ELEMENTS OF THE NATIONAL SPATIAL REFERENCE SYSTEM

MINERALS MANAGEMENT SERVICE

METAIRIE, LA

September 13, 2000

Dave Doyle
National Geodetic Survey
Senior Geodesist
Dave.Doyle@noaa.gov, (301) 713-3178

NATIONAL GEODETIC SURVEY

INFORMATION CENTER

(301) 713-3242

info_center@ngs.noaa.gov

WEB SITE

http://www.ngs.noaa.gov

NATIONAL SPATIAL REFERENCE SYSTEM

The National Spatial Reference System (NSRS) is that component of the National Spatial Data Infrastructure (NSDI) - [http://www.fgdc.gov/nsdi/nsdi.html] which contains all geodetic control contained in the National Geodetic Survey (NGS) Data Base. This includes: A, B, First, Second and Third-Order horizontal and vertical control, Geoid models such as GEOID 99, precise GPS orbits and Continuously Operating Reference Stations (CORS), and the National Shoreline as observed by NGS as well as data submitted by other Federal, State, and local agencies, Academic Institutions and the private sector

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.)

METADATA

METADATA IS DATA ABOUT DATA

DATUMS

NAD 27, NAD 83(1986), NAD83 (199X), NGVD29, NAVD88

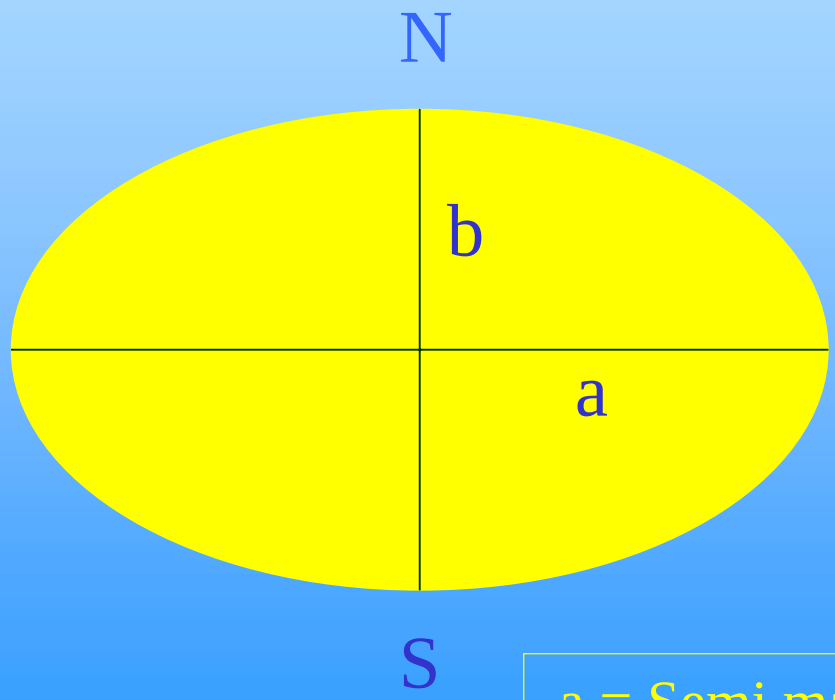
UNITS

Meters, U.S. Survey Feet, International Feet, Chains, Rods, Pole

ACCURACY

A, B, 1st, 2nd, 3rd, 3cm, Scaled

THE ELLIPSOID
MATHEMATICAL MODEL OF THE EARTH



a = Semi major axis
b = Semi minor axis
f = $\frac{a-b}{a}$ = Flattening

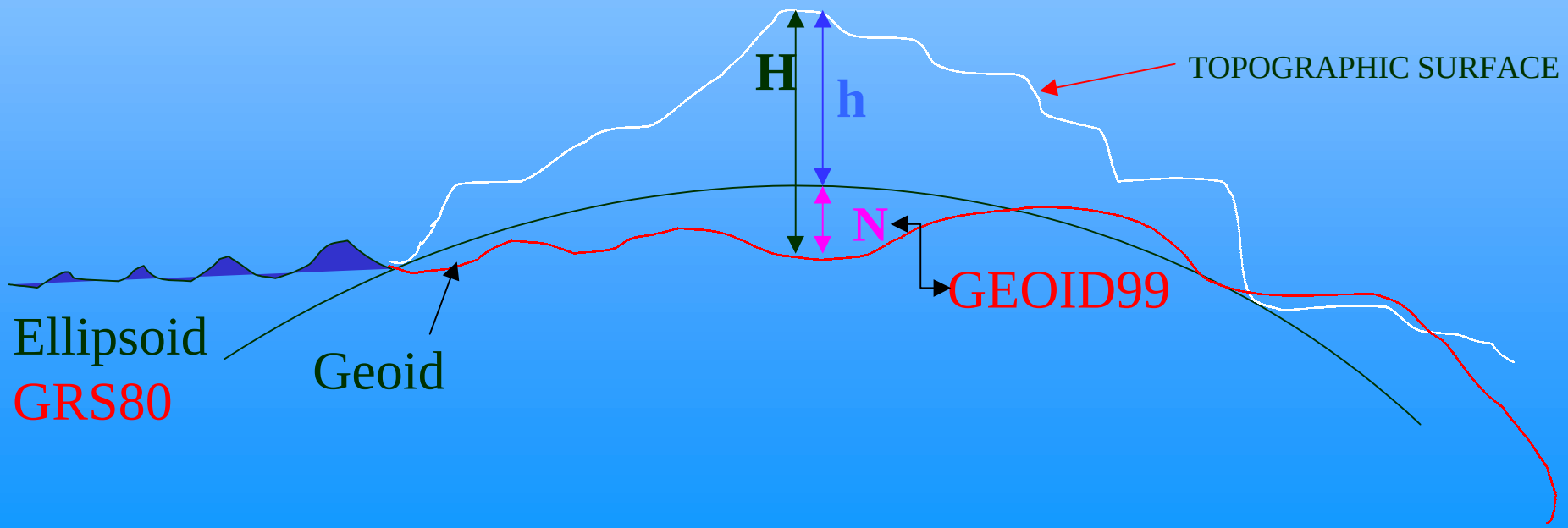
ELLIPSOID - GEOID RELATIONSHIP

H = Orthometric Height (NAVD 88)

h = Ellipsoidal Height (NAD 83)

N = Geoid Height (GEOID 99)

$$H = h - N$$



UNITED STATES ELLIPSOID DEFINITIONS

BESSEL 1841

a = 6,377,397.155 m 1/f = 299.1528128

CLARKE 1866

a = 6,378,206.4 m 1/f = 294.97869821

GEODETIC REFERENCE SYSTEM 1980 - (GRS 80)

a = 6,378,137 m 1/f = 298.257222101

WORLD GEODETIC SYSTEM 1984 - (WGS 84)

a = 6,378,137 m 1/f = 298.257223563

HORIZONTAL DATUMS

BESSEL 1841 ----------

LOCAL ASTRO DATUMS (1816-1879)

CLARKE 1866

NEW ENGLAND DATUM (1879-1901)
U.S. STANDARD DATUM (1901-1913)
NORTH AMERICAN DATUM (1913-1927)
NORTH AMERICAN DATUM OF 1927
OLD HAWAIIAN DATUM

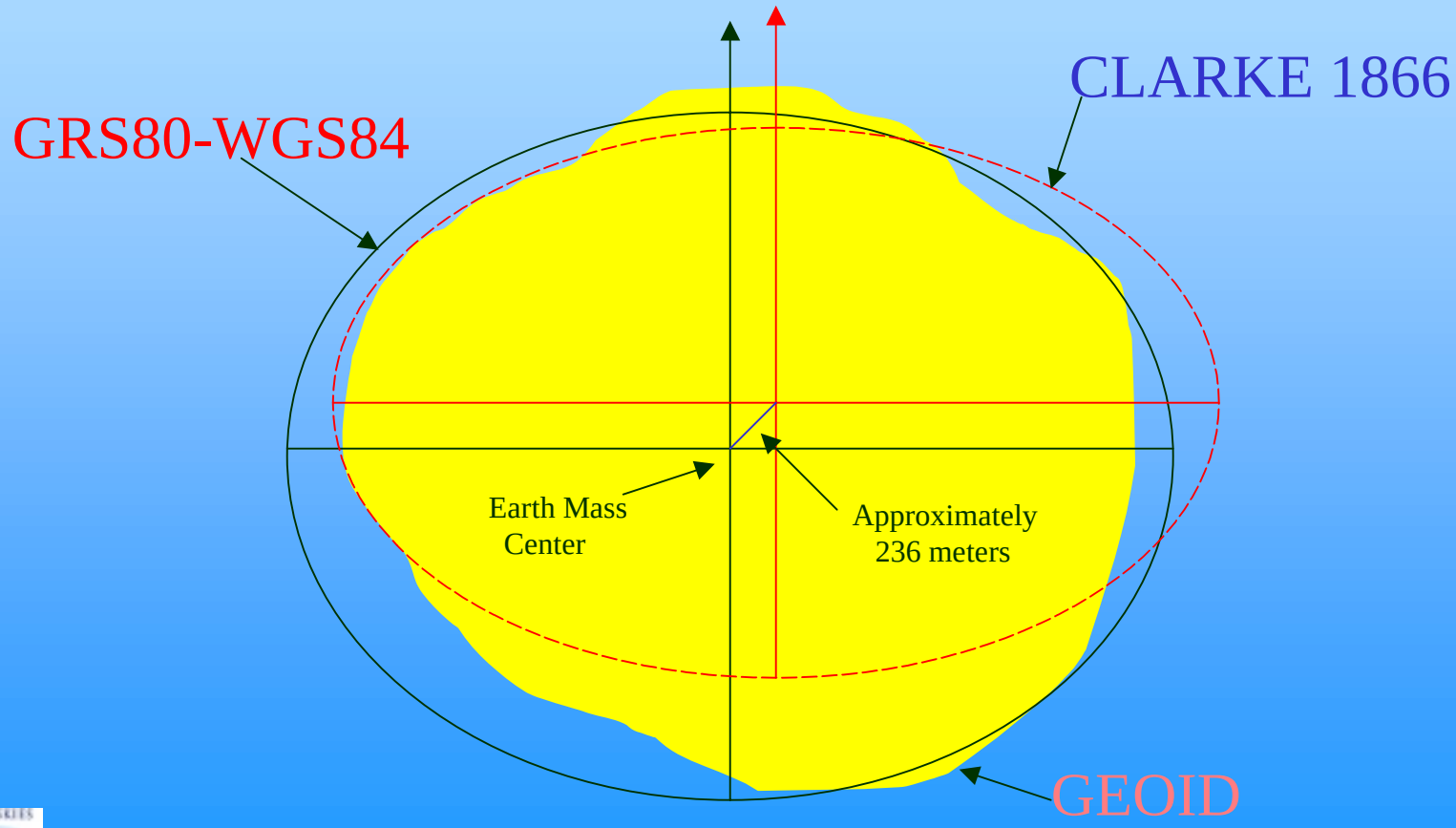
PUERTO RICO DATUM
ST. GEORGE ISLAND - ALASKA
ST. LAWRENCE ISLAND - ALASKA
ST. PAUL ISLAND - ALASKA
AMERICAN SAMOA 1962
GUAM 1963

GRS80 ----------

NORTH AMERICAN DATUM OF 1983

(As of June 14, 1989)

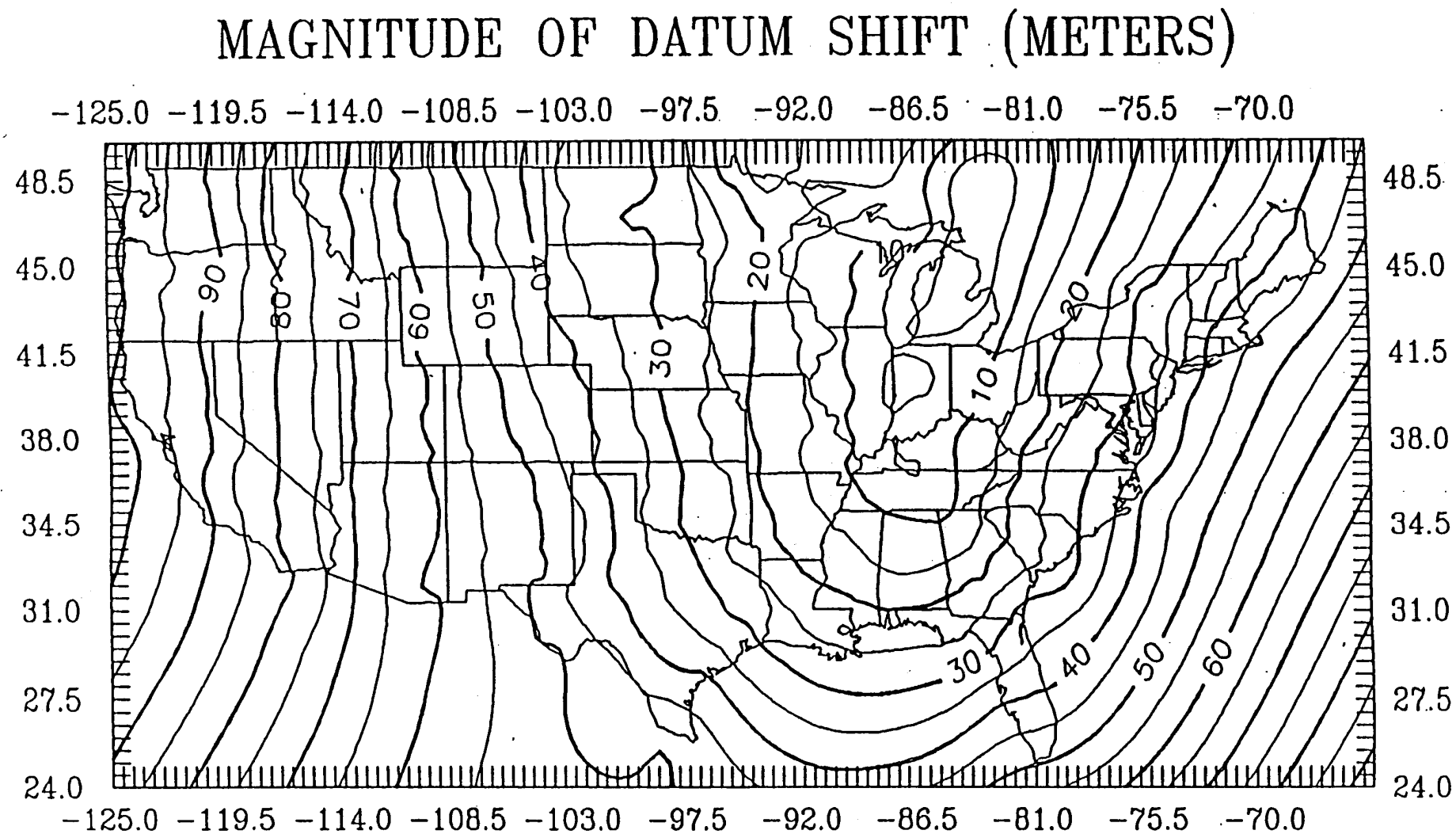
THE GEOID AND TWO ELLIPSOIDS



COMPARISON OF DATUM ELEMENTS

	NAD 27	NAD 83
ELLIPSOID	CLARKE 1866 a = 6,378,206.4 m 1/f = 294.9786982	GRS80 a = 6,378,137. M 1/f = 298.257222101
DATUM POINT	Triangulation Station MEADES RANCH, KANSAS	NONE EARTH MASS CENTER
ADJUSTMENT	25k STATIONS Several Hundred Base Lines Several Hundred Astro Azimuths	250k STATIONS Appox. 30k EDMI Base Lines 5k Astro Azimuths Doppler Point Positions VLBI Vectors
BEST FITTING	North America	World-Wide

NAD 27 and NAD 83



GEODETIC CONTROL

NETWORK OF MONUMENTED POINTS

PRECISELY MEASURED IN ACCORDANCE WITH STANDARD PROCEDURES

MEET ACCURACY SPECIFICATIONS

ADJUSTED TO TIE TOGETHER

DOCUMENTED FOR MULTIPLE USE


ADJUSTABLE

INTERNATIONAL TERRESTRIAL REFERENCE SYSTEM

DEVELOPED AND MAINTAINED BY THE INTERNATIONAL EARTH ROTATION SERVICE PARIS, FRANCE FROM:
(http://hpiers.obspm.fr/)

VERY LONG BASELINE INTERFEROMETRY - (VLBI)
SATELLITE LASER RANGING - (SLR)
GLOBAL POSITIONING SYSTEM - (GPS)
DOPPLER ORBITOGRAPHY AND RADIO POSITIONING INTEGRATED BY SATELLITE - (DORIS)

INTERNATIONAL TERRESTRIAL REFERENCE SYSTEM

GEOCENTRIC +/- 3 to 4 CM

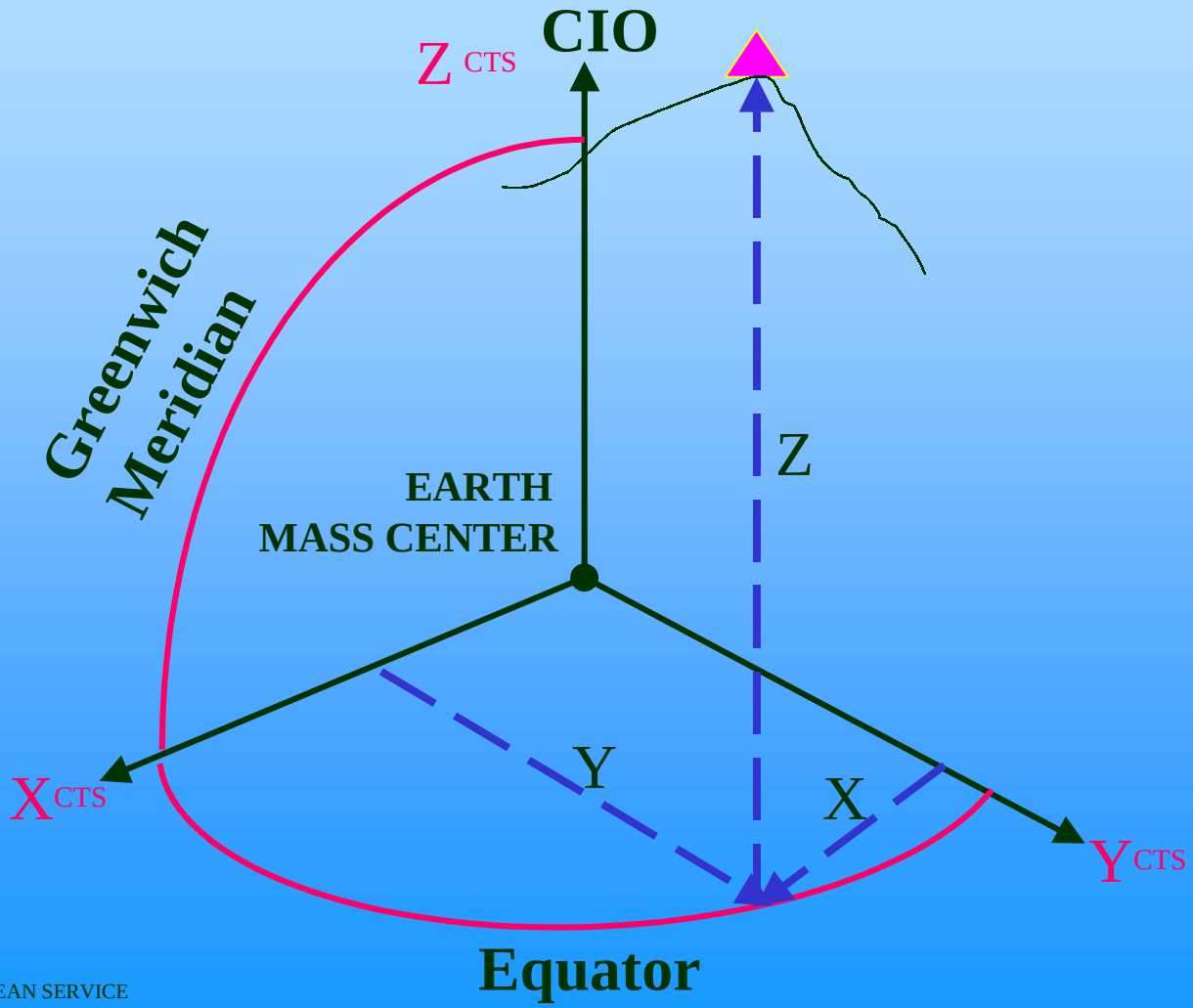
MODELS FOR PLATE TECTONICS

STATION VELOCITIES

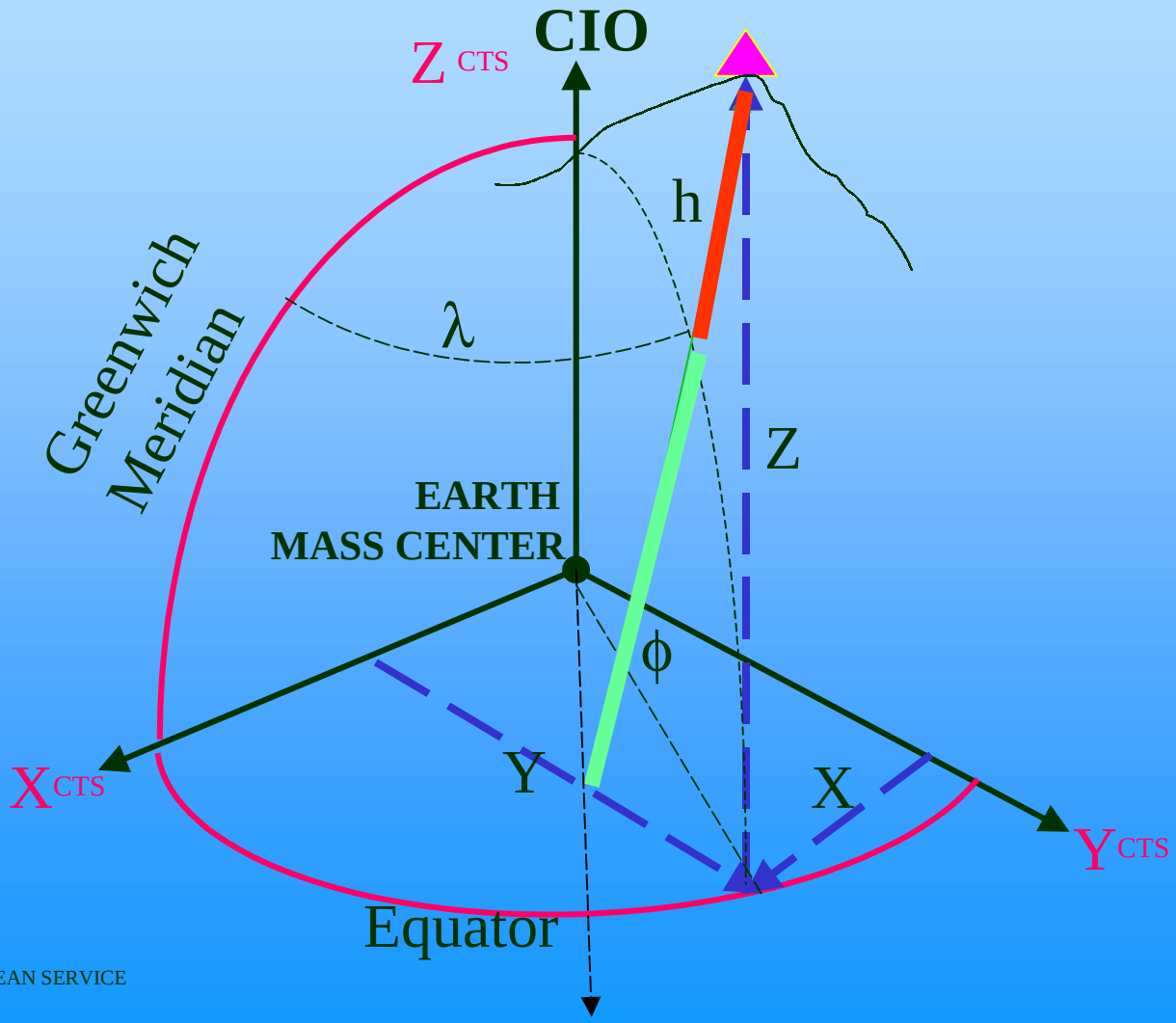
POSITIONAL STANDARD ERRORS

REALIZED AS THE INTERNATIONAL TERRESTERIAL REFERENCE FRAME

CONVENTIONAL TERRESTRIAL SYSTEM (CTS)

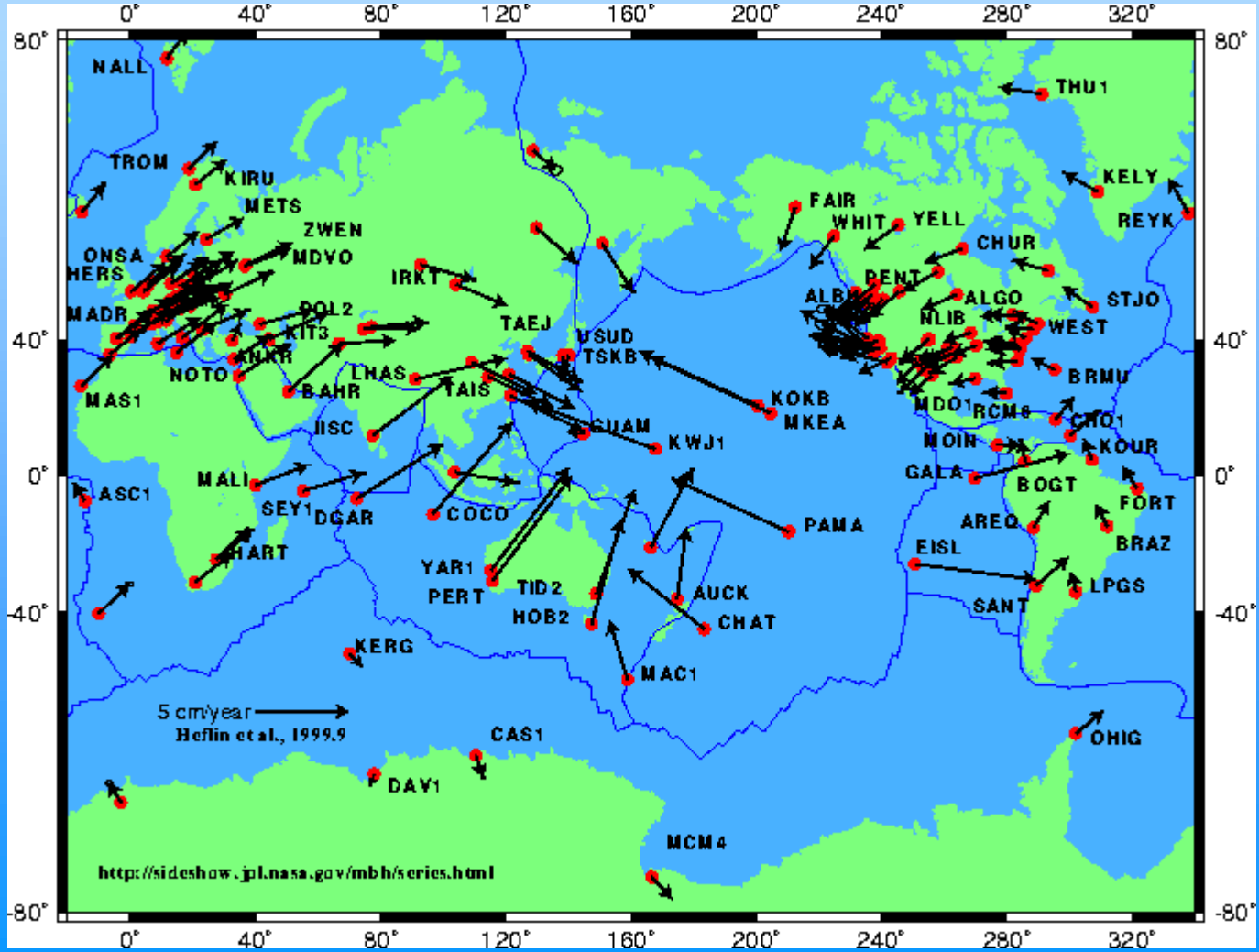


CONVENTIONAL TERRESTRIAL SYSTEM (CTS)

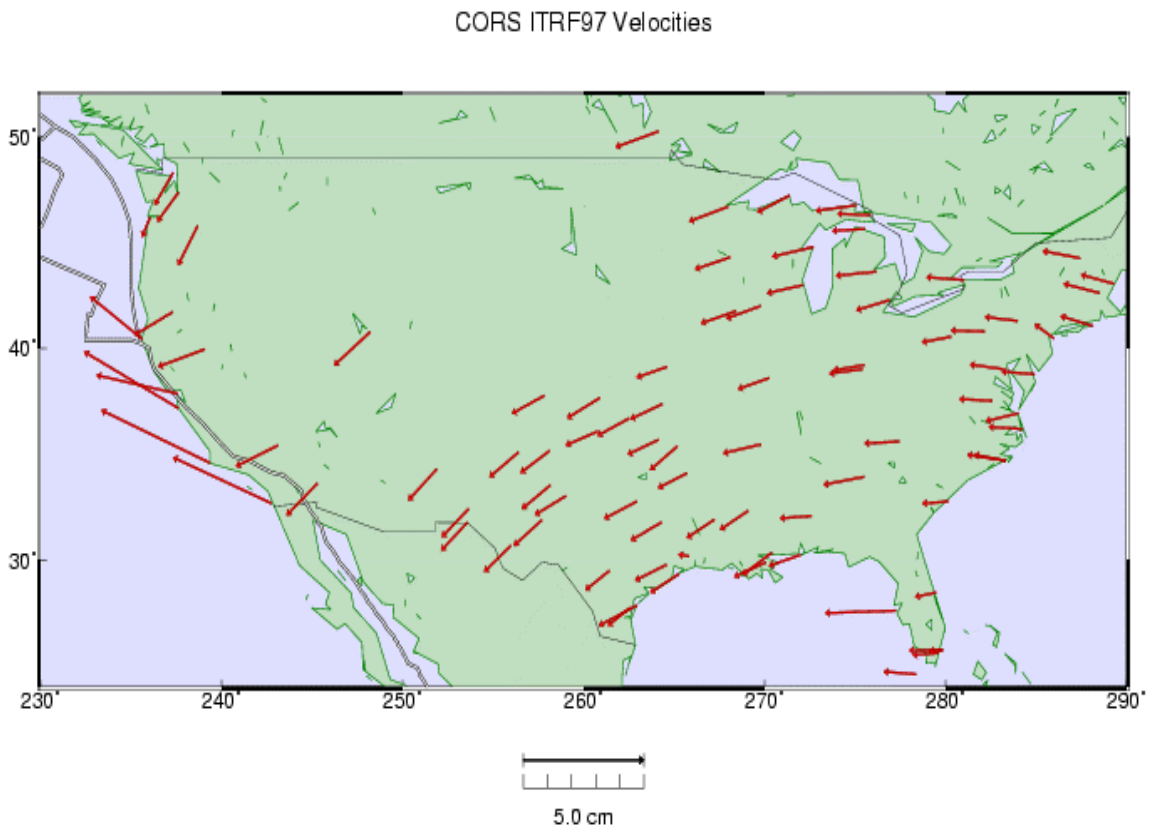


NATIONAL OCEAN SERVICE

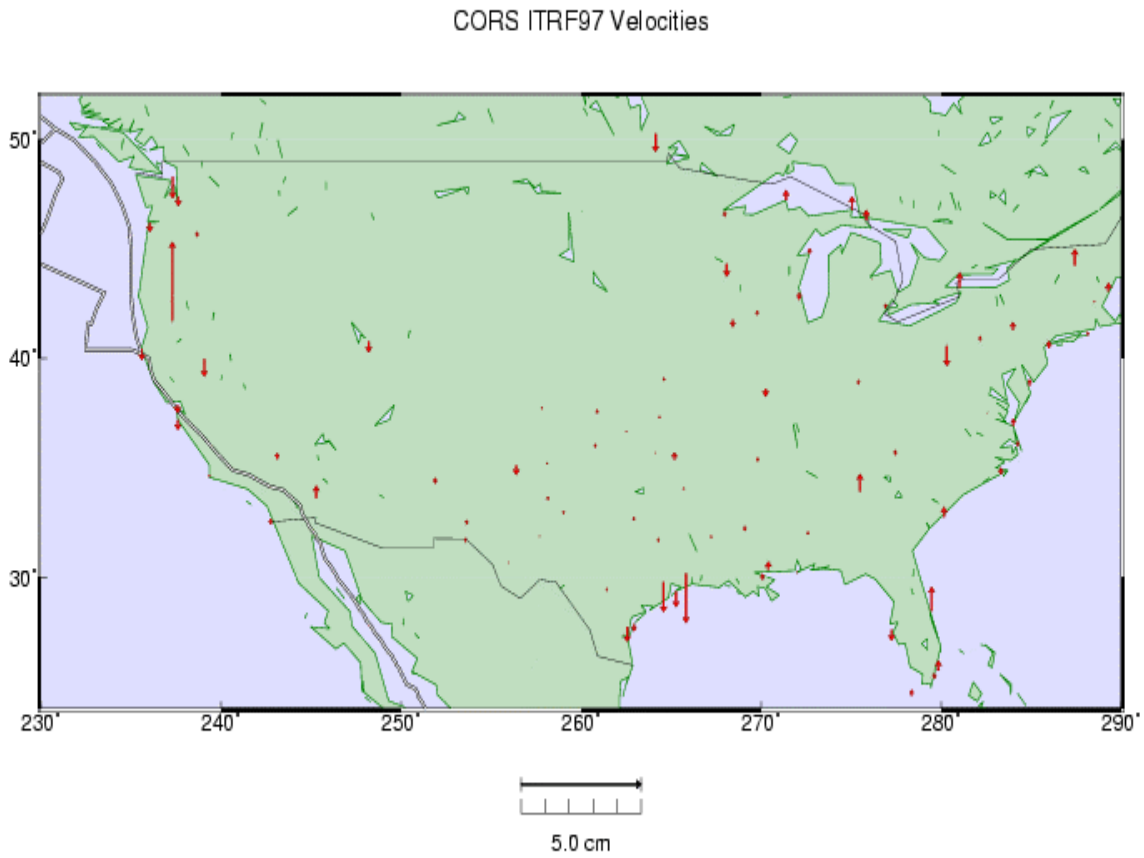
TECTONIC MOTIONS



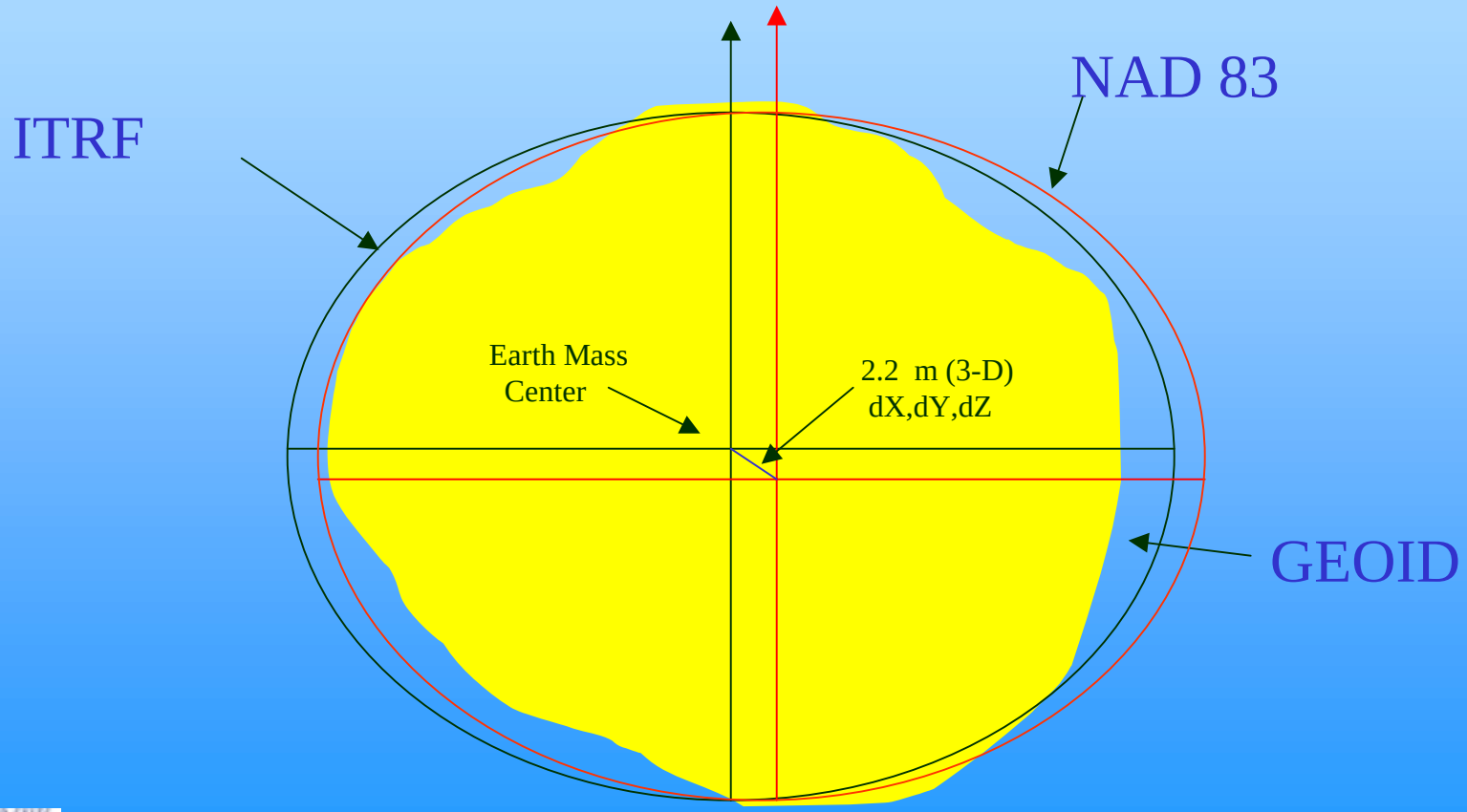
HORIZONTAL TECTONIC MOTIONS

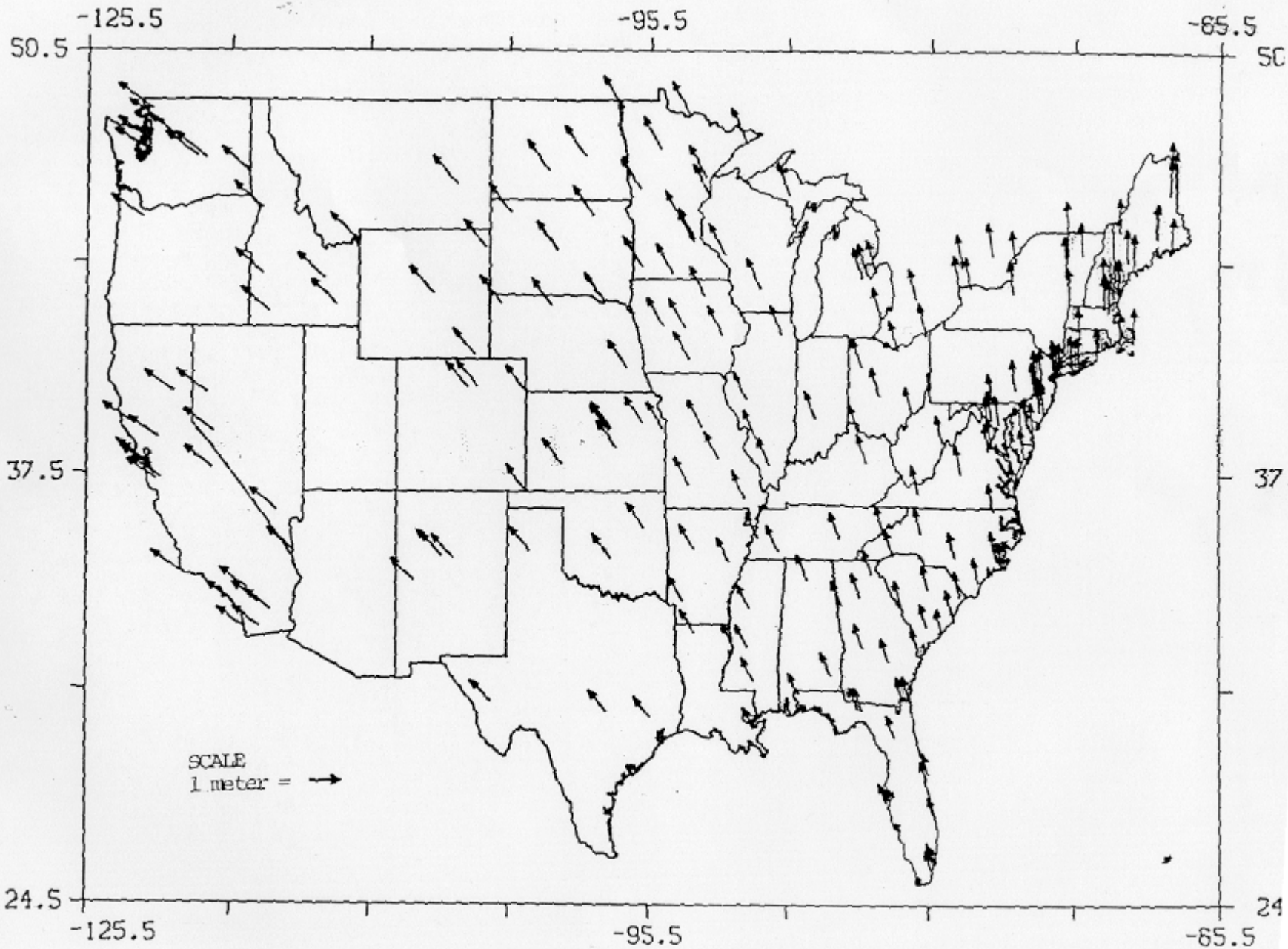


VERTICAL TECTONIC MOTIONS



NAD 83 and ITRF




-125.5
-95.5
-65.5
50.5
37.5
24.5
SCALE
1 meter =

GEODETIC CONTROL DATA SHEET

```
1        National Geodetic Survey,   Retrieval Date = SEPTEMBER  7, 2000
**********************************************************************
 AT0838  DESIGNATION -  CATC 43 A
 AT0838  PID         -  AT0838
 AT0838  STATE/COUNTY-  LA/PLAQUEMINES
 AT0838  USGS QUAD   -
 AT0838
 AT0838                         *CURRENT SURVEY CONTROL
 AT0838  ______________________________________________________________
 AT0838* NAD 83(1992)-  28 59 54.10753(N)    089 51 26.78424(W)     ADJUSTED
 AT0838* NAVD 88     -        -0.     (meters)      -0.     (feet)  SCALED
 AT0838  ______________________________________________________________
 AT0838  LAPLACE CORR-           0.48  (seconds)                    DEFLEC99
 AT0838  GEOID HEIGHT-         -23.58  (meters)                     GEOID99
 AT0838
 AT0838  HORZ ORDER  -  SECOND
 AT0838
 AT0838.The horizontal coordinates were established by classical geodetic
        methods and adjusted by the National Geodetic Survey in January 1993.
 AT0838
 AT0838.The orthometric height was scaled from a topographic map.
 AT0838.The Laplace correction was computed from DEFLEC99 derived deflections.
 AT0838.The geoid height was determined by GEOID99.
```

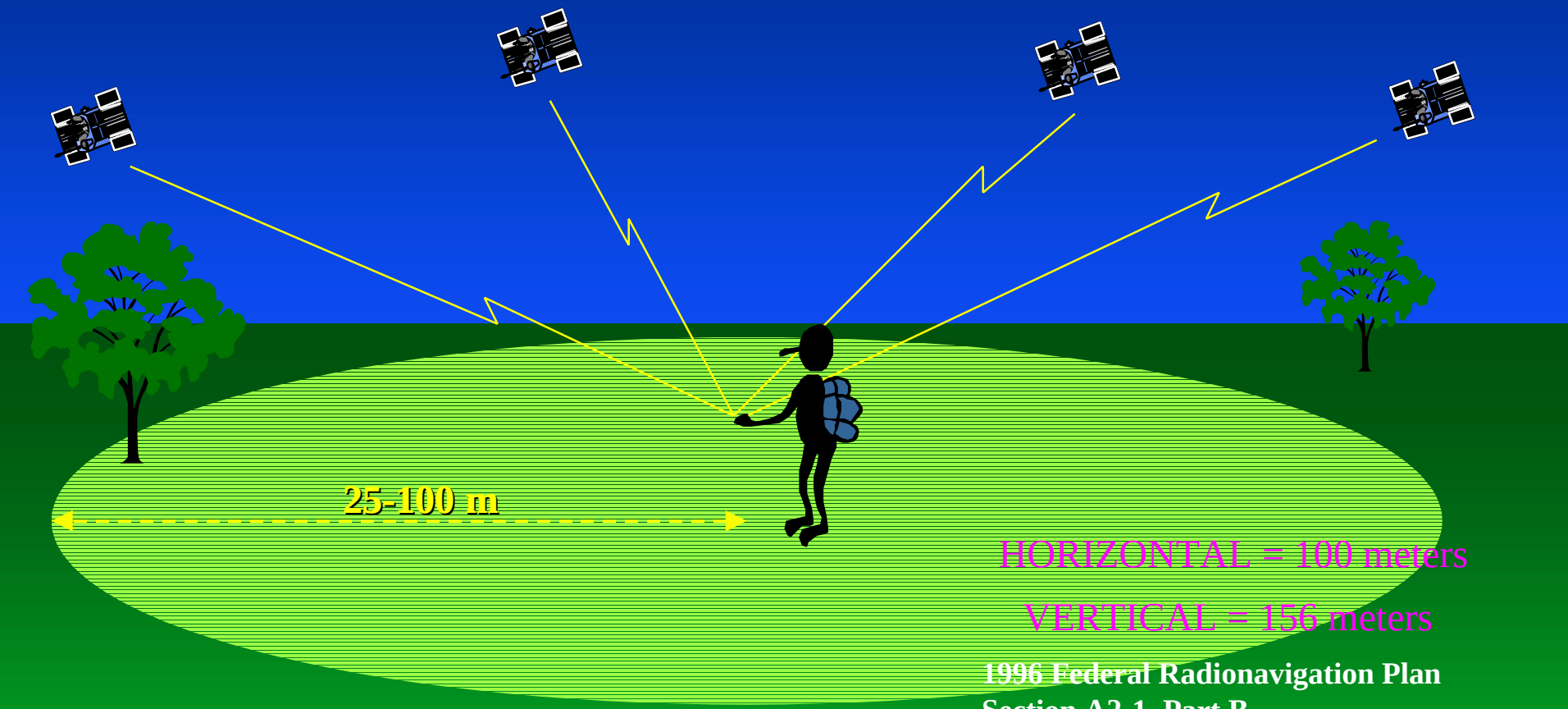
GEODETIC CONTROL DATA SHEET

```
AT0838;                      North         East      Units   Scale      Converg.
 AT0838;SPC LA S     -    56,169.742 1,143,818.867   MT  1.00007753 +0 44 16.7
 AT0838;UTM  16      - 3,211,171.267   221,619.551   MT  1.00055643 -1 23 10.1
 AT0838
 AT0838:                 Primary Azimuth Mark                     Grid Az
 AT0838:SPC LA S     -  CATC 48 D                                 256 21 06.4
 AT0838:UTM  16      -  CATC 48 D                                 258 28 33.2
 AT0838
 AT0838|-------------------------------------------------------------------|
 AT0838| PID    Reference Object                    Distance      Geod. Az  |
 AT0838|                                                          dddmmss.s |
 AT0838| AT0840 CATC 70-3                        APPROX. 4.8 KM 1224125.8 |
 AT0838|        CATC 43 A RM 1                     6.443 METERS 14001     |
 AT0838|        CATC 43 A RM 2                    11.955 METERS 25505     |
 AT0838| TZ0097 CATC 48 D                        APPROX.18.6 KM 2570523.1 |
 AT0838|-------------------------------------------------------------------|
 AT0838
 AT0838                          SUPERSEDED SURVEY CONTROL
 AT0838
 AT0838  NAD 83(1986)-  28 59 54.11948(N)    089 51 26.79809(W) AD(       ) 2
```

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 →	

Autonomous Positioning: Before May 1, 2000



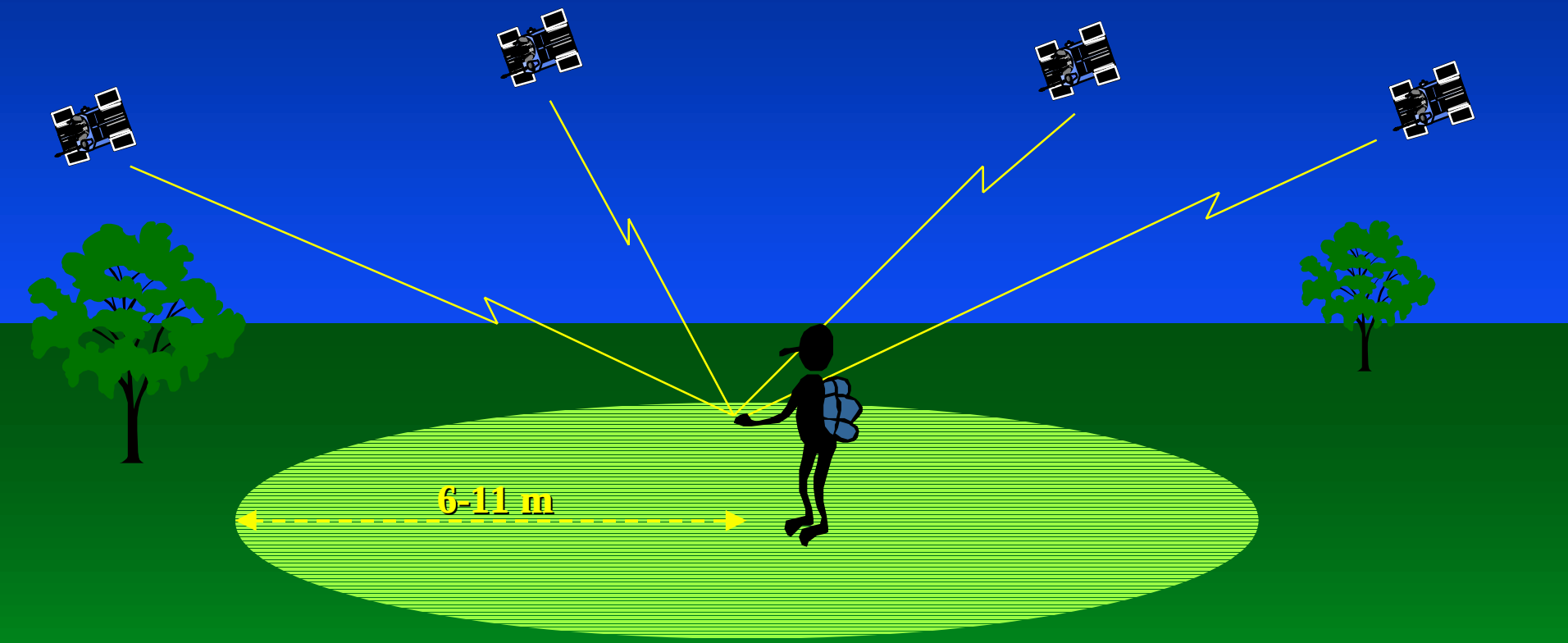
HORIZONTAL = 100 meters

VERTICAL = 156 meters

1996 Federal Radionavigation Plan
Section A2-1, Part B
http://www.navcen.uscg.mil/policy/frp1996

- C/A Code on L1
- Selective Availability

Standalone Positioning: Since May 1, 2000



- C/A Code on L1
- No Selective Availability

GLOBAL POSITIONING SYSTEM

GPS BLOCK IIF

Potential Future Developments

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

30 - 32 satellites

Second and Third Civil Frequency

(1227.60 MHZ & 1176.45 MHZ)

More Robust Signal Transmissions

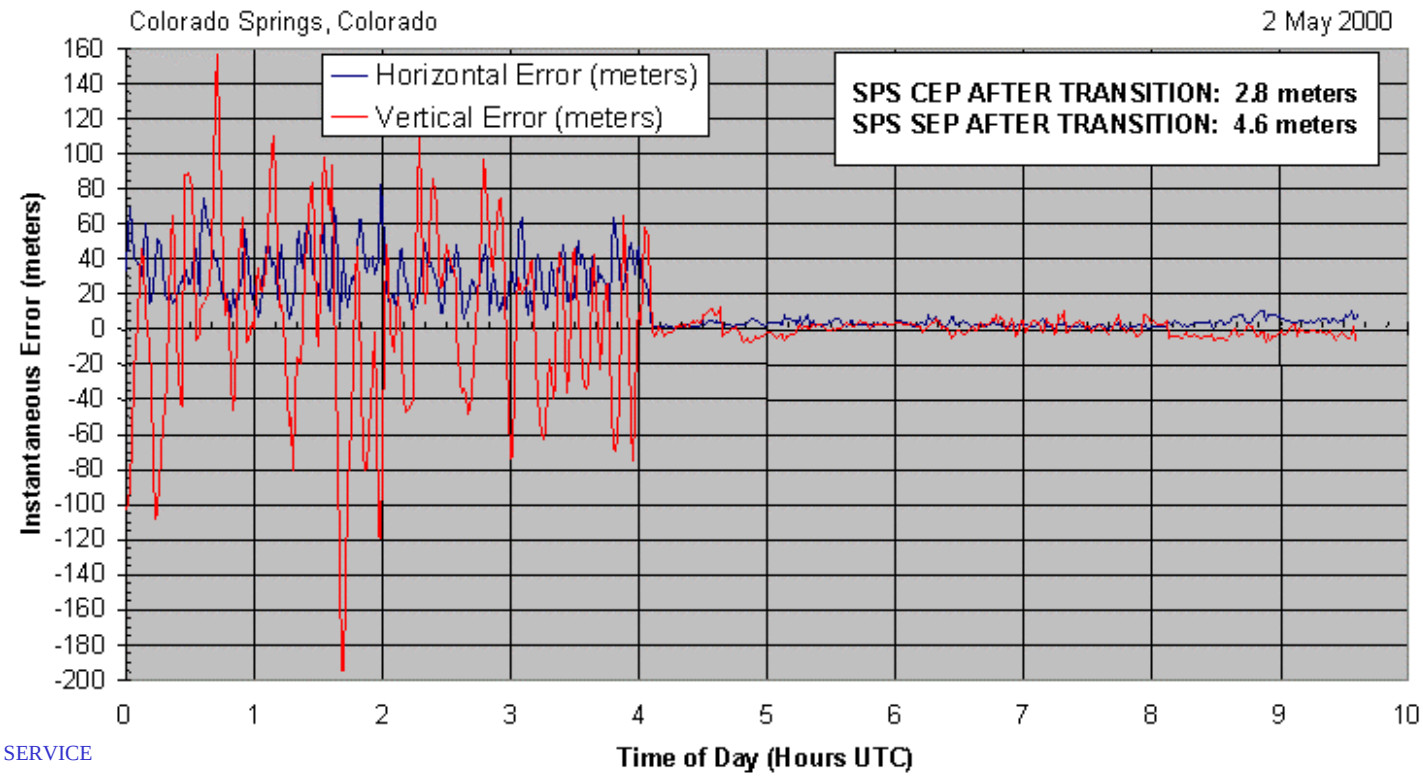
Real-Time Unaugmented 1 Meter Accuracy

Initial Launches ~ 2005

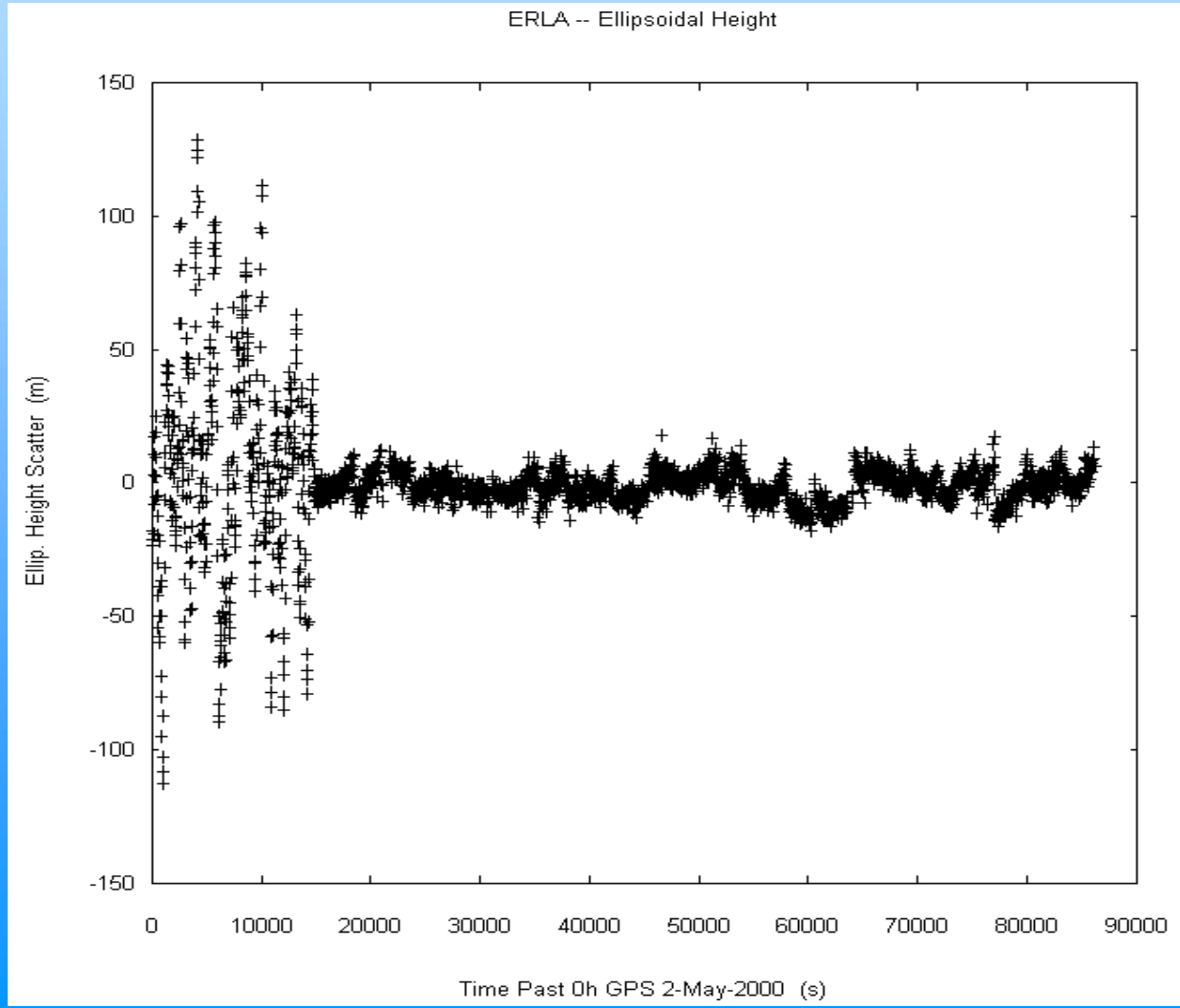
Complete Replacements ~ 2011

SELECTIVE AVAILABILITY OFF

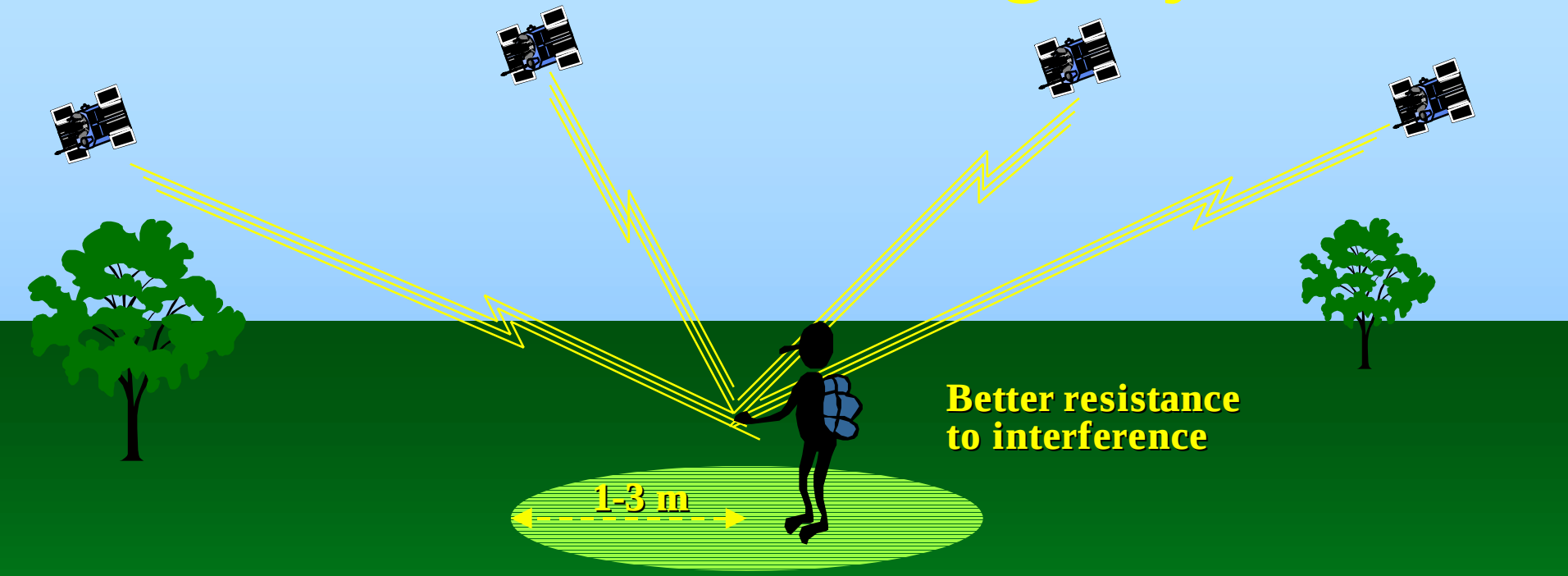
SA Transition -- 2 May 2000



SELECTIVE AVAILABILITY OFF



Standalone Positioning: By 2011

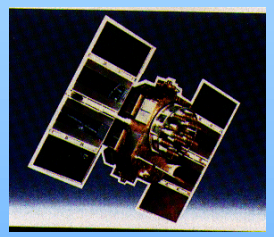


- C/A Code on L1
- C/A Code on L2
- New Code on L5

GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

POTENTIAL FUTURE DEVELOPMENTS

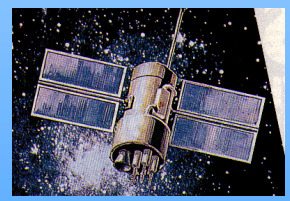
(2005 - 2011)



US GPS MODERNIZATION - BLOCK IIF

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

NAD 83 NETWORK PROBLEMS

NOT “GPSABLE”

POOR STATION ACCESSIBILITY

IRREGULARLY SPACED

POSITIONAL ACCURACY

HIGH ACCURACY REFERENCE NETWORKS

"GPSABLE"

Clear Horizons for Satellite Signal Acquisition

EASY ACCESSIBILITY

Few Special Vehicle or Property Entrance Requirements

REGULARLY SPACED

Always within 20-100 Km

HIGH HORIZONTAL ACCURACY

A-Order (5 mm + 1:10,000,000)

B-Order (8mm + 1:1,000,000)

FEDERAL BASE NETWORK

NGS FUNDED

NGS MARK MAINTENANCE

MAXIMUM 100 KM STATION SPACING

A and B-ORDER HORIZONTAL ACCURACY

FIRST-ORDER CLASS II ORTHOMETRIC HEIGHTS

or

SECOND-ORDER CLASS I ORTHOMETRIC HEIGHTS

SECOND-ORDER CLASS I ELLIPSOIDAL HEIGHTS

REVISIT EVERY 3 TO 5 YEARS

COOPERATIVE BASE NETWORK

STATE/LOCAL SUPPORTED

STATE/LOCAL MARK MAINTENANCE

25 TO 30 KM STATION SPACING

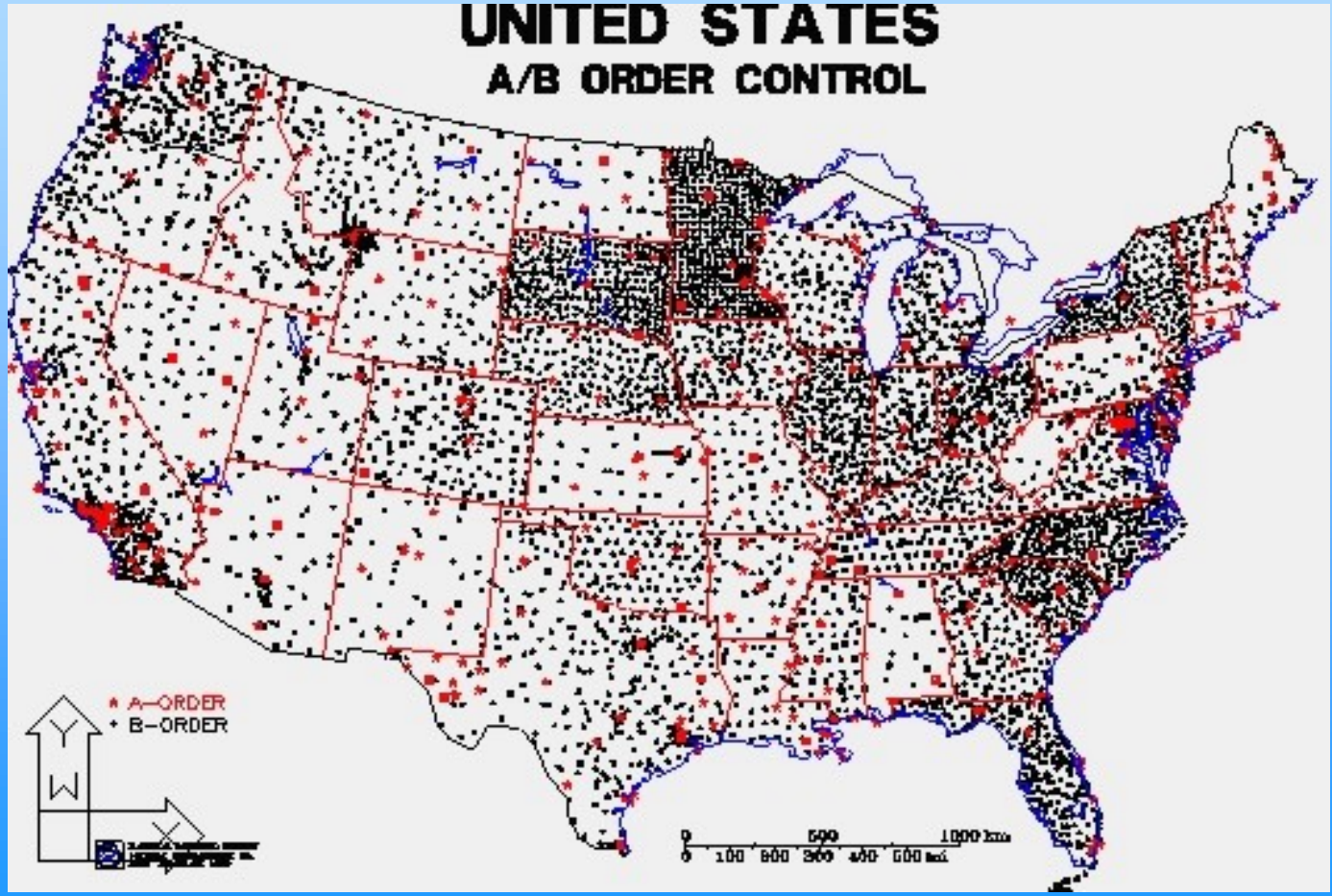
B-ORDER HORIZONTAL ACCURACY

THIRD-ORDER CLASS I ORTHOMETRIC HEIGHTS

THIRD-ORDER CLASS I ELLIPSOIDAL HEIGHTS

REVISIT AS NECESSARY

HIGH ACCURACY REFERENCE NETWORKS



USER Ddensification NETWORK

FEDERAL-STATE-LOCAL FUNDING

STATION SPACING AS REQUIRED

GPS OBSERVATIONS ONLY (HORIZONTAL)

FIRST-ORDER HORIZONTAL ACCURACY

REVISIT AS NEEDED

HARN ADJUSTMENT

NAD 83 Data that is **NOT** Part of NSRS must
be readjusted by contractor/user with original observations

NAD 83 READJUSTMENT

HARN COMPLETION - SEPTEMBER 1997
(Indiana)

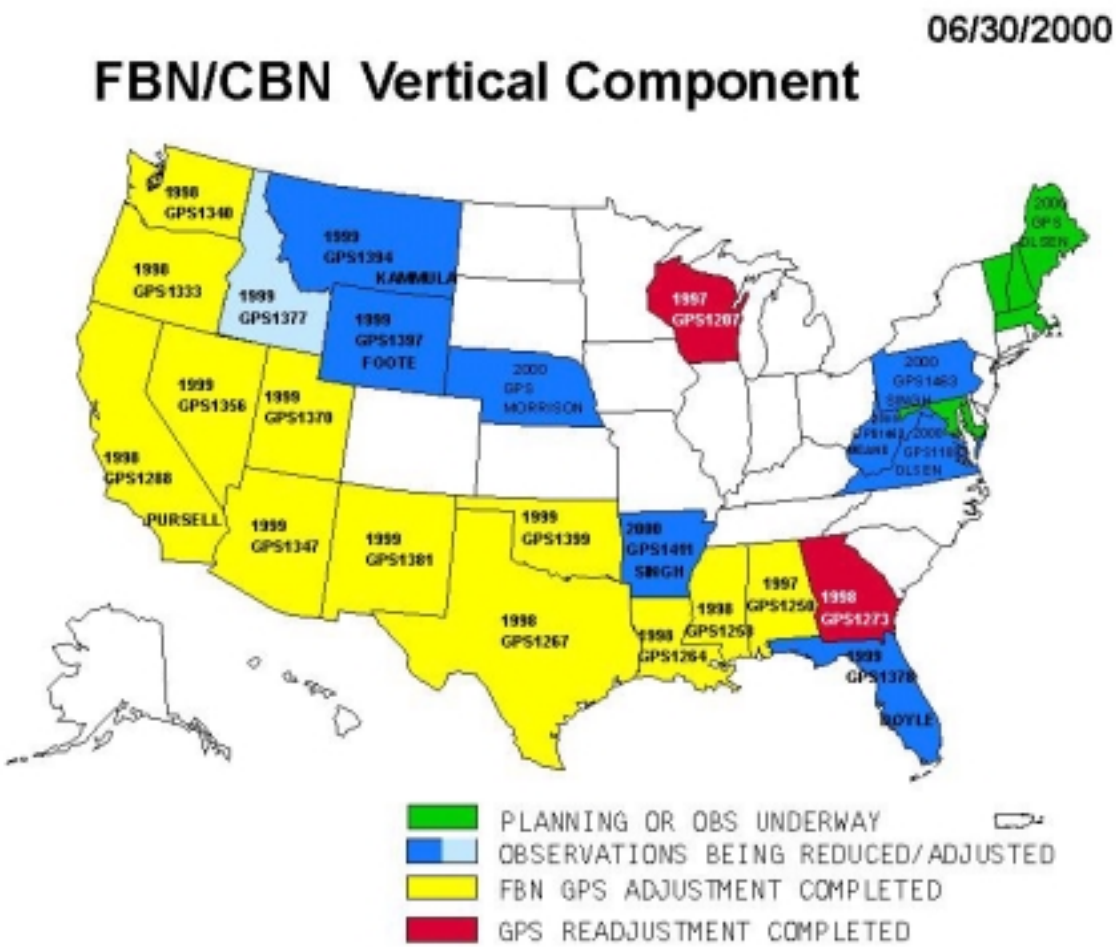
GPS HEIGHT MODERNIZATION OBSERVATIONS
(1997 - 2003?)
(Louisiana observed 1997)
(http://www.ngs.noaa.gov/initiatives/height_modernization.shtml)

COMPLETE GPS NAD 83 3-D ADJUSTMENT
(http://www.ngs.noaa.gov/initiatives/new_reference.shtml)
(2003?)

REMOVAL OF SMALL REGIONAL DISTORTIONS
(3 - 6 CM)

UNIFORM COORDINATE TAG
NAD 83 (NSRS)

NAD 83 READJUSTMENT



NAD 83 READJUSTMENT

ONLY GPS DATA

CONTINUOUSLY OPERATING REFERENCE STATIONS

FEDERAL BASE NETWORK

COOPERATIVE BASE NETWORK

AIRPORT SURVEYS

USER DENSIFICATION NETWORK

SPECIAL SURVEYS

NEW STANDARDS FOR GEODETIC CONTROL

Two accuracy standards

(http://fgdc.er.usgs.gov/standards/status/swgstat.html)

local accuracy ---------- adjacent points

network accuracy ---------- relative to CORS

Numeric quantities, units in cm (or mm)

Both are relative accuracy measures

Do not use distance dependent expression

Horizontal accuracies are radius of 2-D 95% error circle

Ellipsoidal/Orthometric heights are 1-D (linear) 95% error

DATUM TRANSFORMATIONS

1. WHAT DATUM ARE THE EXISTING COORDINATES ON?
2. WHAT DATUM DO I WANT THE NEW COORDINATES ON?
3. HOW LARGE A GEOGRAPHICAL AREA DO I WANT TO CONVERT AT ONE TIME?
4. HOW MANY POINTS ARE COMMON TO BOTH DATUMS?
5. WHAT IS THE DISTRIBUTION OF THE COMMON POINTS?
6. HOW ACCURATE ARE THE EXISTING COORDINATES?

    0.1 Foot

    1.0 Foot

    10. Feet

7. HOW ACCURATE DO I WANT THE NEW COORDINATES?

DATUM TRANSFORMATIONS

MOLODENSKY

Converts latitude, longitude and ellipsoidal height to X,Y,Z Earth-Centered Coordinates.

Applies a 3-dimensional change in the origin (dX, dY,dZ)

Applies a change in the size and shape of the reference ellipsoid

Converts new X,Y,Z Earth-Centered Coordinates back to latitude, longitude and ellipsoidal height

DATUM TRANSFORMATIONS

MOLODENSKY

For continental regions accuracy can be +/- 8 to 10 meters

Does not model network distortions very well.

Assumes heights in both systems are ellipsoidal (NAD 27 did not have ellipsoidal heights).

DATUM TRANSFORMATION - IDEAL METHOD

- SATISFIES ALL USERS' REQUIREMENTS
- CAPABLE OF TRANSFORMING LARGE HOLDINGS OF COORDINATE DATA
- NEAR-REAL TIME APPLICATIONS
- SIMPLE - METHOD SHOULD NOT REQUIRE AN EXPERT OR DECISIONS TO BE MADE
- ACCURATE

NADCON

DESIGNED TO SATISFY THE MAJORITY OF THE "IDEAL METHOD" DESIGN AND HAS DEFINED AS THE NATIONAL STANDARD.

DESIGN CRITERIA:

- **Relies only on NGS archived data existing in both NAD 27 and NAD 83**
- **More the 150,000 common stations used in the development of grids**
- **Provides consistent results, both forward and inverse**
- **Fast**
- **Not tied to NGS Data Base**
- **Small - Fit on PC**
- **Accurate**
  - **15 cm (1 sigma) in Conterminous U.S. NAD 27 - NAD 83(1986)**
  - **5 cm (1 sigma) per State/Region NAD 83 (1986) - HARN**

COORDINATE COMPARISON
NAD 27 to NAD 83(1986)

MOLODENSKY

(http://164.214.2.59/GandG/pubs.html)

ADJUSTED vs. TRANSFORMED

Station: CATC 43 A

LATITUDE	LONGITUDE	
28-59-54.11948	089-51-26.79809	- PUBLISHED
28-59-54.35447	089-51-26.85794	- MOLODENSKY
.23499”	.05985”	
7.235 m	1.620 m	

THIS CORRESPONDS TO A POSITIONAL

DIFFERENCE OF 7.414 m (24.32 ft)

COORDINATE COMPARISON
NAD 27 to NAD 83(1986)

NADCON

(ftp://ftp.ngs.noaa.gov/pub/pcsoft/nadcon/)

ADJUSTED vs. TRANSFORMED

Station: CATC 43 A

LATITUDE	LONGITUD	
28-59-54.11948	089-51-26.79809	- PUBLISHED
28-59-54.12573	089-51-26.77673	- NADCON
.00625”	.02136”	
0.192 m	0.578 m	

THIS CORRESPONDS TO A POSITIONAL DIFFERENCE OF 0.609m (1.20 ft)

COORDINATE COMPARISON
NAD 83 (1986) to NAD 83(1992)

NADCON

ADJUSTED vs. TRANSFORMED

Station: CATC 43 A

LATITUDE	LONGITUDE	
28-59-54.10753	089-51-26.78424	- PUBLISHED
28-59-54.10757	089-51-26.78408	- NADCON
.00004”	.00016”	
0.001 m	0.022 m	

THIS CORRESPONDS TO A POSITIONAL DIFFERENCE OF 0.022 m (0.07 ft)

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

Installed and Operated by various Federal-State-local Agencies

NOAA/National Geodetic Survey
NOAA/OAR Forecast Systems Lab
U.S. Coast Guard - DGPS/NDGPS
Corps of Engineers - DGPS
FAA - WAAS/LAAS (Future)
State DOTs
County and City
Academia
Private Companies

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

Variety of “Geodetic Quality” Dual-Frequency Antennas and Receivers

Allen-Osborne
(SNR 8000 & SNR 12 ACT)

Ashtech
(Z-XII3, UZ-12)

Leica
(SR9500 & CRS1000)

Trimble
(4000SSE & 4000SSI)

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

Some stations provide real-time code phase observations

5 - 15 - 30” post-process carrier phase observations

Free access via Internet (RINEX-2 Format)

More than 190 Station National Network

CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS)

NGS PROVIDES

Reference Site Survey Monumentation

Horizontal and Vertical NSRS Connections

NAD 83, ITRF94, ITRF96, ITRF97 Coordinates

Network Data Collection - Hourly & Daily

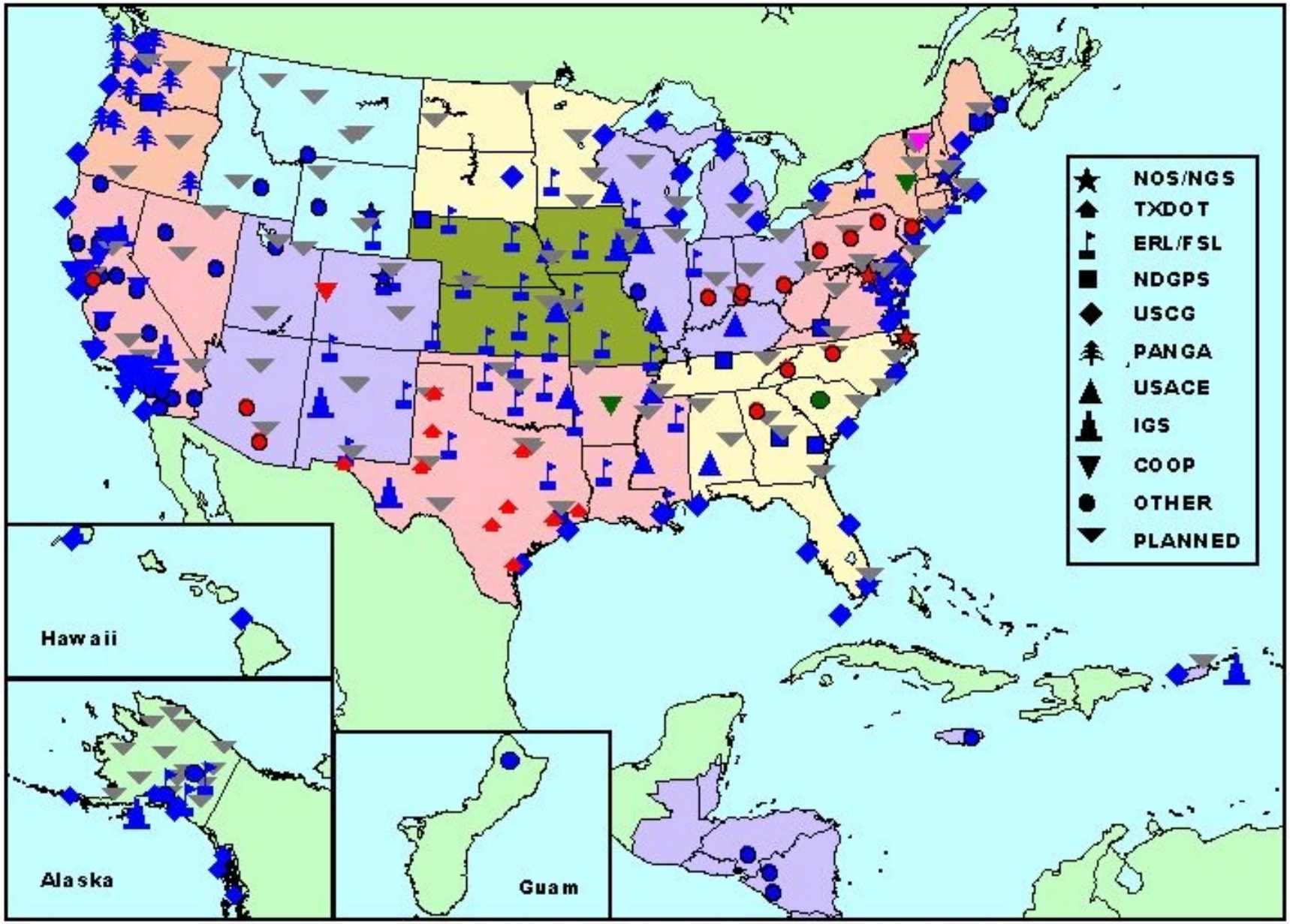
Daily 3D Network Integrity Adjustment

Public Data Distribution - Internet

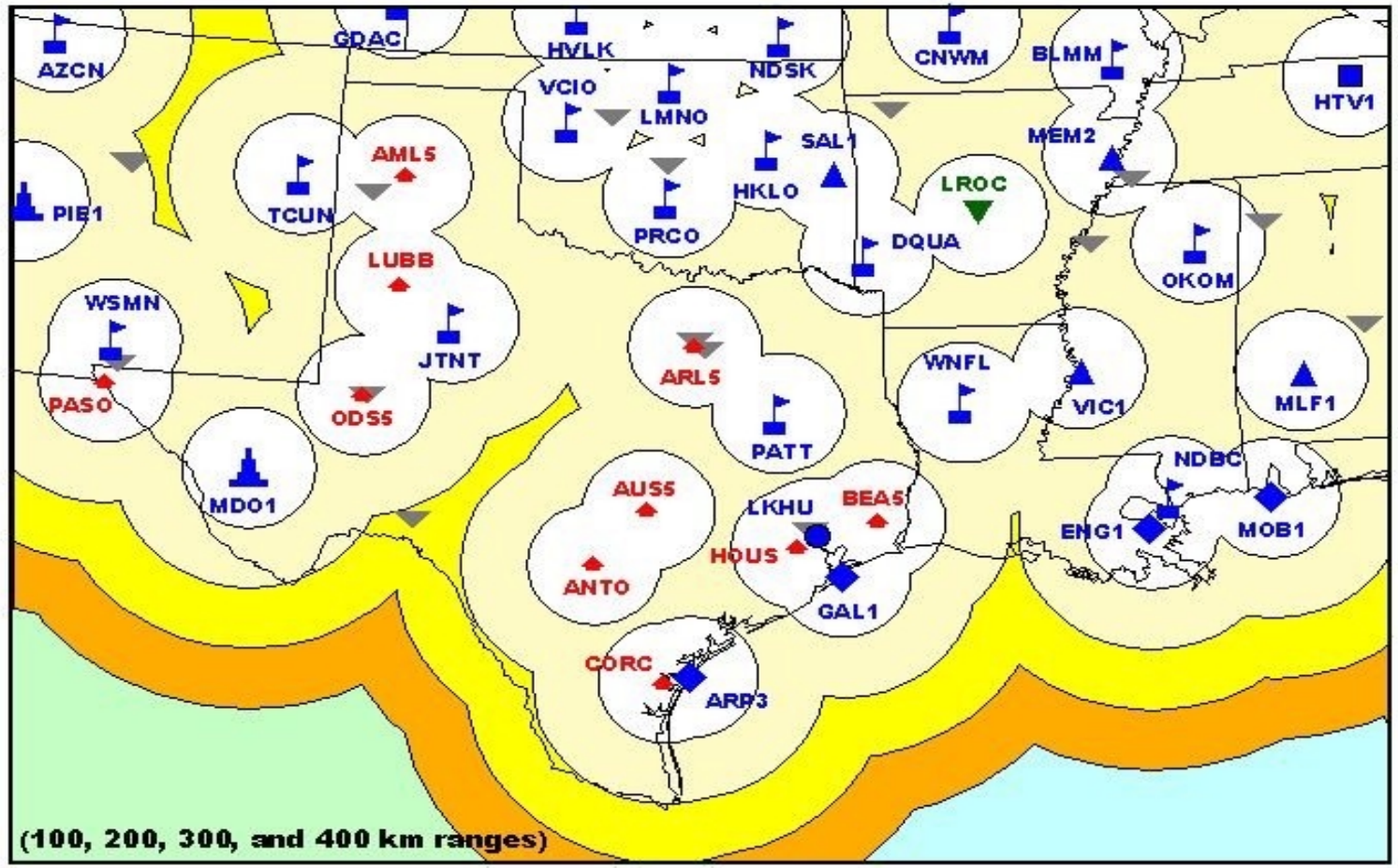
(http://www.ngs.noaa.gov/CORS/cors-data.html)

2 Year On-Line Data Holding

CORS Coverage in the U.S. and Territories - July 2000



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



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

CORS DATA SHEET

ITRF 96

ENGLISH TURN 1 (ENG1), LOUISIANA

Retrieved from NGS DataBase on 09/28/98 at 08:38:52.

Antenna Reference Point(ARP): ENGLISH TURN 1 CORS ARP

PID = AF9544

ITRF96 POSITION (EPOCH 1997.0)
Computed in Mar., 1998 using 50 days of data.

X =	5629.331 m	latitude =	29 52 44.26553 N
Y =	-5534933.971 m	longitude =	089 56 30.21746 W
Z =	3158737.799 m	ellipsoid height =	-18.579 m

ITRF96 VELOCITY
Computed in Mar., 1998 using 50 days of data.

VX =	-0.0138 m/yr	northward =	-0.0028 m/yr
VY =	-0.0014 m/yr	eastward =	-0.0138 m/yr
VZ =	-0.0024 m/yr	upward =	0.0000 m/yr

CORS DATA SHEET

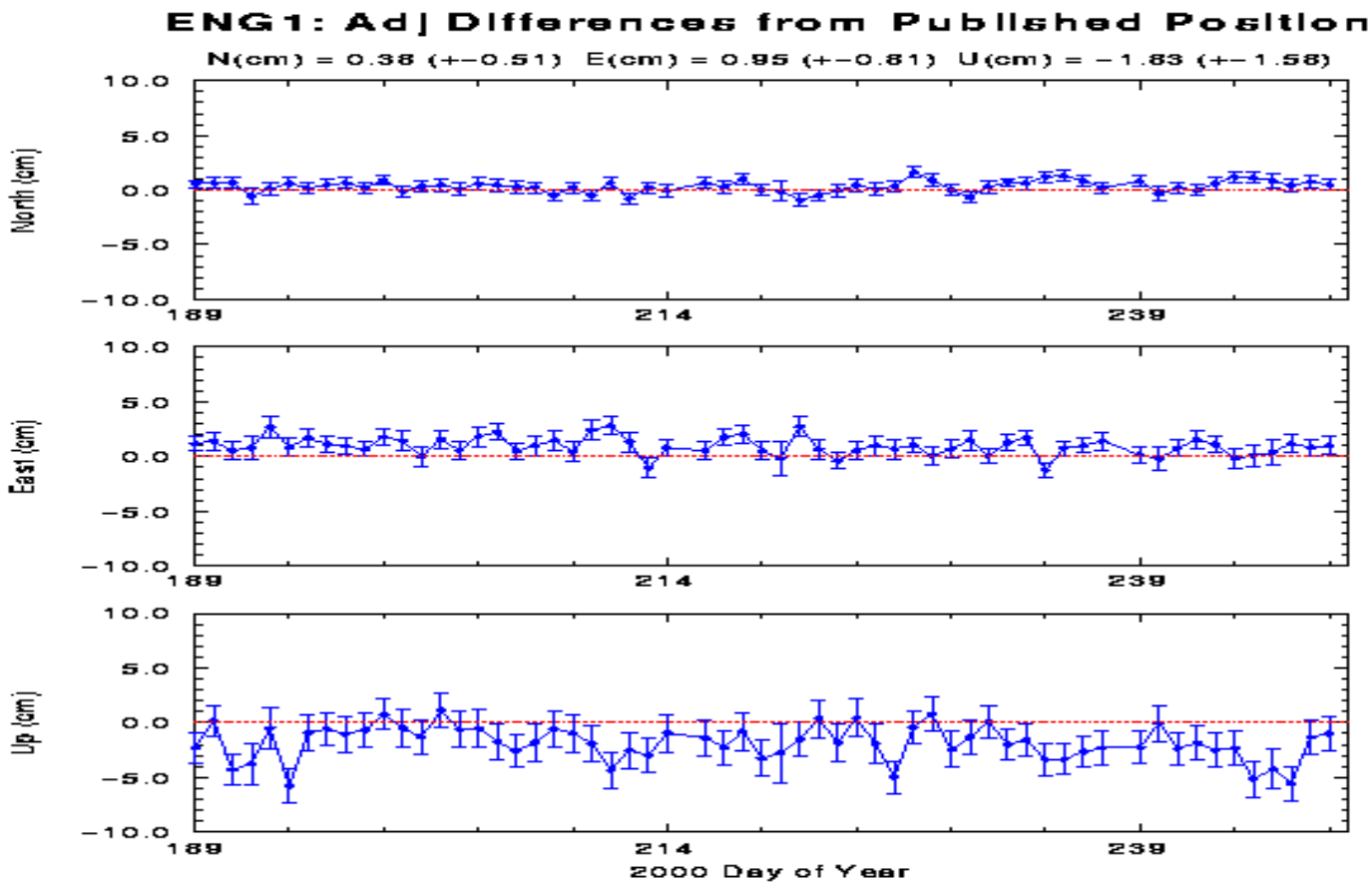
NAD 83

ENGLISH TURN 1 (ENG1), LOUISIANA

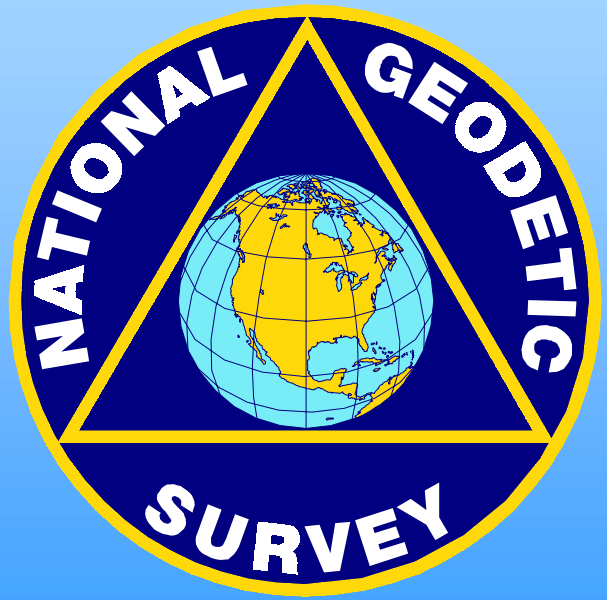
Retrieved from NGS DataBase on 09/28/98 at 08:38:52.

NAD_83 POSITION (EPOCH 1997.0)			
Transformed from ITRF94 (epoch 1996.00) position.			
X =	5629.870 m	latitude =	29 52 44.24594 N
Y =	-5534935.487 m	longitude =	089 56 30.19744 W
Z =	3158737.975 m	ellipsoid height =	-17.176 m
NAD_83 VELOCITY			
Predicted with HTDP_2.0 in Apr., 1996.			
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 DATA QUALITY



GOOD COORDINATION BEGINS WITH GOOD COORDINATES



GEOGRAPHY WITHOUT GEODESY IS A FELONY