National Geodetic Survey

REAL-TIME POSITIONING AND THE ROLE OF THE NGS

NAVIGATION CENTER
The Navigation Center of Excellence

U.S. Department of Homeland Security
UNITED STATES COAST GUARD

CORS USERS FORUM
CGSIC- 47TH MEETING
FORT WORTH
SEPTEMBER 25, 2007

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Geodesist
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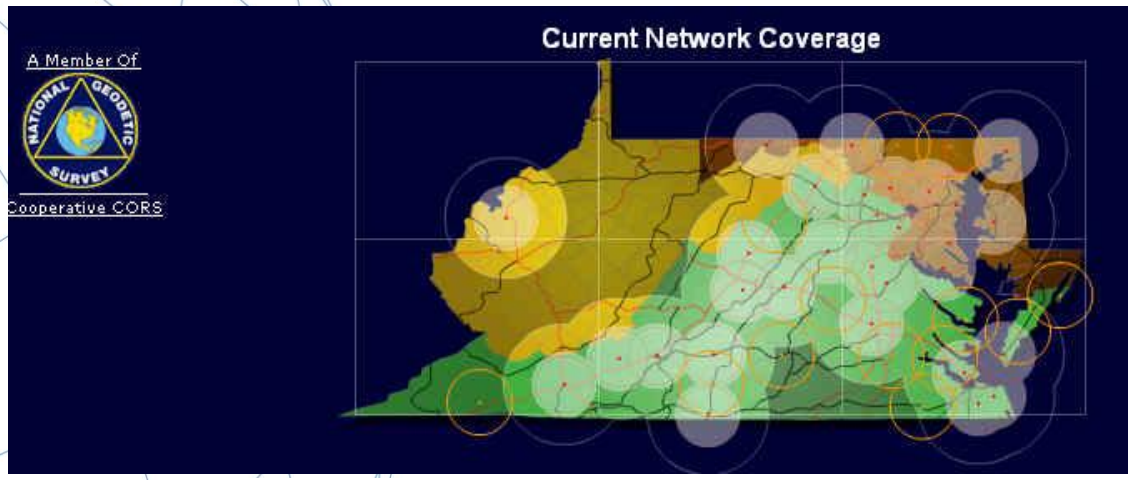
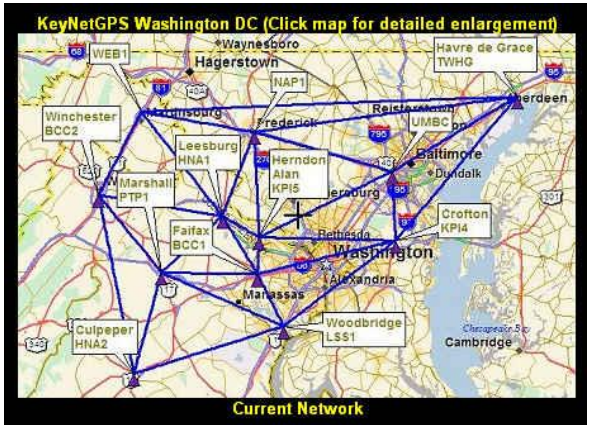
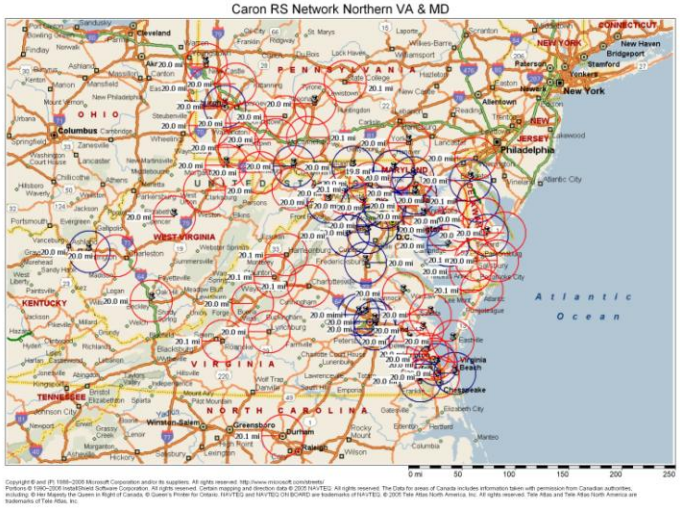
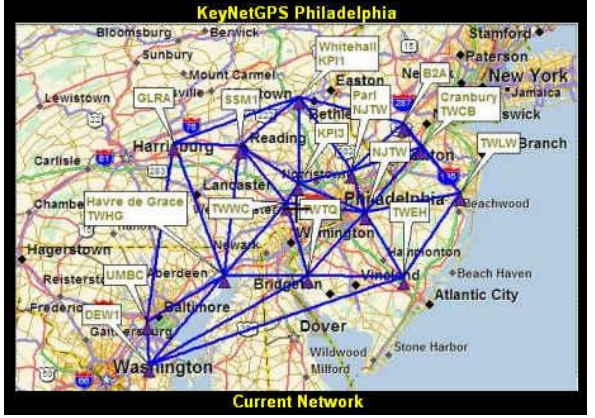
National Oceanic and Atmospheric Administration

RTN OVERLAP – 3 DIFFERENT GNSS VENDORS - PRIVATE SECTOR NETWORKS

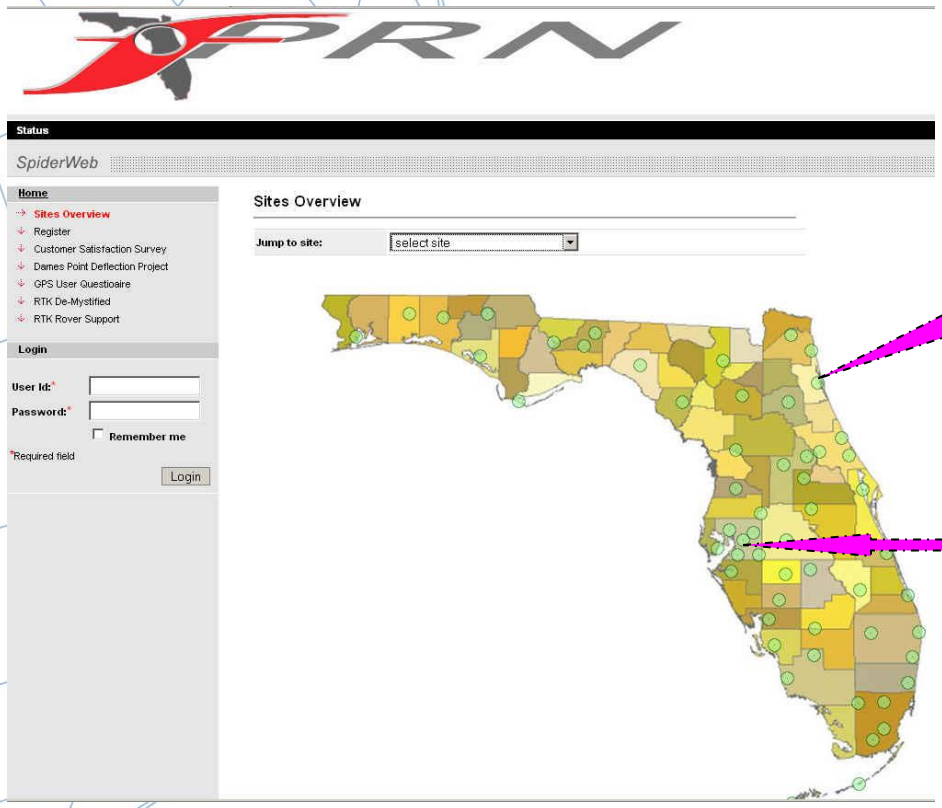


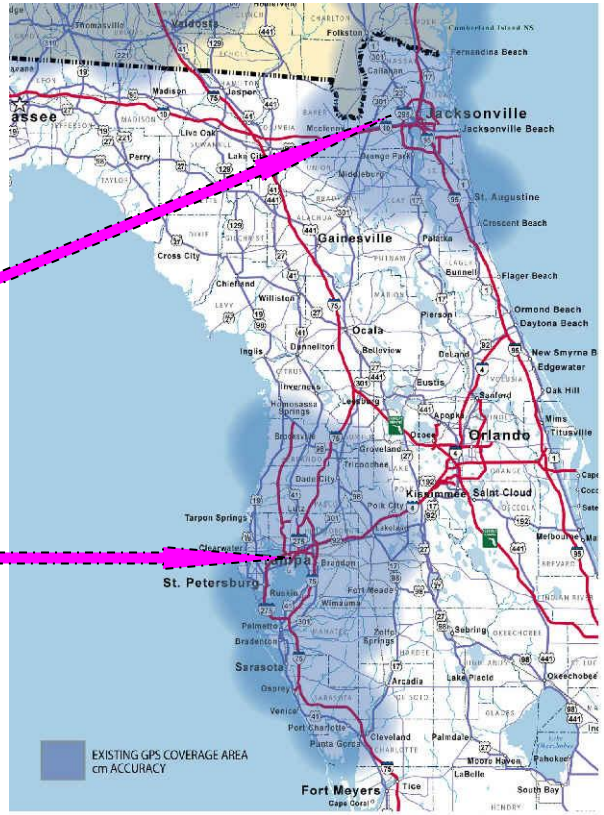


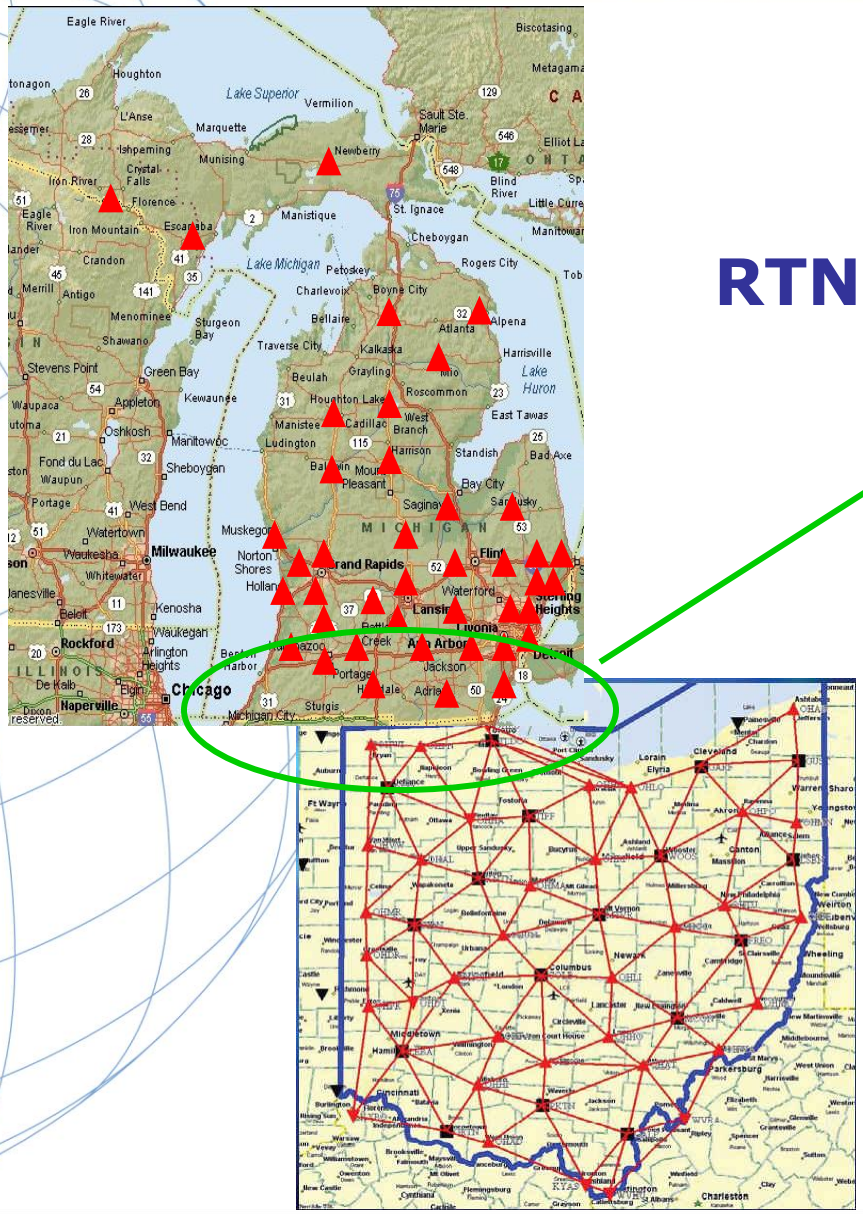




RTN OVERLAP – DOT & PRIVATE SECTOR







RTN OVERLAP – VRS DOT & MAC DOT

OLD FIRMS – SCALED HORIZONTAL

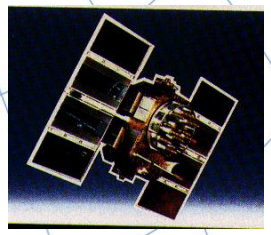
OLD REMOTE SENSING

MACHINE CONTROL FROM RTN OR SITE RT POSITIONING

Machine Control

Slide by Jim Waters, TNDOT
Graphics Courtesy of Caterpiller Inc.

GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)



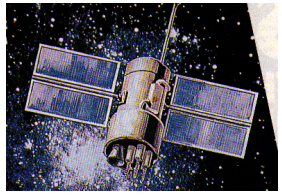
POTENTIAL FUTURE DEVELOPMENTS
(2005 – 2017?)

GPS MODERNIZATION – BLOCK IIF & III

GLONASS ENHANCEMENTS (K & M)

EUROPEAN UNION - GALILEO

CHINA - COMPASS



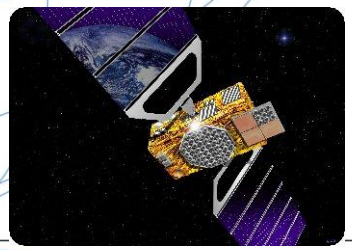
115+ Satellites

Second and Third Civil Frequency - GPS

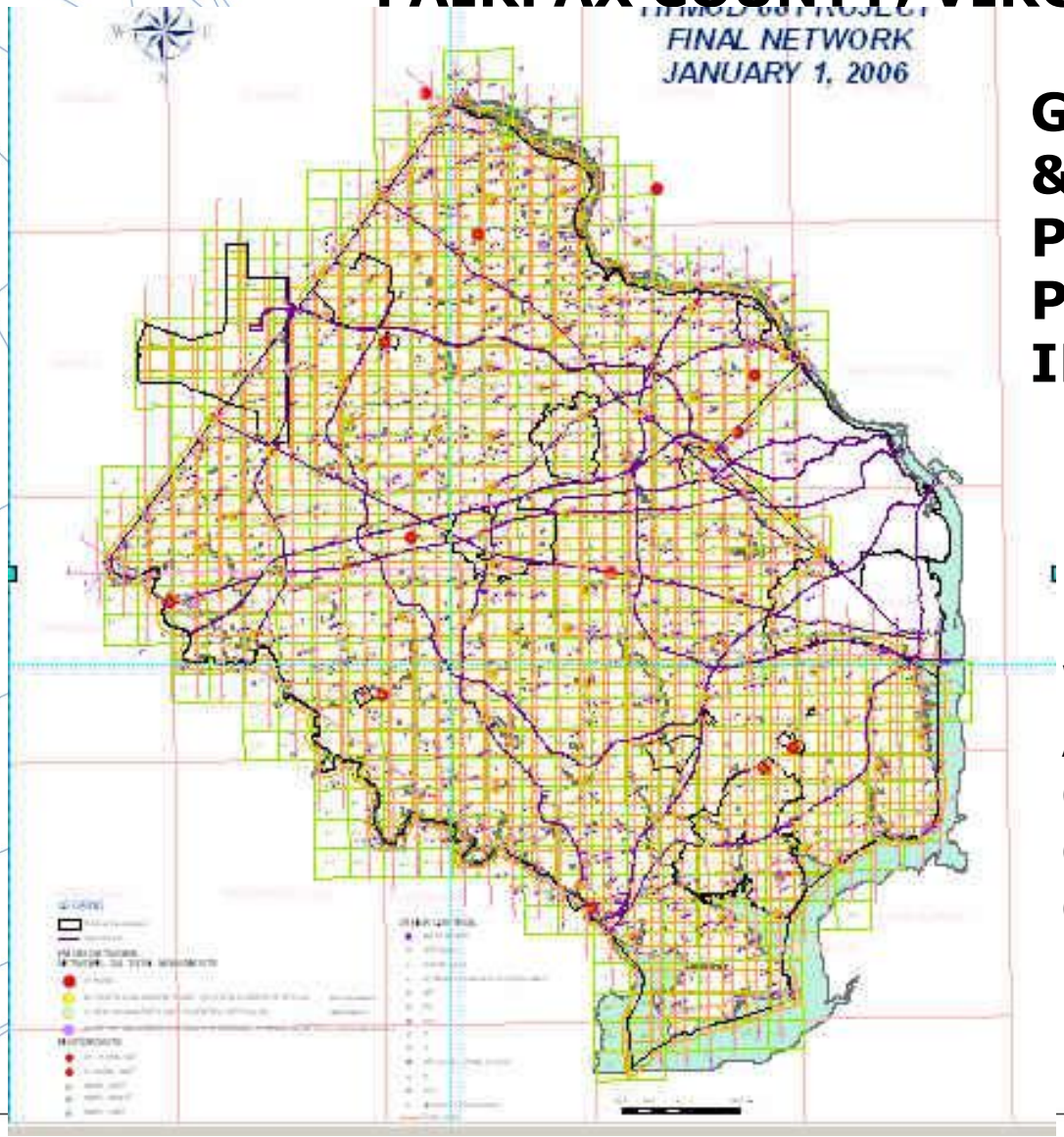
No Signal Encryption - GLONASS & GALILEO

More Robust Signal Transmissions

Real-Time Unaugmented 1 Meter (or better!) Accuracy



FAIRFAX COUNTY, VIRGINIA



GEODETIC CONTROL & PHOTOGRAMMETRIC PROJECTS MANAGED IN GIS SOFTWARE

HEIGHT MODERNIZATION PROJECT

WHAT ADVANTAGE COULD RTN HAVE GIVEN TO GEOSPATIAL PLANS?


Identify Results
1: Pointlist1.txt - GPS 14 AZ
Point
GPS 14 AZ
6934084.29800
11867351.14700
4.30000
HV9601
Clear
Clear All

GNSS DERIVED HEIGHTS

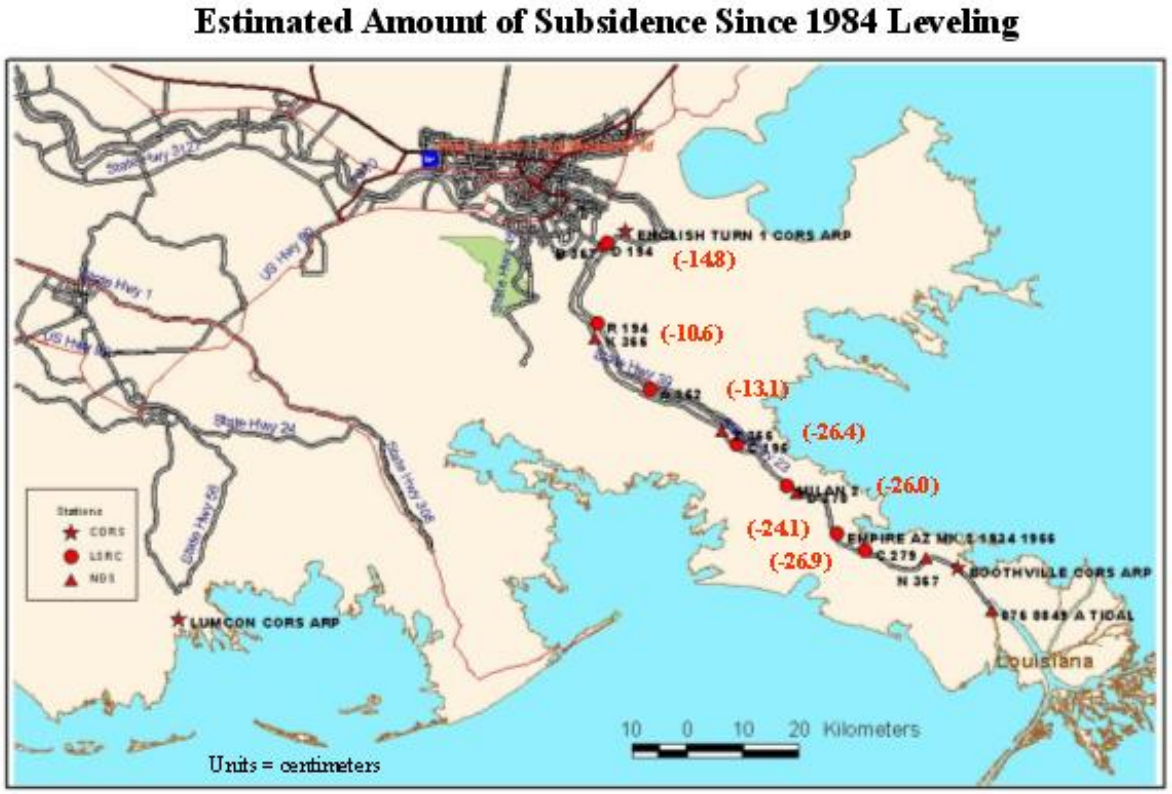
PASSIVE ACTIVE

- NOS-NGS 58 WITH DRAFT ORTHO GUIDELINES-
  0.05 M TO NSRS, 0.02 M LOCAL
- DGPS – 15 SECONDS, 0.5 TO 2 M
- OPUS > 4 HRS = 0.02 M (h), 0.05 (H)
- CORS- SAME AS OPUS
- OPUS-RS 15 MINUTES =0.10 M
- SINGLE BASE RTK- "IT DEPENDS!"
  5 SECONDS (better than 0.03 M expected)
- RTN – "IT DEPENDS!"
  5 SECONDS (better than 0.04 M expected)

Error	Value
Ionosphere	4.0 meters
Clock	2.1 meters
Ephemeris	2.1 meters
Troposphere	0.7 meters
Receiver	0.5 meters
Multipath	1.0 meter
Total	**10.4 meters**

Subsidence Areas

Questionable Elevation Data



Monumented Points Deterioration

Disturbed Geodetic Control

Coordinates/Elevations Questionable

Destroyed Geodetic Control

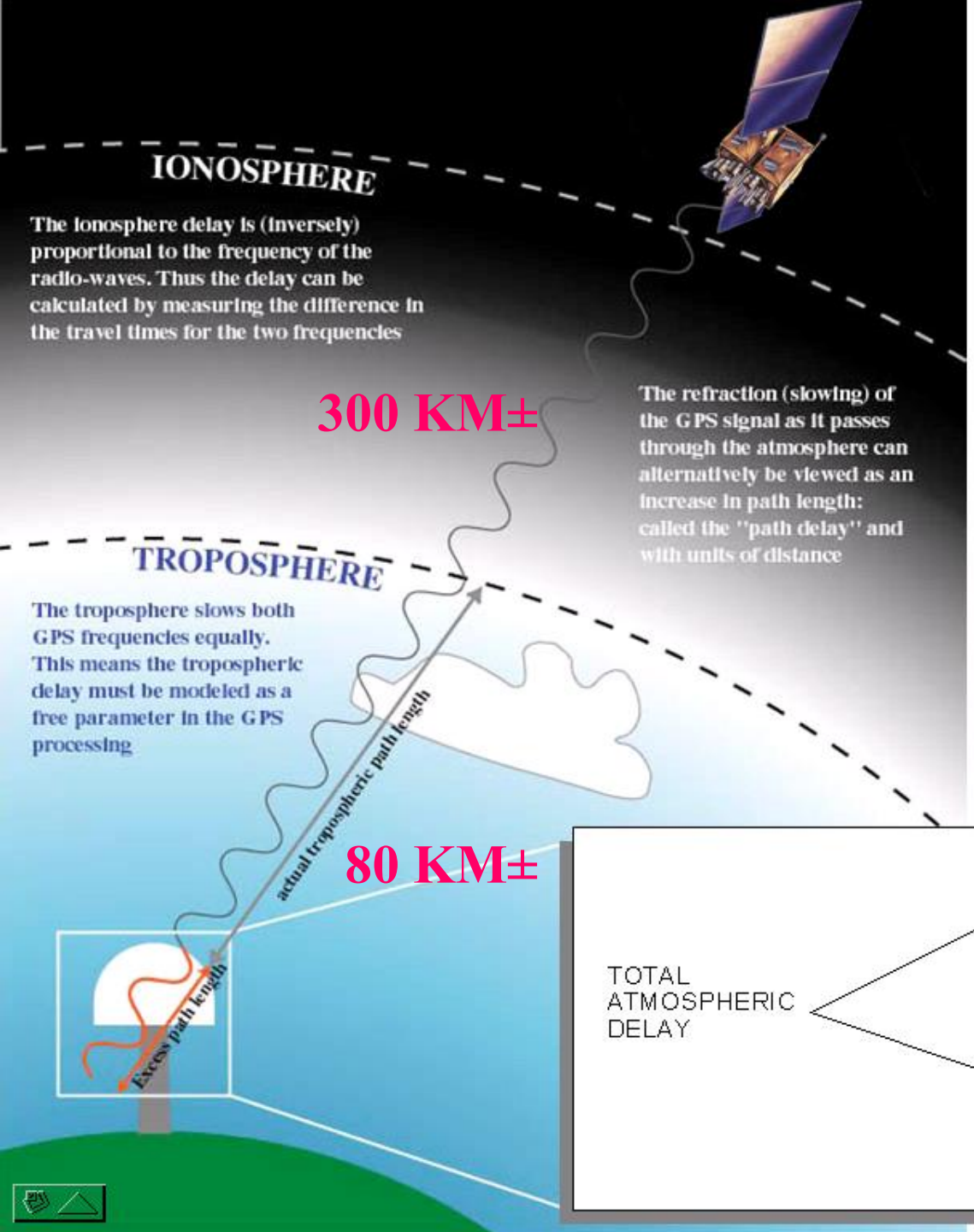
No Coordinates/Elevation

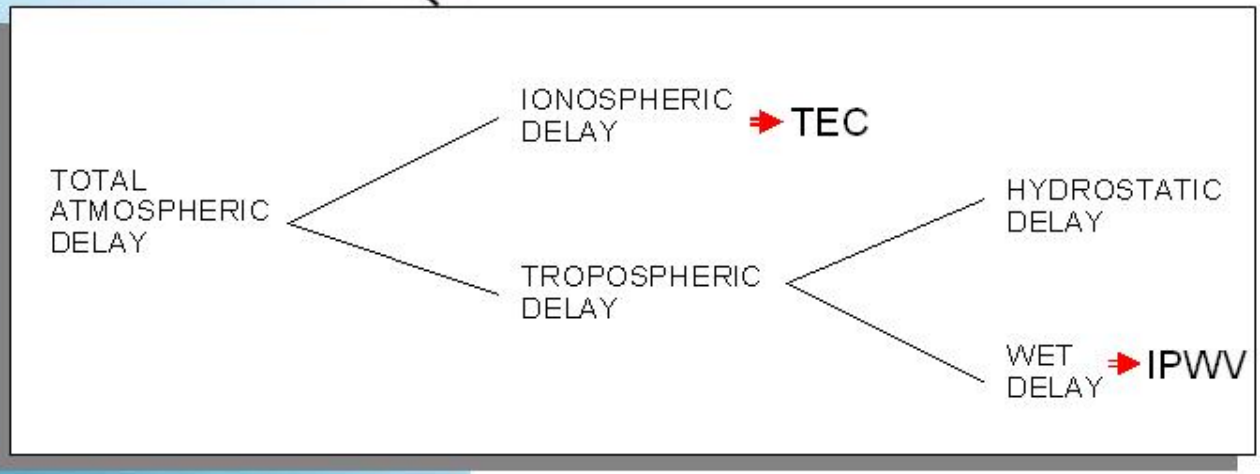
CLASSICAL REAL TIME POSITIONING

- PDOP
- MULTIPATH
- ~~SATELLITES~~
- ~~BASE ACCURACY~~
- ~~BASE SECURITY~~
- REDUNDANCY, REDUNDANCY, REDUNDANCY
- ~~PPM – IONO, TROPO MODELS, ORBIT ERRORS~~
- ~~SPACE WEATHER – "K" INDICES~~
- ~~GEOID QUALITY~~
- ~~POSITIONS TIED TO NSRS?~~
- BUBBLE ADJUSTMENT
- ~~LATENCY, UPDATE RATE~~

KNOWLEDGE OF ALL THE ABOVE = OPERATOR EXPERTISE

GPS Signal Delays Caused by the Atmosphere

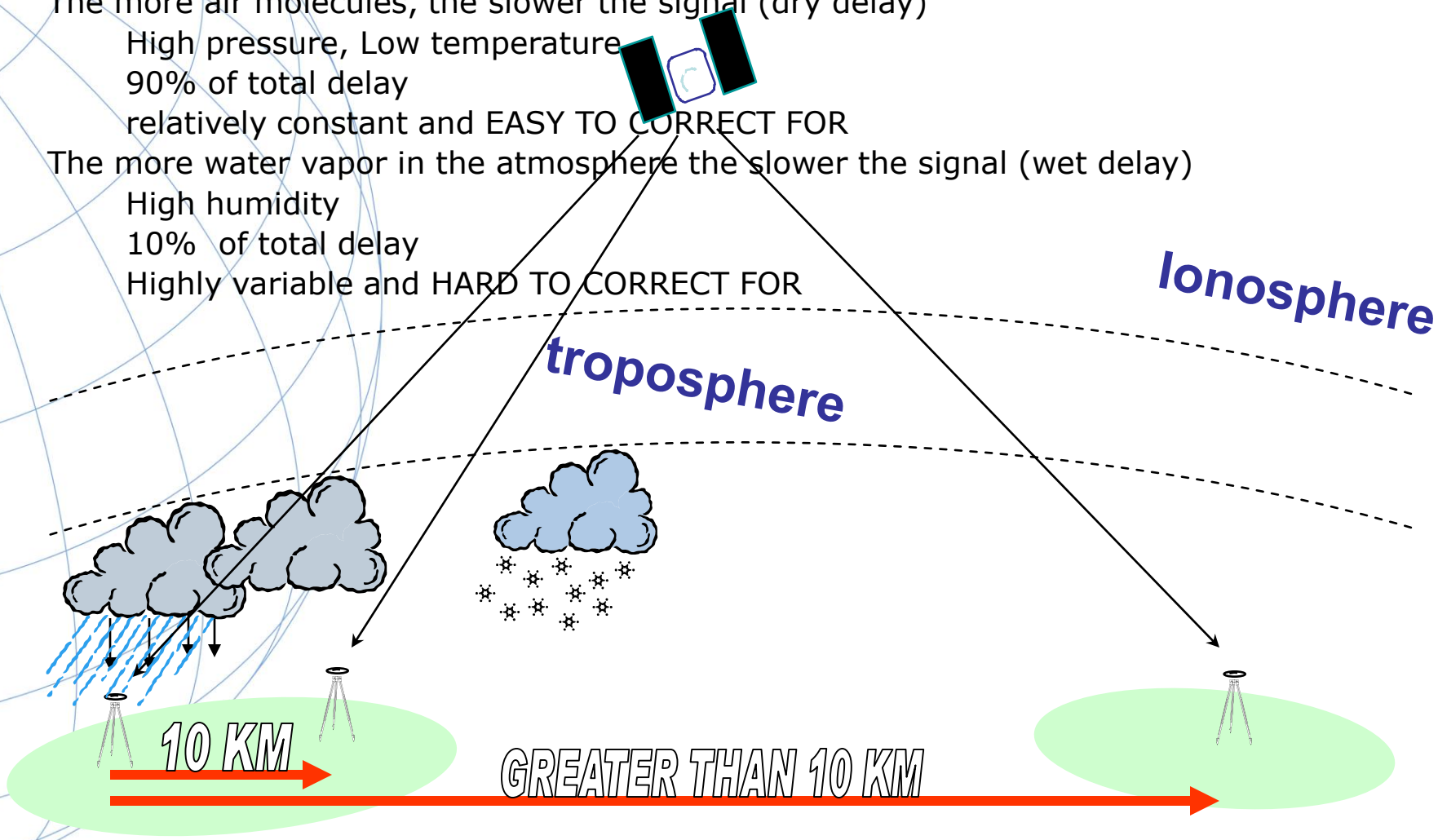




TROPOSPHERE DELAY

The more air molecules, the slower the signal (dry delay)
- High pressure, Low temperature
- 90% of total delay
- relatively constant and EASY TO CORRECT FOR

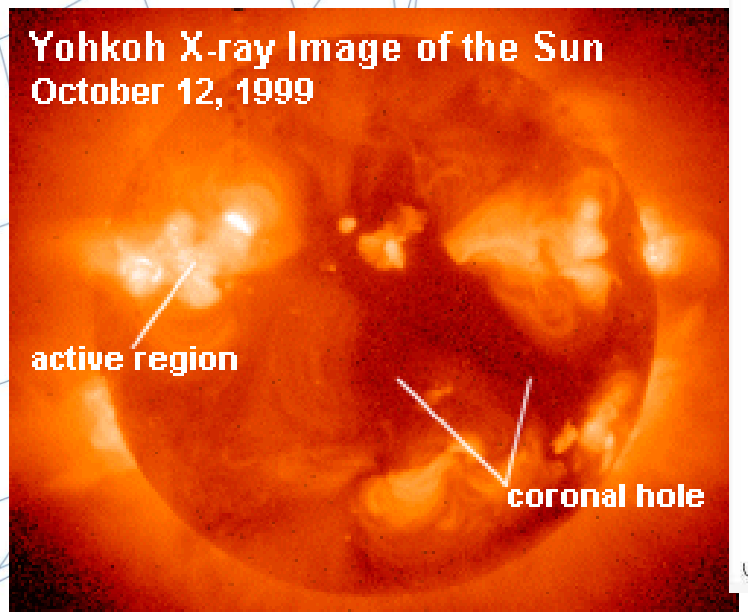
The more water vapor in the atmosphere the slower the signal (wet delay)
- High humidity
- 10% of total delay
- Highly variable and HARD TO CORRECT FOR

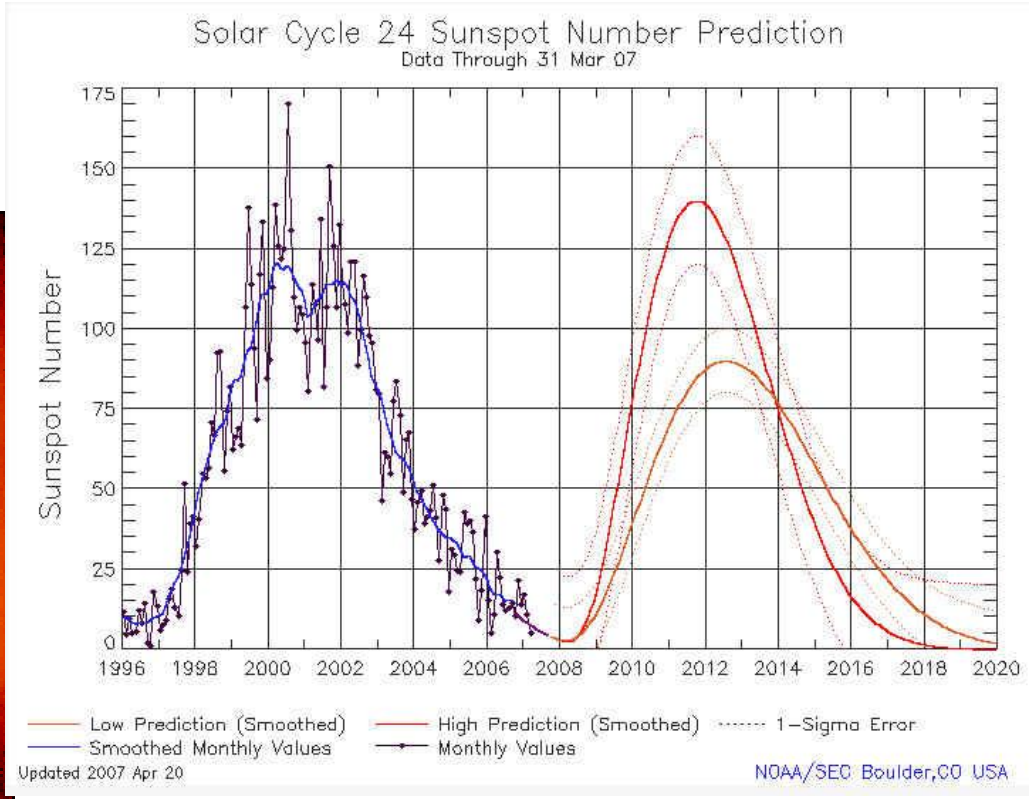


SUNSPOT CYCLE

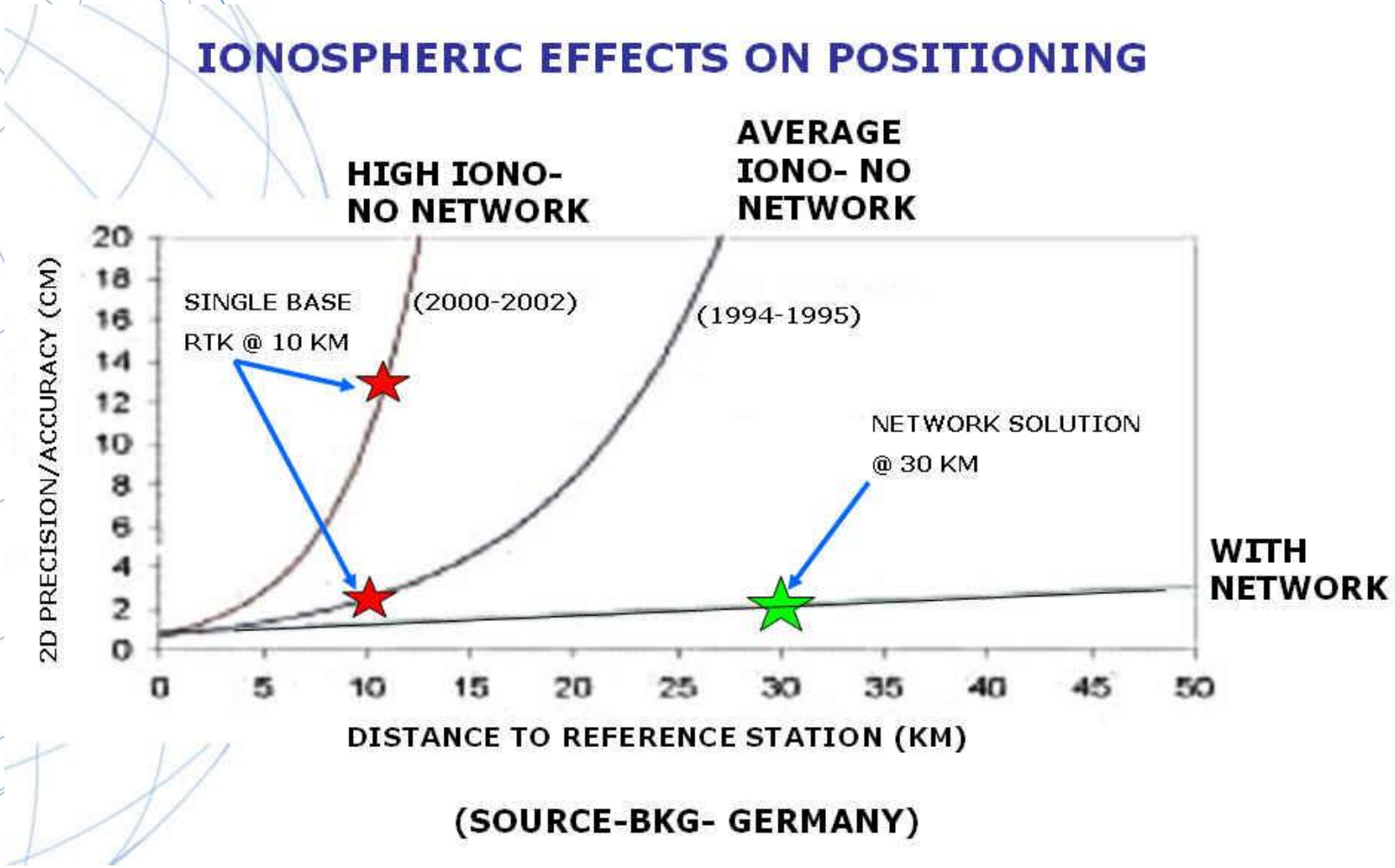
- Sunspots follow a regular 11 year cycle
- We are just past the low point of the current cycle
- Sunspots increase the radiation hitting the earth's upper atmosphere and produce an active and unstable ionosphere

http://www.sec.noaa.gov/





IONOSPHERIC EFFECTS ON POSITIONING



Comparison of 30 Minute Solutions - Precise Orbit; Hopfield (0); IONOFREE

(30 Minute solutions computed on the hour and the half hour)

MOLA to RV22 10.8 Km

THE IMPORTANCE OF REDUNDANCY

Day 264	dh (m)	Hours Diff.	Day 265	dh (m)	Day 264 minus Day 265 (cm)	* diff >2 cm	Mean dh (m)	Mean dh minus "Truth" (cm)	* diff >2 cm
14:00-14:30	-10.281	27hrs	17:00-17:30	-10.279	-0.2		-10.280	-0.5	
14:30-15:00	-10.278	27hrs	17:30-18:00	-10.270	-0.8		-10.274	0.2	
15:00-15:30	-10.281	27hrs	18:00-18:30	-10.278	-0.3		-10.280	-0.4	
15:30-16:00	-10.291	27hrs	18:30-19:00	-10.274	-1.7		-10.283	-0.7	
16:00-16:30	-10.274	27hrs	19:00-19:30	-10.274	0.0		-10.274	0.2	
16:30-17:00	-10.287	27hrs	19:30-20:00	-10.276	-1.1		-10.282	-0.6	
17:00-17:30	-10.279	27hrs	20:00-20:30	-10.261	-1.8		-10.270	0.6	
17:30-18:00	-10.270	27hrs	20:30-21:00	-10.251	-1.9		-10.261	1.5	
18:00-18:30	-10.277	21hrs	15:00-15:30	-10.270	-0.7		-10.274	0.2	
18:30-19:00	-10.271	21hrs	15:30-16:00	-10.276	0.5		-10.274	0.2	
19:00-19:30	-10.277	21hrs	16:00-16:30	-10.278	0.1		-10.278	-0.2	
19:30-20:00	-10.271	21hrs	16:30-17:00	-10.286	1.5		-10.279	-0.3	
20:00-20:30	-10.259	18hrs	14:00-14:30	-10.278	1.9		-10.269	0.7	
20:30-21:00	-10.254	18hrs	14:30-15:00	-10.295	4.1	*	-10.275	0.1	
							"Truth"		
14:00-21:00	-10.275		14:00-21:00	-10.276	0.1		-10.276		

Two Days/Same Time

-10.254
-10.251 > -10.253

Difference = 0.3 cm

"Truth" = -10.276

Difference = 2.3 cm

Two Days/ Different Times

-10.254
-10.295 > -10.275

Difference = 4.1 cm

"Truth" = -10.276

Difference = 0.1 cm

GNSS TO ANY DATUM

- **GNSS ECEF X,Y,Z (WGS 84 & PZ90)**

→ **NAD 83 (ϕ,λ,h)** → **SPC N,E,h**

+ GEOID XX → **= SPC N,E,H**

OR

CALIBRATE TO 4-5 SITE POINTS IN THE DESIRED DATUM. THIS TECHNIQUE LOCKS TO PASSIVE MONUMENTATION IN THE PROJECT AREA.

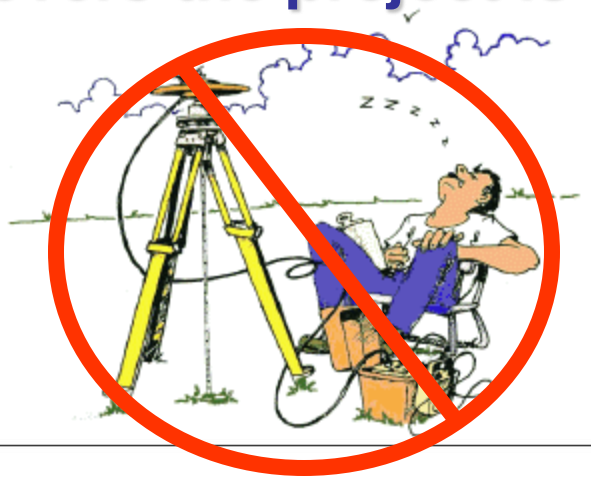
WHY NETWORK RTK (RTN)?

Because the requirement for a user base station is removed:

- No reconnaissance/recovery of passive control
- No time lost setting up and breaking down a base static
- No base baby sitting, therefore labor cost is reduced

No base means with two rovers the project is completed in half the time

- = $$$ savings



WHY NETWORK RTK (RTN)?

- RTNs CAN BE SEAMLESSLY CONNECTED TO THE NSRS –
  This means:

- Regional Inter-GIS compatibility
- Continual accuracy and integrity monitoring
- Easy datum adjustment/change updates
- NO DISTANCE CORRELATED ERROR - Atmospheric, ephemeris corrections for the site of survey Data degrade gracefully outside of the network or if a reference station is down
- Overlapping RTN give the same results!

EXAMPLES OF RTN ADMINISTRATORS IN THE USA

- ACADEMIC/SCIENTIFIC
- SPATIAL REFERENCE CENTERS
- VARIOUS DOTS
- COUNTY
- CITY
- GEODETIC SURVEYS
- MANUFACTURER
- VENDOR NETWORKS
- AGRICULTURE
- MA & PA NETWORKS

THE ROLE OF THE NGS IN SUPPORT OF RTN

- The NGS should provide real time RTCM data streams (via NTRIP) from a subset of the National CORS network- perhaps in a 200 Km spacing grid. These data streams will aid in the establishment, validation and monitoring of the RTNs by network administrators. NO CORRECTORS WILL BE BROADCAST.
- NGS encourages the institutions, who are providing real-time positioning services, to use the NGS-provided raw data in their operations so as to:
  (1) SUPPLEMENT the data from other GNSS base reference stations, and
  (2) use the positional coordinates and velocities of the GNSS stations contained in the NGS real-time network as FIDUCIAL VALUES for the positional coordinates and velocities of other real-time GNSS stations.
- The NGS could ASSESS AND ACCREDIT proposed or even current RTN reference station sites for obstructions, multipath, positional integrity - in short, for anything that might affect optimal performance of the RTN.

NGS TESTING SITES – CORS STATIONS HNPT & MDSI

Welcome to NGS Ntrip Broadcaster (Prototype)

Protocol: *NTRIP 0.1.5*
NGS (National Geodetic Survey) streams raw GNSS data in RTCM format via NTRIP Broadcaster. This server name is *realtime.ngs.noaa.gov*, running on Port *2101*

Details about GNSS data streams on the NGS Ntrip Broadcaster are available through

- Source Table.

To receive GNSS data streams via NTRIP in real-time you may use the Ntrip Client - GNSS Internet Radio. The Ntrip Client program designed to run on a PC or Laptop (Windows, Linux). It retrieves data from any NTRIP supporting Broadcaster. The program handles the HTTP communication and transfers received GNSS data to a Serial or IP port to feed an application.

This is a prototype of NGS Ntrip Broadcaster. Authorization will be provided using a user ID and a user password through a *Registration* form for NGS tracking purpose.

For more information about NTRIP

- NTRIP for the real-time GNSS data dissemination technique
- A list of other Ntrip Broadcaster servers

Date Last Updated: September 11, 2007
ngs.realtime.gnss@noaa.gov

User Registration for NGS Ntripcaster (Prototype)

Please complete this form to apply for free access to real-time GNSS data streams from the NGS Ntrip Broadcaster at *realtime.ngs.noaa.gov* (port 2101).

User data (* mandatory):

Full Name* :

Organization* :

Street :

City* :

OR ZIP CODE ONLY

State/Country* : – US states –

Phone :

E-mail* :

The user ID and password you will receive by email in response to your request is only valid for your personal use.

Send Registration Form | Clear This Form

National Geodetic Survey (NGS)
Maryland, U.S.A
ngs.realtime.gnss@noaa.gov

THE ROLE OF THE NGS IN SUPPORT OF RTN

TO BE AN RTN "RECOGNIZED" BY THE NGS:

4. Initial RTN reference station coordinates are produced by the individual RTN administrator. However, promulgated coordinates and velocities for the corresponding GNSS base reference stations will be compatible with the National Spatial Reference System at the level of 2-cm Horizontal and 4-cm (ellipsoid) height.
   Automated processes will enable RTN administrators to push daily data for all RTN reference stations to the NGS where a specific version of OPUS-DB will position the stations and archive the data.
   → Three National CORS *that are part of the RTN* will be used as control stations for this OPUS-DB processing.
   TEQC may be utilized to QA/QC the data.
   Then, 60 day plots will be developed to graphically depict the deviation from predicted daily coordinates for each and every reference station.

THE ROLE OF THE NGS IN SUPPORT OF RTN

- Additionally, NOAA/NGS could stream satellite ephemerides, satellite clock parameters, iono and tropo models and even crustal motion models for public use.

- The NGS, continuing its role in support of accurate, reliable positioning, would study temporal macro variations in positions (seasonal, daily, ocean loading, atmospheric loading, subsidence, tectonic, etc.) and would study phenomena affecting accurate positioning (satellite orbits, refraction, multipath, antenna phase centers, geoid, etc.)

- *The NGS will not stream data that is being streamed via NTRIP by another organization.*

EXAMPLE OF WHY RTN REFERENCE STATIONS SHOULD BE MONITORED

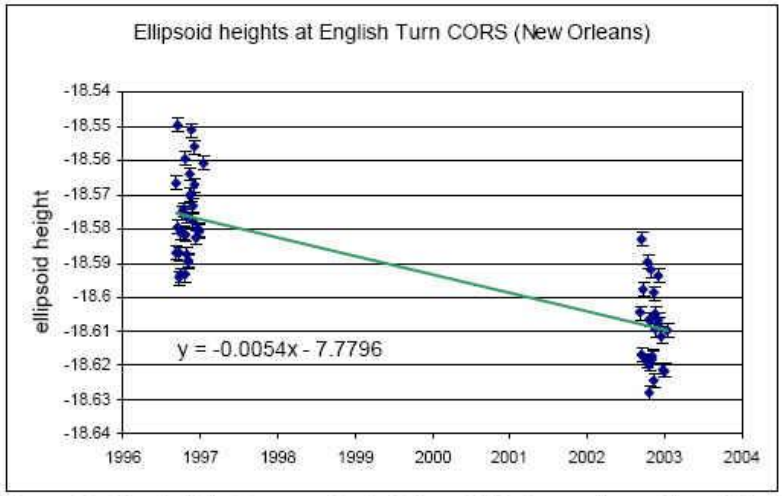
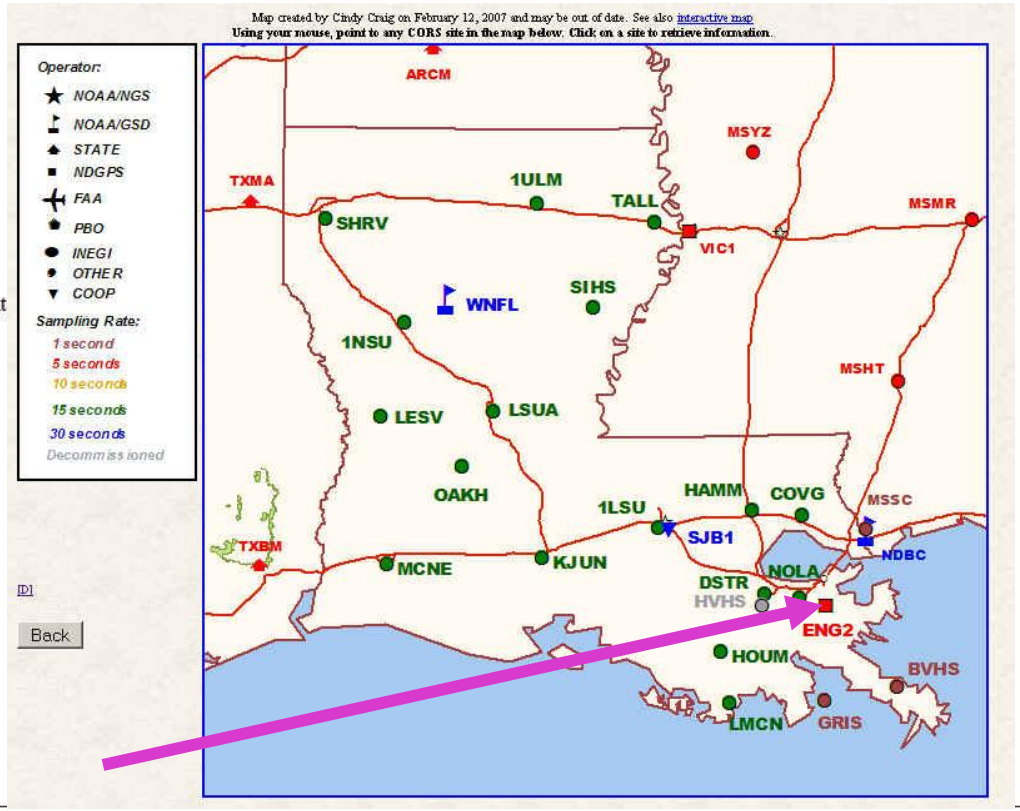


Figure 13. Vertical displacement derived from GPS observations; ellipsoid height meters.

SUBSIDENCE

≈ 6 MM / YEAR

ENGLISH TURN CORS



THE ROLE OF THE NGS IN REAL TIME POSITIONING

DYNAMIC DOCUMENTS:

1. **"NGS User Guidelines for Single Base GNSS Real Time Positioning" DRAFT FINISHED**
   FOUR ACCURACY CLASSES
   CONDITIONS/PROCEDURES

2. **"NGS User Guidelines for GNSS Real Time Positioning in RTN" FY 2008-9**

3. **"NGS Guidelines for GNSS RTN Administrators" FY 2009**

EXPEDITING THE GUIDELINES

FIRST RTN TEAM MEETING AT ION CONFERENCE CENTER 9/26/2007

ROOM 103B 9:00 AM TO 11:00 AM

- THE NGS ENCOURAGES RTN USERS AND ADMINISTRATORS TO BECOME COOPERATIVE PARTNERS TO PROVIDE INPUT THAT WILL ENABLE VALUABLE DOCUMENTS TO BE DRAFTED THAT WILL BENEFIT THE PUBLIC WELFARE.

  - ESTABLISHING REFERENCE STATIONS
  - ADJUSTING NETWORKS
  - ACCURACY EXPECTATIONS VS. OBTAINED
  - BASELINE DISTANCES
  - ERROR MODELING
  - COMMUNICATION ISSUES

NGS SUPPORT OF RTN: SUMMARY

- NGS STREAMS UNCORRECTED RTCM DATA FROM THE BACKBONE CORS
- RTN NSRS COMPATIBILITY LEVEL- 2-cm H, 4-cm V
- RTN OVERLAP ACCURACY?
- ESTABLISHING REFERENCE STATIONS (COORDINATE INTEGRITY, SITE EVALUATION,)
- MODELS & TOOLS
- DATA ARCHIVING (OPUS-DB)
- DATA QA/QC


CELEBRATING
1807
U.S. Coast and Geodetic Survey
2007
200
YEARS
of Science, Service, & Stewardship
NOAA
NATIONAL GEODETIC SURVEY
2007
U.S. COAST AND GEODETIC SURVEY
1807
1807
William.henning@noaa.gov

NGS FTP LINK FOR PRESENTATION

ftp://ftp.ngs.noaa.gov/dist/whenning/CORS FORUM/CORS FORUM.ppt

(May be case Sensitive)