Processing of GPS Data at the Taiwan Central Weather Bureau (CWB) for Station Coordinate and Troposphere Estimation

Overview

This document contains the operational instructions to analyze GPS data for PWV retrieval using the Bernese V5.0 software at CWB. It contains information regarding external data sources and types, necessary a-priori information, instructions on how to initiate automatic processing, and a summary of significant output files that are generated from the processing. Figure 1 contains a brief schematic description of the daily analysis of data. Additional information regarding GPS theory, external data sources, and processing strategies can be found in the presentation files from the August 2007 training classes at CWB, and the Bernese V5.0 software manual.

The processing for CWB ground-based GPS data analysis contains near-real-time processing (NRT) and daily processing (DP). NRT processes 1-hour and 2-hour GPS data separately with the input of NRT data and a part of DP product. DP is similar to NRT in data flow design but processes 24-hour data instead, and finally outputs weekly coordinate data for NRT as an a priori parameter.

The result is shown on the TiMREX web site at taccop3g (http://taccop3g.cwb.gov.tw/timrex/). A part of important files will be archived to MSS at CWB.

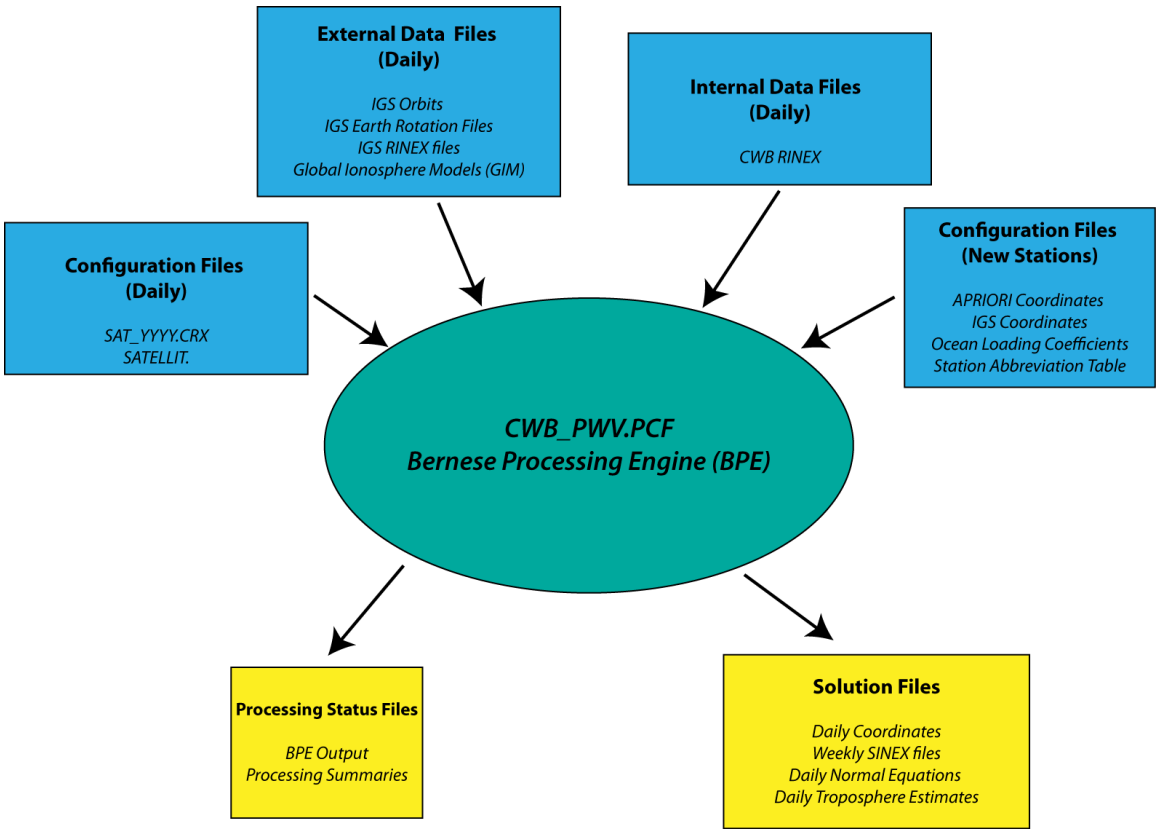

Figure 1: Flow chart of daily processing with Bernese. Input files (blue), Bernese processing (green), and output files (yellow) are shown.

Installation guide

The software is designed for Linux platform. Currently it is installed and run on CentOS Linux 4.6. Software requirements as below:

- Bernese Version 5.0
- Perl (see Bernese software requirements)
- Fortran compiler (see Bernese software requirements)
- GMT Version 4.2.1 (for web interface)
- Mason, the latest version (for web interface)
- Apache server, the latest version (for web interface)

Define the environment variable %MEMSIZE% with LARGE in Bernese for a large number of baselines during Bernese install. Update Bernese with new releases in Version 5.0 if available.

Campaign configuration

Please refer to the Bernese manual (Chapters 1 and 3) for a detailed description of the directory structure of the Bernese software environment and work area. The initial step in data analysis with Bernese is to define a work environment to store and create observation and solution files. This analysis area is called a campaign area. A new campaign should be created using the menu system. First define a new name (Campaign -> Edit list of campaigns), and then create a new campaign work area (Campaign -> Create new campaign). This campaign should then be selected when using the menu system for analysis (Campaign -> Select active campaign). Once the campaign area has been created, the following list of configuration and input files needs to be created.

Station abbreviation file: A translation table is needed to help naming the zero and single difference files based on the 16-character name of each station. This table is used to create all observation files in the campaign OBS directory (e.g. $P/CWB_NRT/OBS). These files use an eight-character structure to define the base name with the first four characters used to specify the station (or stations) and the last four characters to specify the session. The station abbreviation information is contained within a single file in the campaign STA directory (e.g. $P/CWB_NRT/STA). The default name of this file is ABBREV.ABB, the ABB extension is mandatory but the base name can be modified (although this is not recommended). An example of this file is shown in Table 1. The abbreviation file can be manually edited, or updated in the program RXOBV3 when a new station name is found within a RINEX file (PID 020). Currently the CWB_PWV.PCF will update the abbreviation file when a new station name is found.

Table 1: Station abbreviation file (ABBREV.ABB) used to name Bernese observation files.

```
BPE TRANSLATION OF RINEX FILES SESSION 08SS                    28-FEB-08 06:24
------------------------------------------------------------------------------

Station name             4-ID    2-ID    Remark
****************         ****     **     ***************************************
AKND                     AKND     AK     Added by SR updabb
ALIS                     ALIS     AL     Added by SR updabb
BAKO 23101M002           BAKO     BA     Added by SR updabb
BJFS 21601M001           BJFS     BJ     Added by SR updabb
BLOW                     BLOW     BL     Added by SR updabb
CCJM 21732S003           CCJM     CC     Added by SR updabb
CHNT                     CHNT     CH     Added by SR updabb
CHUN                     CHUN     CU     Added by SR updabb
CTOU                     CTOU     CT     Added by SR updabb
DAEJ 23902M002           DAEJ     DA     Added by SR updabb
DAHU                     DAHU     DH     Added by SR updabb
DARR 50134M001           DARR     DR     Added by SR updabb
DCHU                     DCHU     DC     Added by SR updabb
DNAN                     DNAN     DN     Added by SR updabb
```

```
DPIN                    DPIN     DP     Added by SR updabb
DSIN                    DSIN     DS     Added by SR updabb
DULI                    DULI     DU     Added by SR updabb
FENP                    FENP     FE     Added by SR updabb
```

Fixed network files: Accurate and precise GPS estimates of coordinate and troposphere products require solutions that are properly aligned to a global reference frame. Currently, the IGS products are produced within the IGS05 frame. Please refer to the Bernese manual (Chapter 10) for a more detailed discussion on this topic. The CWB network is constrained to the IGS05 when computing network station coordinate solutions. The constraints are applied through the selection of stations (IGS tracking stations) to either a-priori coordinates or through the minimization of a transformation of selected stations onto the published IGS05 coordinates. Two files must be created. The first is named HELMER.FIX, it should be saved to the campaign STA directory (e.g. $P/CWB_NRT/STA/). An example of this file is shown in Table 2. This file is used when computing network coordinate solutions in the program ADDNEQ2 (PID 045 and 061 for NRT; 045, 070 and 076 for DP).

Table 2: HELMER.FIX file used to specify which stations to use for minimum constraint solutions in the program ADDNEQ2.

```
Stations to Use for Minimum Network Constraints to IGS_00B       07-SEP-07 10:33
------------------------------------------------------------------------------

Station name
****************
DARR 50134M001
GUAM 50501M002
LHAS 21613M001
NTUS 22601M001
SHAO 21605M002
TSKB 21730S005
```

The second file should be named NETWORK.SIG. It should also be saved to the campaign STA directory (e.g. $P/CWB_DP/STA). This file is used when computing the daily network coordinate solutions using the program GPSEST (PID 060 for DP). An example is shown in Table 3.

Table 3: NETWORK.SIG file used to constrain station coordinates onto their a-priori values in the program GPSEST (PID 060).

```
NETWORK STATION CONSTRAINTS                                    22-AUG-07 11:14
------------------------------------------------------------------------------

Station name            sigma1    sigma2    sigma3
****************       **.****   **.****   **.****
DARR 50134M001          0.0005    0.0005    0.0005
GUAM 50501M002          0.0005    0.0005    0.0005
LHAS 21613M001          0.0005    0.0005    0.0005
```

```
NTUS 22601M001          0.0005    0.0005    0.0005
```

CWB Data Sources

There are two data sets of ground-based CWB GPS input data files: 2 hour data in T00 format for DP and 2-hour NRT; 1 hour data in RINEX format for DP, 1-hour NRT and 2-hour NRT. Both data sets are received by Seismology Center and forwarded by AMDP in CWB to /pub/cwb/t00 directory on taccop4g. The file sequence number (or letter) at the 8th digit of each file indicates the first epoch of each file: number 0 indicates 00 UT; 1 indicates 01 UT; A indicates 10 UT, B indicates 11 UT, etc.

External Data Sources

The precise and accurate analysis of GPS data to retrieve PW estimates requires multiple external data products. This includes raw data from IGS stations, IGS satellite orbit and earth rotation files, ionosphere model files from the Center for Orbit Determination in Europe (CODE), a-priori station coordinates for IGS reference stations, and ocean loading information for all GPS stations that are to be analyzed. Specific locations and details for each data type are given in the following sections.

IGS Orbit and Earth Rotation Information: IGS orbit and earth rotation files can be retrieved from the IGS archive centers. A list of centers is given in Table 4. Satellite orbit must be used with their accompanying earth orientation files. These two files help define the global reference frame. Orbit and earth rotation files are should be downloaded into the campaign ORB directory (e.g. $P/CWB_07/ORB).

Table 4: IGS Archive Centers with Orbit and Earth Rotation Information

Archive Center	Path
CDDIS	ftp://cddis.gsfc.nasa.gov/gps/products/WWWW/
SOPAC	ftp://garner.ucsd.edu/pub/products/WWWW/
IGN	ftp://igs.ensg.ign.fr/pub/igs/products/WWWW/
IGSCB	ftp://igscb.jpl.nasa.gov/pub/product/WWWW/

NOTE: A perl program called GetOrb.pl, located in the ~john/bin directory on the taccop4g computer, can be used to download satellite orbit and earth orientation files from the various IGS archive centers.

IGS RINEX: Raw data from IGS tracking stations are needed to properly constrain the CWB network into a global reference frame and ensure that the aperture of the GPS network that is to be analyzed is large enough to guarantee that the zenith wet delay estimates are absolute quantities. Failure to include these files into the analysis will create systematic errors in the station coordinate solutions and zenith wet delay estimates. A suggested list of IGS stations to include in the CWB analysis is given in Table 5. It is not

necessary to include all the listed stations into the daily analysis, but it is highly recommended to include as many stations as possible. Coordinate and total zenith delay estimates from these sites can be compared to official IGS solutions to evaluate the accuracy of CWB solutions.

Table 5: IGS Tracking Stations Near Taiwan. Stations in parenthesis indicate no data released currently.

(BAKO)	(BJFS)	CCJM	DAEJ	(DARR)	GUAM	(KUNM)
(LAE1)	(LHAS)	(MCIL)	MIZU	(NTUS)	PIMO	SHAO
(TCMS)	(TNML)	TSKB	(WUHN)	(XIAN)		

Data from the IGS tracking stations are available in RINEX format from the archive centers listed in Table 6. All stations produce daily files, and some stations produce files at hourly and 15-minute intervals. These sub-daily files are used for near real-time processing which will be addressed later. Daily RINEX files should be placed in the RAW directory of the processing area (e.g. $P/CWB_DP/RAW).

Table 6: IGS Archive Centers with Tracking Data

Archive Center	URL
CDDIS	ftp://cddis.gsfc.nasa.gov/pub/gps/data/hourly/YYYY/ ftp://cddis.gsfc.nasa.gov/pub/gps/data/highrate/YYYY/ ftp://cddis.gsfc,nasa.gov/pub/gps/data/daily/YYYY/
SOPAC	ftp://garner.ucsd.edu/pub/nrtdata/YYYY/ ftp://garner.ucsd.edu/pub/rinex/YYYY/
KSI	ftp://nfs.kasi.re.kr/gps/data/hourly/YYYY/
CORS	ftp://cors.ngs.noaa.gov/cors/rinex/YYYY/
UNAVCO	ftp://data-out.unavco.org/pub/rinex/obs/YYYY/

A perl program named GetRnx.pl and GetRnx_rt.pl, located in the ~john/bin directory on the taccop4g computer, can be used to assist in the download of RINEX data from IGS archive centers.

CODE Global Ionosphere Model (GIM) Files: Global Ionosphere Models (GIMs) are used in the CWB_NRT.PCF and CWB_PWV.PCF when resolving ambiguities using the Quasi-Ionosphere Free (QIF) method within the Bernese software. QIF ambiguity resolution is performed in PID 050, 051, and 052. Please refer to Chapters 8 and 12 of the Bernese V5.0 manual for further details regarding ionosphere modeling and QIF ambiguity resolution.

A GIM file must be downloaded from the CODE anonymous ftp area (ftp://ftp.unibe.ch/aiub/CODE/) and placed in the campaign ATM directory (e.g. $P/CWB_NRT/ATM). The perl program named GetIon.pl, located in the ~john/bin directory on the taccop4g computer, can be used to download GIM files produced by the Center for Orbit Determination in Europe (CODE).

A-priori Coordinate Information: The published coordinates of the IGS tracking stations that comprise the ITRF and IGS reference frames should be used as a-priori information. Coordinate and station velocity files are available from the University of Bern anonymous ftp site (ftp://ftp.unibe.ch/aiub/BSWUSER50/STA/). The current reference frame for GPS analysis is the IGS05 frame. Download the published coordinate IGS05.CRD or IGS_*MMYY*.CRD (e.g., IGS_0608.CRD for June 2008) and velocity (IGS05.VEL) file and place this into the campaign STA directory (e.g. $P/CWB_DP/STA). These files can be edited to include only the coordinate and velocity information for the selected IGS tracking stations that will be included in the daily analysis.

The a-priori coordinates for all CWB stations must be specified in the APRIORI.CRD or APR_*MMYY*.CRD file in the campaign STA directory (e.g. $P/CWB_DP/STA). All stations that are to be included in the analysis should have an entry in either the IGS05.CRD (and IGS05.VEL) or the APRIORI.CRD coordinate file. The processing will fail if a station is included in the analysis that does not have an entry in either of these two a-priori coordinate files.

Ocean Loading Information: Ocean loading coefficients are needed to properly model the deformation of the Earth's surface due to mass loading of ocean tides. The Onsala Space Observatory (OSO) provides a free service to compute ocean loading tidal coefficients. This service can be access through the following URL: http://www.oso.chalmers.se/~loading/. The table below defines the various options to select within the OSO tidal page.

Table 7: Ocean Loading Information

Option	Selection
Ocean tide model	FES2004
Type of loading	Vertical and horizontal displacements
Correct for motion	NO
Type of output	BLQ

Each GPS station that will be analyzed will need its own set of tidal coefficients. Submit a station name and coordinate (in either earth-centered earth-fixed Cartesian coordinates or in ellipsoidal coordinates) to the OSO service and the tidal coefficients (in BLQ format) will be mailed to a specified email address after they have been successfully computed. Save the resulting BLQ information within the STA directory of the processing directory (e.g. $P/CWB_NRT/STA). The file needs to have the BLQ extension on the file name (e.g. FES2004.BLQ).

Satellite Problem File: CODE maintains a file identifying problems with satellites that impact data quality and usefulness. This file is updated continuously as problems with

individual satellites are discovered. A current copy is available through the CODE anonymous ftp area (ftp://ftp.unibe.ch/aiub/BSWUSER50/GEN/SAT_YYYY.CRX, where YYYY is the specific year). A copy of this file should be kept in the $X/GEN/ directory, using the same SAT_YYYY.CRX name format.

Satellite Information File: GPS satellites have slightly different dimensions, mass, and antenna phase center characteristics depending on what block type of the satellite (II, IIA, II-R, etc). This information must be known to accurately compute satellite orbits and model the GPS observations. CODE maintains a file with each of the satellites characteristics and makes it available through their anonymous ftp server (ftp://ftp.unibe.ch/aiub/BSWUSER50/GEN/
SATELLIT.). This file should be downloaded and saved to the $X/GEN directory, it needs to be updated with the launch of each new satellite.

Processing Data

Processing Scheduling: Six processings should be scheduled: satellite problem file fetching, DP, 1-hour NRT [TBD], 2-hour NRT, NRT status reporting and data archiving [TBD]. An example of how the scheduling is used by crontab in Linux platform is shown in Table 8.

Table 8: An example of crontab

```
# CRON SCRIPT TO FETCH SATCRUX FILE FROM BERN
45 12 * * * sh ~john/bin/b50_gen_cron_cmd 1 ;
# CRON SCRIPT FOR DAILY PROCESSING WITH IGR ORBITS
30 3 * * * sh ~john/bin/cwb_day_cron ;
# CRON SCRIPT FOR CWB NEAR-REALTIME ANALYSIS (2-HOUR SESSIONS)
5 1,3,5,7,9,11,13,15,17,19,21,23 * * * sh ~john/bin/cwb_nrt_cron ;
# CRON JOB FOR CWB NEAR-REALTIME STATUS REPORT
*/15 * * * * sh ~john/bin/nrt_oper ;
```

In this crontab, satellite problem files of the previous day are retrieved at 1245 CST (Central Standard Time in Taiwan) every day; DP is executed at 0330 CST (and lasts for ~2 hours); 2-hour NRT is executed 0105, 0305, 0505, etc. CST (and lasts for ~30 minutes where ~7 minutes for data pulling and the rest for processing); NRT status is reported every 15 minutes.

Daily Processing: Data analysis can begin only after the campaign analysis area (e.g. $P/CWB_DP) has been properly created and the input data files (orbit files, earth rotation files, a-priori coordinates, RINEX observations, GIM files, etc.) have been placed in their appropriate locations. DP can then be initiated either through the menu system (Menu -> BPE -> Start BPE Process), or through a command line instruction (e.g., cwb_day, which is called by cwb_day_cron in Table 8). The shell script cwb_day calls several sub-scripts as below:

- GetRnx.pl: Fetch daily RINEX observation files from IGS network
- GetMet.pl: Fetch daily RINEX meteorology files from IGS network (perl file not available)
- GetCwbRnx.pl: Convert 2-hour CWB T00 files to RINEX format
- UPPERC2: Convert data file names to uppercase
- SmosGrd: Interpolate AWS and Mesonet records
- GetOrb,pl: Fetch IGR orbit files from IGS
- GetIon.pl: Fetch GIM files from CODE
- cwb_pcs.pl: Initiate BPE processing

The perl script $U/WORK/cwb_pcs.pl can also be used to initiate BPE processing through the command line (see $U/WORK/cwb_test).

Near-Real-Time Processing: The shell script cwb_nrt, which is called by cwb_nrt_cron in Table 8, includes sub-scripts as below:

- GetRnx_rt: Fetch hourly RINEX observation files from IGS network
- GetCwbRnxNrt.pl: Convert 2-hour T00 files to RINEX format
- GetCwbRnxNrt_rt17.pl: [TBD]
- UPPERC2: See above
- SmosGrd: See above
- GetOrb.pl: See above
- GetIon.pl: See above
- cwb_nrt.pl: Initiate BPE processing
- cwb_grid_pwv.pl [TBD]
- parseStaPwv.pl: [TBD]
- pltStaTimeSeries.pl: [TBD]

The August 2007 lectures at CWB, and the Bernese manual (Chapter 19), both contain detailed information on how to BPE is designed and initiated. Please refer to these documents for further details.

PCF Design

The procedure control file (PCF) is designed for BPE processing, which includes PID (process ID), script names, option directory (OPT_DIR), etc. (see Appendix 1)

Daily Processing: Daily PCF (e.g., $U/PCF/CWB_PWV.PCF) is designed as Appendix 1. Description for the series of Bernese programs as below:

- COOVEL: Extrapolate velocity field from IGS coordinate file to compute the current coordinates for all applied IGS stations
- CRDMERGE: Merge coordinate files using station flags (there is no velocity field provided by CWB so this script does not merge velocity files here)
- POLUPD: Create pole file in Bernese format
- PRETAB: Generate a tabular file from precise ephemeride
- ORBGEN: Generate standard orbits from tabular ephermeride
- RNXGRA: Create graphic table of RINEX observations for investigation of data quality
- RXOBV3: Transform a RINEX observation file into Bernese files
- CODSPP: Process pseudo-range observables
- CODXTR: Extract the result from CODSPP output
- SNGDIF: Form single difference files from zero difference files (phase or code?)
- MAUPRP: Preprocessing program for single difference files
- MPRXTR: Extract the most important informations from the MAUPRP output file
- GPSEDTAP: Prepare parallel double difference data screening step
- GPSEDT_P: Double difference data screening
- GPSRMSCK: Check double difference data screening results and reject, when indicated, data of misbehaving stations [TBD]
- ADDNEQ2: Stack normal equations to check if any stations have bad solution (no ambiguity here)
- GPSXTR: Extract statistic information of the ADDNEQ2 job output files for all baselines solution
- GPSQIFAP: Prepare parallel QIF ambiguity resolution process for a set of selected baselines, which solves as many ambiguities as possible
- GPSQIF_P: Execute GPSEST for QIF ambiguity resolution
- GPSXTR: Extract information of the GPSEST job output files in a format suitable to be included into the daily protocols [TBR]
- GPSEST: Estimate relevant parameters, including daily tropospheric delay,

coordinates of all receivers, all of ambiguity solutions, etc., from GPS carrier phase observables (and code observables?)

- ADDNEQ2: Combine seven NQ0 files into a weekly NQ0 files (as the solution at the beginning and the end of epochs are looser in accuracy; the combination makes the solution at the final epoch of the previous day identical with the solution at the first epoch of the next day, i.e., no data jump occurs)
- GPSEST: Estimate relevant parameters daily from GPS carrier phase observables (and code observables?) with fixed (precise) coordinates
- ADDNEQ2: Estimate ZTD for 2-day worth of data (i.e., TD_wwwwd.TRP; but this program has been skipped, see $$bpe{SCRIPT_SKIP} in $U/SCRIPT/cwb_pcs.pl)
- TRO_2PW: Estimate PW from ZTD and surface parameters [TBR]
- SES_CLN: Delete unnecessary files related to session processing
- SES_SUM: Create summary files of daily processing

Near-Real-Time PCF: NRT PCF (e.g., $U/PCF/CWB_NRT.PCF) is designed as Appendix 2. Description for the series of Bernese programs as below:

- POLUPD: Translate pole files into Bernese format
- PRETAB: Generate a tabular file from precise ephemeride
- ORBGEN: Generate standard orbits and satellite clocks from tabular ephemeride
- RNXGRA: Create graphic table of RINEX observations for investigation of data quality
- RXOBV3: Transform a RINEX observation file into Bernese files
- CODSPP: Process pseudo-ranges to compute receiver's clocks, which allows the following double difference own true distance between GPS satellites and receivers
- CODXTR: Extract the result from CODSPP output
- SNGDIF: Form single difference files from zero difference files (phase only and only n-1 files if there are n stations)
- MAUPRP: Clean single differences of cycle slips
- MPRXTR: Extract the important informations from the MAUPRP output file
- GPSEDTAP: Prepare parallel double difference data screening step
- GPSEDT_P: (includes GPSEST, RESRMS, SATMRK, GPSEST): Double difference data screening

- GPSRMSCK (includes RESRMS, RESRMS, RESCHK): Check double difference data screening results and reject, when indicated, data of misbehaving stations [TBD]
- ADDNEQ2: Stack normal equations (i.e., combine all baseline solution) to check if any stations have bad solution
- GPSXTR: Extract information from ADDNEQ2 job output files for all baselines solution in a format suitable to be included into the daily protocols [TBD]
- GPSQIFAP (includes BASLST): Prepare parallel QIF ambiguity resolution process for a set of selected baselines
- GPSQIF_P (includes GPSEST): Compute network solution based on ambiguity-free solutions
- GPSXTR: Extract information from GPSEST job output files in a format suitable to be included into the daily protocols [TBD]
- GPSEST: Estimate relevant parameters from GPS carrier phase observations (and code observables?)
- STK_NEQ (includes ADDNEQ2): Estimate 2-hour ZTD and then combine them into 12-hour TRP
- TRO_2PW: Estimate PW from TRP files and surface parameters [TBD]
- TRO_2PW: [TBD]
- SES_CLN: Delete unnecessary files related to session processing
- SES_SUM: Create summary files of the NRT processing
- DUMMY: [TBD]

Checking Process Status

Assuming that a campaign has been properly set up and that all internal RINEX observation files and external data (orbits, IGS RINEX files, etc) are available, the BPE should automatically run through each section of the analysis. Please refer to the August 2007 CWB training notes and the Bernese manual (Chapter 19) for a more complete description on how to interpret the status files produced by the BPE. The progress of the analysis can be monitored through a number of output files that are written to the campaign BPE directory (e.g. $P/CWB_NRT/BPE). These files are described in the following section.

BPE Server Status: When data for an individual session is being analyzed, the BPE server creates a log file that summarizes all processes that have been completed. An example of this summary file is shown in Table 9. This file contains the start and stop

times of each PID and script that is executed by the BPE. It also contains a status report identifying the exist status of each PID. Problems with BPE processing can first be identified from this file, quickly identifying what PID failed in the analysis.

Table 9: BPE server output and status file (RUNBPE.OUT).

```
Time                 Sess PID      Script   Option     Status
-------------------------------------------------------------------------------
11-Jun-2008 01:28:53  162O YR:2008  CWB_NRT           : Server started at 44231
11-Jun-2008 01:28:57  162O 003_000  POLUPD   NRT_ORB  : Client started
11-Jun-2008 01:28:57  162O 003_000  POLUPD   NRT_ORB  : Script started
11-Jun-2008 01:28:58  162O 003_000  POLUPD   NRT_ORB  : Script finished  OK
11-Jun-2008 01:28:58  162O 010_000  PRETAB   NRT_ORB  : Client started
11-Jun-2008 01:28:58  162O 010_000  PRETAB   NRT_ORB  : Script started
11-Jun-2008 01:28:59  162O 010_000  PRETAB   NRT_ORB  : Script finished  OK
11-Jun-2008 01:28:59  162O 011_000  ORBGEN   NRT_ORB  : Client started
11-Jun-2008 01:28:59  162O 011_000  ORBGEN   NRT_ORB  : Script started
11-Jun-2008 01:29:03  162O 011_000  ORBGEN   NRT_ORB  : Script finished  OK
11-Jun-2008 01:29:03  162O 019_000  RNXGRA   NRT_ZDP  : Client started
11-Jun-2008 01:29:03  162O 019_000  RNXGRA   NRT_ZDP  : Script started
11-Jun-2008 01:29:06  162O 019_000  RNXGRA   NRT_ZDP  : Script finished  OK
11-Jun-2008 01:29:06  162O 020_000  RXOBV3   NRT_ZDP  : Client started
11-Jun-2008 01:29:06  162O 020_000  RXOBV3   NRT_ZDP  : Script started
11-Jun-2008 01:29:12  162O 020_000  RXOBV3   NRT_ZDP  : Script finished  OK
11-Jun-2008 01:29:12  162O 021_000  CODSPP   NRT_ZDP  : Client started
11-Jun-2008 01:29:12  162O 021_000  CODSPP   NRT_ZDP  : Script started
11-Jun-2008 01:29:39  162O 021_000  CODSPP   NRT_ZDP  : Script finished  OK
11-Jun-2008 01:29:39  162O 022_000  CODXTR   NRT_ZDP  : Client started
```

BPE protocol files: Each PID in the PCF produces its own protocol file (with extension PRT) file in the BPE output directory (e.g. $P/CWB_NRT/BPE). An example protocol file is shown in Table 10. This file contains the general configuration of the processing run (Campaign, session, year, PCF, etc) and then lists each script and program that is execute within the specific process ID (PID). This PRT file is used to confirm the successful completion of a processing step and to initially identify a problem when the BPE process does not successfully finish. When problems arise within the data analysis, the PRT files are the first place to investigate the potential points of failure.

Table 10: BPE protocol file for an individual process id.

```
PROTOCOL FILE FOR BPE SCRIPT
----------------------------
Campaign           : ${P}/CWB_NRT
Year               : 08
Session            : 162O
PCF name           : CWB_NRT.PCF
Script name        : TRO_2PW
Path to executables: ${XG}
Option directory   : NO_OPT
Process ID         : 063
Sub-process ID     : 000
Server host        : taccop4g.cwb.gov.tw
Remote host        : taccop4g.cwb.gov.tw
```

```
CPU name           : localhost
Path to work area  : /home/john/GPSTEMP/BPE_CWB_NRT_44231_08_162O_063_000
User name          : john

Date         Time      Run time  Pgm.time  Sta Program   Message
-------------------------------------------------------------------------
11-JUN-2008  01:37:29  00:00:00            MSG RUNBPE.pm SCRIPT  STARTED
11-JUN-2008  01:37:29  00:00:00            MSG RUNBPE.pm SCRIPT  STARTED
11-JUN-2008  01:37:32  00:00:03            MSG RUNBPE.pm SCRIPT  ENDED
-------------------------------------------------------------------------
```

Significant Output Files

When the processing for a day has successfully been completed, there are a number of significant output files. These files include daily coordinate estimates, weekly coordinate estimates, weekly SINEX solutions' daily normal equation files, daily troposphere estimate files, and a summary file that contains information on the quality of each solution. These files should all be properly saved to ensure a minimally complete summarization of each session solution. These files are described in the following sections.

Daily coordinate solutions: A coordinate file is produced for each daily session that is processed. This network solution is computed in PID 060 of the CWB_PWV.PCF. The output coordinate file is written to the campaign STA directory (e.g. $P/CWB_DP/STA) and will have the format NETWWWWD.CRD (where the WWWW is the GPS week number and the D is the day of the week). One file is produced for each day that is analyzed.

Daily Normal Equation files (NQ0): The daily NQ0 file associated with the coordinate estimates is saved in the campaign SOL directory (e.g. $P/CWB_DP/SOL), and has the format: NETWWWWD.NQ0 where the WWWW is the GPS week and D is the day of week of the session. These files are produced in PID 060, and are used to compute the weekly coordinate solutions using the program ADDNEQ. Many days of NQ0 files can be combined to estimate station coordinate and velocity information for tectonic deformation studies.

Weekly coordinate solutions: The daily coordinate solutions are combined together to produce a weekly coordinate solution (PID 070 and 071). This combination results in a coordinate file that is written to the campaign STA directory (e.g. $P/CWB_DP/STA) and will have a name format NETWWWW7.CRD (where WWWW is the GPS week and the 7 represents the 7-day combination of solutions). On the first day of the week (Sunday, or day "0"), the weekly solution will be identical to the daily solution. As the week of analysis progresses, this combined solution will include all days that have been successfully analyzed. These weekly coordinate solutions are used to tightly constrain the

a-priori coordinates of all stations during the following week's troposphere estimation solutions. For instance, the seven-day coordinate solutions for week 1450 will be used to constrain the coordinates for week 1451 during the troposphere estimation steps (PID 075 and 076).

Weekly SINEX files: The weekly network coordinate estimates, and the covariance of these estimates, are stored within a Solution Independent Exchange (SINEX) format file. These SINEX files are located in the campaign SOL directory (e.g. $P/CWB_DP/SOL). These solution files can be used for a number of purposes, including the combination of solution estimates from multiple weeks into a single coordinate estimate. Like the weekly normal equation file and coordinate solution, one SINEX file is produced for each week of solutions.

Daily Troposphere Estimates: The zenith troposphere estimates for all stations analyzed for a session are written to a single file. This file has the naming format TD_YYSSSS.TRP (where YY are the last two digits of the year, and SSSS is the session number of the solution). These files are written to the campaign ATM directory (e.g. $P/CWB_DP/ATM). The format of these files is described in the Bernese manual (Chapter 22.9). Each file contains the a-priori zenith delay, the estimated correction to the zenith delay, the summation of the a-priori and estimated correction, and the formal error of the estimate. These zenith delays are a combination of both the hydrostatic and wet zenith term. A surface pressure measurement is required to isolate the wet zenith delay (and therefore precipitable water vapor), from the total zenith delay.

A troposphere SINEX file is also created for each daily solution. This file has the same base name as the regular troposphere estimate file, but has the extension TRO. The format of the name is TD_YYSSS.TRO (where YY is the last two digits of the year, and SSSS is the session number). The regular troposphere estimate file and the SINEX estimate file contain essentially the same information, but have a different format. Please refer to the Bernese manual (Chapter 22.9) for a description of this format.

Daily Summary Files: At the successful completion of a BPE data analysis run, a summary of the significant components characterizing the quality of the solution is summarized into a single file. This file is located in the campaign OUT directory (e.g. $P/CWB_DP/OUT) and has the name format CWBYYSSSS.PRC (where YY are the last two digits of the year and the SSSS is the session number). It has the following information:

1. The identification of any inconsistencies in the input RINEX files used in the analysis. This information is often useful to identify unintended changes in station metadata.

2. Root mean square (RMS) repeatability in the input satellite orbits.
3. A short summary of the quality of the single point positions used to synchronize the receiver clocks.
4. Statistics on the pre-processing of individual baseline data to repair cycle slips, delete short observation segments, and evaluate the quality of the carrier phase data for later solutions.
5. A summary of residual screening for undetected problems in the carrier phase data.
6. A report on the ability to resolve carrier phase ambiguities.
7. The statistics of the weekly combination of coordinate solutions.

Appendix 1: Process Control File CWB_PWV.PCF

```
# Procedure Control File (PCF)
# All comment lines start with a #
# Comments:
#
PID SCRIPT   OPT_DIR  CAMPAIGN CPU      P WAIT FOR....
3** 8******* 8******* 8******* 8******* 1 3** 3** 3** 3** 3** 3** 3** 3** 3** 3**
#
# Update APRIORI coordinates
#
001 COOVEL   COOVEL            ANY      0
002 CRDMERGE COOVEL            ANY      0 001
#
# Translate Pole Files in ORB/ Directory
#
003 POLUPD   IGS_POL           ANY      0
#
# Generate Standard Orbits and Sat. Clocks
#
010 PRETAB   MKPORB            ANY      0 003
011 ORBGEN   MKPORB            ANY      0 010
#
# Zero Difference File Processing (RXOBV3 and CODSPP)
#
#018 PREP_RNX ZDP               any        002
019 RNXGRA   ZDP               ANY      0 011
020 RXOBV3   ZDP               ANY      0 019
021 CODSPP   ZDP               ANY      0 020 011
022 CODXTR   ZDP               ANY      0 021
#
# Single Difference Creation (SNGDIF)
#
030 SNGDIF   SDIFMAXO          ANY      0 022
#
# Clean Single Differences of Cycle Slips (MAUPRP)
#
040 MAUPRP   BSLCLEAN          ANY      0 030
041 MPRXTR   BSLCLEAN          ANY      0 040
042 GPSEDTAP BSLCLEAN          ANY      0 041
043 GPSEDT_P BSLCLEAN          ANY      0 042
044 GPSRMSCK BSL_CHK           ANY      0 043
#
# Compute network solution based on amb free basline solutions
#
045 ADDNEQ2  BSL_CHK           ANY      1 044
046 GPSXTR   BSL_CHK           ANY      1 045
#
# Resolve Ambiguities Baseline Wise (GPSEST)
#
050 GPSQIFAP QIF_AMB           ANY      0 046
051 GPSQIF_P QIF_AMB           ANY      0 050
052 GPSXTR   QIF_AMB           ANY      0 051
#
# Compute Network Geodetic Solution (GPSEST)
#
060 GPSEST   NET_EST           ANY      0 052
#
# Compute ADDNEQ Solution for the week (ADDNEQ)
#
070 ADDNEQ2  WK_SOLN           ANY      0 060
#
# Compute Troposphere Solution
#
075 GPSEST   CMB_TRP           ANY      0 070
076 ADDNEQ2  CMB_TRP           ANY      0 075
077 TRO_2PW  NO_OPT            ANY      0 075
```

```
#
# Clean up and create summary  files
#
090 SES_CLN  NO_OPT            ANY      0 076
091 SES_SUM  NO_OPT            ANY      0 090
#
# additional parameters required for PID's
#
PID USER          PASSWORD PARAM1    PARAM2    PARAM3    PARAM4    PARAM5    PARAM6    PARAM7
PARAM8   PARAM9
3** 12********** 8******* 8******* 8******* 8******* 8******* 8******* 8******* 8*******
8******* 8*******
#
001                       IGS05
#
042                       $042
043                       PARALLEL $042
044                       NEXTJOB  030
050                       $050
051                       PARALLEL $050
#
077                       TD_      suomiday Bv95     CWB_DP   SUOMI    LOCAL
#
091                       CWB
#
#
VARIABLE DESCRIPTION                                DEFAULT
8******* 40************************************** 16**************
V_O      TWO CHARACTER PREFIX FOR ORBITS           IGR
```

Appendix 2: Process Control File CWB_NRT.PCF

```
# Procedure Control File (PCF)
# All comment lines start with a #
# Comments:
#
#
PID SCRIPT   OPT_DIR  CAMPAIGN CPU      P WAIT FOR....
3** 8******* 8******* 8******* 8******* 1 3** 3** 3** 3** 3** 3** 3** 3** 3** 3**
#
# Translate Pole Files in ORB/ Directory
#
003 POLUPD   NRT_ORB           ANY      0
#
# Generate Standard Orbits and Sat. Clocks
#
010 PRETAB   NRT_ORB           ANY      0 003
011 ORBGEN   NRT_ORB           ANY      0 010
#
# Zero Difference File Processing (RXOBV3 and CODSPP)
#
#018 PREP_RNX ZDP               any        002
019 RNXGRA   NRT_ZDP           ANY      0 011
020 RXOBV3   NRT_ZDP           ANY      0 019
021 CODSPP   NRT_ZDP           ANY      0 020 011
022 CODXTR   NRT_ZDP           ANY      0 021
#
# Single Difference Creation (SNGDIF)
#
030 SNGDIF   NRT_MAXO          ANY      0 022
#
# Clean Single Differences of Cycle Slips (MAUPRP)
#
040 MAUPRP   NRTCLEAN          ANY      0 030
041 MPRXTR   NRTCLEAN          ANY      0 040
042 GPSEDTAP NRTCLEAN          ANY      0 041
043 GPSEDT_P NRTCLEAN          ANY      0 042
044 GPSRMSCK NRT_CHK           ANY      0 043
#
# Compute network solution based on amb free basline solutions
#
045 ADDNEQ2  NRT_CHK           ANY      1 044
046 GPSXTR   NRT_CHK           ANY      1 045
#
# Resolve Ambiguities Baseline Wise (GPSEST)
#
050 GPSQIFAP NRT_QIF           ANY      0 046
051 GPSQIF_P NRT_QIF           ANY      0 050
052 GPSXTR   NRT_QIF           ANY      0 051
#
# Compute Troposphere Solution
#
060 GPSEST   NRT_TRP           ANY      0 052
061 STK_NEQ  NRT_TRP           ANY      0 060
062 TRO_2PW  NO_OPT            ANY      0 060
063 TRO_2PW  NO_OPT            ANY      0 061
#
# Clean up and create summary  files
#
090 SES_CLN  NO_OPT            ANY      0 061
091 NRT_SUM  NO_OPT            ANY      0 090
#
#
999 DUMMY    NO_OPT            ANY      1 091
#
# additional parameters required for PID's
#
```

```
PID USER          PASSWORD PARAM1    PARAM2    PARAM3    PARAM4    PARAM5    PARAM6    PARAM7
PARAM8   PARAM9
3** 12********** 8******* 8******* 8******* 8******* 8******* 8******* 8******* 8*******
8******* 8*******
#
042                        $042
043                        PARALLEL $042
044                        NEXTJOB  030
050                        $050
051                        PARALLEL $050
#
062                        TD_      suomiday Bv95     CWB_NRT  SUOMI    LOCAL
063                        TRP      suomiday Bv95     CWB_NRT  SUOMI    LOCAL
#
091                        CWB_NRT
#
#
VARIABLE DESCRIPTION                                 DEFAULT
8******* 40************************************** 16**************
V_O      TWO CHARACTER PREFIX FOR ORBITS             IGU
V_PLUS   VARIABLE FOR NUMBER OF FORWARD SES          0
V_MINUS  VARIABLE FOR NUMBER OF PREV SESS            -6
```