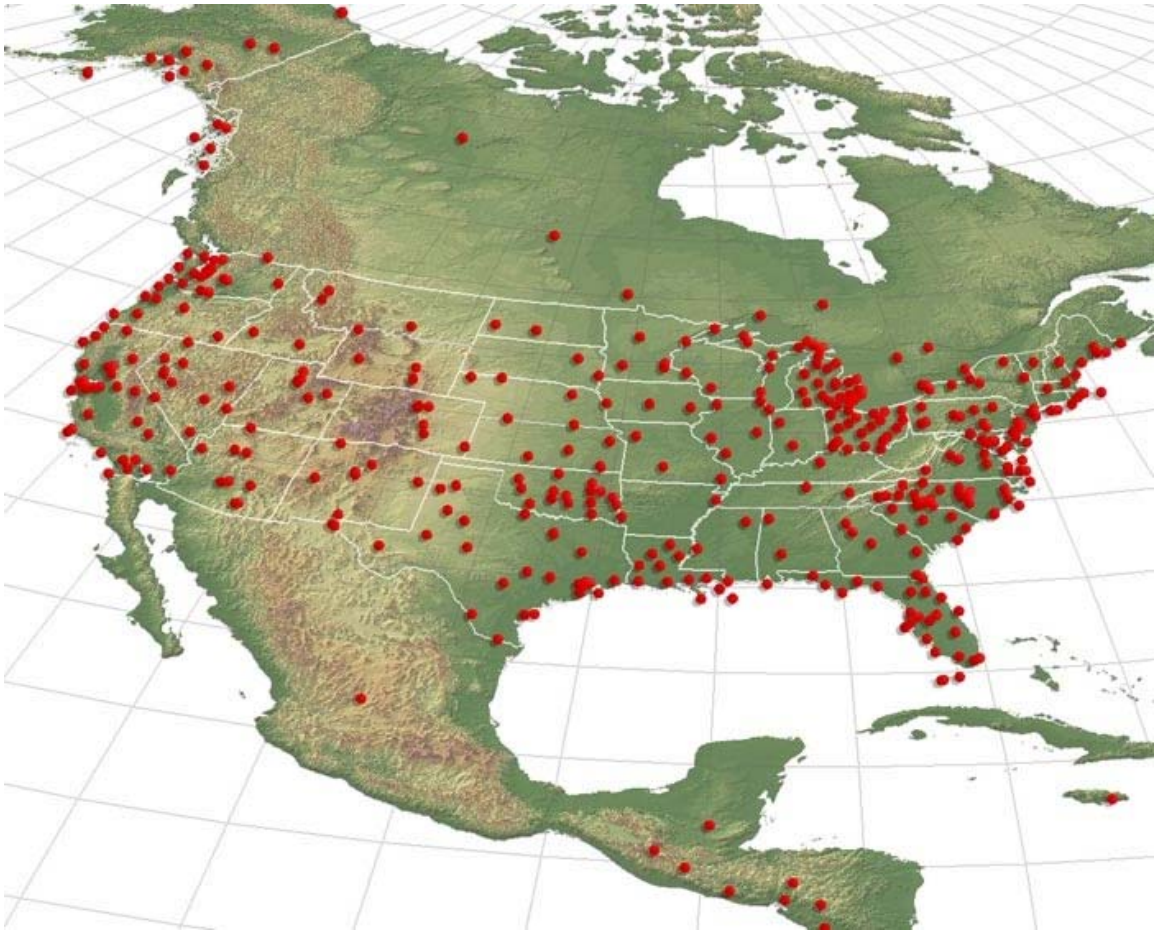
6th Annual CORS Users Forum
Fort Worth, Texas
September 26th, 2006

NOAA's National Geodetic Survey (NGS)--in cooperation with the U.S. Department of Transportation and the U.S. Coast Guard--organized a CORS (Continuously Operating Reference Station) Users Forum on 26 September 2006. This Forum was an integral part of the Civil GPS Service Interface Committee (CGSIC) meeting, 25-26 September 2006, at the Renaissance Worthington Hotel in Fort Worth, TX. The Institute of Navigation's GNSS Conference convened 26-29 September 2006 in the Fort Worth Convention Center.

The National and Cooperative CORS networks are comprised of numerous subnetworks operated by more than 180 organizations. Collectively, these networks include more than 970 sites--each containing a geodetic quality, dual-frequency GPS receiver--and these networks are growing at a rate of about 15 sites per month. NGS and its partners collect, process, and distribute data from the CORS sites on a continuous basis in support of numerous activities including land surveying, navigation, GIS/LIS development, remote sensing, weather forecasting, satellite tracking, geophysics, and time transfer.



AGENDA

1:30 Welcome and Opening Presentation
CORS/OPUS: Overview and Status
Richard Snay, NOAA's National Geodetic Survey

1:45 **On-GRID: An Initiative to Promote Regional Real-Time GNSS Networks**
Gavin Schrock, City of Seattle, WA

2:05 **OPUS-DB and Other OPUS-Related Innovations**
Rick Foote & Joe Evjen, NOAA's National Geodetic Survey

2:25 **The Texas Spatial Reference Center**
Gary Jeffress, Texas A&M Univ., Corpus Christi, TX

2:45 **NGS Support for Regional Real-Time GNSS Networks**
Neil Weston, NOAA's National Geodetic Survey

3:05 **EarthScope's Plate Boundary Observatory: Status Update**
Greg Anderson, UNAVCO, Inc.

3:25 Question & Answer Session with Panel of the Speakers

3:45 Break

4:00 Interactive Sessions within Small Discussion Groups
Group A: Real-Time Positioning
Facilitators: Neil Weston, Bill Henning and Richard Snay, NGS
Group B: OPUS
Facilitators: Joe Evjen & Rick Foote, NGS
Group C: Texas Spatial Reference Center
Facilitators: Cliff Middleton & Casey Brennan, NGS
Group D: Ionospheric Modeling
Facilitator: Joe Kunches, NOAA's Space Environment Center
Group E: Tropospheric Modeling
Facilitator: Seth Gutman, NOAA's Earth Systems Research Laboratory
5:00 End of Forum
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The PowerPoint files for each of the six formal presentations may be viewed and/or downloaded at http://www.ngs.noaa.gov/CORS/ . Click on "General Information" and then on "Presentations".

CORS/OPUS: Overview & Status
Richard Snay, NOAA's National Geodetic Survey

Richard Snay provided an overview of the session. He stated that 985 CORS stations were operational at last count; 817 National CORS and 168 Cooperative CORS. The network is currently growing at about 15 sites per month. Most of these sites are operated by more than 180 partners, rather than by NGS.

CORS are mainly used for post-mission static positioning, although they are also used for post-mission kinematic positioning, geophysics, meteorology, and space weather.

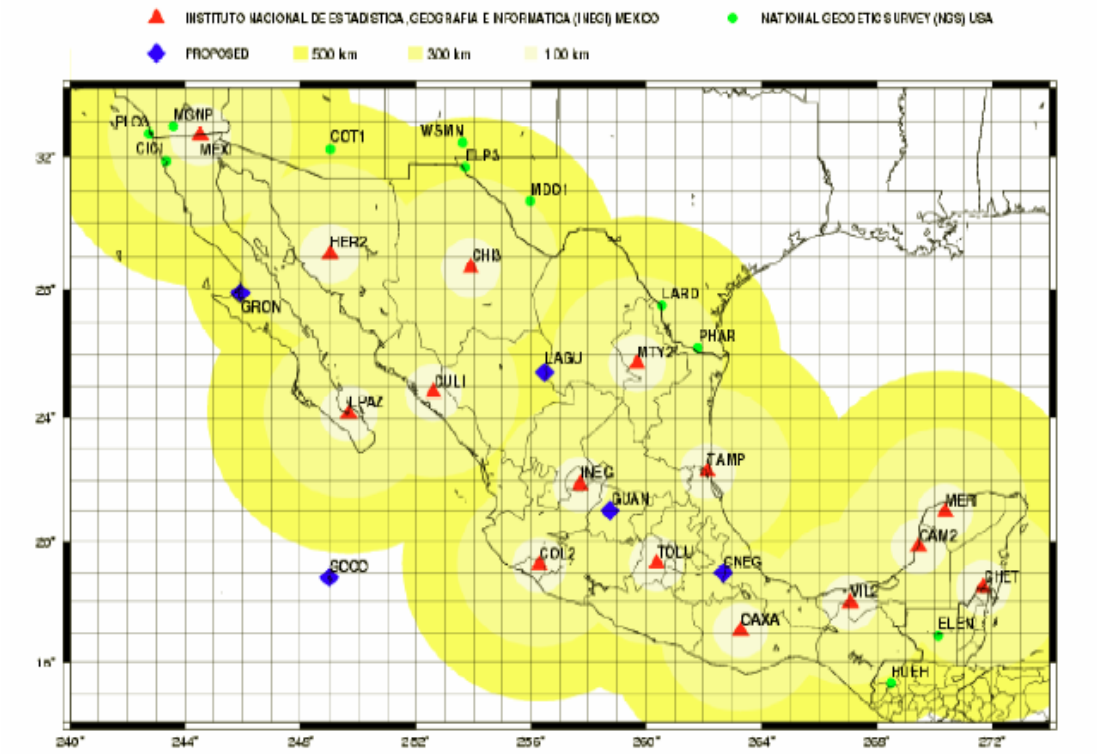


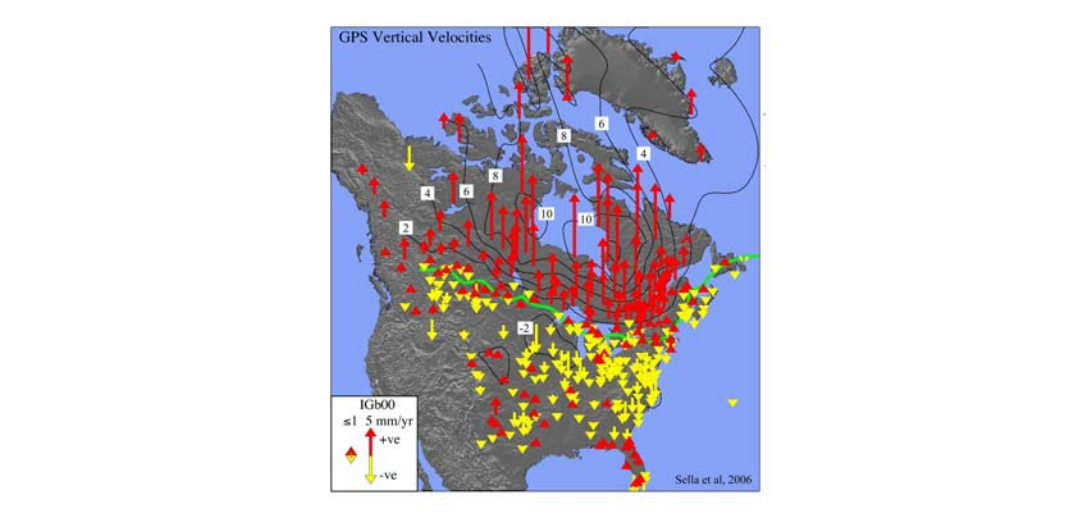
Figure 1. National Active Geodetic Network RGNA

During the past year the Mexican CORS network merged with the U.S. CORS network, expanding upon previous agreements with Canada and many Cenral American and Caribbean countries. As a result CORS data are freely available throughout North America and its immediate surroundings.

In December 2006, NGS adopted the new CORS guidelines developed by Giovanni Sella.

Other FY 2006 accomplishments:

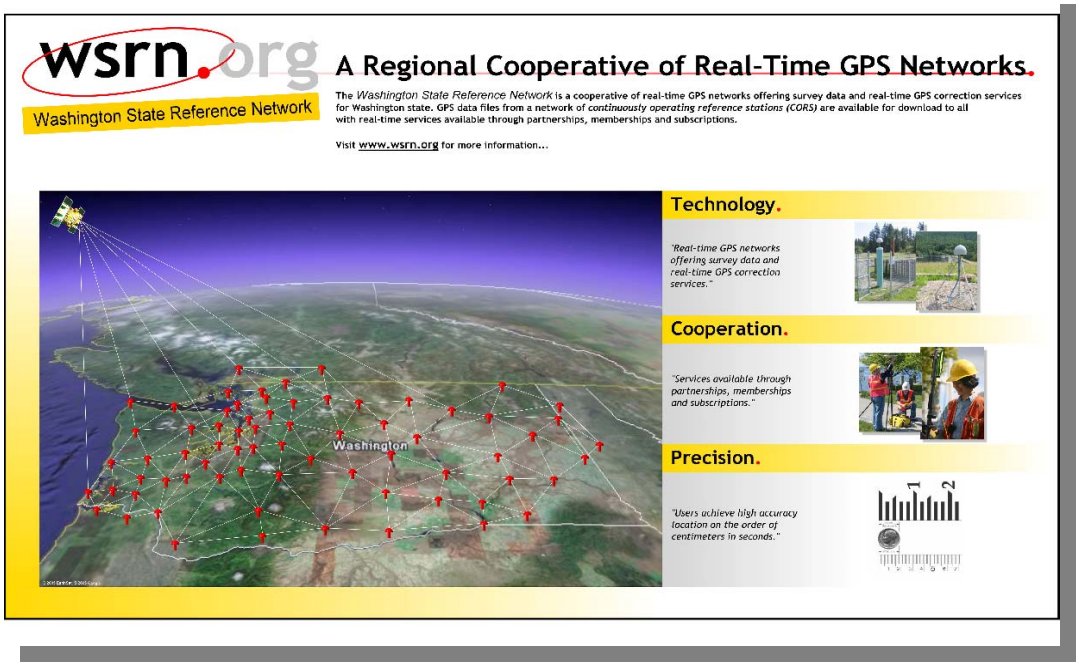
- 180 new CORS sites, most of which came from the Plate Boundary Observatory (PBO) and regional real-time networks.
- The Online Positioning User Service (OPUS) performed 166,000 solutions in 12 months.
- The User Friendly CORS (UFCORS) delivered 792,000 GPS data packages in 12 months.
- Bill Stone (the NM State Advisor) published an article on CORS and OPUS.
- CORS websites now features Google Maps and includes satellite photos of individual CORS sites.
- CORS data now contribute to measure post glacial rebound.
- CORS data are also serving to monitor the distribution of free electrons in the ionosphere.



On the CORS horizon:

- ITRF 2005 positional coordinates and velocities will be computed for all CORS.
- NGS procured 11 new GPS+GLONASS receivers to deploy as part of the CORS network.
- NOAA will install at least 4 new CORS sites at U.S. tide gauges.
- NOAA will publish article on using CORS data to calibrate tide gauge stations, which will help measure global sea level rise.

On-GRID: Resources and Support for High-Precision Real-Time GNSS Networks
Gavin Schrock, City of Seattle



On-Grid Goals and Objectives: Help acquire the Resources, Expertise, Policy Assistance and Cooperative efforts to establish regional real-time GNSS networks.
What it is NOT: Rules, big funding, public sector only, proprietary solutions

Gavin stated that the goals of On-Grid program are high precision real-time positioning applications, such as surveying, monitoring the deformation of critical structures, construction and science (in the 5 cm or less range). This program will establish lots of reference stations and you won't need a high end rover to use this network.

There are already about 200 real-time GNSS networks (RTN's) in various places around the world. Japan has a number of them. Germany is completely covered. Ohio is already covered with 51 stations. The state of Washington is about 2/3 of the way there.

The NTRIP protocol is being used promoted for transporting GPS data via the Internet.

The users segment is growing. People are finding out that network RTK offers several advantages as compared to single-base RTK:

- improved accuracy,
- increased range from base stations, and
- users do not need to operate/maintain their own base stations.

Real-Time GNSS Networks will introduce thousands of new CORS. This will lead to additions to National CORS, better modeling, more rovers being sold.

On-Grid early objectives: Support the real-time initiatives across the nation. Support public safety and commerce.

Starting in 2006 On-Grid hit the road. We attended several meetings: ACSM, NSPS, RTN administrators, local and state industry associations and the 2006 NGS CORS Forum.

Current issues:

- Little local expertise
- With higher precision, there are new considerations
- Migration from legacy reference systems

Expertise and Education:

- Few publications
- No risk assessments have been undertaken
- Infrastructure developed without considering RTN utility
- Little outreach
- Few applicable guidelines and standards

Cost Benefit Analysis:

- Few case studies have been done
- Few business model examples
- Big ticket public works projects often don't consider using RTN

Policy:

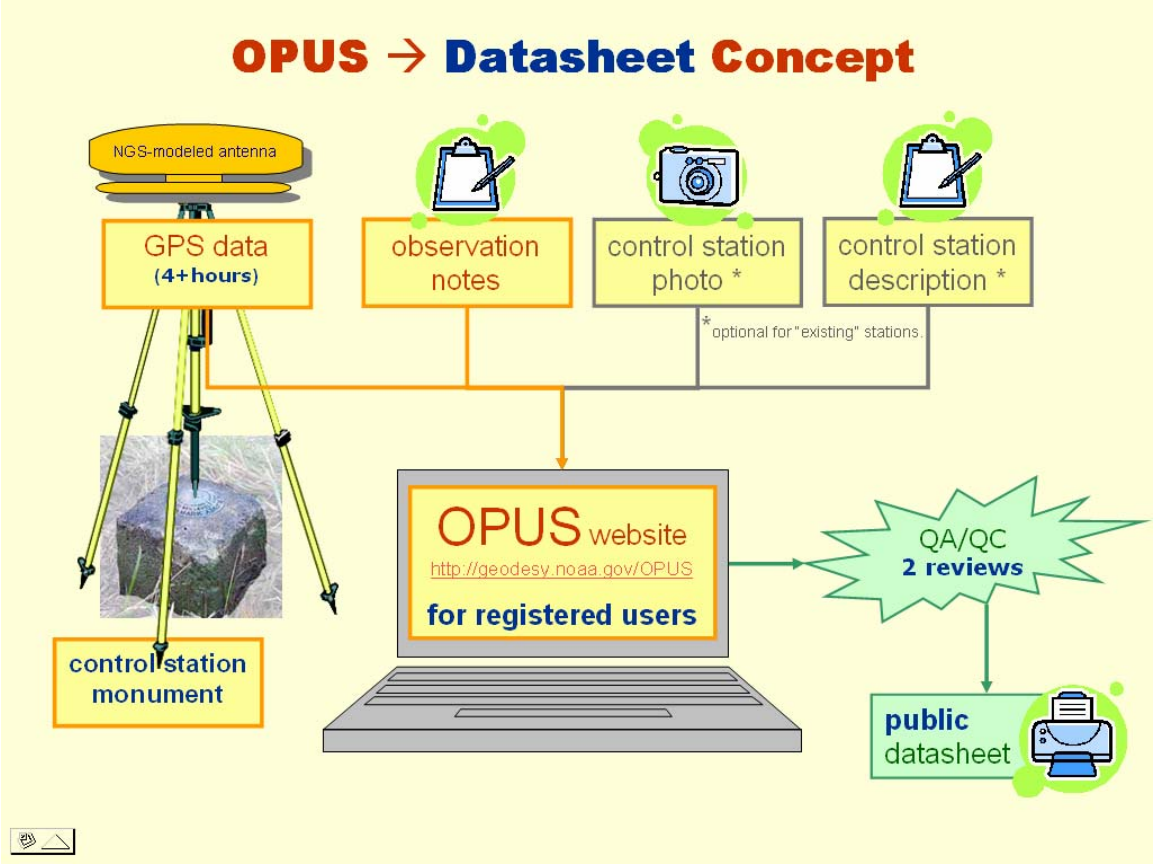
- Security is often misinterpreted
- High precision is not often discussed at higher levels

Proposed actions:

- Support NGS role by including RTN's into the National Spatial Reference System.
- Guidelines and standards
- Publications
- Academic studies
- Security issue position papers are needed
- Application case studies
- Raw data stream sharing from existing publicly funded reference stations
- Identify public works projects that would benefit from RTN infrastructure
- Conduct cost-benefit studies and business model examples
- Make cooperative agreement boilerplates
- Outline other PNT (position-navigation-timing) benefits
- Support/Develop outreach
- Support NDGPS
- Seek interface with PNT

The future: On-Grid will continue as a grass roots effort.

OPUS: The Online Positioning Users Service
Rick Foote and Joe Evjen, NOAA's National Geodetic Survey



User need submit only four pieces of information to OPUS: an e-mail address, a RINEX file, the type of antenna used and the height of that antenna.

The Future of OPUS:

- OPUS-DB (data base)
- OPUS-Projects
- OPUS-RS (rapid static)
- OPUS-GIS

OPUS-DB: Enables users to share the positional coordinates derived from their GPS data. User's data is submitted to NGS, processed, and the results are returned via e-mail. To share your data, you need to occupy a survey monument that is stable and permanent. You need to submit a minimum of 4 hours of dual-frequency, carrier-phase GPS data, photos of the monument, information about the GPS antenna and any other notes that might be useful. With the users' consent, the resulting coordinates will be archived in the NGS Integrated Database and these coordinates will be publicly disseminated in the traditional NGS datasheet format. Contributors will need to register with NGS and leave contact information so that other people who would use the resulting positional coordinates will be able to contact them.

Limitations:

- GPS only
- PAGES software only
- No tie to local survey monuments
- No redundancy
- Reduced oversight

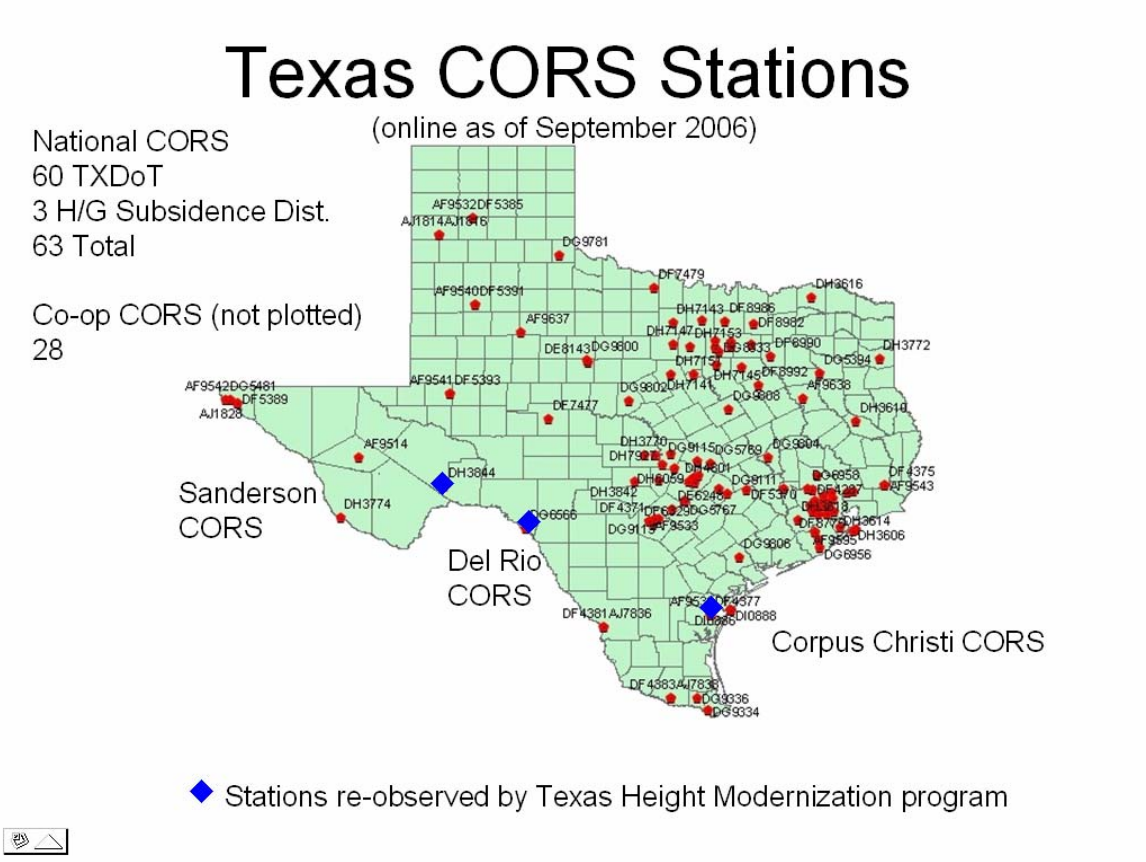
Other flavors of OPUS:

OPUS Projects: Will process dual-frequency, carrier-phase data for a GPS survey involving multiple sites and multiple observing sessions such that the resulting positional coordinates will best fit the combined set of observations in a least squares sense.

OPUS-RS (Rapid Static): The observer will be able to submit dual-frequency, carrier-phase GPS data for an observing session as short as 15 minutes. OPUS-RS may use more than 3 CORS for control to better estimate tropospheric and ionospheric refraction delays.

OPUS-GIS: Will process single-frequency pseudorange GPS data.

The Texas Spatial Reference Center
Gary Jeffress, Texas A&M Univ., Corpus Christi



The Texas Spatial Reference Center (TSRC) has been proposed and will require an act of the TX state legislature. The Governor of TX has signed a letter supporting the center.

The current challenge is determining NAVD 88 heights for the antenna reference points associated with CORS stations. There are 63 National CORS stations in TX and more are coming. Many of these are in the Houston-Galveston Subsidence District, which has major subsidence issues.

The central facility of the TSRC is located in Corpus Christi and features a CORS station. We recently ran levels to that station to help obtain a good NAVD 88 height for it. Don Mulcare, the TX State Geodetic Advisor, was in charge of this project.

We also verified that GPS can be used with a good geoid model to determine elevations.

Other work:

- Selected 100 benchmarks that will be observed with GPS to provide good data for improving the geoid model
- Developed software for handheld PDAs

- Produced elevation profiles for hurricane evacuation routes using the Applanix Pos-LV system
- Will establish a CORS at the NOS tide gauge station located on the Galveston Pleasure Pier

On November 15-16,2006, we will convene a Height Mod forum in Austin TX.

NGS Support for Regional Real-Time GNSS Networks
Neil Weston, NOAA's National Geodetic Survey

Modify selected CORS sites to enable real-time of their GNSS data.
NGS would identify 200 CORS stations and then stream their GNSS data, not GNSS correctors, via NTRIP and TCP/IP over the Internet.

The site modifications:

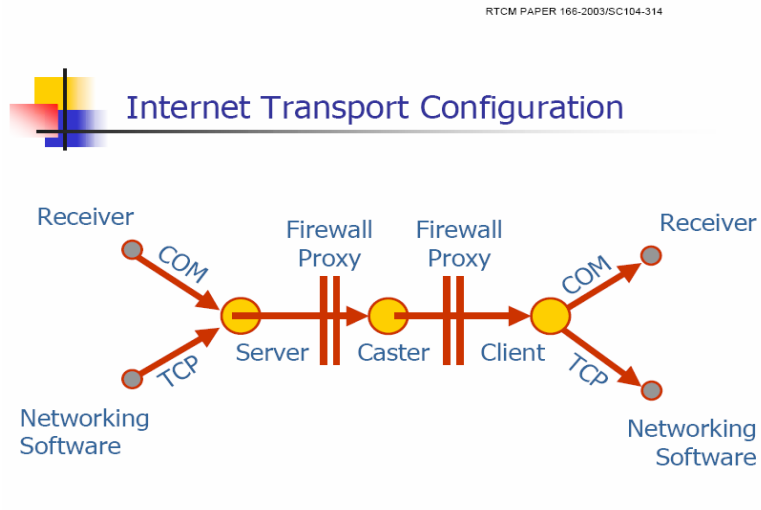
- Receiver modifications
- Communications/network changes
- Software changes

Network design issue:

- what format
- which stations
- what software
- what distances
- what data rate
- what latency

Data Distribution Formats

Data Collection Formats



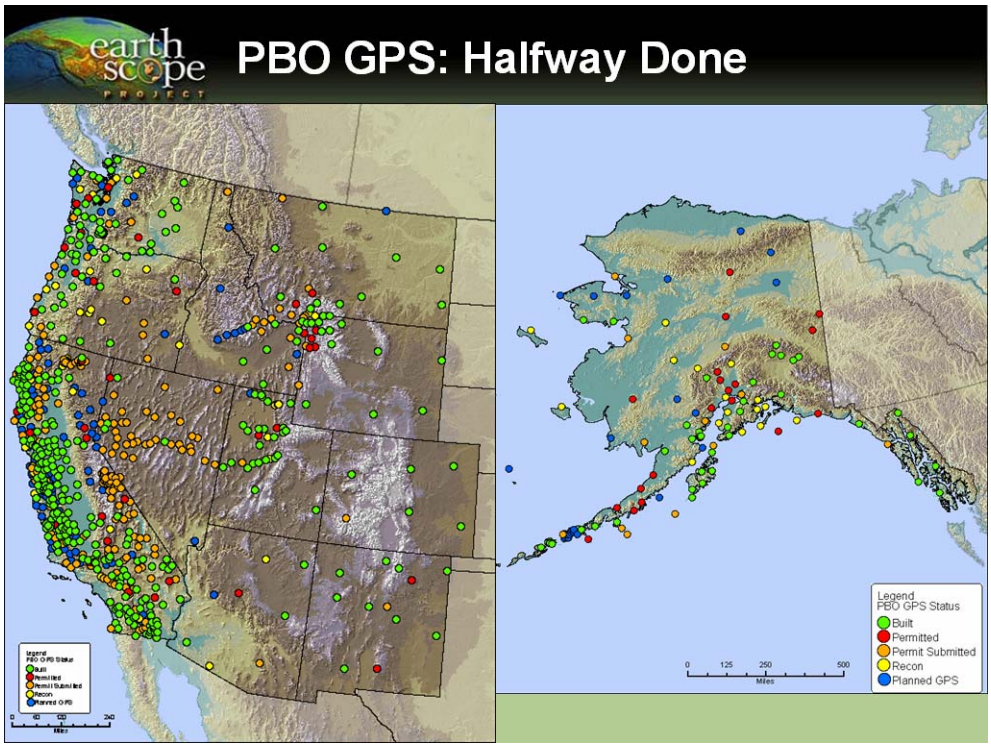
Communications:

- Frame relay
- Internet
- Satellite/modem
- NTRIP

Real Time Applications:

- Structural monitoring
- GIS
- Rapid response
- Meteorology
- Space weather

EarthScope's Plate Boundary Observatory: Status Update
Greg Anderson, UNAVCO, Inc.



What is the Plate Boundary Observatory (PBO): A project for studying continental scale problems related to earthquake and magmatic activities in North America. The PBO project will establish 852 new GPS base stations, and at the end of the project there will be over 1100 such stations. As of August 2006, UNAVCO has installed half of the proposed new GPS base stations. On any given day, 90% of the sites are up and running.

The GPS data flows to two archiving facilities for backup reasons, and all the data are available through the PBO website. There are a variety of GPS data products available. To access data and see what has been built or is going to be built, which stations are running and which ones are not, more information about a particular stations (including images of the station) go to the status map on our website. (pboweb.unaco.org)

To obtain data go to the website:
http://pboweb.unaco.org/gps_data

Special data requests:
http://pboweb.unaco.org/data_request

There are 40 some stations with RTK capabilities, mainly for the land owners. If you want to get involved with RTK issues with PBO sites, please call Greg Anderson. (303-381-7555) or anderson@unavco.org

Question and Answer Session:

Q: (for Greg Anderson) Are there plans to expand the PBO sites into the eastern United States?
A: There are some small networks out there already. But I am not aware of any plans to build a "PBO East", but we have talked with folks about incorporating existing stations into the network.

Q: (For Gary Jeffress) What benchmarks were selected for the TX program?
A: We selected sites to cover as much of the state as possible and give work to as many surveyors as possible. The idea is that the HtMod will be the branch of NGS in the state, and that the surveyors will be doing most of the work, but doing it to NGS standards. We have been running workshops to show how to meet these standards. We are trying to get the surveyors to support height mod.

Q: (For Greg Anderson) What is the highest data rate available from PBO?
A: 15 seconds.
Q: What is the highest you can deliver?
A: We could go as high as 1 second.

Q: After 30 days data is removed from NGS site… Can you improve it; can you supply the data after 30 days? At COOP CORS sites?
A: For COOP CORS sites, we only keep the data for 30 days.
A: (Giovanni Sella) We only keep the 1 second data for 30 days. If there are requests to keep it longer we can talk about it. Also, if you know you need high rate data for a handful of sites, make that request to us

Q: (for Rick Foote and Joe Evjen) Can you talk about when other flavors of OPUS will be available:
A: Some of the other flavors are out in a testing mode right now. We don't have a formal date planned for a release of the other products. OPUS-RS is probably being used more than any of the others. Contact us at (ngs.opus@noaa.gov).

Q: (for Niel Weston) What is the communication media for real time processing between user and server? 2: Real time services are based on single stations, are you planning on using network systems and if not, why?
A: The communications mode is through the Internet, so users will have access to GPS data streams. (Q: Can you use a cellular phone?) A: People can use cellular phones to access the data. If you are in the field and have a cellular connection to the Internet, you can access the GPS data through the Internet.
2A: NGS will provide real-time GPS data via the Internet, but NGS will not provide GPS correctors. We are looking to provide data to organizations that provide positioning services, rather than provide the services ourselves. We provide the data to people to supplement their their networks so that they can provide positioning services. NGS is just making the data available; we will not be providing a real-time positioning service.

Discussion Group A: Real-Time Positioning
Facilitators: Bill Henning, Neil Weston, and Richard Snay

Participants:

Georg Weber, German Federal Agency for Cartography and Geodesy
Dmitry Kolosa, TopCon
Dave Newcomer, Trimble
Chuang Shi, Wuhan Univ.
Greg Anderson, UNAVCO Inc.
Karen Van Dyke, US DOT/Research & Innovative Technology Administration
Christa Von Hildebrandt, University of Puerto Rico
Sumio Usui, Mitsubishi Elec., Taiwan
Ryan Keenan, Leica
James Stowell, Leica
Eric Gakstatter, GPS World Magazine
Ken Bays, Oregon DOT
Marc Cheves, The American Surveyor Magazine.

Real-Time GNSS Network (RTN) discussion take-away:

- ✓ NOAA's National Geodetic Survey (NGS) should be proactive in supporting the development of regional RTN's across the USA.
- ✓ Regional RTNs should have a direct link to the National Spatial Reference System through the CORS network
- ✓ One or more sites in each RTN (a "representative sampling") should be included in the National and/or Cooperative CORS networks.
- ✓ Attendees were receptive to the idea of regularly validating positional coordinates for RTN reference stations. OPUS provides a good way to uniformly monitor these positional coordinates.
- ✓ Since the CORS network is expected to continue growing rapidly--approaching 3000 sites in the near future, mainly due to the establishment of new RTN reference stations--there should be automated procedures to check positional coordinates and error messages (daily? weekly?). Software procedures should be certified, e.g. who will receive error messages.
- ✓ NGS guidelines and standards should be developed for establishing and maintaining an RTN. By adhering to these criteria the RTN becomes "sanctioned" by the NGS and becomes more readily accepted by the users.
- ✓ A representative of one GPS vendor expressed the concern that NGS may stream GNSS data from more than 200 sites, because adding more than 200 stations may take away from other organizations installing new stations through vendors. There seemed to be no concern about NGS streaming data from only 200 or so stations, however. It should be noted that the number of Plate Boundary Observatory (PBO) stations will reach approximately 1200 and thus blanket much of the western USA, presenting a dense network for possible RT streams and causing concern among vendors in at least that area. Others may contend that GPS base stations established and maintained through public funds (such as those in the PBO network) should have their

data accessible to the public in current formats, which would include RT. According to Greg Anderson, a few organizations have already contacted UNAVCO about incorporating PBO sites into their regional RTNs.

- ✓ As RTCM 3.1 becomes available, consider a switch to a "world view" of GNSS by using ITRF coordinates as opposed to NAD 83 coordinates. Autonomous positioning done in the near future can show differences between NAD_83 and ITRF/WGS_84 as accuracy increases.
- ✓ As there is real user concern over the future of the NDGPS network, it is thought that RT data could be streamed from some of these stations via the Internet, and thus provide greater support for funding the development of the NDGPS network.
- ✓ Data latency should be closely considered through all the communication links.
- ✓ Consider installing more CORS near tide gauge stations.
- ✓ The NGS should be proactive in outreach and education in all of these areas.

Discussion Group B: OPUS

Facilitators: Joe Evjen and Rick Foote, NGS

Participants:

Delaine Meyer	ND DOT
Pierre Tetrault	Geodetic Survey Division, Canada
Alan Ip	Applanix
Jim Rumberg	Boeing

General Comments:

Thanks for outreach and accessibility to OPUS personnel, putting faces with names.
Add southern Canadian Active Control Stations to National CORS network to increase coverage for states contained in the northern tier of the U.S.
OPUS has successfully replaced traditional network; ND-DOT is skipping monuments, uses OPUS info on project control instead of datasheet info.

What version of OPUS most interest you? DB, RS, Projects, GIS?

Desire any support for RTK.
General interest in all flavors.

What OPUS functionality would you like to add?

The standard output should provide linear coordinates in units of feet.

OPUS-DB is currently proposed to update our database for scaled positions (lat/long or elev.) or for new marks. Should other updates be made?

General agreement with NGS proposal; replace inferior positions when applicable.
ACTION: Send OPUS-DB link to Delaine Meyer

OPUS output - XML? Web?

Applanix is interested in building applications which use OPUS.

Discussion Group C: Texas Spatial Reference Center
Facilitators: Cliff Middleton and Casey Brennan, NGS

Participants:

Steve Schmidt, TxDOT
Dr. Gary Jeffress, Texas A&M University, Corpus Christi
Dr. Stacy Lyle, Texas A&M University, Corpus Christi
Randy Hurtt, MAGELLAN/Thales
Also, several representatives from TxDOT met separately with Giovanni Sella during this time frame.

The question to kick off the session was: What can the TxSRC do to meet the needs of the GPS/NAV community? The following were suggested:

1. Support for RTK surveying.

2. Allow use of TxDOT VRS to public (currently only TxDOT contractors are allowed use outside of TxDOT. The point was raised that since private companies were offering such a service on a fee basis in some areas, that there may be conflicts. The data stream vs Network Solution Correctors was discussed.

3. Promote a unified Vertical Datum

4. Improve the GEOID model

5. Perform outreach and training to improve understanding of Heights/GPS/GEOID.

6. Provide easy to understand standards and specifications for contractors.

Follow up discussion:

What would you like to see at the TX Spatial Reference Center?

(Answer from a TX surveyor) I would like to see the real time capability of TxDOT, and the end users ability to tie into RT surveys, and see a proliferation of real time networks.

TxDOT is still looking into this. It is in the development stage.

There are a few private RTK networks out there. Dallas and the Dallas-FortWorth area have one. They are spread out all over the place.

(from a TX surveyor) I am interested in being able to freely tie into these rather than have to pay for it.

You run into problems because government can do it for free, or should we let private businesses do it for a fee? Private business gets upset when government starts doing stuff they get paid for.

Height mod work is more about getting better heights, than getting RTK systems. NGS is currently looking to get more gravity data for the US to improve the geoid model.

Q: What is happening to the geoid model in an area of subsidence? Do they move?
A: Well as the earth sinks, gravity should change too. But the short answer is that you will have to remeasure gravity every so often as the Earth changes.

Q: Do you think there would be local geoid models that get updated more often than the entire geoid model?
A: Well they do some of that, but what they really do is just make their own correction and just ignore the geoid. They know how far off it is and then they just make their own correction.

Q: What steps are NGS or TXDOT doing to educate the public on this stuff?
A: Well, we have been talking with politicians about this stuff and telling them it needs to be done. There are a few articles that explain this too. We also hold height mod forums, and have talks and conferences.

DISCUSSION GROUP D. IONOSPHERIC MODELING
Facilitator: Joseph Kunches, NOAA's Space Environment Center

Participants:

Marc Cheves, Editor, The American Surveyor Magazine

There's great interest in moving RTK techniques forward in the future. One of the most significant error sources for RTK -- or a factor requiring a long time on-station -- is the behavior of the ionosphere. NOAA's Space Environment Center (SEC) is now providing a specification in near real-time in the USTEC product, using CORS data as the primary input. In the future, SEC hopes to actually predict the behavior of the ionosphere, using solar wind data measured upstream of Earth, and then incorporate those predictions into USTEC. If this prediction technique proves to be successful, it will enable greater efficiency for future RTK applications.

Discussion Group E: Tropospheric Modeling
Facilitator: Seth Gutman, NOAA's Earth Systems Research Laboratory

The Tropospheric Modeling Breakout Section met to discuss issues involving the practical implementation of a weather model-based tropospheric signal delay correctors. The session was attended by representatives of only one GPS receiver manufacturer. They suggested that rather than transmit the entire CONUS grid to all users that provisions be made for users to specify a region of interest and only that subset of the entire model be transmitted and updated to the user. Some high level technical options to accomplish this were explored.