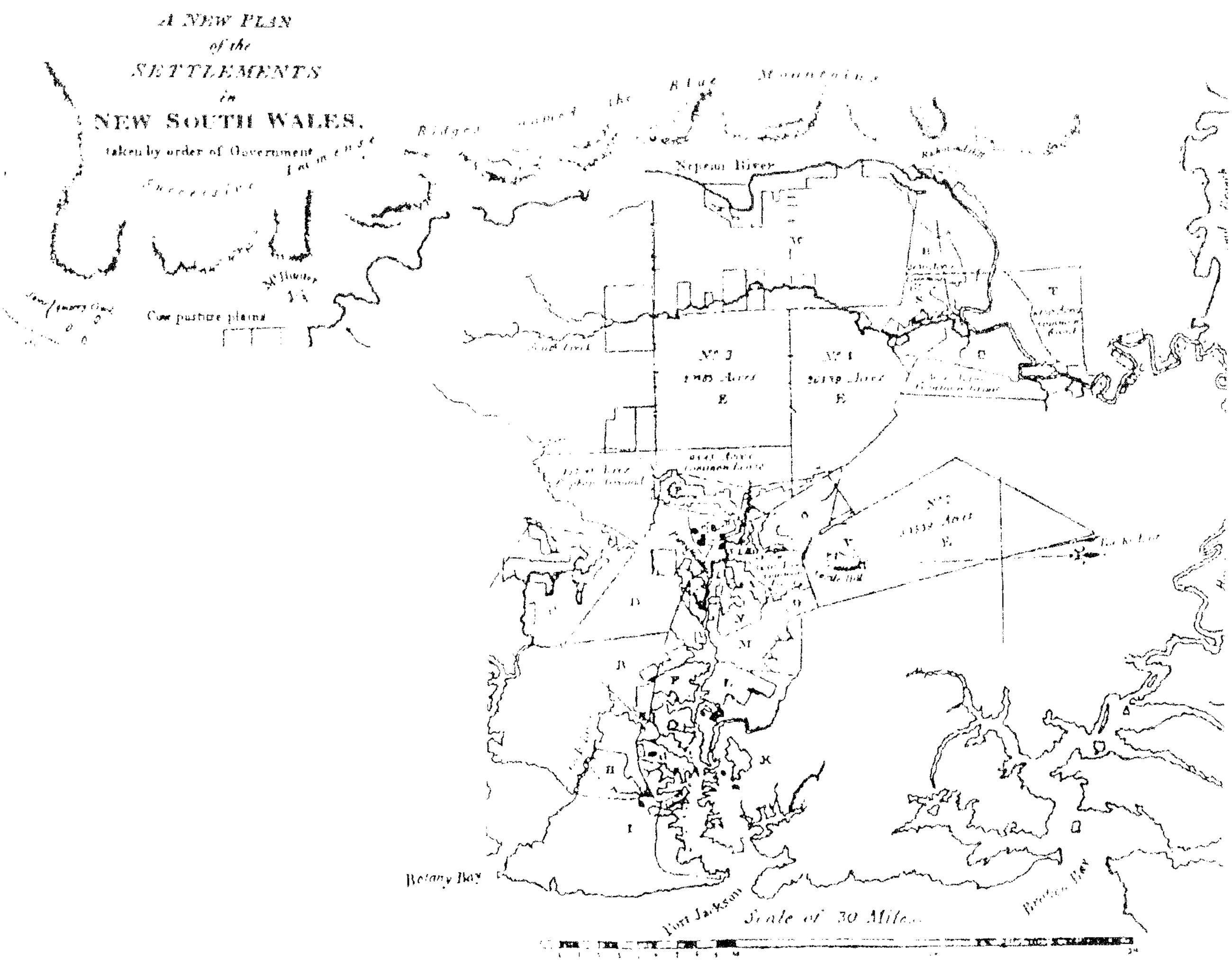
A FIRST-ORDER NETWORK FOR NEW ZEALAND

Peter MORGAN and Merrin B. PEARSE



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PETER MORGAN AND MERRIN PEARSE

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Editor's Note

The Unisurv-S series has been, since its beginnings in the mid-1960's, the vehicle the vehicle for publishing research theses and major projects carried out within the School of Geomatic Engineering (formerly Surveying), University of New South Wales.

In recent years there has been an increase in research activity in other Australian Schools and Departments. In order to assist in the dissemination of this research, this School has decided that, where it is of sufficient quality and relevance, such research will be published within the Unisurv S Series. UNISURV S 56 is the detailed report by Peter Morgan and Merrin Pearse of the first-order GPS survey and adjustment of New Zealand.

Dr Morgan is Associate Professor in the School of Computing, University of Canberra, and Visiting Professor at the School of Geomatic Engineering, UNSW (peterm@ise.canberra.edu.au).
Dr Pearse is Research Geodesist at Land Information New Zealand (mpearse@linz.govt.nz).

A.H.W. Kearsley
Publications Manager
School of Geomatic Engineering
University of New South Wales
December, 1999

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As with most large projects the project could not have been accomplished without the help and cooperation of many individuals and organizations.

At the University of Canberra Peter Morgan enjoyed support from the University Research Office who provide basic research infrastructure including the computational hardware used in this project. He was also supported by Mr. Ross Johnson who supplied SOLARIS and network support to the Survey Laboratory and Mr Laurie Spencer who supplied general hardware support.

Without the dedicated support and commitment of Land Information New Zealand to the establishment of New Zealand Geodetic Datum 2000 this sub-project would not have been possible. Merrin Pearse was supported by the Office of the Surveyor-General, the Contracts Group and the former Geodetic System group. There were many employees of the former Department of Survey and Land Information who were involved in the trials, data collection and processing that without their efforts we would not have had been able to complete this project. Those people included Tony Bevin. Don Grant. Graeme Blick, Jim Hall, Chris Crook, Geoff Linnell. George Williamson, John Ritchie, Hari Lal, Brent George, Glen Rowe, Vince Belgrave and Kelvin Tait.

We are particular appreciated of the support and cooperation that we received from Dr. Paul Denys of Otago University's Department of Surveying. Dr Denys was particular helpful in unraveling the antenna offset problems that we encountered for station OUSD. It was his uncertainties over the connection of the old OTAG mark through a transfer mark that resulted in the discarding of the tie information between OTAG and OUSD.

Finally we wish to thank our colleagues at the Crown Research Institute, Geological and Nuclear Sciences for their cooperation and the spirit in which they provided a peer review and validation of our work. The Team at Geological and Nuclear Sciences was led by Dr John Bevan. Dr Bevan's review of our results was instrumental in finding the error in assigning an incorrect antenna type for the 1996 Ashtechs. He also prompted us to consider errors and outliers at several other stations. Both us spent many hours comparing vectors and plots. At the beginning of the process we thought that a 10 mm rms figure would be acceptable. We were not prepared for the nothing worse than 5 mm final comparison that the inter comparison process produced. To be sure there are difference, one quite large difference is the tie at Windsor Castle. On such issue we have agreed to be different. However we both have the certain knowledge that the difference introduces no nasty or large difference in the solutions. Peer review in a cooperative environment found most of the errors and corrected them delivering to Land Information New Zealand the best possible results. Thank you John for running the process the way you did.

Caveat Emptor

The results in this report are not New Zealand Geodetic Datum 2000 coordinates.

The results tabulated in this report are in the International Earth Rotation Services' International Terrestrial Reference Frame 1996, ITRF96. The vectors and their rate of change as reported in this report refer to three principal epochs:

1. To the solution date which is the last observation date. This date is important due to the non-modelable nature of the Earth's rotation and the necessity to compute quantities such as satellite orbits in an inertial frame while station vectors need to be reported in a terrestrial frame.
2. A time which minimizes the correlation between the position vector and its rate of change. This date is usually near the mid-point of the observations.
3. A convenient comparison date. This date was chosen as 1996.5. This date is near the mean uncorrelated date. By choosing this date for inter comparisons with IGNS we minimised error propagation.

The third date was chosen by Land Information New Zealand as the starting date for the computation of their Geodetic Datum 2000 values. These values were determined by applying Geological and Nuclear Science velocities to the 1996.5 values to arrive at the 2000 positions.

The velocities in this report are known to be in close agreement with those determined by Geological and Nuclear Science. However small but important difference exist and hence New Zealand Geodetic Datum 2000 values cannot be determined from only information contained in this report. Readers wanting more information on the velocities used to define Geodetic Datum 2000 are referred to *Revised Horizontal Velocity Model for the New Zealand Geodetic Datum*. Client Report 43865B, by R. John Beavan. Institute of Geological and Nuclear Sciences, Wellington. New Zealand, prepared for Land Information New Zealand.

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Chapter 1

Introduction

New Zealand. like many other nations was quick to grasp hold of GPS as the most appropriate tool for maintaining and updating its aging 1949 geodetic datum. However unlike many of its near neighbours, especially Australia. New Zealand is a country that sits astride the plate boundary between the Australian and Pacific plates. Thus there is the necessity to at least measure crustal motion so that it can be accounted for if not fully understood.

GPS measurements in New Zealand date from at least 1988 when the U.S Naval Observatory site at Black Birch in the South Island was occupied. Shortly after a permanent tracker was established in Wellington atop of Heaphy House which then housed the Department of Survey and Land Information, DOSLI. This site contributed data to the CIGNET network and made an invaluable contribution to southern hemisphere campaigns.

Epoch style campaigns for datum definition work and crustal motion studies have been a regular feature of the New Zealand GPS activity since 1992 when the first pilot studies were undertaken. The 1993 and 1994 epoch campaigns were reduced by DOSLI staff using commercial software and by Pearse (1997) as part of his doctoral studies using the GAMIT/GLOBK (King & Bock 1994 and Herring 1994). In these studies Pearse used the fiducial approach, primarily because there was no high quality IGS control in New Zealand yet there was a need to express the new coordinates in terms of the International Terrestrial Reference Frame, ITRF, which is the physical realization of the International Earth Rotation Services's terrestrial reference system.

From 1994 GPS activity in New Zealand branched into four main streams:

1. DOSLI (and following restructuring Land Information New Zealand, LINZ) continued its annual campaigns aimed at defining a new geodetic datum for New Zealand. It is primarily data from these annual campaigns that is the subject of this report.

2. The Crown Research Institute, Geological and Nuclear Sciences commenced a study of crustal motion in New Zealand under the leadership of John Beavan. There has been considerable cooperation and data shearing between Geological and Nuclear Sciences and Land Information New Zealand.

3. A strong academic group with a permanent station operating close to IGS standards became a reality at the University of Otago.

4. Private contractor use of GPS.

In January 1997 the authors and A/Prof Richard Coleman reduced the 1995 and 1996 data using the latest versions of GAMIT at the University of Tasmania where a major study was being conducted into Southern Hemisphere GPS sites. This study showed that the new data was very clearly superior to the earlier data. Major reasons for this superiority included:

- The campaigns made use of P-code receivers allowing the formation of the wide-lane observable.
- The receivers were run continuously for at least three days at each station.
- The receivers were not reset on a daily basis at the site of interest.
- New Zealand had an emerging regional network of fixed. permanent, stations at Auckland, Wellington. Dunedin and Chatham Islands.

The superiority of this data prompted Land Information New Zealand to perform two additional annual surveys to provide the data necessary for the definition of their new semi-dynamic (kinematic) datum.

In 1998 a large number of improvements were made to GAMIT/GLOBK. Some of the more important improvements in version 9.72 as compared to version 9.28 were :

- Antenna modeling was incorporated.
- The software was able to handle multiple sessions within a day with different antenna heights.
- The orbital modeling was improved.
- Stochastic atmospheres were introduced.

These improvements and the reference frame work done at the University of Tasmania suggested that a full reprocessing of the early data was now worthwhile and would produce meaningful station vectors and their rates of change. velocities. Thus a project was initiated for a consistent reduction of all data collected by Land Information New Zealand and its predecessor organization for the task of defining the new New Zealand geodetic datum.

Land Information New Zealand had now elected to provide the new geodetic datum as a semi-dynamic datum. This report covers the computation of coordinates of the First Order 2000 stations at the mid-observation epoch of 1996.5.

The GAMIT/GLOBK software suite is under continual development. Recent improvements/enhancements include full Y2K compliance. Readers with an interest in the latest enhancements are referred to King & Bock (1999) and Herring (1999).

Chapter 2

Modelling

In conventional GPS processing it is normal for many effects to be modelled rather than carried as part of the parameter list. The rationals for these choices are often dependant on the a mixture of the size of the modelled effect and the complexity of applying the corrections. In other cases a clear choice is made between various algorithms with the intent of maximizing certain desriable effects.

2.1 GPS Theory

Gamit uses the double difference formulation of the GPS observable. This formulation is used in other GPS programs, e.g. the Bernese software (Rothacher & Mervart 1996). The formulation is widely documented, see for example King et al (1985), Strang and Borre (1997) and Kaplan (1996).

The following treatment, adapted from King et al. (1985), is intended to set the scene for the adopted modelling strategy and the tests that were conducted in order to define an optimal solution for the New Zealand network.

Figure 2.1 shows the relations that exist between a pair of satellites and a pair of ground stations which are used in the double difference formulation.

2.1.1 The one-way phase observable

King et al. (ibid.) define the carrier beat phase observable between satellite i and ground station j as

$$\begin{aligned}\phi_j^i(t_j) &= -\left[f_0 + a^i + b^i(t_j - t^0)\right]\tau_j^i(t_j) + \frac{1}{2}b^i(\tau_j^i)^2(t_j) \\ &\quad +\phi_t^i(t^0) + f_0(t_j - t^0) + a^i(t_j - t^0) + \frac{1}{2}b^i(t_j - t^0)^2 \\ &\quad -\phi_{LO_j}(t^0) - f_{LO_j}(t_j - t^0) - f_{LO_j}q_j - f_{LO_j}r_j(t_j - t^0) - \frac{1}{2}f_{LO_j}s_j(t_j - t^0)^2 \\ &\quad +n_j^i + \phi_{noise}\end{aligned} \tag{2.1}$$

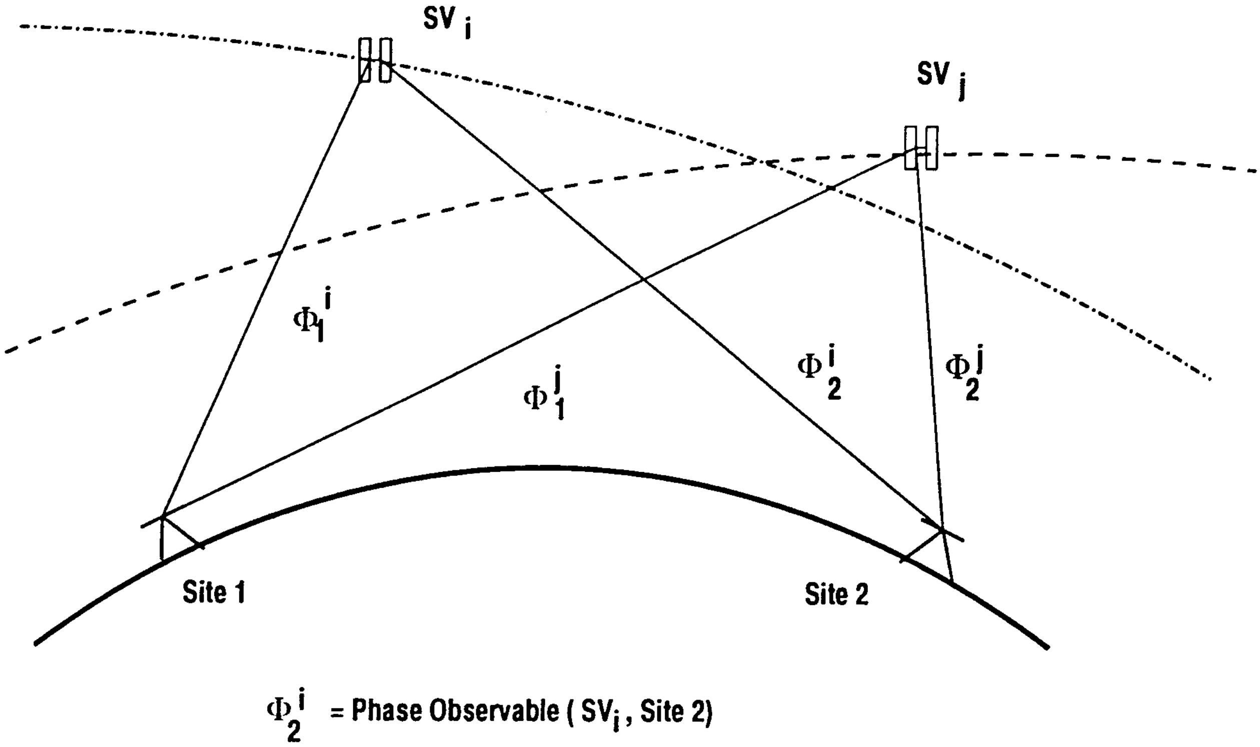

Figure 2.1: Simple schematic of a pair of ground stations simultaneously observing a pair of GPS satellites

where $\phi_j^i(t_j)$ is the phase between satellite i and station j at epoch t_j as recorded by the local receiver oscillator.
τ_j^i is the propagation time delay, including both the geometric delay and the delay introduced by the troposphere and ionosphere,
$\phi_t^i(t^0)$ is the phase of the transmitted signal with respect to the chosen reference epoch t^0,
ϕ_{LO_j} and f_{LO_j} are the phase and frequency of the station (receiver) oscillator, respectively,
q_j, r_j, s_j are the coefficients of the polynomial equation used to model the station oscillator,
n_j^i is an integer representing the n-cycle ambiguity in the observed phase and ϕ_{noise} represents the random measurement noise.
f_0, a^i and b^i are associated with the performance of the satellite clock. f_0 is the nominal frequency of the satellite, a^i is the current offset from the nominal frequency while b^i is the linear drift term. All satellite clocks are driven by cesium standards. The performance of these standards is best modelled by linear equations of the form

$$f^i(t) = f_0 + a^i + b^i(t - t^0)$$

where t^0 is a reference epoch usually chosen to be at the centre of the span, which for daily solutions is 12:00:00 UT.

The station oscillator, like the satellite oscillator, is modelled with a linear parameter model usually a second or third order polynomial. The second order polynomial, typically used for quartz oscillators, has the form

$$t_j' - t_j = \delta t = q_j + r_j(t_j - t^0) + \frac{1}{2}s_j(t_j - t^0)^2$$

This equation, for the difference between the true receiver epoch (t_j) and the observed receiver epoch (t_j') is then used to evaluate the true phase of the local oscillator in the receiver, $\phi_{LO}(t)$.

It is to be noted that Equation 2.1 has the following structure:

- Terms on the first line are proportional to the propagation delay τ_j^i and hence can be interpreted as reflecting the geometry of the satellite and receiver.
- The parameters on line two involve the satellite clock.
- The parameters on line three involve the receiver oscillator.
- The parameters on line four involve the unknown integer ambiguity and the noise in the system as a whole. Note that the integer ambiguity n_j^i is indistinguishable from the phase differences at the reference epoch t^0.

A careful examination of the above equation also indicates that some additional cancellation occurs if the satellite clock and the receiver clocks have the same nominal reference frequency. This assumption is not valid even for satellites or receivers that are connected to atomic standards. due to drift in the clocks.

2.1.2 Between-station differences

It is readily seen from Figure 2.1 that it is possible to take the undifferenced phase between a pair of stations and difference the observations to form a new observable called *between-station differences*. The between-station differences are also known as single differenced observations. It is defined in the following equation, for stations 1 and 2 observing to satellite i, as

$$\Delta\phi_{12}^i = \phi_2^i(t_2) - \phi_1^i(t_1) \tag{2.2}$$

Expanding the above equation. it is usual to make the following assumptions:

- That the phase is sampled at the same epoch at both receivers, except for the fact that the clocks are not perfectly synchronised since they run at different rates. This assumption is not true when mixed instruments, that sample at different epochs, are used in the same network.
- That terms in $(\tau_j^i)^2$ can be neglected as being small.
- That the nominal or base frequency of all satellite and all ground receiver clocks is the same f_0 frequency. This is commonly 5 MHz.
- That the time argument of $\tau_j^i(t_j)$ is neglected for simplicity reducing the delay to τ_j^i.

This leads to an observable of

$$\begin{aligned}\Delta\phi_{12}^i &= -f_0\left[\tau_2^i - \tau_1^i\right] - \left[a^i + b^i(t_1 - t^0)\right](\tau_2^i - \tau_1^i) - b^i(t_2 - t_1)\tau_2^i \\ &\quad + a^i(t_2 - t_1) + \frac{1}{2}b^i(t_2 - t_1)\left[2(t_1 - t^0) + (t_2 - t_1)\right]\end{aligned}$$

$$
\begin{aligned}
&-f_0(r_2 - r_1)(t_1 - t^0) - f_0 r_2(t_2 - t_1) - \frac{1}{2} f_0(s_2 - s_1)(t_1 - t^0)^2 \\
&-\frac{1}{2} f_0 s_2(t_2 - t_1)\left[2(t_1 - t^0) + (t_2 - t_1)\right] \\
&-\left[\phi_{LO_2}(t^0) - \phi_{LO_1}(t^0)\right] - f_0(q_2 - q_1) + (n_2^i - n_1^i) + \Delta\phi_{noise}
\end{aligned} \qquad (2.3)
$$

The previous method of collecting terms has been maintained. Thus the first line contains the geometric terms and the second line contains the satellite clock terms. Lines 3, 4 and 5 all relate to the receiver. Only terms involving $(t_j - t^0)$ have been cancelled.

2.1.3 Between-satellite differences

Using Equation 2.1, it is also possible to difference the equation using a pair of satellites to a common ground station. This difference is referred to as the *between-satellite difference* and for satellites i and j with observations to station 1

$$\nabla\phi_1^{ij} = \phi_1^j(t_1) - \phi_1^i(t_1) \qquad (2.4)$$

Using the same simplifications as for the between-station differences, the following observable is derived.

$$
\begin{aligned}
\nabla\phi_1^{ij} = &-f_0\left[\tau_1^j - \tau_1^i\right] \\
&-\left[a^j\tau_1^j - a^i\tau_1^i\right] - \left[b^j\tau_1^j - b^i\tau_1^i\right](t_1 - t^0) \\
&+(a^j - a^i)(t_1 - t^0) + \frac{1}{2}(b^j - b^i)(t_1 - t^0)^2 \\
&+\left[\phi_t^j(t^0) - \phi_t^i(t^0)\right] + (n_1^j - n_1^i) \\
&+\nabla\phi_{noise}
\end{aligned} \qquad (2.5)
$$

As before, the first line represents the geometric effect. Lines two and three contain the effects of frequency differences between the satellites while line four contains the initial satellite phase differences and the integer part of the phase observations. Note that there are no receiver clock terms in this observable as the sampling is carried out at the same time.

2.1.4 Double differences

Just as it is possible to difference between-satellites and between-stations, it is also possible to difference these differenced observations. That is, use is made of all of the components shown in Figure 2.1. This observable is called the double difference observable and, for stations 1 and 2 and satellites i and j, the observable can be written as

$$\nabla\Delta\phi_{12}^{ij} = \nabla\phi_2^{ij} - \nabla\phi_1^{ij} = \Delta\phi_{12}^j - \Delta\phi_{12}^i \qquad (2.6)$$

where

$$
\begin{aligned}
\nabla\Delta\phi_{12}^{ij} &= -f_0\left[\tau_2^j - \tau_1^j - \tau_2^i + \tau_1^i\right] \\
&\quad - \left[a^j + b^j(t_2 - t^0)\right](\tau_2^j - \tau_1^j) \\
&\quad + \left[a^i + b^i(t_1 - t^0)\right](\tau_2^i - \tau_1^i) \\
&\quad + (n_2^j - n_1^j - n_2^i + n_1^i) + \nabla\Delta\phi_{noise}
\end{aligned} \tag{2.7}
$$

As in the previous single difference observables. the arrangements of the terms is to draw attention to the various components. The first line contains the now familiar geometric terms. The second and third lines are associated with the drifting of the satellite clock. These terms are often neglected for short baselines but become important for long baselines. They are also important to account for clock dithering associated with selective availability. Under optimal conditions these terms are small. particulary the b^i and b^j terms, due to onboard rubidium and cesium oscillators. The final line. line 4. is now free of all initial phase unknowns. Indeed, the terms consists simply of the combination of the four unknown integer biases and the system noise. Unfortunately, system noise can be quite large.

2.2 Modelling

2.2.1 Clock Modelling

It is seen from the double difference equation that all receiver clock terms are cancelled out as a result of forming the double difference operator. Only the satellite offset and the rate difference effect the model. Since the satellite frequency. f_0. is maintained by the United States Naval Observarory to better than $1 : 10^{11}$ of the working definition of TAI these corections are small. These satellite clock terms are estimated. in GAMIT. external of the main parametric process in the routine called *makej*. Their estimation requires an orbit, usually the onboard or broadcast orbit and a-priori station positions, usually better than 100 meters.

An alternative source of these parameters is via the IGS SP3 daily orbit product. While there are slight difference between these IGS combined solution values and those determined within the GAMIT suite the differences are not statistically significant or important.

We also performed station clock modelling. Station clock modelling is necessary if use is made of the one-way phase observable. the between-station difference or the between-satellite differences. While these representations of the phase observable are not used in the determination of unknown parameters in GAMIT they are used in a number of GAMIT's routines to validate and resolve phase ambiguities. We also used the stability of our determination of the receiver clock as a measure of the quality of the raw RINEX data. Poorly performing clock were a feature of the 1993 data. Known periods of poorly performing receiver clocks were edited from the data using the facilities of the *autcln.cmd* file. This editing improved the overall nrms of the solution and hence the joining of regional and global solutions was less problematical.

2.2.2 Antenna Modelling

All solutions were performed with the IGS Antenna Phase Model for elevation turned on. While GAMIT allows for the asymetric azimuth terms to also be used we did not activate this option. There were two principal reasons for this:

1. We were not confident that the application of these corrections would improve the results as the early data was plagued by receiver noise. due to poor Ashtec firmware.
2. We believed that a solution with constant modelling would provide a more appropriate and understandable solution compared with one that used modelling in a some what arbitary manner.

2.2.3 Choice of Observable and Ambiguity resolution

The derived difference equations hold for L_1. L_2 and L_c observables. We used the conventional ionospheric free observable L_c. We didn't fix or resolve the ambiguities in the double difference equation to integer values although the network was sufficiently dense to allow this to done. Our rational was similar to that used for antenna modelling. The early data was obtained with instruments where the noise component was large due to a combination of receiver design and the level of ionospheric activity. The choice of integer. fixed, versus real or free ambiguitity terms is known to only effect the vertical component of the solution. The effect is usually small for good networks like the New Zealand network.

Since bias fixed solutions could not be guaranteed in the 1992. 1993 and 1994 data all solutions were performed with all biases being estimated according to free concept and thus estimates of the bias term contain a non-determinable component of system noise which would include antenna offset errors.

2.2.4 Earth Tides including loading models.

GAMIT allows for the following earth tide models:

1. The Whar solid earth tide model.
2. The Whar solid earth tide model with the K_1 frequency terms.
3. The Pole tide model due to the motion of the instantaneous pole about the origin of the terrestrial reference system.
4. Ocean tide model.

The magnitude of these components is discussed by many authors. Morgan (1994) discusses the effects on Australian GPS stations located at precise tide guages. In general the effects of the pole tide. which has a cyclical period of 6.4 years, and the ocean tide terms are small and are likely to be masked by other random noise components due to receivers and the fact that each campaign used a non-reproducable antenna set up. As the strategy in the early campaign data was for a different setup for each session. to minimise blunders in the setup proceedure, setup and instrument noise was thought to dominate during these campaigns. Thus we adopted the more conventional approach of only turning on the Whar solid earth model with K_1 frequency terms.

The effect of not turning on the ocean tide model was mittigated by performing most of the observation campaigns in the Autumn or the Spring at annual intervals. The use of epoch campaigns is known to introduce a small biases in heights compared to continuous operating stations. (Neilan et al 1997). However the use of annual campaign data generally lowers height residuals, as compared to random epoch campaigns, as environmental factors which are generally unmodelled are more uniform and repeatable at annual periods.

2.2.5 Satellite Attitude

GPS satellites undergo attitude changes in their orbiting of the earth. These changes are most significant during the eclipse passage of the satellite behind the earth. GAMIT models this change in yaw as well as deleting phase data received while the satellite is eclipsing.

Satellites that experienced changes and manoeuvres due to orbit maintenance were excluded for the full day on which these events occurred. That is there was no attempt to model the manoeuvre.

2.3 Solution Parameters

In the above section on Modelling we discussed those parameters which are used in the GAMIT process but are not solved for in the least squares adjustment. This section deals with the parameters that are part of the least square estimation process.

2.3.1 The Station Coordinates Vector

GAMIT estimates the station vector in a loose and constrained geocentric system. The constrained solution uses analysist defined constraints while the loose solution removes all analysist enforced constraints. The former is used by the analysist to estimate quality assurance tests while the latter is passed onto the the GLOBK modules.

2.3.2 Atmospheric Parameters and Modelling

GAMIT allows for a number of different models and stratagies to be turned on during processing. We estimated corrections to the observed phase using an a-priori standard atmosphere delay with the Saastamoinen (1972) model and the Niell(1996) mapping function at 2 hourly intervals. This procedure is the conventional practice for generating these terms by IGS Analysis Centers.

2.3.3 Orbital Parameters and Modelling

GAMIT provides the user with a number of orbit options. We used the IGS combined solution orbit as the starting point for all post 1994 data. For data pre 1994 we used the broadcast orbit as the initial orbit and itterated the process so that corrections were small. The IGS orbit is supplied in a fixed terrestrial reference frame. This frame is the annual ITRF frame. We transformed this orbit into an inertial refrence frame orbit using Bulletin B values of the Earth rotation parameters as GAMIT performs its solution in inertial sapace. The transformation process involves the following:

- The determination of satelite initial state vector, the six Keplerian elements, in the terrestrial reference system.
- The rotation, transformation, of the state vector from the terrestrial frame to the inertial frame using Earth rotation information.
- The integration of these initial conditions over the required day. This produces the GAMIT tabular ephemeris.
- A least squares adjustment of the GAMIT tabular ephemeris to the IGS tabular ephemeris. Note this process implies that the tabulated IGS orbit is rotated into the inertial system used by GAMIT and the determination of parameters associated with the chosen non-gravitational model.
- A reintegration of the state vector which now contains Keplerian and non-gravitational terms.

We used the Berne model (Beutler et al 1994) which contains three non-gravitational terms and six once per revolution terms in addition to the conventional six Keplerian terms. This model is the current model recommended by the IGS and used by all Analysis Centers such as Scripps Institution of Oceanography who use GAMIT.

We used the IGS 1992 Reference System for constants such as the velocity of light and the mass of the Earth in performing the orbital integrations. The use of the IGS Refernce System is the recommended practice for a system that is to be made consistent with the IERS Terrestrial Reference System.

2.3.4 Earth Rotation Parameters and Modelling

GAMIT provides a wide range of estimation strategies with these parameters. We used the IERS Bulletin B service as the a-priori input for all of our work. This Earth rotation series is a combined solution with input from Very Long Baseline Interferometry and Laser Ranging techniques. As such it is not consistent with the pure GPS series published by IGS. However since it is only used as a-priori information or to apply weak constraints, the distinction is of minor importance.

We estimated both the mid-epoch value and the daily rate for all three cpmponemts. That is the two wobble components, x and y, and the rotation component UT_1.

Chapter 3

Data

This chapter details the data that was used in the computation of the New Zealand Zero & First Order Network.

The data is presented by year in separate sections. Data used in a solution is indicated by one of the following symbols:

- The bullet symbol. •. is used to indicate New Zealand data that was used in the daily regional solution or the daily global solution which was used as a substitute for the daily regional solution.
- The spadesite symbol.♠. is used to indicate New Zealand data that was used in both the daily global and regional solutions. That is this data was part of the fiducial tie that existed between the regional and global networks.

Two main strategies were adopted for processing the New Zealand GPS data:

- When the number of New Zealand stations was less than five preference was given to the direct incorporation of the New Zealand data into a well distributed global network which has regions of concentration. In general three regions of concentration were used. The first region is Australasia. The second is North America with a concentration in western USA and western Canada. The third region is Europe. The adoption of this regional concentration approach provides AUTCLN with a large number of double difference pairs with which to automatically resolve cycle slips as it is possible to construct double difference pairs between different station combinations using the same satellite combinations in this scheme. This approach was used for the 1992, 1993 and 1994 campaigns. It was also used to perform the ties between close stations and then to incorporate this data into the general solution.
- When the number of New Zealand stations exceeded five preference was given to a regional fiducial network with the New Zealand network being near the centroid of the fiducial network and a well balanced global network. Permanent New Zealand sites that either contributed to IGS or operated from permanent monuments were included in the global network to add further fiducial strength to the tie between the regional and global

networks. This approach was used by Morgan et al (1996) in their work on the Australian Zero Order Network.

In the following tables we have chosen to list the major GPS stations even when no data was collected. That is the null entry makes for easy recognition that a station was not occupied during a sequence of campaigns.

3.1 1992 Campaign

This was a sequence of two days performed mainly as a trail of procedures. The data was directly placed within a 35 station global network. Station D485 (not plotted) is one of several alternative witness marks on top of Heaphy House that is in close proximity to the station WELL. No ties were enforced between these witness marks and the WELL station.

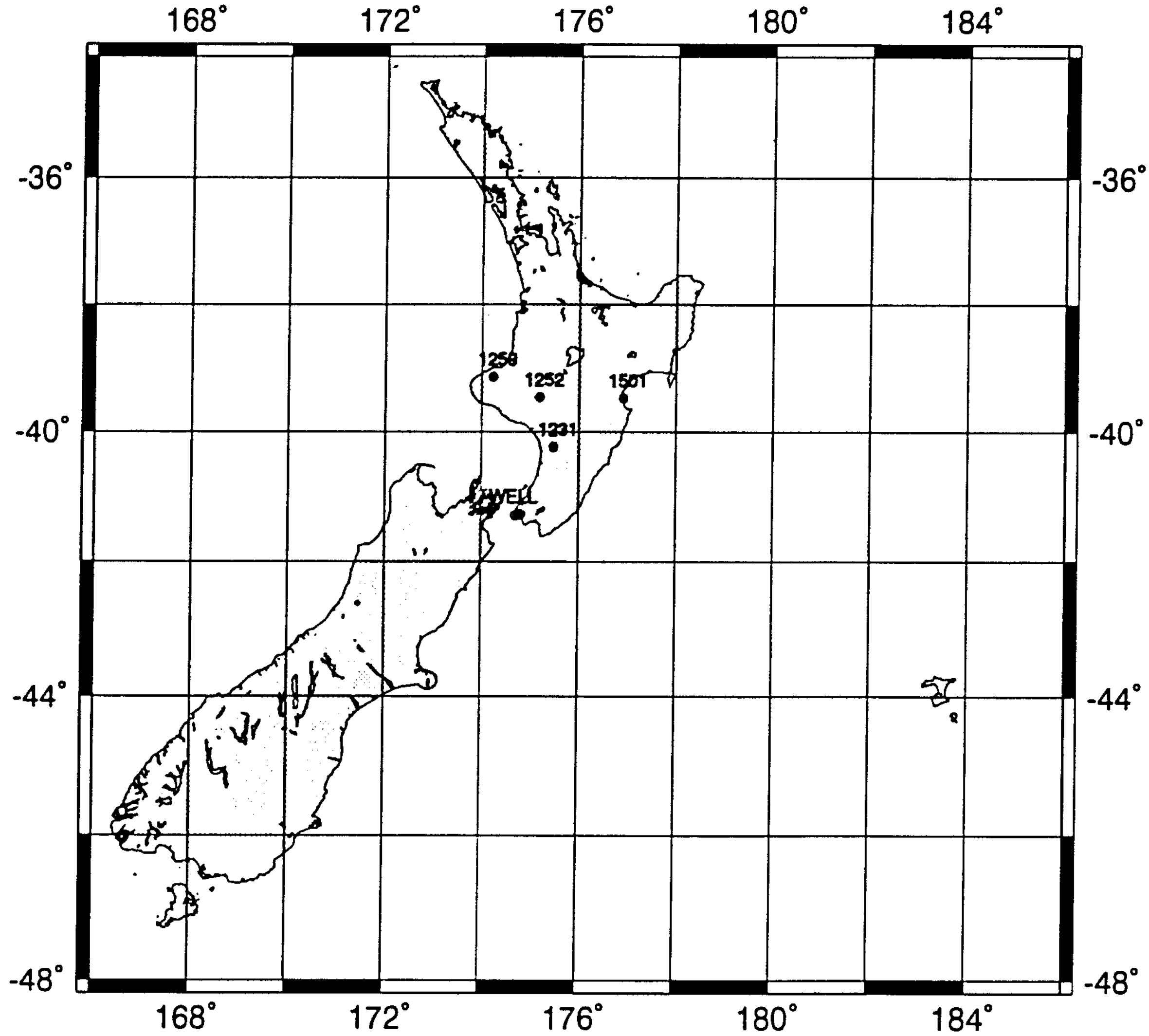

Figure 3.1: Map of regional stations occupied in 1992

Table 3.1: Table of regional New Zealand GPS stations observed in 1992

Station	Day of 1992	
	245	246
1004		
1017		
1103		
1153		
1181		
1215		
1231	•	•
1252	•	•
1259	•	•
1273		
1305		
1314		
1344		
1361		
1367		
1394		
1501	•	•
2085		
5508		
5509		
6731		
A31C		
A33D		
A70X		
AUCK		
B03W		
B28C		
CHAT		
OUSD		
WELL	•	•
D485	•	•

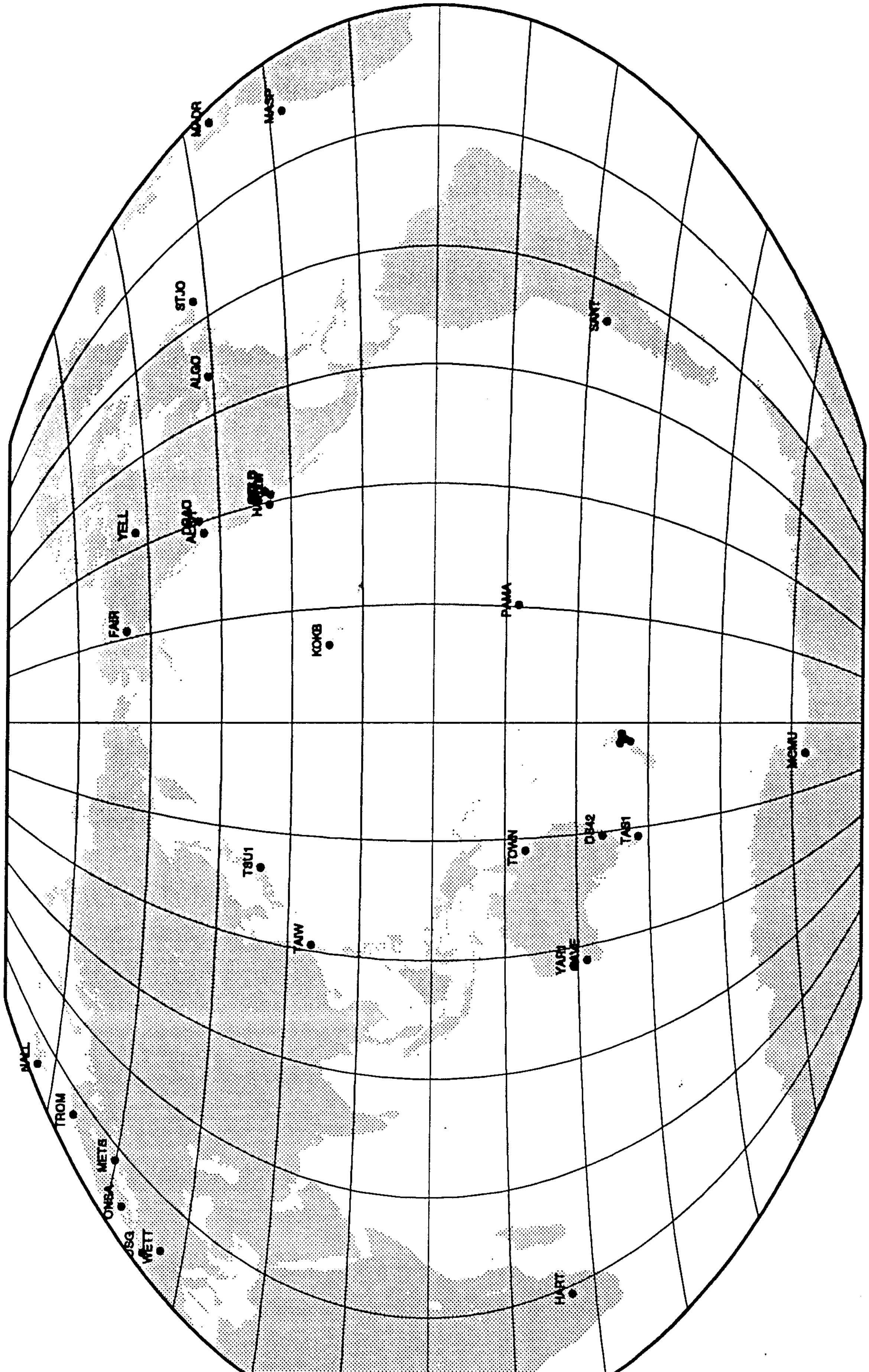

Figure 3.2: Map of global stations used in generation the 1992 solutions.

3.2 1993 Campaign

This campaign is fully described by Pearse (1997). In particular the campaign used two observing sessions each with an independent antenna set up. In this analysis we used the old clean GAMIT x-files to produce new clean RINEX files. These RINEX files were then concatenated into a single daily file and an appropriate entry made in the station.info file as to when the new antenna height was to be applied. This meant that the data for these stations more closely resembled a conventional daily data set and hence residual effects due to earth tides and atmospheric effects would be much smaller.

The ties between WELL and the witness marks D482 and D483 were not enforced.

The 1993 data was reduced with the single global strategy despite the fact that several days had significant number of New Zealand stations and hence option two was more appropriate. In this case the overriding issue was one of consistency for the reduction of the 1993 data.

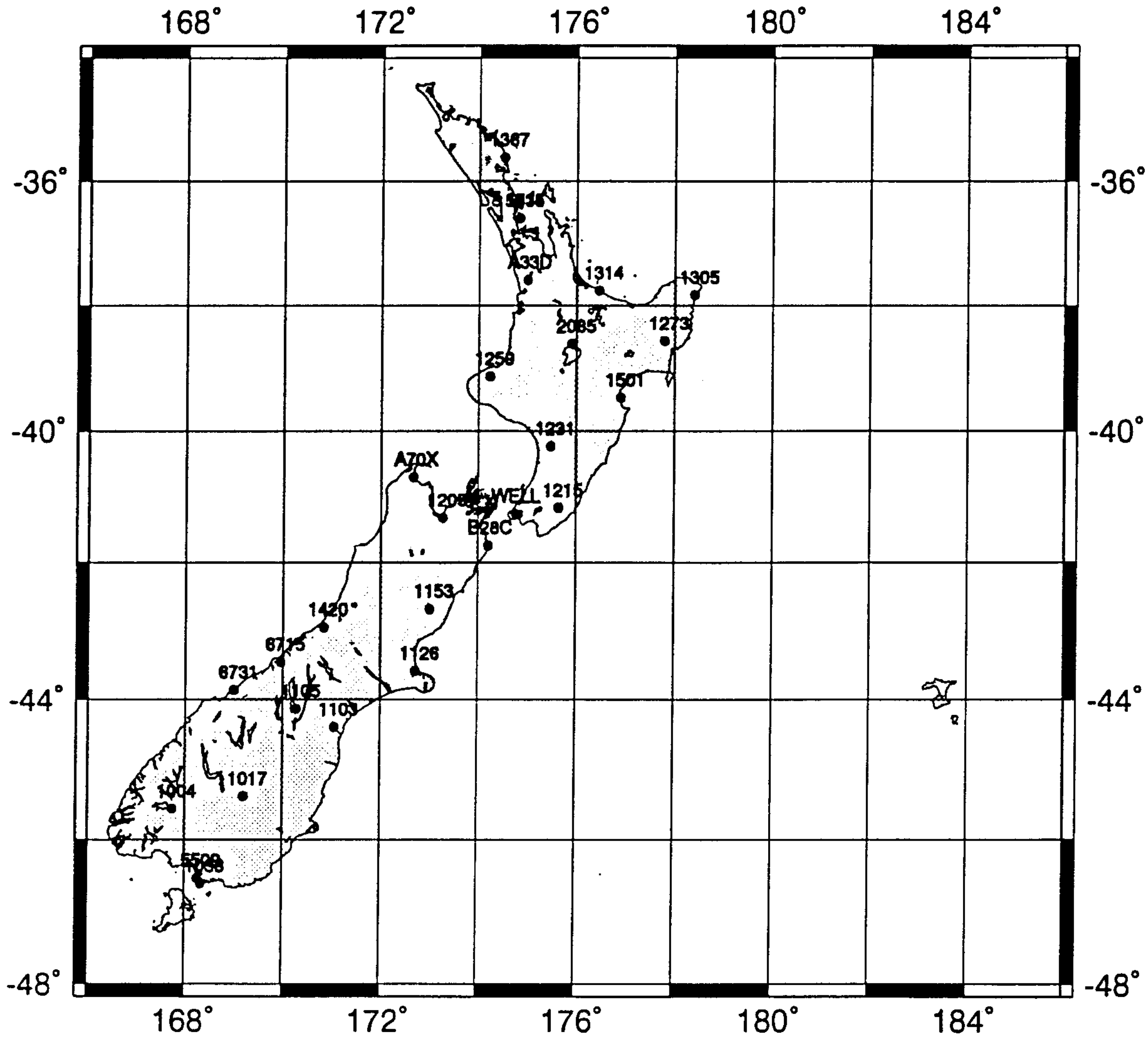

Figure 3.3: Map of regional stations occupied in 1993

Table 3.2: Table of regional New Zealand GPS stations observed in 1993

Station	Day of 1993													
	067	068	069	070	071	072	073	074	075	076	077	078	080	081
1104	●													
1103														
1017	●		●											
1038	●													
1103		●												
1105		●		●	●									
1126					●	●								
1153						●								
1181														
1205							●							
1215								●		●				
1231										●				
1259											●			
1273												●	●	
1305												●	●	
1314											●		●	
1334								●	●	●	●	●		●
1344														
1361														
1367												●		
1394														
1420				●	●	●								
1501										●			●	
2085											●	●		
5508														
5509	●	●	●	●	●	●	●	●	●					
5515														●
6715			●	●										
6731			●											
A31C														
A33D											●			
A70X							●		●					
AUCK														
B03W														
B28C							●	●						
CHAT														
OUSD														
WELL		●	●	●	●	●		●	●	●	●	●	●	
D482											●			
D483												●	●	

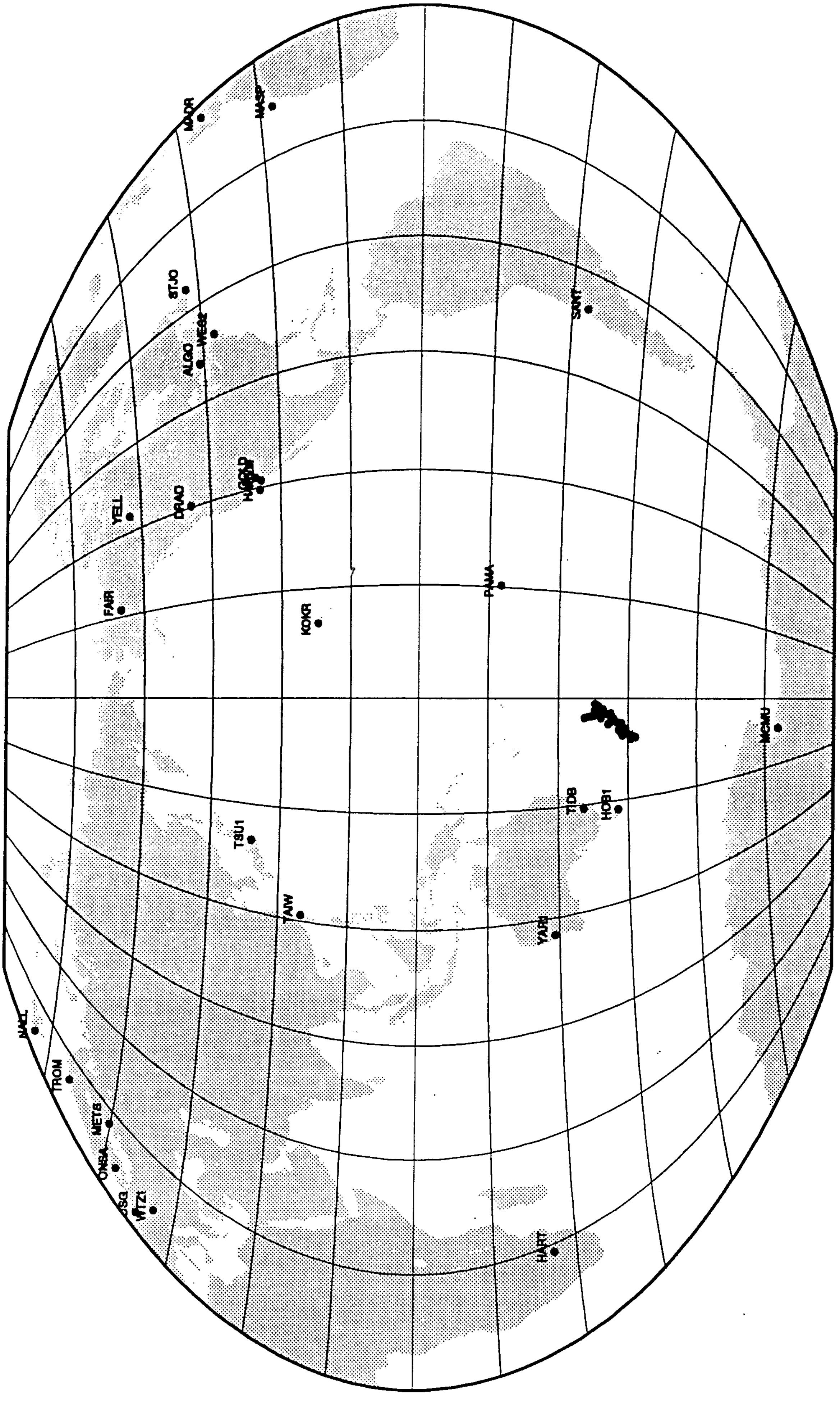

Figure 3.4: Map of global stations used in generation the 1993 solutions.

3.3 1994 Campaign

This was a difficult campaign to process from a philosophical point of view as the number of New Zealand regional stations warranted the fiducial approach. However the availability of quality fiducial stations was limited. In particular the IGS stations at McMurdo and Macquarie Island were not fully functional while the Hobart and the Tahiti stations were experiencing problems that limited data availability and quality. Thus rather than make regional solutions that might have week connections to a global network we opted for rather large, usually greater than 40 stations. global solution in which the New Zealand data was embedded. This had the effect of ensuring that the New Zealand stations were correctly estimated by ensuring that the orbital information was not compromised by a weak fiducial network.

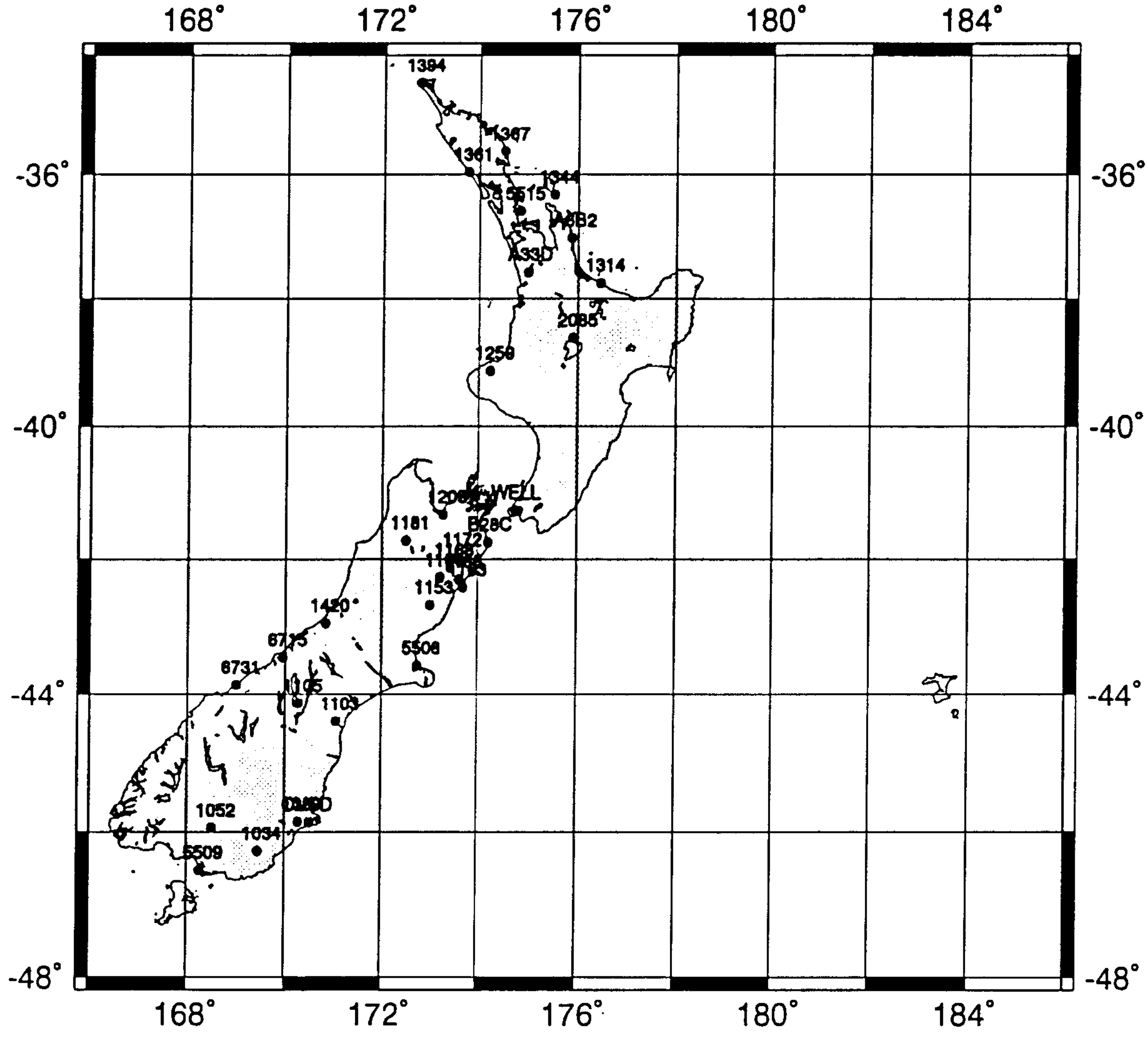

Figure 3.5: Map of regional stations occupied in 1994

Table 3.3: Table of regional New Zealand GPS stations observed in 1994

Station	Day of 1994								
	054	055	059	062	066	069	071	073	074
1004									
1017									
1034					•				
1052				•					
1080				•	•				
1103			•	•					
1105				•					
1153	•	•	•						
1163	•	•							
1165	•	•							
1166	•	•							
1168	•	•							
1172	•	•							
1165									
1181	•	•							
1205			•						
1215									
1231									
1259							•	•	
1273									
1305									
1314								•	
1344						•			
1361						•	•		
1367						•	•		
1394							•		
1420			•						
1501									
2085								•	•
5508			•						
5509			•	•	•	•	•	•	
5515			•	•	•	•	•	•	
6715			•						
6731				•					
A31C									
A33D						•		•	
A70X									
A6B2						•		•	•
AUCK									
B03W									
B28C	•	•							
CHAT									
OUSD				•	•				
WELL	•	•	•	•	•	•	•	•	•

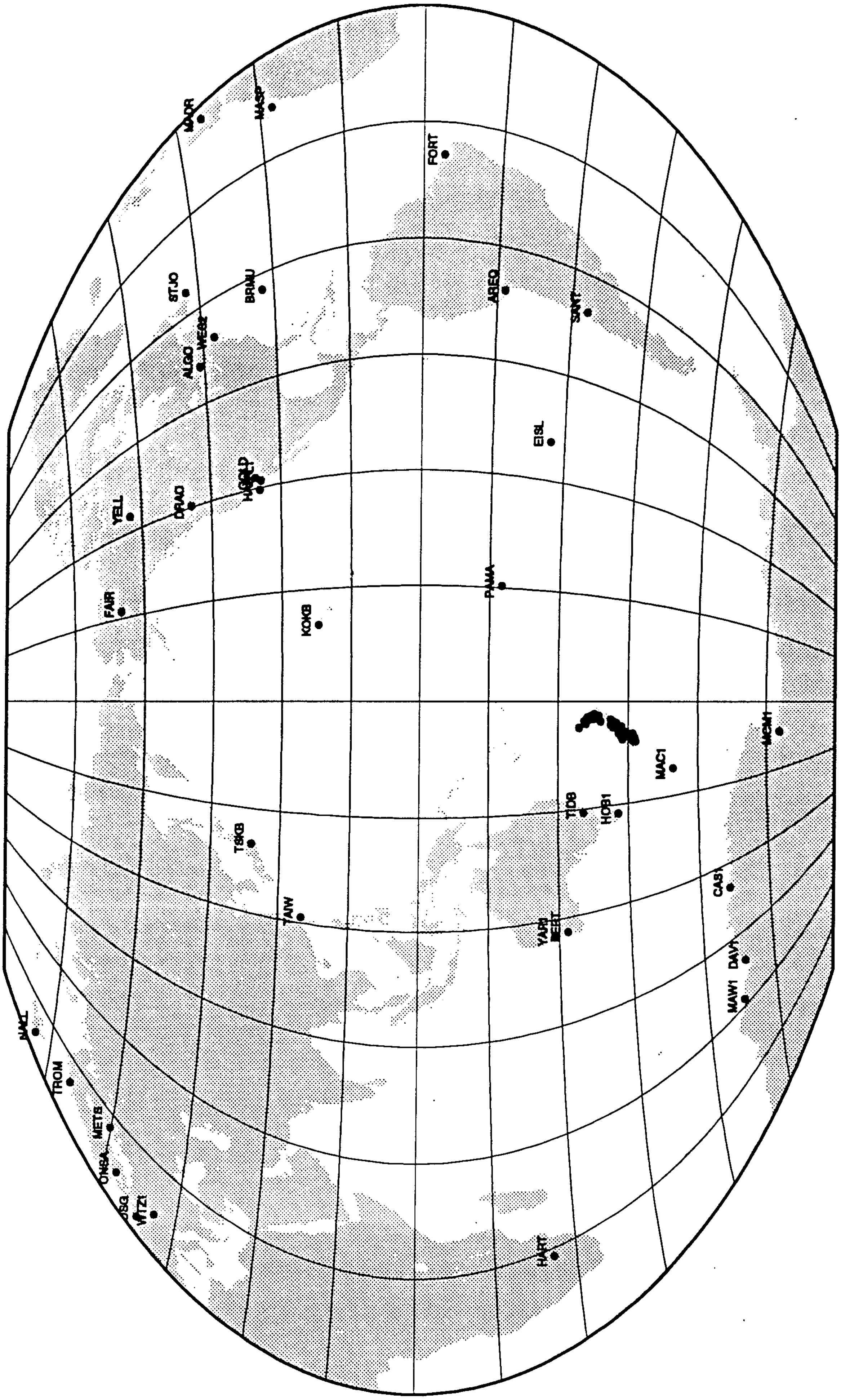

Figure 3.6: Map of global stations used in generation the 1994 solutions.

3.4 1995 Campaigns

Two major campaigns were run in 1995. The first in the early part of the year saw all stations simultaneously observed for the first time. Additionally 1995 saw the introduction of permanent installations at AUCK, CHAT and OUSD. Unfortunately CHAT was not available during the 1995 campaign.

Ties were performed and implemented at Windsor Castle, 5508, between 1126 and 5508, and at Auckland between AUCK, 1334 and 5515. No ties were implemented between OUSD and the old, now destroyed OTAG/OATA marks, as the two stage tie could not reliably be decoded due naming conventions. Tie sites have been omitted from the maps and the data tables.

The early 1995 campaign was the first campaign where the full network was observed simultaneously. The simultaneously observation of 27 New Zealand regional stations clearly required the adoption of the fiducial approach as the size of a single daily global solution would have exceeded 65 stations. The computational resources needed to perform this type of analysis are not generally available and hence the fiducial approach is adopted.

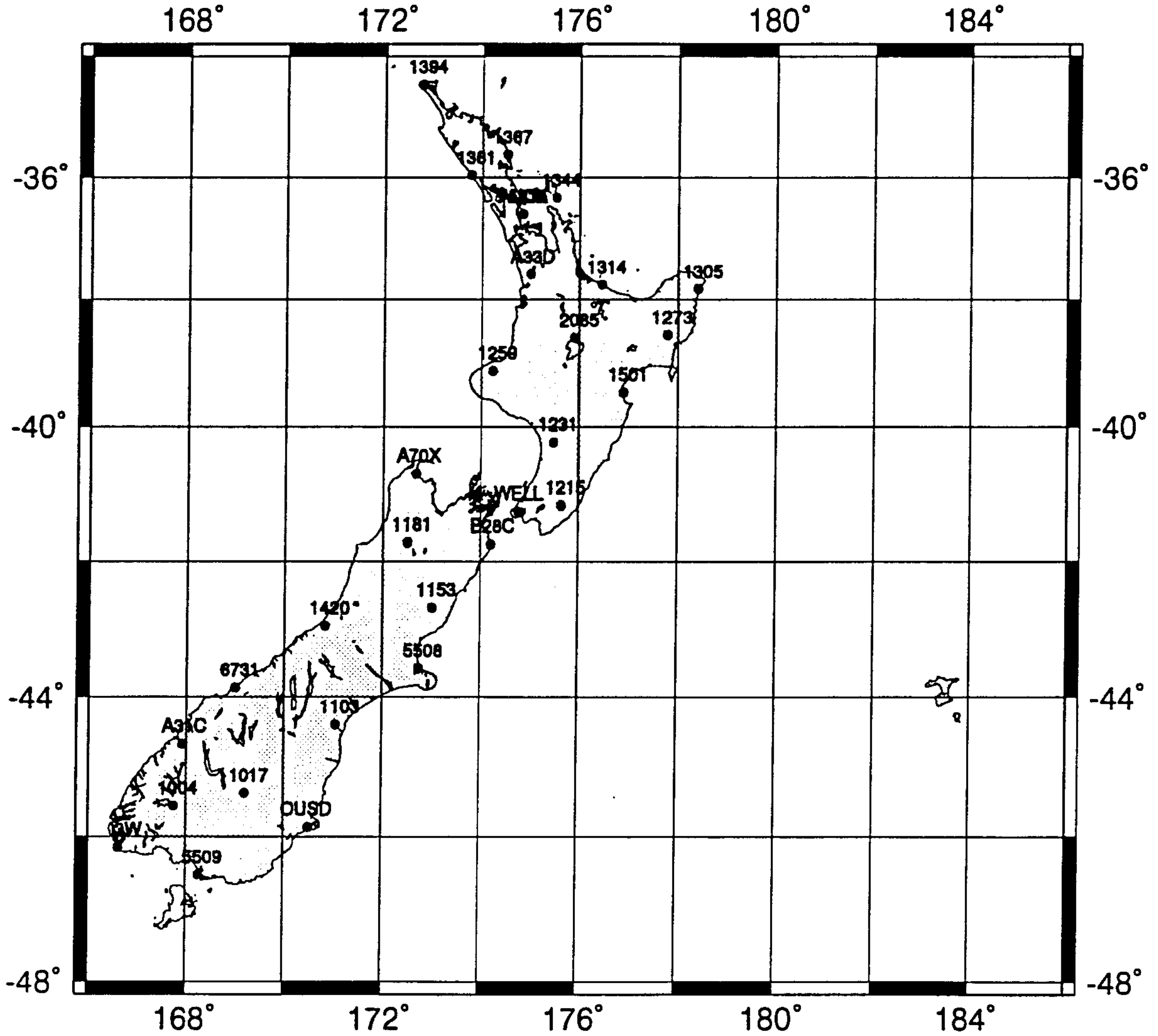

Figure 3.7: Map of regional stations occupied in 1995

Table 3.4: Table of regional New Zealand GPS stations observed in 1995

Station	Day of 1995									
	008	045	066	067	068	108	109	110	151	152
1004			•	•	•					
1017			•	•	•					
1103			•	•	•	•	•	•		
1153			•	•	•	•	•	•		
1181			•	•	•	•	•	•		
1215			•	•	•					
1231			•	•	•					
1259			•	•	•					
1273			•	•	•					
1305			•	•	•					
1314			•	•	•					
1334										•
1344	•		•	•	•					
1361			•	•	•					
1367			•	•	•					
1394			•	•	•					
1420						•	•	•		
1501			•	•	•					
2085			•	•	•					
5508		•	•	•	•	•	•	•		
5509			•	•	•					
5515	•		•	•	•				•	
6731						•	•	•		
A31C			•	•	•					
A33D			•	•	•					
A70X			•	•	•					
AUCK									•	•
B03W			•	•	•					
B28C			•	•	•					
CHAT										
OUSD			♠	♠	♠	♠	♠	♠		
WELL			♠	♠	♠	♠	♠	♠		

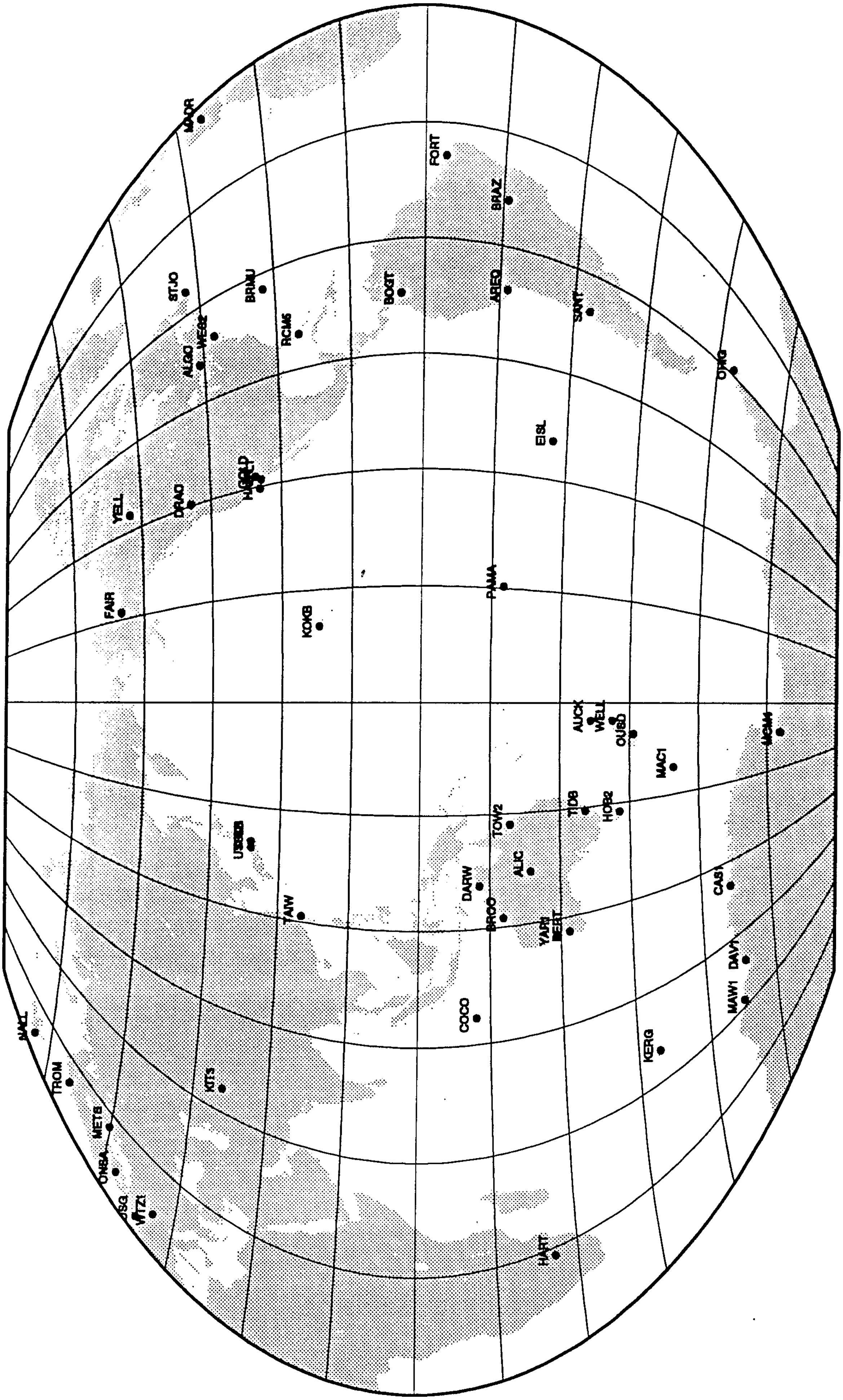

 Figure 3.8: Map of global stations used in generation the 1995 solutions.

3.5 1996 Campaigns

A simple repeat of the 1995 survey almost exactly one year later is the major feature of the 1996 data. Addition tie data at Auckland between AUCK and 5515 was processed and used in tying these stations.

It is to be noted that 1996 is the first occurrence of the Chatham Island station which is part of New Zealand's contribution to the IGS. The other contribution is AUCK.

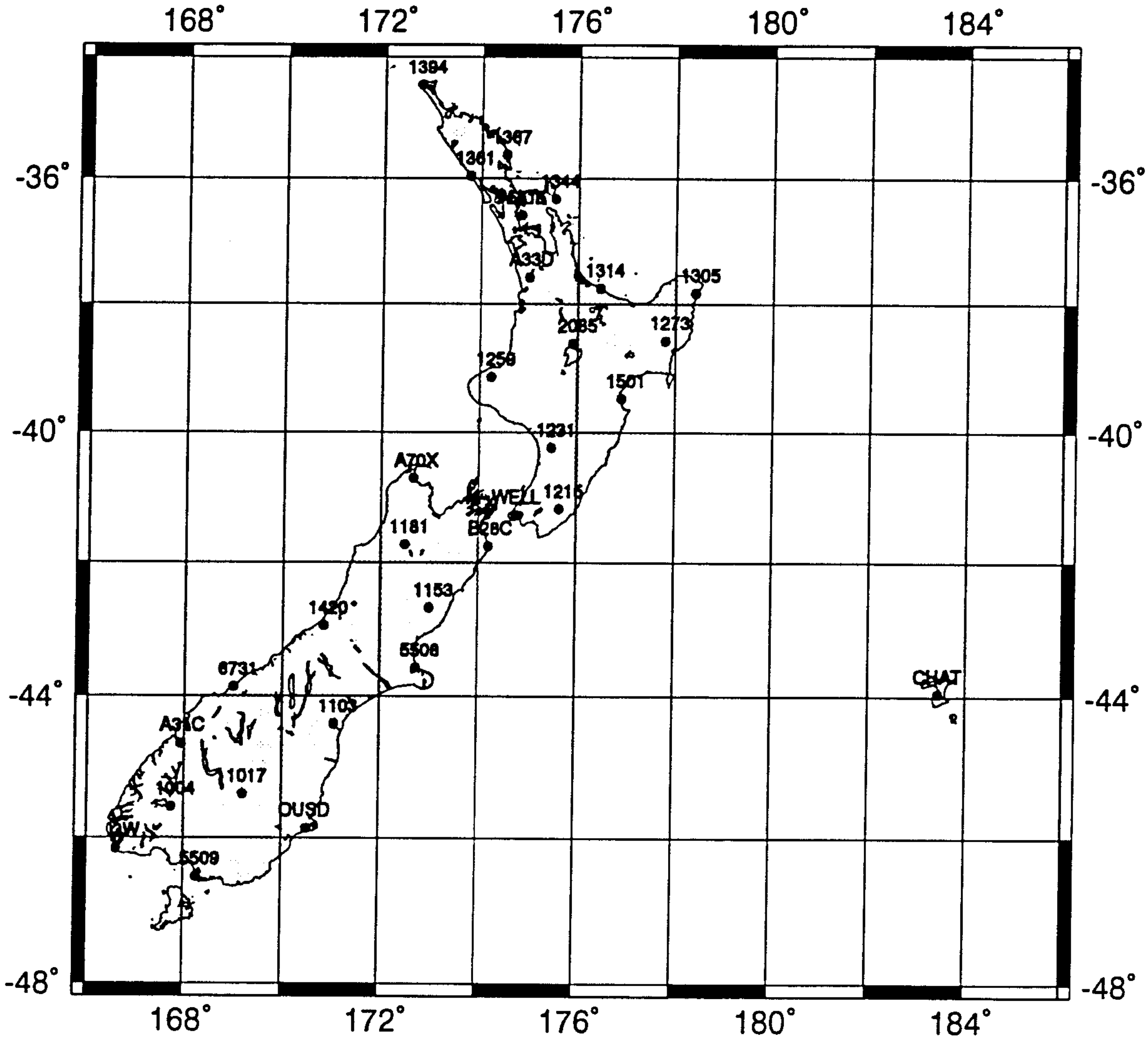

Figure 3.9: Map of regional stations occupied in 1996

Table 3.5: Table of regional New Zealand GPS stations observed in 1996

Station	Day of 1996					
	065	066	067	068	364	365
1004	•	•	•	•		
1017	•	•	•	•		
1103	•	•	•			
1153	•	•	•			
1181	•	•	•			
1215	•	•	•			
1231	•	•	•			
1259	•	•	•			
1273	•	•	•			
1305	•	•	•			
1314	•	•	•			
1344	•	•	•			
1361	•	•	•			
1367	•	•	•			
1394	•	•	•			
1420	•	•	•			
1501	•	•	•			
2085	•	•	•			
5508	•	•	•			
5509	•	•	•	•		
5515					•	•
6731	•	•	•			
A31C	•	•	•	•		
A33D	•	•	•			
A70X	•	•	•			
AUCK	♠	♠	♠	♠	•	•
B03W	•	•	•	•		
B28C	•	•	•			
CHAT	♠	♠	♠	♠	•	•
OUSD	♠	♠	♠	♠		
WELL	•	•	•	•		

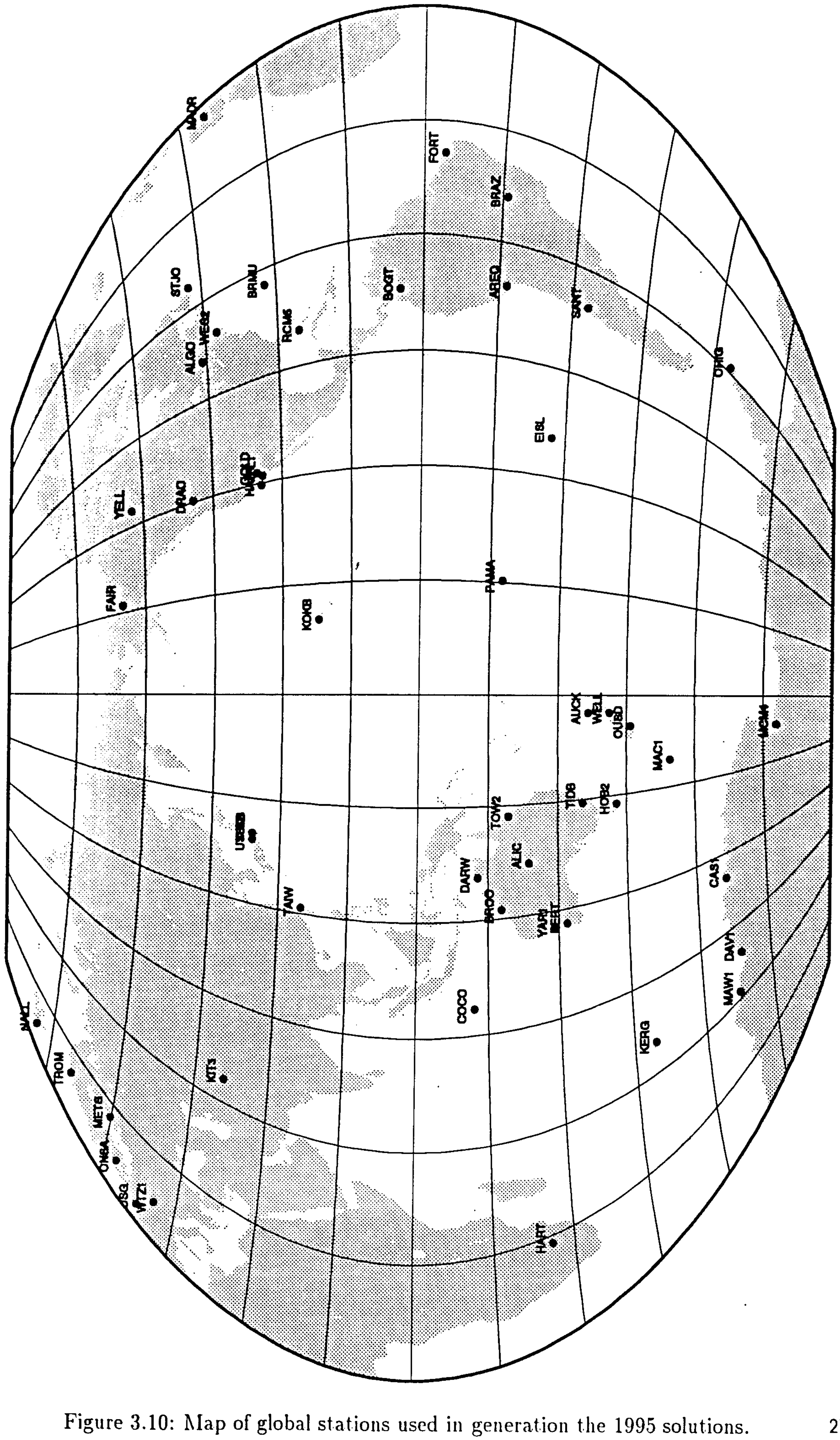

Figure 3.10: Map of global stations used in generation the 1995 solutions.

3.6 1997 Campaigns

A third repeat of the New Zealand network in early March in 1997 provides three annual occupations. The site on top of Heaphy House, WELL, was decommissioned in the first half of the year and replaced by a site out at the Wellington airport, WGTN. While this data could be classified as tie data an in-depth analysis will show that there is differential movement between the situations which means that the tie cannot be enforced.

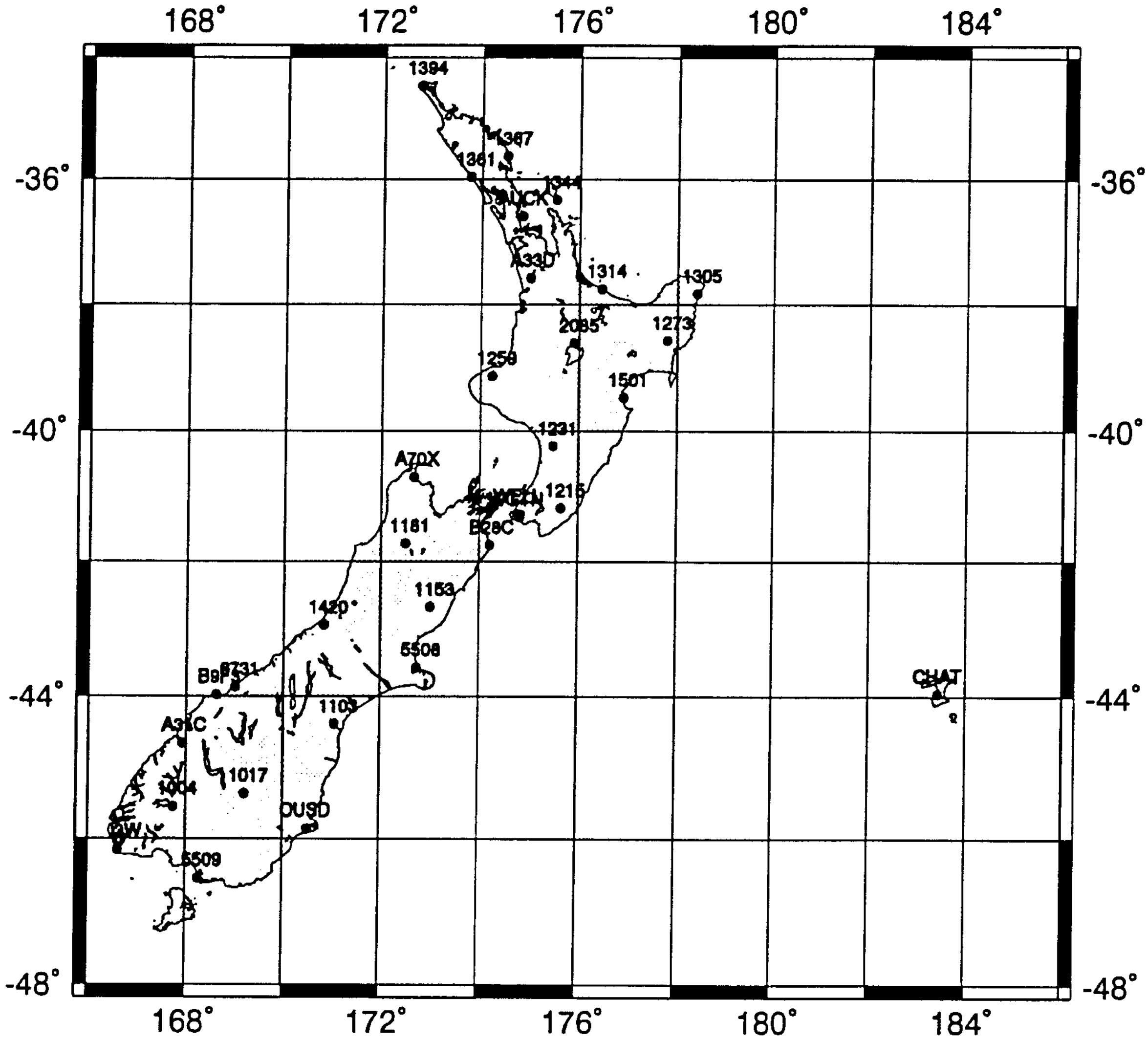

Figure 3.11: Map of regional stations occupied in 1997

Table 3.6: Table of regional New Zealand GPS stations observed in 1997

Station	Day of 1997									
	069	070	071	099	100	107	113	114	119	120
1004	●	●	●	●	●					
1017	●			●	●					
1103	●	●	●		●					
1153	●	●	●			●				
1181	●	●	●			●			●	●
1215	●	●	●							
1231	●	●	●							
1252										
1259	●	●	●				●	●		
1273	●	●	●							
1305	●	●	●							
1314	●	●	●				●	●		
1344	●	●	●				●			
1361	●	●	●							
1367	●	●	●				●			
1394	●	●	●							
1420	●	●	●			●				●
1501	●	●	●				●	●		
2085	●	●	●				●	●		
5508	●	●	●							
5509	●	●	●	●	●					
6731	●	●	●	●	●					
A31C	●	●	●	●	●					
A33D	●	●	●				●	●		
A70X	●	●	●			●				
AUCK	♠	♠	♠	♠	♠	♠	♠	♠	♠	♠
B03W	●	●	●	●						
B28C	●	●	●						●	
B9F3	●	●		●	●					
CHAT	♠	♠	♠	♠	♠	♠	♠	♠	♠	♠
OUSD	●	●	●	●	●	●	●	●	●	●
WELL	●	●	●	●	●					
WTGN	●	●	●	●	●		●	●	●	●

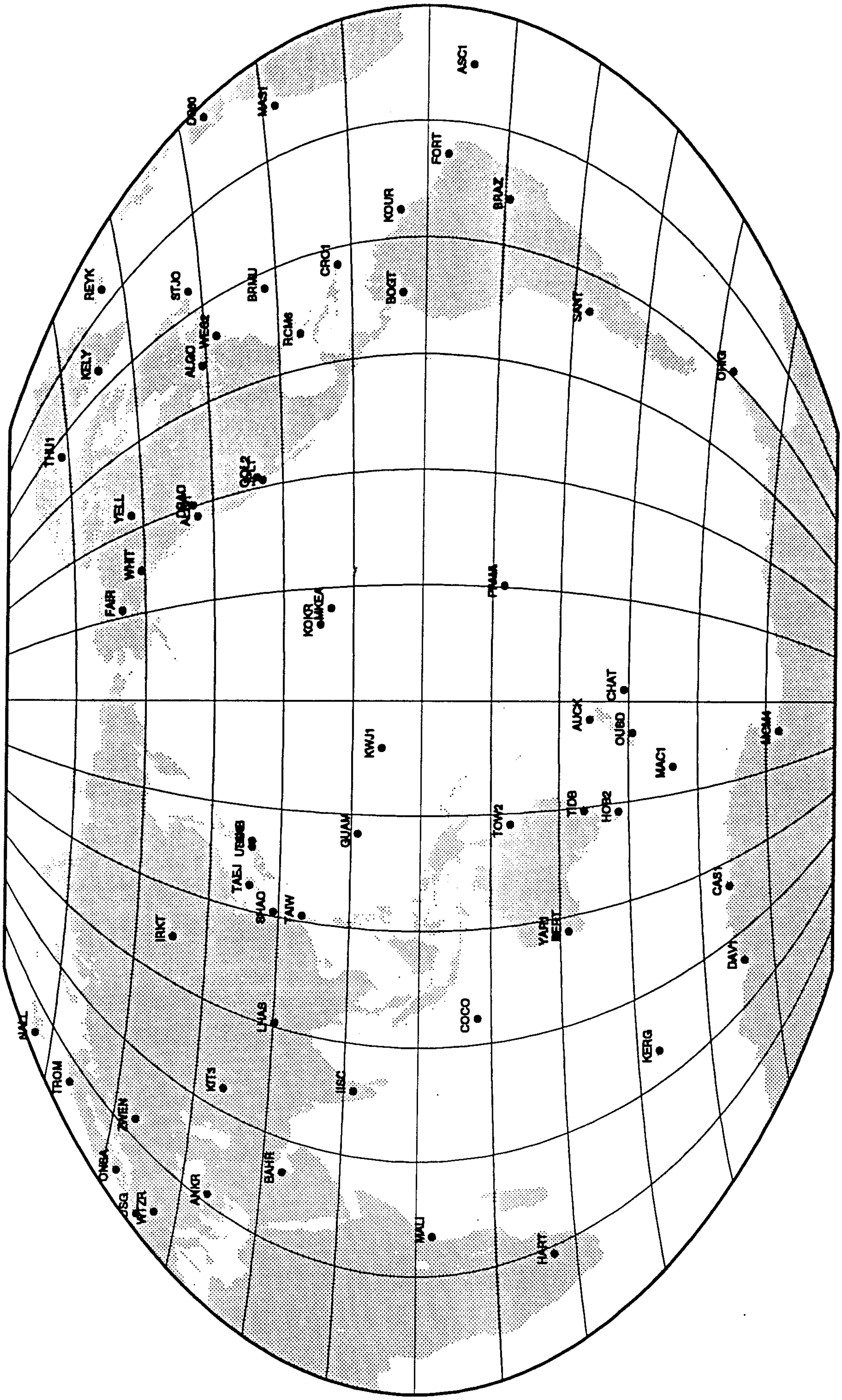

Figure 3.12: Map of global stations used in generation the 1997 solutions.

3.7 1998 Campaigns

This is a spring rather than the now standard autumn data set. It is seen that the network was observed in three parts with some stations appearing in two of the parts. The principal function of this campaign was to provide a minimum of 4 high quality epochs for the high priority stations that were to form the frame for the definition of the new datum.

The permanent sites at AUCK. WGTN. OUSD. HOKI and CHAT are constant throughout the three parts. These stations together with the now good southern hemisphere coverage means that correctly executed piecemeal campaigns are able to yield the same high quality results as the earlier all site simultaneously occupied model that was previously adopted.

Some processing dilemmas are evident for days 250 and 251 when University of Otago, OUSD, data was limited. In general OUSD was regularly used as a tie station providing north/south and east/west control. The new permanent station at Wellington Airport, WGTN, was substituted for OUSD on days 250 and 251. However this didn't appear to offer sufficient strength on day 251 when there was no OUSD data. The permanent station at Hokitika, HOKI, was substituted. While we were concerned with consistency between the daily solutions in a campaign sequence we were also concerned with ensuring the tightest possible connection between the regional fiducial solution and the global solution. We don't believe we have compromised either consistency or quality by the substitutions indicated.

Further fiducial strength between the daily solutions is evident by the fact that stations in addition to AUCK. CHAT. HOKI. WGTN and OUSD which were consistently observed on all days. were processed. An example is 1420 which was observed on days 250, 151 and 257. Another is station 1259 which was observed on days 257 and 263.

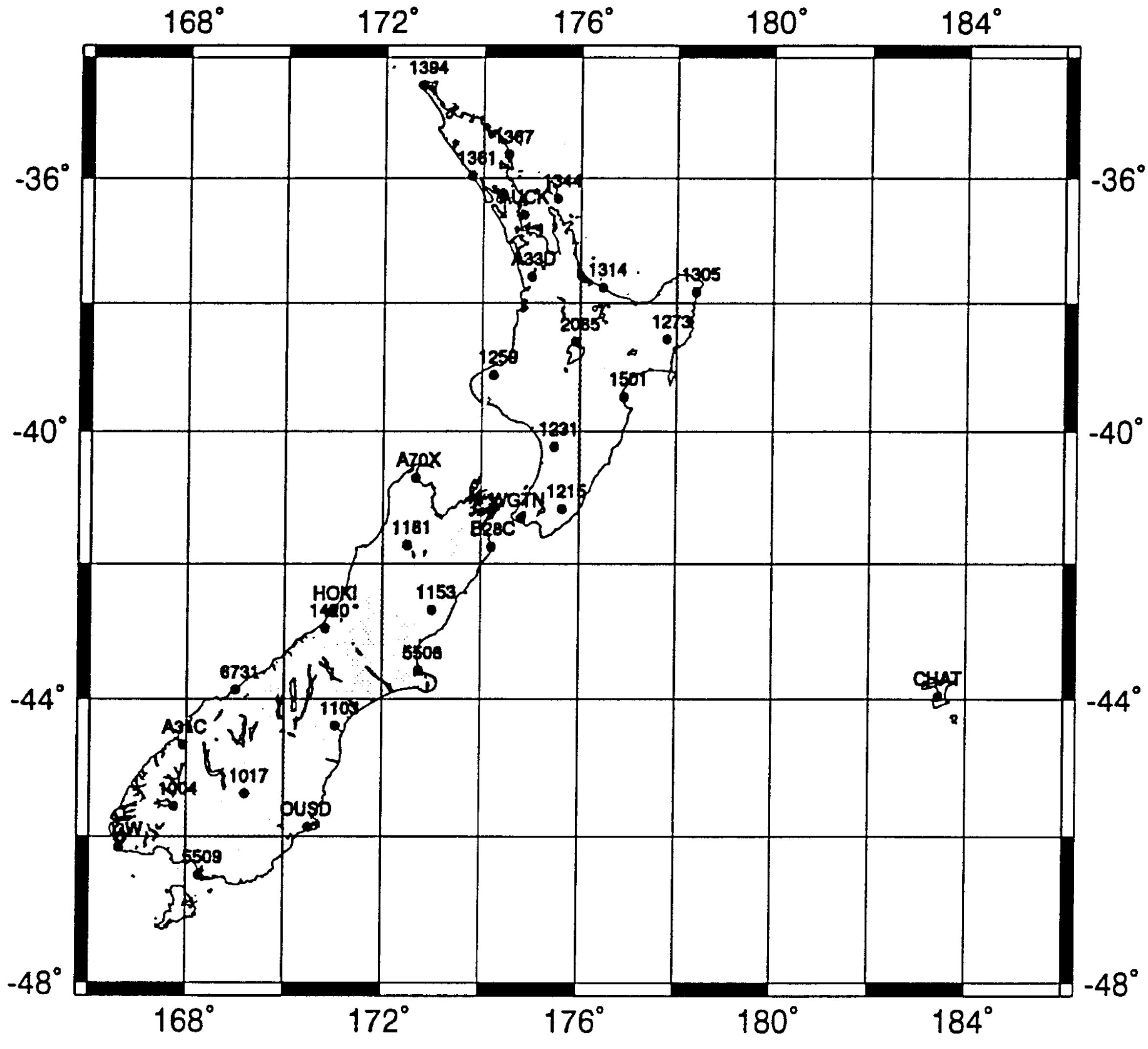

Figure 3.13: Map of regional stations occupied in 1998

Table 3.7: Table of regional New Zealand GPS stations observed in 1998

Station	Day of 1998					
	250	251	257	258	263	264
1004	•	•				
1017	•	•				
1103	•	•				
1153	•		•			
1181			•	•		
1215			•	•		
1231			•	•		
1252						
1259			•		•	
1252						
1259						
1273			•		•	
1305					•	•
1314					•	•
1344					•	•
1361					•	•
1367					•	•
1394					•	•
1420	•	•	•			
1501			•	•		
2085			•		•	
5508	•	•				
5509	•	•				
6731	•	•				
A31C	•	•				
A33D					•	•
A70X			•	•		
AUCK	♠	♠	♠	♠	♠	♠
B03W						
B28C			•	•		
B9F3						
CHAT	♠	♠	♠	♠	♠	♠
HOKI	•	♠	•	•	•	•
OUSD	•		♠	♠	♠	♠
WELL						
WGTN	♠	♠	•	•	•	•

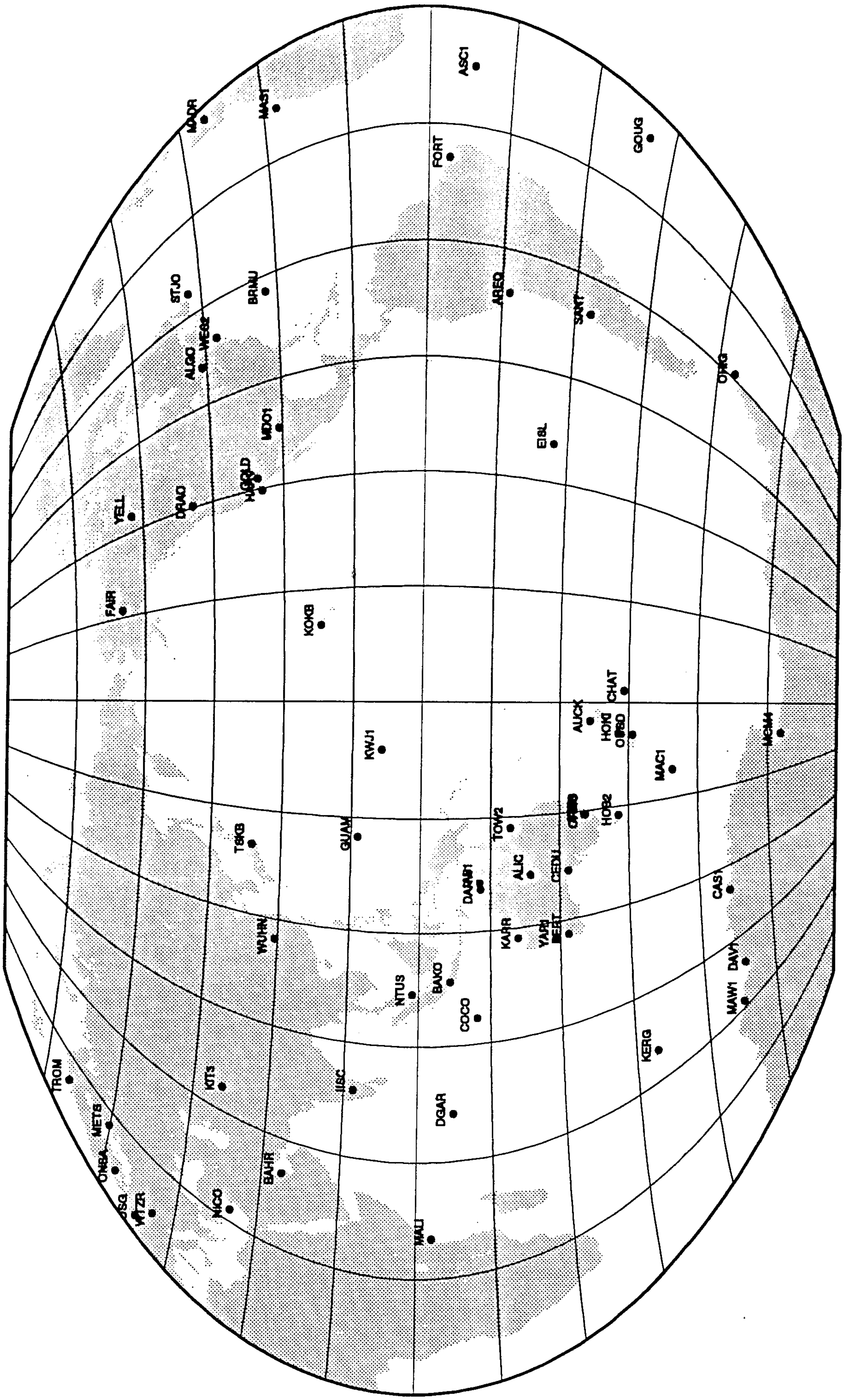

Figure 3.14: Map of global stations used in generation the 1998 solutions.

Chapter 4

Methodology

The basic flow for the analysis procedure is outlined in Figure 4.1. This figure shows that the analysis process is divided into three main components.

1. The GAMIT process in which the individual daily GPS observations are reduced to daily positions along with ancillary parameters such as satellite orbits, earth rotation parameters and other parameters described in Section 2.2.1.

2. The GLOBK process when the output from the GAMIT process, *hfiles*, are unified into a single system.

3. The GLORG stabilization process in which the loosely constrained GLOBK system is scaled, rotated and translated to the terrestrial reference frame.

4.1 The daily GAMIT solutions

The daily GAMIT solutions provide the basic positional data. As such there is a requirement that these solutions be of the highest possible standard. In particular it is a requirement that bias ambiguities be consistently and reliably resolved. In this study biases were not fixed, see Section 2.2.1.

In general incorrect or inconsistent bias resolution, especially un-flagged and unresolved jumps in phase will effect the quality of a sequence of double difference observations. In GAMIT, each sequence of double difference observations has an associated standard deviation computed. This quantity is generally distributed as an exponential function with its peak value about 0.1 of a cycle. The tail has values that exceed 0.3 of a cycle. GAMIT also computes a global statistic, called nrms for normalised root mean square, which is a global estimate of the differences between the observed phases and phases computed through the model. This value is effected by the quality of the individual sequences. That is sequences of observations with a high standard deviation, generally due to poor or inadequate modeling, will have a greater contribution to nrms than sequences that are correctly meddled. That is high values of nrms are indicative of poor or inadequate modeling.

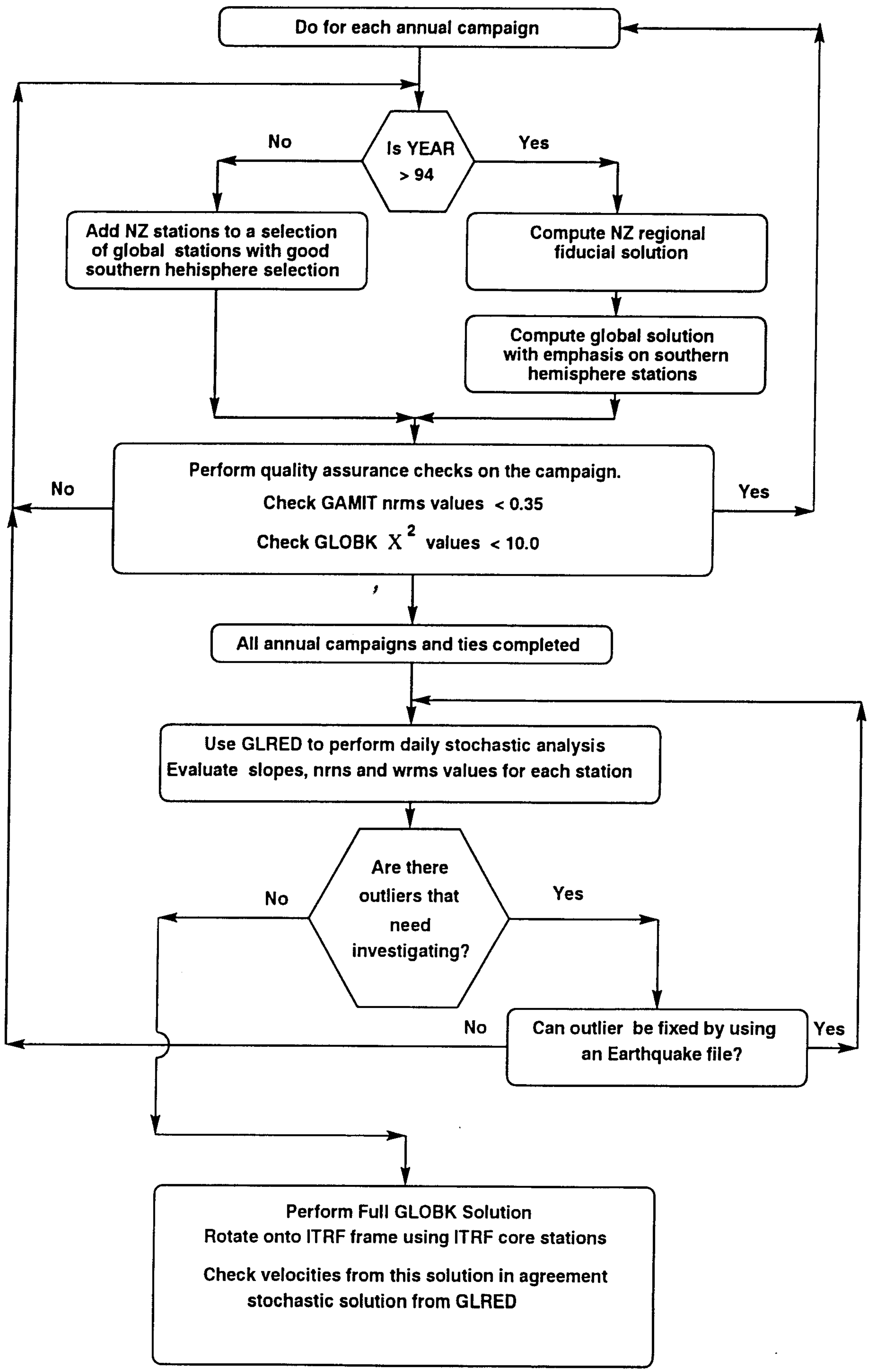

Figure 4.1: Diagram of work flow, methodology and points at which quality assurance was applied during analysis.

In this study we studied all solutions where nrms was greater than 0.30. Solutions with nrms vales exceeding 0.35 were reprocessed. Strategies for cleaning the sequences so that their contributions were acceptable included the following:

- Running SCANDD and then obtaining a list of the 75 worst cases where there were unflagged jumps. These jumps were examined in CVIEW and corrective measures taken when appropriate.
- The SCANDD output was sorted so that the full rms values were sorted in reverse order, largest to smallest. These values were then examined in CVIEW for non-linear and non-modeled effects causing the rms of the data series to remain high and usually with a significant trend. The usual corrective measure was to delete the data. In those cases where a particular station or satellite was producing this type of data exclusion was undertaken in AUTCLN where site and satellite exclusion are possible on an epoch by epoch basis or in the solution bat file where stations and satellite are fully excluded.
- A careful examination of the bias flags added by AUTCLN is made. The normal AUTCLN.SUM picture is for less than 10 bias flags to be needed in sequences that involve either stations or satellites. It is usual for a bad station to show with high bias numbers across all satellites and for a bad satellite to shows across all stations. The usual course of action is to exclude data from the bad satellite or station.

Table 4.1: NRMS values for New Zealand Regional solutions. These solutions include the pre 1995 global solutions and those solutions used to compute ties.

Year							
1992	1993	1994	1995	1996	1997	1998	TIES
0.216	0.150	0.223	0.197	0.207	0.229	0.222	0.166
0.220	0.156	0.265	0.184	0.194	0.210	0.196	0.211
	0.173	0.237	0.254	0.195	0.218	0.229	0.215
	0.177	0.217	0.214	0.214	0.267	0.230	0.188
	0.166	0.236	0.261		0.196	0.248	0.203
	0.187	0.313	0.271		0.240	0.199	0.248
	0.180	0.227			0.205		0.211
	0.189	0.267			0.198		
	0.164	0.218			0.211		
	0.156				0.226		
	0.149						
	0.148						
	0.157						

The nrms values for the regional solutions, including the pre-1995 solutions, are given in Table 4.1. The values for the associated global solutions were also subjected to the same procedures.

A feature of the GAMIT solutions was the level of constraints applied to these daily solutions. In general they were made as loose as possible so as to detect anomalous situations. GAMIT was set up to perform the standard constrained solution whose nrms values are reported in Table 4.1. GAMIT also performed an unconstrained solution in which the constraints imposed on the satellite orbit, the earth rotation parameters and the station parameters are relaxed. An nrms value is computed for this relaxed solution which is carried forward to the GLOBK analysis by way of the output *hfile*. We checked that the loose nrms was always just smaller than the constrained solution value. Large difference in these values are indicative of incorrect values for parameters associated with orbits and station coordinates which will show in the GLOBK analysis.

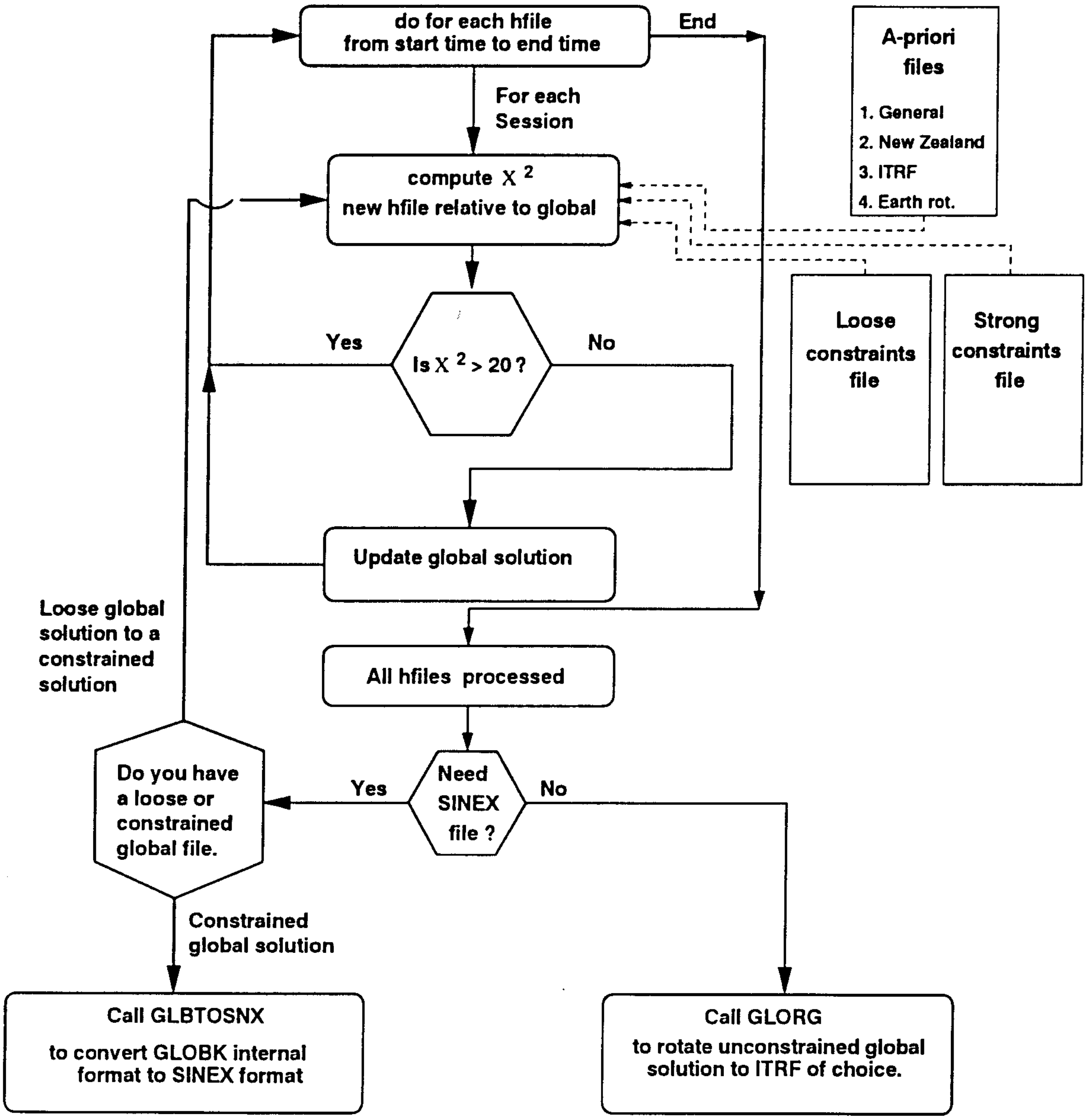

Figure 4.2: Schematic of GLOBK process

4.2 The GLOBK analysis

The GLOBK analysis was done in several parts or sections. Figure 4.2 is a schematic of the Globk process and some of its options.

4.2.1 Proofing of the annual campaigns

The *hfiles* associated with each day in each of the campaigns were joined together using GLOBK.

In this process we were interested in ensuring that the solutions were consistent with each other. Thus we were primarily concerned with the GLOBK χ^2 value which is a measure of how well each day is joined to the overall solution. We placed an arbitrary limit of 10 on this process. In actuality individual values never exceeded 3.0 indicating that each of the campaigns was internally consistent.

4.2.2 Repeatability analysis with GLRED

With the individual campaigns proofed we then set about proofing the quality of all days reduced by performing a daily stochastic analysis using the GLRED module.

In the GLRED module all the solutions performed on the same day are joined together by GLOBK. This joined system was a single GAMIT solution for campaigns before 1995. From 1995 the joined solutions had a regional New Zealand component and a global component. The joined system. which included the thirteen *core* stations defined in coordinated systems that predated ITRF96. were then rotated to the global terrestrial reference frame. ITRF96. This was performed for each day making the determined daily values stochastically independent. It is possible to then estimate a number of parameters from these stochastic values including:

- The mean value and the associated standard deviation.
- The linear trend or slope of the data and the associated standard deviation.
- Statistics describing the scatter of the stochastic values about the selected model values.

We plotted these stochastically determined values as a time series using the GMT suite (Wessel & Smith. 1998) along with trend and precision information. see Figures 4.3 and 4.4. We also extracted statistics for consistency and uniformity. see Table 4.2. It is readily seen, especially in the Up component that the results fall into two principal groupings. The first grouping is typified by station 1259. The second grouping is typified by station A31C. The second grouping has nrms and wrms values that are more than twice that of the first group. A careful examination of the stochastic panels shows that there is a large group of outliers for the 1996 campaign.

Table 4.2: Statistics from daily stochastic analysis for repeatability. This table describes the statistics as initially determined with the 1996 data set incorrectly set up.

Site	North component			East component			Up component		
	σ_{slope} mm/yr	nrms mm	wrms mm	σ_{slope} mm/yr	nrms mm	wrms mm	σ_{slope} mm/yr	nrms mm	wrms mm
1004	1.4	2.41	8.9	1.9	1.67	8.8	2.8	5.86	45.6
1017	1.6	2.92	11.1	2.2	1.57	8.8	3.2	4.08	33.7
1103	1.2	1.45	5.4	1.6	1.73	9.5	2.2	4.95	38.5
1153	0.9	2.89	10.4	1.3	2.11	11.5	1.8	4.38	33.1
1181	0.8	2.74	9.6	1.2	2.09	11.1	1.7	5.28	40.3
1215	1.1	3.04	10.8	1.7	2.38	12.9	2.2	5.19	37.8
1231	1.0	3.39	12.4	1.4	2.21	12.5	2.0	4.40	33.3
1259	0.5	1.76	6.3	0.8	1.72	9.0	1.2	1.67	12.7
1273	1.2	1.62	5.9	2.0	3.20	18.2	2.5	3.05	22.7
1305	1.2	1.86	6.7	2.0	1.76	10.1	2.6	3.08	23.1
1314	1.0	2.23	8.3	1.6	1.97	11.5	2.1	3.17	24.4
1344	1.4	0.91	3.2	2.1	2.18	12.1	2.8	2.90	21.6
1361	1.3	1.05	3.7	2.0	1.51	8.5	2.6	3.02	23.3
1367	1.2	1.35	4.9	1.8	2.04	12.0	2.4	2.83	22.2
1394	1.3	0.79	2.6	2.1	1.85	9.9	2.7	2.76	20.1
1501	0.9	2.37	9.0	1.4	2.03	11.9	1.9	3.98	31.2
2085	1.1	2.25	9.0	1.6	2.25	14.0	2.2	3.72	31.4
5508	1.3	1.21	4.1	1.8	1.69	8.7	2.3	5.49	39.0
5509	0.8	2.15	10.1	1.1	1.73	11.7	1.4	4.91	46.6
6731	1.1	2.63	9.5	1.6	2.11	11.4	2.2	5.42	42.7
A31C	0.6	2.31	7.4	0.9	1.51	6.7	1.6	8.55	61.6
A33D	1.1	2.38	8.9	1.6	2.02	11.6	2.2	3.18	24.6
A70X	1.0	2.00	6.9	1.6	2.76	14.2	2.1	6.97	51.6
AUCK	1.4	2.12	7.7	2.2	1.64	9.2	2.9	2.40	18.0
B03W	1.4	2.71	9.3	2.0	2.23	10.9	2.8	7.63	55.7
B28C	0.9	2.75	10.0	1.3	2.17	11.6	1.8	5.09	37.9
CHAT	2.0	2.04	8.2	2.8	1.73	9.7	3.4	2.42	16.6
OUSD	0.9	2.14	8.0	1.2	2.13	11.0	1.7	7.71	54.4
WEL1	2.1	2.24	7.6	3.5	2.08	10.8	5.4	2.99	24.2
WELL	0.8	2.35	15.8	1.2	1.55	15.8	1.7	2.87	39.4

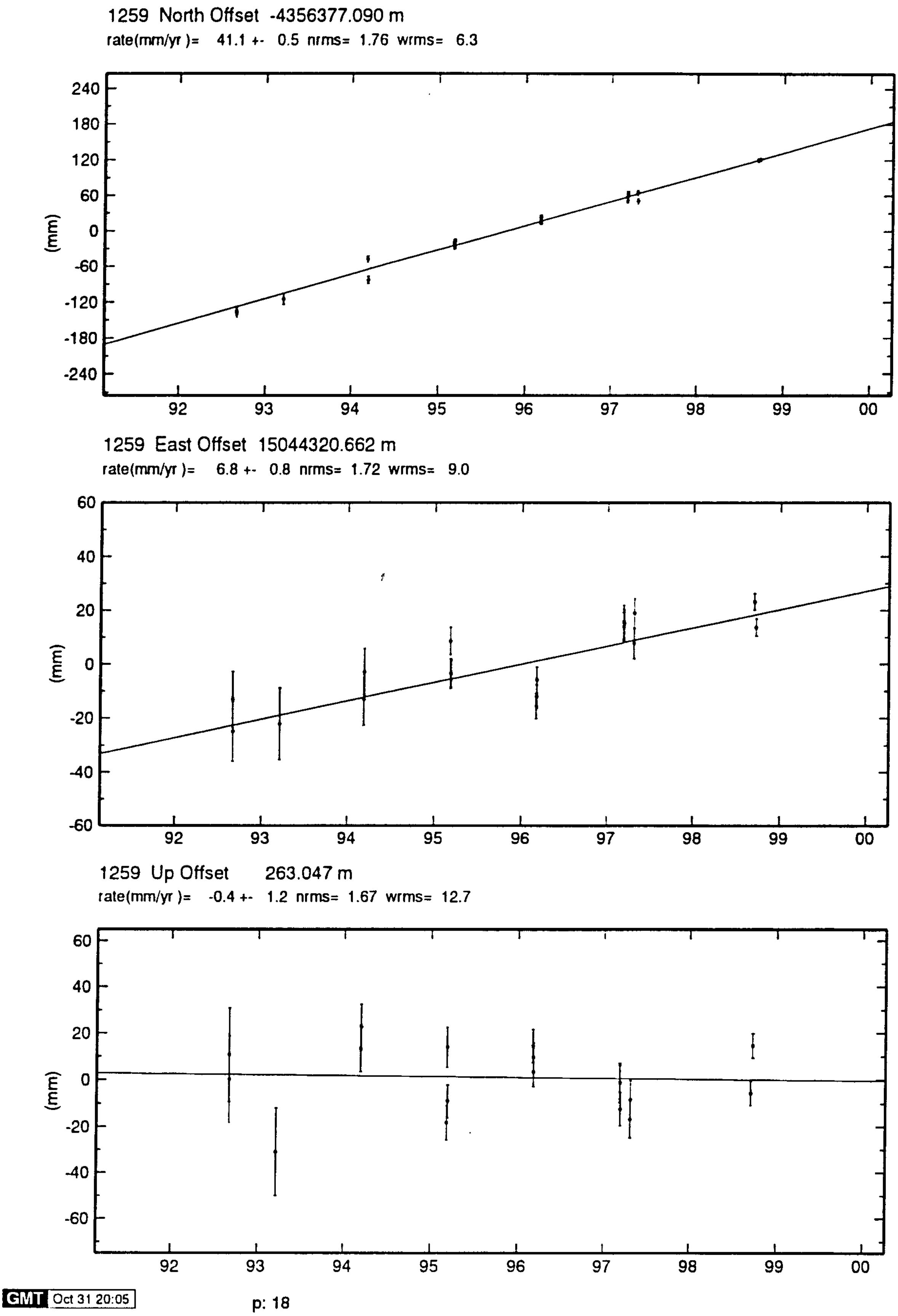

Figure 4.3: First stochastic panels for 1259

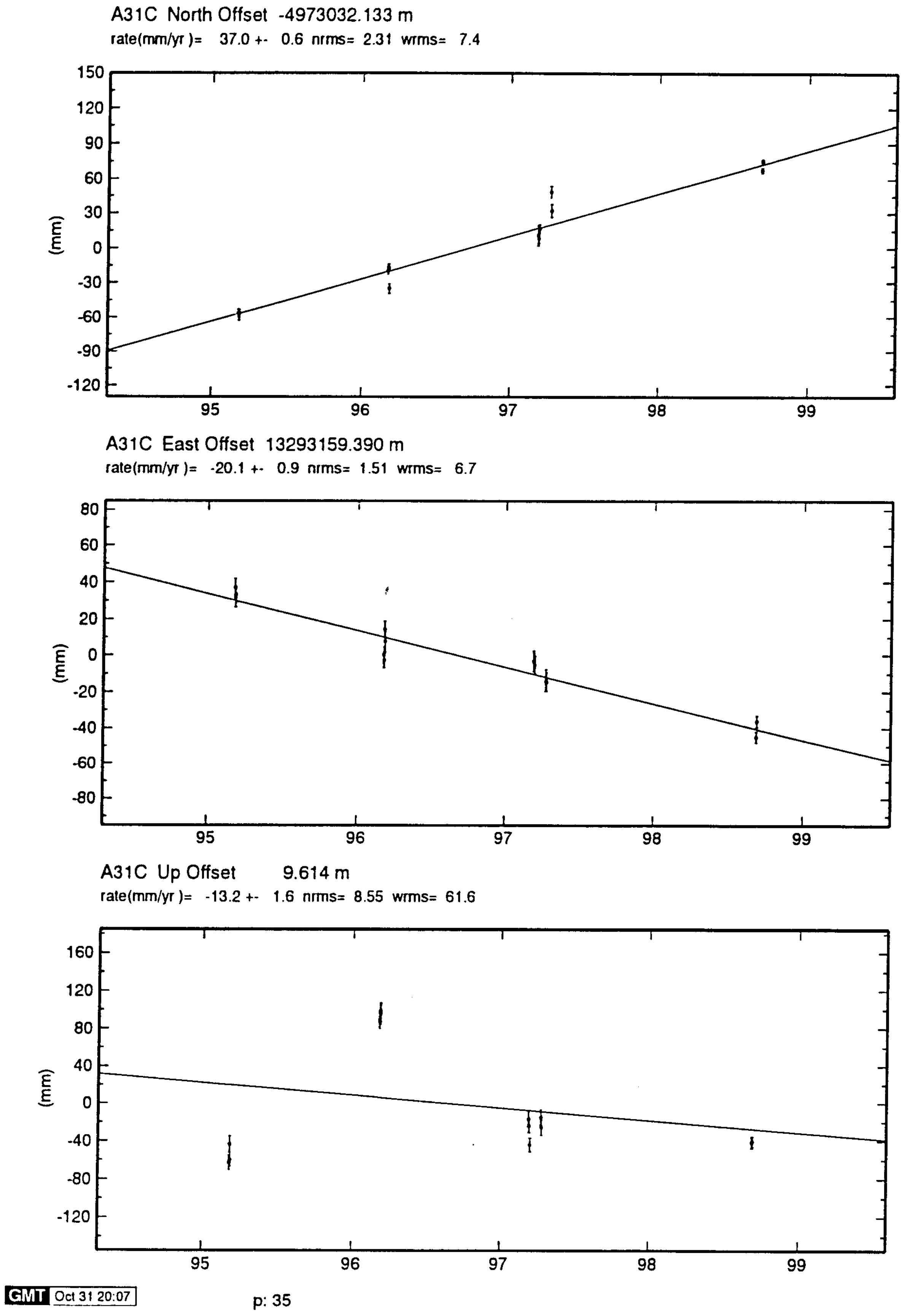

Figure 4.4: First stochastic panels for A31C with the Ashtech antennas incorrectly described for 1996.

After some careful analysis work and much consultation and comparison with Bevan (1998), we were able to show that this effect was restricted to South Island stations where Ashtech receivers were used except at OUSD where the instrument was a Trimble. Initially this was a puzzle as IGS antenna modelling was switched on and excursions of the detected magnitude in mixed antenna networks were expected to be much smaller. The answer to the problem at the Ashtech sites was the incorrect coding of the antenna while at OUSD there was a change in definition of the antenna reference point. Applying the model for the correct antenna model corrected the problem. Figure A.22 is the corrected figure for site A31C.

Table 5.2 tabulates statistics for all stations after correcting the Ashtech antenna problem. It is readily apparent that while there is still significant variation that the variation is significantly limited. Much more extensive work needs to be undertaken to further reduce the tabulated variation.

4.2.3 The full GLOBK run

No problems were encountered in running the full GLOBK run, primarily due to the proofing and analysis work that proceeded this stage. Figure 4.5 shows the individual χ^2 values generated when each new solution is attached. It is difficult to quantify both causes of the variation and the magnitude of the mismatch in large processes. However stong, well established, rules of thumb are employed. These rules require an analysis of all sessions that produce χ^2 values in excess of 20 with the mean value being well under 5.0. In general this means that values should not be exceeding 10.0. Two sessions, both global IGSB series sessions from the Scrips Institution of Oceanography (SIO) on consecutive days in 1997, were rejected by these rules of thumbs as we were unable to isolate the causes of the χ^2 mismatches which were well above 100 indicating a significant problem. The exclusion of these sessions is not expected to have any effect on the attachment of the regional New Zealand solution due to the strength of the system that was already in existance at this stage and the fact that some of the important regional fiducial sites were in the global A series session IGSA, also produced by SIO. It is to be noted that we made all the global solutions except for the 1997 globals which used the SIO-SOPAC IGSA and IGSB series. The use of these series stemmed from the earlier work of the authors when this data was reduced in Hobart as part of our Southern Hemisphere work.

A plot of the χ^2 values as each session was attached is shown in Figure 4.5. It is to be noted that for the 1992, 1993 and 1994 data only the global session was computed. This is discussed in the Data Chapter, Chapter 2.

The overall χ^2 value is 1.8. This was achieved with uniform unit weights on all sessions. It is regarded as being in the high quality area. The impact of the overall χ^2 value is discussed in the Results Chapter, Chapter 5. Variations in the average level of the χ^2 value are dependent on many correlated parameters including ionospheric noise, know to be rising in the latter part of the data set and the geometry of the tracking stations to be used.

The choice of stabilization sites followed the concepts and philosophy that Morgan et al (1996) used to stabilize the Australian Zero Order Network. Specifically the long running well determined stations MADR-GPS, SANT-GPS, ALGO-GPS, YELL-GPS, GOLD-GPS, FAIR-GPS, TIDB-GPS, YAR1-GPS, HART-GPS, TROM-GPS and KOSG-GPS were used. These stations formed the original core group of GPS stations. They are long running, well determined in the ITRF frame and have good geometry for high quality orientation of the loosely constrained solution.

There is some overlap in the use of Tidbinbilla. TIDB-GPS, in that it was used for stabilization and for regional fiducial attachment. Again this was the case for the Australaian Fiducial network. The use of regional fiducials to also provide stabilization of the solution to the ITRF frame was a major part of the Australaian solution where it was shown to be most desirable.

The use of these 11 stations means that 33 observations for both position and velocity were available to resolve the 7 Helmert parameters. This provides a good ratio for the degrees of freedom to reduced parameters which is generally required to be four or above.

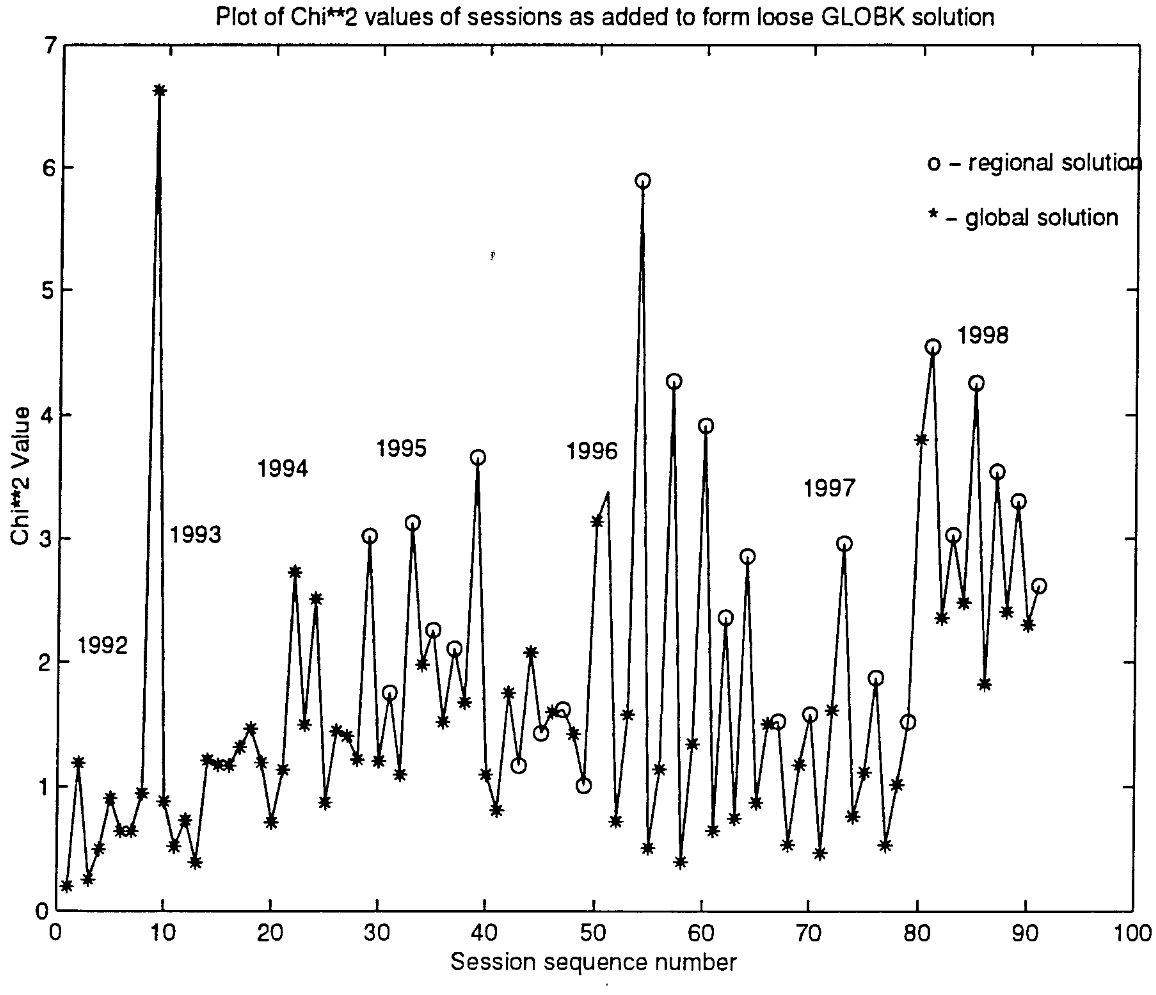

Figure 4.5: χ^2 values of each session as added to the loose GLOBK solution for all global and regional data.

Chapter 5

Results

The analysis of the various annual data sets indicated that there were several classes of points:

1. Stations which were observed for multiple years and for which reliable velocity parameters could be extracted.
2. Stations which were observed for one year or less and hence velocity parameters are either unreliable or not determinable.
3. Stations whose principle function was to tie pre-existing data to a new mark

This section deals only with stations in the first category. Where tie data is available and has been used the estimates reflect the inclusion of this tie data. Tie data has been used at AUCK and 5509 but not at WELL.

There has been considerable discussion on the correct designation and labelling of GPS points as used in national reference systems. It is generally agreed that the most reliable stations are those permanent stations that are regularly reduced by two or more IGS Analysis Centres. These IGS Analysis Center solutions carry considerable weight in the IERS epoch solutions for the determination of the terrestrial reference frame. Examples of this category of station are AUCK and CHAT.

The next level is generally considered to be permanent stations that operate in accordance with IGS specifications but are not part of the IGS network. An example of this type of station is OUSD.

The third level of stations are the episodic stations. These stations are high quality surveying marks which are re-occupied on an episodic schedule, usually annual. It is common for different instruments and antenna to be used at each reoccupation. Initially it was thought that setup errors and biases could be trapped and removed by performing daily setups. Experience has shown this to be flawed and daily or session setups have given way to campaign setups. The majority of stations in this analysis are annual episodic stations with campaign setups.

In general two types of analysis were undertaken. The first, the conventional fully modelled least squares solution forms the basis of the data passed onto LINZ. The second, the daily stochastic solution. where parameterization is at a lower level. is used for a wide range of validation procedures including the estimation of the appropriate scaling factors. Results from both analysis are detailed in the Appendix: Abridged station data, in three parts.

1. A table of the geocentric cartesian and ellipsoidal. GRS80 ellipsoid, coordinates at the epoch of 1965.5 without velocity estimates. These results were generated by the full model and conventional GAMIT/GLOBK procedures of maintaining a loosely constrained system until the end when the need to fix this system onto the ITRF frame was necessary. It was these values that were subject to peer review and eventually accepted by LINZ as a component of their Geodetic Datum 2000 work. It is again to be emphasised that the values in these table are not part of the new datum definition but rather were used as one of the inputs for the process of generating the new datum.

2. A verbatim table extracted from the constrained GLORG output file. Like the item above these data were generated with the full model and conventional process. This table is interpreted as follows:

   - The first six lines are the geocentric values at the solution epoch, 22 September 1998, 1998.7242. The left most numbers are the position of this parameter in the variance-covariance matrix. The third last column is the adjusted parameter. The penultimate column is the correction from the a-priori value while the last column is the one-sigma uncertainity of the parameter. This one-sigma value is unscaled. That is to obtain the formal one-sigma value this value need to be multiplied by the solution χ^2 value. The value for χ^2 for the solution was 1.89. Another consideration is the confidence interval. The one-sigma corresponds to a 67% confidence interval while the two-sigma level corresponds to the 95% level.

     It is usually only considered meaningful to talk about precisions in a uniformly scaled system. In the ellipsoidal coordinate system there is a large scale factor that needs to be applied as a result of the variation in latitude. This variation is overcome if precision is considered in terms of local topocentric coordinates which are very close to map coordinates. Thus there is a preference for either cartesian precision estimates or the transformed local topocentric estimates.

   - The next line changes the date for the parameters from the solution date, 1998.7242, to the mean uncorrelated date. The individual positions of the uncorrelated time, with respect to the solution date. in years then follows.

   - The next three lines give the Uncorrelated positions, at the mean uncorrelated epoch for each component along with the corrections to a-priori values and the one sigma uncertainity of these positions.

   - The line beginning with Unc. is a composite representation of the data just described. This line allows this data to be readily extracted from the large GLORG print file. There is no change in the velocity estimated due to the change of reference time as the velocity parameters are linear.

   - The next group of lines represent a transformation of the uncorrelated position from geocentric coordinates to a local coordinate system where the heights have close physical meaning. This transformation, while precise, is usually to a non specific coordinate system. in this case it is a local topocentric system. These systems are unsuitable for datum definition work.

   - The final group of four lines represent the transformation of the cartesian velocities into a local coordinate system of North. East and Up which has physical meaning.

The columns are, as before, with the middle column being the adjusted coordinate, the penultimate column being the correction to a-priori, while the last column is the one sigma uncertainities of the estimated velocities.

3. The results in these tables are the prefered results for generating estimates at other epoch as well as computing uncertainities and confidence intervals associated with stations. In computing precision estimates a number of considerations must be made. The first is the overall χ^2 of the solution, 1.81 in this case. The second is the well known under-estimation of formal errors in large least squares processes. The determination of the correct factor to be applied to take account of the correlation that exists between the daily data sets as well as the correlation that exist between some of the parameters is still a judgemental process. Factors up to 2.5 are commonly applied.

4. The panels in the figure were derived from a daily stochastic analysis of each day by combining the available daily data into a single unified solution and then rotating this system to ITRF96. Because only daily values were rotated to the ITRF frame a time series plot of these values shows the change and variability associated with these stations. The mean position and rates determined from this daily stochasic process are not the same as the full process where all data is rigorously combined. Care must be exercised in comparing parameters estimated from this stochastic process with those of the full process given in the preceeding tables.

The precision and ultimately the accuracy of the analysis process are always considered important results. The parameters that specify the precision of the coordinates and their velocities are given in the verbatim slices for each site in the appendices. As always, the geocentric cartesian system is the most fundamental, however it lacks easy understanding. We therefore choose to discuss station precision in terms of a local topocentric system. The transformation between the two systems is a 1:1 mapping.

It is to be noted that Table 5.2 doesn't tabulate precsion statistics on position since the procesdure is a daily estimation process. The point precisions are indicated on the appendix plots with the conventional vertical bar. One-sigma values are plotted. Thus it is only possible to compare the rates between the two estimation processes.

One of the most striking features of Table 5.1 is the constancy of the estimated rates and their quite small values. The constancy is thought to be due to the relatively small geographical extent of New Zealand coupled with the relative consistancy of the fiducial network used to attach the New Zealand data from 1995 and the uniformity of the global solutions. It is to be recalled that prior to 1995 the global solutions had the New Zealand data embeded within them.

It is readily noticed that the north estimates are tighter than the east estimates which are in turn tighter than the up or vertical parameters. This is a well observed phenomena. The track of the GPS satellites, inclined to the local equator at about 55°, accounts for the difference in the local north and east values due to the along track error propagating mainly into the north component and the across component propagating into the east component. The Up component has traditionally been a factor of two worse than the horizontal components due to increased effects of tropospheric delays and antenna characteristics.

The consistancy of these values has considerable impact on the next stage of the datum definition proces as undertaken by LINZ. The consistancy/regularity and not too large a ratio

Table 5.1: One-sigma precisions for local North. East and Up positions and rates from the conventional parametric least squares solution

Station	North (mm)	East (mm)	Up (mm)	North rate (mm/yr)	East rate (mm/yr)	Up rate (mm/yr)
1004	0.9	1.4	2.9	0.3	0.6	1.3
1017	0.9	1.3	2.7	0.3	0.5	1.1
1103	0.9	1.3	2.6	0.3	0.5	0.9
1153	0.9	1.3	2.4	0.3	0.5	0.8
1181	0.9	1.3	2.5	0.3	0.5	0.9
1215	0.9	1.4	2.6	0.3	0.5	1.0
1231	0.9	1.4	2.7	0.3	0.5	1.1
1259	0.8	1.3	2.4	0.3	0.5	0.9
1273	0.9	1.4	2.7	0.3	0.5	1.1
1305	0.9	1.4	2.7	0.3	0.6	1.1
1314	0.9	1.4	2.5	0.3	0.5	1.0
1344	0.9	1.4	2.7	0.3	0.6	1.1
1361	0.9	1.4	2.7	0.3	0.5	1.0
1367	0.9	1.4	2.6	0.3	0.5	1.0
1394	0.9	1.4	2.8	0.3	0.5	1.1
1420	0.9	1.3	2.5	0.3	0.6	1.1
1501	0.9	1.3	2.4	0.3	0.5	1.1
2085	0.9	1.3	2.6	0.3	0.5	0.9
5508	0.9	1.3	2.6	0.3	0.5	0.9
5509	0.8	1.2	2.3	0.3	0.4	0.7
6731	0.8	1.3	2.5	0.3	0.5	0.9
A31C	0.9	1.4	2.8	0.3	0.6	1.3
A33D	0.8	1.3	2.5	0.3	0.5	1.0
A70X	0.9	1.3	2.5	0.3	0.5	1.0
AUCK	0.8	1.2	1.7	0.3	0.4	0.7
B03W	0.9	1.3	2.6	0.3	0.5	1.2
B28C	0.9	1.3	2.5	0.3	0.5	0.9
CHAT	0.8	1.2	1.7	0.4	0.6	1.1
OUSD	0.8	1.1	1.6	0.3	0.4	0.6
WELL	1.0	1.8	3.9	0.3	0.5	1.0

between the components means that assumptions of uniformitity of the starting variance-covariance matrix are not seriously violated.

We attempted several analysis on these tables. Clearly when one of the parameters, for example the precision on the local North from the least square analysis is constant then no meaningful regression can be undertaken against the stochastic values except at the level of the means. At this level it is seen that the ratio between the stochastic values to the parametric values is close to 2. This is without considering the χ^2 factor that should be applied to the parametric values. This factor is close to 1.35 making the global factor about 1.5. A scaling of the parametric values by 2.0 to ensure the correct levels of the one-sigma estimates is at the lower end of values commonly adopted. It is considered low because of the uniformly high quality of the work. The application of this scaling means that all rates are determined better than 1 mm/yr. While this has no effect on the LINZ process it does mean that the correcting the uncorrelated point to the common epoch of 1996.5 is unlikely to introduce errors into these 1996.5 values. This is even more so when the uncorrelated time is close to 1996.5.

The application of the same factor to the position estimates cannot be substantiated. Conservative approaches might adopt these factors where formal approaches would only apply a factor of 1.35 resulting from the unit variance weighting factor. The application of this factor means that local horizontal positions will have one-sigma precisions near 2 millimeters where the up component will be just over 3 millimeters.

It is instructive to review the WRMS statistcs of Table 5.2 particulary since this statistic was used to isolate antenna errors. It is now seen that apart from WELL all values are under 30 mm with many stations being under 20 mm. The fixed stations. AUCK. CHAT and OUSD generally perform better than the epoch stations although 1394 and 1374 are particulary tight. The table provides strong evidence for a weighted root mean square residual of about 15 mm from epoch occupations of stations. This over a period of 5 to 6 years seems capable of producing vertical rates which have well established precisions near the 2 mm/yr level. after scaling. These rate agree well with a simulation study made by Morgan (1994). In this study he estimated that vertical rate precision would be near 2 mm/yr from annual epochs with data which would have 20 mm of noise on the annual epoch determination. Stastical averaging. accomplished by multiple days of occupation will reduce this level. The results of this study indicate the following:

1. That there are no major sites of uplift. positive or negative. in the New Zealand network. In all cases the 95% confidence interval for the vertical uplift includes the zero rate.
2. If a goal of 1 mm/yr is required for uplift studies then a continuation of the current annual epoch campaigns is likey to yield the required precision within three to four years, if the locations are acceptable.

Table 5.2: Precisions for stochastically determined local North. East and Up rates. The quantities determined are the one-sigma precision on the rate, the normalised root mean square residual and the weighted root mean square residual

Station	North			East			Up		
	Rate (mm/yr)	NRMS (mm)	WRMS (mm)	Rate (mm/yr)	NRMS (mm)	WRMS (mm)	Rate (mm/yr)	NRMS (mm)	WRMS (mm)
1004	0.8	2.06	8.4	1.1	1.00	5.4	1.8	1.77	14.8
1017	0.6	2.97	11.5	0.9	1.26	6.7	1.5	2.06	17.3
1103	0.5	1.45	5.4	0.8	1.37	7.5	1.2	1.74	14.4
1153	0.5	2.86	10.5	0.7	1.76	9.3	1.1	1.79	14.4
1181	0.5	1.96	7.1	0.7	1.22	6.2	1.2	2.18	17.7
1215	0.6	1.43	5.3	0.9	1.14	6.0	1.4	2.15	17.3
1231	0.6	2.21	8.0	1.0	1.35	6.9	1.5	1.95	15.2
1259	0.5	1.68	6.6	0.8	1.20	6.9	1.2	1.58	13.3
1273	0.6	1.04	3.9	1.0	1.78	10.0	1.5	1.07	8.7
1305	0.6	1.12	4.3	1.0	1.49	8.4	1.5	1.23	10.1
1314	0.6	1.55	6.0	0.9	1.53	8.7	1.4	1.59	13.3
1344	0.7	1.08	4.0	1.1	1.15	6.2	1.6	1.60	13.1
1361	0.7	1.16	4.2	1.0	0.84	4.6	1.5	1.24	10.3
1367	0.6	1.21	4.6	1.0	1.25	7.2	1.4	2.62	22.4
1394	0.6	1.18	4.1	1.0	0.94	5.0	1.5	1.00	8.1
1420	0.7	2.90	9.7	1.0	1.70	8.1	1.7	2.86	22.2
1501	0.6	1.63	6.4	0.9	1.44	8.0	1.3	1.63	13.6
2085	0.6	1.79	7.2	0.9	1.45	8.6	1.3	1.45	13.0
5508	0.5	1.62	6.1	0.8	1.25	6.9	1.2	2.19	18.1
5509	0.4	2.02	9.3	0.6	1.67	10.7	0.9	2.47	23.5
6731	0.5	2.29	8.2	0.8	1.66	8.5	1.3	2.82	22.4
A31C	0.7	2.14	7.7	1.0	1.29	6.5	1.7	2.22	18.1
A33D	0.6	1.70	6.6	1.0	1.00	5.6	1.4	1.27	10.7
A70X	0.6	1.49	5.4	0.9	1.35	7.0	1.3	3.34	26.8
AUCK	0.4	2.12	7.8	0.7	1.45	7.9	0.9	2.10	16.1
B03W	0.7	1.74	6.1	0.9	1.37	6.6	1.6	2.60	20.0
B28C	0.5	2.00	7.6	0.8	1.40	7.3	1.2	2.25	18.0
CHAT	0.9	2.26	7.8	1.2	1.18	5.4	1.5	1.89	11.7
OUSD	0.4	2.01	6.6	0.6	1.63	7.1	0.9	2.00	13.1
WELL	0.7	2.11	11.5	1.0	1.66	13.6	1.5	2.83	34.1

Chapter 6

The Results in SINEX format

The results from the analysis were written to a CD-ROM in SINEX (Software INdependent EXchange) format.

While GAMIT/GLOBK supports and makes use of the SINEX format it uses an internal format called *hfiles*. *Hfiles* perform a similar function to SINEX files in that all information is stored including the final variance-covariance matrix. A significant difference is that *hfiles* also store satellite vehicle information in addition to station information. This allows the satellite orbit to play a key role in the unification of the daily regional and global solutions. It is this use of satellite information that begins the divergence path between the GLOBK processes used in this analysis and most other analysis proceedures.

Another significant difference between the GLOBK approach and other approaches is the nature of the enforcement of the terrestrial reference frame. We enforced the terrestrial reference frame of choice, ITRF96, by enforcing the coordinates of 13 well known, long running GPS stations distributed in a semi-optimal manner around the globe, see (Morgan et al 1996). It is also possible to attach to the reference system by just using the regional fiducial sites or by holding fixed in the adjustment the IGS orbits and the associated earth rotation parameters. We believe our approach which forces the scaling, orientation and positioning of our weakly constrained global network onto the global network frees us from the necessity to consider the effects of changing terrestrial system definition and the effect that this has on orbits although Angermann (1998) states that this is small.

The final points to consider include the correlation that exists between the reduced observations and the parameters and the fact that velocity is assumed to be linear and unchanging over the duration of the campaign except in the immediate vacinity of earthquakes where there is rupture. There are two important epochs in GLOBK output files. The first is the date, epoch, of the solution. This date is usually the last day processed. It is necessary because the terrestrial reference frame is dependant on Earth rotation parameters which are epoch dependant. The second date is the epoch where the correlations between the positions and the rates are minimum. This is usually near the mid-point of the available data.

To produce the required SINEX file the following steps were undertaken.

Step 1 The full *hfile* associated with the weakly constrained global solution, was saved

Table 6.1: Difference between the conventional GLOBK/GLORG process of network stabilization and a conventional SINEX file stabilized at the solution epoch.

	Coordinate Differences (m)			Velocity Differences (m/yr)			Sigma differencs (m)		
	X	Y	Z	Xdot	Ydot	Zdot	X	Y	Z
CHAT	-0.00310	0.00620	-0.00007	-0.00030	0.00010	-0.00070	-0.00080	-0.00100	-0.00080
1305	-0.00312	0.00626	-0.00007	-0.00020	0.00010	-0.00070	-0.00060	-0.00110	-0.00080
1273	-0.00313	0.00619	-0.00011	-0.00020	0.00010	-0.00060	-0.00060	-0.00110	-0.00080
1501	-0.00318	0.00625	-0.00019	-0.00020	0.00010	-0.00060	-0.00070	-0.00110	-0.00090
1314	-0.00322	0.00632	-0.00014	-0.00020	0.00010	-0.00070	-0.00070	-0.00110	-0.00090
2085	-0.00327	0.00623	-0.00018	-0.00020	0.00010	-0.00060	-0.00070	-0.00110	-0.00080
1215	-0.00326	0.00620	-0.00030	-0.00020	0.00010	-0.00060	-0.00070	-0.00110	-0.00080
1344	-0.00309	0.00636	-0.00007	-0.00020	0.00010	-0.00070	-0.00060	-0.00110	-0.00080
1231	-0.00341	0.00625	-0.00031	-0.00010	0.00010	-0.00050	-0.00070	-0.00110	-0.00080
A33D	-0.00318	0.00628	-0.00028	-0.00010	0.00010	-0.00060	-0.00060	-0.00110	-0.00090
AUCK	-0.00315	0.00618	-0.00011	-0.00020	0.00010	-0.00060	-0.00080	-0.00110	-0.00090
WGTN	-0.00321	0.00630	-0.00023	-0.00020	0.00010	-0.00060	-0.00070	-0.00110	-0.00070
WELL	-0.00336	0.00631	-0.00014	-0.00010	0.00010	-0.00060	-0.00090	-0.00110	-0.00090
1367	-0.00317	0.00624	-0.00004	-0.00020	0.00020	-0.00060	-0.00070	-0.00110	-0.00090
1259	-0.00330	0.00629	-0.00027	-0.00010	0.00010	-0.00060	-0.00070	-0.00110	-0.00080
B28C	-0.00346	0.00624	-0.00024	-0.00010	0.00010	-0.00060	-0.00080	-0.00110	-0.00090
1361	-0.00329	0.00618	-0.00011	-0.00010	0.00010	-0.00060	-0.00060	-0.00110	-0.00080
1153	-0.00354	0.00645	-0.00038	-0.00010	0.00010	-0.00060	-0.00080	-0.00120	-0.00080
1394	-0.00321	0.00627	-0.00001	-0.00020	0.00020	-0.00060	-0.00060	-0.00110	-0.00080
5508	-0.00354	0.00625	-0.00036	0.00000	0.00000	-0.00050	-0.00090	-0.00110	-0.00080
A70X	-0.00340	0.00624	-0.00025	-0.00010	0.00010	-0.00060	-0.00070	-0.00110	-0.00080
1181	-0.00348	0.00637	-0.00032	-0.00010	0.00010	-0.00050	-0.00080	-0.00110	-0.00080
1103	-0.00364	0.00631	-0.00047	-0.00010	0.00010	-0.00050	-0.00090	-0.00110	-0.00080
1420	-0.00345	0.00637	-0.00036	-0.00010	0.00010	-0.00050	-0.00080	-0.00110	-0.00070
OUSD	-0.00360	0.00629	-0.00051	-0.00010	0.00010	-0.00040	-0.00090	-0.00110	-0.00090
1017	-0.00354	0.00628	-0.00047	-0.00010	0.00010	-0.00050	-0.00070	-0.00110	-0.00070
6731	-0.00362	0.00640	-0.00045	0.00000	0.00010	-0.00040	-0.00080	-0.00120	-0.00080
5509	-0.00360	0.00638	-0.00065	-0.00010	0.00010	-0.00040	-0.00090	-0.00120	-0.00080
A31C	-0.00363	0.00632	-0.00062	0.00000	0.00010	-0.00040	-0.00070	-0.00110	-0.00070
1004	-0.00366	0.00639	-0.00049	0.00000	0.00010	-0.00040	-0.00080	-0.00110	-0.00080
B03W	-0.00355	0.00637	-0.00060	0.00000	0.00010	-0.00040	-0.00080	-0.00110	-0.00070
MEAN	-0.00337	0.00629	-0.00028	-0.00013	0.00010	-0.00055	-0.00074	-0.00111	-0.00081
Std	0.00019	0.00007	0.00018	0.00008	0.00003	0.00010	0.00010	0.00004	0.00007
RMS	0.00337	0.00629	0.00033	0.00015	0.00011	0.00056	0.00075	0.00111	0.00081

prior to the step in which the global reference frame was scaled, rotated and positioned on the 1996 epoch International Terrestrial Reference Frame.

That is a weakly constrained solution in a terrestrial reference frame with a solution epoch equal to the last processed day was obtained. It is important to note that Earth rotation parameters specifing the relationship of the weakly constrained system to the terrestrial reference system were updated to this final date, 22 September 1998.

Step 2 The loose file was now passed back into GLOBK. In this pass tight constraints are enforced on those stations that are used to enforce the reference frame. The same loose constraints that were used on the other stations in the previous pass were again used. We entered the one-sigma uncertainities of the thirteen IGS stations used to tie the loose solution to the terrestrial reference frame in the GLORG module. This effectively created the same system that GLORG module created. Small difference can arise as the weights are not strictly preserved in this process. An example is a frequently ocurring non-defining station whose weight will change from the nominal value according to the something akin to the root n law.

The system and its associated variance-covariance matrix are again written out in GLOBK *hfile* format.

Step 3 The new, constrained *hfile* with its Earth orientation date of 22 September 1998 is now transformed into the standard SINEX file format using the module GLBTOSNX.

We then tested the results written to the SINEX file by applying the velocities to the 1996.5 positions as determined by the constrained GLORG estimation process. That is we updated the 1996.5 results to 1998.7242 (22 September 1998). The results are presented in Table 6.1. The results tabulated in this table show a clear shift of -0.00337 in X, 0.00629 in Y and -0.00028 in Z. That is there was a shift in the centre of the coordinate systems of 7 mm. While this shift is surprising additional tests showed that it was a function of the level of the constraints and at what stage they were applied. We did not run a sequence attempting to minimise these differences as the constraints from such a process could not be substanciated on any other grounds other than the minimization criteria when it was well understood that there were difference in methodology. Perhaps the constancy of the differences is more meaningful and important than the magnitude. It is readily seen that in position and velocity the results of one method are comparable to the other at sub-millimeter levels.

Chapter 7

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Appendix A

Abridged station data

This appendix provides abridged information on each major station in the New Zealand network.

The stations are organised in increasing numerical order followed by alphabetic ordering of those stations that have alphabetic names.

It is to be stressed that the abridged information comes from the full GLOBK/GLORG process in which the loose GLOBK solution was constrained to ITRF96 thus the application of a weighted Hermert transformation process on a number of selected stations. Thus this abridged information has small differences to the results published in SINEX format.

A.1 1004

Table A.1: Coordinates of 1004 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X			Y			Z
1004	-4371448.5075			950019.3554			-4531598.9505
	Ellipsoidal Coordinates Latitude			Longitude			Height
	Deg	Mn	Sec	Deg	Mn	Sec	Meters
1004	S45	33	43.61099	E167	44	20.13029	411.0683

Table A.2: Coordinates of 1004 in ITRF96 at solution epoch and the Uncorrelated time

```
 559. 1004_GPS X coordinate  (m)          -4371448.5548      0.2127       0.0022
 560. 1004_GPS Y coordinate  (m)            950019.4239     -0.0466       0.0015
 561. 1004_GPS Z coordinate  (m)          -4531598.9059      0.2030       0.0021
 562. 1004_GPS X rate       (m/yr)              -0.0212      0.0623       0.0009
 563. 1004_GPS Y rate       (m/yr)               0.0308     -0.0132       0.0006
 564. 1004_GPS Z rate       (m/yr)               0.0201      0.0601       0.0009
 Postion of 1004_GPS referred to 1996.7652  XYZ offsets  -1.9538  -1.9587  -1.9686 years
Loc.  1004_GPS X uncorr pos. (m)          -4371448.5131      0.0906       0.0012
Loc.  1004_GPS Y uncorr pos. (m)            950019.3636     -0.0207       0.0009
Loc.  1004_GPS Z uncorr pos. (m)          -4531598.9452      0.0852       0.0011
Unc. 1004_GPS -4371448.5131   950019.3636 -4531598.9452 -0.0212  0.0308  0.0201 1996.765
                                                         0.0012  0.0009  0.0011
Loc.  1004_GPS N coordinate  (m)          -5071951.3994     -0.0134       0.0009
Loc.  1004_GPS E coordinate  (m)          13073430.3038      0.0004       0.0014
Loc.  1004_GPS U coordinate  (m)               411.2069     -0.2974       0.0029
    NE,NU,EU position correlations        0.0252        0.1417       -0.0742
Loc.  1004_GPS N rate       (m/yr)               0.0335     -0.0034       0.0003
Loc.  1004_GPS E rate       (m/yr)              -0.0256     -0.0003       0.0006
Loc.  1004_GPS U rate       (m/yr)               0.0048     -0.0874       0.0013
    NE,NU,EU rate correlations            0.0238        0.1587       -0.0521
```

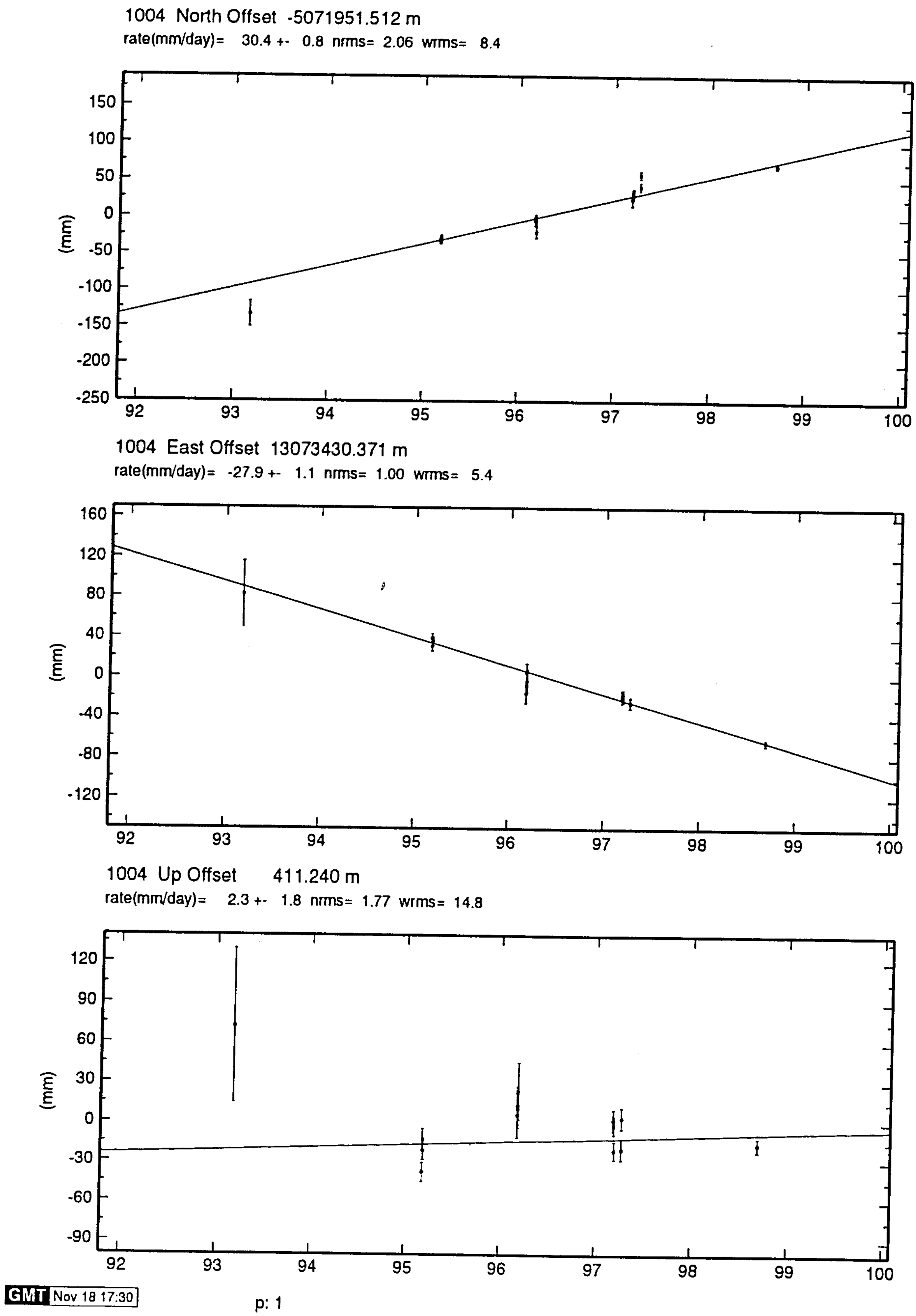


Figure A.1: Stochastic panels for 1004

A.2 1017

Table A.3: Coordinates of 1017 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1017	-4408673.2994	841182.5695	-4518904.6774

Station	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
1017	S45	23	15.52431	E169	11	51.73163	1680.7992

Table A.4: Coordinates of 1017 in ITRF96 at solution epoch and the Uncorrelated time

```
 517. 1017_GPS X coordinate  (m)           -4408673.3505       0.1308       0.0020
 518. 1017_GPS Y coordinate  (m)             841182.6382       0.0049       0.0014
 519. 1017_GPS Z coordinate  (m)           -4518904.6420       0.1133       0.0019
 520. 1017_GPS X rate        (m/yr)              -0.0230       0.0285       0.0008
 521. 1017_GPS Y rate        (m/yr)               0.0309       0.0055       0.0006
 522. 1017_GPS Z rate        (m/yr)               0.0159       0.0246       0.0008
 Postion of 1017_GPS referred to 1996.8147  XYZ offsets   -1.9077  -1.9037  -1.9212 years
Loc.  1017_GPS X uncorr pos. (m)           -4408673.3066       0.0762       0.0013
Loc.  1017_GPS Y uncorr pos. (m)             841182.5792      -0.0056       0.0009
Loc.  1017_GPS Z uncorr pos. (m)           -4518904.6724       0.0662       0.0012
Unc. 1017_GPS -4408673.3066   841182.5792 -4518904.6724 -0.0230  0.0309  0.0159 1996.815
                                                         0.0013  0.0009  0.0012
Loc.  1017_GPS N coordinate  (m)           -5052529.5414      -0.0112       0.0009
Loc.  1017_GPS E coordinate  (m)           13228082.1828      -0.0293       0.0013
Loc.  1017_GPS U coordinate  (m)               1680.8283      -0.1702       0.0027
     NE,NU,EU position correlations         0.0244       0.1337       -0.0904
Loc.  1017_GPS N rate        (m/yr)               0.0314      -0.0019       0.0003
Loc.  1017_GPS E rate        (m/yr)              -0.0260      -0.0107       0.0005
Loc.  1017_GPS U rate        (m/yr)               0.0086      -0.0365       0.0011
     NE,NU,EU rate correlations             0.0239       0.1521       -0.0848
```

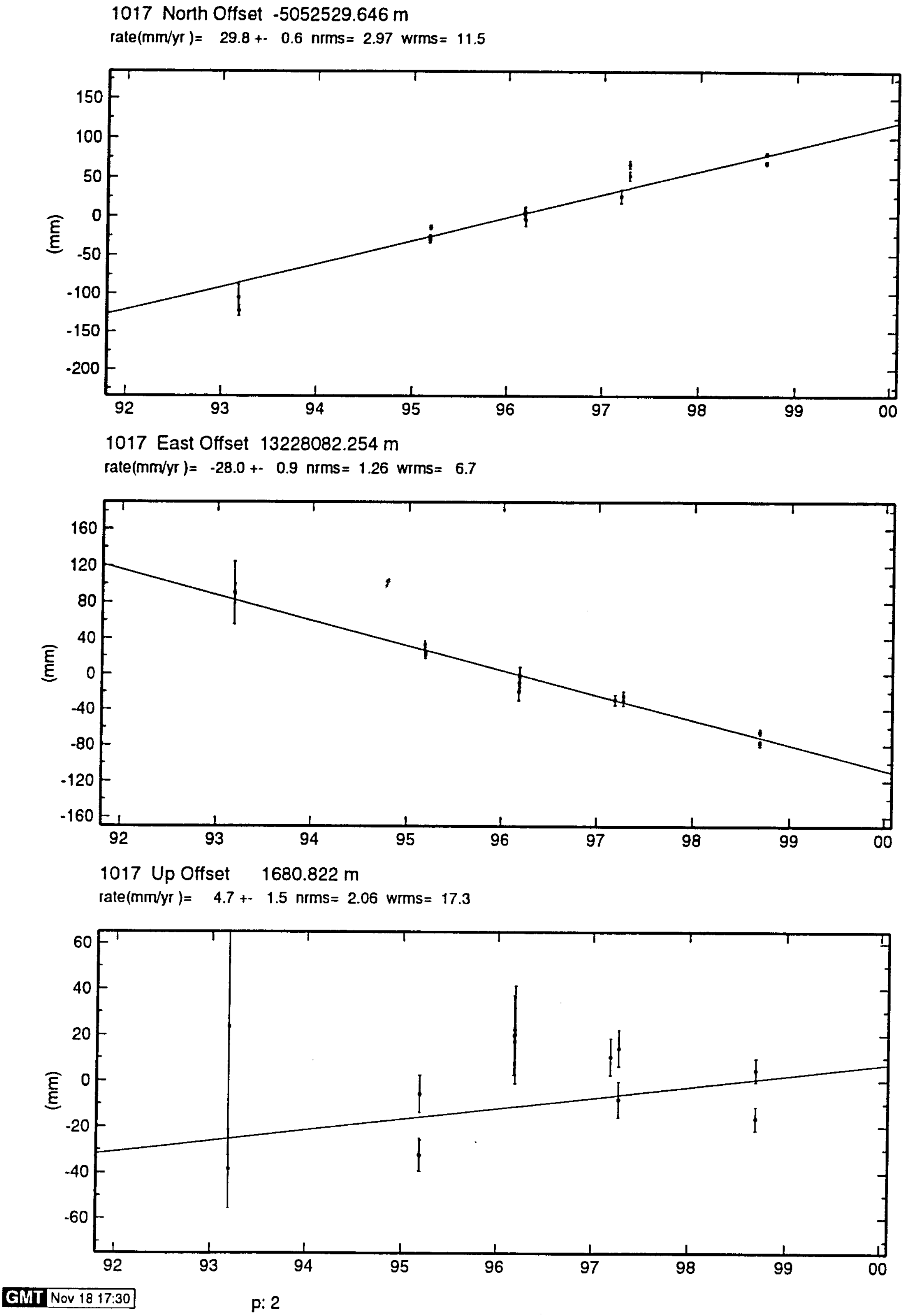


Figure A.2: Stochastic panels for 1017

A.3 1103

Table A.5: Coordinates of 1103 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1103	-4509242.3472	709568.1505	-4440278.8618

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1103	S44 24 2.04846	E171 3 26.44540	396.9878

Table A.6: Coordinates of 1103 in ITRF96 at solution epoch and the Uncorrelated time

```
463. 1103_GPS X coordinate  (m)          -4509242.3892       0.1249        0.0020
464. 1103_GPS Y coordinate  (m)            709568.2239      -0.0110        0.0014
465. 1103_GPS Z coordinate  (m)          -4440278.8142       0.1298        0.0018
466. 1103_GPS X rate        (m/yr)             -0.0189       0.0262        0.0007
467. 1103_GPS Y rate        (m/yr)              0.0330      -0.0002        0.0005
468. 1103_GPS Z rate        (m/yr)              0.0214       0.0298        0.0006
Postion of 1103_GPS referred to 1996.4426   XYZ offsets   -2.3393  -2.1505  -2.3590 years
Loc.  1103_GPS X uncorr pos. (m)          -4509242.3461       0.0651        0.0011
Loc.  1103_GPS Y uncorr pos. (m)            709568.1486      -0.0105        0.0009
Loc.  1103_GPS Z uncorr pos. (m)          -4440278.8630       0.0618        0.0010
Unc. 1103_GPS -4509242.3461   709568.1486 -4440278.8630 -0.0189  0.0330  0.0214 1996.443
                                                         0.0011  0.0009  0.0010
Loc.  1103_GPS N coordinate  (m)          -4942648.8358       0.0052        0.0009
Loc.  1103_GPS E coordinate  (m)          13604634.4015      -0.0086        0.0013
Loc.  1103_GPS U coordinate  (m)               397.1611      -0.1802        0.0026
     NE,NU,EU position correlations          0.0323        0.1301       -0.0890
Loc.  1103_GPS N rate        (m/yr)             0.0319       0.0031        0.0003
Loc.  1103_GPS E rate        (m/yr)            -0.0296      -0.0039        0.0005
Loc.  1103_GPS U rate        (m/yr)             0.0020      -0.0394        0.0009
     NE,NU,EU rate correlations              0.0120        0.1448       -0.1198
```

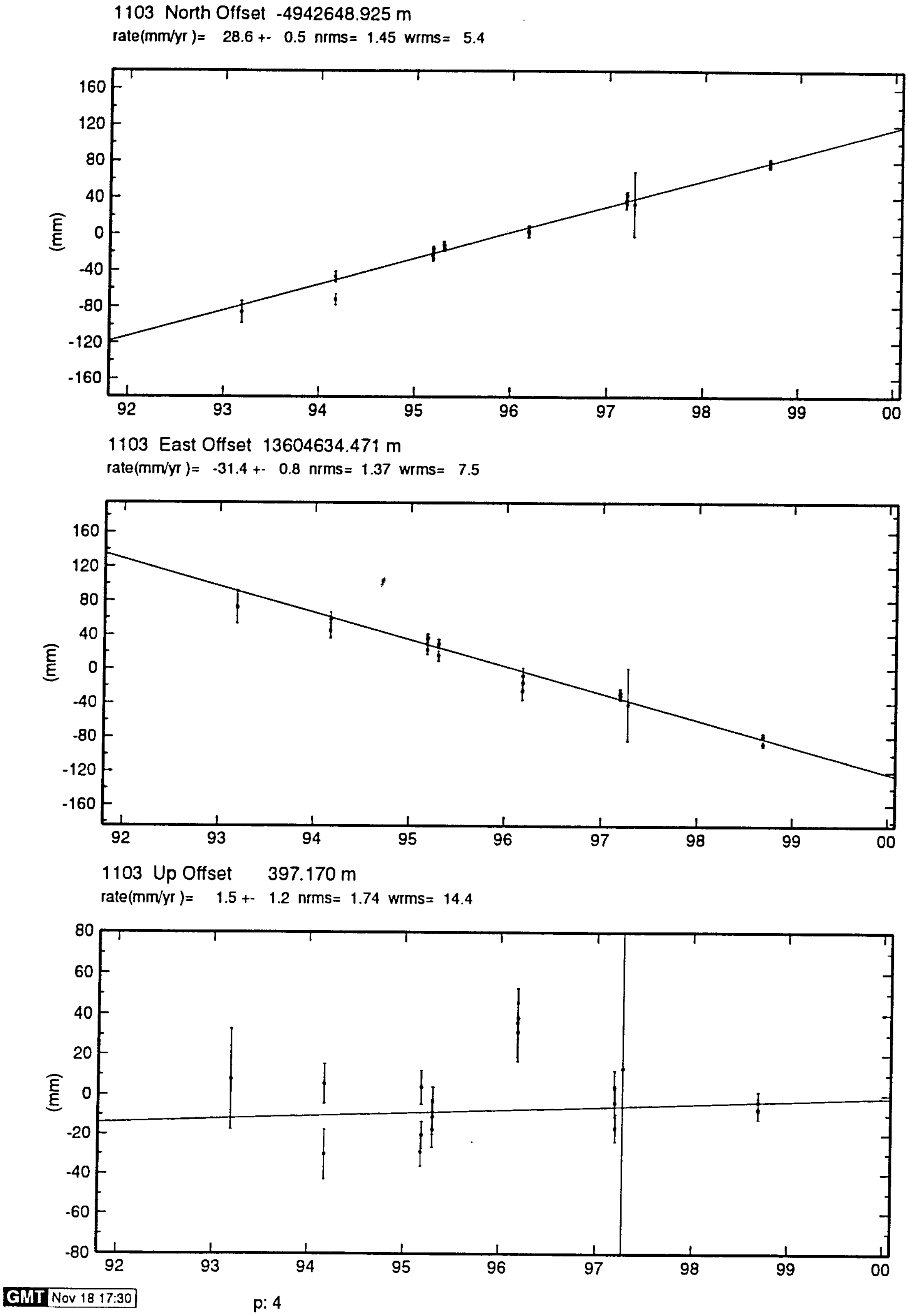


Figure A.3: Stochastic panels for 1103

A.4 1153

Table A.7: Coordinates of 1153 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1153	-4660964.4128	571445.6612	-4302316.2921

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1153	S42 41 14.70310	E173 0 37.00578	405.3720

Table A.8: Coordinates of 1153 in ITRF96 at solution epoch and the Uncorrelated time

```
 433. 1153_GPS X coordinate  (m)          -4660964.4506        0.0298        0.0019
 434. 1153_GPS Y coordinate  (m)            571445.7263        0.0313        0.0013
 435. 1153_GPS Z coordinate  (m)          -4302316.2350        0.0455        0.0017
 436. 1153_GPS X rate        (m/yr)             -0.0170       -0.0031        0.0007
 437. 1153_GPS Y rate        (m/yr)              0.0293        0.0130        0.0005
 438. 1153_GPS Z rate        (m/yr)              0.0256        0.0044        0.0006
 Postion of 1153_GPS referred to 1996.4291  XYZ offsets   -2.3673  -2.1397  -2.3821 years
Loc.  1153_GPS X uncorr pos. (m)          -4660964.4116        0.0369        0.0011
Loc.  1153_GPS Y uncorr pos. (m)            571445.6591        0.0015        0.0008
Loc.  1153_GPS Z uncorr pos. (m)          -4302316.2939        0.0353        0.0010
Unc. 1153_GPS -4660964.4116   571445.6591 -4302316.2939 -0.0170  0.0293  0.0256 1996.429
                                                        0.0011  0.0008  0.0010
Loc.  1153_GPS N coordinate  (m)          -4751941.6541        0.0159        0.0009
Loc.  1153_GPS E coordinate  (m)          14156662.9481       -0.0347        0.0013
Loc.  1153_GPS U coordinate  (m)               405.4993       -0.0498        0.0024
     NE,NU,EU position correlations        0.0455        0.1128        -0.1028
Loc.  1153_GPS N rate        (m/yr)              0.0327        0.0064        0.0003
Loc.  1153_GPS E rate        (m/yr)             -0.0270       -0.0125        0.0005
Loc.  1153_GPS U rate        (m/yr)             -0.0024        0.0004        0.0008
     NE,NU,EU rate correlations            0.0218        0.1268        -0.1408
```

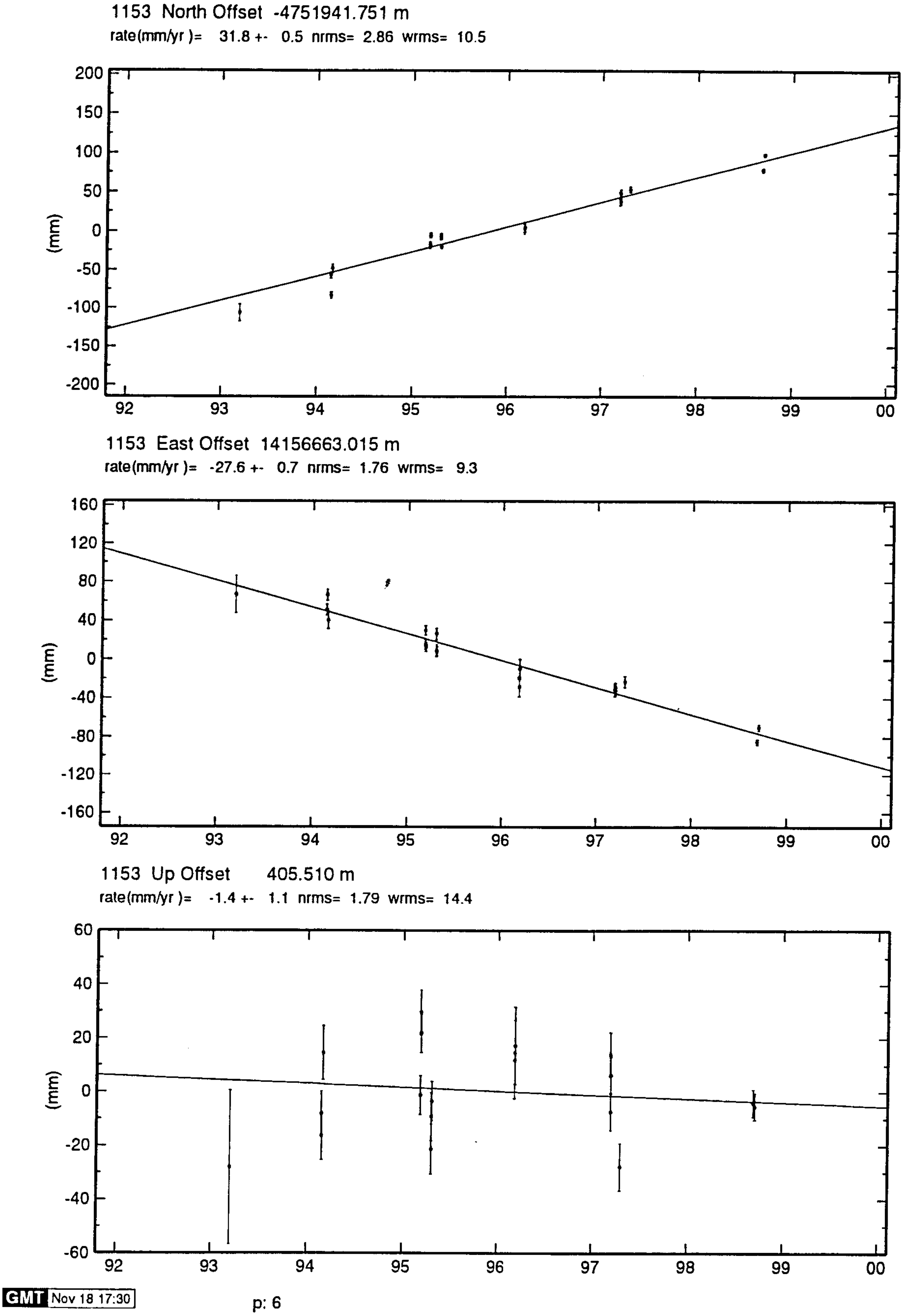


Figure A.4: Stochastic panels for 1153

A.5 1181

Table A.9: Coordinates of 1181 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Cartesian Coordinates Y	Cartesian Coordinates Z
1181	-4727392.4998	622413.0045	-4224184.0035

	Ellipsoidal Coordinates						
	Latitude			Longitude			Height
	Deg	Mn	Sec	Deg	Mn	Sec	Meters
1181	S41	43	44.70521	E172	29	58.28554	1486.7287

Table A.10: Coordinates of 1181 in ITRF96 at solution epoch and the Uncorrelated time

```
 457. 1181_GPS X coordinate  (m)          -4727392.5604        0.2082        0.0020
 458. 1181_GPS Y coordinate  (m)            622413.0236       -0.0322        0.0014
 459. 1181_GPS Z coordinate  (m)          -4224183.9282        0.1247        0.0017
 460. 1181_GPS X rate        (m/yr)             -0.0272        0.0590        0.0007
 461. 1181_GPS Y rate        (m/yr)              0.0086       -0.0084        0.0005
 462. 1181_GPS Z rate        (m/yr)              0.0338        0.0362        0.0006
 Postion of 1181_GPS referred to 1996.4414  XYZ offsets   -2.3503  -2.1503  -2.3517 years
Loc.  1181_GPS X uncorr pos. (m)          -4727392.4982        0.0736        0.0011
Loc.  1181_GPS Y uncorr pos. (m)            622413.0040       -0.0130        0.0009
Loc.  1181_GPS Z uncorr pos. (m)          -4224184.0055        0.0420        0.0010
Unc. 1181_GPS -4727392.4982   622413.0040 -4224184.0055 -0.0272  0.0086  0.0338 1996.441
                                                         0.0011  0.0009  0.0010
Loc.  1181_GPS N coordinate  (m)          -4645260.2786       -0.0472        0.0009
Loc.  1181_GPS E coordinate  (m)          14330957.4155        0.0047        0.0013
Loc.  1181_GPS U coordinate  (m)              1486.6425       -0.2402        0.0025
     NE,NU,EU position correlations         0.0425        0.1215       -0.1079
Loc.  1181_GPS N rate        (m/yr)              0.0440       -0.0126        0.0003
Loc.  1181_GPS E rate        (m/yr)             -0.0050        0.0006        0.0005
Loc.  1181_GPS U rate        (m/yr)             -0.0015       -0.0686        0.0009
     NE,NU,EU rate correlations             0.0326        0.1292       -0.1281
```

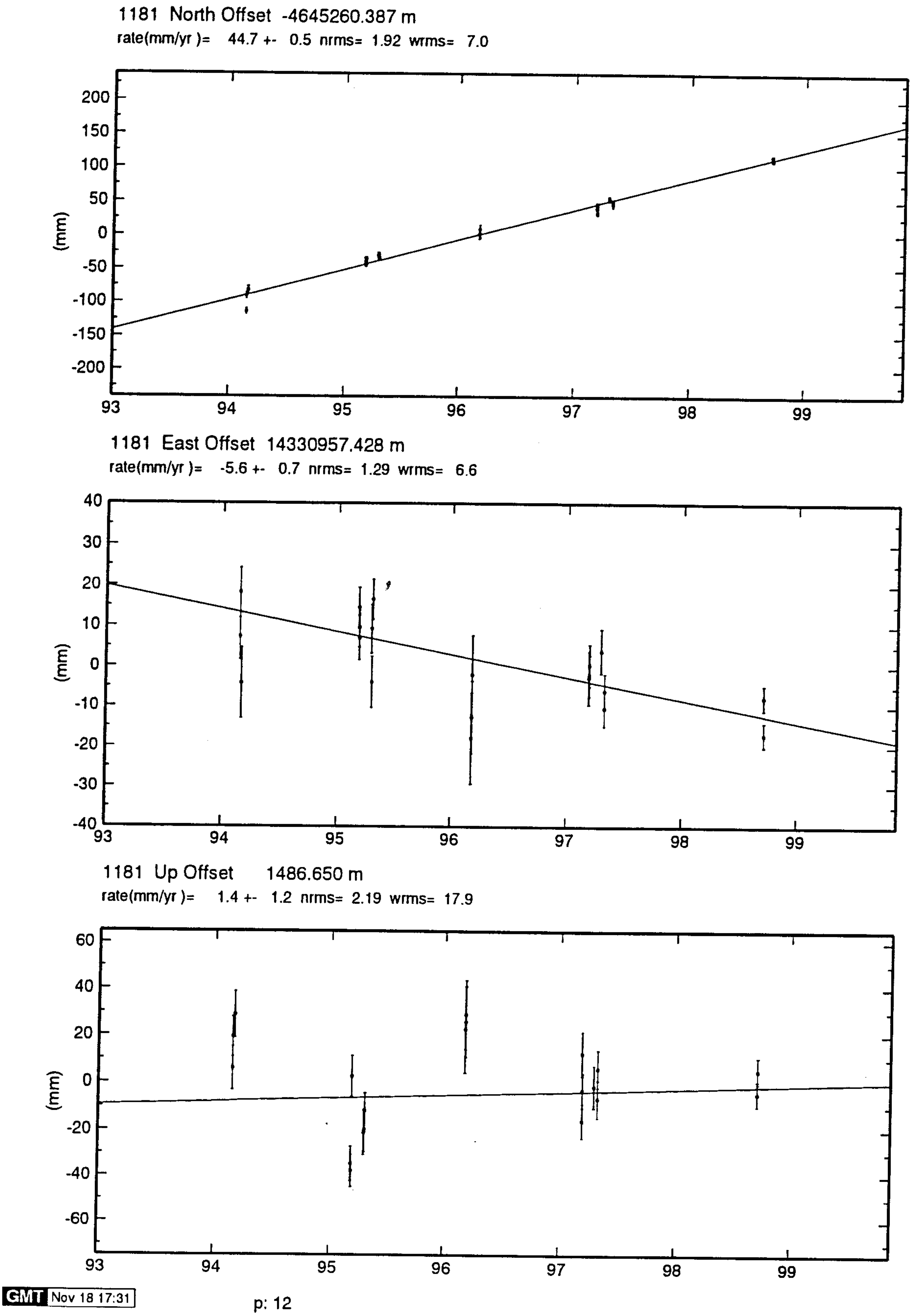


Figure A.5: Stochastic panels for 1181

A.6 1215

Table A.11: Coordinates of 1215 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1215	-4794050.7239	364491.7827	-4177890.1677

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1215	S41 10 48.51754	E175 39 7.79539	590.8790

Table A.12: Coordinates of 1215 in ITRF96 at solution epoch and the Uncorrelated time

```
 289. 1215_GPS X coordinate  (m)          -4794050.7739      0.2307       0.0021
 290. 1215_GPS Y coordinate  (m)            364491.8508     -0.0274       0.0014
 291. 1215_GPS Z coordinate  (m)          -4177890.1176      0.0947       0.0018
 292. 1215_GPS X rate        (m/yr)             -0.0225      0.0697       0.0008
 293. 1215_GPS Y rate        (m/yr)              0.0306     -0.0066       0.0005
 294. 1215_GPS Z rate        (m/yr)              0.0225      0.0288       0.0007
 Postion of 1215_GPS referred to 1996.7499  XYZ offsets   -1.9891  -1.9139  -2.0239 years
Loc.  1215_GPS X uncorr pos. (m)          -4794050.7295      0.0929       0.0013
Loc.  1215_GPS Y uncorr pos. (m)            364491.7903     -0.0144       0.0009
Loc.  1215_GPS Z uncorr pos. (m)          -4177890.1621      0.0378       0.0011
Unc. 1215_GPS -4794050.7295   364491.7903 -4177890.1621 -0.0225  0.0306  0.0225 1996.750
                                                       0.0013  0.0009  0.0011
Loc.  1215_GPS N coordinate  (m)          -4584152.4601     -0.0816       0.0009
Loc.  1215_GPS E coordinate  (m)          14716498.3082      0.0099       0.0014
Loc.  1215_GPS U coordinate  (m)               590.7998     -0.2370       0.0026
     NE,NU,EU position correlations         0.0320       0.0878      -0.0849
Loc.  1215_GPS N rate        (m/yr)              0.0332     -0.0244       0.0003
Loc.  1215_GPS E rate        (m/yr)             -0.0288      0.0013       0.0005
Loc.  1215_GPS U rate        (m/yr)              0.0038     -0.0717       0.0010
     NE,NU,EU rate correlations             0.0266       0.1141      -0.0814
```

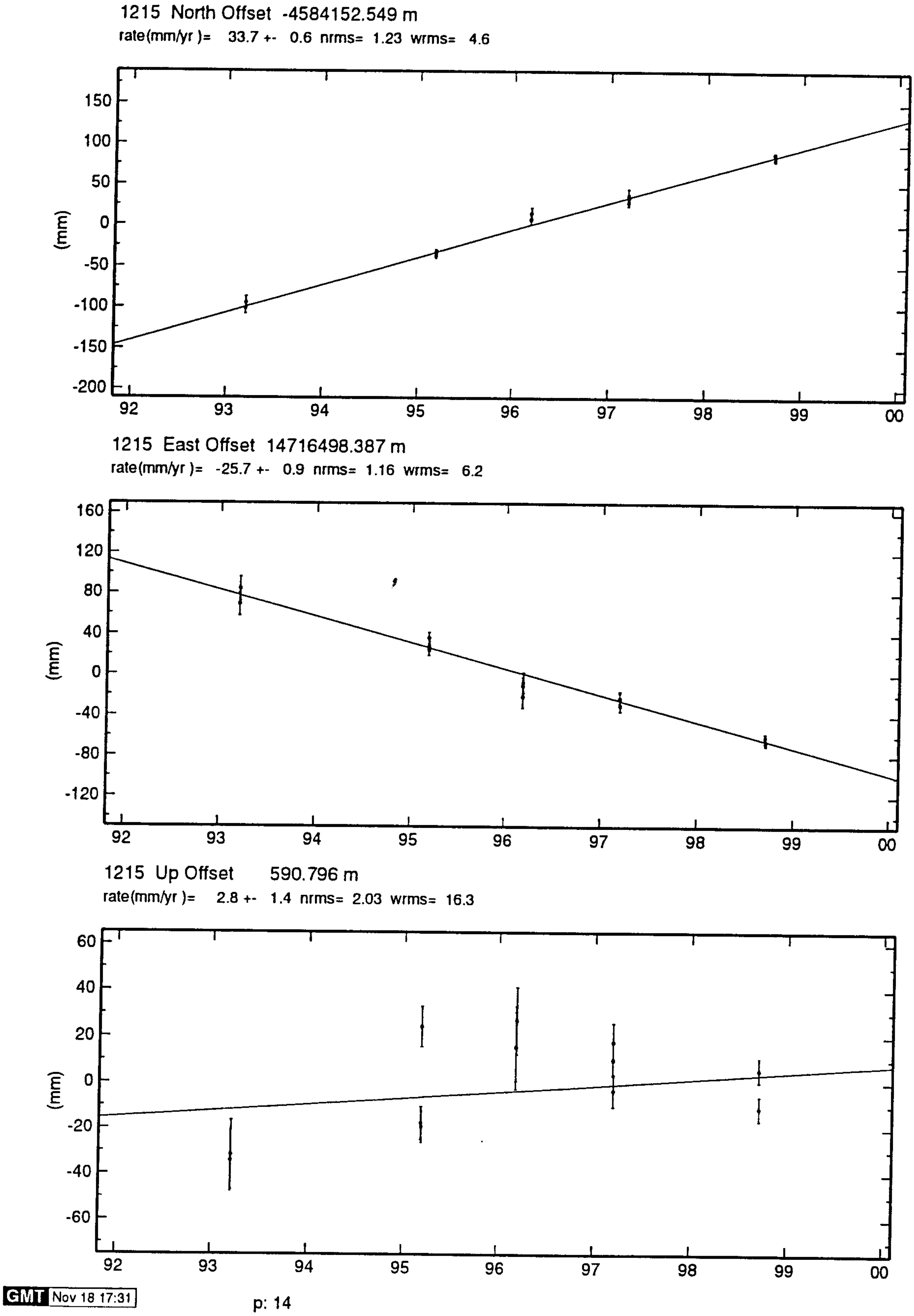


Figure A.6: Stochastic panels for 1215

A.7 1231

Table A.13: Coordinates of 1231 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1231	-4860522.6007	383529.0690	-4098473.4963

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
1231	S40	14	24.72009	E175	29	17.92451	143.6986

Table A.14: Coordinates of 1231 in ITRF96 at solution epoch and the Uncorrelated time

```
 301. 1231_GPS X coordinate  (m)          -4860522.6434       0.0403        0.0022
 302. 1231_GPS Y coordinate  (m)            383529.0960       0.0058        0.0014
 303. 1231_GPS Z coordinate  (m)          -4098473.4383       0.0217        0.0018
 304. 1231_GPS X rate        (m/yr)             -0.0192       0.0004        0.0009
 305. 1231_GPS Y rate        (m/yr)              0.0121       0.0041        0.0005
 306. 1231_GPS Z rate        (m/yr)              0.0261      -0.0008        0.0007
 Postion of 1231_GPS referred to 1996.7991  XYZ offsets   -1.9332  -1.8777  -1.9684 years
Loc.  1231_GPS X uncorr pos. (m)          -4860522.6064       0.0396        0.0013
Loc.  1231_GPS Y uncorr pos. (m)            383529.0726      -0.0022        0.0009
Loc.  1231_GPS Z uncorr pos. (m)          -4098473.4885       0.0233        0.0011
Unc. 1231_GPS -4860522.6064   383529.0726 -4098473.4885 -0.0192  0.0121  0.0261 1996.799
                                                         0.0013  0.0009  0.0011
Loc.  1231_GPS N coordinate  (m)          -4479518.3976      -0.0091        0.0009
Loc.  1231_GPS E coordinate  (m)          14912367.0155      -0.0089        0.0014
Loc.  1231_GPS U coordinate  (m)               143.6059      -0.0443        0.0027
      NE,NU,EU position correlations       0.0417       0.0880       -0.0975
Loc.  1231_GPS N rate        (m/yr)              0.0329      -0.0007        0.0003
Loc.  1231_GPS E rate        (m/yr)             -0.0106      -0.0041        0.0005
Loc.  1231_GPS U rate        (m/yr)             -0.0015       0.0005        0.0011
      NE,NU,EU rate correlations           0.0286       0.1162       -0.0892
```

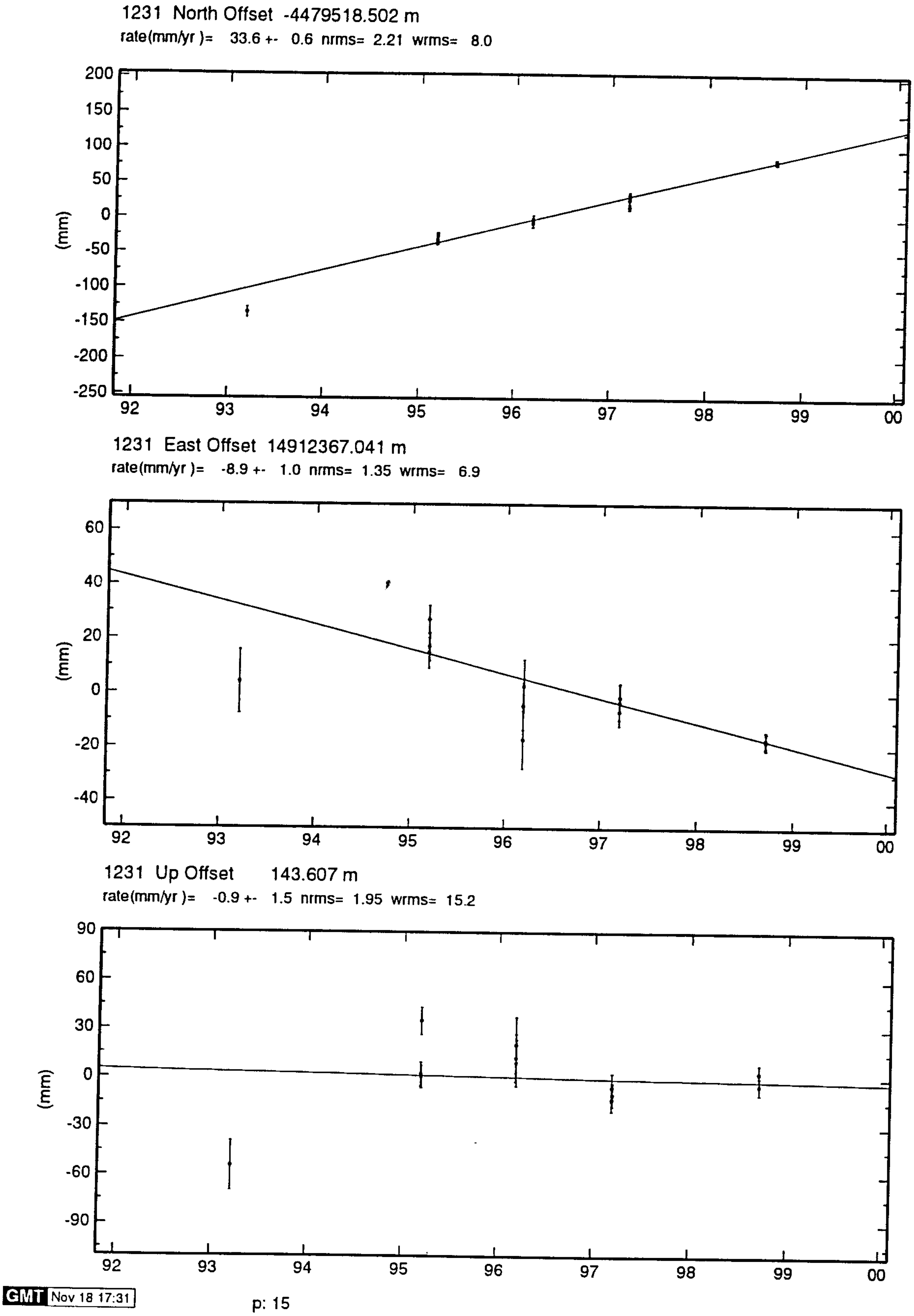


Figure A.7: Stochastic panels for 1231

A.8 1259

Table A.15: Coordinates of 1259 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1259	-4929040.0365	498221.5794	-4004033.1713

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1259	S39 8 2.39544	E174 13 41.56772	262.8459

Table A.16: Coordinates of 1259 in ITRF96 at solution epoch and the Uncorrelated time

```
379. 1259_GPS X coordinate  (m)          -4929040.0942      0.0801      0.0020
380. 1259_GPS Y coordinate  (m)            498221.5738     -0.0010      0.0013
381. 1259_GPS Z coordinate  (m)          -4004033.1015      0.0316      0.0016
382. 1259_GPS X rate        (m/yr)             -0.0259      0.0153      0.0007
383. 1259_GPS Y rate        (m/yr)             -0.0025      0.0028      0.0005
384. 1259_GPS Z rate        (m/yr)              0.0313      0.0037      0.0006
Postion of 1259_GPS referred to 1996.5530  XYZ offsets  -2.2205  -2.0740  -2.2231 years
Loc. 1259_GPS X uncorr pos. (m)          -4929040.0379      0.0469      0.0012
Loc. 1259_GPS Y uncorr pos. (m)            498221.5793     -0.0071      0.0009
Loc. 1259_GPS Z uncorr pos. (m)          -4004033.1696      0.0235      0.0010
Unc. 1259_GPS -4929040.0379  498221.5793 -4004033.1696 -0.0259 -0.0025  0.0313 1996.553
                                                  0.0012  0.0009  0.0010
Loc. 1259_GPS N coordinate  (m)          -4356376.9626     -0.0259      0.0008
Loc. 1259_GPS E coordinate  (m)          15044320.6802     -0.0070      0.0013
Loc. 1259_GPS U coordinate  (m)               263.0414     -0.0819      0.0024
     NE,NU,EU position correlations        0.0593       0.0709      -0.1087
Loc. 1259_GPS N rate        (m/yr)              0.0404     -0.0065      0.0003
Loc. 1259_GPS E rate        (m/yr)              0.0051     -0.0043      0.0005
Loc. 1259_GPS U rate        (m/yr)              0.0000     -0.0139      0.0009
     NE,NU,EU rate correlations            0.0392       0.0832      -0.1539
```

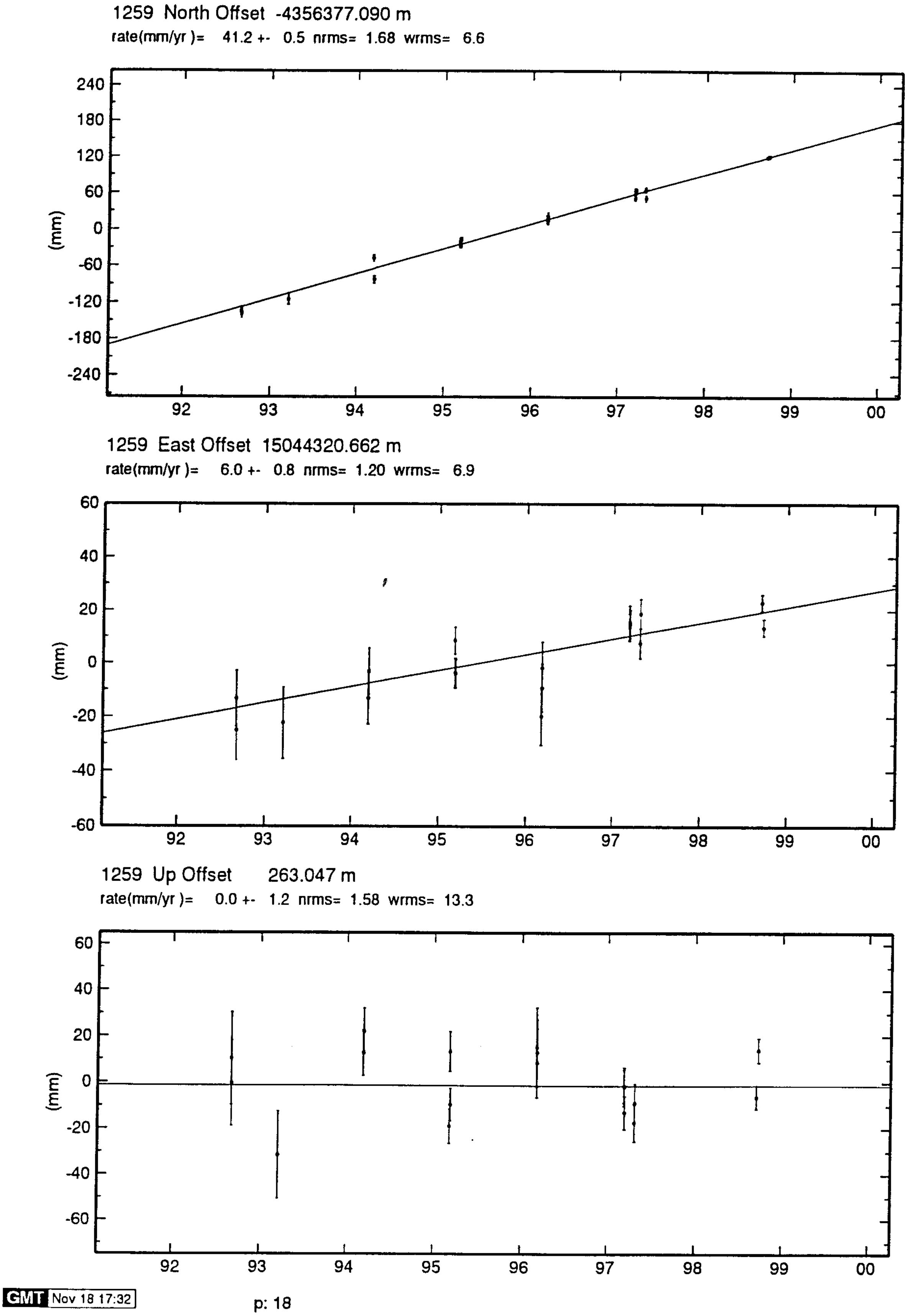


Figure A.8: Stochastic panels for 1259

A.9 1273

Table A.17: Coordinates of 1273 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1273	-4989460.4509	191252.5588	-3955756.5268

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
1273	S38	34	30.54887	E177	48	17.46848	323.3737

Table A.18: Coordinates of 1273 in ITRF96 at solution epoch and the Uncorrelated time

```
 259. 1273_GPS X coordinate  (m)          -4989460.4841       0.0193        0.0022
 260. 1273_GPS Y coordinate  (m)            191252.5461      -0.0203        0.0014
 261. 1273_GPS Z coordinate  (m)          -3955756.4928      -0.0357        0.0018
 262. 1273_GPS X rate        (m/yr)             -0.0149      -0.0061        0.0009
 263. 1273_GPS Y rate        (m/yr)             -0.0057      -0.0024        0.0006
 264. 1273_GPS Z rate        (m/yr)              0.0153      -0.0186        0.0007
 Postion of 1273_GPS referred to 1996.7757  XYZ offsets   -1.9659  -1.8827  -2.0008 years
Loc.  1273_GPS X uncorr pos. (m)          -4989460.4550       0.0312        0.0014
Loc.  1273_GPS Y uncorr pos. (m)            191252.5572      -0.0156        0.0009
Loc.  1273_GPS Z uncorr pos. (m)          -3955756.5226       0.0006        0.0011
Unc. 1273_GPS -4989460.4550   191252.5572 -3955756.5226 -0.0149 -0.0057  0.0153 1996.776
                                                       0.0014  0.0009  0.0011
Loc.  1273_GPS N coordinate  (m)          -4294166.3247      -0.0404        0.0009
Loc.  1273_GPS E coordinate  (m)          15474222.5779       0.0196        0.0014
Loc.  1273_GPS U coordinate  (m)               323.4113       0.0066        0.0027
     NE,NU,EU position correlations         0.0448       0.0663       -0.0807
Loc.  1273_GPS N rate        (m/yr)              0.0211      -0.0108        0.0003
Loc.  1273_GPS E rate        (m/yr)              0.0063       0.0027        0.0005
Loc.  1273_GPS U rate        (m/yr)              0.0019       0.0163        0.0011
     NE,NU,EU rate correlations             0.0426       0.0927       -0.0778
```

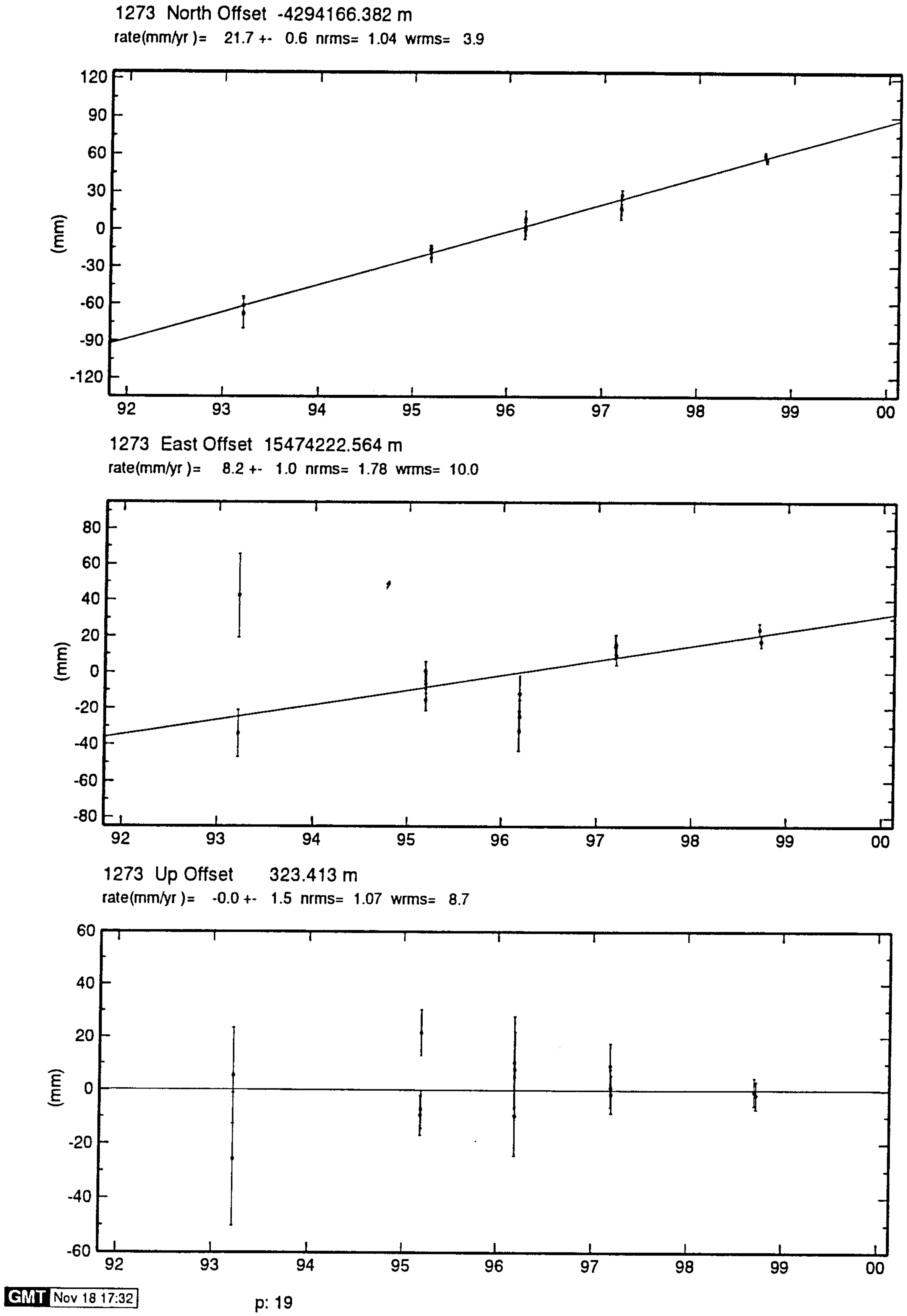


Figure A.9: Stochastic panels for 1273

A.10 1305

Table A.19: Coordinates of 1305 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1305	-5042731.0363	140230.6367	-3890300.2647

	Ellipsoidal Coordinates Latitude			Longitude			Height
	Deg	Mn	Sec	Deg	Mn	Sec	Meters
1305	S37	49	28.35529	E178	24	25.56910	360.5153

Table A.20: Coordinates of 1305 in ITRF96 at solution epoch and the Uncorrelated time

```
 253. 1305_GPS X coordinate  (m)         -5042731.0583       0.0183       0.0022
 254. 1305_GPS Y coordinate  (m)           140230.6022       0.0556       0.0014
 255. 1305_GPS Z coordinate  (m)         -3890300.2362      -0.0417       0.0018
 256. 1305_GPS X rate       (m/yr)             -0.0099      -0.0070       0.0009
 257. 1305_GPS Y rate       (m/yr)             -0.0155       0.0200       0.0006
 258. 1305_GPS Z rate       (m/yr)              0.0128      -0.0206       0.0007
 Postion of 1305_GPS referred to 1996.7490  XYZ offsets   -1.9794  -1.9261  -2.0240 years
Loc.  1305_GPS X uncorr pos. (m)         -5042731.0388       0.0321       0.0014
Loc.  1305_GPS Y uncorr pos. (m)           140230.6328       0.0161       0.0009
Loc.  1305_GPS Z uncorr pos. (m)         -3890300.2615      -0.0010       0.0011
Unc. 1305_GPS -5042731.0388   140230.6328 -3890300.2615 -0.0099 -0.0155  0.0128 1996.749
                                                       0.0014  0.0009  0.0011
Loc.  1305_GPS N coordinate  (m)         -4210608.7668      -0.0432       0.0009
Loc.  1305_GPS E coordinate  (m)         15687522.7142      -0.0561       0.0014
Loc.  1305_GPS U coordinate  (m)              360.4531       0.0123       0.0027
     NE,NU,EU position correlations      0.0393        0.0585       -0.0764
Loc.  1305_GPS N rate         (m/yr)            0.0159      -0.0116       0.0003
Loc.  1305_GPS E rate         (m/yr)            0.0158      -0.0198       0.0006
Loc.  1305_GPS U rate         (m/yr)           -0.0004       0.0186       0.0011
     NE,NU,EU rate correlations          0.0408        0.0924       -0.0737
```

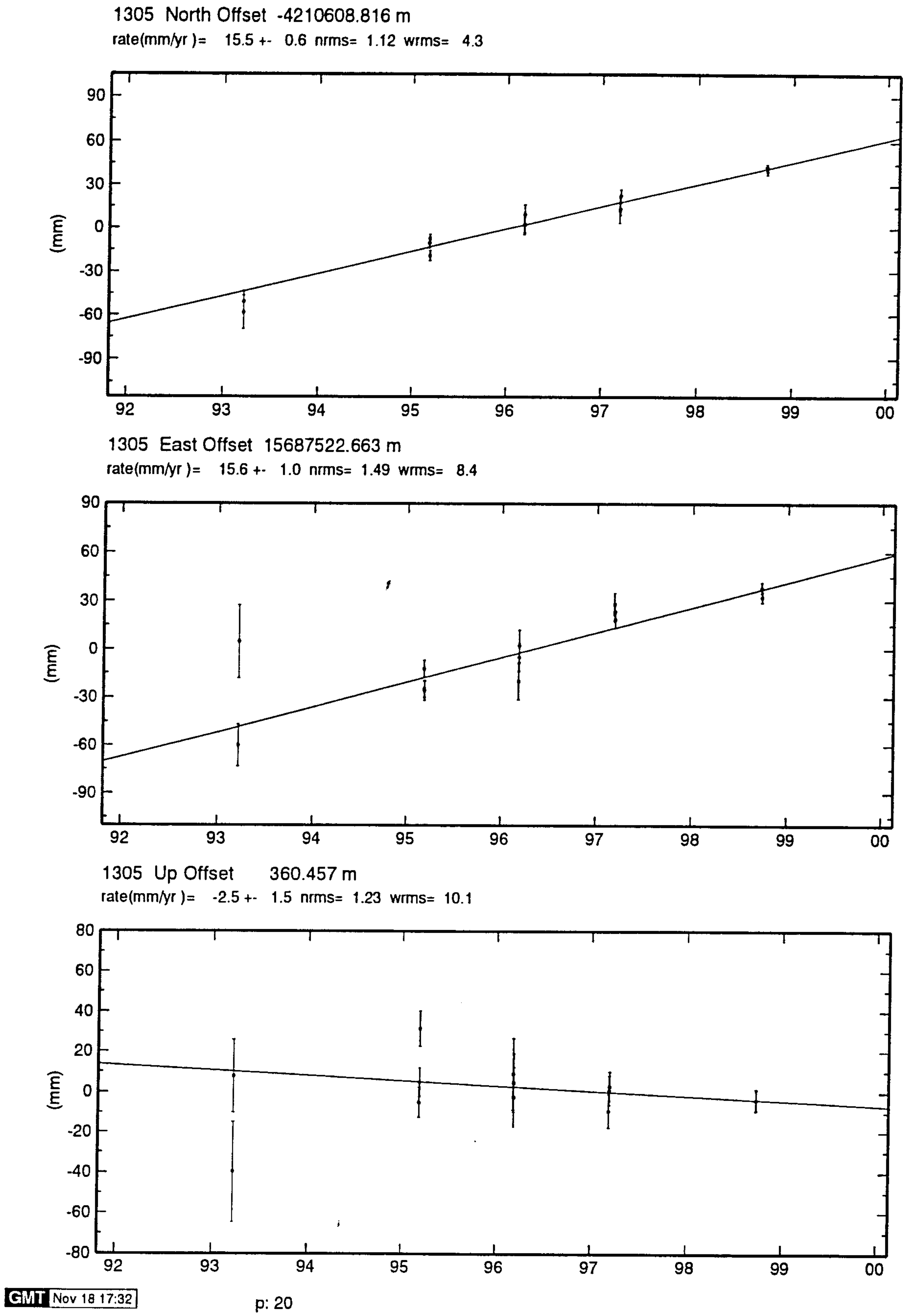


Figure A.10: Stochastic panels for 1305

A.11 1314

Table A.21: Coordinates of 1314 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1314	-5039298.7570	311182.2840	-3884430.0717

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1314	S37 45 34.08169	E176 27 59.07232	95.6869

Table A.22: Coordinates of 1314 in ITRF96 at solution epoch and the Uncorrelated time

```
 271. 1314_GPS X coordinate  (m)           -5039298.7996       0.0167        0.0021
 272. 1314_GPS Y coordinate  (m)             311182.2706       0.0443        0.0014
 273. 1314_GPS Z coordinate  (m)           -3884429.9962      -0.0339        0.0016
 274. 1314_GPS X rate        (m/yr)               -0.0192     -0.0057        0.0008
 275. 1314_GPS Y rate        (m/yr)               -0.0060      0.0171        0.0005
 276. 1314_GPS Z rate        (m/yr)                0.0339     -0.0175        0.0006
 Postion of 1314_GPS referred to 1996.6944  XYZ offsets   -2.0467  -1.9639  -2.0829 years
Loc.  1314_GPS X uncorr pos. (m)           -5039298.7607       0.0282        0.0013
Loc.  1314_GPS Y uncorr pos. (m)             311182.2828       0.0095        0.0009
Loc.  1314_GPS Z uncorr pos. (m)           -3884430.0651       0.0015        0.0010
Unc. 1314_GPS -5039298.7607   311182.2828 -3884430.0651 -0.0192 -0.0060  0.0339 1996.694
                                                        0.0013  0.0009  0.0010
Loc.  1314_GPS N coordinate  (m)           -4203364.6211      -0.0354        0.0009
Loc.  1314_GPS E coordinate  (m)           15530718.7488      -0.0452        0.0014
Loc.  1314_GPS U coordinate  (m)                 95.7139       0.0097        0.0025
     NE,NU,EU position correlations          0.0464       0.0596       -0.0984
Loc.  1314_GPS N rate        (m/yr)               0.0383      -0.0097        0.0003
Loc.  1314_GPS E rate        (m/yr)               0.0071      -0.0167        0.0005
Loc.  1314_GPS U rate        (m/yr)              -0.0059       0.0160        0.0010
     NE,NU,EU rate correlations              0.0390       0.0892       -0.0971
```

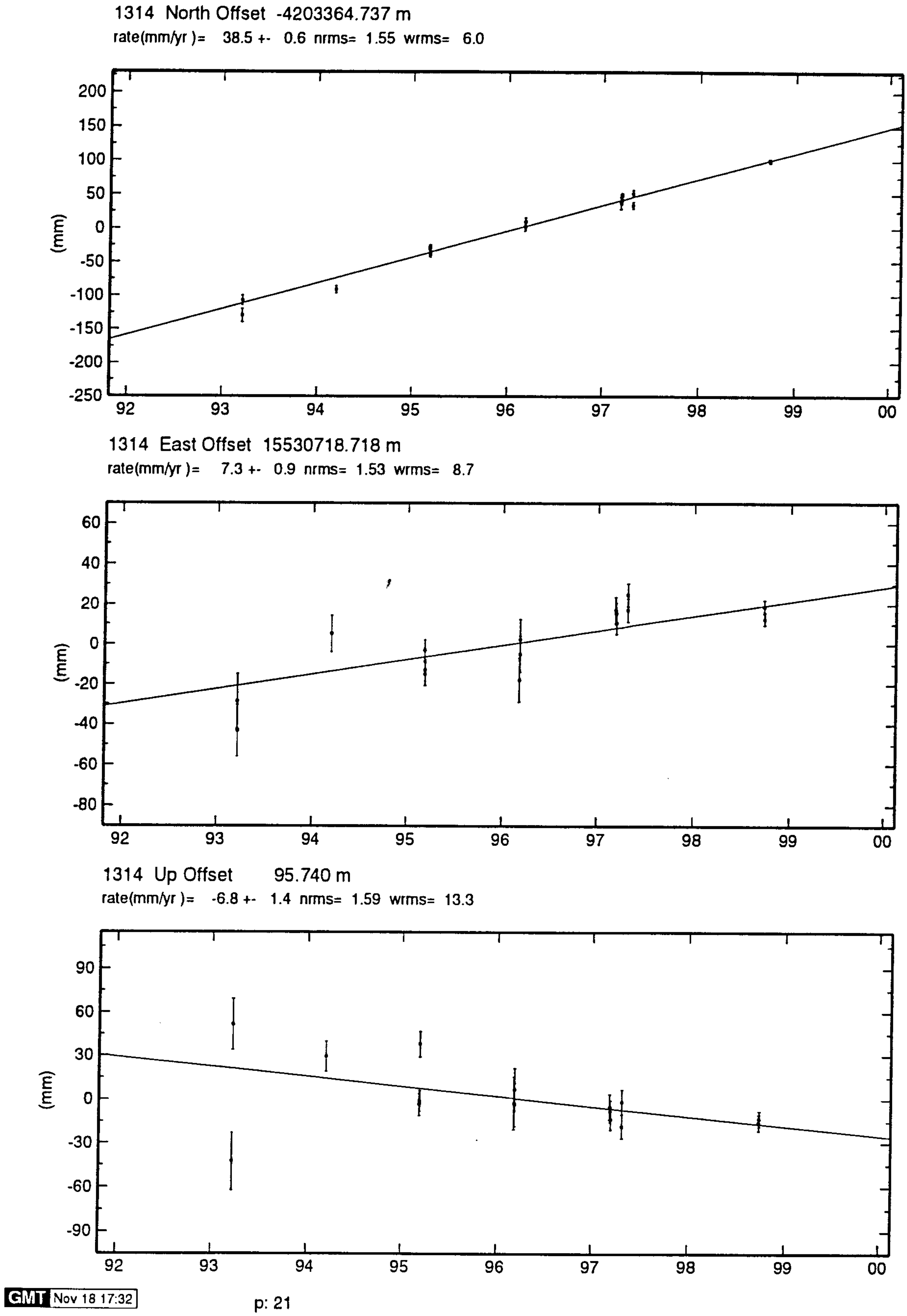


Figure A.11: Stochastic panels for 1314

A.12 1344

Table A.23: Coordinates of 1344 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Cartesian Coordinates Y	Cartesian Coordinates Z
1344	-5128814.1647	401970.9159	-3758286.4184

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1344	S36 19 59.00175	E175 31 6.97077	437.9782

Table A.24: Coordinates of 1344 in ITRF96 at solution epoch and the Uncorrelated time

```
 295. 1344_GPS X coordinate  (m)         -5128814.2298       0.0535       0.0023
 296. 1344_GPS Y coordinate  (m)           401970.9070       0.0148       0.0014
 297. 1344_GPS Z coordinate  (m)         -3758286.3554       0.0221       0.0017
 298. 1344_GPS X rate        (m/yr)            -0.0293       0.0040       0.0009
 299. 1344_GPS Y rate        (m/yr)            -0.0040       0.0080       0.0006
 300. 1344_GPS Z rate        (m/yr)             0.0283      -0.0008       0.0007
 Postion of 1344_GPS referred to 1996.8141  XYZ offsets   -1.9194  -1.8751  -1.9396 years
Loc.  1344_GPS X uncorr pos. (m)         -5128814.1739       0.0457       0.0014
Loc.  1344_GPS Y uncorr pos. (m)           401970.9146      -0.0006       0.0009
Loc.  1344_GPS Z uncorr pos. (m)         -3758286.4095       0.0235       0.0011
Unc. 1344_GPS -5128814.1739  401970.9146 -3758286.4095 -0.0293 -0.0040  0.0283 1996.814
                                                       0.0014  0.0009  0.0011
Loc.  1344_GPS N coordinate  (m)         -4044577.2419      -0.0131       0.0009
Loc.  1344_GPS E coordinate  (m)         15739810.4748      -0.0189       0.0014
Loc.  1344_GPS U coordinate  (m)              438.0169      -0.0551       0.0027
     NE,NU,EU position correlations       0.0494       0.0424      -0.0929
Loc.  1344_GPS N rate        (m/yr)             0.0399      -0.0026       0.0003
Loc.  1344_GPS E rate        (m/yr)             0.0062      -0.0083       0.0006
Loc.  1344_GPS U rate        (m/yr)             0.0065      -0.0023       0.0011
     NE,NU,EU rate correlations           0.0560       0.0557      -0.1029
```

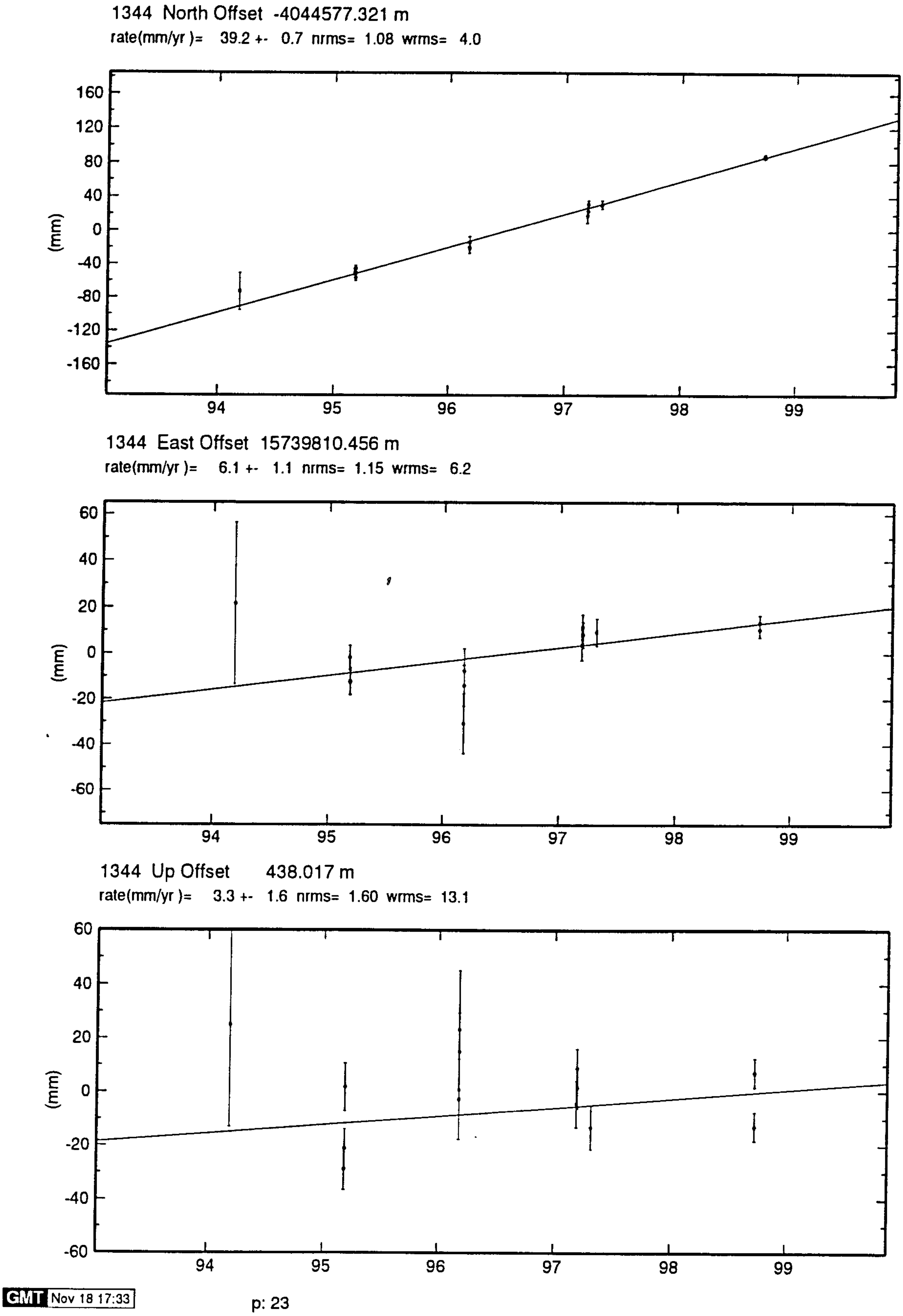


Figure A.12: Stochastic panels for 1344

A.13 1361

Table A.25: Coordinates of 1361 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1361	-5138072.4076	560948.4993	-3724886.3265

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
1361	S35	57	43.58496	E173	46	9.89657	164.8335

Table A.26: Coordinates of 1361 in ITRF96 at solution epoch and the Uncorrelated time

```
 391. 1361_GPS X coordinate  (m)          -5138072.4636       0.0377        0.0023
 392. 1361_GPS Y coordinate  (m)            560948.4880       0.0302        0.0014
 393. 1361_GPS Z coordinate  (m)          -3724886.2510      -0.0043        0.0017
 394. 1361_GPS X rate        (m/yr)             -0.0252      -0.0001        0.0008
 395. 1361_GPS Y rate        (m/yr)             -0.0051       0.0120        0.0005
 396. 1361_GPS Z rate        (m/yr)              0.0339      -0.0077        0.0006
 Postion of 1361_GPS referred to 1996.6196   XYZ offsets  -2.1521  -2.0151  -2.1507 years
Loc.  1361_GPS X uncorr pos. (m)          -5138072.4106       0.0379        0.0014
Loc.  1361_GPS Y uncorr pos. (m)            560948.4987       0.0049        0.0009
Loc.  1361_GPS Z uncorr pos. (m)          -3724886.3224       0.0119        0.0011
Unc. 1361_GPS -5138072.4106   560948.4987 -3724886.3224 -0.0252 -0.0051  0.0339 1996.620
                                                        0.0014  0.0009  0.0011
Loc.  1361_GPS N coordinate  (m)          -4003283.5273      -0.0235        0.0009
Loc.  1361_GPS E coordinate  (m)          15657118.3780      -0.0341        0.0014
Loc.  1361_GPS U coordinate  (m)               164.9697      -0.0251        0.0027
    NE,NU,EU position correlations           0.0540       0.0428       -0.0966
Loc.  1361_GPS N rate        (m/yr)              0.0418      -0.0054        0.0003
Loc.  1361_GPS E rate        (m/yr)              0.0078      -0.0119        0.0005
Loc.  1361_GPS U rate        (m/yr)             -0.0001       0.0057        0.0010
    NE,NU,EU rate correlations               0.0472       0.0504       -0.1270
```

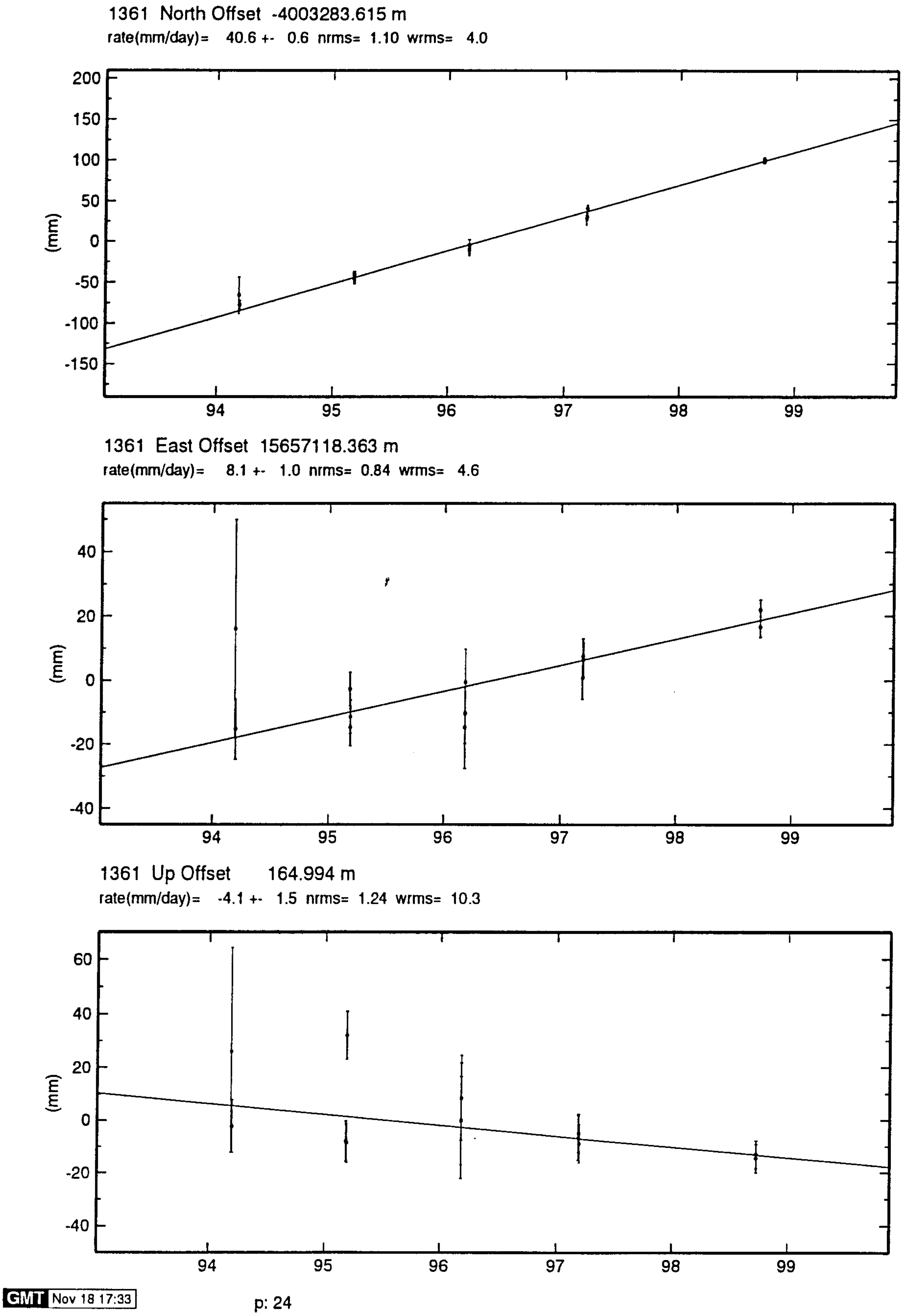


Figure A.13: Stochastic panels for 1361

A.14 1367

Table A.27: Coordinates of 1367 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Cartesian Coordinates Y	Cartesian Coordinates Z
1367	-5167214.3444	496239.2149	-3693852.2014

Station	Ellipsoidal Coordinates Latitude (Deg Mn Sec)	Ellipsoidal Coordinates Longitude (Deg Mn Sec)	Height Meters
1367	S35 37 2.07796	E174 30 51.69225	174.2906

Table A.28: Coordinates of 1367 in ITRF96 at solution epoch and the Uncorrelated time

```
 373. 1367_GPS X coordinate  (m)          -5167214.4325      -0.0047      0.0022
 374. 1367_GPS Y coordinate  (m)            496239.2099       0.0255      0.0014
 375. 1367_GPS Z coordinate  (m)          -3693852.1483      -0.0329      0.0017
 376. 1367_GPS X rate        (m/yr)             -0.0396      -0.0123      0.0008
 377. 1367_GPS Y rate        (m/yr)             -0.0022       0.0119      0.0005
 378. 1367_GPS Z rate        (m/yr)              0.0239      -0.0172      0.0006
 Postion of 1367_GPS referred to 1996.6637  XYZ offsets   -2.0957  -1.9877  -2.1022 years
Loc.  1367_GPS X uncorr pos. (m)          -5167214.3509       0.0206      0.0013
Loc.  1367_GPS Y uncorr pos. (m)            496239.2145       0.0010      0.0009
Loc.  1367_GPS Z uncorr pos. (m)          -3693852.1975       0.0026      0.0010
Unc. 1367_GPS -5167214.3509   496239.2145 -3693852.1975 -0.0396 -0.0022  0.0239 1996.664
                                                         0.0013  0.0009  0.0010
Loc.  1367_GPS N coordinate  (m)          -3964893.5157      -0.0226      0.0009
Loc.  1367_GPS E coordinate  (m)          15792406.6150      -0.0249      0.0014
Loc.  1367_GPS U coordinate  (m)              174.4432       0.0249      0.0026
     NE,NU,EU position correlations         0.0564       0.0390      -0.0938
Loc.  1367_GPS N rate        (m/yr)              0.0422      -0.0062      0.0003
Loc.  1367_GPS E rate        (m/yr)              0.0060      -0.0106      0.0005
Loc.  1367_GPS U rate        (m/yr)              0.0179       0.0209      0.0010
     NE,NU,EU rate correlations             0.0467       0.0510      -0.1146
```

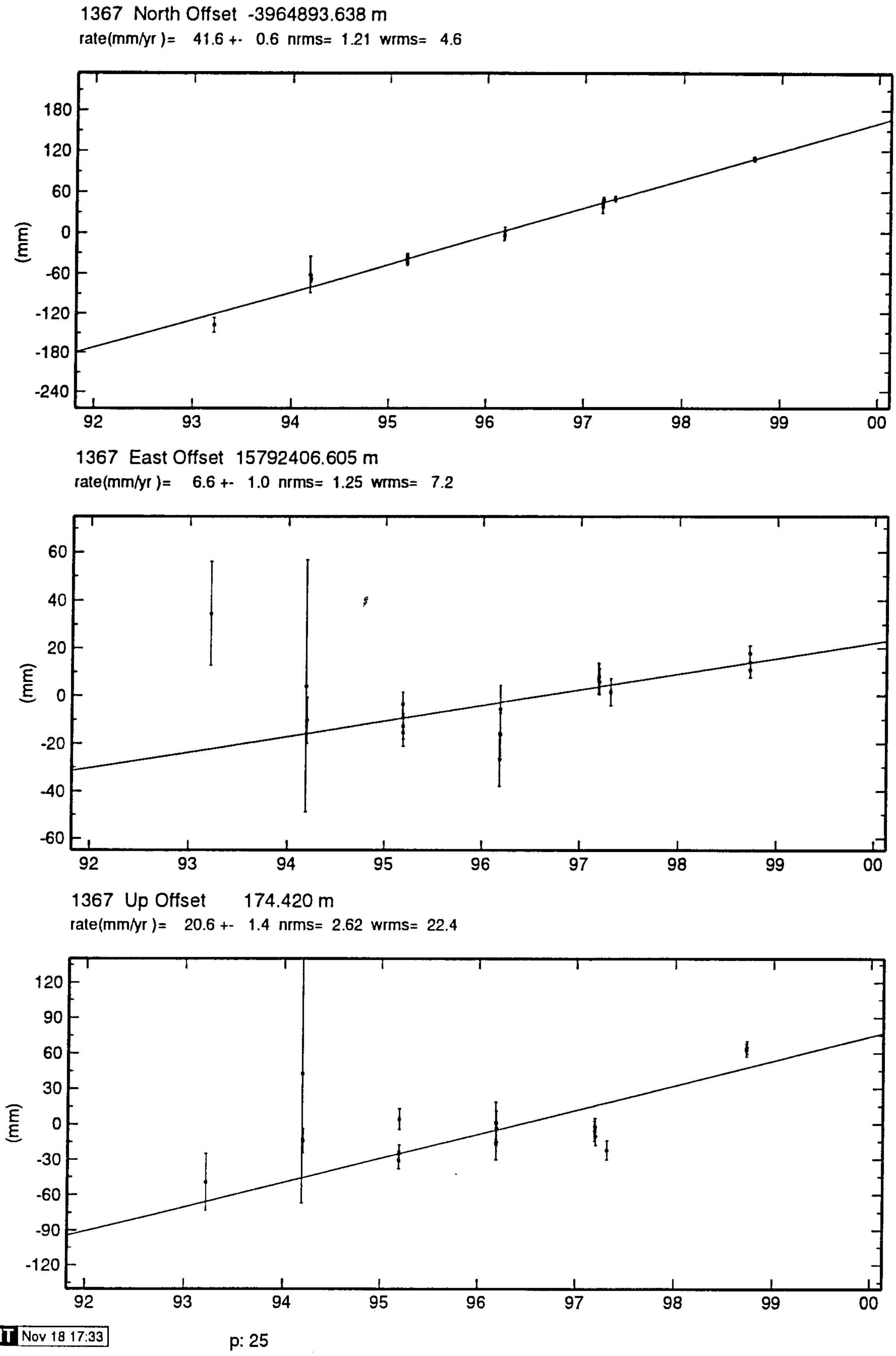


Figure A.14: Stochastic panels for 1367

A.15 1394

Table A.29: Coordinates of 1394 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1394	-5222589.7334	662414.3972	-3589435.3680

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
1394	S34 27 59.71589	E172 46 17.07183	351.0817

Table A.30: Coordinates of 1394 in ITRF96 at solution epoch and the Uncorrelated time

```
 439. 1394_GPS X coordinate  (m)          -5222589.7905        0.0018       0.0023
 440. 1394_GPS Y coordinate  (m)            662414.3826        0.0326       0.0014
 441. 1394_GPS Z coordinate  (m)          -3589435.2875       -0.0315       0.0017
 442. 1394_GPS X rate       (m/yr)              -0.0257       -0.0112       0.0009
 443. 1394_GPS Y rate       (m/yr)              -0.0065        0.0142       0.0005
 444. 1394_GPS Z rate       (m/yr)               0.0362       -0.0165       0.0006
 Postion of 1394_GPS referred to 1996.6642  XYZ offsets   -2.0924  -2.0012  -2.0903 years
Loc.  1394_GPS X uncorr pos. (m)          -5222589.7376        0.0248       0.0014
Loc.  1394_GPS Y uncorr pos. (m)            662414.3961        0.0034       0.0009
Loc.  1394_GPS Z uncorr pos. (m)          -3589435.3621        0.0025       0.0011
Unc. 1394_GPS -5222589.7376   662414.3961 -3589435.3621 -0.0257 -0.0065  0.0362 1996.664
                                                        0.0014  0.0009  0.0011
Loc.  1394_GPS N coordinate  (m)          -3836802.8530       -0.0247       0.0009
Loc.  1394_GPS E coordinate  (m)          15856644.1505       -0.0326       0.0014
Loc.  1394_GPS U coordinate  (m)               351.0491        0.0197       0.0028
      NE,NU,EU position correlations        0.0744        0.0344      -0.0839
Loc.  1394_GPS N rate        (m/yr)              0.0438       -0.0063       0.0003
Loc.  1394_GPS E rate        (m/yr)              0.0097       -0.0127       0.0005
Loc.  1394_GPS U rate        (m/yr)             -0.0002        0.0199       0.0011
      NE,NU,EU rate correlations            0.0629        0.0421      -0.1095
```

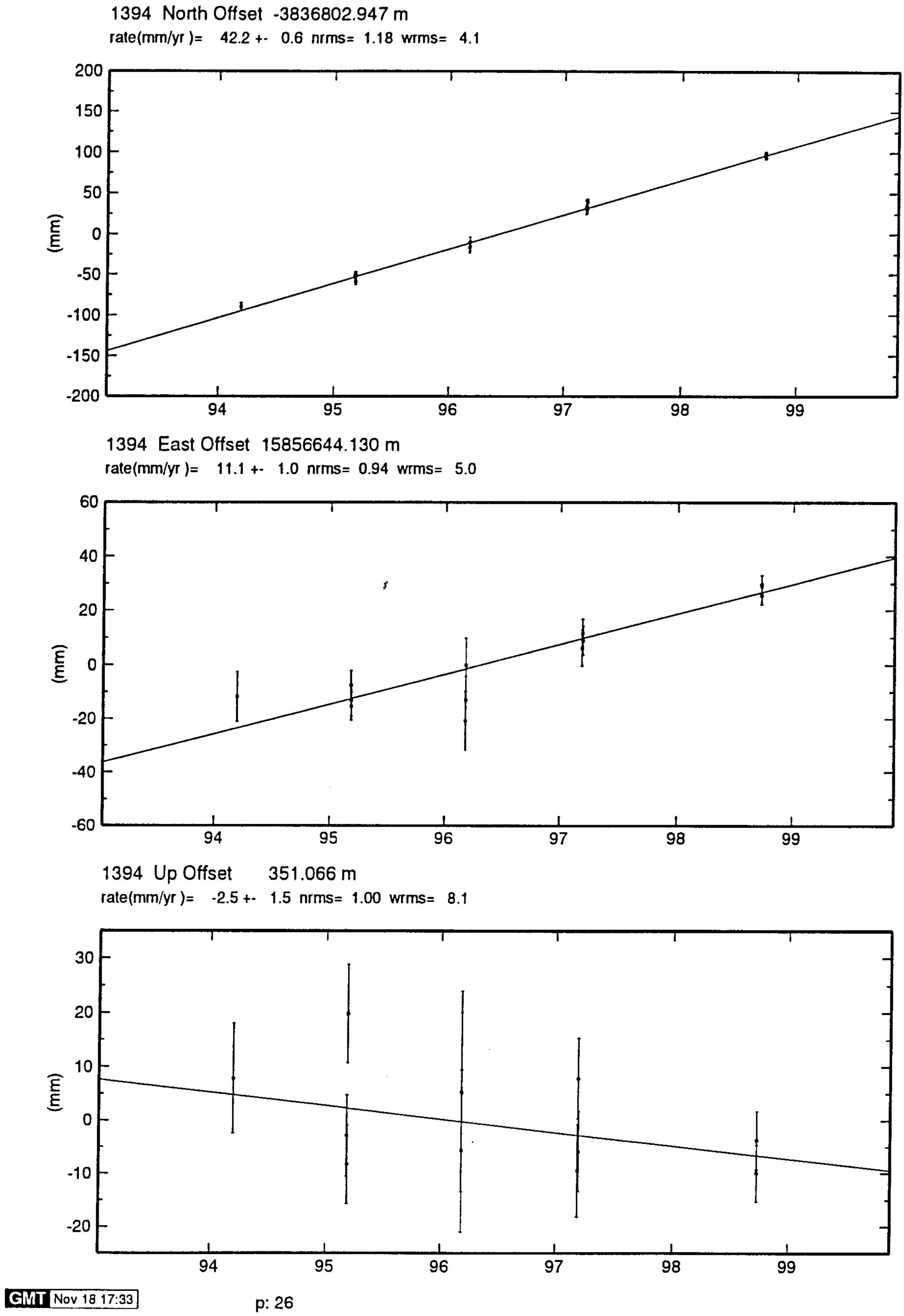


Figure A.15: Stochastic panels for 1394

A.16 1420

Table A.31: Coordinates of 1420 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1420	-4616400.1962	745241.5885	-4324328.2132

Station	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
1420	S42	57	11.69413	E170	49	46.76990	919.3744

Table A.32: Coordinates of 1420 in ITRF96 at solution epoch and the Uncorrelated time

```
475. 1420_GPS X coordinate  (m)          -4616400.2640     0.1603     0.0019
476. 1420_GPS Y coordinate  (m)            745241.6081    -0.0220     0.0013
477. 1420_GPS Z coordinate  (m)          -4324328.1516     0.1460     0.0017
478. 1420_GPS X rate        (m/yr)             -0.0305     0.0385     0.0009
479. 1420_GPS Y rate        (m/yr)              0.0088    -0.0031     0.0006
480. 1420_GPS Z rate        (m/yr)              0.0277     0.0377     0.0008
Postion of 1420_GPS referred to 1997.0018  XYZ offsets  -1.7266  -1.7163  -1.7221 years
Loc.  1420_GPS X uncorr pos. (m)         -4616400.2115     0.0939     0.0012
Loc.  1420_GPS Y uncorr pos. (m)           745241.5929    -0.0166     0.0009
Loc.  1420_GPS Z uncorr pos. (m)         -4324328.1993     0.0810     0.0011
Unc. 1420_GPS -4616400.2115  745241.5929 -4324328.1993 -0.0305  0.0088  0.0277 1997.002
                                                        0.0012  0.0009  0.0011
Loc.  1420_GPS N coordinate  (m)         -4781533.5708    -0.0034     0.0009
Loc.  1420_GPS E coordinate  (m)         13918774.6008    -0.0039     0.0013
Loc.  1420_GPS U coordinate  (m)              919.3158    -0.2178     0.0025
      NE,NU,EU position correlations      0.0483      0.1198      -0.0805
Loc.  1420_GPS N rate        (m/yr)             0.0417     0.0014     0.0003
Loc.  1420_GPS E rate        (m/yr)            -0.0038    -0.0031     0.0006
Loc.  1420_GPS U rate        (m/yr)             0.0042    -0.0539     0.0011
      NE,NU,EU rate correlations          0.0695      0.1230      -0.0440
```

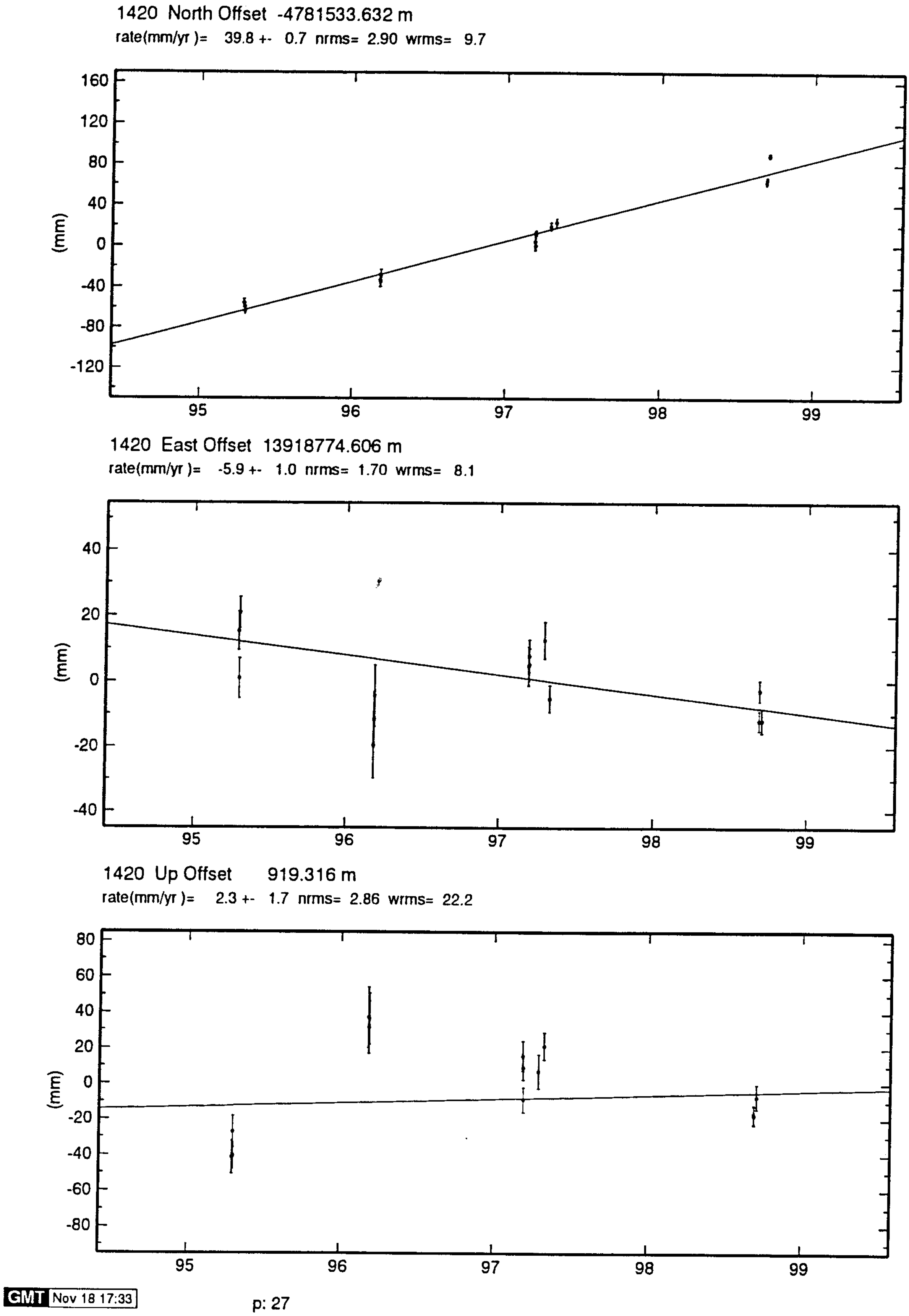


Figure A.16: Stochastic panels for 1420

A.17 1501

Table A.33: Coordinates of 1501 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
1501	-4922647.7706	265115.0502	-4033578.8178

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
1501	S39	28	44.35027	E176	55	2.08506	119.2918

Table A.34: Coordinates of 1501 in ITRF96 at solution epoch and the Uncorrelated time

```
 265. 1501_GPS X coordinate  (m)         -4922647.8024        0.0610        0.0020
 266. 1501_GPS Y coordinate  (m)           265115.0593        0.0045        0.0013
 267. 1501_GPS Z coordinate  (m)         -4033578.7766        0.0090        0.0016
 268. 1501_GPS X rate       (m/yr)             -0.0143        0.0063        0.0008
 269. 1501_GPS Y rate       (m/yr)              0.0041        0.0038        0.0005
 270. 1501_GPS Z rate       (m/yr)              0.0185       -0.0046        0.0006
 Postion of 1501_GPS referred to 1996.7710   XYZ offsets   -1.9669  -1.8938  -2.0029 years
Loc.  1501_GPS X uncorr pos. (m)         -4922647.7745        0.0487        0.0013
Loc.  1501_GPS Y uncorr pos. (m)           265115.0513       -0.0029        0.0009
Loc.  1501_GPS Z uncorr pos. (m)         -4033578.8128        0.0179        0.0010
Unc. 1501_GPS -4922647.7745   265115.0513 -4033578.8128 -0.0143  0.0041  0.0185 1996.771
                                                         0.0013  0.0009  0.0010
Loc.  1501_GPS N coordinate  (m)         -4394780.5624       -0.0316        0.0009
Loc.  1501_GPS E coordinate  (m)         15201035.9960       -0.0078        0.0013
Loc.  1501_GPS U coordinate  (m)              119.2700       -0.0526        0.0024
     NE,NU,EU position correlations       0.0437        0.0756       -0.1143
Loc.  1501_GPS N rate       (m/yr)              0.0235       -0.0074        0.0003
Loc.  1501_GPS E rate       (m/yr)             -0.0033       -0.0041        0.0005
Loc.  1501_GPS U rate       (m/yr)             -0.0006       -0.0018        0.0010
     NE,NU,EU rate correlations           0.0296        0.1056       -0.1324
```

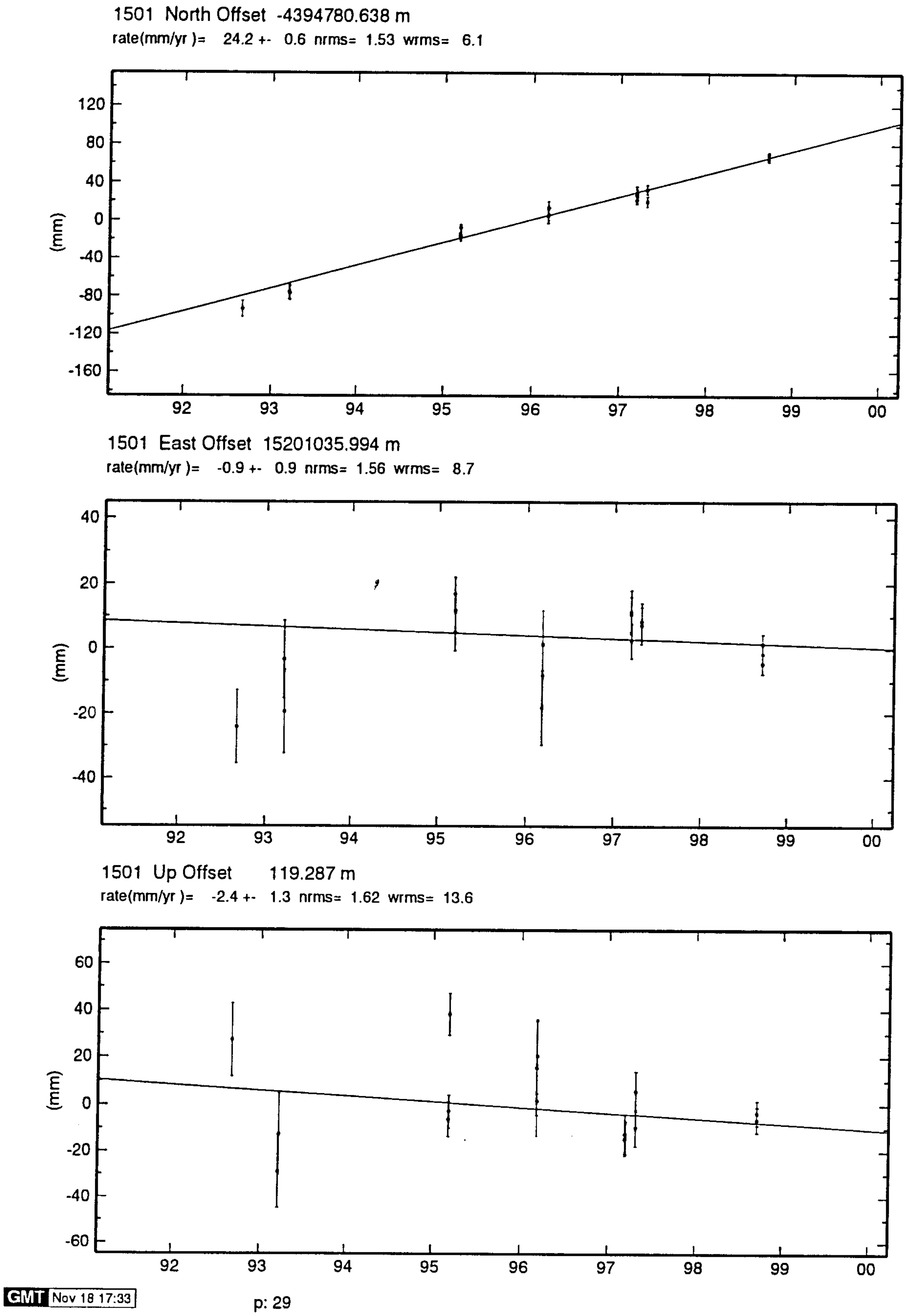


Figure A.17: Stochastic panels for 1501

A.18 2085

Table A.35: Coordinates of 2085 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
2085	-4977955.1164	355512.0203	-3959577.4526

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
2085	S38	36	57.77131	E175	54	54.09655	760.2075

Table A.36: Coordinates of 2085 in ITRF96 at solution epoch and the Uncorrelated time

```
 277. 2085_GPS X coordinate  (m)          -4977955.1528       0.0043       0.0021
 278. 2085_GPS Y coordinate  (m)            355512.0119       0.0118       0.0014
 279. 2085_GPS Z coordinate  (m)          -3959577.3809      -0.0286       0.0017
 280. 2085_GPS X rate       (m/yr)              -0.0164      -0.0120       0.0008
 281. 2085_GPS Y rate       (m/yr)              -0.0038       0.0080       0.0005
 282. 2085_GPS Z rate       (m/yr)               0.0322      -0.0179       0.0006
 Postion of 2085_GPS referred to 1996.5928  XYZ offsets  -2.1815  -2.0109  -2.2058 years
Loc.  2085_GPS X uncorr pos. (m)          -4977955.1179       0.0299       0.0013
Loc.  2085_GPS Y uncorr pos. (m)            355512.0199      -0.0053       0.0009
Loc.  2085_GPS Z uncorr pos. (m)          -3959577.4496       0.0096       0.0011
Unc. 2085_GPS -4977955.1179   355512.0199 -3959577.4496 -0.0164 -0.0038  0.0322 1996.593
                                                        0.0013  0.0009  0.0011
Loc.  2085_GPS N coordinate  (m)          -4298718.7571      -0.0245       0.0009
Loc.  2085_GPS E coordinate  (m)          15301201.3771      -0.0121       0.0013
Loc.  2085_GPS U coordinate  (m)               760.2554       0.0151       0.0026
      NE,NU,EU position correlations        0.0480       0.0625      -0.0967
Loc.  2085_GPS N rate       (m/yr)               0.0352      -0.0062       0.0003
Loc.  2085_GPS E rate       (m/yr)               0.0049      -0.0072       0.0005
Loc.  2085_GPS U rate       (m/yr)              -0.0075       0.0210       0.0009
      NE,NU,EU rate correlations            0.0318       0.0853      -0.1145
```

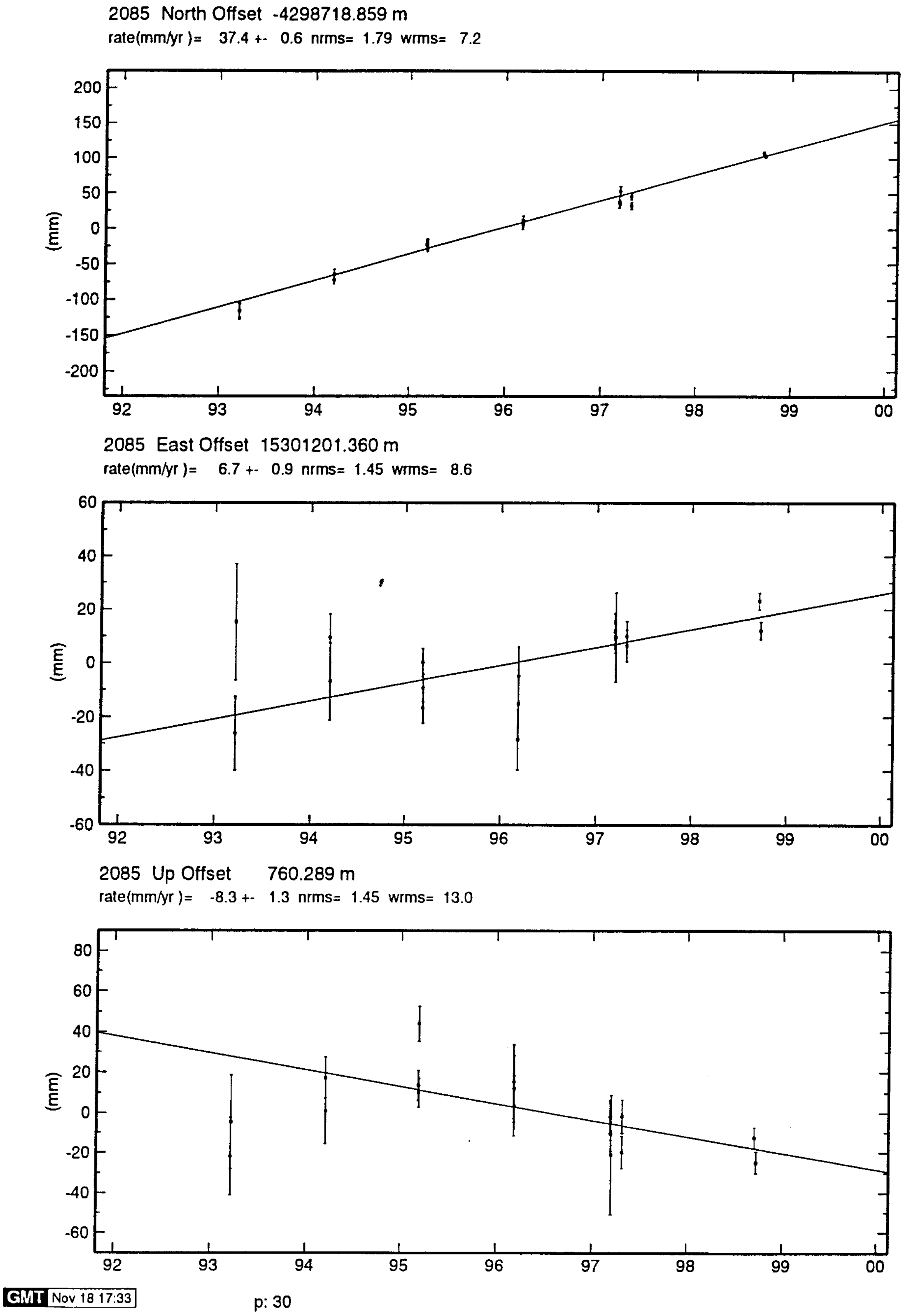


Figure A.18: Stochastic panels for 2085

A.19 5508

Table A.37: Coordinates of 5508 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
5508	-4590826.0493	584593.0086	-4374757.1067

	Ellipsoidal Coordinates Latitude			Longitude			Height
	Deg	Mn	Sec	Deg	Mn	Sec	Meters
5508	S43	34	53.41704	E172	44	34.96763	335.3518

Table A.38: Coordinates of 5508 in ITRF96 at solution epoch and the Uncorrelated time

```
 445. 5508_GPS X coordinate  (m)          -4590826.0954       0.1087        0.0020
 446. 5508_GPS Y coordinate  (m)            584593.0887       0.0142        0.0013
 447. 5508_GPS Z coordinate  (m)          -4374757.0576       0.0992        0.0018
 448. 5508_GPS X rate       (m/yr)              -0.0207       0.0200        0.0007
 449. 5508_GPS Y rate       (m/yr)               0.0359       0.0078        0.0005
 450. 5508_GPS Z rate       (m/yr)               0.0221       0.0198        0.0006
 Postion of 5508_GPS referred to 1996.4658  XYZ offsets   -2.3266  -2.1137  -2.3389 years
Loc.  5508_GPS X uncorr pos. (m)          -4590826.0486       0.0636        0.0011
Loc.  5508_GPS Y uncorr pos. (m)            584593.0074      -0.0035        0.0009
Loc.  5508_GPS Z uncorr pos. (m)          -4374757.1075       0.0545        0.0010
Unc. 5508_GPS -4590826.0486   584593.0074 -4374757.1075 -0.0207  0.0359  0.0221 1996.466
                                                         0.0011  0.0009  0.0010
Loc.  5508_GPS N coordinate  (m)          -4851470.8442      -0.0012        0.0009
Loc.  5508_GPS E coordinate  (m)          13929693.0904      -0.0278        0.0013
Loc.  5508_GPS U coordinate  (m)               335.3613      -0.1451        0.0026
     NE,NU,EU position correlations         0.0292       0.1227       -0.0944
Loc.  5508_GPS N rate        (m/yr)              0.0333       0.0013        0.0003
Loc.  5508_GPS E rate        (m/yr)             -0.0330      -0.0103        0.0005
Loc.  5508_GPS U rate        (m/yr)              0.0030      -0.0272        0.0009
     NE,NU,EU rate correlations             0.0149       0.1331       -0.1227
```

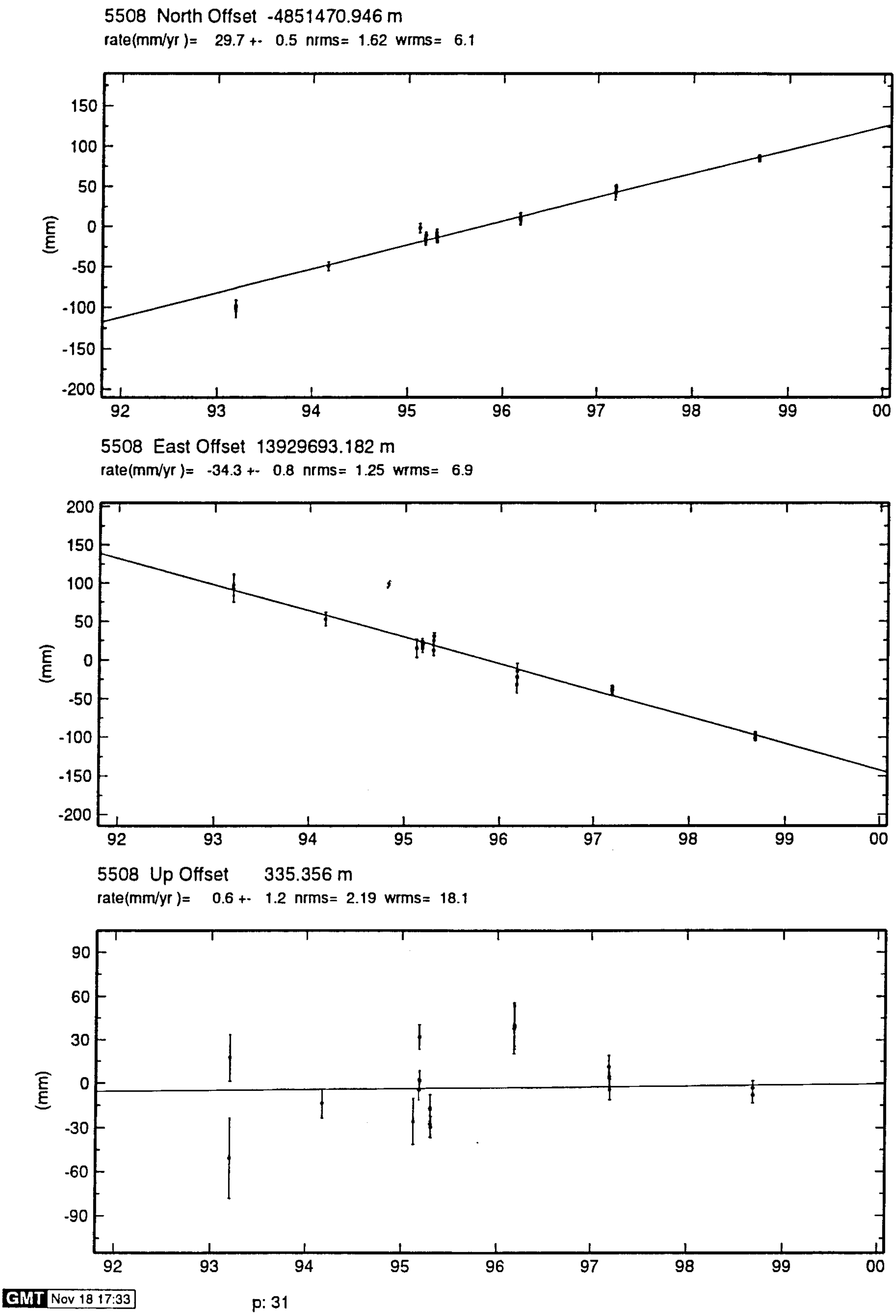


Figure A.19: Stochastic panels for 5508

A.20 5509

Table A.39: Coordinates of 5509 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
5509	-4303267.1299	894811.2916	-4606633.3149

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
5509	S46 32 12.94544	E168 15 12.38486	176.1738

Table A.40: Coordinates of 5509 in ITRF96 at solution epoch and the Uncorrelated time

```
 547. 5509_GPS X coordinate  (m)          -4303267.1724        0.0775        0.0018
 548. 5509_GPS Y coordinate  (m)            894811.3565        0.0008        0.0013
 549. 5509_GPS Z coordinate  (m)          -4606633.2724        0.0542        0.0017
 550. 5509_GPS X rate       (m/yr)              -0.0191        0.0087        0.0006
 551. 5509_GPS Y rate       (m/yr)               0.0292        0.0053        0.0004
 552. 5509_GPS Z rate       (m/yr)               0.0191        0.0014        0.0005
 Postion of 5509_GPS referred to 1996.2196  XYZ offsets   -2.5874  -2.2496  -2.6808 years
Loc.  5509_GPS X uncorr pos. (m)          -4303267.1246        0.0556        0.0010
Loc.  5509_GPS Y uncorr pos. (m)            894811.2834       -0.0124        0.0008
Loc.  5509_GPS Z uncorr pos. (m)          -4606633.3202        0.0507        0.0010
Unc. 5509_GPS -4303267.1246   894811.2834 -4606633.3202 -0.0191  0.0292  0.0191 1996.220
                                                        0.0010  0.0008  0.0010
Loc.  5509_GPS N coordinate  (m)          -5180467.3629       -0.0176        0.0008
Loc.  5509_GPS E coordinate  (m)          12884301.9218       -0.0166        0.0012
Loc.  5509_GPS U coordinate  (m)               176.3494       -0.0914        0.0023
     NE,NU,EU position correlations        0.0202        0.1520        -0.1009
Loc.  5509_GPS N rate        (m/yr)              0.0310       -0.0045        0.0003
Loc.  5509_GPS E rate        (m/yr)             -0.0247       -0.0069        0.0004
Loc.  5509_GPS U rate        (m/yr)              0.0031       -0.0062        0.0007
     NE,NU,EU rate correlations           -0.0087        0.1859        -0.1659
```

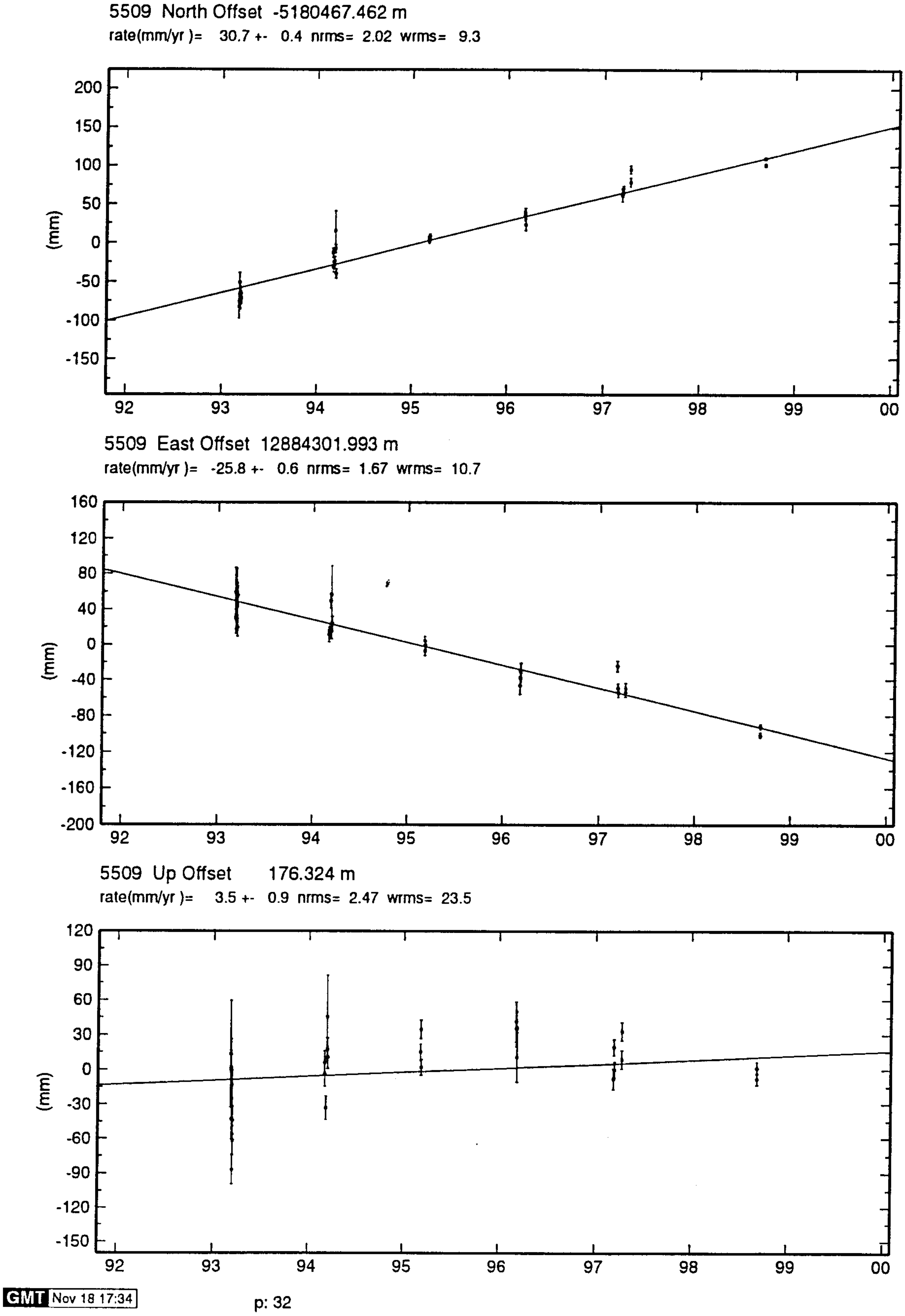


Figure A.20: Stochastic panels for 5509

A.21 6731

Table A.41: Coordinates of 6731 in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
6731	-4521641.7253	878624.0131	-4396964.2932

	Ellipsoidal Coordinates Latitude			Longitude			Height
	Deg	Mn	Sec	Deg	Mn	Sec	Meters
6731	S43	51	38.94908	E169	0	12.92788	14.4595

Table A.42: Coordinates of 6731 in ITRF96 at solution epoch and the Uncorrelated time

```
 523. 6731_GPS X coordinate  (m)          -4521641.7881       0.1150       0.0019
 524. 6731_GPS Y coordinate  (m)            878624.0335      -0.0181       0.0013
 525. 6731_GPS Z coordinate  (m)          -4396964.2283       0.1143       0.0017
 526. 6731_GPS X rate       (m/yr)              -0.0282       0.0223       0.0007
 527. 6731_GPS Y rate       (m/yr)               0.0092      -0.0009       0.0005
 528. 6731_GPS Z rate       (m/yr)               0.0292       0.0245       0.0006
 Postion of 6731_GPS referred to 1996.5701  XYZ offsets  -2.1946  -2.0670  -2.2047 years
Loc.  6731_GPS X uncorr pos. (m)          -4521641.7273       0.0670       0.0011
Loc.  6731_GPS Y uncorr pos. (m)            878624.0137      -0.0161       0.0008
Loc.  6731_GPS Z uncorr pos. (m)          -4396964.2912       0.0615       0.0010
Unc. 6731_GPS -4521641.7273   878624.0137 -4396964.2912 -0.0282  0.0092  0.0292 1996.570
                                                          0.0011  0.0008  0.0010
Loc.  6731_GPS N coordinate  (m)          -4882563.9157       0.0018       0.0008
Loc.  6731_GPS E coordinate  (m)          13565086.2264      -0.0042       0.0013
Loc.  6731_GPS U coordinate  (m)                14.4137      -0.1631       0.0025
      NE,NU,EU position correlations       0.0319       0.1355      -0.0969
Loc.  6731_GPS N rate        (m/yr)              0.0415       0.0024       0.0003
Loc.  6731_GPS E rate        (m/yr)             -0.0036      -0.0034       0.0005
Loc.  6731_GPS U rate        (m/yr)              0.0010      -0.0329       0.0009
      NE,NU,EU rate correlations           0.0177       0.1470      -0.1153
```

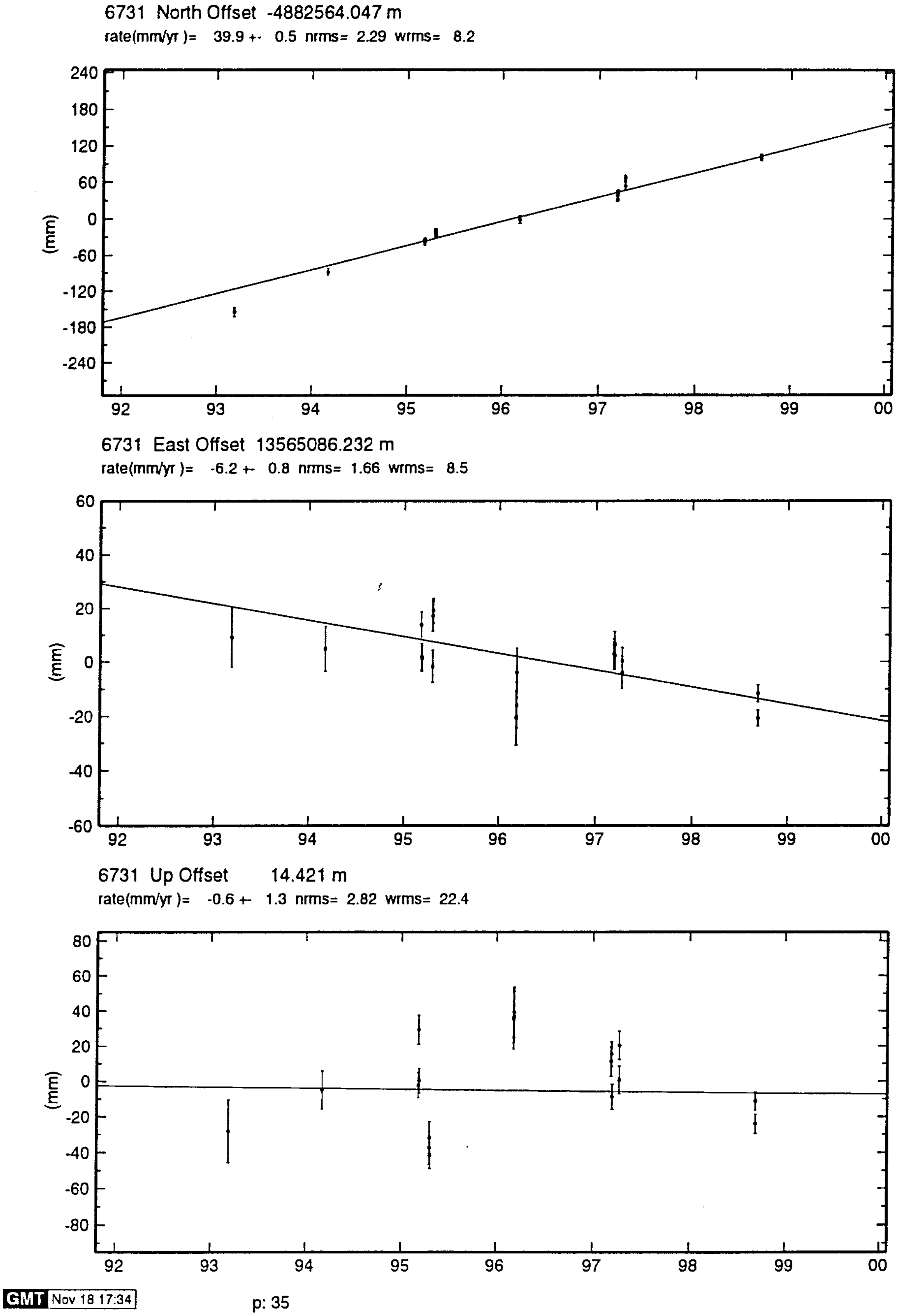


Figure A.21: Stochastic panels for 6731

A.22 A31C

Table A.43: Coordinates of A31C in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
A31C	-4442644.9822	950468.8627	-4461626.4858

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
A31C	S44 40 24.62952	E167 55 26.64030	9.5795

Table A.44: Coordinates of A31C in ITRF96 at solution epoch and the Uncorrelated time

```
 553. A31C_GPS X coordinate  (m)           -4442645.0486      0.2697      0.0021
 554. A31C_GPS Y coordinate  (m)             950468.9196     -0.0725      0.0014
 555. A31C_GPS Z coordinate  (m)           -4461626.4365      0.2454      0.0020
 556. A31C_GPS X rate        (m/yr)              -0.0298      0.0789      0.0010
 557. A31C_GPS Y rate        (m/yr)               0.0256     -0.0207      0.0006
 558. A31C_GPS Z rate        (m/yr)               0.0222      0.0729      0.0009
 Postion of A31C_GPS referred to 1996.9173  XYZ offsets  -1.8007  -1.8212  -1.8028 years
Loc.  A31C_GPS X uncorr pos. (m)           -4442644.9946      0.1270      0.0013
Loc.  A31C_GPS Y uncorr pos. (m)             950468.8734     -0.0350      0.0009
Loc.  A31C_GPS Z uncorr pos. (m)           -4461626.4765      0.1137      0.0012
Unc. A31C_GPS -4442644.9946   950468.8734 -4461626.4765 -0.0298  0.0256  0.0222 1996.917
                                                         0.0013  0.0009  0.0012
Loc.  A31C_GPS N coordinate  (m)           -4973032.0622     -0.0215      0.0009
Loc.  A31C_GPS E coordinate  (m)           13293159.3585      0.0144      0.0014
Loc.  A31C_GPS U coordinate  (m)                  9.5661     -0.3708      0.0028
      NE,NU,EU position correlations         0.0599      0.1542      -0.0855
Loc.  A31C_GPS N rate        (m/yr)               0.0400     -0.0055      0.0003
Loc.  A31C_GPS E rate        (m/yr)              -0.0188      0.0038      0.0006
Loc.  A31C_GPS U rate        (m/yr)               0.0090     -0.1091      0.0013
      NE,NU,EU rate correlations             0.0735      0.1682      -0.0594
```

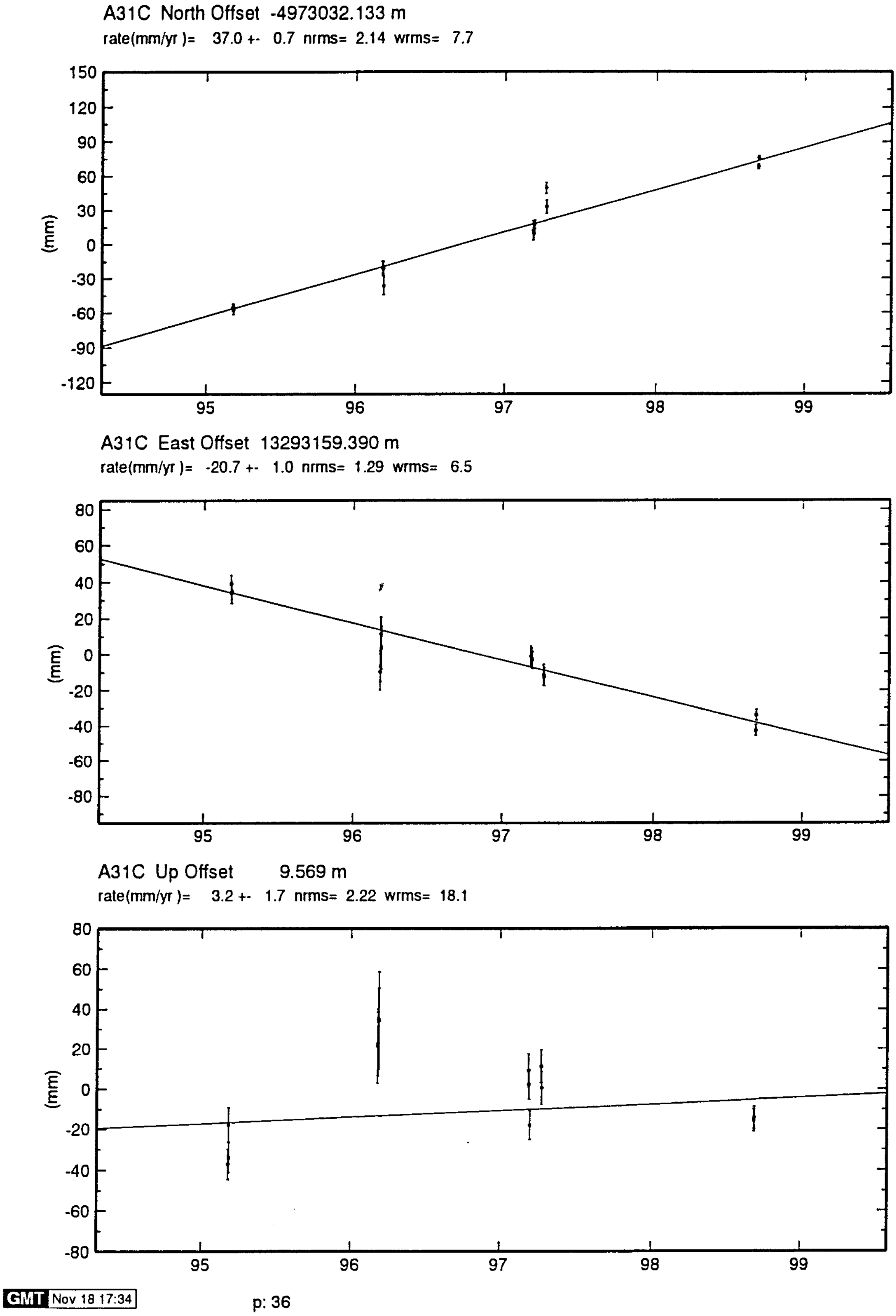


Figure A.22: Stochastic panels for A31C

A.23 A33D

Table A.45: Coordinates of A33D in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
A33D	-5041355.0102	441059.3734	-3869624.5298

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
A33D	S37 35 21.78530	E175 0 0.08278	318.8688

Table A.46: Coordinates of A33D in ITRF96 at solution epoch and the Uncorrelated time

```
 319. A33D_GPS X coordinate  (m)           -5041355.0749        0.0703        0.0021
 320. A33D_GPS Y coordinate  (m)             441059.3636        0.0114        0.0014
 321. A33D_GPS Z coordinate  (m)           -3869624.4609        0.0261        0.0016
 322. A33D_GPS X rate       (m/yr)               -0.0290        0.0110        0.0008
 323. A33D_GPS Y rate       (m/yr)               -0.0044        0.0063        0.0005
 324. A33D_GPS Z rate       (m/yr)                0.0309        0.0023        0.0006
 Postion of A33D_GPS referred to 1996.6782  XYZ offsets  -2.0717  -1.9835  -2.0867 years
Loc.  A33D_GPS X uncorr pos. (m)           -5041355.0154        0.0479        0.0013
Loc.  A33D_GPS Y uncorr pos. (m)             441059.3726       -0.0016        0.0009
Loc.  A33D_GPS Z uncorr pos. (m)           -3869624.5243        0.0213        0.0010
Unc. A33D_GPS -5041355.0154   441059.3726 -3869624.5243 -0.0290 -0.0044  0.0309 1996.678
                                                         0.0013  0.0009  0.0010
Loc.  A33D_GPS N coordinate  (m)           -4184431.1385       -0.0215        0.0008
Loc.  A33D_GPS E coordinate  (m)           15436785.5723       -0.0175        0.0013
Loc.  A33D_GPS U coordinate  (m)                318.9202       -0.0706        0.0025
     NE,NU,EU position correlations          0.0515        0.0551        -0.0991
Loc.  A33D_GPS N rate        (m/yr)               0.0419       -0.0045        0.0003
Loc.  A33D_GPS E rate        (m/yr)               0.0069       -0.0073        0.0005
Loc.  A33D_GPS U rate        (m/yr)               0.0037       -0.0096        0.0010
     NE,NU,EU rate correlations              0.0456        0.0709        -0.1182
```

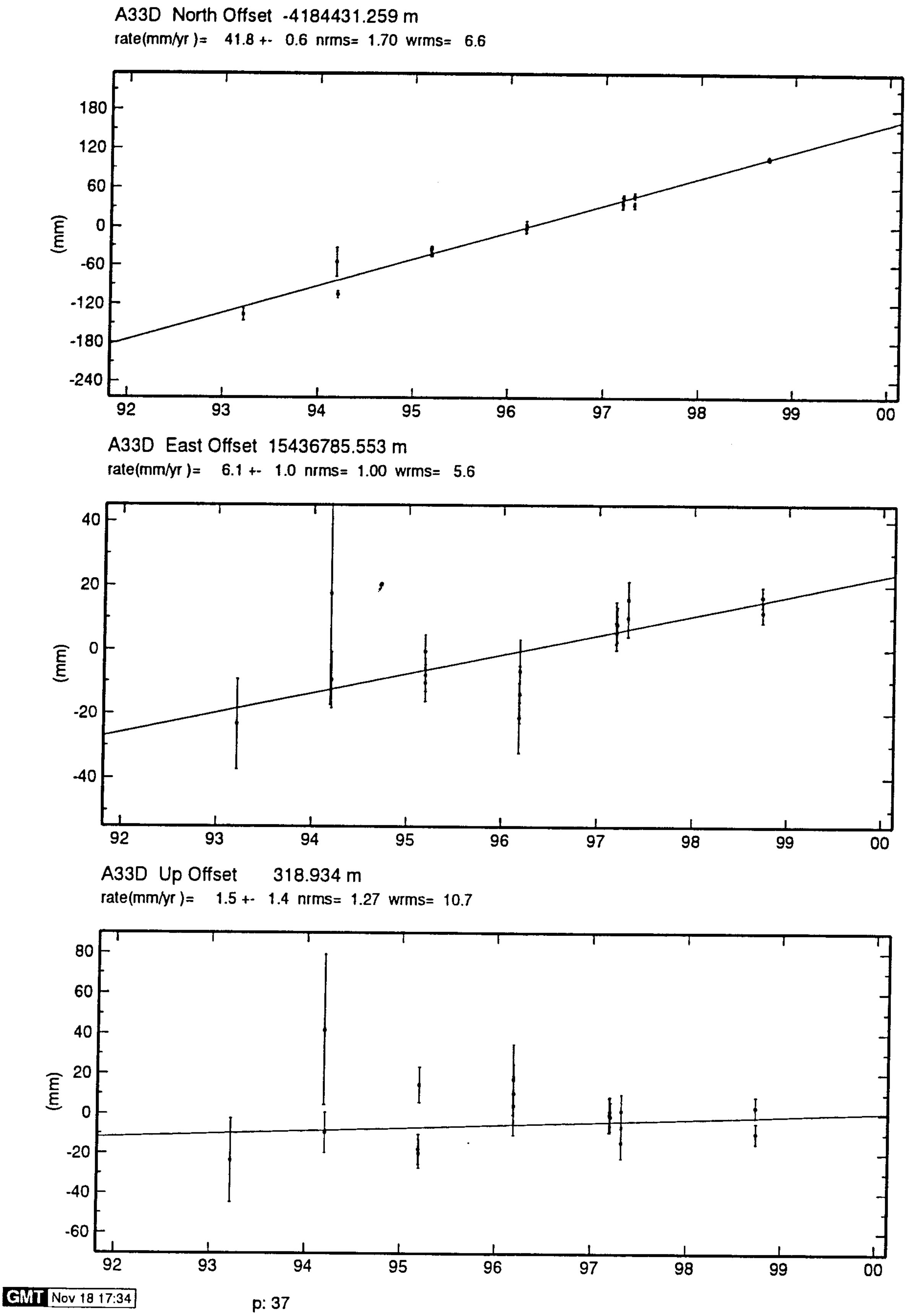


Figure A.23: Stochastic panels for A33D

A.24 A70X

Table A.47: Coordinates of A70X in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
A70X	-4802026.1733	617521.2601	-4138427.8351

	Ellipsoidal Coordinates Latitude			Longitude			Height
	Deg	Mn	Sec	Deg	Mn	Sec	Meters
A70X	S40	42	46.80170	E172	40	19.95436	169.3831

Table A.48: Coordinates of A70X in ITRF96 at solution epoch and the Uncorrelated time

```
451. A70X_GPS X coordinate  (m)           -4802026.2590      0.3052      0.0020
452. A70X_GPS Y coordinate  (m)             617521.2738     -0.0474      0.0014
453. A70X_GPS Z coordinate  (m)           -4138427.7830      0.2172      0.0017
454. A70X_GPS X rate        (m/yr)              -0.0385      0.0929      0.0008
455. A70X_GPS Y rate        (m/yr)               0.0061     -0.0135      0.0005
456. A70X_GPS Z rate        (m/yr)               0.0234      0.0672      0.0007
Postion of A70X_GPS referred to 1996.7730  XYZ offsets  -1.9632  -1.9030  -1.9914 years
Loc.  A70X_GPS X uncorr pos. (m)          -4802026.1838      0.1238      0.0013
Loc.  A70X_GPS Y uncorr pos. (m)            617521.2618     -0.0212      0.0009
Loc.  A70X_GPS Z uncorr pos. (m)          -4138427.8287      0.0860      0.0011
Unc. A70X_GPS -4802026.1838   617521.2618 -4138427.8287 -0.0385  0.0061  0.0234 1996.773
                                                         0.0013  0.0009  0.0011
Loc.  A70X_GPS N coordinate  (m)          -4532150.5663     -0.0367      0.0009
Loc.  A70X_GPS E coordinate  (m)          14570127.5581      0.0081      0.0013
Loc.  A70X_GPS U coordinate  (m)               169.5703     -0.3757      0.0025
      NE,NU,EU position correlations        0.0564      0.1011     -0.0950
Loc.  A70X_GPS N rate        (m/yr)              0.0432     -0.0103      0.0003
Loc.  A70X_GPS E rate        (m/yr)             -0.0012      0.0015      0.0005
Loc.  A70X_GPS U rate        (m/yr)              0.0143     -0.1150      0.0010
      NE,NU,EU rate correlations            0.0484      0.1243     -0.0766
```

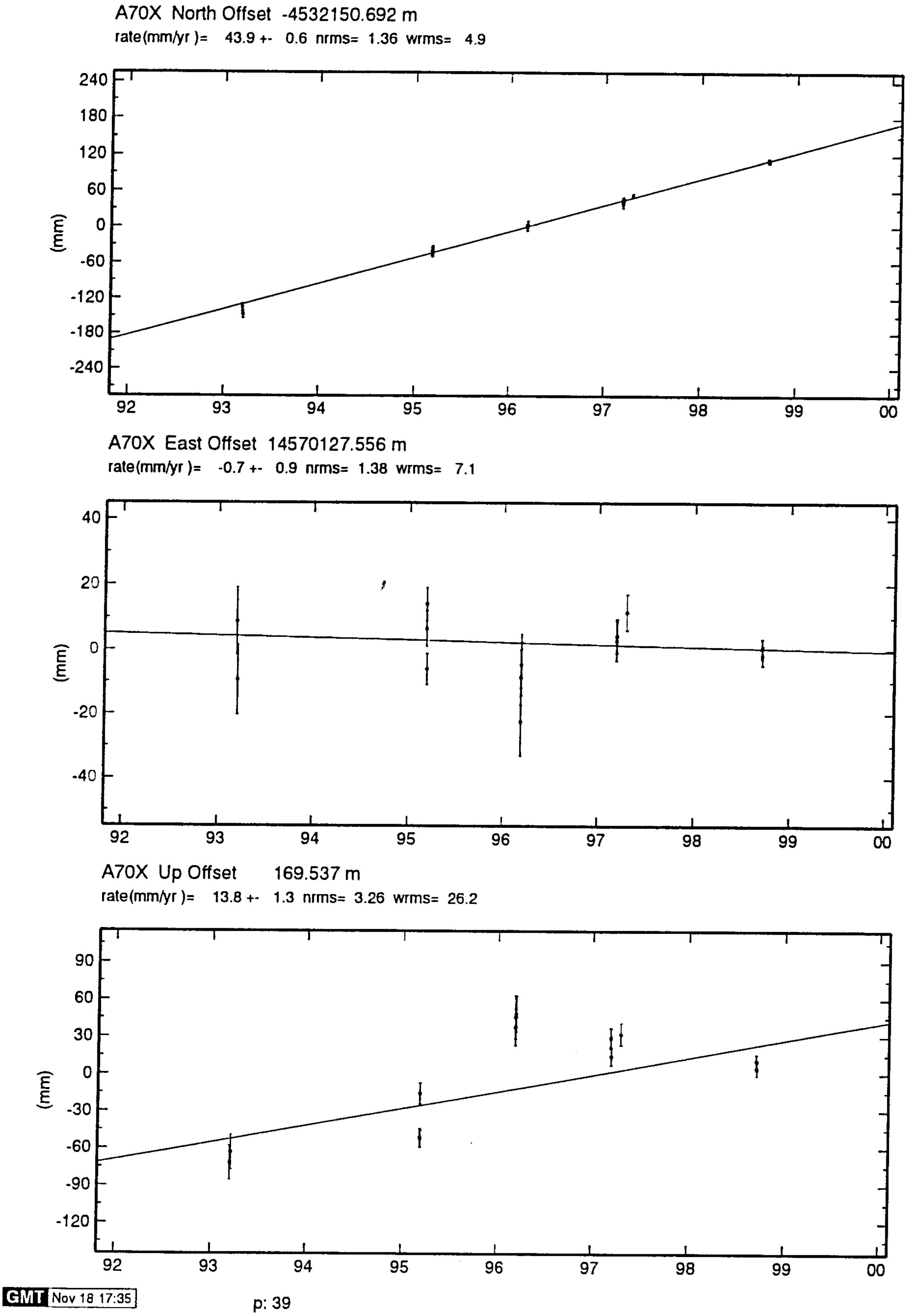


Figure A.24: Stochastic panels for A70X

A.25 AUCK

Table A.49: Coordinates of AUCK in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
AUCK	-5105680.9900	461564.0481	-3782181.7734

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
AUCK	S36	36	10.24696	E174	50	3.78731	132.7615

Table A.50: Coordinates of AUCK in ITRF96 at solution epoch and the Uncorrelated time

```
337. AUCK_GPS X coordinate  (m)          -5105681.0565      0.0061       0.0015
338. AUCK_GPS Y coordinate  (m)            461564.0424      0.0298       0.0012
339. AUCK_GPS Z coordinate  (m)          -3782181.7082      0.0036       0.0012
340. AUCK_GPS X rate       (m/yr)              -0.0299     -0.0052       0.0006
341. AUCK_GPS Y rate       (m/yr)              -0.0026      0.0168       0.0005
342. AUCK_GPS Z rate       (m/yr)               0.0293     -0.0027       0.0004
 Postion of AUCK_GPS referred to 1996.7328  XYZ offsets   -1.9737  -2.0236  -1.9808 years
Loc.  AUCK_GPS X uncorr pos. (m)         -5105680.9970      0.0164       0.0010
Loc.  AUCK_GPS Y uncorr pos. (m)           461564.0475     -0.0037       0.0008
Loc.  AUCK_GPS Z uncorr pos. (m)         -3782181.7666      0.0090       0.0008
Unc. AUCK_GPS -5105680.9970   461564.0475 -3782181.7666 -0.0299 -0.0026  0.0293 1996.733
                                                       0.0010  0.0008  0.0008
Loc.  AUCK_GPS N coordinate  (m)         -4074610.0611      0.0009       0.0008
Loc.  AUCK_GPS E coordinate  (m)         15624081.8314     -0.0303       0.0012
Loc.  AUCK_GPS U coordinate  (m)              132.7253     -0.0049       0.0017
     NE,NU,EU position correlations         0.0793      0.0606      -0.1622
Loc.  AUCK_GPS N rate          (m/yr)           0.0411      0.0018       0.0003
Loc.  AUCK_GPS E rate          (m/yr)           0.0053     -0.0163       0.0004
Loc.  AUCK_GPS U rate          (m/yr)           0.0062      0.0070       0.0007
     NE,NU,EU rate correlations             0.0607      0.0630      -0.1977
```

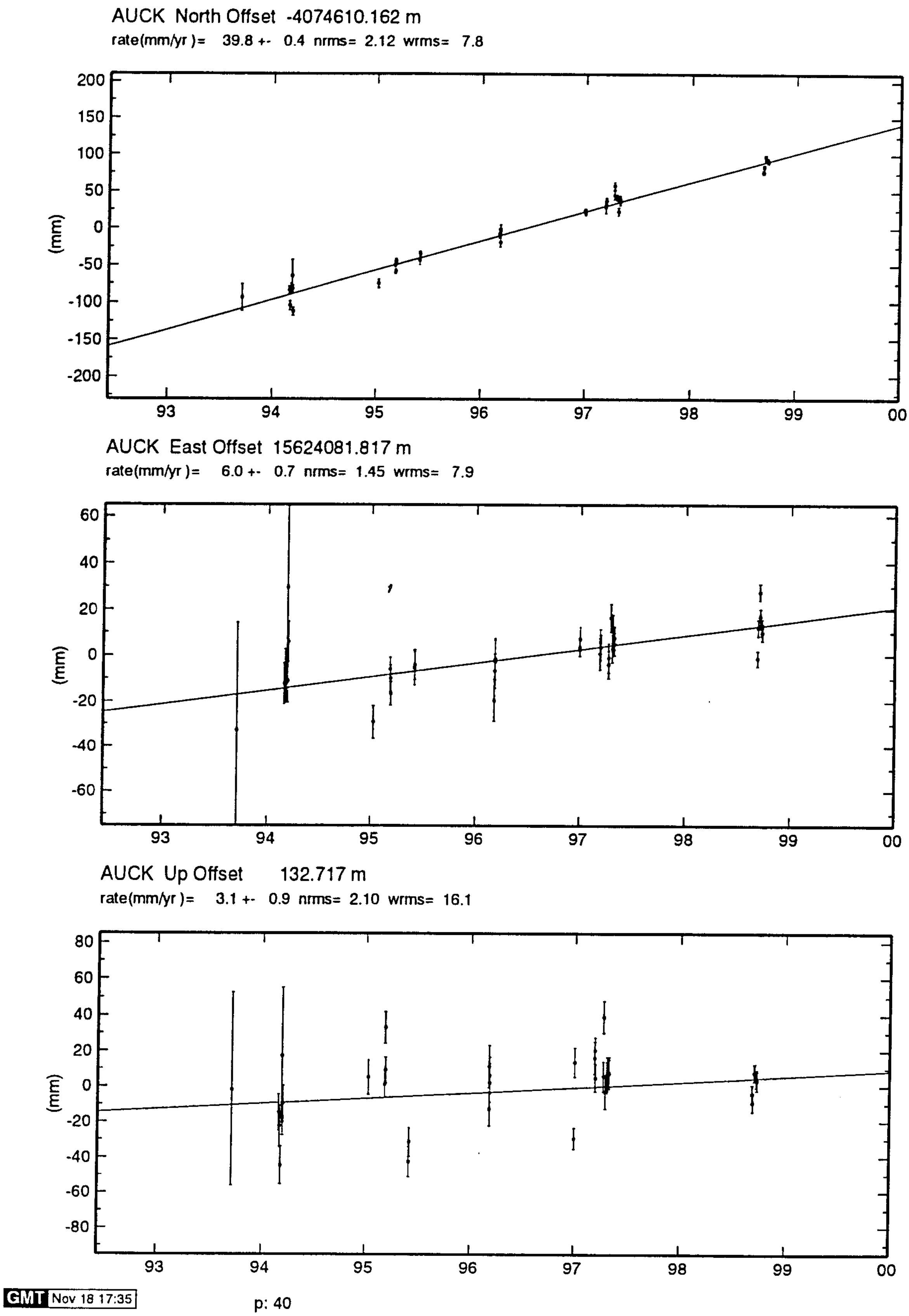


Figure A.25: Stochastic panels for AUCK

A.26 B03W

Table A.51: Coordinates of B03W in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
B03W	-4305507.2672	1024975.8577	-4577337.9602

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
B03W	S46	9	23.00573	E166	36	33.57839	44.0287

Table A.52: Coordinates of B03W in ITRF96 at solution epoch and the Uncorrelated time

```
 589. B03W_GPS X coordinate  (m)        -4305507.3294      0.2435      0.0020
 590. B03W_GPS Y coordinate  (m)         1024975.9204     -0.0730      0.0014
 591. B03W_GPS Z coordinate  (m)        -4577337.9197      0.2180      0.0019
 592. B03W_GPS X rate        (m/yr)           -0.0279      0.0713      0.0008
 593. B03W_GPS Y rate        (m/yr)            0.0282     -0.0208      0.0006
 594. B03W_GPS Z rate        (m/yr)            0.0182      0.0646      0.0008
 Postion of B03W_GPS referred to 1996.8786  XYZ offsets   -1.8322  -1.8711  -1.8376 years
Loc.  B03W_GPS X uncorr pos. (m)        -4305507.2778      0.1118      0.0012
Loc.  B03W_GPS Y uncorr pos. (m)         1024975.8684     -0.0345      0.0009
Loc.  B03W_GPS Z uncorr pos. (m)        -4577337.9533      0.0987      0.0012
Unc. B03W_GPS -4305507.2778  1024975.8684 -4577337.9533 -0.0279  0.0282  0.0182 1996.879
                                                        0.0012  0.0009  0.0012
Loc.  B03W_GPS N coordinate  (m)        -5138106.0300     -0.0320      0.0009
Loc.  B03W_GPS E coordinate  (m)        12846967.8533      0.0147      0.0013
Loc.  B03W_GPS U coordinate  (m)              44.2873     -0.3330      0.0026
      NE,NU,EU position correlations      0.0191       0.1480      -0.0876
Loc.  B03W_GPS N rate        (m/yr)            0.0369     -0.0087      0.0003
Loc.  B03W_GPS E rate        (m/yr)           -0.0209      0.0038      0.0005
Loc.  B03W_GPS U rate        (m/yr)            0.0102     -0.0980      0.0012
      NE,NU,EU rate correlations          0.0185       0.1587      -0.0574
```

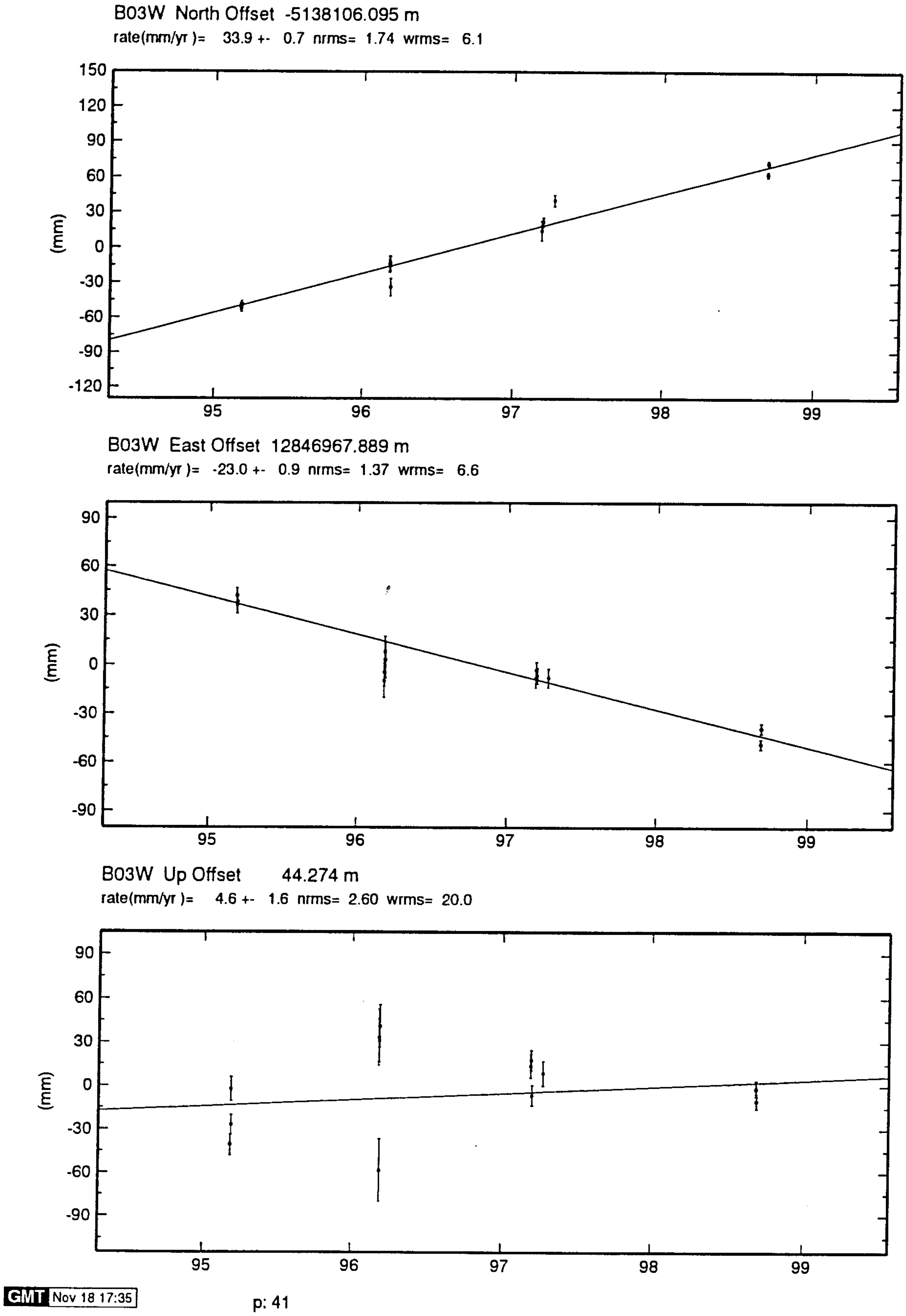


Figure A.26: Stochastic panels for B03W

A.27 B28C

Table A.53: Coordinates of B28C in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
B28C	-4741512.9504	480470.7493	-4225018.4524

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
B28C	S41 44 56.57258	E174 12 49.71439	254.6260

Table A.54: Coordinates of B28C in ITRF96 at solution epoch and the Uncorrelated time

```
 385. B28C_GPS X coordinate  (m)          -4741512.9927      0.0524      0.0020
 386. B28C_GPS Y coordinate  (m)            480470.8067      0.0023      0.0013
 387. B28C_GPS Z coordinate  (m)          -4225018.3998      0.0077      0.0017
 388. B28C_GPS X rate        (m/yr)             -0.0190      0.0044      0.0007
 389. B28C_GPS Y rate        (m/yr)              0.0258      0.0037      0.0005
 390. B28C_GPS Z rate        (m/yr)              0.0236     -0.0060      0.0006
 Postion of B28C_GPS referred to 1996.5653  XYZ offsets  -2.2135  -2.0370  -2.2301 years
Loc.  B28C_GPS X uncorr pos. (m)          -4741512.9516      0.0430      0.0012
Loc.  B28C_GPS Y uncorr pos. (m)            480470.7510     -0.0057      0.0009
Loc.  B28C_GPS Z uncorr pos. (m)          -4225018.4509      0.0206      0.0010
Unc. B28C_GPS -4741512.9516   480470.7510 -4225018.4509 -0.0190  0.0258  0.0236 1996.565
                                                       0.0012  0.0009  0.0010
Loc.  B28C_GPS N coordinate  (m)          -4647482.5844     -0.0288      0.0009
Loc.  B28C_GPS E coordinate  (m)          14468858.4236     -0.0076      0.0013
Loc.  B28C_GPS U coordinate  (m)               254.5357     -0.0438      0.0025
      NE,NU,EU position correlations        0.0437      0.1000      -0.1039
Loc.  B28C_GPS N rate        (m/yr)              0.0320     -0.0071      0.0003
Loc.  B28C_GPS E rate        (m/yr)             -0.0237     -0.0041      0.0005
Loc.  B28C_GPS U rate        (m/yr)              0.0003      0.0010      0.0009
      NE,NU,EU rate correlations            0.0272      0.1142      -0.1170
```

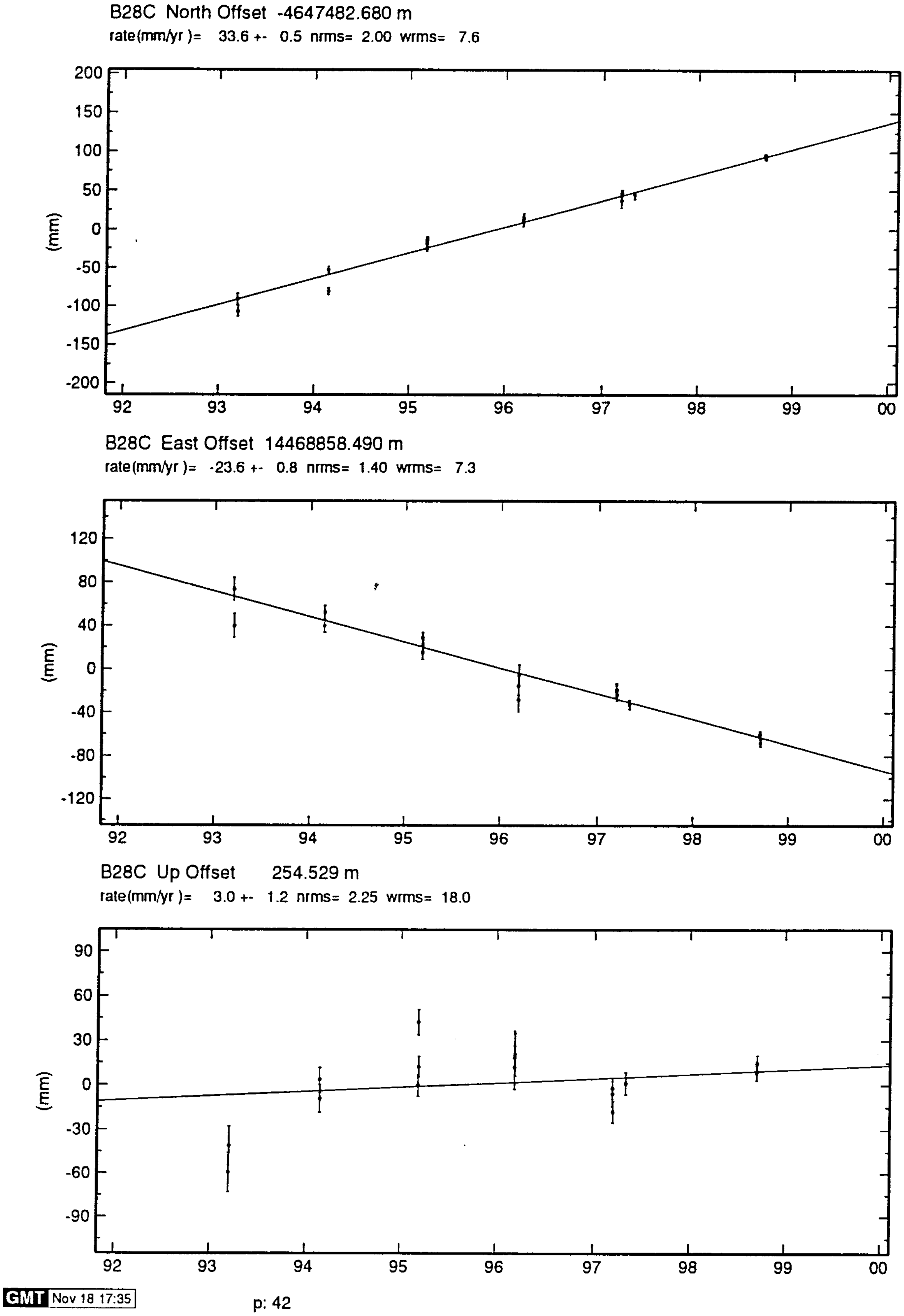


Figure A.27: Stochastic panels for B28C

A.28 CHAT

Table A.55: Coordinates of CHAT in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
CHAT	-4590670.8927	-275483.0135	-4404596.7866

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
CHAT	S43	57	20.83025	E183	26	2.98367	57.8071

Table A.56: Coordinates of CHAT in ITRF96 at solution epoch and the Uncorrelated time

```
 247. CHAT_GPS X coordinate  (m)           -4590670.9678      -0.0075       0.0014
 248. CHAT_GPS Y coordinate  (m)            -275482.9288       0.0475       0.0012
 249. CHAT_GPS Z coordinate  (m)           -4404596.7486      -0.0032       0.0013
 250. CHAT_GPS X rate        (m/yr)              -0.0338      -0.0098       0.0009
 251. CHAT_GPS Y rate        (m/yr)               0.0381       0.0243       0.0006
 252. CHAT_GPS Z rate        (m/yr)               0.0171      -0.0076       0.0008
 Postion of CHAT_GPS referred to 1997.5780  XYZ offsets   -1.0910  -1.2733  -1.0721 years
Loc.  CHAT_GPS X uncorr pos. (m)           -4590670.9291       0.0037       0.0010
Loc.  CHAT_GPS Y uncorr pos. (m)            -275482.9724       0.0196       0.0009
Loc.  CHAT_GPS Z uncorr pos. (m)           -4404596.7682       0.0055       0.0009
Unc. CHAT_GPS -4590670.9291  -275482.9724 -4404596.7682 -0.0338  0.0381  0.0171 1997.578
                                                         0.0010  0.0009  0.0009
Loc.  CHAT_GPS N coordinate  (m)           -4893135.8403       0.0009       0.0008
Loc.  CHAT_GPS E coordinate  (m)           14699991.3526      -0.0478       0.0012
Loc.  CHAT_GPS U coordinate  (m)                 58.0051       0.0055       0.0017
      NE,NU,EU position correlations         0.0170        0.1040        -0.1671
Loc.  CHAT_GPS N rate        (m/yr)               0.0341       0.0003       0.0004
Loc.  CHAT_GPS E rate        (m/yr)              -0.0401      -0.0249       0.0006
Loc.  CHAT_GPS U rate        (m/yr)               0.0108       0.0113       0.0011
      NE,NU,EU rate correlations             0.0112        0.1099        -0.0987
```

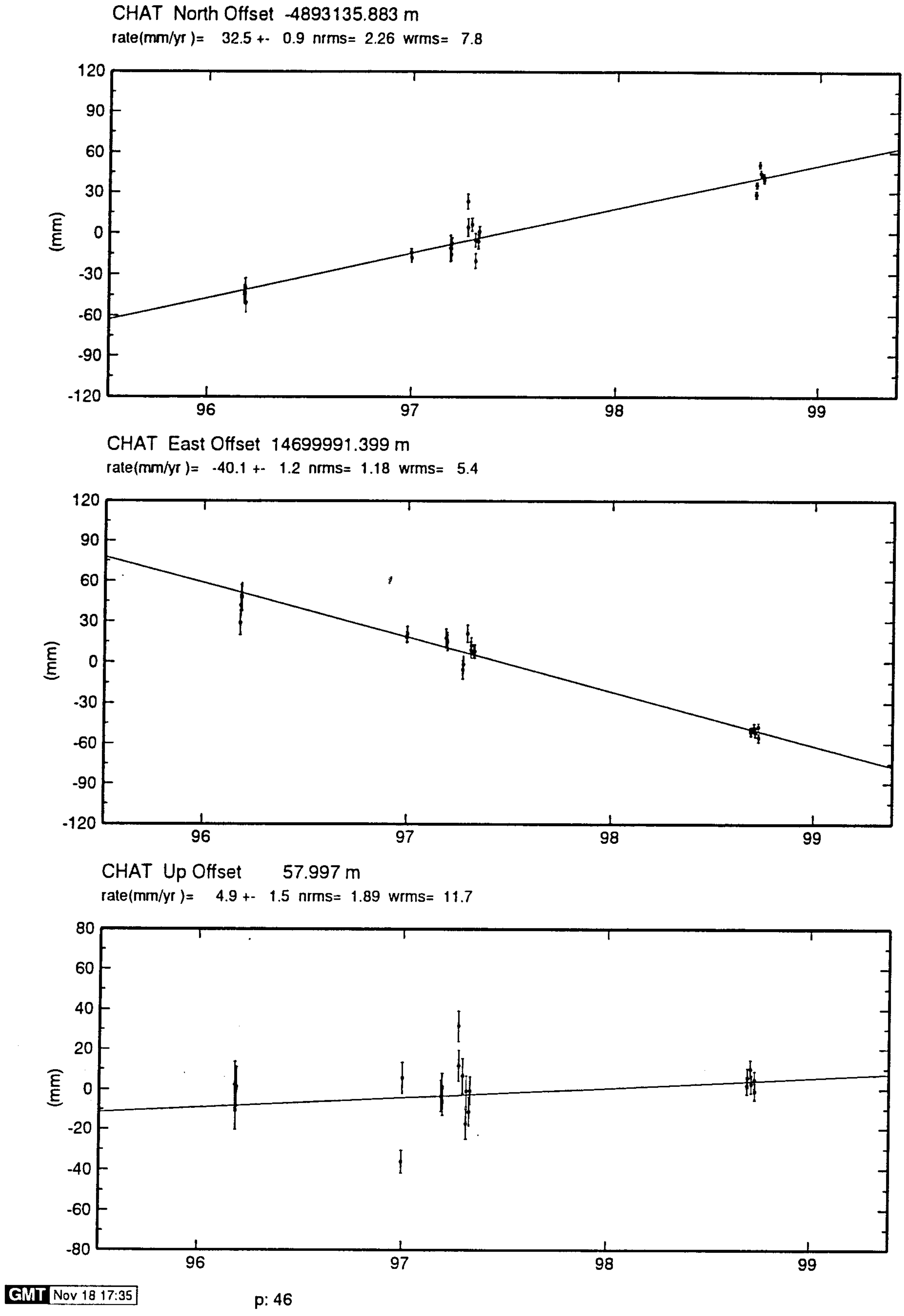


Figure A.28: Stochastic panels for CHAT

A.29 OUSD

Table A.57: Coordinates of OUSD in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
OUSD	-4387888.5501	733420.8700	-4555178.5944

	Ellipsoidal Coordinates Latitude Deg Mn Sec	Longitude Deg Mn Sec	Height Meters
OUSD	S45 52 10.21222	E170 30 39.31974	26.2890

Table A.58: Coordinates of OUSD in ITRF96 at solution epoch and the Uncorrelated time

```
 487. OUSD_GPS X coordinate  (m)          -4387888.5760        0.1767        0.0013
 488. OUSD_GPS Y coordinate  (m)            733420.9368       -0.0407        0.0011
 489. OUSD_GPS Z coordinate  (m)          -4555178.5338        0.1567        0.0012
 490. OUSD_GPS X rate        (m/yr)             -0.0117        0.0586        0.0005
 491. OUSD_GPS Y rate        (m/yr)              0.0300       -0.0122        0.0004
 492. OUSD_GPS Z rate        (m/yr)              0.0273        0.0548        0.0005
 Postion of OUSD_GPS referred to 1996.8275  XYZ offsets   -1.9047  -1.8977  -1.8918 years
Loc.  OUSD_GPS X uncorr pos. (m)          -4387888.5539        0.0654        0.0009
Loc.  OUSD_GPS Y uncorr pos. (m)            733420.8798       -0.0176        0.0008
Loc.  OUSD_GPS Z uncorr pos. (m)          -4555178.5855        0.0527        0.0008
Unc. OUSD_GPS -4387888.5539   733420.8798 -4555178.5855 -0.0117  0.0300  0.0273 1996.827
                                                        0.0009  0.0008  0.0008
Loc.  OUSD_GPS N coordinate  (m)          -5106169.6028       -0.0208        0.0008
Loc.  OUSD_GPS E coordinate  (m)          13216780.6947        0.0111        0.0011
Loc.  OUSD_GPS U coordinate  (m)                26.1785       -0.2385        0.0016
     NE,NU,EU position correlations         0.0165         0.1608        -0.1902
Loc.  OUSD_GPS N rate        (m/yr)              0.0308       -0.0048        0.0003
Loc.  OUSD_GPS E rate        (m/yr)             -0.0277        0.0024        0.0004
Loc.  OUSD_GPS U rate        (m/yr)             -0.0081       -0.0810        0.0006
     NE,NU,EU rate correlations            -0.0039         0.1735        -0.1953
```

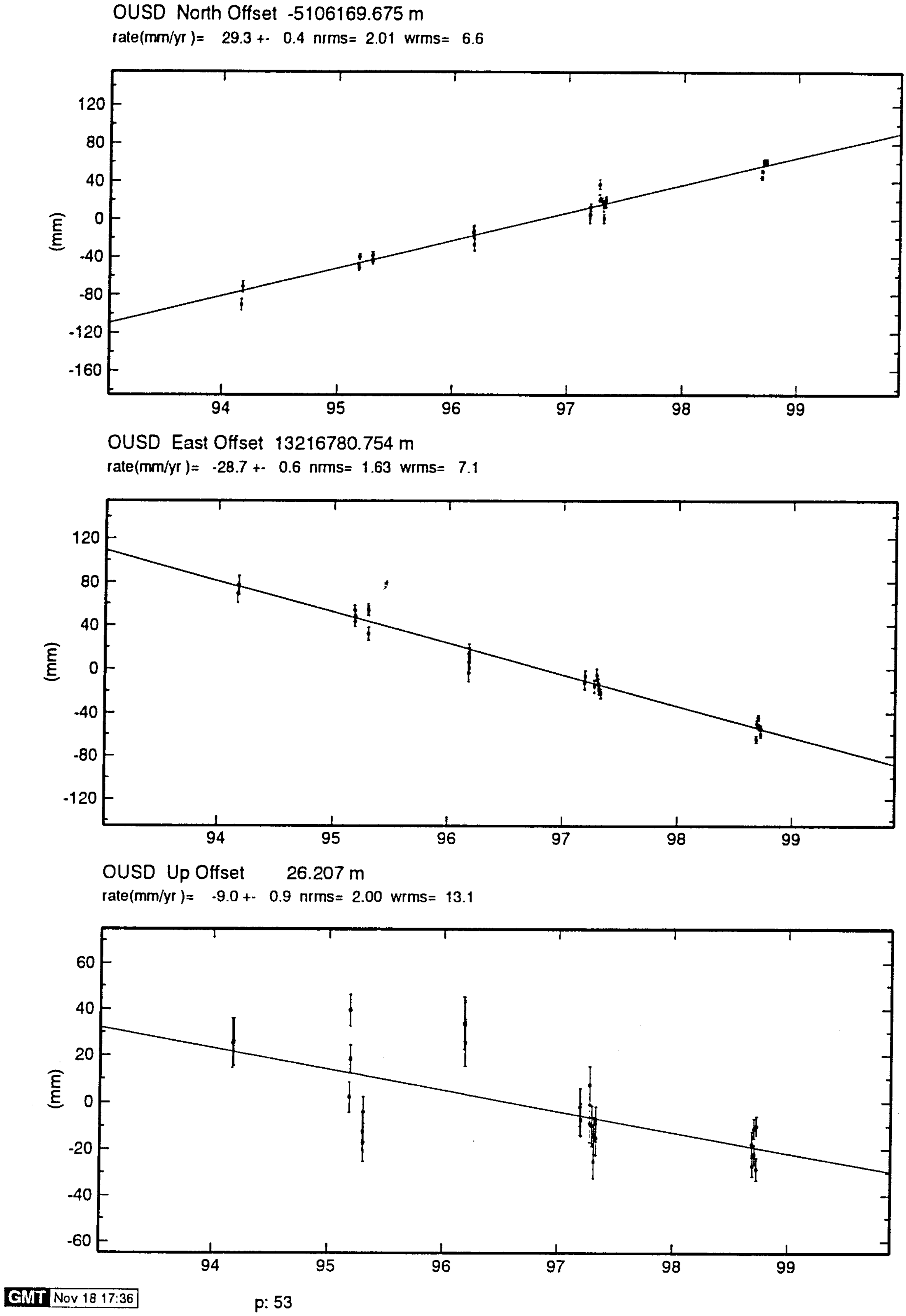


Figure A.29: Stochastic panels for OUSD

A.30 WELL

Table A.59: Coordinates of WELL in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Cartesian Coordinates Y	Cartesian Coordinates Z
WELL	-4780648.7640	436507.2008	-4185440.2375

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
WELL	S41	16	29.60811	E174	46	58.63539	37.4692

Table A.60: Coordinates of WELL in ITRF96 at solution epoch and the Uncorrelated time

```
 367. WELL_GPS X coordinate  (m)          -4780648.8063       0.0020       0.0031
 368. WELL_GPS Y coordinate  (m)            436507.2478       0.0871       0.0018
 369. WELL_GPS Z coordinate  (m)          -4185440.1801       0.2738       0.0026
 370. WELL_GPS X rate        (m/yr)             -0.0190      -0.0190       0.0008
 371. WELL_GPS Y rate        (m/yr)              0.0211       0.0211       0.0005
 372. WELL_GPS Z rate        (m/yr)              0.0258       0.0258       0.0007
 Postion of WELL_GPS referred to 1995.4590  XYZ offsets  -3.4420  -2.8965  -3.4592 years
Loc.  WELL_GPS X uncorr pos. (m)          -4780648.7442       0.0641       0.0013
Loc.  WELL_GPS Y uncorr pos. (m)            436507.1788       0.0181       0.0010
Loc.  WELL_GPS Z uncorr pos. (m)          -4185440.2644       0.1895       0.0011
Unc. WELL_GPS -4780648.7442   436507.1788 -4185440.2644 -0.0190  0.0211  0.0258 1995.459
                                                         0.0013  0.0010  0.0011
Loc.  WELL_GPS N coordinate  (m)          -4594700.0379       0.2097       0.0010
Loc.  WELL_GPS E coordinate  (m)          14622515.5685      -0.0869       0.0018
Loc.  WELL_GPS U coordinate  (m)                37.6825      -0.1762       0.0039
     NE,NU,EU position correlations         0.0261       0.1088      -0.0664
Loc.  WELL_GPS N rate        (m/yr)              0.0332       0.0332       0.0003
Loc.  WELL_GPS E rate        (m/yr)             -0.0193      -0.0193       0.0005
Loc.  WELL_GPS U rate        (m/yr)             -0.0013      -0.0013       0.0010
     NE,NU,EU rate correlations             0.0163       0.1218      -0.1277
```

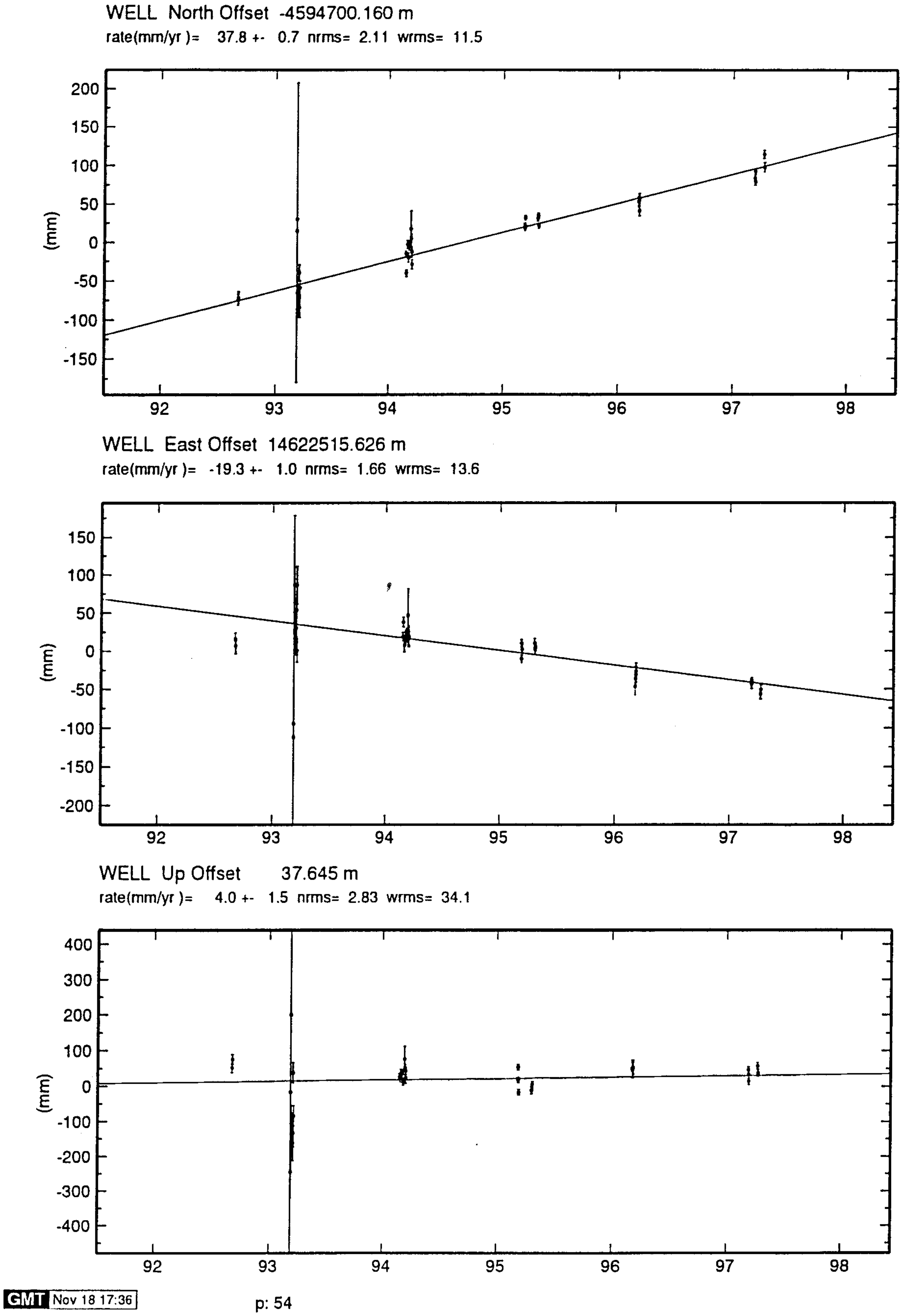


Figure A.30: Stochastic panels for WELL

A.31 WGTN

Table A.61: Coordinates of WGTN in ITRF96 at Epoch 1996.50

Station	Cartesian Coordinates X	Y	Z
WGTN	-4777269.3496	434269.9758	-4189484.6522

	Ellipsoidal Coordinates Latitude Deg	Mn	Sec	Longitude Deg	Mn	Sec	Height Meters
WGTN	S41	19	24.45203	E174	48	21.22232	26.1512

Table A.62: Coordinates of WGTN in ITRF96 at solution epoch and the Uncorrelated time

```
 343. WGTN_GPS X coordinate  (m)           -4777269.3834      -0.0157       0.0027
 344. WGTN_GPS Y coordinate  (m)             434270.0365      -0.0273       0.0023
 345. WGTN_GPS Z coordinate  (m)           -4189484.5979       0.0241       0.0022
 346. WGTN_GPS X rate        (m/yr)              -0.0152      -0.0228       0.0019
 347. WGTN_GPS Y rate        (m/yr)               0.0273      -0.0170       0.0015
 348. WGTN_GPS Z rate        (m/yr)               0.0244       0.0113       0.0015
 Postion of WGTN_GPS referred to 1997.4308   XYZ offsets   -1.2585  -1.3894  -1.2303 years
Loc.  WGTN_GPS X uncorr pos. (m)           -4777269.3638       0.0138       0.0012
Loc.  WGTN_GPS Y uncorr pos. (m)             434270.0012      -0.0054       0.0009
Loc.  WGTN_GPS Z uncorr pos. (m)           -4189484.6295       0.0095       0.0011
Unc. WGTN_GPS -4777269.3638   434270.0012 -4189484.6295 -0.0152  0.0273  0.0244 1997.431
                                                         0.0012  0.0009  0.0011
Loc.  WGTN_GPS N coordinate  (m)           -4600106.2472       0.0268       0.0013
Loc.  WGTN_GPS E coordinate  (m)           14613518.0136       0.0286       0.0022
Loc.  WGTN_GPS U coordinate  (m)                 26.0670      -0.0061       0.0033
     NE,NU,EU position correlations          0.0171       0.1964      -0.0746
Loc.  WGTN_GPS N rate        (m/yr)               0.0300       0.0225       0.0008
Loc.  WGTN_GPS E rate        (m/yr)              -0.0258       0.0190       0.0015
Loc.  WGTN_GPS U rate        (m/yr)              -0.0029       0.0084       0.0023
     NE,NU,EU rate correlations              0.0124       0.2034      -0.0399
```

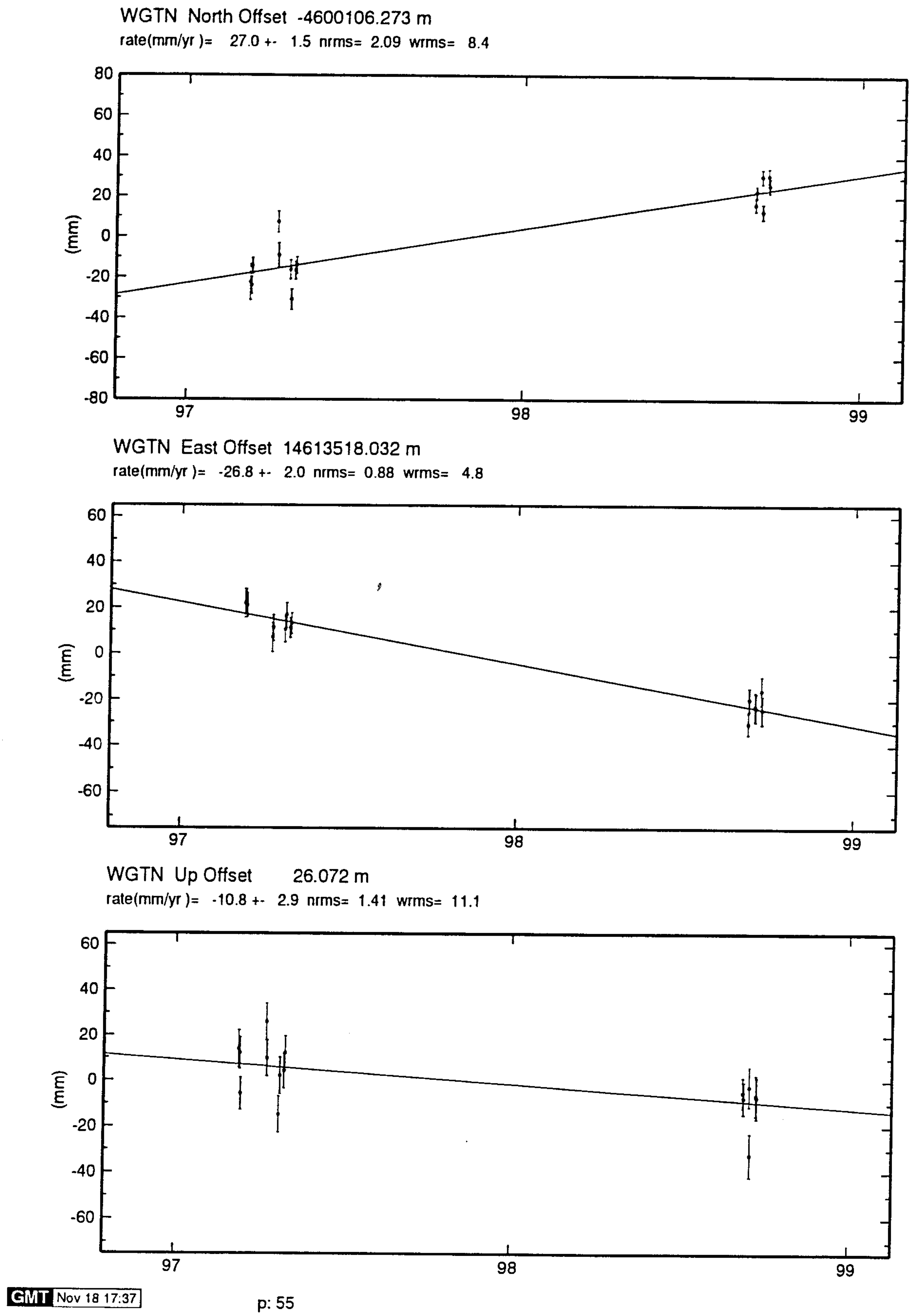


Figure A.31: Stochastic panels for WGTN

Appendix B

Description of Deposited Materials

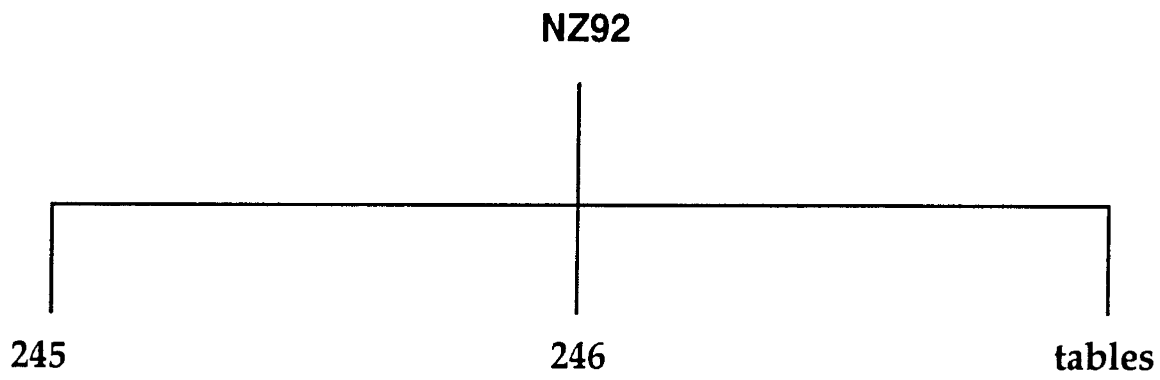
The deposition to LINZ consisted of all associated material.

In particular the daily log books which describe fitting to the global orbit, editing of satellites and observed data were deposited with LINZ. Their principal value will be to indicate areas of difficulty and concern in the reduction/analysis process. LINZ intends to scan these working records so that the documentation of the project is as complete as possible.

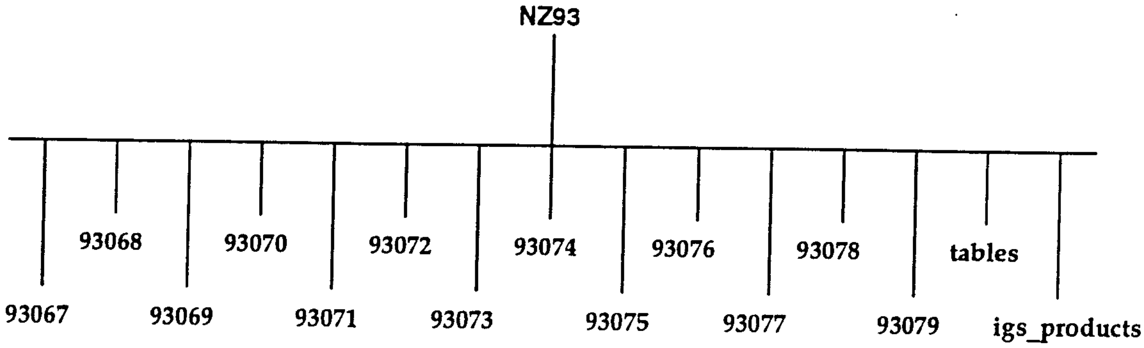
The deposition also consisted of a series of CD-ROMs which preserves a great deal of the file structure. In particular. we preserved sufficient data to allow us, or any GAMIT user to re-evaluate our proceedures and analysis. The full preservation is on a pair of father/son EXABYTE tapes held at the University of Canberra. The deposited CD-ROMs form a data set that is almost equivalent to these tapes. The University of Canberra is willing to copy it master set.

This appendix provides abridged information on the contents of each of the submitted cd's.

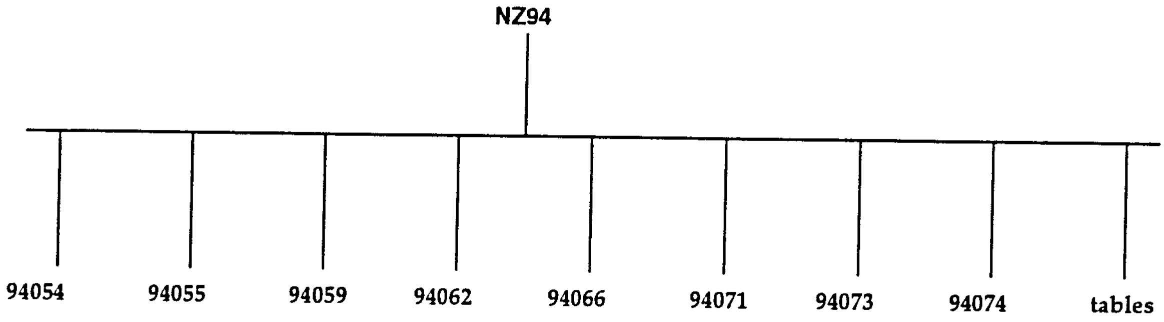
NZ92: 1992 GAMIT day solutions.



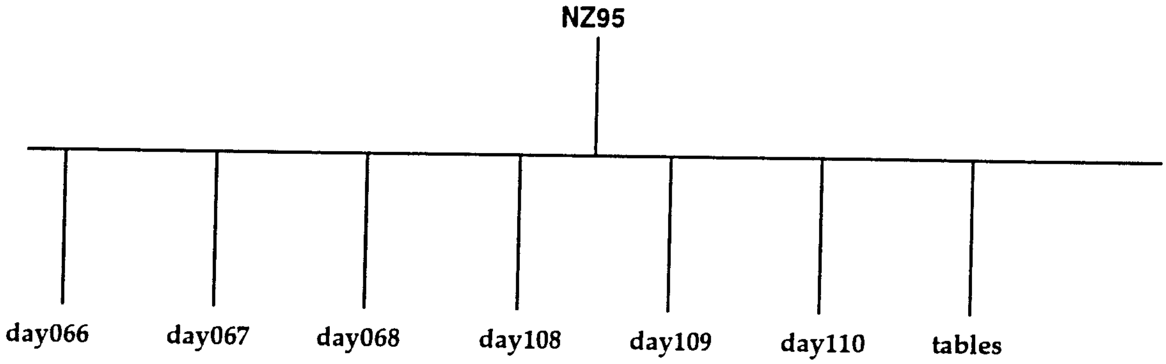
NZ93: 1993 GAMIT day solutions.



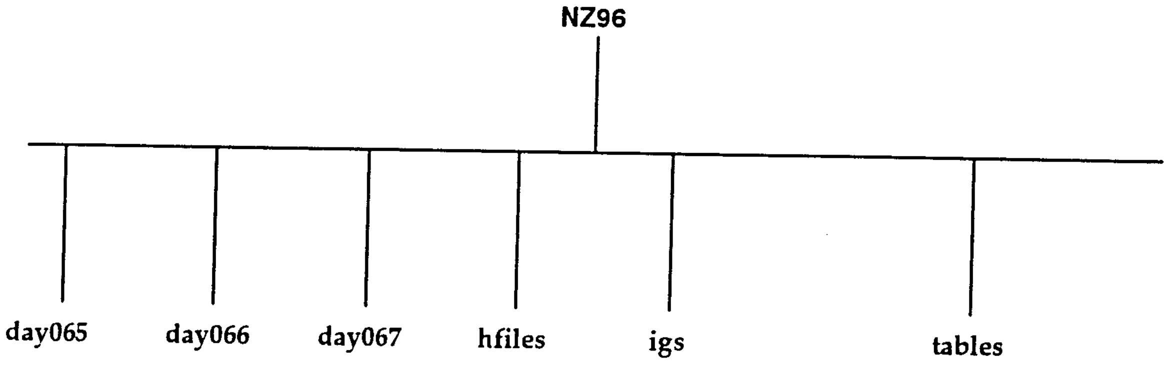
NZ94: 1994 GAMIT day solutions.



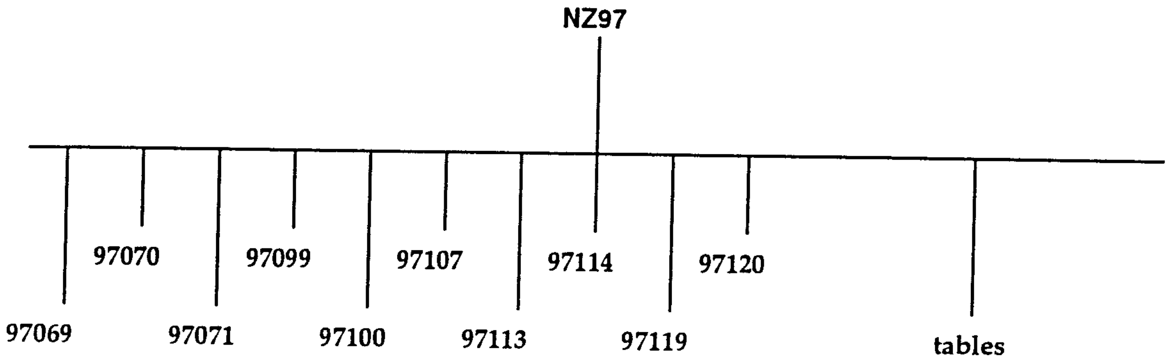
NZ95: 1995 GAMIT day solutions.



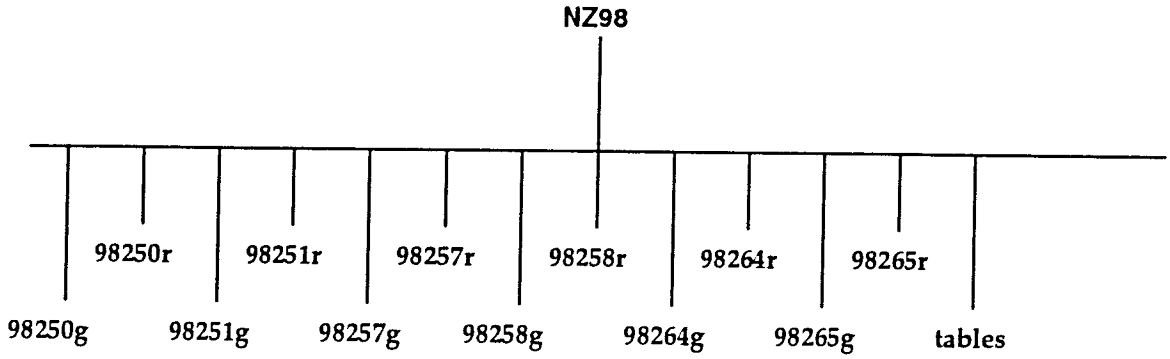
NZ96: 1996 GAMIT day solutions.



NZ97: 1997 GAMIT day solutions.



NZ98: 1998 GAMIT day solutions.



File structure of a typical GAMIT day solution

(see Chapter 3 of GAMMIT Documentation)

- Tracking information files — ~~xfiles,~~ usually cleaned and compressed.
- Clock files
  - kfiles, one per each receiver site.
  - ifile, a summary of receiver clock performance.
  - jfile, a summary of satellie clock performance.
- Satellite and orbit files
  - igs sp3 file, only in latter years
  - gfiles, these are initial state vector files
  - broadcast ephemeris files, various formats.
  - tfiles, integrated tabular ephemeris files, (binary).
  - yfiles, yaw attitude information.
  - sp3 fit files, only present when igs.sp3 orbit is available.
- Earth orientation files — usually BIH Bulletin B values of the pole and UT1 (pole and ut1)
- Files for precession and nutation — solar, lunar and nutation tables.
- Files associated with data cleaning — all AUTCLN files begin with autcln the summary file and command files are usually saved.
- Solution output files
  - hfile; loose covariance for use in GLOBK
  - mfile; includes adjuatments to partials and other setup info
  - ofile; solution output in abreviated but regular format
  - qfile; a print file of the solutio.
- A-priori information files
  - session.info; satellites used in session
  - station.info; antenna and other station specific data.
  - sittbl.; model constrains and site specific modelling options.
  - sestbl. parameters used to control solution type and options.
  - lfile, apriori station coordinates in spherical coordinates
  - svnav.dat contains satellite data for orbit integration
  - leap.sec allows computation of offset between TAI, UTC and GPS time

File structure of a typical table directory

(see Chapters 3 & 4 of GAMIT Documentation)

- Station specific files
  - lfile a-priori station info in spherical coordinates
  - station.info basic station info. including antenna info.
  - sittbl. station constraints and models.
- Satellie specific files
  - svnav.dat table of satellite equivalences and parameters
- Other files
  - antmod.dat antenna phase center offsets etc
  - rcvant.dat receiver/antenna equivalences and aliases
  - gdetic.dat some common geodetic datums.
  - autcln.cmd specialised cleaning commands.
- Earth orientation information
- precession and nutation tables

NZ_soln CD-ROM

(Solution 11 is the correct solution)

- **bak_soln**
  - globk_ nzbak.prt — An old solution used for testing purposes
- **glred_soln** — This directory contains a sequence of directories and files associated with the daily stochastic analysis. plotting11 is the pertinent directory.
  - older solutions
  - **plotting11**
    - psbase.SITE
- **sinex** — This directory contains the internal, binary, GLOBK files used in passing the loose GLOBK solution back thru GLOBK where the tight constraints were applied
  - com_nz11.GLX — The loose GLOBK file
  - h9809221159_11_x.gls.orig — The conversion of GLOBK output (GLX) to an input file for GLOBK
  - nz_snx_globk.cmd — The command file used to generate the SINEX versions
  - com_nz11_snx.GLX — The output from GLOBK after applying constraints
  - glbcom_nz11_snx.bin — a companion file to above
  - glbsol_nz11_snx.bin — a companion to the previous two files.
  - nz_11_sinex03.snx — The tested and submitted sinex file
- **nz_cdrom** (see description of SINEX CD-ROM)
- **ties**
  - auck
  - wc

  GLOBK file structures for the optimal estimation of the ties at Auckland and Windsor Castle. GLOBK uses to multiple ties performed at these station
- glbcom_nz11.bin — The major output file from GLOBK. It is used as input, together with the next 2 files to GLORG
- glbsol_nz11.bin — Accompanies glbcom
- glbsrt_nz11.bin — Accompanies the above two files
- glorg_nz11.prt — Output from the GLORG stabilization process
- nz11.log — The log file from the GLOBK process
- nz11.prt — The print file from the GLOBK process.

The SINEX CD-ROM

- glorg_nz11.prt — This is the full, conventioal solution output from which the extracts were obtained in the main station appendix.
- nz11_globk_sinex.prt — This is the loose globk solution prepared for the SINEX generation process. This solution is pass through GLOBK again where tight constraints are now applied.
- nz11_sixex — The submitted SINEX file containing all SINEX information including session information
- nz11_tar — A compress tar file containing the above three files

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