USING CORS WORKSHOP
(Continuously Operating Reference Stations)

Presented by:

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In cooperation with the
Land Surveyors' Association of Washington

November 9, 2001

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Ocean Service
National Geodetic Survey

Positioning America for the Future

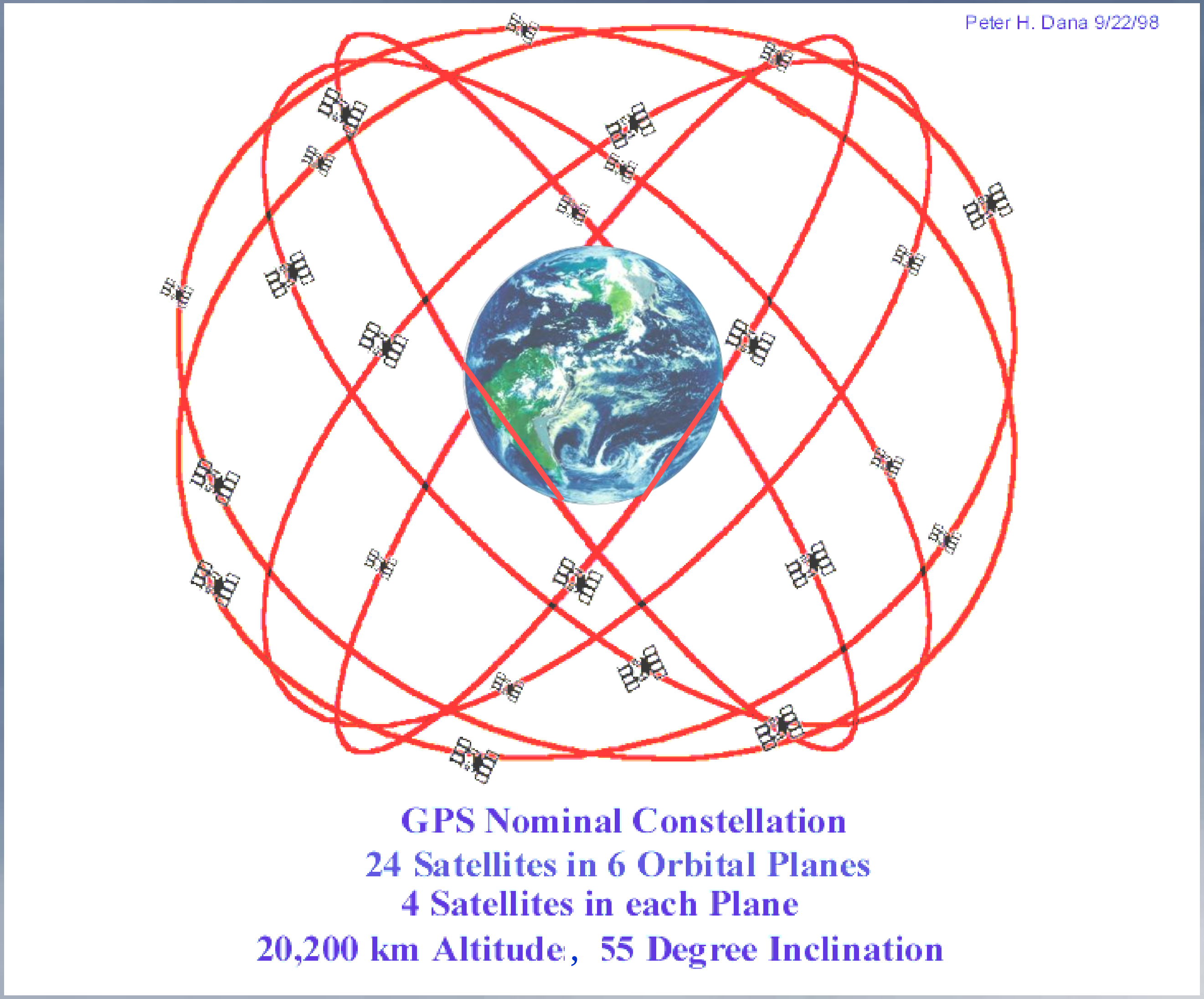
CORS Information

Web site: http://www.ngs.noaa.gov/CORS

Email: cors@ngs.noaa.gov

Telephone: 301-713-3563

Global Positioning System
GPS

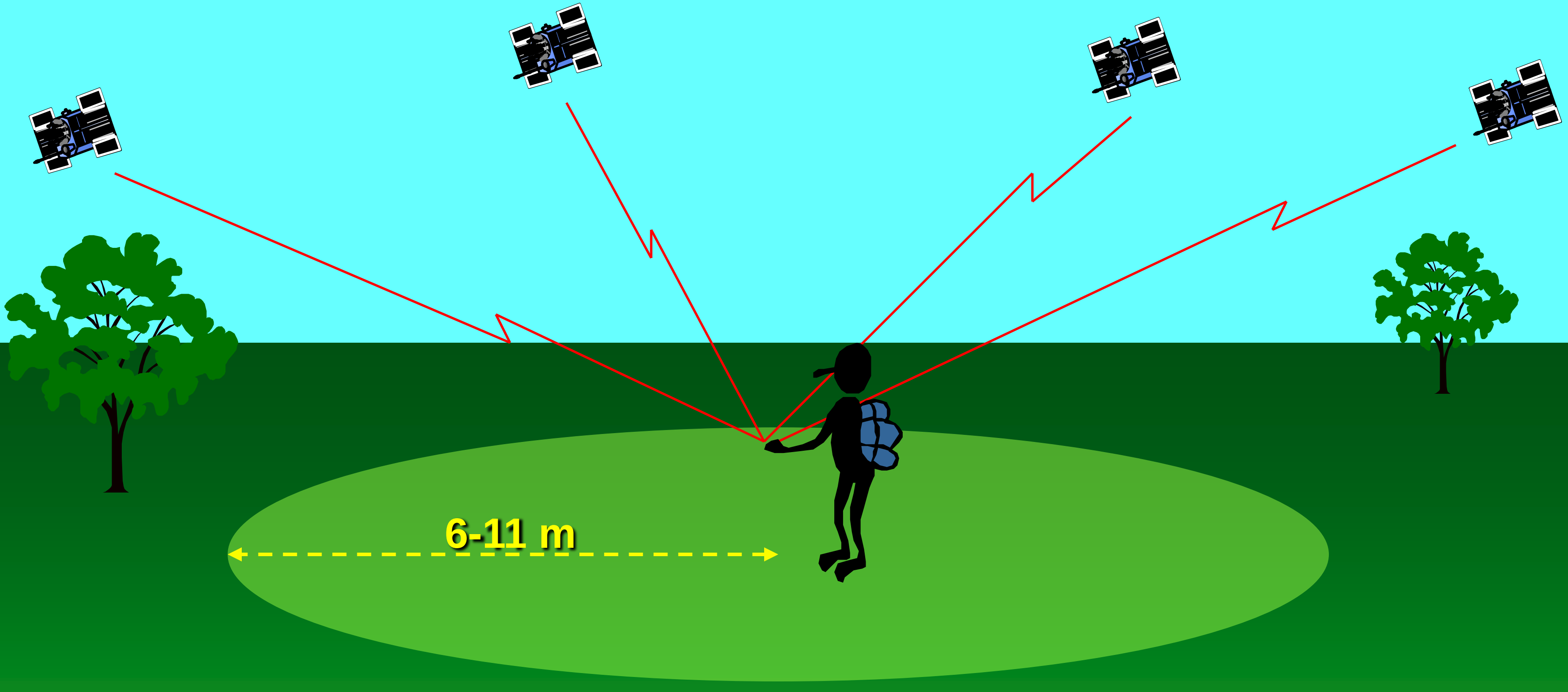


GPS Satellite

The Macrometer V1000 -- the first GPS receiver owned by NOAA!!

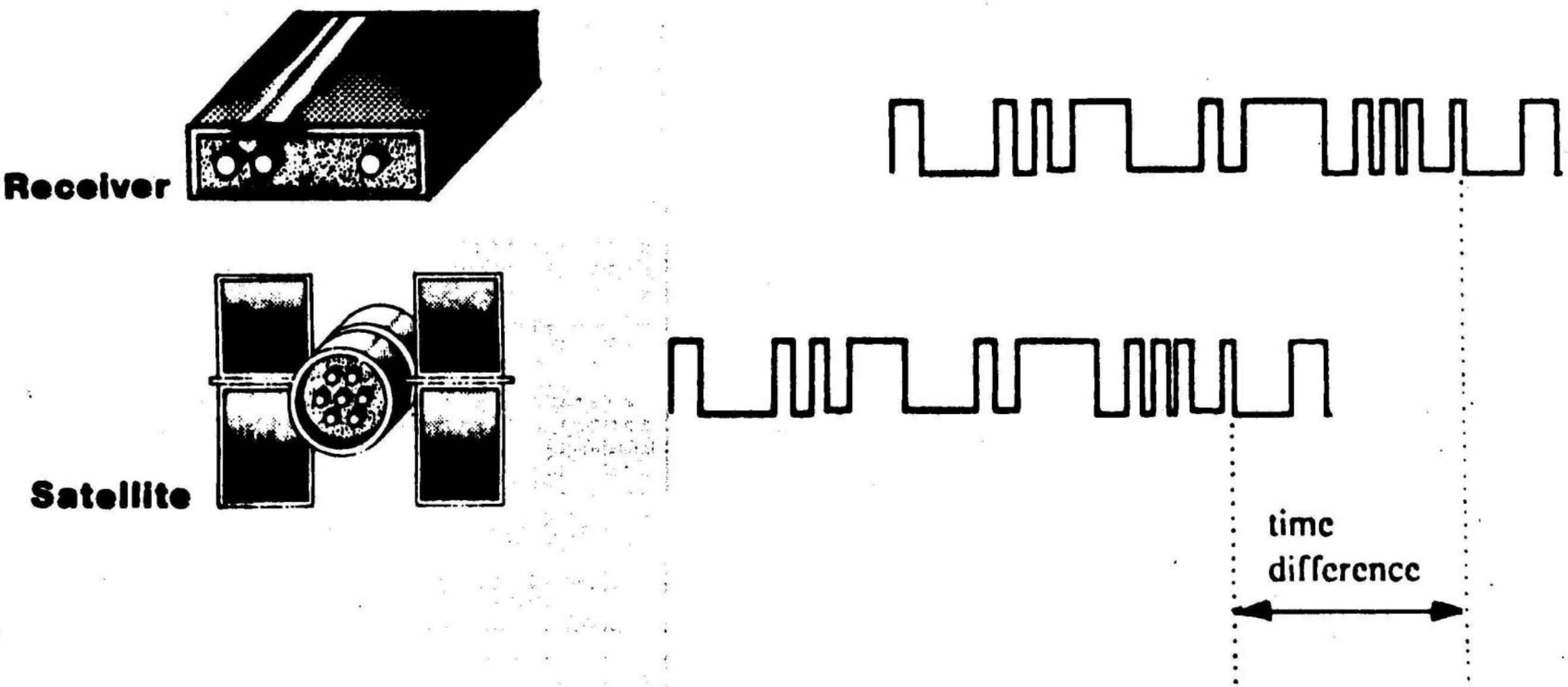
The GPS Pathfinder – puts a whole new spin on WHEN and WHERE!!

Standalone Positioning: Since May 1, 2000

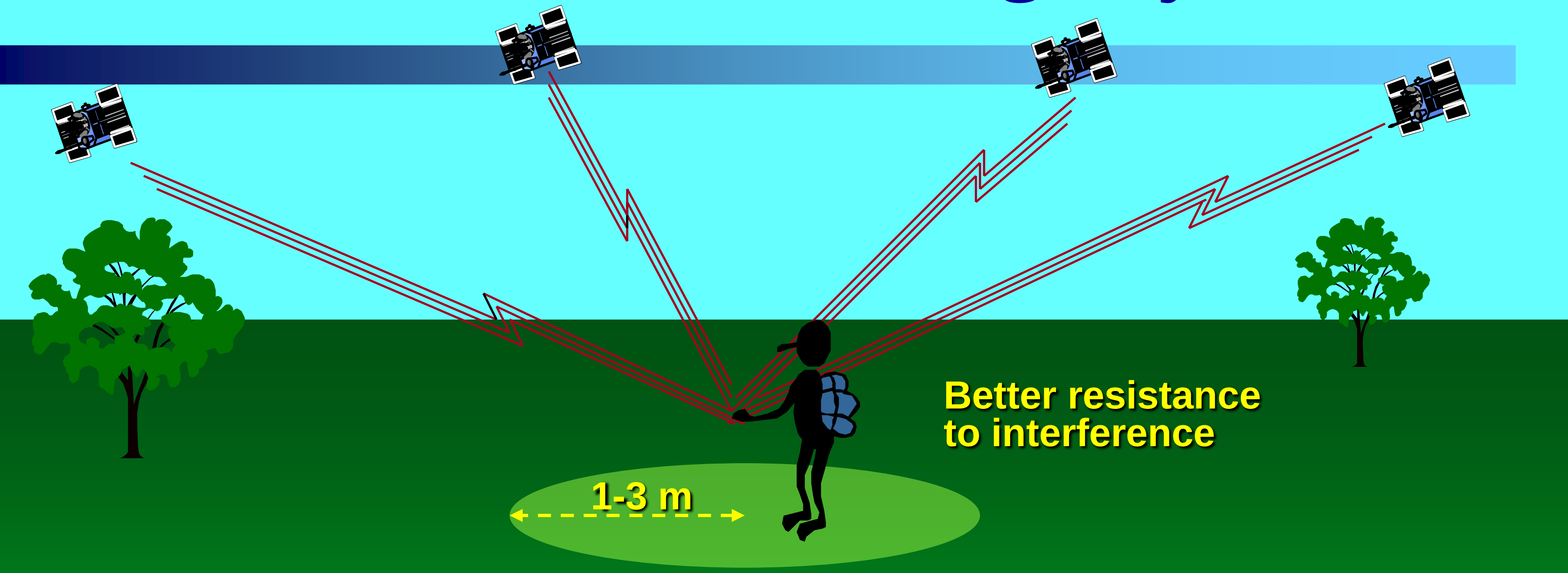


- C/A Code on L1
- No Selective Availability

PSEUDORANGE FROM CODE DATA



Standalone Positioning: By 2011

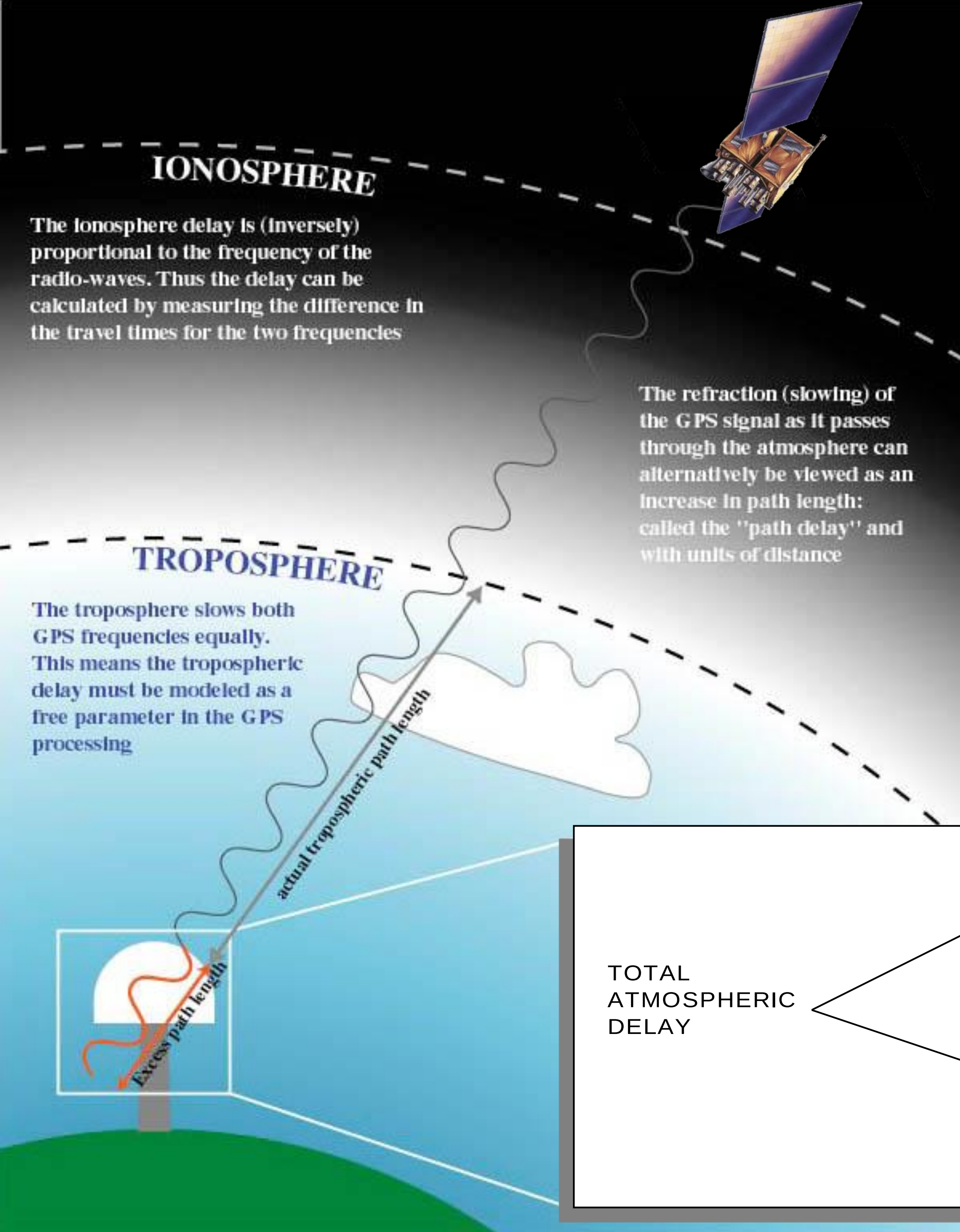


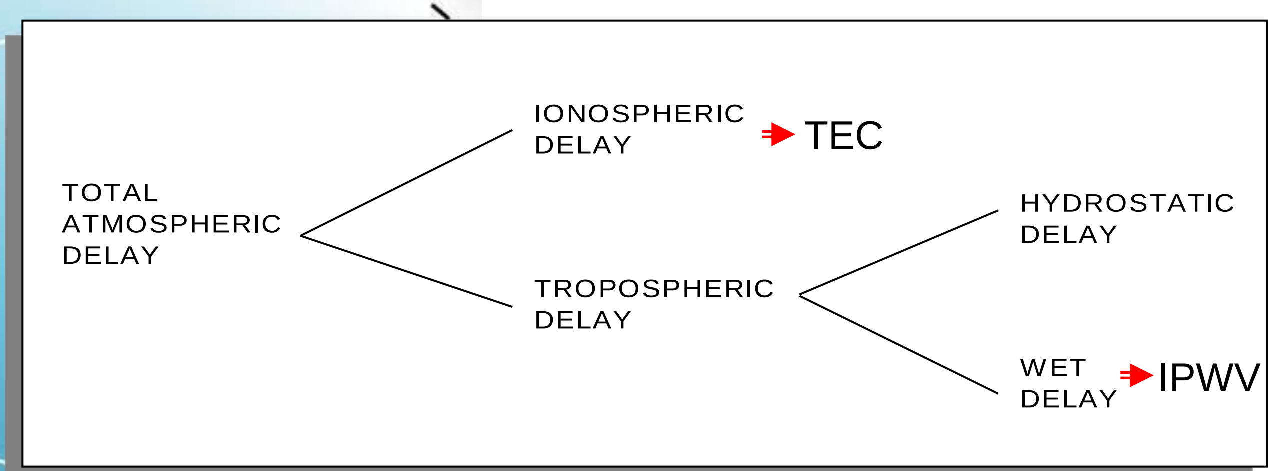
- C/A Code on L1
- C/A Code on L2
- New Code on L5

GPS ERROR SOURCES

* Receiver clock error
* Satellite clock error
* Satellite orbit error
* Ionospheric delay
* Neutral atmosphere delay
* Multipath

GPS Signal Delays Caused by the Atmosphere





Signal Multipath

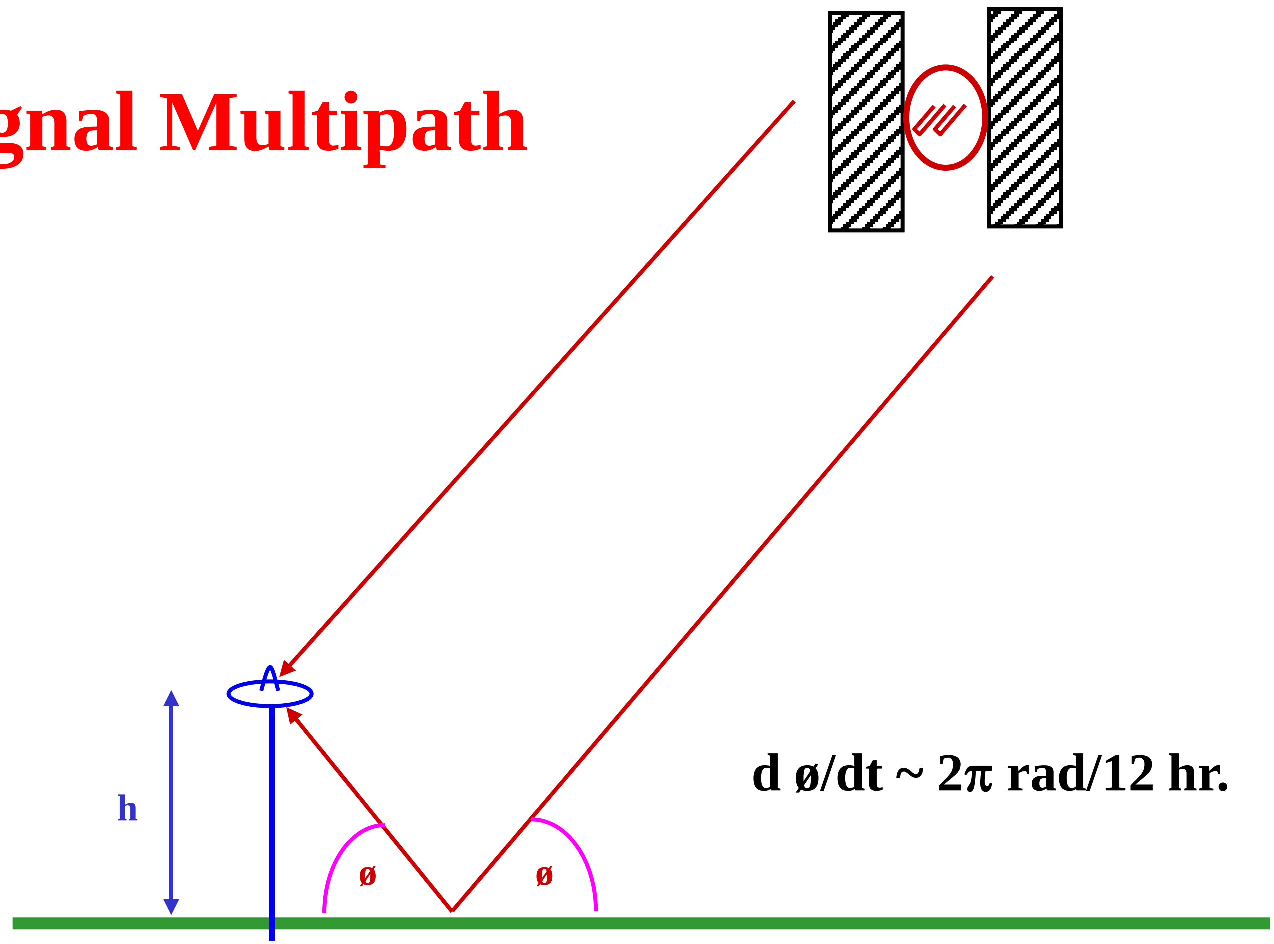
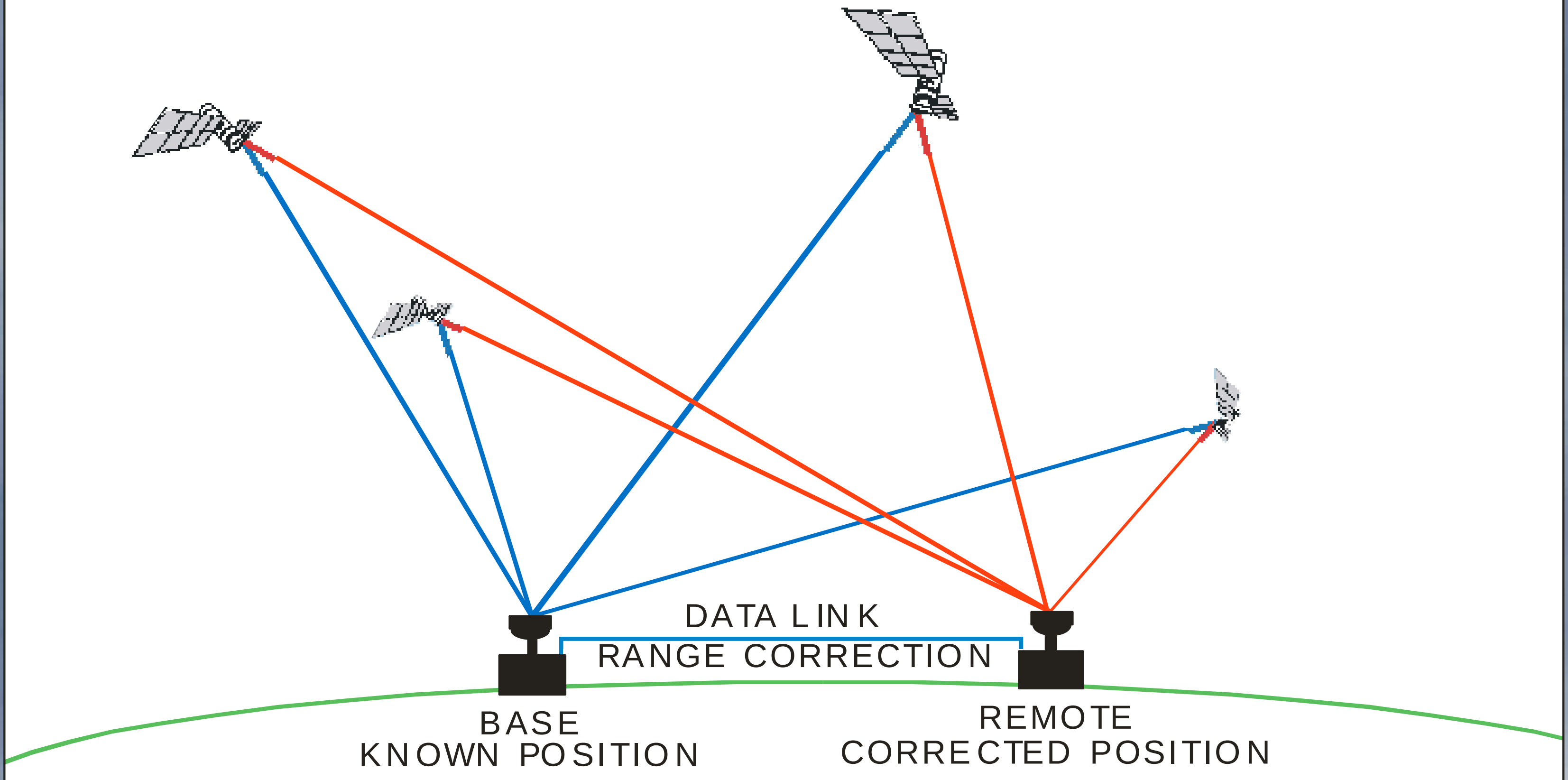


Figure 1
Multipath Description

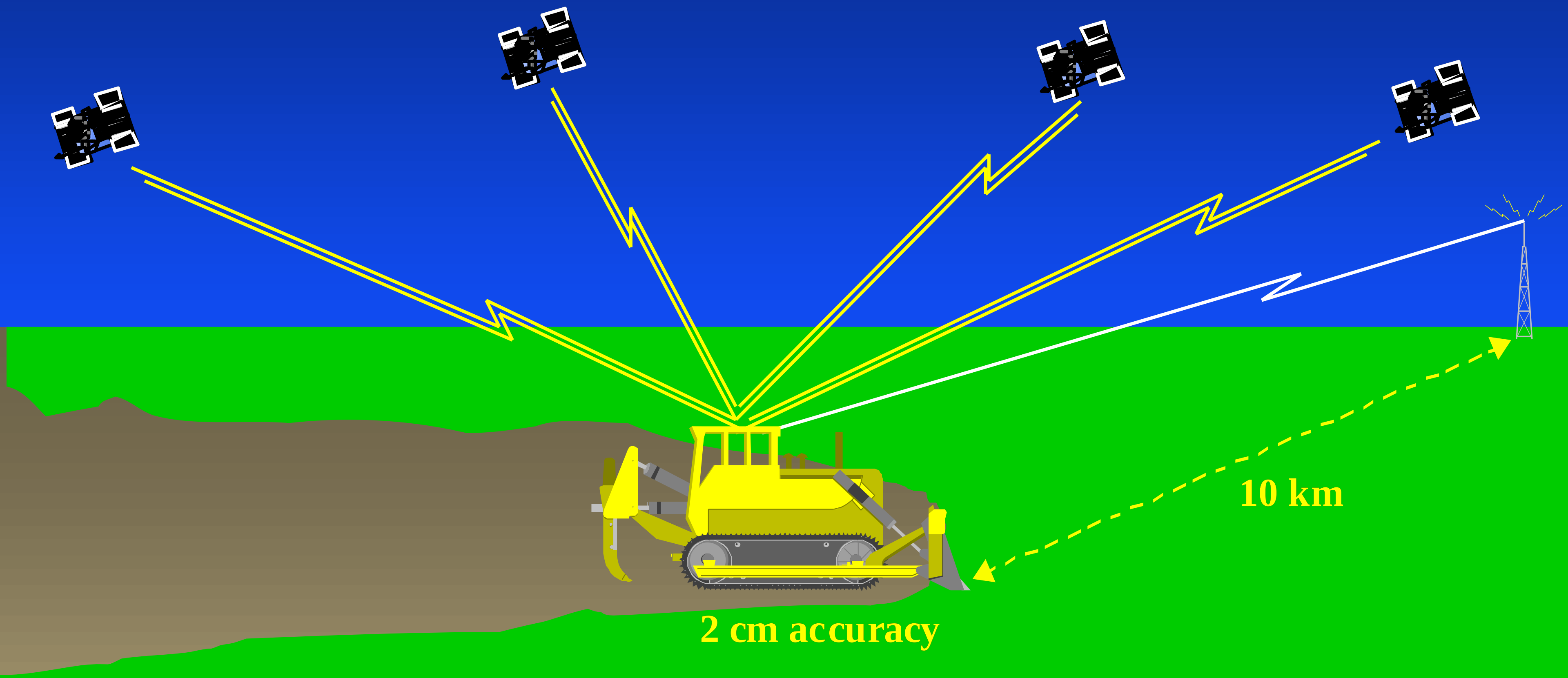
August 1987 -Ionospheric refraction and Multipath Effects in GPS Carrier Phase Observations
Yola Georgiadou and Alfred Kleusberg
IUGG XIX General Assembly Meeting, Vancouver, Canada

DIFFERENTIAL GPS POSITIONING



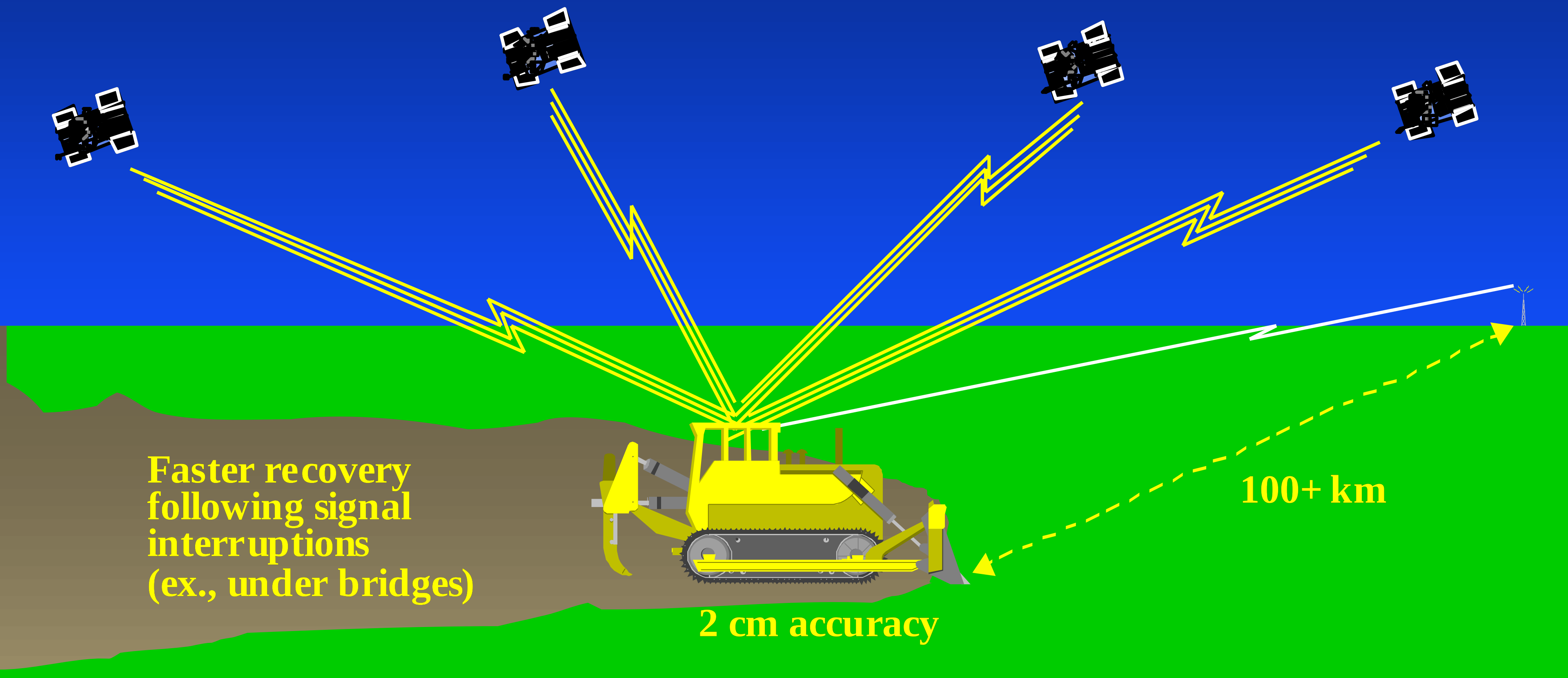
P H DANA 10/92

Real-Time Kinematic: Today



- L1 Code and Carrier
- L2 Carrier
- Data Link

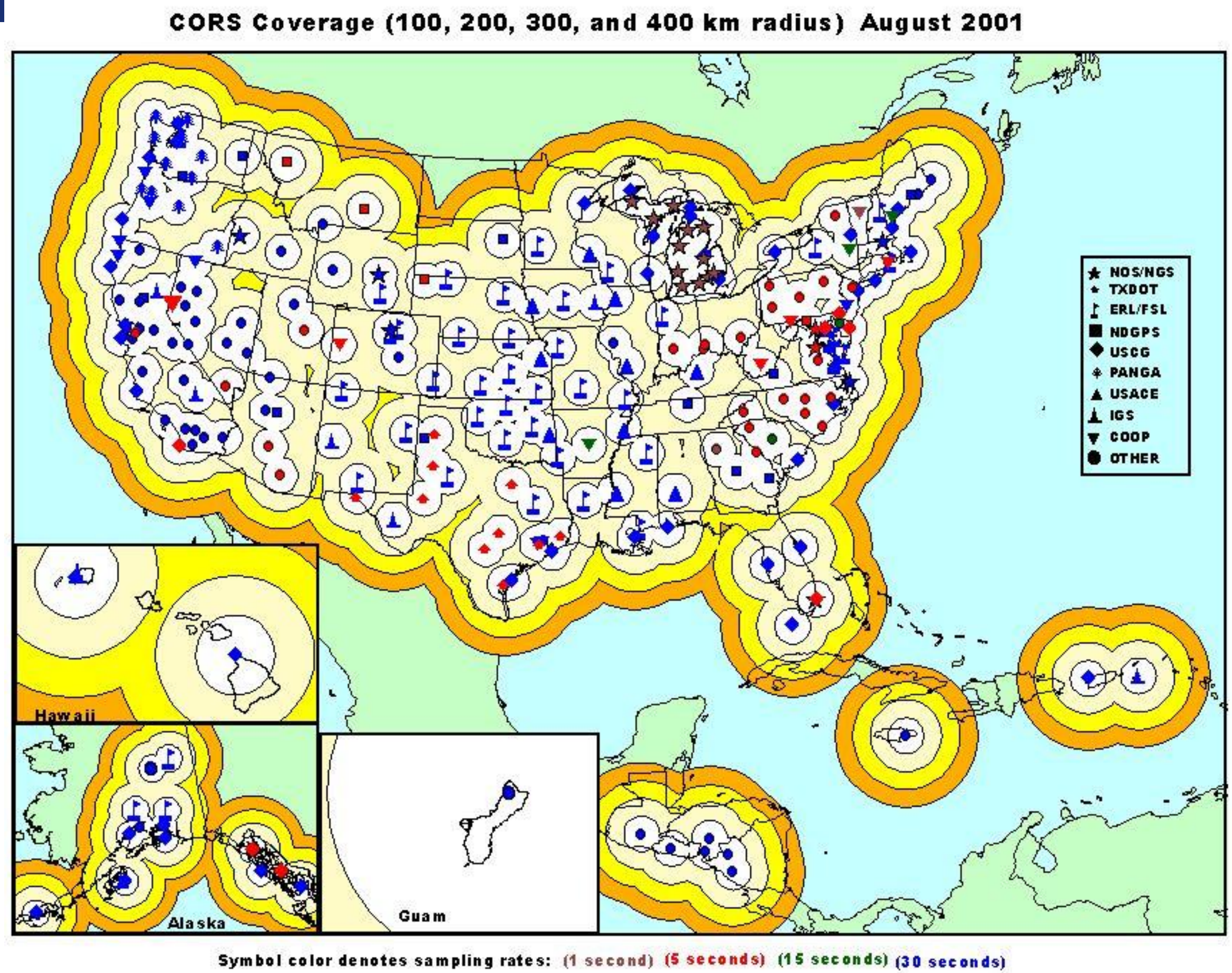
Real-Time Kinematic: Tomorrow



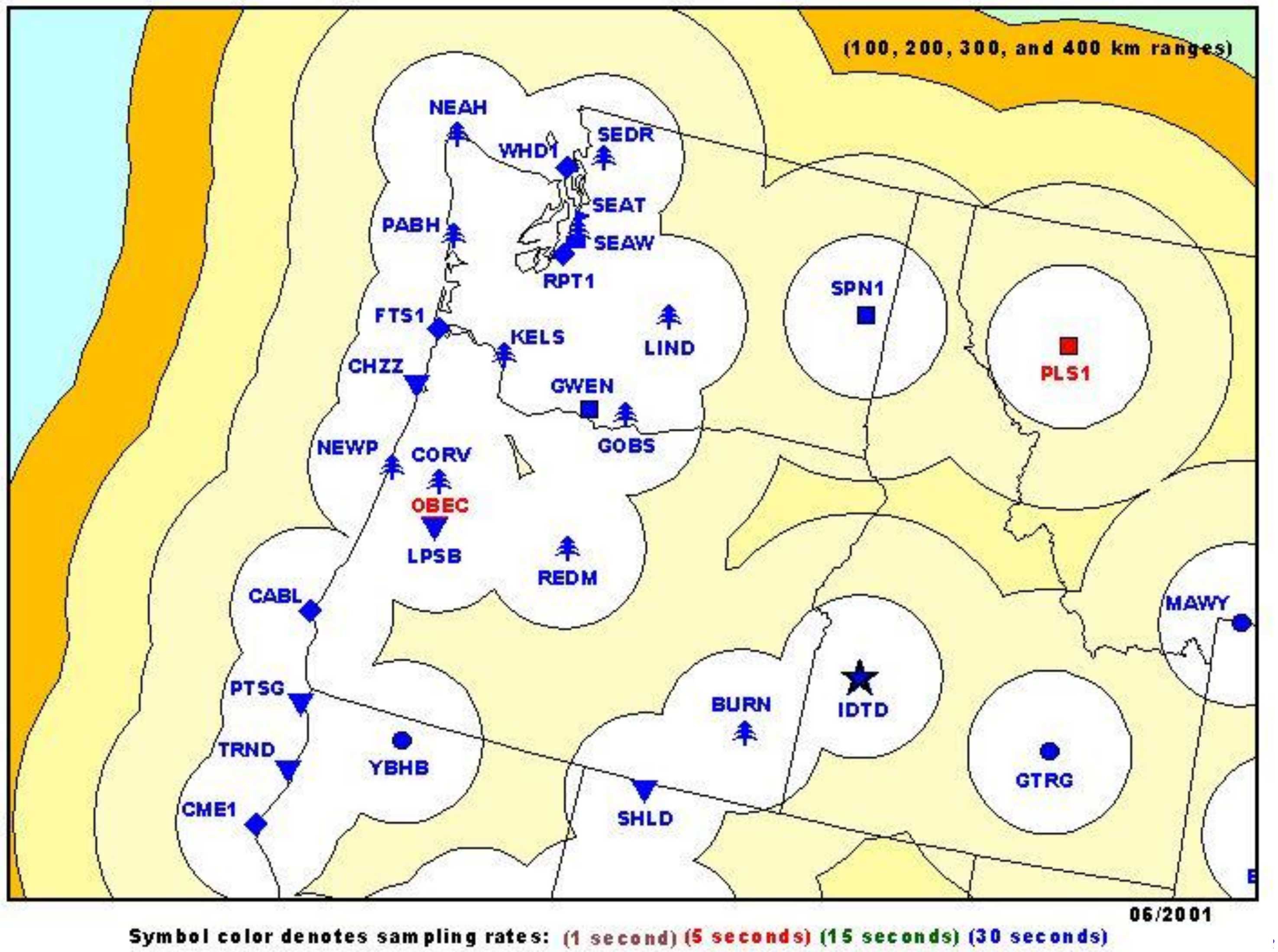
- L1 Code and Carrier
- L2 Code and Carrier
- L5 Code and Carrier
- Data Link

National CORS Accuracy

Continuously Operating Reference Stations



Regional CORS Coverage



Local CORS Coverage

CORS SITES

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CORS OVERVIEW

- Network contained 232 sites as of October 2001
- Growing at rate of 3 sites per month
- Provides code range (C/A, P1, P2)
  - and carrier phase observations (L1, L2)
- Provides meteorological data at some sites
- Designed to meet post-processing requirements for
  - Positioning
  - Navigation
  - Meteorology
  - Geophysics

CORS OVERVIEW-CONTINUED

- All CORS data transferred to NGS's office in MD
- GPS and "met" data converted to RINEX format
- Data made available to public via:
  - World Wide Web
  - File transfer protocol
- Data kept online for at least 4 years
- Data archived on CD-ROMs

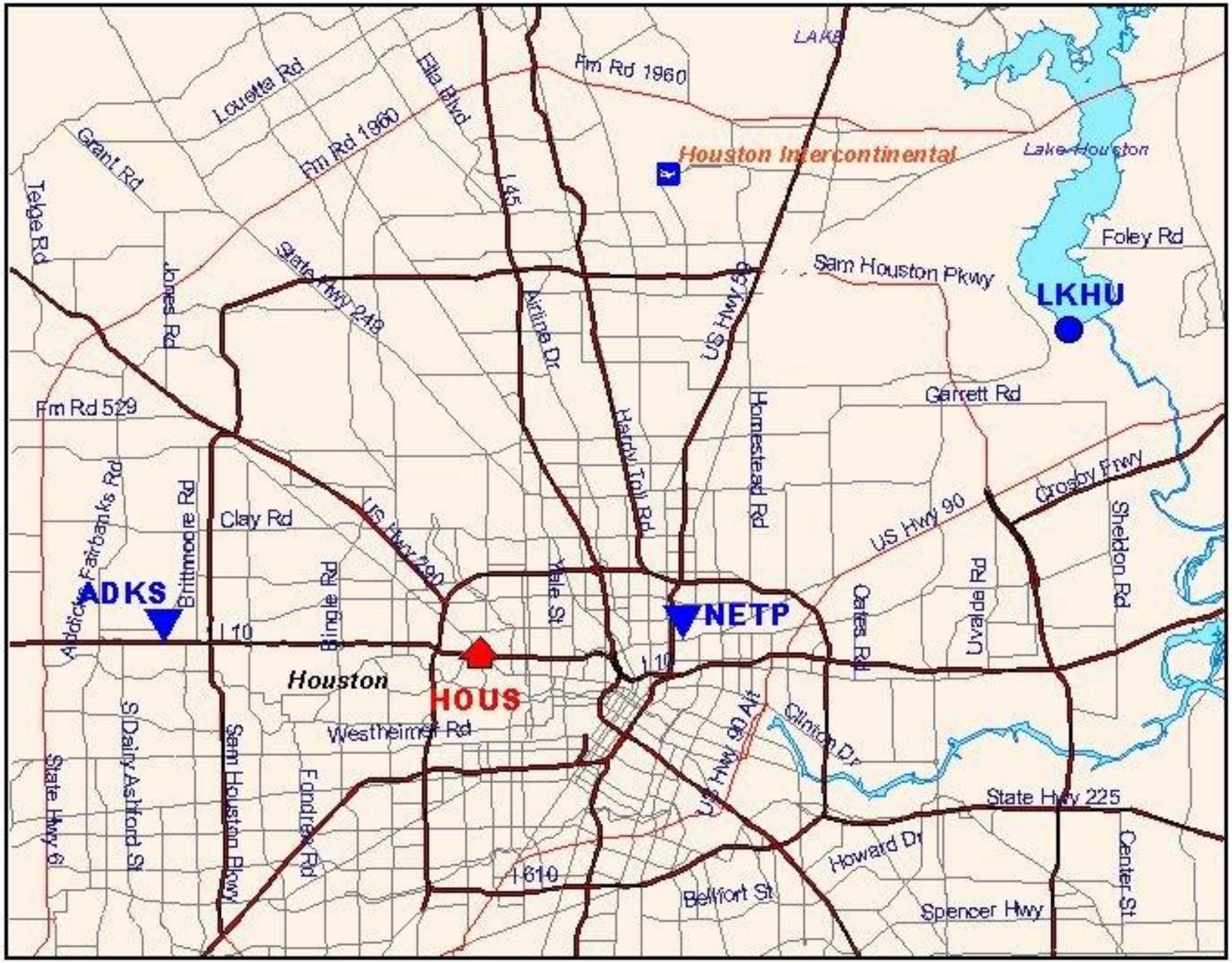
COOPERATIVE CORS

- GPS base stations whose data are freely disseminated by cooperating organizations
- NGS provides link from its web site to that of each cooperating organization
- Site coordinates must be consistent with the National Spatial Reference System

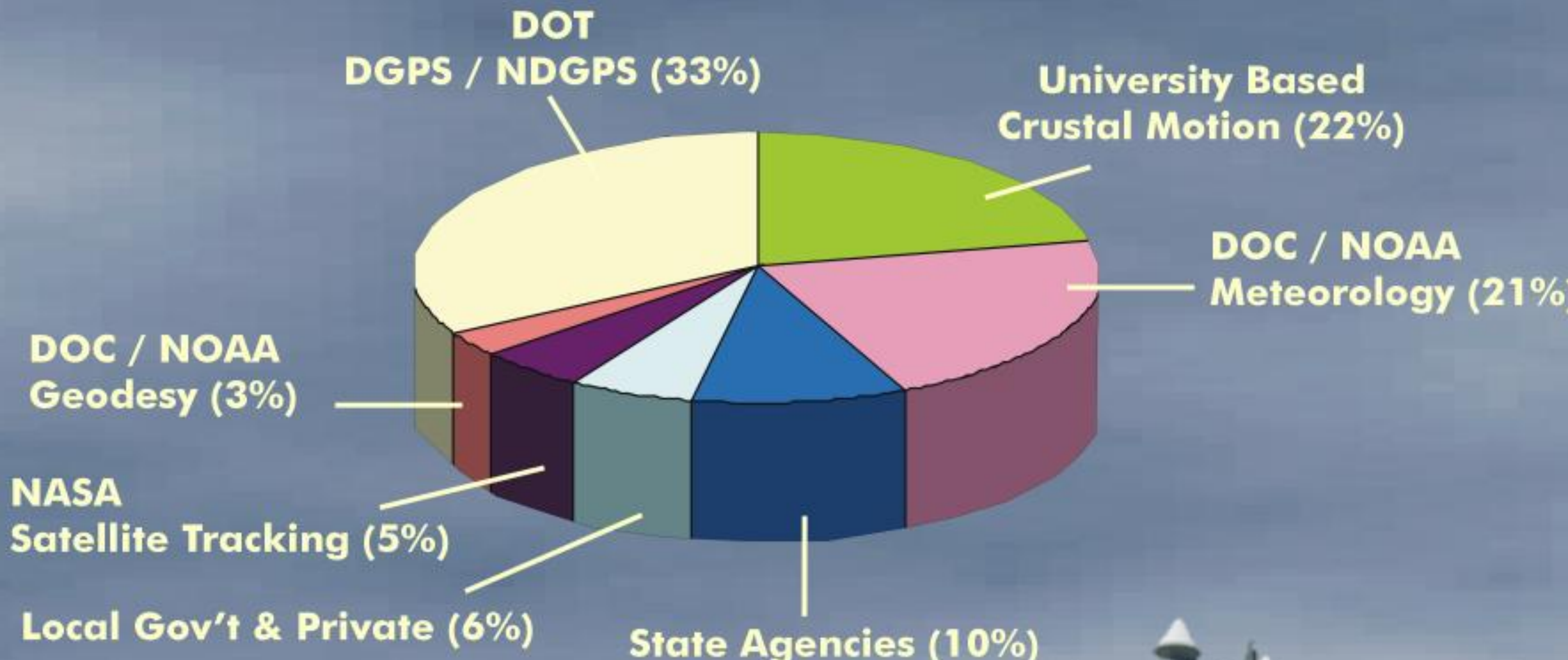
National CORS & Cooperative CORS

National CORS	Cooperative CORS
- Station commits to a long-term and continuous operation	- Station operates at least 8hrs/day; 5days/week
- Data are available online via the NGS CORS web page	- Provides a link to the participant's web page
- All data are permanently archived in NGS	- Minimum 7 days' data online at the participant's web site
- antenna position re-computed everyday	- antenna position re-computed every 90 days or less

CORS Sites near Houston, TX



National CORS Partners



CORS PARTNERS: FEDERAL

Federal Highway Administration

Federal Railway Administration

Federal Aviation Administration

Forecast Systems Laboratory

NASA

US Geological Survey

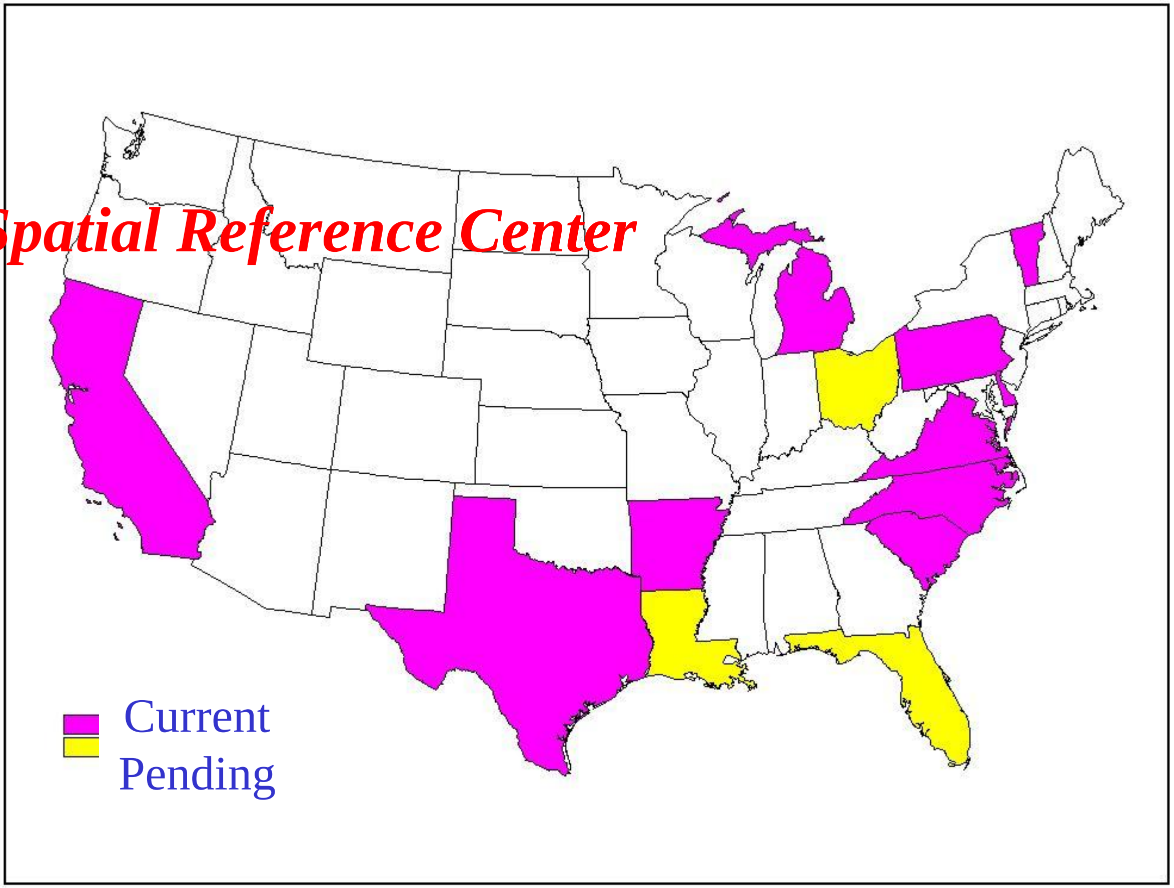
US Army Corps of Engineers

US Air Force

US Naval Observatory

CORS PARTNERS: STATES

California Spatial Reference Center



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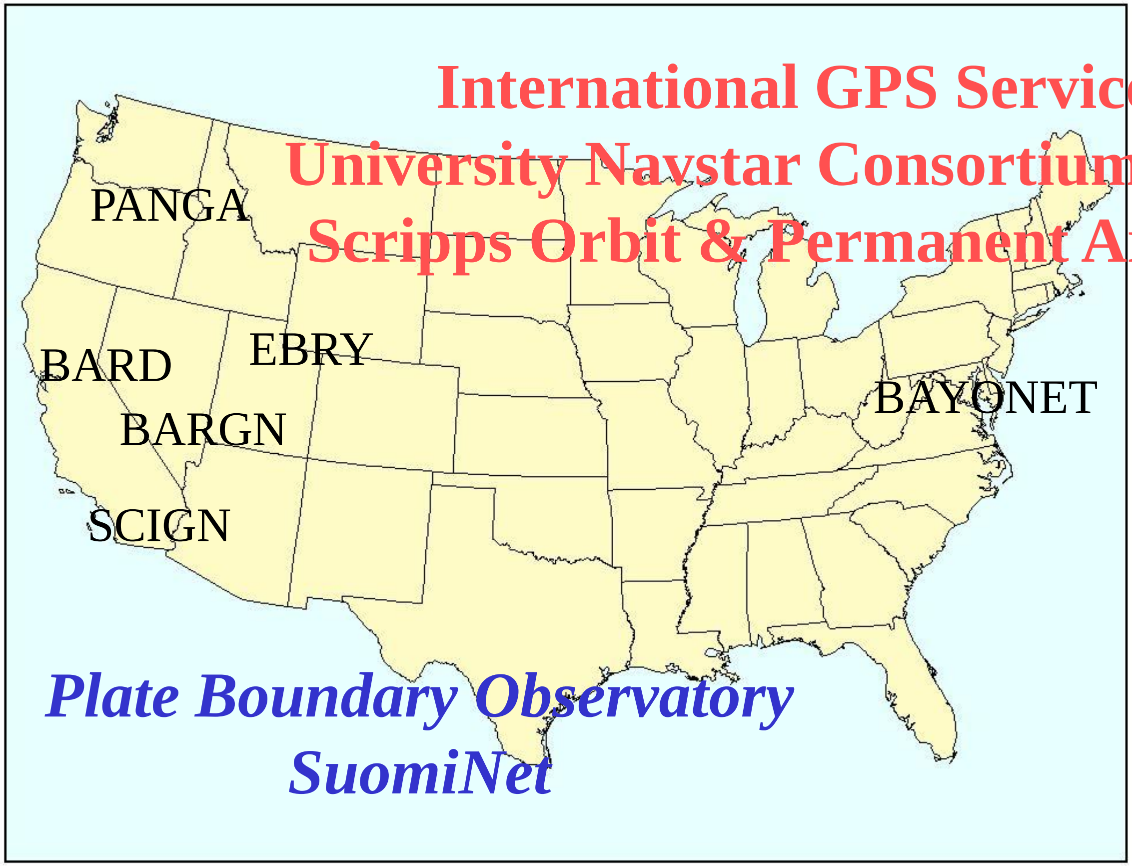
CORS PARTNERS: SCIENTIFIC



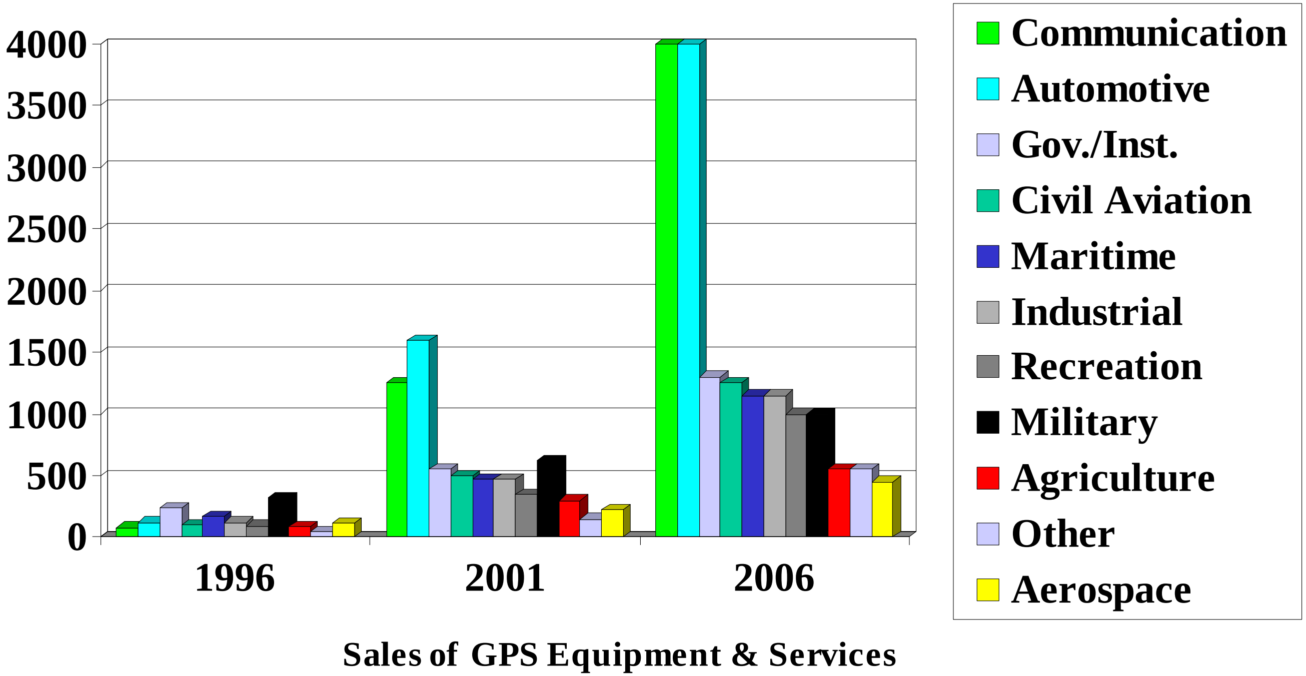
CORS PARTNERS: INTERNATIONAL


Civil GPS Use
Power Grid Interfaces
Personal Navigation
Satellite Ops -- Ephemeris, Timing
Surveying & Mapping
Trucking & Shipping
Aviation
Recreation
Communications -- Network Synchronization and Timing
Railroads
Fishing & Boating
Off shore Drilling

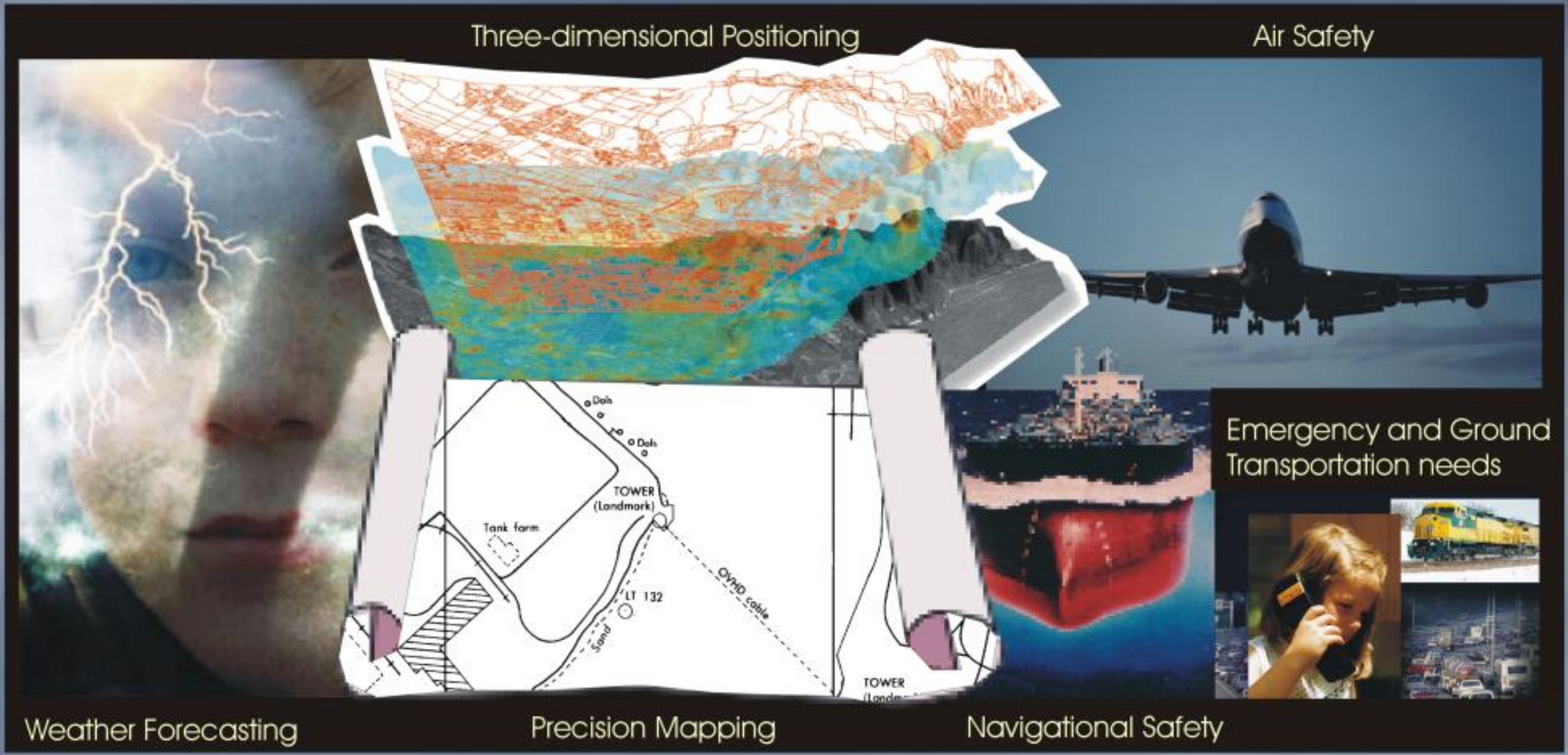
Consumer/Recreational

- $3.8B market by 2003
- Portable receivers for fishermen, hunters, campers, hobbyists, etc.
- Recreational facilities
- Estimated 40M potential users in the U.S. alone
- Highly elastic demand
- Integration of GPS into cellular phones expected to generate huge volume

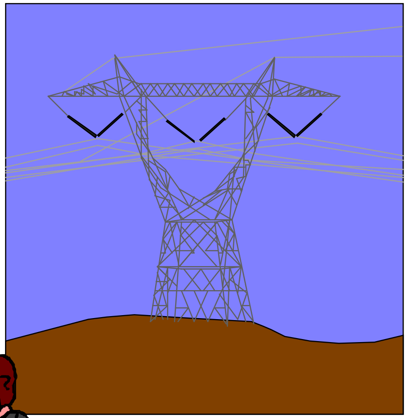
Future GPS User Sectors - $M
(Freedonia Group Report - 1997)

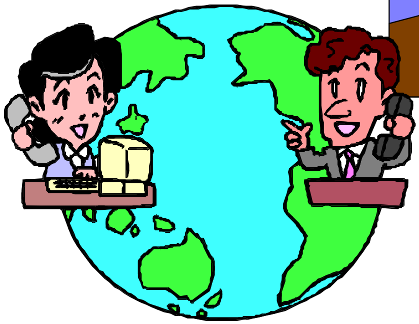


Examples Requiring Higher Accuracy



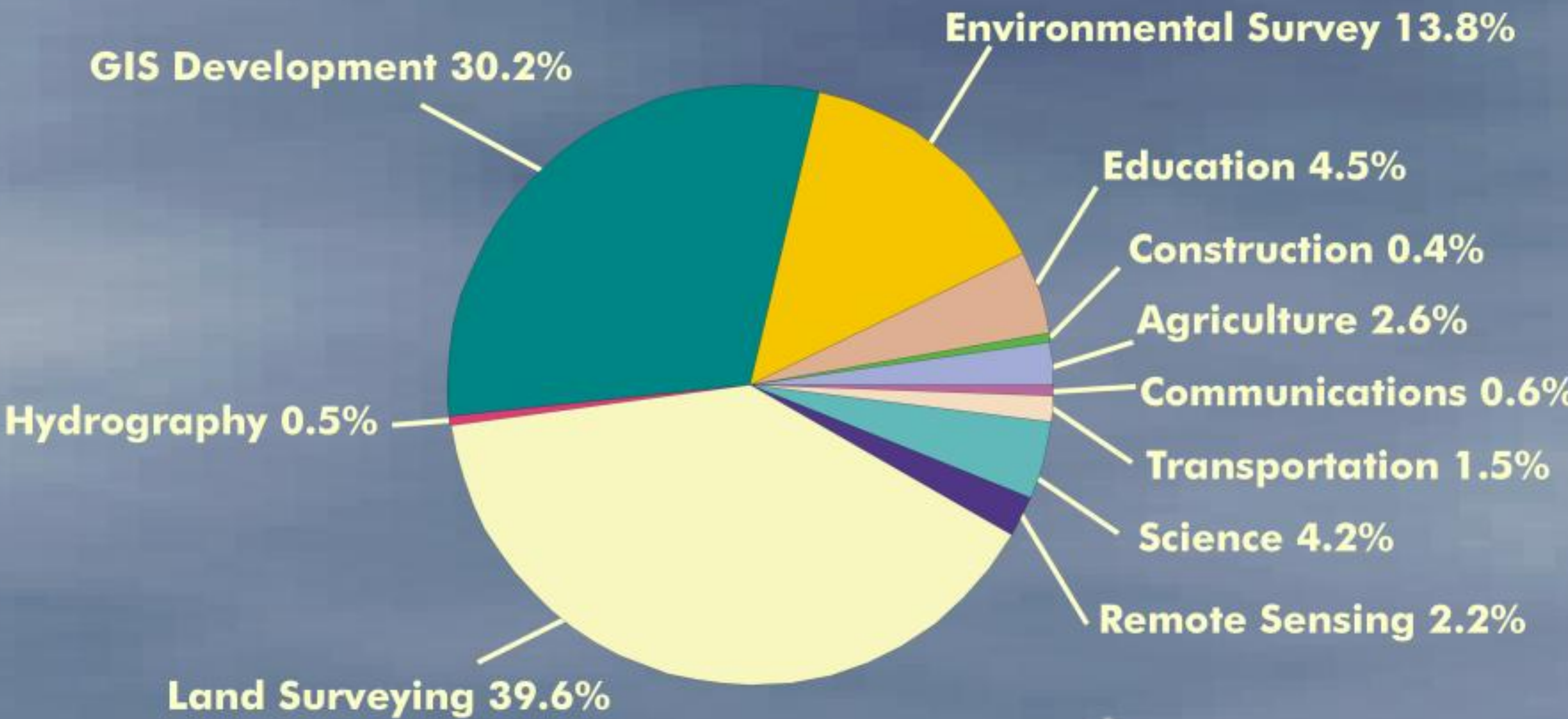
Timing Applications





- Some estimate the timing market at $40-100M
- Communications network synchronization and management
  - Phone, wireless systems
  - LANs, WANs, Internet
- Power grid management and fault location
- Financial transactions
- E-commerce signatures

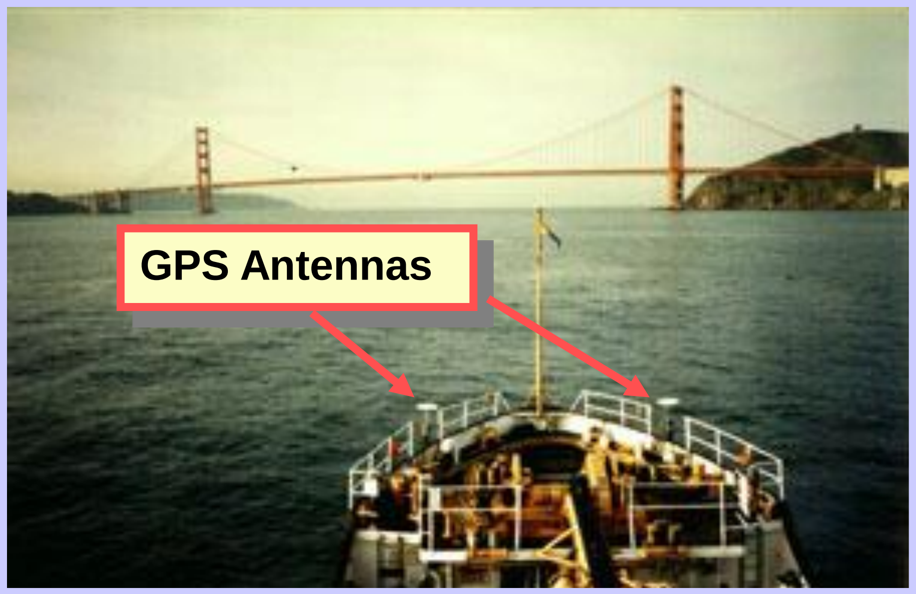
CORS Applications



5,646
Survey responses
Fall 1999

Positioning: Height Modernization

GPS-guided aircraft operations



GPS Cm-level Positioning of Ship’s Pitch, Roll and Squat

GPS Buoy Monitoring Water Levels

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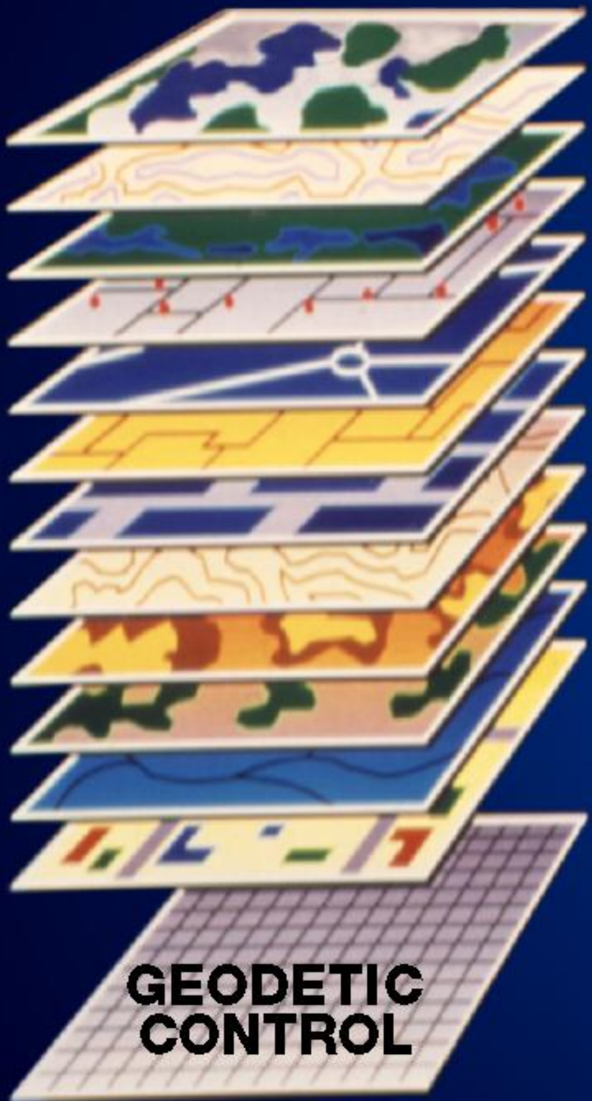
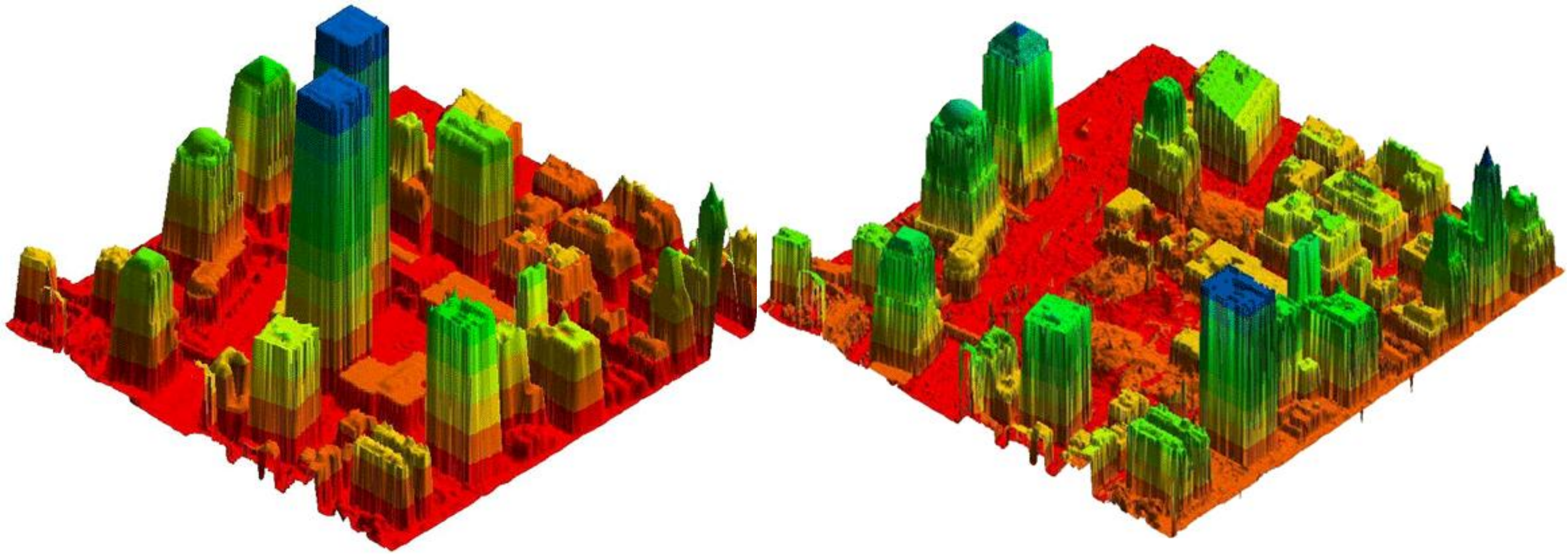
National Geodetic Survey

Geographic Information Systems (GIS)



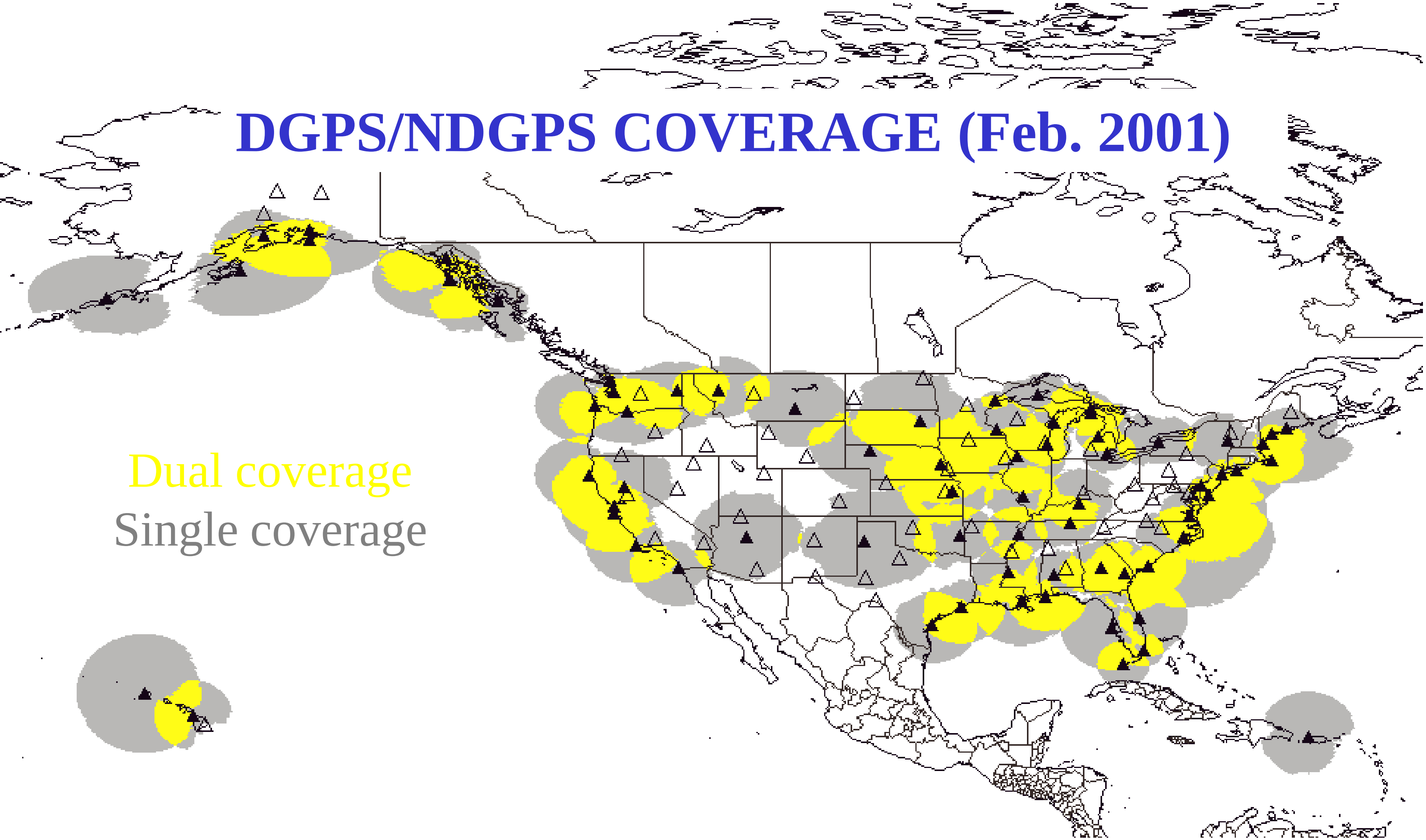
Wards and Precincts
Demographics
Structures
Water Utilities
Sewerage
Electrical Utilities
Roads
Boundaries
Land Use
Hydrology
Soils
Topography

LIDAR images of Manhattan before and after 11 SEP 2001



These images are computerized visualizations of elevation information of the World Trade Center from before (July 2000) and after (September 15, 2001) the attack. These maps were produced using an airborne LIDAR (Light Detection and Ranging) system. The LIDAR system creates detailed and highly accurate elevation information by the precise timing of thousands of laser pulses striking the ground surface. These data can be manipulated in the digital environment to create an array of maps and views of the project site and to obtain precise measuresments of structures, debris fields, and other vital information. These images were generated by EarthData (www.earthdata.com), and the aircraft was positioned using CORS data from the NJI2 site which is operated by the New Jersey Institute of Technology.

DGPS/NDGPS COVERAGE (Feb. 2001)



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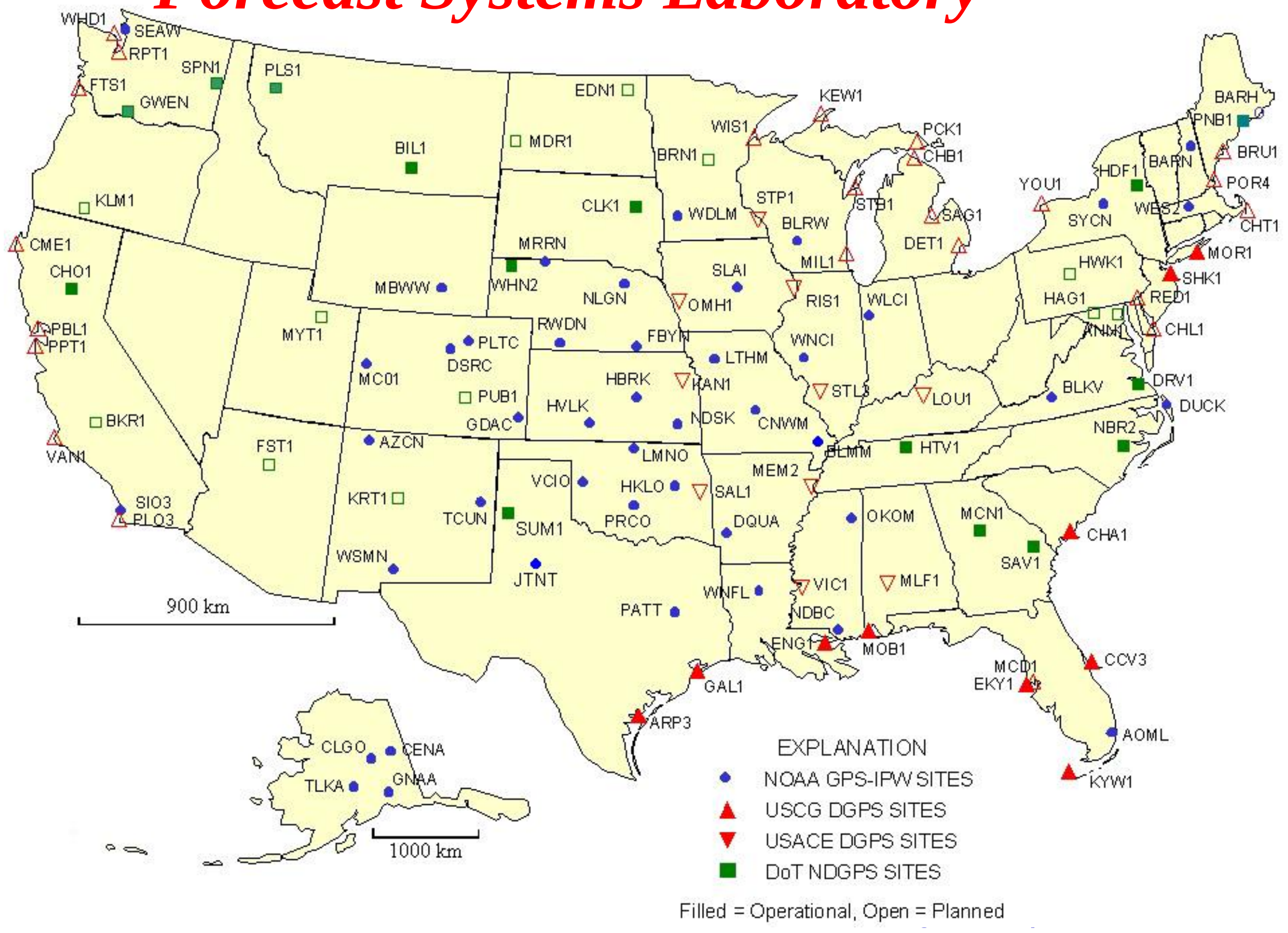
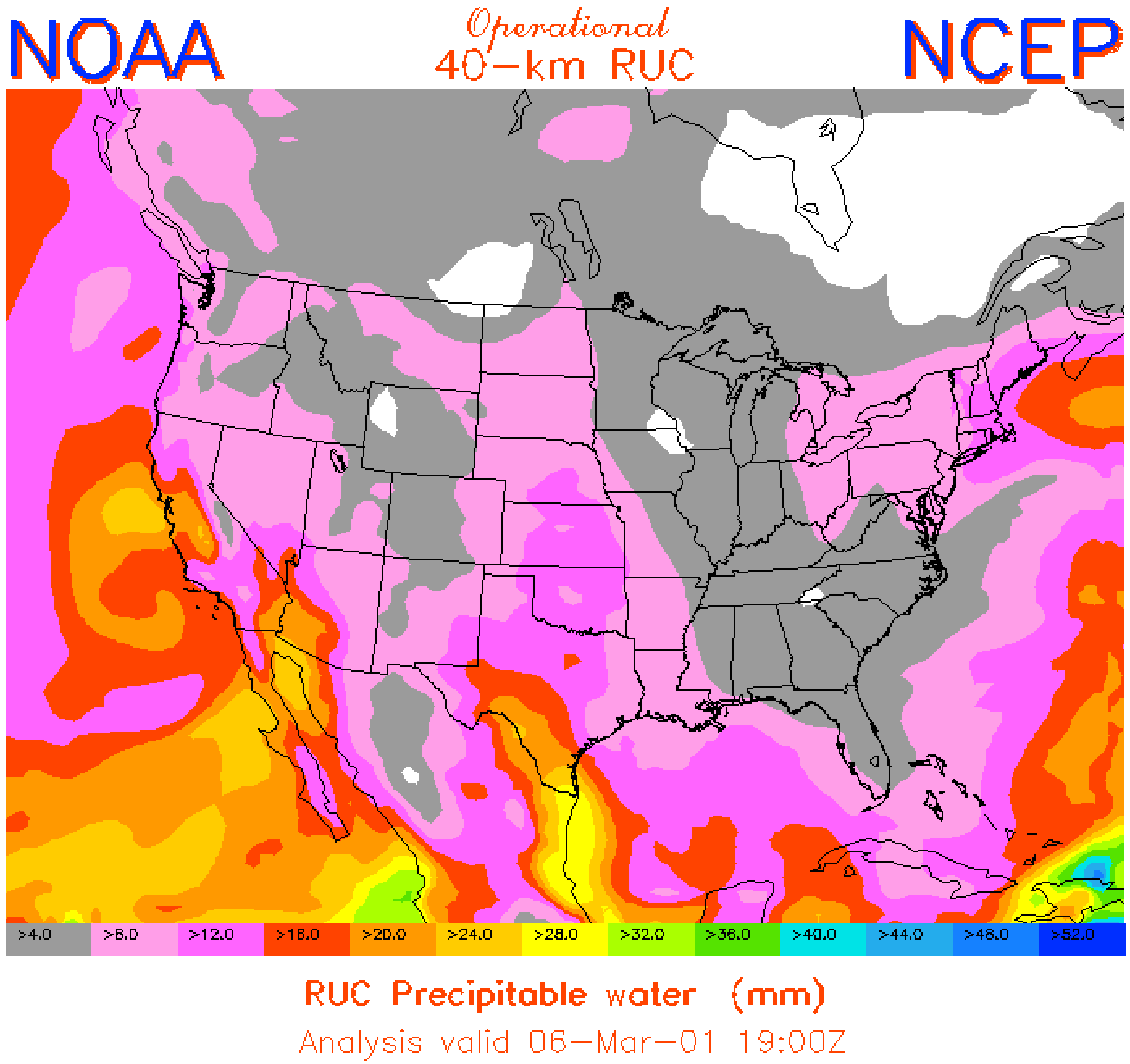
SITES WITH "MET" SENSORS

Forecast Systems Laboratory

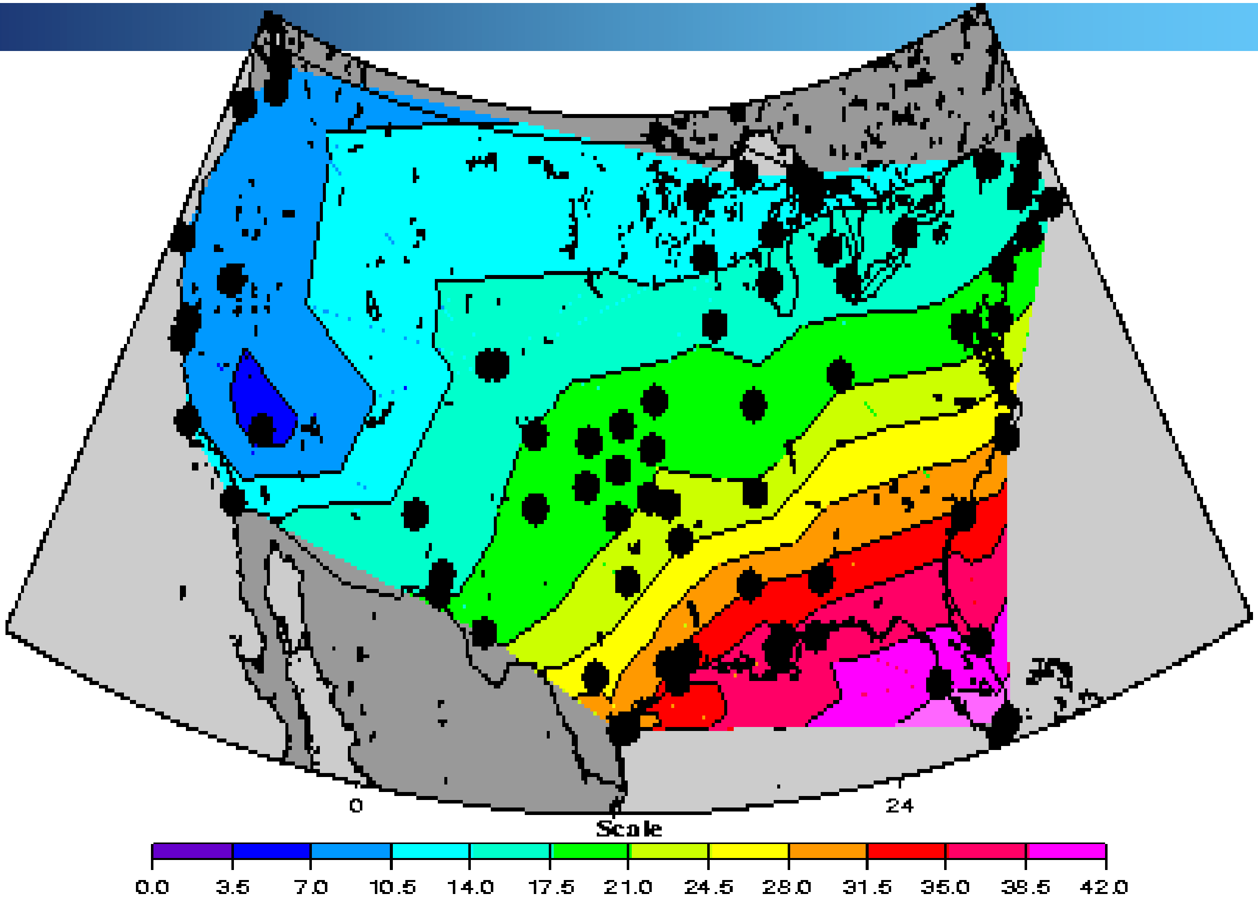


MONITORING PRECIPITABLE WATER VAPOR



ure

MAPPING TOTAL ELECTRON CONTENT (TEC)



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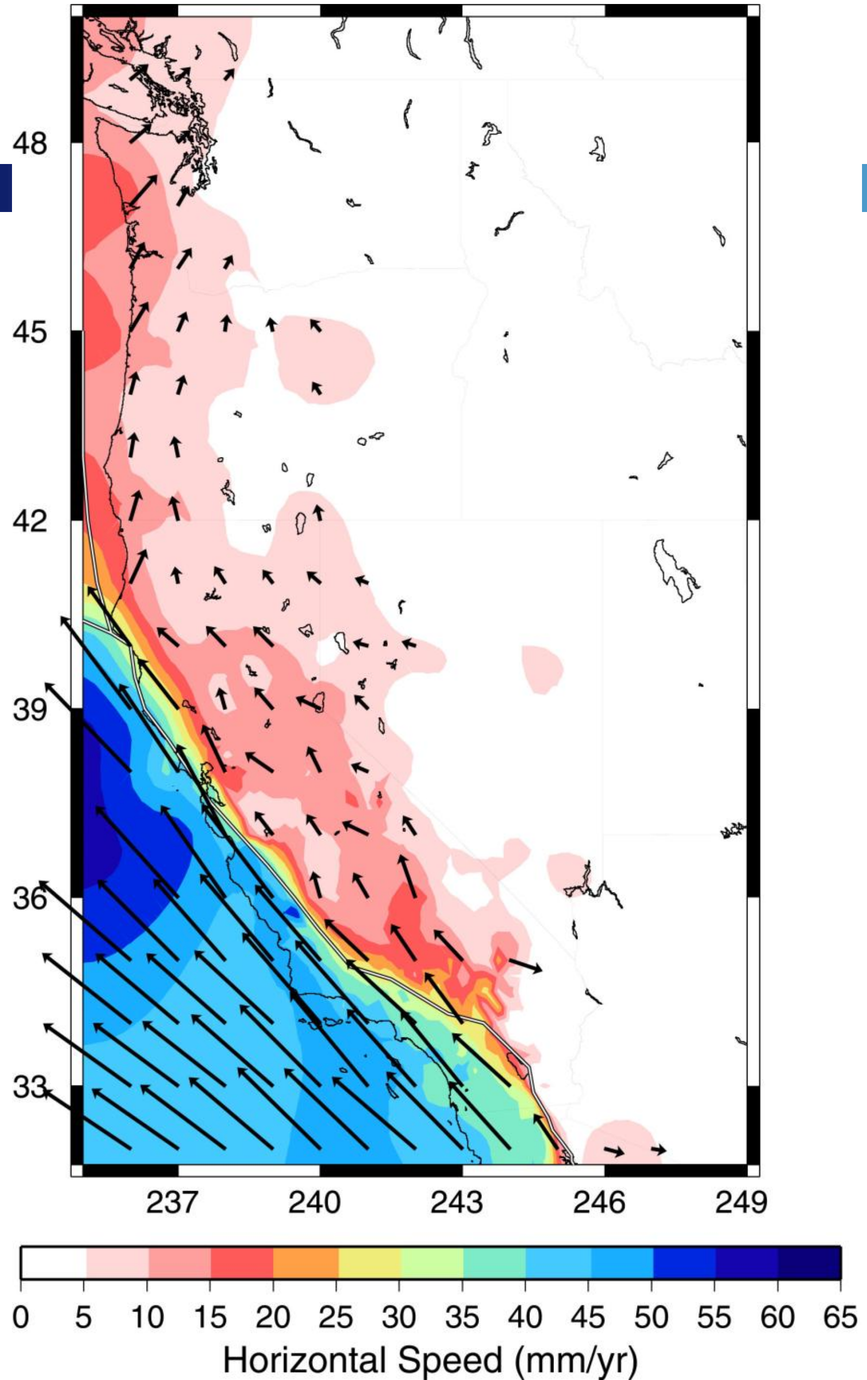
Monitoring Crustal Motion



Horizontal speed in western US relative to stable North America

Everyone is able to know where they are and

where other things are anytime, anyplace!

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NATIONAL SPATIAL REFERENCE SYSTEM

The National Spatial Reference System (NSRS) is a consistent national coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the Nation, as well as how these values change with time.

"A geodetic reference framework forms the spatial foundation for the creation of any Land-Information System (LIS)."

National Research Counsel Procedures and Standards for a Multipurpose Cadastre (1983, p. 20).

NATIONAL SPATIAL REFERENCE SYSTEM

ACCURATE -- cm accuracy on a global scale

MULTIPURPOSE -- Supports Geodesy, Geophysics, Land Surveying, Navigation, Mapping, Charting and GIS activities

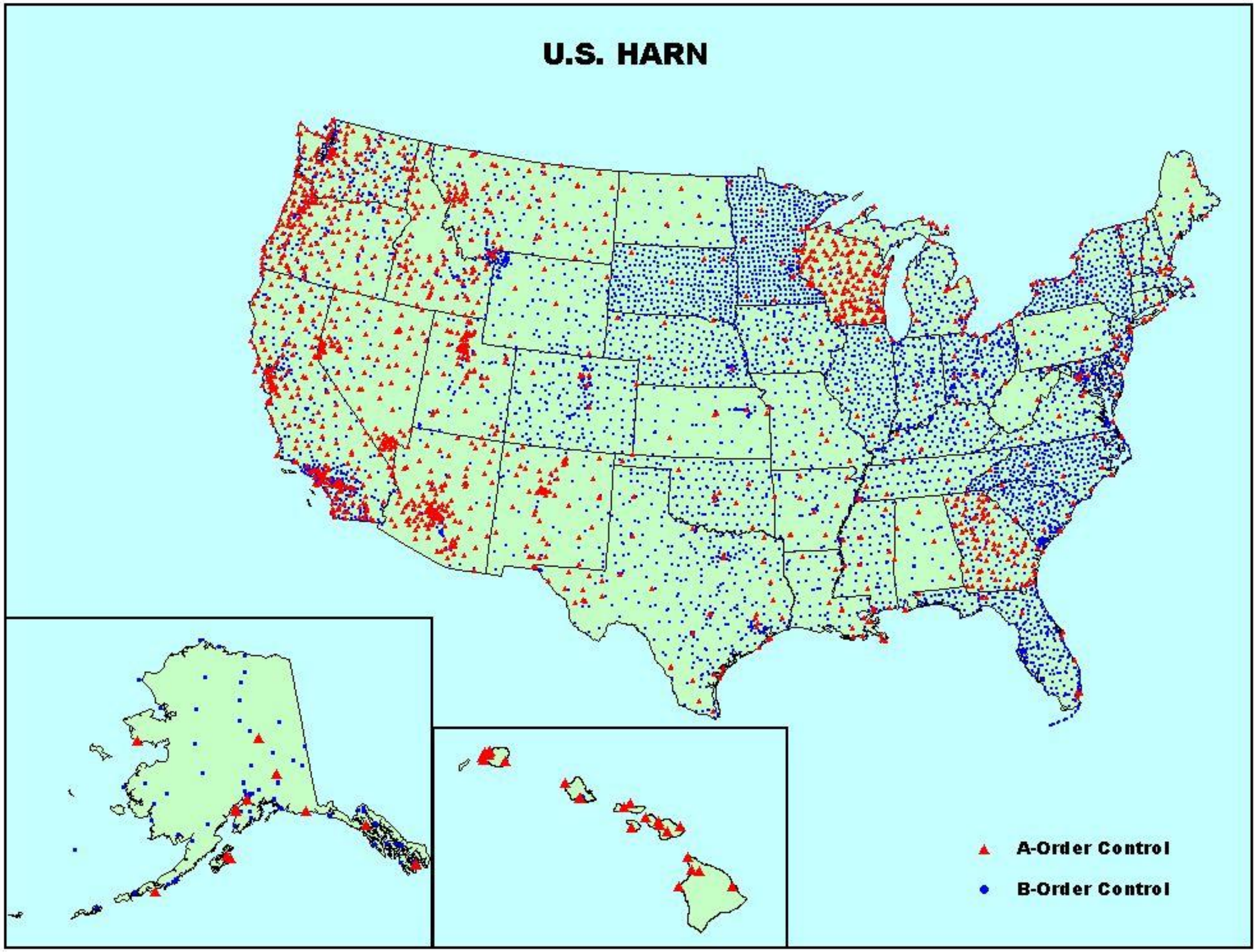
ACTIVE -- Accessible through Continuously Operating Reference Stations (CORS) and derived products

INTEGRATED -- Related to International services and standards (e.g. International Earth Rotation Service, International GPS Service etc.)

IMPROVING POSITIONAL ACCURACY

NETWORK	TIME SPAN	NETWORK ACCURACY	LOCAL ACCURACY
NAD 27	1927-1986	10 Meters	First-Order (1 part in 0.1 million)
NAD 83	1986-1990	1 Meter	First-Order (1 part in 0.1 million)
HARN	1987-1997	0.1 Meter	B-Order (1 part in 1 million) A-Order (1 part in 10 million)
CORS	1994 -	← 0.02 Meter - Horizontal → ← 0.04 Meter - Ellipsoid Height →	

HIGH ACCURACY REFERENCE NETWORKS



NAD 83 READJUSTMENT

HARN COMPLETION - SEPTEMBER 1997

(Indiana)

GPS HEIGHT MODERNIZATION OBSERVATIONS

(1997 - 2004?)

(Virginia, Maryland and Delaware Observed 2000)

(http://www.ngs.noaa.gov/initiatives/height_modernization.shtml)

COMPLETE GPS NAD 83 3-D ADJUSTMENT

(http://www.ngs.noaa.gov/initiatives/new_reference.shtml)

(2005?)

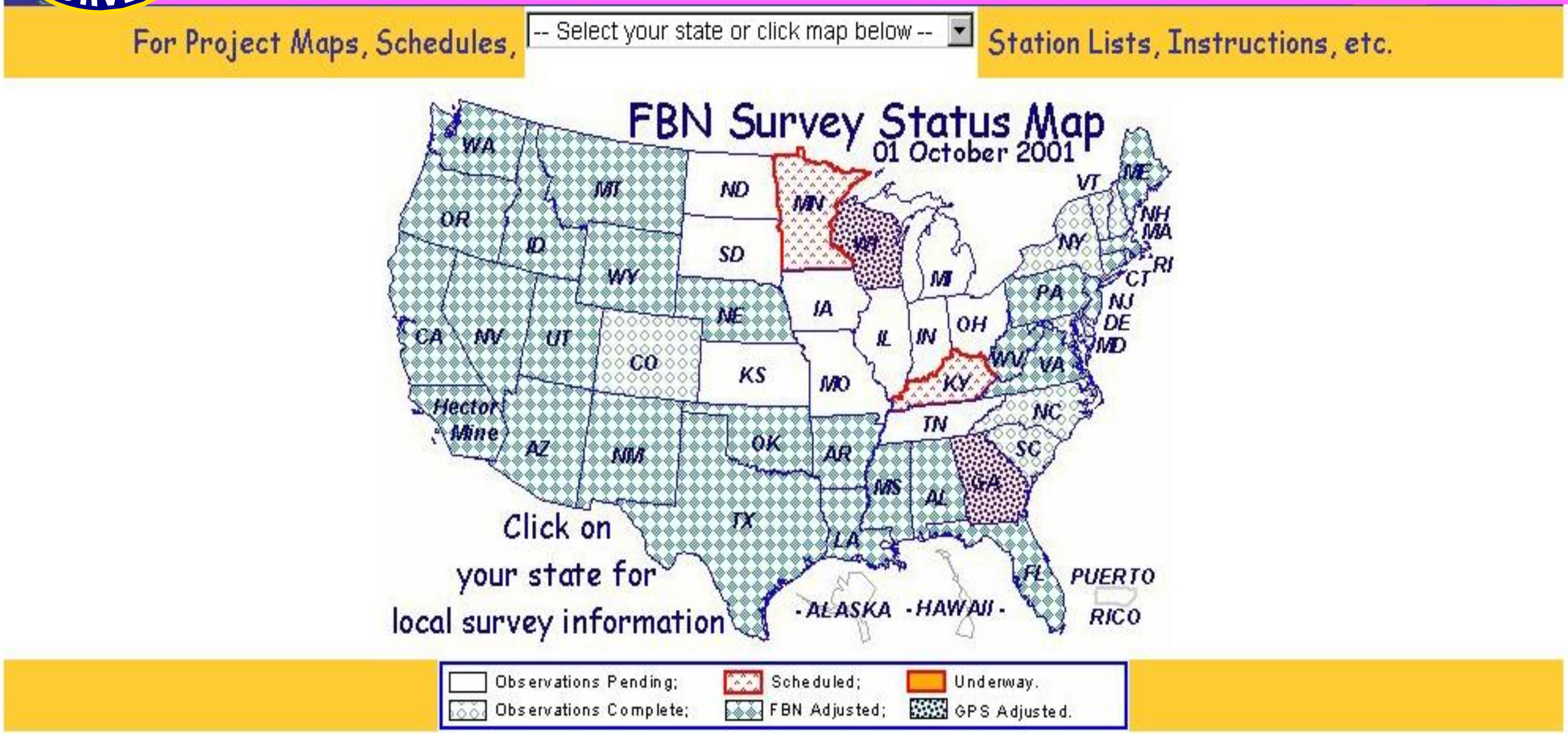
REMOVAL OF SMALL REGIONAL DISTORTIONS

(3 - 6 CM)

UNIFORM COORDINATE TAG

NAD 83 (NSRS)

NAD 83 READJUSTMENT



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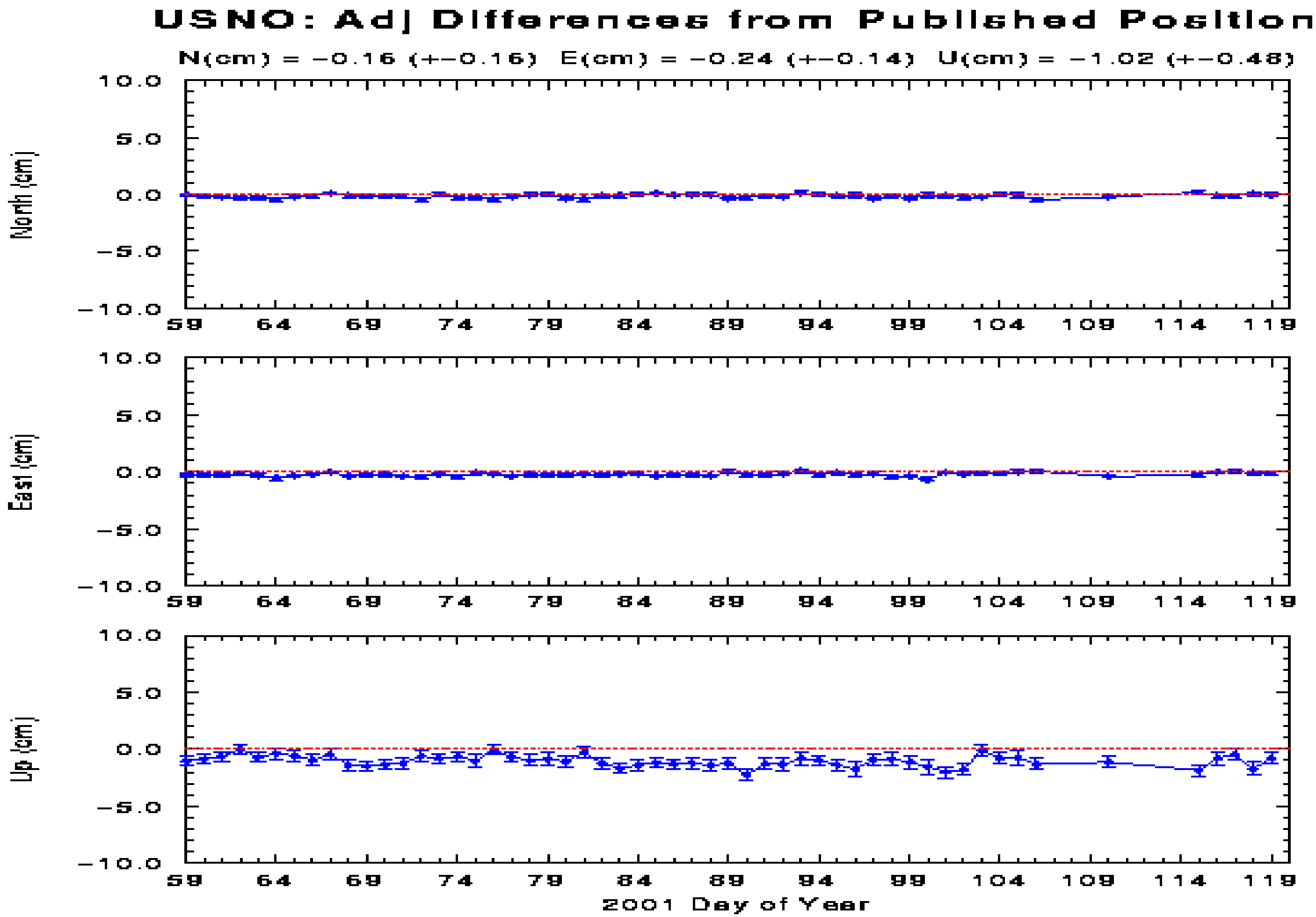
CORS ADVANTAGES

- 3-dimensional.
- Users do not need to reconn control points.
- Users do not need to set up instruments at control points.
- CORS positional coordinates are more accurate than those of other control points.
- Direct tie to National Spatial Reference System.
- CORS positions and velocities are available in both NAD 83 and ITRF coordinate systems.
- CORS positions are continuously monitored and will be updated if the site moves.

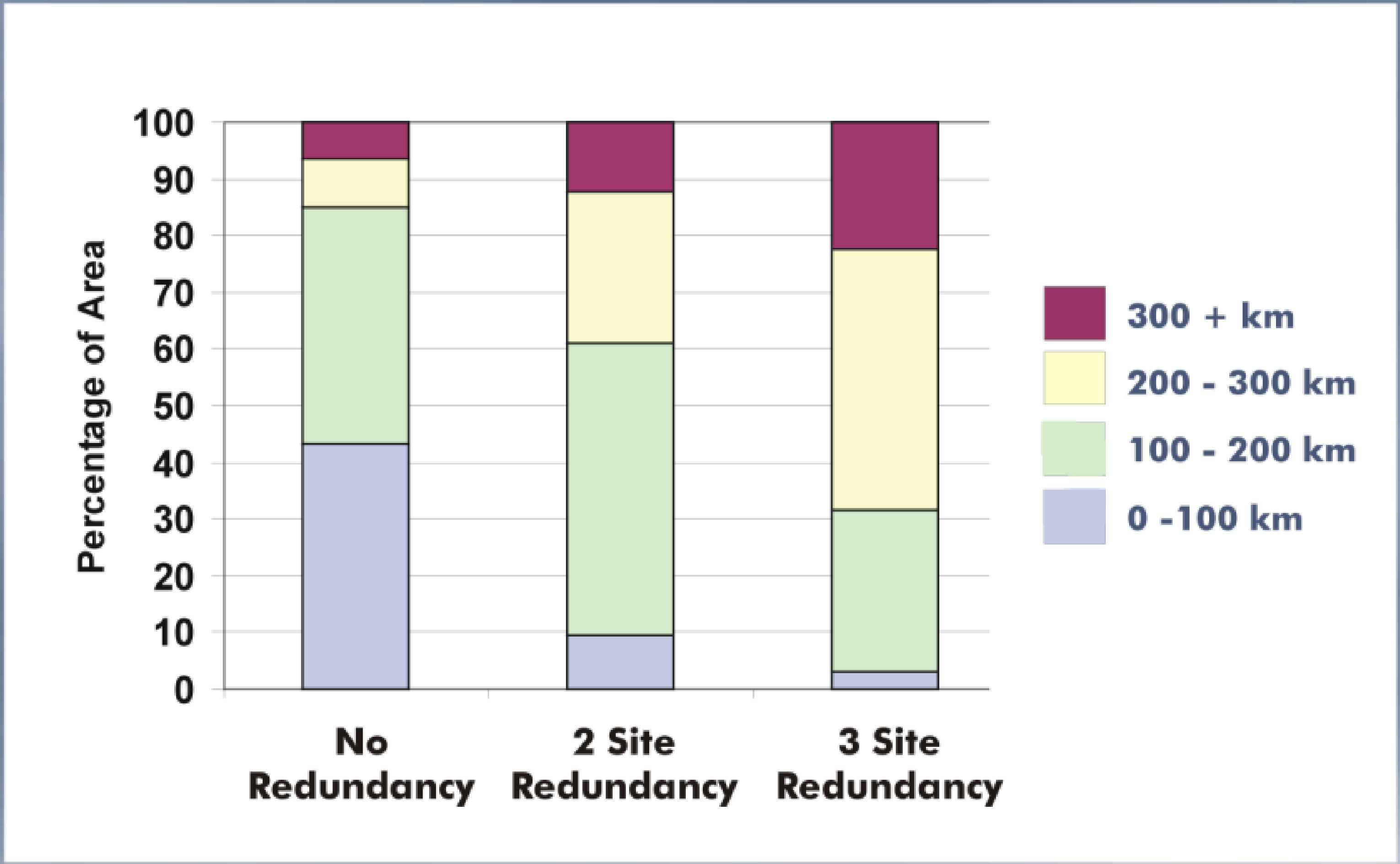
CORS DATA QUALITY



CORS DISADVANTAGES

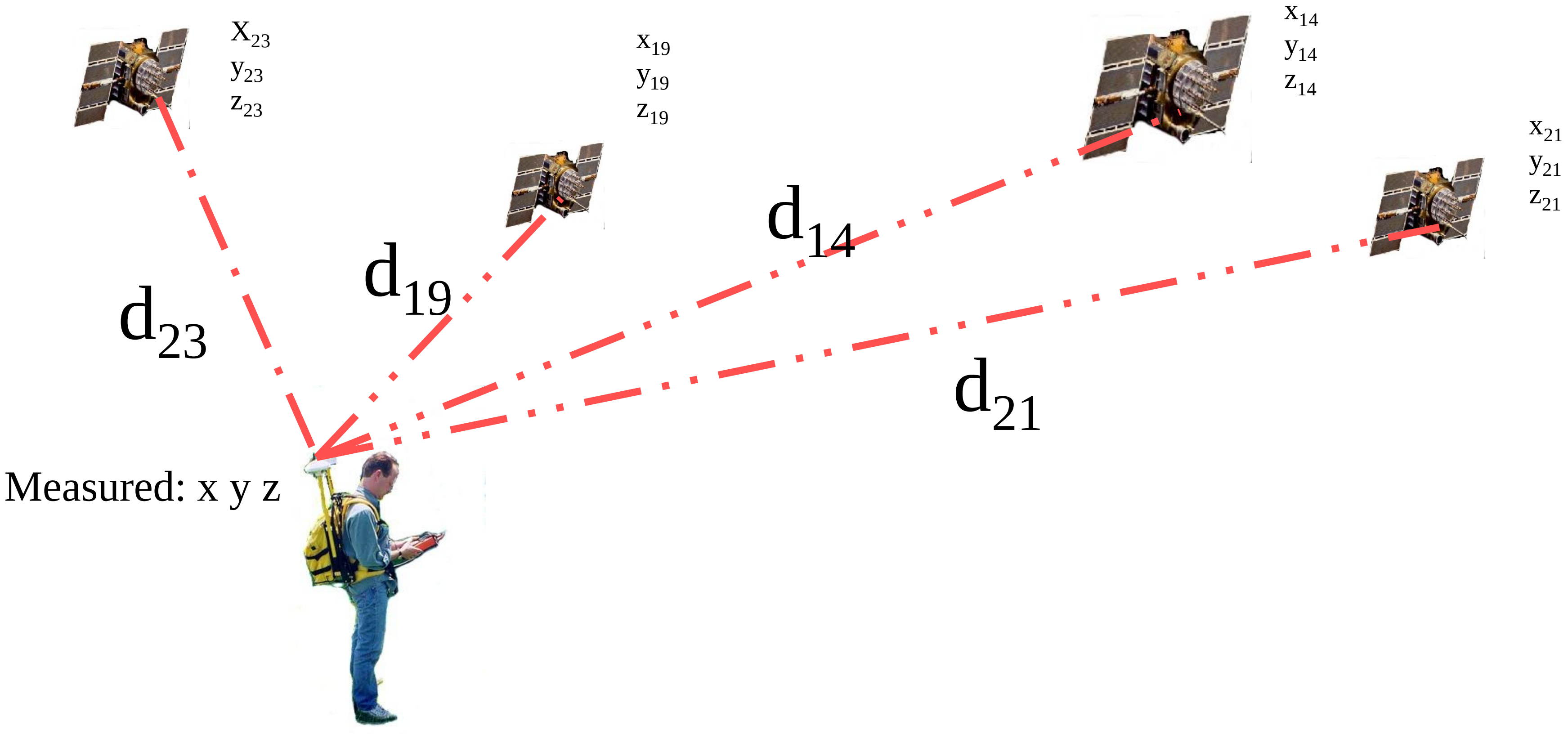
- Distances to sites are currently excessive.
- CORS hardware may differ from user’s hardware.

CORS Density and Position Redundancy (48 States)

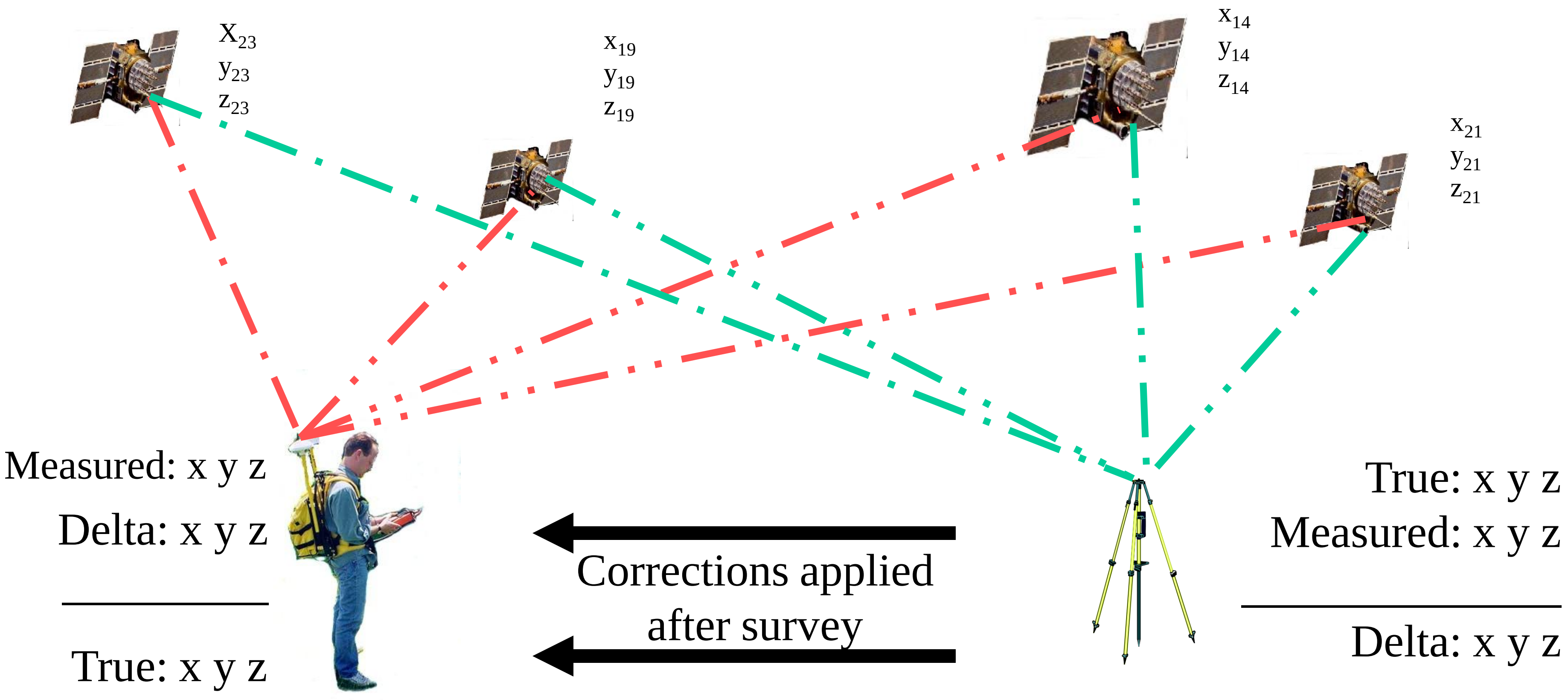


Non-Differential GPS

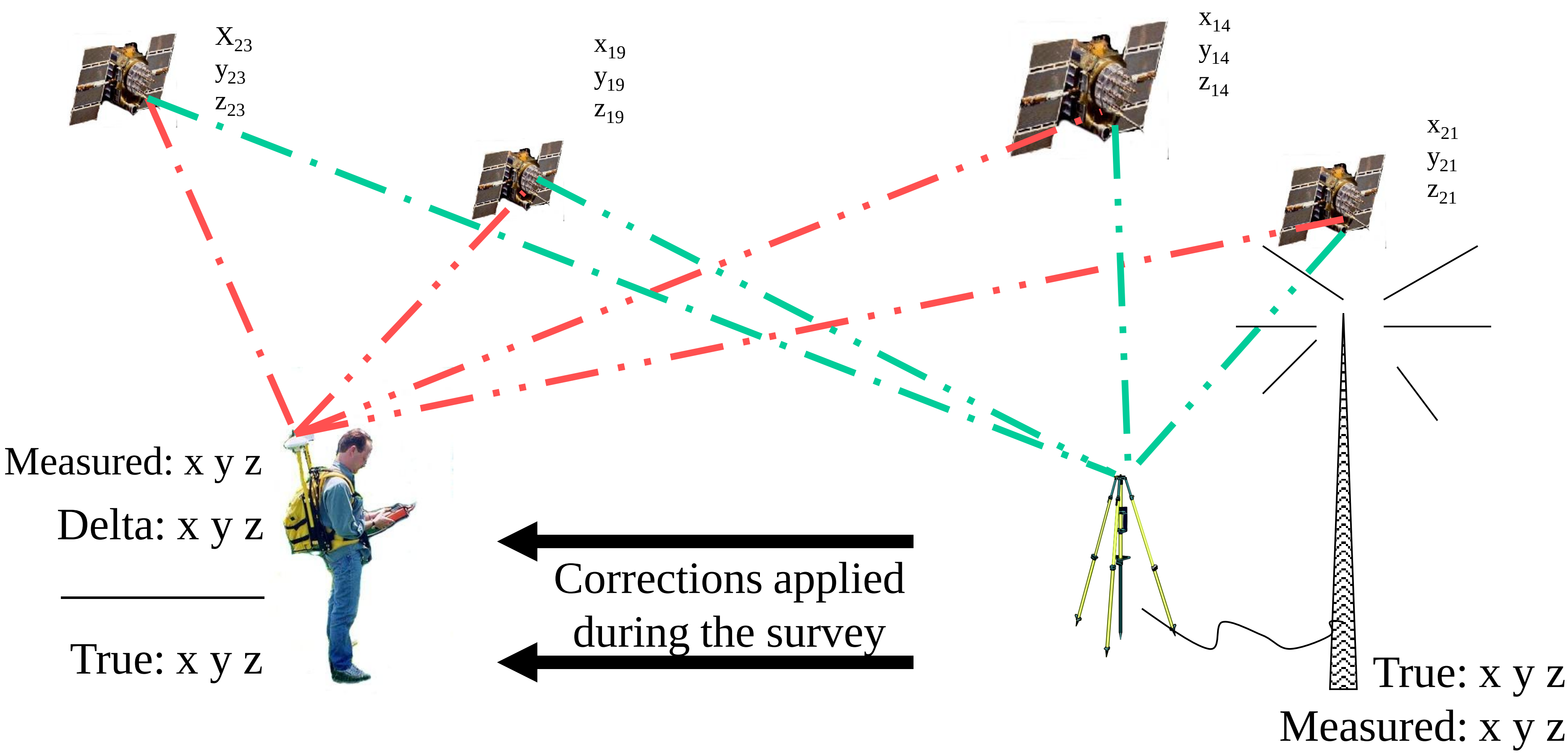
(Autonomous or Stand-alone)



Differential GPS



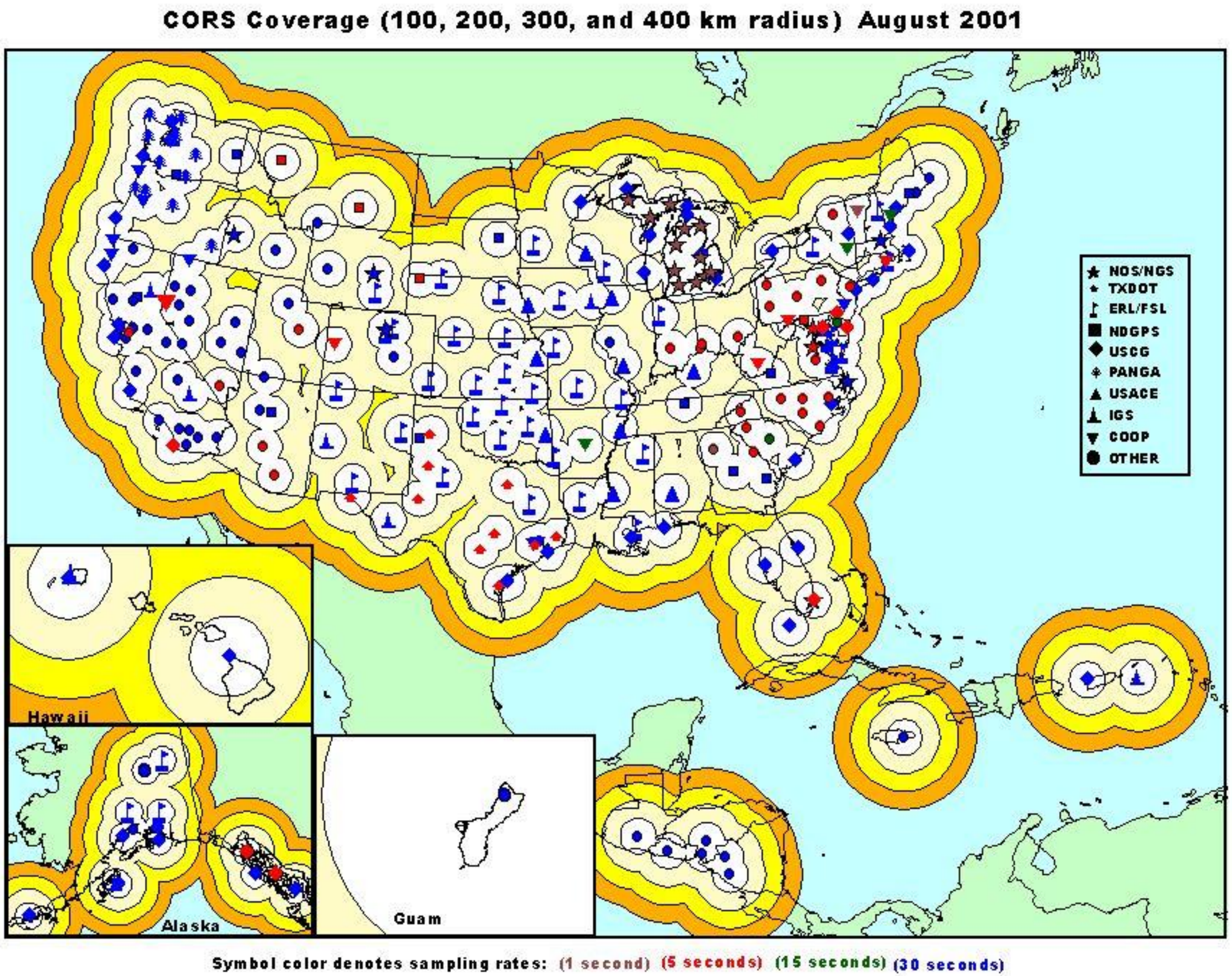
Real-Time Differential GPS



Variations on GPS Positioning

- Stand-alone or Differential
- Real-Time or Post-processed
- Code or Carrier-phase observations
- Short or Long baselines

Continuously Operating Reference Stations



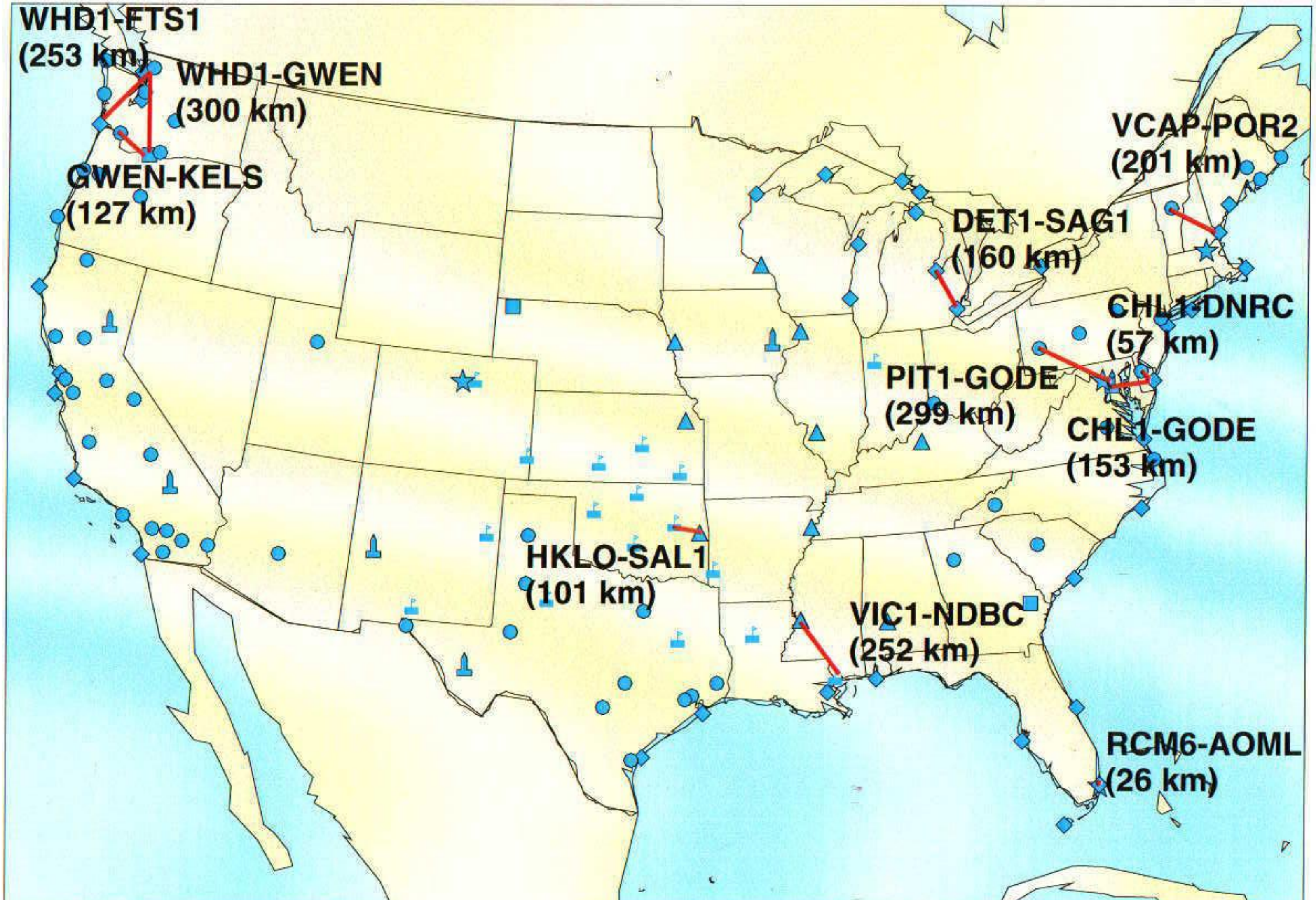
Three Tests for Positioning Precision

- Dual Frequency Carrier Phase
- Single Frequency Code
- Maritime DGPS & Nationwide DGPS

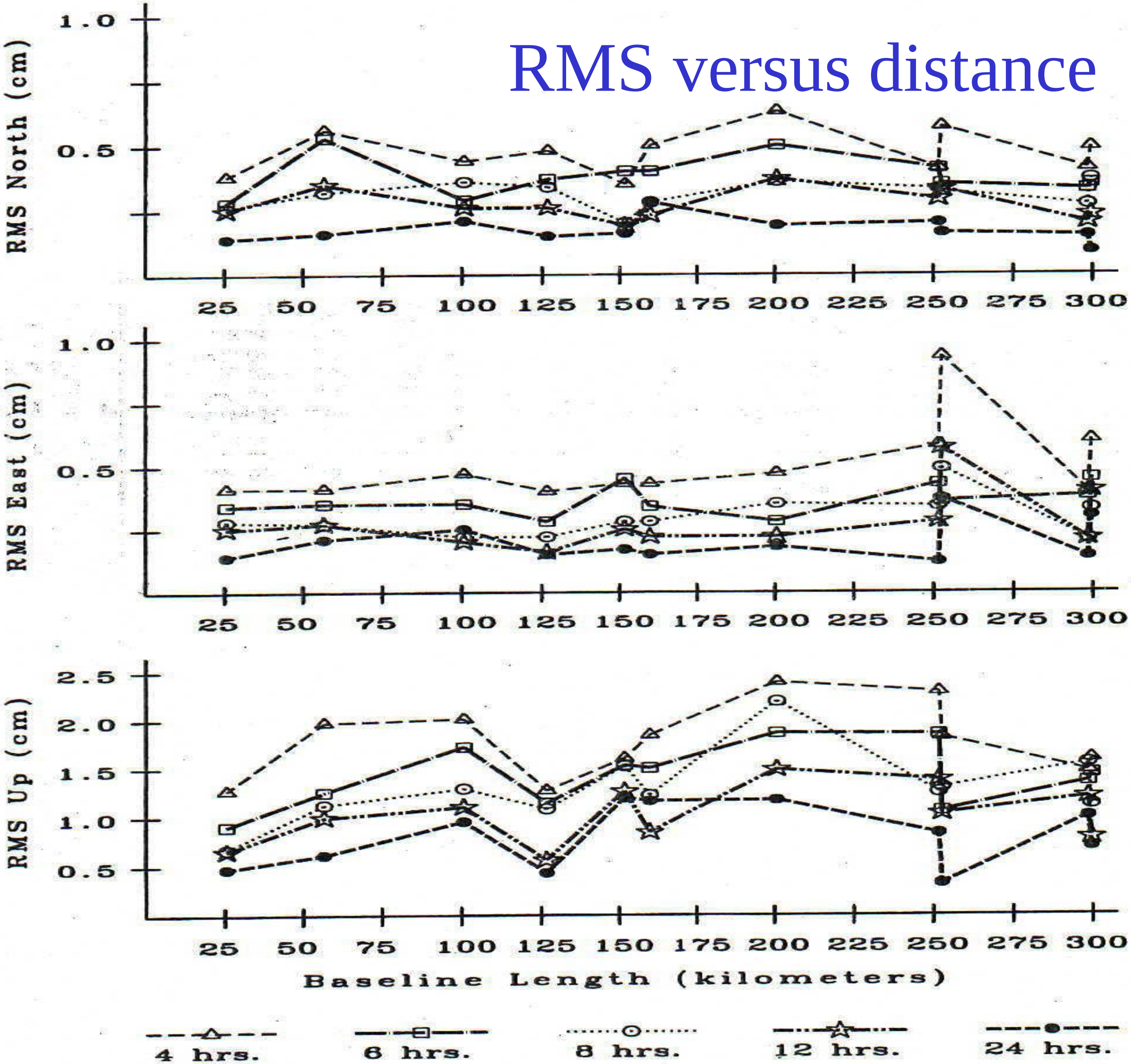
Test Design: dual-frequency carrier phase

- Dual Frequency Geodetic Receivers
- Post-Processed with a Precise Orbits
- Pairs of CORS sites forming 11 Baselines
- Baseline lengths ranging from 26 to 300 km
- Various Observation Session Durations (1, 2, 4, 6, 8, 12, and 24 hours)

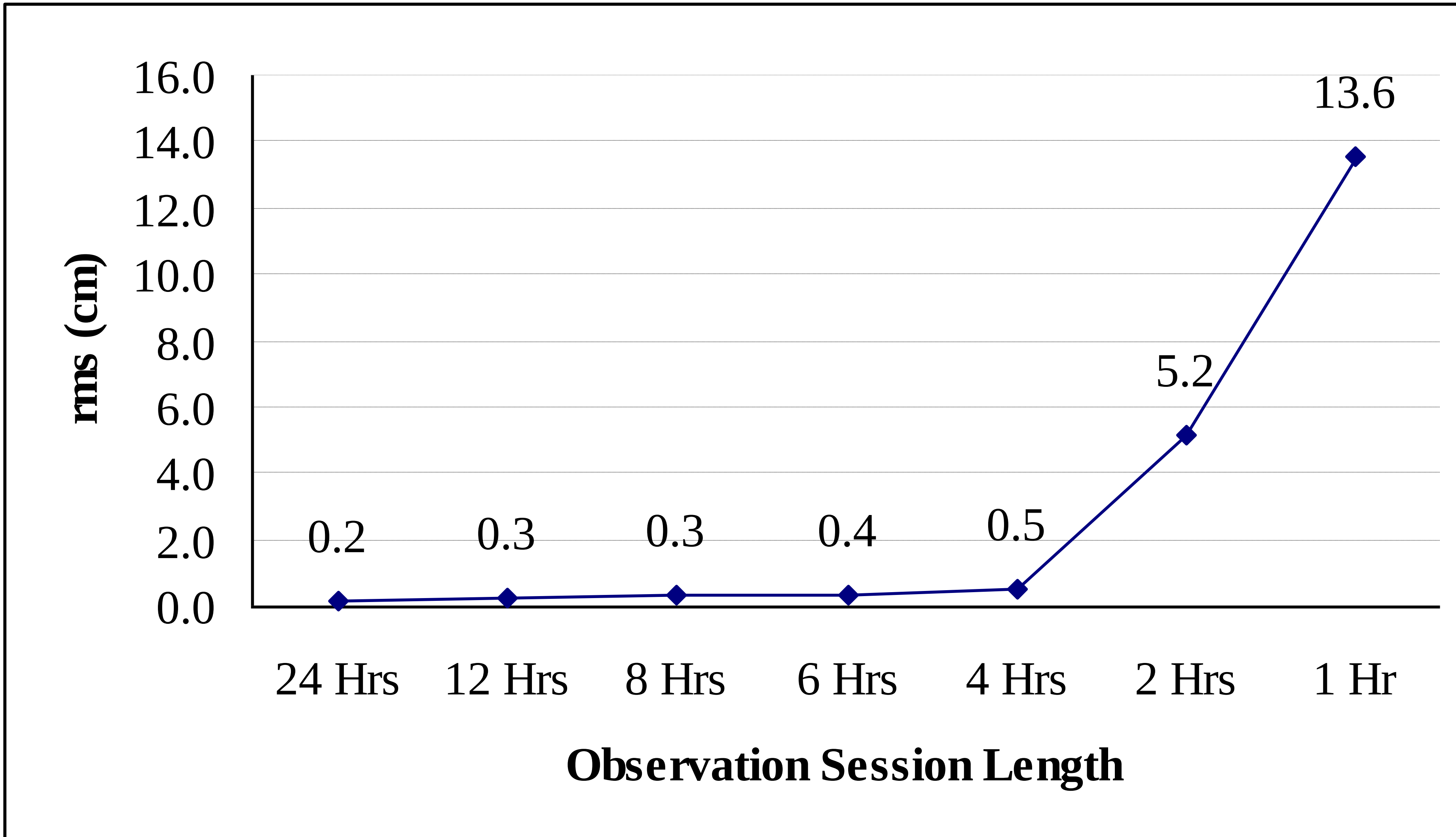
BASELINES USED IN ACCURACY TESTS



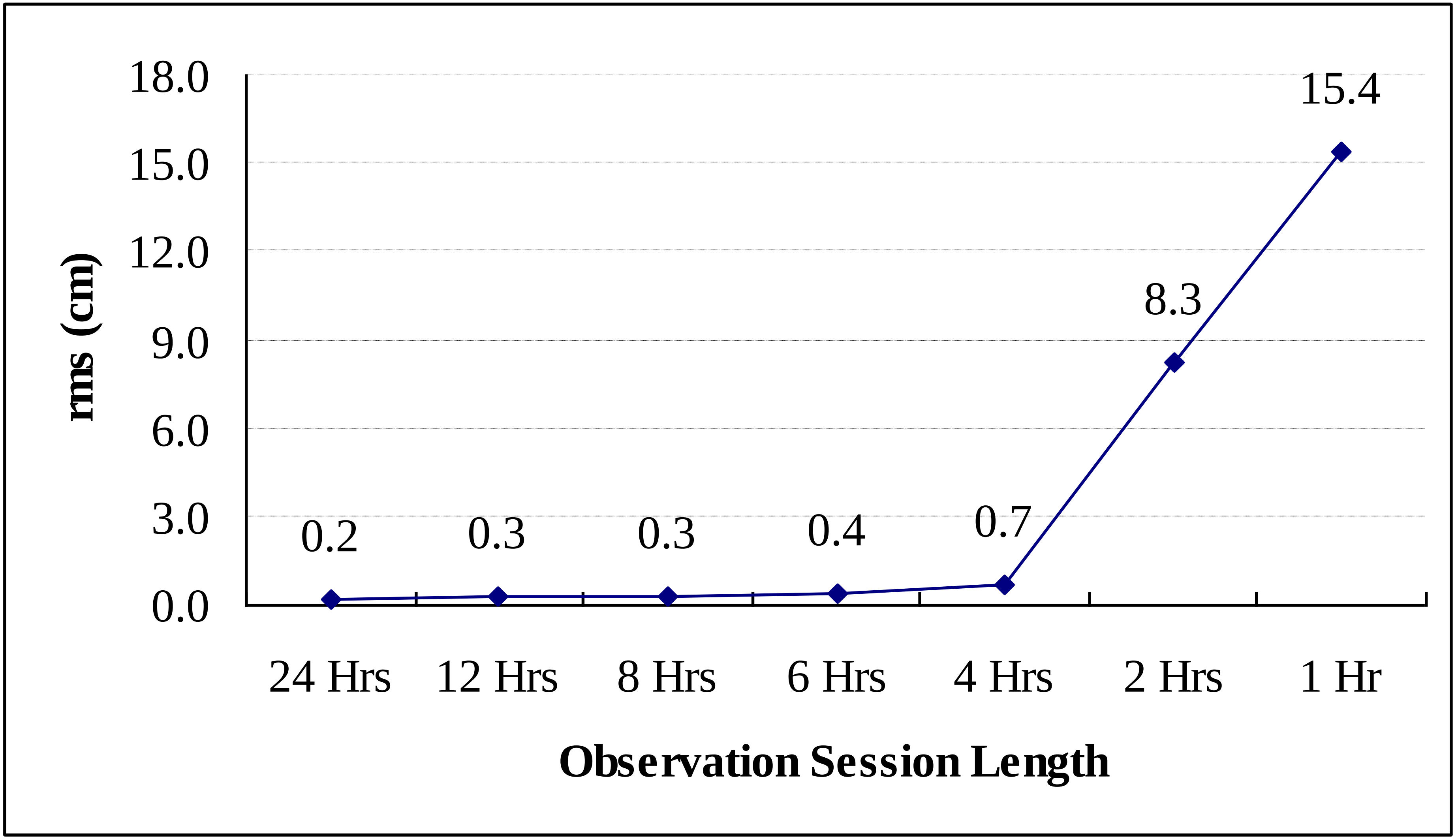
RMS versus distance



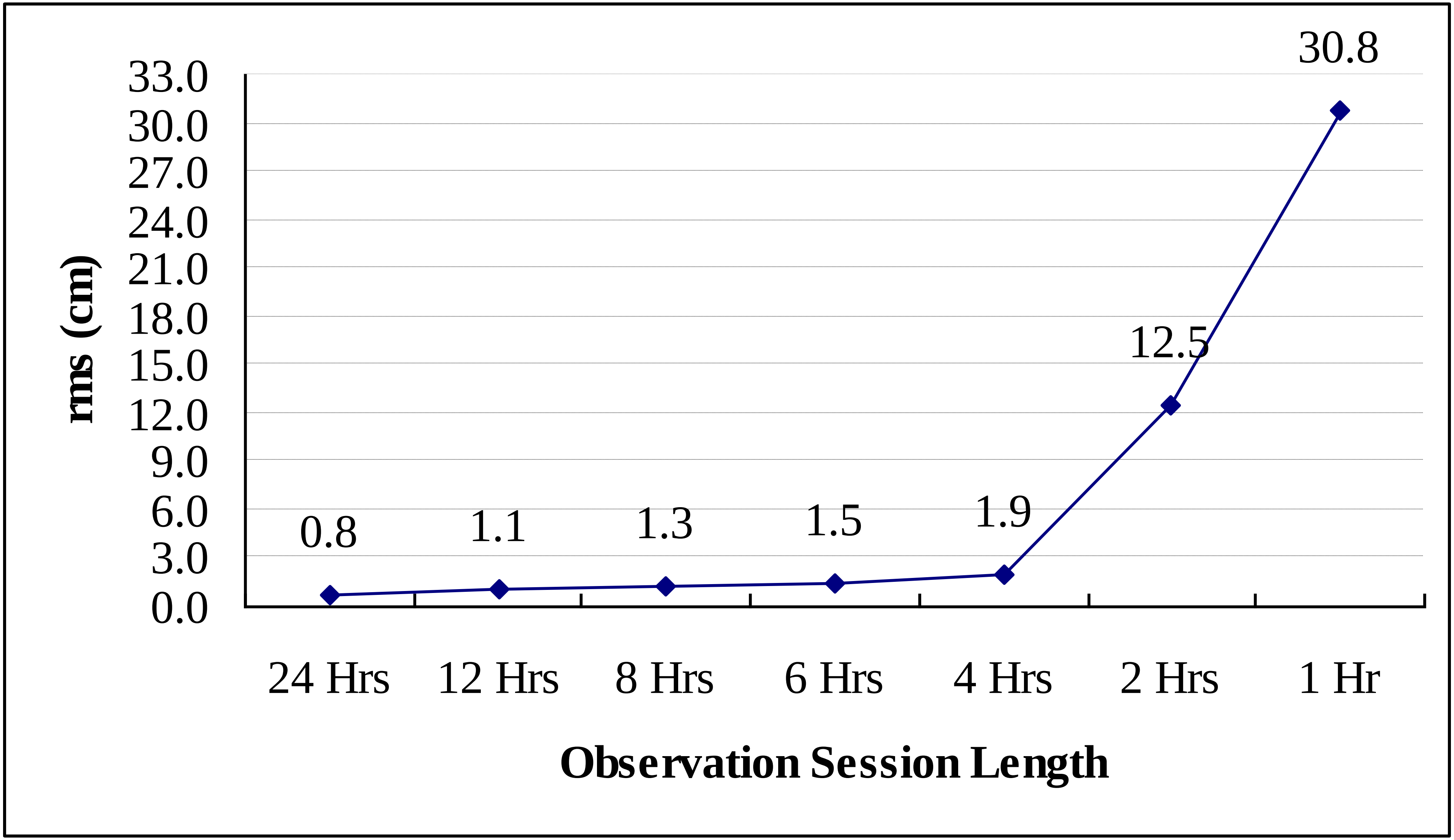
RMS versus Time
Carrier-Phase (North)

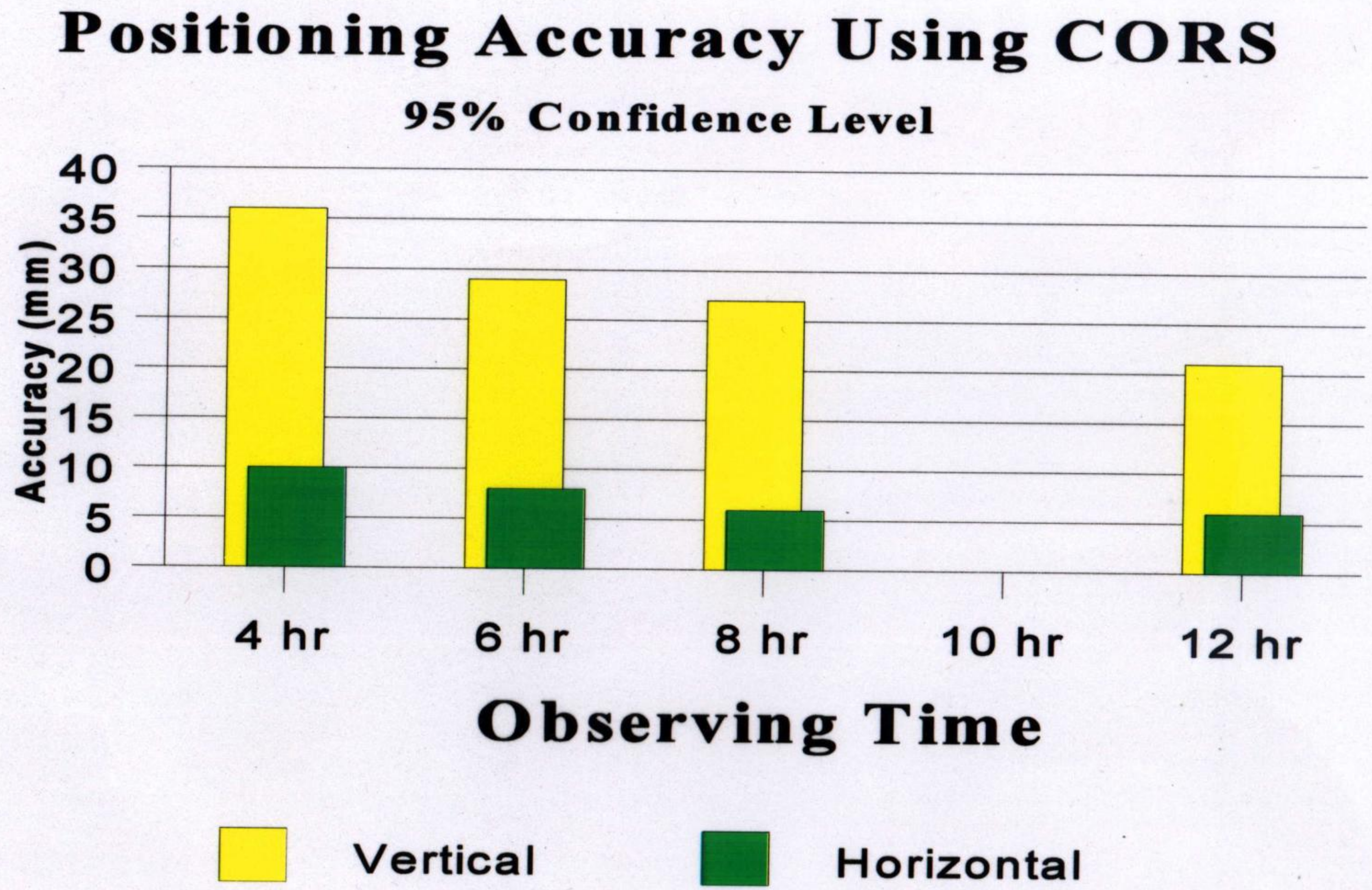


RMS versus Time
Carrier-Phase (East)



RMS versus Time
Carrier-Phase (Up)




Positioning Accuracy Using CORS
95% Confidence Level
40
35
30
25
20
15
10
5
0
Accuracy (mm)
4 hr
6 hr
8 hr
10 hr
12 hr
Observing Time
Vertical
Horizontal

National CORS Accuracy

Multiple Sessions (North) twice the rms (cm)

#Sess	1	2	3	4	5	6
1 hr.	27.2	19.2	15.7	13.6	12.2	11.1
2 hr.	10.4	7.4	6.0	5.2	4.7	4.2
4 hrs.	1.0	0.7	0.6	0.5	0.4	0.4
6 hrs.	0.8	0.6	0.5	0.4		
8 hrs	0.7	0.5	0.4			

Multiple Sessions (East) twice the rms (cm)

#Sess	1	2	3	4	5	6
1 hr.	30.8	21.8	17.8	15.4	13.8	12.6
2 hr.	16.6	11.7	9.6	8.3	7.4	6.8
4 hrs.	1.3	0.9	0.8	0.7	0.6	0.5
6 hrs.	0.7	0.5	0.4	0.4		
8 hrs	0.7	0.5	0.4			

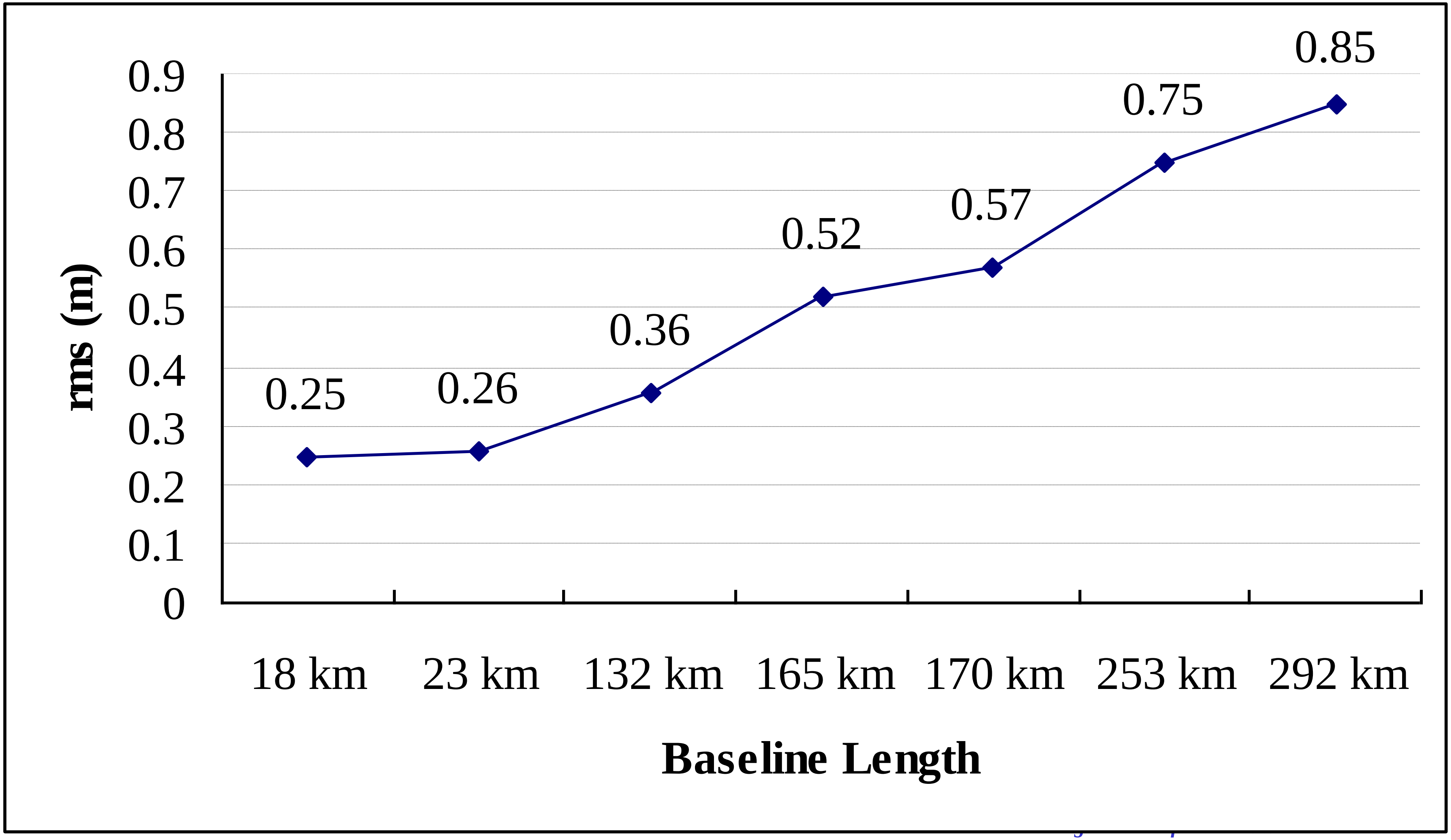
Comments

- Baseline lengths had little effect on the precision of the measurements
- Always use a precise ephemeris
- Short occupation times approach the precision of code measurements

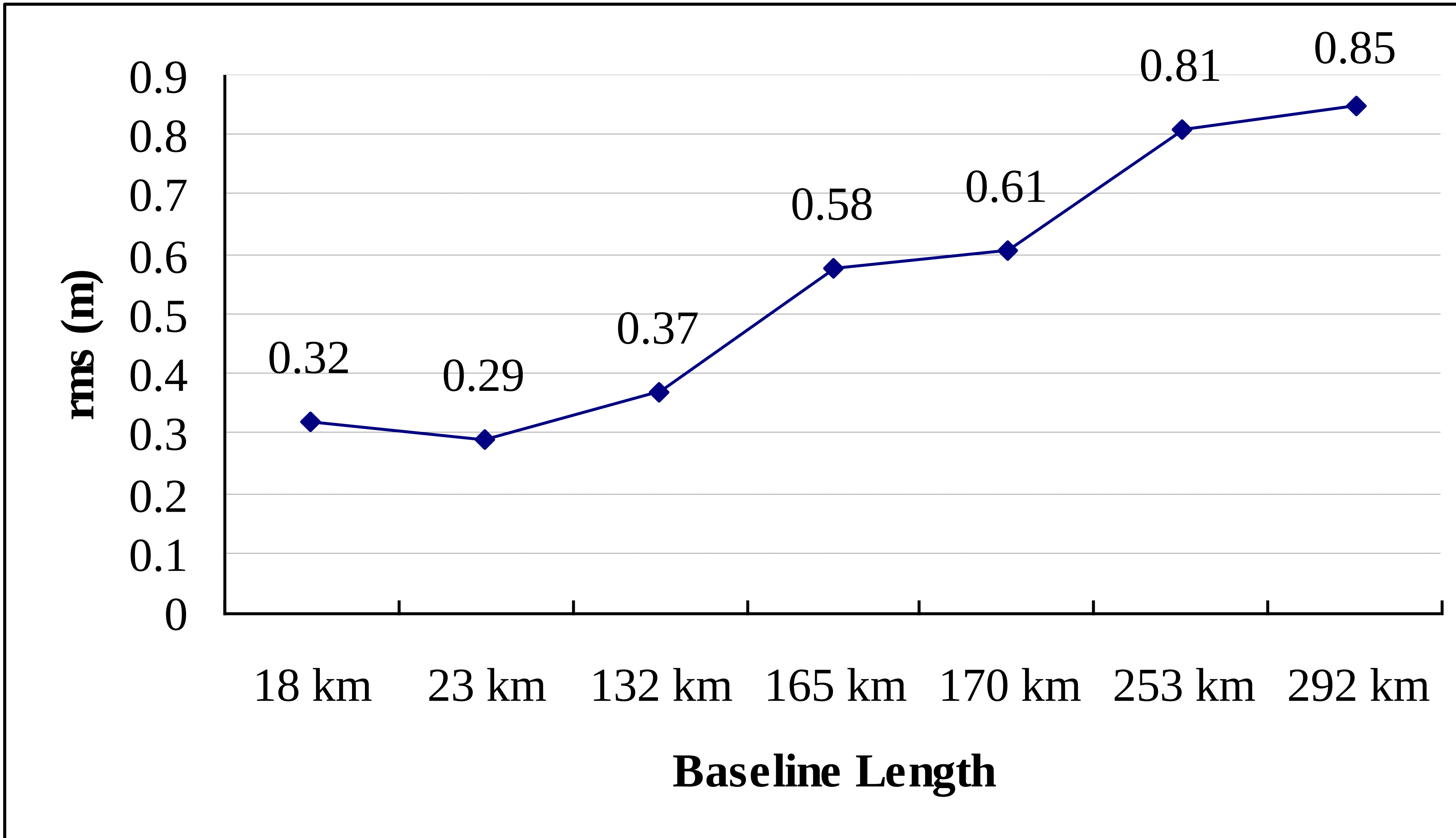
Test Design: Single-Frequency Code

- Positioned 12 points relative to each of seven CORS sites
- Baseline lengths of 18, 23, 132, 165, 170, 253, and 292 kilometers
- Observed 1-minute sessions at a 5-second record rate (interpolated CORS data from 30 to 5 seconds)
- Repeated experiment 4 times over a 2-day period

Precision Relative to Baseline Length GPS Code (North)



Precision Relative to Baseline Length Code (East)



Multiple Sessions (North) twice the rms (m)

#Sess	1	2	3	4	5	6
18 km	0.5	0.4	0.3	0.3	0.2	0.2
23 km	0.5	0.4	0.3	0.3	0.2	0.2
132 km	0.7	0.5	0.4	0.4	0.3	0.3
165 km	1.0	0.7	0.6	0.5	0.5	0.4
170 km	1.1	0.8	0.7	0.6	0.5	0.5
253 km	1.5	1.1	0.9	0.8	0.7	0.6
292 km	1.7	1.2	1.0	0.9	0.8	0.7

Multiple Sessions (East) twice the rms (m)

#Sess	1	2	3	4	5	6
18 km	0.6	0.5	0.4	0.3	0.3	0.3
23 km	0.6	0.4	0.3	0.3	0.3	0.2
132 km	0.7	0.5	0.4	0.4	0.3	0.3
165 km	1.2	0.8	0.7	0.6	0.5	0.5
170 km	1.2	0.9	0.7	0.6	0.5	0.5
253 km	1.6	1.1	0.9	0.8	0.7	0.7
292 km	1.7	1.2	1.0	0.9	0.8	0.7

Comments

- Sub-Meter precision is possible with baseline lengths < 300 kilometers
- This precision is possible using interpolated CORS data
- Most CORS data are available within 1-hour of the survey

Maritime/Nationwide DGPS

Recording position every 2-seconds for over 6 hours.

	Mean (m)	rms (m)
North	0.2403	0.9559
East	0.1342	0.4771
Up	0.6295	1.6173
CEP95	1.8178	Count
CEP99	2.2548	11114 Pts

Overall Summary

- Use Precise Ephemeris (Final, Rapid, Ultra-Rapid) for processing carrier phase data.
- To position a point at the few cm level, at least 4 hours of carrier phase data are required when the associated baseline exceeds 26 km in length.
- Most National CORS data are available within one hour.
- Sub-meter positioning is achievable when using 1 minute of code data in a differential, post-processed mode.

Surveying Applications Using CORS

- Precise Positioning
  - Tie survey to National Spatial Reference System (NSRS)
  - Establish GPS base station (for local survey via RTK, Fast Static, etc.)
  - Set azimuth pairs
  - Blunder tracing - resolve conflicting results

Surveying Applications Using CORS

- Sub-meter Applications
  - Environmental inventories
  - As-Builts (utilities, roads)
  - Tree locations
  - Corner Recovery
  - Dredging (DGPS)
  - Roughing-in roads, building pads, etc. (DGPS)

Surveying Applications Using CORS

- Archives
  - Tie previous GPS campaigns to the NSRS
  - Data recovery (in case your primary base station goes down)

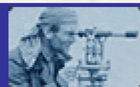
Surveying Applications Using CORS

- How have you used CORS?

- What are your ideas for using CORS?

ACCESSING CORS DATA & METADATA

- Web address = http://www.ngs.noaa.gov/CORS/
- Metadata = data about data
- CORSAGE = CORS Amiable Geographic Environment



Products/Services

Welcome to the National CORS

The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, coordinates a network of continuously operating reference stations (CORS) that provide Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories (map).

Surveyors, GIS/LIS professionals, engineers, scientists, and others can apply CORS data to position points at which GPS data have been collected. The CORS system enables positioning accuracies that approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically.

The CORS system benefits from a multi-purpose cooperative endeavor involving many government, academic, commercial and private organizations. New sites are evaluated for inclusion according to established criteria. The CORS system is currently growing at a rate of a few sites per month. See our newest sites

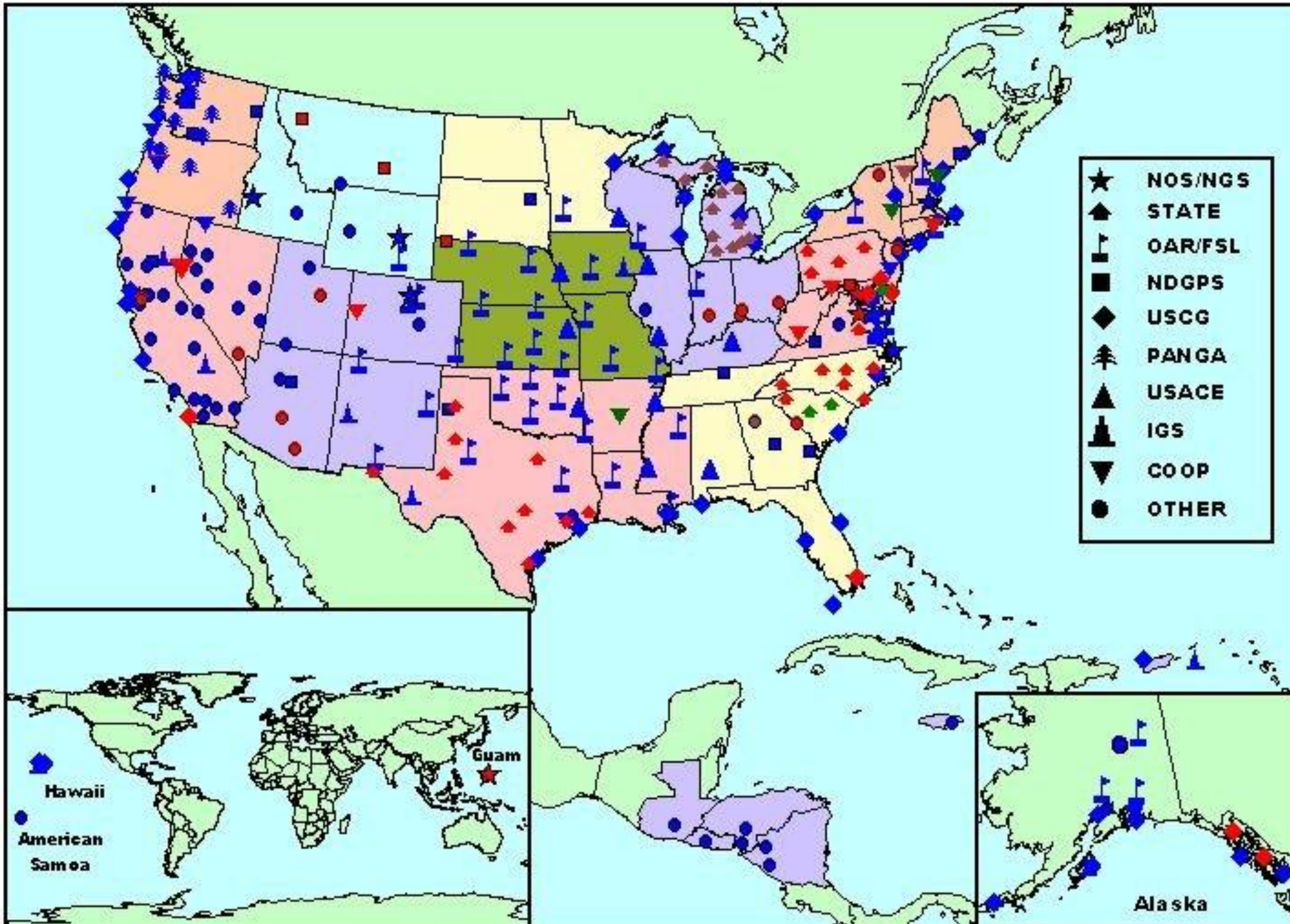
Download DATA	
Customized Files - UFCORS	Standard Download

Click *Standard Download* to get today's data

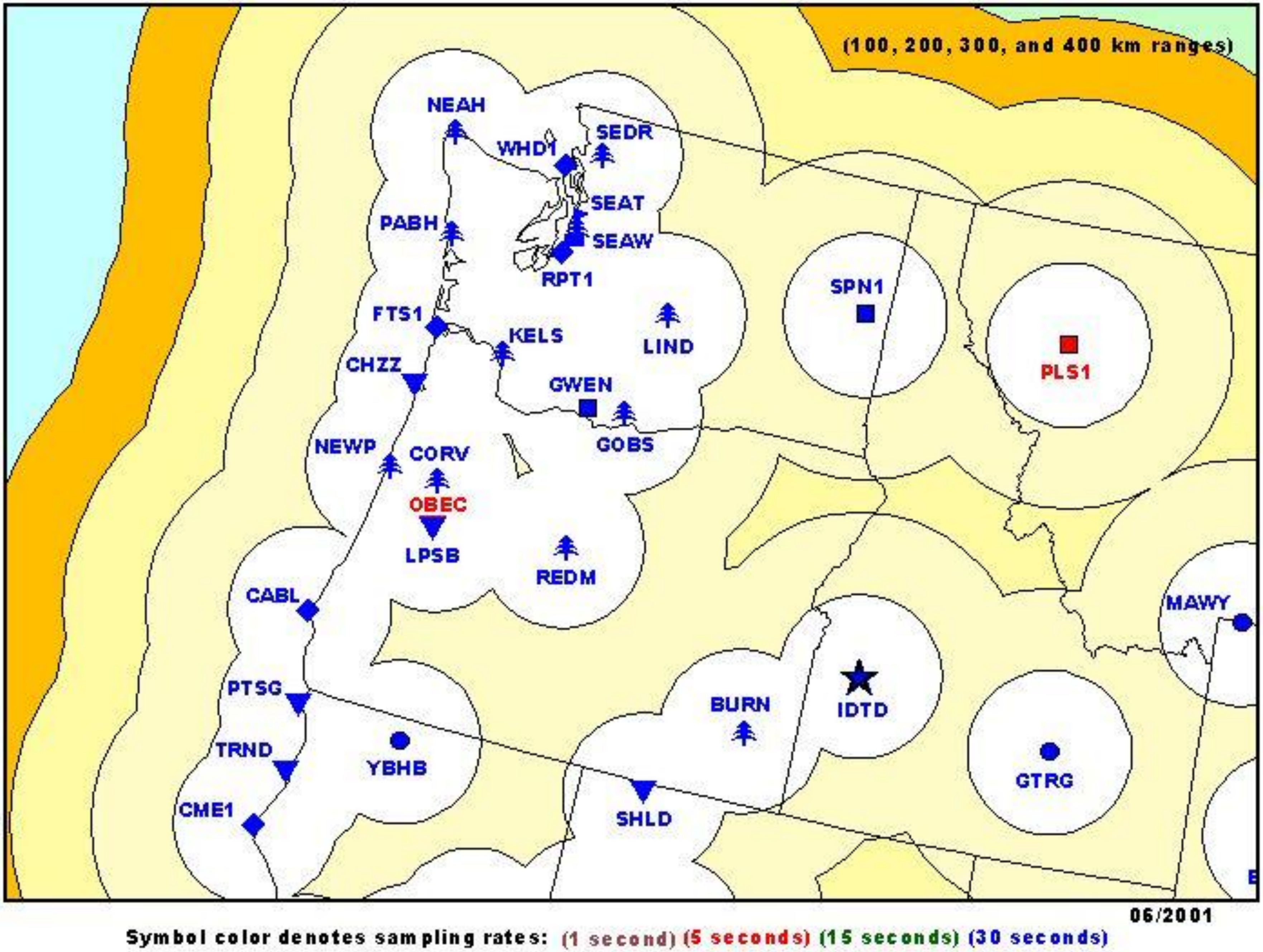
Register for the CORS Industry Forum to be held on March 26, 2001 in Silver Spring, MD

Are you wondering which CORS is the most popular? Get a list of the 60 most requested sites using UFCORS
Updated Oct 17, 2000

CORS Coverage - September 2001



Symbol color denotes sampling rates: (1 second) (5 seconds) (15 seconds) (30 seconds)



(100, 200, 300, and 400 km ranges)
NEAH
WHD1
SEDR
SEAT
PABH
SEAW
RPT1
SPN1
FTS1
KELS
LIND
PLS1
CHZZ
GWEN
NEWP
CORV
GOBS
OBEC
LPSB
REDM
CABL
MAWY
PTSG
BURN
IDTD
TRND
YBHB
SHLD
GTRG
CME1
06/2001
Symbol color denotes sampling rates: (1 second) (5 seconds) (15 seconds) (30 seconds)

SEAW
SEAT
STHY 520
Seattle
Lake Washington
UNIVERSITY OF WASHINGTON MEDIC
FIFTH AVENUE MEDICAL CENTER
HOSPITAL
VIRGINIA MASON HOSPITAL
MEDICAL CENTER
NORTHWEST HOSPITAL
132nd Ave NE
Harbor Ave SW

METADATA FOR A CORS SITE

- Coordinates (positions & velocities)
- Data availability profiles (charts showing times for which data has been collected)
- Data sheets (descriptive information)
- Log files (descriptive information)
- Site photos
- Time series of positional coordinates

CORS Position & Velocity (NAD 83)

```
U.S. NAVAL OBSERV (USNO),  DISTRICT OF COLUMBIA

Retrieved from NGS DataBase on 09/11/00 at 09:19:17.

 ______________________________________________________________________
|                                                                      |
| NAD_83 POSITION (EPOCH 1997.0)                                       |
| Transformed from ITRF97 (epoch 1997.0) position in July 2000.        |
|     X =   1112190.435 m     latitude    =  38 55 08.23678 N          |
|     Y =  -4842956.500 m     longitude   = 077 03 58.39707 W          |
|     Z =   3985352.386 m     ellipsoid height =    50.177   m          |
|                                                                      |
| NAD_83 VELOCITY                                                      |
| Transformed from ITRF97 velocity in July 2000.                       |
|     VX =   0.0000 m/yr      northward =   0.0000 m/yr                |
|     VY =   0.0000 m/yr      eastward  =   0.0000 m/yr                |
|     VZ =   0.0000 m/yr      upward    =   0.0000 m/yr                |
|______________________________________________________________________|
```

CORS POSITION & VELOCITY (ITRF)

```
                    U.S. NAVAL OBSERV (USNO),  DISTRICT OF COLUMBIA

                  Retrieved from NGS DataBase on 09/11/00 at 09:19:17.
 _____________________________________________________________________________
|                                                                             |
|        Antenna Reference Point(ARP): U.S. NAVAL OBSERV CORS ARP             |
|        --------------------------------------------------------             |
|                            PID = AI7403                                     |
|                                                                             |
|                                                                             |
| ITRF97 POSITION (EPOCH 1997.0)                                              |
| ARP computed from the SITEIGS.BIN file in Jul., 2000                        |
|     X =   1112189.901 m     latitude    =  38 55 08.26445 N                 |
|     Y =  -4842955.035 m     longitude   = 077 03 58.40504 W                 |
|     Z =   3985352.234 m     ellipsoid height =   48.878   m                 |
|                                                                             |
| ITRF97 VELOCITY                                                             |
| Velocities adopted by NGS Jul., 2000.                                       |
|     VX =  -0.0144 m/yr      northward =   0.0013 m/yr                       |
|     VY =  -0.0023 m/yr      eastward  =  -0.0145 m/yr                       |
|     VZ =   0.0009 m/yr      upward    =  -0.0002 m/yr                       |
|                                                                             |
```

Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.ngs.noaa.gov/cgi-cors/support.prl?siteID=barh What's Rela

Instant Message Internet Lookup New&Cool

DATA AVAILABILITY PROFILE

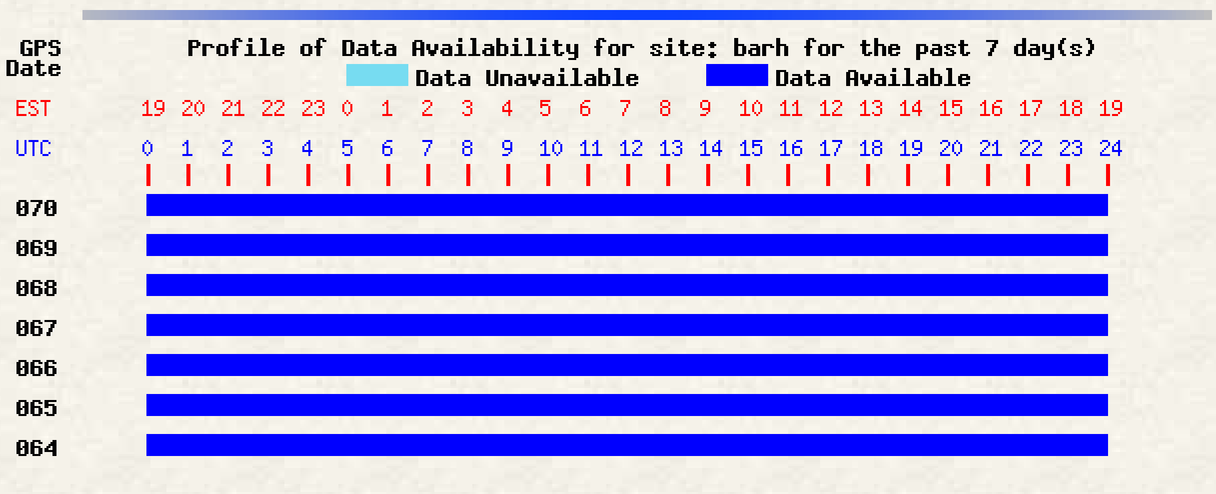
SiteID-----------------GPS Date------------Zone------Days

barh | March 11, 2001 - day of year 070 | EST | 7

Submit

NOTE: Reset options and click 'Submit' to view data availability for another time period.

Get Customized Data | Get Uncustomized Data



Document: Done

Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.ngs.noaa.gov/cgi-cors/support.prl?siteID=ashv What's Rela

Instant Message Internet Lookup New&Cool

DATA AVAILABILITY PROFILE

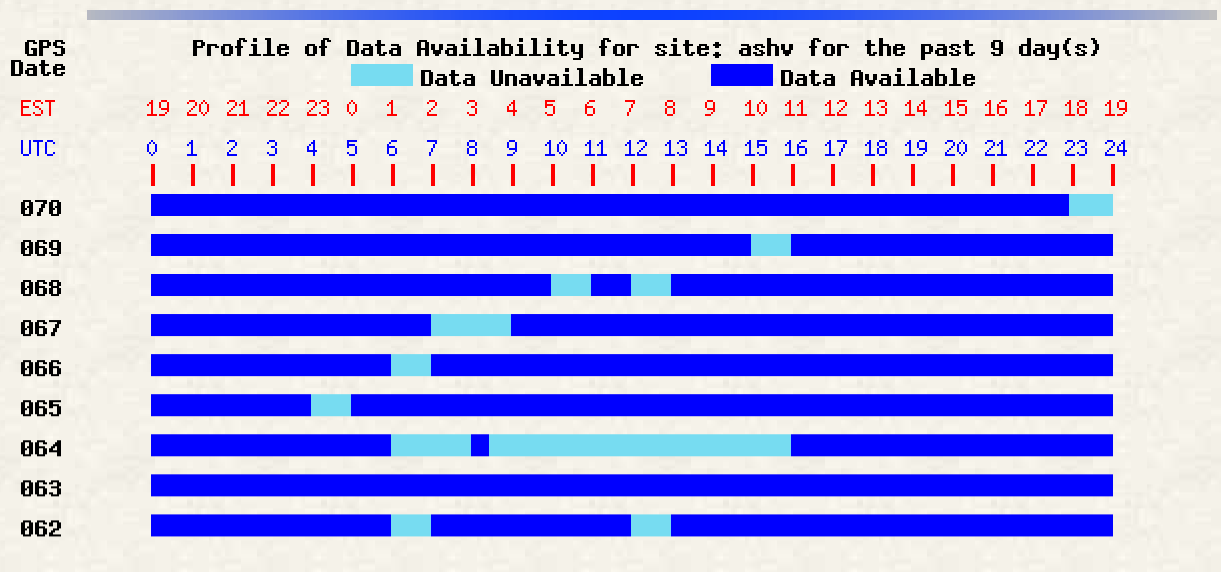
SiteID------------------GPS Date------------Zone------Days

ashv | March 11, 2001 - day of year 070 | EST | 9

Submit

NOTE: Reset options and click 'Submit' to view data availability for another time period.

Get Customized Data | Get Uncustomized Data



Document: Done

CORS SITES PHOTO

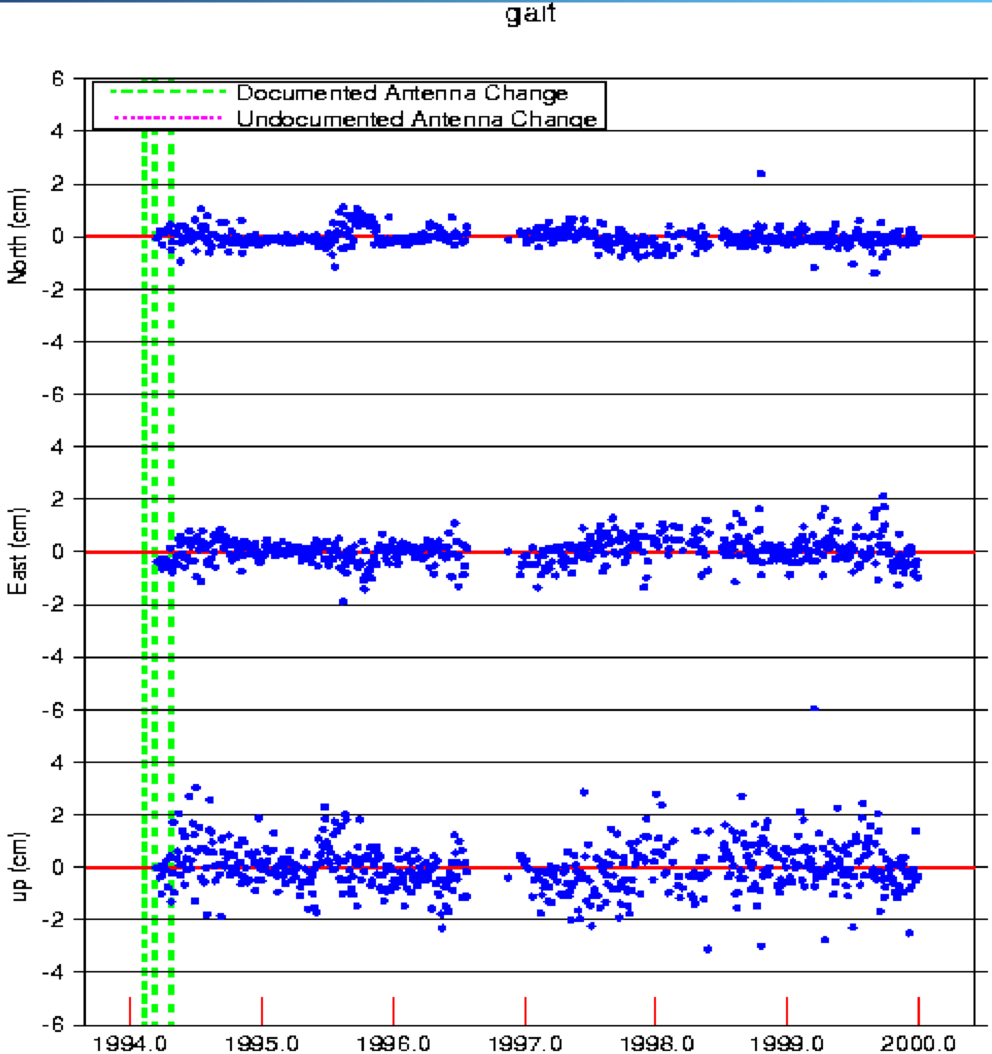
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

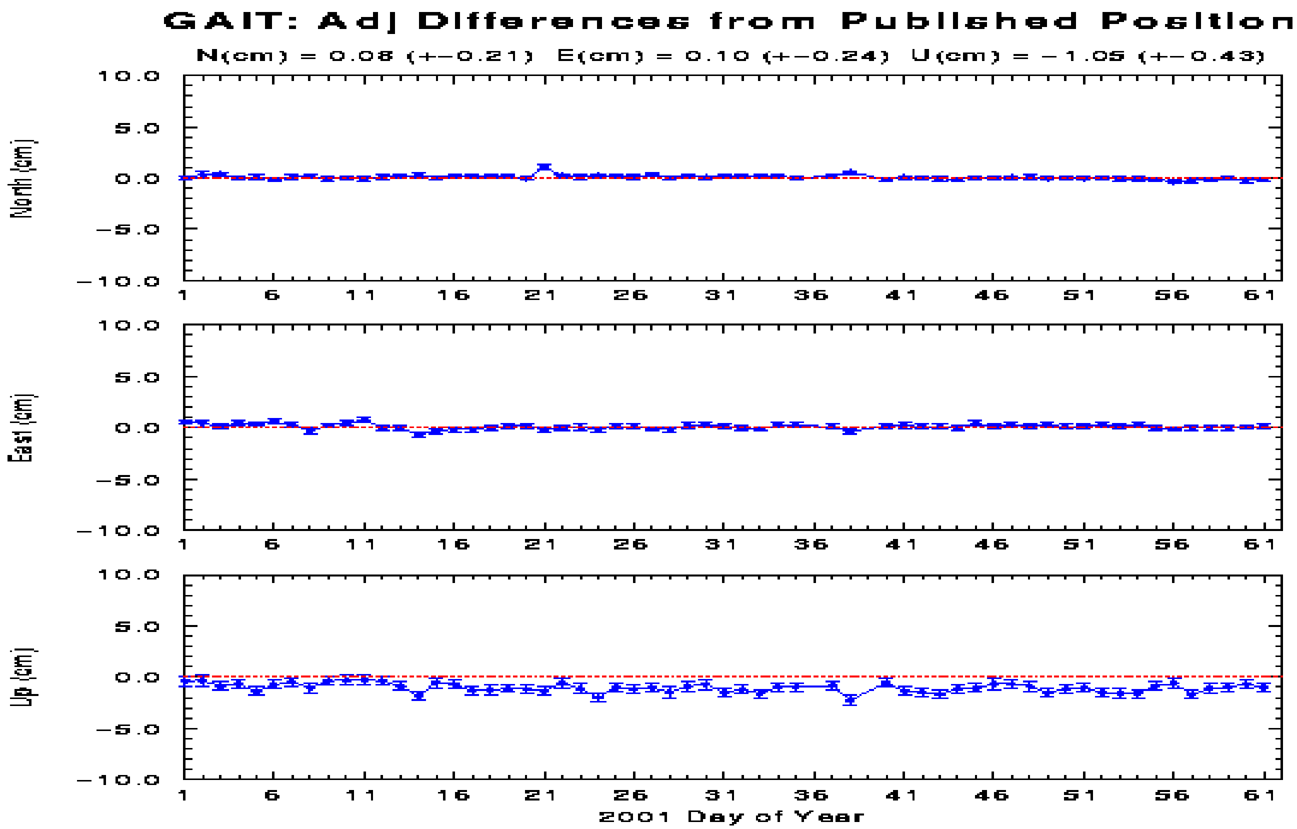
National Geodetic Survey

Positioning America for the Future

Position Time Series (long-term)



Position Time Series (last 60 days)



STATION LOG FILE

```
************************************************************
       CONTINUOUSLY OPERATING REFERENCE STATION (CORS)
                     SITE INFORMATION FORM
************************************************************
0. Form

          Prepared by (full name) : Paul Spofford
          Date                          : 13NOV95
          Report type                   : UPDATE

        NOTE: COORDINATE POINT IS THE ANTENNA L1 PHASE CENTER

1.        Site Identification of GPS Monument 1   (reference site)

          Site Name           : Whidbey Island 1
          4 char ID           : whi1
          Monument Inscription          : None
          IERS DOMES Number   : N/A
          CDP Number                    : Not assigned
          Date                          : 20SEP95
          Additional information        : No monument.

2. Site Location

          City                          : Whidbey Island
          State                         : WA
          Country                       : USA
          Tectonic Plate                : North American
          Additional information        : See position.whi1 document
```

Station Log File (continued)

```
3. GPS Receiver

     i.   Type                         : Ashtech Z_XII3
          Serial Number                :
          Firmware Version    : 1C75
          Date                         : 08 June 1995
          Operation           : Receiver installed  /                    /
                                   Receiver removed    /                 /
                                   Firmware update     /                 /
                                   Frequency standard  /                 /
                                   Other                   /             /

4. GPS Antenna

     i.   Type                         : Ashtech Geodetic L1-L2 Rev. D
          Model Number                 : 700829 (3)
          Serial Number                :
          Vertical Antenna Height      : 0.000
          Antenna Reference Point      : Bottom of Pre-Amplifier
          Date                         :

5. Local Site Ties

   Monument            CDP       DOMES                Components            Accuracy     Date
   Inscription         Number   Number      dX        dY        dZ       mm       YY-mm-dd
```

Station Log File (continued)

```
6. Frequency Standard

          H-maser /    /         Cesium /    /     Quartz /    /     Internal / X  /
          Other (specify)              :
          Date                         :

          (Mark with 'X')
7. Collocation

          SLR /    /         VLBI /    /       DORIS /    /      PRARE /    /
          Other Instrumentation        :

          (Mark with 'P' for permanent, 'M' for mobile collocation)
8. On-site, Point of Contact Agency Information

          Agency                       : USCG
          Contact                      :
          Address                      :

          Telephone          :
          E-mail                       :
          Fax                          :
9. Responsible Operations Agency
   ( if different from item 8)

          Agency                       : USCG
          Contact                      : Lt. Russo
          Address                      :

          Telephone          : (609) 523-7363
          E-mail                       : N.RUSSO/EECENng@cgsmtp.comdt.uscg.mil
          Fax                          : (619) 523-7387
```

Station Log File (continued)

10. Please insert here the character graphics corresponding to the antenna type. Check, complete or change if necessary, the antenna dimensions.

```
          Type                              : Ashtech Geodetic L1-L2 Rev.D
                part number     : 700829 (3)


                           +                            <-- 0.0904 L1
                 +-------------------+
 +---* +---------`---------0---------`---------+ *---+  <-- 0.0648 TGP
 (_-+   +-----------+-------------+-----------+   +-_)
                   _|      +      |                     <-- 0.0618 L2
                  | |             |
                  |_|             |
                    |___       ___|
                        |__x__|                         <--  0.0000 ARP=BPA

                    <-- 0.0947  -->
      <--               0.3474                 -->         top of notch (outer)
  <--                   0.3683                     -->


    ARP: Antenna Reference Point
    L1 : L1 Phase Center                          L2 : L2 Phase Center
    TGP: Top of Ground Plane                      BPA: Bottom of Preamplifier
```

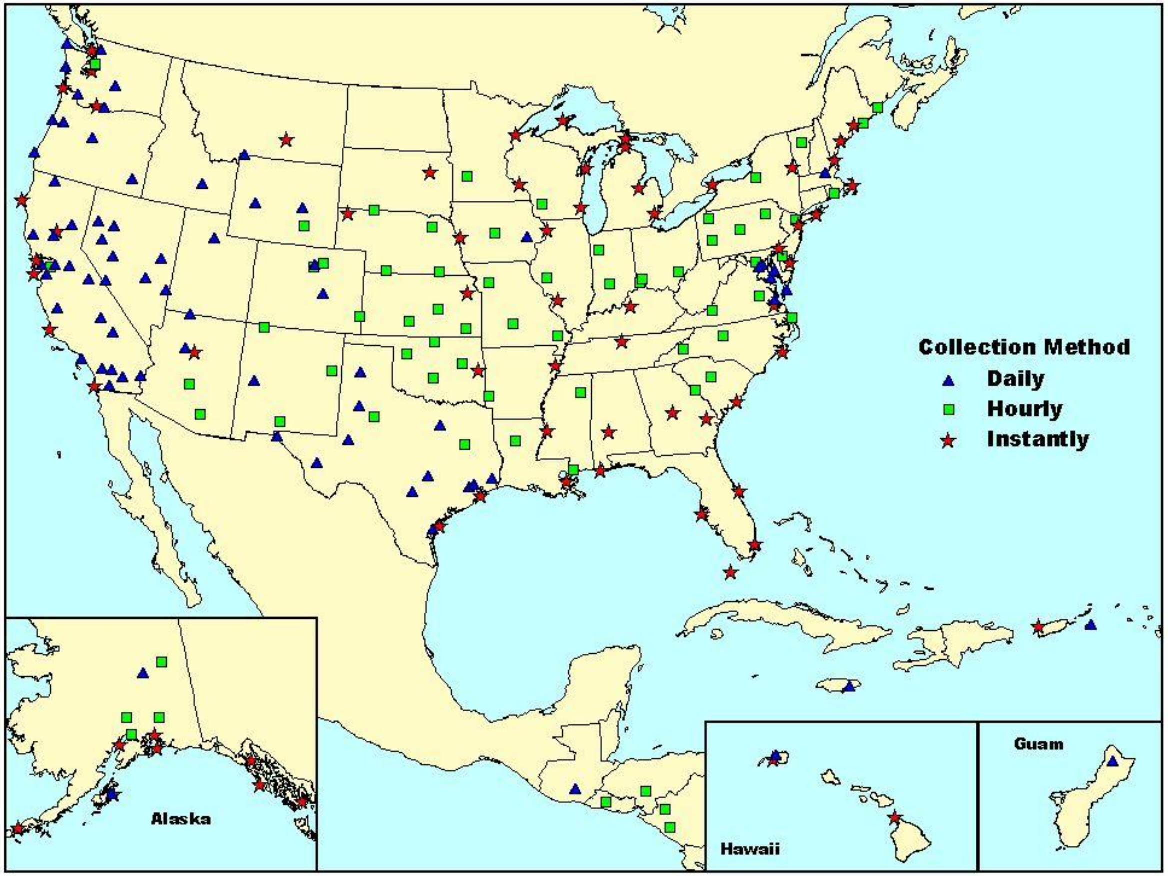
PRIMARY DATA FILES

- GPS observations at a CORS site
- Meteorological observations at a CORS site
- Satellite orbits (ephemerides)

GPS Data Files – Rinex Format v2.10

- Types of data files:
  - hourly files, daily files,
    and customized files (UFCORS)
- Data sampling rates:
  - 1sec, 5sec, 15sec, or 30sec
- Shelf life of data files
  - hourly files: 2 days + today
  - daily files: permanently

HOW DOES NGS COLLECT CORS DATA



NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

National Geodetic Survey

Positioning America for the Future

RINEX FILE NAMING CONVENTION

The RINEX file naming convention is as follows:
{SSSS}{DDD}{H}.{YY}{T}

where	**SSSS**	**is the four character site identifier,**
	DDD	**is the day of year,**
	H	**is a letter which corresponds to an hour long UTC time block,**
	YY	**is the year,**
	T	**is the file type.**

For daily files, the format would be {SSSS}{DDD}0.{YY}{T}.
Hour long UTC time block identifier (H):

00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x

File type	Ending (T)
Meteorological	m
Observation	o
Navigation	n
Summary	s

```
     2              OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
GPS Data Logger     GRDL                21-Mar-2001 00:00   PGM / RUN BY / DATE
Jamaica Met Service                                         COMMENT
                                                            COMMENT
                                                            COMMENT
JAMA                                                        MARKER NAME
42601S001                                                   MARKER NUMBER
CR                  JamaicaMet                              OBSERVER / AGENCY
UZ01603             ASHTECH UZ-12       UG00                REC # / TYPE / VERS
114                 AOAD/M_TA_NGS   SNOW                    ANT # / TYPE
   1388123.458  -5909144.607   1951948.314                  APPROX POSITION XYZ
          0000          0000          0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     5    C1    L1    L2    P1    P2                        # / TYPES OF OBSERV
    30                                                      INTERVAL
  2001     3    21     0     0     0                        TIME OF FIRST OBS
  2001     3    21    23    59    30                        TIME OF LAST OBS
                                                            END OF HEADER
 01  3 21  0  0  0.0000000  0 11 24  6 30 23  9 26 17 10 18  5  4
  22525107.968   -12004584.60101  -9307794.83601  22525107.310    22525113.601
  21407074.677   -21302765.63901 -16590892.08801  21407074.328    21407080.397
  24273111.188    -6817866.50901  -5269844.90201  24273110.761    24273125.339
  23992113.232    -5222731.73501  -4038165.96501  23992112.838    23992125.979
  24740791.562    -3375069.26001  -2600636.54801  24740793.020    24740812.294
  19829141.060   -28015349.71301 -21809187.84301  19829140.818    19829145.446
  24987202.822    -3519780.28501  -2735504.94601  24987202.593    24987213.187
  22285216.503   -15947032.36401 -11887374.74201  22285215.306    22285221.233
  24749918.403     -652695.17911   -473382.45901  24749918.770    24749934.463
  24264723.697    -3160535.55801  -2408534.86401  24264722.253    24264739.440
  25147913.811    -9528713.53001  -7369147.23701  25147913.155    25147921.207
```

Meteorological Data

Instrument:

- Accuracies: 1.0% humidity; 0.1 mbar pressure; 0.5 deg C temperature.
- Data frequency: 5 minutes

Met instrument operated by:

- NOAA’s Forecast System Lab
- NGS

# of stations: currently 52; will grow rapidly

NGS Satellite Ephemerides

http://www.ngs.noaa.gov/GPS/GPS.html

- NGS is one of the seven International GPS Service (IGS) Analysis Centers (AC) participating in the production of accurate GPS orbits:
  - Final Precise (~ 13 days latency)[accuracy < 5 cm]
  - Rapid (14 hours latency) [accuracy < 10 cm]
  - Ultra-Rapid (real-time) [accuracy < 25 cm]
- Satellite positions in SP3 format are given (once every 15 minutes) in current ITRFxx frame

Three ways to download CORS Information

- Web-based User-Friendly CORS (UFCORS)
- Web-based “Standard” download
- FTP (File Transfer Protocol)

Edit View Go Communicator Help

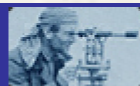
Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.ngs.noaa.gov/CORS/ What's Rela

Instant Message Internet Lookup New&Cool

National Geodetic Survey

- Newsletter
- Downloads
- Site Metadata
- General Information
- Cooperative CORS
- Instructions
- GPS Links
- Utilities
- CORS Home



Products/Services

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Data Sheets Search

NGS NOAA

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Updated Oct 17, 2000

Document: Done

UFCORS - page 1

UFCORS Form - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.ngs.noaa.gov/cgi-cors/ufcors2.prl What's Related

Version 2.13 - May, 2001

This utility allows you to obtain a specific block of Global Positioning System (GPS) data for a continously operating reference station (CORS) contained in the network of GPS sites managed by the National Geodetic Survey.

The GPS data will be in "receiver independent exchange" (RINEX) format, version 2.

Version Info, Bug fixes | UFCORS Page Info

Questions or Comments? Send email to cors@ngs.noaa.gov

**** NOTE: Whenever possible, please use the new Problem/Comment form below or at the bottom of the following page to report problems.**

UFCORS Problem/Comment Form

Time Zone UTC (GMT) **relative to observation location.** Time Zone Info

Starting Day October 17, 2001 - day of year 290 **and Start Time** 00:00 **of the field observations**

Number of hours 1 **of data you wish to receive. PLEASE LIMIT 1 SECOND DATA TO 2 HOURS**

CONTINUE | CLEAR

Document: Done

UFCORS - page 2

UFCORS Form - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.ngs.noaa.gov/cgi-cors/ufcors2.prl What's Related

Version 2.13 - May, 2001

GPS data are available for the following sites for your specified time interval: [seat] [Site Info] [Site Map]

This utility will interpolate or decimate the GPS data. [Interpolation Info]

How many seconds do you want between individual data points? [As Is] LIMIT FOR 1 SECOND DATA IS 2 HOURS

You will automatically receive the corresponding log file, coordinate file, and any available met data for your selected sites.

[Log File Info] [Coordinate File Info] [Met File Info]

Would you like the corresponding NGS data sheet? [yes]

You will automatically receive the appropriate broadcast orbits.

Do you wish to receive corresponding IGS Orbits in SP3 format? [yes] [Orbit Info]

Files can be compressed using: [pkzip] [Compression Info]

Processing will take several minutes. A window will appear after processing that allows you to select where on your hard drive to save the transmitted files.

Also, a window displaying icons for several directories (folders) and files may appear. You may use this window to view the transmitted files. This feature is browser dependent and may not work on your browser.

Please Wait.

[SUBMIT] [CLEAR]

To Report Problems [UFCORS Problem/Comment Form]

Document: Done

Standard Download

CORS DATA - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location: http://www.ngs.noaa.gov/CORS/Data.html What's Related

Thu, 18 Oct 2001 15:03:40 GMT (UTC)

Please choose SITE, OPTION (and if necessary) DATE

sort by state - sort by city - sort by site ID

SITE (sorted by state)	OPTION	YEAR
WA Goldendale Observatory , GOBS	RINEX2 Data	2001
WA Kelso Airport , KELS	Data Availability	Month*
WA Lind Hall , LIND	Coordinates (NAD83 & ITRF97)	October
WA Neah Bay , NEAH	Logfile (Site logs)	Day*
WA Pacific Beach , PABH	Time Series (60-day)	15
WA Robinson Point , RPT1	Time Series (longterm)	
WA Robinson Point , RPT2	Broadcast Ephemeris	
WA Seattle , SEAT	IGS Ephemeris (precise,rapid or ultra-rapid)	
WA Seattle Weather FSL , seaw	NGS Precise Ephemeris	
WA Sedro Woolley , SEDR		
WA Spokane , SPN1		

or

Enter Day of Year (e.g. 2, 93, 365) *

This will override the **Month** and **Day** boxes if selected! **Find Files**

Do not be confused by the times listed to the right of the next page. They are the times the files were posted. The 8th character in the file name indicates the data range: "a" 0:00 UT - 0:59 UT , "b" 1:00 UT - 1:59 UT, ..., "x" 23:00 UT - 23:59 UT. The files with 24 hours worth of data have a 0 (zero) in the 8th place.

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Talk to Us | CORS Home Page | Coop CORS | Additional Sites | About Gzip | CORS Map | When did that site come online ? | NGS Home

Document: Done

ACCESS TO CORS ARCHIVE VIA FTP

To access the CORS public directories, follow the steps below.

Type the "ftp" command followed by the Internet address as follows

ftp cors.ngs.noaa.gov

Respond to the following:

Name(cors.ngs.noaa.gov): anonymous

Password: user@company.com

FILE TRANSFER PROTOCOL (FTP)

FTP is a user interface to the File Transfer Protocol. FTP copies files over a network connection between the local ``client'' (user) computer and a remote ``server'' computer. FTP runs on the client computer.

The user's system must have access to the INTERNET and support the File Transfer Protocol (FTP). Some useful ftp commands are given below.

ascii	**set ascii transfer type**
binary	**set binary transfer type**
bye	**terminate ftp session and exit**
cd	**change remote working directory**
dir	**list contents of remote directory**
get	**retrieve one file**
help	**print local help information**
mget	**retrieve multiple files**
mput	**send multiple files**
prompt	**force interactive prompting on multiple commands**
put	**send one file**
quit	**terminate ftp session and exit**
show	**display the contents of an ASCII file**

*** Actual commands may vary among operating systems.**

DIRECTORIES

You will arrive at the ftp command level indicated by the prompt "ftp>". If you have trouble, type "help" to print local help information or review the section FILE TRANSFER PROTOCOL for help with additional commands.

The following sub-directories contain additional files and information

- coord	**NAD83 and ITRF positional information.**
- graphics	**CORS network maps.**
- itrf	**Files on the IERS Terrestrial Reference Frame.**
- rinex	**Rinex data files.**
- station_log	**Station information, antenna specifications, and site contacts.**
- utilities	**Programs for manipulating the RINEX files.**

What is OPUS?

- On-line Positioning User Service
- Provide GPS users faster & easier access to the National Spatial Reference System (NSRS)

How does OPUS work?

- Submit RINEX file through NGS web page
- Processed automatically with NGS computers & software
- With respect to 3 suitable National CORS
- Solution via email in minutes

How do I use OPUS?

- Go to OPUS web page   www.ngs.noaa.gov/OPUS
- Enter your email address
- Use browse feature to select RINEX file on your computer
- Select antenna type from menu
- Enter antenna height in meters
- Option to select State Plane Zone
- Click UPLOAD
- Check your email in a few minutes

What is OPUS

OPUS Guidelines

GPS Height Measurements

Antenna Types

Output Description

Discussion

Expected Precisions

Questions - Comments

Privacy Statement

OPUS File Upload

1. Enter your email address

2. Browse... Browse to enter your RINEX file

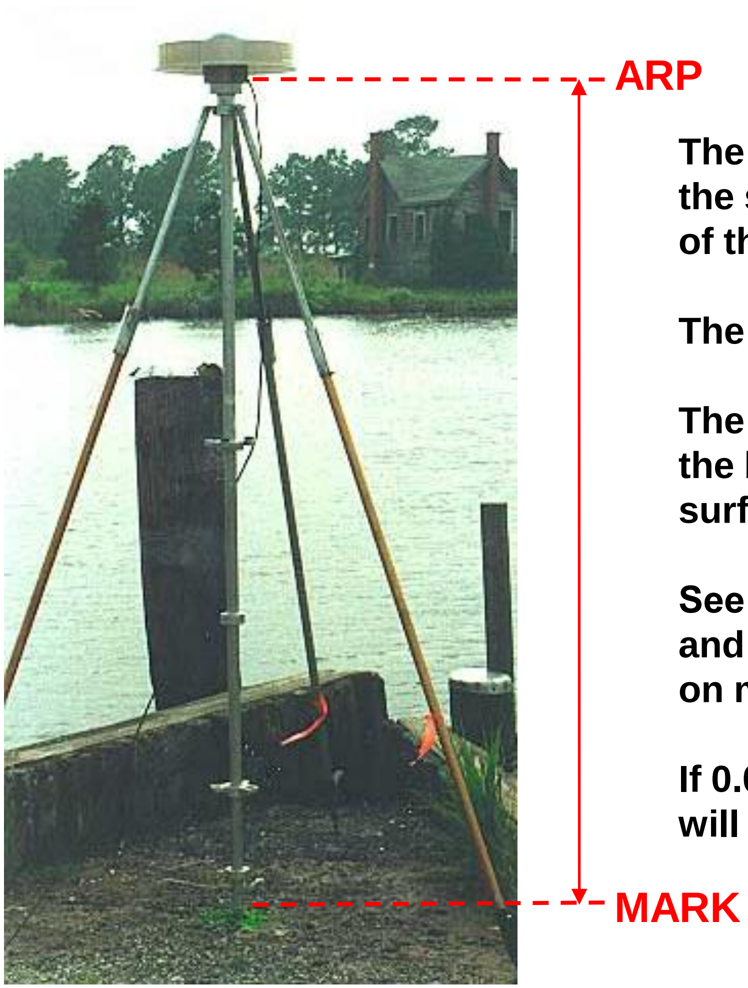
3. NONE NONE
Select the antenna type

4. meters
Enter the antenna height

5. 0 none
Optional: State Plane Coordinates

6. Upload File

How is the antenna height measured?



The height is measured vertically (NOT the slant height) from the mark to the ARP of the antenna.

The height is measured in meters.

The ARP is almost always the center of the bottom-most, permanently attached, surface of the antenna.

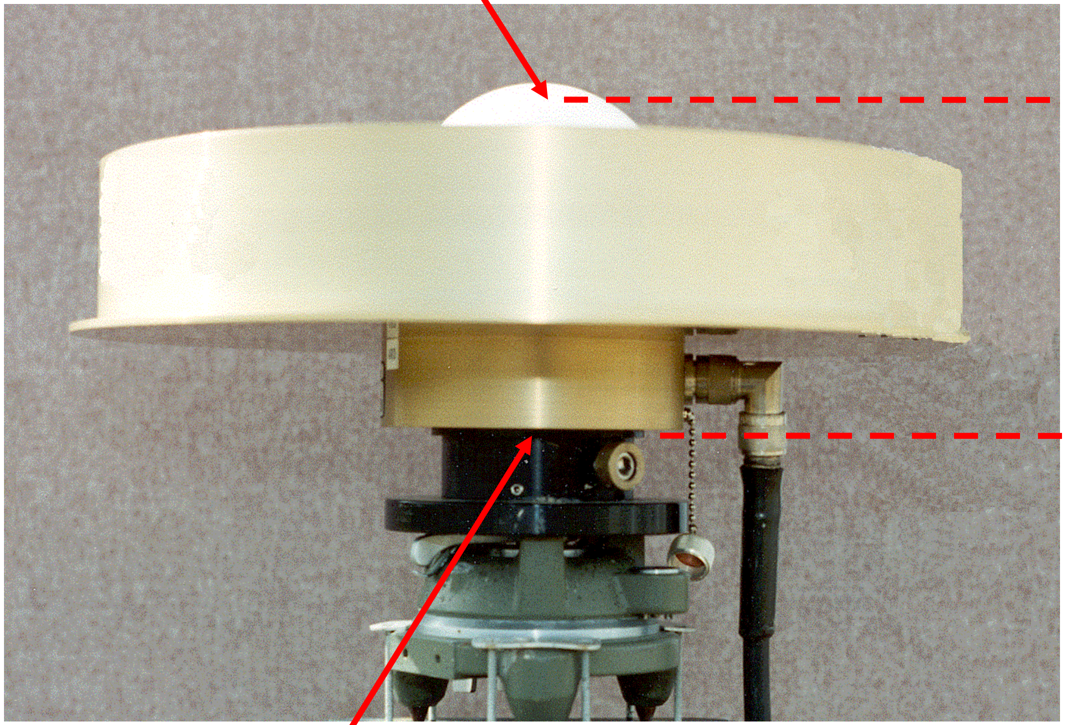
See GPS Antenna Calibration for photo's and diagrams that show where the ARP is on most antennas.

If 0.0000 is entered for the height, OPUS will return the position of the ARP.

Why do I need antenna type?

The antenna phase centers are located somewhere around here.

The user does not need to know these offsets. They are passed to the processing software through the antenna type



The antenna offsets are the distance between the phase centers and the ARP

If the user selects NONE as the antenna type, the offsets are set to 0.000 and the antenna phase center becomes the reference

The Antenna Reference Point (ARP) is almost always located in the center of the bottom surface of the antenna.

Incorrect or missing antenna type → big vertical errors

What does OPUS output look like?

```
                         NGS OPUS SOLUTION REPORT
                         ========================

      USER: gerry@mozart.grdl.noaa.gov   DATE: March 10, 2000
RINEX FILE: 0008322x.99o                 TIME: 18:55:54 UTC

  SOFTWARE: page5 0003.09               START: 1999/11/18 13:32:00
 EPHEMERIS: igs10364.eph (SP3AP)         STOP: 1999/11/18 18:05:00
  NAV FILE: brdc3220.99n             OBS USED: 9302 / 9447
  ANT NAME: ASH700936C_M          # FIXED AMB: 20 / 37
ARP HEIGHT: 2.0001                OVERALL RMS: .0188 (m)

 REF FRAME: ITRF96                  REF FRAME: NAD83

      X(m):    855249.5411  0.0192       855250.0502  0.0320
      Y(m):  -5488771.0160  0.1068     -5488772.5734  0.0891
      Z(m):   3123538.3983  0.0054      3123538.6595  0.0329

       LAT:  29 30 48.37447 0.0473    29 30 48.35598 0.0385
     E LON: 278 51 23.39245 0.0323   278 51 23.40223 0.0179
     W LON:   81  8 36.60755 0.0323    81  8 36.59777 0.0179
    EL HGT:        -25.5803  0.0916         -24.0442  0.0865

BASELINE LENGTH(m)

0008 TO ccv3 130479.3953
0008 TO cha1 380400.1523
0008 TO eky1 264510.5766
```

This position was computed without any knowledge by the National Geodetic Survey regarding equipment characteristics or field operating procedures.

How are OPUS positions computed?

- NGS PAGES software
- Ionosphere free
- Tropospheric scale height adjusted
- Fixed ambiguities
- Average solution to 3 suitable CORS
- ITRF and NAD83 positions reported

How are OPUS errors estimated?

- Overall root mean square
- Peak to Peak errors
  - allows 3 redundant baselines
  - computed separately for ITRF and NAD83
  - max coordinate spread from 3 CORS
  - better indicator than rms

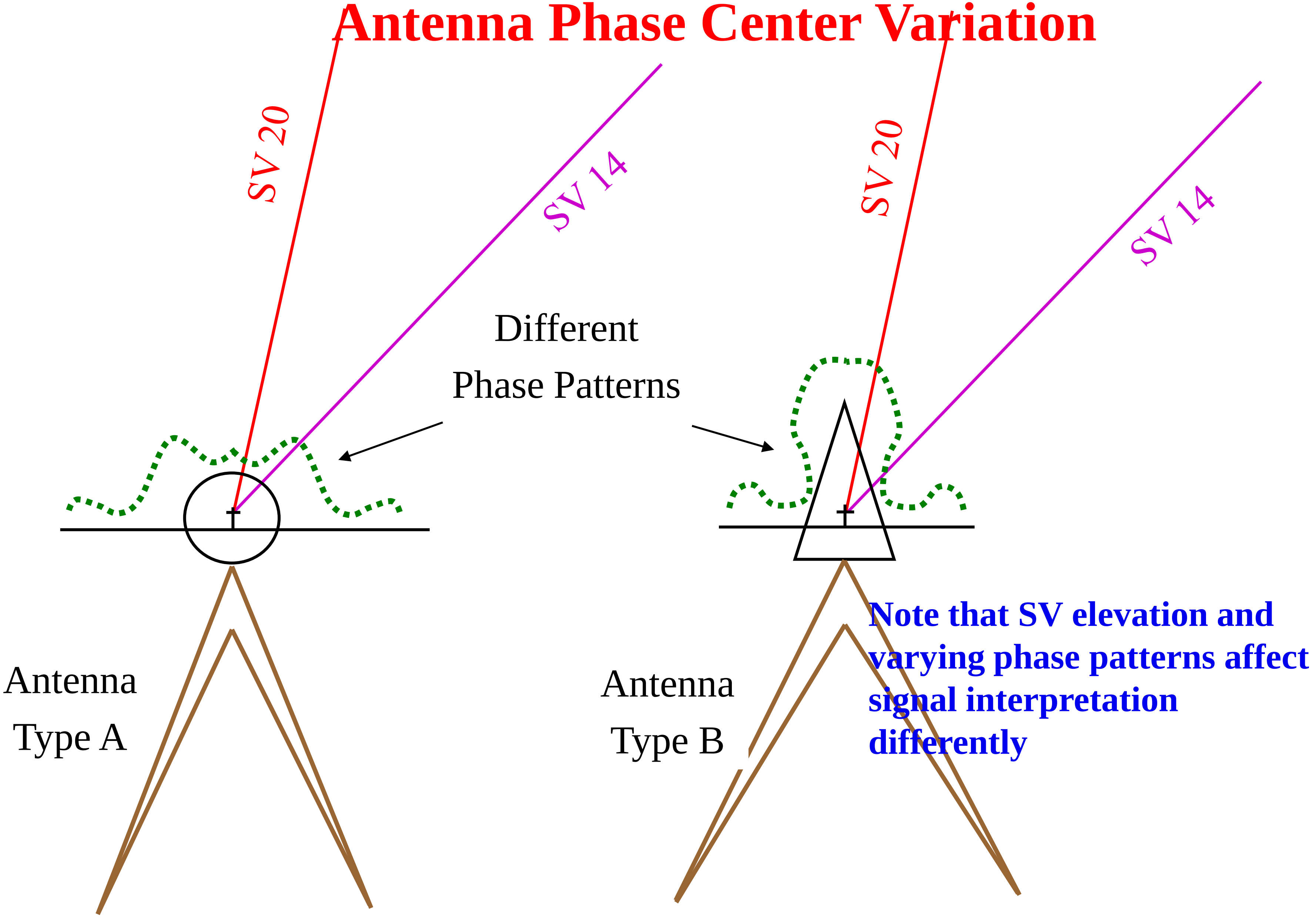
How would I get Help?

- First use the Links on the OPUS page
  - detailed discussions of guidelines
  - description of processing techniques
  - description of output
  - guidelines for successful use
- Submit specific questions at OPUS web page

What are some OPUS guidelines?

- Must submit dual-frequency (L1/L2) data
- Must submit at least 2 hrs of data
- No kinematic/Rapid Static
- No Glonass
- Correct vertical requires:
  - antenna type
  - antenna height

Antenna Phase Center Variation



Note that SV elevation and varying phase patterns affect signal interpretation differently

GPS Antenna Phase Pattern Calibrations

http://www.grdl.noaa.gov/GRD/GPS/Projects/ANTCAL

- Each antenna type has a unique phase pattern
- GPS antennas must be calibrated
- Mixing uncorrected antenna types can produce errors of up to 10 cm in the vertical component
- NGS is at the forefront in relative field calibration of GPS antennas
- NGS maintains a calibration database with parameters for 88 antenna types (03-26-01)

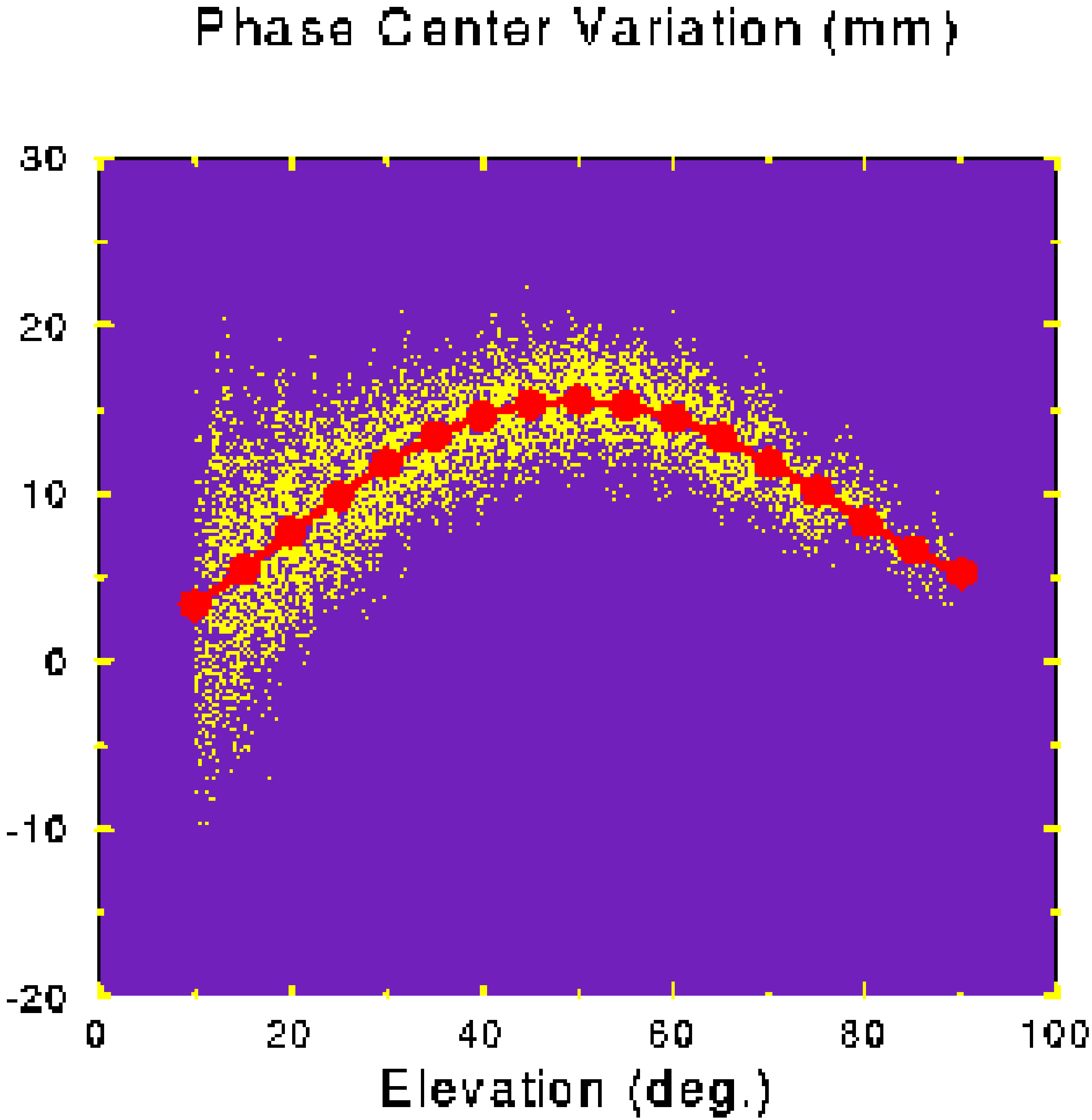
Antenna Calibration Facility in Corbin, Virginia

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

National Geodetic Survey

Positioning America for the Future


Phase Center Variation (mm)
30
20
10
0
-10
-20
0
20
40
60
80
100
Elevation (deg.)

FILE COMPRESSION FORMAT

RINEX files on the CORS file server are stored in a gzip compressed mode. These compressed files will have the extension .gz . An example is given below.

ais12330.98o.gz

All compressed files and executables should be transferred in binary mode. Text files should be transferred in ascii mode.

Before downloading files using the FTP protocol, set the transfer mode by typing "binary" or "ascii" at the ftp prompt. Then use "get" or "mget" to retrieve the files.

SOFTWARE / RINEX UTILITIES

Several DOS based utility programs are available to manipulate the RINEX data files. Versions also exist for other platforms such as Silicon Graphics (sgi), Sun Microsystems (sun), and Hewlett Packard (hp).

cato.exe	**Utility to join two or more RINEX observation files. Records the type and order of the first file. This order is used in all subsequent files.**
decimate.exe	**Utility program to decimate 5 second data to a user specified rate.**
gzip386.exe	**Executable file which contains the utility "gzip.exe".**
inflate.exe	**Self-extracting utility program to uncompress files with the ".Z" extension.**
interpo.exe	**Utility program to interpolate between data epochs. Please read the documentation for this utility for more details.**
join24pc.exe	**Utility program to join two or more hourly RINEX observation or navigation files.**

UTILITY EXAMPLES

CATO

Concatenate two or more RINEX observation files. Also allows a user to decimate a file.

cato {-i interval} file file{s}

cato   ais1233a.98o ais1233b.98o > ais1.out

cato -i 30 ais1233a.98o ais1233b.98o > ais1.out

GZIP

Compress / decompress utility for RINEX files.

-d	**decompress**
-N	**preserve original name**
-S	**decompress files with suffix xxx**

gzip   -d   -N   -S   .8oz   ais12330.8oz

gzip   -d   -N   -S   .8oz *.8oz

Utility examples (continued)

INTERPO

Interpolate RINEX observational data at faster rates using Neville's algorithm for polynomial interpolation.

interpo -i <input file> -o <output file> [-s <start time> -e < end time>] -n <interpolation interval>

*** Fields between [ ] are optional.**

interpo -i ais1030a.96o -o ais1030a.out -n 5

Estimated Cost for CORS Equipment

* Geodetic grade GPS receiver & chokering antenna and/or a high accuracy meteorological sensor (~ $14 - 20k)

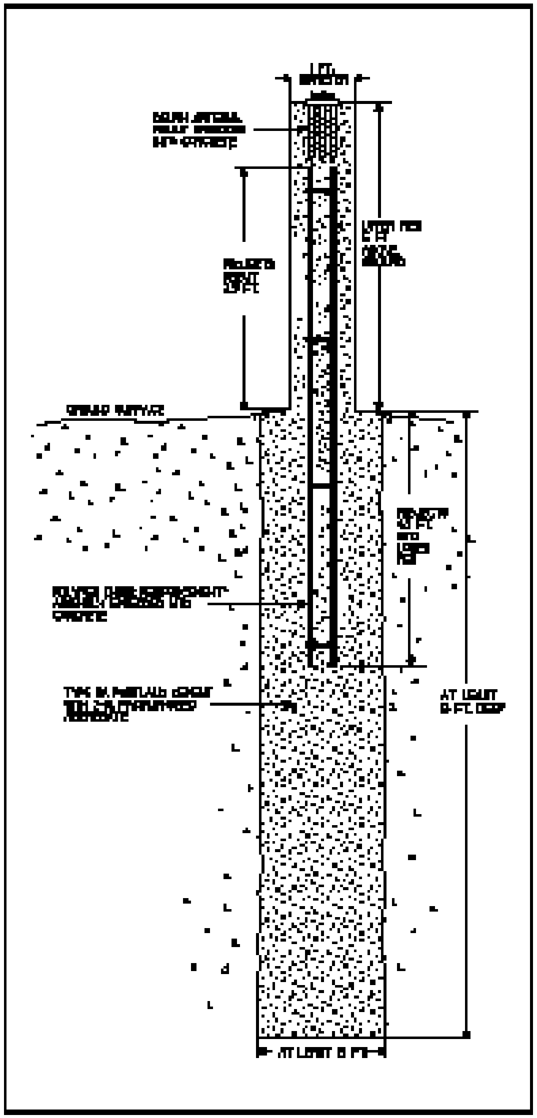
* Antenna monument construction (~ $1 – 3k)

* Antenna cable conduit and a low lost antenna cable for underground installation (~ $0.5 – 3k)

* PC, electrical power backup system, Internet connection, and accessories (~ $3k)

* Total ~ $19 – 29k

GUIDELINES FOR SETTING A NATIONAL CORS MONUMENT



Submitted by

Guidelines for Constructing a CORS Antenna Mount

For stability:

* the antenna mount should be constructed of concrete to minimize thermal expansion, and

* this concrete pillar should be buried at least 10 feet deep or attached to bedrock.

Guidelines for Constructing a CORS Antenna Mount - continued

* To avoid multipath, the the antenna should be between 0.5 and 2.0 meters above the ground, and the diameter of the concrete pillar should be less than the diameter of the antenna.

* To suppress resonance of the GPS signal, minimize the distance between the top of the concrete pillar and the bottom of the antenna.

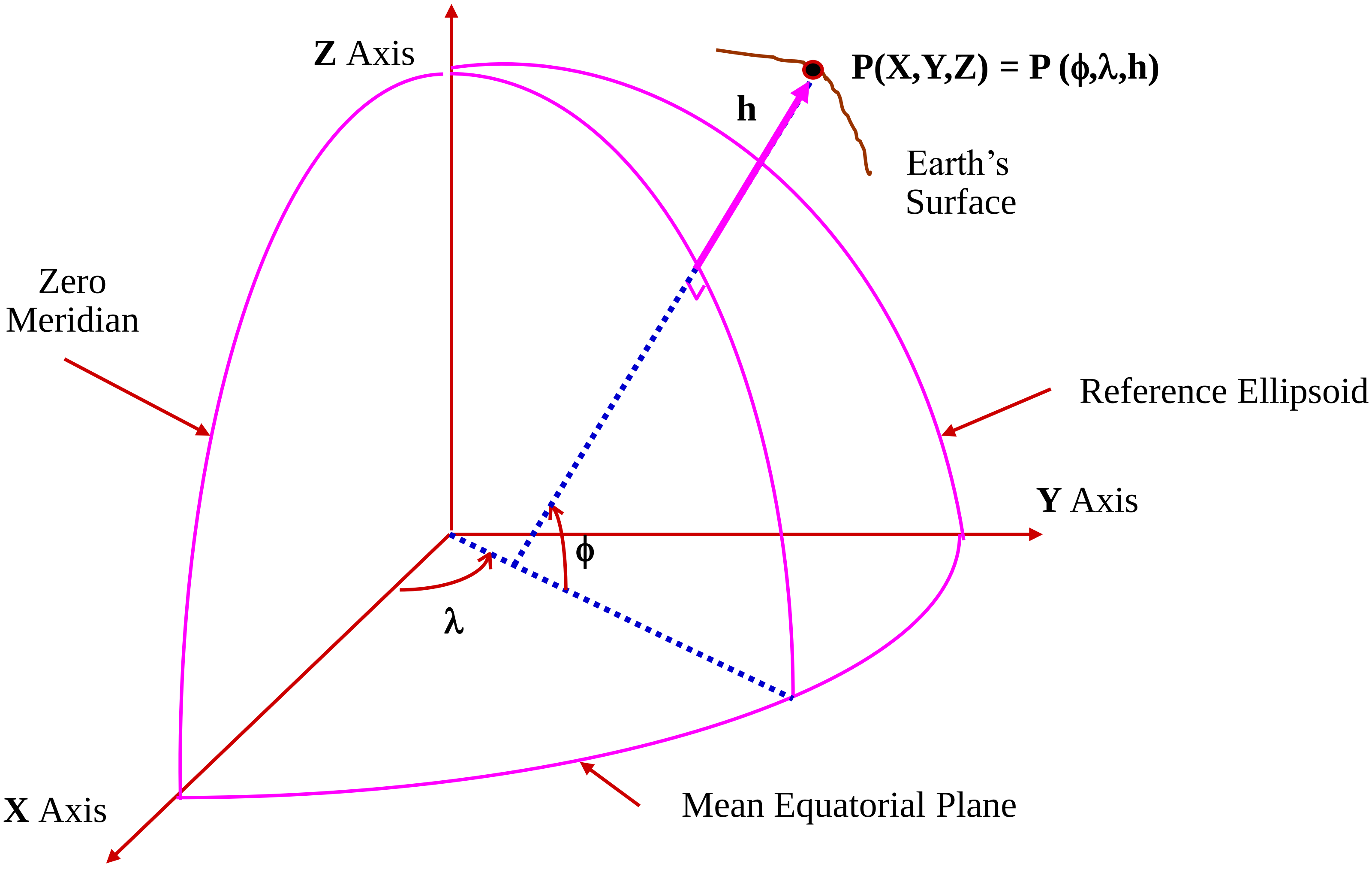
* Use non-metallic material as much as possible.

Defining a ECEF Reference System

* ECEF = Earth centered, Earth fixed
* Z-axis = Earth's pole of rotation
* X-axis = Intersection of equator and prime meridian
* Y-axis = Forms right-handed system with X- and Z-axes
* Scale = meter or distance that light travels in a vacuum during 1/299,792,458 seconds
* Ellipsoid = needed to define latitude and ellipsoidal height
* Complications arise from Earth's dynamics

(Polar motion, plate tectonics, earthquakes, subsidence, etc.)

3-D ECEF Coordinates



North American Datum of 1983 (NAD 83)

* Legal reference system in the United States

* National Geodetic Survey is responsible agency in U.S.

* First realized in 1986, revised for HARN,
  revised again for CORS

* Originally, NAD 83 was mostly a horizontal reference
  system

* Evolving to a 3-dimensional reference system,
  thanks to GPS

North American Datum of 1983 (NAD 83) (continued)

* Origin is located about 2 meters from Earth's center

* Orientation of axes differs from current international standard

* Scale has been changed to agree with current international standard

* Discrepancies exist between HARN and CORS positional coordinates

World Geodetic System of 1984 (WGS 84)

* GPS broadcast orbits give satellite positions in WGS 84

* Department of Defense is responsible agency

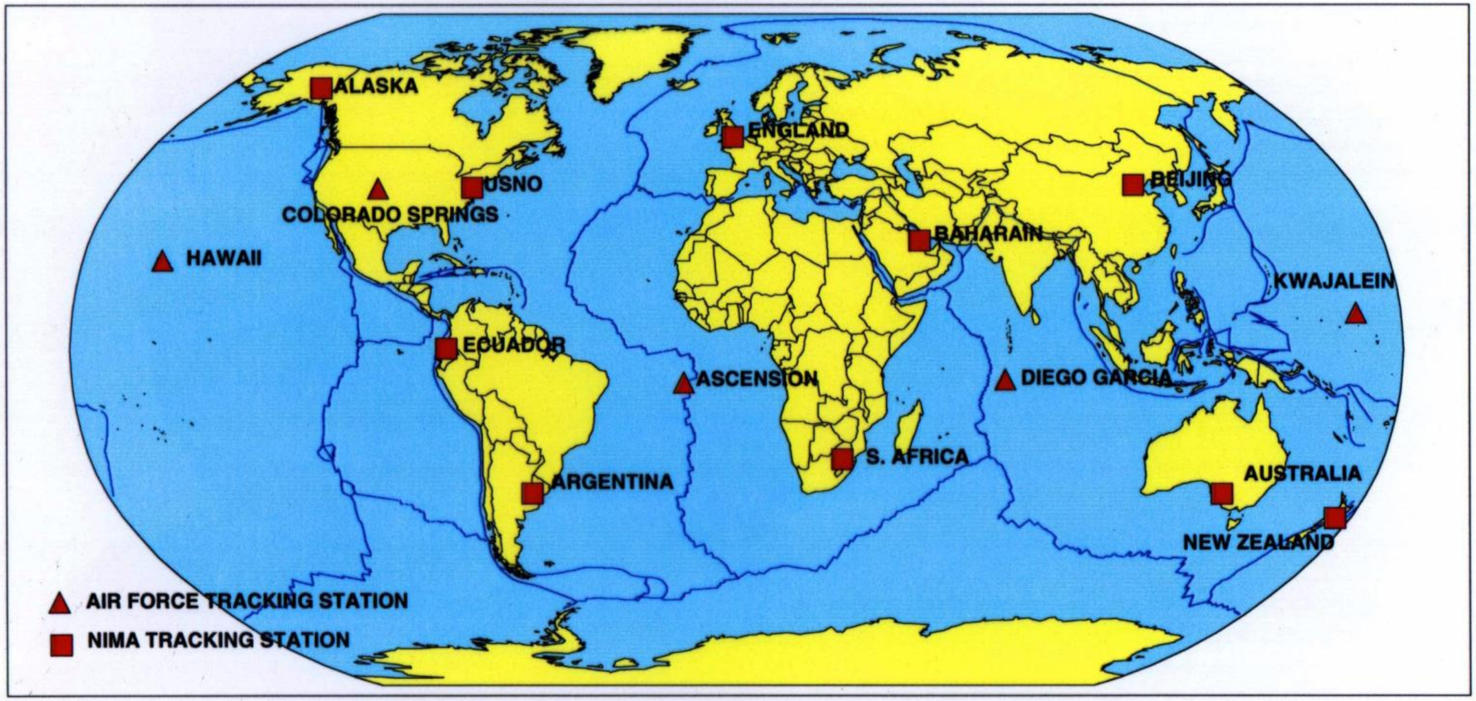
* System originally agreed with NAD 83

* Revised to agree with International Terrestrial Reference Frame (ITRF)

* Supports stand-alone positioning

* Does not support high-precision differential positioning

TRACKING NETWORK DEFINING WGS 84



International Terrestrial Reference Frame (ITRF)

* Supports accurate 3-dimensional positioning

* International Earth Rotation Service is responsible organization

* Defines international standard for origin, orientation, and scale

* Provides positions and velocities for several hundred sites worldwide

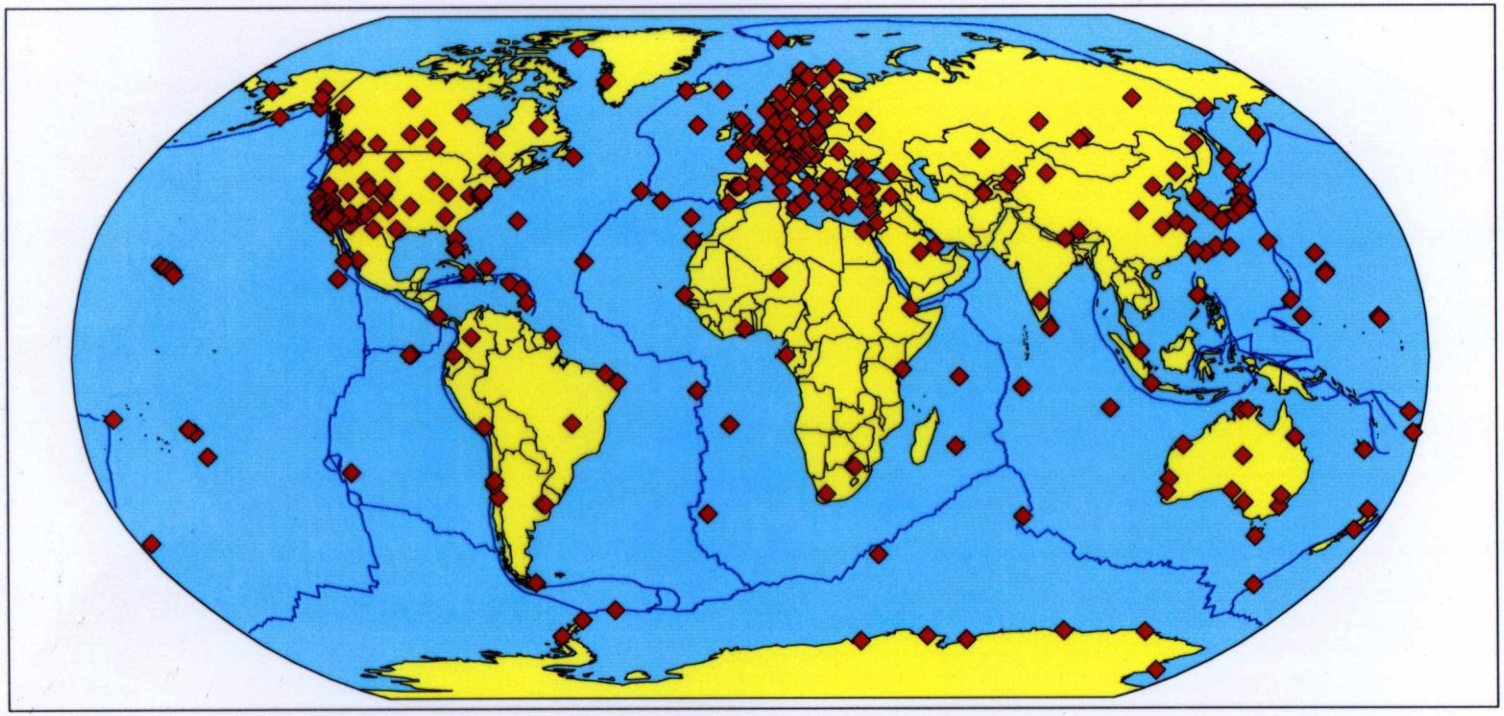
International Terrestrial Reference Frame (ITRF) - (continued)

* Postions and velocities revised almost yearly:
  ITRF88, ITRF89, …, ITRF97

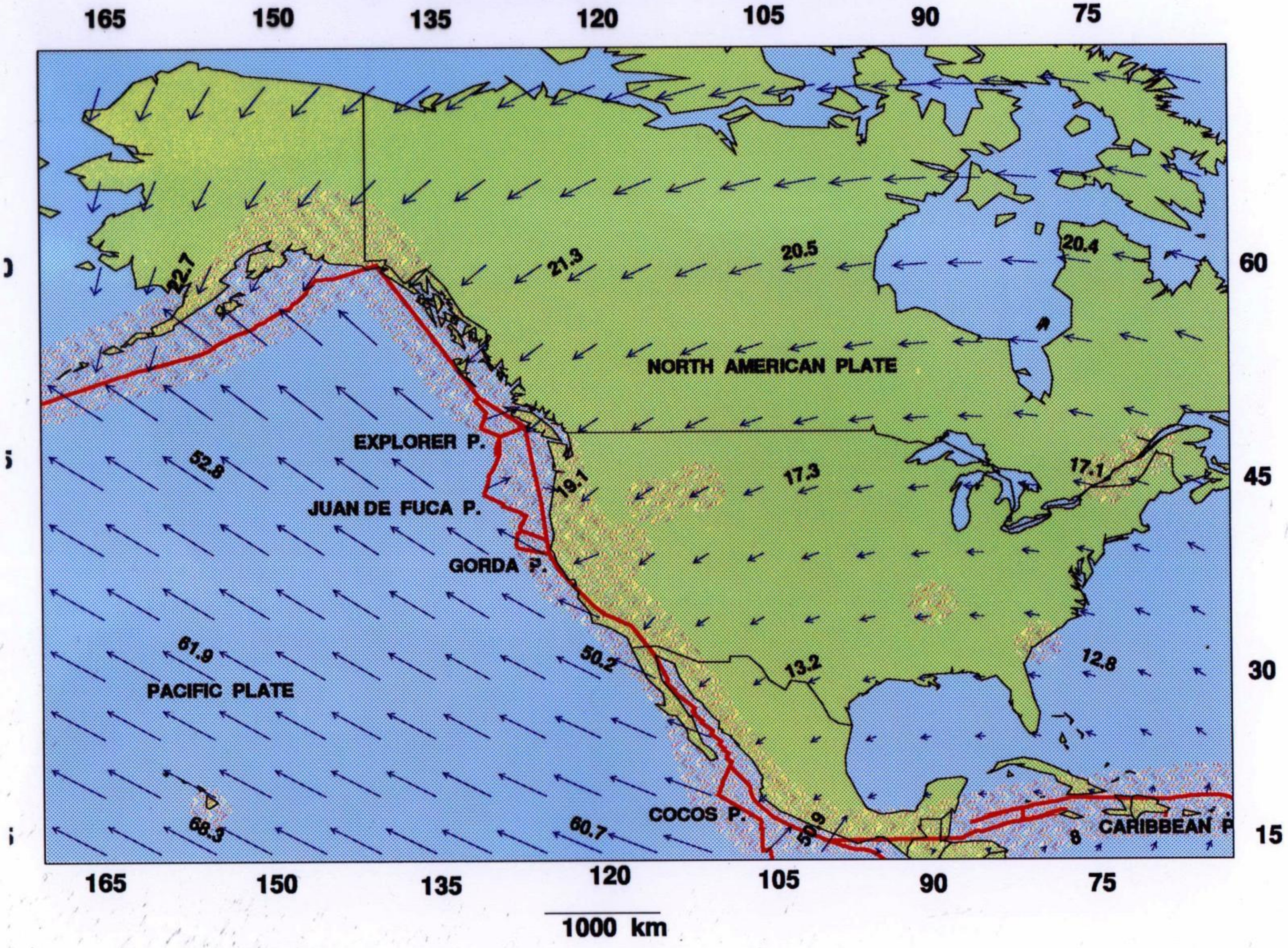
* Integrates various observing techniques:
  - Global Positioning System (GPS)
  - Very Long Baseline Interferometry (VLBI)
  - Satellite Lase Ranging (SLR)
  - Lunar Lasr Ranging (LLR)
  - Doppler Orbitography & Radiopositioning Integrated by Satellite (DORIS)

* Combination of several solutions, each performed independently by an analysis center

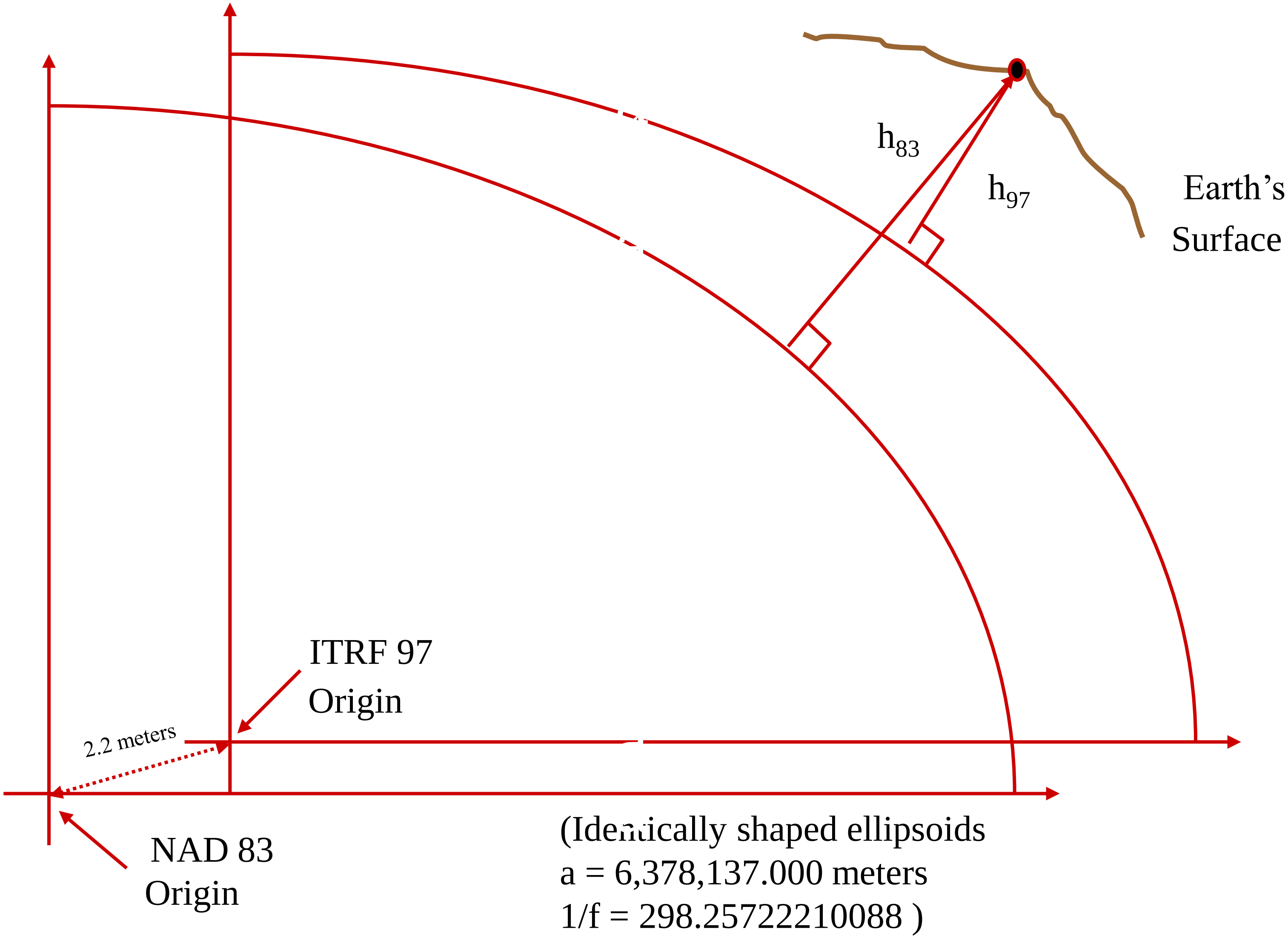
SITES DEFINING ITRF96



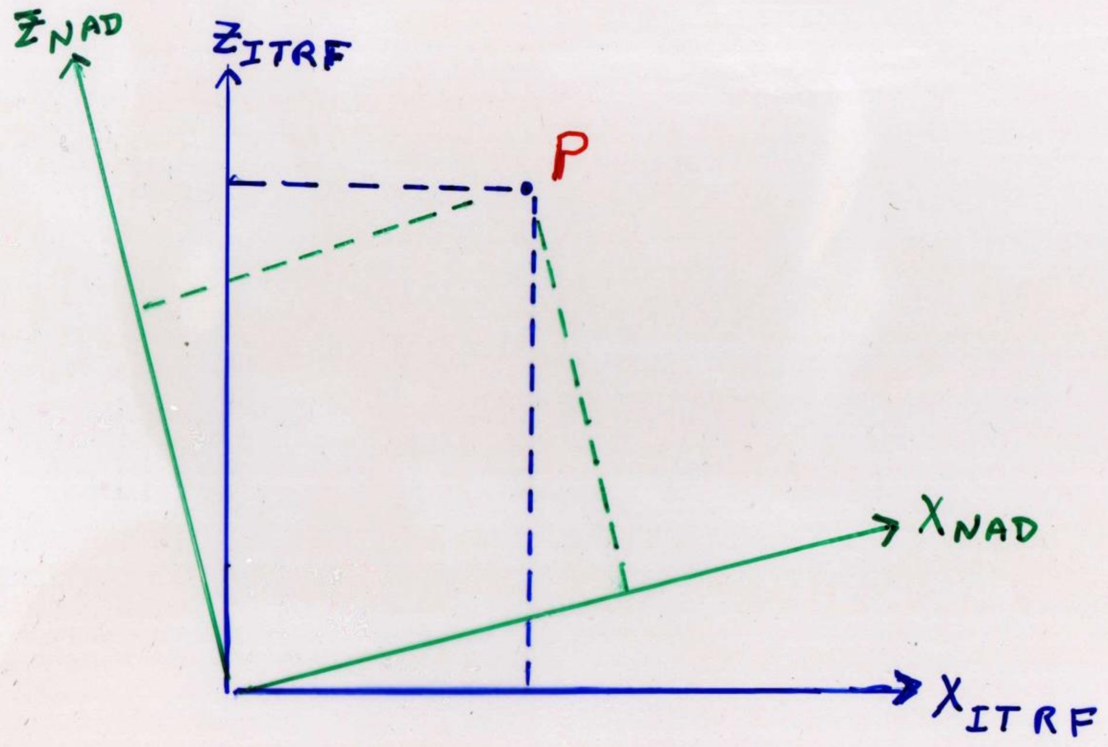
ITRF HORIZONTAL VELOCITIES



Simplified Concept of ITRF 97 vs. NAD 83



Effect of rotation about the Y-axis



Reference Frame Transformation

$$x_{NAD} = T_x + (1+S) \cdot x_{ITRF} + R_z \cdot y_{ITRF} - R_y \cdot z_{ITRF}$$

$$y_{NAD} = T_y - R_z \cdot x_{ITRF} + (1 + S) \cdot y_{ITRF} + R_x \cdot z_{ITRF}$$

$$z_{NAD} = T_z + R_y \cdot x_{ITRF} - R_x \cdot y_{ITRF} + (1 + S) \cdot z_{ITRF}$$

Transformation Parameters ITRF96 --> NAD_83

Translations: T_x = 0.9910 meters
T_y = -1.9072 meters
T_z = -0.5129 meters

Rotations: R_x = [25.79 + 0.0532👍(t - 1997.0)]👍k radians
R_y = [9.65 - 0.7423👍(t - 1997.0)]👍k radians
R_z = [11.66 - 0.0316👍(t - 1997.0)]👍k radians

Scale change: S = 0.0 (unitless)

where t = date in years (eg., 1999.3096 = 23 APR 1999)
and k = 4.84813681 👍 (10**-9)

Transforming Positions

* Use HTDP software to transform positions between reference frames

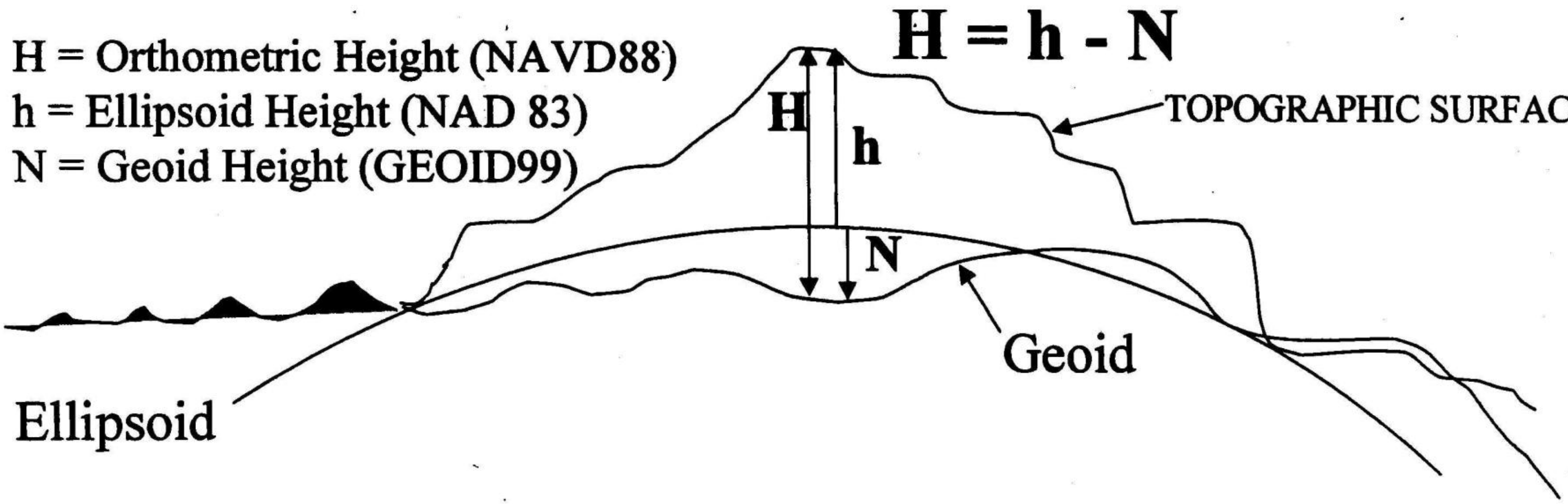
* HTDP = Horizontal Time-Dependent Positioning

* Available at http://www.ngs.noaa.gov
  Click on “Geodetic Tool Kit”, then on “HTDP”

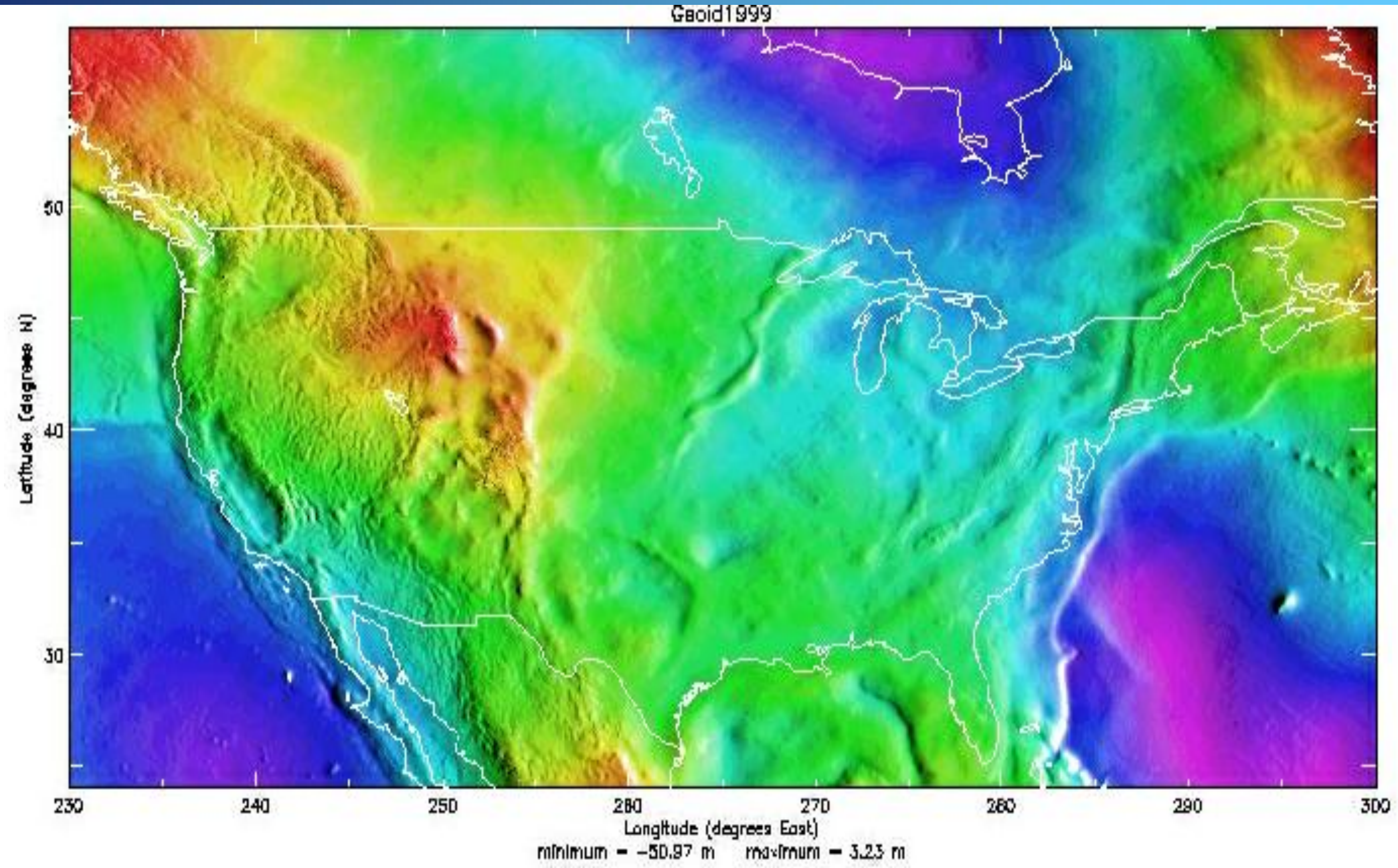
* HTDP can also be used to transform positions from one epoch date to another

* HTDP can also be used to predict horizontal velocities

GPS measures ellipsoidal heights. Leveling measures orthometric heights.



GEOID99 the Link Between GPS Heights and Leveling



NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

National Geodetic Survey

Positioning America for the Future

Future Directions of the National CORS

* Incorporate additional sites:

- Nationwide Differential GPS (NDGPS)
- Cooperative CORS
- Wide Area Augmentation System (WAAS)
- SuomiNet
- Plate Boundary Observatory (PBO)
- Statewide CORS Networks

Future Directions of the National CORS (continued)

* Enhance auxiliary models to improve positioning accuracy and shorten observing sessions:

- Satellite orbits
- Neutral atmosphere delay
- Ionospheric delay
- Multipath
- Crustal motion

* Emphasize earlier access to data and models (under 1 hour)

GPS Modernization

GPS III

http://206.65.196.30/gps/issues/dotgpspressreleases.htm

30 - 32 satellites

Second and Third Frequencies to contain civilian signal

(L2 = 1227.60 MHz) & (L5 = 1176.45 MHz)

More Robust Signal Transmissions

Real-Time Unaugmented 1 Meter Accuracy

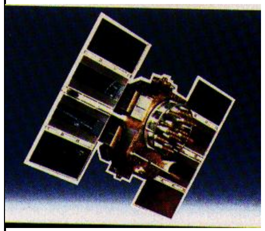
Initial Launches ~ 2005

Complete Replacements ~ 2011

GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

POTENTIAL DEVELOPMENTS

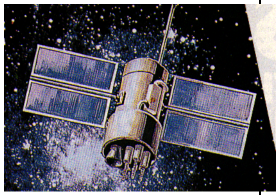
(2005 - 2011)



US GPS MODERNIZATION - BLOCK III

RUSSIAN GLONASS ENHANCEMENTS

EUROPEAN UNION - GALILEO



60+ Satellites

Second and Third Civil Frequency - GPS

No Signal Encryption - GLONASS & GALILEO

More Robust Signal Transmissions

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