1 Presentation on regional network processing:

SNARF 2.0: A Regional Reference Frame for North America

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Regional reference frames fixed to the stable part of a tectonic plate are often required for national spatial reference systems and to facilitate geophysical interpretation and inter-comparison of geodetic solutions of crustal motions. In 2003, the Stable North American Reference Frame (SNARF) Working Group was established under the auspices of UNAVCO and IAG Regional Sub-Commission 1.3c to address the needs of the EarthScope project. The goal was to define a regional reference frame stable at the sub-mm/yr level. The SNARF Working Group identified and dealt with several issues in order to define and generate such a regional frame, including (1) the selection of "frame sites" based on geologic and engineering criteria for stability, (2) the selection of a subset of "datum sites" which represent the stable part of the plate and were used to define the no-net rotation condition, (3) the modeling of both the vertical and horizontal effects of glacial isostatic adjustment using a relatively dense GPS velocity field, and (4) the generation and distribution of products for general use, in particular for Earthscope investigators. Version 1.0 of the SNARF has been released and is available through the UNAVCO web site. In this paper, we discuss the development of SNARF Version 2.0, which will incorporate more input analyses than SNARF Version 1.0 and will be related to the North American plate through a more complete Glacial Isostatic Adjustment (GIA) model. SNARF Version 1.0 is used in the reference frame definition for the plate boundary observatory (PBO) and we will compare the SNARF realizations with the PBO determined station velocities in North America.

2 Presentation on regional network processing:

RNAAC combinations in the IGS

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We discuss the combination of regional analyses, submitted in the form of SINEX files, with global IGS SINEX files. In these combinations, the regional analyses have used IGS final earth orientation parameters and orbits. We examine the quality of these combinations and some of the issues associated with them. The number of centers submitting RNAAC SINEX files has fluctuated with GSI and SIR being the two most consistent submitters. Some issues to be discussed include constraint removal, variance-scaling factors for different processing centers, and other non-IGS regional analyses available in SINEX format such as the products available from the Plate Boundary Observatory.

3 Poster on regional network processing:

Vertical velocities at tide gauges from a completely reprocessed global GPS network of stations: How well do they work?

Guy Wöppelmann, Marie-Noëlle Bouin, Z. Altamimi, C. Letetrel, A. Santamaria, X. Collilieux, G. Valladeau and F. Lefèvre

The reprocessing of a global network of GPS stations has recently been completed at the ULR analysis centre consortium using a consistent GPS analysis strategy over a 10-year data period. The GPS data reprocessing was performed with the GAMIT software (King and Bock, 2006). Important features of the reprocessing include the use of: the IGS absolute phase centre corrections for the tracking and the transmitting antennas, the GMF troposphere mapping functions based on data from the global ECMWF numerical weather model, the application of the IERS 2003 conventions, the adjustment of satellite orbit parameters together with station coordinates using a global free network approach. The global GPS network solutions were combined into daily and weekly solutions, and were aligned to the ITRF2005 datum using the minimum constraint approach implemented in the CATREF Software. In this way, a consistent set of weekly GPS position time series and a global velocity field were obtained and expressed in the ITRF2005 reference frame for 225 stations distributed worldwide, among which ~160 are within 10km distance from a tide gauge station. The average length of the time series is 6.5 years, within the period 1997.0-2006.9. To test the quality of our GPS results we reproduced three types of analysis from the literature, illustrating three different applications. The first analysis indicates a clear reduction in the noise level of our GPS reprocessed time series which allows a better detection of the anomalous harmonics discovered by Ray et al. (2008) in the spectra of the IGS non-linear position residuals generated in the ITRF2005 combination. The second application demonstrates how sea level trend estimates from long term tide gauge records benefit from the GPS-derived velocities to account for the vertical land motion at the tide gauges by reproducing the analyses of Douglas (2001) and Peltier (2001), which aim at estimating a global rate of sea level change. The third exercise is under work: we attempt to estimate the drifts in satellite radar altimetry biases using an approach similar to the one developed by Mitchum (2000) based on a global set of tide gauges. The application of land motion corrections at the tide gauges from our GPS-derived vertical velocities indicates an improvement in the estimated drifts of T/P, Jason-1, GFO and Envisat missions, although these are very preliminary results which need to be further analysed in detail and confirmed.

4 Poster on regional network processing:

IAG Working Group “Regional Dense Velocity Fields”: Objectives and Future Plans

C. Bruyninx, Z. Altamimi, M. Becker, M. Craymer, L. Crombrinck, A. Crombrink, R. Fernandes, R. Govind, A. Kenyeres, B. King, C. Kreemer, D. Lavallée, J. Legrand, L. Sanchez, G. Sella

(no abstract available)

5 Poster on regional network processing:

Reference Frame Definition in a Regional GNSS Network: Global or Regional?

J. Legrand and C. Bruyninx

The EUREF Permanent Network (EPN) includes about 200 GNSS stations in . Today, the EPN is tied to the IGS05 by using minimal constraints on more than 20 EPN stations also included in the IGS05. This means that only regional stations are used for the reference frame definition. We have investigated different ways of fixing, using minimum constraints, the datum of a GNSS network computed originally as a free network. We distinguished between regional and global solutions and used both the IGS05 and ITRF2005 as reference datum. We show that different regional solutions present biases with respect to each other which can reach the centimeter level. These differences depend on the set of fiducial stations as well as the frame (IGS05 or ITRF2005) to which the solution is tied.

6 Poster on regional network processing:

Testing Processing Methodologies for the Computation of AFREF Solutions

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AFREF (African Reference Frame) is an effort carried out by the international community, in particular by the African countries, to establish a continental reference system that will serve as the basis of the future national reference networks based on the modern geodetic spatial techniques, in particular on GNSS (Global Navigation Satellite Systems) fiducial points.

We discuss here the approaches used to compute AFREF08. This solution intends to be a test case for the methodologies to be adopted for the computation of the first official solution for AFREF. AFREF08 is realized by simultaneously computing the accurate positions of an extended set of GNSS stations distributed by the entire African continent. The positions are referred to the latest realization of ITRS (International Terrestrial Reference System), ITRF2005, by aligning the continental solution into this global frame at a defined epoch (1st May 2008).

AFREF08 is fixed to a certain epoch in order to be the backbone system that will allow every country to realize its national system fully and directly consistent with the national realizations produced by the neighboring countries. To respect the dynamics due to the existence of several tectonic blocks, AFREF08 is fixed to the Nubia plate and the differential motions with respect to this block for stations located in different plates have been accurately modeled.

This first solution is being produced by combining two individual solutions produced using two different software packages. The issues rose during the data acquisition, data processing and solution combination processes will be thoroughly discussed by the involved partners at the AFREF project in order to establish the methodologies for the computation of the first official AFREF solution.

7 Presentation on multi-GNSS processing:

ESOC Combined GNSS Processing

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ESOC and CODE are the only two analysis centres in the IGS which provide all “classical” GPS based IGS products ***and*** provide true combined “GNSS” based IGS products. Although the IGS stands for “GNSS” service since 2005 it still is mainly a GPS based service. The IGS does provide GPS and GLONASS products but no truly combined GNSS products. The disinterest of the IGS in GLONASS may be explained by the poor situation GLONASS was in for several years. However, since 2001 there have been very significant improvements in the GLONASS programme on the Russian side. This has resulted in a satellite constellation now totalling 16 satellites with 6 more satellites scheduled for launch this year. This should bring the GLONASS constellation to at least 18 satellites in 2008 and the full, 21 +3, constellation should be reached in 2009. At ESOC, but also at CODE, we are convinced that if the IGS want to remain a key player in the GNSS arena it will have to provide true GNSS products. Furthermore, dealing with GPS and GLONASS will help the whole IGS to prepare and learn how to integrate future GNSS like the European Galileo and the Chinese Compass system. Today there are commercial service providers which offer real-time GNSS corrections whereas the IGS does not even offer a “final” GNSS product! This is not enough considering the IGS claim of being “the authority concerning the scientific exploitation of all GNSS”.

In this presentation we will show the current state of the IGS GNSS tracking network in comparisons with the IGS GPS tracking network; a really shocking picture! In addition we will show some of the technical challenges related to generating true GNSS solutions with a focus on the biases between the different systems, e.g., inter-system bias, inter-frequency bias, and other “nice” effects. Last but not least, if we receive any signals from the recently launched Giove-B satellite in time for the workshop, we will show some results of analysing that data with a special focus on the behaviour of the on board passive hydrogen maser. In the conclusions we hope to stimulate a discussion on the following topics:

- Where is the IGS heading in respect to true GNSS products
    - Current focus is GPS!
    - When are we going to really incorporate GLONASS
    - How does IGS plan to prepare for Galileo and/or Compass
    - IGS is ***NOT*** leading in GNSS, only in GPS
- How can the IGS improve its GNSS tracking network
    - Soon may have more GLONASS satellites than IGS GNSS stations
    - How can we increase the GLONASS network
- Which enhancements are needed within the IGS for true GNSS products
    - Formats and generation of intersystem bias products
    - Formats and generation of inter frequency bias products
    - Other biases (code-phase, code-code, etc. etc.)
    - Combined GNSS orbit

8 Presentation on multi-GNSS processing:

Galileo Ground Mission Segment Performances

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The Galileo system, under development by ESA, will provide world-wide positioning services, with demanding levels of accuracy, continuity and integrity. For each of these services, and for an arbitrary location, service availability is defined as the "a priori" probability during the system life-time, of having a pre-specified level of accuracy, continuity and integrity satisfied.

The specified Galileo services availability has to be demonstrated at each location on Earth and under conservative and demanding environmental assumptions in terms of interference, multi-path and ionospheric/ tropospheric perturbations, in particular in terms of ionospheric environment it has been considered that the sunspot number could be as high as 250, what implies the need of coping within the analyses, with scenarios with a considerable high level of ionospheric scintillation (both in equatorial and polar regions).

For each Galileo service, the availability is conceptually verified by the user by checking whether the broadcast navigation and integrity data quality is sufficient to meet the integrity and continuity risk specifications. Concretely, in the Galileo context, the broadcast navigation data quality is given by the Signal-In Space Accuracy (SISA) while the broadcast integrity data quality is indicated by the Signal-In Space Monitoring Accuracy (SISMA), which detailed definitions are as follows:

- The Signal-In Space Accuracy indicator (SISA) is a prediction of the minimum standard deviation (1-sigma) of the unbiased Gaussian distribution, which over-bounds the Signal-In-Space Error (SISE) predictable distribution, for all possible user locations, being the SISE the range error, within the satellite coverage area due to its navigation message clock and ephemeris errors
- The Signal-In Space Monitoring Accuracy indicator (SISMA) is a prediction of the minimum standard deviation (1-sigma) of the unbiased Gaussian distribution which over bounds the SISE estimation error as determined by the ground segment integrity monitoring function.

This paper analyzes in depth the quality of the broadcast navigation data and the quality of the broadcast integrity data, generated by the Galileo Ground Mission Segment. In particular the paper provides an overview of the achieved:

- Broadcast orbit and clock quality in terms of induced ranging error at the worst possible user location within the applicability period of the navigation message; for the less accurate navigation message within those originated in the same processing batch.
- Broadcast orbit and clock quality in terms of the induced ranging rate error (first derivative) at the worst possible user location within the applicability period of the navigation message; for the less accurate navigation message within those originated in the same processing batch
- Broadcast Signal In Space Accuracy (SISA), as defined above, at the worst possible user

location within the applicability period of the navigation message; for the less accurate navigation message within those originated in the same processing batch.

- Broadcast ionospheric parameters quality in terms of the root mean squared of the Slant Total Electron Content error (STEC error) as a function of the elevation, and within pre-defined geomagnetic latitude bands (northern, northern-middle, equatorial, southern-middle and southern)
- Broadcast Signal-In-Space-Monitoring-Accuracy, as defined above, at the worst possible user location within the applicability period of the integrity message (integrity table), and for the satellite for which the integrity monitoring is predicted to be less accurate within the applicability period of the integrity message.
- Satellite continuity risk, due to Galileo Ground Mission Segment internal (externally or internally induced) events degrading the navigation message(s) and/or the integrity message(s) correctness (and/or availability), leading to an unplanned interruption in the service provision (e.g. transitory unavailability of the real time integrity monitoring due to a network communication outage). The continuity risk is evaluated as a probability over 15 seconds.
- Satellite integrity risk, due to Galileo Ground Mission Segment internal (externally or internally induced) feared events, degrading the navigation message(s) correctness, without being this detected by the real-time integrity monitoring (e.g. non-flagged abnormal on-board clock), and/or degrading the integrity message(s) correctness (e.g. modified flag) in presence of an incorrect navigation message(s). The integrity risk is evaluated as a probability over 150 seconds.

This paper addresses exclusively the broadcast navigation data quality for the Galileo Open Service (OS), and the broadcast navigation and integrity data quality for the Galileo Safety-of-Life service (SoL).

9 Poster on multi-GNSS processing:

Inter-satellite ranging and inter-satellite communication links for enhancing satellite broadcast navigation data

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The ESA "GNSS+" Project is devoted to assess the benefits of inter-satellite ranging, inter-satellite communication links and auxiliary on-board orbit/clock determination processing in enhancing satellite broadcast navigation data quality. It targets the definition of an evolved GNSS system architecture, named as "GNSS+ Architecture", which takes advantage of the above mentioned technologies, assessing the performance improvements that this evolution would bring. The "GNSS+" Project analyzes the achievable broadcast-orbit data and broadcast-clock data accuracy in nominal and degraded scenarios. The nominal scenarios consider the availability of all Space-Segment and Ground-Segment elements including those in charge of the Inter-Segment data-exchange, while the degraded scenarios consider that either some Space-Segment/Ground-Segment elements are not available or that the contact between these two Segments is interrupted; the performances in this last degraded scenario are named as "autonomy-mode performances".

The "GNSS+ Architecture" is derived from a detailed evaluation of the potential evolutions in a number of key dimensions of the problem, in particular the:

1. Characteristics of the observables processed by the orbit and clock determination functions
2. Set of satellite-to-satellite, satellite-to-station and station-to-satellite observables processed by the orbit and clock determination functions
3. Identification of what sub-functions of the orbit and clock determination functions should be allocated to the Ground-Segment (on-ground processing) and to the Space-Segment (on-board processing)
4. Set of exchanged information via satellite-to-satellite, station-to-satellite and satellite-to-station communication links, which includes orbit, clock, observables, telemetry, telecommand and navigation auxiliary data.
5. Characteristics of the orbit and clock determination algorithms located both on-board and on-ground, as well as the broadcast-orbit and broadcast-clock refresh rates
6. Definition of the Navigation System Time Reference, and the means to ensure its linkage to UTC
7. Characteristics of the inter-satellite ranging and inter-satellite communication signals and links
8. Characteristics of the on-board/on-ground transmitting and receiving chains for ranging, including the antenna sub-function
9. Characteristics of the on-board/on-ground transmitting and receiving chains for communication, including the antenna sub-function

The definition of the "GNSS+ Architecture" requires of a complex software simulation environment, developed as part of the “GNSS+ Project”, that comprises the on-board and on-ground orbit determination and clock determination algorithms, as well as the simulation of the satellite-to-satellite, satellite-to-ground and ground-to-satellite observables. The “GNSS+ Architecture” definition requires of the feasibility demonstration for those critical technologies brought into play for the architecture solution.

10 Poster on multi-GNSS processing:

The Galileo Terrestrial Reference Frame and its linkage to the IGS

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One of the main elements of the upcoming Galileo system is the Galileo Terrestrial Reference Frame (GTRF) as the basis for all Galileo products and services. The realization and maintenance of such a TRF has been given to an external consortium, named the Galileo Geodetic Service Provider (GGSP) Prototype, which consists of seven institutions under the lead of GeoForschungsZentrum Potsdam. The project funded within the sixth framework programme (FP6) of the European Union will last until May 2009.

The GTRF will be a realisation of the International Terrestrial Reference Frame (ITRF) on a position precision level of 3 cm (2 sigma). An initial realisation of the GTRF has to be based on other station positioning data because the GTRF will already be required by the time when the first Galileo signals are going to be emitted.

The presentation describes the strategy for the GTRF realisation following the “state of the art” TRF implementation. Since the Galileo tracking stations, named Galileo Sensor Stations (GSS), will form a sparse global network, it is necessary to densify the network with additional IGS stations to get the highest possible precision and stability for the GTRF. The connection to the ITRF is realized and validated by IGS stations, which are part of the ITRF, and especially by local ties to other geodetic techniques like satellite laser ranging and VLBI. Results from the first analysis campaigns will be shown with special concern to the so-called Galileo Experimental Sensor Stations (GESS).

11 Poster on multi-GNSS processing:

Developing a Generic Multi-GNSS Software Package

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The Bernese GPS Software was originally designed to analyze single- and dual-frequency GPS data. In 1999, the GLONASS capability was implemented by adapting the present program structure. Upcoming GNSS (Galileo and Compass) may offer a wide variety of signals on more than two carriers. They may also include geostationary satellites.

A complete redesign of the GNSS analysis software package (and internal data formats) is indispensable being confronted with multiple frequencies, many different observables (and biases to be dealt with). We address related issues.