OCCAM 5.0. USER'S GUIDE

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ABSTRACT

OCCAM 5.0 has new limits: 20 stations and 100 radiosources can be processed simultaneously. The number of baselines under study is 190, correspondingly. The current version of OCCAM supports IERS Conventions 2000. The ephemeride DE405/LE405 takes the place of DE403/LE403. To correct subdiurnal EOP variations two models can be chosen: proposed by Ray (recommended by IERS Conventions 1996) and by Eanes (IERS Conventions 2000) which takes into account many more tidal terms. A new least-squares approach based on the Gauss-Markov model is available with the new version.

USER'S GUIDE MODIFICATIONS LOG

#	WRITER	INSTITUTION	DATE	VERSION NUMBER
1.	N. Zarraoa	IAG, Madrid	18.03.1991	2.0
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6.	O. Titov	SPbU, St.Petersburg		
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DISTRIBUTION LIST

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PREFACE

1. OCCAM V 5.0 is a Research and Development package for the analysis of geodetic and geodynamics VLBI experiments. It is distributed freely.

2. The OCCAM Coordinator will be responsible for maintaining the configuration control on the standard OCCAM. Modifications that prove their worth and usefulness may be incorporated to the standard version and distributed to all users.

3. Presently the OCCAM Coordinator name and address is:

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4. Please, do not distribute the package OCCAM by yourself without informing the OCCAM Coordinator. This formality will help the distribution of upgraded versions of the package to all interested users.

5. If you find any part of this User's Guide difficult to understand, incomplete or in disagreement with your experience as OCCAM user, please send your comments and suggestions to the OCCAM coordinator preferably via electronic or standard mail.

6. If you find serious problems using the OCCAM package, we may provide some assistance, only if you send to the OCCAM Coordinator a written report, as complete as possible, on the problem found.

7. We strongly recommend that if you find any bug or error in the source code of OCCAM, you send a report about it to the OCCAM Coordinator to distribute a corrected version to all the users.

8. You may have implemented new modules or upgraded already existent ones in OCCAM that could be useful for other users. If you want your changes to be definitely implemented in the standard version of OCCAM, send the new source code with complete information about the new features to the OCCAM Coordinator. Upgraded versions of OCCAM will be periodically distributed to all users.

CONTENTS

PRELIMINARY INFORMATION

INTRODUCTION

The package OCCAM V 5.0 provides a useful tool to process VLBI sessions with an Personal Computer (PC) running with WINDOWS (version 95 or higher). Complete tests have been carried out with Pentium II/Pentium III based processors. Additionally, the version 5.0 is in regular use with LINUX.

The software package OCCAM consists of several executable programs, which must be used in strict order to get a solution of a VLBI session. There are some auxiliary programs in the package, too. The executables can be started manually or automatically via batch files. Please note that the batches work with WINDOWS only. Their use is not supported by LINUX.

It is recommended to use powerful computers for data analysis because the modern observational experiments include the tremendous number of observations.

This user's guide will concentrate on the use of OCCAM on a PC environment.

Since the previous OCCAM 4.0 version the following changes have been done

- IERS Conventions 2000 replaced the IERS Conventions 1996;
- Least squares method was added as an option to get a solution;
- Troposphere gradients can be estimated optionally;
- Reference station can be chosen manually;
- Elevation cut off angle can be specified at the *.opt file;
- OCCAM does not use virtual disks anymore

CONFIGURE YOUR COMPUTER TO RUN OCCAM

It is recommended to have at least 10 Mbytes free space on Hard Disk to contain the program, data files and solution outputs. The executable code would need 4 Mbytes of space.

Your computer must have as many Mbytes of RAM memory as available. But it is possible to compile all FORTRAN files with advanced compiler (Lahey, Fortran Power Station, etc.) to make use all available RAM memory.

The best configuration to keep the program in your computer is to separate the program directory from the working directory where you process your data. If you have a comressed Version of the OCCAM software, all files will be in the right path after the decomression. A suitable configuration may read like this:

C:\OCCAM	Executable code of OCCAM 5.0
C:\OCCAM\BAT	BATCH Files to run OCCAM Menu System
C:\OCCAM\SCR	Screen files for the menu system
C:\OCCAM\COMPILE	Source code of OCCAM
C:\OCCAM\EPHEM	Ephemerides and EOP files
C:\OCCAM\ATM	Atmospheric loading data
C:\OCCAM\WORK	Working directory

C:\OCCAM\FIL	Useful information
C:\OCCAM\DOC	Documentation

These are the files that are installed into your work directory:

CHOOSE.COM	COLLOCAT.OPT	EPHEM.DAT	OCCAM.BAT
KVLBI.OPT	KVLBI_IE.OPT	LOADING.OCE	LSM.OPT
THERMAL.DEF	OCCAM.SCR		

You will also need to have a catalog file (with extension .CAT) contains information about positions of stations and radiosources and velocities of stations. The current version includes a ITRF2000.CAT file as well. The file contains ITRF2000 catalog for station coordinates and velocities and ICRF extension 1 for radiosources coordinates.

Pay attention that the disk C is used on default. OCCAM and data files to be stored into the disk C. Corresponding paths are included in all *.BAT files. If you use another disk, the *.BAT file must be updated for data analysis.

WHAT DO I REALLY NEED TO PROCESS DATA

1. INPUT DATA FILES FOR THE EXPERIMENT.

OCCAM uses VLBI data in NGS-Format. If your data is in any other format you must change it to NGS before using OCCAM. NGS files can be downloaded from data servers of the IVS, like ftp://cddisa.gsfc.nasa.gov/vlbi/ivsdata/ngs.

If you have NGS-Format data follow the instructions in Chapter #1.

2. NECESSARY FILES

When you install OCCAM several files are copied to your work directory. Some of them are examples of the necessary files described below. Some other files may also be necessary. It may be very useful for you to create similar files (e.g. own catalogs, ephemerids tables, option files, etc.) according to your needs.

These are the files you need to run OCCAM:

A. CATALOG. Required from beginning to end. You should create your own catalog containing the coordinates and velocities (if you wish to apply an a-priori velocity model) of the stations and the celestial coordinates of the sources involved in the experiment. It would be useful to create a global catalog with all the stations and sources you may need.

The installation of the OCCAM 5.0 provides you with the file ITRF2000.CAT as an example. See Appendix B for a description. Any name is valid for this file.

B. EPHEMERIS TABLE. Required for 'Precession and Nutation' option in Model Computation Menu (#1.2). You must create a file called EPHEM.DAT for your experiment. This file should contain:

Earth Orientation Parameters (hereafter EOP): You can obtain this information from the International Earth Rotation Service (IERS) C04 series from IERS (http://hpiers.obspm.fr/eop-pc). You will have to include EOP data not only for the experiment's date but also for several days around. Nine or more data records should provide a more precise interpolation. OCCAM 5.0 version makes use of the Lagrangian interpolation scheme and can add subdiurnal EOP corrections as recommended by the IERS.

Sun, Earth and Moon ephemerids: This information is available from DE/LE405 code in accordance with IERS 2000 Conventions. It is advisable to include 5-6 days of data in your table for a better interpolation. OCCAM requires an information with 0.5-day steps.

OCCAM can generate the EPHEM.DAT file for the experiment automatically. In order to do that, you have to provide a complete ephemeride catalog for the year of the experiment you want to run, and a similar file for EOP. The name of the files must be EPHEM.ye and EOP.ye, where "ye" is the year of the experiment (99,00,01,...). They should be stored in the ..\OCCAM\EPHEM subdirectory. A description of the files can be found in appendix B.

C. OCEAN LOADING DATA. Required for "Station Corrections and Derivatives" option in the Model Computation Menu (#1.3). If you want to add corrections due to the ocean loading effect, you must provide the amplitudes and phases of the main tidal components at each station. The example file LOADING.OCE contains real data for several antennas. The name of the file must be LOADING.OCE so you can simply add the information for your antennas to the present file or update the existing information if better data is available. The files are provided by Hans-George Scherneck via ftp service (ftp://gere.oso.chalmers.se/pub/hgs/oload/olrs19_VLBI.blq). A close description of the strategy to obtain the coefficients can be found at the Web address http://www.oso.chalmers.se/~hgs. One version of the file is enclosed. See appendix B for a detailed explanation of the file and its format.

D. THERMAL DEFORMATION DATA. Required for the "Station Corrections and Derivatives" option in the Model Computation Menu (#1.3) and recommended by the IERS Conventions. The description of the model used can be found in Haas et al,1999 http://www.dgfi.badw.de/dgfi/DOC/report71.pdf). The antenna dimensions information is taken from the file THERMAL.DAT from the IVS Analysis Coordinator's homepage (http://miro.geod.uni-bonn.de/vlbi/IVS-AC). The initial mean temperature has been chosen using some summarized experiences. If we did not have a reliable amount of data, the value is equal to 999°C and no correction will be applied. The user can change it. A description of the THERMAL.DEF file can be found in appendix B.

E. ATMOSPHERIC LOADING DATA. Also required for the "Station Corrections and Derivatives" option in the Model Computation Menu (#1.3) and recommended by the IERS Conventions. The data must be stored in a subdirectory ..\.OCCAM\ATM. Each station has got an own time series of corrections, though a own [station_name].ATM file. The version 5.0 interpolates the quarter-daily corrections computed by Scherneck, which can be found and downloaded on http://www.oso.chalmers.se/˜hgs/apload.html. These data sets are computed with the today's probably most reliable approach. This approach additionally needs the file ATMEAN97 which consists of 'correction offsets' due to a mean pressure for each station (http://www.oso.chalmers.se/˜hgs/apload.html). These are subtracted from the corrections by the software. A description of the files is to be found in appendix B.

F. CONTROL FILES. All *.OPT files are required for running the solutions with the Solution Computation Menu (Chapter #2). KVLBI.OPT is used for the "Kalman Filter Process (Multibaseline)"(#2.1). KVLBI_IE.OPT is used for the 'Kalman Filter Process (Multibaseline)"(#2.2). COLLOCAT.OPT is used for the "Least Squares Collocation Technique"(#2.3). .OPT is used for the "Least squares method (LSM)"(#2.4).A description of these files is provided in Chapter #2.

G. To use some utilities you may need other files. You will find descriptions of those files either in appendix B or the chapter referring to the utility itself.

H. There are other necessary files created by OCCAM like the OCCAM Standard Data Files (SDF) or the clock model file. These are described in chapter #1 and appendix C.

RUNNING OCCAM V 5.0

Once you have configured your computer and installed the basic files into your hard disk, you just have to enter "OCCAM" and your screen will look like this:

OCCAM V 5.0
S Y S T E M   M E N U

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1 - Compute Model and Create Standard Data Files

2 - Compute Experiment Solution

3 - Utilities

<Return> - Exit to DOS

Detailed descriptions of the different options will follow. To select any item you only have to enter the corresponding number.

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IMPORTANT!
Remember not to hit <RETURN> after the number, because the option is only used to quit or go one menu back.
If your Menu present options like "1.2", you must only enter the last digit as selection. First digit corresponds to the main menu option number. So, for "1.2" you only enter "2".
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The normal sequence of operations needed to process an experiment is the following:

A. Select Option 1 to get the Model Computation Menu (MCM).
B. From the MCM choose options #1.2, #1.3, #1.4 and #1.5 in this order. All four options have to be completed. If you want to repeat any of them, the following ones have to be repeated as well. With option #1.1 (Automatic mode) you make the complete chain.
C. Go back to the System Menu and select Option #2 to get the Solution Computation Menu (SCM).
D. OCCAM 5.0 version supports Kalman filter, least squares method and least squares collocation technique to get the solution.

CHAPTER #1.

COMPUTE MODEL AND CREATE STANDARD DATA FILES.

INTRODUCTION

When you enter option #1 in the System Menu your screen will look this way:

OCCAM V 5.0
M O D E L   C O M P U T A T I O N   M E N U

1.1 - Automatic Model Computation
1.2 - Data Handling
1.3 - Precession and Nutation
1.4 - Station Corrections and Derivatives
1.5 - Geometric Model

<Return> - Previous Menu

These options allow you to reformat your data set into OCCAM SDF, compute models and corrections to generate theoreticals for the observables and compute partial derivatives for the adjustment.

You can choose between the automatic model generation in option #1.1 or step by step model generation using options from #1.2 to #1.5. Before running any of this options all the previous ones must have been already completed.

More detailed descriptions of these options follow.

1.1 - AUTOMATIC MODEL COMPUTATION.

This option is equivalent to running options #1.2, #1.3, #1.4 and #1.5 in this order. Thus, refer to the following items for explanations.

1.2 - DATA HANDLING (Equivalent to running the program DTAU0).

Files: DTAU.FOR, OCCAM_N.FI, DTAU1.FOR, LSM_OPT.FOR, OPT.FOR, ARC.FOR, OPENING.FOR

* Purpose

This option reads the original VLBI data files for the experiment given in NGS format and converts them into OCCAM SDF, which are used by the rest of the options in the package. Detailed description of the NGS Format is provided in Appendix A.

The program reads global Ephemeris and EOP catalogs and creates the file EPHEM.DAT specific for the experiment to be processed. The user can also create EPHEM.DAT himself. The file format is described in Appendix B. The information needed is described in the option #1.3 PRECESSION AND NUTATION.

The package OCCAM generates and uses several SDF. These are called SORTIM, STATIM, BASTIM, BATCH, DICTIO and STACAT. All these files are created by this option. A file called METEOR containing the meteorological data from the stations is also generated but it is not used any more by the package.

This option creates the files with their final size. The rest of the options only add or read information on them. SORTIM stores information regarding sources and time. One record is reserved for each source-time combination. It contains the observation time tag (UTC), the source observed and its coordinates, interpolated EOP, Ephemeris of Sun, Earth and Moon, sidereal time, etc.

STATIM includes information regarding stations. It reserves one record for each pair station-observation time. Station coordinates corrected for Earth Tides, Ocean Loading, Pole Tide, etc. are stored here as well as tropospheric models, axis offsets and partial derivatives with respect to source and station coordinates. Local meteorological data and source coordinates (azimuth, hour angle and elevation) are also included here.

BASTIM has one record for each single scan (pair baseline-time). It contains the observed and theoretical delays and rates, ionospheric corrections, etc.

STACAT is a catalog of the stations included in the experiment.

DICTIO is a directory of "where to look for" different items of data. For each baseline it specifies in which record of BASTIM each scan is included.

These files are Direct Access files. Their contents can be read using #3.1 "Extract information from OCCAM Standard Files".

BATCH is a list of the present baselines of. It also specifies which catalogue is used and whose stations should be run.

METEOR is an ASCII file containing surface meteorological data and cable calibrations extracted from the original Data File. It can be used to check if any station has no meteorological data available.

A detailed description of all these files is found in appendix C.

In following steps the package generates other files that will be described when necessary.

* How to use DATA HANDLING

When you select this option you are advised that any existent OCCAM SDF will be erased. As the names of the files are fixed, erasing them at the beginning avoids errors in the future.

The program will ask the user to provide some information:

A. Experiment Name (8 characters). It gives a key for the experiment that can be followed when backing up files, etc. A name related to the Experiment's date and type is a good choice (e.g. IRISA570).
B. Catalog to be used (12 characters). You must enter the name of the catalog for Source and Station coordinates. See appendix B for a description of the format of the catalog. An example of catalog is copied to your work directory when installing OCCAM with the name ITRF2000.CAT
C. Data File Name (12 characters). The name of the NGS-Format data file must be entered.

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If the program does not find any of these files, it repeats the request for the file name.

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If any source or station included on the data set is not available on the catalog the program flags warning messages. It is recommended to quit and update the catalog before continuing.

D. The next step asks you if OCCAM shall create the *.OPT files automatically. The default is Y for yes, but have in mind that it is not necessarily the optimal choice for each individual session. If you choose Y, the next options below (E, F, G) to be answered more. If you choose N, there will be no more questions and you will follow to step H.
E. The program shows a list of the existing stations and asks which of them is to be taken as reference. If your input is not one of the observing stations, the first station listed is chosen.
F. The following question 'estimate atmosphere gradients ?' is valid for the Kalman filter approach only.
G. The following question '24-hour or INTENISIVE 2-hour experiment? (24/02) specify which type of session to be analyzed.

The package has some limits in the number of observations it can handle. Version 5.0 is limited to 20 Stations, 100 Sources and 1000 different scans (observation to a single source at the same time by two or more stations). If these limits are overflown then error messages are displayed and the program aborts.

H. The program can generate automatically the file EPHEM.DAT used by the #1.3 option PRECESSION AND NUTATION. To do so the user has to provide the path to search for the global ephemerides and EOP files. The pathway ..\OCCAM\EPHEM is recommended. More details about EPHEM.DAT can be found in appendix B.

1.3 - PRECESSION AND NUTATION (equivalent to running the program PN).
Files: PN.FOR, EANES.FOR, VLPN.FOR, NUTATION.FOR, MHB.FOR, HERR_NUT.FOR, ARC.FOR, OPENING.FOR, RAY.FOR, MATRIX.FOR, ROT.FOR

* Purpose

This option transforms between the J2000.0 Celestial Reference Frame for the quasars to their apparent positions in the observation time.

EOP and Ephemeris data for Sun, Earth and Moon are read from a file called EPHEM.DAT and interpolated to each observation's epoch. See appendix B for a complete description of the formats of the file. This information is stored on file SORTIM for further use.

The information for EPHEM.DAT can be obtained in several ways:

Earth Orientation Parameters: IERS distributes EOP C04 yearly time series from IERS Web site(http://hpiers.obspm.fr/eop-pc/).

Ephemeris: Global catalogs of ephemerides can provide barycentric Earth position and velocity and Sun and Moon geocentric position and velocities. That info can be included under the headers EARTD, SUND, MOOND. If global catalogs are available for the user, the option #1.2 can be used to generate directly EPHEM.DAT, entering the path where those files are. Their name has to be EPHEM.ye or EOP.ye, where "ye" means the year (99, 00, 01, etc.). Check the formats of those files in appendix B.. DE405/LE405 ephemerides are used for OCCAM 5.0.

* How to use PRECESSION AND NUTATION

During the execution of this program, you can turn off several models that are applied in this program. The following menu is displayed:

DEFAULT MODELS WILL BE APPLIED FOR:
A. - SHORT PERIOD UT1 VARIATIONS
B. - EFFECT OF OCEANIC TIDES ON UT1 AND POLAR MOTION

DO YOU WANT TO CHANGE THIS (Y, (N), Q TO QUIT)?

You can turn off any of them at this step. The default is applying them both.

The next step will be a more detailed question on the model for the effect of oceanic tides on UT1 and polar motion (if model option B chosen before):

CHOOSE MODEL TO BE APPLIED FOR:

A. - RAY MODEL – IERS 96 CONVENTIONS
B. - EANES MODEL – IERS 2000 CONVENTIONS – (ON DEFAULT)

The default in OCCAM is B. Both options A and B use the Lagrangian interpolation scheme for EOP, as recommended by the IERS.

The test calculations showed that for UT1-UTC there is a good agreement between observational and model subdiurnal variations. For pole coordinates difference are larger due to unknown reasons. Perhaps, there are strong non-tidal effects in pole motion.

Then the user will have to choose the a-priori nutation model:

A. - IAU 1980 NUT.MODEL ? (ON DEFAULT)
B. - HERRING MODEL ?
C. - MBH_2000 MODEL ?

Default is A, but the choice depends on the goal of the solution. The most precise model should be MBH_2000.

The next option is to choose the Short Period UT1 variations to apply (if option A selected in the very first step of this program):

FOR THE TIDAL UT1 VARIATIONS YOU CAN CHOOSE BETWEEN:

A. - IERS-STANDARDS (1989) (UT1–UT1R SHORT PERIOD < 35 DAYS)
B. - IERS-CONVENTIONS (1992) (UT1–UT1S SHORT AND LONG PERIODS)

SELECT YOUR PREFERENCE

For good interpolation of UT1 we need to subtract short-term variations with periods less than 35 days. The default in OCCAM is A, because the updated model of the IERS Conventions 1996 includes the terms that are already present on the EOP tables that are standard in OCCAM. The bulletin B 1-days series (EOP1 code in EPHEM.DAT) has no terms with period shorter than 35 days applied. Thus, after interpolation, option A is applied to restore the terms in final UT1 time series.

Overall, there are three steps

1. Subtraction of short-term (< 35 days) terms
2. Interpolation
3. Restoration of short-term (<35 days) terms

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IMPORTANT! Other sources for EOP may require a special use of the UT1 corrections and/or interpolation methods that are not included in OCCAM 5.0. Before using any other source for EOP, please read carefully its description and check which options in OCCAM are best for using that data.

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1.4 - STATION CORRECTIONS AND DERIVATIVES (equivalent to running the program STATION).

Files: STATION.FOR, OCCAM_N.FI, CORREC.FOR, PARTIALS.FOR, TROPOSPH.FOR, ATM_SCH.FOR, MATTEW.FOR, ARC.FOR, OPENING.FOR.

* Purpose

This program stores the following information on file STATIM.

A. Corrections to the catalog station coordinates due to earth tides
B. Further such corrections due to antenna deformations, ocean loading, atmospheric loading and the secular pole tide (can be deselected).
C. Antenna axis offset contributions to delays and rates.
D. Troposphere models by A. Niell.
E. Local source coordinates (azimuth, elevation, hour angle)
F. Partial derivatives of the delay with respect to station, source coordinates, nutation parameters and EOP.

The model for the solid earth tides used in OCCAM 5.0 is the model by Matthews and Dehant (1999), as recommended by the IERS CONVENTIONS 2000, exception the part for permanent tide correction. In accordance with conventional approach (different from IERS official recommendations!) the part for permanent tide “restitution” has not been activated. Thus OCCAM’s reference surface on the earth is the artificial surface as used by almost all known space geodetic softwares. For further information, the user is referred to MATTHEWS (1999) (http://www.dgfi.badw.de/dgfi/DOC/report71.pdf).

To apply the ocean loading corrections the program needs an external file with the amplitudes and arguments of the main tidal components for the model. This file must be called "LOADING.OCE" and when installing the package an example with real data for all VLBI stations is copied into your work directory. In Appendix B you can find a description of the format in case you need to update this information.

* How to use STATION CORRECTIONS AND DERIVATIVES

The program allows the user to select if any correction to station coordinates should be neglected. By default all corrections are included, but the user can neglect up to four effects:

BY DEFAULT ALL CORRECTIONS WILL BE ADDED TO THE DATA BASES. DO YOU WANT TO CHANGE THIS?

Answering Yes, you will receive the following message:

THIS CORRECTIONS ARE APPLIED...
A. ANTENNA DEF.   B. OCEAN LOAD.   C. ATMOS. LOAD.   D. POLE TIDE
SELECT THE CORRECTIONS YOU WANT TO NEGLECT
- - - -
And the user can select which of them to drop.

1.5 - GEOMETRIC MODEL (equivalent to running the program GEOMET).

Files: GEOMET.FOR, QUASAR1.FOR, SLOG.FOR, ARC.FOR, OPENING.FOR

* Purpose

This program computes the theoretical delays and delay rates for each observable included in the original data file. It considers the geometrical configuration of antennas and all relativistic effects. The information is stored on the file BASTIM.

* How to use GEOMETRIC MODEL

The program can use one of three available geometric models:

SELECT THE RELATIVISTIC MODEL TO BE APPLIED

A. – IERS - 1992 MODEL
B. – IERS - 1996 MODEL
C. – IAU - 1997 MODEL

Enter your selection ((A)/B/C)   (Q to quit)'/)

The default model is A from IERS Conventions (1992), what differs from previous OCCAM version. The user can also choose whether to apply Earth Gravity correction to light propagation or not. Default option is to apply it. This option is not available for IAU-1997 model. It always applies the Earth Gravity correction to light propagation that can not be deselected.

Meanwhile, the choice of correct relativistic model is not a simple problem. Sergey Klioner kindly prepared a short description on the topic (see below). If you use ITRF2000 system you will have to choose the option A (default). If you want to use the IAU-1997 option you will have to scale the coordinates of stations from ITRF catalogue.

The VLBI model can be symbolically written as

c * (t(2) – t(1)) = -k * (x(2) – x(1)) + additional terms.
Here c – the speed of light, t(1) – time epoch of arrival the wave front to site x(1), t(2) – time epoch of arrival the wave front to site x(2), k – scaling factor.

The exact form of these additional terms depends also on the scaling you use for t(i) and x(i). The possibilities for t(i).

1. use TCG
2. use TT

The possibilities for x(i)

A. use no additional scaling (that is, use directly the spatial coordinates of the Geocentric Celestial Reference System as defined by the IAU). We call this choice x^GRS(i)

B. use scaling $x\hat{}TT(i) = x\hat{}GRS(i) * (1 - L(G)$, where $L(G) = 6.969 * 10^{-10}$.

What we observe is actually the delay in terms of TT, so the choice between 1 and 2 is clear: choice 2 should be used. Absolutely INDEPENDENT of the choice between 1 and 2, we have to choose between the possibilities A and B. The IAU in 1997 in Kyoto has officially prohibited to use the scaled coordinates x^TT(i). So the "IAU" choice is A and the "IAU approach" is 2A (2 for time, A for coordinates), IERS1992 is 1A (this is also equivalent to 2B, that is the formula for 2B is absolutely the same as for 1A within the required accuracy). Note that IERS1996 was wrong in all meanings (different and wrong choices of scaling).

However, the ITRF2000 was decided to be represented by scaled coordinates x^TT(i) (this is against the IAU resolutions, but it was decided by a ITRF meeting in November 2000). Therefore, it is expected that the new IERS Conventions will support both the IAU choice 2A and the ITRF choice 2B with appropriate explanations.

CHAPTER #2. COMPUTE EXPERIMENT SOLUTION

INTRODUCTION

Before running this option, the SDF must have been generated and completely filled by option #1. They must be present at your work directory.

When you select this option your screen will show you the following menu:

OCCAM V 5.0
S O L U T I O N   C O M P U T A T I O N   M E N U

2.1 – Kalman Filter Process (geodetic)
2.2 – Kalman Filter Process (EOP service)
2.3 – Least squares collocation method
2.4 – Least squares method

<Return> - Previous Menu

Detailed description of this menu follows.

2.1 - MULTIBASELINE KALMAN ANALYSIS (Equivalent to running the program KVLBI).

Files: KVLBI.FOR, KALMAN.FOR, MATRIX.FOR, ARC.FOR, OPENING.FOR.

* Purpose

OCCAM 5.0 can perform a direct multibaseline analysis using the Kalman Filter theory to get the least squares results for the station positions and nutation offsets, while considering clock and atmospheric terms as stochastic processes (random walks model).

This estimation program has been tested by Nestor Zarraoa (about 1992) with respect to the program SOLVE developed by the NASA/Goddard Space Flight Center VLBI group, showing the equivalence of both programs at the formal error level of the VLBI results. Similar results have been found with respect to other implementation of the Kalman Filter method for VLBI analysis by Tom Herring (MIT).

You are able to estimate the station positions with fixed EOP parameters and without fixing of them. At the former case all systematic in a priori EOP will move to your geodetic results, but it will be a 'unificated' system of results with errors. At the latter case you will prevent your geodetic results from EOP incompleteness using some constrained. But you will have to apply for the same constrains (fixing a set of stations) from session to session to a reference frame. Practically it is impossible case because set of station in frame of one special network is not fixed. When you compare your resulting EOP time series you must remember that the set of constrained stations are kept for all sessions. Therefore it is reasonable to fix EOP in spite of loss of your result accuracy.

* How to use MULTIBASELINE KALMAN ANALYSIS (for geodetic tasks)

The program is controlled by file KVLBI.OPT file. An example of the file is shown below:

```
========================================================
SIGMA ADDED   .01   FACTOR ADDED    5.  DWN-MAN-IGN D      (METERS)
TROPOSPHERIC MODEL:  NIELL
NIELL  85.
YES  NUTATION OFFSET
NO  EARTH ORIENTATION PARAMETERS
NO  ATMOPSPHERIC GRADIENTS
NO. STATIONS  3   V  CONSTRNT __N_ECC __E_ECC __H_ECC
WETTZELL  0.0     N  0.00
ONSALA60  0.0     N  0.00
TRYSILNO  0.0     N  0.00        .066   -.018   2.823
CONSTRAINED DIRECTIONS 1
WETTZELL  ONSALA60
A PRIORI PARAM.  AND FORMAL ERRORS  (M)  (NO. ST. – 1) ∗ 6 + 1
0.0                      1.
0.0                      10.
0.0                      10.
0.0                      10.
0.0                      10000.
0.0                      .010
0.0                      1.
0.0                      10.
0.0                      10.
0.0                      10.
0.0                      10000.
0.0                      .010
0.0                      1.
A PRIORI POWER SP. DENSITY  (PS∗∗2/S)  (NO. STAT. – 1) ∗ 6 + 1
0.1
0.0
0.0
0.0
1.0
0.0
0.1
0.0
0.0
0.0
1.0
0.0
0.1
========================================================
```

A detailed explanation of every option follows:

The first line gives the user a chance to reweight and edit the data. SIGMA ADDED means a constant factor to add quadratically to the a-priori sigmas of the observables as they come in the data file. It is given in meters. FACTOR ADDED refers to the threshold for data editing. The program computes the expected sigma of the observed-calculated delays. If the difference is bigger than FACTOR times the expected sigma, then it may act according to the following option DWN-MAN-IGN: If D the observation will be Downweighted; if M the user will be asked to take a decision interactively (Manually); if I it will be used as such (Ignore the warning). The format of the line is (12X,F8.4,12X,F8.4,12X,A1).

The 2nd and 3rd lines specify that troposphere model by Niell is available and which will be used respectively. Also the 3rd line specifies a limit of zenith distance (Z, in degrees). Below the limit all observations will be downloaded by multiplication on factor to sec(Z)**2. The 2nd line is not read and the format of the 3rd is (A3, 4X, F3.0).

The 4th line allows the user to turn off ("NO NUTATION...") or on ("YES NUTATION...") the estimation of nutation offsets. 5th line works the same way with the estimation of EOP. Both are read with (A1) format. If the user wants to estimate only some of the EOP or only one of the nutation offsets it can be done by constraining the sigma of the a-priori value as is explained below.

The 6th line indicates if the troposphere gradients to be estimated or not. (A1)

The 7th line specifies the number of stations to be processed, in format (13X,I2).

There is one line for each station to be processed, in which the following information is provided: NAME, ADDED SIGMA, VERTICAL CONSTRAIN, SIGMA OF CONSTRAIN, ECCENTRICITIES (NORTH, EAST, UP). The NAME must coincide with the name on the data file and catalogs. The ADDED SIGMA is used for reweighting the data from that station. The value will be added quadratically to the a-priori sigma of the observable. VERTICAL CONSTRAIN (Y or N) indicates if the height component of the stations will remain fixed or not to the a-priori value. SIGMA OF CONSTRAIN limits the strength of the constraint (default 0.001m). The ECCENTRICITIES apply only to mobile sites, and are the North, East and Up component of the antenna with respect to the geodetic mark. All values are in meters and the format is (A8,2X,F6.3,2X,A1,2X,F8.5,3F8.5).

The next line asks how many directions will be constrained in the analysis. Format (23X,I3).

If the number of fixed directions is not 0, there follow as many lines as constrained directions, specifying the fixed baseline. The constrain will be given 0.001 m sigma. Format is (A8,1X,A8).

Next line is just a comment line, but it must be there. It helps to find where the parameter count starts.

Then there are as many lines as parameters to be solved, with their a-priori value and sigma of such a-priori. The number of parameters are as follows. The first station, which will be considered master station for the coordinates (fixed) and clock (fixed), will only contribute the first parameter, its tropospheric term (and, if necessary two troposphere gradients). All the other stations will contribute 6 or 8 parameters: X, Y, Z position, clock offset, rate and tropospheric term (and, if necessary two troposphere gradients). If nutation is to be estimated, 2 more parameters will be there. If Earth Orientation is to be solved, 3 parameters more are to be included.

In brief, the order of the parameters is: Trop. of St.#1 (and, if necessary two troposphere gradients); X,Y, Z, Clk. offset, Clk. rate, Trop. of St.#2 (and, if necessary two troposphere gradients); ...; X, Y, Z, Clk. offset, Clk. rate, Trop. of St.#n (and, if necessary two troposphere gradients); Nutation in obliquity, Nut. in longitude (if on); X wobble, Y wobble, UT1-UTC corrections (if on). This order will be kept all over the program and is the order in which the parameters and sigmas are displayed in the output files (KVLBI.RES, KVLBI, etc).

Units are meters for all the station parameters, including clock terms, and arc-seconds for nutation and EOP. Format of each line is (2F20.3).

If the user wants to constrain parameters to their a-priori value then the a-priori sigma must be reduced accordingly. It permits that in practice some parameters are not estimated but are fixed to their a priori values.

Then we have a new comment line, that permits to identify where the stochastic characterization of the parameters start. All parameters are in principle considered RANDOM WALK stochastic processes. So all of them can be given a rate of change with time.

For a random walk, the sigma of the change of the value after a time interval DT, comes as SQRT (PSD∗DT). PSD is the power spectral density of the WHITE NOISE associated with the random walk. If PSD = 0 then the parameter is not allowed to change with time, so it is considered a constant parameter. The user has to provide the PSD values for all the parameters. The units required are picoseconds**2/second for all the station parameters and arcseconds∗∗2/day for the nutation and orientation terms. There is one line for each parameter with format (F10.3) in the same order as for the a-priori values and sigmas.

In general only troposphere (term and gradients) and clock offsets are considered random walks, but orientation terms could be allowed a small rate of change, specially if long experiments (more than 24 hours) are analyzed.

The final results of the program are stored in the file KVLBI.RES that can be directly printed. Information about the evolution of the parameters with the successive filter iterations can be either seen in files KVLBI.

The program displays the post-fit Chi-squared of the residuals during process, to check that the options selected are in accordance with the data.

2.2 KALMAN FILTER PROCESS (for operational EOP service in frame of IVS).
(equivalent to running the program KVLBI_IE).

Files: KVLBI_IE.FOR, KALMAN.FOR, MATRIX.FOR, ARC.FOR, OPENING.FOR

It is a approach for operational EOP analysis, similar to 2.1. Station positions are fixed using reference frame recommended by IERS.

The program is controlled by the file KVLBI_IE.OPT. An example of the file is shown below:

```
===================================================================
SIGMA ADDED   .01   FACTOR ADDED    5.  DWN-MAN-IGN D      (METERS)
TROPOSPHERIC MODEL:  NIELL
NIELL  85.
YES  NUTATION OFFSET
YES  EARTH ORIENTATION PARAMETERS
NO  STATION COORDINATES
YES  ATMOPSPHERIC GRADIENTS
NO. STATIONS  3   V  CONSTRNT __N_ECC __E_ECC __H_ECC
WETTZELL  0.0     N  0.00
ONSALA60  0.0     N  0.00
TRYSILNO  0.0     N  0.00
CONSTRAINED DIRECTIONS 0
A PRIORI PARAM. AND FORMAL ERRORS  (M)  (NO. ST. – 1) ∗ 5 + 3 + 5
0.0                      1.
0.0                      0.010
0.0                       0.010
```

```
0.0                    10000.
0.0                        0.010
0.0                       1.
0.0                       0.010
0.0                        0.010
0.0                    10000.
0.0                        0.010
0.0                       1.
0.0                       0.010
0.0                        0.010
0.0                        1.
0.0                        1.
0.0                        1.
0.0                        1.
0.0                        1.
A PRIORI POWER SP. DENSITY  (PS∗∗2/S)  (NO. STATIONS – 1) ∗ 5 + 3 + 5
0.1
0.001
0.001
1.0
0.0
0.1
0.001
0.001
1.0
0.0
0.1
0.001
0.001
0.0
0.0
0.0
0.0
0.0
========================================================
```

A detailed explanation of every option follows:

The first line gives the user a chance to reweight and edit the data. SIGMA ADDED means a constant factor to add quadratically to the a-priori sigmas of the observables as they come in the data file. It is given in meters. FACTOR ADDED refers to the threshold for data editing. The program computes the expected sigma of the observed-calculated delays. If the difference is bigger than FACTOR times the expected sigma, then it may act according to the following option DWN-MAN-IGN: If D the observation will be downweighted; if M the user will be asked to take a decision interactively (Manually); if I it will be used as such (Ignore the warning). The format of the line is (12X,F8.4,12X,F8.4,12X,A1).

The 2nd and 3rd lines specify that troposphere model by Niell is available and which will be used respectively. Also the 3rd line specifies a limit of zenith distance (Z, in degrees). Below the limit all observations will be downloaded by multiplication on factor to sec(Z)**2. The 2nd line is not read and the format of the 3rd is (A3, 4X, F3.0).

The 4th line establishes the estimation of nutation offsets. 5th line works the same way with the estimation of EOP. Both are read with (A1) format. If the user wants to estimate only some of the EOP or only one of the nutation offsets it can be done by constraining the sigma of the a-priori value as is explained below.

The 6th line indicates that station coordinates are not estimated. (A1)

The 7th line indicates if the troposphere gradients to be estimated or not. (A1)

The 8th line specifies the number of stations to be processed, in format (13X,I2).

There is one line for each station to be processed, in which the following information is provided: NAME, ADDED SIGMA, VERTICAL CONSTRAIN, SIGMA OF CONSTRAIN, ECCENTRICITIES (NORTH, EAST, UP). The NAME must coincide with the name on the data file and catalogs. The ADDED SIGMA is used for reweighting the data from that station. The value will be added quadratically to the a-priori sigma of the observable. VERTICAL CONSTRAIN (Y or N) indicates if the height component of the stations will remain fixed or not to the a-priori value. At the option it should be N always. SIGMA OF CONSTRAIN limits the strength of the constraint (default 0.001 m).

The ECCENTRICITIES apply only to mobile sites, and are the North, East and Up component of the antenna with respect to the geodetic mark. All values are in meters and the format is (A8,2X,F6.3,2X, A1,2X,F8.5,3F8.5).

The next line asks how many directions will be constrained in the analysis. Format (23X,I3). At the option should be 0 always.

Next line is just a comment line, but it must be there. It helps to find where the parameter count starts. Then there are as many lines as parameters to be solved, with their a-priori value and sigma of such a-priori. The number of parameters are as follows. The first station, which will be considered master station for the coordinates (fixed) and clock (fixed), will only contribute the first parameter, its tropospheric term (and, if necessary two troposphere gradients). All the other stations will contribute 3 (or 5) parameters: clock offset, rate and tropospheric term (and, if necessary two troposphere gradients). After 2 nutation parameters and 3 EOP need to be estimated.

In brief, the order of the parameters is:Trop. of St.#1; Clk. offset, Clk. rate, Trop. of St.#2 (and, if necessary two troposphere gradients); ...; Clk. offset, Clk. rate, Trop. of St.#n (and, if necessary two troposphere gradients); Nutation in obliquity, Nut. in longitude; X-, Y-wobbles, UT1-UTC corrections. This order will be kept all over the program and is the order in which the parameters and sigmas are displayed in the output files (KVLBI.RES, KVLBI).

Units are meters for all the station parameters, including clock terms, and arc-seconds for nutation and EOP. Format of each line is (2F20.3).

If the user wants to constrain parameters to their a-priori value then the a-priori sigma must be reduced accordingly. It permits that in practice some parameters are not estimated but are fixed to their a-priori values.

Then we have a new comment line, that permits to identify where the stochastic characterization of the parameters start. All parameters are in principle considered RANDOM WALK stochastic processes. So all of them can be given a rate of change with time.

For a random walk, the sigma of the change of the value after a time interval DT, comes as SQRT (PSD∗DT). PSD is the power spectral density of the WHITE NOISE associated with the random walk. If PSD=0 then the parameter is not allowed to change with time, so it is considered a constant parameter. The user has to provide the PSD values for all the parameters. The units required are arcseconds∗∗2/day for the nutation and orientation terms. There is one line for each parameter with format (F10.3) in the same order as for the a-priori values and sigmas.

In general only troposphere and clock offsets are considered random walks, but orientation terms could be allowed a small rate of change, specially if long experiments (more than 24 hours) are analyzed. Otherwise, the troposphere gradients can be considered as a constant parameters.

If the control file has some errors (more stations than quoted, not enough parameter lines for a-priori values, sigmas or PSD, etc.), the program flags a warning message and aborts. Check that the number of lines coincides with the number of parameters or stations in each block.

The final results of the program are stored in the file KVLBI.RES. Information about the evolution of the parameters with the successive filter iterations can be either seen in files KVLBI.

The program displays the post-fit chi-squared of the residuals during process, to check that the options selected are in accordance with the data.

2.3 LEAST SQUARES COLLOCATION METHOD

(Equivalent to running the program COLL)

Files: COLL.FOR, COLL_ALL.FOR, C_EOP_0.FOR, DSINV.FOR, INFORM.FOR, MK1.FOR, READING.FOR, SUBS1.FOR, SUBS2.FOR, ARC.FOR, OPENING.FOR

The collocation technique allows to estimate subdiurnal variations of the EOPs with time resolution which corresponds to rate VLBI observation performance (one point per a few minutes). Station positions are fixed using reference frame recommended by IERS.

The program is controlled by the file COLLOCAT.OPT. An example of the file is shown below:

```
===========================================================
SIGMA ADDED   .01   FACTOR ADDED   15.  DWN-MAN-IGN D (METERS)
TROPOSPHERIC MODEL:  LANYI   DAVIS   MARINI   CHAO
NIELL  85.
YES  NUTATION OFFSET
YES  EARTH ORIENTATION PARAMETERS
NO ATMOSPHERIC GRADIENTS
NO. STATIONS 6    V  CONSTRNT __N_ECC __E_ECC __H_ECC
WESTFORD  0.0     N  0.0          .0      .0      .0
GILCREEK  0.0     Y  0.0          .0      .0      .0
HARTRAO   0.0     N  0.0          .0      .0      .0
HOBART26  0.0     N  0.0          .0      .0      .0
ALGOPARK  0.0     N  0.0          .0      .0      .0
MATERA    0.0     N  0.0          .0      .0      .0
CONSTRAINED DIRECTIONS 1
WESTFORD MATERA
==============================================================
```

A detailed explanation of every option follows:

The first line gives the user a chance to reweight and edit the data. SIGMA ADDED means a constant factor to add quadratically to the a-priori sigmas of the observables as they come in the data file. It is given in meters. FACTOR ADDED refers to the threshold for data editing. The program computes the expected sigma of the observed-calculated delays. If the difference is bigger than FACTOR times the expected sigma, then it may act according to the following option DWN-MAN-IGN: If D the observation will be downweighted; if M the user will be asked to take a decision interactively (Manually); if I it will be used as such (Ignore the warning). The format of the line is (12X,F8.4,12X,F8.4,12X,A1).

The 2nd and 3rd lines specify that troposphere model by Niell is available and which will be used respectively. Also the 3rd line specifies a limit of zenith distance (Z, in degrees). Below the limit all observations will be downloaded by multiplication on factor to sec(Z)**2. The 2nd line is not read and the format of the 3rd is (A3, 4X, F3.0).

The 4th line establishes the estimation of nutation offsets. 5th line works the same way with the estimation of EOP. Both are read with (A1) format.

The 6th line indicates if the troposphere gradients to be estimated or not. (A1)

The 7th line specifies the number of stations to be processed, in format (13X,I2).

There is one line for each station to be processed, in which the following information is provided: NAME, ADDED SIGMA, VERTICAL CONSTRAIN, SIGMA OF CONSTRAIN, ECCENTRICITIES (NORTH, EAST, UP). The NAME must coincide with the name on the data file and catalogs. The ADDED SIGMA is used for reweighting the data from that station. The value will be added quadratically to the a-priori sigma of the observable. VERTICAL CONSTRAIN (Y or N) indicates if the height component of the stations will remain fixed or not to the a-priori value. At the option it should be N always. SIGMA OF CONSTRAIN limits the strength of the constraint (default 0.001 m).

The ECCENTRICITIES apply only to mobile sites, and are the North, East and Up component of the antenna with respect to the geodetic mark. All values are in meters and the format is (A8,2X,F6.3,2X, A1,2X,F8.5,3F8.5).

The next line asks how many directions will be constrained in the analysis. Format (23X,I3).

If the number of fixed directions is not 0, there follow as many lines as constrained directions, specifying the fixed baseline. The constraint will be given 0.001 m sigma. Format is (A8,1X, A8).

Also you will be asked to input manually the following information:

- troposphere dispersion (in cm**2)
- clock dispersion (in cm**2)
- pole coordinates dispersion (in cm**2)
- UT1-UTC parameter dispersion (in cm**2)
- Pole parameters exponential coefficients
- UT1-UTC parameter exponential coefficient
- Phase for pole components
- Phase for UT1-UTC

The expected values follow the questions on the screen. Alternative choice can be made on user's feeling.

The amount of VLBI stations is limited to 8 ones for the option. At the first step the observations are adjusted using weighted least squares method. The post-fit residuals are calculated to fix the outliers which are downweighted at the next step.

The output files – UT1.DAT, X_EOP.DAT, Y_EOP.DAT contain the high-frequency EOPs. Format is (F15.8,2X,F10.7) – for UT1.DAT; (F15.8, 2X, F9.6) – for others.

Output files are also: INFORM.DAT; SKO.DAT, EPS.DAT, ERP.DAT

The file INFORM.DAT contains a priori information used for the session analysis

The file SKO.DAT contains the calculated values: normalized chi-squared and weighted root-mean squared - w.r.m.s – (in cm).
The file EPS.DAT contains post-fit residuals without separation on baselines. The order numbers of VLBI sites are included here as well (in cm).
The file contains a daily estimates of five EOPs (as average values) for the session (all - in arcsec).

2.4 LEAST SQUARES METHOD BASED ON THE GAUSS-MARKOV MODEL (LSM) (Equivalent to running the program LSM).

Files: LSM.FOR, LSM_OPT.FOR, MNK.FOR, DSINV.FOR, OUTB.FOR, READOPT.FOR, PREPARE.FOR, TIMSPLIT.FOR, ABAT2.FOR, ARC.FOR, OPENING.FOR

* Purpose

OCCAM 5.0 is able to do a classical least squares estimation with a large variety of parameters that can be determined during the analysis. Principally, LSM is a two-step approach with bad observations being downweighted after the first estimation step.

The basic number of parameters nr1 to be estimated for a 24 hour experiment is:

$$nr1 = 1 + (\text{nantenna} - 1) * 7 + (2) + (3)$$ nantenna - the number of stations

i.e. for the reference station OCCAM 5.0 only solves for one troposphere (wet) zenith delay, whereas for the other antennas, the station coordinates (x, y, z) and three clock parameters (offset, rate and rate squared) are also adjusted. Additionally two nutation parameters and three earth orientation parameters can be estimated once per 24 hour session.

Moreover LSM allows the estimation of further (auxiliary) parameters:

-) atmospheric gradients (offset and rate)

-) continuous piecewise linear functions:

$$\Delta L(t) = \Delta L_{offset} + \Delta L_{rate,0}(t_1 - t_0) + ... + \Delta L_{rate,n}(t - t_n)$$

This example shows a continuous piecewise linear function (plf) for the zenith delay, i.e. OCCAM 5.0 solves for one offset and several rates. Plf's can also be used for the clocks and gradients. Mind that auxiliary parameters for the clocks are always estimated in addition to the quadratic function mentioned above.

-) discontinuous functions:

OCCAM 5.0 also offers the possibility to solve for other kinds of functions for the auxiliary parameters (zenith delay, clock, gradients). For instance, there is the chance to estimate offsets only for certain time intervals. More details can be found in the description of the options file lsm.opt.

-) Constraints:

Constraints can be set for the offsets and rates of the auxiliary parameters. Those constraints prevent the parameters from varying too much. Furthermore the setting of the constraints might be necessary in order to avoid the singularity of the normal equations. This is the case if parameters are estimated for a certain time interval with no observations contributing to this parameter.
Constraints are set by specifiying the sigmas for observation equations:

$\Delta L_{offset} = 0 \pm sigma$ for the offset

$\Delta L_{rate} = 0 \pm sigma$ for the rate

Additionally the sigmas for the constraints can be further modified by setting an 'inverse fractional weight' ifw of the constraints. The reason for this option is that there is a difference whether you set a constraint for a parameter with 300 or 100 observations contributing to it. In other words, the more observations you have the smaller must be the sigma to have an equally powerful constraint.

Example:

300 observations contributing to a parameter (time interval: 2 hours)
sigma (random walk) is set to 20 mm/sqrt(h) in the options file
ifw is set to 10

variance = (20**2)/2 [mm**2/h**2] = 200 [mm**2/h**2]
variance = 200 / 300 * 10

So, the sigma 2.58 [mm/h] is used for the observation equation. If we only had 100 observations the sigma would be 4.47 [mm/h].

Nevertheless, if you are not sure about this option, just set the ifw to 999. By doing so, no ifw is applied.

* How to use the LEAST SQUARES METHOD

The program is controlled by the file LSM.OPT. An example of the file is shown below:

```
========================================================
SIGMA ADDED 0.010   FACTOR ADDED   5.00 DWN-MAN-IGN D
TROPOSPHERIC MODEL:  NIELL
NIELL
CUTOFF ELEVATION: 10.0
NO   DOWNWEIGHTING FOR LOW ELEVATIONS:  COSZ    COSZ**2
20.0  COSZ**2
YES  NUTATION OFFSET
NO   EARTH ORIENTATION PARAMETERS
NO   FREE SOLUTION
NO. STATIONS  5   V  N  E  CONSTRNT __N_ECC __E_ECC __H_ECC
```

```
KOKEE      0.000  N  N  N   0.00000   0.000   0.000   0.000
GILCREEK   0.000  N  N  N   0.00000   0.000   0.000   0.000
NRAO20     0.000  N  N  N   0.00000   0.000   0.000   0.000
WETTZELL   0.000  N  N  N   0.00000   0.000   0.000   0.000
FORTLEZA   0.000  N  N  N   0.00000   0.000   0.000   0.000
CONSTRAINED DIRECTIONS   1
WETTZELL FORTLEZA
-----------------------------------------------------------
AUXILIARY PARAMETERS
TIME INT.      ZD   ZDR   ZRS    CO    CR   CRS    GR   GRR
KOKEE       99.99  2.00  0.00  0.00  0.00  0.00 12.00  0.00
GILCREEK    99.99  2.00  0.00 99.99  1.00 99.99 12.00  0.00
NRAO20       2.00  2.00  0.00 99.99  1.00 99.99 12.00  0.00
WETTZELL    99.99  2.00  0.00  1.00  1.00  1.00 12.00  0.00
FORTLEZA    99.99  2.00  0.00 99.99  1.00 99.99 12.00  0.00
PIECEWISE LINEAR FUNCTIONS AND CONSTRAINTS
INVERSE FRACTIONAL WEIGHT OF CONSTRAINTS: 999
#RATES     RW  ZDR PL   RW  CLR PL   RW  GRR PL
           MM/SQRT(H)   MM/SQRT(H)   MM/SQRT(H)
KOKEE       15.000  Y     0.000  N     0.000  N
GILCREEK    15.000  Y    20.000  Y     0.000  N
NRAO20      15.000  N    20.000  Y     0.000  N
WETTZELL    15.000  Y    20.000  N     0.000  N
FORTLEZA    15.000  Y    20.000  Y     0.000  N
#OFFSETS   SIG ZDO EX   SIG CLO EX   SIG GRO EX
            MM           MM           MM
KOKEE        0.000  N     0.000  N     0.500  N
GILCREEK     0.000  N     0.000  N     0.500  N
NRAO20       0.000  N     0.000  N     0.500  N
WETTZELL     0.000  N     0.000  N     0.500  N
FORTLEZA     0.000  N     0.000  N     0.500  N
========================================================
```

A detailed explanation of every option follows:

The first line gives the user a chance to reweight and edit the data. SIGMA ADDED means that a constant number is added quadratically to the apriori sigmas of the observables as they defined in the (ngs-) data file. It is given in meters. FACTOR ADDED refers to the threshold for the editing of observations. The smaller this factor is, the more observations are downweighted. The following criterion is used for the downweighting of the observation i:

(v(i)**2)/sqrt(cofactor(i)) > factor

v(i) is the residual of the observation, and cofactor(i) is the cofactor aposteriori of the residual.
The format of the line is (12X,F8.4,12X,F8.4,12X,A1).
The second and third lines specify which troposphere models are available and which will be used respectively. Presently, the only option is the Niell mapping function (A3). Mind that with OCCAM 5.0 (LSM) the dry zenith delay is calculated apriori and the wet zenith delay is estimated by the least squares analysis.

The fourth line specifies the cutoff elevation angle. The format is (18X,F4.1). The fifth line gives the user the chance to downweight low obervations (A1). The next line is then intended to provide the elevation angle from which downweighting should be started and the way of downweighting itself. (F4.1,2X,A7)

The next two lines allow the user to decide whether nutation and earth orientation parameters should be solved for. Both are read with (A1) format. Mind that presently only one set of nutation and/or eop parameters can be estimated for one 24 hour experiment.

The next line is intended to specify whether a free network solution should be estimated. This option does not work yet. (A1)

The next line specifies the number of stations to be processed. The format that is used is (13X,I2).

There is one line for each station to be processed, in which the following information is provided: NAME, ADDED SIGMA, CONSTRAINT (VERTICAL, NORTH, EAST), SIGMA OF VERTICAL CONSTRAINT, ECCENTRICITIES (NORTH, EAST, UP). The NAME must coincide with the name in the data file and catalogs. The ADDED SIGMA is used for reweighting the data from that particular station. This value will be added quadratically to the apriori sigma of the observable. VERTICAL CONSTRAINT (Y or N) indicates if the height component of the stations will remain fixed or not to the apriori value. The NORTH and EAST CONSTRAINTS do not work yet. The SIGMA OF VERTICAL CONSTRAINT limits the strength of the vertical constraint (default 0.001m). The ECCENTRICITIES apply only to mobile sites, and are the North, East and Up component of the antenna with respect to the geodetic mark. All values are in meters and the format is (A8,2X,F6.3,2X,3(A1,2X),F8.5,3F8.5).

The next line asks how many directions will be constrained in the analysis. Format (23X,I3). If the number of fixed directions is not 0, there follow as many lines as constrained directions, specifying the fixed baseline. Format is (A8,1X,A8).

Hint: If all station coordinates should be fixed to their apriori values all directions and all heights have to be constrained.

In the next paragraph the time intervals for the estimation of the the auxiliary parameters have to be set. Mind that there is no estimation of clock parameters for the first (reference) station. If you want to solve for a piecewise linear function plf you have to set one offset for the whole experiment (24.00 or just take 99.99) and additionally the time intervals for the rates have to be specified (e.g. 2.00 for a two hours' time interval).

The lsm.opt file above shows some examples for the parametrization:

-) plf for the zenith delay at KOKEE e.g. (two hours time interval)
-) one-hour discontinuous quadratic functions for the clock at WETTZELL
-) two-hours discontinuous functions for the zenith delay at NRAO20
-) twelve-hours offsets for the gradients for all stations

In particular the items are: NAME, ZENITH DELAY OFFSET, ZENITH DELAY RATE, ZENITH DELAY RATE SQUARED, CLOCK OFFSET, CLOCK RATE, CLOCK RATE SQUARED, GRADIENT OFFSET, GRADIENT RATE. The format is (A8,3X,8(F5.2,1X)).

The inverse fractional weight of constraints should be set to 999 by default. By using it the sigmas of the constraints for the plf's can be adapted to the numbers of observations within a certain time interval. (42X,I3)

The next paragraph specifies the constraints for the rates of the plf's. Mind that plf's have to be marked with 'Y' in order to distinguish them from discontinuous functions. The units of the constraints (sigmas) are comparable to those of random walk parameters (mm/sqrt(h)). The items are: NAME, ZENITH DELAY RATE, PLF (Y or N), CLOCK RATE, PLF, GRADIENT RATE, PLF. (A8,3(3X,F7.3,2X,A1))

The last paragraph contains information for the offsets of the auxiliary parameters. Do not use an offset constraint for the (wet) zenith delay, but do use a constraint for the gradient offset. If the sigma for the offset is set to 0.000 no constraint will be applied
The items are: NAME, ZENITH DELAY OFFSET, EX, CLOCK OFFSET, EX, GRADIENT OFFSET, EX. (A8,3(3X,F7.3,2X,A1)) The symbol EX means that external information (e.g. zenith delays by GPS) can be introduced but this options does not work with this version.

CHAPTER #3. UTILITIES

INTRODUCTION

In this option we have included some programs that usually are not needed during standard processing but that may be useful in certain cases.

With this option, the user will see the following menu:

```
:------------------------------------------------------------------------

:                        OCCAM  V 5.0
                    U T I L I T I E S    M E N U
:------------------------------------------------------------------------
:
:        3.1 - Extract information from OCCAM Standard Files
:        3.2 - Extract Obs-Calc Files
:        <Return> - Previous Menu
:
:------------------------------------------------------------------------
```

3.1. EXTRACT INFORMATION FROM OCCAM STANDARD FILES (DUMPTHEO)

Files: DUMPTHEO.FOR, OPENING.FOR, ARC.FOR

This options allows to extract information from OCCAM SDF. Data can be extracted from BASTIM, STATIM, SORTIM and STACAT. Information from BASTIM can be extracted by record number, by source, by station or the whole file. There are interactive menus to select how to extract the data for all files. Information from STATIM can be extracted from the whole file, by source or by record number. Information from SORTIM is extracted by record number. If file STACAT is to be read, the full file is processed. File "OUTPUT.XTC" contains the extracted information.

3.2. EXTRACT OBS-CALC FILES (Code EXTRACT)

Files: EXTRACT.FOR, OPENING.FOR, ARC.FOR

This option reads the SDF and generates a series of outputs with several information:

OUTPUT.OMC includes the Obs-Calc values plus the tropospheric calibrations (DAVIS model). It writes the station names, source name, year, day of year, hour, minute, integer second, observed minus computed delay, atmospheric correction for station 1 and 2. The format is (1X,A8,1X,A8,2X,A8,2X,I4,1X,I3,1X,3I2,2X, 3D22.16).

OUTPUT.THE includes the theoretical delays. The variables written are: record number, station names, source name, year, day of year, hour, minute, second, theoretical without atmospheric model and theoretical with atmospheric model. The format used is: (I3,A8,1X,A8,2X,A8,2X,I4,1X,I3,1X,3I2,2X,2D22.16).

OUTPUT.PAR lists the partial derivatives respect to all parameters. It writes the station names, source name, year, day of year and hour, minute, second, observed minus computed delay and the partial derivatives with respect to X, Y, Z (1st station), X, Y, Z (2nd station), atmospheric parameter (1st and 2nd station), RA and Declination of source, nutation obliquity and longitude. The format is: (A8,1X,A8,2X,A8,2X,I4,1X,I3,1X,3I2,2X, 13D15.8)

These files are useful for plotting, comparison or debugging.

APPENDIX A.

DESCRIPTION OF THE NGS VLBI FORMAT

NGS VLBI DATA FORMAT

1. Site cards
   Col. 1- 8: Site name
   Col. 11-25: Site X component (m)
   Col. 26-40: Site Y component (m)
   Col. 41-55: Site Z component (m)
   Col. 57-60: Axis type
   Col. 61-70: Axis offset
 End of site cards is indicated by $END

2. Source cards
   Col. 1- 8: Source name
   Col. 11-28: Right ascension HH MM SS.SSSSSSSSS
   Col. 31-48: Declination   sDD MM SS.SSSSSSSSS
 End of source cards is indicated by $END

3. Auxiliary parameters
   Col. 1-20: Reference frequency
   Col. 21-30: Group delay ambiguity spacing
   Col. 32-33: Delay type (GR or PH)
   Col. 35-36: Delay rate type (GR or PH)
 End of this card is indicated by $END

4. Data cards
  Card # 1
   Col. 1-18: Names of site #1 and site #2
   Col. 21-28: Source name
   Col. 30-60: Time YYYY MM DD HH MM SS.SSSSSSSSSSS
   Col. 61-70: Run identification code
   Col. 71-78: Sequence number
   Col. 79-80: 01

  Card # 2
   Col. 1-20: Observed delay (ns)
   Col. 21-30: Formal error of observed delay (ns)
   Col. 31-50: Observed delay rate (ps/sec)
   Col. 51-60: Formal error of observed delay rate (ps/sec)
   Col. 61-62: Data quality flag (0 means good data)

Col. 64-68: Delay and delay rate type
Col. 69-69: I if ionospheric calibration applied
Col. 70-70: C if cable calibration applied
Col. 71-78: Sequence number
Col. 79-80: 02

Card # 3
Col. 1-20: Correlation coefficient and formal error
Col. 21-40: Fringe amplitude and formal error (J)
Col. 41-70: Total fringe phase and formal error (rad)
Col. 71-78: Sequence number
Col. 79-80: 03

Card # 4
Col. 1-15: System temperature at site 1 and formal error (K)
Col. 16-30: System temperature at site 2 and formal error (K)
Col. 31-45: Antenna temp. at site 1 and formal error (K)
Col. 46-60: Antenna temp. at site 2 and formal error (K)
Col. 71-78: Sequence number
Col. 79-80: 04

Card # 5
Col. 1-20: Cable cal. correction for sites 1 and 2 (ns)
Col. 21-40: WVR parameter at site 1 and formal error (ns)
Col. 41-60: WVR parameter at site 2 and formal error (ns)
Col. 62-64: WVR parameter definition code at sites 1 and 2:
    0.- parameter is zenith path delay
    1.- parameter is path delay along line of sight
Col. 71-78: Sequence number
Col. 79-80: 05

Card # 6
Col. 1-20: Ambient atmosph. temperature at sites 1 and 2 (C)
Col. 21-40: Ambient barometric pressure at sites 1 and 2 (mb)
Col. 41-60: Atmospheric humidity parameter at sites 1 and 2
Col. 62-64: Humidity parameter definition at sites 1 and 2
    0.- Relative humidity (%)
    1.- Dew point (C)
    2.- Wet bulb temperature (C)
Col. 71-78: Sequence number
Col. 79-80: 06

Card # 7
Col. 1-10: Time difference between reference epoch and the
    start of observation (sec)
Col. 11-20: Duration of observation (sec)
Col. 21-30: A priori UTC offset at site 1 (sec)
Col. 31-50: Observation frequency (MHz)
Col. 51-60: Group delay ambiguity (ns)

Col. 71-78: Sequence number
Col. 79-80: 07

Card # 8
Col. 1-20: Ionospheric delay (ns)
Col. 21-30: Formal error of ionospheric delay (ns)
Col. 31-50: Ionospheric delay rate (ps/sec)
Col. 51-60: Formal error of ionospheric delay rate (ps/sec)
Col. 71-78: Sequence number
Col. 79-80: 08

APPENDIX B.

FORMATS AND EXAMPLES OF EXTERNAL FILES USED IN OCCAM

1. CATALOG. File name - any
First two columns determine the record code (RC).

RC = TC (terrestrial coordinates)
Col. 1- 2: Record code
Col. 4-11: Station name
Col. 12-28: X component (m)
Col. 29-43: Y component (m)
Col. 44-58: Z component (m)
Col. 60-63: Axis type. Valid types are:
AZEL.- Azimuth-elevation mounting
EQUA.- Equatorial mounting
X-Y1.- X-Y mounting North-South
X-Y2.- X-Y mounting East-West
Col. 64-73: Axis offset (m)

RC = TV (terrestrial velocities)
Col. 1- 2: Record code
Col. 4-11: Station name
Col. 12-19: X velocity (m/year)
Col. 20-27: Y velocity (m/year)
Col. 28-35: Z velocity (m/year)

RC = CC (celestial coordinates)
Col. 1- 2: Record code
Col. 4-11: Source name
Col. 13-27: Right ascension HH MM ss.sssssss
Col. 32-47: Declination sDD MM ss.sssss
Col. 50-57 Deviation in right ascension ss.sssssss
Col. 60-66 Deviation in declination ss.ssssss
Source coordinates must be provided in J2000.0 reference frame

RC = HH
Col. 1- 2: Record code
Col. 4-70: Comments

RC = EP (epoch of the terrestrial coordinates/velocities)
Col. 1- 2: Record code
Col. 4- 9: Epoch (years)

2. EPHEMERIS FILE. File name.- EPHEM.DAT
First four columns determine the record code (RC).

RC = EOP1 or (Earth orientation parameters)
Col. 1- 4: Record code
Col. 7-13: Modified Julian date of the data
Col. 15-22: X wobble (arcsec)
Col. 23-30: Y wobble (arcsec)
Col. 33-41: UT1–UTC (sec)
Col. 44-45: TAI–UTC (integer number of seconds)
Col. 47-53: Nutation angle Dpsi (arcsec)
Col. 55-61: Nutation angle Deps (arcsec)

RC = MOOND (Moon ephemeris position and velocity)
Col. 1- 5: Record code
Col. 6- 13: Modified Julian date of data
Col. 14-157: X, Y, Z geocentric coordinates, X, Y, Z velocities

RC = EARTD
Col. 1- 5: Record code
Col. 6- 13: Modified Julian date of data
Col. 14-157: X, Y, Z barycentric coordinates, X, Y, Z velocities

RC = SUND
Col. 1- 5: Record code
Col. 6- 13: Modified Julian date of data
Col. 14-157: X, Y, Z geocentric coordinates, X, Y, Z velocities

The program assumes that the tables are given in UTC time for interpolation.

If you generate EPHEM.DAT automatically, you need global files for ephemerids and EOP.

The ephemerids file for one year must be called EPHEM.ye, and it is convenient that it overlaps a little with the previous and next year. Each record must contain all the information for each epoch in free format. The variables are:

Record number; Epoch; Earth barycentric coordinates X,Y,Z, velocities X,Y,Z; Sun geocentric coordinates X,Y,Z and velocities X,Y,Z; Moon geocentric coordinates X,Y,Z and velocities X,Y,Z.

The EOP file for one year must correspond to the EOP1 series in the current implementation of OCCAM and the format is free in the following order:

Epoch (MJD), X wobble, Y wobble, UT1–UTC, UT1–TAI

3. OCEAN LOADING DATA. File name – LOADING.OCE

The data is organized in blocks. One block for each station. Each block contains:

Record #1: Station name from column 1 to 8
Record #2: Amplitude of radial displacement for each component. 7 characters per value (m).
Record #3: Amplitude of horizontal north-south displacement for each component.

7 characters per value (m).

Record #4: Amplitude of horizontal east-west displacement for each component.
7 characters per value (m).

Record #5: Phase of radial displacement for each component. 7 characters per value (Deg).

Record #6: Phase of horizontal north-south displacement for each component.
7 characters per value (Deg).

Record #7: Phase of horizontal east-west displacement for each component.
7 characters per value (Deg).

The tidal components are indexed in the following order:
M2, S2, N2, K2, K1, O1, P1, Q1, MF, MM, SSA
Example of block. Only nine components shown but can be up to 11.

```
ONSALA60            R, PHR, TNS, PHNS, TEW, PHEW
  0.384  0.091  0.084  0.019  0.224  0.120  0.071  0.003  0.084
  0.058  0.027  0.021  0.008  0.032  0.017  0.009  0.004  0.007
  0.124  0.034  0.031  0.009  0.042  0.041  0.015  0.006  0.018
 -56.0  -46.1  -90.7  -34.4  -44.5 -123.2  -49.6  178.4   14.9
  84.2  131.3   77.7  103.9   17.2  -55.0   25.2 -165.0  173.3
  75.4   97.6   40.8   94.8  119.0   25.4   98.7  -14.1 -177.0
```

4. ATMOSPHERIC LOADING CORRECTION DATA.
File names: [station_name].ATM and ATMEAN97

These files have to be stored in the /ATM directory.
Each line of the *.ATM files, which contain the corrections for one station include the following:

- Time of correction (mjd, four epoches per day)
- corrections up, east, north [m]

Format of the lines in ATMEAN97, which contains corrections due to average pressure on sites. It is subtracted from the correction to avoid offsets:

- eight character station name,
- correction-offsets up, east, north [m]

5. THERMAL DEFORMATION CONTROL FILE. File name – THERMAL.DEF

The file THERMAL.DEF contains mainly the info from the file titled 'thermal.dat' from the homepage of IVS Analysis Coordinator (A. Nothnagel) homepage (http://miro.geod.uni-bonn.de/vlbi/IVS-AC). Its format is:

The data is organized in blocks. Each block contains two lines:
line 1:

- eight character station name

line 2 (f9.5,f6.1,1x,f11.6,4(f6.1),i6,f6.1):

- gf [1/°C] (expansion coefficient for foundation)

- hf [m] (height of concrete foundation)
- ga [1/°C] (expansion coefficient for antenna)
- hp [m] (height of antenna pillar)
- hv [m] (height of vertex)
- hs [m] (height of subreflector)
- hd [m] (height of declination shaft)
- ifo (10 => factor for hs is 0.9 (for prime focus antennas only),
  20 => factor for hs is 1.8)
- reference temperature [°C] (The usual reference temperature used for designing and constructing buildings is 20°C. In this approach, mean temperatures at the sites are used for not generating offsets to the coordinates)

APPENDIX C

DESCRIPTION OF OCCAM INTERNAL FILES

1. SORTIM (19)

Direct access file with record length of 752 bytes

1- 4 Dummy integer. On first record, total number of records
5- 12 Source name (Character*8)
13- 28 Right ascension and declination at 2000.0 (Real*8)
29- 40 Modif. Julian date and fraction of day in radians (Integer*4 and Real*8)
41- 48 Integer number of seconds between UTC and TAI (Real*8)
49-168 Apparent RA and Dec, and geocentric source direction unit vector (3) for one second before, one after and at the observation time. All Real*8.
169-240 Earth barycentric coordinates (X,Y,Z) one second before, after and at the observation time. Real*8.
241-312 Earth barycentric velocity (X,Y,Z) one second before, after and at the observation time. Real*8.
313-384 Earth barycentric acceleration (X,Y,Z) one second before, after and at the observation time. Real*8
385-432 Greenwich sidereal time and hour angle one second before, one after and at the observation time. Real*8.
433-440 Earth Rotation velocity. Real*8
441-488 X wobble and Y wobble one second before, one after and at the observation time.
489-560 Moon X,Y,Z geocentric coordinates one second before, one after and at the observation time. Real*8
561-632 Geocentric sun coordinates (X,Y,Z) one second before, one after and at the observation time. Real*8.
633-680 Partial derivatives of the source direction unit vector with respect to nutation obliquity (3) and longitude (3). All Real*8.
681-752 Final matrix of precession and nutation (nine components, all Real*8).

2. STATIM (18)

Direct access file with a record length of 480 bytes.

1- 4 Dummy integer. Total number of records on first one.
5- 8 Record number for this station in file STACAT
9- 12 Record number of this observation in SORTIM
13- 40 Temperature, Pressure, Humidity and humidity factor. All Real*8. Last one integer.
41- 48 Cable calibration. Real *8.
49-120 Station coordinates (X,Y,Z) one second before, one after and at the observation time. Real*8
121-192 Station Coordinates (Longitude, latitude, height) one second before, one after

and at the observation time.
193-264 Zenith distance, hour angle and local sidereal time one second before, one after and at the observation time.
265-280 Zenith tropospheric path delay "dry" and "wet".
281-312 Tropospheric mapping functions or corrections for delays and rates. Models Niell (2 values).
313-328 Axis offset corrections (delay and rate).
329-408 Partial derivatives with respect to Z, X, Y, RA, Dec for delay and rate.
409-424 Partial derivatives with respect to the nutation offsets (obliquity and longitude). Real*8
425-448 Partial derivatives with respect to the EOP (X,Y, UT1–UTC). Real*8
449-456 Thermal deformation of antenna. Real*8
457-464 Source azimuth. Real*8
465-480 Partial derivatives with respect to troposphere gradients. Real*8

3. BASTIM (17)

Direct access file with a record length of 144 bytes.

1- 4 Dummy integer. Total number of records in first one.
5- 8 Record number of the observation in file SORTIM
9- 16 Record number of the observation for station on STATIM
17- 48 Observed delay and rate with formal errors.
49- 80 Ionospheric correction for delay and rate and errors
81-104 Theoretical delay one second before, one after and at the observation time.
105-128 Theoretical rate one second before, one after and at the observation time.
129-136 Ambiguity correction term

4. DICTIO (21)

Direct access file with a record length of 2128 bytes

Each record represents one baseline, and it contains the list of record numbers in BASTIM in which there is data of that baseline. An ambiguity correction term for the baseline is also stored.

5. STACAT (20)

Direct access file with a record length of 128 bytes

1- 4 Dummy integer. Total number of stations on first record.
5- 12 Station name. (Character*8)
13- 36 Station a priori coordinates (X,Y,Z). Real*8
37- 44 Epoch for the a-priori coordinates. Real*8
45- 68 A-priori velocity of the station (X,Y,Z). Real*8
69- 72 Mounting type

73- 88 Axis offsets
89-112 Longitude, latitude and height
113-120 Geocentric radius of station
121-128 Equatorial component of station vector.

6. BATCH

ASCII file with the list of the involved baselines

7. METEOR

ASCII file with the meteorological data and cable calibration extracted from NGS-format input file.

8. CLOCK BREAKS MODEL. Filename BREAKS.RES

Each record contains information about one single clock break but the Kalman Filter program only reads columns 1 to 3. The third column information is not use now. The format is (I3,2x,I3)

Col 1- 3: Station Code number
Col 5- 8: Time Code number
Col 11-14: Clock break type:
+1 .- Clock offset jump
-1 .- Clock rate variation

Example of file:

```
  4   55  -1.0
  1   63  -1.0
```