Regional Network Associate Analysis Centers

The EUREF RNAAC: 1997 Annual Report

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1 Introduction

The IAG Subcommission for the European Reference Frame (EUREF) continued in 1997 to monitor and process the European GPS tracking network. Ten European analysis centers process each a subnetwork and the individual subnetwork solutions are then combined into the official weekly EUREF solution. Coordinate time series for all the European stations are made available at the EUREF Permanent Network Web site :

`http://www.oma.be//KSB-ORB/EUREF/eurefhome.html`

2 The Proposed Network

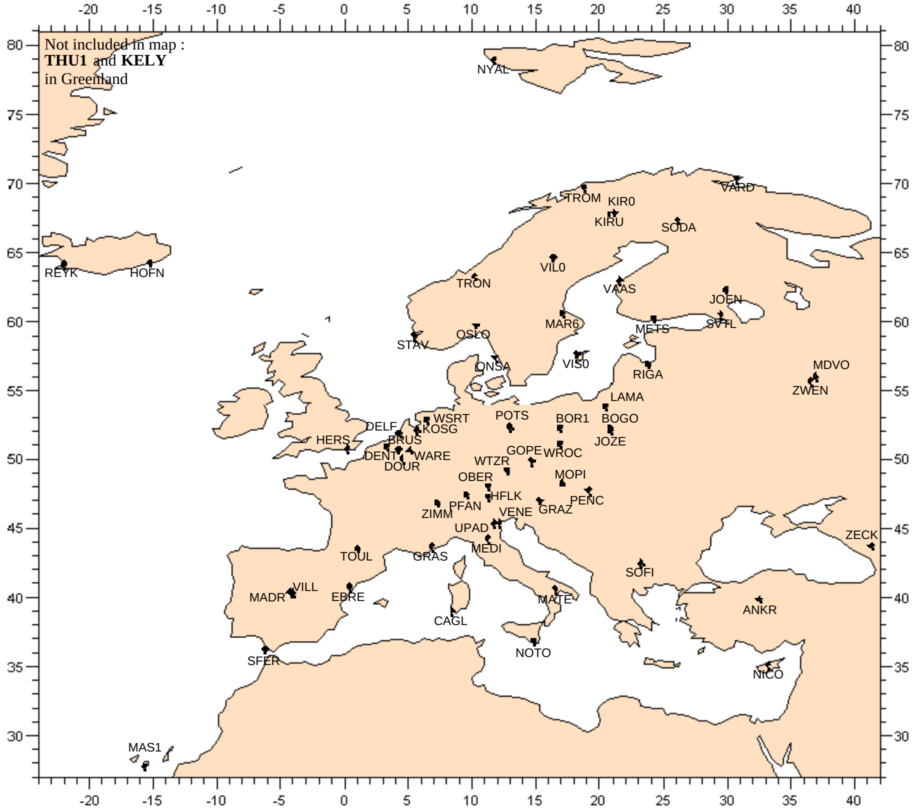

Figure 1. Network of EUREF Tracking Stations, as of January 1 1998.

The EUREF network, which consisted of 56 stations (January '97), was extended in 1997 with 9 new stations : Höfn (Iceland), Oberpfaffenhofen. (Germany), Nicosia (Cyprus), Pfänder (Austria), Sodankylä (Finland), Sofia (Bulgaria), Toulouse (France), Westerbork (Netherlands), Zelenchukskaya (Russia). The present network is shown in Figure 1.

3 The EUREF Local Analysis

Since mid 1996, weekly SINEX contributions from 10 European Local Analysis Centers are combined into one official weekly EUREF solution.

Since the summer of 1997, the EUREF local analysis centers follow all the analysis recommendations set up at the "EUREF Analysis Workshop" held in Brussels (April 1997) :

- common elevation cut-off angle of 15°
- use precise satellite orbits (IGS or CODE), all centers perform a fixed-orbit processing
- use consistent orbits and Earth Rotation Parameters
- adopt the IGS tables modeling the constant and elevation dependent antenna phase eccentricities
- adopt similar strategies for the modeling of the troposphere ; estimation of a tropospheric zenith path delay/2 hours

Also in the summer of 1997, a proposal for redistribution of the subnetworks was approved by the EUREF analysis centers and it has been effective since September 1997. Presently 18% of the EUREF stations have their data routinely analyzed by 2 EUREF analysis centers, 79% by 3 centers and 3% by 4 analysis centers.

Figure 2 shows, as an example, the RMS values derived from the Helmert residuals of the ASI/CGS analysis center with respect to the weekly combined EUREF solution. The results for the other EUREF Local Analysis Centers are similar.

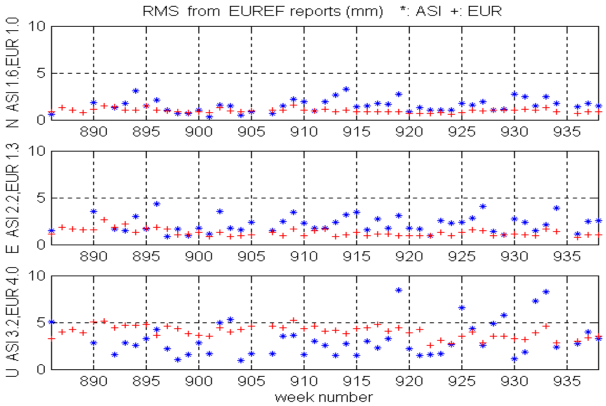

Fig. 2. RMS values derived from the Helmert residuals for ASI/CGS and EUR (combined solution) in 1997.

4 The EUREF Regional Analysis

4.1 The EUREF Combined Solution

In the combination scheme of the weekly SINEX solutions, delivered by the 10 local analysis centers, first all the applied constraints are removed and the covariance matrices are rescaled. In the final step new constraints are applied to tie the solution to the terrestrial reference frame, currently ITRF96.

Two different solutions are generated each week :

- a free network solution : well suited for the detection of problems within the combined solution and as a consistency check of the various subnetwork solutions ;
- a solution tightly constrained to the ITRF96 : the official weekly EUREF solution.

In addition, a combination of the most recent solution with the previous six weekly solutions is generated. This gives an insight into the behaviour of the sites over a period of almost two months and provides a measure of the inner consistency of the network. The RMS of this combination is below 2 mm horizontally and below 5 mm in height.

Since March 1, 1998 (GPS week 0947), the official EUREF combined solution is tied to the ITRF96. Before this time it was tied to the ITRF94. The following sites were selected for the realization of the new reference frame : BOR1, GRAZ, KOSG, MATE, ONSA, POTS, REYK, VILL, WTZR, ZIMM and ZWEN. These stations are tightly constrained (0.1 mm) to their ITRF96 coordinates.

The SINEX files of the combined EUREF solution is submitted every week to the CDDIS, BKG, ROB and CODE. More details about the combination scheme can be found in (Bruyninx et al, 1997).

4.2 Submission to the IERS (EUREF97)

As is the case for the ITRF96 realization, EUREF will contribute to the realization of the ITRF97 with a combined solution for the European permanent GPS network (EUREF97).

One of the major problems with regional solutions, like the EUREF solution, is that they are generated using the IGS (or CODE) orbits without orbit improvement. As a consequence, the reference frame changes of the orbits show up in the coordinate estimates of the regional solutions. Especially changes from ITRF92 to ITRF93 and subsequently from ITRF93 to ITRF94 led to a significant change in the reference frame, mainly caused by the ITRF93 being differently defined. These reference frame differences had to be removed before combining the weekly EUREF solutions.

The EUREF 97 contribution was done as follows :

- First, the reference frame change due to the transition from ITRF93 to ITRF94 (GPS week 860) was eliminated by estimating the values of a 7-parameter Helmert transformation between the two reference frames. No significant translations or rotations were found between ITRF94 and ITRF96 (GPS week 0947).
- Solutions for problematic sites had to be removed for some time periods, e.g. an 'old' receiver (MADR), snow on the antenna (SODA), and changes of the antenna/radome set-up (MOPI). More problems existed in the original EUREF solutions, but they were noticed and handled during the generation of the weekly EUREF solutions.
- If significant coordinate jumps were detected, then a new coordinate solution was set up, e.g. for the sites OSLO, STAV, TRON and VARD, due to equipment changes.
- The reference frame was defined by constraining the coordinates (1 mm) and the velocities (1 mm/y) of the following sites to their ITRF96 coordinates and velocities: BOR1, GRAZ, KOSG, MATE, ONSA, POTS, REYK, THU1, VILL, WTZR, ZIMM and ZWEN.
- All weekly EUREF solutions since GPS week 0834 to 0957 were used, and the coordinates and velocities of all stations were estimated.

The EUREF97 solution was compared to the ITRF96 and EUREF96 solutions by performing a 7-parameter Helmert transformation. The resulting RMS errors in position and velocity are given in Table 2. The agreement is excellent and is very consistent with the internal precision of the weekly solutions (1 mm and 5 mm for the horizontal and vertical component, respectively).

In Figure 3, the estimated EUREF97 velocities are plotted relative to the motion of the Eurasian plate as defined by the NUVEL-1A model. Plotting the relative velocities allows to detect easily sites with unexpected motions. The velocities for the sites STAV, TRON and OSLO differ significantly from their expected Eurasian motion. In these cases, the GPS velocity estimates are not reliable due to a change in GPS equipment, causing the short observation history to be split into two independent pieces. The site REYK shows a large (expected) relative velocity because it is located on the North-American plate. Many sites in the Mediterranean area show some movement, e.g. ANKR, NICO, MATE, and MEDI. This may be explained by the fact that the Mediterranean area is a tectonically active area where the African and Arabian plate are colliding with the Eurasian plate.

Table 2. Position and velocity RMS derived from the comparison of ITRF96, EUREF96 and EUREF97.

	# STA	POS RMS [mm]				VEL.RMS
		N	E	U	TOT	[mm/y]
EUREF96 - ITRF96	52	0.8	0.8	4.5	2.7	4.5
EUREF97 - ITRF96	53	1.3	1.7	4.2	2.8	4.7
EUREF97 - EUREF96	52	1.1	1.3	3.1	2.1	4.1

5 Outlook

A temptative list with about 20 future EUREF stations can be found at

`http: //www.oma.be//KSB-ORB/EUREF/planned.html.`

In order to assess the velocity of the European plate with respect to neighbouring tectonic plates, EUREF will try to include permanent stations from outside Europe (North-Africa,

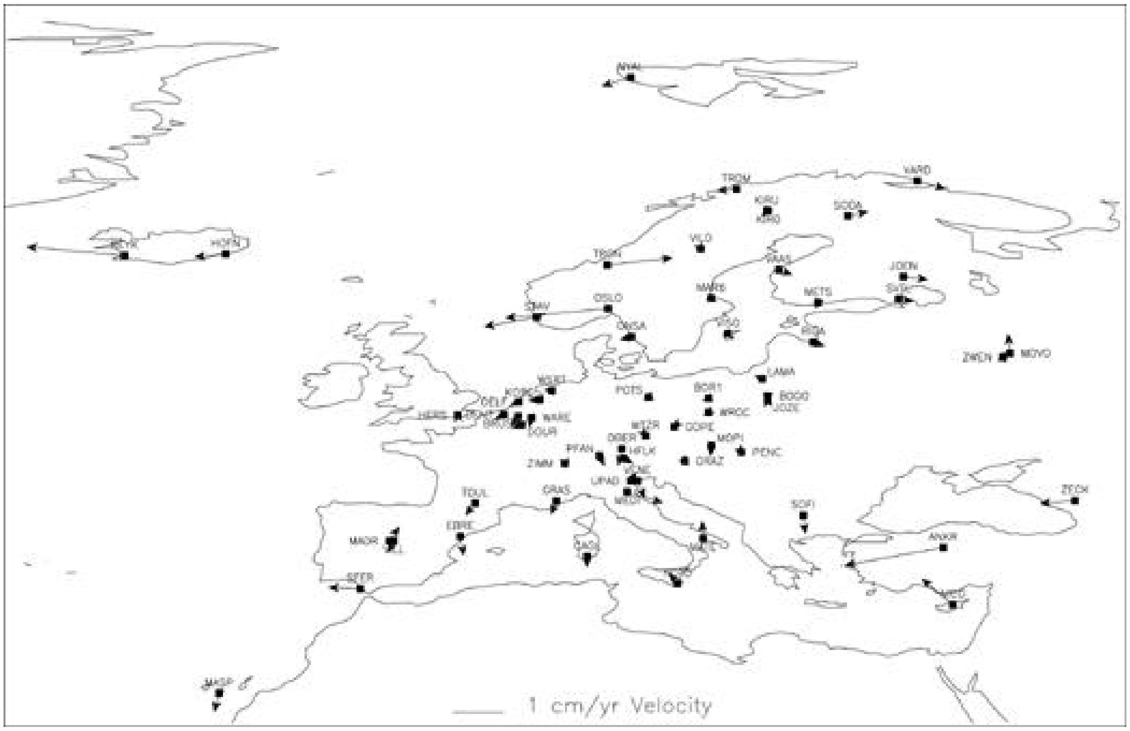

Fig. 3. : Map of the EUREF97 velocities relative to the motion of the Eurasian plate.

Middle-East) into its routine network processing. These stations will be considered as "Associated EUREF stations".

In the course of 1998, a supplementary local analysis center, located at IGN France, will be contributing to EUREF including the new permanent stations planned in France.

6 Acknowledgments

Without the labour and the commitment of the responsible agencies, their representatives at the observation sites, the data centers and the analysis centers, the EUREF network would not be the success that is it today. The authors would like to acknowledge especially the responsibles of the EUREF analysis centers who have contributed to this report : J. Dousa (Geodetic Observatory Pecny, Czech Republic), W. Ehrnsperger (Bayerische Kommission für die Internationale Erdmessung, Germany), C. Ferraro, M. Fermi, A. Nardi, C. Sciarretta and F. Vespe, (ASI Space Geodesy Center, Italy), M. Figurski and J. Rogowski (Warsaw University of Technology, Poland).

7 References

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Report of the Regional Network Associate Analysis Center for Far-East Asia.

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1 Introduction

In early 1996, a pilot project aimed at analyzing the performance of Regional Network Associate Analysis Center (RNAACs) was initiated to prove the feasibility of the concept of distributed data processing in its operational services. In response to the International GPS Service for Geodynamics (IGS)'s call for participation,Geographical Survey Institute of Japan (GSI) started to process 7 sites from its dense network with other IGS global sites.

2 Outline of the Processing

7 sites are selected for the pilot project and have been processed with International GPS Service (IGS) global tracking station. (Figure 1a,1b). Daily coordinate solutions are generated using GAMIT version 9.45 and they are combined with GLOBK version 4.0 to generate weekly constraint solutions.

- Characterizing features of the performed solutions are
- Final IGS orbits and Earth orientation parameters are applied.
- Measurement elevation angle cut off 20 degrees, sampling rate 2 minutes for single-day adjustments.
- Tropospheric zenith delays are estimated every 3 hours.
- Orbit relaxation strategy is used.
- Station coordinates estimated in the International Terrestrial Reference Frame (ITRF), applying a priori sigma of _}10 .

3 Summary

Estimated parameters are obtained as Software/Solutions Independent Exchangeable (SINEX) format and submitted to Crustal Dynamics Data Information System (CDDIS). Densification of ITRF is important in Eastern Asia Region to construct a rigorous reference frame.

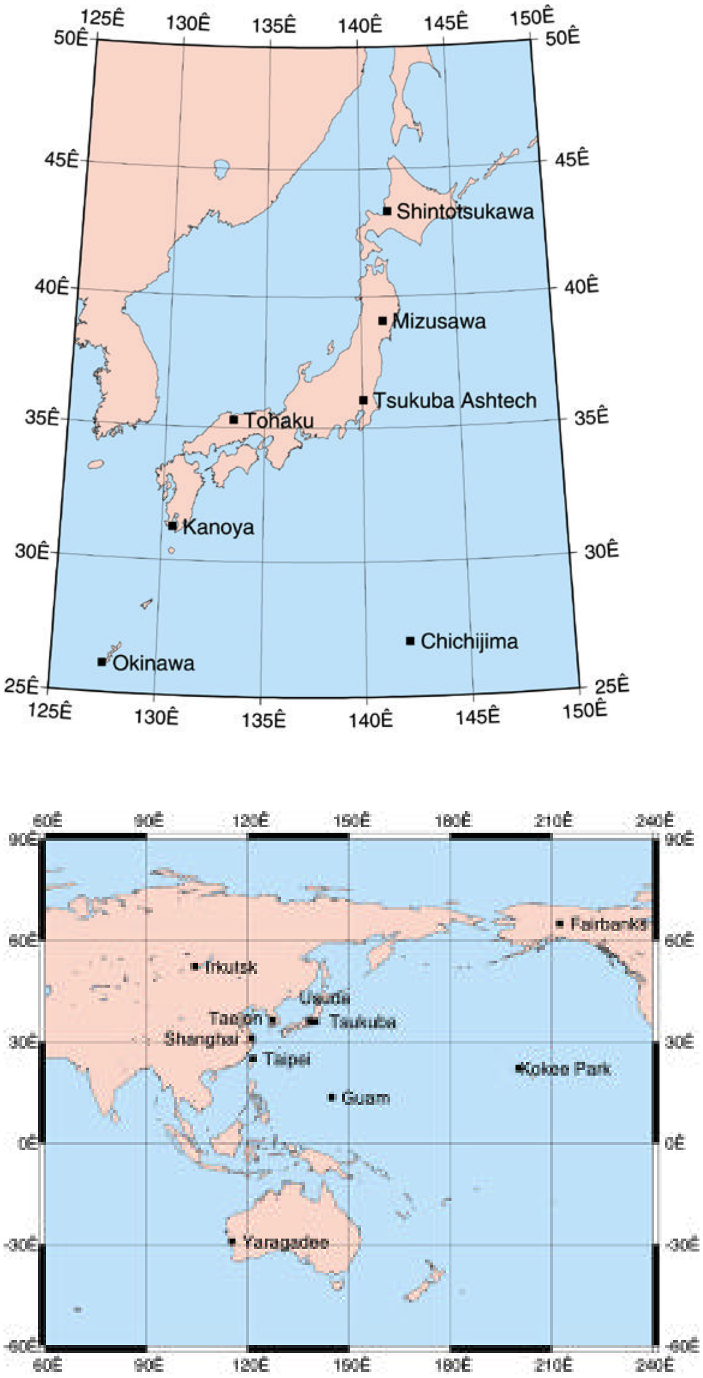

Figure 1. International GPS Service (IGS) global tracking station.

The PGC Regional Network Associate Analysis Centre: 1997 Annual Report

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1 Introduction

The Western Canada Deformation Array (WCDA) is a regional network of continuous GPS tracking stations in southwestern British Columbia established by the Geological Survey of Canada (GSC) beginning in 1991. This network currently consists of 8 sites (see Table 1) whose data, along with data from Whitehorse and Neah Bay, are analyzed at the Pacific Geoscience Centre (PGC) located in Sidney, British Columbia, 17 km north of Victoria. The purpose of the WCDA is to monitor crustal deformation along the northern Cascadia margin and thereby provide a better understanding of crustal dynamic processes and earthquake hazard in this region.

TABLE 1

Location:	Site ID:	Domes No.:	Latitude:	Longitude:	Start:
Whitehorse, Y.T.	WHIT	40136M001	60.7508	-135.2203	Jun-96
Williams Lk, B.C.	WILL	40134M001	52.2369	-122.1678	Oct-93
Holberg, B.C.	HOLB	40130M001	50.6403	-128.1350	Jul-92
Whistler, B.C.	WSLR	40141M001	50.1265	-122.9212	Sep-96
Penticton, B.C.	DRAO	40105M001	49.3225	-119.6250	Feb-91
Nanoose, B.C.	NANO	40138M001	49.2948	-124.0865	May-95
Ucluelet, B.C.	UCLU	40140M001	48.9256	-125.5413	May-94
Sidney, B.C.	PGC1	40129M002	48.6486	-123.4511	Dec-89
Victoria, B.C.	ALBH	40129M003	48.3897	-123.4875	May-92
Neah Bay, WA	NEAH	40139M001	48.2978	-124.6249	Jul-95

Table 1: *GPS sites included in the regional network analyses carried out at PGC . All sites except NEAH are operated by the Geological Survey of Canada; NEAH is operated by the University of Washington as part of the Pacific Northwest Geodetic Array (PANGA). All GSC sites use Rogue SNR-8000 receivers and Dorne-Margolin chokering antennas; NEAH currently uses an Ashtech Z12 receiver with an Ashtech Dorne-Margolin chokering antenna.*

The GSC also operates two additional stations in central Canada (see Table 2). Data for all Canadian sites (except PGC1 which is a site for testing receivers) are available via anonymous ftp from our server sikanni.pgc.nrcan.gc.ca. Alternatively, the files can be accessed through the WCDA home page at:

http://www.pgc.nrcan.gc.ca/geodyn/wcda.htm.

The daily data files are also forwarded to the Geodetic Survey of Canada, Ottawa, and to NASA's CDDIS located at Goddard.

TABLE 2

Location:	**Site**	**Domes No.:**	**Latitude:**	**Longitude**	**Start:**
Flin Flon, Man.	**FLIN**	**40135M001**	**54.7257**	**-101.9780**	**May-96**
Lac Dubonnet, Man.	**DUBO**	**40137M001**	**50.2588**	**-95.8662**	**Oct-96**

Table 2: *Continuous GPS sites in central Canada operated by the Geological Survey of Canada under a cooperative program with NASA to study glacial rebound. The Rogue SNR-8000 receivers at these sites have been provided by NASA and are supported by UNAVCO. Support for site operations is also provided in part by Manitoba Hydro.*

2 Data Analysis

Daily station solutions are obtained using an L3 double-differencing strategy with IGS final orbits held fixed and a fixed reference station (DRAO). All other stations are loosely constrained (sigmas = 10 m). The variance-covariance matrix from this differential solution is scaled by a factor of 9 to facilitate a less rigid network integration of these regional results with global results and augmented to a full matrix by including the reference station position as a loosely (sigmas = 10 m) constrained observation. (To avoid a potential non-positive definite condition of the matrix arising from numerical precision of the computing platform, the nominal XX, YY, and ZZ variances for DRAO were set at 100 + 1E-08.) Daily station solution files are combined into a weekly solution using the program "stacomb" from the Geodetic Survey Division, NRCan, Ottawa. The input files are the 7 daily station-solution Sinex files generated at PGC as well as a reduced version of the commensurate EMR weekly Sinex file which provides the coordinates and the covariances of sites common to both analyses as *a priori* constraints. The common sites are DRAO, ALBH, WILL, and WHIT. Currently, the *a priori* covariances introduced from the reduced version of the EMR weekly solution has been limited to the diagonal terms only; i.e. the *a priori* correlation between sites has been removed.

Other parameters used to characterize the WCDA regional network solution are summarized in the list below (for details see Dragert et al., 1995, and Chen, 1998):

Solution Identifier:	UT date and time stamp of combined weekly file
Software Used:	CGPS22 V1.0 (UNIX) (Kouba and Popelar, 1990)
Reference Frame:	Defined by IGS orbits (nominally ITRF94 during 1997)
Reference Epoch:	Current date
GM:	398600.4415 km^3/s^2
Gravity Model:	GEMT3(8,8) + C21 + S21
Tidal Corrections:	Solid earth tide and pole tide corrections
Ocean Loading:	Pagiatakis, global_model Note: A new table of ocean loading corrections was generated and applied beginning with GPS Week 892. The Schwiderski 1 x 1 degree global modal was used to calculate the M2, S2, K1, O1, N2, & P1 constituents; beginning with Week 894, nine constituents were used by adding K2, Q1, and Mf.
Tropospheric Model:	Stochastic coloured noise with a correlation time of 10 hr
Solution Type:	L3 double-differenced phase (ionosphere-free linear combination of L1 and L2) with orbits held fixed & ambiguities not held fixed
Solution Basis:	120 sec intervals using all available satellites (max. 8) above 15^o elevation

3 Results

The precision of the daily network solutions is gauged by the L3 double-difference phase range residuals averaged over all satellites and all stations. In general, the average of these residuals vary from 6 to 9 mm. Formal errors for the daily solutions of network station locations relative to the reference station (DRAO) are less than 1, 2 , and 4 mm for relative latitude, longitude, and height respectively. More realistic estimates of errors are given by the day-to-day variations of relative positions which have sigmas that are double the values listed above.

Detailed analysis of temporal variations in the relative positions of network sites have resolved secular motions at the level of a few millimetres per year and also revealed significant transient signals of non-tectonic origin. For sites on southern Vancouver Island, velocity estimates based on linear trends in daily solutions of relative positions are in general agreement with current (pseudo) three-dimensional elastic models of a locked thrust fault. The margin-parallel motion of the GPS site on northern Vancouver Island (HOLB) is more consistent with shear-strain expected from Pacific Plate/North America Plate interaction across northwest trending strike-slip faults as opposed to elastic shortening across a locked convergent margin.

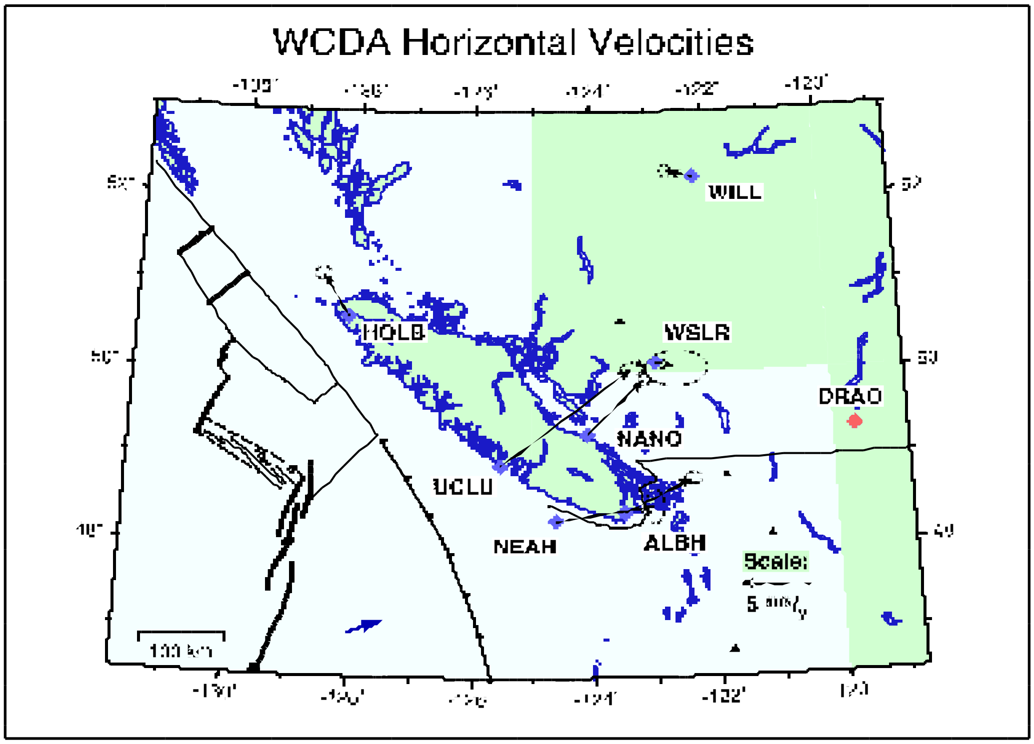

Figure 1: *Horizontal motions of WCDA network sites relative to DRAO estimated from linear trends in the daily solutions. Length of observations at each site vary from over 4 yr to less than 2 yr.*

The linear trends obtained from regressions on daily GPS solutions of relative site positions which form the basis of the crustal velocity estimates are made more uncertain by instrumental effects and by transient signals of non-tectonic origin. For example, changes in the position of the antenna phase centres as large as 3 mm in the horizontal and 19 mm in the vertical have been observed to accompany changes in the physical mounting of the antennas. Annual and semi-annual signals with amplitudes of several millimetres have been observed predominantly in the relative vertical components for almost all network sites. Non-stationary spectral peaks with amplitudes as large as 7 mm also appear in the relative vertical components in the period range of 10 to 20 days. The exact causes of these non-linear temporal variations are not known. However, the amplitudes of some of these signals appear to vary with elevation cut-off used in the analyses, indicating a near-field multipathing effect as a possible factor in these phase-centre changes.

Large sudden offsets in the phase centres of antennas are the most detrimental to unbiased estimates of linear trends in a station's time series. Table 3 provides a chronology for all WCDA sites of when physical changes were made in the set-up of the antennas which resulted in an apparently significant (2 to 3 mm in the horizontal; 5 to 20 mm in the vertical) change of relative position. The magnitudes of these changes are strongly dependent on the nature of the GPS data analysis (L3 solution; double differencing; elevation cut-off; etc.); consequently, no absolute calibration of these steps can be provided. If data from WCDA sites are being used to estimate absolute or relative crustal motions, Table 3 can be used to flag times when discontinuities may have occurred.

Table 3

Date	Site	Description of Changes
94:041	DRAO	New antenna; New antenna mount;
94:124	HOLB	New antenna;
94:173	WILL	Added acrylic dome & mounting ring;
95:011	ALBH	New antenna mount;
95:103	DRAO	New antenna mount;
95:158	ALBH	New antenna;
95:189	WILL	New antenna mount; Added RF screening skirt;
95:202	ALBH	Added RF screening skirt;
95:223	UCLU	Added RF screening skirt;
96:010	DRAO	Added RF screening skirt;
96:046	NANO	Added RF screening skirt;
96:089	HOLB	New antenna mount;
97:033	NEAH	New antenna; New Ashtech cone dome;

Table 3: Listing of changes in the antenna set-up at WCDA sites which affected the mean phase-centre positions. Dates give year followed by the Julian day.

4 References

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Annual Report 1997 of the RNAAC SIRGAS

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1 Introductions

The IGS Regional Network Associate Analysis Center for the South American Reference System (RNAAC SIRGAS) is processing, on a weekly basis, all available data of permanently observing GPS stations in the mainland of South America and the surrounding areas. The resulting station coordinates solutions are routinely forwarded as SINEX files to the IGS Global Data Centers, and then combined within the polyhedron solutions of the Global Network Associate Analysis Centers (GNAAC). In early 1998, there are 22 stations included in these solutions.

2 Station Network

The RNAAC SIRGAS configuration has been extended in 1997 by including four new stations in Brazil (Cuiaba, Imperatriz, Manaus, Vicosa), and one in Venezuela (Maracaibo). Instead of the two global IGS stations Bermuda and Richmond, the new station Barbados was included as a reference station. The complete actual network is shown in Figure 1.

Figure 1: Network processed by the IGS RNAAC SIRGAS

3 Processing and Results

The processing is continuously done using the automated Bernese Software Version 4.0 (Rothacher and Mervart 1996). The results are controlled by daily and weekly time series comparisons (see also Seemueller and Drewes 1998). A typical example is shown for the new station Vicosa in figure 2. We clearly see the broad variations of the diurnal solutions (only weakly constrained in the IGS orbits reference frame) and the smooth behaviour in the GNAAC‘s weekly global polyhedron solutions (constrained by IGS stations in the ITRF). The deviations between both solutions, RNAAC and GNAAC, are typically in the sub-centimeter level for horizontal components and one to two centimeters in the vertical.

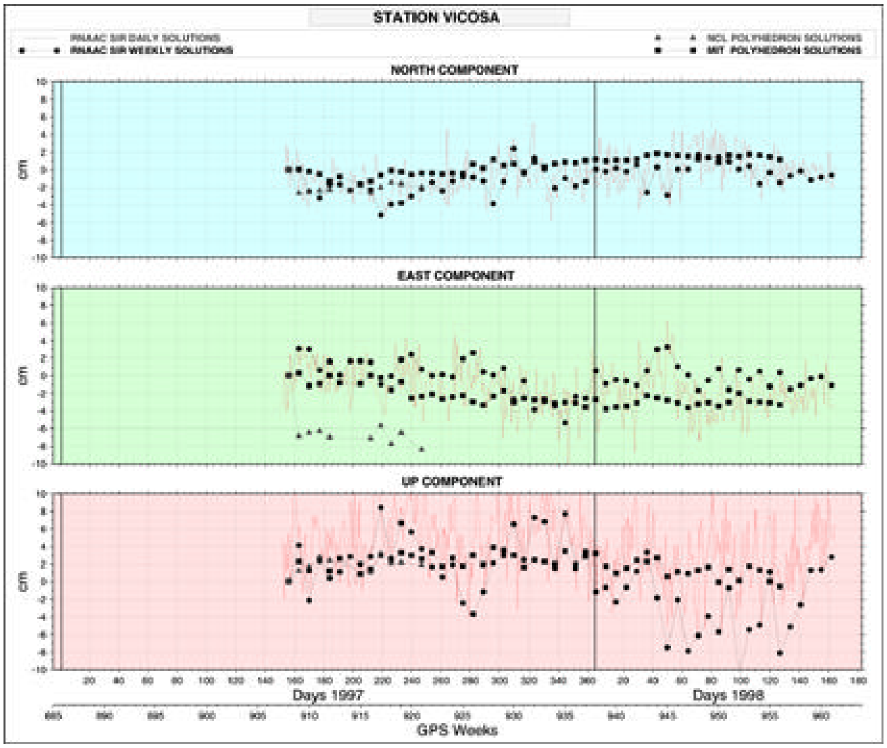

Figure 2: Variations of coordinate solutions for station Vicosa (Brazil)

4 References

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Seemueller, W. and H. Drewes: The IGS Regional Network Associate Analysis Center for South America at DGFI. Proc. IGS Analysis Center Workshop, Darmstadt, 1998