Used for MODEL_TRACKS only.
 *
 * Type: double
```

```
 * Default: 3
 * Min value: 1
 * Max value: 10
 */
dbz_hist_interval = 3;

/*
 * Option to override the storm ellipse shapes with circles of
 *   constant radius.
 * If set the same weight is given to all storms for those properties
 *   which are computed spatially. See circle_radius.
 *
 * Type: boolean
 * Default: FALSE
 */
override_ellipse = FALSE;

/*
 * Radius of circle for overriding the ellipses.
 * See override_ellipse.
 *
 * Type: double
 * Default: 10
 * Min value: 0
 */
circle_radius = 10;
```

A.6 The rview.grid_stats params file

```
###########################################################################
# parameters file for rview - test data
#
# Mike Dixon RAP NCAR Boulder Colorado USA
#
# April 1991
#
###########################################################################
.
.
.
.
.

#
# data fields and their servers. These are not treated in the same way as
# the other params. They are read in by read_field_control().
# Lines start with '#fc' - '##fc' comments them out
#

#-------------------------------------------------------------------------
#  Field controls
#
# Label    Server          Defaults    Fld  Time  X Color  Ps Color  Contours
#       vvvvvvvvvvvvvvvv  vvvvvvvvvvv     vvvvvv vvvvvv   vvvvvvv   vvvvvvvvv
#       subtype instance  Host   Port     window  file      file    lo-hi-int
#-------------------------------------------------------------------------

#fc dbz Cidd MDV grid_stats local 93500 0  1800 number_color number_gray 0.0 500.0 25.0
##fc dbz Cidd MDV grid_stats local 93500 1 1800 number_color number_gray 0.0 500.0 25.0
##fc dbz Cidd MDV grid_stats local 93500 2 1800 number_color number_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 3  1800 percent_color percent_gray 0.0  100.0  5.0
##fc dbz Cidd MDV grid_stats local 93500 4 1800 number_color number_gray 0.0  500.0 25.0
##fc dbz Cidd MDV grid_stats local 93500 5 1800 number_color number_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 6  1800 season_p_color season_p_gray 0.0 1000.0 12.5
#fc dbz Cidd MDV grid_stats local 93500 7  1800 vol_color vol_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 8  1800 dbz_color dbz_gray 0.0   70.0  5.0
#fc dbz Cidd MDV grid_stats local 93500 9  1800 tops_color tops_gray 0.0   20.0  1.0
#fc dbz Cidd MDV grid_stats local 93500 10 1800 motion_color motion_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 11 1800 motion_color motion_gray 0.0  500.0 25.0
```

```
#fc dbz Cidd MDV grid_stats local 93500 12 1800 motion_color motion_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 13 1800 number_color number_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 14 1800 number_color number_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 15 1800 number_color number_gray 0.0  500.0 25.0
##fc dbz Cidd MDV grid_stats local 93500 16 1800 precip_color precip_gray 0.0  600.0 20.0
#fc dbz Cidd MDV grid_stats local 93500 17 1800 area_color area_grey 0.0  600.0 20.0
#fc dbz Cidd MDV grid_stats local 93500 18 1800 number_color number_gray 0.0  500.0 25.0
#fc dbz Cidd MDV grid_stats local 93500 19 1800 number_color number_gray 0.0  600.0 20.0
```

A.7 The MDV_server.grid_stats params file

```
/**************************************************
 * TDRP params for MDV_server
 **************************************************/

/*
 * Debug option.
 * If set, debug messages will be printed appropriately.
 *
 * Type: enum
 * Default: DEBUG_OFF
 * Legal values: DEBUG_OFF, DEBUG_NORM, DEBUG_VERBOSE.
 */
debug = DEBUG_OFF;

/*
 * Malloc debug level.
 * 0 - none, 1 - corruption checking, 2 - records all malloc blocks
 *   and checks, 3 - printout of all mallocs etc.
 *
 * Type: long
 * Default: 0
 * Min value: 0
 * Max value: 3
 */
malloc_debug_level = 0;

/*
 * Server subtype.
 * Used for registration with servmap.
 *
 * Type: string
 * Default: "MDV"
 */
subtype = "MDV";

/*
 * Process and server instance.
 * Used for registration with procmap and servmap.
 *
```

```
 * Type: string
 * Default: "Test"
 */
instance = "grid_stats";

/*
 * Server info.
 * Used for registration with servmap.
 *
 * Type: string
 * Default: "Test"
 */
info = "Test";

/*
 * Server port number.
 * TCP/IP port for this server.
 *
 * Type: long
 * Default: 43000
 * Min value: 10000
 */
port = 93500;

/*
 * Data directories.
 * List of directories holding the storm data.
 *
 * Type: string
 * Array elem size: 4 bytes
 * Array has no max number of elements
 */
data_dirs = {"$(TITAN_HOME)/grid_stats"};

/*
 * Suffix on data files.
 *
 * Type: string
 * Default: "mdv"
 */
data_file_suffix = "mdv";
```

```
/*
 * Real-time flag.
 * If set, indicates real-time data is available, shmem is created.
 *
 * Type: boolean
 * Default: FALSE
 */
realtime_avail = FALSE;

/*
 * Option to use real-time file.
 * If set, servers uses a single file for GET_NEW requests.
 *
 * Type: boolean
 * Default: FALSE
 */
use_realtime_file = FALSE;

/*
 * Path to realtime file.
 * See use_realtime_file.
 *
 * Type: string
 */
realtime_file_path = "none";

/*
 * Option to compress data for transfer.
 * If set, data is run-length encoded for transfer over slow links.
 *
 * Type: boolean
 * Default: FALSE
 */
compress_for_transfer = FALSE;

/*
 * Time offset (secs).
 * Search for data which is offset by this amount from the requested
 *   time.
 *
 * Type: long
```

```
 * Default: 0
 */
time_offset = 0;

/*
 * Grid projection.
 * Local area flat grid, or lat-lon grid.
 *
 * Type: enum
 * Default: PROJ_FLAT
 * Legal values: PROJ_FLAT, PROJ_LATLON.
 */
projection = PROJ_FLAT;
```